Title: High-Energy Amplitudes in the Next-to-Leading Order

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Abstract: The high-energy behavior of gauge theory amplitudes can be studied using the operator expansion in Wilson lines. I review the next-to-leading order calculations of the high-energy amplitudes in N=4 SYM and QCD.

Outline

- Regge limit in a conformal theory.
- High-energy scattering and Wilson lines.
- Evolution equation for color dipoles.
- Leading order: BK equation.
- NLO BK kernel in $\mathcal{N} = 4$.
- NLO amplitude in $\mathcal{N} = 4$ SYM
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$$A(x,y,x',y') = (x-y)^4(x'-y')^4 N_c^2 \langle \mathcal{O}(x)\mathcal{O}^\dagger(y)\mathcal{O}(x')\mathcal{O}^\dagger(y')\rangle$$

$\mathcal{O} = \mathrm{Tr}\{Z^2\}$ $(Z = \frac{1}{\sqrt{2}}(\phi_1 + i\phi_2))$ - chiral primary operator

In a conformal theory the amplitude is a function of two conformal ratios

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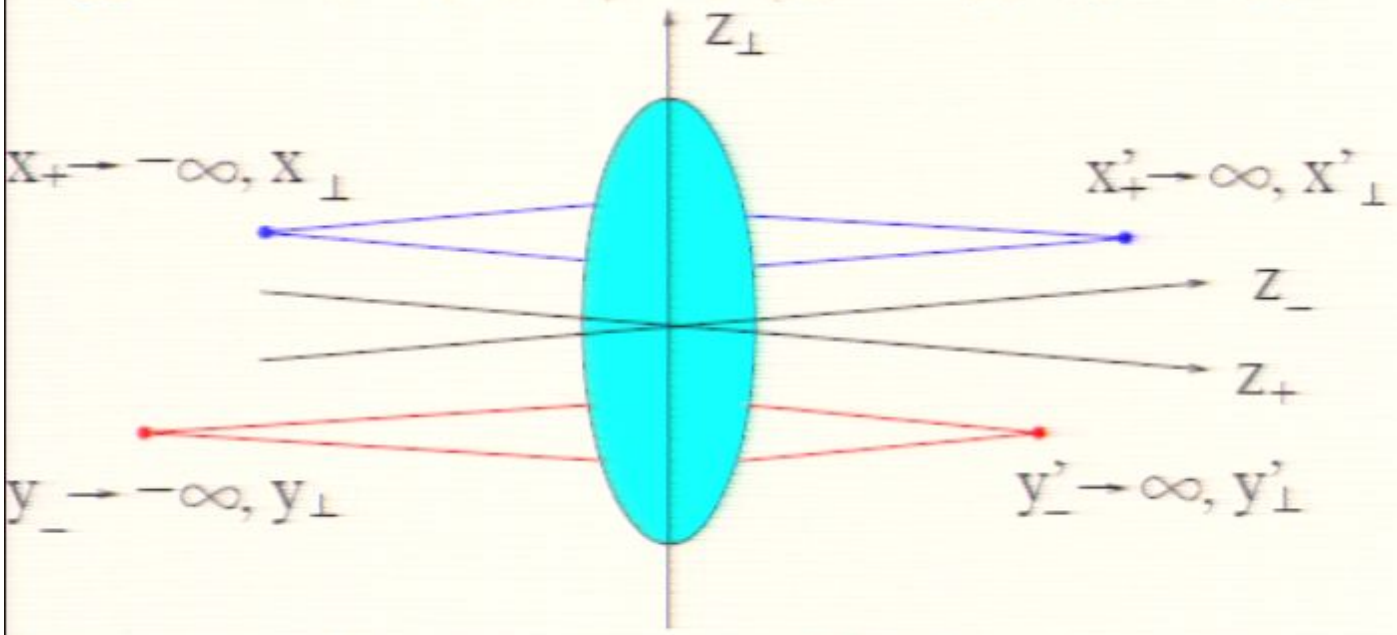
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Regge limit in the coordinate space

Regge limit: $x_+ \to \rho x_+,\ x'_+ \to \rho x'_+, y_- \to \rho' y_-,\ y'_- \to \rho' y_-_ \qquad \rho, \rho' \to \infty$



Full 4-dim conformal group: $A = F(R, r)$

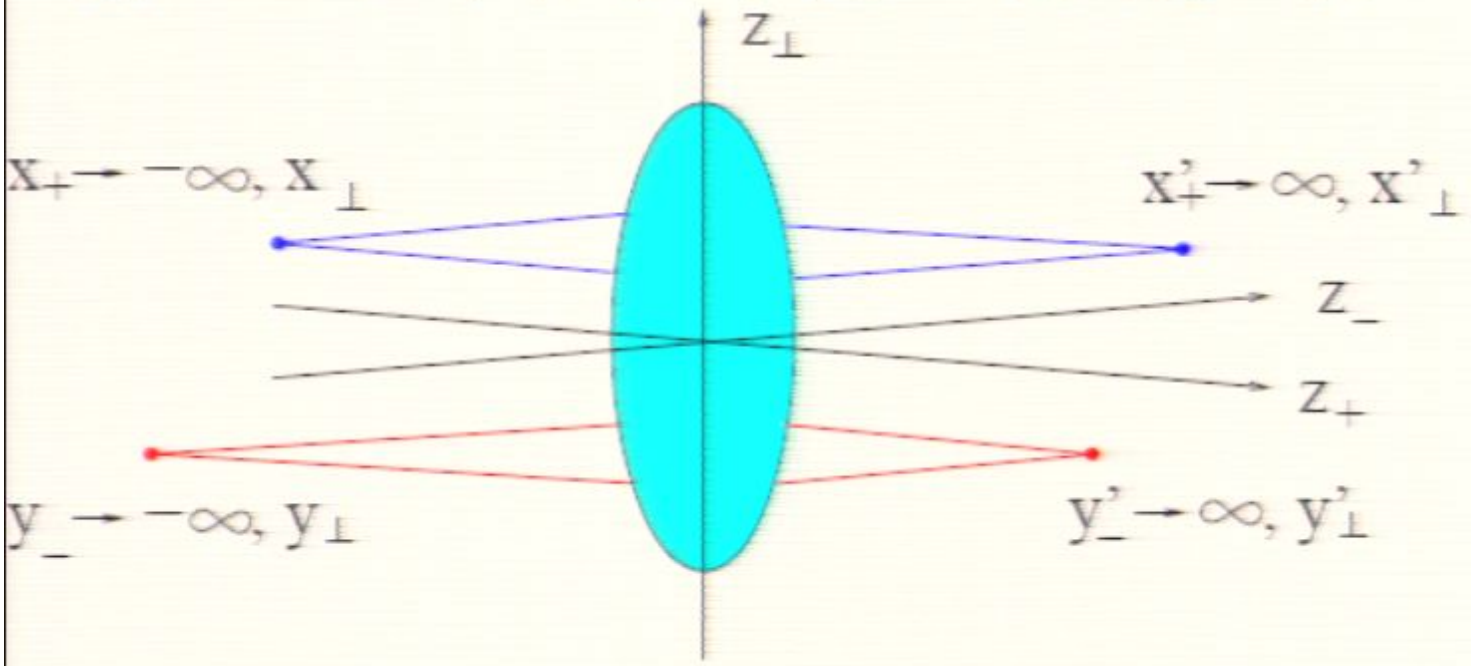
$$R = \frac{(x-y)^2(x'-y')^2}{(x-x')^2(y-y')^2} \to \frac{\rho^2\rho'^2 x_+ x'_+ y_- y'_-}{(x-x')^2_\perp (y-y')^2_\perp} \to \infty$$

$$r = \frac{[(x-y)^2(x'-y')^2 - (x'-y)^2(x-y')^2]^2}{(x-x')^2(y-y')^2(x-y)^2(x'-y')^2}$$

$$\to \frac{[(x'-y')^2_\perp x_+ y_- + x'_+ y'_- (x-y)^2_\perp + x_+ y'_- (x'-y)^2_\perp + x'_+ y_- (x-y')^2_\perp]^2}{(x-x')^2_\perp (y-y')^2_\perp x_+ x'_+ y_- y'_-}$$

4-dim conformal group versus $SL(2,C)$

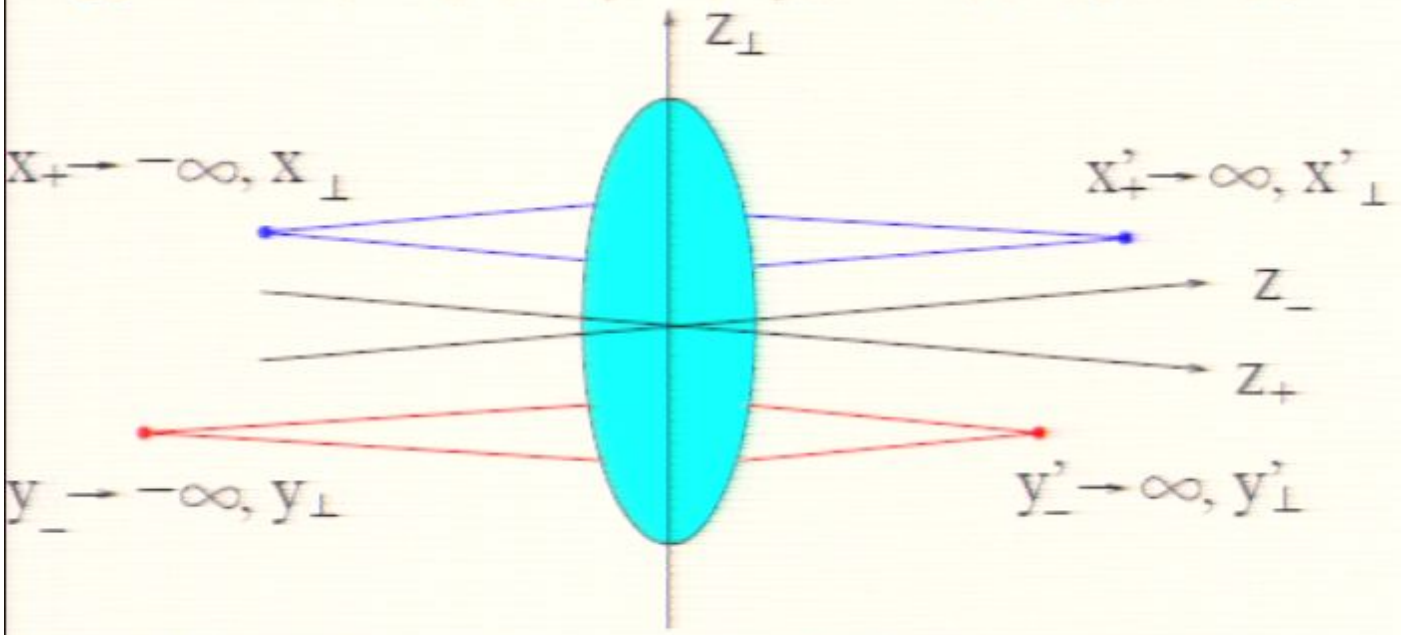
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Regge limit symmetry: 2-dim conformal group $SL(2,C)$ formed from P_1, P_2, M^{12}, D, K_1 and K_2 which leave the plane $(0,0,z_\perp)$ invariant.

Regge limit in the coordinate space

Regge limit: $x_+ \to \rho x_+,\ x'_+ \to \rho x'_+,\ y_- \to \rho' y_-,\ y'_- \to \rho' y'_-$ $\qquad \rho, \rho' \to \infty$



Full 4-dim conformal group: $A = F(R, r)$

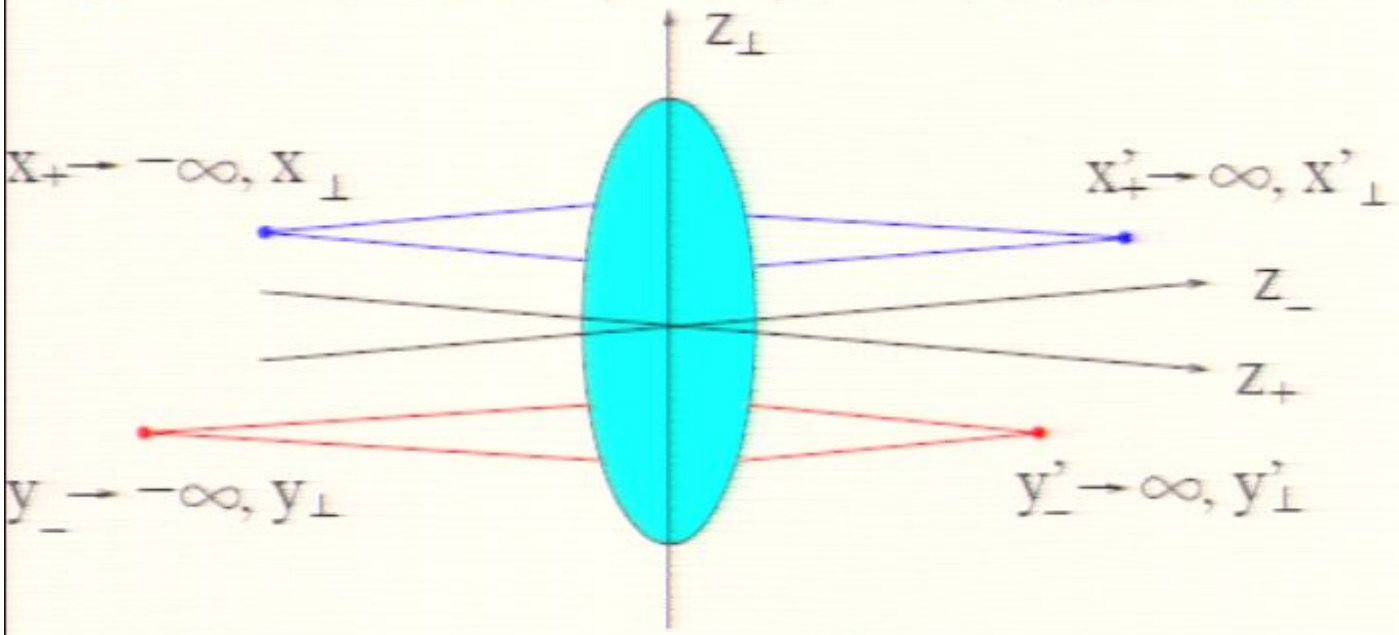
$$R = \frac{(x-y)^2(x'-y')^2}{(x-x')^2(y-y')^2} \to \frac{\rho^2\rho'^2 x_+ x'_+ y_- y'_-}{(x-x')^2_\perp (y-y')^2_\perp} \to \infty$$

$$r = \frac{[(x-y)^2(x'-y')^2 - (x'-y)^2(x-y')^2]^2}{(x-x')^2(y-y')^2(x-y)^2(x'-y')^2}$$

$$\to \frac{[(x'-y')^2_\perp x_+ y_- + x'_+ y'_- (x-y)^2_\perp + x_+ y'_- (x'-y)^2_\perp + x'_+ y_- (x-y')^2_\perp]^2}{(x-x')^2_\perp (y-y')^2_\perp x_+ x'_+ y_- y'_-}$$

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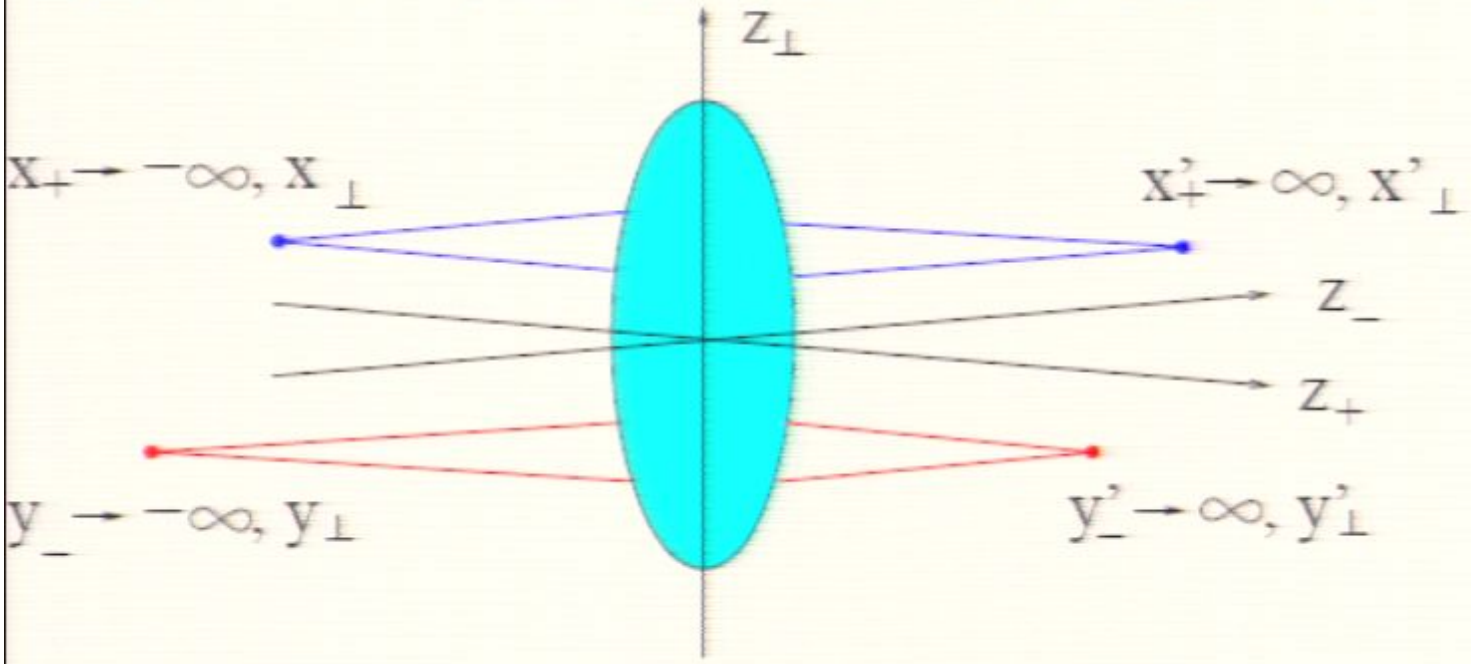
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4-dim conformal group versus $SL(2,C)$

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Regge limit symmetry: 2-dim conformal group $SL(2,C)$ formed from P_1, P_2, M^{12}, D, K_1 and K_2 which leave the plane $(0,0,z_\perp)$ invariant.

Pomeron in a conformal theory

$$A(x,y;x',y') \overset{s\to\infty}{=} \frac{i}{2}\int d\nu\, f_+(\omega(\lambda,\nu))F(\lambda,\nu)\Omega(r,\nu)R^{\omega(\lambda,\nu)/2}$$

L. Cornalba (2007)

$f_+(\omega) = \frac{e^{i\pi\omega}-1}{\sin\pi\omega}$ - signature factor

$\Omega(r,\nu)$ - solution of the eqn $(\Box_{H_3}+\nu^2+1)\Omega(r,\nu)=0$.

Explicit form:

$$\Omega(r,\nu) = \frac{\nu^2}{\pi^3}\int d^2z\left(\frac{\kappa^2}{(2\kappa\cdot\zeta)^2}\right)^{\frac{1}{2}+i\nu}\left(\frac{\kappa'^2}{(2\kappa'\cdot\zeta)^2}\right)^{\frac{1}{2}-i\nu} = \frac{\sin\nu\rho}{\sinh\rho}, \qquad \cosh\rho = \frac{\sqrt{r}}{2}$$

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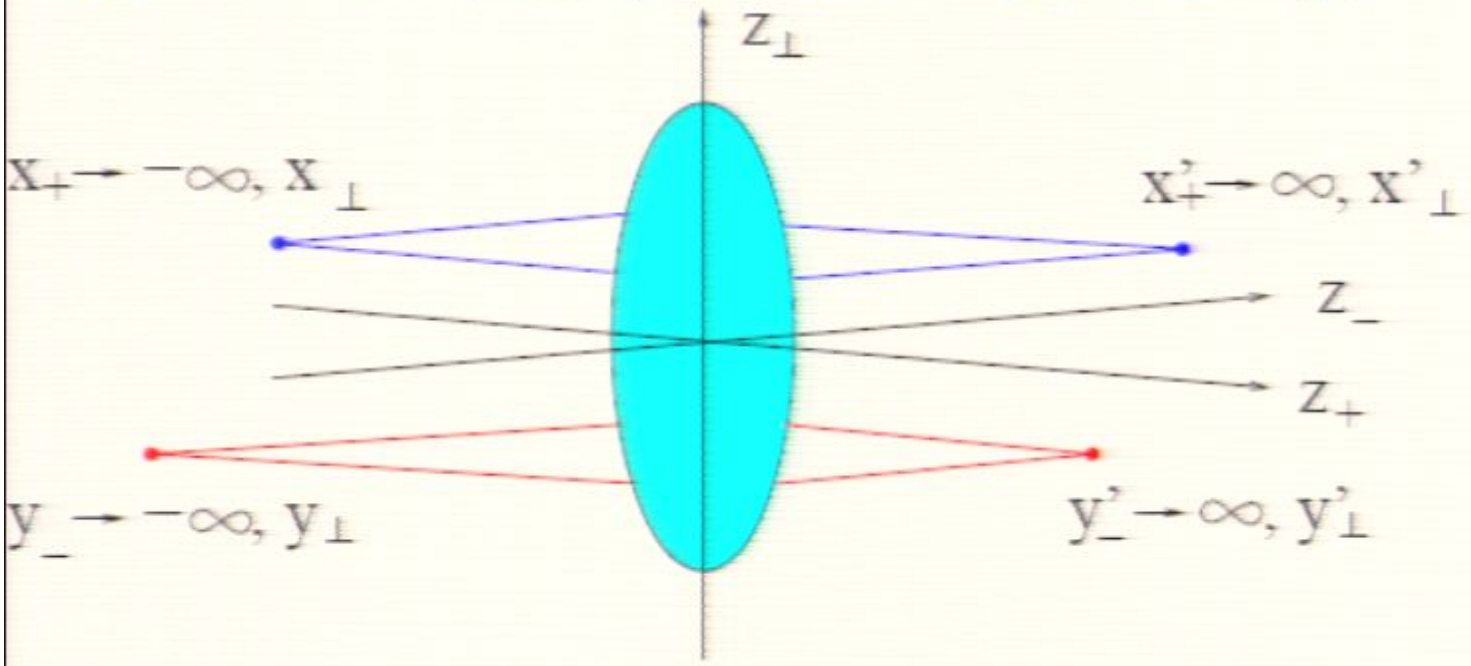
$$\kappa = \frac{1}{2x_+}(p_1 - \frac{x^2}{s}p_2 + x_\perp) - \frac{1}{2y_+}(p_1 - \frac{y^2}{s}p_2 + y_\perp), \qquad \kappa^2\kappa'^2 = \frac{1}{R}$$

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The dynamics is described by $\omega(\lambda,\nu)$ and $F(\lambda,\nu)$.

4-dim conformal group versus $SL(2,C)$

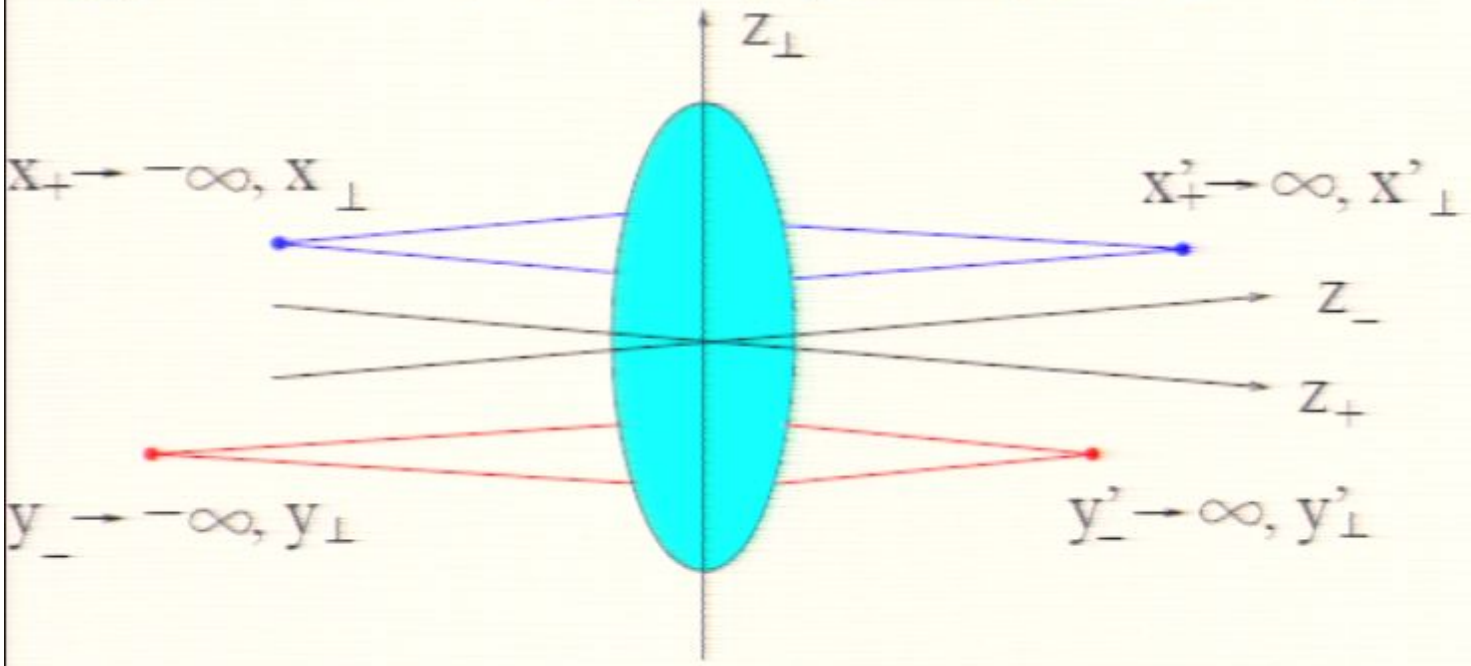
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4-dim conformal group versus $SL(2,C)$

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Pomeron intercept $\omega(\nu,\lambda)$ is known in two limits:

1. $\lambda \to 0:$ $\omega(\nu,\lambda) = \frac{\lambda}{\pi}\chi(\nu) + \lambda^2\omega_1(\nu) + ...$

$\chi(\nu) = 2\psi(1) - \psi(\frac{1}{2}+i\nu) - \psi(\frac{1}{2}-i\nu)$ - BFKL intercept,

$\omega_1(\nu)$ - NLO BFKL intercept Lipatov, Kotikov (2000)

2. $\lambda \to \infty:$ $AdS/CFT \Rightarrow \omega(\nu,\lambda) = 2 - \frac{\nu^2+4}{2\sqrt{\lambda}} + ...$

2 = gravition spin , next term - Brower, Polchinski, Strassler, Tan (2006)
Cornalba, Costa, Penedones (2007)

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1. $\lambda \to 0$: $\quad F(\nu,\lambda) = \lambda^2 F_0(\nu) + \lambda^3 F_1(\nu) + \ldots$

$F_0(\nu) = \frac{\pi \sinh \pi\nu}{4\nu \cosh^2 \pi\nu}$ Cornalba, Costa, Penedones (2007)

$F_1(\nu)$ = see below G. Chirilli and I.B. (2009)

2. $\lambda \to \infty$: $\quad AdS/CFT \quad \Rightarrow \quad \omega(\nu,\lambda) = \pi^3\nu^2 \frac{1+\nu^2}{\sinh^2 \pi\nu} + \ldots$

L.Cornalba (2007)

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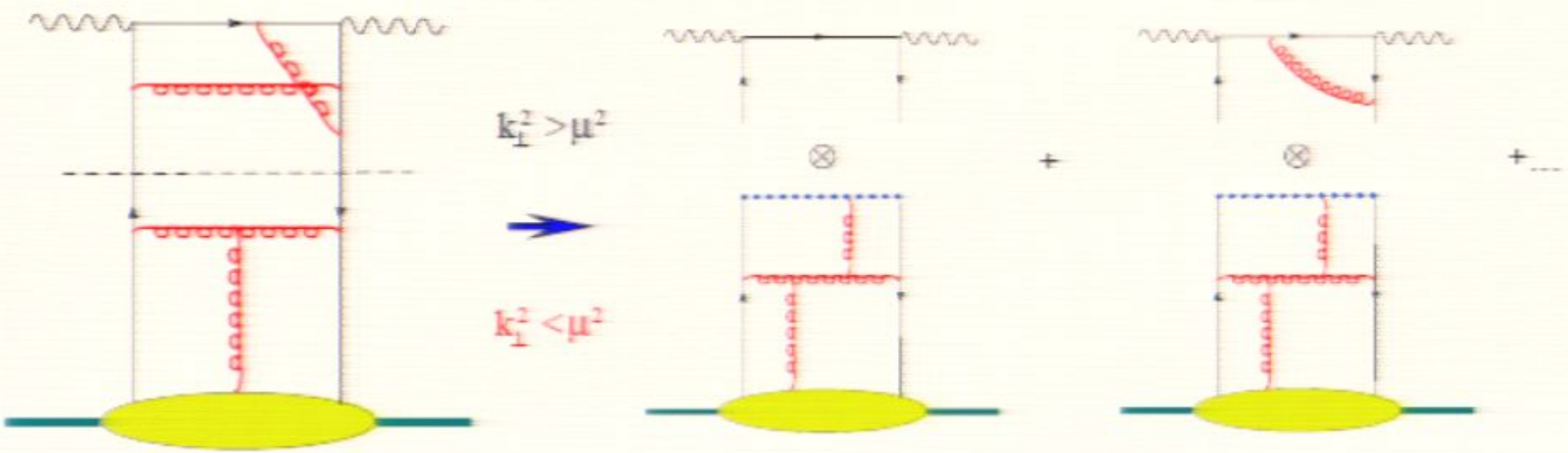
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Light-cone expansion and DGLAP evolution in the NLO

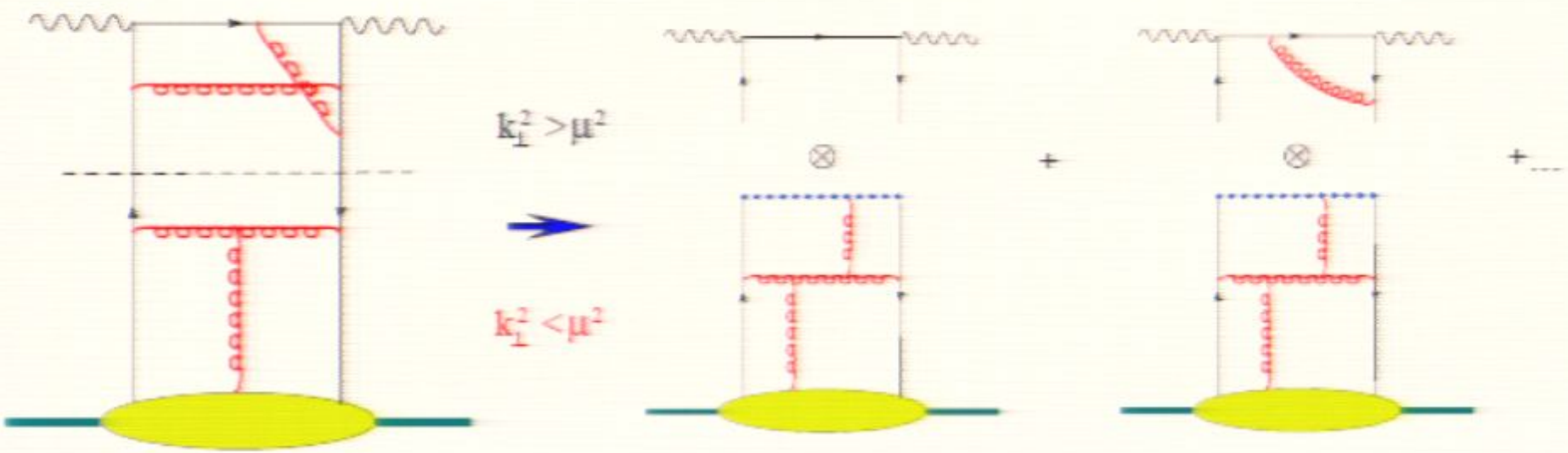


μ^2 - factorization scale (normalization point)

$k_\perp^2 > \mu^2$ - coefficient functions

$k_\perp^2 < \mu^2$ - matrix elements of light-ray operators (normalized at μ^2)

Light-cone expansion and DGLAP evolution in the NLO

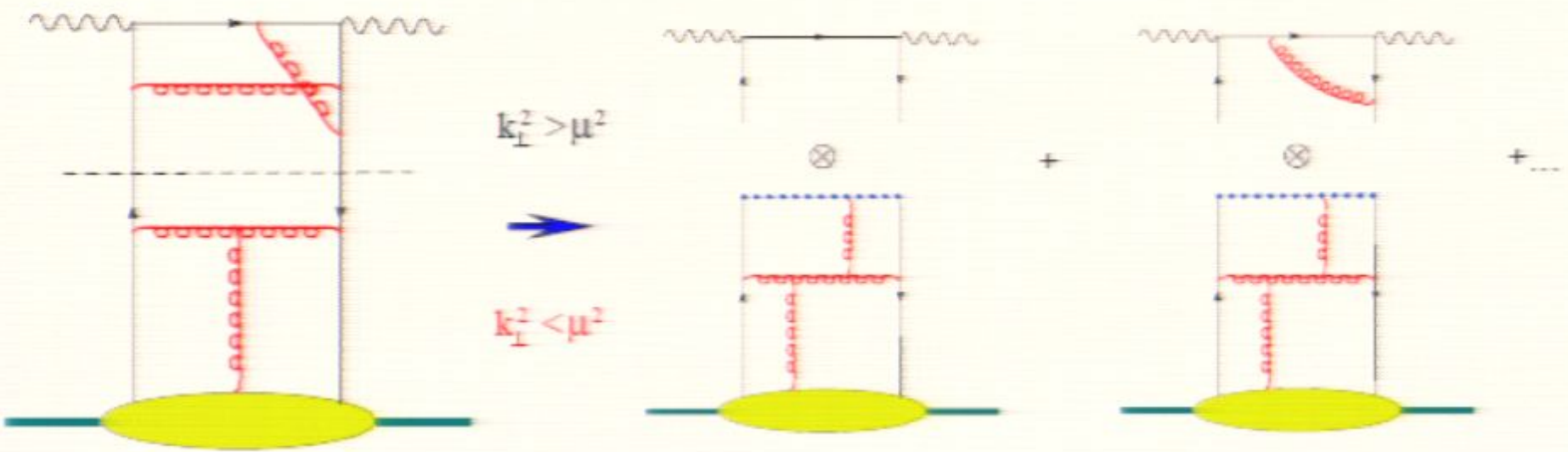


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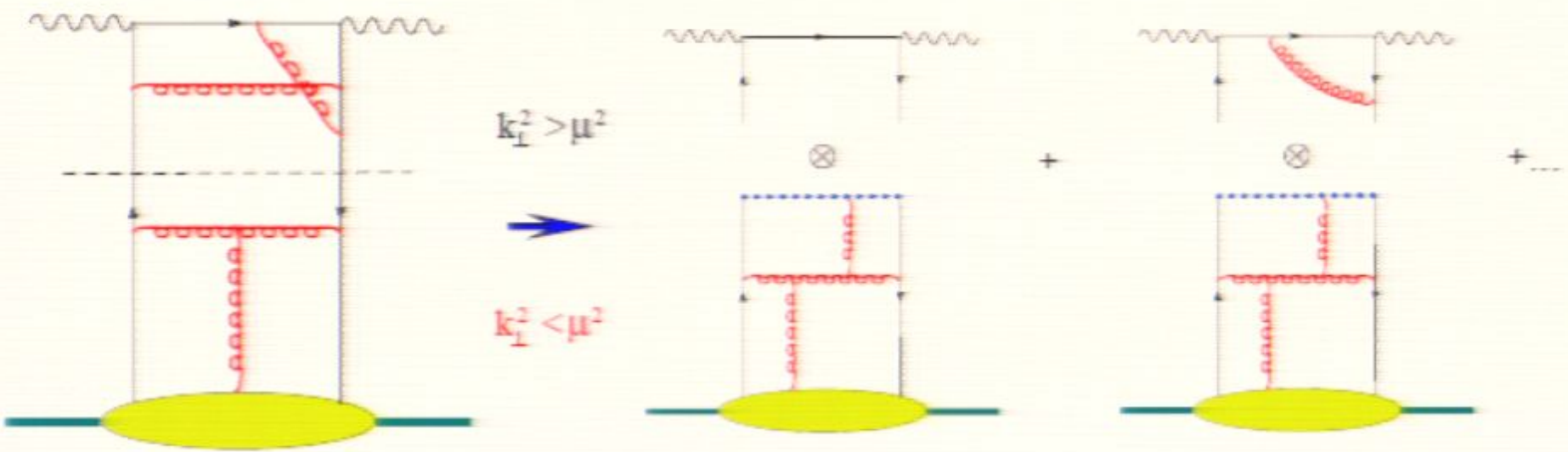
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OPE in light-ray operators $\qquad (x-y)^2 \to 0$

$$T\{j_\mu(x) j_\nu(y)\} = \frac{x_\xi}{2\pi^2 x^4}\left[1 + \frac{\alpha_s}{\pi}(\ln x^2\mu^2 + C)\right]\bar\psi(x)\gamma_\mu\gamma^\xi\gamma_\nu[x,y]\psi(y) + O(\frac{1}{x^2})$$

$$[x,y] \equiv P e^{ig\int_0^1 du\ (x-y)^\mu A_\mu(ux+(1-u)y)}$$ - gauge link

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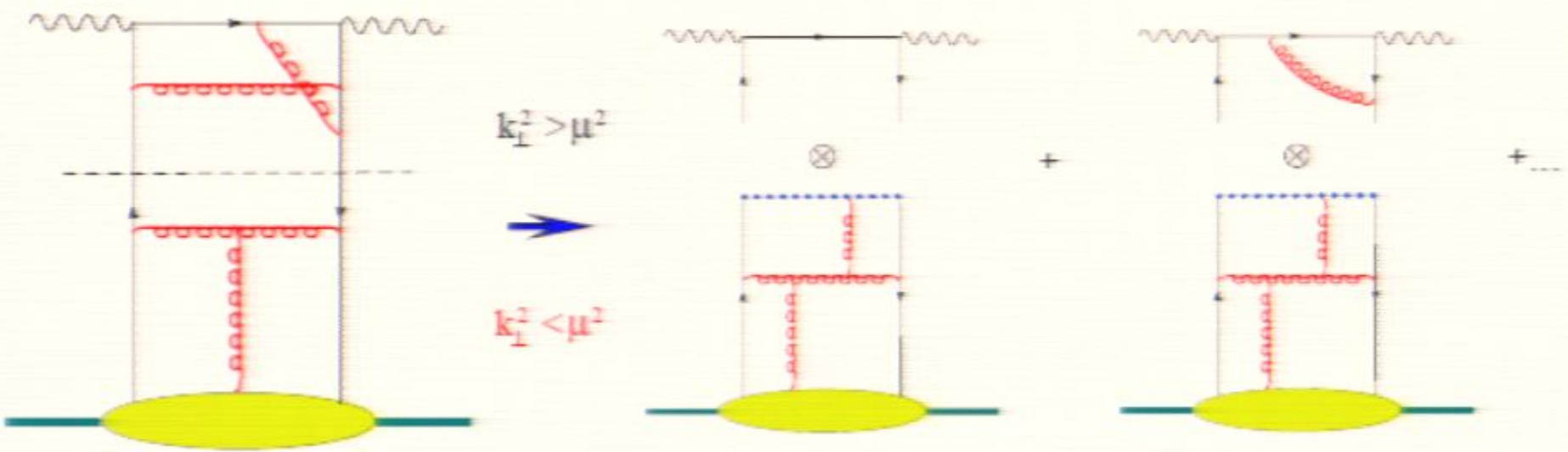
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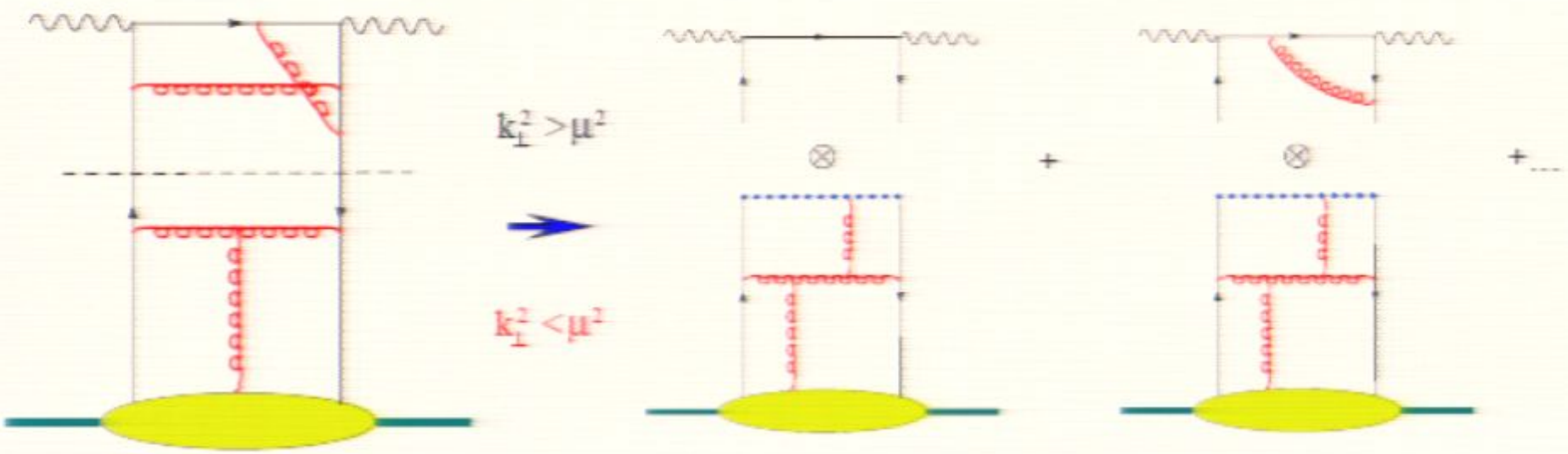
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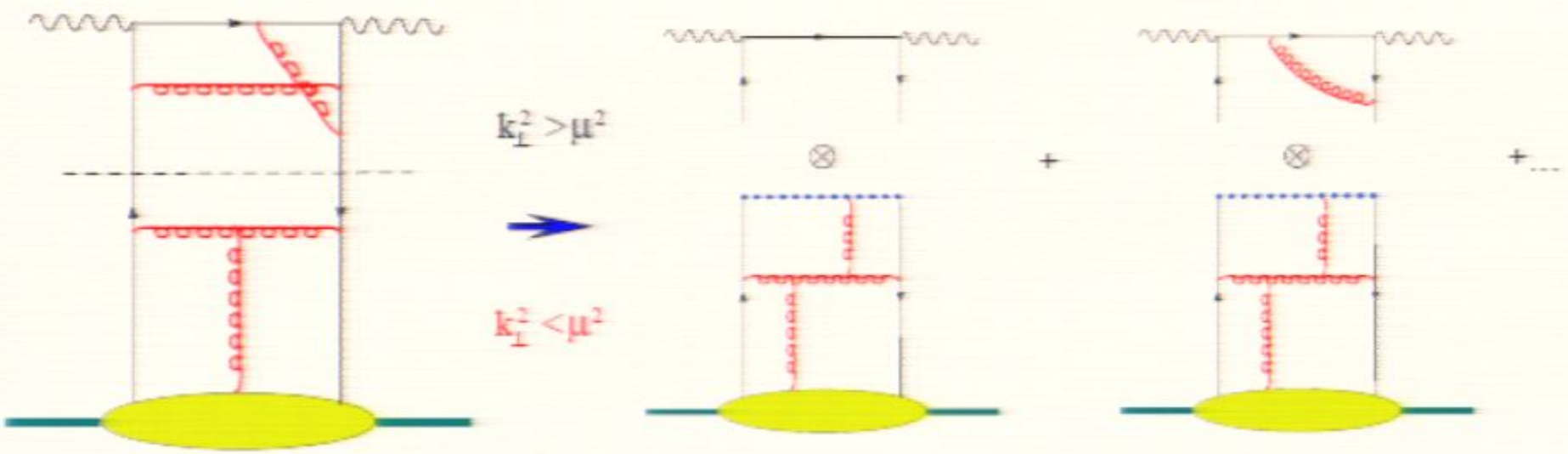
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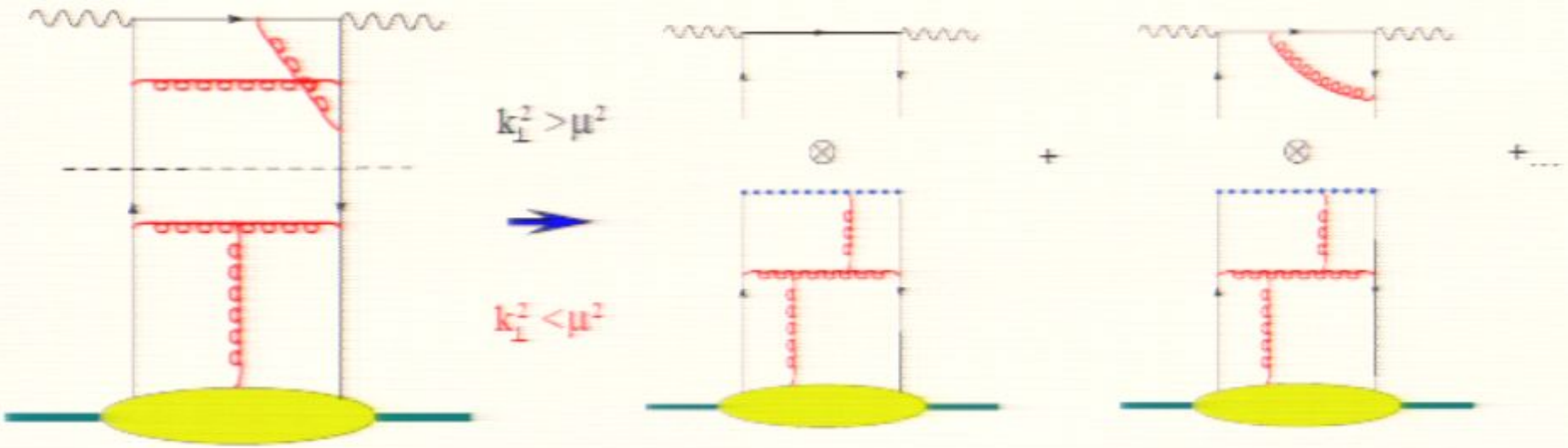
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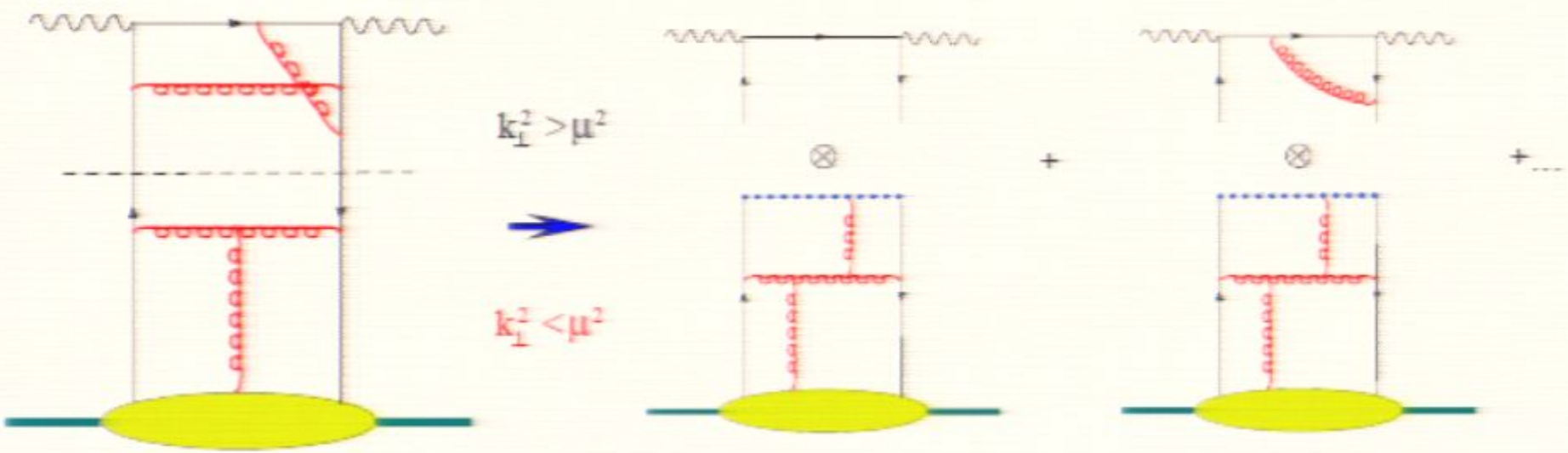
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OPE in light-ray operators $(x-y)^2 \to 0$

$$T\{j_\mu(x) j_\nu(y)\} = \frac{x_\xi}{2\pi^2 x^4}\left[1 + \frac{\alpha_s}{\pi}(\ln x^2\mu^2 + C)\right]\bar{\psi}(x)\gamma_\mu\gamma^\xi\gamma_\nu[x,y]\psi(y) + O(\frac{1}{x^2})$$

$$[x,y] \equiv P e^{ig\int_0^1 du\,(x-y)^\mu A_\mu(ux+(1-u)y)}$$ - gauge link

Light-cone expansion and DGLAP evolution in the NLO



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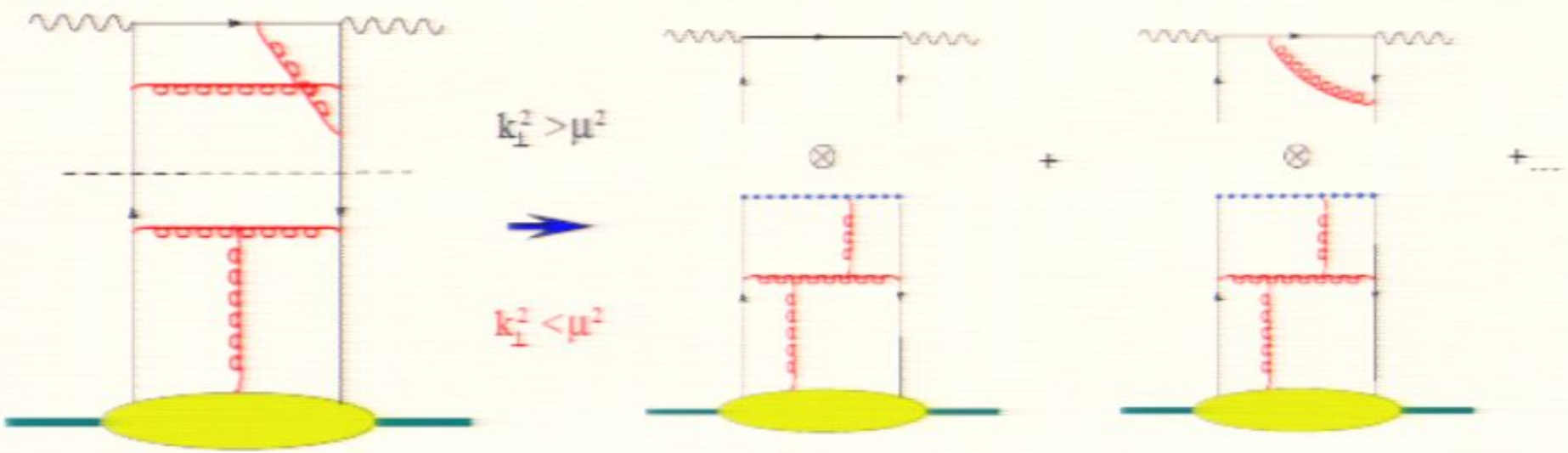
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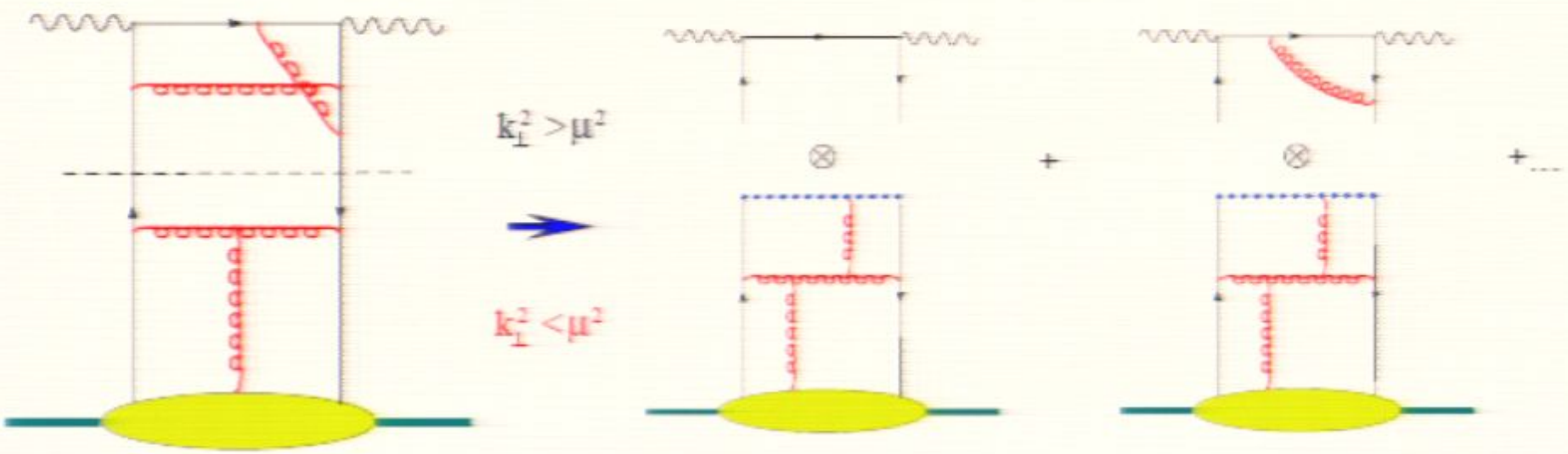
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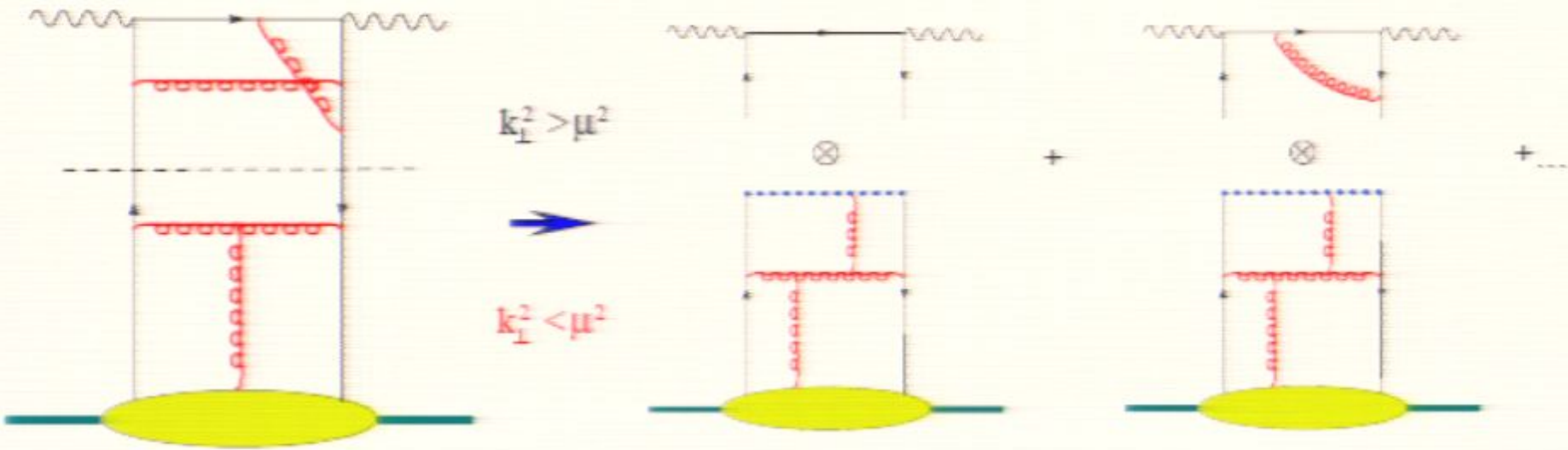
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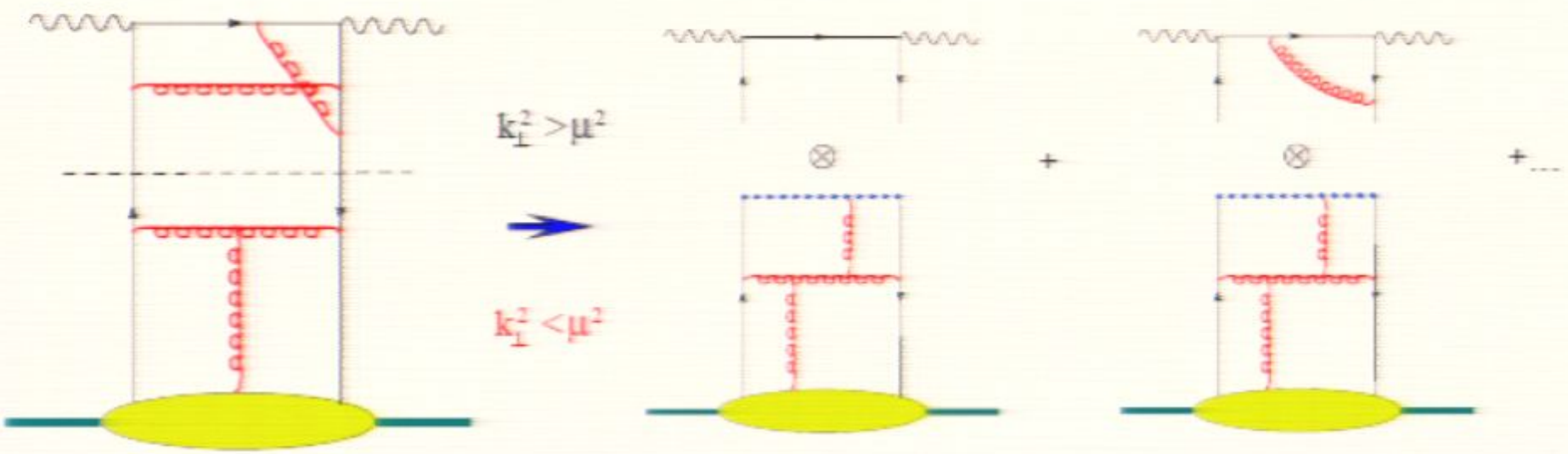
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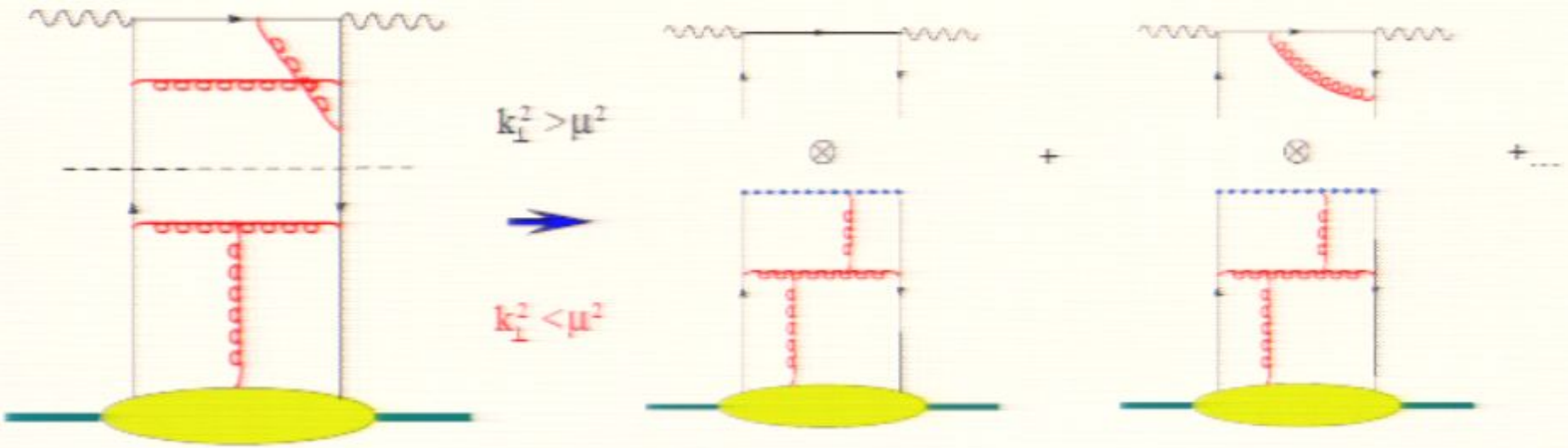
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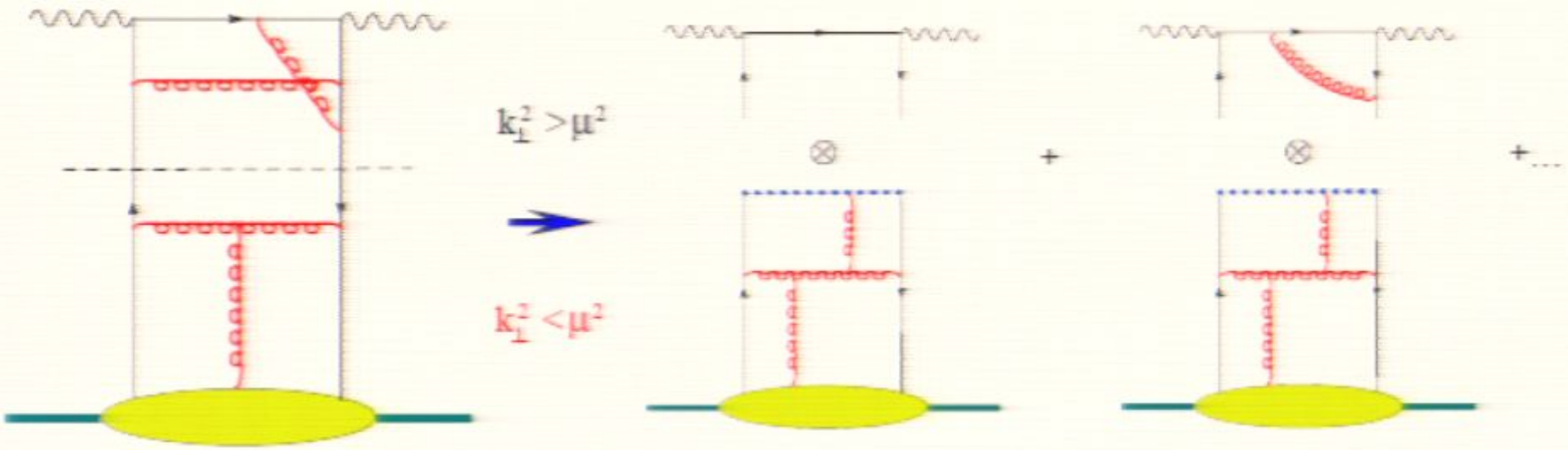
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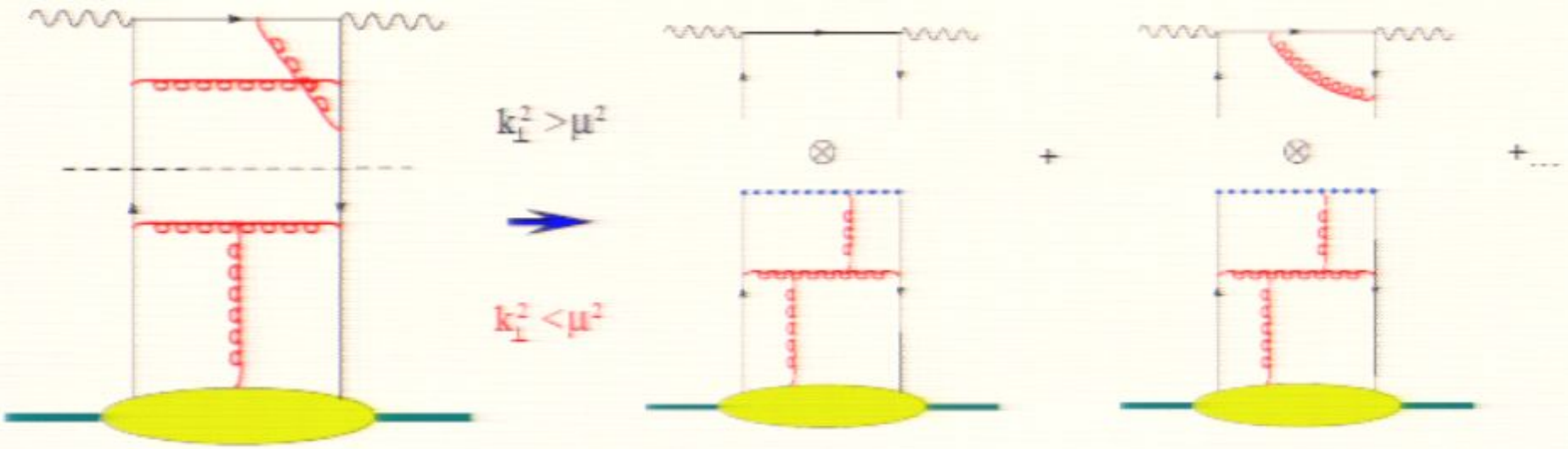
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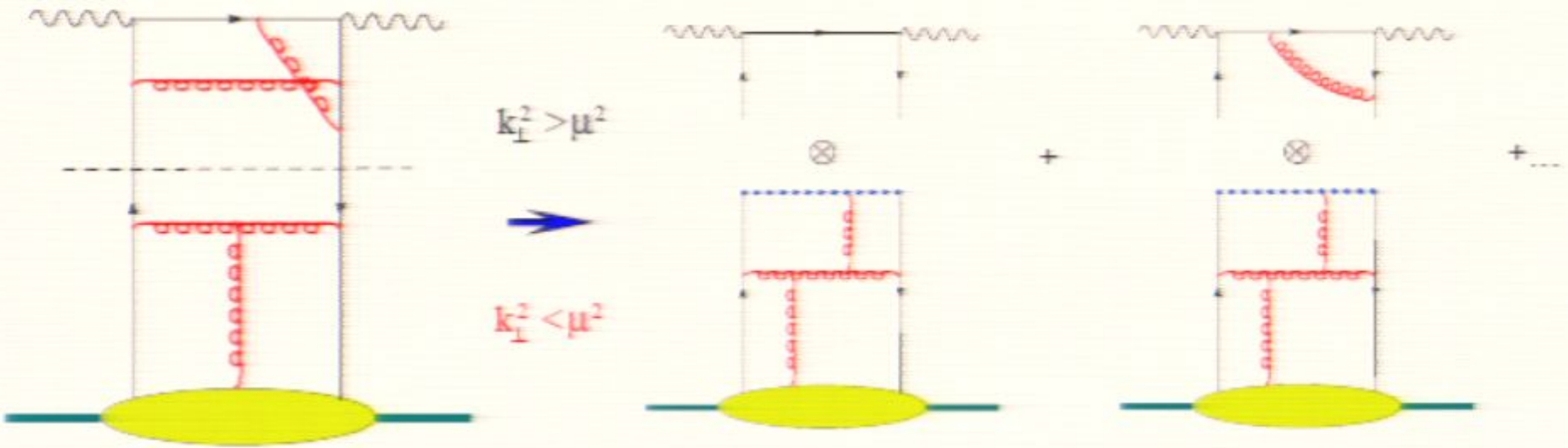
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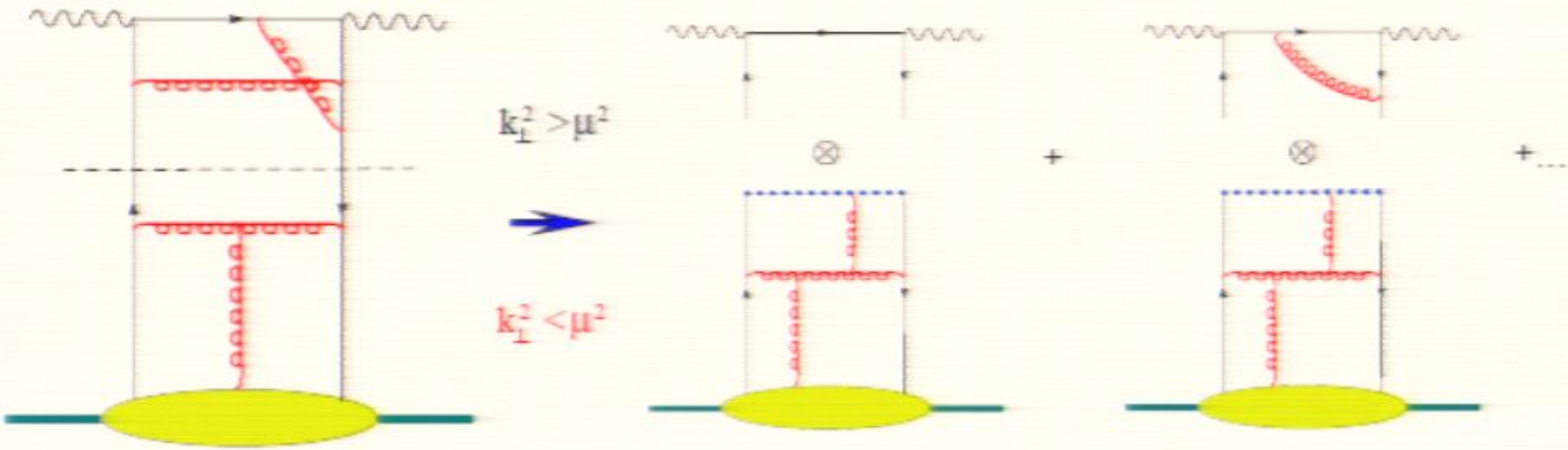
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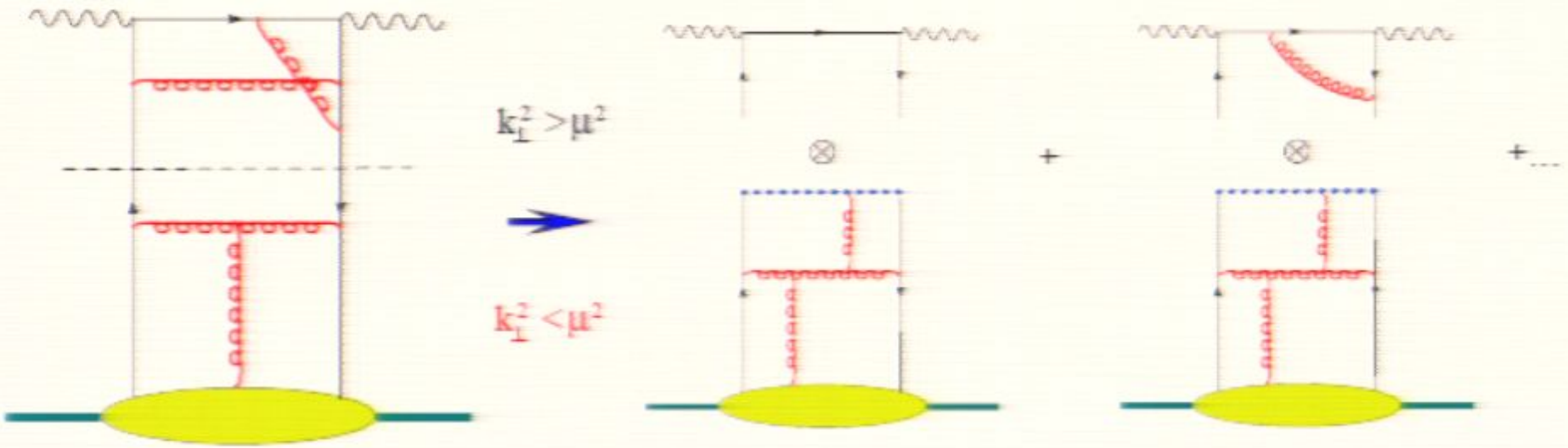
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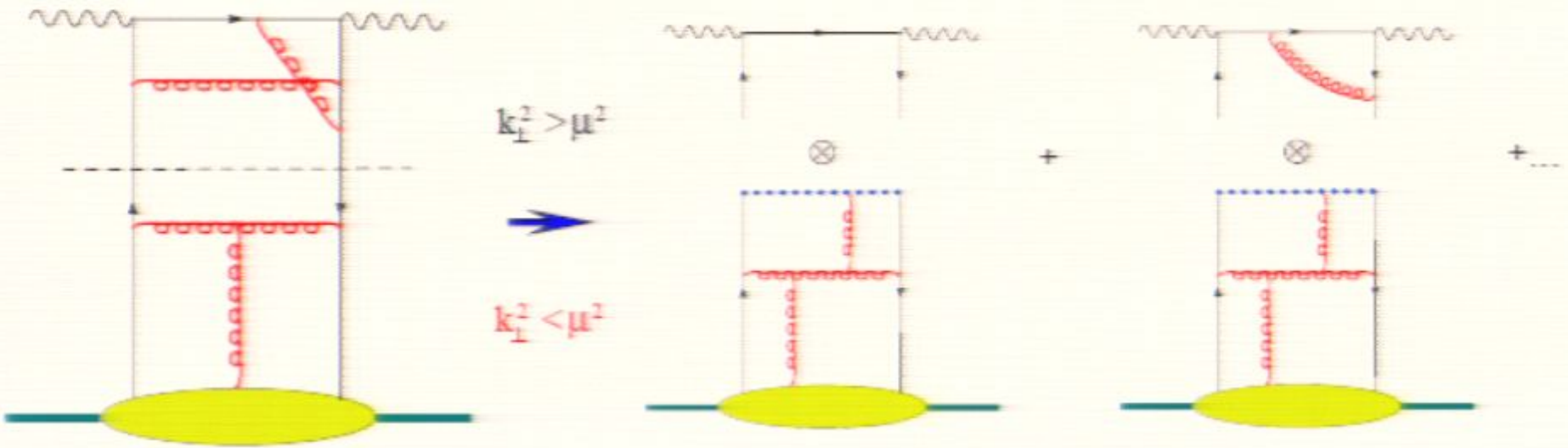
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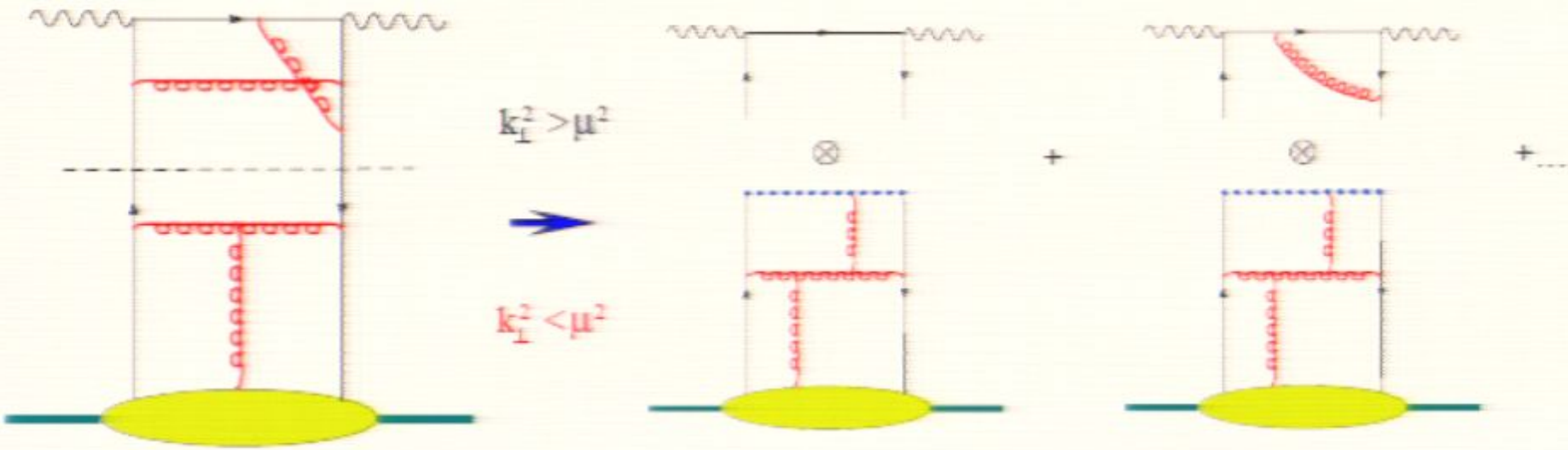
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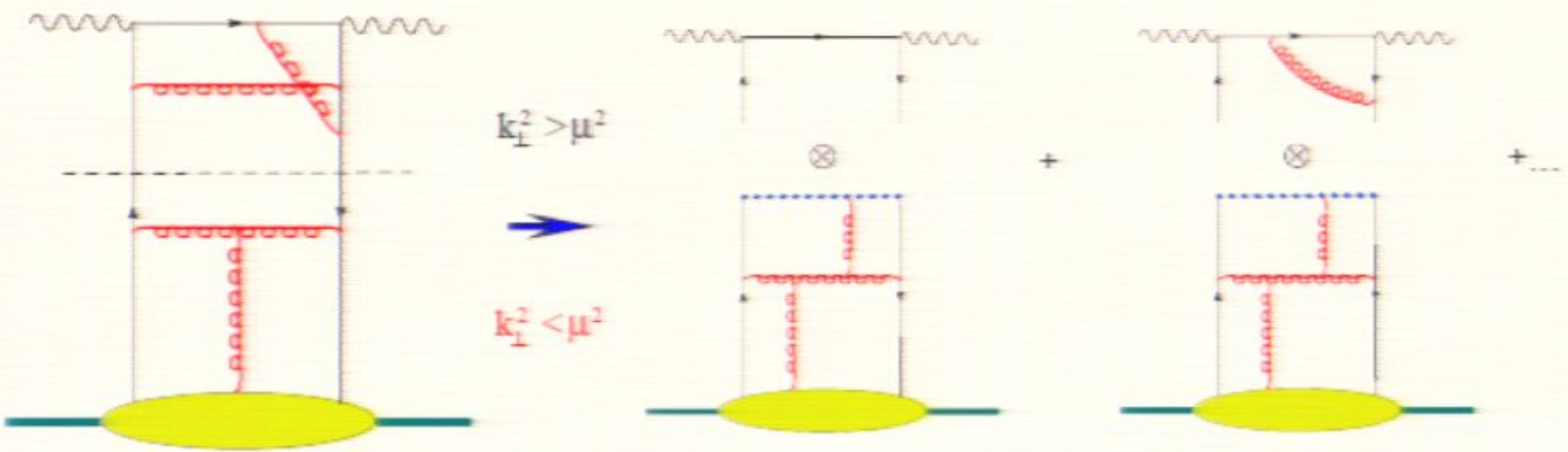
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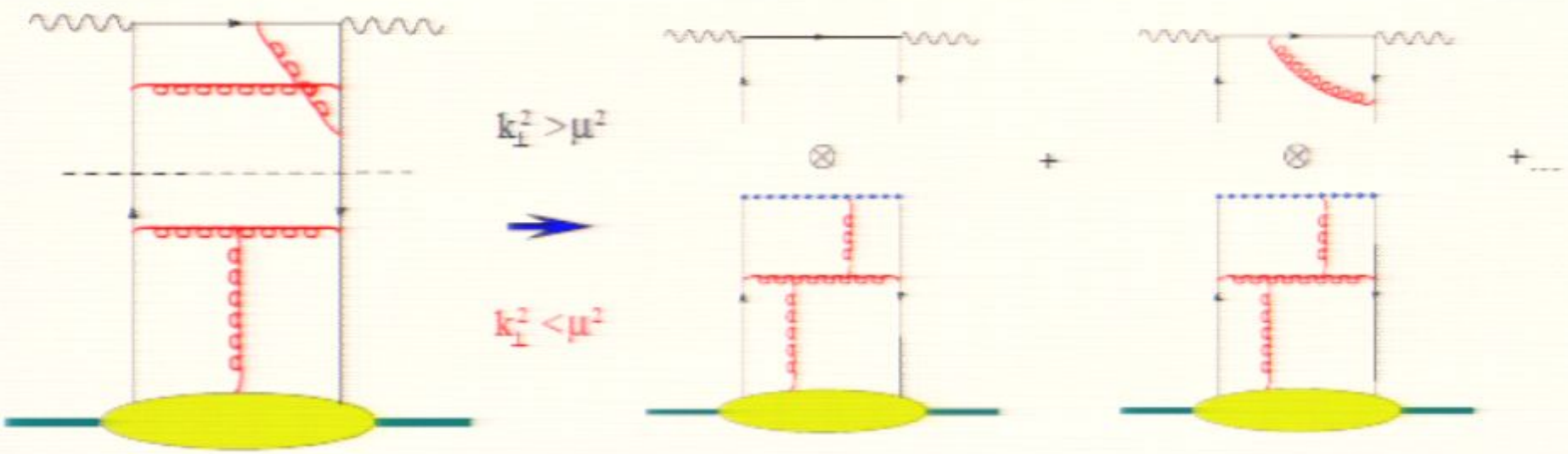
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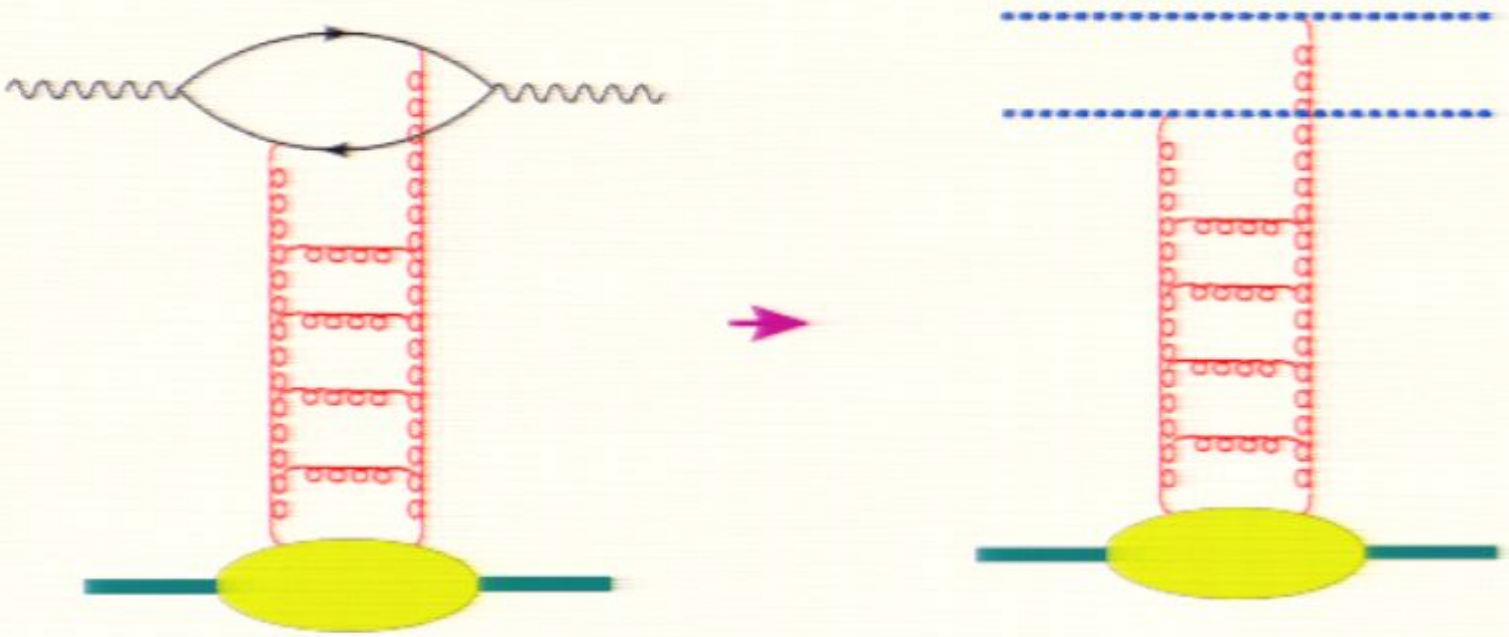
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- At high energies, particles move along straight lines $\Rightarrow$ the amplitude of $\gamma^* A \to \gamma^* A$ scattering reduces to the matrix element of a two-Wilson-line operator (color dipole):

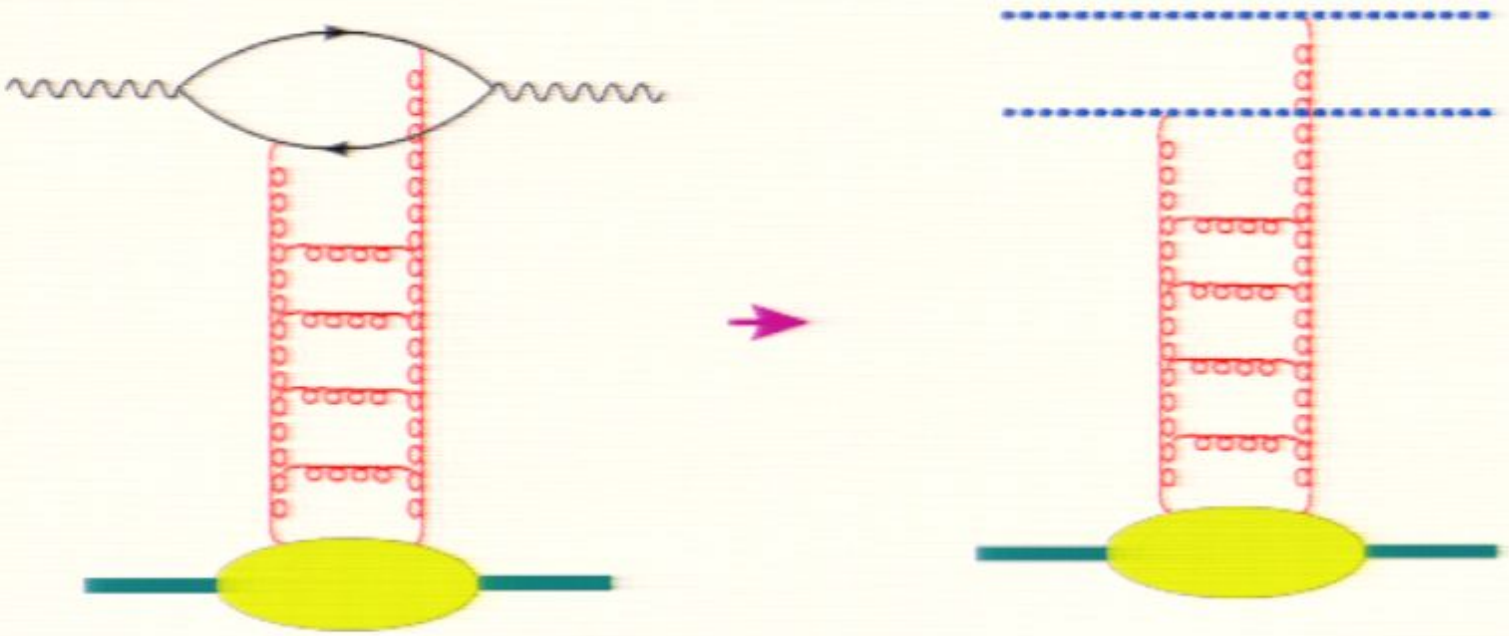


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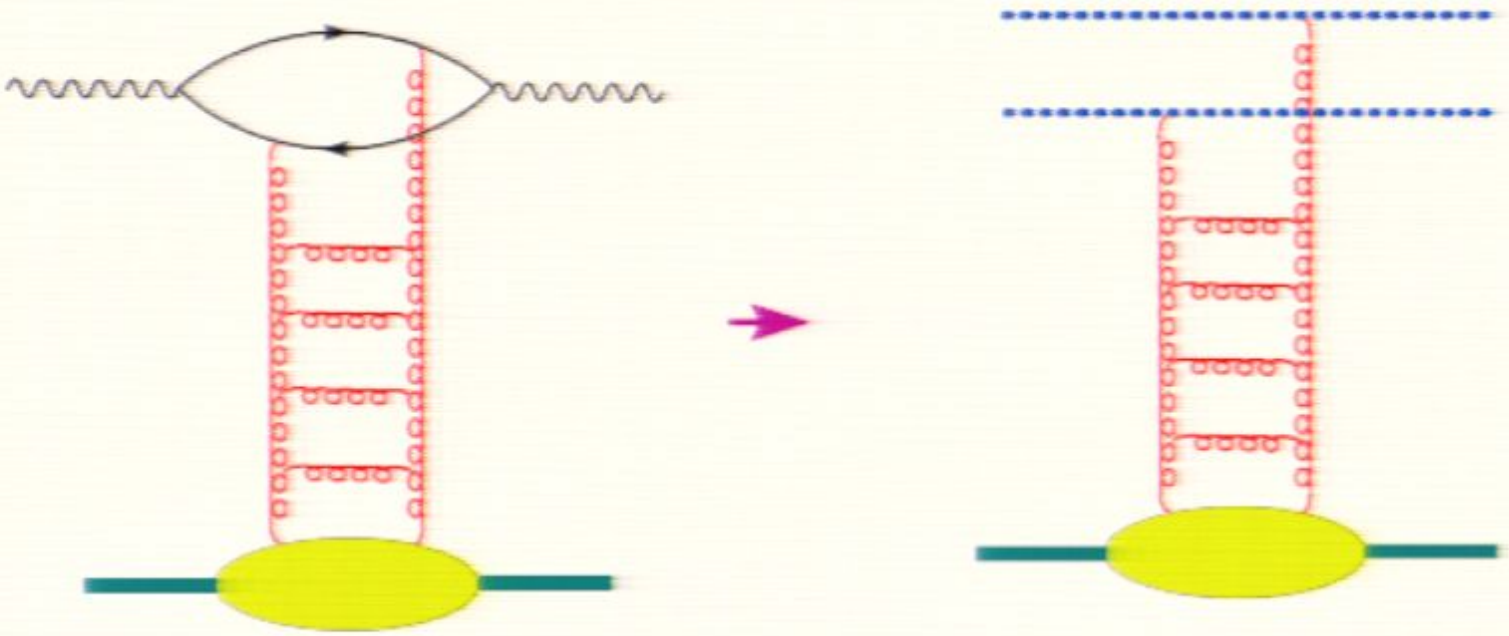
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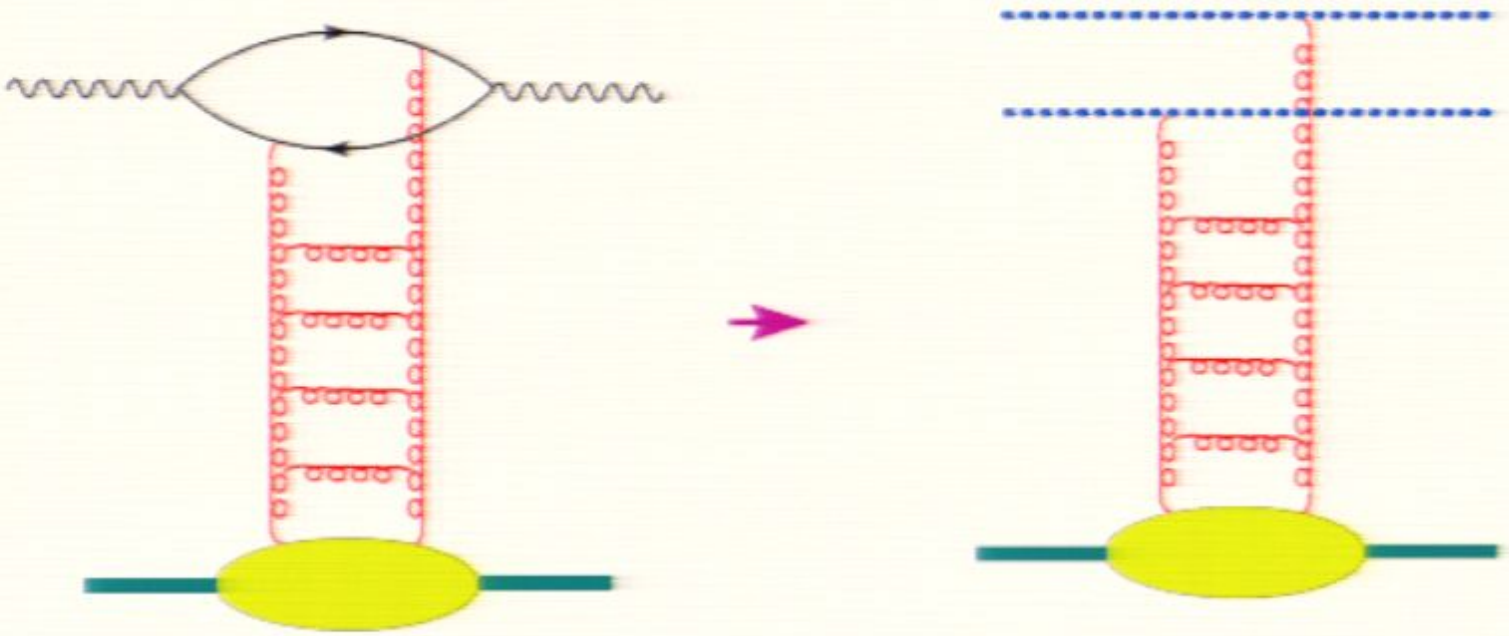


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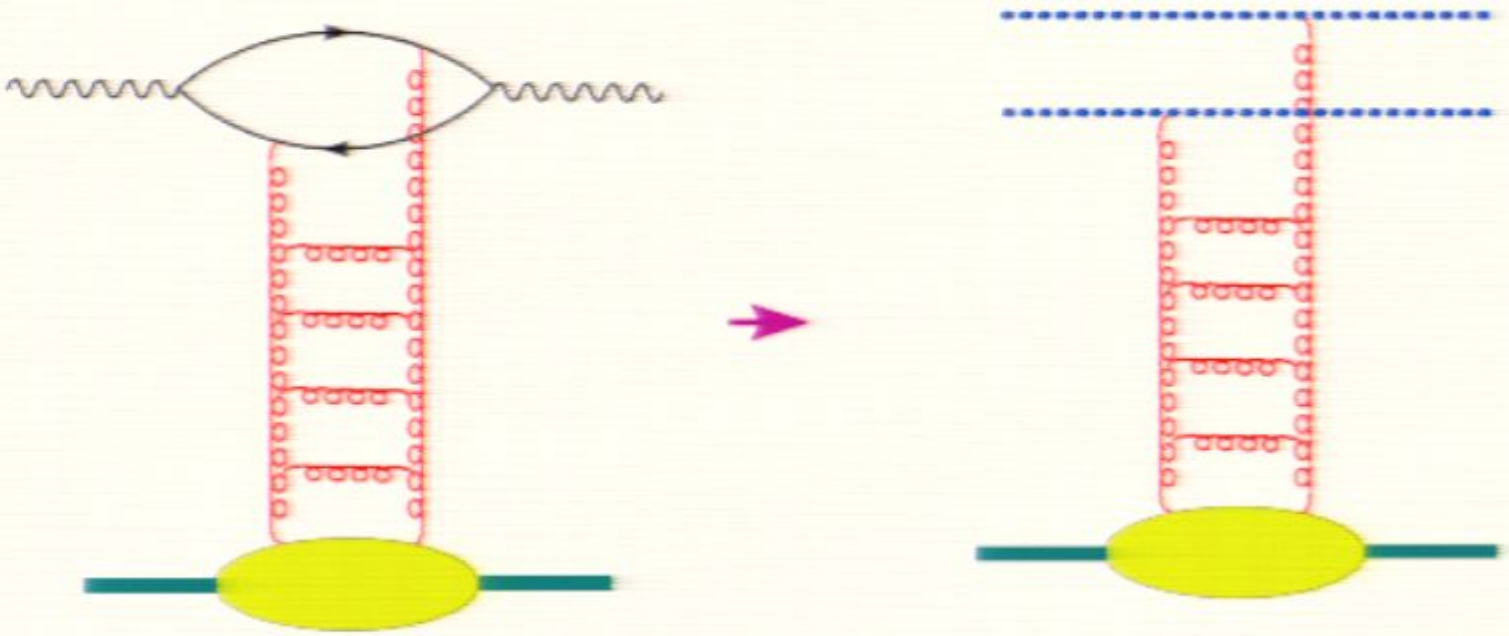
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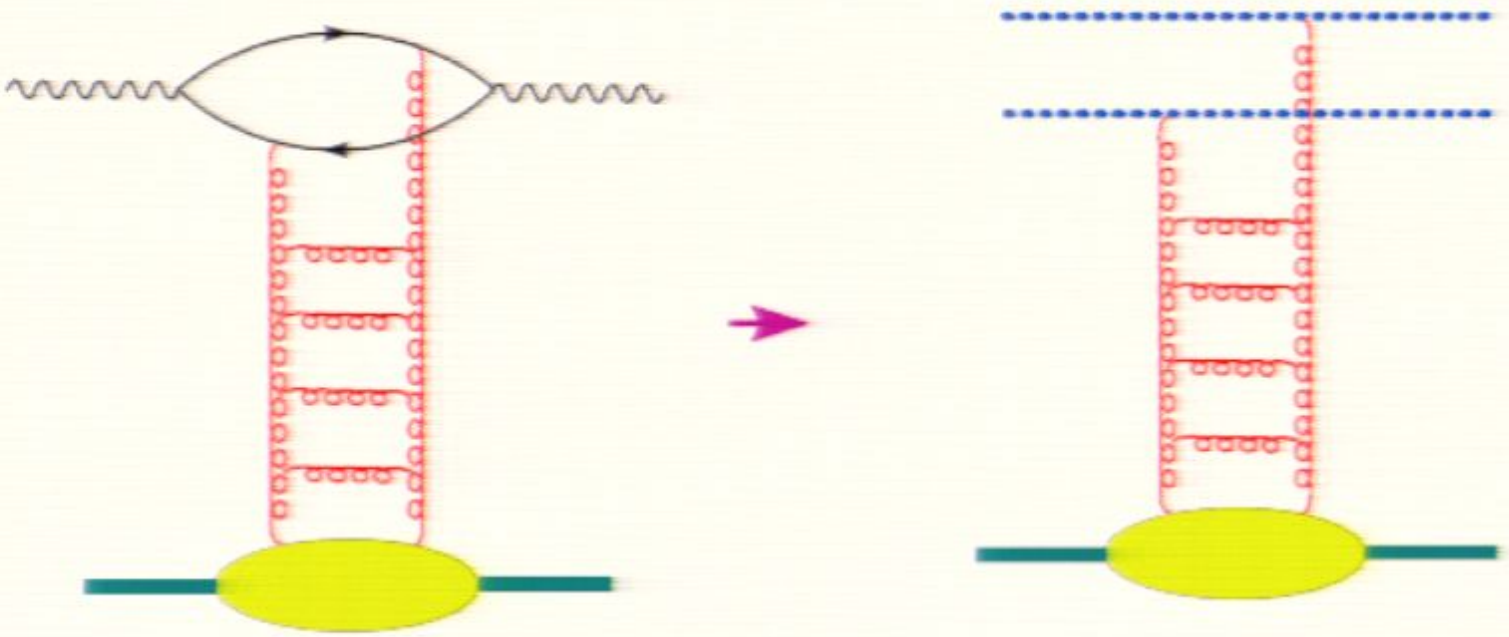
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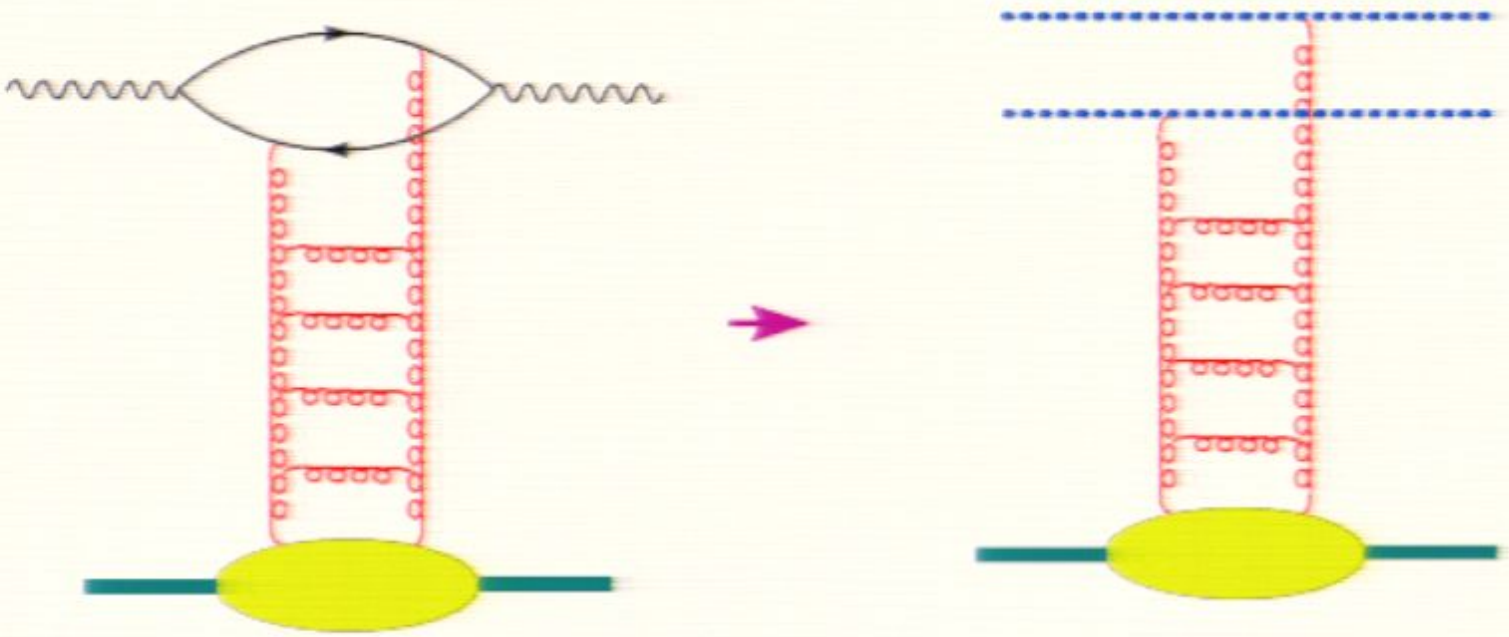
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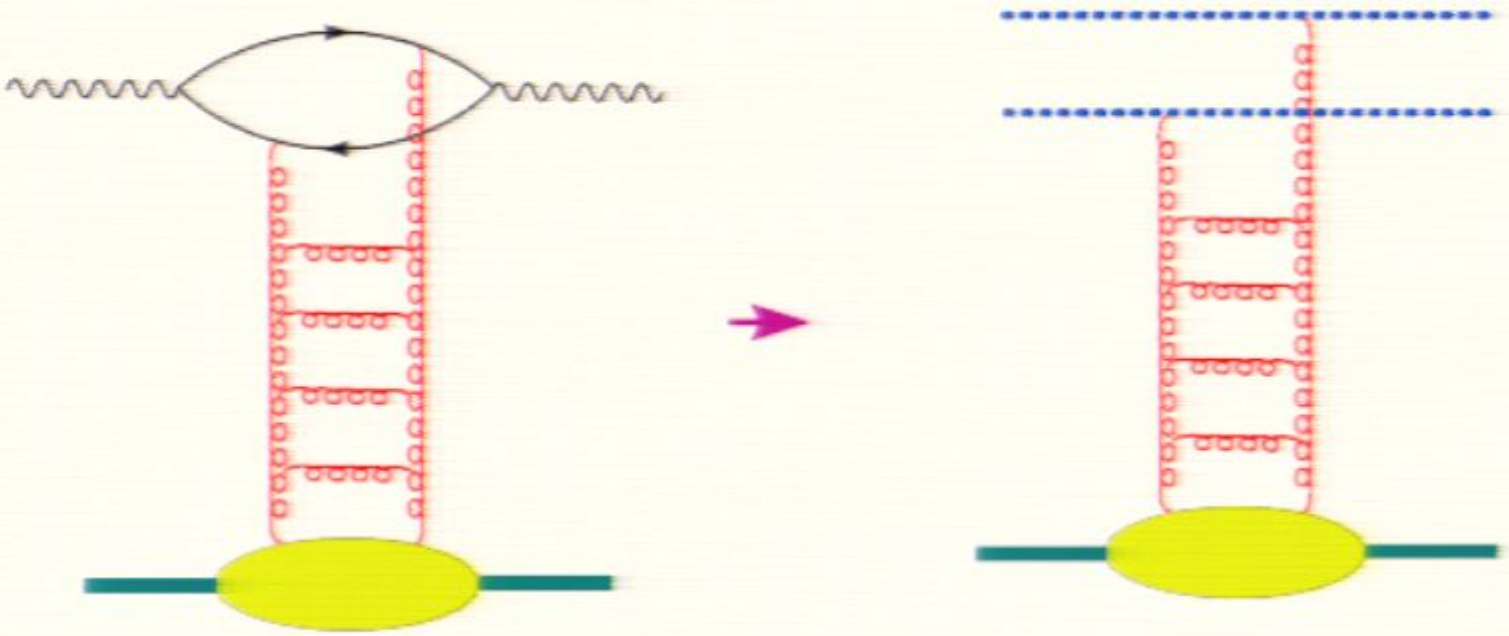
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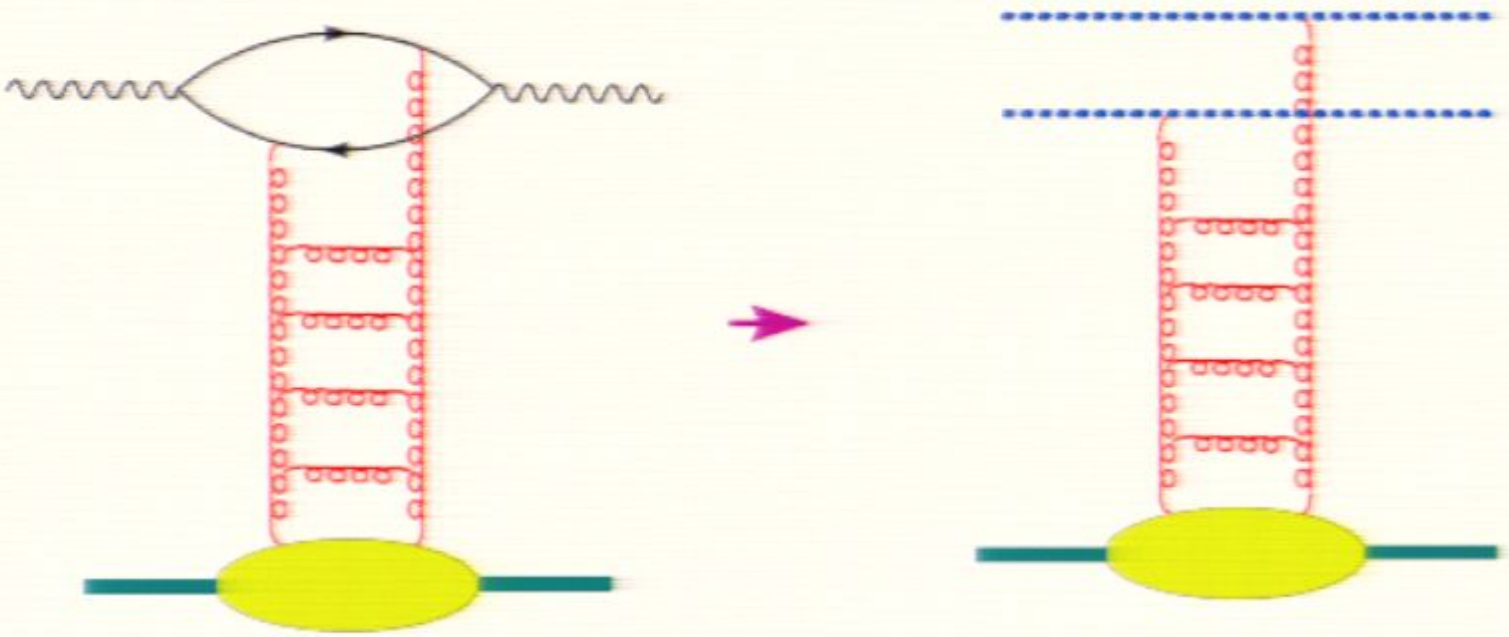
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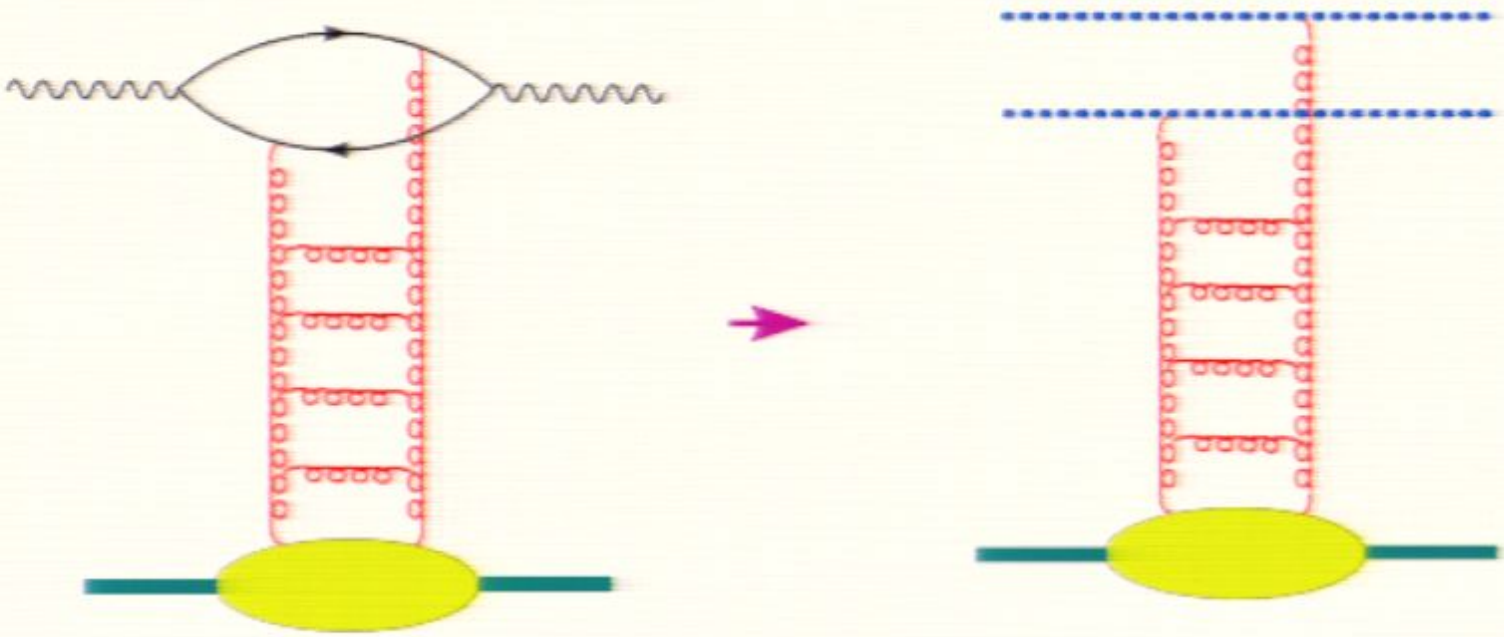
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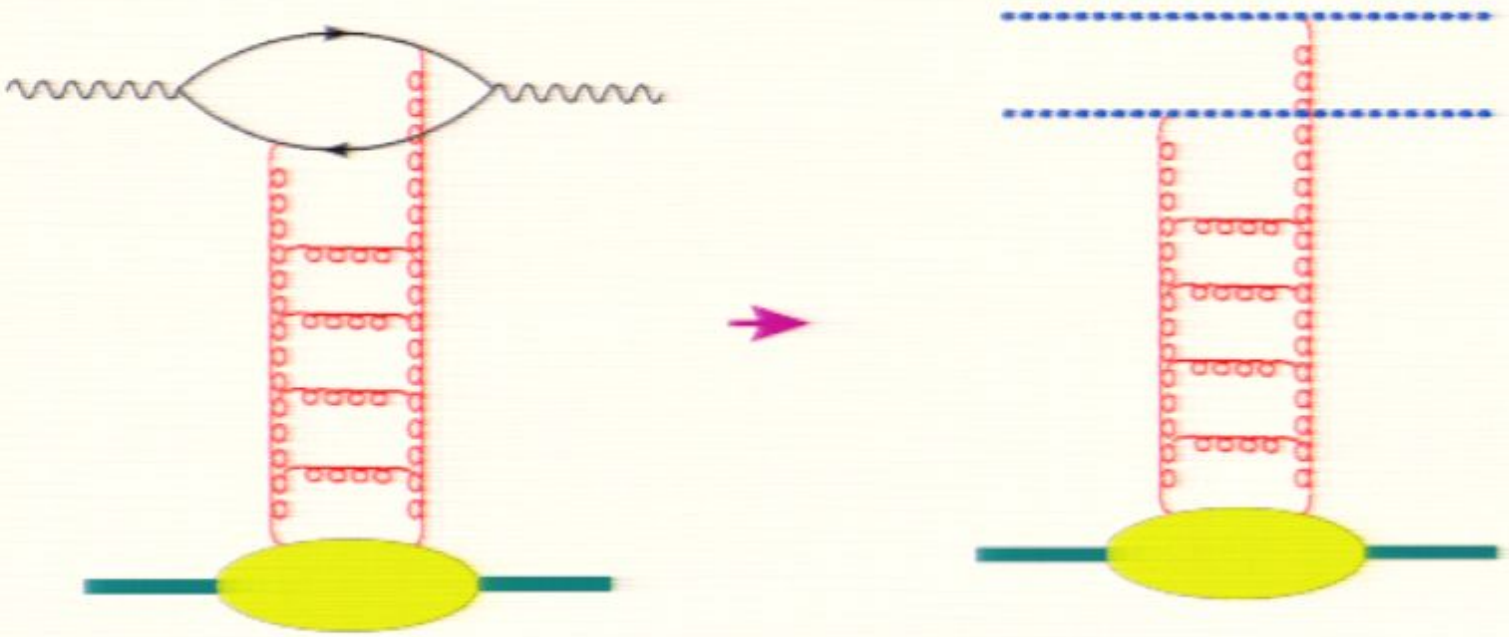
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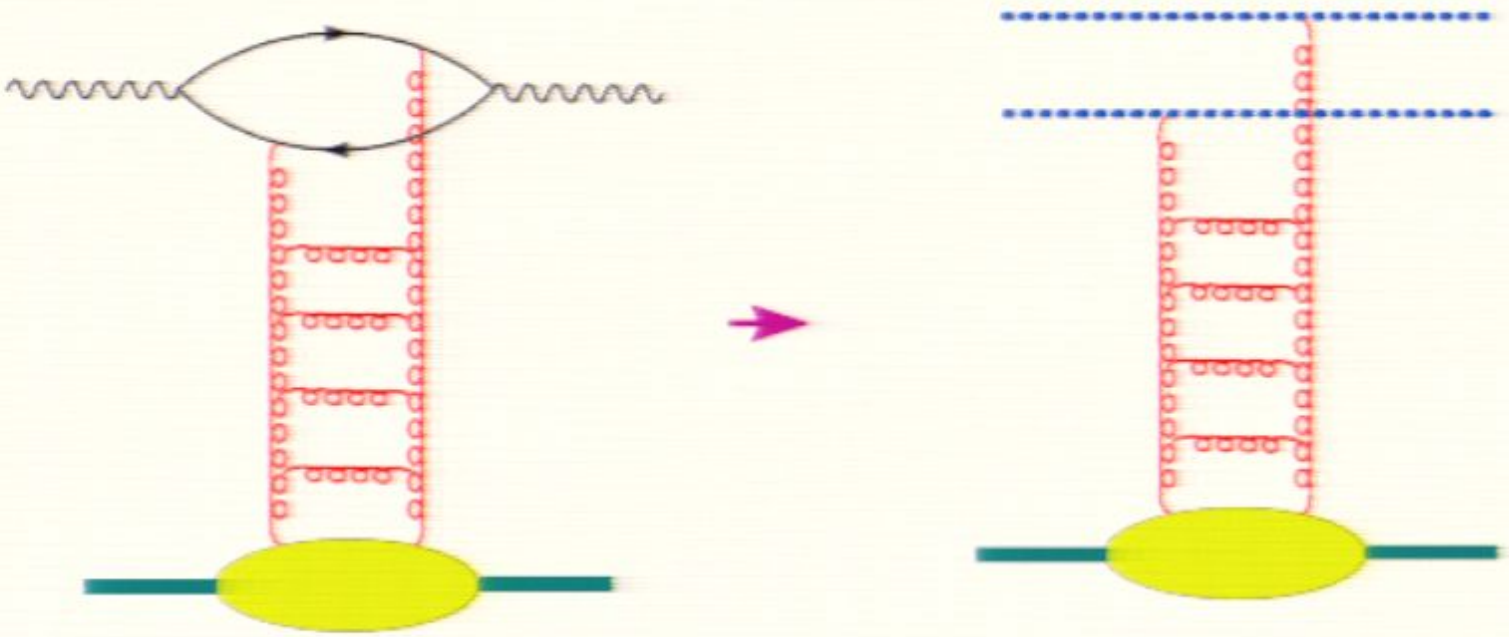
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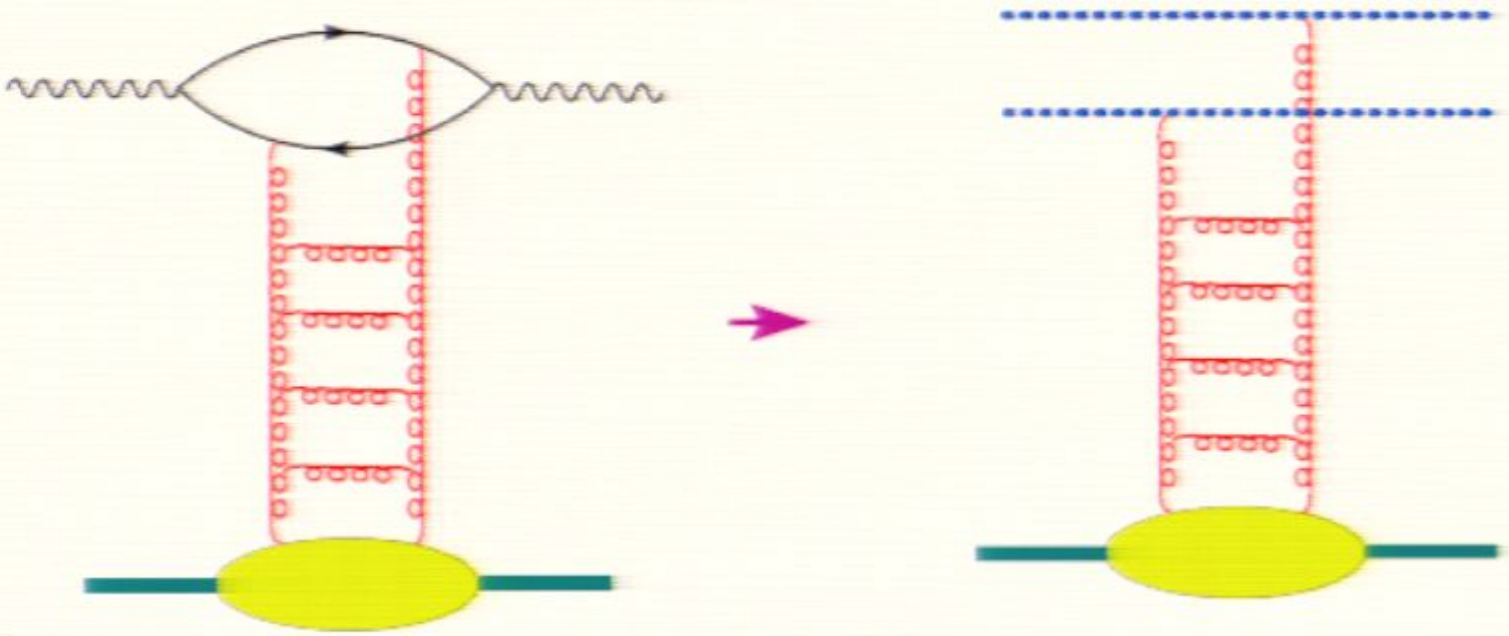
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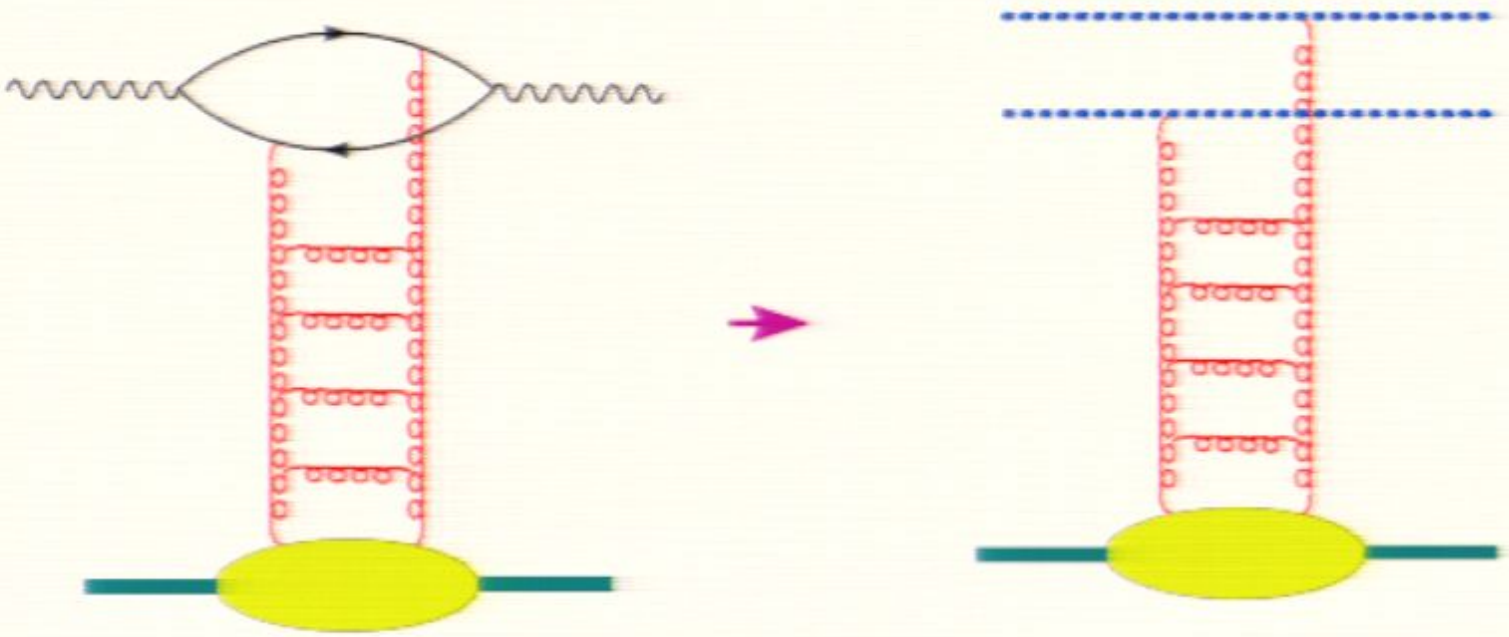
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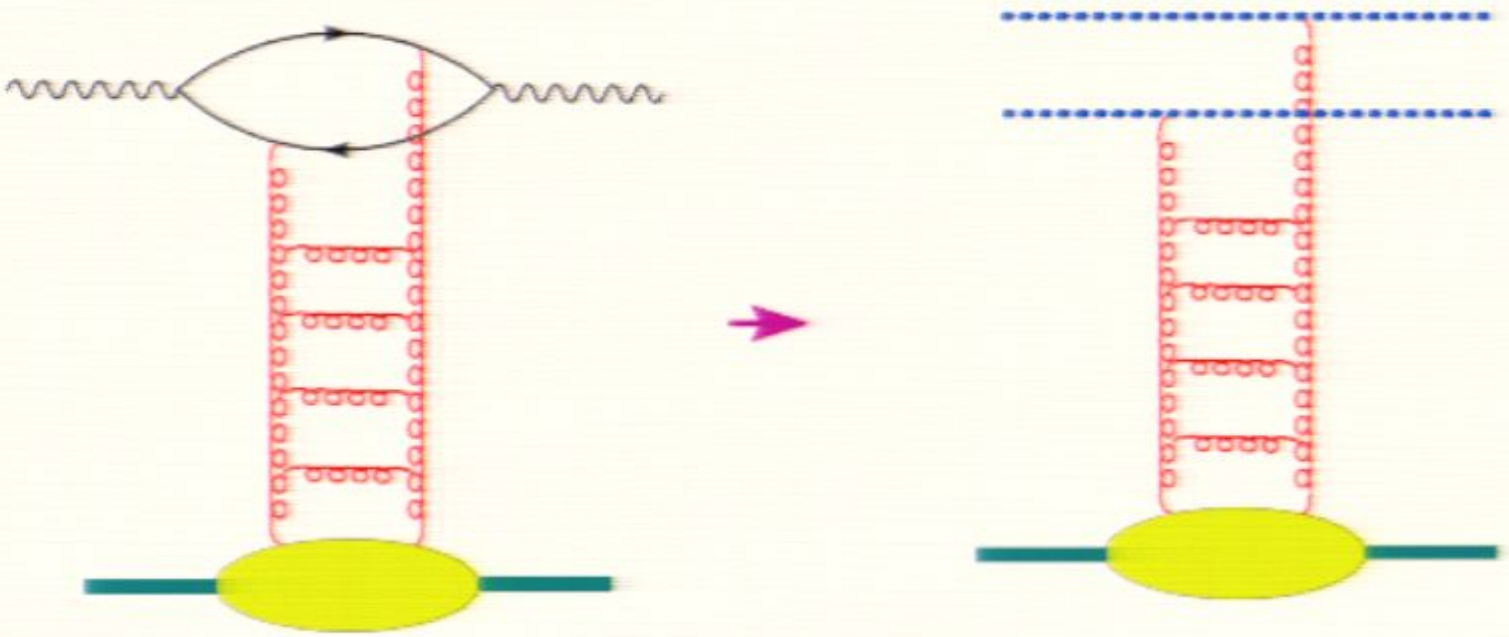
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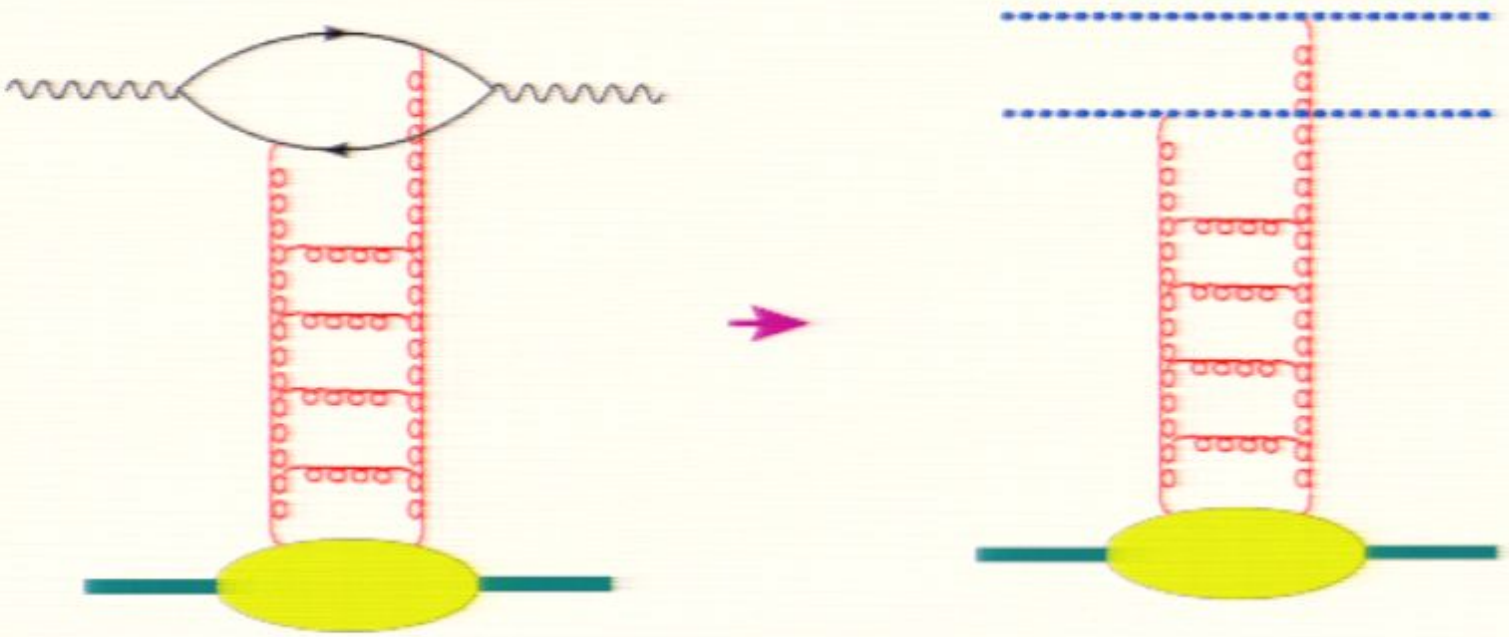
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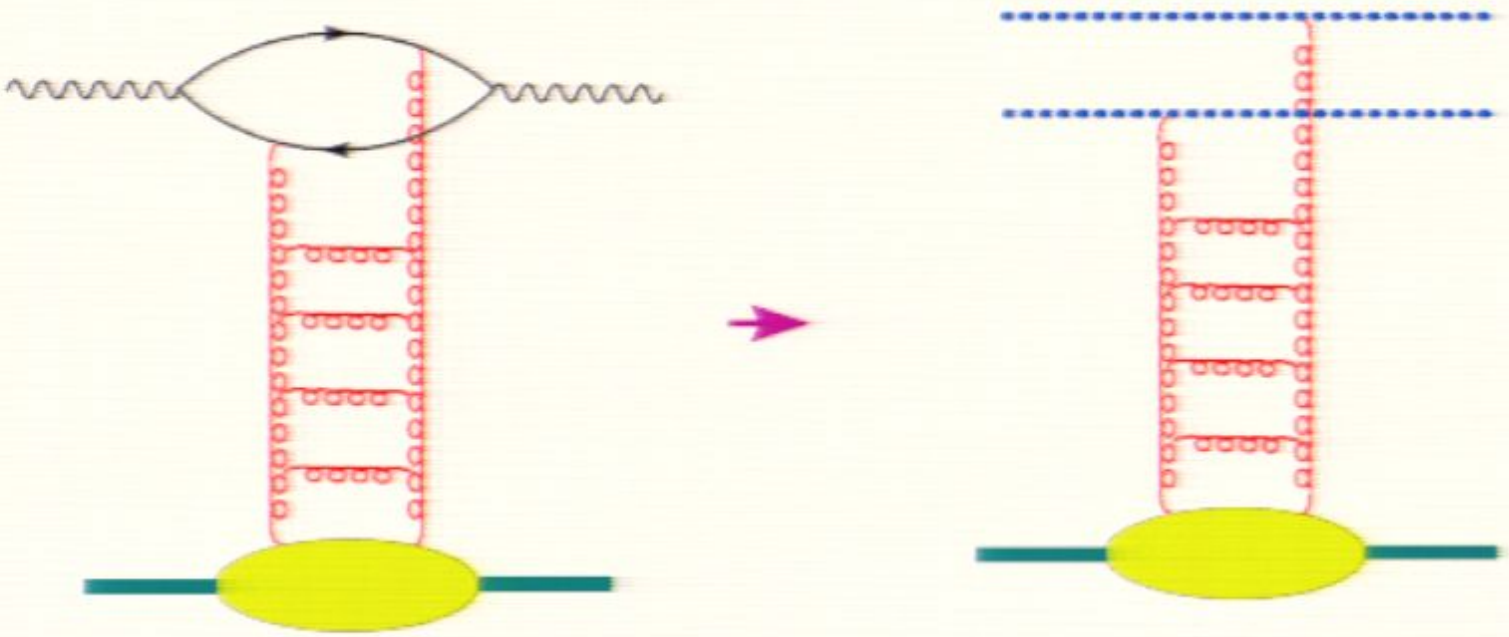
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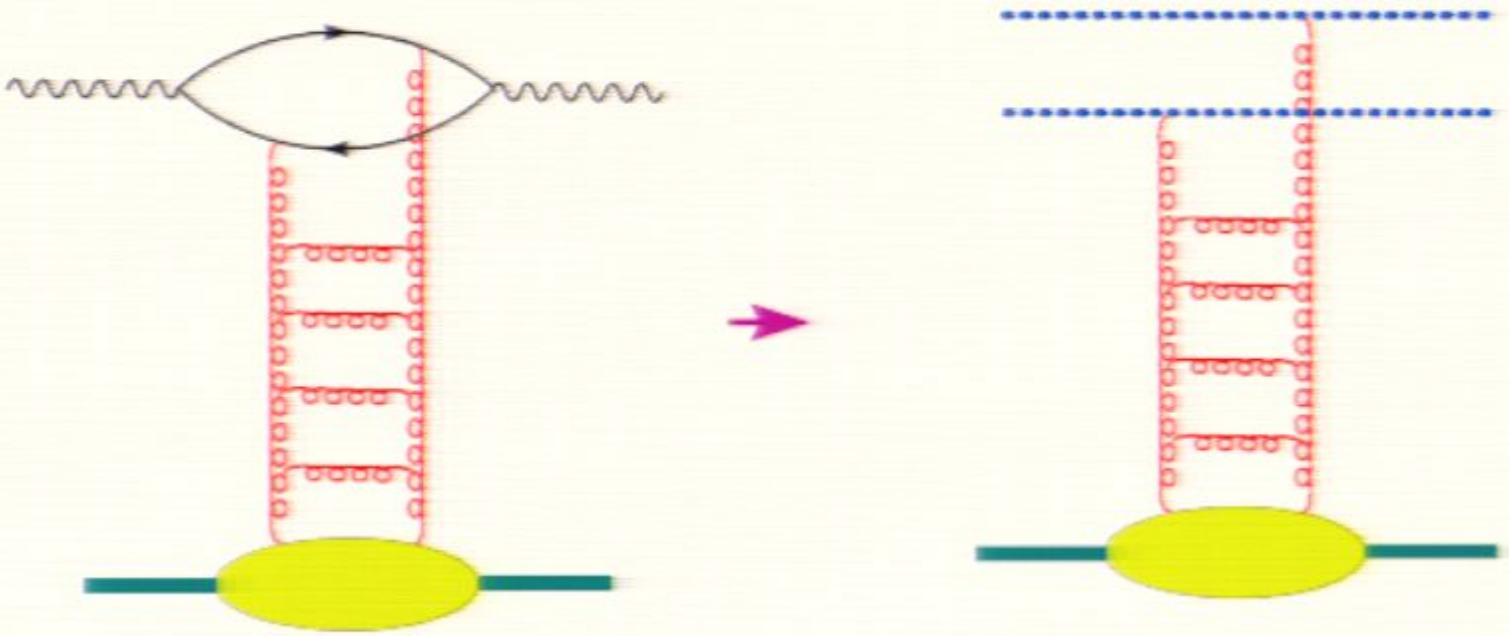
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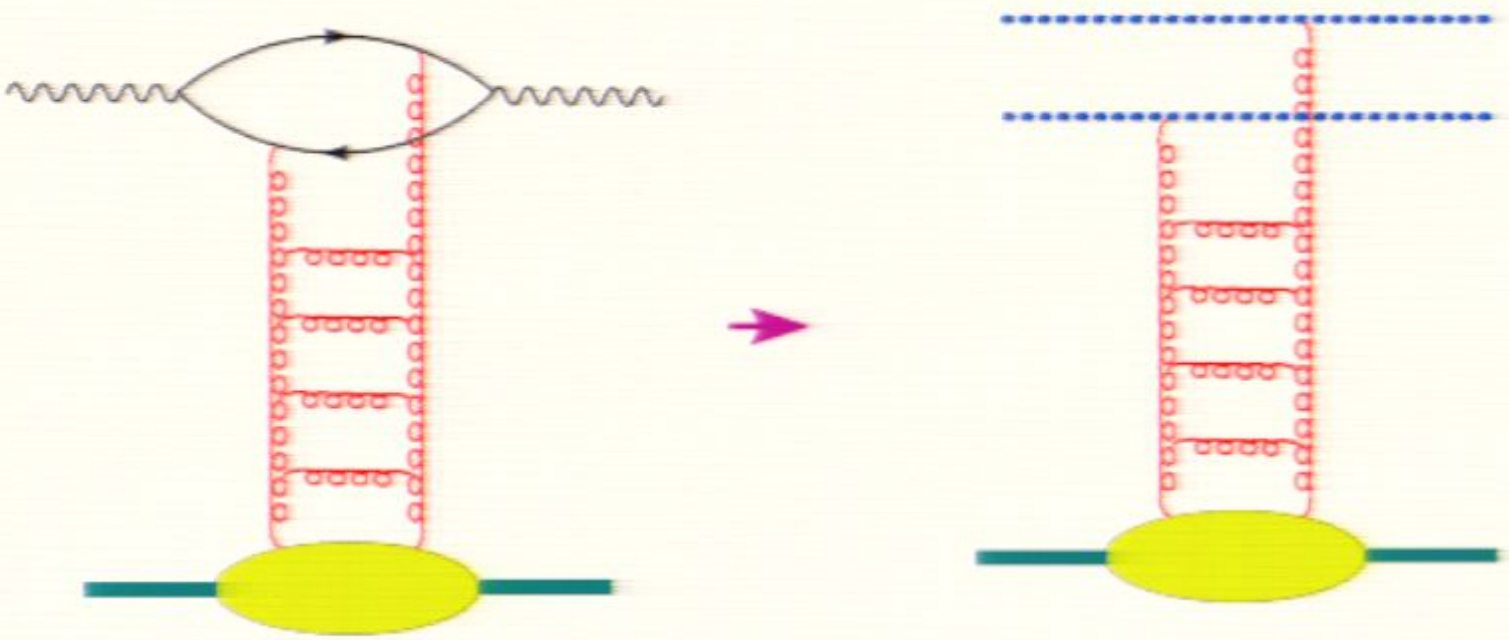
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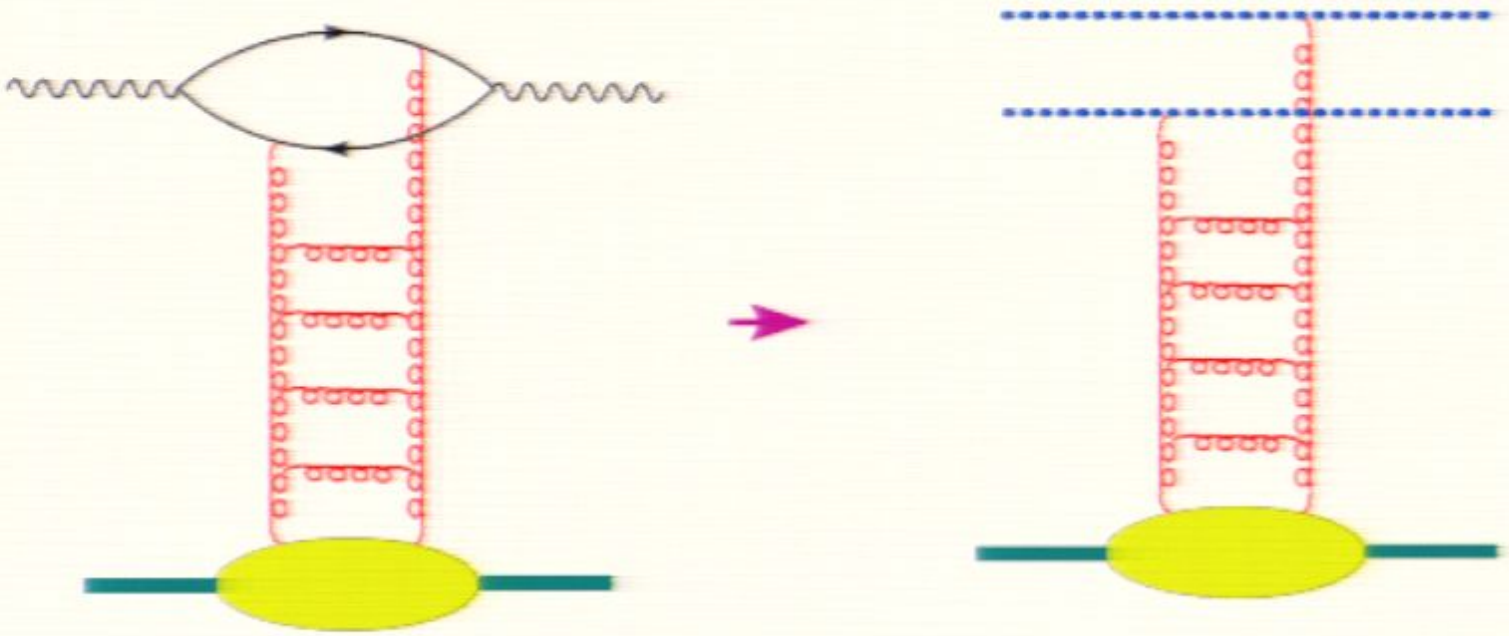
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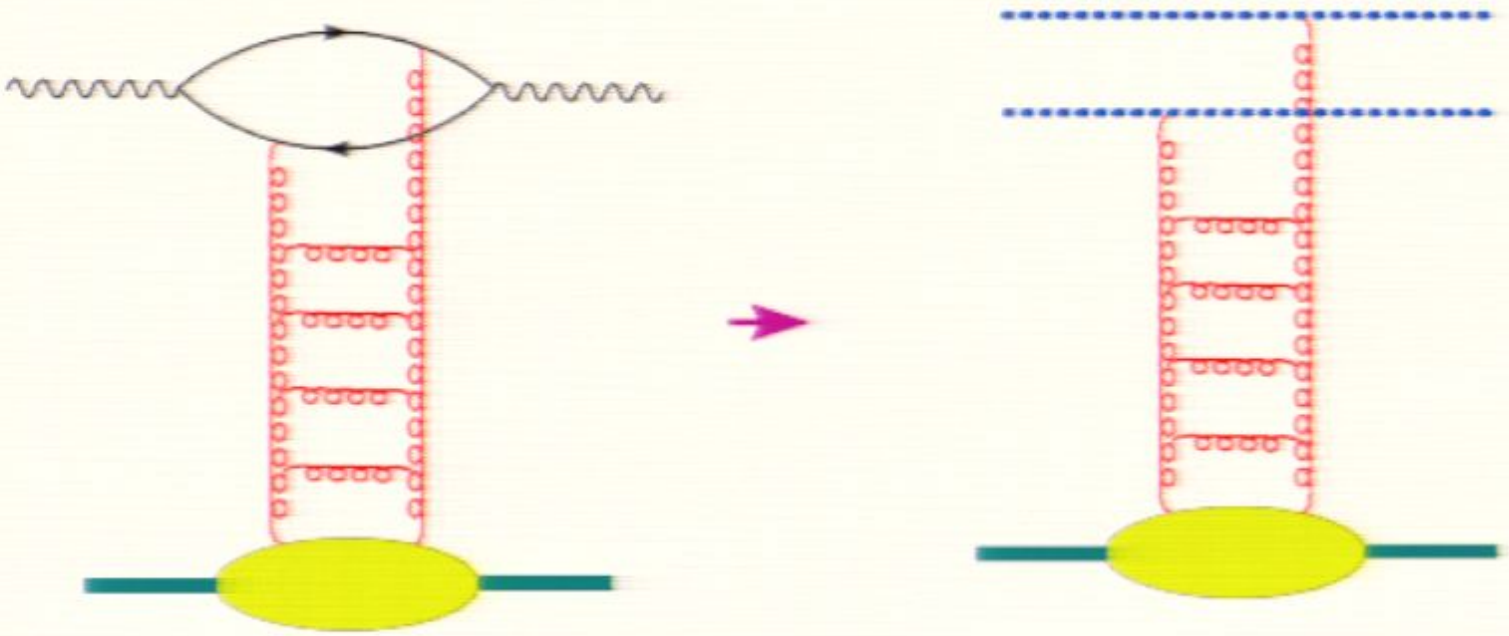
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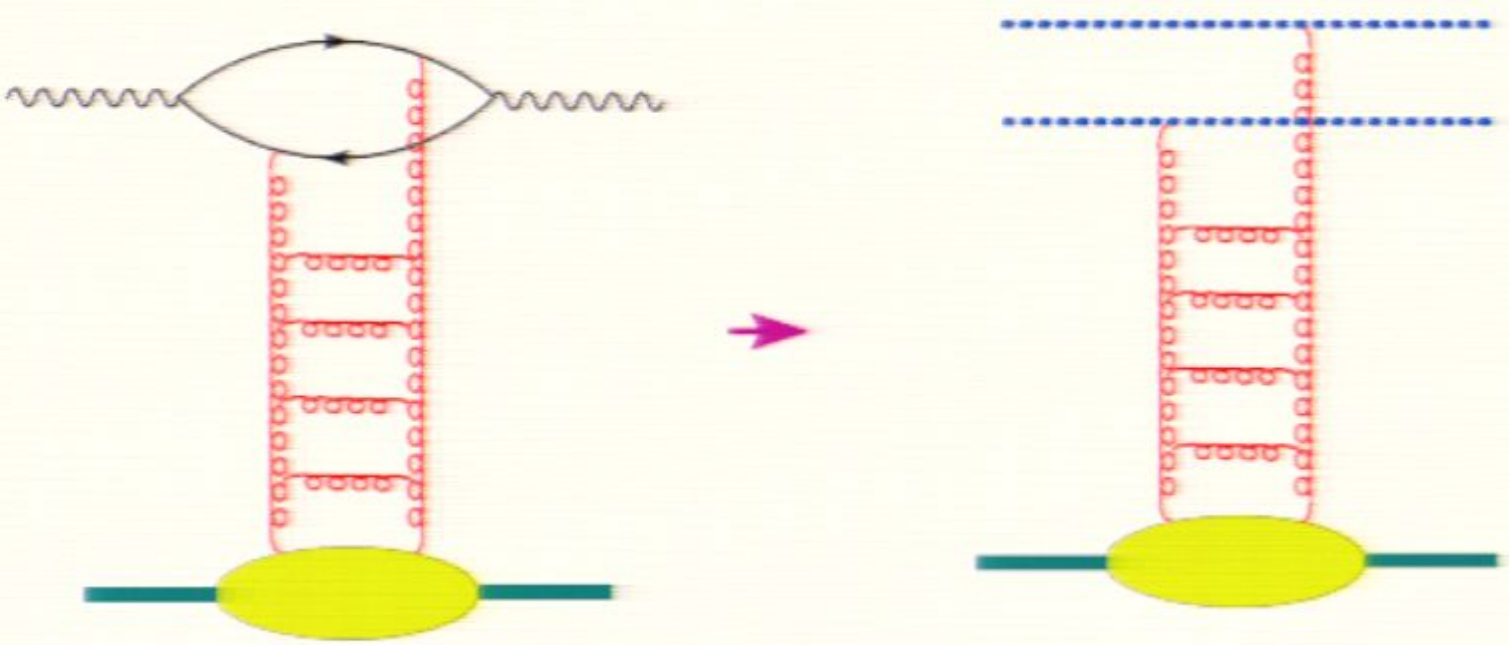
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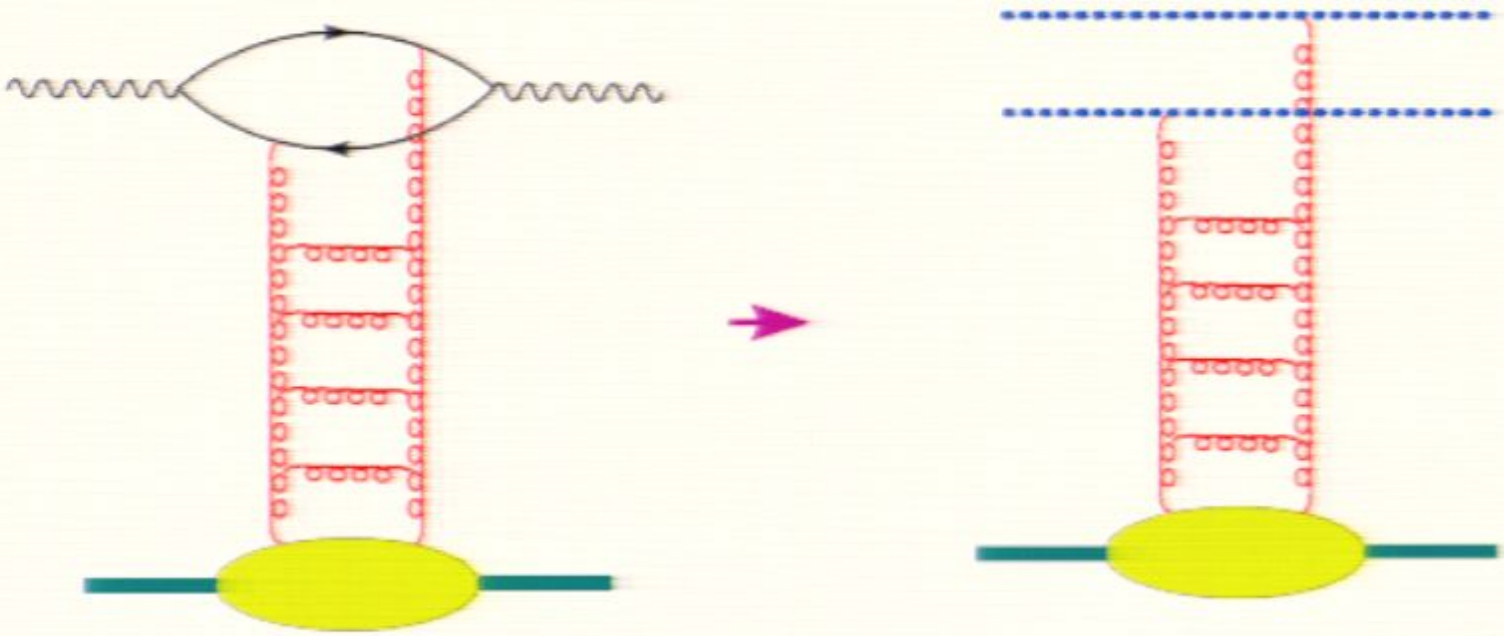
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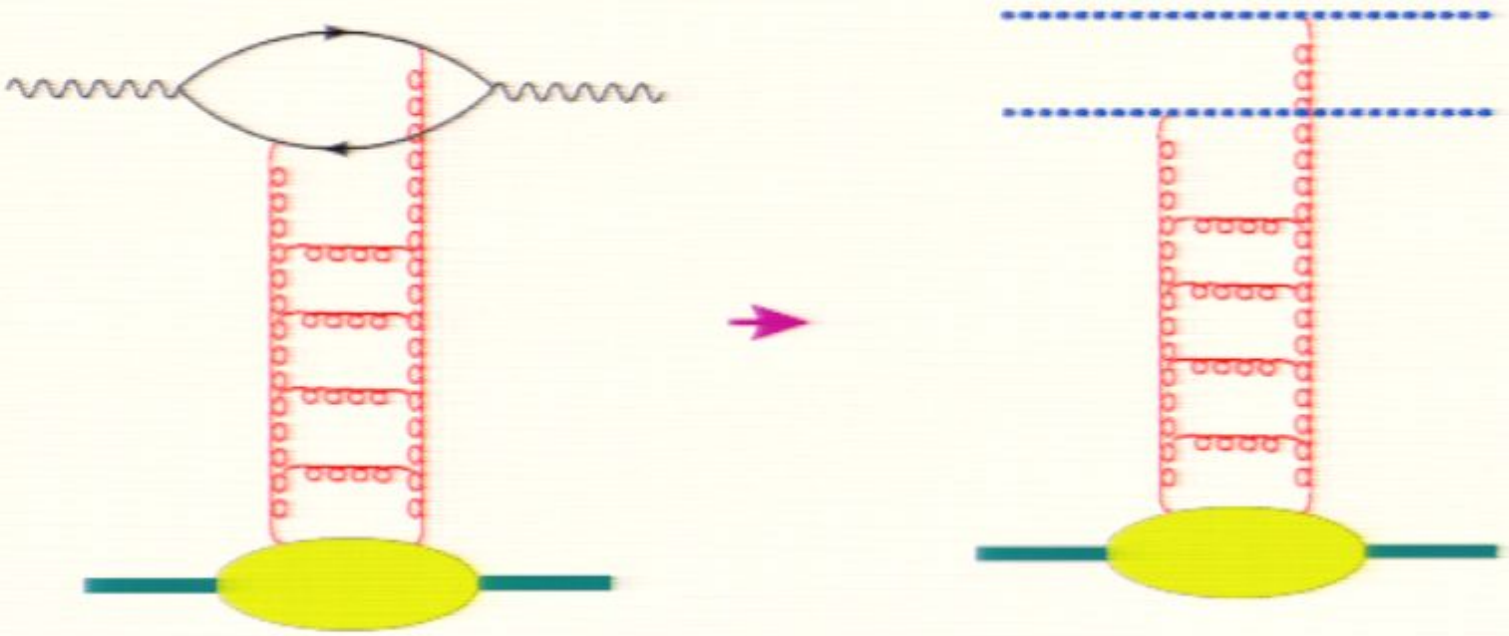
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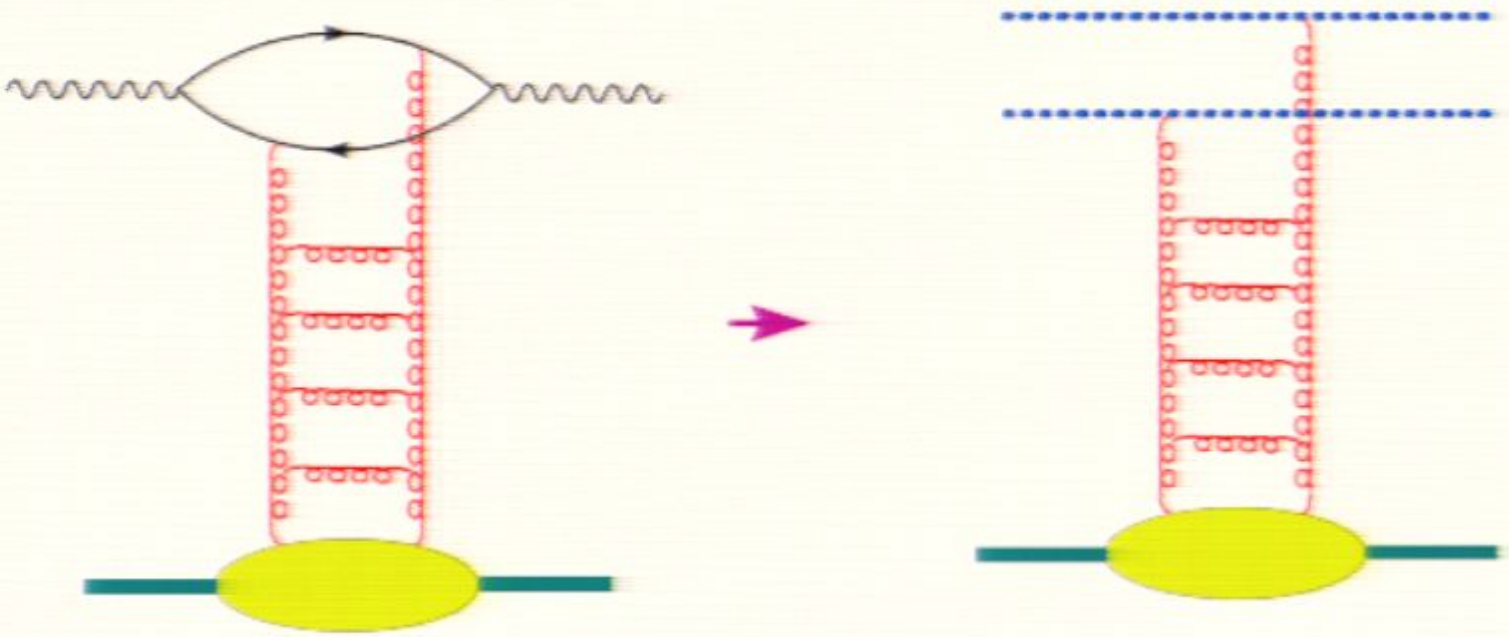
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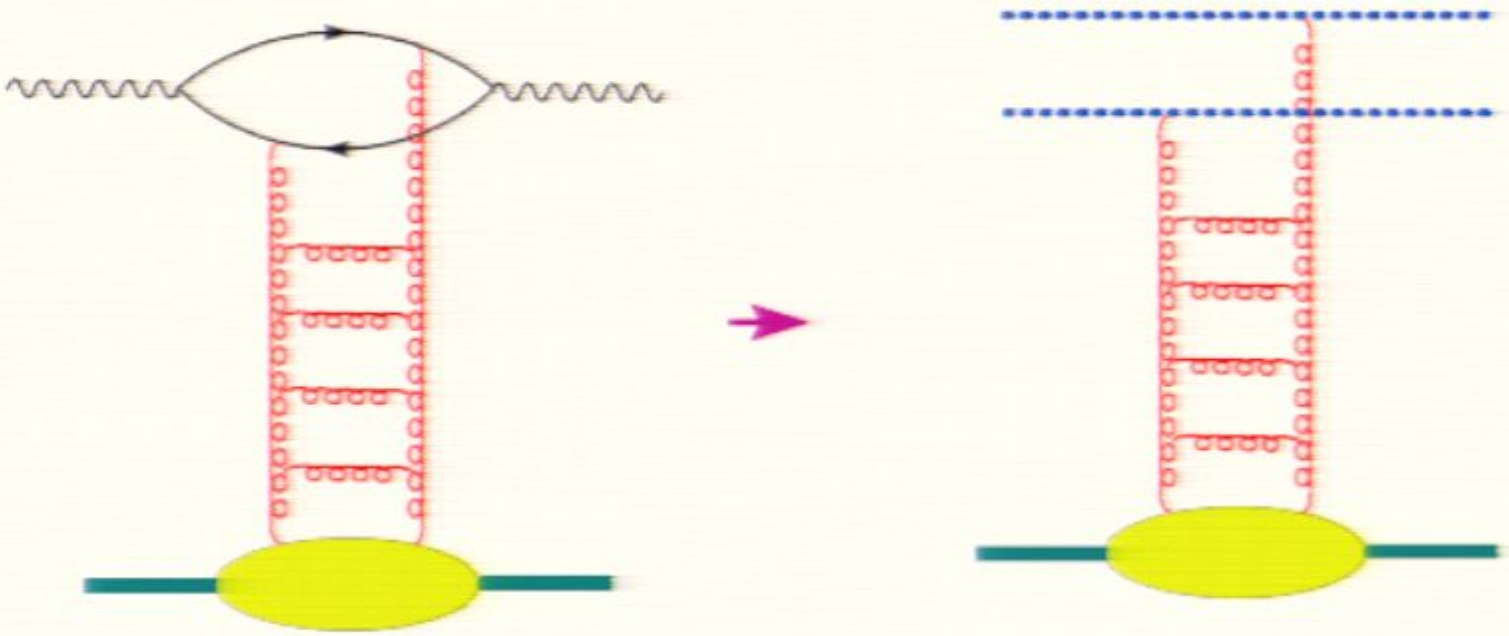
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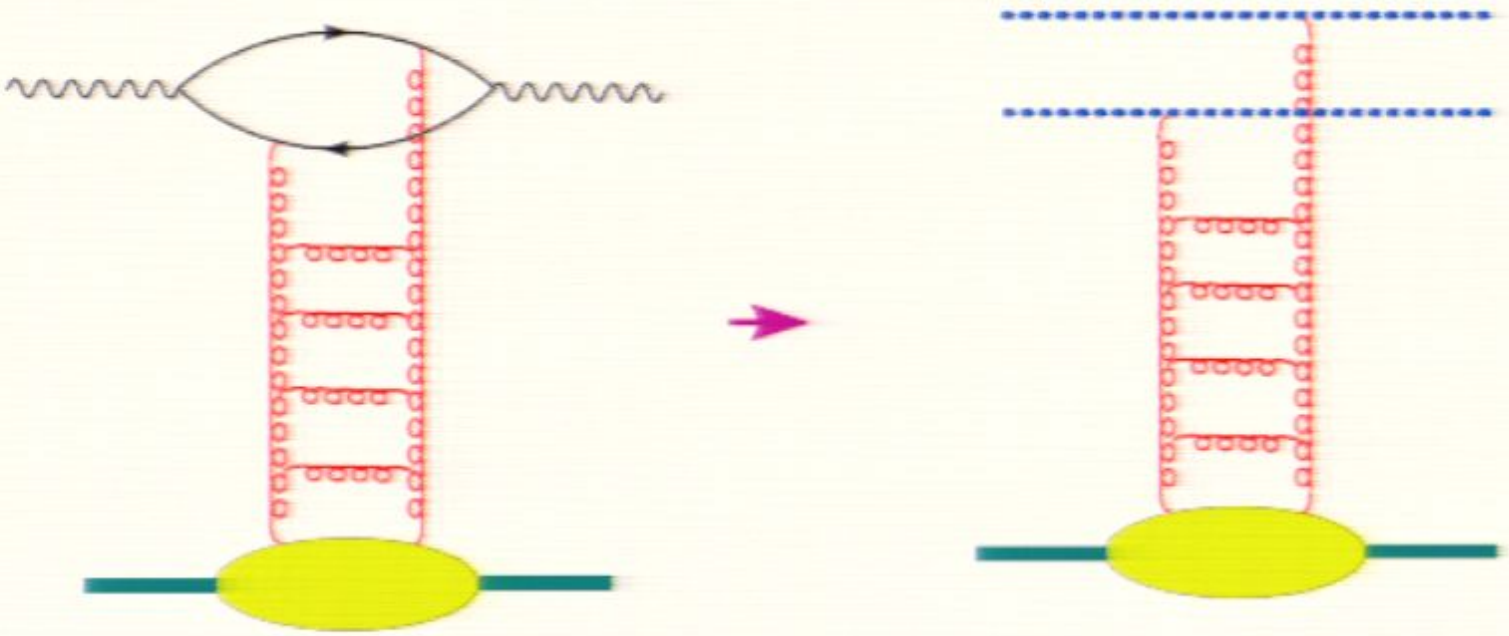
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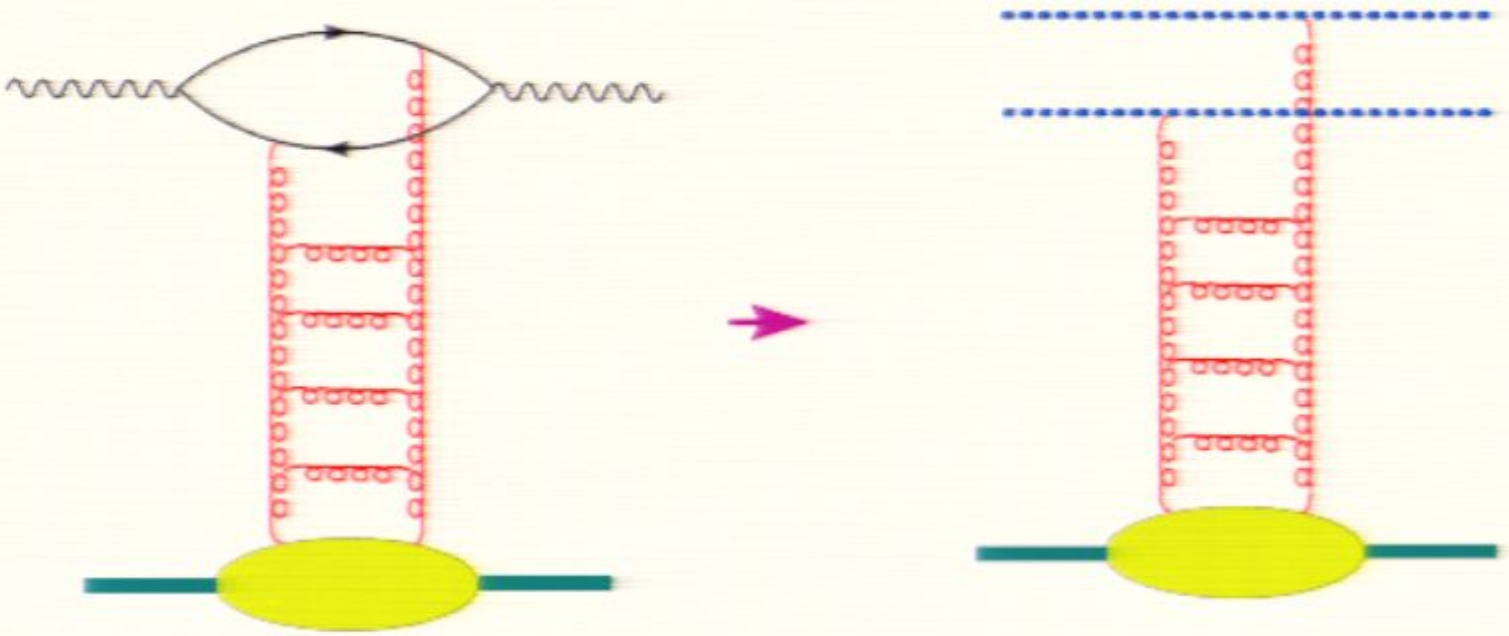
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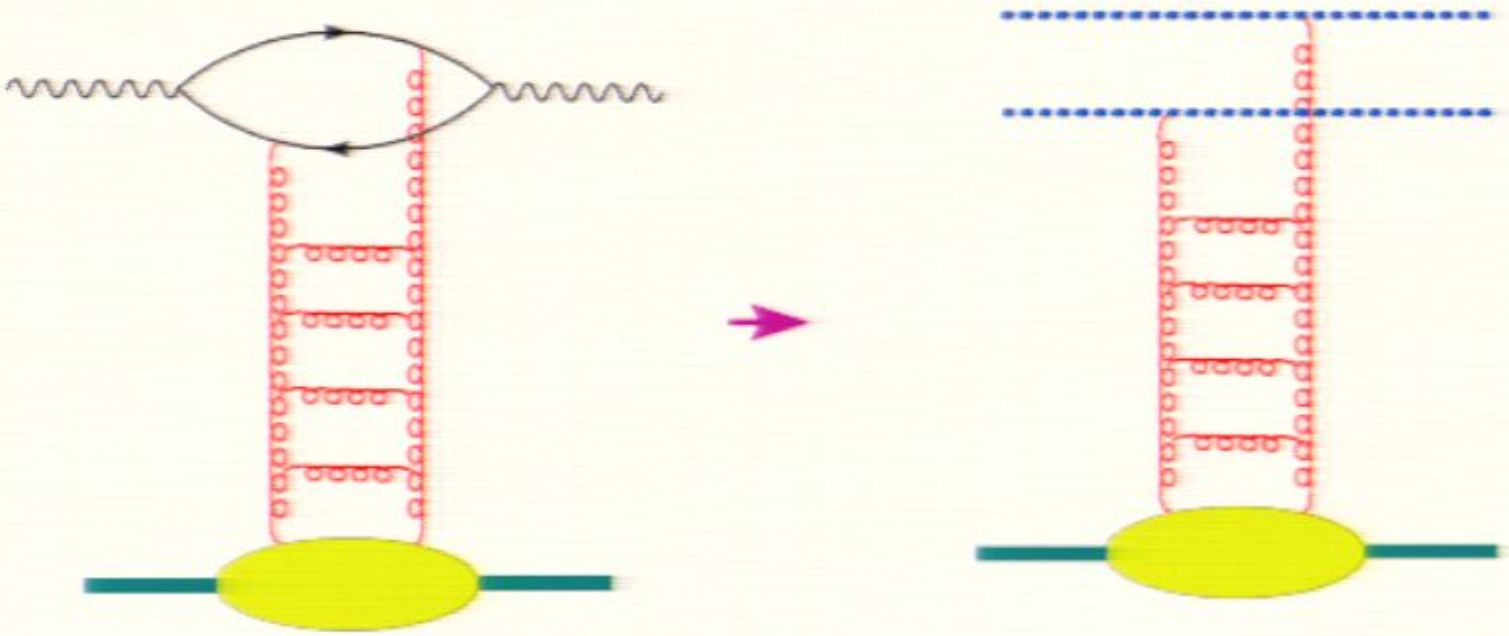
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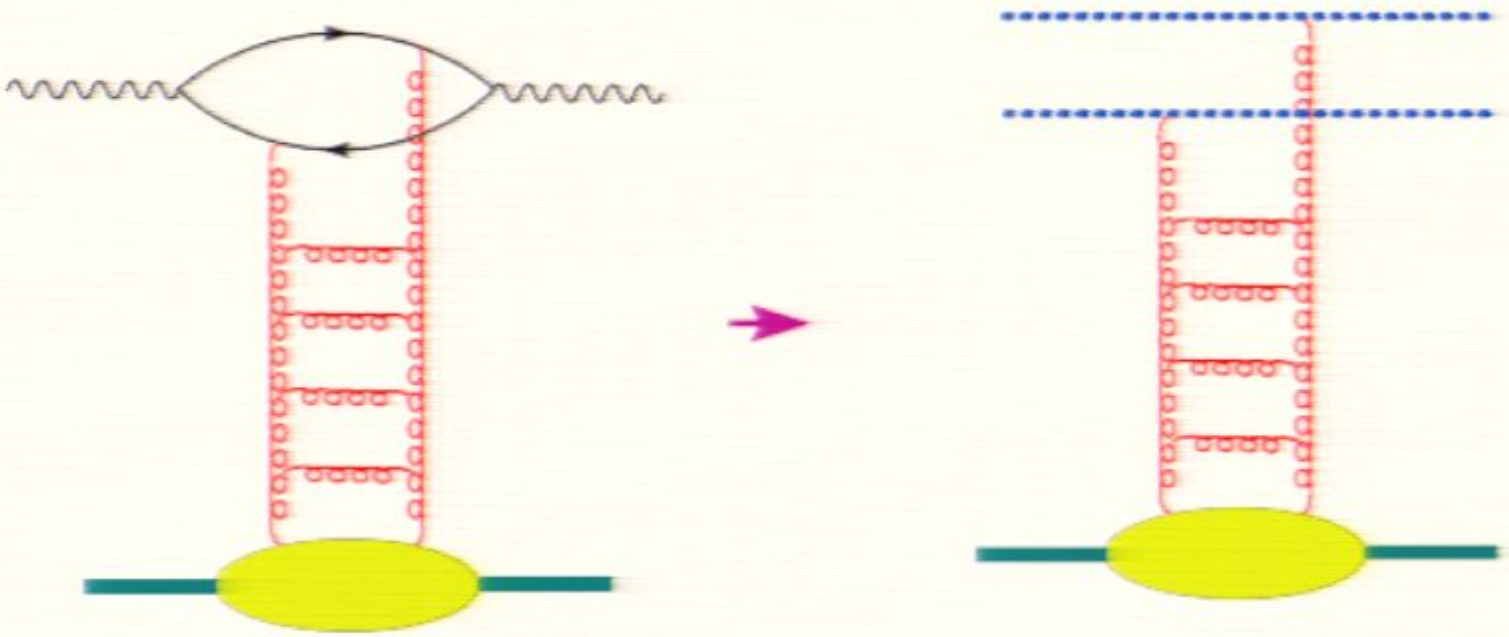
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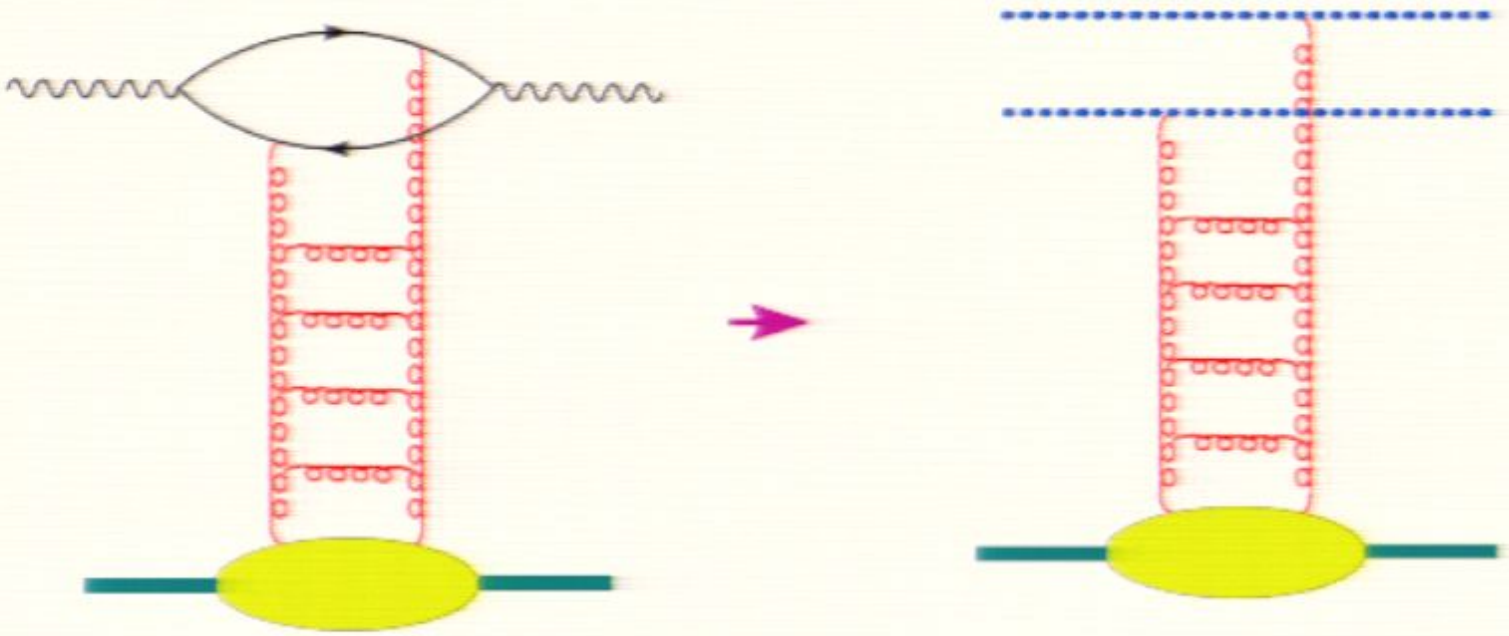
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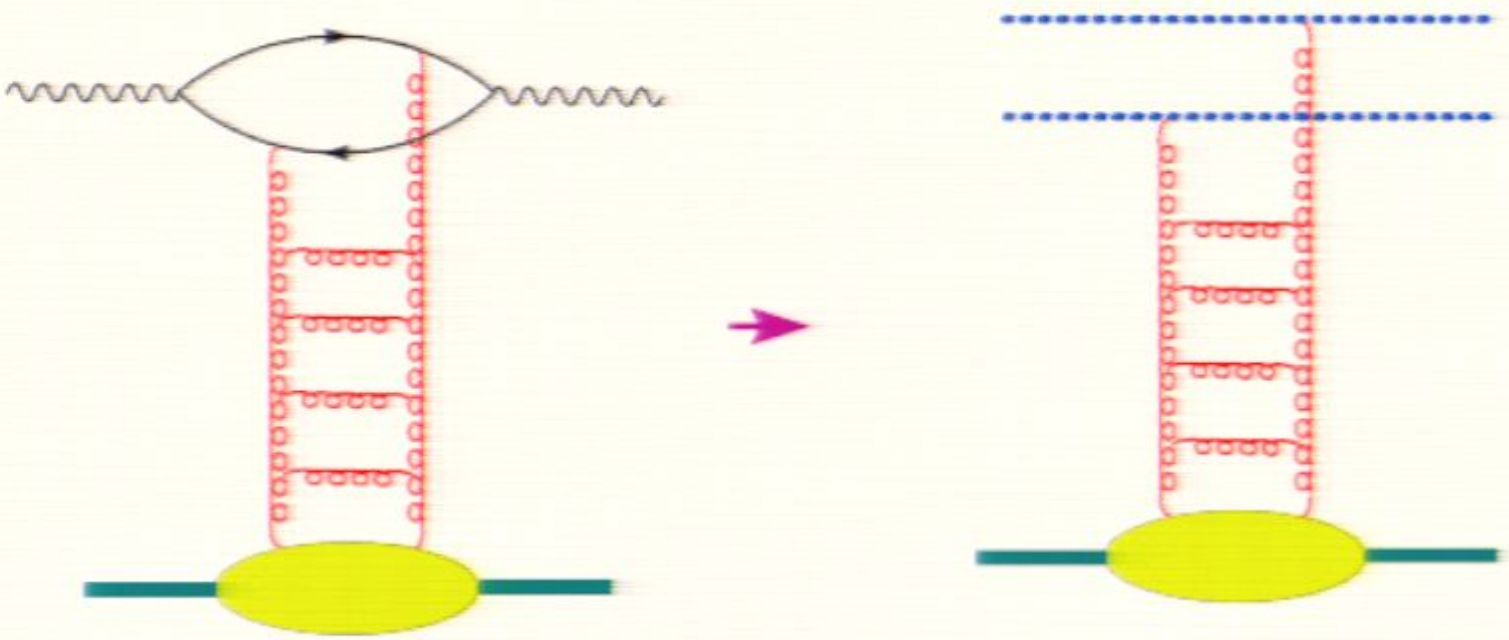
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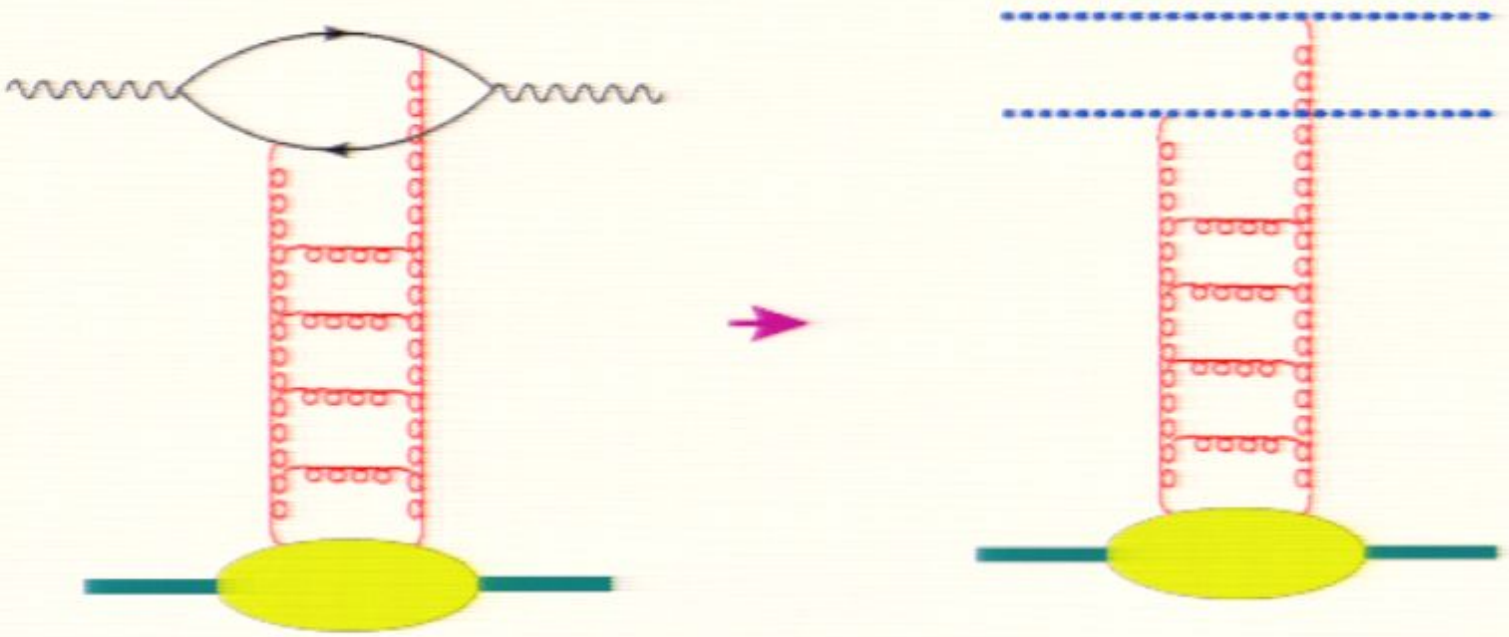
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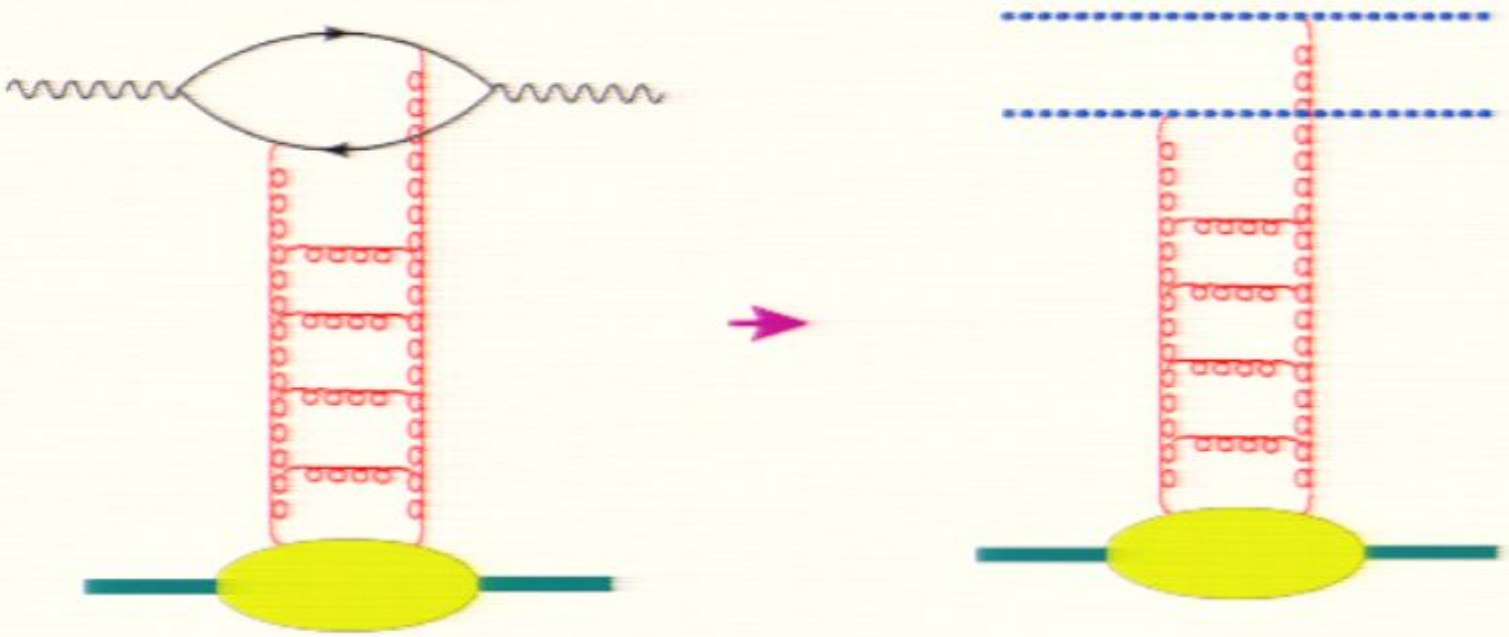


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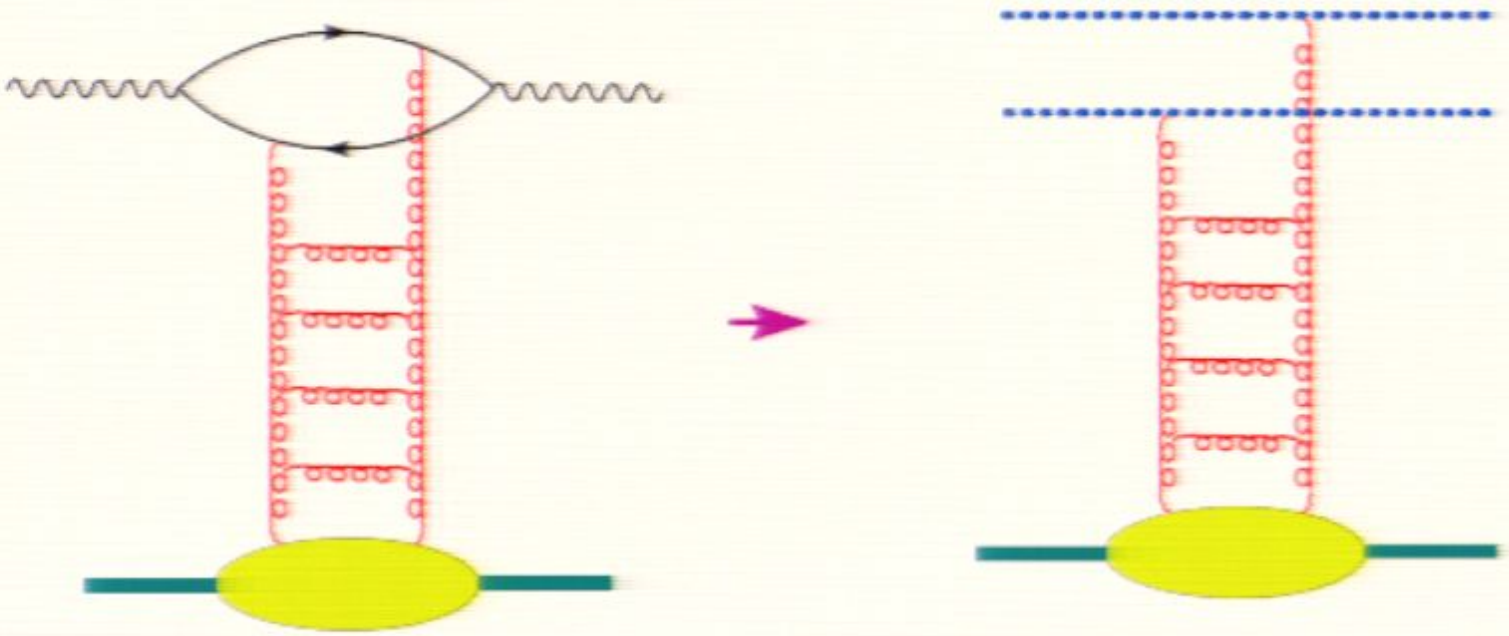
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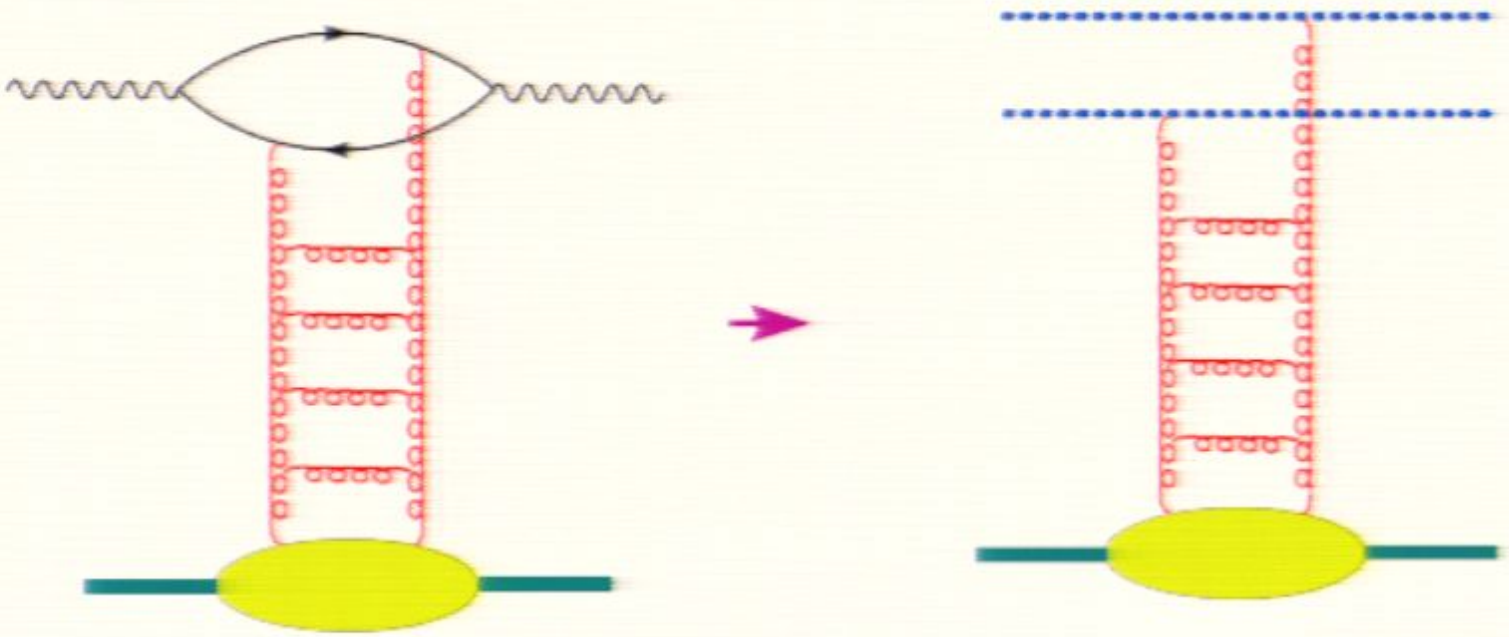
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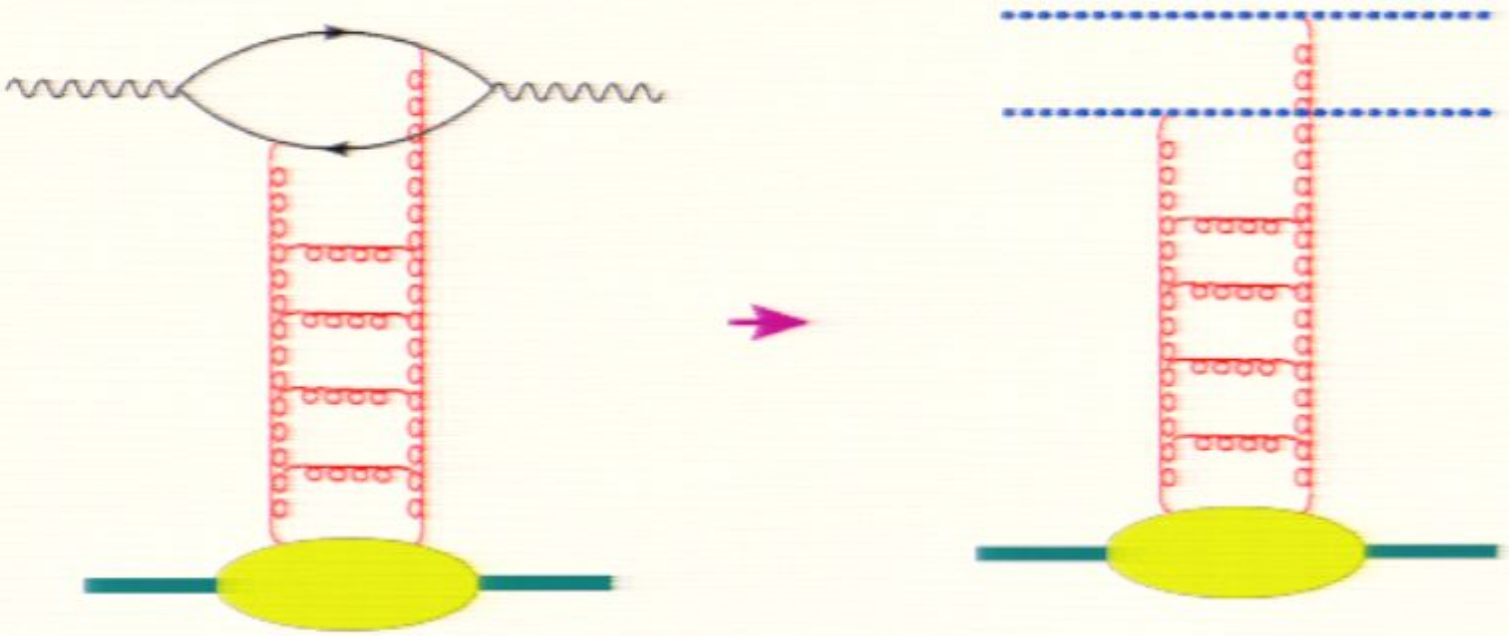
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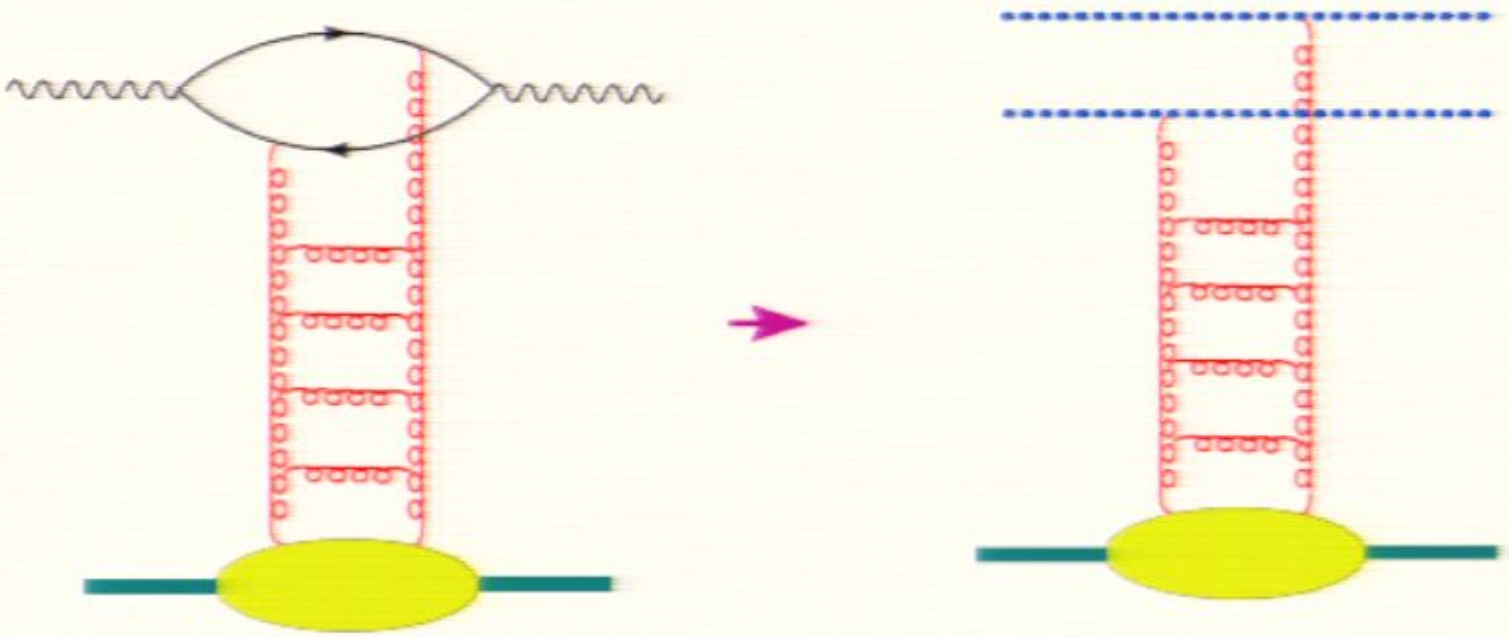
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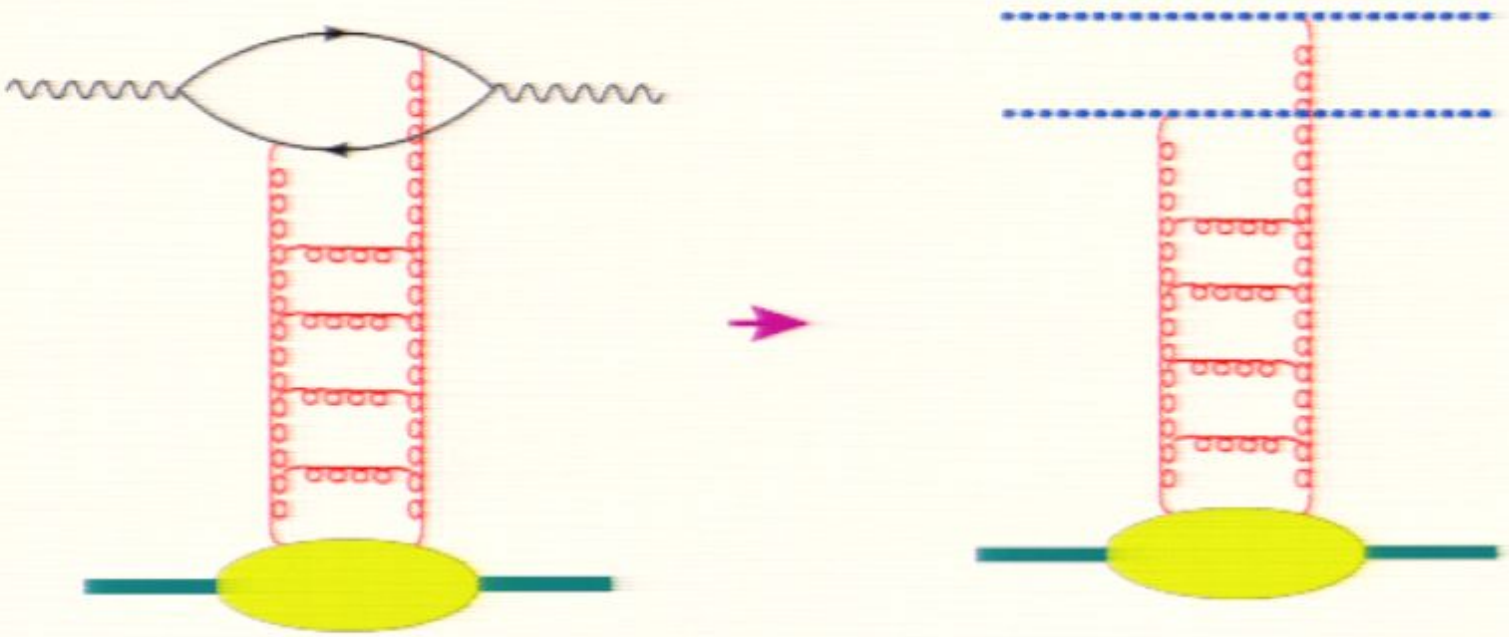
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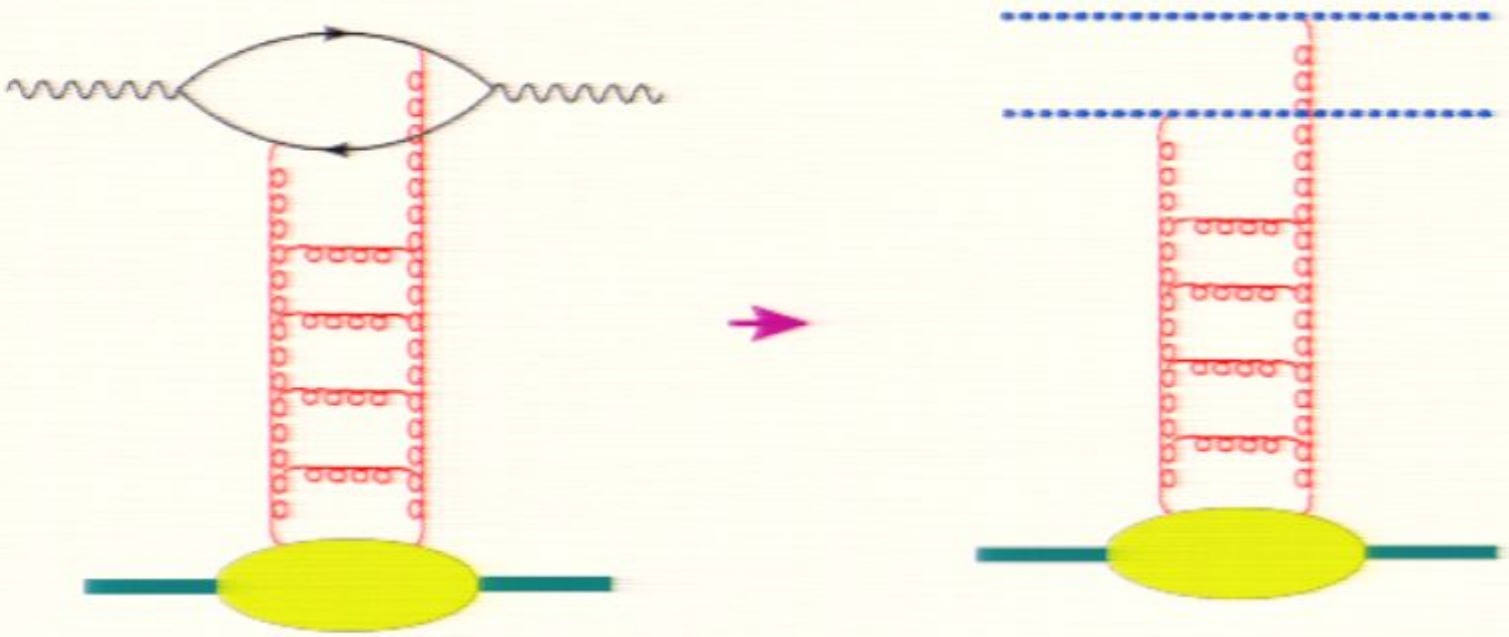
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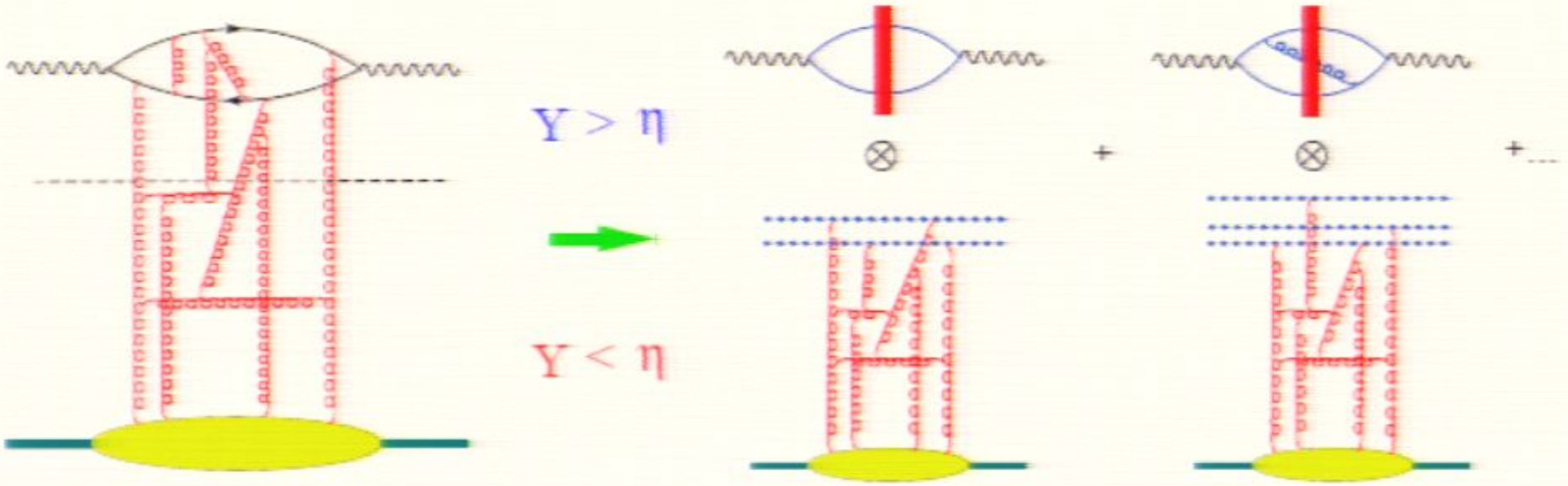


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Rapidity factorization



η - rapidity factorization scale

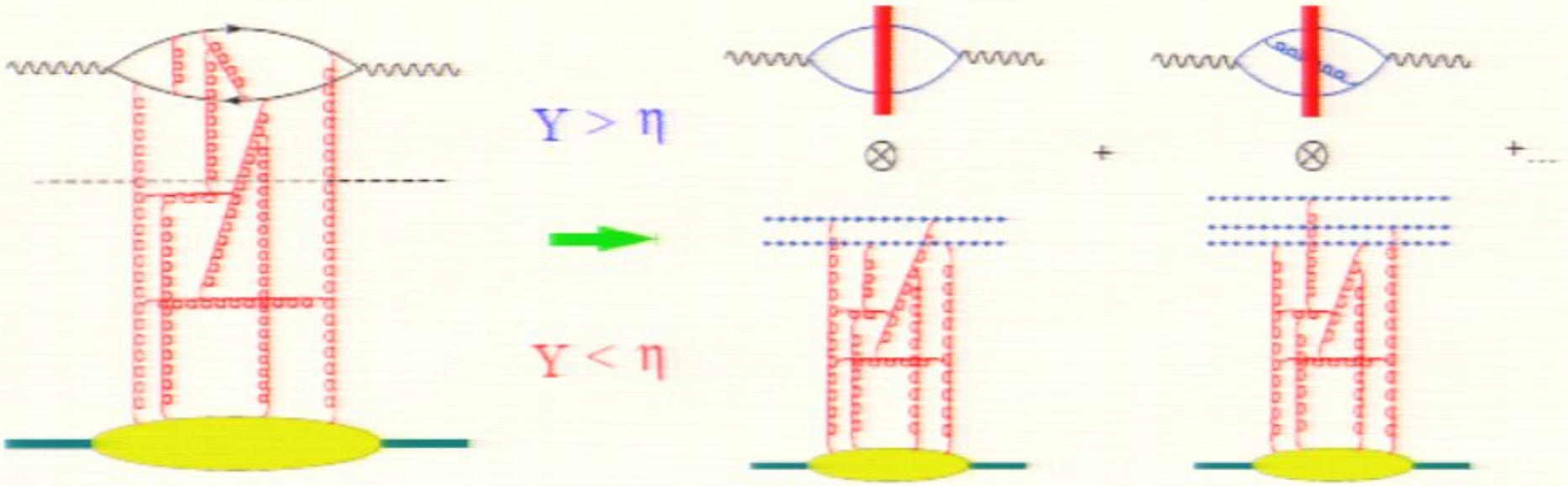
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Rapidity Y < η - matrix elements of (light-like) Wilson lines with rapidity divergence cut by η

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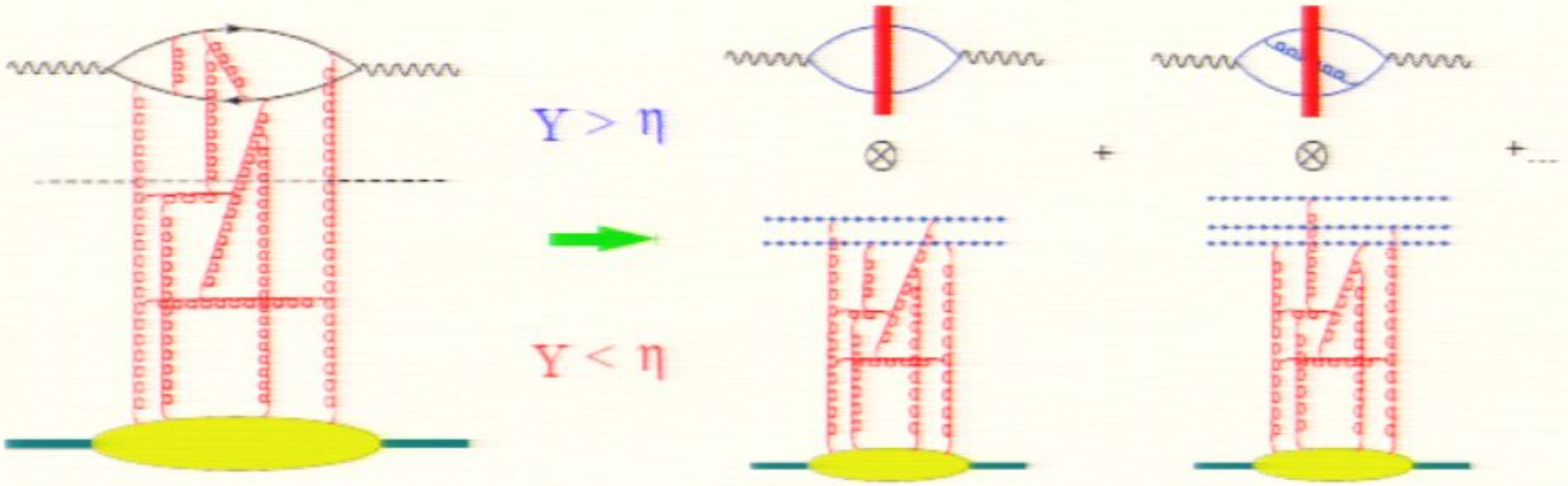
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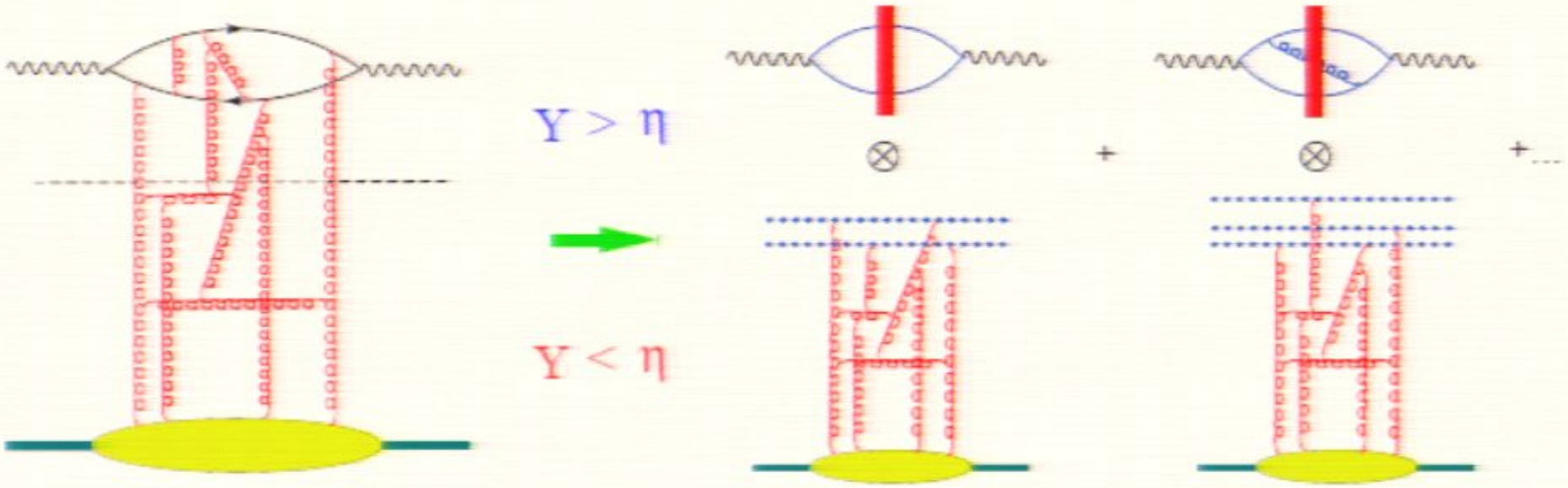
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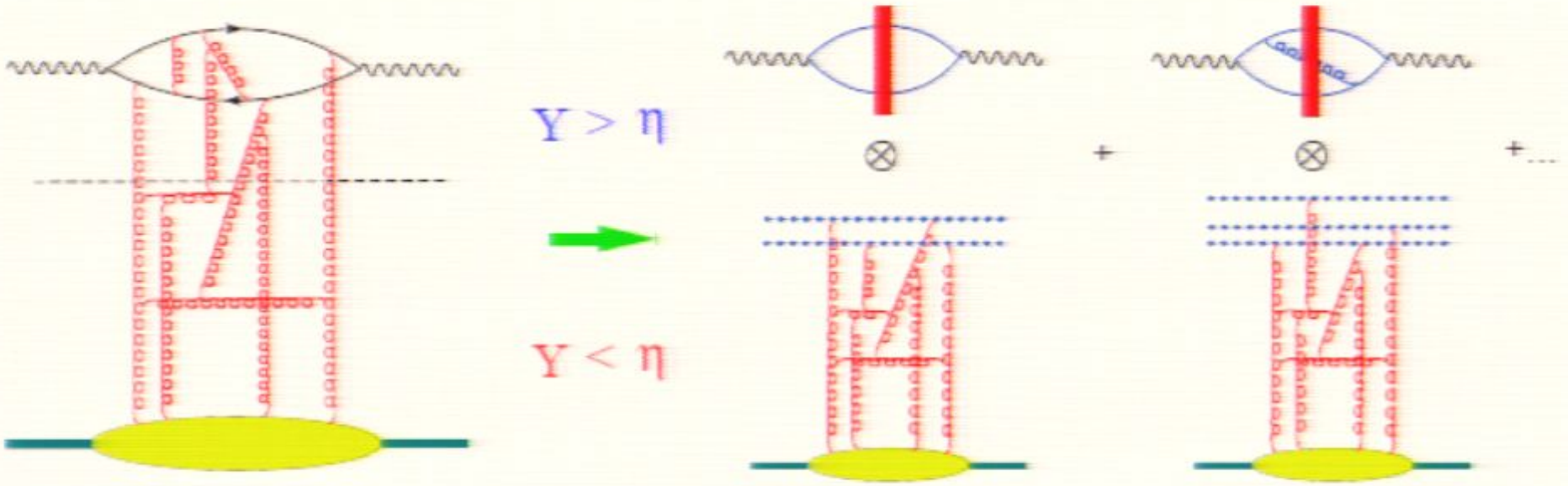
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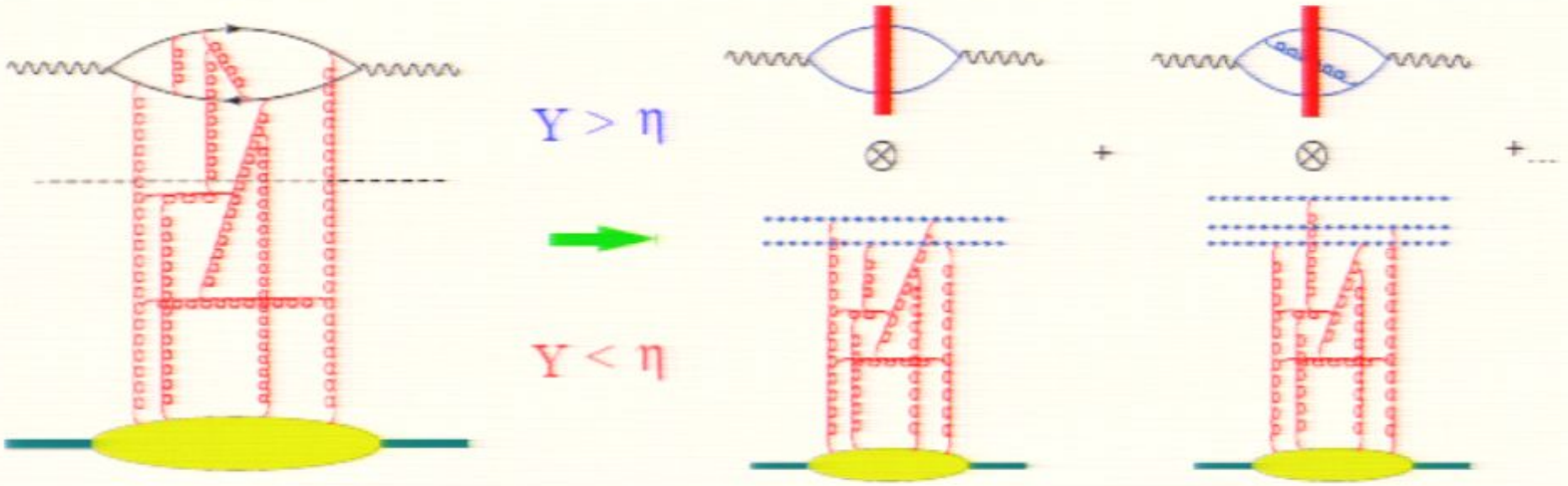
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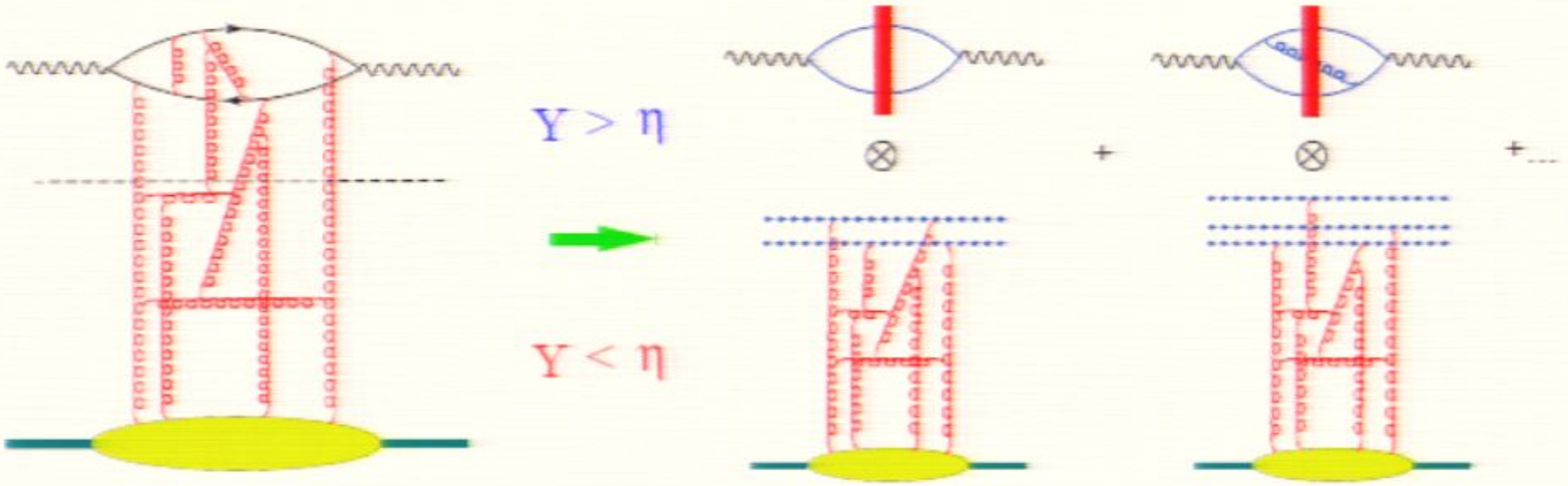
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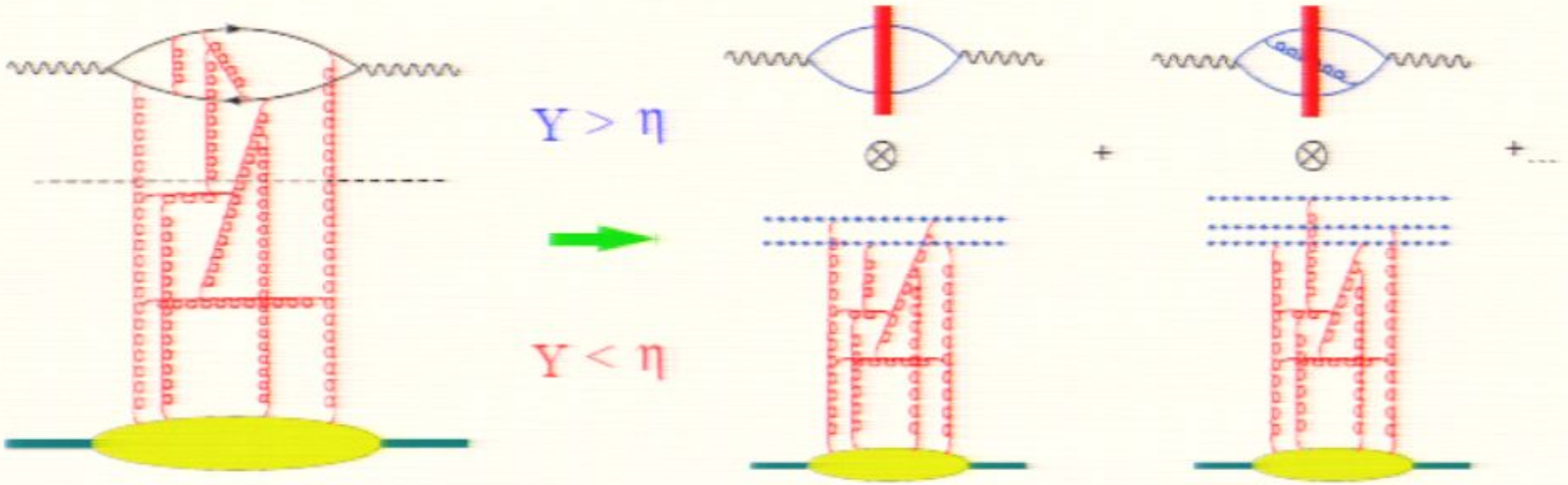
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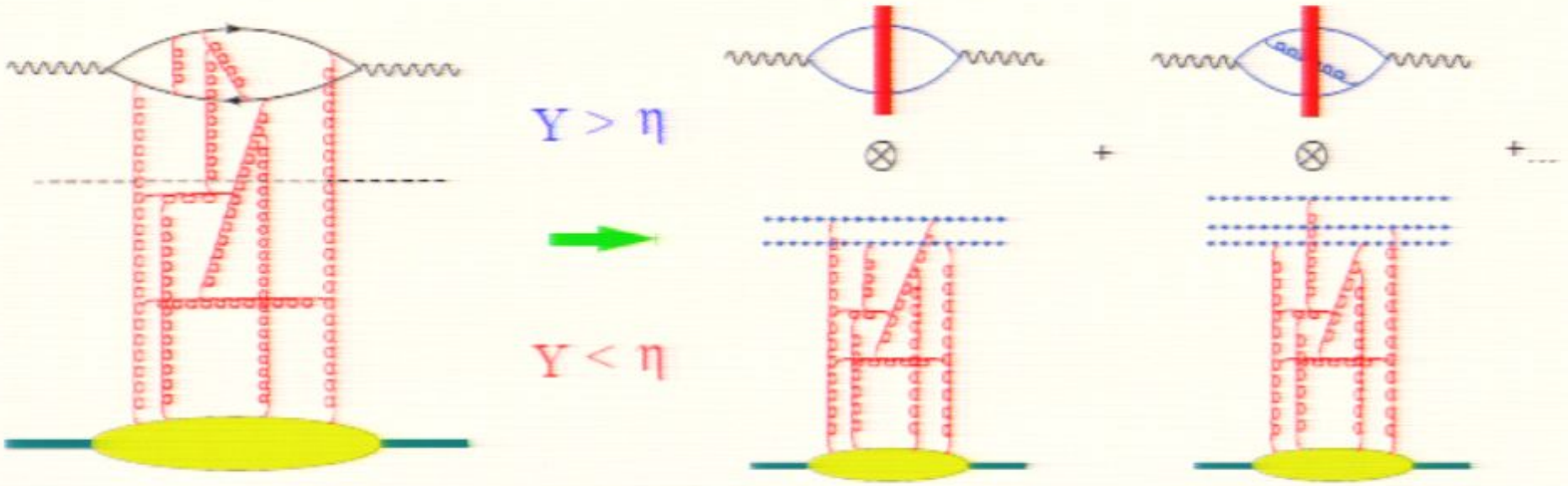
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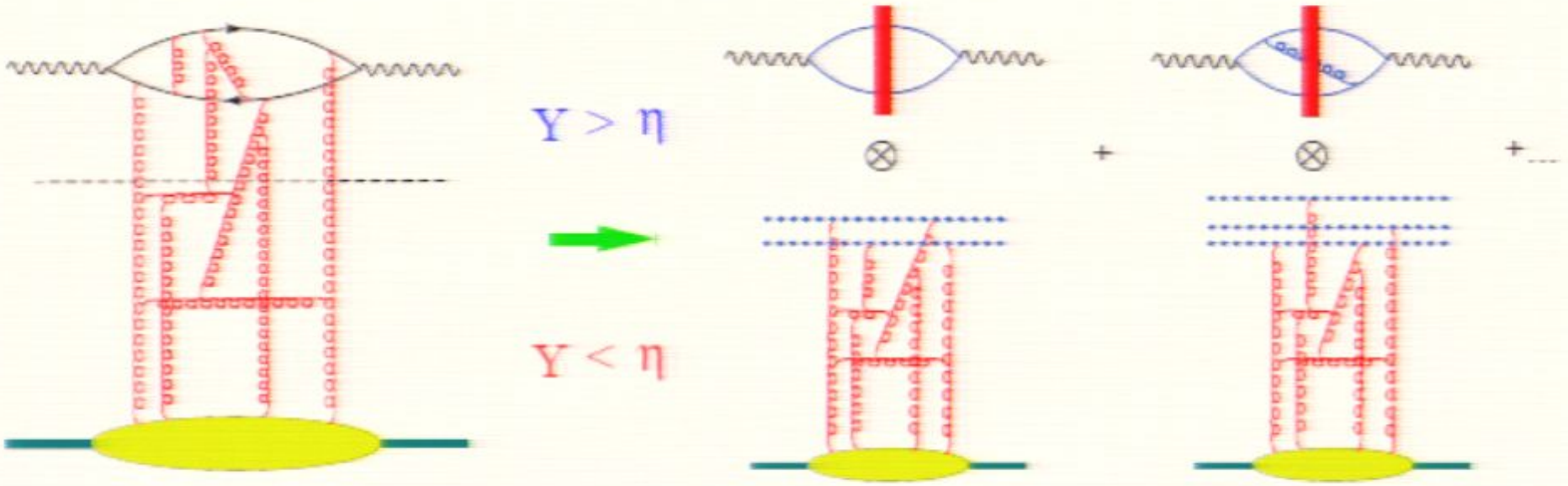
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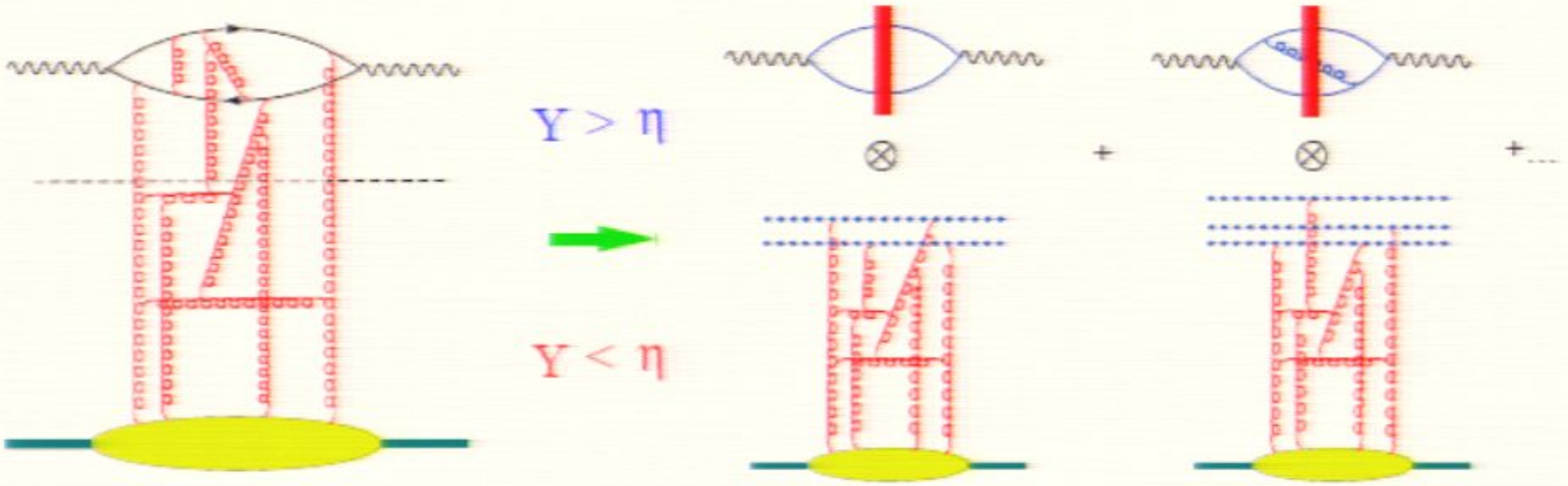
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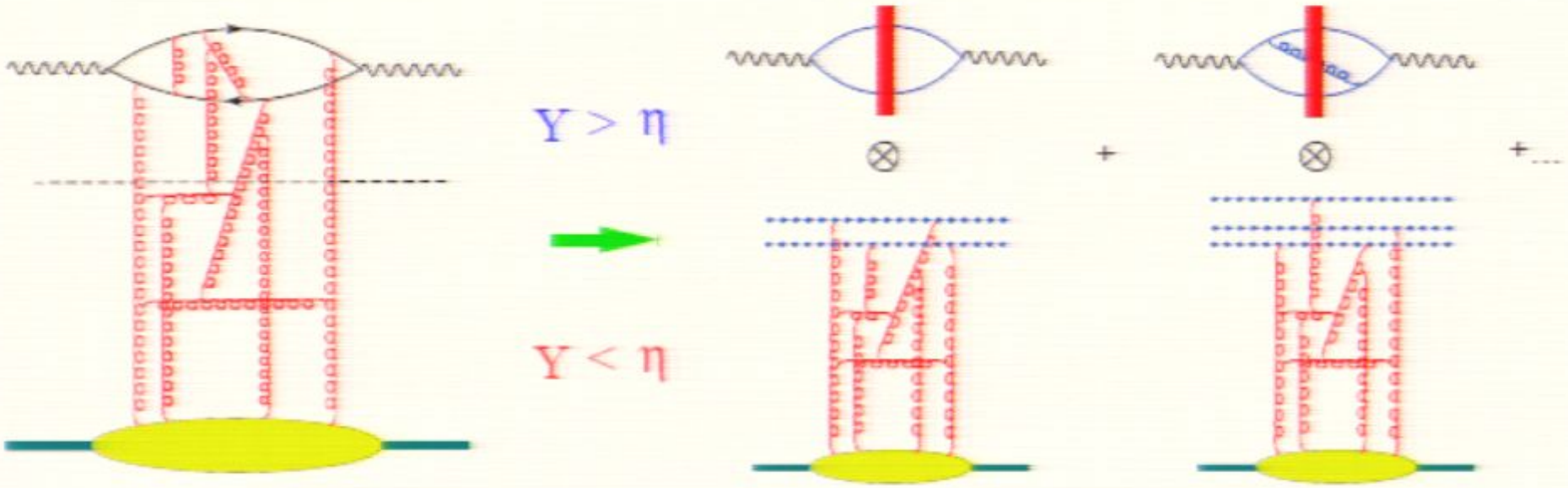
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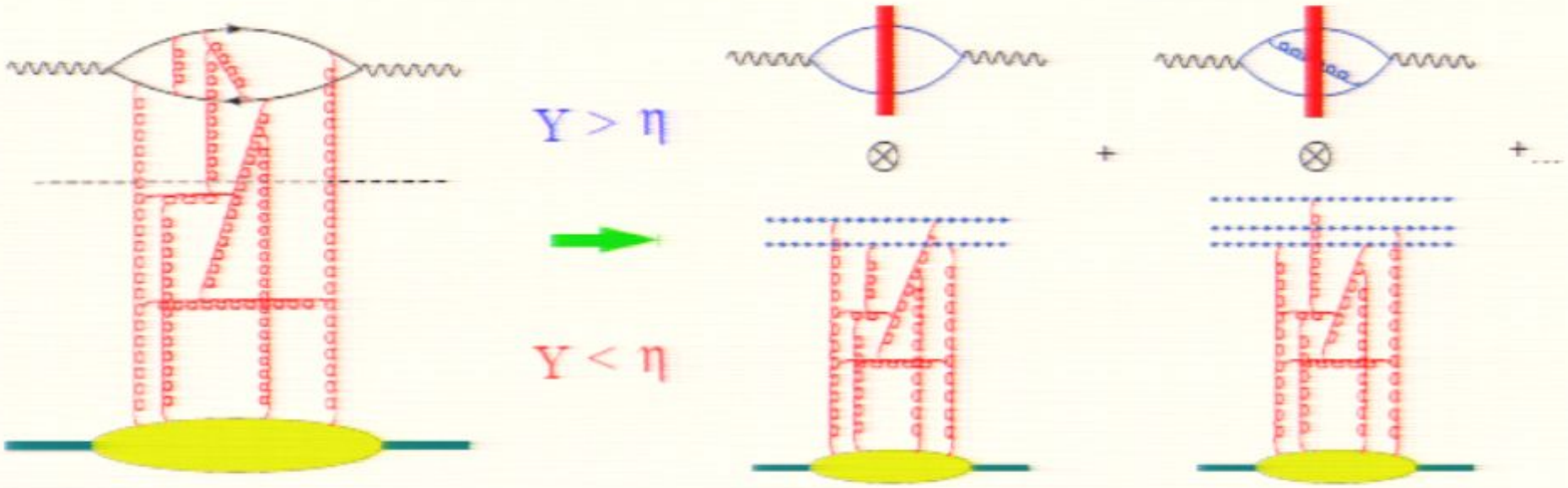
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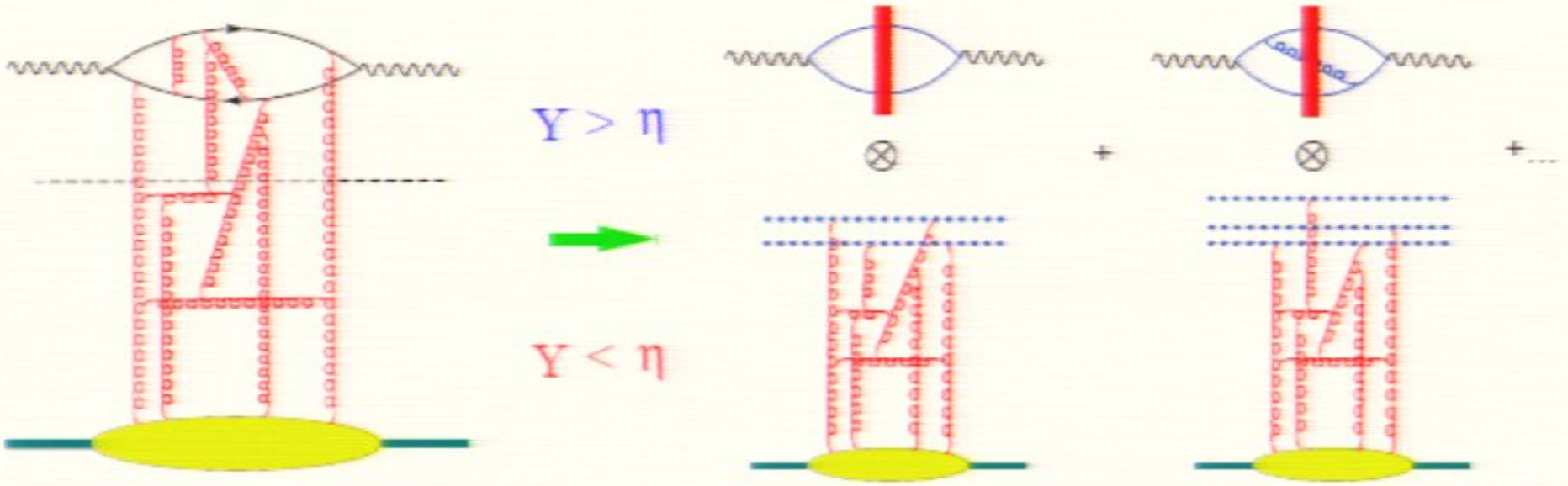
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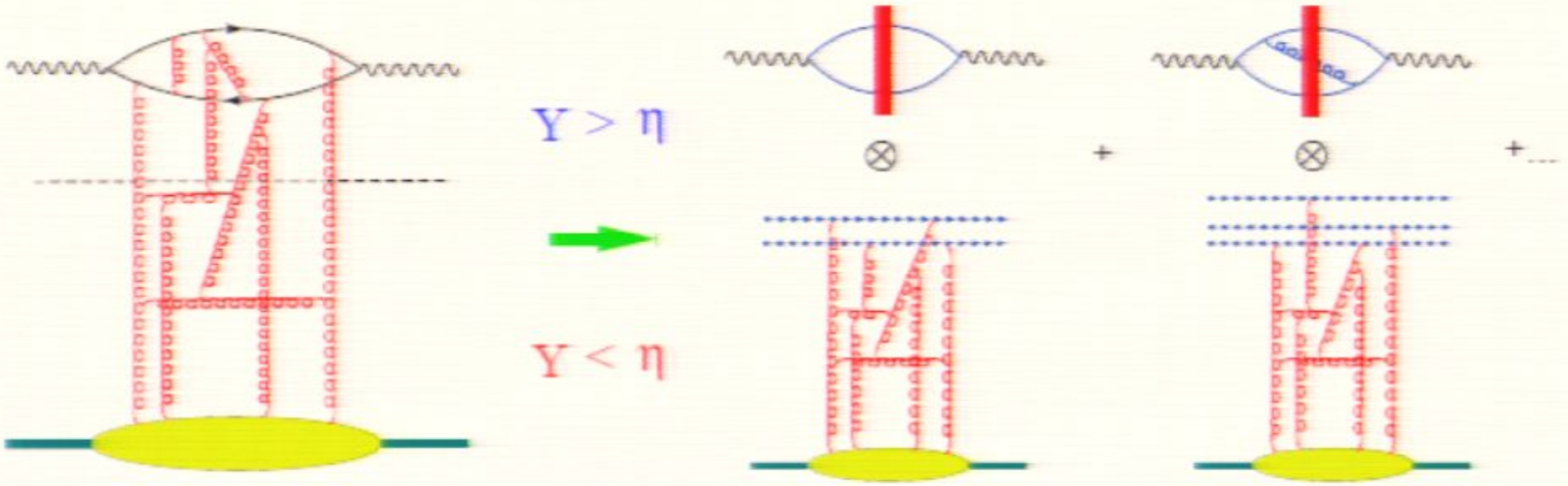
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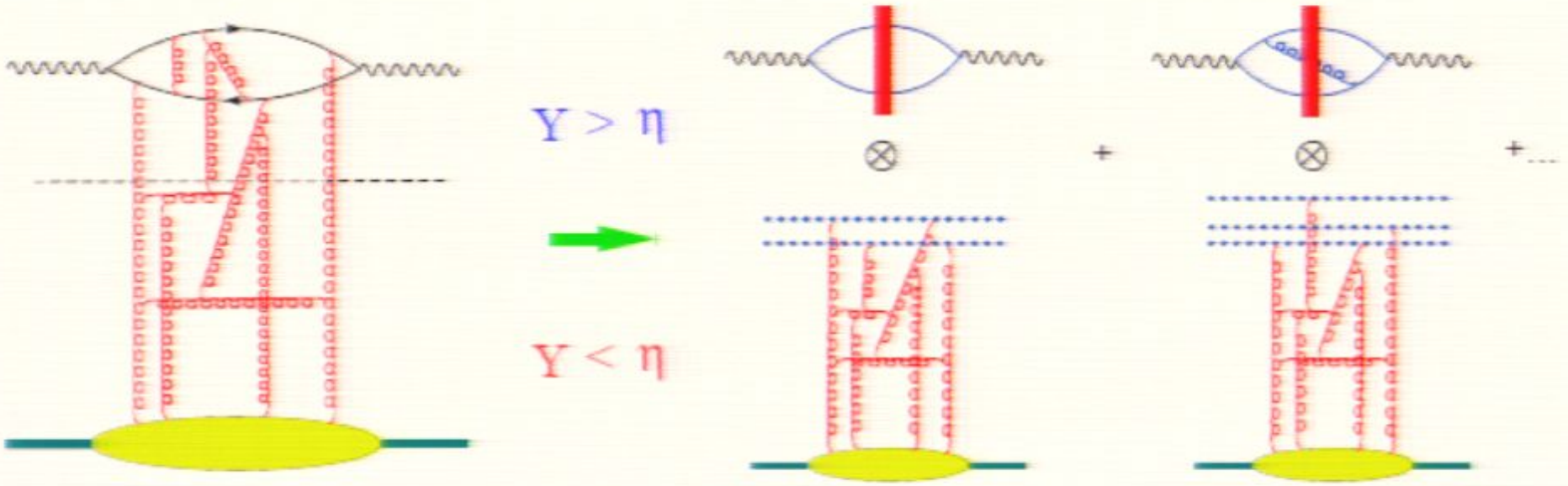
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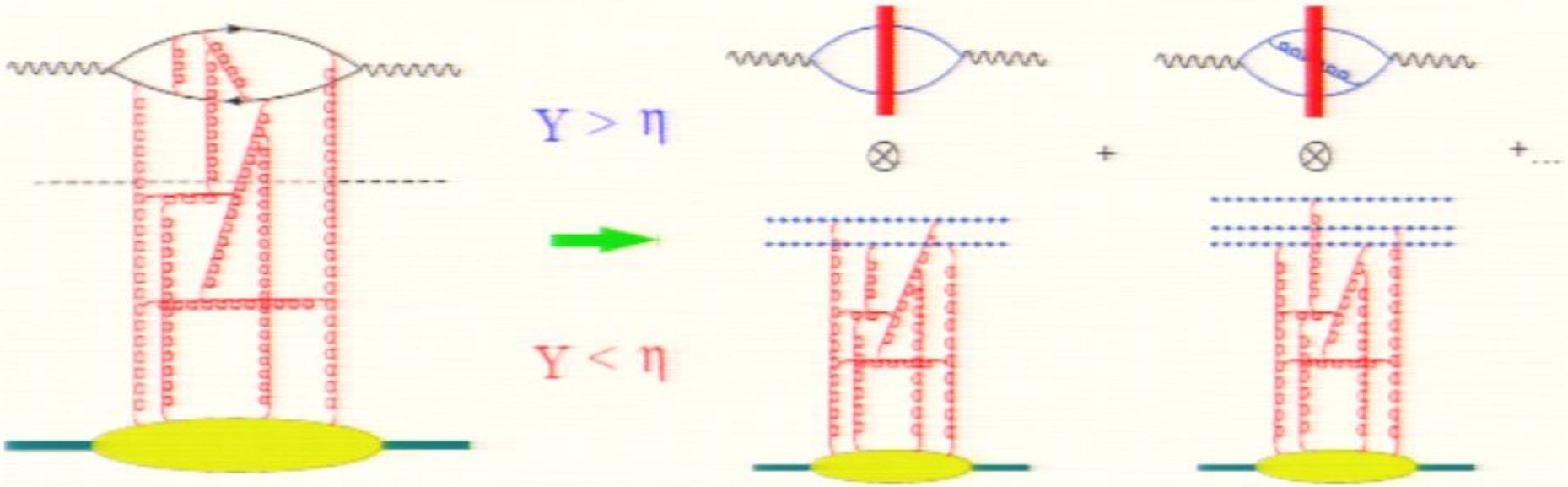
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Rapidity factorization



η - rapidity factorization scale

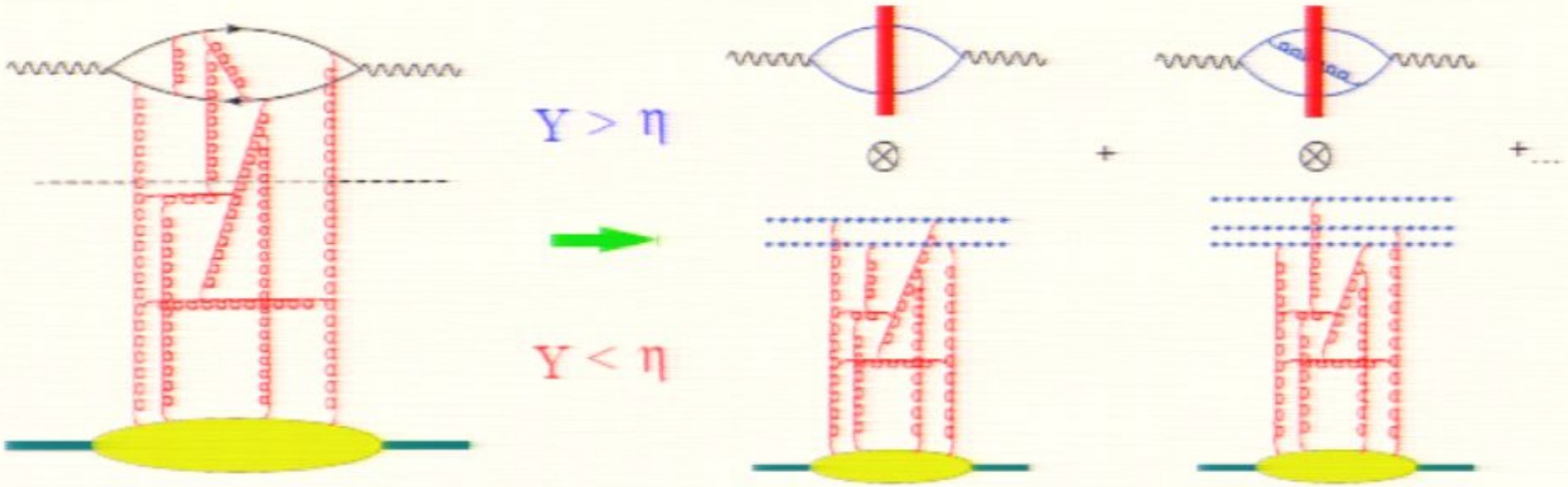
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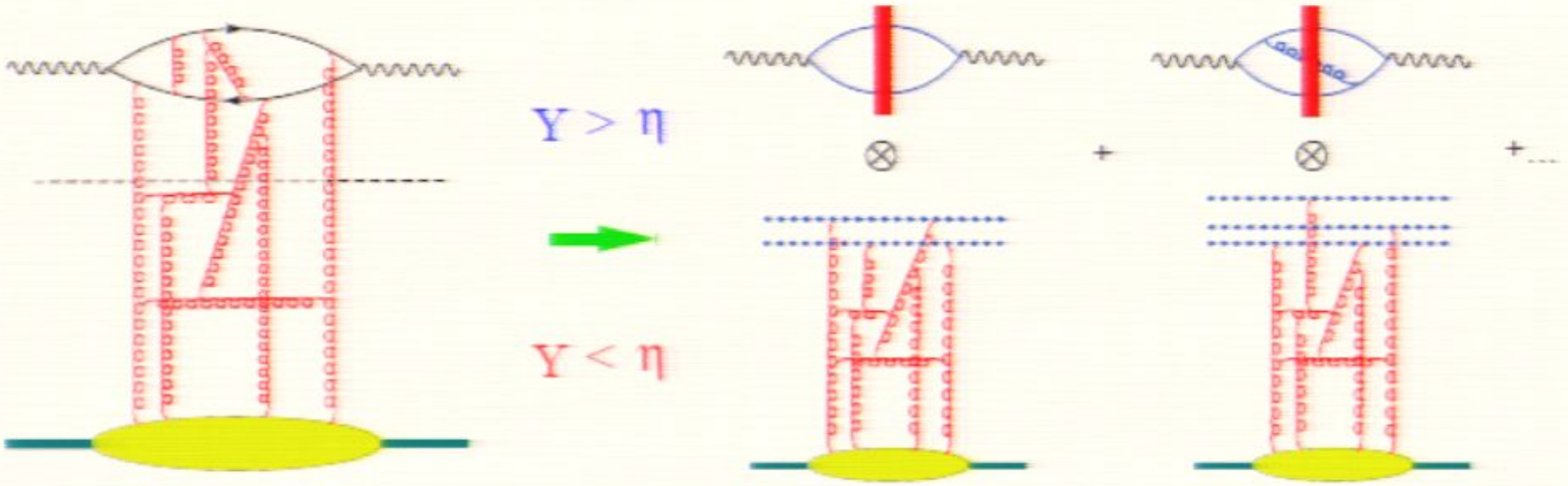
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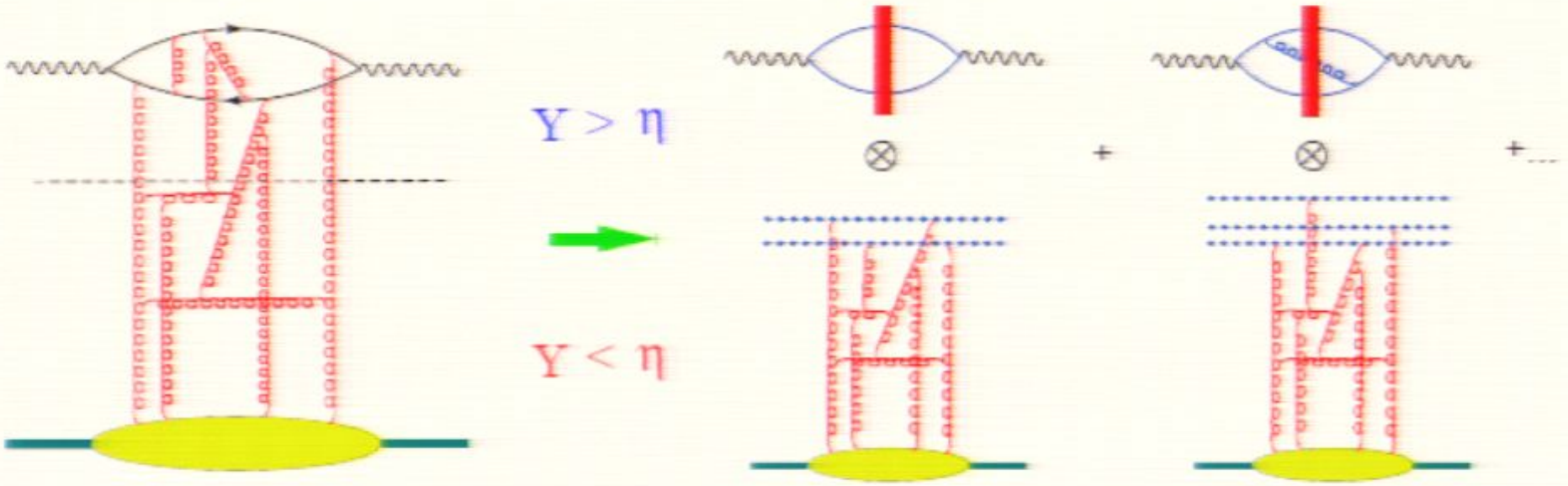
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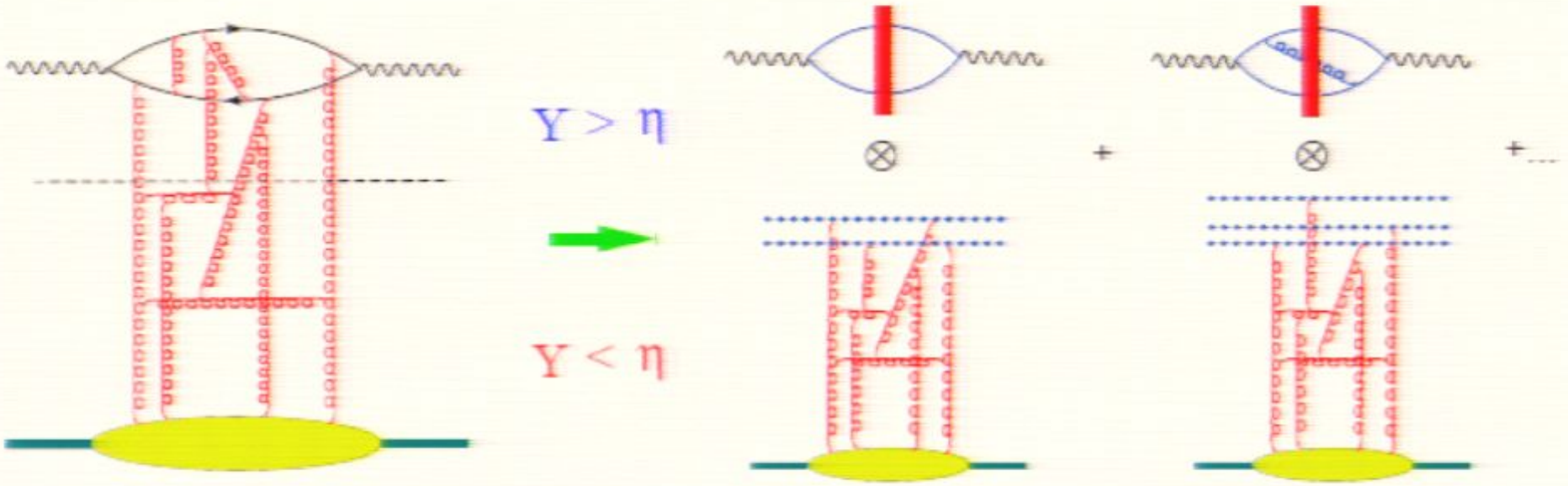
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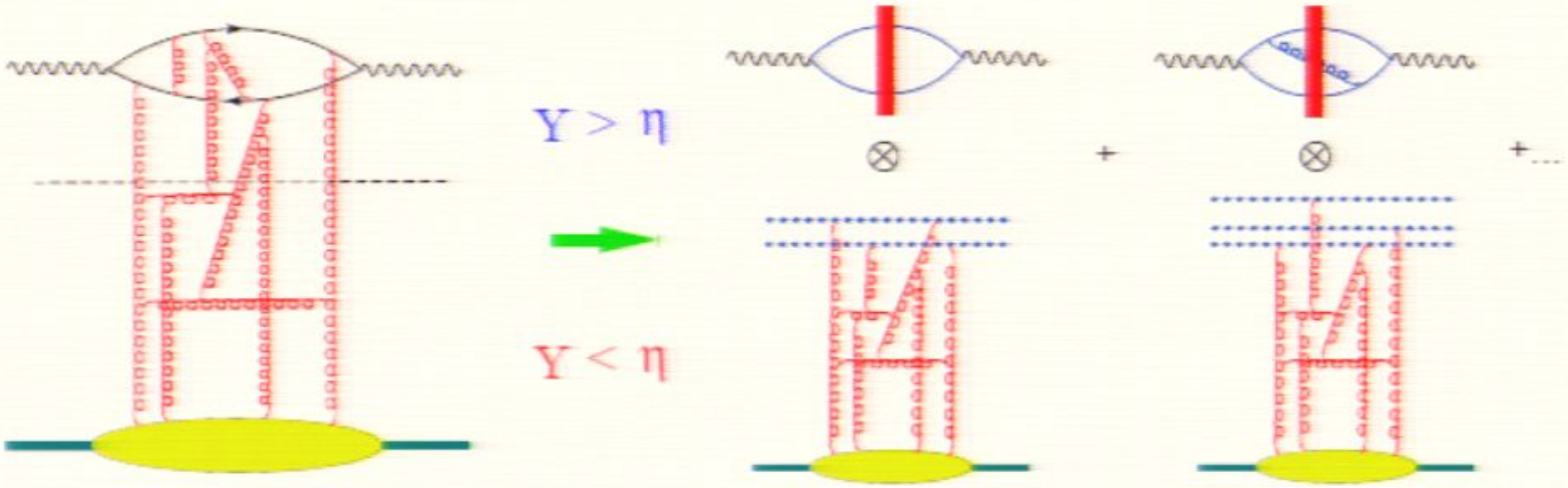
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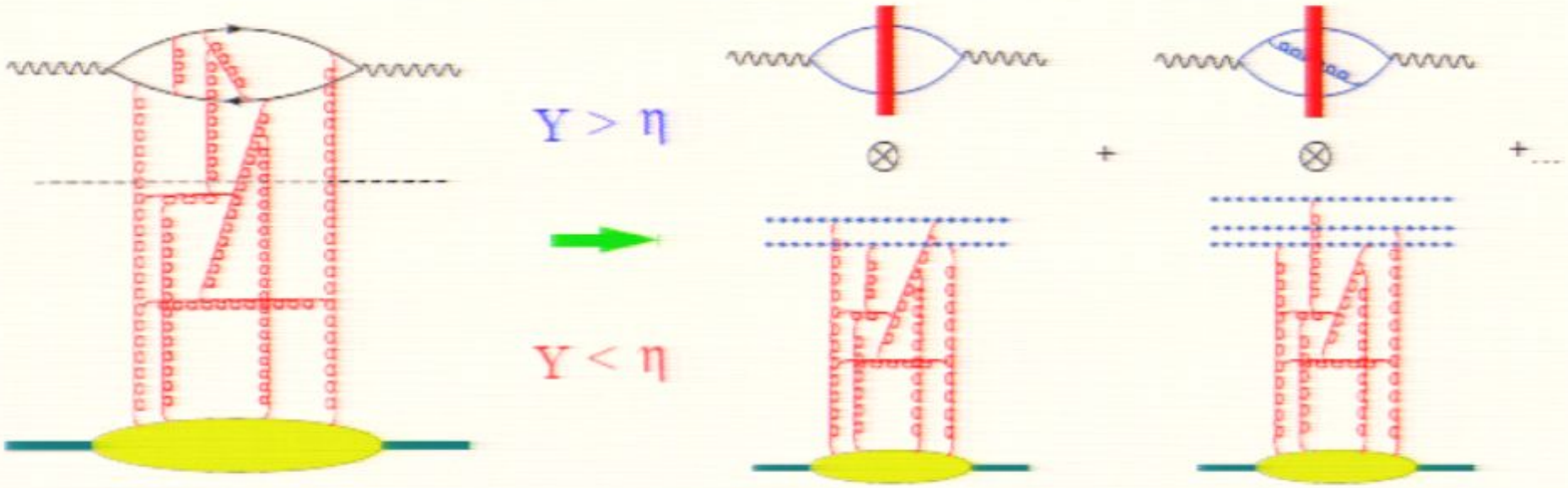
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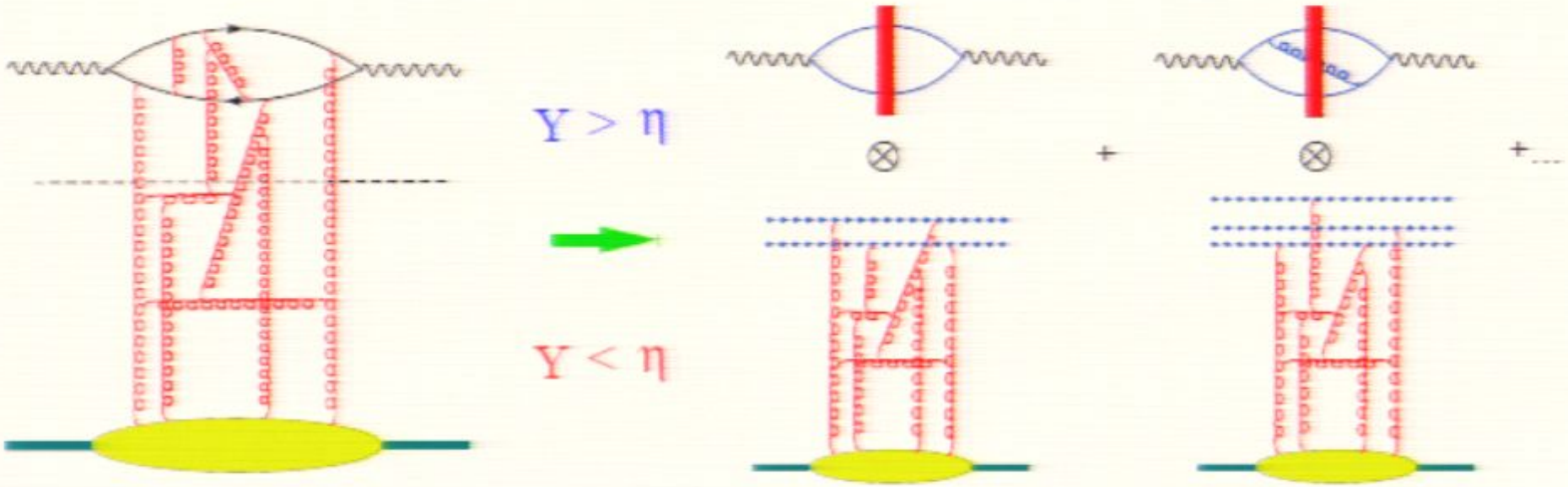
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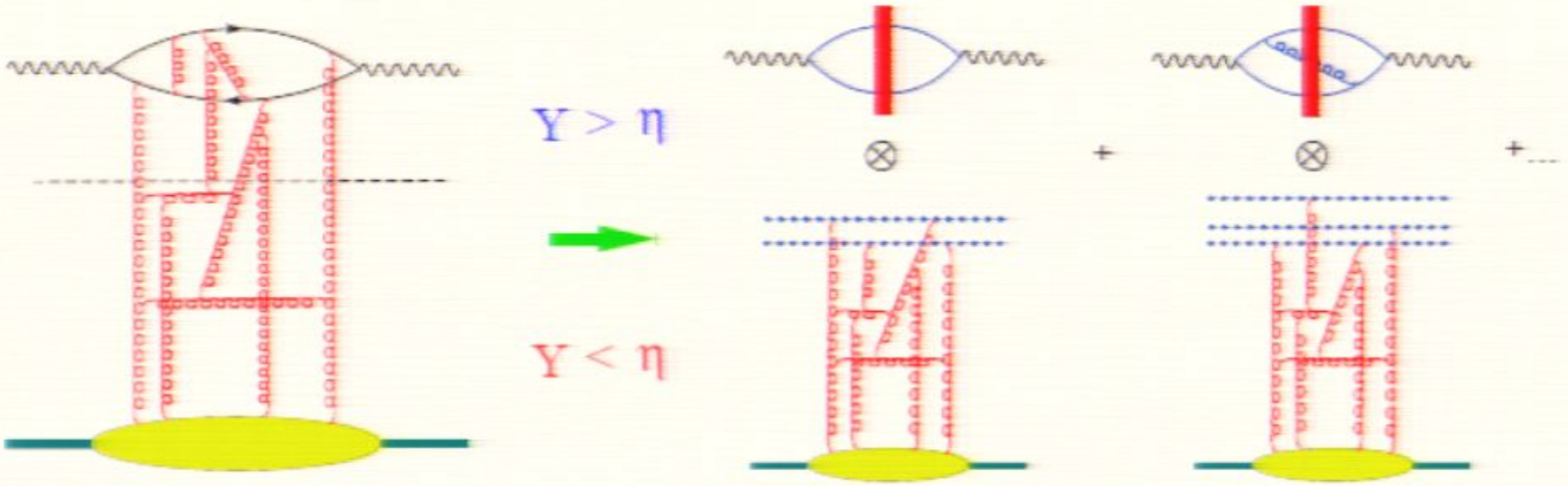
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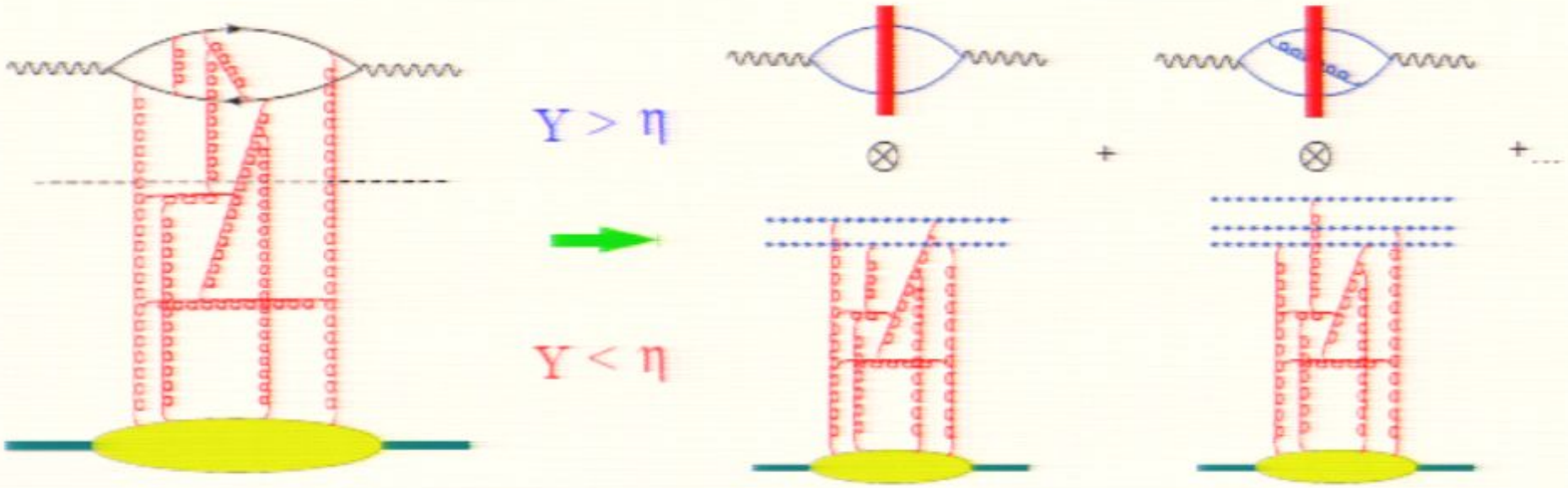
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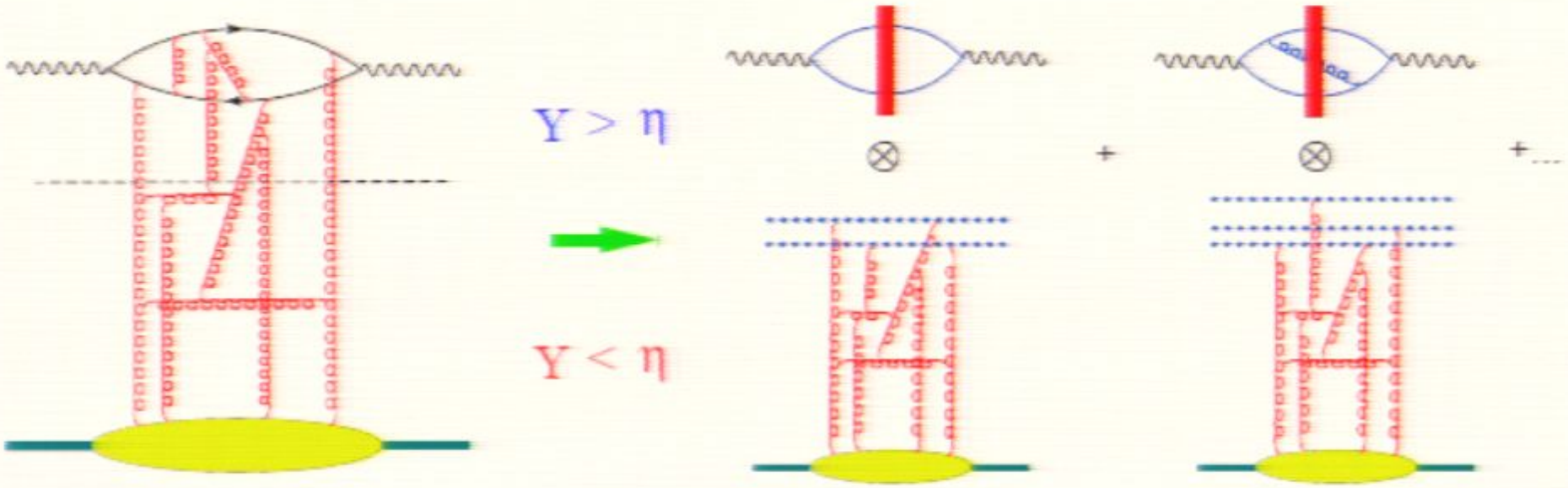
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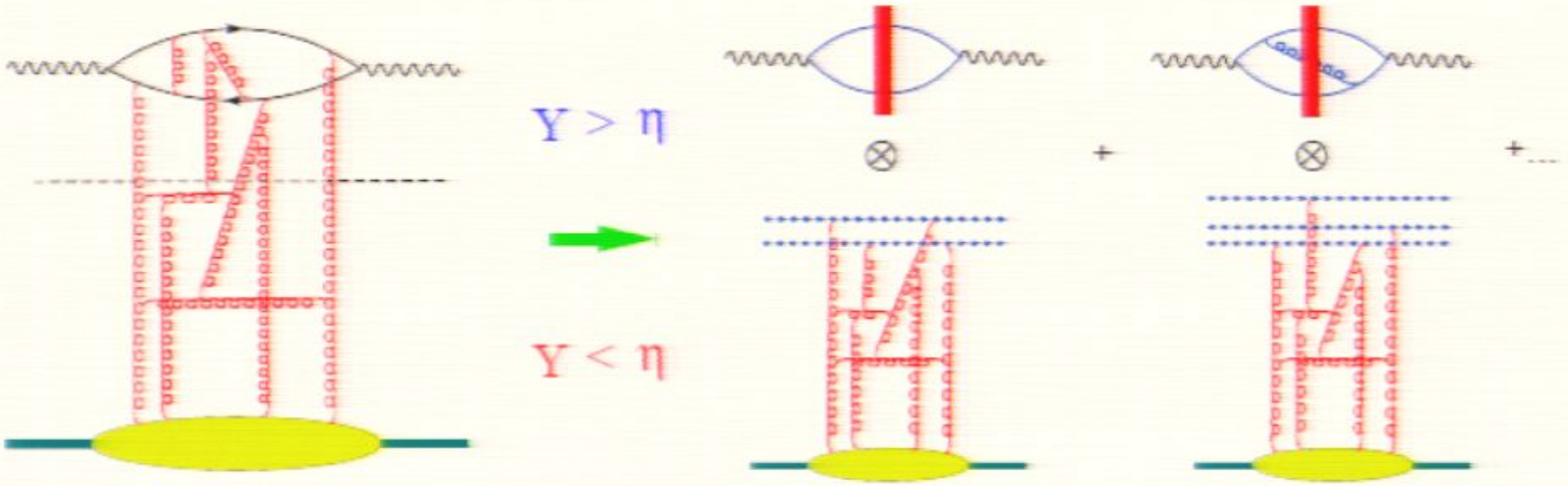
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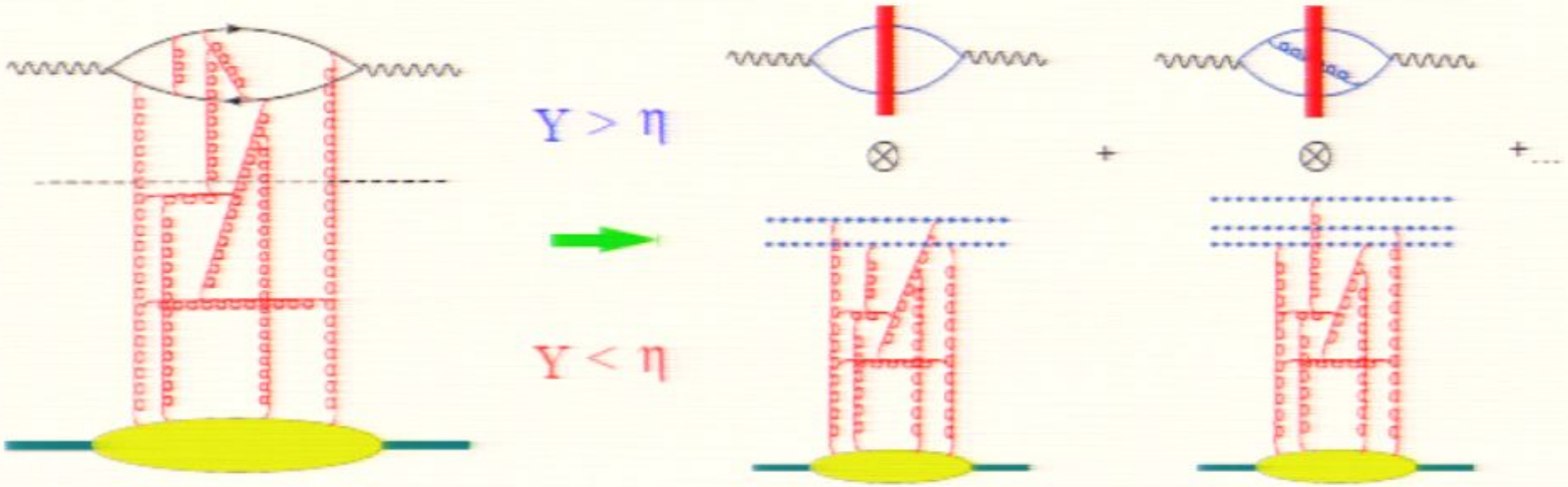
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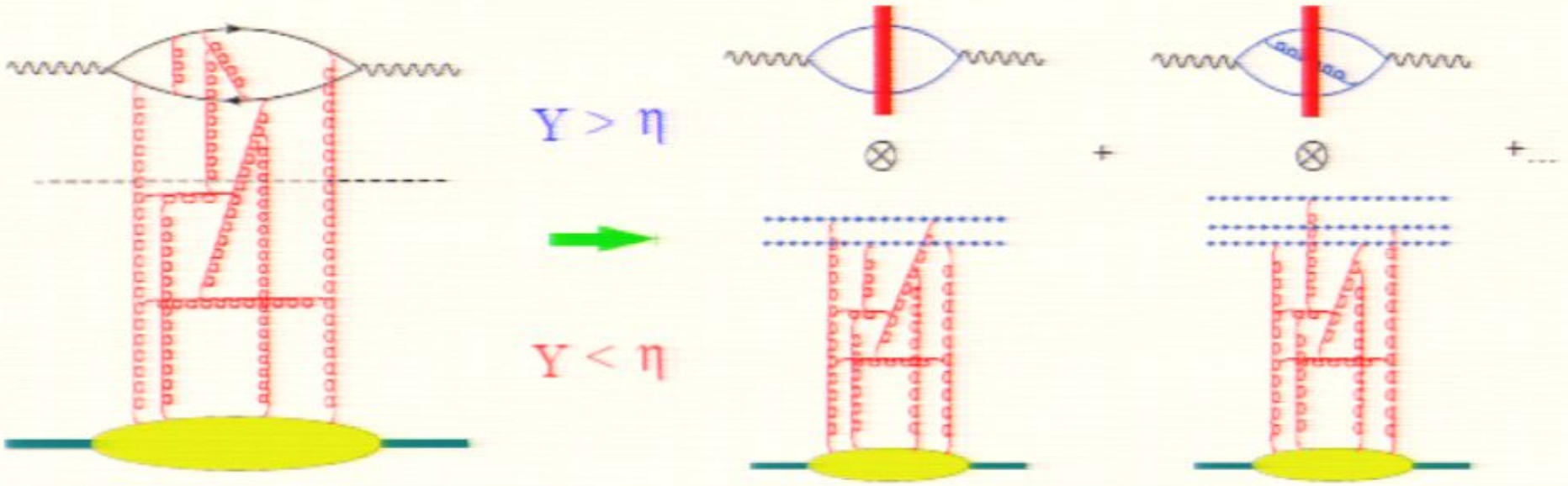
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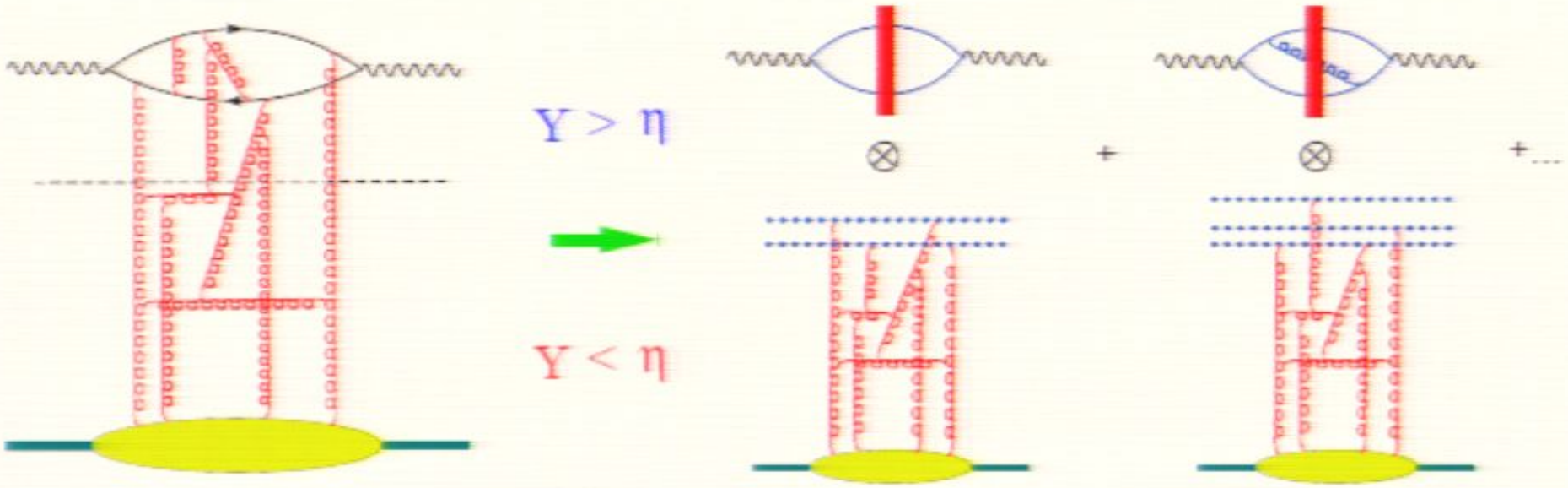
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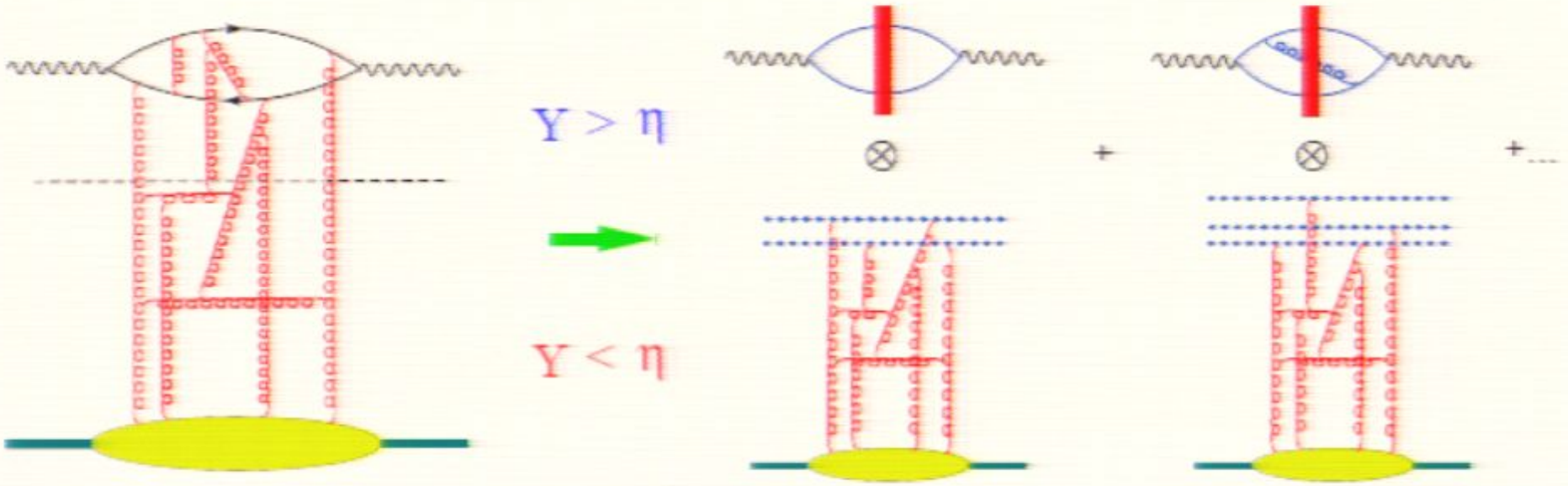
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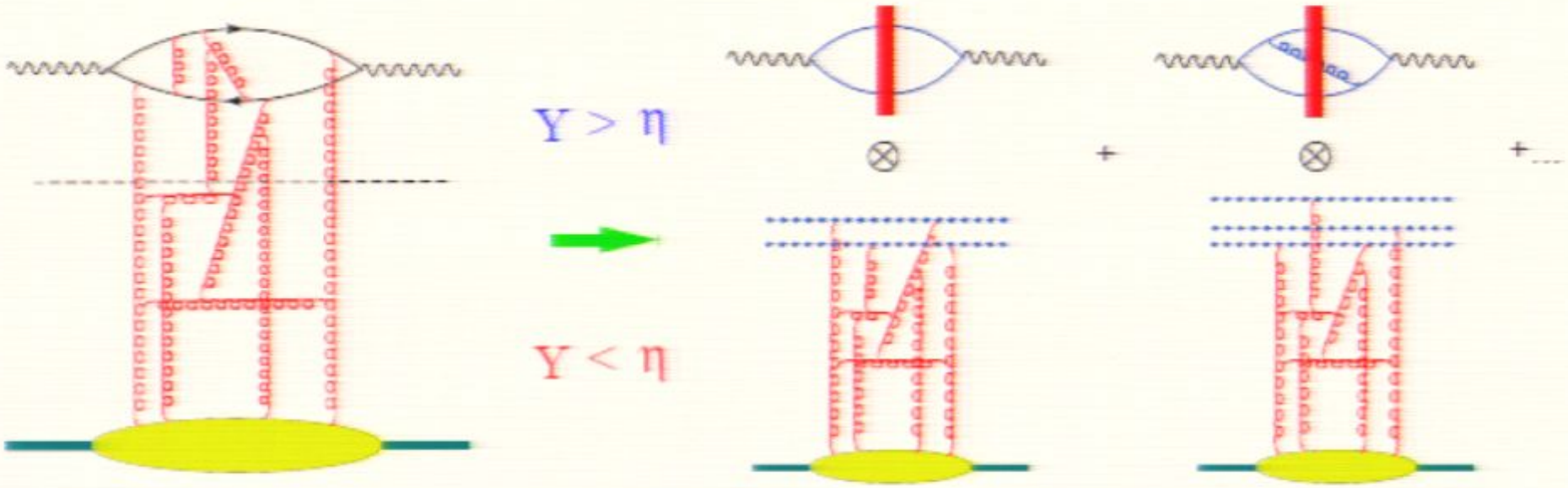
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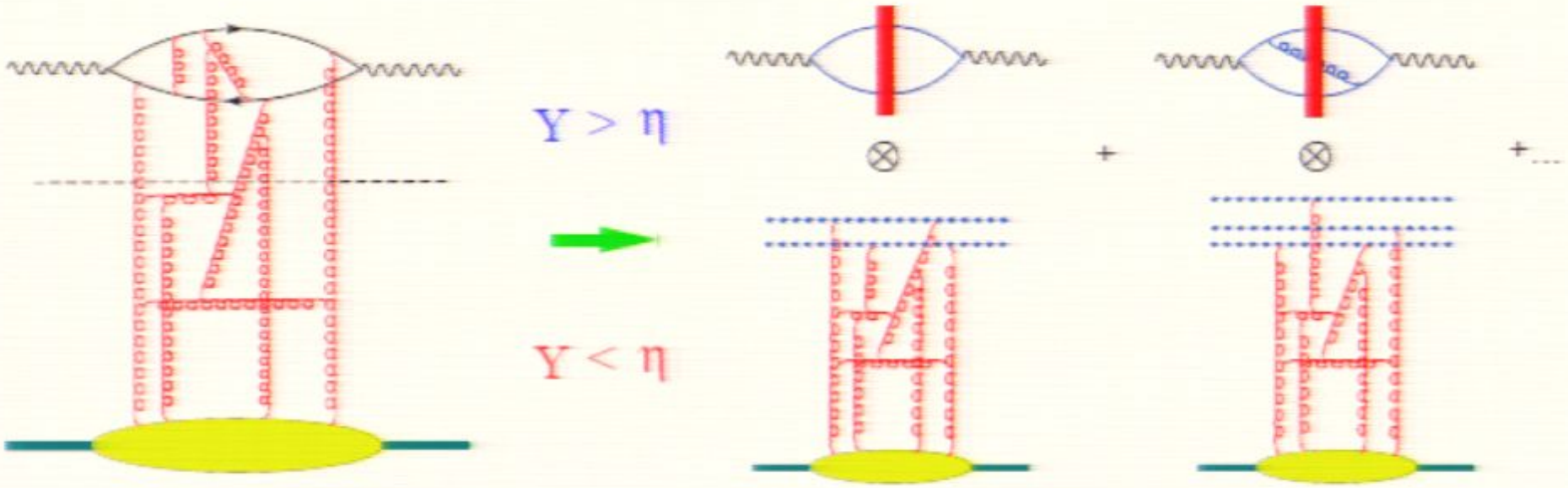
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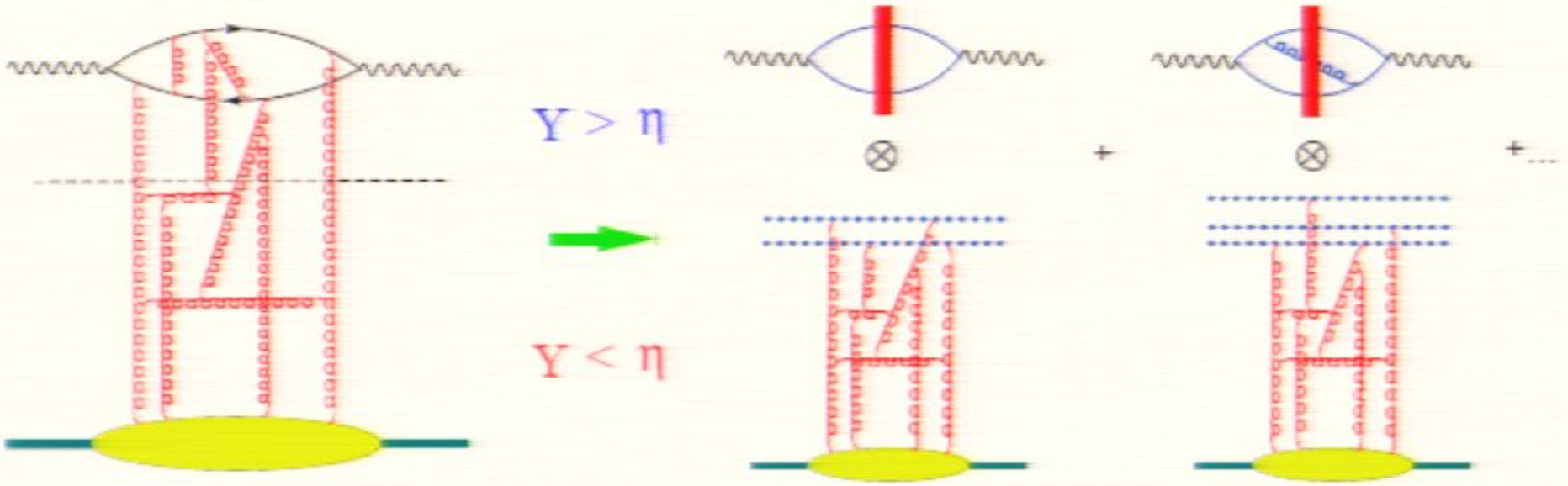
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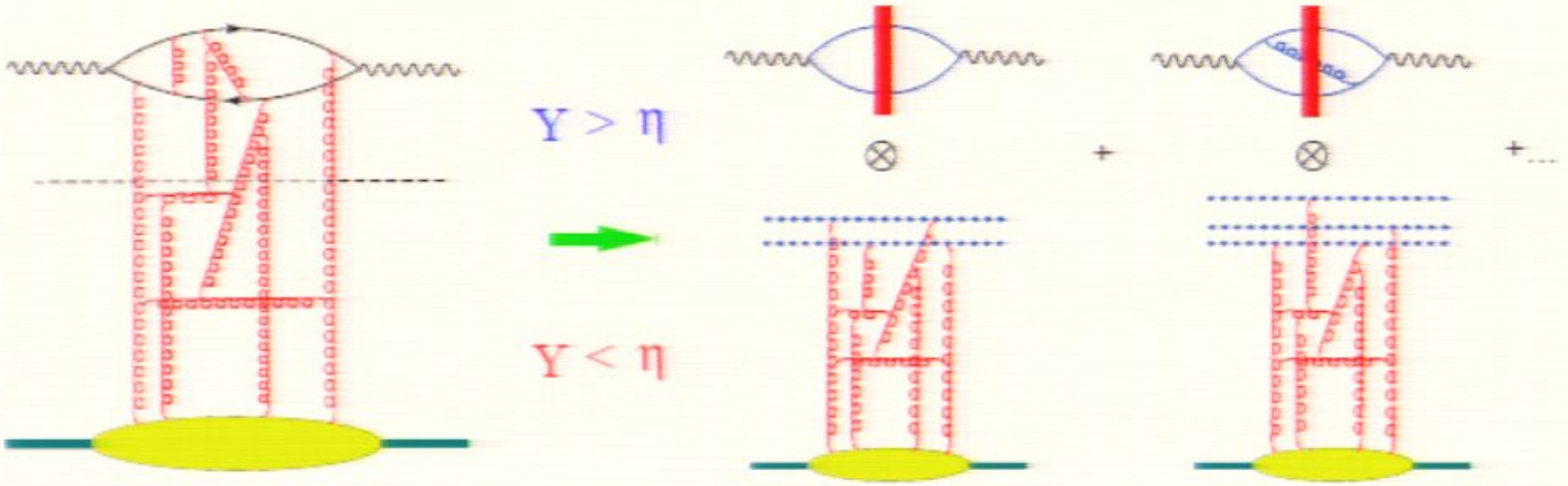
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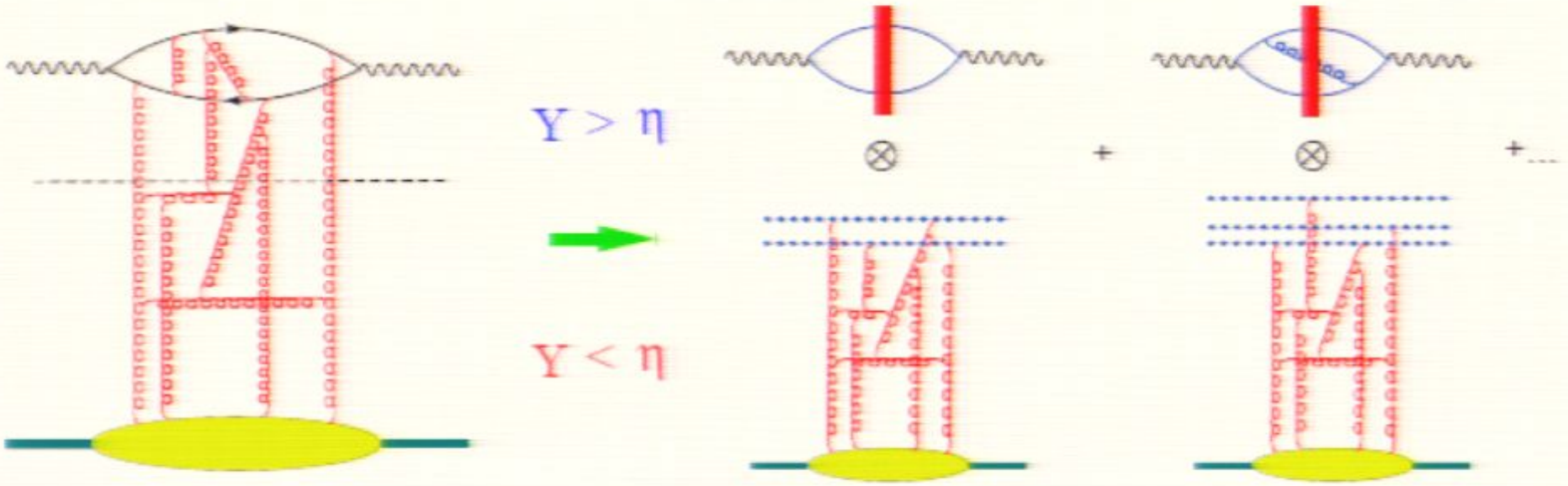
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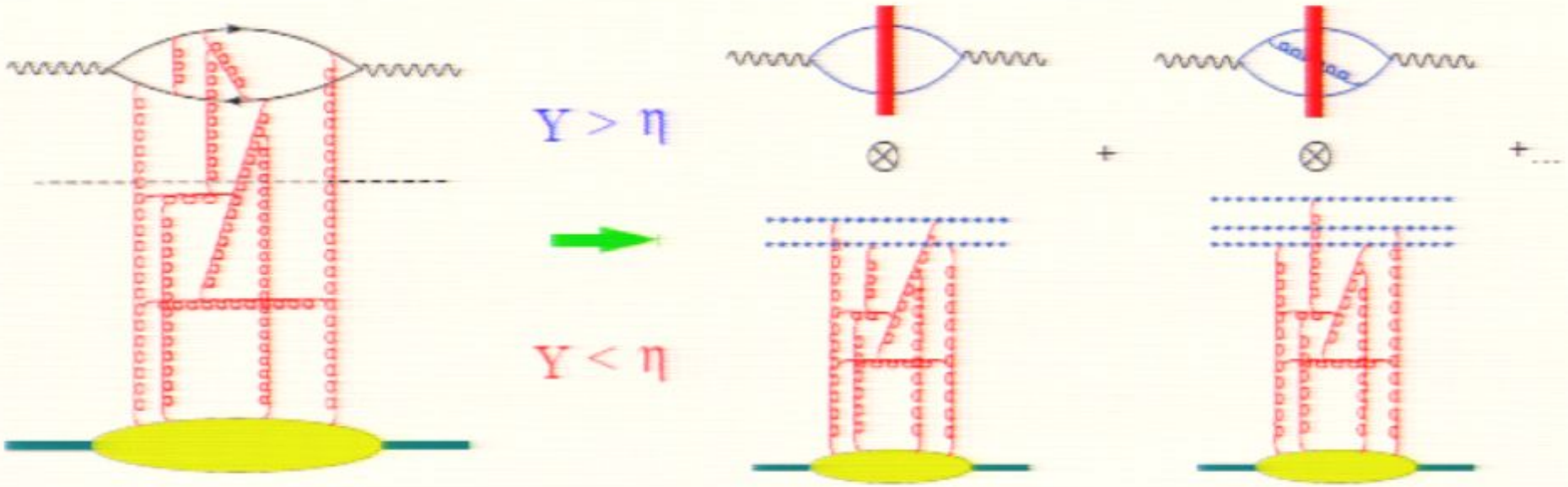
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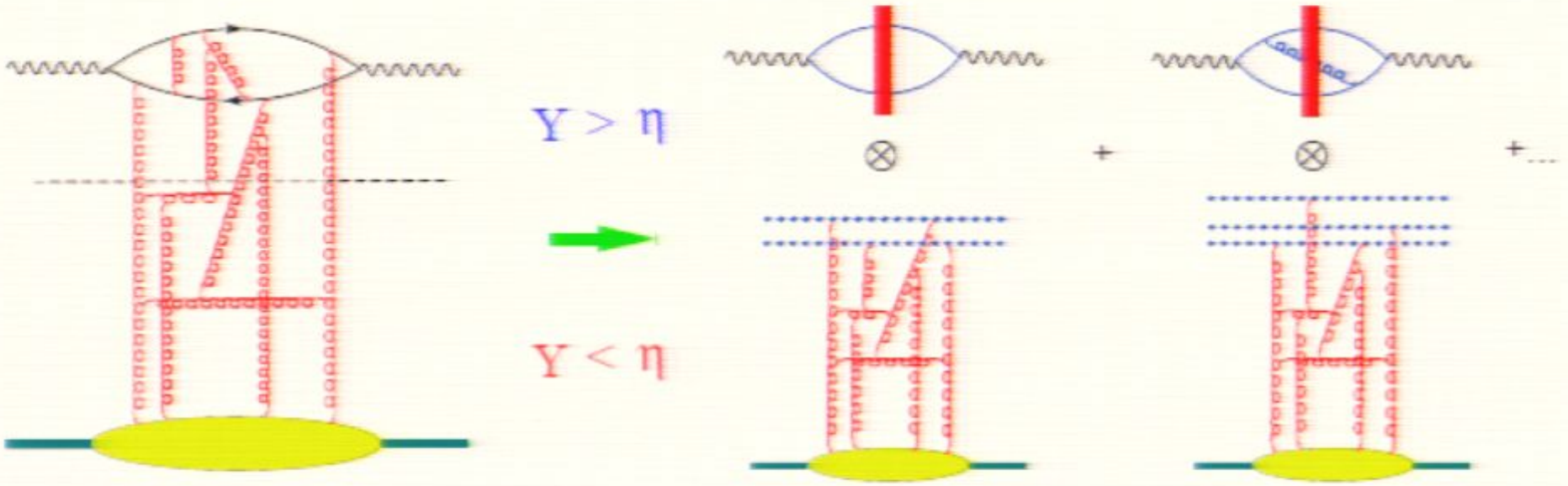
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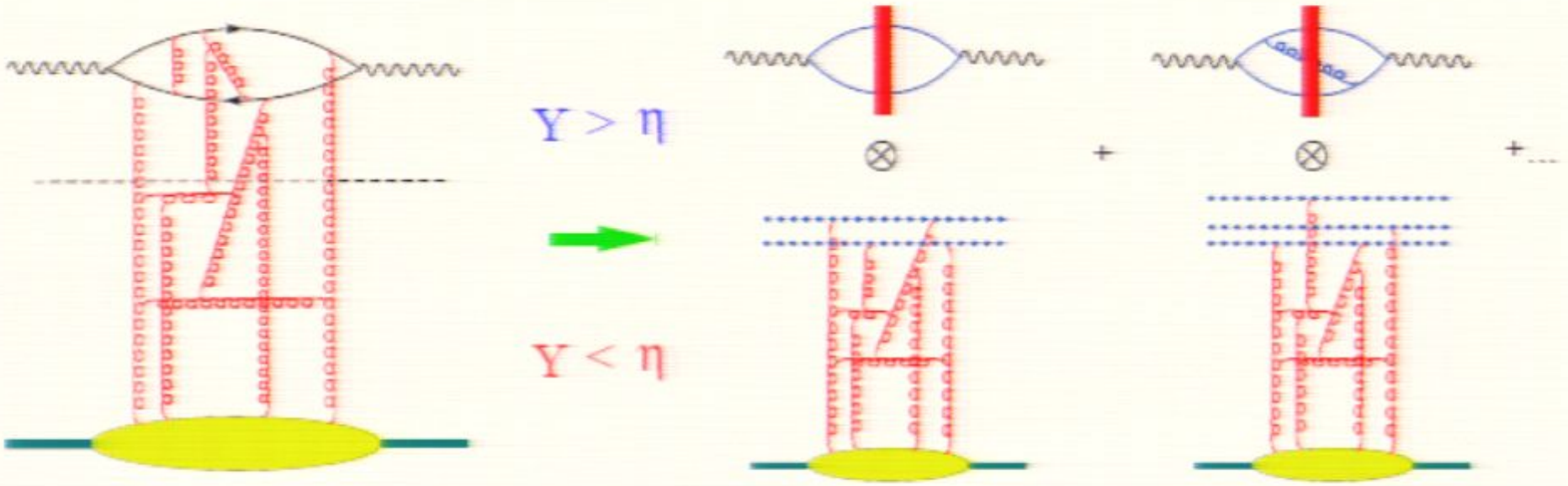
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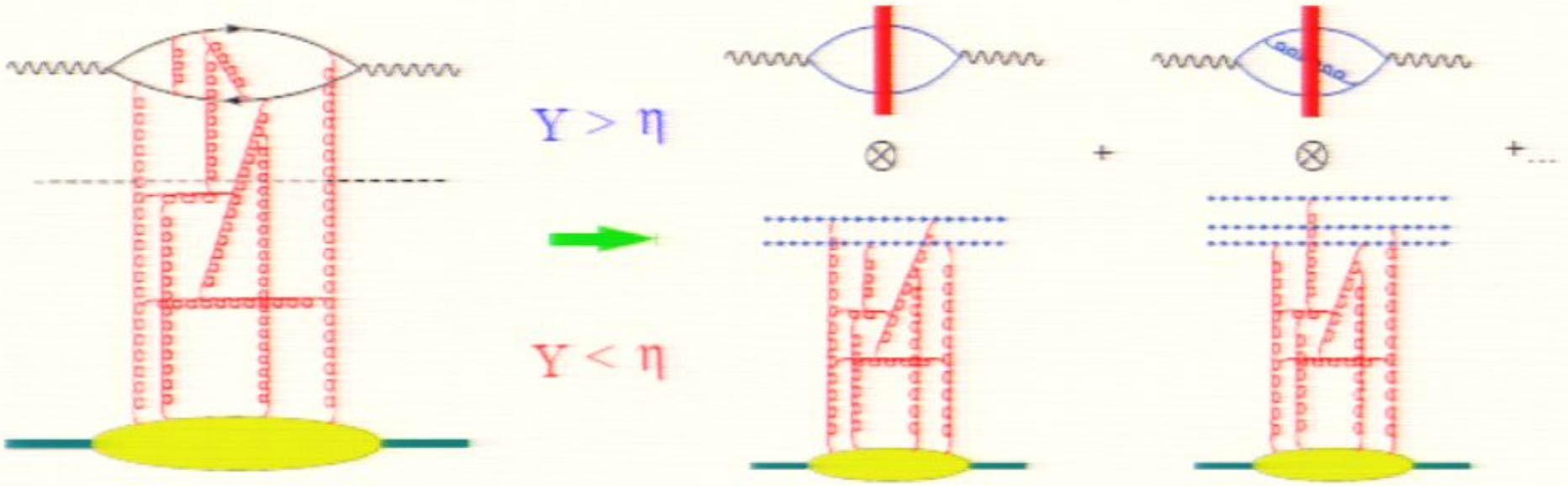
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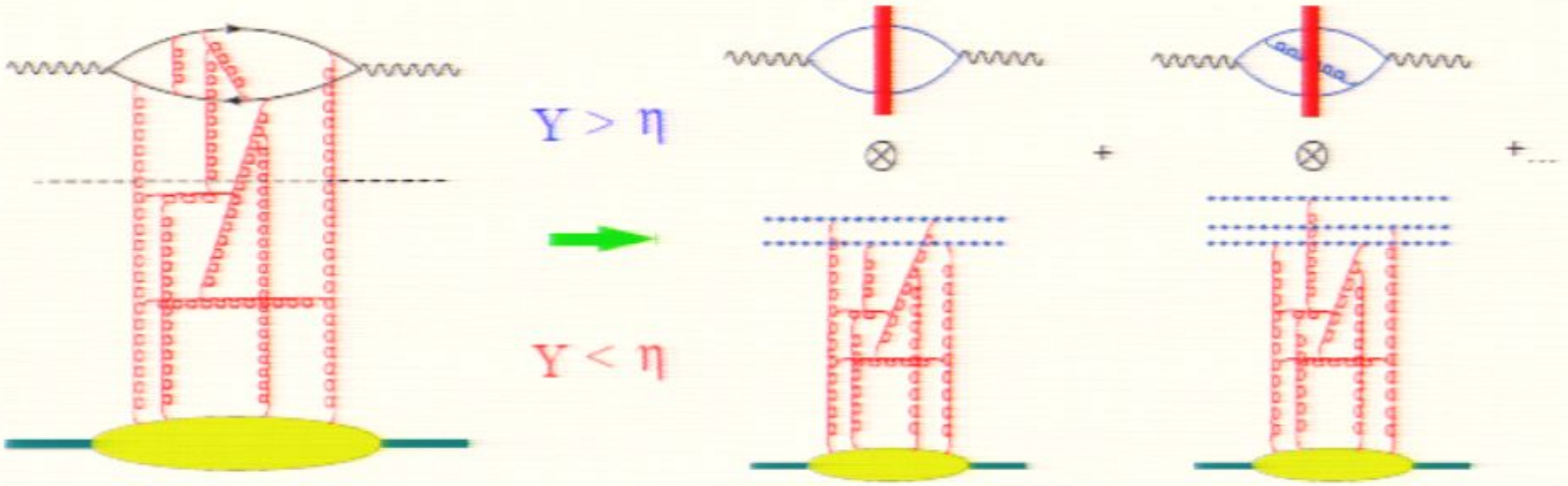
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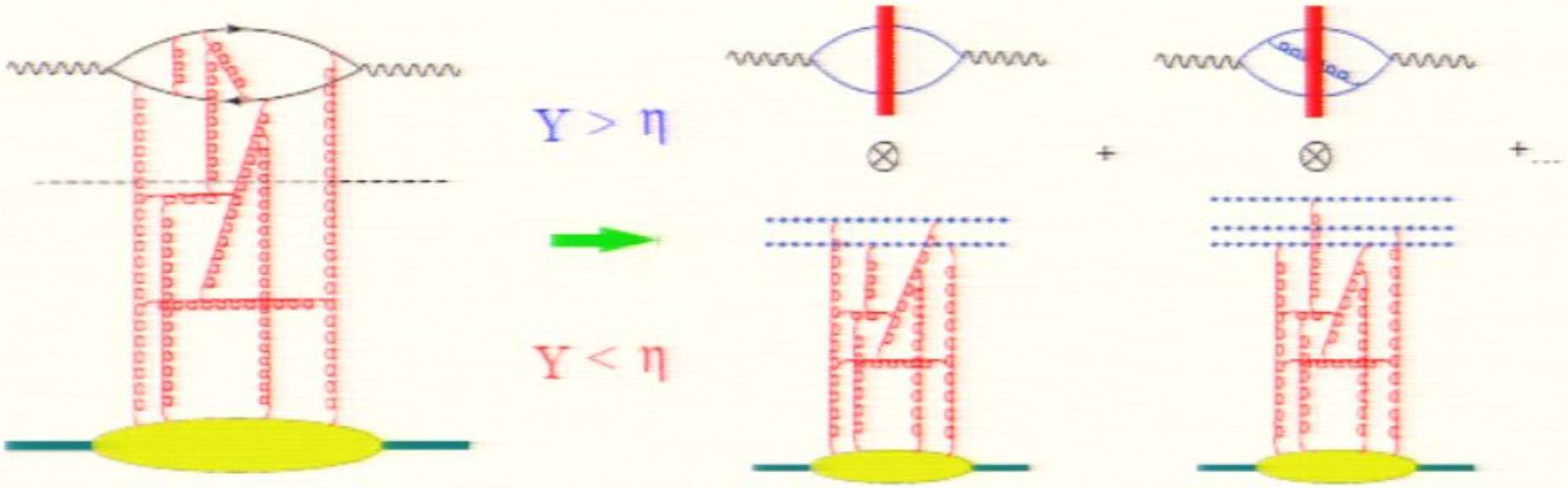
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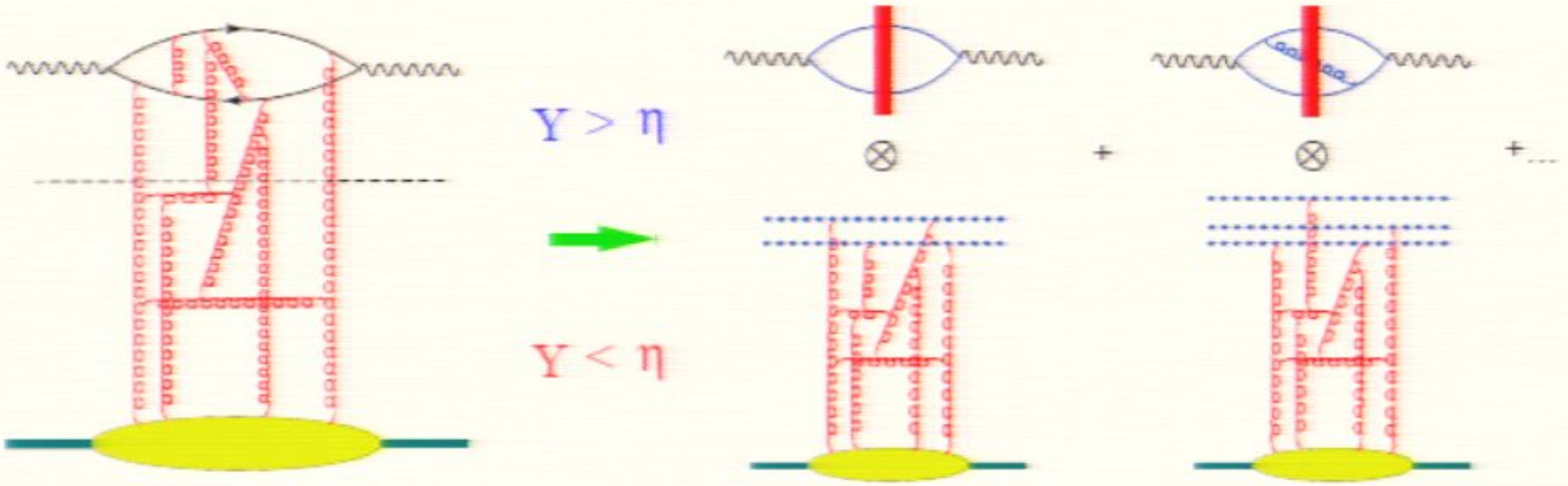
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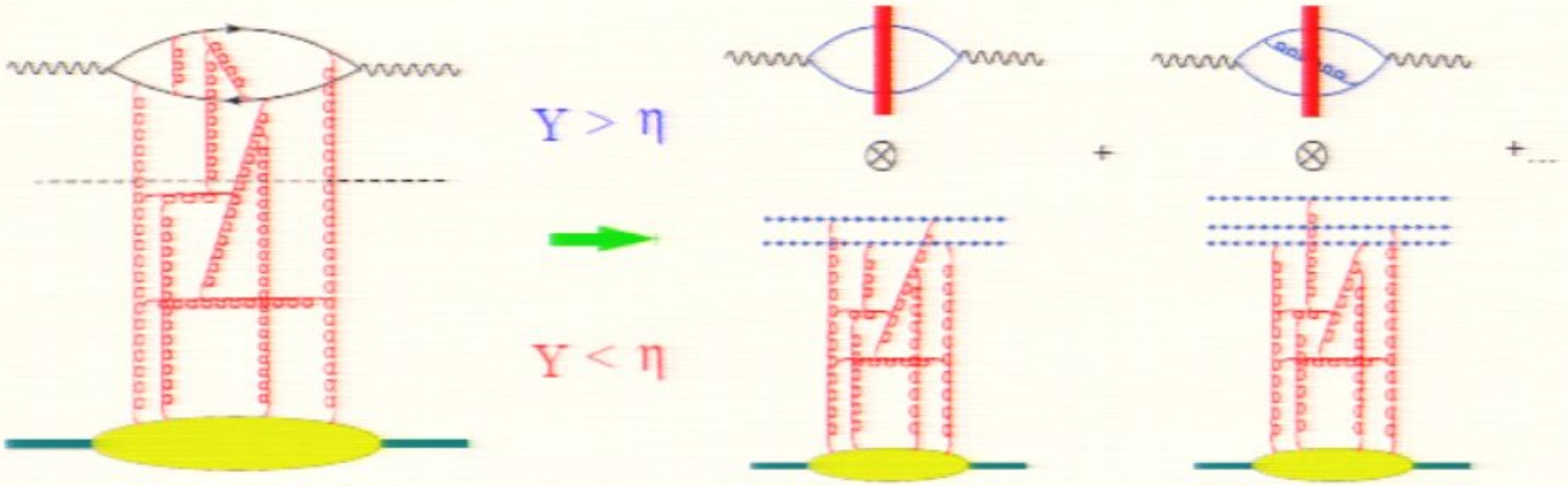
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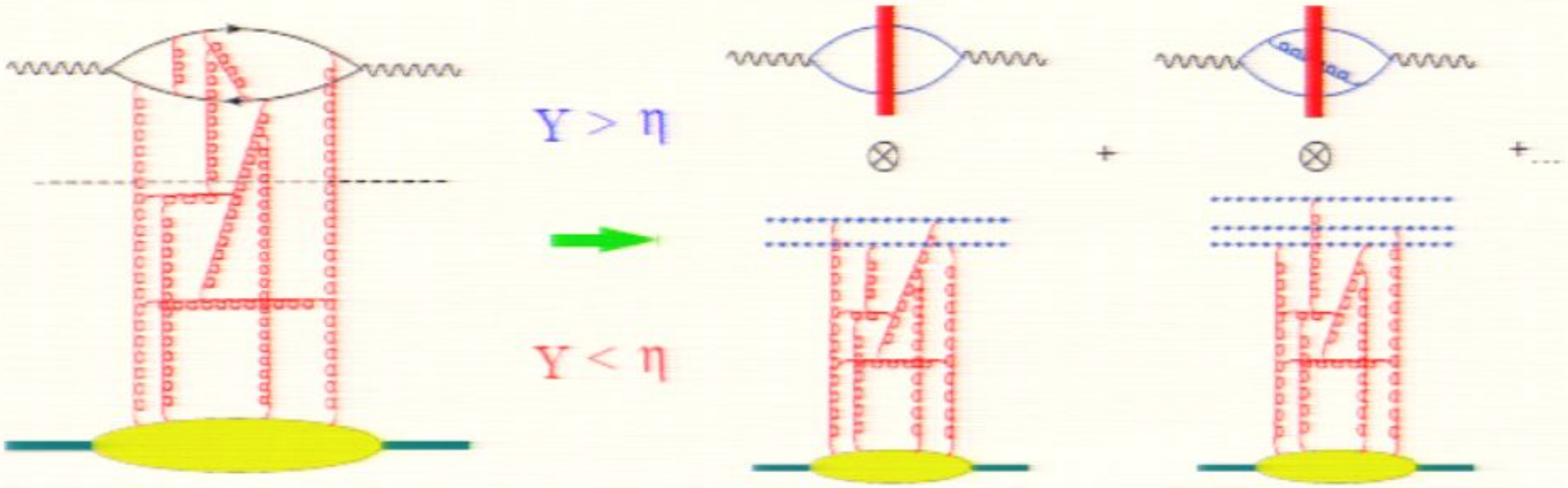
Rapidity Y > η - coefficient function ("impact factor")

Rapidity Y < η - matrix elements of (light-like) Wilson lines with rapidity divergence cut by η

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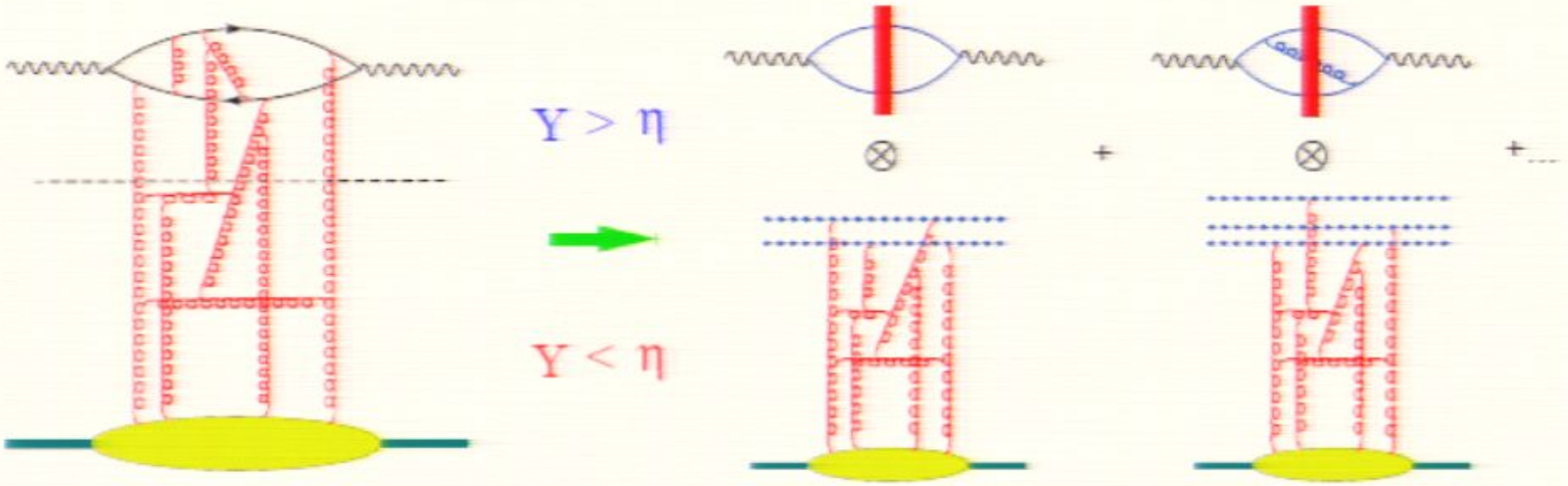
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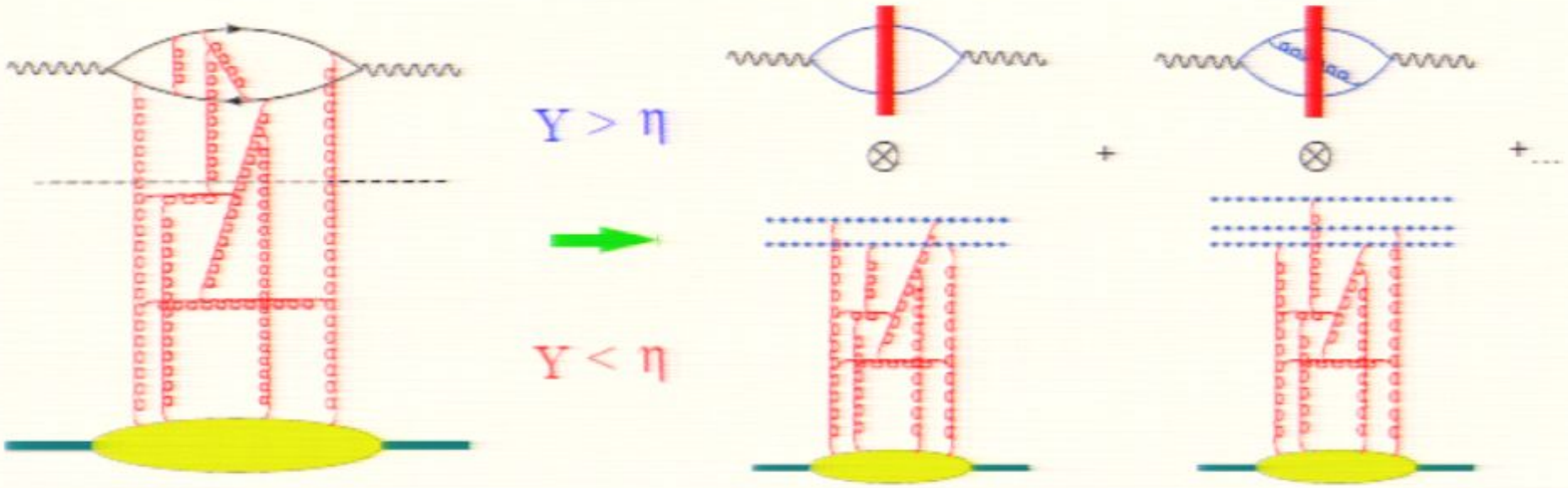
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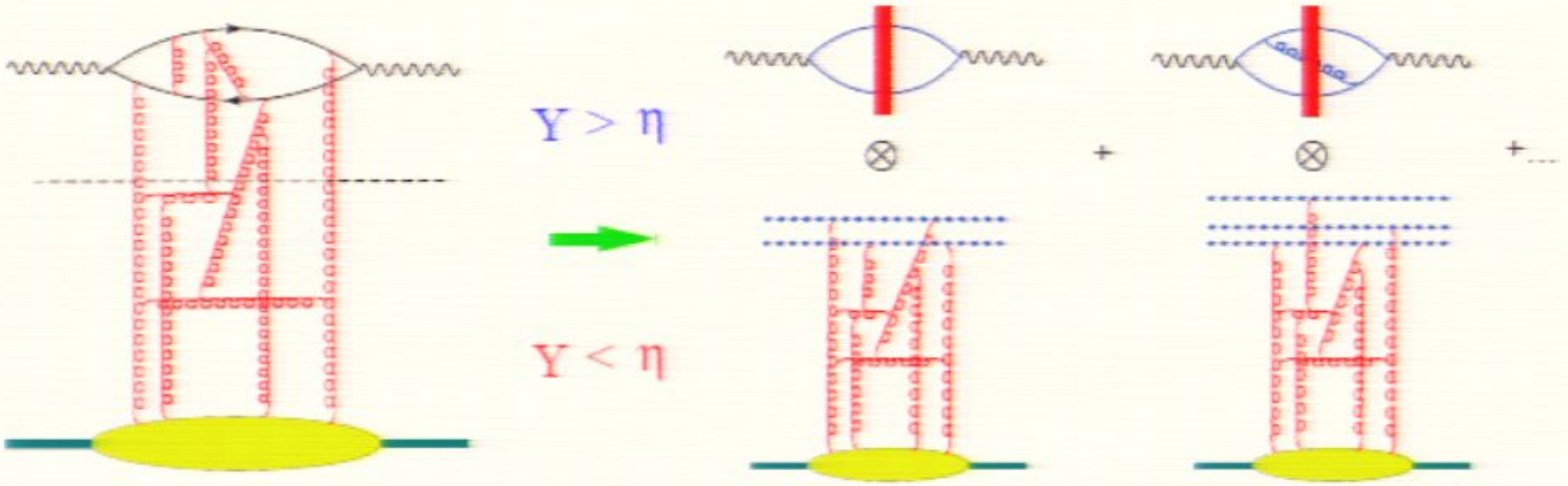
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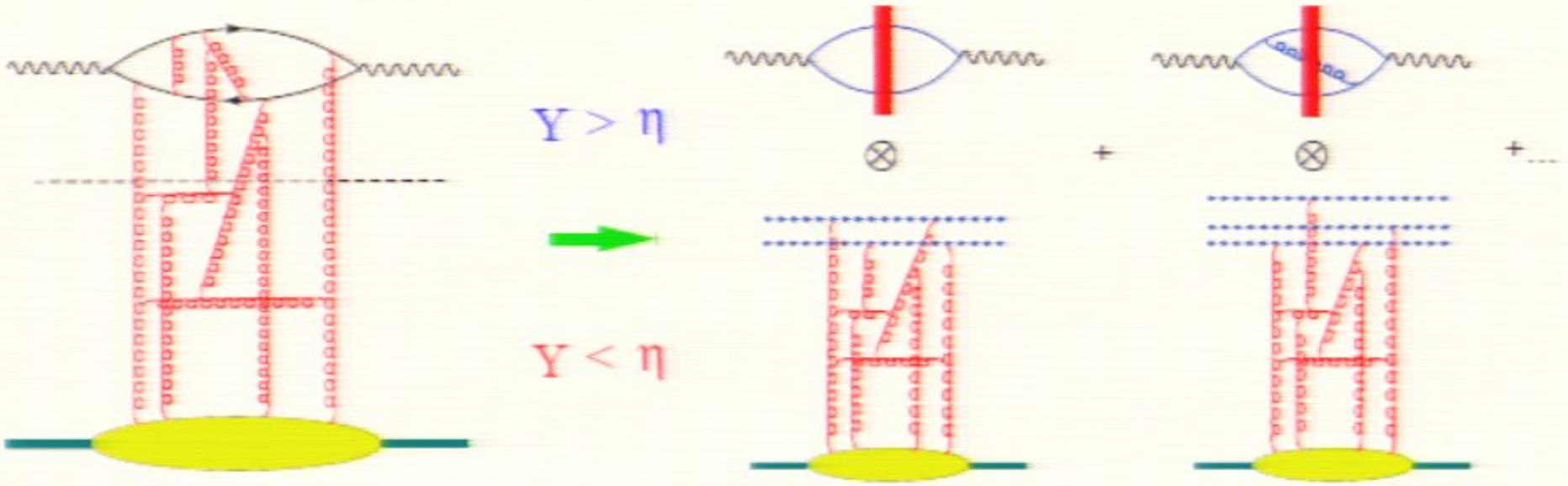
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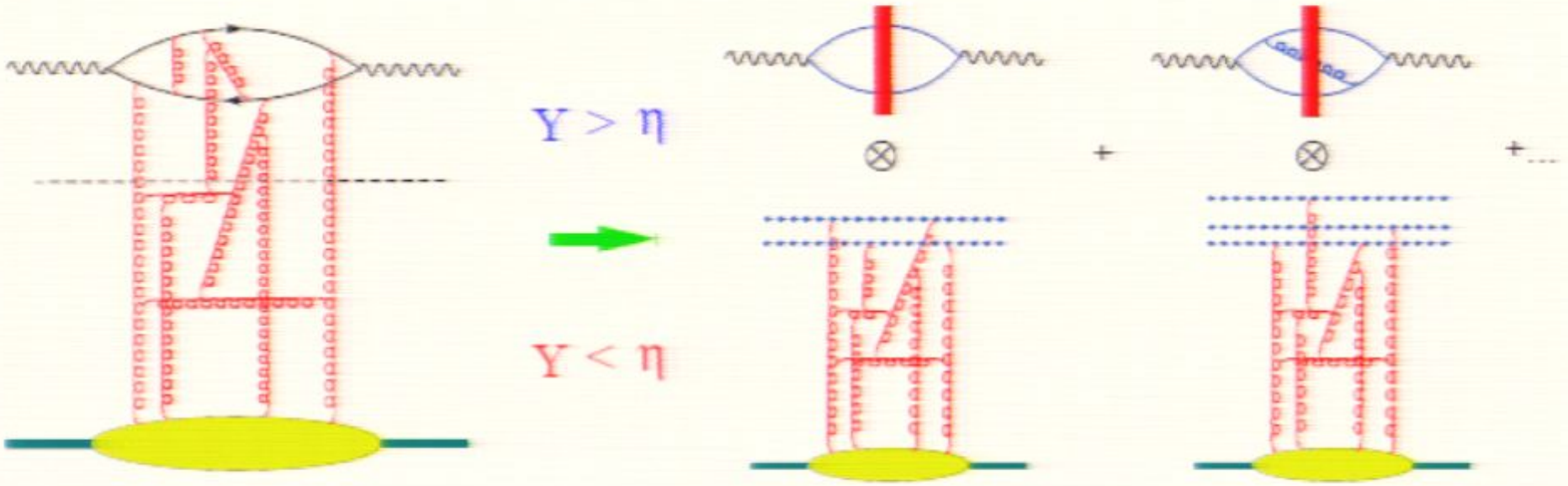
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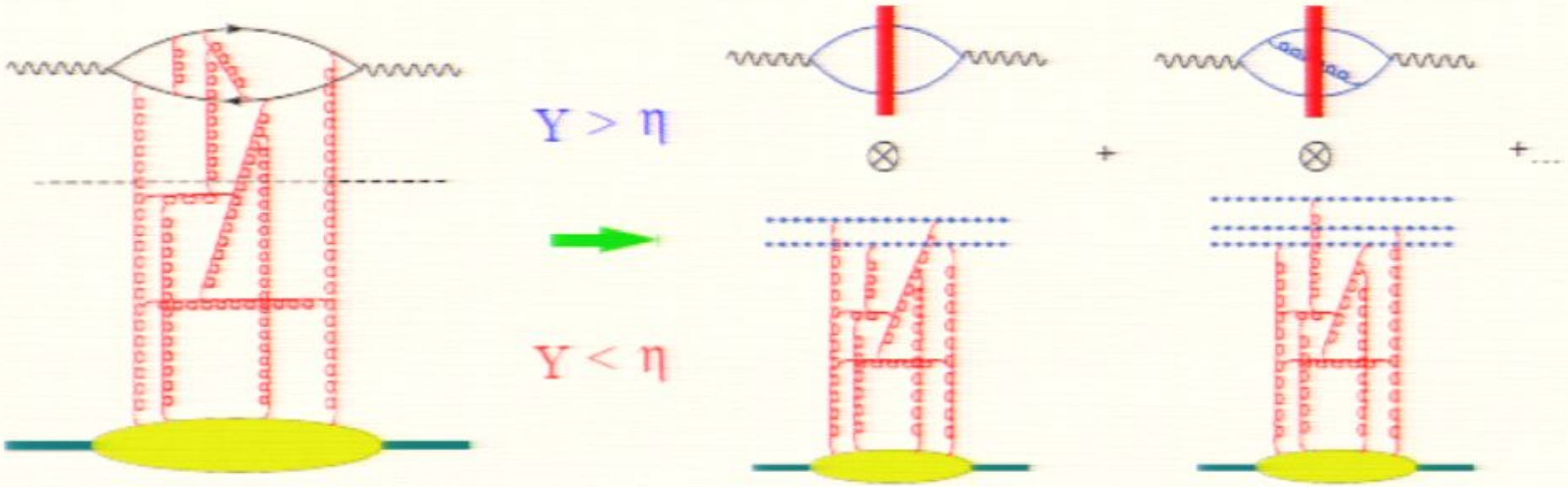
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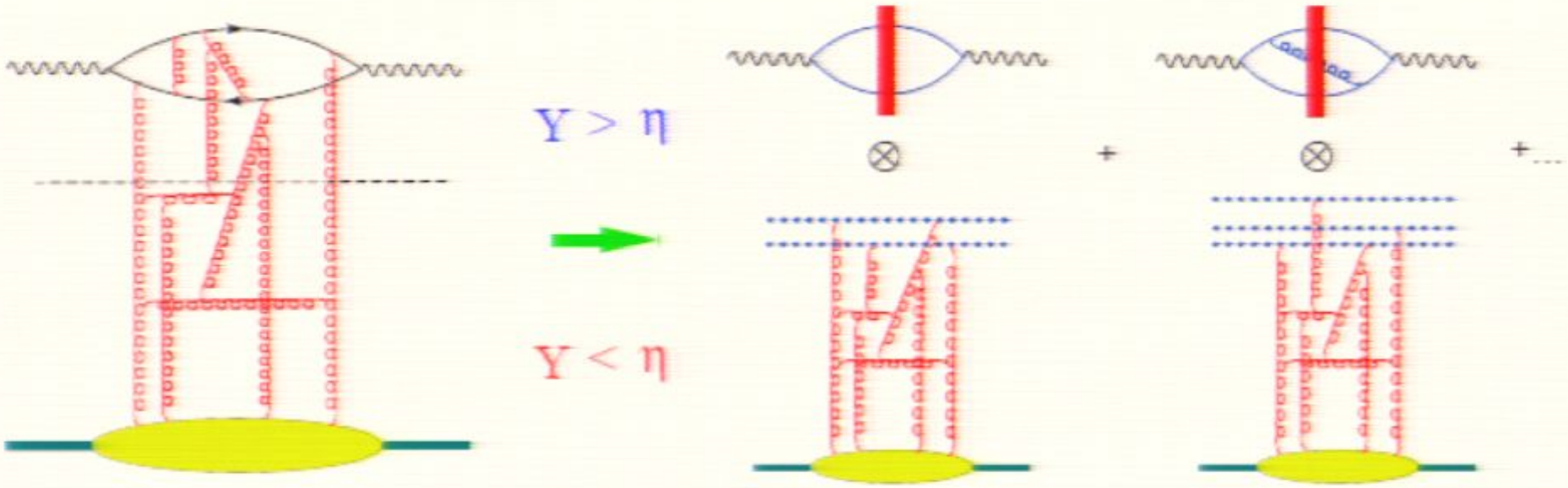
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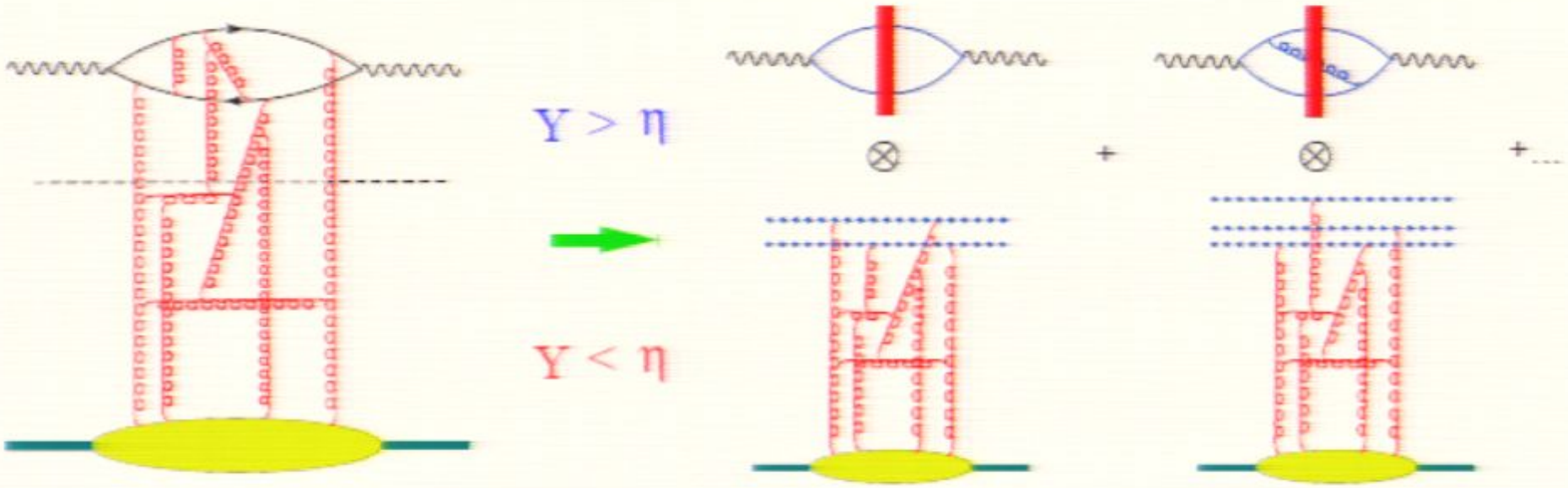
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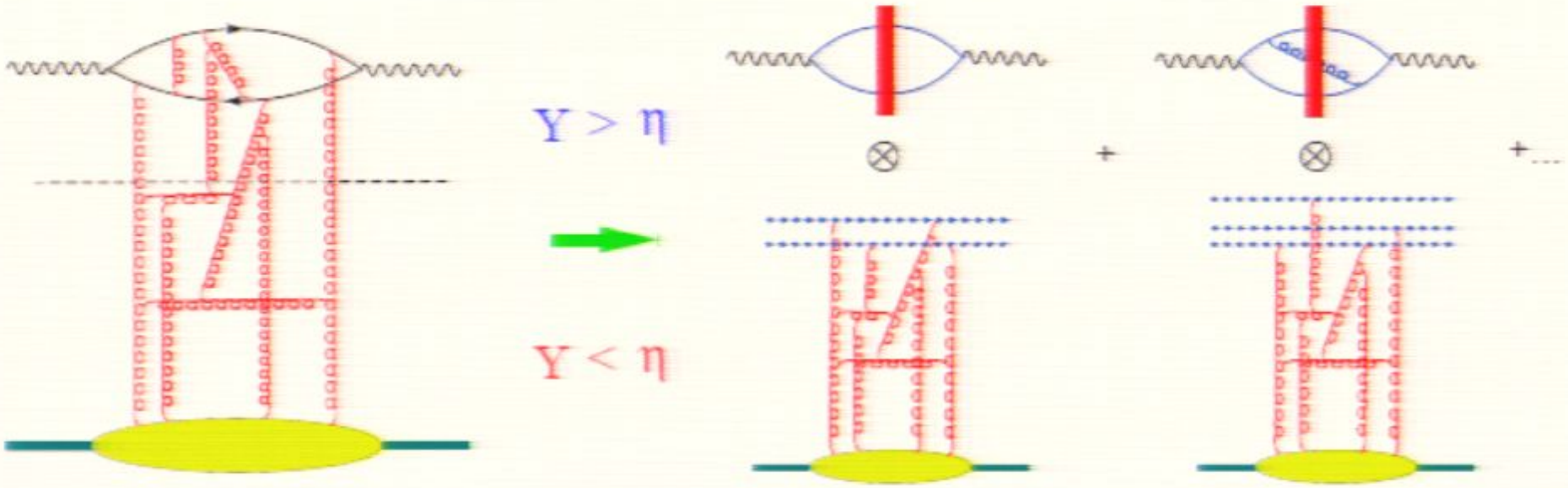
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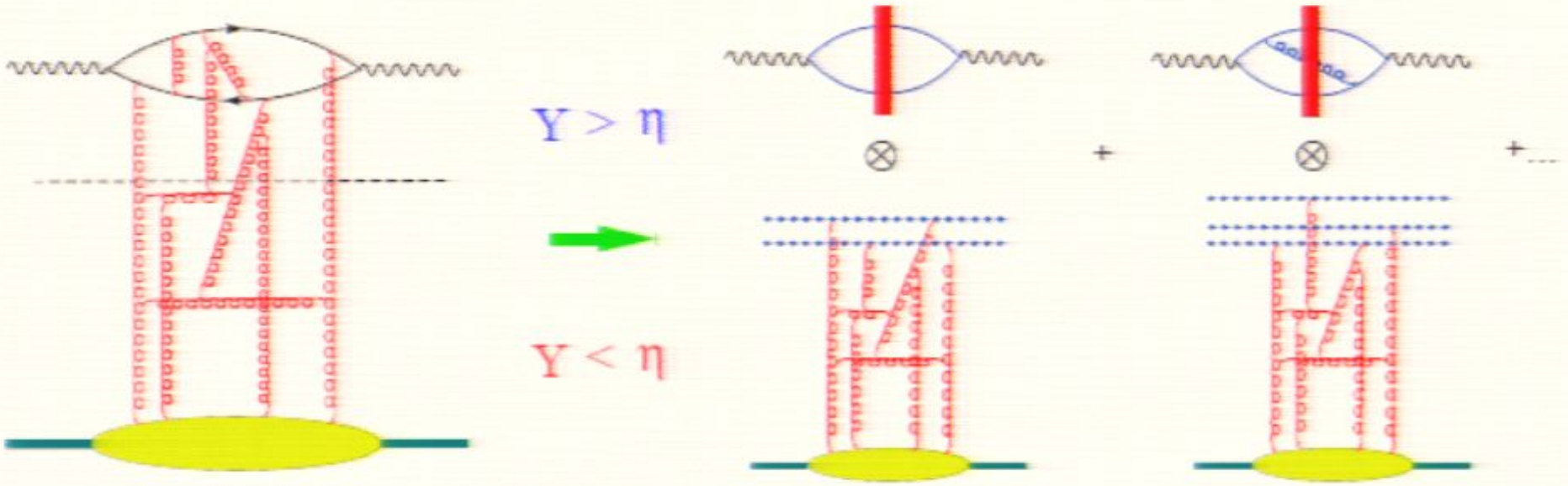
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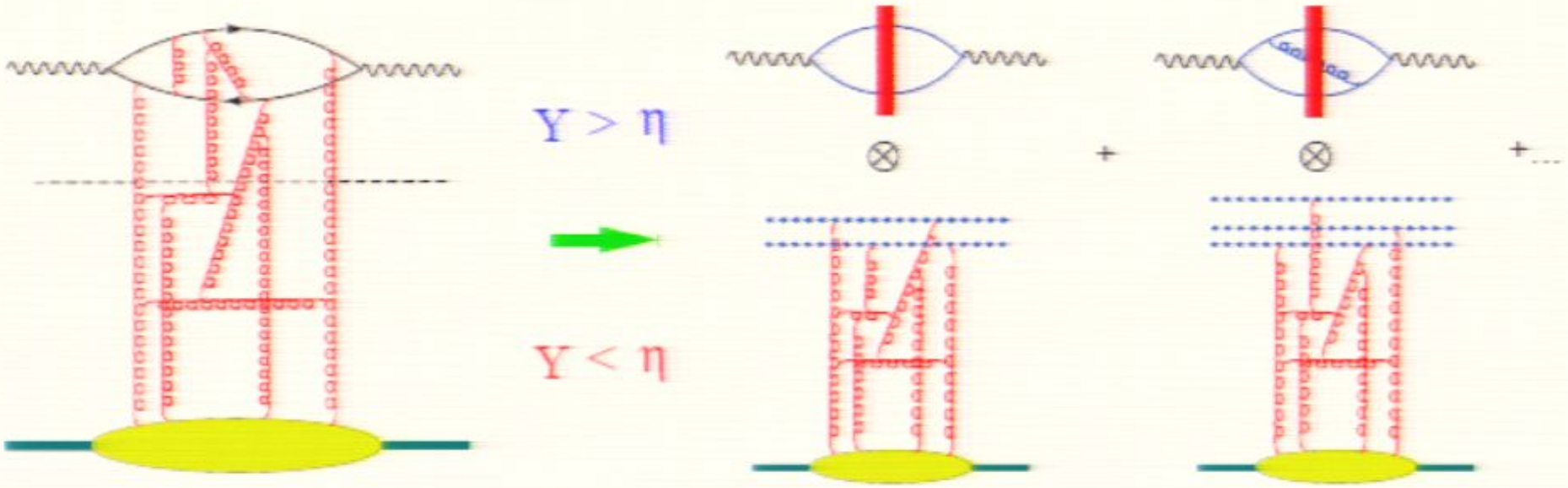
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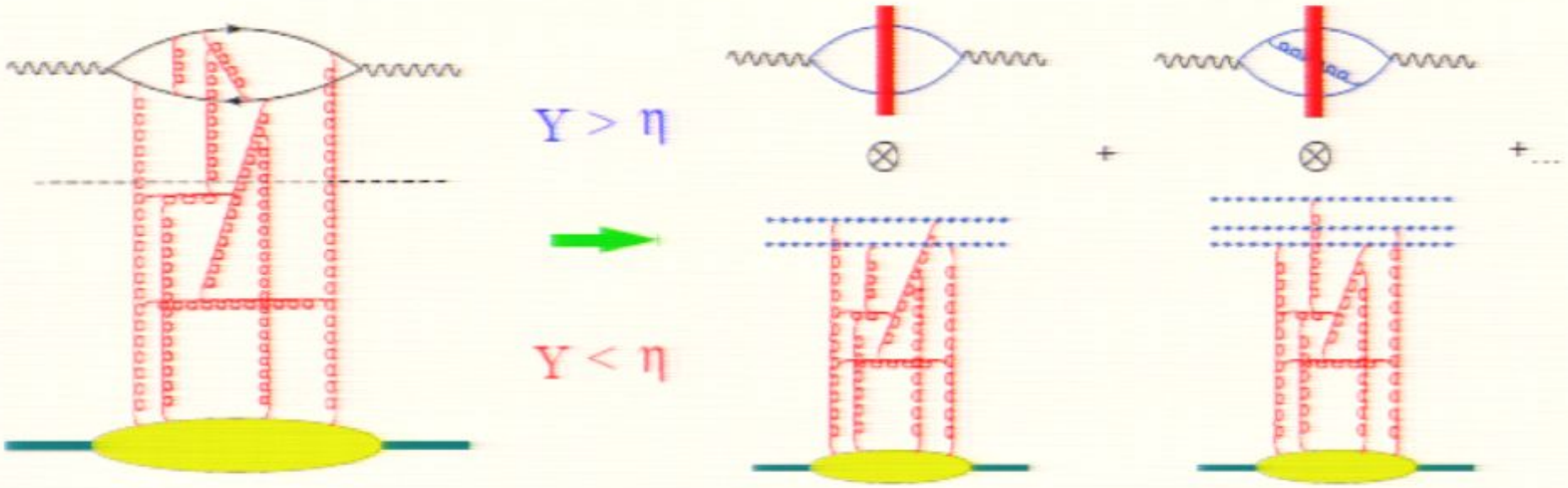
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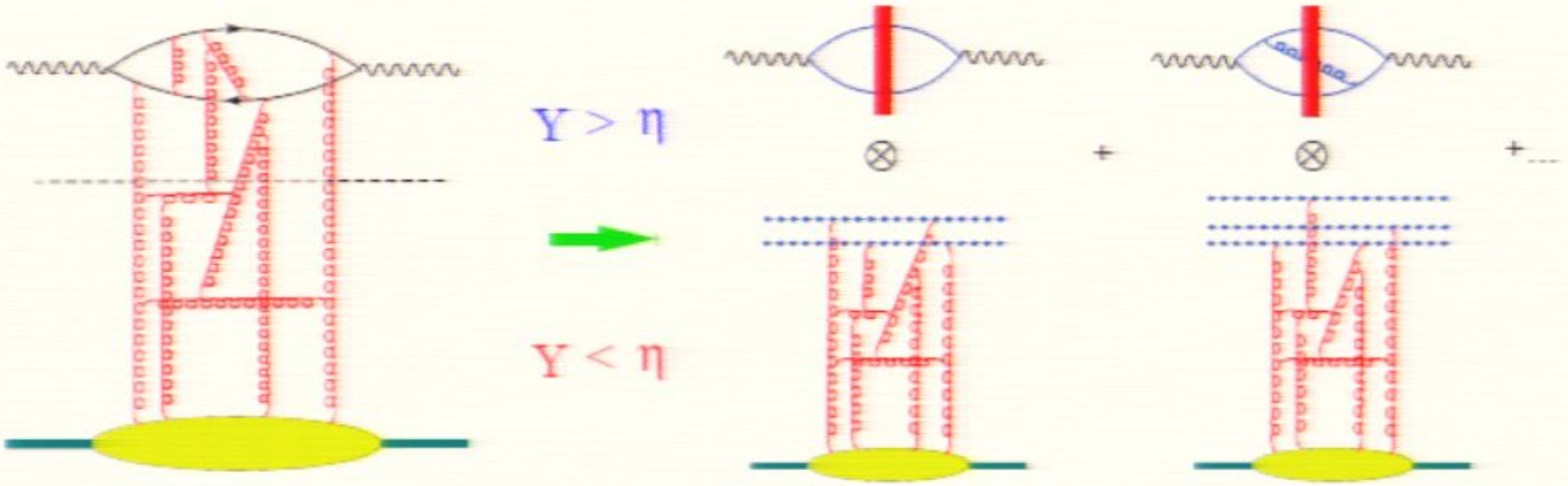
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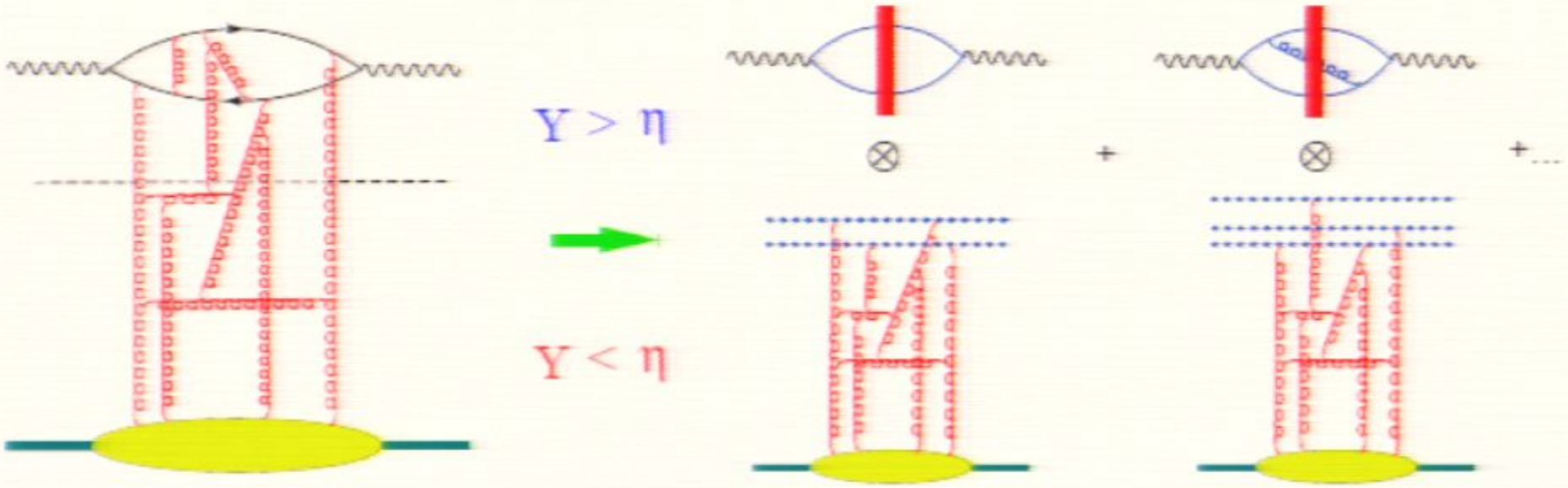
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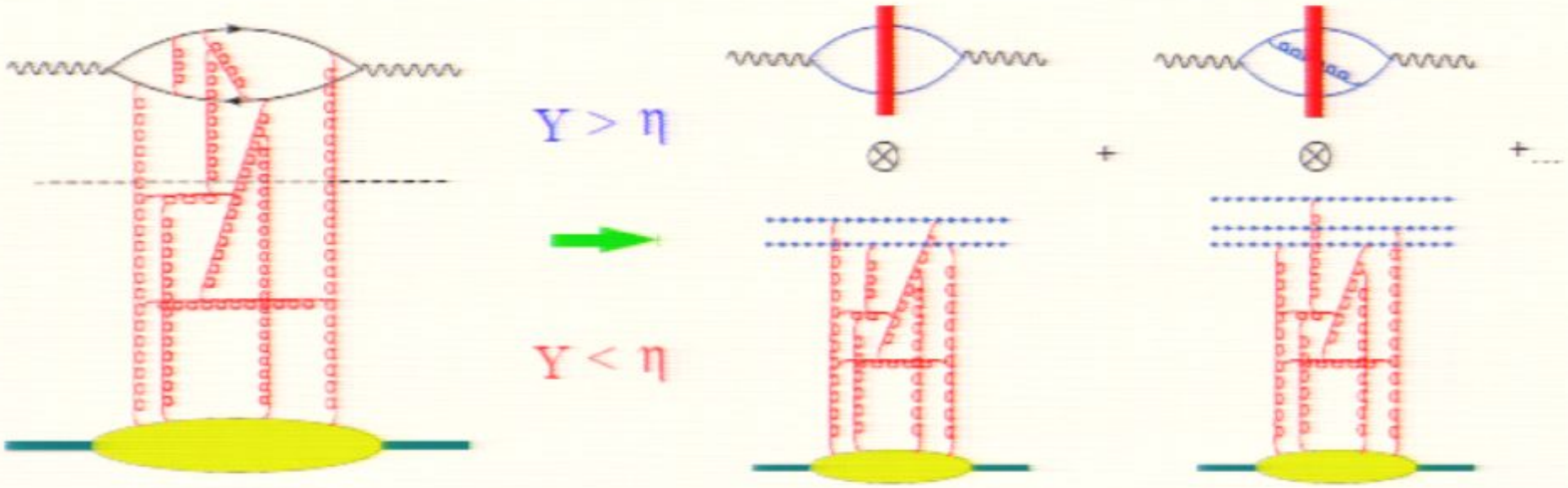
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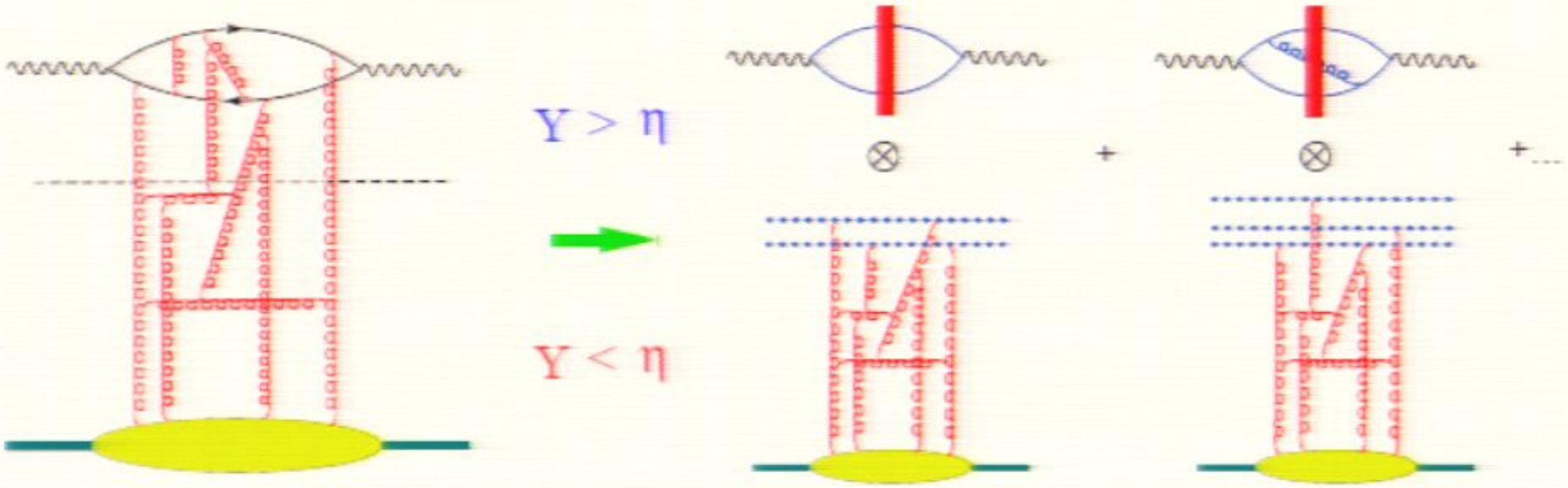
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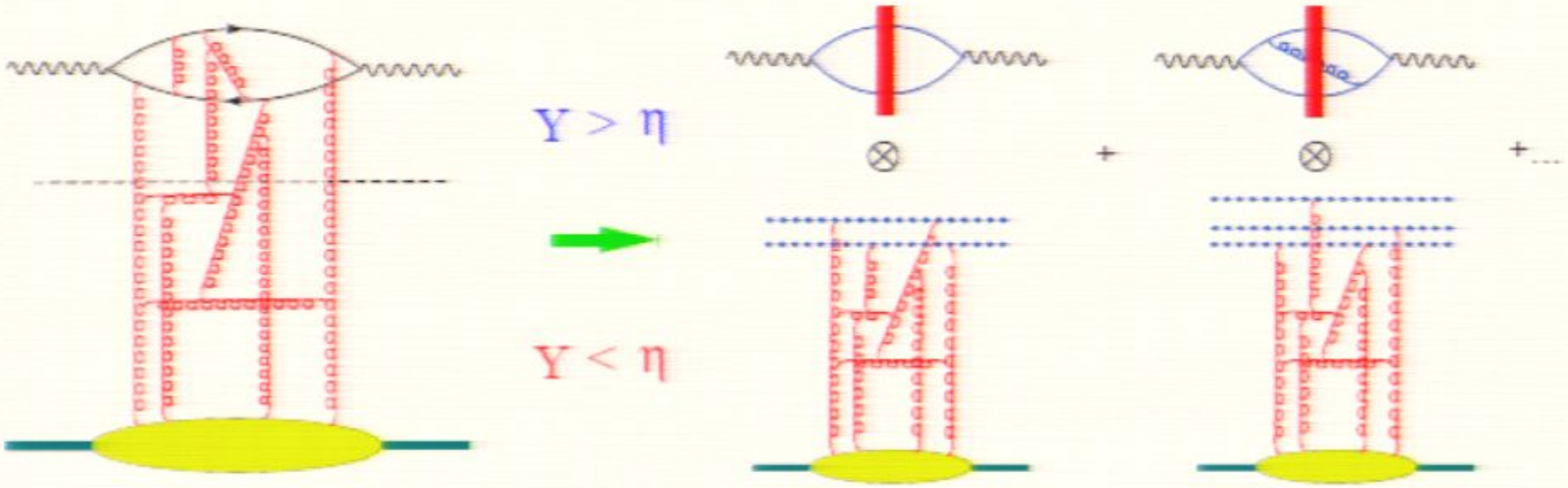
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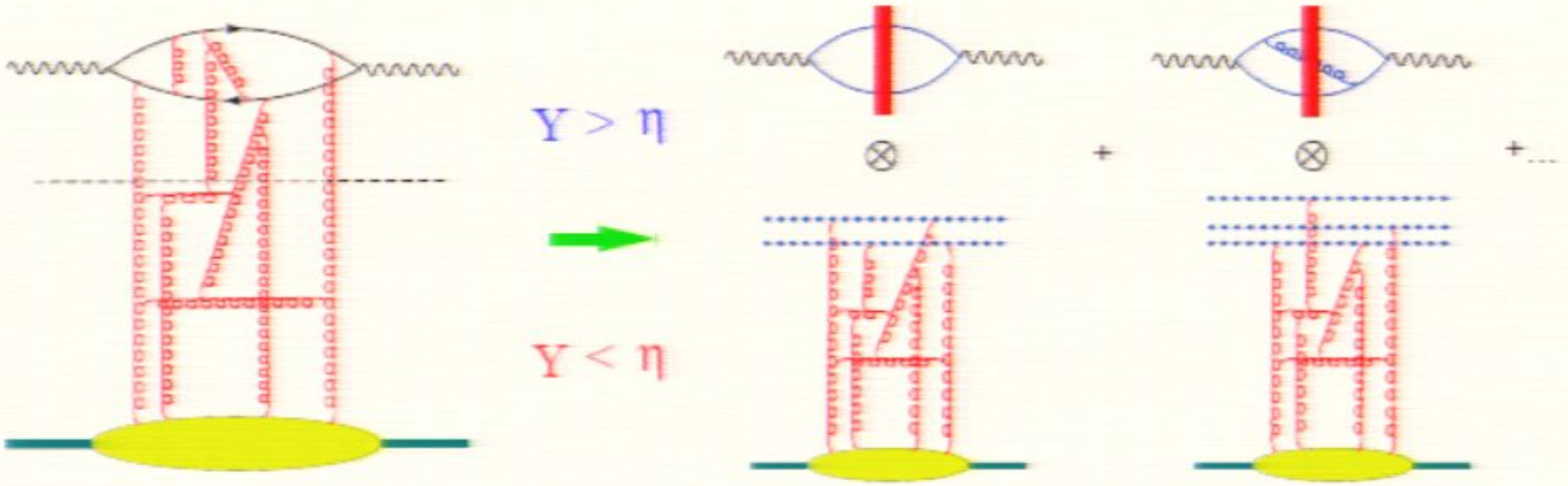
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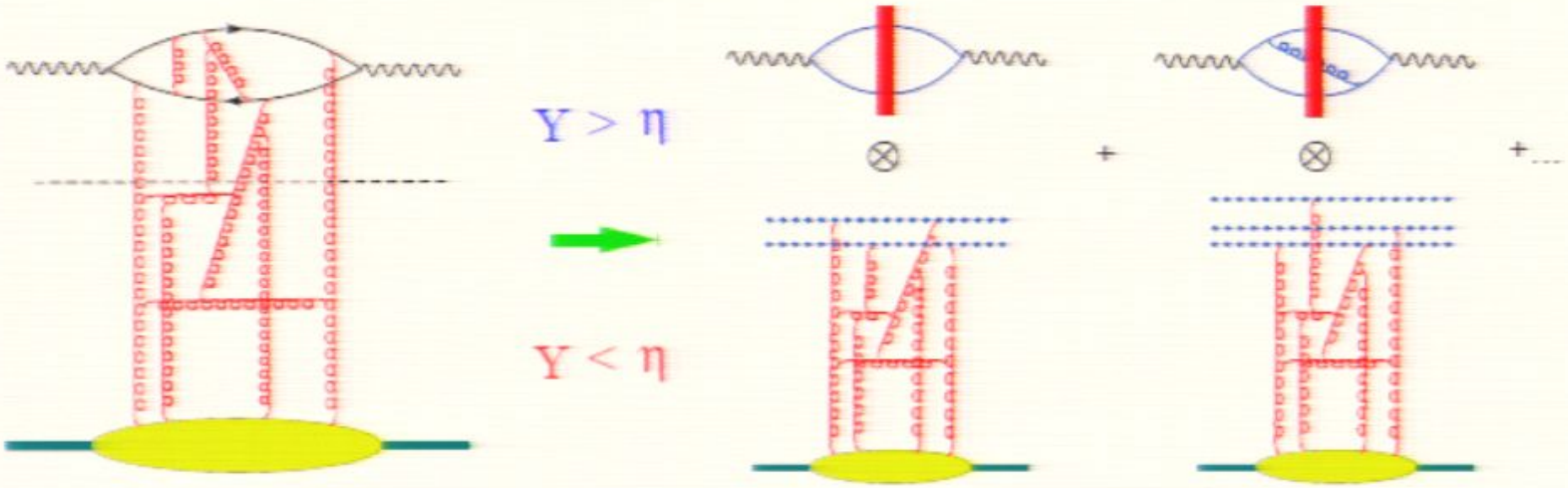
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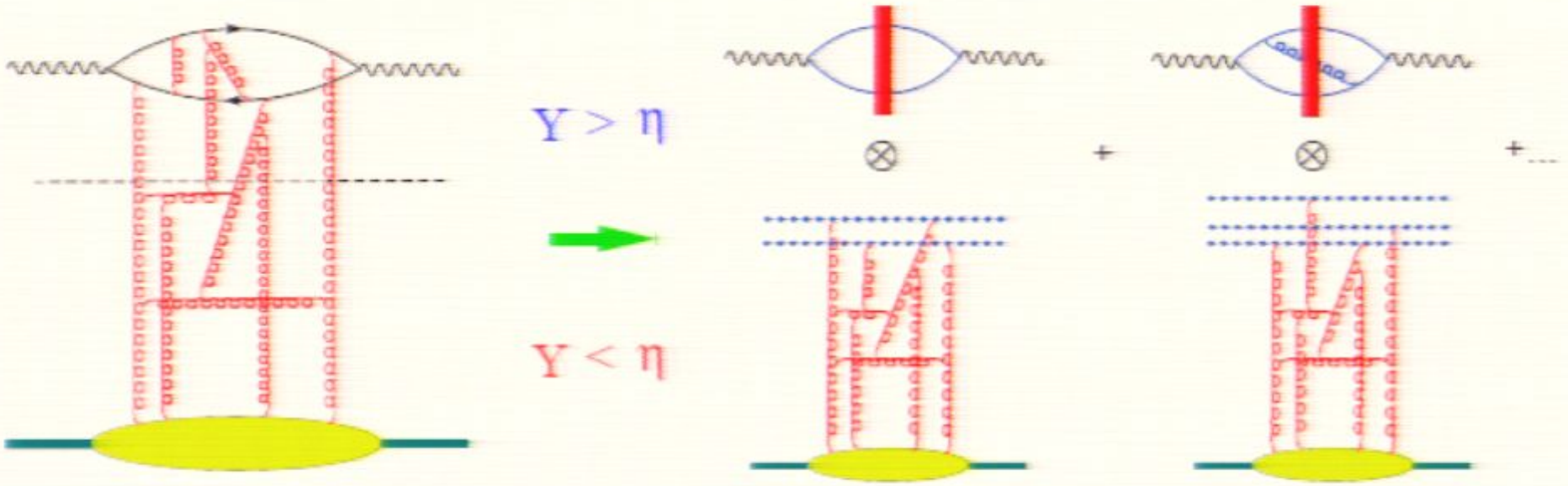
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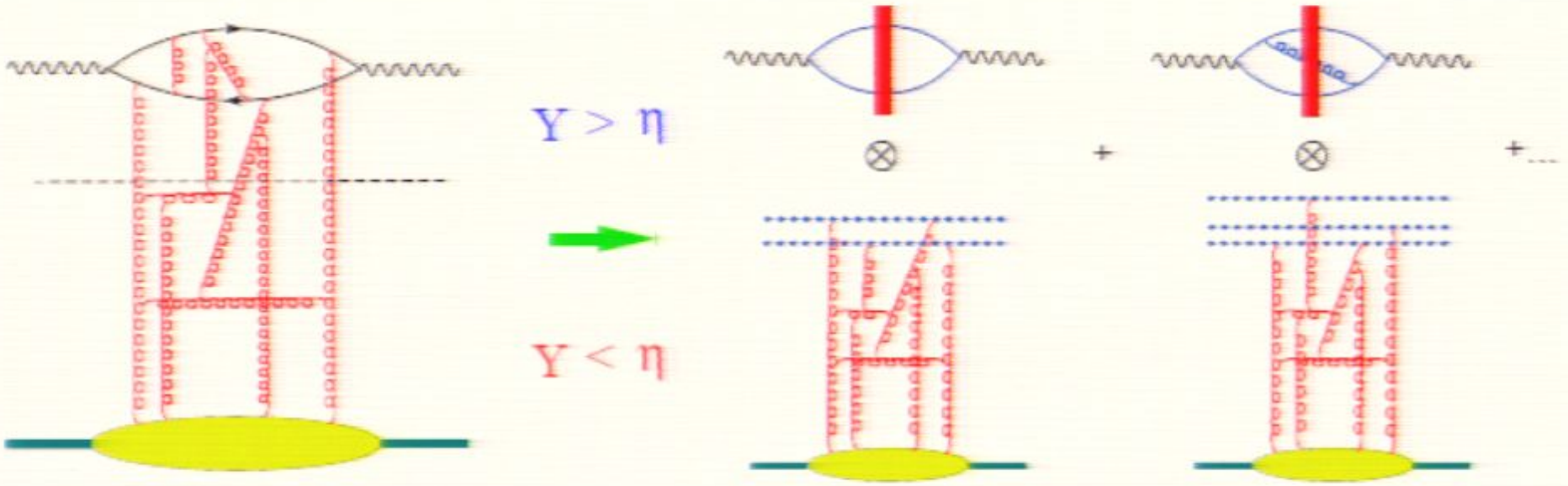
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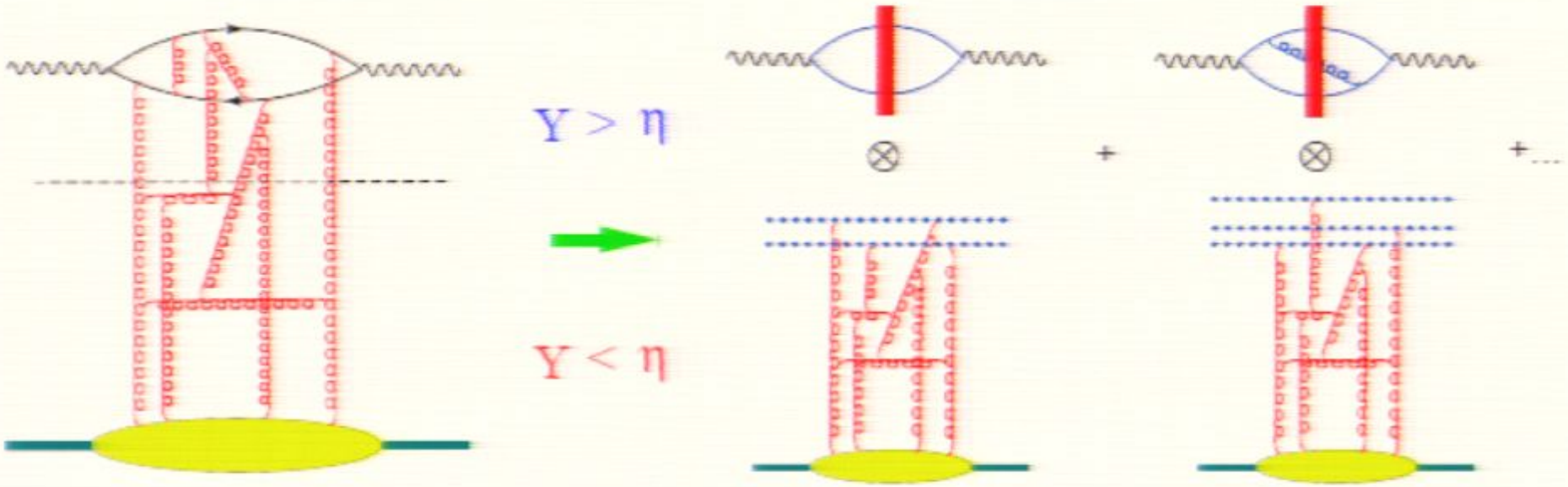
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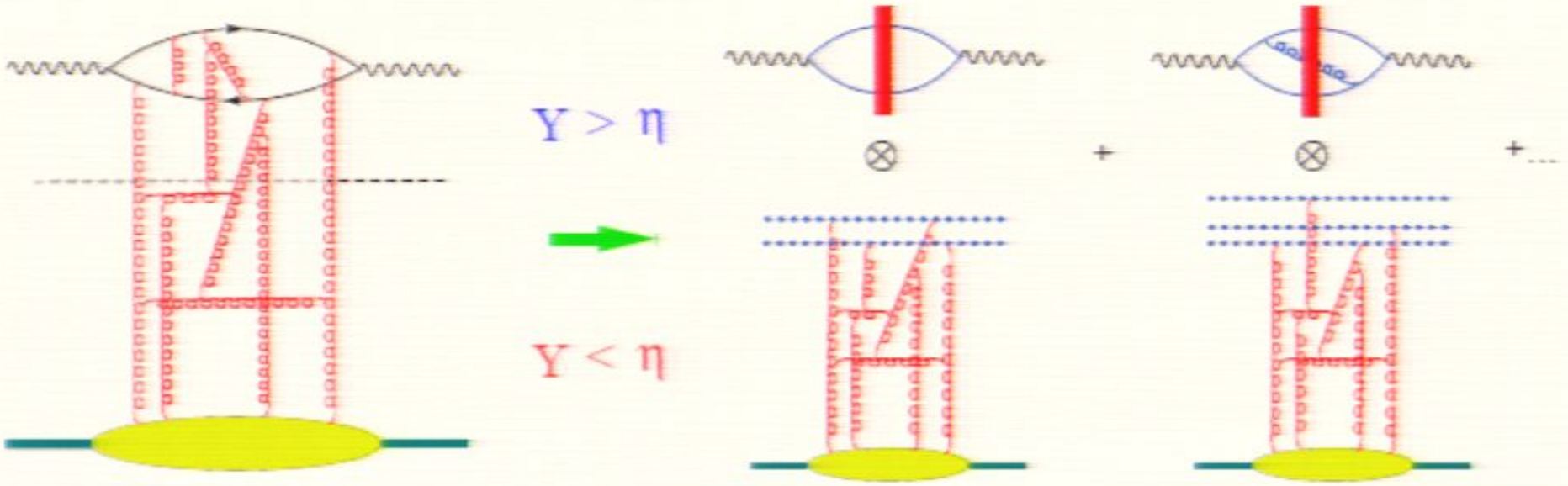
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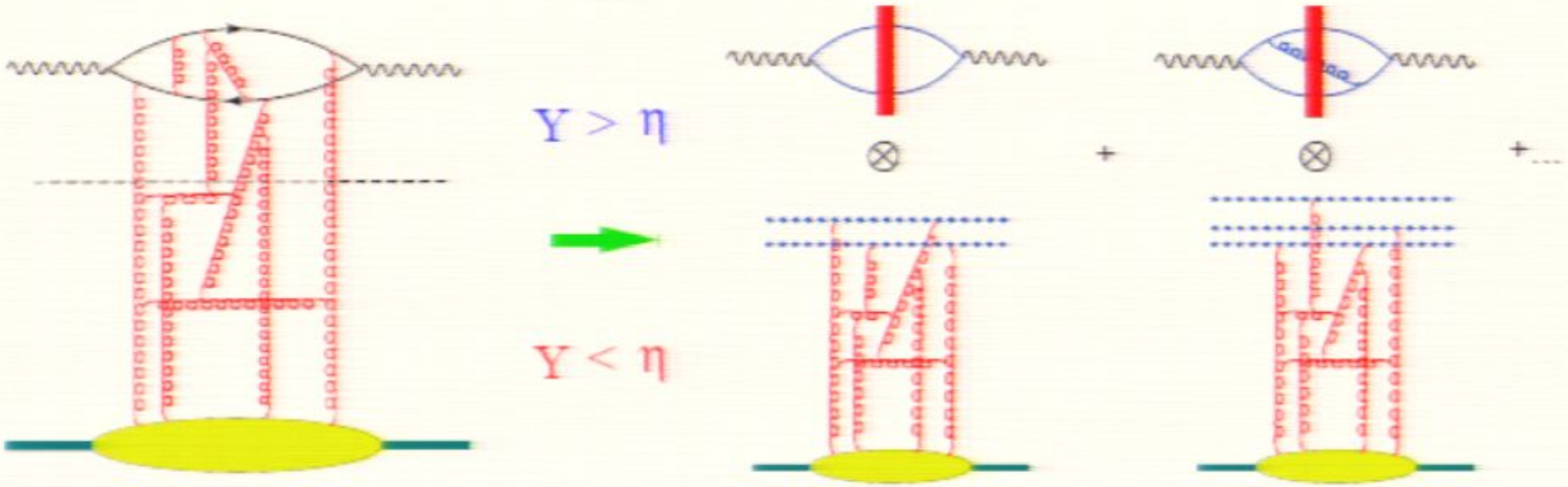
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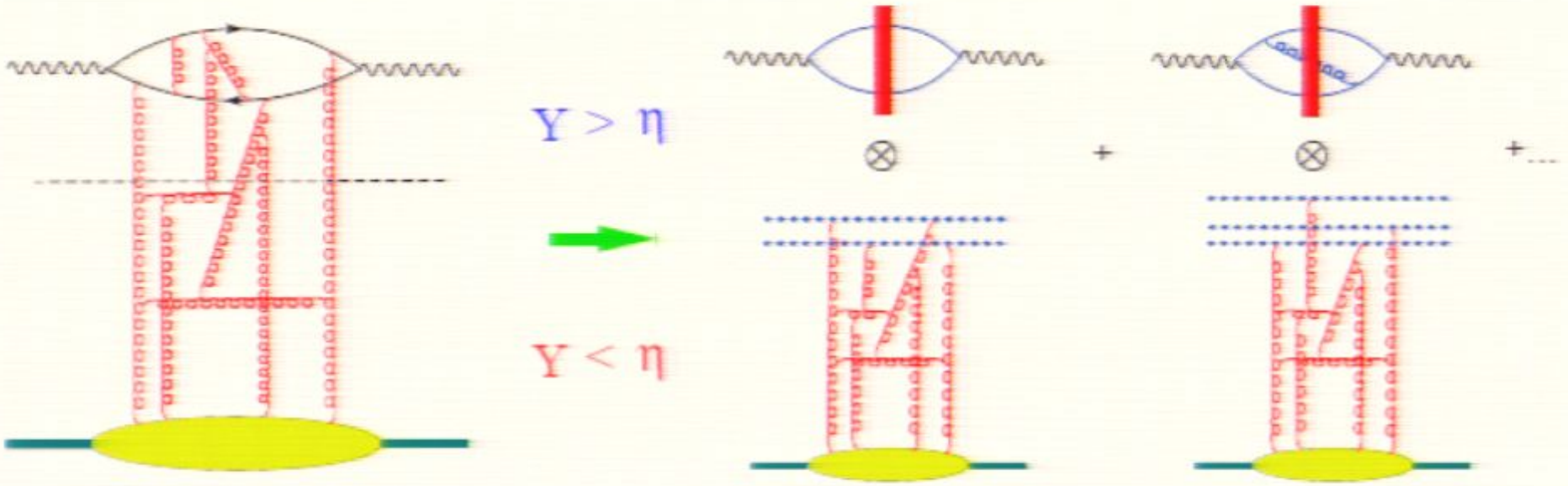
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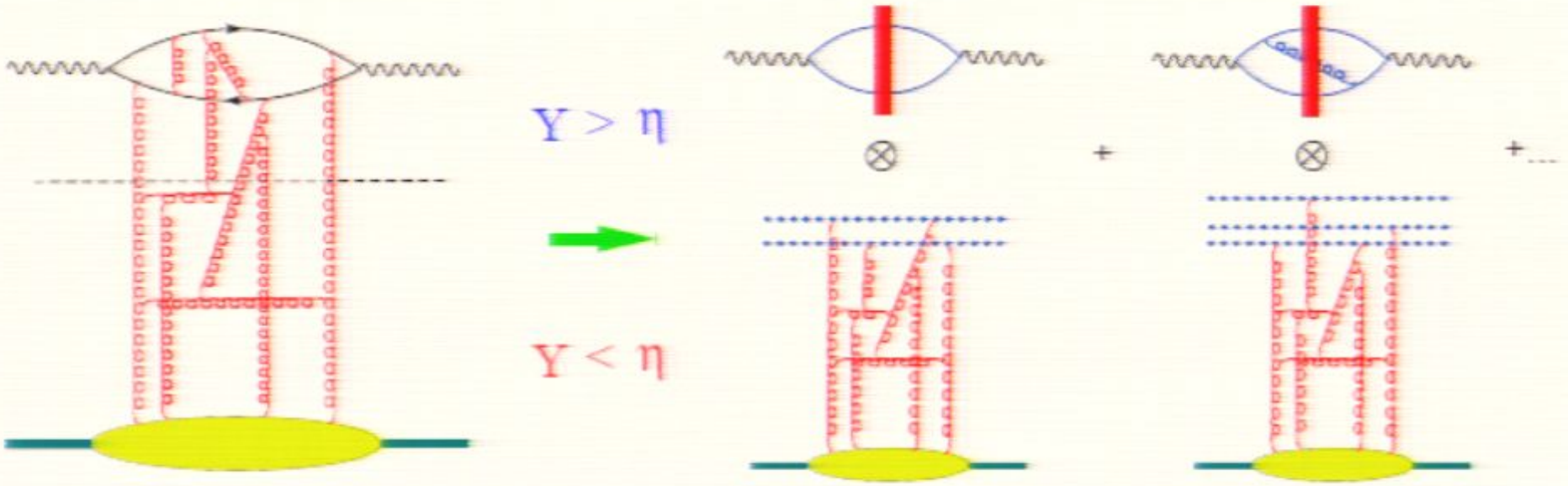
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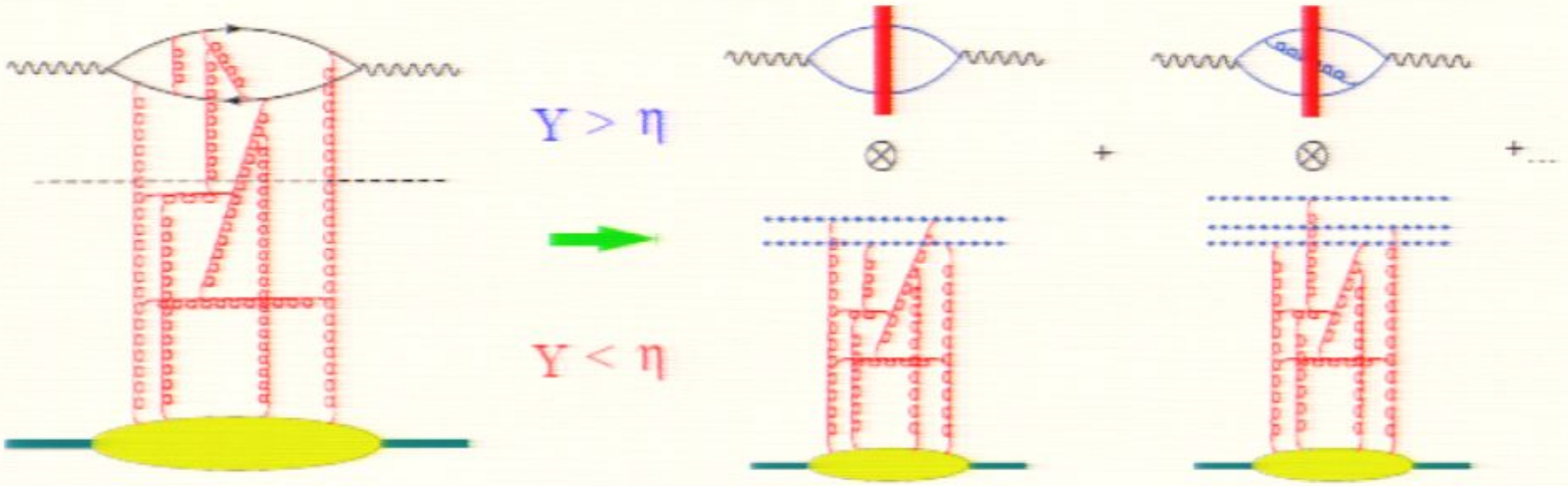
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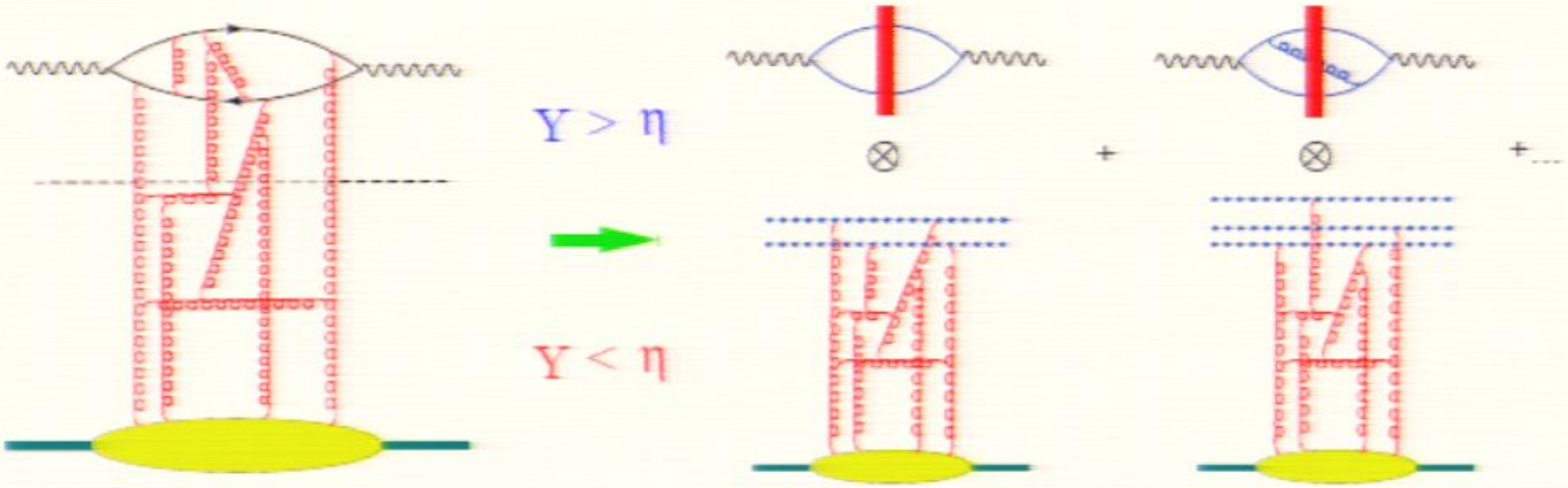
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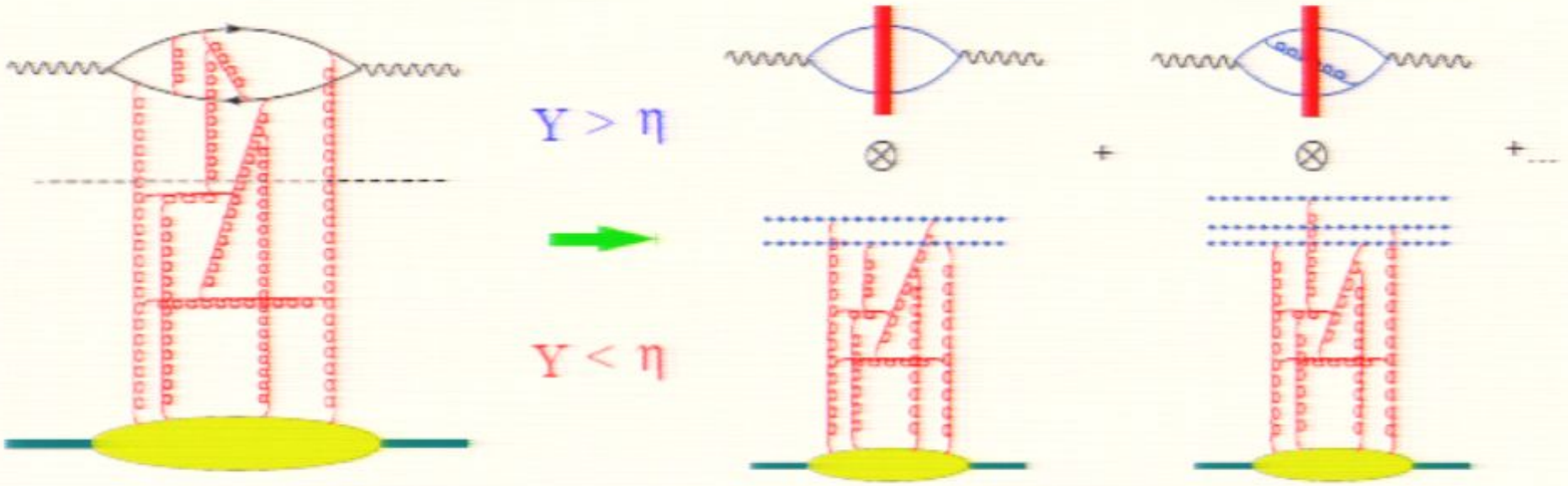
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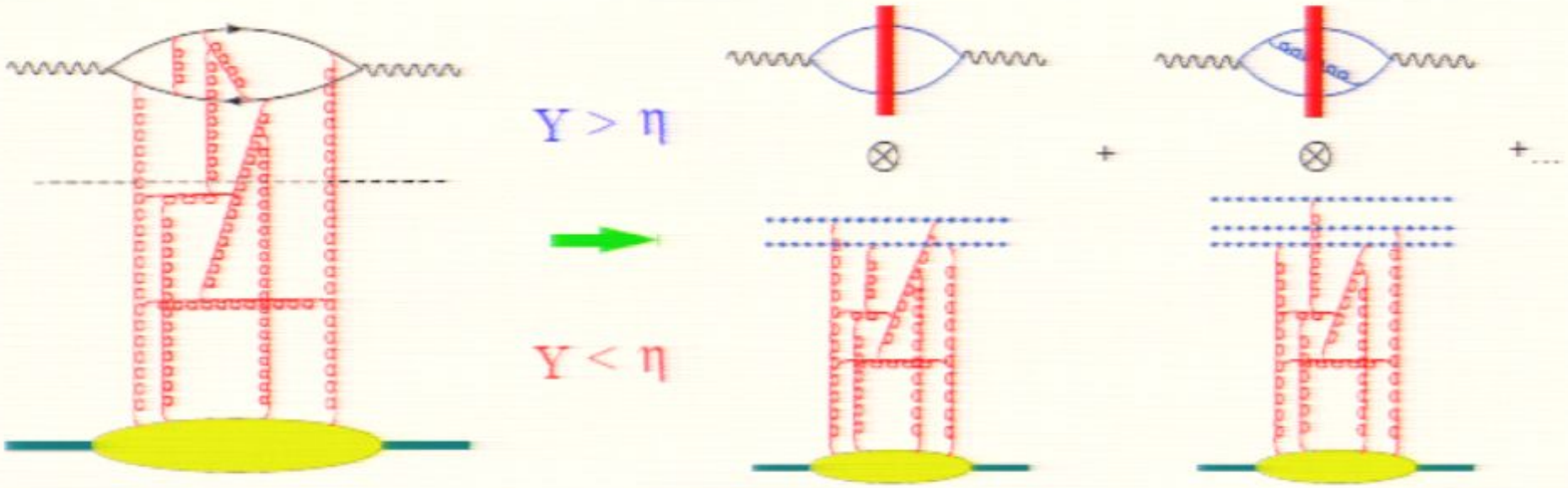
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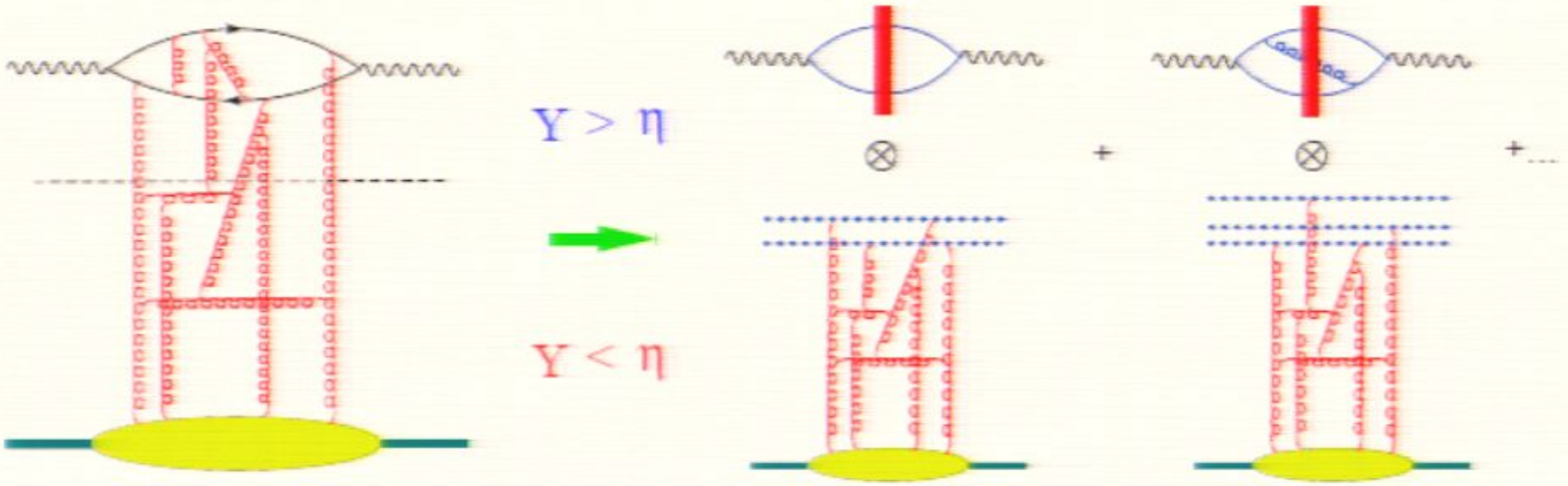
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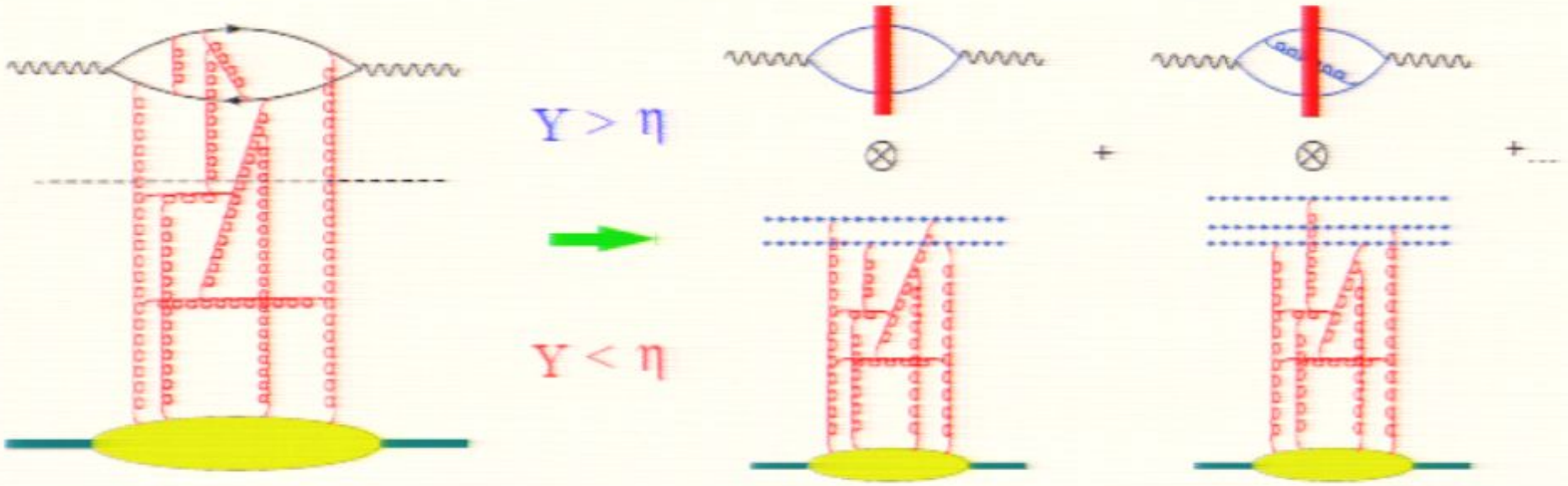
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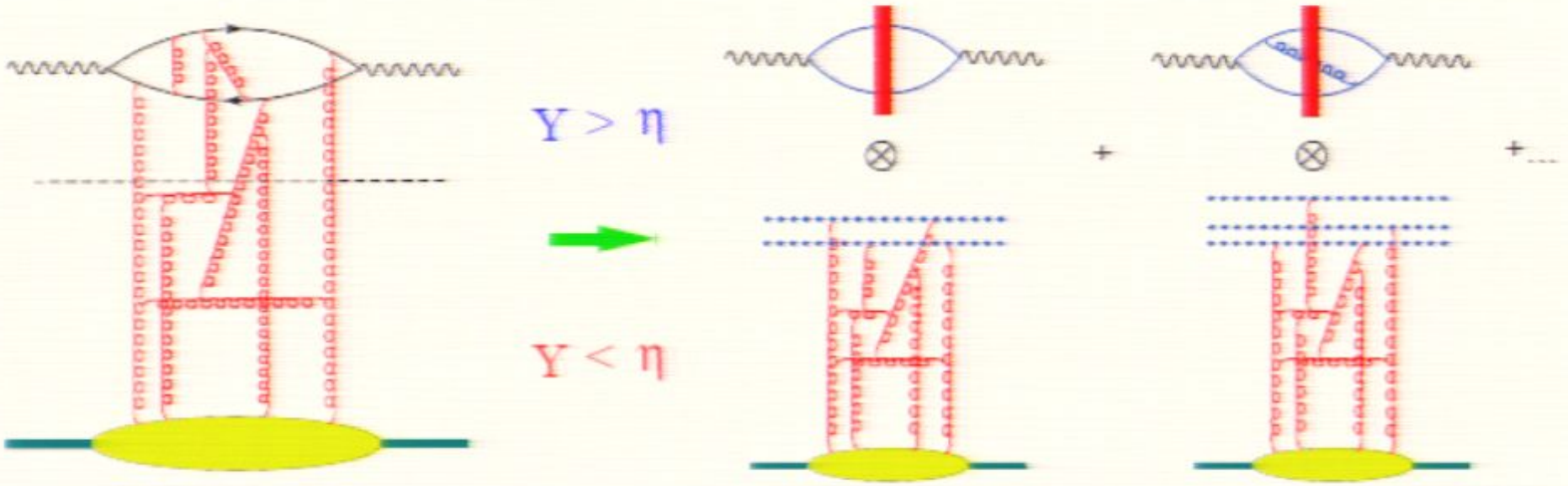
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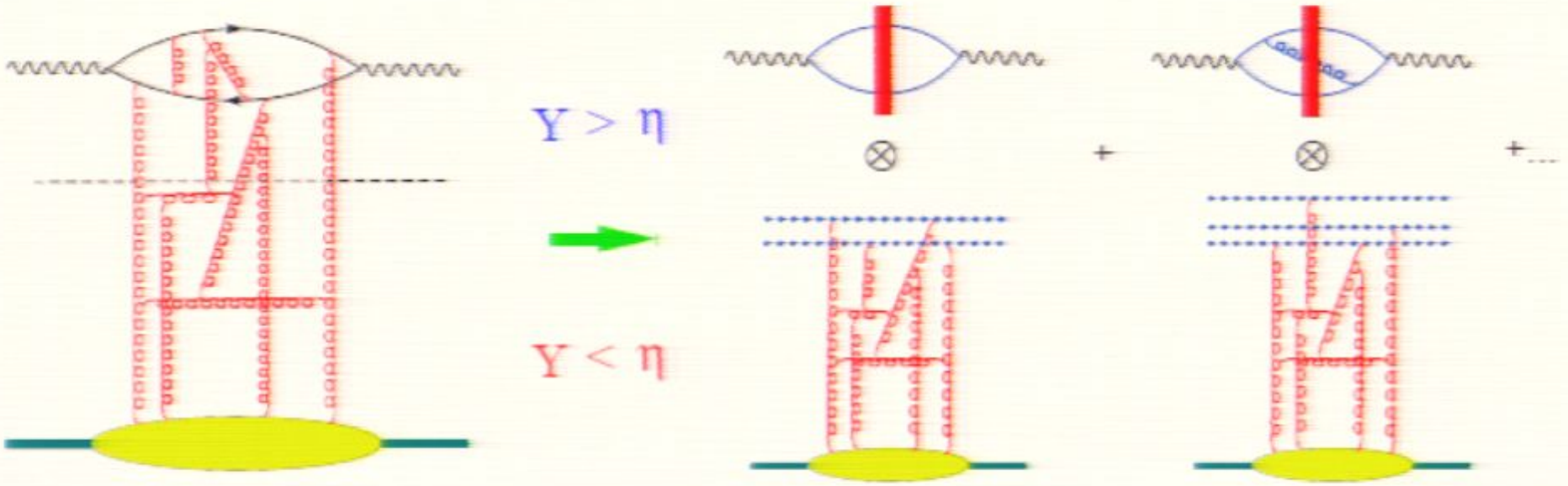
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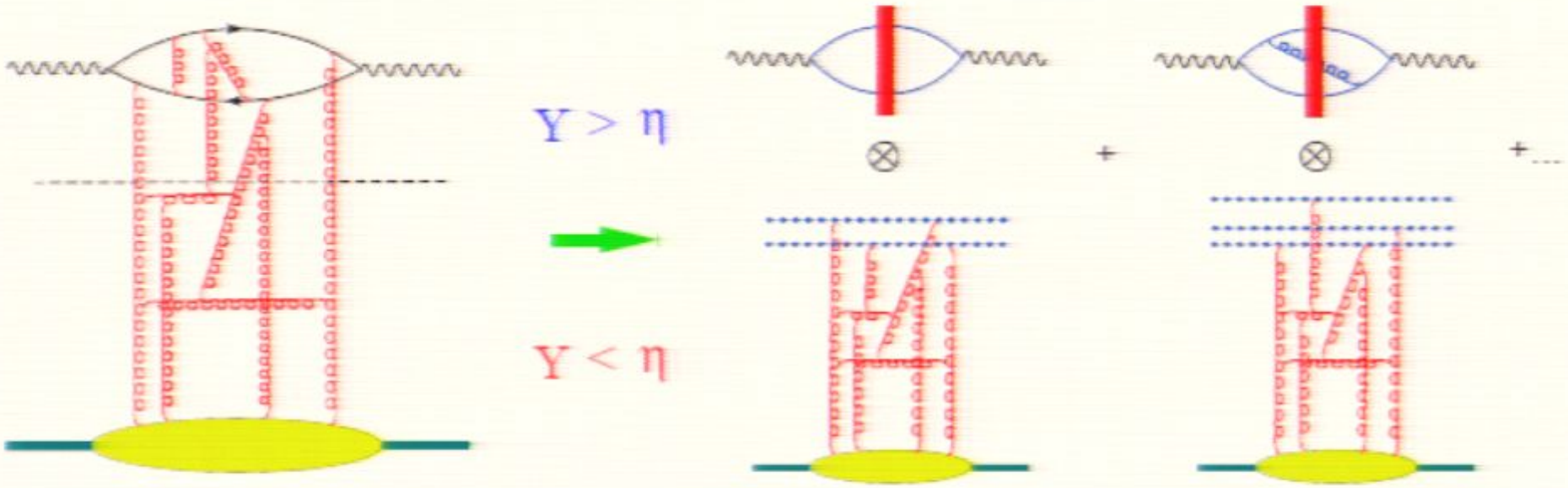
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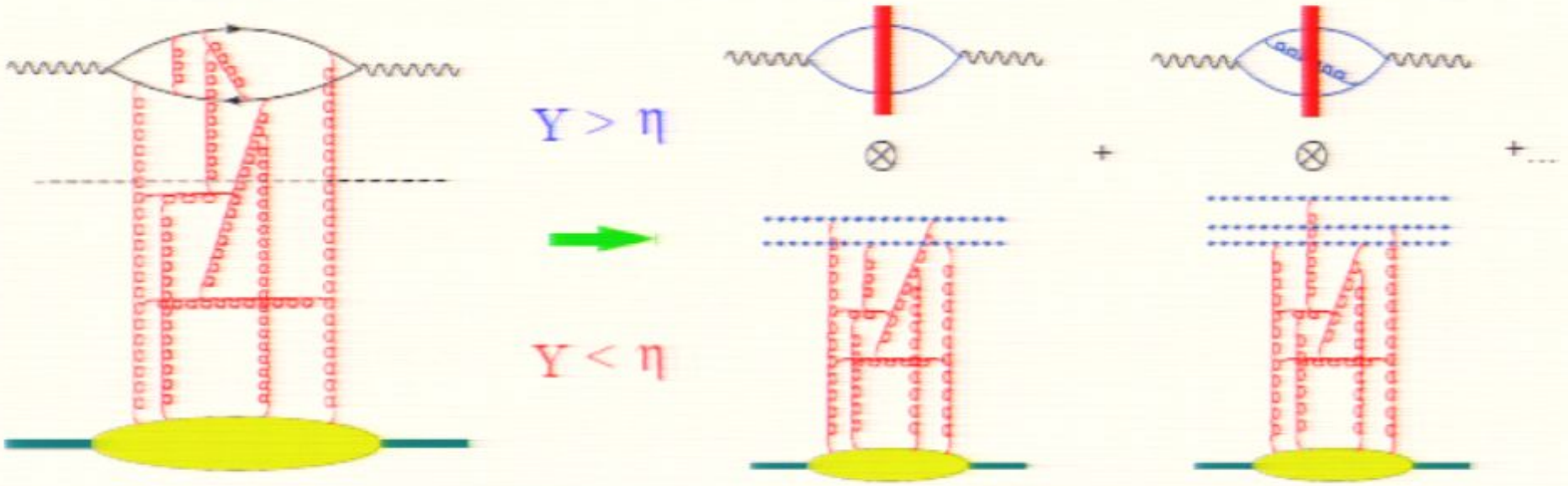
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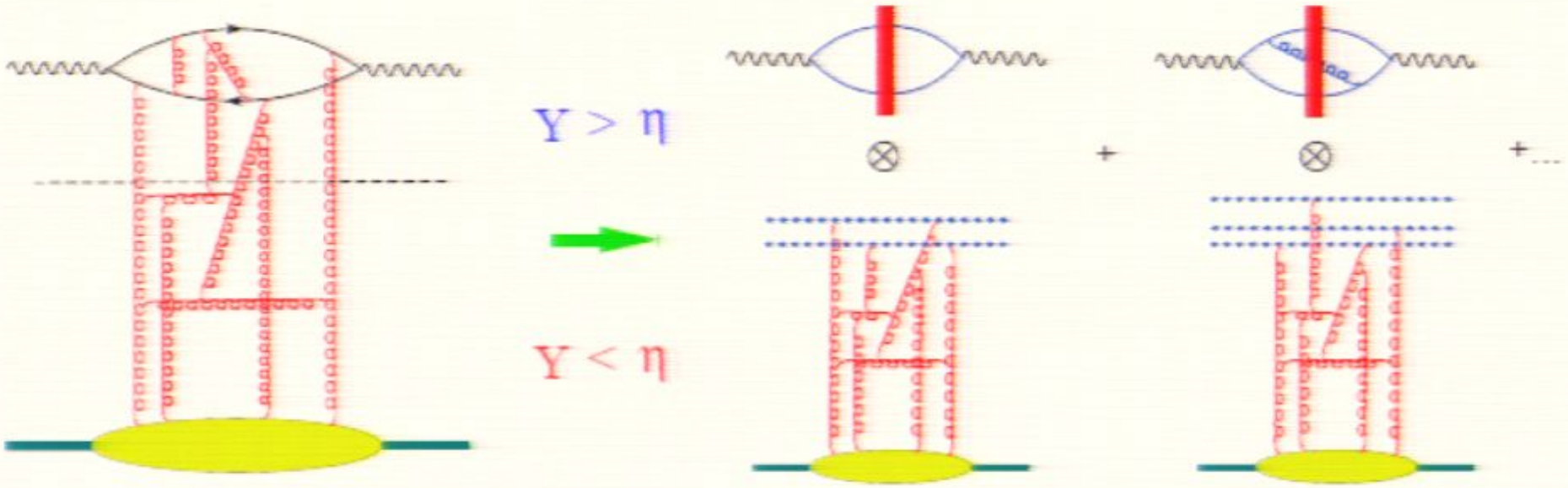
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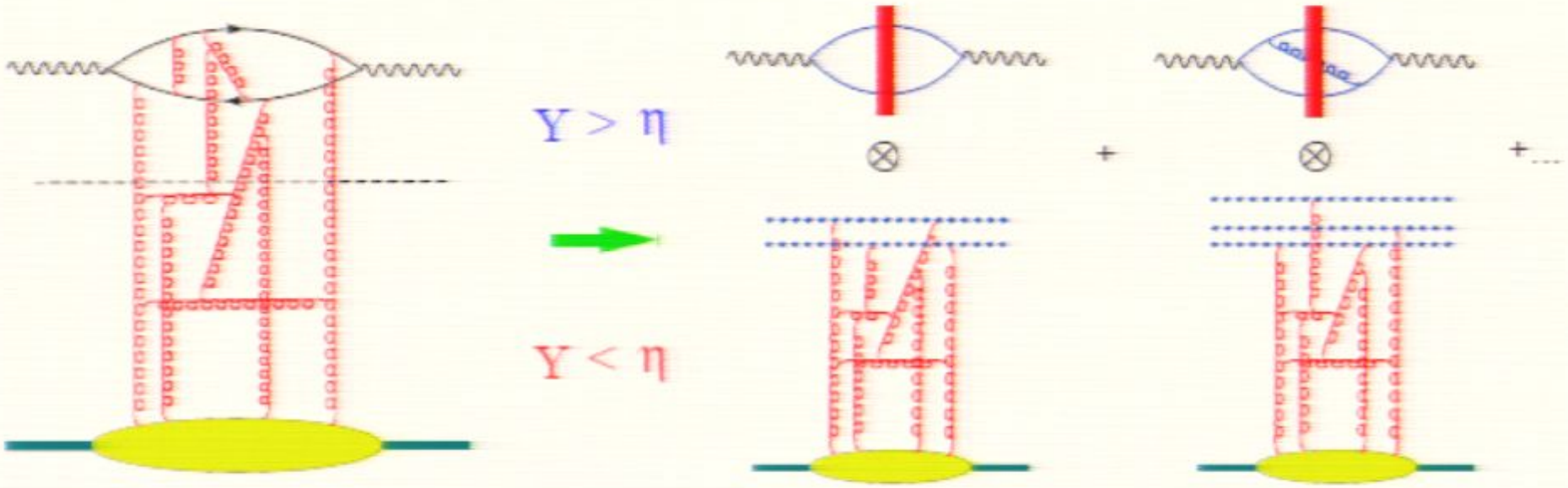
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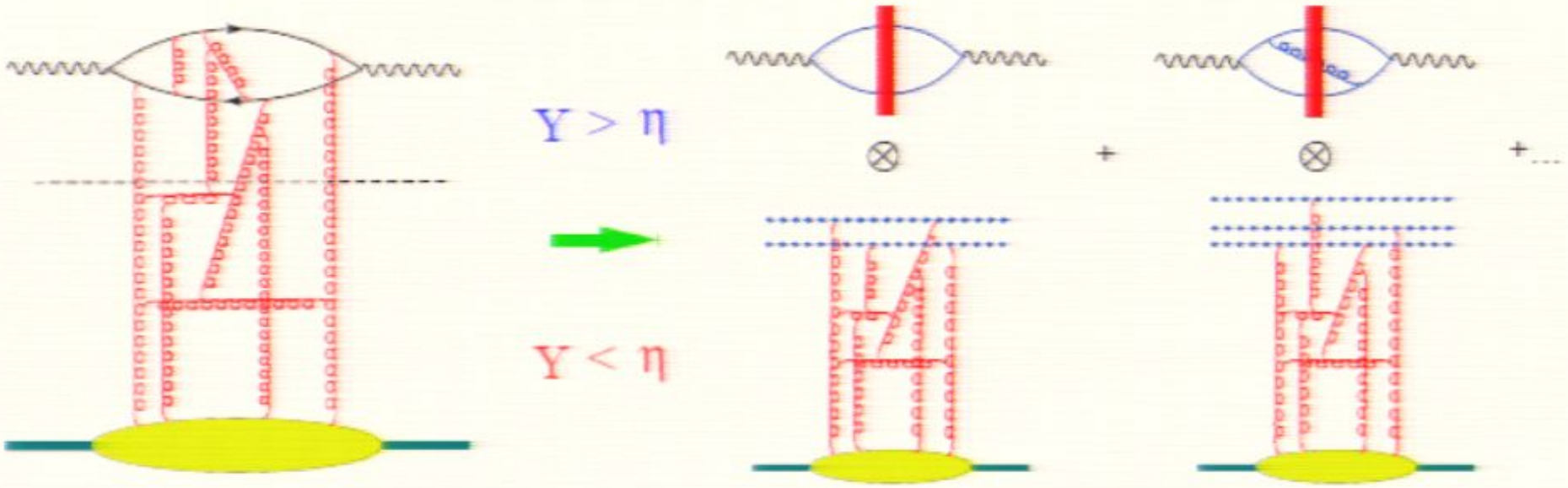
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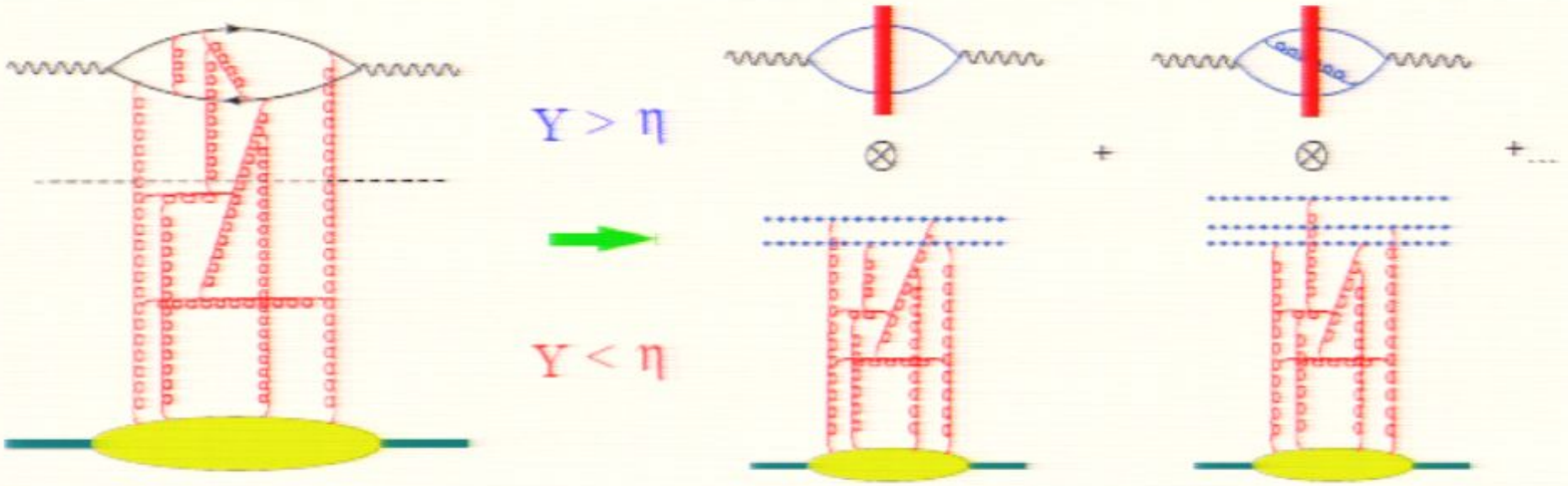
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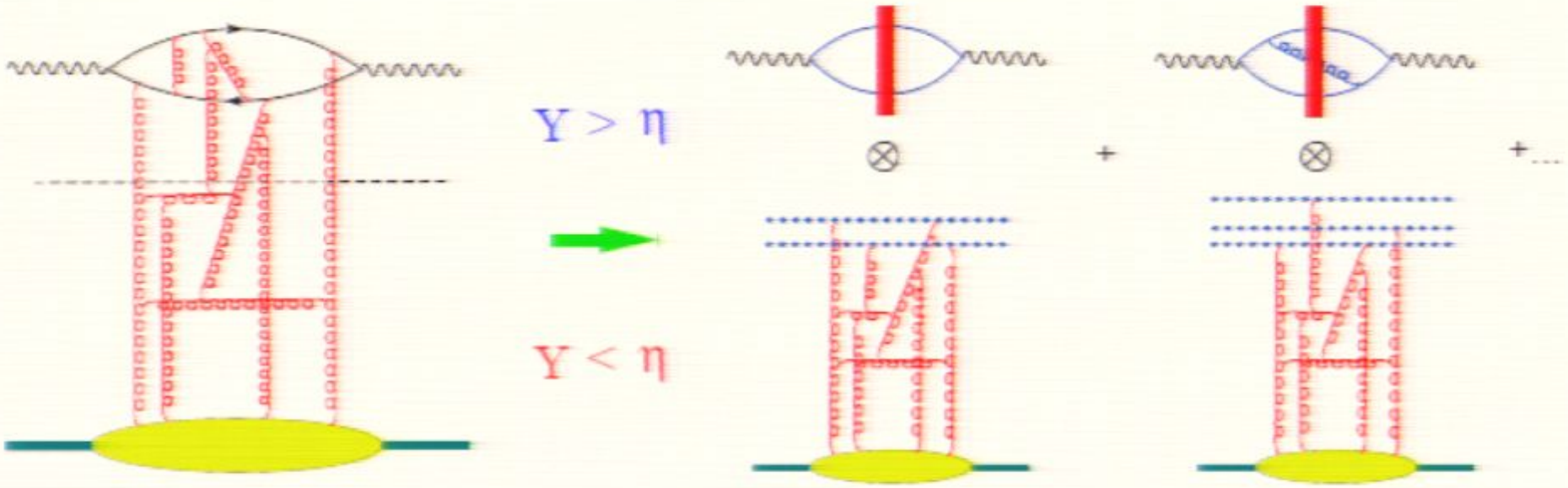
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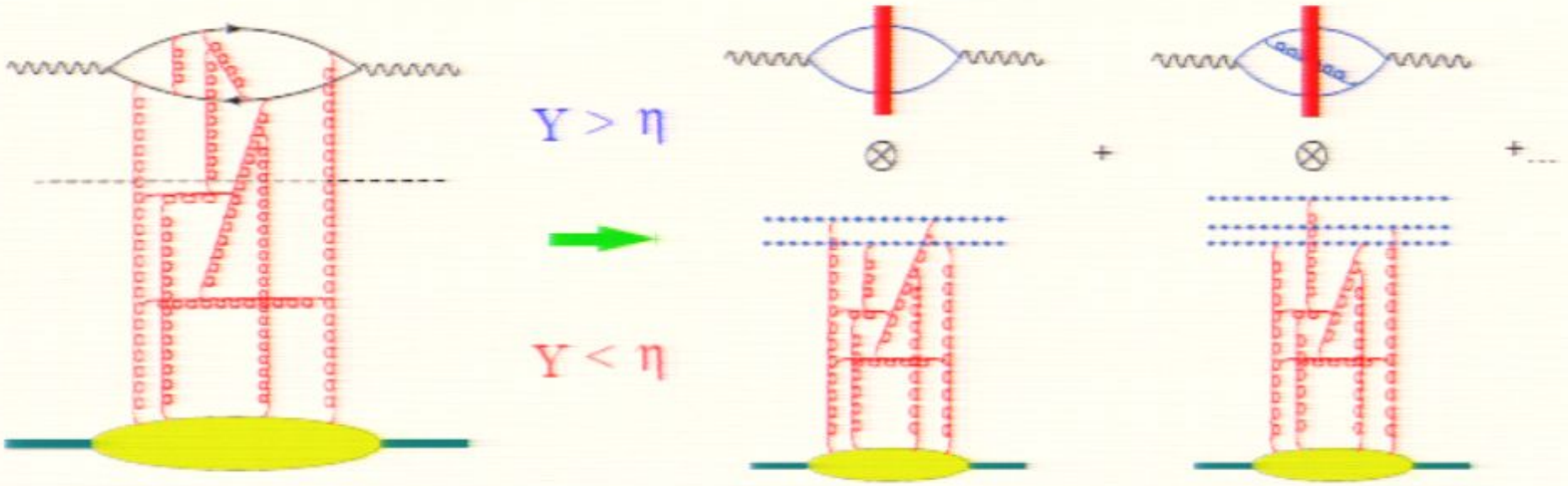
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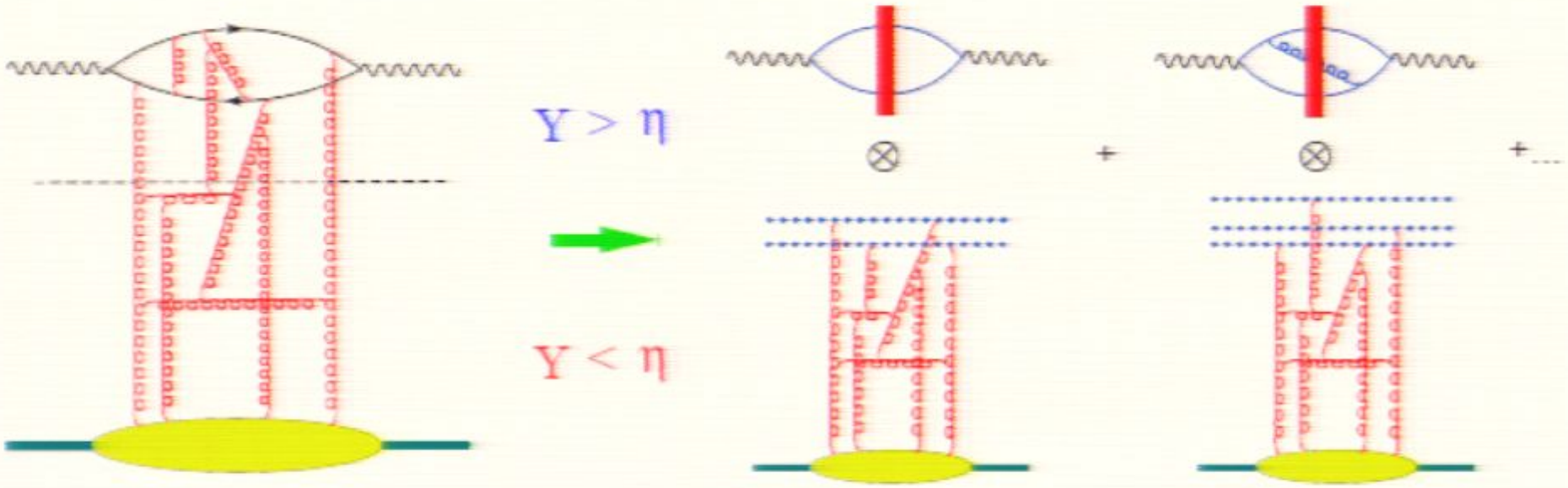
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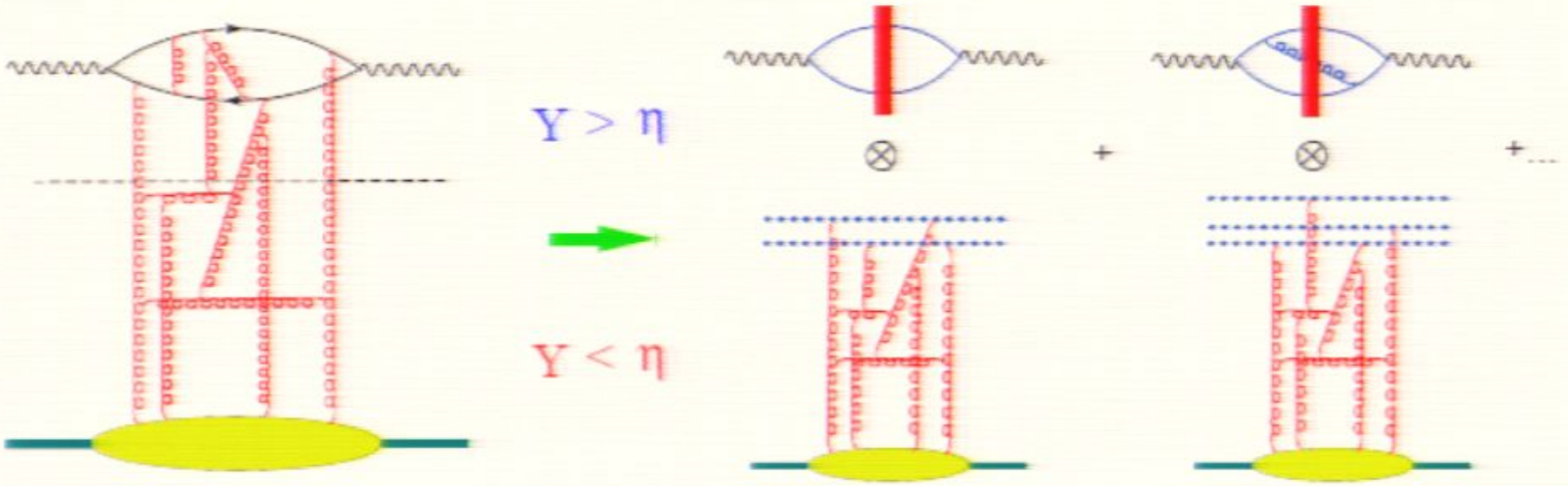
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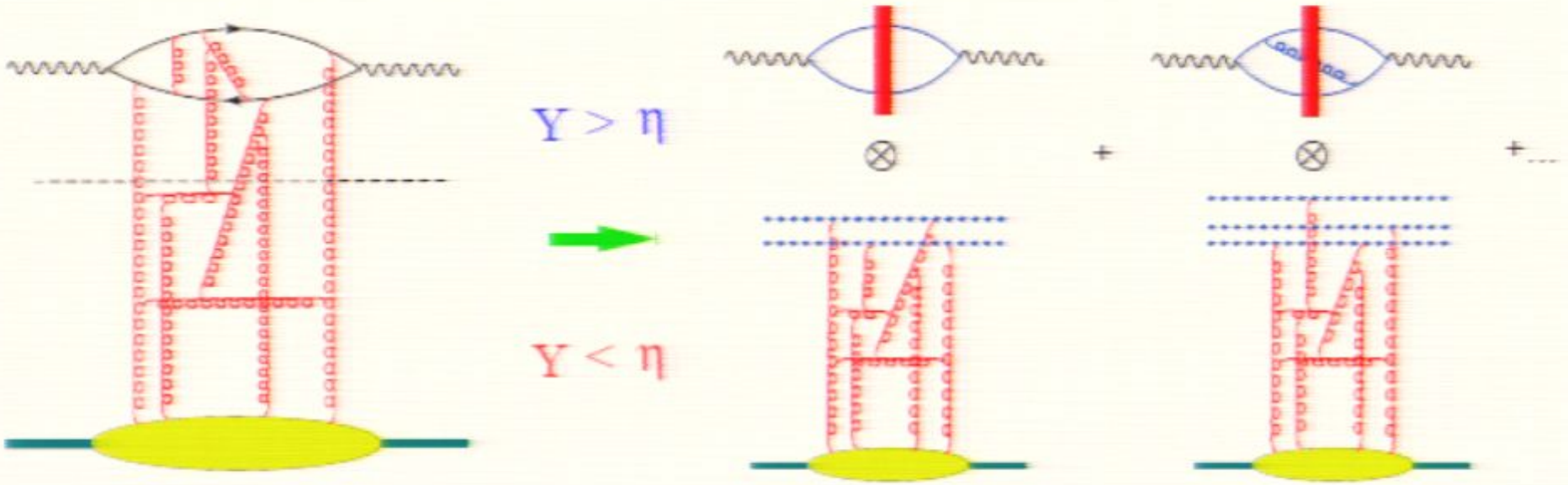
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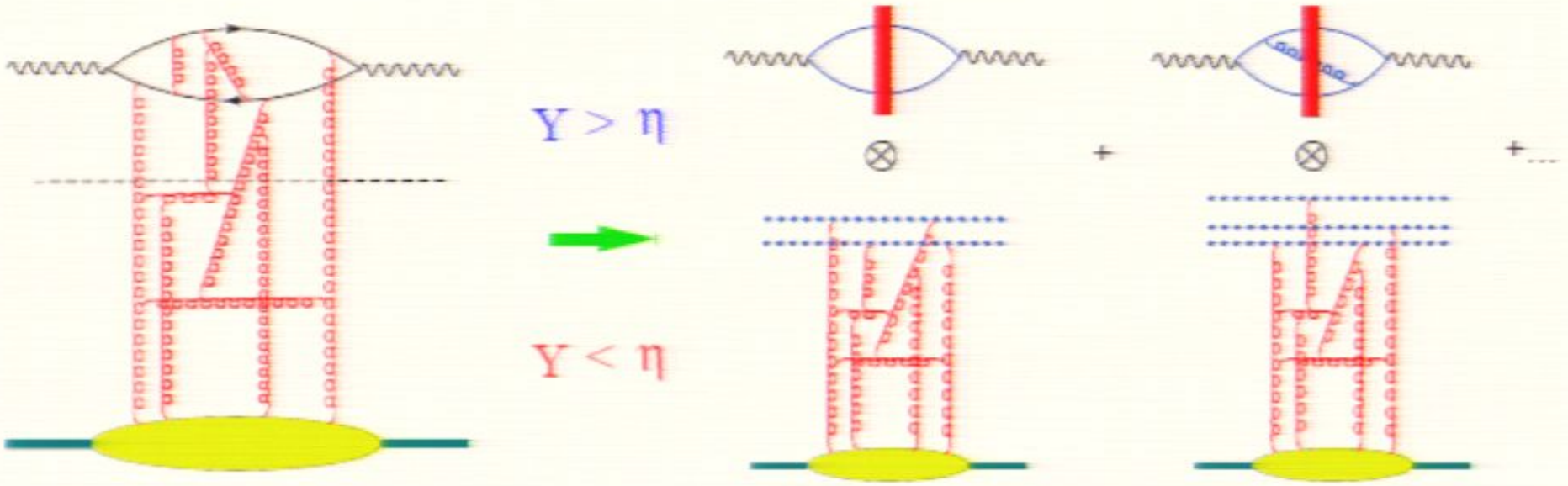
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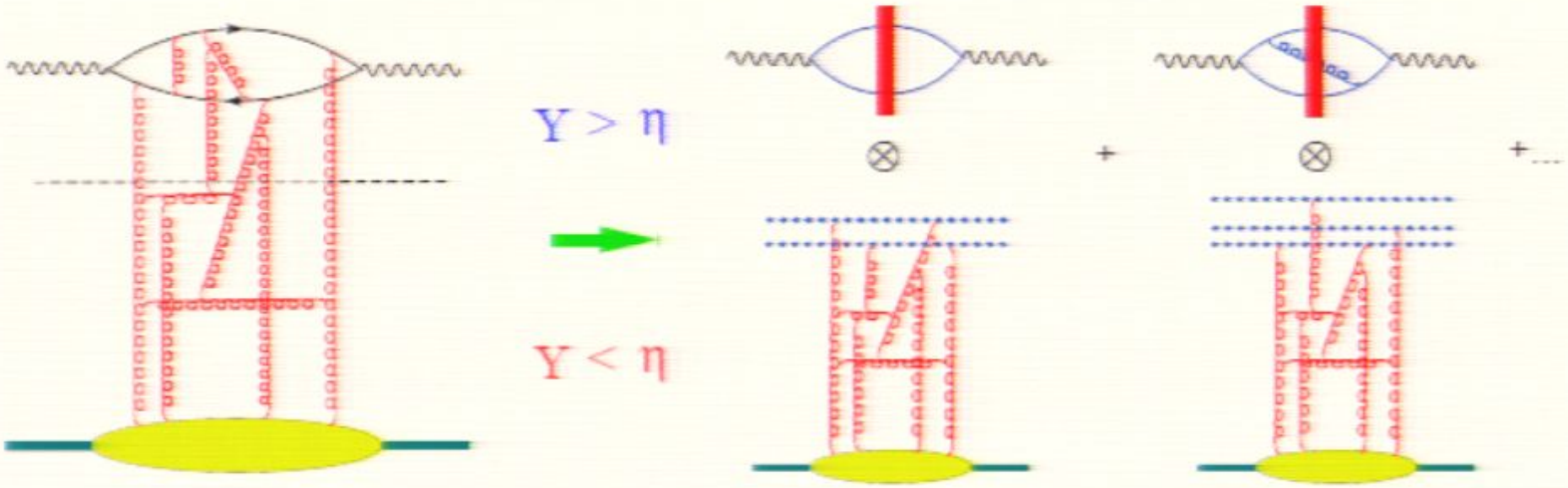
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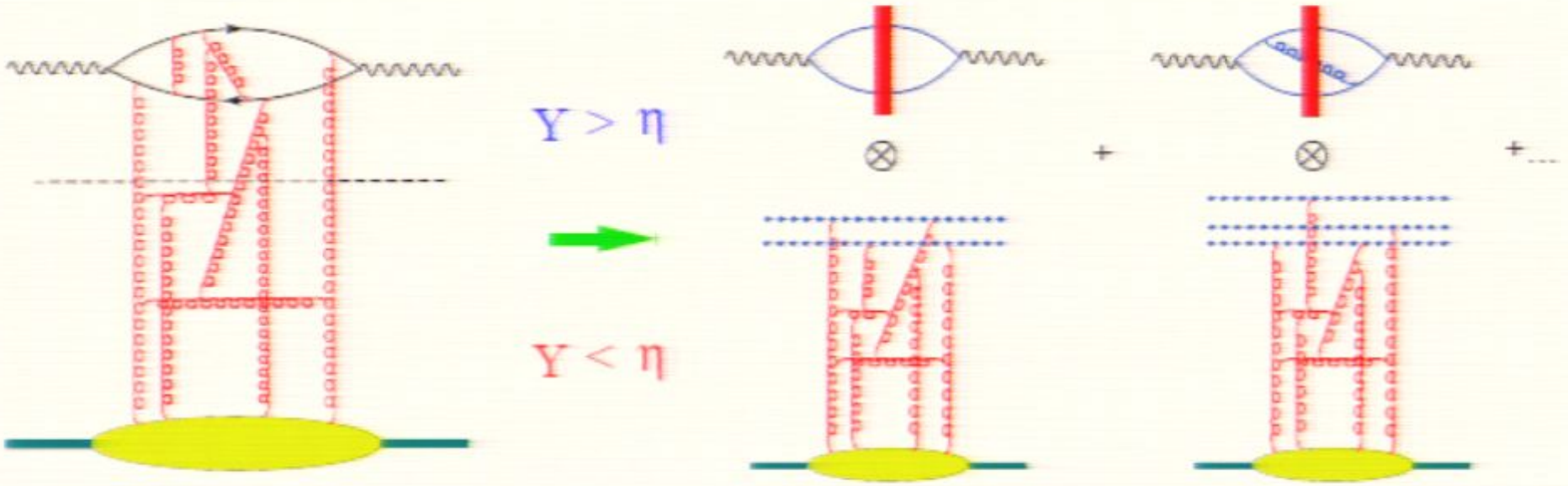
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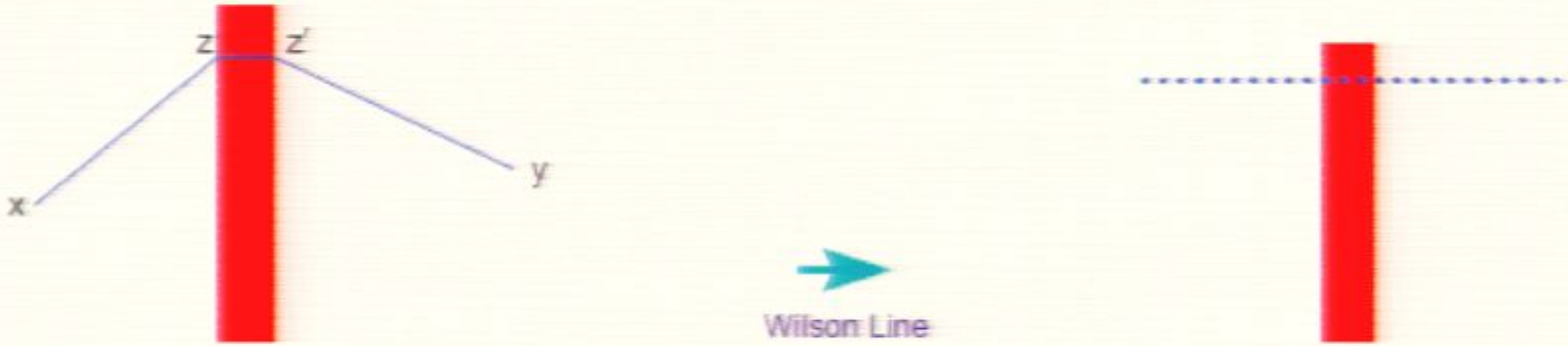
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Spectator frame: propagation in the shock-wave background.



Each path is weighted with the gauge factor $Pe^{ig\int dx_\mu A^\mu}$. Quarks and gluons do not have time to deviate in the transverse space $\Rightarrow$ we can replace the gauge factor along the actual path with the one along the straight-line path.



$[x \to z$: free propagation$]\times$

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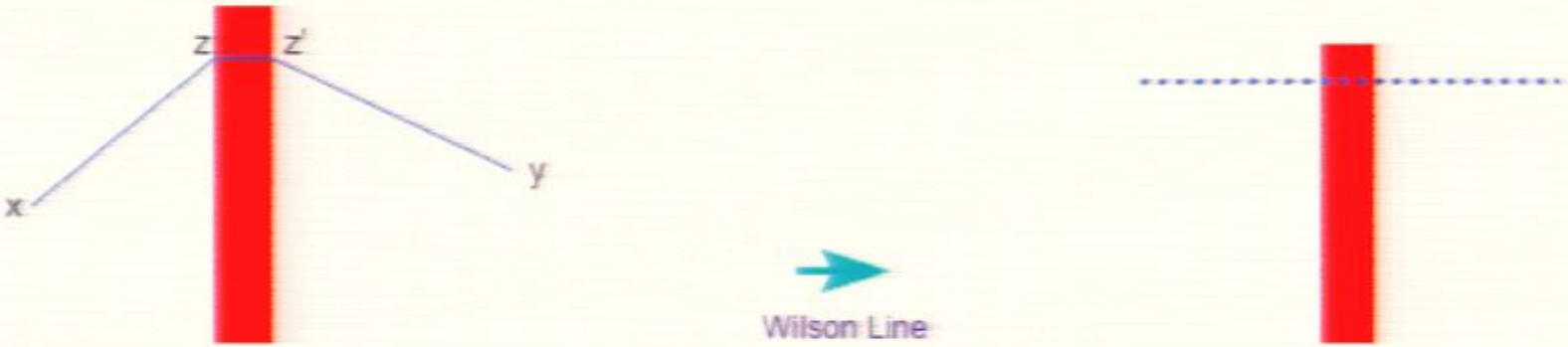
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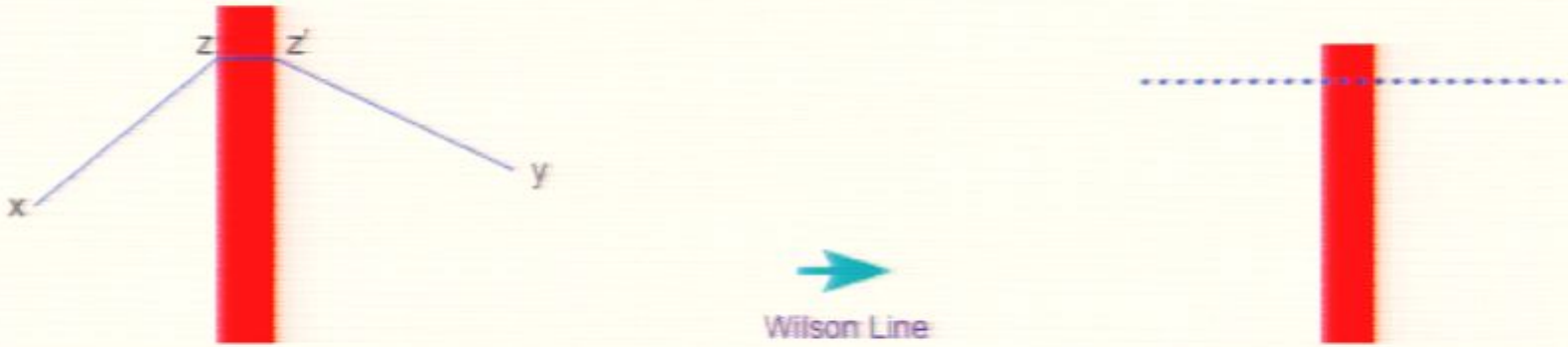
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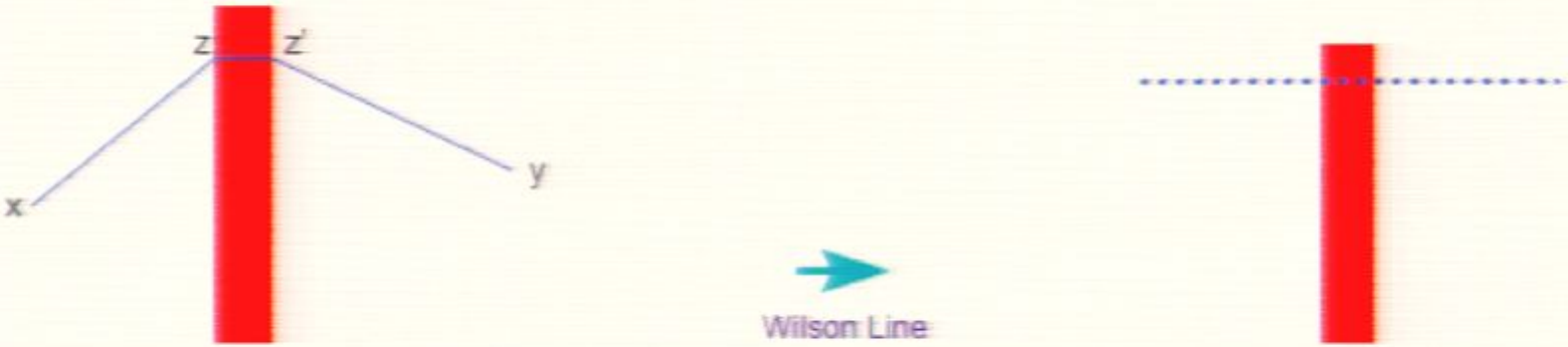
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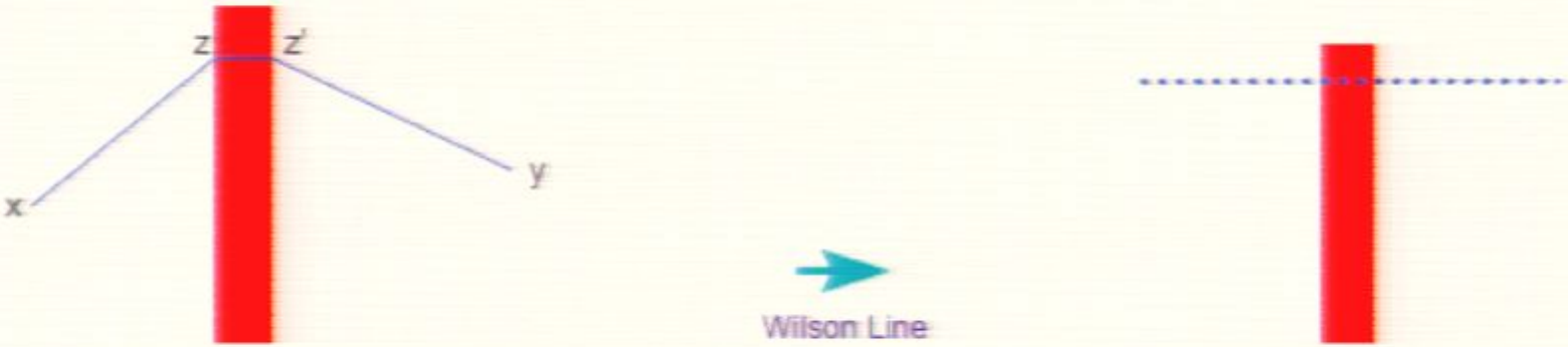
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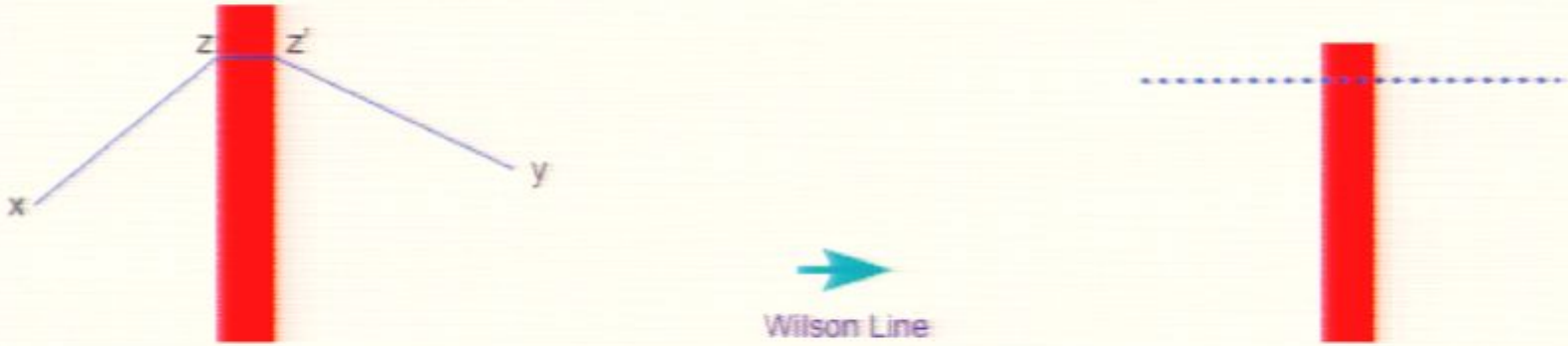
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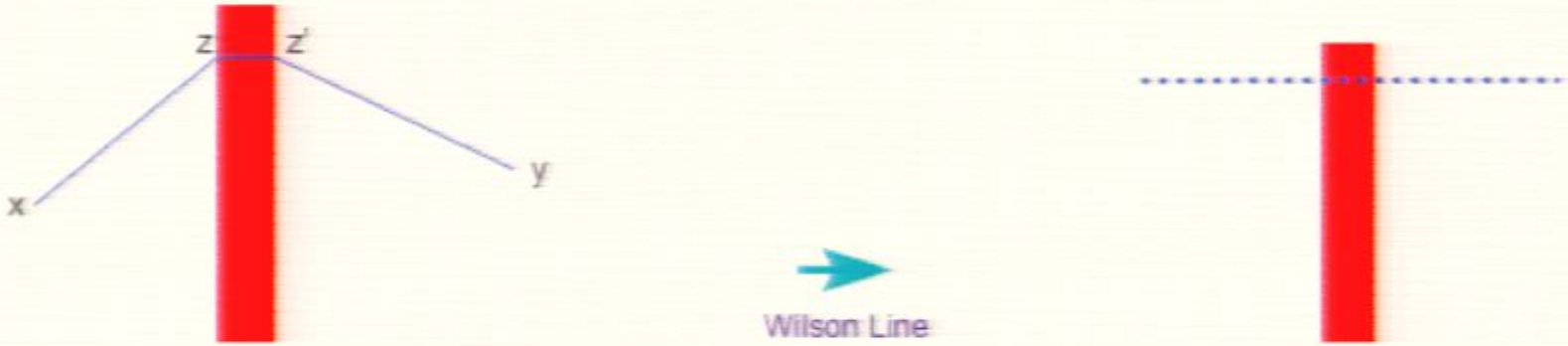


$[x \to z$: free propagation$]\times$
$[U^{ab}(z_\perp)$ - instantaneous interaction with the $\eta < \eta_2$ shock wave$]\times$
$[z \to y$: free propagation $]$

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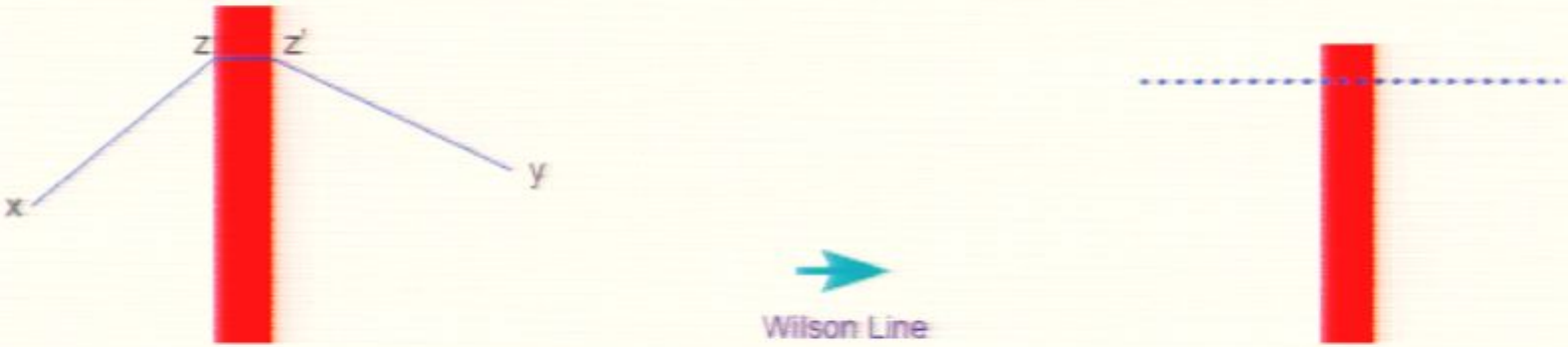
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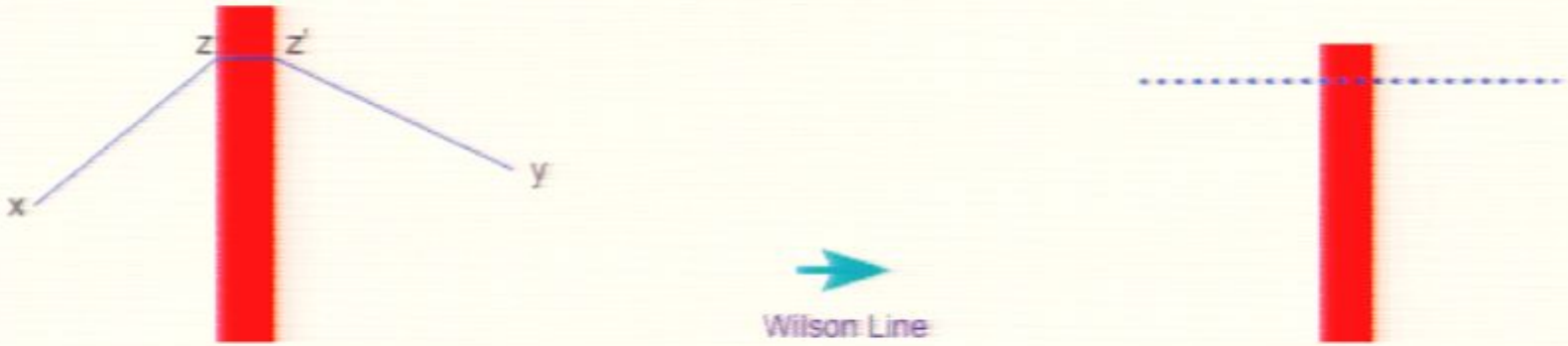
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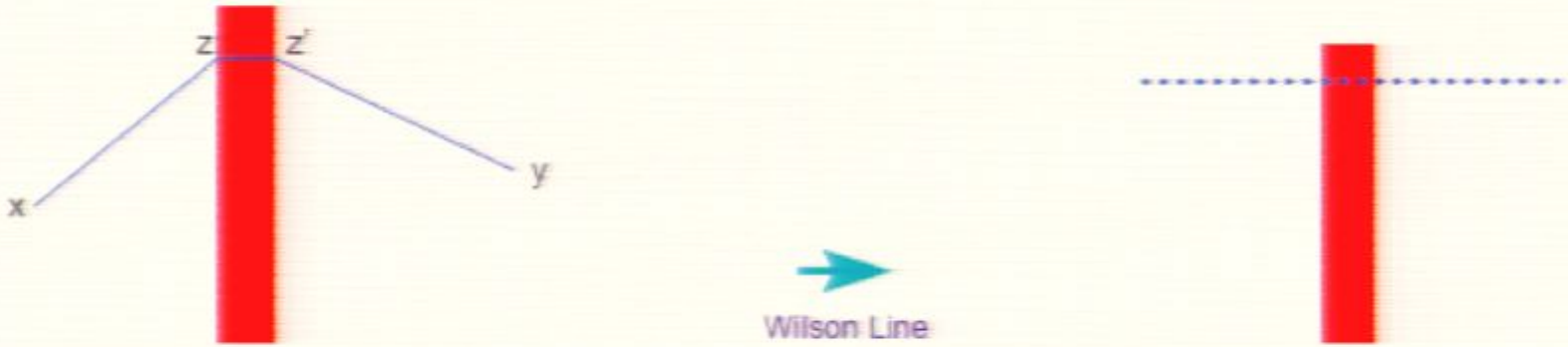
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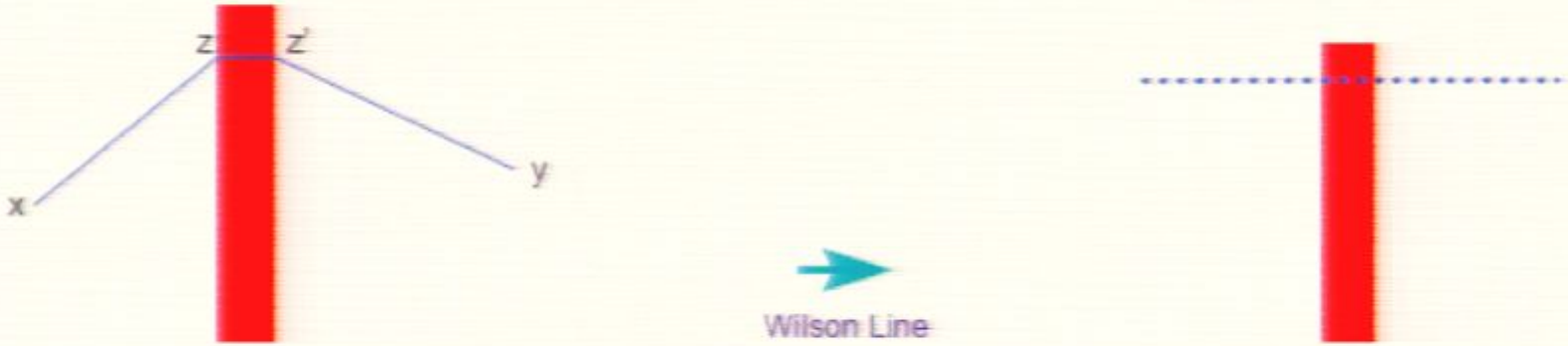
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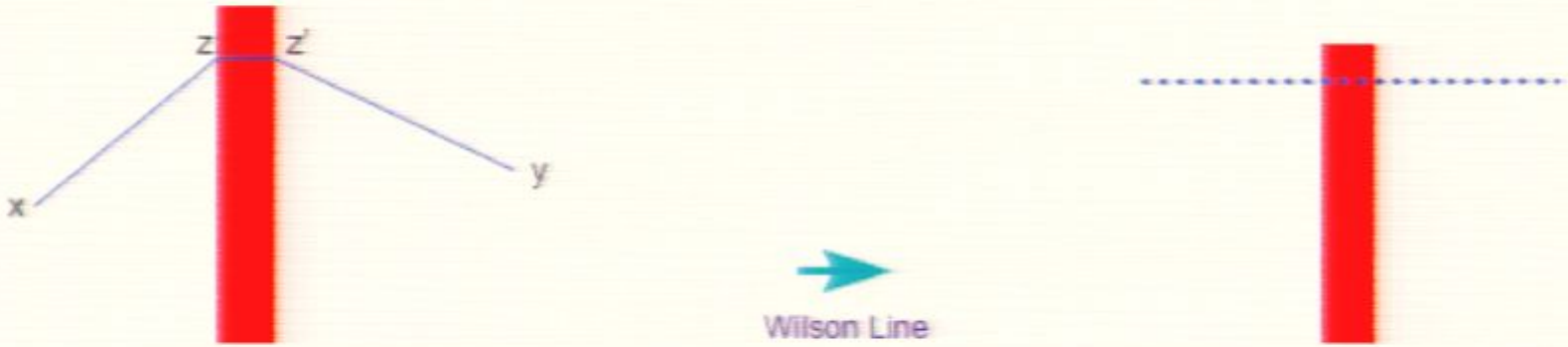
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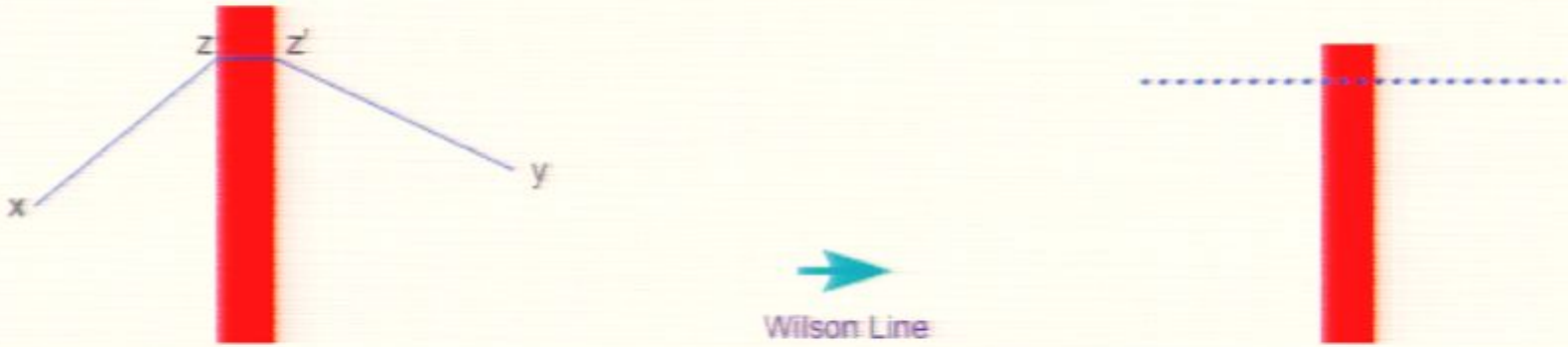
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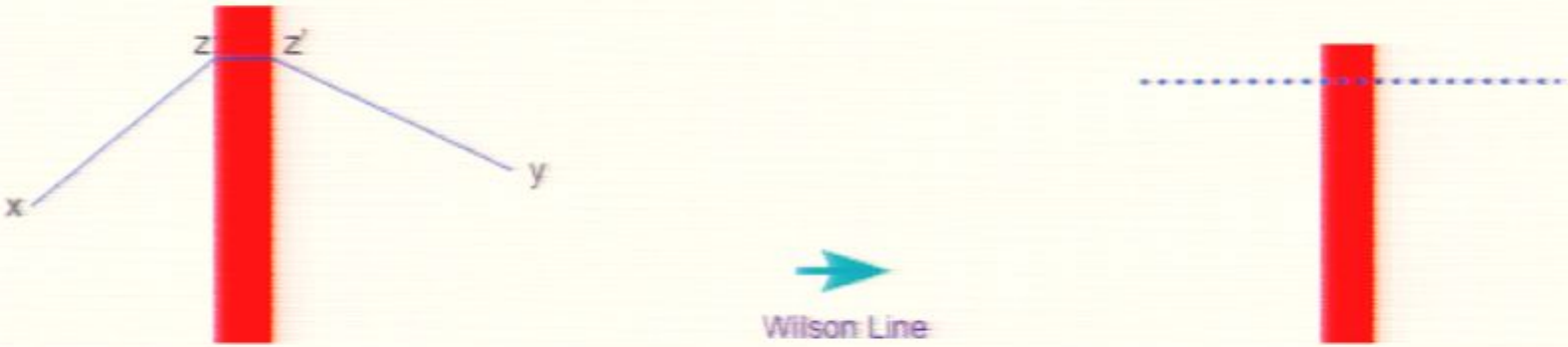
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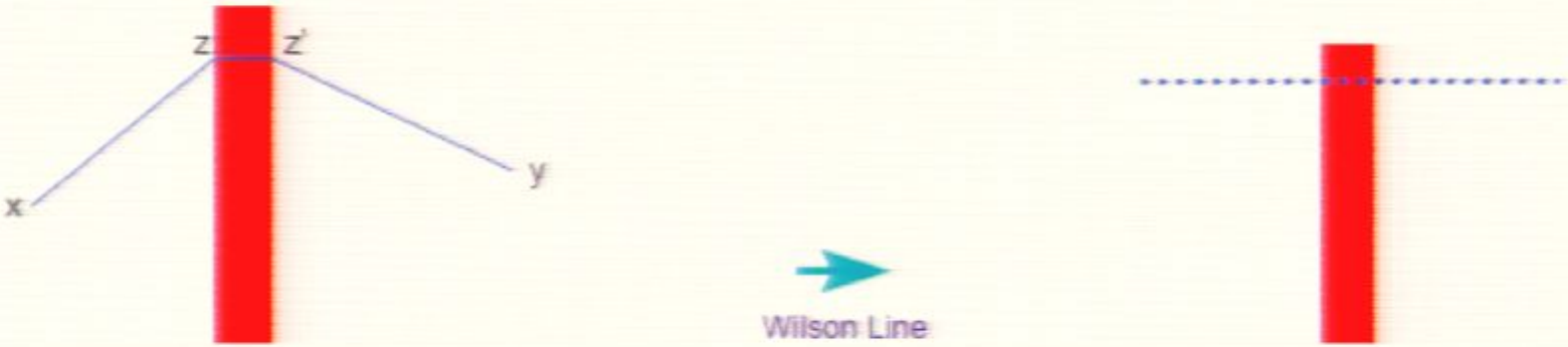
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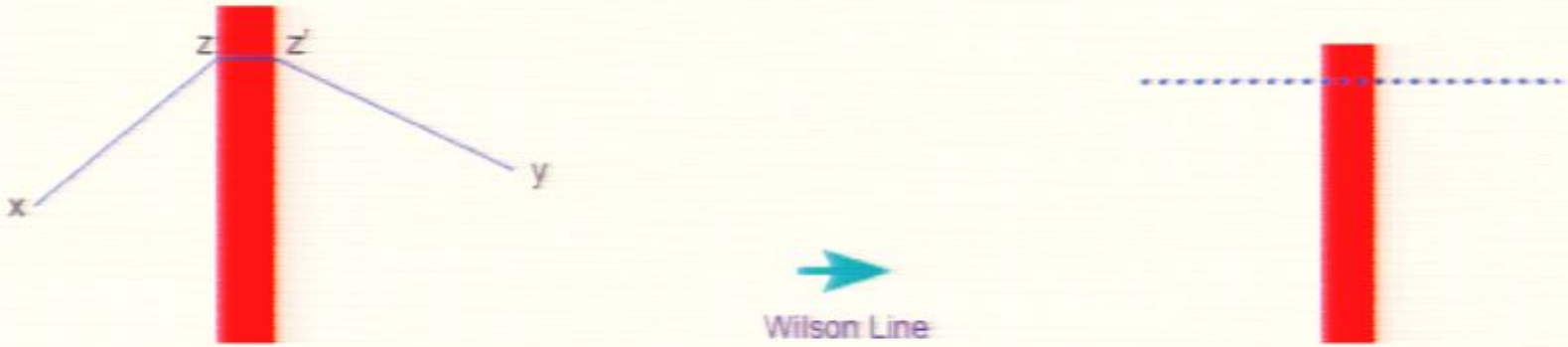
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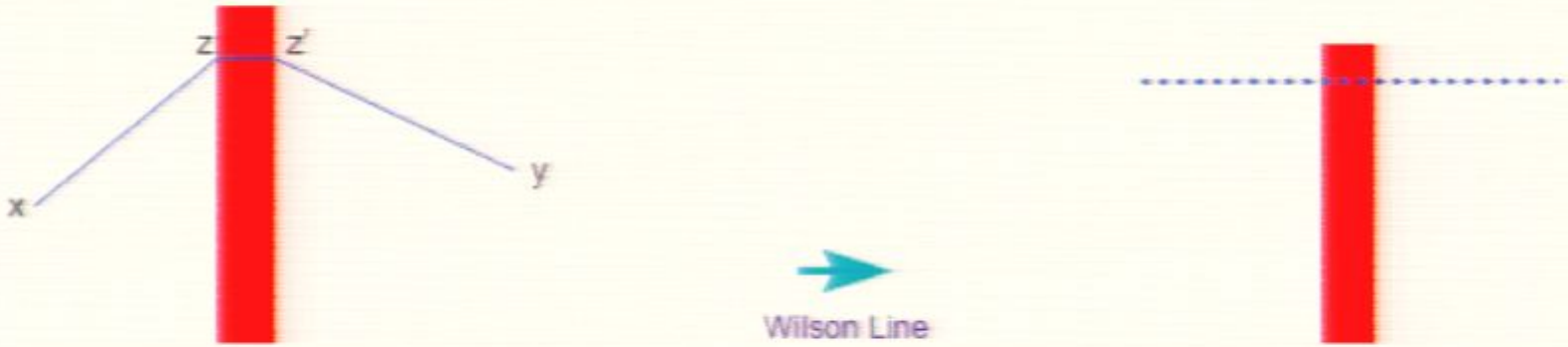


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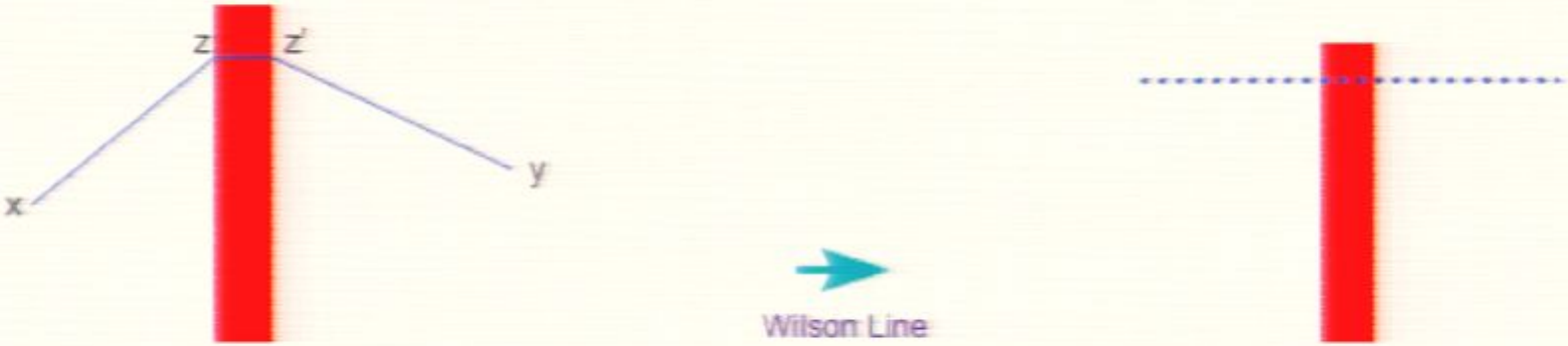
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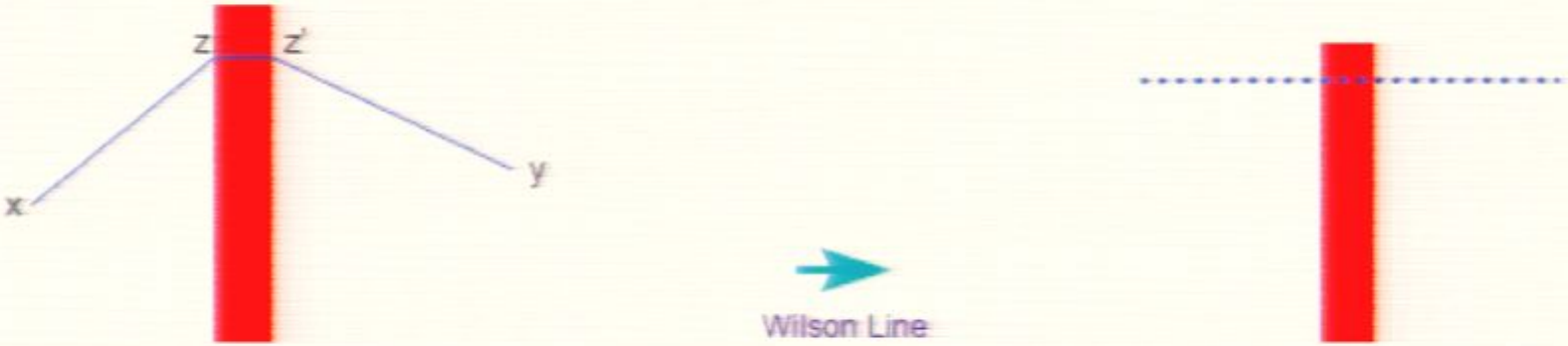
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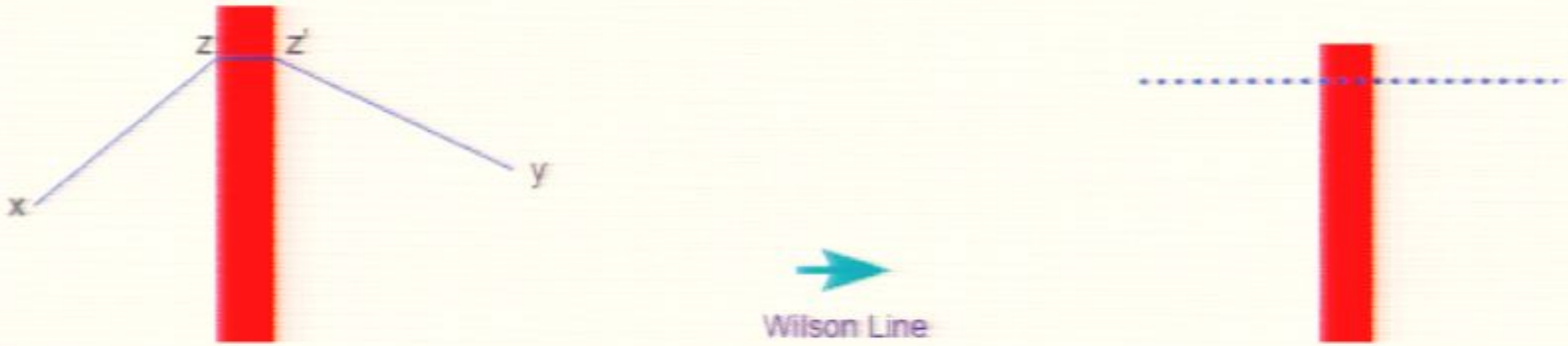
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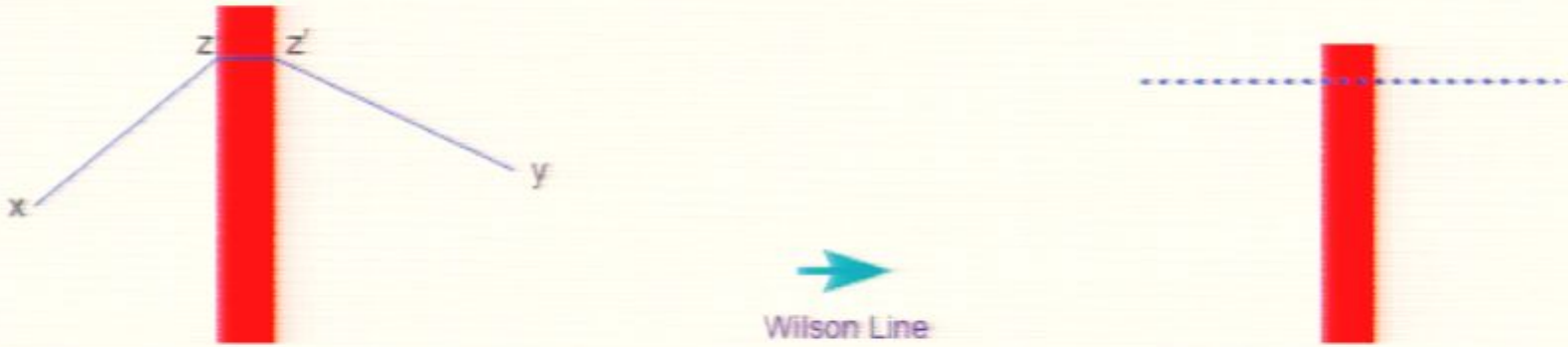
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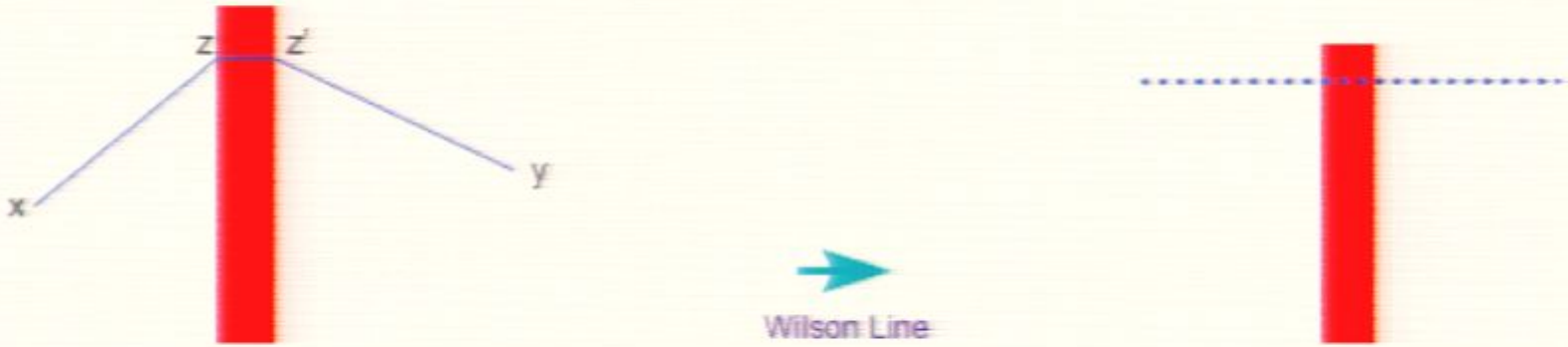
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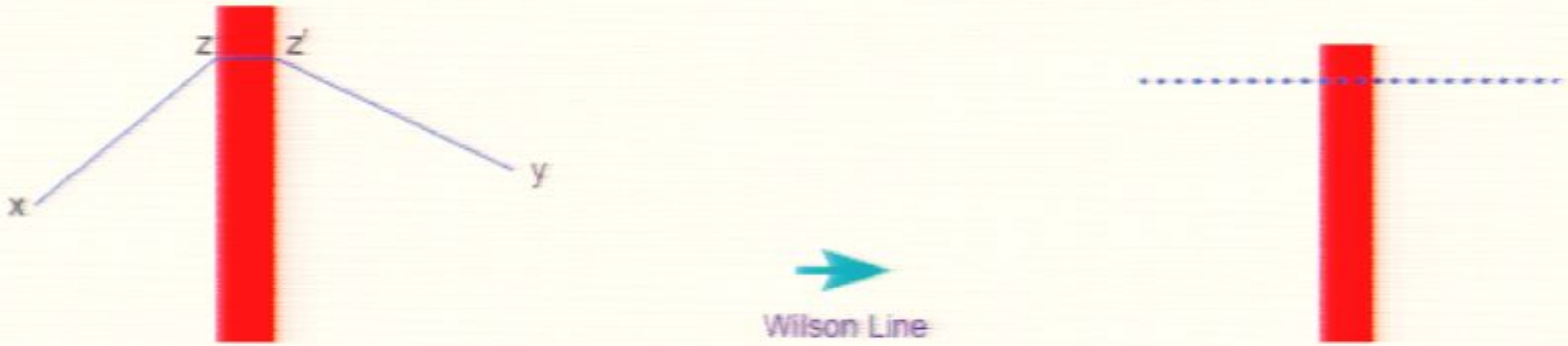
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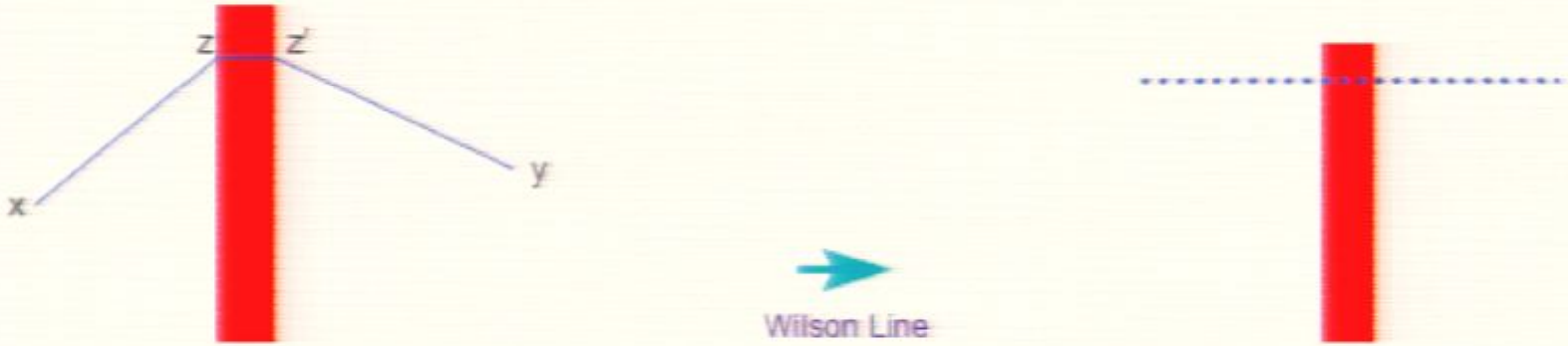
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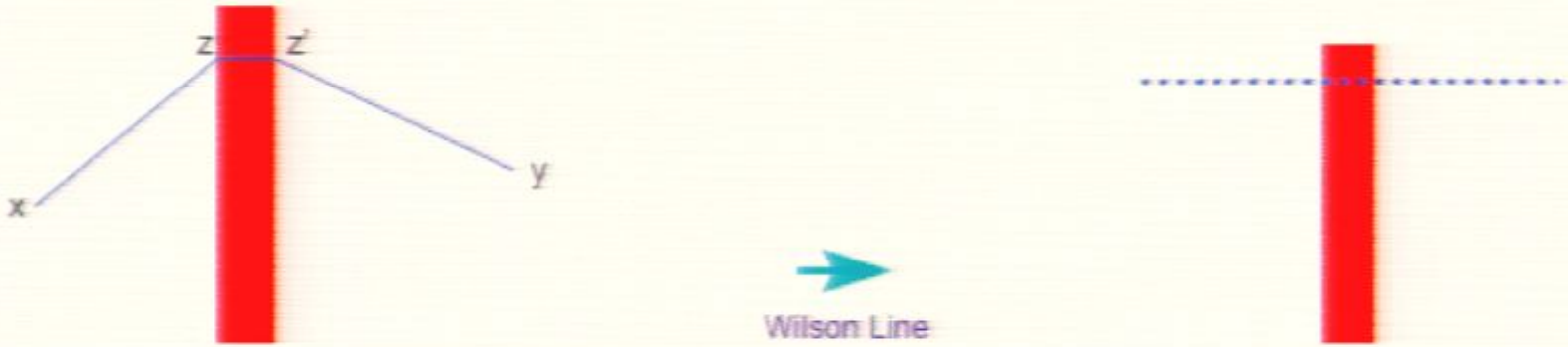
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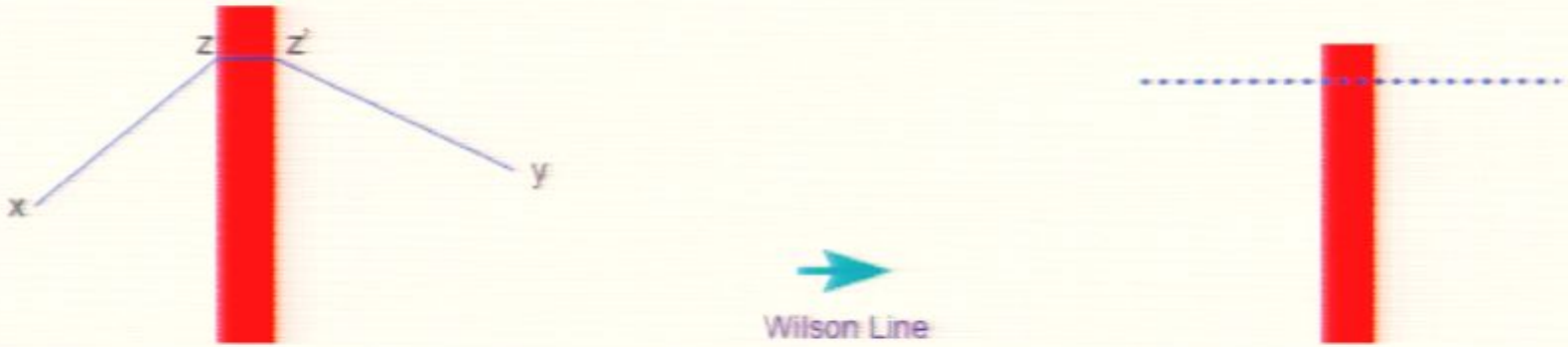
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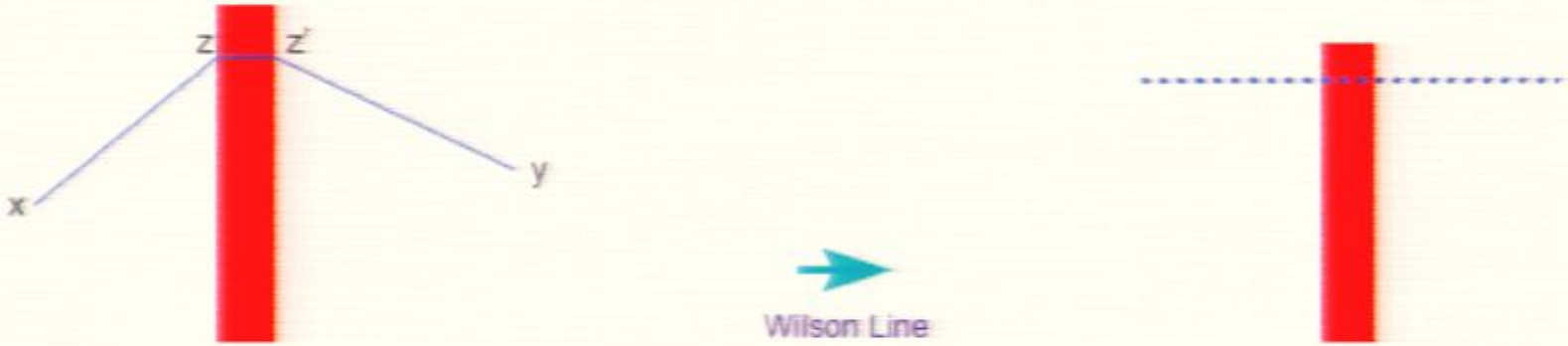
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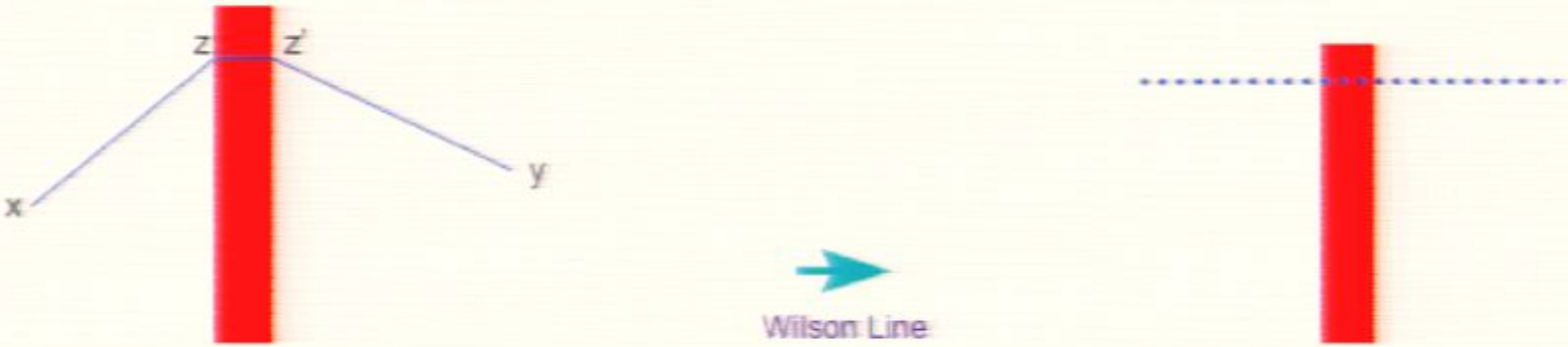
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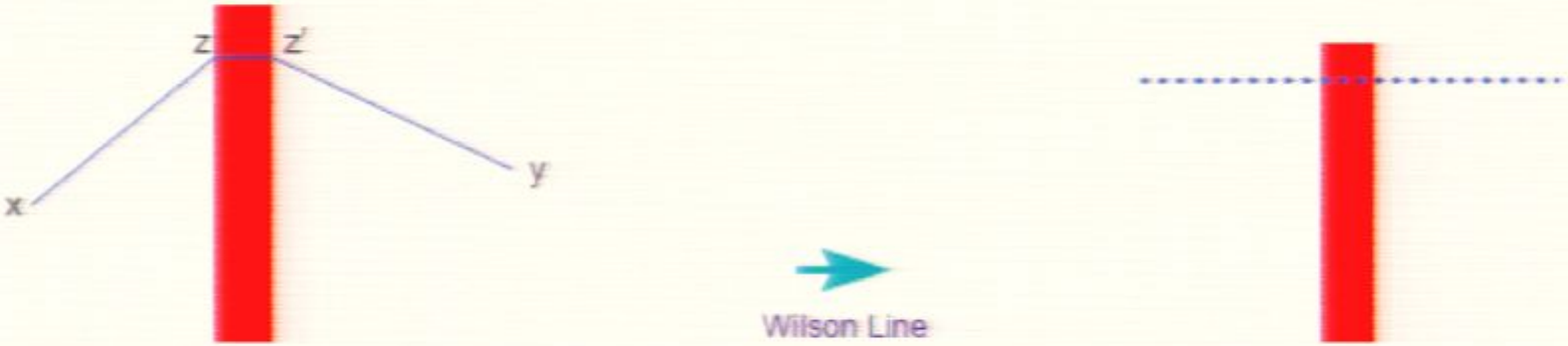
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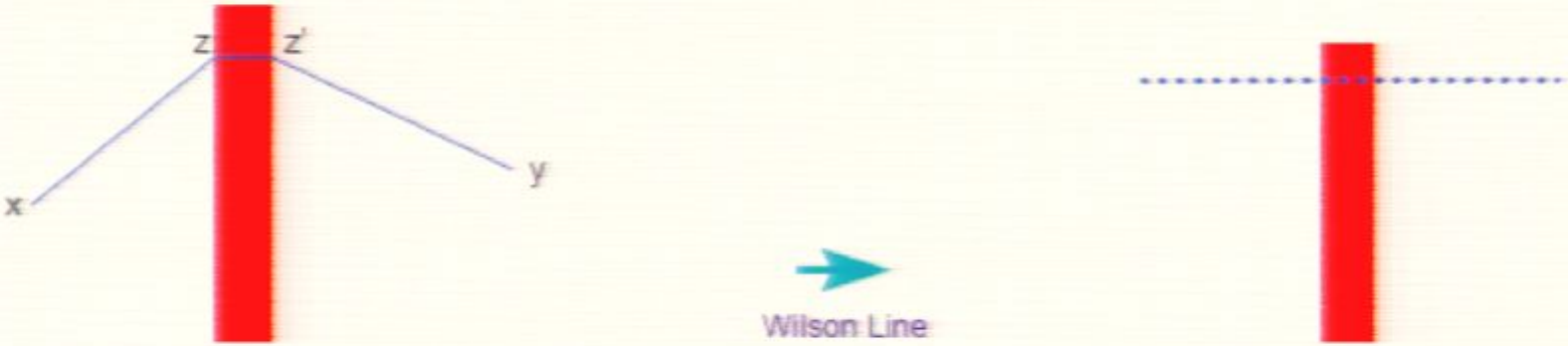
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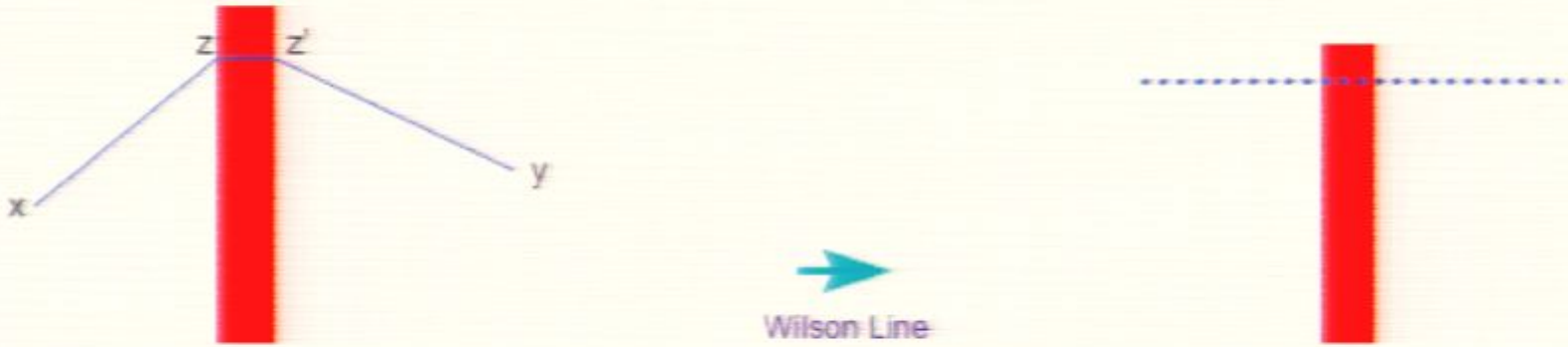
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$[z \to y$: free propagation $]$

Spectator frame: propagation in the shock-wave background.



Each path is weighted with the gauge factor $Pe^{ig\int dx_\mu A^\mu}$. Quarks and gluons do not have time to deviate in the transverse space $\Rightarrow$ we can replace the gauge factor along the actual path with the one along the straight-line path.

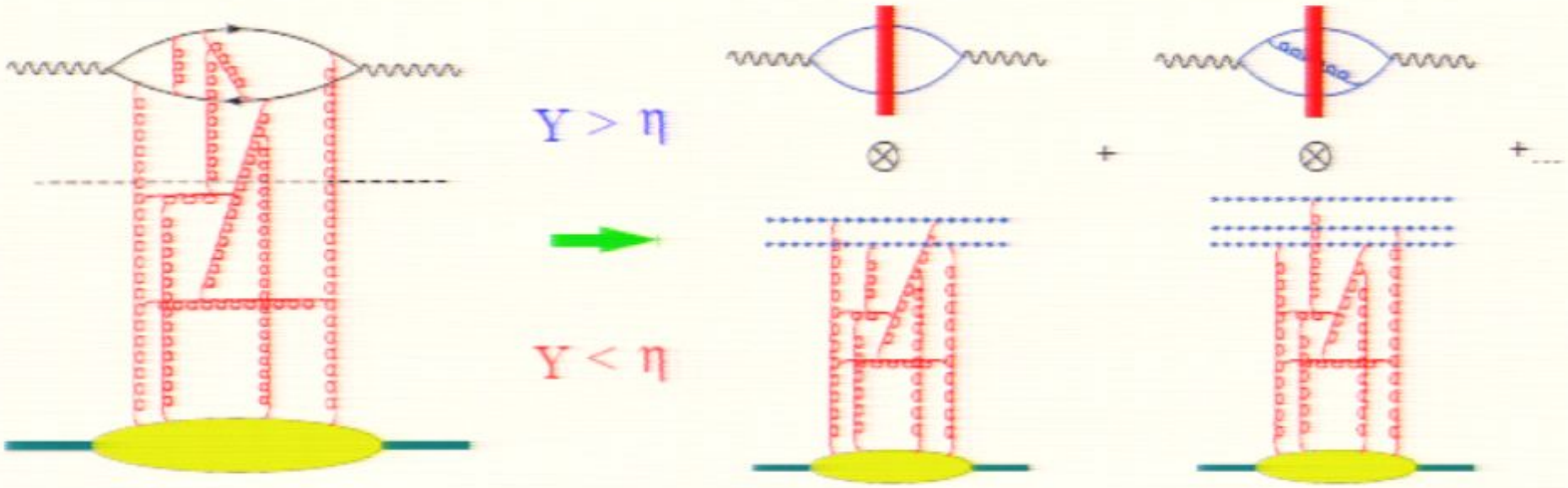


$[x \to z$: free propagation$]\times$

$[U^{ab}(z_\perp)$ - instantaneous interaction with the $\eta < \eta_2$ shock wave$]\times$

$[z \to y$: free propagation $]$

High-energy expansion in color dipoles

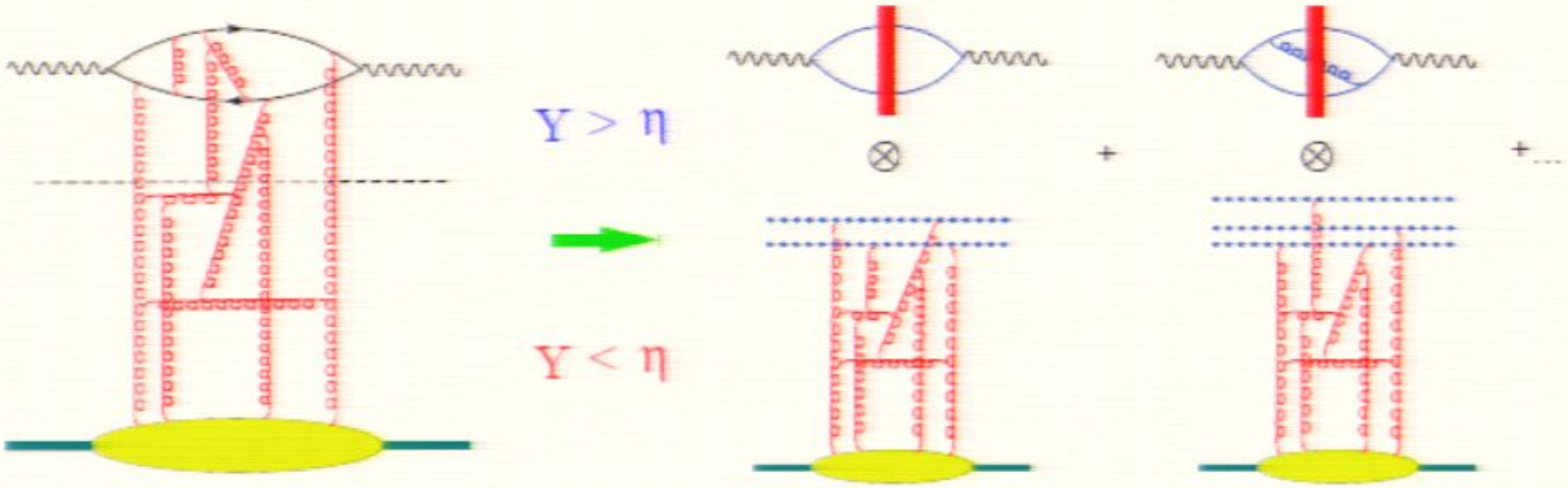


The high-energy operator expansion is

$$T\{\hat{j}_\mu(x)\hat{j}_\nu(y)\} = \int d^2z_1 d^2z_2\, I^{\mathrm{LO}}_{\mu\nu}(z_1, z_2, x, y)\,\mathrm{Tr}\{\hat{U}^{\eta}_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}$$

$+$ NLO contribution

High-energy expansion in color dipoles

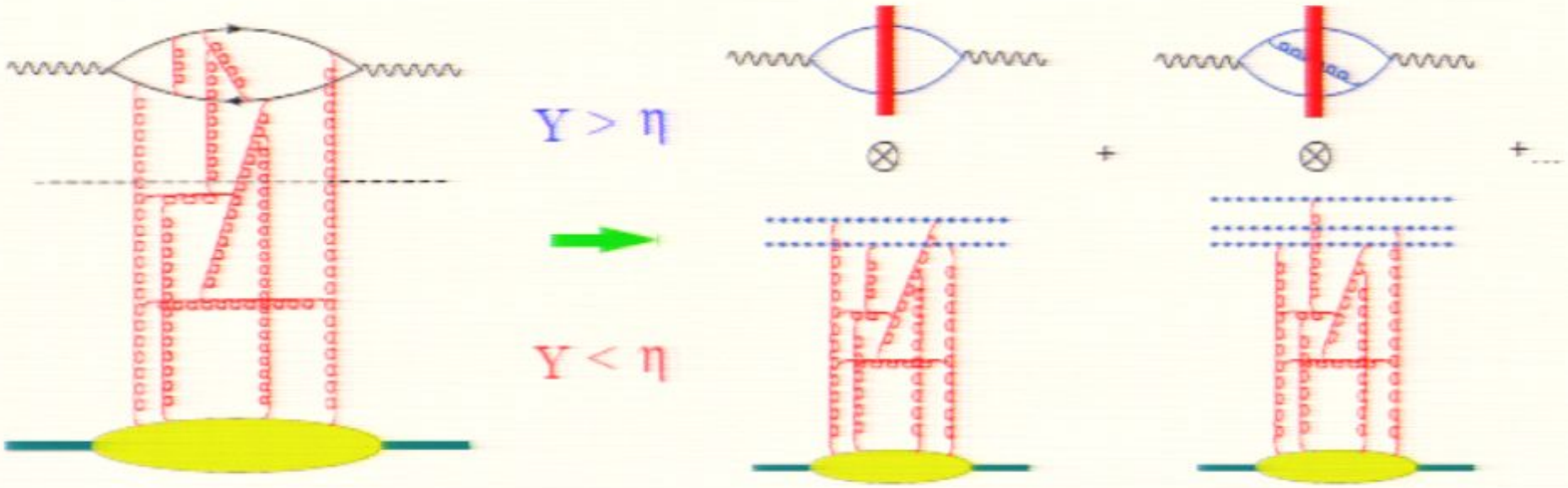


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High-energy expansion in color dipoles

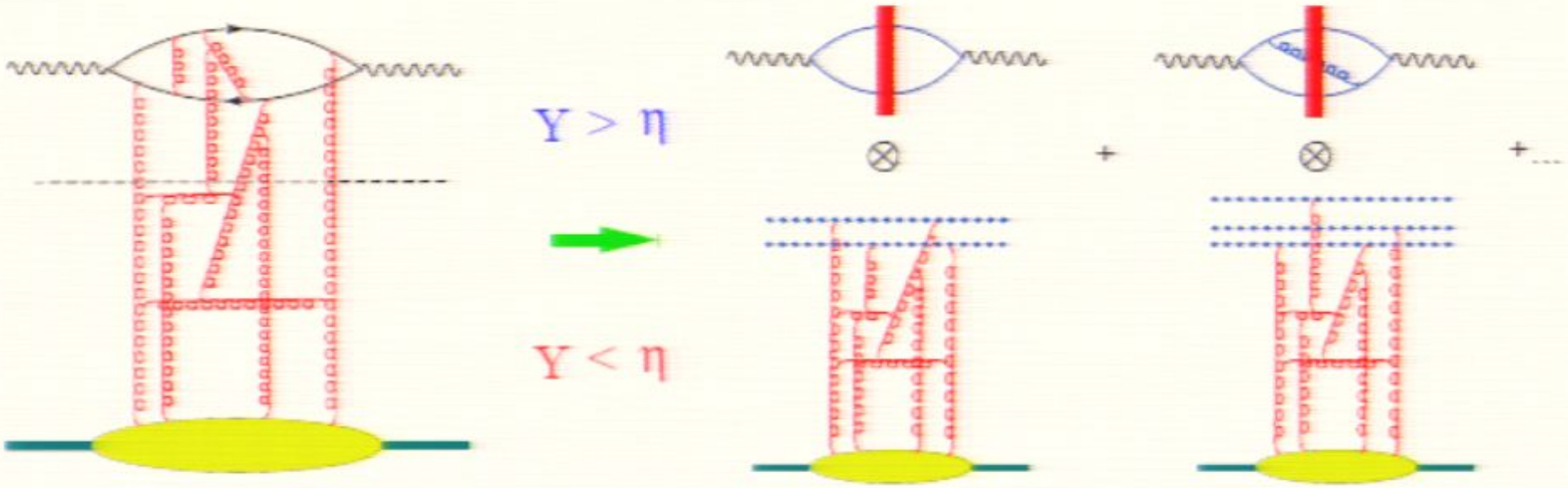


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High-energy expansion in color dipoles

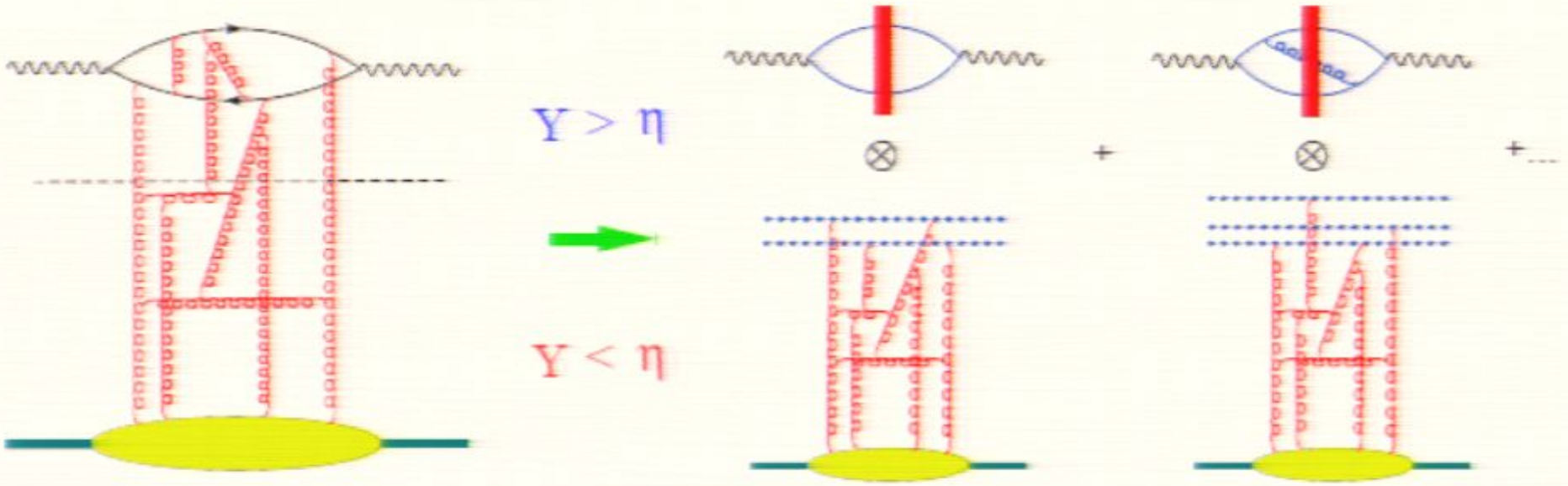


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High-energy expansion in color dipoles

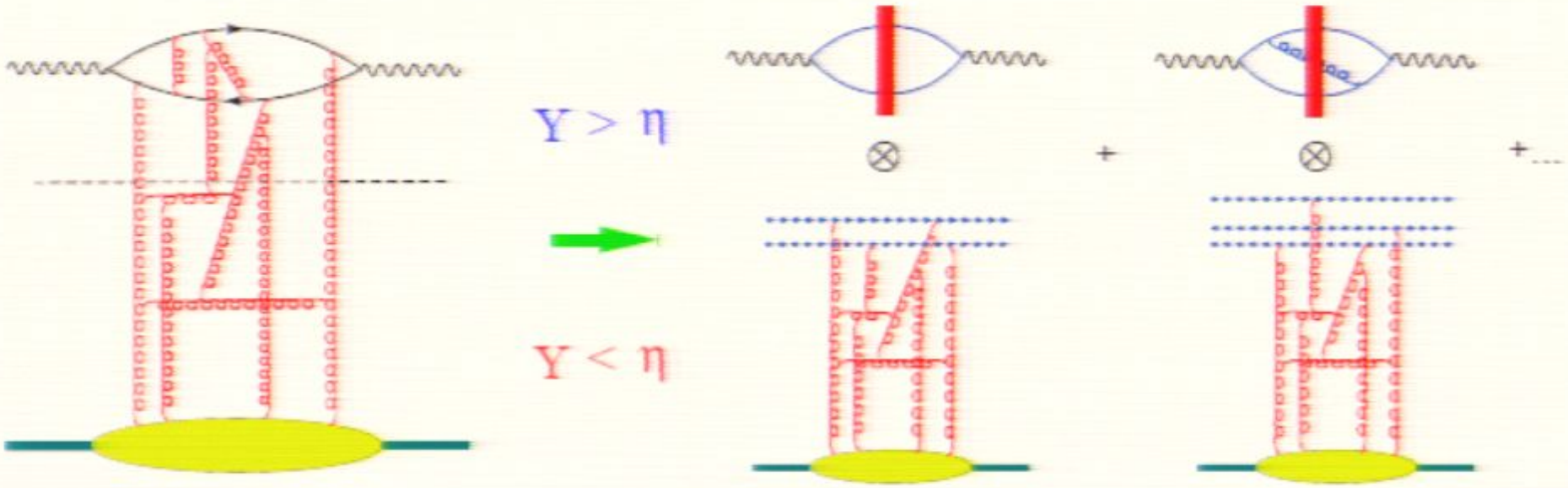


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High-energy expansion in color dipoles

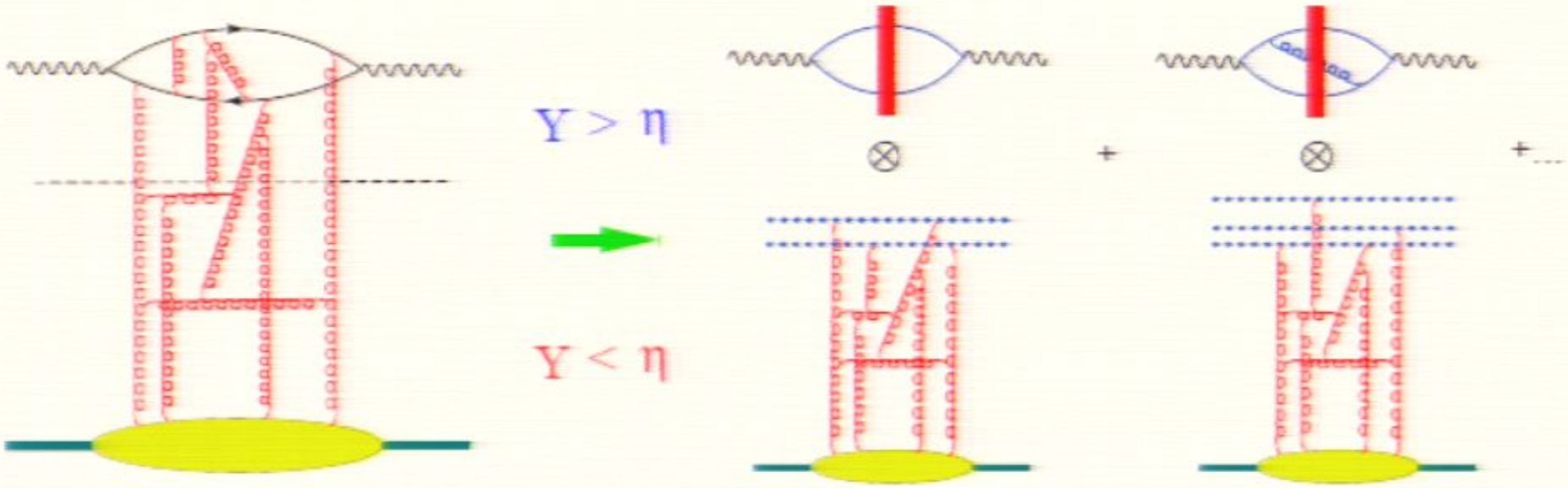


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High-energy expansion in color dipoles

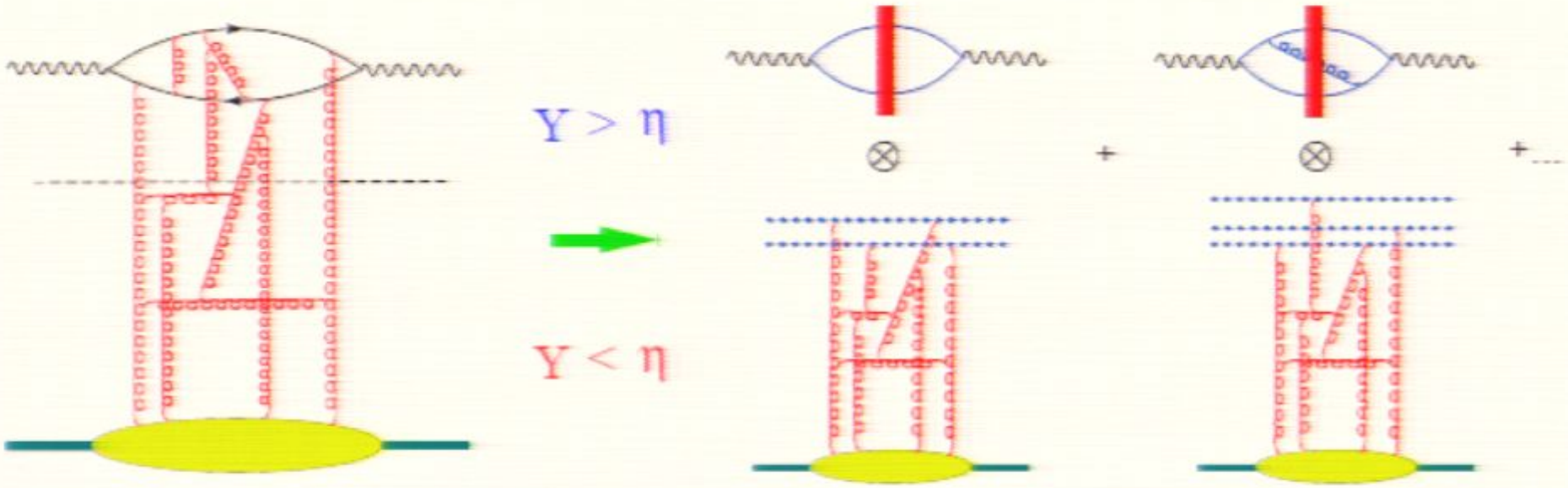


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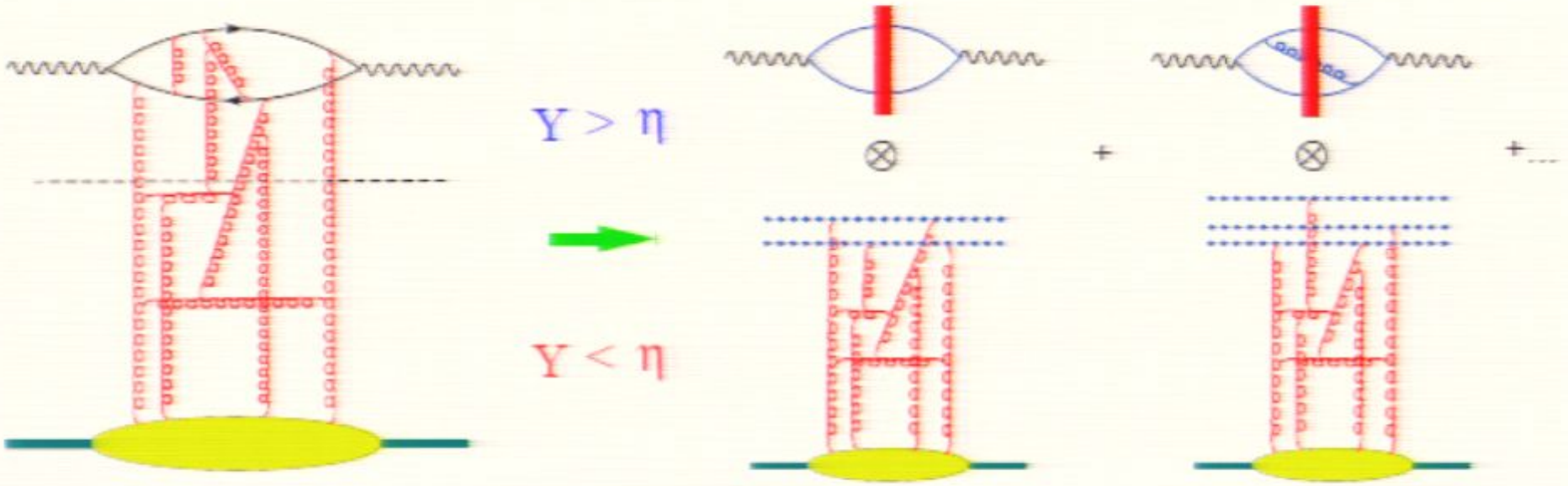


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High-energy expansion in color dipoles

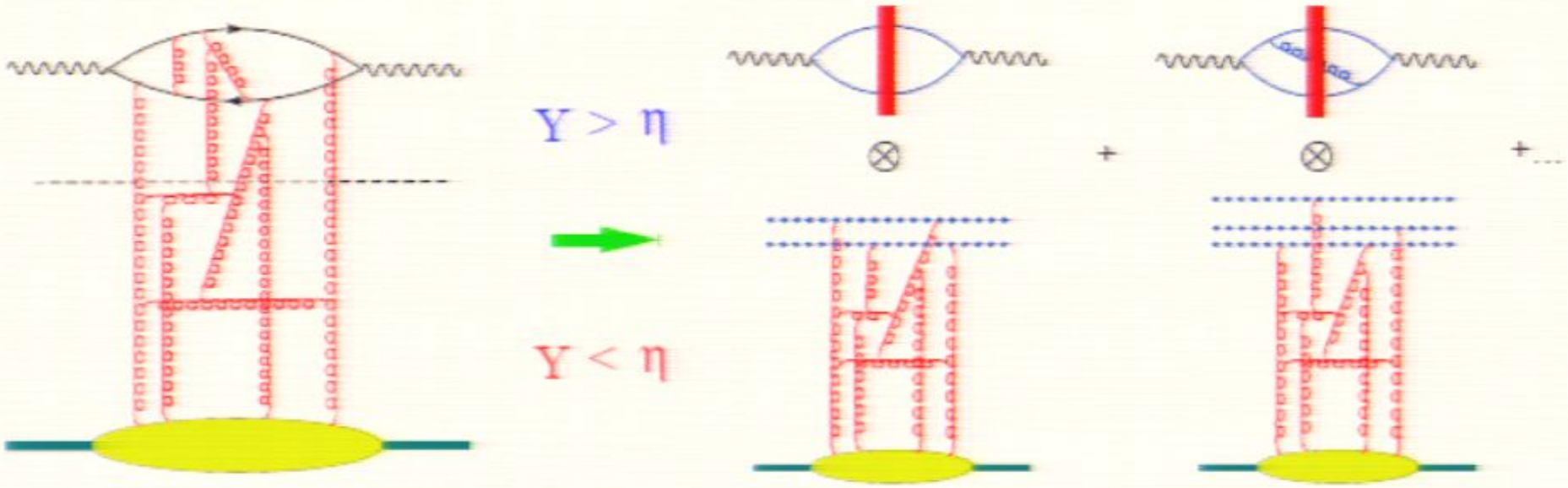


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High-energy expansion in color dipoles

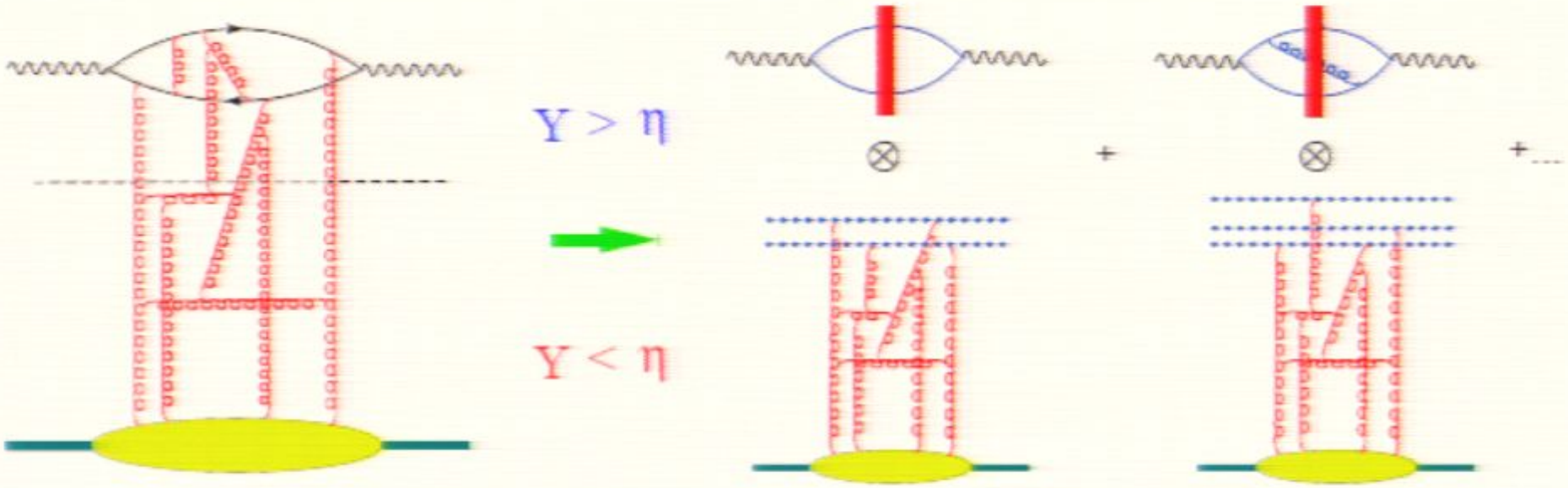


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High-energy expansion in color dipoles

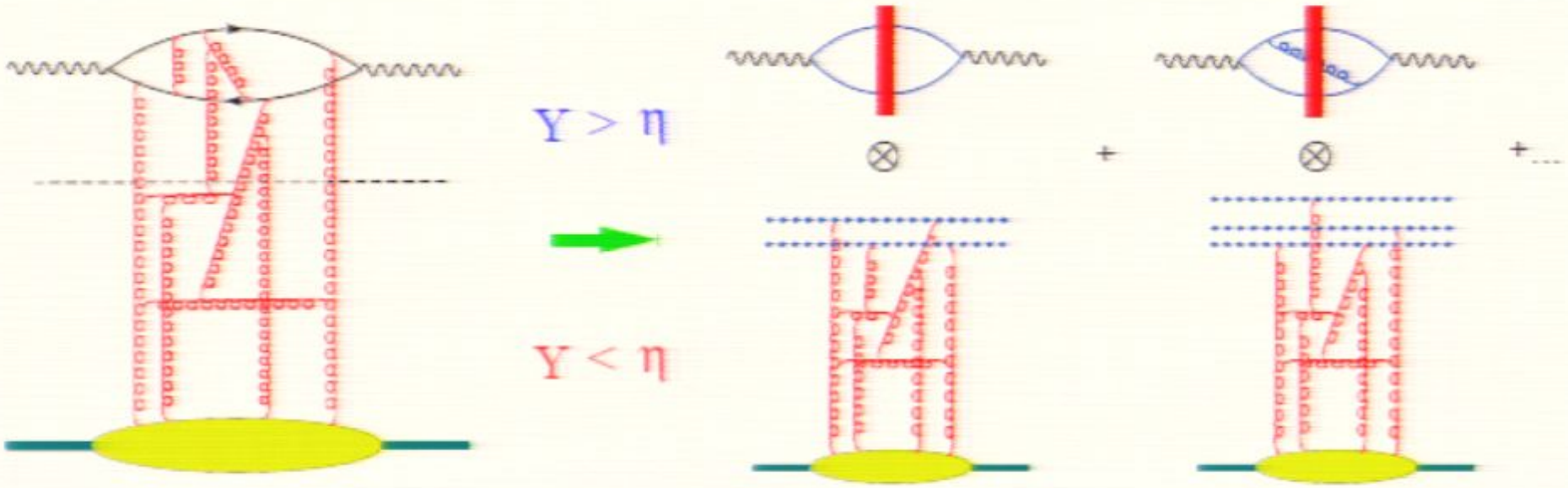


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High-energy expansion in color dipoles

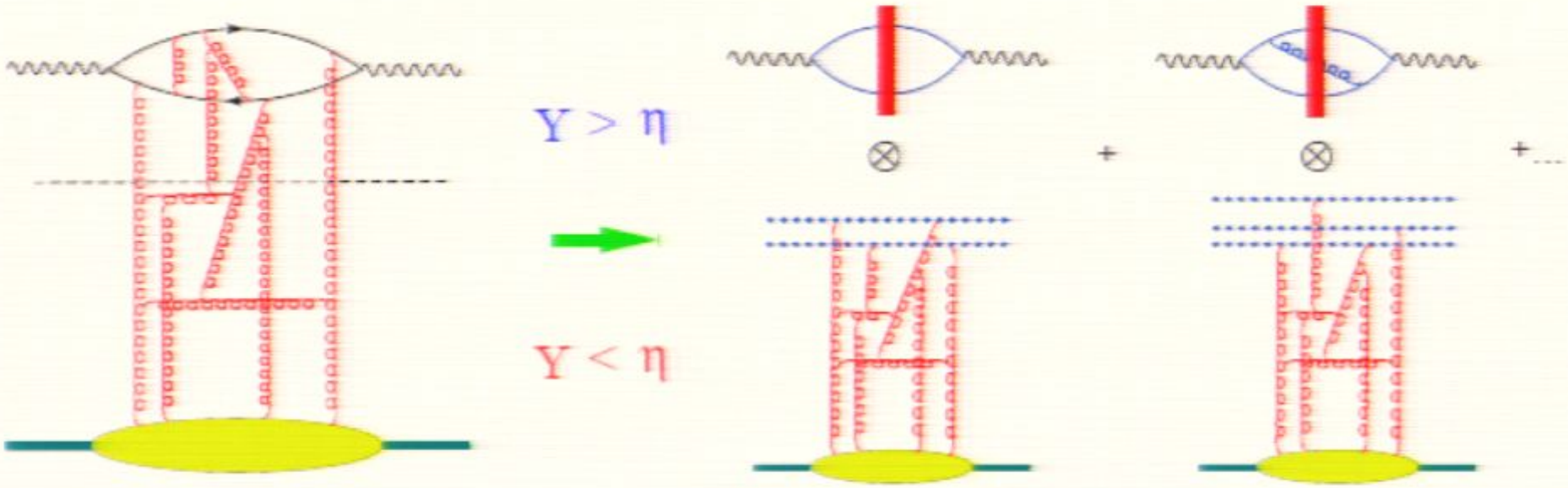


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High-energy expansion in color dipoles

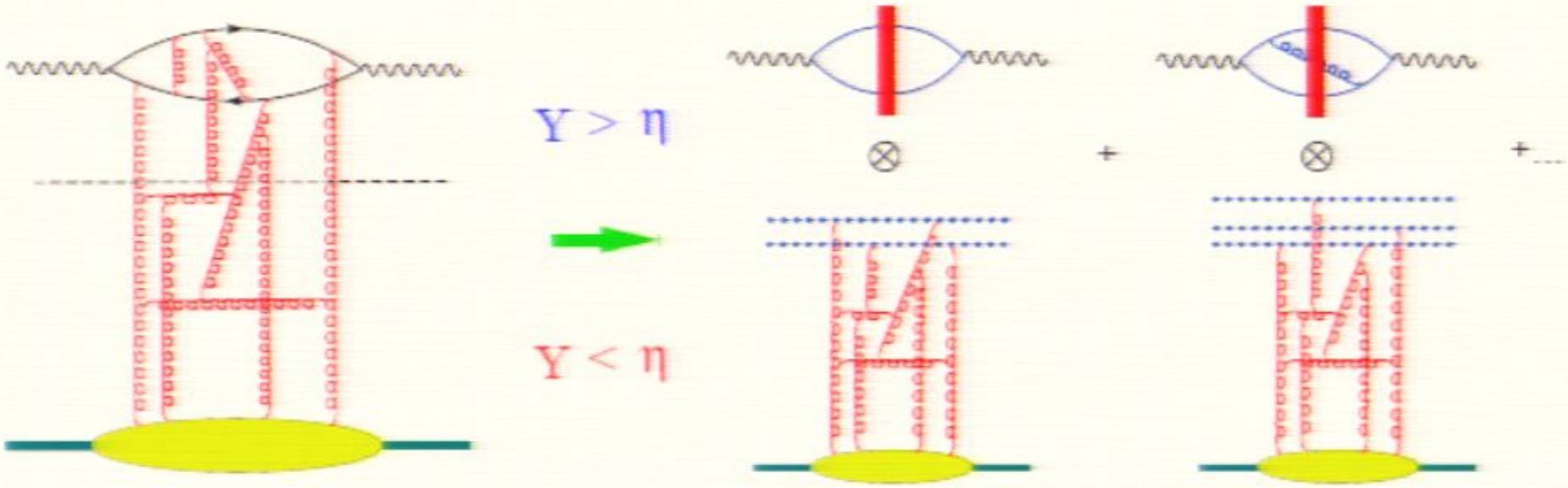


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High-energy expansion in color dipoles

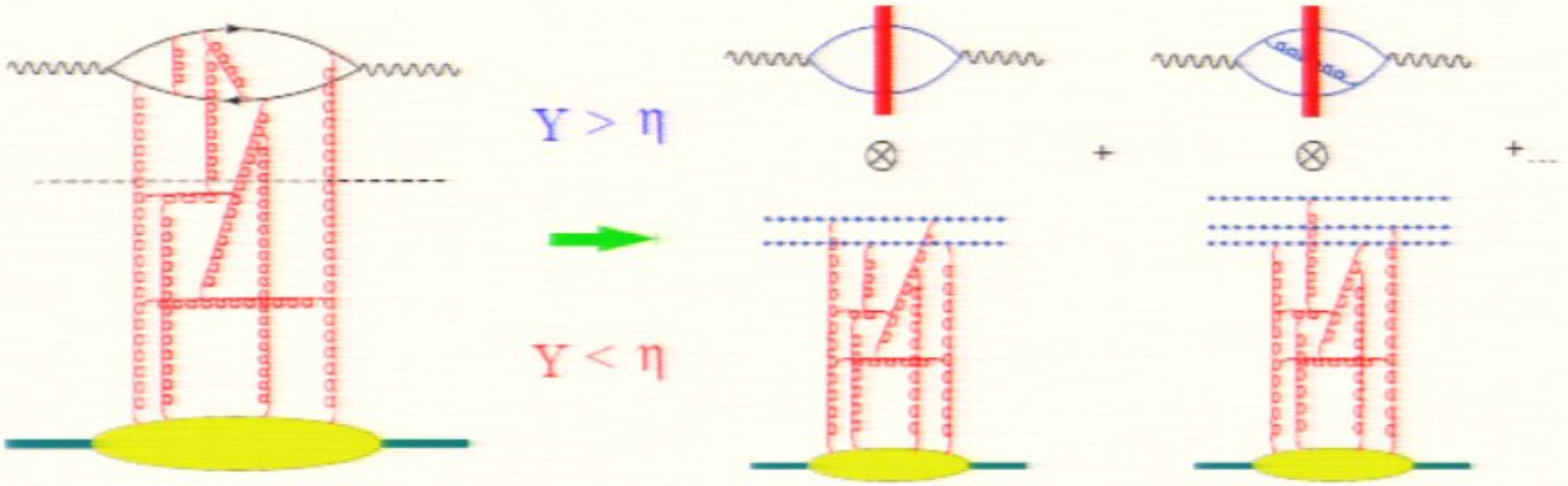


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High-energy expansion in color dipoles

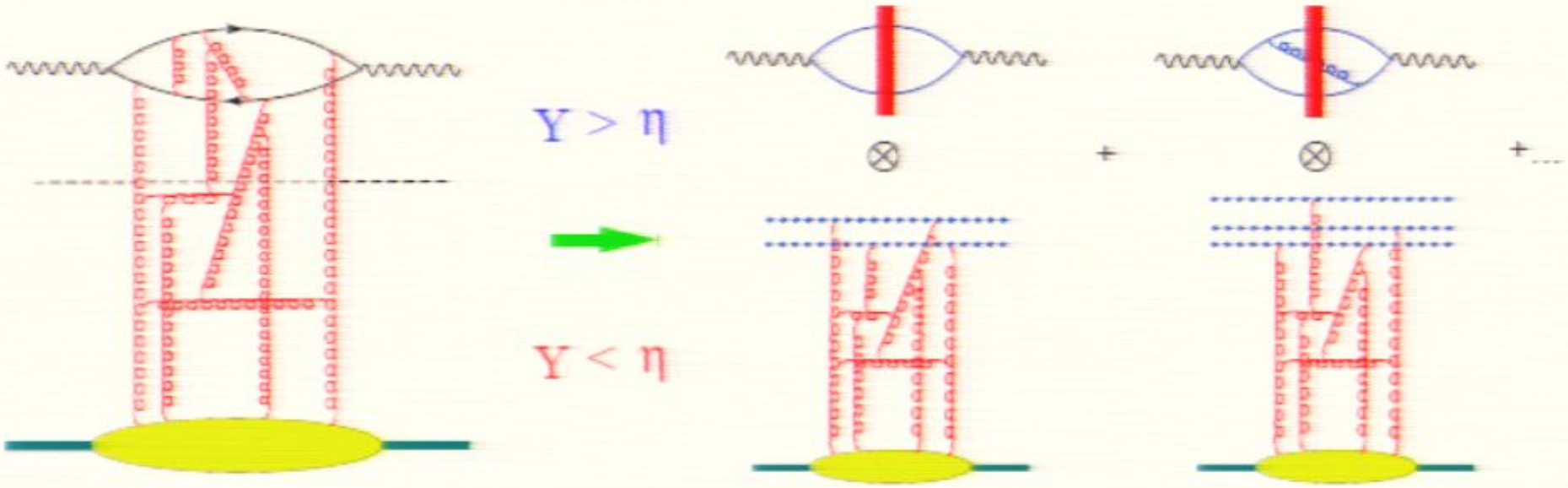


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High-energy expansion in color dipoles

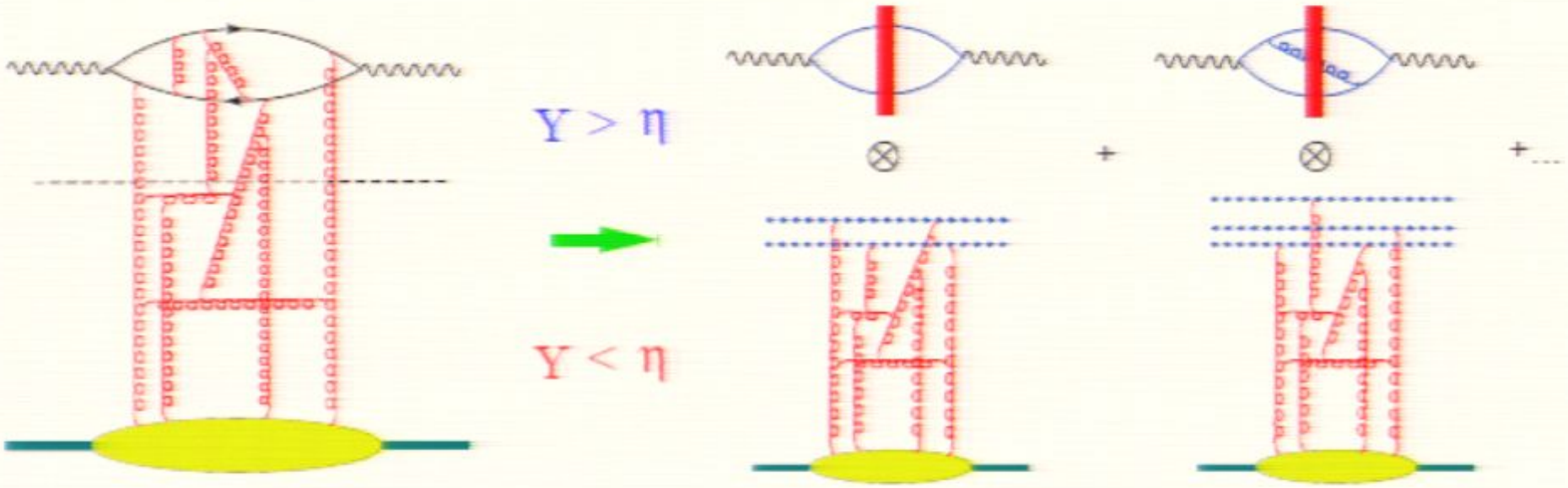


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High-energy expansion in color dipoles



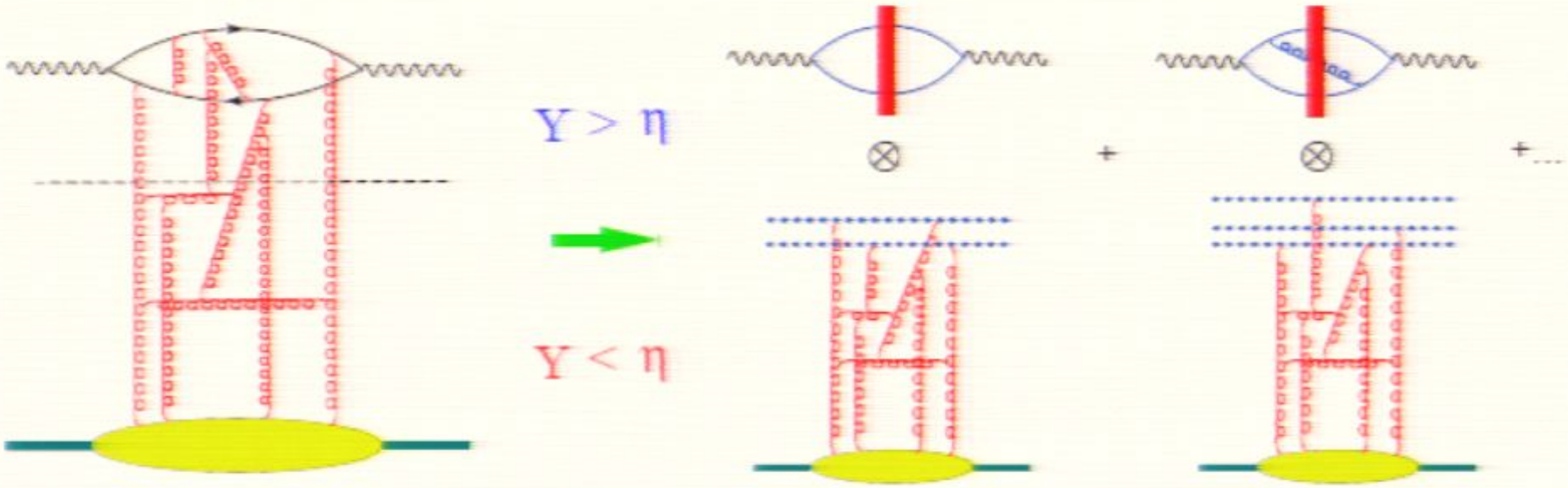
η - rapidity factorization scale

Evolution equation for color dipoles

$$\frac{d}{d\eta}\mathrm{tr}\{U_x^\eta U_y^{\dagger\eta}\} = \frac{\alpha_s}{2\pi^2}\int d^2z \frac{(x-y)^2}{(x-z)^2(y-z)^2}[\mathrm{tr}\{U_x^\eta U_y^{\dagger\eta}\}\mathrm{tr}\{U_x^\eta U_y^{\dagger\eta}\} - N_c\mathrm{tr}\{U_x^\eta U_y^{\dagger\eta}\}] + \alpha_s K_{\mathrm{NLO}}\mathrm{tr}\{U_x^\eta U_y^{\dagger\eta}\} + O(\alpha_s^2)$$

(Linear part of $K_{\mathrm{NLO}} = K_{\mathrm{NLO\ BFKL}}$)

High-energy expansion in color dipoles

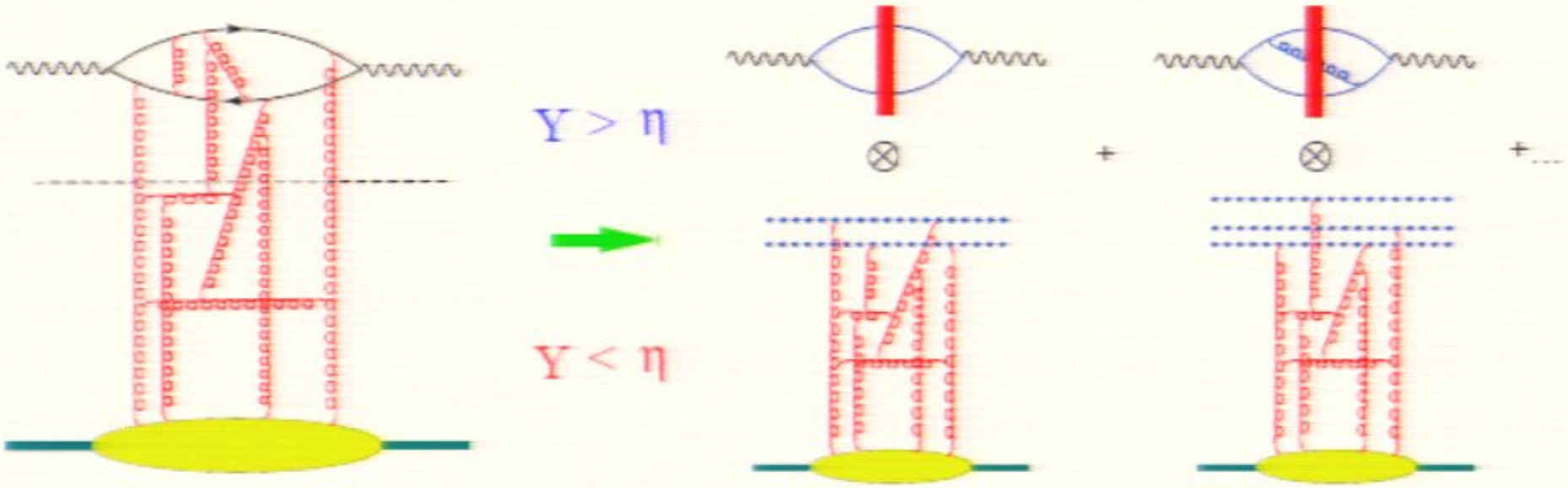


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High-energy expansion in color dipoles

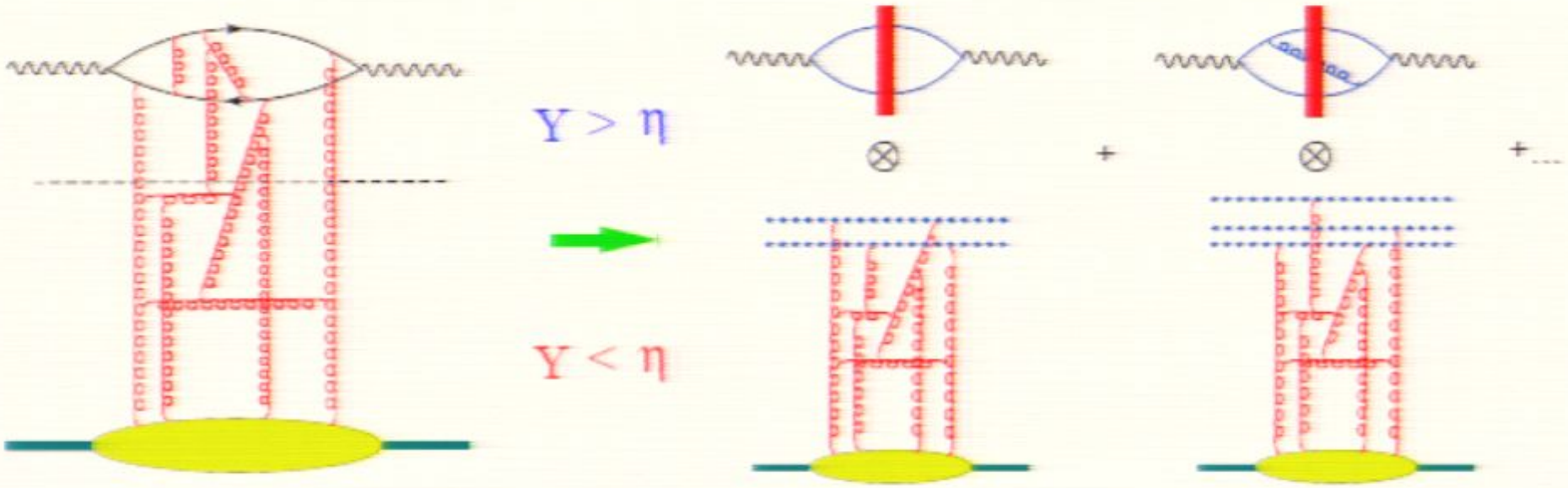


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High-energy expansion in color dipoles

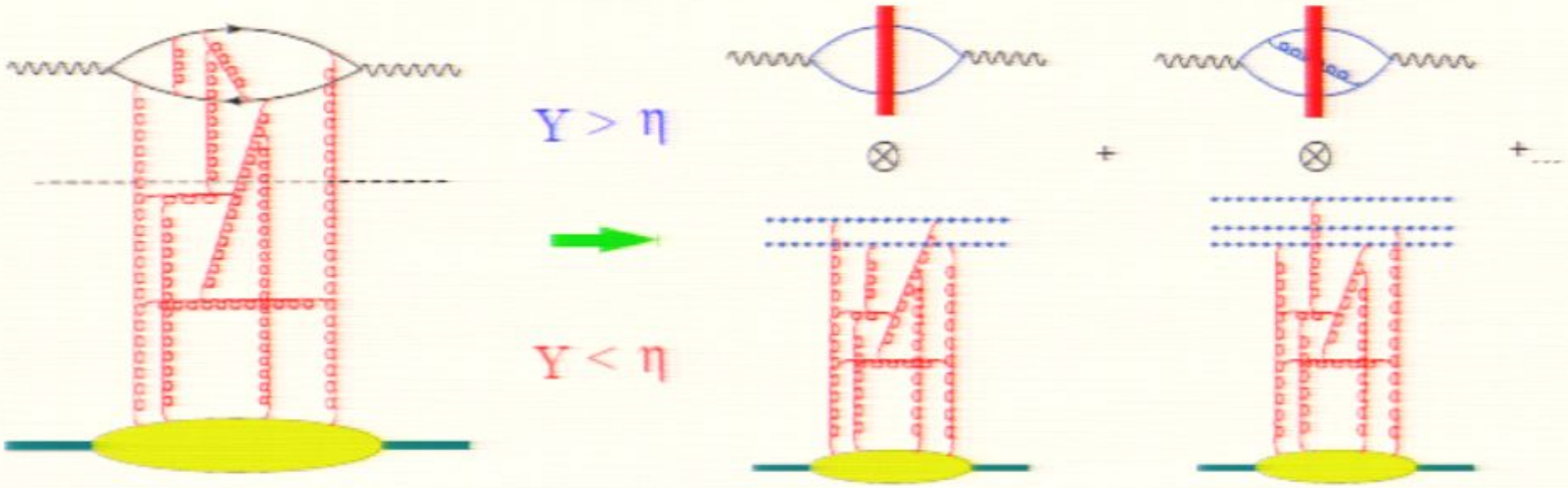


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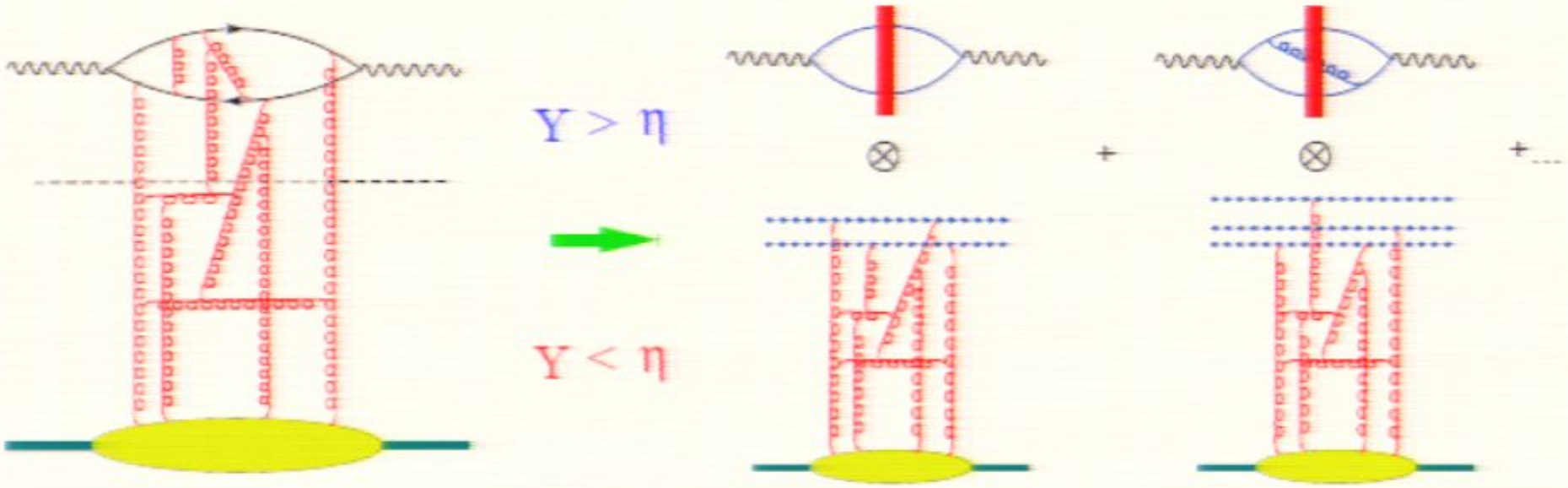


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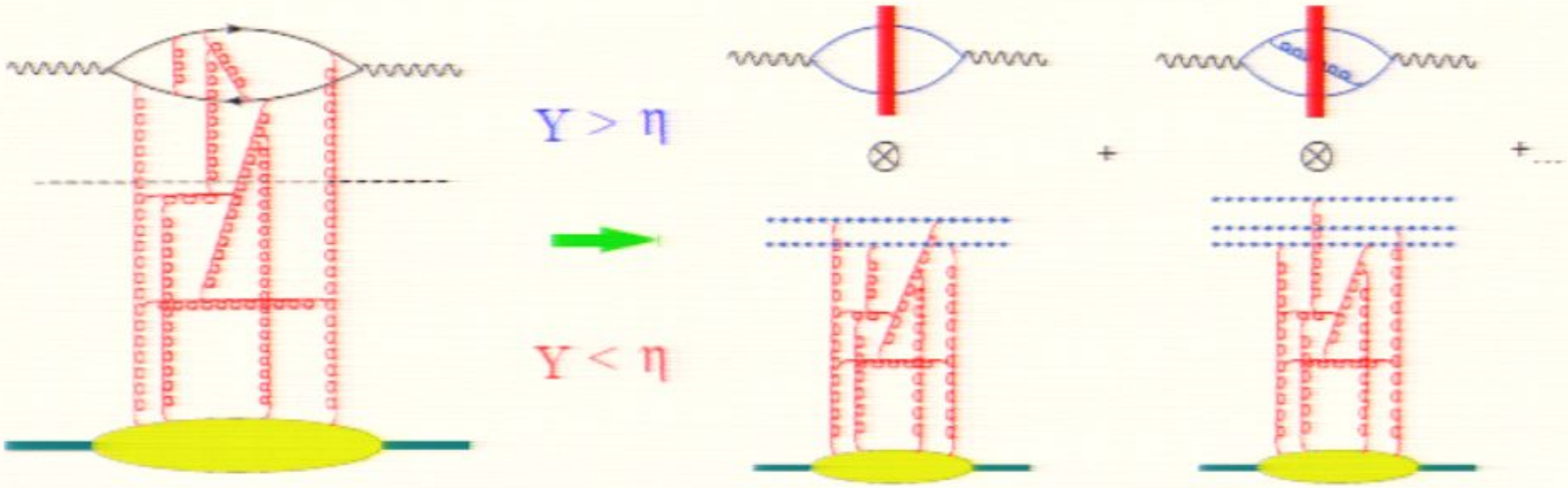


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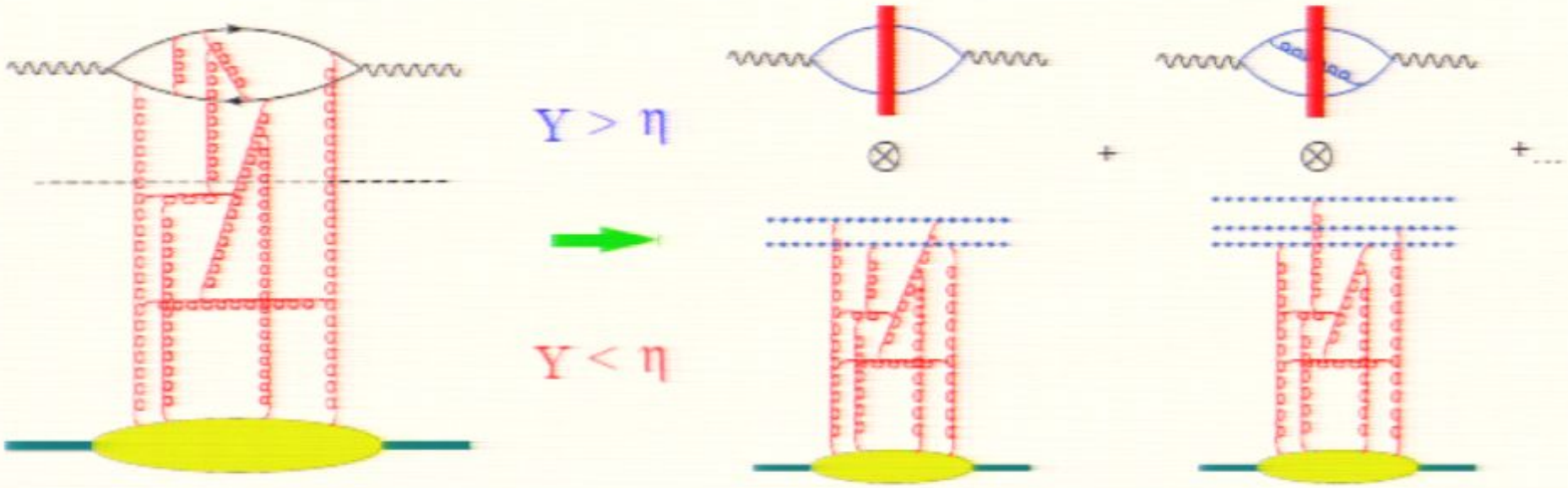


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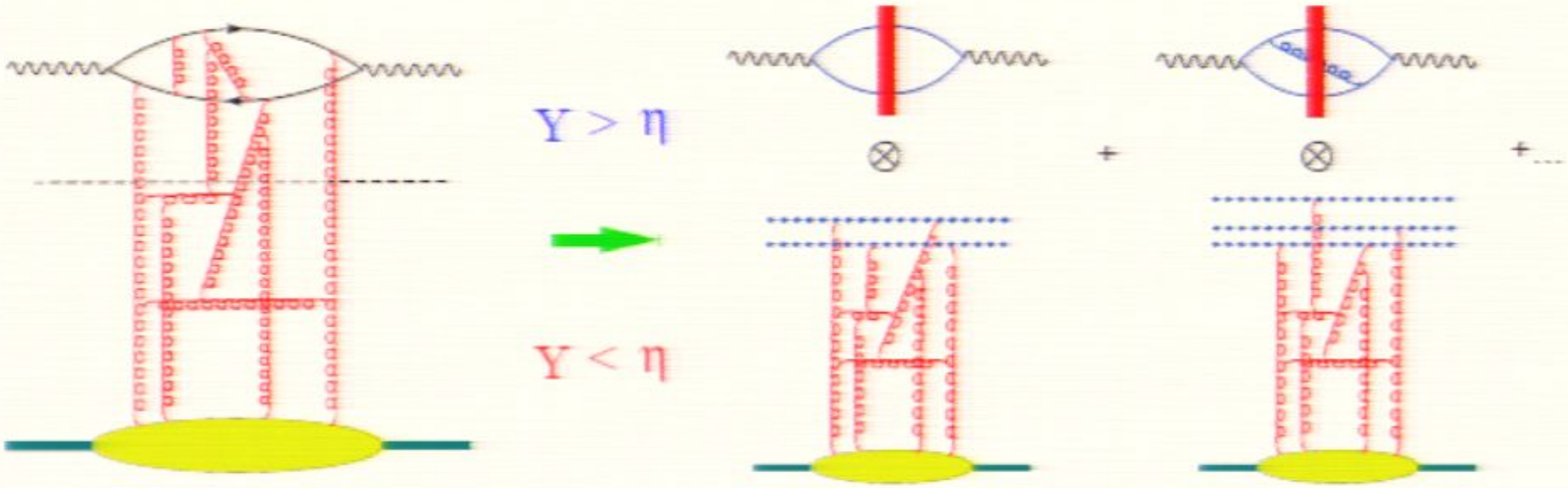


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High-energy expansion in color dipoles

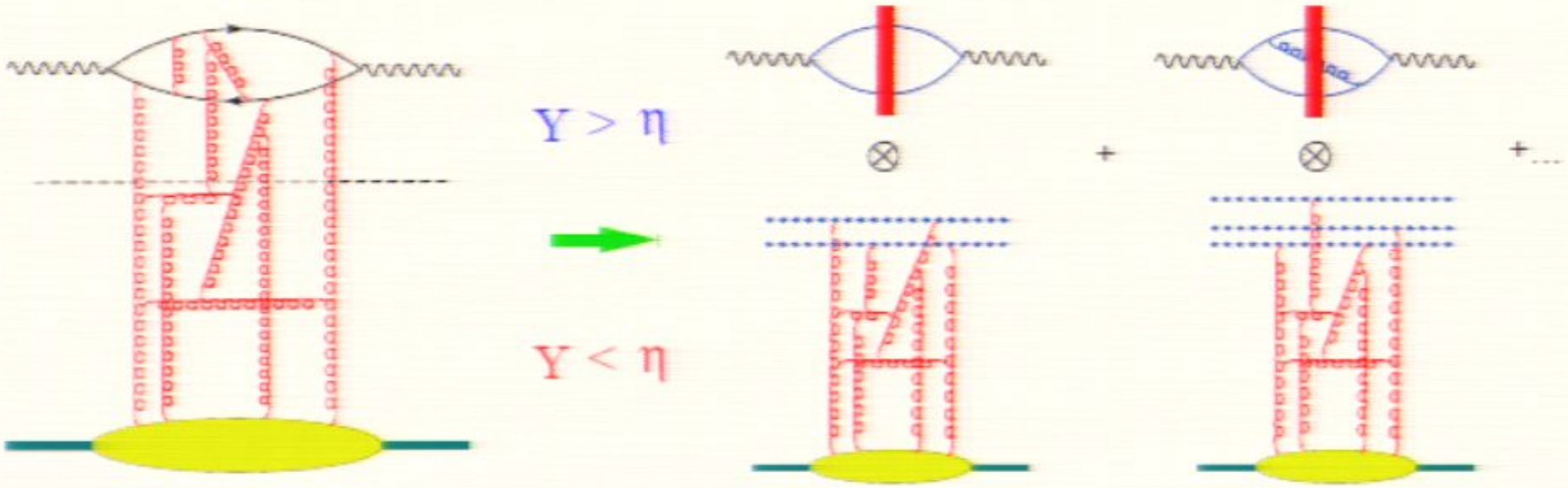


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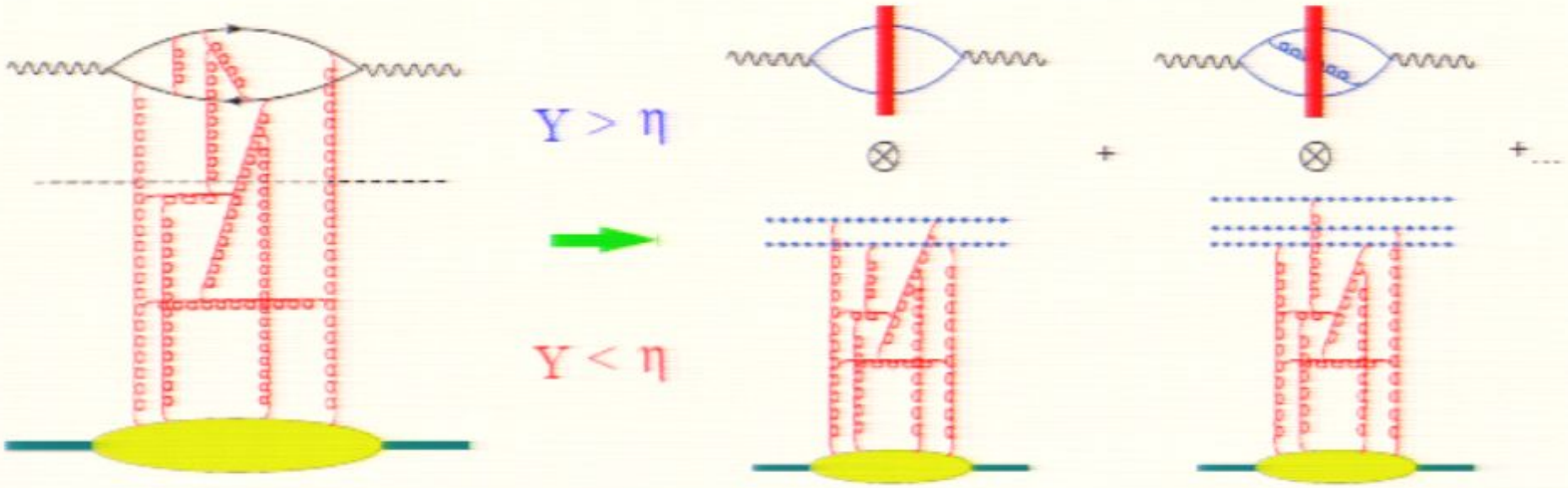


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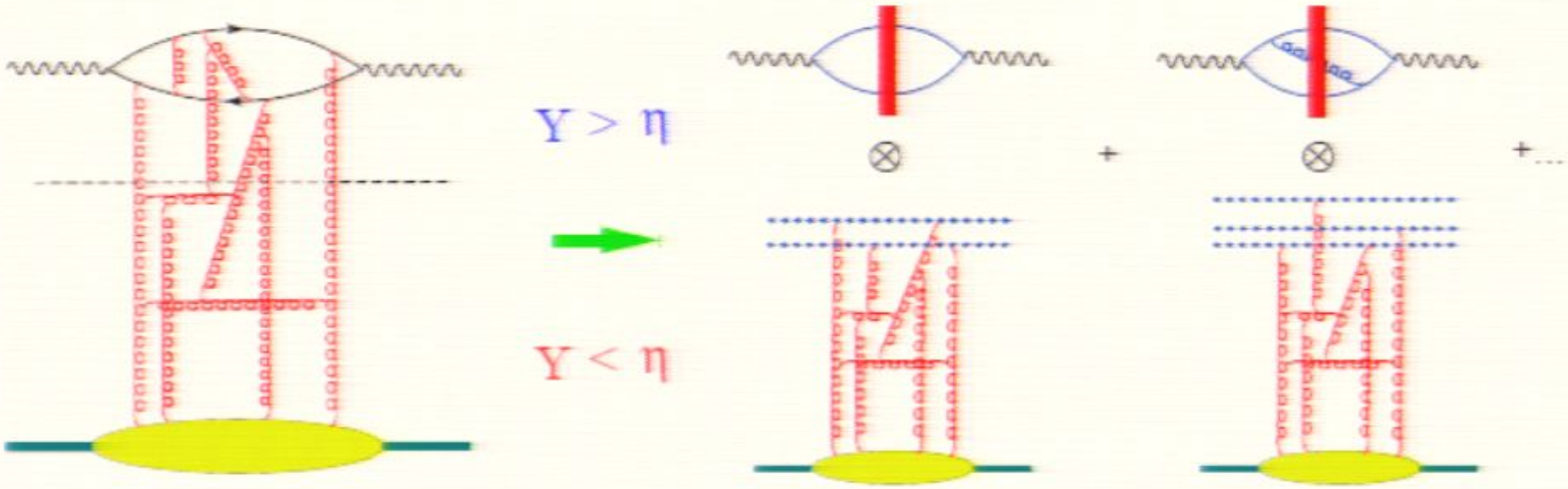


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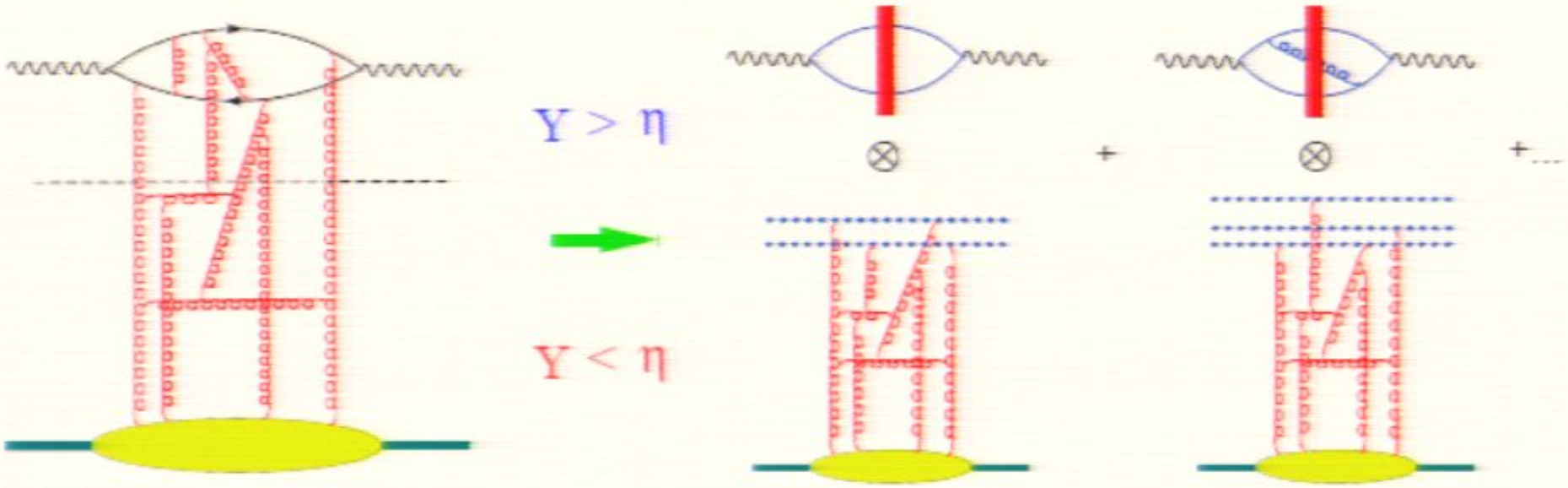


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High-energy expansion in color dipoles

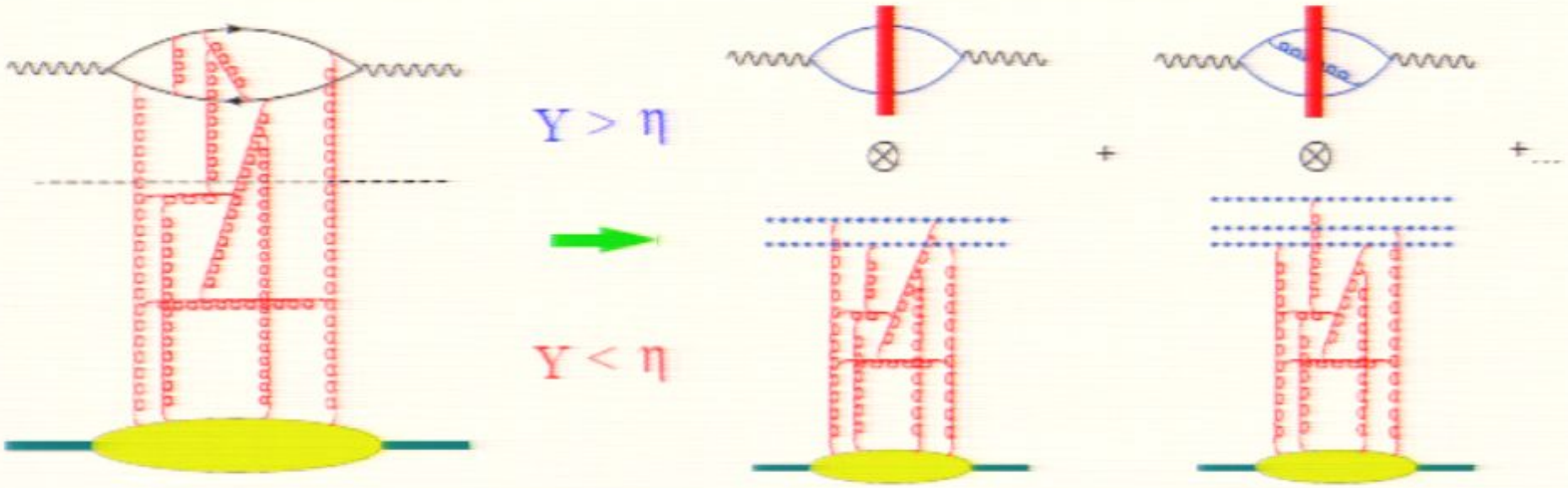


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High-energy expansion in color dipoles



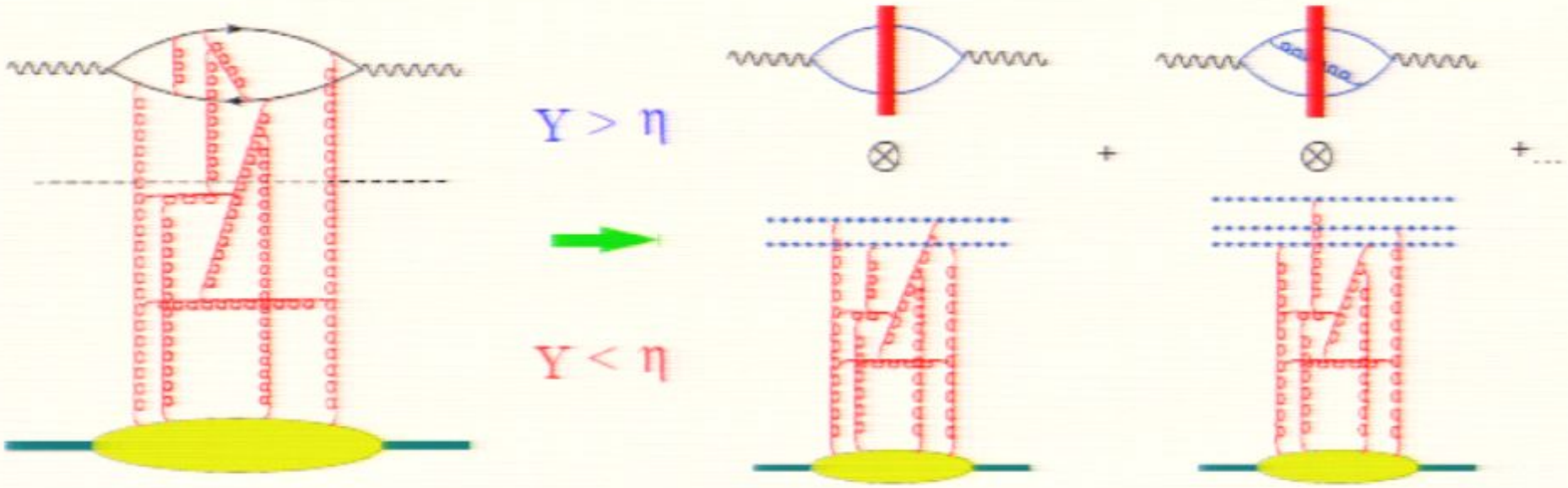
η - rapidity factorization scale

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(Linear part of K_{NLO} = $K_{\mathrm{NLO\ BFKL}}$)

High-energy expansion in color dipoles



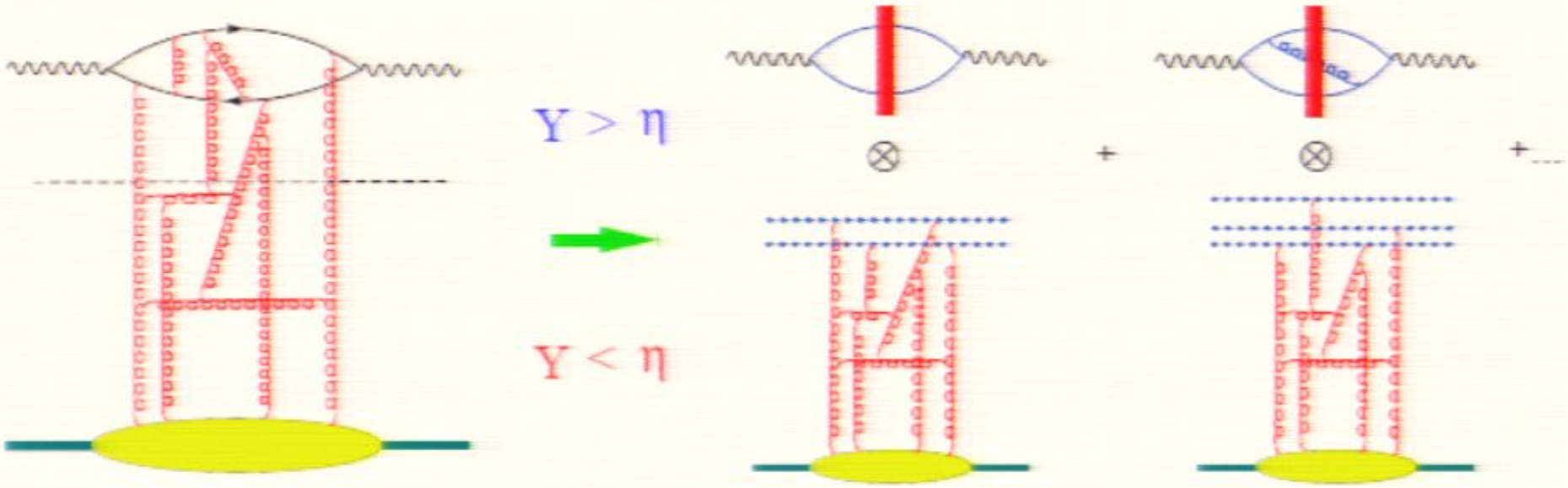
η - rapidity factorization scale

Evolution equation for color dipoles

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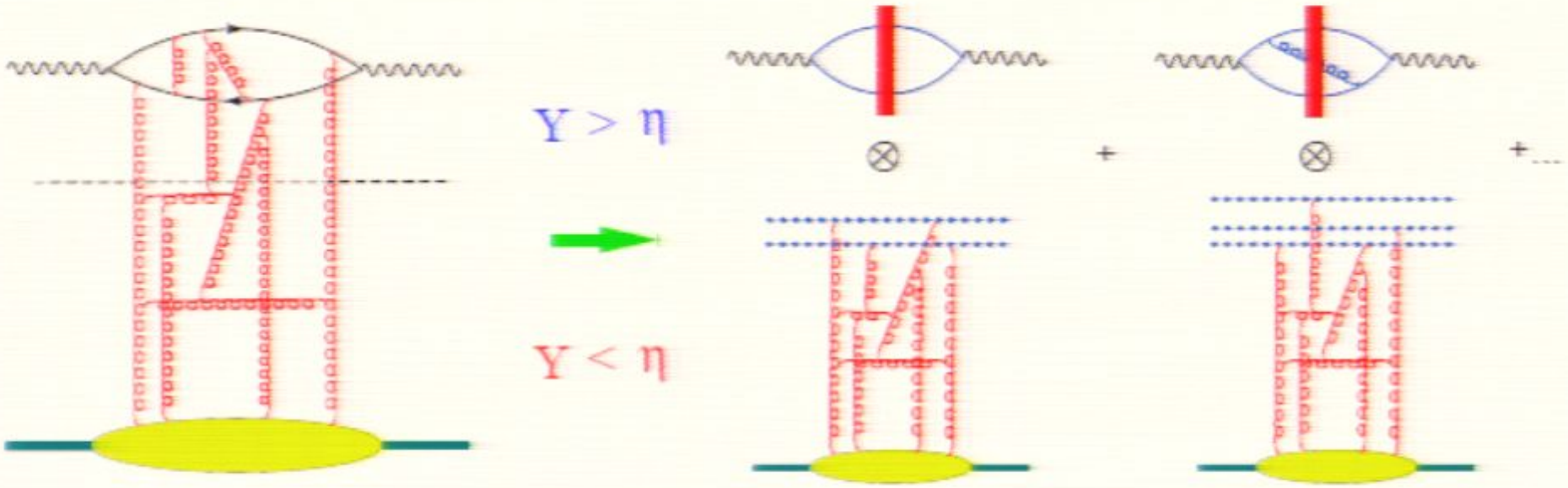
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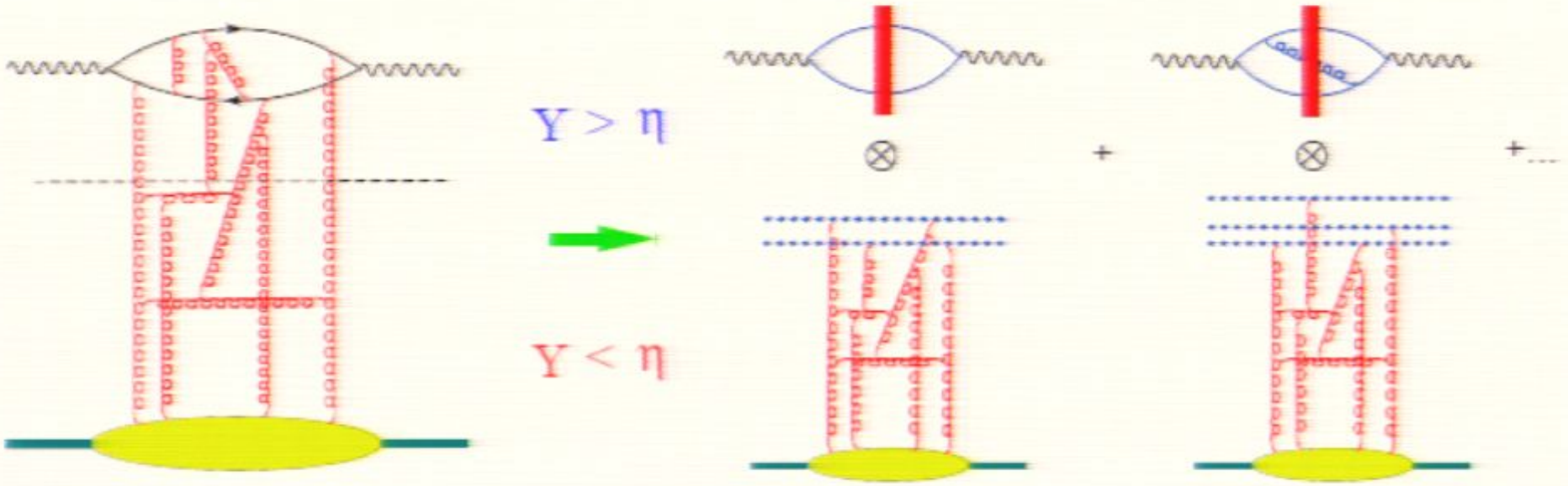
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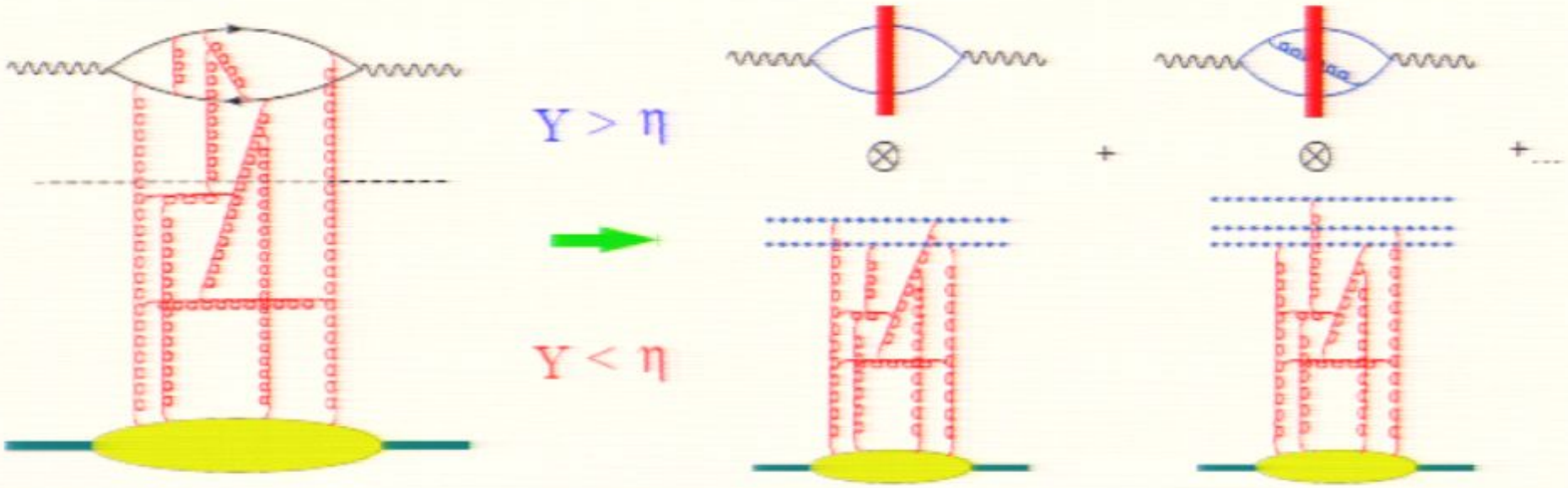
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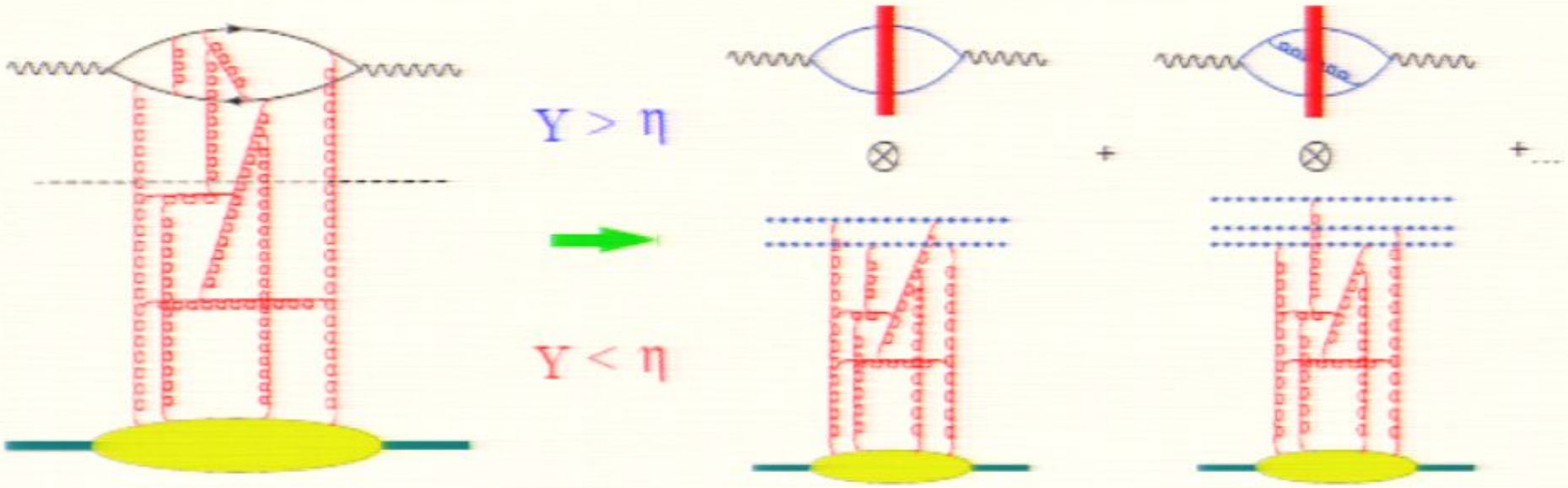
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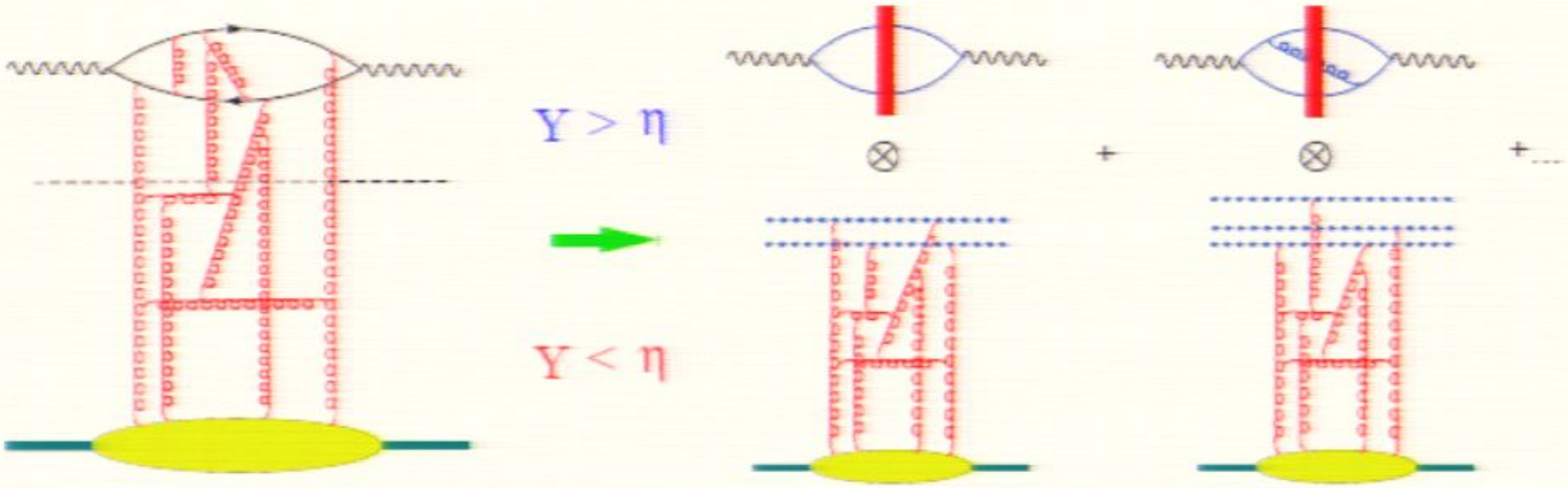
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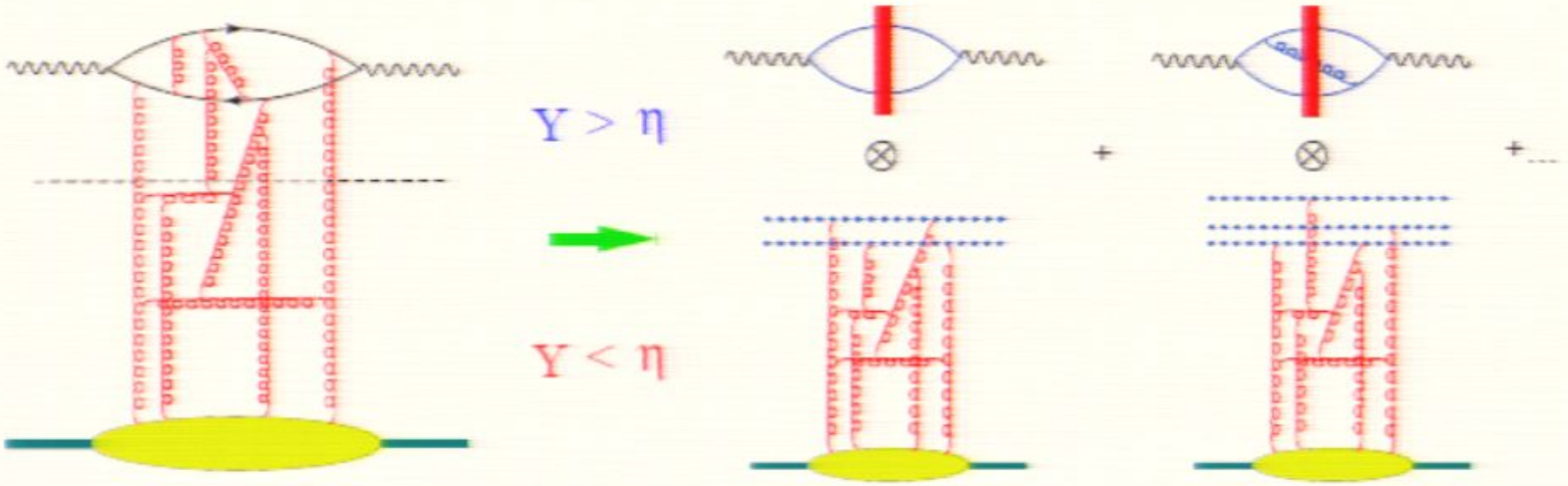
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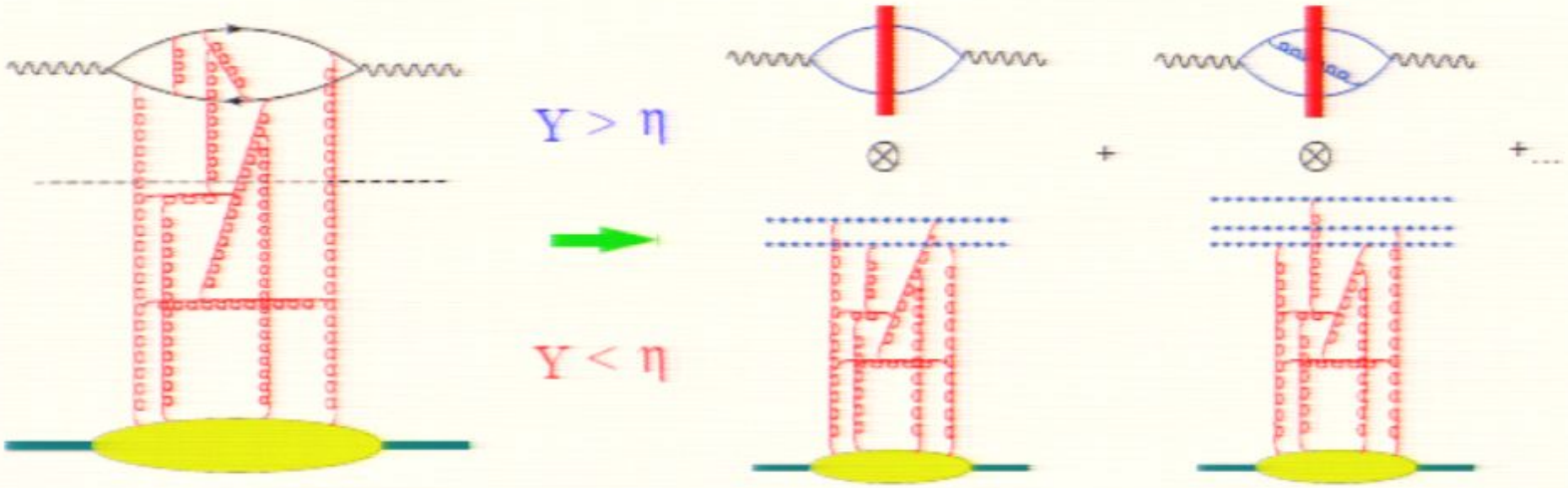
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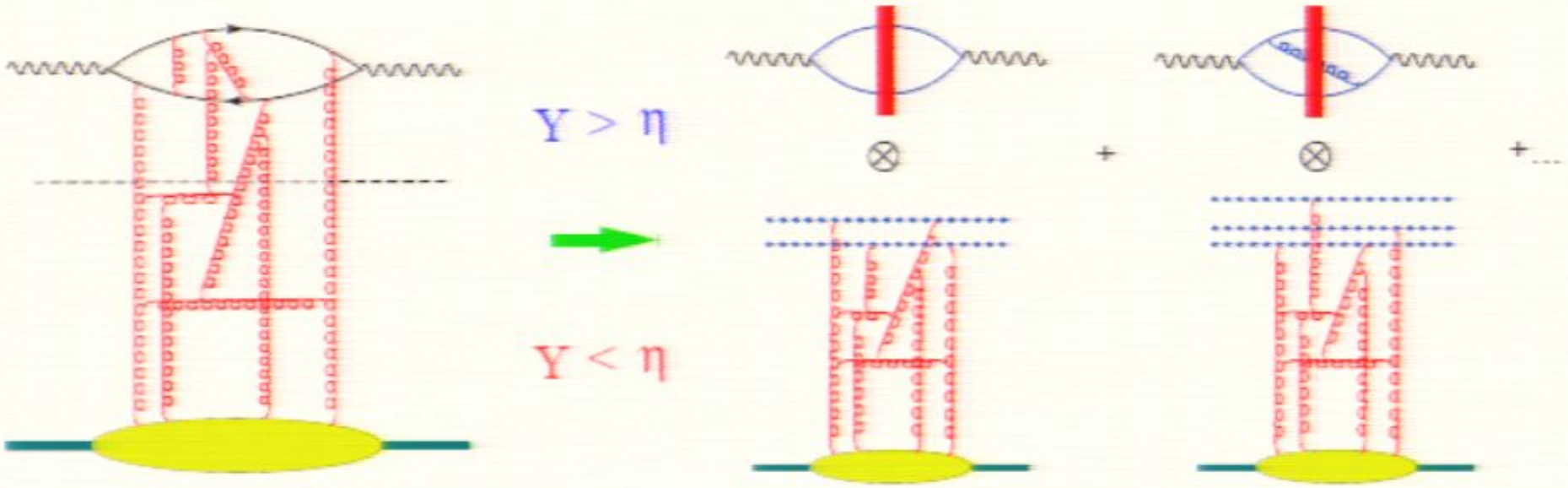
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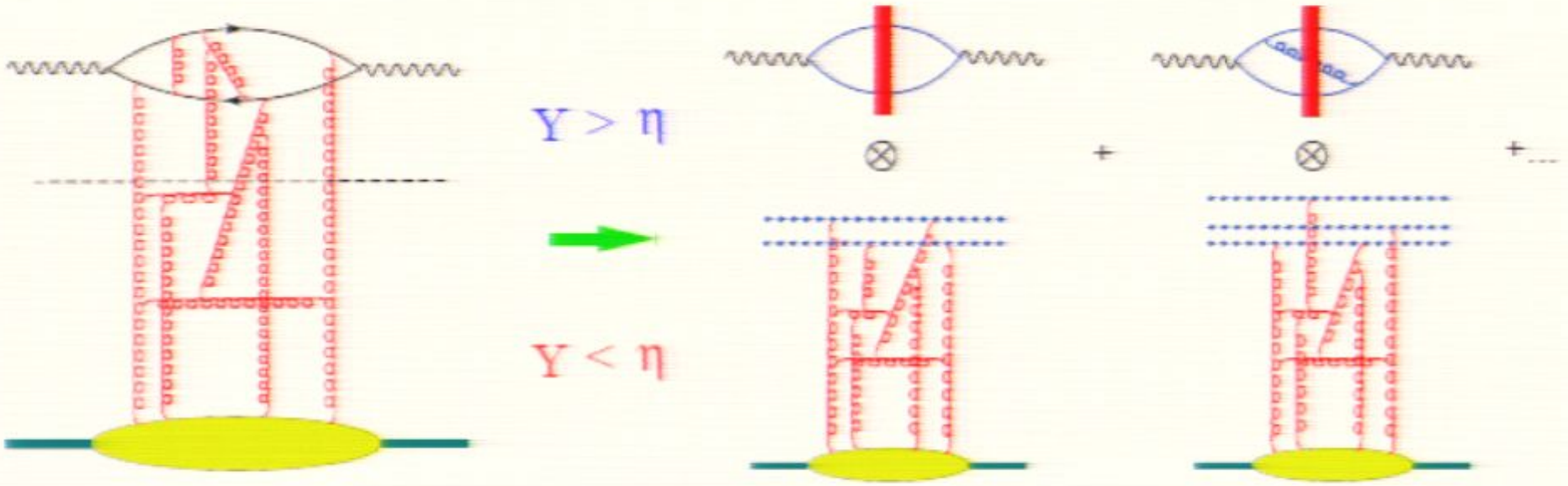
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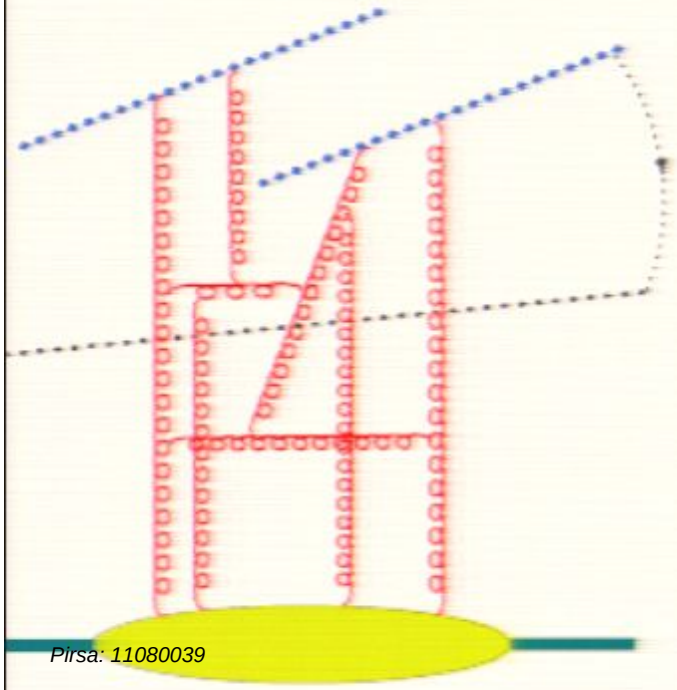
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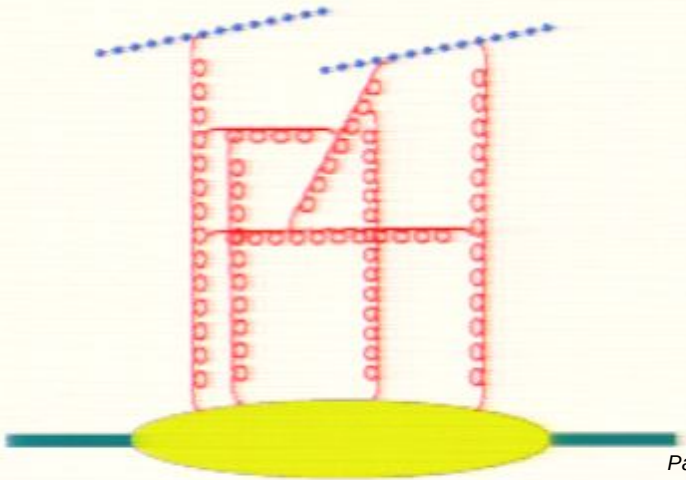
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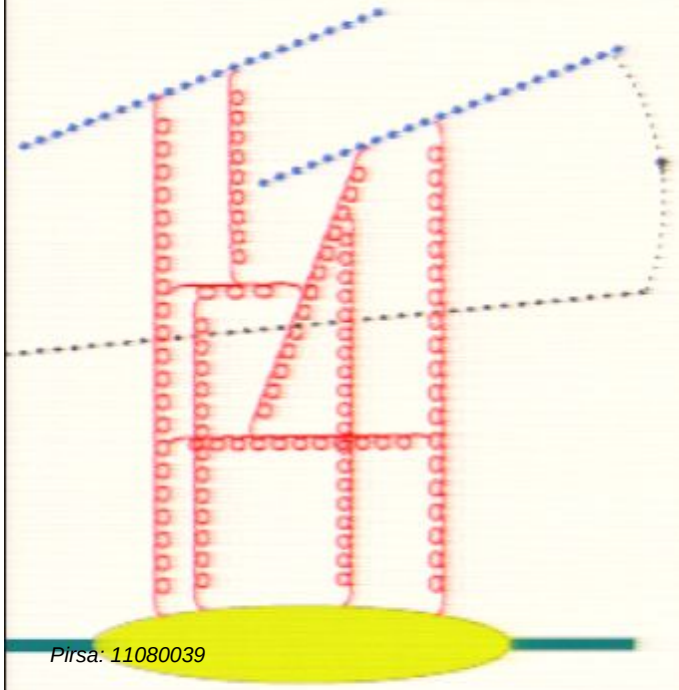


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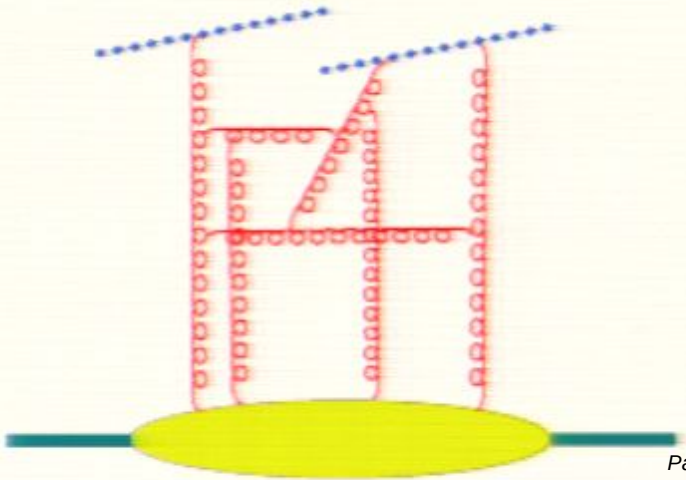


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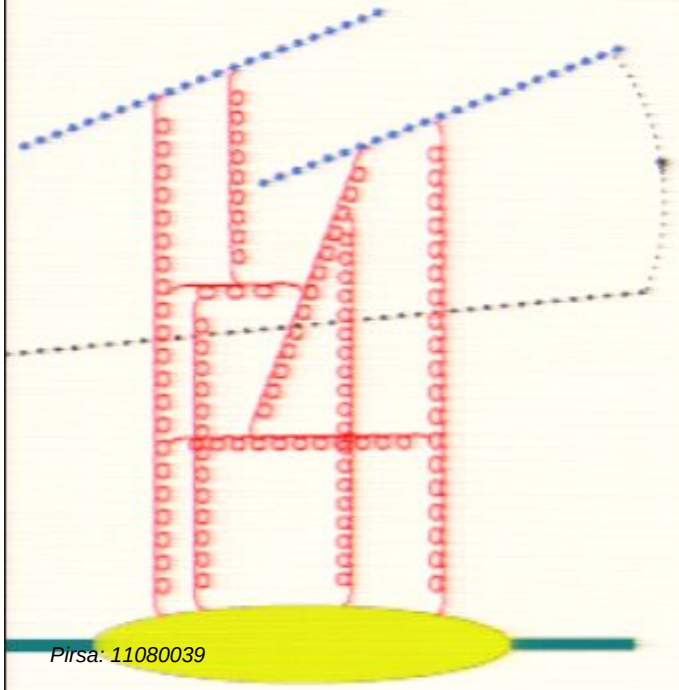


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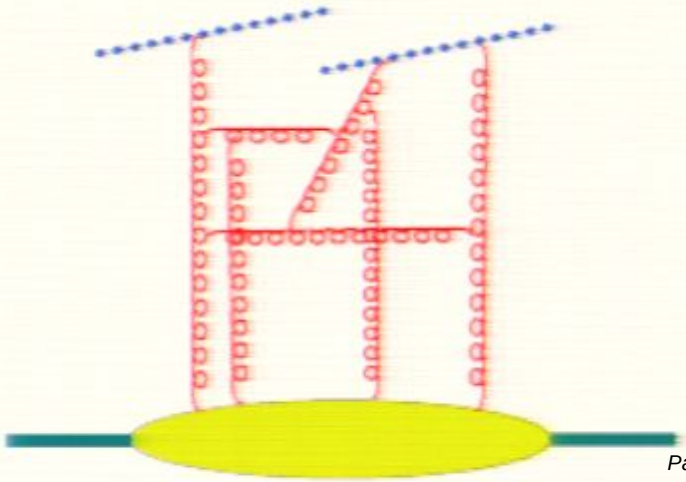


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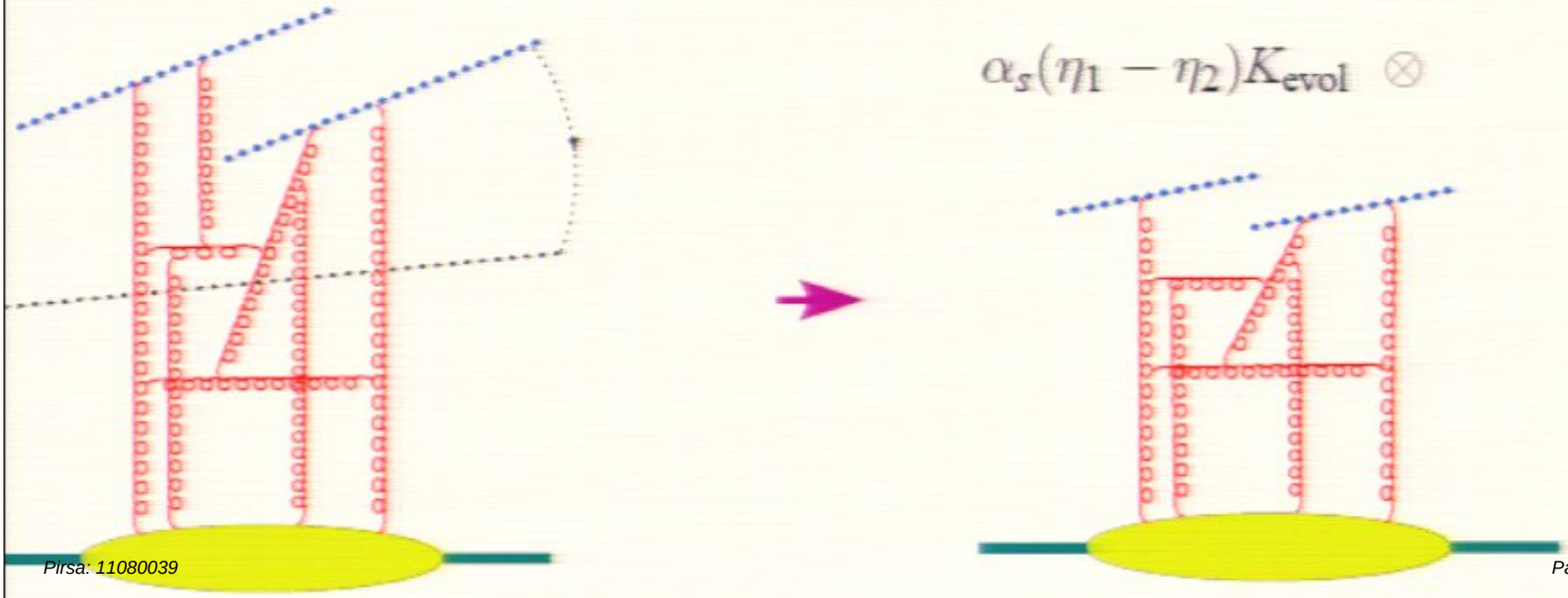


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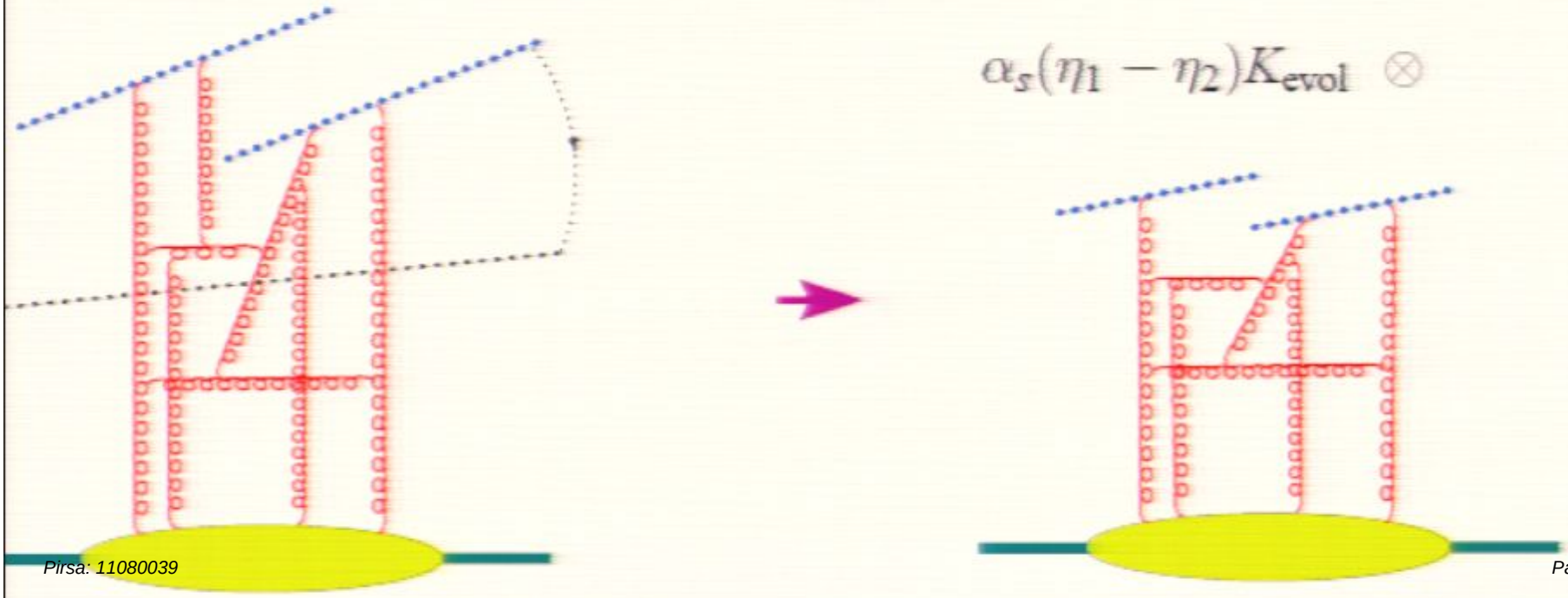
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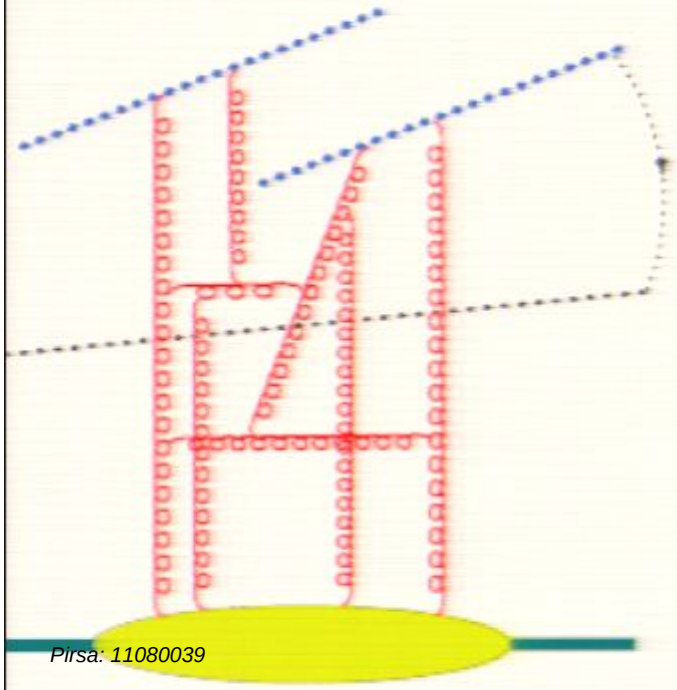
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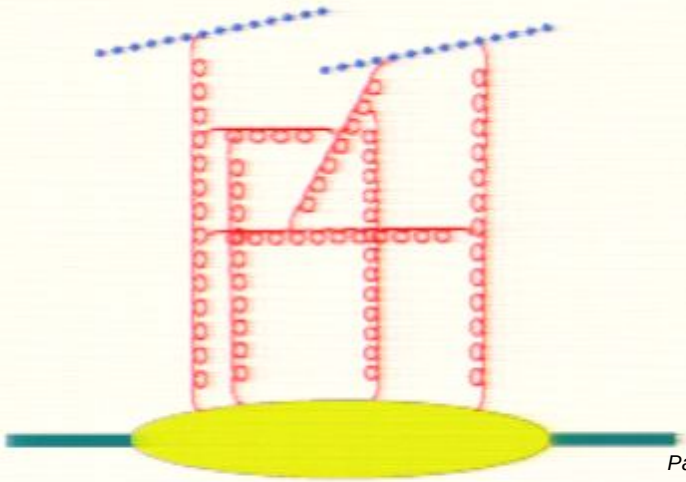


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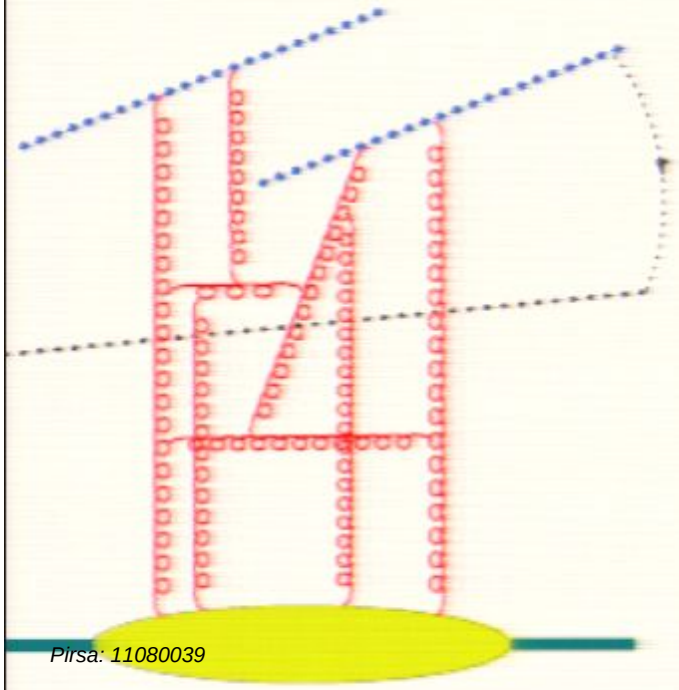


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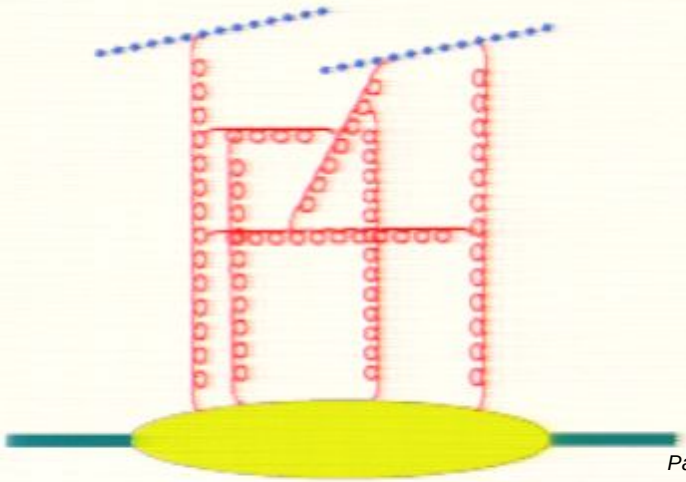


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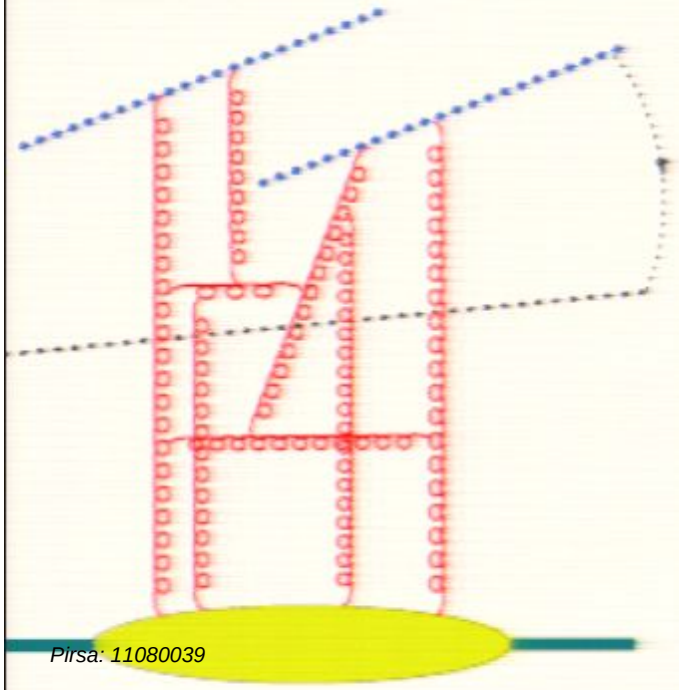


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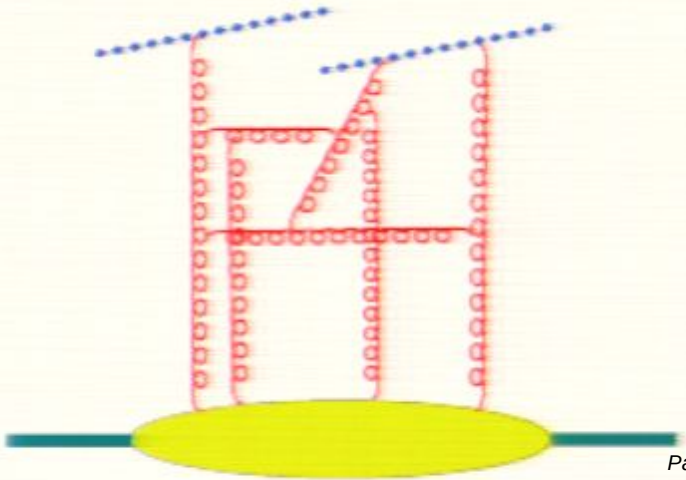


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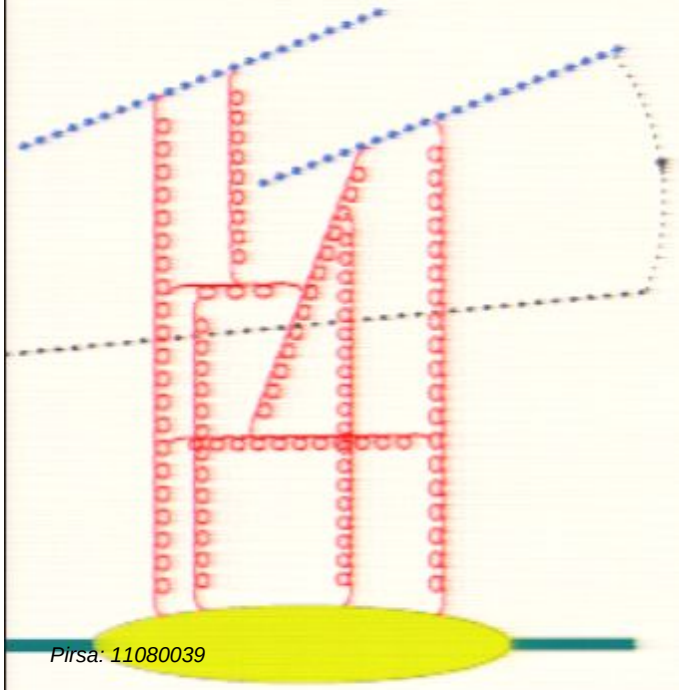


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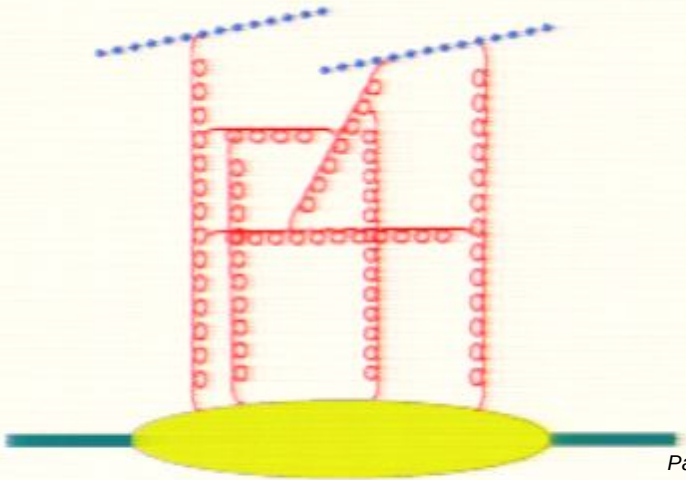


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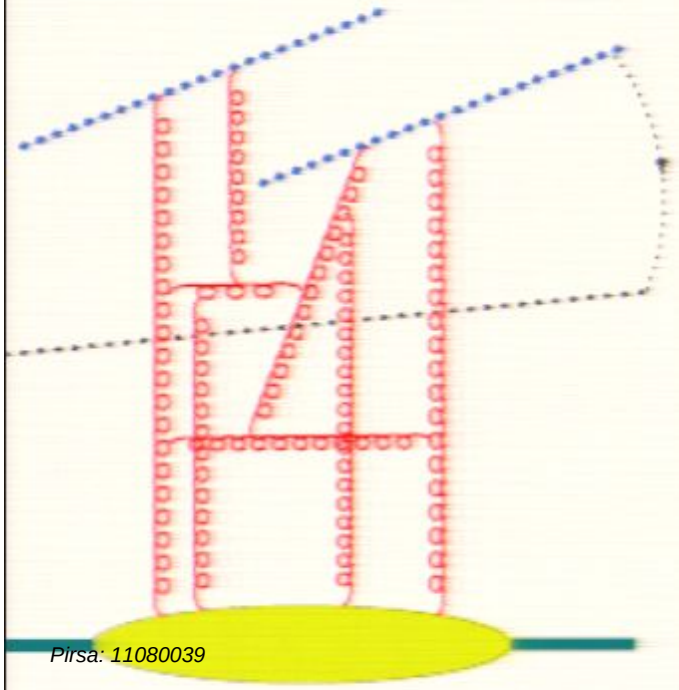


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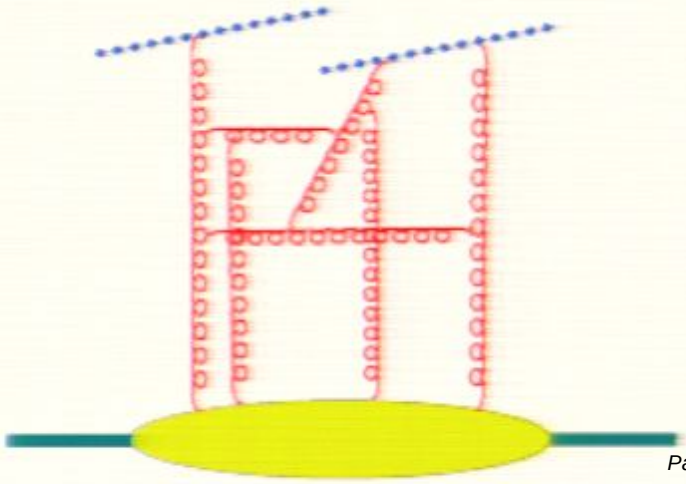


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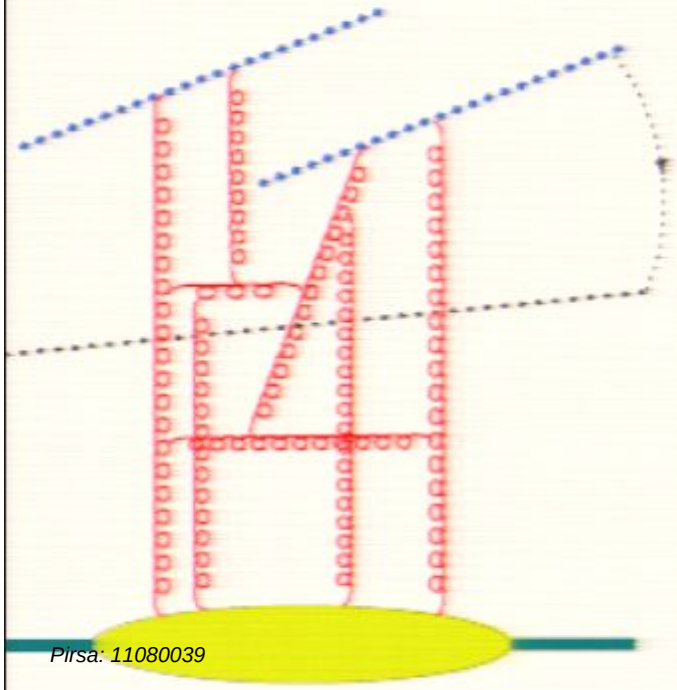


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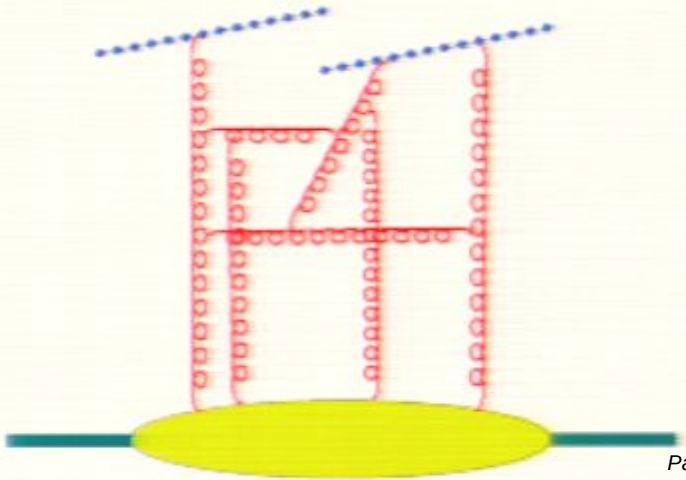


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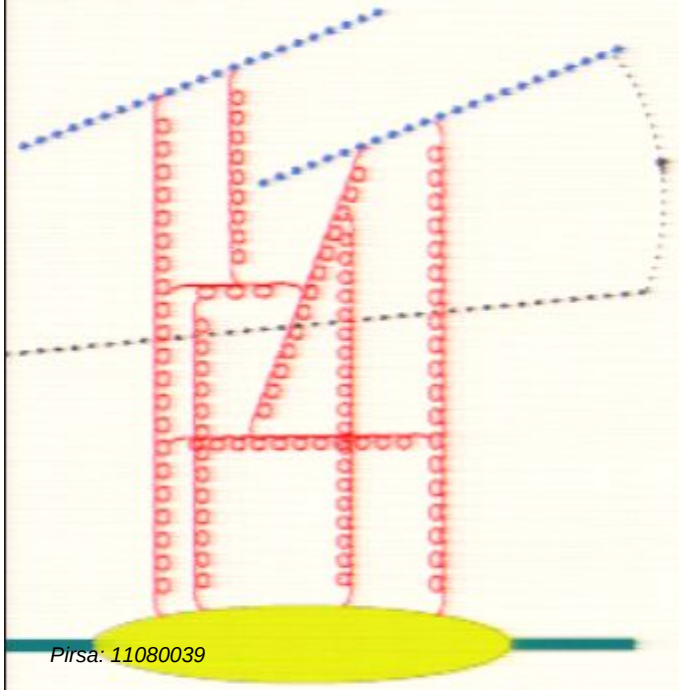


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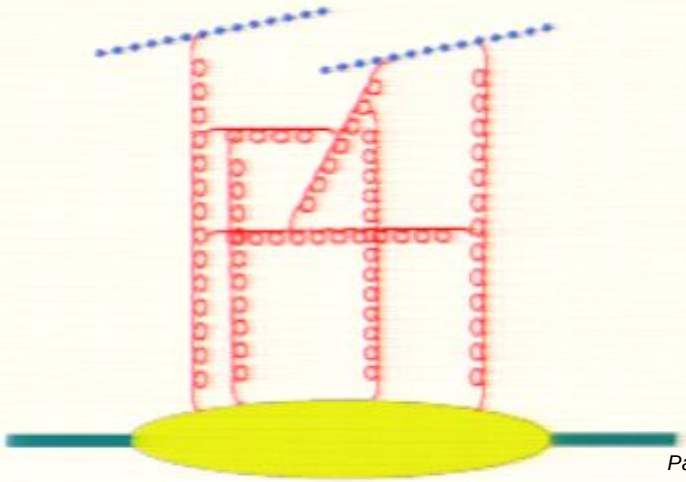


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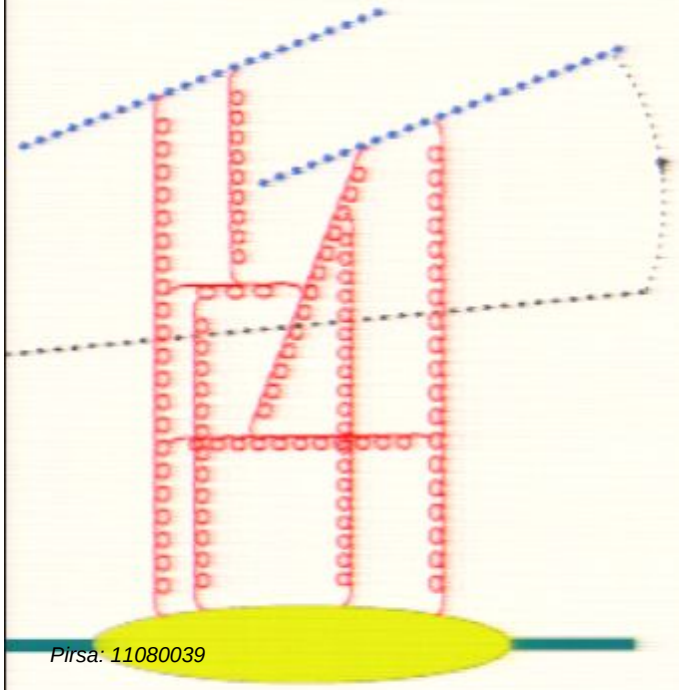


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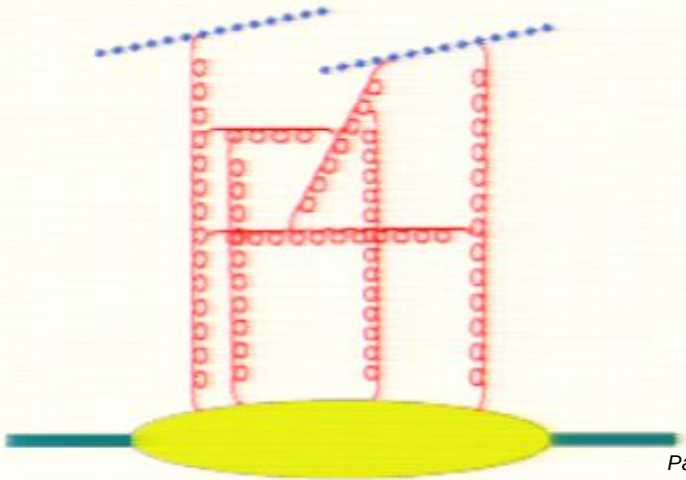


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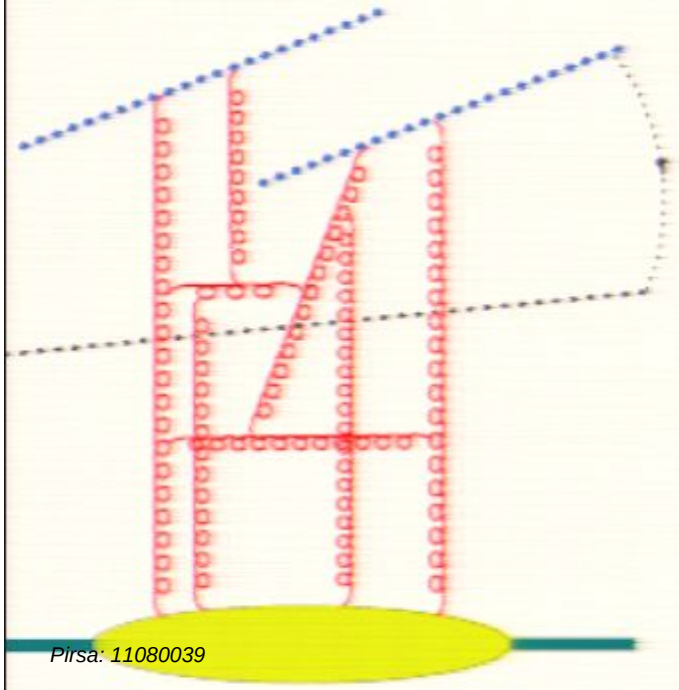


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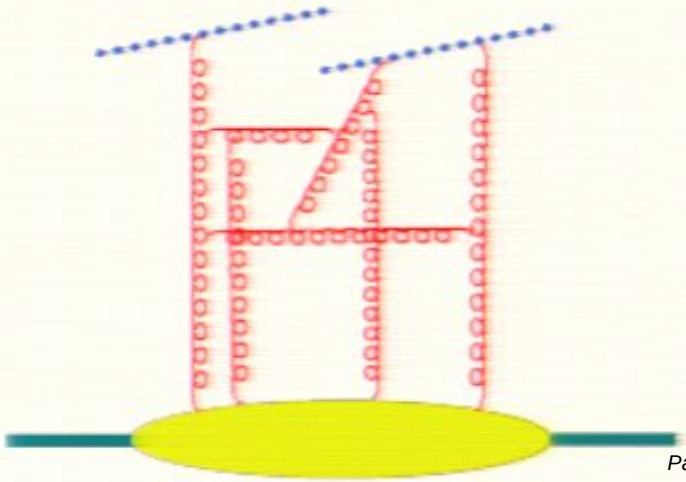


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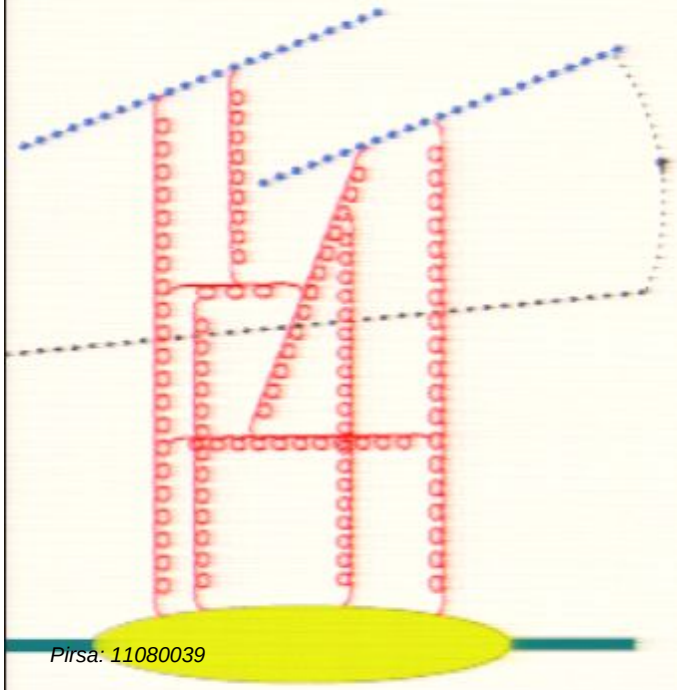


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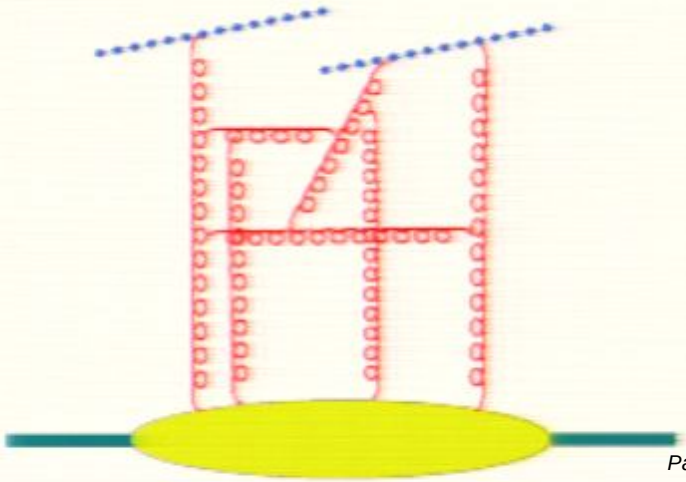


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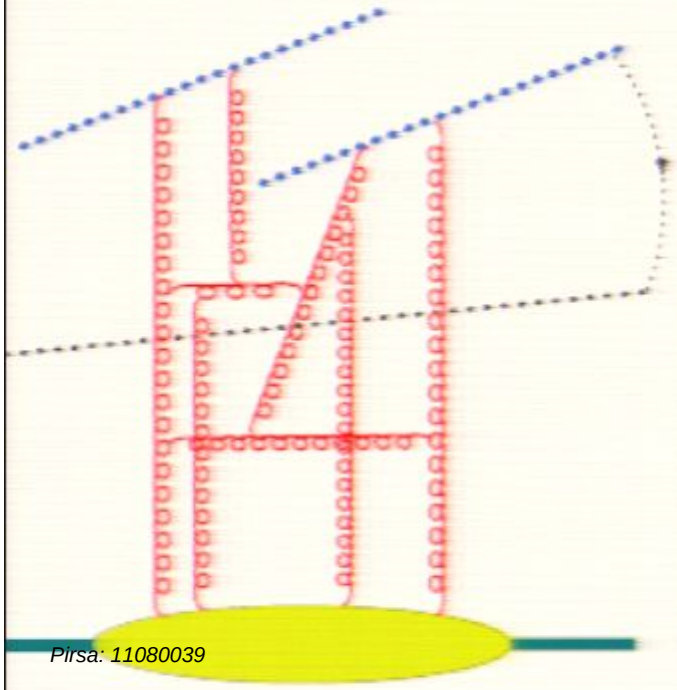


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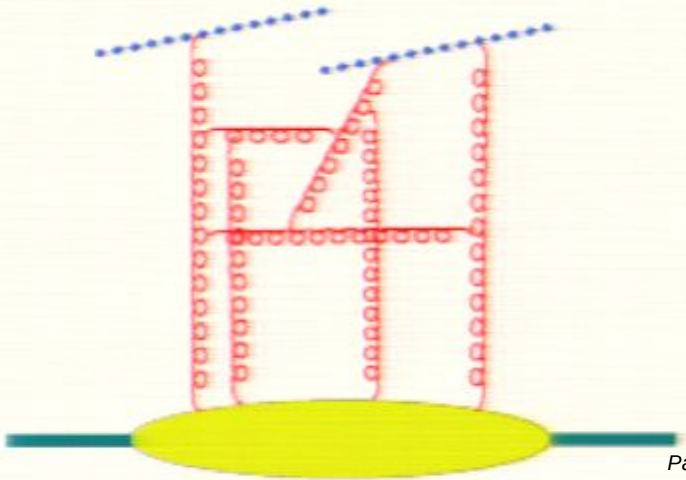


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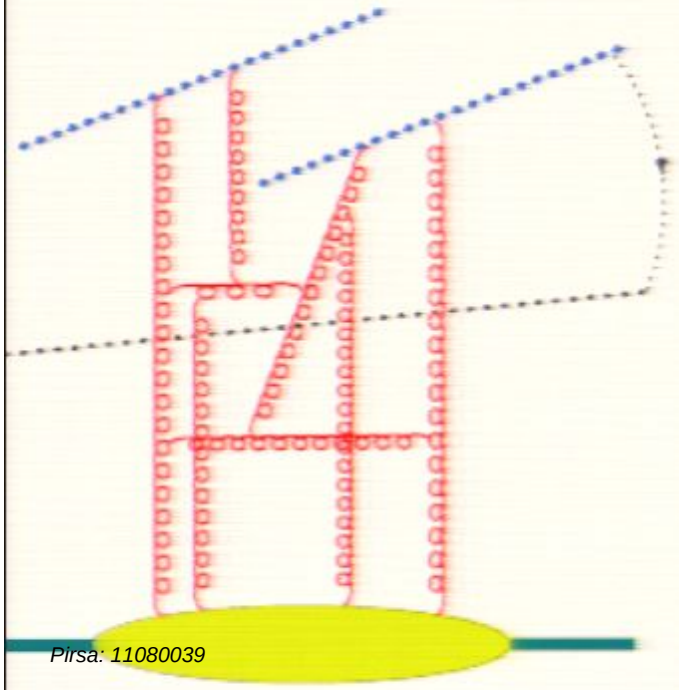


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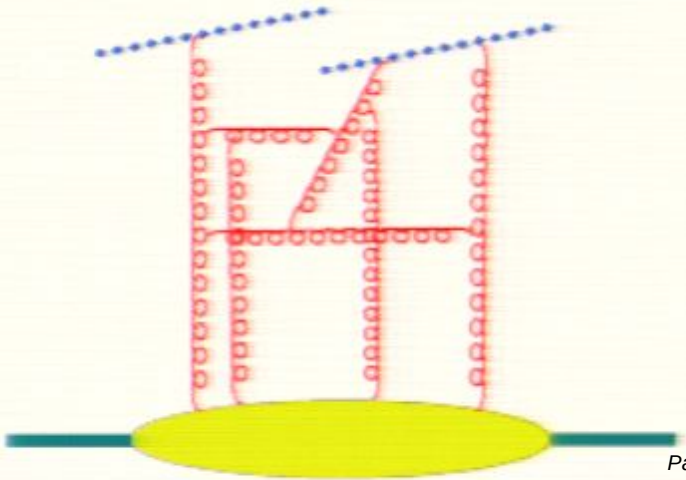


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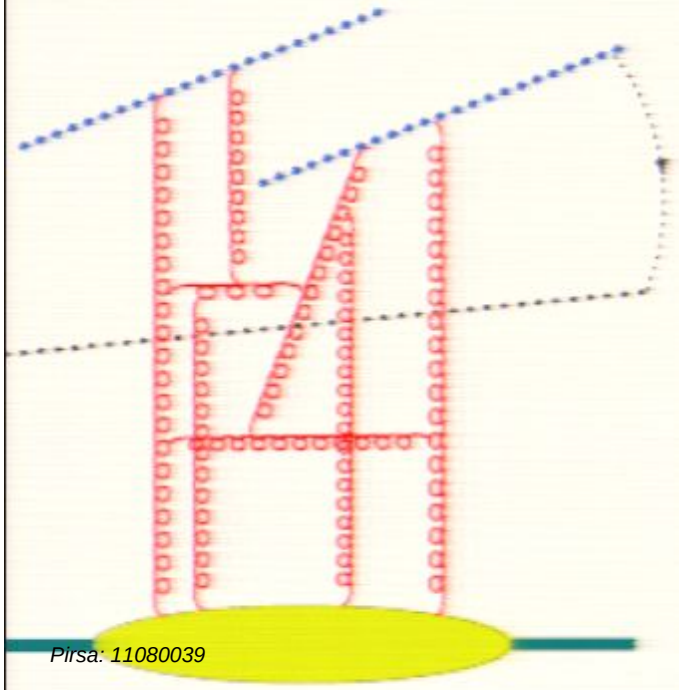


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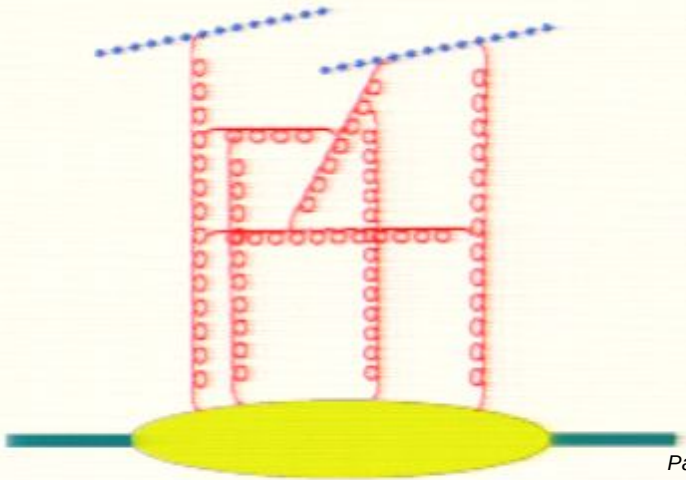


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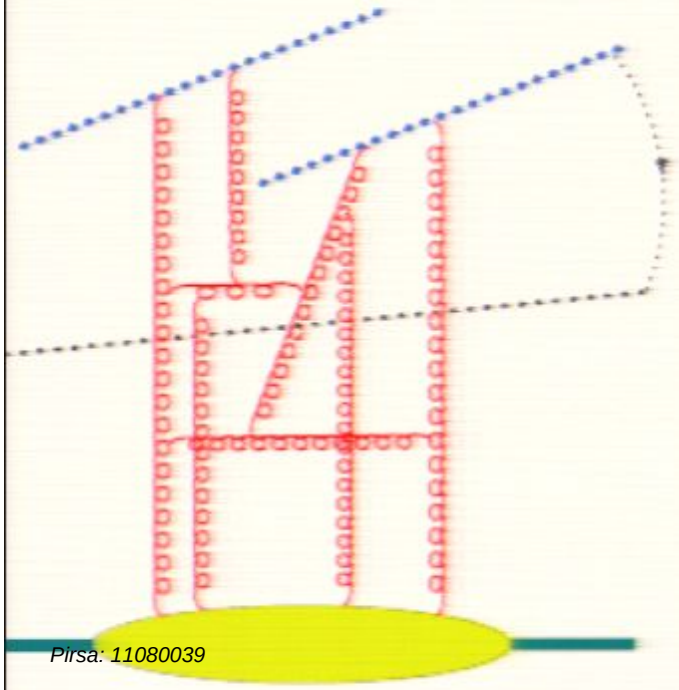


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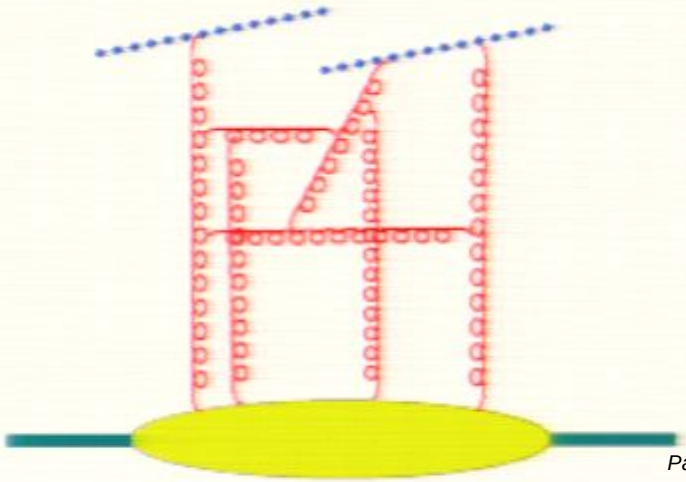


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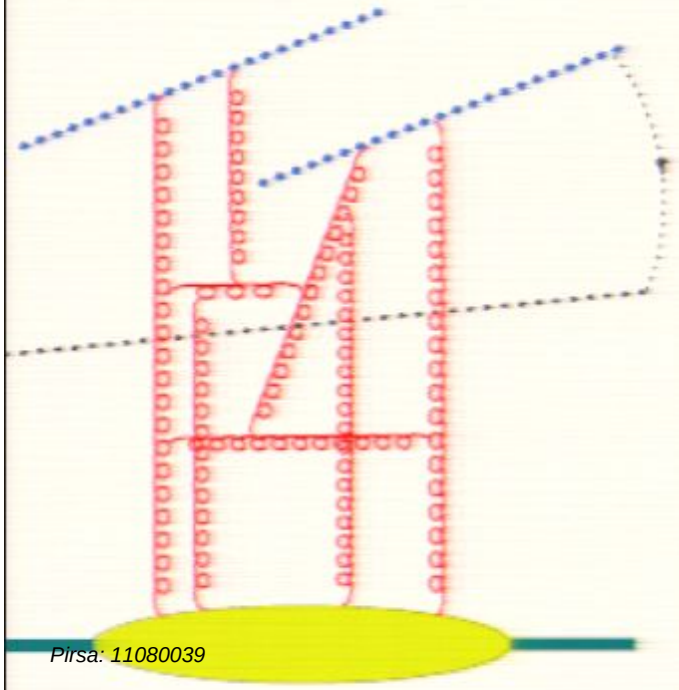


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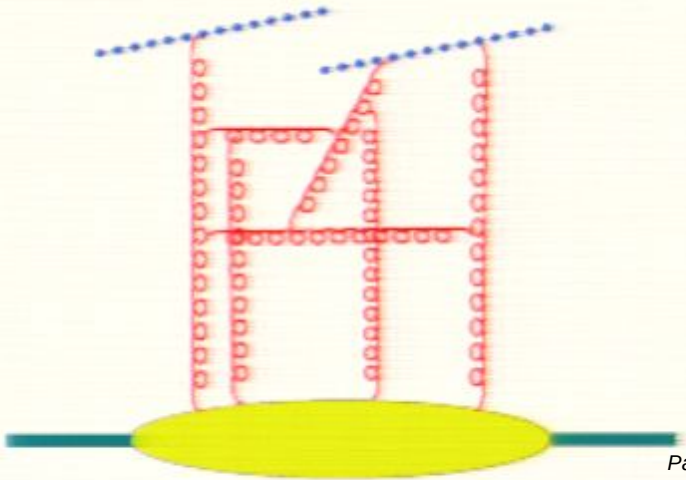


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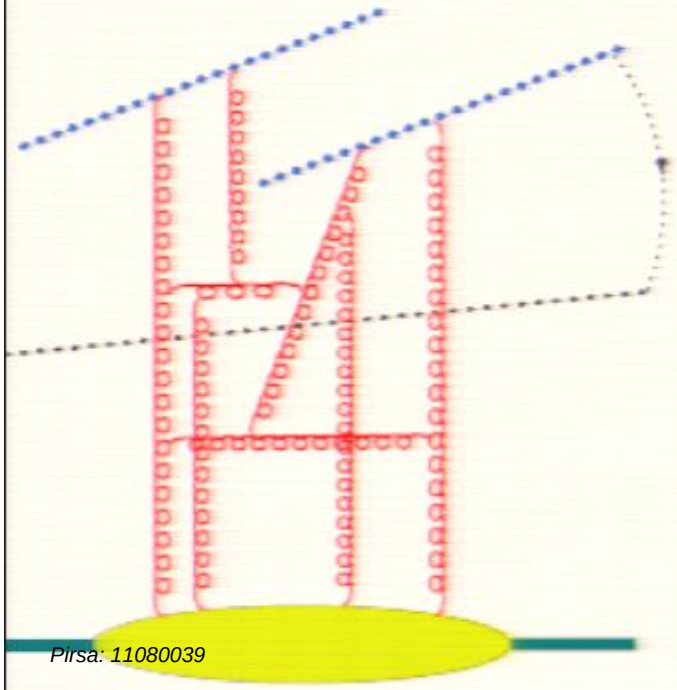


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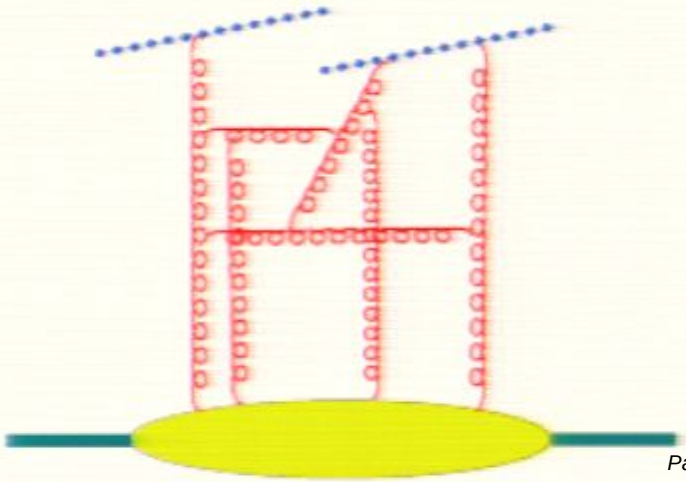


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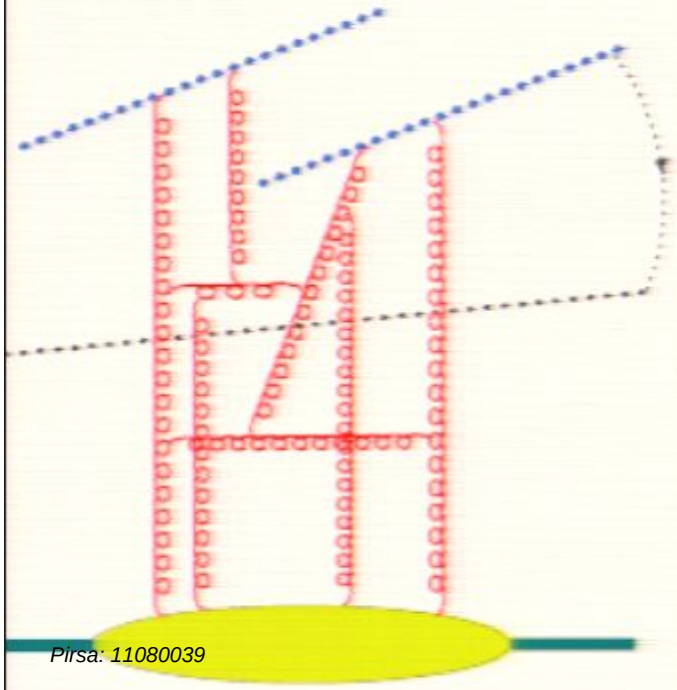


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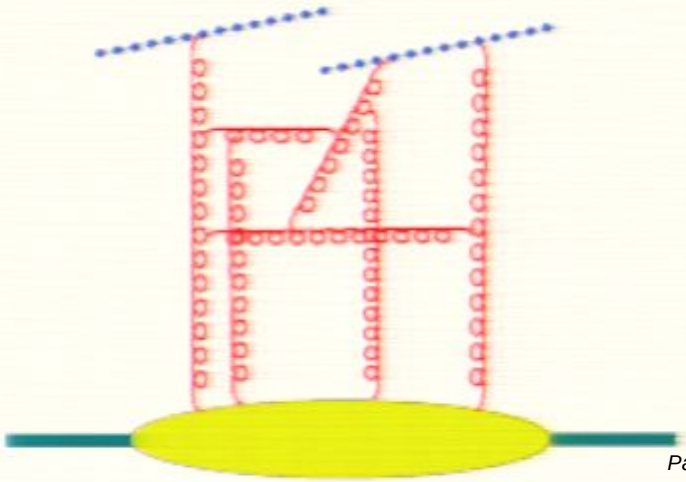


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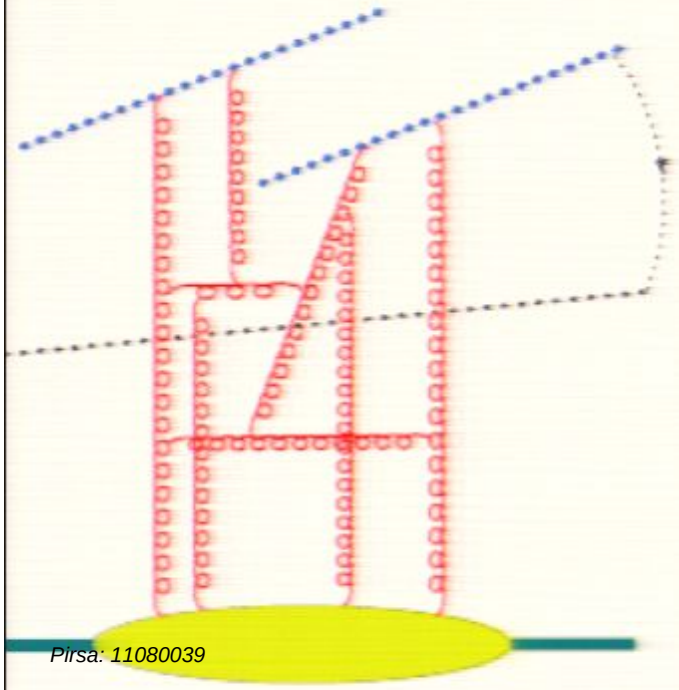


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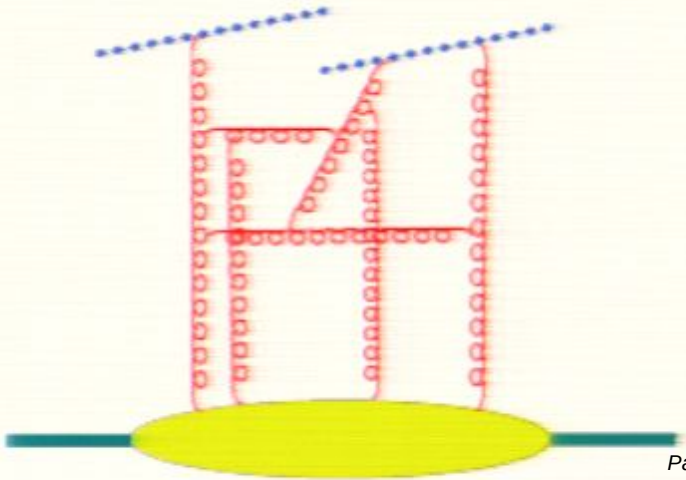


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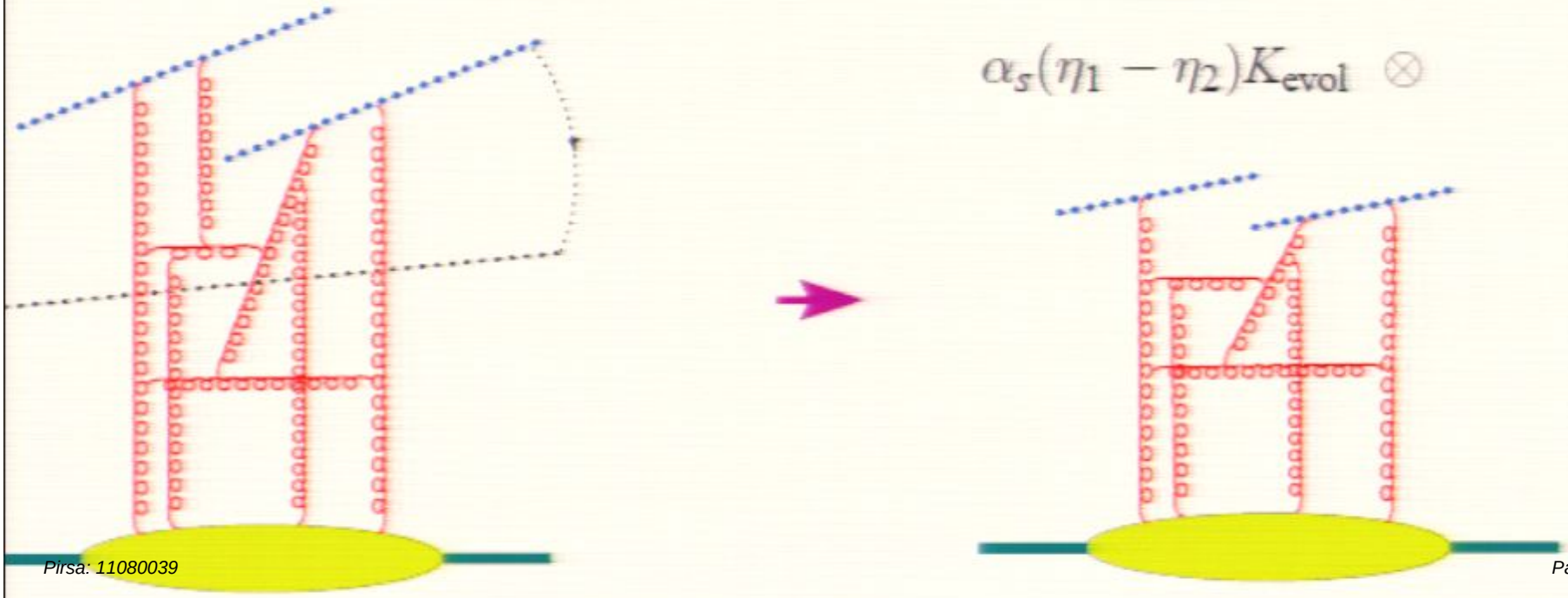


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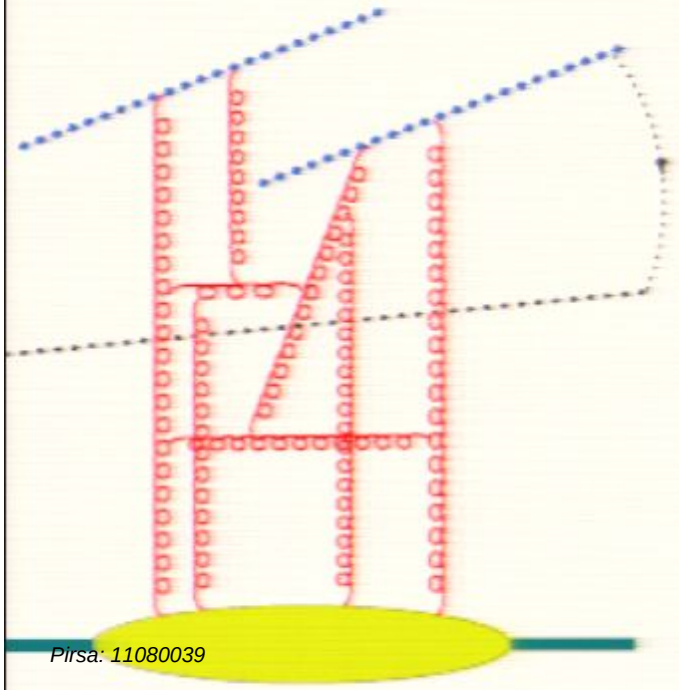
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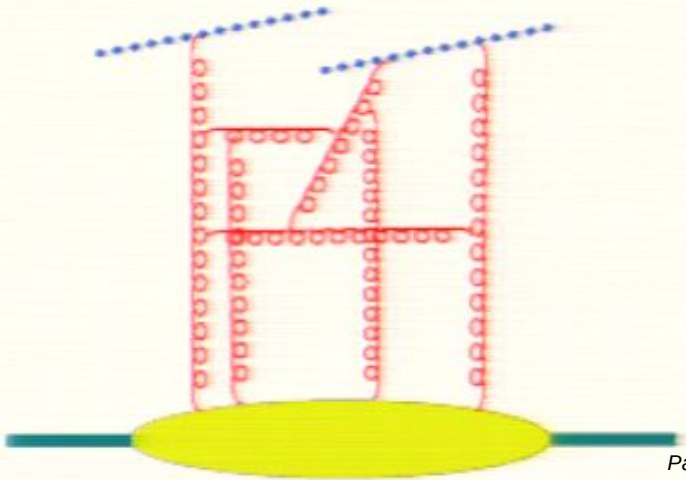


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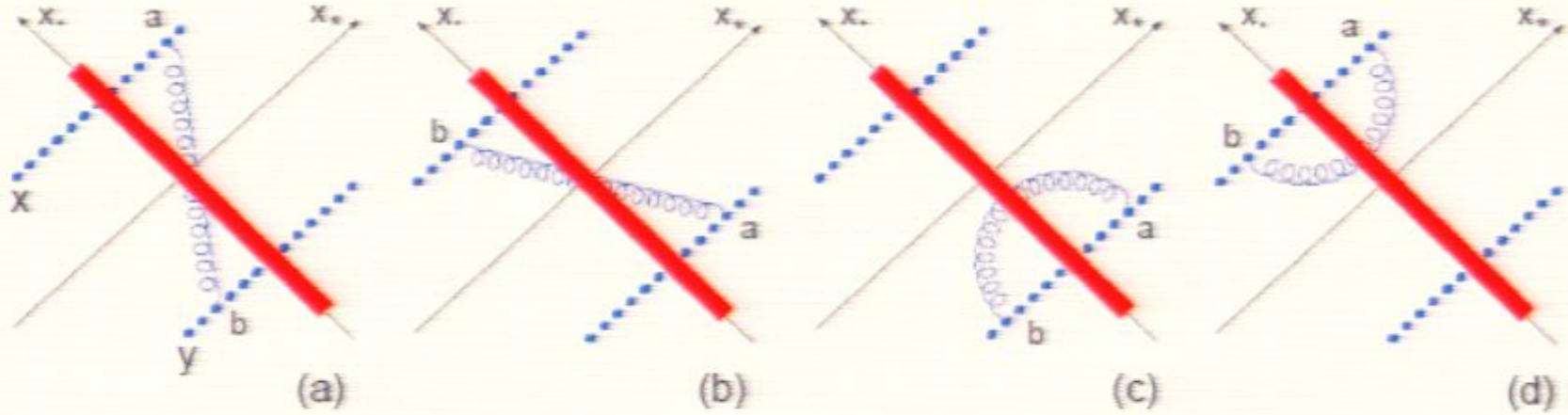
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$$\frac{d}{d\eta}\mathrm{Tr}\{\hat{U}_x\hat{U}_y^\dagger\} = K_{\mathrm{LO}}\mathrm{Tr}\{\hat{U}_x\hat{U}_y^\dagger\} + \ldots \Rightarrow$$

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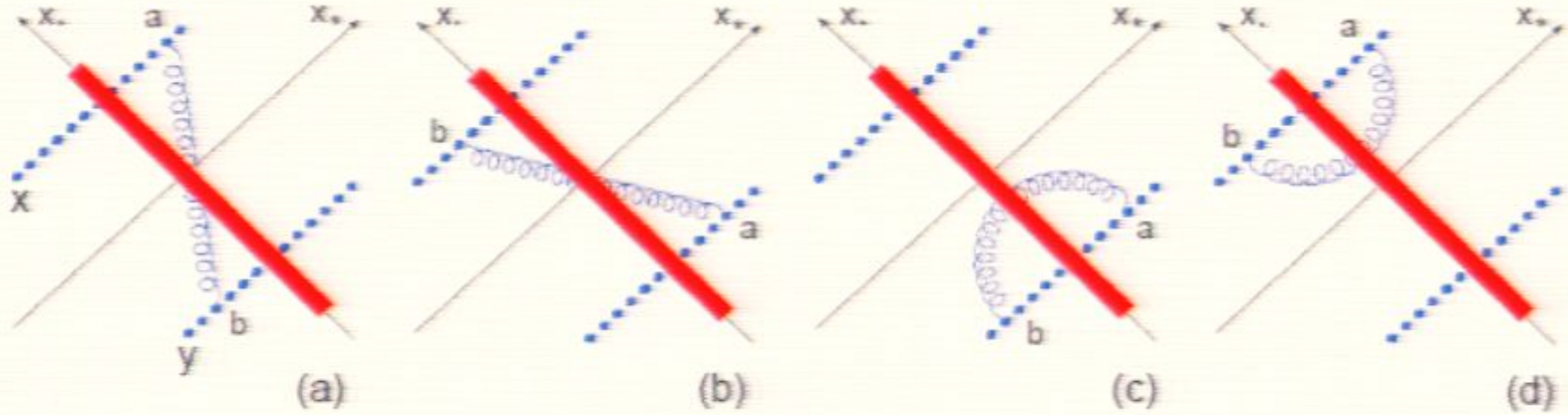
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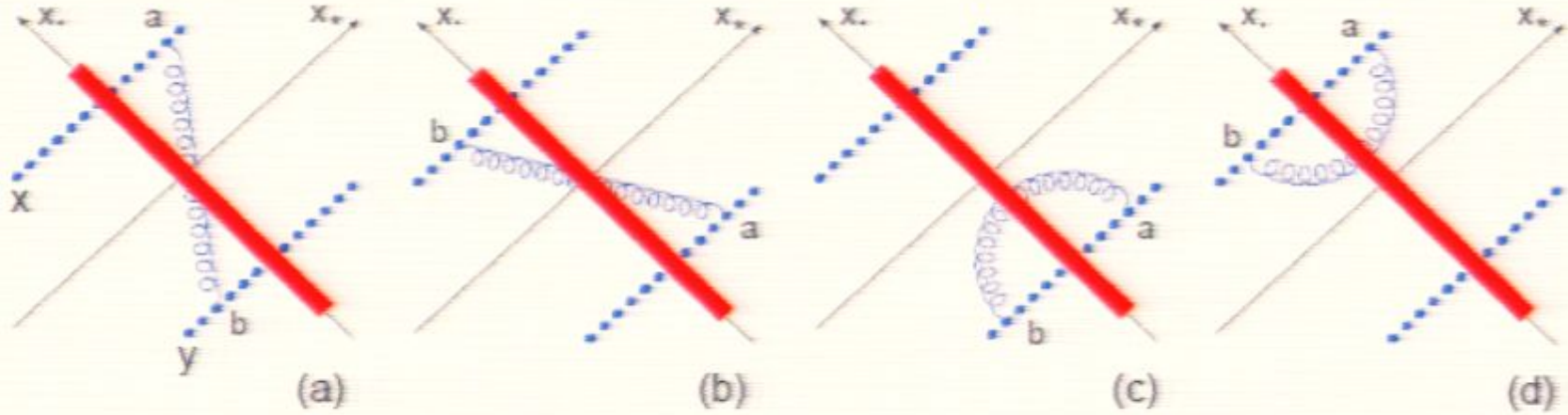
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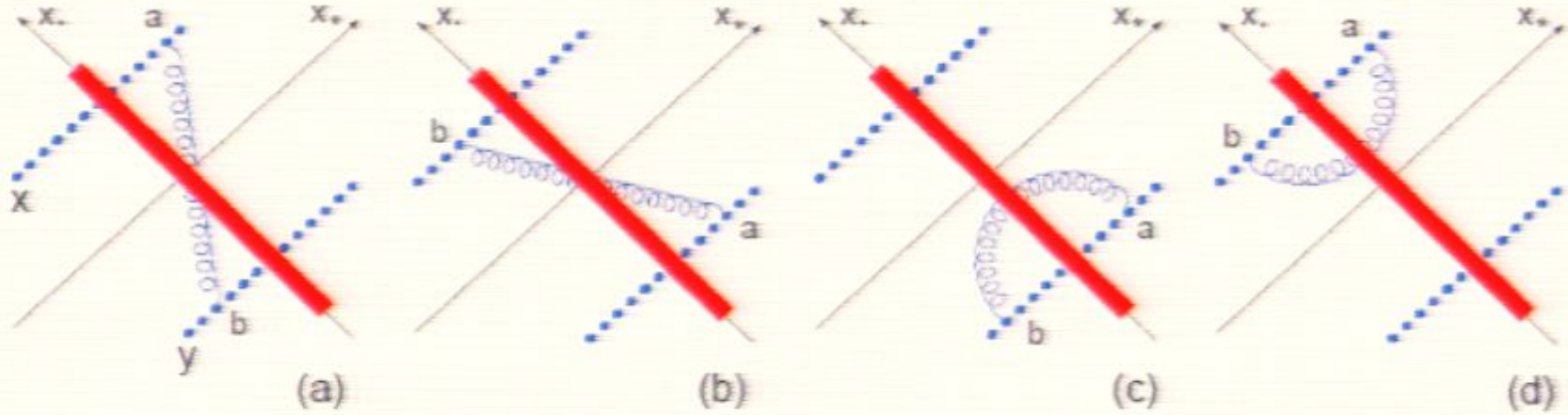
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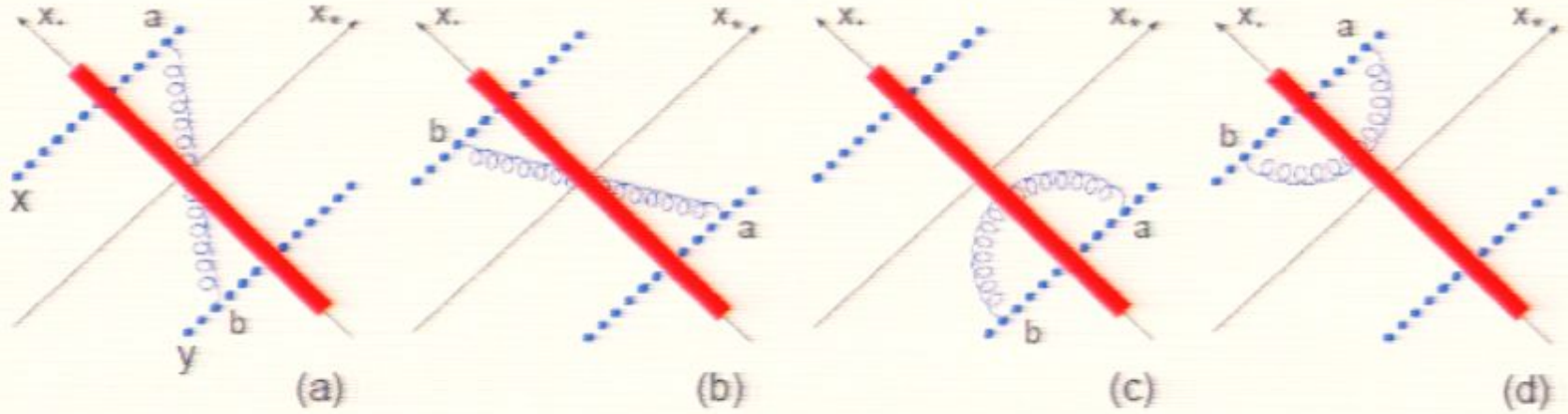
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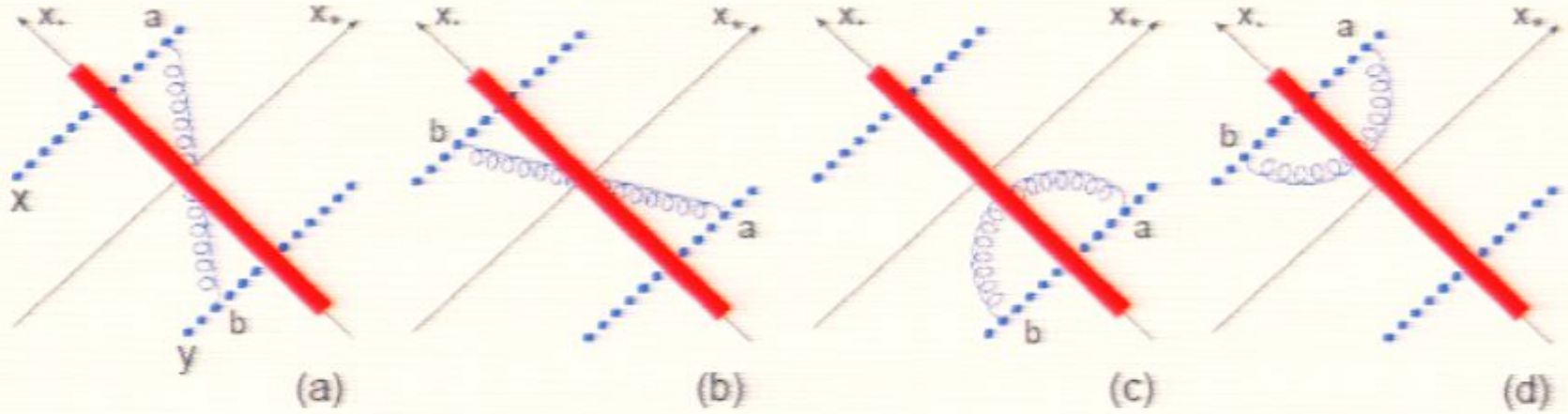
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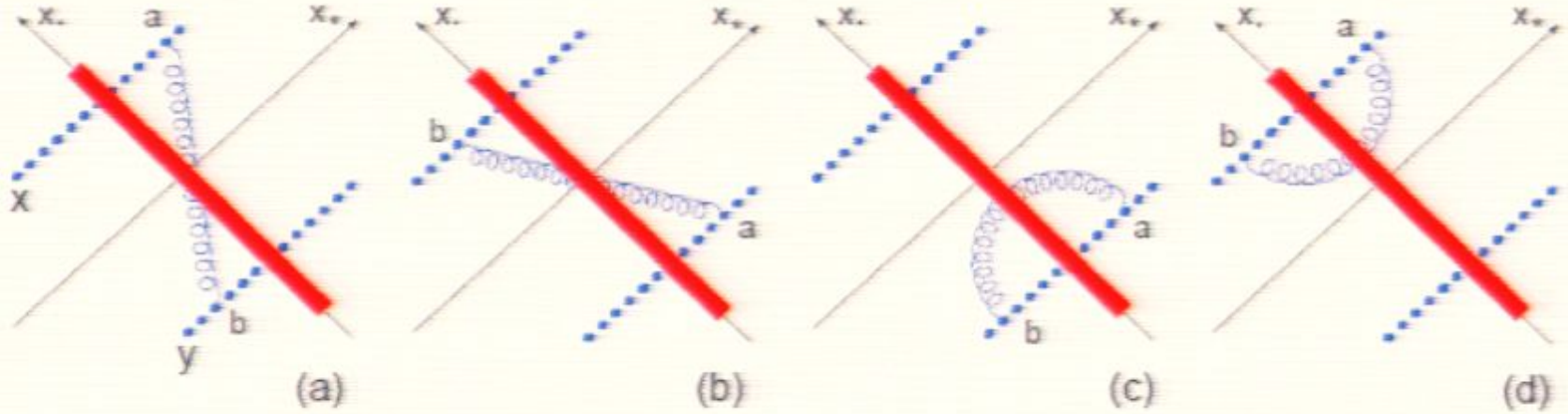
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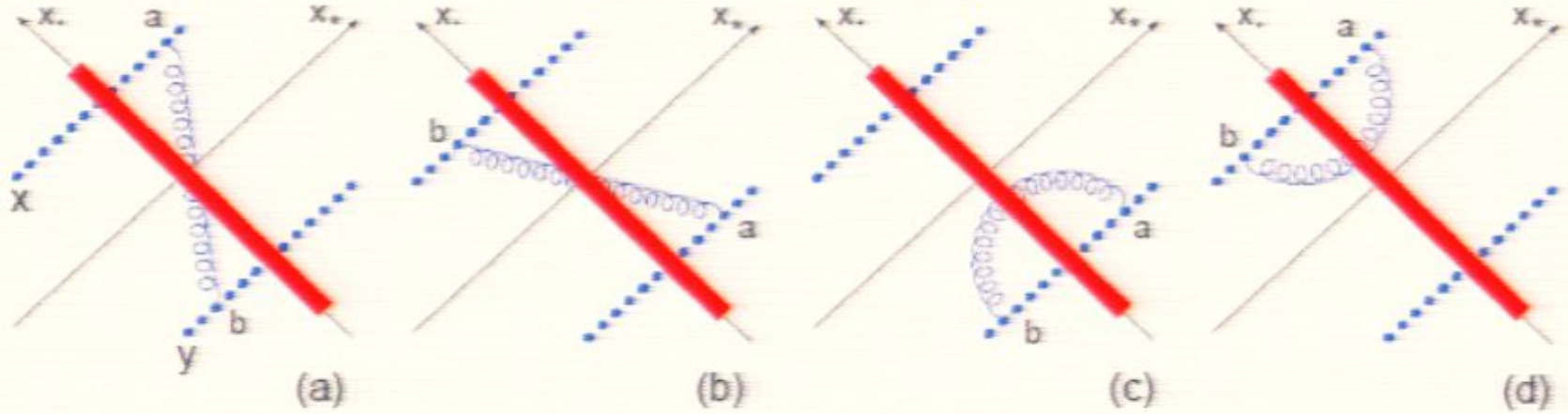
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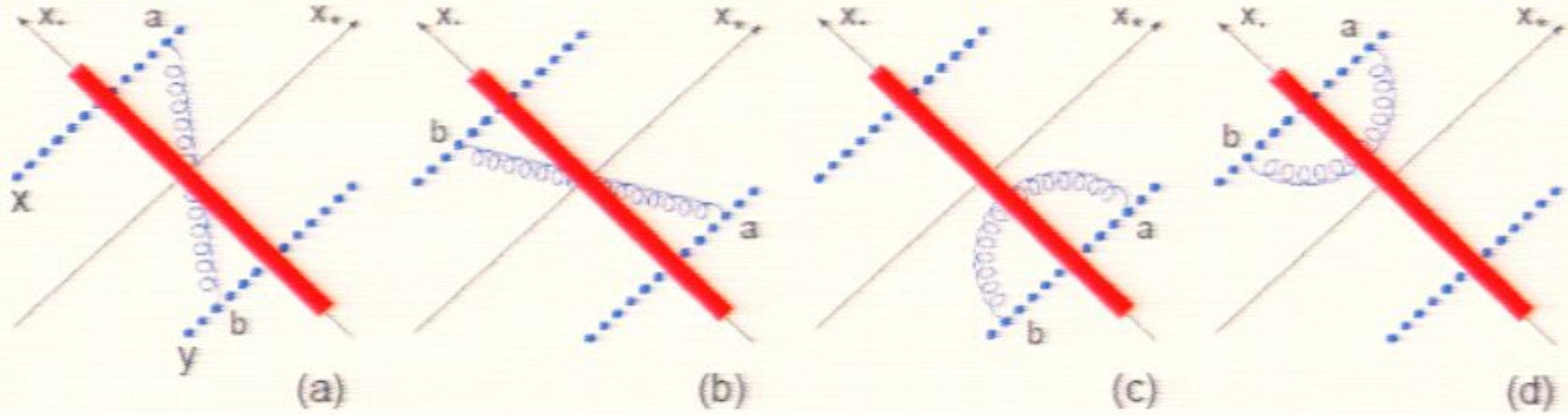
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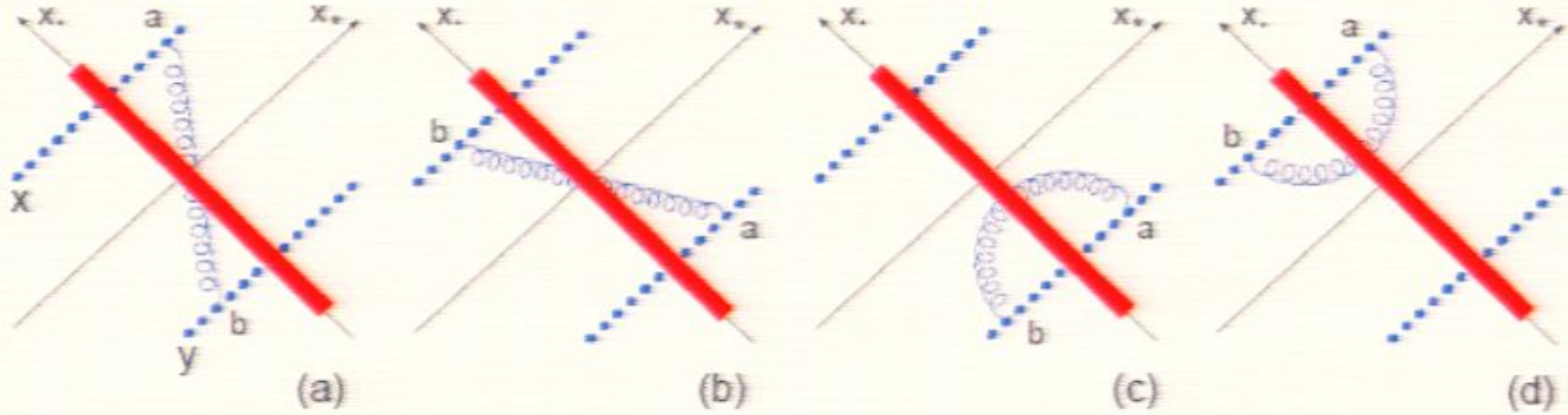
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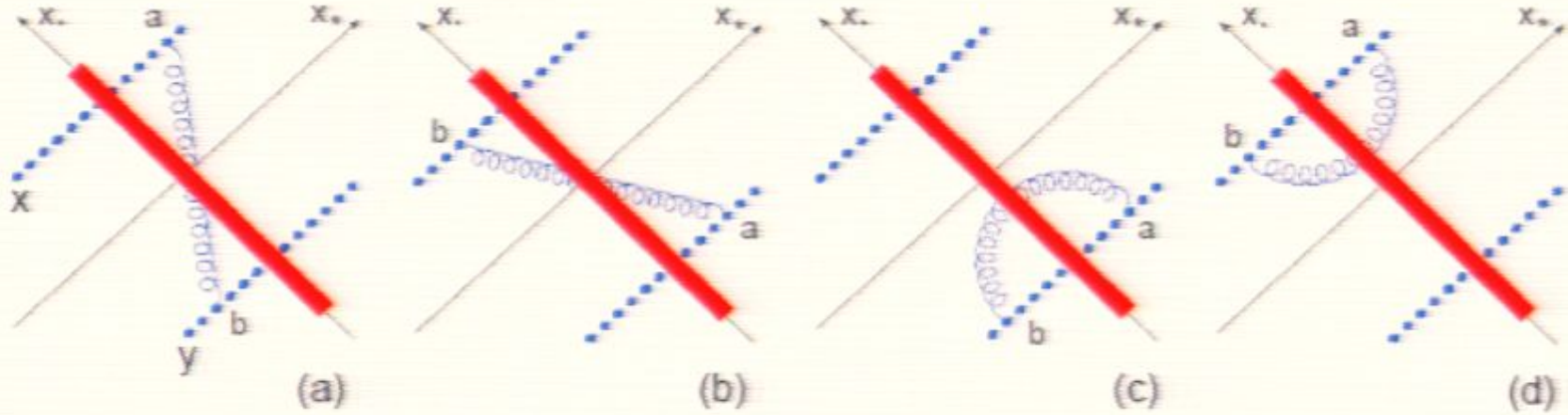
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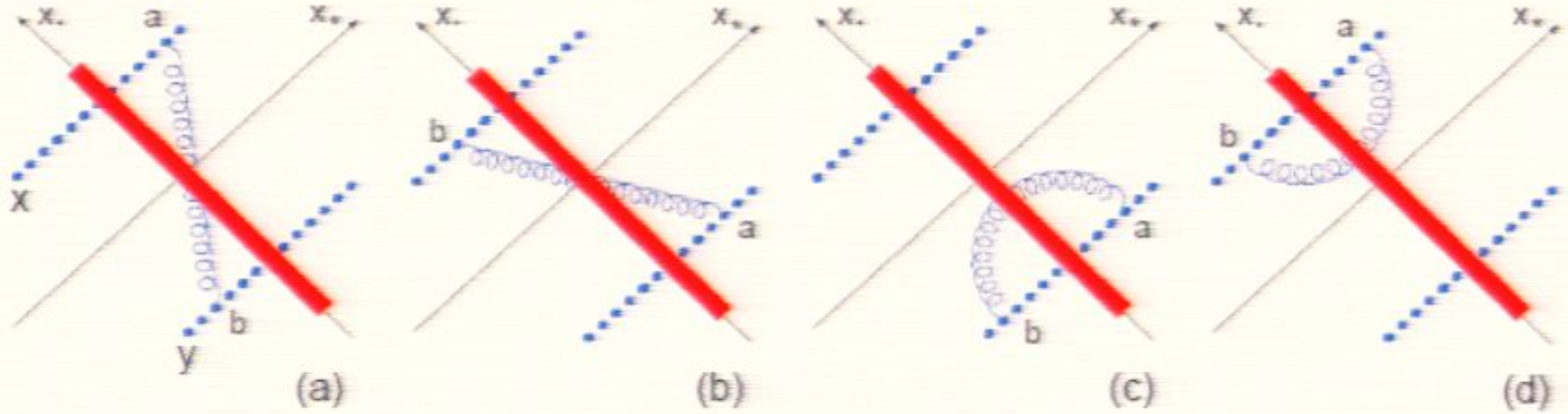
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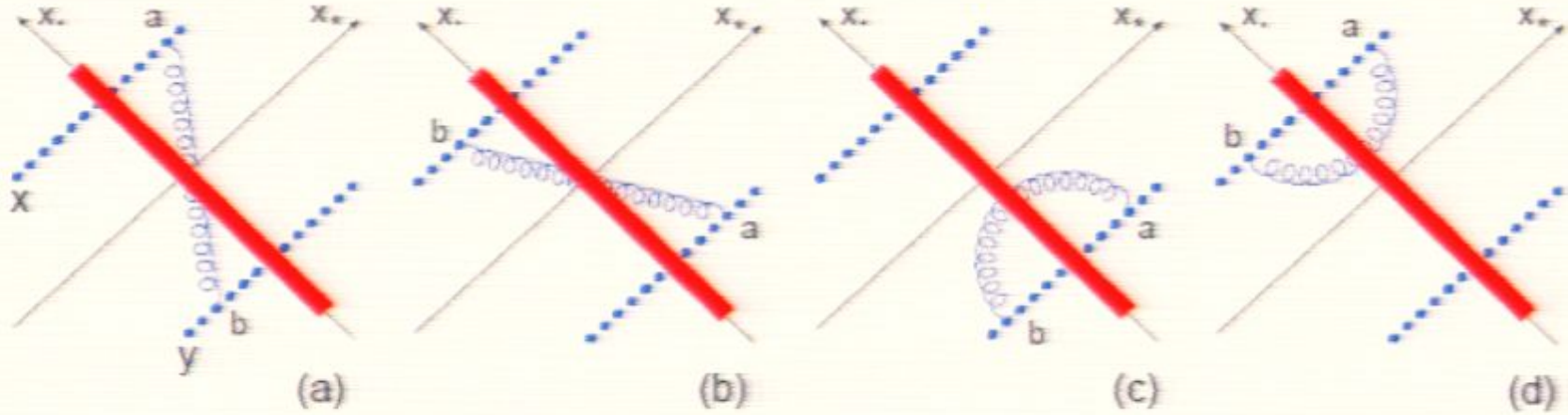
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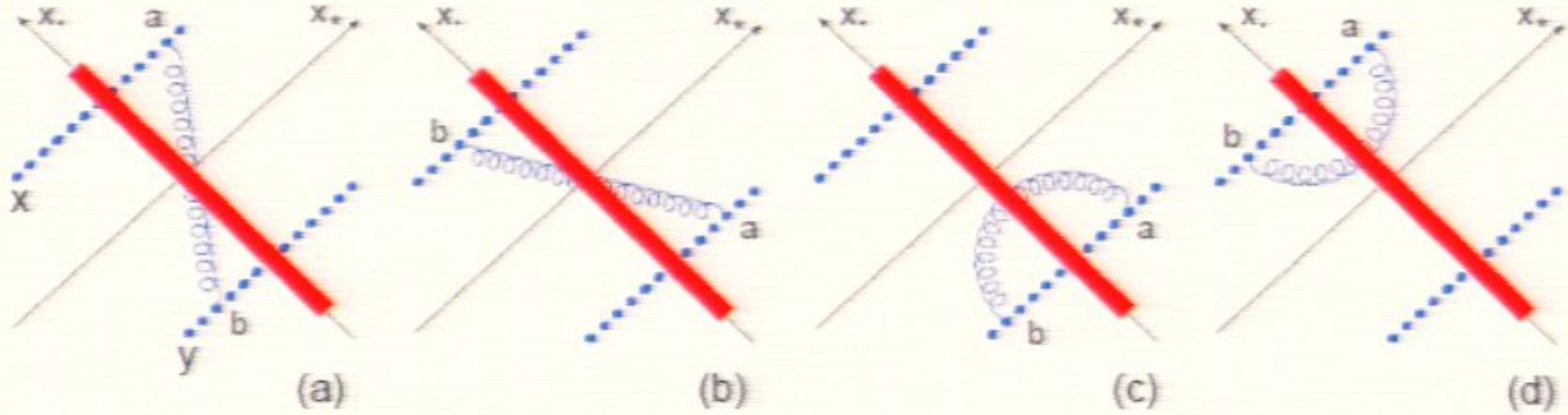
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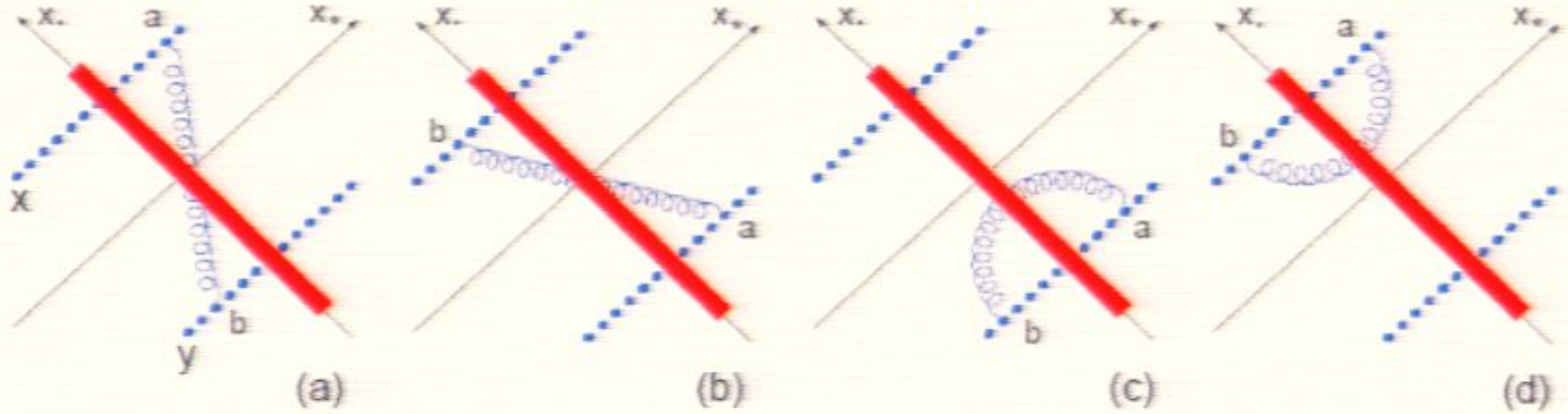
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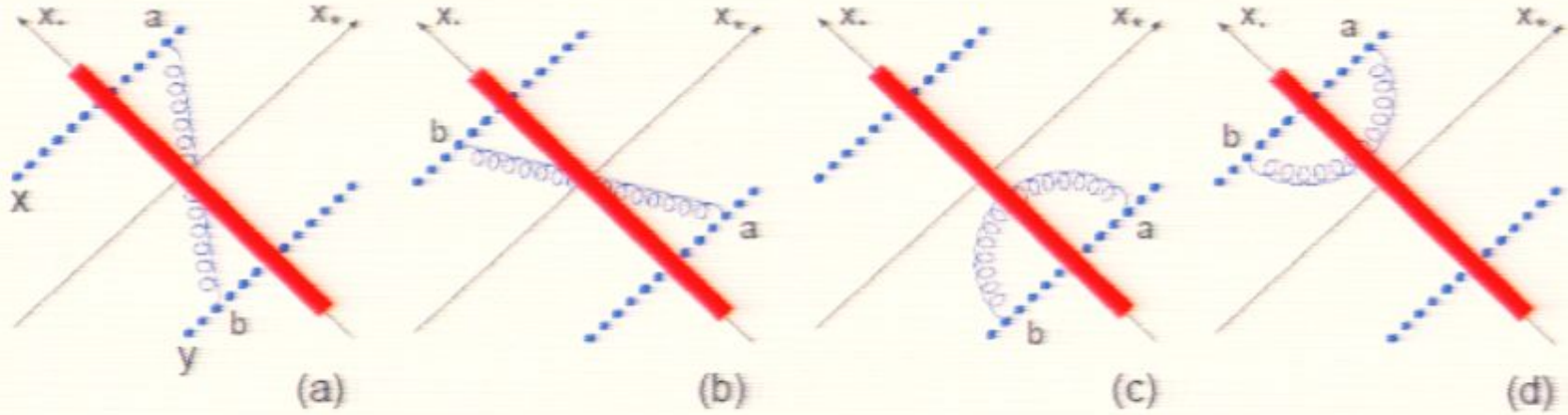
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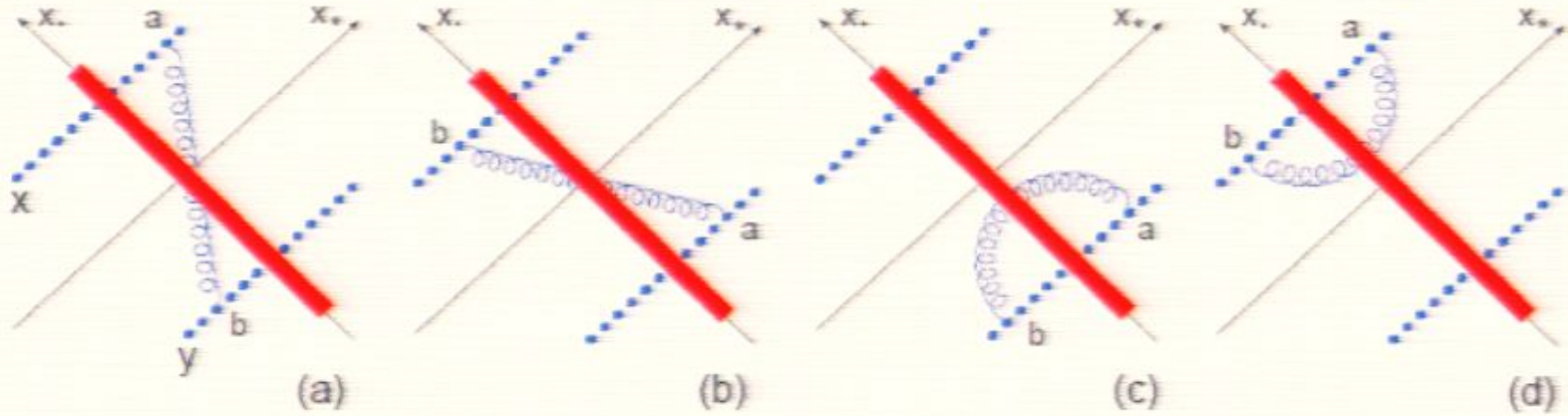
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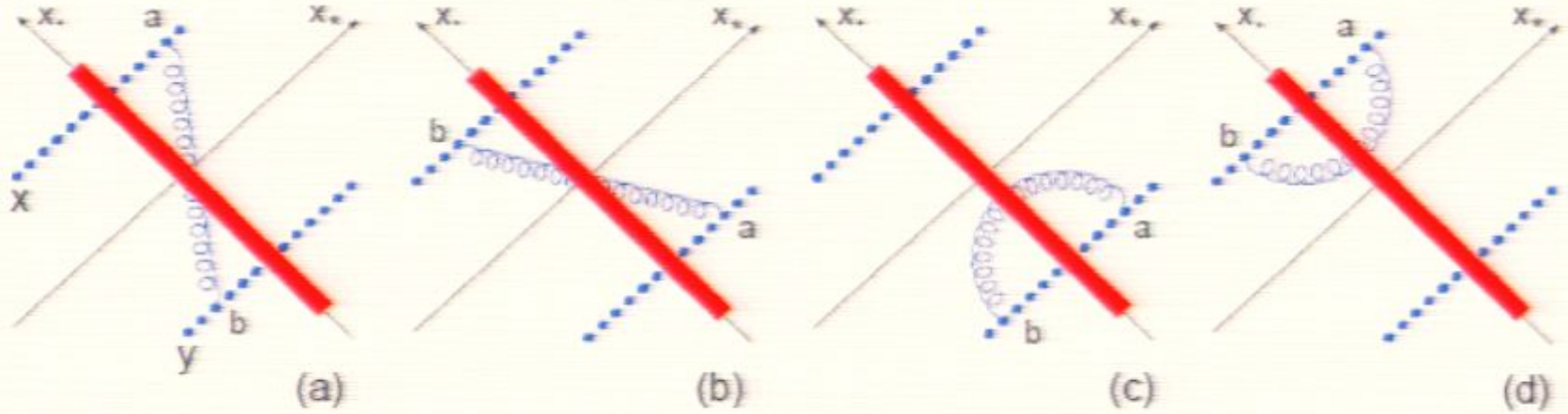
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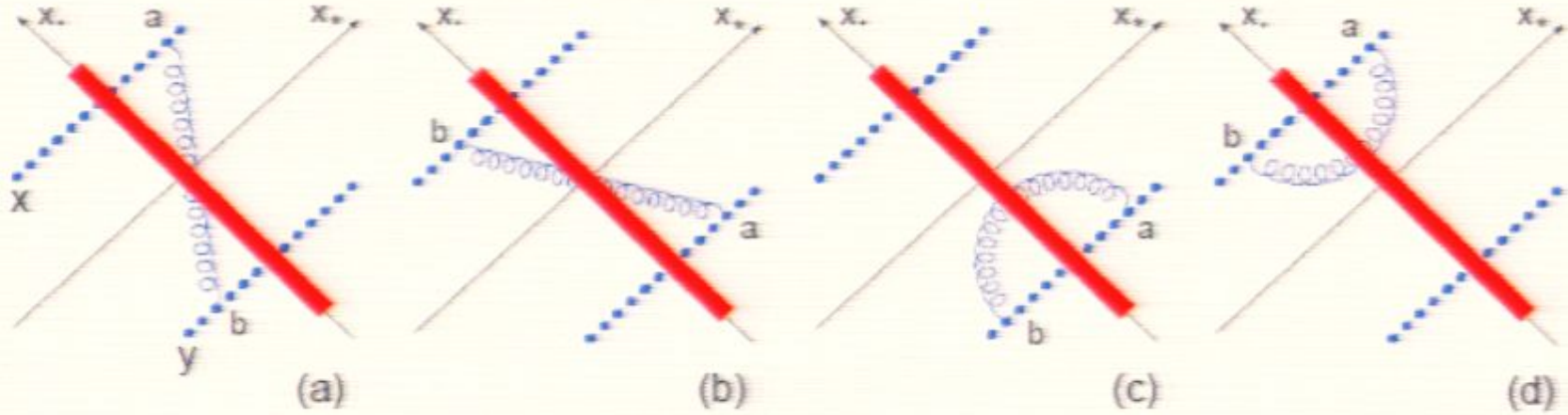
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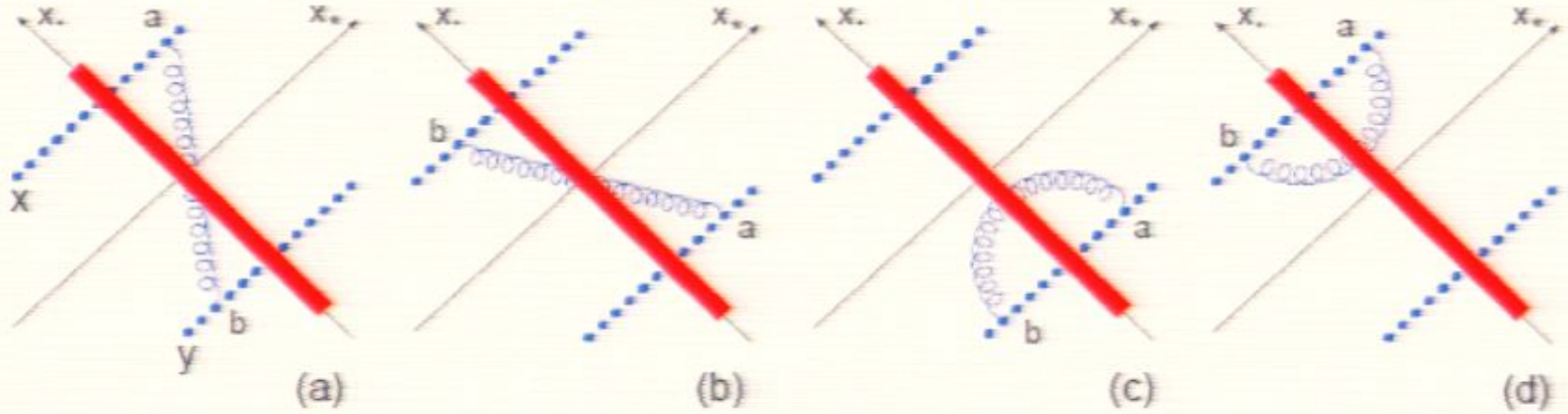
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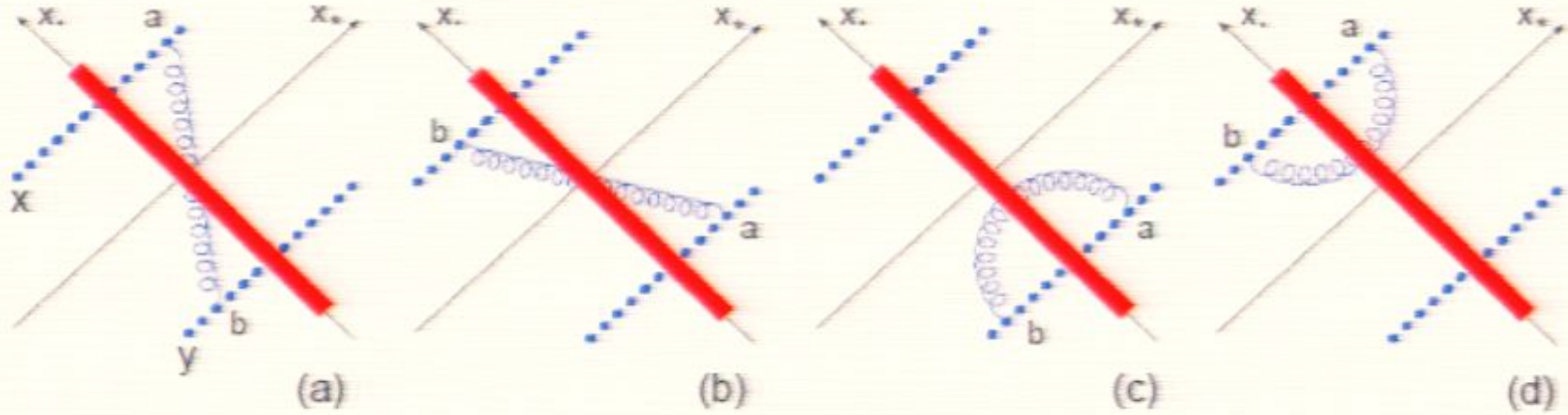
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Non linear evolution equation

$$\hat{U}(x,y) \equiv 1 - \frac{1}{N_c}\mathrm{Tr}\{\hat{U}(x_\perp)\hat{U}^\dagger(y_\perp)\}$$

BK equation

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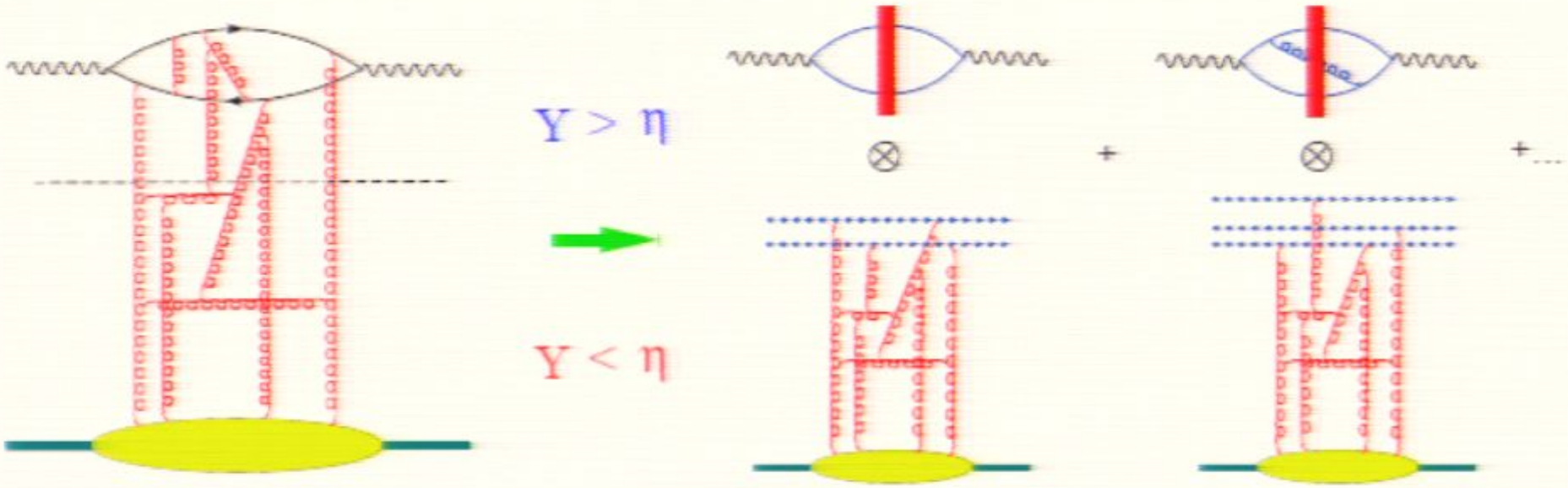
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Expansion of the amplitude in color dipoles in the NLO



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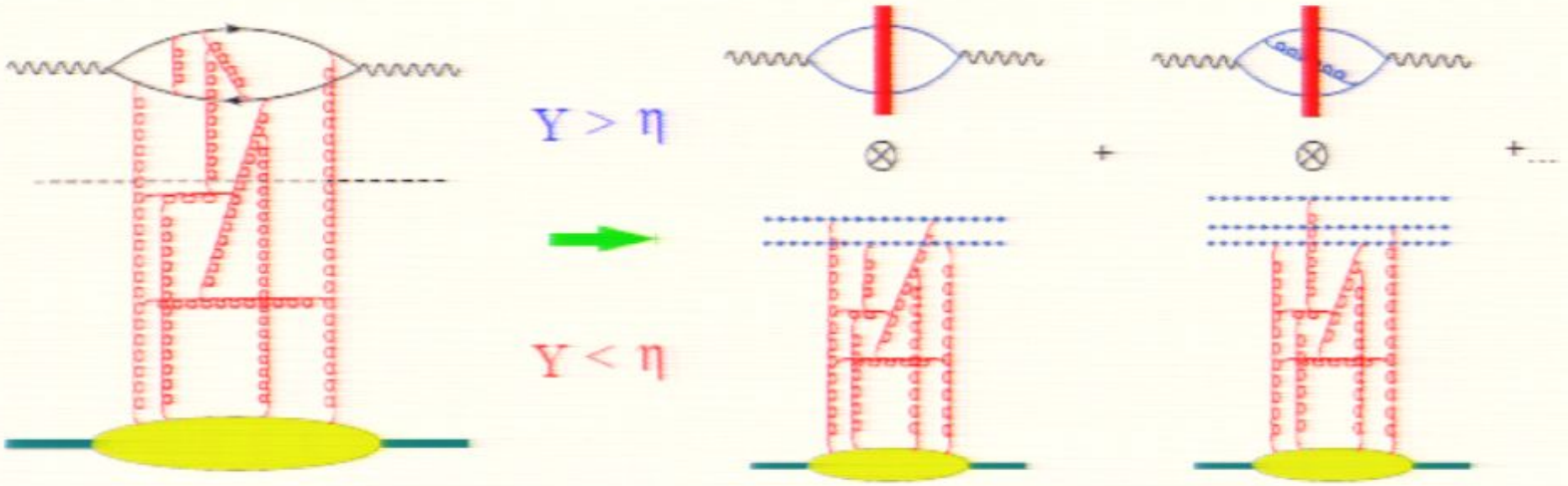
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CCP, 2007

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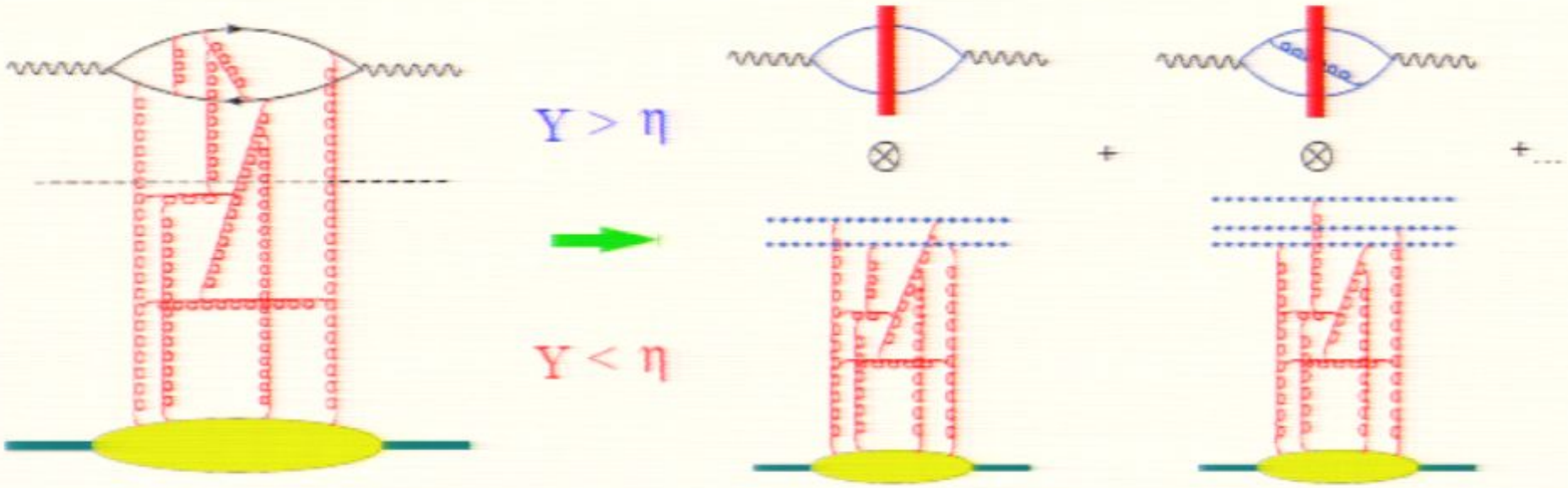
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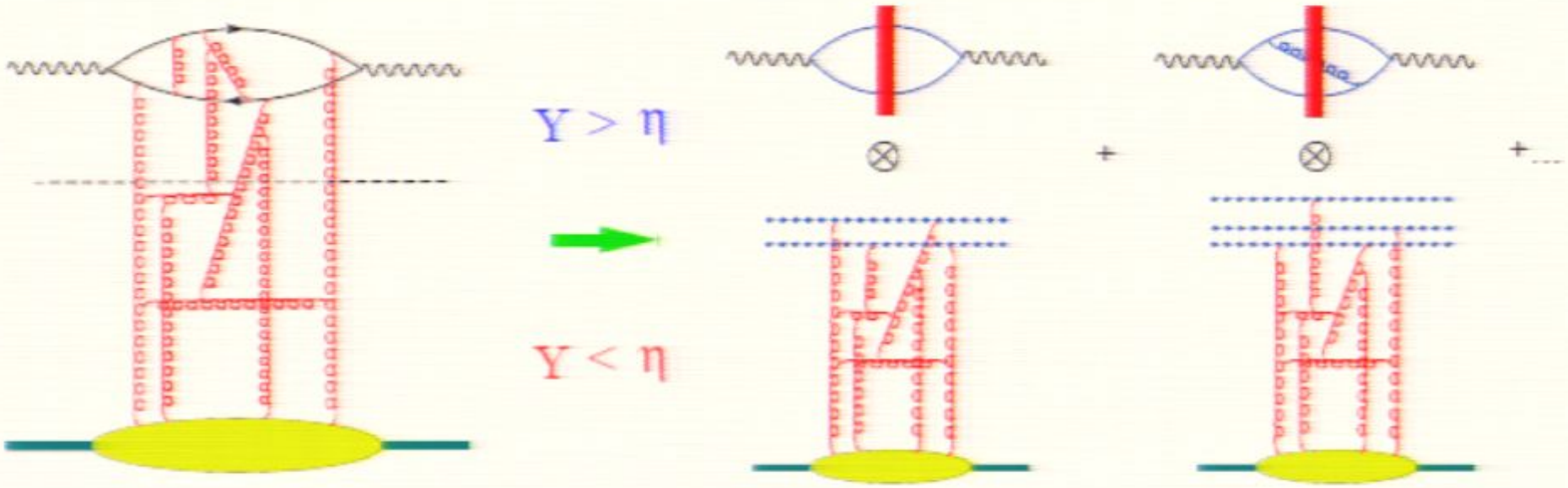
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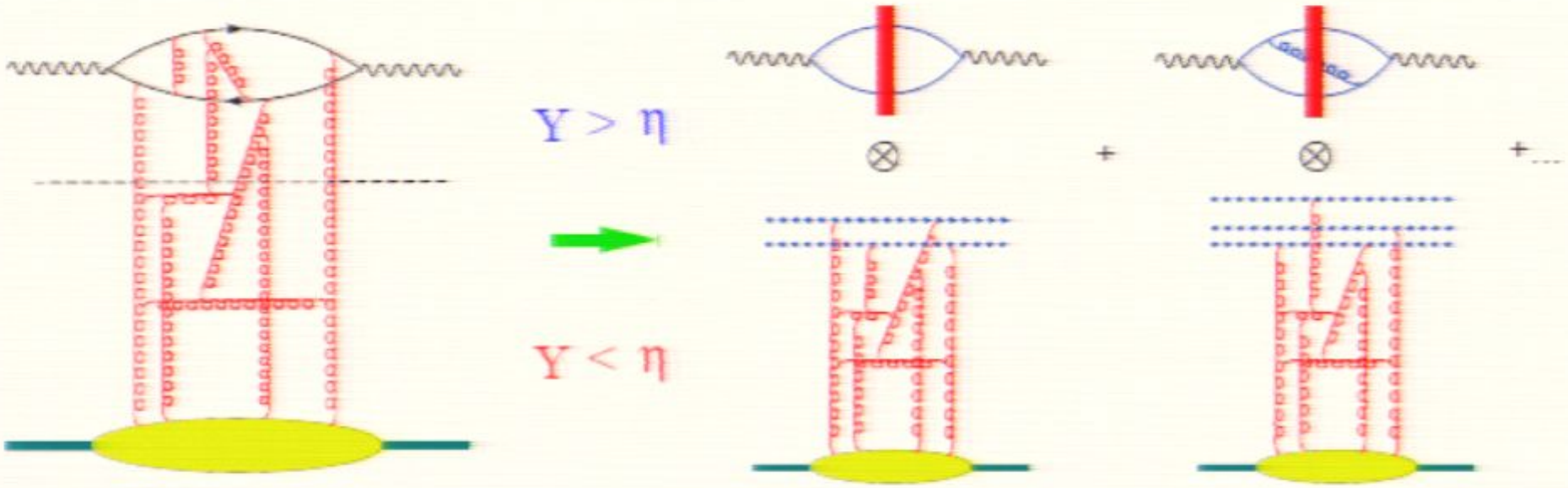
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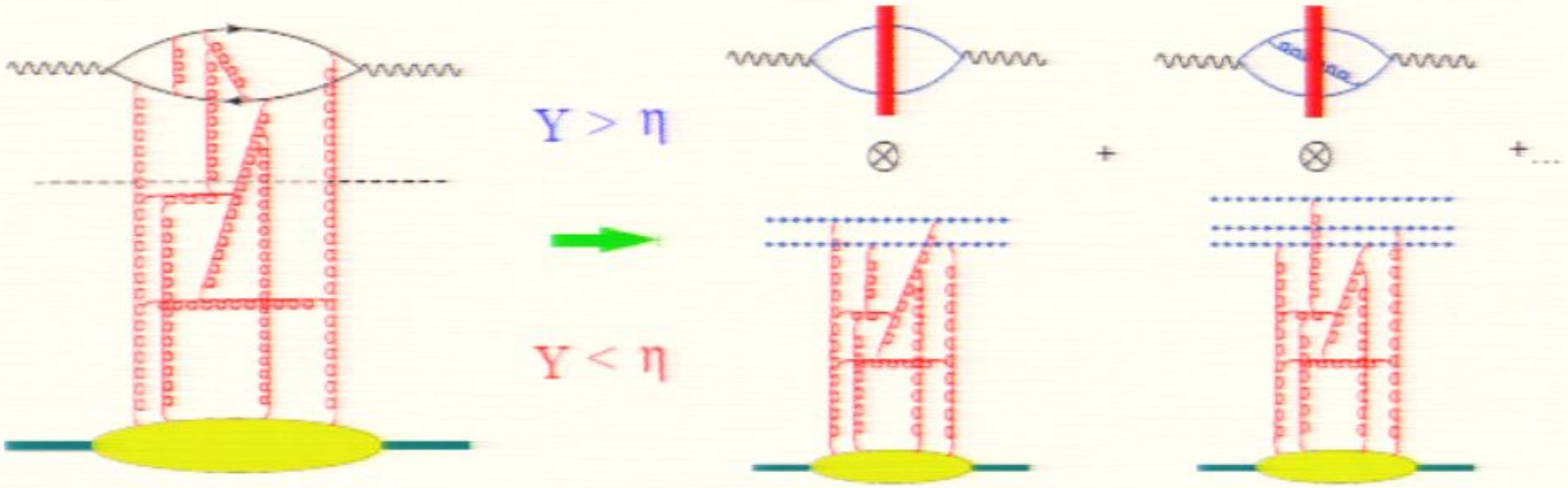
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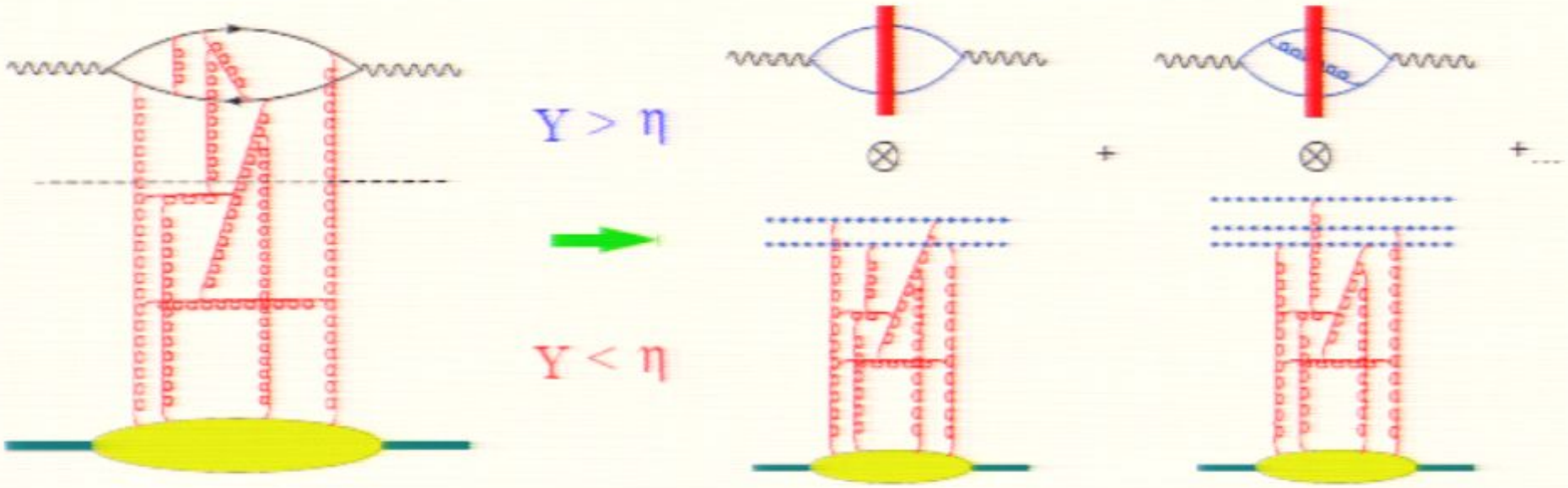
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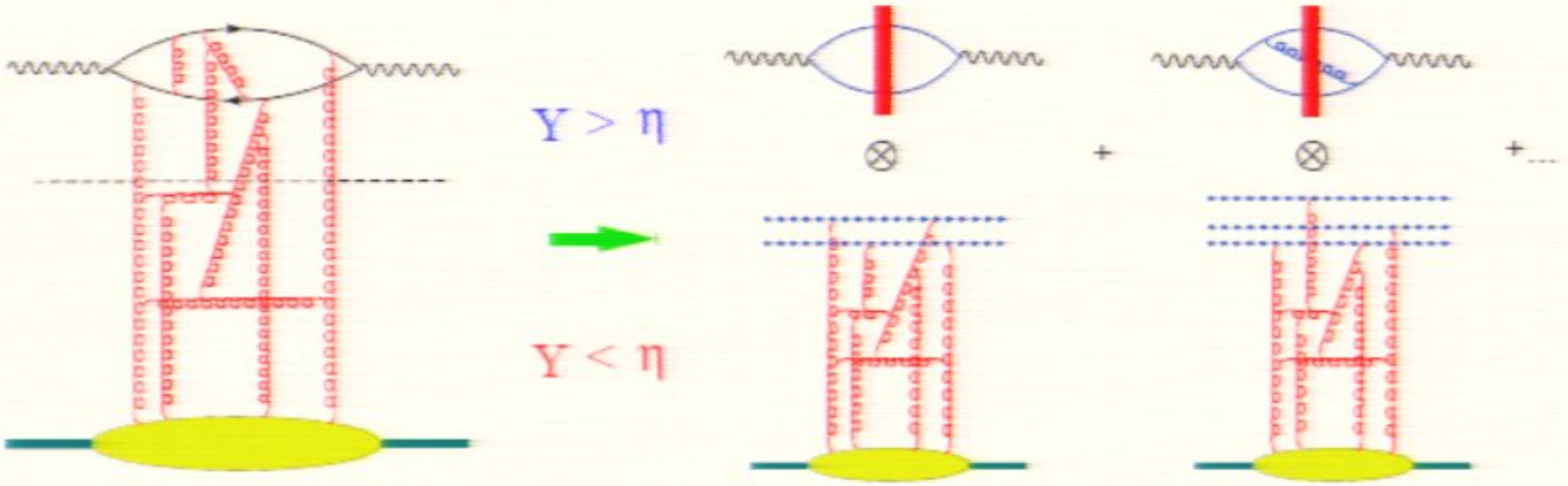
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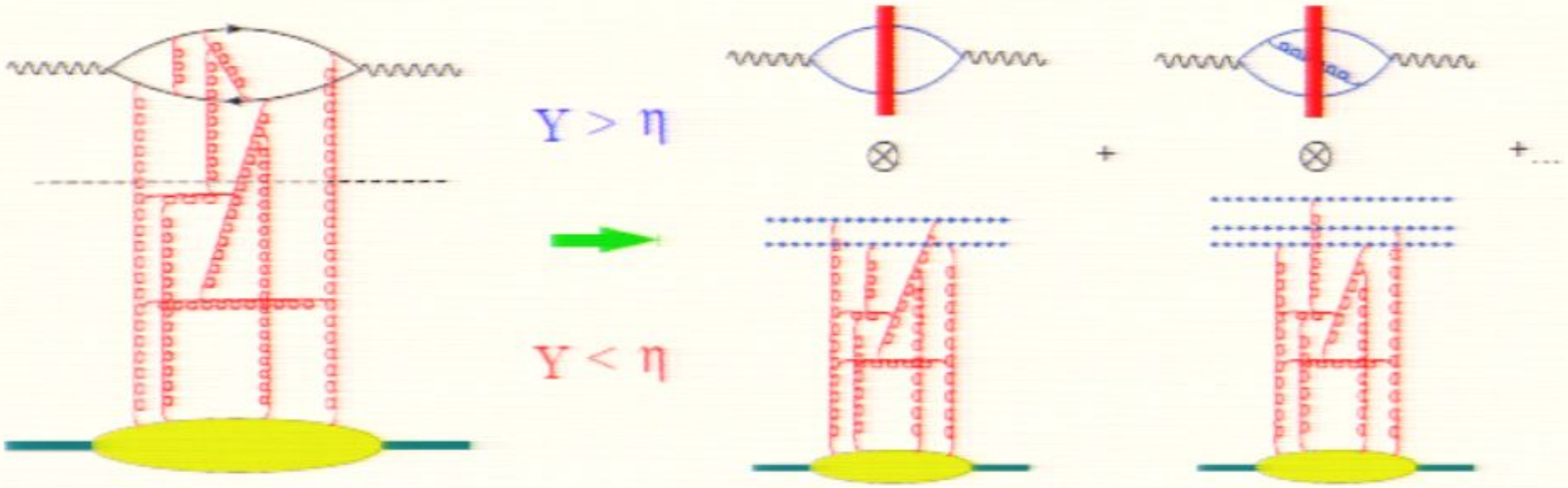
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CCP, 2007

Expansion of the amplitude in color dipoles in the NLO



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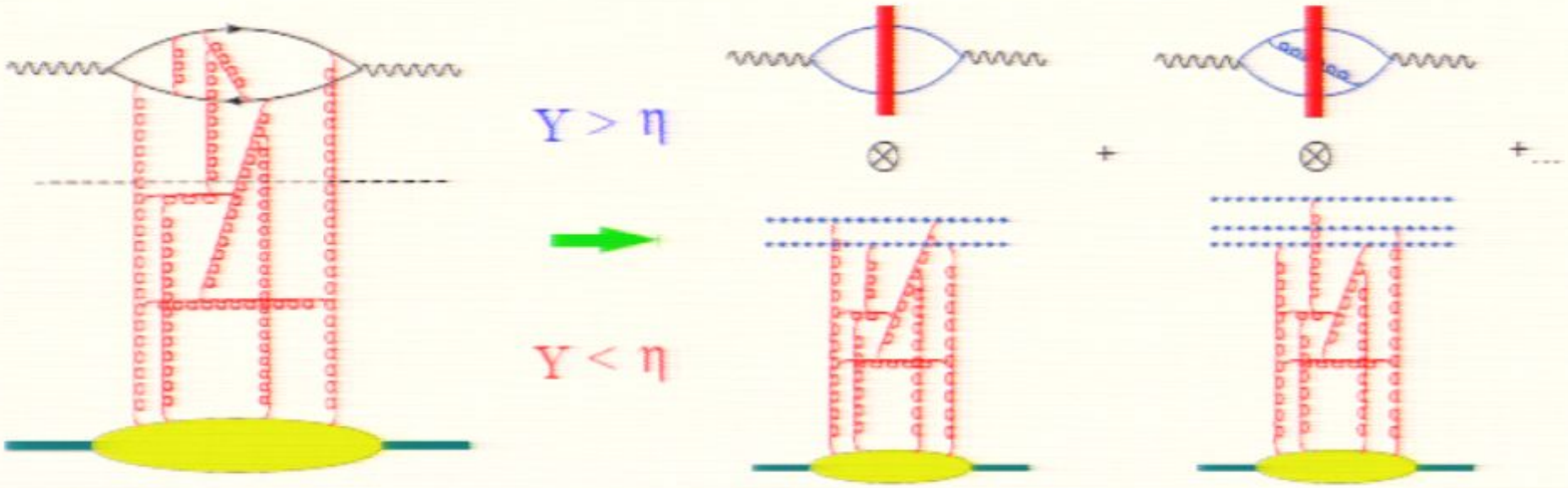
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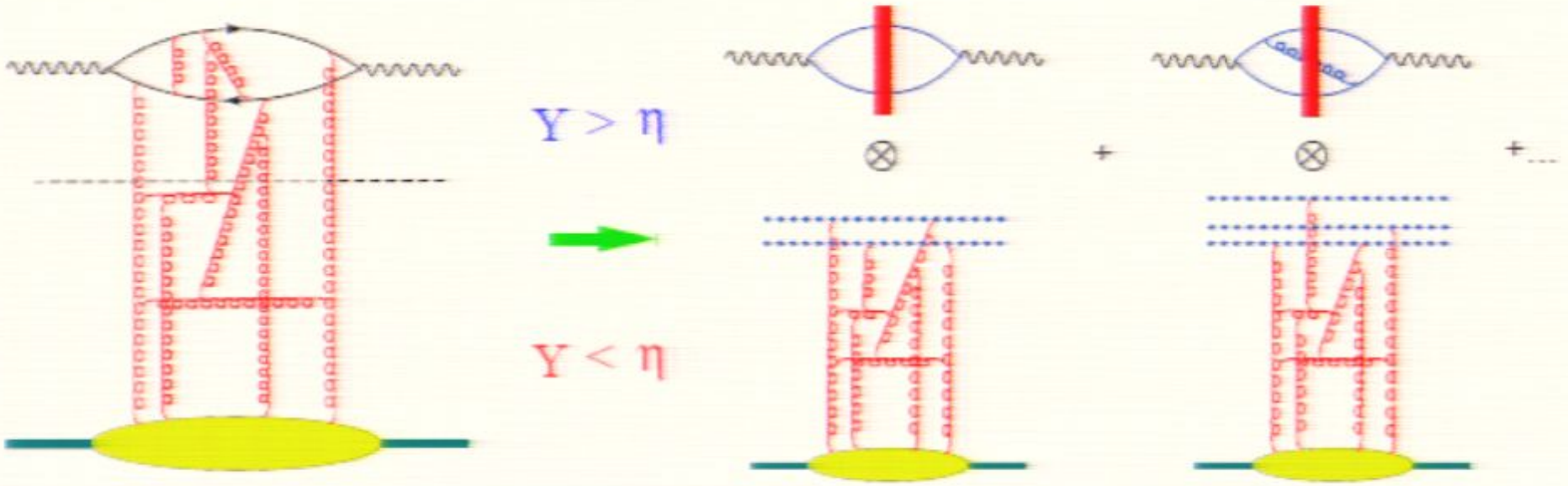
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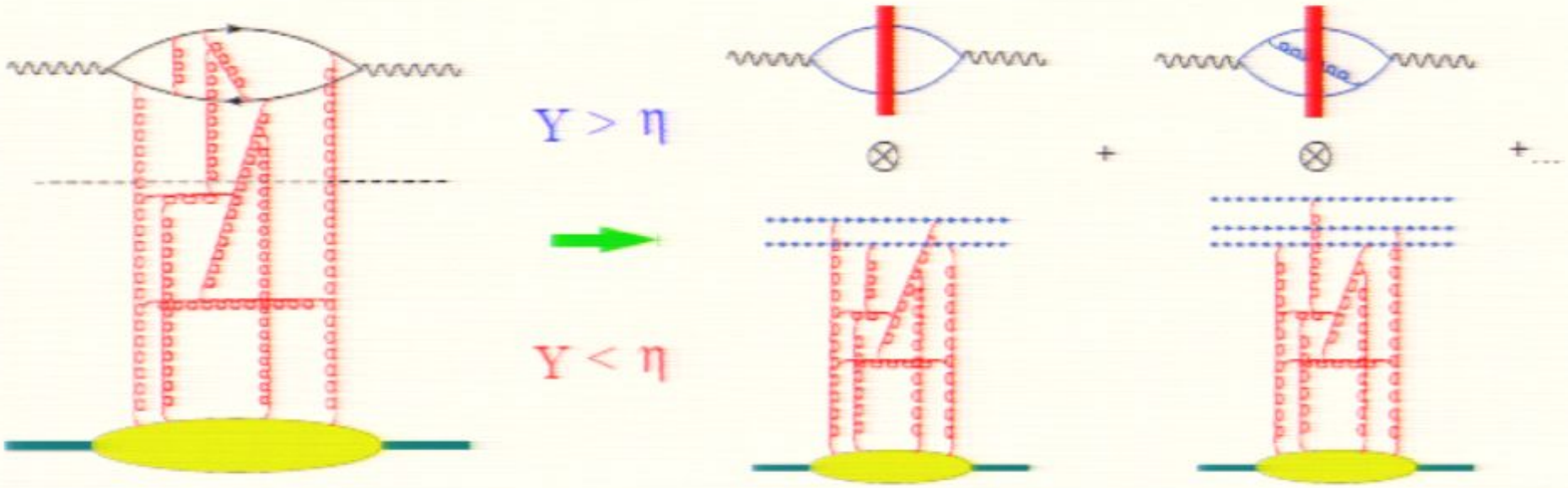
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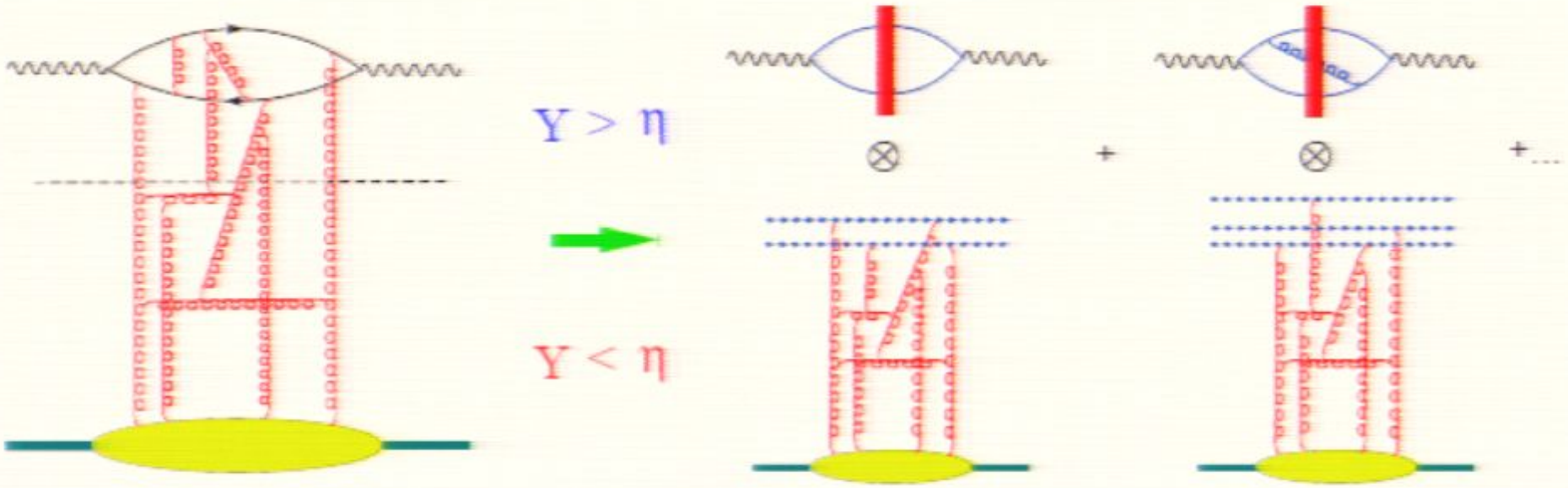
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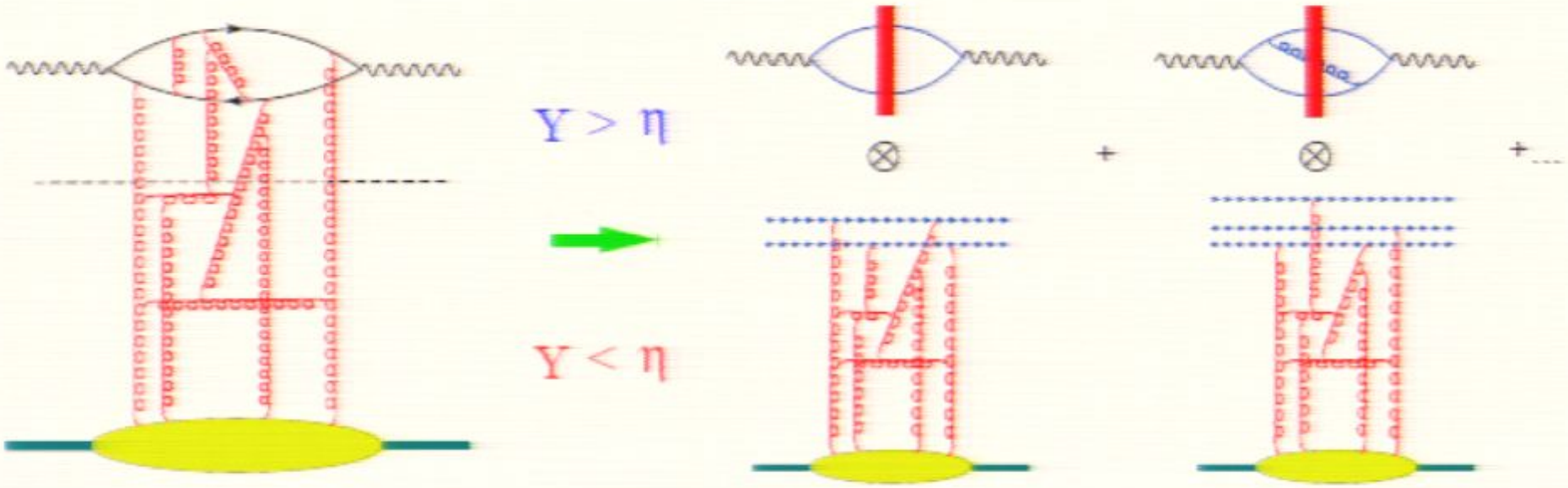
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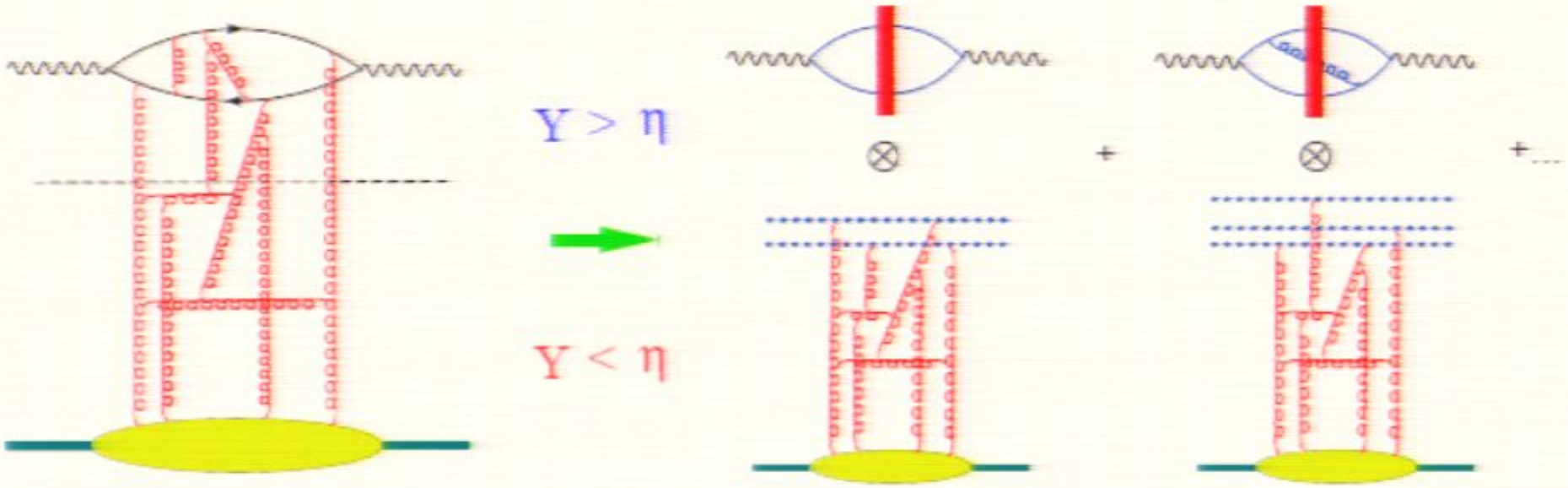
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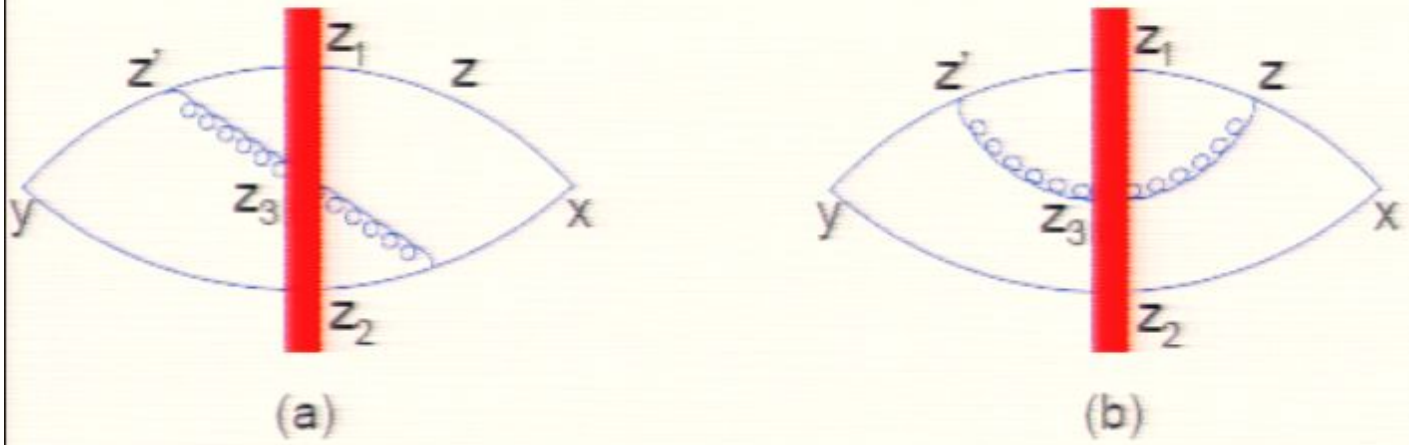
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CCP, 2007

NLO impact factor



$$I^{\rm NLO}(x,y;z_1,z_2,z_3;\eta) = -I^{\rm LO}\times\frac{\lambda}{\pi^2}\frac{z_{13}^2}{z_{12}^2 z_{23}^2}\left[\ln\frac{\sigma s}{4}z_3 - \frac{i\pi}{2} + C\right]$$

The NLO impact factor is not Möbius invariant $\Rightarrow$ the color dipole with the cutoff η is not invariant

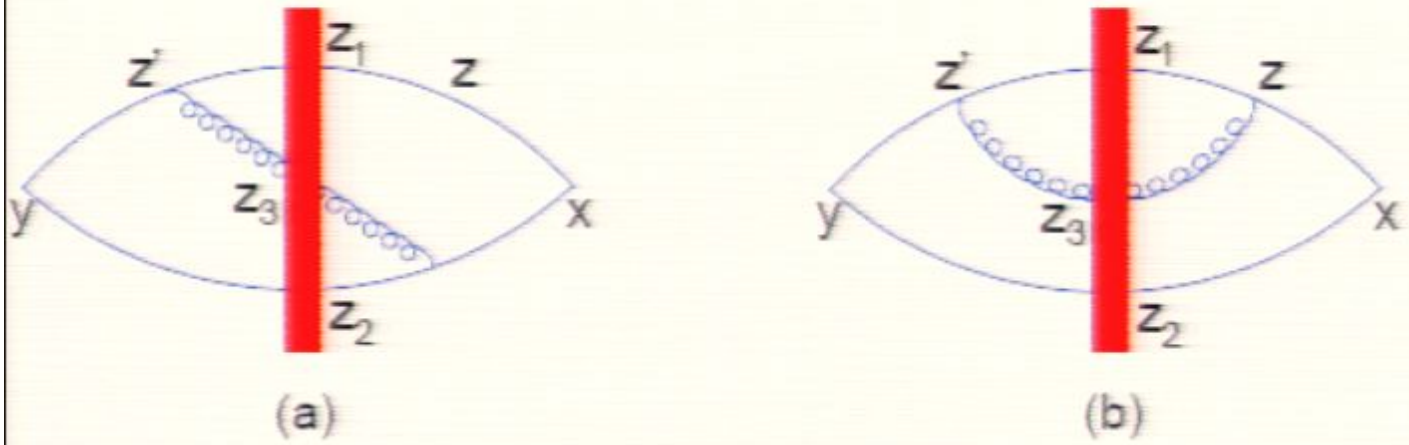
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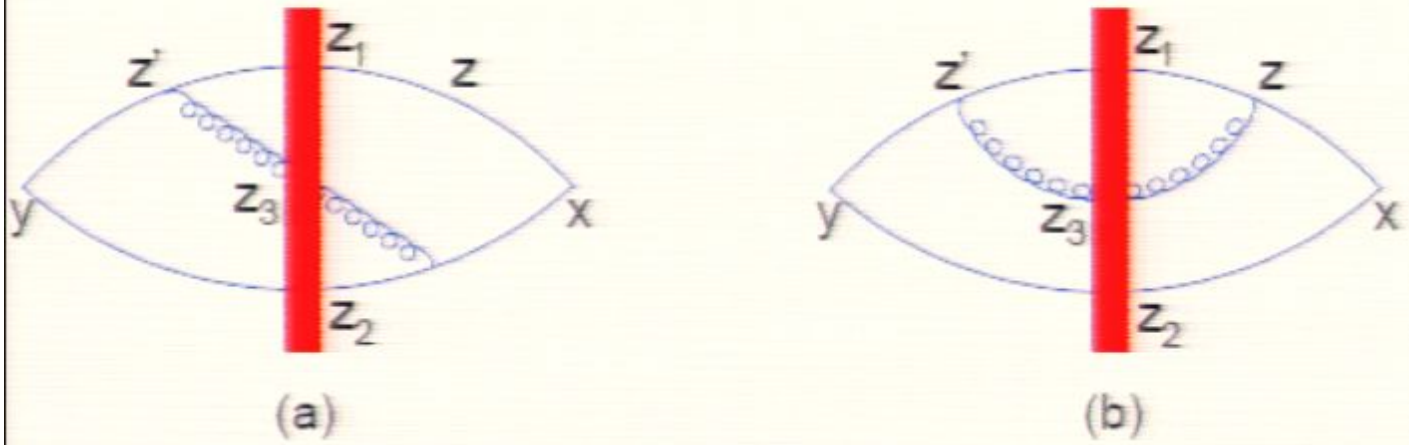
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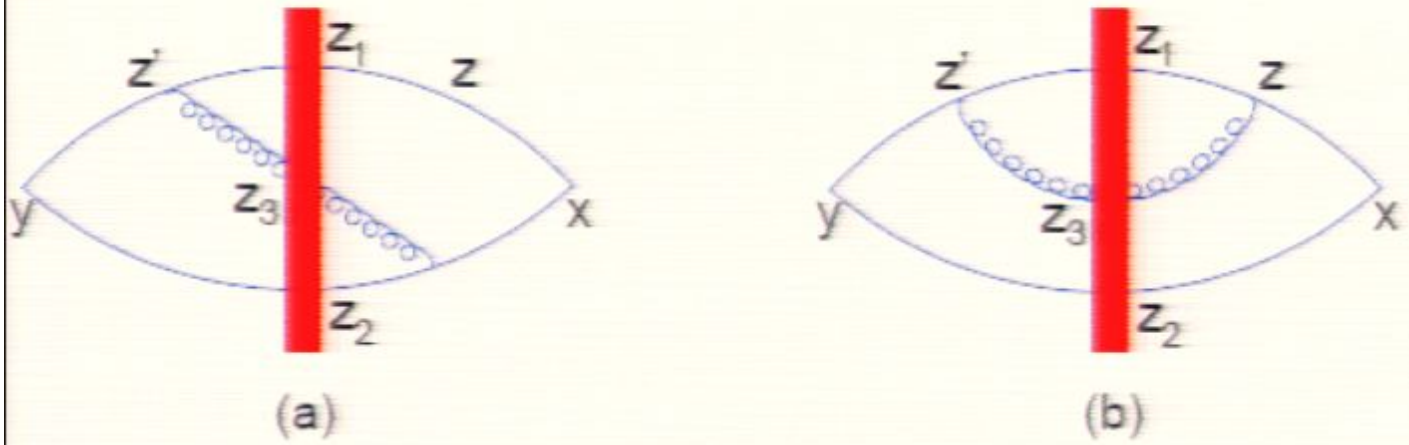
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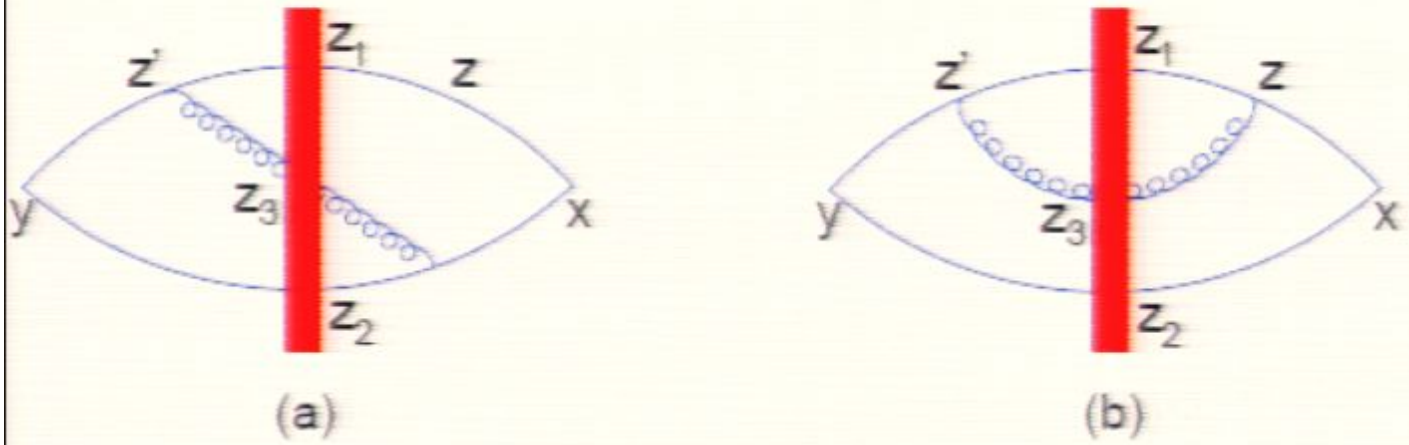
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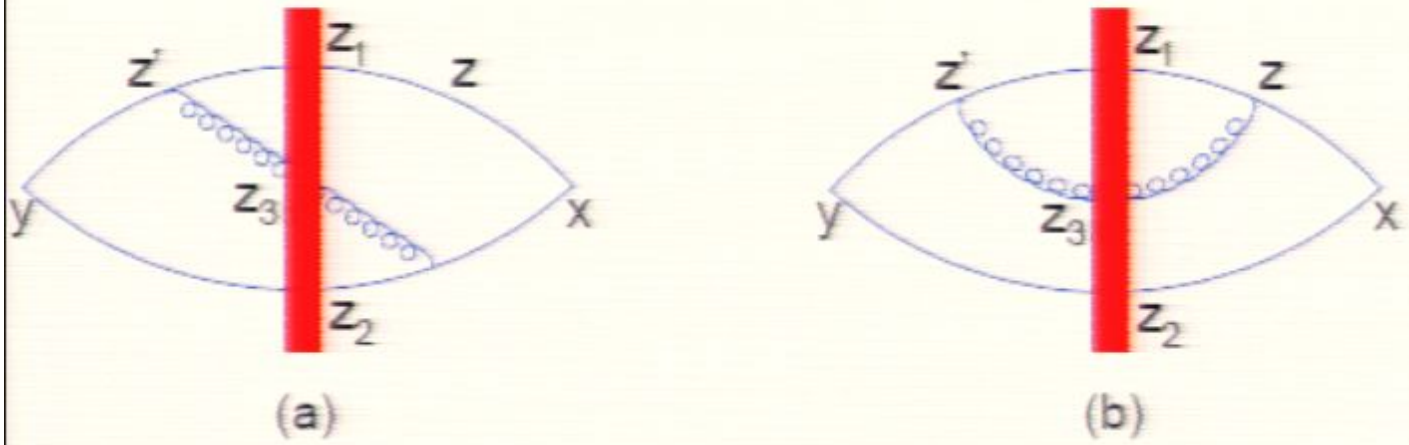
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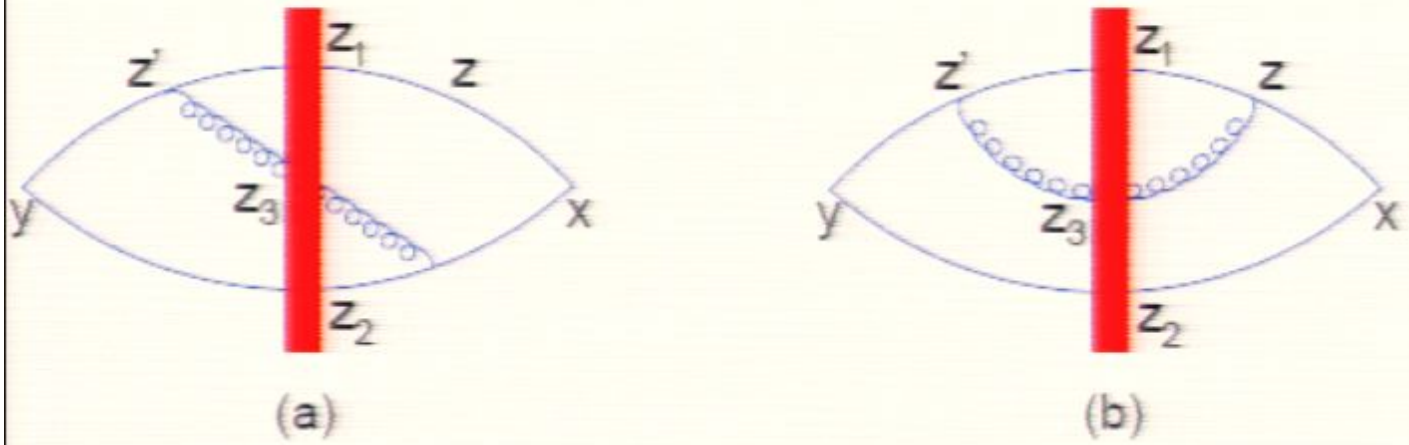
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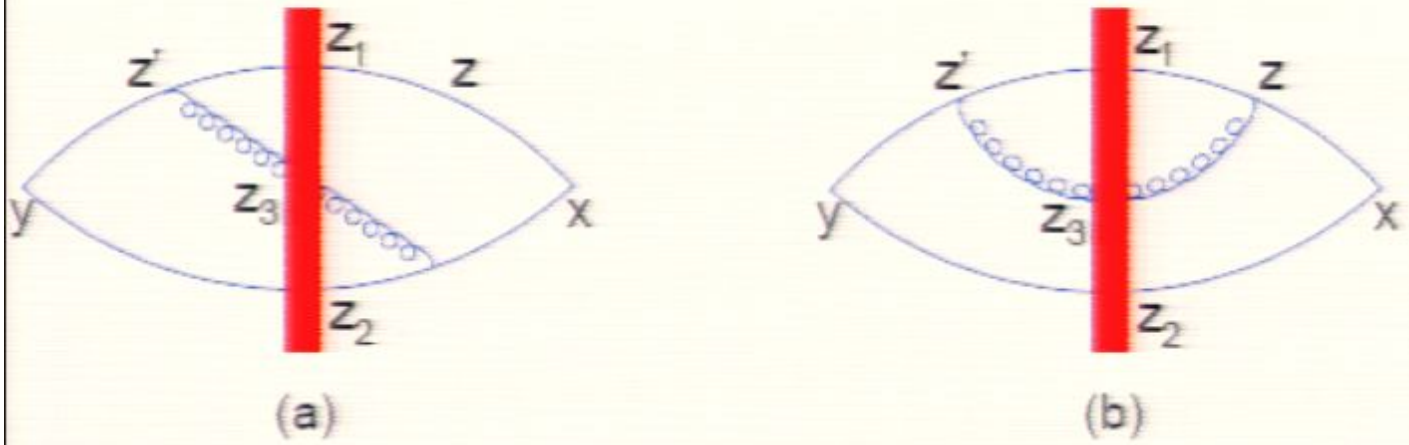
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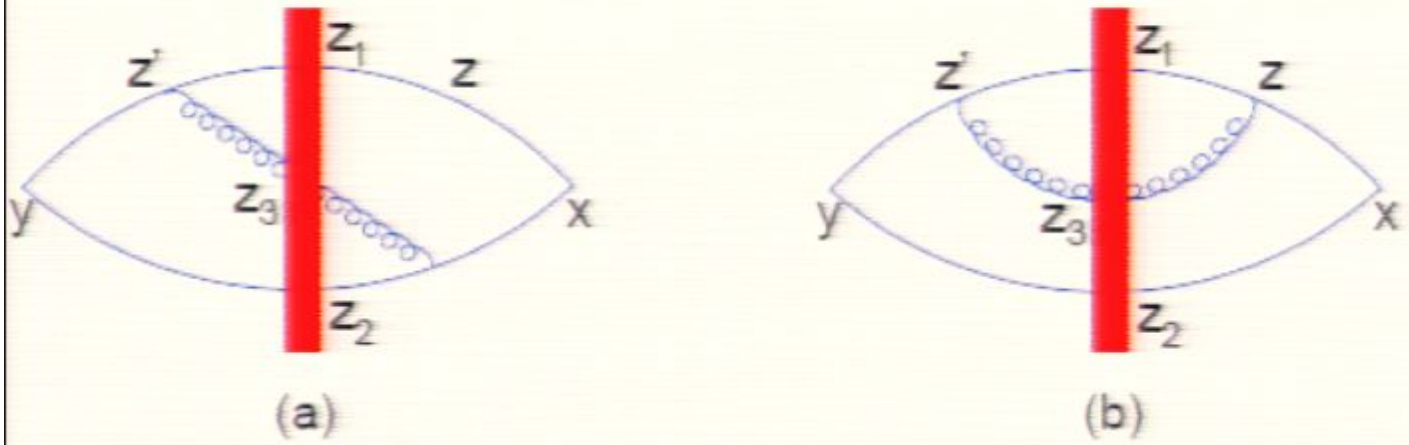
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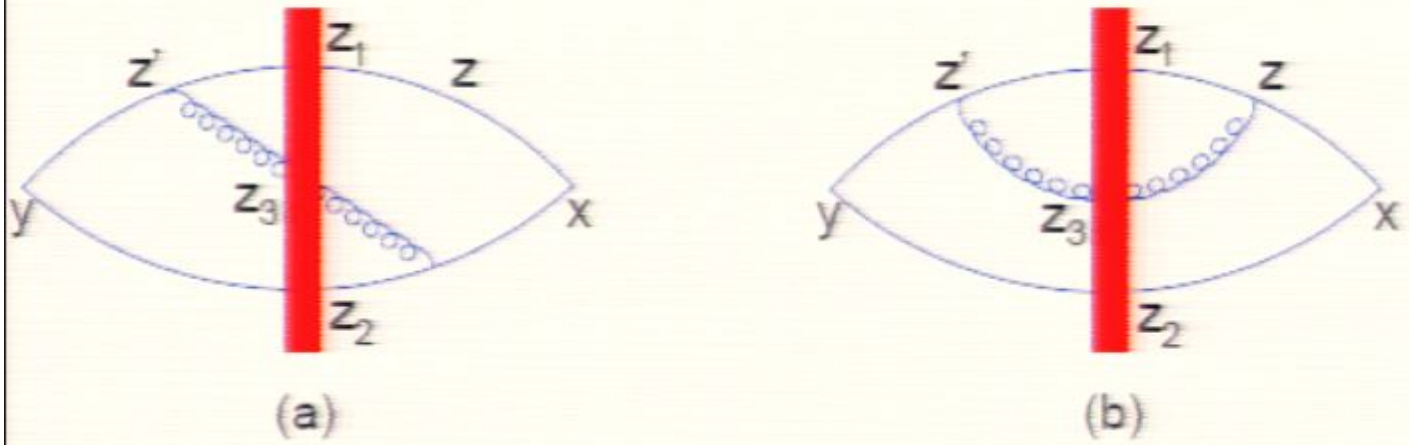
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NLO impact factor



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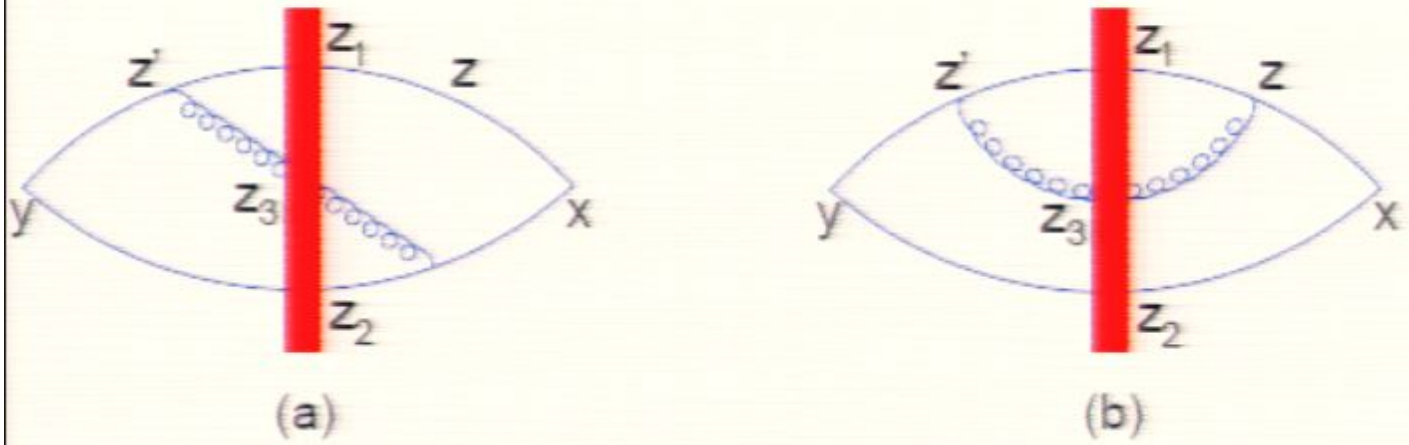
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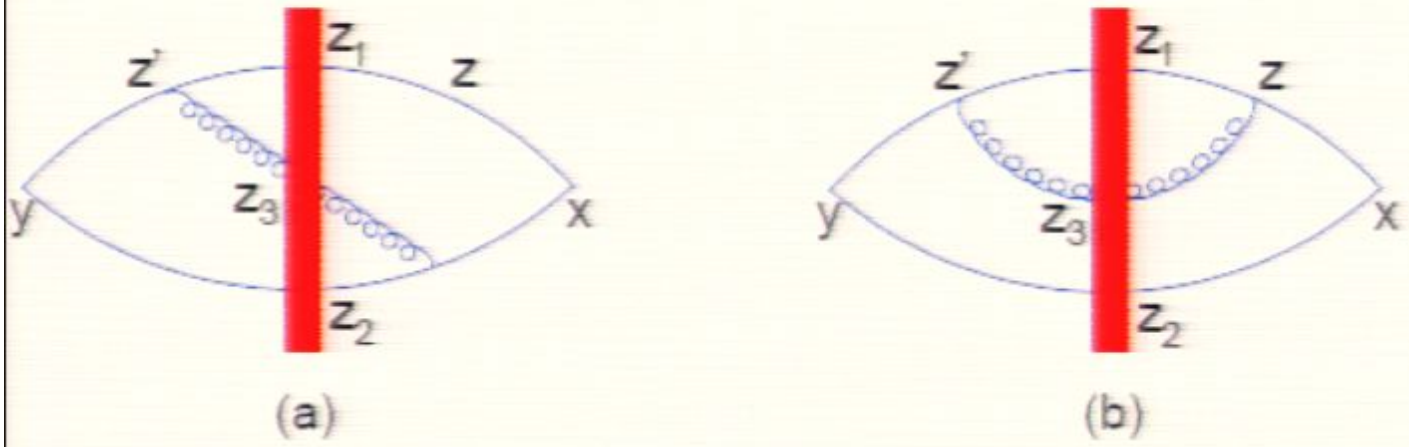
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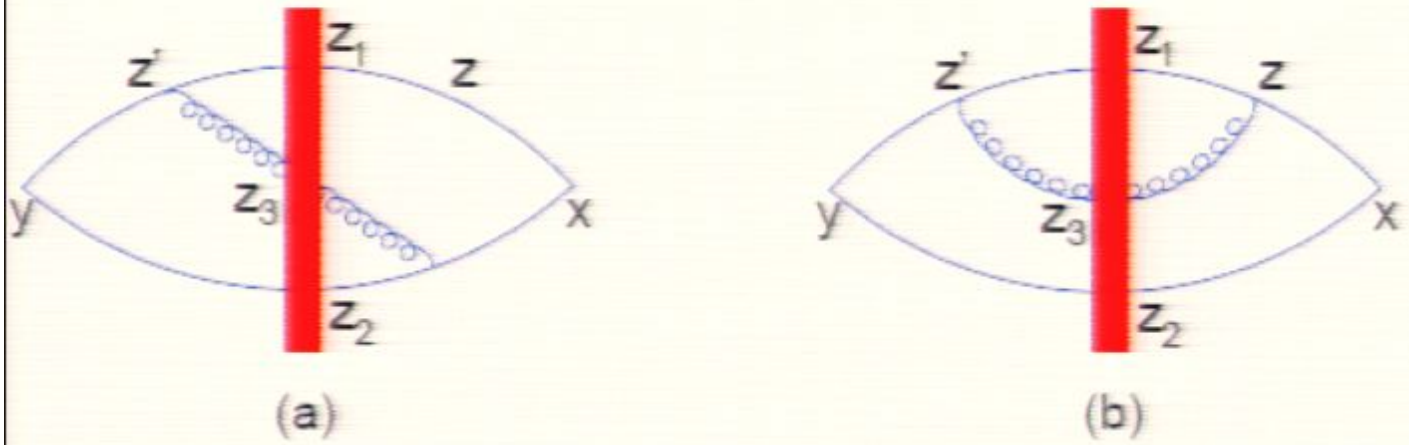
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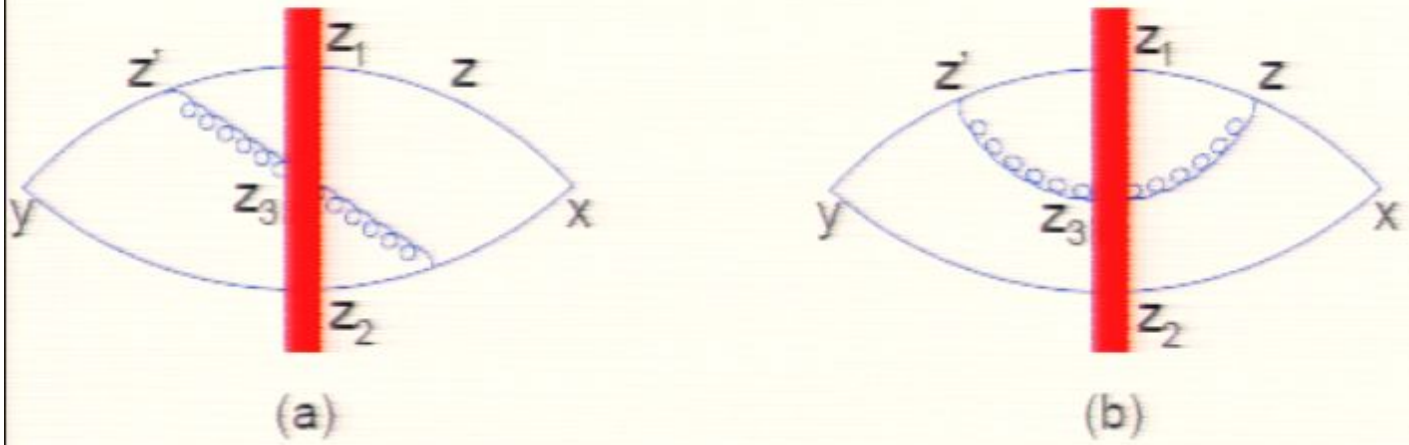
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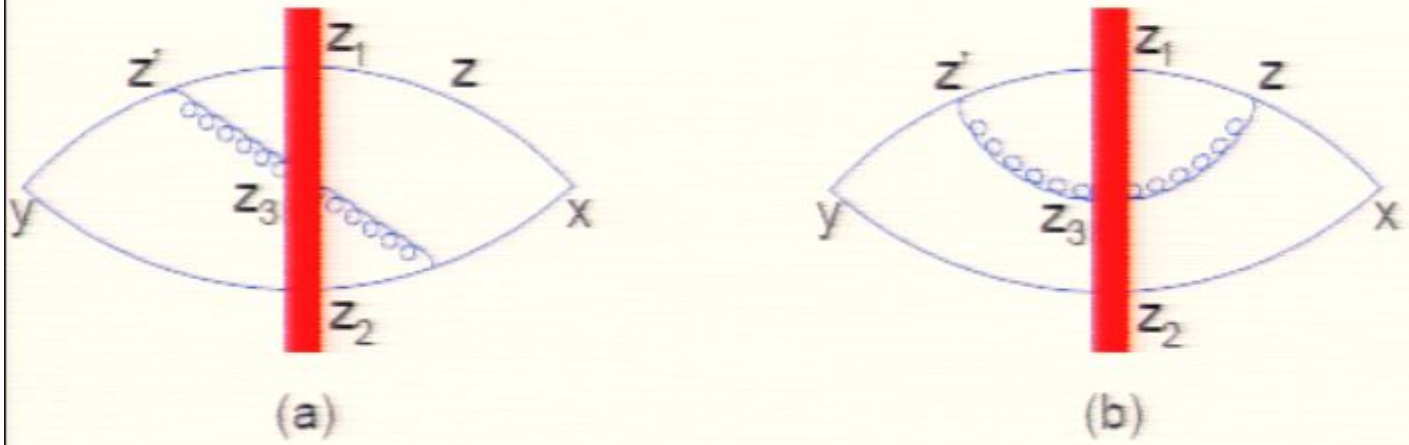
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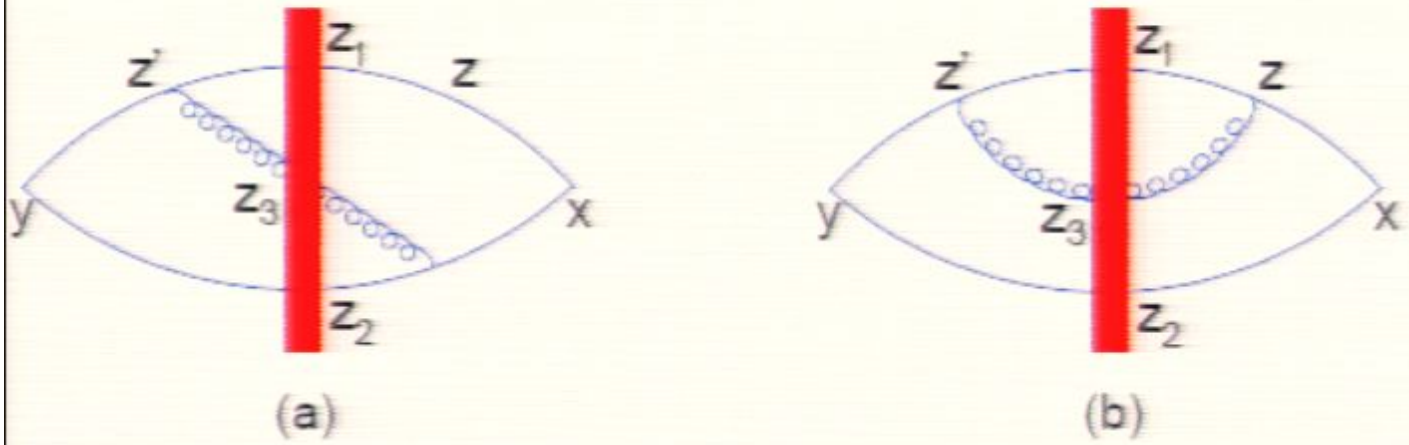
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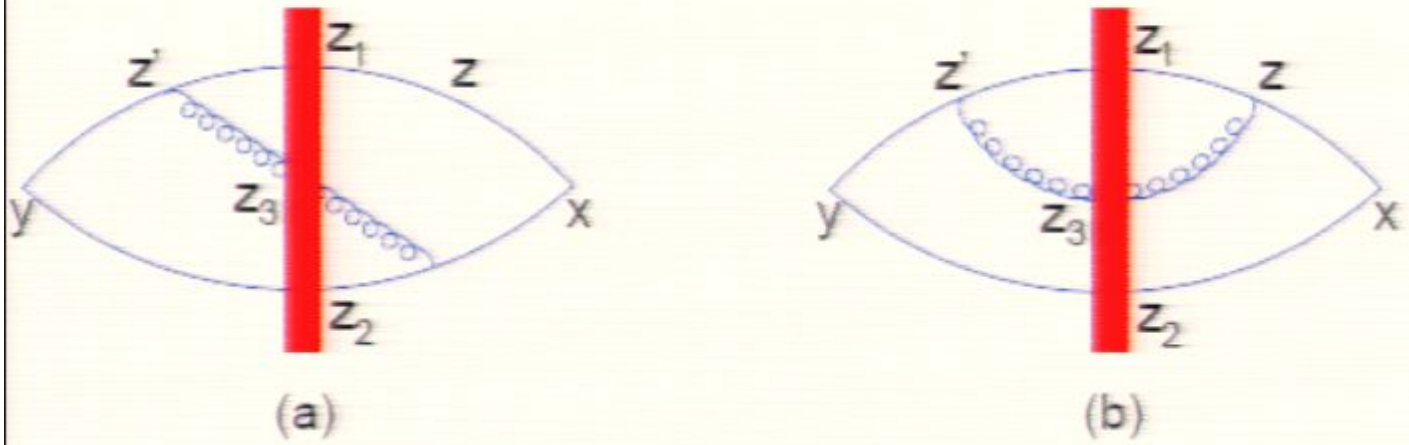
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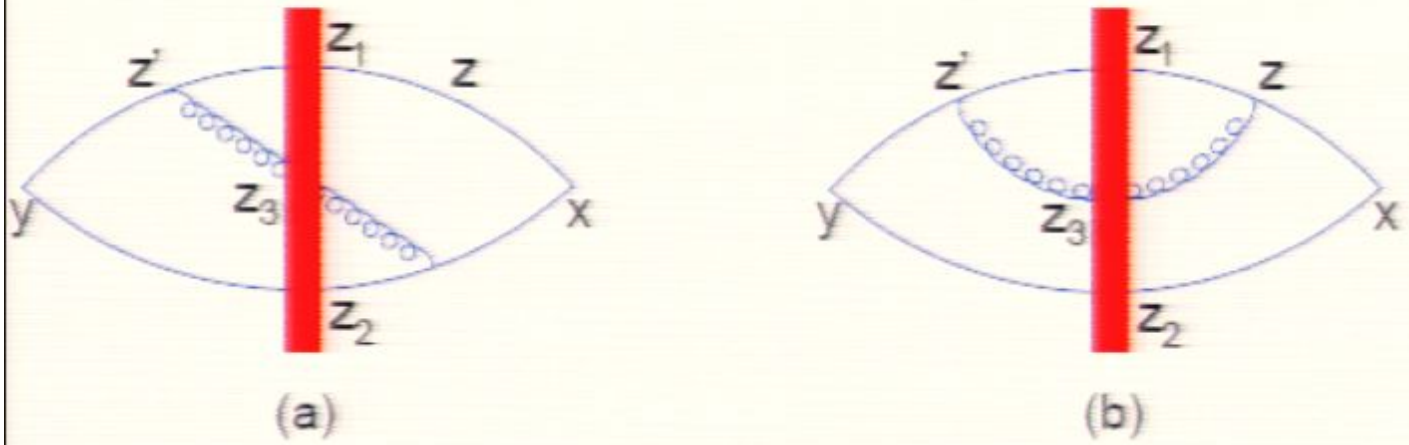
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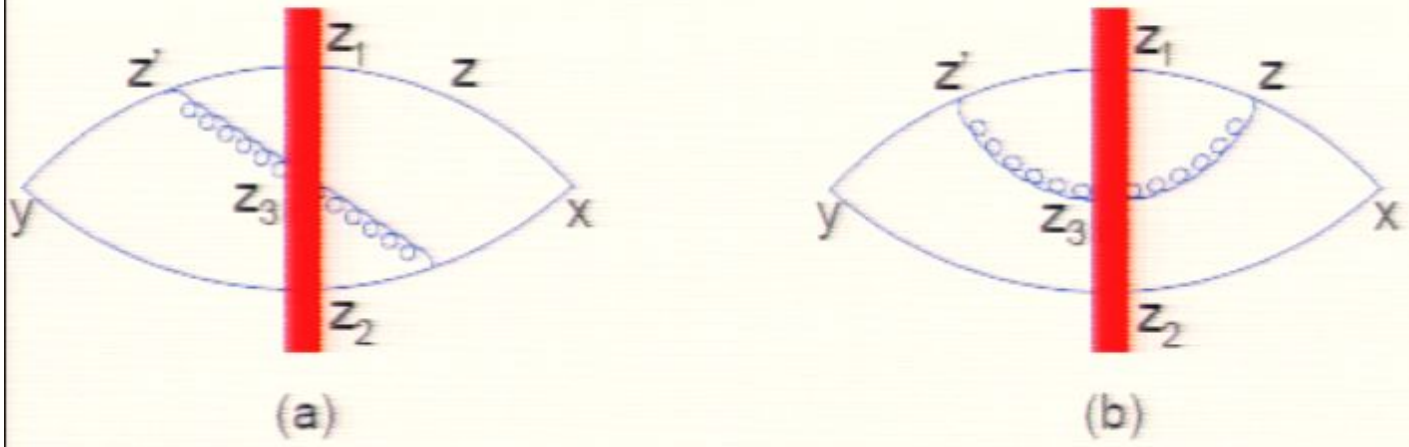
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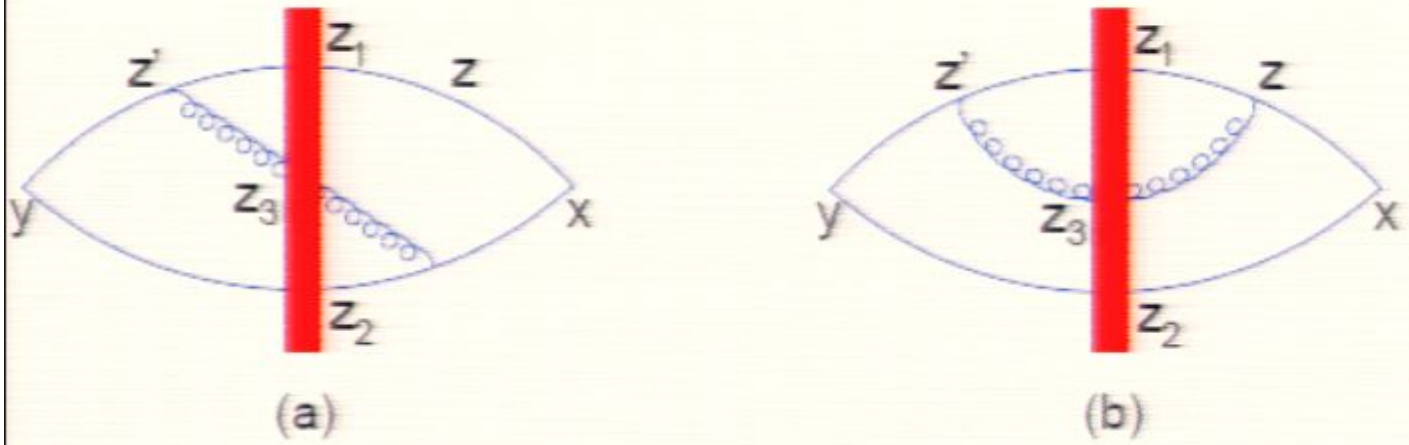
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$\Rightarrow$ ${\rm Tr}\{\hat{U}^{\eta}_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}^{\rm conf}$ is Möbius invariant

We think that one can construct the composite conformal dipole operator order by order in perturbation theory.

Analogy: when the UV cutoff does not respect the symmetry of a local operator, the composite local renormalized operator in must be corrected by finite counterterms order by order in perturbaton theory.

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Definition of the NLO kernel

In general

$$\frac{d}{d\eta}\mathrm{Tr}\{\hat{U}_x\hat{U}_y^\dagger\} = \alpha_s K_{\mathrm{LO}}\mathrm{Tr}\{\hat{U}_x\hat{U}_y^\dagger\} + \alpha_s^2 K_{\mathrm{NLO}}\mathrm{Tr}\{\hat{U}_x\hat{U}_y^\dagger\} + O(\alpha_s^3)$$

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We think that one can construct the composite conformal dipole operator order by order in perturbation theory.

Analogy: when the UV cutoff does not respect the symmetry of a local operator, the composite local renormalized operator in must be corrected by finite counterterms order by order in perturbaton theory.

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In general

$$\frac{d}{d\eta}\mathrm{Tr}\{\hat{U}_x\hat{U}_y^\dagger\} = \alpha_s K_{\mathrm{LO}}\mathrm{Tr}\{\hat{U}_x\hat{U}_y^\dagger\} + \alpha_s^2 K_{\mathrm{NLO}}\mathrm{Tr}\{\hat{U}_x\hat{U}_y^\dagger\} + O(\alpha_s^3)$$

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Subtraction of the (LO) contribution (with the rigid rapidity cutoff)

$\Rightarrow$ $\left[\frac{1}{v}\right]_+$ prescription in the integrals over Feynman parameter v

Typical integral

$$\int_0^1 dv\,\frac{1}{(k-p)_\perp^2 v + p_\perp^2(1-v)}\left[\frac{1}{v}\right]_+ = \frac{1}{p_\perp^2}\ln\frac{(k-p)_\perp^2}{p_\perp^2}$$

Definition of the NLO kernel

In general

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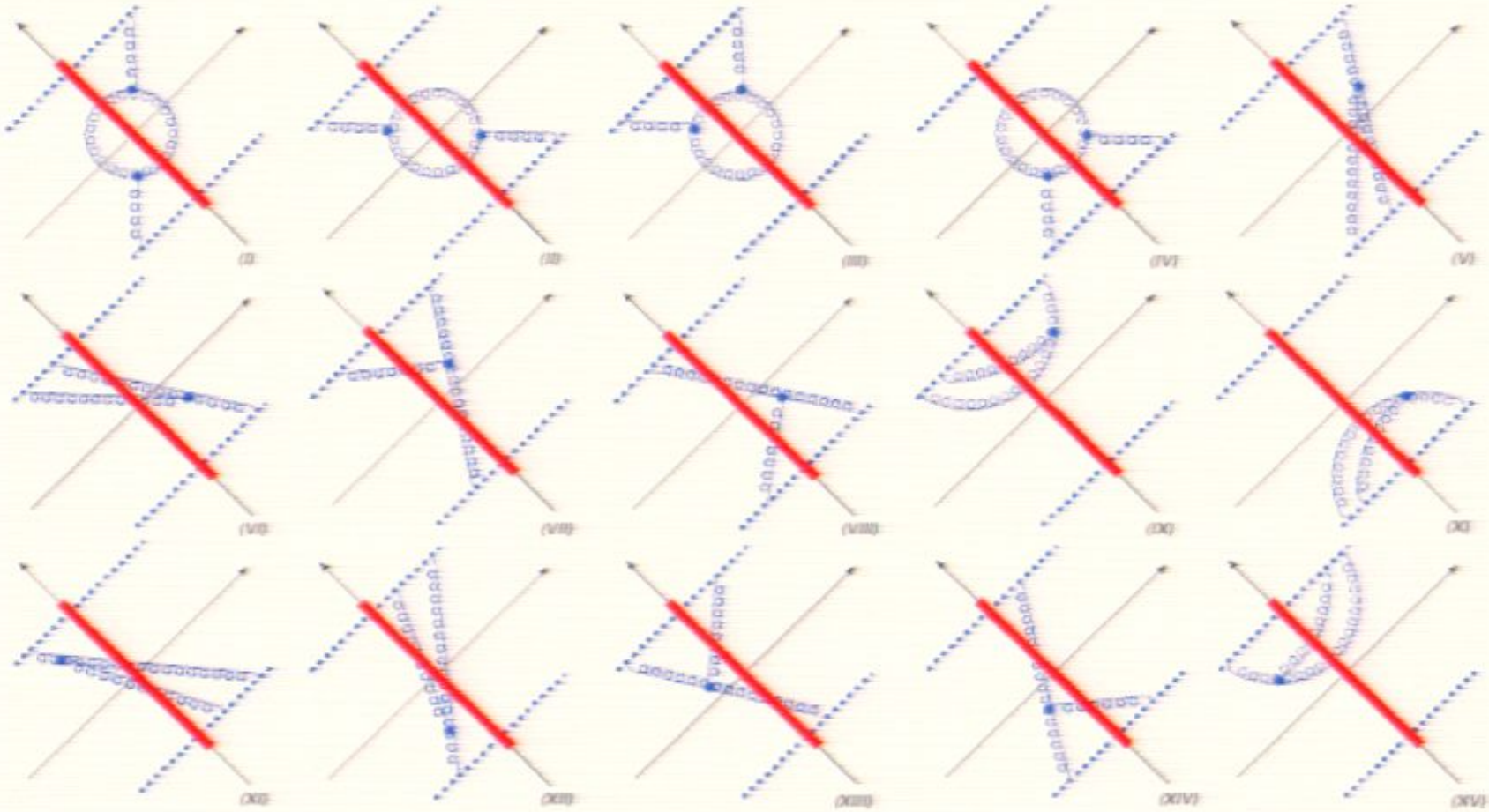
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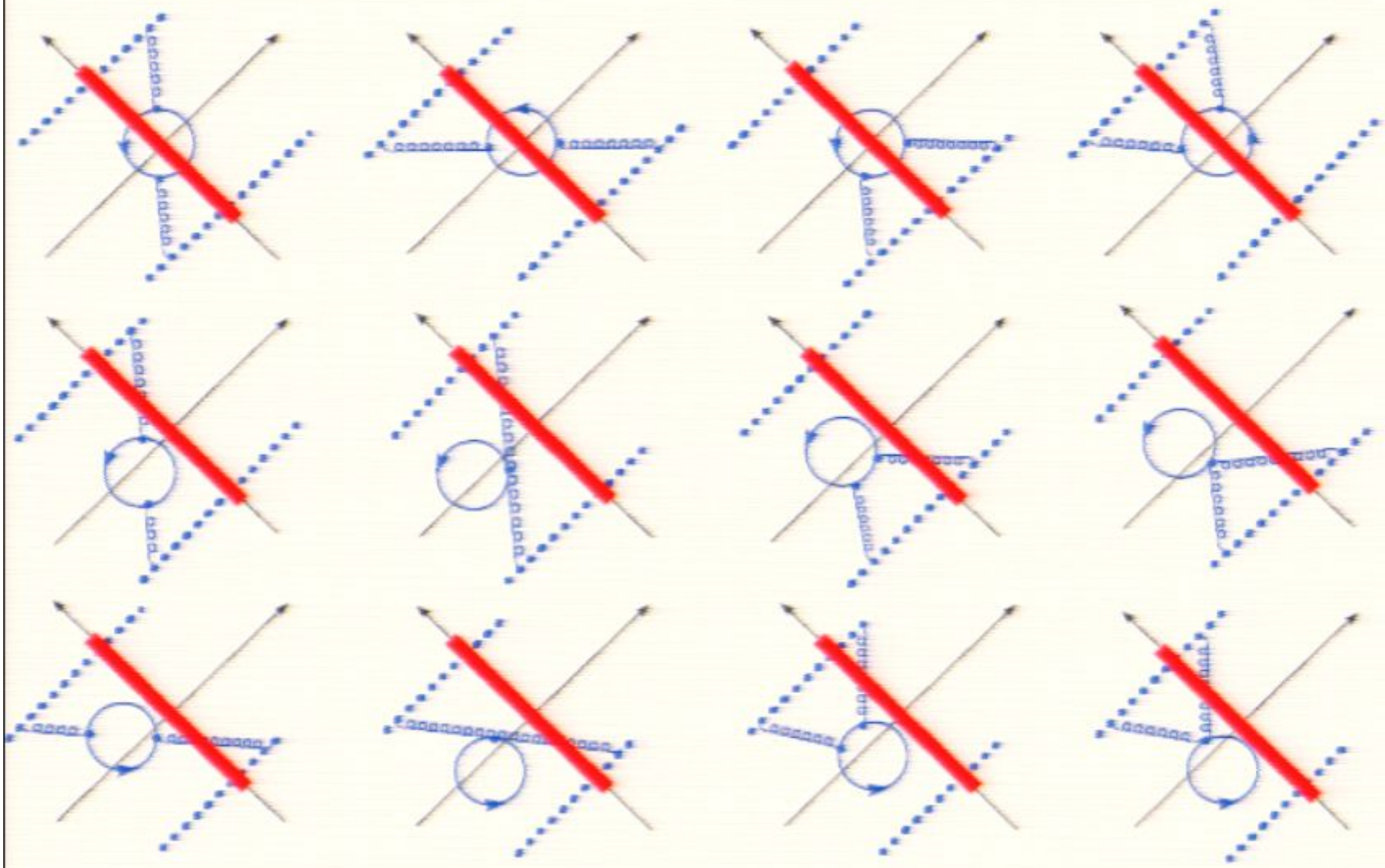
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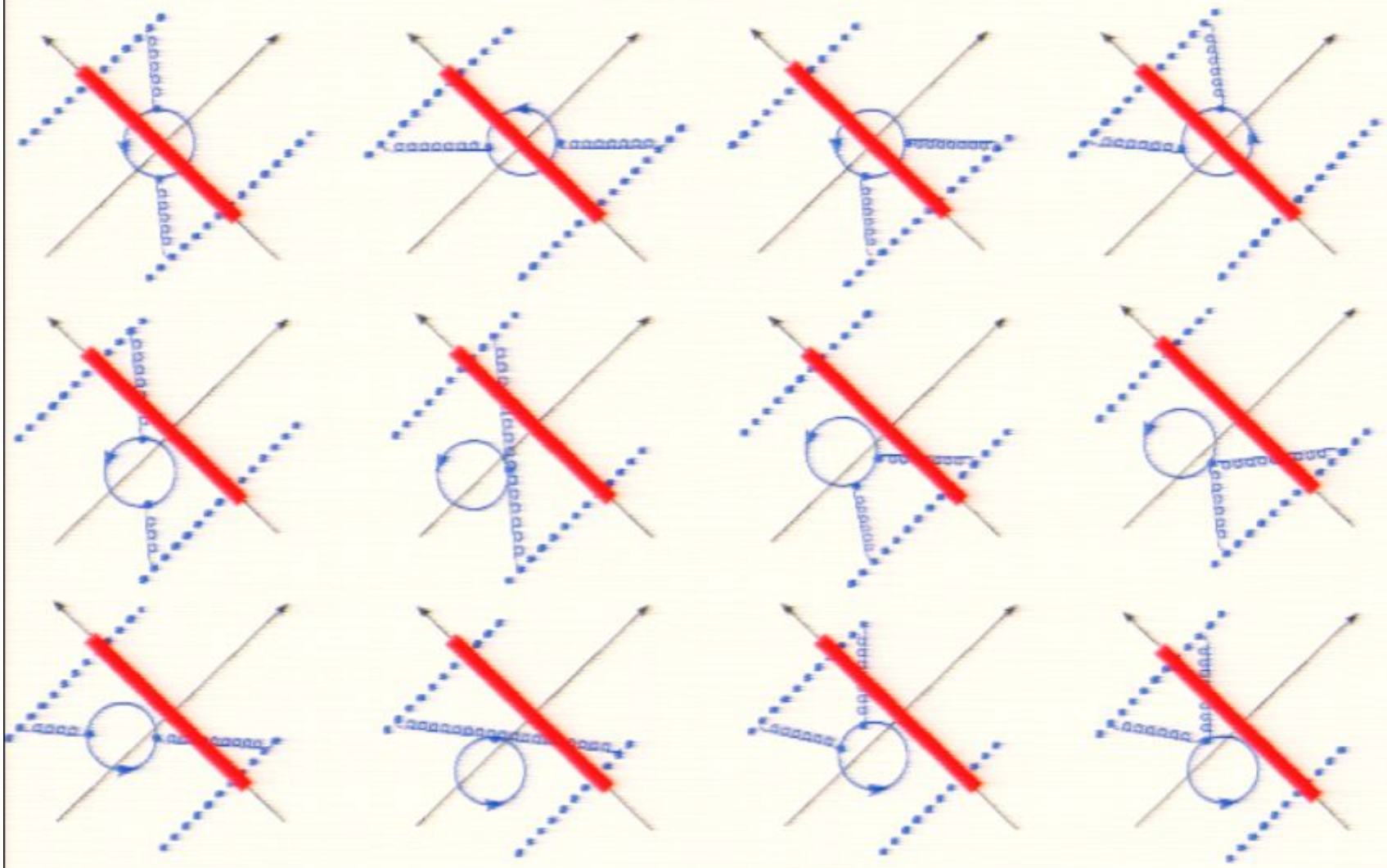
Gluon part of the NLO BK kernel: diagrams



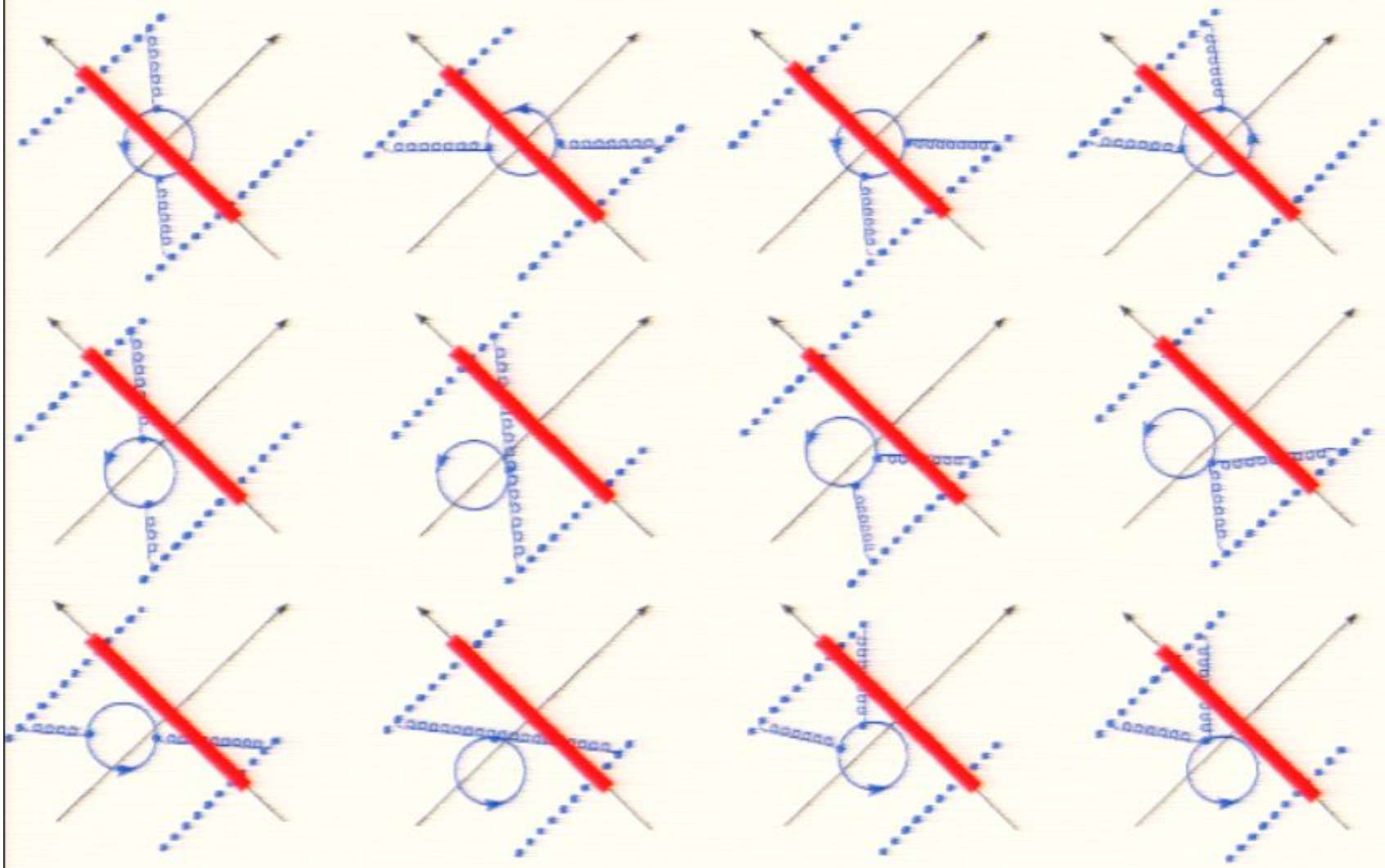
Gluino and scalar loops



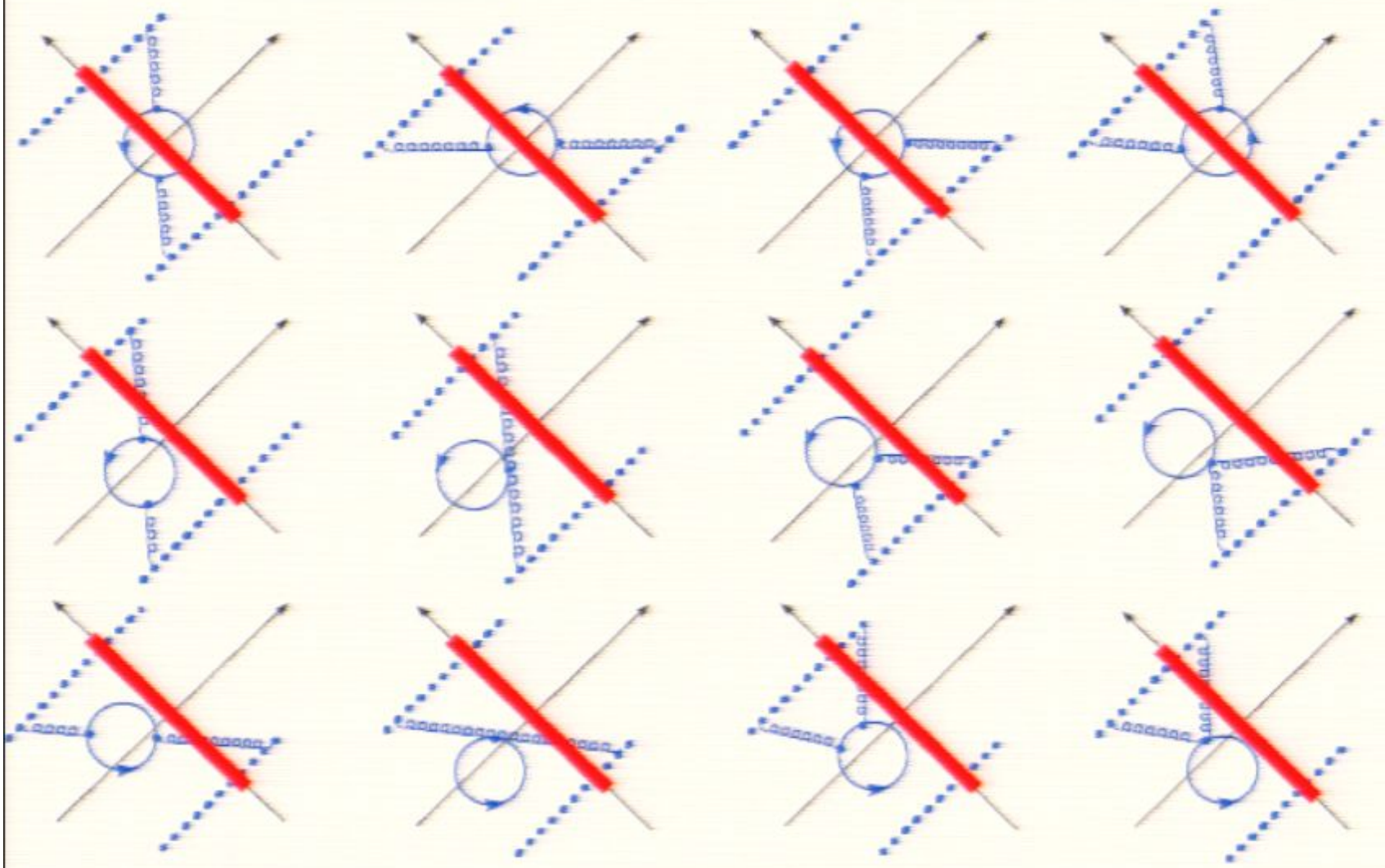
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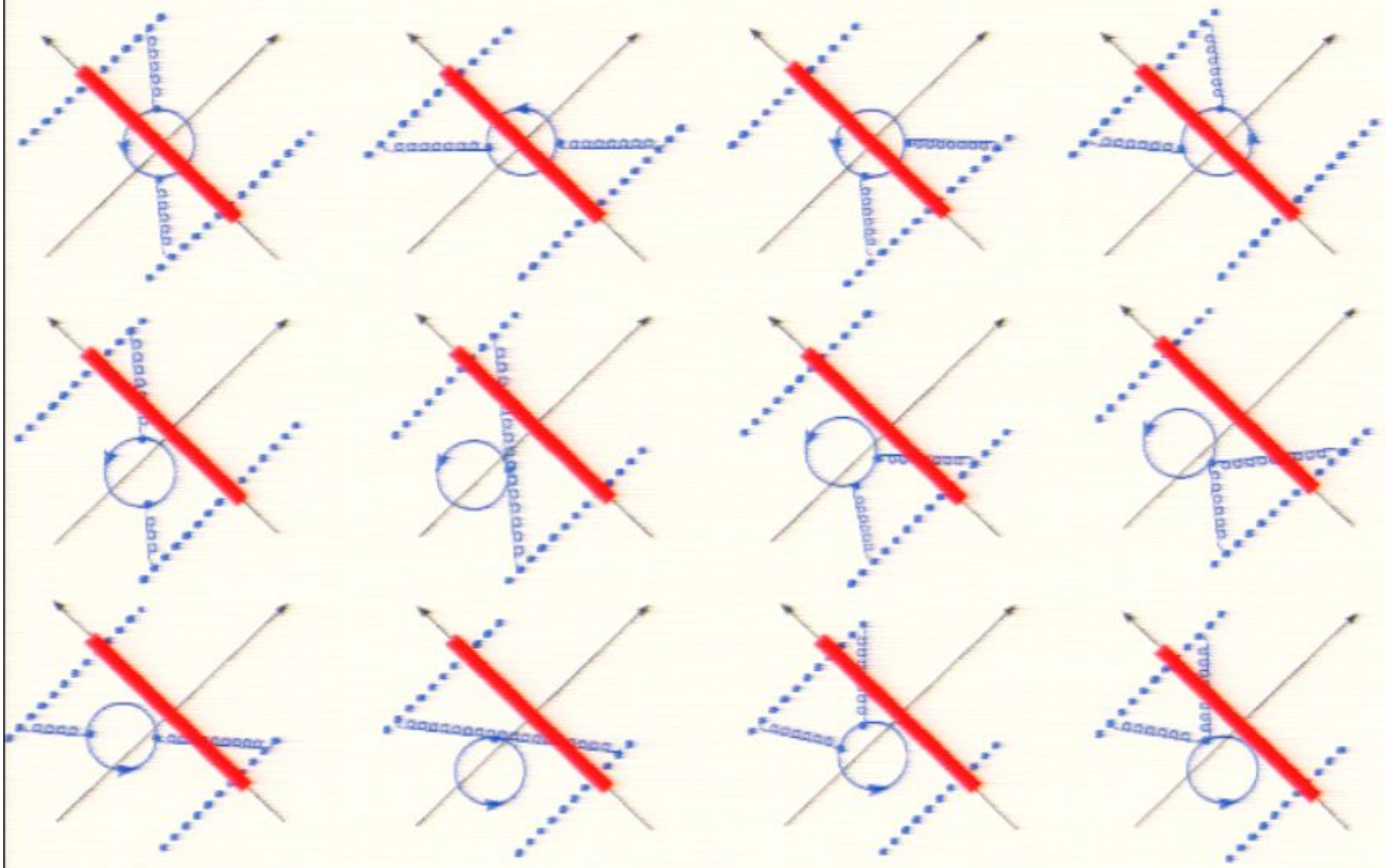
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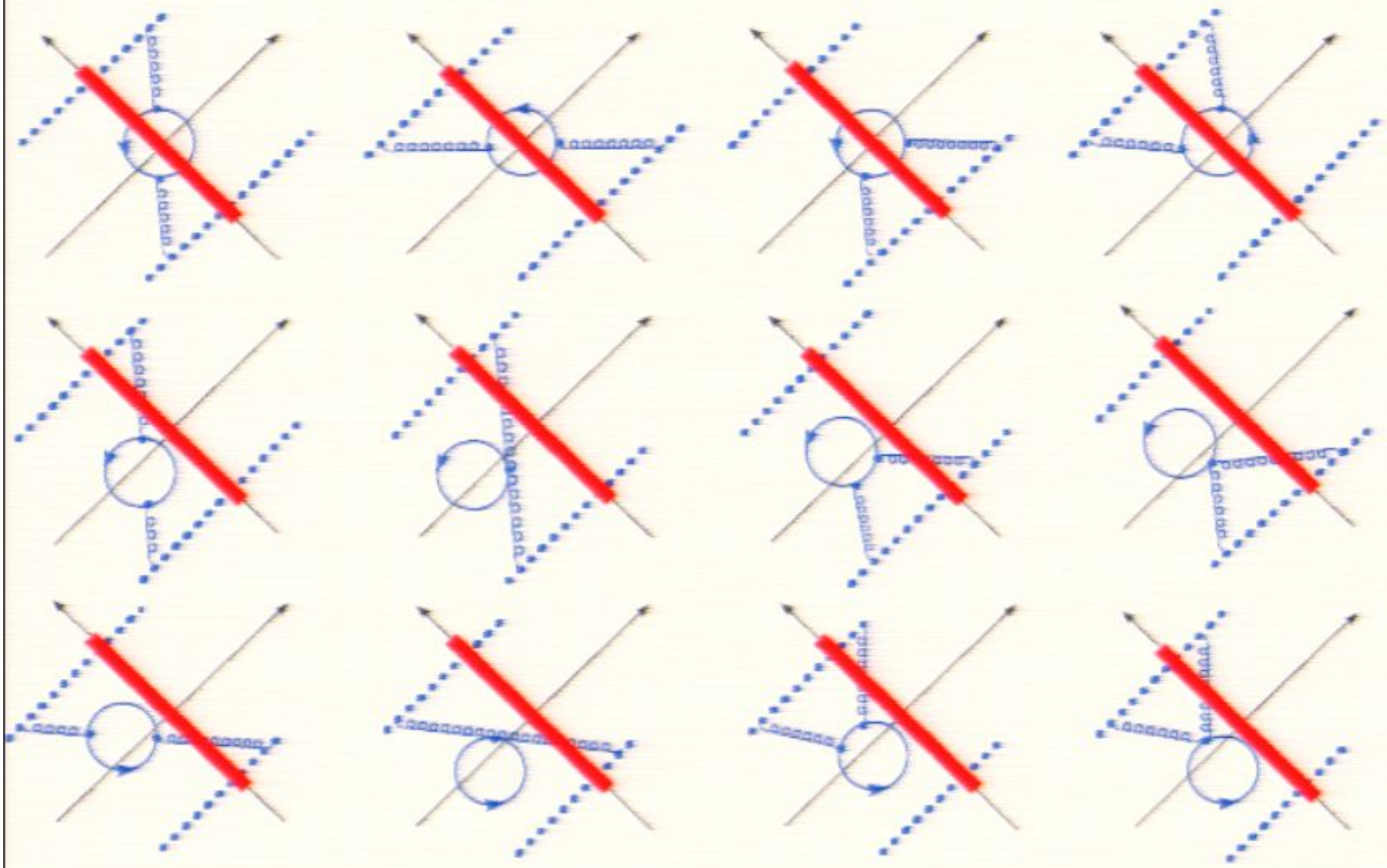
Gluino and scalar loops



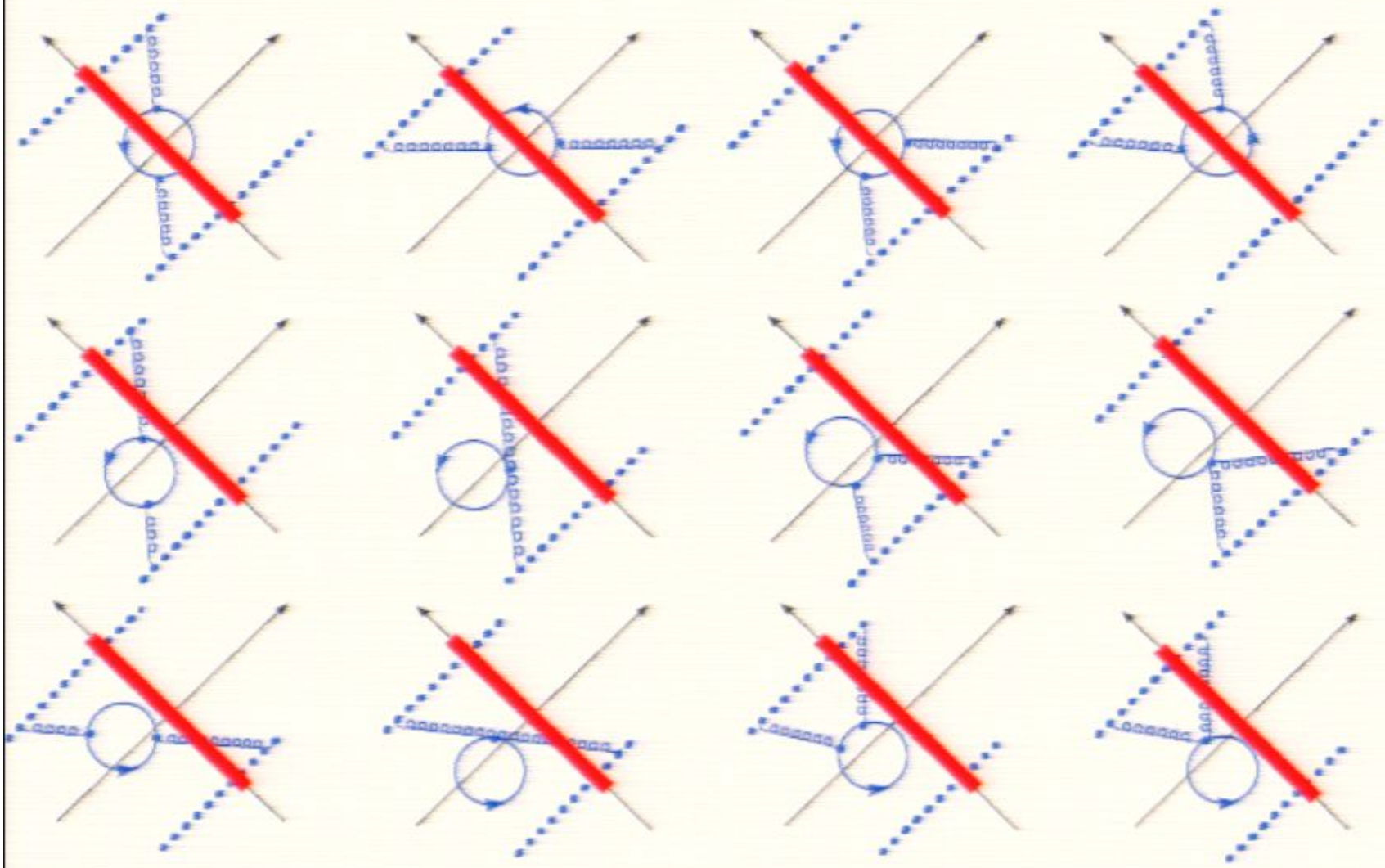
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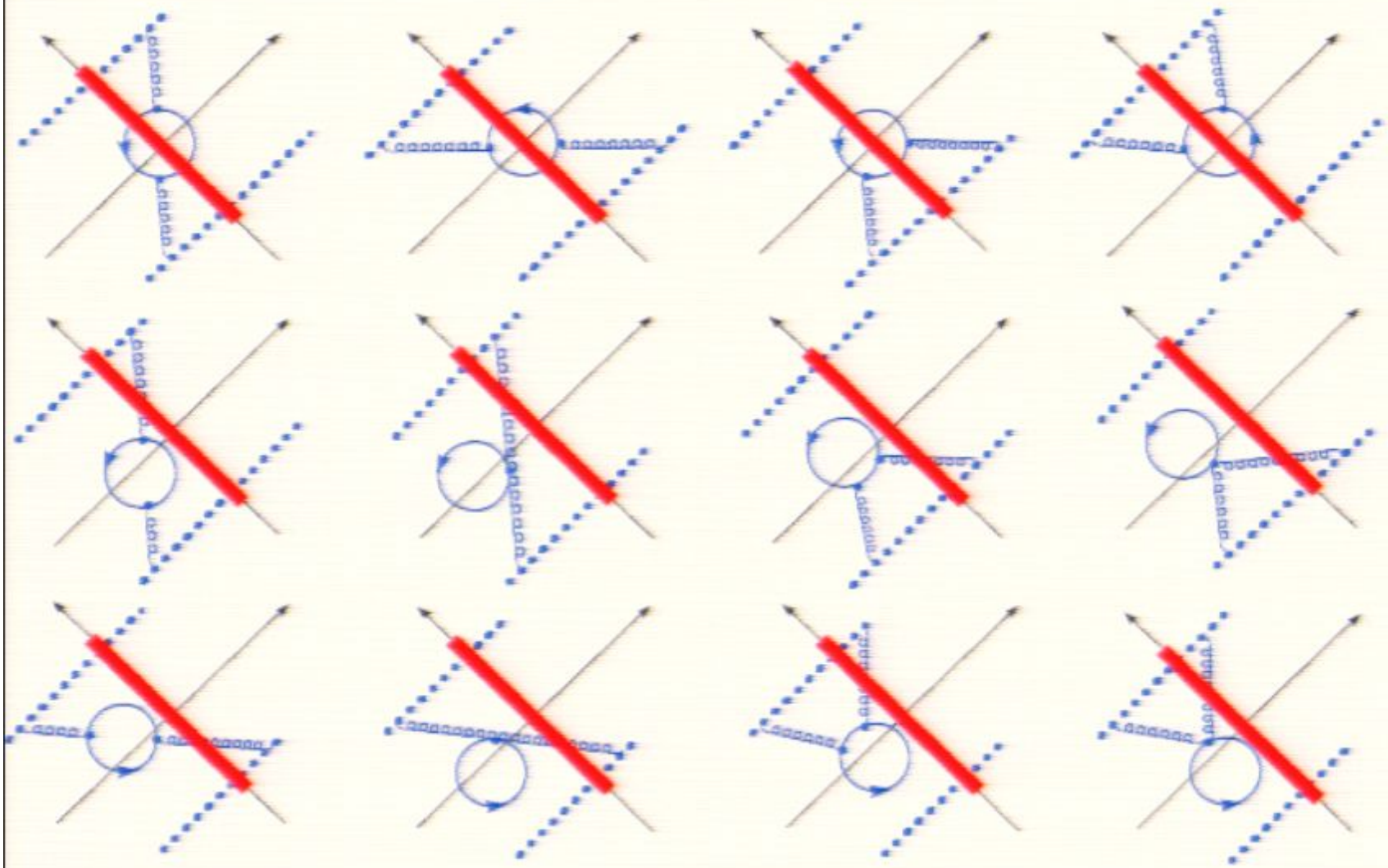
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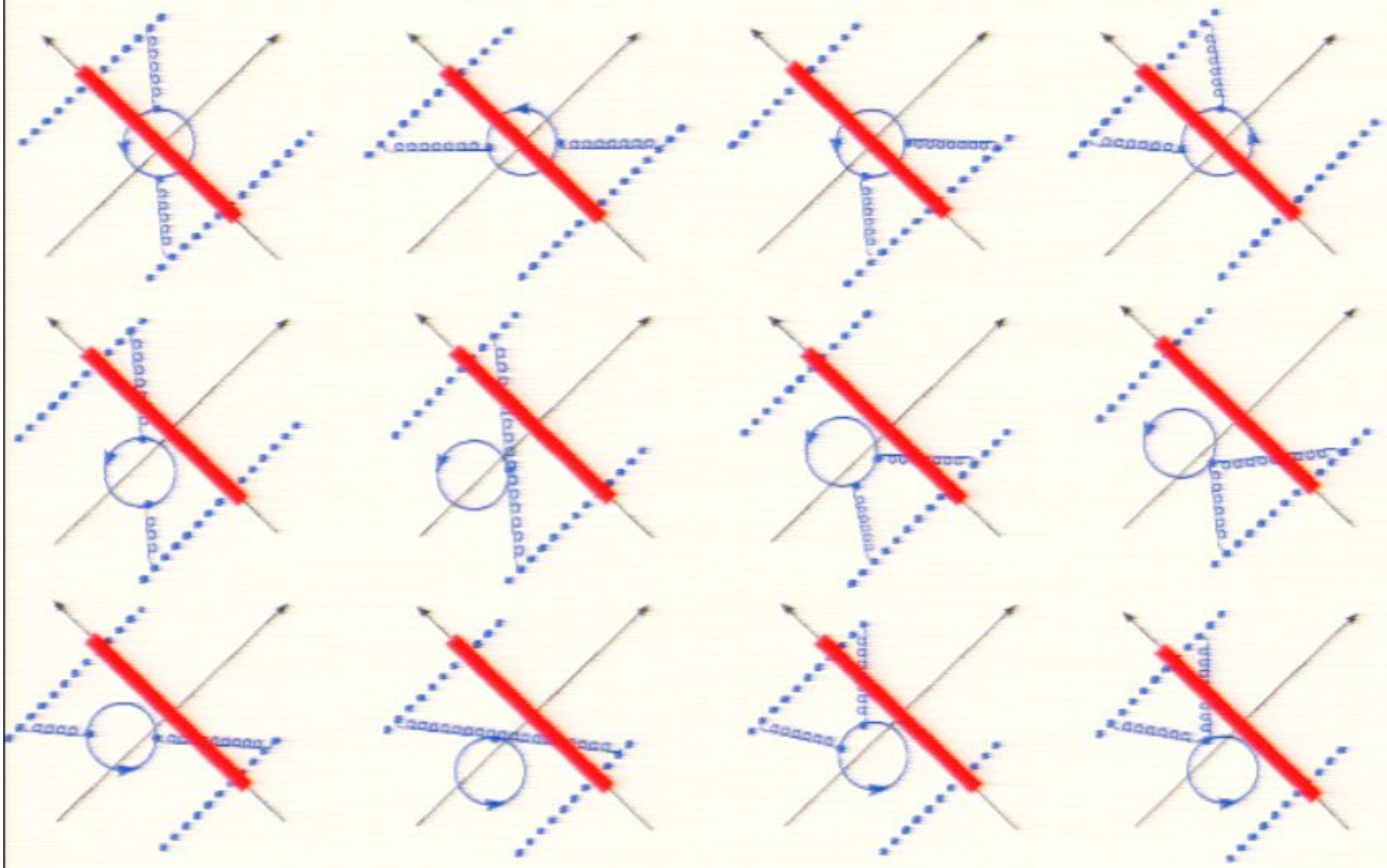
Gluino and scalar loops



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Evolution equation for color dipole in $\mathcal{N}=4$ (I.B. and G. Chirilli)

$$\frac{d}{d\eta}\mathrm{Tr}\{\hat{U}^{\eta}_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}$$

$$= \frac{\alpha_s}{\pi^2}\int d^2z_3\,\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left\{1-\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}+2\ln\frac{z_{13}^2}{z_{12}^2}\ln\frac{z_{23}^2}{z_{12}^2}\right]\right\}$$

$$\times\left[\mathrm{Tr}\{T^a\hat{U}^{\eta}_{z_1}\hat{U}^{\dagger\eta}_{z_3}T^a\hat{U}^{\eta}_{z_3}\hat{U}^{\dagger\eta}_{z_2}\}-N_c\mathrm{Tr}\{\hat{U}^{\eta}_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}\right]$$

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NLO kernel = Non-conformal term + Conformal term.

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Evolution equation for color dipole in $\mathcal{N}=4$ (I.B. and G. Chirilli)

$$\frac{d}{d\eta}\mathrm{Tr}\{\hat{U}^{\eta}_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}$$

$$= \frac{\alpha_s}{\pi^2}\int d^2z_3\,\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left\{1-\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}+2\ln\frac{z_{13}^2}{z_{12}^2}\ln\frac{z_{23}^2}{z_{12}^2}\right]\right\}$$

$$\times\left[\mathrm{Tr}\{T^a\hat{U}^{\eta}_{z_1}\hat{U}^{\dagger\eta}_{z_3}T^a\hat{U}^{\eta}_{z_3}\hat{U}^{\dagger\eta}_{z_2}\}-N_c\mathrm{Tr}\{\hat{U}^{\eta}_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}\right]$$

$$-\frac{\alpha_s^2}{4\pi^4}\int\frac{d^2z_3d^2z_4}{z_{34}^4}\,\frac{z_{12}^2z_{34}^2}{z_{13}^2z_{24}^2}\left[1+\frac{z_{12}^2z_{34}^2}{z_{13}^2z_{24}^2-z_{23}^2z_{14}^2}\right]\ln\frac{z_{13}^2z_{24}^2}{z_{14}^2z_{23}^2}$$

$$\times\,\mathrm{Tr}\{[T^a,T^b]\hat{U}^{\eta}_{z_1}T^{a'}T^{b'}\hat{U}^{\dagger\eta}_{z_2}+T^bT^a\hat{U}^{\eta}_{z_1}[T^{b'},T^{a'}]\hat{U}^{\dagger\eta}_{z_2}\}(\hat{U}^{\eta}_{z_3})^{aa'}(\hat{U}^{\eta}_{z_4}-\hat{U}^{\eta}_{z_3})^{bb'}$$

NLO kernel = Non-conformal term + Conformal term.

Non-conformal term is due to the non-invariant cutoff $\alpha<\sigma=e^{2\eta}$ in the rapidity of Wilson lines.

For the conformal composite dipole the result is Möbius invariant

Evolution equation for composite conformal dipoles in $\mathcal{N}=4$

$$\frac{d}{d\eta}\left[\mathrm{Tr}\{\hat{U}^{\eta}_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}\right]^{\mathrm{conf}}$$

$$= \frac{\alpha_s}{\pi^2}\int d^2z_3\,\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left[1-\frac{\alpha_s N_c}{4\pi}\frac{\pi^2}{3}\right]\left[\mathrm{Tr}\{T^a\hat{U}^{\eta}_{z_1}\hat{U}^{\dagger\eta}_{z_3}T^a\hat{U}_{z_3}\hat{U}^{\dagger\eta}_{z_2}\}-N_c\mathrm{Tr}\{\hat{U}^{\eta}_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}\right]^{\mathrm{conf}}$$

$$-\frac{\alpha_s^2}{4\pi^4}\int d^2z_3 d^2z_4\,\frac{z_{12}^2}{z_{13}^2 z_{24}^2 z_{34}^2}\left\{2\ln\frac{z_{12}^2 z_{34}^2}{z_{14}^2 z_{23}^2}+\left[1+\frac{z_{12}^2 z_{34}^2}{z_{13}^2 z_{24}^2-z_{14}^2 z_{23}^2}\right]\ln\frac{z_{13}^2 z_{24}^2}{z_{14}^2 z_{23}^2}\right\}$$

$$\times\,\mathrm{Tr}\{[T^a,T^b]\hat{U}^{\eta}_{z_1}T^{a'}T^{b'}\hat{U}^{\dagger\eta}_{z_2}+T^bT^a\hat{U}^{\eta}_{z_1}[T^{b'},T^{a'}]\hat{U}^{\dagger\eta}_{z_2}\}[(\hat{U}^{\eta}_{z_3})^{aa'}(\hat{U}^{\eta}_{z_4})^{bb'}-(z_4\to z_3)]$$

Now Möbius invariant!

Evolution equation for composite conformal dipoles in $\mathcal{N}=4$

$$\frac{d}{d\eta}\left[\mathrm{Tr}\{\hat{U}^{\eta}_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}\right]^{\mathrm{conf}}$$

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$$\times\,\mathrm{Tr}\{[T^a,T^b]\hat{U}^{\eta}_{z_1}T^{a'}T^{b'}\hat{U}^{\dagger\eta}_{z_2}+T^bT^a\hat{U}^{\eta}_{z_1}[T^{b'},T^{a'}]\hat{U}^{\dagger\eta}_{z_2}\}[(\hat{U}^{\eta}_{z_3})^{aa'}(\hat{U}^{\eta}_{z_4})^{bb'}-(z_4\to z_3)]$$

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$$-\frac{\alpha_s^2}{4\pi^4}\int d^2z_3 d^2z_4\,\frac{z_{12}^2}{z_{13}^2 z_{24}^2 z_{34}^2}\left\{2\ln\frac{z_{12}^2 z_{34}^2}{z_{14}^2 z_{23}^2}+\left[1+\frac{z_{12}^2 z_{34}^2}{z_{13}^2 z_{24}^2-z_{14}^2 z_{23}^2}\right]\ln\frac{z_{13}^2 z_{24}^2}{z_{14}^2 z_{23}^2}\right\}$$

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Now Möbius invariant!

NLO BFKL equation in $\mathcal{N}=4$ SYM

To find $A(x,y;x',y')$ we need the linearized (NLO BFKL) equation. With two-gluon accuracy

$$\hat{U}^{\eta}(x,y) = 1 - \frac{1}{N_c^2-1}\mathrm{Tr}\{\hat{U}_x^{\eta}\hat{U}_y^{\dagger\eta}\}$$

Conformal dipole operator in the BFKL approximation

$$\hat{U}^{\eta}_{\mathrm{conf}}(z_1,z_2) = \hat{U}^{\eta}(z_1,z_2)+\frac{\alpha_s N_c}{4\pi^2}\int d^2z\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\ln\frac{az_{12}^2}{z_{13}^2 z_{23}^2}[\hat{U}^{\eta}(z_1,z_3)+\hat{U}^{\eta}(z_2,z_3)-\hat{U}^{\eta}(z_1,z_2)]$$

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NLO BFKL equation in $\mathcal{N}=4$ SYM

To find $A(x,y;x',y')$ we need the linearized (NLO BFKL) equation. With two-gluon accuracy

$$\hat{U}^{\eta}(x,y) = 1 - \frac{1}{N_c^2-1}\mathrm{Tr}\{\hat{U}_x^{\eta}\hat{U}_y^{\dagger\eta}\}$$

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$$\hat{U}^{\eta}_{\mathrm{conf}}(z_1,z_2) = \hat{U}^{\eta}(z_1,z_2)+\frac{\alpha_s N_c}{4\pi^2}\int d^2z\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\ln\frac{az_{12}^2}{z_{13}^2 z_{23}^2}[\hat{U}^{\eta}(z_1,z_3)+\hat{U}^{\eta}(z_2,z_3)-\hat{U}^{\eta}(z_1,z_2)]$$

Define

$$\hat{U}^{a}_{\mathrm{conf}}(z_1,z_2) = \hat{U}^{\eta}(z_1,z_2)+\frac{\alpha_s N_c}{4\pi^2}\int d^2z\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\ln\frac{ae^{2\eta}z_{12}^2}{z_{13}^2 z_{23}^2}[\hat{U}^{\eta}(z_1,z_3)+\hat{U}^{\eta}(z_2,z_3)-\hat{U}^{\eta}(z_1,z_2)]+\ldots$$

such that $\frac{d}{d\eta}\hat{U}^{a}_{\mathrm{conf}}(z_1,z_2)=0$.

$\Rightarrow$ The evolution can be rewritten in terms of a

NLO BFKL equation in $\mathcal{N}=4$ SYM

To find $A(x,y;x',y')$ we need the linearized (NLO BFKL) equation. With two-gluon accuracy

$$\hat{U}^{\eta}(x,y) = 1 - \frac{1}{N_c^2-1}\mathrm{Tr}\{\hat{U}_x^{\eta}\hat{U}_y^{\dagger\eta}\}$$

Conformal dipole operator in the BFKL approximation

$$\hat{U}^{\eta}_{\mathrm{conf}}(z_1,z_2) = \hat{U}^{\eta}(z_1,z_2)+\frac{\alpha_s N_c}{4\pi^2}\int d^2z\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\ln\frac{az_{12}^2}{z_{13}^2 z_{23}^2}[\hat{U}^{\eta}(z_1,z_3)+\hat{U}^{\eta}(z_2,z_3)-\hat{U}^{\eta}(z_1,z_2)]$$

Define

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such that $\frac{d}{d\eta}\hat{U}^{a}_{\mathrm{conf}}(z_1,z_2)=0$.

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NLO BFKL equation in $\mathcal{N}=4$ SYM

NLO BFKL

$$a\frac{d}{da}\hat{\mathcal{U}}^a_{\rm conf}(z_1,z_2)$$
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$$+\frac{\alpha_s^2 N_c^2}{8\pi^4}\int\frac{d^2z_3 d^2z_4}{z_{34}^4}\,\frac{z_{12}^2 z_{34}^2}{z_{13}^2 z_{24}^2}\left\{2\ln\frac{z_{12}^2 z_{34}^2}{z_{14}^2 z_{23}^2}+\left[1+\frac{z_{12}^2 z_{34}^2}{z_{13}^2 z_{24}^2-z_{14}^2 z_{23}^2}\right]\ln\frac{z_{13}^2 z_{24}^2}{z_{14}^2 z_{23}^2}\right\}\hat{\mathcal{U}}^a_{\rm conf}(z_3,z_4)$$
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Eigenfunctions are determined by conformal invariance

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$$+\frac{\alpha_s^2 N_c^2}{8\pi^4}\int\frac{d^2z_3 d^2z_4}{z_{34}^4}\,\frac{z_{12}^2 z_{34}^2}{z_{13}^2 z_{24}^2}\left\{2\ln\frac{z_{12}^2 z_{34}^2}{z_{14}^2 z_{23}^2}+\left[1+\frac{z_{12}^2 z_{34}^2}{z_{13}^2 z_{24}^2-z_{14}^2 z_{23}^2}\right]\ln\frac{z_{13}^2 z_{24}^2}{z_{14}^2 z_{23}^2}\right\}\hat{\mathcal{U}}^a_{\rm conf}(z_3,z_4)$$

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$$\hat{\mathcal{U}}^a_{\rm conf}(z_1,z_2) = \sum_{n=0}^{\infty}\int d^2z_0\int d\nu\, E_{\nu,n}(z_{10},z_{20})\hat{\mathcal{U}}^a_{z_0,\nu,n} \quad\Rightarrow\quad a\frac{d}{da}\hat{\mathcal{U}}^a_{z_0,\nu,n} = \omega(n,\nu)\hat{\mathcal{U}}^a_{z_0,\nu,n}$$

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NLO BFKL equation in $\mathcal{N}=4$ SYM

NLO BFKL

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The expansion in eigenfunctions

$$\hat{\mathcal{U}}^a_{\rm conf}(z_1,z_2) = \sum_{n=0}^{\infty}\int d^2z_0\int d\nu\, E_{\nu,n}(z_{10},z_{20})\hat{\mathcal{U}}^a_{z_0,\nu,n} \quad\Rightarrow\quad a\frac{d}{da}\hat{\mathcal{U}}^a_{z_0,\nu,n} = \omega(n,\nu)\hat{\mathcal{U}}^a_{z_0,\nu,n}$$

$\omega(n,\nu)\equiv$ pomeron intercept = eigenvalue of the BFKL equation

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$$\omega(n,\nu) = \frac{\alpha_s}{\pi} N_c \left[\chi(n, \frac{1}{2} + i\nu) + \frac{\alpha_s N_c}{4\pi} \delta(n, \frac{1}{2} + i\nu) \right],$$

$$\delta(n,\gamma) = 6\zeta(3) - \frac{\pi^2}{3}\chi(n,\gamma) - \chi''(n,\gamma) - 2\Phi(n,\gamma) - 2\Phi(n,1-\gamma)$$

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NLO impact factor

$$(x-y)^4 T\{\hat{O}(x)\hat{O}(y)\} = \frac{(x-y)^4}{\pi^2}\int d^2z_1 d^2z_2 \frac{(x_+y_+)^{-2}}{z_1^2 z_2^2}\left\{\hat{U}^{\text{conf}}\right.$$

$$\left. -\frac{\lambda}{2\pi^2}\int \frac{d^2z_3\, z_{12}^2}{z_{13}^2 z_{23}^2}\left[\ln\frac{a z_{12}^2 z_3^2}{z_{13}^2 z_{23}^2} - i\pi\right]\left[\hat{U}^{\text{conf}}(z_1,z_3)+\hat{U}^{\text{conf}}(z_2,z_3)-\hat{U}^{\text{conf}}(z_1,z_2)\right]\right\}$$

With two-gluon accuracy ($\mathcal{R} \equiv \frac{(x-y)^2 z_{12}^2}{x_+y_+ z_1 z_2}$ - conformal ratio)

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The impact factor should not scale with energy $\Rightarrow$ $a = \frac{x_+y_+}{(x-y)^2}$ (analog of $\mu^2 = Q^2$ in DIS)

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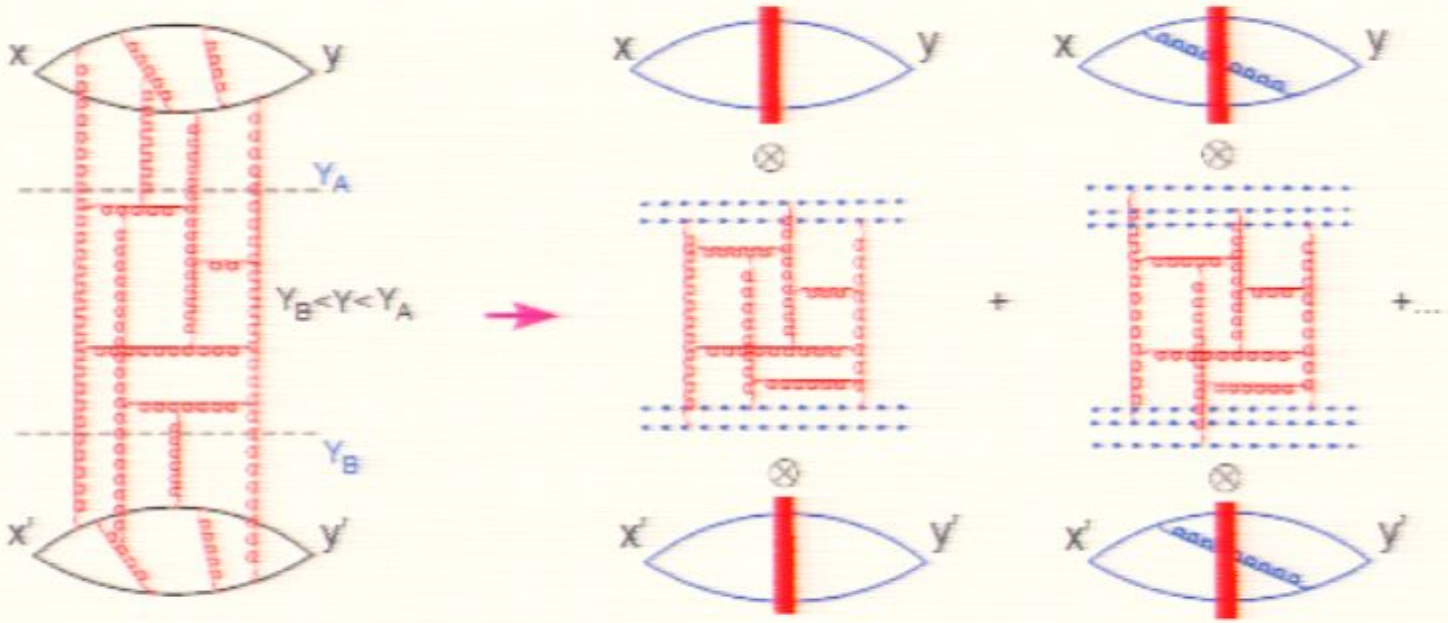
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NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity



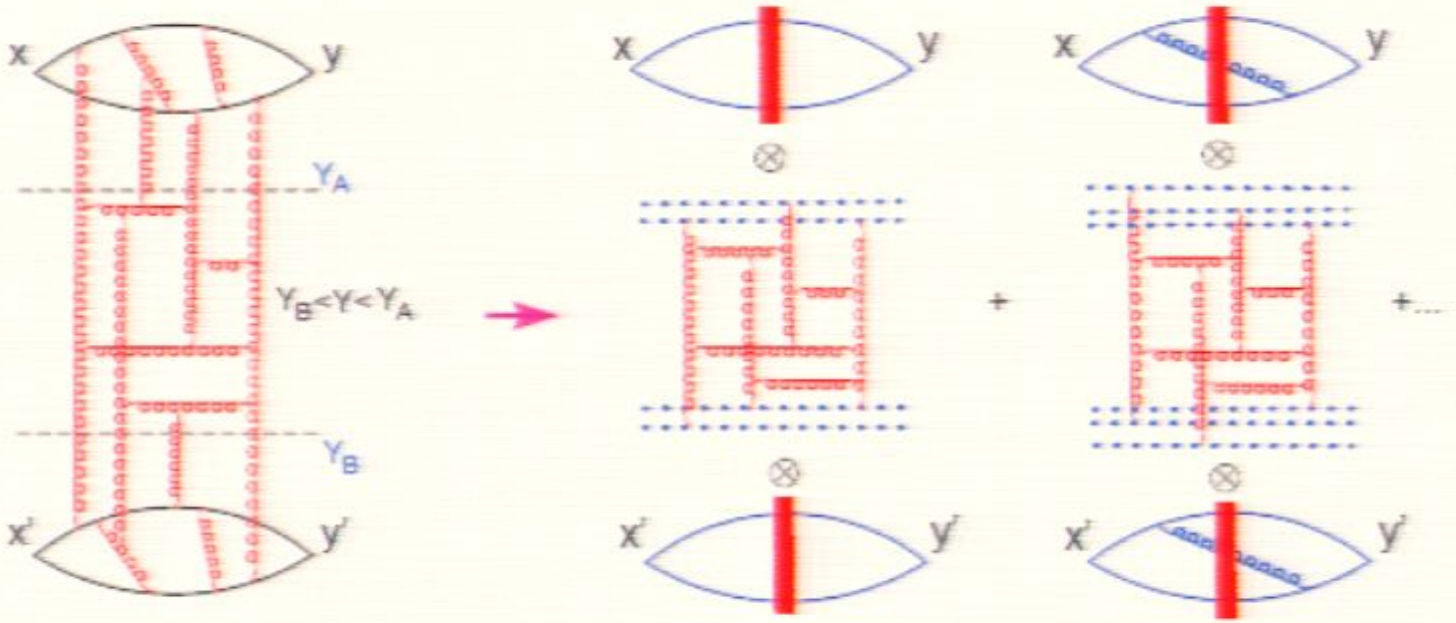
$$(x-y)^4(x'-y')^4\langle T\{\hat{\mathcal{O}}(x)\hat{\mathcal{O}}^\dagger(y)\hat{\mathcal{O}}(x')\hat{\mathcal{O}}^\dagger(y')\}\rangle$$

$$= \int d^2z_{1\perp}d^2z_{2\perp}d^2z'_{1\perp}d^2z'_{2\perp}\,\mathrm{IF}^{a_0}(x,y;z_1,z_2)[\mathrm{DD}]^{a_0,b_0}(z_1,z_2;z'_1,z'_2)\mathrm{IF}^{b_0}(x',y';z'_1,z'_2)$$

$a_0 = \frac{x_+y_+}{(x-y)^2}$, $b_0 = \frac{x'_-y'_-}{(x'-y')^2}$ $\Leftrightarrow$ impact factors do not scale with energy

$\Rightarrow$ all energy dependence is contained in $[\mathrm{DD}]^{a_0,b_0}$ $(a_0b_0 = R)$

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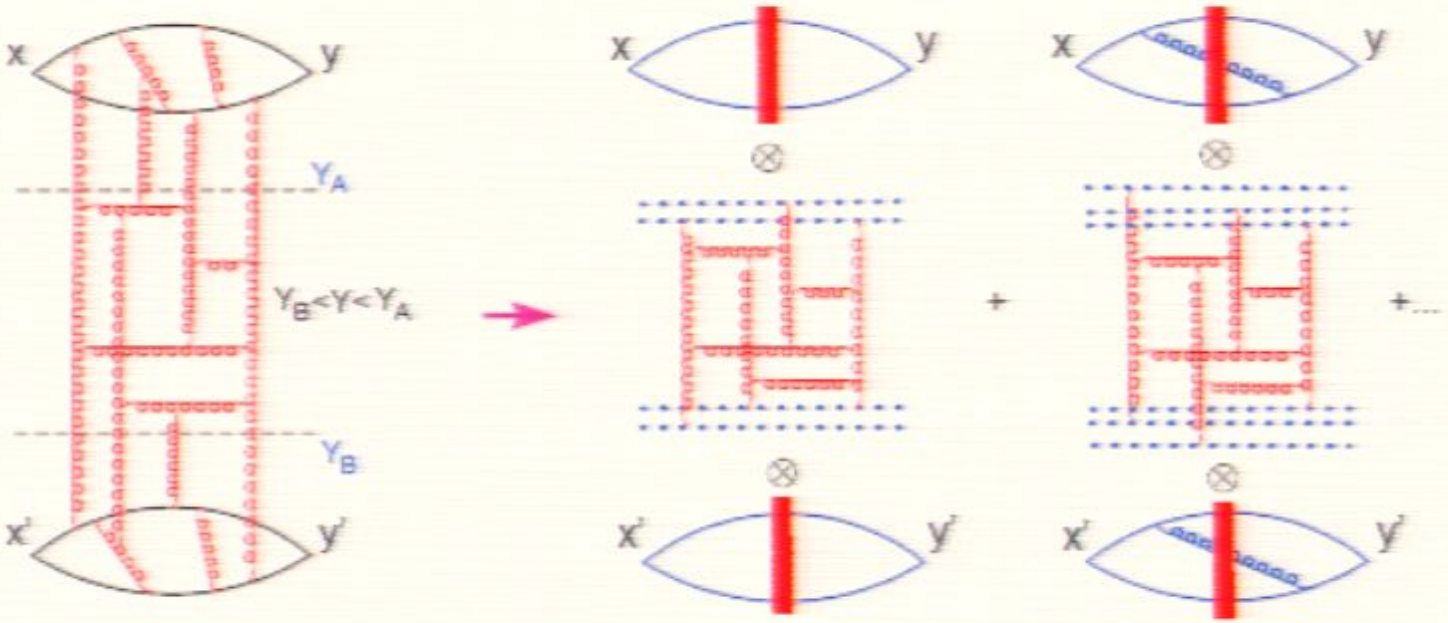


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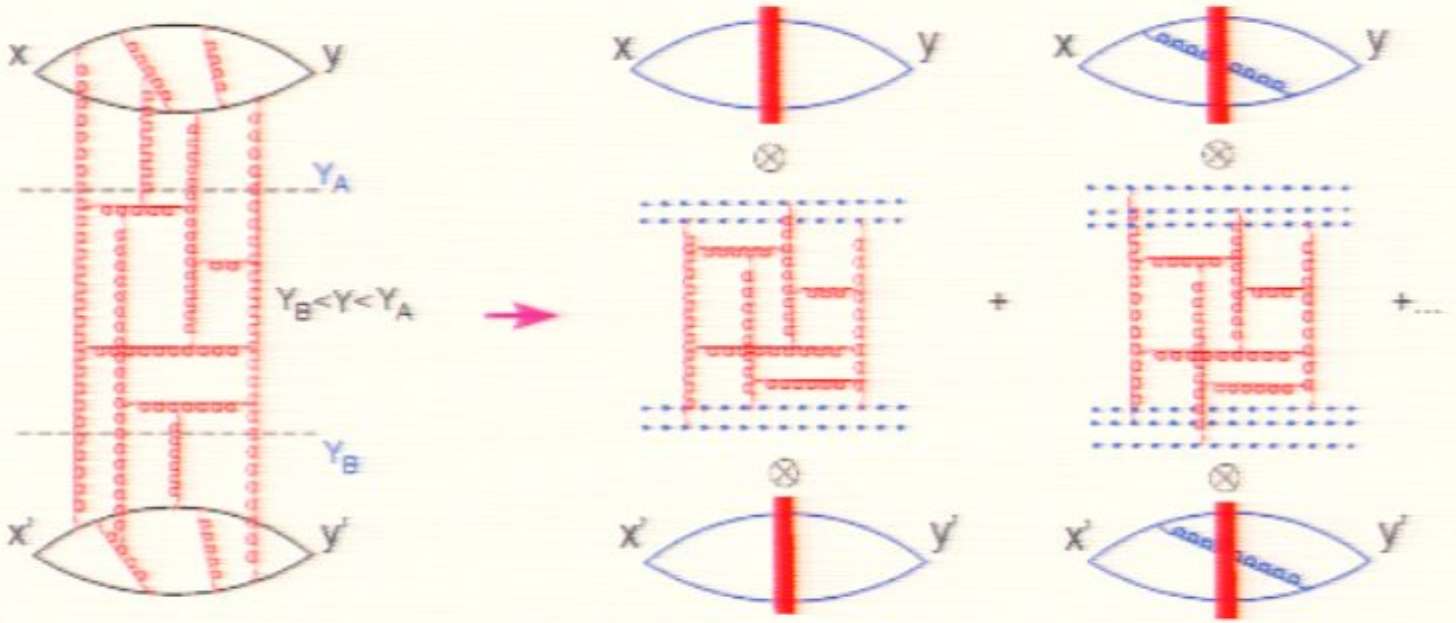
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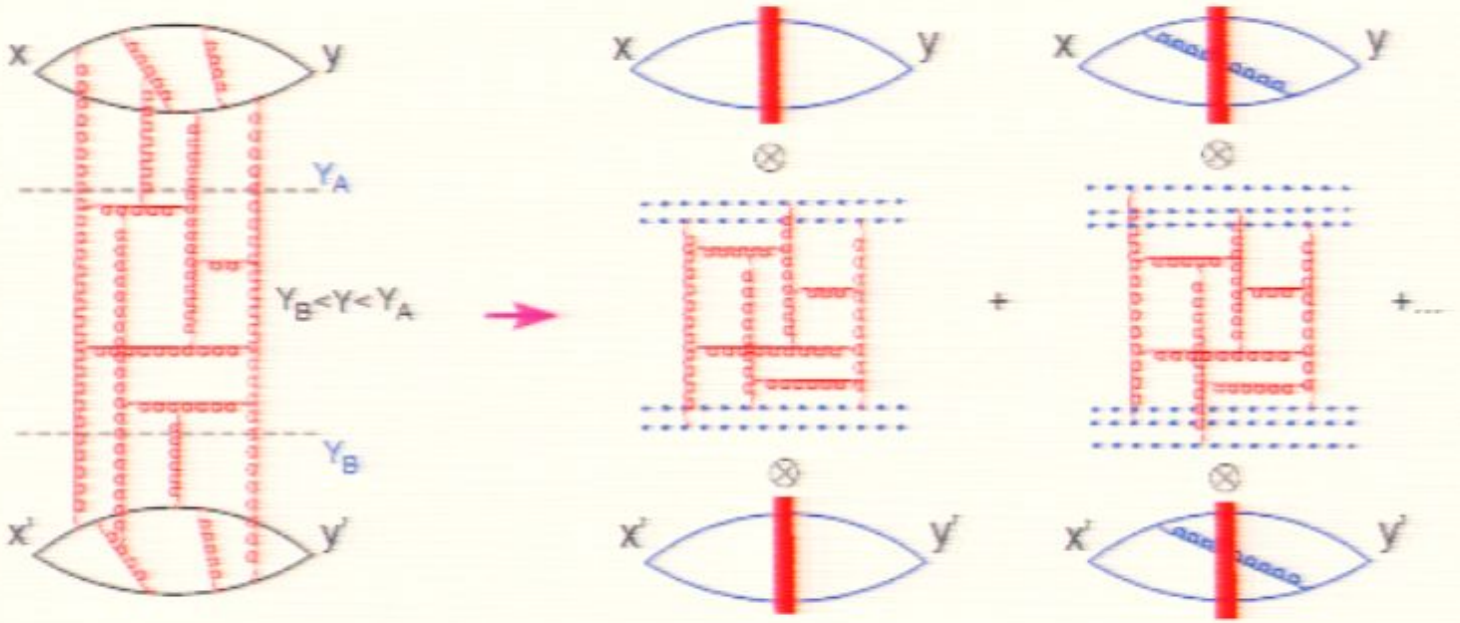
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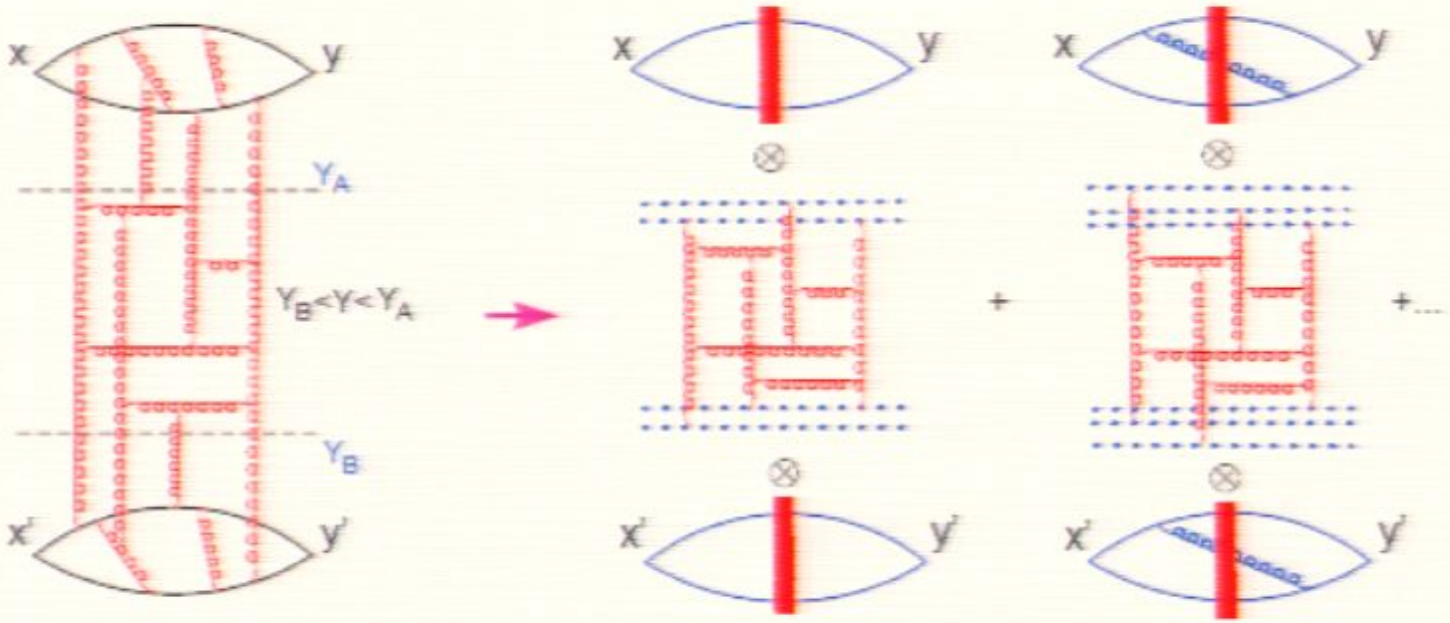
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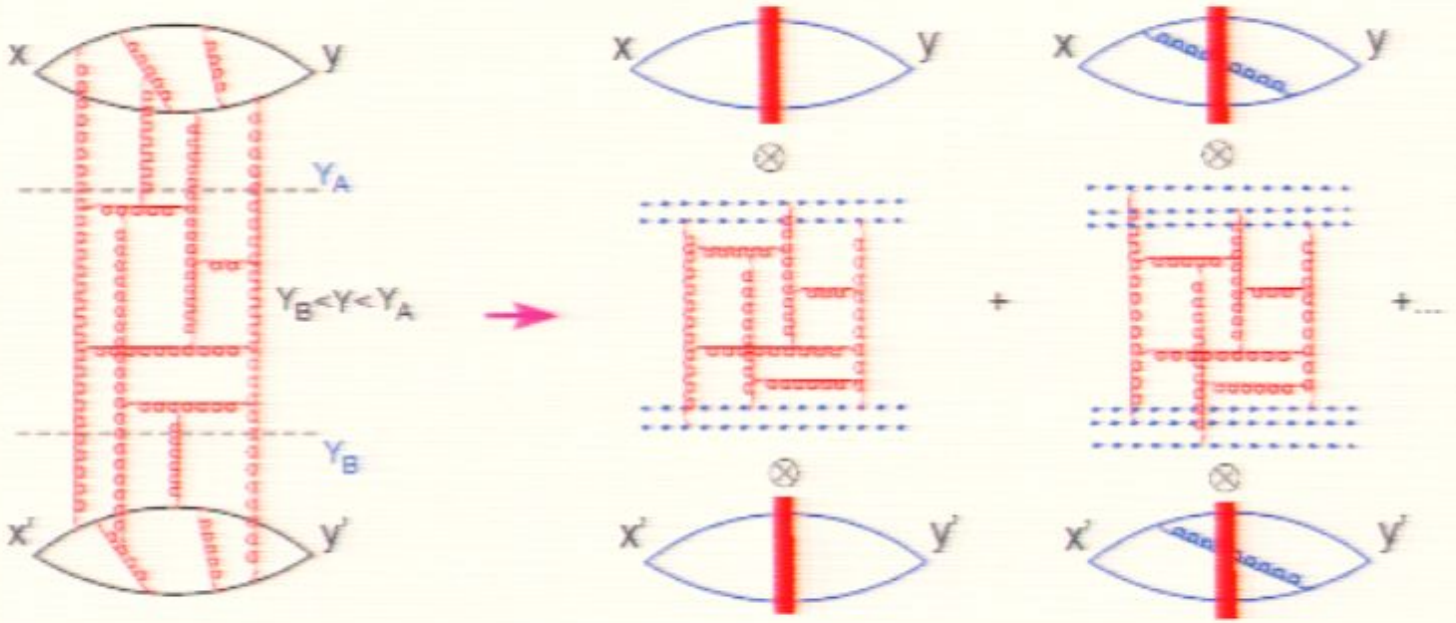
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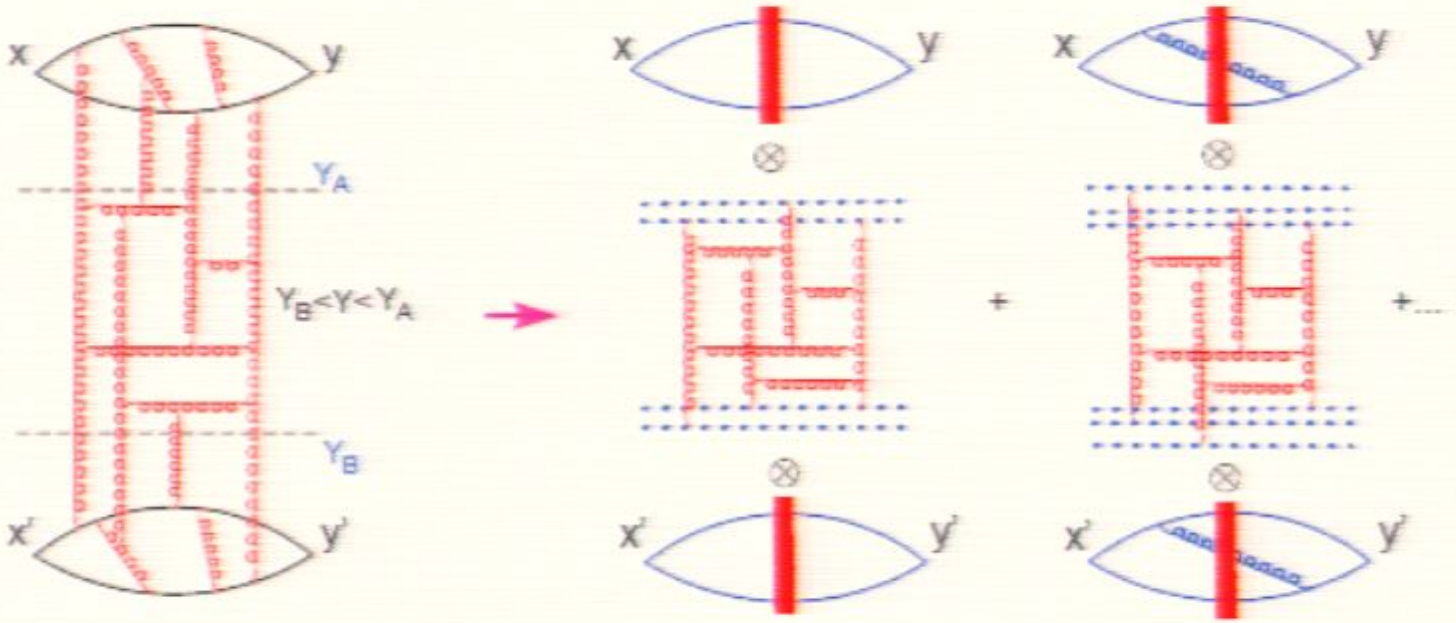
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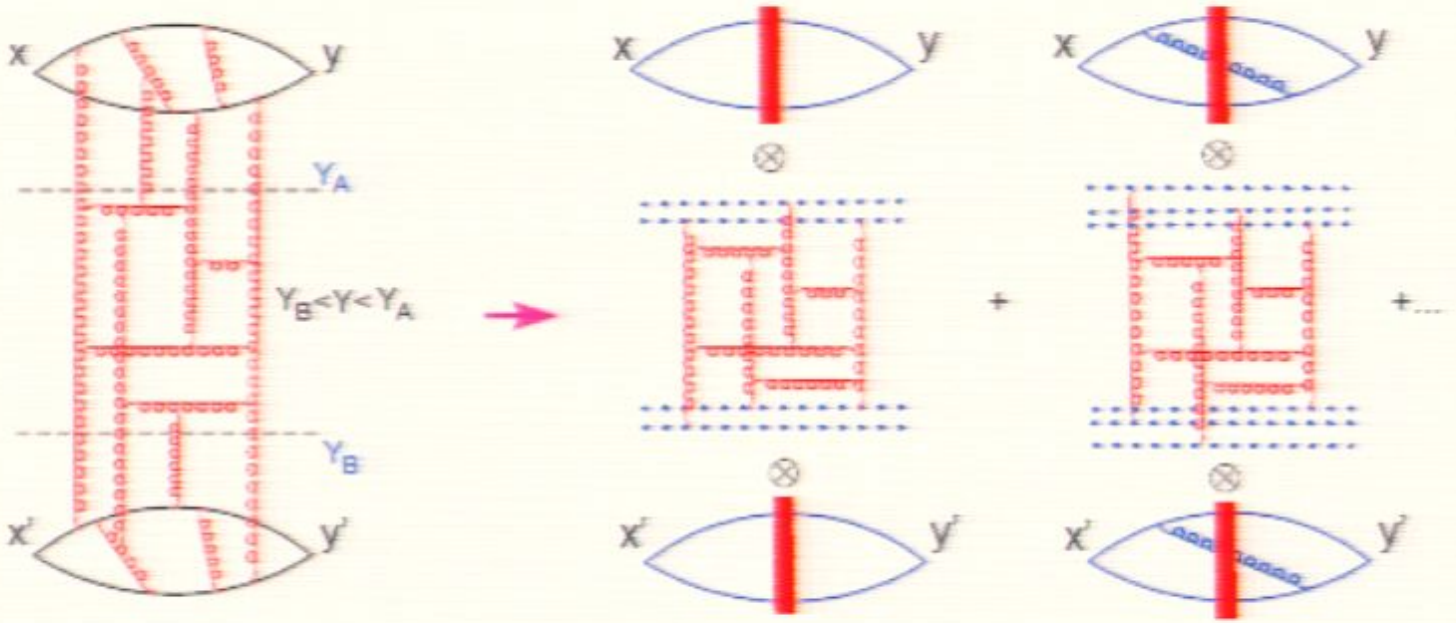
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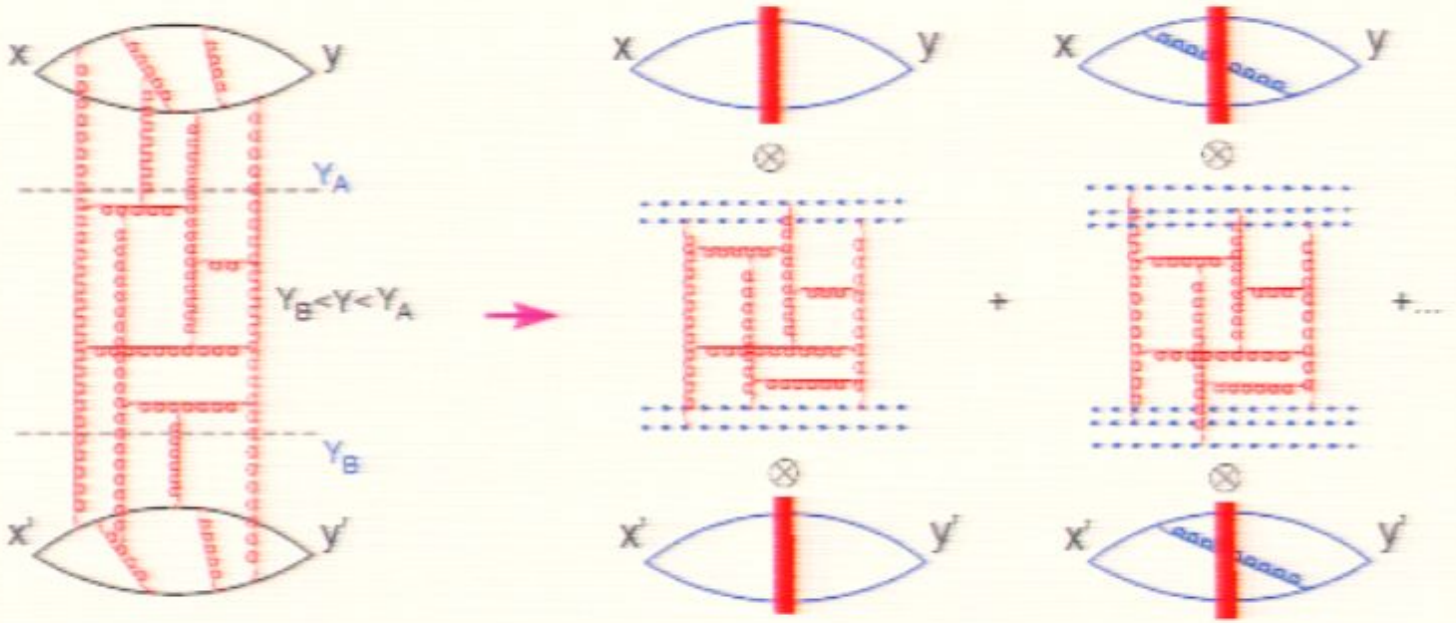


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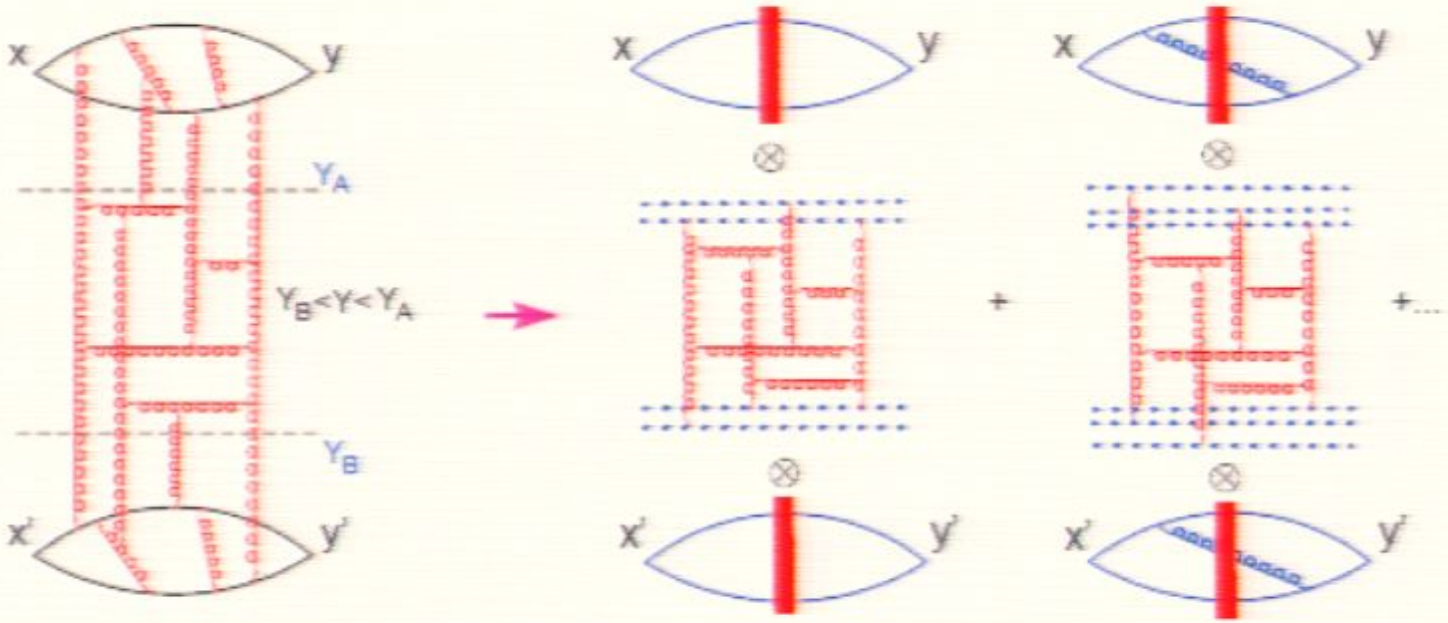


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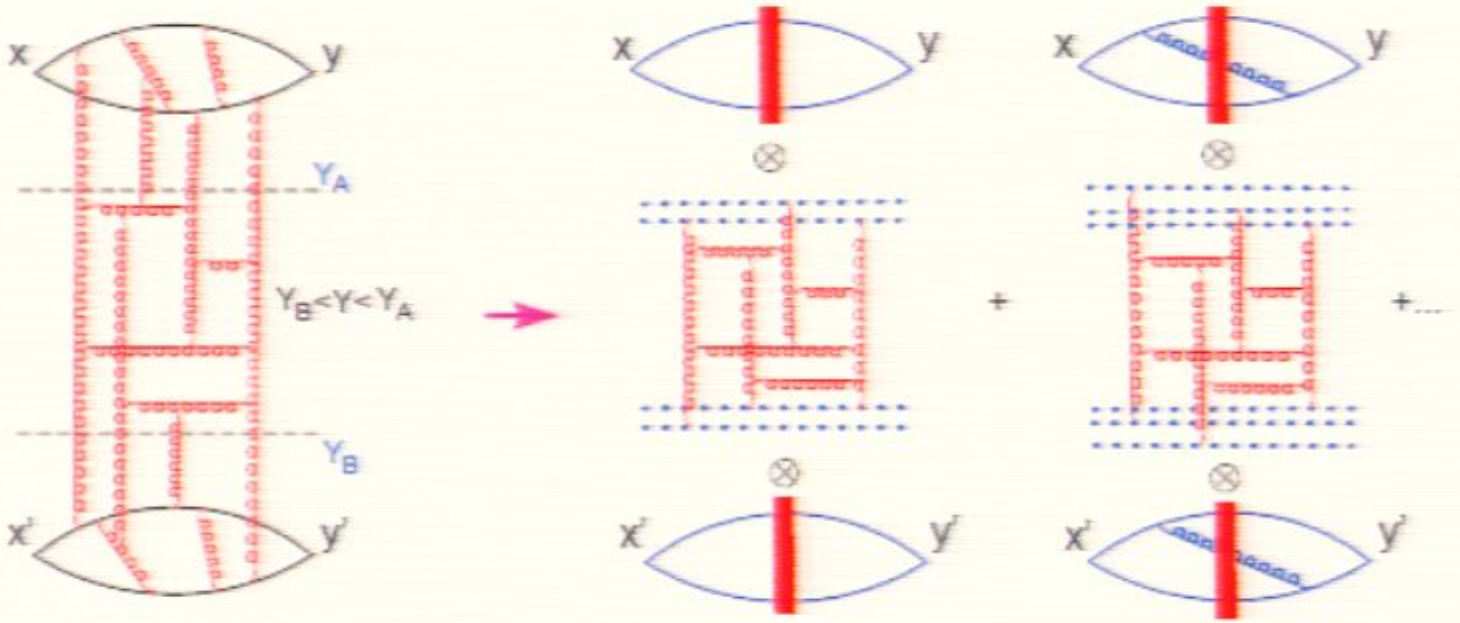
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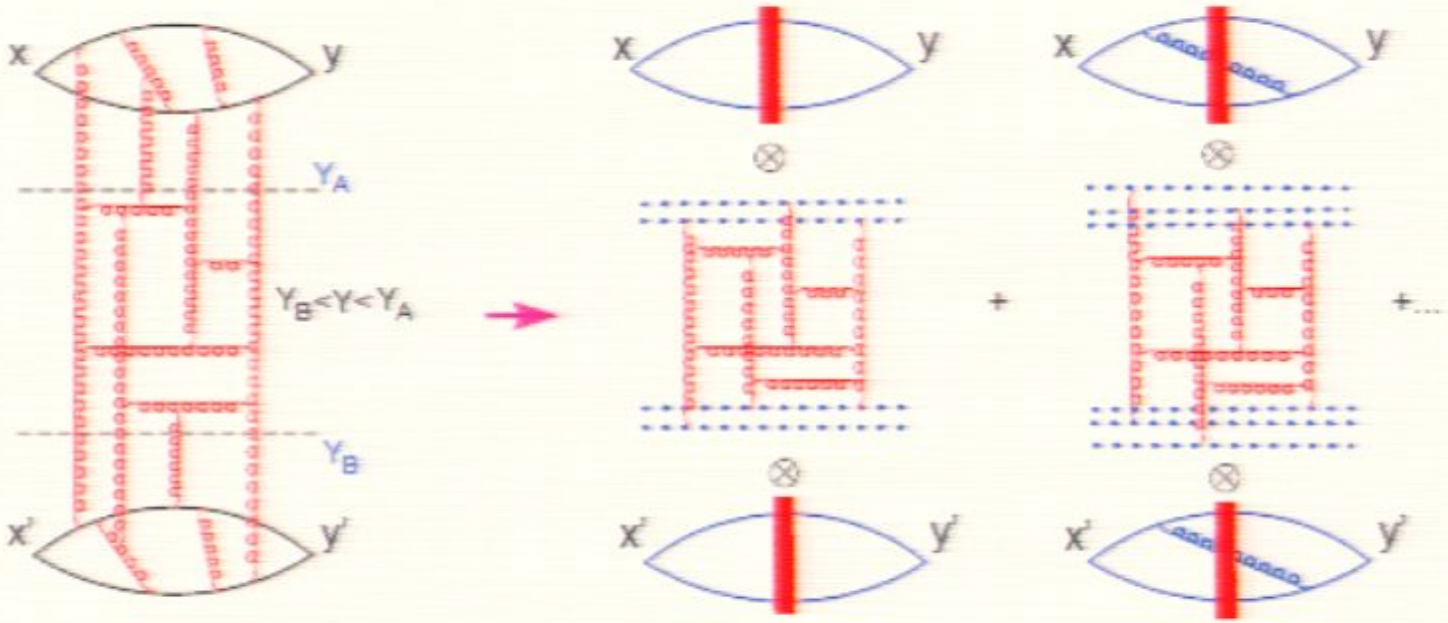
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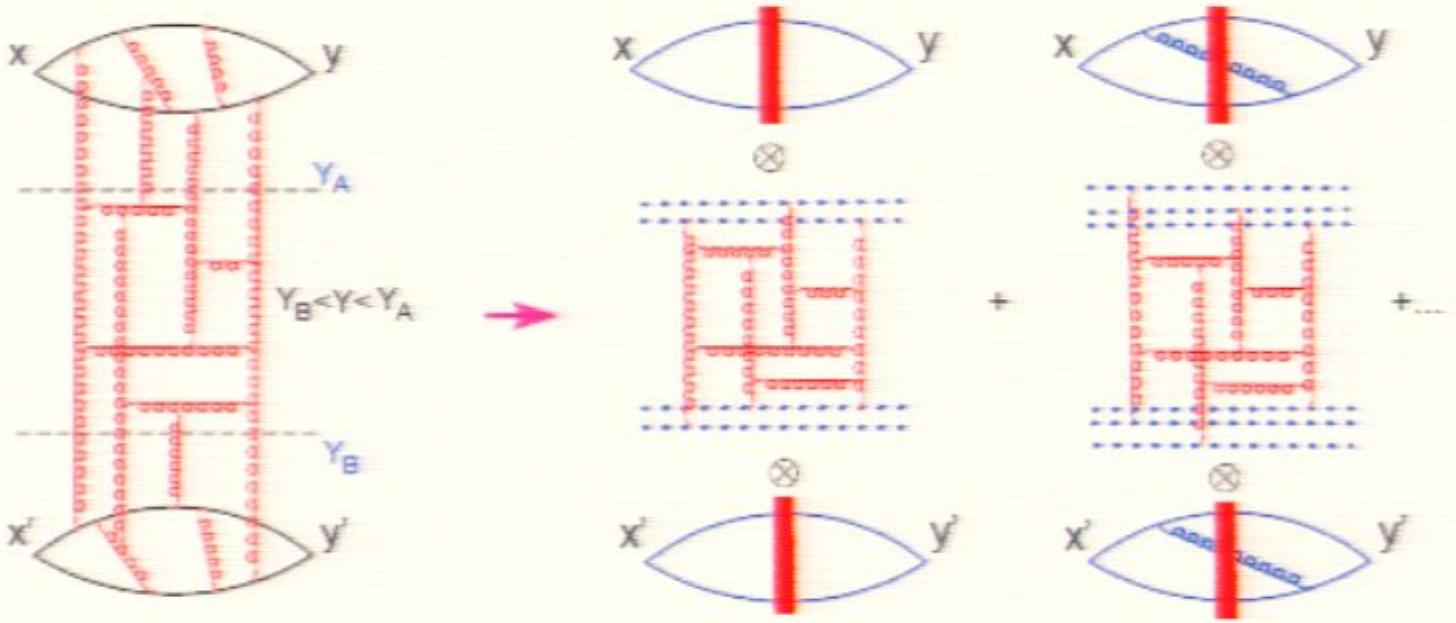
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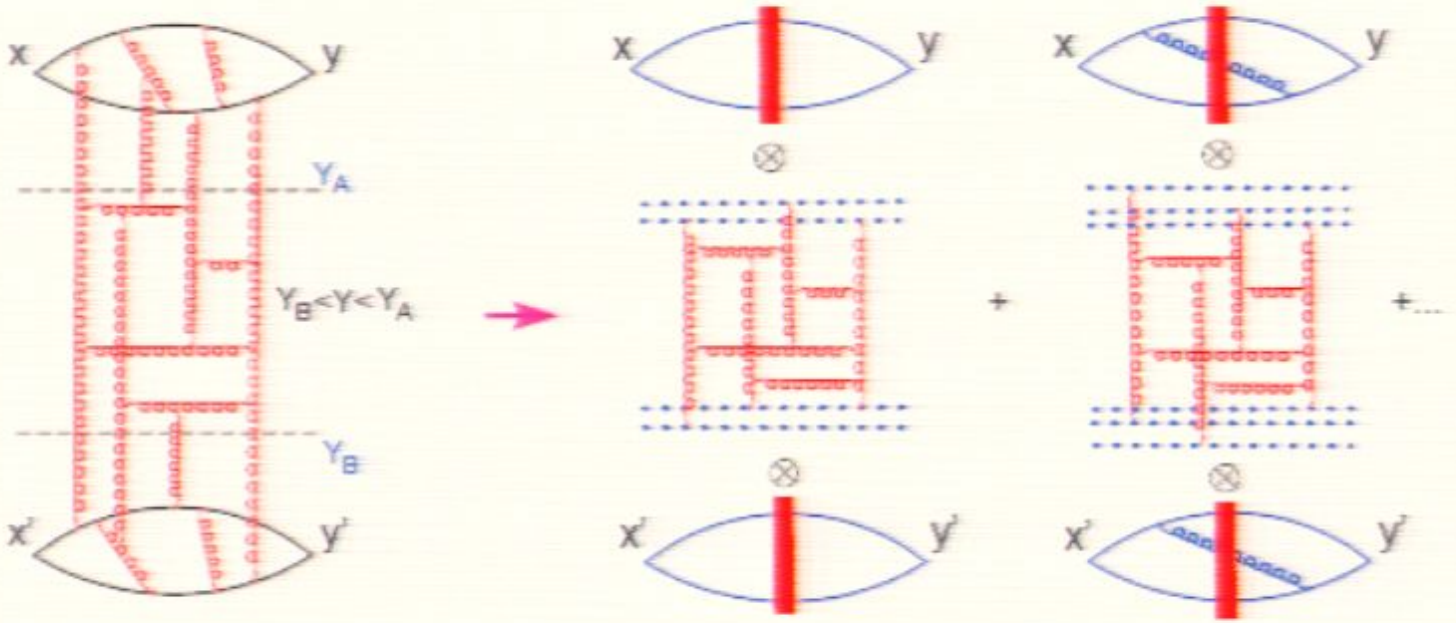
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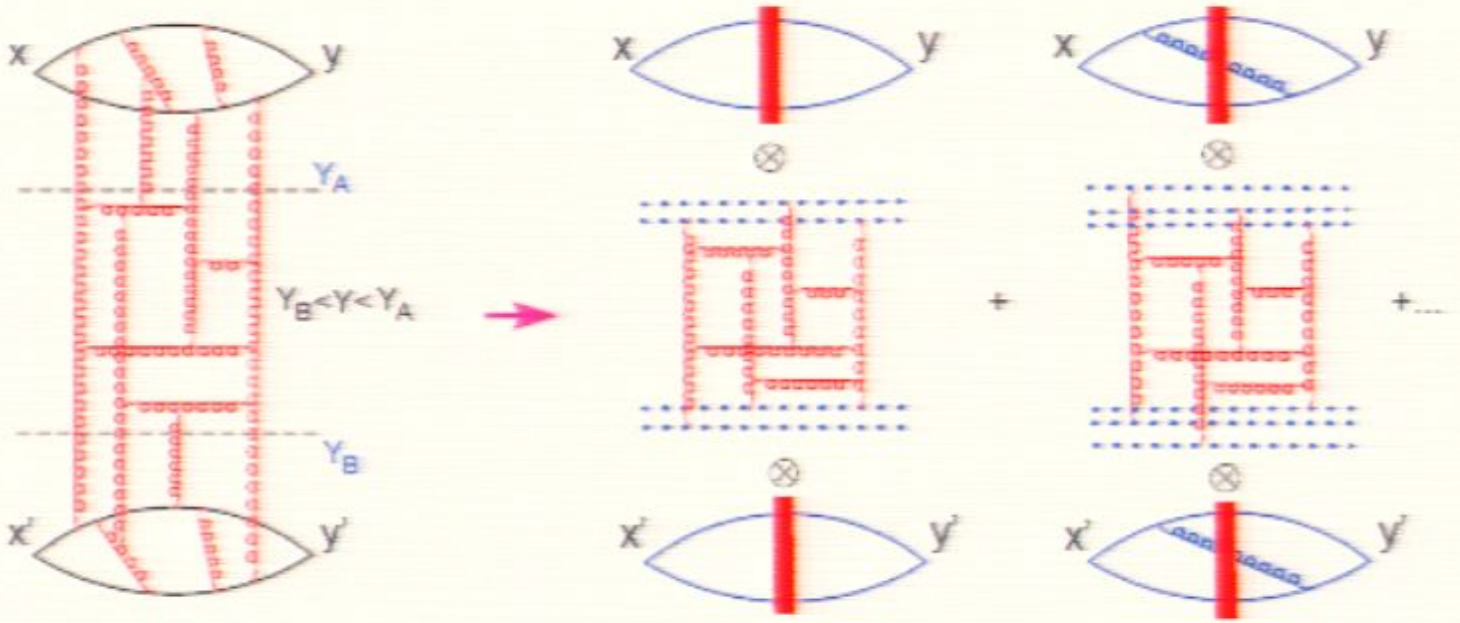
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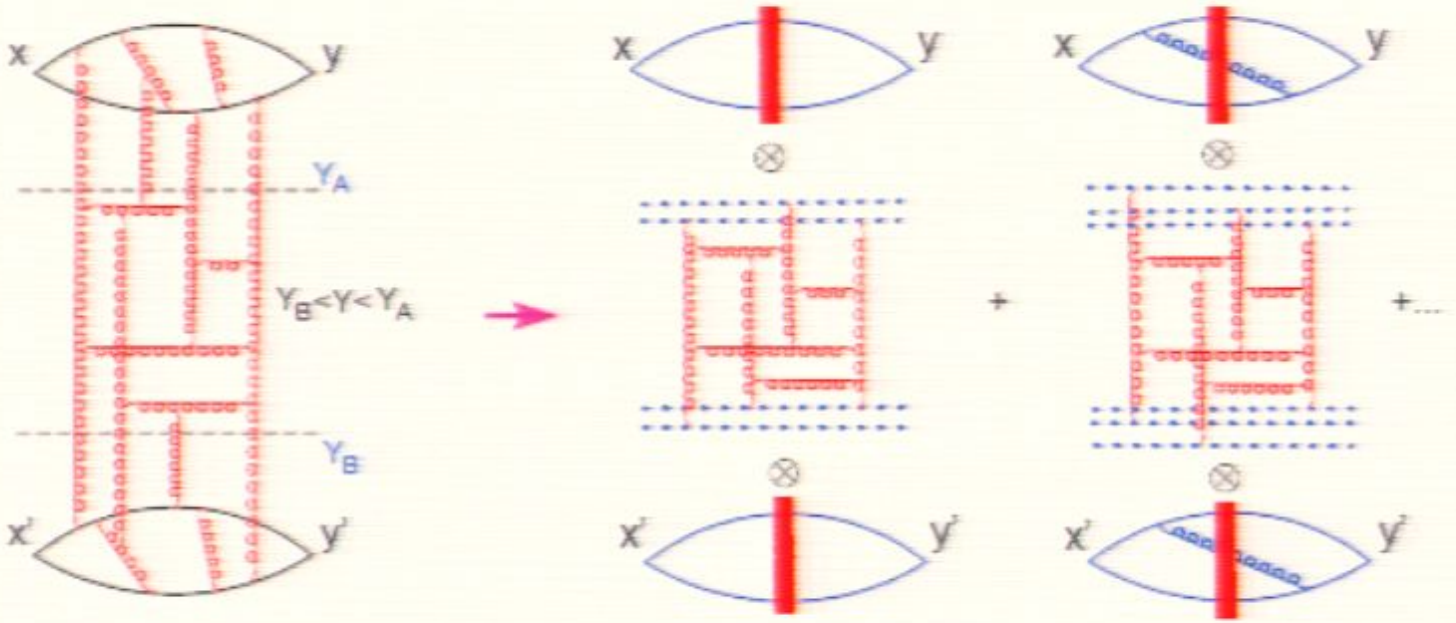
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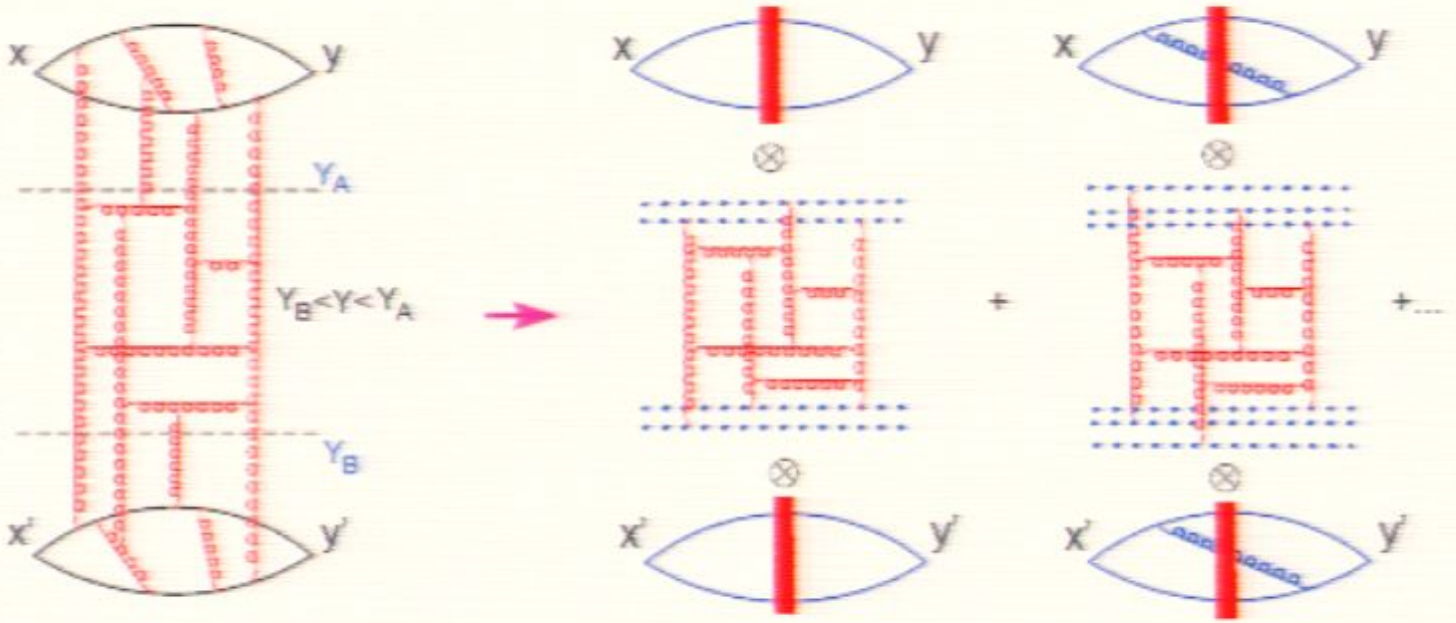
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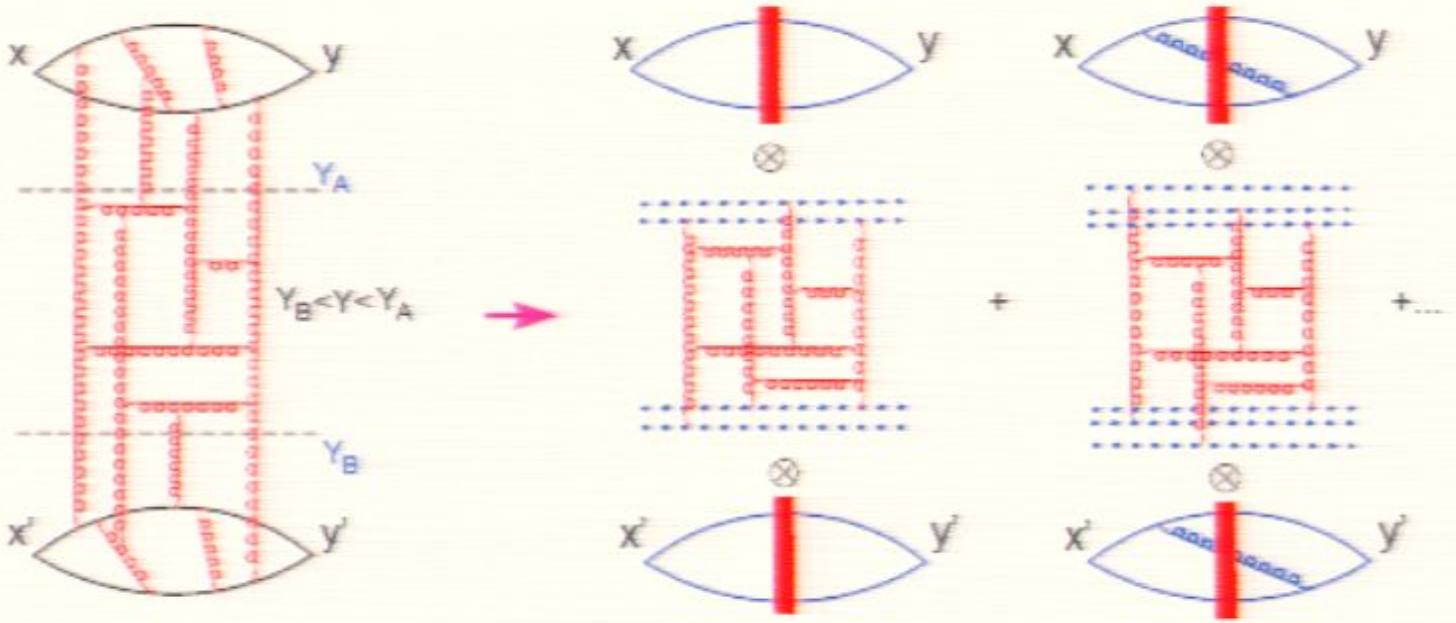


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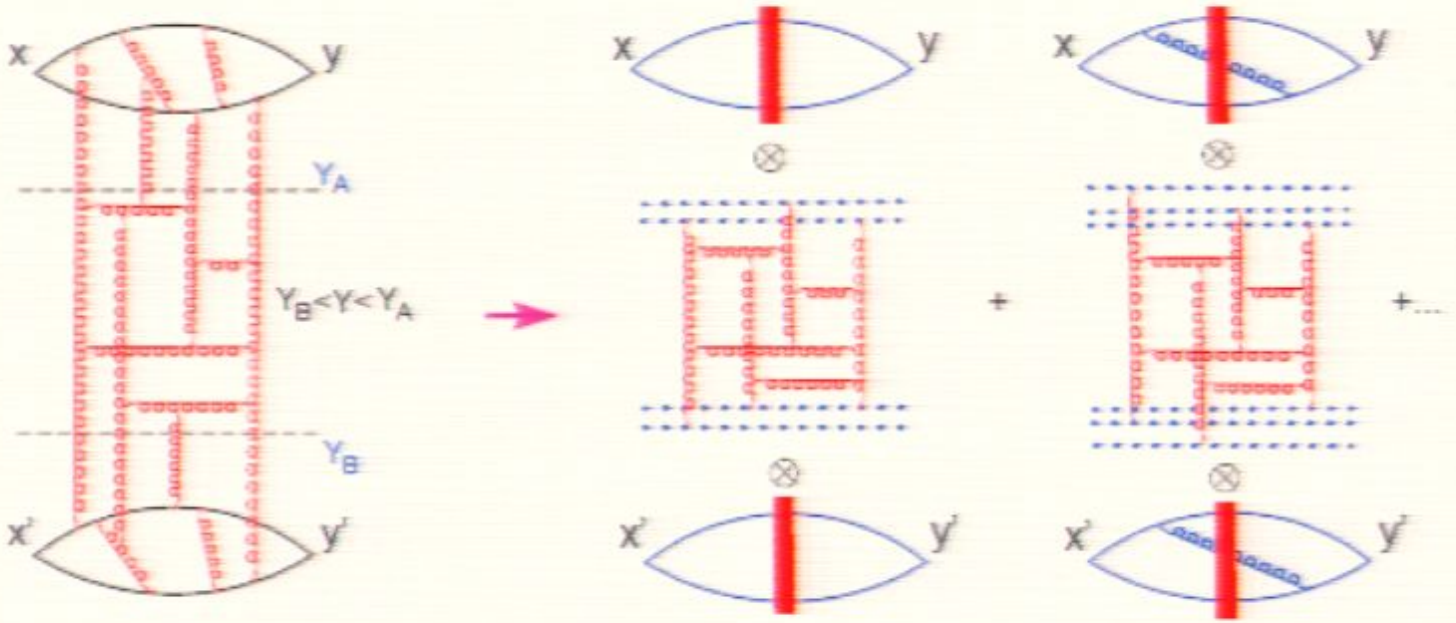
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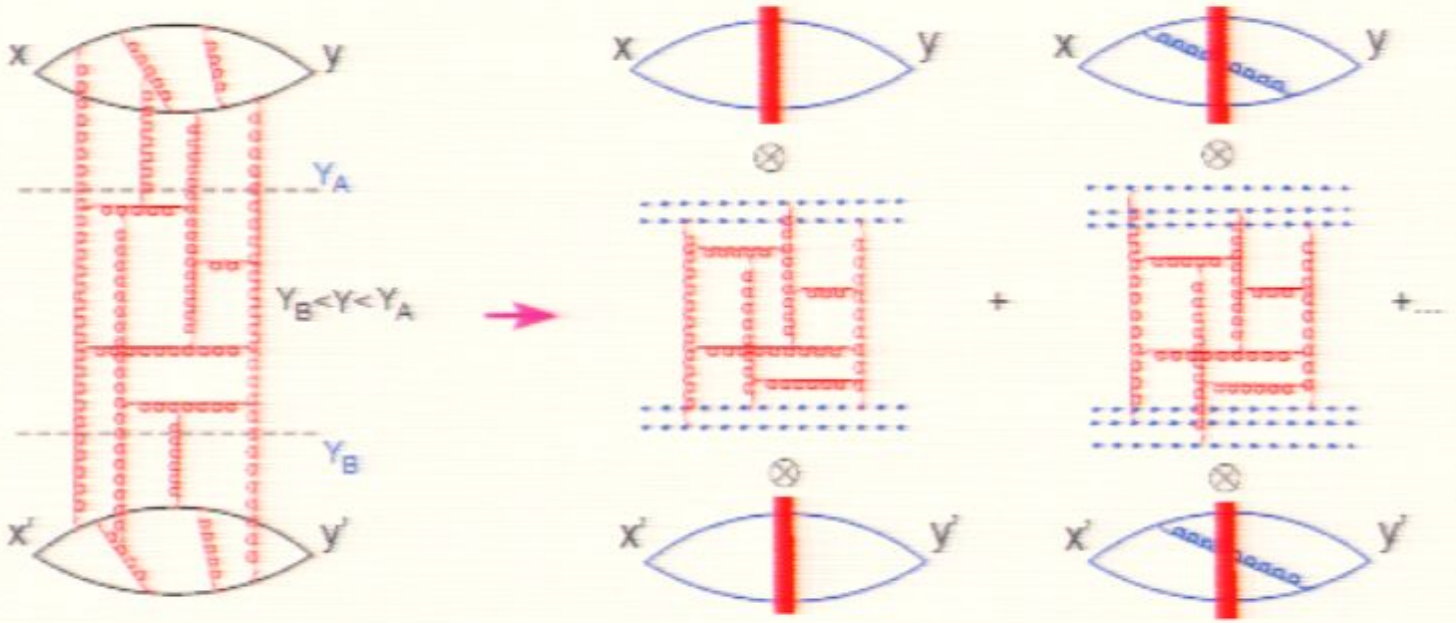
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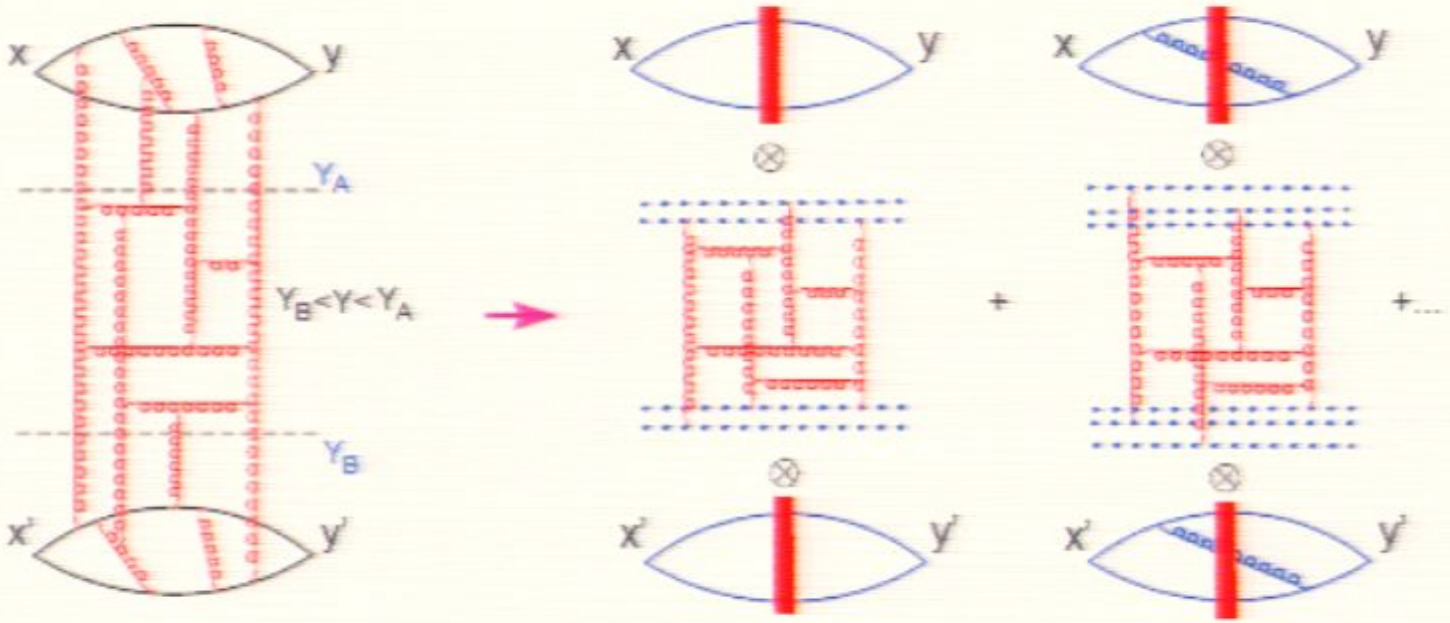
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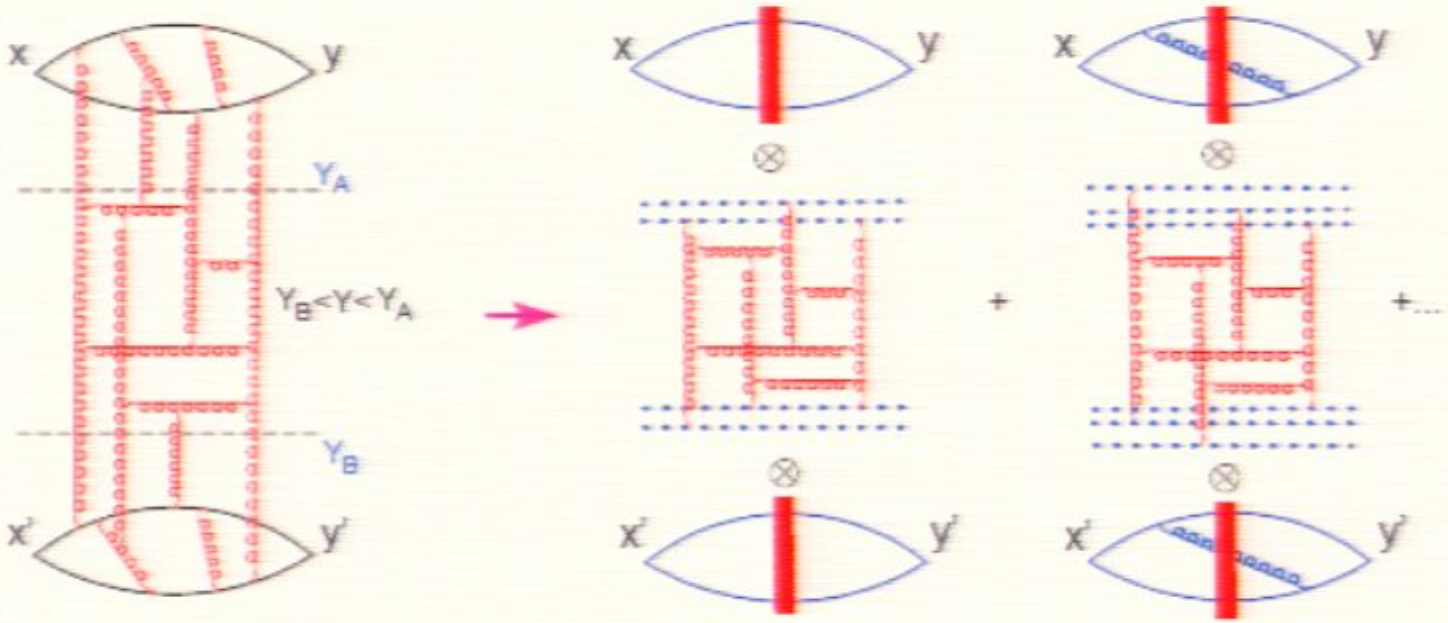
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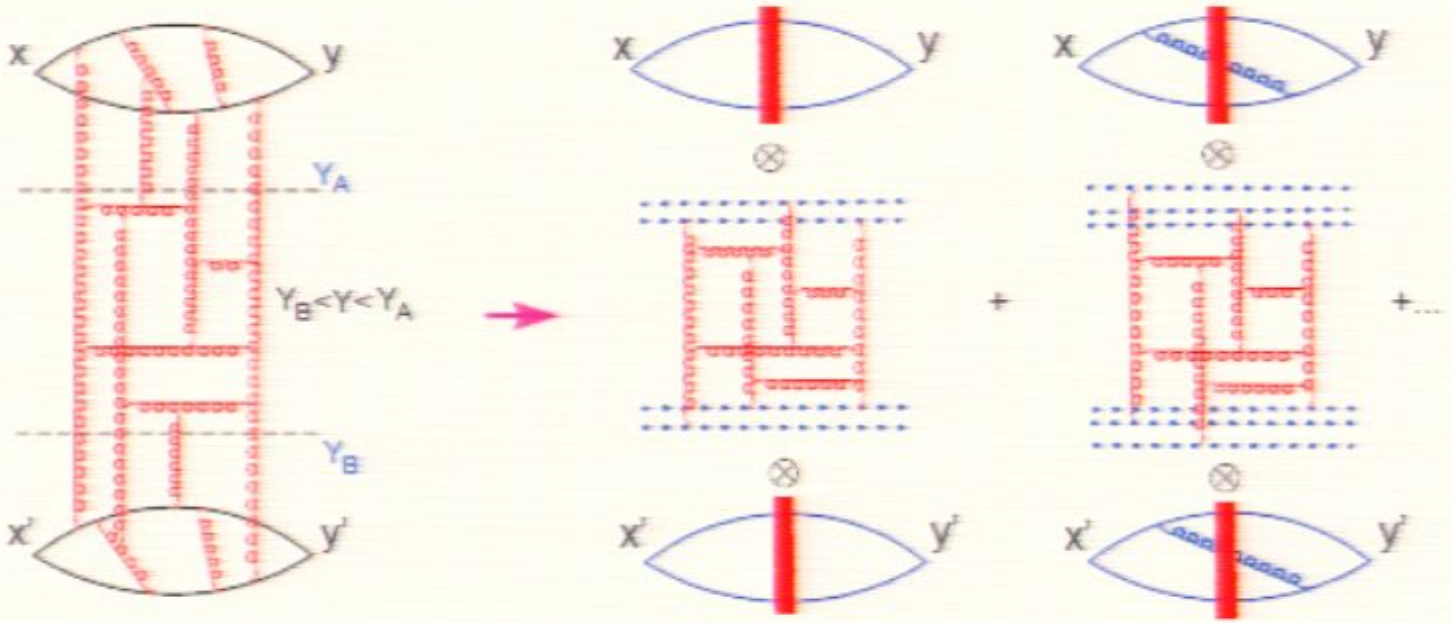
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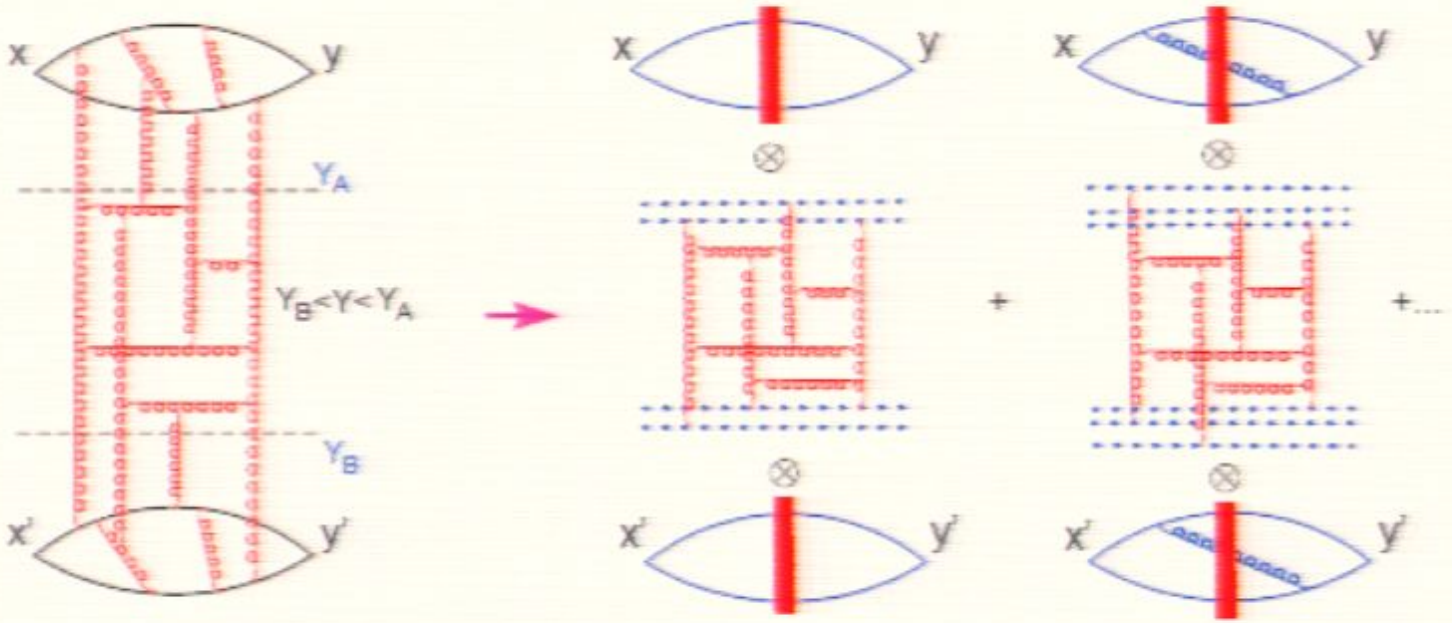
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$a_0 = \frac{x_+y_+}{(x-y)^2}$, $b_0 = \frac{x'_-y'_-}{(x'-y')^2}$ $\Leftrightarrow$ impact factors do not scale with energy

$\Rightarrow$ all energy dependence is contained in $[\mathrm{DD}]^{a_0,b_0}$ $(a_0b_0 = R)$

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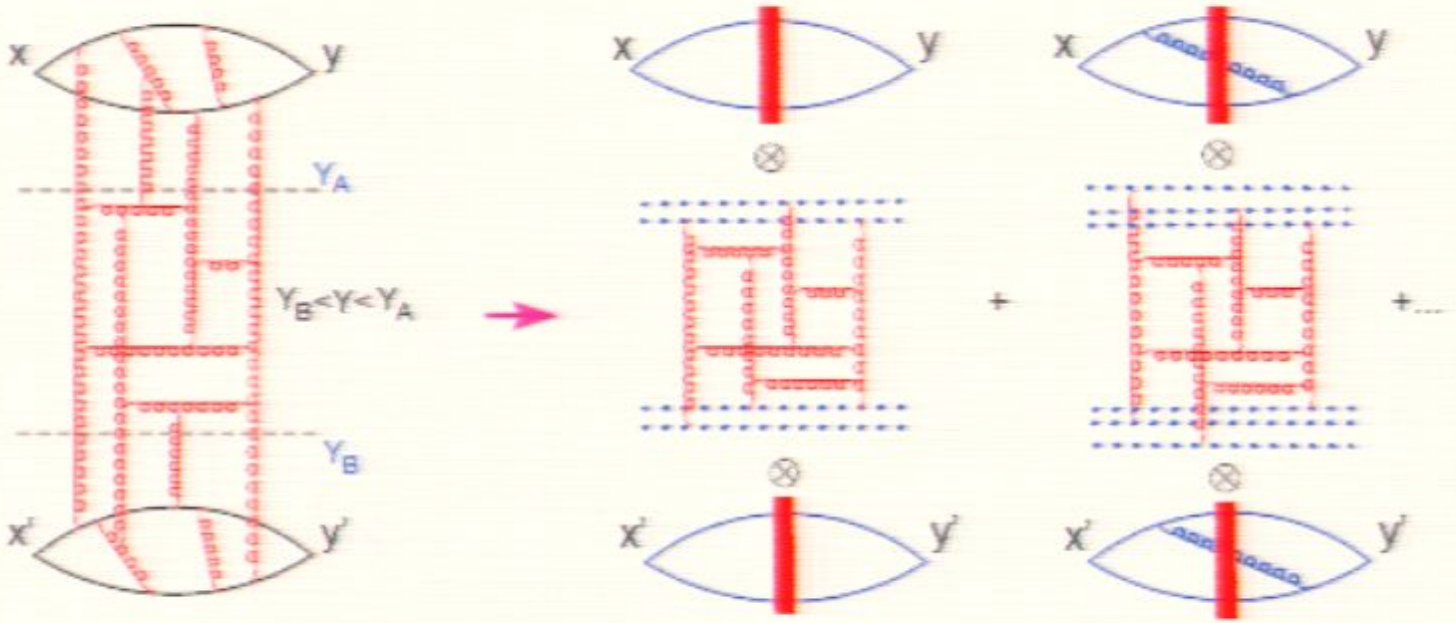


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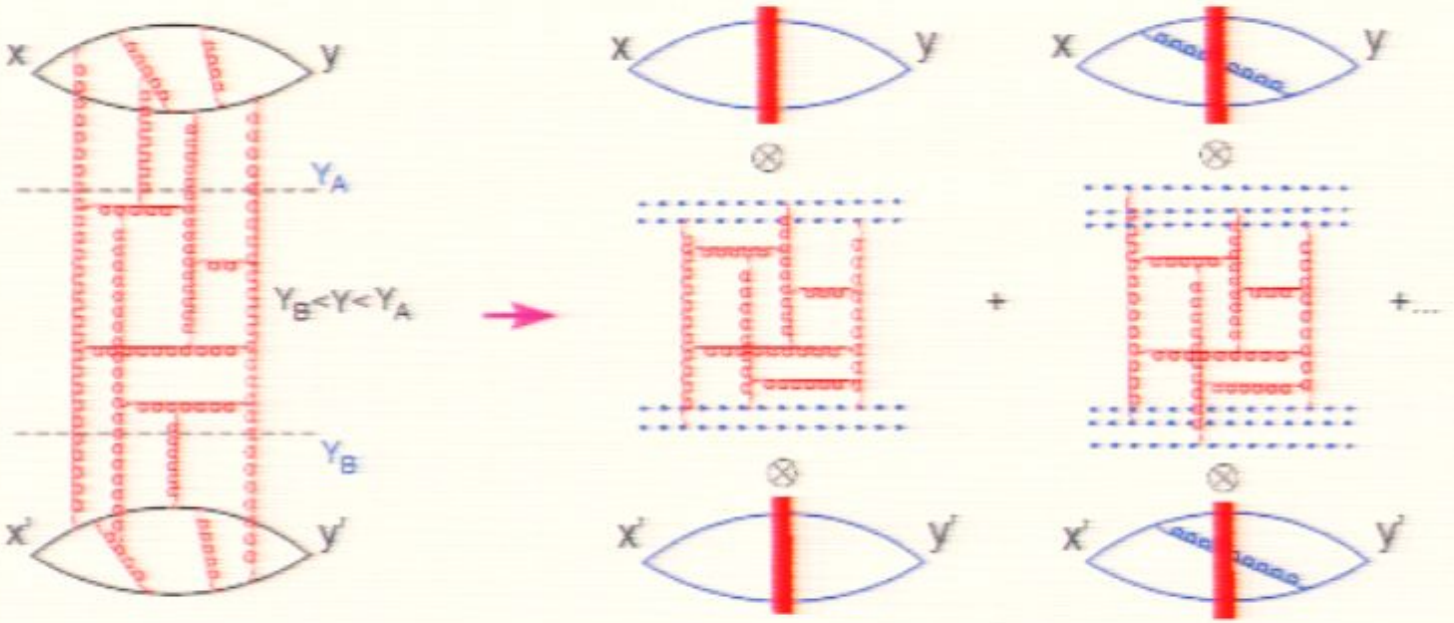
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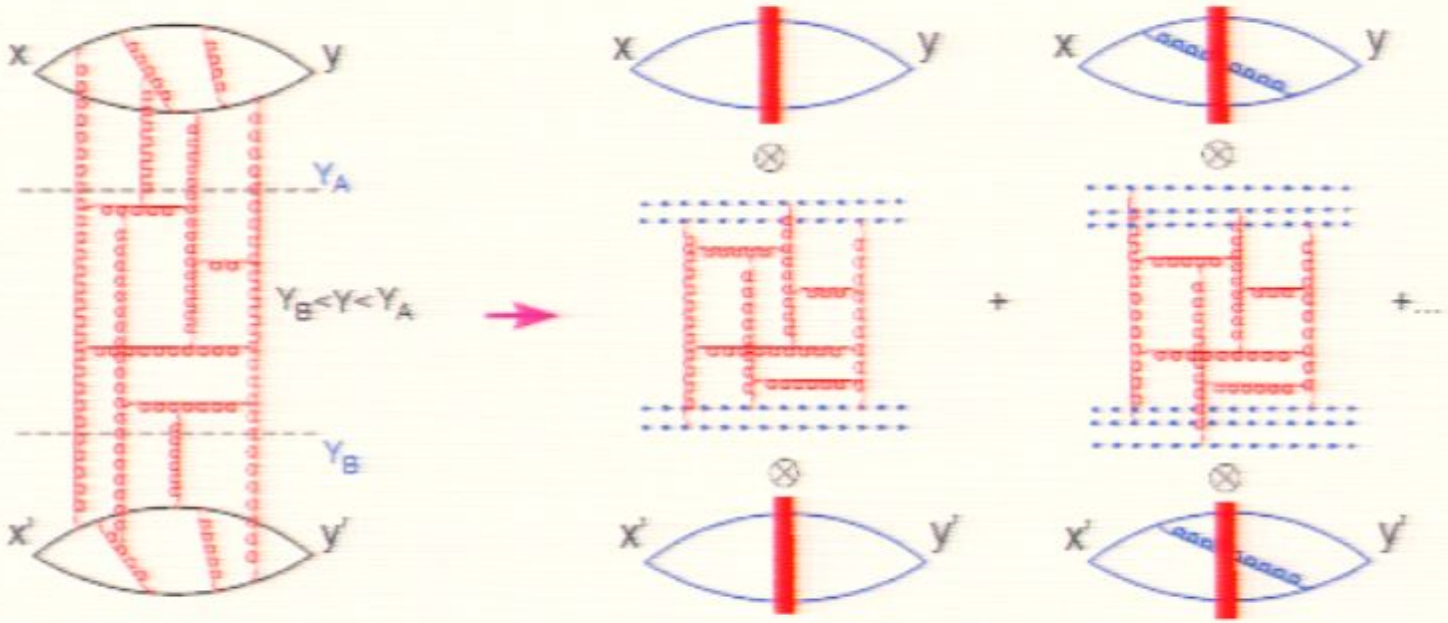
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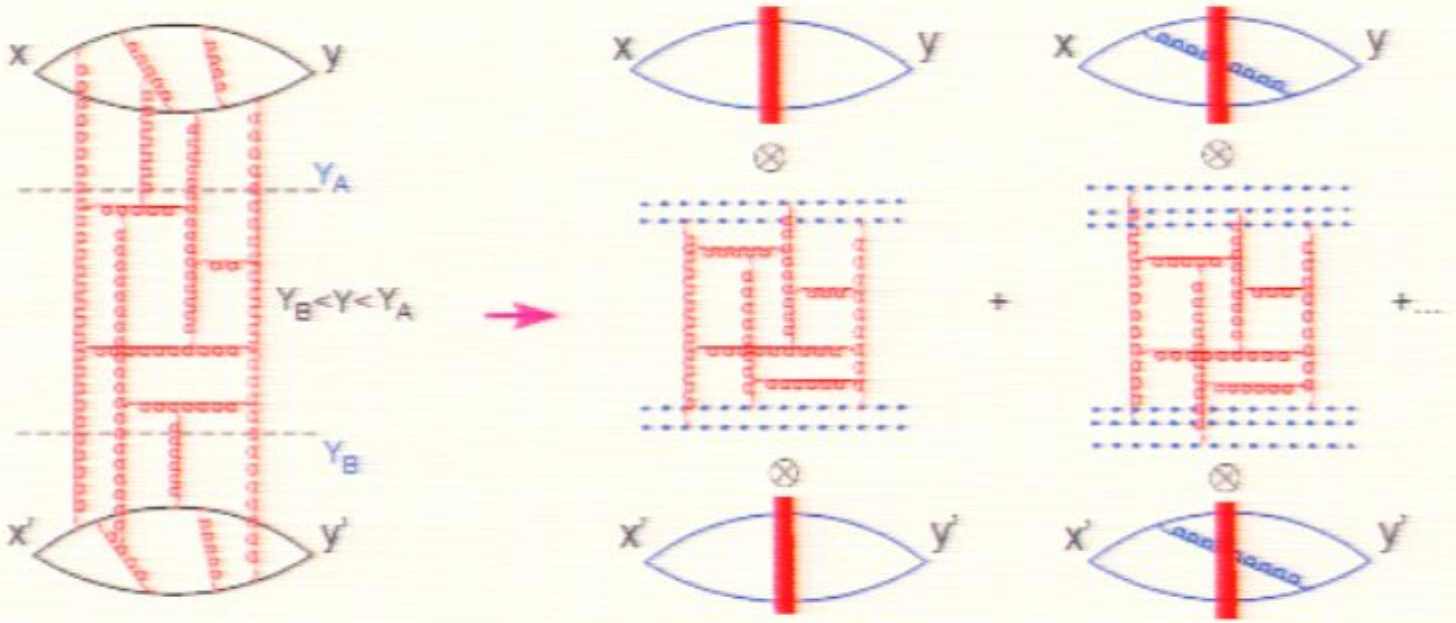
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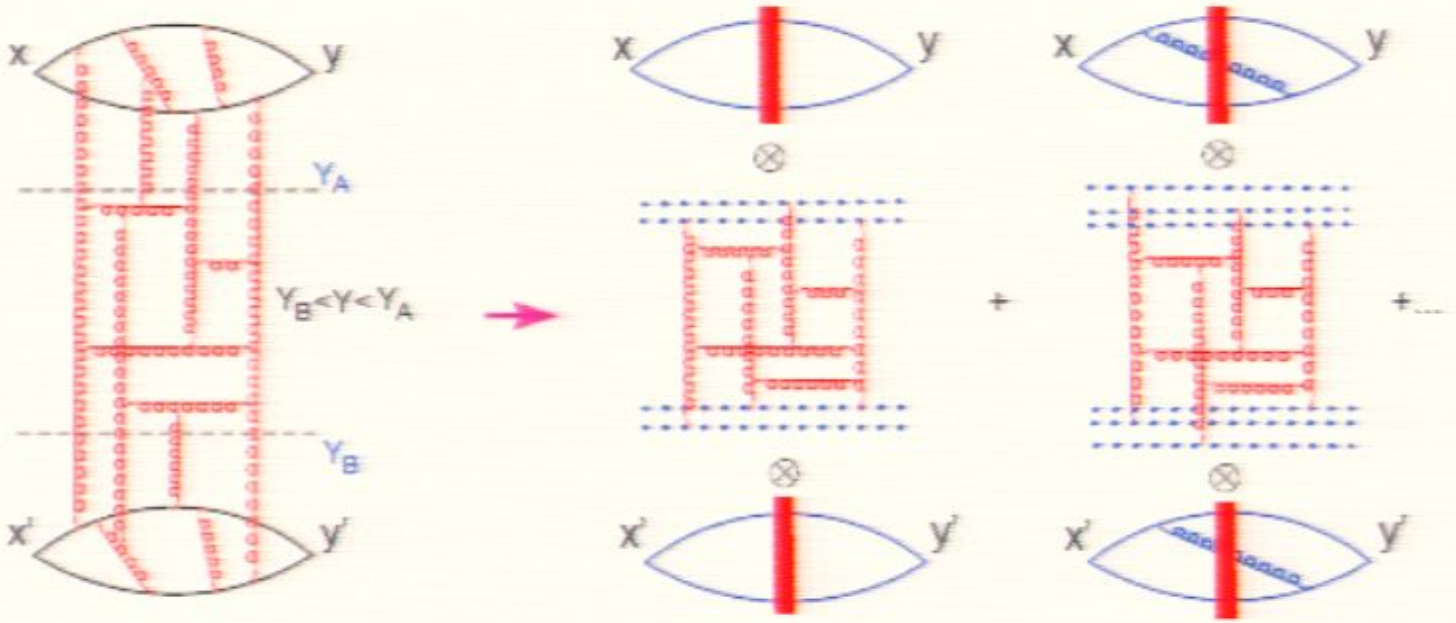


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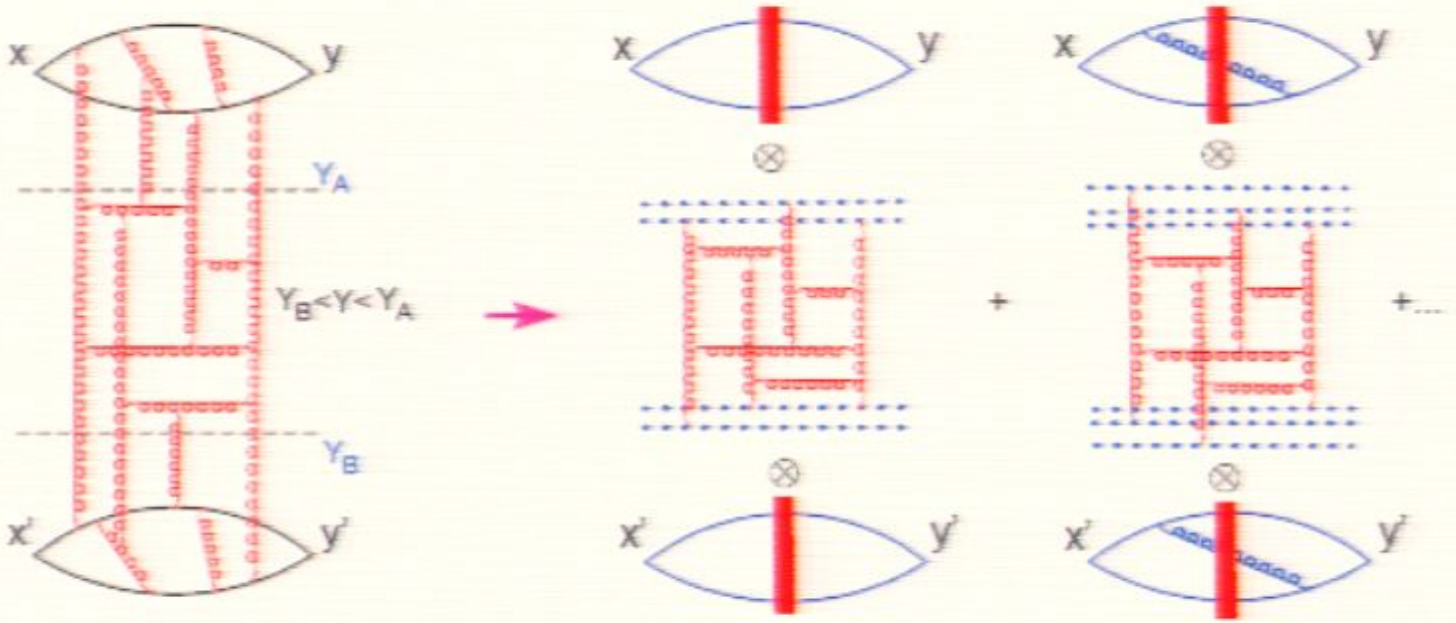
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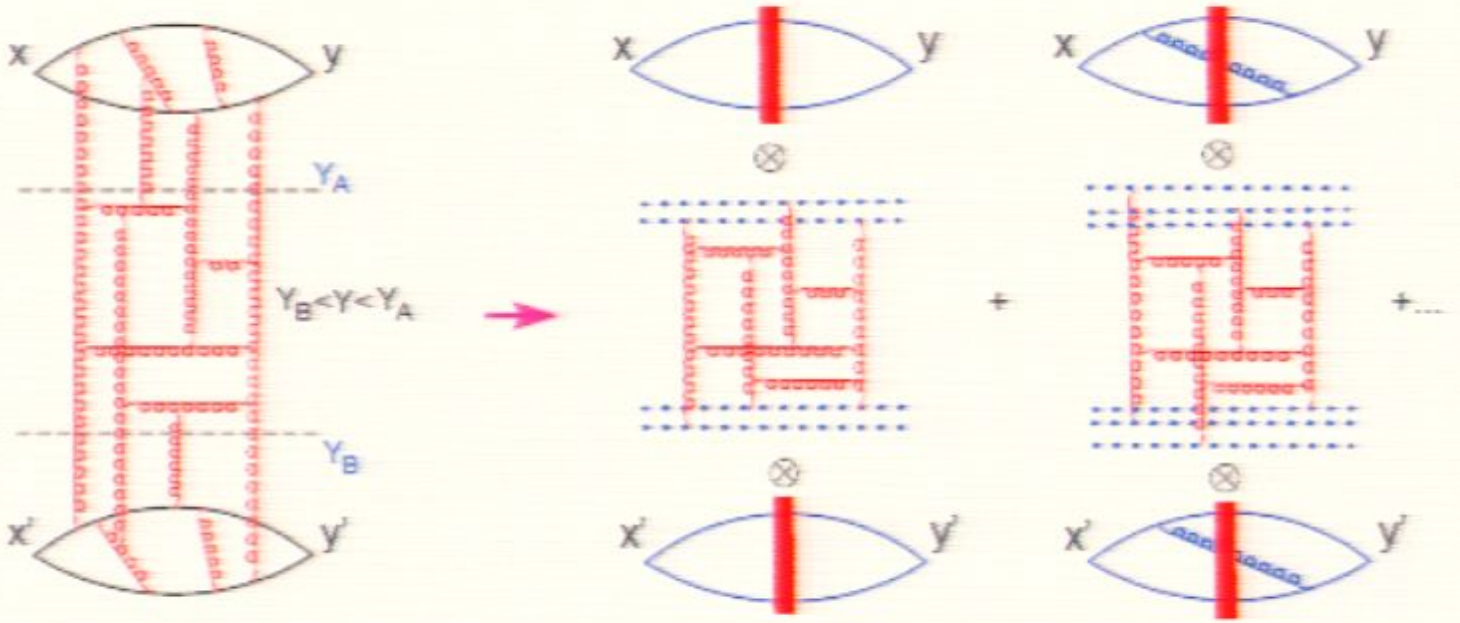
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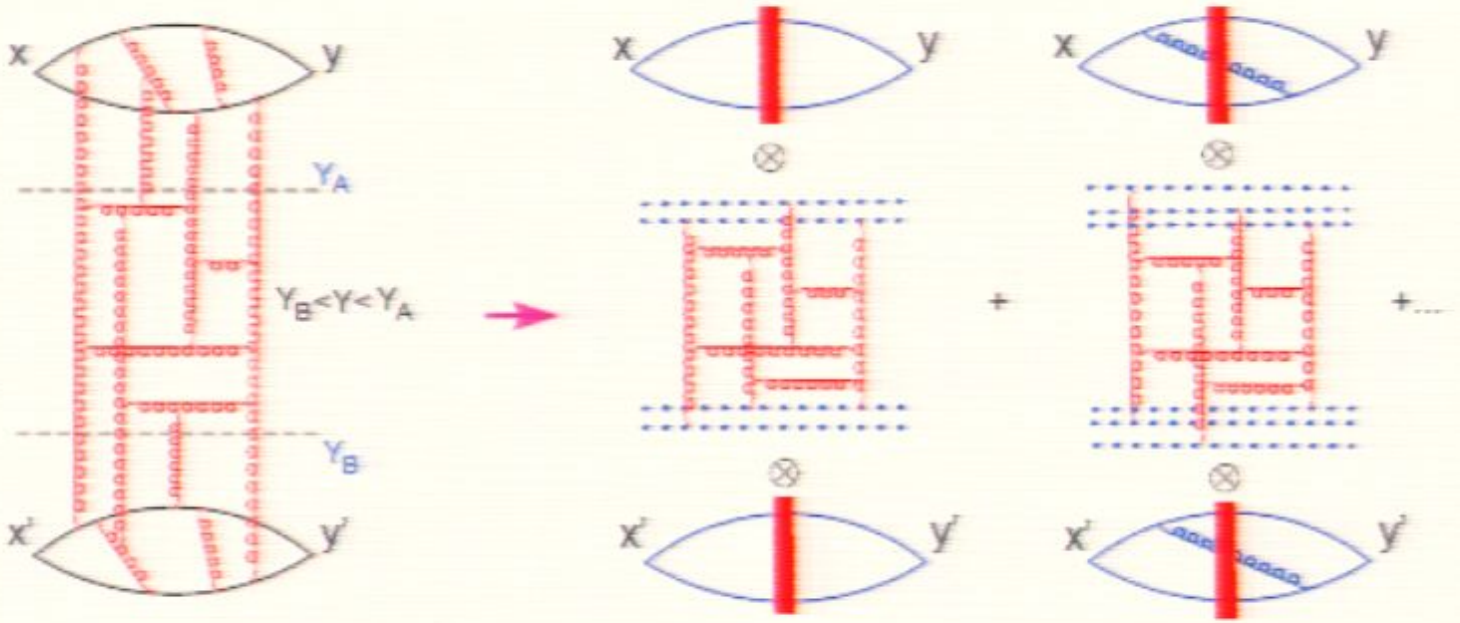
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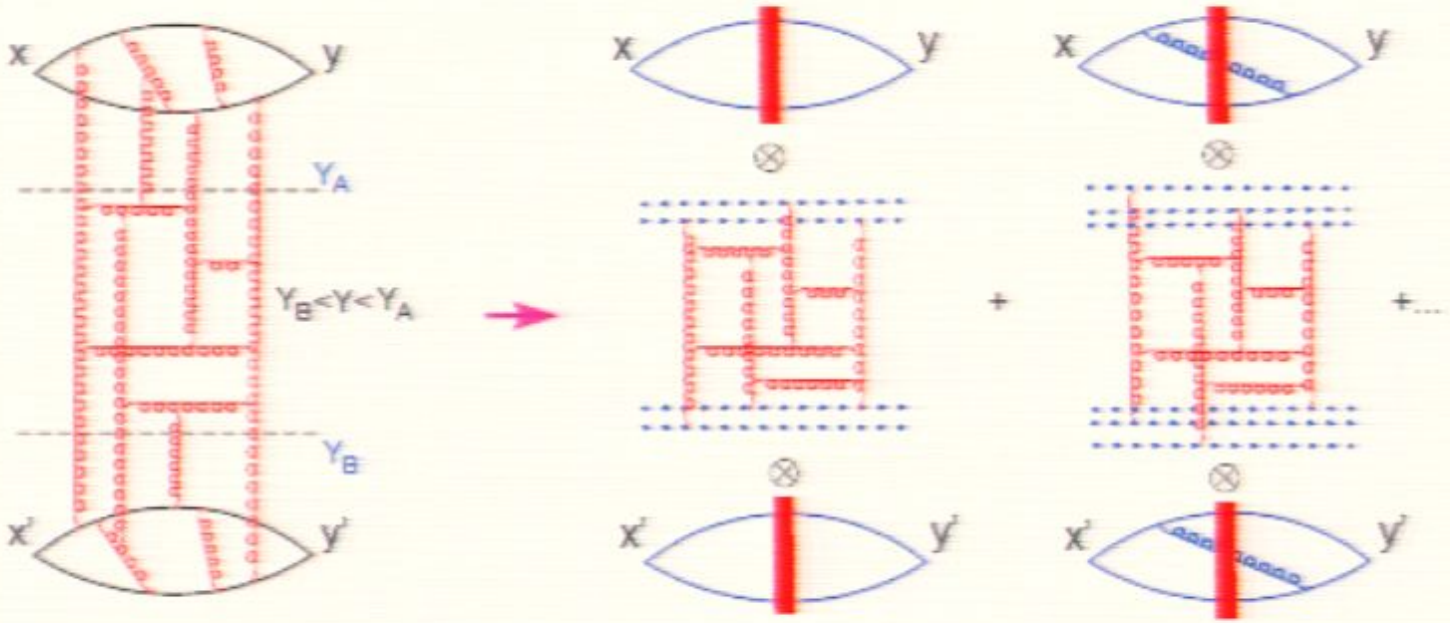


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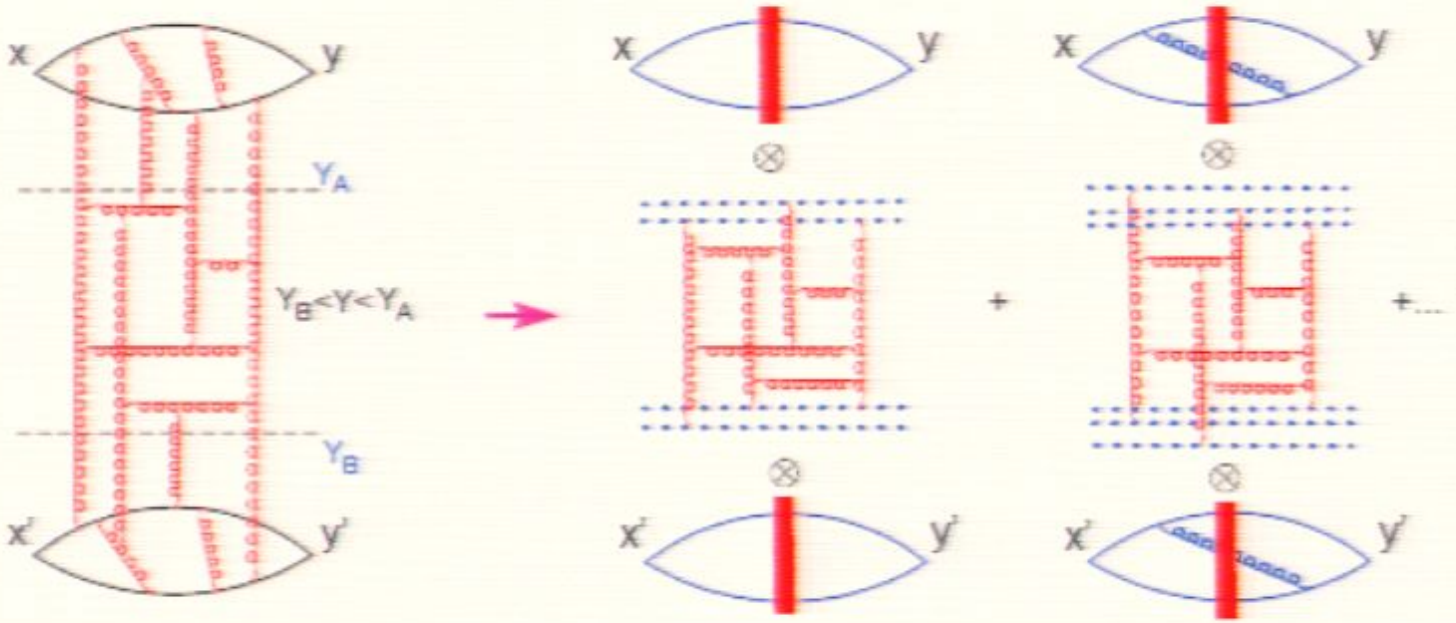
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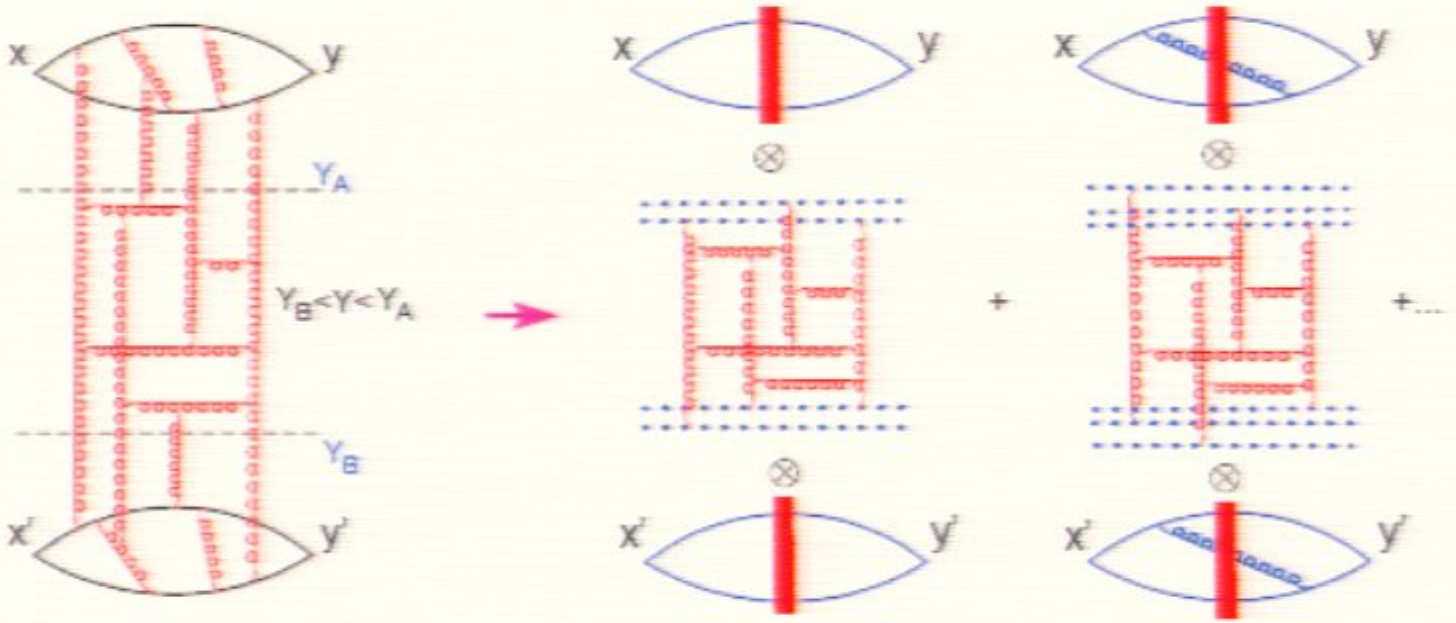
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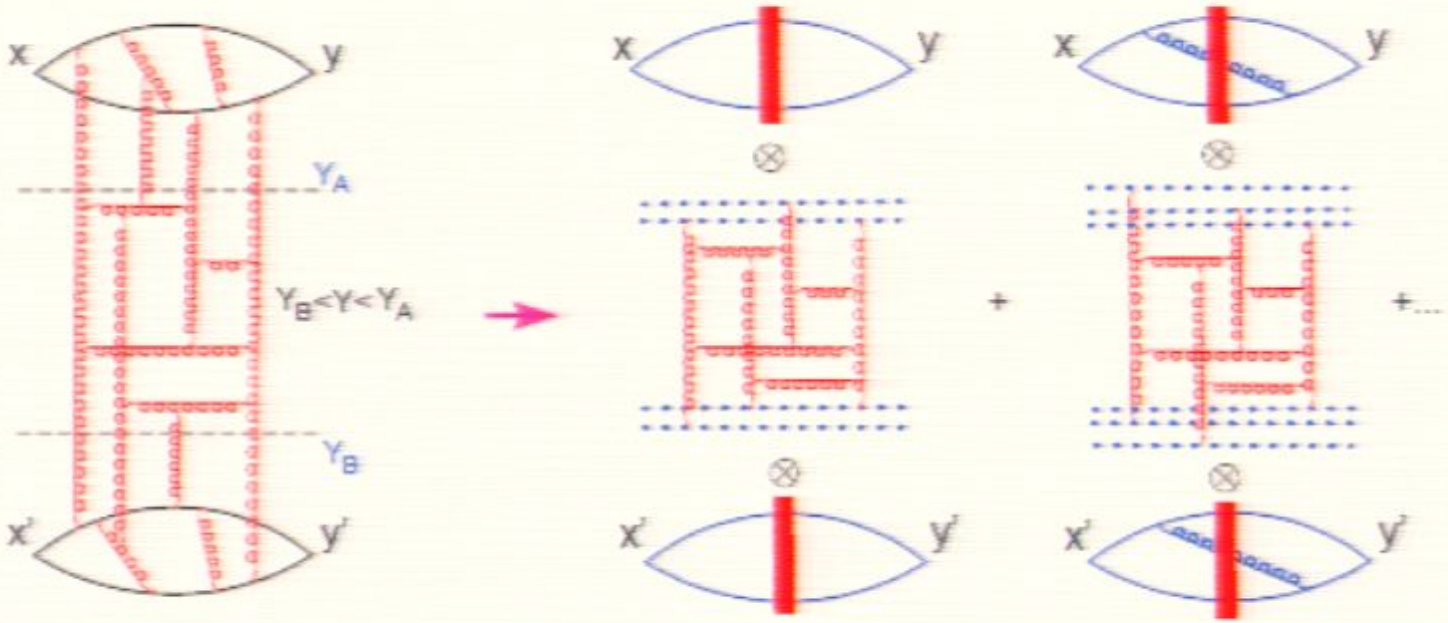
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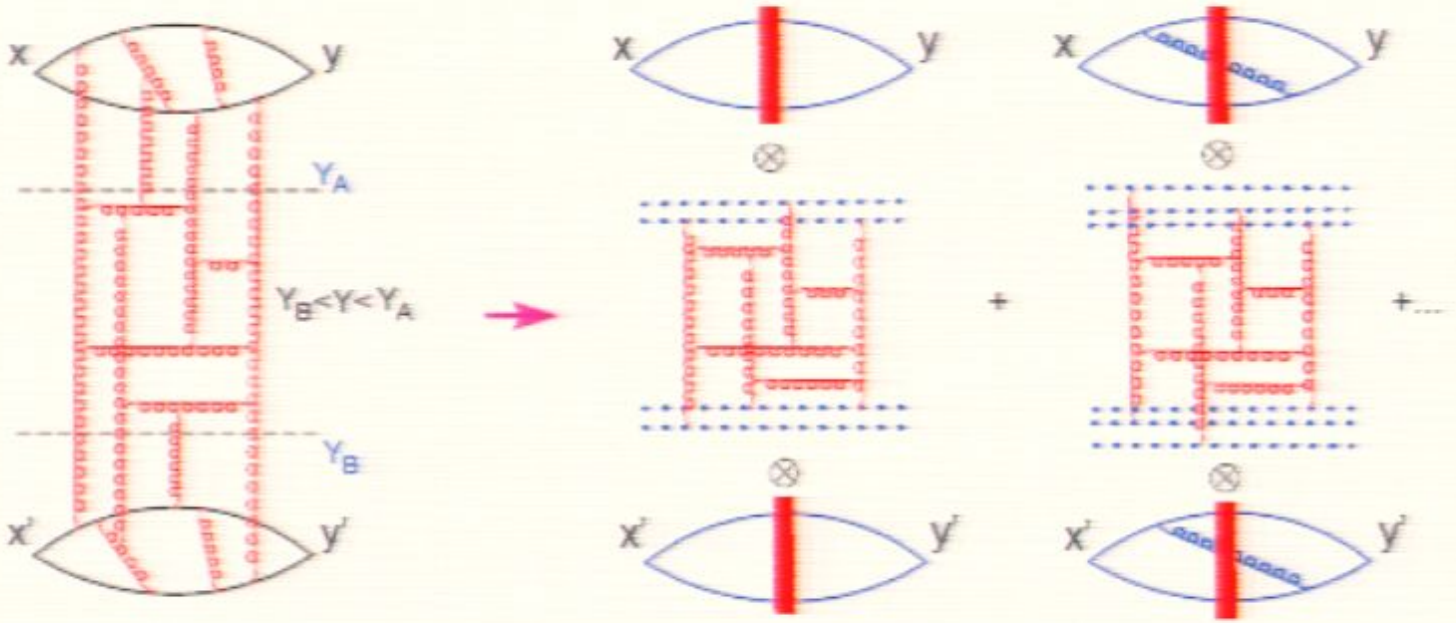
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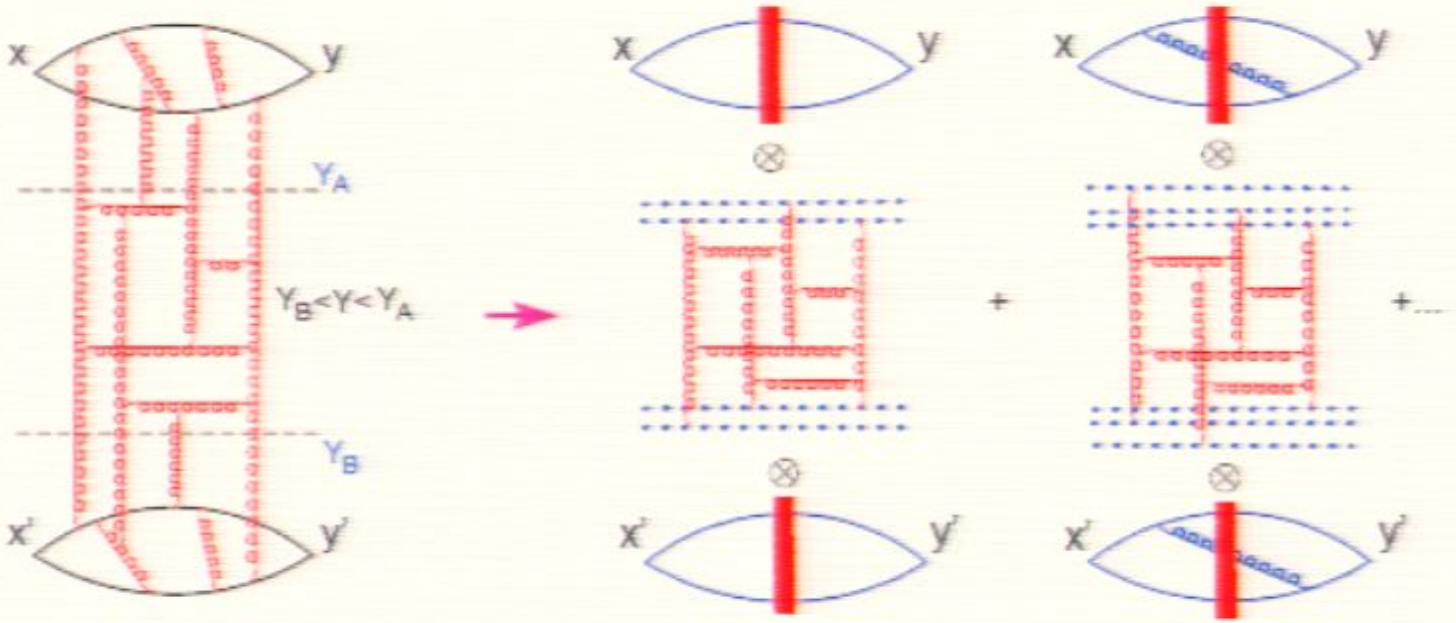
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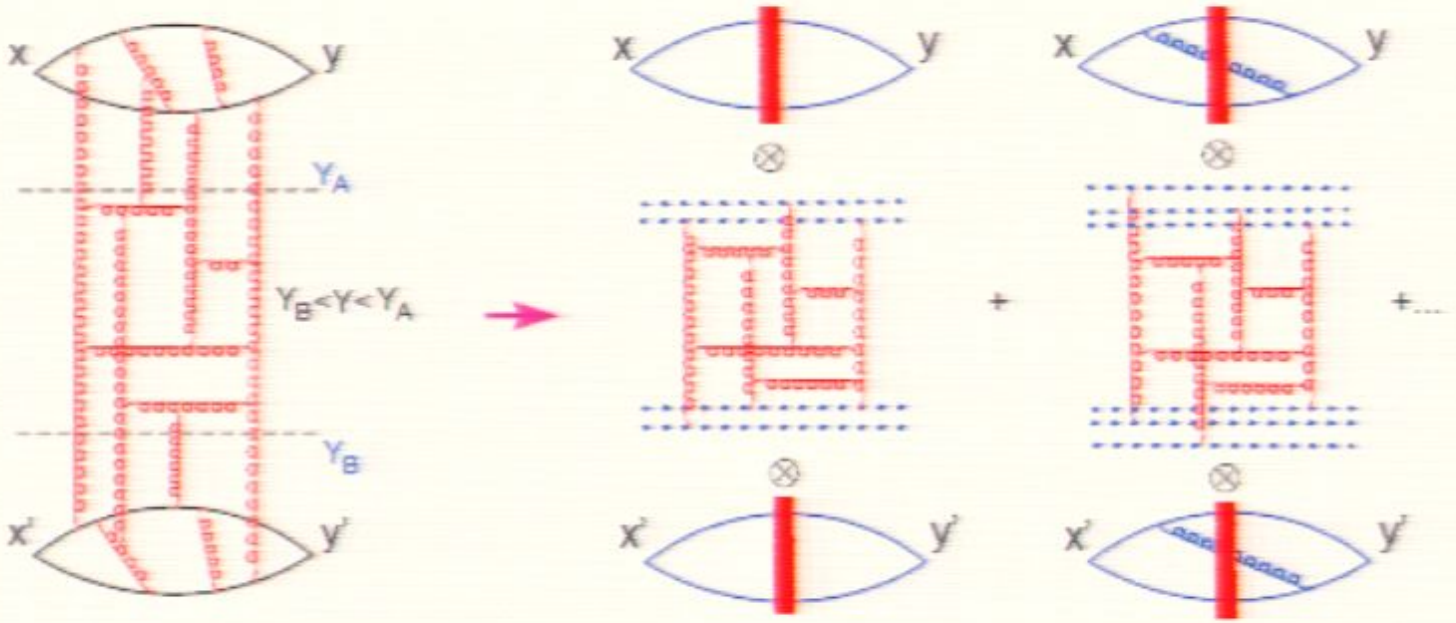
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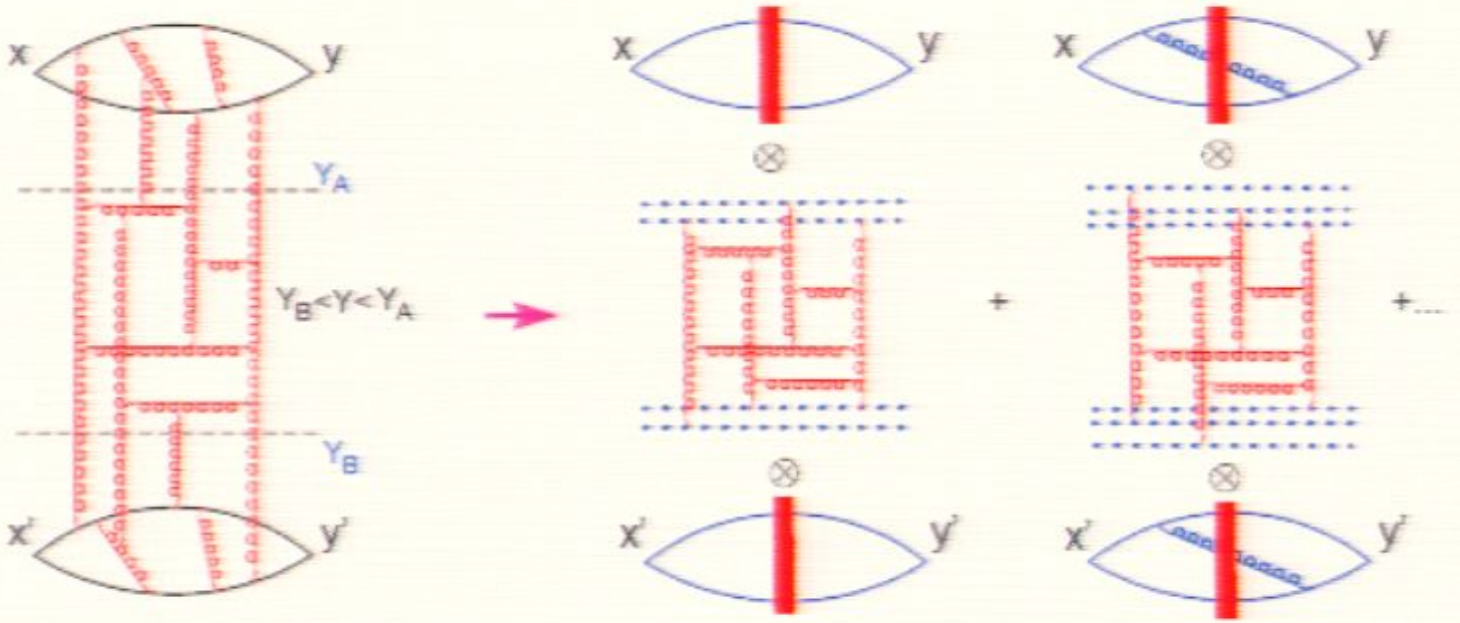
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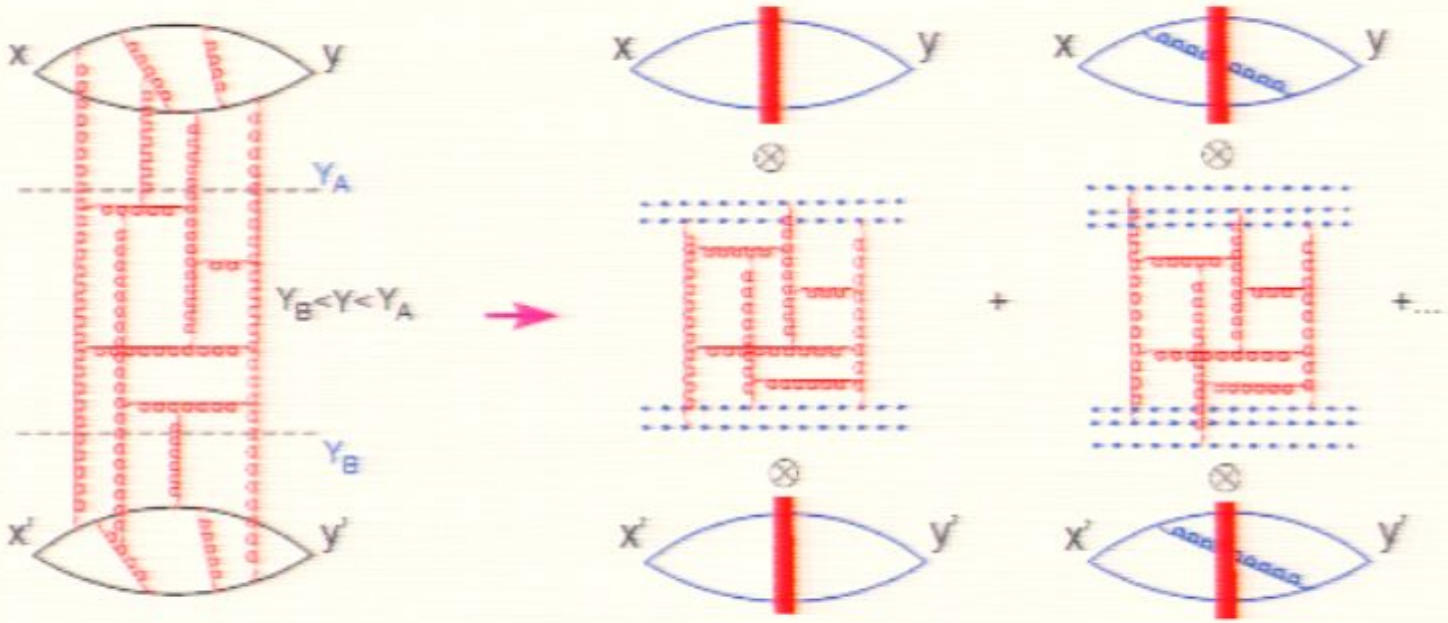
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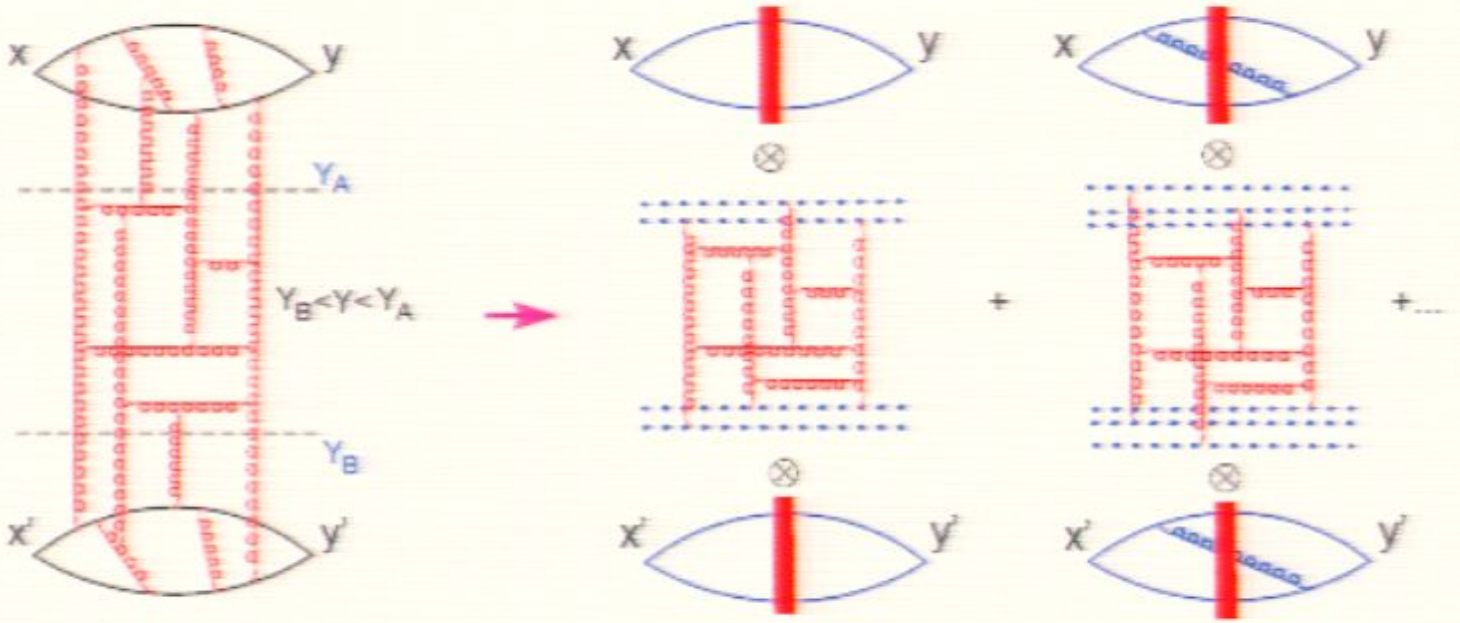
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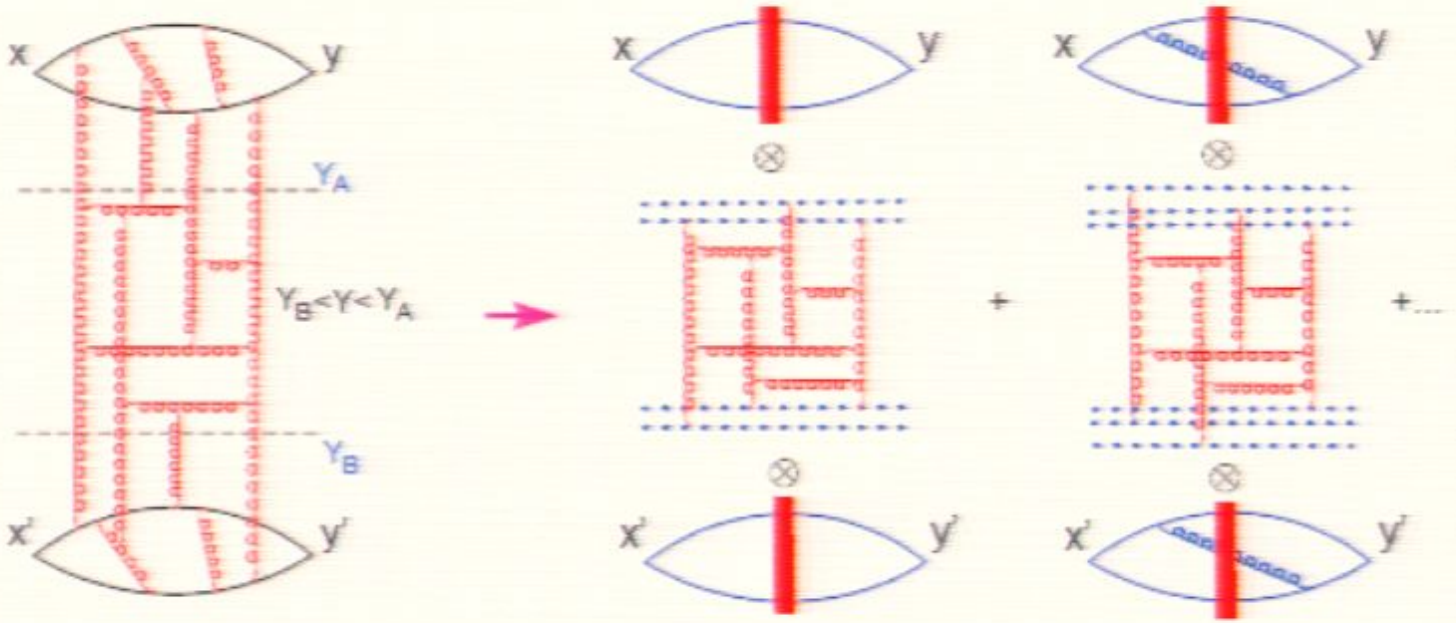
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NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity

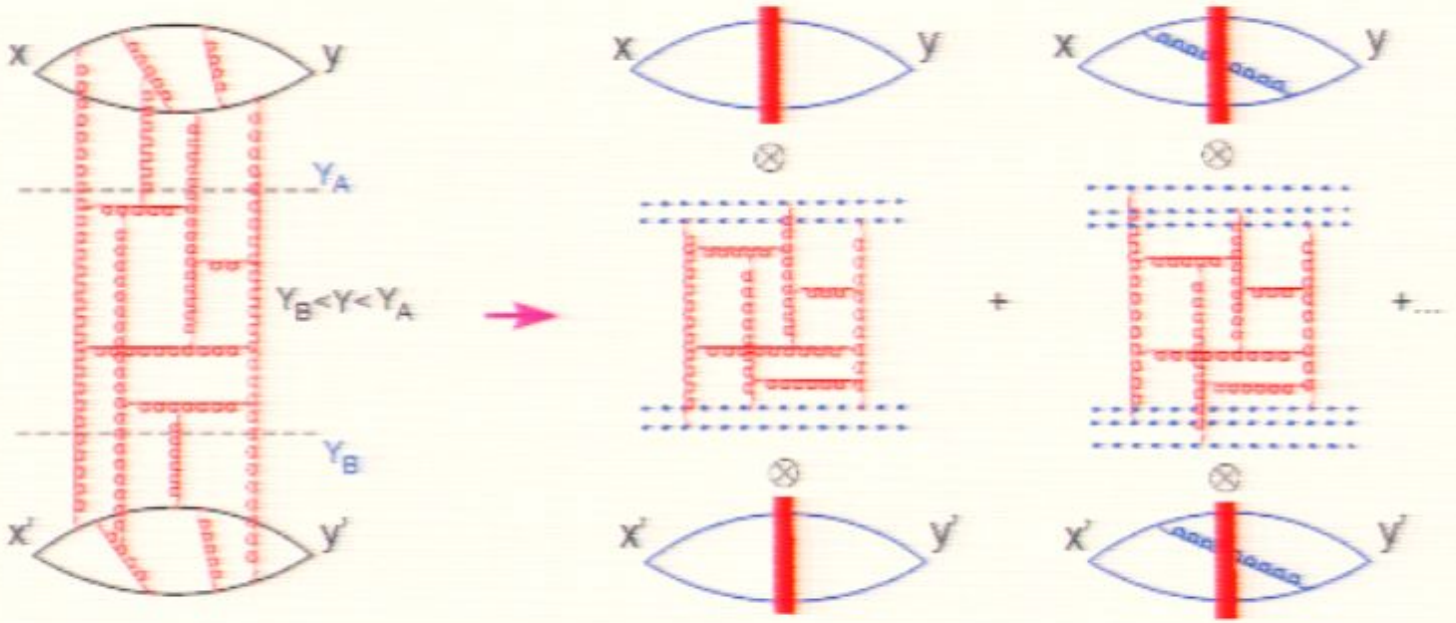


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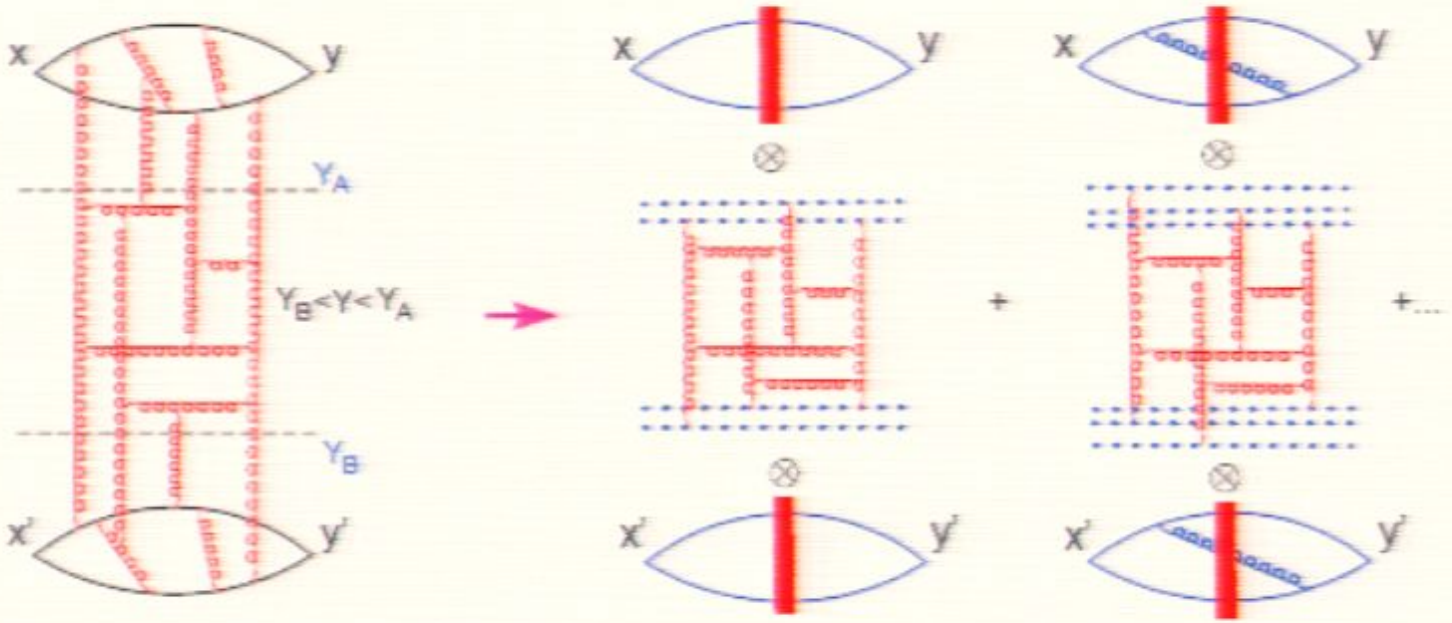
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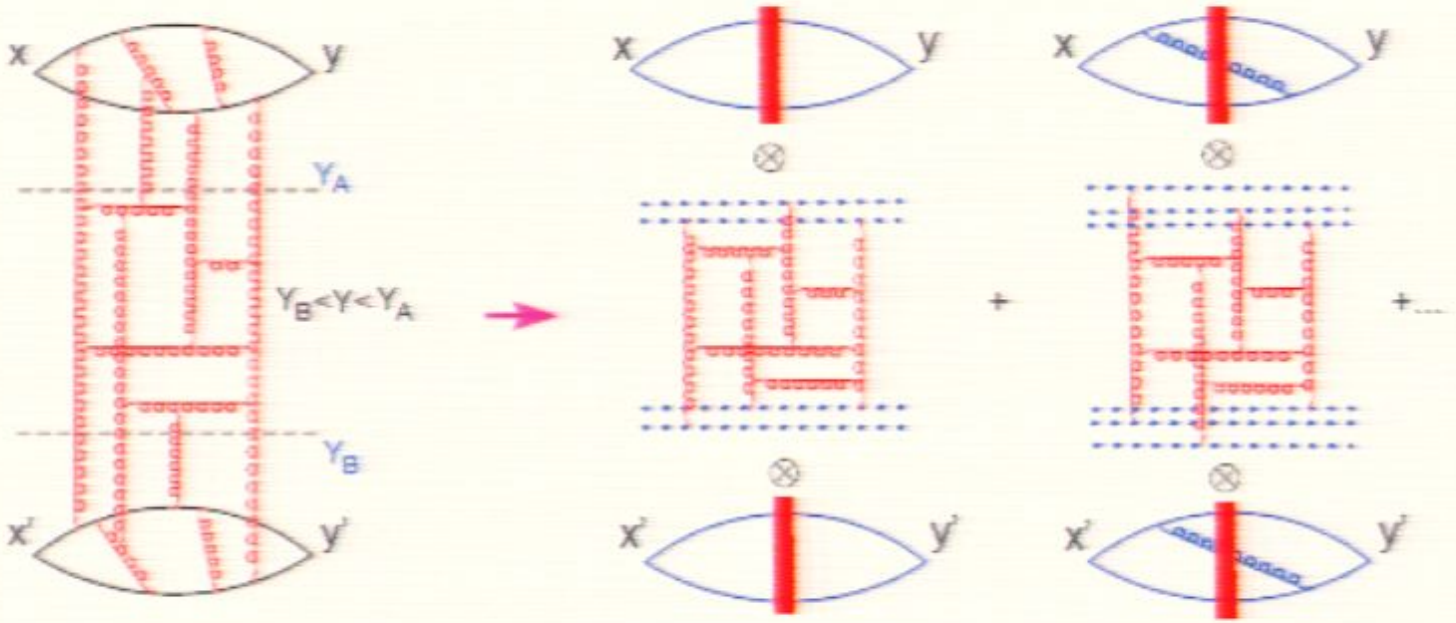
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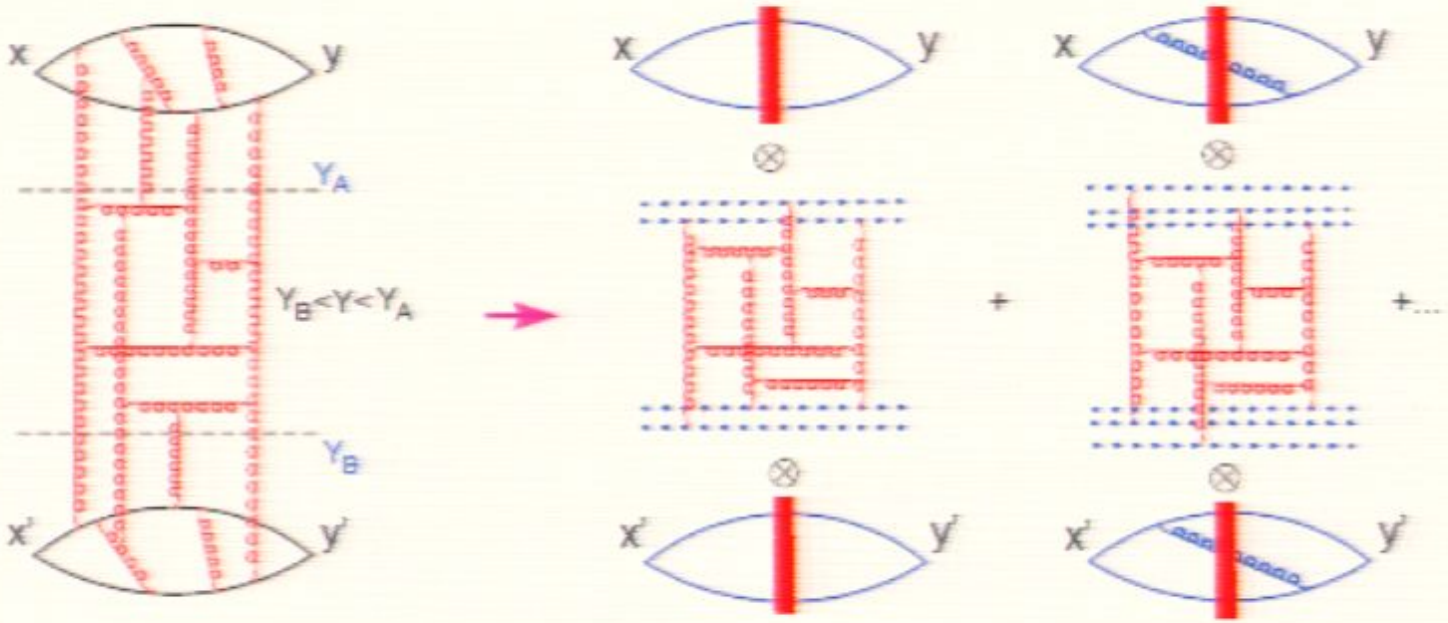
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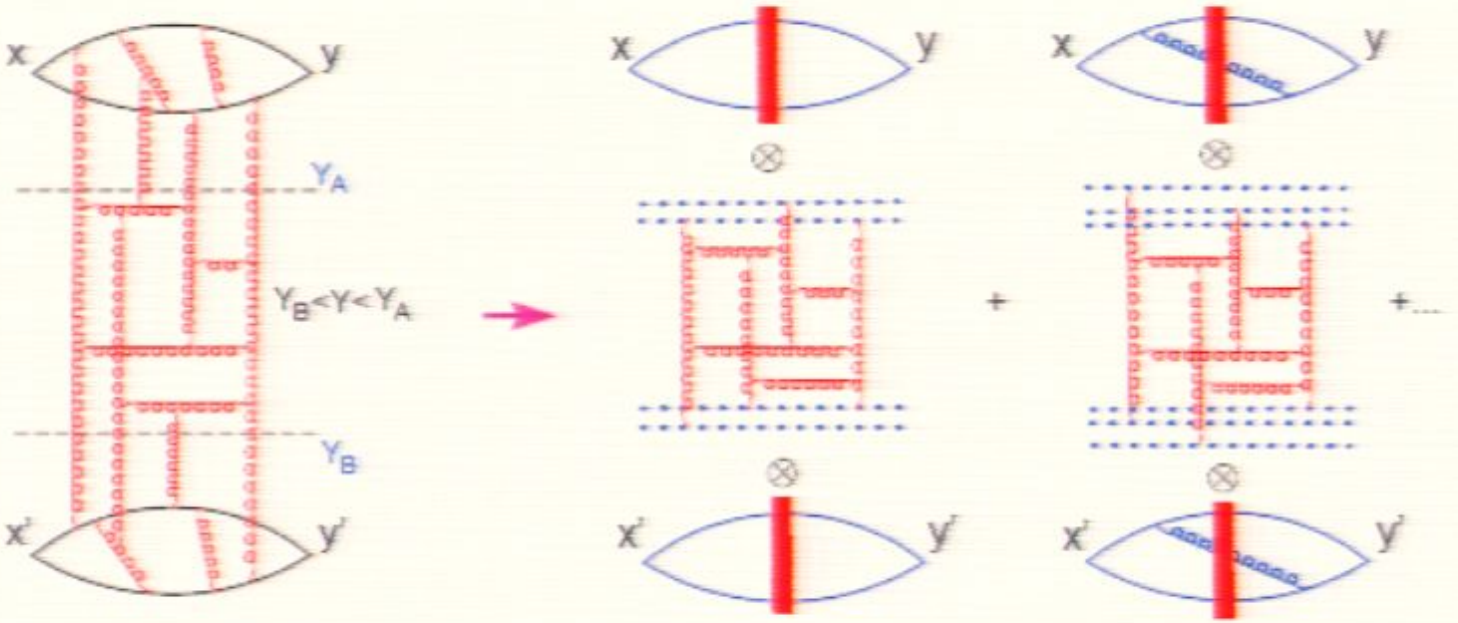
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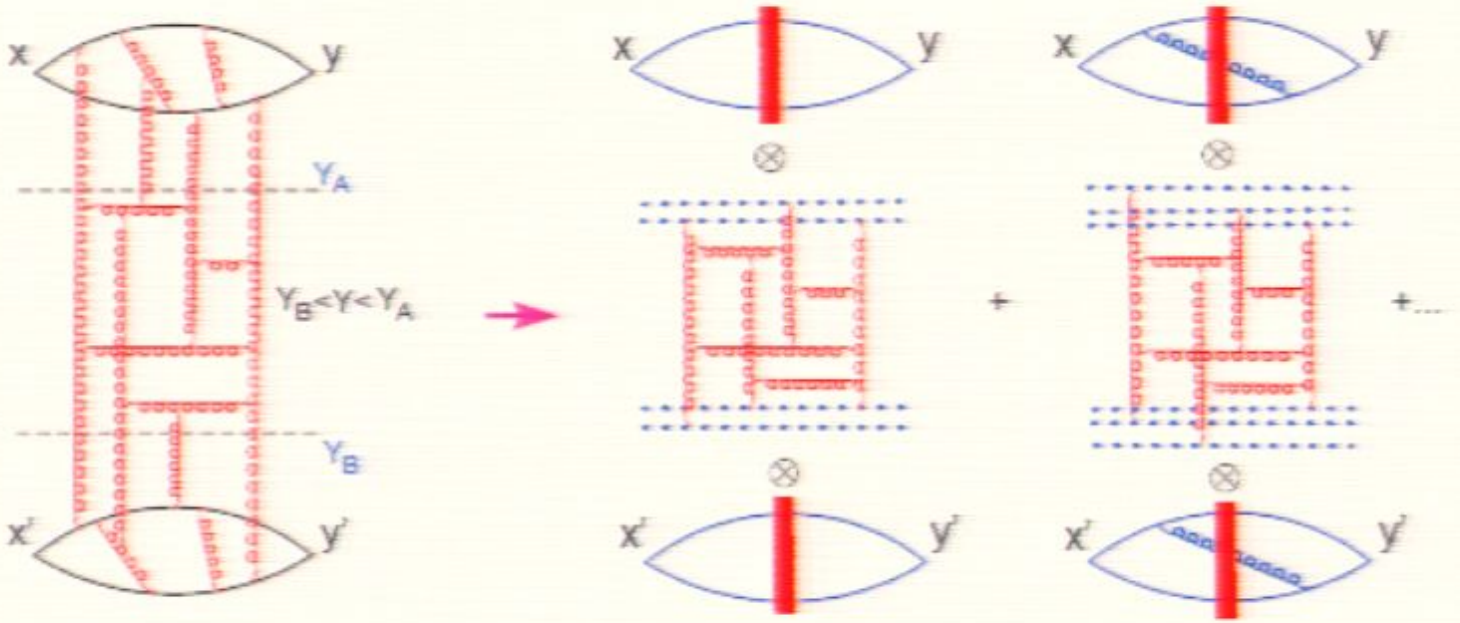
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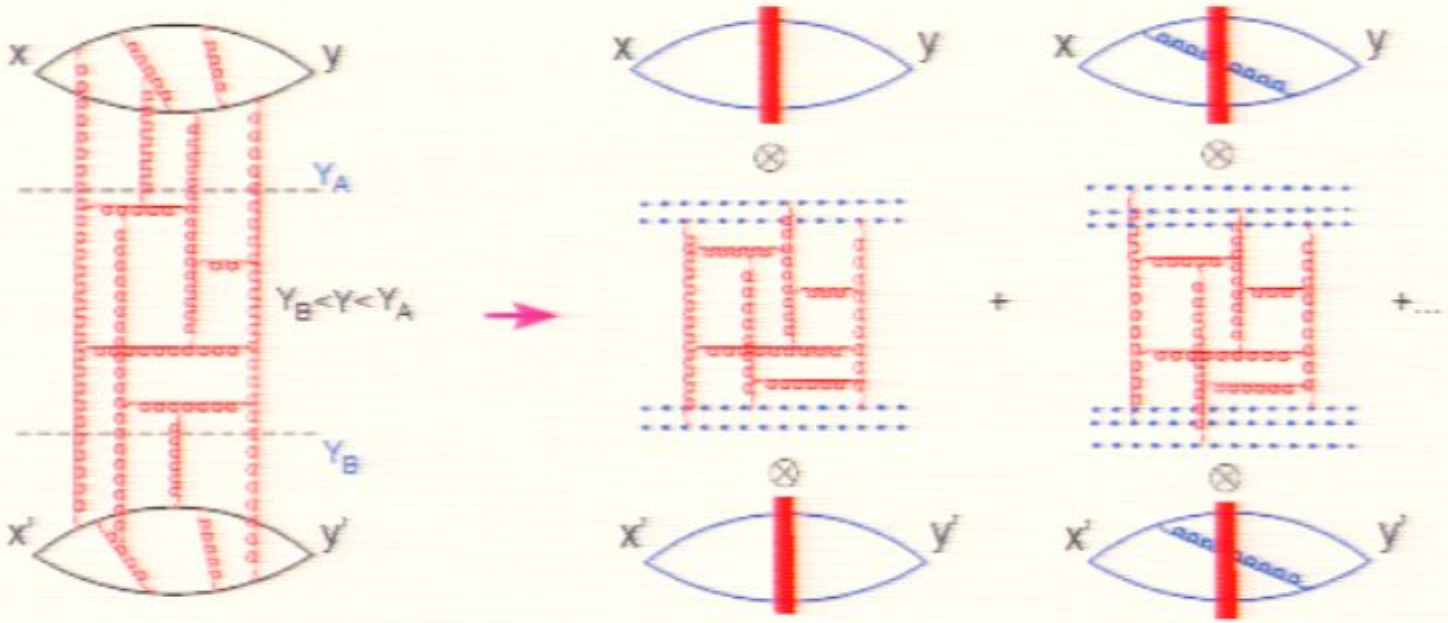
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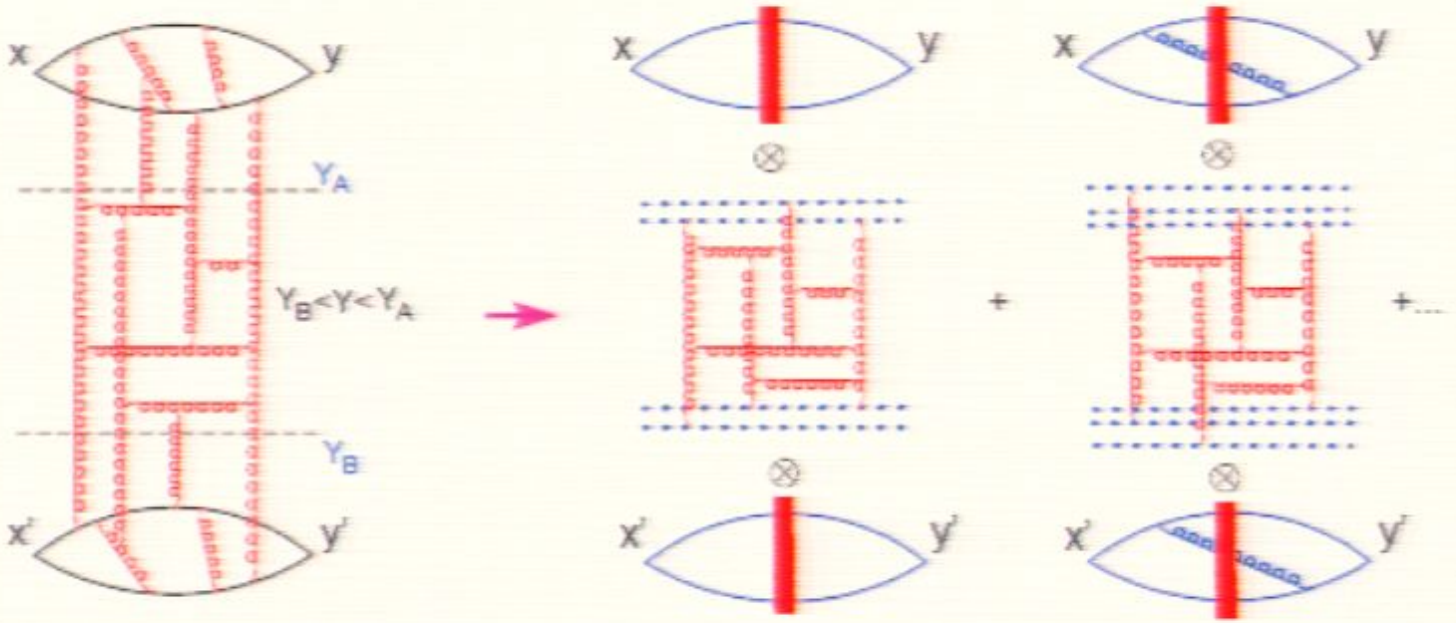
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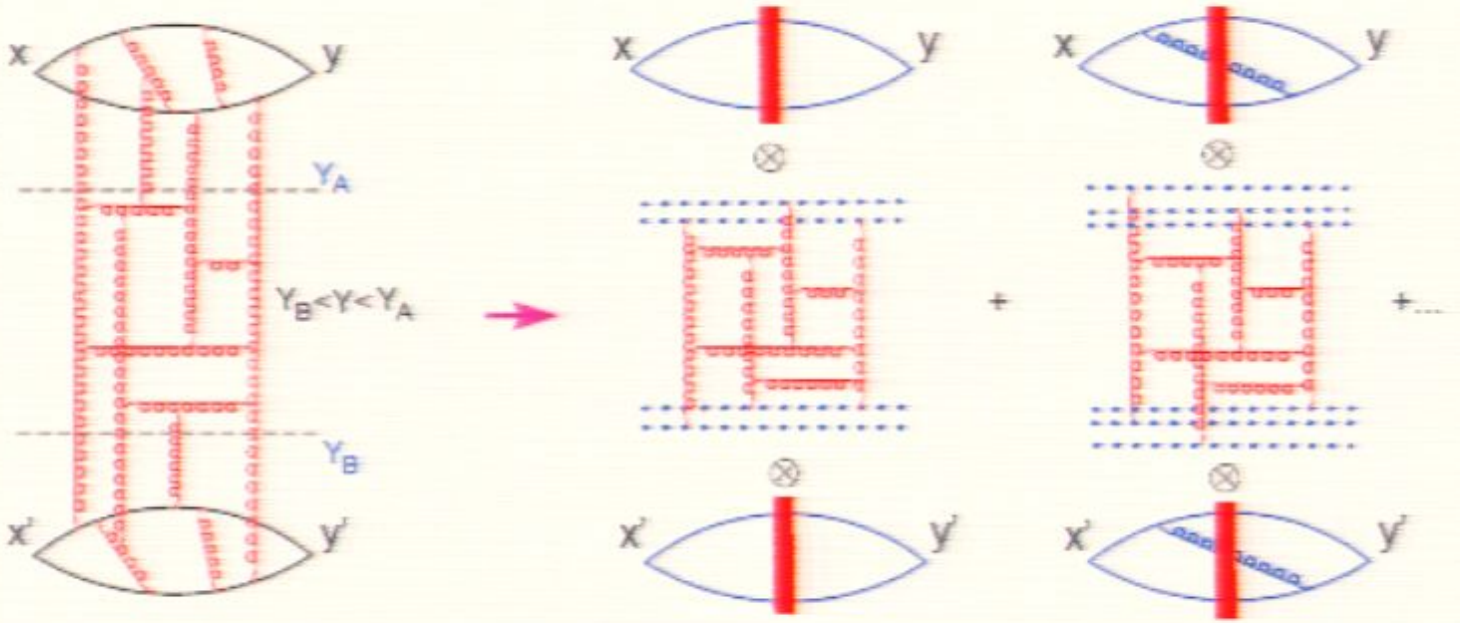
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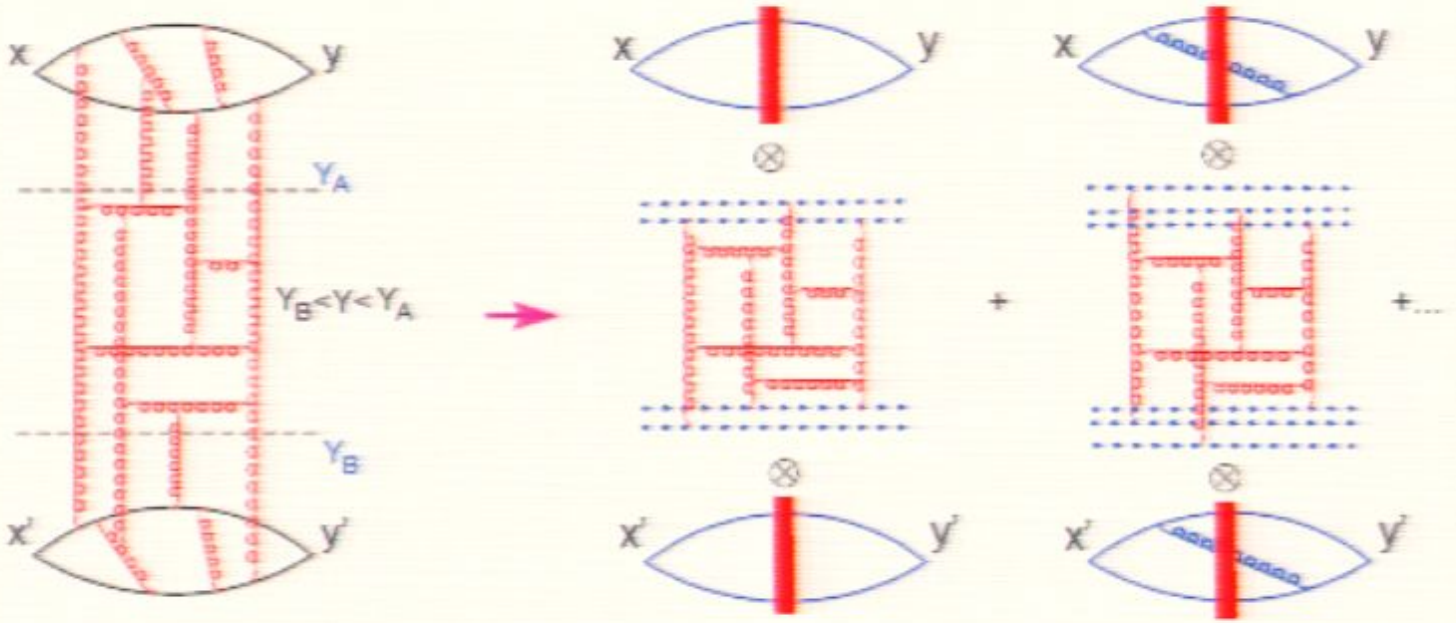
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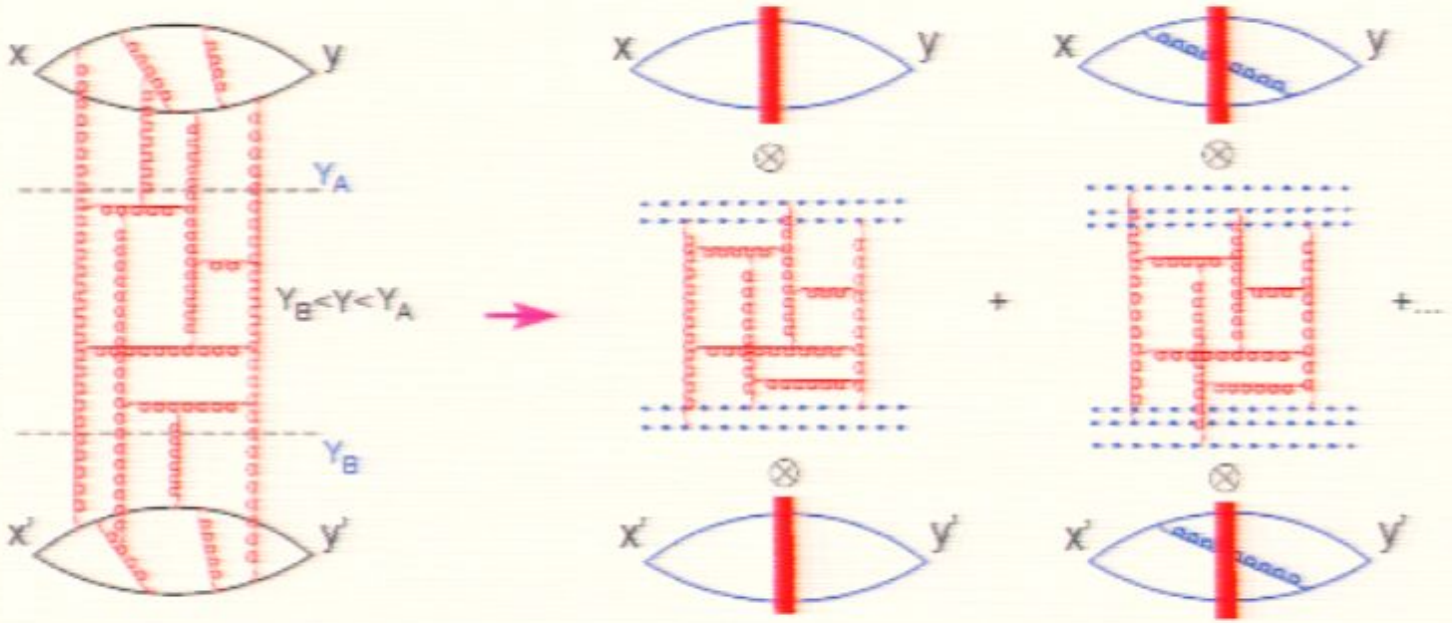
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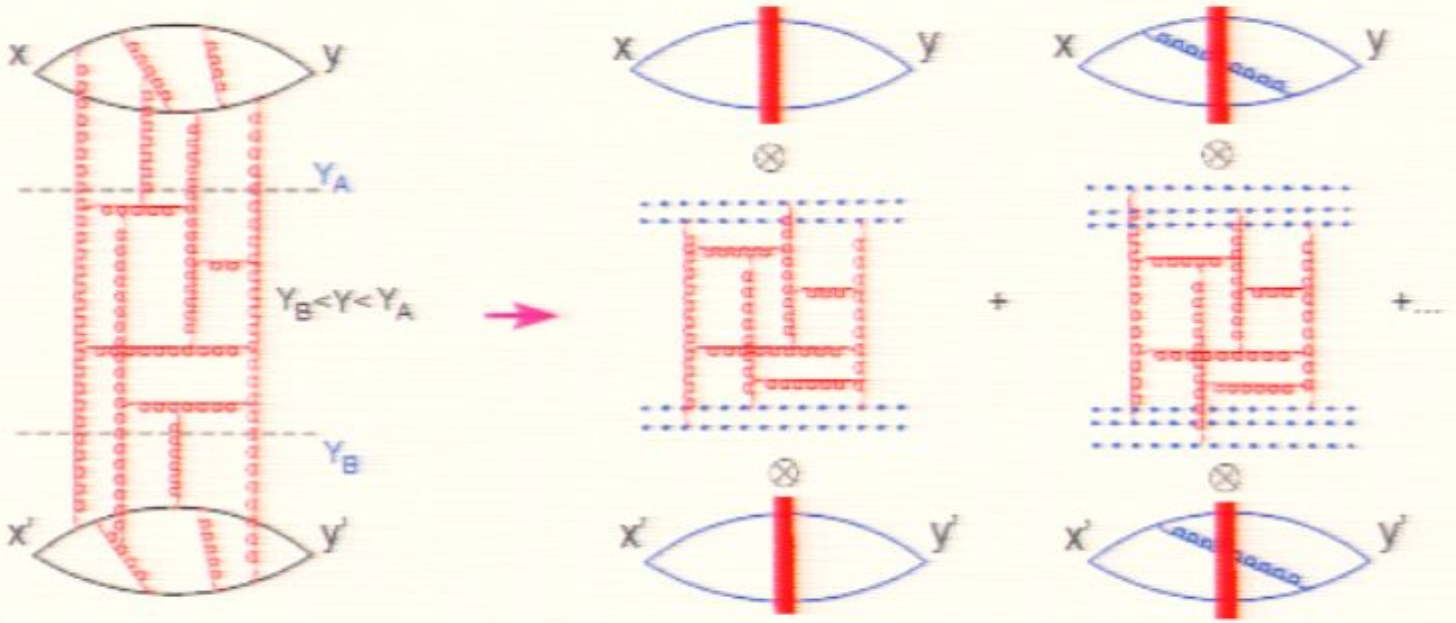
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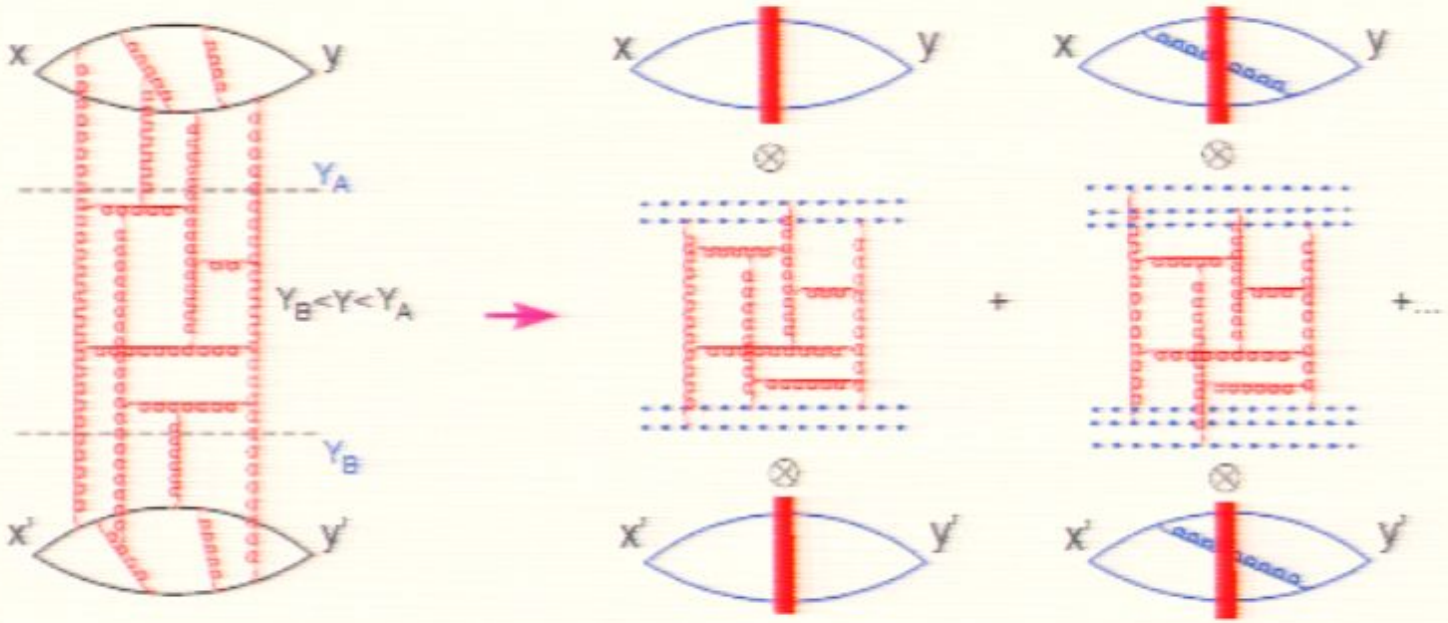
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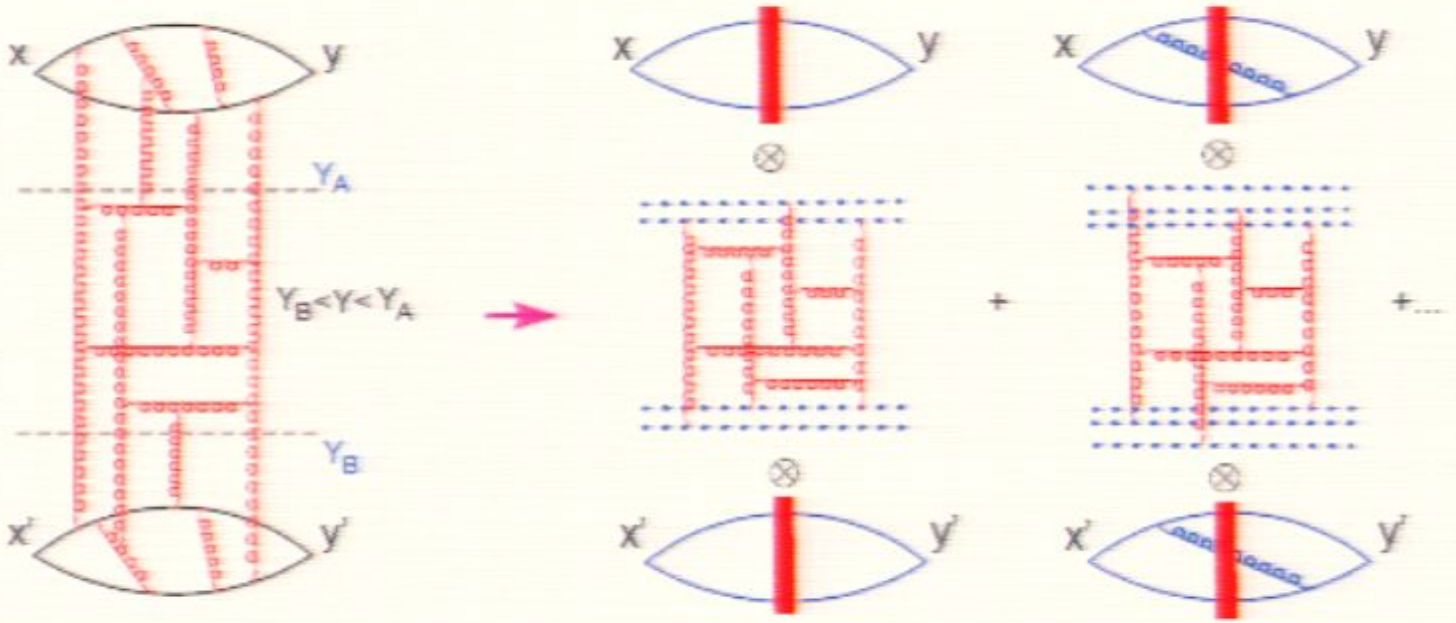
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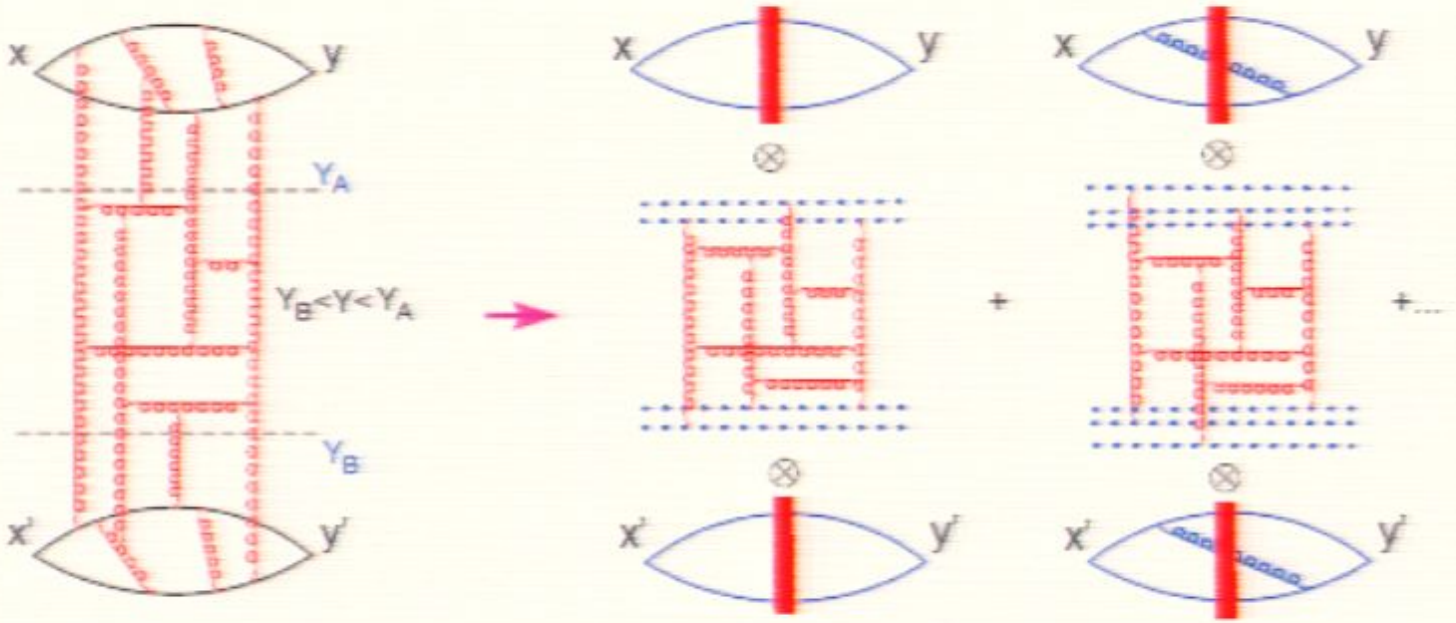
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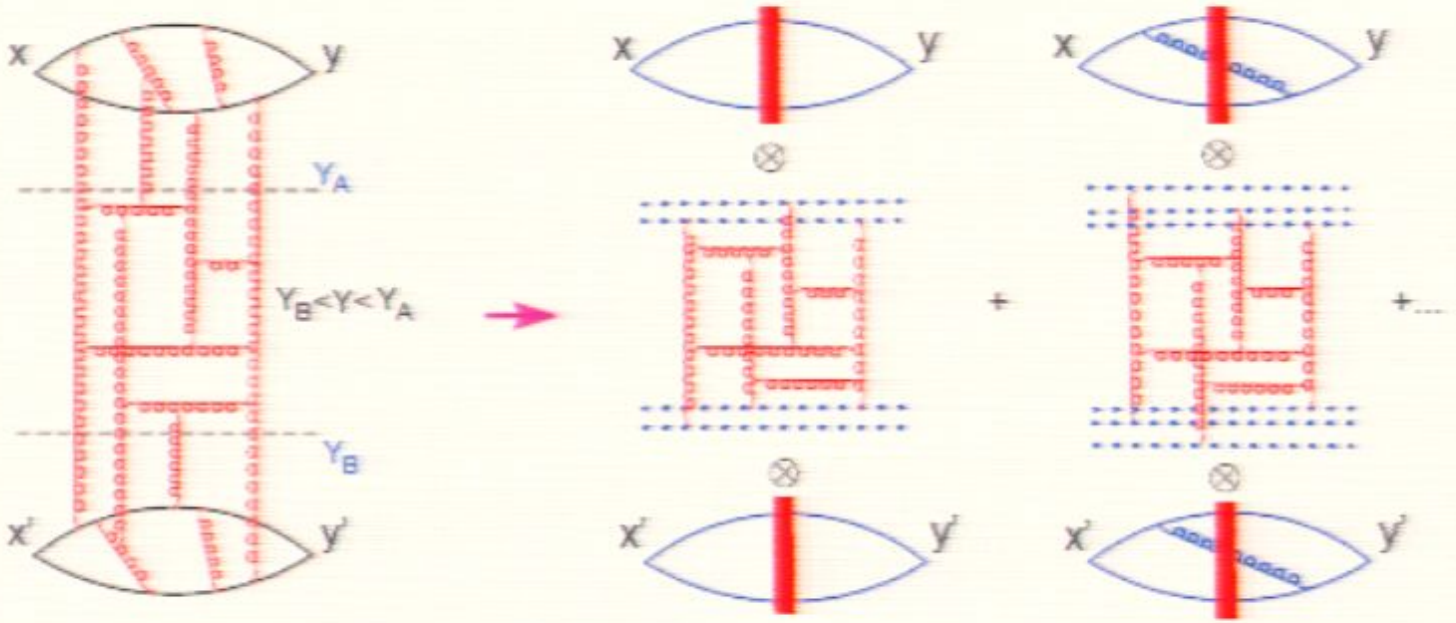
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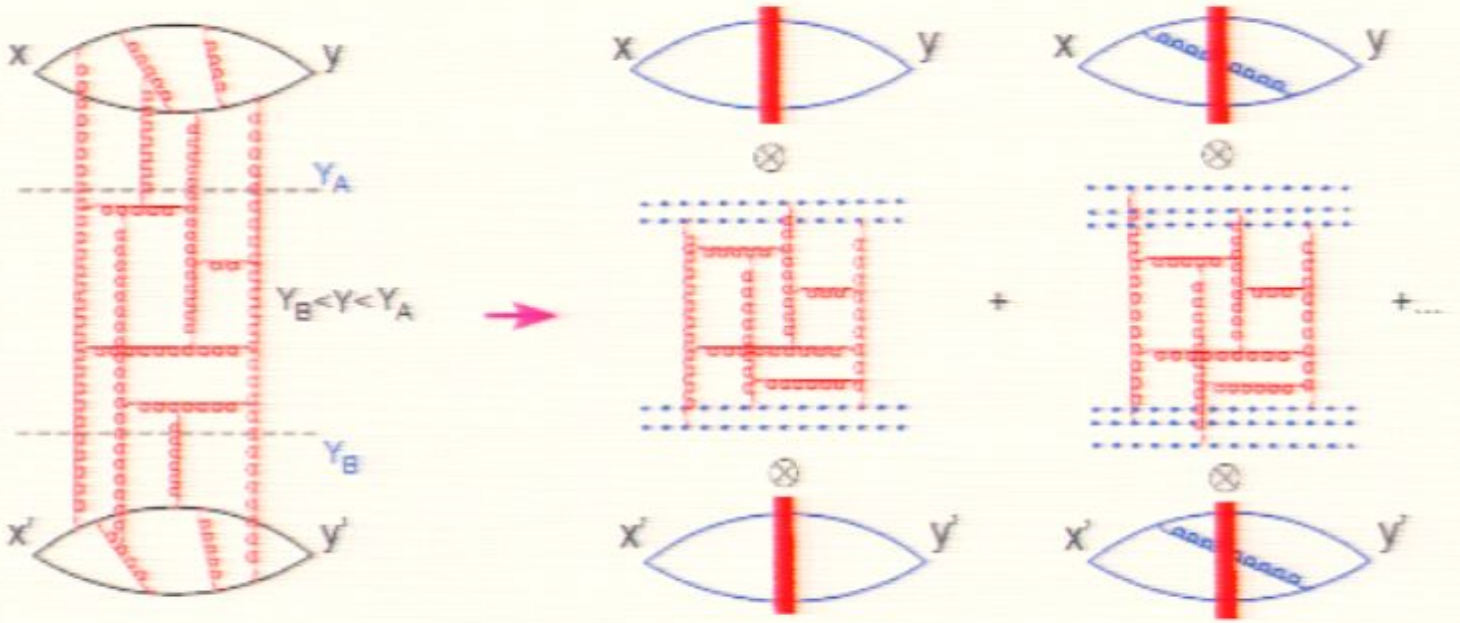
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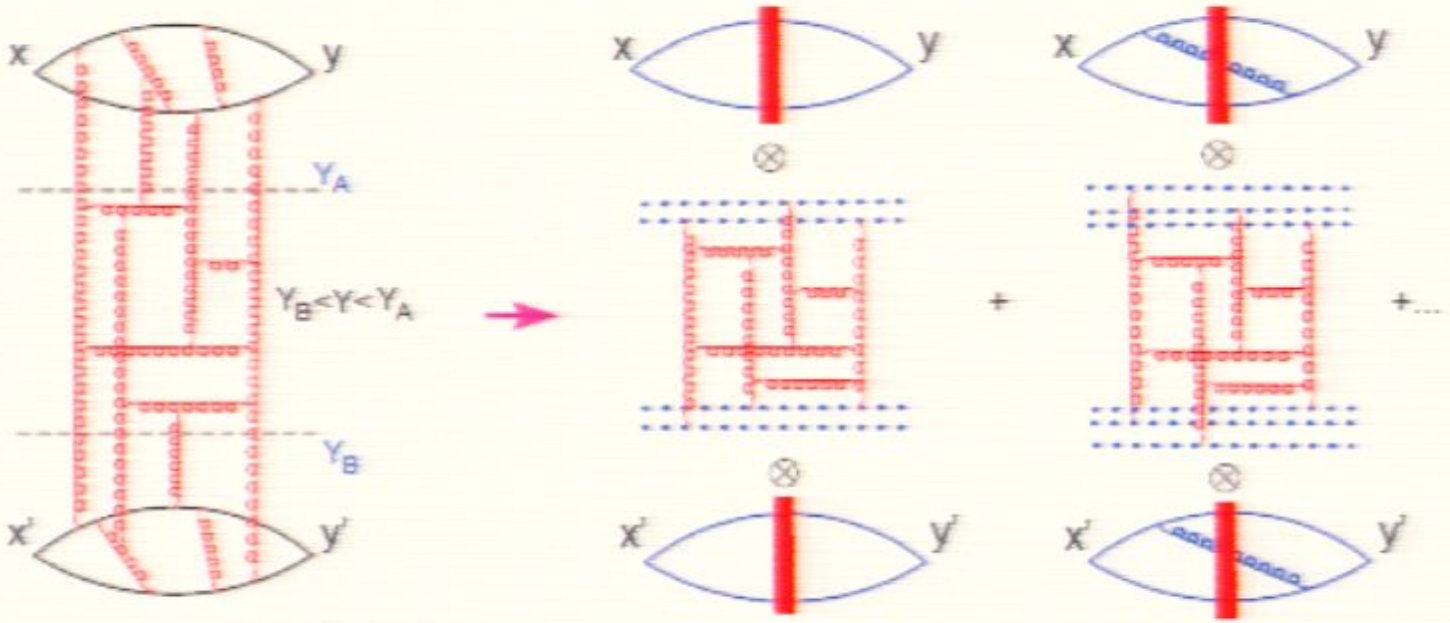
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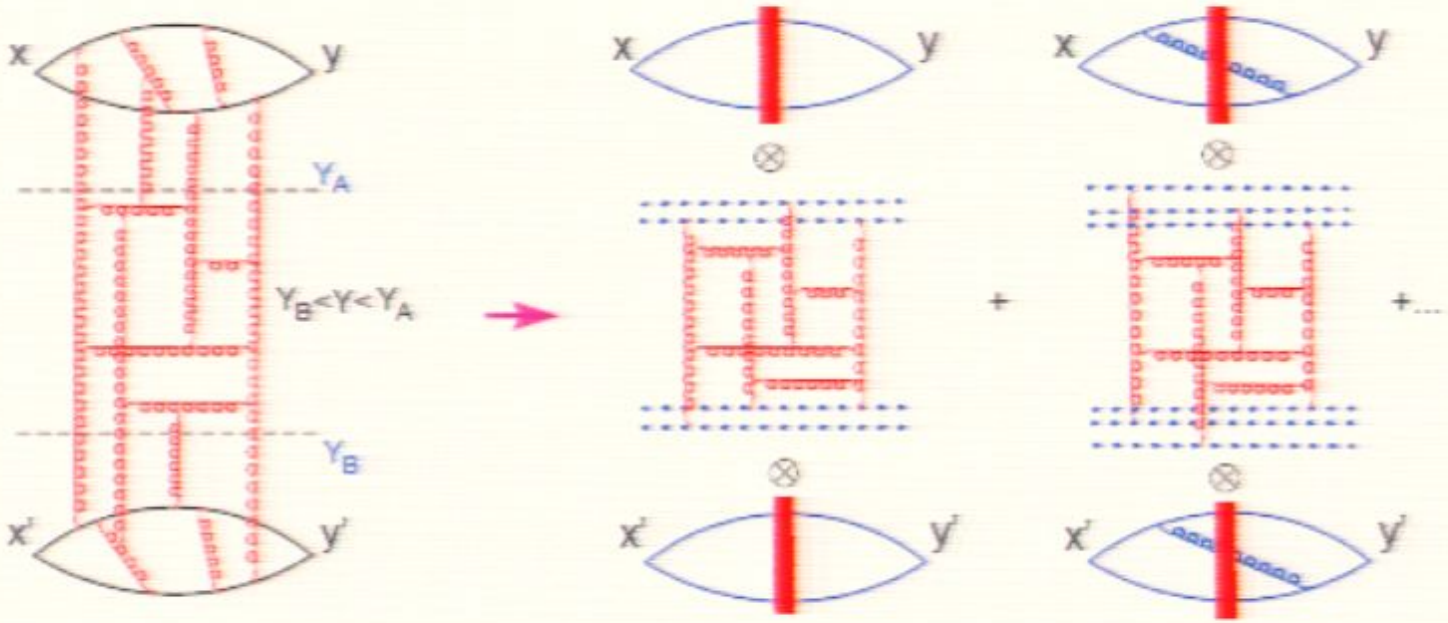
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NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity

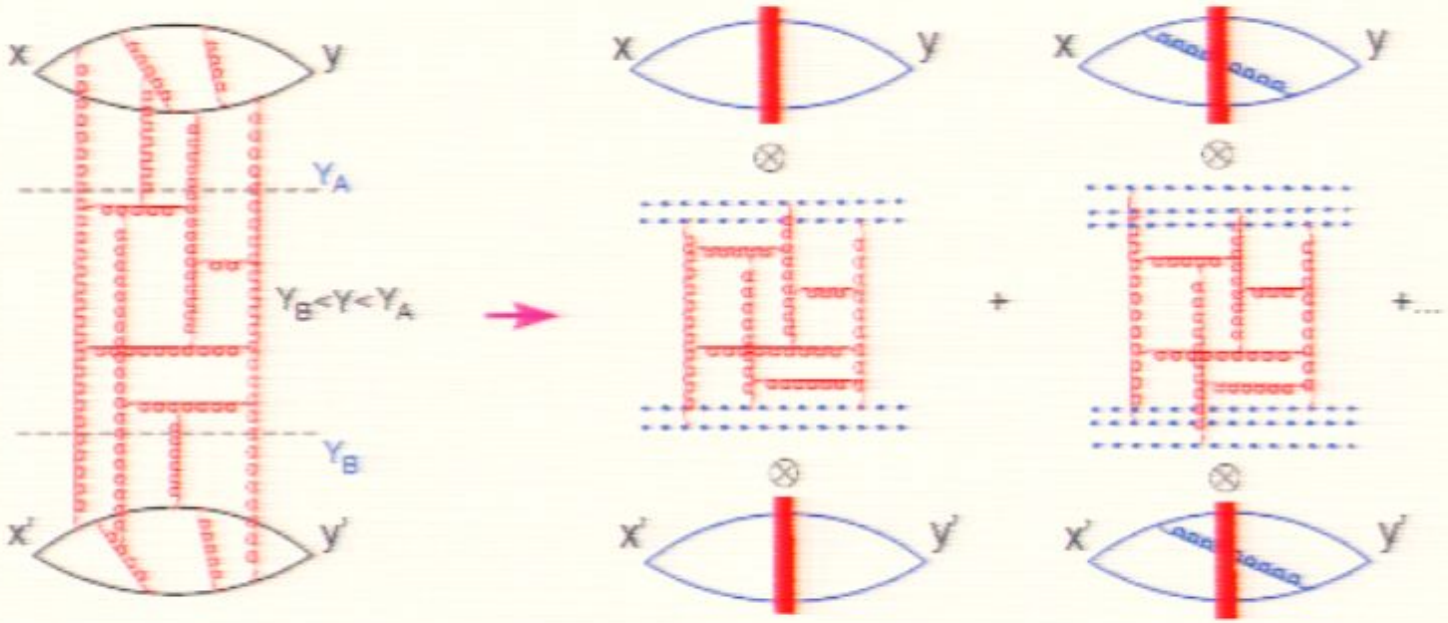


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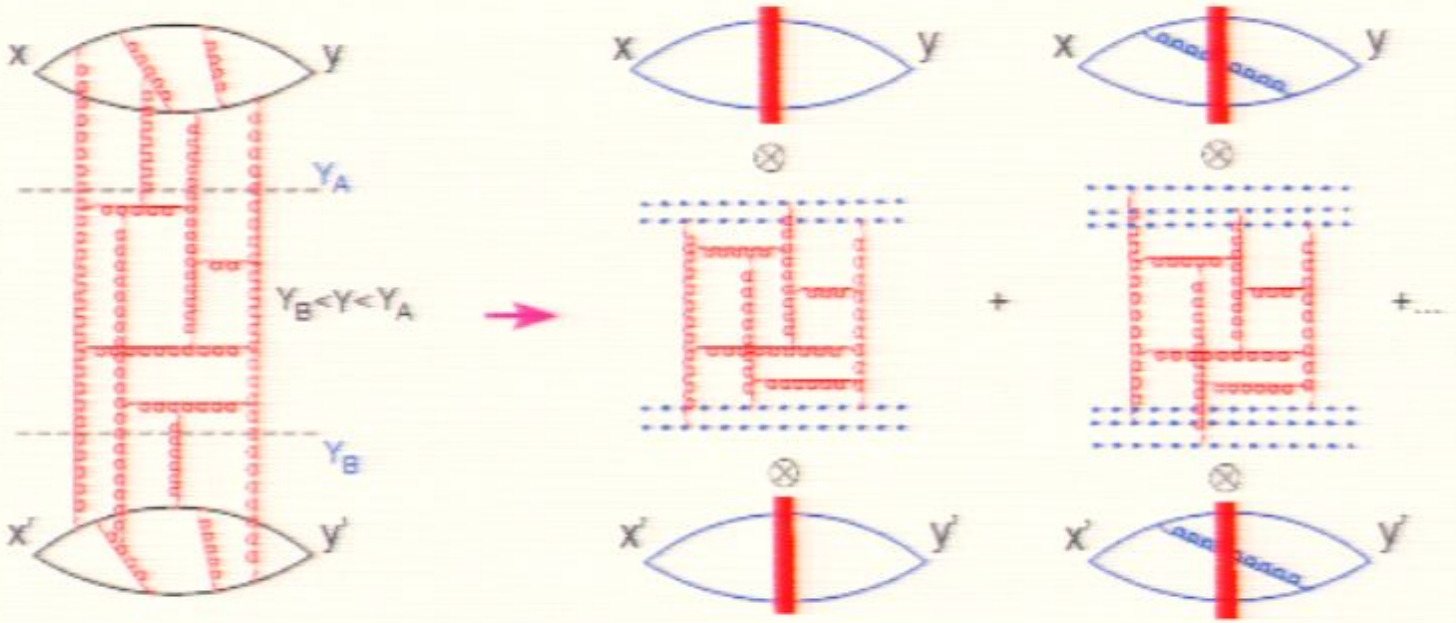


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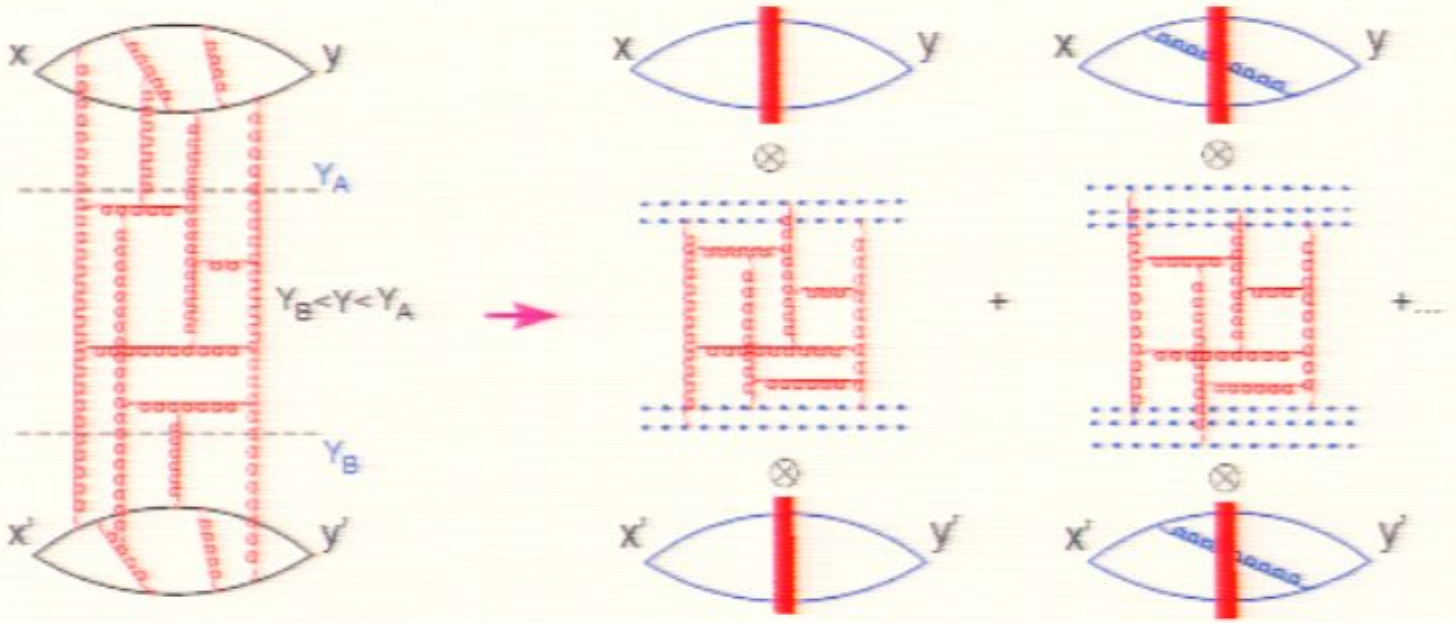
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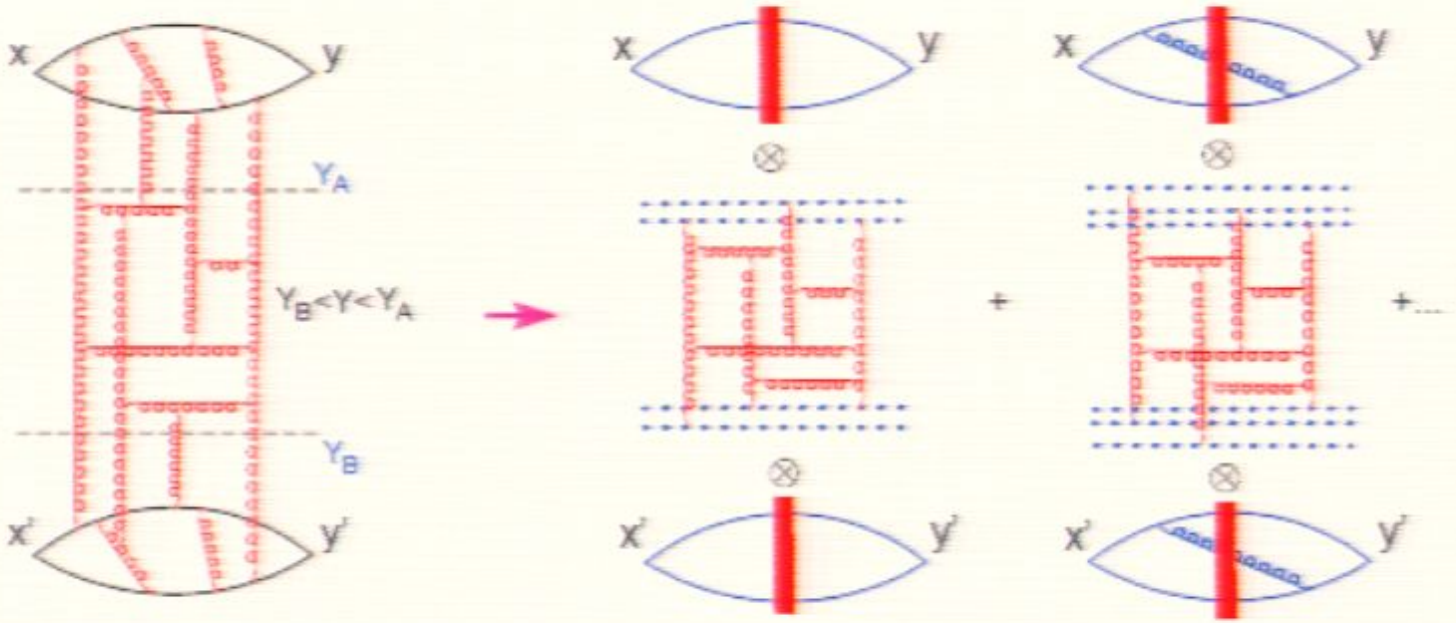
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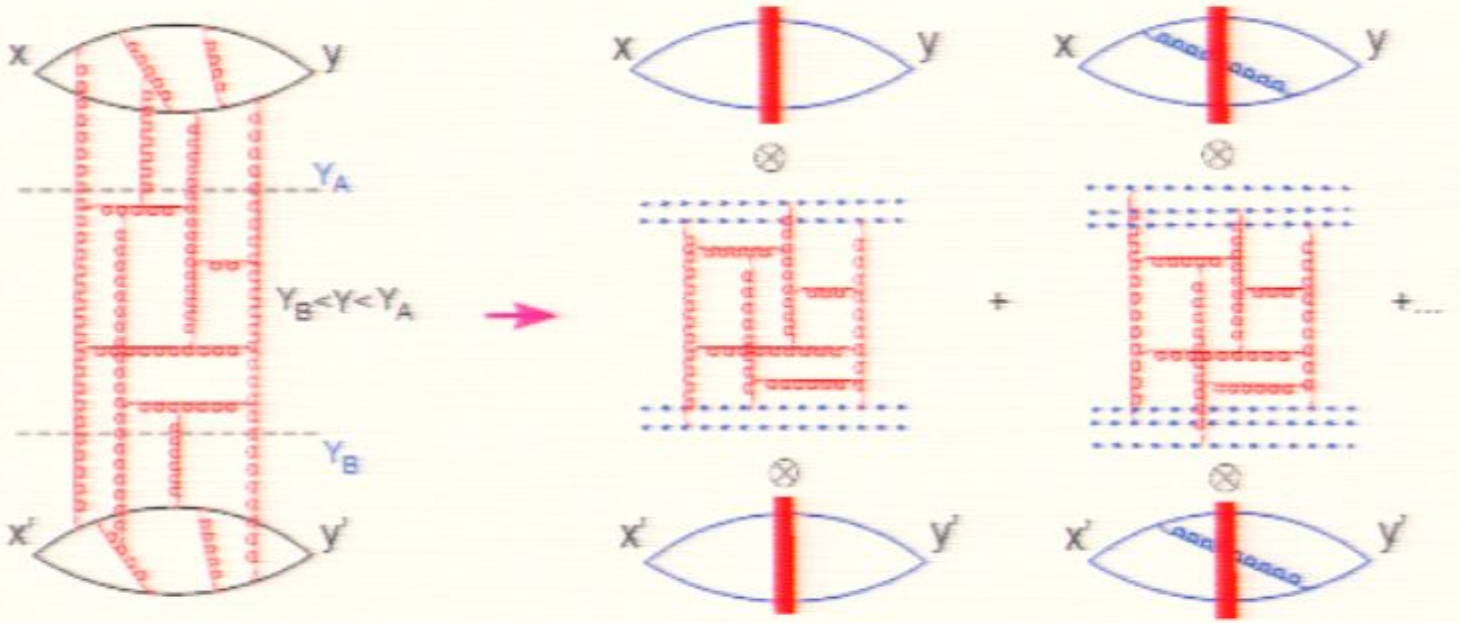
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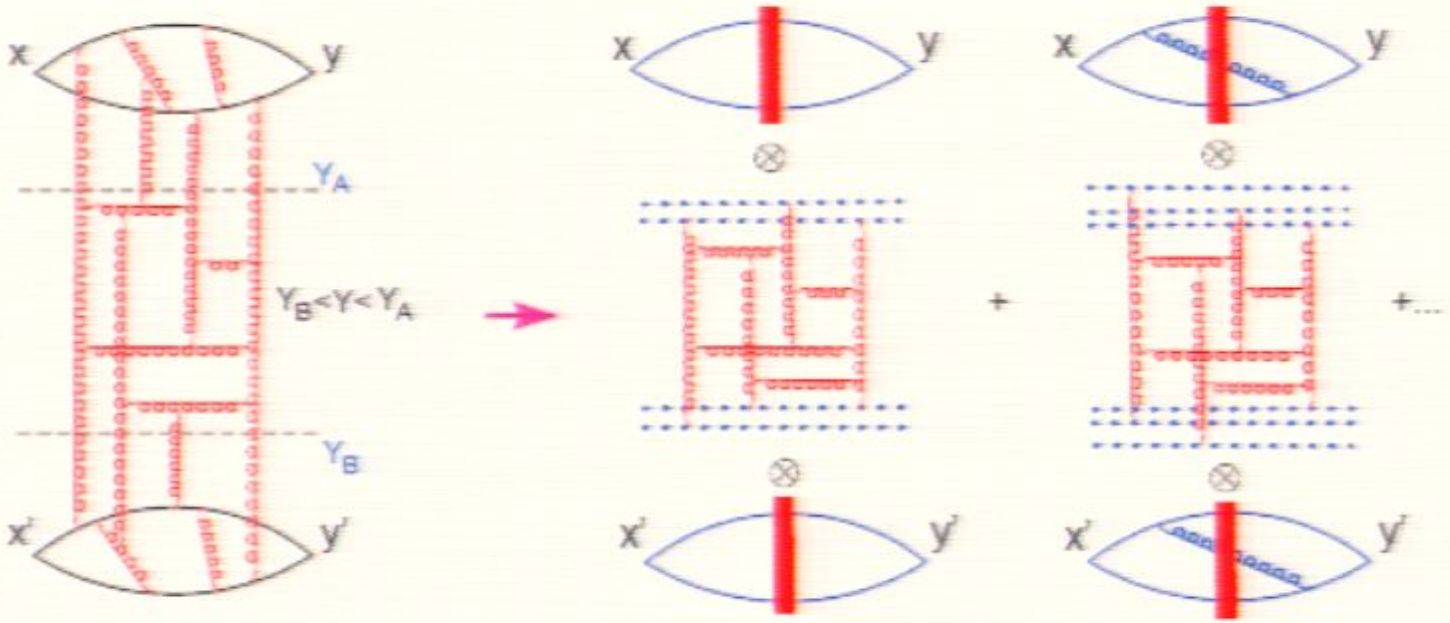


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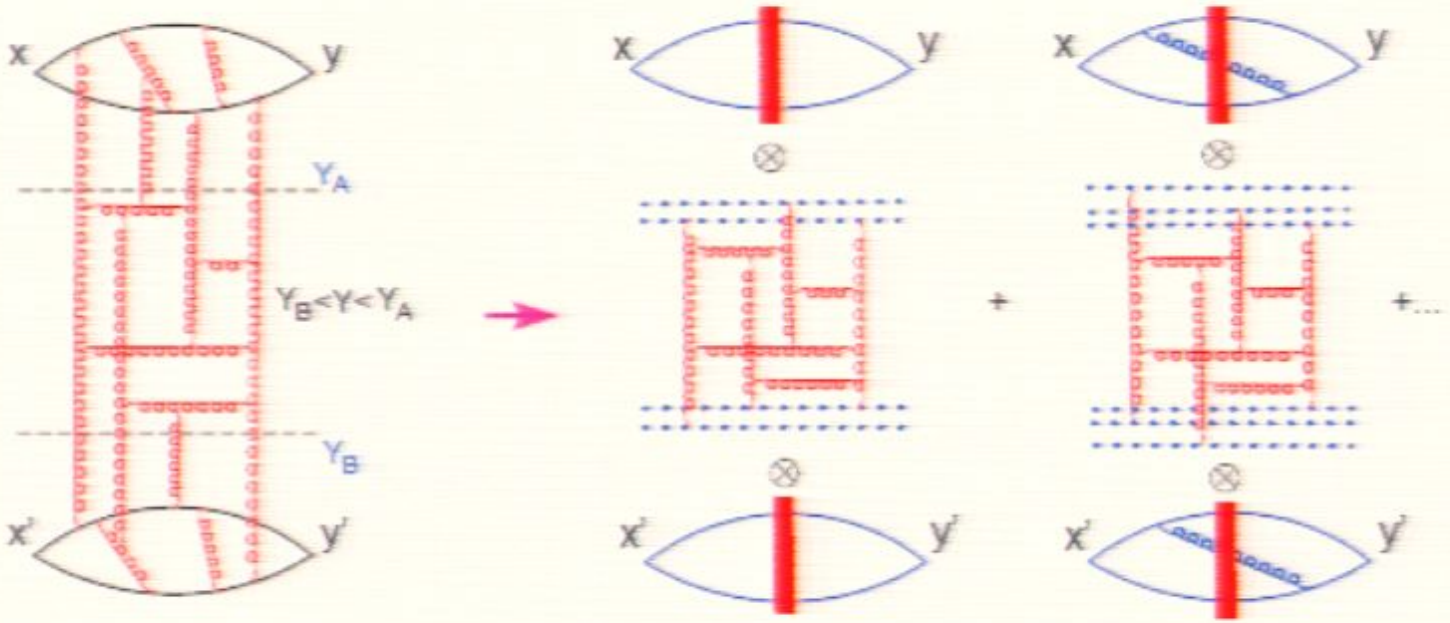


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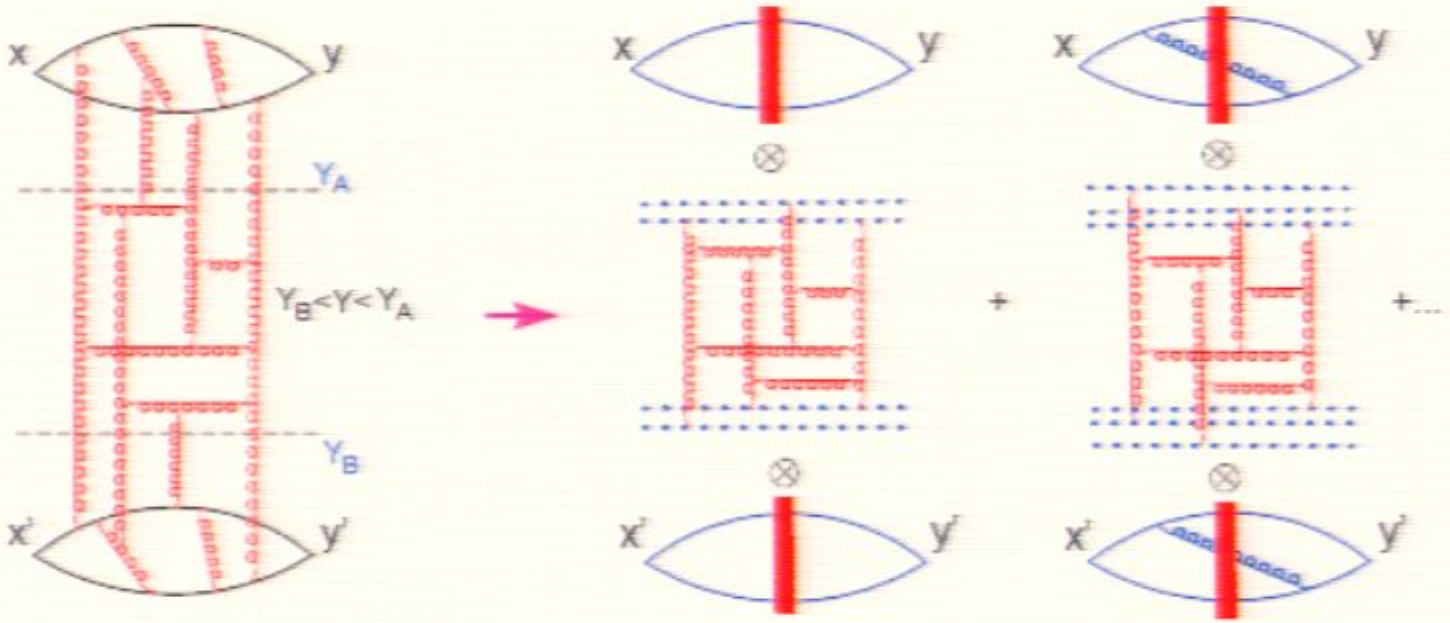
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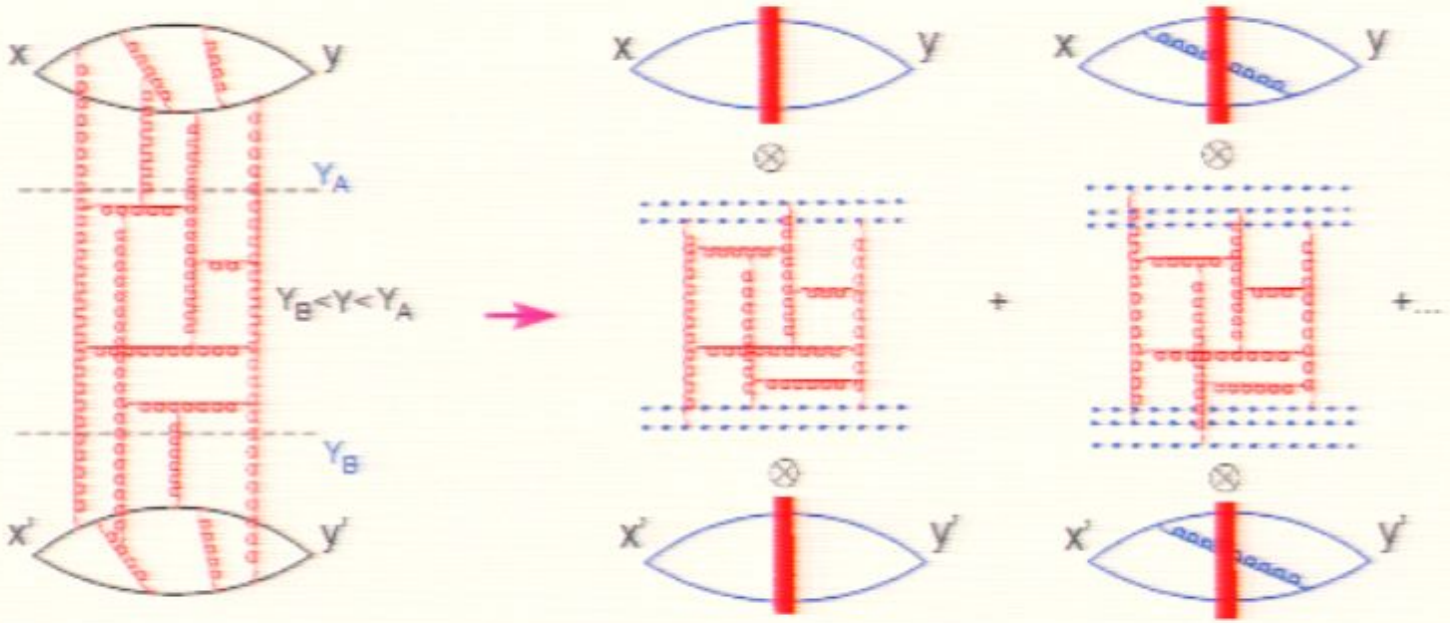
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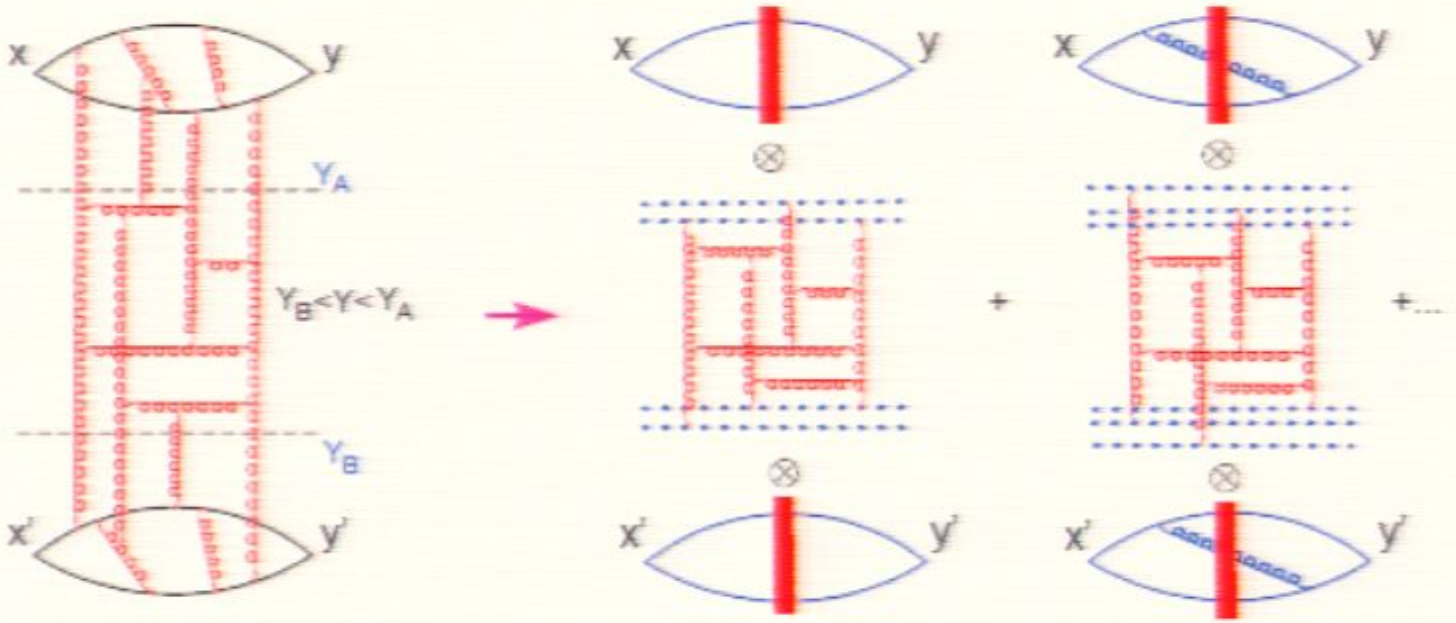
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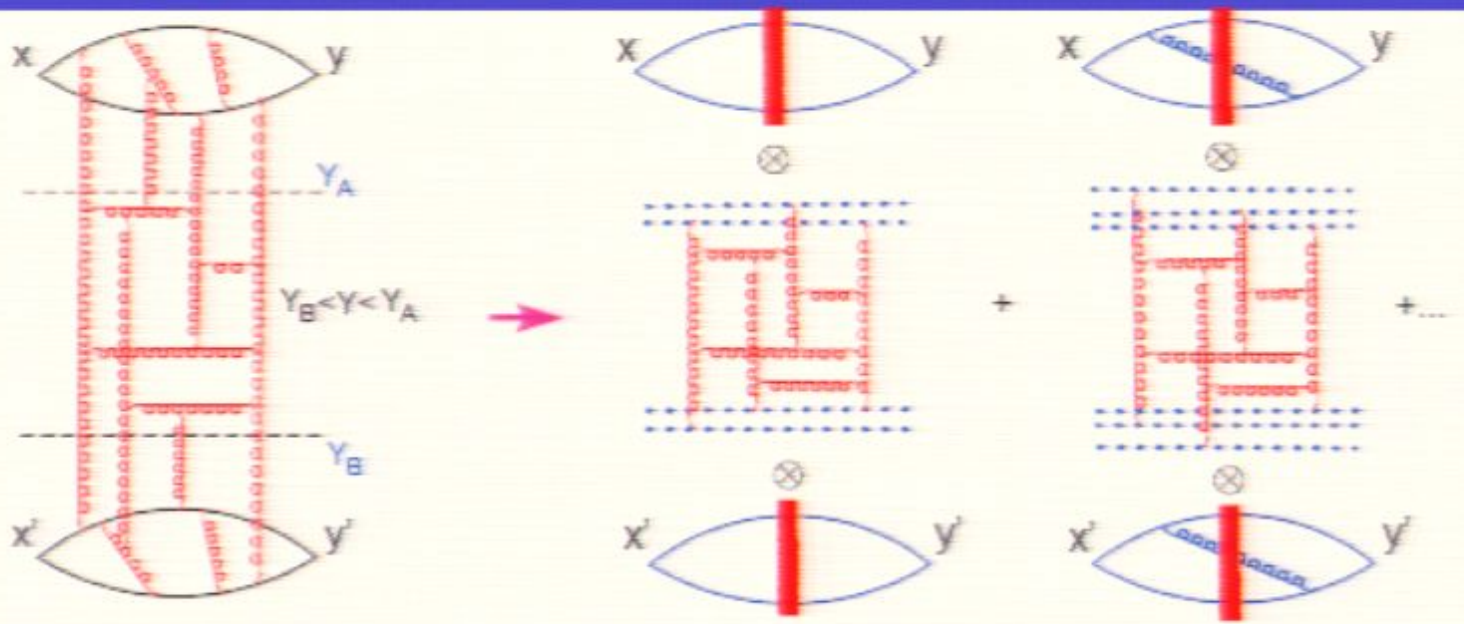
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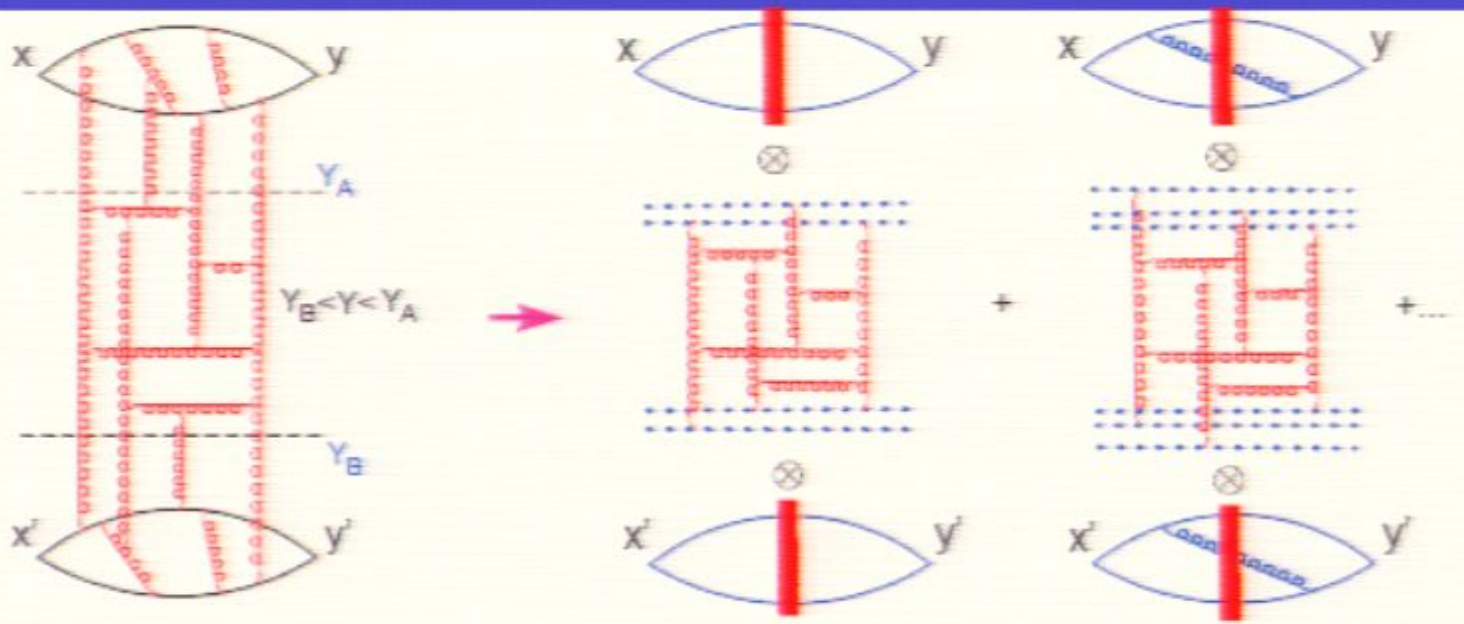
Dipole-dipole scattering

$$\chi(\gamma)\equiv 2C-\psi(\gamma)-\psi(1-\gamma)$$

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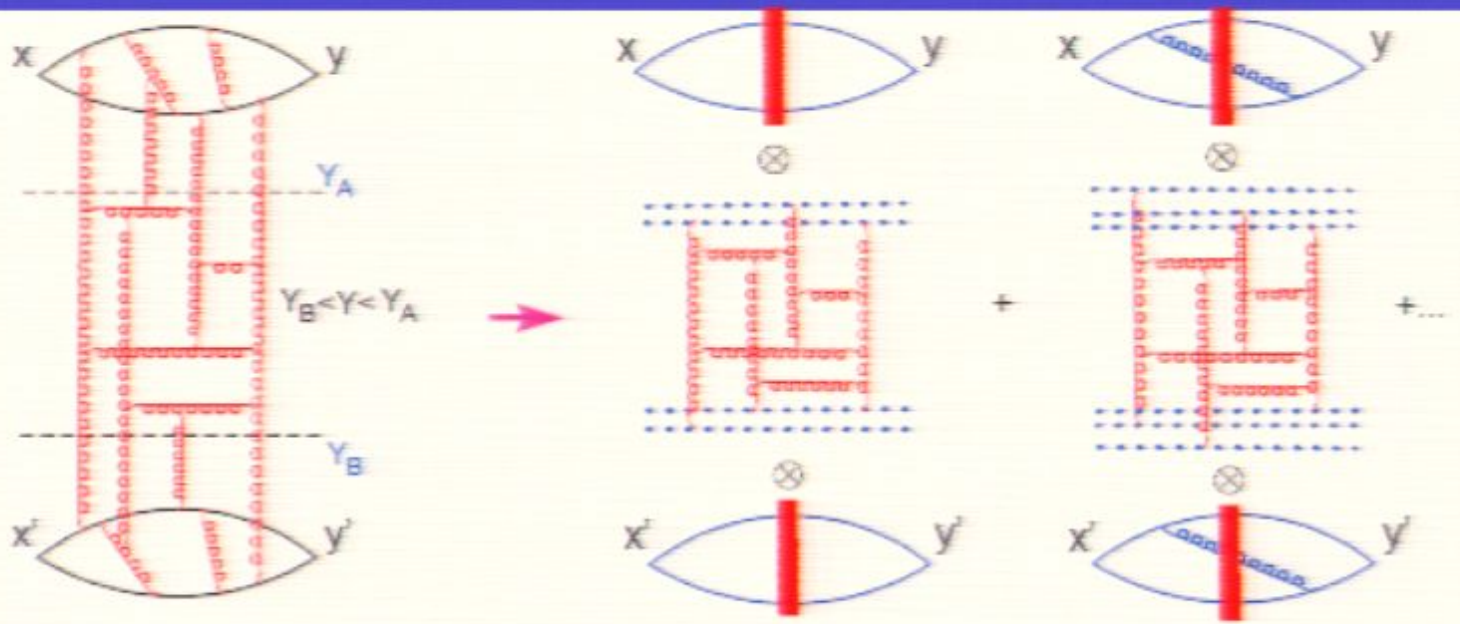
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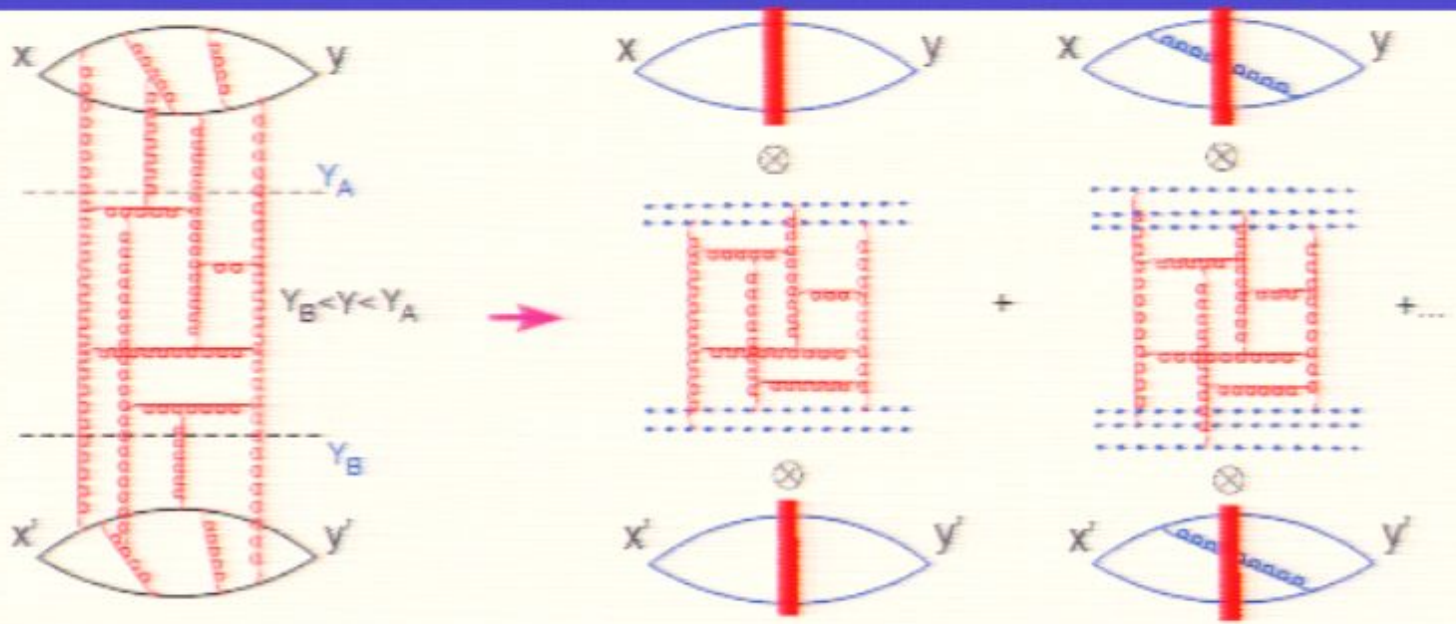
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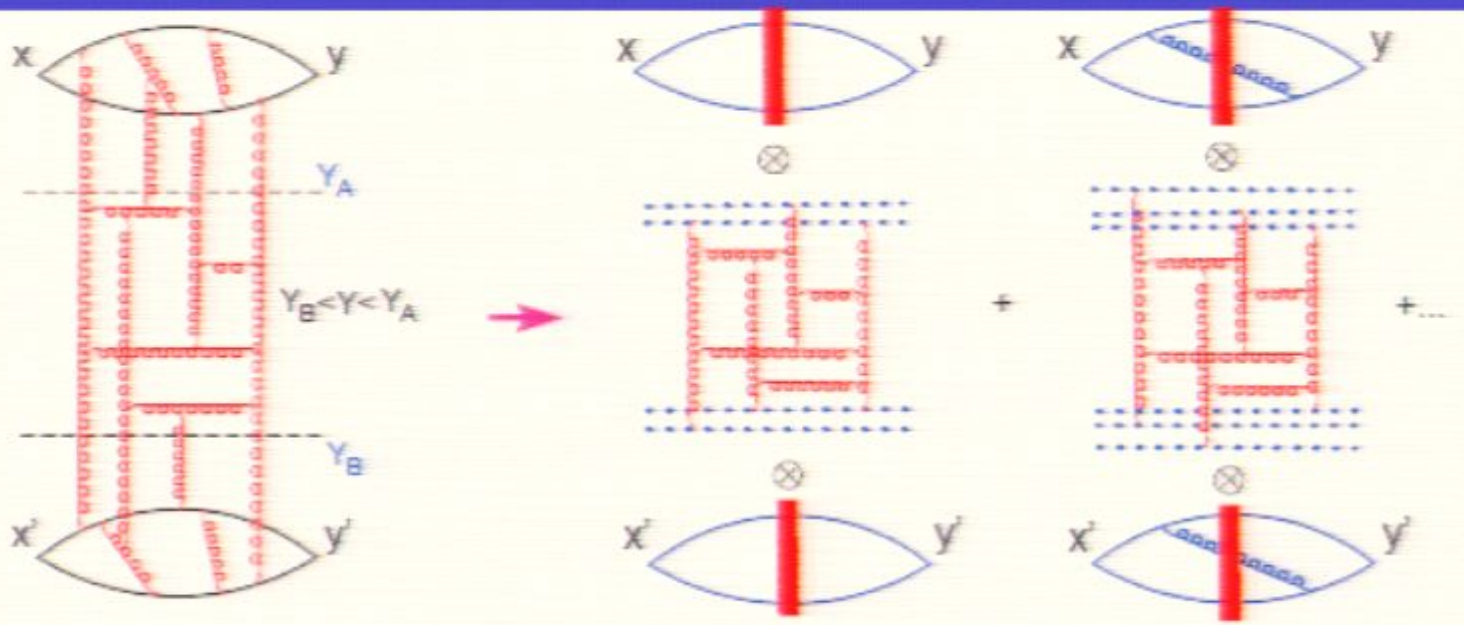
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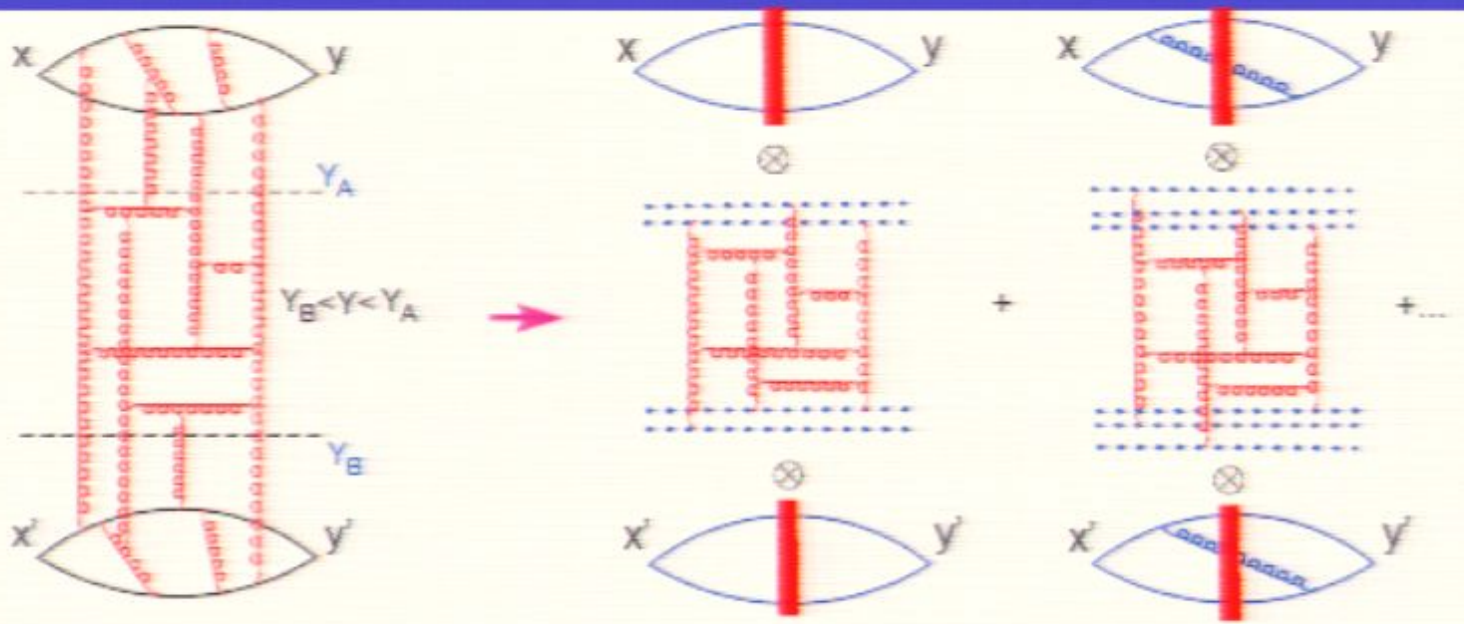
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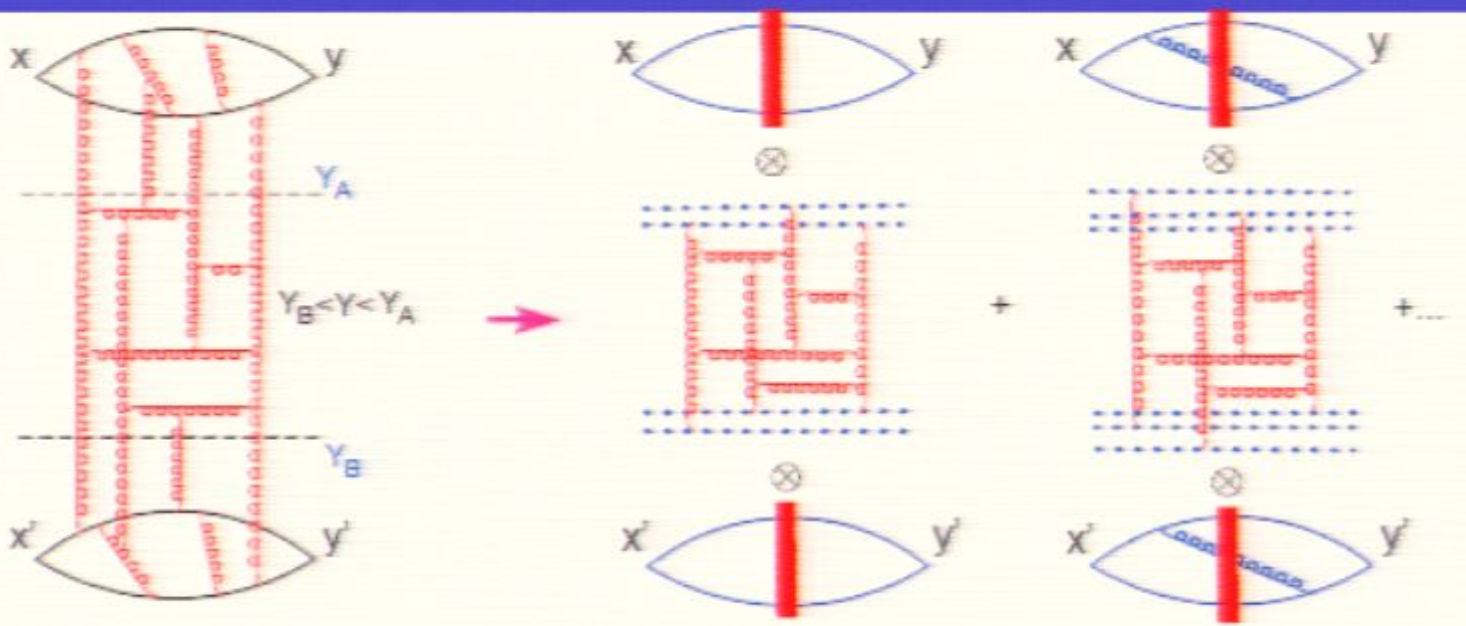
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NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity



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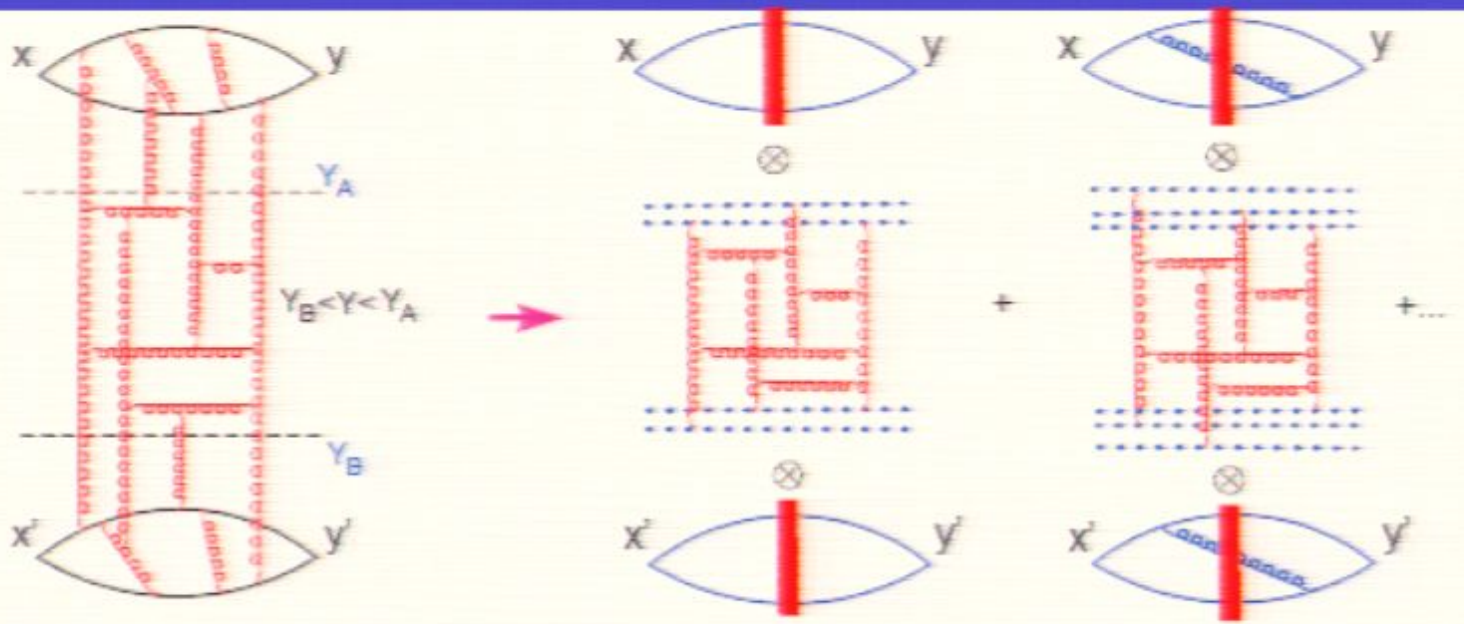
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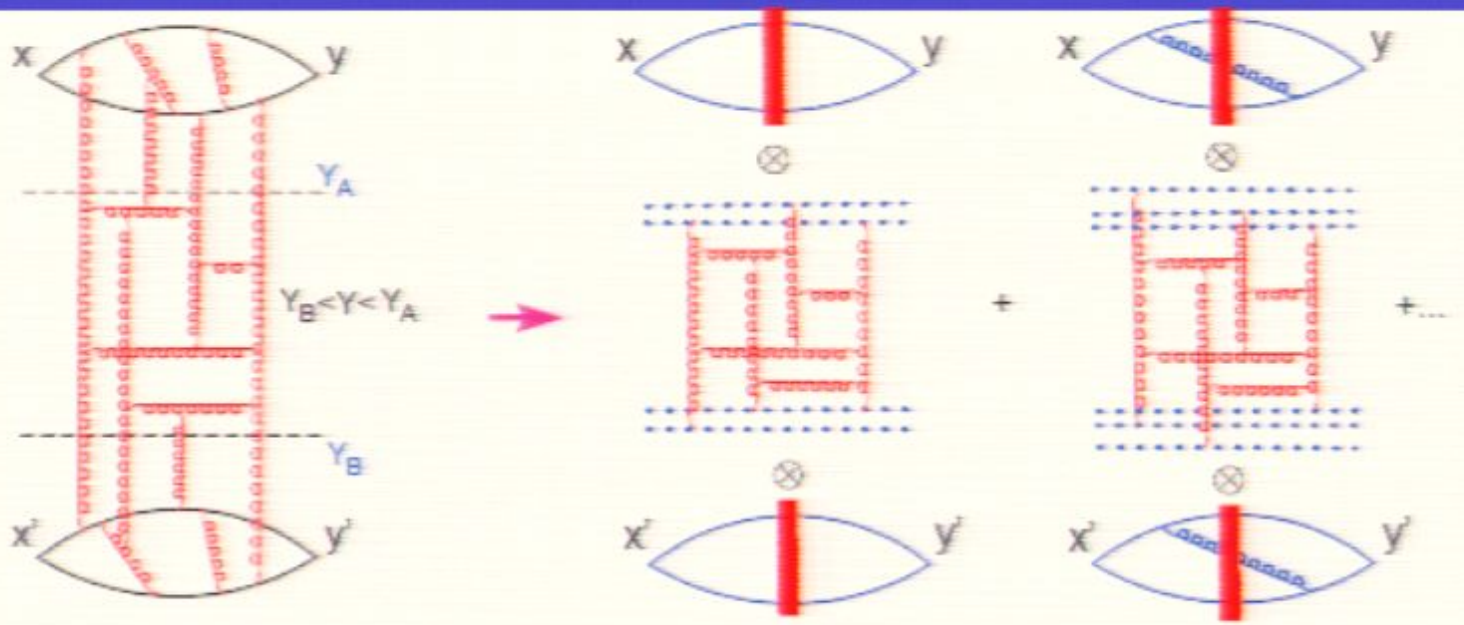
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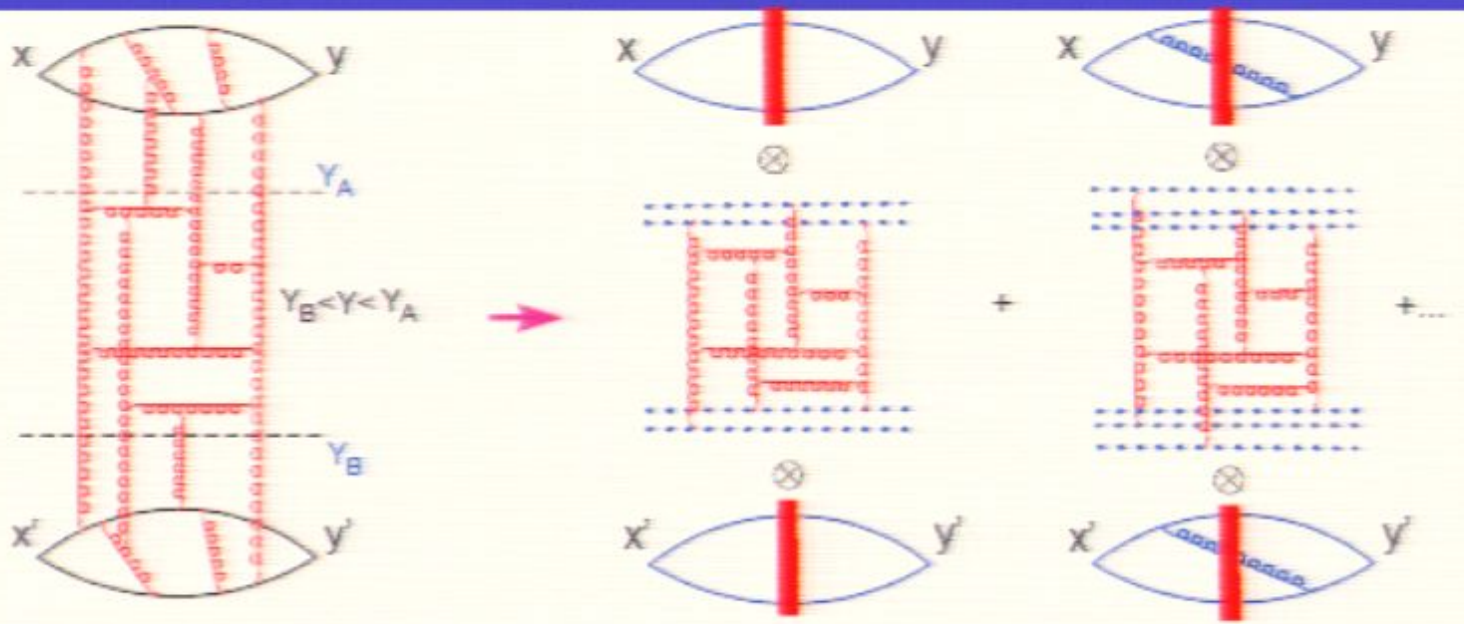
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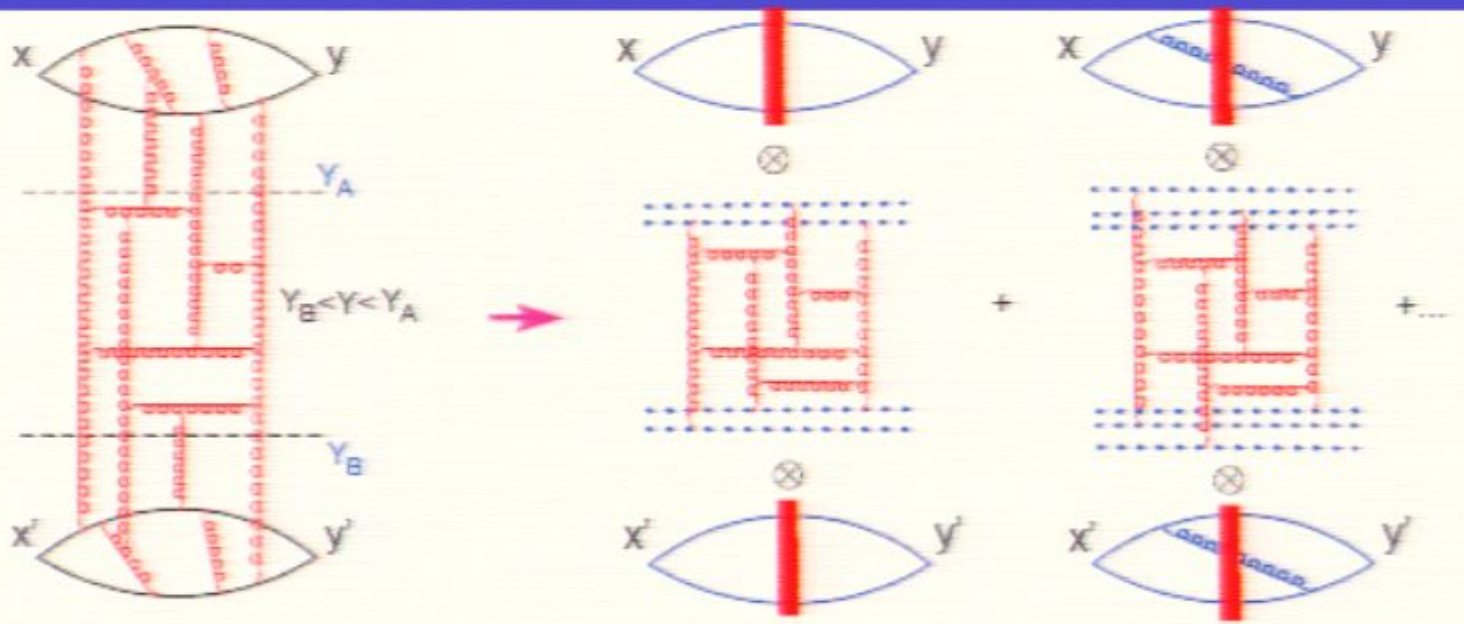
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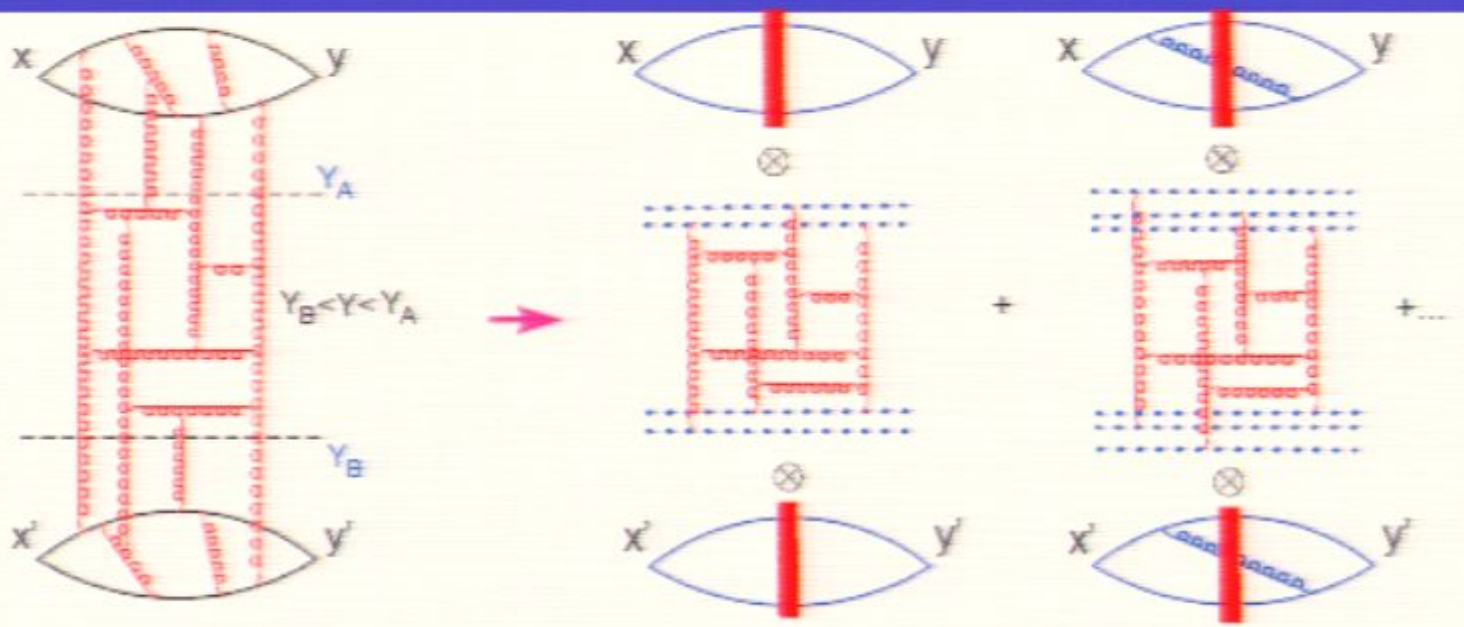
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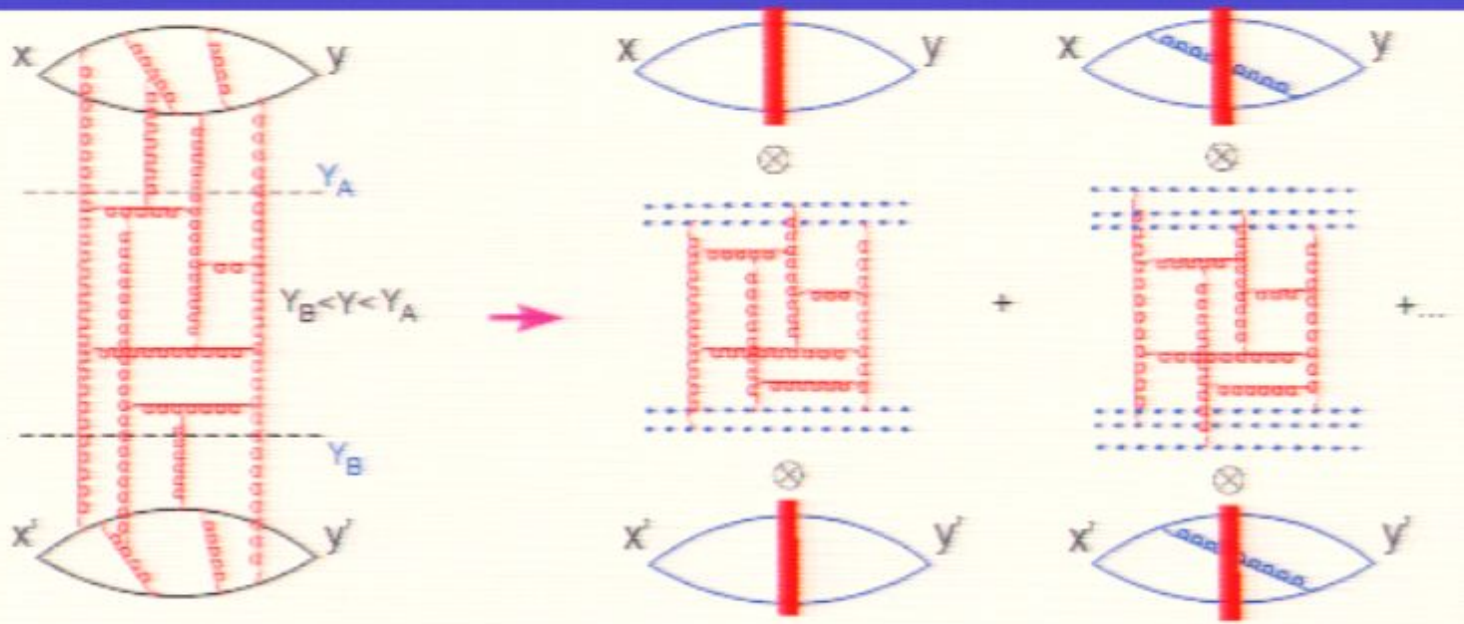
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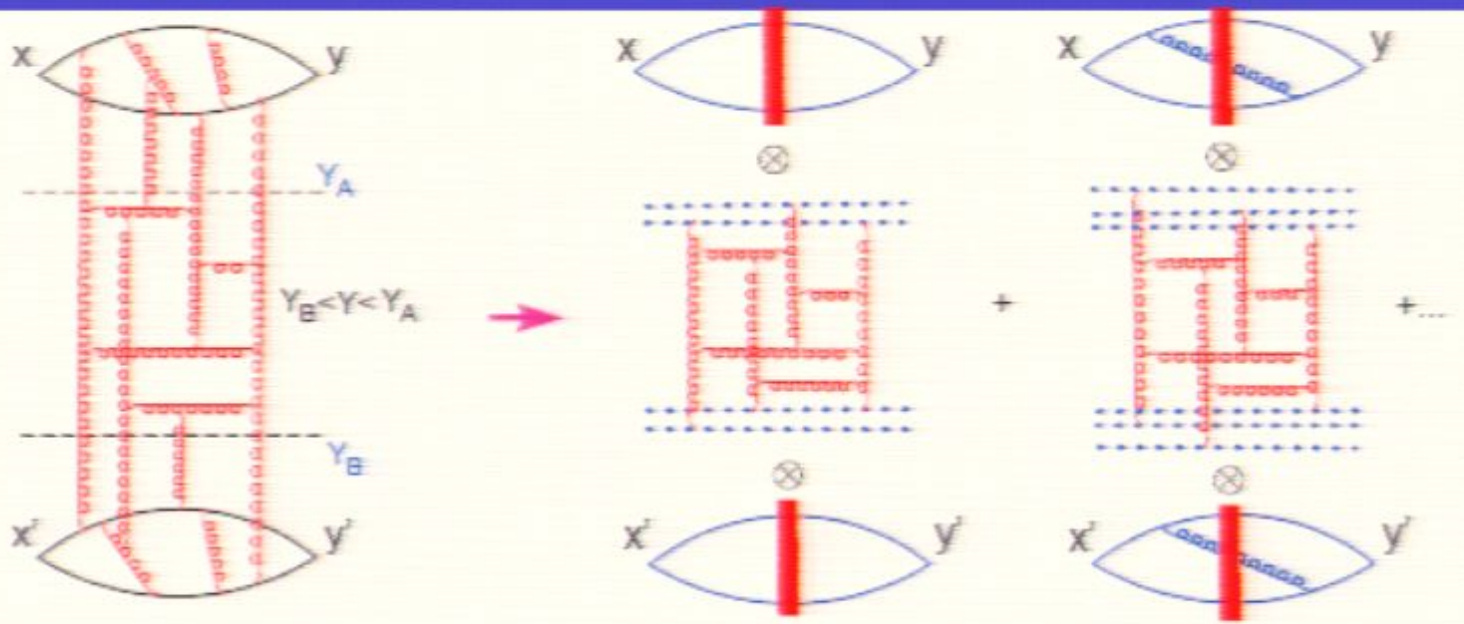
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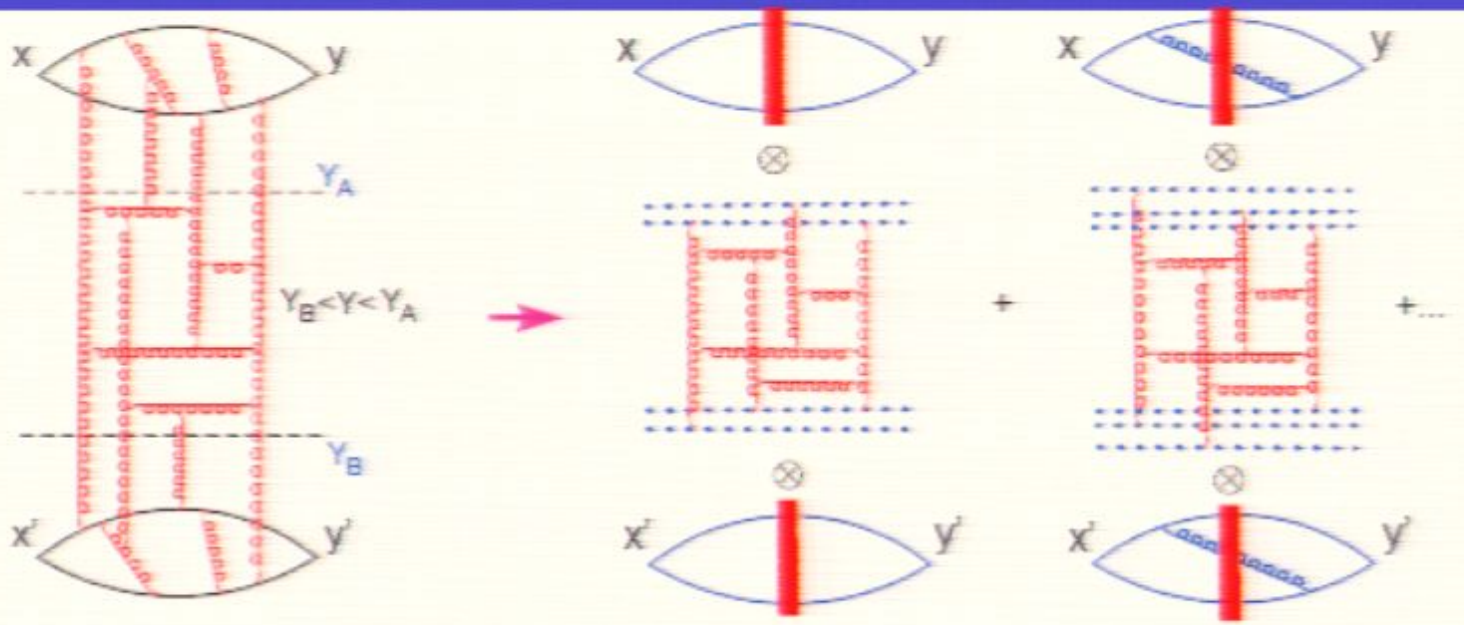
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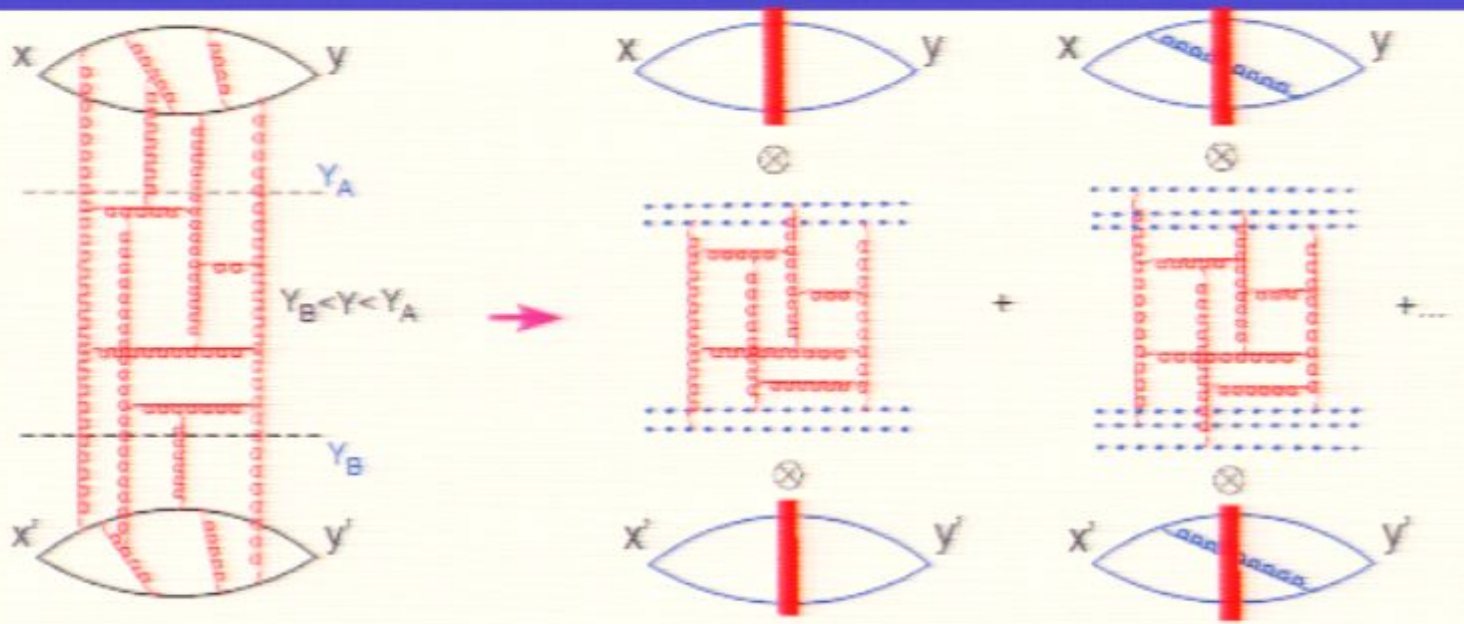
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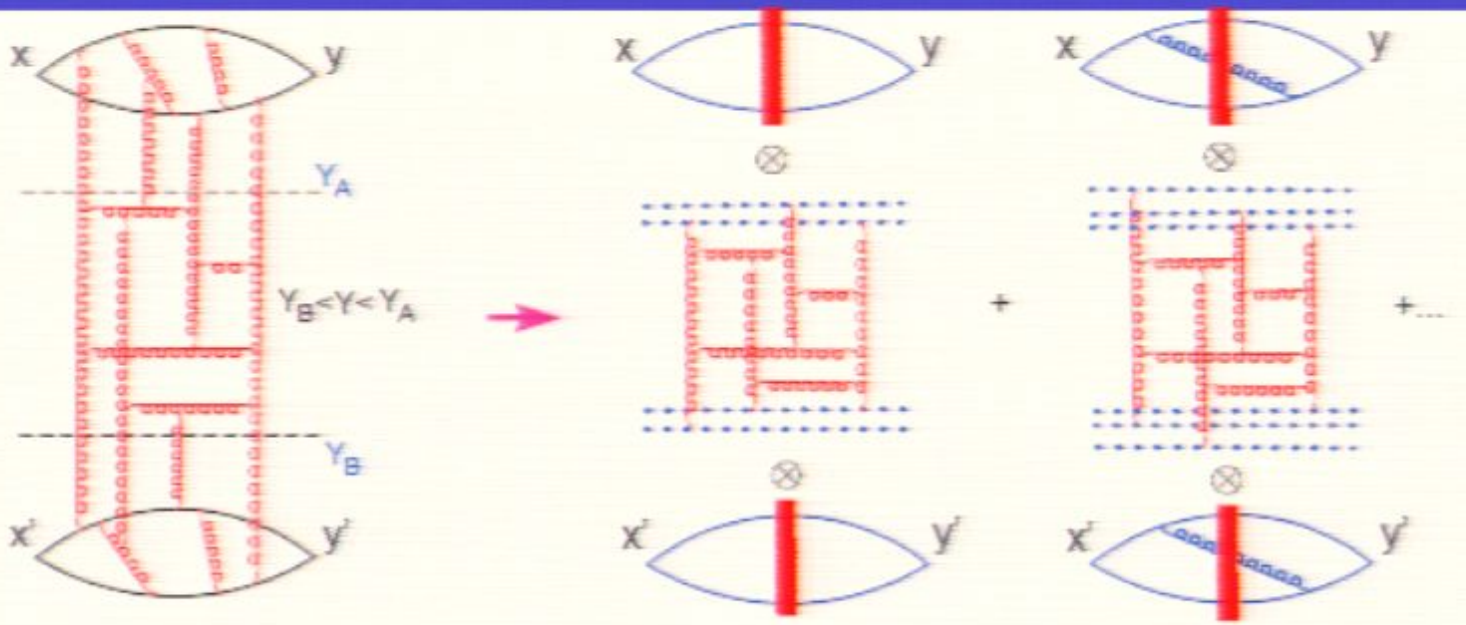
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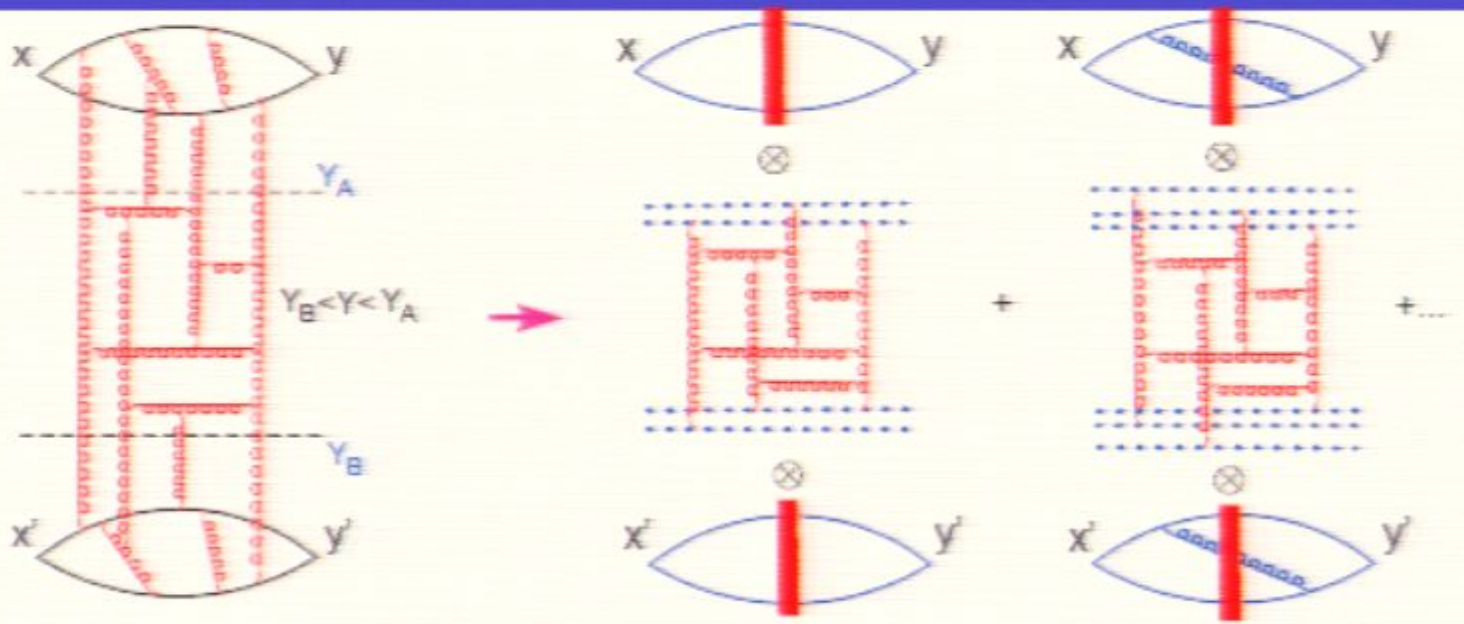
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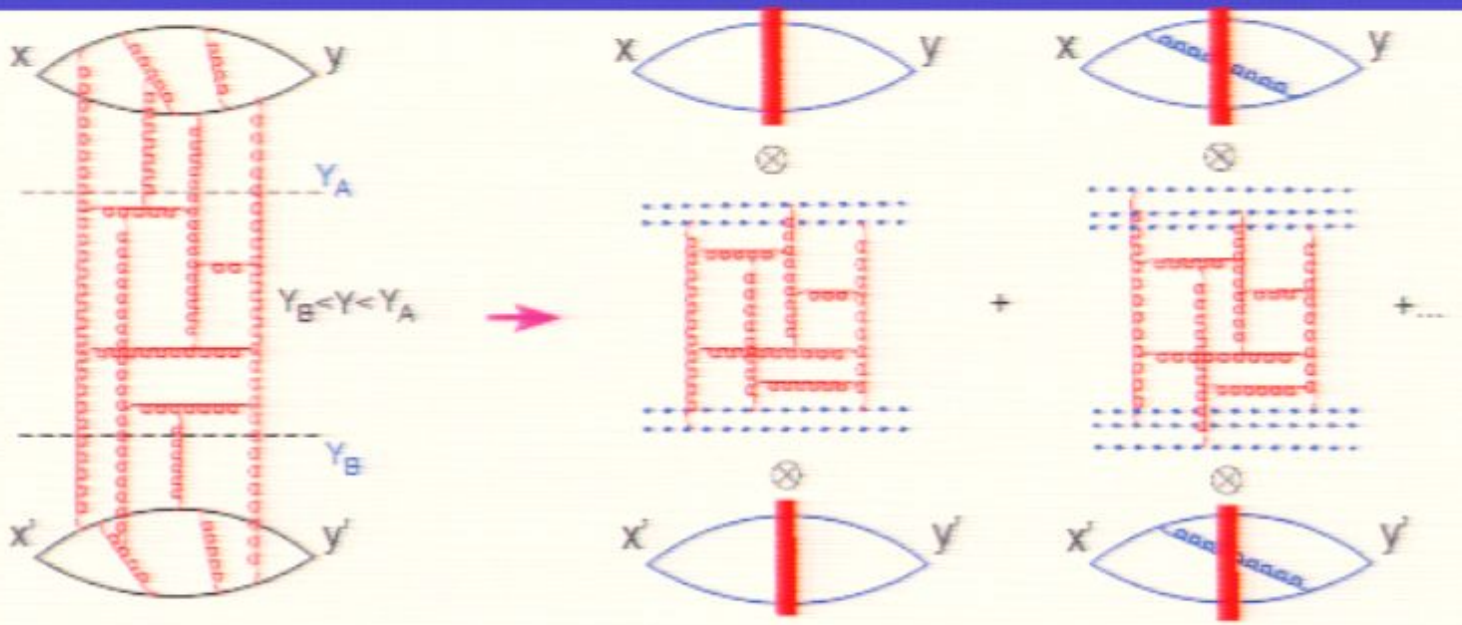
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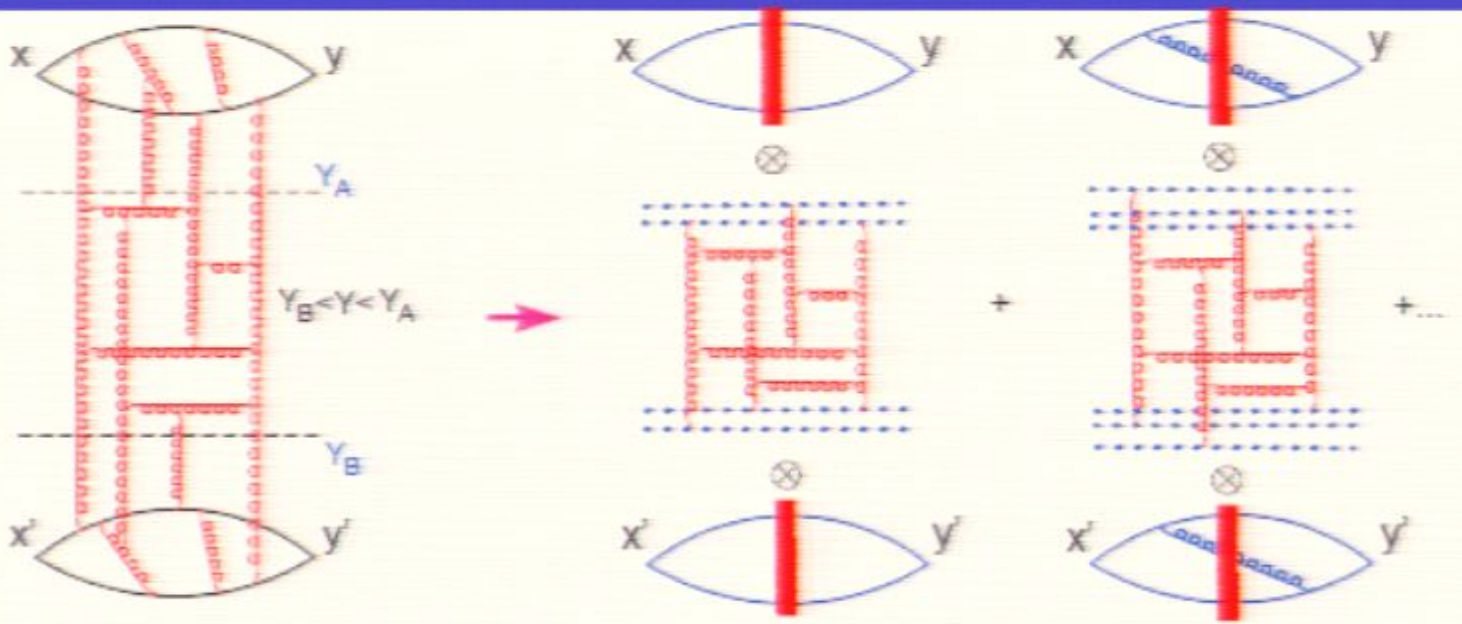
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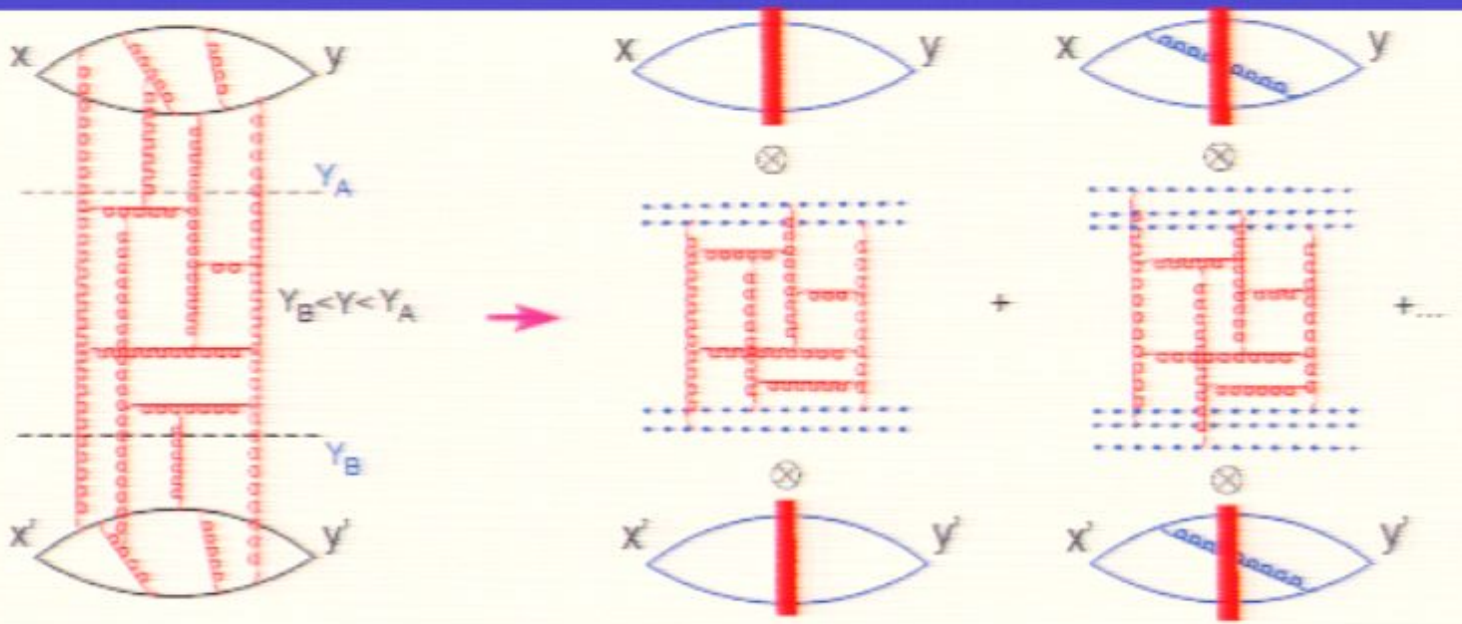
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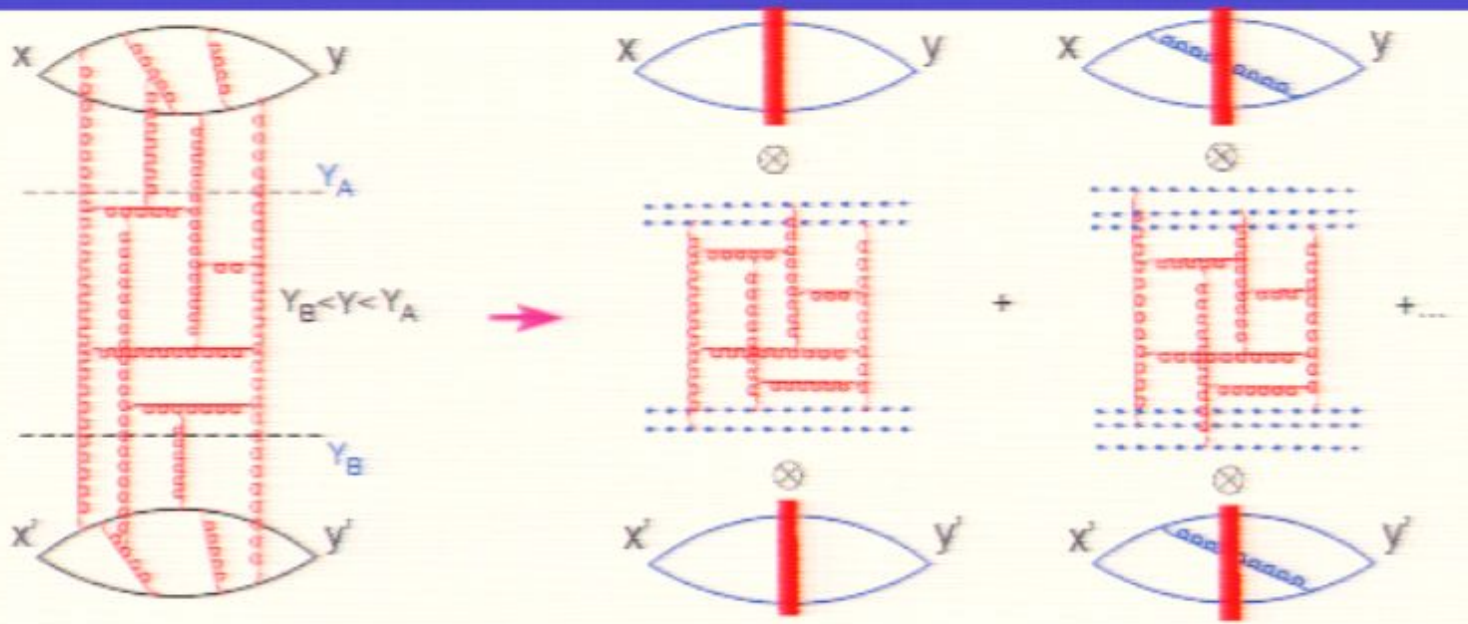
Dipole-dipole scattering

$$\chi(\gamma)\equiv 2C-\psi(\gamma)-\psi(1-\gamma)$$

$$[DD]=\int d\nu\int dz_0\left(\frac{z_{12}^2}{z_{10}^2z_{20}^2}\right)^{\frac{1}{2}+i\nu}\left(\frac{z_{12}^2}{z_{10}^2z_{20}^2}\right)^{\frac{1}{2}-i\nu}D\left(\frac{1}{2}+i\nu;\lambda\right)R^{\omega(\nu)/2}$$

$$D(\gamma;\lambda)=\frac{\Gamma(-\gamma)\Gamma(\gamma-1)}{\Gamma(1+\gamma)\Gamma(2-\gamma)}\left\{1-\frac{\lambda}{4\pi^2}\left[\frac{\chi(\gamma)}{\gamma(1-\gamma)}-\frac{\pi^2}{3}\right]+O(\lambda^2)\right\}$$

NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity



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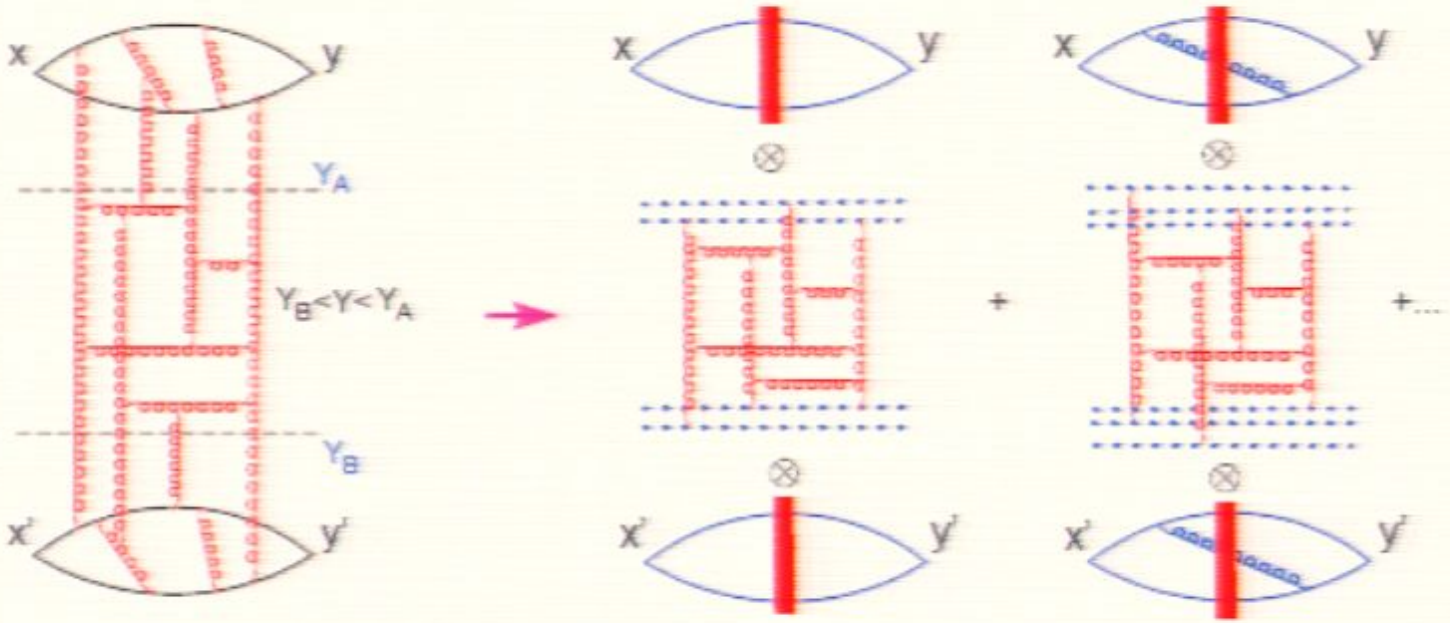
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NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity



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$a_0 = \frac{x_+y_+}{(x-y)^2}$, $b_0 = \frac{x'_-y'_-}{(x'-y')^2}$ $\Leftrightarrow$ impact factors do not scale with energy

$\Rightarrow$ all energy dependence is contained in $[\mathrm{DD}]^{a_0,b_0}$ $(a_0b_0 = R)$

NLO impact factor

$$(x-y)^4 T\{\hat{O}(x)\hat{O}(y)\} = \frac{(x-y)^4}{\pi^2}\int d^2z_1 d^2z_2 \frac{(x_+y_+)^{-2}}{z_1^2 z_2^2}\left\{\hat{U}^{\text{conf}}\right.$$

$$\left. -\frac{\lambda}{2\pi^2}\int \frac{d^2z_3\, z_{12}^2}{z_{13}^2 z_{23}^2}\left[\ln\frac{a z_{12}^2 z_3^2}{z_{13}^2 z_{23}^2} - i\pi\right]\left[\hat{U}^{\text{conf}}(z_1,z_3)+\hat{U}^{\text{conf}}(z_2,z_3)-\hat{U}^{\text{conf}}(z_1,z_2)\right]\right\}$$

With two-gluon accuracy ($\mathcal{R} \equiv \frac{(x-y)^2 z_{12}^2}{x_+y_+ z_1 z_2}$ - conformal ratio)

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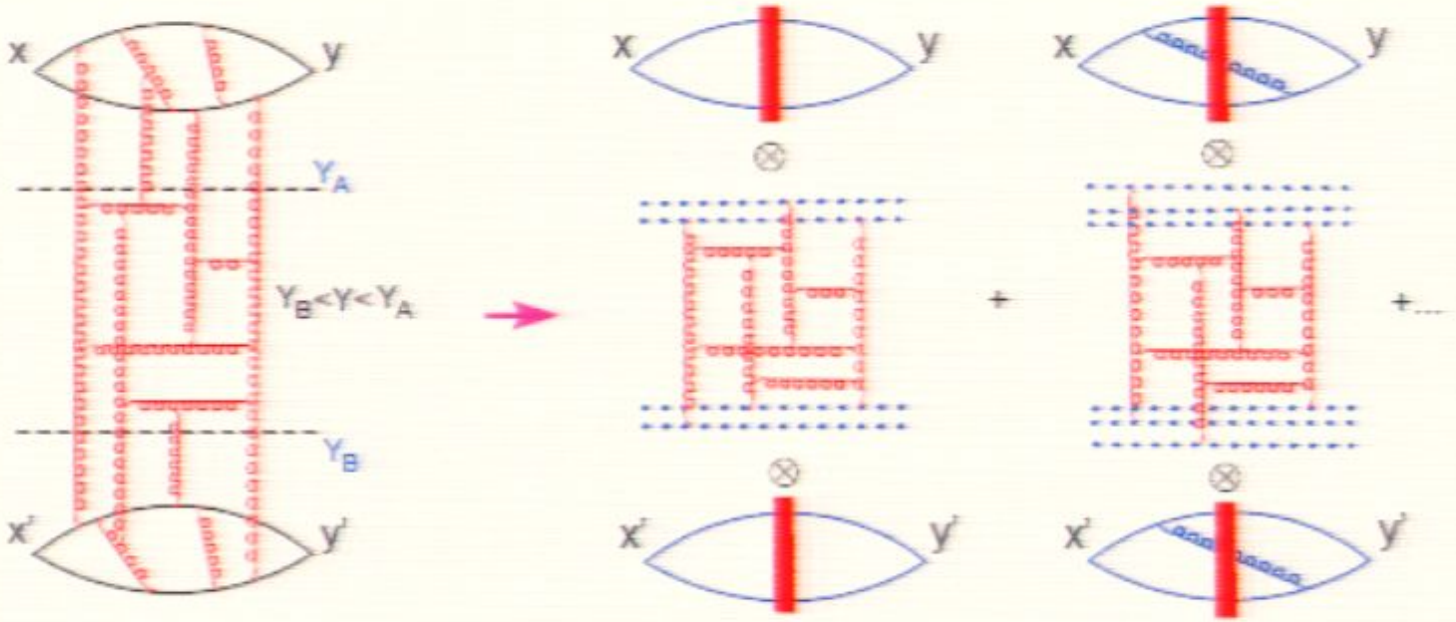
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NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity



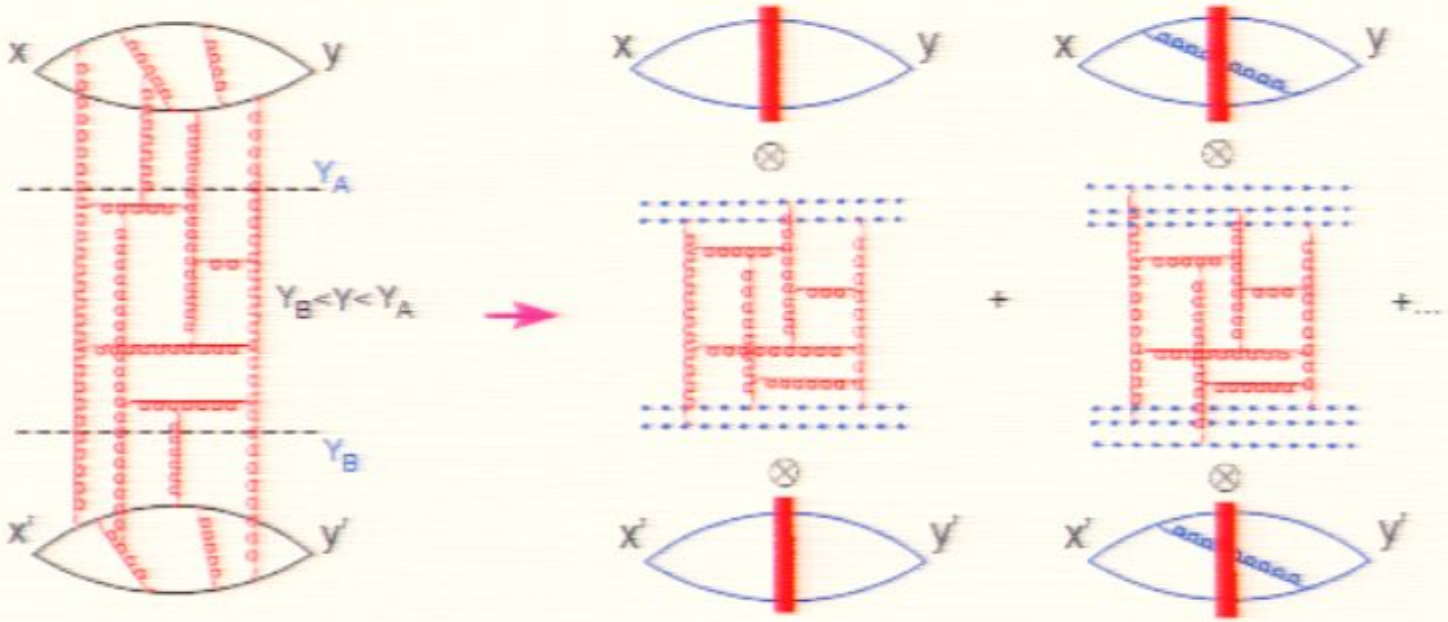
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Result : (G.A. Chirilli and I.B.)

$$F(\nu) = \frac{N_c^2}{N_c^2-1}\frac{4\pi^4\alpha_s^2}{\cosh^2\pi\nu}\left\{1+\frac{\alpha_s N_c}{\pi}\left[\frac{\pi^2}{2}-\frac{2\pi^2}{\cosh^2\pi\nu}-\frac{8}{1+4\nu^2}\right]+O(\alpha_s^2)\right\}$$

NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity



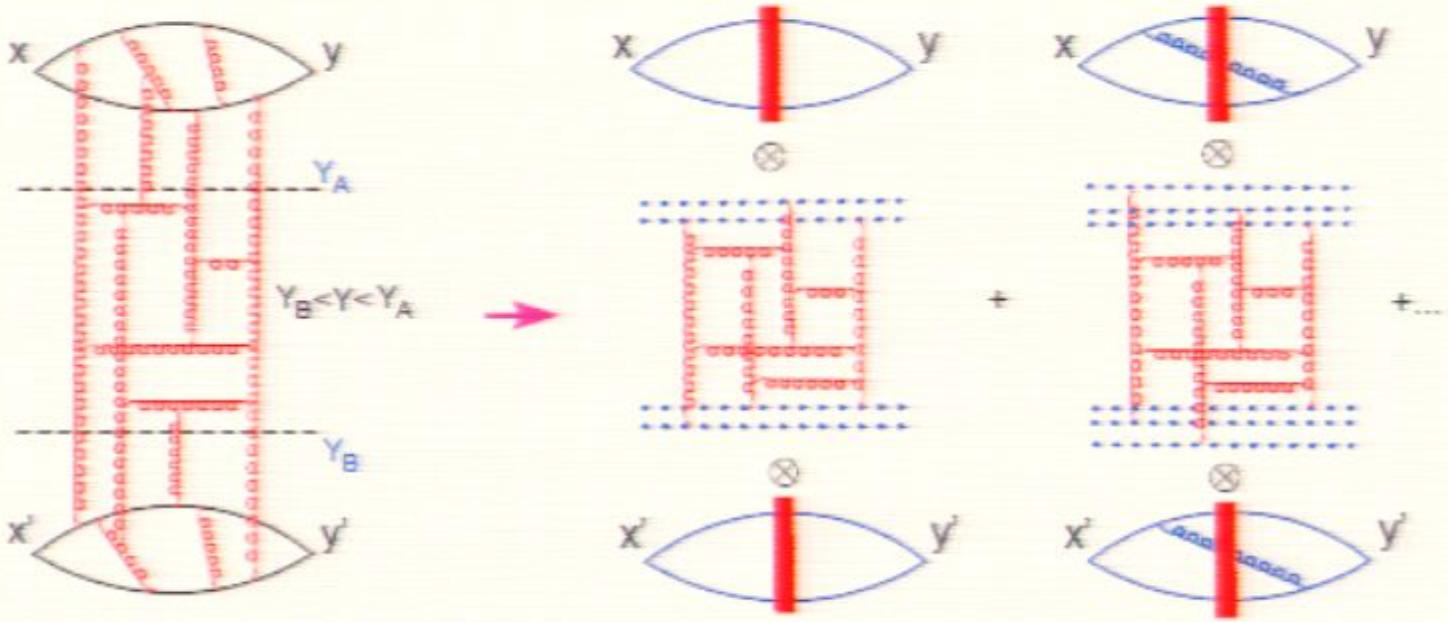
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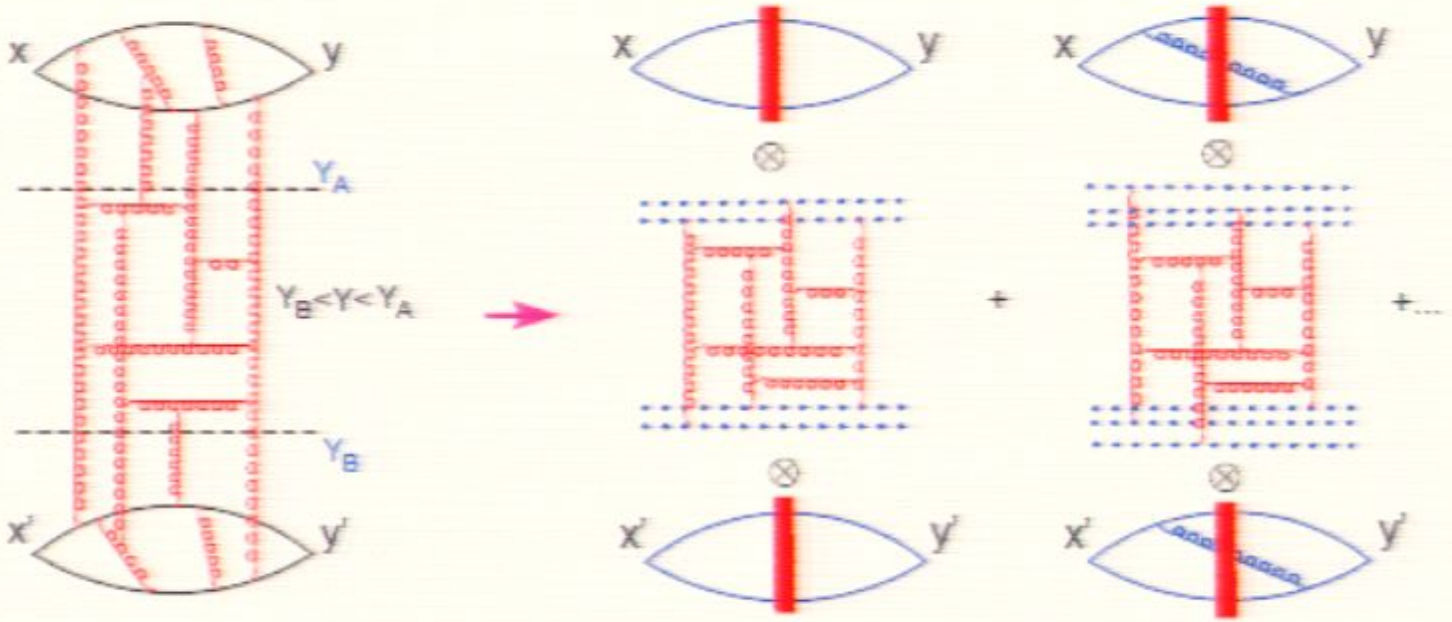
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NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity



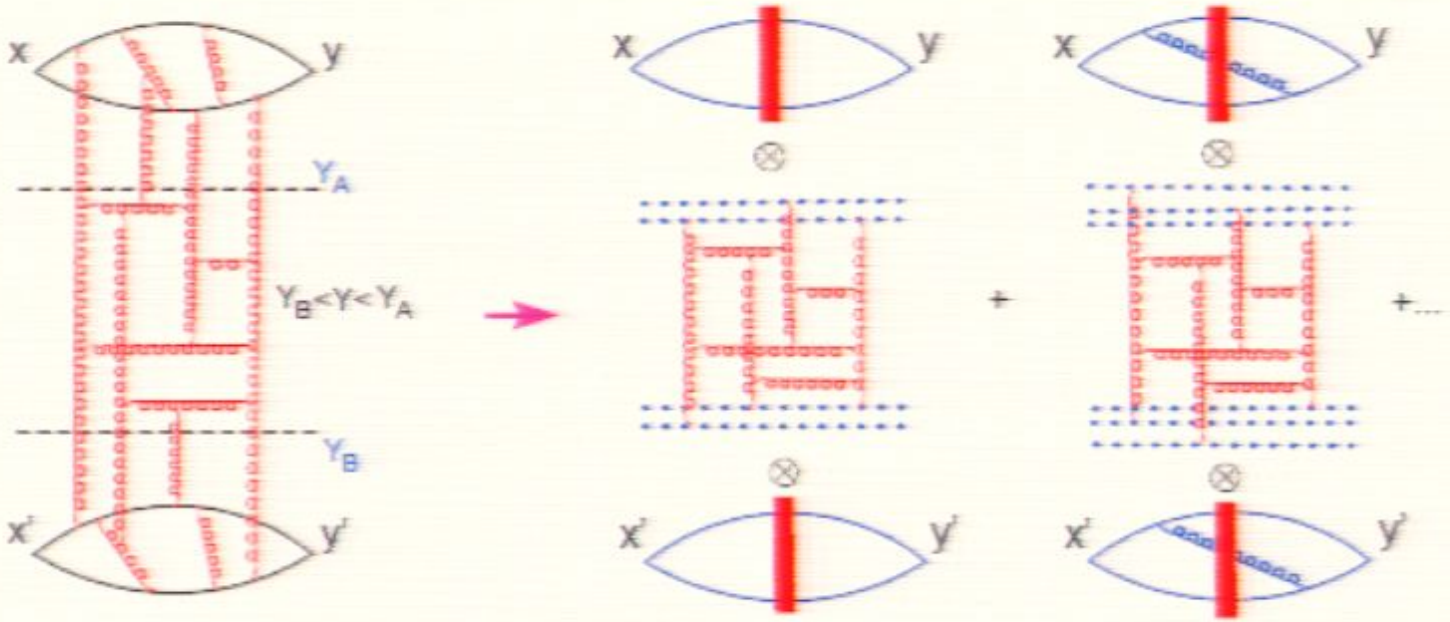
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NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity



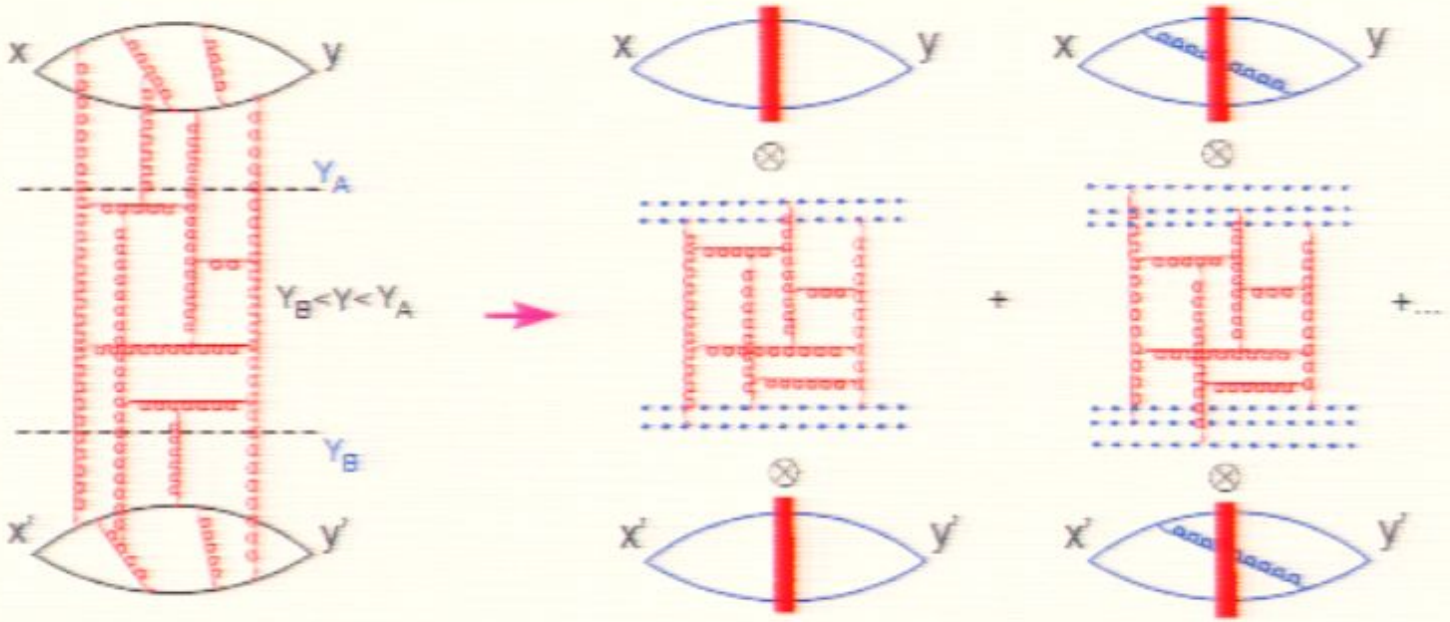
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NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity



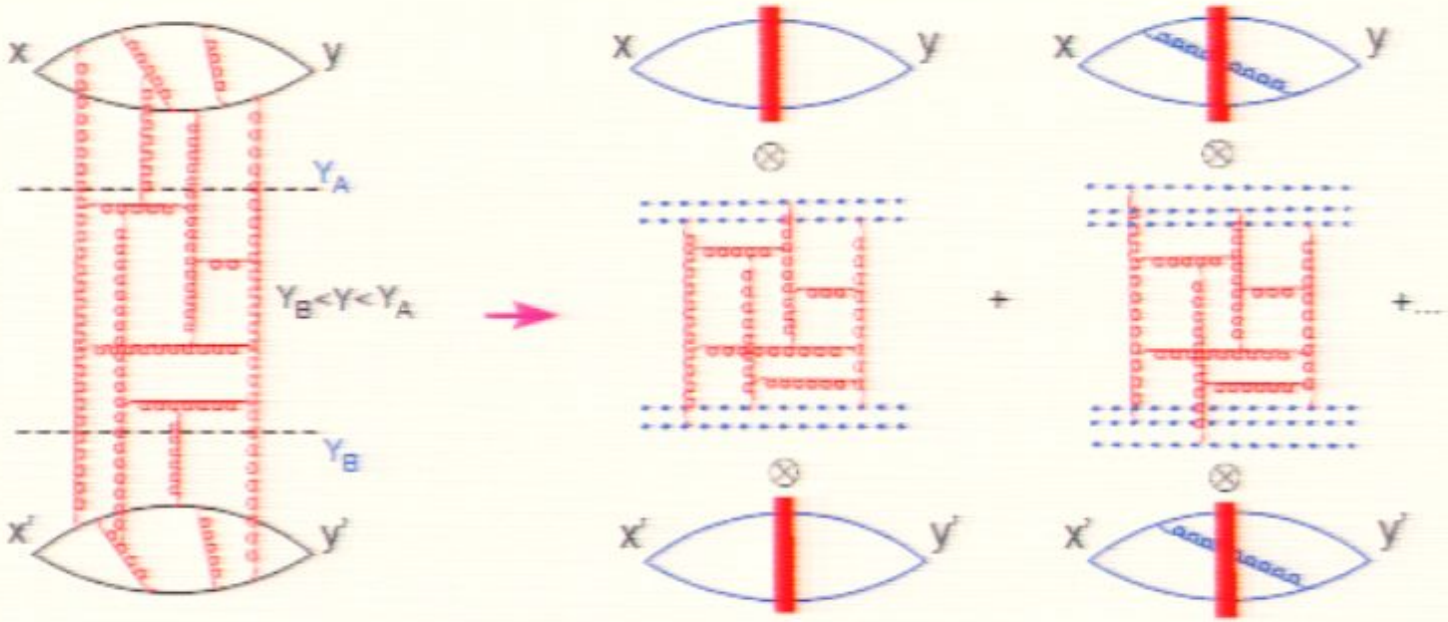
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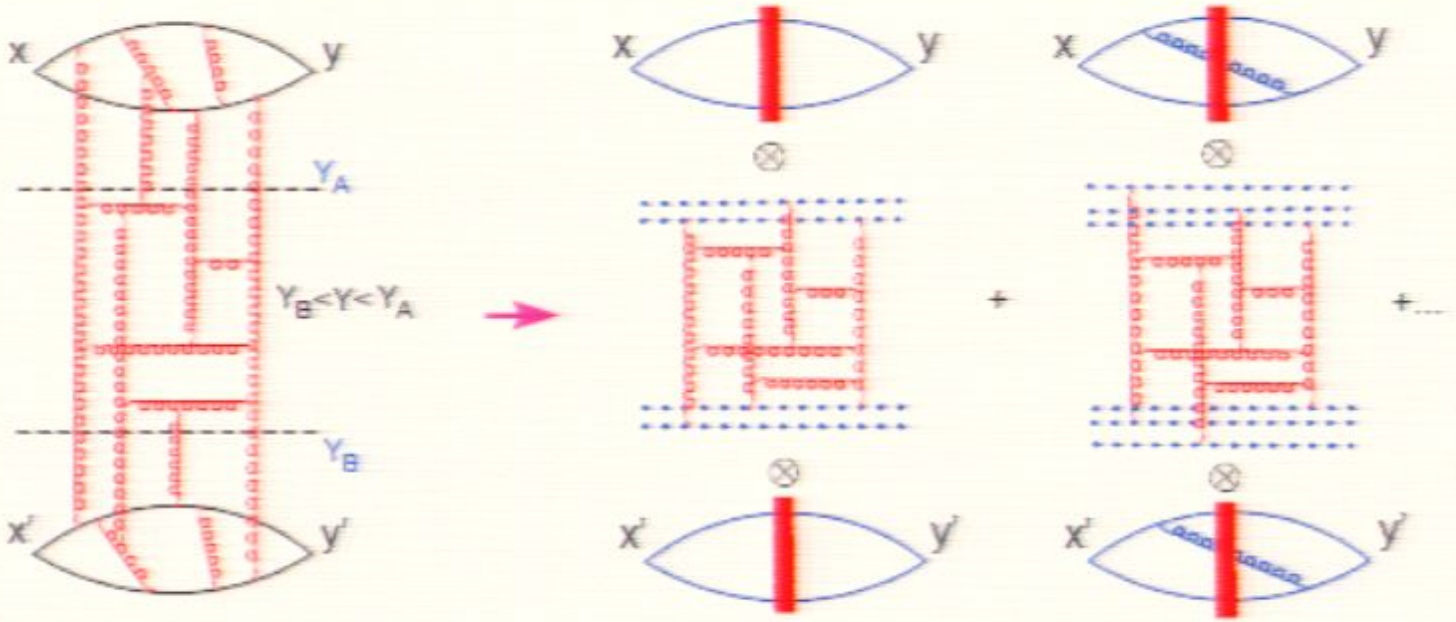
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NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity



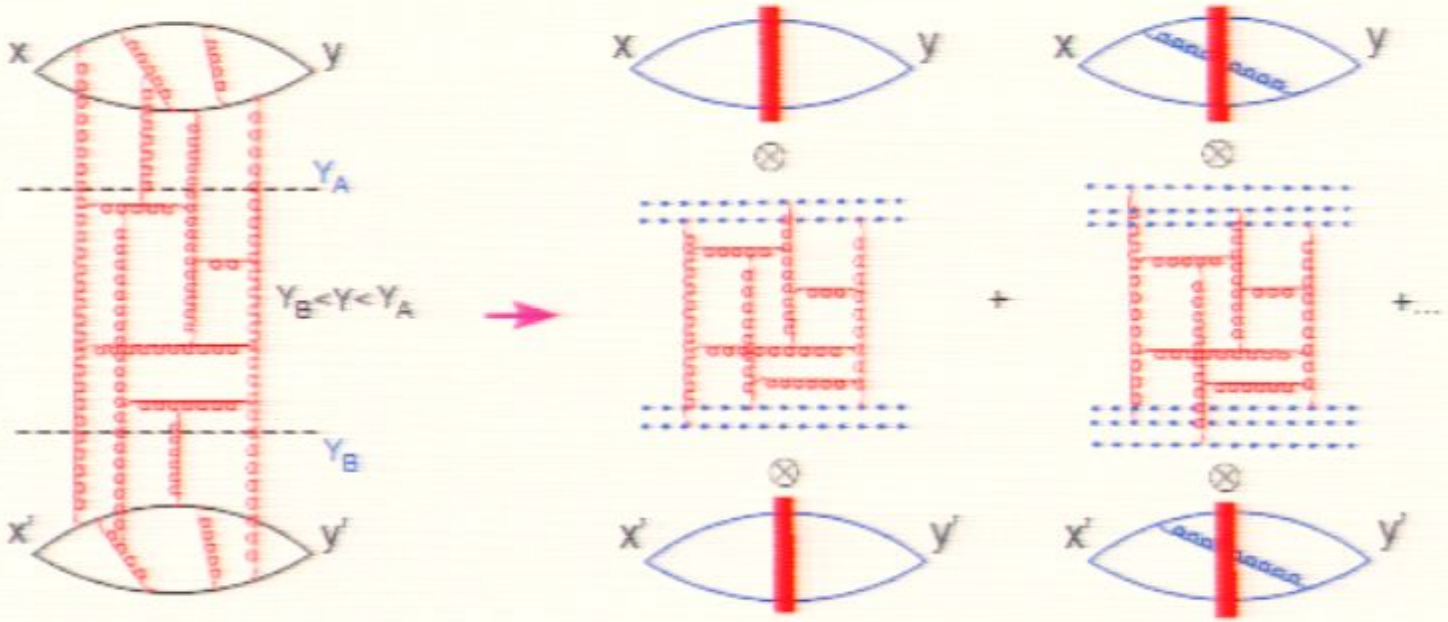
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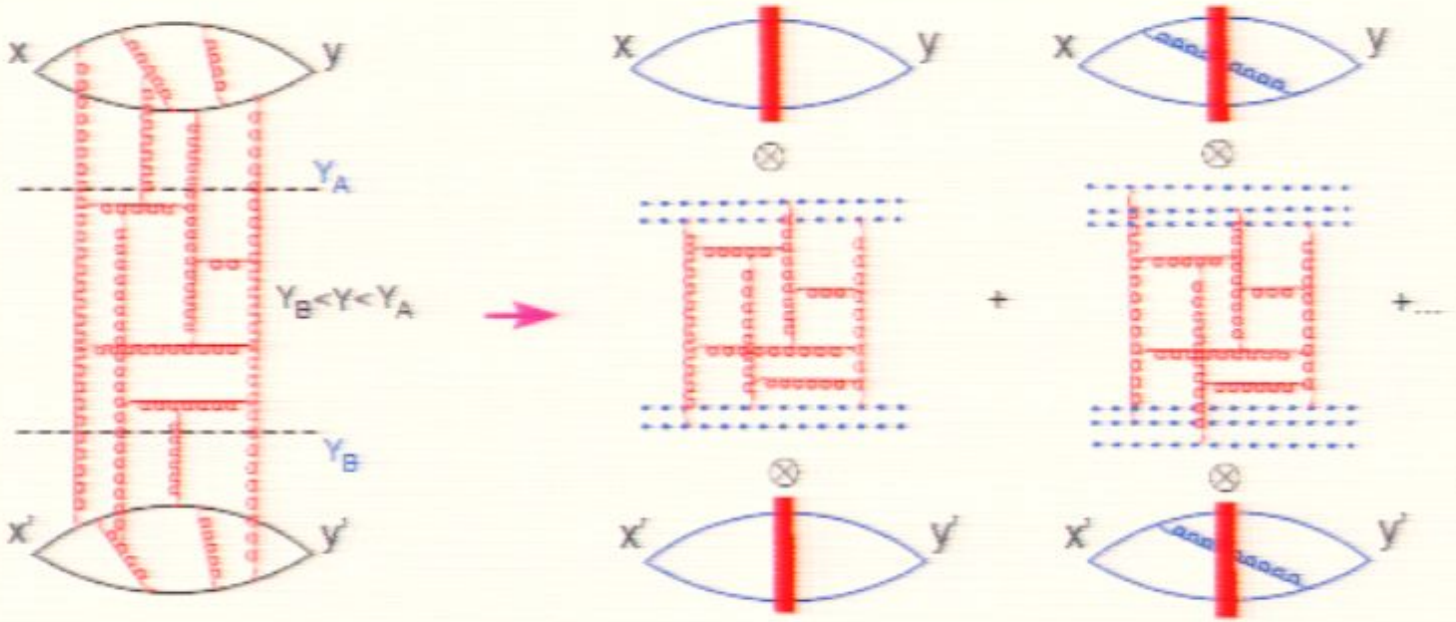
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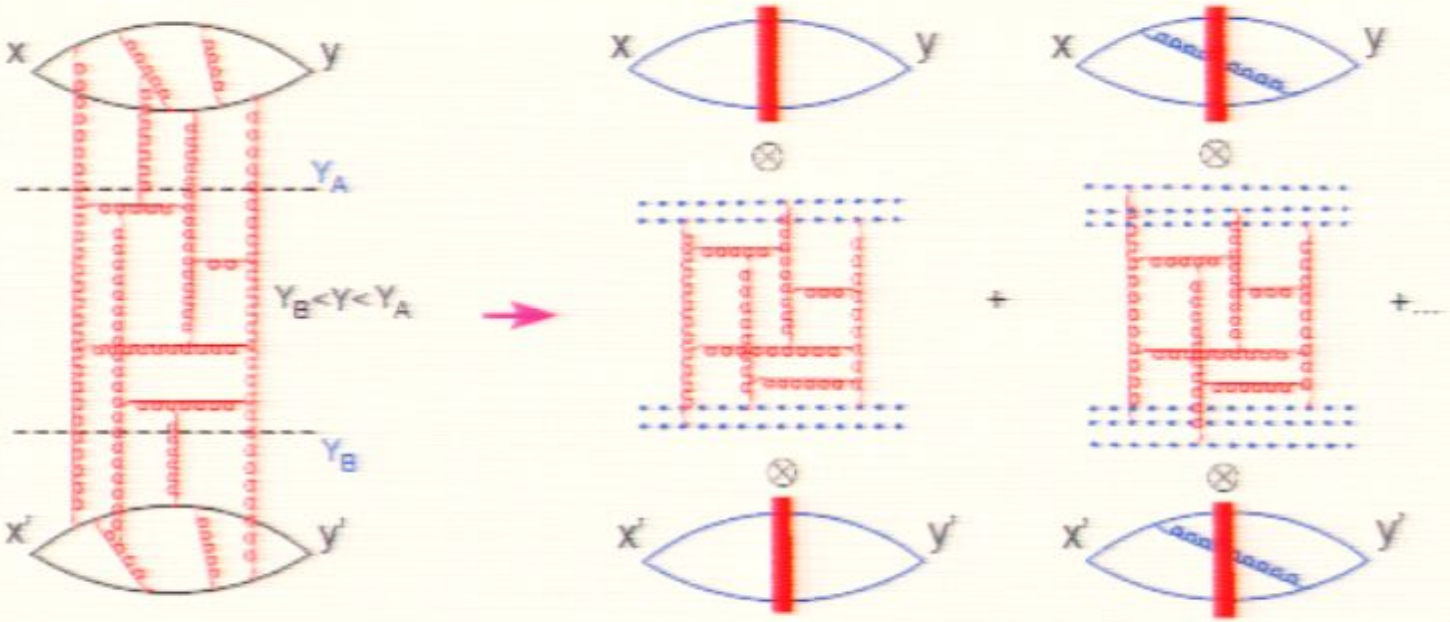
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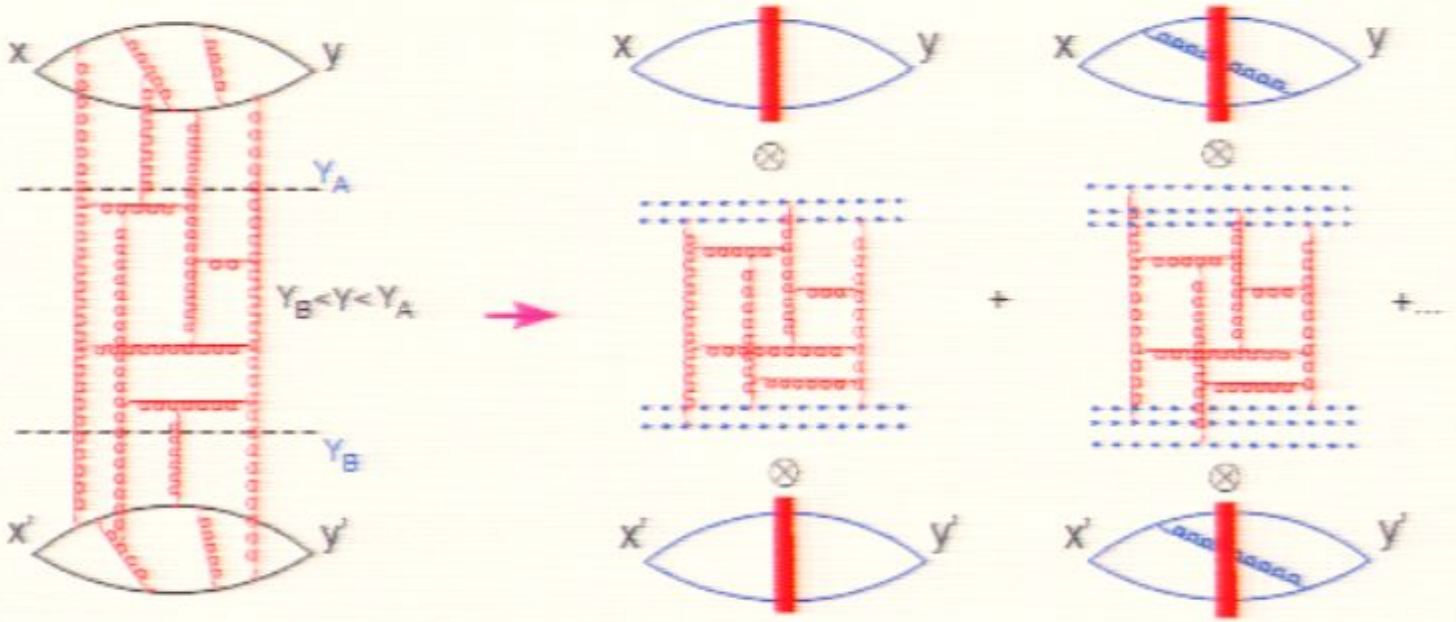
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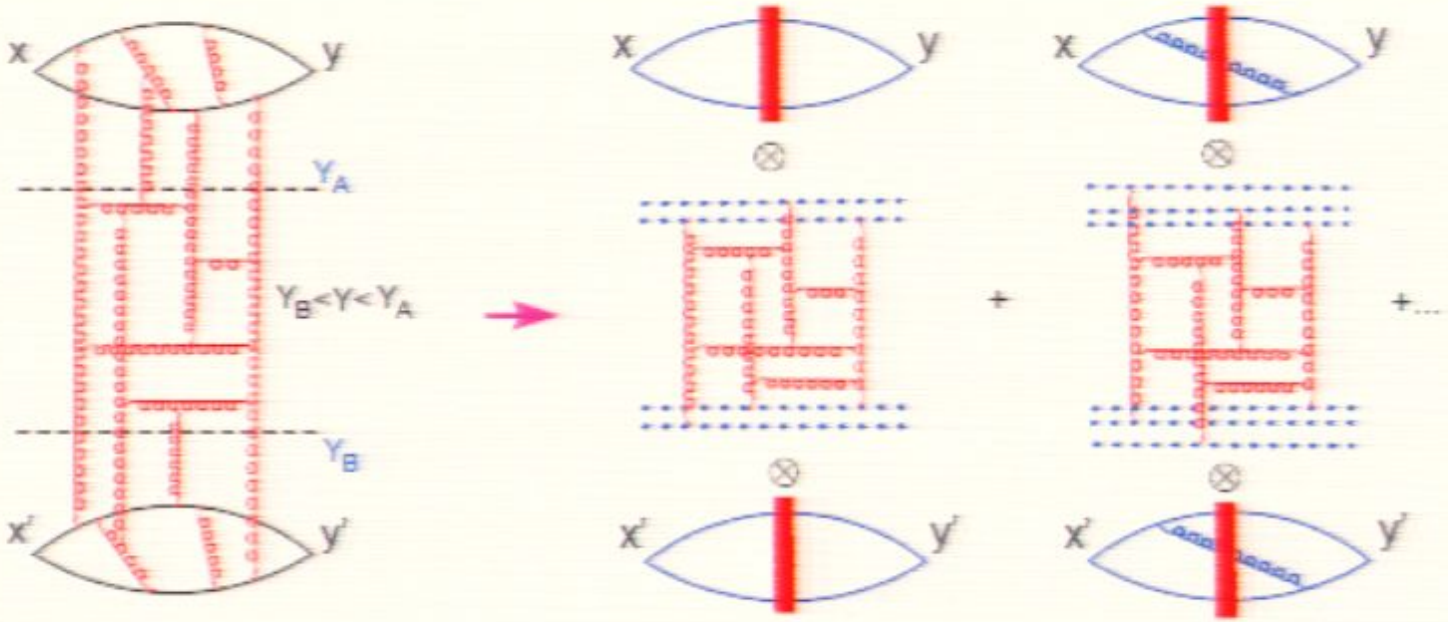
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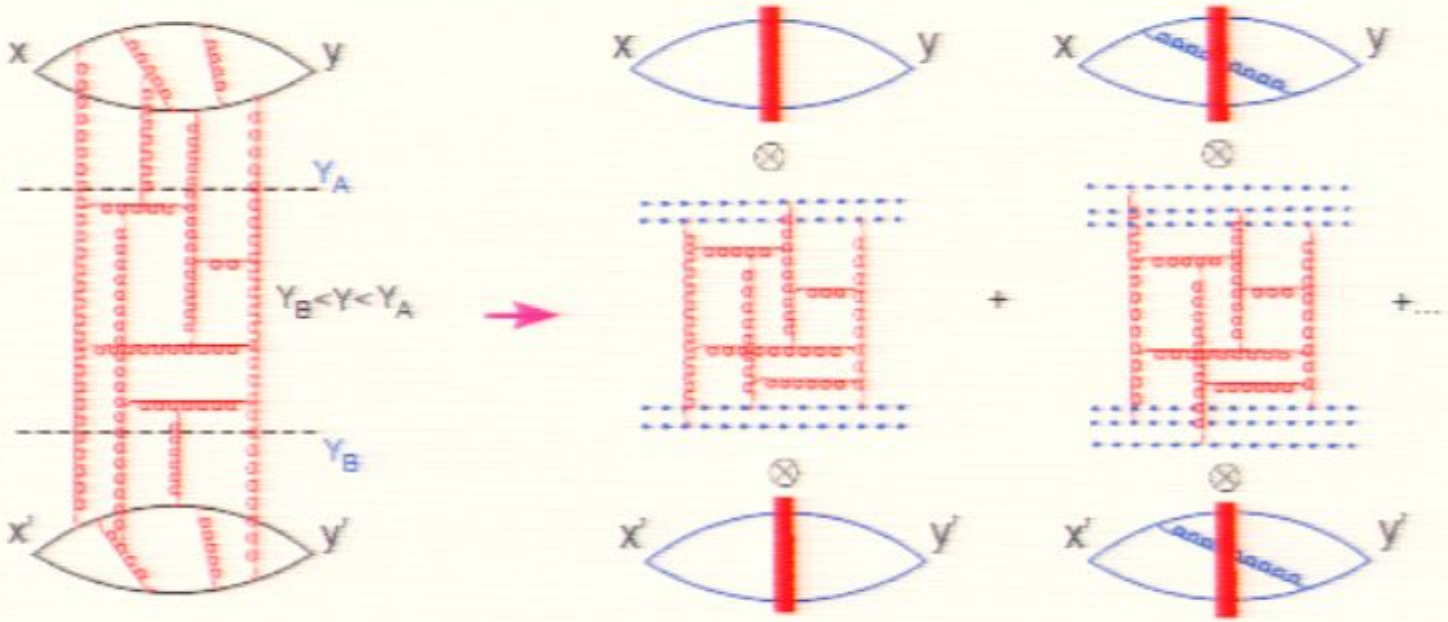
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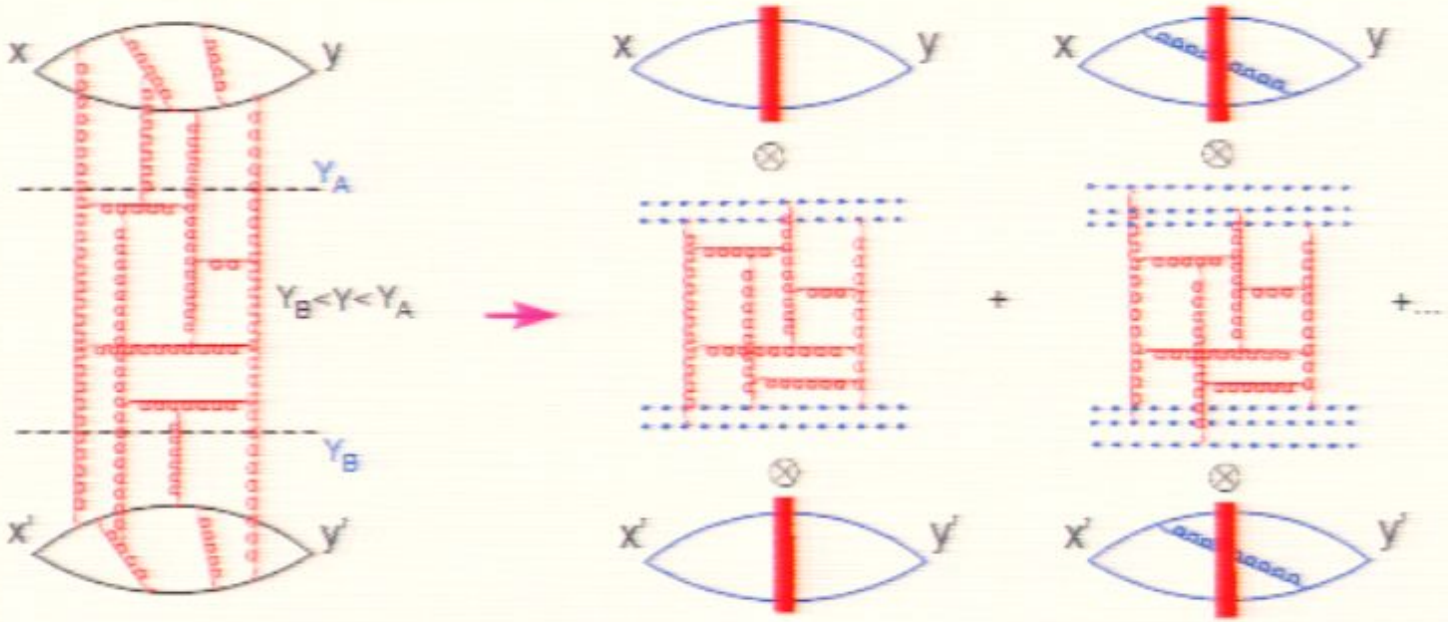
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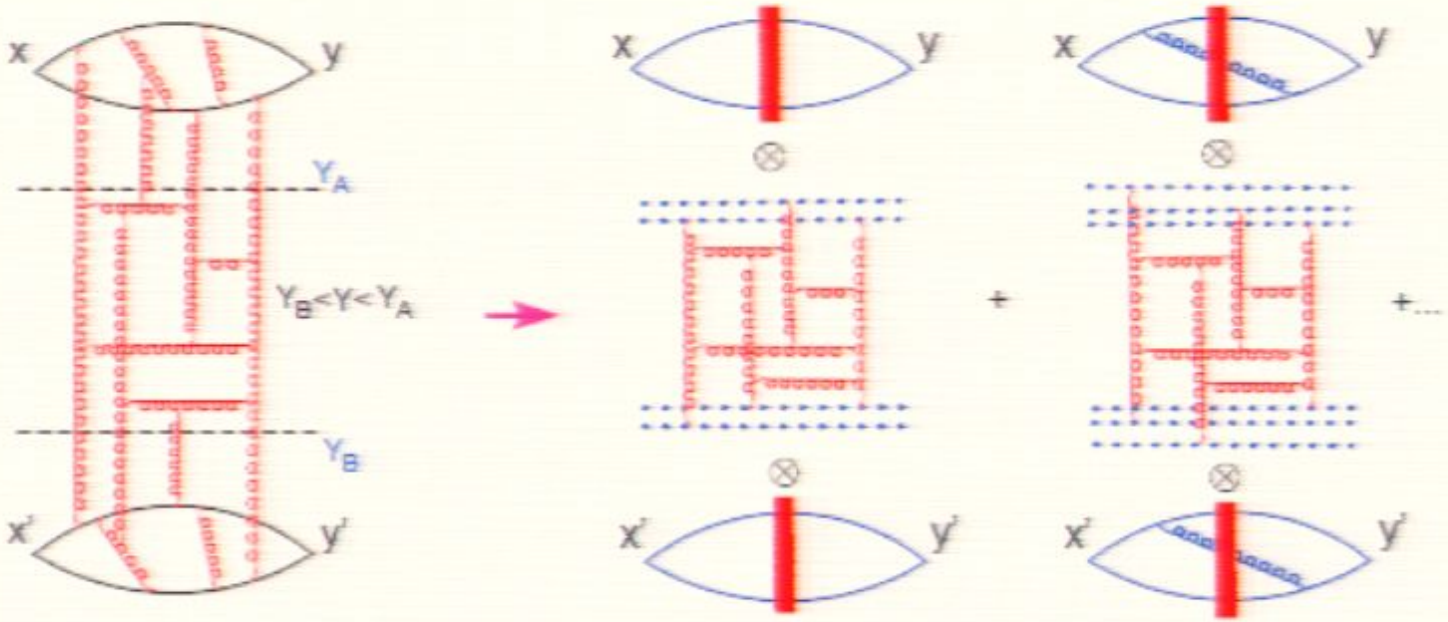
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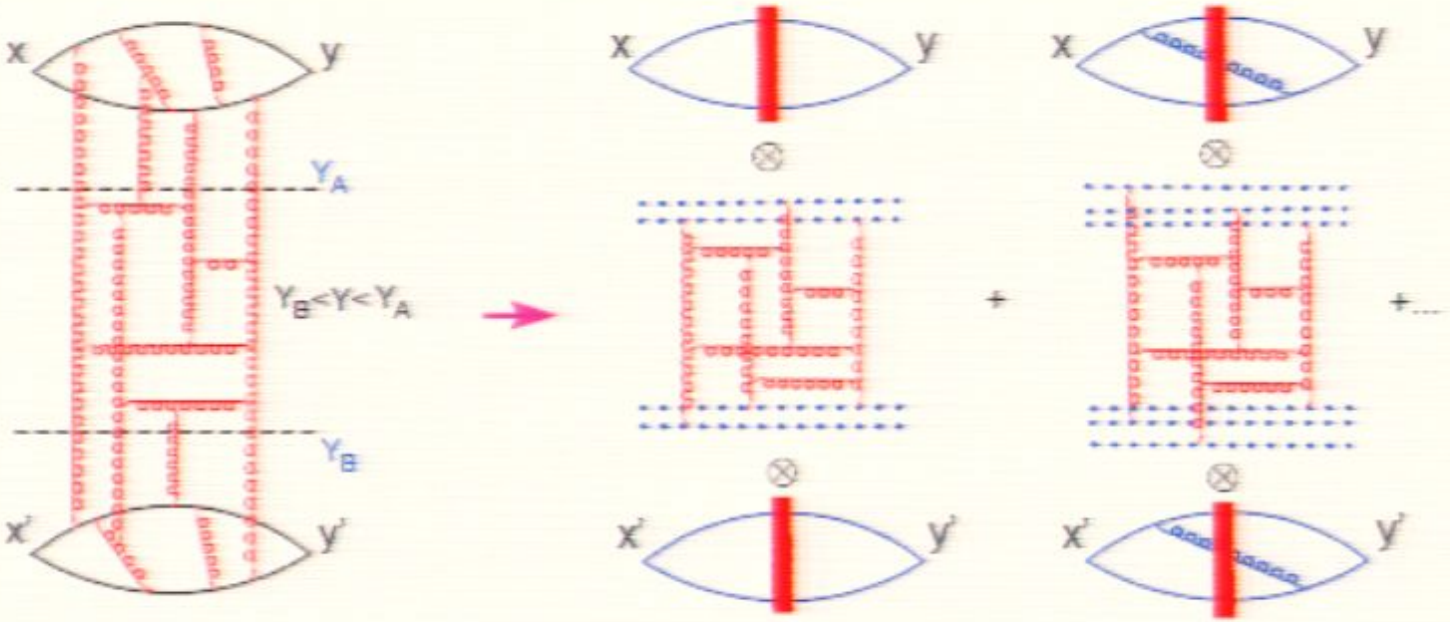
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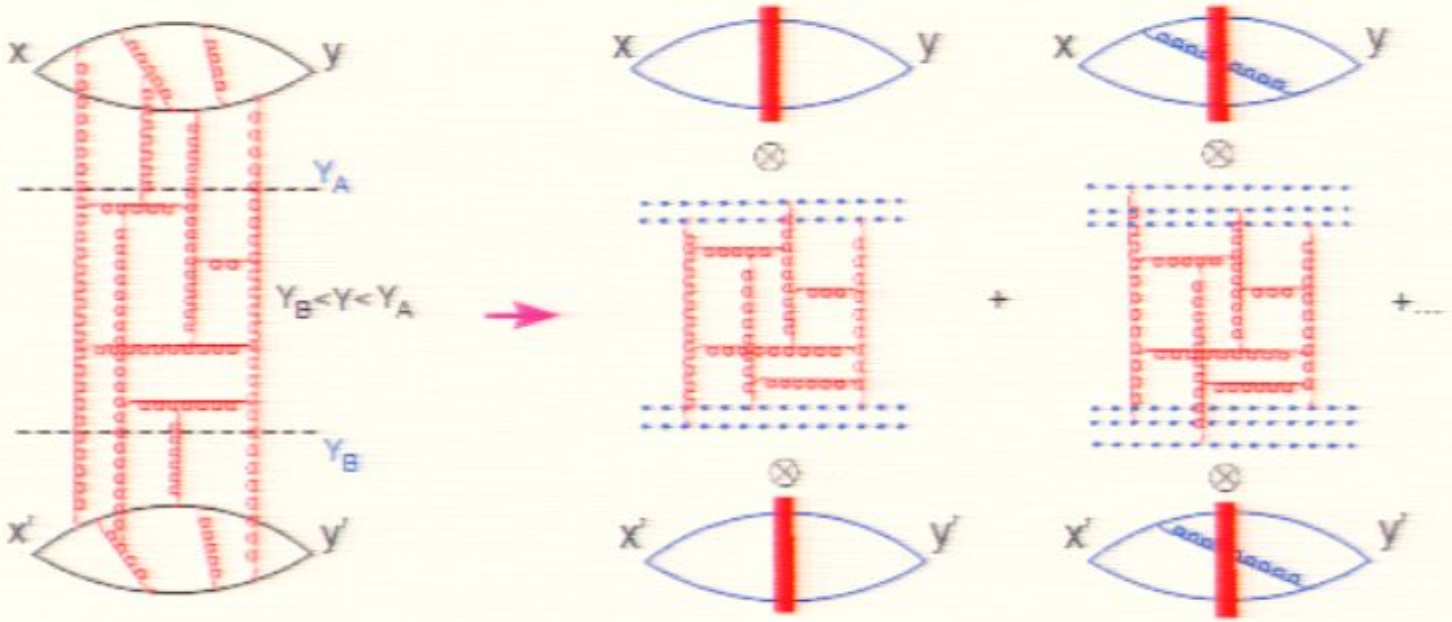
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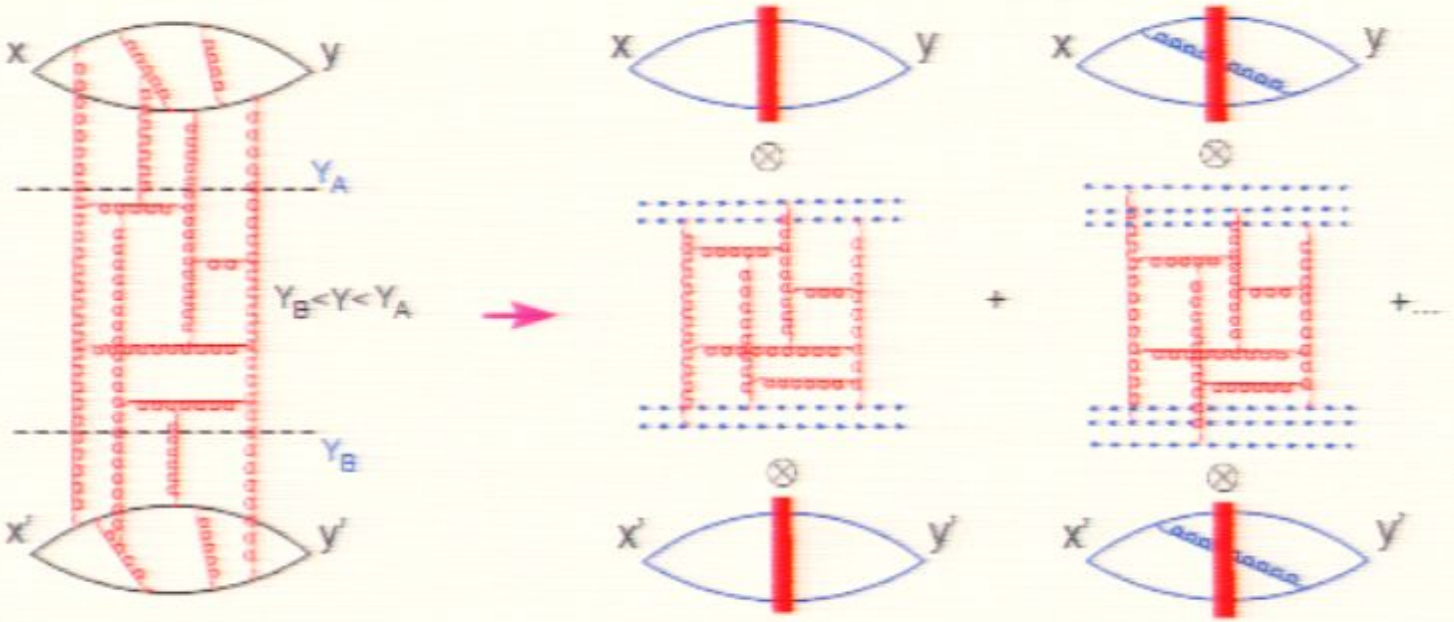
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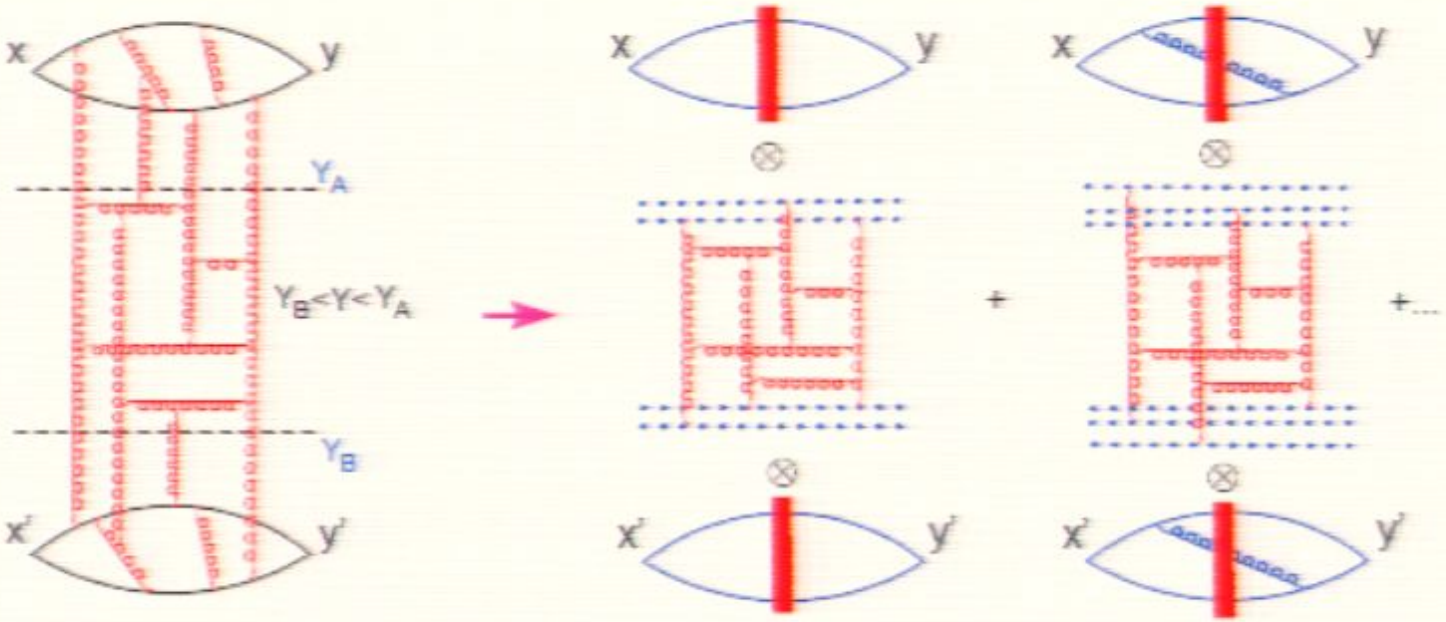
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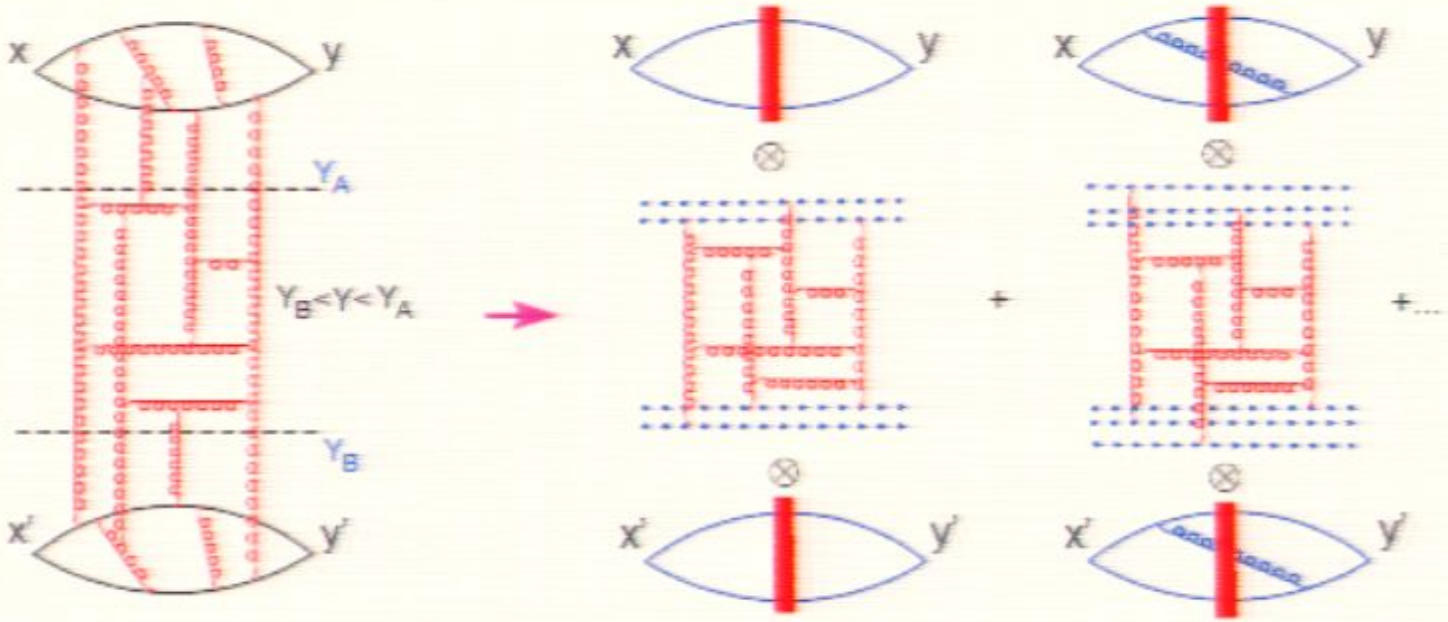
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NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity



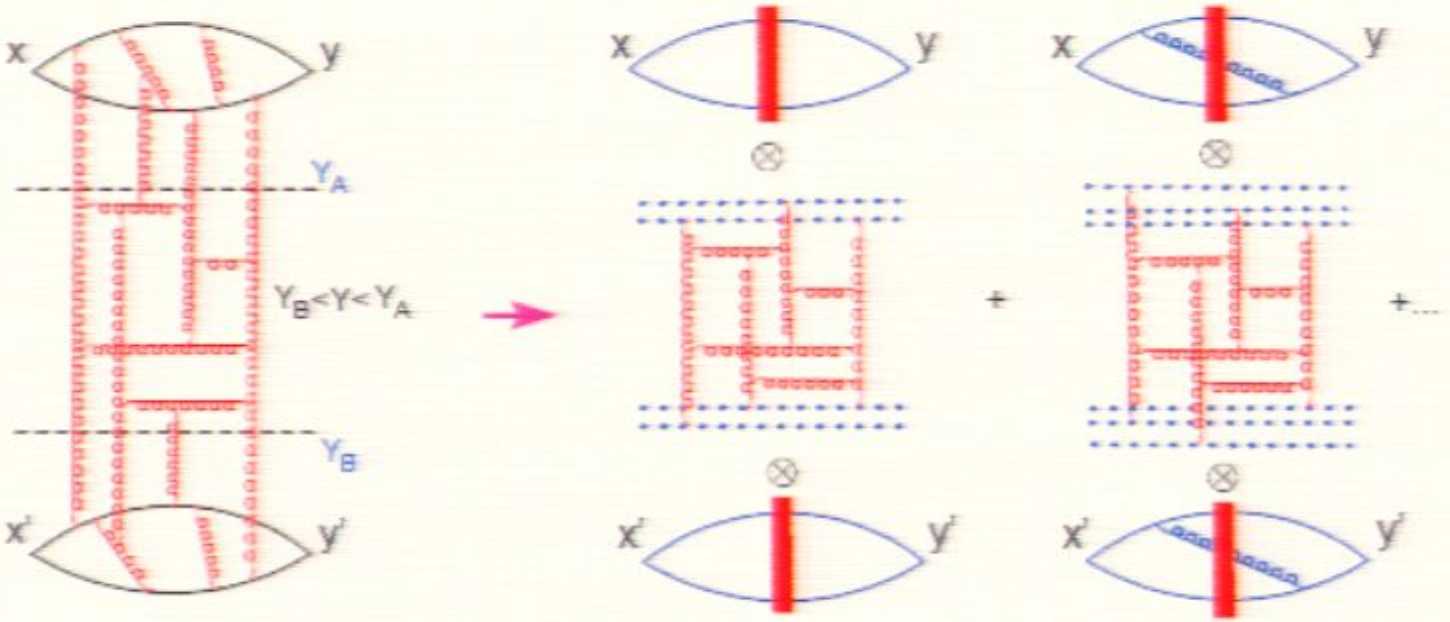
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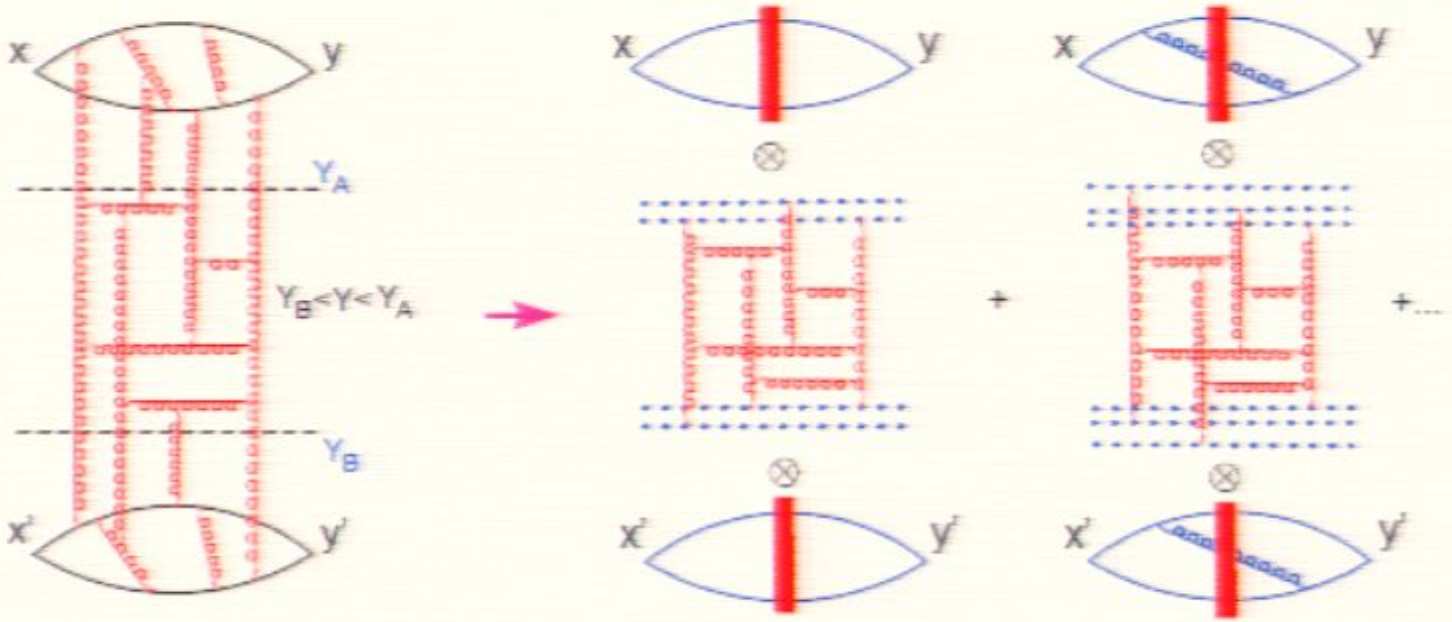
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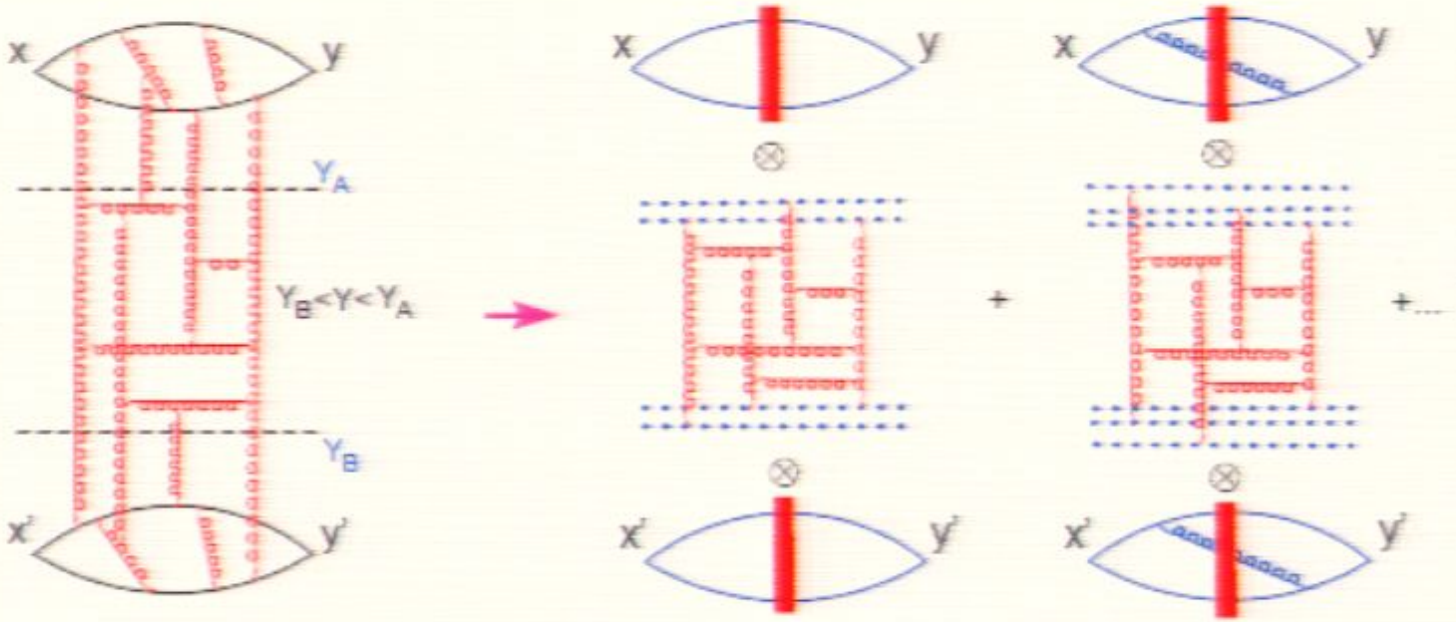
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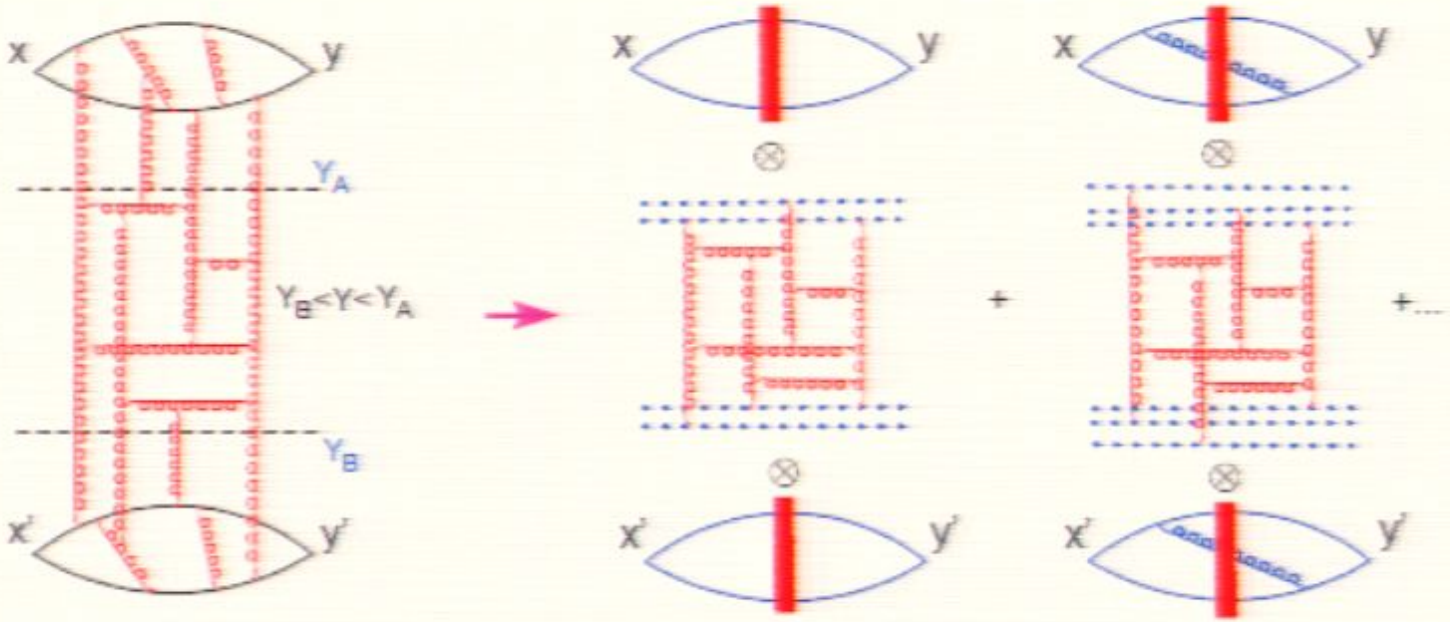
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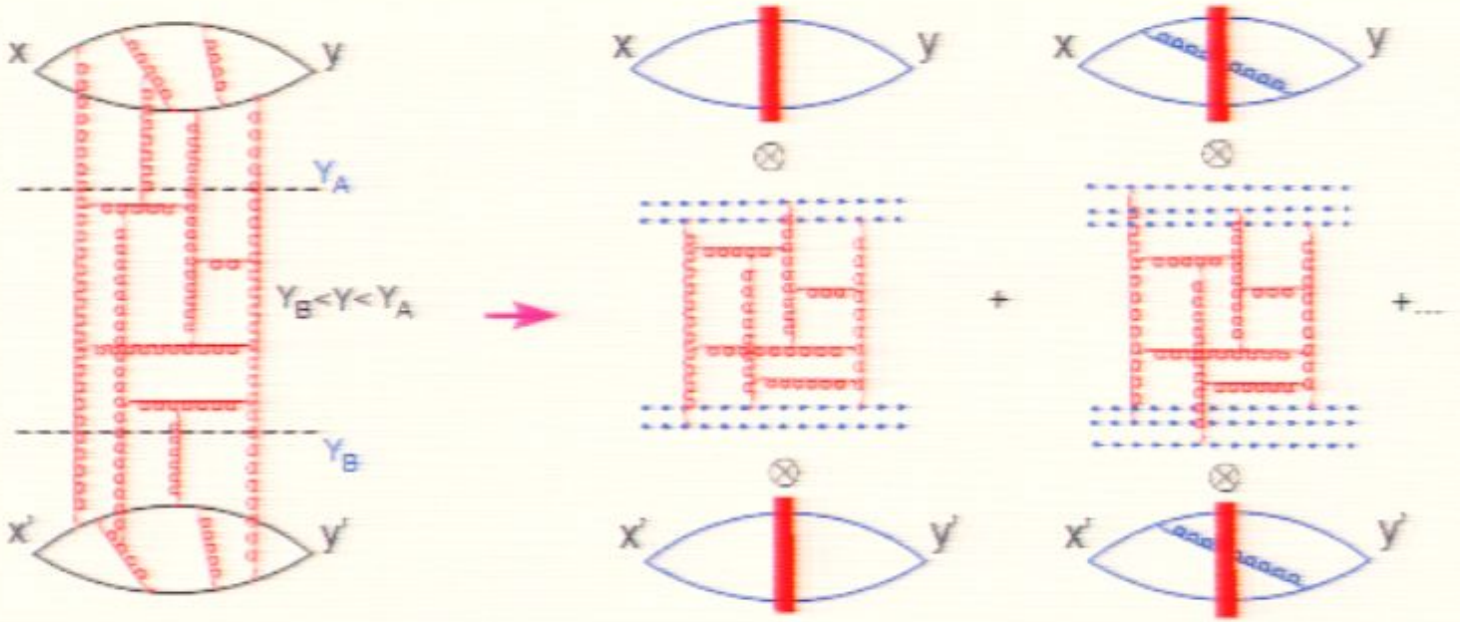
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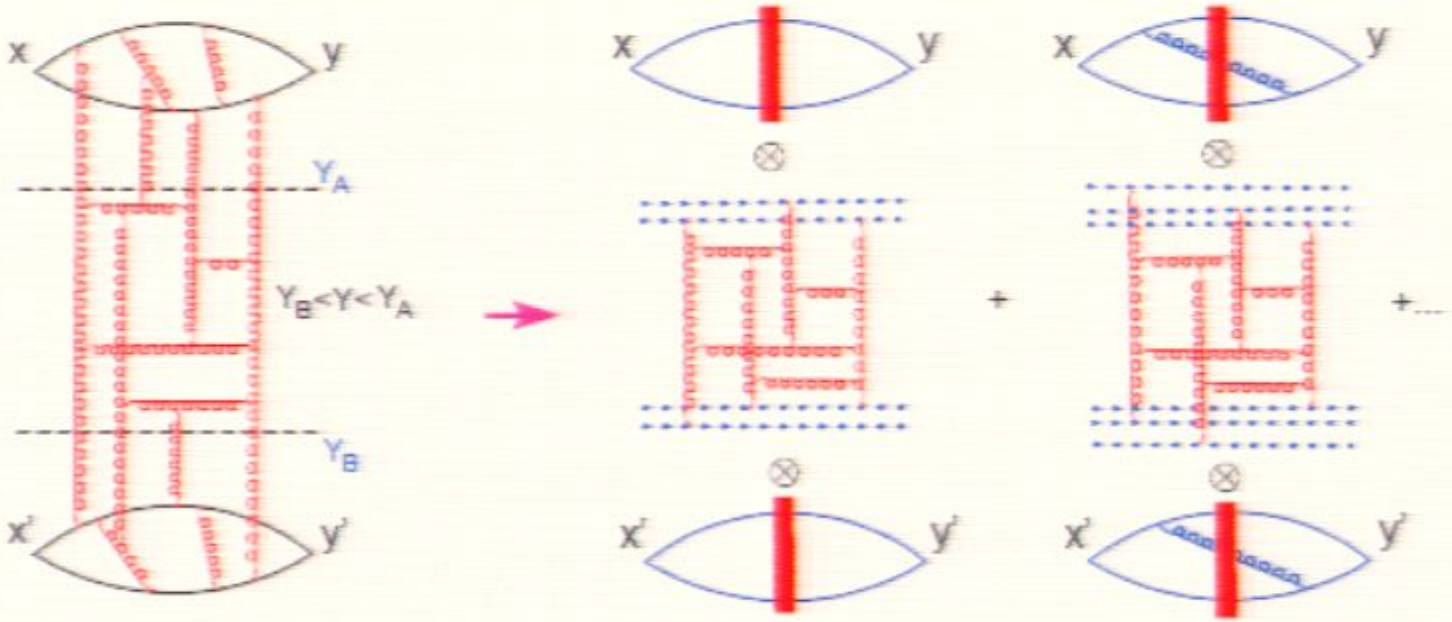
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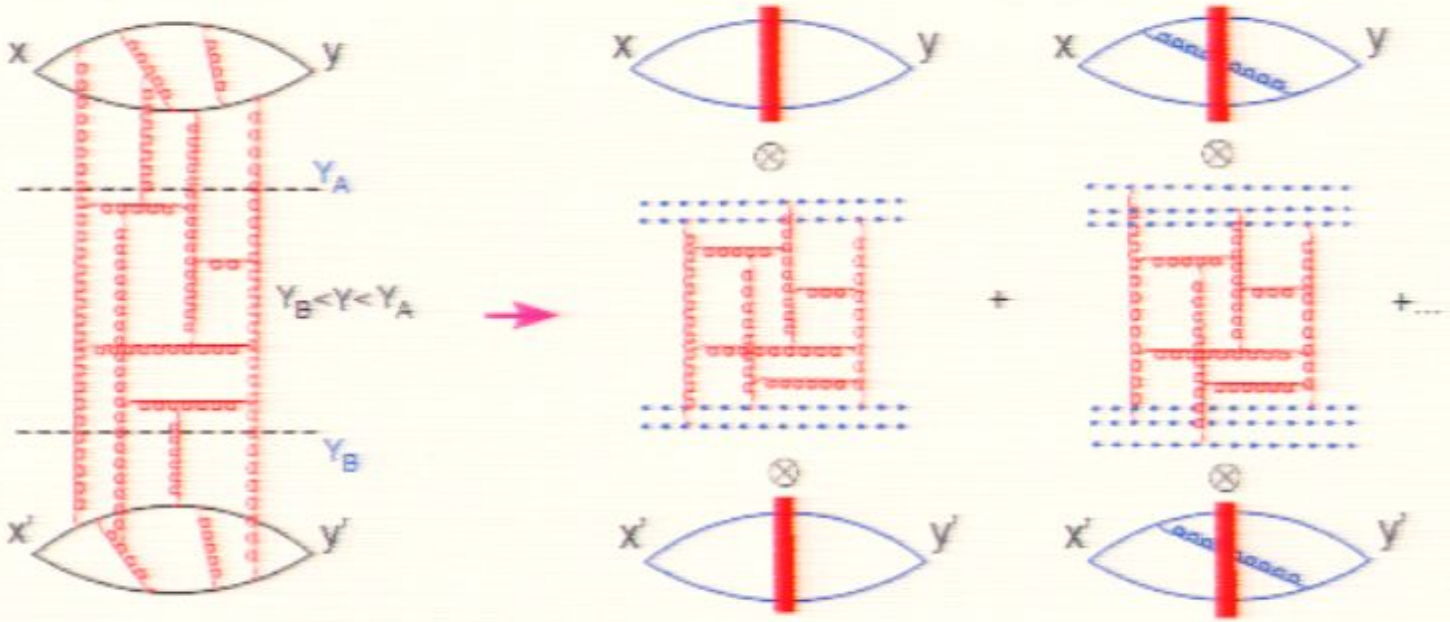
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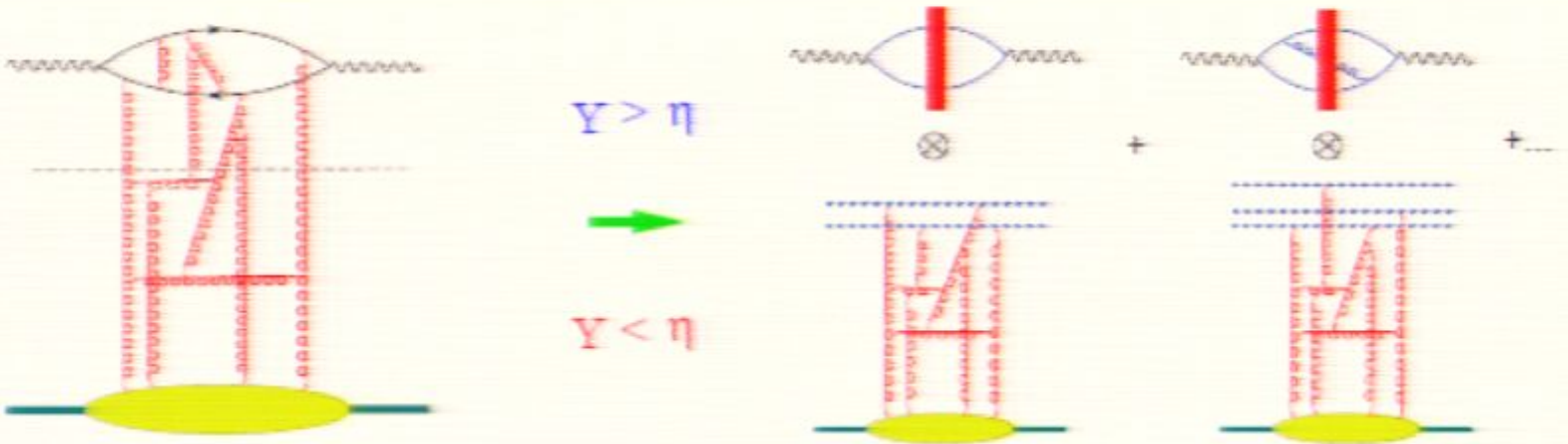


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$$= \int d^2z_{1\perp}d^2z_{2\perp}d^2z'_{1\perp}d^2z'_{2\perp}\,\mathrm{IF}^{a_0}(x,y;z_1,z_2)[\mathrm{DD}]^{a_0,b_0}(z_1,z_2;z'_1,z'_2)\mathrm{IF}^{b_0}(x',y';z'_1,z'_2)$$

Result : (G.A. Chirilli and I.B.)

$$F(\nu) = \frac{N_c^2}{N_c^2-1}\frac{4\pi^4\alpha_s^2}{\cosh^2\pi\nu}\left\{1+\frac{\alpha_s N_c}{\pi}\left[\frac{\pi^2}{2}-\frac{2\pi^2}{\cosh^2\pi\nu}-\frac{8}{1+4\nu^2}\right]+O(\alpha_s^2)\right\}$$



DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

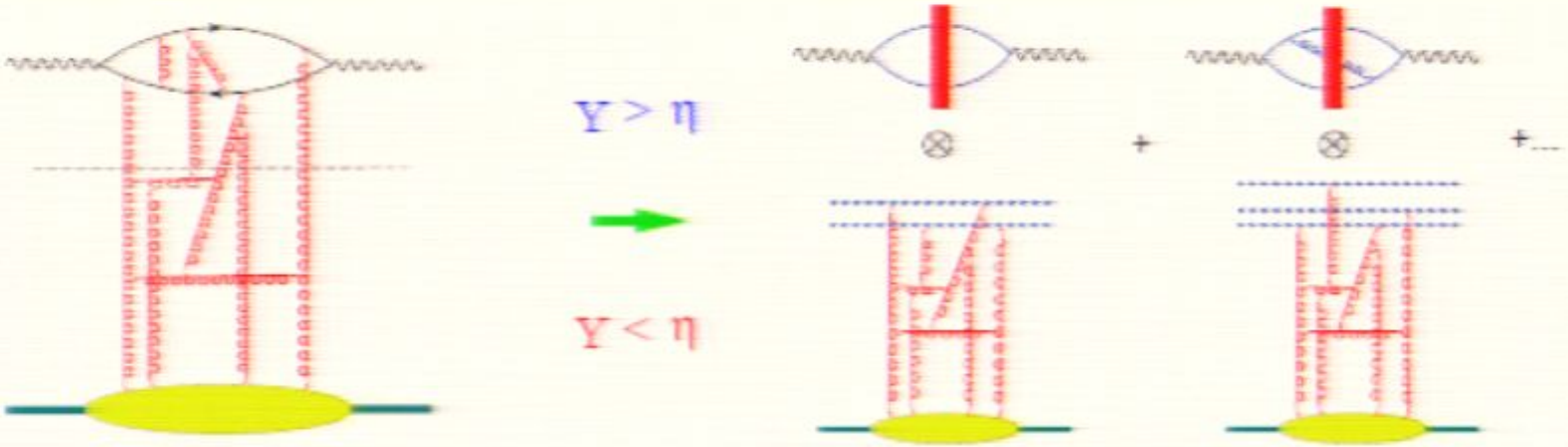
Photon impact factor in the LO

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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

Photon impact factor in the LO

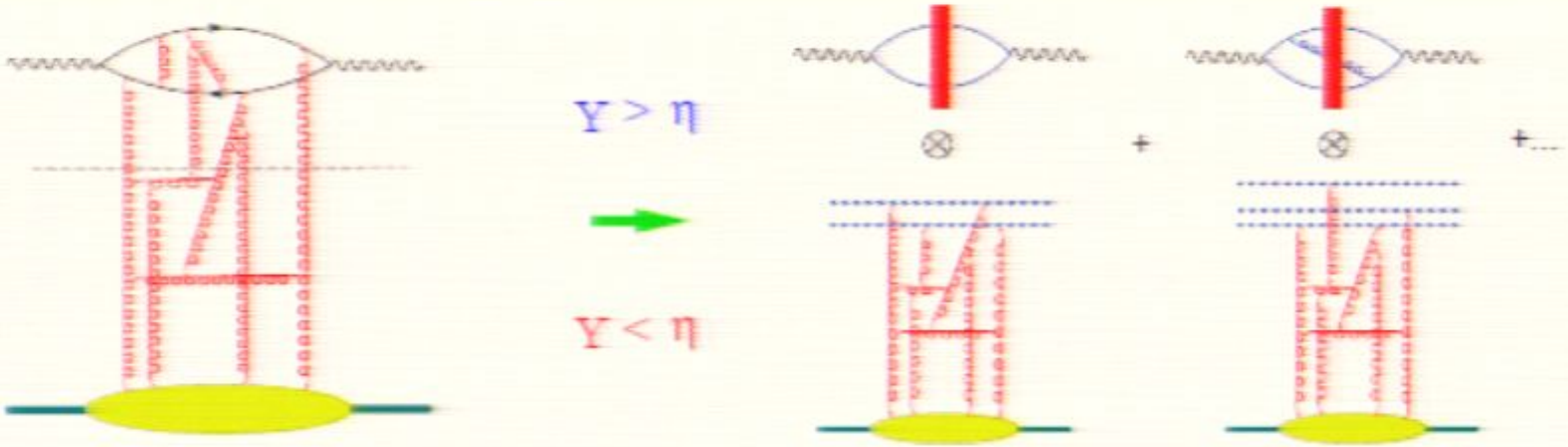
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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

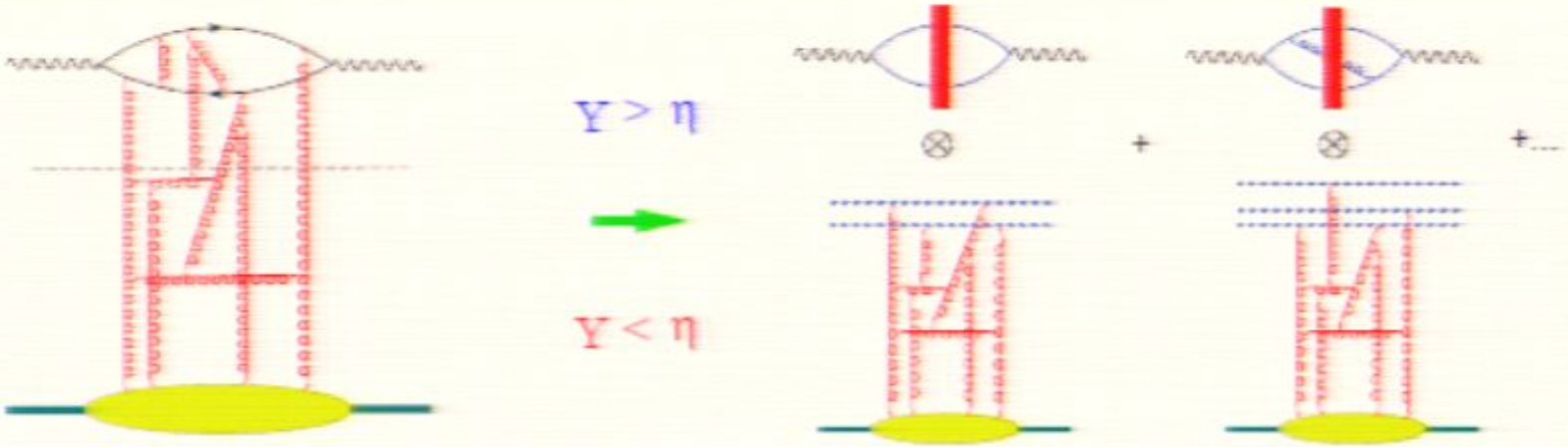
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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

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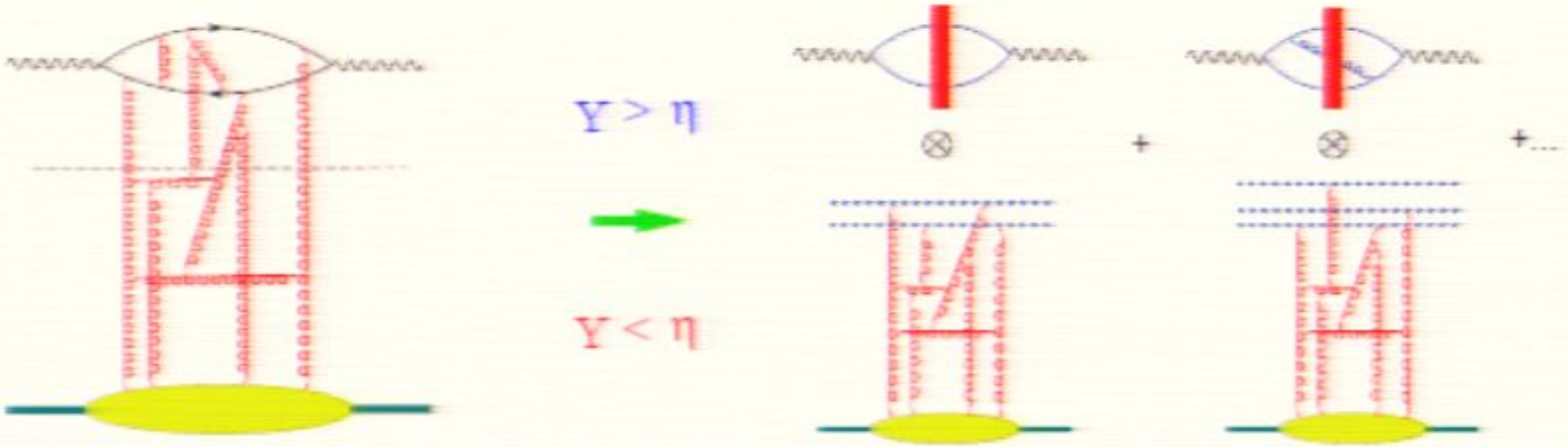
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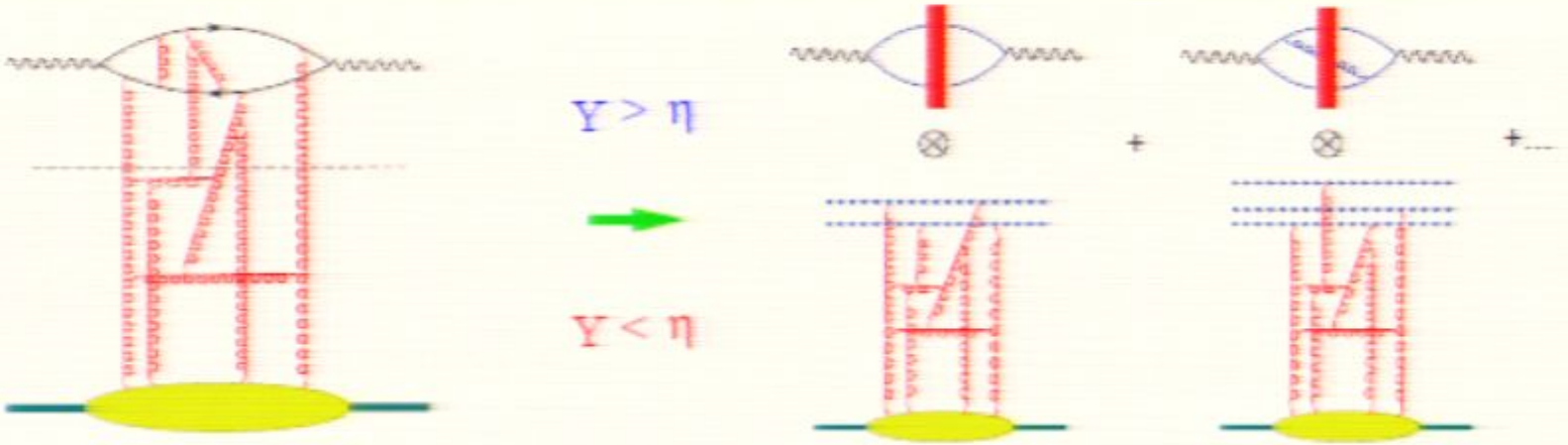
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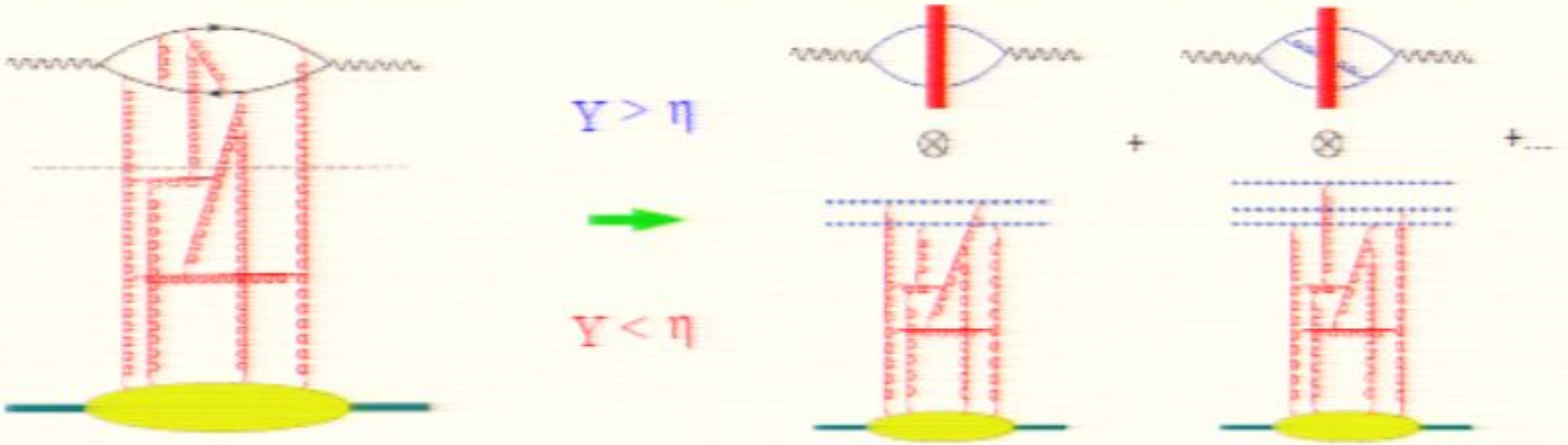
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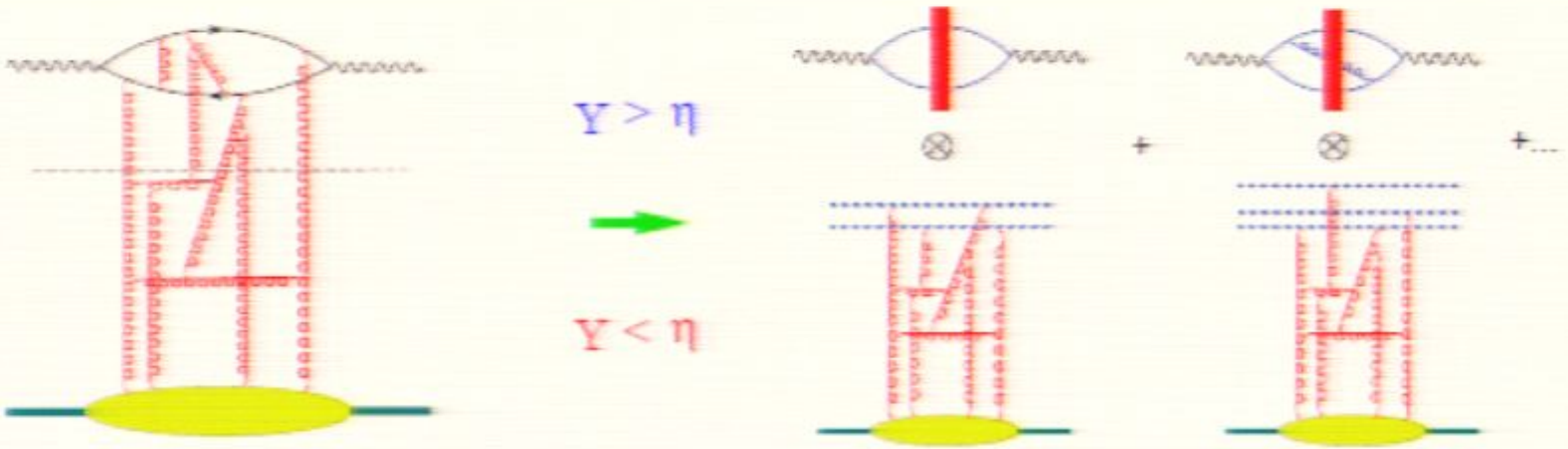
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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

Photon impact factor in the LO

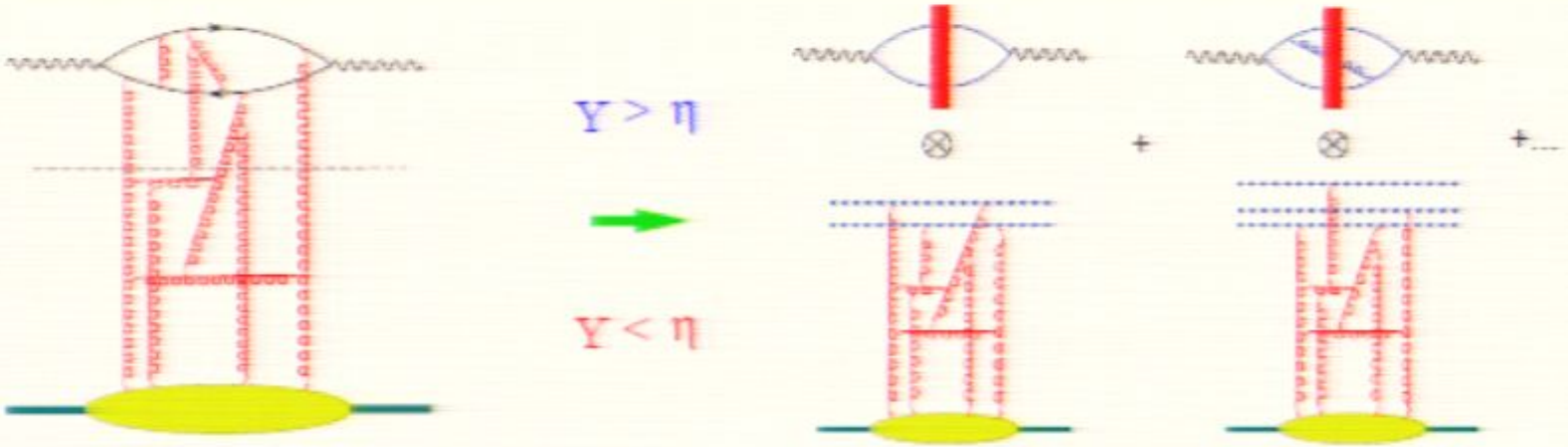
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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

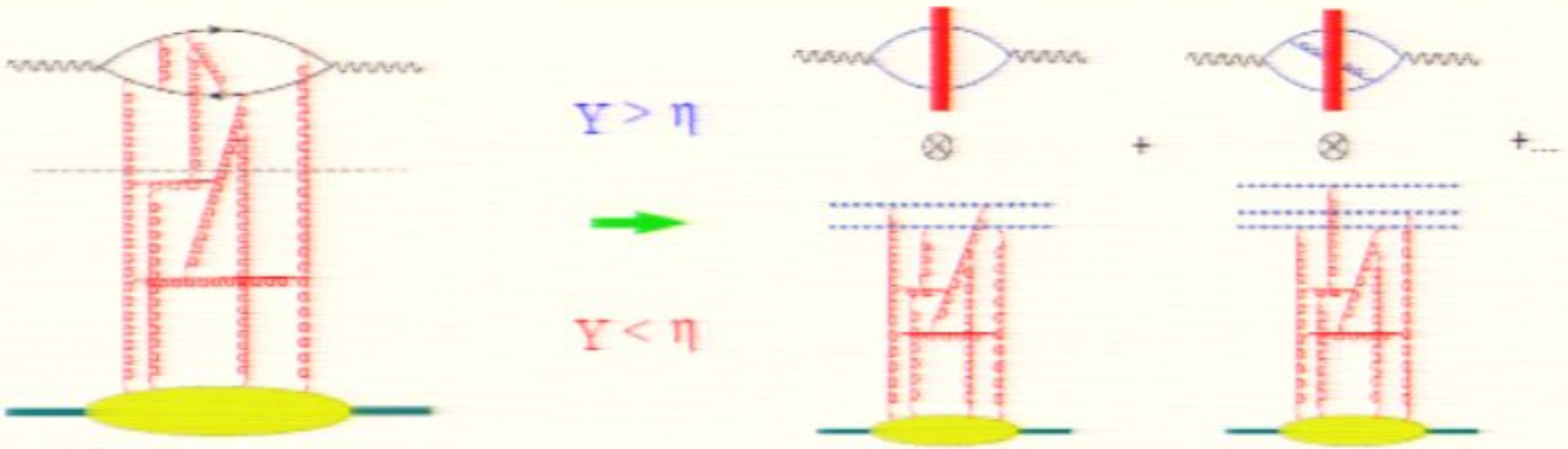
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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

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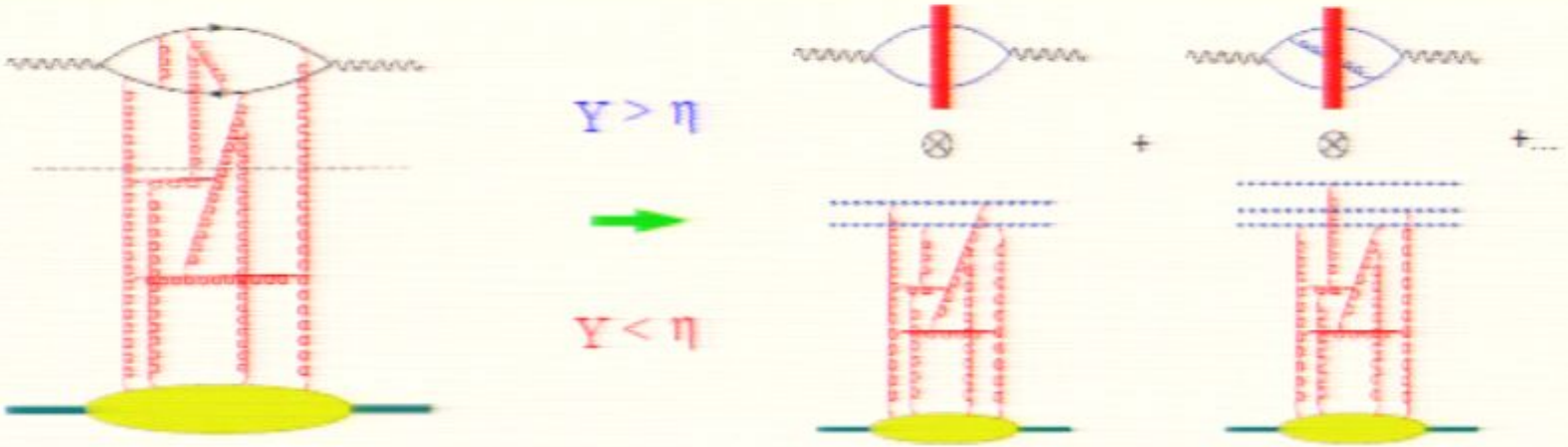
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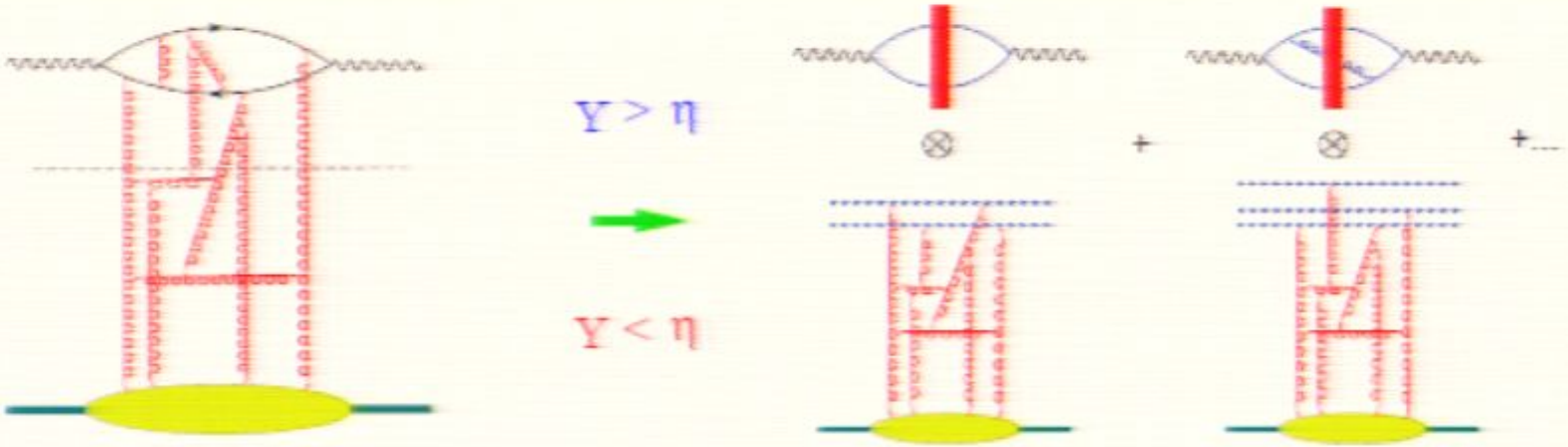
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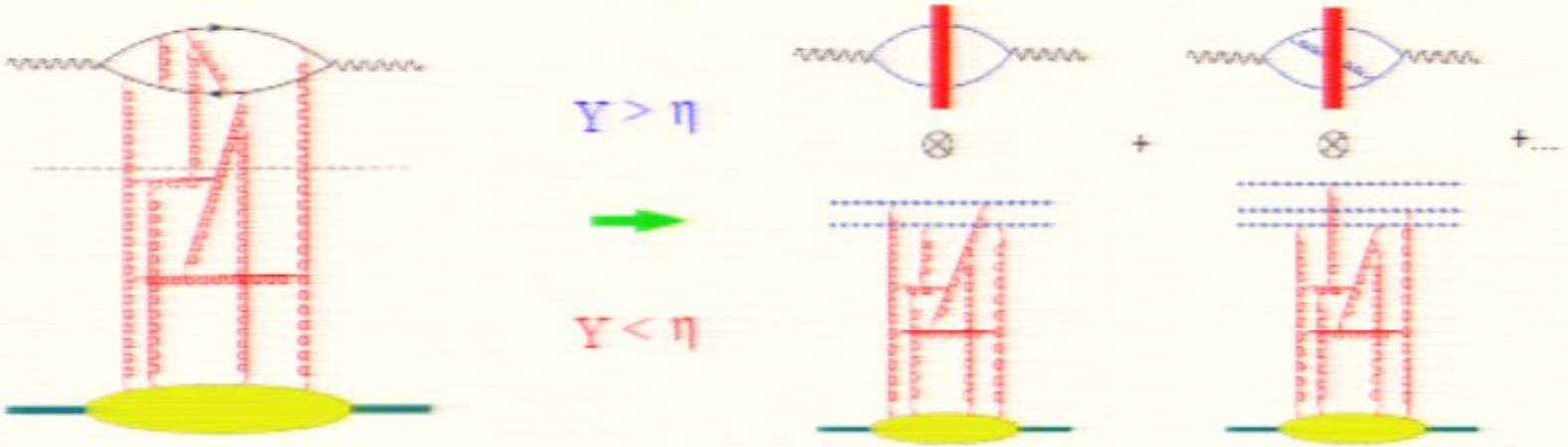
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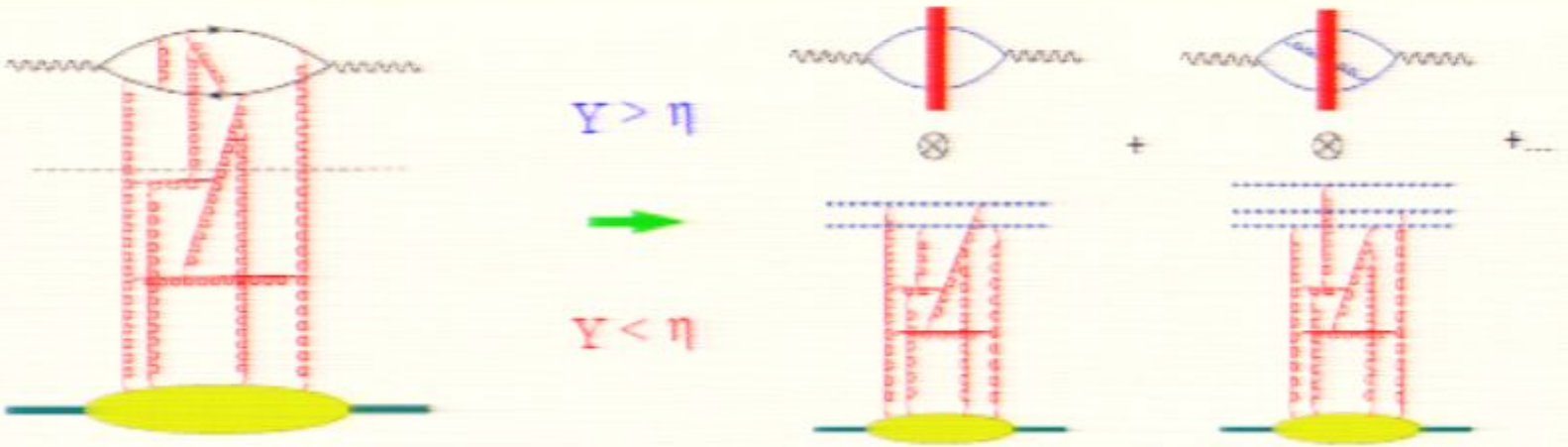
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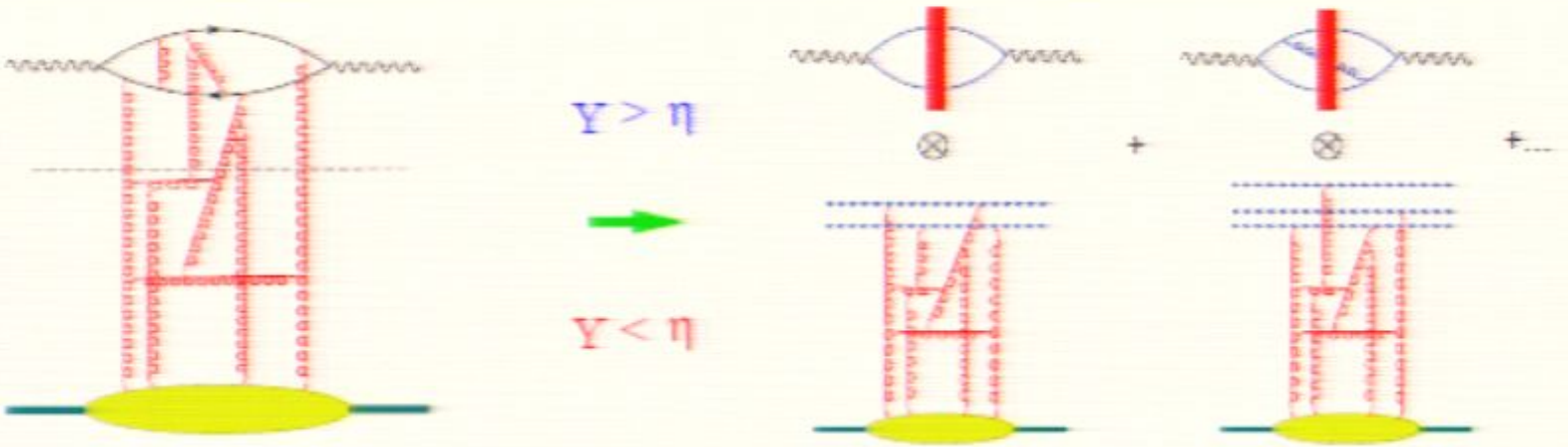
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$$\kappa \equiv \frac{1}{\sqrt{s}x^+}\left(\frac{p_1}{s} - x^2 p_2 + x_\perp\right) - \frac{1}{\sqrt{s}y^+}\left(\frac{p_1}{s} - y^2 p_2 + y_\perp\right)$$

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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

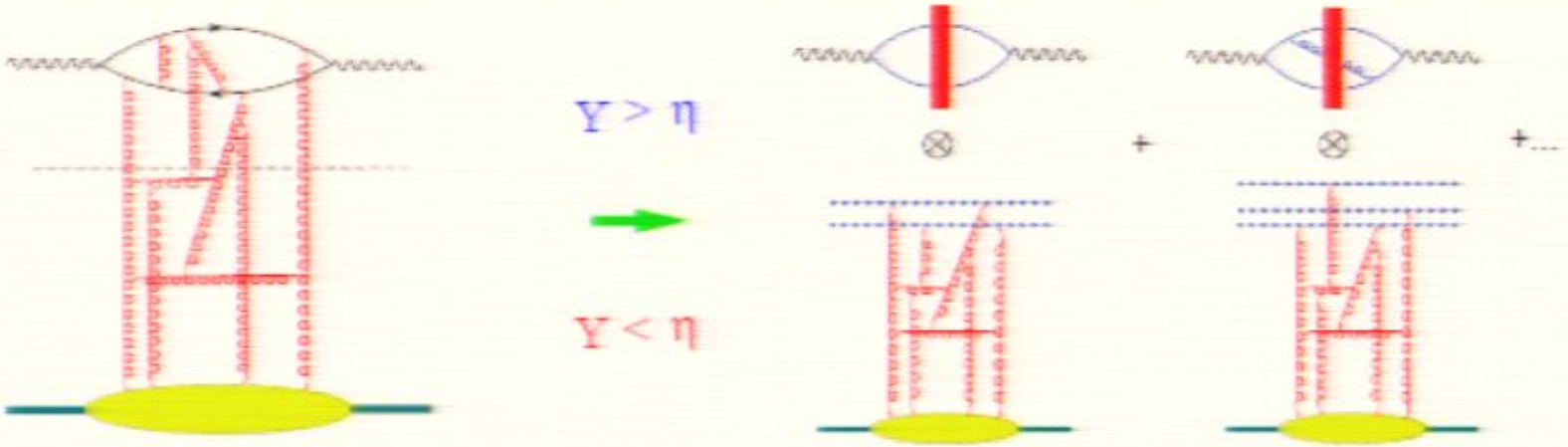
Photon impact factor in the LO

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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

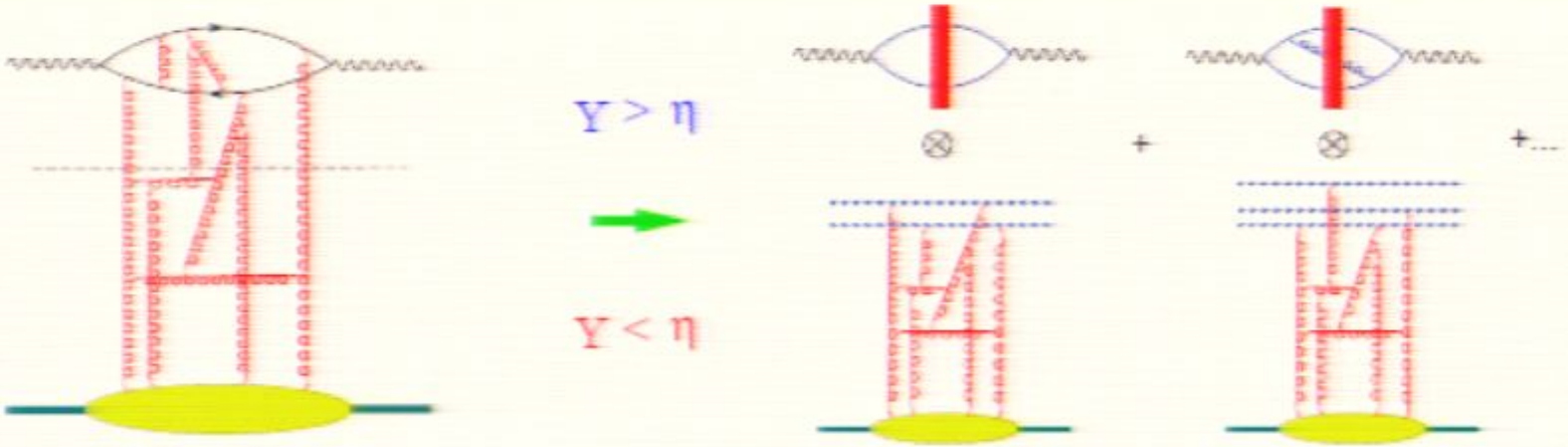
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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

Photon impact factor in the LO

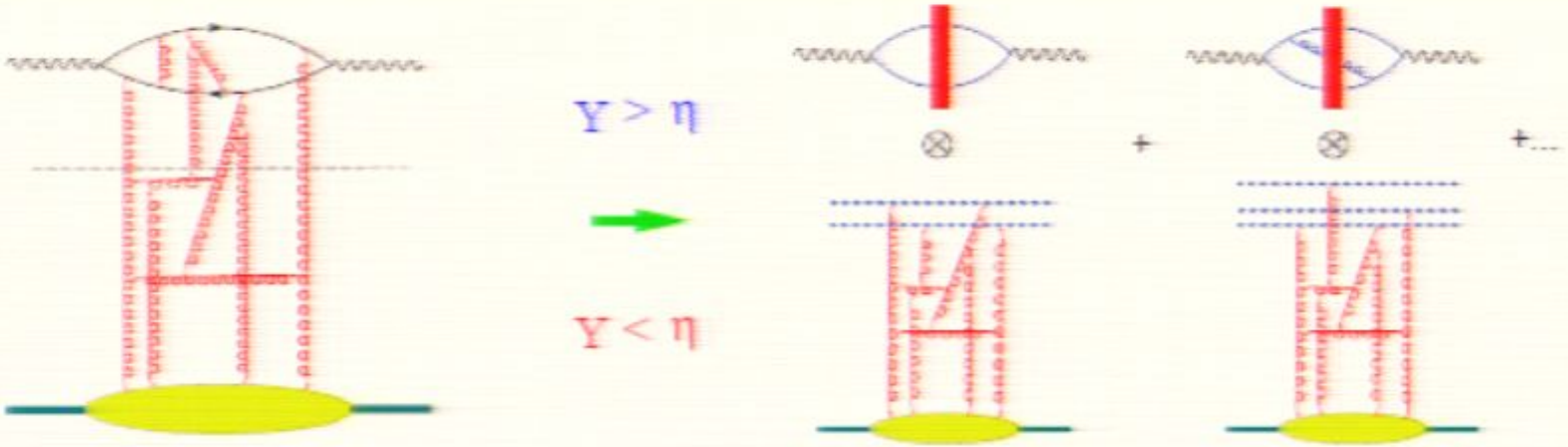
$$(x-y)^4 T\{\bar{\psi}(x)\gamma^\mu\hat{\psi}(x)\bar{\psi}(y)\gamma^\nu\hat{\psi}(y)\} = \int \frac{d^2z_1 d^2z_2}{z_{12}^4} I^{LO}_{\mu\nu}(z_1,z_2)\,\mathrm{tr}\{\hat{U}^\eta_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}$$

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n QCD



DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

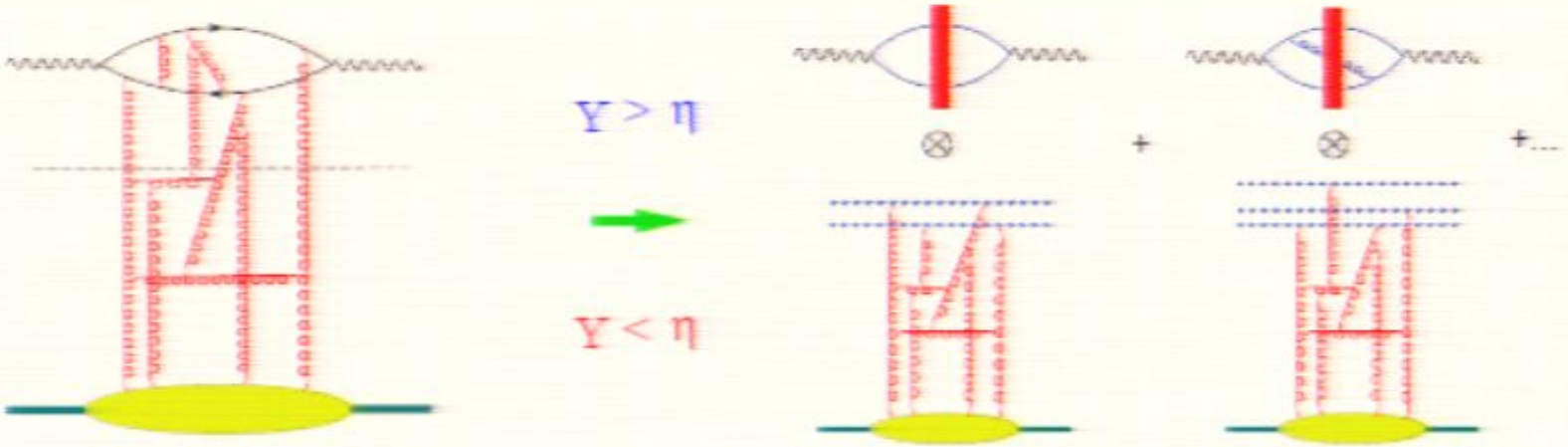
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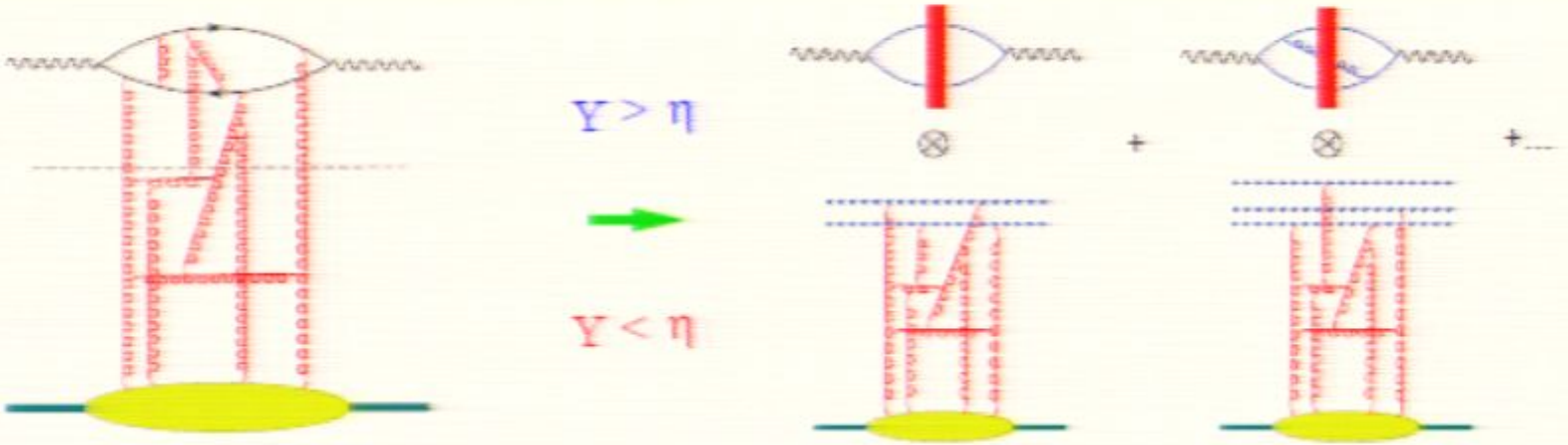
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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

Photon impact factor in the LO

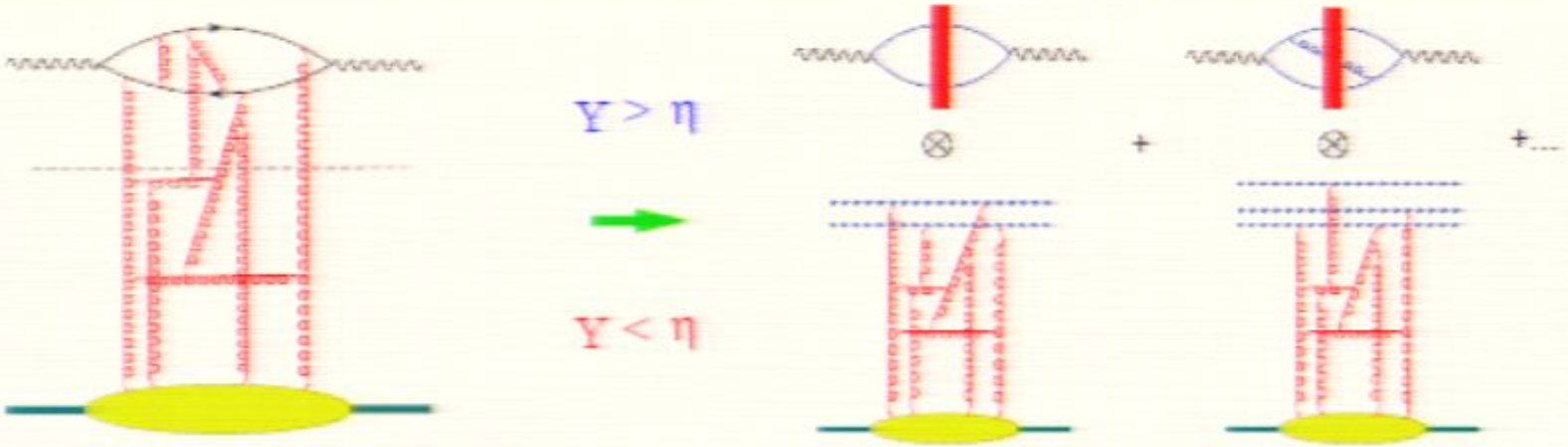
$$(x-y)^4 T\{\bar{\psi}(x)\gamma^\mu\hat{\psi}(x)\bar{\psi}(y)\gamma^\nu\hat{\psi}(y)\} = \int \frac{d^2z_1 d^2z_2}{z_{12}^4} I^{\rm LO}_{\mu\nu}(z_1,z_2)\,{\rm tr}\{\hat{U}^\eta_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}$$

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n QCD



DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

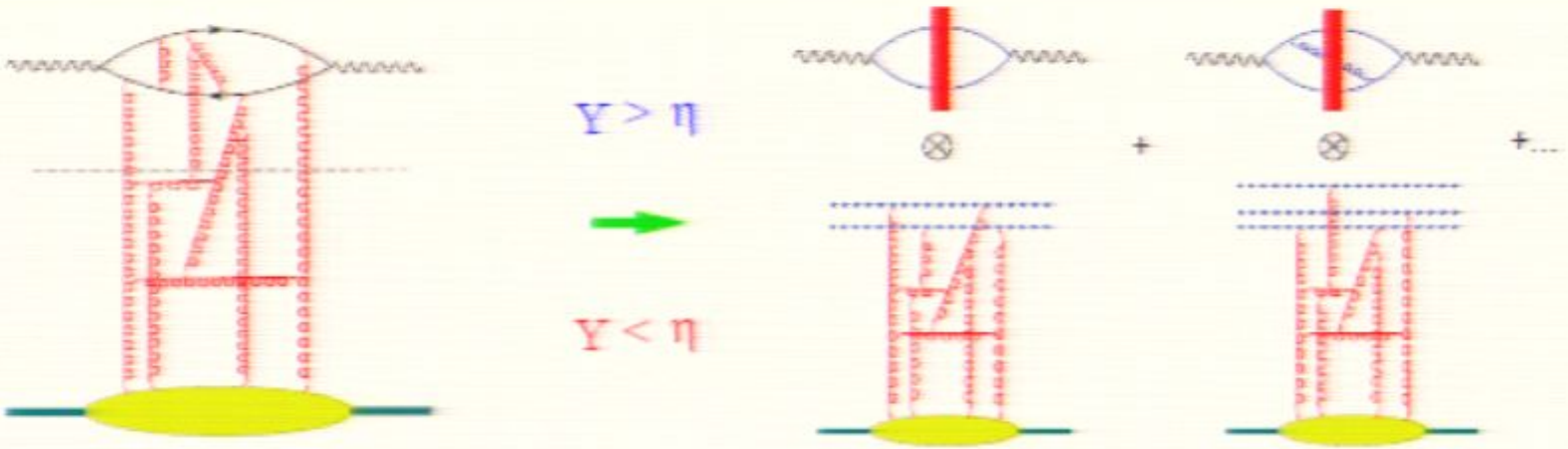
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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

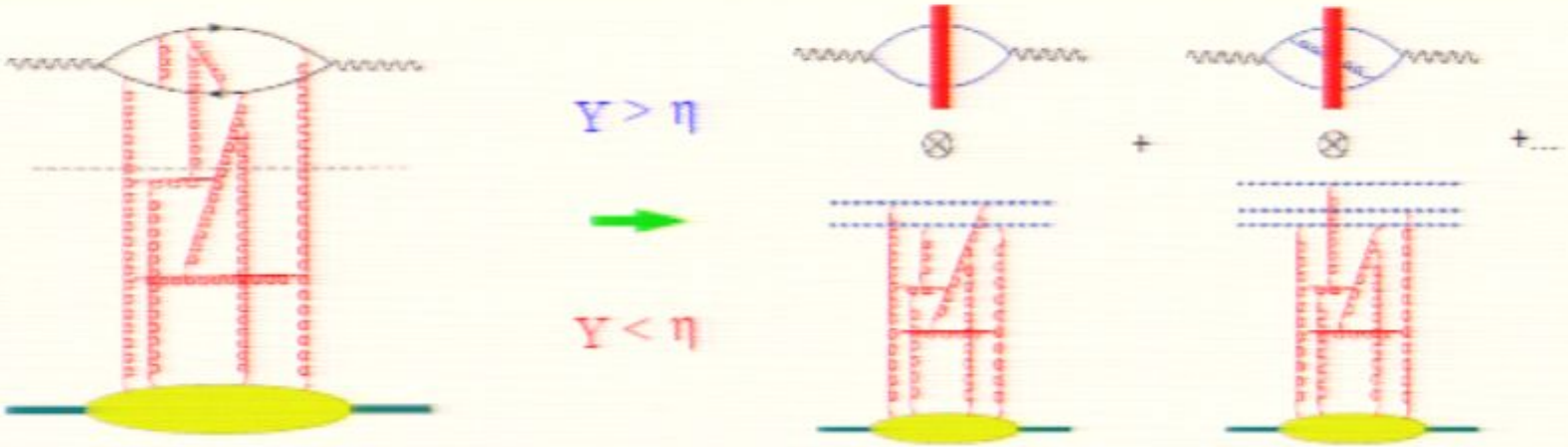
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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

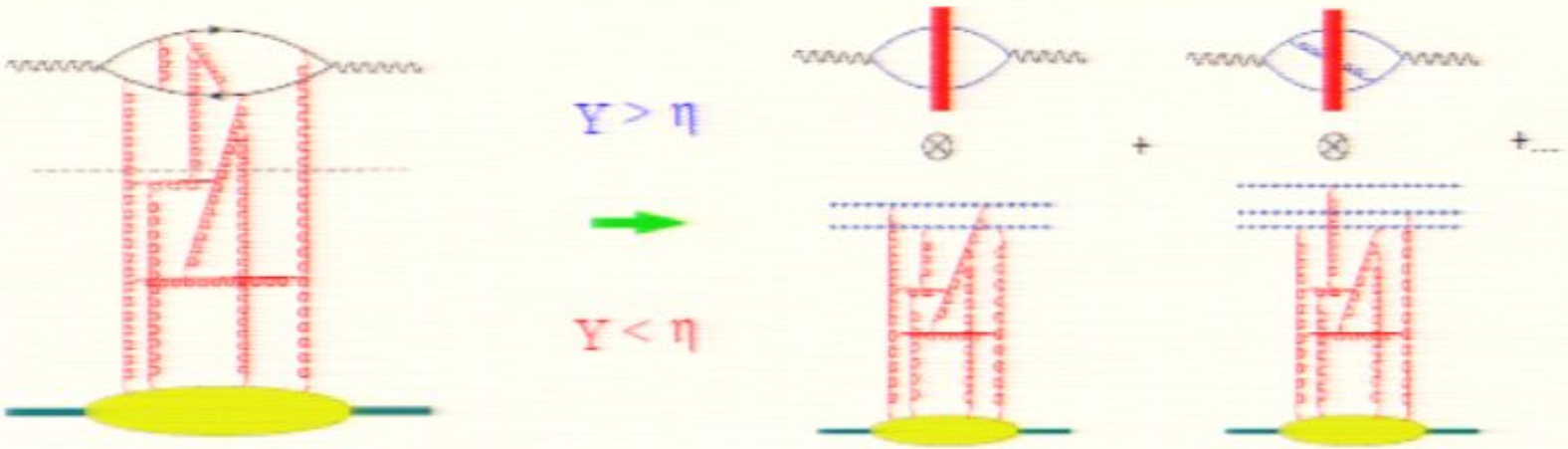
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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

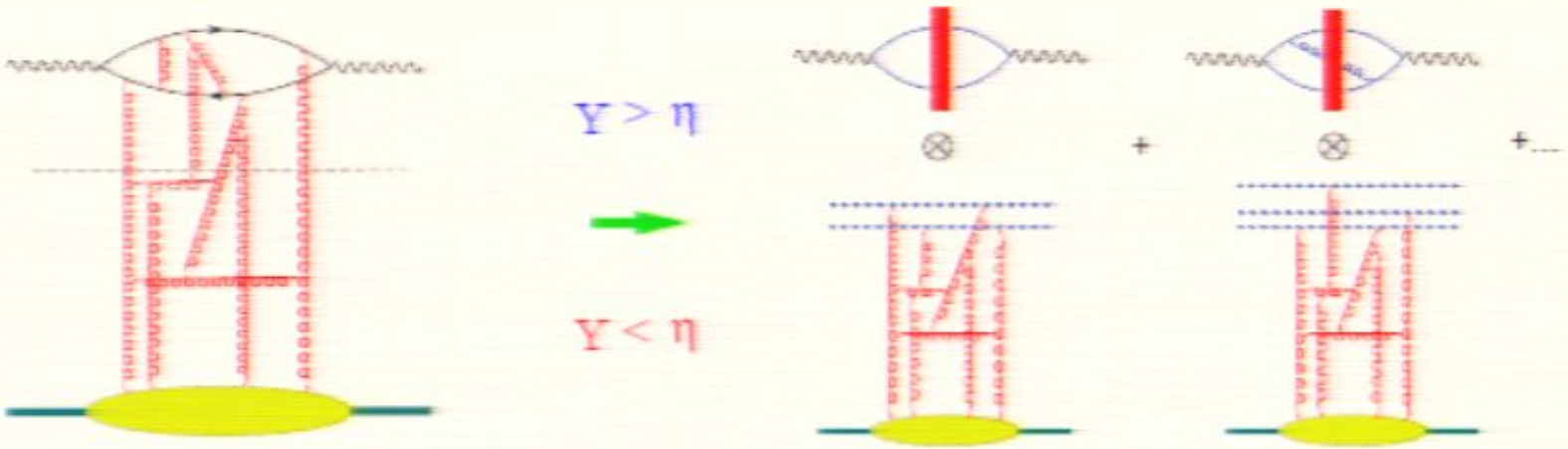
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DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

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Composite "conformal" dipole $[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}$ - same as in $\mathcal{N}=4$ case.

$$(x-y)^4 T\{\bar{\hat{\psi}}(x)\gamma^{\mu}\hat{\psi}(x)\bar{\hat{\psi}}(y)\gamma^{\nu}\hat{\psi}(y)\}$$
$$= \int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left\{I^{\mu\nu}_{\mathrm{LO}}(z_1,z_2)\left[1+\frac{\alpha_s}{\pi}\right][\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right.$$
$$+\int d^2z_3\left[\frac{\alpha_s}{4\pi^2}\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left(\ln\frac{\kappa^2(\zeta_1\cdot\zeta_3)(\zeta_1\cdot\zeta_3)}{2(\kappa\cdot\zeta_3)^2(\zeta_1\cdot\zeta_2)}-2C\right)I^{\mu\nu}_{\mathrm{LO}}+I_2^{\mu\nu}\right]$$
$$\left.\times[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_3}\}\mathrm{tr}\{\hat{U}_{z_3}\hat{U}^{\dagger}_{z_2}\}-N_c\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right\}$$

$$(I_2)_{\mu\nu}(z_1,z_2,z_3) = \frac{\alpha_s}{16\pi^8}\frac{\mathcal{R}^2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\left\{\frac{(\kappa\cdot\zeta_2)}{(\kappa\cdot\zeta_3)}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[-\frac{(\kappa\cdot\zeta_1)^2}{(\zeta_1\cdot\zeta_3)}\right.\right.$$
$$\left.+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)(\zeta_1\cdot\zeta_2)}{(\zeta_1\cdot\zeta_3)(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}\right]$$
$$\left.+\frac{(\kappa\cdot\zeta_2)^2}{(\kappa\cdot\zeta_3)^2}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)}{(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_3)}{2(\zeta_2\cdot\zeta_3)}\right]+(\zeta_1\leftrightarrow\zeta_2)\right\}$$

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$$\left.\times[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_3}\}\mathrm{tr}\{\hat{U}_{z_3}\hat{U}^{\dagger}_{z_2}\}-N_c\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right\}$$

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$$\left.+\frac{(\kappa\cdot\zeta_2)^2}{(\kappa\cdot\zeta_3)^2}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)}{(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_3)}{2(\zeta_2\cdot\zeta_3)}\right]+(\zeta_1\leftrightarrow\zeta_2)\right\}$$

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$$(x-y)^4 T\{\bar{\hat{\psi}}(x)\gamma^{\mu}\hat{\psi}(x)\bar{\hat{\psi}}(y)\gamma^{\nu}\hat{\psi}(y)\}$$

$$= \int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left\{I^{\mu\nu}_{\mathrm{LO}}(z_1,z_2)\left[1+\frac{\alpha_s}{\pi}\right][\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right.$$

$$+\int d^2z_3\left[\frac{\alpha_s}{4\pi^2}\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left(\ln\frac{\kappa^2(\zeta_1\cdot\zeta_3)(\zeta_1\cdot\zeta_3)}{2(\kappa\cdot\zeta_3)^2(\zeta_1\cdot\zeta_2)}-2C\right)I^{\mu\nu}_{\mathrm{LO}}+I_2^{\mu\nu}\right]$$

$$\left.\times[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_3}\}\mathrm{tr}\{\hat{U}_{z_3}\hat{U}^{\dagger}_{z_2}\}-N_c\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right\}$$

$$(I_2)_{\mu\nu}(z_1,z_2,z_3) = \frac{\alpha_s}{16\pi^8}\frac{R^2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\left\{\frac{(\kappa\cdot\zeta_2)}{(\kappa\cdot\zeta_3)}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[-\frac{(\kappa\cdot\zeta_1)^2}{(\zeta_1\cdot\zeta_3)}\right.\right.$$

$$+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)(\zeta_1\cdot\zeta_2)}{(\zeta_1\cdot\zeta_3)(\zeta_2\cdot\zeta_3)}-\left.\frac{\kappa^2(\zeta_1\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}\right]$$

$$+\frac{(\kappa\cdot\zeta_2)^2}{(\kappa\cdot\zeta_3)^2}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)}{(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_3)}{2(\zeta_2\cdot\zeta_3)}\right]+(\zeta_1\leftrightarrow\zeta_2)\left.\right\}$$

Composite "conformal" dipole $[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}$ - same as in $\mathcal{N}=4$ case.

$$(x-y)^4 T\{\bar{\hat{\psi}}(x)\gamma^{\mu}\hat{\psi}(x)\bar{\hat{\psi}}(y)\gamma^{\nu}\hat{\psi}(y)\}$$
$$= \int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left\{I^{\mu\nu}_{\mathrm{LO}}(z_1,z_2)\left[1+\frac{\alpha_s}{\pi}\right][\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right.$$
$$+\int d^2z_3\left[\frac{\alpha_s}{4\pi^2}\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left(\ln\frac{\kappa^2(\zeta_1\cdot\zeta_3)(\zeta_1\cdot\zeta_3)}{2(\kappa\cdot\zeta_3)^2(\zeta_1\cdot\zeta_2)}-2C\right)I^{\mu\nu}_{\mathrm{LO}}+I_2^{\mu\nu}\right]$$
$$\left.\times[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_3}\}\mathrm{tr}\{\hat{U}_{z_3}\hat{U}^{\dagger}_{z_2}\}-N_c\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right\}$$

$$(I_2)_{\mu\nu}(z_1,z_2,z_3) = \frac{\alpha_s}{16\pi^8}\frac{\mathcal{R}^2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\left\{\frac{(\kappa\cdot\zeta_2)}{(\kappa\cdot\zeta_3)}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[-\frac{(\kappa\cdot\zeta_1)^2}{(\zeta_1\cdot\zeta_3)}\right.\right.$$
$$\left.+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)(\zeta_1\cdot\zeta_2)}{(\zeta_1\cdot\zeta_3)(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}\right]$$
$$\left.+\frac{(\kappa\cdot\zeta_2)^2}{(\kappa\cdot\zeta_3)^2}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)}{(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_3)}{2(\zeta_2\cdot\zeta_3)}\right]+(\zeta_1\leftrightarrow\zeta_2)\right\}$$

Composite "conformal" dipole $[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}$ - same as in $\mathcal{N}=4$ case.

$$
\begin{aligned}
&(x-y)^4 T\{\bar{\hat{\psi}}(x)\gamma^{\mu}\hat{\psi}(x)\bar{\hat{\psi}}(y)\gamma^{\nu}\hat{\psi}(y)\} \\
&= \int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left\{I^{\mu\nu}_{\mathrm{LO}}(z_1,z_2)\left[1+\frac{\alpha_s}{\pi}\right][\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right. \\
&+\int d^2z_3\left[\frac{\alpha_s}{4\pi^2}\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left(\ln\frac{\kappa^2(\zeta_1\cdot\zeta_3)(\zeta_1\cdot\zeta_3)}{2(\kappa\cdot\zeta_3)^2(\zeta_1\cdot\zeta_2)}-2C\right)I^{\mu\nu}_{\mathrm{LO}}+I_2^{\mu\nu}\right] \\
&\left.\times[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_3}\}\mathrm{tr}\{\hat{U}_{z_3}\hat{U}^{\dagger}_{z_2}\}-N_c\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right\}
\end{aligned}
$$

$$
\begin{aligned}
(I_2)_{\mu\nu}(z_1,z_2,z_3) &= \frac{\alpha_s}{16\pi^8}\frac{R^2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\left\{\frac{(\kappa\cdot\zeta_2)}{(\kappa\cdot\zeta_3)}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[-\frac{(\kappa\cdot\zeta_1)^2}{(\zeta_1\cdot\zeta_3)}\right.\right. \\
&+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)(\zeta_1\cdot\zeta_2)}{(\zeta_1\cdot\zeta_3)(\zeta_2\cdot\zeta_3)}-\left.\frac{\kappa^2(\zeta_1\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}\right] \\
&+\frac{(\kappa\cdot\zeta_2)^2}{(\kappa\cdot\zeta_3)^2}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)}{(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_3)}{2(\zeta_2\cdot\zeta_3)}\right]+(\zeta_1\leftrightarrow\zeta_2)\left.\right\}
\end{aligned}
$$

Composite "conformal" dipole $[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}$ - same as in $\mathcal{N}=4$ case.

$$(x-y)^4 T\{\bar{\hat{\psi}}(x)\gamma^{\mu}\hat{\psi}(x)\bar{\hat{\psi}}(y)\gamma^{\nu}\hat{\psi}(y)\}$$
$$= \int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left\{I^{\mu\nu}_{\mathrm{LO}}(z_1,z_2)\left[1+\frac{\alpha_s}{\pi}\right][\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right.$$
$$+\int d^2z_3\left[\frac{\alpha_s}{4\pi^2}\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left(\ln\frac{\kappa^2(\zeta_1\cdot\zeta_3)(\zeta_1\cdot\zeta_3)}{2(\kappa\cdot\zeta_3)^2(\zeta_1\cdot\zeta_2)}-2C\right)I^{\mu\nu}_{\mathrm{LO}}+I_2^{\mu\nu}\right]$$
$$\left.\times[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_3}\}\mathrm{tr}\{\hat{U}_{z_3}\hat{U}^{\dagger}_{z_2}\}-N_c\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right\}$$

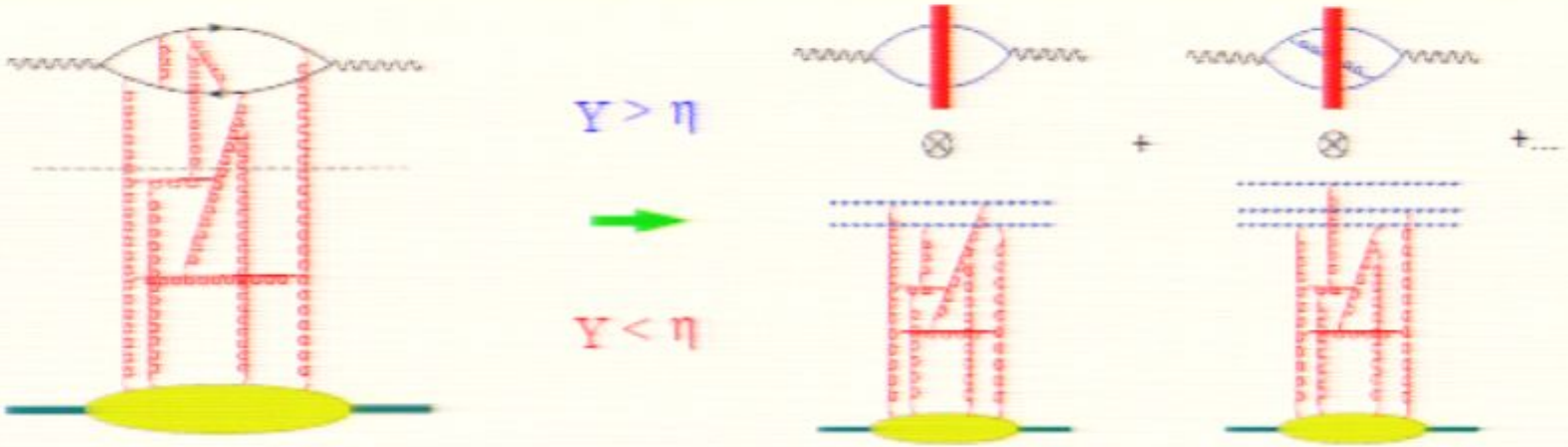
$$(I_2)_{\mu\nu}(z_1,z_2,z_3) = \frac{\alpha_s}{16\pi^8}\frac{\mathcal{R}^2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\left\{\frac{(\kappa\cdot\zeta_2)}{(\kappa\cdot\zeta_3)}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[-\frac{(\kappa\cdot\zeta_1)^2}{(\zeta_1\cdot\zeta_3)}\right.\right.$$
$$\left.+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)(\zeta_1\cdot\zeta_2)}{(\zeta_1\cdot\zeta_3)(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}\right]$$
$$\left.+\frac{(\kappa\cdot\zeta_2)^2}{(\kappa\cdot\zeta_3)^2}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)}{(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_3)}{2(\zeta_2\cdot\zeta_3)}\right]+(\zeta_1\leftrightarrow\zeta_2)\right\}$$

Composite "conformal" dipole $[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}$ - same as in $\mathcal{N}=4$ case.

$$
\begin{aligned}
&(x-y)^4 T\{\bar{\hat{\psi}}(x)\gamma^{\mu}\hat{\psi}(x)\bar{\hat{\psi}}(y)\gamma^{\nu}\hat{\psi}(y)\} \\
&= \int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left\{I^{\mu\nu}_{\mathrm{LO}}(z_1,z_2)\left[1+\frac{\alpha_s}{\pi}\right][\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right. \\
&+\int d^2z_3\left[\frac{\alpha_s}{4\pi^2}\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left(\ln\frac{\kappa^2(\zeta_1\cdot\zeta_3)(\zeta_1\cdot\zeta_3)}{2(\kappa\cdot\zeta_3)^2(\zeta_1\cdot\zeta_2)}-2C\right)I^{\mu\nu}_{\mathrm{LO}}+I_2^{\mu\nu}\right] \\
&\qquad\left.\times[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_3}\}\mathrm{tr}\{\hat{U}_{z_3}\hat{U}^{\dagger}_{z_2}\}-N_c\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right\}
\end{aligned}
$$

$$
\begin{aligned}
(I_2)_{\mu\nu}(z_1,z_2,z_3) &= \frac{\alpha_s}{16\pi^8}\frac{R^2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\left\{\frac{(\kappa\cdot\zeta_2)}{(\kappa\cdot\zeta_3)}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[-\frac{(\kappa\cdot\zeta_1)^2}{(\zeta_1\cdot\zeta_3)}\right.\right. \\
&+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)(\zeta_1\cdot\zeta_2)}{(\zeta_1\cdot\zeta_3)(\zeta_2\cdot\zeta_3)}-\left.\frac{\kappa^2(\zeta_1\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}\right] \\
&+\frac{(\kappa\cdot\zeta_2)^2}{(\kappa\cdot\zeta_3)^2}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)}{(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_3)}{2(\zeta_2\cdot\zeta_3)}\right]+(\zeta_1\leftrightarrow\zeta_2)\left.\right\}
\end{aligned}
$$

n QCD



DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

Photon impact factor in the LO

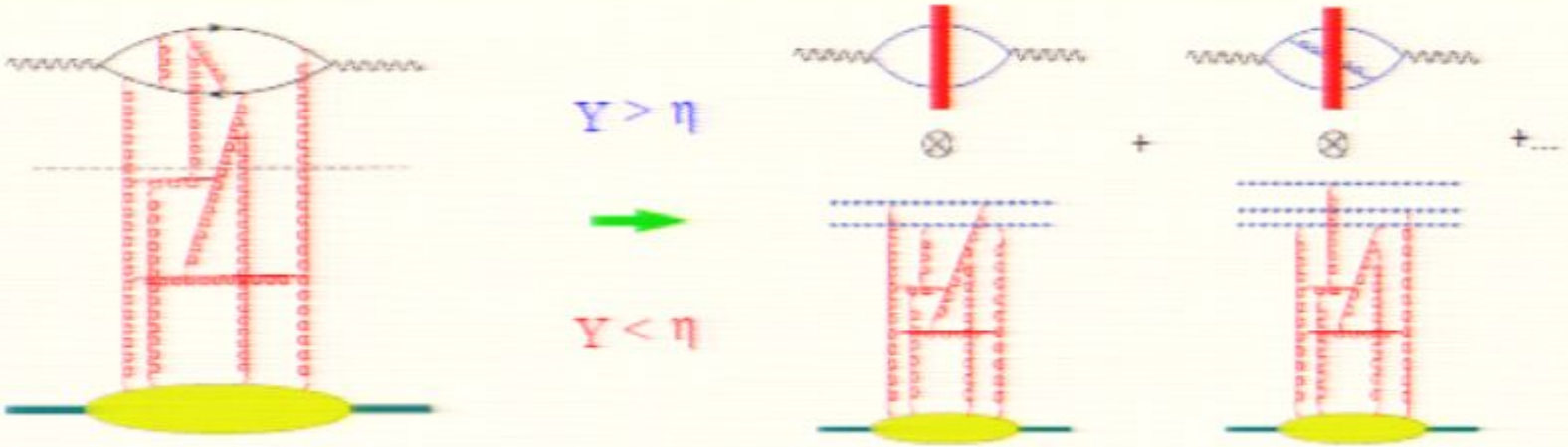
$$(x-y)^4 T\{\bar{\psi}(x)\gamma^\mu\hat{\psi}(x)\bar{\psi}(y)\gamma^\nu\hat{\psi}(y)\} = \int \frac{d^2z_1 d^2z_2}{z_{12}^4} I^{LO}_{\mu\nu}(z_1,z_2)\,\mathrm{tr}\{\hat{U}^\eta_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}$$

$$I^{LO}_{\mu\nu}(z_1,z_2) = \frac{\mathcal{R}^2}{\pi^6(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\frac{\partial^2}{\partial x^\mu \partial y^\nu}\left[(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2) - \frac{1}{2}\kappa^2(\zeta_1\cdot\zeta_2)\right].$$

$$\kappa \equiv \frac{1}{\sqrt{s}x^+}\left(\frac{p_1}{s} - x^2 p_2 + x_\perp\right) - \frac{1}{\sqrt{s}y^+}\left(\frac{p_1}{s} - y^2 p_2 + y_\perp\right)$$

$$\zeta_i \equiv \left(\frac{p_1}{s} + z_{i\perp}^2 p_2 + z_{i\perp}\right), \qquad \mathcal{R} \equiv \frac{\kappa^2(\zeta_1\cdot\zeta_2)}{2(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}$$

n QCD



DIS structure function $F_2(x)$: photon impact factor + evolution of color dipoles+ initial conditions for the small-x evolution

Photon impact factor in the LO

$$(x-y)^4 T\{\bar{\psi}(x)\gamma^\mu\psi(x)\bar{\psi}(y)\gamma^\nu\psi(y)\} = \int \frac{d^2z_1 d^2z_2}{z_{12}^4} I^{LO}_{\mu\nu}(z_1,z_2)\,\mathrm{tr}\{\hat{U}^\eta_{z_1}\hat{U}^{\dagger\eta}_{z_2}\}$$

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Composite "conformal" dipole $[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}$ - same as in $\mathcal{N}=4$ case.

$$
\begin{aligned}
&(x-y)^4 T\{\bar{\hat{\psi}}(x)\gamma^{\mu}\hat{\psi}(x)\bar{\hat{\psi}}(y)\gamma^{\nu}\hat{\psi}(y)\} \\
&= \int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left\{ I^{\mu\nu}_{\mathrm{LO}}(z_1,z_2)\left[1+\frac{\alpha_s}{\pi}\right][\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right. \\
&+\int d^2z_3\left[\frac{\alpha_s}{4\pi^2}\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left(\ln\frac{\kappa^2(\zeta_1\cdot\zeta_3)(\zeta_1\cdot\zeta_3)}{2(\kappa\cdot\zeta_3)^2(\zeta_1\cdot\zeta_2)}-2C\right)I^{\mu\nu}_{\mathrm{LO}}+I_2^{\mu\nu}\right] \\
&\qquad\left.\times[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_3}\}\mathrm{tr}\{\hat{U}_{z_3}\hat{U}^{\dagger}_{z_2}\}-N_c\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right\}
\end{aligned}
$$

$$
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(I_2)_{\mu\nu}(z_1,z_2,z_3) &= \frac{\alpha_s}{16\pi^8}\frac{\mathcal{R}^2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\left\{\frac{(\kappa\cdot\zeta_2)}{(\kappa\cdot\zeta_3)}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[-\frac{(\kappa\cdot\zeta_1)^2}{(\zeta_1\cdot\zeta_3)}\right.\right. \\
&+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)(\zeta_1\cdot\zeta_2)}{(\zeta_1\cdot\zeta_3)(\zeta_2\cdot\zeta_3)}-\left.\frac{\kappa^2(\zeta_1\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}\right] \\
&+\frac{(\kappa\cdot\zeta_2)^2}{(\kappa\cdot\zeta_3)^2}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)}{(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_3)}{2(\zeta_2\cdot\zeta_3)}\right]+(\zeta_1\leftrightarrow\zeta_2)\left.\right\}
\end{aligned}
$$

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$$
\begin{aligned}
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&+\int d^2z_3\left[\frac{\alpha_s}{4\pi^2}\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left(\ln\frac{\kappa^2(\zeta_1\cdot\zeta_3)(\zeta_1\cdot\zeta_3)}{2(\kappa\cdot\zeta_3)^2(\zeta_1\cdot\zeta_2)}-2C\right)I^{\mu\nu}_{\mathrm{LO}}+I_2^{\mu\nu}\right] \\
&\qquad\left.\times[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_3}\}\mathrm{tr}\{\hat{U}_{z_3}\hat{U}^{\dagger}_{z_2}\}-N_c\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right\}
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&+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)(\zeta_1\cdot\zeta_2)}{(\zeta_1\cdot\zeta_3)(\zeta_2\cdot\zeta_3)}-\left.\frac{\kappa^2(\zeta_1\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}\right] \\
&+\frac{(\kappa\cdot\zeta_2)^2}{(\kappa\cdot\zeta_3)^2}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)}{(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_3)}{2(\zeta_2\cdot\zeta_3)}\right]+(\zeta_1\leftrightarrow\zeta_2)\left.\right\}
\end{aligned}
$$

Composite "conformal" dipole $[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}$ - same as in $\mathcal{N}=4$ case.

$$(x-y)^4 T\{\bar{\hat{\psi}}(x)\gamma^{\mu}\hat{\psi}(x)\bar{\hat{\psi}}(y)\gamma^{\nu}\hat{\psi}(y)\}$$
$$= \int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left\{I^{\mu\nu}_{\mathrm{LO}}(z_1,z_2)\left[1+\frac{\alpha_s}{\pi}\right][\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right.$$
$$+\int d^2z_3\left[\frac{\alpha_s}{4\pi^2}\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left(\ln\frac{\kappa^2(\zeta_1\cdot\zeta_3)(\zeta_1\cdot\zeta_3)}{2(\kappa\cdot\zeta_3)^2(\zeta_1\cdot\zeta_2)}-2C\right)I^{\mu\nu}_{\mathrm{LO}}+I_2^{\mu\nu}\right]$$
$$\left.\times[\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_3}\}\mathrm{tr}\{\hat{U}_{z_3}\hat{U}^{\dagger}_{z_2}\}-N_c\mathrm{tr}\{\hat{U}_{z_1}\hat{U}^{\dagger}_{z_2}\}]_{a_0}\right\}$$

$$(I_2)_{\mu\nu}(z_1,z_2,z_3) = \frac{\alpha_s}{16\pi^8}\frac{R^2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\left\{\frac{(\kappa\cdot\zeta_2)}{(\kappa\cdot\zeta_3)}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[-\frac{(\kappa\cdot\zeta_1)^2}{(\zeta_1\cdot\zeta_3)}\right.\right.$$
$$\left.+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}+\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)(\zeta_1\cdot\zeta_2)}{(\zeta_1\cdot\zeta_3)(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_2)}{(\zeta_2\cdot\zeta_3)}\right]$$
$$\left.+\frac{(\kappa\cdot\zeta_2)^2}{(\kappa\cdot\zeta_3)^2}\frac{\partial^2}{\partial x^{\mu}\partial y^{\nu}}\left[\frac{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_3)}{(\zeta_2\cdot\zeta_3)}-\frac{\kappa^2(\zeta_1\cdot\zeta_3)}{2(\zeta_2\cdot\zeta_3)}\right]+(\zeta_1\leftrightarrow\zeta_2)\right\}$$

With two-gluon (NLO BFKL) accuracy

$$\frac{1}{N_c}(x-y)^4 T\{\bar{\psi}(x)\gamma^\mu\hat{\psi}(x)\bar{\psi}(y)\gamma^\nu\hat{\psi}(y)\} = \frac{\partial\kappa^\alpha}{\partial x^\mu}\frac{\partial\kappa^\beta}{\partial y^\nu}\int\frac{dz_1 dz_2}{z_{12}^4}\hat{\mathcal{U}}_{a_0}(z_1,z_2)\left[\mathcal{I}^{\rm LO}_{\alpha\beta}\left(1+\frac{\alpha_s}{\pi}\right)+\mathcal{I}^{\rm NLO}_{\alpha\beta}\right]$$

$$\mathcal{I}^{\alpha\beta}_{\rm LO}(x,y;z_1,z_2) = \mathcal{R}^2\frac{g^{\alpha\beta}(\zeta_1\cdot\zeta_2)-\zeta_1^\alpha\zeta_2^\beta-\zeta_2^\alpha\zeta_1^\beta}{\pi^6(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}$$

$$\begin{aligned}\mathcal{I}^{\alpha\beta}_{\rm NLO}(x,y;z_1,z_2) = \frac{\alpha_s N_c}{4\pi^7}\mathcal{R}^2\Bigg\{&\frac{\zeta_1^\alpha\zeta_2^\beta+\zeta_1\leftrightarrow\zeta_2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[4{\rm Li}_2(1-\mathcal{R})-\frac{2\pi^2}{3}+\frac{2\ln\mathcal{R}}{1-\mathcal{R}}+\frac{\ln\mathcal{R}}{\mathcal{R}}\\&-4\ln\mathcal{R}+\frac{1}{2\mathcal{R}}-2+2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}-2\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)-4C-\frac{2C}{\mathcal{R}}\Big]\\&+\Big(\frac{\zeta_1^\alpha\zeta_1^\beta}{(\kappa\cdot\zeta_1)^2}+\zeta_1\leftrightarrow\zeta_2\Big)\Big[\frac{\ln\mathcal{R}}{\mathcal{R}}-\frac{2C}{\mathcal{R}}+2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{1}{2\mathcal{R}}\Big]-\frac{2}{\kappa^2}\Big(g^{\alpha\beta}-2\frac{\kappa^\alpha\kappa^\beta}{\kappa^2}\Big)\\&+\Big[\frac{\zeta_1^\alpha\kappa^\beta+\zeta_1^\beta\kappa^\alpha}{(\kappa\cdot\zeta_1)\kappa^2}+\zeta_1\leftrightarrow\zeta_2\Big]\Big[-2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{\ln\mathcal{R}}{\mathcal{R}}+\ln\mathcal{R}-\frac{3}{2\mathcal{R}}+\frac{5}{2}+2C+\frac{2C}{\mathcal{R}}\Big]\\&+\frac{g^{\alpha\beta}(\zeta_1\cdot\zeta_2)}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[\frac{2\pi^2}{3}-4{\rm Li}_2(1-\mathcal{R})\\&-2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}+\frac{1}{2\mathcal{R}^2}-3\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)+6\ln\mathcal{R}-\frac{2}{\mathcal{R}}+2+\frac{3}{2\mathcal{R}^2}\Big]\Bigg\}\end{aligned}$$

5 tensor structures (CCP, 2009)

Photon Impact Factor at NLO

I. B. and G. A. C.

With two-gluon (NLO BFKL) accuracy

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$$\mathcal{I}^{\alpha\beta}_{\rm LO}(x,y;z_1,z_2) = \mathcal{R}^2\frac{g^{\alpha\beta}(\zeta_1\cdot\zeta_2)-\zeta_1^\alpha\zeta_2^\beta-\zeta_2^\alpha\zeta_1^\beta}{\pi^6(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}$$

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& -4\ln\mathcal{R}+\frac{1}{2\mathcal{R}}-2+2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}-2\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)-4C-\frac{2C}{\mathcal{R}}\Big] \\
& +\Big(\frac{\zeta_1^\alpha\zeta_1^\beta}{(\kappa\cdot\zeta_1)^2}+\zeta_1\leftrightarrow\zeta_2\Big)\Big[\frac{\ln\mathcal{R}}{\mathcal{R}}-\frac{2C}{\mathcal{R}}+2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{1}{2\mathcal{R}}\Big]-\frac{2}{\kappa^2}\Big(g^{\alpha\beta}-2\frac{\kappa^\alpha\kappa^\beta}{\kappa^2}\Big) \\
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& +\frac{g^{\alpha\beta}(\zeta_1\cdot\zeta_2)}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[\frac{2\pi^2}{3}-4{\rm Li}_2(1-\mathcal{R}) \\
& -2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}+\frac{1}{2\mathcal{R}^2}-3\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)+6\ln\mathcal{R}-\frac{2}{\mathcal{R}}+2+\frac{3}{2\mathcal{R}^2}\Big]\Bigg\}
\end{aligned}$$

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$$\begin{aligned}\mathcal{I}^{\alpha\beta}_{\rm NLO}(x,y;z_1,z_2) = \frac{\alpha_s N_c}{4\pi^7}\mathcal{R}^2\Bigg\{&\frac{\zeta_1^\alpha\zeta_2^\beta+\zeta_1\leftrightarrow\zeta_2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[4{\rm Li}_2(1-\mathcal{R})-\frac{2\pi^2}{3}+\frac{2\ln\mathcal{R}}{1-\mathcal{R}}+\frac{\ln\mathcal{R}}{\mathcal{R}}\\&-4\ln\mathcal{R}+\frac{1}{2\mathcal{R}}-2+2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}-2\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)-4C-\frac{2C}{\mathcal{R}}\Big]\\&+\Big(\frac{\zeta_1^\alpha\zeta_1^\beta}{(\kappa\cdot\zeta_1)^2}+\zeta_1\leftrightarrow\zeta_2\Big)\Big[\frac{\ln\mathcal{R}}{\mathcal{R}}-\frac{2C}{\mathcal{R}}+2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{1}{2\mathcal{R}}\Big]-\frac{2}{\kappa^2}\Big(g^{\alpha\beta}-2\frac{\kappa^\alpha\kappa^\beta}{\kappa^2}\Big)\\&+\Big[\frac{\zeta_1^\alpha\kappa^\beta+\zeta_1^\beta\kappa^\alpha}{(\kappa\cdot\zeta_1)\kappa^2}+\zeta_1\leftrightarrow\zeta_2\Big]\Big[-2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{\ln\mathcal{R}}{\mathcal{R}}+\ln\mathcal{R}-\frac{3}{2\mathcal{R}}+\frac{5}{2}+2C+\frac{2C}{\mathcal{R}}\Big]\\&+\frac{g^{\alpha\beta}(\zeta_1\cdot\zeta_2)}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[\frac{2\pi^2}{3}-4{\rm Li}_2(1-\mathcal{R})\\&-2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}+\frac{1}{2\mathcal{R}^2}-3\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)+6\ln\mathcal{R}-\frac{2}{\mathcal{R}}+2+\frac{3}{2\mathcal{R}^2}\Big]\Bigg\}\end{aligned}$$

5 tensor structures (CCP, 2009)

With two-gluon (NLO BFKL) accuracy

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5 tensor structures (CCP, 2009)

Photon Impact Factor at NLO

Reminder

$$\kappa^\mu = \frac{1}{\sqrt{s}x^+}\left(\frac{p_1^\mu}{s} - x^2 p_2^\mu + x_\perp^\mu\right) - \frac{1}{\sqrt{s}y^+}\left(\frac{p_1^\mu}{s} - y^2 p_2^\mu + y_\perp^\mu\right)$$

$$\zeta_1^\mu = \left(\frac{p_1^\mu}{s} + z_{1\perp}^2 p_2^\mu + z_{1\perp}^\mu\right), \qquad \zeta_2^\mu = \left(\frac{p_1^\mu}{s} + z_{2\perp}^2 p_2^\mu + z_{2\perp}^\mu\right)$$

DIS photon impact factor is a linear combination of the following tensor basis

$$\mathcal{I}_1^{\mu\nu} = g^{\mu\nu} \qquad \mathcal{I}_2^{\mu\nu} = \frac{\kappa^\mu \kappa^\nu}{\kappa^2}$$

$$\mathcal{I}_3^{\mu\nu} = \frac{\kappa^\mu \zeta_1^\nu + \kappa^\nu \zeta_1^\mu}{\kappa \cdot \zeta_1} + \frac{\kappa^\mu \zeta_2^\nu + \kappa^\nu \zeta_2^\mu}{\kappa \cdot \zeta_2}$$

$$\mathcal{I}_4^{\mu\nu} = \frac{\kappa^2 \zeta_1^\mu \zeta_1^\nu}{(\kappa \cdot \zeta_1)^2} + \frac{\kappa^2 \zeta_2^\mu \zeta_2^\nu}{(\kappa \cdot \zeta_2)^2} \qquad \mathcal{I}_5^{\mu\nu} = \frac{\zeta_1^\mu \zeta_2^\nu + \zeta_2^\mu \zeta_1^\nu}{\zeta_1 \cdot \zeta_2}$$

Cornalba, Costa, Penedones (2010)

Mellin representation of the LO impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^2} I_{LO}^{\mu\nu}(z_1,z_2)\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^\gamma = \frac{1}{\pi^4} B(1-\gamma,1-\gamma)\Gamma(\gamma+2)\Gamma(3-\gamma)$$

$$\times\left\{\frac{\gamma(1-\gamma)D_1}{12(1+\gamma)(2-\gamma)} + \frac{D_2}{2(1+\gamma)(2-\gamma)} - \frac{D_3^{\mu\nu}}{8(1+\gamma)(2-\gamma)}\right.$$

$$\left. - \frac{\gamma(1-\gamma)D_4^{\mu\nu}}{16(1+2\gamma)(3-2\gamma)(1+\gamma)(2-\gamma)} - \frac{D_1^{\mu\nu}+D_2^{\mu\nu}}{8}\right\}_{\mu\nu}\left(\frac{\kappa^2}{(\kappa\cdot\zeta_0)^2}\right)^\gamma$$

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where

$$(D_1+D_2)^{\mu\nu} = -2\Delta^2 x^+ y^+ \kappa^{-2}\partial_x^\mu\partial_y^\nu\kappa^2$$
$$D_2^{\mu\nu} = -\Delta^2 x^+ y^+ \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2$$
$$D_3^{\mu\nu} = 4\gamma\Delta^2 x^+ y^+\left[(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - (\partial_x^\mu\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right]$$
$$D_4^{\mu\nu} = 4\gamma(1+2\gamma)\Delta^2 x^+ y^+\left[-\frac{1}{3}\partial_x^\mu\partial_y^\nu\ln\kappa^2 - \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right.$$
$$\left.(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - 2\partial_\mu^x\ln(\kappa\cdot\zeta_0)\partial_\nu^y\ln(\kappa\cdot\zeta_0)\right]$$

$B(a,b) = \frac{\Gamma(a)\Gamma(b)}{\Gamma(a+b)}$, $C = -\psi(1)$ is the Euler constant, and $\psi'(a) = \frac{d}{da}\ln\Gamma(a)$

Mellin representation of the LO impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^2} I_{LO}^{\mu\nu}(z_1,z_2)\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^\gamma = \frac{1}{\pi^4} B(1-\gamma)\Gamma(\gamma+2)\Gamma(3-\gamma)$$
$$\times\left\{\frac{\gamma(1-\gamma)D_1^{\mu\nu}}{12(1+\gamma)(2-\gamma)} + \frac{D_2^{\mu\nu}}{2(1+\gamma)(2-\gamma)} - \frac{D_3^{\mu\nu}}{8(1+\gamma)(2-\gamma)}\right.$$
$$\left. - \frac{\gamma(1-\gamma)D_4}{16(1+2\gamma)(3-2\gamma)(1+\gamma)(2-\gamma)} - \frac{D_1^{\mu\nu}+D_2^{\mu\nu}}{8}\right\}_{\mu\nu}\left(\frac{\kappa^2}{(\kappa\cdot\zeta_0)^2}\right)^\gamma$$

where

$$(D_1+D_2)^{\mu\nu} = -2\Delta^2 x^+ y^+ \kappa^{-2}\partial_x^\mu\partial_y^\nu\kappa^2$$
$$D_2^{\mu\nu} = -\Delta^2 x^+ y^+ \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2$$
$$D_3^{\mu\nu} = 4\gamma\Delta^2 x^+ y^+\left[(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - (\partial_x^\mu\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right]$$
$$D_4^{\mu\nu} = 4\gamma(1+2\gamma)\Delta^2 x^+ y^+\left[-\frac{1}{3}\partial_x^\mu\partial_y^\nu\ln\kappa^2 - \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right.$$
$$\left.(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - 2\partial_\mu^x\ln(\kappa\cdot\zeta_0)\partial_\nu^y\ln(\kappa\cdot\zeta_0)\right]$$

$B(a,b) = \frac{\Gamma(a)\Gamma(b)}{\Gamma(a+b)}$, $C = -\psi(1)$ is the Euler constant, and $\psi'(a) = \frac{d}{da}\ln\Gamma(a)$

Mellin representation of the LO impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^2} I_{LO}^{\mu\nu}(z_1,z_2)\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^\gamma = \frac{1}{\pi^4} B(1-\gamma)\Gamma(\gamma+2)\Gamma(3-\gamma)$$
$$\times\left\{\frac{\gamma(1-\gamma)D_1^{\mu\nu}}{12(1+\gamma)(2-\gamma)} + \frac{D_2^{\mu\nu}}{2(1+\gamma)(2-\gamma)} - \frac{D_3^{\mu\nu}}{8(1+\gamma)(2-\gamma)}\right.$$
$$\left. - \frac{\gamma(1-\gamma)D_4}{16(1+2\gamma)(3-2\gamma)(1+\gamma)(2-\gamma)} - \frac{D_1^{\mu\nu}+D_2^{\mu\nu}}{8}\right\}_{\mu\nu}\left(\frac{\kappa^2}{(\kappa\cdot\zeta_0)^2}\right)^\gamma$$

where

$$(D_1+D_2)^{\mu\nu} = -2\Delta^2 x^+ y^+ \kappa^{-2}\partial_x^\mu\partial_y^\nu\kappa^2$$
$$D_2^{\mu\nu} = -\Delta^2 x^+ y^+ \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2$$
$$D_3^{\mu\nu} = 4\gamma\Delta^2 x^+ y^+\left[(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - (\partial_x^\mu\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right]$$
$$D_4^{\mu\nu} = 4\gamma(1+2\gamma)\Delta^2 x^+ y^+\left[-\frac{1}{3}\partial_x^\mu\partial_y^\nu\ln\kappa^2 - \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right.$$
$$\left.(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - 2\partial_\mu^x\ln(\kappa\cdot\zeta_0)\partial_\nu^y\ln(\kappa\cdot\zeta_0)\right]$$

$B(a,b) = \frac{\Gamma(a)\Gamma(b)}{\Gamma(a+b)}$, $C = -\psi(1)$ is the Euler constant, and $\psi'(a) = \frac{d}{da}\ln\Gamma(a)$

Mellin representation of the LO impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^2} I^{\mu\nu}_{LO}(z_1,z_2)\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^\gamma = \frac{1}{\pi^4} B(1-\gamma)\Gamma(\gamma+2)\Gamma(3-\gamma)$$
$$\times\left\{\frac{\gamma(1-\gamma)D_1^{\mu\nu}}{12(1+\gamma)(2-\gamma)} + \frac{D_2^{\mu\nu}}{2(1+\gamma)(2-\gamma)} - \frac{D_3^{\mu\nu}}{8(1+\gamma)(2-\gamma)}\right.$$
$$\left. - \frac{\gamma(1-\gamma)D_4}{16(1+2\gamma)(3-2\gamma)(1+\gamma)(2-\gamma)} - \frac{D_1^{\mu\nu}+D_2^{\mu\nu}}{8}\right\}_{\mu\nu}\left(\frac{\kappa^2}{(\kappa\cdot\zeta_0)^2}\right)^\gamma$$

where

$$(D_1+D_2)^{\mu\nu} = -2\Delta^2 x^+ y^+ \kappa^{-2}\partial_x^\mu\partial_y^\nu\kappa^2$$
$$D_2^{\mu\nu} = -\Delta^2 x^+ y^+ \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2$$
$$D_3^{\mu\nu} = 4\gamma\Delta^2 x^+ y^+\left[(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - (\partial_x^\mu\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right]$$
$$D_4^{\mu\nu} = 4\gamma(1+2\gamma)\Delta^2 x^+ y^+\left[-\frac{1}{3}\partial_x^\mu\partial_y^\nu\ln\kappa^2 - \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right.$$
$$\left.(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - 2\partial_\mu^x\ln(\kappa\cdot\zeta_0)\partial_\nu^y\ln(\kappa\cdot\zeta_0)\right]$$

$B(a,b) = \frac{\Gamma(a)\Gamma(b)}{\Gamma(a+b)}$, $C = -\psi(1)$ is the Euler constant, and $\psi'(a) = \frac{d}{da}\ln\Gamma(a)$

Mellin representation of the LO impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^2} I^{\mu\nu}_{LO}(z_1,z_2)\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^\gamma = \frac{1}{\pi^4} B(1-\gamma)\Gamma(\gamma+2)\Gamma(3-\gamma)$$
$$\times\left\{\frac{\gamma(1-\gamma)D_1^{\mu\nu}}{12(1+\gamma)(2-\gamma)} + \frac{D_2^{\mu\nu}}{2(1+\gamma)(2-\gamma)} - \frac{D_3^{\mu\nu}}{8(1+\gamma)(2-\gamma)}\right.$$
$$\left. - \frac{\gamma(1-\gamma)D_4}{16(1+2\gamma)(3-2\gamma)(1+\gamma)(2-\gamma)} - \frac{D_1^{\mu\nu}+D_2^{\mu\nu}}{8}\right\}_{\mu\nu}\left(\frac{\kappa^2}{(\kappa\cdot\zeta_0)^2}\right)^\gamma$$

where

$$(D_1+D_2)^{\mu\nu} = -2\Delta^2 x^+ y^+ \kappa^{-2}\partial_x^\mu\partial_y^\nu\kappa^2$$
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$$D_3^{\mu\nu} = 4\gamma\Delta^2 x^+ y^+\left[(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - (\partial_x^\mu\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right]$$
$$D_4^{\mu\nu} = 4\gamma(1+2\gamma)\Delta^2 x^+ y^+\left[-\frac{1}{3}\partial_x^\mu\partial_y^\nu\ln\kappa^2 - \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right.$$
$$\left.(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - 2\partial_\mu^x\ln(\kappa\cdot\zeta_0)\partial_\nu^y\ln(\kappa\cdot\zeta_0)\right]$$

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Mellin representation of the LO impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^2} I_{LO}^{\mu\nu}(z_1,z_2)\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^\gamma = \frac{1}{\pi^4} B(1-\gamma)\Gamma(\gamma+2)\Gamma(3-\gamma)$$
$$\times\left\{\frac{\gamma(1-\gamma)D_1^{\mu\nu}}{12(1+\gamma)(2-\gamma)} + \frac{D_2^{\mu\nu}}{2(1+\gamma)(2-\gamma)} - \frac{D_3^{\mu\nu}}{8(1+\gamma)(2-\gamma)}\right.$$
$$\left. - \frac{\gamma(1-\gamma)D_4}{16(1+2\gamma)(3-2\gamma)(1+\gamma)(2-\gamma)} - \frac{D_1^{\mu\nu}+D_2^{\mu\nu}}{8}\right\}_{\mu\nu}\left(\frac{\kappa^2}{(\kappa\cdot\zeta_0)^2}\right)^\gamma$$

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$$D_4^{\mu\nu} = 4\gamma(1+2\gamma)\Delta^2 x^+ y^+\left[-\frac{1}{3}\partial_x^\mu\partial_y^\nu\ln\kappa^2 - \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right.$$
$$\left.(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - 2\partial_\mu^x\ln(\kappa\cdot\zeta_0)\partial_\nu^y\ln(\kappa\cdot\zeta_0)\right]$$

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Mellin representation of the LO impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^2} I_{LO}^{\mu\nu}(z_1,z_2)\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^\gamma = \frac{1}{\pi^4} B(1-\gamma)\Gamma(\gamma+2)\Gamma(3-\gamma)$$
$$\times\left\{\frac{\gamma(1-\gamma)D_1^{\mu\nu}}{12(1+\gamma)(2-\gamma)} + \frac{D_2^{\mu\nu}}{2(1+\gamma)(2-\gamma)} - \frac{D_3^{\mu\nu}}{8(1+\gamma)(2-\gamma)}\right.$$
$$\left. - \frac{\gamma(1-\gamma)D_4}{16(1+2\gamma)(3-2\gamma)(1+\gamma)(2-\gamma)} - \frac{D_1^{\mu\nu}+D_2^{\mu\nu}}{8}\right\}_{\mu\nu}\left(\frac{\kappa^2}{(\kappa\cdot\zeta_0)^2}\right)^\gamma$$

where

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$$D_3^{\mu\nu} = 4\gamma\Delta^2 x^+ y^+\left[(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - (\partial_x^\mu\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right]$$

$$D_4^{\mu\nu} = 4\gamma(1+2\gamma)\Delta^2 x^+ y^+\left[-\frac{1}{3}\partial_x^\mu\partial_y^\nu\ln\kappa^2 - \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right.$$
$$\left.(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - 2\partial_\mu^x\ln(\kappa\cdot\zeta_0)\partial_\nu^y\ln(\kappa\cdot\zeta_0)\right]$$

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Mellin representation of the LO impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^2} I_{LO}^{\mu\nu}(z_1,z_2)\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^\gamma = \frac{1}{\pi^4} B(1-\gamma)\Gamma(\gamma+2)\Gamma(3-\gamma)$$
$$\times\left\{\frac{\gamma(1-\gamma)D_1^{\mu\nu}}{12(1+\gamma)(2-\gamma)} + \frac{D_2^{\mu\nu}}{2(1+\gamma)(2-\gamma)} - \frac{D_3^{\mu\nu}}{8(1+\gamma)(2-\gamma)}\right.$$
$$\left. - \frac{\gamma(1-\gamma)D_4}{16(1+2\gamma)(3-2\gamma)(1+\gamma)(2-\gamma)} - \frac{D_1^{\mu\nu}+D_2^{\mu\nu}}{8}\right\}_{\mu\nu}\left(\frac{\kappa^2}{(\kappa\cdot\zeta_0)^2}\right)^\gamma$$

where

$$(D_1+D_2)^{\mu\nu} = -2\Delta^2 x^+ y^+ \kappa^{-2}\partial_x^\mu\partial_y^\nu\kappa^2$$
$$D_2^{\mu\nu} = -\Delta^2 x^+ y^+ \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2$$
$$D_3^{\mu\nu} = 4\gamma\Delta^2 x^+ y^+\left[(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - (\partial_x^\mu\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right]$$
$$D_4^{\mu\nu} = 4\gamma(1+2\gamma)\Delta^2 x^+ y^+\left[-\frac{1}{3}\partial_x^\mu\partial_y^\nu\ln\kappa^2 - \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right.$$
$$\left.(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - 2\partial_\mu^x\ln(\kappa\cdot\zeta_0)\partial_\nu^y\ln(\kappa\cdot\zeta_0)\right]$$

$B(a,b) = \frac{\Gamma(a)\Gamma(b)}{\Gamma(a+b)}$, $C = -\psi(1)$ is the Euler constant, and $\psi'(a) = \frac{d}{da}\ln\Gamma(a)$

Mellin representation of the LO impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^2} I_{LO}^{\mu\nu}(z_1,z_2)\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^\gamma = \frac{1}{\pi^4} B(1-\gamma)\Gamma(\gamma+2)\Gamma(3-\gamma)$$
$$\times\left\{\frac{\gamma(1-\gamma)D_1^{\mu\nu}}{12(1+\gamma)(2-\gamma)} + \frac{D_2^{\mu\nu}}{2(1+\gamma)(2-\gamma)} - \frac{D_3^{\mu\nu}}{8(1+\gamma)(2-\gamma)}\right.$$
$$\left. - \frac{\gamma(1-\gamma)D_4}{16(1+2\gamma)(3-2\gamma)(1+\gamma)(2-\gamma)} - \frac{D_1^{\mu\nu}+D_2^{\mu\nu}}{8}\right\}_{\mu\nu}\left(\frac{\kappa^2}{(\kappa\cdot\zeta_0)^2}\right)^\gamma$$

where

$$(D_1+D_2)^{\mu\nu} = -2\Delta^2 x^+ y^+ \kappa^{-2}\partial_x^\mu\partial_y^\nu\kappa^2$$
$$D_2^{\mu\nu} = -\Delta^2 x^+ y^+ \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2$$
$$D_3^{\mu\nu} = 4\gamma\Delta^2 x^+ y^+\left[(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - (\partial_x^\mu\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right]$$
$$D_4^{\mu\nu} = 4\gamma(1+2\gamma)\Delta^2 x^+ y^+\left[-\frac{1}{3}\partial_x^\mu\partial_y^\nu\ln\kappa^2 - \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right.$$
$$\left.(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - 2\partial_\mu^x\ln(\kappa\cdot\zeta_0)\partial_\nu^y\ln(\kappa\cdot\zeta_0)\right]$$

$B(a,b) = \frac{\Gamma(a)\Gamma(b)}{\Gamma(a+b)}$, $C = -\psi(1)$ is the Euler constant, and $\psi'(a) = \frac{d}{da}\ln\Gamma(a)$

Mellin representation of the LO impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^2} I_{LO}^{\mu\nu}(z_1,z_2)\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^\gamma = \frac{1}{\pi^4} B(1-\gamma)\Gamma(\gamma+2)\Gamma(3-\gamma)$$
$$\times\left\{\frac{\gamma(1-\gamma)D_1^{\mu\nu}}{12(1+\gamma)(2-\gamma)} + \frac{D_2^{\mu\nu}}{2(1+\gamma)(2-\gamma)} - \frac{D_3^{\mu\nu}}{8(1+\gamma)(2-\gamma)}\right.$$
$$\left. - \frac{\gamma(1-\gamma)D_4}{16(1+2\gamma)(3-2\gamma)(1+\gamma)(2-\gamma)} - \frac{D_1^{\mu\nu}+D_2^{\mu\nu}}{8}\right\}_{\mu\nu}\left(\frac{\kappa^2}{(\kappa\cdot\zeta_0)^2}\right)^\gamma$$

where

$$(D_1+D_2)^{\mu\nu} = -2\Delta^2 x^+ y^+ \kappa^{-2}\partial_x^\mu\partial_y^\nu\kappa^2$$
$$D_2^{\mu\nu} = -\Delta^2 x^+ y^+ \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2$$
$$D_3^{\mu\nu} = 4\gamma\Delta^2 x^+ y^+\left[(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - (\partial_x^\mu\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right]$$
$$D_4^{\mu\nu} = 4\gamma(1+2\gamma)\Delta^2 x^+ y^+\left[-\frac{1}{3}\partial_x^\mu\partial_y^\nu\ln\kappa^2 - \partial_x^\mu(\ln\kappa^2)\partial_y^\nu\ln\kappa^2\right.$$
$$\left.(\partial_x^\mu\ln\kappa^2)\partial_\nu^y\ln(\kappa\cdot\zeta_0) + (\partial_y^\nu\ln\kappa^2)\partial_\mu^x\ln(\kappa\cdot\zeta_0) - 2\partial_\mu^x\ln(\kappa\cdot\zeta_0)\partial_\nu^y\ln(\kappa\cdot\zeta_0)\right]$$

$B(a,b) = \frac{\Gamma(a)\Gamma(b)}{\Gamma(a+b)}$, $C = -\psi(1)$ is the Euler constant, and $\psi'(a) = \frac{d}{da}\ln\Gamma(a)$

Mellin representation of the photon impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left[I_{LO}^{\mu\nu}(z_1,z_2)+{}_{NLO}^{\mu\nu}(z_1,z_2)\right]\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^{\gamma} = \frac{N_c}{4\pi^6\Delta^4}\frac{\Gamma(\gamma+1)\Gamma(2-\gamma)}{\Delta^2 x^+ y^+}$$

$$\times\left[\frac{\bar\gamma\gamma D_1}{3}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma-\frac{1}{\gamma\bar\gamma}+\frac{1}{2}--\frac{\chi_\gamma}{\gamma\bar\gamma}\right]\right\}\right.$$

$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

$\bar\gamma \equiv 1-\gamma$

Mellin representation of the photon impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left[I^{\mu\nu}_{LO}(z_1,z_2)+{}^{\mu\nu}_{NLO}(z_1,z_2)\right]\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^{\gamma} = \frac{N_c}{4\pi^6\Delta^4}\frac{\Gamma(\gamma+1)\Gamma(2-\gamma)}{\Delta^2 x^+ y^+}$$

$$\times\left[\frac{\bar\gamma\gamma D_1}{3}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma-\frac{1}{\gamma\bar\gamma}+\frac{1}{2}--\frac{\chi_\gamma}{\gamma\bar\gamma}\right]\right\}\right.$$

$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

$\bar\gamma \equiv 1-\gamma$

Mellin representation of the photon impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left[I^{\mu\nu}_{LO}(z_1,z_2)+I^{\mu\nu}_{NLO}(z_1,z_2)\right]\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^{\gamma} = \frac{N_c}{4\pi^6\Delta^4}\frac{\Gamma(\gamma+1)\Gamma(2-\gamma)}{\Delta^2 x^+ y^+}$$

$$\times\left[\frac{\bar\gamma\gamma D_1}{3}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma-\frac{1}{\gamma\bar\gamma}+\frac{1}{2}--\frac{\chi_\gamma}{\gamma\bar\gamma}\right]\right\}\right.$$

$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

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$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

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$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

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$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

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$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

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$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)} \qquad \bar\gamma\equiv 1-\gamma$$

Mellin representation of the photon impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left[I^{\mu\nu}_{LO}(z_1,z_2)+{}^{\mu\nu}_{NLO}(z_1,z_2)\right]\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^{\gamma} = \frac{N_c}{4\pi^6\Delta^4}\frac{\Gamma(\gamma+1)\Gamma(2-\gamma)}{\Delta^2 x^+ y^+}$$

$$\times\left[\frac{\bar\gamma\gamma D_1}{3}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma-\frac{1}{\gamma\bar\gamma}+\frac{1}{2}--\frac{\chi_\gamma}{\gamma\bar\gamma}\right]\right\}\right.$$

$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$\times\left[\frac{\bar\gamma\gamma D_1}{3}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma-\frac{1}{\gamma\bar\gamma}+\frac{1}{2}--\frac{\chi_\gamma}{\gamma\bar\gamma}\right]\right\}\right.$$

$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\right]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$\times\left[\frac{\bar\gamma\gamma D_1}{3}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma-\frac{1}{\gamma\bar\gamma}+\frac{1}{2}--\frac{\chi_\gamma}{\gamma\bar\gamma}\right]\right\}\right.$$

$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\right]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$\times\left[\frac{\bar\gamma\gamma D_1}{3}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma-\frac{1}{\gamma\bar\gamma}+\frac{1}{2}--\frac{\chi_\gamma}{\gamma\bar\gamma}\right]\right\}\right.$$

$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$\times\left[\frac{\bar\gamma\gamma D_1}{3}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma-\frac{1}{\gamma\bar\gamma}+\frac{1}{2}--\frac{\chi_\gamma}{\gamma\bar\gamma}\right]\right\}\right.$$

$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$\times\left[\frac{\bar\gamma\gamma D_1}{3}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma-\frac{1}{\gamma\bar\gamma}+\frac{1}{2}--\frac{\chi_\gamma}{\gamma\bar\gamma}\right]\right\}\right.$$

$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$\times\left[\frac{\bar\gamma\gamma D_1}{3}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma-\frac{1}{\gamma\bar\gamma}+\frac{1}{2}--\frac{\chi_\gamma}{\gamma\bar\gamma}\right]\right\}\right.$$

$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

$\bar\gamma \equiv 1-\gamma$

Mellin representation of the photon impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left[I_{LO}^{\mu\nu}(z_1,z_2)+{}^{\mu\nu}_{NLO}(z_1,z_2)\right]\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^{\gamma} = \frac{N_c}{4\pi^6\Delta^4}\frac{\Gamma(\gamma+1)\Gamma(2-\gamma)}{\Delta^2 x^+ y^+}$$

$$\times\left[\frac{\bar\gamma\gamma D_1}{3}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma-\frac{1}{\gamma\bar\gamma}+\frac{1}{2}--\frac{\chi_\gamma}{\gamma\bar\gamma}\right]\right\}\right.$$

$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

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$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

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$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

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$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

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$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

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$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

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$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

$\bar\gamma \equiv 1-\gamma$

Mellin representation of the photon impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left[I_{LO}^{\mu\nu}(z_1,z_2)+{}_{NLO}^{\mu\nu}(z_1,z_2)\right]\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^{\gamma} = \frac{N_c}{4\pi^6\Delta^4}\frac{\Gamma(\gamma+1)\Gamma(2-\gamma)}{\Delta^2 x^+ y^+}$$

$$\times\left[\frac{\bar\gamma\gamma D_1}{3}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma-\frac{1}{\gamma\bar\gamma}+\frac{1}{2}--\frac{\chi_\gamma}{\gamma\bar\gamma}\right]\right\}\right.$$

$$+2D_2\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}C\chi_\gamma-\frac{3}{4\gamma\bar\gamma}+\frac{1}{2}\chi_\gamma+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_3}{2}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{1}{\gamma\bar\gamma}+\frac{\chi_\gamma}{4}+\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$+\frac{\bar\gamma\gamma D_4}{4(3+4\bar\gamma\gamma)}\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}-\frac{4}{\gamma\bar\gamma}+\frac{3}{2\gamma^2\bar\gamma^2}-\frac{\chi_\gamma}{2\gamma\bar\gamma}\right]\right\}$$

$$-\frac{D_1+D_2}{2}(2+\bar\gamma\gamma)\left\{1+\frac{\alpha_s N_c}{4\pi}\left[\frac{\pi^2}{3}-\frac{\pi^2}{\sin^2\pi\gamma}-C\chi_\gamma+\frac{1}{2}\right.\right.$$

$$\left.\left.-\frac{4\gamma\bar\gamma+3}{2\gamma\bar\gamma(2+\bar\gamma\gamma)}+\frac{1+2\gamma\bar\gamma}{\gamma\bar\gamma(2+\bar\gamma\gamma)}\chi_\gamma\right]\right\}\Bigg]^{\mu\nu}\left(\frac{\kappa^2}{(2\kappa\cdot\zeta_0)^2}\right)^{\gamma}\frac{\Gamma^2(\bar\gamma)}{\Gamma(2\bar\gamma)}$$

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$\bar\gamma \equiv 1-\gamma$

Mellin representation of the impact factor for polarized DIS

Contribution of spin 2 in t-channel:

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^4}\left(I^{\mu\nu}_{LO}(z_1,z_2)+I^{\mu\nu}_{NLO}(z_1,z_2)\right)\left(\frac{z_{12}}{z_{10}z_{20}}\right)^{\gamma+1}\left(\frac{\bar{z}_{12}}{\bar{z}_{10}\bar{z}_{20}}\right)^{\gamma+1} = B(2-\gamma)\Gamma(3-\gamma)\Gamma(2+\gamma)$$

$$\times\left[1+\frac{\alpha_s N_c}{4\pi}\left\{4\psi'(1+\gamma)+4\psi'(2-\gamma)-8\psi'(3)-\frac{6\chi(2,\gamma)}{(1+\gamma)(2-\gamma)}+6+4C\chi(2,\gamma)\right.\right.$$

$$\left.\left.-\frac{6C}{(2-\gamma)(1+\gamma)}-\frac{6}{(1+\gamma)(2-\gamma)}\right\}\right]\left(\frac{\kappa^2}{(\kappa\cdot\zeta_0)^2}\right)^{\gamma}\left(\partial^x_\mu\frac{X^2\bar{Y}-Y^2\bar{X}}{x_+y_+(\kappa\cdot\zeta_0)}\right)\left(\partial^y_\nu\frac{X^2\bar{Y}-Y^2\bar{X}}{x_+y_+(\kappa\cdot\zeta_0)}\right)$$

$$\chi(2,\gamma)=2\psi(1)-\psi(2-\gamma)-\psi(1+\gamma) \qquad X\equiv x-z_0,\ Y\equiv y-z_0$$

Fourier transformation for the "forward case" (DIS) is straightforward.

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I. B. and G. Chirilli

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$$\times\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left[1+\frac{\alpha_s N_c}{4\pi}\left(b\ln z_{12}^2\mu^2 + b\frac{z_{13}^2-z_{23}^2}{z_{13}^2 z_{23}^2}\ln\frac{z_{13}^2}{z_{23}^2}+\frac{67}{9}-\frac{\pi^2}{3}\right)\right]$$

$$+\frac{\alpha_s}{4\pi^2}\int\frac{d^2z_4}{z_{34}^4}\left\{\left[-2+\frac{z_{23}^2 z_{23}^2+z_{24}^2 z_{13}^2-4z_{12}^2 z_{34}^2}{2(z_{23}^2 z_{23}^2 - z_{24}^2 z_{13}^2)}\ln\frac{z_{23}^2 z_{23}^2}{z_{24}^2 z_{13}^2}\right]\right.$$

$$\times[\mathrm{tr}\{U_{z_1}U^\dagger_{z_3}\}\mathrm{tr}\{U_{z_3}U^\dagger_{z_4}\}\{U_{z_4}U^\dagger_{z_2}\} - \mathrm{tr}\{U_{z_1}U^\dagger_{z_3}U_{z_4}U^\dagger_{z_2}U_{z_3}U^\dagger_{z_4}\} - (z_4\to z_3)]$$

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$$\times\frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left[1+\frac{\alpha_s N_c}{4\pi}\left(b\ln z_{12}^2\mu^2 + b\frac{z_{13}^2-z_{23}^2}{z_{13}^2 z_{23}^2}\ln\frac{z_{13}^2}{z_{23}^2}+\frac{67}{9}-\frac{\pi^2}{3}\right)\right]$$

$$+\frac{\alpha_s}{4\pi^2}\int\frac{d^2z_4}{z_{34}^4}\left\{\left[-2+\frac{z_{23}^2 z_{23}^2 + z_{24}^2 z_{13}^2 - 4z_{12}^2 z_{34}^2}{2(z_{23}^2 z_{23}^2 - z_{24}^2 z_{13}^2)}\ln\frac{z_{23}^2 z_{23}^2}{z_{24}^2 z_{13}^2}\right]\right.$$

$$\times[\mathrm{tr}\{U_{z_1}U^\dagger_{z_3}\}\mathrm{tr}\{U_{z_3}U^\dagger_{z_4}\}\{U_{z_4}U^\dagger_{z_2}\} - \mathrm{tr}\{U_{z_1}U^\dagger_{z_3}U_{z_4}U^\dagger_{z_2}U_{z_3}U^\dagger_{z_4}\} - (z_4\to z_3)]$$

$$+\frac{z_{12}^2 z_{34}^2}{z_{13}^2 z_{24}^2}\left[2\ln\frac{z_{12}^2 z_{34}^2}{z_{23}^2 z_{23}^2}+\left(1+\frac{z_{12}^2 z_{34}^2}{z_{13}^2 z_{24}^2 - z_{23}^2 z_{23}^2}\right)\ln\frac{z_{13}^2 z_{24}^2}{z_{23}^2 z_{23}^2}\right]$$

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$K_{\mathrm{NLO\ BK}}$ = Running coupling part + Conformal "non-analytic" (in j) part
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$$+\frac{\alpha_s}{4\pi^2}\int\frac{d^2z_4}{z_{34}^4}\left\{\left[-2+\frac{z_{23}^2 z_{23}^2 + z_{24}^2 z_{13}^2 - 4z_{12}^2 z_{34}^2}{2(z_{23}^2 z_{23}^2 - z_{24}^2 z_{13}^2)}\ln\frac{z_{23}^2 z_{23}^2}{z_{24}^2 z_{13}^2}\right]\right.$$

$$\times[\mathrm{tr}\{U_{z_1}U^\dagger_{z_3}\}\mathrm{tr}\{U_{z_3}U^\dagger_{z_4}\}\{U_{z_4}U^\dagger_{z_2}\} - \mathrm{tr}\{U_{z_1}U^\dagger_{z_3}U_{z_4}U^\dagger_{z_2}U_{z_3}U^\dagger_{z_4}\} - (z_4\to z_3)]$$

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Argument of coupling constant

$$\frac{d}{d\eta}\hat{U}(z_1,z_2) =$$

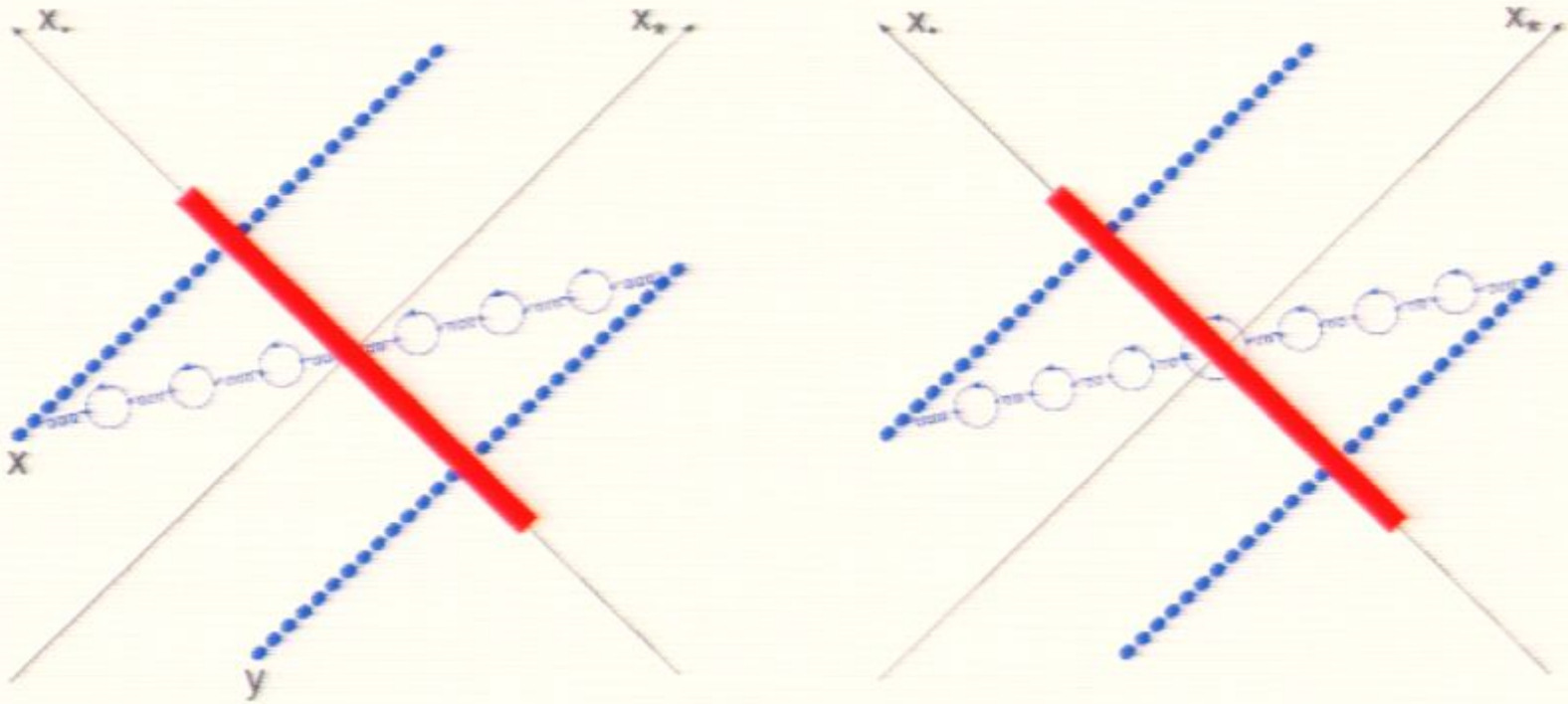
$$\frac{\alpha_s(?_\perp)N_c}{2\pi^2}\int dz_3 \frac{z_{12}^2}{z_{13}^2 z_{23}^2}\left\{\hat{U}(z_1,z_3)+\hat{U}(z_3,z_2)-\hat{U}(z_1,z_2)-\hat{U}(z_1,z_3)\hat{U}(z_3,z_2)\right\}$$

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Renormalon-based approach: summation of quark bubbles



$$-\frac{2}{3}n_f \to b = \frac{11}{3}N_c - \frac{2}{3}n_f$$

Argument of coupling constant

$$\frac{d}{d\eta}\mathrm{Tr}\{\hat{U}_{z_1}\hat{U}^\dagger_{z_2}\} = \frac{\alpha_s(z^2_{12})}{2\pi^2}\int d^2z\,[\mathrm{Tr}\{\hat{U}_{z_1}\hat{U}^\dagger_{z_3}\}\mathrm{Tr}\{\hat{U}_{z_3}\hat{U}^\dagger_{z_2}\} - N_c\mathrm{Tr}\{\hat{U}_{z_1}\hat{U}^\dagger_{z_2}\}]$$

$$\times\left[\frac{z^2_{12}}{z^2_{13}z^2_{23}} + \frac{1}{z^2_{13}}\left(\frac{\alpha_s(z^2_{13})}{\alpha_s(z^2_{23})} - 1\right) + \frac{1}{z^2_{23}}\left(\frac{\alpha_s(z^2_{23})}{\alpha_s(z^2_{13})} - 1\right)\right] + \ldots$$

I.B.; Yu. Kovchegov and H. Weigert (2006)

When the sizes of the dipoles are very different the kernel reduces to:

$$\frac{\alpha_s(z^2_{12})}{2\pi^2}\frac{z^2_{12}}{z^2_{13}z^2_{23}} \qquad |z_{12}| \ll |z_{13}|, |z_{23}|$$

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$$\frac{\alpha_s(z^2_{23})}{2\pi^2 z^2_{23}} \qquad |z_{23}| \ll |z_{12}|, |z_{13}|$$

$\Rightarrow$ the argument of the coupling constant is given by the size of the smallest dipole.

Argument of coupling constant

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$$\frac{\alpha_s(z^2_{13})}{2\pi^2 z^2_{13}} \qquad |z_{13}| \ll |z_{12}|, |z_{23}|$$

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$$\times\left[\frac{z^2_{12}}{z^2_{13}z^2_{23}} + \frac{1}{z^2_{13}}\left(\frac{\alpha_s(z^2_{13})}{\alpha_s(z^2_{23})} - 1\right) + \frac{1}{z^2_{23}}\left(\frac{\alpha_s(z^2_{23})}{\alpha_s(z^2_{13})} - 1\right)\right] + \ldots$$

I.B.; Yu. Kovchegov and H. Weigert (2006)

When the sizes of the dipoles are very different the kernel reduces to:

$$\frac{\alpha_s(z^2_{12})}{2\pi^2}\frac{z^2_{12}}{z^2_{13}z^2_{23}} \qquad |z_{12}| \ll |z_{13}|, |z_{23}|$$

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$\Rightarrow$ the argument of the coupling constant is given by the size of the smallest dipole.

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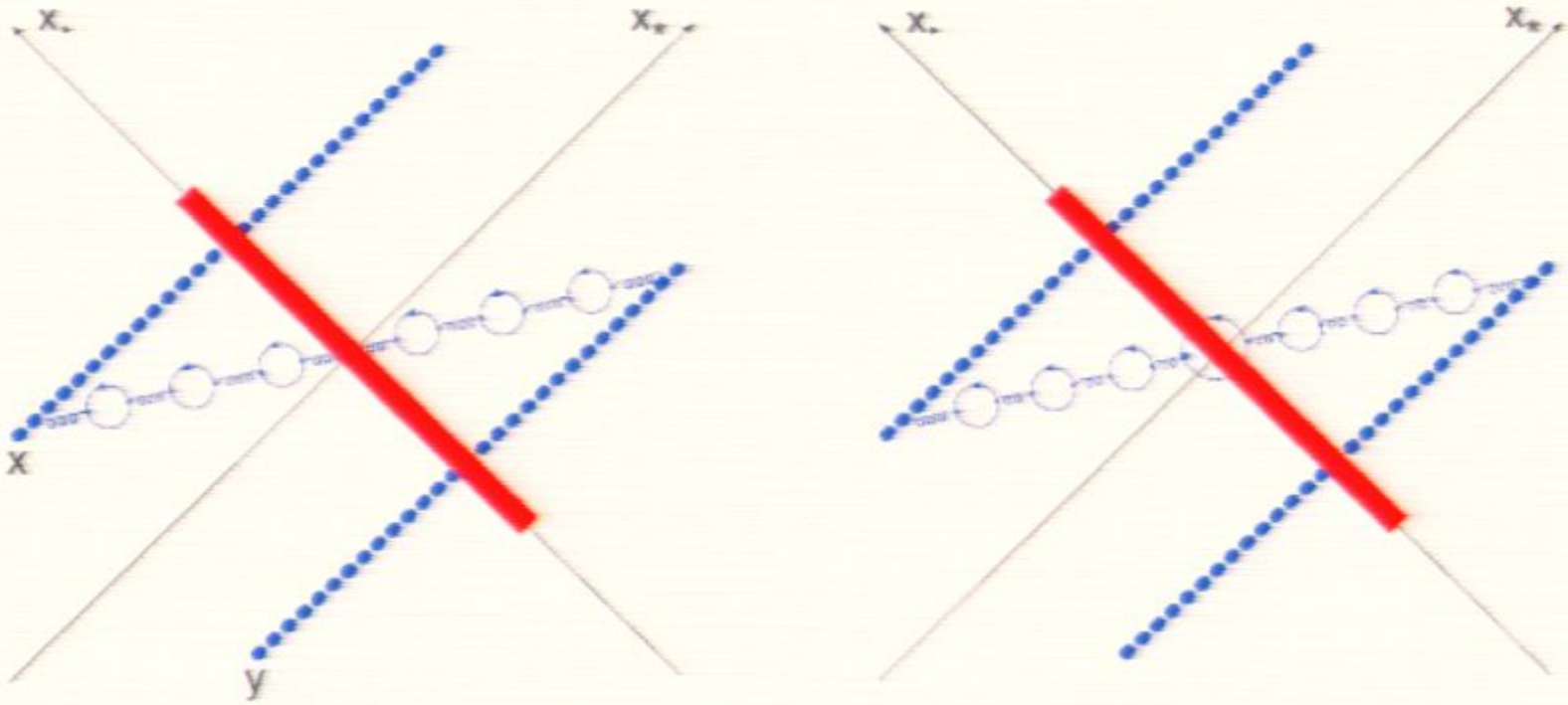
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Renormalon-based approach: summation of quark bubbles



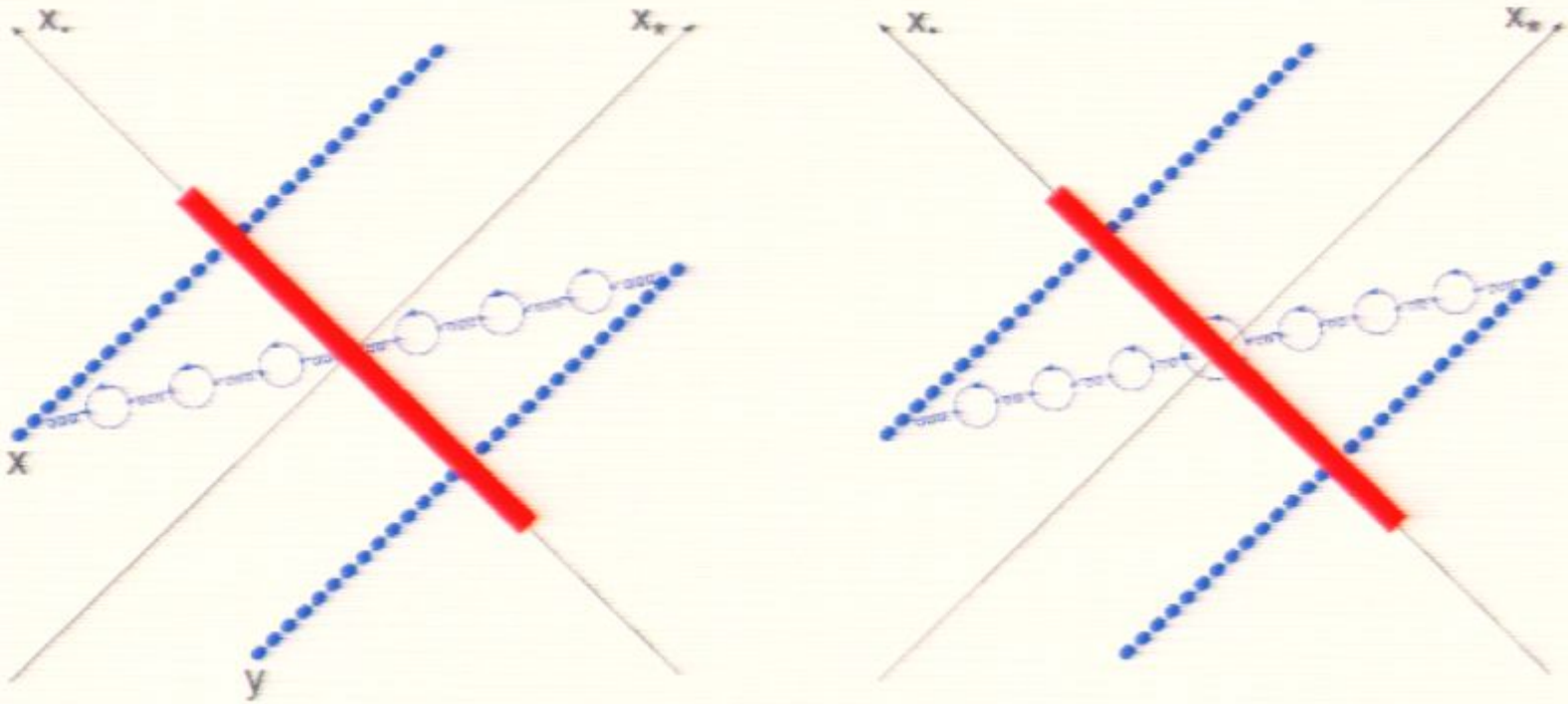
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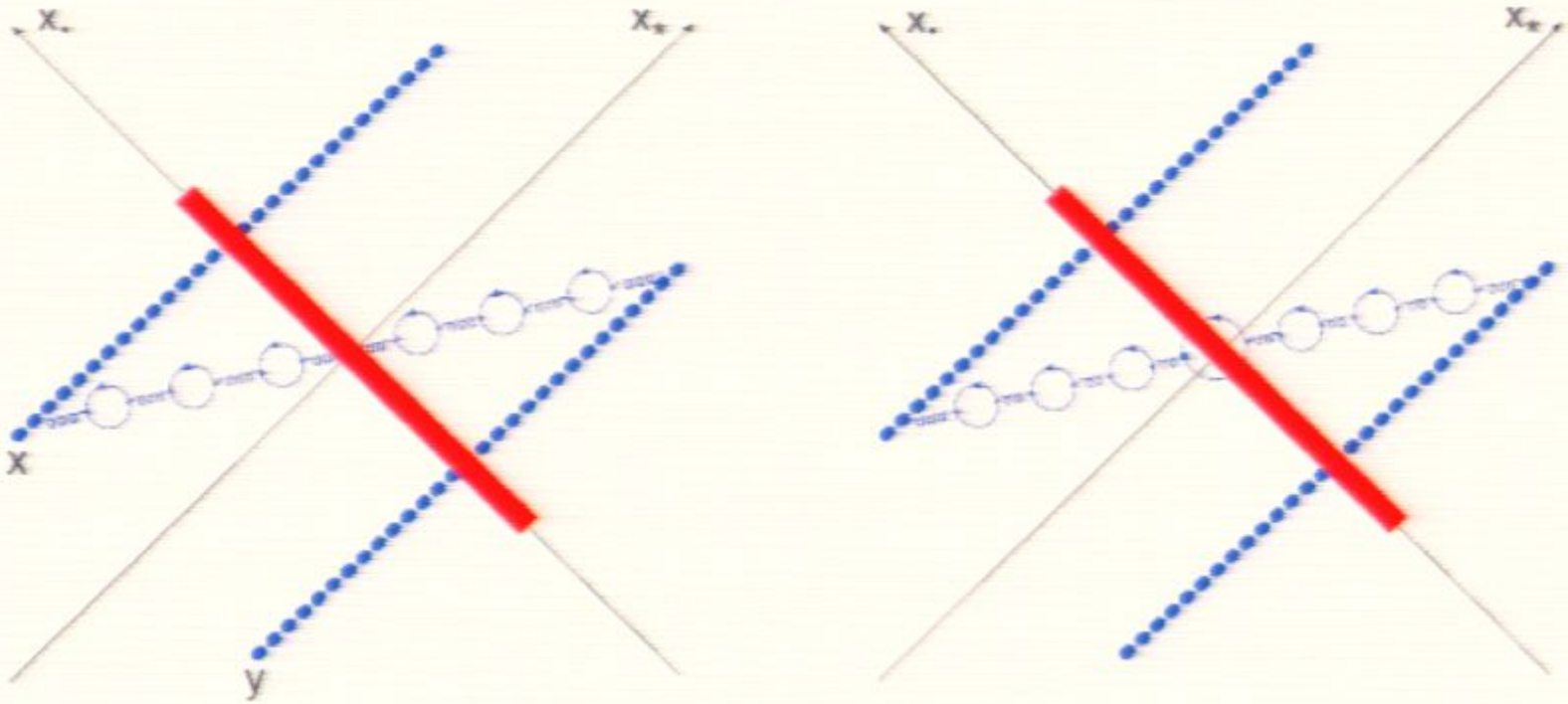
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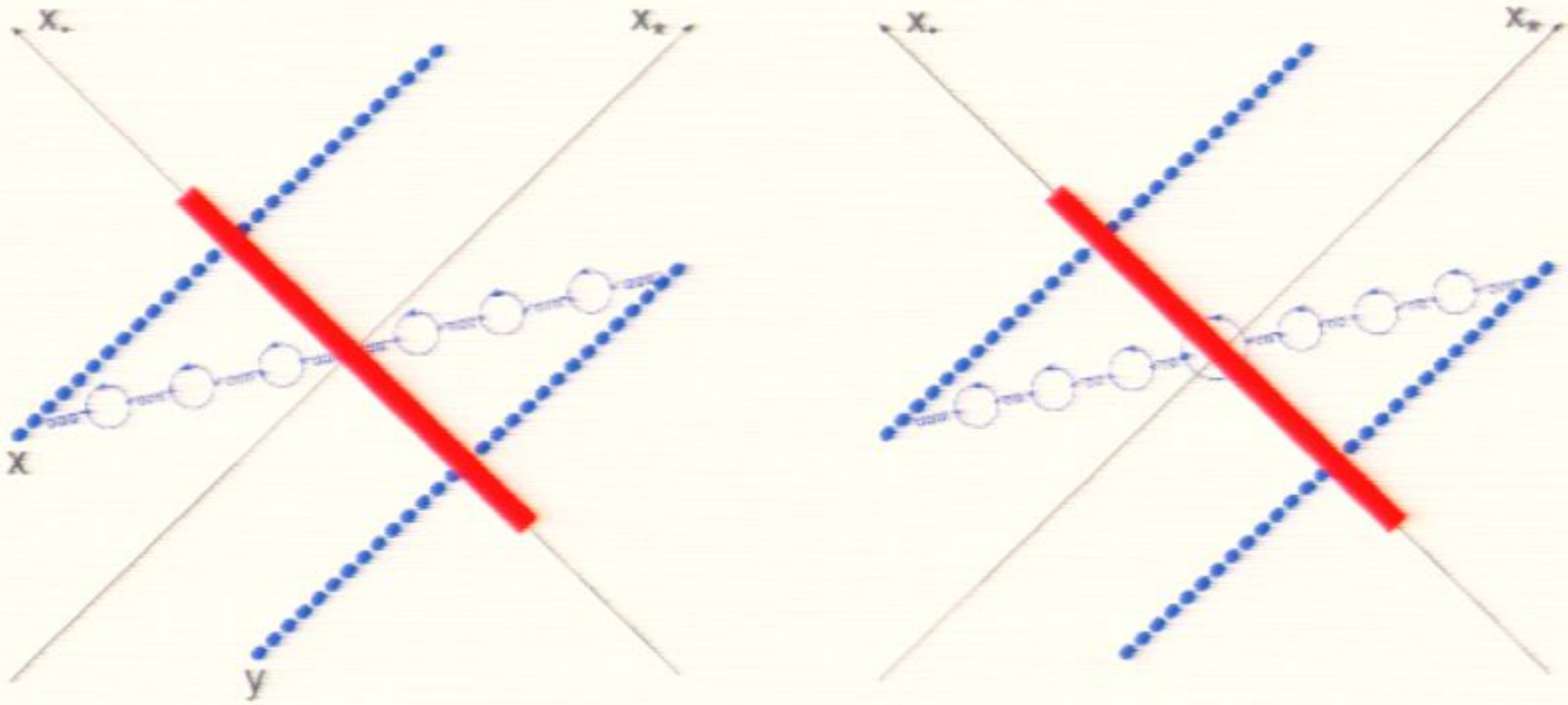
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Outlook: relation to conformal light-ray operators

Gluon parton density $D(x_B, \mu^2)$ is proportional to matrix element of the light-ray operator

$$\mathcal{O}(x_B, \mu^2) = \int d\lambda \, e^{i\lambda x_B} \, \mathrm{Tr}\{G_{+i}(\lambda e^+)[\lambda e^+, 0] G_{+i}(0)[0, \lambda e^+]\}^\mu$$

Conformal light-ray operator $\mathcal{O}_j$ (j - conformal spin in $SL(2,R)$ group)

$$\mathcal{O}_j^\mu = \int d\lambda \, \lambda^{1-j} \, \mathrm{Tr}\{G_{+i}(\lambda e^+)[\lambda e^+, 0] G_{+i}(0)[0, \lambda e^+]\}^\mu$$

Anomalous dimension

$$\mu \frac{d}{d\mu} \mathcal{O}_j = \gamma_j(\alpha_s) O_j$$

At $j = n$ γ_n is an anomalous dimension of the local twist-2 operator

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In the leading order relation this expansion is trivial: $x_\perp^2$ is the normalization point of gluon light-ray operator and $x_B = e^{-\eta}$:

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Outlook: relation to conformal light-ray operators

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Conclusions

- High-energy operator expansion in color dipoles works at the NLO level.

Argument of coupling constant

$$\frac{d}{d\eta}\mathrm{Tr}\{\hat{U}_{z_1}\hat{U}^\dagger_{z_2}\} = \frac{\alpha_s(z^2_{12})}{2\pi^2}\int d^2z\,[\mathrm{Tr}\{\hat{U}_{z_1}\hat{U}^\dagger_{z_3}\}\mathrm{Tr}\{\hat{U}_{z_3}\hat{U}^\dagger_{z_2}\} - N_c\mathrm{Tr}\{\hat{U}_{z_1}\hat{U}^\dagger_{z_2}\}]$$

$$\times\left[\frac{z^2_{12}}{z^2_{13}z^2_{23}} + \frac{1}{z^2_{13}}\left(\frac{\alpha_s(z^2_{13})}{\alpha_s(z^2_{23})} - 1\right) + \frac{1}{z^2_{23}}\left(\frac{\alpha_s(z^2_{23})}{\alpha_s(z^2_{13})} - 1\right)\right] + \ldots$$

I.B.; Yu. Kovchegov and H. Weigert (2006)

When the sizes of the dipoles are very different the kernel reduces to:

$$\frac{\alpha_s(z^2_{12})}{2\pi^2}\frac{z^2_{12}}{z^2_{13}z^2_{23}} \qquad |z_{12}| \ll |z_{13}|, |z_{23}|$$

$$\frac{\alpha_s(z^2_{13})}{2\pi^2 z^2_{13}} \qquad |z_{13}| \ll |z_{12}|, |z_{23}|$$

$$\frac{\alpha_s(z^2_{23})}{2\pi^2 z^2_{23}} \qquad |z_{23}| \ll |z_{12}|, |z_{13}|$$

$\Rightarrow$ the argument of the coupling constant is given by the size of the smallest dipole.

Mellin representation of the LO impact factor

$$\int \frac{d^2z_1 d^2z_2}{z_{12}^2} I_{LO}^{\mu\nu}(z_1,z_2)\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^\gamma = \frac{1}{\pi^4} B(1-\gamma,1-\gamma)\Gamma(\gamma+2)\Gamma(3-\gamma)$$

$$\times\left\{\frac{\gamma(1-\gamma)D_1}{12(1+\gamma)(2-\gamma)} + \frac{D_2}{2(1+\gamma)(2-\gamma)} - \frac{D_3^{\mu\nu}}{8(1+\gamma)(2-\gamma)}\right.$$

$$\left. - \frac{\gamma(1-\gamma)D_4^{\mu\nu}}{16(1+2\gamma)(3-2\gamma)(1+\gamma)(2-\gamma)} - \frac{D_1^{\mu\nu}+D_2^{\mu\nu}}{8}\right\}_{\mu\nu}\left(\frac{\kappa^2}{(\kappa\cdot\zeta_0)^2}\right)^\gamma$$

With two-gluon (NLO BFKL) accuracy

$$\frac{1}{N_c}(x-y)^4 T\{\bar{\psi}(x)\gamma^\mu\hat{\psi}(x)\bar{\psi}(y)\gamma^\nu\hat{\psi}(y)\} = \frac{\partial\kappa^\alpha}{\partial x^\mu}\frac{\partial\kappa^\beta}{\partial y^\nu}\int\frac{dz_1 dz_2}{z_{12}^4}\hat{\mathcal{U}}_{a_0}(z_1,z_2)\left[\mathcal{I}^{\rm LO}_{\alpha\beta}\left(1+\frac{\alpha_s}{\pi}\right)+\mathcal{I}^{\rm NLO}_{\alpha\beta}\right]$$

$$\mathcal{I}^{\alpha\beta}_{\rm LO}(x,y;z_1,z_2) = \mathcal{R}^2\frac{g^{\alpha\beta}(\zeta_1\cdot\zeta_2)-\zeta_1^\alpha\zeta_2^\beta-\zeta_2^\alpha\zeta_1^\beta}{\pi^6(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}$$

$$\begin{aligned}\mathcal{I}^{\alpha\beta}_{\rm NLO}(x,y;z_1,z_2) = \frac{\alpha_s N_c}{4\pi^7}\mathcal{R}^2\Bigg\{&\frac{\zeta_1^\alpha\zeta_2^\beta+\zeta_1\leftrightarrow\zeta_2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[4{\rm Li}_2(1-\mathcal{R})-\frac{2\pi^2}{3}+\frac{2\ln\mathcal{R}}{1-\mathcal{R}}+\frac{\ln\mathcal{R}}{\mathcal{R}}\\&-4\ln\mathcal{R}+\frac{1}{2\mathcal{R}}-2+2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}-2\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)-4C-\frac{2C}{\mathcal{R}}\Big]\\&+\Big(\frac{\zeta_1^\alpha\zeta_1^\beta}{(\kappa\cdot\zeta_1)^2}+\zeta_1\leftrightarrow\zeta_2\Big)\Big[\frac{\ln\mathcal{R}}{\mathcal{R}}-\frac{2C}{\mathcal{R}}+2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{1}{2\mathcal{R}}\Big]-\frac{2}{\kappa^2}\Big(g^{\alpha\beta}-2\frac{\kappa^\alpha\kappa^\beta}{\kappa^2}\Big)\\&+\Big[\frac{\zeta_1^\alpha\kappa^\beta+\zeta_1^\beta\kappa^\alpha}{(\kappa\cdot\zeta_1)\kappa^2}+\zeta_1\leftrightarrow\zeta_2\Big]\Big[-2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{\ln\mathcal{R}}{\mathcal{R}}+\ln\mathcal{R}-\frac{3}{2\mathcal{R}}+\frac{5}{2}+2C+\frac{2C}{\mathcal{R}}\Big]\\&+\frac{g^{\alpha\beta}(\zeta_1\cdot\zeta_2)}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[\frac{2\pi^2}{3}-4{\rm Li}_2(1-\mathcal{R})\\&-2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}+\frac{1}{2\mathcal{R}^2}-3\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)+6\ln\mathcal{R}-\frac{2}{\mathcal{R}}+2+\frac{3}{2\mathcal{R}^2}\Big]\Bigg\}\end{aligned}$$

5 tensor structures (CCP, 2009)

Photon Impact Factor at NLO — I. B. and G. A. C.

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& -2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}+\frac{1}{2\mathcal{R}^2}-3\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)+6\ln\mathcal{R}-\frac{2}{\mathcal{R}}+2+\frac{3}{2\mathcal{R}^2}\Big]\Bigg\}
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5 tensor structures (CCP, 2009)

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$$\frac{1}{N_c}(x-y)^4\mathcal{T}\{\bar{\psi}(x)\gamma^\mu\hat{\psi}(x)\bar{\psi}(y)\gamma^\nu\hat{\psi}(y)\} = \frac{\partial\kappa^\alpha}{\partial x^\mu}\frac{\partial\kappa^\beta}{\partial y^\nu}\int\frac{dz_1dz_2}{z_{12}^4}\hat{\mathcal{U}}_{a_0}(z_1,z_2)\left[\mathcal{I}^{\rm LO}_{\alpha\beta}\left(1+\frac{\alpha_s}{\pi}\right)+\mathcal{I}^{\rm NLO}_{\alpha\beta}\right]$$

$$\mathcal{I}^{\alpha\beta}_{\rm LO}(x,y;z_1,z_2) = \mathcal{R}^2\frac{g^{\alpha\beta}(\zeta_1\cdot\zeta_2)-\zeta_1^\alpha\zeta_2^\beta-\zeta_2^\alpha\zeta_1^\beta}{\pi^6(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}$$

$$\begin{aligned}\mathcal{I}^{\alpha\beta}_{\rm NLO}(x,y;z_1,z_2) = \frac{\alpha_s N_c}{4\pi^7}\mathcal{R}^2\Bigg\{&\frac{\zeta_1^\alpha\zeta_2^\beta+\zeta_1\leftrightarrow\zeta_2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[4{\rm Li}_2(1-\mathcal{R})-\frac{2\pi^2}{3}+\frac{2\ln\mathcal{R}}{1-\mathcal{R}}+\frac{\ln\mathcal{R}}{\mathcal{R}}\\&-4\ln\mathcal{R}+\frac{1}{2\mathcal{R}}-2+2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}-2\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)-4C-\frac{2C}{\mathcal{R}}\Big]\\&+\Big(\frac{\zeta_1^\alpha\zeta_1^\beta}{(\kappa\cdot\zeta_1)^2}+\zeta_1\leftrightarrow\zeta_2\Big)\Big[\frac{\ln\mathcal{R}}{\mathcal{R}}-\frac{2C}{\mathcal{R}}+2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{1}{2\mathcal{R}}\Big]-\frac{2}{\kappa^2}\Big(g^{\alpha\beta}-2\frac{\kappa^\alpha\kappa^\beta}{\kappa^2}\Big)\\&+\Big[\frac{\zeta_1^\alpha\kappa^\beta+\zeta_1^\beta\kappa^\alpha}{(\kappa\cdot\zeta_1)\kappa^2}+\zeta_1\leftrightarrow\zeta_2\Big]\Big[-2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{\ln\mathcal{R}}{\mathcal{R}}+\ln\mathcal{R}-\frac{3}{2\mathcal{R}}+\frac{5}{2}+2C+\frac{2C}{\mathcal{R}}\Big]\\&+\frac{g^{\alpha\beta}(\zeta_1\cdot\zeta_2)}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[\frac{2\pi^2}{3}-4{\rm Li}_2(1-\mathcal{R})\\&-2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}+\frac{1}{2\mathcal{R}^2}-3\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)+6\ln\mathcal{R}-\frac{2}{\mathcal{R}}+2+\frac{3}{2\mathcal{R}^2}\Big]\Bigg\}\end{aligned}$$

5 tensor structures (CCP, 2009)

Photon Impact Factor at NLO — I. B. and G. A. C.

With two-gluon (NLO BFKL) accuracy

$$\frac{1}{N_c}(x-y)^4 T\{\bar{\psi}(x)\gamma^\mu\hat{\psi}(x)\bar{\psi}(y)\gamma^\nu\hat{\psi}(y)\} = \frac{\partial\kappa^\alpha}{\partial x^\mu}\frac{\partial\kappa^\beta}{\partial y^\nu}\int\frac{dz_1 dz_2}{z_{12}^4}\hat{\mathcal{U}}_{a_0}(z_1,z_2)\left[\mathcal{I}^{\rm LO}_{\alpha\beta}\left(1+\frac{\alpha_s}{\pi}\right)+\mathcal{I}^{\rm NLO}_{\alpha\beta}\right]$$

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$$\begin{aligned}
\mathcal{I}^{\alpha\beta}_{\rm NLO}(x,y;z_1,z_2) = \frac{\alpha_s N_c}{4\pi^7}\mathcal{R}^2\Bigg\{ & \frac{\zeta_1^\alpha\zeta_2^\beta+\zeta_1\leftrightarrow\zeta_2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[4{\rm Li}_2(1-\mathcal{R})-\frac{2\pi^2}{3}+\frac{2\ln\mathcal{R}}{1-\mathcal{R}}+\frac{\ln\mathcal{R}}{\mathcal{R}} \\
& -4\ln\mathcal{R}+\frac{1}{2\mathcal{R}}-2+2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}-2\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)-4C-\frac{2C}{\mathcal{R}}\Big] \\
& +\Big(\frac{\zeta_1^\alpha\zeta_1^\beta}{(\kappa\cdot\zeta_1)^2}+\zeta_1\leftrightarrow\zeta_2\Big)\Big[\frac{\ln\mathcal{R}}{\mathcal{R}}-\frac{2C}{\mathcal{R}}+2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{1}{2\mathcal{R}}\Big]-\frac{2}{\kappa^2}\Big(g^{\alpha\beta}-2\frac{\kappa^\alpha\kappa^\beta}{\kappa^2}\Big) \\
& +\Big[\frac{\zeta_1^\alpha\kappa^\beta+\zeta_1^\beta\kappa^\alpha}{(\kappa\cdot\zeta_1)\kappa^2}+\zeta_1\leftrightarrow\zeta_2\Big]\Big[-2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{\ln\mathcal{R}}{\mathcal{R}}+\ln\mathcal{R}-\frac{3}{2\mathcal{R}}+\frac{5}{2}+2C+\frac{2C}{\mathcal{R}}\Big] \\
& +\frac{g^{\alpha\beta}(\zeta_1\cdot\zeta_2)}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[\frac{2\pi^2}{3}-4{\rm Li}_2(1-\mathcal{R}) \\
& -2\Big(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}+\frac{1}{2\mathcal{R}^2}-3\Big)\Big(\ln\frac{1}{\mathcal{R}}+2C\Big)+6\ln\mathcal{R}-\frac{2}{\mathcal{R}}+2+\frac{3}{2\mathcal{R}^2}\Big]\Bigg\}
\end{aligned}$$

5 tensor structures (CCP, 2009)

With two-gluon (NLO BFKL) accuracy

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$$\begin{aligned}\mathcal{I}^{\alpha\beta}_{\rm NLO}(x,y;z_1,z_2) = \frac{\alpha_s N_c}{4\pi^7}\mathcal{R}^2\Bigg\{&\frac{\zeta_1^\alpha\zeta_2^\beta+\zeta_1\leftrightarrow\zeta_2}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[4{\rm Li}_2(1-\mathcal{R})-\frac{2\pi^2}{3}+\frac{2\ln\mathcal{R}}{1-\mathcal{R}}+\frac{\ln\mathcal{R}}{\mathcal{R}}\\&-4\ln\mathcal{R}+\frac{1}{2\mathcal{R}}-2+2\left(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}-2\right)\left(\ln\frac{1}{\mathcal{R}}+2C\right)-4C-\frac{2C}{\mathcal{R}}\Big]\\&+\left(\frac{\zeta_1^\alpha\zeta_1^\beta}{(\kappa\cdot\zeta_1)^2}+\zeta_1\leftrightarrow\zeta_2\right)\left[\frac{\ln\mathcal{R}}{\mathcal{R}}-\frac{2C}{\mathcal{R}}+2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{1}{2\mathcal{R}}\right]-\frac{2}{\kappa^2}\left(g^{\alpha\beta}-2\frac{\kappa^\alpha\kappa^\beta}{\kappa^2}\right)\\&+\left[\frac{\zeta_1^\alpha\kappa^\beta+\zeta_1^\beta\kappa^\alpha}{(\kappa\cdot\zeta_1)\kappa^2}+\zeta_1\leftrightarrow\zeta_2\right]\left[-2\frac{\ln\mathcal{R}}{1-\mathcal{R}}-\frac{\ln\mathcal{R}}{\mathcal{R}}+\ln\mathcal{R}-\frac{3}{2\mathcal{R}}+\frac{5}{2}+2C+\frac{2C}{\mathcal{R}}\right]\\&+\frac{g^{\alpha\beta}(\zeta_1\cdot\zeta_2)}{(\kappa\cdot\zeta_1)(\kappa\cdot\zeta_2)}\Big[\frac{2\pi^2}{3}-4{\rm Li}_2(1-\mathcal{R})\\&-2\left(\ln\frac{1}{\mathcal{R}}+\frac{1}{\mathcal{R}}+\frac{1}{2\mathcal{R}^2}-3\right)\left(\ln\frac{1}{\mathcal{R}}+2C\right)+6\ln\mathcal{R}-\frac{2}{\mathcal{R}}+2+\frac{3}{2\mathcal{R}^2}\Big]\Bigg\}\end{aligned}$$

5 tensor structures (CCP, 2009)

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5 tensor structures (CCP, 2009)

With two-gluon (NLO BFKL) accuracy

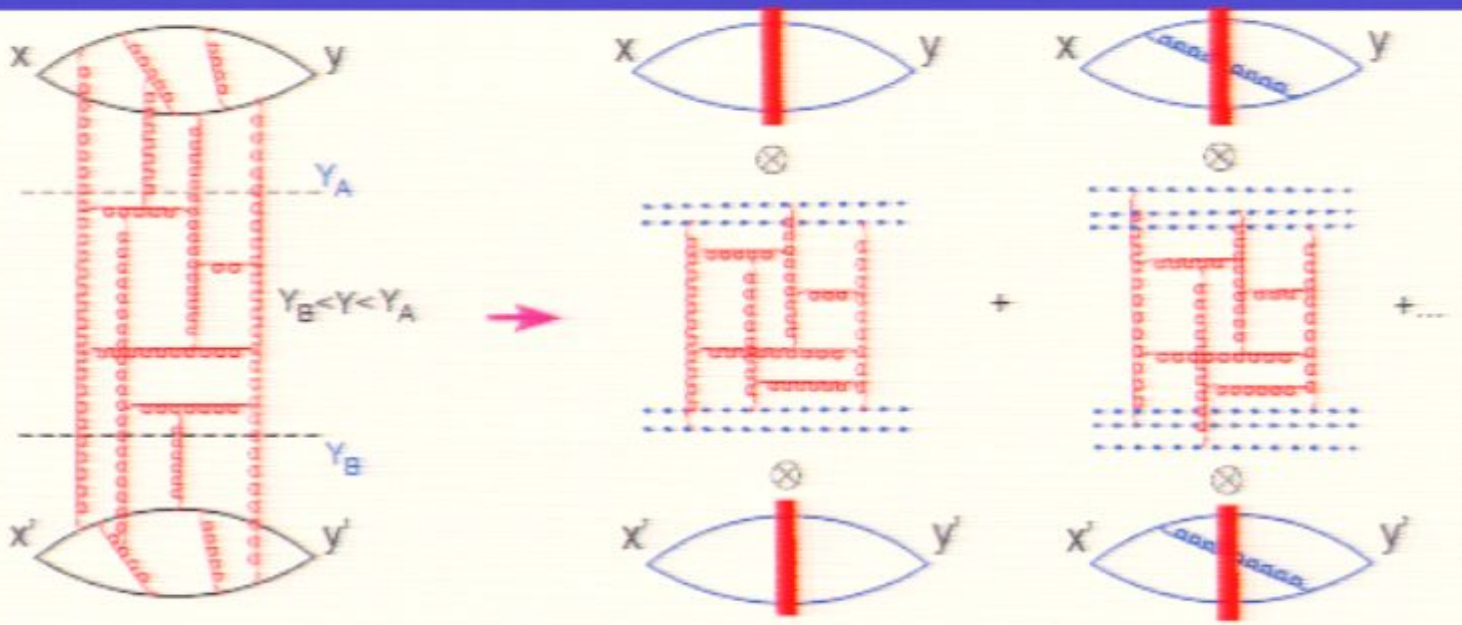
$$\frac{1}{N_c}(x-y)^4 T\{\bar{\psi}(x)\gamma^\mu\hat{\psi}(x)\bar{\psi}(y)\gamma^\nu\hat{\psi}(y)\} = \frac{\partial\kappa^\alpha}{\partial x^\mu}\frac{\partial\kappa^\beta}{\partial y^\nu}\int\frac{dz_1 dz_2}{z_{12}^4}\hat{\mathcal{U}}_{a_0}(z_1,z_2)\left[\mathcal{I}^{\rm LO}_{\alpha\beta}\left(1+\frac{\alpha_s}{\pi}\right)+\mathcal{I}^{\rm NLO}_{\alpha\beta}\right]$$

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5 tensor structures (CCP, 2009)

NLO Amplitude in $\mathcal{N}$=4 SYM theory: factorization in rapidity



$$(x-y)^4(x'-y')^4\langle T\{\hat{\mathcal{O}}(x)\hat{\mathcal{O}}^\dagger(y)\hat{\mathcal{O}}(x')\hat{\mathcal{O}}^\dagger(y')\}\rangle$$

$$= \int d^2z_{1\perp}d^2z_{2\perp}d^2z'_{1\perp}d^2z'_{2\perp}\,\mathrm{IF}^{a_0}(x,y;z_1,z_2)[\mathrm{DD}]^{a_0,b_0}(z_1,z_2;z'_1,z'_2)\mathrm{IF}^{b_0}(x',y';z'_1,z'_2)$$

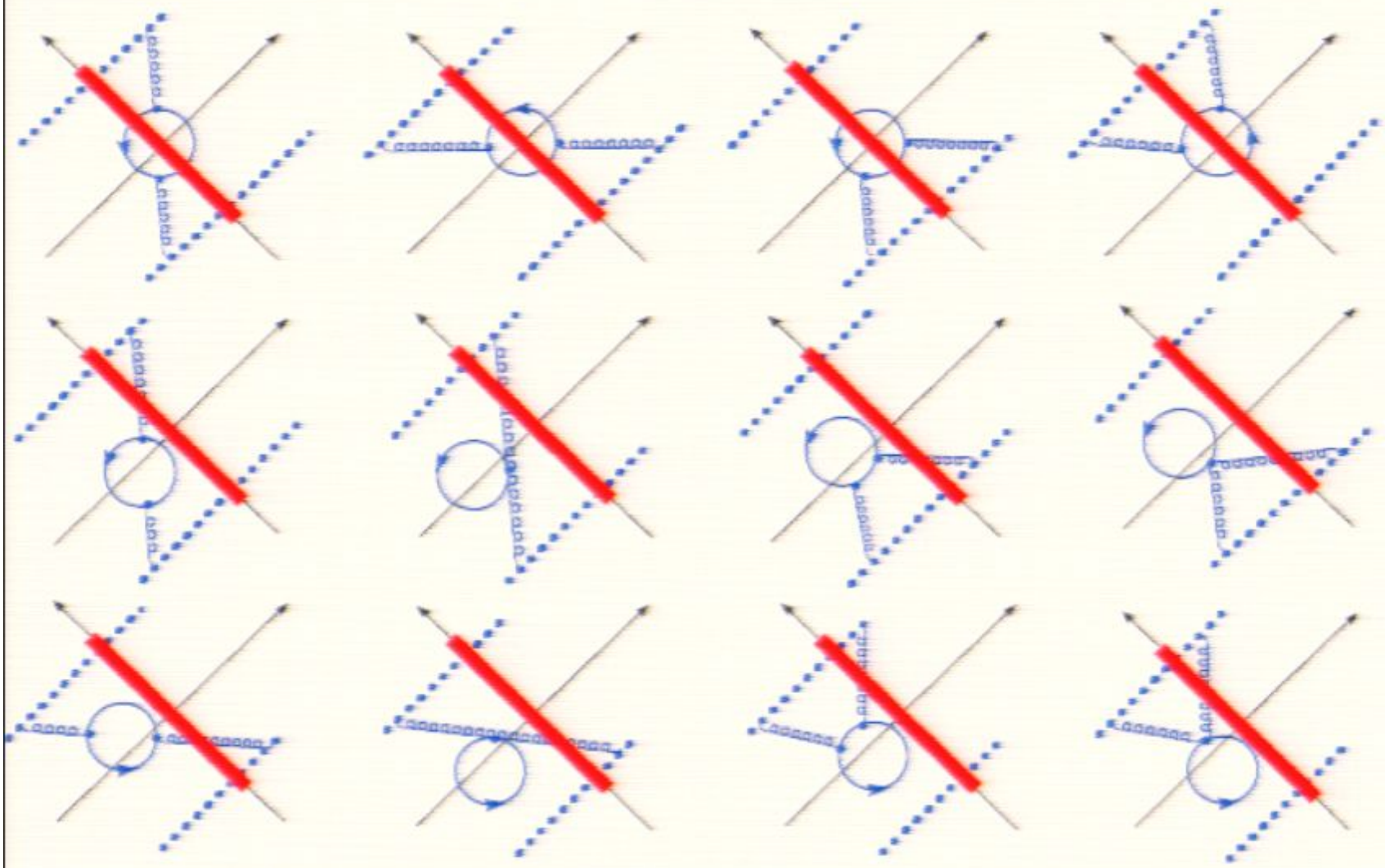
Dipole-dipole scattering

$$\chi(\gamma) \equiv 2C - \psi(\gamma) - \psi(1-\gamma)$$

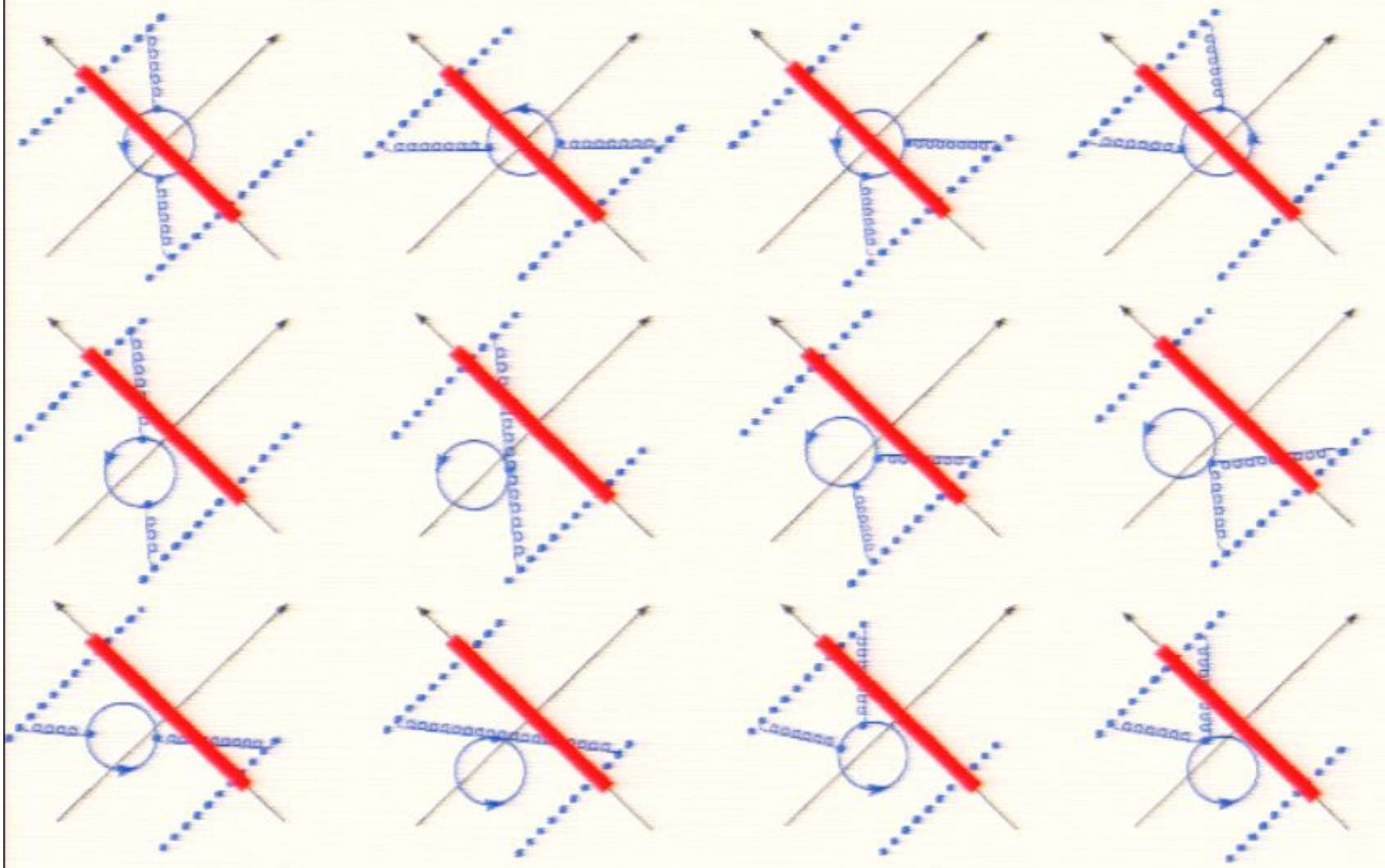
$$[DD] = \int d\nu \int dz_0 \left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^{\frac{1}{2}+i\nu}\left(\frac{z_{12}^2}{z_{10}^2 z_{20}^2}\right)^{\frac{1}{2}-i\nu} D\left(\frac{1}{2}+i\nu;\lambda\right)R^{\omega(\nu)/2}$$

$$D(\gamma;\lambda) = \frac{\Gamma(-\gamma)\Gamma(\gamma-1)}{\Gamma(1+\gamma)\Gamma(2-\gamma)}\left\{1-\frac{\lambda}{4\pi^2}\left[\frac{\chi(\gamma)}{\gamma(1-\gamma)}-\frac{\pi^2}{3}\right]+O(\lambda^2)\right\}$$

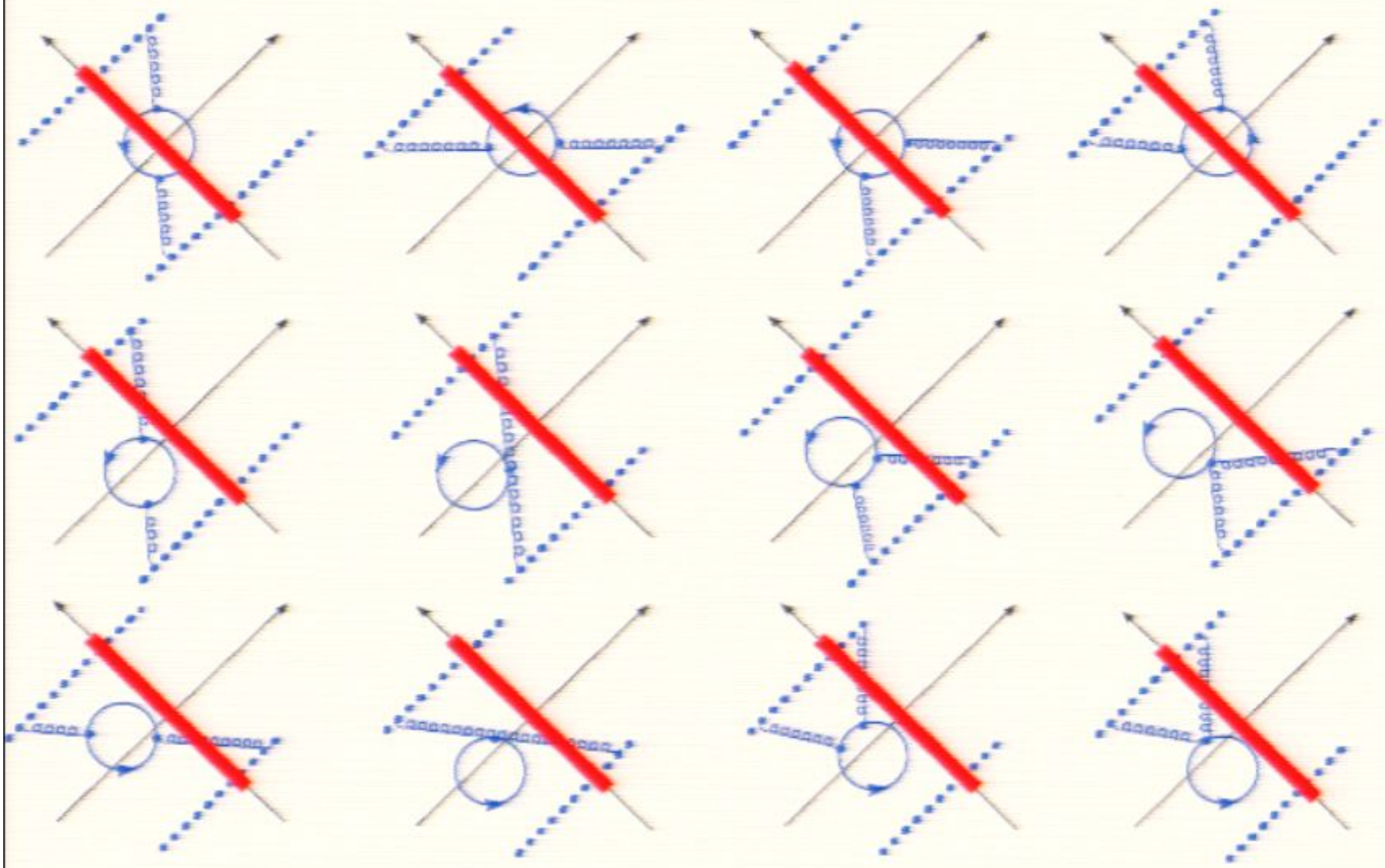
Gluino and scalar loops



Gluino and scalar loops



Gluino and scalar loops



Gluino and scalar loops

