

Title: String Theory #3

Date: Jan 29, 2008 06:30 PM

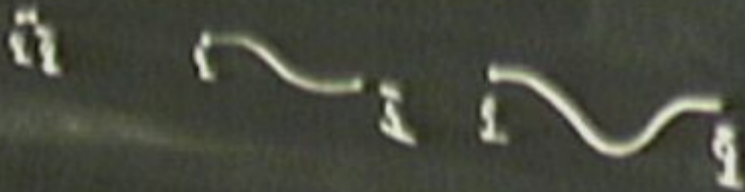
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Abstract: Strings vs. particles. Branes and Holography in quantum gravity.



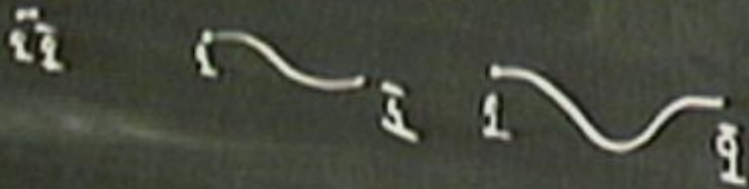


$\bar{1}$



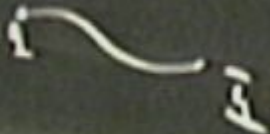


$$\alpha' M^2 = \sum_n n N_n + \text{const}$$

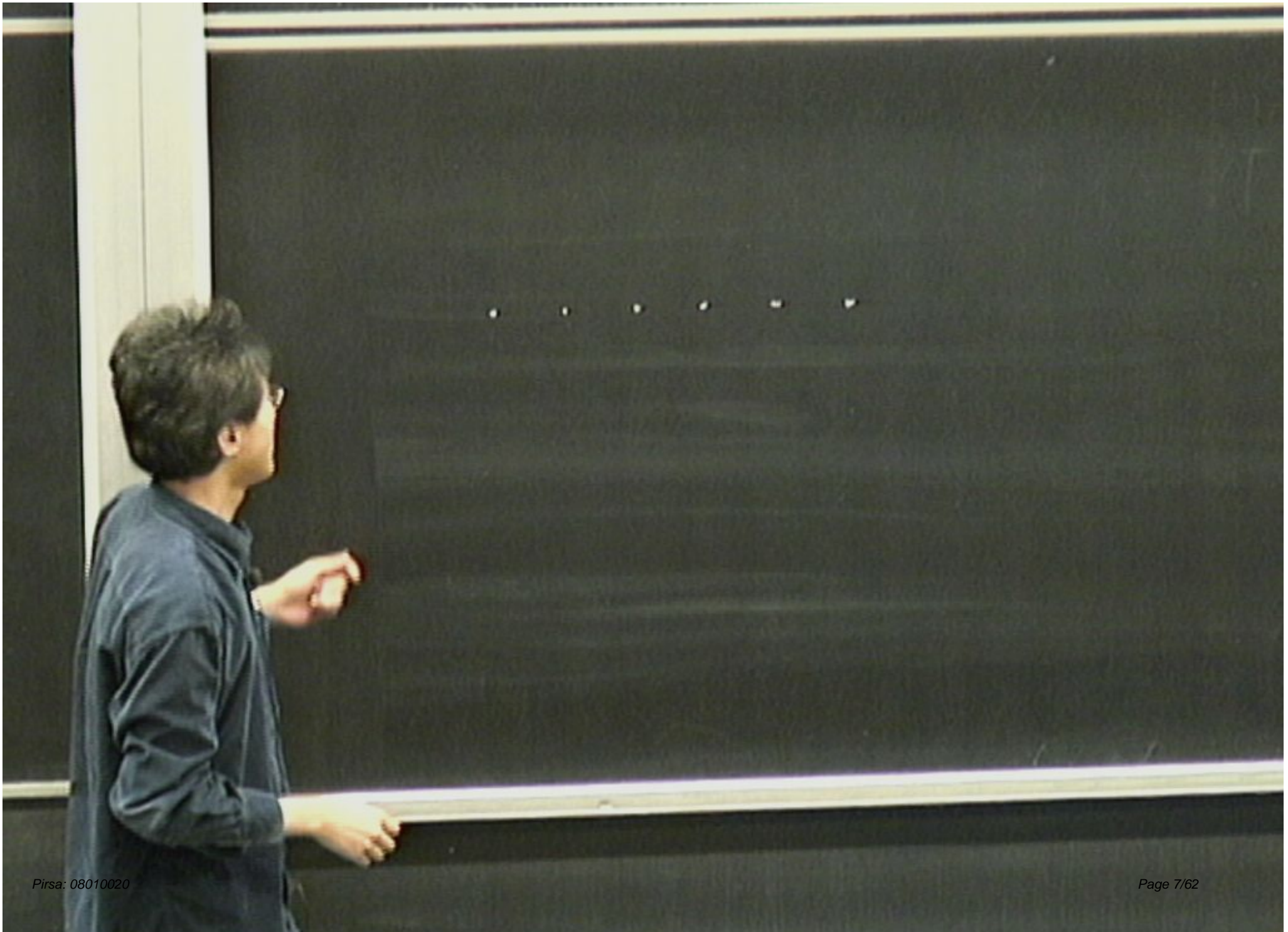


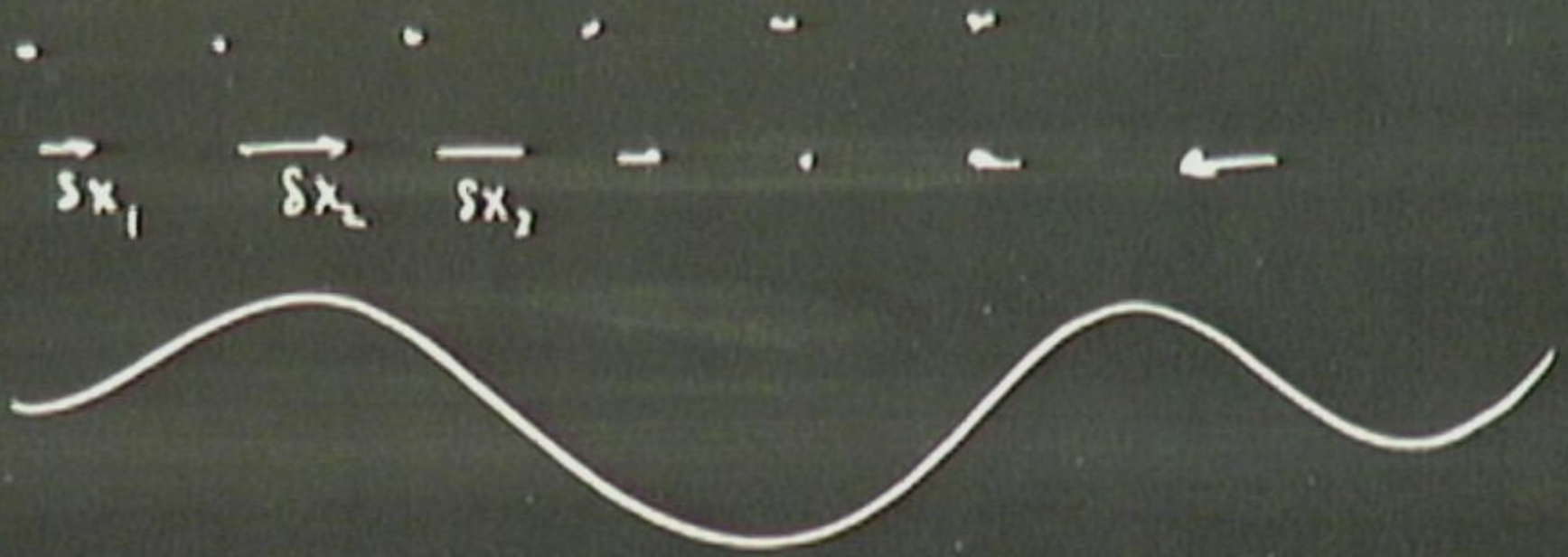


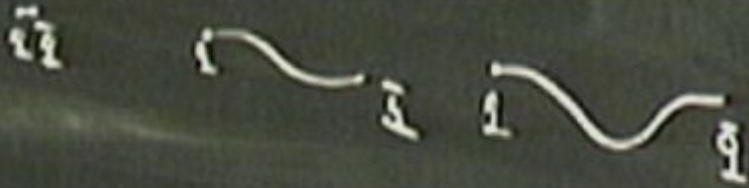
$\bar{1} \bar{2}$



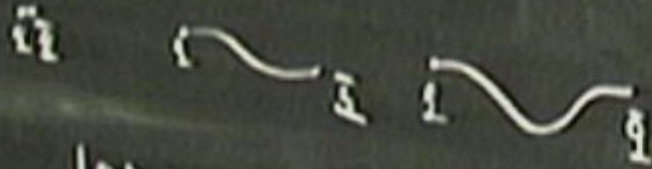
$$\alpha' M^2 = \sum_n n N_n + \text{const}$$





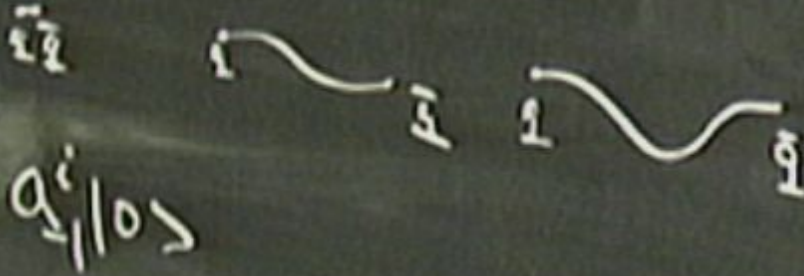


$$\alpha' M^2 = \sum_n n N_n + \text{const}$$



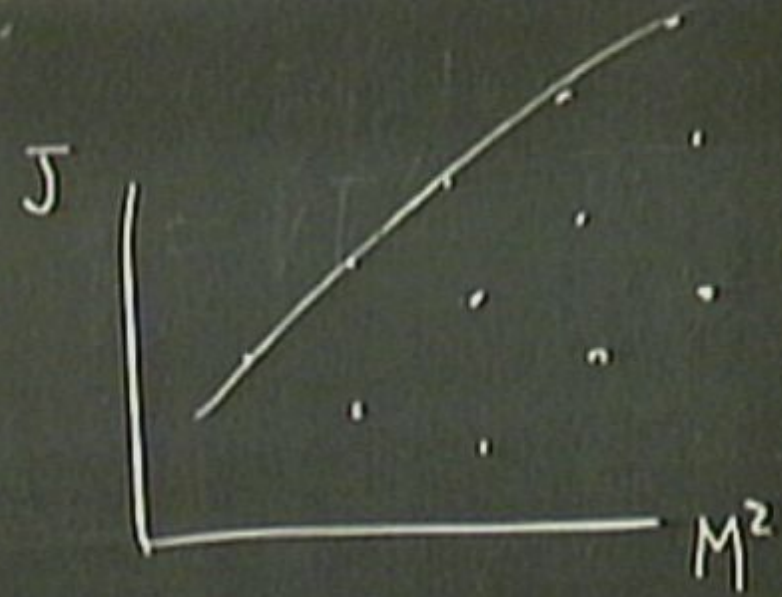
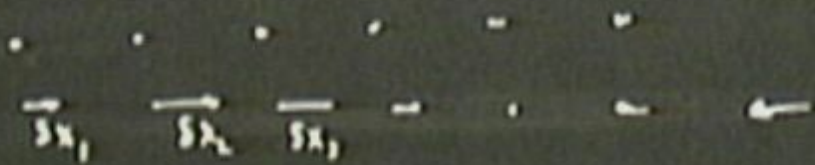
105

$$\alpha' M^2 = \sum_n n N_n + \text{const}$$

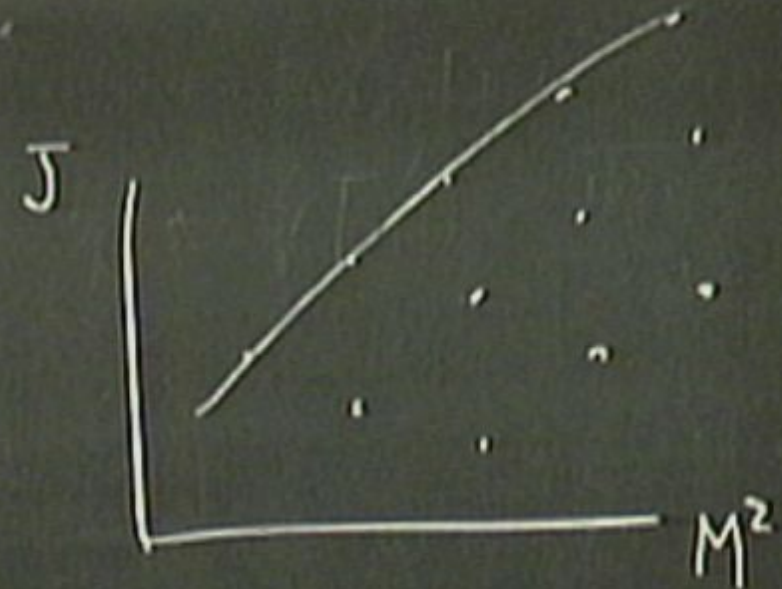


$$\alpha' M^2 = \sum_n n N_n + \text{const}$$

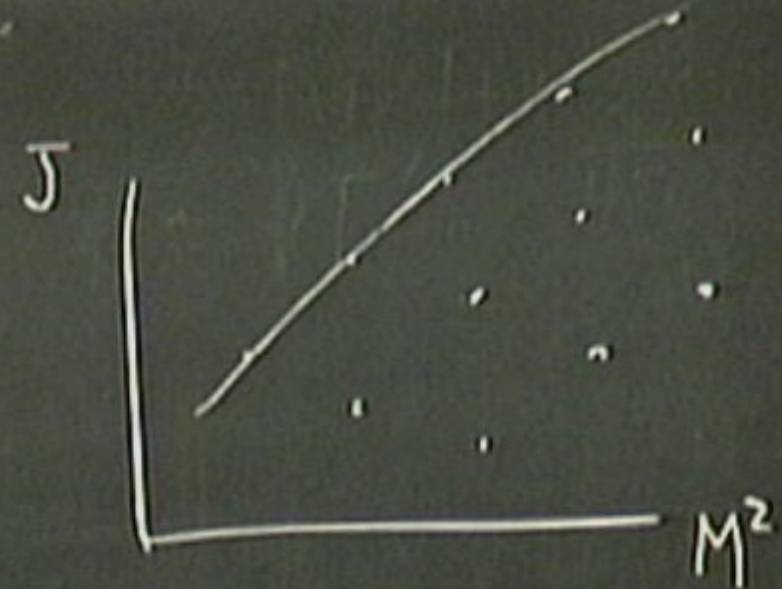
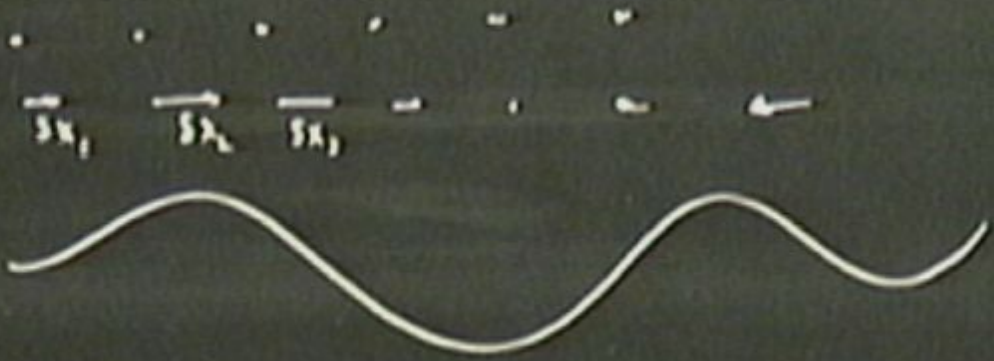
$$|n\rangle = \frac{(\alpha^+)^n}{\sqrt{n!}} |0\rangle$$



\vec{s}_{x_1} \vec{s}_{x_2} \vec{s}_{x_1}



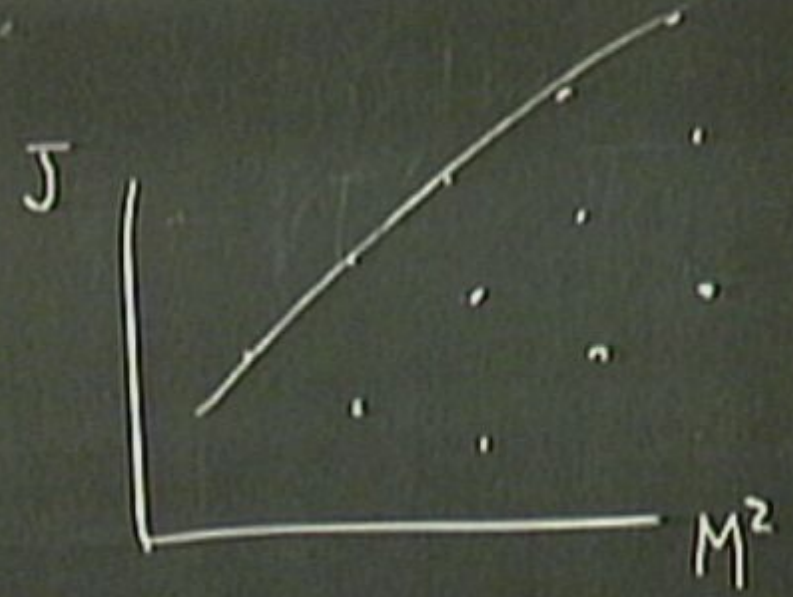
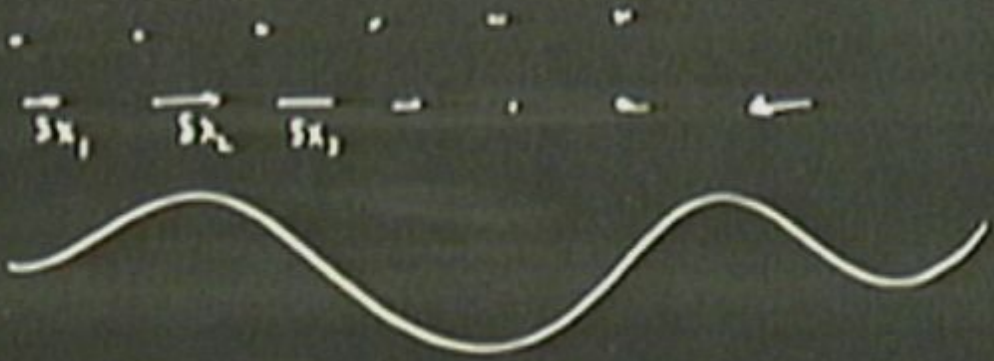
$$J^2 = \alpha^2 M^2$$



$$J^2 = \alpha' M^2 + \text{const}$$

$$\alpha' \sim (1 \text{ GeV})^{-2}$$

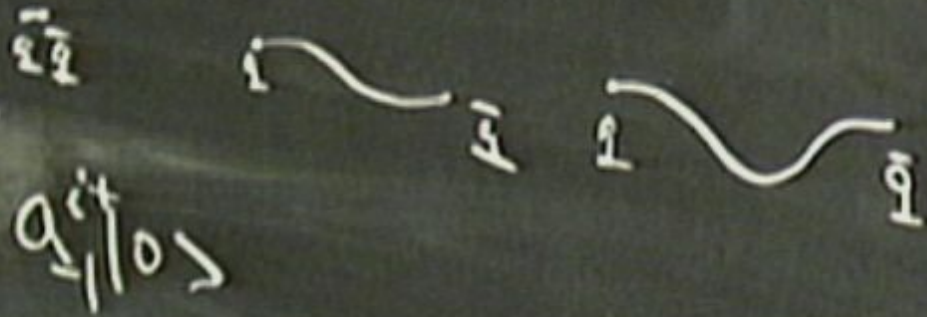
$$1 \text{ GeV} = 10^9 \text{ eV}$$



$$J^2 = \alpha' M^2 + \text{const}$$

$$\alpha' \sim (1 \text{ GeV})^{-2}$$

$$1 \text{ GeV} = 10^9 \text{ eV}$$



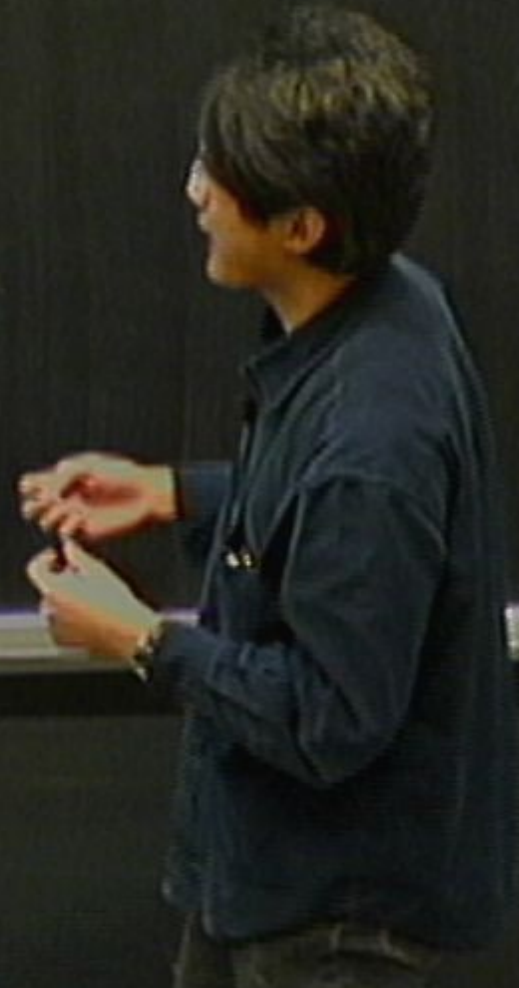
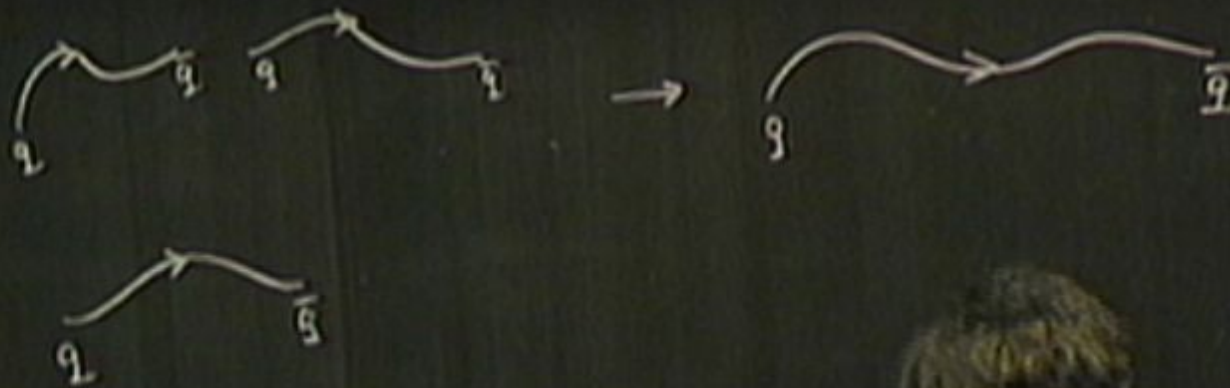
$$\alpha' M^2 = \sum_n n N_n + \text{const}$$

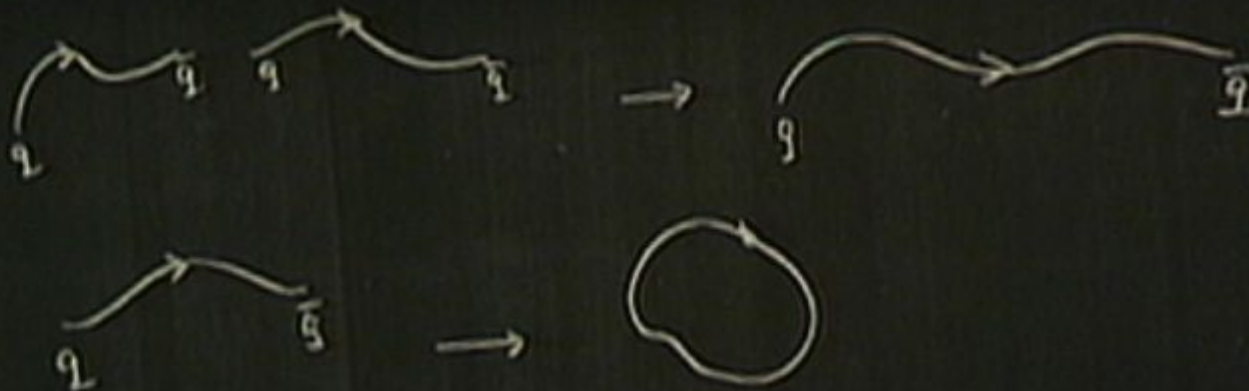
$$|n\rangle = \frac{(\alpha^+)^n}{\sqrt{n!}} |0\rangle$$

$\frac{1}{\alpha'}$





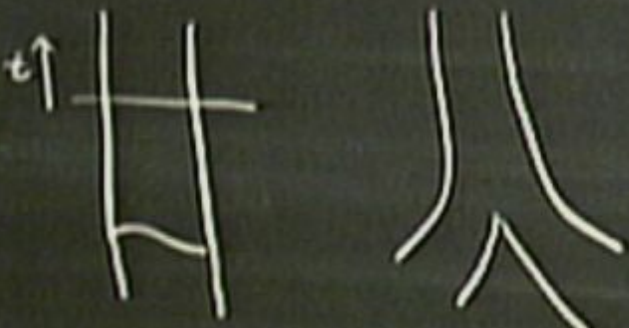


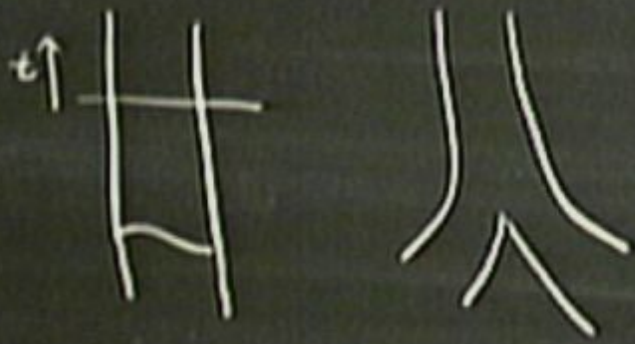


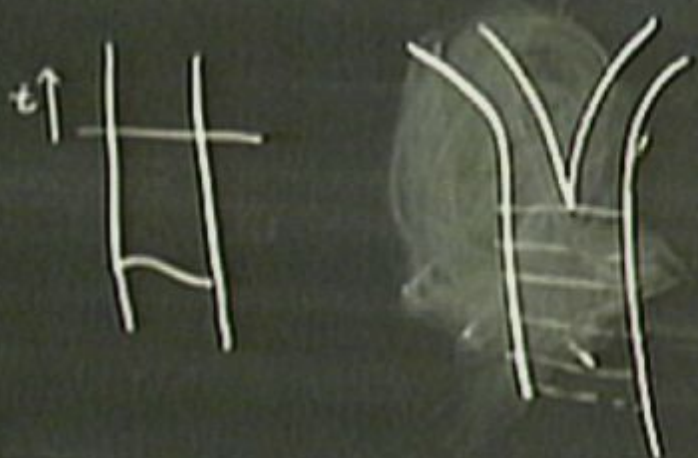
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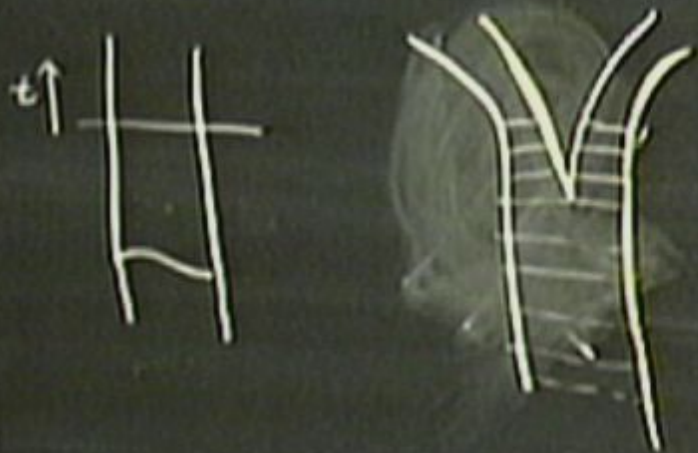


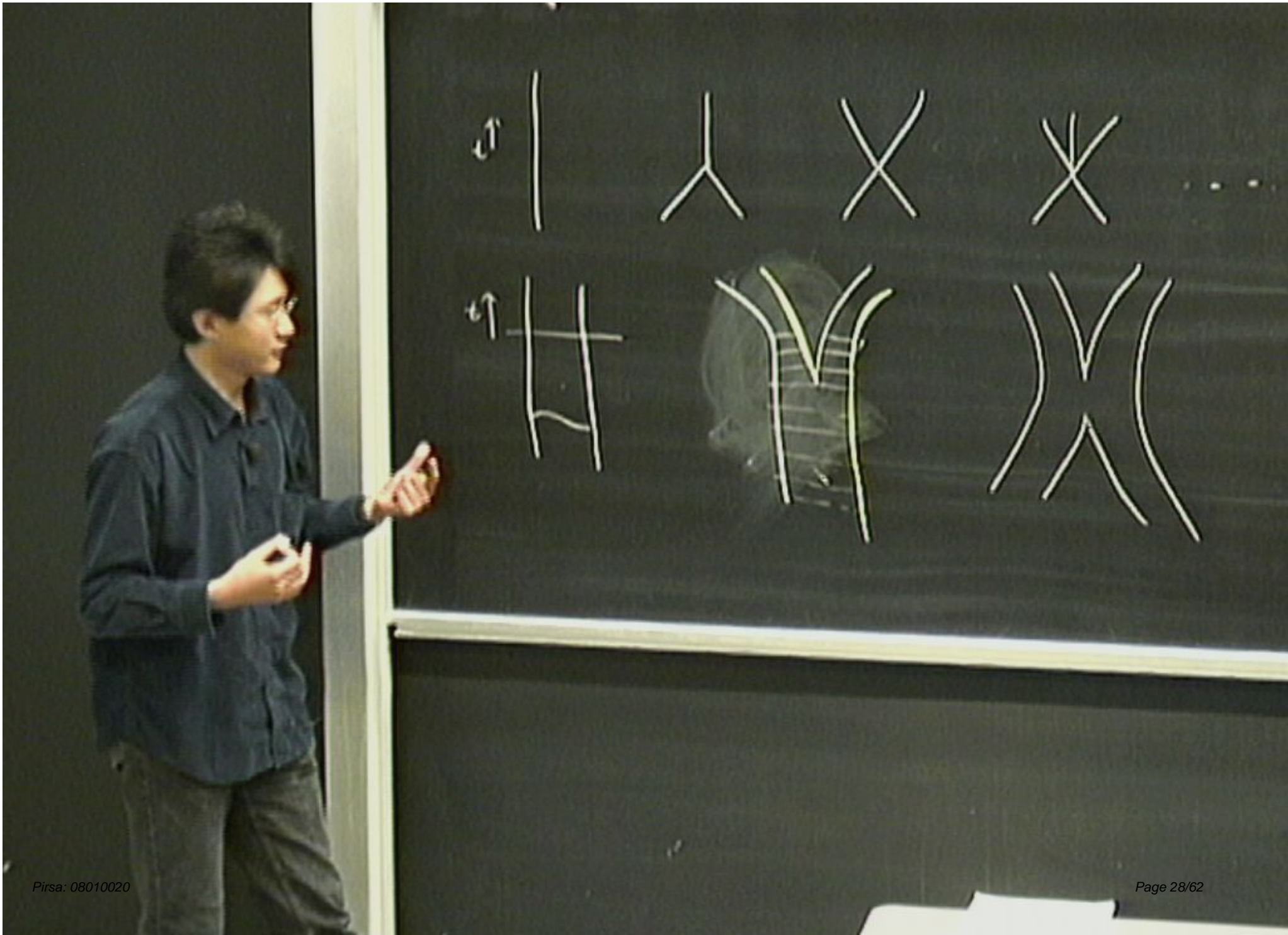












$$H_{i,t} = H_0 + \Delta H$$

$$H_{1,t} = H_0 + \Delta H$$

$$H_{1,t} = H_0 + \Delta H$$



$$H_{tot} = H_0 + \Delta H$$



$$\Delta H$$

$$H_{\text{tot}} = H_0 + H_{\text{int}}$$



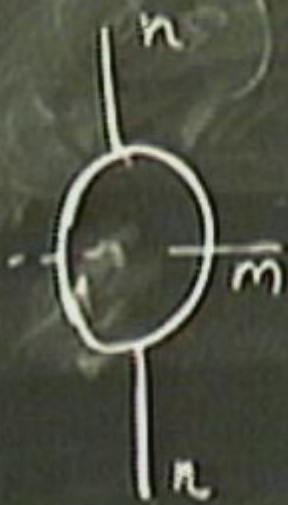
$$\Delta E_n = \sum \langle H_{\text{int}} | n \rangle$$

$$H_{int} = H_0 + H_{int}$$



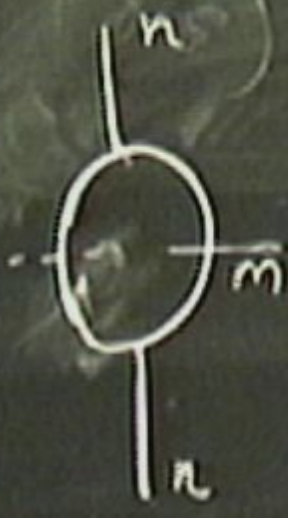
$$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} +$$

$$H_{tot} = H_0 + H_{int}$$



$$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} +$$

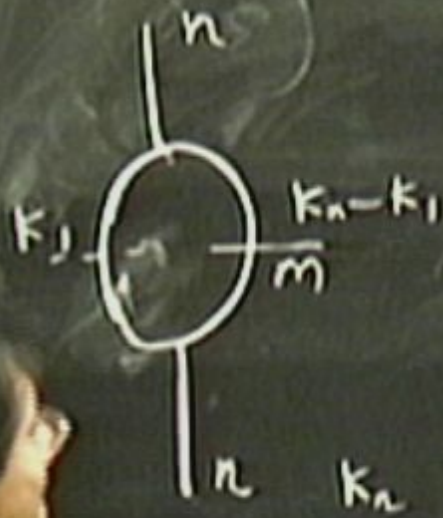
$$H_{tot} = H_0 + H_{int}$$



$$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} +$$

$$= \int$$

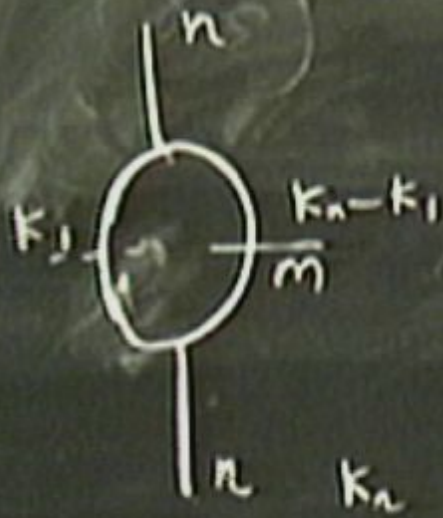
$$H_{int} = H_0 + \text{rest } H_{int}$$



$$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} +$$

$$= \int$$

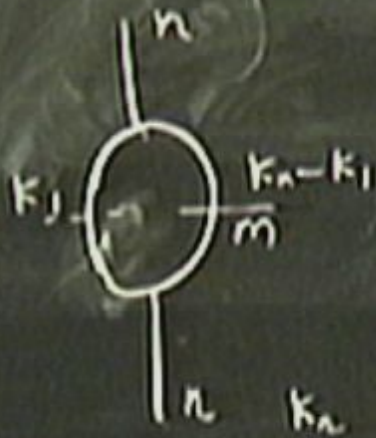
$$H_{int} = H_0 + H_{int}$$



$$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} +$$

$$= \int d^3 k_1 \frac{|\langle k_1, k_2 - k_1 | H_{int} | k_2 \rangle|^2}{E_n - E_m}$$

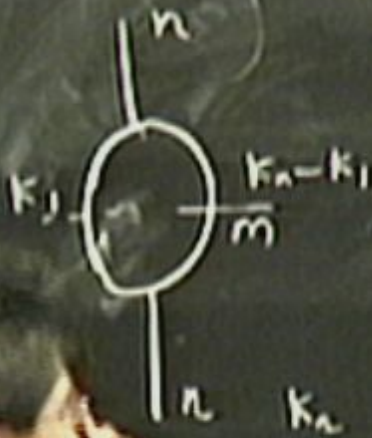
$$H_{\text{tot}} = H_0 + H_{\text{int}}$$



$$\Delta E_n = \sum_m \frac{|\langle m | H_{\text{int}} | n \rangle|^2}{E_n - E_m} + \dots$$

$$= \int_0^\Lambda d^3 k_j \frac{|\langle k_j, k_n - k_j | H_{\text{int}} | k_n \rangle|^2}{E_n - E_m}$$

$$H_{\text{tot}} = H_0 + \text{int} H_{\text{int}}$$

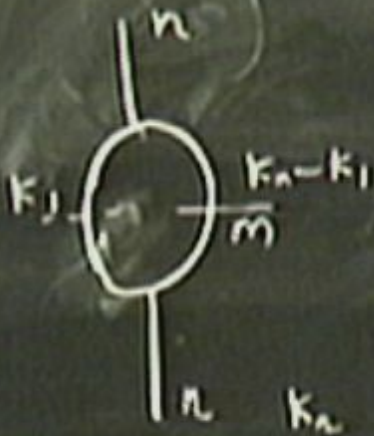


$$\Delta E_n = \sum_m \frac{|\langle m | H_{\text{int}} | n \rangle|^2}{E_n - E_m} + \dots$$

$$= \int_0^\Lambda d^3 k_1 \frac{|\langle k_1, k_n - k_1 | H_{\text{int}} | k_n \rangle|^2}{E_n - E_m}$$

$$= f(\Lambda)$$

$$H_{int} = H_0 + \text{rest } H_{int}$$

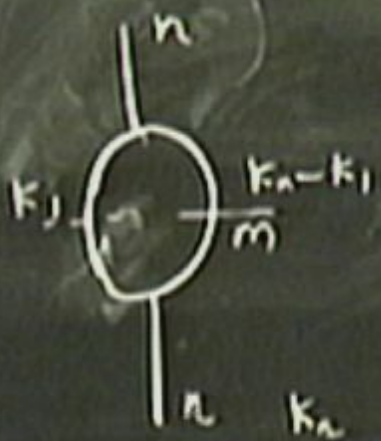


$$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} + \dots$$

$$= \int_0^\Lambda d^3 k_1 \frac{|\langle k_1, k_n - k_1 | H_{int} | k_n \rangle|^2}{E_n - E_m}$$

$$= f(\Lambda, g)$$

$$H_{\text{tot}} = H_0 + H_{\text{int}}$$

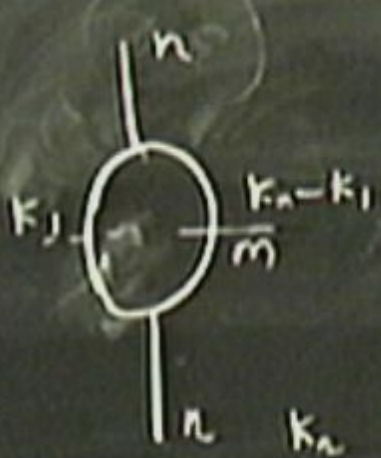


$$\Delta E_n = \sum_m \frac{|\langle m | H_{\text{int}} | n \rangle|^2}{E_n - E_m} + \dots$$

$$= \int_0^\Lambda d^3 k_j \frac{|\langle k_j, k_n - k_j | H_{\text{int}} | k_n \rangle|^2}{E_n - E_m}$$

$$= f(\Lambda, g) = g$$

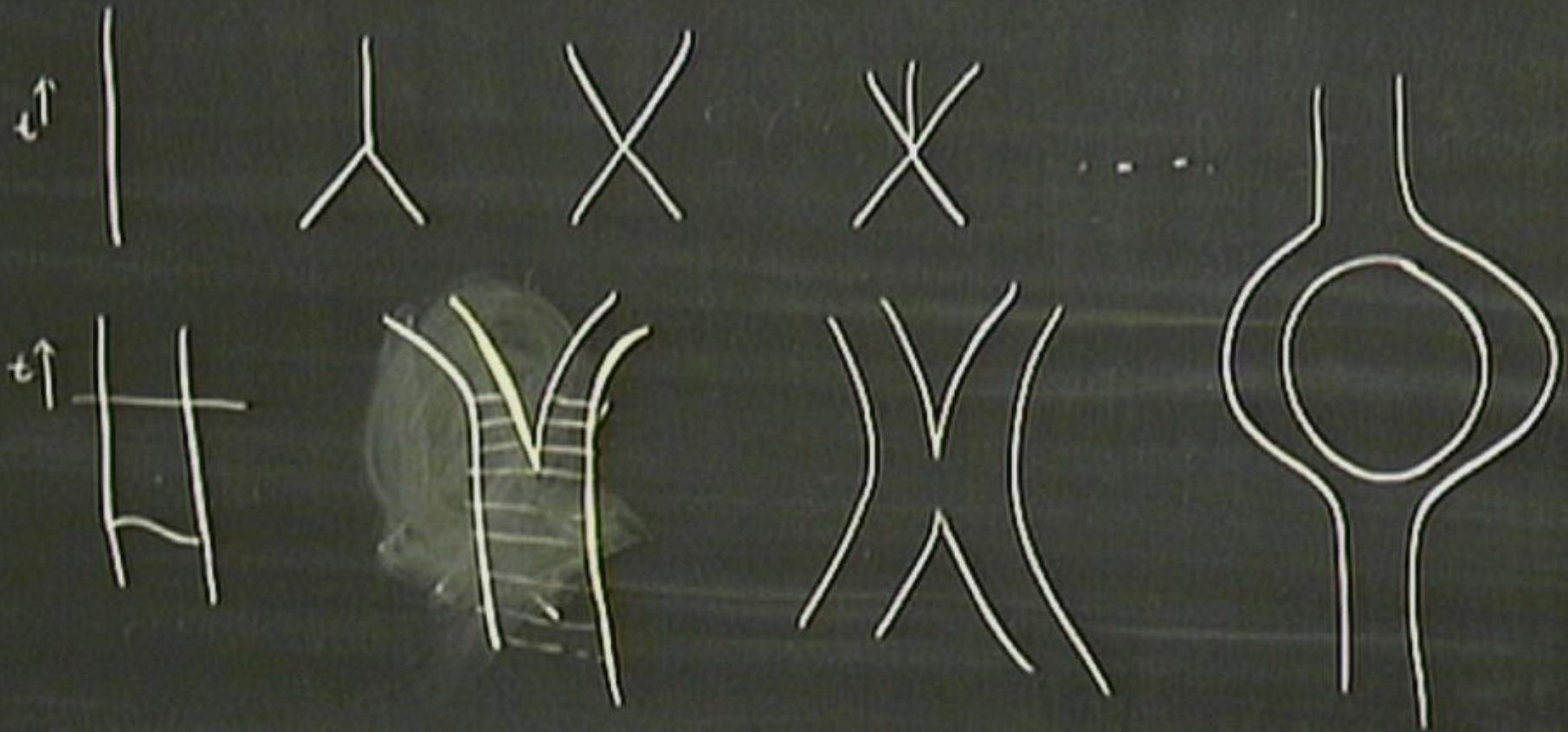
$$H_{int} = H_0 + \dots + H_{int}$$



$$\Delta E_n = \sum_m \frac{|\langle m | H_{int} | n \rangle|^2}{E_n - E_m} + \dots$$

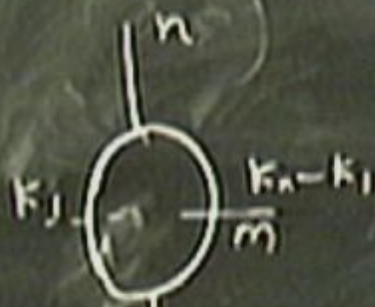
$$= \int_0^{\Lambda} d^3k \frac{|k_n - k_1 \langle H_{int} | k_n \rangle|^2}{-E_m}$$

$$= f(\Lambda) g_{measure}$$

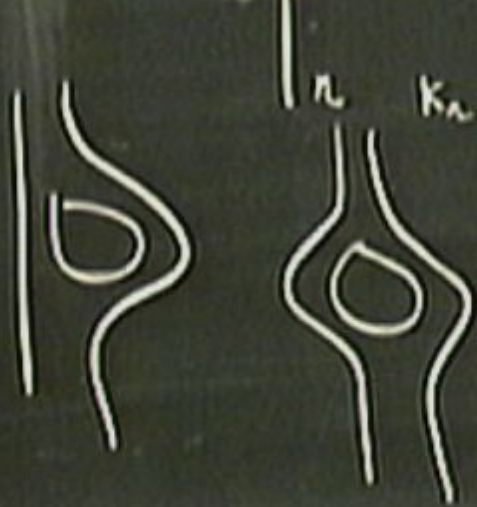




$$H_{\text{tot}} = H_0 + H_{\text{int}}$$



$$\Delta E_n = \sum_m \frac{|\langle m | H_{\text{int}} | n \rangle|^2}{E_n - E_m}$$



$$= \int_0^\Lambda d^3 k_1 \frac{|\langle k_1, k_n - k_1 | H_{\text{int}} | k_n \rangle|^2}{E_n - E_m}$$

$$= f(\Lambda, g_{\text{int}}) = g_{\text{renorm}}$$

$M^{1.4}$

$$M^{1.4} = M^{1.3} \times S'$$

$$M^{1.4} = M^{1.3} \times S'_R$$

$$P = \frac{1}{2}$$

$$M^{1.4} = M^{1.3} \times S_R^1$$

$$P = \frac{P}{P}$$

$$M^{1.4} = M^{1.3} \times (S'_R)$$

$$P = \frac{P}{P}$$

$$E^2 = P^2 + m^2$$

$$= P^2_{(1.3)} + P^2_{(S')} + m^2$$

$$M^{1.4} = M^{1.3} \times S'_R$$

$$P_r = \frac{P}{R}$$

$$E^r = P^r + m^2$$

$$= P^r_{(1.3)} + (P^r_{(S')} + m^2)$$

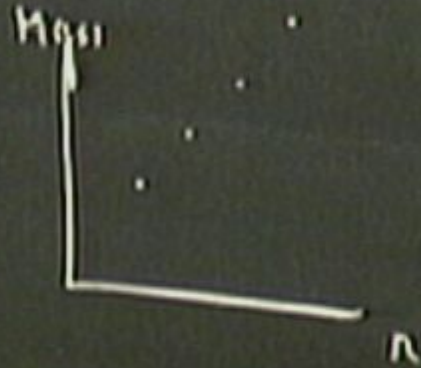
$$M^{1.4} = M^{1.3} \times S'_R$$

$$P_r = \frac{r}{R}$$

$$E_r = P_r + m^2$$

$$= P_{r(0.3)} + \left(P_{r(0.3)} + m^2 \right)$$

$$\underbrace{\hspace{10em}}_{M^2_{(0.3)}}$$



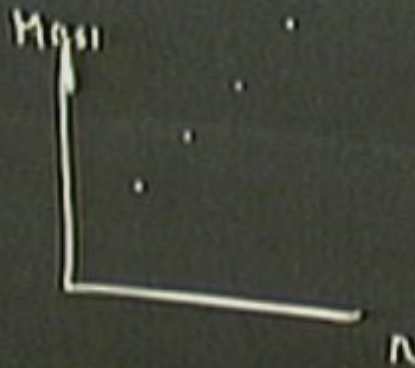
$$M^{1.4} = M^{1.3} \times S'_R$$

$$P_\mu = \frac{p_\mu}{R}$$

$$E^2 = p^2 + m^2$$

$$= p_{(\mu, \nu)}^2 + \left(p_{(\mu, \nu)}^2 + m^2 \right)$$

$$M_{(\mu, \nu)}^2$$



$k(\text{aluz})$ $k(\text{lar})$
particles

$$g_{MN} = \begin{pmatrix} & & & & \\ & & & & \\ & & g_{\mu\nu} & & \\ & & & & g_{M4} \\ & & & & \\ g_{a4} & & & & \\ & & & & g_{44} \end{pmatrix}$$

$M, N = 0, \dots, 4$

$M, \nu = 0, \dots, 3$

$$g_{MN} = \begin{pmatrix} g_{\mu\nu} & g_{\mu 4} \\ g_{\alpha\nu} & g_{44} \end{pmatrix}$$

$M, N = 0, \dots, 3$

$M, N = 0, \dots, 4$

$$M^{1,4} = M^{1,3} \times S^1$$

$$g_{\mu\nu} = A_{\mu\nu}$$

$\mu = 0, \dots, 3$

$$ds^2 = g_{MN} dx^M dx^N$$



$$g_{MN} = \begin{pmatrix} g_{\mu\nu} & g_{\mu 4} \\ g_{4\nu} & g_{44} \end{pmatrix}$$

$\mu, \nu = 0, \dots, 3$

$M, N = 0, \dots, 4$

$$M^{1,4} = M^{1,3} \times S^1$$

$$g_{\mu 4} = g_{4\mu} = A_\mu$$

$$\mu = 0, \dots, 3$$

$$ds^2 = g_{MN} dx^M dx^N$$

$$g_{MN} = \begin{pmatrix} g_{\mu\nu} & g_{\mu 4} \\ g_{4\nu} & g_{44} \end{pmatrix}$$

$\mu, \nu = 0, \dots, 3$

$M, N = 0, \dots, 4$

$$M^{1,4} = M^{1,3} \times S^1$$

$$g_{\mu 4} = g_{4\mu} = A_\mu$$

$$\mu = 0, \dots, 3$$

$$ds^2 = g_{MN} dx^M dx^N$$

$$g_{MN} = \begin{pmatrix} g_{\mu\nu} & g_{\mu 4} \\ g_{4\nu} & g_{44} \end{pmatrix}$$

$\mu, \nu = 0, \dots, 3$

$M, N = 0, \dots, 4$

$$M^{1,4} = M^{1,3} \times S^1$$

$$g_{\mu 4} = g_{4\mu} = A_\mu$$

$$\mu = 0, \dots, 3$$

$$ds^2 = g_{MN} dx^M dx^N$$

$$g_{MN} = \begin{pmatrix} g_{\mu\nu} & g_{\mu 4} \\ g_{4\nu} & g_{44} \end{pmatrix}$$

$\mu, \nu = 0, \dots, 3$

$M, N = 0, \dots, 4$

$$M^{1,4} = M^{1,3} \times S^1$$

$$g_{\mu 4} = g_{4\mu} = A_\mu$$

$$\mu = 0, \dots, 3$$

$$ds^2 = g_{MN} dx^M dx^N$$

$$S = \int d^5x \sqrt{|g_5|} R_5$$

$$g_5 = \det(g_{MN})$$

$$g_{MN} = \begin{pmatrix} g_{\mu\nu} & g_{\mu 4} \\ g_{4\nu} & g_{44} = \sigma \end{pmatrix} \quad M, N = 0, \dots, 3$$

$$M^{1,4} = M^{1,3} \times S^1$$

$$g_{\mu 4} = g_{4\mu} = A_\mu$$

$$ds^2 = g_{MN} dx^M dx^N = 2\pi R \int d^4x \sqrt{-g_4} (R_4 + e^{2\sigma} F_{\mu\nu} F^{\mu\nu}) \cdot e^{-\sigma}$$

$$S = \int d^5x \sqrt{-g_5} R_5 \quad \underbrace{g_5 = \det(g_{MN})}$$

$$g_{MN} = \begin{pmatrix} g_{\mu\nu} & g_{\mu 4} \\ g_{4\nu} & g_{44} = \sigma \end{pmatrix} \quad M, N = 0, \dots, 3$$

$$M^{1,4} = M^{1,3} \times S^1$$

$$g_{\mu 4} = g_{4\mu} = A_\mu$$

$$ds^2 = g_{MN} dx^M dx^N = 2\pi R \int d^4x \sqrt{g_4} (R_4 + e^{2\sigma} F_{\mu\nu} F^{\mu\nu}) \cdot e^{-\sigma}$$

$$S = \int d^5x \sqrt{g_5} R_5 \quad \underline{g_5 = \det(g_{MN})}$$