

Title: Particle Phenomenology

Date: Jun 30, 2005 02:30 PM

URL: <http://pirsa.org/05060108>

Abstract:

• DERIVE, MOTIVATE $\mathcal{L} = \mathcal{L}_{\text{SUSY}} + \mathcal{L}_{\text{SOFT}}$

• MSSM: SM + SUPERPARTNERS, 3-2-1,
2 HIGGS DOUBLET, R-PARITY

• CALCULATE HIGGS SECTOR
-- DERIVE HIGGS MECHANISM,
HIGGS BOSONS

• APPLY TO VIRTUAL PROCESSES WITH
GOOD WINDOW

$B \rightarrow \phi K, \eta' K$

EDMs

$J_{\mu-2}$

$B_s \rightarrow \mu^+ \mu^-$

• APPLY TO COLLIDERS

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LHC TIME SCHEDULE

* JAN-MAR 07 COOL DOWN

* APRIL 07 COMMISSIONING

* JUNE - OCT 07 TWO BEAMS,
FIRST COLLISIONS

$$\rightarrow \mathcal{L} \sim 5 \times 10^{32} \text{ cm}^{-2} \text{ sec}^{-1}$$

* NOV 07 - JUN 08 PHYSICS RUN,

$$\mathcal{L} \sim 10^{33} \text{ cm}^{-2} \text{ sec}^{-1}$$

$$\Rightarrow \sim 5 \text{ fb}^{-1}$$

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[http://www.th.cern.ch/lhcOlympics/
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TYPICAL SUPERPARTNER DECAY

$$\Gamma \sim \alpha_2 M \Rightarrow \text{few GeV}$$

$\swarrow \quad \searrow$
 $\sim \frac{1}{30} \quad \sim 100 \text{ GeV}$

$$\Rightarrow \text{LIFETIME} \sim 10^{-23} \text{ SEC}$$

$$\gamma c \tau \sim 10^{-12} \text{ cm}$$

$\Rightarrow$ ONLY DECAY PRODUCTS ENTER DETECTOR

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DISCOVER SUPERPARTNERS AT COLLIDERS

• $\tilde{N}_1$ ESCAPES DETECTOR — STABLE

• FINE-TUNING ARGUMENTS + GCM + DM

⇒ GAUGINOS LIGHT ($\tilde{g}, \tilde{N}_i, \tilde{C}_i$)

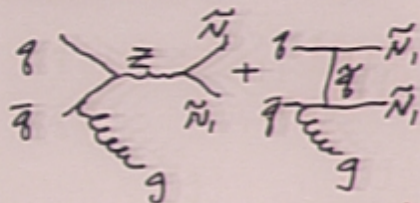
-- SLEPTONS, SQUARKS -- COULD BE LIGHT ($\tilde{E} \dots$)

• TEVATRON -- $\tilde{C}, \tilde{N} \lesssim 200 \text{ GeV}$, $\tilde{g} \lesssim 500-600 \text{ GeV}$ ---- LHC

• $\tilde{N}_1 + \tilde{N}_1$? -- NO SIGNATURE

-- MONO JETS -- BUT BACKGROUND

ESCAPES
DETECTOR



SUPRESSED IF
SQUARKS HEAVY

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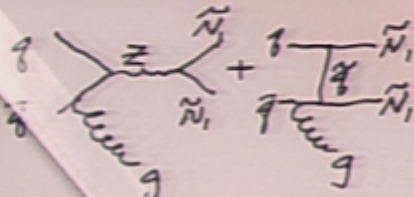
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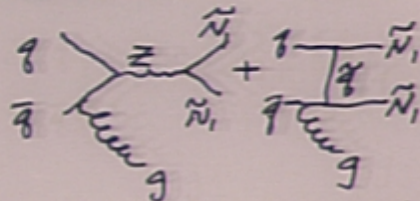
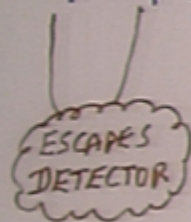
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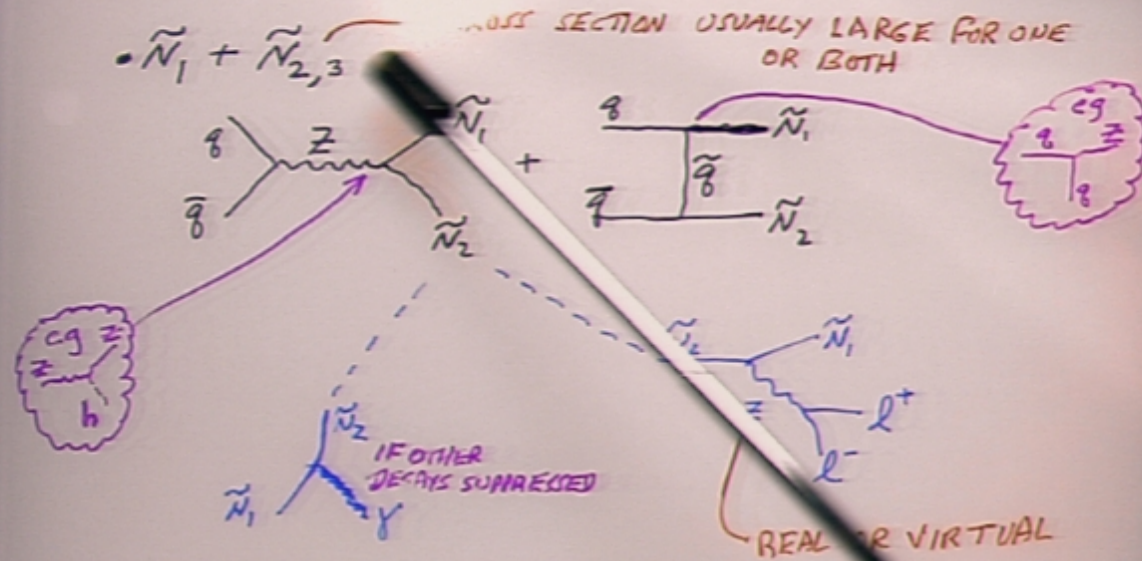
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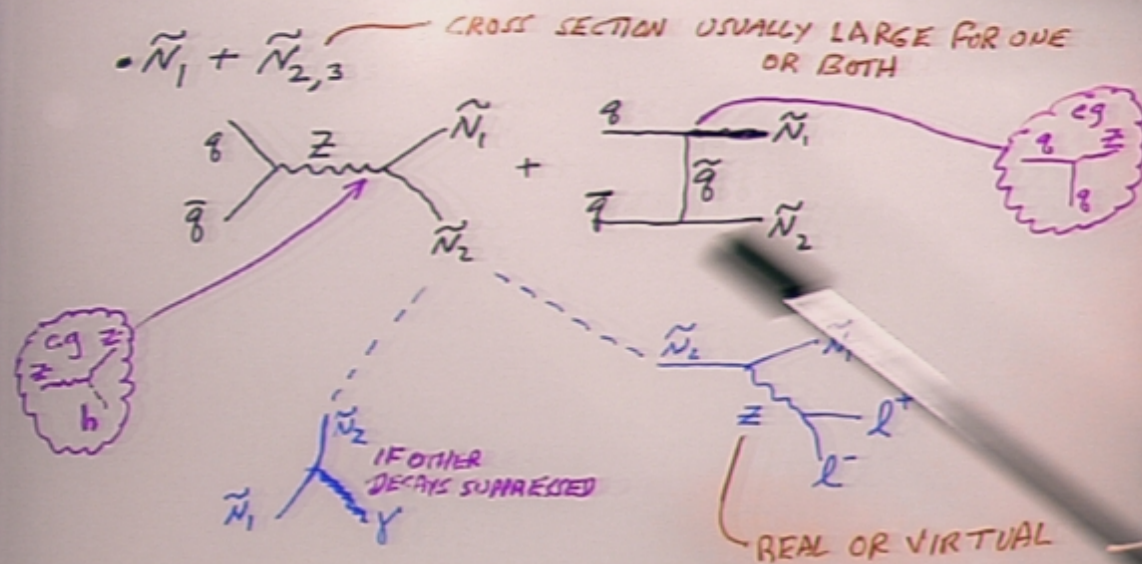


SUPRESSED IF
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- $\sigma \gtrsim 50 \text{ fb}$ AT TEVATRON (WITH BR)
- $1/2 \text{ fb}^{-1}$ INTEGRATED LUMINOSITY $\rightarrow \gtrsim 25 \text{ EVENTS}$
- $\text{BR}(Z \rightarrow \mu^+ \mu^- + e^+ e^-) = 6\%$
- SIGNATURE $l^+ l^- \cancel{E_T}$ OR $\gamma \cancel{E_T}$

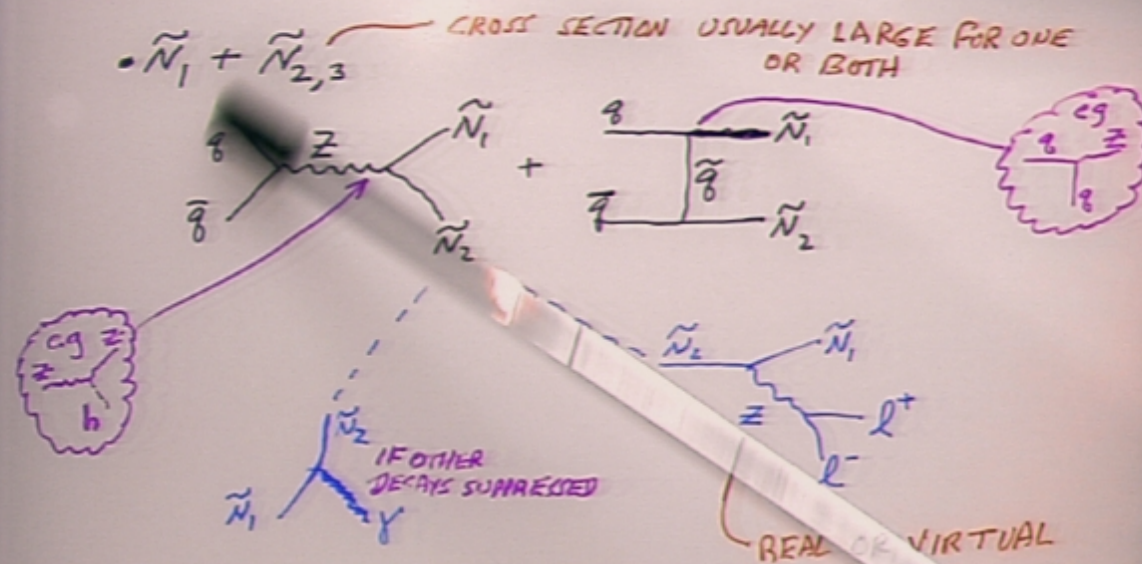
BACKGROUND
 $w^+ w^- \rightarrow l^+ l^- \nu \bar{\nu}$



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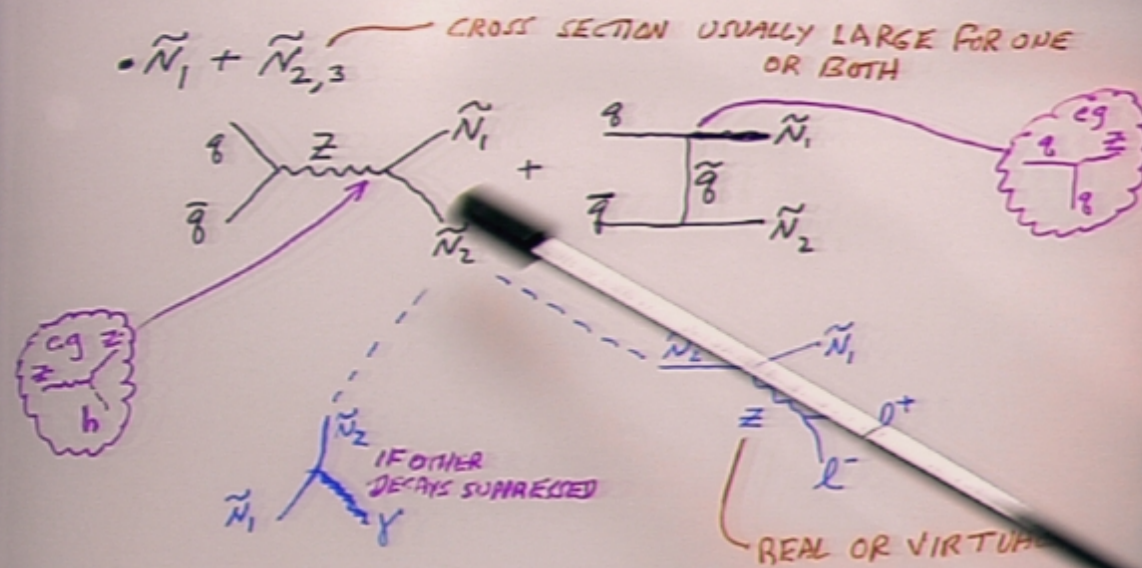
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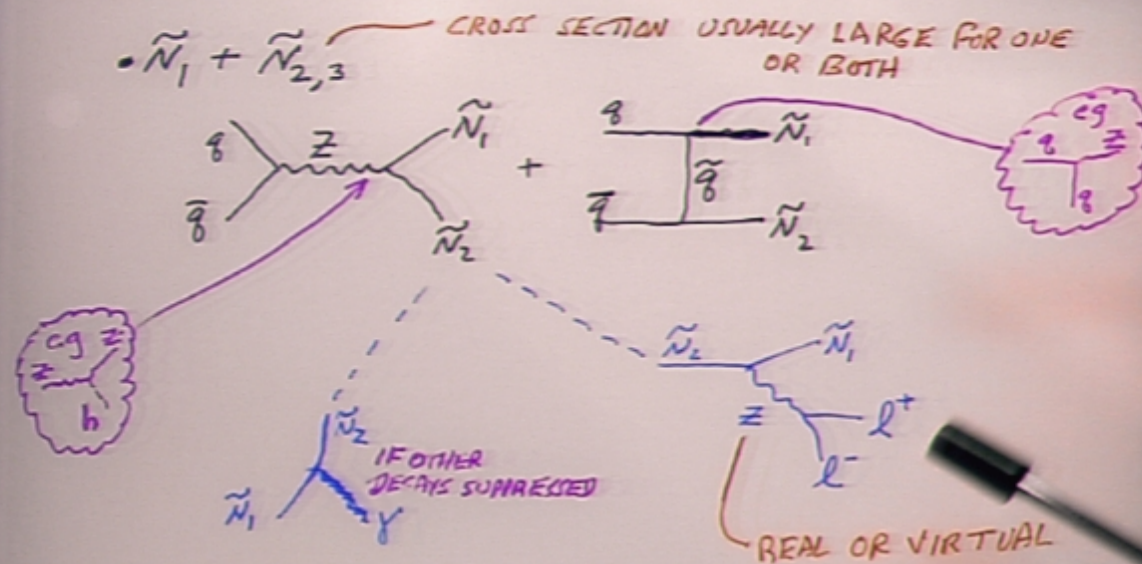
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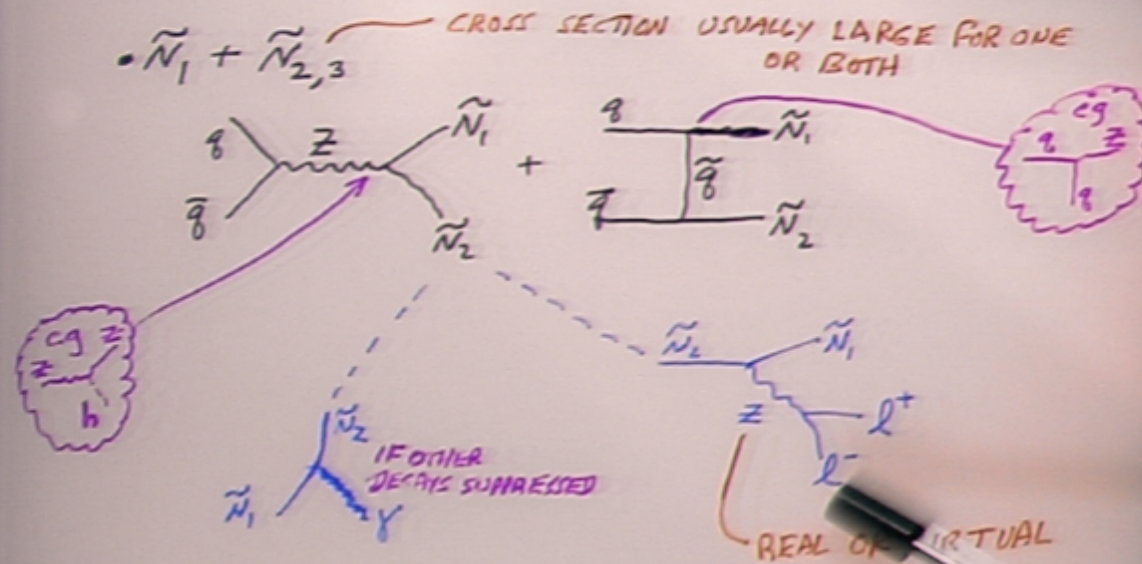
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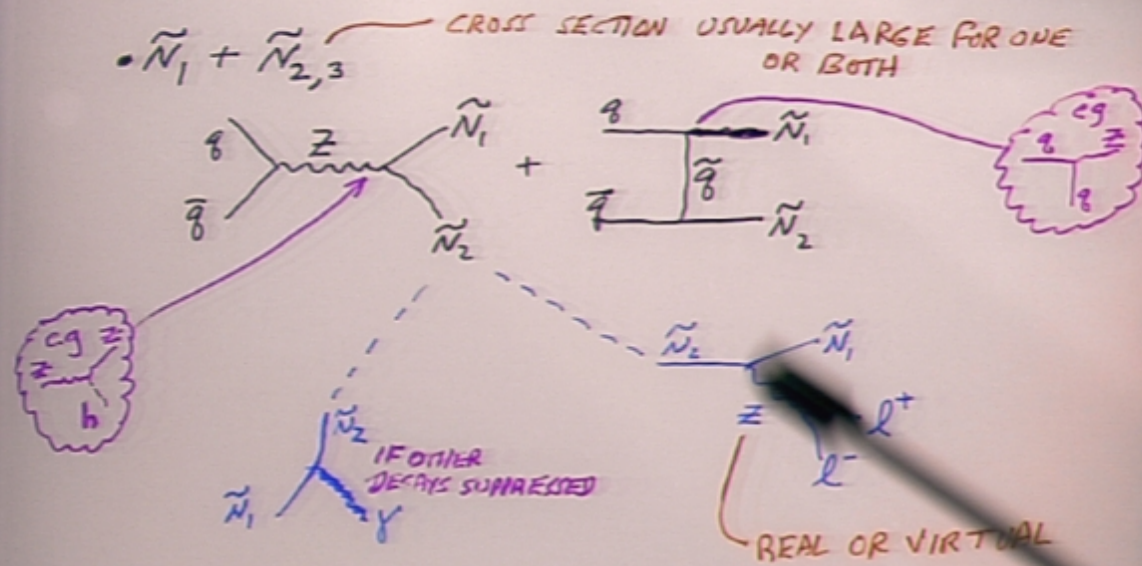
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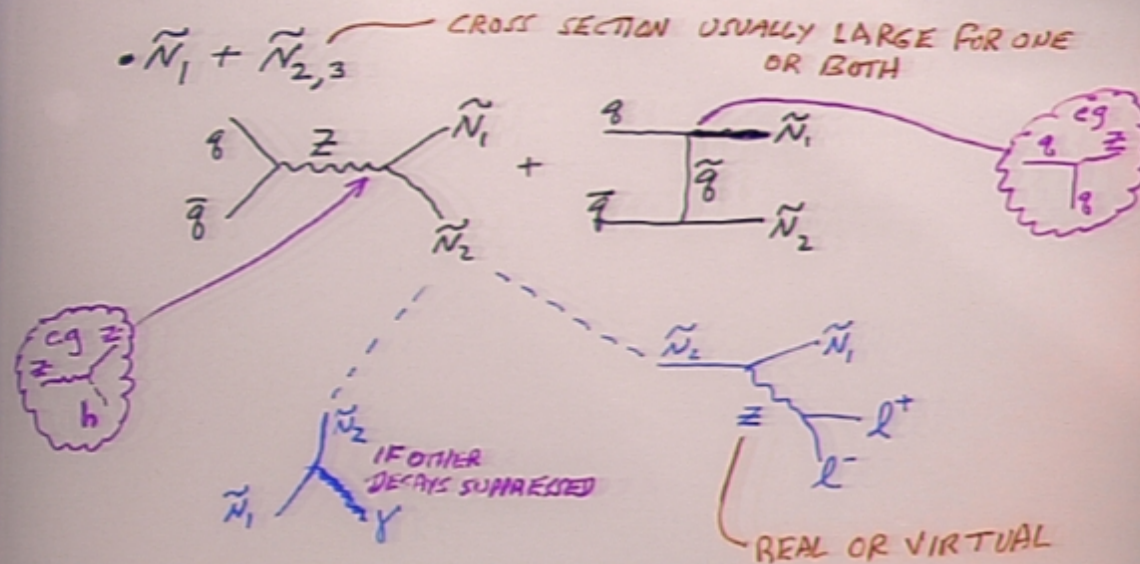
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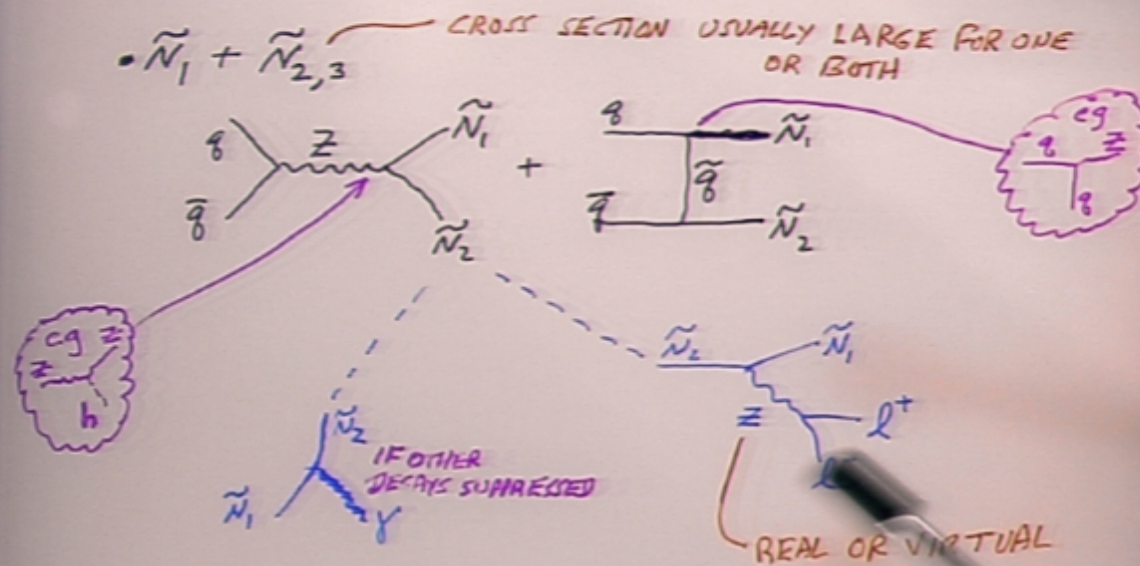
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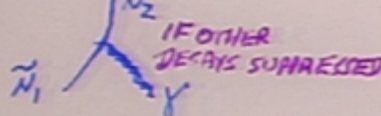
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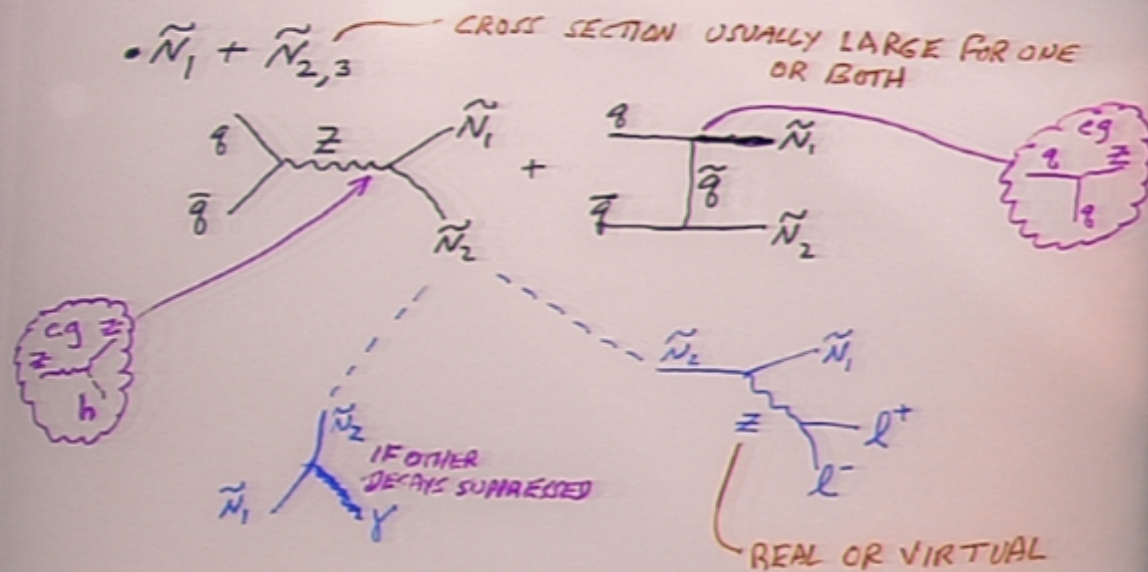
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$$\bullet \tilde{N}_1 + \tilde{N}_{2,3}$$


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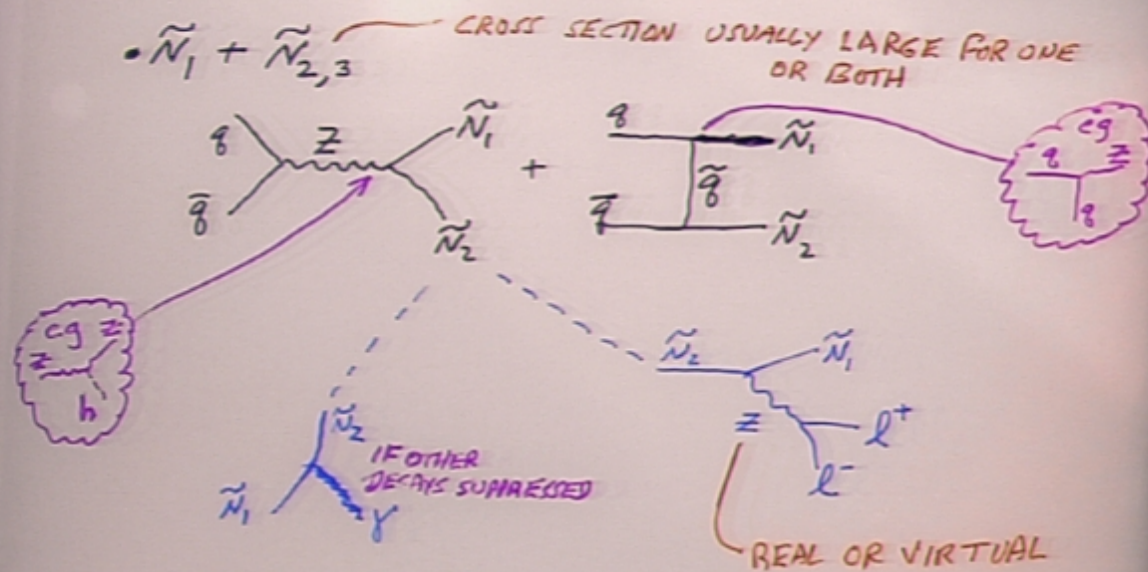
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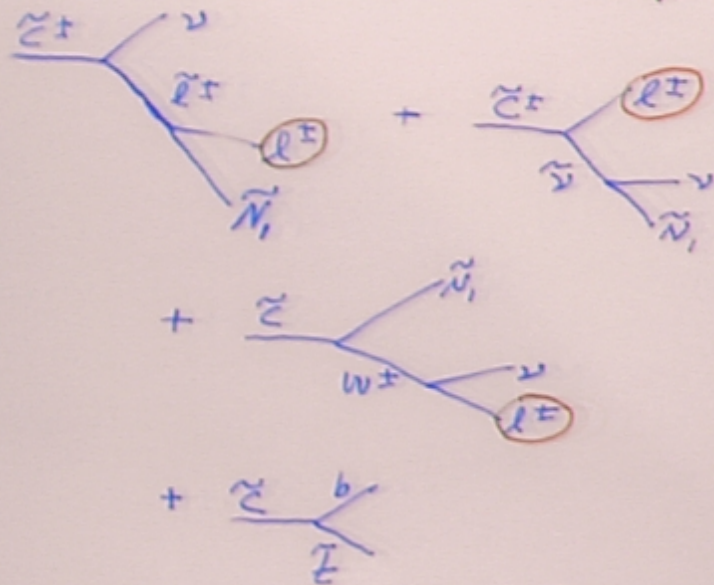
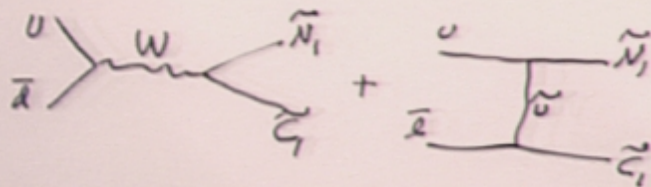
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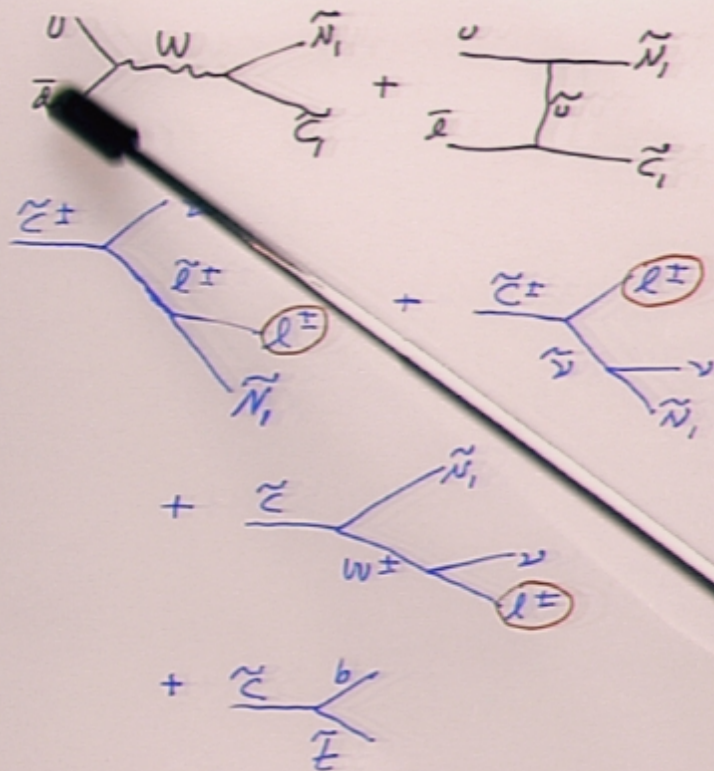
• $\tilde{N}_1 + \tilde{C}_1$



SO SIGNATURE ONE PROMPT $l^\pm + \cancel{E_T}$

Background $W^\pm \rightarrow \nu\bar{\nu}$
 $L \rightarrow l\nu$

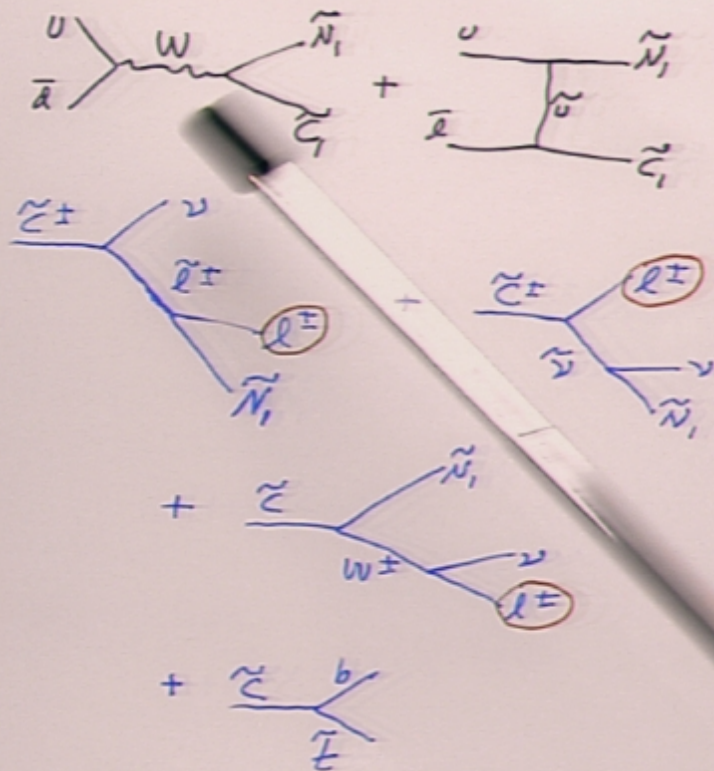
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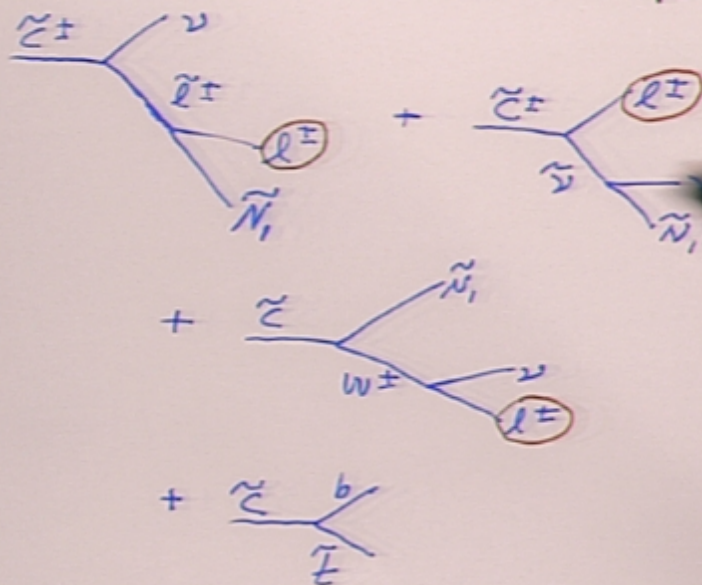
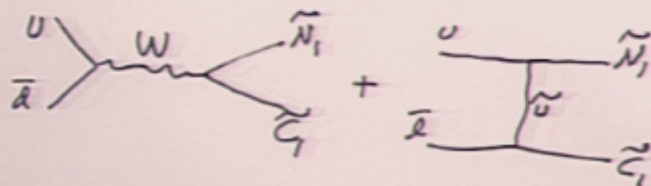
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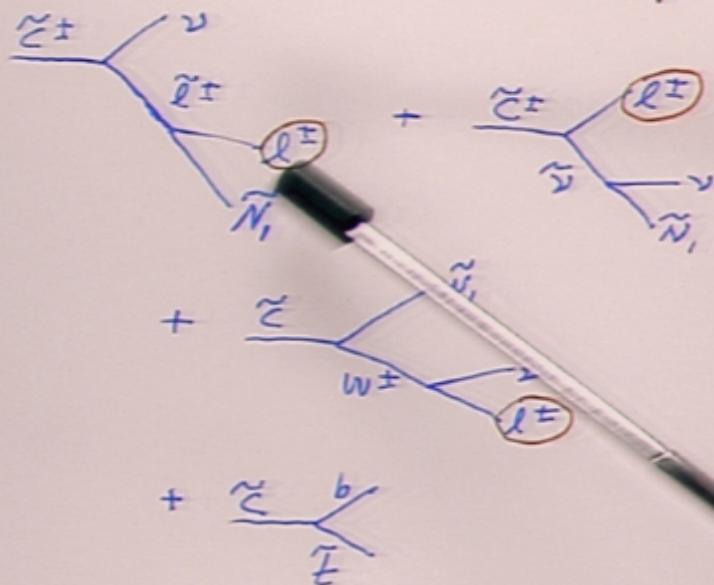
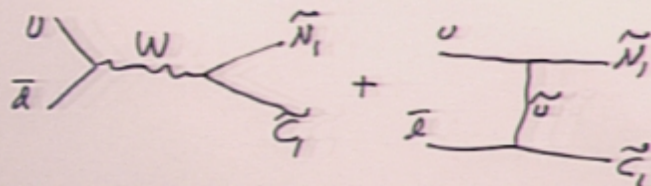
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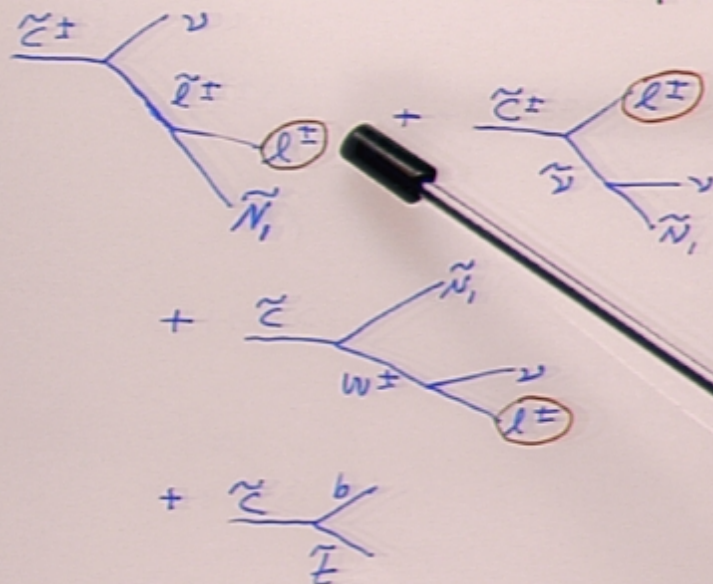
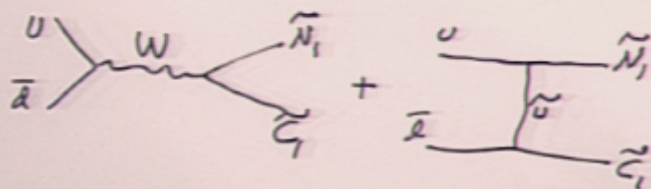
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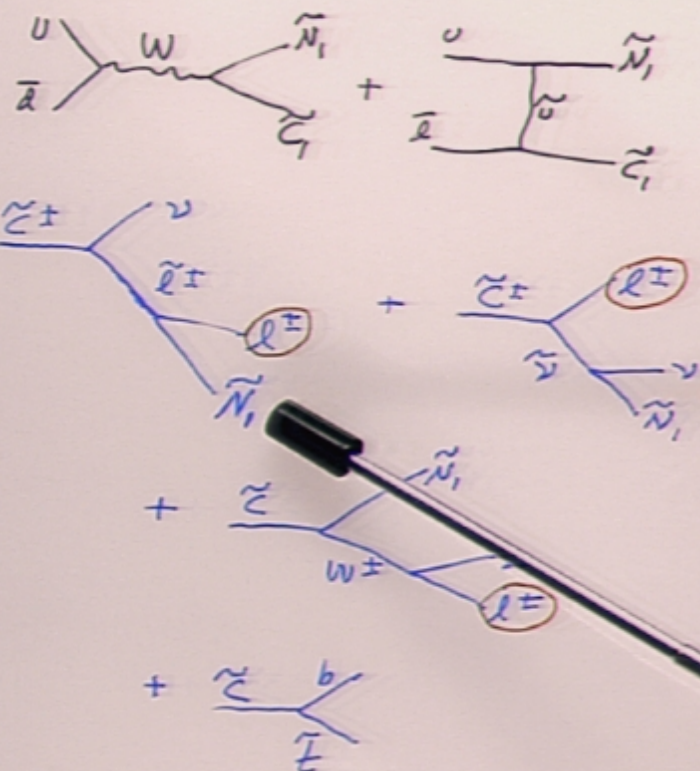
• $\tilde{N}_1 + \tilde{C}_1$



SO SIGNATURE ONE PROMPT $l^\pm + \cancel{E_T}$

Background $WZ \rightarrow \nu\nu$
 $\rightarrow l\nu$

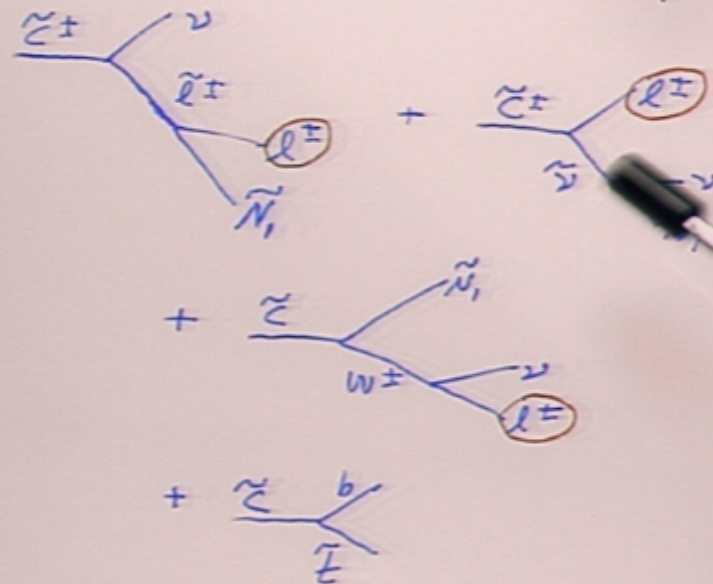
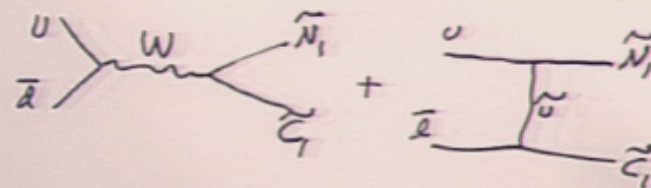
• $\tilde{N}_1 + \tilde{C}_1$



SO SIGNATURE ONE PROMPT $l^\pm + \cancel{E}_T$

Background $WZ \rightarrow \nu\bar{\nu}$
 $L \rightarrow l\nu$

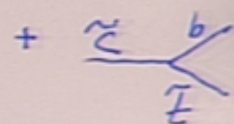
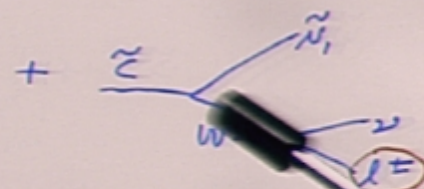
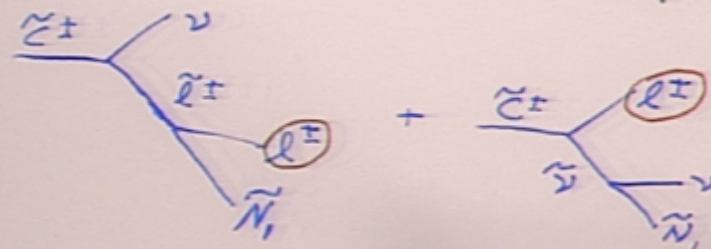
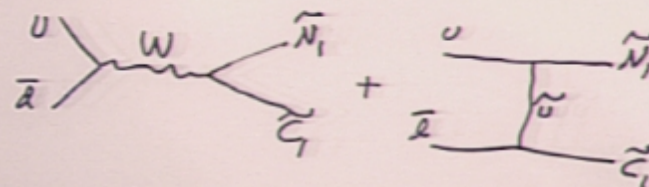
• $\tilde{N}_1 + \tilde{C}_1$



SO SIGNATURE ONE PROMPT $l^\pm + \cancel{E_T}$

Background $WZ \rightarrow \nu\bar{\nu}$
 $L \rightarrow l\nu$

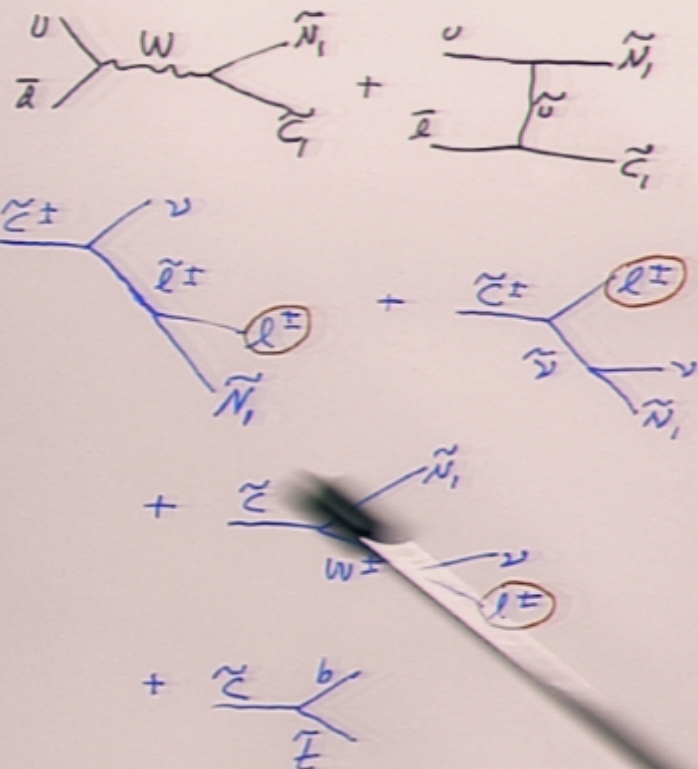
• $\tilde{N}_1 + \tilde{C}_1$



SO SIGNATURE ONE PROMPT $l^\pm + \cancel{E_T}$

Background $WZ \rightarrow \nu\bar{\nu}$
 $L \rightarrow l\nu$

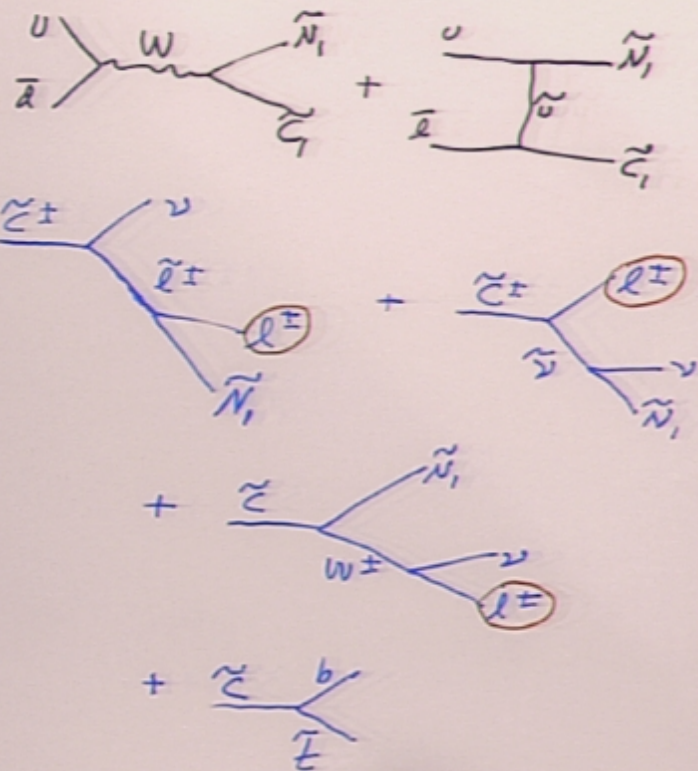
$$\bullet \tilde{N}_1 + \tilde{C}_1$$



SO SIGNATURE ONE PROMPT $l^\pm + \cancel{E}_T$

Background $W Z \rightarrow \nu \nu$
 $L \rightarrow l \nu$

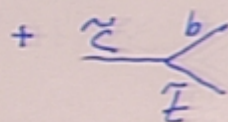
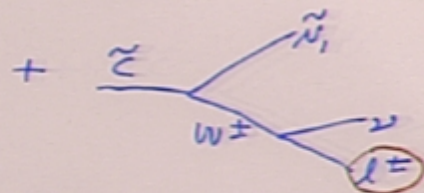
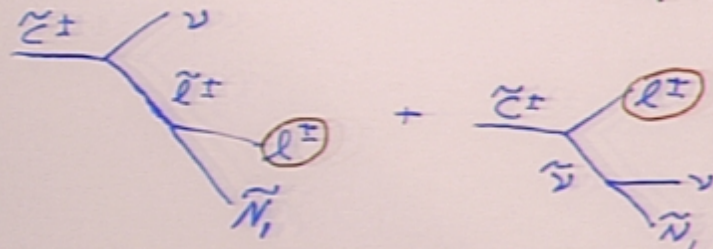
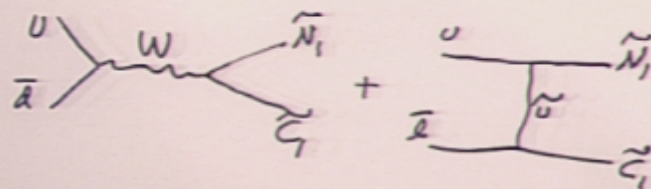
• $\tilde{N}_1 + \tilde{C}_1$



SO SIGNATURE ONE PROMPT $l^\pm + \cancel{E_T}$

Background $W Z \rightarrow \nu \nu$
 $L \rightarrow l \nu$

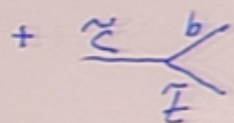
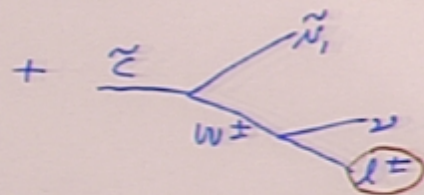
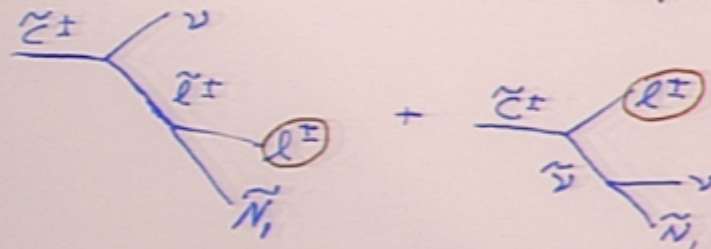
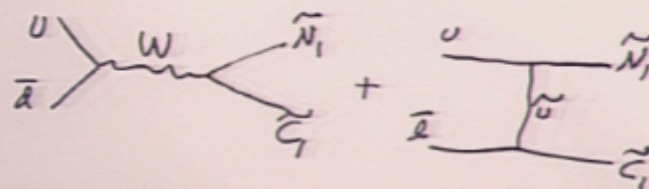
• $\tilde{N}_1 + \tilde{C}_1$



SO SIGNATURE ONE PROMPT $l^\pm + \cancel{E_T}$

Background $W \rightarrow \nu \bar{\nu}$
 $L \rightarrow l \nu$

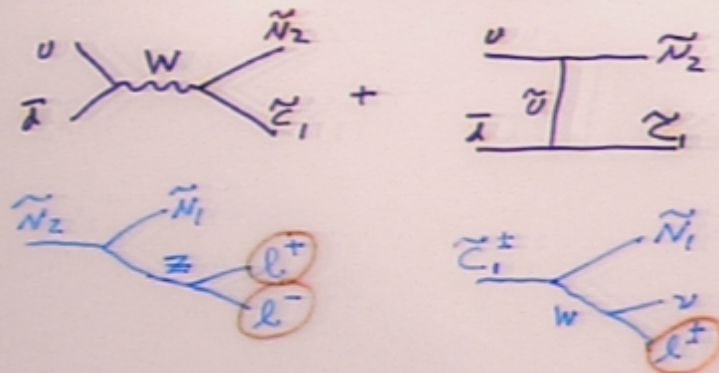
• $\tilde{N}_1 + \tilde{C}_1$



SO SIGNATURE ONE PROMPT $l^\pm + \cancel{E}_T$

Background $W \rightarrow \nu \bar{\nu}$
 $L \rightarrow l \nu$

• $\tilde{N}_2 + \tilde{C}_1$ -- SAME PRODUCTION



$\Rightarrow$ SIGNATURE 3 CHARGED LEPTONS,
NO PROMPT JETS, ~~$\cancel{X}$~~

-- NOTE, IF $\tilde{N}_2 \rightarrow \tilde{N}_1 + \gamma$, THEN $\gamma + l^\pm$

• VERY CLEAN AT HADRON COLLIDERS

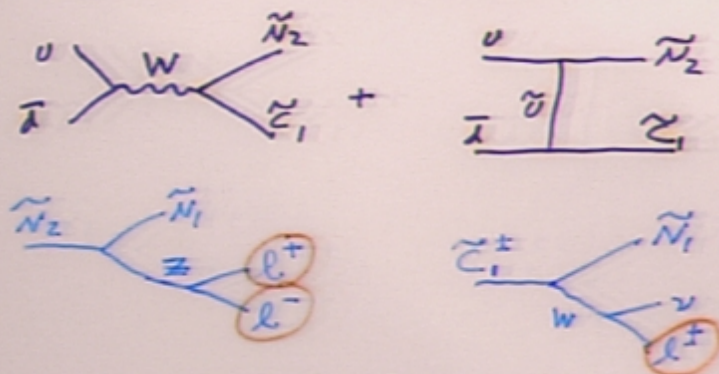
"TRILEPTONS"

• $\sigma \times BR$, KINEMATICS DEPENDS ON $m_{\tilde{C}_1}, m_{\tilde{N}_2},$
 $m_{\tilde{N}_1}, m_{\tilde{u}}, BR(\tilde{C}_1)$

• SM BACKGROUND?

$W^\pm \rightarrow l^\pm \nu, Z \rightarrow l^\pm l^\mp$

• $\tilde{N}_2 + \tilde{C}_1$ -- SAME PRODUCTION



⇒ SIGNATURE 3 CHARGED LEPTONS,
NO PROMPT JETS, $\cancel{E_T}$

-- NOTE, IF $\tilde{C}_1 \rightarrow \tilde{N}_1 + \gamma$, THEN $\gamma + l^\pm$

• VERY CLEAN AT HADRON COLLIDERS

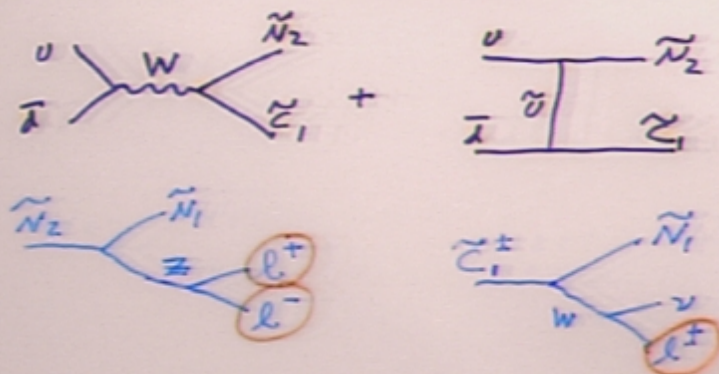
"TRILEPTONS"

• $\sigma \times BR$, KINEMATICS DEPENDS ON $m_{\tilde{C}_1}, m_{\tilde{N}_2},$
 $m_{\tilde{N}_1}, m_{\tilde{U}}, BR(\tilde{C}_1)$

• SM BACKGROUND?

$W^\pm \rightarrow l^\pm \nu, Z \rightarrow l^\pm l^\mp$

• $\tilde{N}_2 + \tilde{C}_1$ --- SAME PRODUCTION



$\Rightarrow$ SIGNATURE 3 CHARGED LEPTONS,
NO PROMPT JETS, $\cancel{E}_T$

-- NOTE, IF $\tilde{N}_2 \rightarrow \tilde{N}_1 + \gamma$, THEN $\gamma + l^\pm$

• VERY CLEAN AT HADRON COLLIDERS

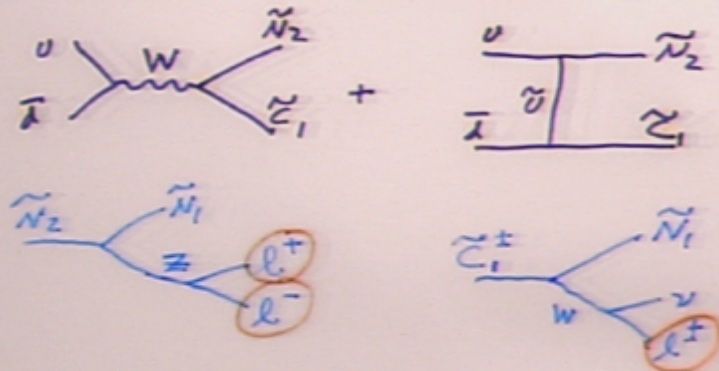
"TRILEPTONS"

• $\sigma \times BR$, KINEMATICS DEPENDS ON $m_{\tilde{C}_1}, m_{\tilde{N}_2},$
 $m_{\tilde{N}_1}, m_{\tilde{u}}, BR(\tilde{C}_1)$

• SM BACKGROUND?

$W^\pm \rightarrow l^\pm \nu, Z \rightarrow l^\pm l^\mp$

• $\tilde{N}_2 + \tilde{C}_1$ --- SAME PRODUCTION



$\Rightarrow$ SIGNATURE 3 CHARGED LEPTONS,
NO PROMPT JETS, ~~$\tilde{g}$~~

-- NOTE, IF $\tilde{N}_2 \rightarrow \tilde{N}_1 + \gamma$, THEN $\gamma + l^\pm$

• VERY CLEAN AT HADRON COLLIDERS

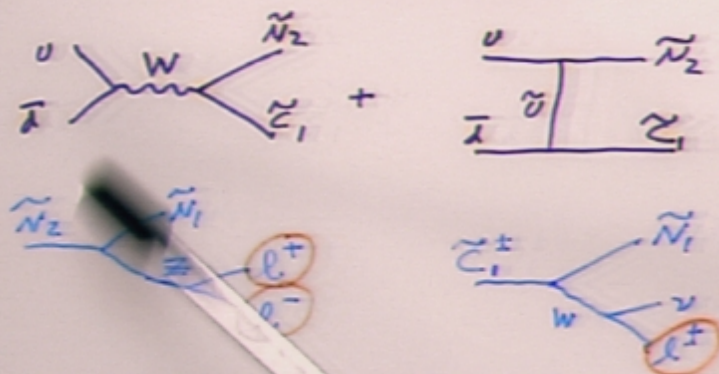
"TRILEPTONS"

• $\sigma \times BR$, KINEMATICS DEPENDS ON $m_{\tilde{C}_1}, m_{\tilde{N}_2},$
 $m_{\tilde{N}_1}, m_{\tilde{g}}, BR(\tilde{C}_1)$

• SM BACKGROUND?

$W^\pm \rightarrow l^\pm \nu, Z \rightarrow l^\pm l^\mp$

• $\tilde{N}_2 + \tilde{C}_1$ --- SAME PRODUCTION



⇒ SIGNATURE 3 CHARGED LEPTONS,
NO PROMPT JETS, $\cancel{E}_T$

--- NOTE, IF $\tilde{N}_2 \rightarrow \tilde{N}_1 + \gamma$, THEN $\gamma + l^\pm$

• VERY CLEAN AT HADRON COLLIDERS

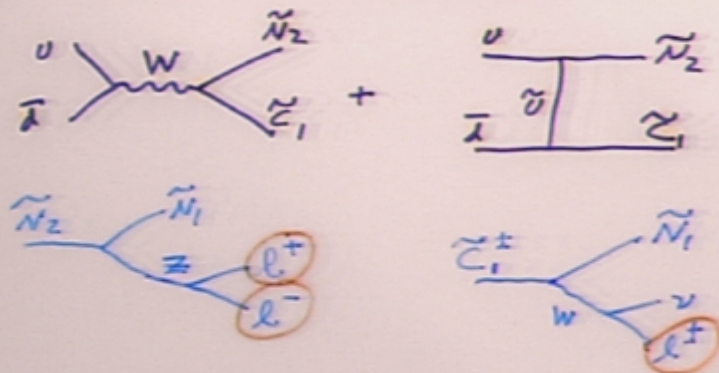
"TRILEPTONS"

• $\sigma \times BR$, KINEMATICS DEPENDS ON $m_{\tilde{C}_1}, m_{\tilde{N}_2},$
 $m_{\tilde{N}_1}, m_{\tilde{U}}, BR(\tilde{C}_1)$

• SM BACKGROUND?

$W^\pm \rightarrow l^\pm \nu, Z \rightarrow l^\pm l^\mp$

• $\tilde{N}_2 + \tilde{C}_1$ --- SAME PRODUCTION



$\Rightarrow$ SIGNATURE 3 CHARGED LEPTONS,
NO PROMPT JETS, ~~$\cancel{X}$~~

-- NOTE, IF $\tilde{N}_2 \rightarrow \tilde{N}_1 + \gamma$, THEN $\gamma + l^\pm$

• VERY CLEAN AT HADRON COLLIDERS

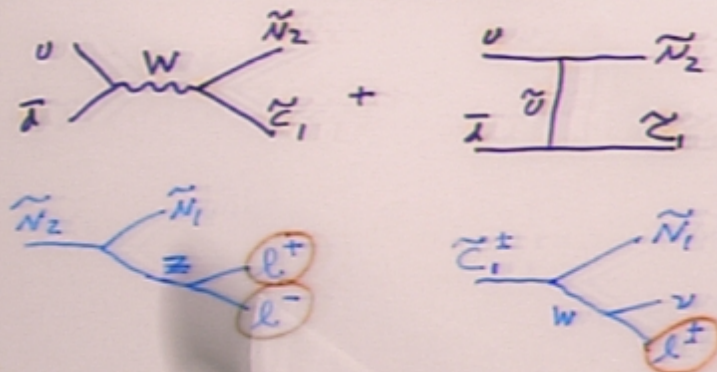
"TRILEPTONS"

• $\sigma \times BR$, KINEMATICS DEPENDS ON $m_{\tilde{C}_1}, m_{\tilde{N}_2},$
 $m_{\tilde{N}_1}, m_{\tilde{g}}, (BR \tilde{C}_1)$

• SM BACKGROUND?

$W^\pm \rightarrow l^\pm \nu, Z \rightarrow l^\pm l^\mp$

• $\tilde{N}_2 + \tilde{C}_1$ --- SAME PRODUCTION



$\Rightarrow$ SIGNATURE 3 CHARGED LEPTONS,
NO PROMPT JETS, ~~$\cancel{X}$~~

-- NOTE, IF $\tilde{N}_2 \rightarrow \tilde{N}_1 + \gamma$, THEN $\gamma + l^\pm$

• VERY CLEAN AT HADRON COLLIDERS

"TRILEPTONS"

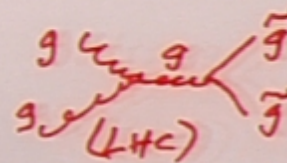
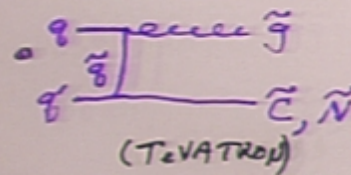
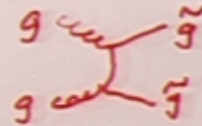
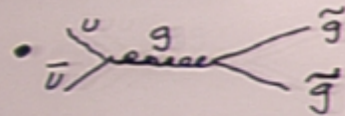
• $\sigma \times BR$, KINEMATICS DEPENDS ON $m_{\tilde{C}_1}, m_{\tilde{N}_2},$
 $m_{\tilde{N}_1}, m_{\tilde{u}}, BR(\tilde{C}_1)$

• SM BACKGROUND?

$W^\pm \rightarrow l^\pm \nu, Z \rightarrow l^\pm l^\mp$

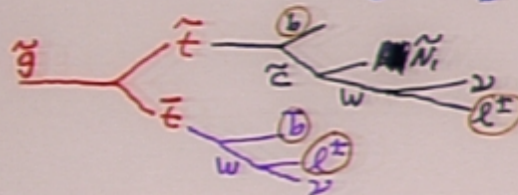
GLUINOS

* PRODUCTION

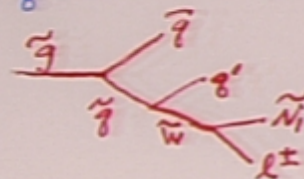


* DECAY

- SUPPOSE $m_{\tilde{g}} > m_t + m_{\tilde{t}}$ OR $> m_b + m_{\tilde{b}}$



- $\tilde{g} < \tilde{q}$



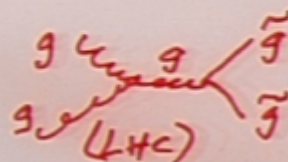
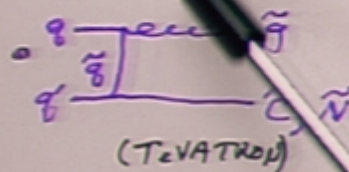
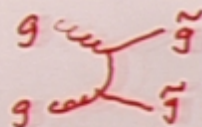
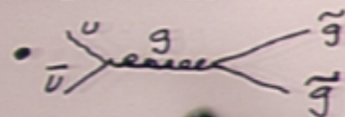
$\Rightarrow$ JETS + $l^\pm$ + $\cancel{E}_T$

ETC

* $\tilde{g}$ MAJORANA, SO $\tilde{g} = \tilde{g}^\dagger \Rightarrow$ EQUAL PROBABILITY OF LIKE-SIGN $l^\pm$ OR OPPOSITE SIGN $l^\pm$ (OR $b, \bar{b}$)! -- NO SM BACKGROUND!

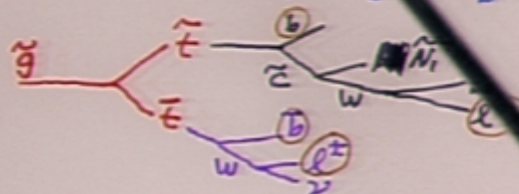
GLUINOS

* PRODUCTION

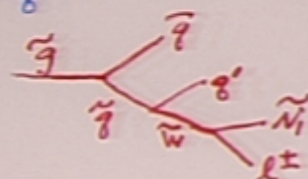


* DECAY

- SUPPOSE $m_{\tilde{g}} > m_t + m_{\tilde{t}}$ OR $> m_b + m_{\tilde{b}}$



- $\tilde{g} < \tilde{q}$



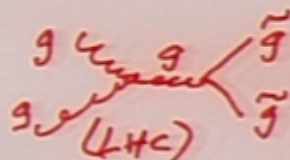
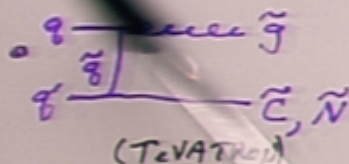
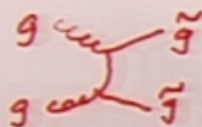
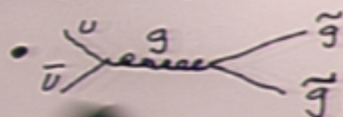
$\Rightarrow$ JETS + χ^0 + $\chi^\pm$

ETC

* $\tilde{g}$ MAJORANA, SO $\tilde{g} = \bar{\tilde{g}} \Rightarrow$ EQUAL PROBABILITY OF LIKE-SIGN $l^\pm$ OR OPPOSITE SIGN $l^\pm$ (OR $b, \bar{b}$)! -- NO SM BACKGROUND!

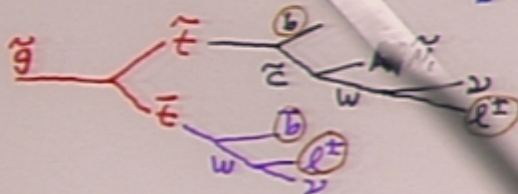
GLUINOS

* PRODUCTION

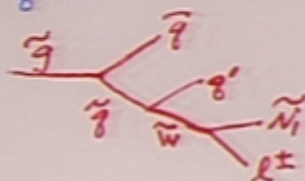


* DECAY

- SUPPOSE $m_{\tilde{g}} > m_t + m_{\tilde{t}}$ OR $> m_b + m_{\tilde{b}}$



- $\tilde{g} < \tilde{q}$



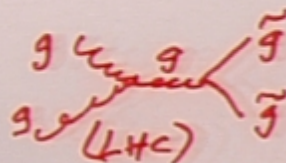
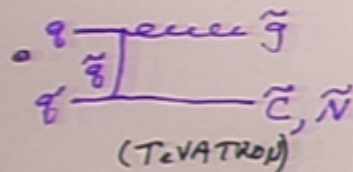
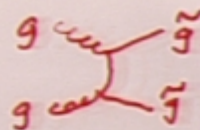
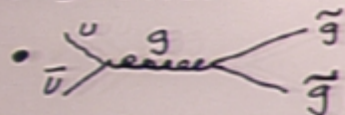
$\Rightarrow$ JETS + $l^\pm$ + E_T

ETC

* $\tilde{g}$ MAJORANA, SO $\tilde{g} = \bar{\tilde{g}}$ $\Rightarrow$ EQUAL PROBABILITY OF LIKE-SIGN $l^\pm$ OR OPPOSITE SIGN $l^\pm$ (OR $b, \bar{b}$)! -- NO SM BACKGROUND!

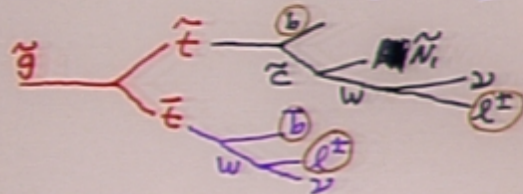
GLUINOS

* PRODUCTION

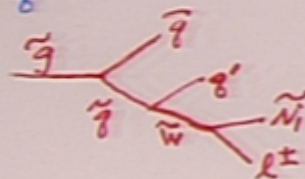


* DECAY

- SUPPOSE $m_{\tilde{g}} > m_t + m_{\tilde{t}}$ OR $> m_b + m_{\tilde{b}}$



- $\tilde{g} < \tilde{q}$



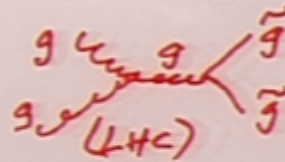
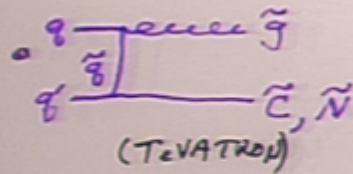
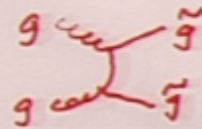
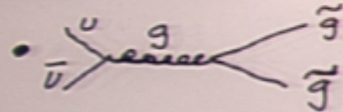
$\Rightarrow$ JETS + $l^\pm$ + $\bar{\nu}_\tau$

ETC

* $\tilde{g}$ MAJORANA, SO $\tilde{g} = \bar{\tilde{g}}$ $\Rightarrow$ EQUAL PROBABILITY OF LIKE-SIGN $l^\pm$ OR OPPOSITE SIGN $l^\pm$ (OR $b, \bar{b}$)! --NO SM BACKGROUND!

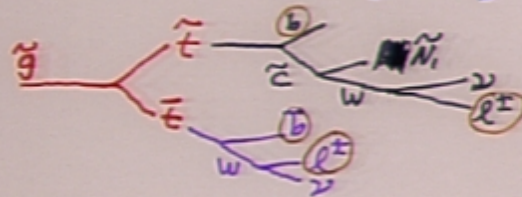
GLUINOS

* PRODUCTION

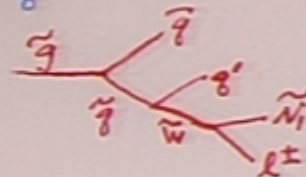


* DECAY

- SUPPOSE $m_{\tilde{g}} > m_t + m_{\tilde{t}}$ OR $> m_b + m_{\tilde{b}}$



- $\tilde{g} < \tilde{q}$



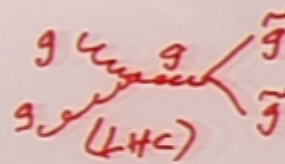
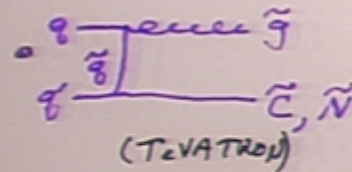
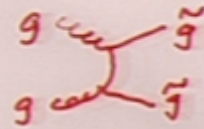
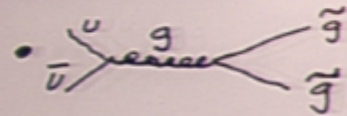
$\Rightarrow$ JETS + $l^\pm$ + $\bar{\nu}_l$

ETC

* $\tilde{g}$ MAJORANA, SO $\tilde{g} = \tilde{g}^\dagger \Rightarrow$ EQUAL PROBABILITY OF LIKE-SIGN $l^\pm$ OR OPPOSITE SIGN $l^\pm$ (OR $b, \bar{b}$)! -- NO SM BACKGROUND!

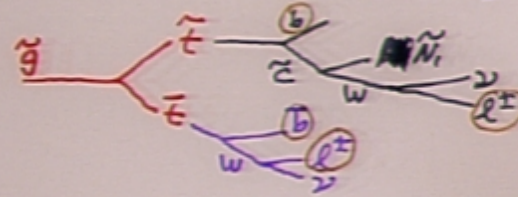
GLUINOS

* PRODUCTION

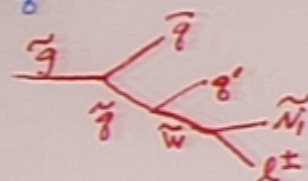


* DECAY

- SUPPOSE $m_{\tilde{g}} > m_t + m_{\tilde{b}}$ OR $> m_b + m_{\tilde{t}}$



- $\tilde{g} < \tilde{q}$



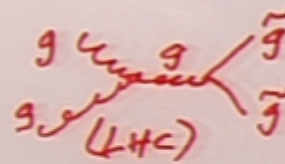
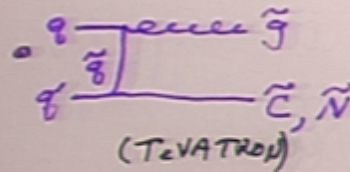
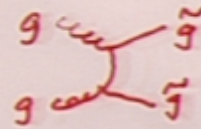
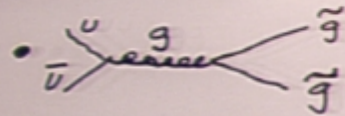
$\Rightarrow$ JETS + $l^\pm$ + $\cancel{E}_T$

ETC

* $\tilde{g}$ MAJORANA, SO $\tilde{g} = \tilde{g}^\dagger \Rightarrow$ EQUAL PROBABILITY OF LIKE-SIGN $l^\pm$ OR OPPOSITE SIGN $l^\pm$ (OR $b, \bar{b}$)! -- NO SM BACKGROUND!

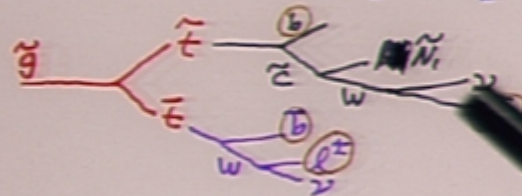
GLUINOS

* PRODUCTION

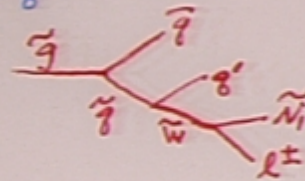


* DECAY

- SUPPOSE $m_{\tilde{g}} > m_t + m_{\tilde{t}}$ OR $> m_b + m_{\tilde{b}}$



- $\tilde{g} < \tilde{q}$



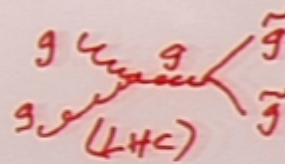
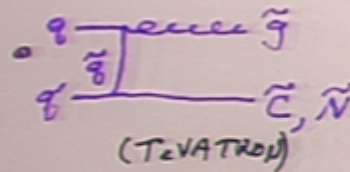
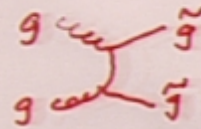
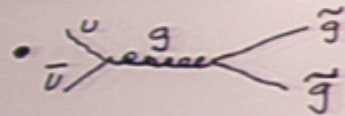
$\Rightarrow$ JETS + $l^\pm$ + $\bar{\nu}_\tau$

ETC

* $\tilde{g}$ MAJORANA, SO $\tilde{g} = \bar{\tilde{g}}$ $\Rightarrow$ EQUAL PROBABILITY OF LIKE-SIGN $l^\pm$ OR OPPOSITE SIGN $l^\pm$ (OR $b, \bar{b}$)! -- NO SM BACKGROUND!

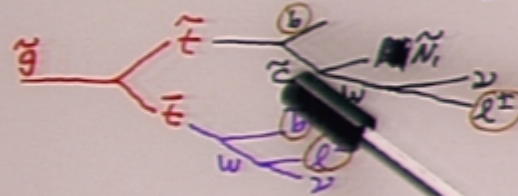
GLUINOS

* PRODUCTION

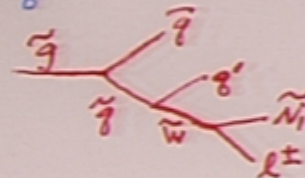


* DECAY

- SUPPOSE $m_{\tilde{g}} > m_t + m_{\tilde{t}}$ OR $> m_b + m_{\tilde{b}}$



- $\tilde{g} < \tilde{q}$



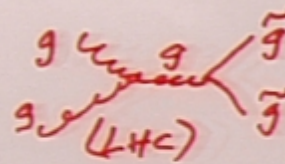
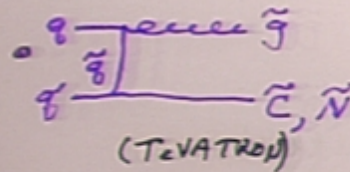
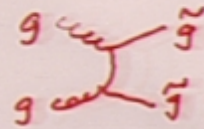
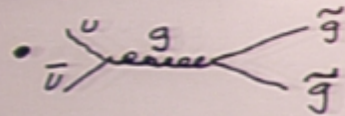
$\Rightarrow$ JETS + $l^\pm + \Sigma \pi$

ETC

- * $\tilde{g}$ MAJORANA, SO $\tilde{g} = \tilde{g}^\dagger \Rightarrow$ EQUAL PROBABILITY OF LIKE-SIGN $l^\pm$ OR OPPOSITE SIGN $l^\pm$ (OR $b, \bar{b}$)! -- NO SM BACKGROUND!

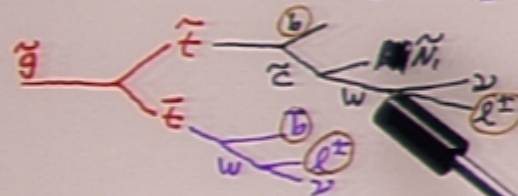
GLUINOS

* PRODUCTION

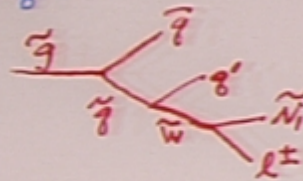


* DECAY

- SUPPOSE $m_{\tilde{g}} > m_t + m_{\tilde{t}}$ OR $> m_b + m_{\tilde{b}}$



- $\tilde{g} < \tilde{g}$



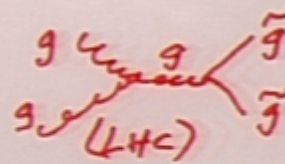
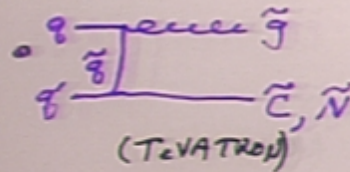
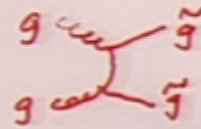
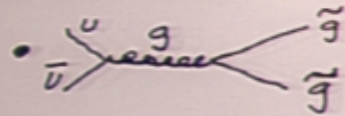
$\Rightarrow$ JETS + $l^\pm$ + $\Sigma \nu$

ETC

* $\tilde{g}$ MAJORANA, SO $\tilde{g} = \bar{\tilde{g}}$ $\Rightarrow$ EQUAL PROBABILITY OF LIKE-SIGN $l^\pm$ OR OPPOSITE SIGN $l^\pm$ (OR $b, \bar{b}$)! -- NO SM BACKGROUND!

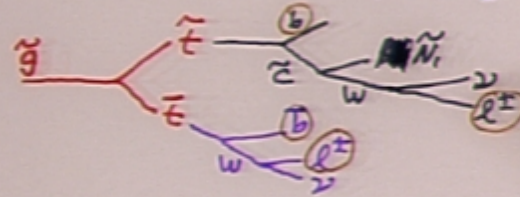
GLUINOS

* PRODUCTION

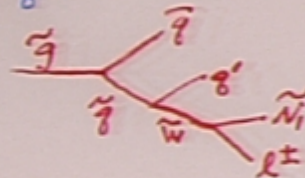


* DECAY

- SUPPOSE $m_{\tilde{g}} > m_t + m_{\tilde{t}}$ OR $> m_b + m_{\tilde{b}}$



- $\tilde{g} < \tilde{q}$



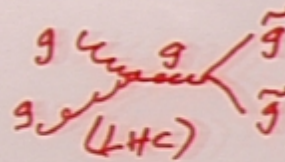
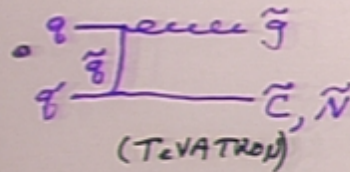
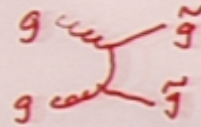
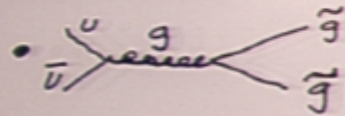
$\Rightarrow$ JETS + $l^\pm$ + $\Sigma \pi$

ETC

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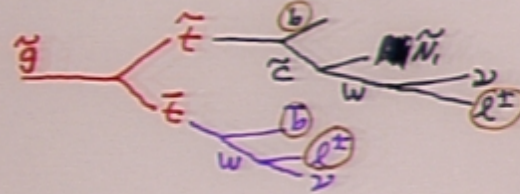
GLUINOS

* PRODUCTION

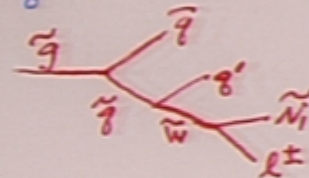


* DECAY

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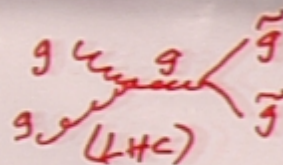
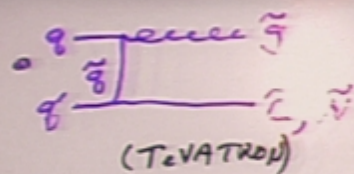
- $\tilde{g} < \tilde{q}$



$\Rightarrow$ JETS + $l^\pm$ + $\Sigma \tau$

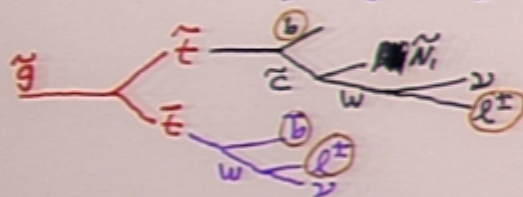
ETC

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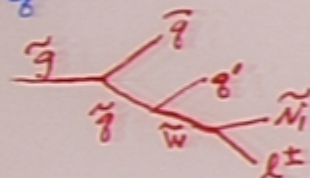


* DECAY

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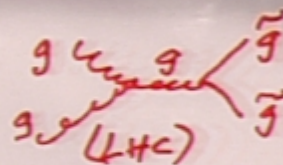
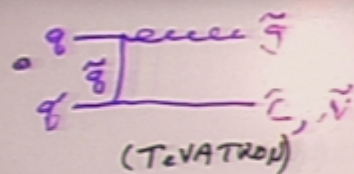
- $\tilde{g} < \tilde{q}$



$\Rightarrow$ JETS + $l^\pm$ + $\cancel{E}_T$

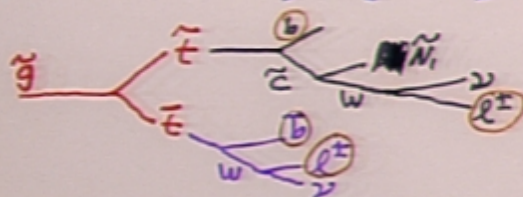
ETC

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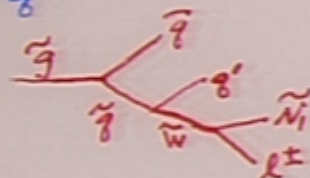


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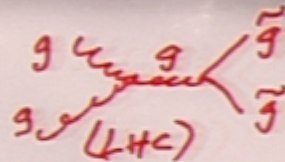
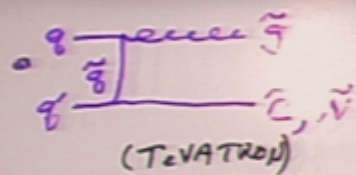
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$\Rightarrow$ JETS + $l^\pm$ + $\cancel{E}_T$

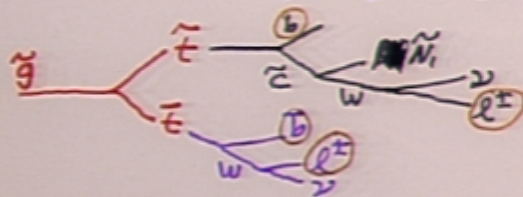
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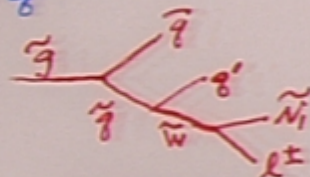


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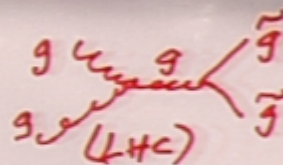
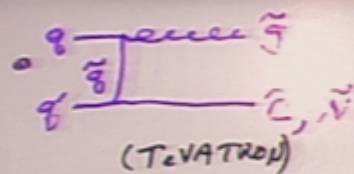
- $\tilde{g} < \tilde{q}$



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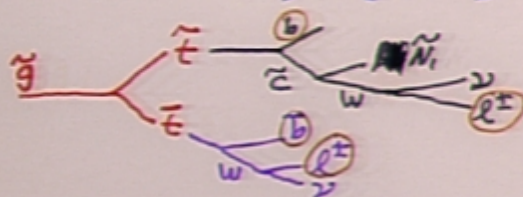
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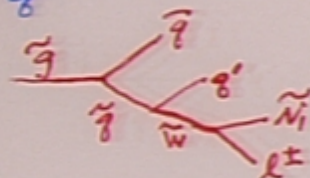


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ETC

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BENCHMARK MODELS -- DO THEY IMPLY
SUPERPARTNERS TOO HEAVY FOR
TEVATRON, LC 500?

NO

CERN, SNOWMASS

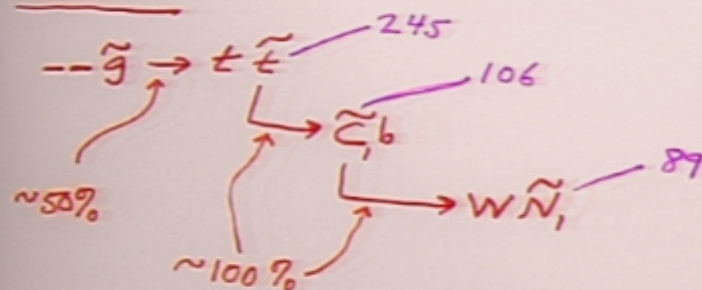
GK, LYKKEN, MRENNA
BRENT NELSON,
LIANTAO WANG,
TING WANG

— CONSTRUCT THEORY MOTIVATED MODELS
BASED ON HETEROTIC STRING

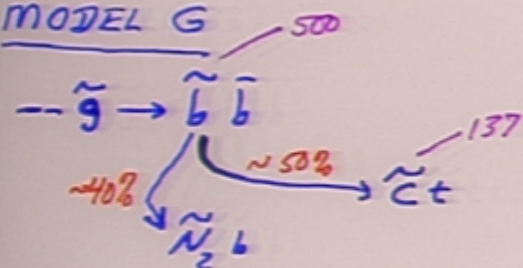
- GAUGINO CONDENSATION
- KÄHLER DILATON STABILIZATION, $V=0$
- DILATON OR MODULI DOMINATION OF SUSY
- PARTIAL HIGH SCALE GAUGE MEDIATION
- NOT FINE-TUNED
- LIGHT SUPERPARTNERS

WILLARD,
BENNETT,
WU,
NELSON

MODEL H



MODEL G

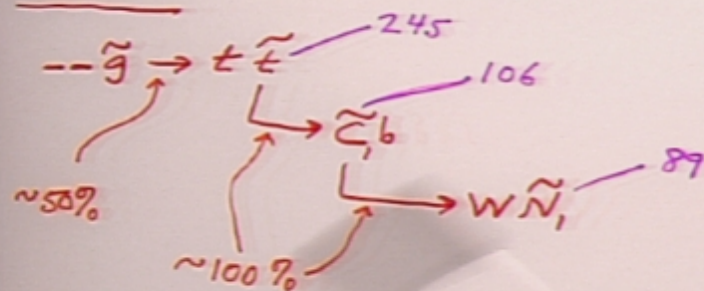


--LIGHT $\tilde{\tau}$

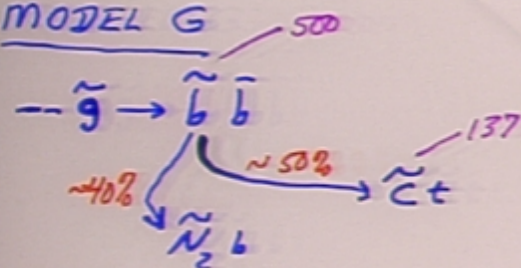
--SO $N_2 \rightarrow \tilde{\tau}\bar{\tau}$, $\tilde{c} \rightarrow \tilde{\tau}\nu_\tau$

$\Rightarrow$ 3 τ LARGE, OPPOSITE SIGN DILEPTONS,
TRILEPTONS REDUCED

MODEL H



MODEL G

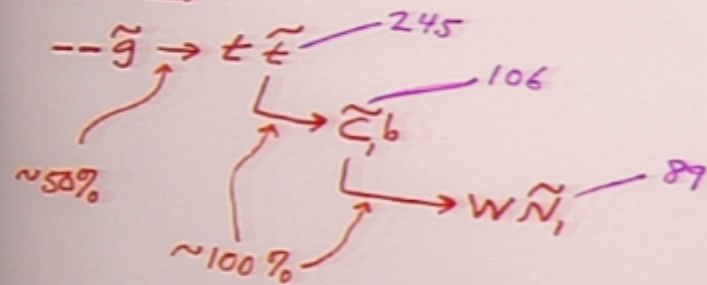


--LIGHT $\tilde{\tau}$

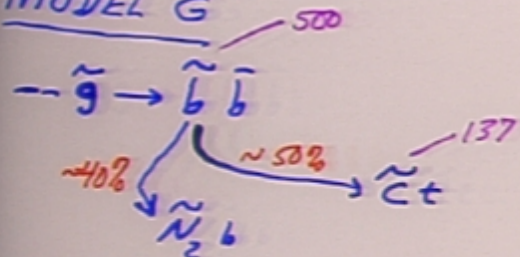
--SO $N_2 \rightarrow \tilde{\tau}\bar{\tau}$, $\tilde{c} \rightarrow \tilde{\tau}\nu_\tau$

$\Rightarrow$ 3 τ LARGE, OPPOSITE SIGN DILEPTONS,
TRILEPTONS REDUCED

MODEL H



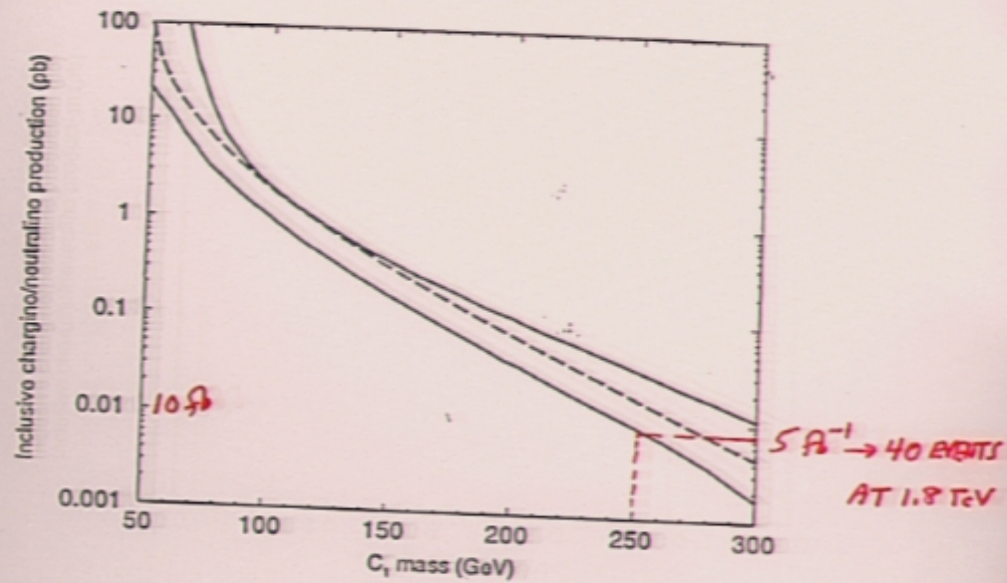
MODEL G



-- LIGHT $\tilde{\tau}$

-- SO $N_2 \rightarrow \tilde{\tau}\bar{\tau}, \tilde{c} \rightarrow \tilde{\tau}\nu_\tau$

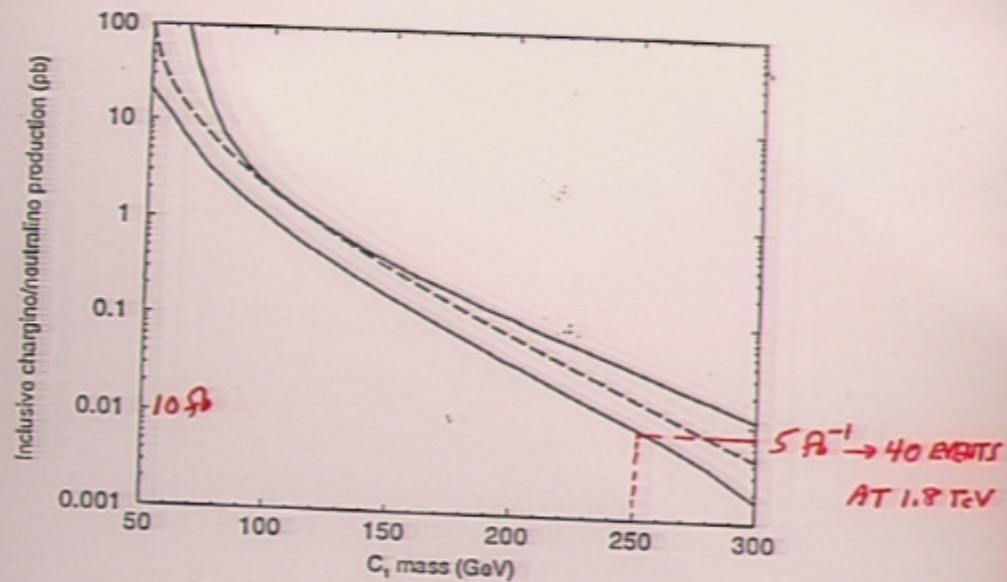
$\Rightarrow 3\tau$ LARGE, OPPOSITE SIGN DILEPTONS,
TRILEPTONS REDUCED



3: As in Fig. 4.2, but as a function of $m_{\tilde{C}_1}$. We find that even when the gaugino mass relation in Eq. (4.3) is not made, the minimum cross section is never significantly less than shown here.

Tevatron today has $\sim 1.6 \text{ fb}^{-1}$ (combining
detectors) -- increasing at rate $\sim 0.03 \text{ fb}^{-1}/\text{week}$

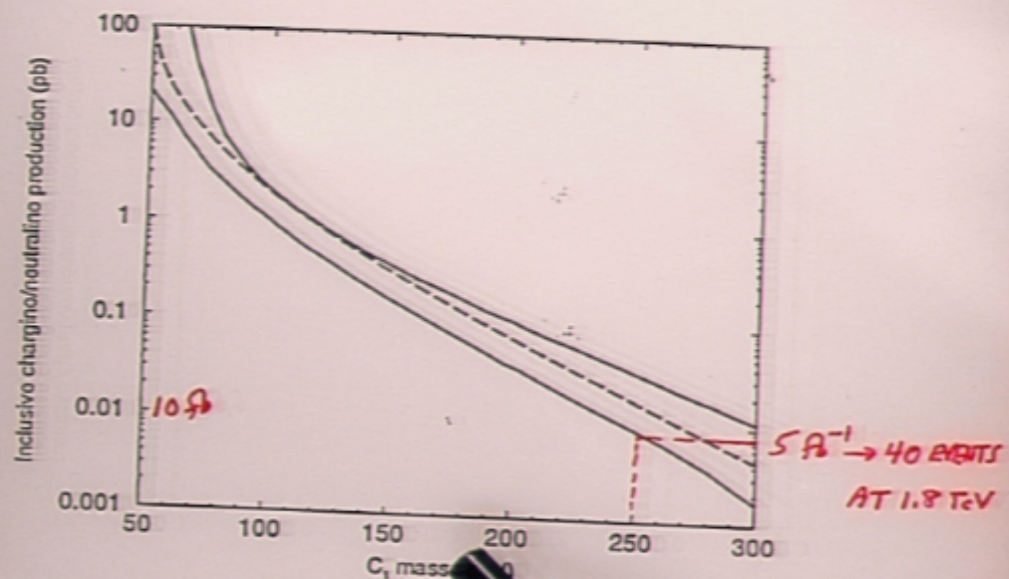
FNL.GOV $\rightarrow$ FERMI LAB TODAY $\rightarrow$ ACCELERATOR
STATUS



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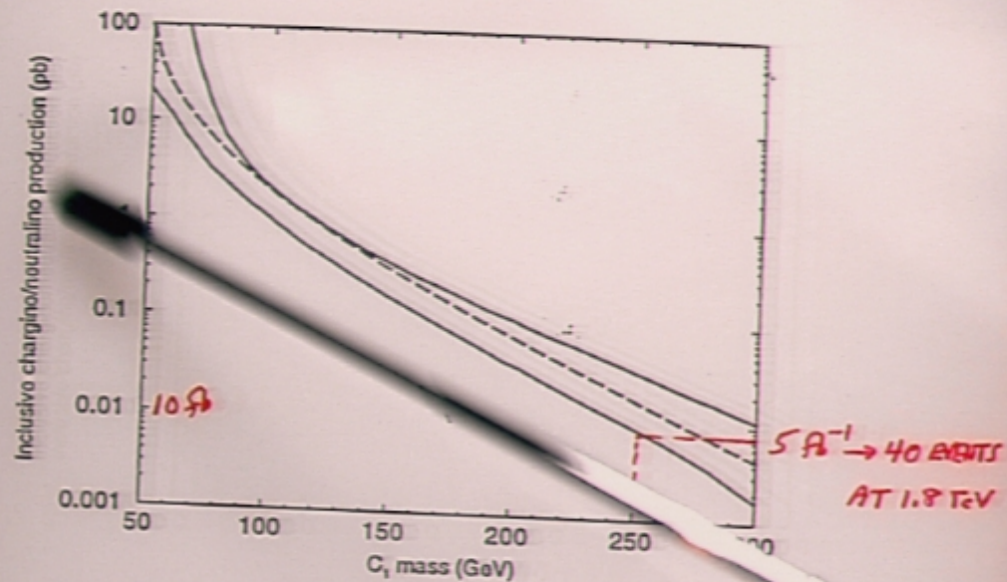
FNL.GOV $\rightarrow$ FERMI LAB TODAY $\rightarrow$ ACCELERATOR
STATUS



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Tevatron today has $\sim 1.6 \text{ fb}^{-1}$ (combining
detectors) -- increasing at rate $\sim 0.02 \text{ fb}^{-1}/\text{week}$

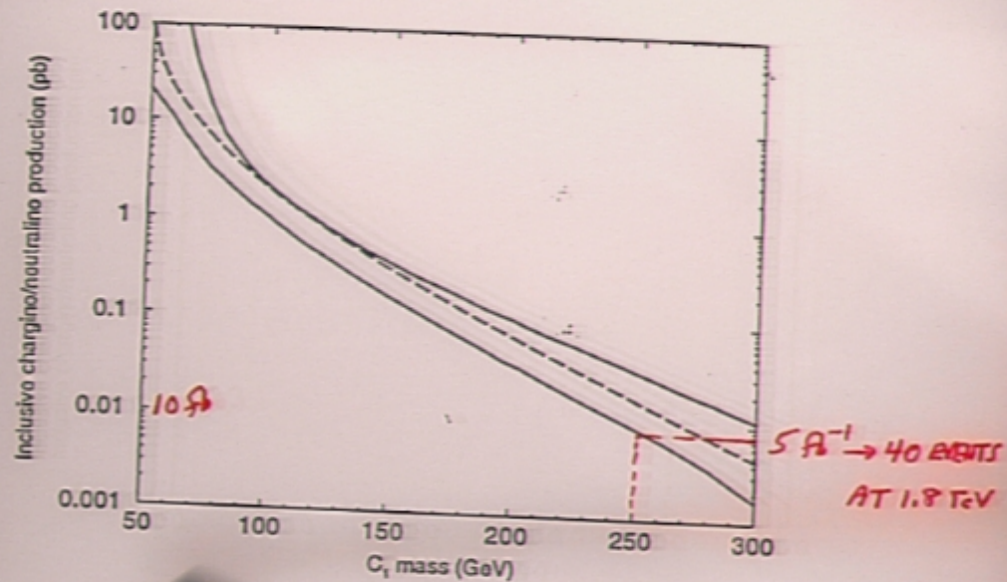
FNL.GOV $\rightarrow$ FERMI LAB TODAY $\rightarrow$ ACCELERATOR
STATUS



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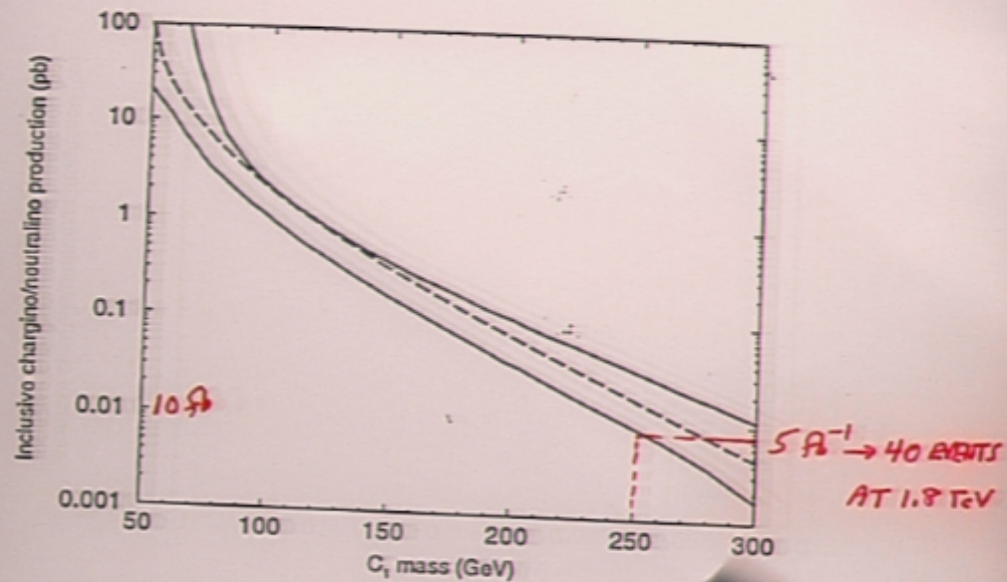
FNL.GOV $\rightarrow$ FERMI LAB TODAY $\rightarrow$ ACCELERATOR STATUS



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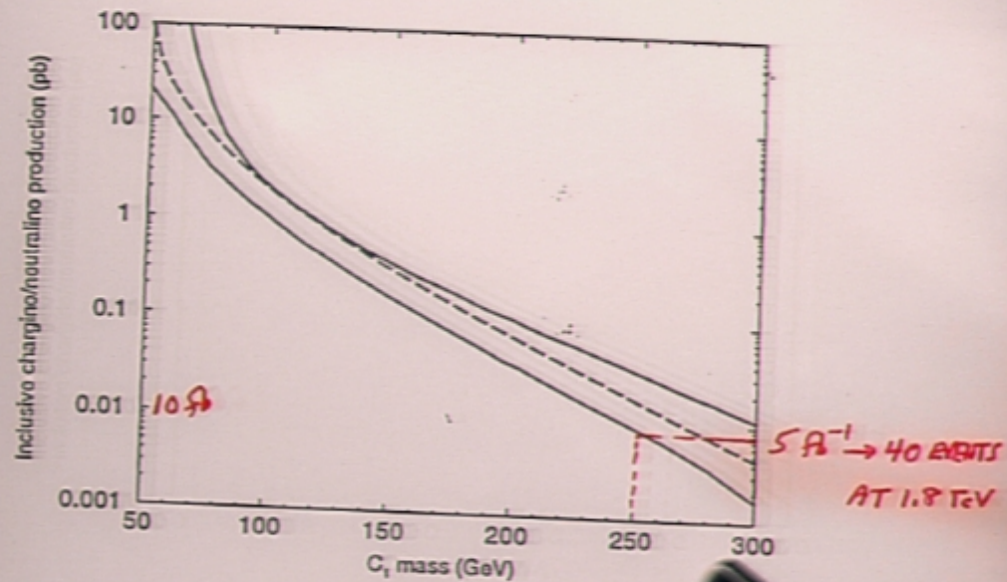
FNAL.GOV $\rightarrow$ FERMIAB TODAY $\rightarrow$ ACCELERATOR STATUS



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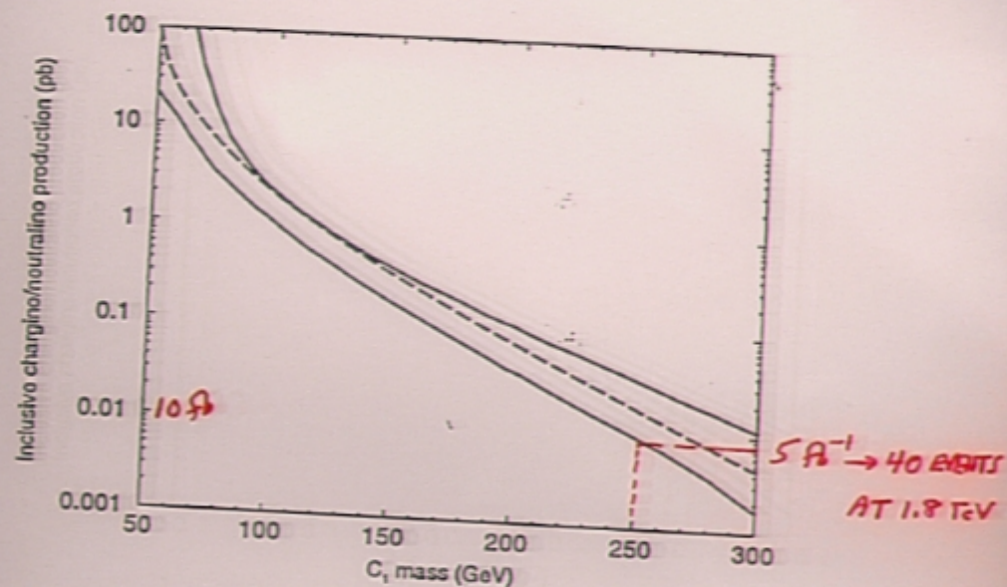
FNL.GOV $\rightarrow$ FERMIAB TODAY $\rightarrow$ ACCELERATOR STATUS



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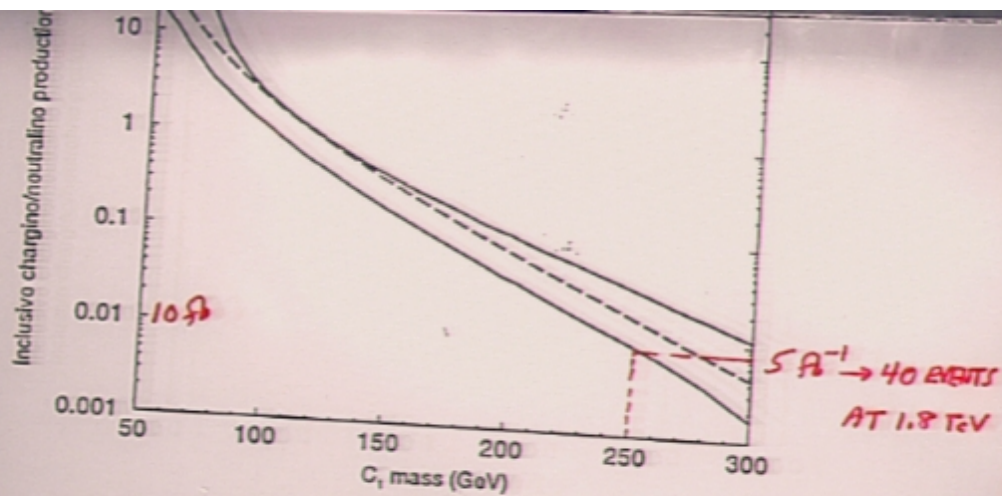
FNAL.GOV $\rightarrow$ FERMIAB TODAY $\rightarrow$ ACCELERATOR STATUS



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FNL.GOV $\rightarrow$ FERMILAB TODAY $\rightarrow$ ACCELERATOR
STATUS

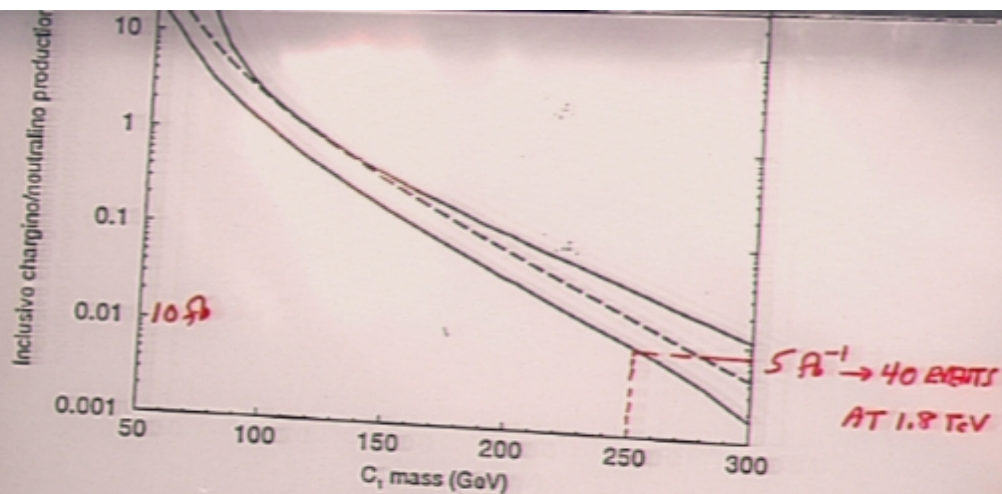


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FNAL.GOV $\rightarrow$ FERMI LAB TODAY $\rightarrow$ ACCELERATOR
STATUS

144



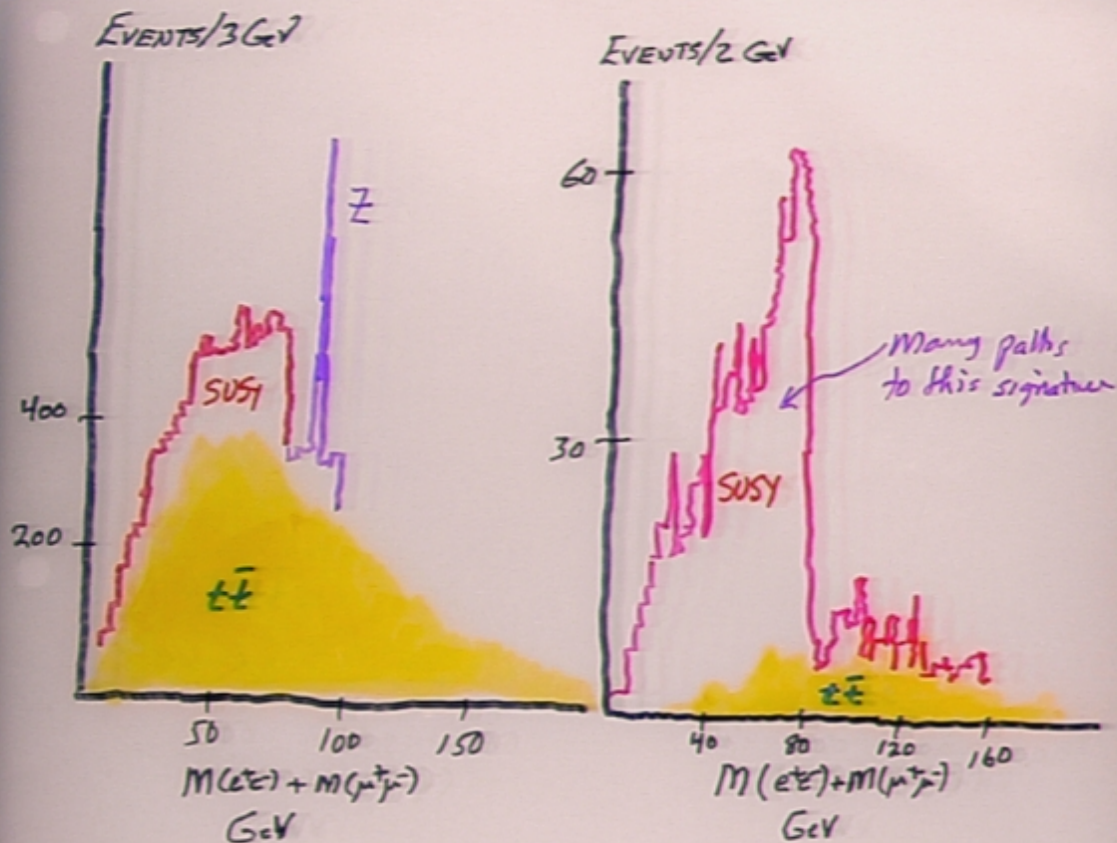
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FNAL.GOV $\rightarrow$ FERMI LAB TODAY $\rightarrow$ ACCELERATOR
STATUS

144

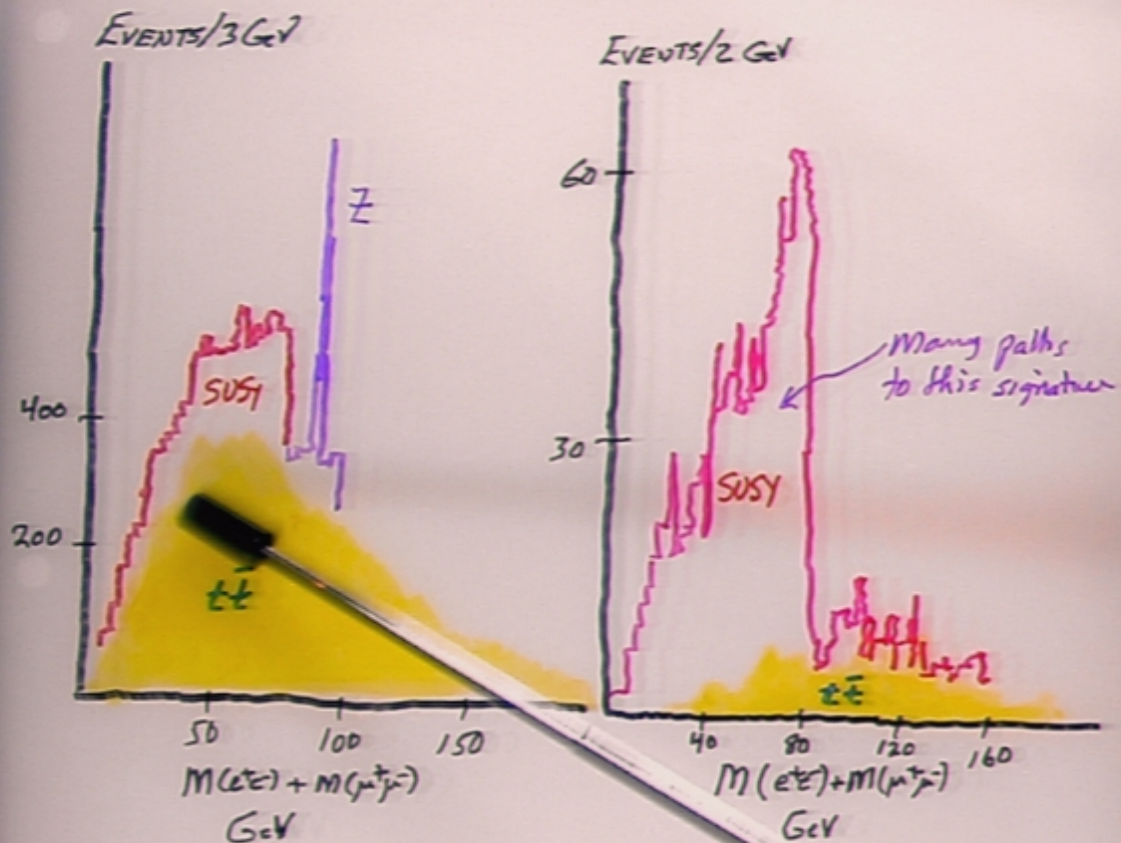
OPPOSITE SIGN DILEPTONS + $\cancel{E}_T > 100 \text{ GeV}$
 + $\geq 2 \text{ JETS } (\geq 100 \text{ GeV})$



CUTS

- form $e^+e^- + \mu^+\mu^- - e^\pm\mu^\mp$
- $M_{1\ell} \neq M_{2\ell} \pm 10 \text{ GeV}$
- $\Delta\phi(\ell^+\ell^-) \leq 150^\circ$

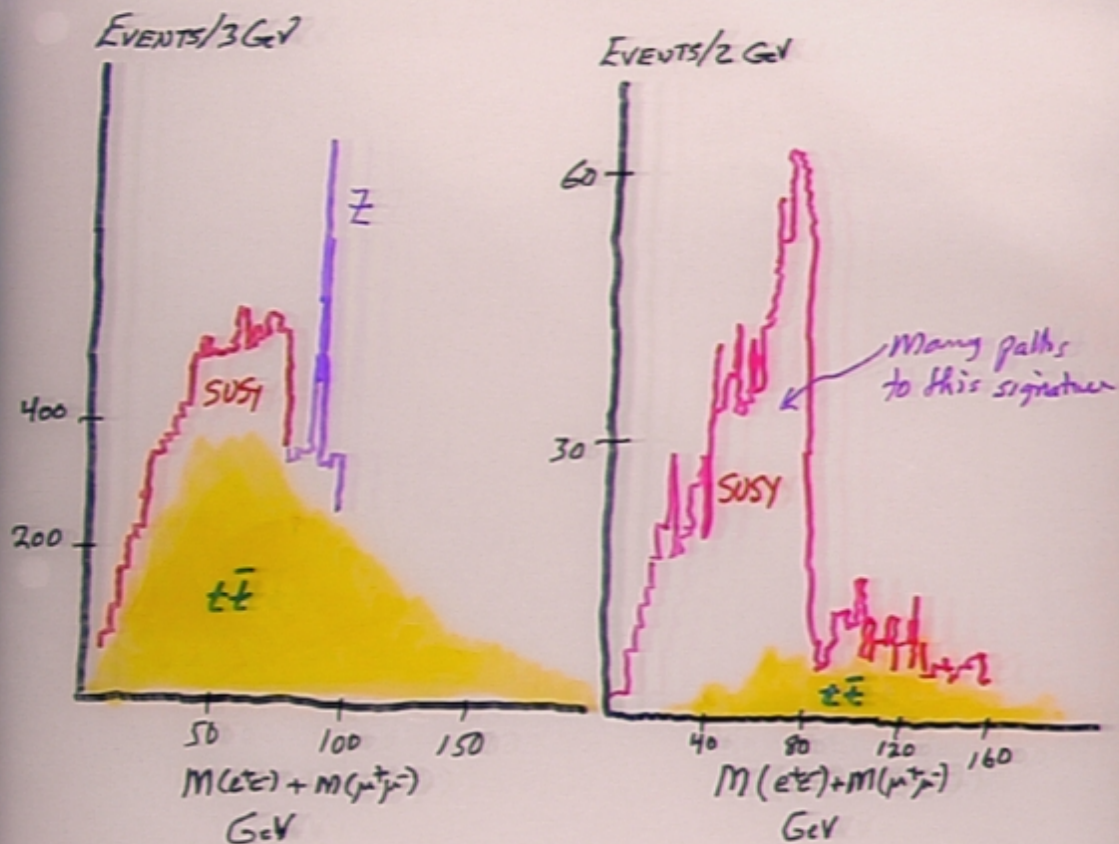
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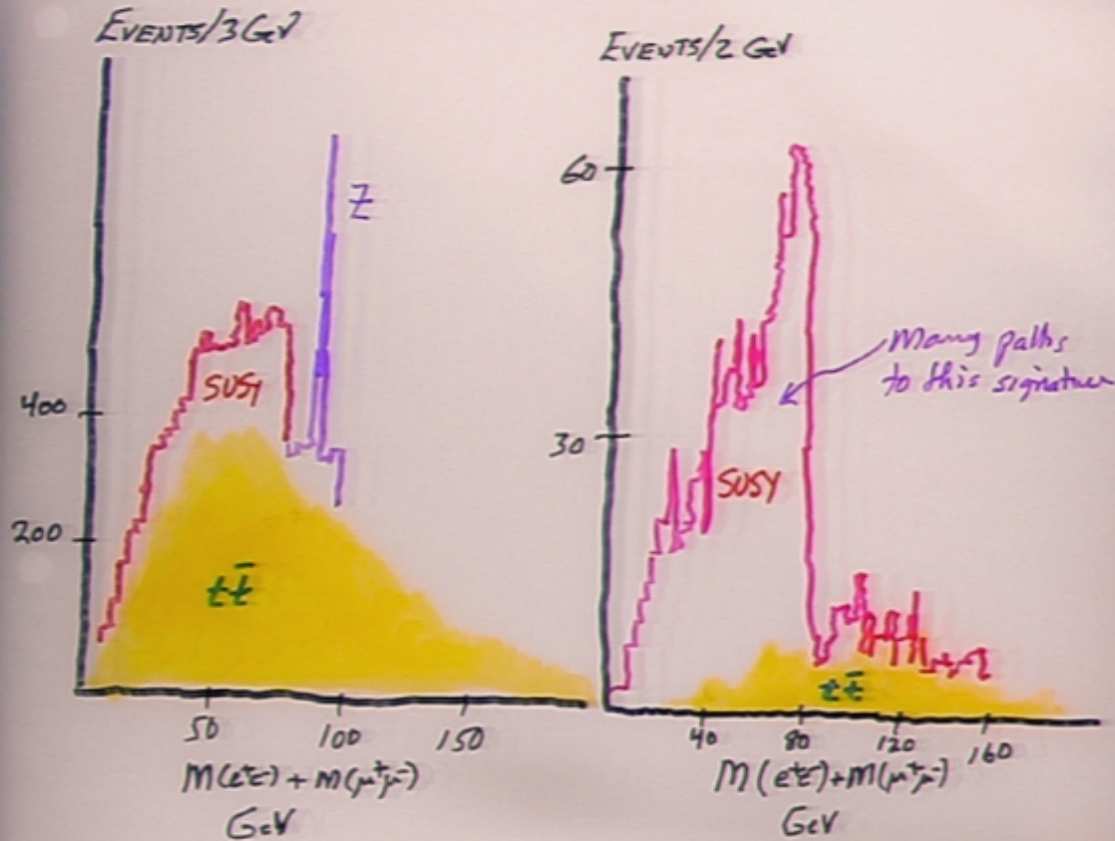
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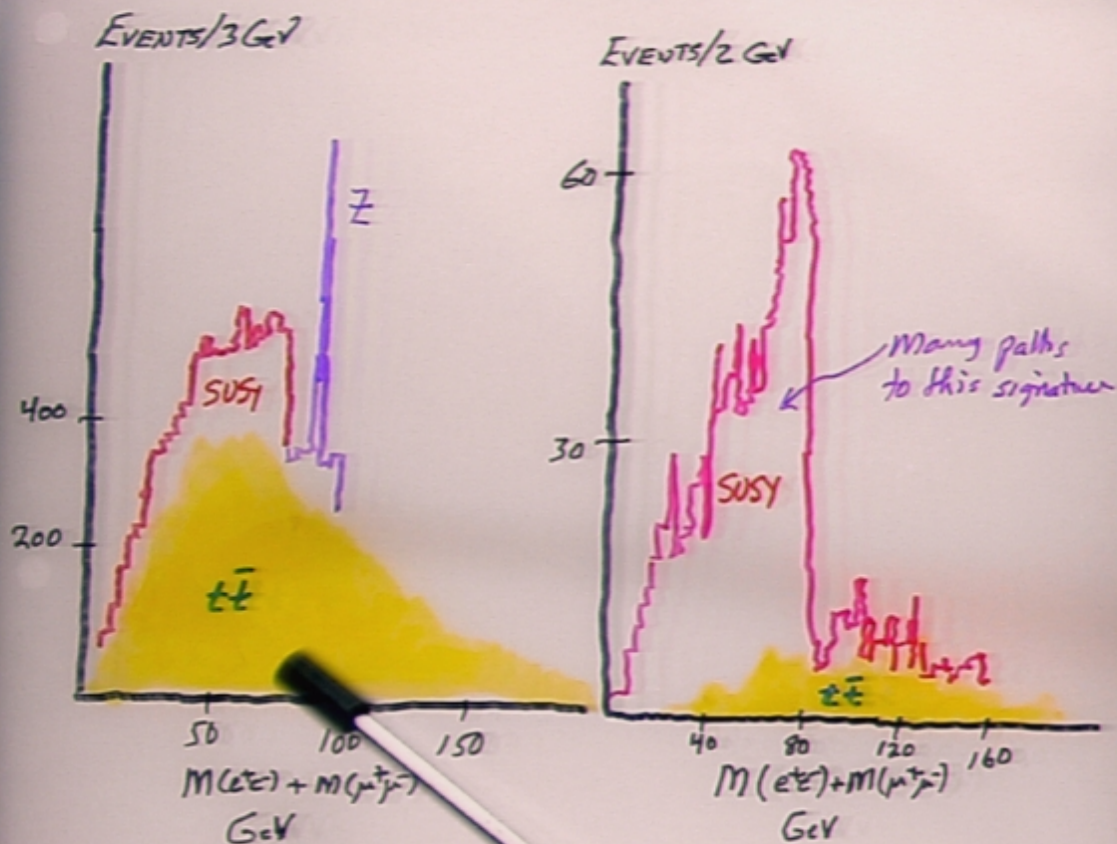
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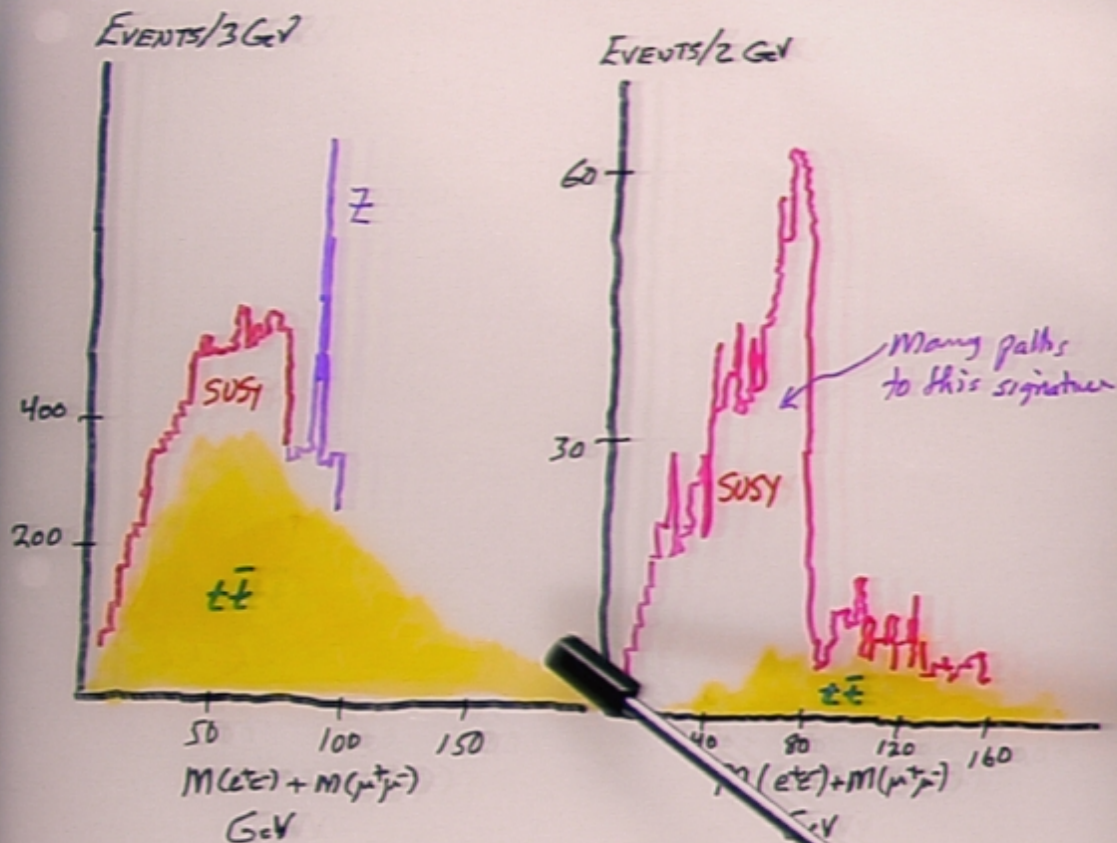
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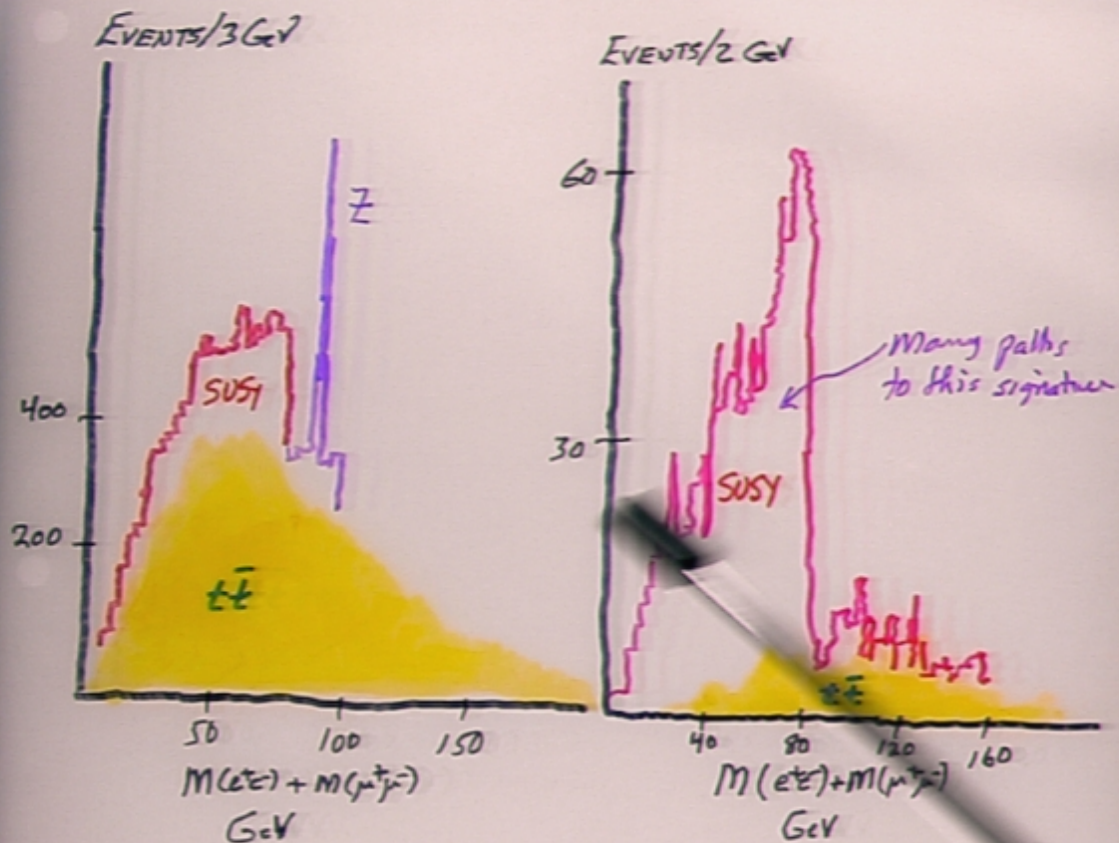
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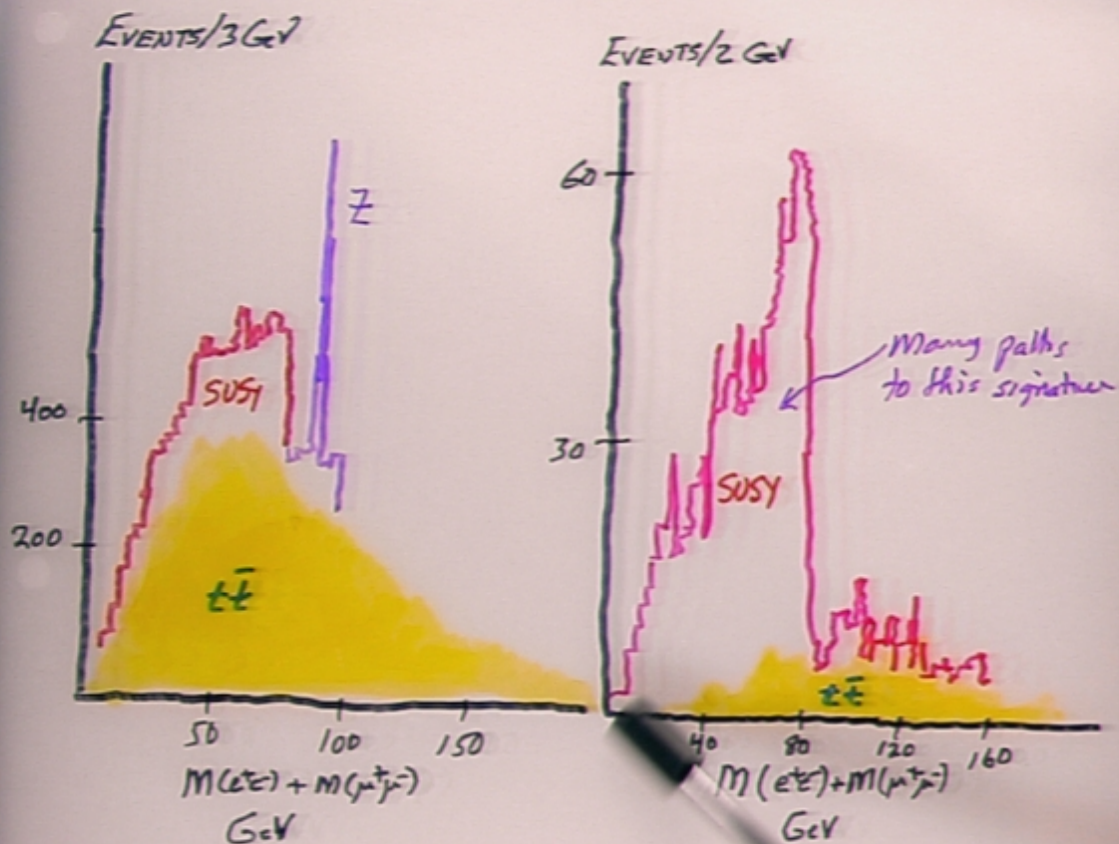
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* WHAT WILL BE MEASURED AT LHC?

- $\sigma \times BR$ FOR SPECIFIC SIGNATURES

e.g. NUMBER OF EVENTS WITH $2l^+l^-$, $E_T > 100$,
 ≥ 2 jets

- KINEMATICAL DISTRIBUTIONS RELATED TO MASSES

- IN GENERAL, MORE LAGRANGIAN PARAMETERS THAN PRACTICAL OBSERVABLES

- FOR HIGGS, $\sigma \times BR$, m_h FOR LIGHTEST, MAY BE FOR HEAVIER ONES

* WHAT DO WE WANT TO LEARN FROM LHC?

- ORIGIN OF EWSB!
- ~~SSX~~ -- MECHANISM, TRANSMISSION!
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ALSO

* TOP-DOWN CALCULATIONS PREDICTING OBSERVABLES?

- $\tan \beta$ NOT IN HIGH-SCALE UNDERLYING THEORY
 - μ GENERATED DIFFERENTLY
- NEED TO CALCULATE THEM, EWSB, FROM STRING THEORY
- BUT PREDICTIONS DEPEND STRONGLY ON THESE

* RGE RUNNING MODEL-DEPENDENT

- INTERMEDIATE SCALE MATTER?
- INITIAL, FINAL SCALES
- INFRARED FIXED POINTS

NOT YET REGULARIZATION SCHEME THAT DOES NOT BREAK SUSY, BUT OK THROUGH 2 LOOPS

* LAGRANGIAN PARAMETERS COMPLEX

- PHASES AFFECT SUPERPARTNER MASSES, $\sigma \times BR$, HIGGS SECTOR, DARK MATTER.....
- NO KNOWN SYMMETRY IMPLIES PHASES SMALL

ETC

- ALL OBSTACLES SOLVABLE WITH SUFFICIENT PRECISION DATA -- NEED NEW TECHNIQUES TO MAKE MAJOR PROGRESS FROM HADRON COLLIDERS

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SUPERPOTENTIAL PARAMETERS

$$t = \ln Q/Q_0$$

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SCALE SENSITIVITY

$$16\pi^2 dY_t/dt = Y_t \left[6|Y_t|^2 + |Y_b|^2 - \frac{16}{3}g_3^2 - 3g_2^2 - \dots \right]$$

FROM $h \dots \begin{array}{c} \nearrow t \\ | h \\ \searrow t \end{array} + \dots \begin{array}{c} \nearrow \\ | g, w, B \\ \searrow \end{array}$

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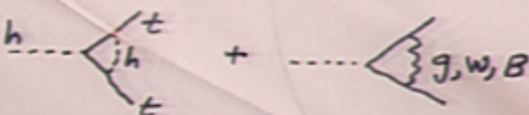
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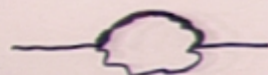
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GAUGNO MASSES

$$dM_a/dt = \frac{b_a}{8\pi^2} g_a^2 M_a, \quad b_a = \left(\frac{33}{5}, 1, -3\right)$$



SAME SOURCE AS GAUGE COUPLINGS, SO RATIOS
CONSTANT AT ONE LOOP

$$M_a(Q)/M_a(Q_0) = g_a^2(Q)/g_a^2(Q_0)$$

$$\text{OR } \frac{d}{dt} \left(M_a/g_a^2 \right) \approx 0$$

TRILINEAR COUPLINGS

- CONSIDER IN SIMPLIFIED MODEL WHERE

$$a_u \approx \begin{pmatrix} 0 \\ a_t \end{pmatrix}$$

ETC, SIMILAR TO YUKAWAS

$$16\pi^2 da_t/dt = a_t \left(18\gamma_t^2 - \frac{16}{3}g_3^2 \right) + 2a_b \gamma_b^* \gamma_t + \gamma_t \left(\frac{32}{3}g_3^2 M_2 + \dots \right)$$

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$$a_u \approx \begin{pmatrix} 0 \\ a_t \end{pmatrix}$$

ETC, SIMILAR TO YUKAWAS

$$16\pi^2 da_t/dt = a_t \left(18Y_t^2 - \frac{16}{3}g_3^2 \right) + 2a_b Y_b^* Y_t + Y_t \left(\frac{32}{3}g_3^2 M_3 + \dots \right)$$

- NOTE — a_t IS THE α_{SOFT} PARAMETER — IN LITERATURE SOMETTIMES $A_t = a_t / Y_t$ —

- NOT PROTECTED BY NON-RENORM THEOREM SINCE Y_t PARAM NOT PROTECTED — EVEN IF a_i, b VANISH AT HIGH SCALE, RG CONTRIBUTION PROPORTIONAL TO M_a GENERATES THEM AT EW SCALE

$$16\pi^2 db/dt = b \left(3|Y_t|^2 - 3g_2^2 + \dots \right) + \mu \left(6a_t Y_t^* + 6g_2^2 M_2 + \dots \right)$$

CONSTANT AT ONE LOOP

$$M_a(Q) / M_a(Q_0) = g_a^2(Q) / g_a^2(Q_0)$$

$$\text{OR } \frac{d}{dt} \left(M_a / g_a^2 \right) \approx 0$$

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$$16\pi^2 \frac{da_t}{dt} = a_t \left(18\gamma_t^2 - \frac{16}{3}g_3^2 \right) + 2a_b \gamma_b^* \gamma_t + \gamma_t \left(\frac{32}{3}g_3^2 M_3 + \dots \right)$$

- NOTE — a_t IS THE λ_{SOFT} PARAMETER — IN LITERATURE SOMETTIMES $A_t = a_t / v$

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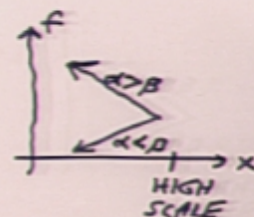
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SCALAR MASSES

- IN APPROXIMATION $\gamma_u \approx \begin{pmatrix} 0 & \gamma_e \end{pmatrix}$, $a_u \approx \begin{pmatrix} 0 & a_e \end{pmatrix}$ THEN SQUARKS, SLEPTONS OF FIRST, 2nd FAMILIES HAVE MAINLY GAUGE INTERACTIONS -- SO IF DIAGONAL AT Q_0 STAY APPROX DIAG AT LOWER SCALES -- 3rd FAMILY FEELS YUKAWA EFFECTS

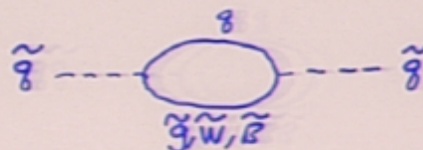
- NOTE $\partial f(x)/\partial x = \beta(x) - \alpha(x)$, THEN $\beta, \alpha > 0$



- 1st, 2nd FAMILIES

$$16\pi^2 \partial m_{\tilde{\varphi}}^2 / \partial t = - \sum_a 8g_a^2 C_a^{\tilde{\varphi}} M_a^2$$

QUADRATIC CASIMIR

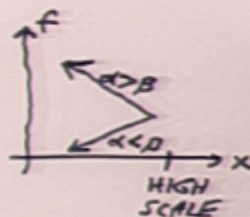


- RHS NEGATIVE, SO $m_{\tilde{\varphi}}^2$ ALL INCREASE FROM INPUT HIGH SCALE TO EW SCALE -- EVEN IF SMALL OR ZERO AT HIGH SCALE WILL GET LARGE POSITIVE $m_{\tilde{\varphi}}^2$ AT EW SCALE IF GAUGINO MASSES NOT SMALL

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- IN APPROXIMATION $Y_U \approx \begin{pmatrix} 0 \\ y_c \end{pmatrix}$, $Q_U \approx \begin{pmatrix} 0 \\ q_c \end{pmatrix}$ THEN SQUARKS, SLEPTONS OF FIRST, 2nd FAMILIES HAVE MAINLY GAUGE INTERACTIONS -- SO IF DIAGONAL AT Q_0 STAY APPROX DIAG AT LOWER SCALES -- 3rd FAMILY FEELS YUKAWA EFFECTS

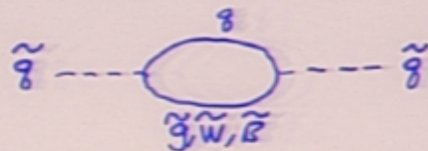
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$$\partial \varphi_{\mu} / \partial t = 0$$

$$\partial \varphi_{M_i} / \partial t = (0)_{1 \text{ LOOP}} + \frac{1}{|M_i|} \left[\sum_{j \neq i} \alpha_j^i |M_j| \sin(\varphi_{M_i} - \varphi_{M_j}) + |A_t| \dots \right]_{2 \text{ LOOP}}$$

e.g. GENERATE $\varphi_3 \approx 10^{-2} |A_t / m_3|$

$$\frac{\partial \varphi_{(b)}}{\partial t} = \frac{1}{|A_t|} \left[6 g_2^2 |M_2| \sin(\varphi_{A_t} - \varphi_{M_2}) + g_1^2 \dots \right]$$

$$\partial \varphi_{A_t} / \partial t = \frac{1}{|A_t|} \left[\frac{32}{3} g_3^2 |M_3| \sin(\varphi_{A_t} - \varphi_{M_3}) + g_2^2 \dots \right]$$

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HIGH SCALE THEORIES FAVORED
BY DATA

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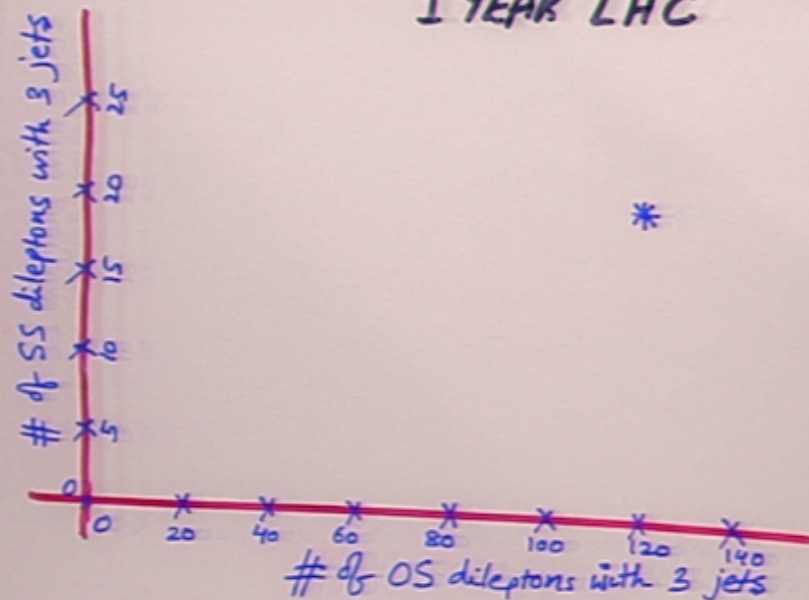
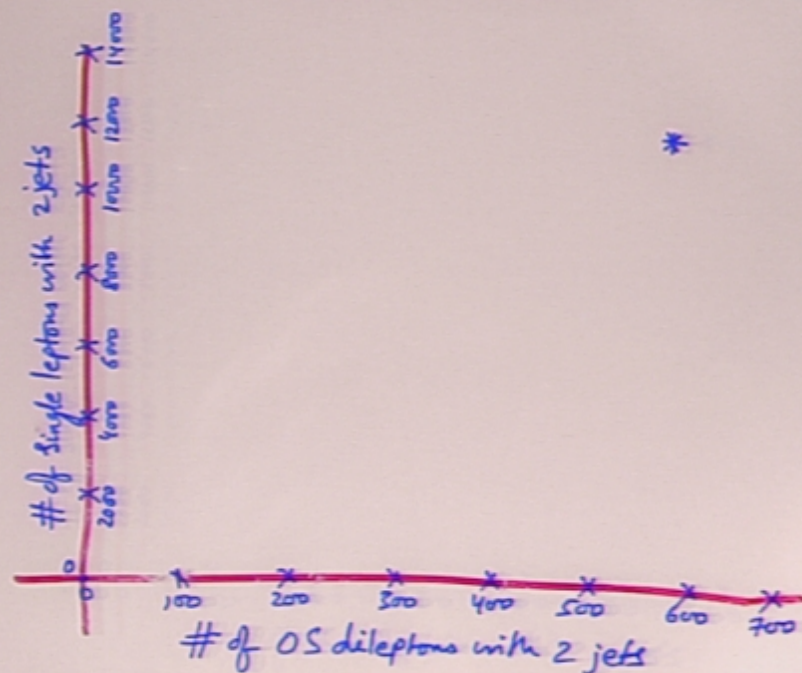
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of events for 10fb^{-1} ($\sim 1\text{yr}$ of LHC) $5 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$

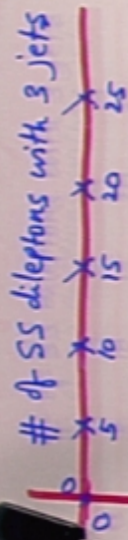


1 YEAR LHC

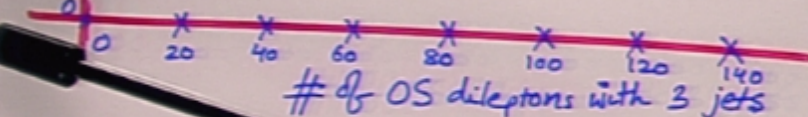
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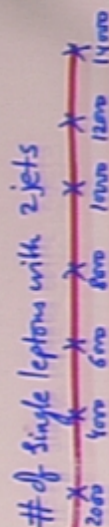
of SS dileptons with 3 jets



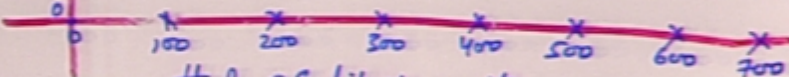
of OS dileptons with 3 jets



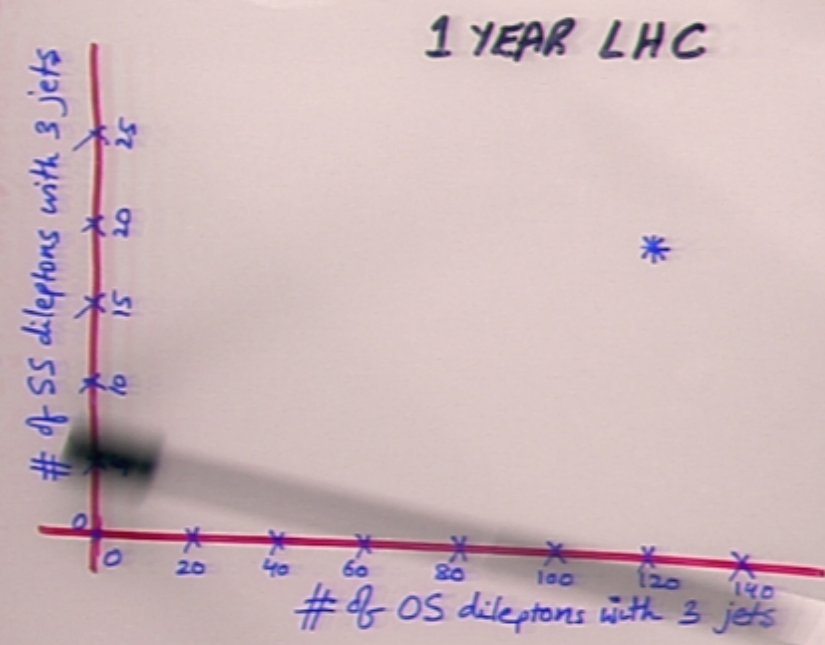
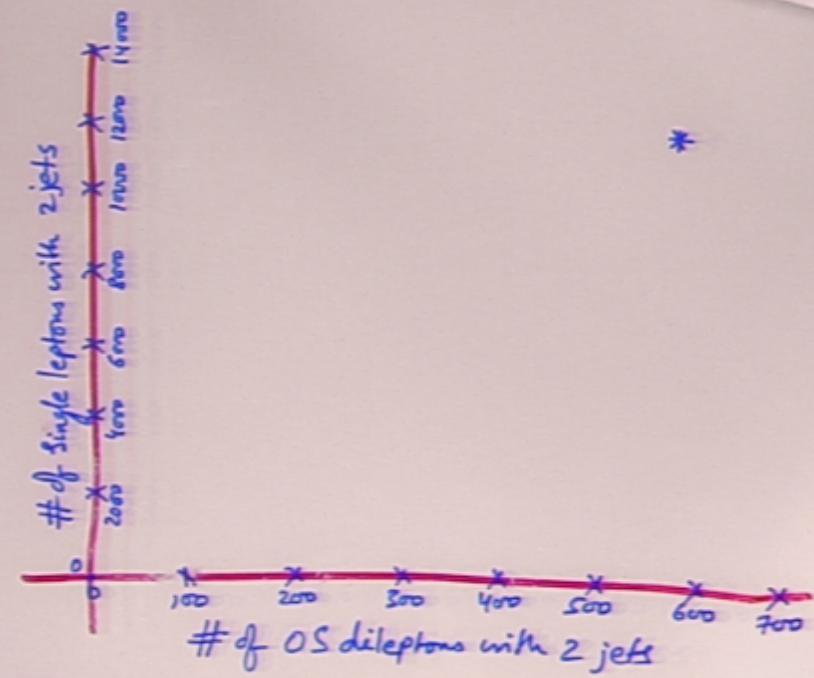
of single leptons with 2 jets



of OS dileptons with 2 jets



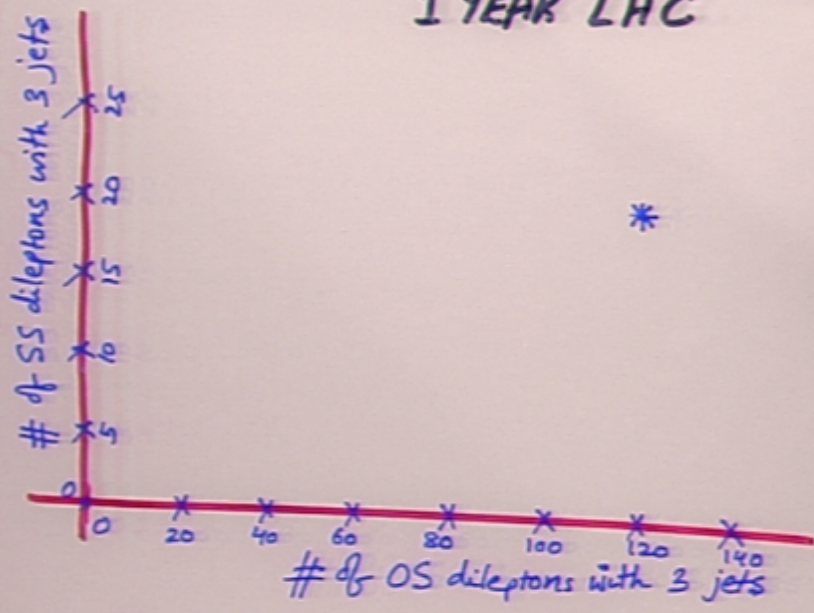
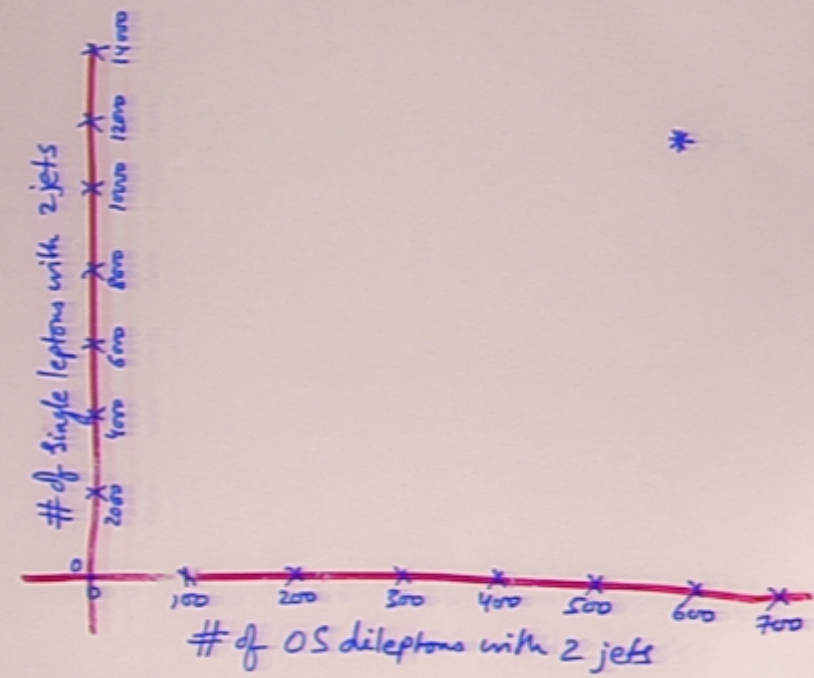
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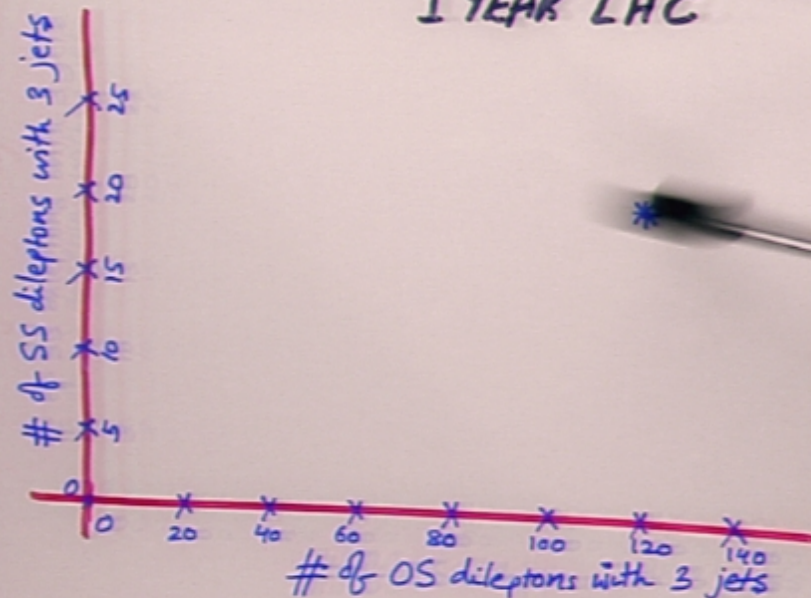
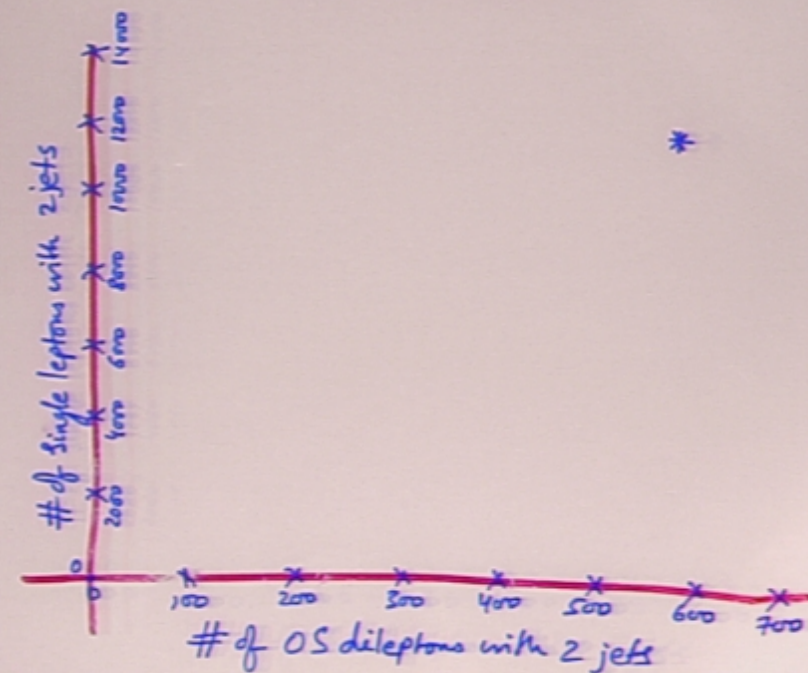
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of events for 10fb^{-1} ($\sim 1\text{yr}$ of LHC) $5 \times 10^{32-2-1} \text{cm}^{-2}\text{s}^{-1}$

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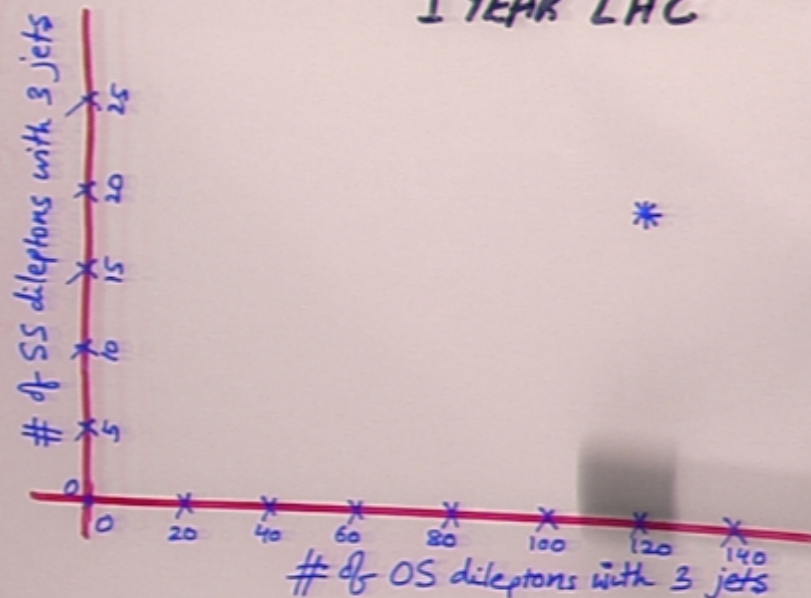
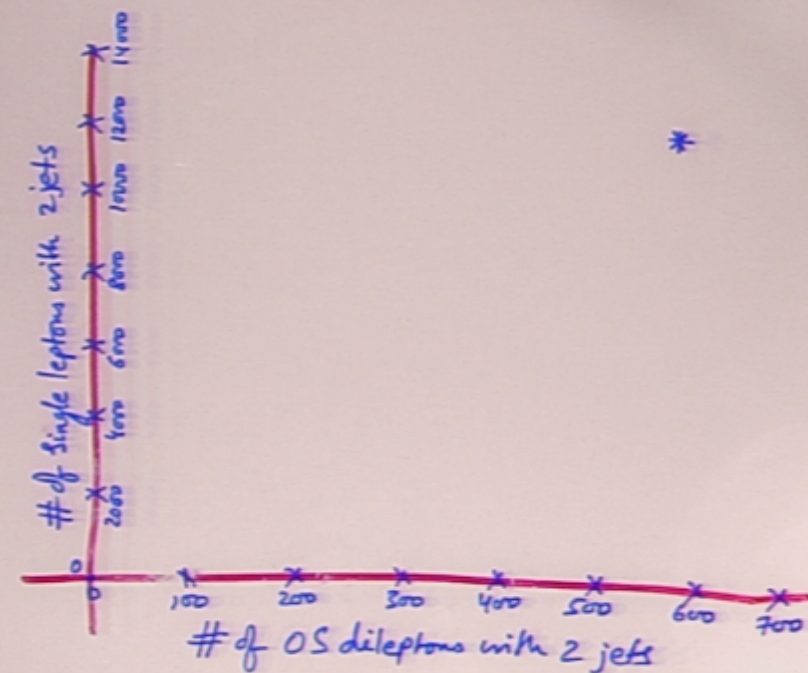


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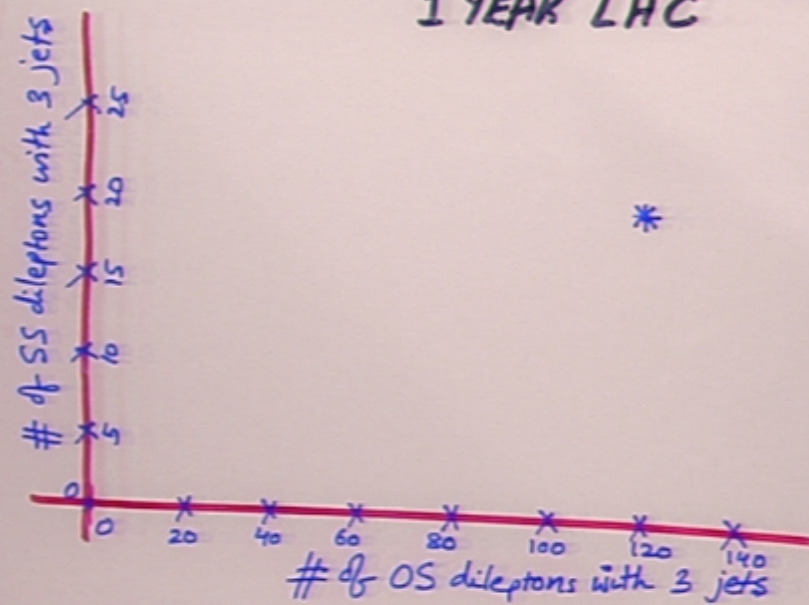
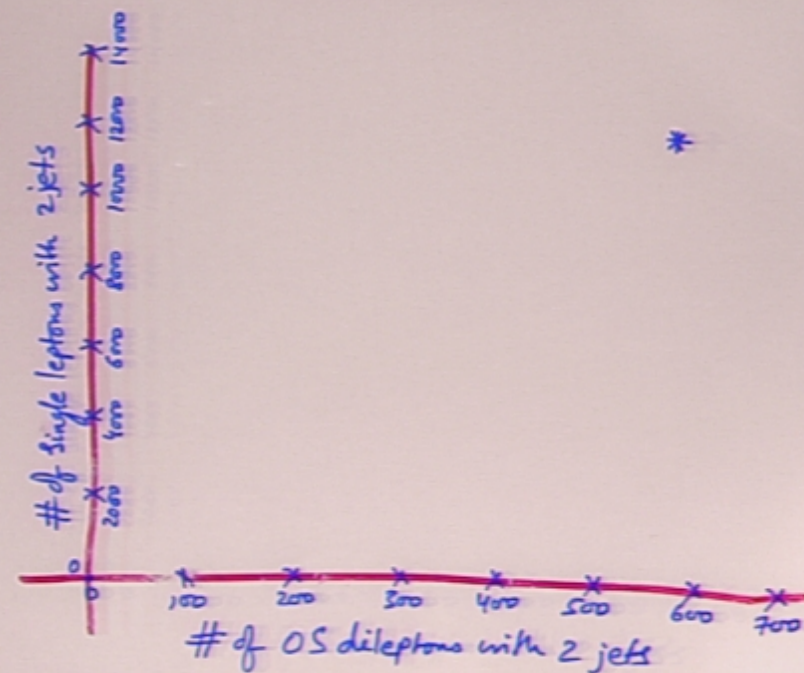
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SOME IMPORTANT HADRON
COLLIDER INCLUSIVE SIGNATURES
FOR THE "CHALLENGE" MODEL

	2 jets	3 jets	≥ 4 jets
0 lepton	21110	6502	638
1 lepton	1219	360	25
SS dilepton	6	2	2
OS dilepton	58	12	0
≥ 3 leptons	0	0	0
$\vdots$	$\vdots$	$\vdots$	$\vdots$

$$\sqrt{M}^{\text{Peak}}_{\text{eff}} : 737.5 \text{ GeV}$$

$$\sqrt{M}^{\text{Peak}}_{\text{ll}} : 7.5 \text{ GeV}$$

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PATTERNS OF INCLUSIVE SIGNATURES CAN POINT TO UNDERLYING THEORY (all events have 2 or more energetic jets and large missing transverse energy)

	A	B	C	D	E	F	G
SS DILEPS	Y	Y	N	Y	Y	Y	
OS DILEPS	Y	Y	N	Y	Y	N	
TRILEPS	N	Y	N	Y	Y	Y	
PROMPT γ	N	N	N	N	N	N	
b-RICH							
Peak of							

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PROMPT γ	N	N	N	N	N	N	
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PIYUSH KUMAR

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OS DILEPS	Y	Y	N	Y	Y	N	
TRILEPS	N	Y	N	Y	Y	Y	
PROMPT γ	N	N	N	N	N	N	
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OS DILEPS	γ	γ	N	γ	γ	N	
TRILEPS	N	γ	N	γ	γ	γ	
PROMPT γ	N	N	N	N	N	N	
b-RICH							
Peak of							

Sunday, May 29, 2005
8:40 AM

"INCLUSIVE SIGNATURE SPACE"

-- ONLY USE SIGNATURES THAT CAN
REALLY BE MEASURED

e.g. number of events with
but not chargino mass etc

-- USE ALL POSSIBLE INFORMATION

* SENSITIVELY EXCLUDE, TEST SOME
THEORIES, MODELS

e.g. mSUGRA, all parameters

* MEASURE QUANTITIES SUCH AS
 $\tan\beta$, m_{LSP}

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-- USE ALL POSSIBLE INFORMATION

* SENSITIVELY EXCLUDE, TEST SOME
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e.g. mSUGRA, all parameters

* MEASURE QUANTITIES SUCH AS
 $\tan\beta$, m_{LSP}

* CAN'T MEASURE GAUGINO MASSES
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UNIFICATION

Sunday, May 29, 2005
8:40 AM

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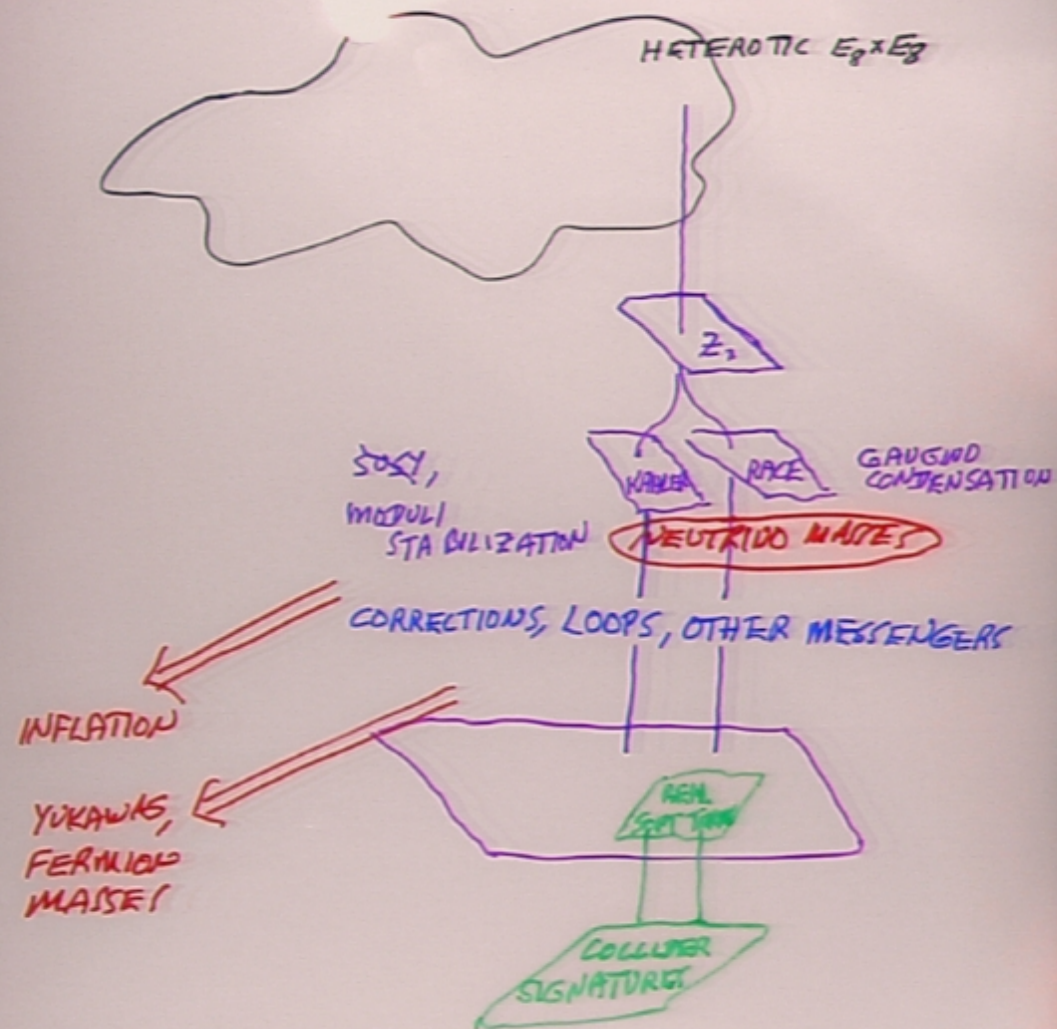
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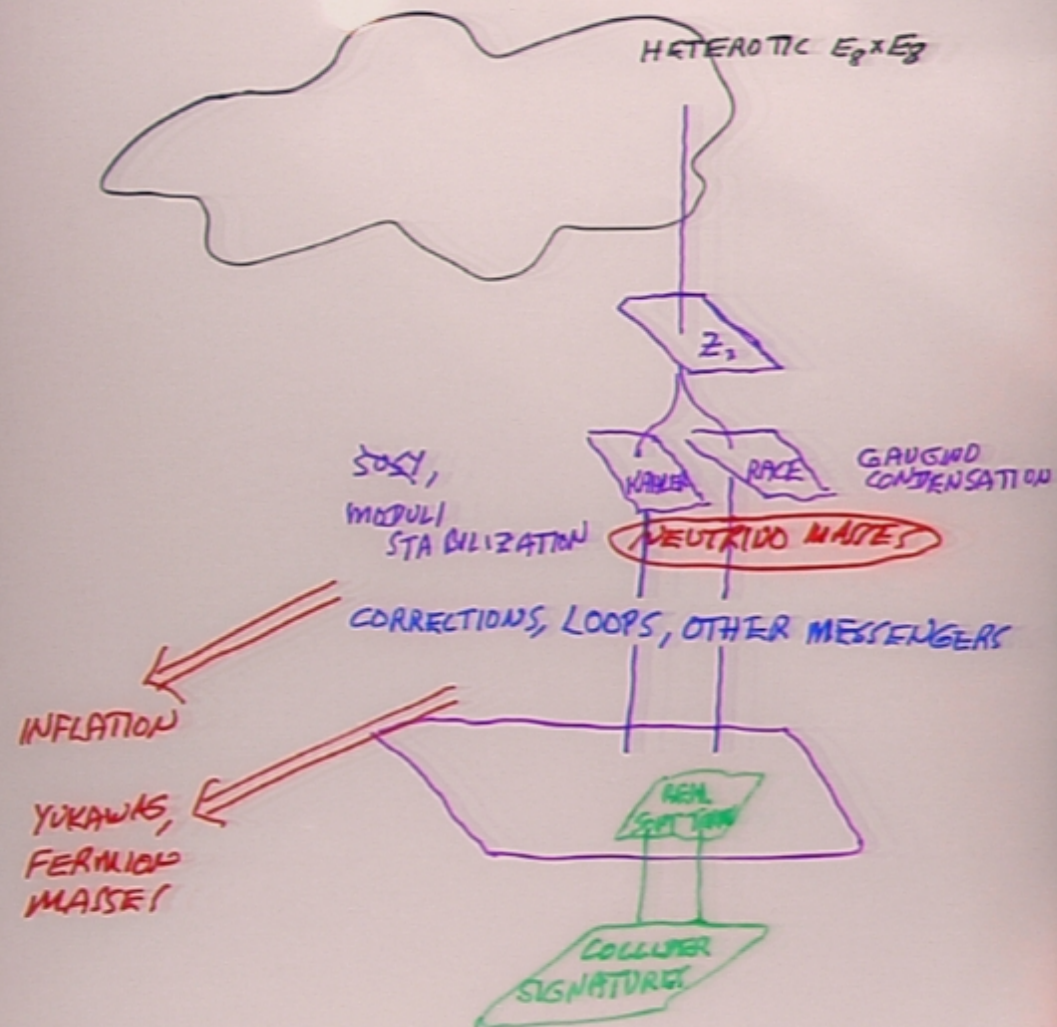
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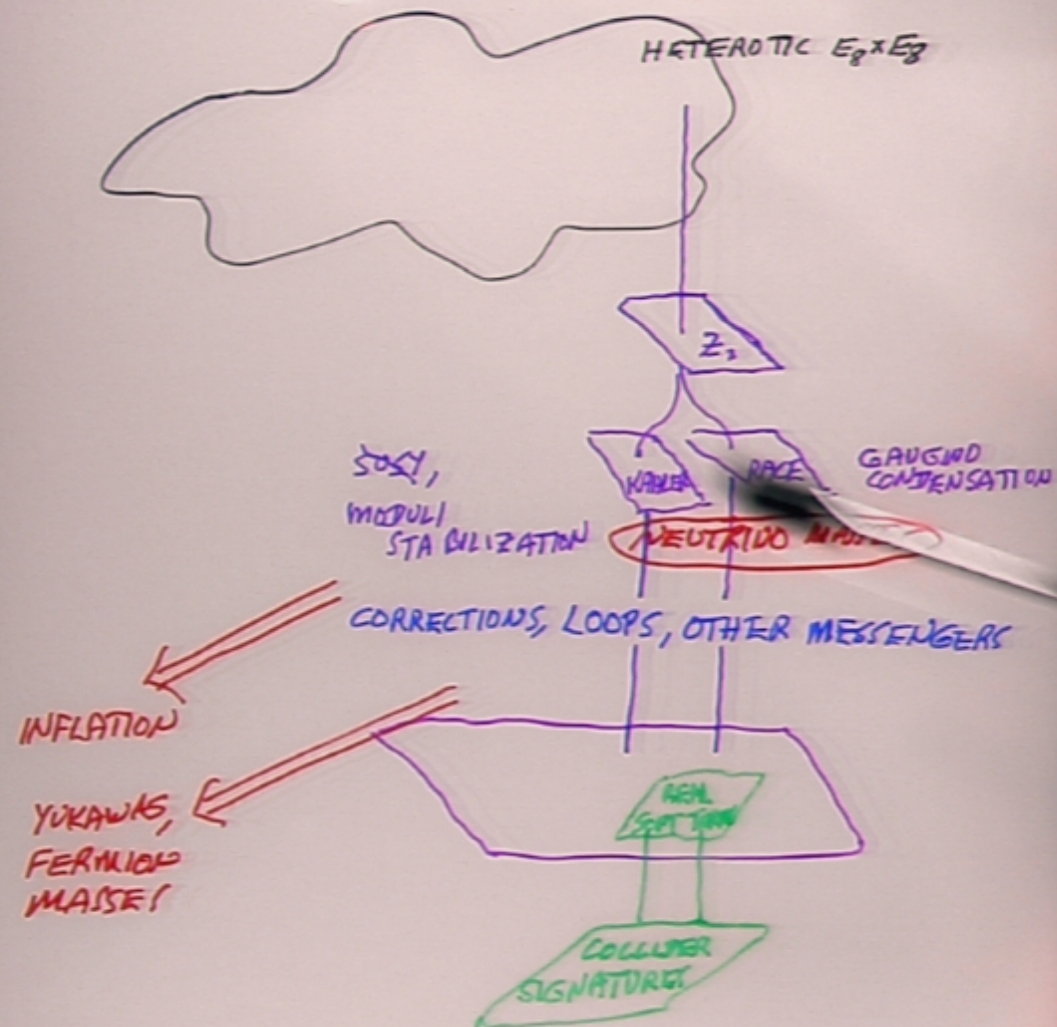
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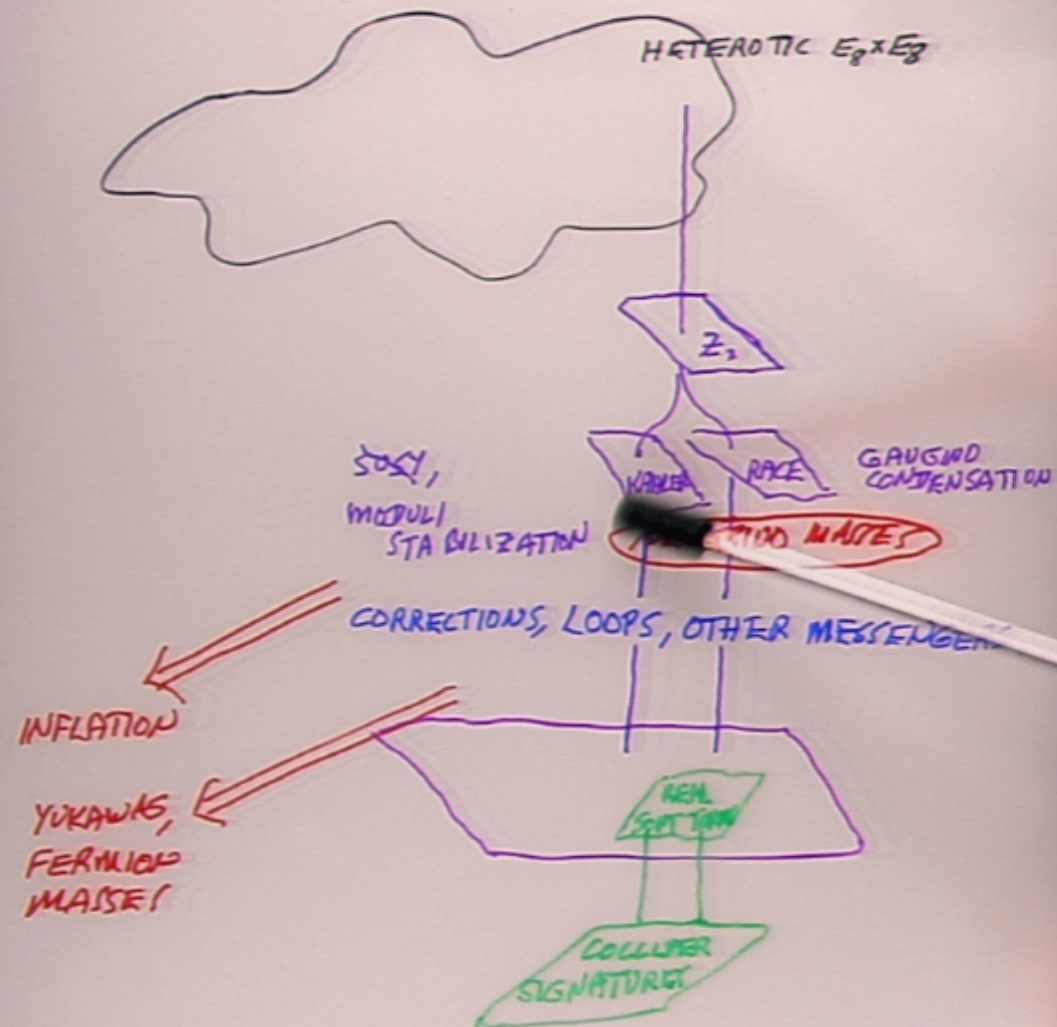
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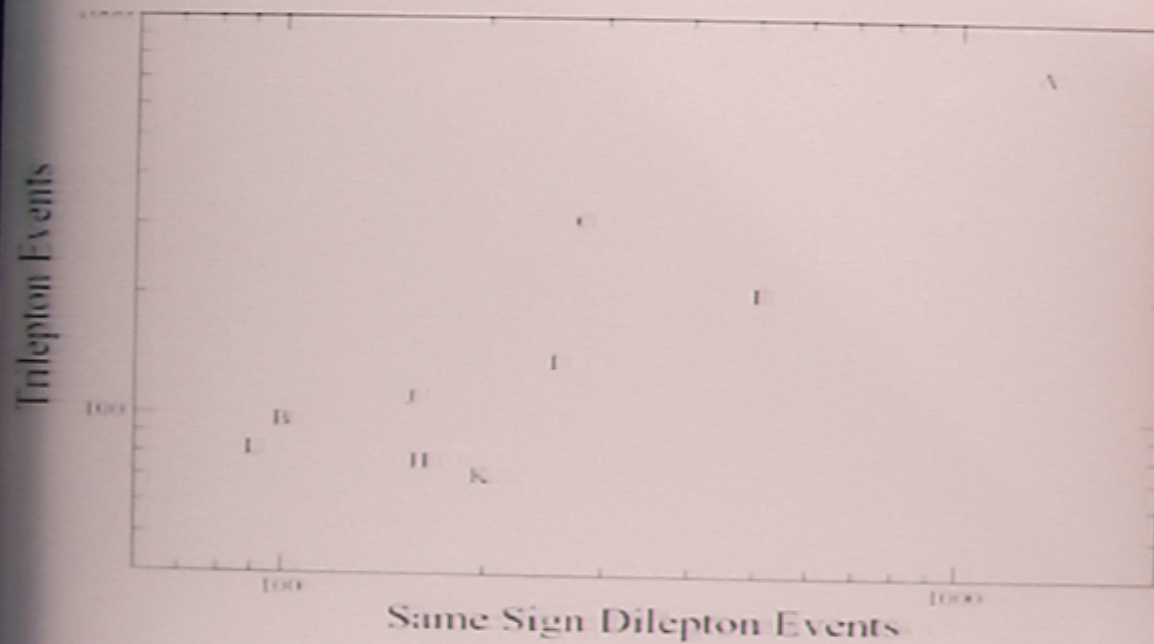




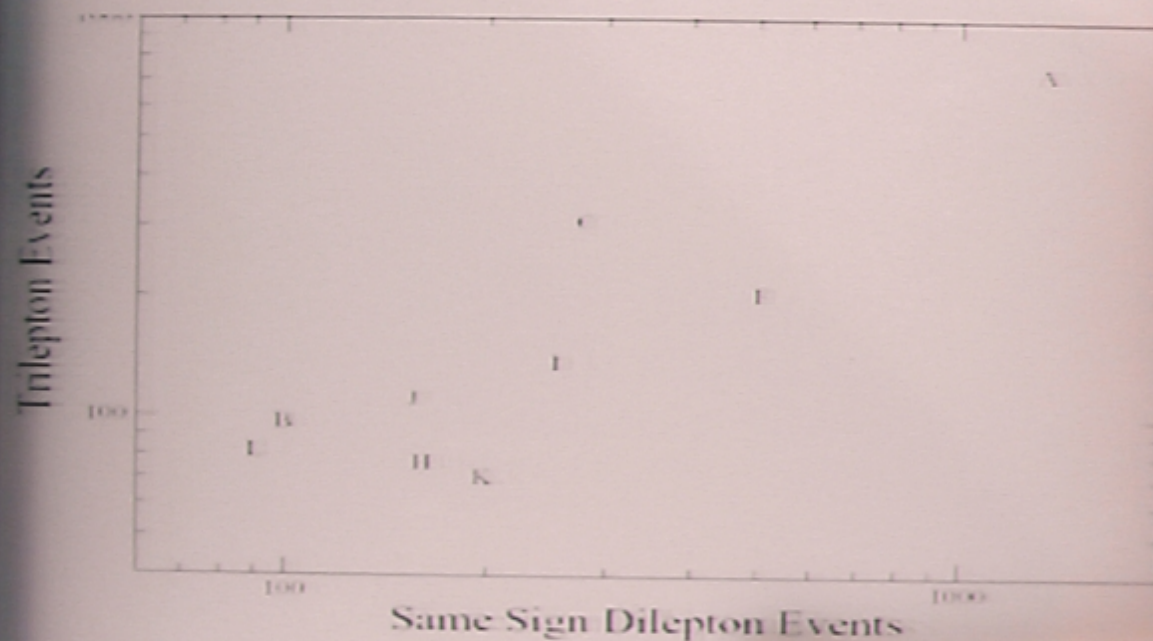




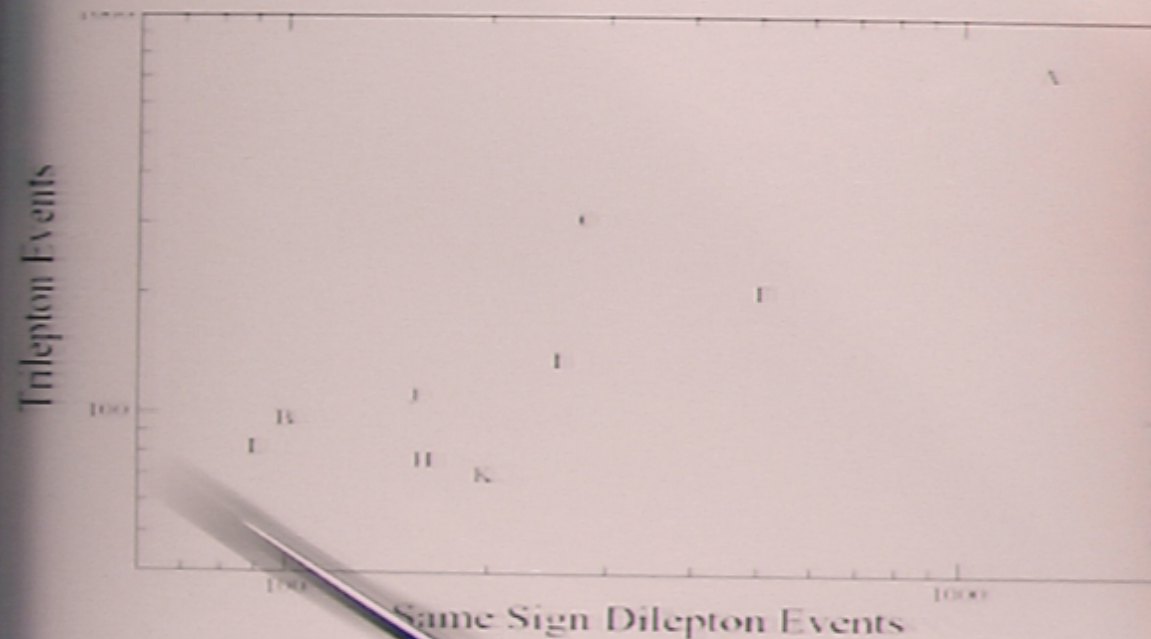
Can get more systematic, study
underlying theories (letters are
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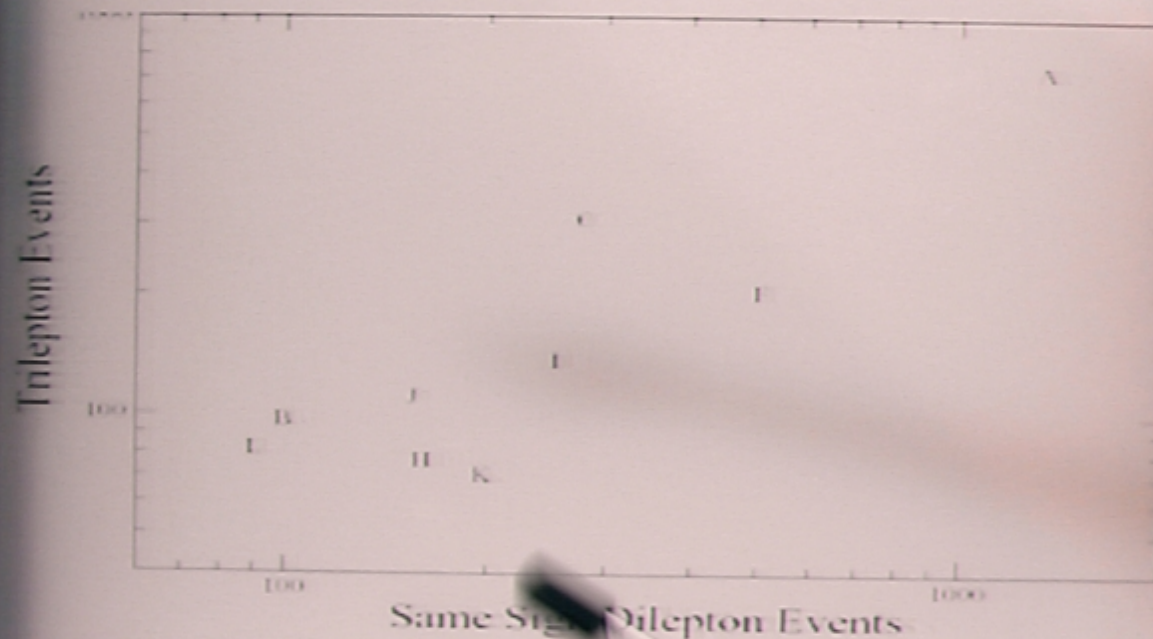
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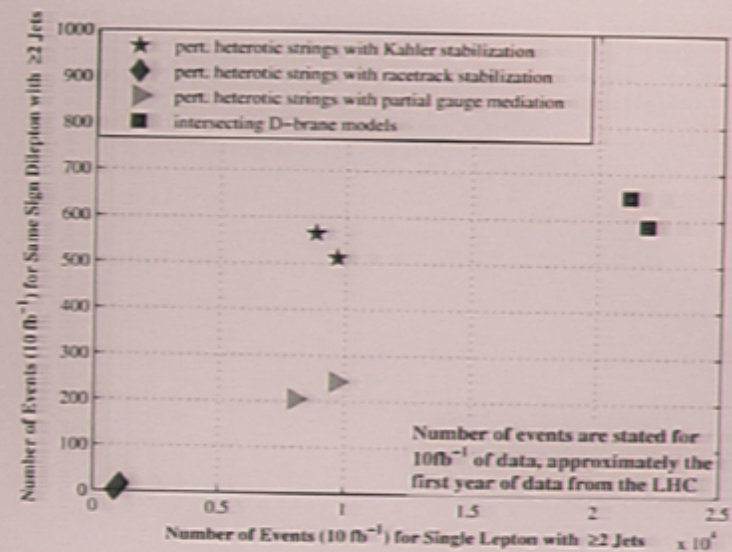


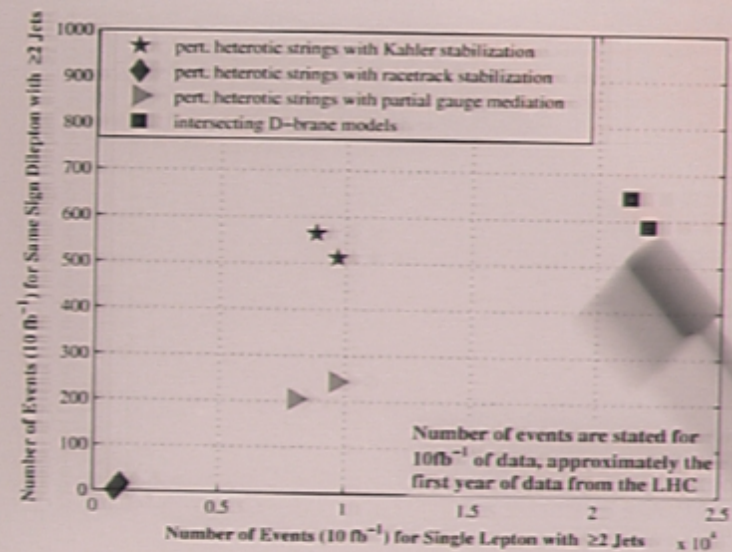
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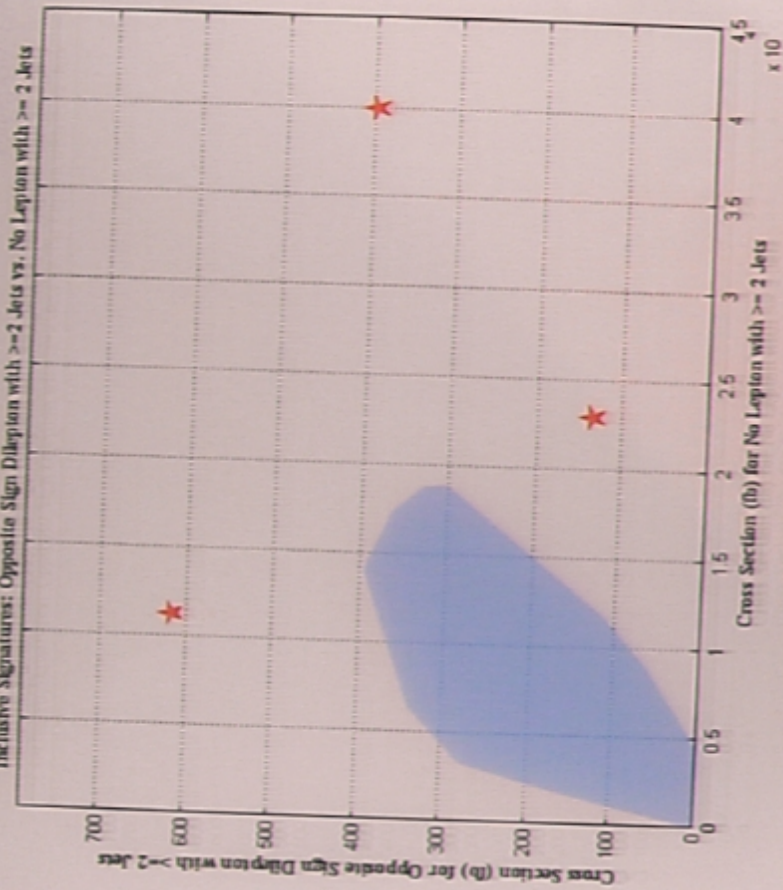
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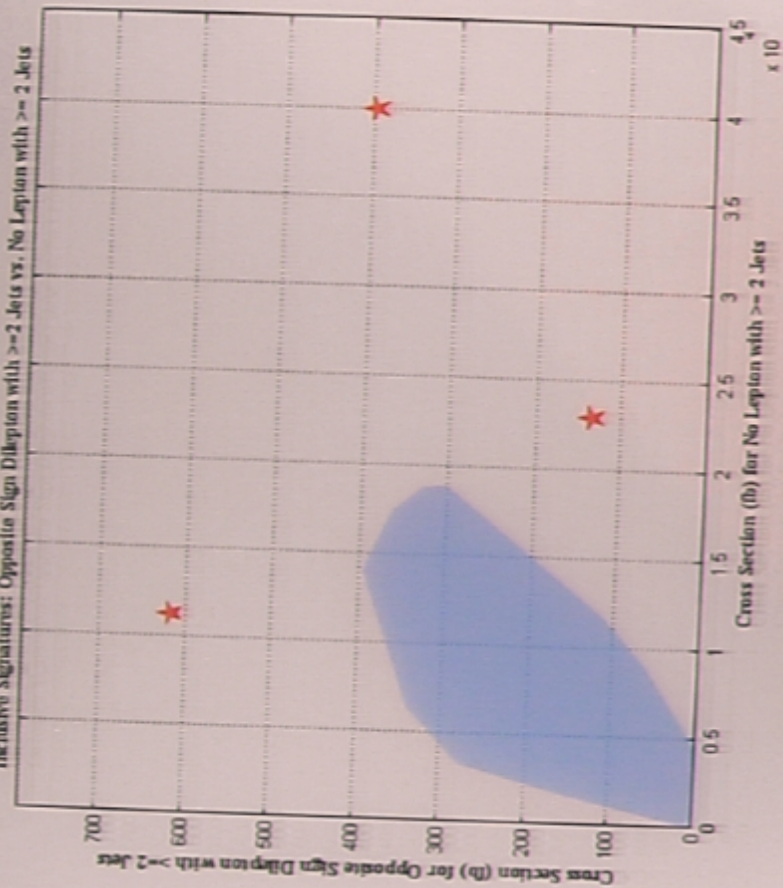


Inclusive Signatures: Opposite Sign Dilepton with ≥ 2 Jets vs. No Lepton with ≥ 2 Jets



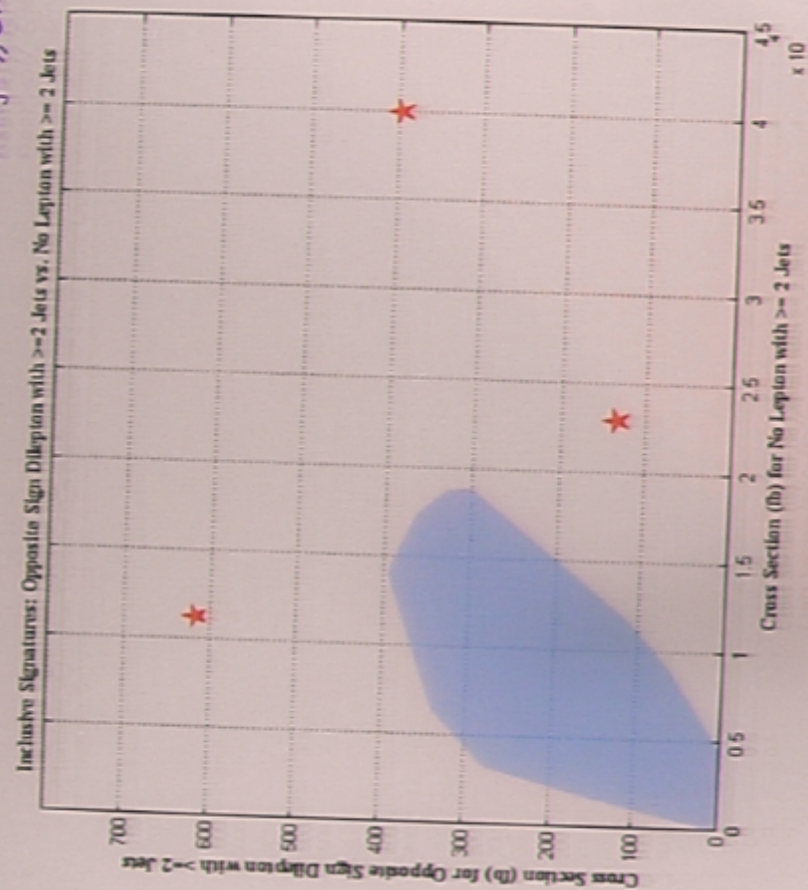
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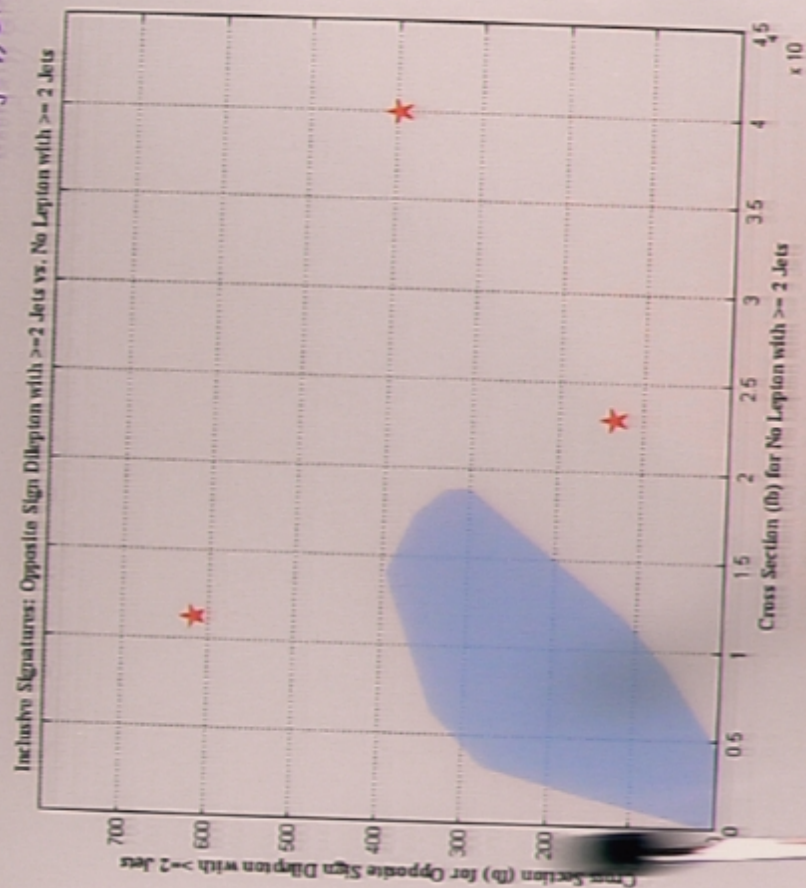


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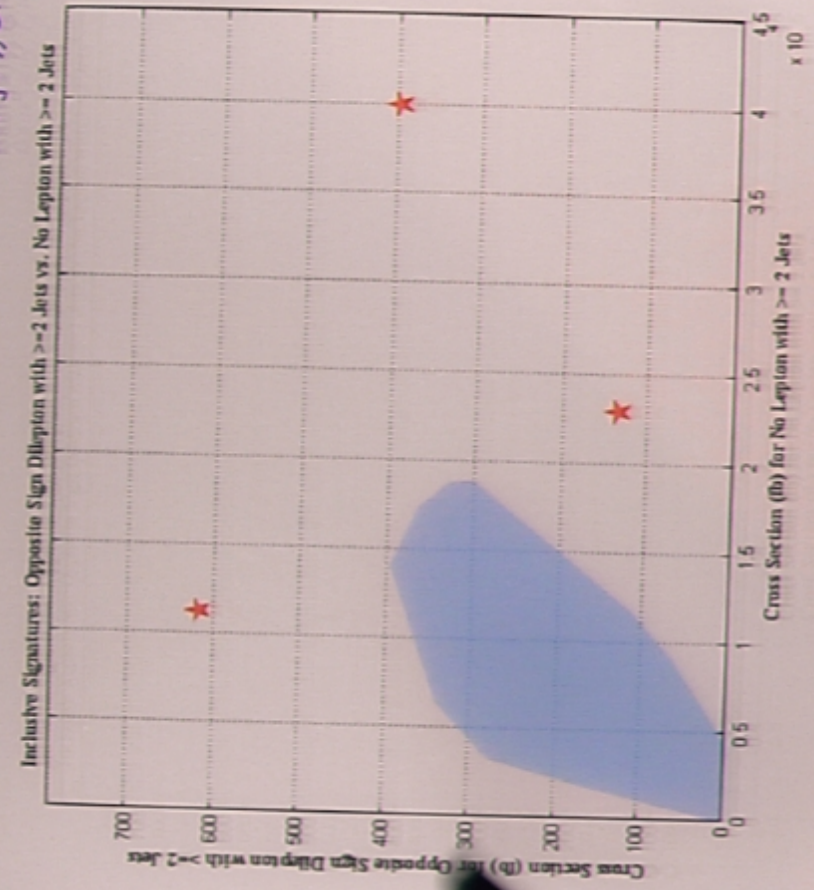
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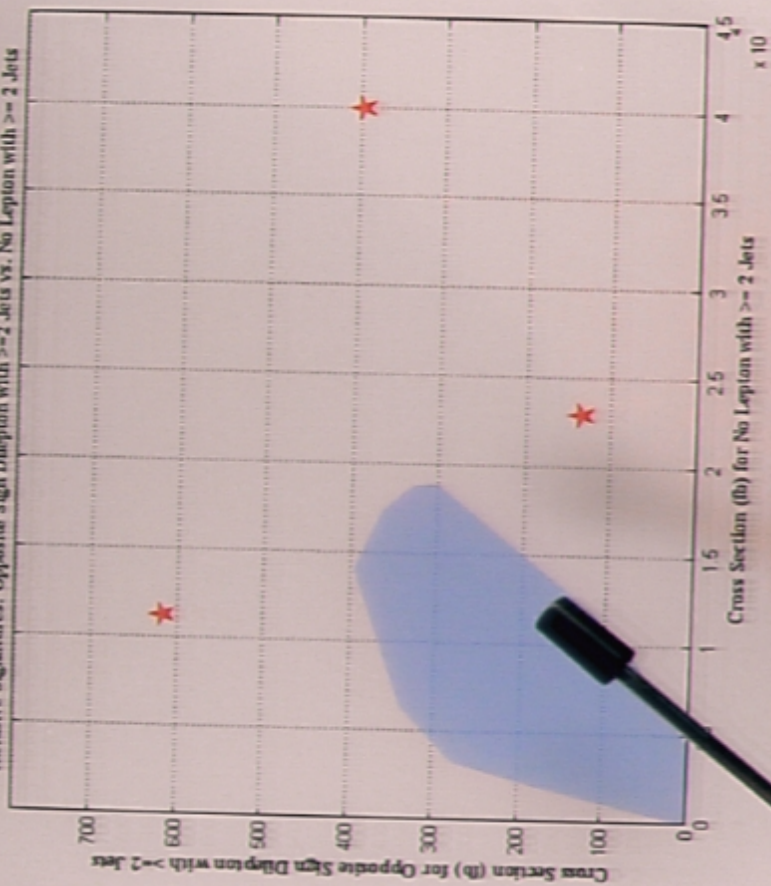
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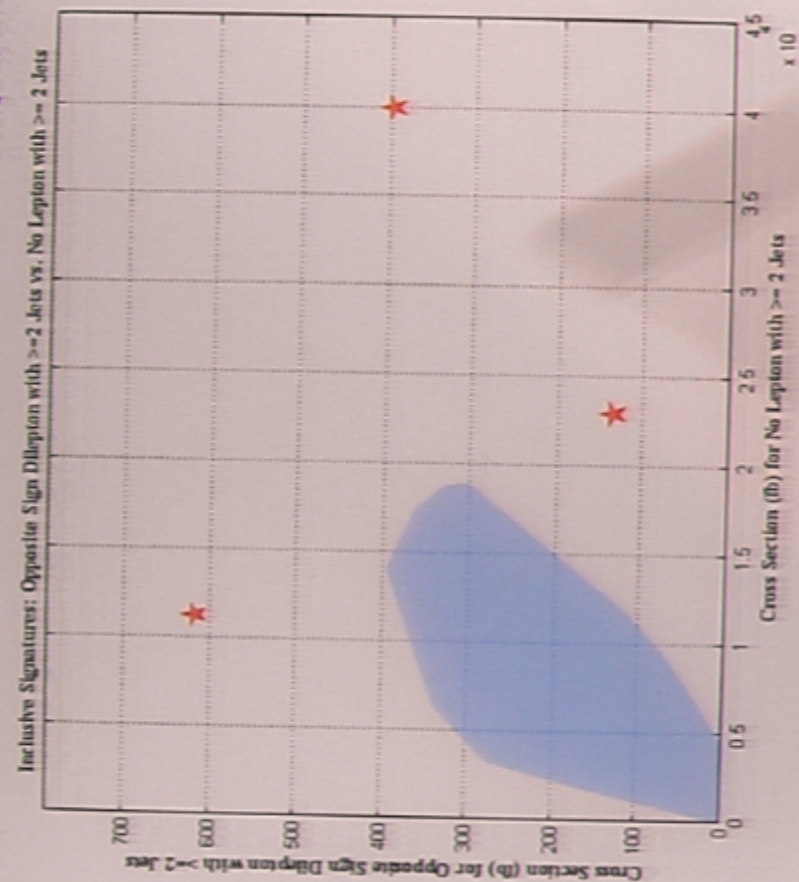


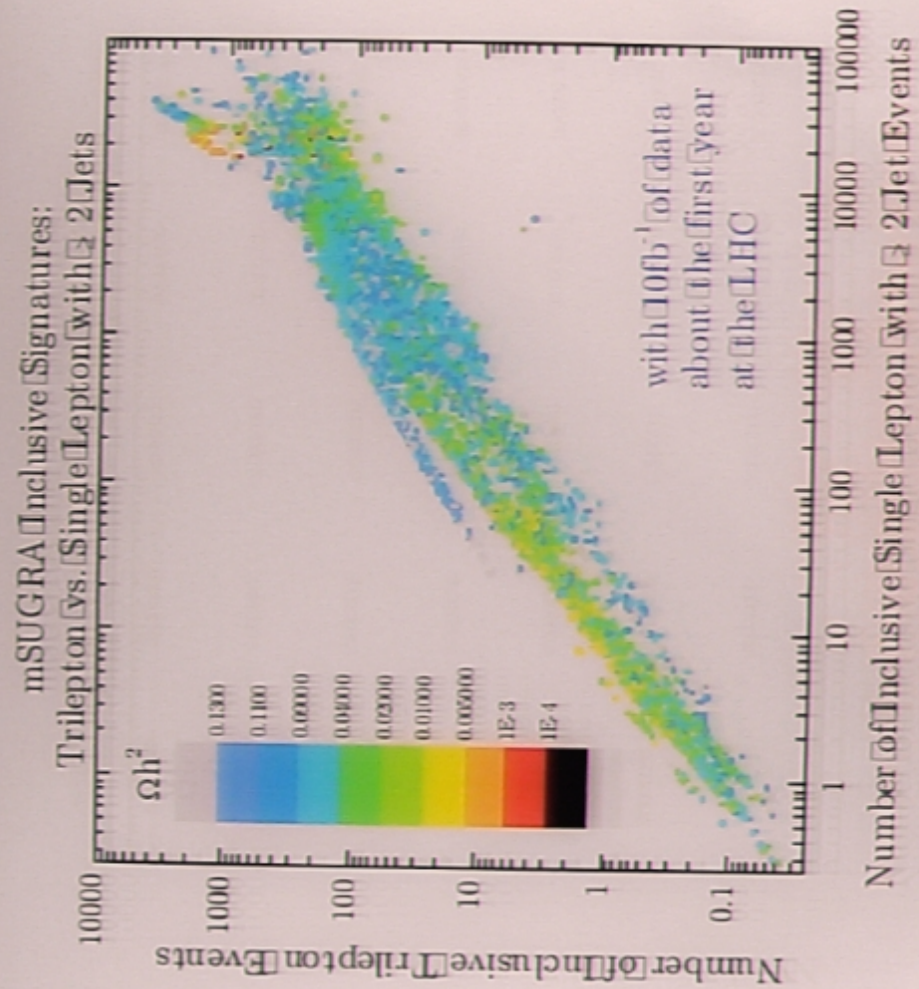
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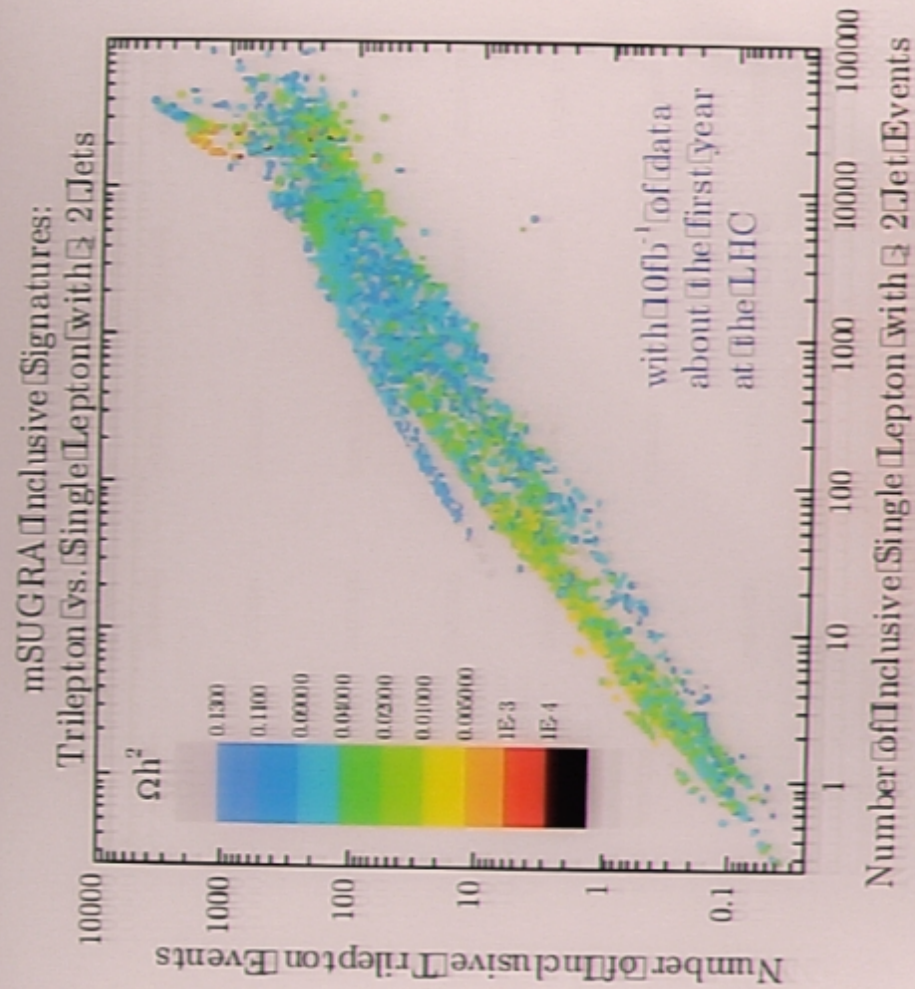


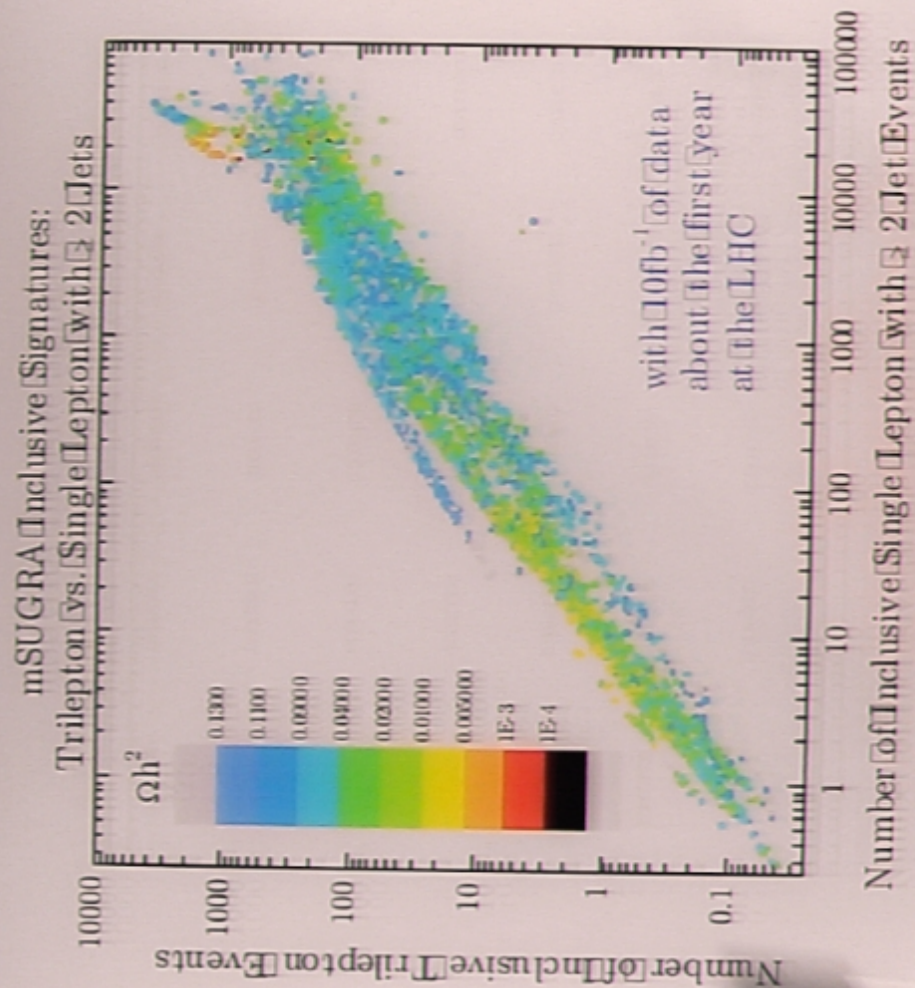
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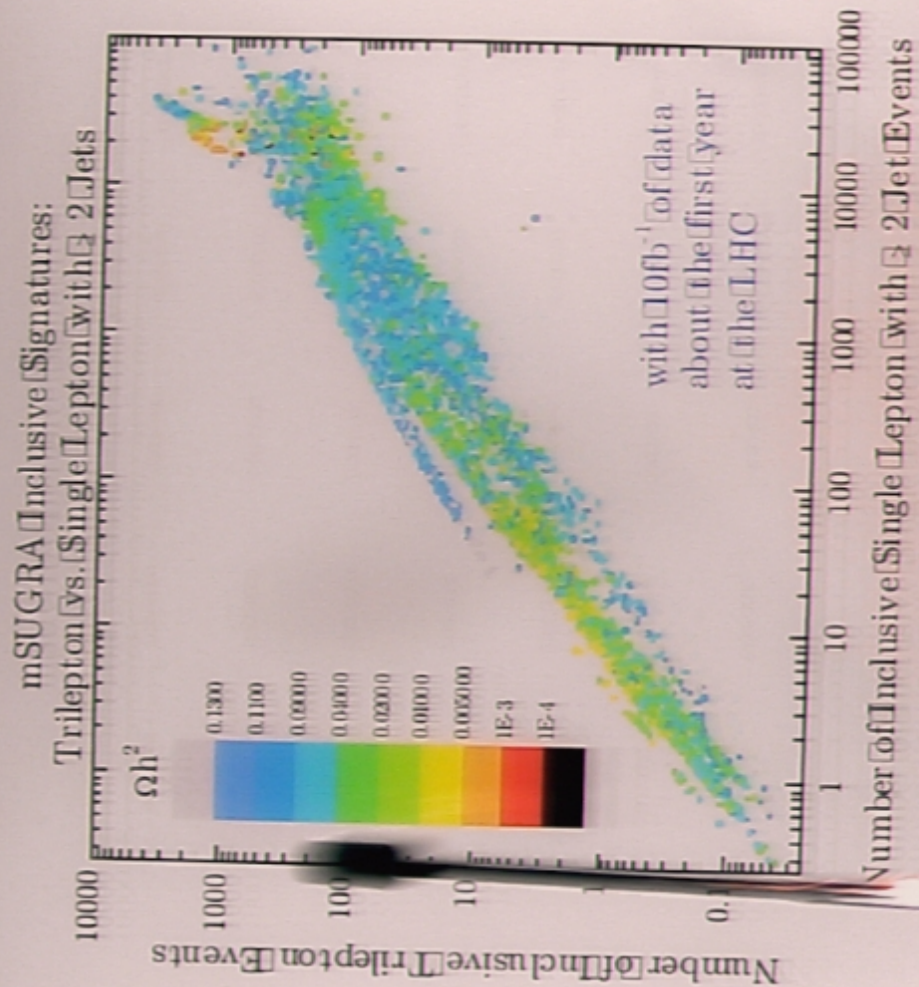
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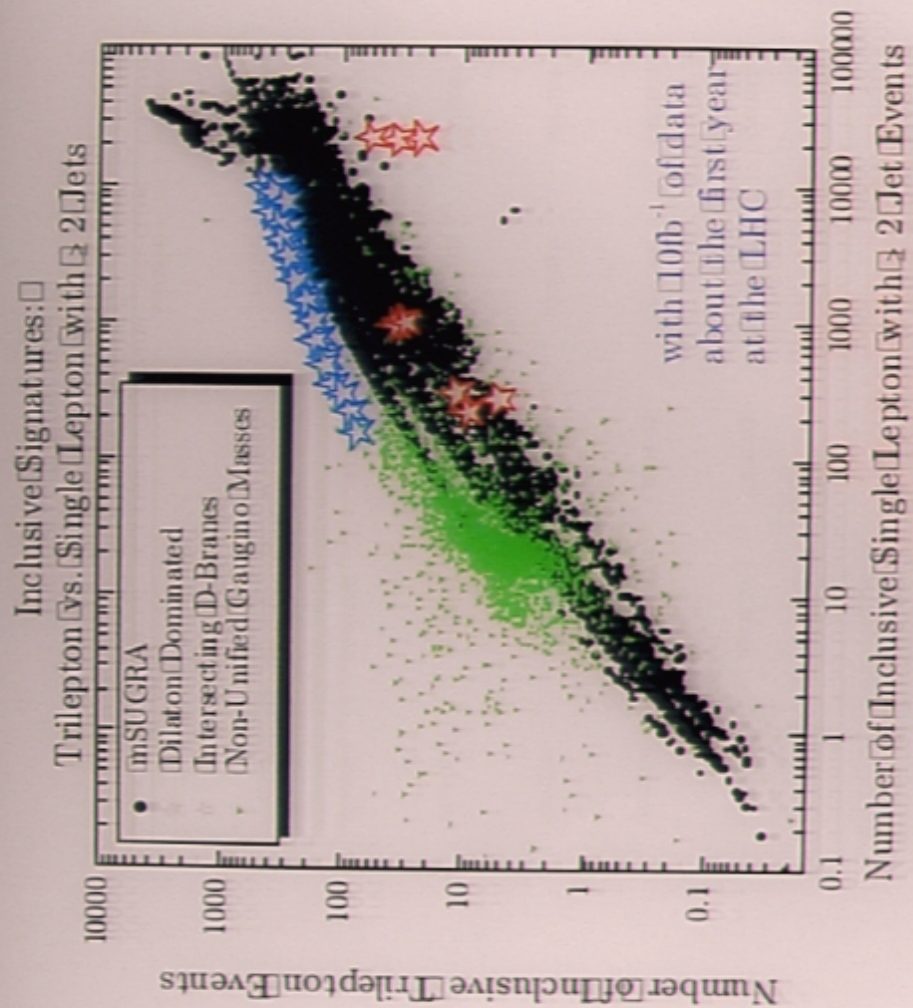


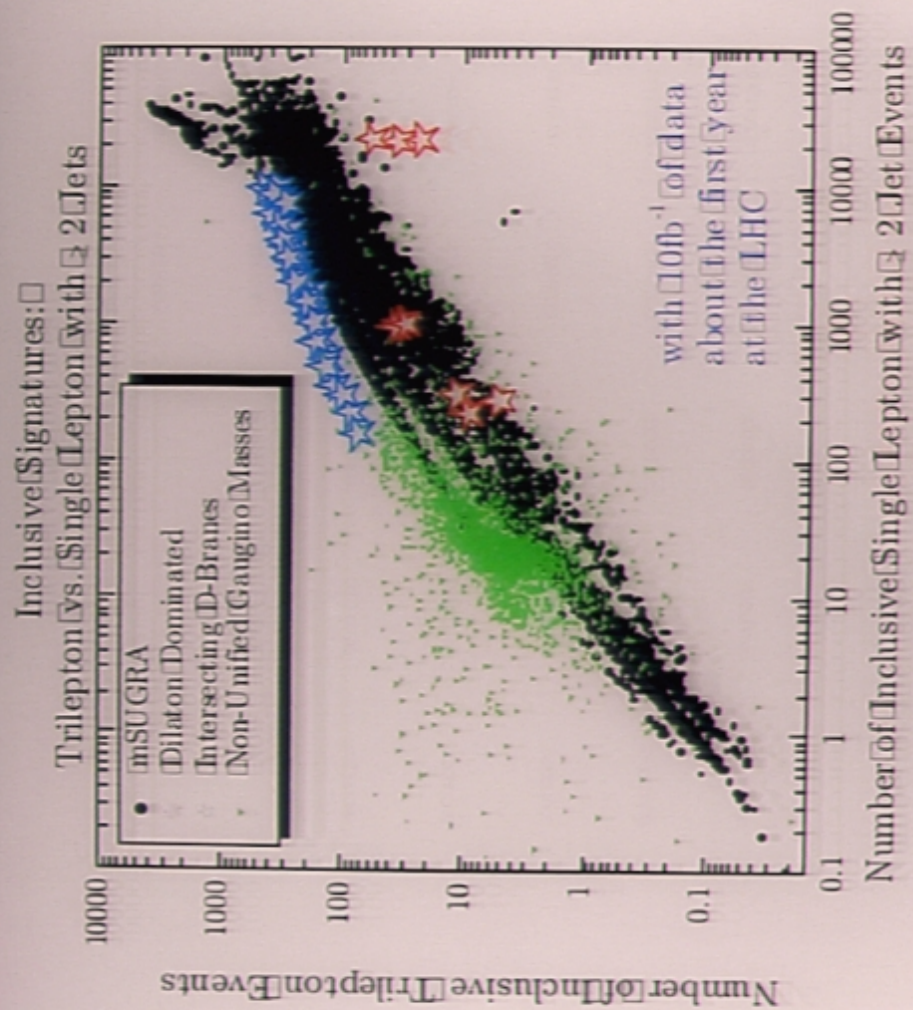


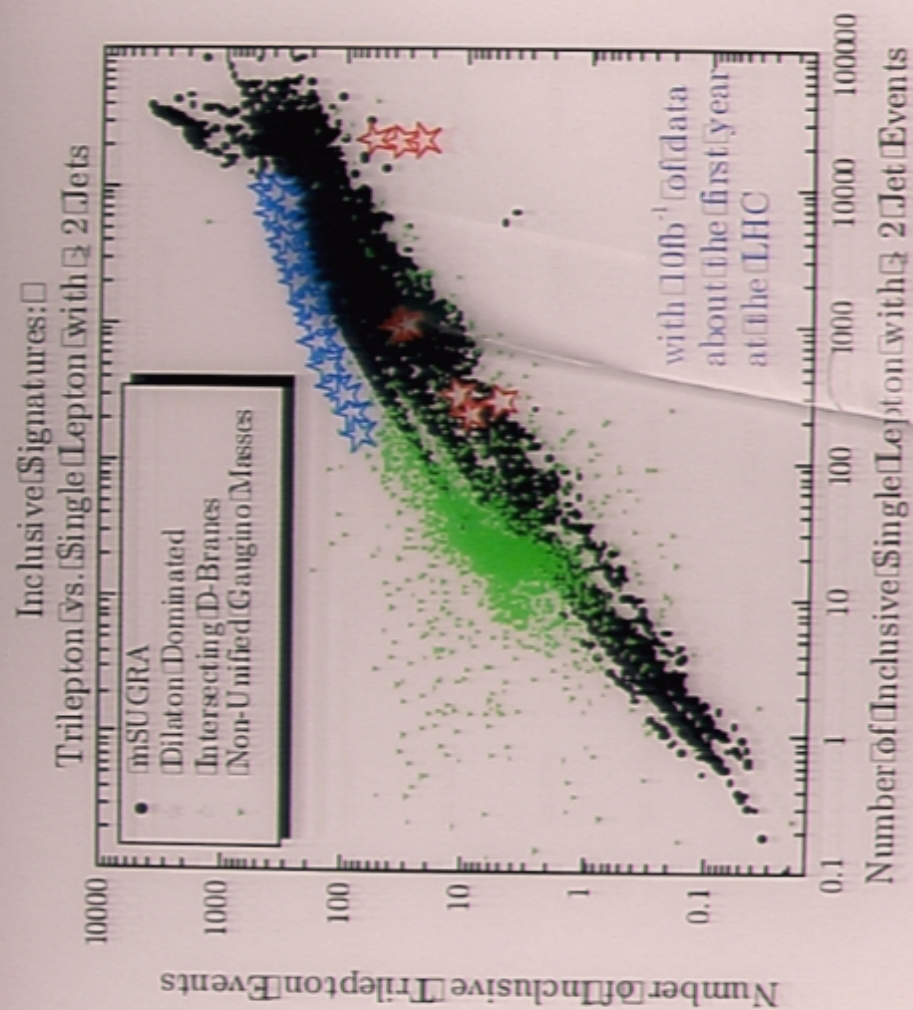


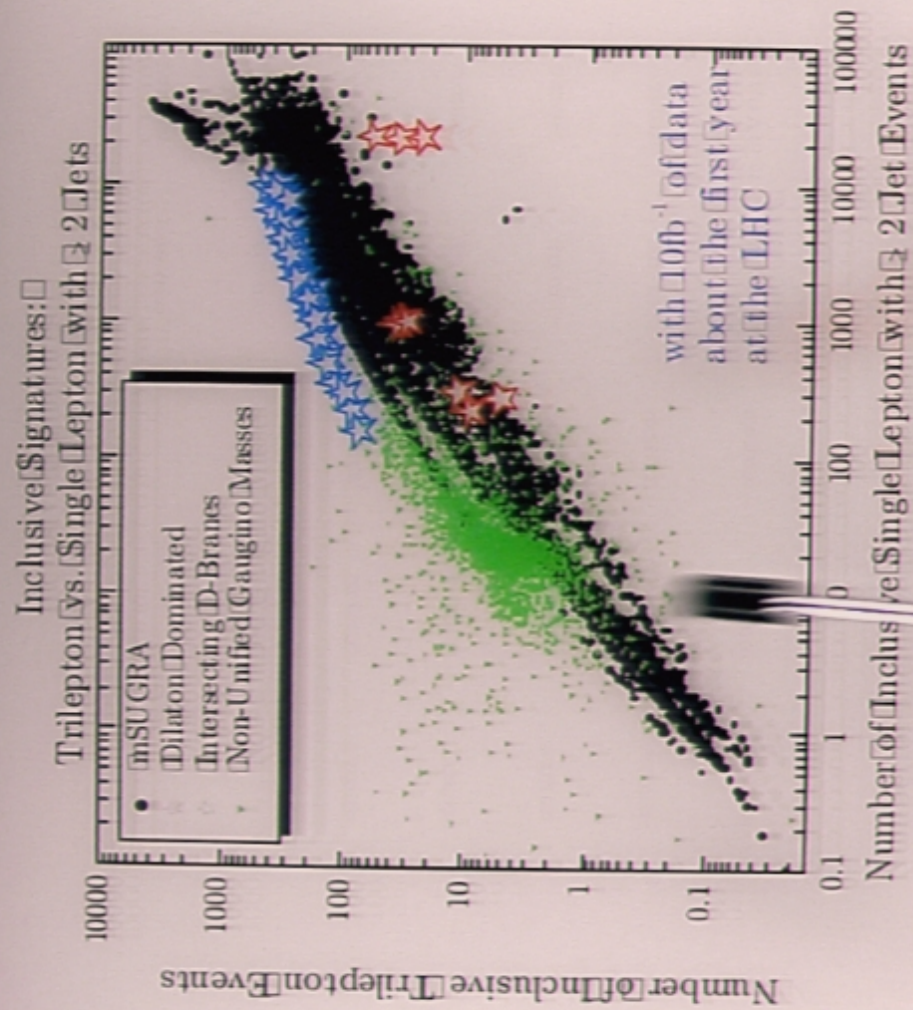


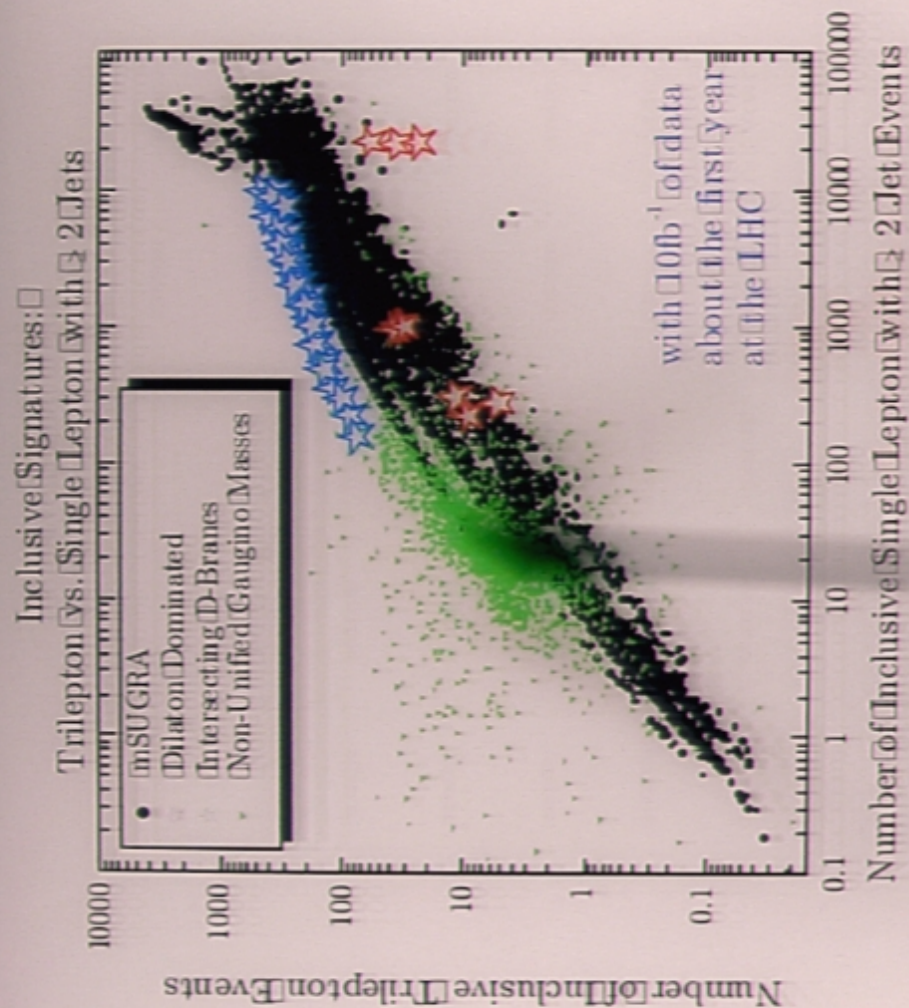


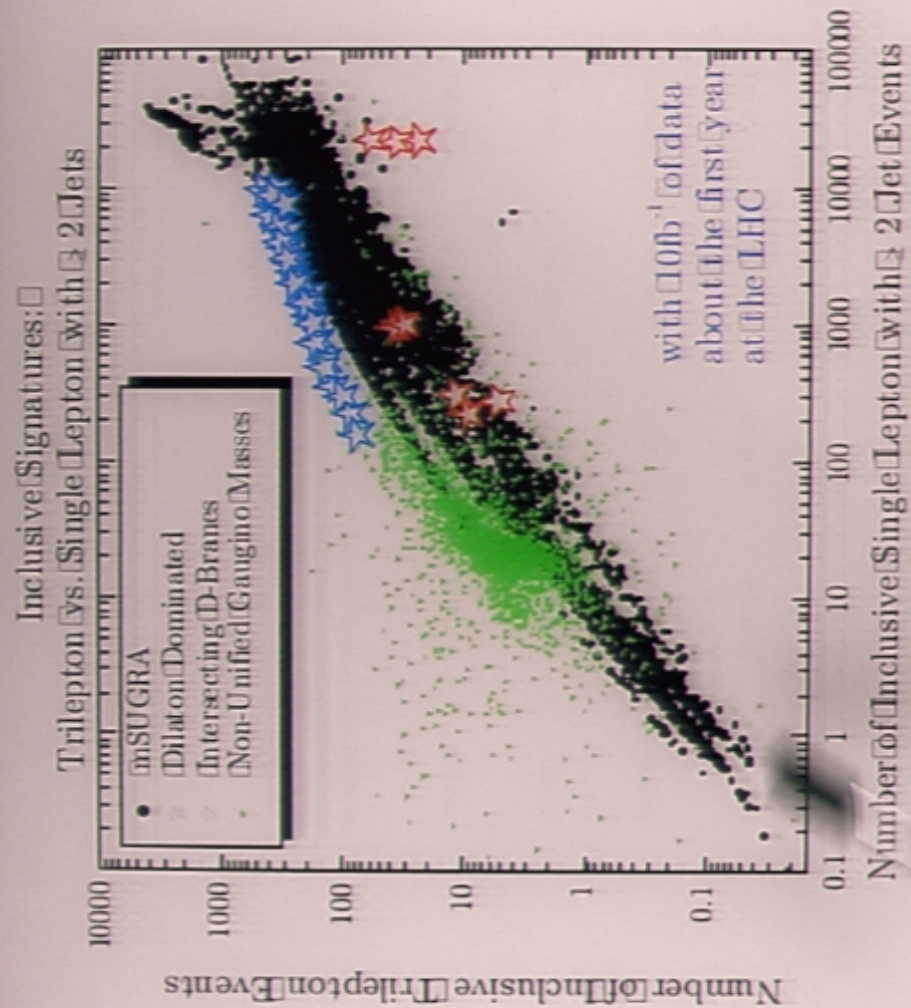


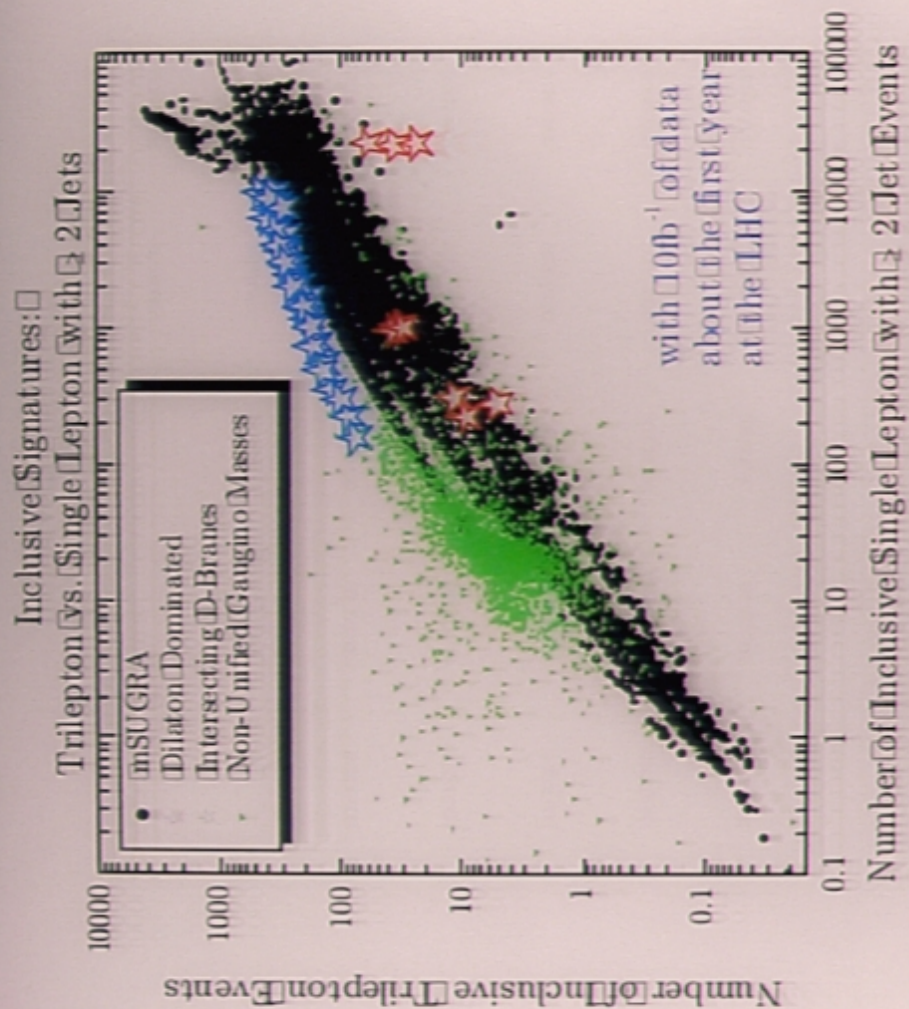












WILL BE ABLE TO STUDY τ AT
~ FEW % AT LHC

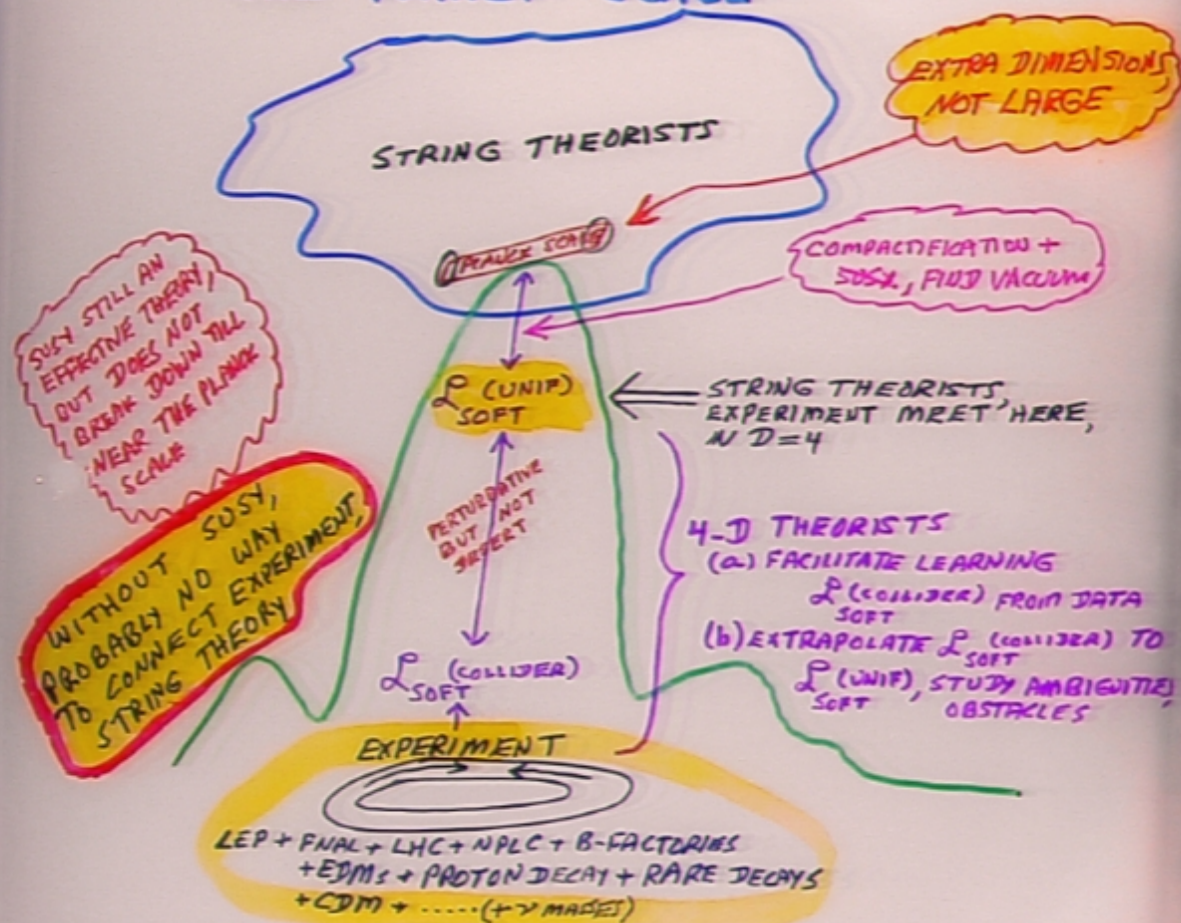
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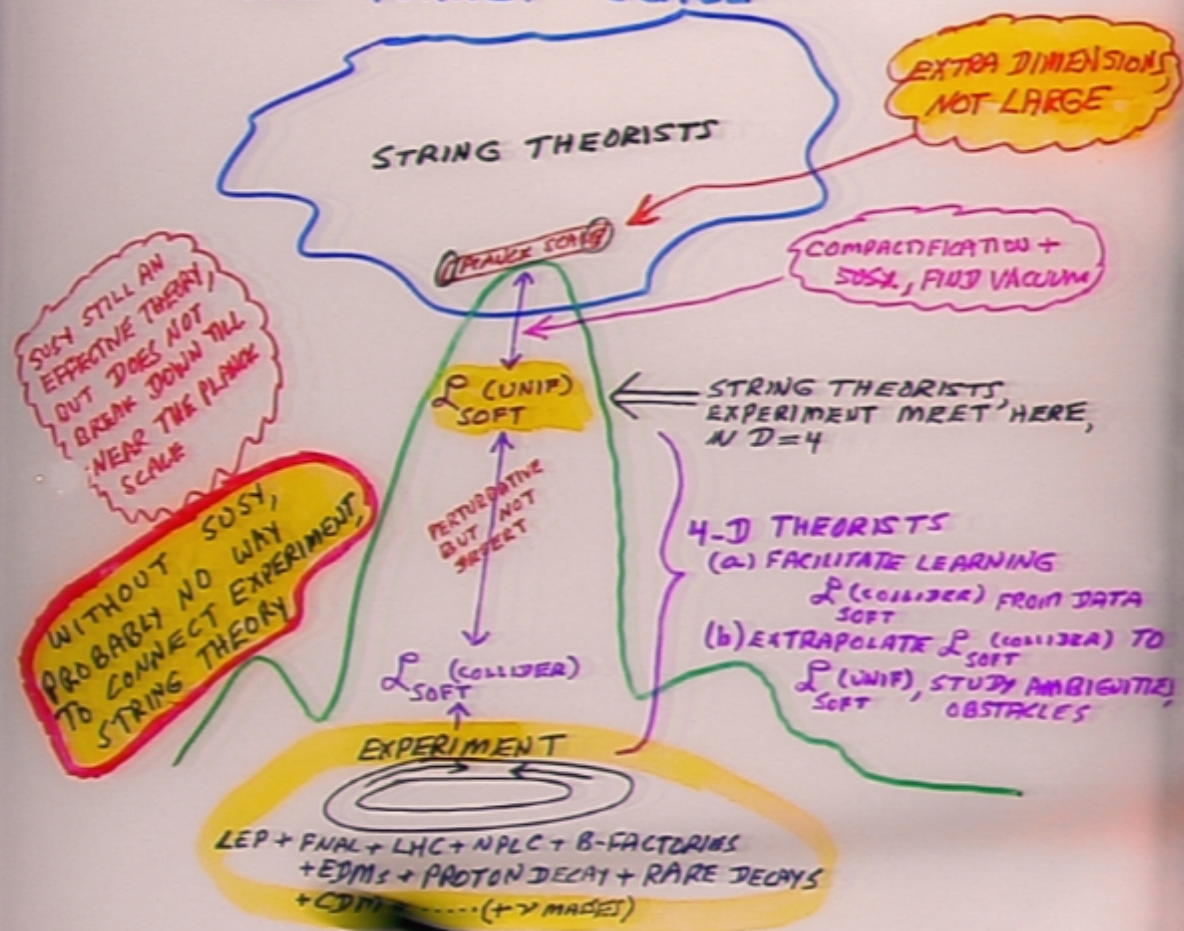
WILL BE ABLE TO STUDY ~~CR~~ AT
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SUPERSYMMETRY WILL BE A WINDOW ON THE PLANCK SCALE



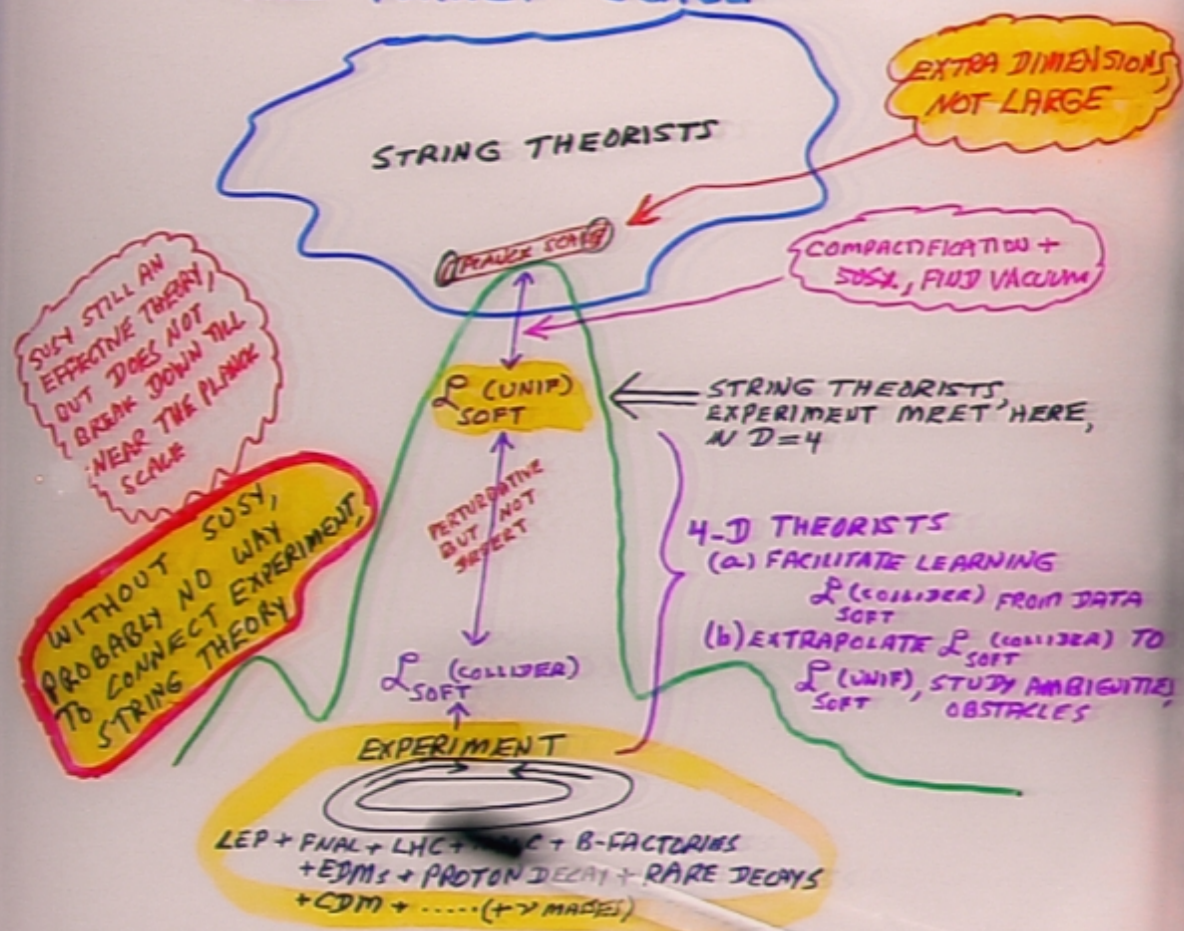
- ASSUMES PERTURBATIVITY SO CAN CONNECT SCALES
 - WELL MOTIVATED BY SUSY -- GAUGE COUPLING UNIFICATION -- DERIVATION OF HIGGS MECHANISM -- LIGHT HIGGS BOSON -- TESTABLE -- JUST PERTURBATIVE, NOT DESERT

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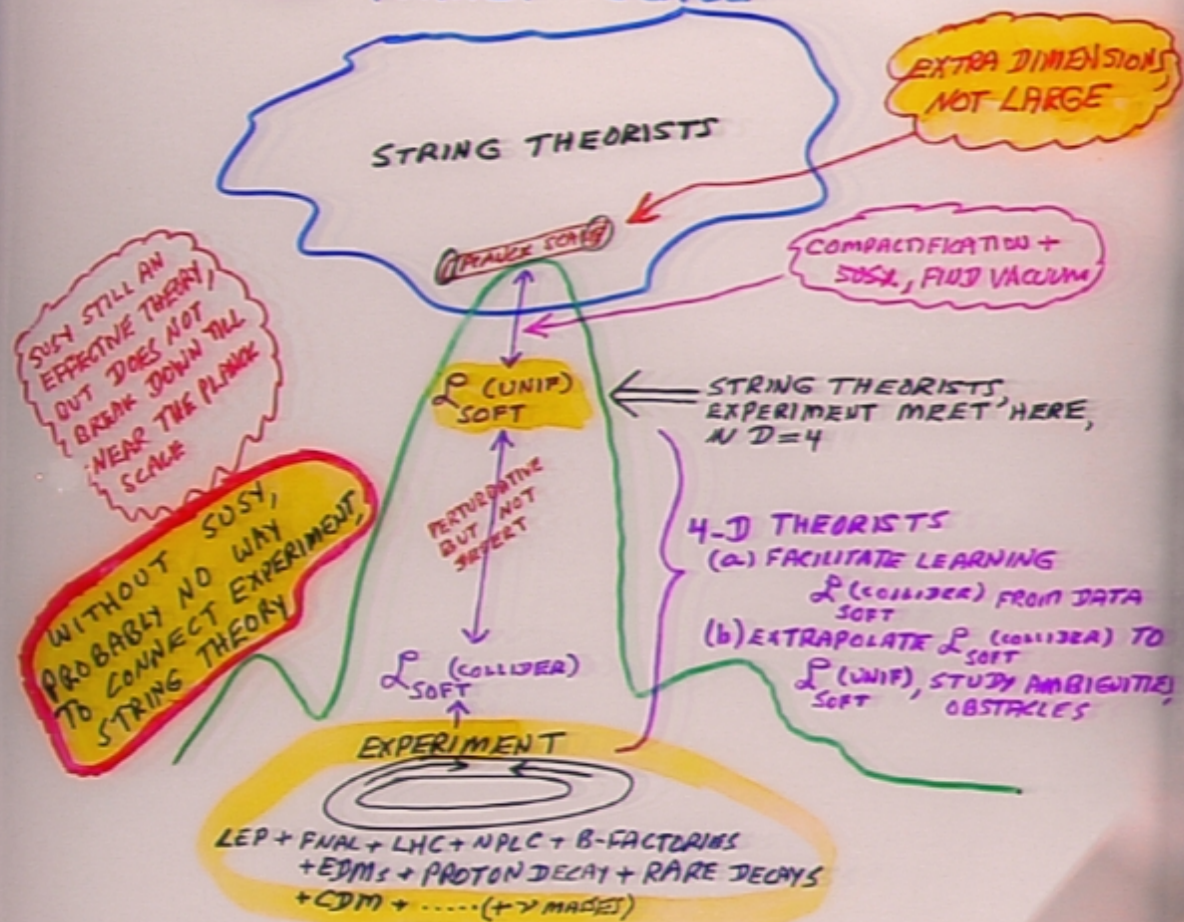
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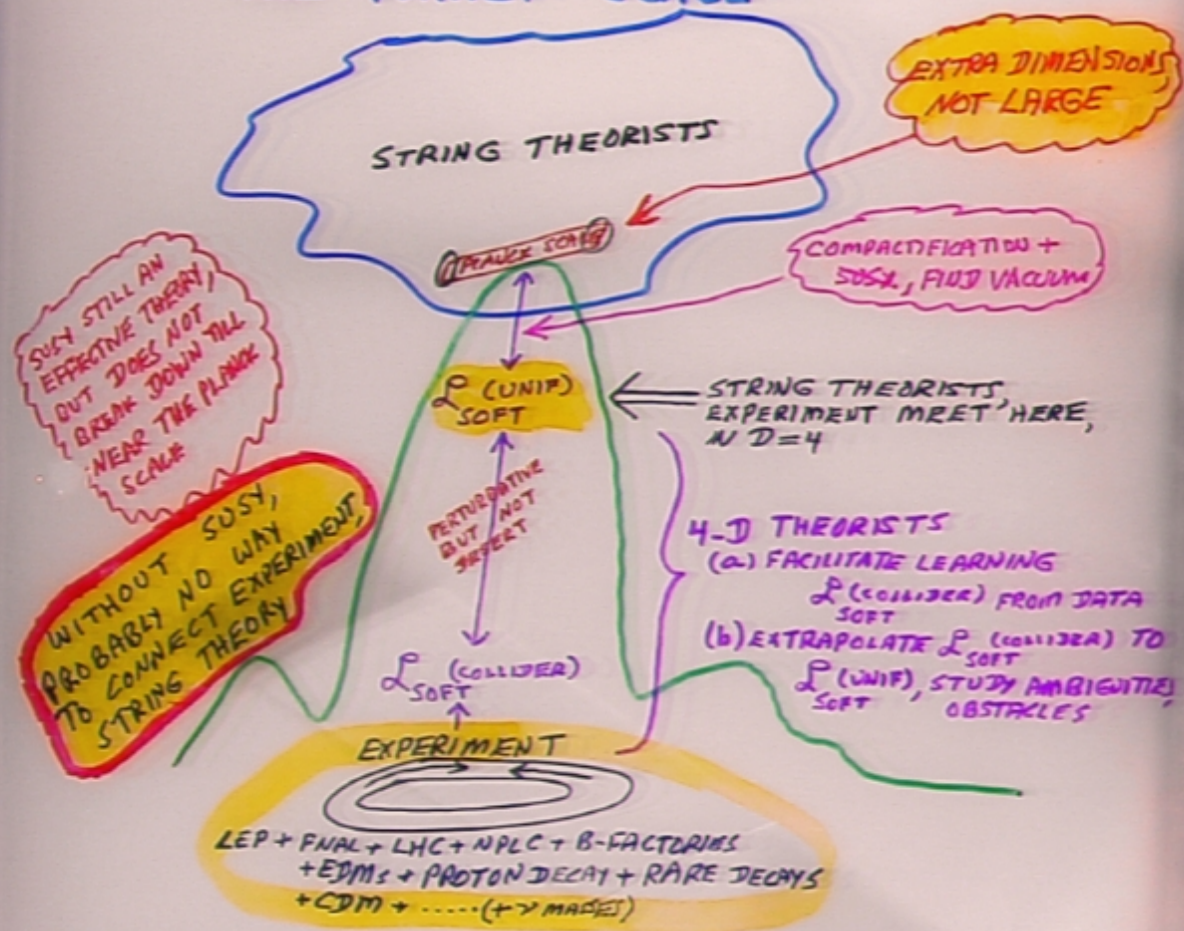
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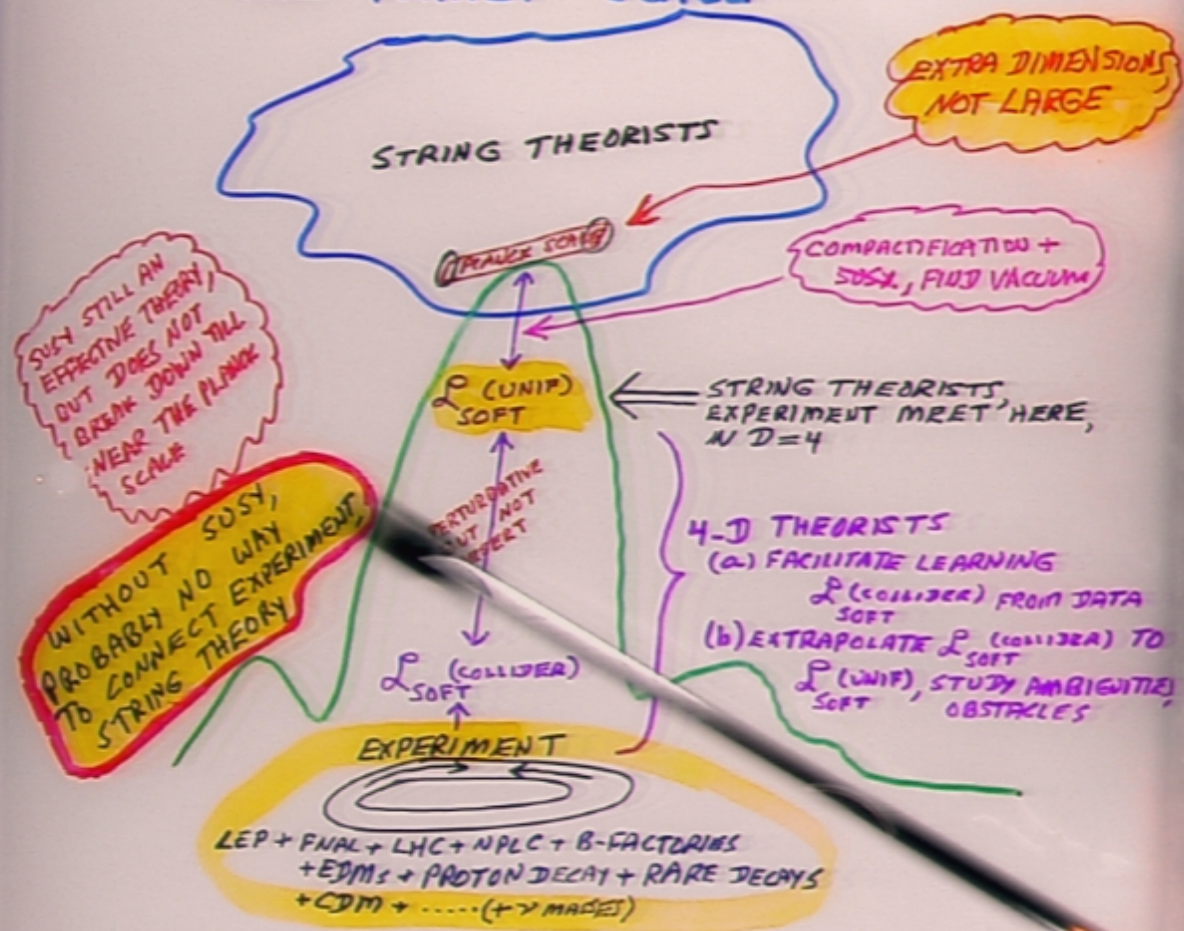
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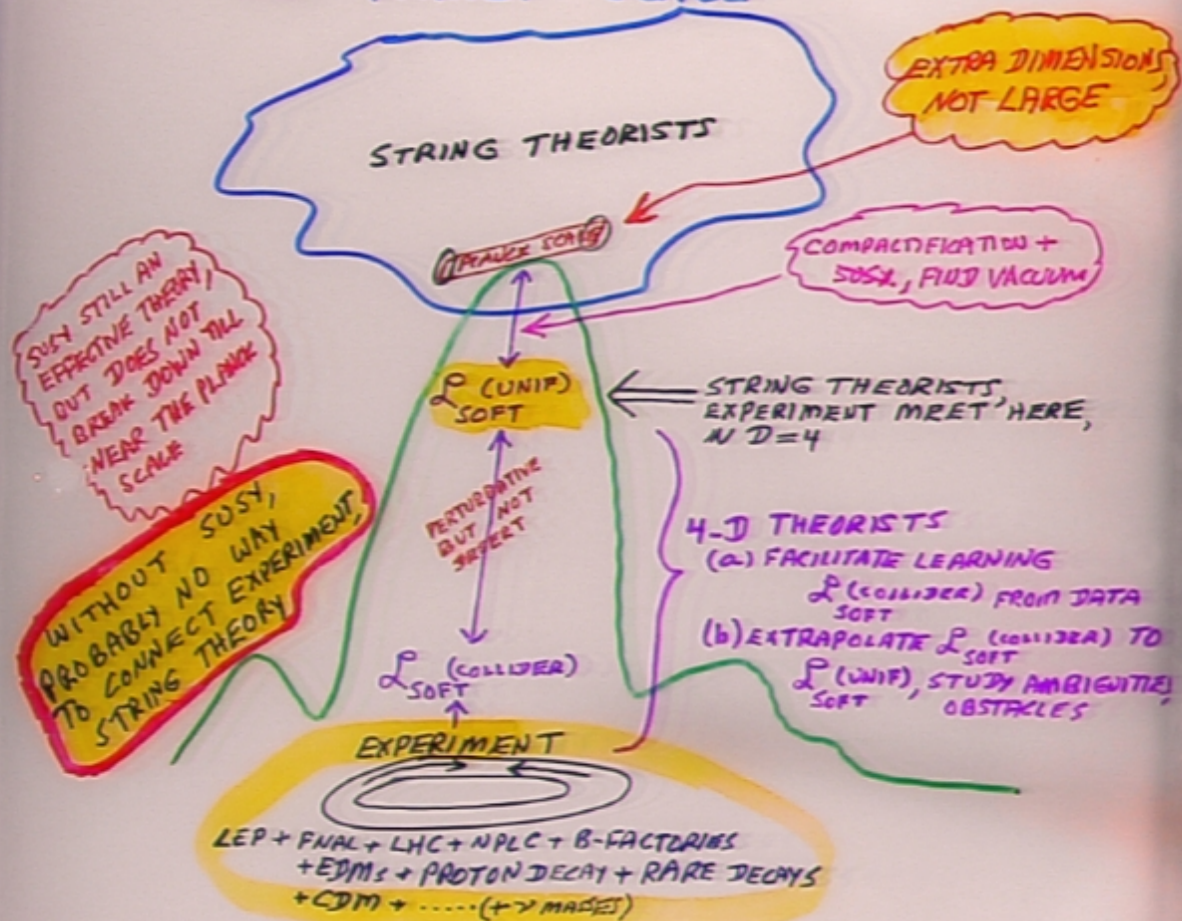
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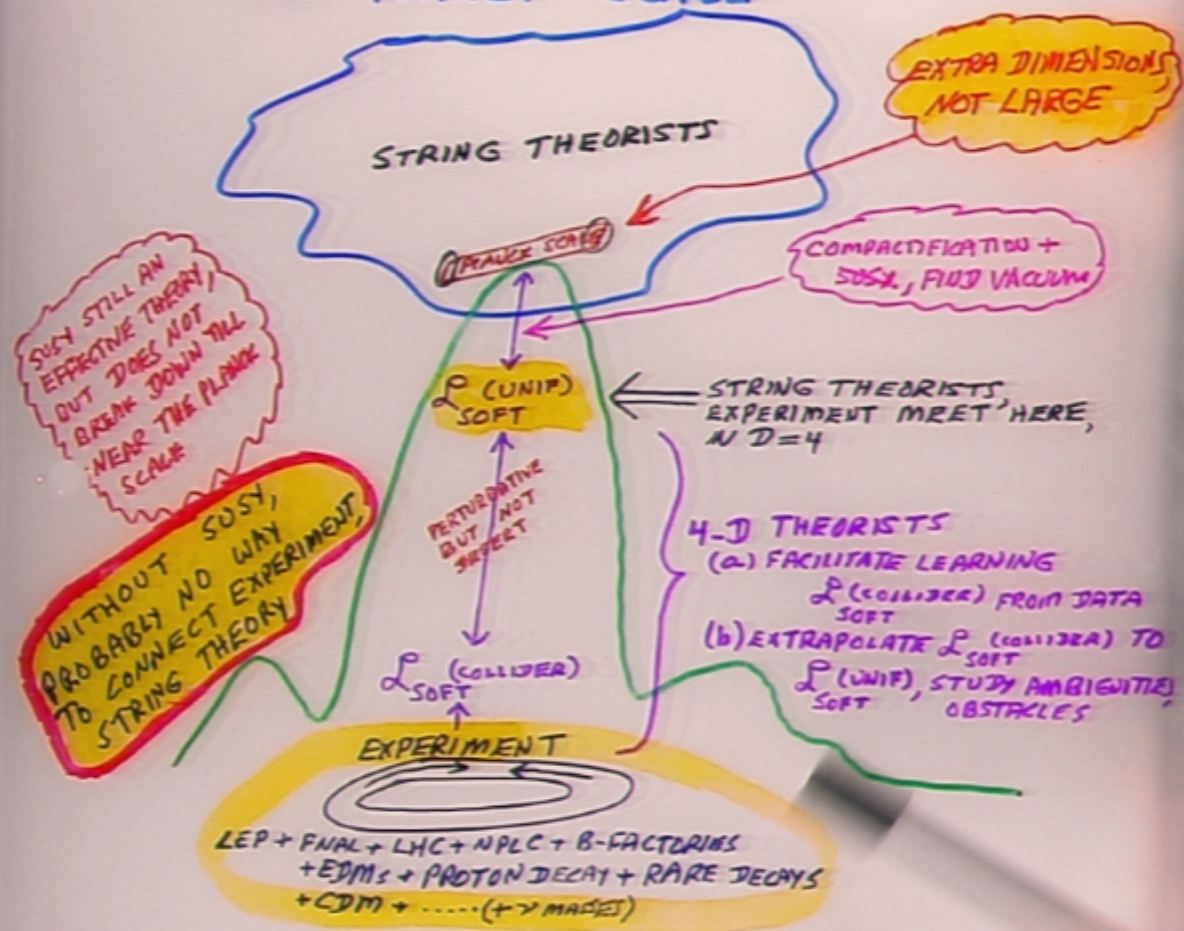
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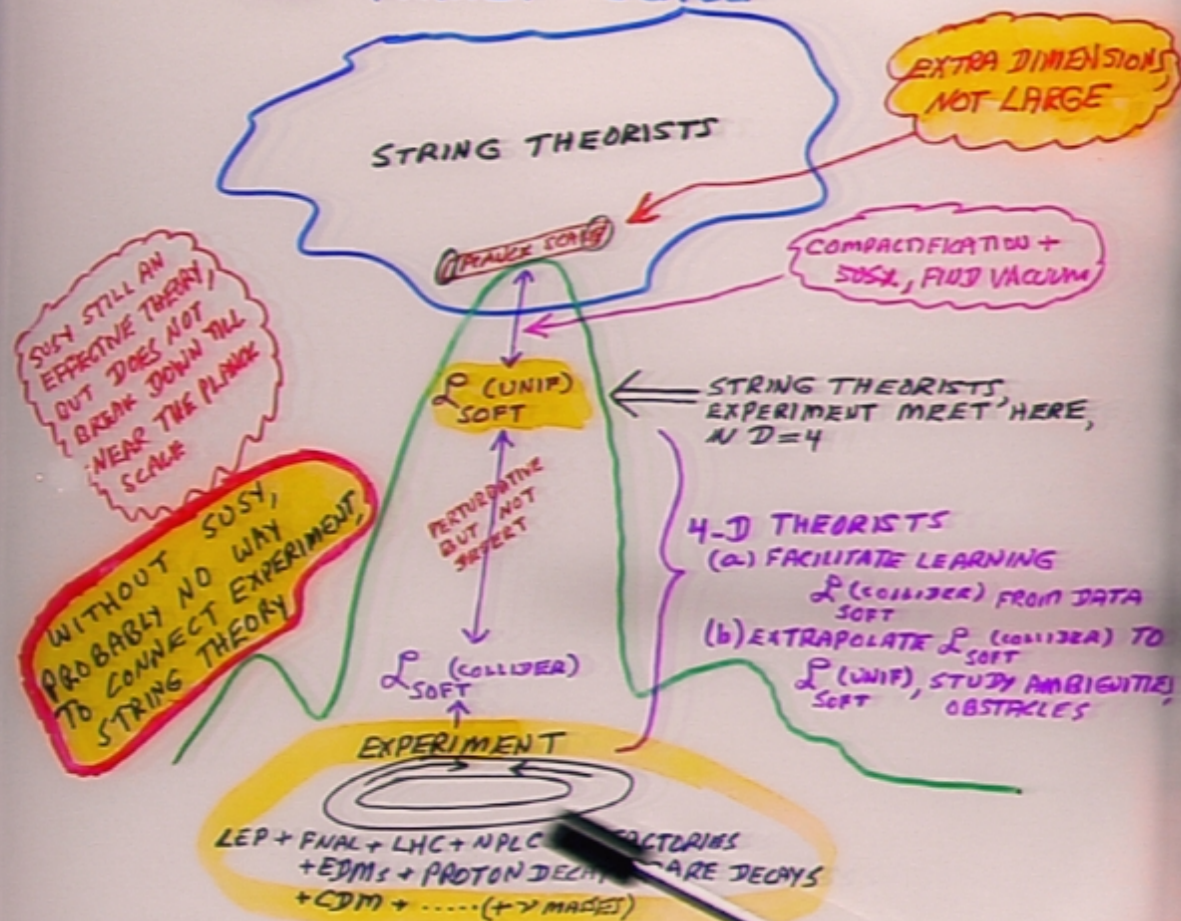
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- WEAK INTERACTIONS WEAK -- HADRON SPECTRO
- DEEP INELASTIC SCATTERING -- 2ν

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SSM? 4D STRING THEORY? 10D STRING THEORY?

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- $\Omega_{TOTAL} = 1$, $\Omega_{DM} \approx 0.3$
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- SUPERPARTNERS
 - * PHASES SMALL?
 - * $\tan \beta$?
 - * SFERMIONS HEAVY?
 - * GAUGINO MASS DEGENERACY?
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