# New Particle Searches at LEP200

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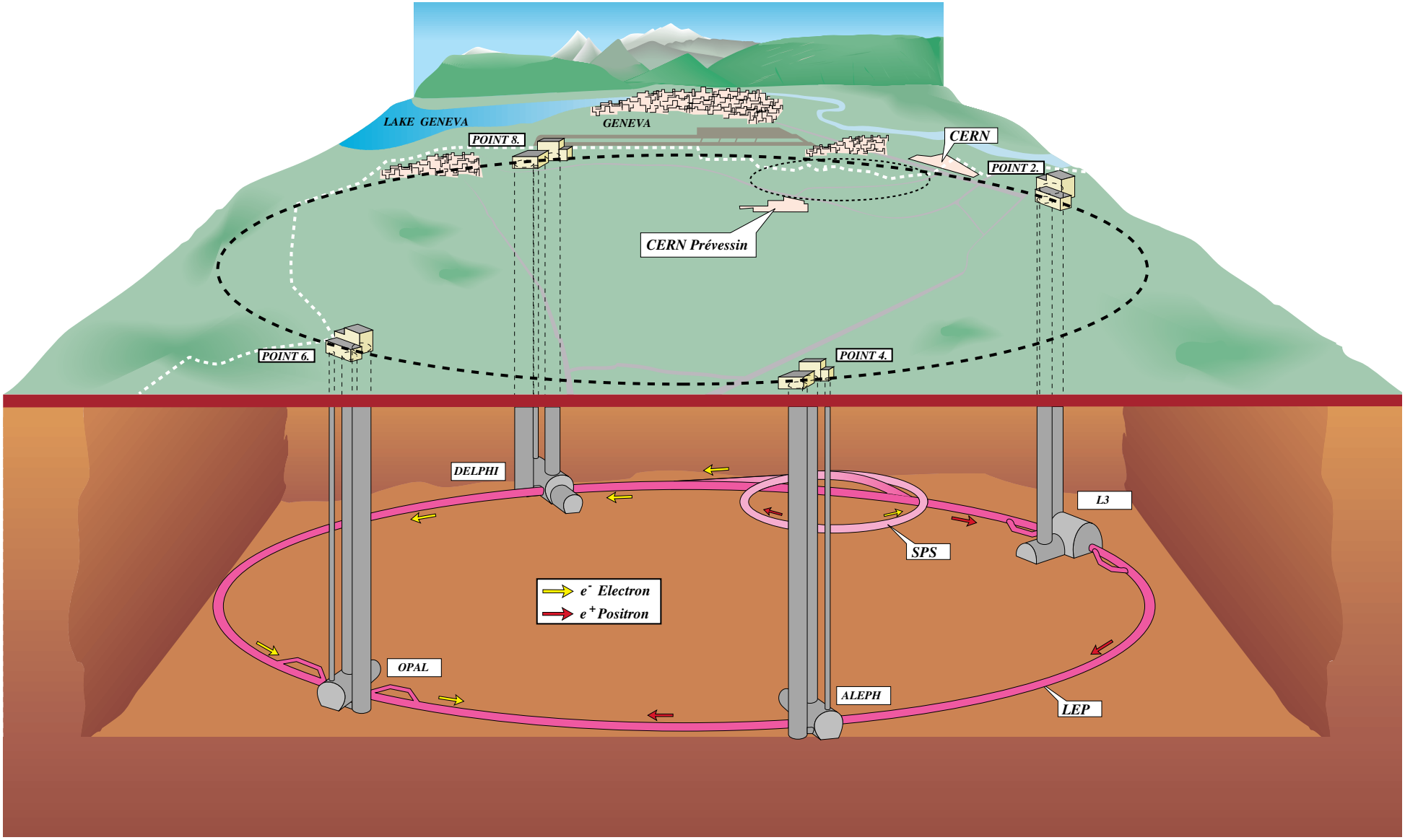
OPAL Collaboration

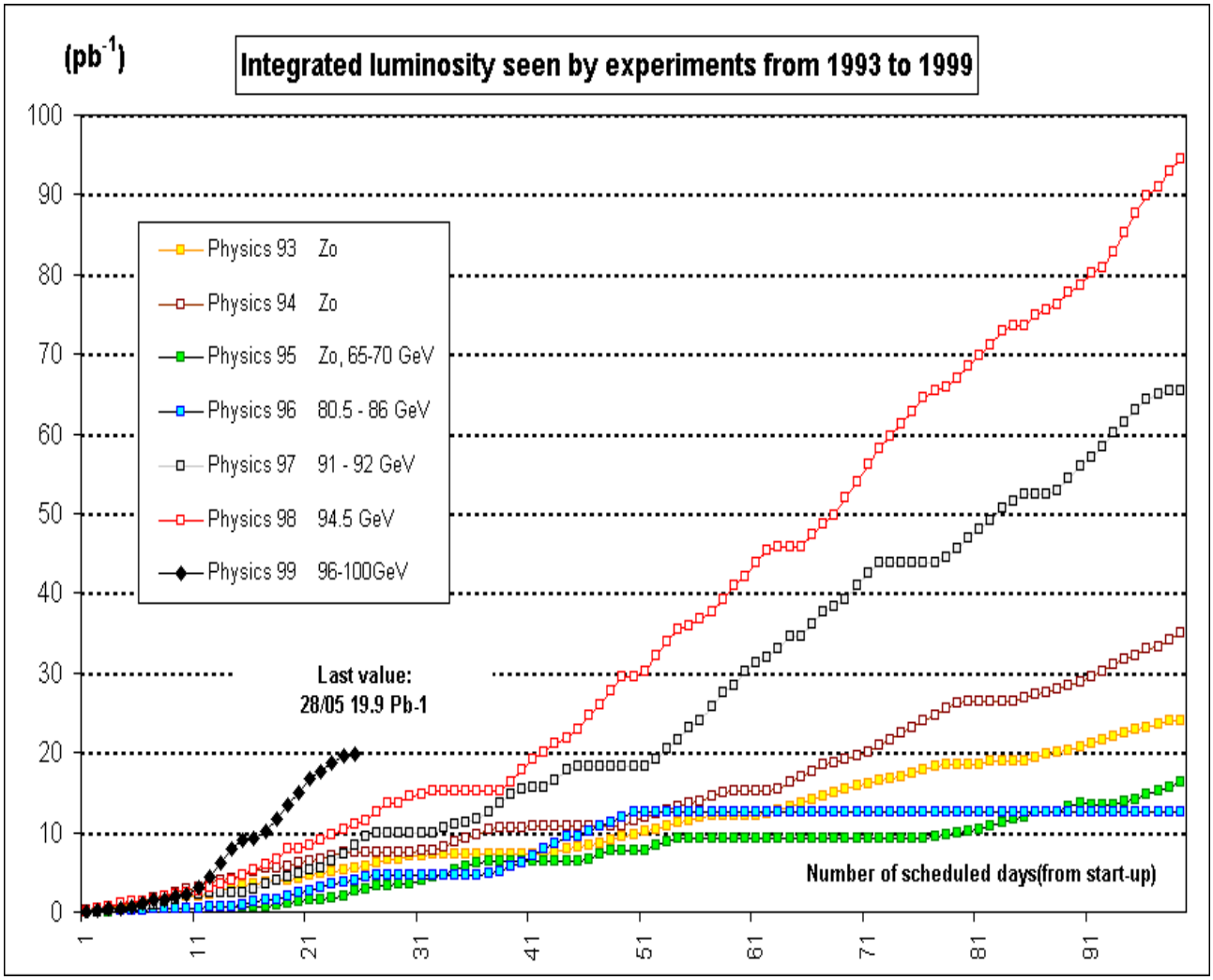
- Update on LEP
- Searches Overview: what to look for?
- Search Results
  - Standard Model Higgs
  - SUGRA/CMSSM SUSY
  - Gauge Mediated SUSY Particles
  - Gravity in extra dimensions
- Conclusions

# The LEP $e^+e^-$ Collider



# The LEP2 $e^+e^-$ Collider

| Stage | $\sqrt{s}$ | Year | Luminosity |
|---|---|---|---|
| LEP 1 | $\approx$ 91 GeV | 1989-1995 | 175 $pb^{-1}$ |
| LEP 1.5 | 130-140 GeV | 1995 | 5 $pb^{-1}$ |
| LEP 2 | 161 GeV | 1996 | 10 $pb^{-1}$ |
| | 172 GeV | 1996 | 10 $pb^{-1}$ |
| | 183 GeV | 1997 | 55 $pb^{-1}$ |
| | 189 GeV | 1998 | 150-180 $pb^{-1}$ |
| | 200 GeV !!! | 1999/2000 | $\sim$ 300 $pb^{-1}$ |



# Why Search? SM and beyond

$\{ W_1\ W_2\ W_3 \quad B \}$ $\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix}$ $\begin{pmatrix} \upsilon_e \\ e \end{pmatrix} \begin{pmatrix} \upsilon_\mu \\ \mu \end{pmatrix} \begin{pmatrix} \upsilon_\tau \\ \tau \end{pmatrix}$

EW

$H^0_{SM}$ $\{ W^{+/-}\ Z^0\ \gamma \}$

MORE? $\begin{pmatrix} t' \\ b' \end{pmatrix} \begin{pmatrix} \upsilon_L \\ L \end{pmatrix}$ composite $\begin{pmatrix} q^* \\ q^{*\prime} \end{pmatrix} \begin{pmatrix} \upsilon_l^* \\ l^* \end{pmatrix}$

Hierarchy Problem

~~SUSY~~ Minimal ⇒ MSSM FCNC ⇒ SUGRA { STRINGY, $\tilde{\chi}^0$ CDM

GMSB { AVOID GRAVITY FCNC, ...

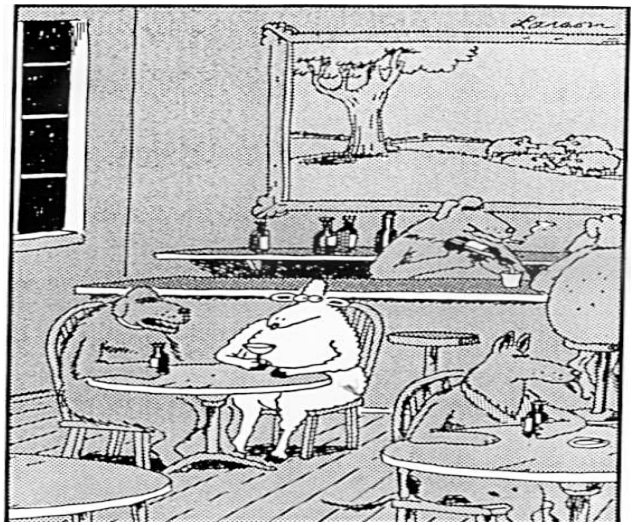
SUSY ⇒ $\tilde{W}^{+/-}\ \tilde{Z}^0\ \tilde{\gamma}$ $\begin{pmatrix} \tilde{u} \\ \tilde{d} \end{pmatrix} \begin{pmatrix} \tilde{c} \\ \tilde{s} \end{pmatrix} \begin{pmatrix} \tilde{t} \\ \tilde{b} \end{pmatrix}$

2HDM $\tilde{h}^0\ \tilde{H}^0\ \tilde{H}^{+/-}$ $\begin{pmatrix} \tilde{\upsilon}_e \\ \tilde{e} \end{pmatrix} \begin{pmatrix} \tilde{\upsilon}_\mu \\ \tilde{\mu} \end{pmatrix} \begin{pmatrix} \tilde{\upsilon}_\tau \\ \tilde{\tau} \end{pmatrix}$

$h^0 H^0 A^0 H^{+/-}$

GRAVITY IN EXTRA DIMENSIONS

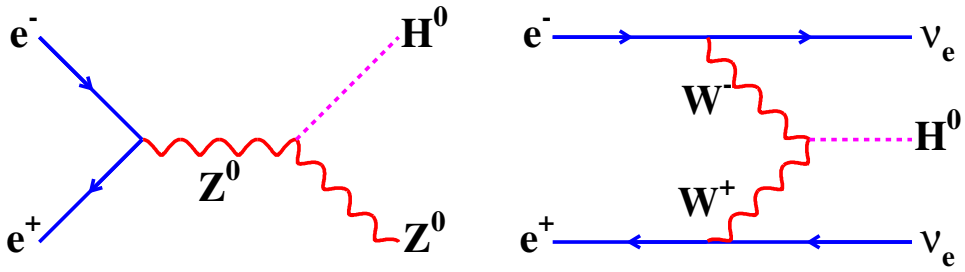
"$M_P$" ≅ $M_{EW}$



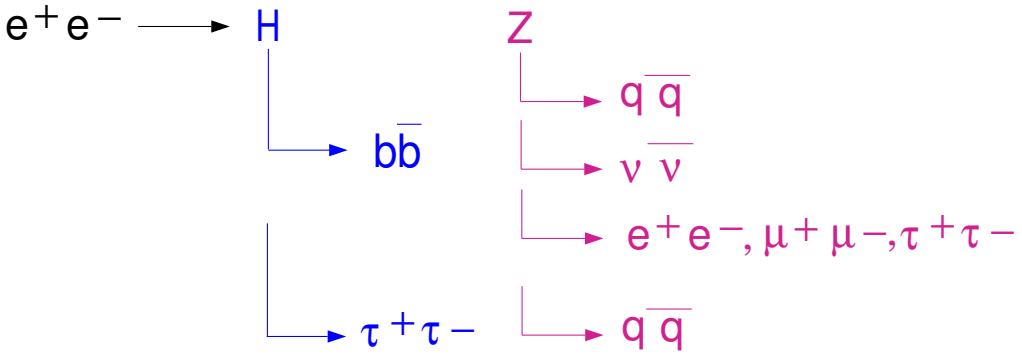
Confession time, Mona: I've lead you astray.

# Standard Model Higgs

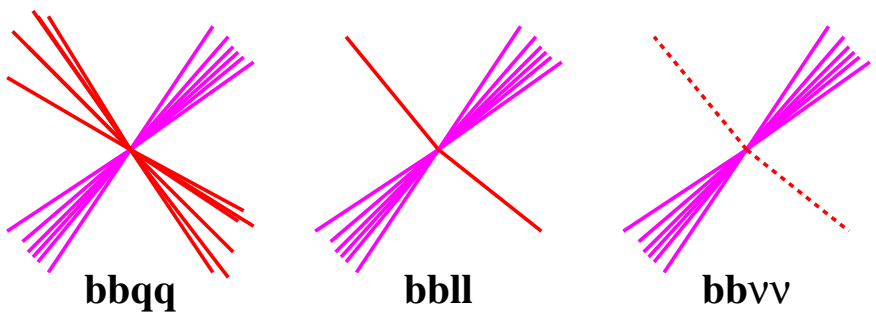
- Production by "Higg-strahlung:" $e^+e^- \rightarrow ZH^0$




- Different Search Topologies:

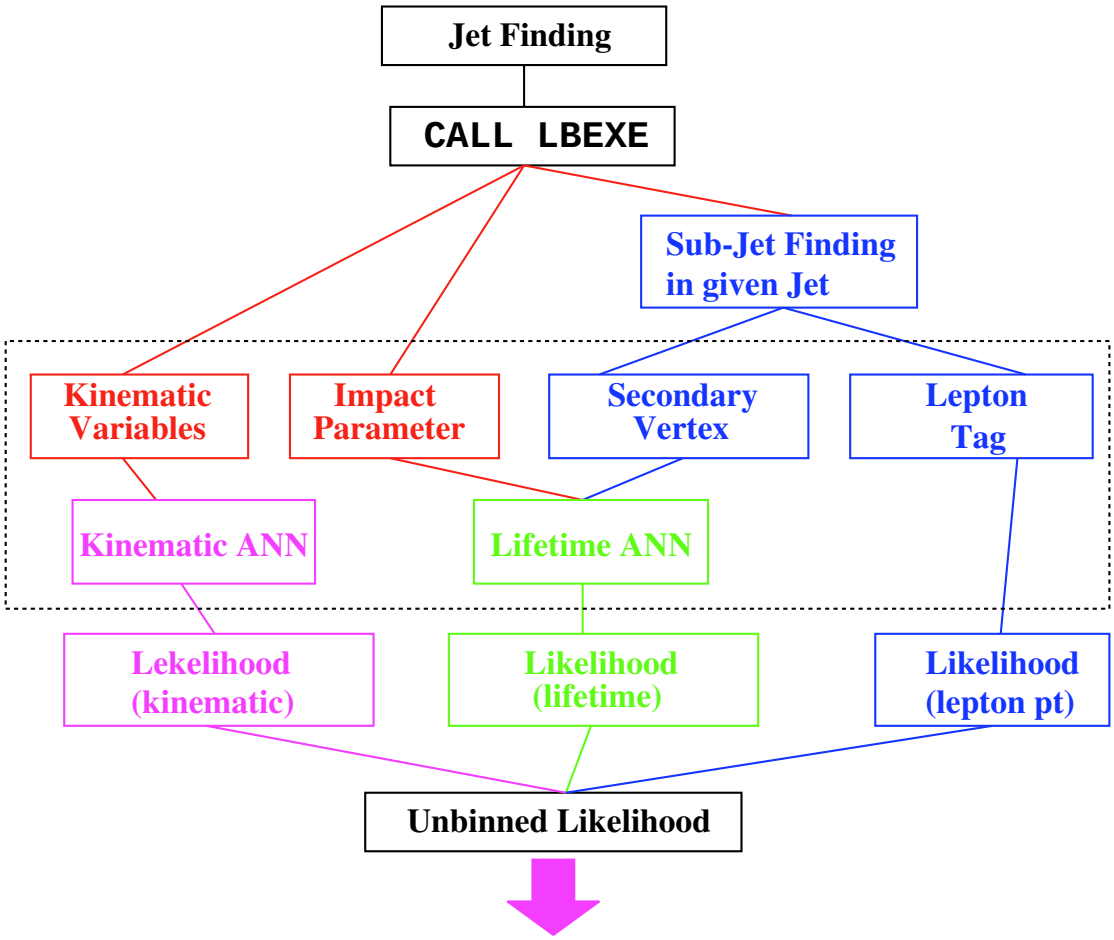


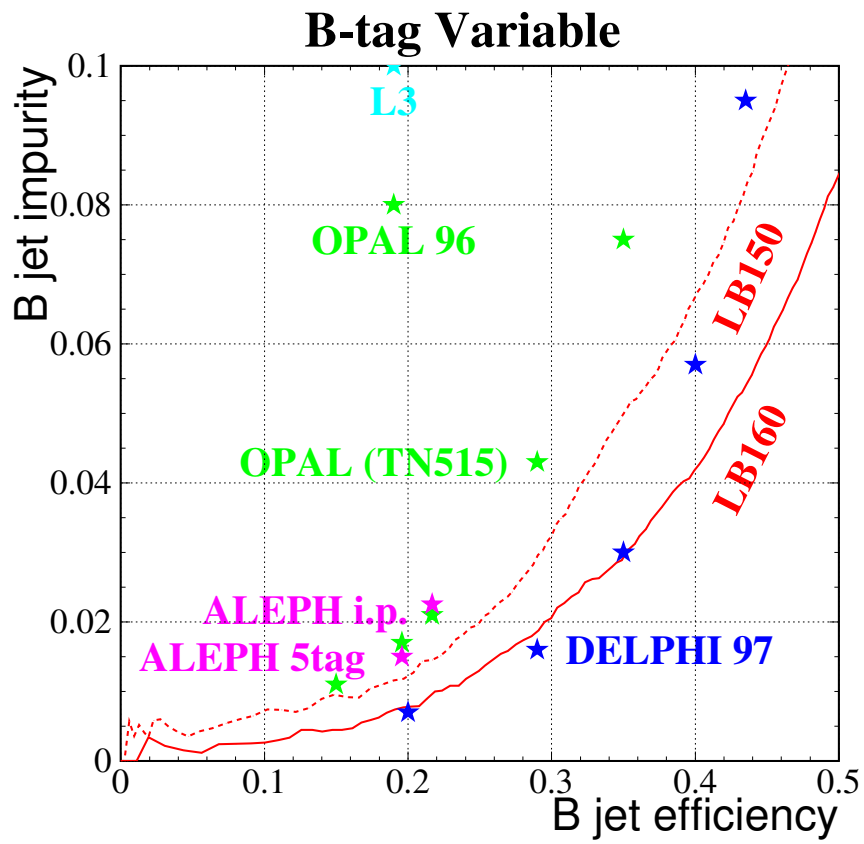

- Dominant Channels:



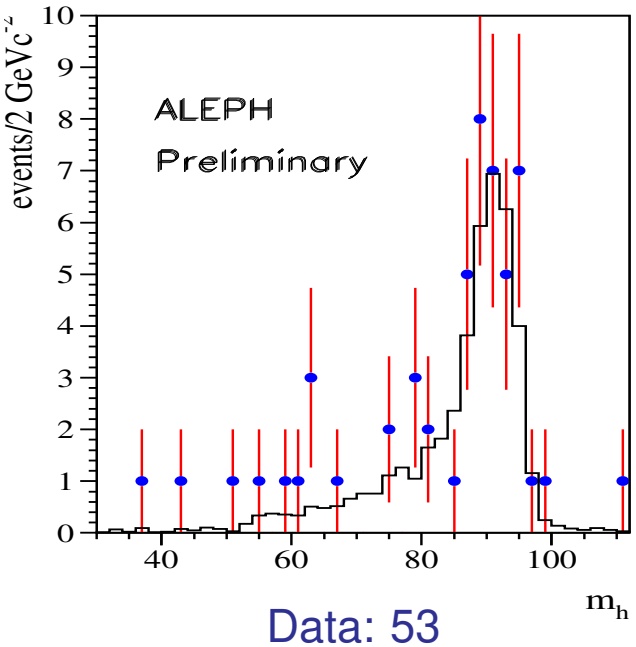

- Key to analysis: b-tagging -

# Example: higgs b-Tagging in OPAL

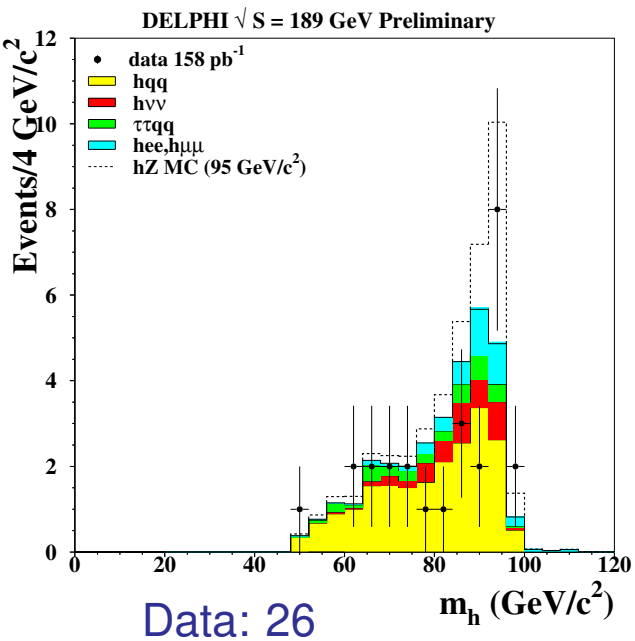


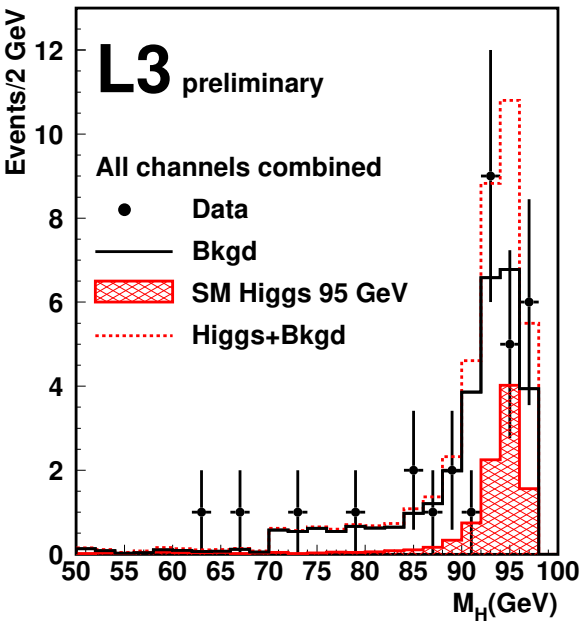
# Higgs Results: Mass Spectra



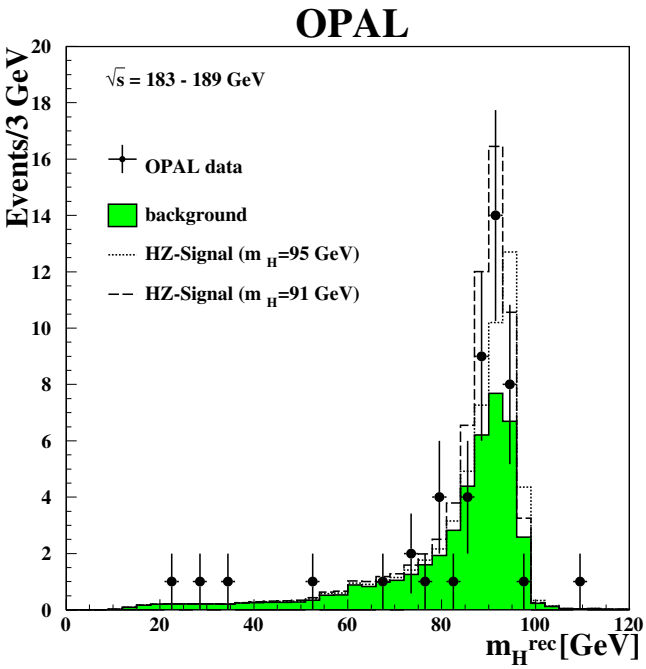

Data: 53
Bkg.: 44.8




Data: 26
Bkg.: 31.3

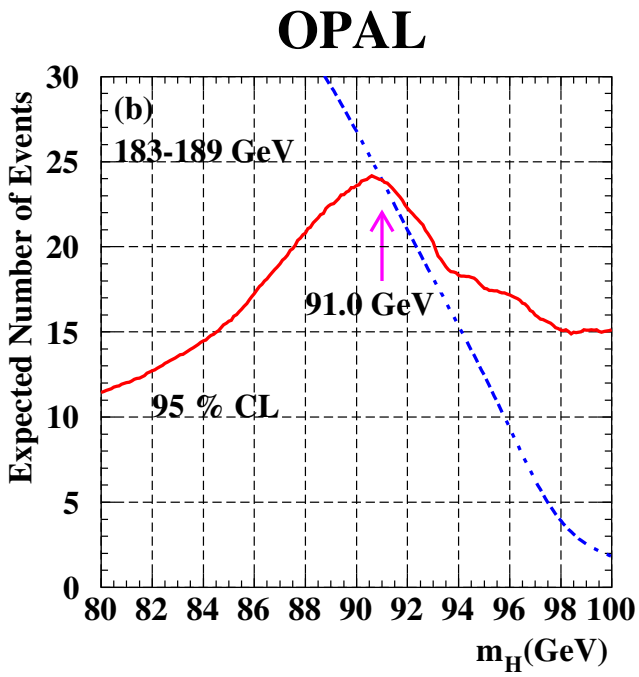


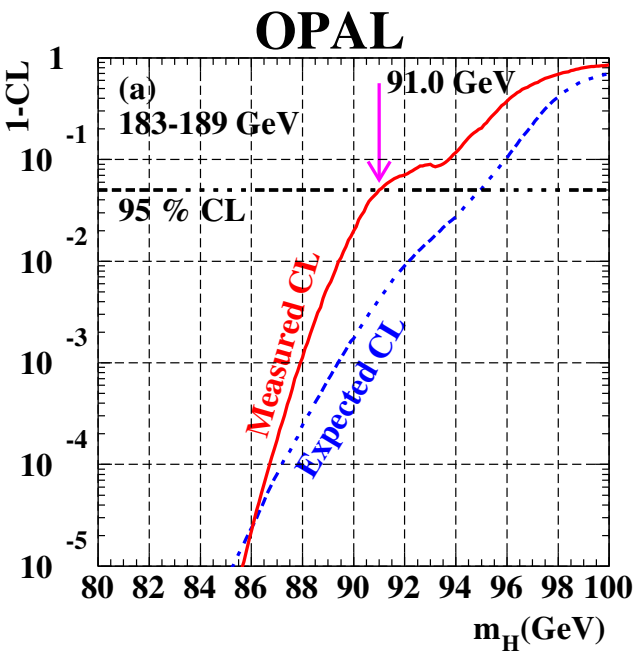

Data: 30
Bkg.: 30.3




Data: 50
Bkg.: 43.9

# SM Higgs: Mass Limits




# Numerical Limits

| Experiment | Observed | Expected | Probability |
|---|---|---|---|
| ALEPH | 90.2 GeV | 95.7 GeV | 1% |
| DELPHI | 95.2 GeV | 94.8 GeV | 68% |
| L3 | 95.2 GeV | 94.4 GeV | 55% |
| OPAL | 91.0 GeV | 94.9 GeV | 4% |

- Overall: not a significant excess
- Need more data

# SUSY MODELS: guide the eye ...

| Spin | 0 | 1/2 | 1 |
|---|---|---|---|
| | $\tilde{\ell}^{\pm}_{\mathrm{L,R}}$ } $\tilde{\ell}^{\pm}_{1,2}$ | $\ell^{\pm}_{\mathrm{L,R}}$ | |
| | $\tilde{\nu}_{\mathrm{L}}$ | $\nu_{\mathrm{L}}$ | |
| | $\tilde{\mathrm{q}}_{\mathrm{L,R}}$ }$\tilde{q}_{1,2}$ | $\mathrm{q}_{\mathrm{L,R}}$ | |
| | | $\tilde{g}$ | $g$ |
| | | $\tilde{\gamma}$ | $\gamma$ |
| | $\mathrm{h}^0, \mathrm{H}^0, \mathrm{A}^0$ | $\tilde{\mathrm{h}}, \tilde{\mathrm{H}}$ } $\tilde{\chi}^0_{\mathrm{j}}$ | |
| | | $\tilde{\mathrm{Z}}^0$ | $\mathrm{Z}^0$ |
| | $\mathrm{H}^{\pm}$ | $\tilde{\mathrm{H}}^{\pm}$ } $\tilde{\chi}^{\pm}_{\mathrm{i}}$ | |
| | | $\tilde{\mathrm{W}}^{\pm}$ | $\mathrm{W}^{\pm}$ |

## "Minimal" Field content: MSSM

| | |
|---|---|
| $M_1, M_2, M_3$ | $U(1), SU(2), SU(3)$ Gaugino Masses |
| $m_{\tilde{f}}$ | sfermion masses |
| $v, \tan\beta, m_{A^0}, \mu$ | Higgs(ino) mass/mixing parameters |
| $A_U, A_D, A_L,$ | Trilinear sfermion/higgs coupling matrices |

105 new parameters, unsupressed FCNC, ...

## (SUGRA) Constrain it $\Rightarrow$ CMSSM

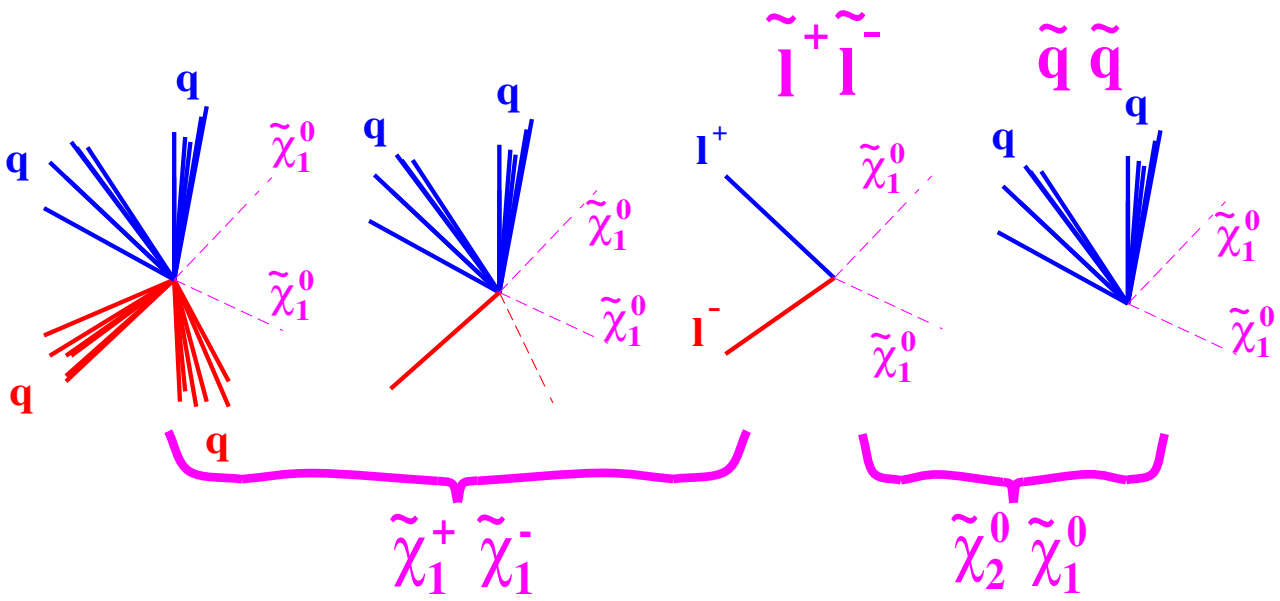
| | |
|---|---|
| $M_2$ | EW-scale $SU(2)$ Gaugino Mass |
| | (GUT Unification gives $M_1$, $M_3$) |
| $m_0$ | Common GUT-scale (Plank!) scalar mass |
| | (EW-scale masses from RGE's) |
| $\tan\beta$ | $v_2/v_1$, Ratio of vev's of two higgs doublets |
| $A_0$ | Common trilinear coupling |
| $\mu$ | Higgs mixing parameter |
| $m_{\mathrm{A}^0}$ | Pseudo Scalar Higgs Mass |

6'ish new parameters, FCNC *etc.* controllable

# Parameters $\leftrightarrow$ Search Channels

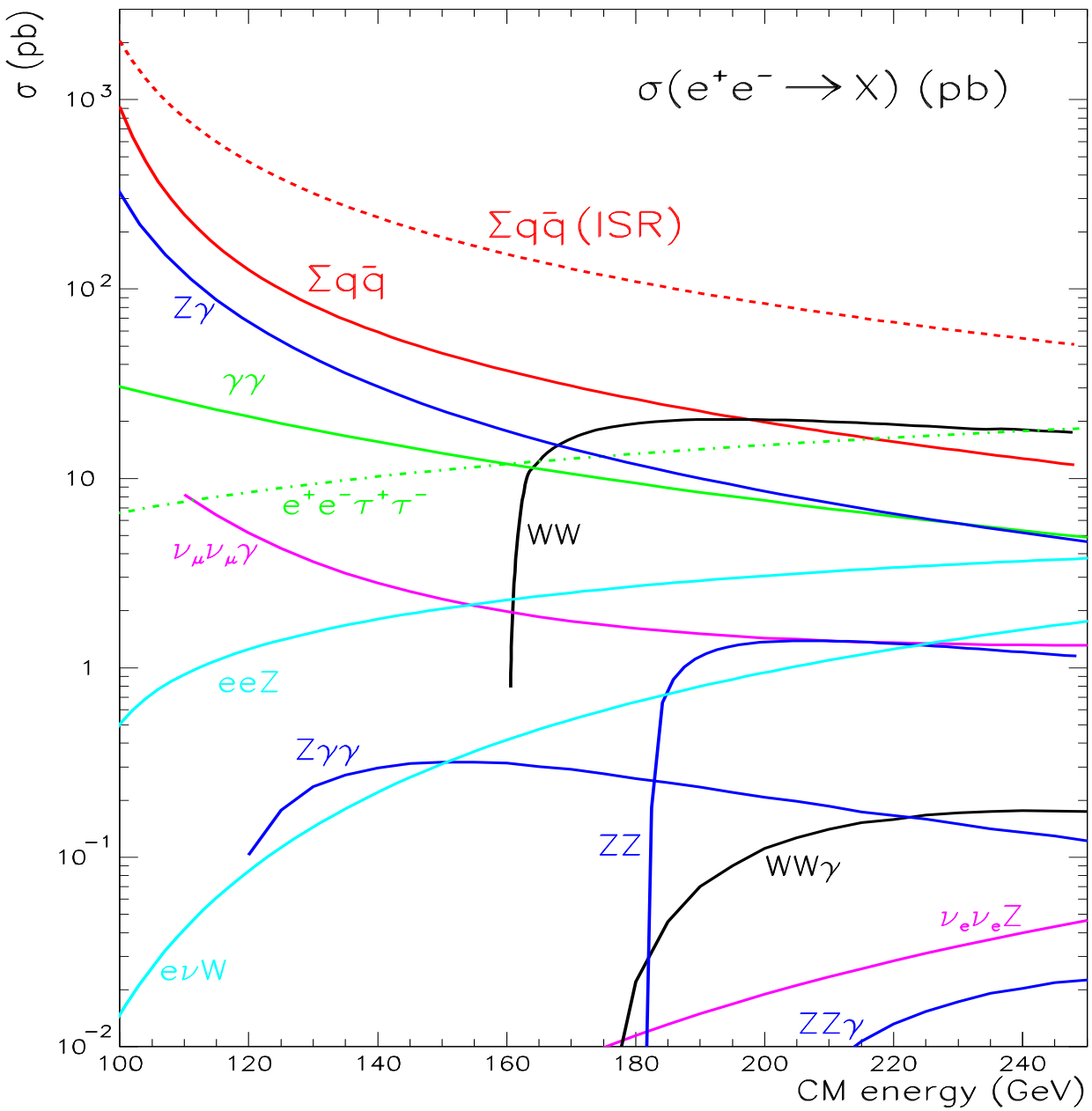
| $\mu << M_2$ Higgsino Region no $\tilde{\nu}$ coupling | $\mu >> M_2$ Gaugino Region | | |
|---|---|---|---|
| | Large $m_0, m_{\tilde{f}}$ | Small $m_0, m_{\tilde{f}}$ | |
| | | | Large $\tilde{q}$ Mix |
| $\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_2^0\tilde{\chi}_1^0$ | | $\tilde{\ell}^+\tilde{\ell}^-$ | $\tilde{t}\tilde{t}, \tilde{b}\tilde{b}$ |

# Primary Search Topologies



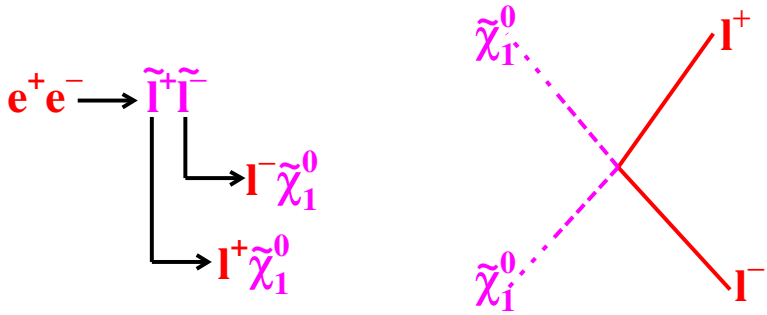

- Select events with significant missing energy
- Categorize using
  - hadronic jets
  - charged leptons
  - Event Visible Energy, jet/lepton energies
- Depend Strongly on $\Delta M = M_{\mathrm{SUSY}} - M_{\mathrm{LSP}}$

# Background from the SM




- 4-Fermion, especially $W^+W^-$
  - $\sigma \sim 20$ pb
  - Large visible energy (large $\Delta M$ region)
- $e^+e^- \to e^+e^-\gamma^{(*)}\gamma^{(*)} \to e^+e^-f\bar{f}$
  - $\sigma$ *enormous* (say $\sim$ 100-10000 pb)
  - Small visible energy (small $\Delta M$ region)

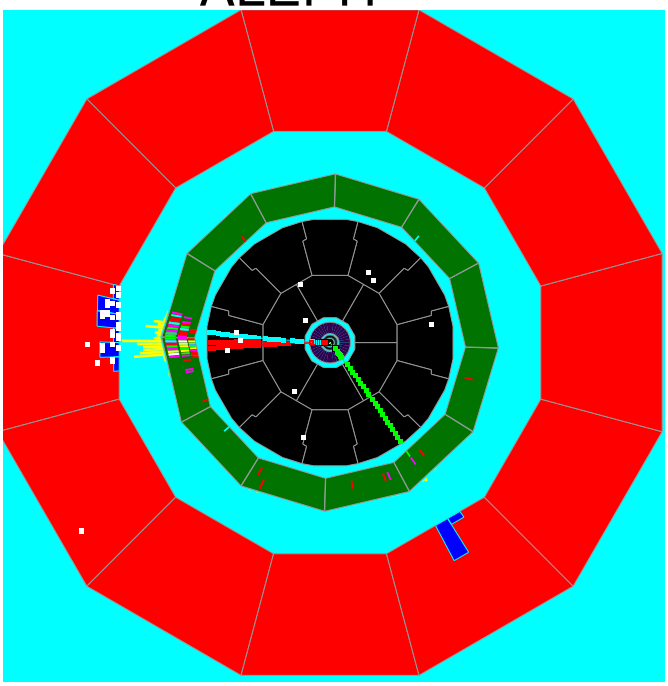
# Scalar Lepton Searches

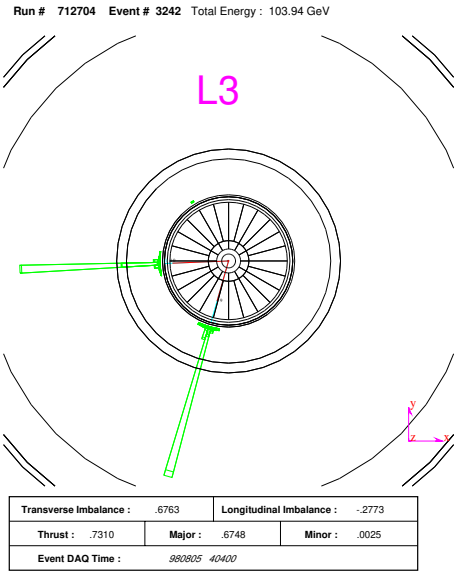



- Acoplanar lepton pair
- Missing $E_T$

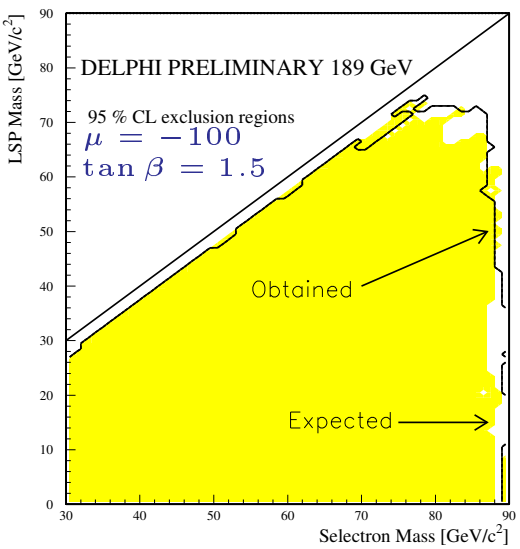
Many Candidates:

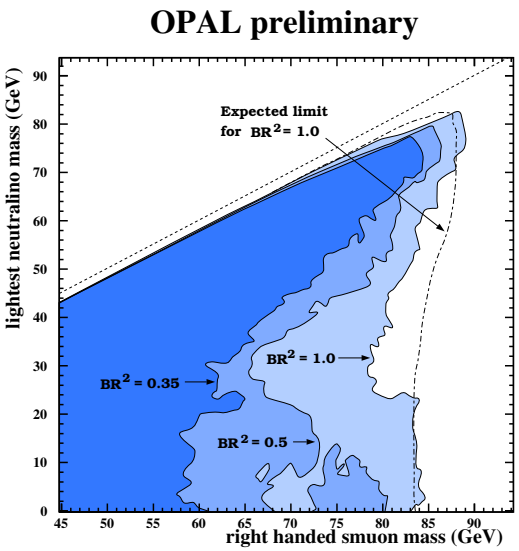
ALEPH





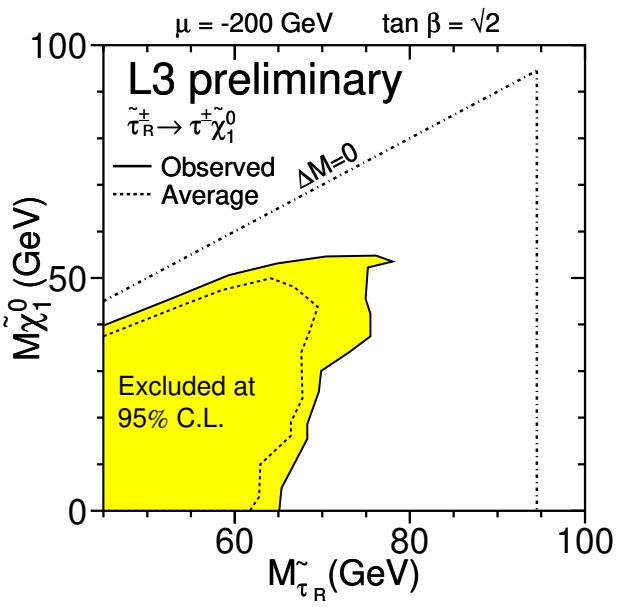

But consistent with SM backgrounds⇒ Limits:

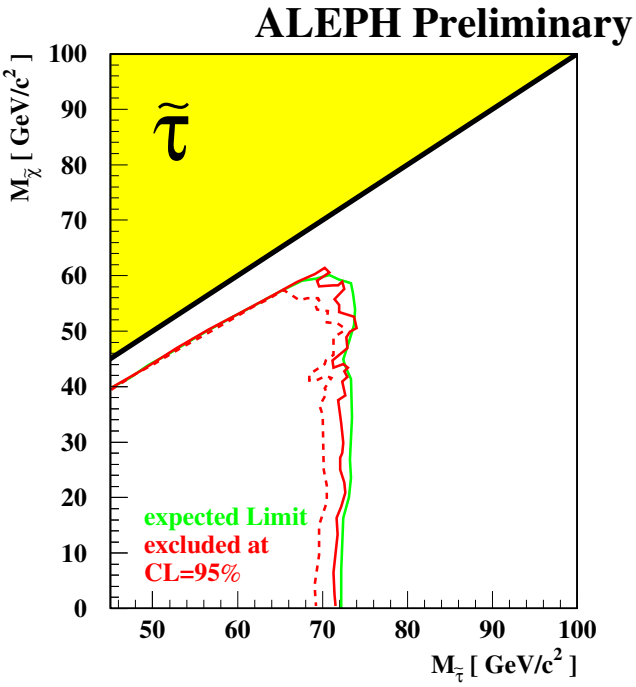


# Stau Loophole?

- $\tilde{\tau}_R, \tilde{\tau}_L$ mix to form the physical mass eigenstates, $\tilde{\tau}_1$, $\tilde{\tau}_2$
  $\tilde{\tau}_1 = \cos\theta_{\tilde{\tau}}\tilde{\tau}_L + \sin\theta_{\tilde{\tau}}\tilde{\tau}_R$
- Mixing big for large $\tan\beta$
- Can decouple $\tilde{\tau}_1$ from $Z^0$



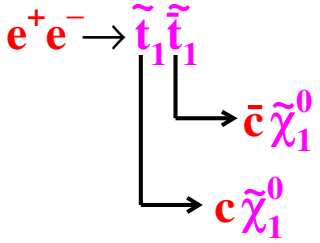

# Slepton Mass Limits

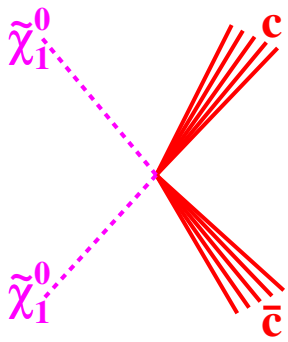
| 189 GeV | $m_{\tilde{e}_R}$ | $m_{\tilde{\mu}_R}$ | $m_{\tilde{\tau}_R}$ |
|---|---|---|---|
| ALEPH | >88 GeV<br>$\Delta M > 10$ GeV, $\tan\beta = 2$ | >80 GeV<br>$\Delta M > 10$ GeV | >67 GeV<br>$\Delta M > 10$ GeV |
| DELPHI | >87 GeV<br>$\Delta M > 10$ GeV, $\tan\beta = 1.5$ | >73 GeV<br>$\Delta M > 5$ GeV | >74 GeV<br>$\Delta M > 15$ GeV |
| L3 | >87 GeV<br>$\Delta M > 10$ GeV, $\tan\beta = \sqrt{2}$ | >77 GeV<br>$\Delta M > 5$ GeV | >65 GeV<br>$\Delta M > 10$ GeV |
| OPAL | >77 GeV<br>$\Delta M > 5$ GeV, $\tan\beta = 1.5$ | >78.4 GeV<br>$\Delta M > 2$ GeV | >69.4 GeV<br>$\Delta M > 10$ GeV |

# Stop & Sbottom Searches

- Loop corrections to $m_{\tilde{t}}$
  $\Rightarrow \tilde{t}_R, \tilde{t}_L$ expected to be lightest of the squarks
- Mix to form the physical mass eigenstates, $\tilde{t}_1, \tilde{t}_2$
  $\tilde{t}_1 = \cos\theta_{\tilde{t}}\tilde{t}_L + \sin\theta_{\tilde{t}}\tilde{t}_R$
- For large $m_{\rm top}$ : $\tilde{t}_1$ can be light.

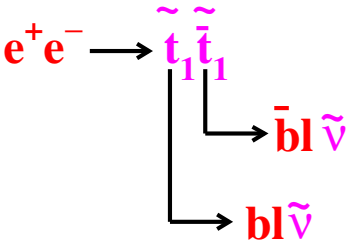
Search for:

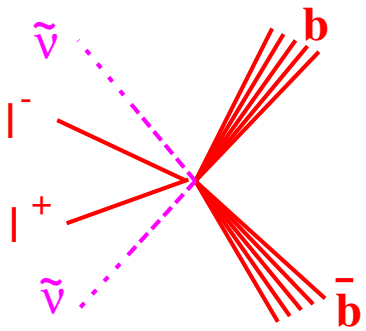


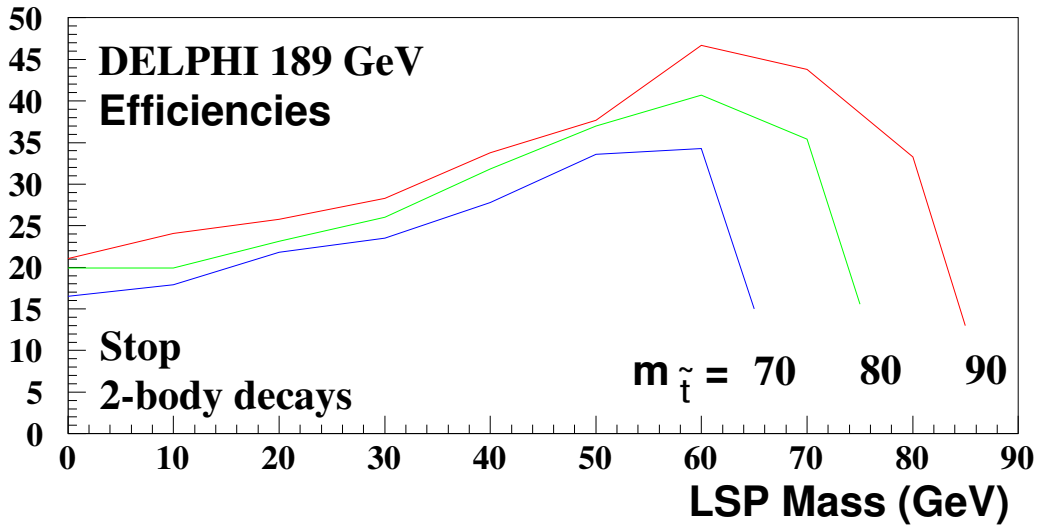

- Acoplanar Jets
- Missing $E_T$

If $m_{\tilde{\nu}} < m_{\tilde{t}_1} + m_{\rm bottom}$, main decay is:



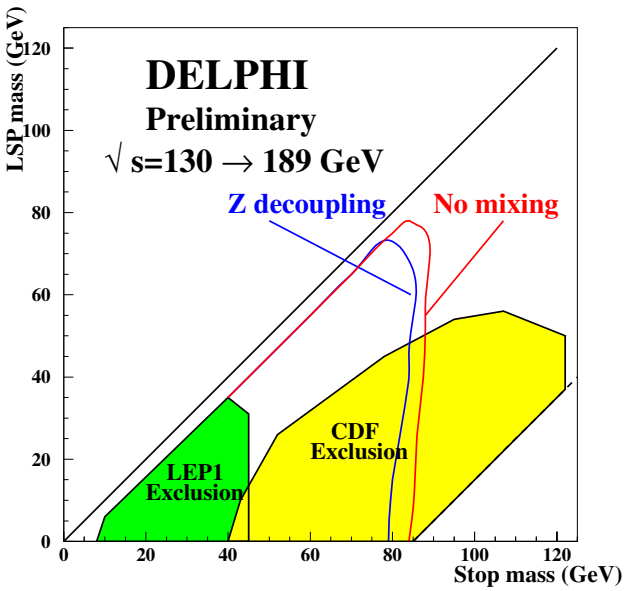



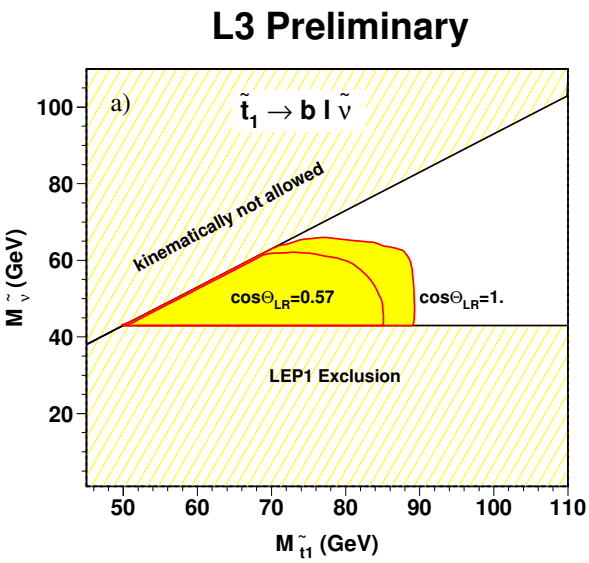

- Acoplanar b Jets
- 2 charged leptons
- Missing $E_T$

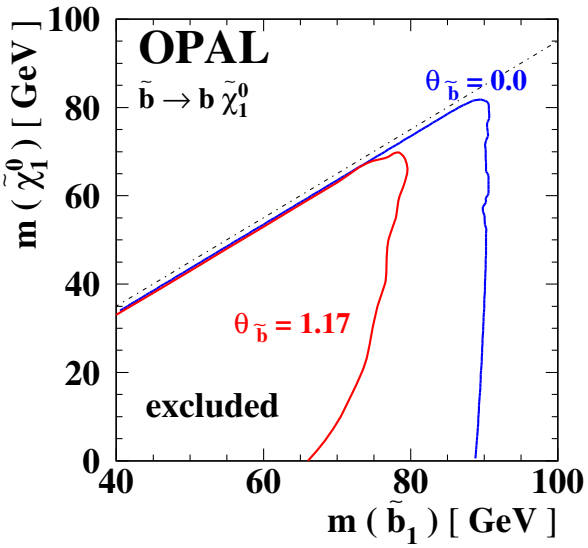


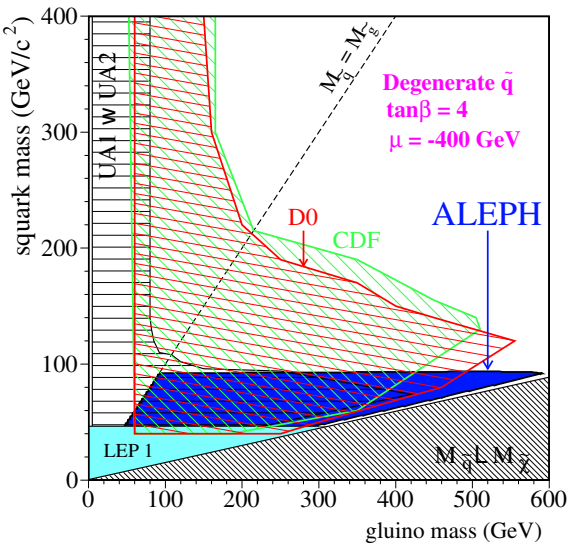

$\Rightarrow$ Candidates

# Stop/Sbottom: Mass Limits



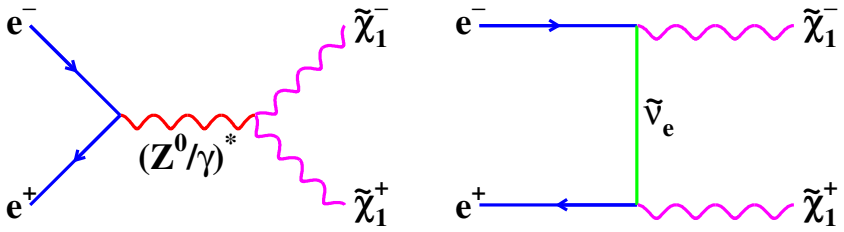




# Assuming Minimum Cross-section

| 189 GeV | $\tilde{t} \to c\tilde{\chi}_1^0$ | $\tilde{t} \to b\ell\tilde{\nu}$ | $\tilde{b} \to b\tilde{\chi}_1^0$ |
|---|---|---|---|
| ALEPH | >84 GeV<br>$\Delta M > 10$ GeV | >86 GeV<br>$\Delta M > 10$ GeV | >76 GeV<br>$\Delta M > 10$ GeV |
| DELPHI | >79 GeV<br>$\Delta M > 10$ GeV | >82 GeV<br>$\Delta M > 15$ GeV | >62 GeV<br>$\Delta M > 10$ GeV |
| L3 | >78 GeV<br>$\Delta M > 20$ GeV | >86 GeV<br>$\Delta M > 10$ GeV | >57 GeV<br>$\Delta M > 35$ GeV |
| OPAL | >87.2 GeV<br>$\Delta M > 10$ GeV | 88.0 GeV<br>$\Delta M > 10$ GeV | 65.8 GeV<br>$\Delta M > 7$ GeV |

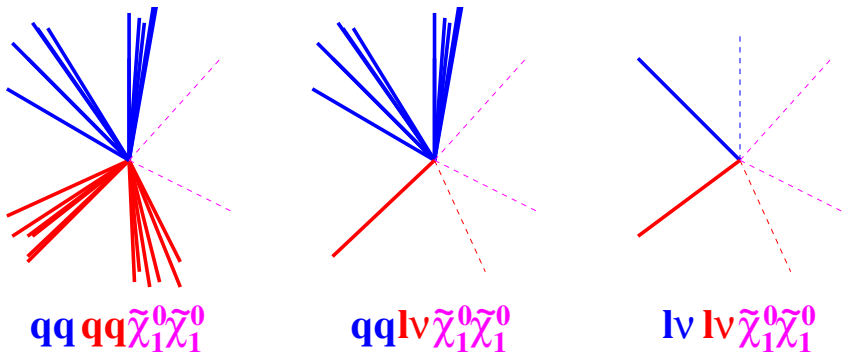
# Charginos




- $\sigma > 4$ pb unless $\tilde{\nu}_e$ is light.
- Chargino decay via W (in a large fraction of MSSM space)

$$\tilde{\chi}_1^+ \tilde{\chi}_1^- \rightarrow (W^+ \tilde{\chi}_1^0)(W^- \tilde{\chi}_1^0)$$

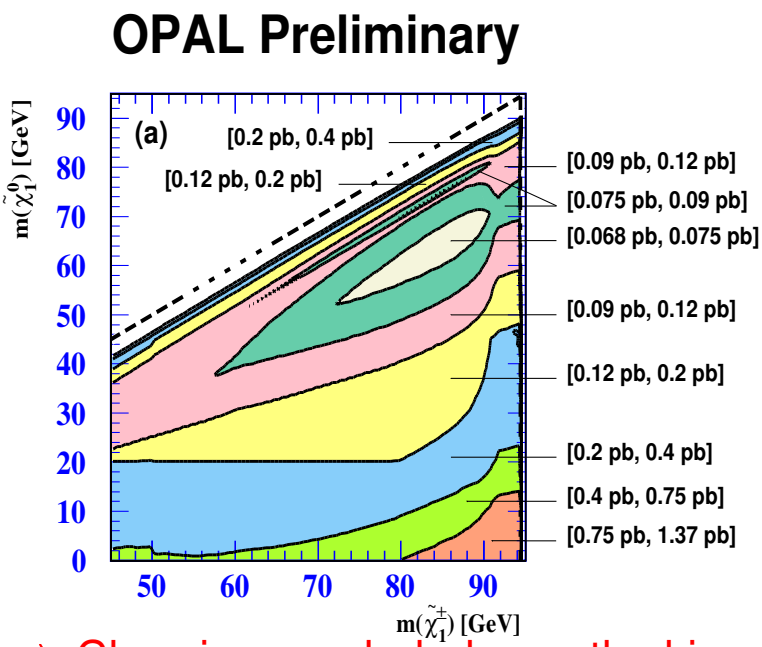
- Signature : $W^+W^-$ plus missing energy




- Many selection $\Rightarrow$ Consistent with SM

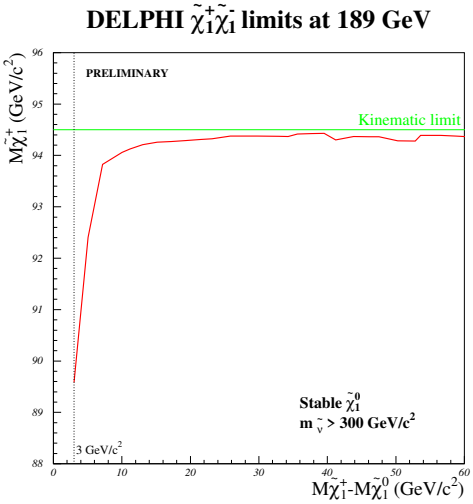
## LIMITS

### Cross-section




### Mass

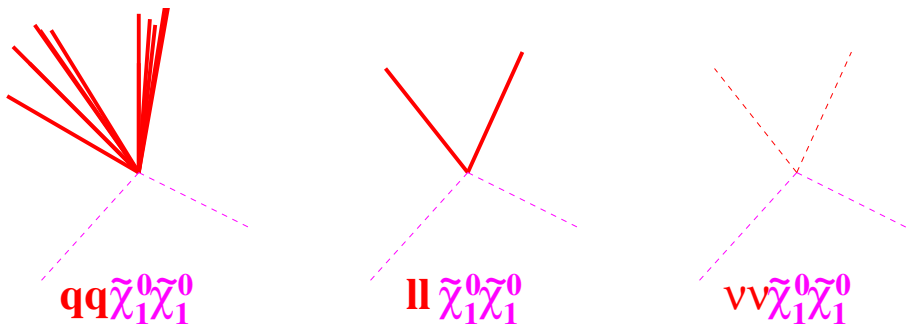
$M_{\tilde{\chi}^\pm} > 89.6$ GeV for $\Delta M = 3$ GeV!




$\Rightarrow$ Charginos excluded near the kinematic limit for large $m_0$

# Neutralino Search

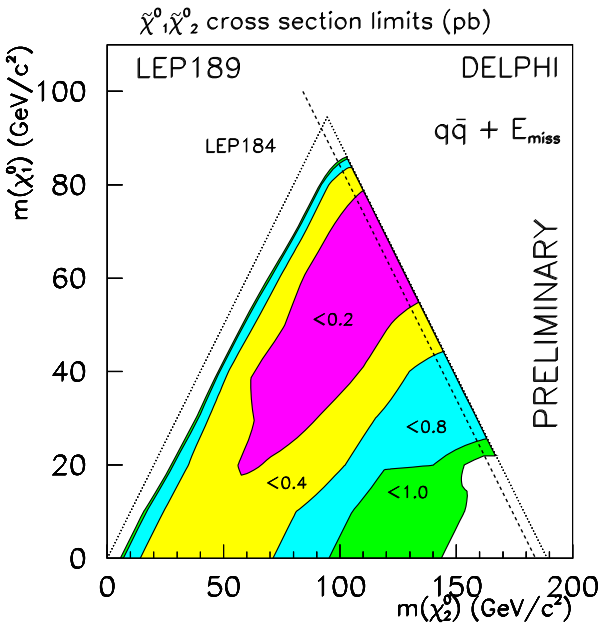
- Enough luminosity to search for neutralino production
- Observed as : $\tilde{\chi}_2^0\tilde{\chi}_1^0 \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 Z^* \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 f\bar{f}$

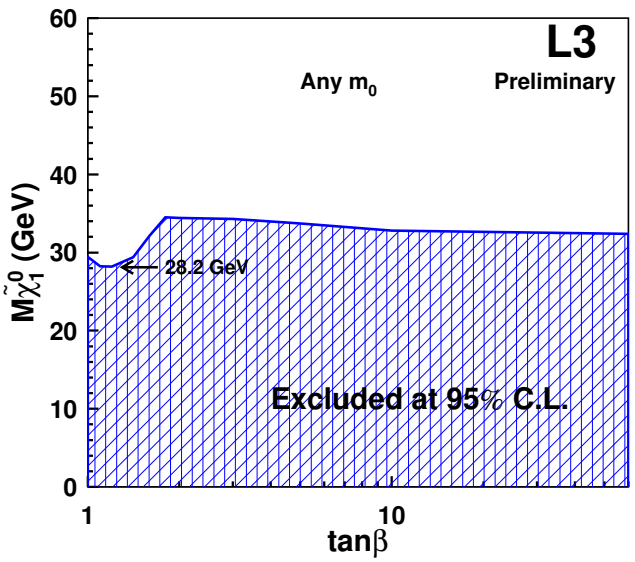



- Everything consistent with SM here too ...

LIMITS

Cross-section Mass



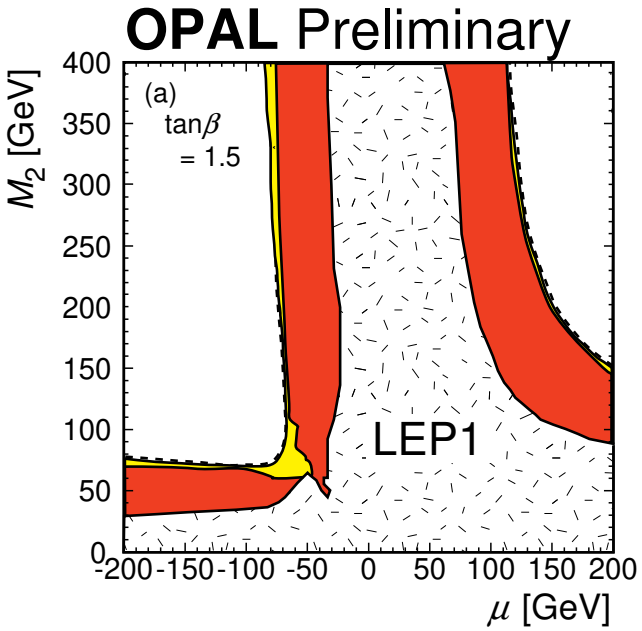

What do mass limits really mean? $\Rightarrow$

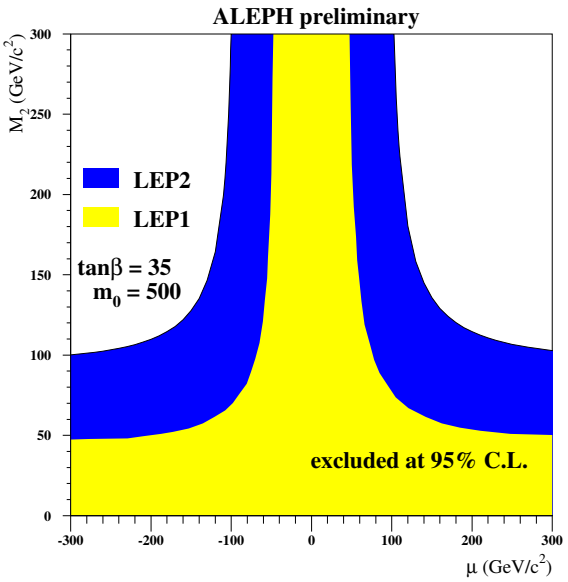
# MSSM Parameter Limits

- Important parameters: $\tan\beta$, $M_2$, $\mu$, $m_0$
- $A_0$ matters for mixing, especially if including MSSM higgs

$\Rightarrow$ Plot $M_2$ *vs.* $\mu$ for different $\tan\beta$

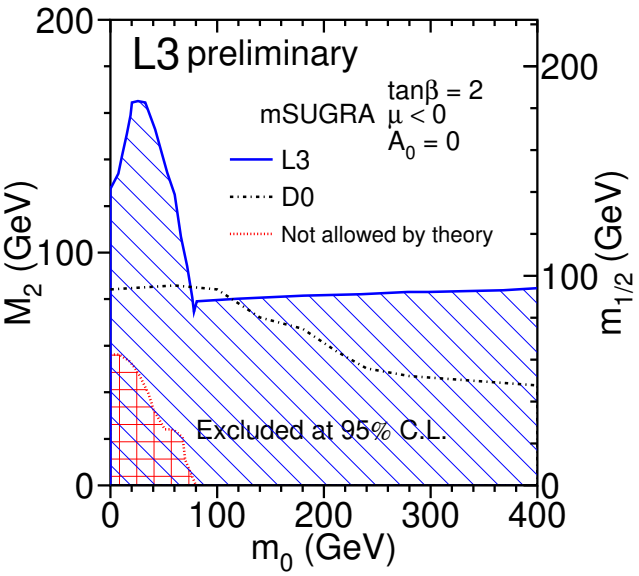
– Show Large and "any" $m_0$ separately (heavy/light $\tilde{\nu}$)
"any" $\Rightarrow$ parameter scan over allowed ranges



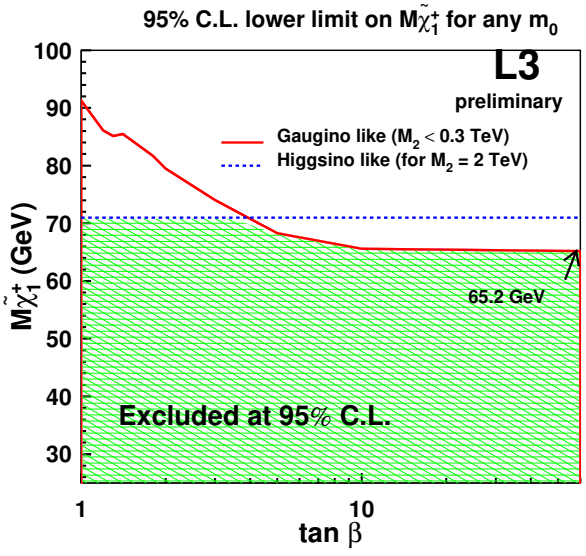




Other views:

$M_2$ *vs.* $m0$



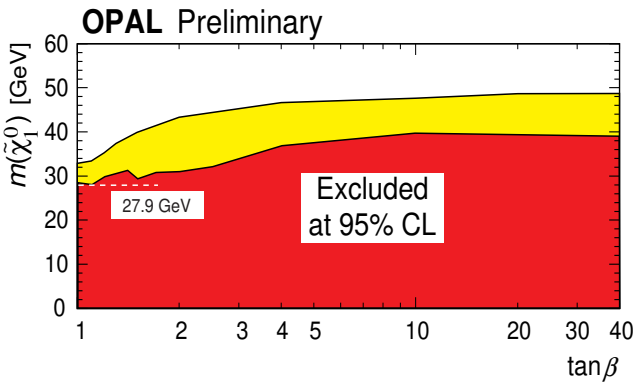

$M_{\tilde{\chi}^{\pm}}$ *vs.* $\tan\beta$

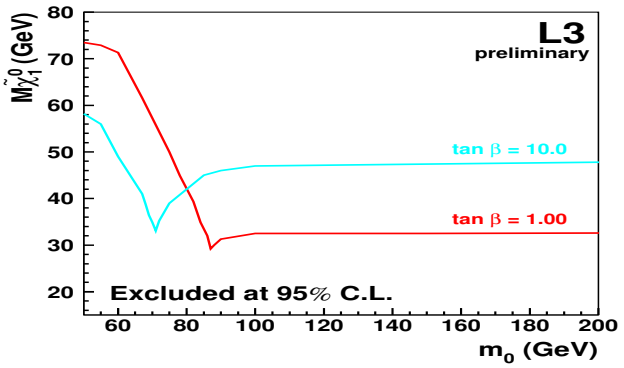



$M_\chi$ Excluded: All $\{\tan\beta, M_2, \mu, m_0, A_0\} \Rightarrow M_\chi$ excluded

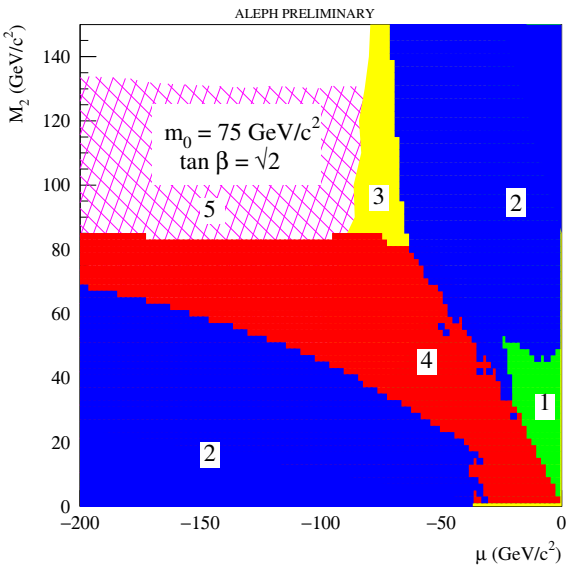
# $\tilde{\chi}_1^0$ LSP Mass Limit

Use $\tilde{\chi}^+\tilde{\chi}^-$, $\tilde{\chi}_2^0\tilde{\chi}_1^0$, $\tilde{\ell}^+\tilde{\ell}^-$




MSSM higgs hA too? Blow up in $M_2$ *vs.* $\mu$ plane:




But still $M_h$ =96 GeV at limiting point

$\Rightarrow$ Not quite yet ...

# Mass Limits

| $\sqrt{s}$ = | LSP $\tilde{\chi}_1^0$ limit (GeV) | |
|---|---|---|
| 189 GeV | Large $m_0$ | Any $m_0$ |
| ALEPH | 32.3 | 32.3! |
| DELPHI | 31.4 | 23.4 |
| L3 | 32.7 | 28.2 |
| OPAL | 32.8 | 27.9 |

# Gauge-Mediated SUSY Breaking

- SUSY breaking mechanism unknown:
- Assume mediation method:

**Gravity**

$M \sim M_P \sim 10^{18}$ GeV

$\sqrt{F} \sim 10^{11}$ GeV

**But: FCNC**

**Hidden**

~~SUSY~~

$\sqrt{F} \sim \sqrt{\frac{M}{G_F^{1/2}}}$

**M**

**Visible**

e,μ,τ,...,$W^-$,$Z^0$

$\tilde{e}$,$\tilde{\mu}$,$\tilde{\tau}$,...,$\tilde{\chi}^-$,$\tilde{\chi}^0$

**Gauge**

$10^3 < M < 10^{15}$ GeV

$10^3 < \sqrt{F} < 10^{10}$ GeV

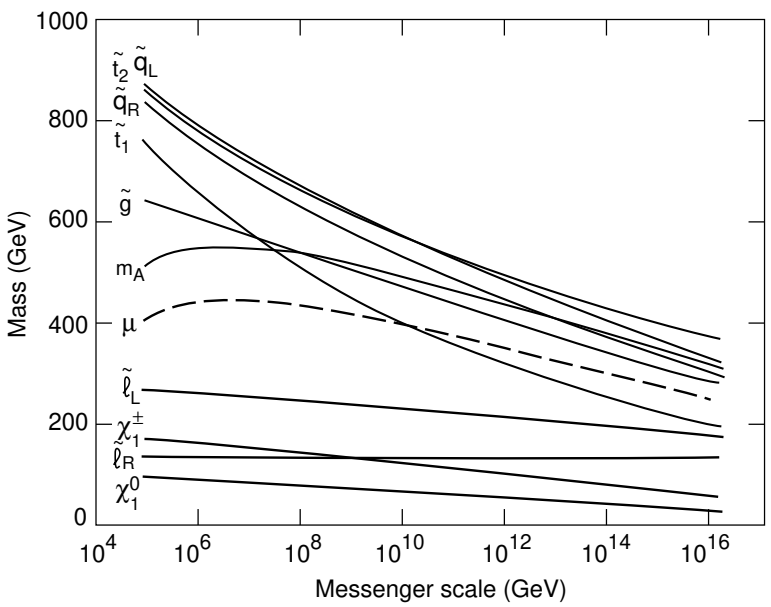
**No FCNC**

Sspectrum: $\Lambda = k\frac{F}{M}$

$M_{\tilde{G}} < 1$ GeV $\Rightarrow$ LSP

$M_{\tilde{G}} \sim 2.5$ TeV

Example GMSB mass spectra
(Dimopoulos *et al.*, hep-ph/9609434):




NLSP

$\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$

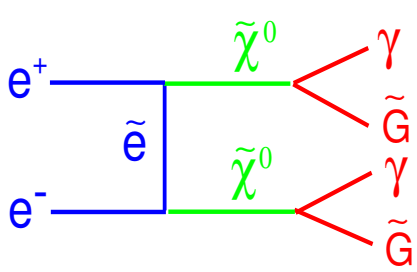
$\tilde{\ell}_R^\pm \rightarrow \ell^\pm\tilde{G}$

NLSP $c\tau =$

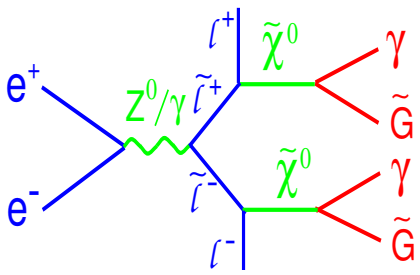
1 $\mu$m–$10^{11}$ km

# $\tilde{\chi}_i^+\tilde{\chi}_i^-$, $\tilde{\chi}_i^0\tilde{\chi}_j^0$, $\tilde{\ell}^+\tilde{\ell}^-$ ...

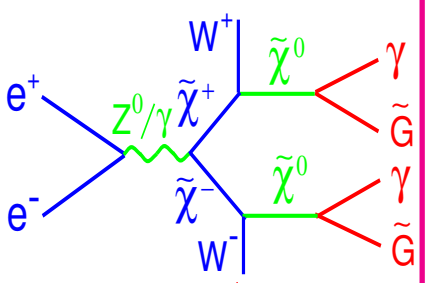
## $\tilde{\chi}_1^0$ NLSP




$c\tau \sim 0$ : $\gamma\gamma + \not{E}_T$
$0 < c\tau < \infty$ : $\gamma + \not{E}_T$
$c\tau \sim \infty$ : $\not{E}_T$

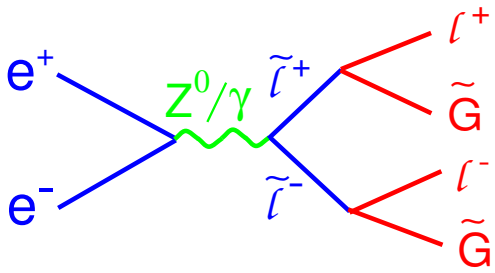


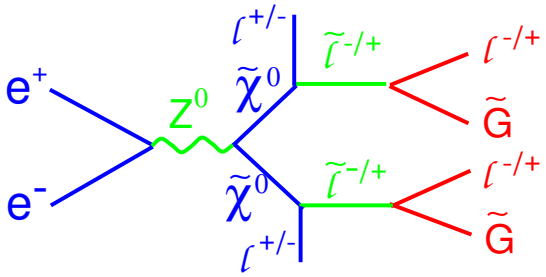

$\ell^+\ell^-\gamma\gamma + \not{E}_T$
$\ell^+\ell^-\gamma + \not{E}_T$
$\ell^+\ell^- + \not{E}_T$




$\gamma\gamma + \text{jets}/\ell^\pm + \not{E}_T$
$\gamma + \text{jets}/\ell^\pm + \not{E}_T$
$\text{jets}/\ell^\pm + \not{E}_T$

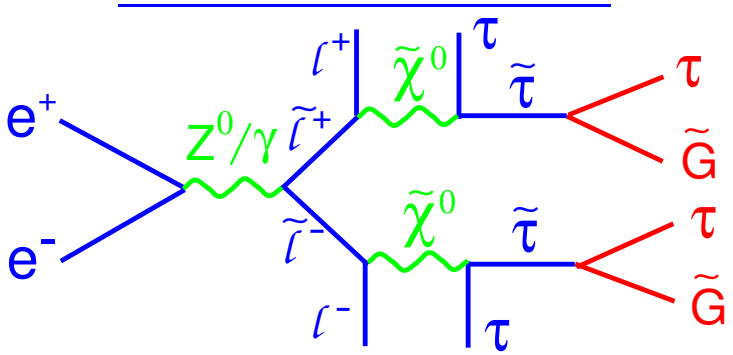
## $\tilde{\ell}^\pm$ NLSP




$c\tau \sim 0$ : $\ell^+\ell^- + \not{E}_T$ $4 \times \ell^\pm + \not{E}_T$
$0 < c\tau < \infty$ : $2 \times$ Kinked Tracks $2 \times \ell^\pm + 2 \times$ Kinked Tracks
$c\tau \sim \infty$ : $2 \times$ Stable Charged $2 \times \ell^\pm + 2 \times$ Stable Charged

## $\tilde{\tau}^\pm$ NLSP ($\tan\beta > 10$)

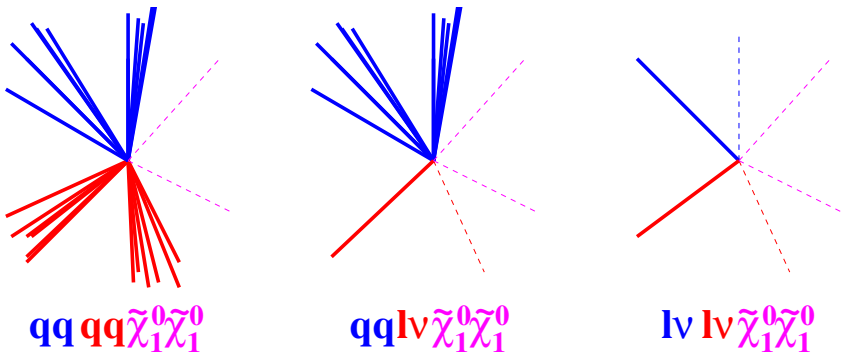



$c\tau \sim 0$ : $\tau^\pm\tau^\pm + (\ell^\pm\tau^\mp\ell^\pm\tau^\mp)$
$0 < c\tau < \infty$ : Kinked Tracks $+ (\ell^\pm\tau^\mp\ell^\pm\tau^\mp)$
$c\tau \sim \infty$ : Stable Charged $+ (\ell^\pm\tau^\mp\ell^\pm\tau^\mp)$

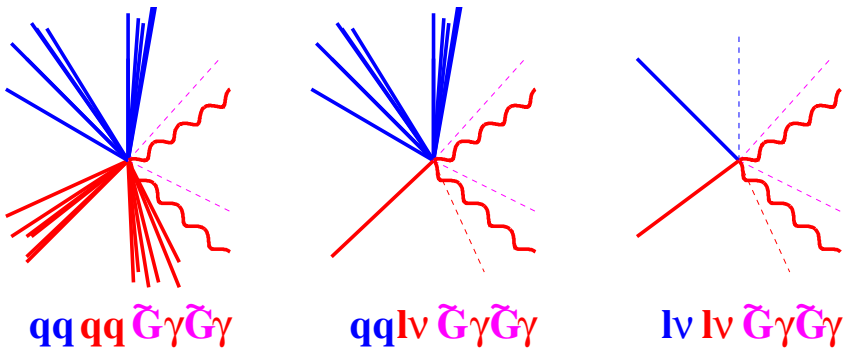
# $\tilde{\chi}_1^+\tilde{\chi}_1^-$ with $\tilde{\chi}_1^0$ NLSP

Final state topology depends on the $\tilde{\chi}_1^0$ decay length ($c\tau$)

Long $\tau$ :




Short $\tau$ :




- Search topology: $\geq 1$ photon + missing energy
- photon may be displaced from origin

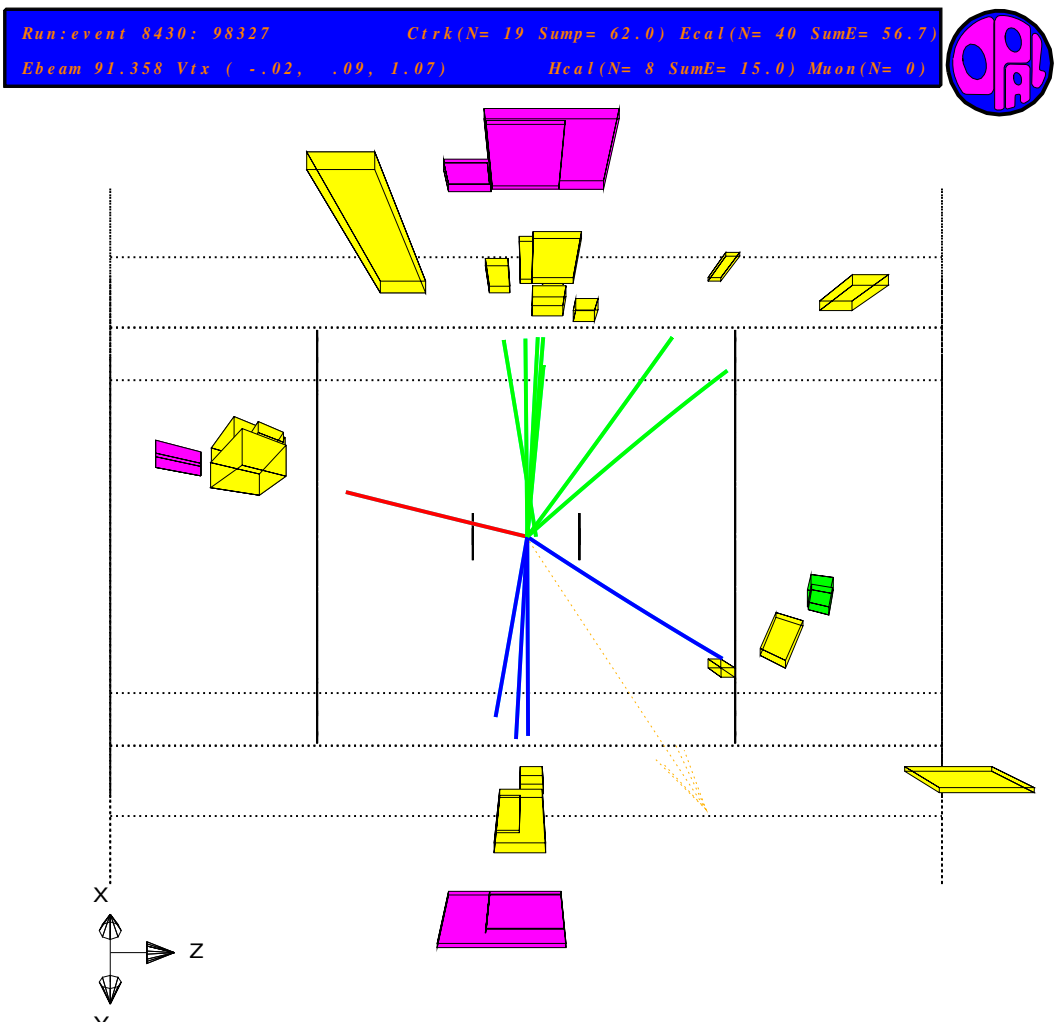
**Model Interesting $\Rightarrow$**

**New Experimental Signatures**

# Results: $\tilde{\chi}_1^+\tilde{\chi}_1^-$ with $\tilde{\chi}_1^0$ NLSP

| OPAL | Channel | Background | Observe |
|---|---|---|---|
| | Low Multiplicity | $13.6 \pm 3.4$ | 21 |
| | High Multiplicity | $13.8 \pm 1.7$ | 8 |

- High Multiplicity Candidate : $E_\gamma = 25$ GeV



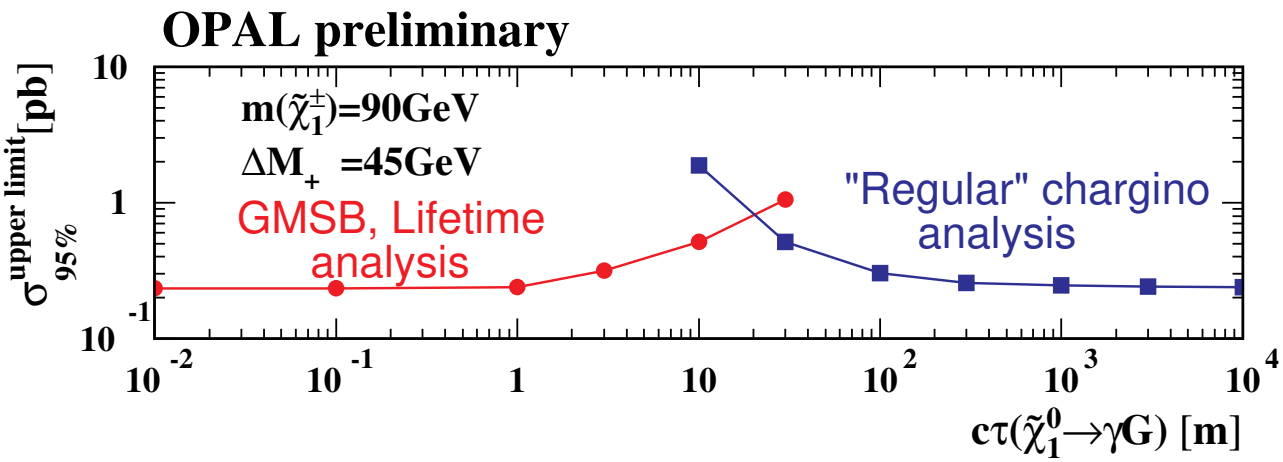

Consistent with :

- Signal : $\tilde{\chi}_1^+\tilde{\chi}_1^- \rightarrow \mathrm{q\bar{q}}\tilde{\chi}_1^0\tau\nu\tilde{\chi}_1^0$
  with 1 $\tilde{\chi}_1^0 \rightarrow \tilde{\mathrm{G}}\gamma$ in the detector
- SM Background : $\mathrm{W^+W^-} \rightarrow \mathrm{q\bar{q}}\tau\bar{\nu}_\tau$ isolated $(\gamma/\pi^0)$

# GMSB Limits

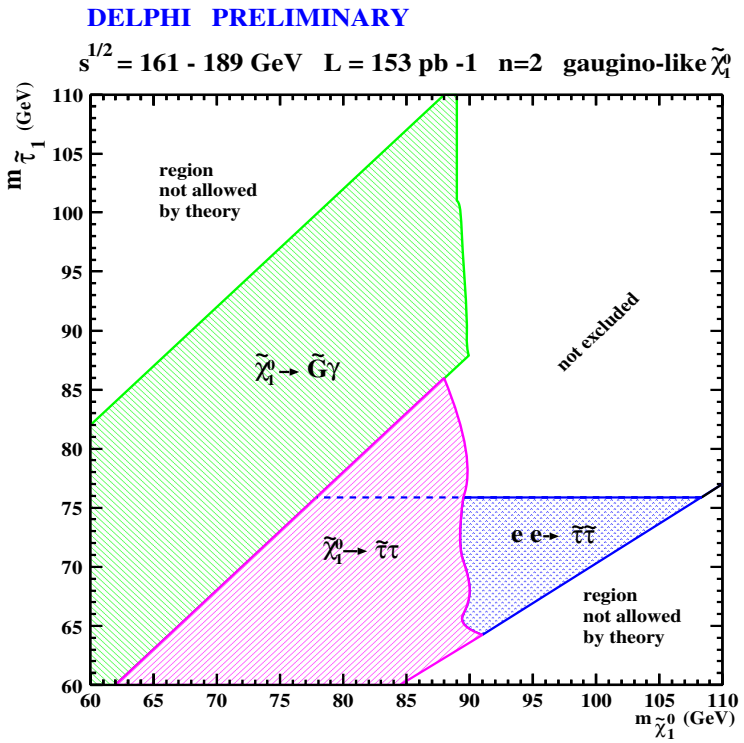
Model Independent:

- Production cross-section vs. NLSP lifetime



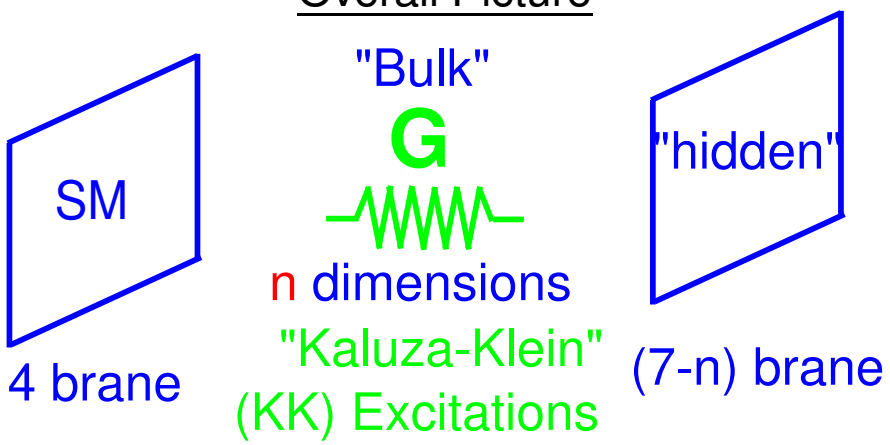

Model Dependent:

- Scan GMSB parameter space, exclude mass regions

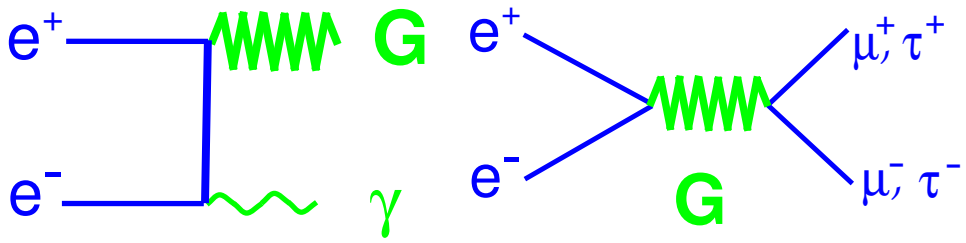


# Gravity in Extra Dimensions

Overall Picture




Can effect Measurable Phenomina




WHY??

- Gravity "diluted"

  $\Rightarrow$ "$M_{\rm plank}$"$= M_D = M_{\rm EW}$
- No heirarchy problem

$$M_{Pl}^2 = R^n \times {M_D}^{n+2}$$

$R$ : Extra dim. Compactification Radius

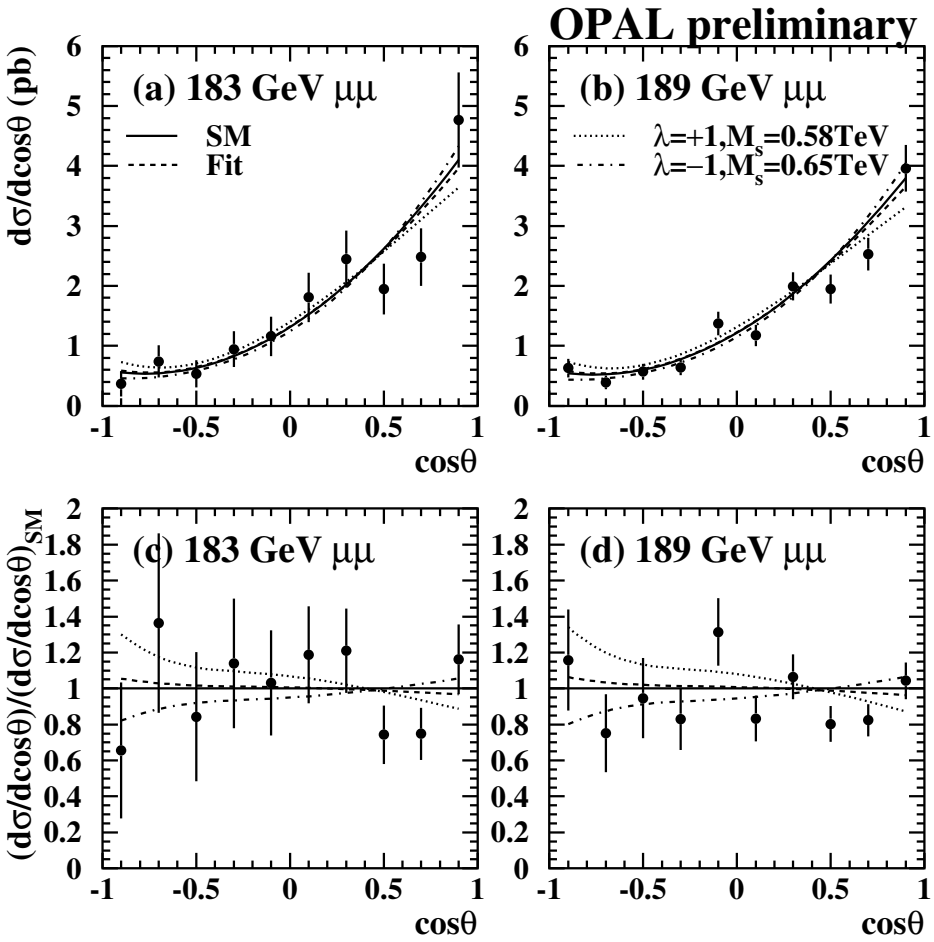
$n$ : Number of large dim., $1 < R < 7$

| $n$ | $R$ | Possible? |
|---|---|---|
| 1 | $10^{13}$ cm | Excluded |
| 2 | 1 mm | Not excluded!! |
| 7 | 1 fm | Not excluded |

# Gravity in Extra Dim: Results

Example: $e^+e^- \to \mu^+\mu^-$

$$\frac{d\sigma}{d\cos\theta} \simeq A(\cos\theta) + B(\cos\theta)\frac{\lambda}{M_D^4} + C(\cos\theta)\left(\frac{\lambda}{M_D^4}\right)^2$$




| Processes | $\sqrt{s}$ [GeV] | $\lambda$ | $M_D$ [TeV] |
|---|---|---|---|
| $e^+e^- \to \mu^+\mu^-$ | 183,189 | $+1$ | $> 0.58$ |
| | | $-1$ | $> 0.65$ |
| $e^+e^- \to \tau^+\tau^-$ | 183,189 | $+1$ | $> 0.63$ |
| | | $-1$ | $> 0.50$ |
| $e^+e^- \to \mu^+\mu^-, \tau^+\tau^-$ | 183,189 | $+1$ | $> 0.65$ |
| | | $-1$ | $> 0.64$ |
| $e^+e^- \to \gamma\gamma$ | 183,189 | $+1$ | $> 0.75$ |
| | | $-1$ | $> 0.60$ |

# Search Channel List

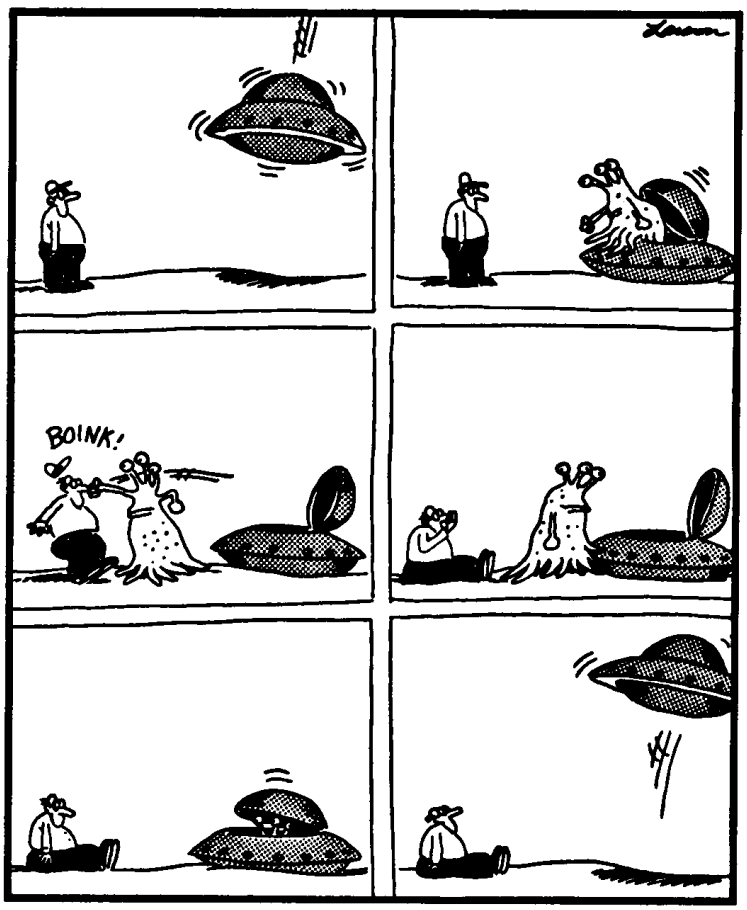
| | | |
|---|---|---|
| $e^+e^- \to hZ$ | $h \to b\bar{b}$ | $b\bar{b}q\bar{q}$, $b\bar{b}\nu\bar{\nu}$, $b\bar{b}\ell^+\ell^-$ |
| | $h \to \gamma\gamma$ | $(q\bar{q}, \ell^+\ell^-, \nu\bar{\nu})+\gamma\gamma$ |
| | $h \to \tilde{\chi}^0\tilde{\chi}^0$ | $q\bar{q}$, $\ell^+\ell^-+\not{E}$ |
| $e^+e^- \to hA$ | $h, A \to b\bar{b}, \tau\tau$ | $b\bar{b}b\bar{b}$, $b\bar{b}\tau^+\tau^-$ |
| | $h \to AA$ | $b\bar{b}b\bar{b}b\bar{b}$ |
| $e^+e^- \to H^+H^-$ | $H^+ \to q\bar{q}, \tau\nu$ | $q\bar{q}q\bar{q}$, $q\bar{q}\tau\nu$, $\tau\nu\tau\nu$ |
| $e^+e^- \to \tilde{\chi}^+\tilde{\chi}^-$ | $\tilde{\chi}^- \to W^*\tilde{\chi}^0$ | jets $(+\ell^\pm)$, $\ell^+\ell^-+\not{E}$ |
| | (In)Direct RPV | jets, $\ell^\pm$, $\nu$ |
| | $(\tilde{\chi}^0 \to \gamma\tilde{G})$ | jets, $\ell^+\ell^-$, $\gamma\gamma+\not{E}$ |
| $e^+e^- \to \tilde{\chi}^0_2\tilde{\chi}^0_1$ | $\tilde{\chi}^0_2 \to Z^0\tilde{\chi}^0_1$ | 2 jets $+\not{E}$ |
| | $\tilde{\chi}^0_2 \to \gamma\tilde{\chi}^0_1$ | $\gamma+\not{E}$ |
| $e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_1$ | $\tilde{\chi}^0_1 \to \gamma\tilde{G}$ | $\gamma\gamma+\not{E}$ |
| | $\tilde{\chi}^0_1$ Lifetime | non-pointing $\gamma$ |
| | RPV Decays | jets, $\ell^\pm$, $\nu$ |
| $e^+e^- \to \tilde{\ell}^+\tilde{\ell}^-$ | $\tilde{\ell}^- \to \ell^-\tilde{\chi}^0_1$ | $\ell^+\ell^-+\not{E}$ |
| | $(\tilde{\chi}^0 \to \gamma\tilde{G})$ | $\ell^+\ell^-\gamma\gamma+\not{E}$ |
| | (In)Direct RPV | 2,4,6$\times\ell^\pm+\not{E}$ |
| | $\tilde{\ell}^\pm$ Lifetime | Kinked Tracks |
| | | Stable, Charged |
| $e^+e^- \to \tilde{\nu}\tilde{\nu}$ | (In)Direct RPV | $\ell^+\ell^-\ell^+\ell^-$ |
| | | jets $+\not{E}$ |
| $e^+e^- \to \tilde{t}_1\tilde{t}_1$ | $\tilde{t}_1 \to c\tilde{\chi}^0_1$ | 2 jets $+\not{E}$ |
| | $\tilde{t}_1 \to b\ell^+\tilde{\nu}$ | 2 jets $+\ell^+\ell^-+\not{E}$ |
| | (In)Direct RPV | $\ell^+q\ell^-q$ |
| $e^+e^- \to N\bar{N}$ | $N \to \ell W$ | jets $+\ell^\pm$ |
| $e^+e^- \to L^+L^-$ | $L^+ \to \nu W$ | jets, $\ell^\pm+\not{E}$ |
| $e^+e^- \to \ell^{*+}\ell^{(*)-}$ | $\ell^{*+} \to \ell^+\gamma$ | $\ell^+\ell^-\gamma(\gamma)$ |
| $e^+e^- \to \nu^*\bar{\nu}^*$ | $\nu^* \to \nu\gamma$ | $\gamma(\gamma)+\not{E}$ |
| $e^+e^- \to \ell^*\ell, \nu^*\nu$ | $\ell^* \to \ell Z$ | jets, $\ell^\pm$, $\nu$ |

# Conclusions

- LEP ran very well at $\sqrt{s} \sim 189$ GeV in 1998
- No significant excesses in new particle search topologies,

  *but...*
  - Some intriguing features in current data
  - Still finding new things to look for

- 1999:
  - LEP has turned on very well at $\sqrt{s} = 192$ GeV
  - Looking forward to $\sqrt{s} \sim 200$ GeV !!
  - ... And remaining ready for the unexpected




Henri never knew what hit him