Non-standard SUSY searches at LEP

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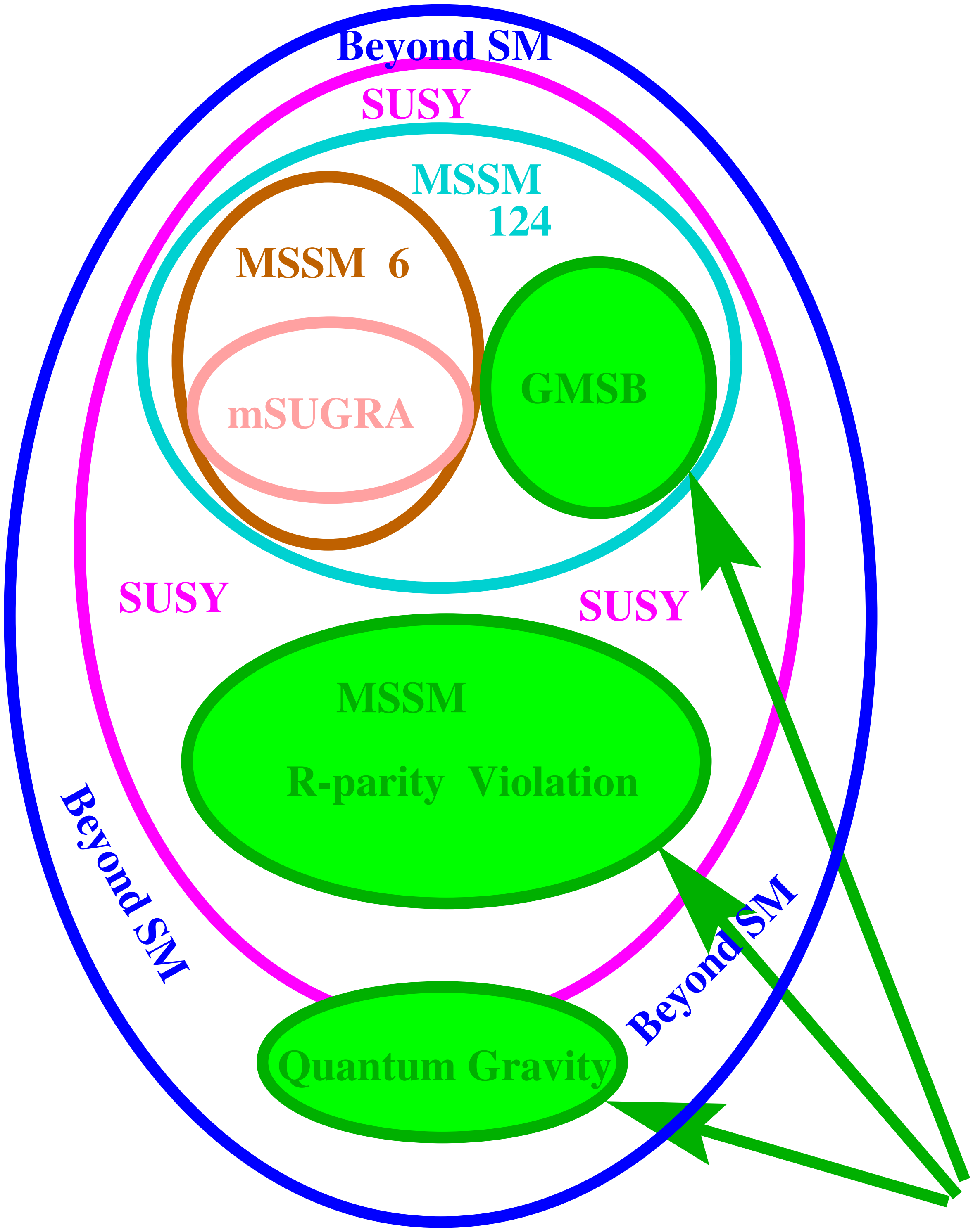
Outline

What “Non-standard SUSY” stands for ?



Outline

R-parity violating SUSY

- Existing limits on $\not{R}_p$ couplings
- Phenomenology at LEP
- Mass limits in the MSSM

Gauge Mediated SUSY Breaking models

- Scalar lepton NLSP
- Neutralino NLSP
- Searches for long-lived particles

Quantum Gravity and new space dimensions

- Indirect effects
- Graviton–γ production

LEP

ALEPH, DELPHI, L3, OPAL

Year	$\sqrt{s}$	$\mathcal{L}$ / Experiment
1989–1995	Z peak	$\approx$ 160 pb^{-1}
1995	130–136 GeV	$\approx$ 6 pb^{-1}
1996	161–172 GeV	$\approx$ 21 pb^{-1}
1997	181–184 GeV	$\approx$ 56 pb^{-1}
1998	189 GeV	$\approx$ 174 pb^{-1}
1999	*192–200 GeV*	$\gtrsim$ *100* pb^{-1}
2000	*200+ϵ GeV*	

Results @ 189 GeV are PRELIMINARY

R–Parity

$$R = (-1)^{3B+L+2S} = \begin{cases} +1 & \text{Particles} \\ -1 & \text{SUSY partners} \end{cases}$$

- R–parity conserved

➤ S-particles are produced in pairs
and decay to their SM partner and the LSP

➤ LSP is stable and weakly interacting

  ➥ LSP escapes detection

    ➠ Missing energy signature

- R–parity violated

➤ S-particles are produced singly or in pairs

➤ LSP is unstable and decays into SM particles

  ➥ Huge variety of experimental signatures

    ➠ from 2 leptons ....
    ➠ .... to 10 hadronic jets

SUSY Framework – $R\!\!\!/_p$

- $R\!\!\!/_p$ term in the superpotential

$$W_{R\!\!\!/_p} = \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

➠ $W_{R\!\!\!/_p}$ now also considered in SUSY searches

- 45 new parameters in the MSSM

$\boxed{9\lambda_{ijk},\ 27\lambda'_{ijk},\ 9\lambda''_{ijk}}$

- in addition to the usual 5 in the CMSSM

$\boxed{\tan\beta,\ \mu,\ M_2,\ m_0,\ A_0}$

❑ Constrained MSSM

Unification of gaugino masses ➩ M_2

Unification of scalar masses ➩ m_0

Unification of trilinear couplings ➩ A_0

➠ This is the framework used at LEP to interpret experimental results

Existing limits on $\lambda_{ijk}, \lambda'_{ijk}, \lambda''_{ijk}$

L and B violation not observed

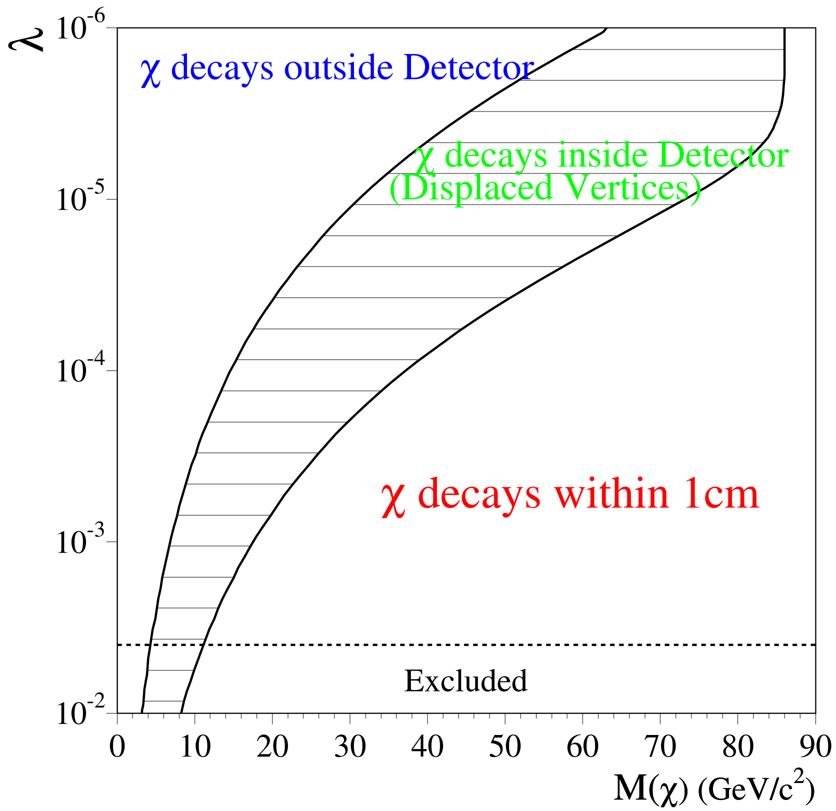
$\lambda_{ijk}, \lambda'_{ijk}, \lambda''_{ijk}$ are bound but not experimentally ruled out

- ➜ $\lambda_{ijk} < 0.06,$ $\lambda_{133} < 0.003$ (ν_e mass)
- ➜ $\lambda'_{ijk} < 0.5,$ $\lambda'_{111} < 0.0003$ $(\beta\beta)_{0\nu}$
- ➜ $\lambda''_{ijk} \lesssim 1,$ $\lambda''_{112} < 10^{-6}$ (double nucleon decay)
- ➜ but also $\lambda'_{ijk}\lambda''_{lmn} < 10^{-10}$ (proton decay)
- ➜ and many other severe bounds on product couplings of $O(10^{-8})$
- ➜ all limits for $m_{\tilde{f}} = 100$ GeV

➠ Searches performed with only one dominant $\not{R}_p$ coupling at a time

Phenomenology at LEP

- → Pair production $e^+e^- \to \tilde{\chi}^{\pm}\tilde{\chi}^{\mp}$ $\sigma \sim 1$ pb, $e^+e^- \to \tilde{f}\bar{\tilde{f}}$ $\sigma \sim 0.1$ pb independent of λ_{ijk}
- → Single resonant production $e^+e^- \to \tilde{\nu}$ σ is λ_{ijk} dependent
- → t-channel exchange in $e^+e^- \to f\bar{f}$, observable effects dependent on λ_{ijk}



$\lambda_{ijk} \lesssim 10^{-6}$ missing energy signature like standard SUSY

$10^{-5} \lesssim \lambda_{ijk} \lesssim 10^{-6}$ search for displaced vertices

$\lambda_{ijk} \gtrsim 10^{-5}$ decays at the interaction vertex

($\lambda_{ijk} \gtrsim 10^{-7}$ for s-fermions)

Phenomenology at LEP

$\mathbf{2} \times \left[\tilde{\chi}^{\pm} \longrightarrow \mathrm{f}\tilde{\mathrm{f}}^{*} \longrightarrow \mathrm{ff'f''}\right]$ ➠ $\mathbf{2} \times \mathbf{3}$ fermions

Chargino decay via $\not{R}_p$ coupling ➠ Direct decay

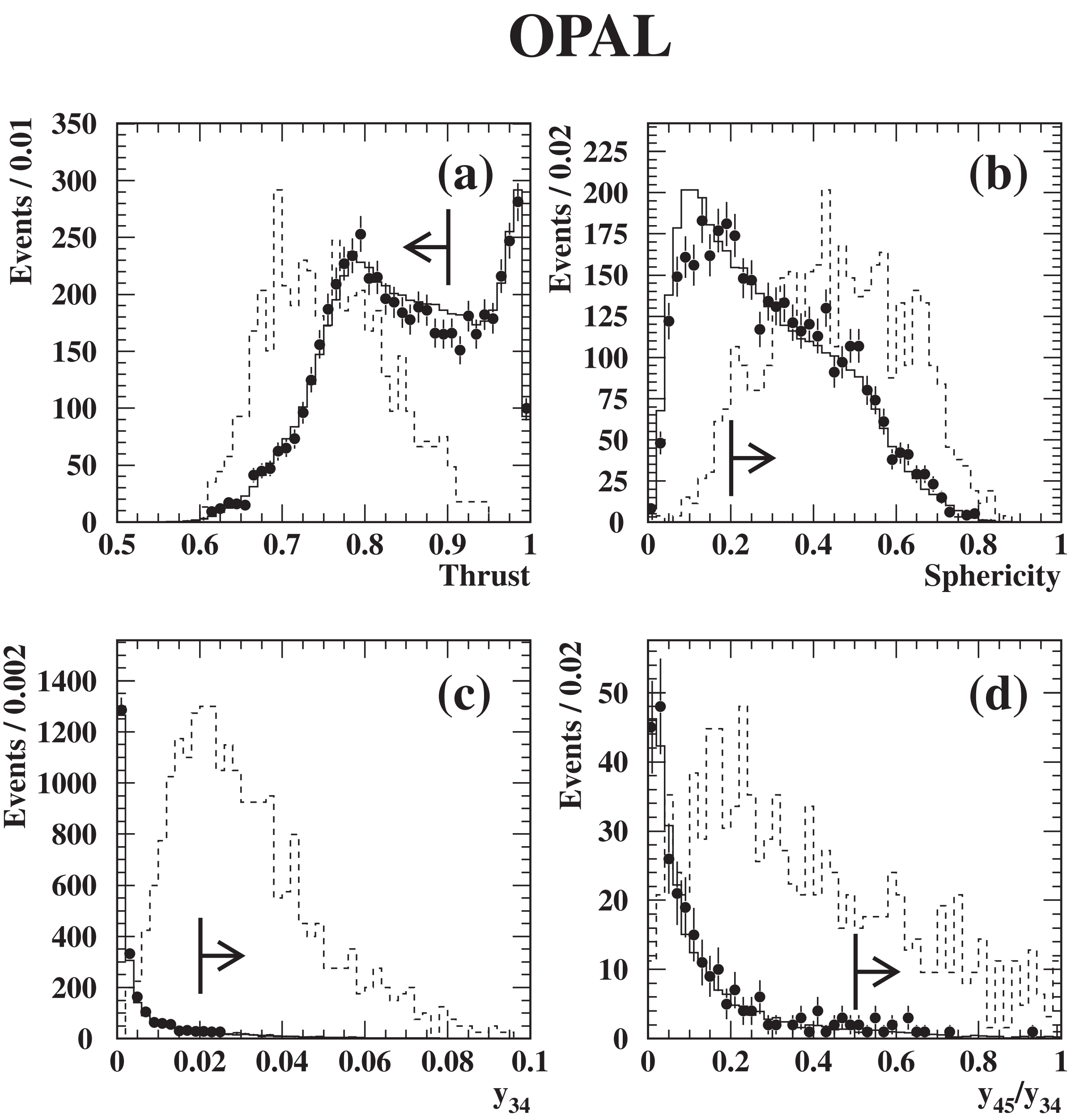
$\mathbf{2} \times \left[\tilde{\chi}^{\pm} \longrightarrow \mathrm{W}^{*}\tilde{\chi}^{0}_{1} \longrightarrow \mathrm{f\bar{f}'f\tilde{f}^{*}} \longrightarrow \mathrm{f\bar{f}'ff'f''}\right]$ ➠ $\mathbf{2} \times \mathbf{5}$ fermions

Chargino decay via SUSY cascades ➠ Indirect decay

➠ In general dominance of Indirect decay (Gaugino mixing and λ dependent)

	$\tilde{\chi}^{\pm}\tilde{\chi}^{\mp}$
λ Direct	$6l$, $4l + \not{E}$, $2l + \not{E}$
λ Indirect	$4jets + 4l + \not{E}$, $2jets + 5l + \not{E}$, $6l + \not{E}$
λ' Direct	$4jets + 2l$, $4jets + 1l + \not{E}$, $4jets + \not{E}$
λ' Indirect	$8jets + 2l$, $8jets + 1l + \not{E}$, $8jets + \not{E}$, $6jets + 3l + \not{E}$, $6jets + 2l + \not{E}$, $6jets + 1l + \not{E}$, $4jets + 4l + \not{E}$, $4jets + 3l + \not{E}$, $4jets + 2l + \not{E}$
λ'' Direct	$6jets$
λ'' Indirect	$10jets$, $8jets + 1l + \not{E}$, $6jets + 2l + \not{E}$

OPAL λ'' selections ➠
background rejection based on jet shape variables:
thrust, sphericity, $y_{\rm cut}$



Analyses Summary

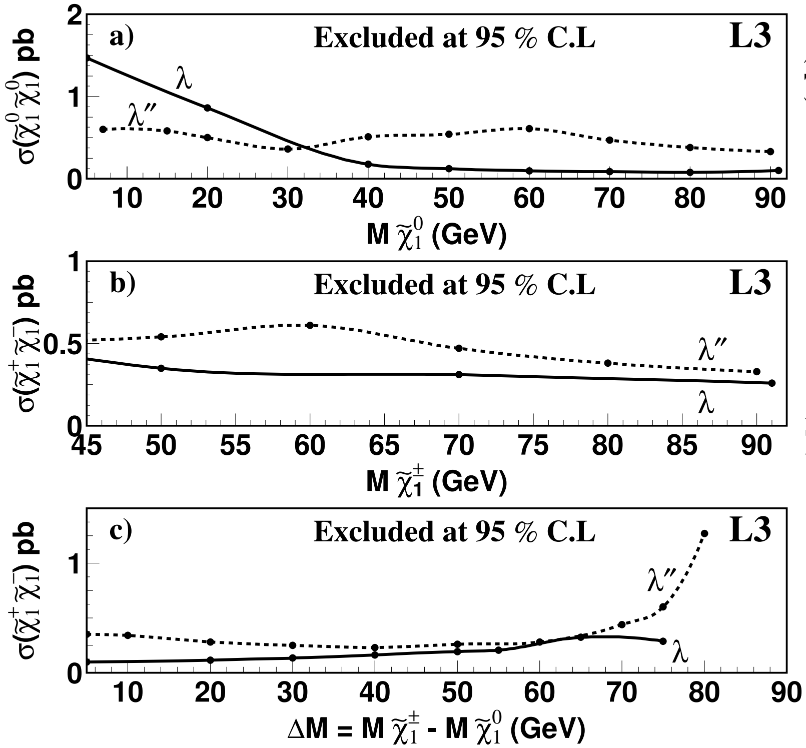
	$\tilde{\chi}^{\pm}$ $\tilde{\chi}^0_1$ $\tilde{\chi}^0_2$		$\tilde{l}\bar{\tilde{l}}$ $\tilde{\nu}\bar{\tilde{\nu}}$ $\tilde{q}\bar{\tilde{q}}$		Remarks
$\not{R}_p$ decay	Direct	Indirect	Direct	Indirect	
A	–	✔	✔	✔	$\lambda_{ijk}, \lambda'_{ijk}, \lambda''_{ijk}$ Gaugino limits hold only for high m_0 values
D	–	✔	✔	✔	λ''_{ijk} up to 183 GeV only $\lambda_{122,\ 133}, \lambda'_{i3k,\ 2jk}$ low m_0 regime not fully investigated
L	✔	✔	–	–	$\lambda_{ijk}, \lambda''_{ijk}$ up to 183 GeV Gaugino limits hold for any λ and m_0 values indirect limits on s-fermions within the CMSSM
O	✔	✔	✔	✔	$\lambda_{ijk}, \lambda'_{ijk}, \lambda''_{ijk}$ No searches for $\tilde{\chi}^0_2$ Gaugino limits hold only for high m_0 values

No excess observed in any channel

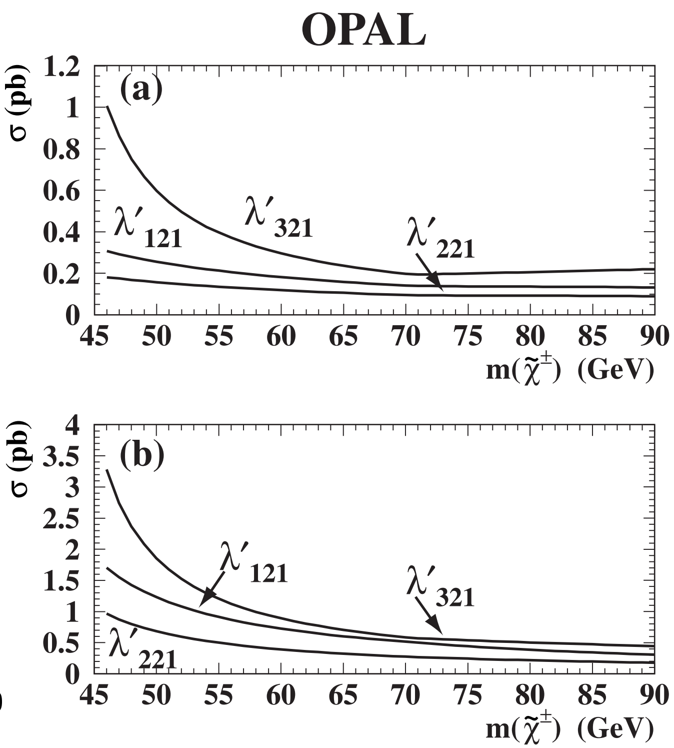
Model Independent Limits

Good agreement between data and SM background is observed in all searches $\Longrightarrow$
Cross section upper limits derived for Gaugino or S-fermion pair production
for any generation index ($\rightarrow \lambda\, \lambda'\, \lambda''$ direct and indirect)

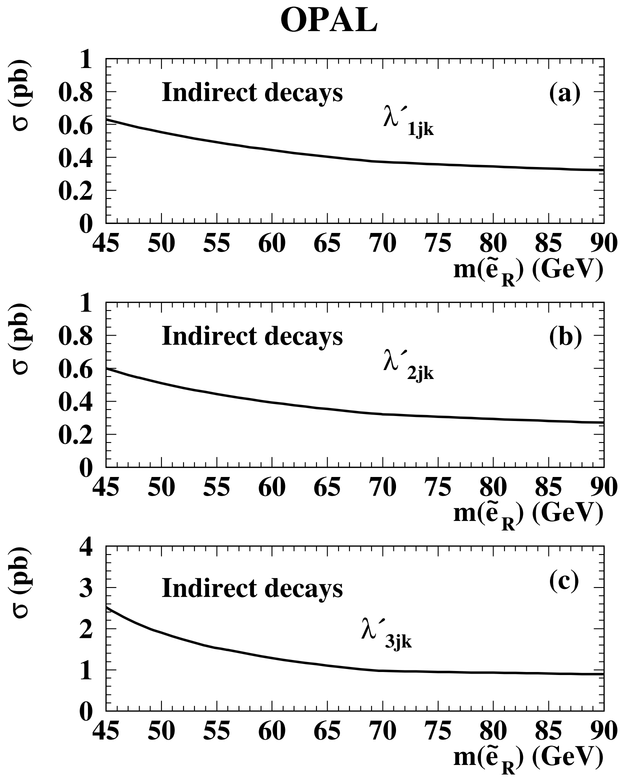
$\tilde{\chi}^{\pm}$, $\tilde{\chi}^0_1$ in/direct with λ or λ''



$\tilde{\chi}^{\pm}$ direct with λ'



$\tilde{e}$ indirect with λ'



Limits in the CMSSM

- Interpret Chargino and Neutralino limits in the $\tan\beta - \mu - M_2$ space
- Include the constraint $\sigma_{\text{SUSY}}/\sigma_{\text{SM}} \cdot \Gamma_{\text{Z}} < \Gamma_{\text{Lim}}$
- Large m_0 – heavy s-fermions
  - ➥ $\tilde{\chi}^{\pm}$ search is the most important, but $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$ may also be essential (-50 GeV $< \mu < 0$ and $M_2 < 50$ GeV, or $M_2 > 1.5$ TeV)
- Small m_0 – light s-fermions

➤ Estimate efficiencies for the new decays of Gauginos into s-fermions

- ➥ Much stronger dependence of the efficiency on λ coupling (direct $\not{R}_p$ decays)

- Provide robust limits using the lowest efficiency:

➤ between direct/indirect $\not{R}_p$ decays

➤ among the different generation indices for λ

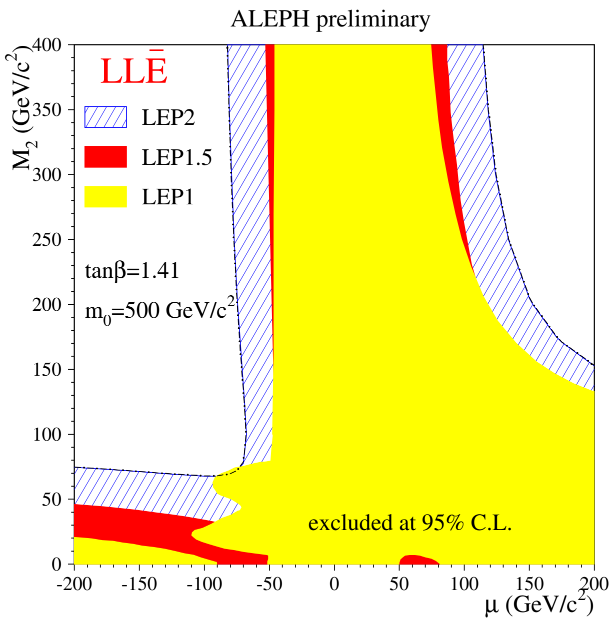
- ➥ couplings with τ for L violating terms
- ➥ couplings with light quarks for B term (no b-tag)

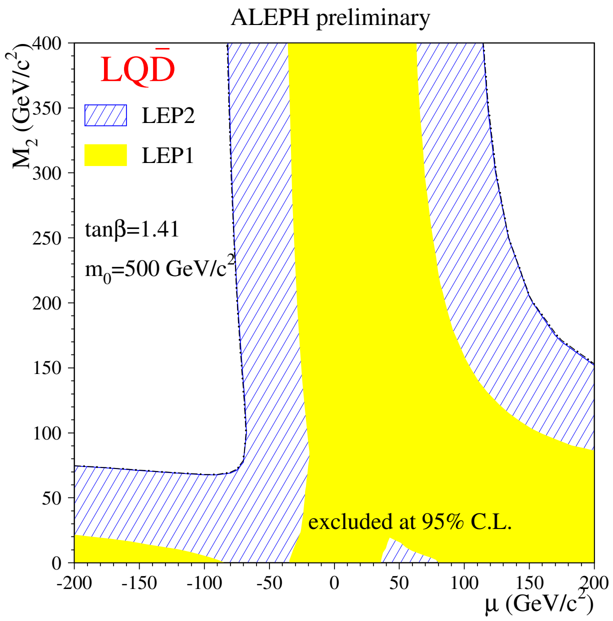
Limits for high m_0

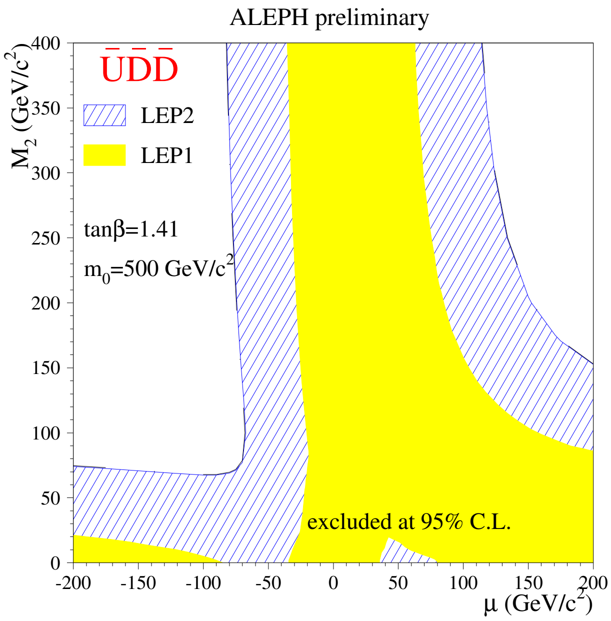
Heavy s-fermions

Excluded regions from Gaugino searches

Charginos excluded up to kinematic limit (94 GeV)





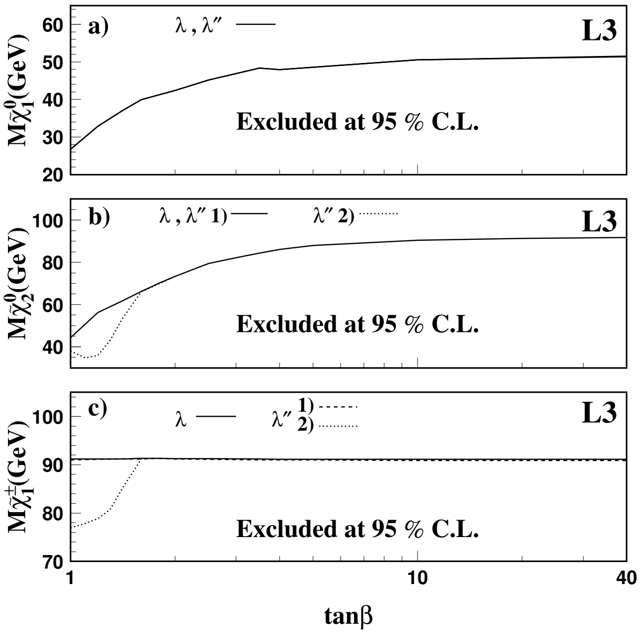


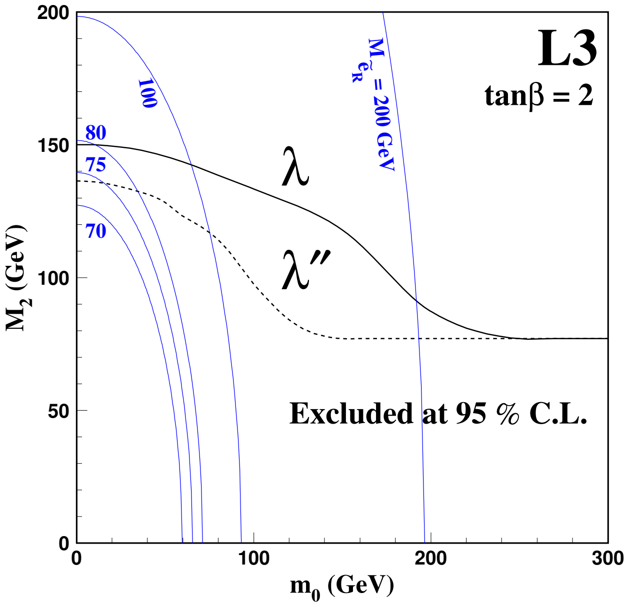
Limits for any m_0

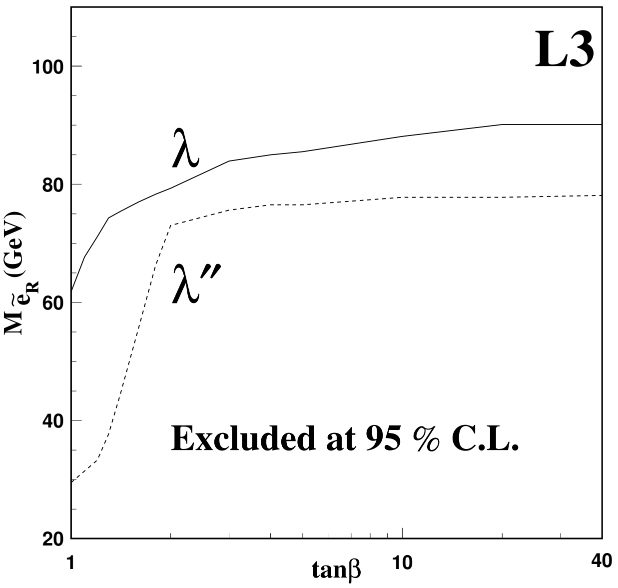
Excluded regions from Gaugino searches
for any s-fermion mass (any m_0)

Charginos excluded up to kinematic limit (91 GeV)
for any $\tan\beta$

Infer indirect limit on s-fermion masses from the
exclusion in the $M_2 - m_0$ plane



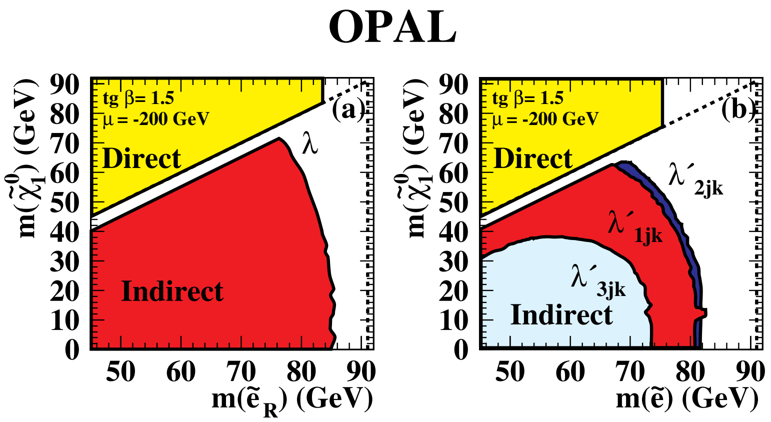


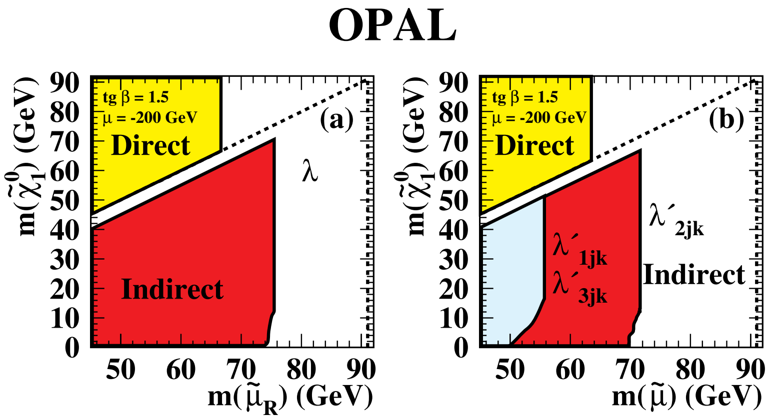


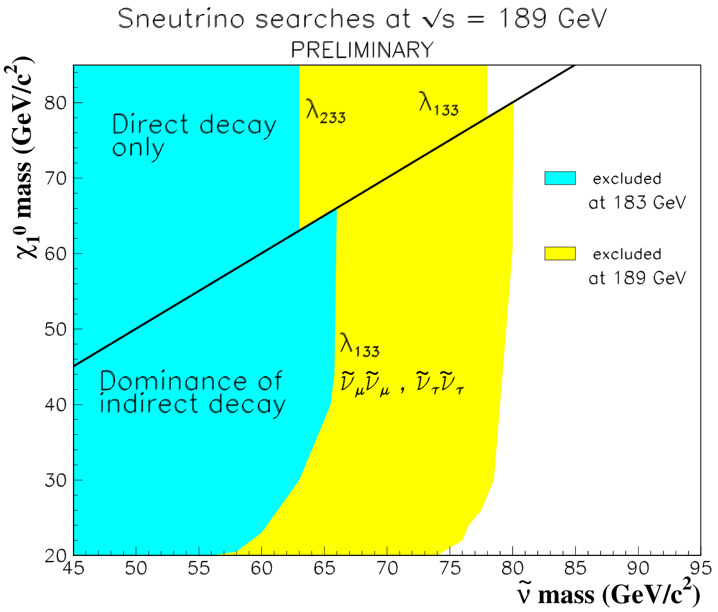
Limits on S-leptons

Excluded regions for S-leptons
with λ and λ' $\not{R}_p$ direct and indirect decays

Much weaker limits for λ' due to the
high $W^{\pm}W^{\mp}$ background

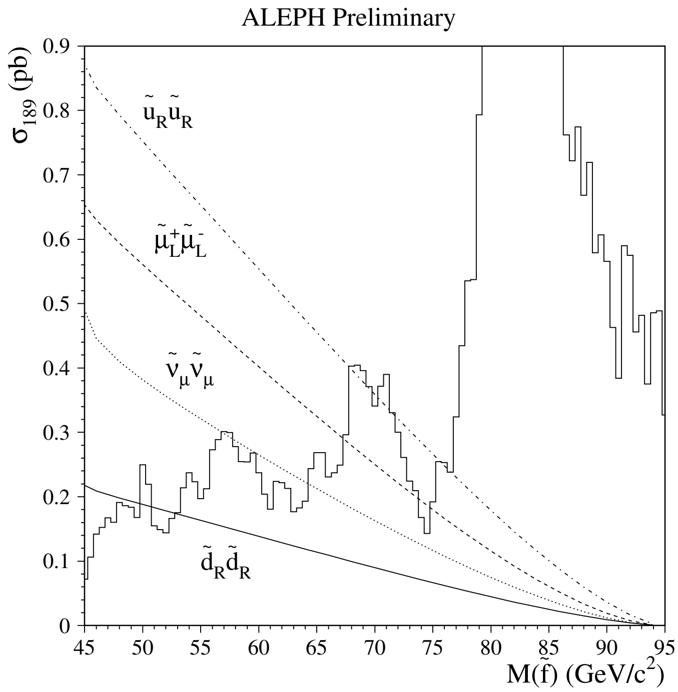


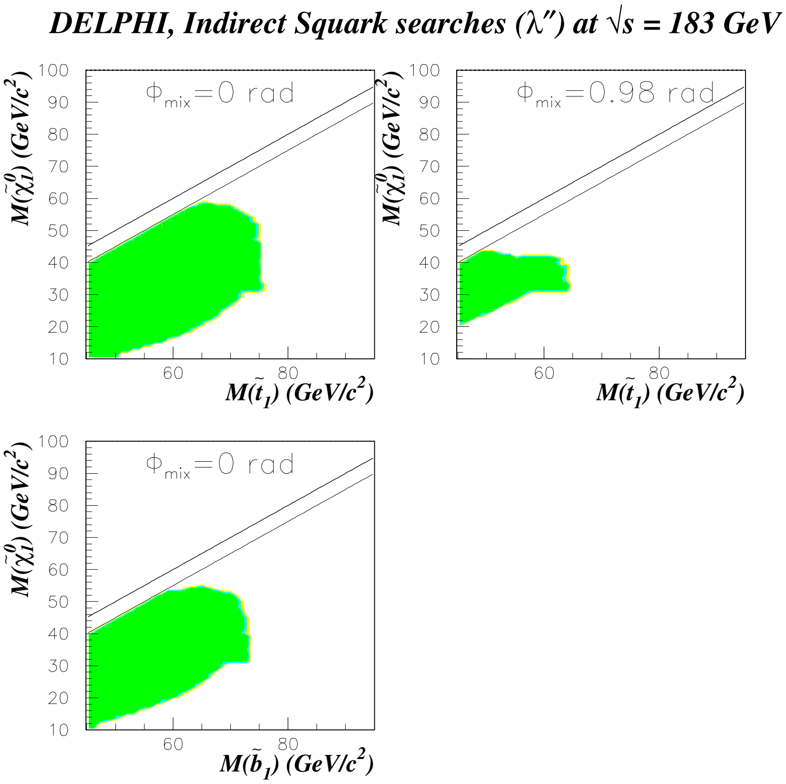




Limits on S-quarks

S-fermions with multi-jets final state
S-leptons with λ' direct $\not{R}_p$ decays and
S-quarks with λ'' direct or indirect decays

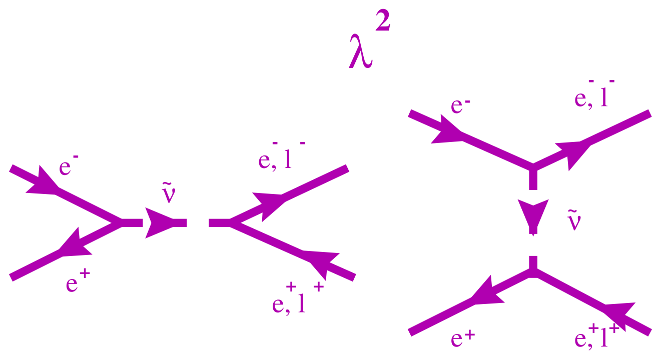




Mass limits – Summary

- $\tilde{\chi}^{\pm}$ $M >$
  - 94 GeV for λ, λ', λ'', large m_0 only (A)
  - 93/94 GeV not for all indices of λ/λ', (87 GeV λ'') (D)
  - 91 GeV for any λ and λ'' and any m_0 (L)
  - 76 GeV for λ, λ', λ'', large m_0 only (O)
- $\tilde{\chi}^0_1$ $M >$
  - 30 GeV not for all indices of λ/λ', (21 GeV λ'') (D)
  - 27 GeV for any λ and λ'' and any m_0 (L)
- $\tilde{\mu}$ $M >$
  - 83, 77, 80 GeV (indirect λ, λ', λ''); 60, 67 GeV (direct λ, λ') (A)
  - 70, 68 GeV (indirect λ, λ''); 61 GeV (direct λ) (D)
  - 62 GeV (λ, inferred from gauginos) (L)
  - 66, 64 GeV (direct λ, λ') (O)
- $\tilde{\nu}_\mu$ $M >$
  - 68, 56 GeV (indirect λ, λ'); 78, 56 GeV (direct λ, λ') (A)
  - 73 GeV (indirect λ); 77 GeV (direct λ) (D)
  - 66, 58 GeV (direct λ, λ') (O)

Single $\tilde{f}$ production/exchange



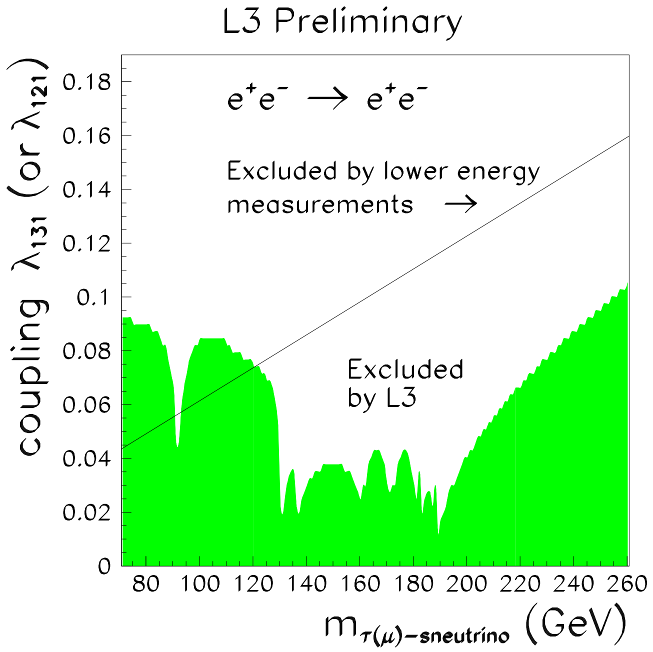
Resonant $\tilde{\nu}$ production via λ coupling

- Direct $R\!\!\!/_p$ decay ⇨ interference with SM two-fermion production
- Indirect $R\!\!\!/_p$ decay ⇨ $e^+e^- \rightarrow \tilde{\nu} \rightarrow \nu\tilde{\chi}^0_1 \rightarrow \nu\nu ll$ look for acoplanar leptons

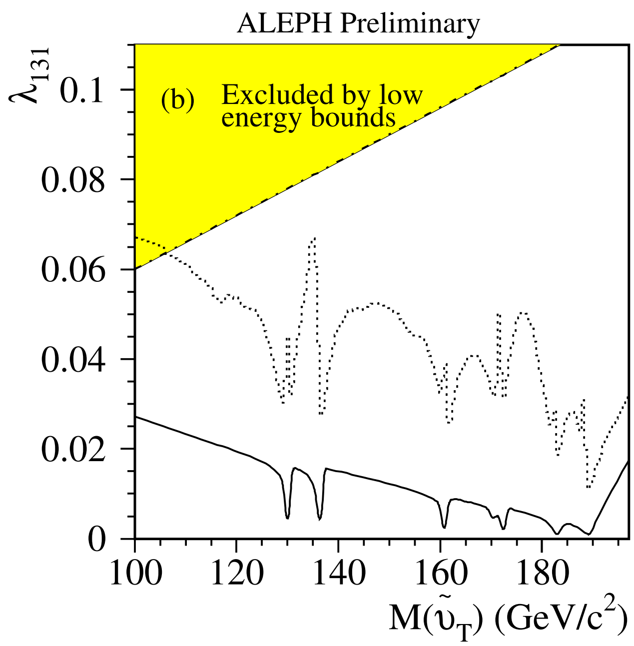
t-channel $\tilde{\nu}$ (λ) and $\tilde{q}$ (λ') exchange ⇒
e^+e^-, $\mu^+\mu^-$, $\tau^+\tau^-$, $q\bar{q}$ distribution would be affected

No deviations from SM ⇨ fit distributions to derive limits on $\lambda(M_{\tilde{\nu}})$ (strong) and $\lambda'(M_{\tilde{q}})$ (weak)

Direct



Indirect



GMSB Framework

SUSY is broken softly $M_{\text{SUSY}} \lesssim$ TeV
Most common is the Gravity SUSY breaking mechanism $\rightarrow$ potentially large FCNC
SUSY breaking in Gauge Mediated models is flavour invariant

Predictive models:

- SUSY mass spectrum defined by 6 parameters

$$\boxed{\tan\beta,\ \mu,\ M,\ F,\ N,\ A_0}$$

Messenger mass scale	➪	M
SUSY breaking mass scale	➪	$\Lambda = F/M$
Number of messenger generations	➪	N
fixed by electroweak breaking (up to a sign)	➪	$sign(\mu)$

The Gravitino mass is related to the SUSY breaking scale ($\sqrt{F}$) by:

$$m_{\tilde{G}} = 1/k(\sqrt{F}/100\ \text{TeV})^2 \cdot 2.4\ \text{eV}$$

10^{-2} eV $\lesssim m_{\tilde{G}} \lesssim 10^3$ eV $\rightarrow$
in GMSB models $\tilde{G}$ is the LSP

Major phenomenological implications at LEP
if R_p conserved:

In GMSB $M_{\tilde{l}} \sim M_{\tilde{\chi}_1^0}$ ➦

- ❊ for small N the $\tilde{\chi}_1^0$ is the NLSP
- ❊ for large N the $\tilde{\tau}$ (due to L–R mixing) is the NLSP

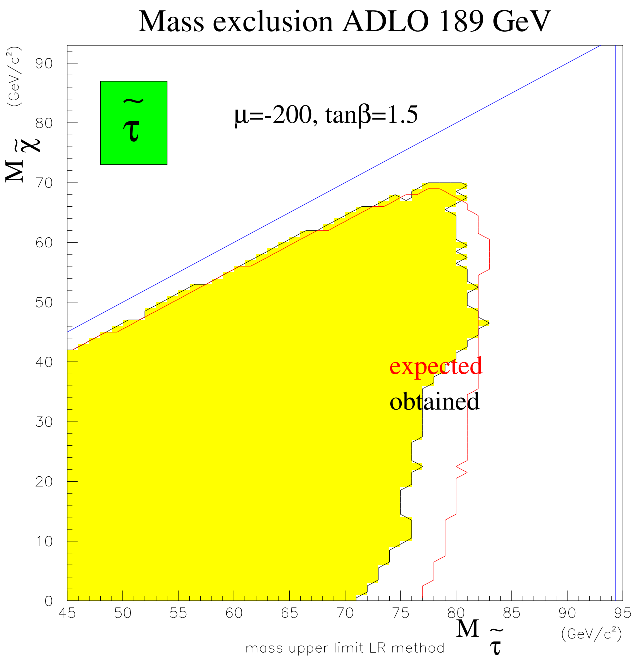
- ❑ $\tilde{\chi}_1^0$ NLSP ➦ $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$ ➦ photons and $\not{E}$ (it is visible !)
- ❑ charged s-lepton NLSP ➦ $\tilde{l} \rightarrow l\tilde{G}$ ➦ leptons and $\not{E}$
- ❑ NLSP decay length depends on $m_{\tilde{G}}$ ➦ $L_{\mathrm{NLSP}} \propto m^2_{\tilde{G}}$

Address searches mainly to s-leptons and neutralinos

$e^+e^- \rightarrow \tilde{l}\bar{\tilde{l}}$ $\quad$ $e^+e^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0$

$\tilde{\tau}$ NLSP

- short-lived $\tilde{\tau}$ ($L < 1$ cm)
  - ➜ acoplanar leptons searches (A,D,L,O)
  - ➜ neutralino (A,D) and chargino (D) pair production with $\tilde{\chi}^0_1 \rightarrow \tau\tilde{\tau}$ and $\tilde{\chi}^{\pm} \rightarrow \nu\tilde{\tau}$
- medium-lived $\tilde{\tau}$ ($1 < L < 100$ cm)
  - ➜ searches for leptons with large IP (A,D)
  - ➜ searches for lepton tracks with kinks (A,D)
  - ➜ searches for chargino (D) pair production with $\tilde{\chi}^{\pm} \rightarrow \nu\tilde{\tau}$
- long-lived $\tilde{\tau}$ ($L > 100$ cm)
  - ➜ searches for highly ionising tracks (A,D,L,O)



Acoplanar τ searches ➪
see J.F. Grivaz talk ➪
$M_{\tilde{\tau}} > 71$ GeV
@ $M_{\tilde{\chi}^0_1} = 0$ LEP

$\tilde{\tau}$ NLSP

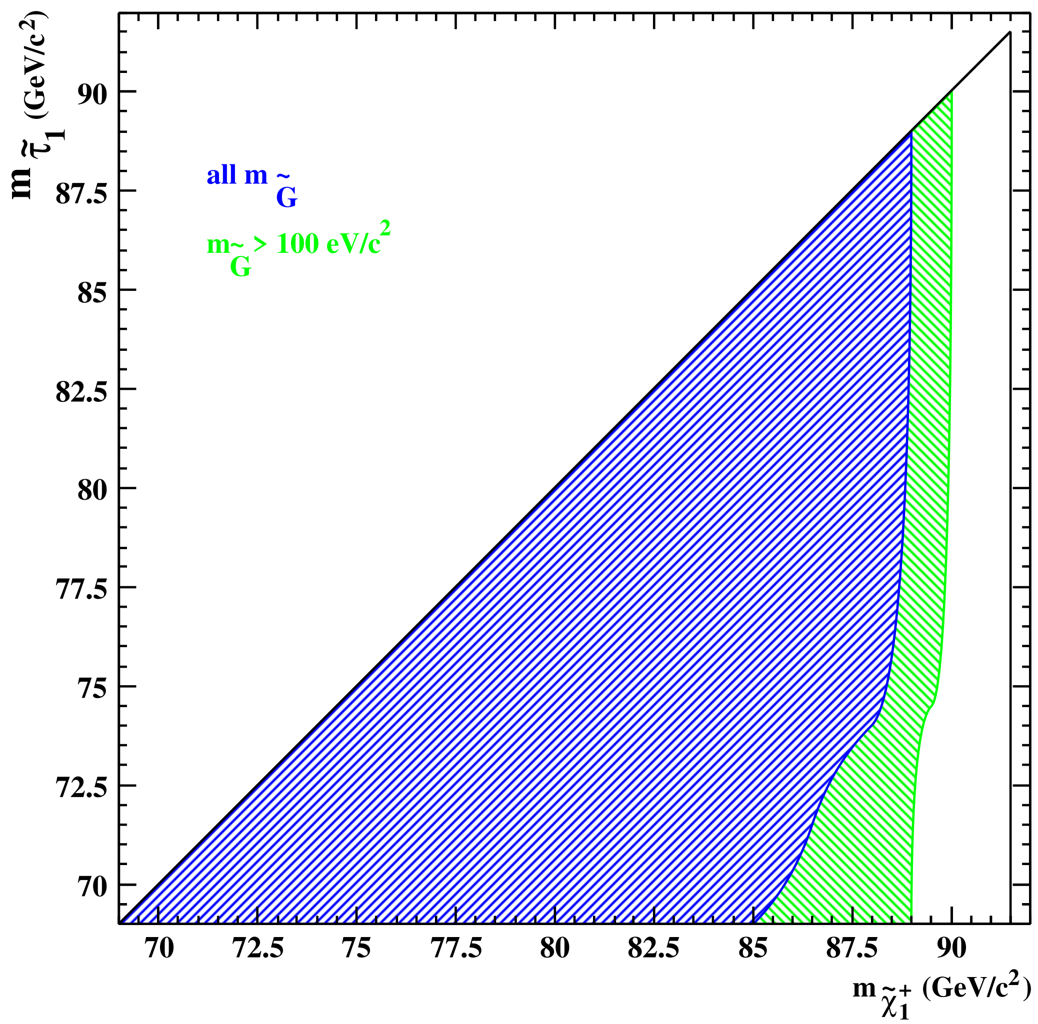
Also for medium-lived $\tilde{\tau}$ ⇨ No signal

	A	D
D/MC$_{SM}$	4/1.8	5/6.0

Better limits for longer decay lengths

$M_{\tilde{\chi}^{\pm}} > 85 - 89$ GeV (D)

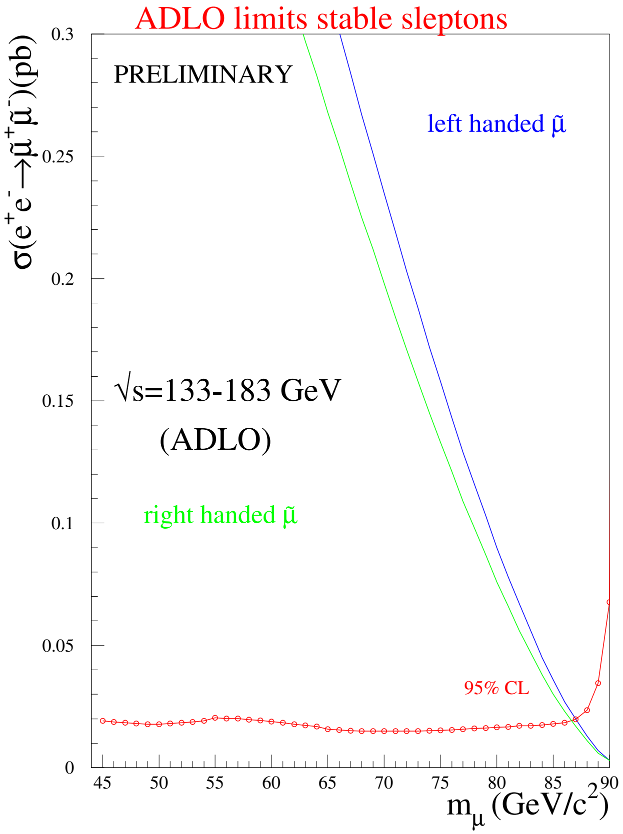
DELPHI PRELIMINARY



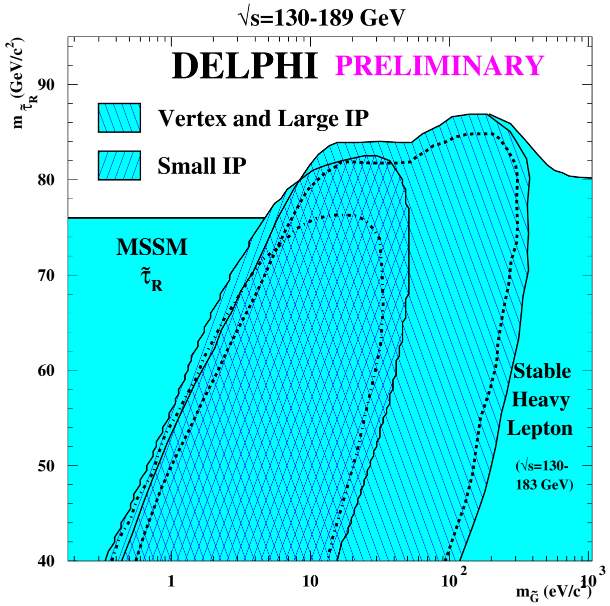
$\tilde{\tau}$ NLSP

Adding the results for long-lived $\tilde{\tau}$ ($M_{\tilde{\tau}} > 87$ GeV LEP).....

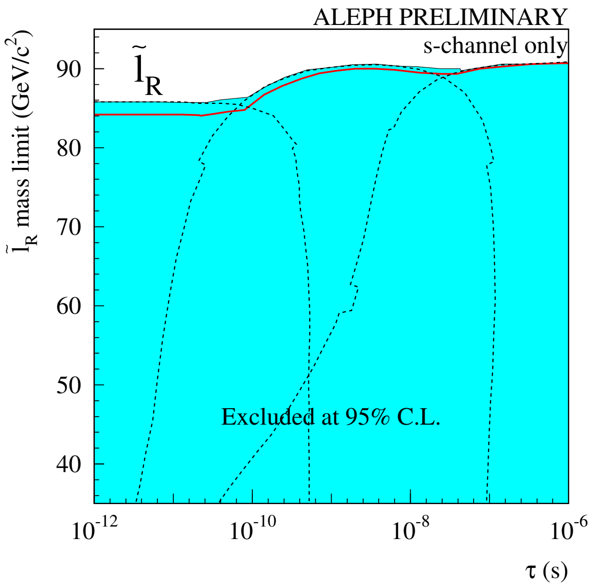
...... we derive a mass limit independent of $m_{\tilde{G}}$ ➪ $M_{\tilde{\tau}} > 71$ GeV (LEP)



$\tilde{\tau}$ any $m_{\tilde{G}}$



3 degenerate $\tilde{l}_R$ any $m_{\tilde{G}}$



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

- short-lived $\tilde{\chi}_1^0$ ($L < 1$ cm)
  - ➜ e$^+$e$^-$$\rightarrow\tilde{\chi}_1^0\tilde{\chi}_1^0$ ➪ acoplanar photons searches (A,D,L,O)
  - ➜ e$^+$e$^-$$\rightarrow\tilde{\chi}_1^0\tilde{G}$ and e$^+$e$^-$ $\rightarrow$ $\tilde{G}\tilde{G}\gamma_{ISR}$ only for super-light $\tilde{G}$ ➪ single photon (A,D,L,O)
  - ➜ s-leptons (A,L) and charginos pair production with $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$ ➪ acoplanar leptons or jets with photons
- long-lived $\tilde{\chi}_1^0$($L > 1$ cm)
  - ➜ searches for non-pointing photons (A,D)

- The signatures for e$^+$e$^-$$\rightarrow\tilde{\chi}_1^0\tilde{\chi}_1^0$, e$^+e^-$$\rightarrow\tilde{\chi}_1^0\tilde{G}$ and e$^+$e$^-$ $\rightarrow$ $\tilde{G}\tilde{G}\gamma_{ISR}$
  suffer from an irreducible background e$^+$e$^-$$\rightarrow\nu\bar{\nu}\gamma(\gamma)$

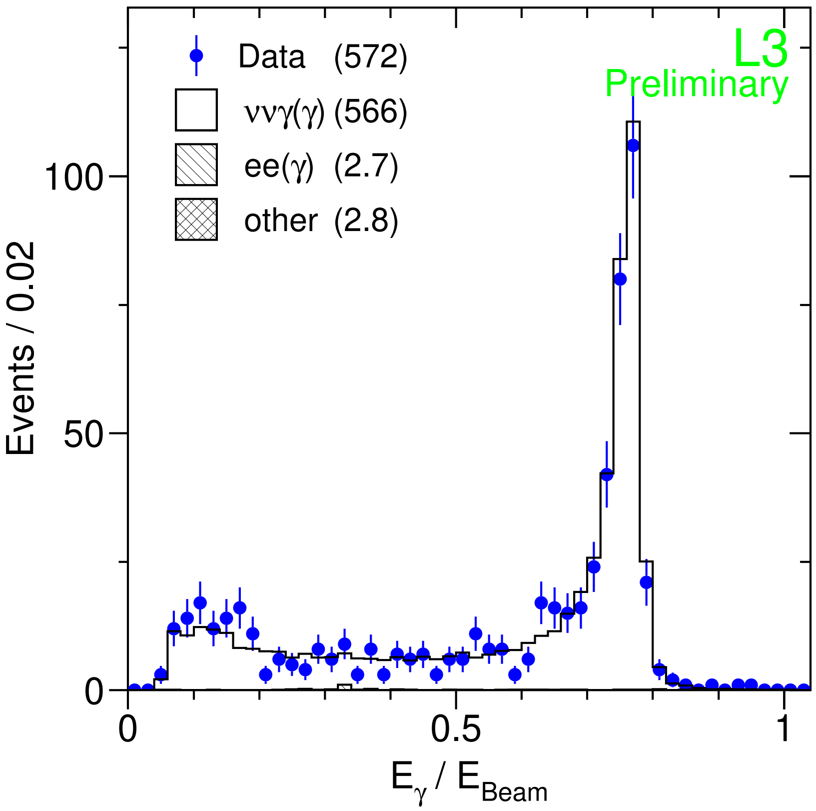
- S-leptons and charginos searches are easier thanks to the photon tag (Charginos excluded up to 94 GeV and s-leptons similar to SUGRA limits)

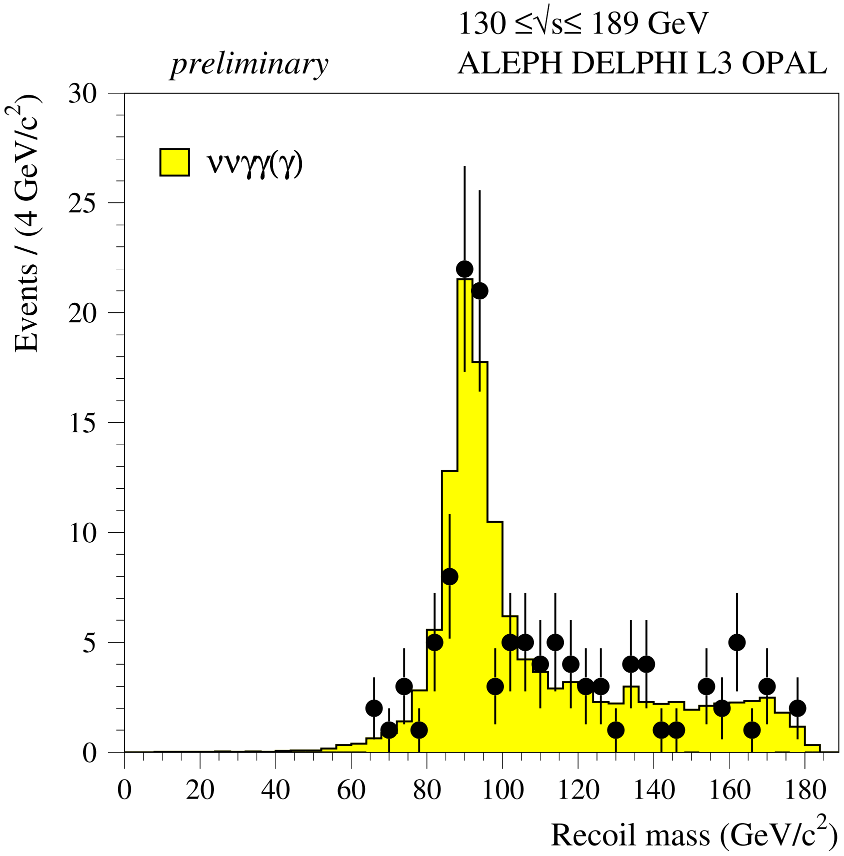
- Searches for non-pointing photons suffer from cosmics background (bremsstrahlung from out-of-time muons)

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

Observed rates of single and multi photon in agreement with SM

	A	D	L	O
D/MC_{SM}	484/492.0	378/373.9	572/571.5	562/615.9



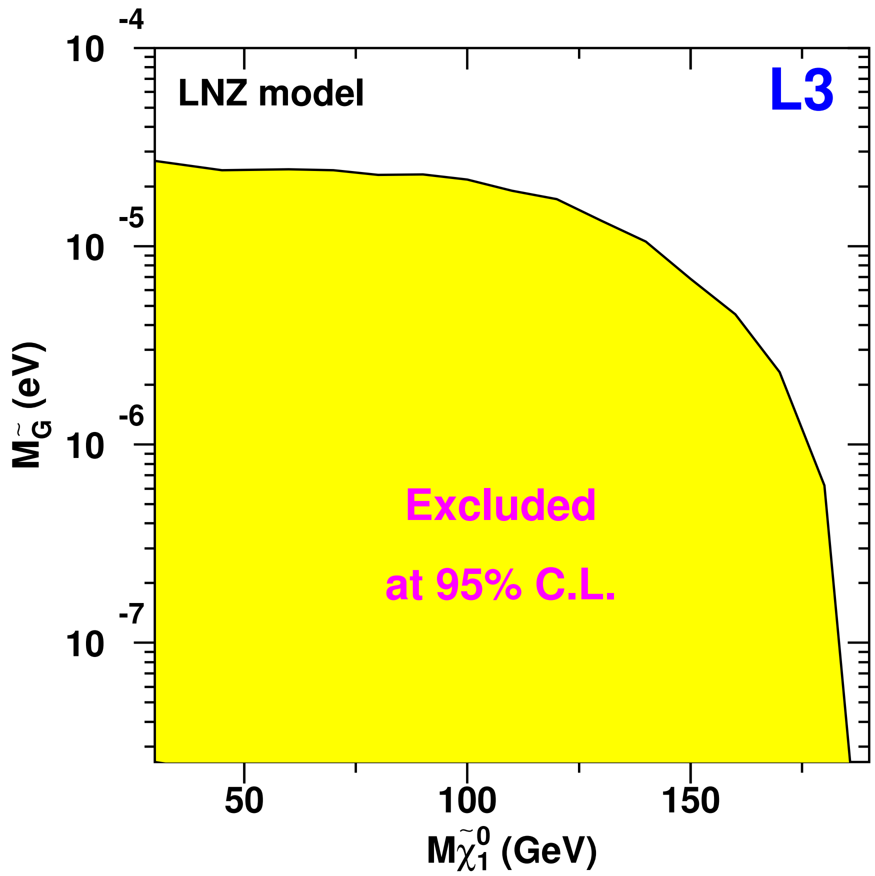


$\tilde{\chi}^0_1$ NLSP

Exclusions from single photon

Mass limit on $m_{\tilde{G}}$ in

no-scale SUGRA (Lopez *et al.*, Phys. Rev. **D 55** (1997) 5813) $(\tilde{\chi}^0_1\tilde{G}\rightarrow\gamma\tilde{G}\tilde{G})$



Brignole *et al.* model (Nucl. Phys. **B 516** (1998) 13) where

$m_{\text{SUSY}} > \sqrt{s}$ except $m_{\tilde{G}}$

$\tilde{G}\tilde{G}\gamma_{\text{ISR}}$ ⇨ signal at low energy and polar angle and $\sigma \propto s^3$

	A	D	L
$m_{\tilde{G}} >$	$1.1\cdot10^{-5}$ eV	$9.1\cdot10^{-6}$ eV	$8.9\cdot10^{-6}$ eV

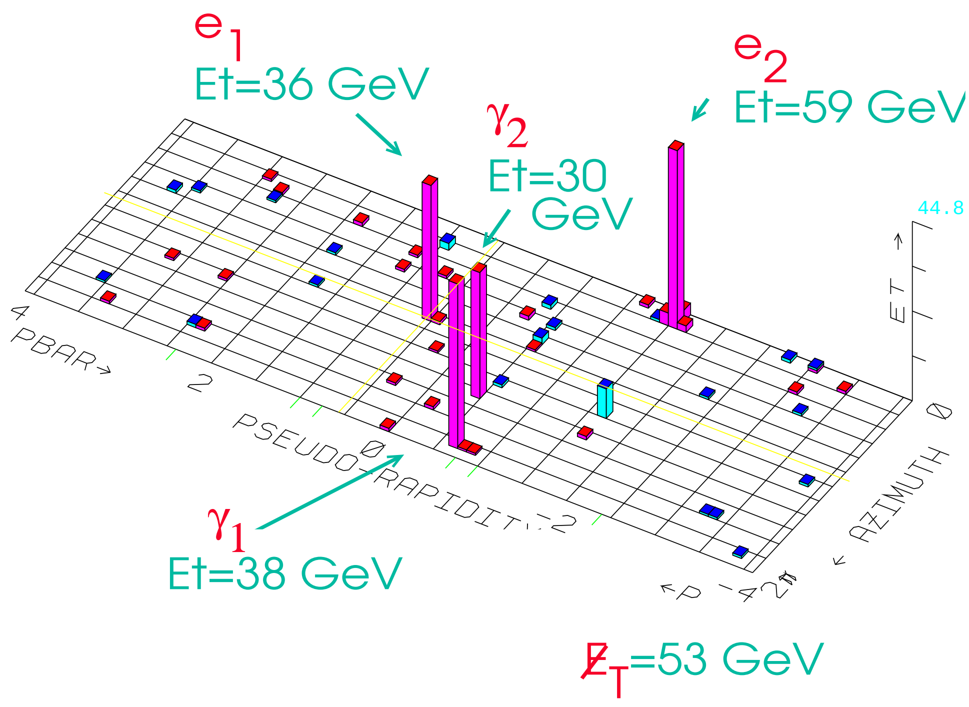
$\tilde{\chi}^0_1$ NLSP

Relighted interest in GMSB models was mainly due to the

CDF event (Phys. Rev. Lett. **81** (1998) 1791): $e^+e^-\gamma\gamma\not{E}$
(SM background $< 10^{-3}$ events)

Natural interpretation in SUSY as: $q\bar{q}\rightarrow\tilde{e}\tilde{e}\rightarrow\tilde{\chi}^0_1\tilde{\chi}^0_1 ee\rightarrow\tilde{G}\tilde{G}\gamma\gamma ee$

Event: $2\,e + 2\,\gamma + \not{E}_T$



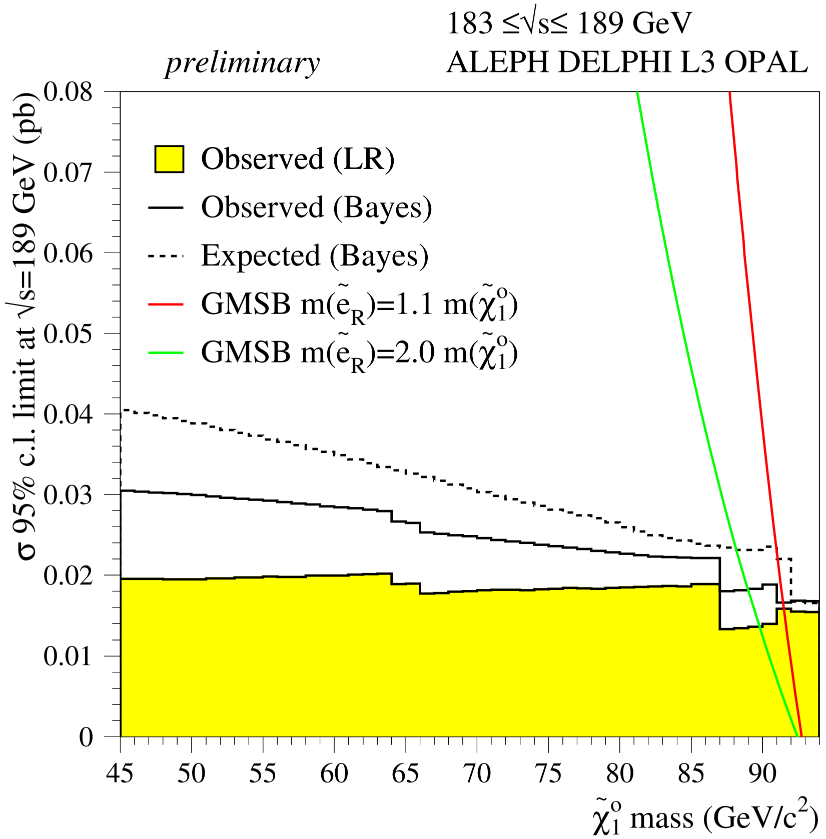
In the light $\tilde{G}$ scenario large cross sections (~ 1 pb) predicted at LEP2 for the processes:

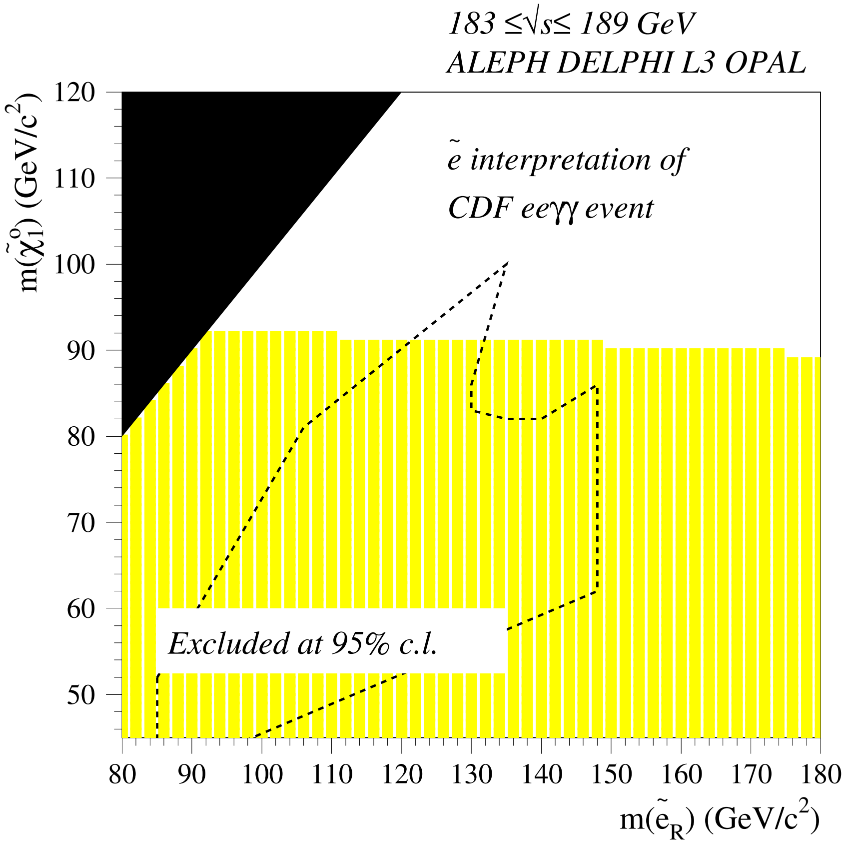
- $e^+e^-\rightarrow\tilde{\chi}^0_1\tilde{\chi}^0_1\rightarrow\tilde{G}\tilde{G}\gamma\gamma$
- $e^+e^-\rightarrow\tilde{\chi}^0_1\tilde{G}\rightarrow\tilde{G}\tilde{G}\gamma$ (for very light $\tilde{G}$, $M_{\tilde{G}} \sim 10^{-4}$ eV)

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

Two photon limits ➪ $M_{\tilde{\chi}_1^0} > 90 - 92$ GeV (LEP)

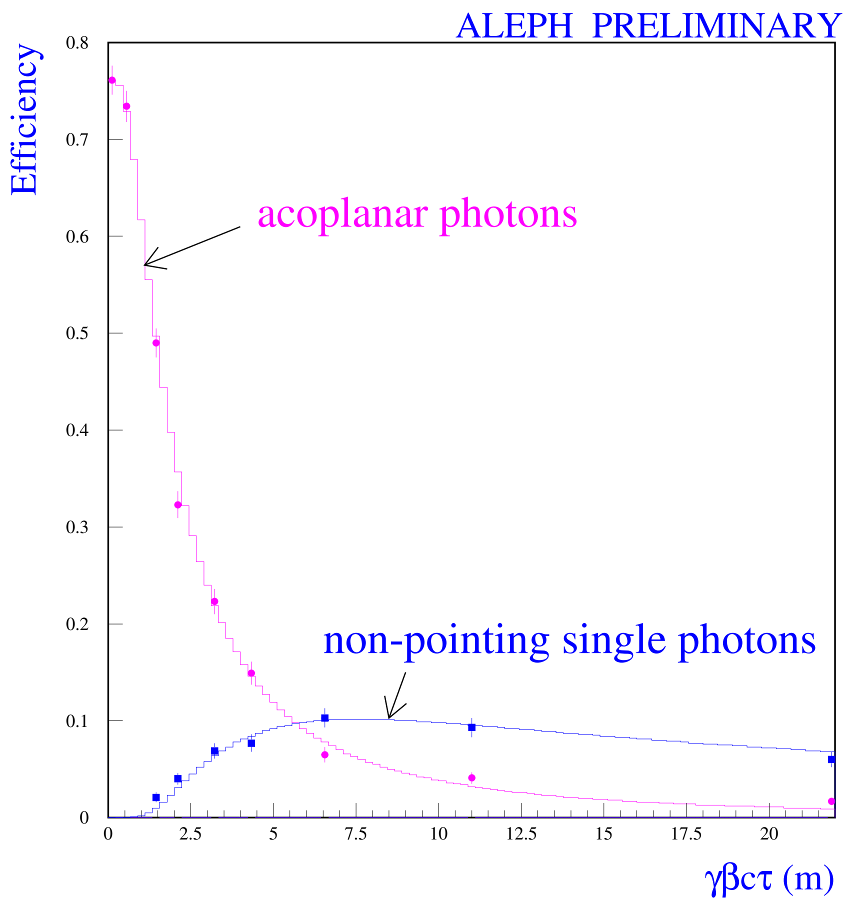
SUSY interpretation of the CDF event almost ruled out by LEP

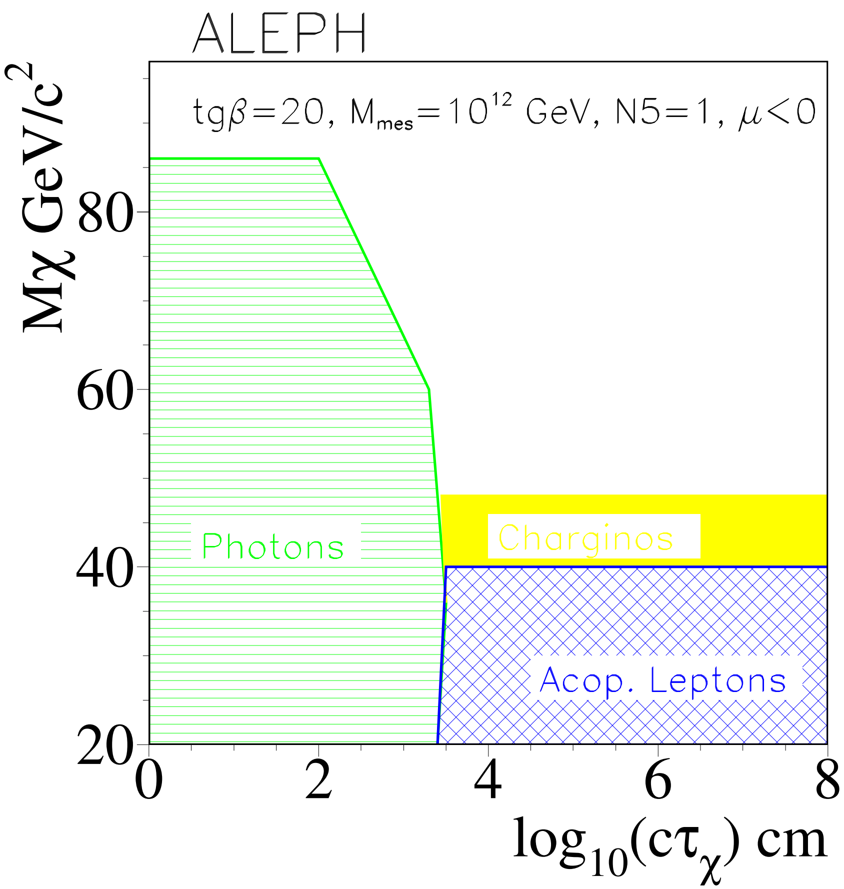




$\tilde{\chi}^0_1$ NLSP

Long-lived $\tilde{\chi}^0_1$ $(10 < L < 1000$ m) ➪ search for non-pointing photons

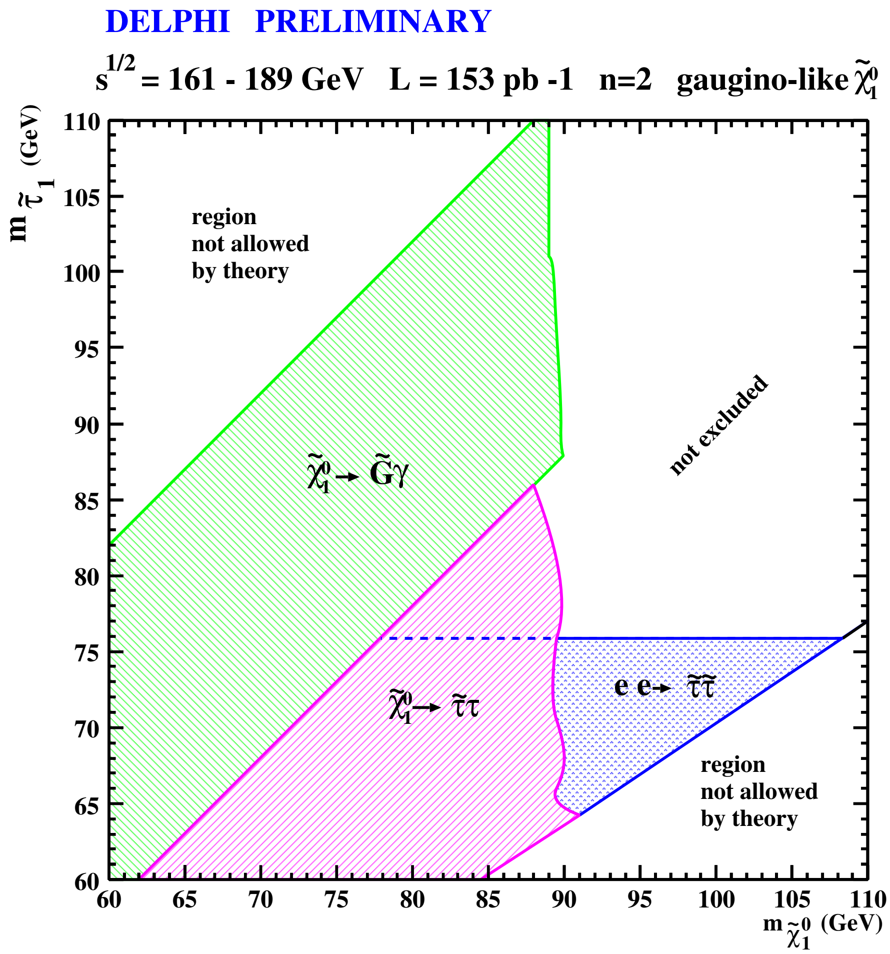




If $\tilde{\chi}^0_1$ decays outside $(L > 10$ m) ➪ also indirect limits from searches for $\tilde{l}$ and $\tilde{\chi}^{\pm}$ with $\not{E}$

Summary – GMSB

- $\tilde{\tau}$ and $\tilde{\chi}_1^0$ NLSP scenarios explored
- $M_{\tilde{\tau}} > 76$ GeV (D), for any decay length
- $M_{\tilde{\chi}_1^0} > 90$ GeV (LEP short-lived),
  45 GeV (A indirect) for any decay length
- SUSY interpretation of the CDF event almost ruled out
- absolute limit on $m_{\tilde{\mathrm{G}}} > 1 \cdot 10^{-5}$ eV



QG and new space dimensions

- Gravity like a Kaluza-Klein theory
  additional space dimensions $\Rightarrow$ $M_P^2 \sim r^n M_D^{n+2}$
  with M_D the fundamental Planck scale
- Size of the additional n dimensions is
  $r \sim 10^{\frac{30}{n}-17}$ cm ➪ $n \geq 2$
- Tight constraint by the supernova (SN1987) bound:
  $M_{D2} > 30$ TeV, $M_{D3} > 2$ TeV;
  and BBN (H–He abundances) requires $M_{D2} > 6$ TeV
- Huge phase space makes the Graviton “visible” at colliders ➪ effects suppressed by $M_{Dn} \sim O($ TeV$)$
- Graviton exchange in 2-fermion and 2-boson production
  - SM cross section modified by a term $\propto \lambda/M_S^4$ with $M_S \sim O(M_D)$ and $\lambda \sim O(1)$ unknown
  - fit differential distributions to extract limits on M_S

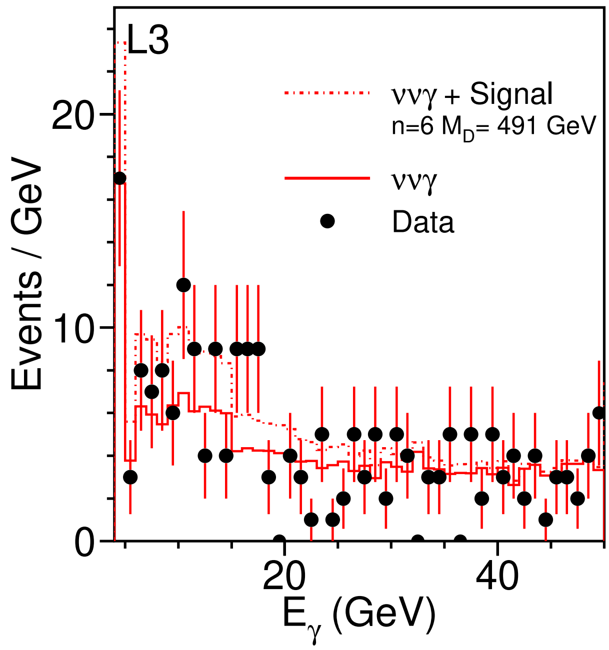
L3	M_S (TeV) $>$	
	λ = -1	λ = +1
$\mu^+\mu^-$	0.52	0.56
$\tau^+\tau^-$	0.53	0.51

OPAL	M_S (TeV) $>$	
	λ = -1	λ = +1
$\mu^+\mu^-$	0.65	0.58
$\tau^+\tau^-$	0.50	0.63
l^+l^-	0.64	0.65
$\gamma\gamma$	0.60	0.75

QG – Graviton–γ production

- Graviton–γ production $\Rightarrow$ $\quad \sigma \sim \sqrt{s}^{n} / M_D^{n+2}$
  - Graviton propagates in $4+n$ dimensions ➪ in the usual world 4–momentum is not conserved ➪ the Graviton appears in 4 dimensions with a continuous mass distribution
  - the expected single photon signal is similar to ISR ➪ fit the low energy part of $e^+e^- \to \nu\bar{\nu}\gamma_{\mathrm{ISR}}$ to extract limits on M_D

OPAL	at 95% C.L.	
	$\sigma_{\mathrm{G}\gamma} <$	➪ $M_D >$
$n = 2$	198 fb	➪ 1161 GeV
$n = 4$	204 fb	➪ 734 GeV
$n = 6$	219 fb	➪ 534 GeV



Conclusions (I)

Unfortunately no signals observed

- $\not R_p$: new searches cover all final states (and all $\lambda, \lambda', \lambda''$) and results are very similar to R_p conserved
  - $M_{\tilde{\chi}^\pm} > 94$ GeV, $M_{\tilde{\chi}_1^0} > 30$ GeV

    ➪ LEP SUSY searches independent of R_p
- GMSB: new searches for both $\tilde{\tau}$ and $\tilde{\chi}_1^0$ NLSP
  - $M_{\tilde{\tau}} > 76$ GeV, $M_{\tilde{\chi}_1^0} > 90$ GeV
    $M_{\tilde{\chi}_1^0} > 45$ GeV for any decay length
- Fresh results on Quantum Gravity with extra dimensions: $M_D \gtrsim 1$ TeV for n=2
- Many thanks to the LEP collaborations and LEP SUSY WG for providing material
- Prospects for year 1999/2000 (LEP $\sqrt{s} \simeq 200$ GeV):
  - $\not R_p$: $M_{\tilde{\chi}^\pm} \sim 100$ GeV, $M_{\tilde{\chi}_1^0} \sim 36$ GeV
  - GMSB: $M_{\tilde{\tau}} \sim 90$ GeV, $M_{\tilde{\chi}_1^0} \sim 100$ GeV

Conclusions (II)

We don't give up .... the hunt is going on ....