

Photonic and gravitino searches at LEP

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Mini-review of results from Aleph, Delphi, L3, Opal and the LEP SUSY working group.

Content:

- Gauge Mediated Supersymmetry Breaking
- Gravitino LSP + Slepton NLSP
- Gravitino LSP + Neutralino NLSP
- GMSB interpretation of the searches

Gauge Mediated Supersymmetry Breaking

The lightest and next-to-lightest SUSY particles:



The Gravitino mass: $m_{\tilde{G}} \sim \frac{(\sqrt{F})^2}{M_{Plank}}$

where \sqrt{F} is the SUSY breaking scale

$\sqrt{F} : 10 - 10\,000 \text{ TeV} \qquad m_{\tilde{G}} : 0.02 \text{ eV} - 20 \text{ keV}$

The NLSP decay length:

$L_{NLSP} \sim m_{NLSP}^{-5} m_{\tilde{G}}^2$

- $\ll \text{Exp.} \longrightarrow$ Acoplanar lepton or γ
- $\approx \text{Exp.} \longrightarrow$ Non-pointing lepton or γ
- $\gg \text{Exp.} \longrightarrow$ Heavy stable particle

Analysis procedure

Different predicted GMSB event topologies have been searched for using the 192-202 GeV LEP data.

No signal was observed in any of the event topologies studied.

New cross section limits have been obtained.

Scans of the minimal GMSB parameter space

- \sqrt{F} The SUSY breaking scale
- M The messenger mass scale
- N The number of messenger pairs
- Λ The sparticle mass scale
- μ The higgsino mass parameter
- $\tan \beta$ Ratio of the expectation values of the two Higgs doublets

yield new exclusion plots

\tilde{G} LSP + \tilde{l} NLSP

Large $\tilde{\tau}_R - \tilde{\tau}_L$ mixing

Large $\tan\beta$

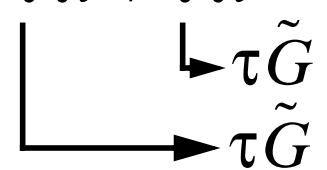
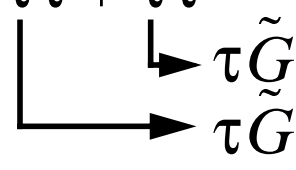
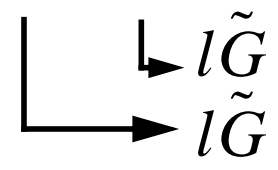
$\tilde{\tau}_1$ NLSP

Small $\tilde{\tau}_R - \tilde{\tau}_L$ mixing

Small $\tan\beta$

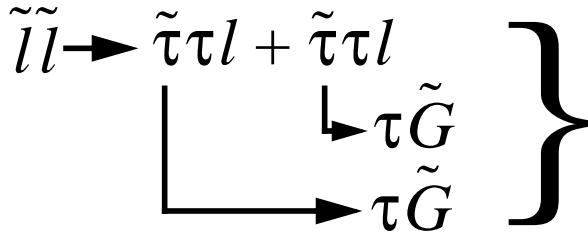
$\tilde{\tau}_R \tilde{e}_R \tilde{\mu}_R$ co-NLSP

$e^+e^- \rightarrow \tilde{l}\tilde{l}$

$\tilde{\tau}\tilde{\tau} \rightarrow \tau\tilde{G} + \tau\tilde{G}$ $2\tau + \cancel{E}$	$\tilde{l}\tilde{l} \rightarrow l\tilde{G} + l\tilde{G}$ $2l + \cancel{E}$ $L_{\tilde{l}} \ll \text{Experiment} :$ Acoplanar leptons
$\tilde{l}\tilde{l} \rightarrow \tilde{\tau}\tau l + \tilde{\tau}\tau l$  $4\tau + 2l + \cancel{E}$	$L_{\tilde{l}} \approx \text{Experiment} :$ Kinks + Impact param. $L_{\tilde{l}} \gg \text{Experiment} :$ Heavy stable particles
$\tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow \tilde{\tau}\tau + \tilde{\tau}\tau$  $4\tau + \cancel{E}$	$\tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow \tilde{l}\tilde{l} + \tilde{l}\tilde{l}$  $4l + \cancel{E}$

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

\tilde{G} LSP + \tilde{l} NLSP



Opal 192-202 GeV data:

5 events observed

5.1 events expected from bkg.

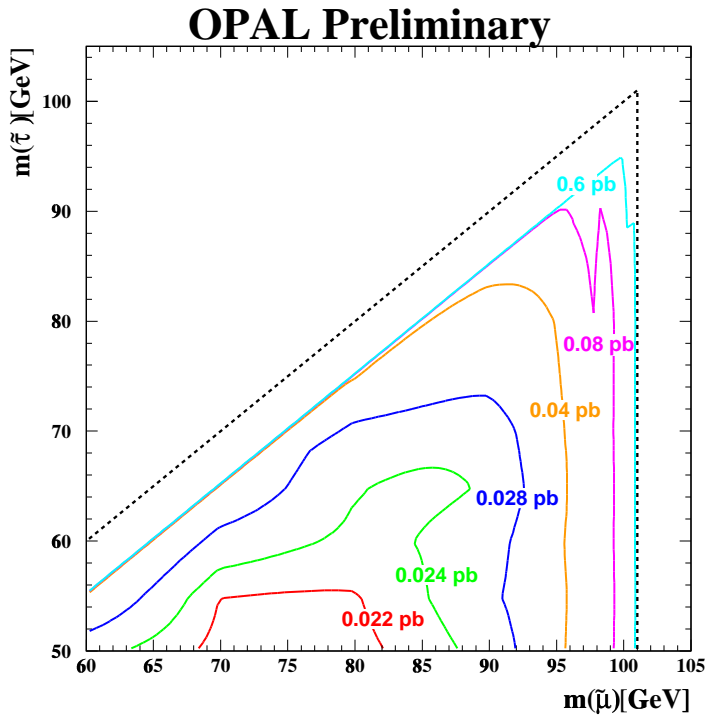
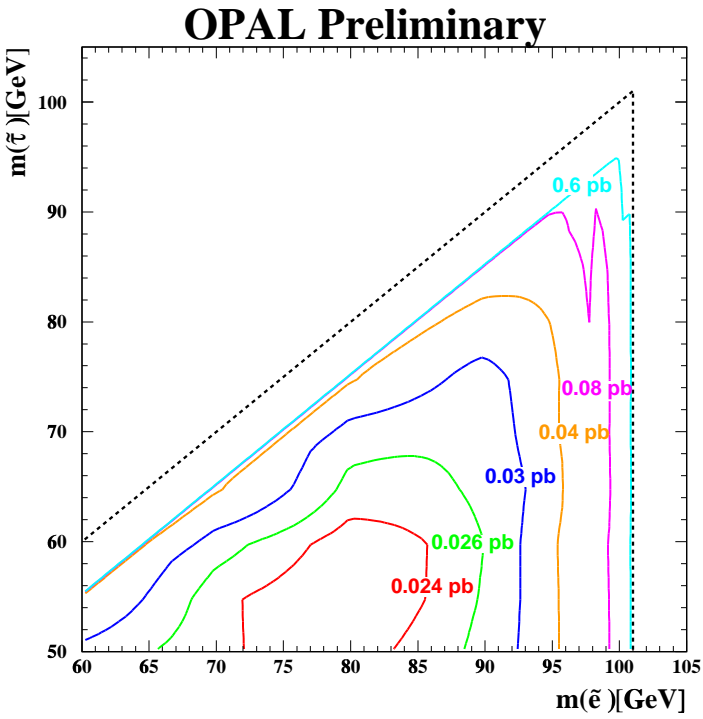
$4\tau + 2l + \cancel{E}$

Cross section limits:

$L_{\tilde{l}} \ll \text{Experiment}$

$m_{\tilde{\tau}}$ versus $m_{\tilde{e}}$

$m_{\tilde{\tau}}$ versus $m_{\tilde{\mu}}$



$$e^+e^- \rightarrow \tilde{l}\tilde{l}$$

$L_{\tilde{l}} \ll \text{Experiment}$:
Acoplanar leptons

MSUGRA

$$\tilde{l}\tilde{l} \rightarrow \tilde{\chi}_1^0 l + \tilde{\chi}_1^0 l$$

$2l + \cancel{E}$

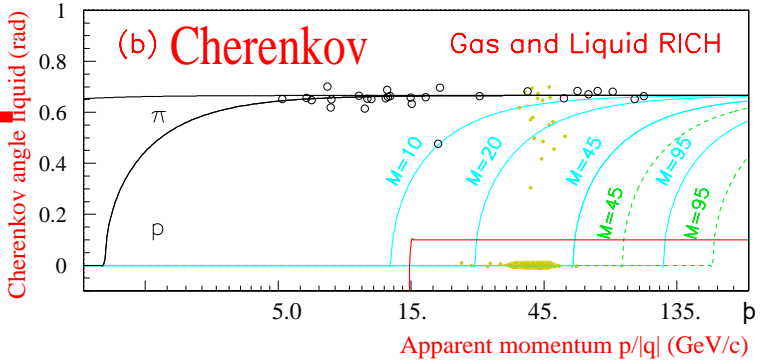
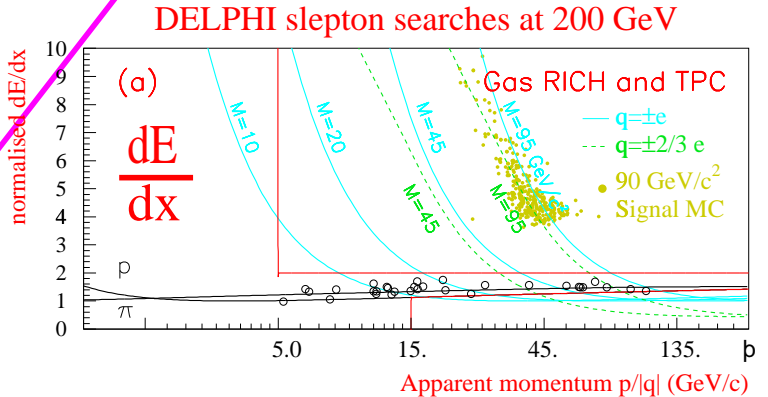
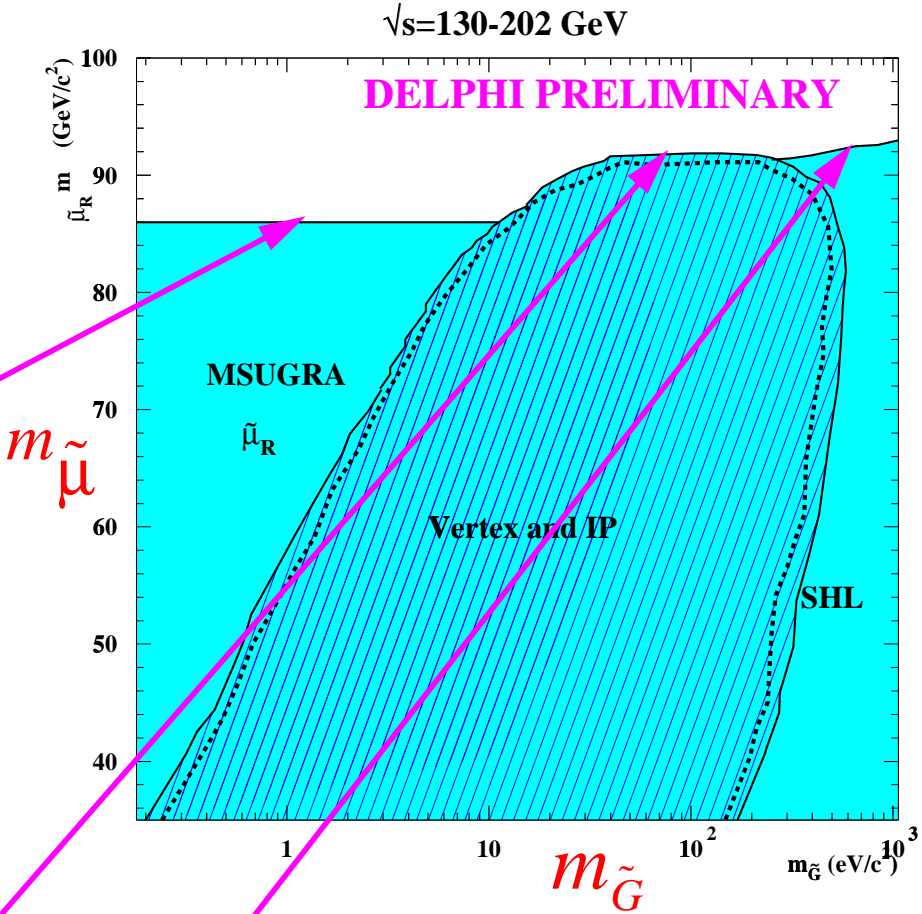
$L_{\tilde{l}} \approx \text{Experiment}$:
Kinks + Displ. vertex

GMSB

$$\tilde{l}\tilde{l} \rightarrow l\tilde{G} + l\tilde{G}$$

$2l + \cancel{E}$

$L_{\tilde{l}} \gg \text{Experiment}$:
Heavy stable particles

$$e^+e^- \rightarrow \tilde{l}\tilde{l}$$


\tilde{G} LSP + $\tilde{\chi}_1^0$ NLSP

Photon pair production:

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

$L_{\tilde{\chi}} \ll \text{Experiment} :$

Acoplanar photon pairs

$L_{\tilde{\chi}} \approx \text{Experiment} :$

Non-pointing single γ

Single photon production with ultralight \tilde{G} :

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

}

$L_{\tilde{\chi}} \ll \text{Experiment} :$

Single photons

Cascade decays to photons:

$$e^+e^- \rightarrow \tilde{l}\tilde{l} \rightarrow \dots \rightarrow 2\gamma + \cancel{E} + \text{leptons}$$

$$e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_2^0 \rightarrow \dots \rightarrow 2\gamma + \cancel{E} + \text{leptons, jets}$$

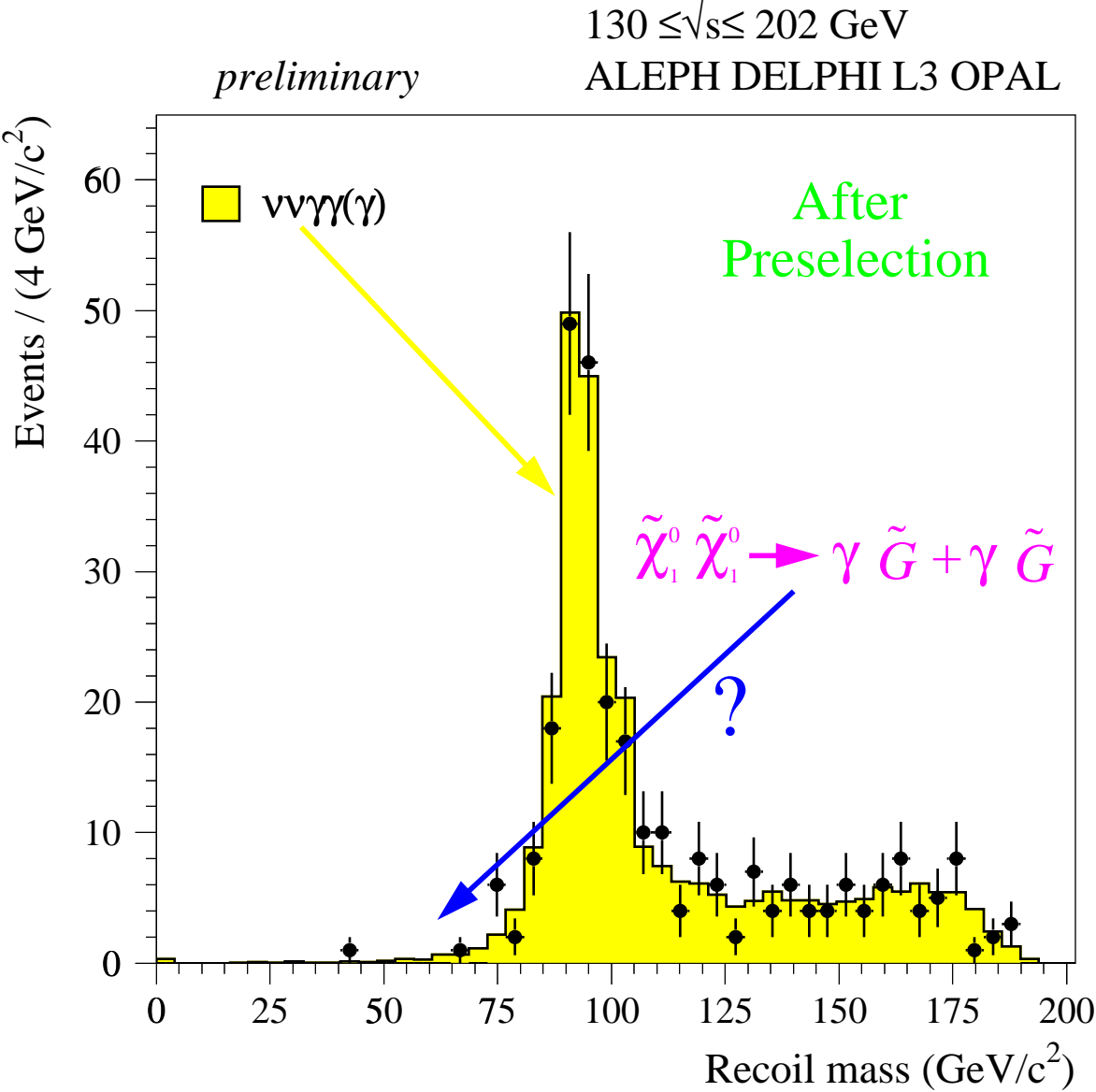
$$e^+e^- \rightarrow \tilde{\chi}_1^+ \tilde{\chi}_1^- \rightarrow \dots \rightarrow 2\gamma + \cancel{E} + \text{jets}$$

$$\tilde{G} \text{ LSP} + \tilde{\chi}_1^0 \text{ NLSP}$$

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

$L_{\tilde{\chi}}$ Experiment : Acoplanar photon pairs + Missing energy

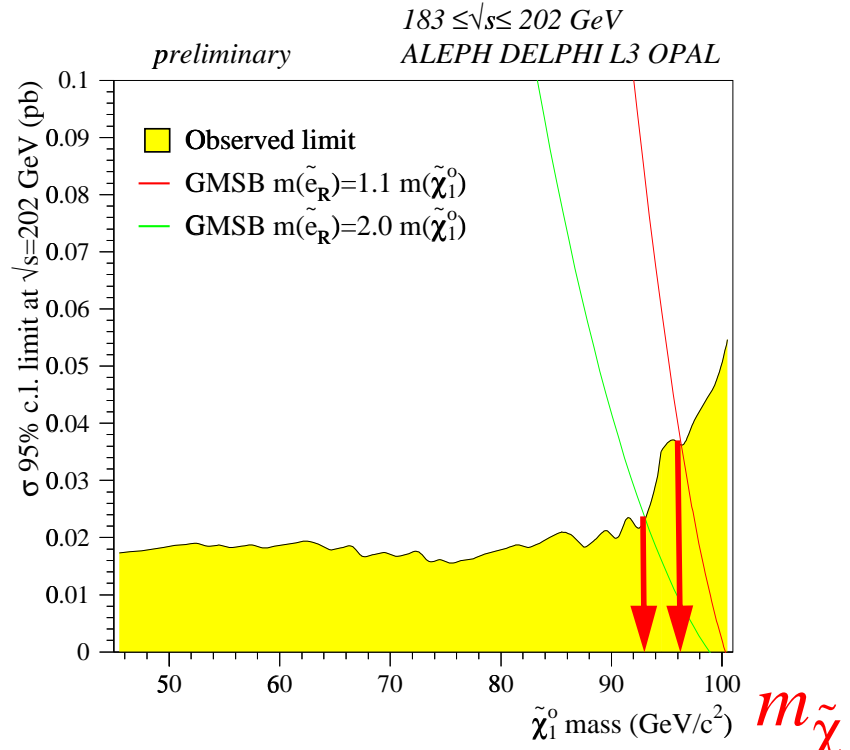
Recoil mass (or missing mass) distribution of $\gamma\gamma$ events:



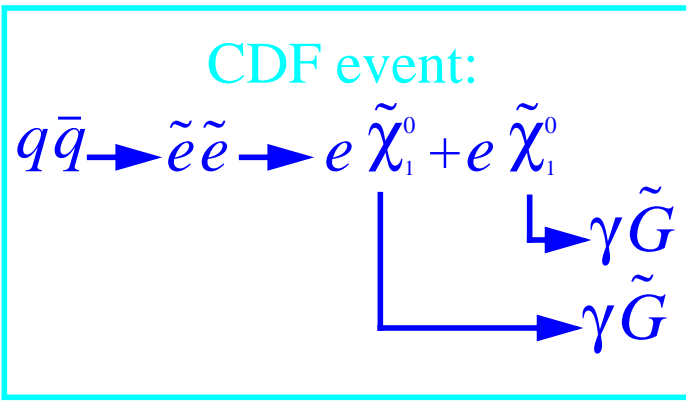
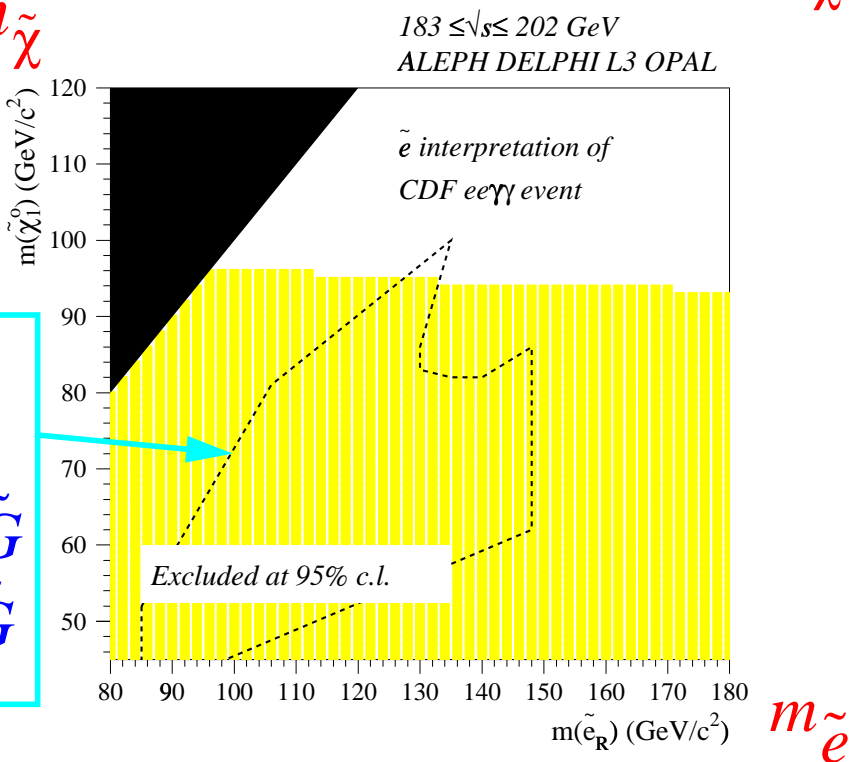
\tilde{G} LSP + $\tilde{\chi}_1^0$ NLSP
 $e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow \gamma \tilde{G} + \gamma \tilde{G}$

$L_{\tilde{\chi}}$ Experiment : Acoplanar photon pairs + Missing energy

Cross section limit →



Exclusion plot →

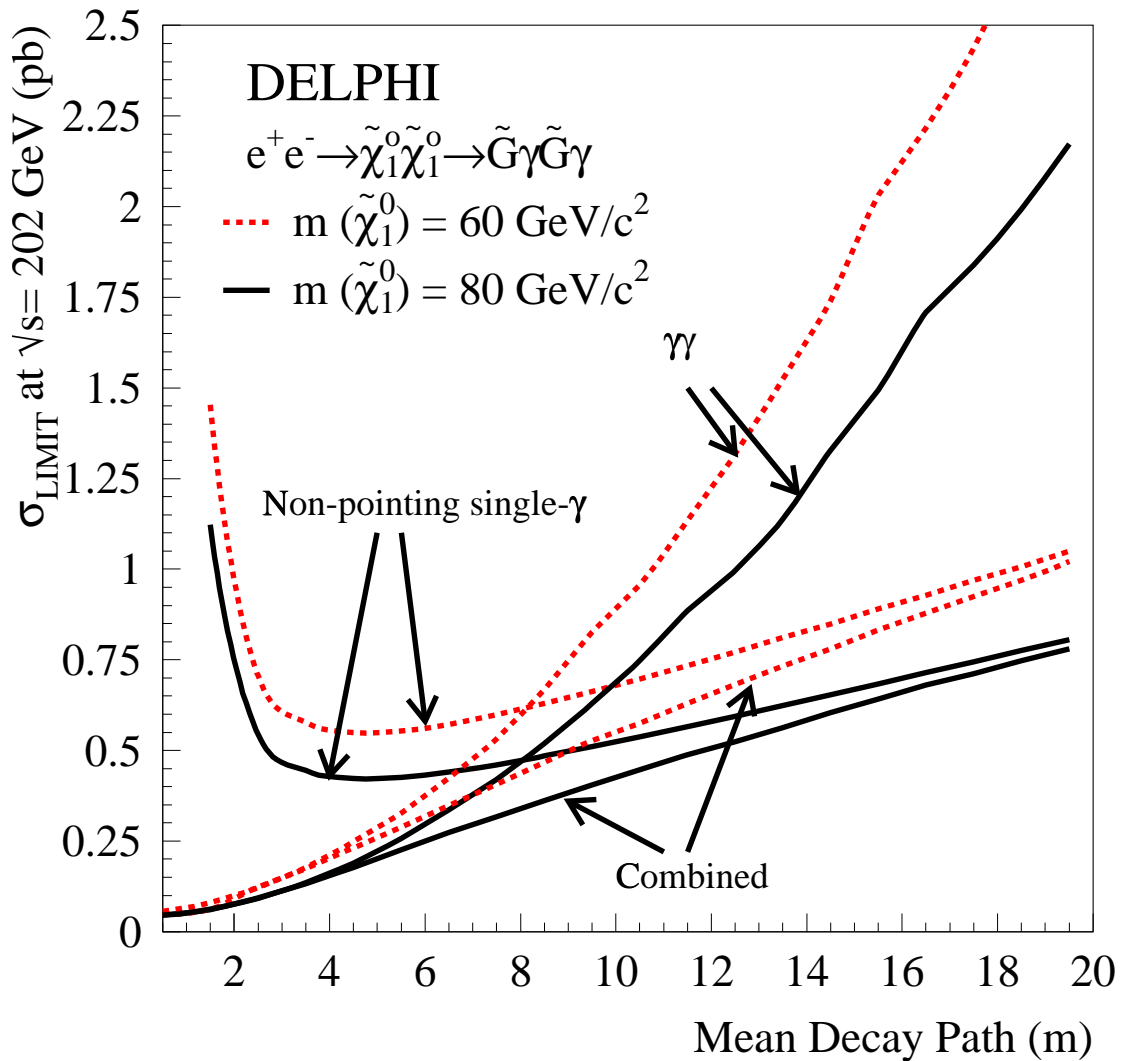


$$\tilde{G} \text{ LSP} + \tilde{\chi}_1^0 \text{ NLSP}$$

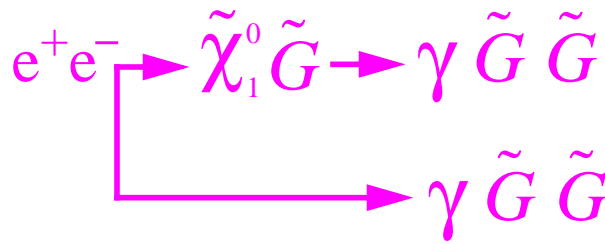
$$e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow \gamma \tilde{G} + \gamma \tilde{G}$$

$L_{\tilde{\chi}} \approx$ Experiment : Single photons which does not point towards the interaction region.

Cross section limit versus $L_{\tilde{\chi}}$:



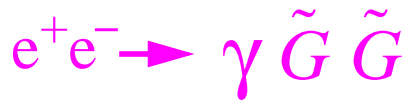
\tilde{G} LSP + $\tilde{\chi}_1^0$ NLSP



The cross section is only sizable for ultra-light gravitinos:

$m_{\tilde{G}} \sim 10^{-4} - 10^{-5} \text{ eV}$ $L_{\tilde{\chi}} \ll \text{Experiment}$

Recoil mass dist. of single photon events:



Gravitino mass limit
using 192-202 GeV
data:

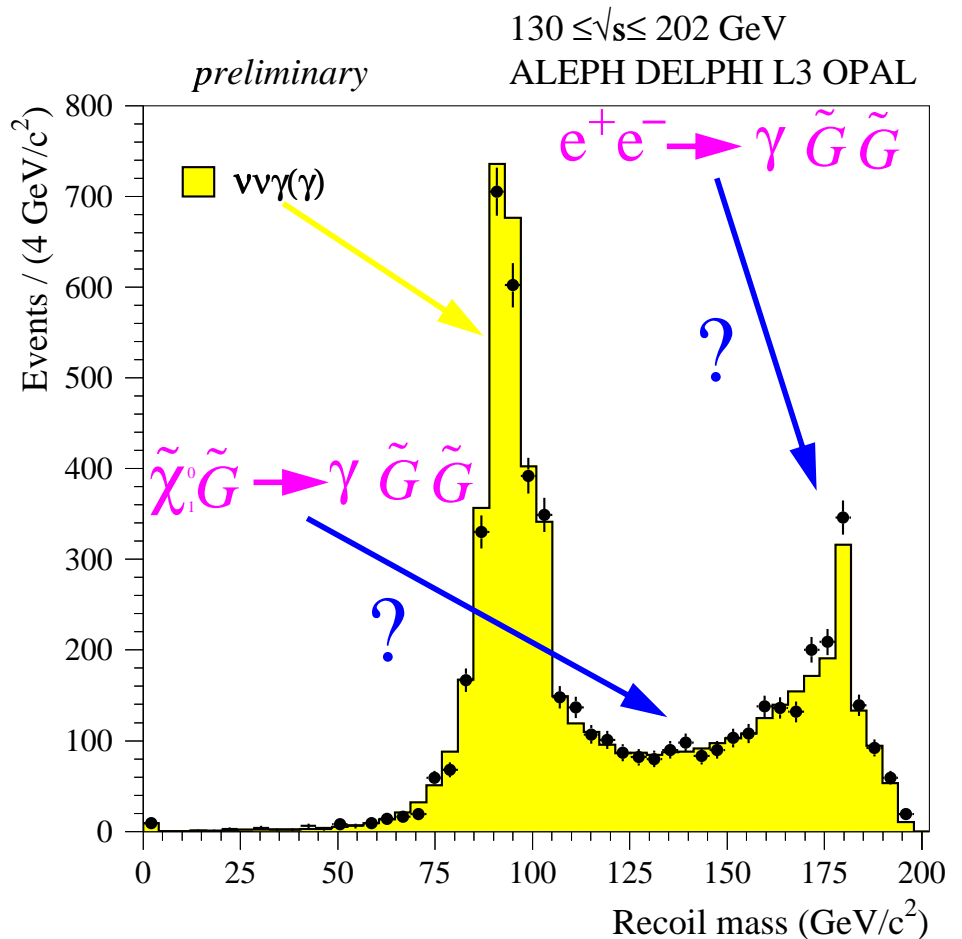
ALEPH

$m_{\tilde{G}} > 1.1 \cdot 10^{-5} \text{ eV}$

DELPHI

$m_{\tilde{G}} > 1.2 \cdot 10^{-5} \text{ eV}$

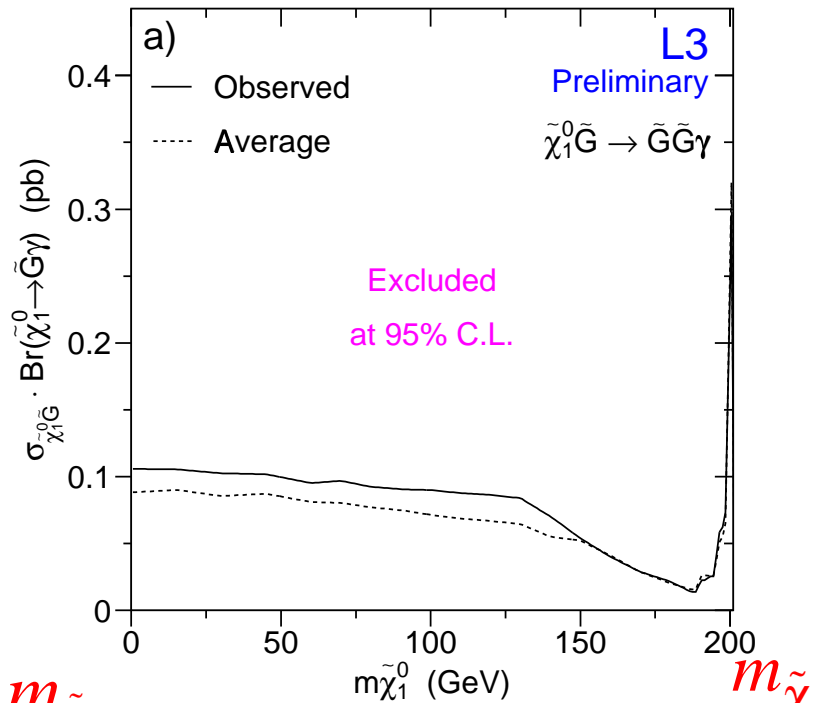
$\sqrt{F} > 225 \text{ GeV}$



\tilde{G} LSP + $\tilde{\chi}_1^0$ NLSP

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

Cross section limit →



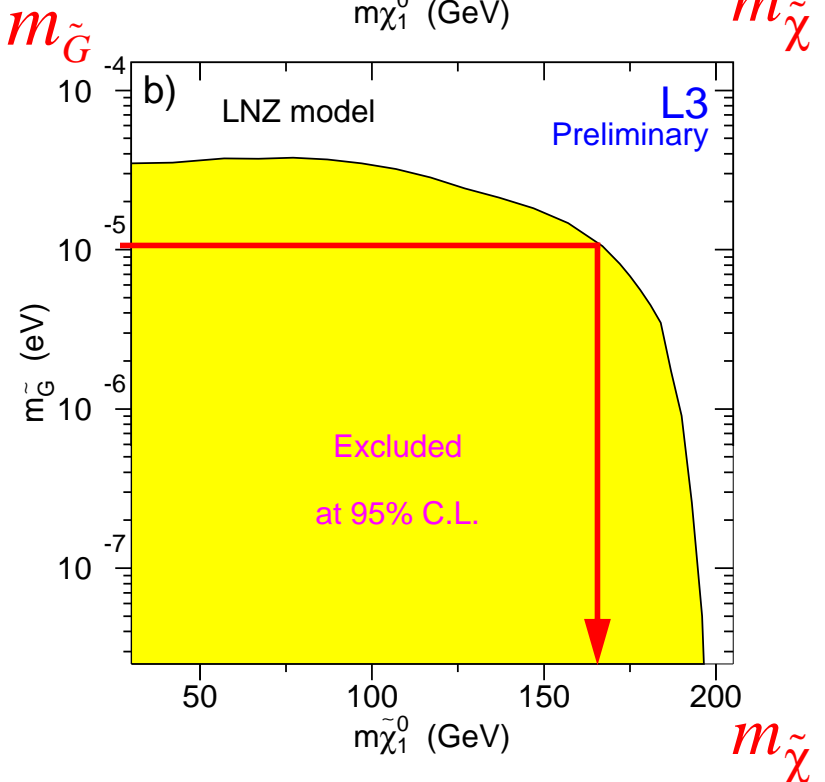
Exclusion plot →

LNZ (no-scale SUGRA)

$$m_{\tilde{G}} > 1.0 \cdot 10^{-5} \text{ eV}$$

for

$$m_{\tilde{\chi}} < 168 \text{ GeV}$$



GMSB interpretation

GMSB: \tilde{G} LSP + $\tilde{\chi}_1^0$ NLSP

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

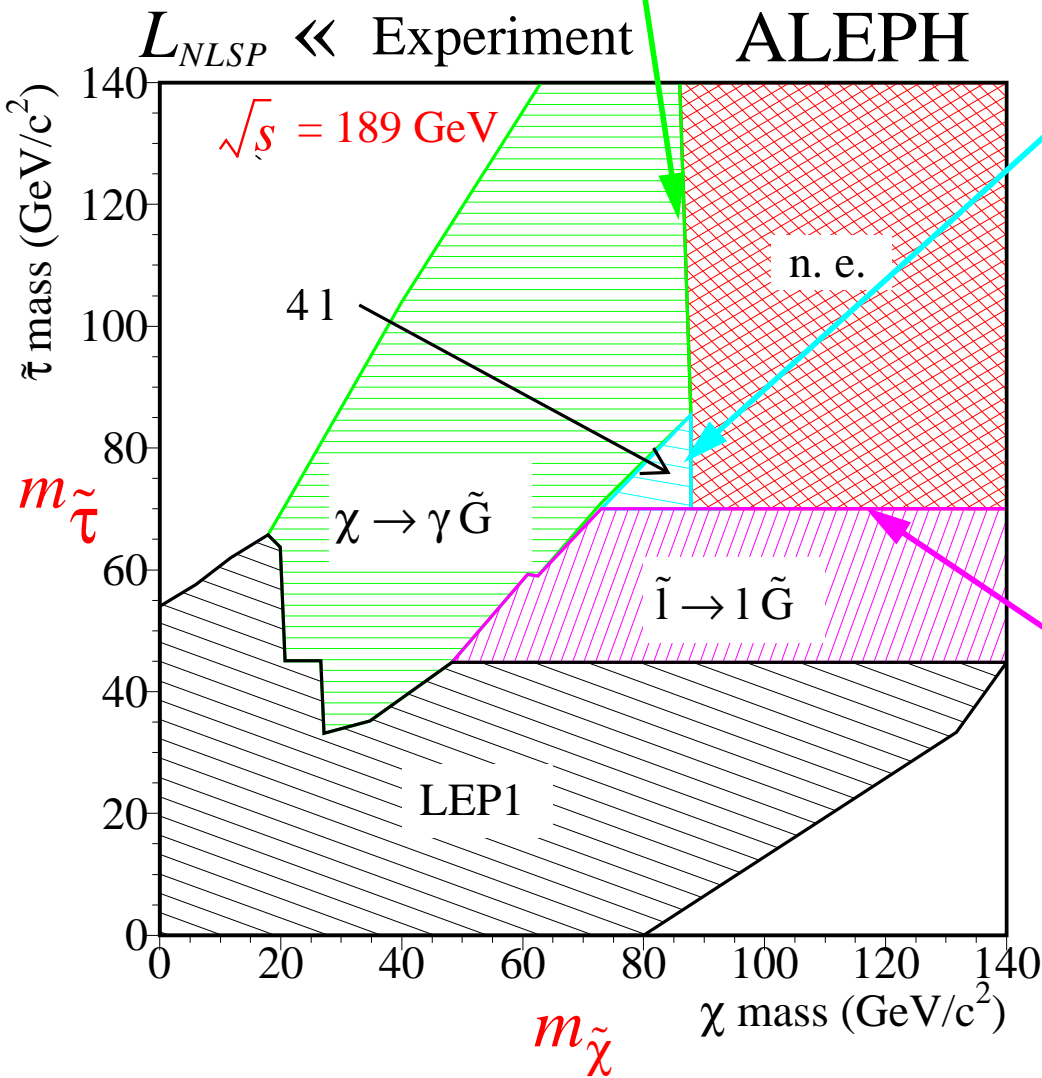
$$2\gamma + \cancel{E}$$

GMSB: \tilde{G} LSP + \tilde{l} NLSP

$$\tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow \tilde{l} \tilde{l} + \tilde{l} \tilde{l}$$

$$\begin{array}{l} \downarrow \\ \tilde{l} \tilde{G} \\ \downarrow \\ \tilde{l} \tilde{G} \end{array}$$

$$4l + \cancel{E}$$



MSUGRA:

$\tilde{\chi}_1^0$ LSP + \tilde{l} NLSP

$$\tilde{l} \tilde{l} \rightarrow l \tilde{\chi}_1^0 + l \tilde{\chi}_1^0$$

$$2l + \cancel{E}$$

Summary

Many LEP SUSY searches with the \tilde{G} as the LSP
has been updated with the data collected at
 $\sqrt{s} = 192\text{-}202$ GeV

No signal has been observed in any of
the topologies studied.



New cross section limits and exclusion plots
have been produced.

The transparencies are available at
<http://hedberg.home.cern.ch/hedberg/osaka.ps>