

Partikeldagarna, April 2002

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DELPHI results on SUpersYmmetry and Extra Dimensions

The single photon analysis

Extra dimensions

- $e^+e^- \rightarrow G + \gamma$

SUSY

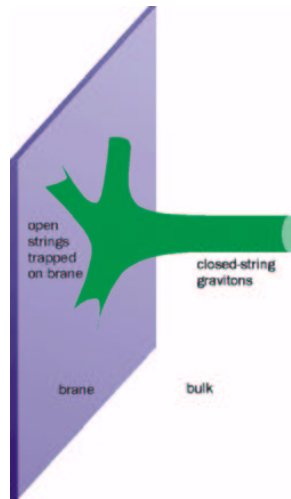
- $e^+e^- \rightarrow \tilde{G}\tilde{G} + \gamma$

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

The chargino analysis

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

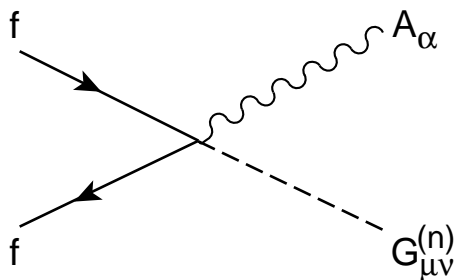
- Gravity alone propagates in $4 + \delta$ dimensions
- The δ compactified dimensions are torus shaped space dimensions



$$M_P^2 = 8\pi R^\delta M_D^{2+\delta}$$

No gravity experiments made below 1 mm distances

$$V(r) = -\frac{1}{8\pi R^\delta M_D^{2+\delta}} \frac{m_1 m_2}{r} = -G_N \frac{m_1 m_2}{r}, \quad r \gg R$$



$$-\frac{i}{2\bar{M}_P} eQ (X_{\mu\nu\alpha} + X_{\nu\mu\alpha})$$

$$\sigma(e^+e^- \rightarrow G + \gamma) \propto \frac{1}{M_P^2}, \quad M_P \sim 10^{19} \text{ GeV}$$

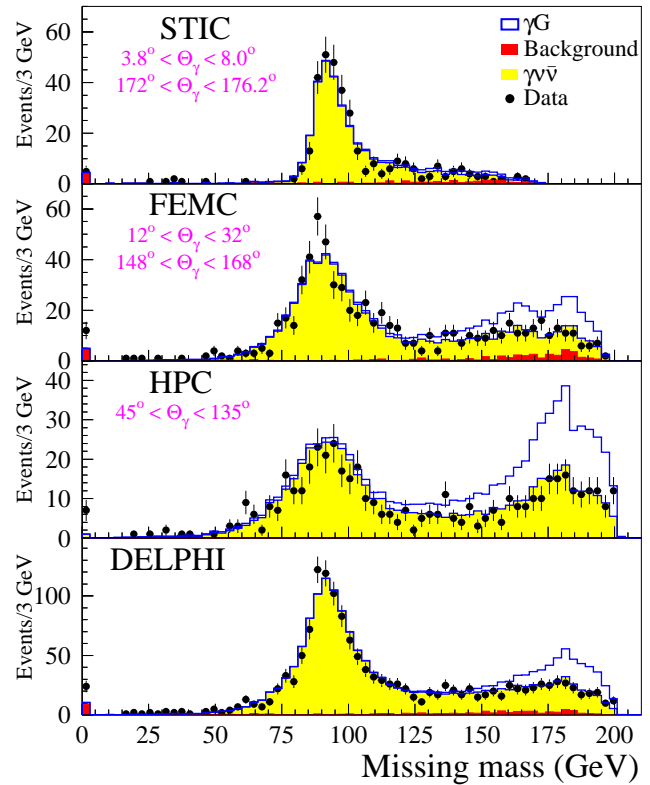
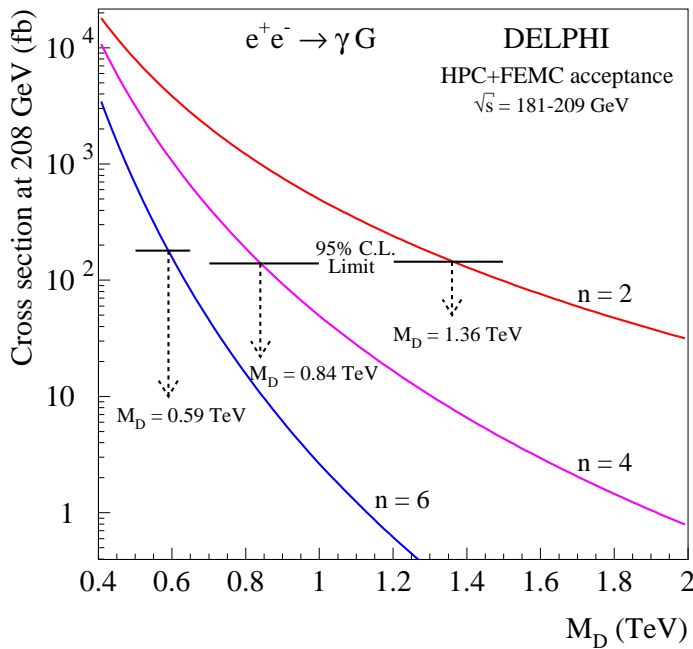
Large phase space from the extra dimensions

$$\sigma(e^+e^- \rightarrow G + \gamma) \propto \frac{\sqrt{s}^\delta}{M_D^{2+\delta}}, \quad \mathcal{O}(M_D) = \text{TeV}$$

$$e^+e^- \rightarrow G + \gamma$$

$$G_N^{-1} = 8\pi R^\delta M_D^{\delta+2} \quad (\leftarrow \text{Giudice et al.})$$

$$\sigma(e^+e^- \rightarrow G + \gamma) = f(M_D, \delta, \sqrt{s})$$



Dimensions	$M_D > (\text{exp})$	$M_D >$	Radius <
2	1.32	1.36 TeV	0.26 mm
3	1.01	1.05 TeV	3.3 nm
4	0.82	0.84 TeV	13 pm
5	0.69	0.69 TeV	0.48 pm
6	0.59	0.59 TeV	54 fm

Sparticles

Names		spin 0	spin 1/2
squarks, quarks (×3 families)	Q	$(\tilde{u}_L \ \tilde{d}_L)$	$(u_L \ d_L)$
	\bar{u}	\tilde{u}_R^*	u_R^\dagger
	\bar{d}	\tilde{d}_R^*	d_R^\dagger
sleptons, leptons (×3 families)	L	$(\tilde{\nu} \ \tilde{e}_L)$	$(\nu \ e_L)$
	\bar{e}	\tilde{e}_R^*	e_R^\dagger
Higgs, higgsinos	H_u	$(H_u^+ \ H_u^0)$	$(\tilde{H}_u^+ \ \tilde{H}_u^0)$
	H_d	$(H_d^0 \ H_d^-)$	$(\tilde{H}_d^0 \ \tilde{H}_d^-)$

Names	spin 1/2	spin 1
gluino, gluon	\tilde{g}	g
winos, W bosons	$\tilde{W}^\pm \ \tilde{W}^0$	$W^\pm \ W^0$
bino, B boson	\tilde{B}^0	B^0
	spin 3/2	spin 2
gravitino, graviton	\tilde{G}	G

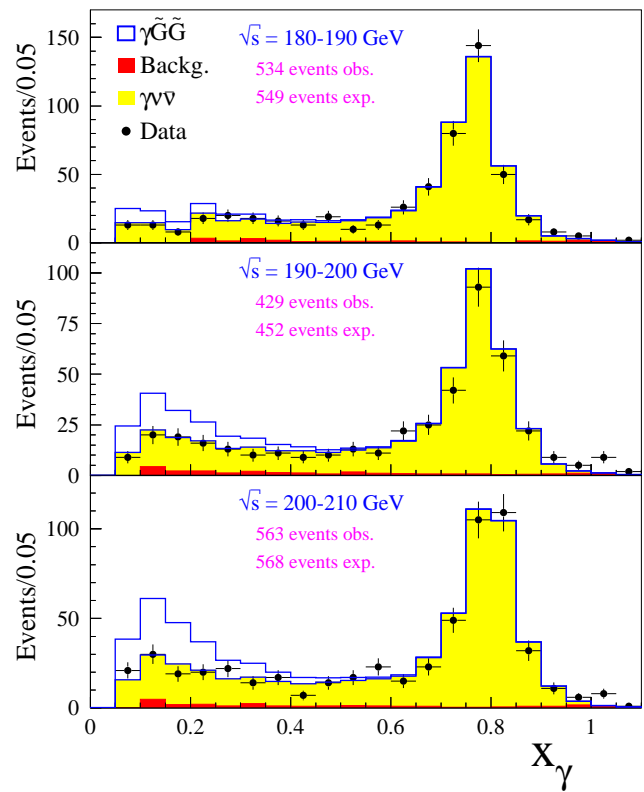
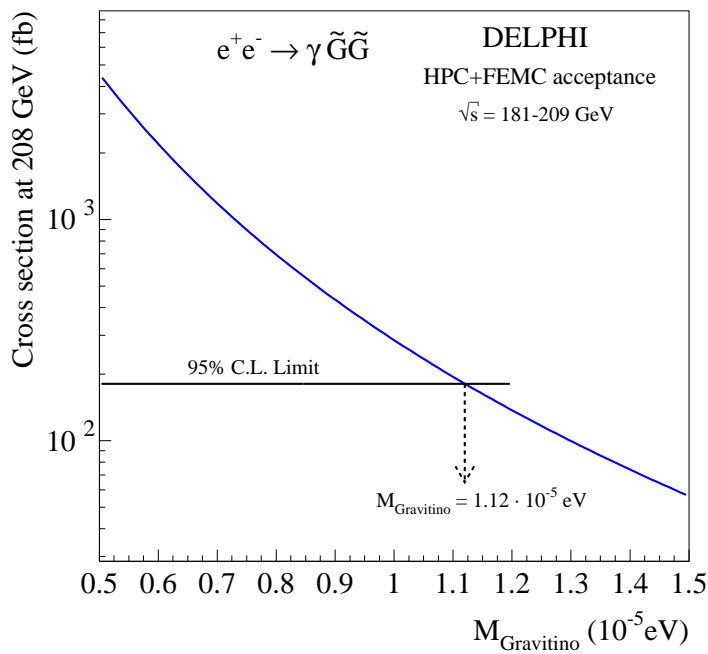
$$[\tilde{W}^\pm, \tilde{H}^\pm] \Rightarrow \tilde{\chi}_i^\pm \quad i=1,2$$

$$[\tilde{B}^0, \tilde{W}^0, \tilde{H}_{1,2}^0] \Rightarrow \tilde{\chi}_i^0 \quad i=1,..,4$$

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

- Gravitino LSP
- All other SUSY-partners to heavy

$$\sigma(e^+e^- \rightarrow \tilde{G}\tilde{G} + \gamma) = f(m_{\tilde{G}}, \sqrt{s})$$



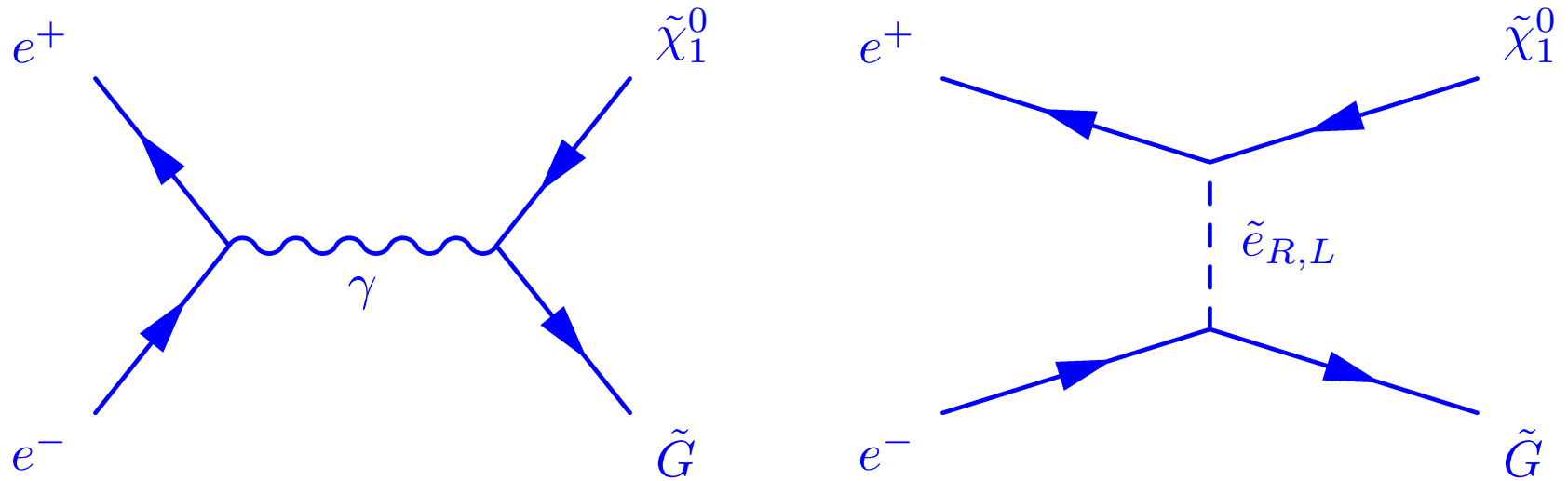
Expected limit: $m_{\tilde{G}} > 1.14 \times 10^{-5} \text{ eV}$

Obtained limit: $m_{\tilde{G}} > 1.12 \times 10^{-5} \text{ eV}$



$\sqrt{F} > 217 \text{ GeV}$

Gravitino-Neutralino production



$$\sigma(e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{G}) = f(m_{\tilde{G}}, m_{\tilde{\chi}_1^0}, m_{\tilde{e}_{R,L}}, N_{11}, N_{12}, \sqrt{s})$$

Scenario:

General

$\tilde{\chi}_1^0 \simeq \tilde{B}$
 GMSB: $|\mu| \gg M_2$
 Independent of $\tan(\beta)$

LNZ

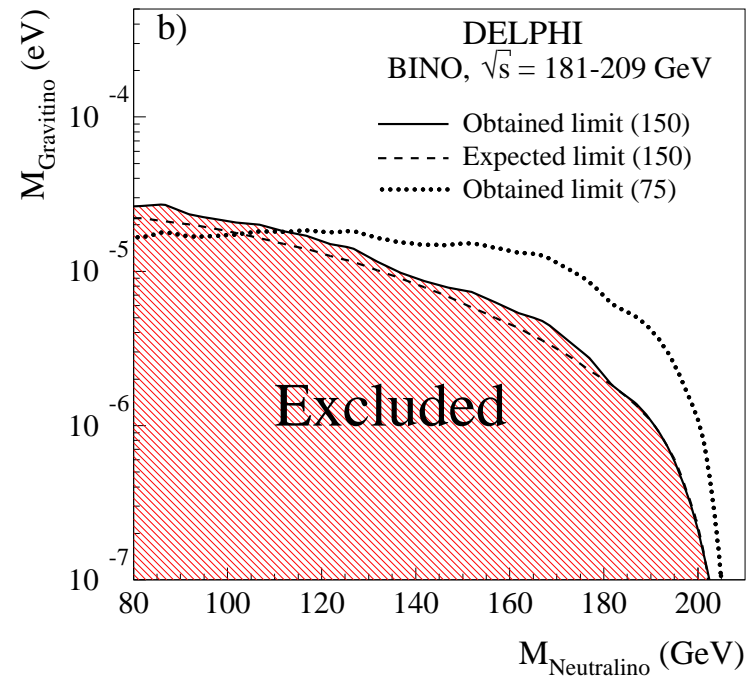
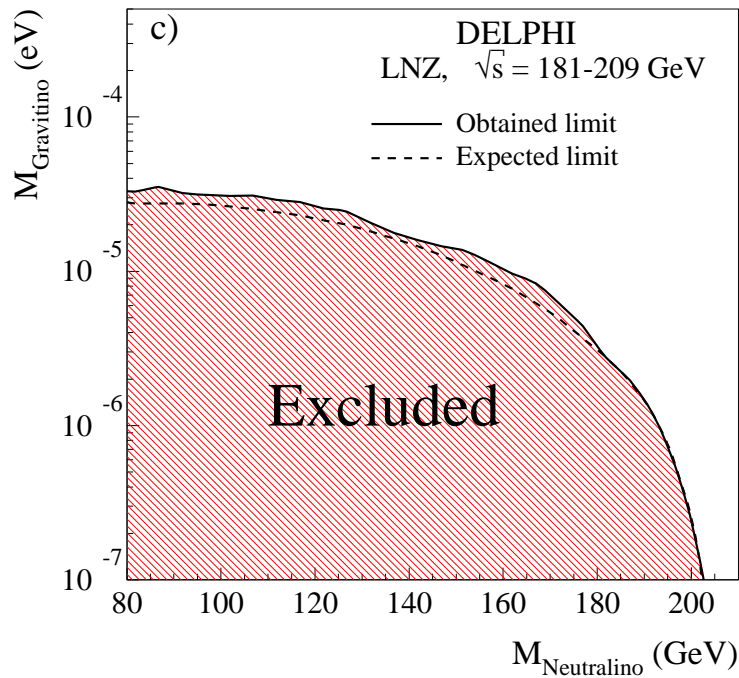
$m_{\tilde{G}}$ & $m_{\tilde{\chi}_1^0}$
 are the only free parameters

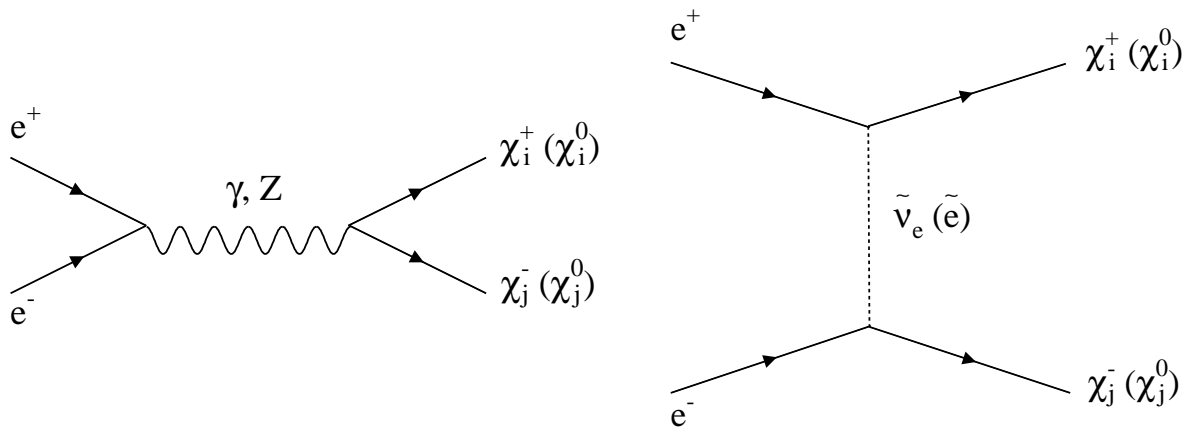
$m_{\tilde{\chi}_1^0} - m_{\tilde{G}}$ exclusion limits

Complement to $m_{\tilde{\chi}_1^0}$ excluded from

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

since there the kinematic limit implies $m_{\tilde{\chi}_1^0} < \frac{\sqrt{s}}{2}$

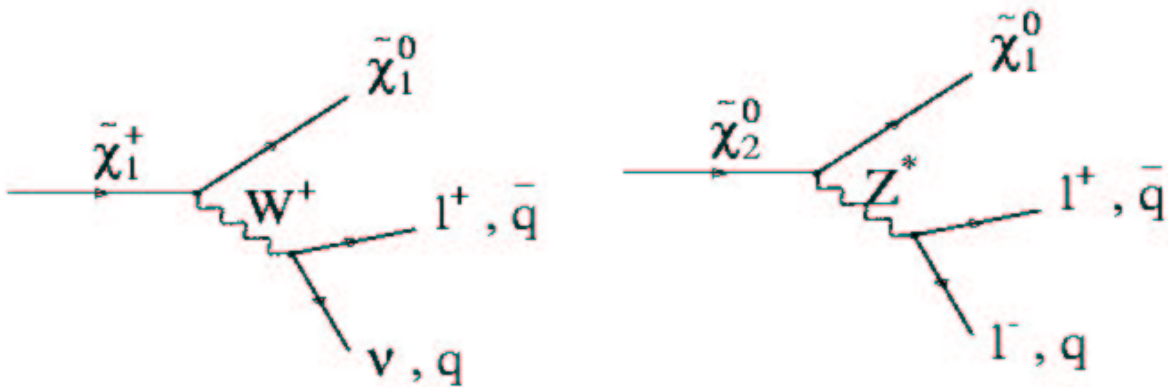




The signal shape depends on:

$$M_{\tilde{\chi}^\pm} - M_{\tilde{\chi}_1^0} = \Delta M$$

$$(m_{\tilde{l}, \tilde{q}, H^\pm, 0, A} > M_{\tilde{\chi}_1^\pm})$$



If $\tilde{\chi}_2^0$ can be produced, cascade decay are possible:

$$\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_2^0 f_1 \bar{f}'_1 \rightarrow \tilde{\chi}_1^0 f_1 \bar{f}'_1 + f_2 \bar{f}_2$$

$$\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_2^0 f_1 \bar{f}'_1 \rightarrow \tilde{\chi}_1^0 f_1 \bar{f}'_1 + \gamma$$

○ Radiative topology:

At least 1 isolated photon

$(E_\gamma > 5 \text{ GeV} ; 15^\circ < \theta_\gamma < 165^\circ ; \alpha_\gamma^{iso} > 15^\circ)$

○ ll topology:

No isolated photons

Number of tracks ≤ 5

○ jl topology:

No isolated photons

Number of tracks > 5

At least 1 isolated lepton ($P_\ell > 3 \text{ GeV}/c ; \alpha_\ell^{iso} > 20^\circ$)

○ jj topology:

No isolated photons

Number of tracks > 5

No isolated leptons

ΔM REGIONS

$3 \leq$	ΔM	< 5	GeV/c^2
$5 \leq$	ΔM	< 10	GeV/c^2
$10 \leq$	ΔM	< 25	GeV/c^2
$25 \leq$	ΔM	< 35	GeV/c^2
$35 \leq$	ΔM	< 50	GeV/c^2
$50 \leq$	ΔM		GeV/c^2

$\tilde{\chi}_1^\pm$ mass limits

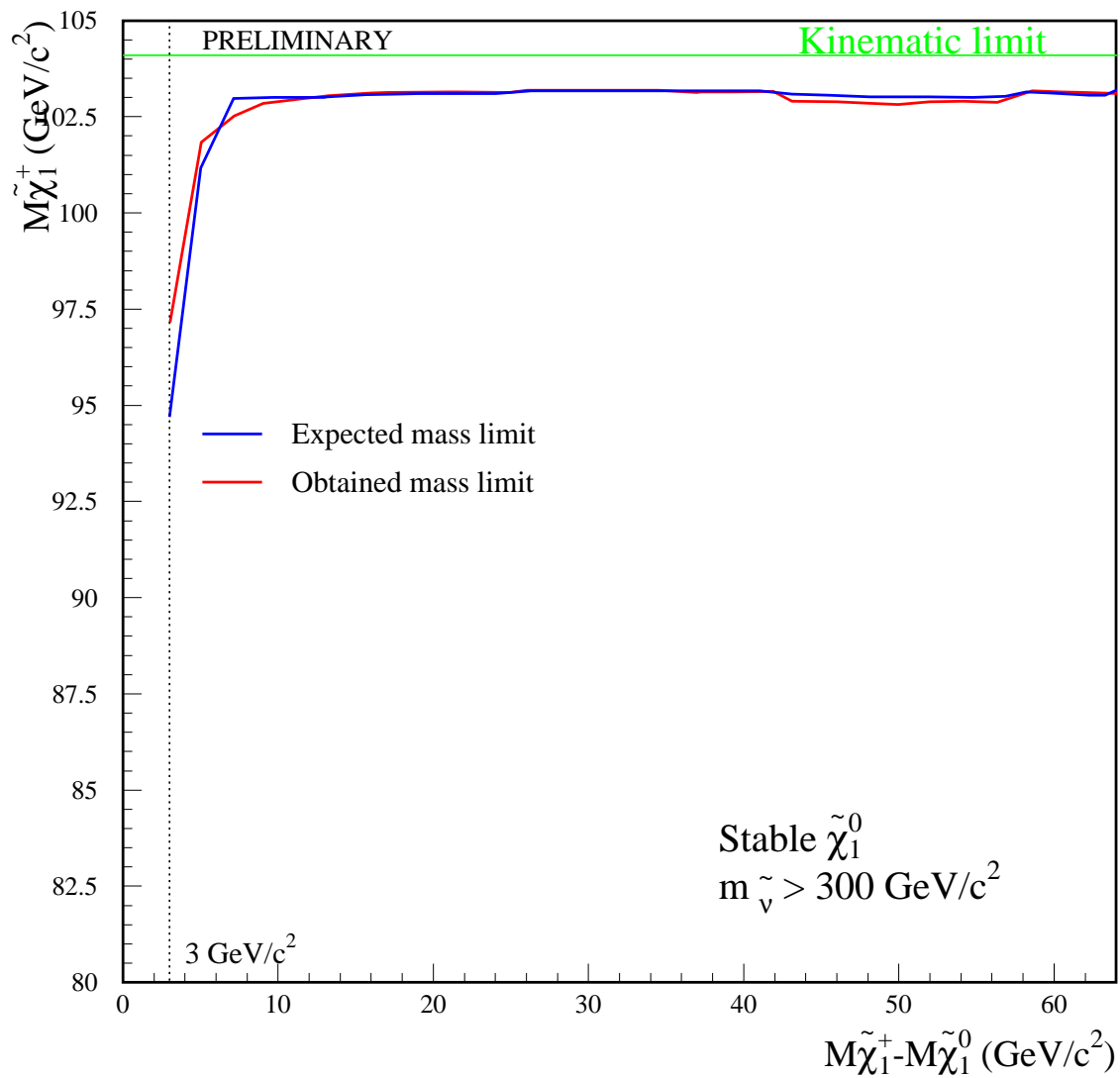
No Excess



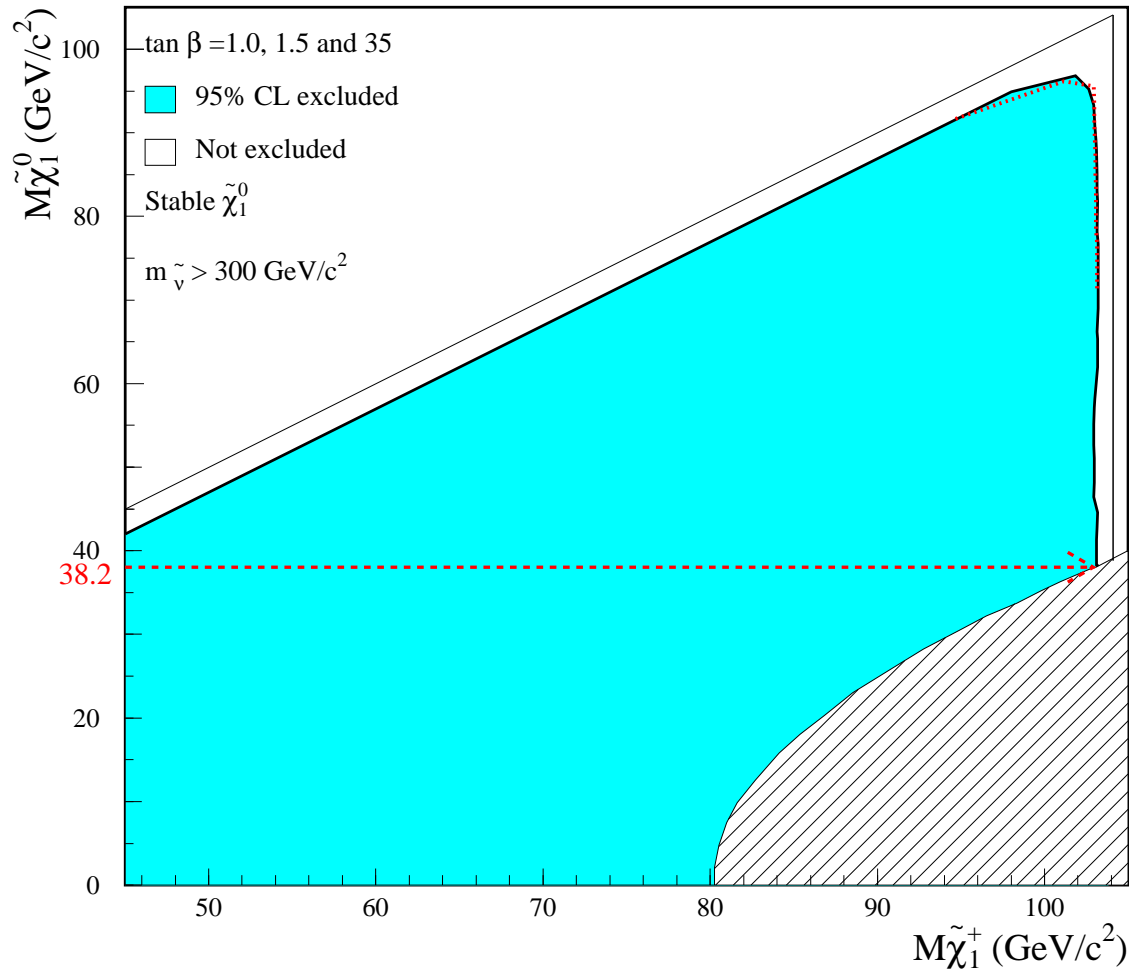
Limits were set at 95 C.L.



DELPHI $\tilde{\chi}_1^\pm$ mass limits



DELPHI $\tilde{\chi}_1^\pm$ mass limits



Implied limit on lightest neutralino mass

$$M_{\tilde{\chi}_1^0} = 38.2 \text{ GeV}/c^2 \text{ for } m_{\tilde{\nu}} > 300 \text{ GeV}/c^2$$

The single photon analysis

Extra dimensions

Dimensions	$M_D > (\text{exp})$	$M_D >$	Radius <
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SUSY

$$\Rightarrow m_{\tilde{G}} > 1 \times 10^{-5} \text{ eV}$$

($\tilde{\chi}_1^0 < 140 \text{ GeV}$, if $\tilde{\chi}_1^0$ is NLSP)

The chargino analysis

$$\Delta M > 10 \text{ GeV}/c^2 \Rightarrow \tilde{\chi}_1^\pm > 102.8 \text{ GeV}$$

$$\Delta M = 5 \text{ GeV}/c^2 \Rightarrow \tilde{\chi}_1^\pm > 101.8 \text{ GeV}$$

$$\Delta M = 3 \text{ GeV}/c^2 \Rightarrow \tilde{\chi}_1^\pm > 97.2 \text{ GeV}$$