Almost degenerate chargino-neutralino at LEP

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L3 collaboration

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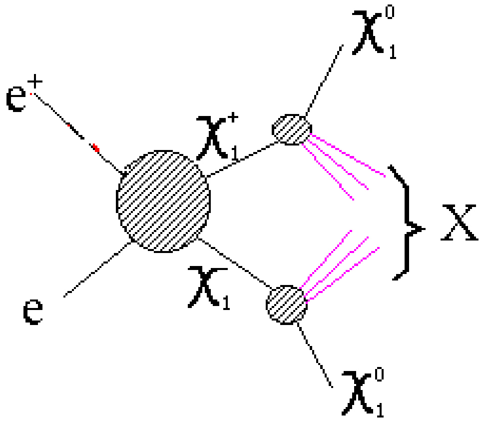
SUSY2000, CERN, June 26-July 1 2000

Standard $\tilde{\chi}_1^{\pm}$ search



R-parity conserved $\Longrightarrow$ $\not{E}$

Standard search done by the 4 LEP experiments

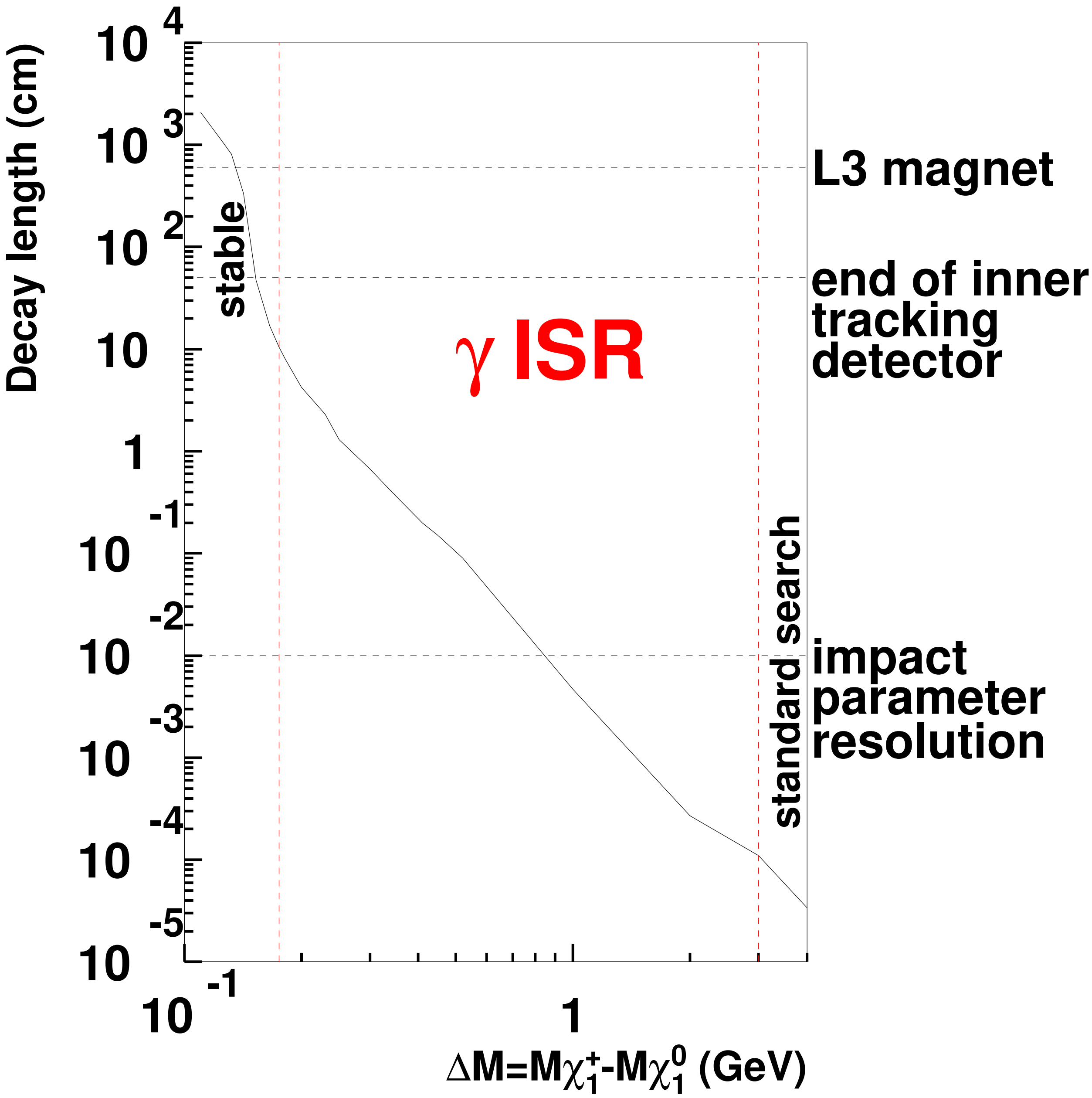
Efficiency $\sim$ 0 for $\mathbf{\Delta M} = M_{\tilde{\chi}_1^{\pm}} - M_{\tilde{\chi}_1^0} \lesssim \mathbf{3\ GeV}$
(background rejection and trigger efficiency)

Non gaugino mass universality at GUT scale can lead in natural way to small $\mathbf{\Delta M}$

$\longrightarrow$ need new approach

Phenomenology is different for heavy and light squarks and sleptons
Unless mentioned, all squarks and sleptons are assumed to be heavy.

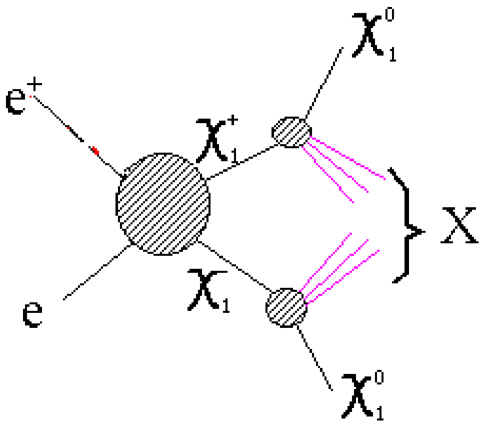
Decay length



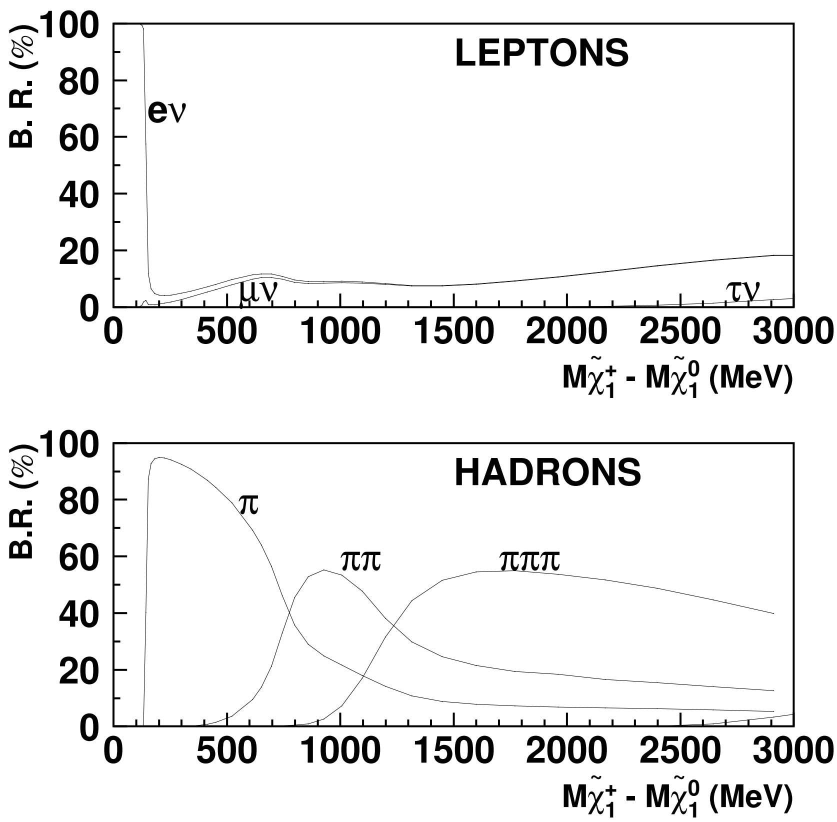
Long lived $\tilde{\chi}_1^{\pm}$: search for heavy charged stable particles
Ask for 2 highly ionizing tracks
Done by the 4 LEP experiments
DELPHI uses also kinks analyses (search for particles decaying in the tracking chamber)

Between stable and standard search : search with an ISR photon
Done by DELPHI and L3

Signal features

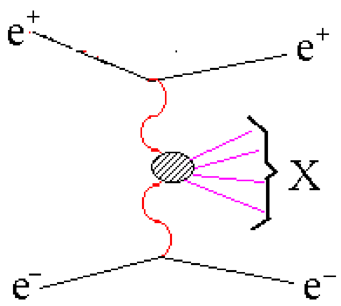


No displaced vertex (short life time)
Small visible energy (small $\mathbf{\Delta M}$)
Many pions



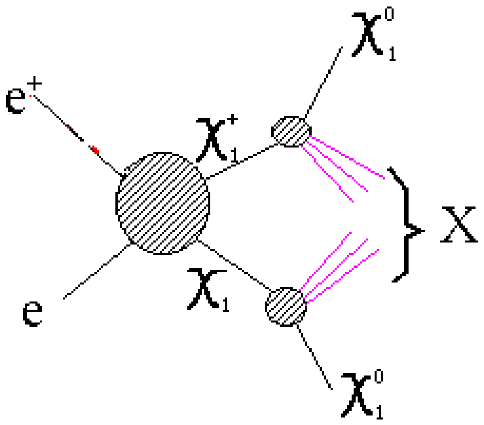
Gunion et al., Phys. Rev. Lett 82 (1999) 3192 - hep-ph/9607421

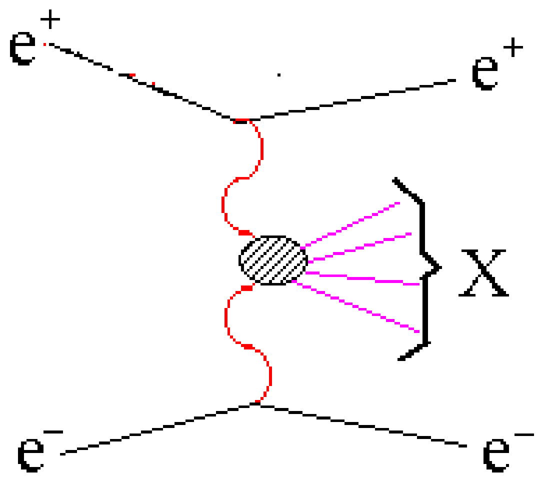
very similar to



Two-photon rejection

vs





$\boldsymbol{\sigma \sim 1 - 10\text{pb}}$ $\boldsymbol{\sigma \sim 10^6\ \text{pb}}$

A photon with a transverse energy high enough can deflect an electron in the detector thus separating signal and background

$$\boldsymbol{E_{T\gamma} \geq 2E_{\mathrm{beam}} \frac{\sin\theta_d}{1+\sin\theta_d}}$$

with

$\boldsymbol{\theta_d \sim 2^\circ}$ minimum detection angle for electrons

$+$: Easier to trigger with a high energy photon

$-$: No Monte Carlo describes completely two-photon interactions with ISR

Preselection

1 photon

$\boldsymbol{E_T}$ cut,
isolated in a 15° (L3) or 30° (DELPHI) cone
Recoil mass$> \mathbf{2M}_{\tilde{\chi}_1^\pm}$

$\tilde{\chi}_1^\pm$ decay products

$$\begin{array}{lll} \boldsymbol{E_{calorimeters} - E_\gamma} & < 12\ \text{GeV} & \text{L3} \\ & < \mathbf{0.06}\sqrt{\boldsymbol{s}} & \text{DELPHI} \end{array}$$

at least 2 tracks
Not too many tracks or energy deposits in calorimeters

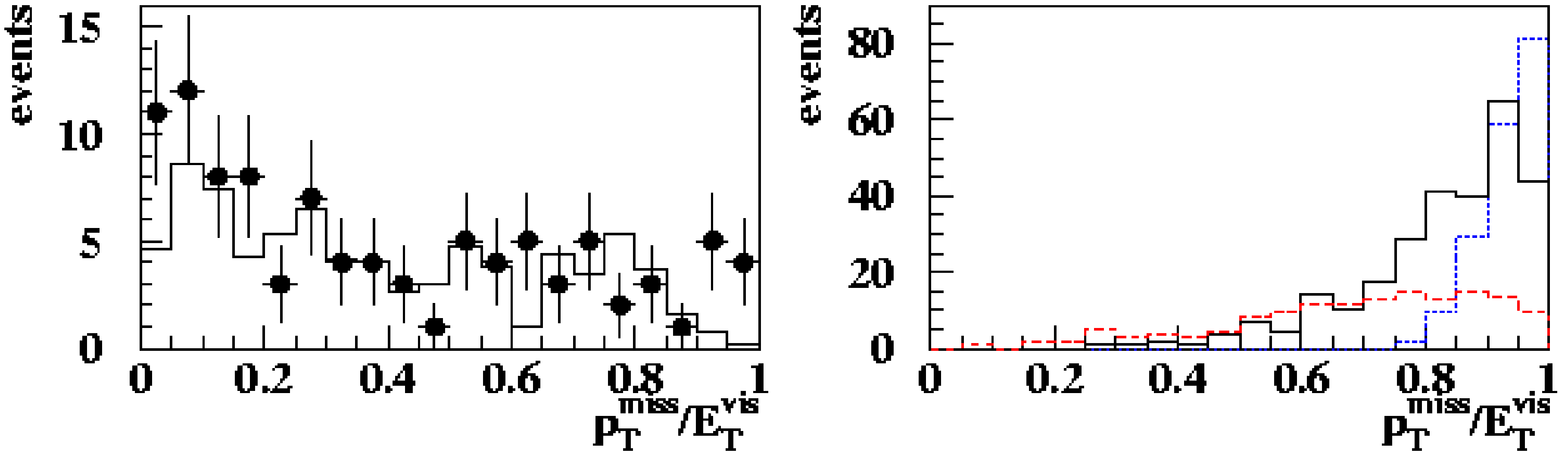
Two-photon rejection

No energy deposit at small angle

$$\text{Specific cut} \quad \begin{array}{lll} \frac{\boldsymbol{E_{Tvis}}}{\boldsymbol{E_{vis}}} > \mathbf{0.1} & \text{L3} \\ \frac{\boldsymbol{P_{Tmis}}}{\boldsymbol{E_{Tvis}}} > \mathbf{0.4} & \text{DELPHI} \end{array}$$

$\frac{P_{Tmis}}{E_{Tvis}}$

DELPHI E_{cms}=189 GeV



Selections

3 selections

low ΔM	very low ΔM	ultra low ΔM
$\Delta M \sim 3$ GeV	$\Delta M \sim 1$ GeV	$\Delta M \sim 300$ MeV

When ΔM $\searrow$:

Event Multiplicity $\searrow$
$E_{calorimeters} - E_{\gamma} \searrow$
Cut on $\frac{E_{Tvis}}{E_{vis}}$ or $\frac{P_{Tmis}}{E_{Tvis}} \nearrow$

low and very low ΔM:

Low energy tracks coming from the interaction point

ultra low ΔM:

Tracks with high impact parameter are allowed.
For L3 also high energy tracks are allowed (kinks)

L3 preliminary results

1998-1999				
selection	low ΔM $\Delta M \sim 3$GeV	very low ΔM $\Delta M \sim 1$GeV	ultra low ΔM $\Delta M \sim 300$MeV	OR
189 GeV(176 pb^{-1})	6/2.3	1/1.1	1/0.9	8/3.1
192-202 GeV(232 pb^{-1})	8/2.9 (7.9)	4/1.5 (1.3)	2/1.4 (1.3)	9/3.8 (10.6)
All (408 pb^{-1})	14/5.2	5/2.6	3/2.3	17/6.8

No two-photon background

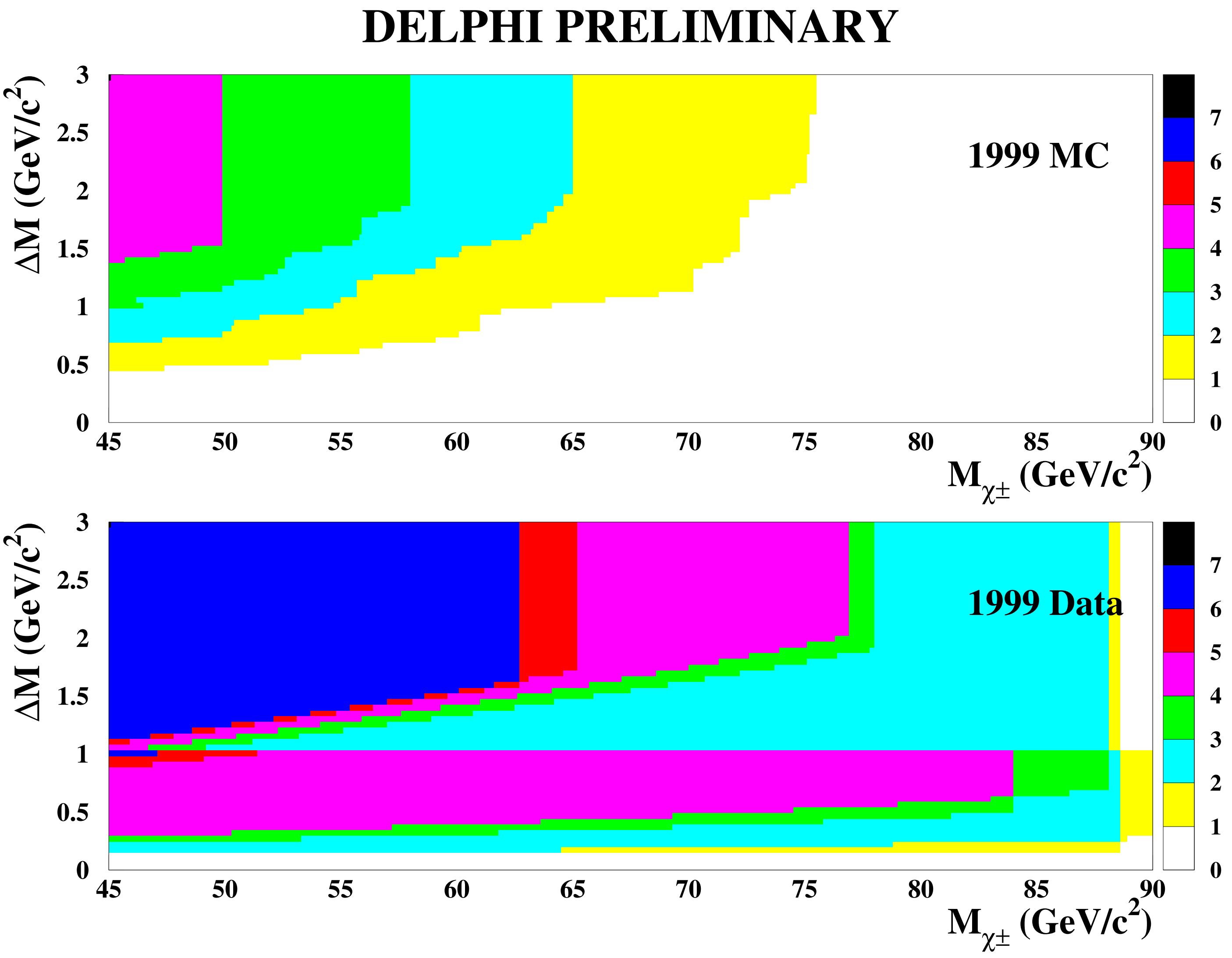
2000				
selection	low ΔM	very low ΔM	ultra low ΔM	OR
200-209 GeV(49 pb^{-1})	1	0	2	3
1998+1999 scaled	1.7	0.6	0.4	2.0

DELPHI preliminary results

DELPHI	
selection	OR
130-183 GeV($81.3\ pb^{-1}$)	5/2.8
189 GeV($152.9\ pb^{-1}$)	8/5.5
All ($234.2\ pb^{-1}$)	13/8.3

No complete phase space for two-photon background and some without ISR

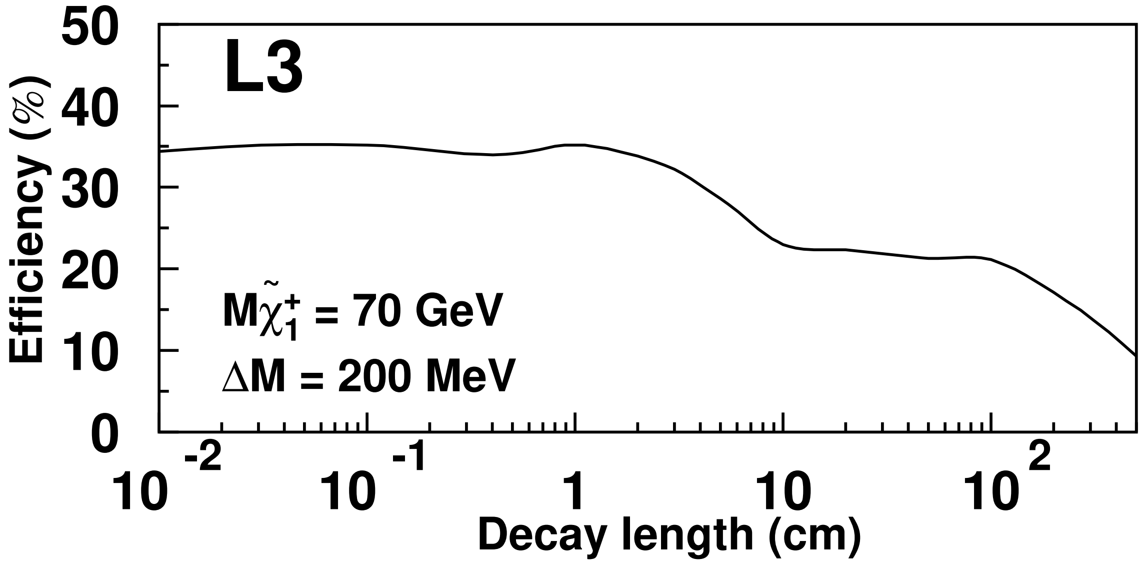
192-202 GeV



Selection efficiency

L3-189 GeV in Phys. Let. B 482 (2000) 31-42

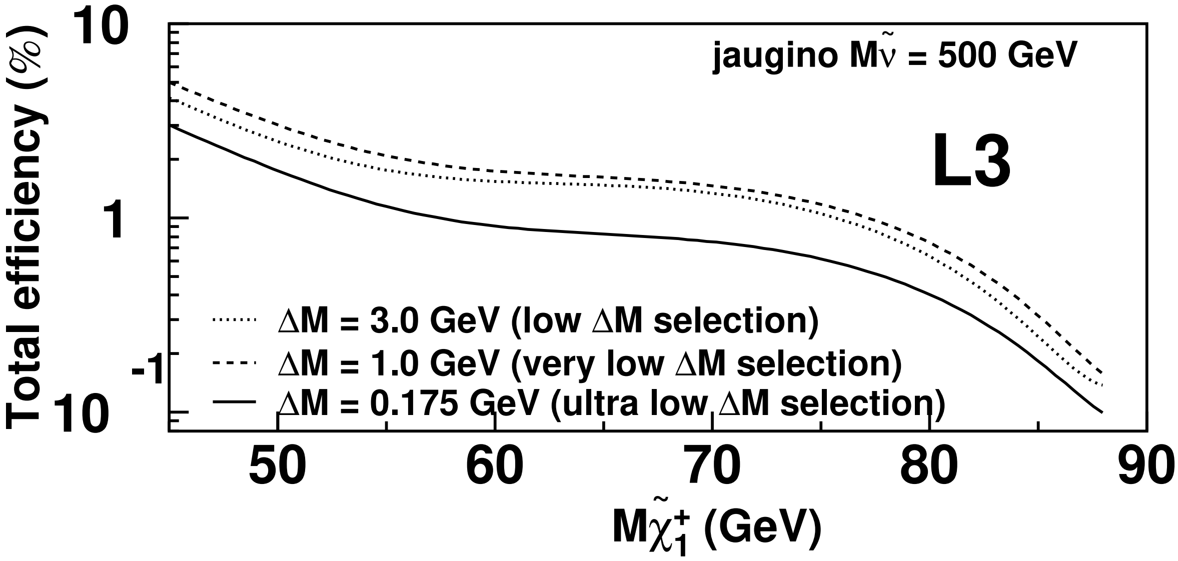
Efficiency for events with $E_\gamma > 4$ GeV and $\Theta_\gamma > 10°$



Global efficiency on $e^+e^- \to \chi_1^+\chi_1^-$ including ISR γ

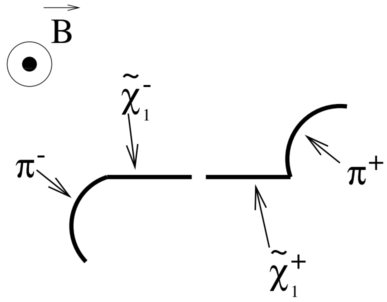
to compare with other analyses

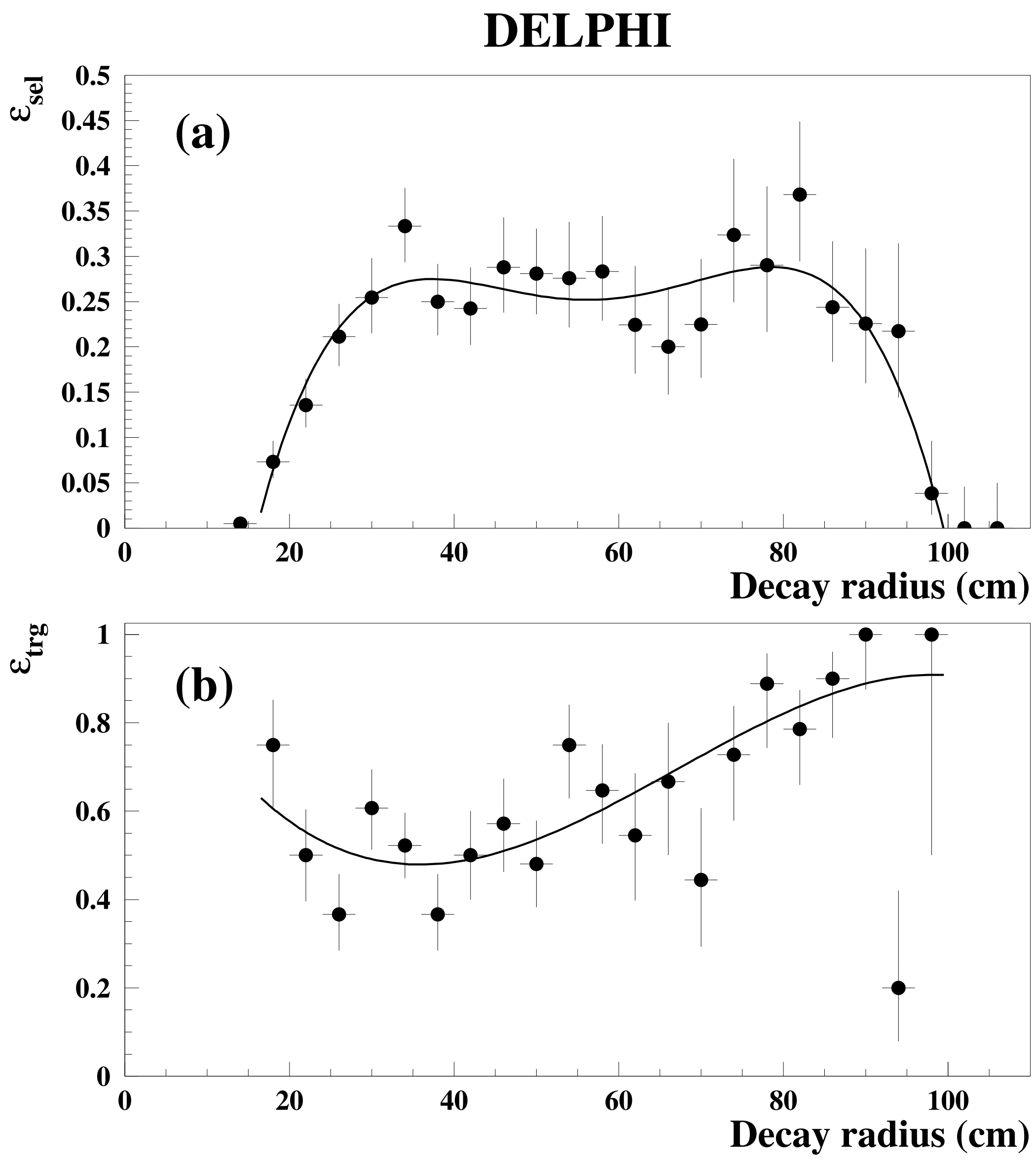
$\Longrightarrow$ efficiency ~ 1 %



Dominated by ISR spectrum

Kinks

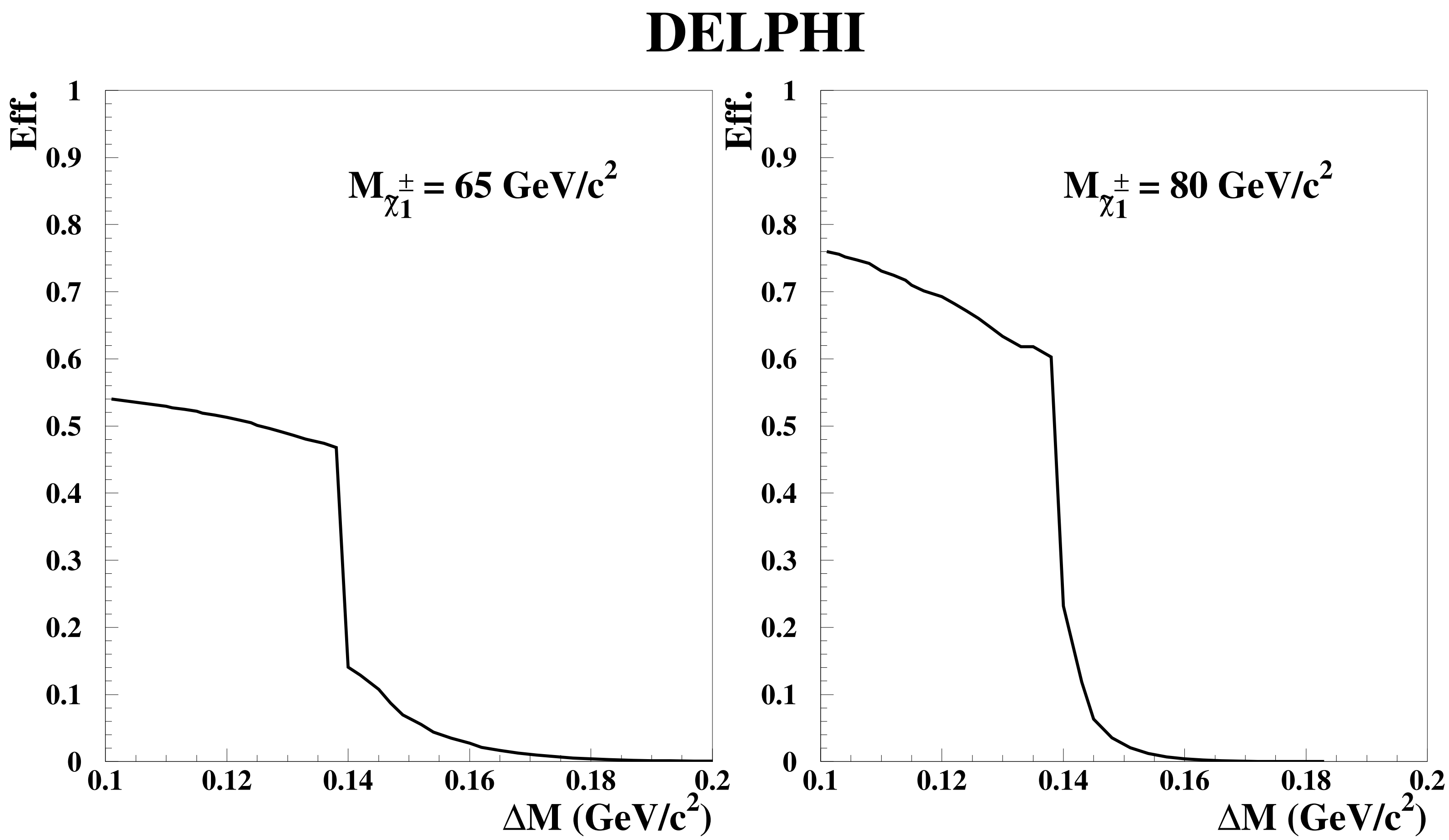




183 GeV in Eur. Phys. J., C 11 (1999) 1-17

Efficiency

183 GeV - gaugino-like $\tilde{\chi}_1^\pm$

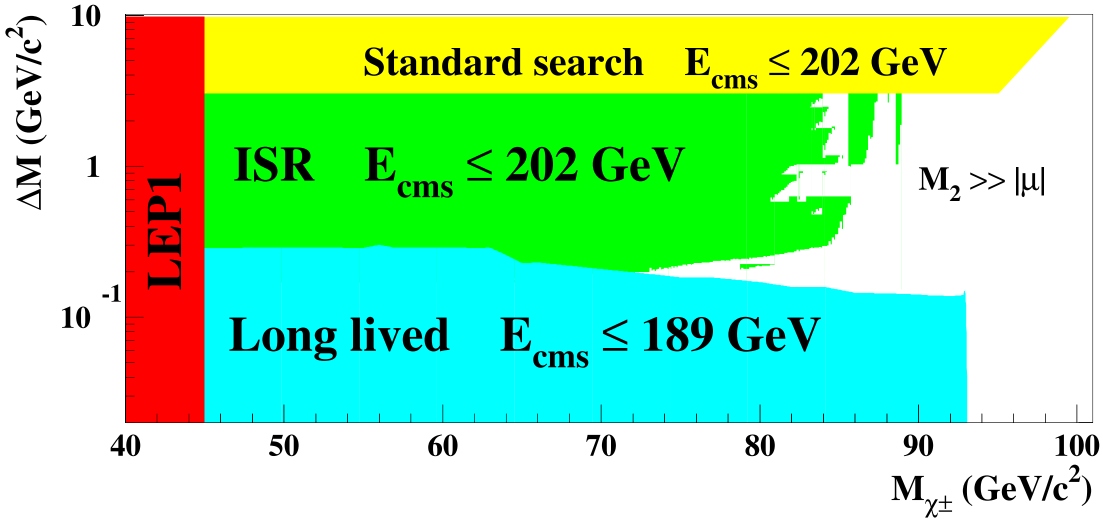


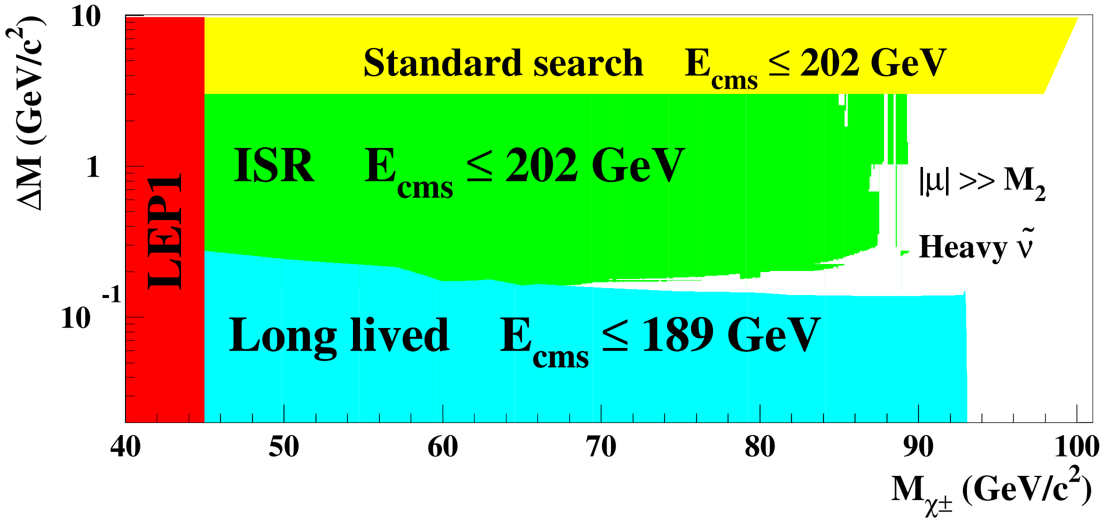
Eur. Phys. J., C 11 (1999) 1-17

Mass exclusion DELPHI

$$\sqrt{s} = 130 - 202 \text{ GeV}$$

DELPHI PRELIMINARY





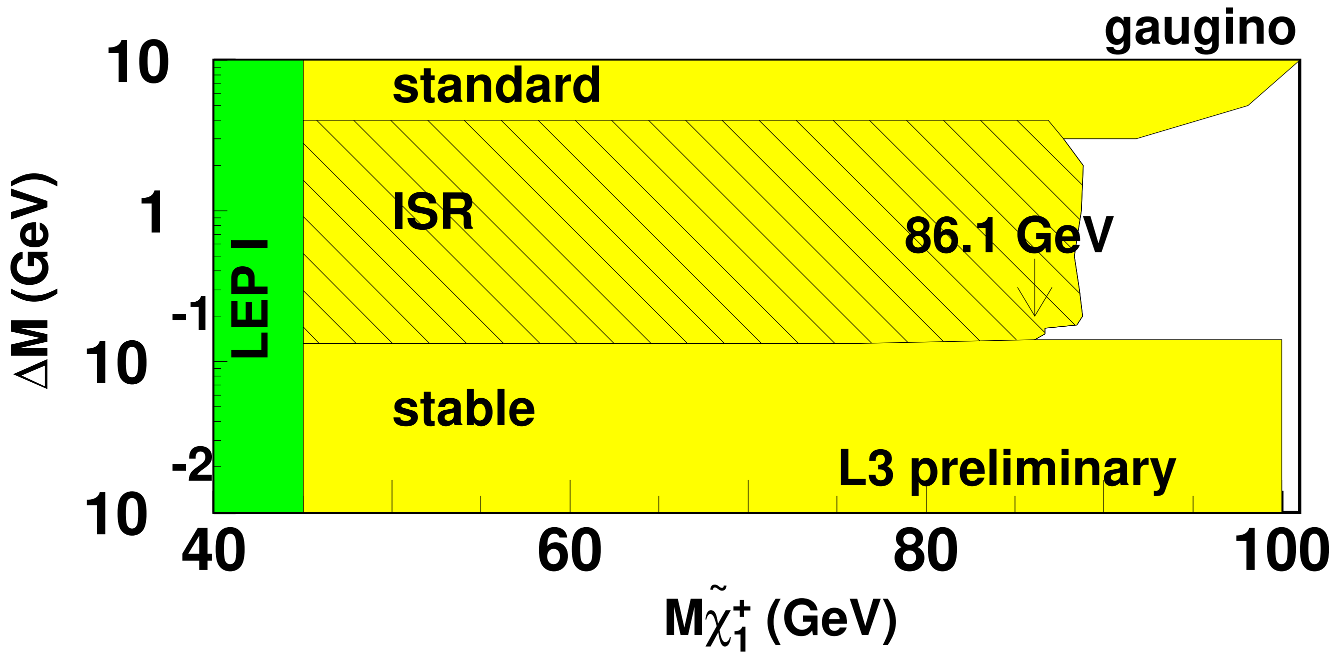
ISR and long lived analyses combined

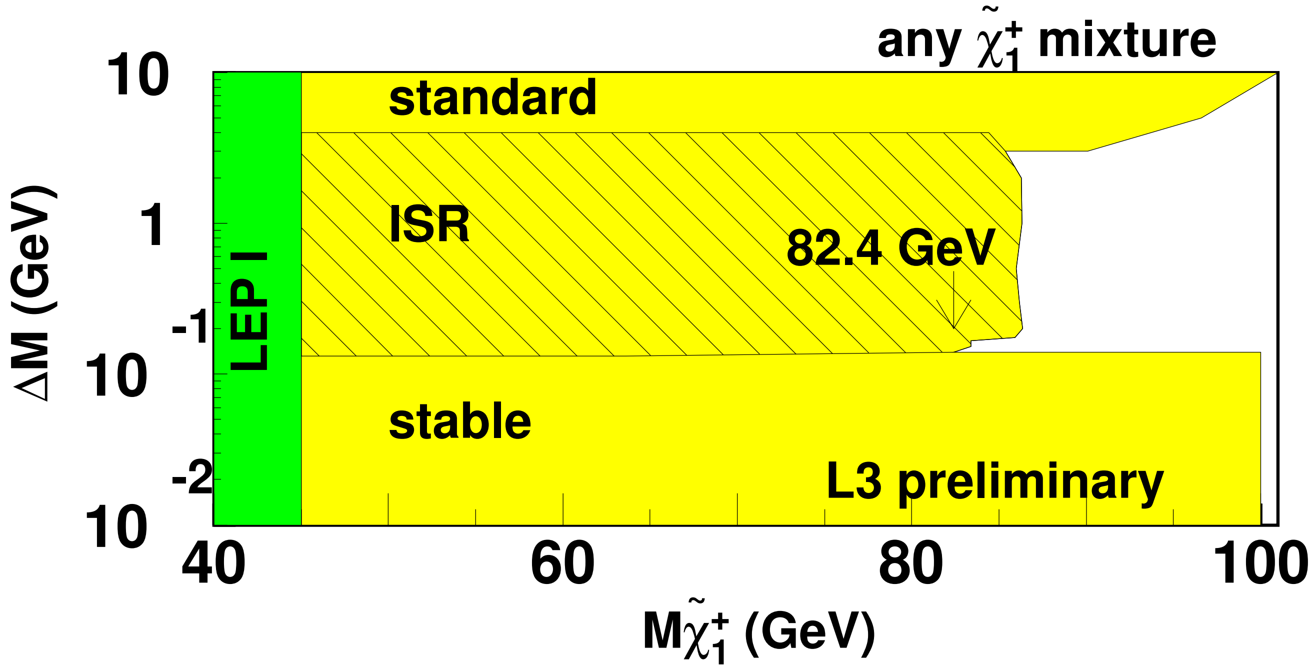
$M_{\tilde{\chi}_1^\pm} > 72.1$ GeV higgsino-like $\tilde{\chi}_1^\pm$

$M_{\tilde{\chi}_1^\pm} > 67.6$ GeV gaugino -like $\tilde{\chi}_1^\pm$

Mass exclusion L3 (I)

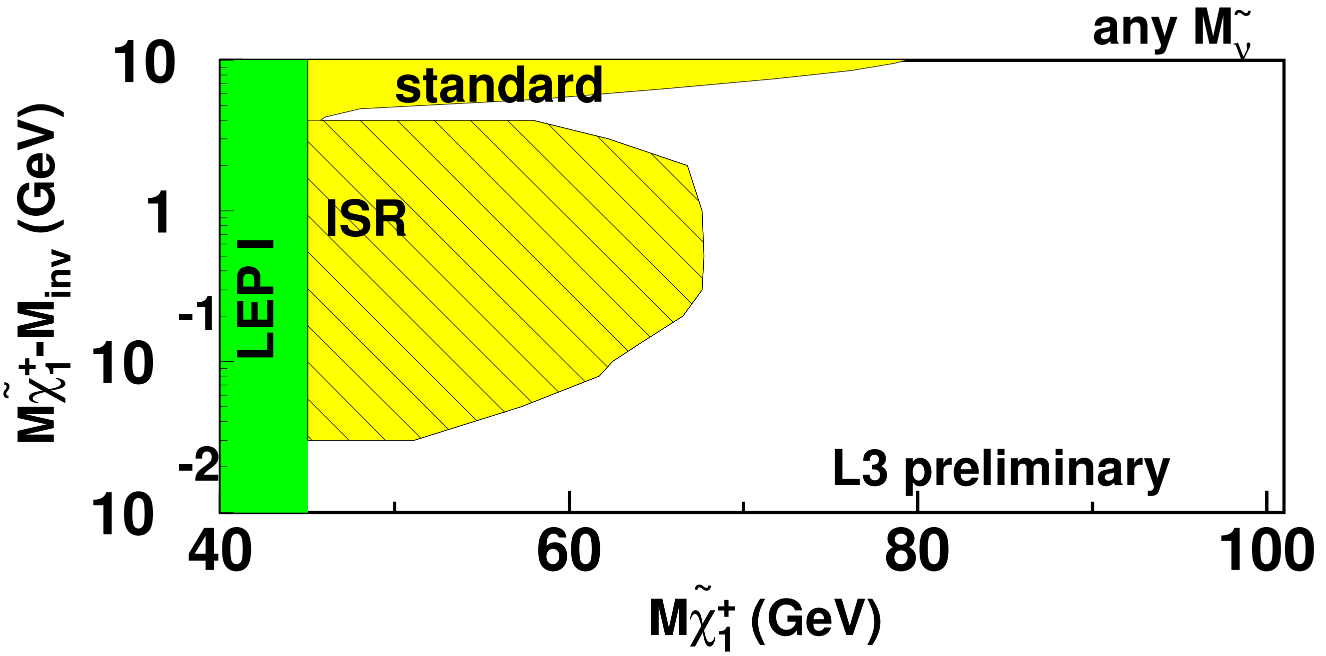
$$\sqrt{s} = 189 - 202 \text{ GeV}$$

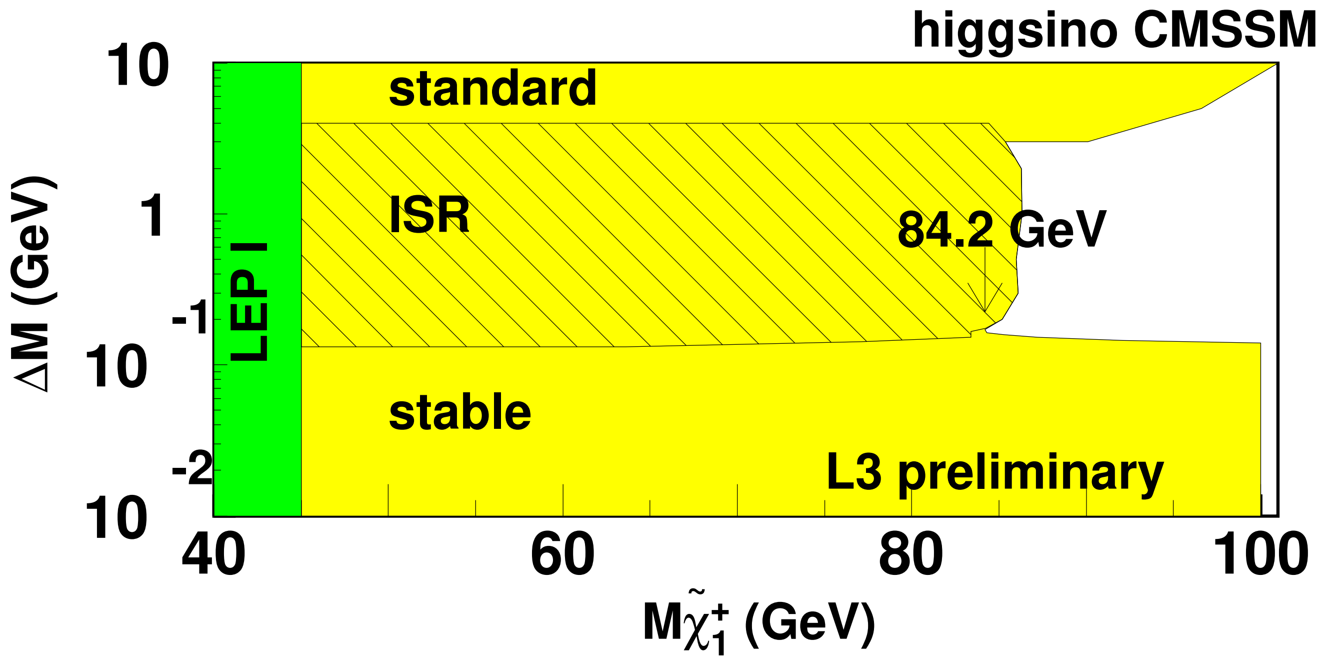




Mass exclusion L3 (II)

$$\sqrt{s} = 189 - 202 \text{ GeV}$$





Conclusion

Direct search of $\tilde{\chi}_1^{\pm}$ with any $\Delta\mathrm{M} = M_{\tilde{\chi}_1^{\pm}} - M_{\tilde{\chi}_1^0}$ and new analysis for ΔM less than few GeV

3 selections needed

$\Delta\mathrm{M}_A$	$>$	$\Delta\mathrm{M}_B$	$>$	$\Delta\mathrm{M}_C$
Standard $\not{E}$		ISR γ		Long lived

$\tilde{\chi}_1^{\pm}$ mass exclusion above 80 GeV is achieved at LEP for $\tilde{\nu}_{\mathrm{e}}$ and $\tilde{\mathrm{e}}^{\pm}$ heavy

If all susy scalars are heavy :

gaugino-like $\tilde{\chi}_1^{\pm}$	86.1 GeV
any $\tilde{\chi}_1^{\pm}$ mixture	82.4 GeV
higgsino CMSSM	84.2 GeV