Searches for Gauge Mediated SUSY Breaking at L3

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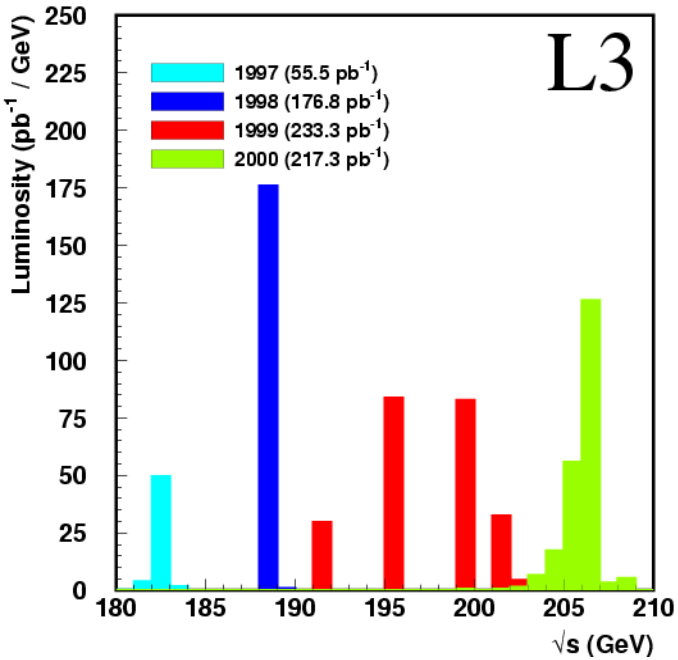
SUSY06, UC Irvine, June 14

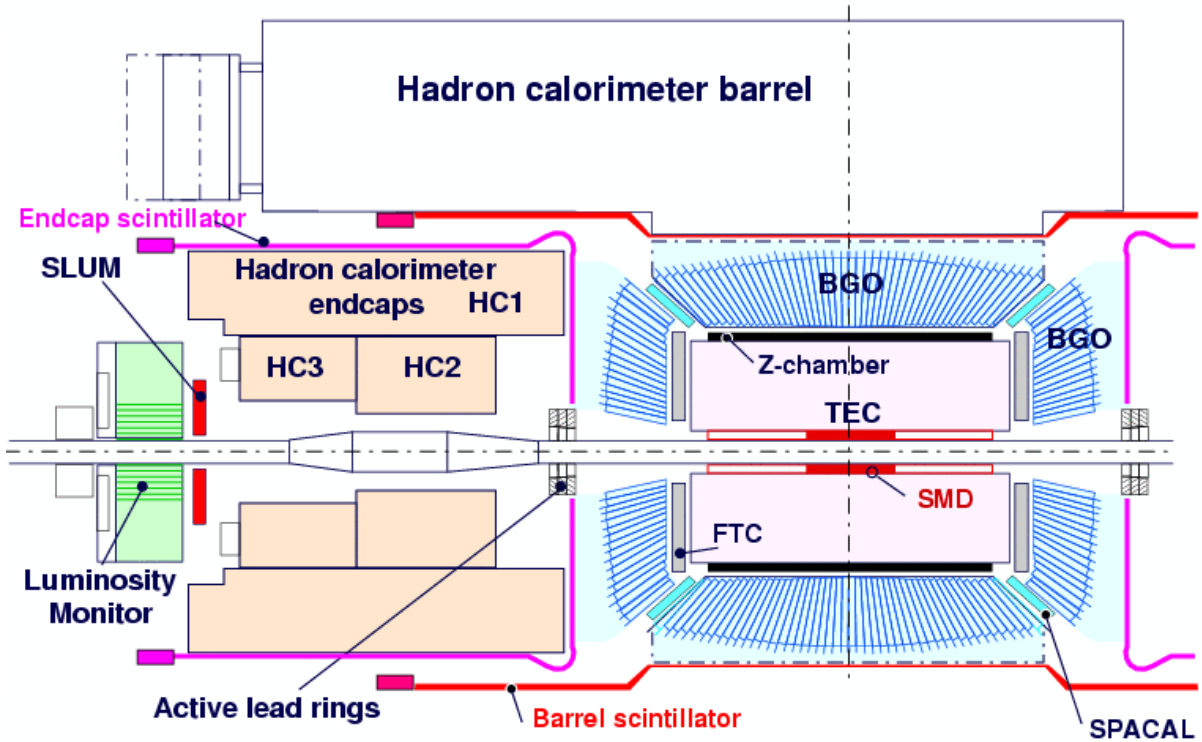
- Searches for topologies with a neutralino NLSP using both ECAL and HCAL
- Searches for topologies with a slepton NLSP covering all slepton lifetimes
- Scan over the GMSB parameter space
- Summary and outlook

All limits are at 95% C.L. All results are preliminary.

L3 Experiment at LEP2

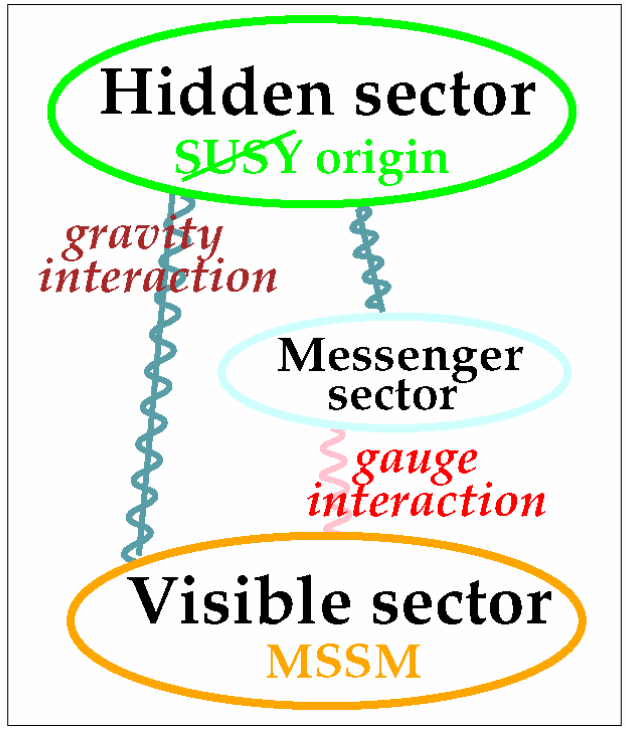
619 pb^{-1} at $\sqrt{s}$ = 189 - 208 GeV collected in 1998-2000





- Electromagnetic calorimeter: 11,000 BGO crystals
- Hadron calorimeter: uranium absorber and wire chambers

GMSB Topologies at LEP



- Minimal GMSB model phenomenology is driven by 6 parameters

$$\sqrt{F},\ M_{mess},\ N_5,\ \Lambda,\ \tan\beta,\ \mathrm{sign}(\mu)$$

- Gravitino is always LSP with a mass $10^{-2} < m_G < 10^4$ eV

GMSB Topologies at LEP

NLSP can either a neutralino or slepton (stau)

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

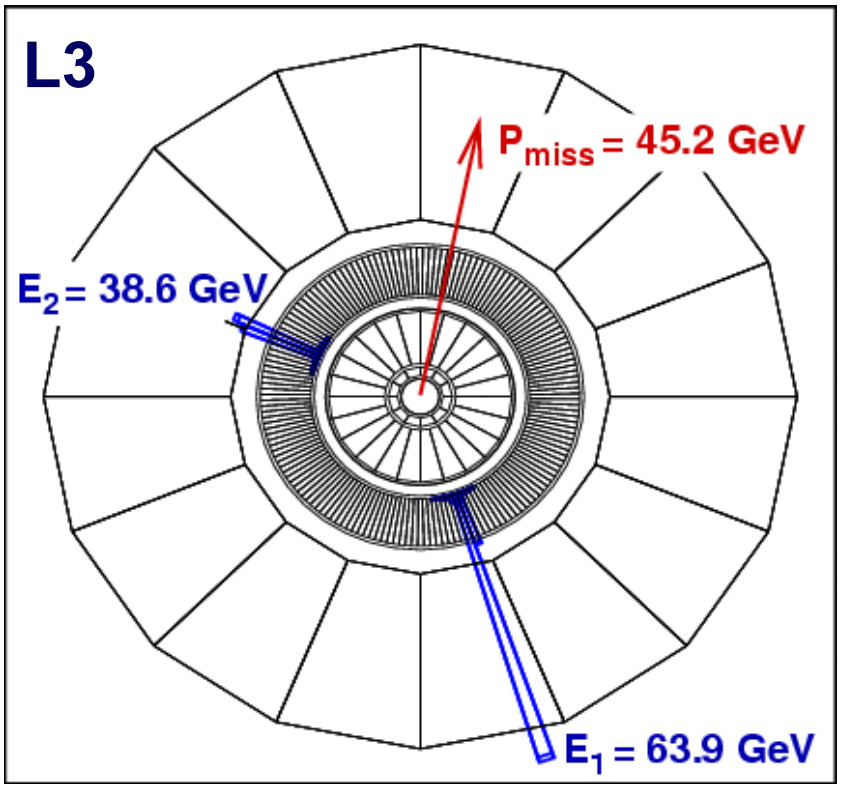
$e^+e^- \to \tilde{\ell}_R\tilde{\ell}_R \to \ell\ell\tilde{G}\tilde{G}$

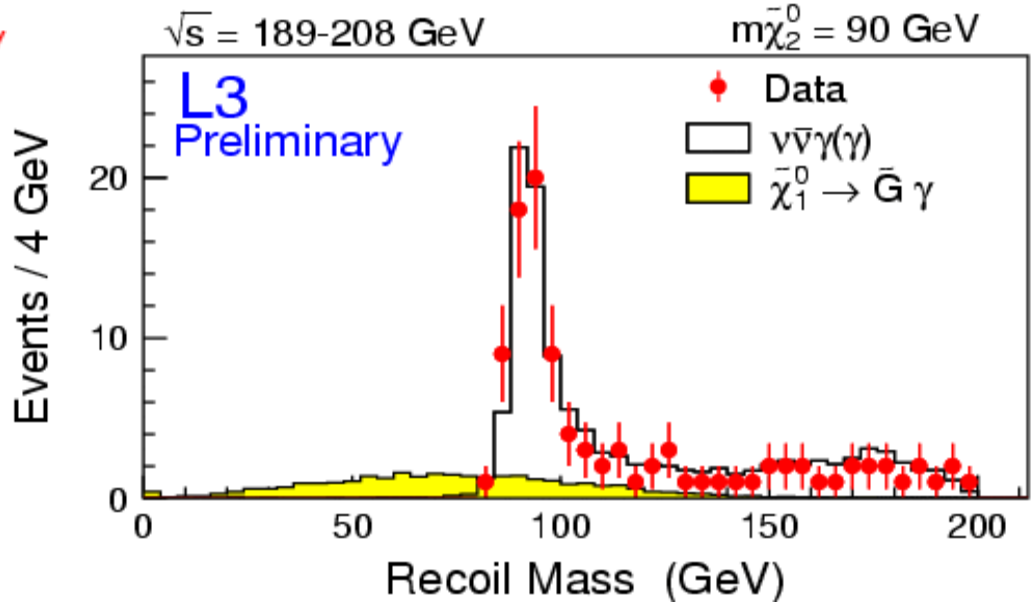
$$L = 1.76{\cdot}10^{-3}\,(\kappa_\gamma)^{-1}\left(\frac{s}{4m^2_{\tilde{\chi}_1^0}}-1\right)^{1/2}\left(\frac{100\ \text{GeV}}{m_{\tilde{\chi}_1^0}}\right)^5\left(\frac{m_{\tilde{G}}}{1\ \text{eV}}\right)^2\text{cm}$$

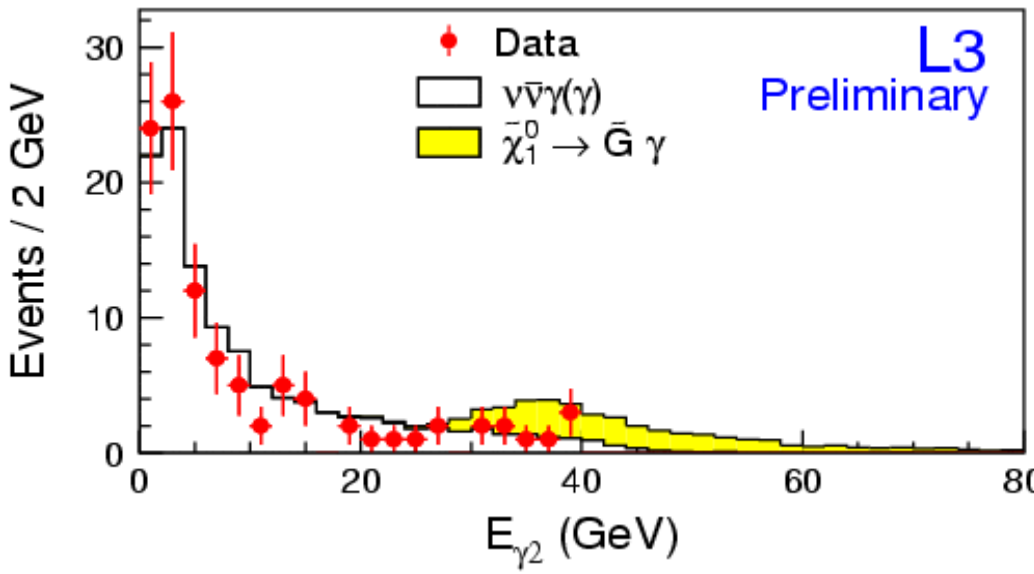
lifetime	$\tilde{\chi}_1^0$ NLSP	Slepton NLSP
short $c\tau \sim 0$	acoplanar photons	acoplanar leptons
medium $0 < c\tau < \infty$	non-pointing photons	kinked track large impact parameter
long $c\tau = \infty$	———————	anomalous dE/dx

Short-Lived Neutralinos

SM background $e^+e^- \to \nu\bar{\nu}\gamma\gamma$



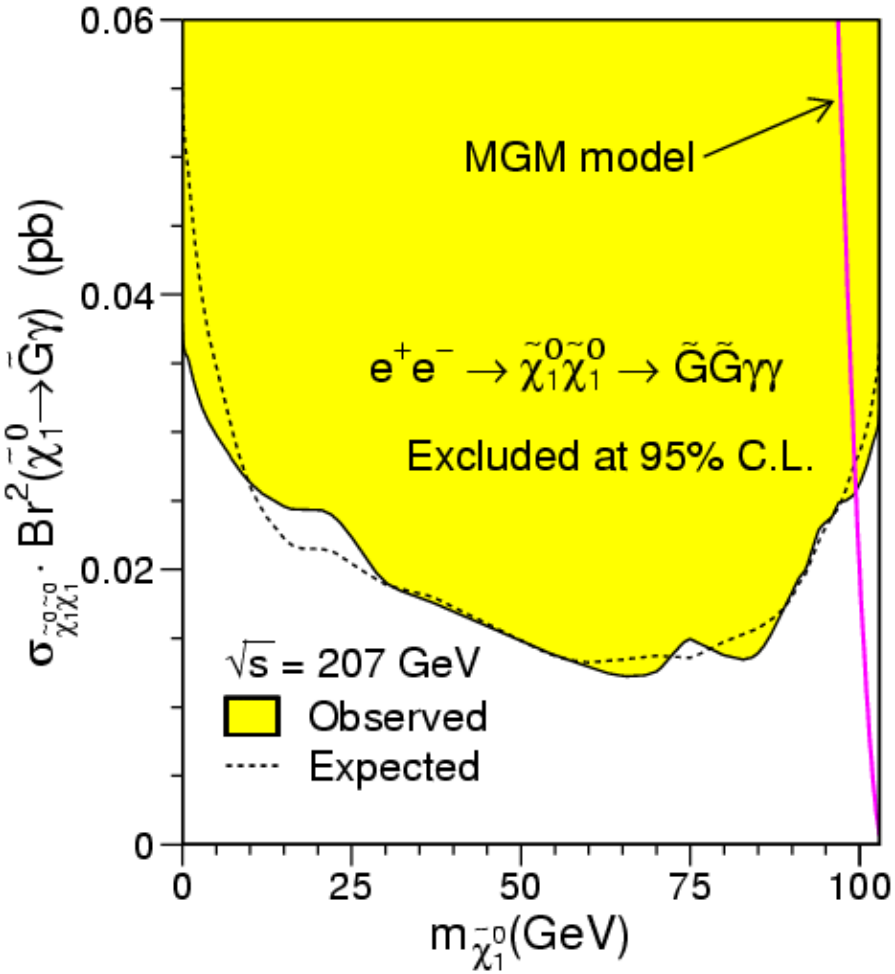




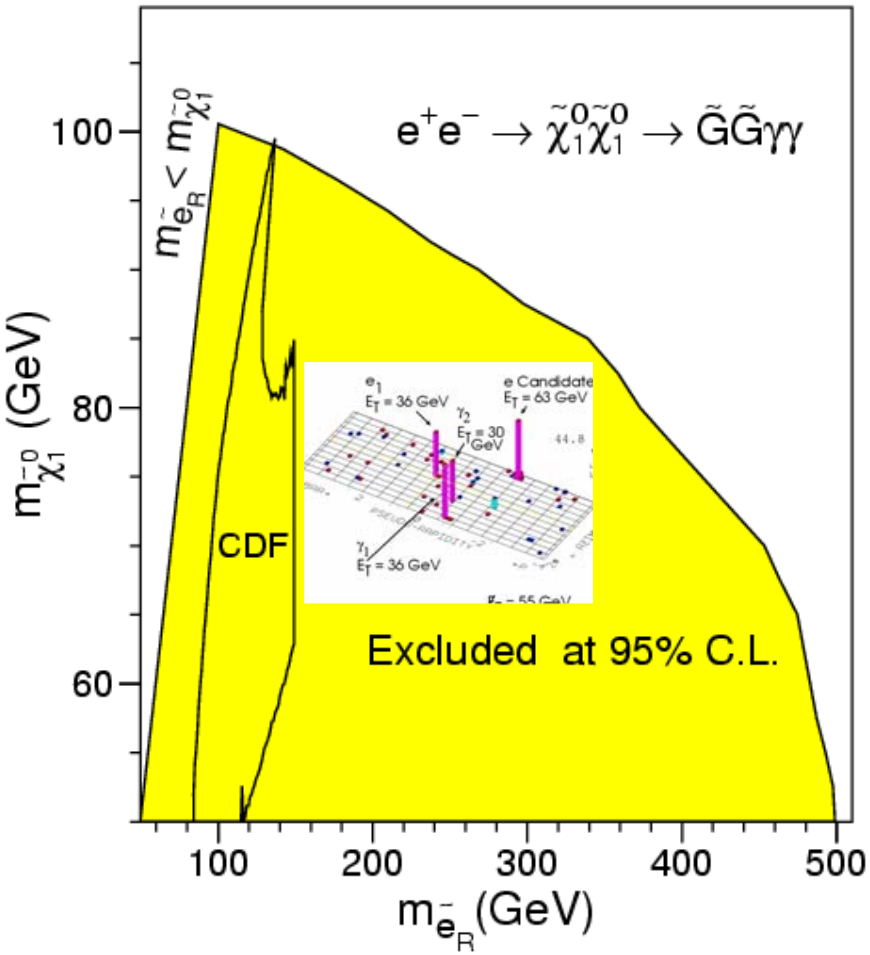
Signal is easy to separate
Efficiency ~ 60-70%

Short-Lived Neutralinos

Cross Section Limit

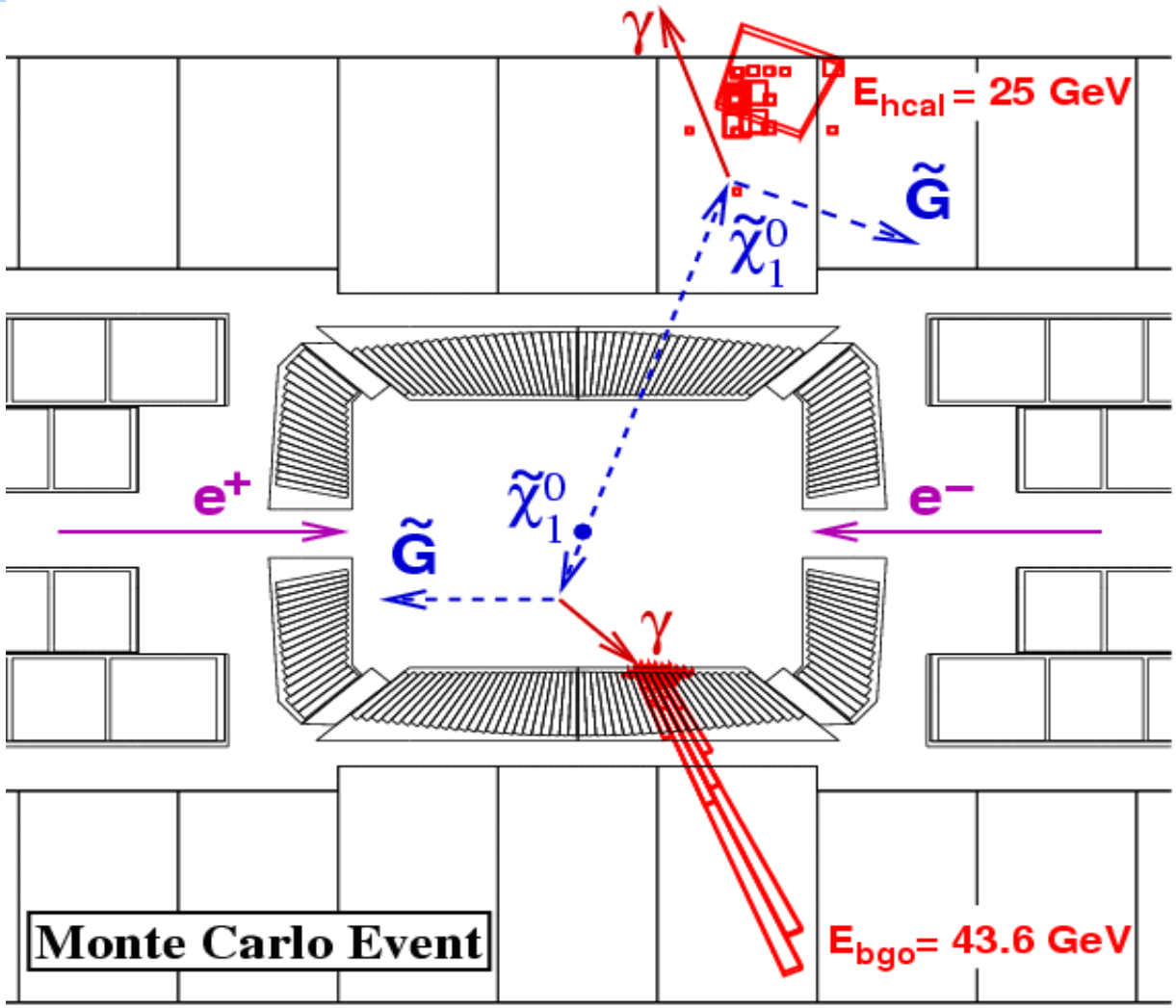


GMSB Interpretation



$$m_{\tilde{\chi}_1^0} > 99.5 \text{ GeV}$$

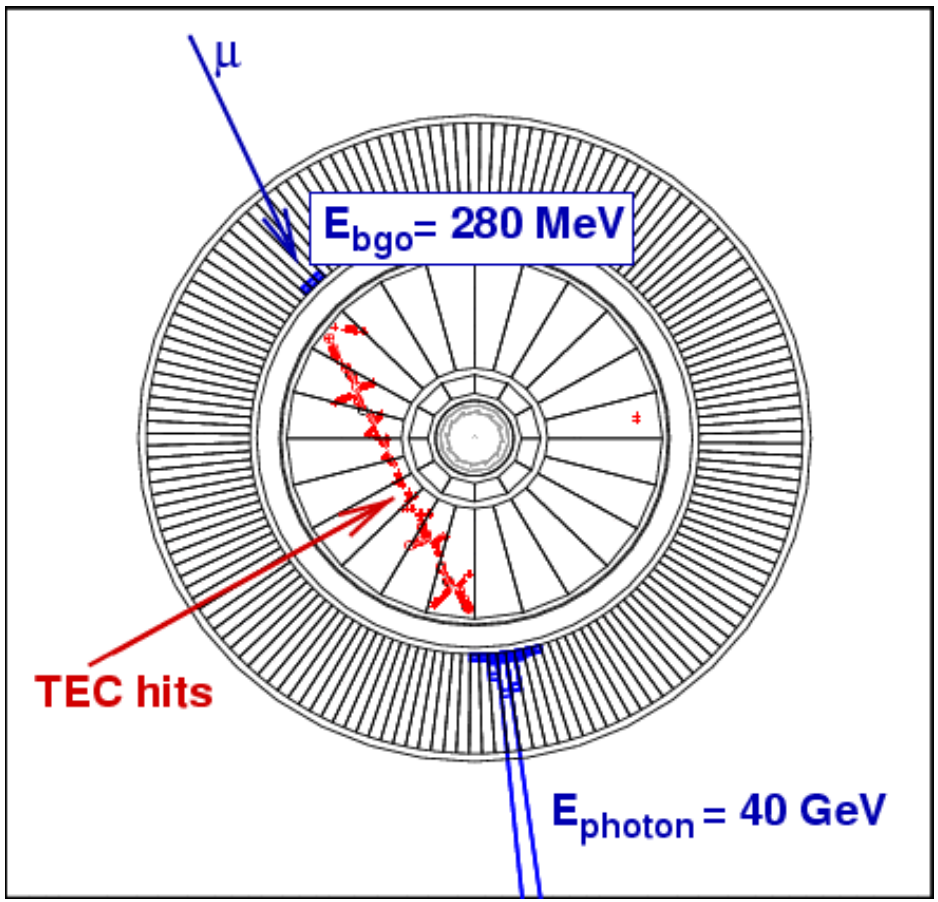
Intermediate Neutralino Lifetimes



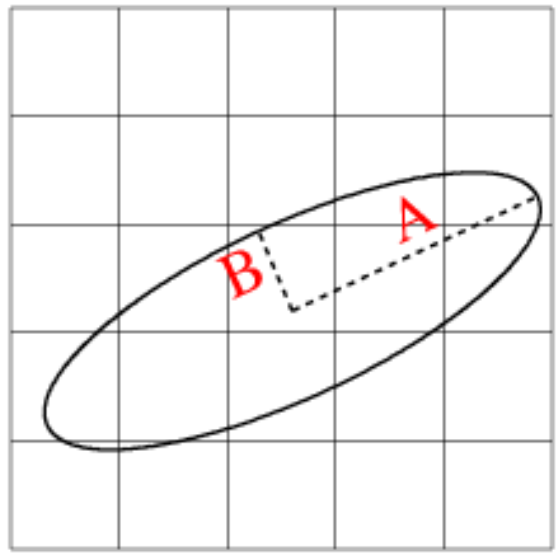
- Non-pointing photons in ECAL: R=0.5 m and L=1.5 m
- Photons in HCAL: 1 m < R < 2 m and L=5 m

Non-Pointing Photons in the ECAL

Significant background comes from cosmic muons.
Rejected by muon chambers, scintillator counters and tracker.



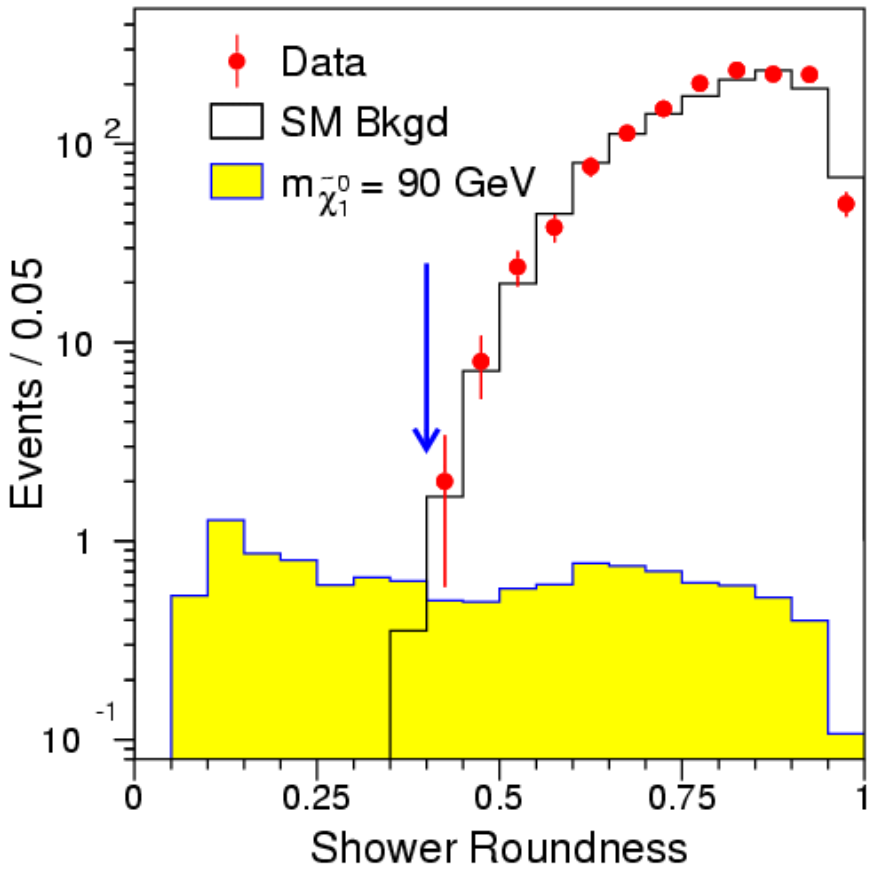
Transverse shower profile

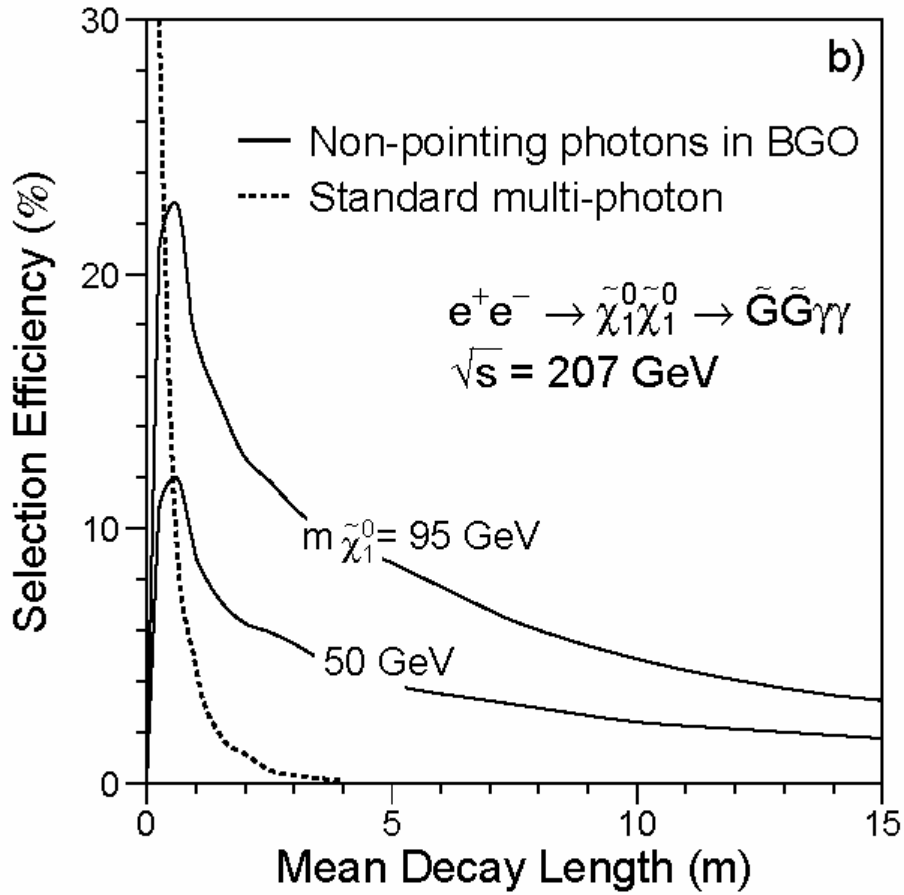


$$\text{Roundness} \equiv \frac{\text{Minor Axis}}{\text{Major Axis}}$$

Non-Pointing Photons in the ECAL

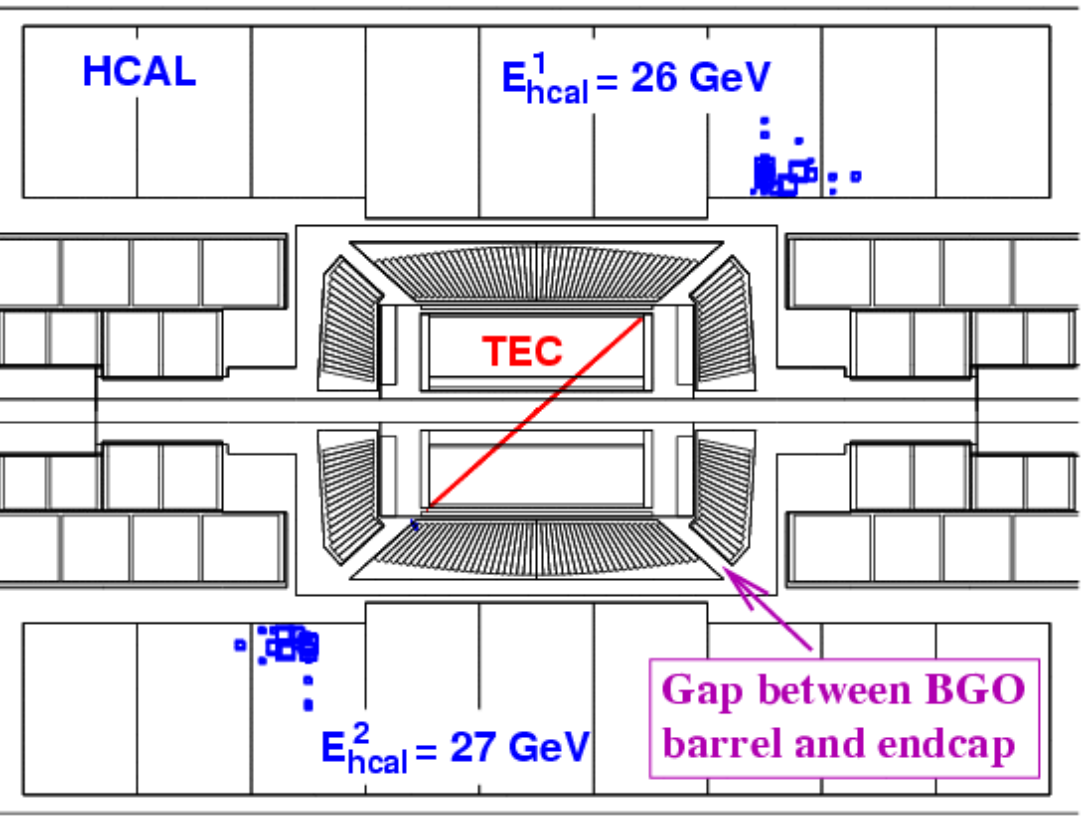
Standard Model background completely suppressed.
Selection efficiency depends on the neutralino mass.

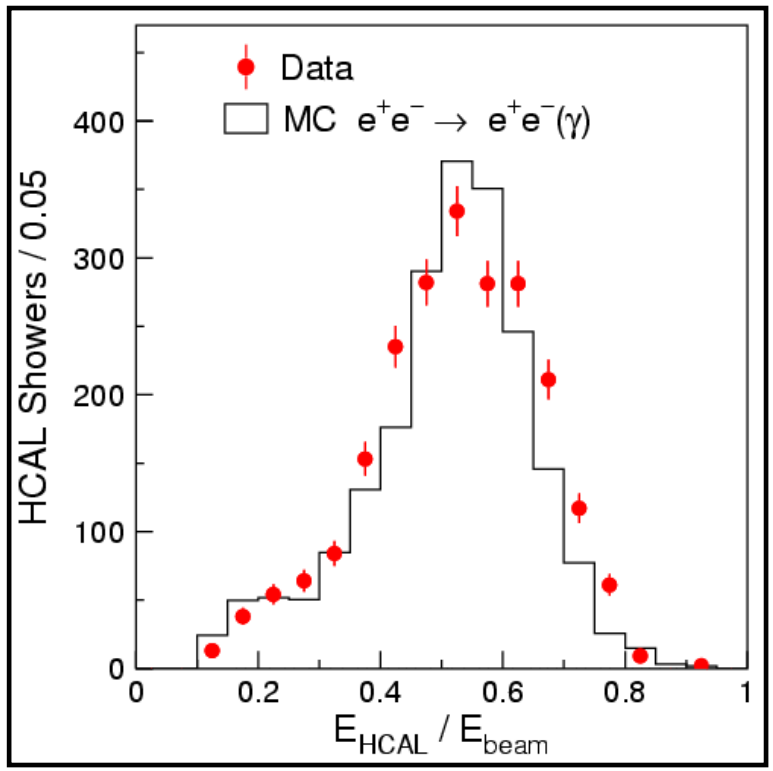




Photons in the HCAL

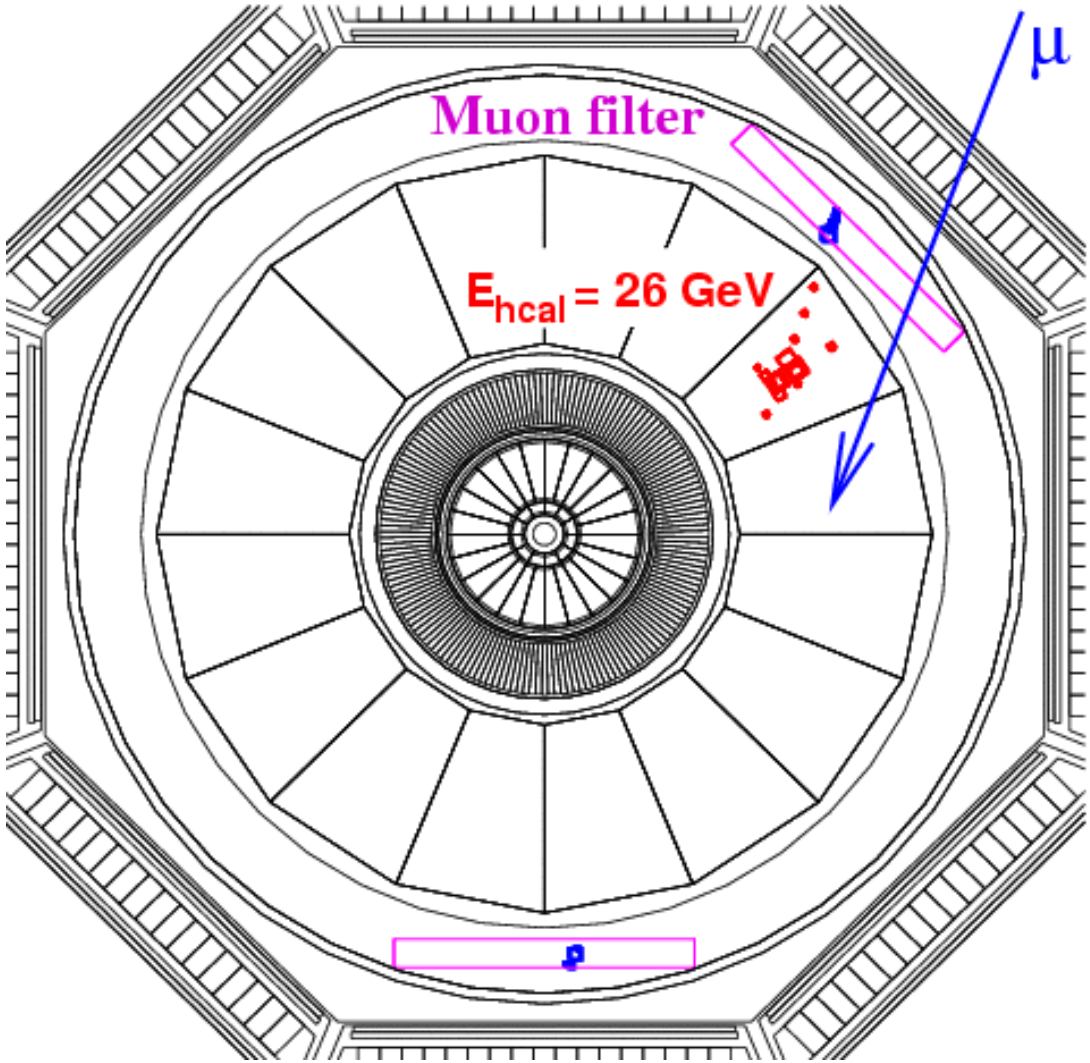
- Selected a sample of HCAL Bhabhas in the 1995 data.
- Data 1110 and MC 1048 events, energy resolution 23%.
- Shower profile and trigger efficiency also in agreement.





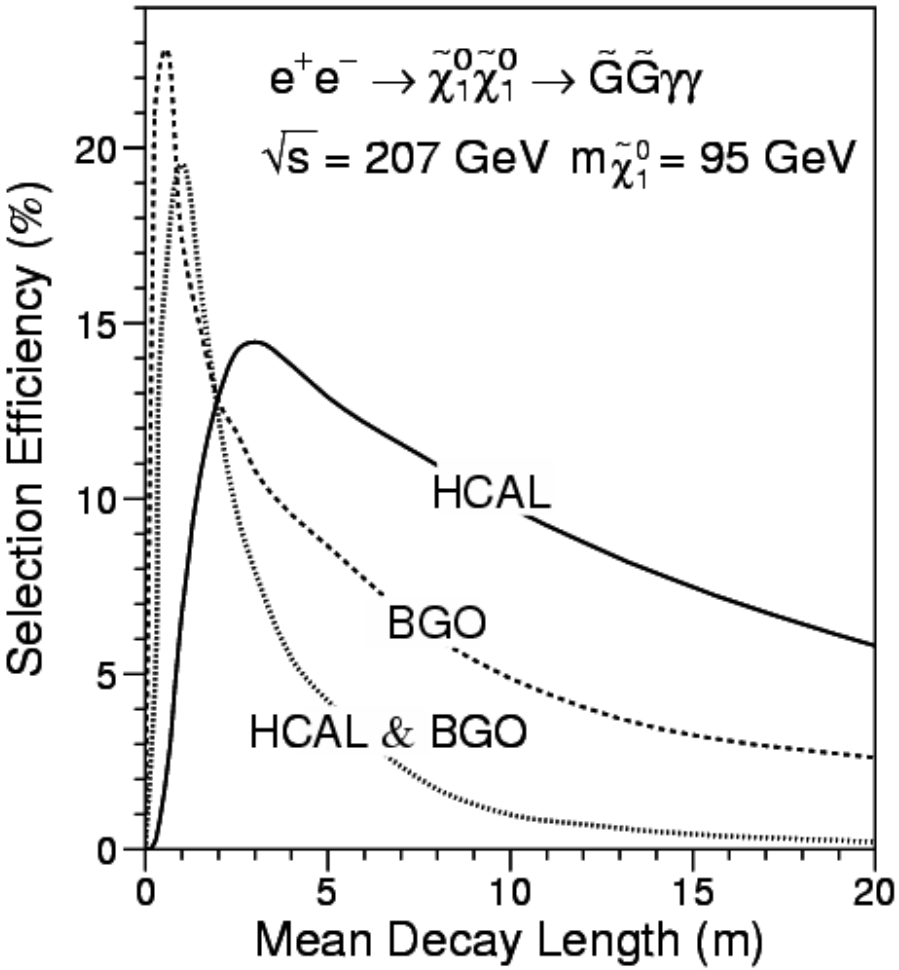
Neutralino Decays in the HCAL

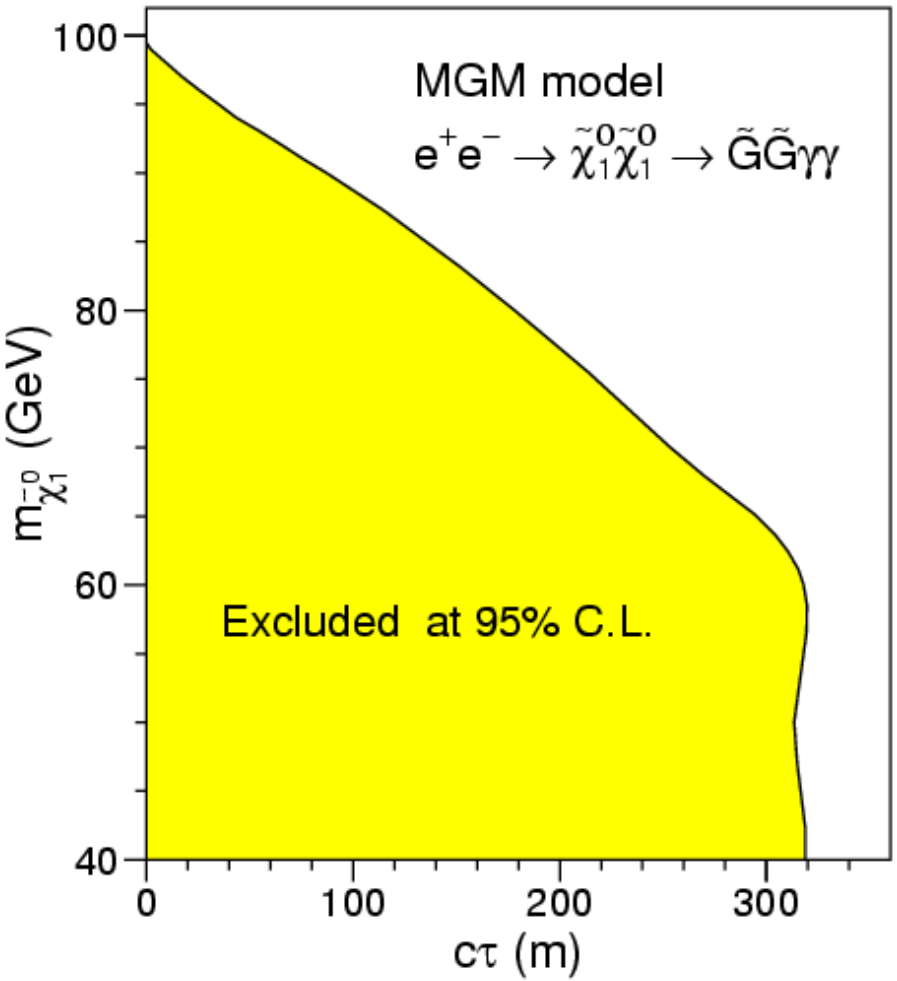
- ✓Spectacular signature.
- ✓Efficiency does not depend on the neutralino mass.
- ✓Radial segmentation of HCAL would provide a measurement of $c\tau$
- ✓No Standard Model background.
- ✓Cosmics rejected using muon chambers and filter.



Non-Pointing Photons

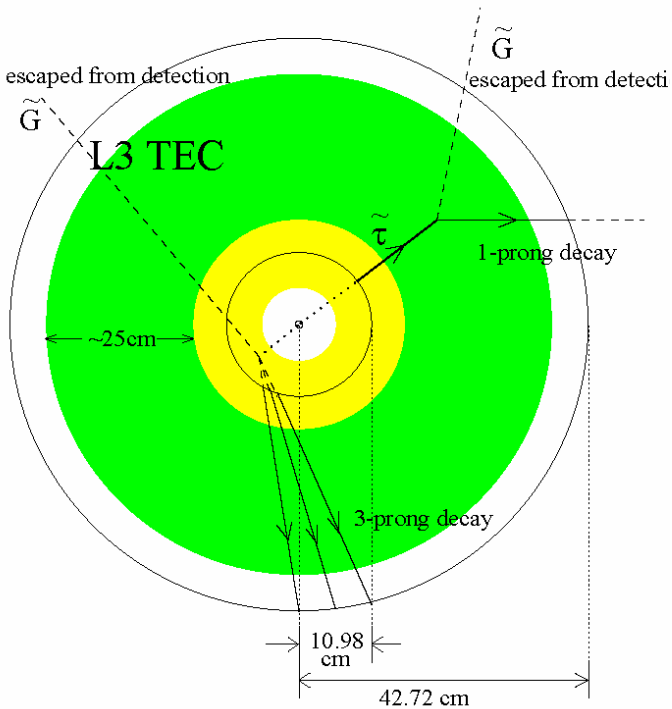
No candidates found and limits derived for decay lengths 1-300 m

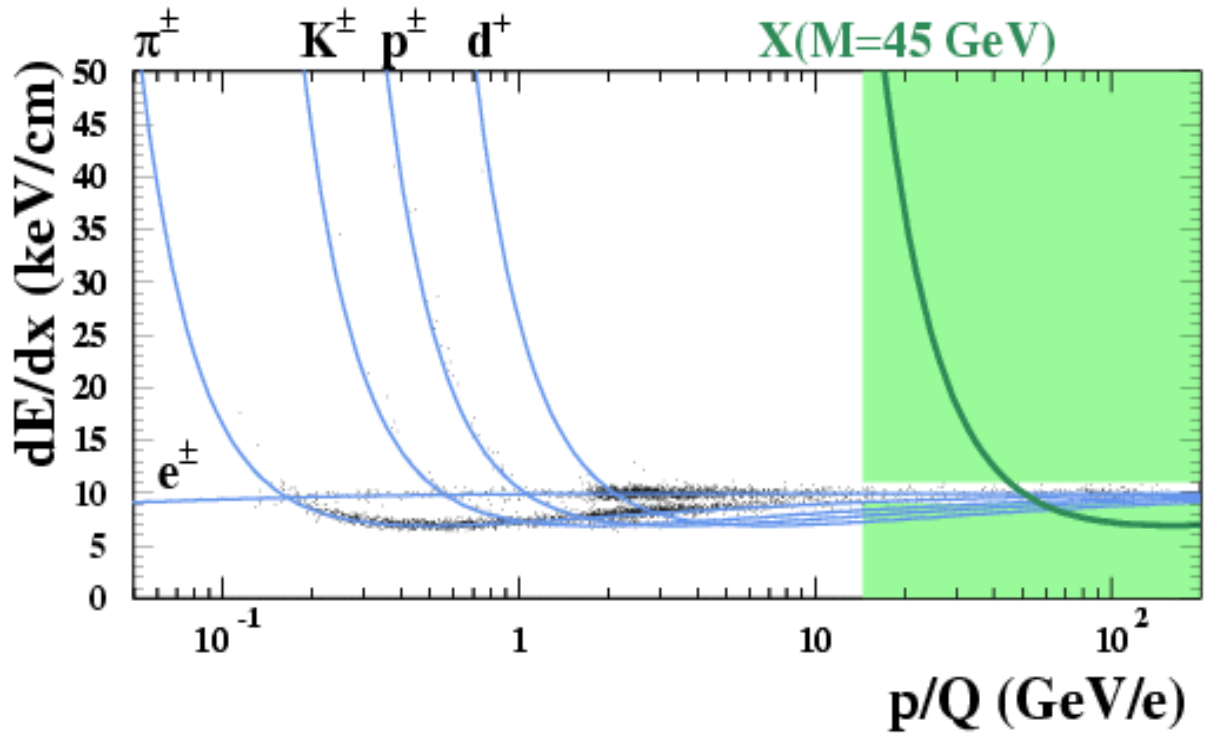




Scalar Lepton NLSP

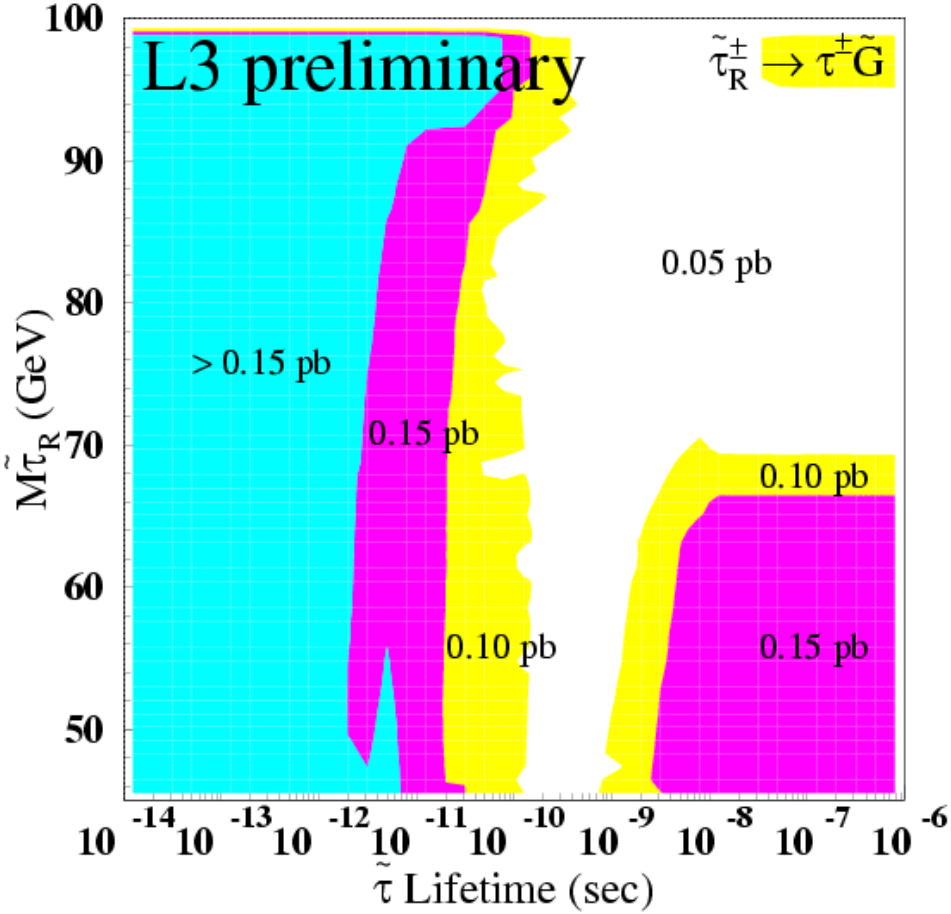
- Prompt decays: search for events with acoplanar leptons
- Intermediate lifetime: search for kinked tracks
- Long decay length: search for tracks with anomalous dE/dx



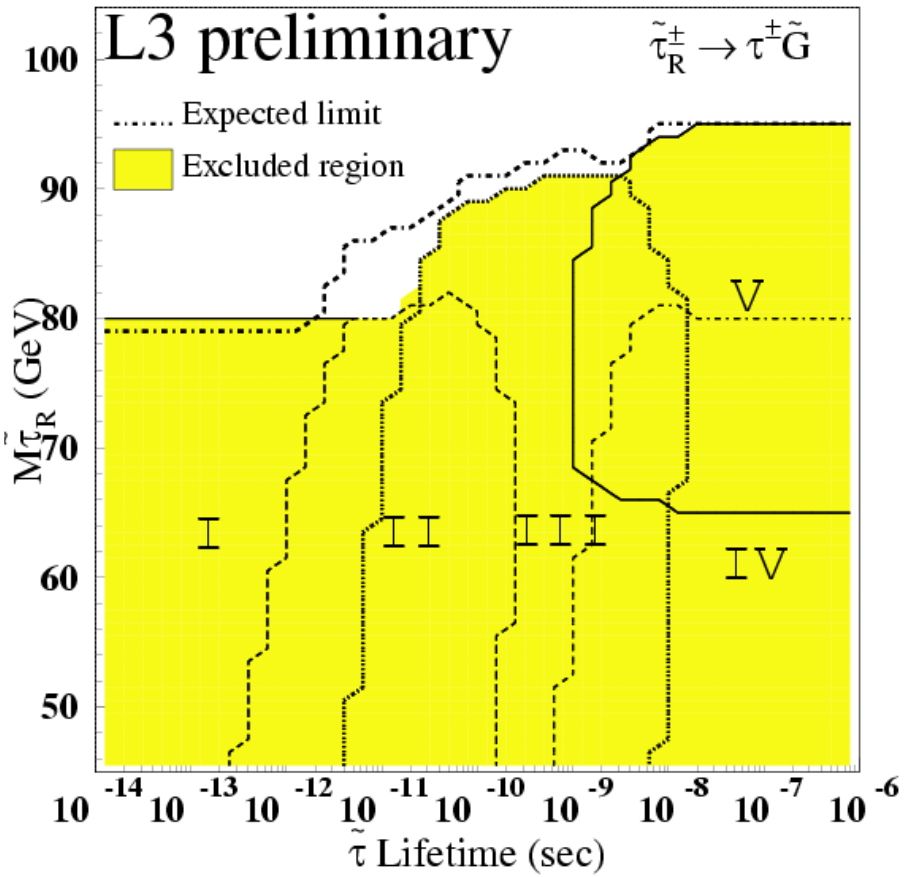


Searches for Scalar Tau Production

Cross Section Limit



GMSB Interpretation

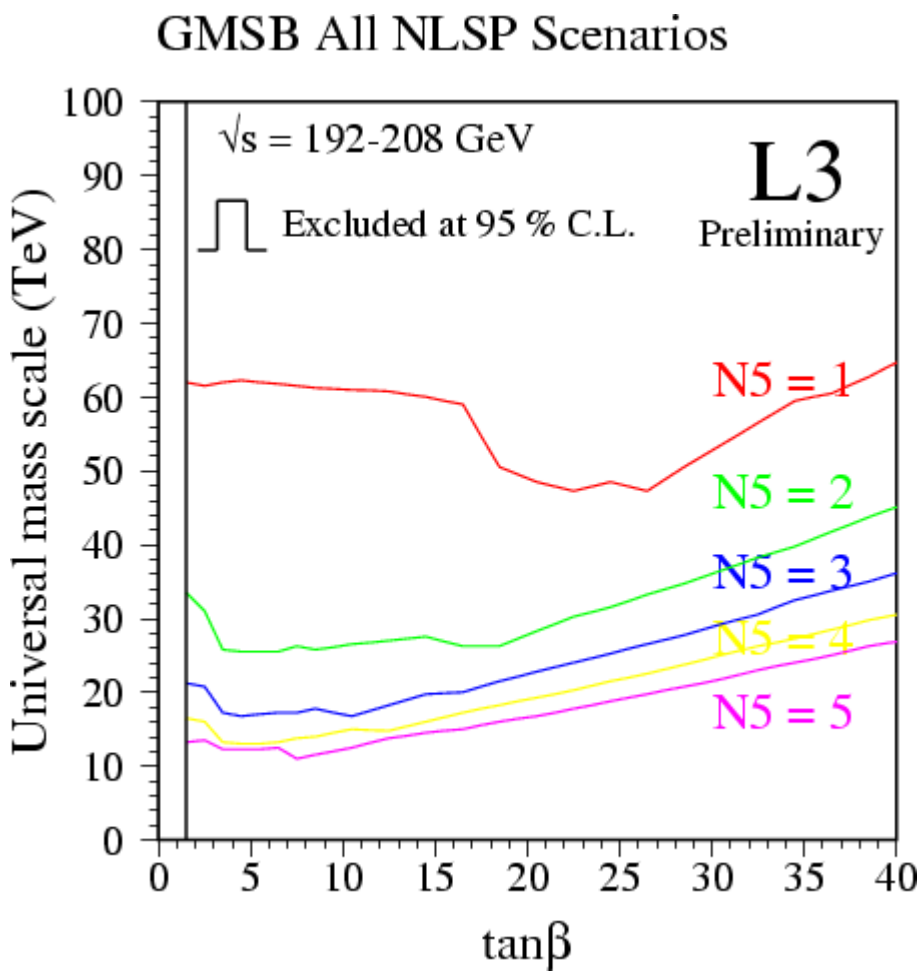


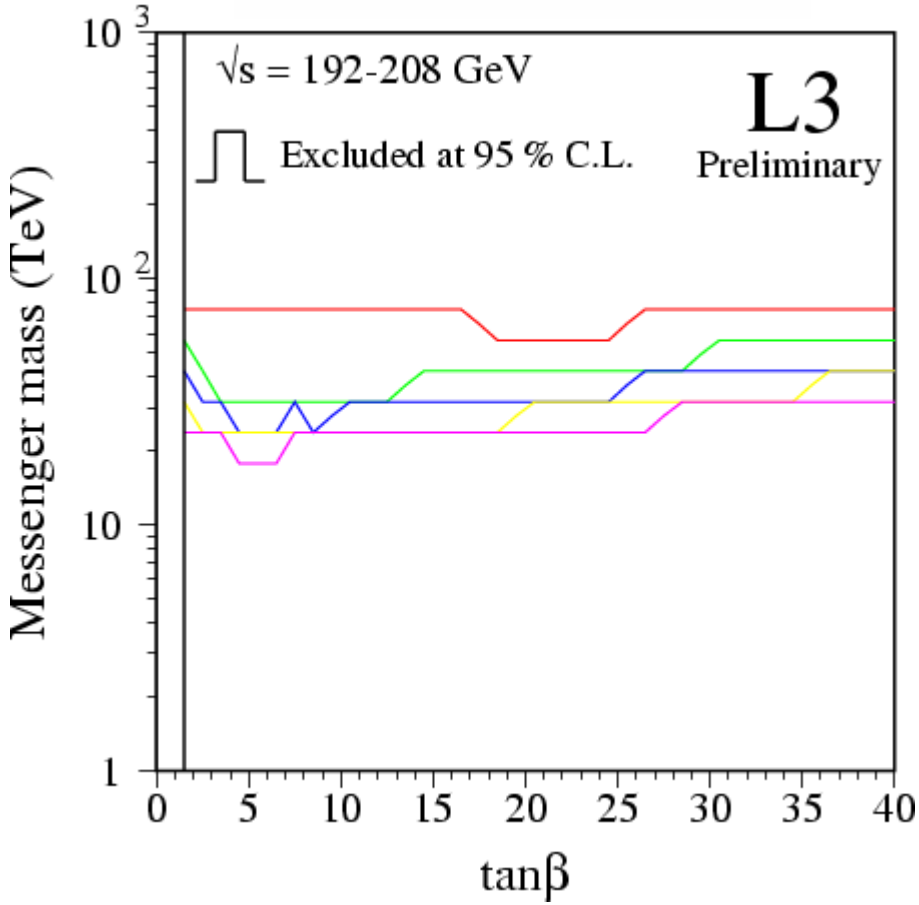
Scalar taus lighter than 80 GeV are excluded

Scan of the GMSB Parameter Space

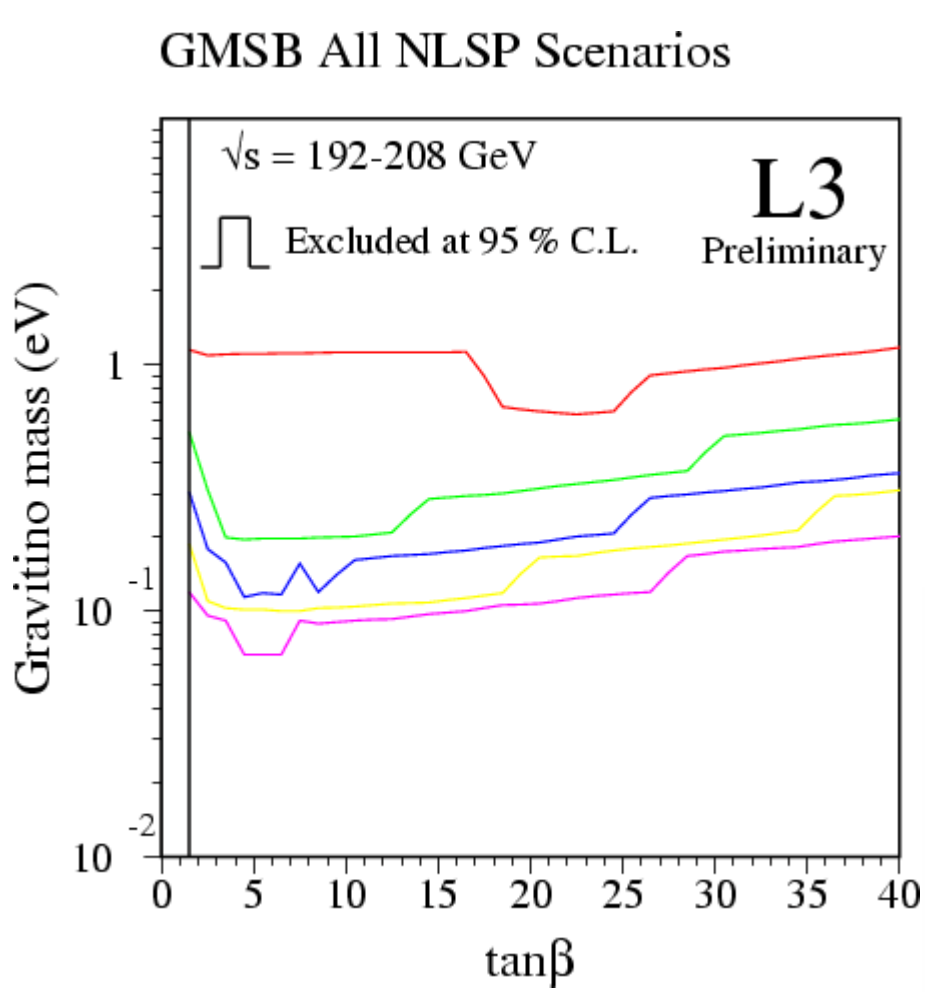
Scan of the GMSB parameter space
6 million points simulated with ISAJET

$$1 \leq N \leq 5$$
$$1.5 \leq \tan\beta \leq 40$$
$$10\ \text{TeV} \leq M \leq 10^9\ \text{TeV}$$
$$sign(\mu) = \pm 1$$
$$1\ \text{TeV} \leq \Lambda \leq min(\sqrt{F}, M)$$





Scan of the GMSB Parameter Space



Neutralino NLSP with L < 100 m

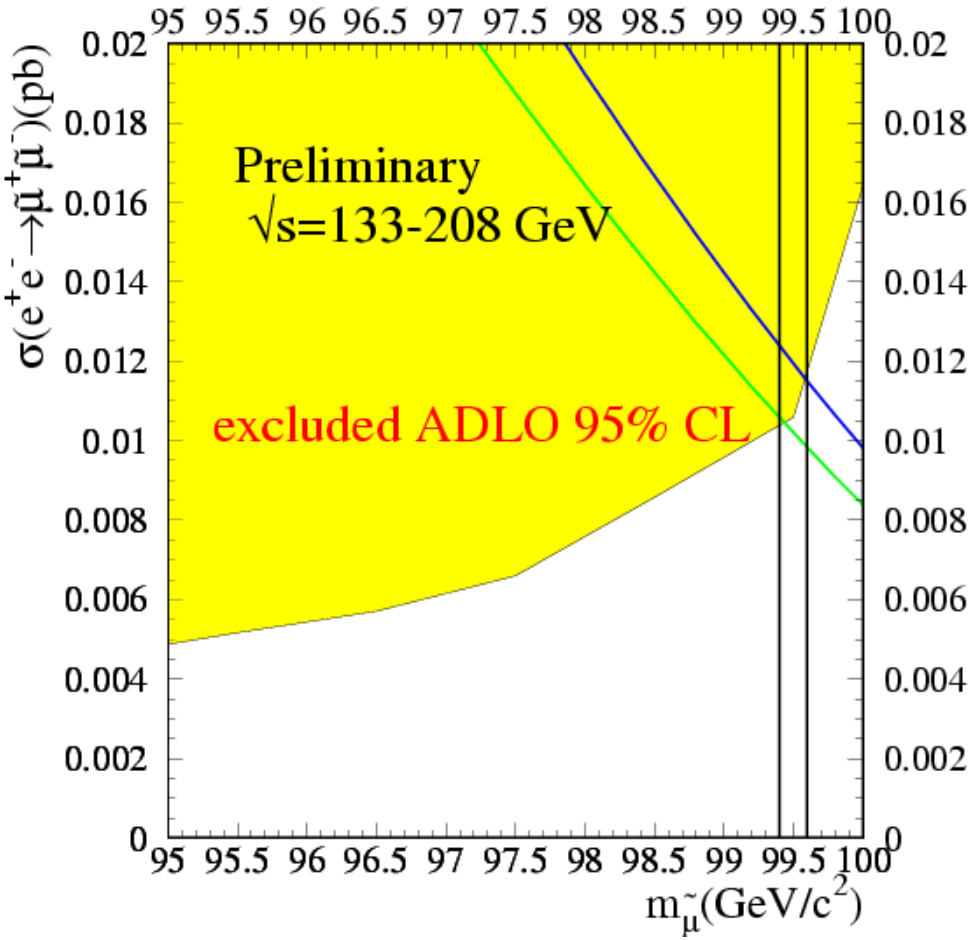
N_{mess}	1	2	3	4
Λ (TeV)	61.5	36.3	25.5	20.3
M_{mess} (TeV)	75	130	10^5	$5.6 \cdot 10^6$
$m_{\tilde{G}}$ (eV)	1.1	1.2	620	$2.7 \cdot 10^4$
$m_{\tilde{\chi}_1^0}$ (GeV)	78.6	83.8	88.0	104.2
$m_{\tilde{\tau}_1}$ (GeV)	82.1	87.1	90.8	106.3
$m_{\tilde{e}_R}, m_{\tilde{\mu}_R}$ (GeV)	107.6	102.2	92.1	107.1

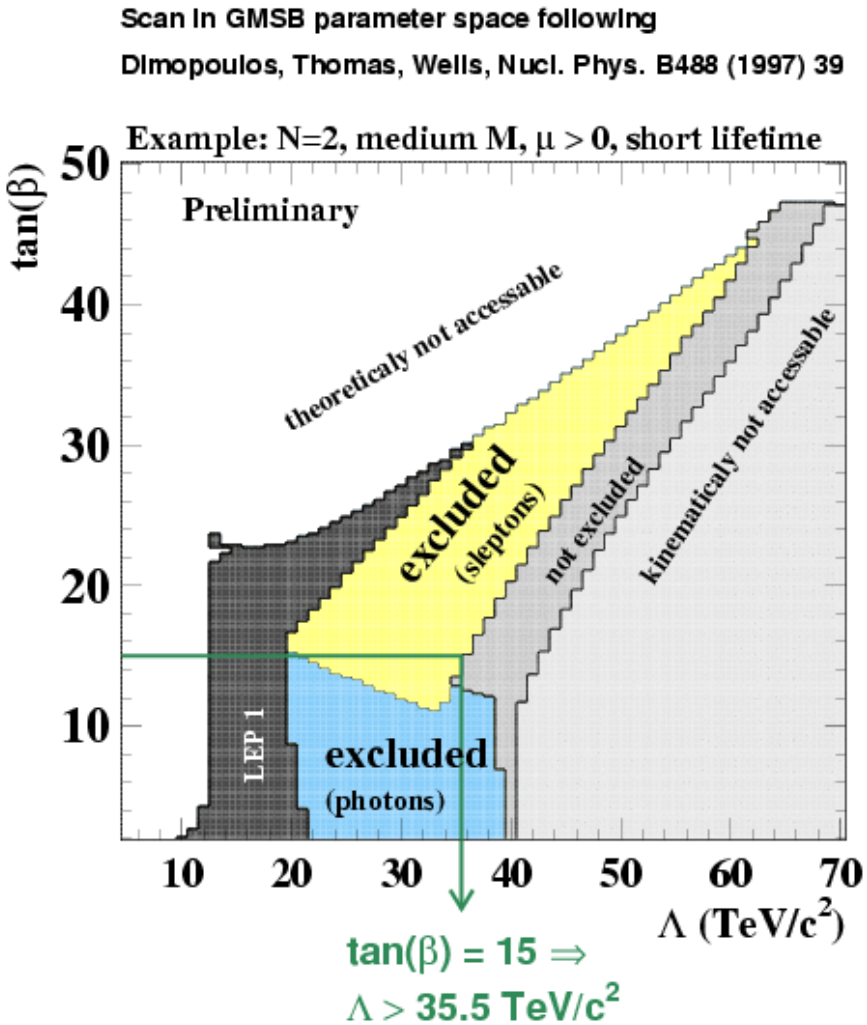
All NLSP scenarios

$N5$	1	2	3	4	5
$\Lambda\ (TeV/c^2)$	47.25	25.5	16.75	13.0	11.0
$M_{mess}\ (TeV/c^2)$	56	32	24	24	18
$m_{\tilde{G}}\ (eV/c^2)$	0.63	0.19	0.11	0.1	0.066
$m_{\tilde{\chi}_1^0}\ (GeV/c^2)$	62.16	65.91	65.64	65.22	72.23
$m_{\tilde{\tau}_1}\ (GeV/c^2)$	62.28	62.17	62.25	62.70	62.84
$m_{\tilde{e_R},\tilde{\mu_R}}\ (GeV/c^2)$	89.60	73.62	71.15	66.94	67.11

LEP Combinations

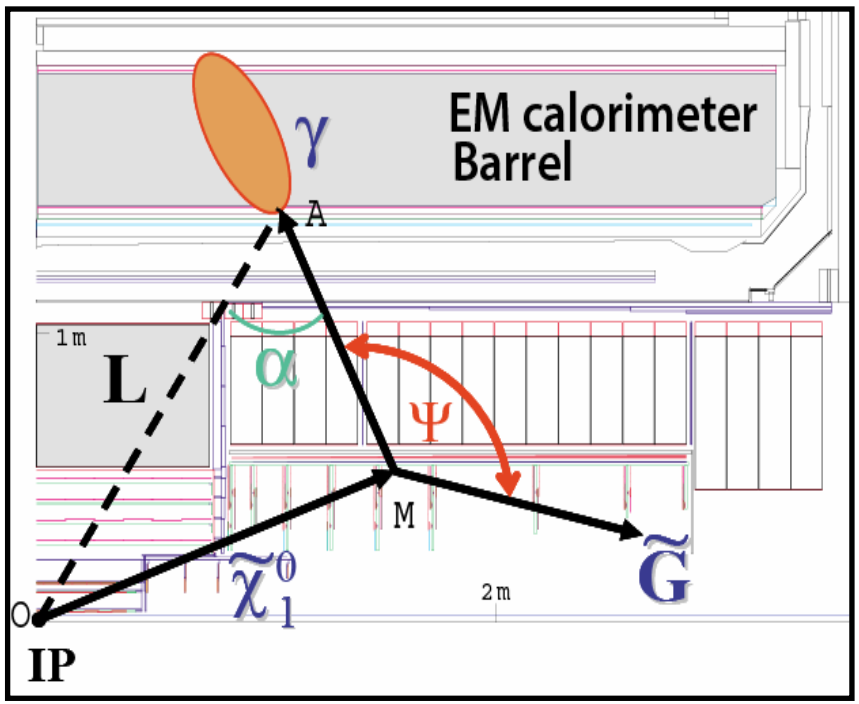
Combinations performed by the LEP SUSY working group
http://lepsusy.web.cern.ch/lepsusy/





Prospects at the LHC (ATLAS)

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



D. Prieur hep-ph/0507083

- **Reconstruct decay vertex**
  - ✓ **Impact position**
  - ✓ **Photon direction α**
  - ✓ **Time of arrival t_γ**
- **Resolution on cτ better than 8% for L=0.1-2 m**

$$\frac{\Delta m_\chi}{m_\chi} \approx 2\% \Rightarrow \frac{\Delta\sqrt{F_0}}{\sqrt{F_0}} \approx 4\% \quad \frac{\Delta m_{\tilde{G}}}{m_{\tilde{G}}} \approx 8\%$$

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

hep-ph/0010081: Decay lengths 0.5m – 1km considered

Measuring stau lifetime gives ~10% precision on $\sqrt{F}$

Summary

- Extensive searches for GMSB signals were performed
- New method developed to search for neutralino NLSP scenario (L < 300 m) using L3 hadron calorimeter (suitable for CMS ?)
- Exciting prospects waiting at the LHC
- My collaborators: L. Xia, H. Yang and S. Rosier
  LEP SUSY Working Group
  http://lepsusy.web.cern.ch/lepsusy/