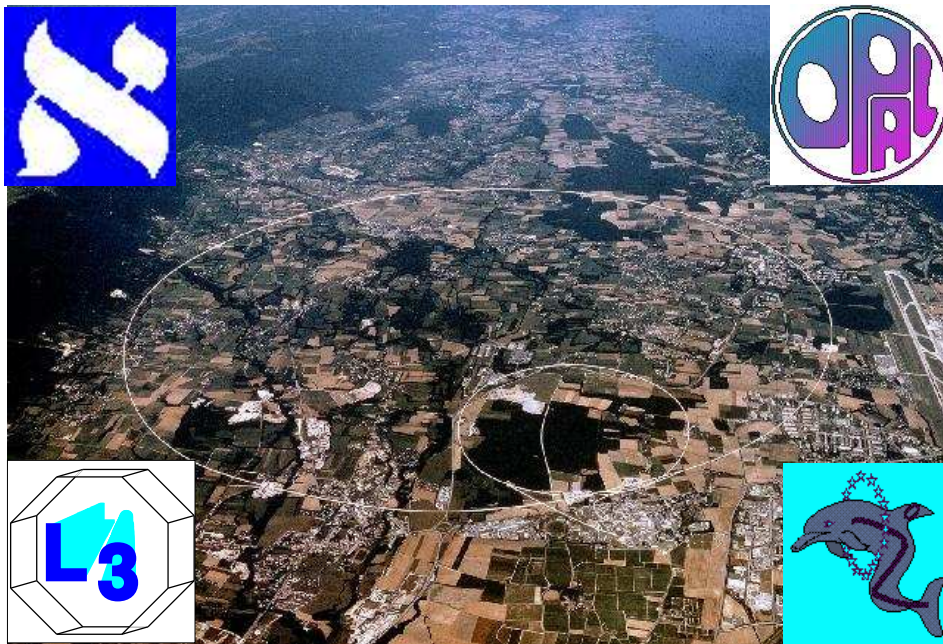
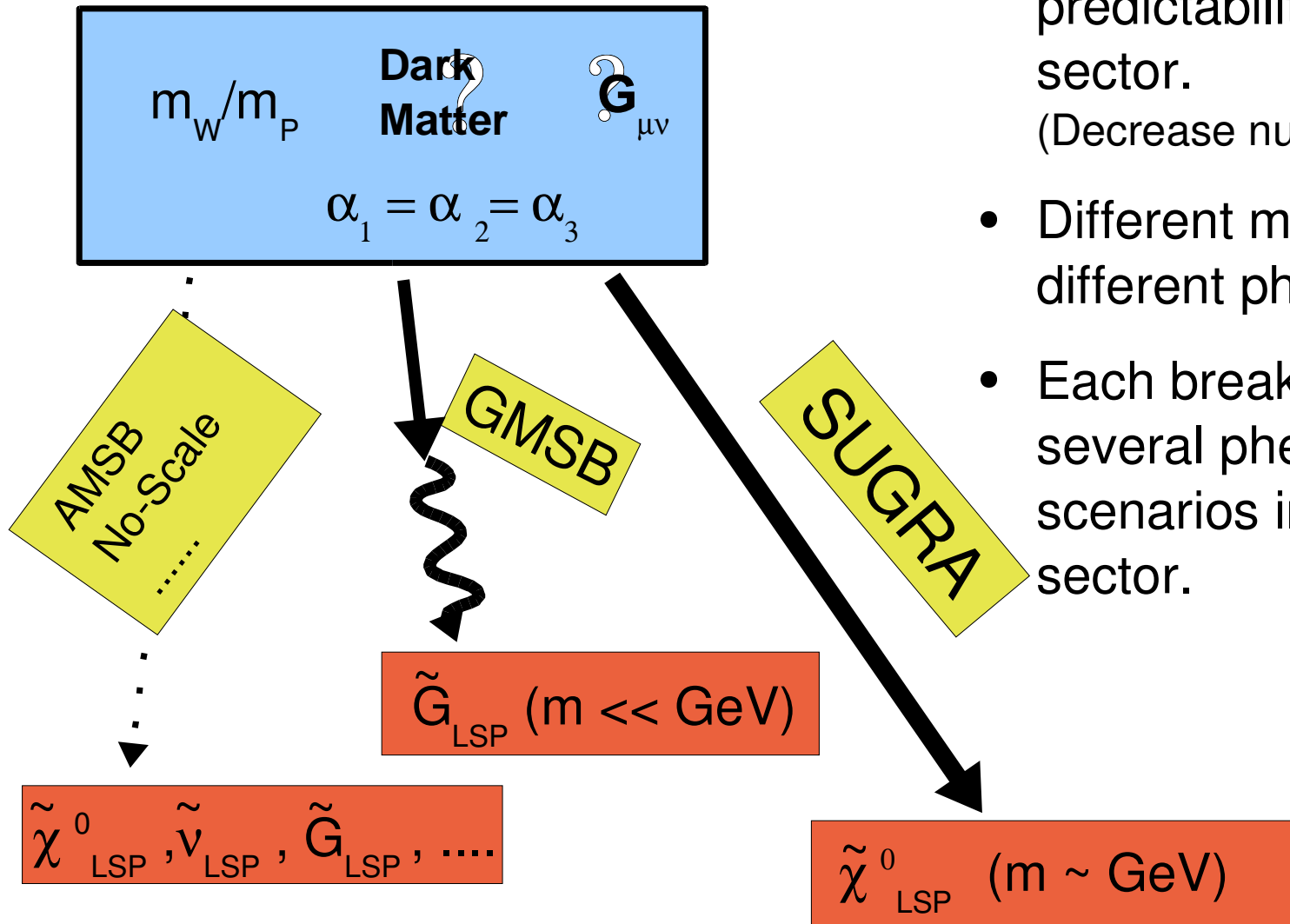


A Review of the SuperSymmetry Searches at LEP



- Results are mainly based on data from year 1996 – 2000
- $E_{\text{cm}} = 161$ to 208 GeV
- $\mathcal{L} = 2.7 \text{ fb}^{-1}$
- No SUSY found
- All limits set at 95% CL
- All σ_{95} limits at $E_{\text{cm}} = 208 \text{ GeV}$

SUSY (MSSM)



- SUSY breaking increase predictability in the observable sector.
(Decrease number of free parameters)
- Different mechanisms give very different phenomenology.
- Each breaking still allows several phenomenological scenarios in the observable sector.

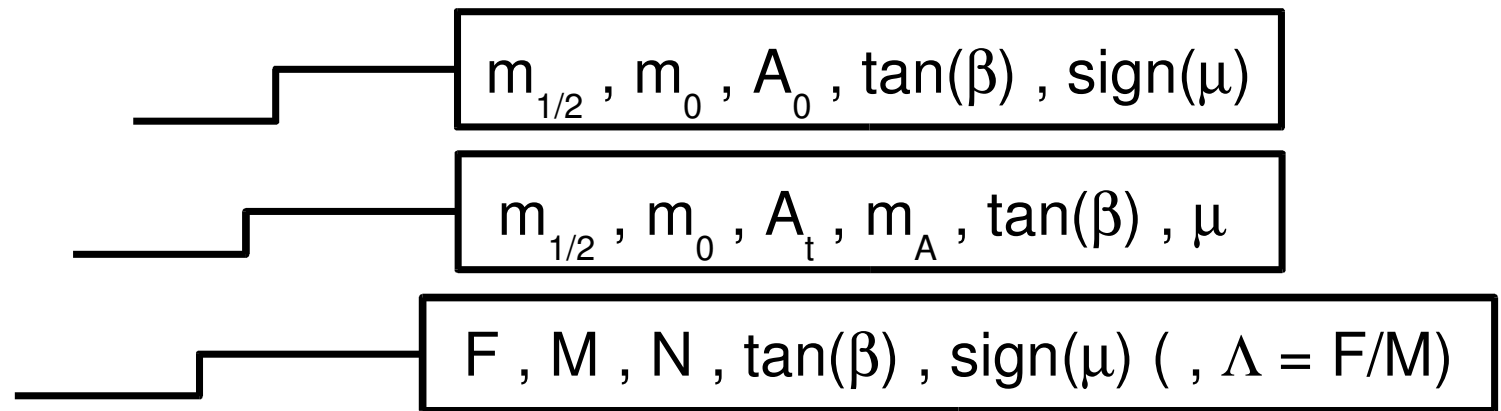
Even more predictive

GUT: Sfermion and Gaugino mass unification, m_0 , $m_{1/2}$, A_0 .

R-parity: Conservation \longrightarrow Stable LSP & Sparticle pair production
 $(R_p = (-1)^{3B+L+2S})$ ~~Conservation~~ \longrightarrow **LLE, LQD, UDD**

EW: Symmetry breaking \longrightarrow $\tan(\beta)$, $\text{sign}(\mu)$

- mSUGRA
- CMSSM
- GMSB



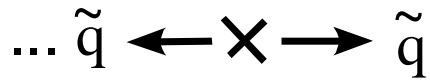
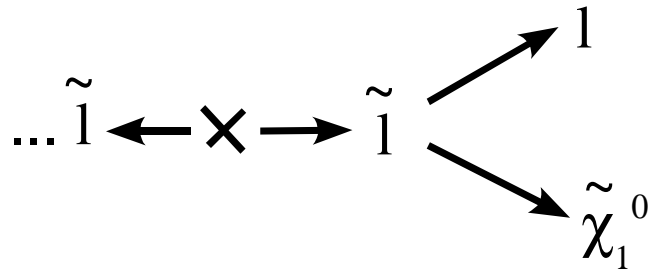
5 - 6 parameters to determine all masses and couplings

BUT still cover most of the realistic scenarios.

LEP

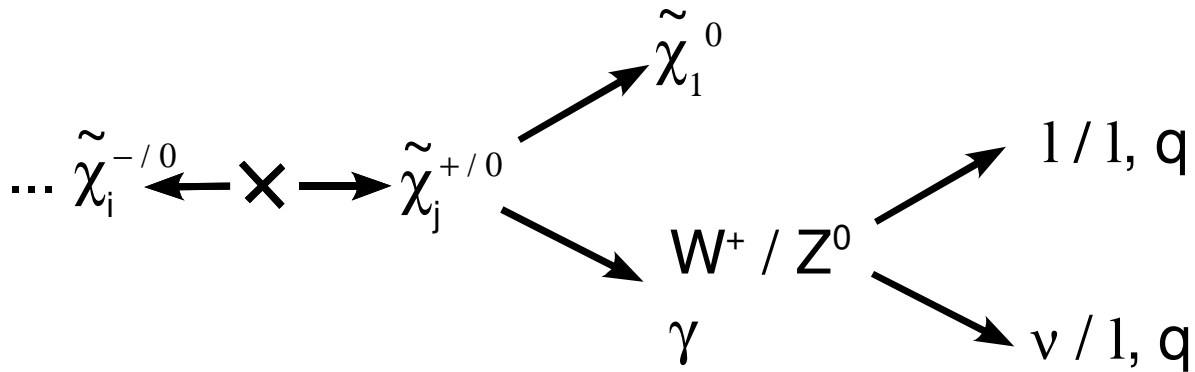
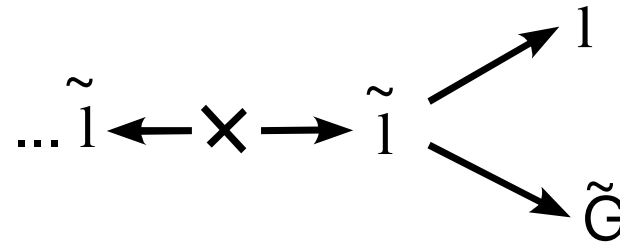
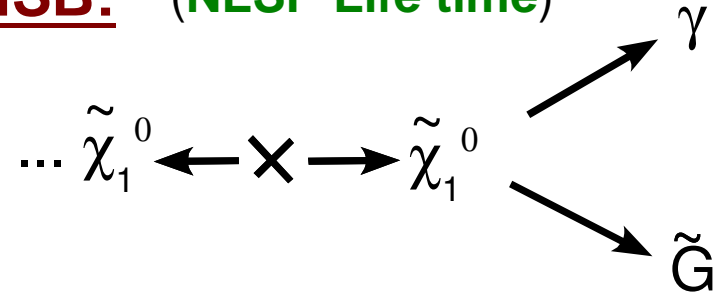


SUGRA:

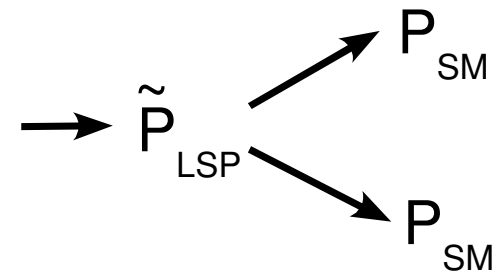


Talk by
A. Kraan

GMSB: (NLSP Life time)



RPV:



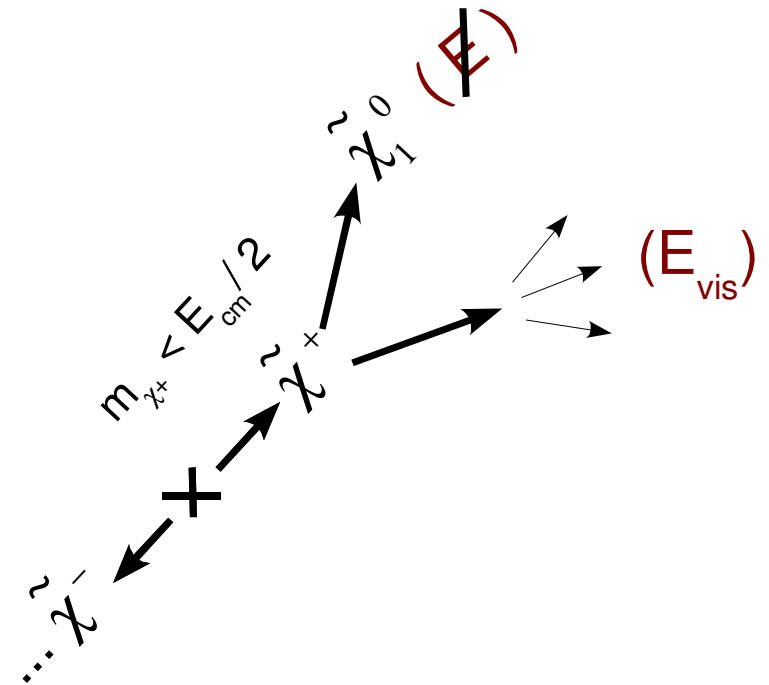
Many topological signatures

BUT with the common signature ~~E~~ from the escaping LSP (R_p -conserved).

Another very important quantity for the signal phenomenology,

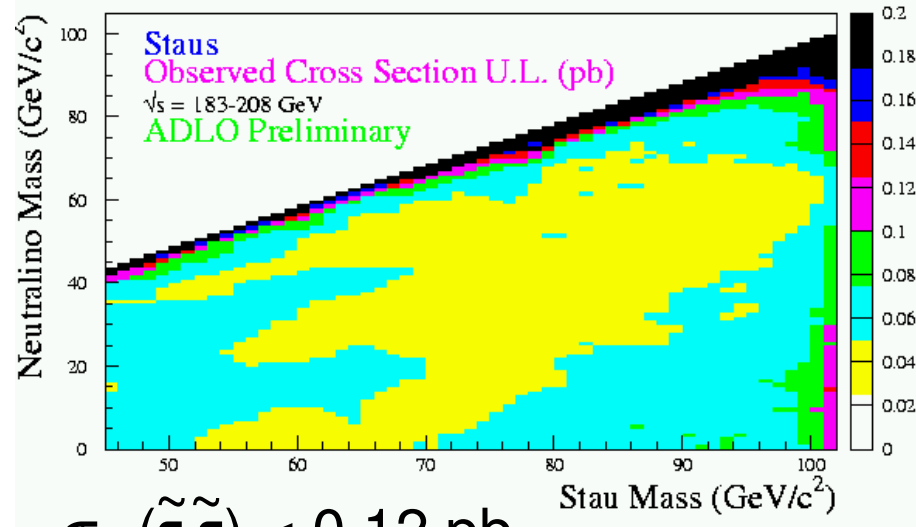
$m_{\text{NLSP}} - m_{\text{LSP}} = \Delta m$, which reflects E_{vis} .

- **Upper limits** on $\sigma(\tilde{p}\tilde{p})$ at 95% CL, as model independent as possible ($\text{Br}(\tilde{p} \rightarrow \dots) = 1$).
(mainly depending on m_{LSP} , m_{NLSP} , Δm , E_{cm})
- **Impossible** to obtain totally **model independent** limits. \longrightarrow The minimum set of required assumptions are based on the most common behavior.
- $\sigma(\tilde{p}\tilde{p})$ interpreted in **mass / parameter exclusion**. Including $\text{Br}(\tilde{p} \rightarrow \dots)$ etc...

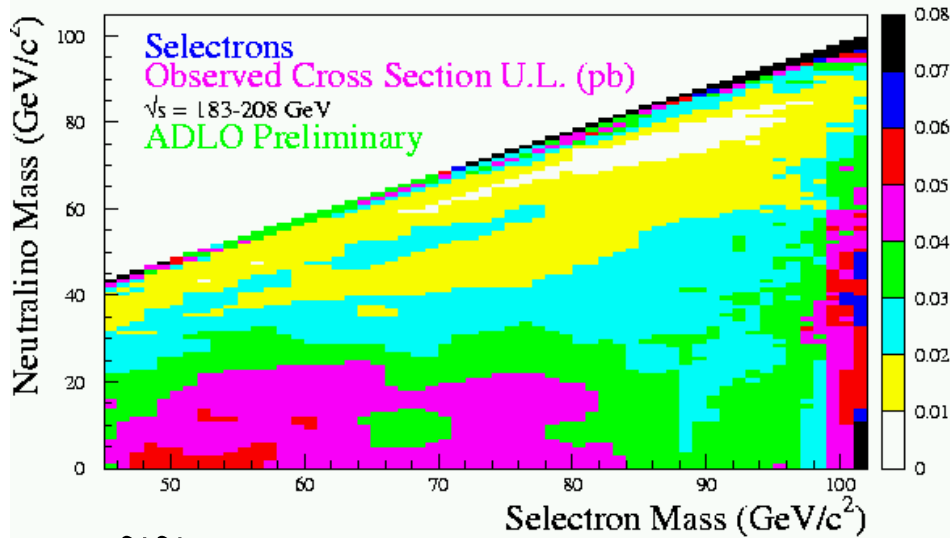


Sleptons (SUGRA)

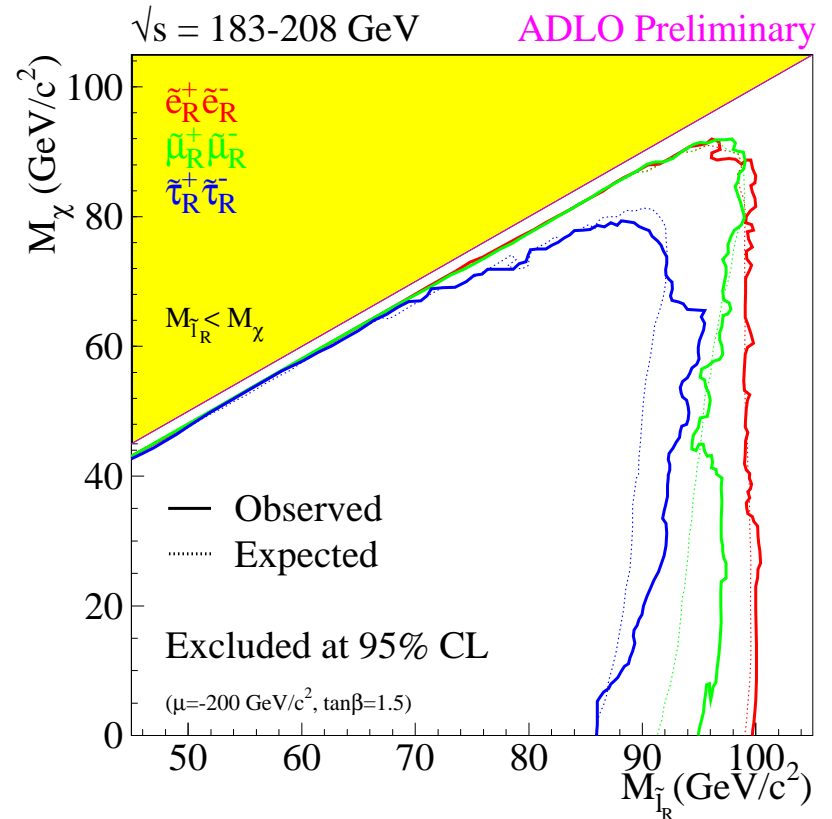
$$\dots \tilde{l} \leftarrow X \rightarrow \tilde{l} \rightarrow l + \tilde{\chi}^0$$



$$\sigma_{95}(\tilde{\tau}\tilde{\tau}) < 0.12 \text{ pb}$$



$$\sigma_{95}(\tilde{e}\tilde{e}) < 0.05 \text{ pb} \quad (\sigma_{95}(\tilde{\mu}\tilde{\mu}) < 0.05 \text{ pb})$$



$$m(\tilde{e}) > 99.6 \text{ GeV}$$

$$\Delta m > 15 \text{ GeV}$$

$$m(\tilde{\mu}) > 94.9 \text{ GeV}$$

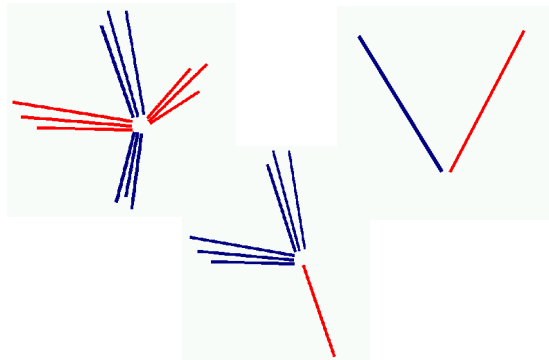
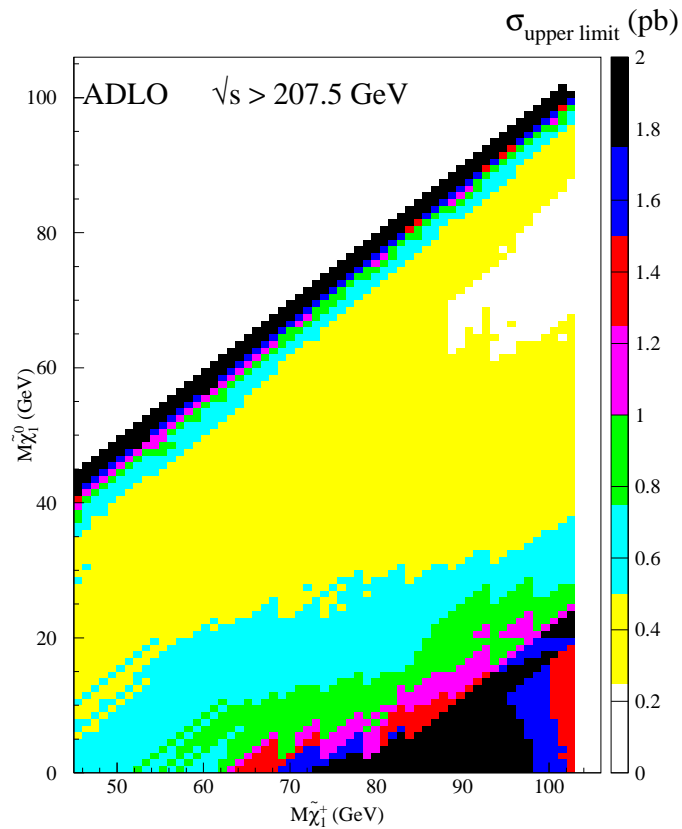
$$\mu = -200$$

$$m(\tilde{\tau}) > 85.9 \text{ GeV}$$

$$\tan\beta = 1.5$$

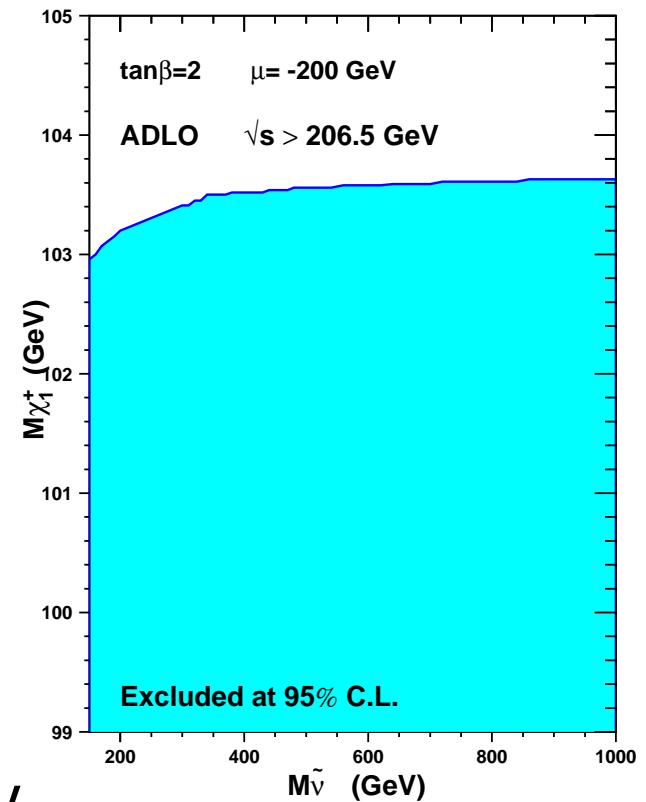
Charginos (SUGRA)

Large m_0 , $\Delta m > 3$ GeV ... $\tilde{\chi}^- \leftarrow X \rightarrow \tilde{\chi}^+ \rightarrow W^+ + \tilde{\chi}^0 \rightarrow ff + \tilde{\chi}^0$



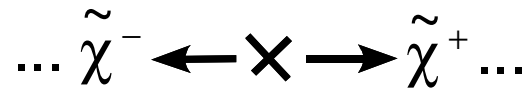
$$\sigma_{95}(\tilde{\chi}^+ \tilde{\chi}^-) < 0.8 \text{ pb}$$

$m(\tilde{\chi}^+) > 103.5$ GeV
for $m(\tilde{\nu}) > 300$ GeV

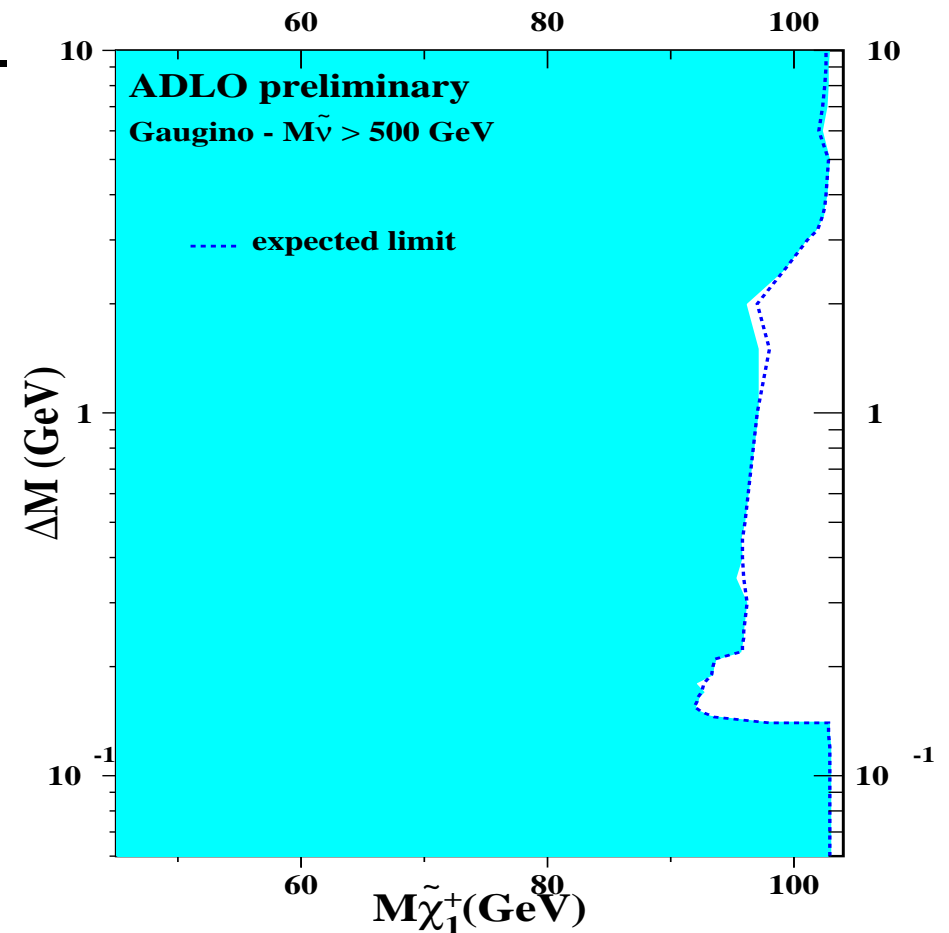


Charginos (SUGRA)

Small Δm



- Large m_0 analysis
 $\Delta m > 3 \text{ GeV}$
- ISR event
 $3 \text{ GeV} > \Delta m > \sim 200 \text{ MeV}$
- Kinks , Large Impact Parameters
+ Heavy stable charged particles
 $\sim 200 \text{ MeV} > \Delta m$



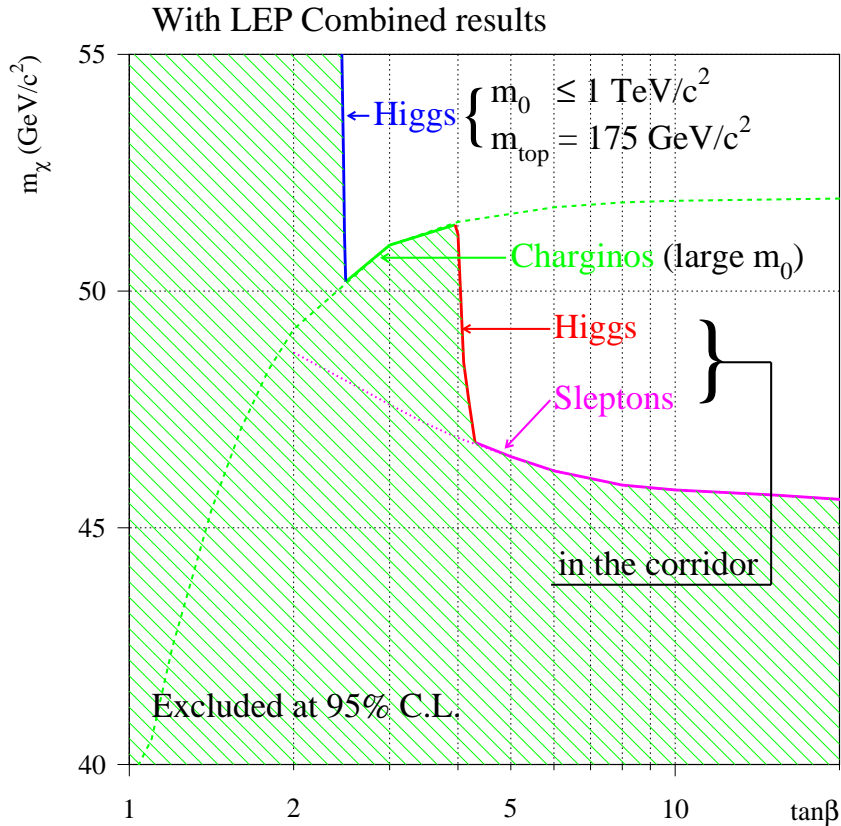
Higgsino scenario: $m(\tilde{\chi}^+) > 92.4 \text{ GeV}$

Gaugino scenario: $m(\tilde{\chi}^+) > 91.9 \text{ GeV}$
(No $m_{1/2}$ GUT assumption)

LSP limit

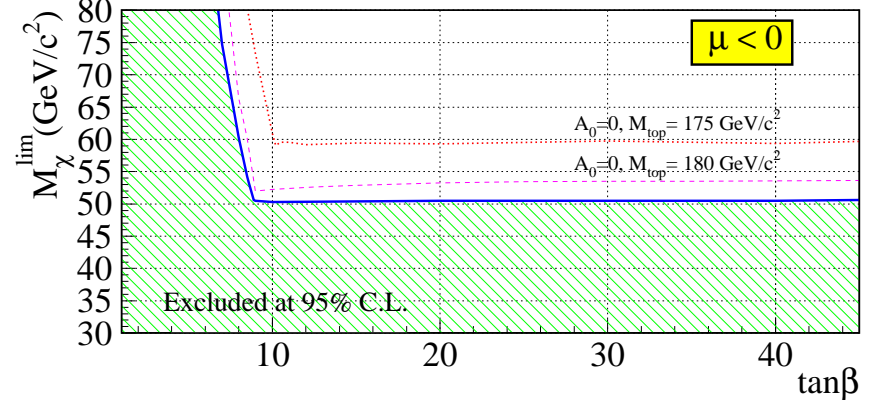
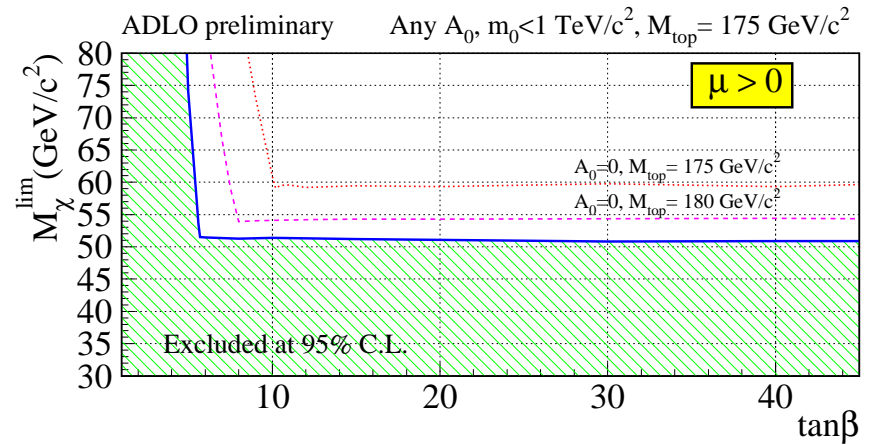
mSUGRA

CMSSM



$$m_{1/2}, m_0, A_t, m_A, \tan(\beta), \mu$$

$$m_{\text{LSP}} > 45 \text{ GeV}$$

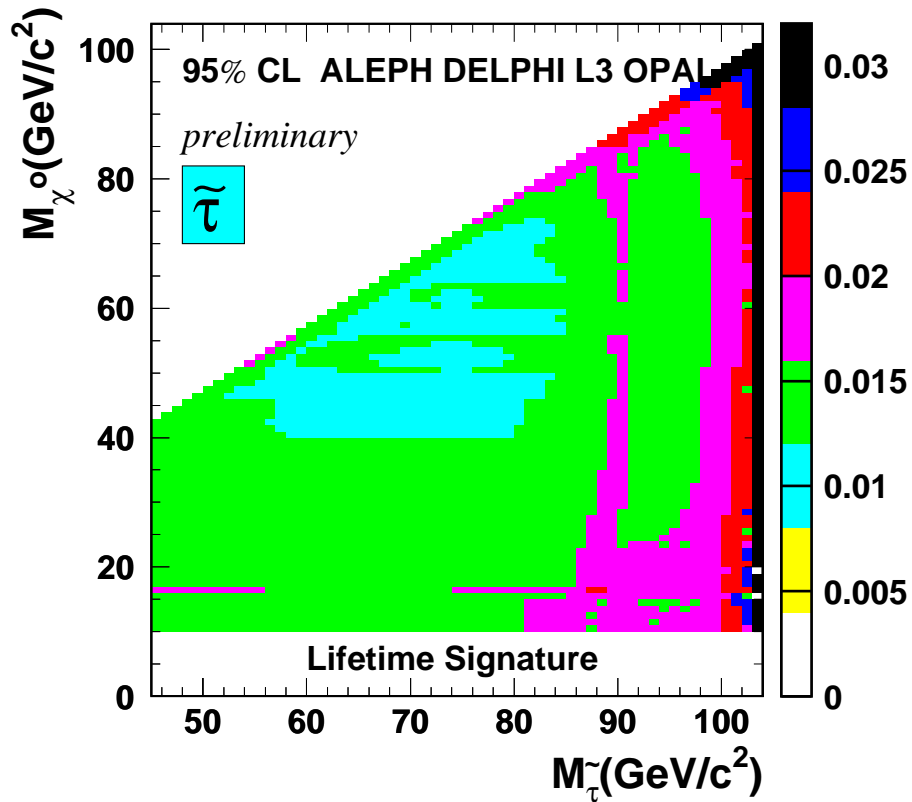


$$m_{1/2}, m_0, A_0, \tan(\beta), \text{sign}(\mu)$$

$$m_{\text{LSP}} > 50.8 \text{ GeV}, \mu > 0$$

$$m_{\text{LSP}} > 50.3 \text{ GeV}, \mu < 0$$

RPV (LLE)



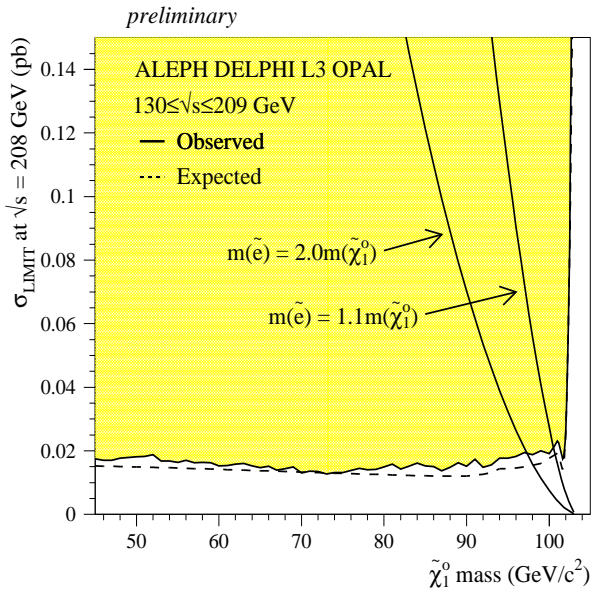
$$\sigma_{95}(\tilde{e}\tilde{e}) < 0.02 \text{ pb}$$

$$\sigma_{95}(\tilde{\mu}\tilde{\mu}) < 0.02 \text{ pb}$$

$$\sigma_{95}(\tilde{\tau}\tilde{\tau}) < 0.02 \text{ pb}$$

$\Delta m > 3 \text{ GeV},$ $m(\tilde{\chi}^0) > 10 \text{ GeV}$	
	$m(\tilde{l}) >$
\tilde{e}	96.6
$\tilde{\mu}$	96.9
$\tilde{\tau}$	95.9
$\tilde{\nu}_e$	98.9
$\tilde{\nu}_\mu$	84.5

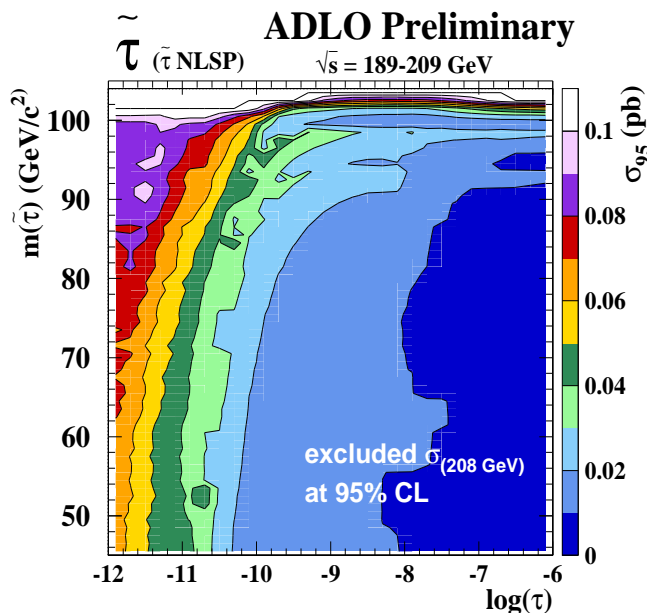
$$(\mu = -200 \quad \tan(\beta) = 1.5)$$



GMSB

$$\tilde{\chi}^0 \tilde{\chi}^0 \rightarrow \gamma\gamma + \cancel{e}$$

$$\sigma_{95}(\tilde{\chi}^0 \tilde{\chi}^0) < 0.025 \text{ pb}$$



+ LEP1 Results

$$\tilde{l} \tilde{l} \rightarrow ll + \cancel{e}$$

Any lifetime

$$m(\tilde{e}) > 65.8 \text{ GeV}$$

$$m(\tilde{\mu}) > 96.3 \text{ GeV}$$

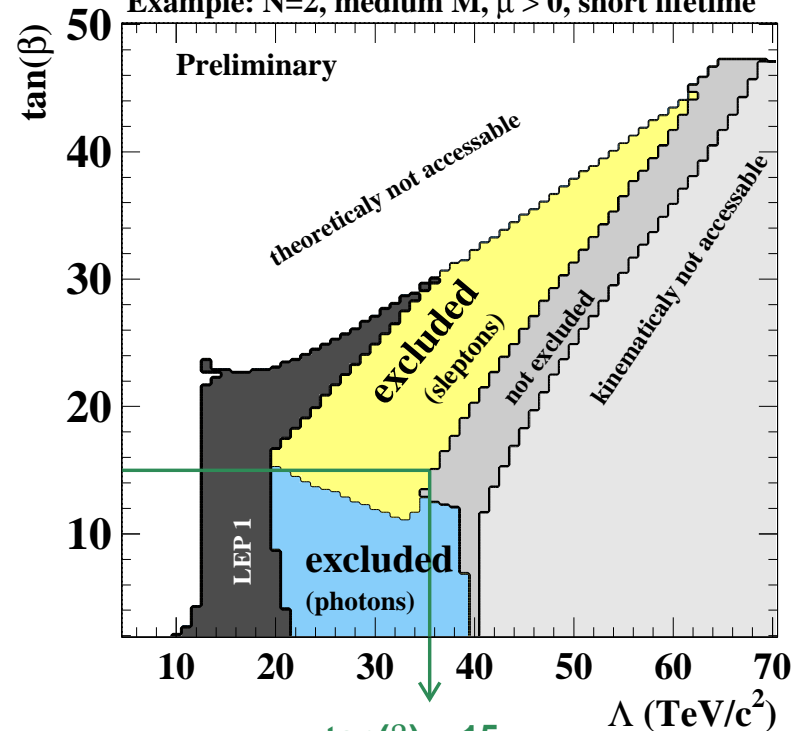
$$m(\tilde{\tau}) > 86.9 \text{ GeV}$$

Instant $\tilde{\chi}^0, \tilde{l}$ decay

Scan in GMSB parameter space following

Dimopoulos, Thomas, Wells, Nucl. Phys. B488 (1997) 39

Example: N=2, medium M, $\mu > 0$, short lifetime

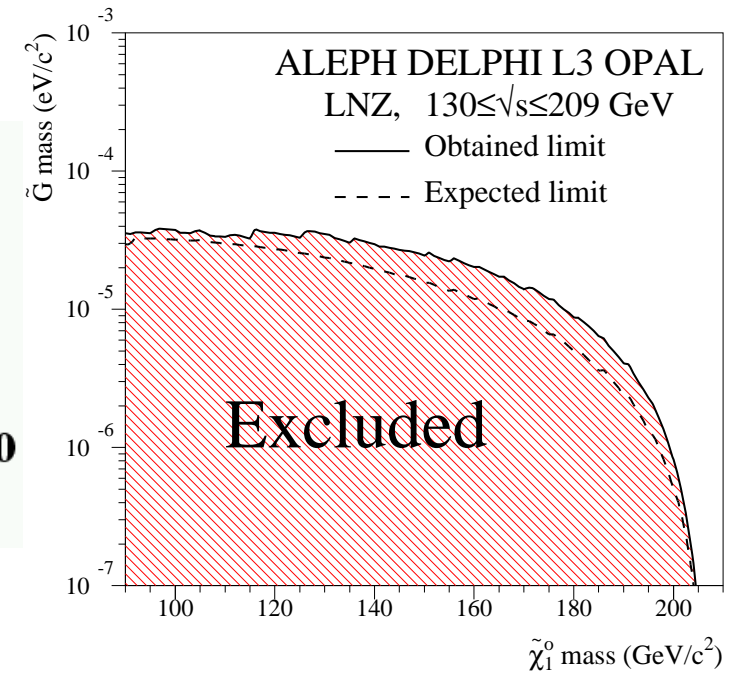
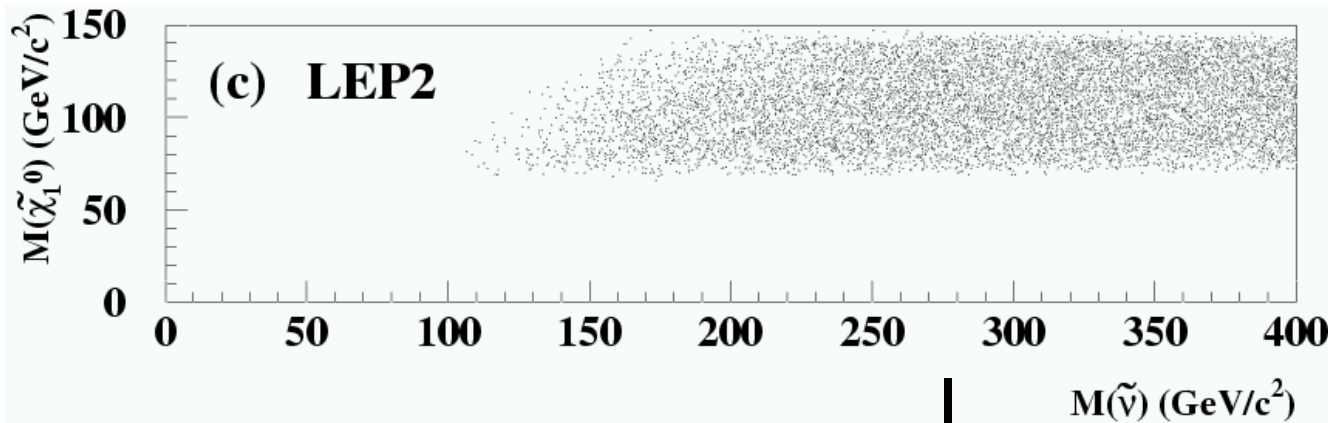


and others

String motivated "one"-parameter model ($m_{\tilde{\chi}_0}$), with $m_{\tilde{G}} < O(1 \text{ KeV})$.

No-Scale model

AMSB (DELPHI)




SUSY broken by anomaly terms in the super potential only.

$$m(\tilde{\nu}) > 98 \text{ GeV}$$

$$m(\tilde{\chi}^0) > 68 \text{ GeV}$$

Conclusions

- No significant indication of SUSY was observed by any of the four experiments during the LEP2 period.


 E_{cm} up to 208 GeV
 $\mathcal{L} = 2.7 \text{ fb}^{-1}$

- Many of the SUSY analyses made at the individual experiments have now been combined and tighter bounds on SUSY have been obtained.

SUGRA		
\tilde{P}	$m_{obs} (m_{exp}) \text{ GeV}$	Assumptions
$\tilde{\tau}$	85.0 (84.7)	$\Delta m > 15 \text{ GeV}, \sigma_{min}, m_{\tilde{\chi}^0} = 0$
	91.7 (88.8)	$\Delta m > 15 \text{ GeV}, \sigma_{min}, m_{\tilde{\chi}^0} = 40$
$\tilde{e}, \tilde{\mu}$	Under preparation	
$\tilde{\chi}^{\pm}$	103.5 (103.3)	Large $m_0, \Delta m > 3 \text{ GeV}, m_{\tilde{\nu}} > 300 \text{ GeV}$
	92.4 (92.8)	Any $\Delta m, \mu \ll M_2, \text{CMSSM}$
	91.9 (91.9)	Any $\Delta m, \text{Gaugino}, m_{\tilde{\nu}} > 500 \text{ GeV}$
$\tilde{\chi}^0$	45	CMSSM
	50.8	mSUGRA, $\mu > 0$
	50.3	mSUGRA, $\mu < 0$
GMSB		
\tilde{e}	65.8 (70)	\tilde{e} NLSP, any lifetime
$\tilde{\mu}$	96.3 (95)	$\tilde{\mu}$ NLSP, any lifetime
$\tilde{\tau}$	86.9 (90)	$\tilde{\tau}$ NLSP, any lifetime
RPV		
\tilde{e}	96.6 (92.9)	$\Delta m > 3 \text{ GeV}, m_{\tilde{\chi}^0} > 10 \text{ GeV}$
$\tilde{\mu}$	96.9 (92.9)	$\Delta m > 3 \text{ GeV}, m_{\tilde{\chi}^0} > 10 \text{ GeV}$
$\tilde{\tau}$	95.9 (92.0)	$\Delta m > 3 \text{ GeV}, m_{\tilde{\chi}^0} > 10 \text{ GeV}$
AMSB		
$\tilde{\nu}$	98	\tilde{e} NLSP, any lifetime
$\tilde{\chi}^0$	68	\tilde{e} NLSP, any lifetime

Transparencies: www.quark.lu.se/~sask/doc/Mortalk03.pdf

Further LEP results: www.cern.ch/LEPSUSY