Interpretation of Neutralino and SLepton Search in minimal GMSB Model

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OUTLINE

- Introduction of GMSB model
- Search for Neutralino (by Marat Gataullin)
- Search for Stau (by Lei Xia)
- Scan over Parameter Space of minimal GMSB
- Scan Results
- Conclusion

Introduction of GMSB model

• Minimal GMSB Model

- Assume R-parity is conserved.
- Gravitino $\tilde{G}$ is the lightest SUSY particle(LSP).
- NLSP can decay into its SM partner and a gravitino.
  - A) $\tilde{\chi}_1^0 \to \gamma\tilde{G}$
  - B) $\tilde{\tau}_1 \to \tau\tilde{G}$
  - C) $\tilde{\ell}_R \to \ell\tilde{G}$ $(\ell = e,\ \mu)$

• Four Benchmark Scenarios

[see Phys. Rev., D56(1997) P1761-1777]

1. Neutralino NLSP (A):

$$m_{\tilde{\chi}_1^0} < m_{\tilde{\tau}_1} - m_\tau$$

2. Stau NLSP (B):

$$m_{\tilde{\tau}_1} < Min[m_{\tilde{\chi}_1^0},\ m_{\tilde{\ell}_R}] - m_\tau$$

3. Slepton co-NLSP (B and C):

$$m_{\tilde{\ell}_R} < Min[m_{\tilde{\chi}_1^0}\, m_{\tilde{\tau}_1} + m_\tau]$$

4. Neutralino-Stau co-NLSP (A and B):

$$|m_{\tilde{\tau}_1} - m_{\tilde{\chi}_1^0}| < m_\tau;\ m_{\tilde{\chi}_1^0} < m_{\tilde{\ell}_R}$$

Introduction of GMSB model

- Parameters of the minimal GMSB

1. The universal mass scale of SUSY particle: Λ
2. Ratio of two Higgs vacuum expectation values: $\tan\beta$
3. The common messenger mass scale: M_{mess}
4. The number of messenger pairs: N_5
5. The higgsino mass parameter: $sign(\mu)$
6. The gravitino mass: $m_{\tilde{G}}$

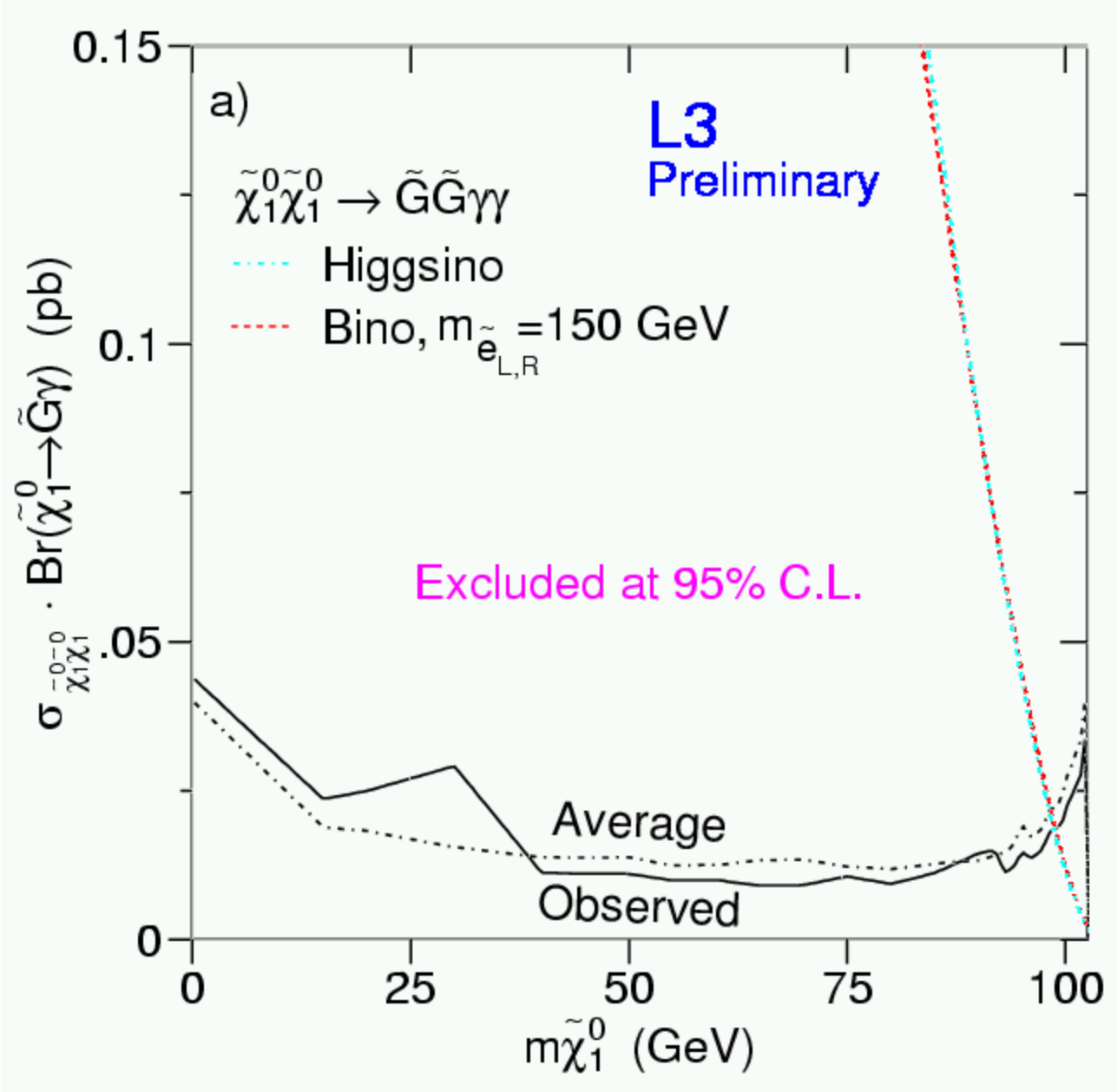
$$m_{\tilde{G}} = \frac{F}{\sqrt{3}M_{Plank}} = 2.37 \times (\frac{\sqrt{F}}{100TeV})^2 \quad eV/c^2$$

- Decay Length of NLSP

$$L_{NLSP} = 9.9 \times 10^{-7}(\frac{m_{NLSP}}{100GeV/c^2})^{-5} \times (\frac{m_{\tilde{G}}}{2.37\times10^{-2}eV/c^2})^2 \times \sqrt{\frac{E^2_{NLSP}}{m^2_{NLSP}} - 1} \quad cm$$

Search for Neutralino

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



⇒ Cross section limit at 95 % C.L..

- [see L3 Note 2644 and 2707]

- Signal Process: (see Lei's talk in Hungary, 2001)

$$e^+e^- \to \tilde{\tau}\tilde{\tau} \to \tau\tilde{G}\tau\tilde{G}$$

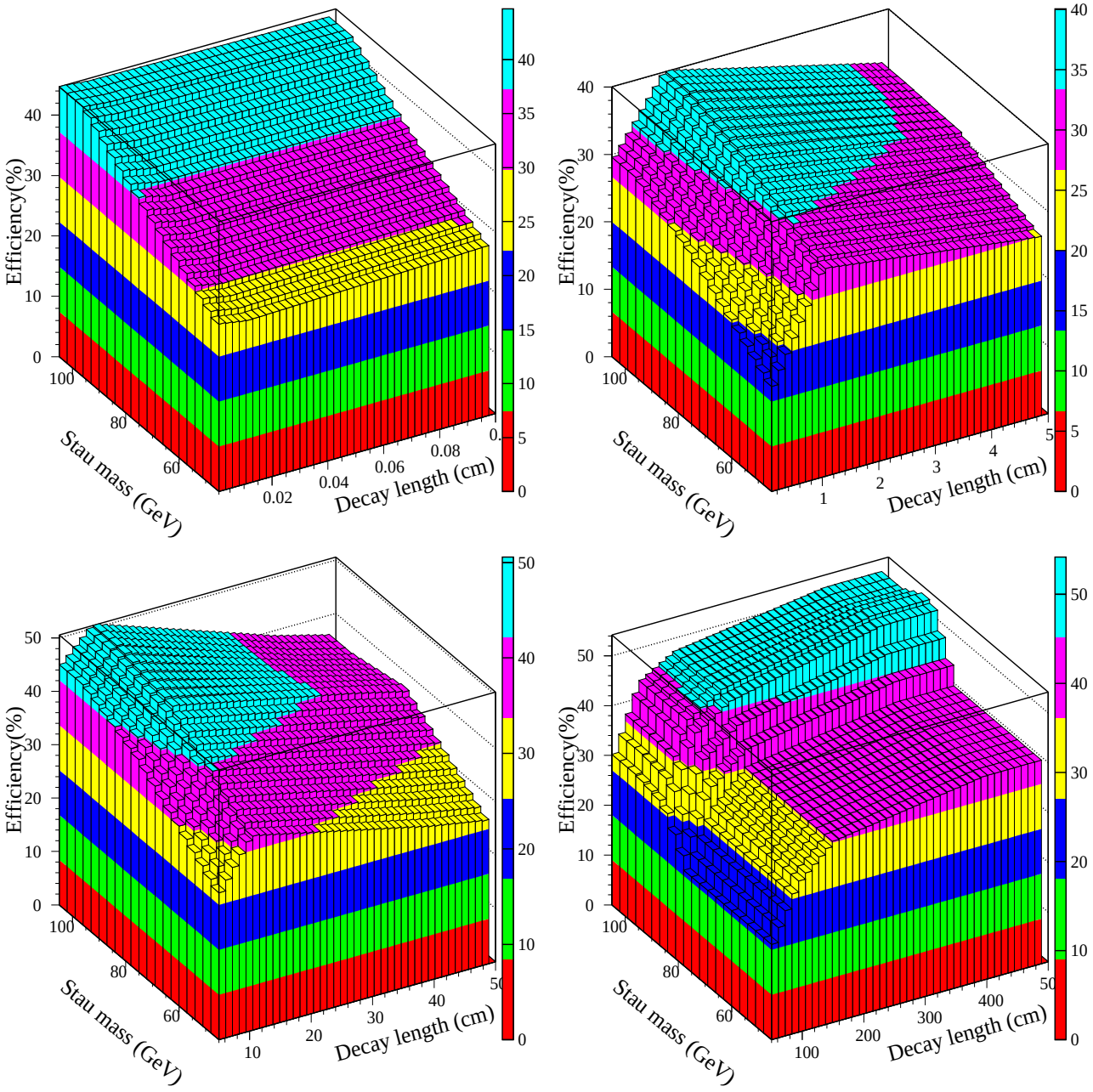
- Event Topologies

Decay Length		Event Signature
Invisible	< 1 mm	Acoplanar leptons + E_{miss}
Short	[1 mm - 5 cm]	non-zero DCA
Medium	[5 cm - 50 cm]	large impact parameter
Long	> 50 cm	heavy charged particles

- Data Samples - $\mathcal{L}_{1999+2000} = 452.8 pb^{-1}$

$$\mathcal{L}_{\sqrt{s}=192GeV} = 29.8 \quad pb^{-1}$$
$$\mathcal{L}_{\sqrt{s}=196GeV} = 84.1 \quad pb^{-1}$$
$$\mathcal{L}_{\sqrt{s}=200GeV} = 84.0 \quad pb^{-1}$$
$$\mathcal{L}_{\sqrt{s}=202GeV} = 39.2 \quad pb^{-1}$$
$$\mathcal{L}_{\sqrt{s}=204GeV} = 24.3 \quad pb^{-1}$$
$$\mathcal{L}_{\sqrt{s}=206GeV} = 182.7 \quad pb^{-1}$$
$$\mathcal{L}_{\sqrt{s}=208GeV} = 8.7 \quad pb^{-1}$$

Stau Selection Efficiency



⇒ Signal Efficiency(interpolated) depends on Stau mass and decay length.

Selection Results

$\sqrt{s}$ (GeV)	Invisible $N_d(N_{mc})$	Short $N_d(N_{mc})$	Medium $N_d(N_{mc})$	Long $N_d(N_{mc})$	Long(dE/dx) $N_d(N_{mc})$
192	10(13.2)	0(2.14)	0(0.35)	6(1.78)	0(0.1)
196	41(34.0)	10(5.9)	1(0.9)	7(5.3)	0(0.04)
200	31(31.1)	4(5.2)	1(0.72)	3(4.5)	1(0.26)
202	14(14.4)	3(2.85)	1(0.42)	2(2.17)	1(0.06)
204	32(26.0)	5(5.3)	1(0.81)	8(5.2)	0(0.19)
206	40(41.7)	11(8.3)	3(1.31)	10(8.2)	0(0.06)
208	3(2.73)	0(0.61)	0(0.09)	0(0.48)	0(0.02)
ALL	171(163.1)	33(30.3)	7(4.6)	36(27.7)	2(0.73)

$\Rightarrow$ Data agree with SM backgrounds though there has small excess in Data.

Scan of minimal GMSB model

- Parameters of the minimal GMSB

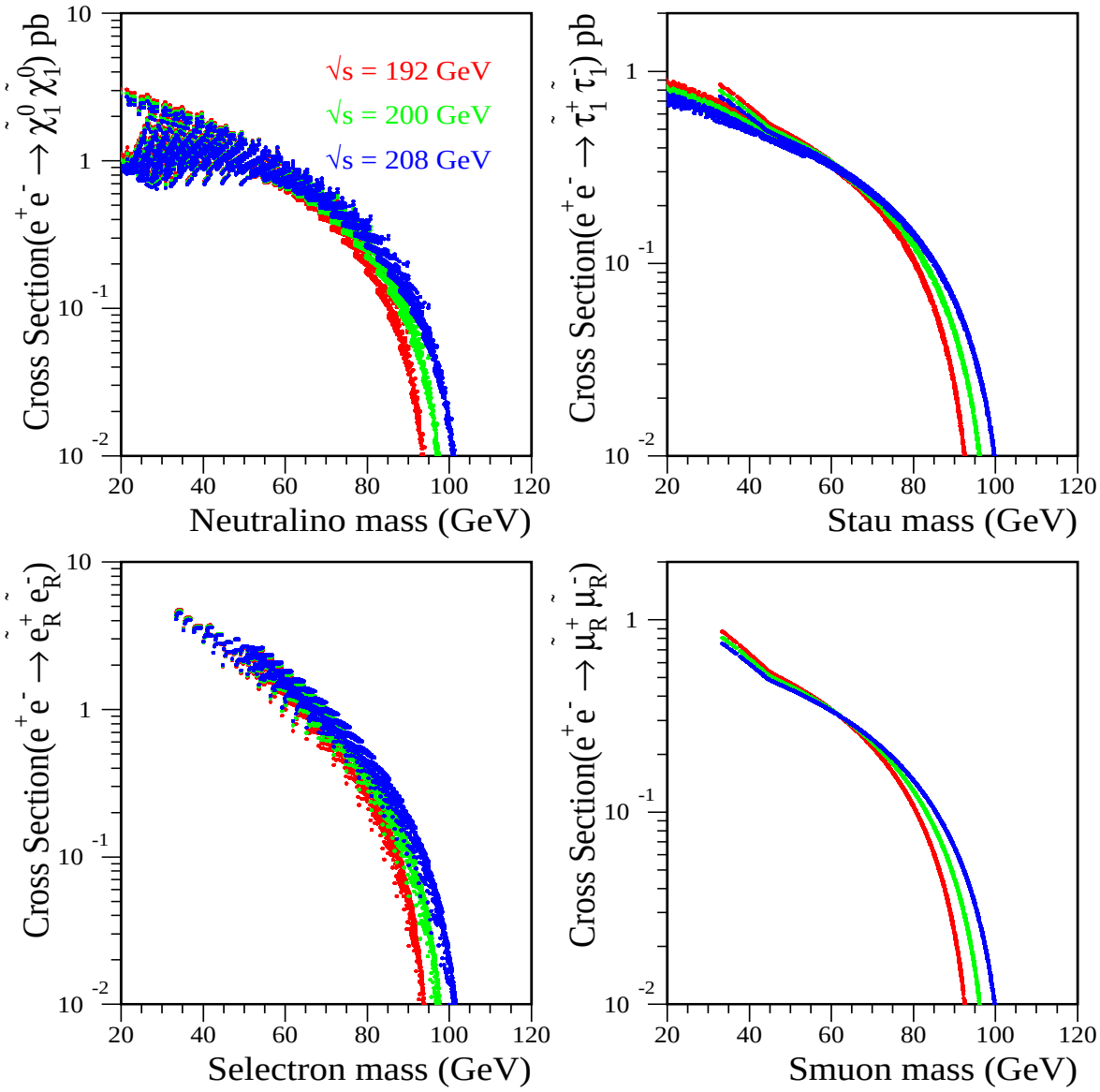
1. The universal mass scale of SUSY particle:
   $10\ TeV \leq \Lambda \leq 100\ TeV$, 46 points with 2 TeV step.
2. Ratio of two Higgs vacuum expectation values:
   $1.5 \leq \tan\beta \leq 40$, 15 points
   1.5, 2, 3, 4, 5, 6, 7, 8, 10, 15, 20, 25, 30, 35, 40
3. The common messenger mass scale:
   $10\ TeV \leq M_{mess} \leq 10000\ TeV$, 16 points
   uniform in logarithmic scale.
4. The number of messenger pairs:
   $N_5 = 1,\ 2,\ 3,\ 4,\ 5$
5. The higgsino mass parameter:
   $sign(\mu) < 0$ or $sign(\mu) > 0$
6. The gravitino mass:
   $0.01\ eV \leq m_{\tilde{G}} \leq 10\ KeV$, 31 points
   uniform in logarithmic scale.

$\Rightarrow$ More than 3.4 million points are scanned in minimal GMSB parameter space.

- scan program based on ISAJET and MSMLIB package
  - see [http://www.cern.ch/paige/]
  - see [http://alephwww.cern.ch/ ganis/MSMLIB/msmlib.html]

Cross Sections of SUSY processes

GMSB parameters, N5=1, Sign(mu) < 0



⇒ Cross sections depend on SUSY particle mass and center of mass energy.

Confidence Level Calculation

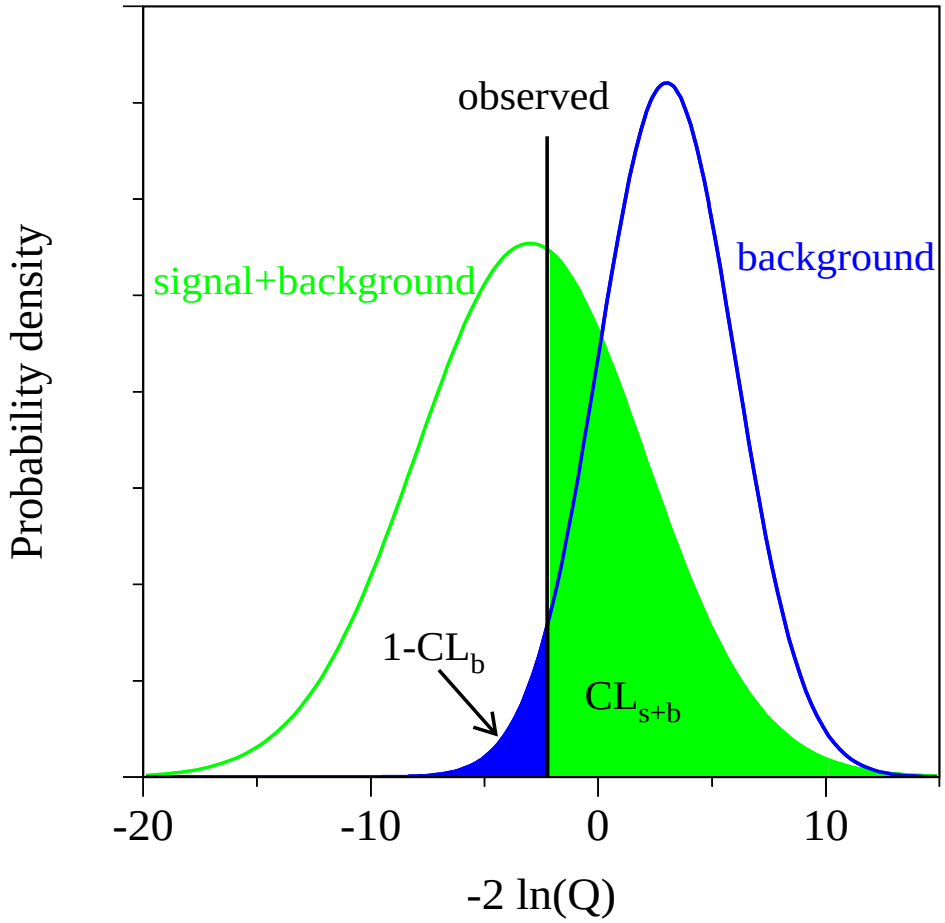
- Binned likelihood technique:

$$\mathcal{L}(s+b) = \prod_{i=1}^{N_{cme}} P(N^i_{data},\ N^i_{sig} + N^i_{bkgd})$$

- Likelihood Ratio test-statistic:

$$Q = \frac{\mathcal{L}(s+b)}{\mathcal{L}(b)}$$

- MC experiments are based on Poisson statistics.



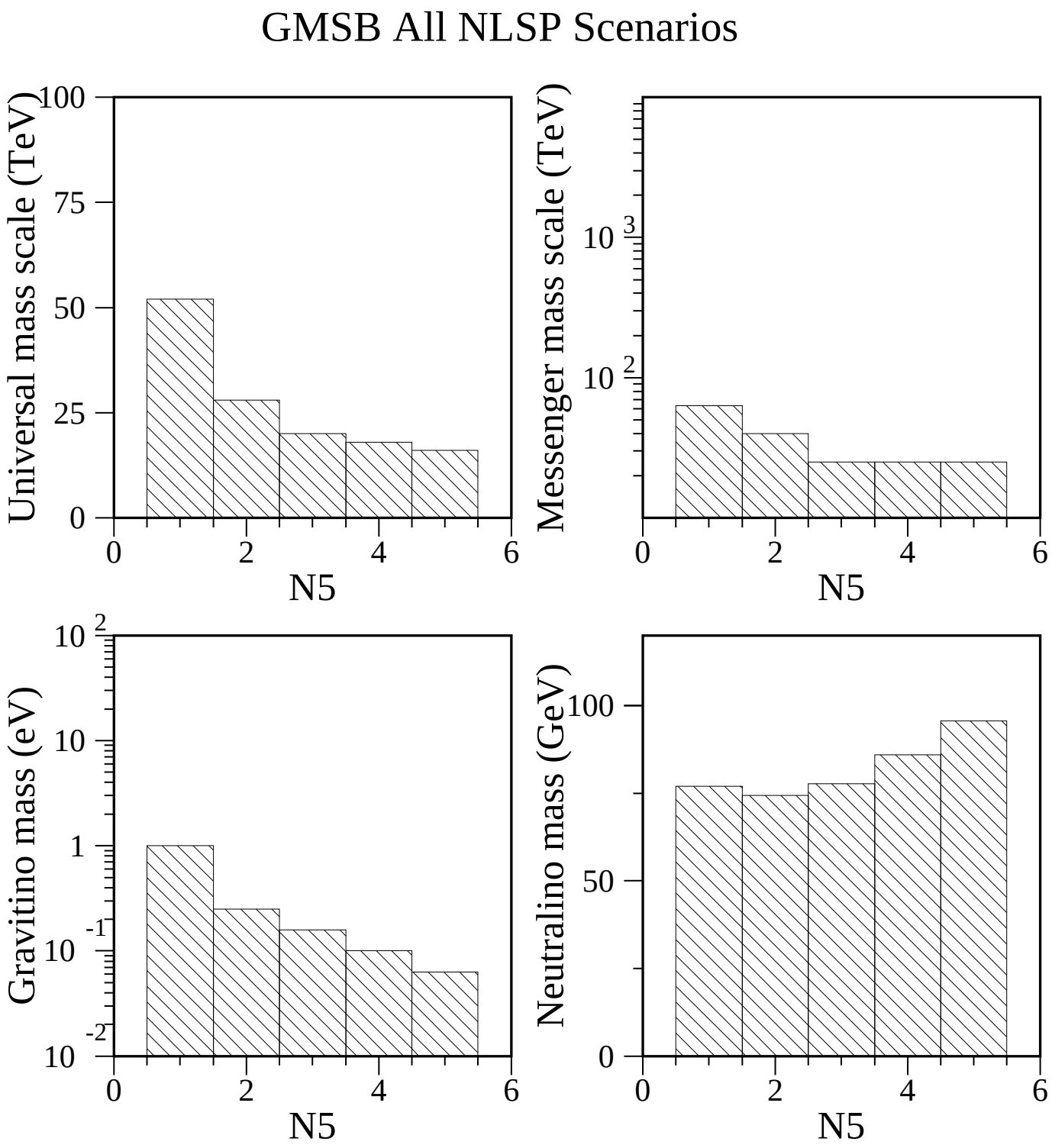
$$\Rightarrow CL_s \equiv CL_{s+b}/CL_b$$

Exclusion Limit at 95% C.L.

- Lower limits for all 4 NLSP scenarios.

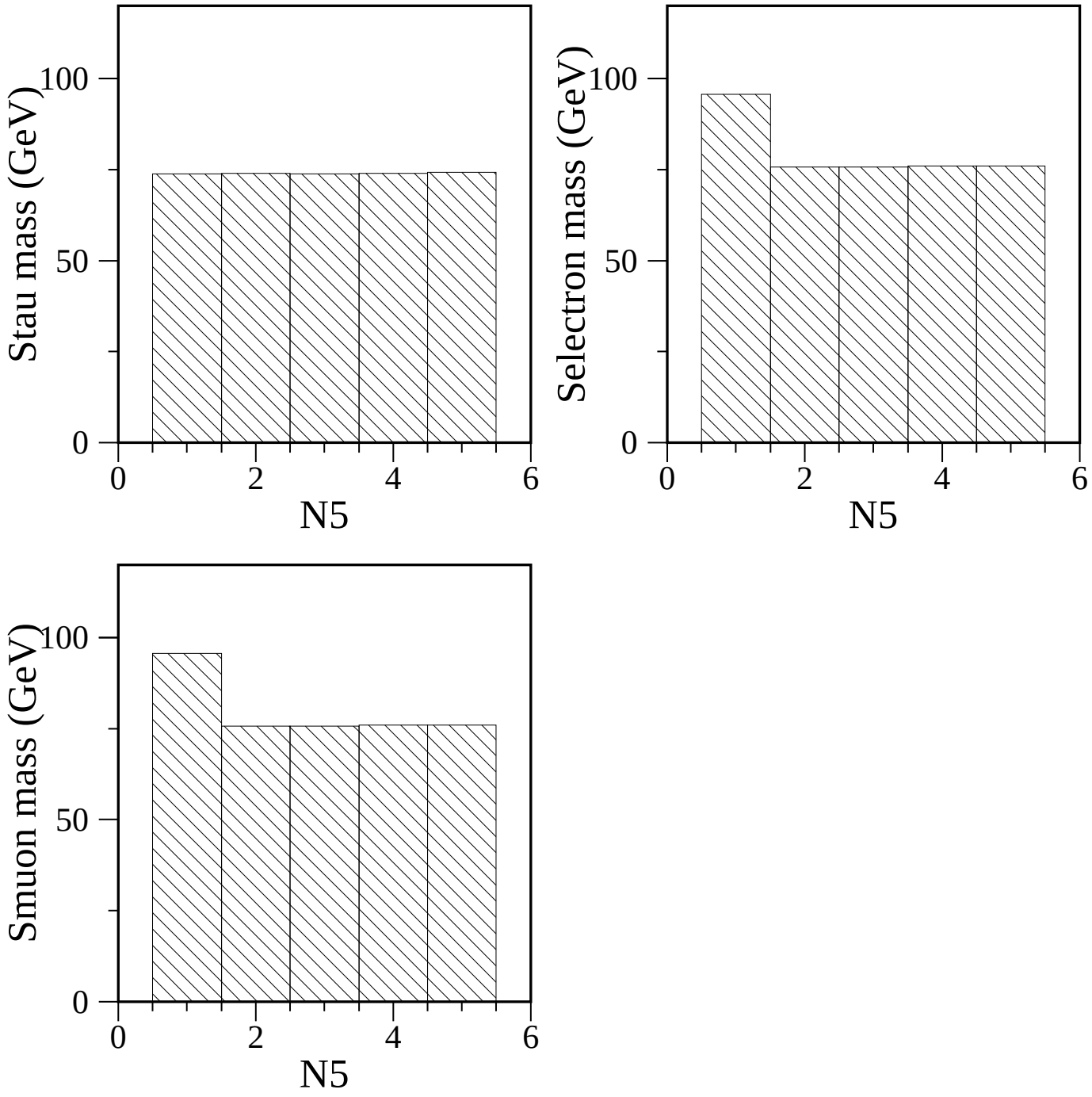
Minimal GMSB Parameters		Number of Messenger Pairs (N5)				
		1	2	3	4	5
Λ	(TeV)	52	28	20	18	16
M_{mess}	(TeV)	63	40	25	25	25
$m_{\tilde{G}}$	(eV)	1	0.25	0.16	0.10	0.06
$m_{\tilde{\chi}_1^0}$	(GeV)	77.03	74.38	77.63	85.94	95.71
$m_{\tilde{\tau}_1}$	(GeV)	73.89	73.97	73.88	74.02	74.27
$m_{\tilde{e}_R}$	(GeV)	95.66	75.75	75.65	75.95	75.95
$m_{\tilde{\mu}_R}$	(GeV)	95.66	75.75	75.65	75.95	75.95

Exclusion Limit at 95% C.L.

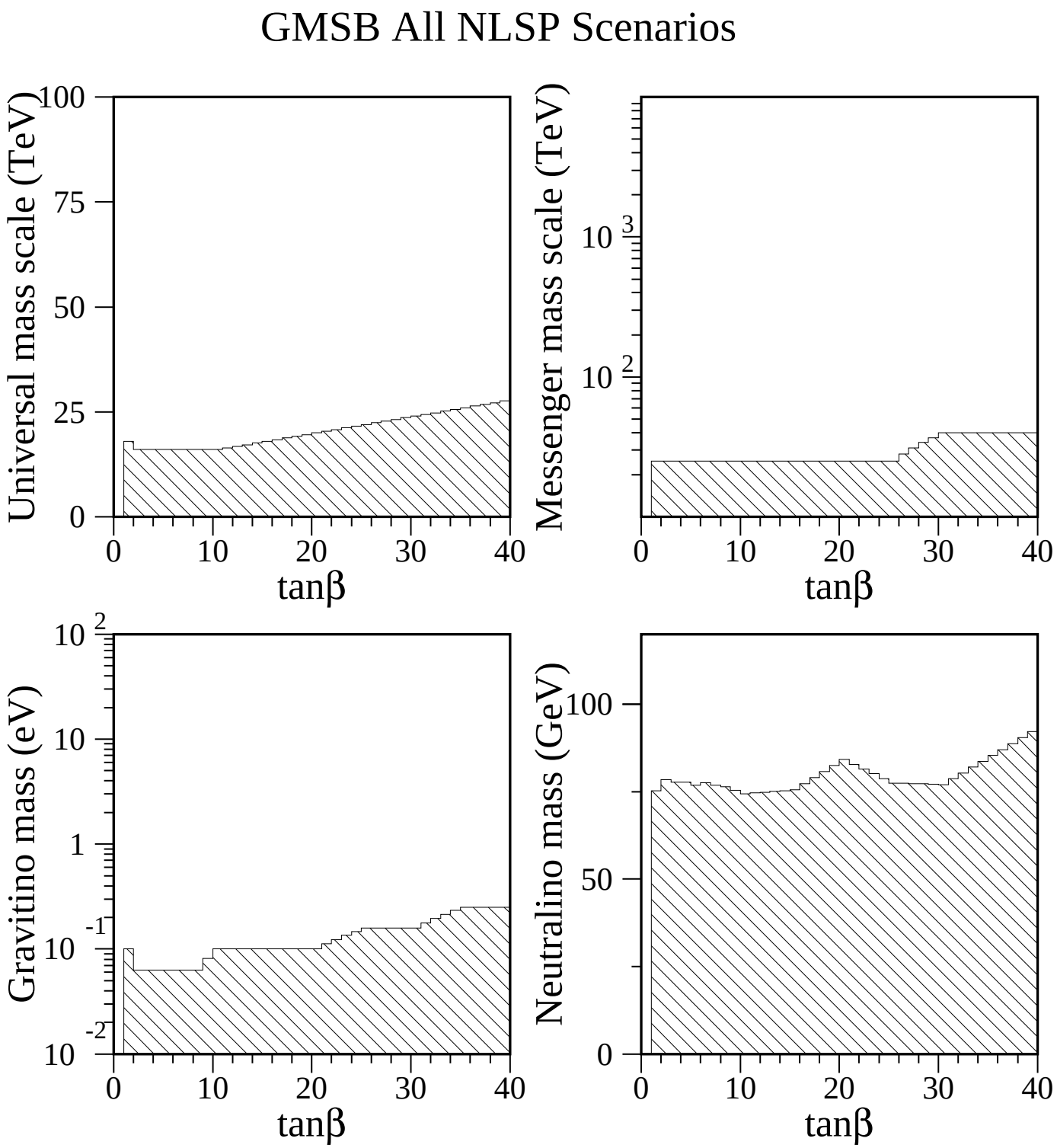


Exclusion Limit at 95% C.L.

GMSB All NLSP Scenarios

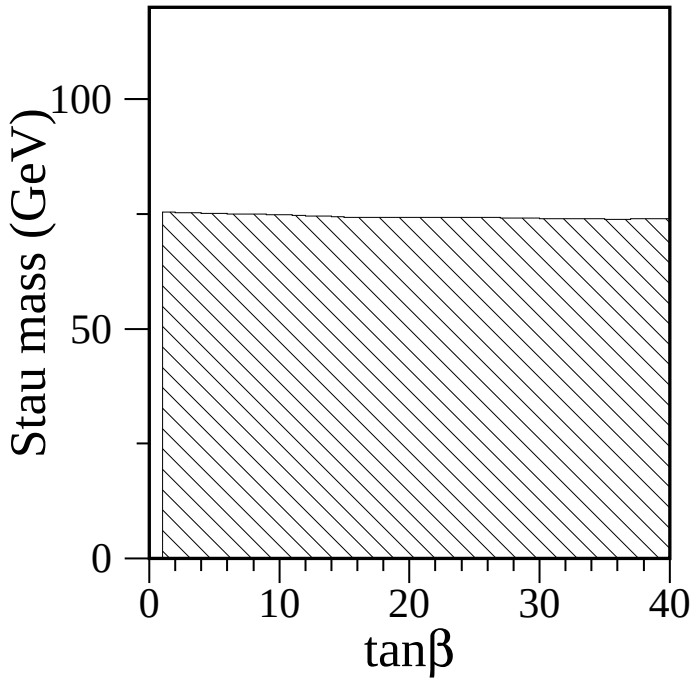


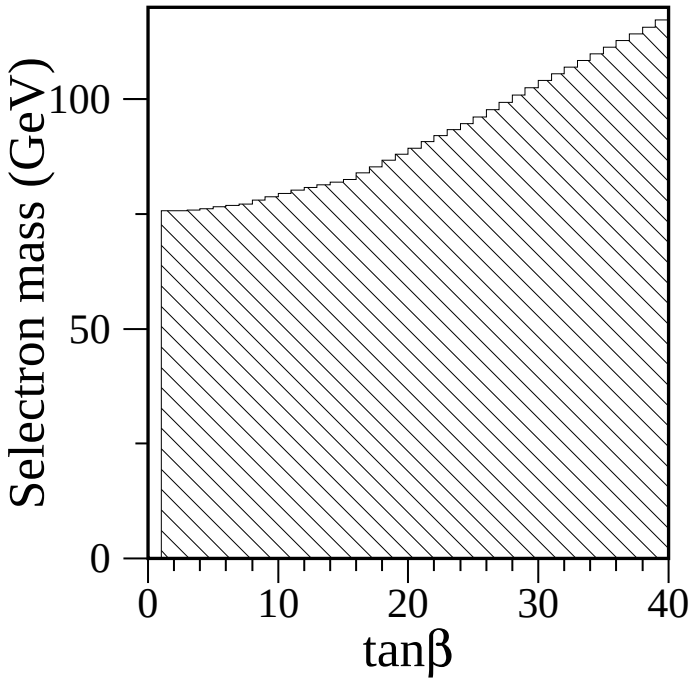
Exclusion Limit at 95% C.L.

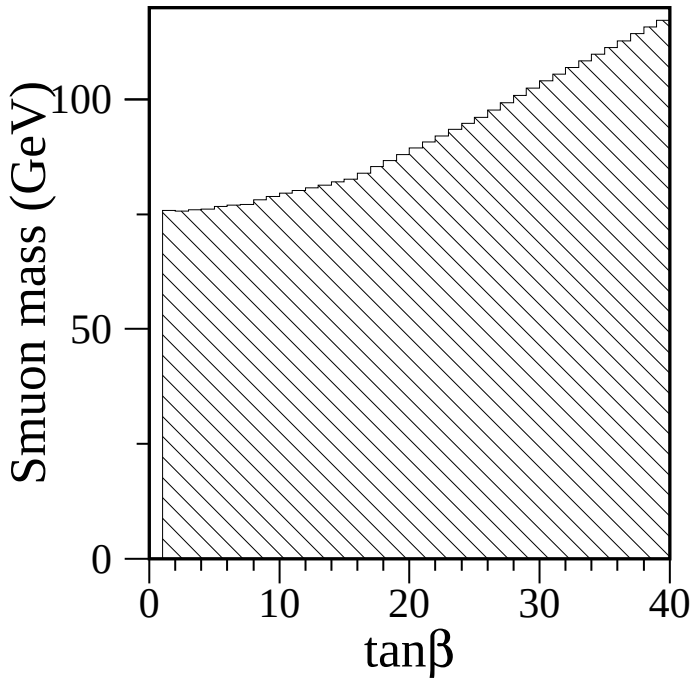


Exclusion Limit at 95% C.L.

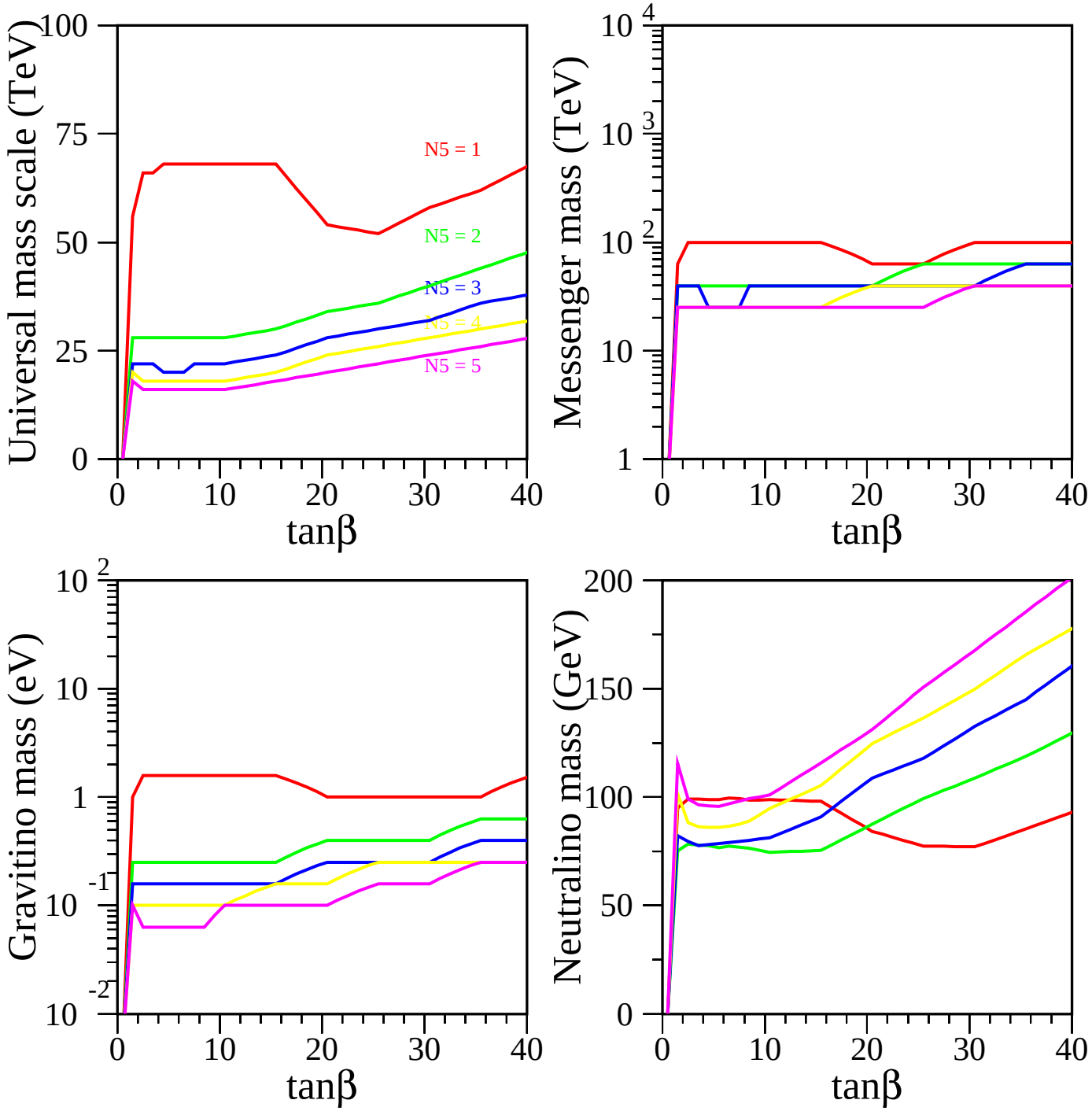
GMSB All NLSP Scenarios





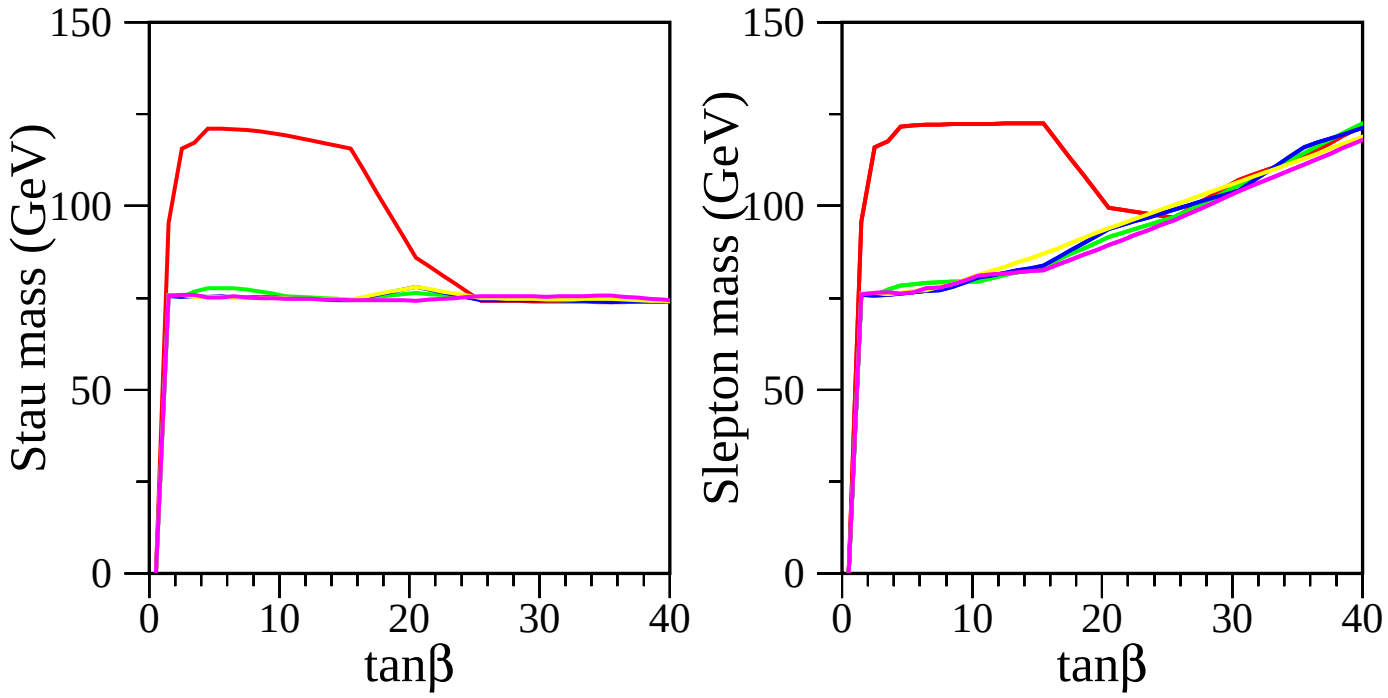


GMSB All NLSP Scenarios

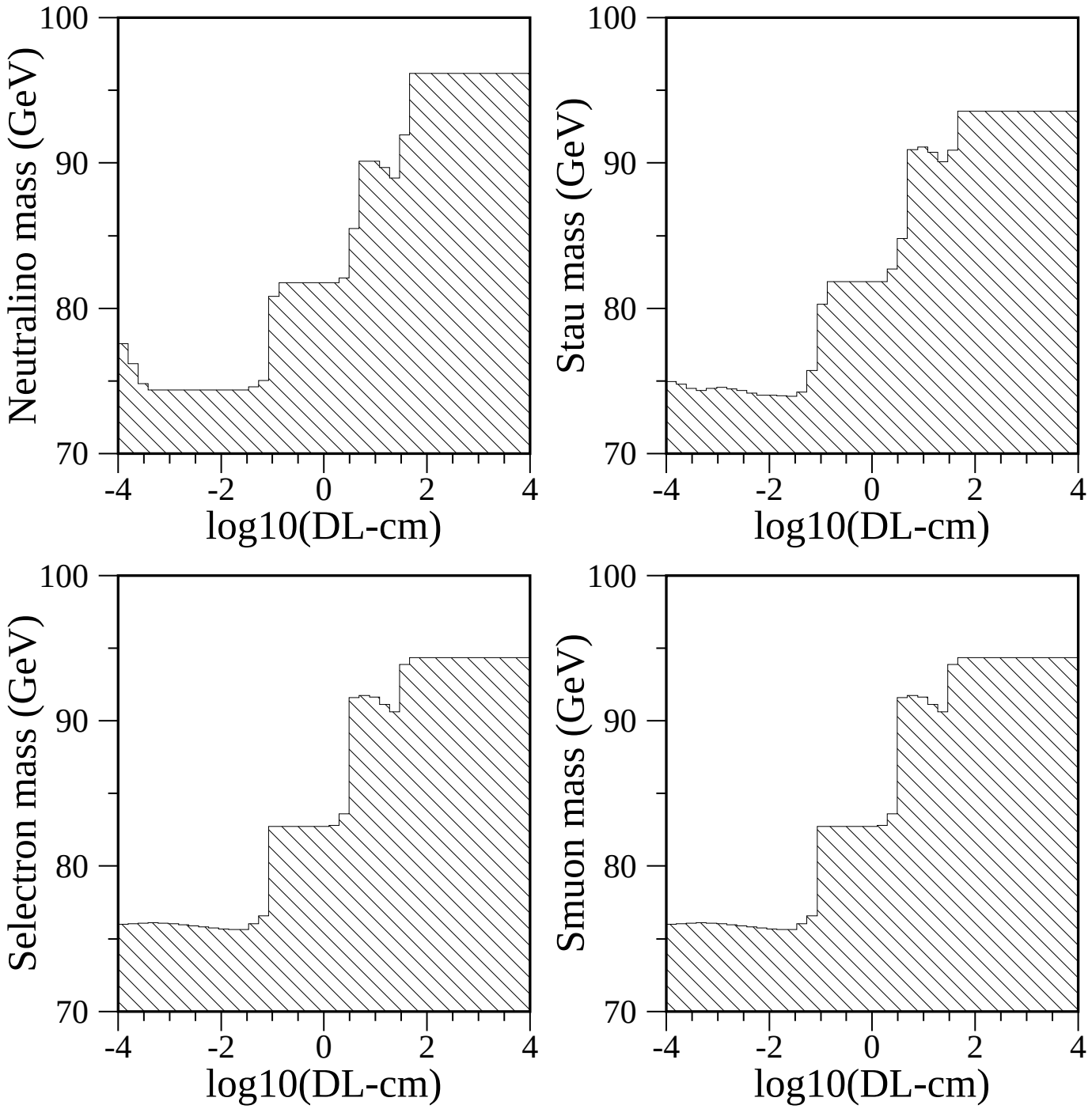


Exclusion Limit at 95% C.L.

GMSB All NLSP Scenarios



Exclusion Limit at 95% C.L.



Conclusions

- More than 450 pb^{-1} data collected in the year 1999 & 2000 are used in this analysis.

$\Rightarrow$ Lower limits at 95% C.L.

Minimal GMSB Parameters		NLSP Benchmark Scenarios				
		$\tilde{\chi}_1^0$	$\tilde{\tau}_1$	$\tilde{\tau}_1$ & $\tilde{\ell}_R$	$\tilde{\chi}_1^0$ & $\tilde{\tau}_1$	ALL
Λ	(TeV)	38	16	16	22	16
M_{mess}	(TeV)	100	25	25	40	25
$m_{\tilde{G}}$	(eV)	0.4	0.06	0.06	0.16	0.06
$m_{\tilde{\chi}_1^0}$	(GeV)	98.10	77.03	77.07	74.38	74.38
$m_{\tilde{\tau}_1}$	(GeV)	102.51	73.88	75.14	74.66	73.88
$m_{\tilde{e}_R}$	(GeV)	105.11	77.11	75.65	77.25	75.65
$m_{\tilde{\mu}_R}$	(GeV)	105.11	77.11	75.65	77.25	75.65