Dilepton end-point signatures of the GMSB scenarios in the CMS detector

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Outline:

Basics of Gauge Mediated Supersymmetry Breaking models

Phenomenological implications

– Nature of the NLSP

– Example of the GMSB search method in the CMS detector

  * SUSY signature: "end-point"

– Accessible range of the parameter space

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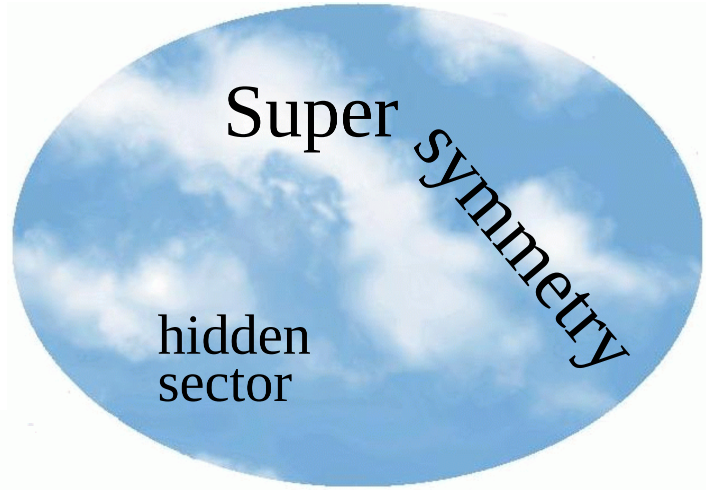
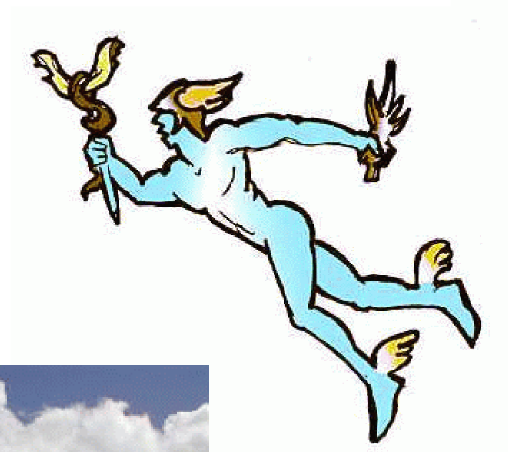
Gauge Mediated Supersymmetry Breaking Models

Λ effective scale of SUSY breaking





messenger sector

N singlets of SU(5)

acquire mass M

ect of SUSY breaking in the hidden sector is transfered to the visible sector

ne-loop correction – gauginos:

$$m_{\lambda_i} = N\frac{\alpha_i}{4\pi}\Lambda$$

• two-loop correction – sleptons and squarks:

$$\tilde{m}^2 = 2N\Lambda^2 \sum_{i=1}^{3}\left[c_i\left(\frac{\alpha_i}{4\pi}\right)^2\right]$$

he larger number of couplings the heavier sfermions.

Masses: $\tilde{q}_L > \tilde{q}_R > \tilde{l}_L > \tilde{\nu} > \tilde{l}_R$

auginos are heavier then sfermions by the factor $\sqrt{N}$.

Masses: $\tilde{g} > \tilde{W}/\tilde{Z} > \tilde{\gamma}$

dditionally SUSY particle masses are split by tg(β) and sign(μ).

$\Lambda\sim$ 10–1000 TeV and $M > \Lambda$ then gravitino : $m_{\tilde{G}} = \frac{M\Lambda}{\sqrt{3M_P}} \simeq 2.4\left(\frac{M\Lambda}{(100\ TeV)^2}\right) eV$
mass of order $\mathcal{O}$(1eV–1keV). It is the lightest supersymmetric particle (LSP).

Phenomenology of GMSB

Λ=30-1000 TeV, M=40-30000 TeV, tanβ=1.5-55, sign(μ)=±1

GMSB models are classified with
ect to the sort of particle which
ays to the stable - gravitino.

didates for the Next to the LSP:

e lightest neutralino – $\tilde{N}_1$

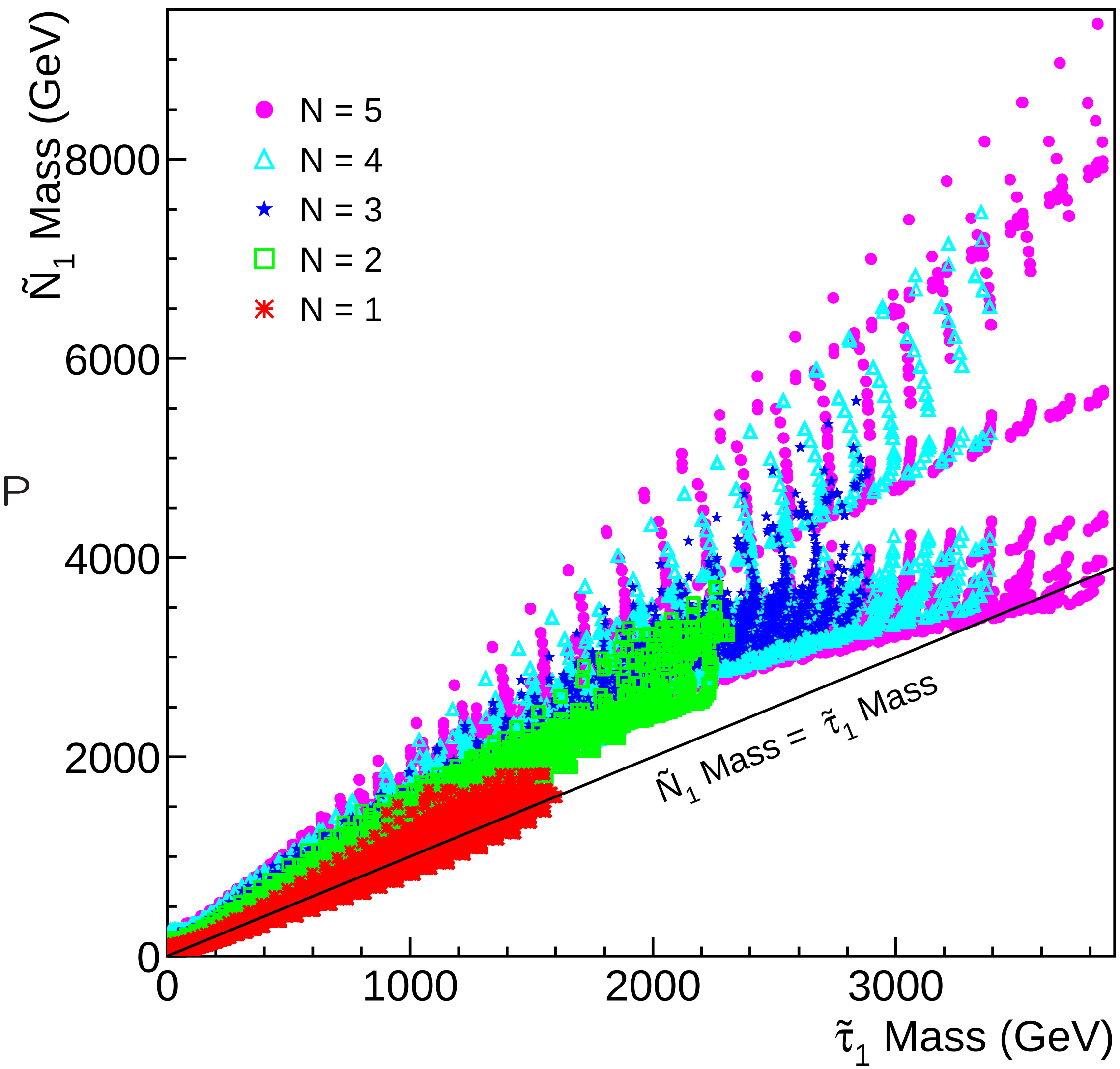
e lightest right slepton – $\tilde{\tau}_1$

generated sleptons – $\tilde{\tau}_1$ $\tilde{\mu}_R$ $\tilde{e}_R$, co–NLSP

AJET 5.73 – event generator with
SB(Λ,M,N,tg(β),sign(μ)) function

tom interface added

ulation of models
ide range of paramter values

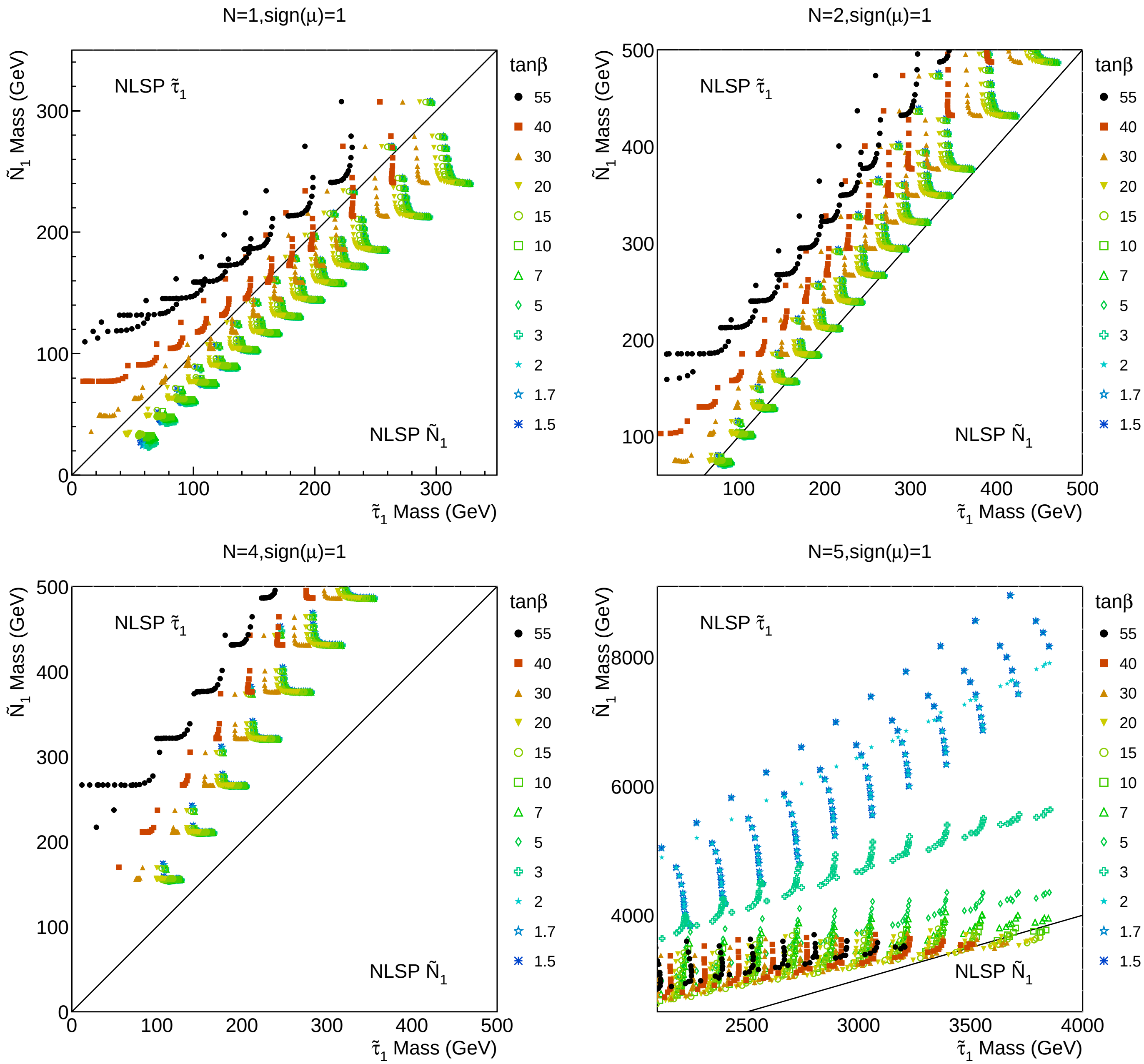


Next to the Lightest Supersymmetry Particle: NLSP

$\tilde{\tau}_1$

or

$\tilde{N}_1$?

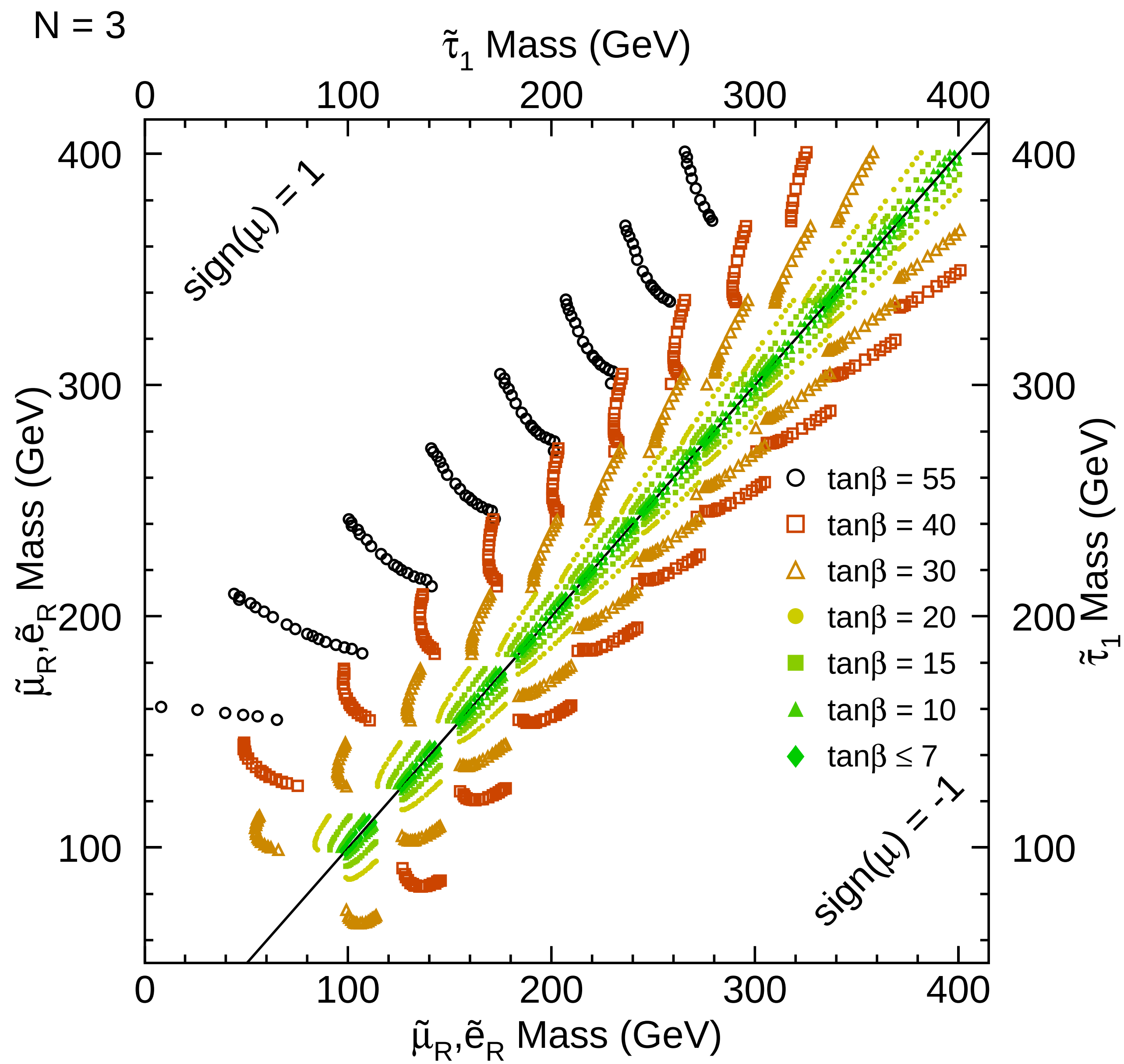


NLSP: slepton degeneracy

$\tilde{\tau}_1$

or

$\tilde{\tau}_1 \quad \tilde{e}_R \quad \tilde{\mu}_R \quad ?$



SUPERsymmetric signature

decay cascade of the heavy sparticle with lepton emission causes **a sharp end–point**
he M_{inv} of all combination of opposite sign lepton pairs: $\mu^+\mu^- + e^+e^- - \mu^+e^- - e^+\mu^-$.
s well–known **edge** originates from

$$\tilde{N}_2 \to \tilde{l}_R + l \qquad \tilde{l}_R \to \tilde{N}_1 + l$$

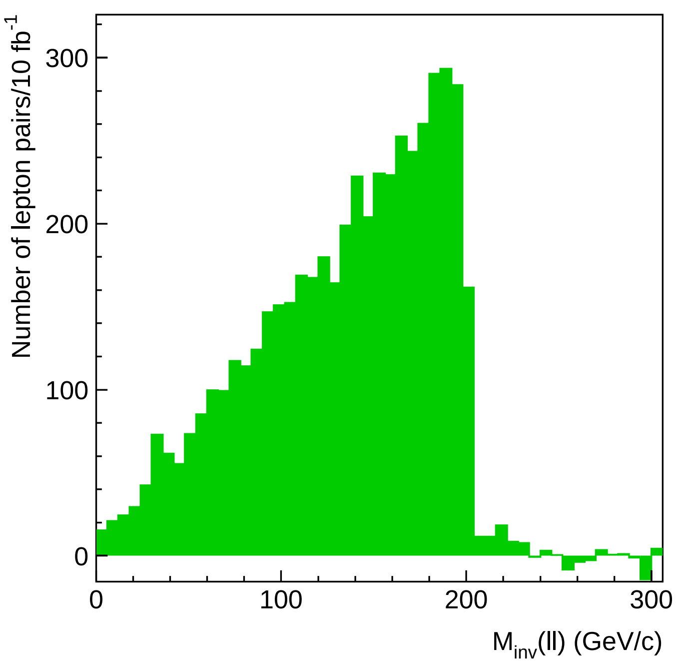
if NLSP is the neutralino $\tilde{N}_1$

$$M_{inv}(ll)_1 = \frac{\sqrt{m^2_{\tilde{N}_2} - m^2_{\tilde{l}_R}}\sqrt{m^2_{\tilde{l}_R} - m^2_{\tilde{N}_1}}}{m_{\tilde{l}_R}}$$

$$\tilde{N}_1 \to \tilde{l}_R + l \qquad \tilde{l}_R \to \tilde{G} + l$$

if NLSP is the slepton $\tilde{\tau}_1$ or/and $\tilde{\mu}_R,\ \tilde{e}_R$

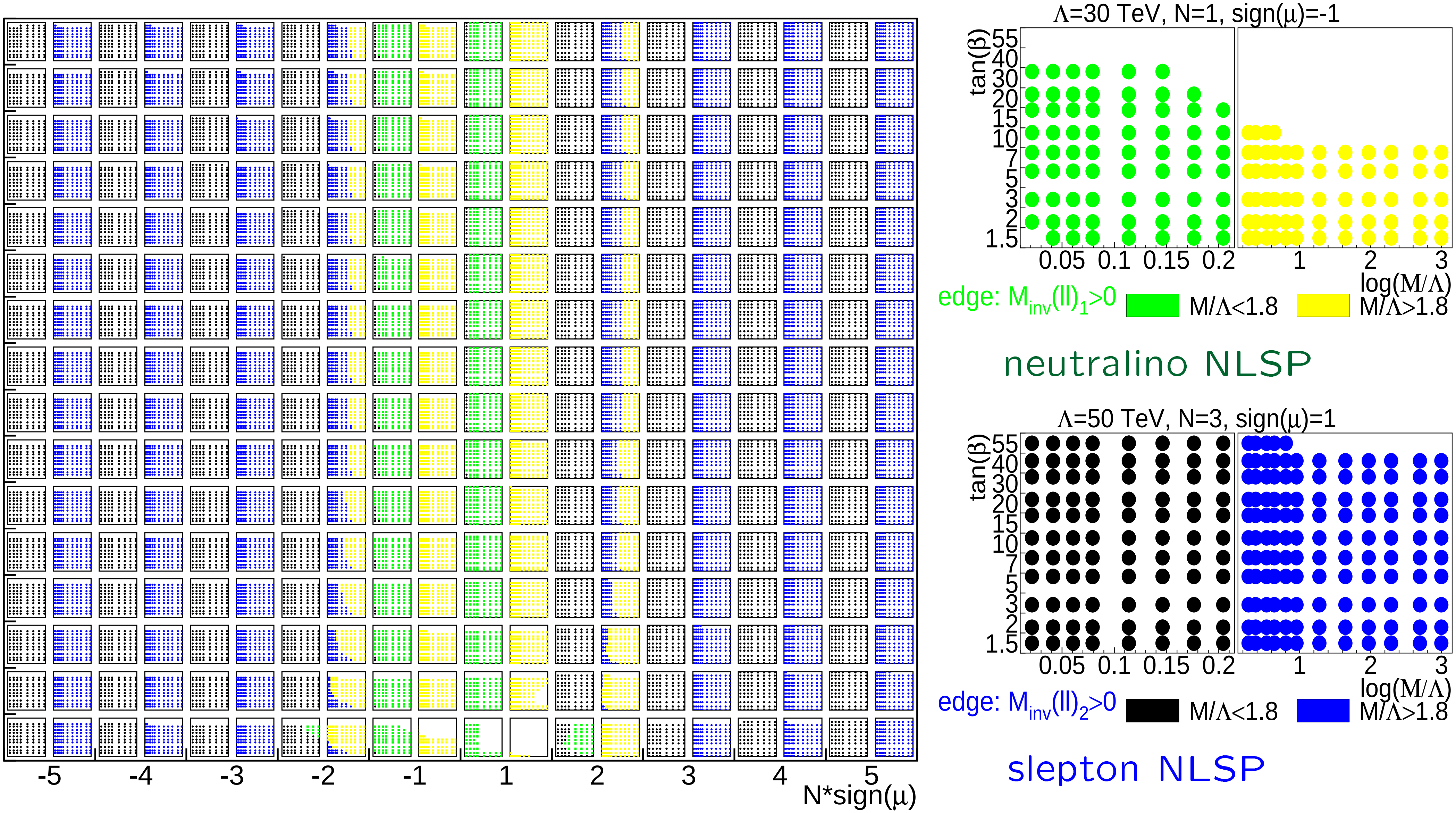
$$M_{inv}(ll)_2 = \sqrt{m^2_{\tilde{N}_1} - m^2_{\tilde{l}_R}}$$



Observability of the edge depends on:

- total σ for the SUSY production
  – partial σ for the neutralino production
- branching ratios of the end-point decays
  – sensitivity to the neutralino contents
- Anti–SM background cuts

End–point position in the parameter space

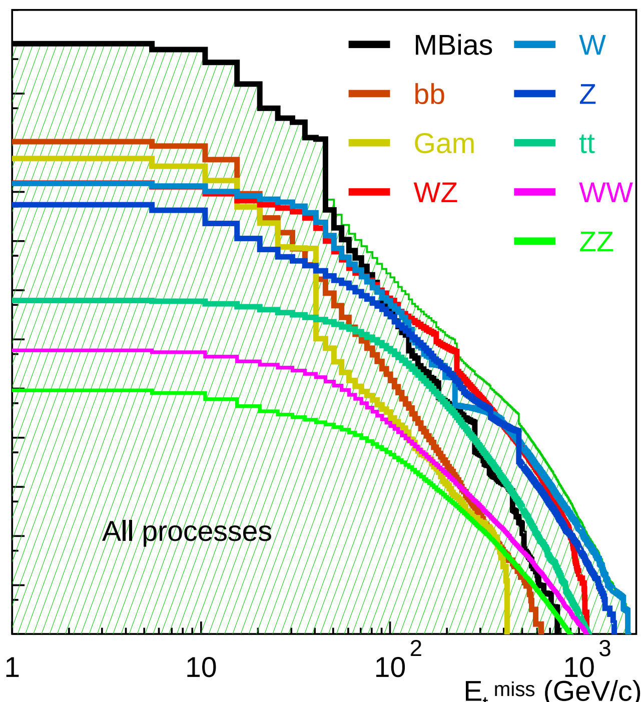


Simulation of the Standard Model processes

THIA 6.157 – event generator
SJET – fast detector simulation

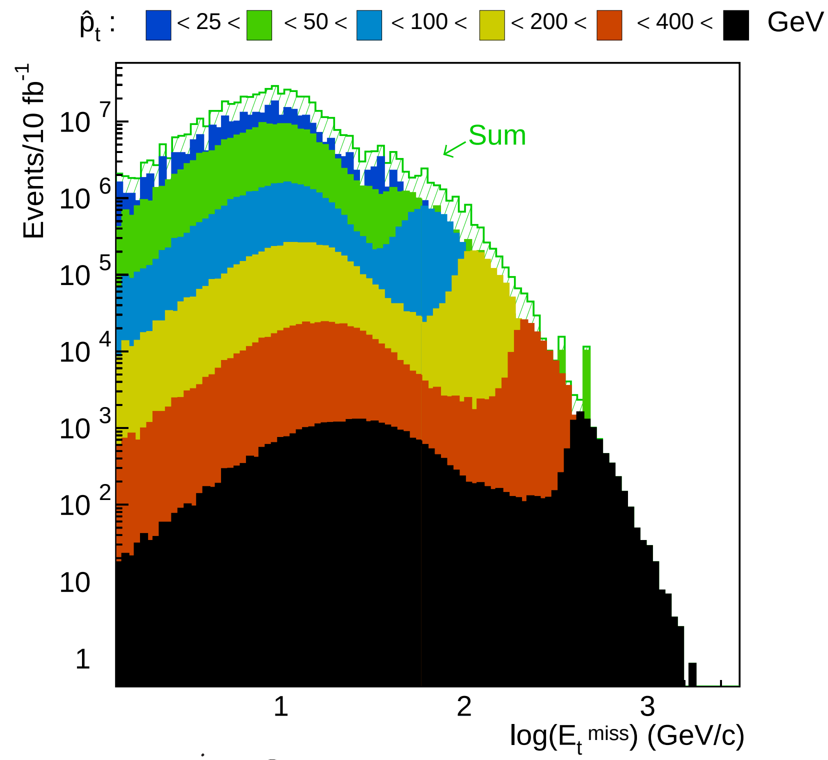
processes in pp collisions at $\sqrt{s}$ 14 TeV:

imum bias, bb, gamma, tt, W, WW, WZ, Z, ZZ



SM contribution to the total background

$$\int L dt = 10/\text{fb}$$



$E_t^{\,miss}$ for Z

Processes simulated in several $\widehat{p}_t$ intervals (50k events each). *The background simulation took 520h 100 CPU 1GHz PC.*

Samples **merged** proportionally to cross sections.

Examples of selected GMSB models

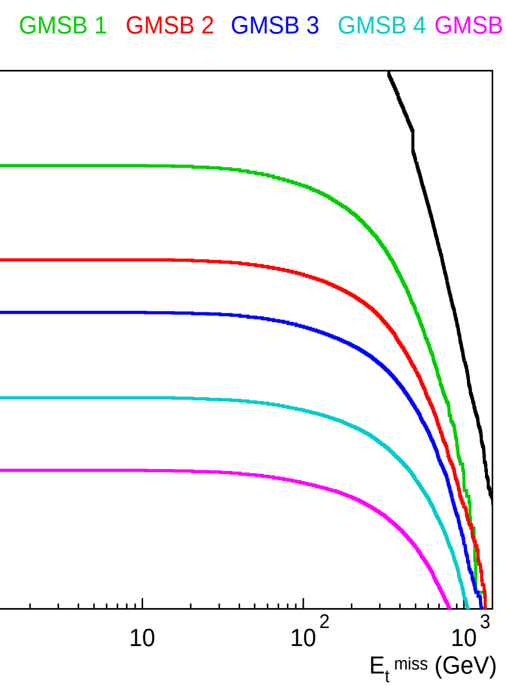
GMSB	Λ [TeV]	M [TeV]	$N*$ sgn(μ)	tg(β)	$m_{\tilde{N}_1}$ [GeV]	$m_{\tilde{\tau}_1}$ [GeV]	$m_{\tilde{u}_L}$ [GeV]	σ [pb]	edge [GeV]
1	30	120	-4	2	165	111	781	1400	120
2	60	114	-3	2	257	183	1247	190	180
3	70	73.5	-3	3	365	207	1466	60	300
4	80	104	4	2	490	283	1957	9.5	400
5	90	306	5	2	621	366	2447	2	500

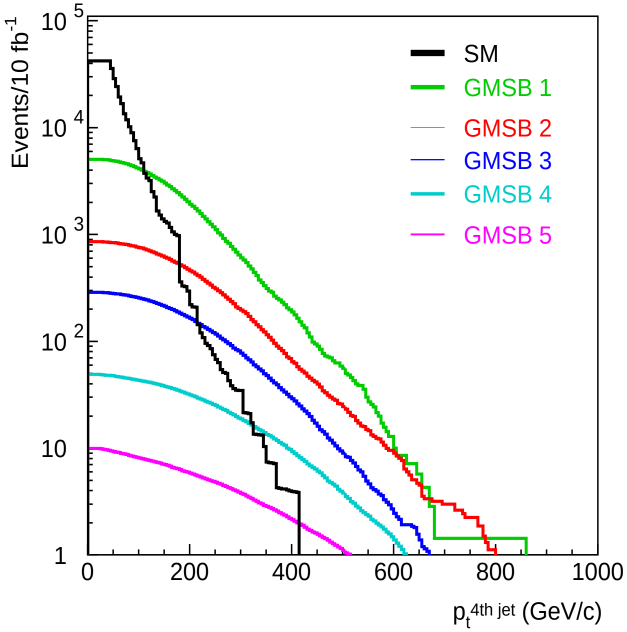
Set of kinematic cuts for SUSY search

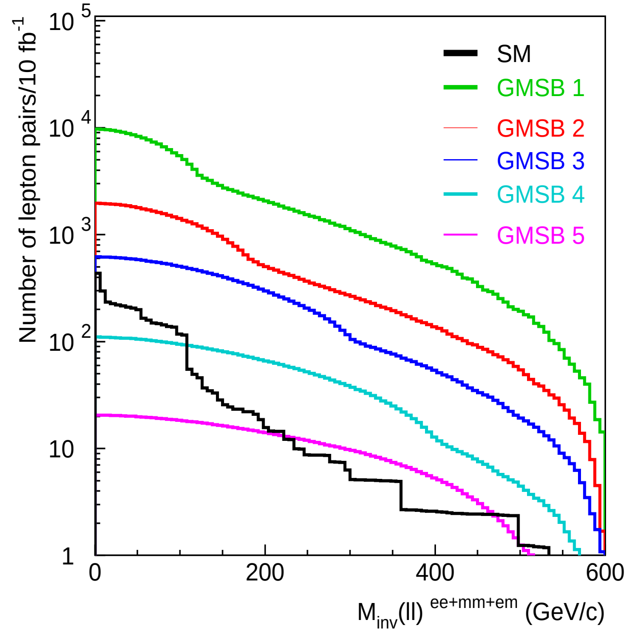
UT0:

tron or muon or isolated gamma with $p_t > 20$ GeV and $|\eta| < 2.4$

et with $p_t > 40$ GeV and $|\eta| < 4.5$





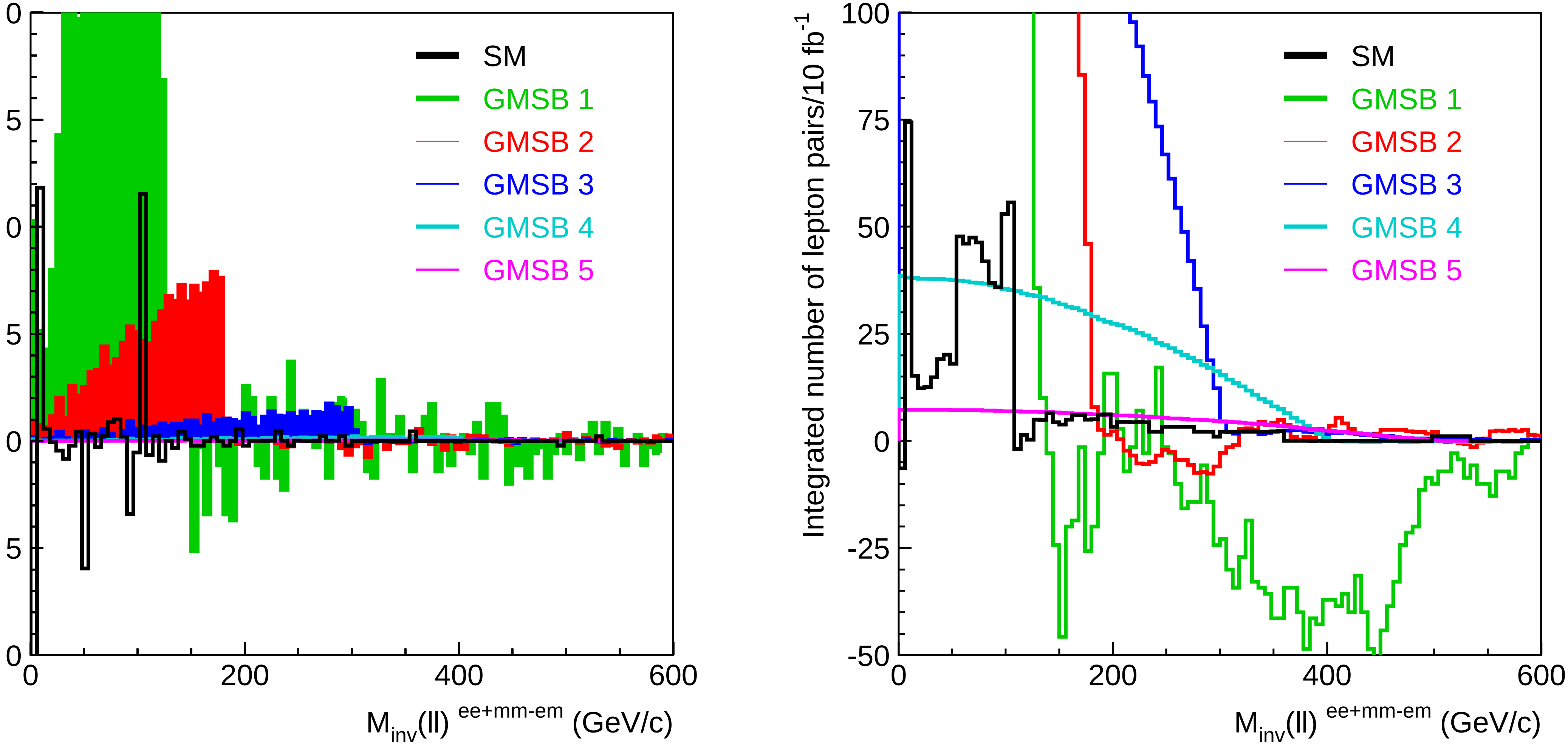


• CUT1:
${E_t}^{miss} > 200$ GeV

• CUT2:
p_t 4th jet > 80 GeV

• CUT3:
2 opposite sign leptons

Is the end–point detectable ?

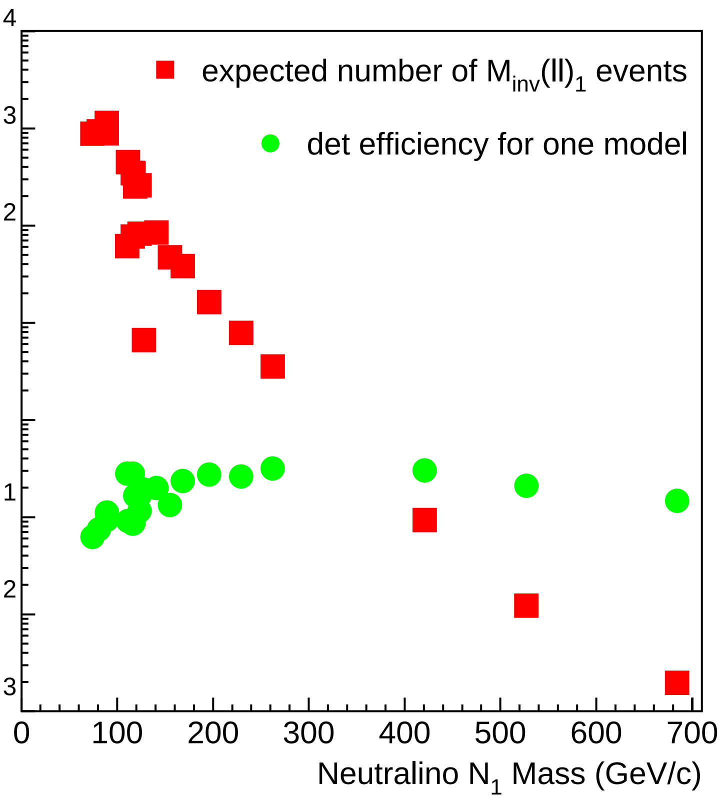


Evidence of the end–point

5σ evidence for the signal is:

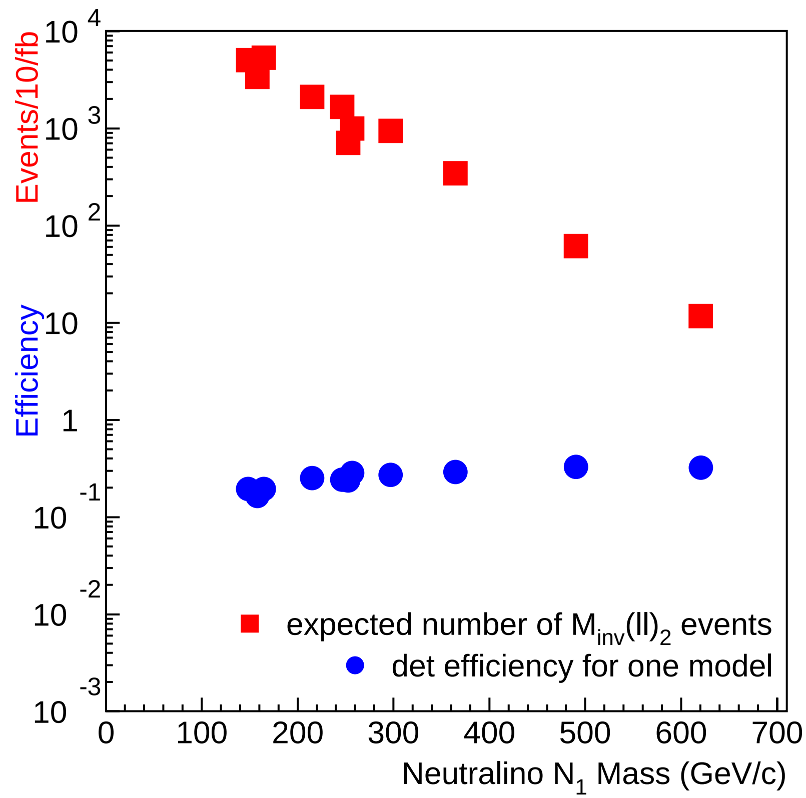
150 lepton pairs for the edge mass **below** 100 GeV
or
30 lepton pairs for the edge mass **above** 100 GeV.

set of kinematical cuts was applied to each model and a detector efficiency was determined.



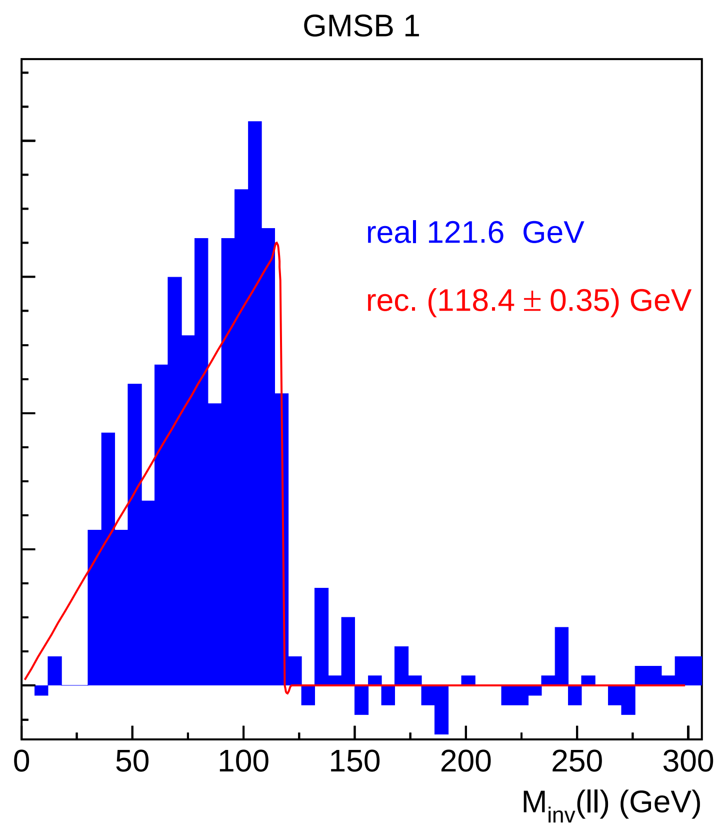
Detection efficiency is evaluated as a ratio of an excess $\mu^+\mu^- + e^+e^- - \mu^+e^- - e^+\mu^-$ events after and before all cuts corrected by the efficiency of the lepton pair selection (model dependent).

The CMS detector response was examined for several models fully simulated with the CMSJET.

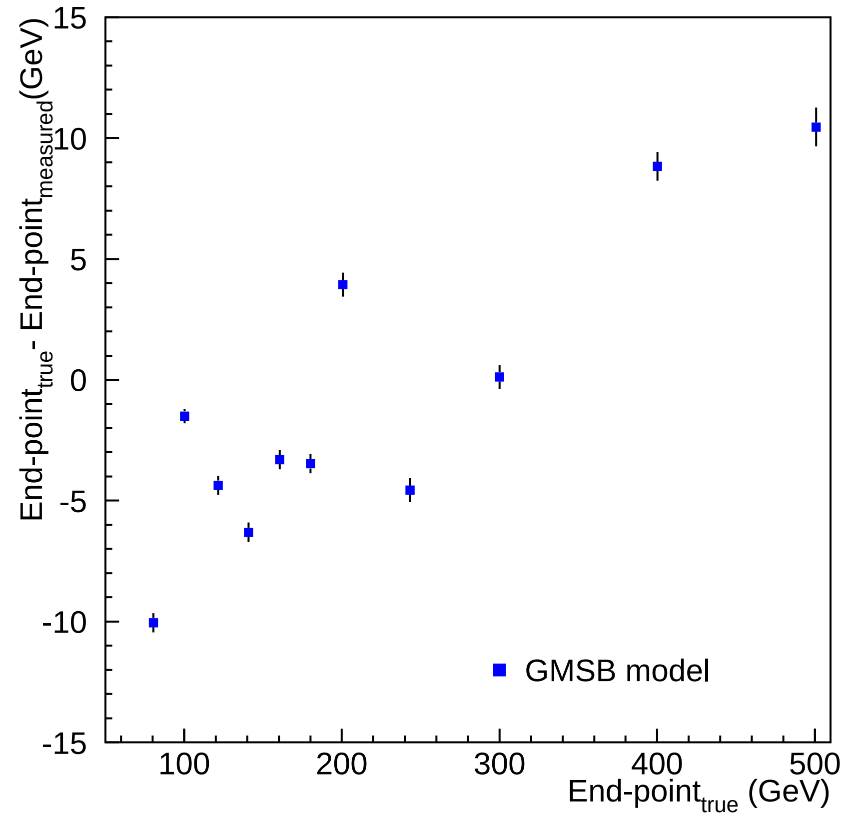


Efficiency of the end–point detection in the CMS detector is not less than 15%

Determination of the end–point value



For each model–sample we fit a triangle–like function, which allows us to find end–point position.



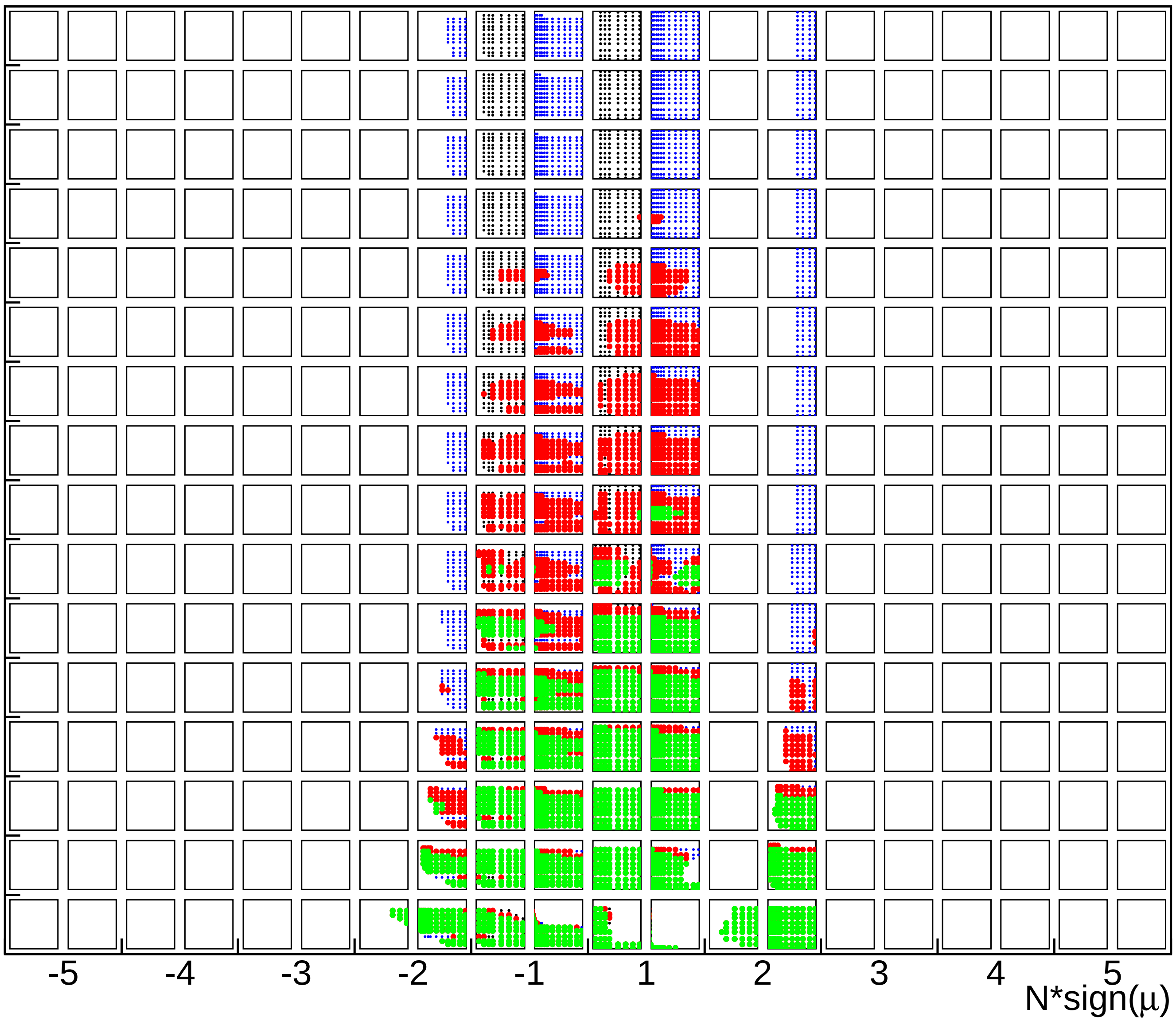
blems:

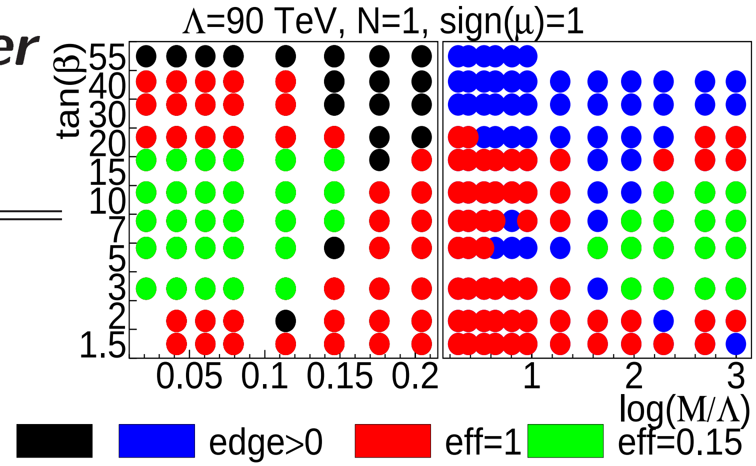
some models presence of the Z^0 peak distorts the picture it can be used to uncover of the neutralino contents)

SY background may change the edge position.

ematic uncertainty the end–point value amounts to few GeV with more sophisticated method could be improved.

Accessible region of the GMSB parameter space for neutralino NLSP, end–point 1





white – no edge

blue,black – edge not detectable

red – edge detectable with

a **perfect** detector $\epsilon = 100\%$

green – edge detectable with

a **realistic** detector $\epsilon = 15\%$

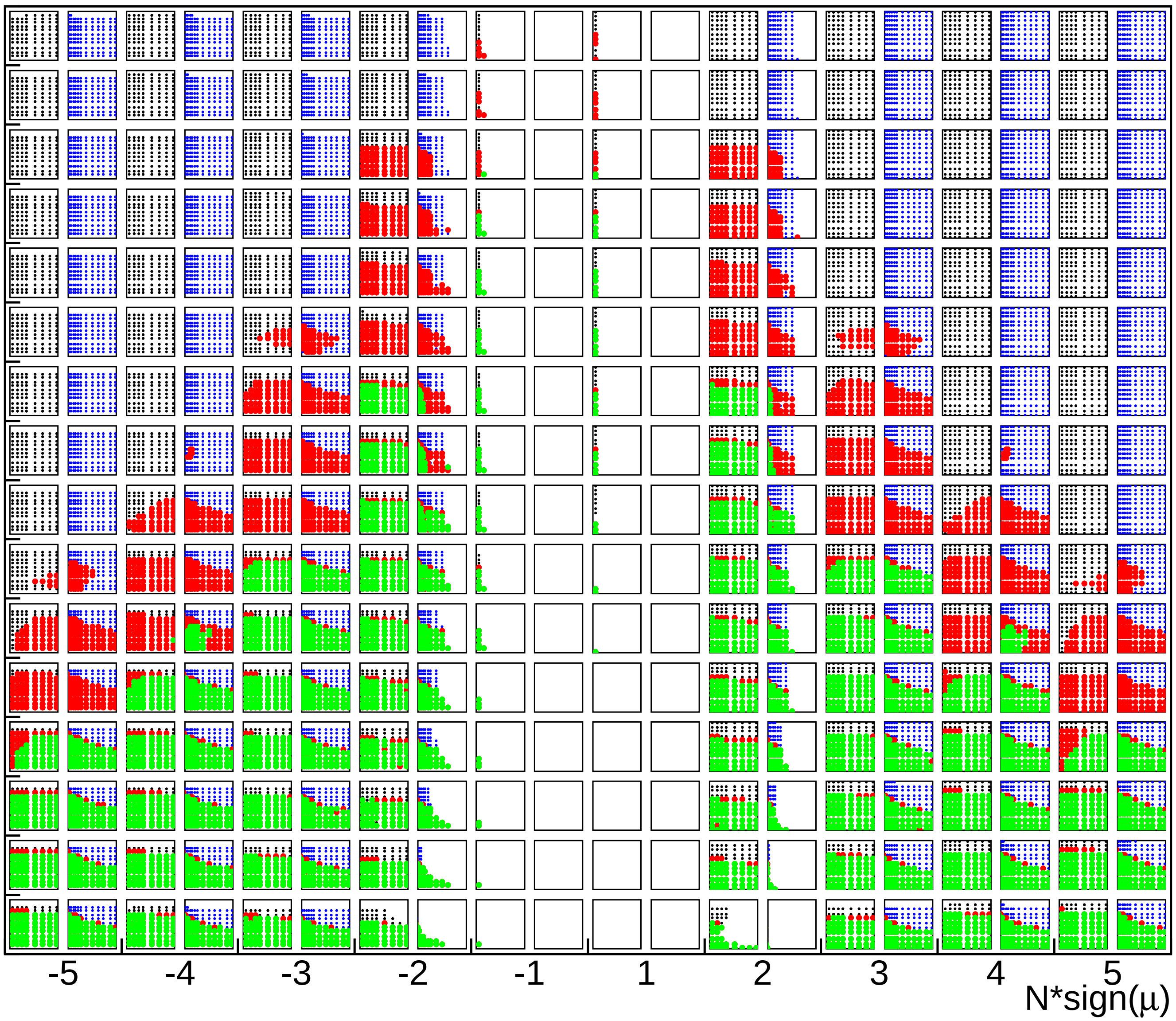
$$M_{inv}(ll)_1 =$$

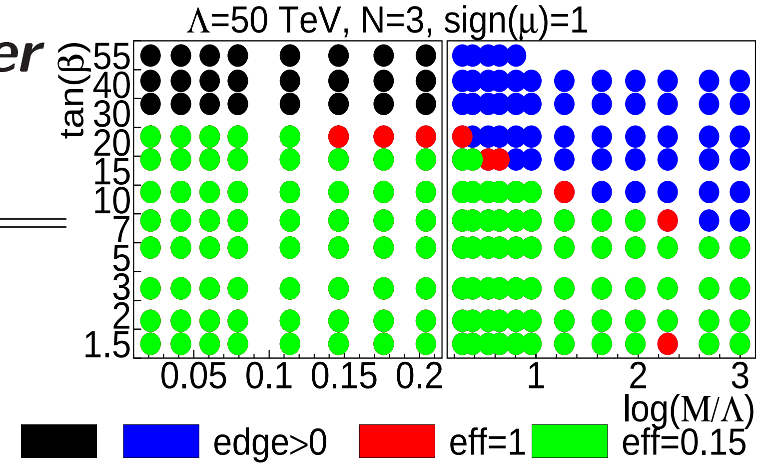
$$= \frac{\sqrt{m^2_{\tilde{N}_2} - m^2_{\tilde{l}_R}}\sqrt{m^2_{\tilde{l}_R} - m^2_{\tilde{N}_1}}}{m_{\tilde{l}_R}}$$

The edge is detectable at 5σ level for $\int Ldt = 10/\text{fb}$

$\Lambda \leq 100$ TeV for $N = 1$

Accessible region of the GMSB parameter space for slepton NLSP, end–point 2





$$M_{inv}(ll)_2 = \sqrt{m^2_{\tilde{N}_1} - m^2_{\tilde{l}_R}}$$

The edge is detectable at the **5**σ level for $\int Ldt = 10/\text{fb}$

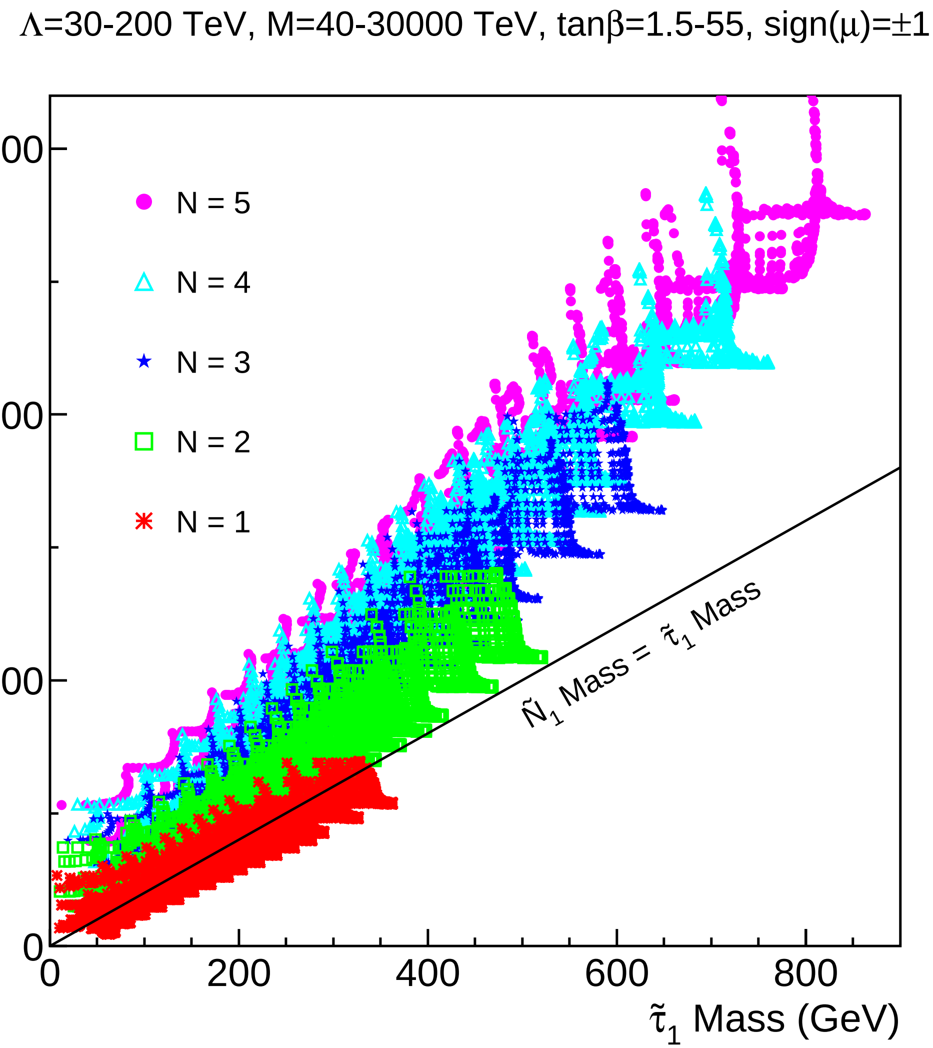
if $\tan(\beta) < 30$

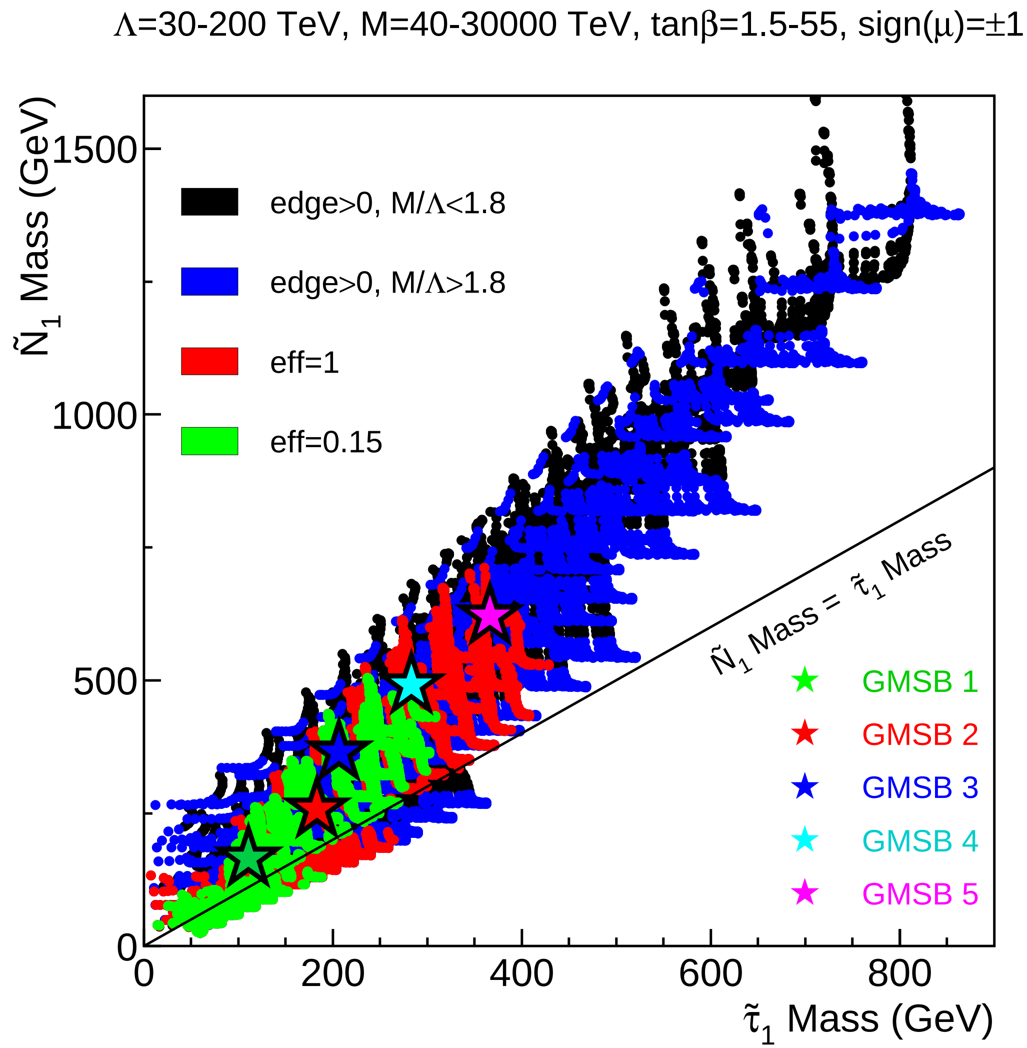
and

$\Lambda < 70$ TeV for $N = 5$
$\Lambda < 90$ TeV for $N = 4$
$\Lambda < 110$ TeV for $N = 3$
$\Lambda < 130$ TeV for $N = 2$

$\Lambda < 170$ TeV for $N = 1$
only for $M/\Lambda < 1.15$

Predicted Mass limits of supersymmetric particles





$$m_{\tilde{\tau}_1} < 350 \text{ GeV and } m_{\tilde{N}_1} < 500 \text{ GeV}$$

Summary

determined the region of the GMSB parameter space:

$$\text{for} \quad \begin{array}{lccccccc} \Lambda & < & 70, & 90, & 110, & 130, & 100 & \text{TeV} \\ N & = & 5, & 4, & 3, & 2, & 1 & \end{array}$$

for $\text{sign}(\mu) \pm 1$ and $\tan(\beta) < 30$ for certain values $1.1 < M/\Lambda < 10^3$

ch can be investigated using the dilepton end–point signature
n 15 % efficiency in the CMS detector.

ertheless the Nature is more sophisticated...

he dilepton edge does not determine the model unambiguously.
ther analysis is nedeed: other multileptons, leptons–jets and leptons–photons
–points enable to solve the puzzle of the SUSY mass hierarchy.