Constraints on sneutrino dark matter from LHC Run 1

arXiv:1503.02960

Ursula Laa
LPSC Grenoble

in collaboration with
Chiara Arina, Maria Eugenia Cabrerea Catalan,
Sabine Kraml and Suchita Kulkarni

GDR Terascale, Saclay, March 31st 2015

Why consider right-handed sneutrino DM?

- SUSY searches mostly consider neutralino LSPs
- How are they constraining alternative scenarios, e.g. sneutrino LSP?

- Left-handed sneutrino LSP cannot explain measured relic abundance and is excluded by direct detection experiments
- Mostly right-handed sneutrino is an interesting candidate, addressing both the origin of neutrino masses and the nature of dark matter

→ we want to explore how LHC results constrain a model with a mostly right-handed sneutrino LSP

The MSSM+RN model

superpotential for Dirac RH neutrino superfield

$$W = \epsilon_{ij}(\mu \hat{H}_i^u \hat{H}_j^d - Y_l^{IJ} \hat{H}_i^d \hat{L}_j^I \hat{R}^J + Y_\nu^{IJ} \hat{H}_i^u \hat{L}_j^I \hat{N}^J)$$

additional terms in the soft-breaking potential

$$V_{\rm soft} = (M_L^2)^{IJ}\, \tilde{L}_i^{I*} \tilde{L}_i^J + (M_N^2)^{IJ}\, \tilde{N}^{I*} \tilde{N}^J - [\epsilon_{ij}(\Lambda_l^{IJ} H_i^d \tilde{L}_j^I \tilde{R}^J + \Lambda_\nu^{IJ} H_i^u \tilde{L}_j^I \tilde{N}^J) + \text{h.c.}]$$

the sneutrino mass eigenstates are then given by

$$\rightarrow \quad \begin{pmatrix} \tilde{\nu}_{k_1} \\ \tilde{\nu}_{k_2} \end{pmatrix} = \begin{pmatrix} -\sin\theta_{\tilde{\nu}}^k & \cos\theta_{\tilde{\nu}}^k \\ \cos\theta_{\tilde{\nu}}^k & \sin\theta_{\tilde{\nu}}^k \end{pmatrix} \begin{pmatrix} \tilde{\nu}_L^k \\ \tilde{N}^k \end{pmatrix}$$

with

$$\sin 2\theta_{\tilde{\nu}}^k = \sqrt{2}\frac{A_{\tilde{\nu}}^k\, v \sin\beta}{(m_{\tilde{\nu}_{k2}}^2 - m_{\tilde{\nu}_{k1}}^2)}$$

Borzumati & Nomura, hep-ph/0007018
Arkani-Hamed et al., hep-ph/0006312

We used MultiNest to sample the parameter space

GUT scale Parameters	Prior range
M_1, M_2	(-4000, 4000) GeV
$log_{10}(M_3/\text{GeV})$	(-4, 4)
$log_{10}(m_Q/\text{GeV})$	(2, 5)
m_L, m_R	(1, 2000) GeV
m_N	(1, 2000) GeV
$log_{10}(A_Q/\text{GeV})$	(-5, 5)
A_L	(-4000, 4000) GeV
$A_{\tilde{\nu}}$	(-1000, 1000) GeV
$log_{10}(m_H/\text{GeV})$	(1, 5)
$\tan\beta$	(3, 50)

We used MultiNest to sample the parameter space

GUT scale Parameters	Prior range
M_1, M_2	(-4000, 4000) GeV
$log_{10}(M_3/\text{GeV})$	(-4, 4)
$log_{10}(m_Q/\text{GeV})$	(2, 5)
m_L, m_R	(1, 2000) GeV
→ m_N	(1, 2000) GeV
$log_{10}(A_Q/\text{GeV})$	(-5, 5)
A_L	(-4000, 4000) GeV
$A_{\tilde{\nu}}$	(-1000, 1000) GeV
$log_{10}(m_H/\text{GeV})$	(1, 5)
$\tan\beta$	(3, 50)

We used MultiNest to sample the parameter space

GUT scale Parameters	Prior range
M_1, M_2	(-4000, 4000) GeV
$log_{10}(M_3/\text{GeV})$	(-4, 4)
$log_{10}(m_Q/\text{GeV})$	(2, 5)
m_L, m_R	(1, 2000) GeV
→ m_N	(1, 2000) GeV
$log_{10}(A_Q/\text{GeV})$	(-5, 5)
A_L	(-4000, 4000) GeV
→ $A_{\tilde{\nu}}$	(-1000, 1000) GeV
$log_{10}(m_H/\text{GeV})$	(1, 5)
$\tan\beta$	(3, 50)

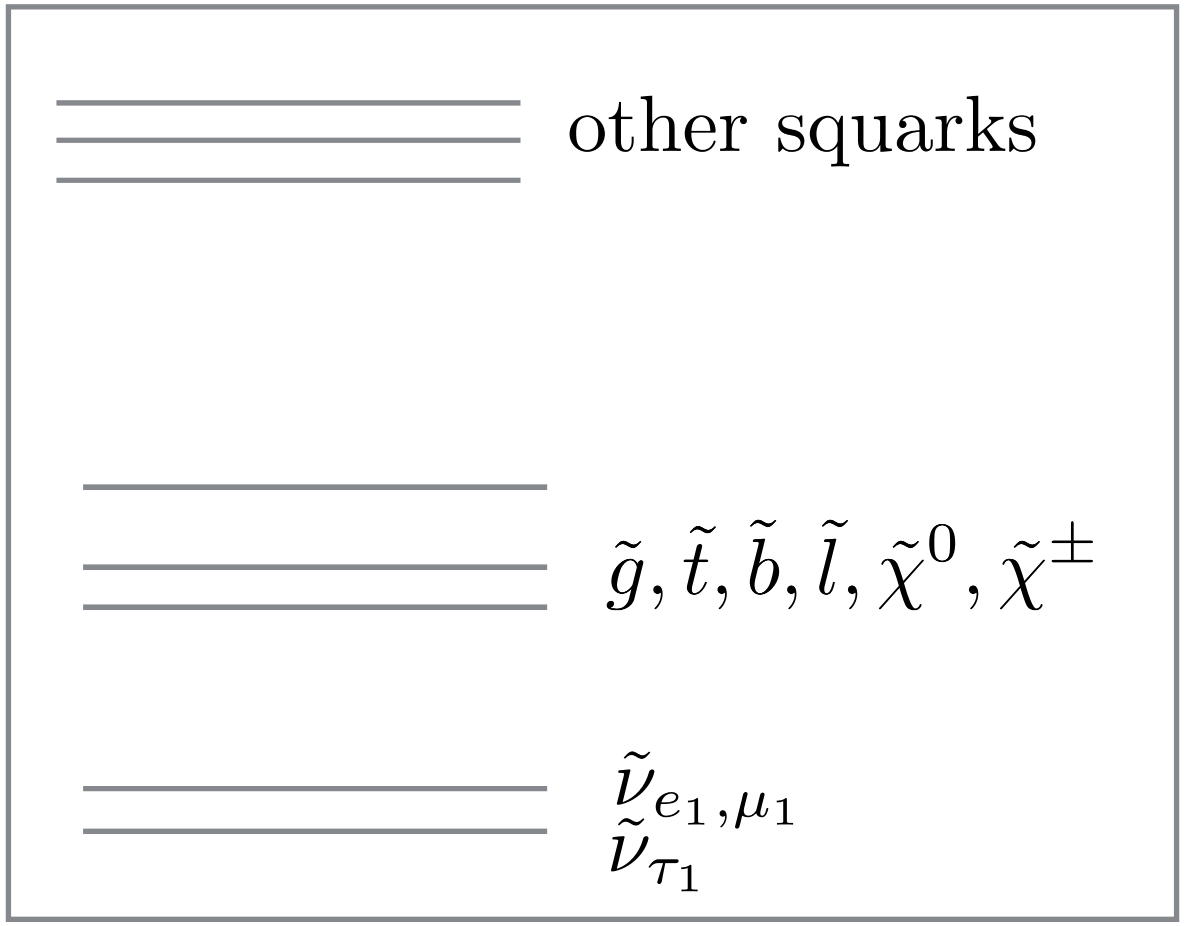
using the following observables and constraints

Observable	Value / constraint
m_h	125.85 ± 0.4 (exp) ± 4 (theo) GeV
$\mathrm{BR}(B \to X_s\gamma) \times 10^4$	3.55 ± 0.24 ± 0.09 (exp)
$\mathrm{BR}(B \to \mu^+\mu^-) \times 10^9$	3.2 (+1.4 -1.2) (stat) (+0.5 -0.3) (sys)
$\Omega_{\mathrm{DM}}h^2$	0.1186 ± 0.0031 (exp) ± 20% (theo)
$\Delta\Gamma_Z^{\mathrm{invisible}}$	< 2 MeV (95% CL)
$\mathrm{BR}(h \to \mathrm{invisible})$	< 20% (95% CL)
$m_{\tilde{\tau}_1^-}$	> 85 GeV (95% CL)
$m_{\tilde{\chi}_1^+}, m_{\tilde{e},\tilde{\mu}}$	>101 GeV (95% CL)
$m_{\tilde{g}}$	> 308 GeV (95% CL)
σ_n^{SI}	$< \sigma_{\mathrm{LUX}}^{SI}$ (90% CL)

Measurements

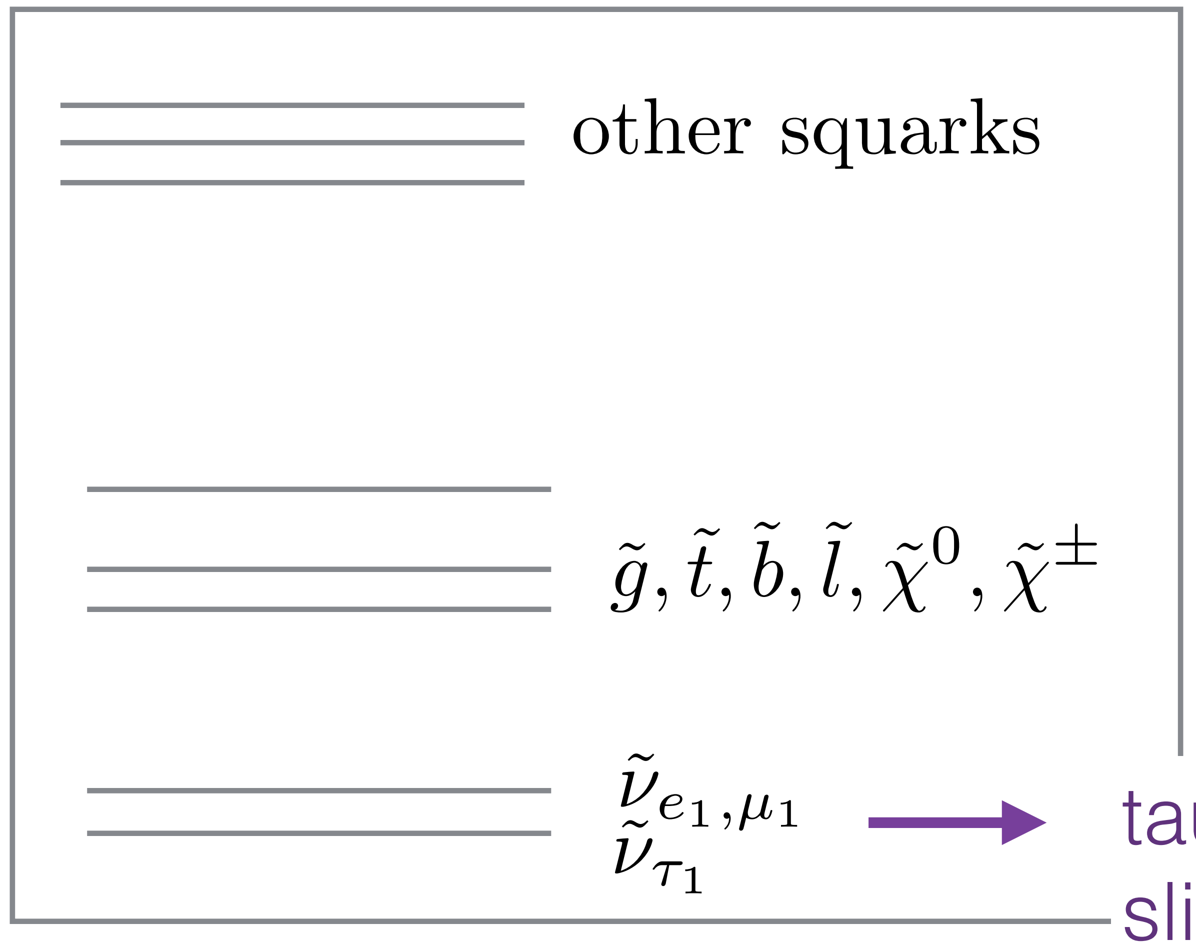
Limits

Typical spectrum



Sampling the parameter space such that we cover different scenarios, requiring either
light gluinos or squarks, light gauginos or light sleptons

Typical spectrum



tau sneutrino slightly lighter

Sampling the parameter space such that we cover different scenarios, requiring either light gluinos or squarks, light gauginos or light sleptons

How can we efficiently test a BSM scenario against existing ATLAS and CMS constraints?

Results in many different channels are available

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: Feb 2015

ATLAS Preliminary
$\sqrt{s}$ = 7, 8 TeV

	Model	e, μ, τ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[fb^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	1405.7875
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 850 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, m(1[st] gen. $\tilde{q}$)=m(2[nd] gen. $\tilde{q}$)	1405.7875
	$\tilde{q}\tilde{q}\gamma, \tilde{q}\to q\tilde{\chi}_1^0$ (compressed)	1 γ	0-1 jet	Yes	20.3	$\tilde{q}$ 250 GeV	$m(\tilde{q})-m(\tilde{\chi}_1^0) = m(c)$	1411.1559
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.33 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	1405.7875
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e, μ	3-6 jets	Yes	20	$\tilde{g}$ 1.2 TeV	$m(\tilde{\chi}_1^0)$<300 GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	1501.03555
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e, μ	0-3 jets	-	20	$\tilde{g}$ 1.32 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	1501.03555
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$ 1.6 TeV	$\tan\beta$ >20	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$ 1.28 TeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	1 $e, \mu + \gamma$	-	Yes	4.8	$\tilde{g}$ 619 GeV	$m(\tilde{\chi}_1^0)$>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	$m(\tilde{\chi}_1^0)$>220 GeV	1211.1167
	GGM (higgsino NLSP)	2 e, μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	m(NLSP)>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale 865 GeV	$m(\tilde{G})>1.8\times10^{-4}$ eV, $m(\tilde{g})=m(\tilde{q})$=1.5 TeV	1502.01518
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.25 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	1407.0600
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	1407.0600
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e, μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	1407.0600
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-620 GeV	$m(\tilde{\chi}_1^0)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{b}_1$ 275-440 GeV	$m(\tilde{\chi}_1^\pm)=2\, m(\tilde{\chi}_1^0)$	1404.2500
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e, μ	1-2 b	Yes	4.7	$\tilde{t}_1$ 110-167 GeV; 230-460 GeV	$m(\tilde{\chi}_1^\pm) = 2m(\tilde{\chi}_1^0)$, $m(\tilde{\chi}_1^0)$=55 GeV	1209.2102, 1407.0583
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	2 e, μ	0-2 jets	Yes	20.3	$\tilde{t}_1$ 90-191 GeV; 215-530 GeV	$m(\tilde{\chi}_1^0)$=1 GeV	1403.4853, 1412.4742
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to t\tilde{\chi}_1^0$	0-1 e, μ	1-2 b	Yes	20	$\tilde{t}_1$ 210-640 GeV	$m(\tilde{\chi}_1^0)$=1 GeV	1407.0583,1406.1122
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-240 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)$<85 GeV	1407.0608
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-580 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1 + Z$	3 e, μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$ 290-600 GeV	$m(\tilde{\chi}_1^0)$<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e, μ	0	Yes	20.3	$\tilde{\ell}$ 90-325 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$ 140-465 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.3	$\tilde{\chi}_1^\pm$ 100-350 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	1407.0350
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e, μ	0	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 700 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e, μ	0-2 jets	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 420 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0, h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$	e, μ, γ	0-2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$ 250 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	1501.07110
	$\tilde{\chi}_2^0\tilde{\chi}_3^0, \tilde{\chi}_{2,3}^0\to\tilde{\ell}_R\ell$	4 e, μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$ 620 GeV	$m(\tilde{\chi}_2^0)=m(\tilde{\chi}_3^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_2^0)+m(\tilde{\chi}_1^0))$	1405.5086
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$ 270 GeV	$m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)$=160 MeV, $\tau(\tilde{\chi}_1^\pm)$=0.2 ns	1310.3675
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$ 832 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	1310.6584
	Stable $\tilde{g}$ R-hadron	trk	-	-	19.1	$\tilde{g}$ 1.27 TeV		1411.6795
	GMSB, stable $\tilde{\tau}, \tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde{\chi}_1^0$ 537 GeV	10<$\tan\beta$<50	1411.6795
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	20.3	$\tilde{\chi}_1^0$ 435 GeV	2<$\tau(\tilde{\chi}_1^0)$<3 ns, SPS8 model	1409.5542
	$\tilde{q}\tilde{q}, \tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$ 1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, $m(\tilde{\chi}_1^0)$=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e + \mu$	2 e, μ	-	-	4.6	$\tilde{\nu}_\tau$ 1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau + X, \tilde{\nu}_\tau\to e(\mu) + \tau$	1 $e, \mu + \tau$	-	-	4.6	$\tilde{\nu}_\tau$ 1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{q}, \tilde{g}$ 1.35 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e, μ	-	Yes	20.3	$\tilde{\chi}_1^\pm$ 750 GeV	$m(\tilde{\chi}_1^0)>0.2\times m(\tilde{\chi}_1^\pm)$, $\lambda_{121}\neq0$	1405.5086
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e, \mu + \tau$	-	Yes	20.3	$\tilde{\chi}_1^\pm$ 450 GeV	$m(\tilde{\chi}_1^0)>0.2\times m(\tilde{\chi}_1^\pm)$, $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e, μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$ 850 GeV		1404.250
Other	Scalar charm, $\tilde{c}\to c\tilde{\chi}_1^0$	0	2 c	Yes	20.3	$\tilde{c}$ 490 GeV	$m(\tilde{\chi}_1^0)$<200 GeV	1501.01325

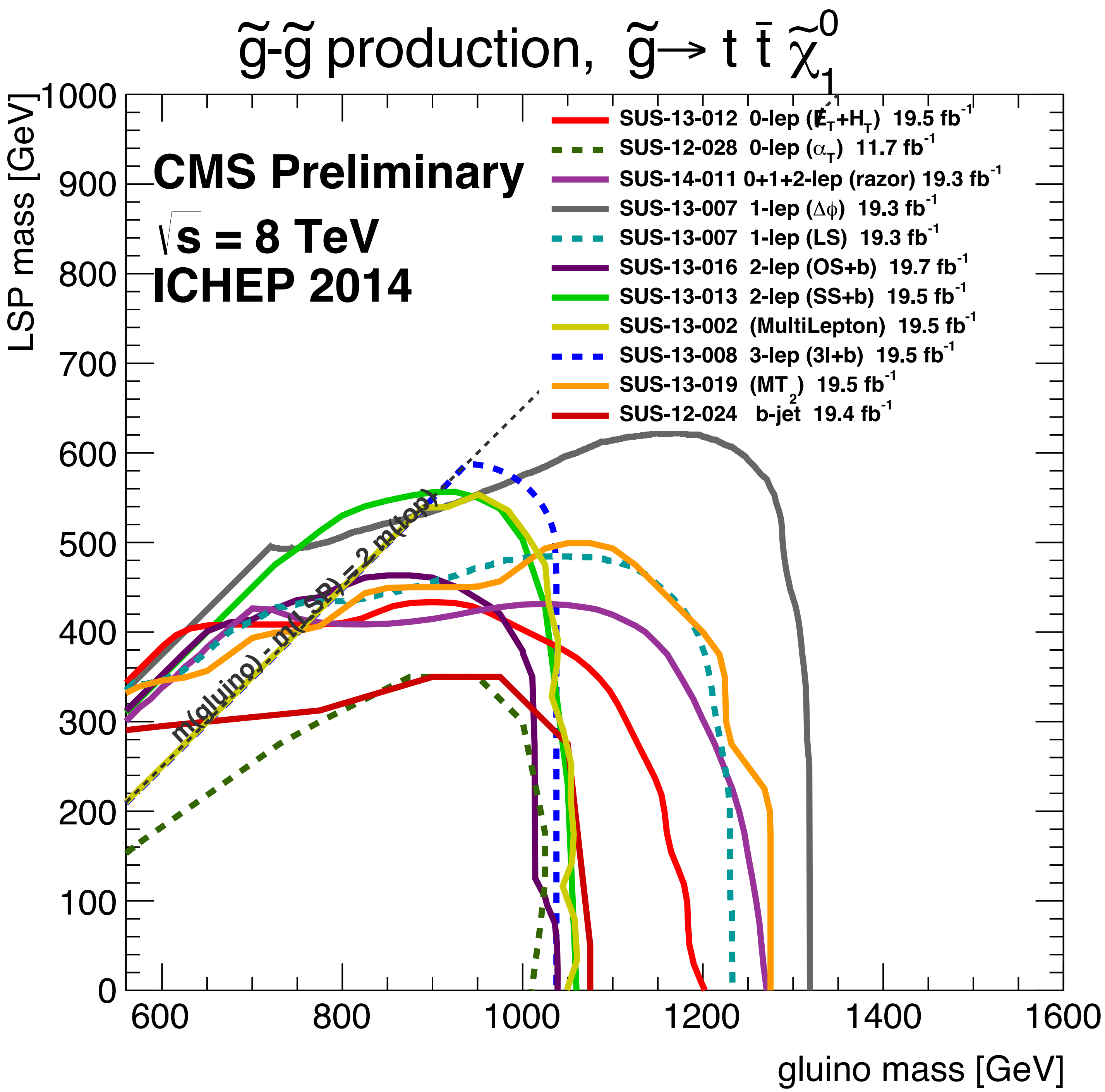
$\sqrt{s}$ = 7 TeV full data | $\sqrt{s}$ = 8 TeV partial data | $\sqrt{s}$ = 8 TeV full data

10^{-1} … 1 — Mass scale [TeV]

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Experimental limits are often obtained in the context of

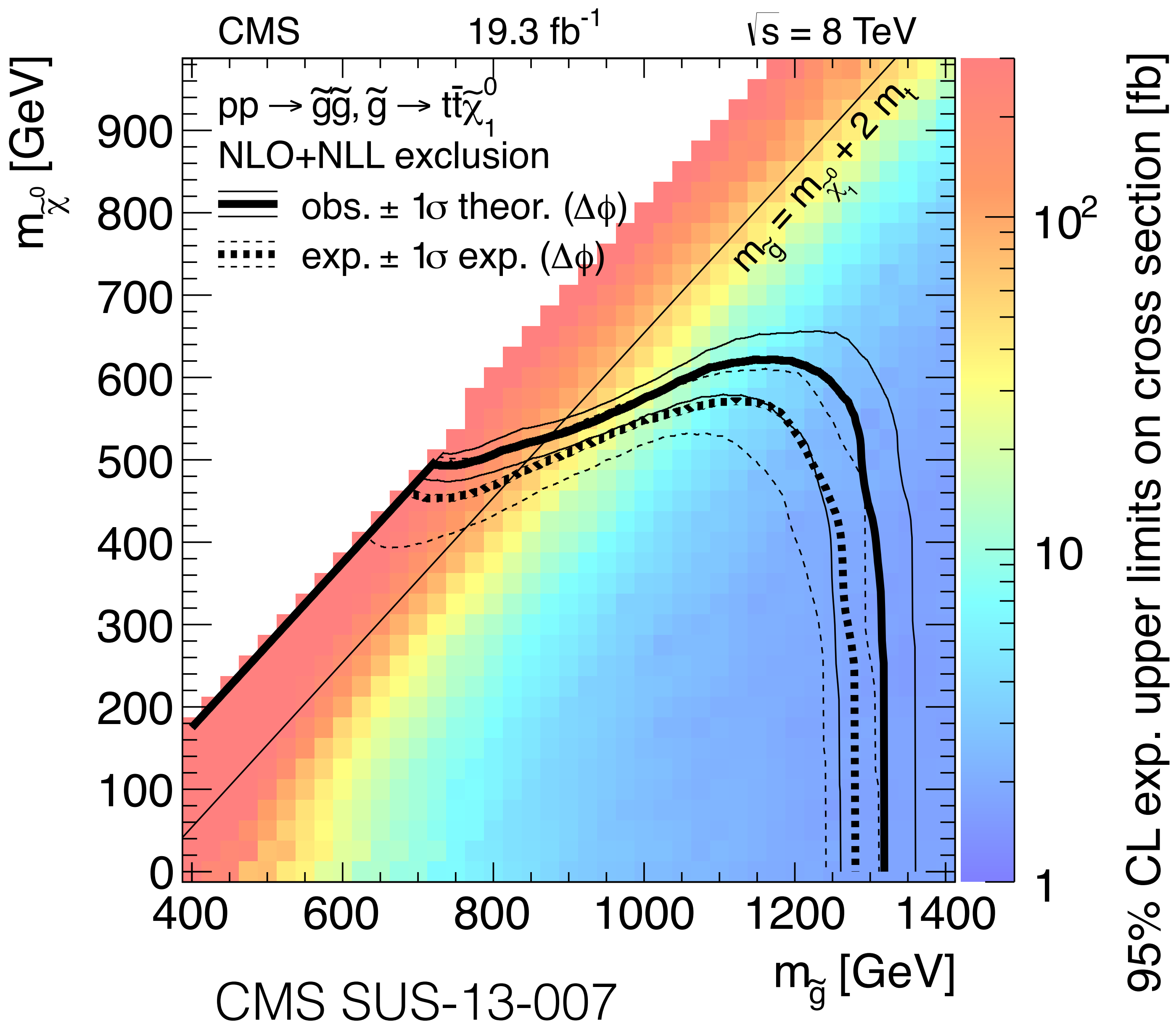
Simplified Model Spectra (SMS)



SMS are an effective Lagrangian description, containing only a few particles, 100% BR

Same SMS probed in many different channels

Using SMS results



CMS SUS-13-007

To test realistic models, use upper limits on $\sigma \times \mathcal{BR}$ (exclusion line only valid in the simplified model)

Assumption: upper limits on $\sigma \times \mathcal{BR}$ are mainly a function of the masses of the new particles

→ other quantum numbers may be neglected in first approximation

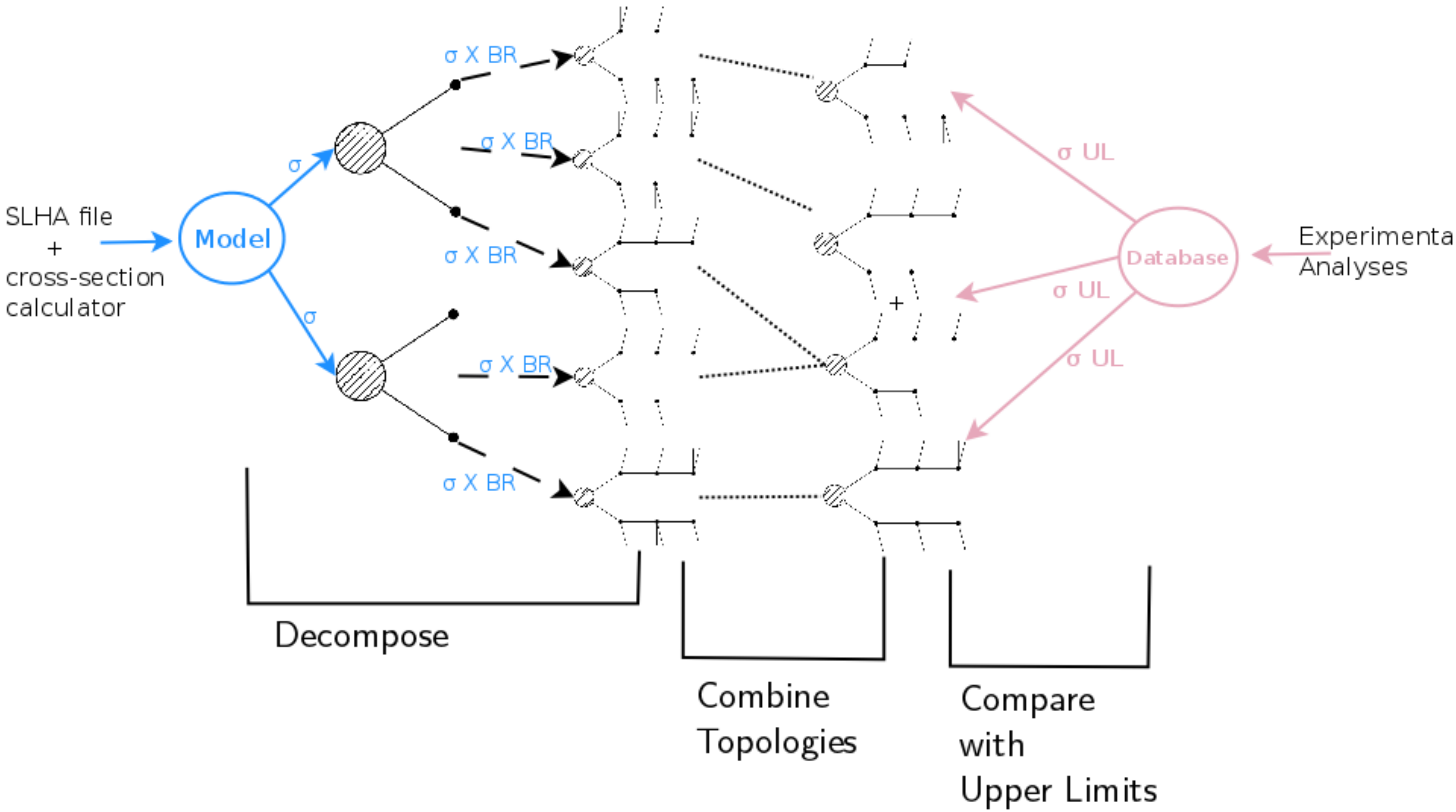
Decompose a BSM model into its
SMS components
and test if

$$(\sigma \times \mathcal{BR})_{theo} > (\sigma \times \mathcal{BR})_{UL}$$

S. Kraml, S. Kulkarni, UL, A. Lessa et al., arXiv:1105.2838

- works for any model with a $\mathbb{Z}_2$ symmetry
- database of more than 60 SMS results
- now publicly available at http://smodels.hephy.at/

SModelS framework

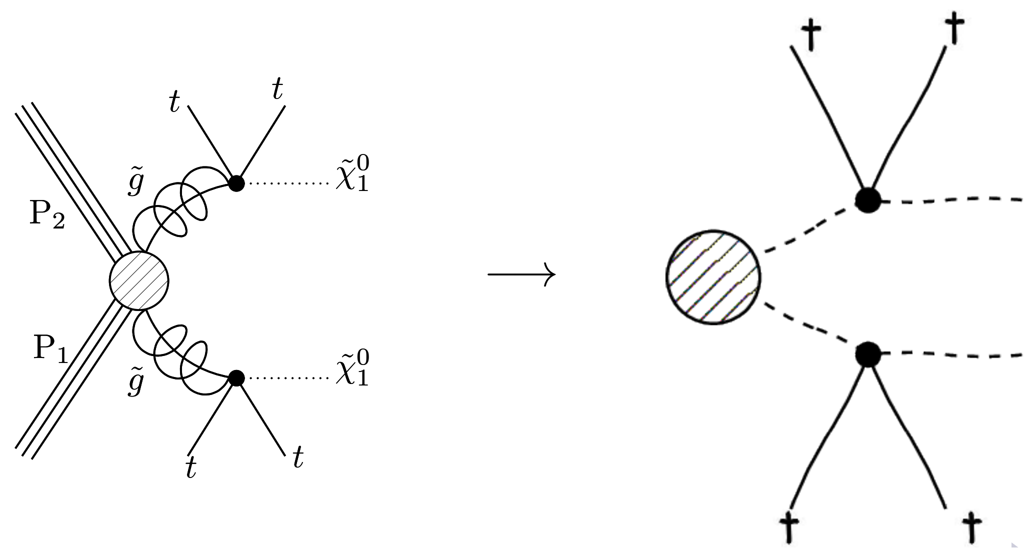


usually SUSY SMS results are obtained for a neutralino LSP

BUT

SMS assumption → upper limits apply to any BSM scenario yielding the same signature as the considered SMS

(a signature is defined by the vertex structure and the outgoing SM particles in each vertex)



we therefore consider SMS constraints on a model with a sneutrino LSP

To use SModelS with a non-MSSM scenario, just define all new particles as r-Even or r-Odd

You can then use SModelS to decompose a point in your BSM scenario, using as input

- an **LHE file** containing simulated events, or
- an **SLHA file** containing the full mass spectrum, decay tables and the SUSY production cross sections

To use SModelS with a non-MSSM scenario, just define all new particles as r-Even or r-Odd

You can then use SModelS to decompose a point in your BSM scenario, using as input

- an **LHE file** containing simulated events, or
- an **SLHA file** containing the full mass spectrum, decay tables and the SUSY production cross sections

↓

additional checks, in particular SModelS can flag points with long-lived particles, where current SMS limits do not apply

Output

for any applicable result

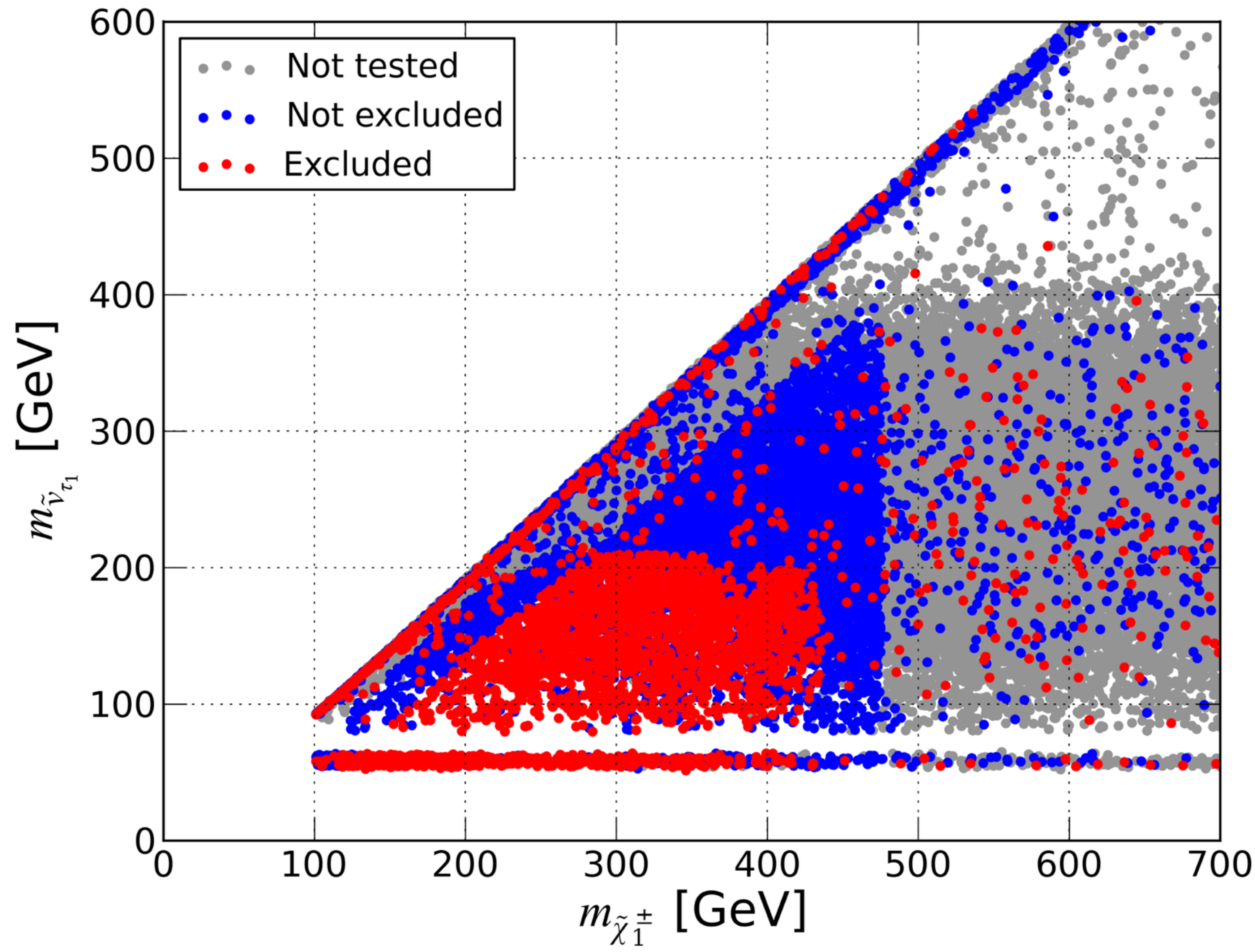
- analysis ID
- topology ID (tX name)
- theory cross section prediction
- experimental upper limit
- ratio prediction/upper limit

additional output

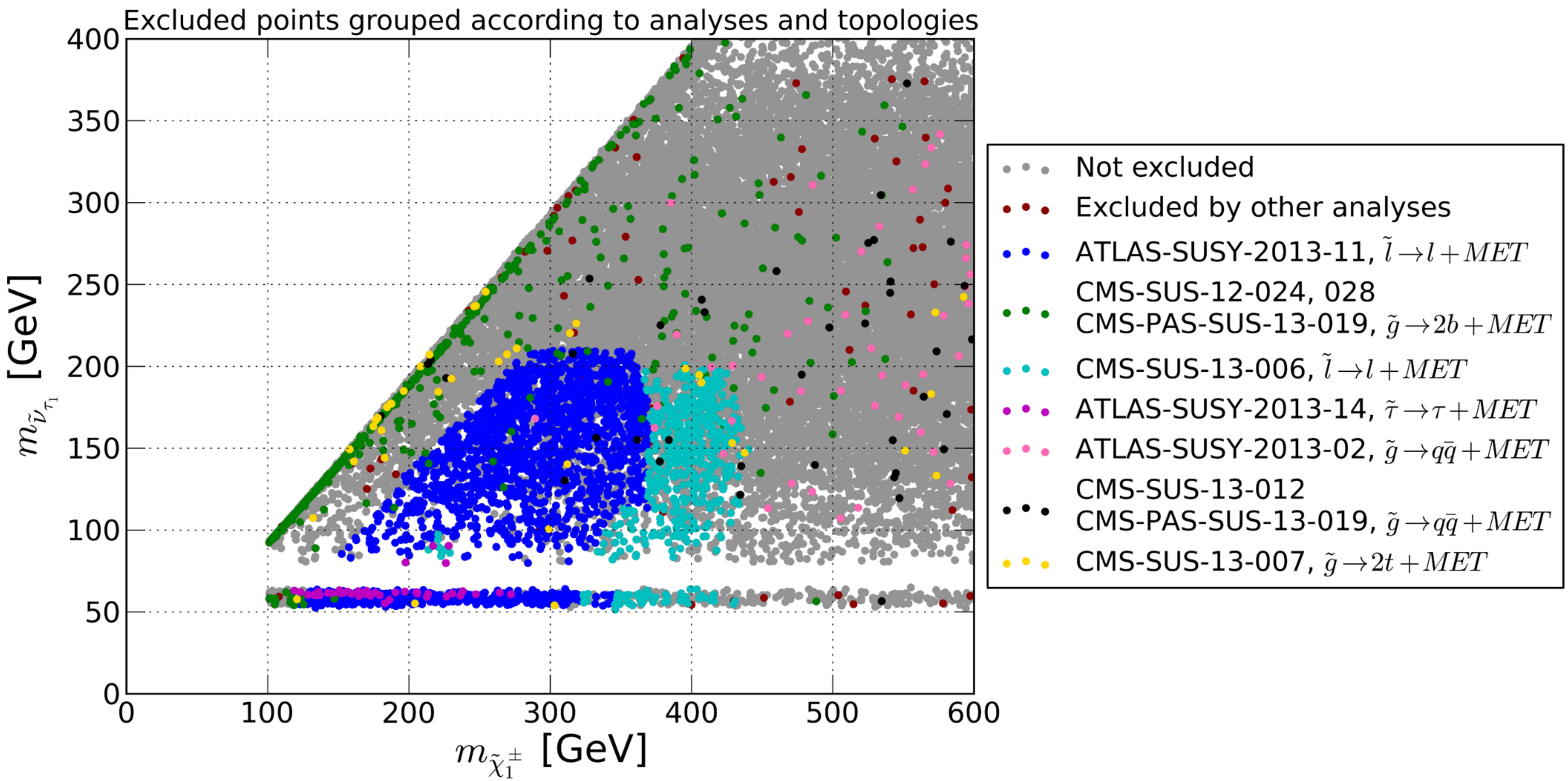
“missing topologies”, i.e. signatures that are not covered by any result in the database

- theory cross section prediction
- description of the signature

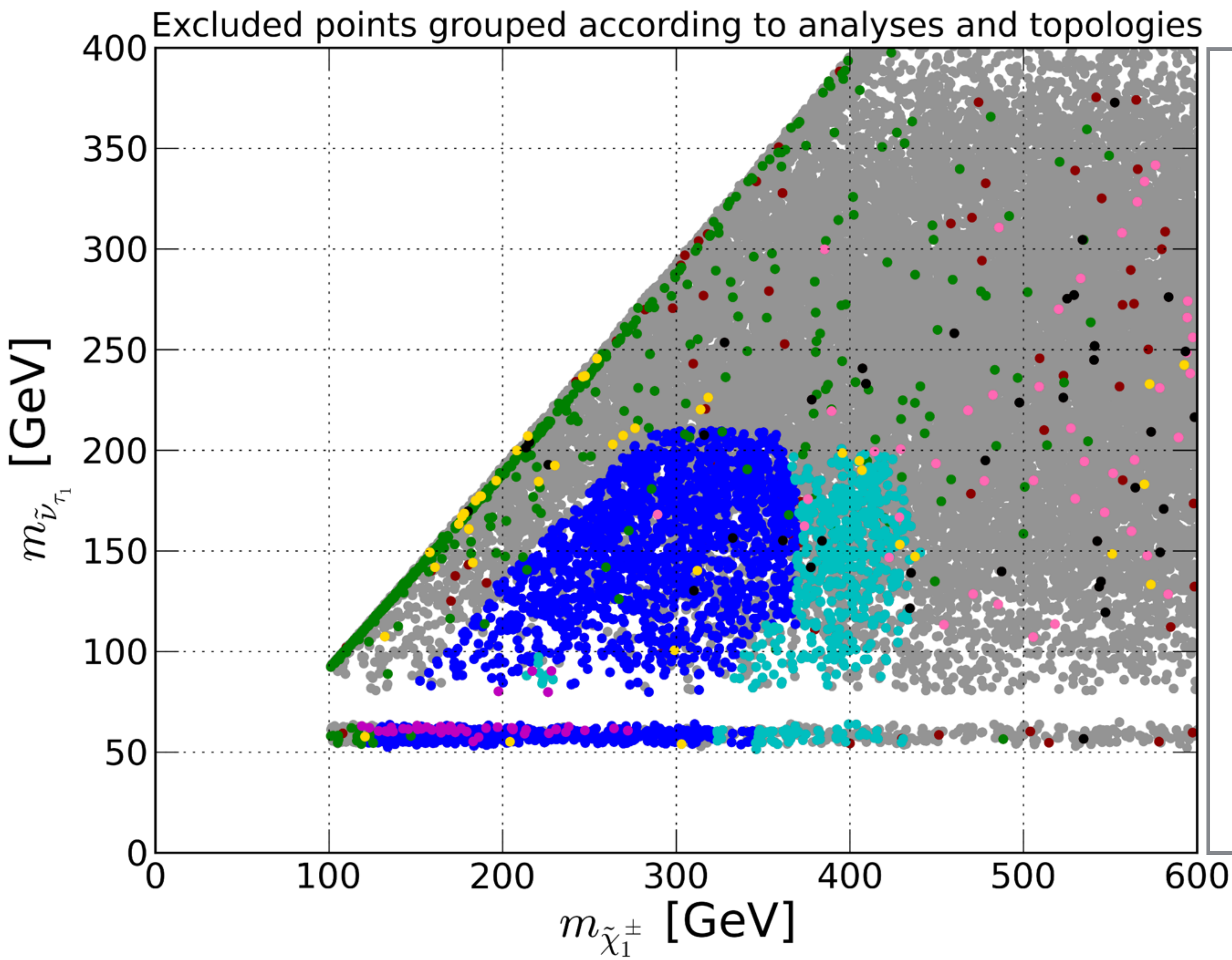
The results in the chargino - LSP mass plane

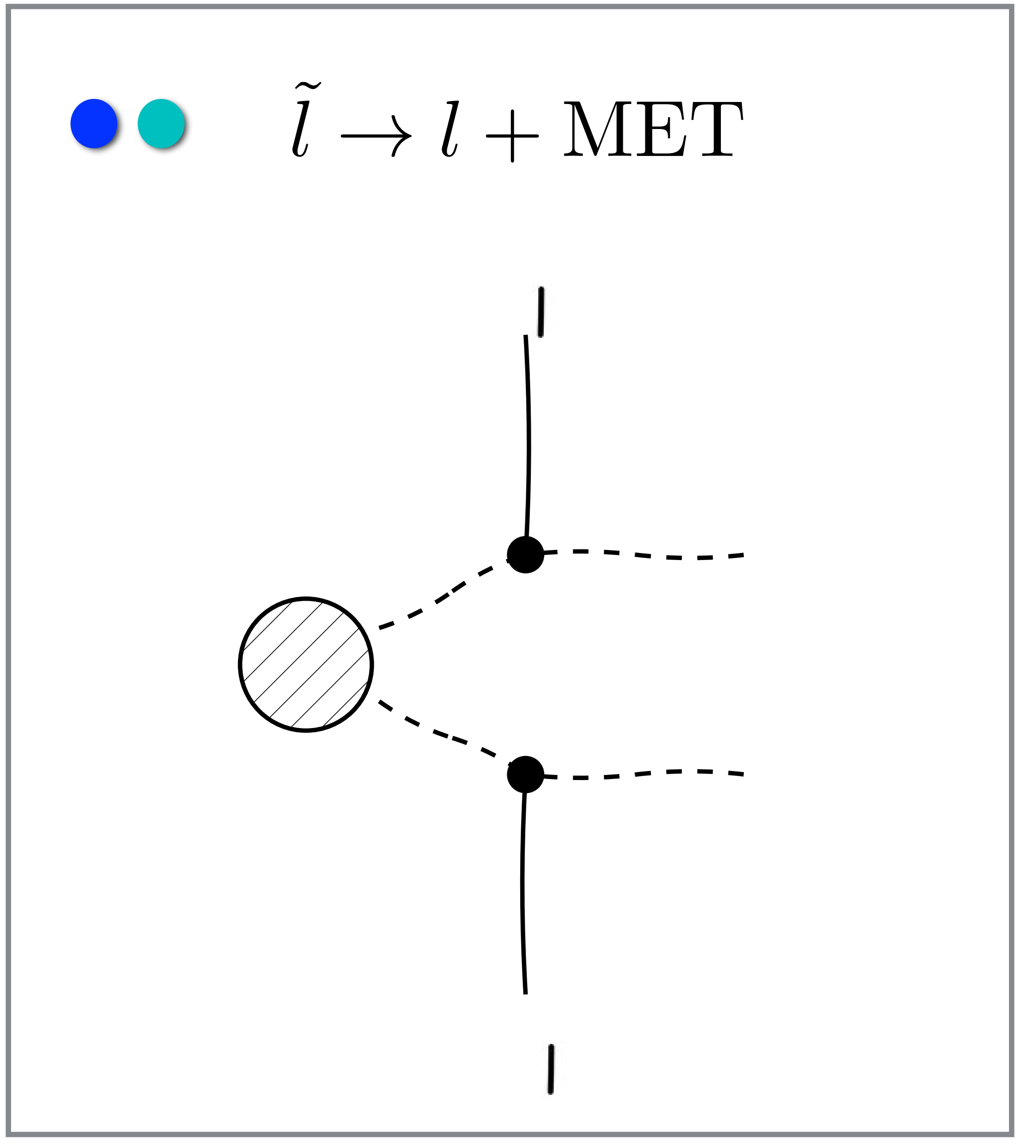


Which analyses give the most important constraints?

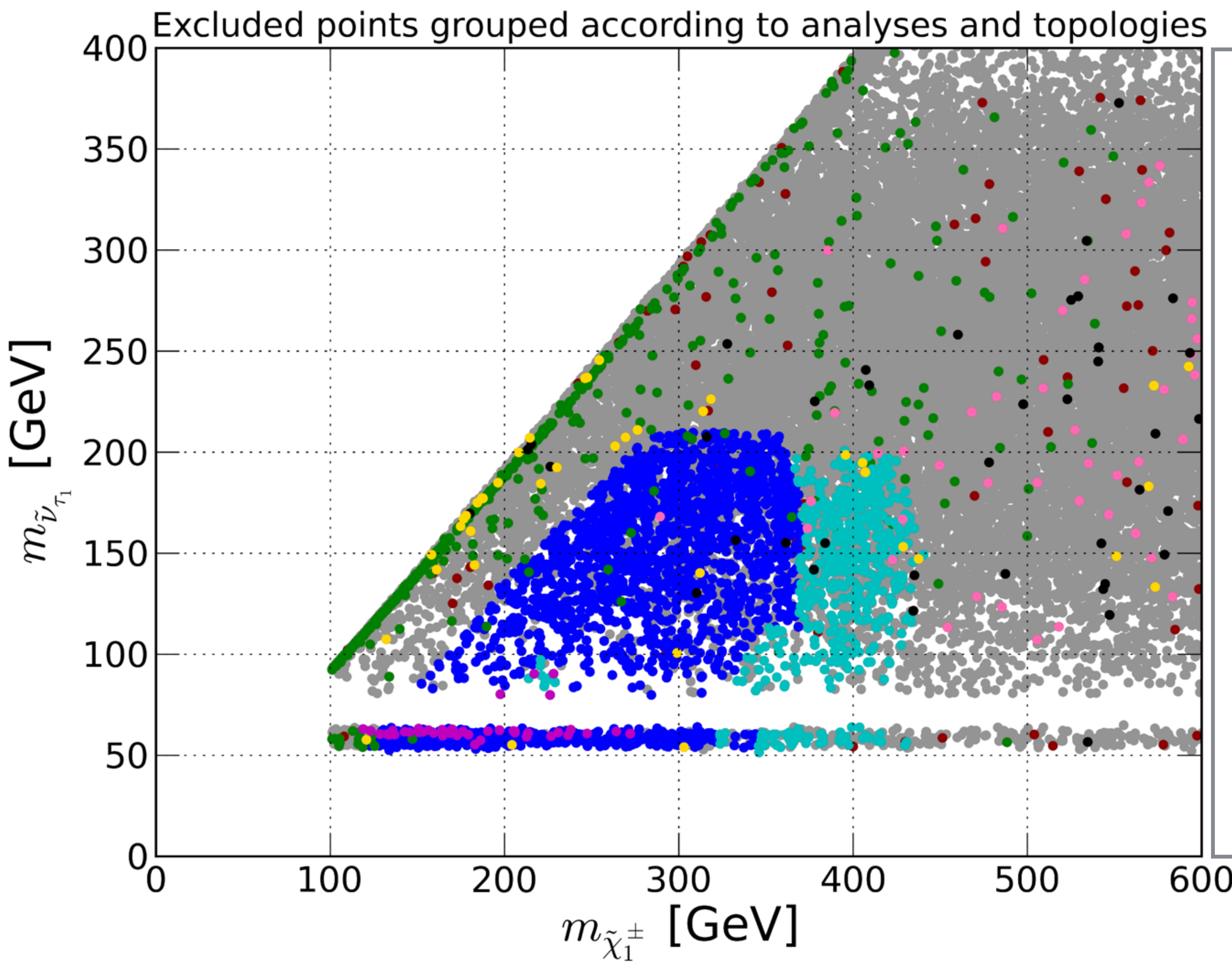


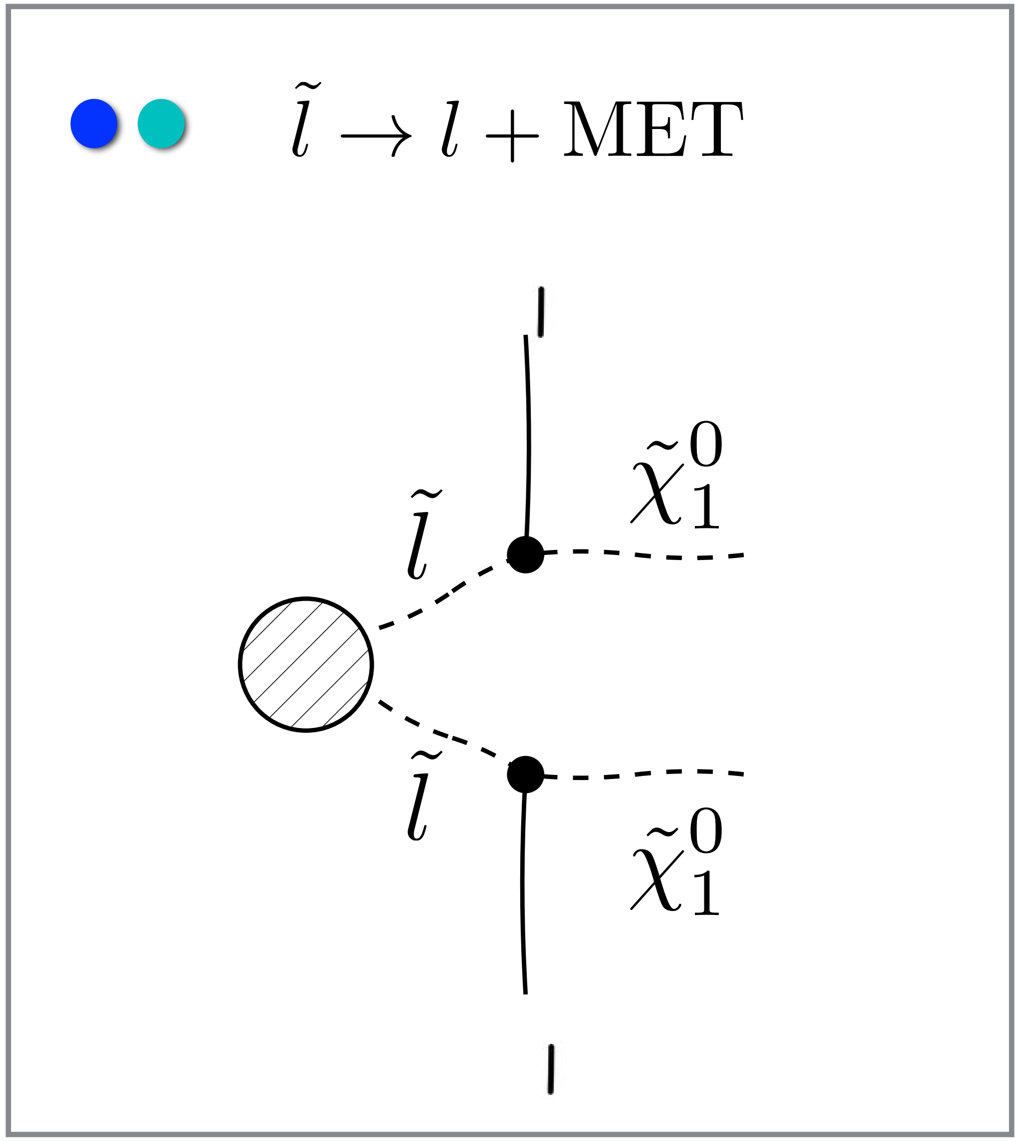
Which analyses give the most important constraints?



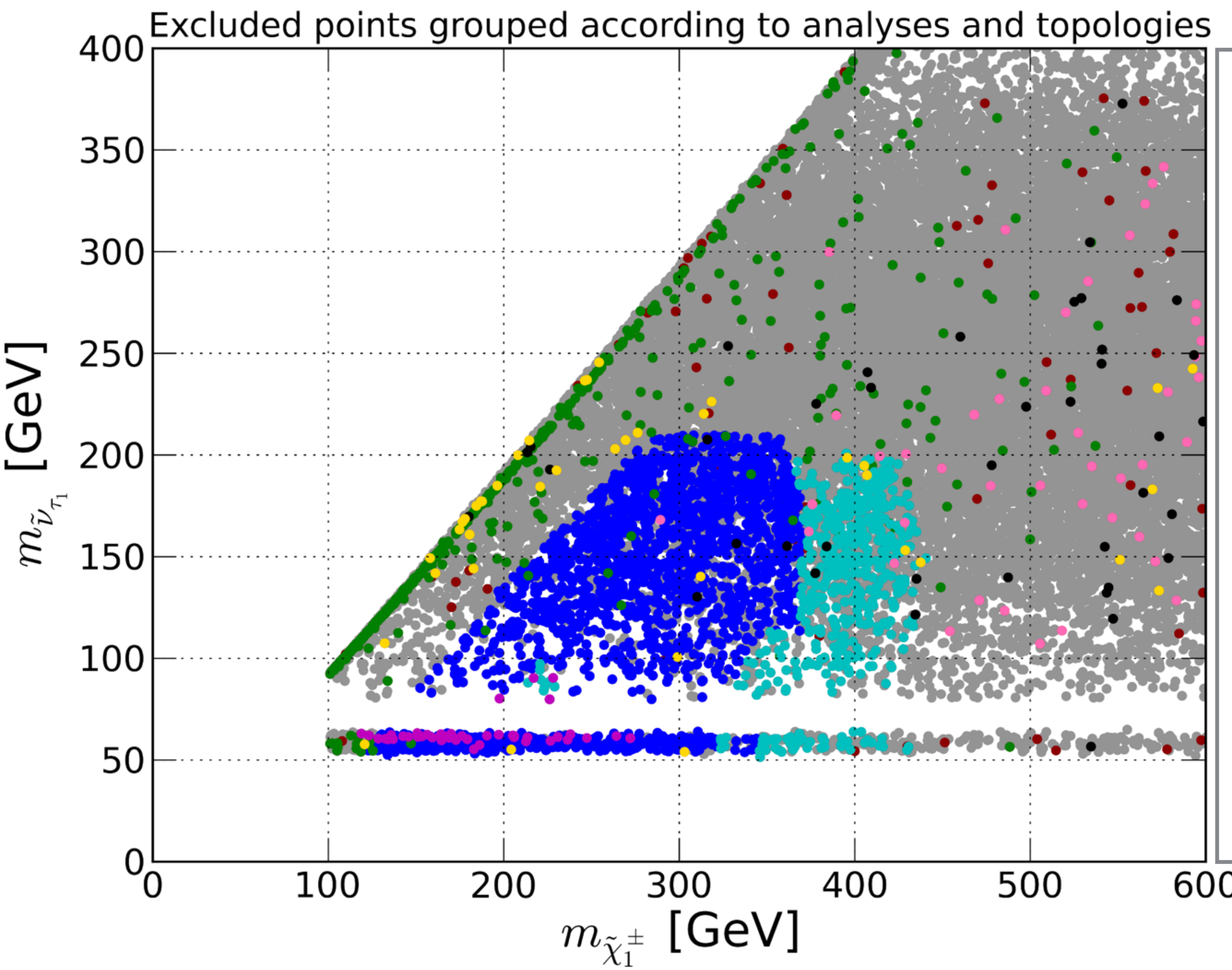


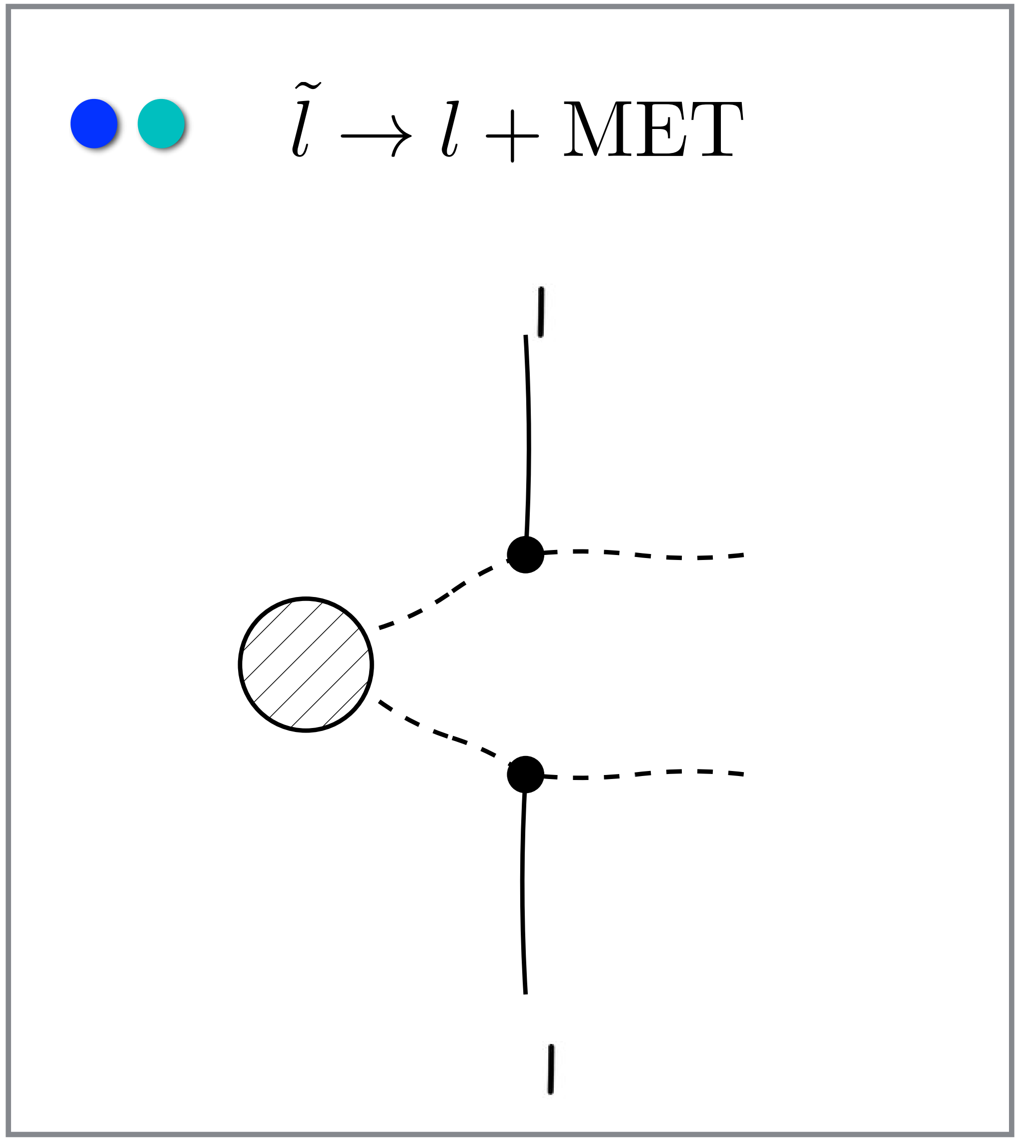
Which analyses give the most important constraints?



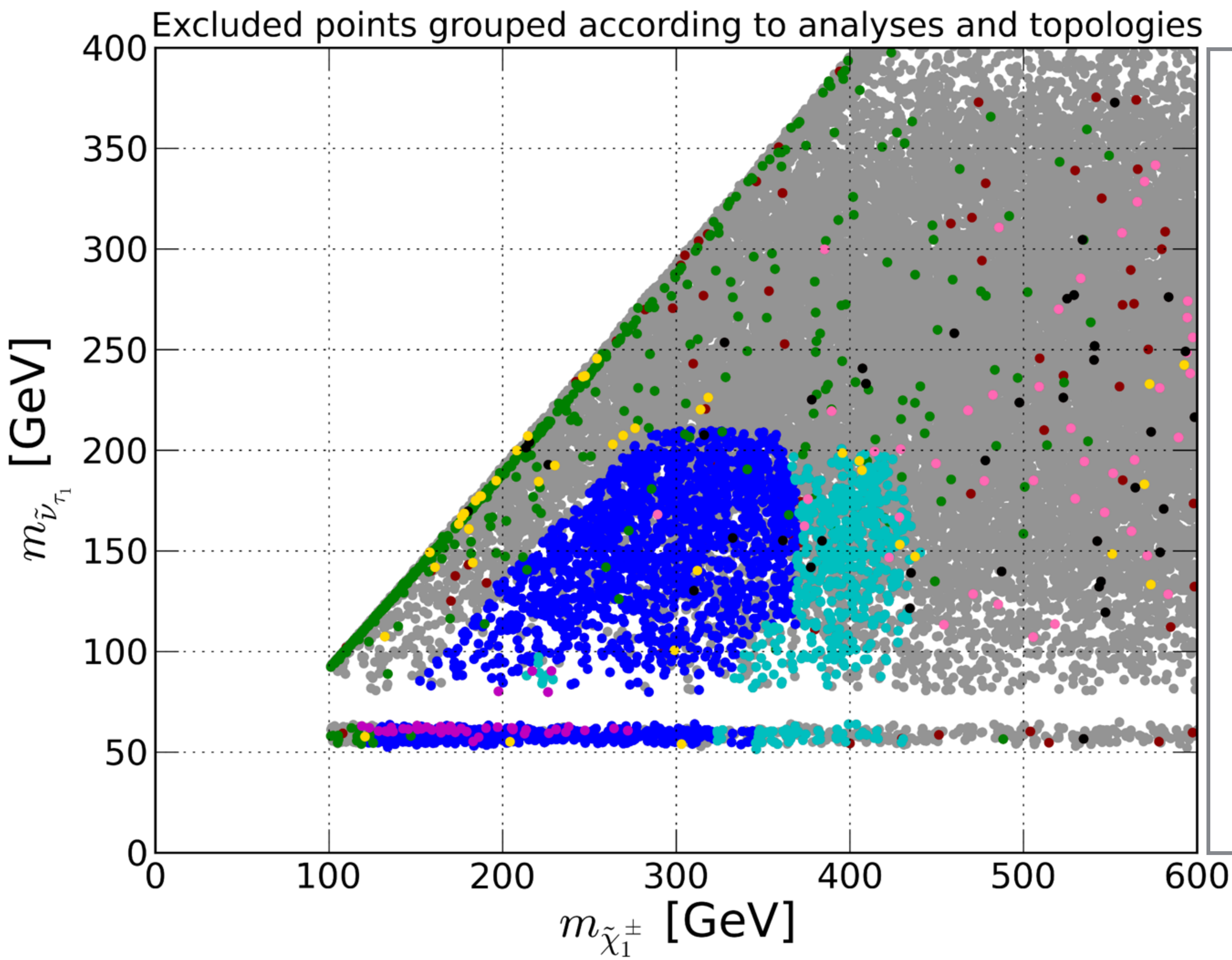


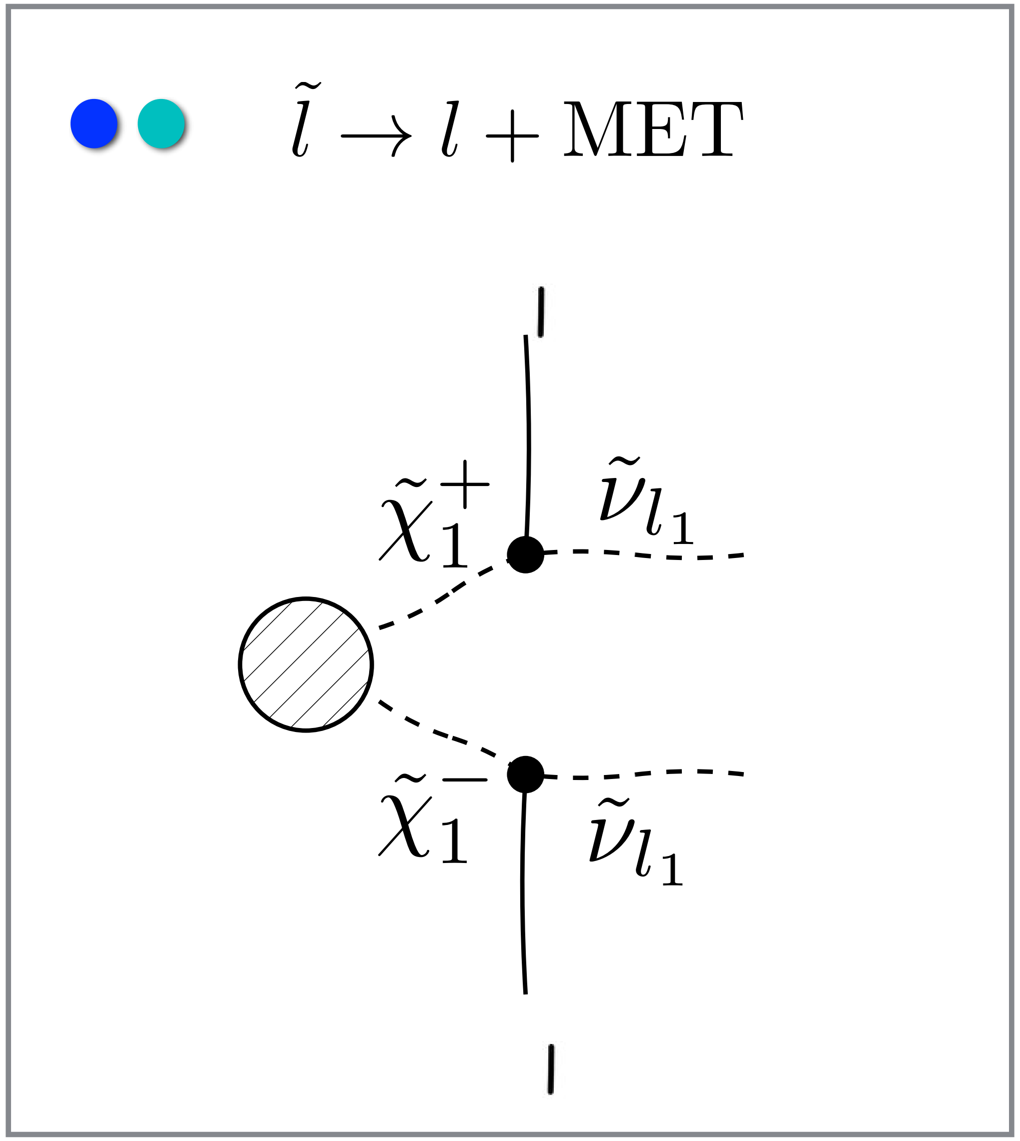
Which analyses give the most important constraints?



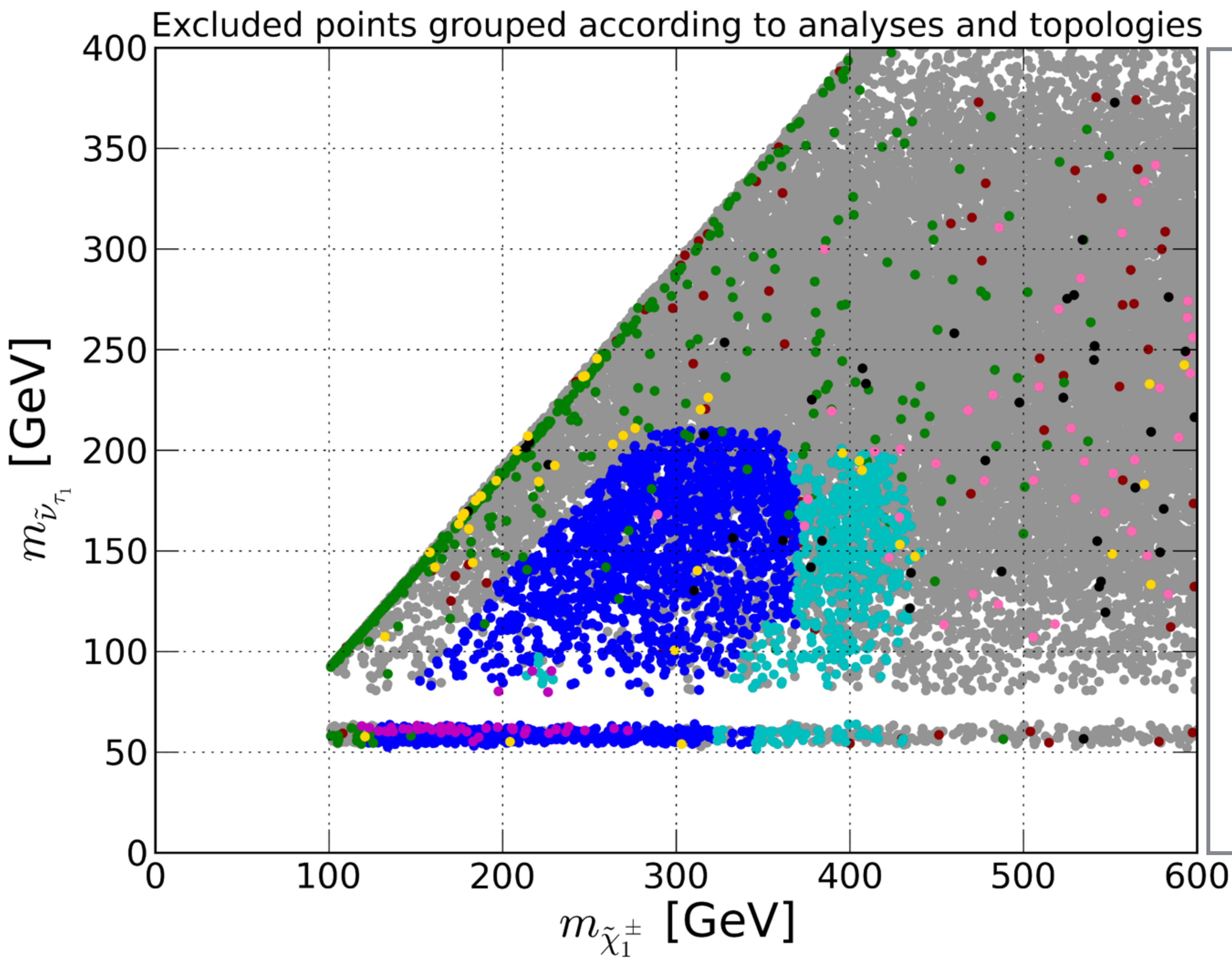


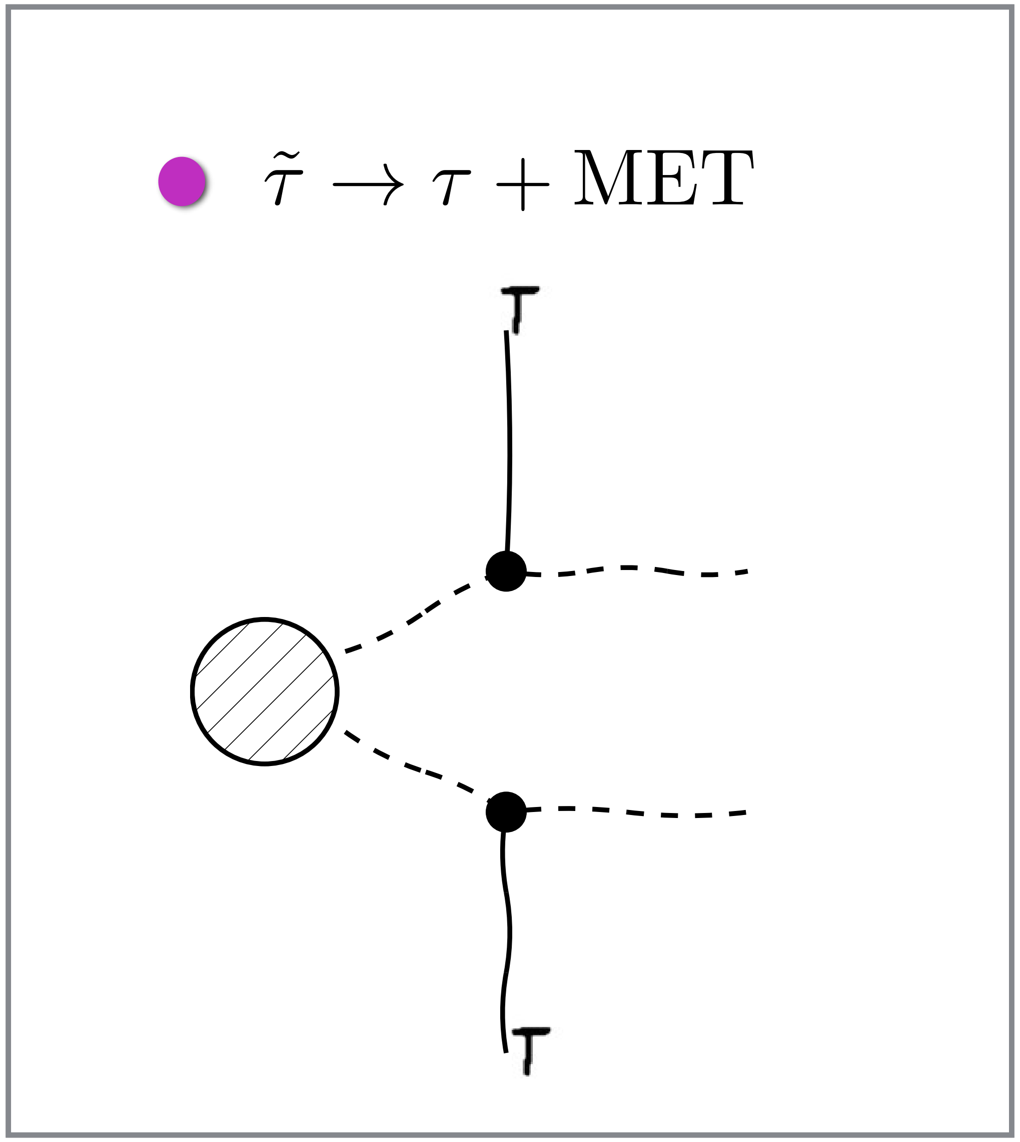
Which analyses give the most important constraints?



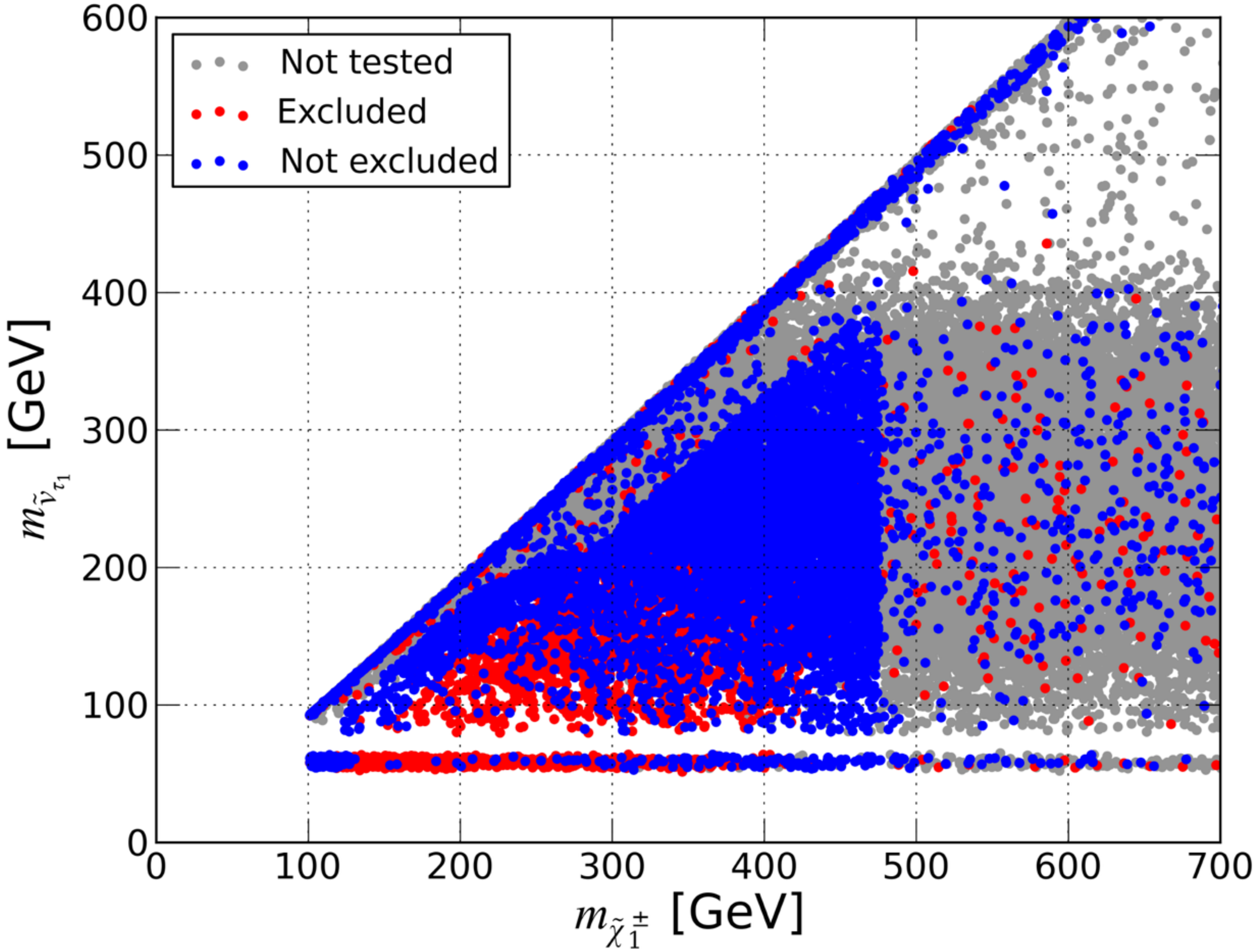


Which analyses give the most important constraints?

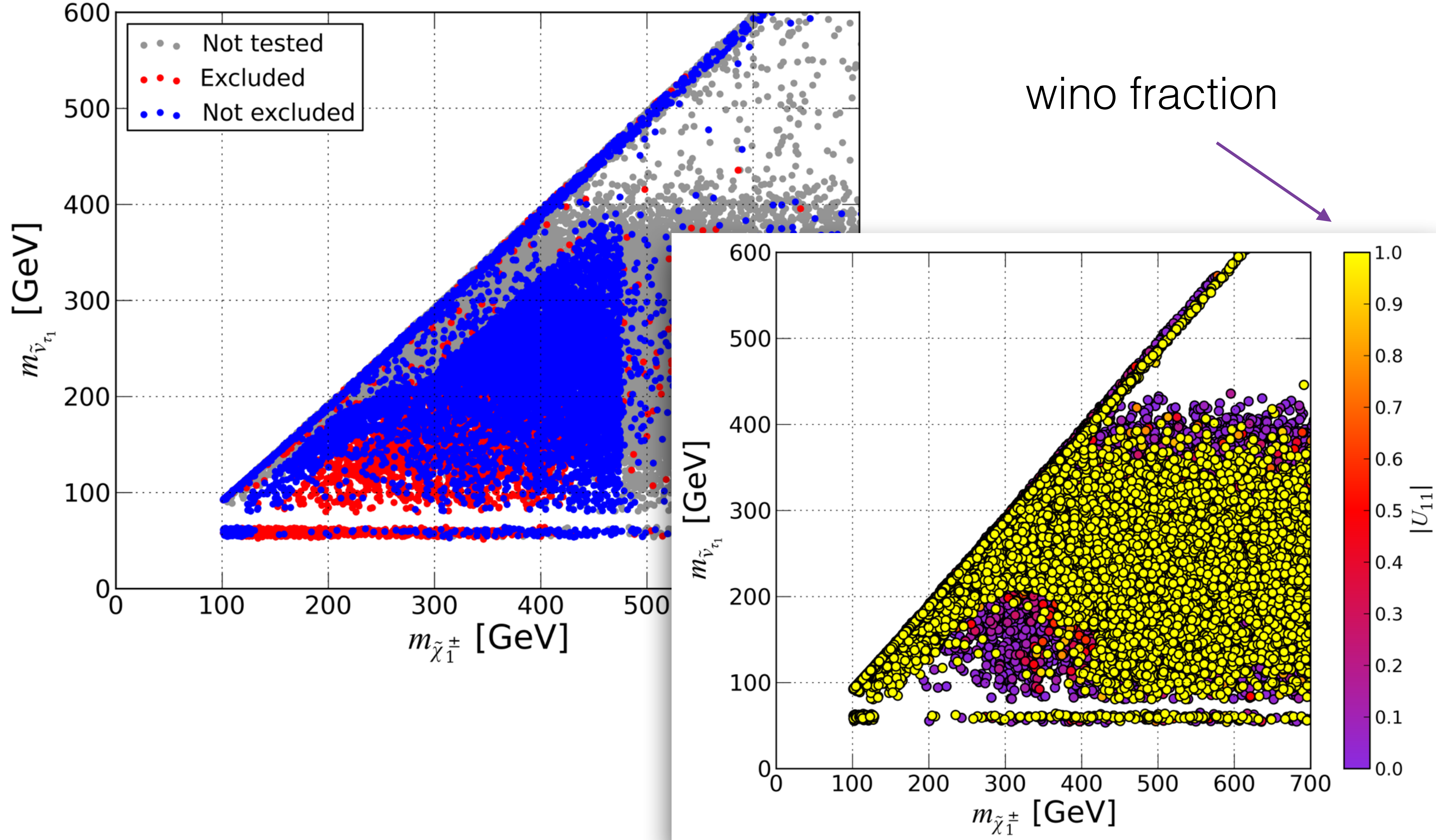




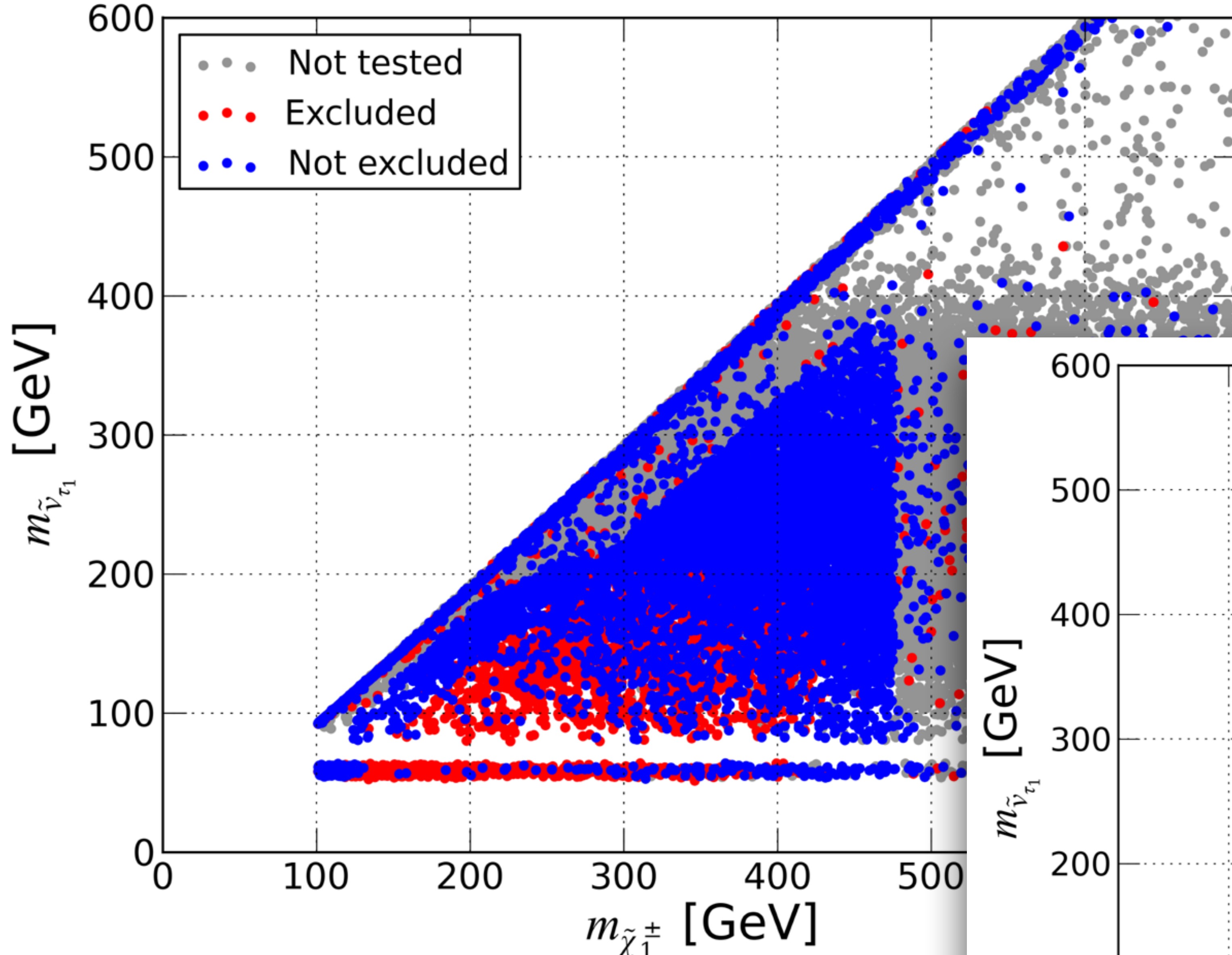
However, many points remain allowed



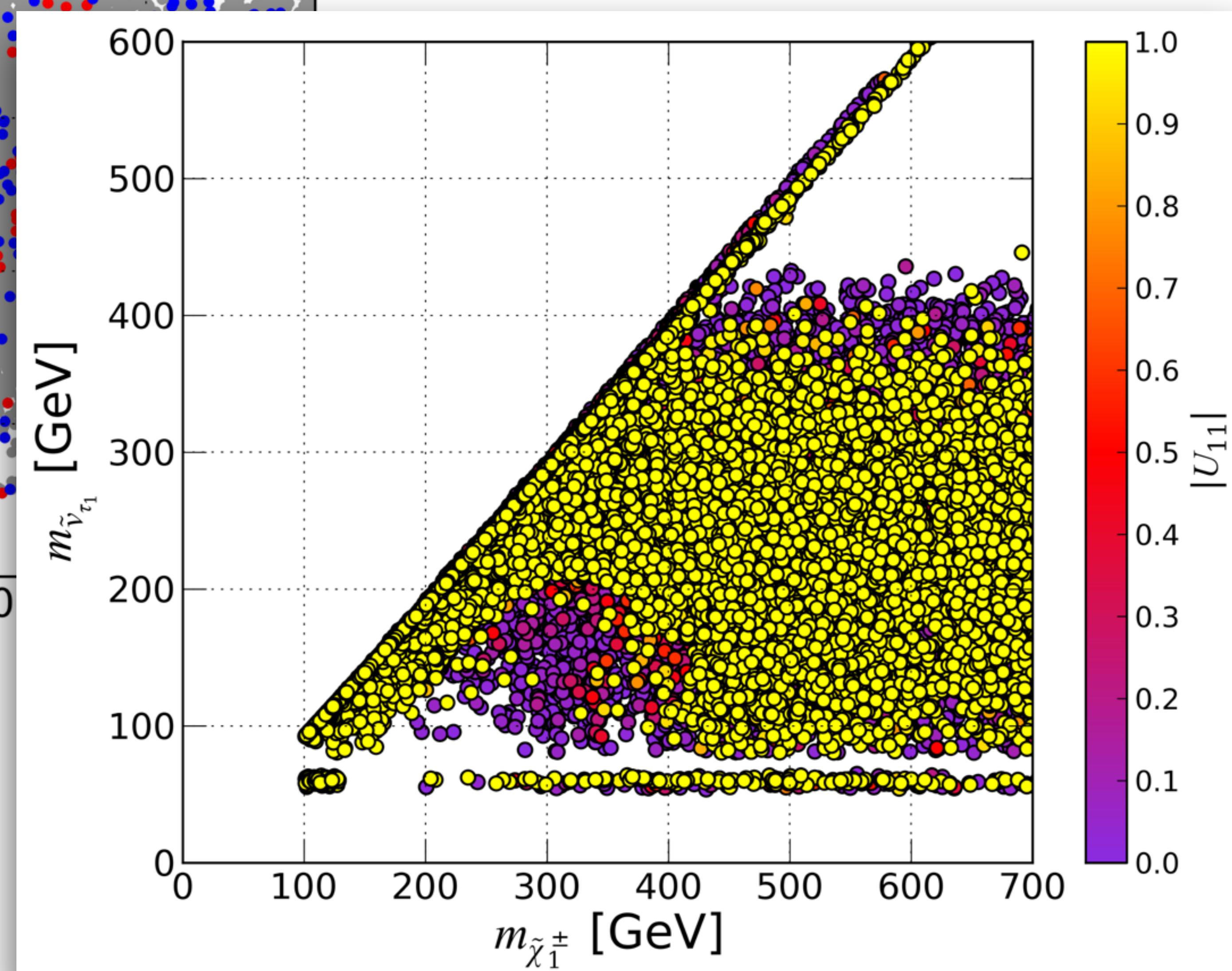
However, many points remain allowed



However, many points remain allowed



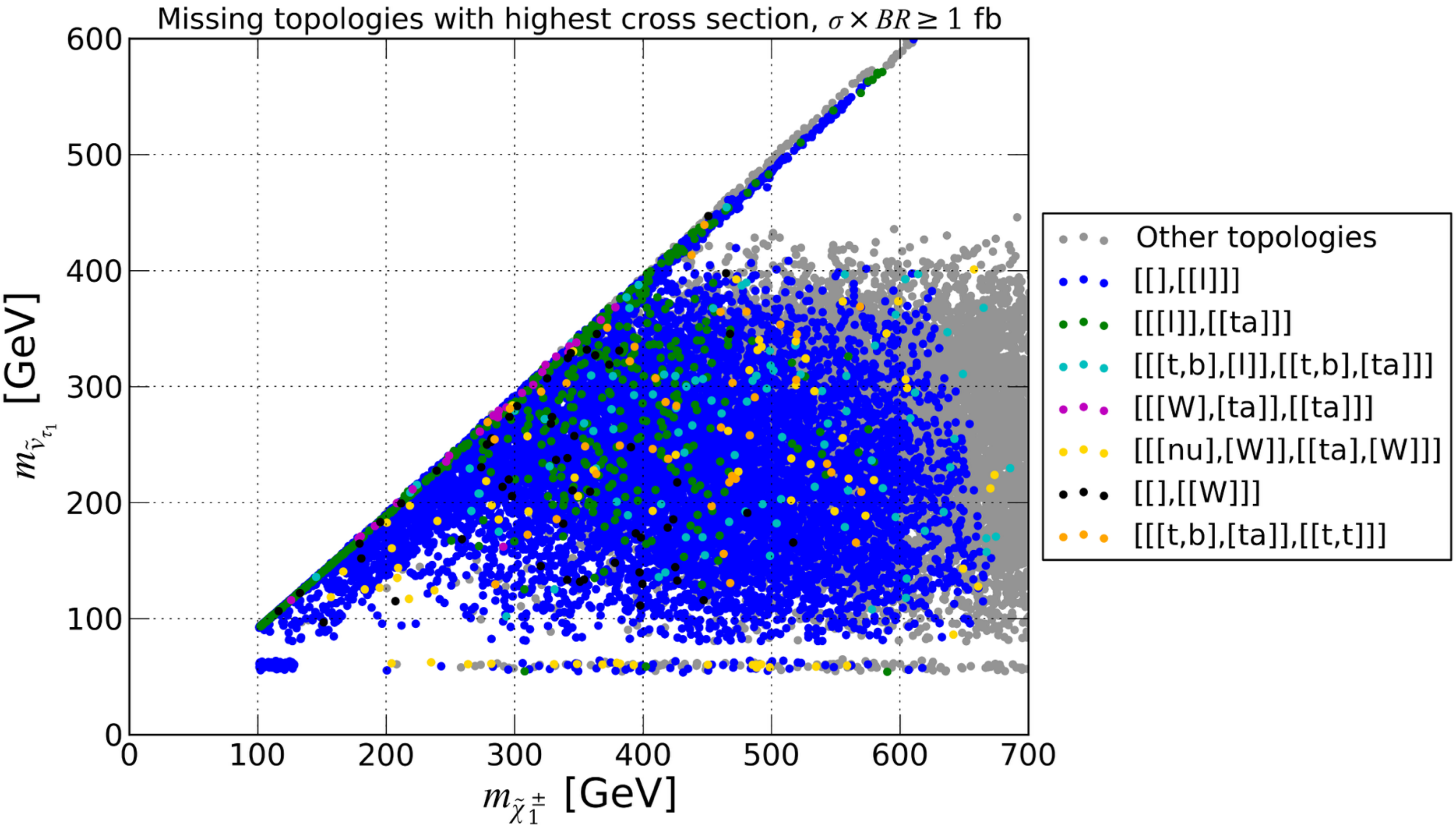
wino fraction



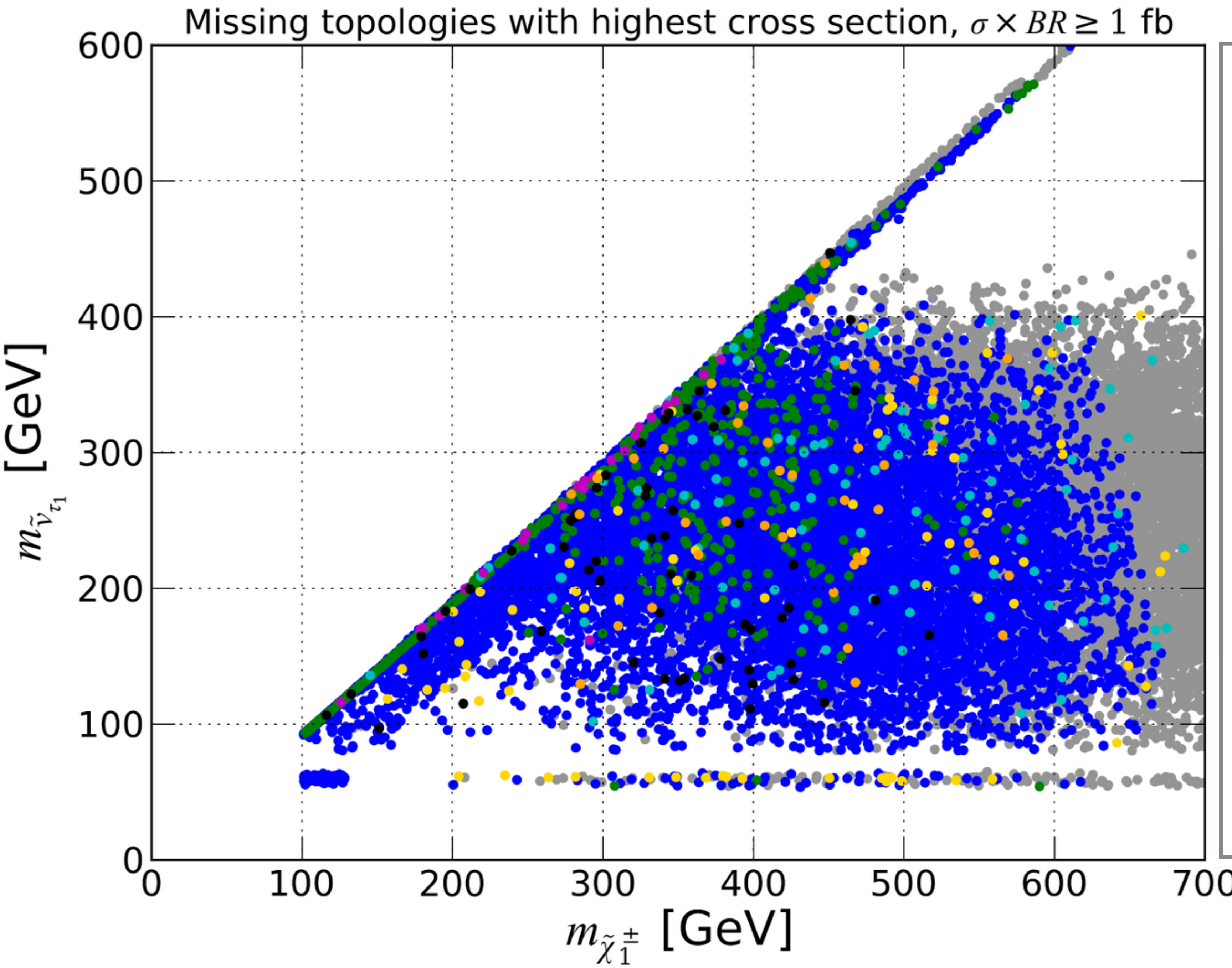
higgsino-like charginos:

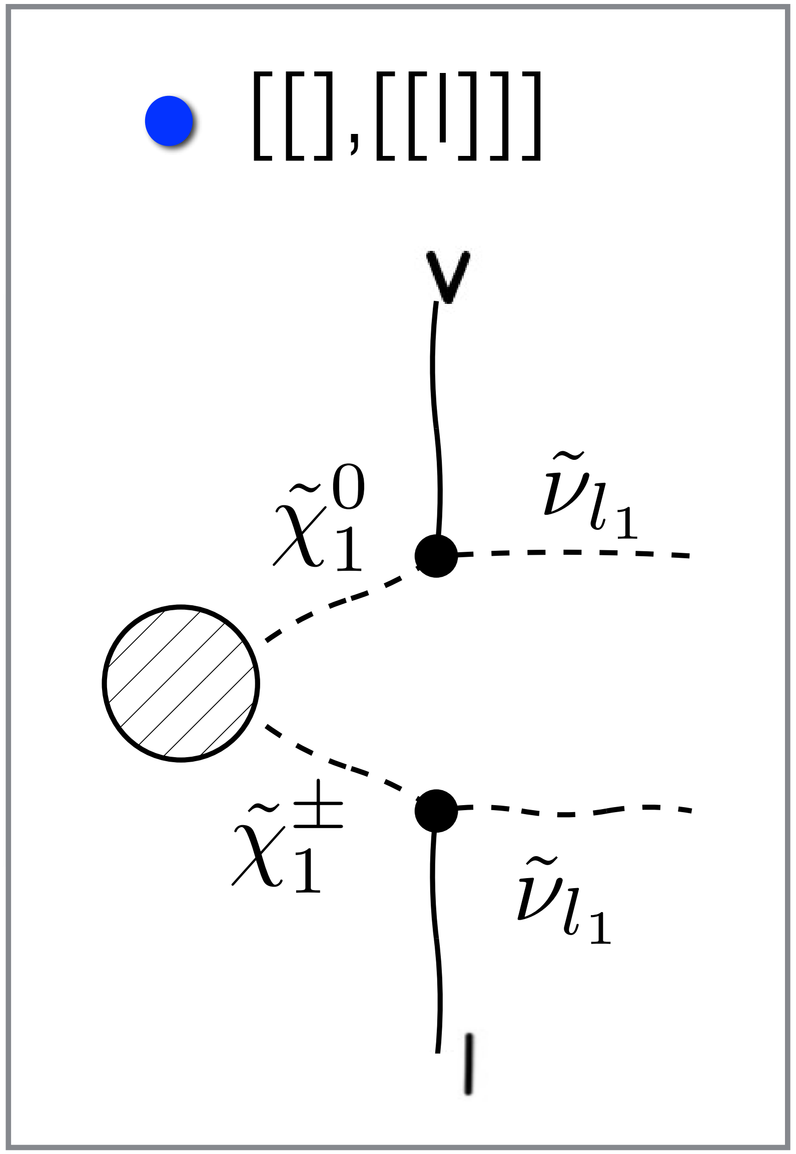
- smaller production cross section
- larger branching to tau final states

What do we miss?

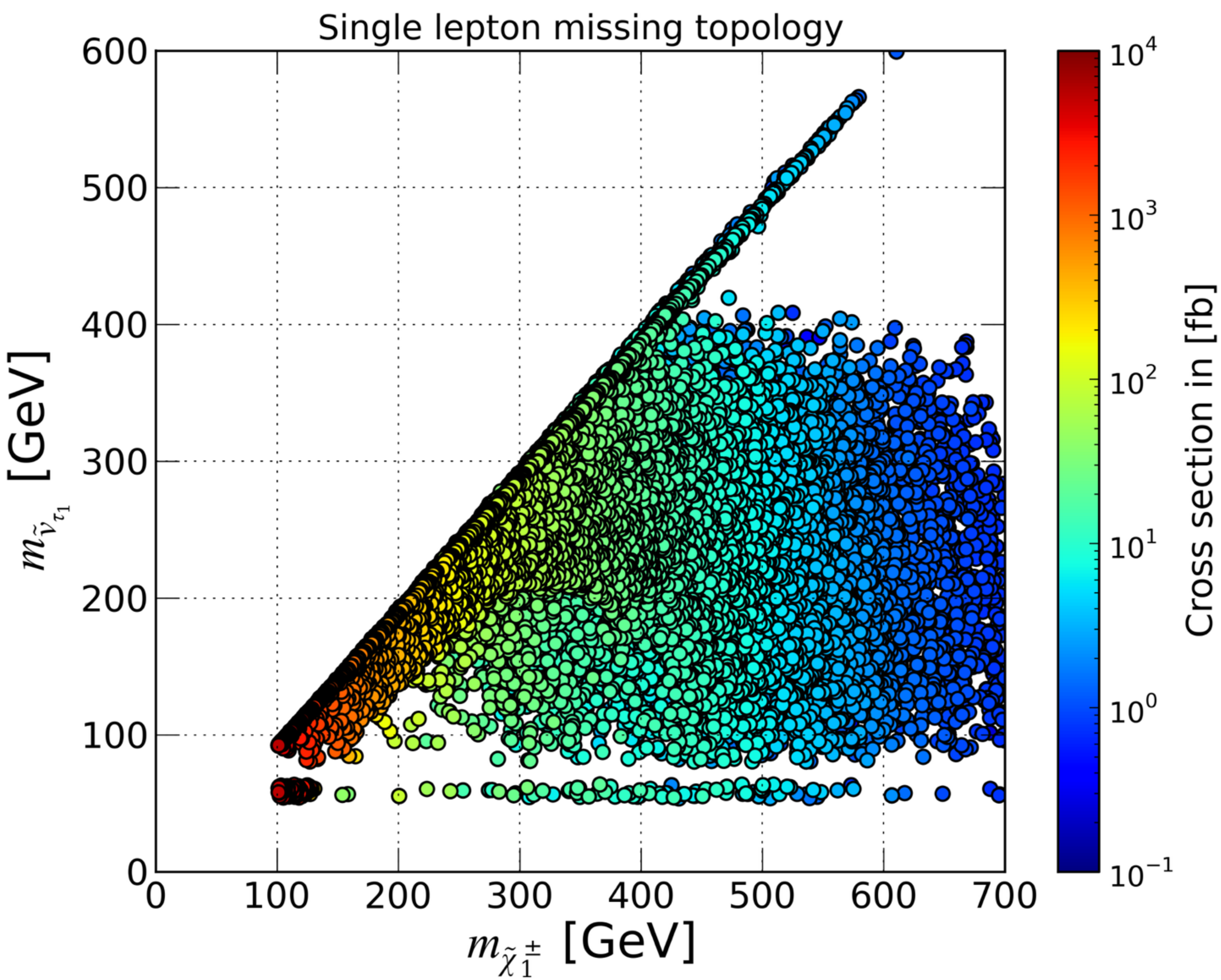


What do we miss?

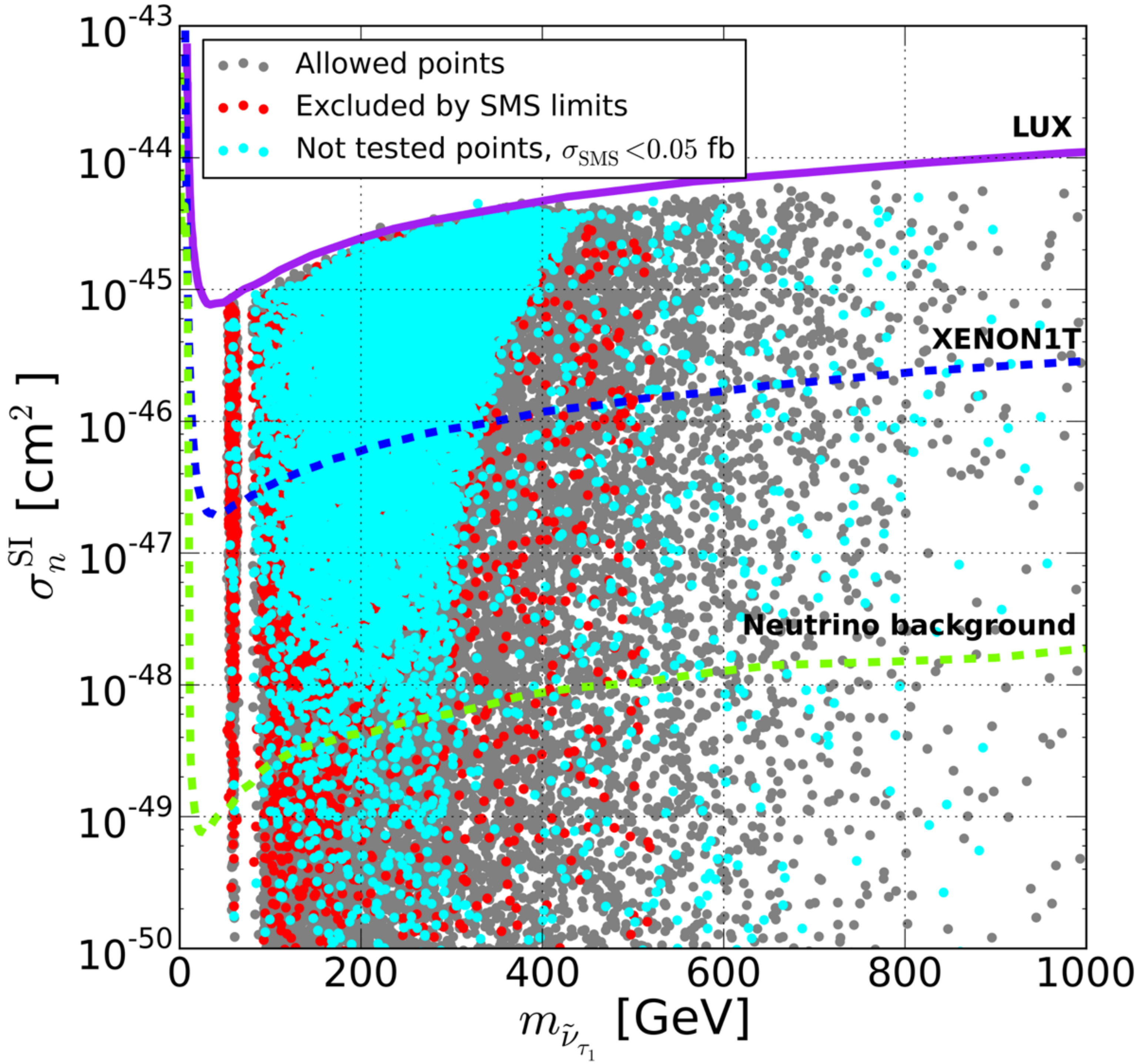




The single lepton topology can have a large cross section



LHC searches and direct dark matter detection experiments are complementary



Conclusion

- Existing LHC results can constrain the MSSM+RN
- In particular dilepton+MET searches constrain chargino pair production
- Constraints obtained for slepton production (followed by a decay to a neutralino) apply to pair produced charginos (decaying to a sneutrino)
- Single lepton searches considering chargino-neutralino production followed by a decay to sneutrino would test the model further
- LHC constraints are complementary to direct dark matter searches
- Long-lived gluinos are symptomatic in the MSSM+RN

Backup

Using SModelS for non-MSSM scenarios

Simply declare all new particles as
R-even or R-odd in smodels/particles.py

Example

```
rOdd = {9000000 : "newROdd"
        1000021 : "gluino",
        1000022 : "N1",
        …

rEven = {8000000: "newREven"
         25 : “higgs",
         …
```

Additional feature for SLHA input files

SModelS can test the consistency of an SLHA input file

In particular

Current experimental constraints require final states containing missing transverse energy

→ results apply only for prompt decays

points with visible displaced vertices or heavy charged particle tracks cannot be tested against existing SMS results

→ we flag points with long-lived particles ($c\tau > 10\,$mm)

Requires additional information on the quantum numbers of the new states

to decide if a displaced vertex is visible or not

this is also defined in smodels/particles.py

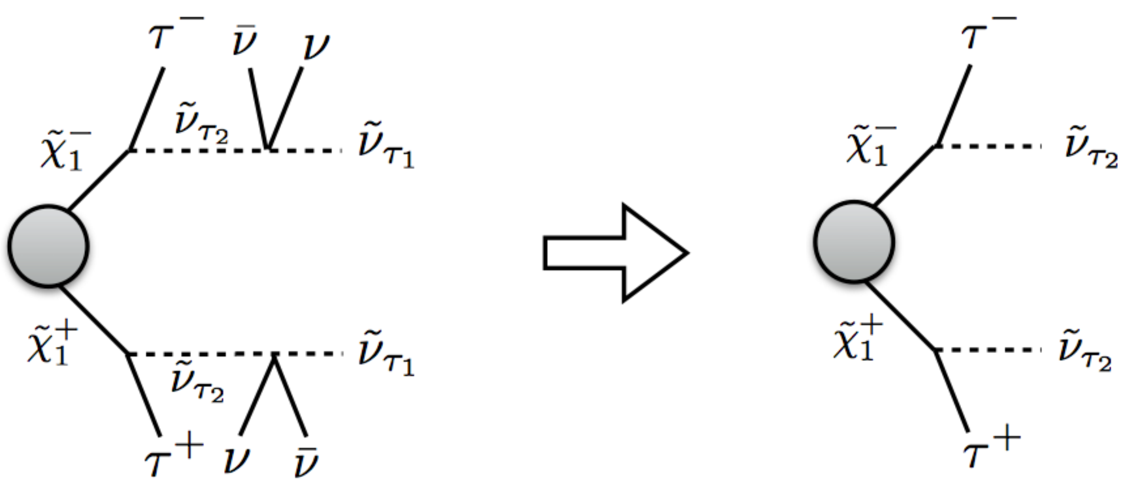
```
qNumbers={
 35:[0,0,1],
 36:[0,0,1],
 37:[0,3,1],
 1000024:[1,3,1],
 …
```

giving 2*spin, 3*electrical charge, colour dimension

Compression of final states

Invisible compression

compress fully invisible vertices at the end of a decay chain



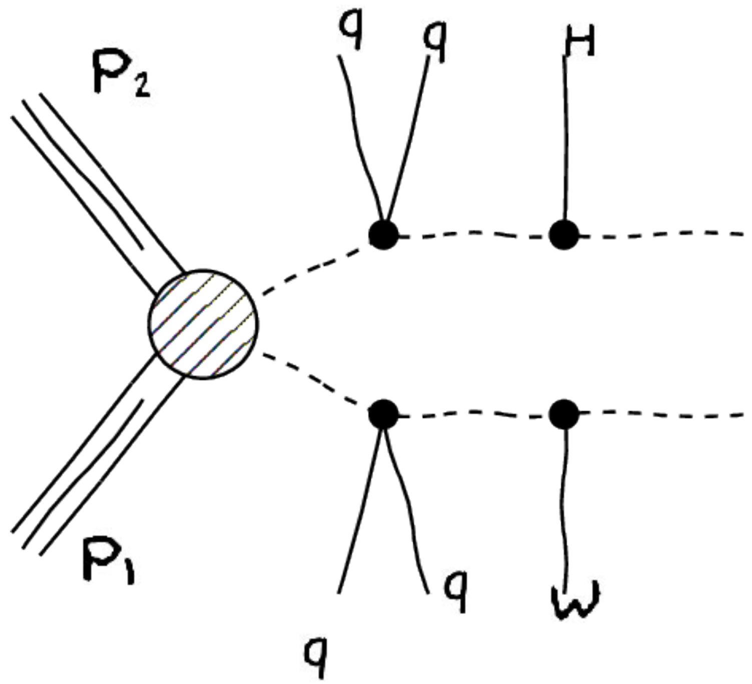
Mass compression

compress vertices where the mass splitting is small, decay products will be too soft to be detected

we used 5 GeV as the threshold value

How to read the element description

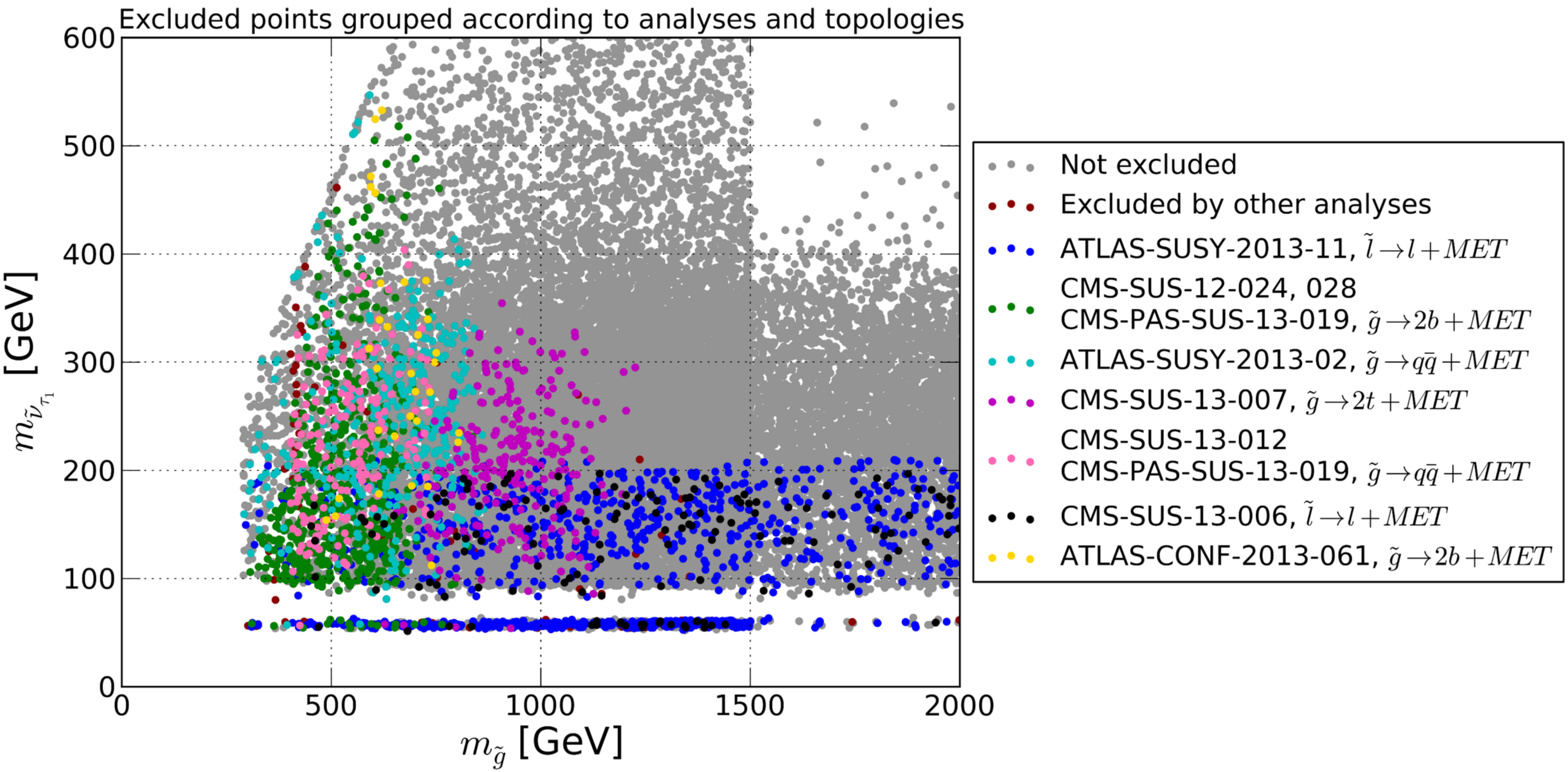
Example: gluino production, decay via chargino/neutralino



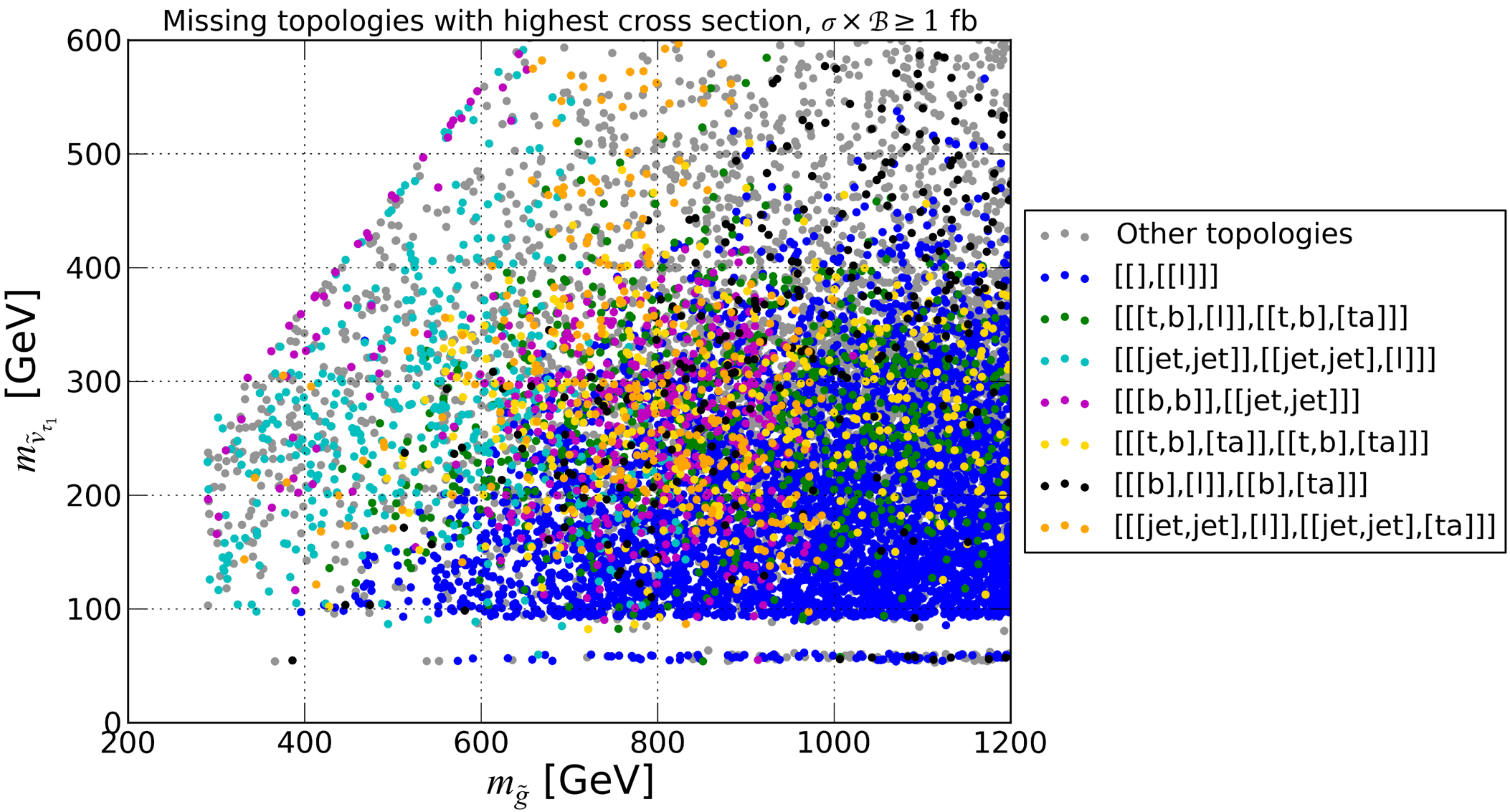
in SModelS language this is

[[[jet,jet],[H]],[[jet,jet],[W]]]

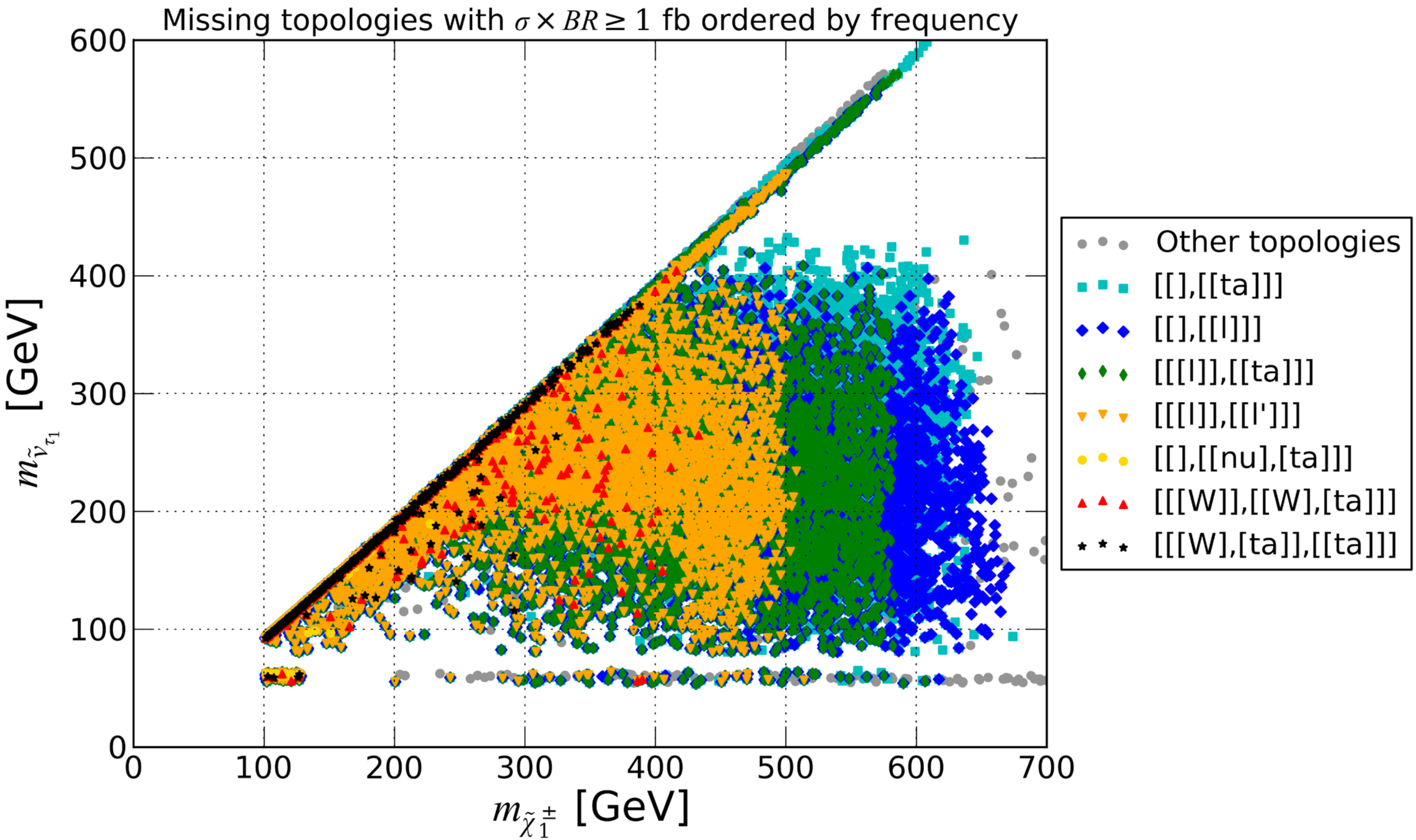
Constraints on the strong sector



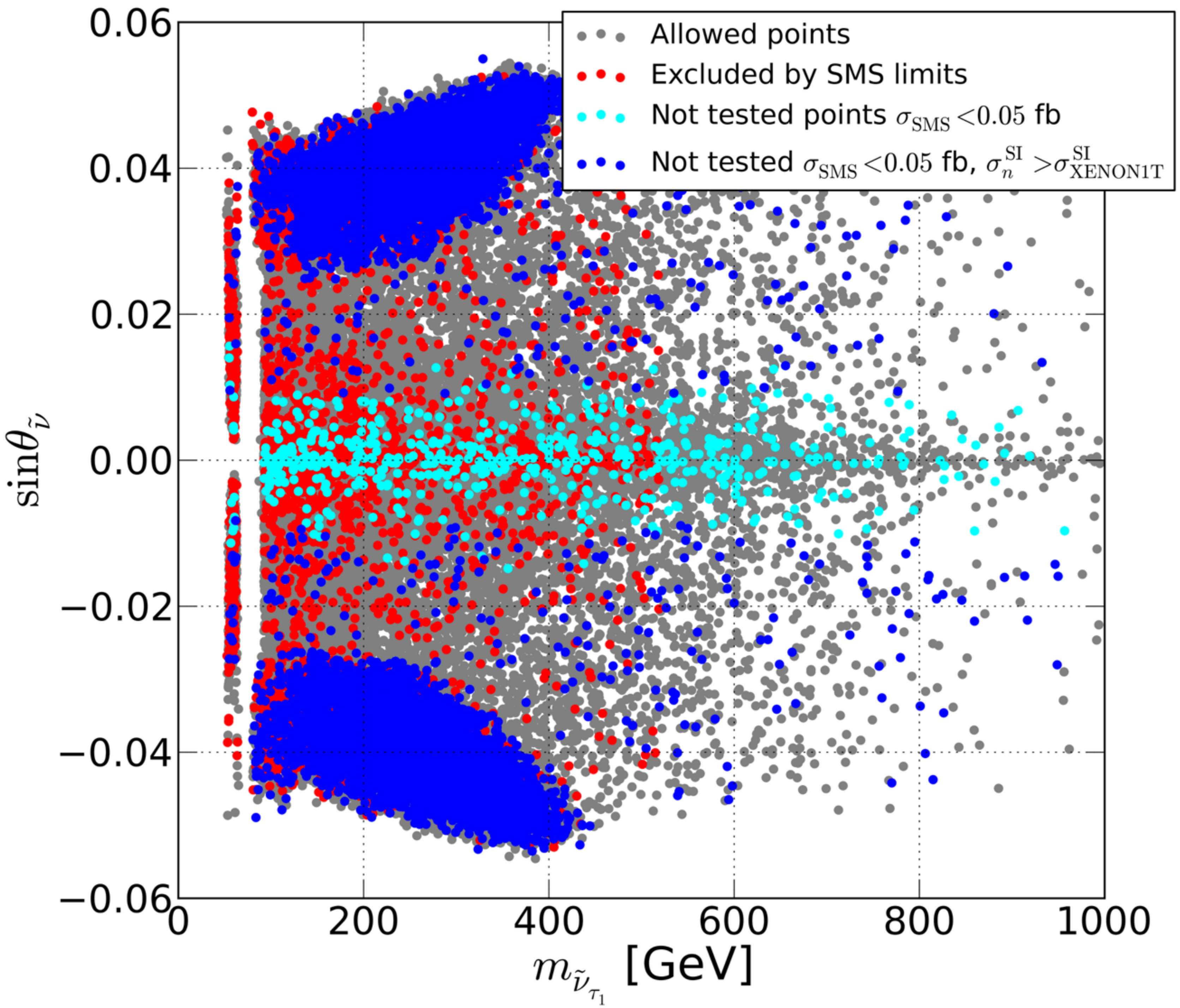
Missing topologies



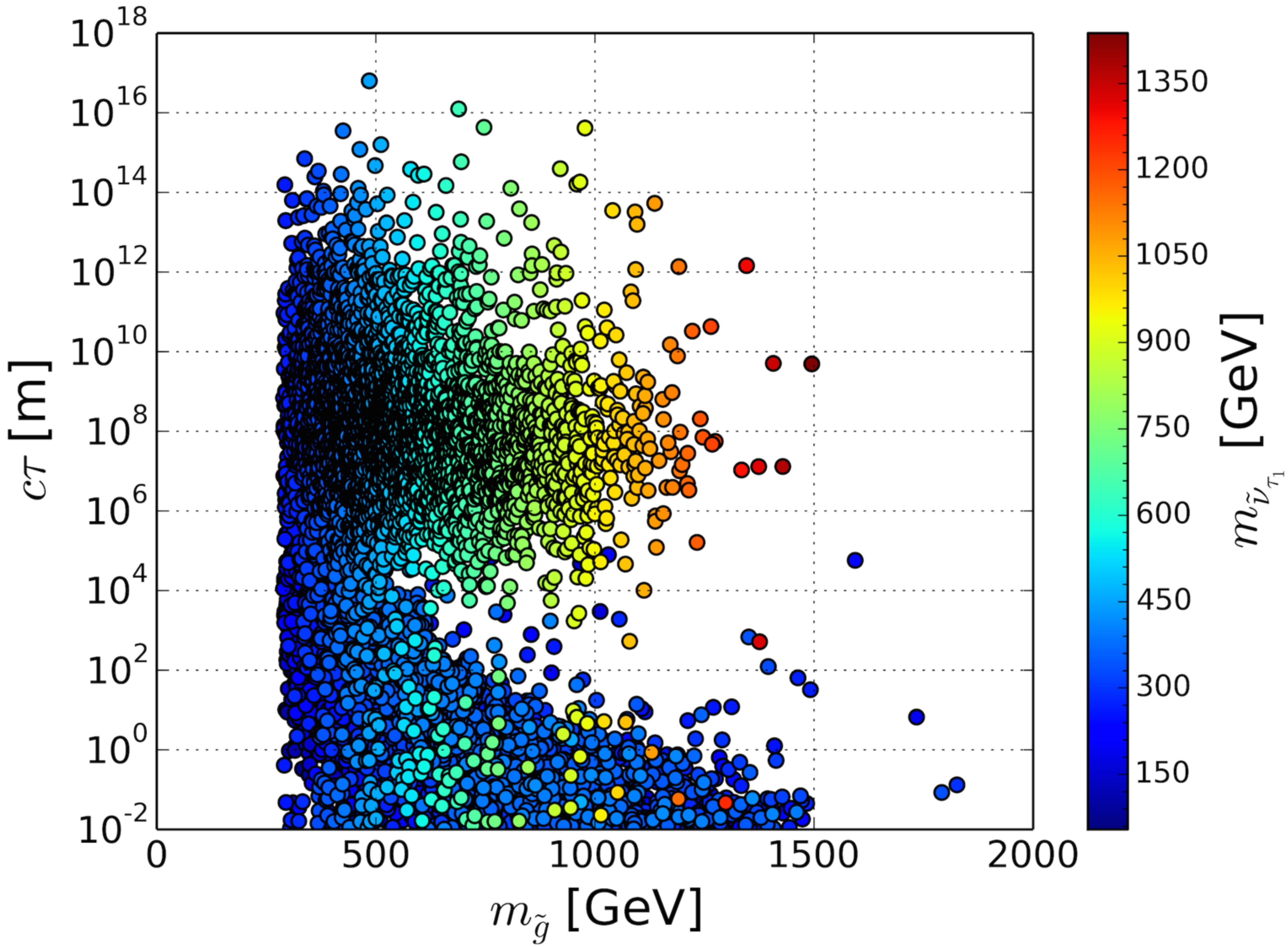
Most frequent missing topologies



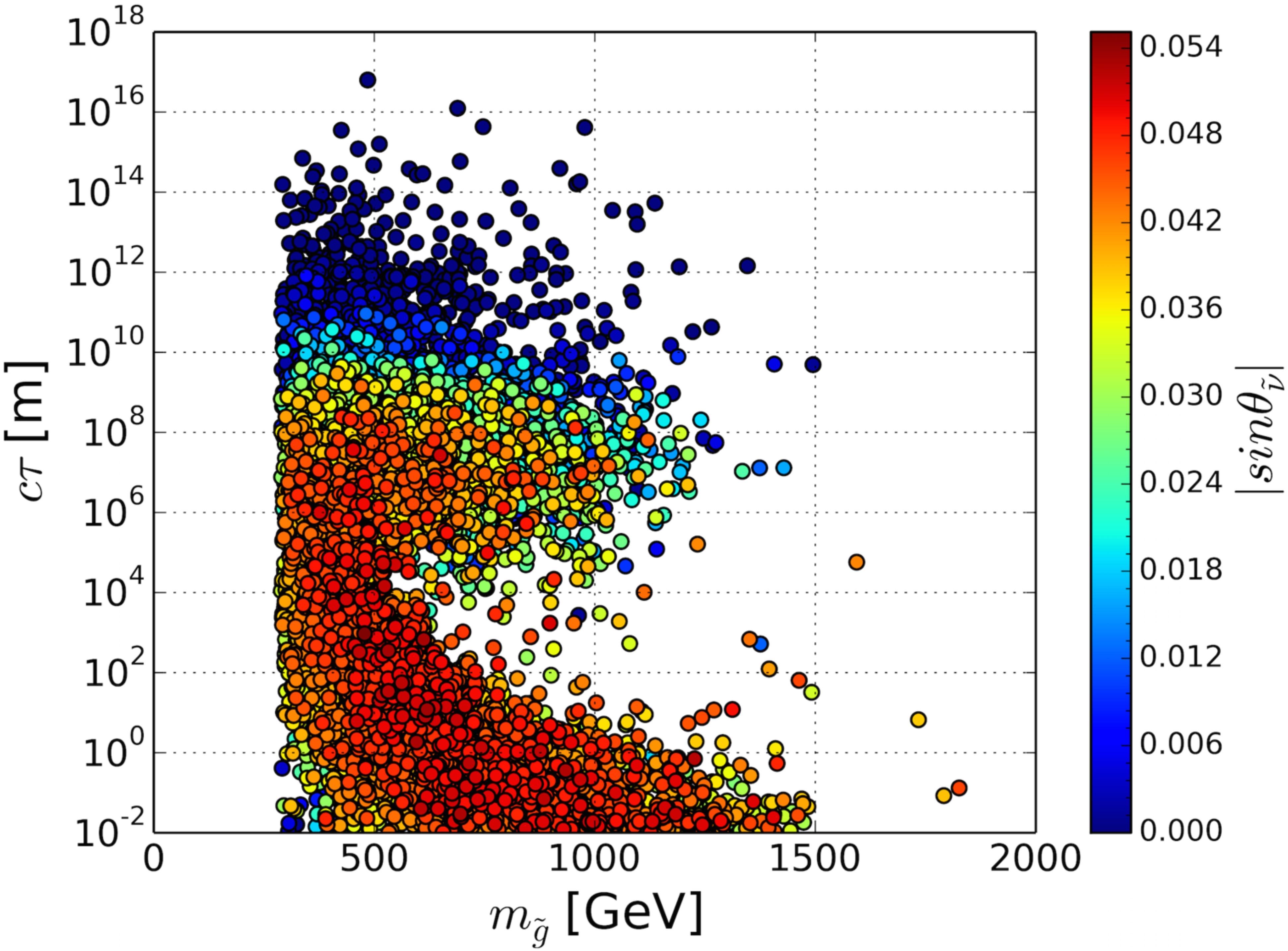
Dependence on the mixing angle



Many points feature long-lived gluinos



Many points feature long-lived gluinos

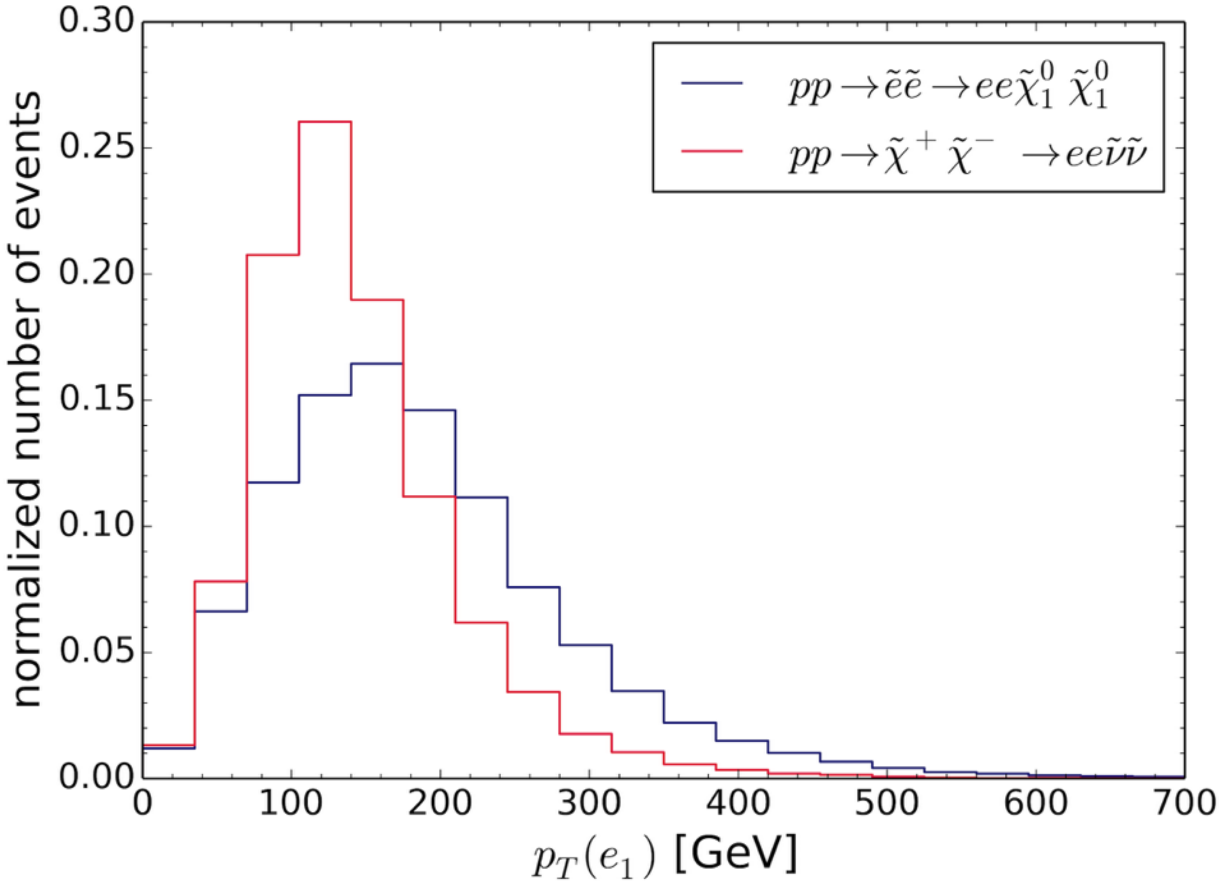


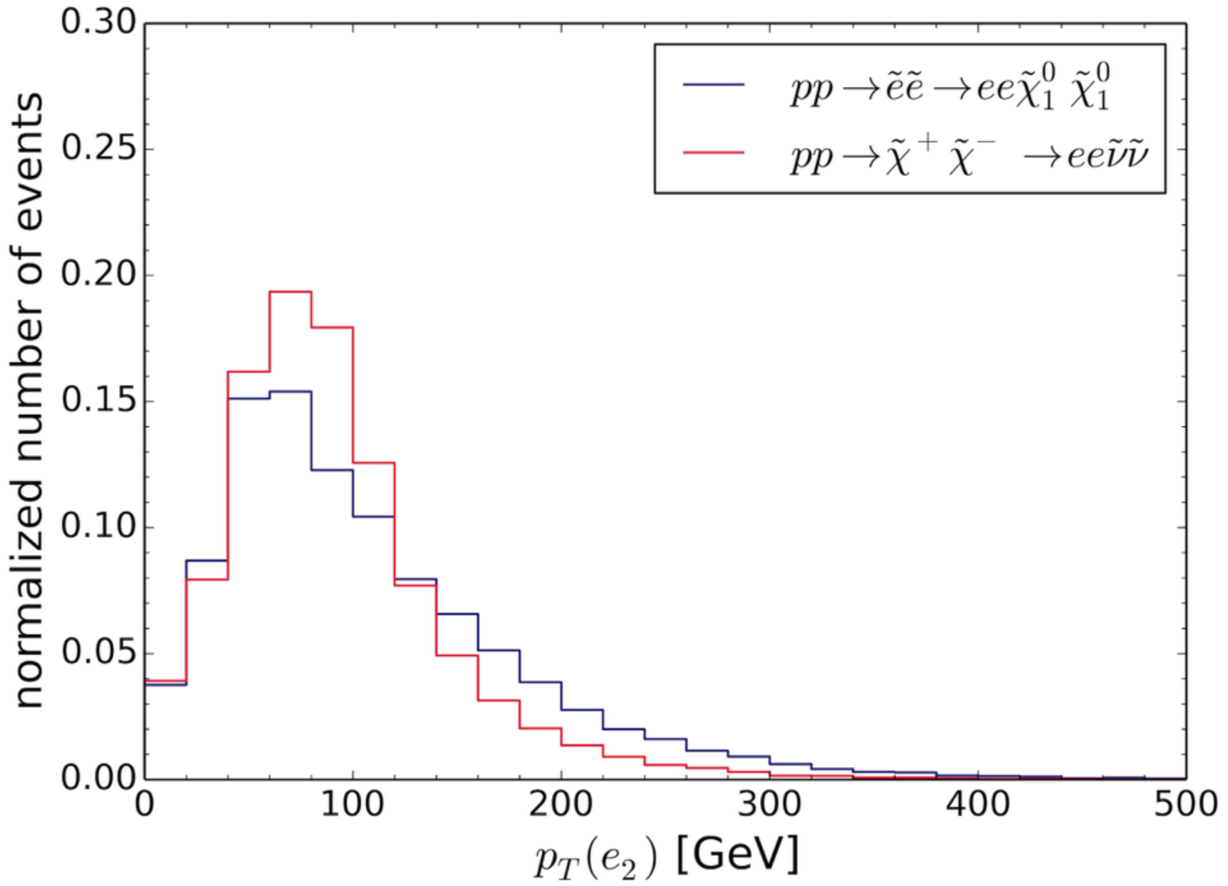
Do the slepton limits apply to chargino production?

test this for ATLAS-SUSY-2013-11, using the MadAnalysis 5 implementation
(B. Dumont, INSPIRE-1326686)

Compare the corresponding efficiencies in a benchmark scenario with

$$m_{mother} = 270 \text{ GeV}, m_{LSP} = 100 \text{ GeV}$$



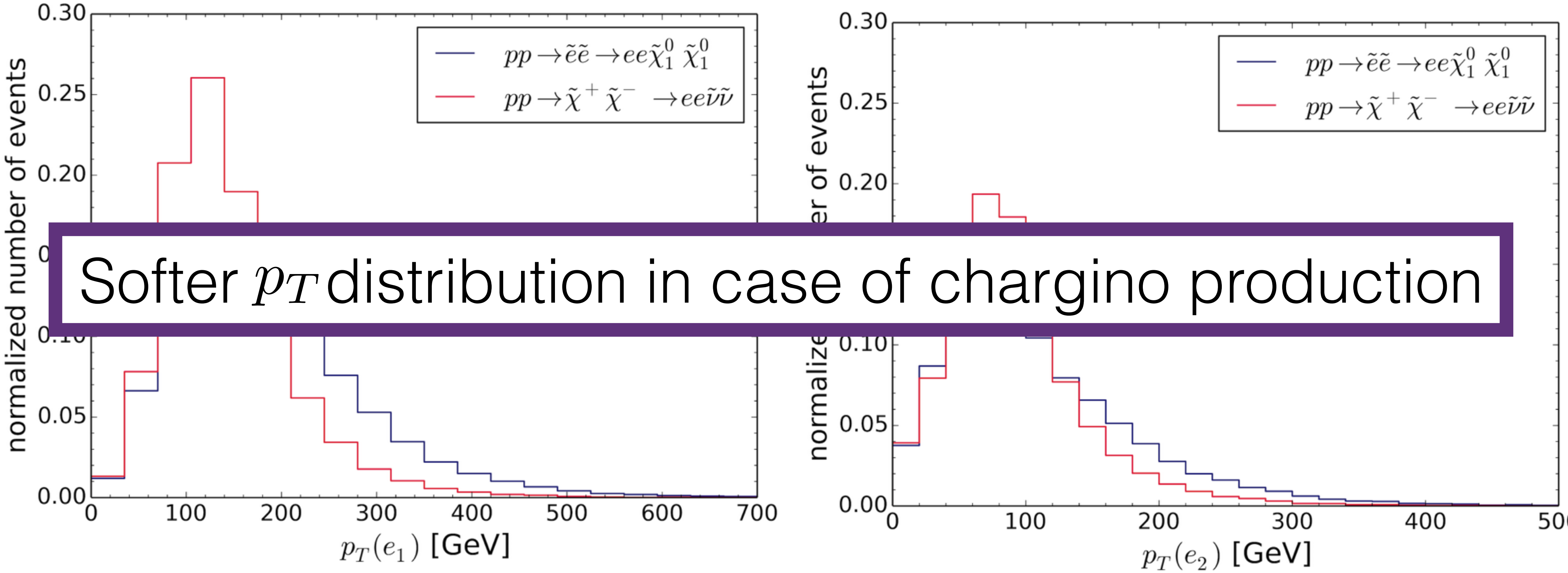


Do the slepton limits apply to chargino production?

test this for ATLAS-SUSY-2013-11, using the MadAnalysis 5 implementation
(B. Dumont, INSPIRE-1326686)

Compare the corresponding efficiencies in a benchmark scenario with

$$m_{mother} = 270 \text{ GeV}, m_{LSP} = 100 \text{ GeV}$$



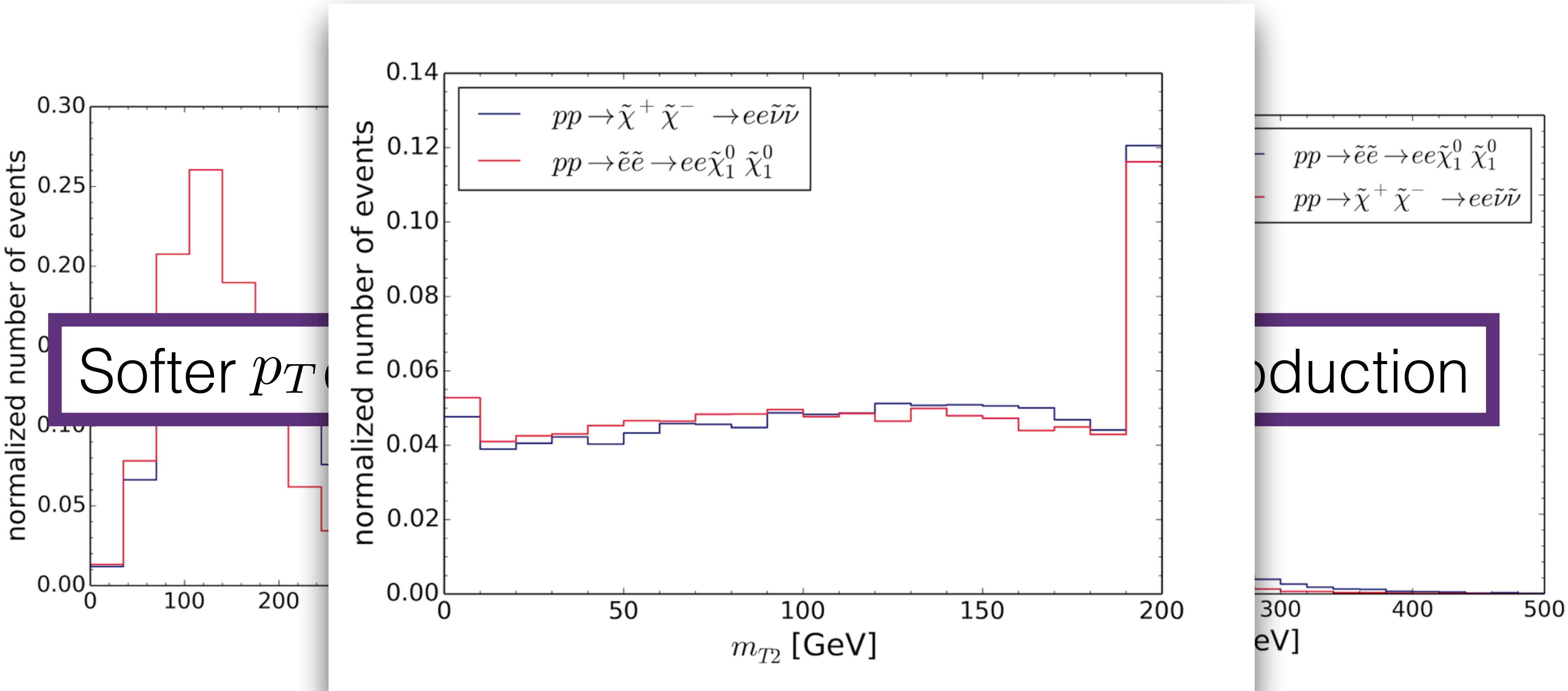
Softer p_T distribution in case of chargino production

Do the slepton limits apply to chargino production?

test this for ATLAS-SUSY-2013-11, using the MadAnalysis 5 implementation
(B. Dumont, INSPIRE-1326686)

Compare the corresponding efficiencies in a benchmark scenario with

$$m_{mother} = 270 \text{ GeV}, m_{LSP} = 100 \text{ GeV}$$

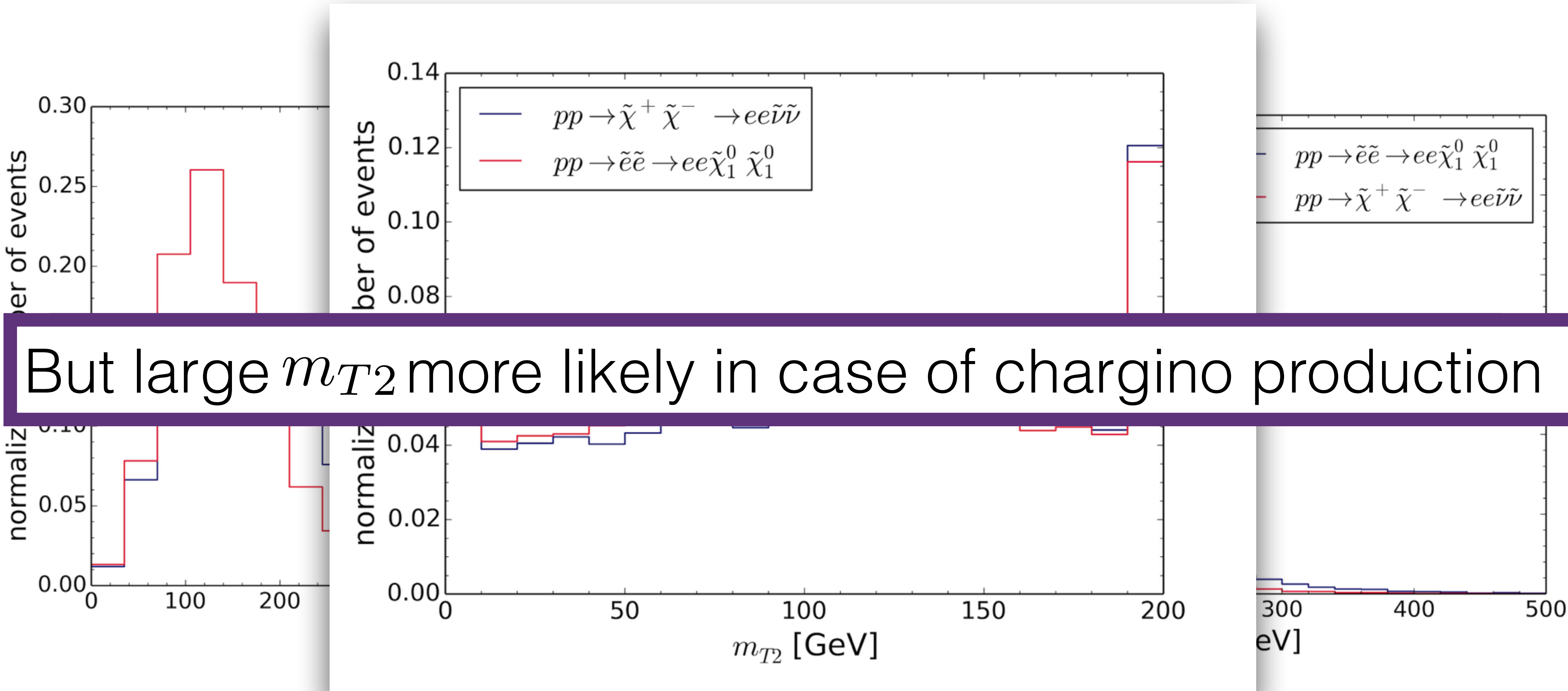


Do the slepton limits apply to chargino production?

test this for ATLAS-SUSY-2013-11, using the MadAnalysis 5 implementation
(B. Dumont, INSPIRE-1326686)

Compare the corresponding efficiencies in a benchmark scenario with

$$m_{mother} = 270 \text{ GeV}, m_{LSP} = 100 \text{ GeV}$$



But large m_{T2} more likely in case of chargino production

Cutflow shows that final efficiencies are comparable

Cut	Slepton production	Chargino production
Common preselection		
Initial number of events	50000	50000
2 OS leptons	35133	33464
$m_{ll} > 20$ GeV	35038	33337
τ veto	35007	33318
ee leptons	35007	33318
jet veto	20176	19942
Z veto	19380	18984
Different m_{T2} regions		
$m_{T2} > 90$ GeV	11346	11594
$m_{T2} > 120$ GeV	8520	8828
$m_{T2} > 150$ GeV	5723	5926

→ We can safely use the results to constrain chargino production

Cutflow comparison for $m_{mother} = 270$ GeV$, m_{LSP} = 200$ GeV

Cut	Slepton production	Chargino production
Common preselection		
Initial number of events	50000	50000
2 OS leptons	29291	27244
$m_{ll} > 20$ GeV	29082	26964
τ veto	29050	26956
ee leptons	29050	26956
jet veto	16834	16114
Z veto	15281	14025
Different m_{T2} regions		
$m_{T2} > 90$ GeV	3028	3198
$m_{T2} > 120$ GeV	85	140
$m_{T2} > 150$ GeV	0	0