ATOM/Fastlim

Recasting LHC constraints on new physics models

Kazuki Sakurai

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ATOM collaboration: Ian-Woo Kim, Michele Papucci, KS, Andreas Weiler

Fastlim collaboration: Michele Papucci, KS, Andreas Weiler, Lisa Zeune

Contents

Introduction

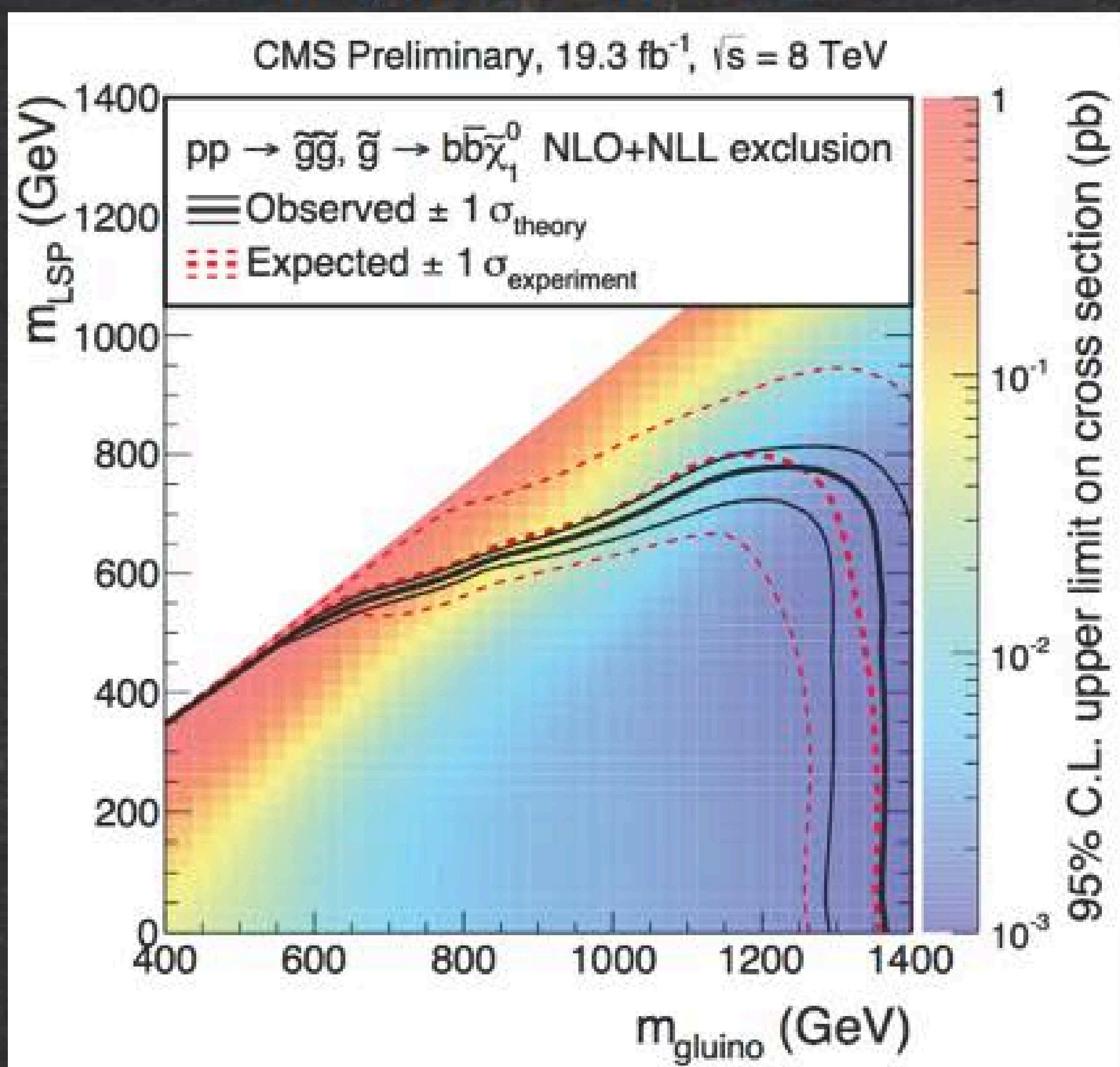
- For the long time (between LEP and LHC), the pheno community had been hungry for data to have hints and inputs into new physics models.
- Now, we have a lot of data from the LHC.

➡ We should make use of the LHC results and extract information on new physics models as much as possible.

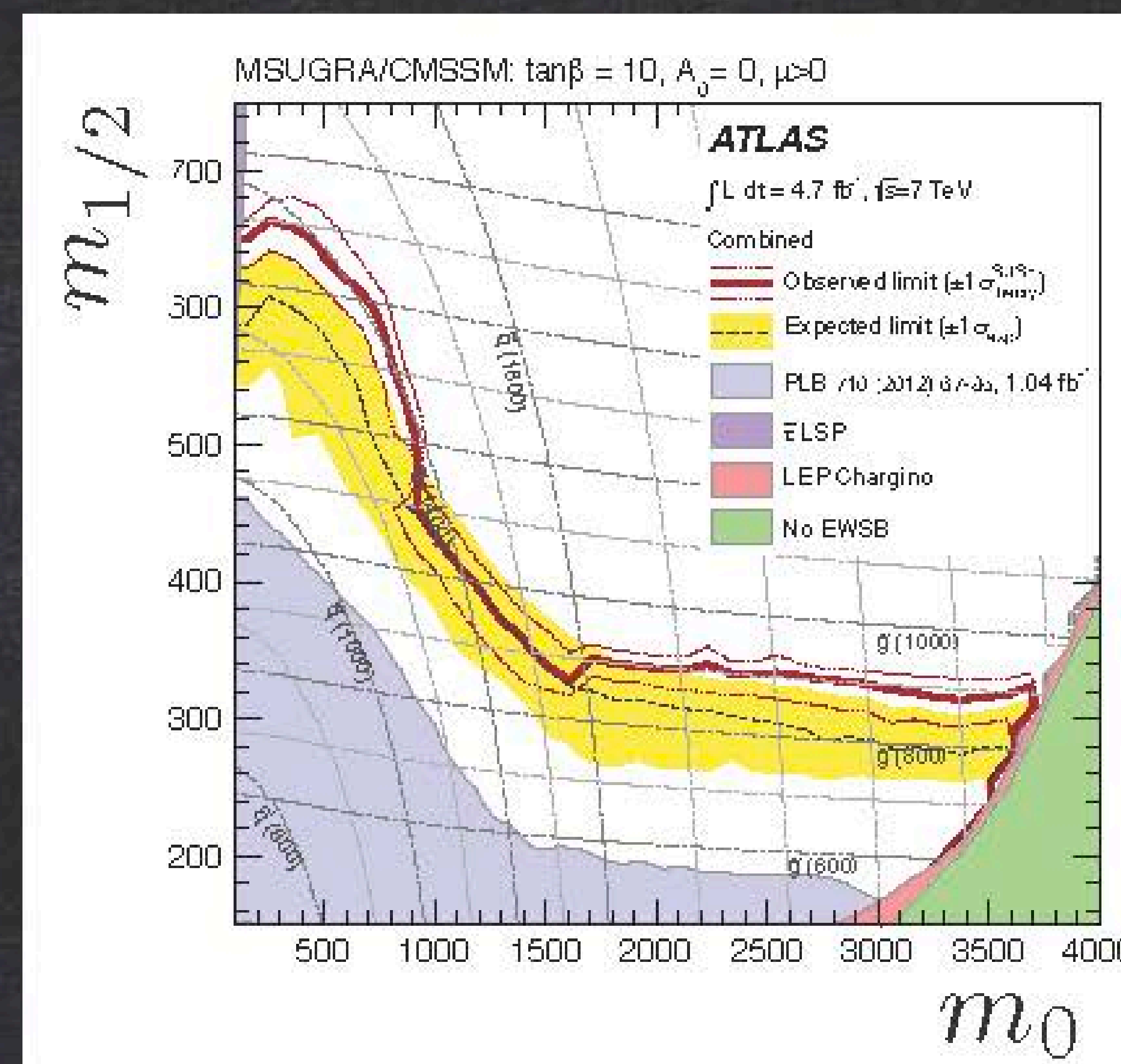
Introduction

- ATLAS and CMS often present their results by showing the constraints on simplified models or the CMSSM.

simplified model



CMSSM



Introduction

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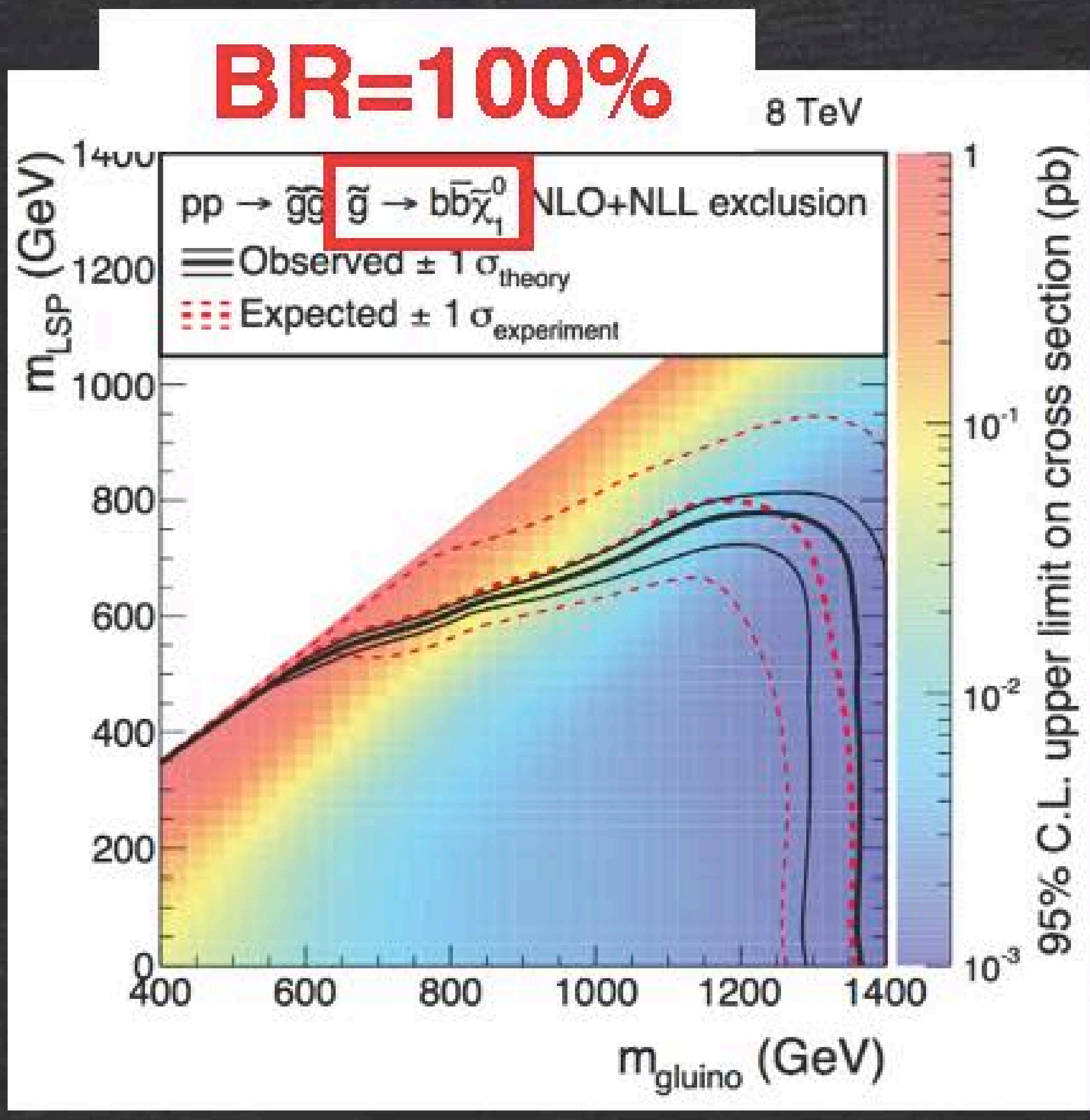
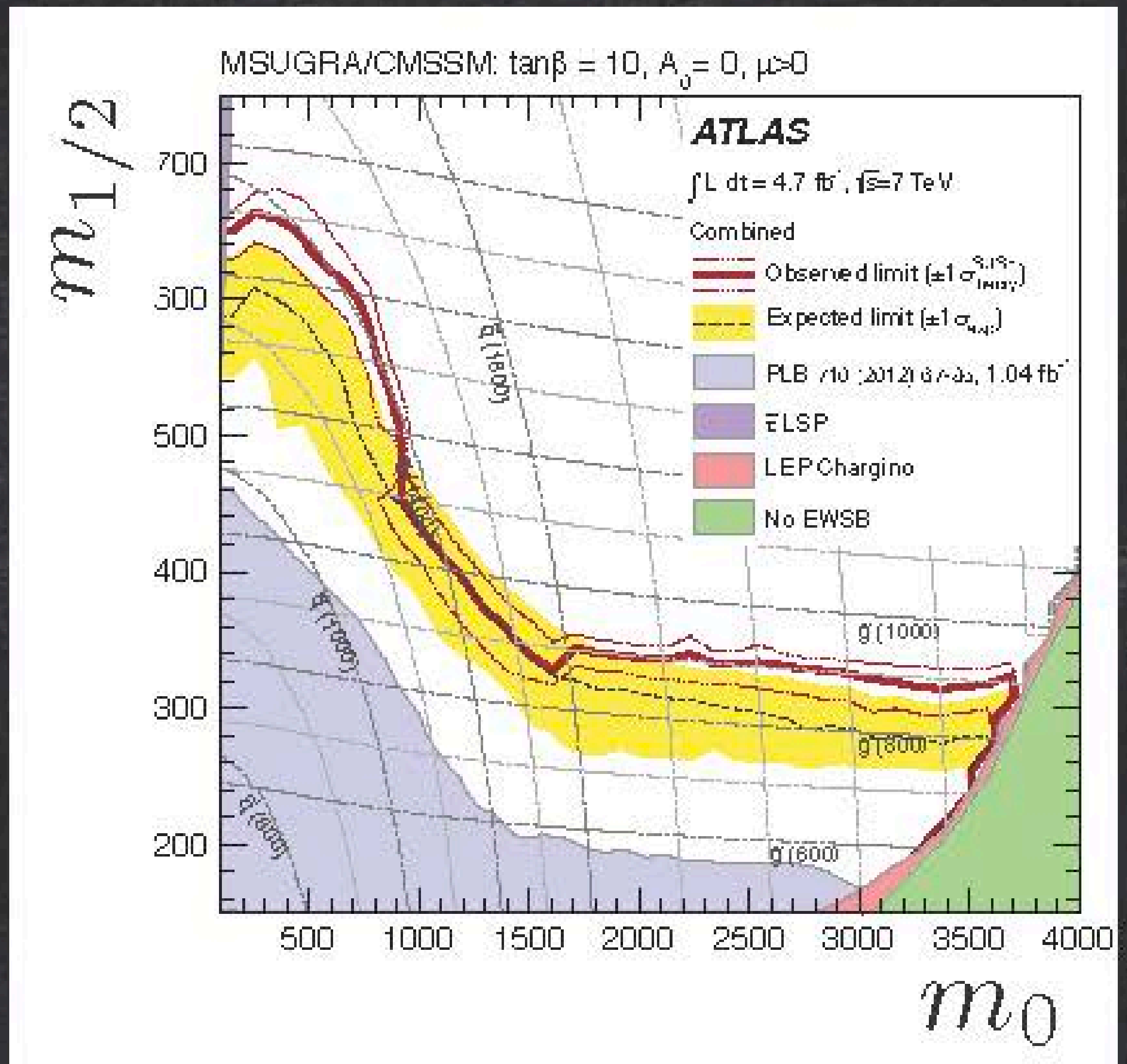


CMSSM



Introduction

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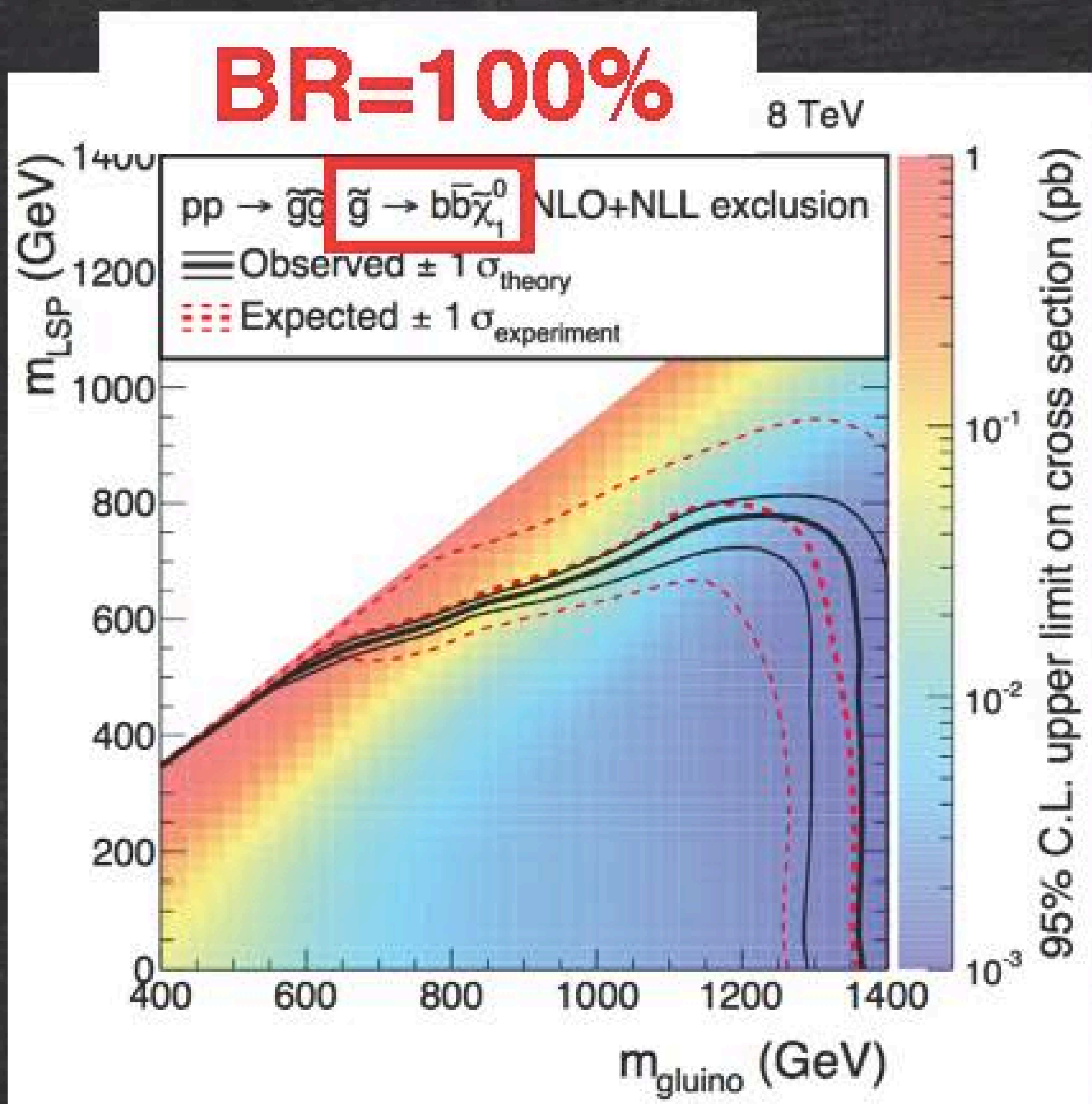
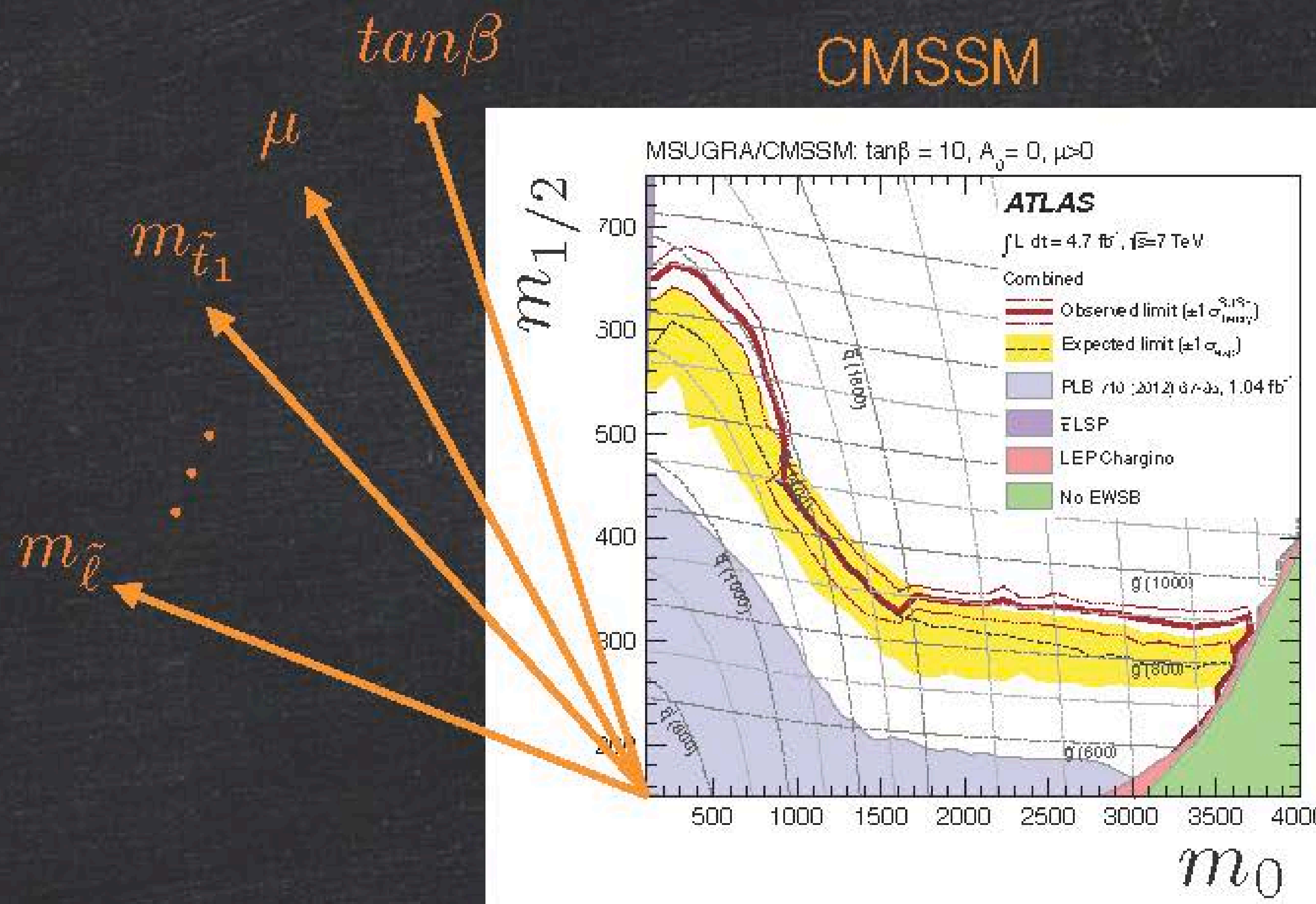
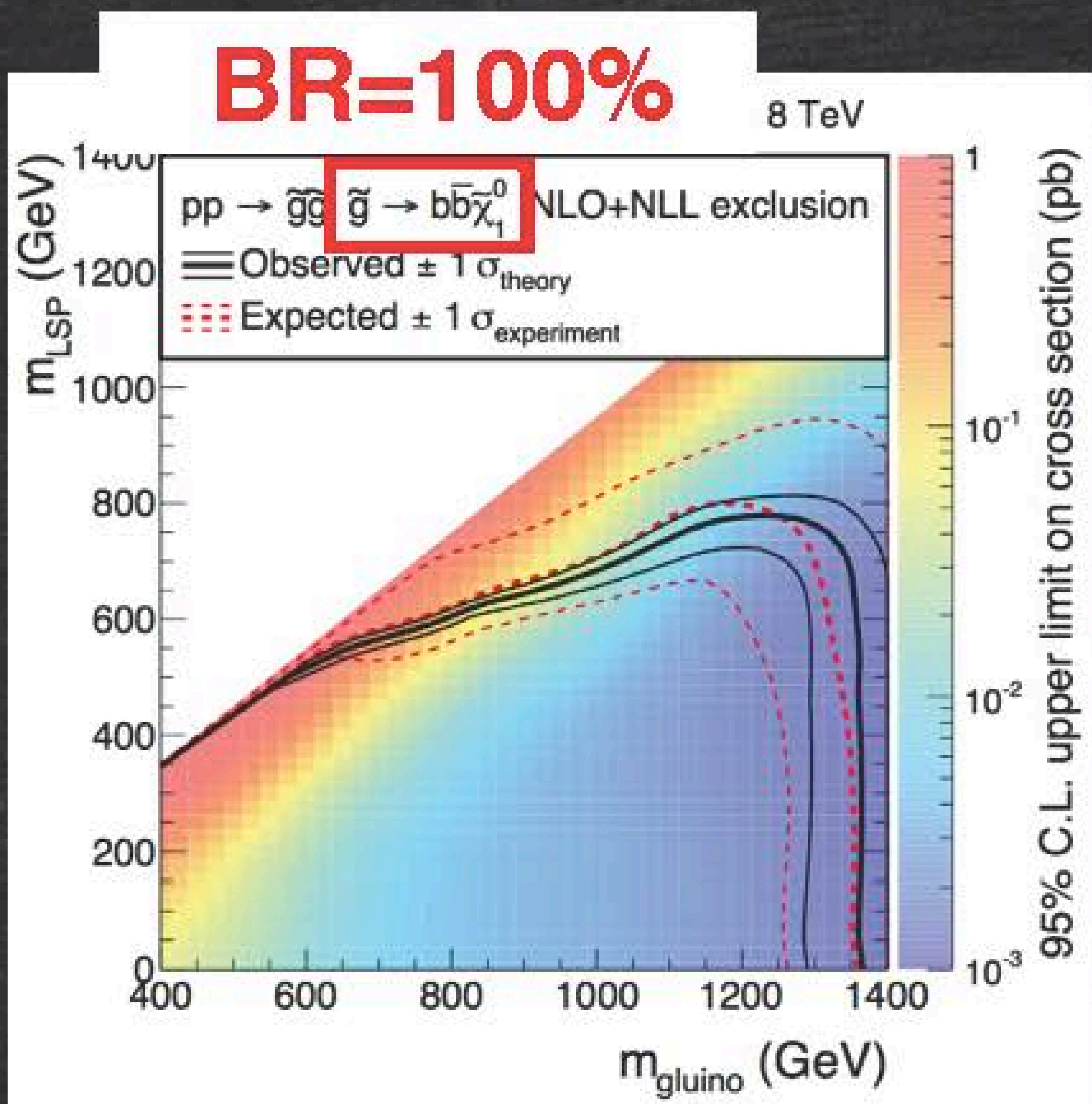
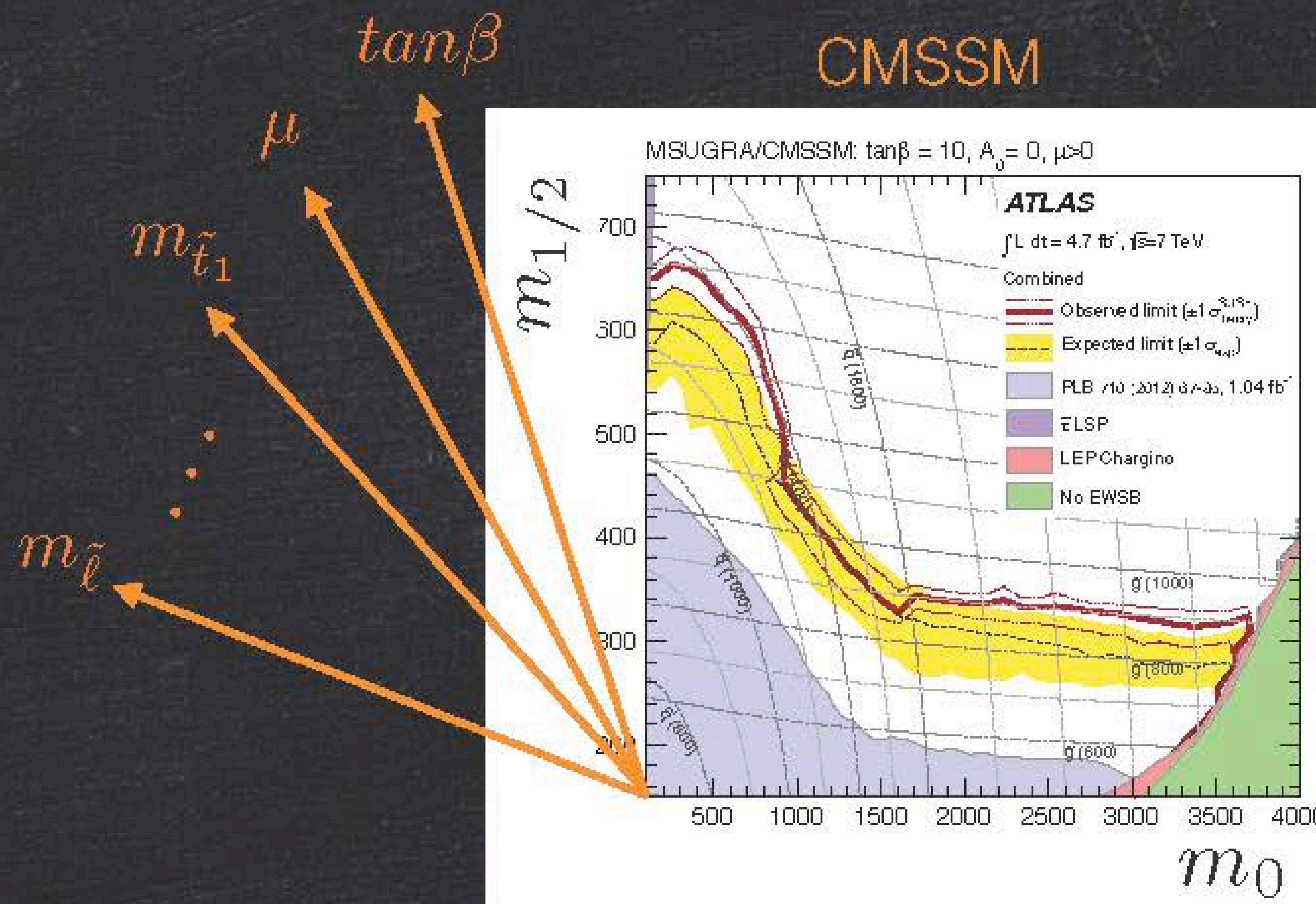




Introduction

- ATLAS and CMS often present their results by showing the constraints on simplified models or the CMSSM.
- To survey the generic pMSSM parameter space, a fast and systematic evaluation of LHC constraints is required.





Testing a Model

ATLAS-CONF-2011-086

Signal Region	≥ 2 jets	≥ 3 jets	≥ 4 jets
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 130	> 130	> 130
Leading jet p_{T} [GeV]	> 130	> 130	> 130
Second jet p_{T} [GeV]	> 40	> 40	> 40
Third jet p_{T} [GeV]	–	> 40	> 40
Fourth jet p_{T} [GeV]	–	–	> 40
$\Delta\phi(\mathrm{jet}_i, E_{\mathrm{T}}^{\mathrm{miss}})_{\mathrm{min}}$ $(i = 1,2,3)$	> 0.4	> 0.4	> 0.4
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}$	> 0.3	> 0.25	> 0.25
m_{eff} [GeV]	> 1000	> 1000	> 1000

Process	Signal Region		
	≥ 2 jets	≥ 3 jets	≥ 4 jets
SM prediction	12.1 ± 2.8	10.1 ± 2.3	7.3 ± 1.7
Observed	10	8	7
$N_{\mathrm{BSM}}^{\mathrm{UL}}$	5.77	4.95	5.77

Testing a Model

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ATLAS-CONF-2011-086

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Fourth jet p_T [GeV]	–	–	> 40
$\Delta\phi(\text{jet}_i, E_T^{miss})_{min}$ $(i = 1,2,3)$	> 0.4	> 0.4	> 0.4
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statistically consistent

Testing a Model

N_{BSM} = ..., 2, ..., 10, ... ?

contribution from BSM should be added

statistically consistent

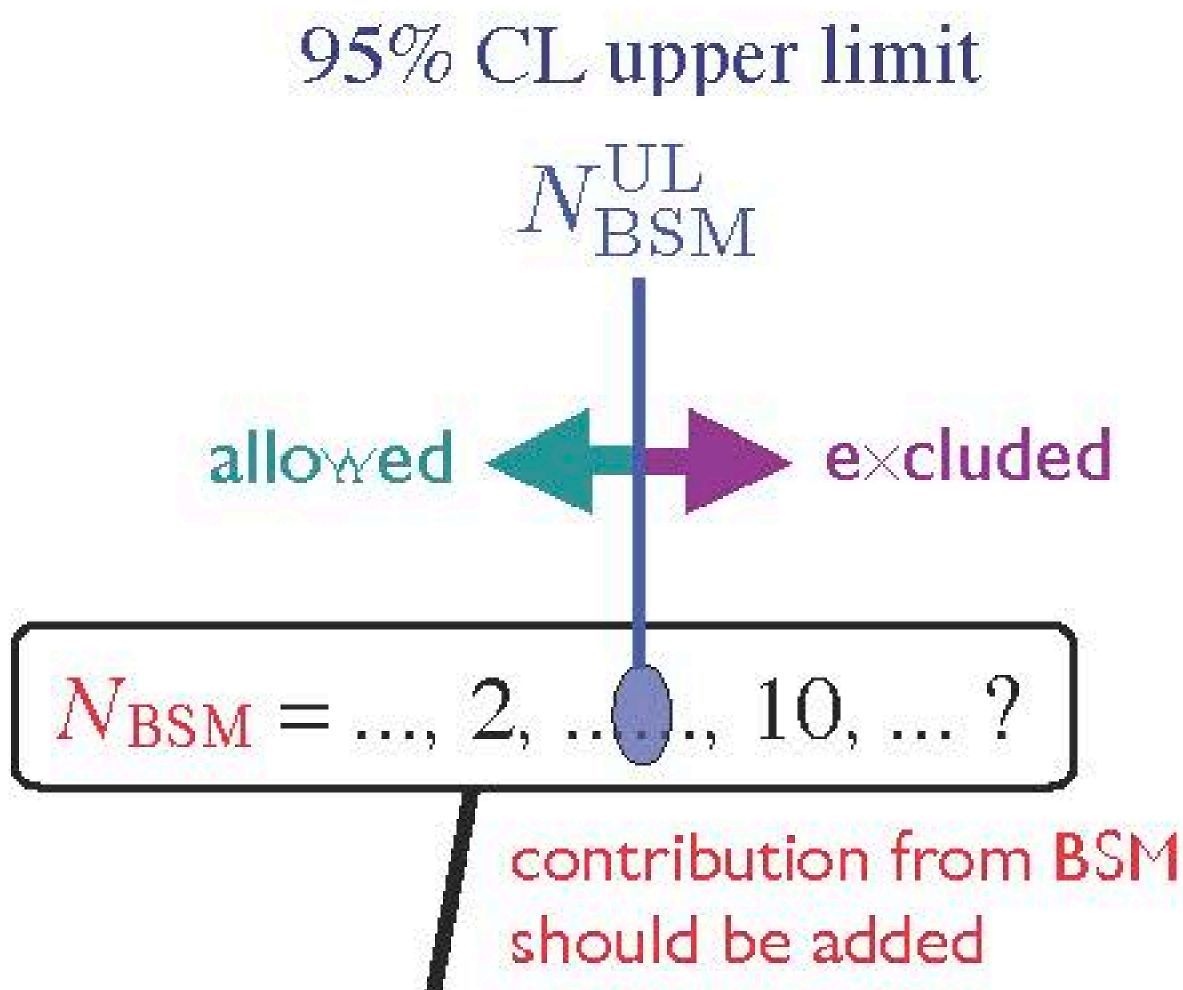
Process	Signal Region		
	≥ 2 jets	≥ 3 jets	≥ 4 jets
SM prediction	12.1 ± 2.8	10.1 ± 2.3	7.3 ± 1.7
Observed	10	8	7
$N_{\mathrm{BSM}}^{\mathrm{UL}}$	5.77	4.95	5.77

Testing a Model

for signal region a,

$$N^{(a)}_{\rm BSM}/N^{(a)}_{\rm UL} \begin{cases} > 1 & : \text{excluded} \\ \leq 1 & : \text{allowed} \end{cases}$$

$$CL_s^{(a)} = p^{(a)}_{\rm excl}(N^{(a)}_{\rm obs}, N^{(a)}_{\rm SM}, N^{(a)}_{\rm BSM}, \sigma^{(a)}_{\rm sys})$$



Process	Signal Region		
	≥ 2 jets	≥ 3 jets	≥ 4 jets
SM prediction	12.1 ± 2.8	10.1 ± 2.3	7.3 ± 1.7
Observed	10	8	7
$N^{\rm UL}_{\rm BSM}$	5.77	4.95	5.77

statistically consistent

Testing a Model

for signal region a,

$$N_{\text{BSM}}^{(a)} / N_{\text{UL}}^{(a)} \begin{cases} > 1 & \text{: excluded} \\ \leq 1 & \text{: allowed} \end{cases}$$

$$CL_s^{(a)} = p_{\text{excl}}^{(a)}(N_{\text{obs}}^{(a)}, N_{\text{SM}}^{(a)}, N_{\text{BSM}}^{(a)}, \sigma_{\text{sys}}^{(a)})$$

several different tests per analysis

Process	Signal Region		
	≥ 2 jets	≥ 3 jets	≥ 4 jets
SM prediction	12.1 ± 2.8	10.1 ± 2.3	7.3 ± 1.7
Observed	10	8	7
$N_{\text{BSM}}^{\text{UL}}$	5.77	4.95	5.77

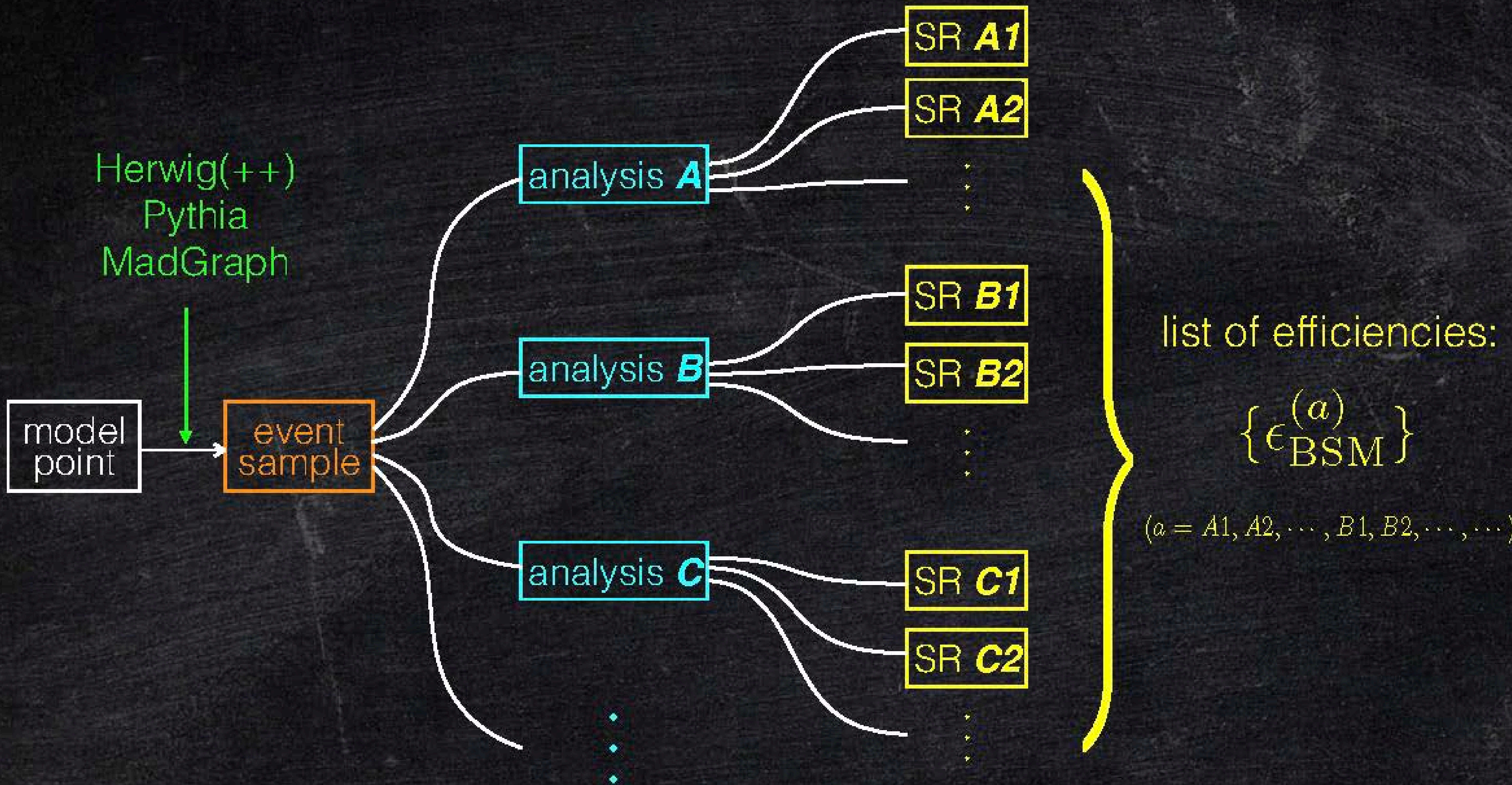
How to calculate $N_{\rm BSM}$?

$$N^{(a)}_{\rm BSM} = \epsilon^{(a)}_{\rm BSM} \cdot \sigma_{\rm BSM} \cdot \mathcal{L}$$

analytically calculable (factorisation)

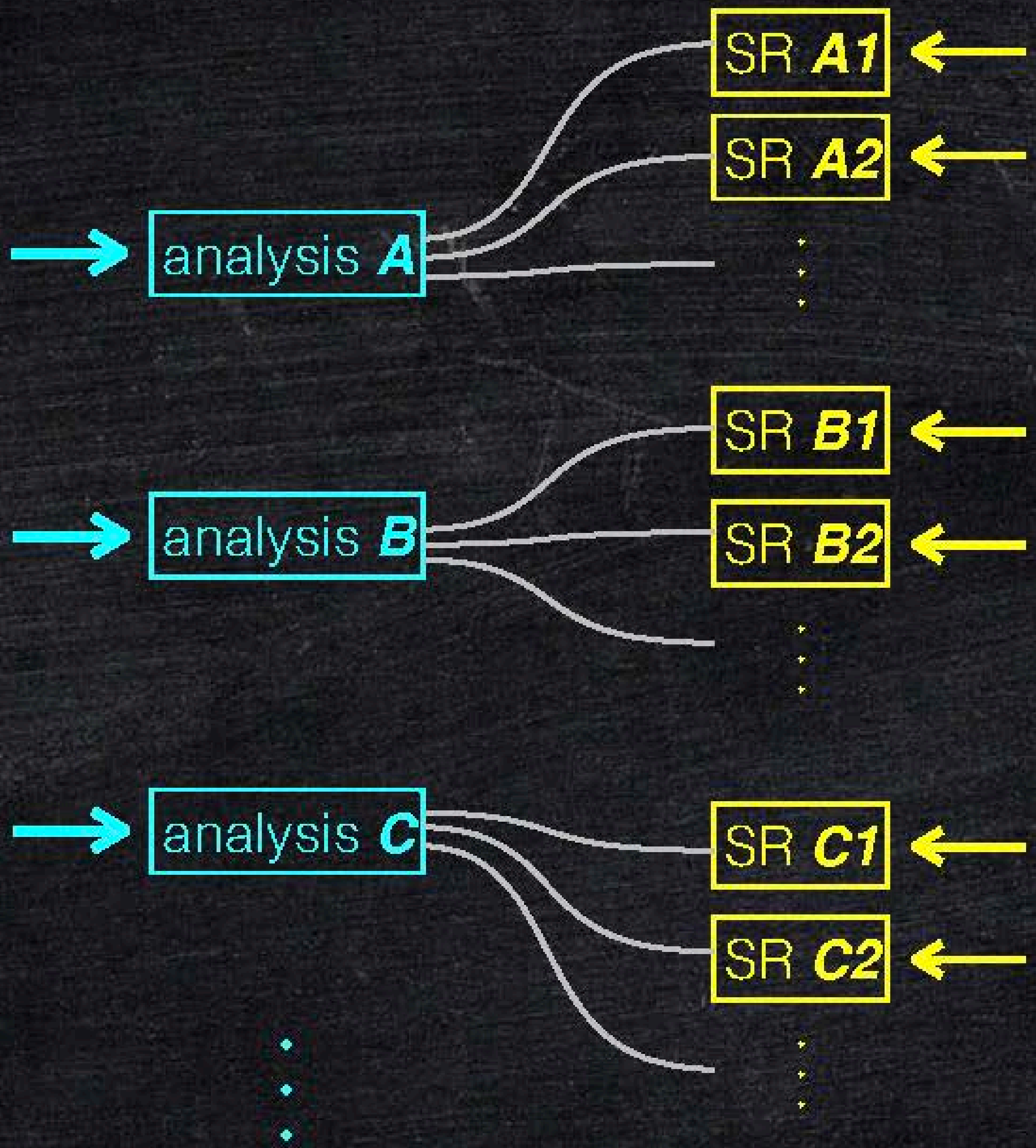
known

$$\epsilon^{(a)}_{\rm BSM} = \lim_{N_{\rm MC} \to \infty} \frac{N\left(\begin{array}{c}\text{Events fall into}\\ \text{signal region } a\end{array}\right)}{N_{\rm MC}}$$


Herwig(++)
Pythia
MadGraph
model point
event sample
analysis A
analysis B
analysis C
SR A1
SR A2
SR B1
SR B2
SR C1
SR C2
list of efficiencies:
$\{\epsilon^{(a)}_{\mathrm{BSM}}\}$
$(a = A1, A2, \cdots, B1, B2, \cdots, \cdots)$

reconstructed objects (jets, electrons, ...) need to be tuned for each analysis

needs to write a detector card and run detector simulation for every analysis



Validation is required for every analysis

generate an event sample at the benchmark point used in the analysis paper and compare the efficiency with the one reported in the paper for every signal region

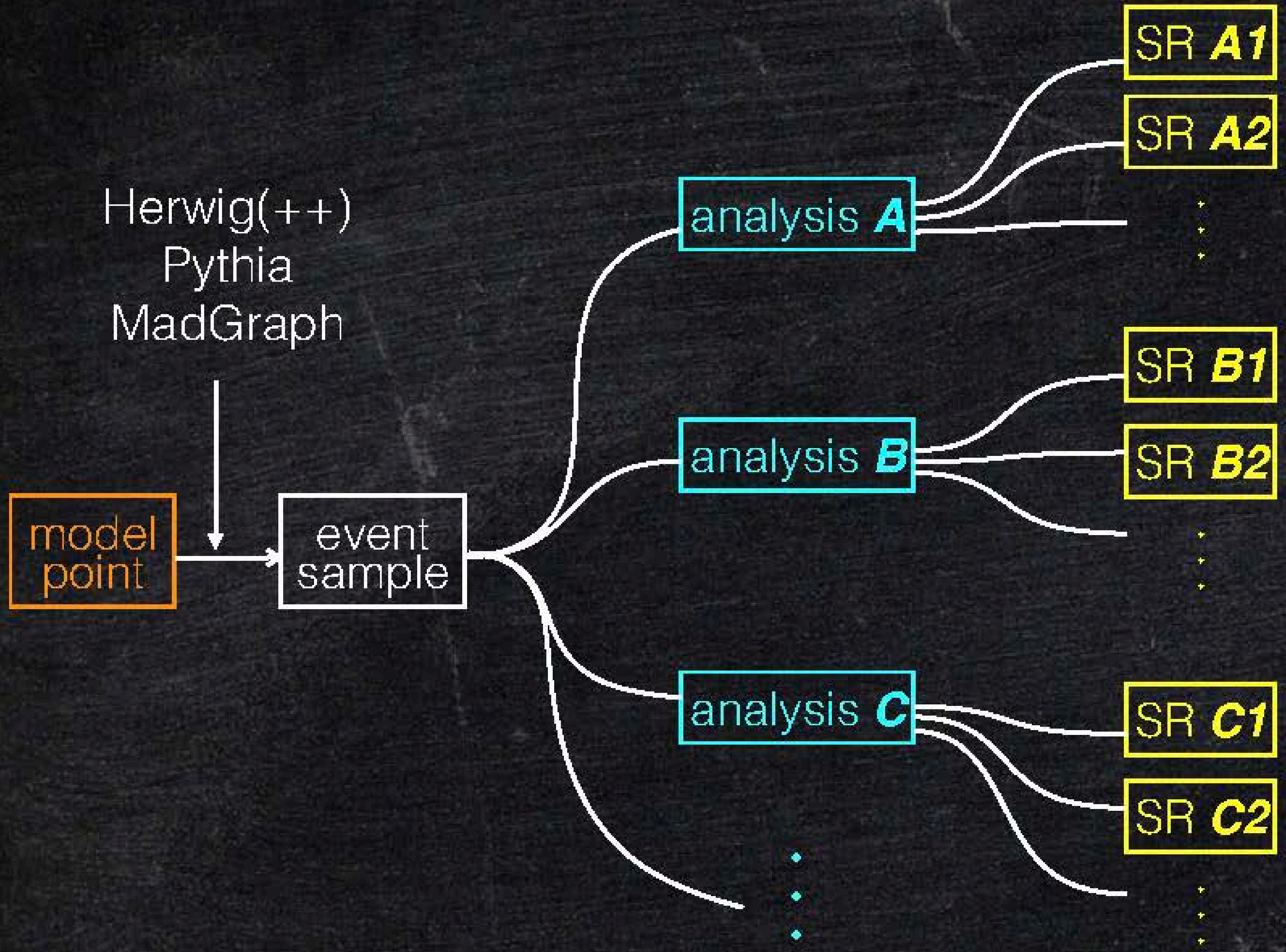
A lot of work!

Y. Kats and D. Shih, JHEP **1108**, 049 (2011) [arXiv:1106.0030 [hep-ph]], M. Lisanti, P. Schuster, M. Strassler and N. Toro, JHEP **1211**, 081 (2012) [arXiv:1107.5055 [hep-ph]], R. Essig, E. Izaguirre, J. Kaplan and J. G. Wacker, JHEP **1201**, 074 (2012) [arXiv:1110.6443 [hep-ph]], C. Brust, A. Katz, S. Lawrence and R. Sundrum, JHEP **1203**, 103 (2012) [arXiv:1110.6670 [hep-ph]], T. J. LeCompte and S. P. Martin, Phys. Rev. D **85**, 035023 (2012) [arXiv:1111.6897 [hep-ph]], B. He, T. Li and Q. Shafi, JHEP **1205**, 148 (2012) [arXiv:1112.4461 [hep-ph]], Y. Kats, P. Meade, M. Reece and D. Shih, JHEP **1202**, 115 (2012) [arXiv:1110.6444 [hep-ph]], K. Sakurai and K. Takayama, JHEP **1112** (2011) 063 [arXiv:1106.3794 [hep-ph]], B. C. Allanach, T. J. Khoo and K. Sakurai, JHEP **1111** (2011) 132 [arXiv:1110.1119 [hep-ph]], M. Badziak and K. Sakurai, JHEP **1202** (2012) 125 [arXiv:1112.4796 [hep-ph]], B. C. Allanach and B. Gripaios, JHEP **1205**, 062 (2012) [arXiv:1202.6616 [hep-ph]], J. Fan, M. Reece and J. T. Ruderman, JHEP **1207**, 196 (2012) [arXiv:1201.4875 [hep-ph]], G. D. Kribs and A. Martin, Phys. Rev. D **85**, 115014 (2012) [arXiv:1203.4821 [hep-ph]], D. Curtin, P. Jaiswal and P. Meade, Phys. Rev. D **87**, no. 3, 031701 (2013) [arXiv:1206.6888 [hep-ph]], J. A. Evans and Y. Kats, JHEP **1304**, 028 (2013) [arXiv:1209.0764 [hep-ph]], P. Bechtle, T. Bringmann, K. Desch, H. Dreiner, M. Hamer, C. Hensel, M. Kramer and N. Nguyen *et al.*, JHEP **1206**, 098 (2012) [arXiv:1204.4199 [hep-ph]], K. Rolbiecki and K. Sakurai, JHEP **1210** (2012) 071 [arXiv:1206.6767 [hep-ph]], M. Asano, K. Rolbiecki and K. Sakurai, JHEP **1301** (2013) 128 [JHEP **1301** (2013) 128] [arXiv:1209.5778 [hep-ph]], M. Redi, V. Sanz, M. de Vries and A. Weiler, JHEP **1308**, 008 (2013) [arXiv:1305.3818, arXiv:1305.388 [hep-ph]], K. Kowalska and E. M. Sessolo, Phys. Rev. D **88**, 075001 (2013) [arXiv:1307.5790 [hep-ph]], J. A. Evans, Y. Kats, D. Shih and M. J. Strassler, arXiv:1310.5758 [hep-ph].

[...]

Many people have been performing similar studies....

duplicating effort


Herwig(++)
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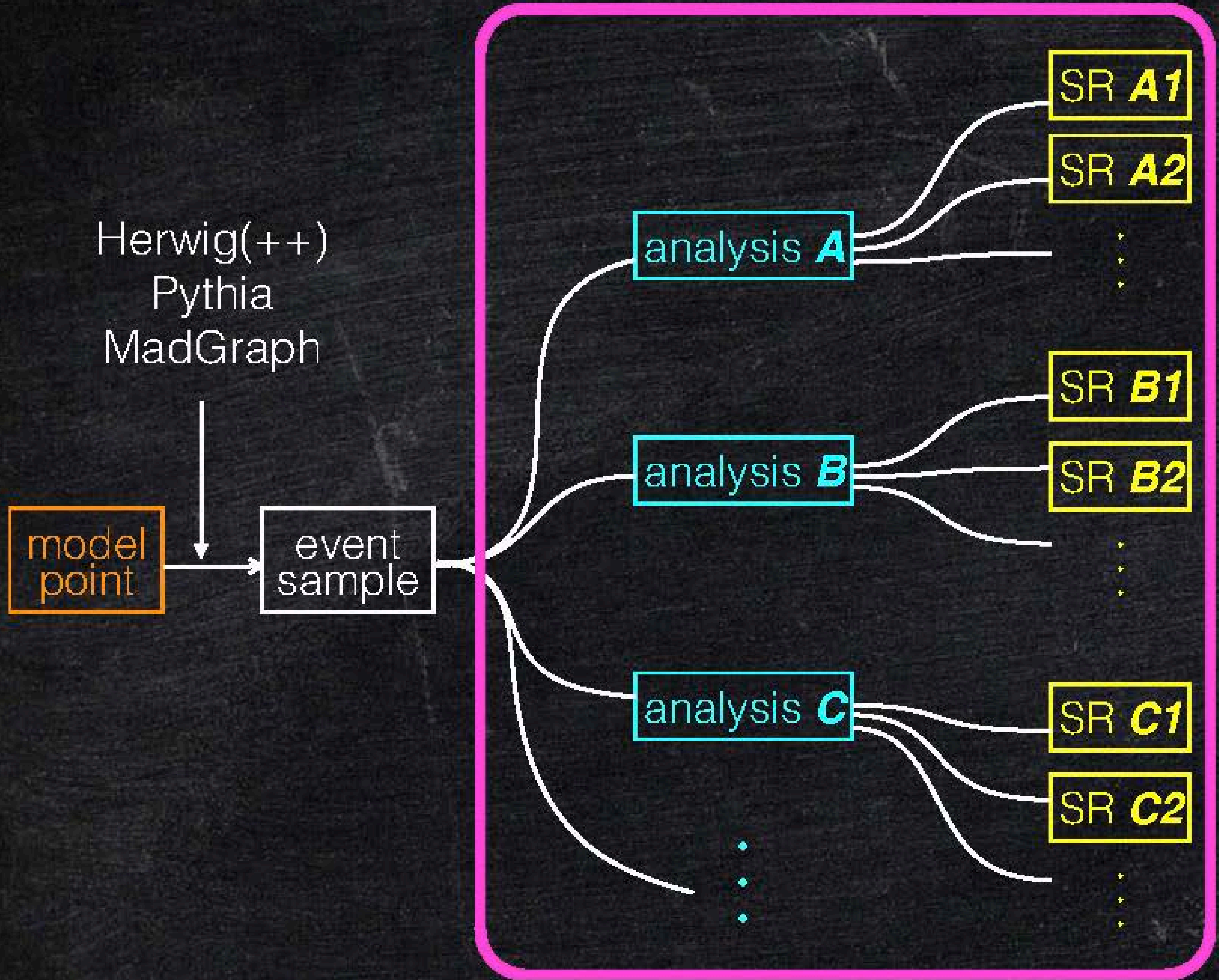


A tool to systematically calculate efficiencies for various signal regions

ATOM

I-W.Kim, M.Papucci, KS, A.Weiler

(Automated Testing Of Models)

A tool to systematically calculate efficiencies for various signal regions

Herwig(++)
Pythia
MadGraph

model point → event file (HepMC, StdHep) →

- efficiency calculations are already validated
- appropriate definitions of reco objects are used for the analysis.

→ $\{\epsilon_{\rm BSM}^{(a)}\}$

→ histograms (MET, Meff, …)

→ reco. objects (jets, leptons, …)

Analyses in ATOM

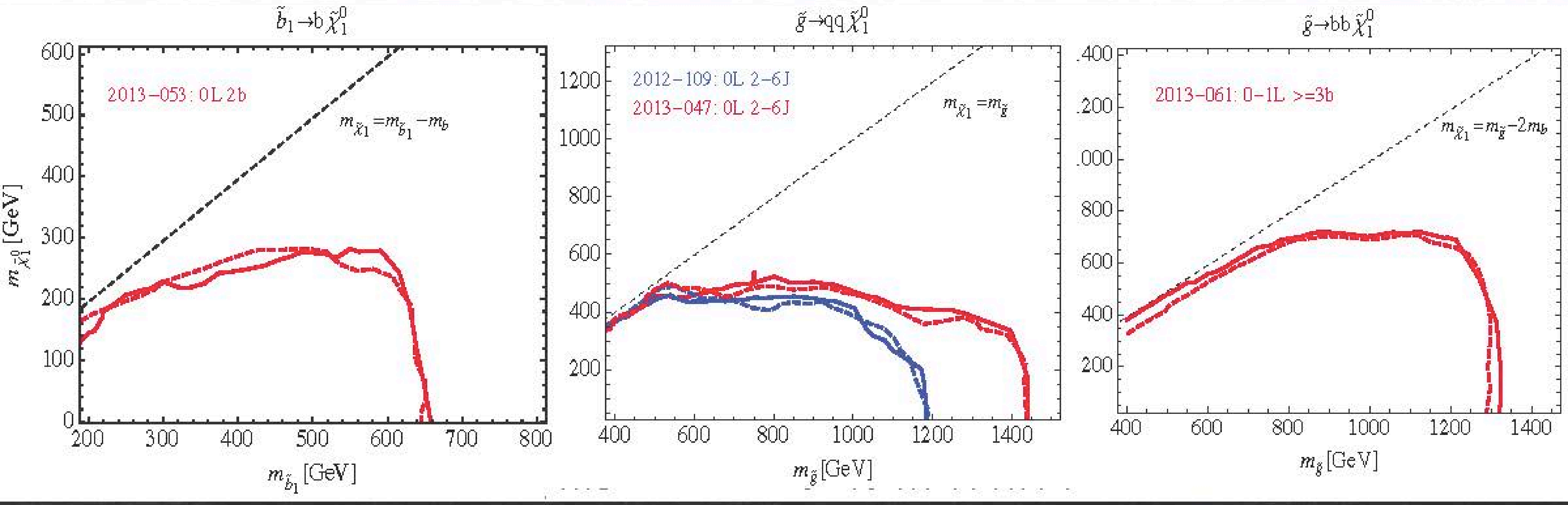
Name	Short description	$E_{\rm CM}$	$\mathcal{L}_{\rm int}$	# SRs	Ref.
ATLAS_CONF_2013_024	0 lepton + (2 b-)jets + MET [Heavy stop]	8	20.5	3	[32]
ATLAS_CONF_2013_035	3 leptons + MET [EW production]	8	20.7	6	[33]
ATLAS_CONF_2013_037	1 lepton + 4(1 b-)jets + MET [Medium/heavy stop]	8	20.7	5	[34]
ATLAS_CONF_2013_047	0 leptons + 2-6 jets + MET [squarks & gluinos]	8	20.3	10	[35]
ATLAS_CONF_2013_048	2 leptons (+ jets) + MET [Medium stop]	8	20.3	4	[36]
ATLAS_CONF_2013_049	2 leptons + MET [EW production]	8	20.3	9	[37]
ATLAS_CONF_2013_053	0 leptons + 2 b-jets + MET [Sbottom/stop]	8	20.1	6	[38]
ATLAS_CONF_2013_054	0 leptons + $\geq$ 7-10 jets + MET [squarks & gluinos]	8	20.3	19	[39]
ATLAS_CONF_2013_061	0-1 leptons + $\geq$ 3 b-jets + MET [3rd gen. squarks]	8	20.1	9	[40]
ATLAS_CONF_2013_062	1-2 leptons + 3-6 jets + MET [squarks & gluinos]	8	20.3	13	[41]
ATLAS_CONF_2013_093	1 lepton + bb(H) + Etmiss [EW production]	8	20.3	2	[42]

⋮

- Many ATLAS (a few CMS) analyses are implemented. Most of the 2013-2014 ATLAS MET searches are implemented.

Validation

- The analyses are validated using the official cut flow tables and exclusion contours.



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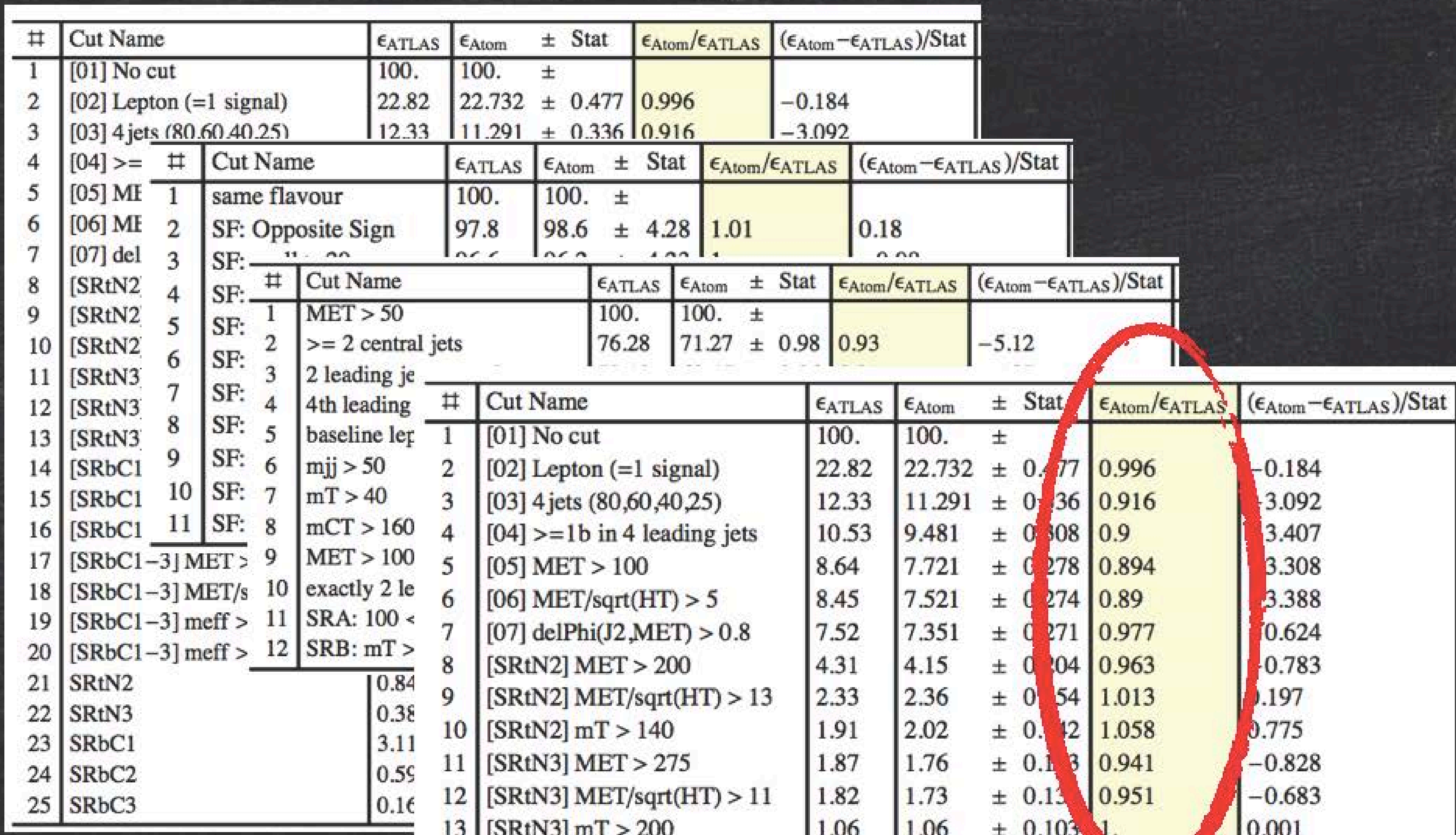

#	Cut Name	ϵ_{ATLAS}	ϵ_{Atom}	± Stat	$\epsilon_{Atom}/\epsilon_{ATLAS}$	$(\epsilon_{Atom}-\epsilon_{ATLAS})$/Stat
1	[01] No cut	100.	100.	±		
2	[02] Lepton (=1 signal)	22.82	22.732	± 0.477	0.996	−0.184
3	[03] 4 jets (80,60,40,25)	12.33	11.291	± 0.336	0.916	−3.092

#	Cut Name	ϵ_{ATLAS}	ϵ_{Atom}	± Stat	$\epsilon_{Atom}/\epsilon_{ATLAS}$	$(\epsilon_{Atom}-\epsilon_{ATLAS})$/Stat
1	same flavour	100.	100.	±		
2	SF: Opposite Sign	97.8	98.6	± 4.28	1.01	0.18

#	Cut Name	ϵ_{ATLAS}	ϵ_{Atom}	± Stat	$\epsilon_{Atom}/\epsilon_{ATLAS}$	$(\epsilon_{Atom}-\epsilon_{ATLAS})$/Stat
1	MET > 50	100.	100.	±		
2	>= 2 central jets	76.28	71.27	± 0.98	0.93	−5.12

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3	[03] 4 jets (80,60,40,25)	12.33	11.291	± [illegible]	0.916	[illegible]3.092
4	[04] >=1b in 4 leading jets	10.53	9.481	± [illegible]	0.9	[illegible]3.407
5	[05] MET > 100	8.64	7.721	± [illegible]	0.894	[illegible]3.308
6	[06] MET/sqrt(HT) > 5	8.45	7.521	± [illegible]	0.89	[illegible]3.388
7	[07] delPhi(J2,MET) > 0.8	7.52	7.351	± [illegible]	0.977	[illegible]0.624
8	[SRtN2] MET > 200	4.31	4.15	± [illegible]	0.963	[illegible]0.783
9	[SRtN2] MET/sqrt(HT) > 13	2.33	2.36	± [illegible]	1.013	[illegible].197
10	[SRtN2] mT > 140	1.91	2.02	± [illegible]	1.058	0.775
11	[SRtN3] MET > 275	1.87	1.76	± [illegible]	0.941	−0.828
12	[SRtN3] MET/sqrt(HT) > 11	1.82	1.73	± [illegible]	0.951	−0.683
13	[SRtN3] mT > 200	1.06	1.06	± 0.103	1.	0.001

Automated Validation

1. sakurai@Kazukis-MacBook-Pro: ~/atom/Atom-validation/Analyses/ATLAS_2013_CONF_2013_047 (zsh)

ATLAS_2013_CONF_2013_047: GQdirect_1612-37

#	cut name	eff_Exp	eff_Atom	Atom/Exp	(Atom-Exp)/Err	#/?	R_Exp	R_Atom	Atom/Exp	(Atom-Exp)/Err
0	No cut	100.0	100.0							
1	base: 0 lepton	98.8 +- 1.41	99.96 +- 0.03	1.01	0.83	0	0.99 +- 0.01	1.0 +- 0.0	1.01	0.83
2	base: MET > 160	95.9 +- 1.38	97.02 +- 0.24	1.01	0.8	1	0.97 +- 0.01	0.97 +- 0.0	1.0	-0.0
3	base: pTj1 > 130	95.8 +- 1.38	97.02 +- 0.24	1.01	0.87	2	1.0 +- 0.01	1.0 +- 0.0	1.0	0.07
4	base: pTj2 > 60	95.2 +- 1.38	96.96 +- 0.24	1.02	1.26	3	0.99 +- 0.01	1.0 +- 0.0	1.01	0.39
5	pTj3 > 60	75.7 +- 1.23	93.02 +- 0.36	1.23	13.51	4	0.8 +- 0.01	0.96 +- 0.0	1.21	12.21
6	B base: dphi_min_23 > 0.4	66.2 +- 1.15	77.58 +- 0.59	1.17	8.8	5	0.87 +- 0.02	0.83 +- 0.01	0.95	-2.46
7	BM: MET/meff_3j > 0.3	31.8 +- 0.8	50.7 +- 0.71	1.59	17.73	6	0.48 +- 0.01	0.65 +- 0.01	1.36	11.46
8	BM: meff_inc > 1800	22.8 +- 0.68	45.48 +- 0.7	1.99	23.25	7	0.72 +- 0.02	0.9 +- 0.01	1.25	7.1

0.1 $\tilde{q}\tilde{q}$ direct (1612, 37): (ATLAS_CONF_2013_047)

- Process: $pp \to \tilde{q}\tilde{q} \to (q\tilde{\chi}_1^0)(qq\tilde{\chi}_1^0)$.
- Mass: $m_{\tilde{g}} = 1612$ GeV, $m_{\tilde{q}} = 1548$ GeV, $m_{\tilde{\chi}_1^0} = 37$ GeV.
- The number of events: $5 \cdot 10^5$.
- Event Generator: MadGraph 5 and Pythia 6. The MLM merging is used with the shower-k_T scheme implemented in MadGraph 5 and Pythia 6, where we take xqcut = qcut = $M_{SUSY}/4$ with MSUSY being the mass of the heavier SUSY particles in the production.

#	cut name	ϵ_{Exp}	ϵ_{Atom}	$\frac{Atom}{Exp}$	$\frac{(Exp-Atom)}{Error}$	#/?	R_{Exp}	R_{Atom}	$\frac{Atom}{Exp}$	$\frac{(Exp-Atom)}{Error}$
0	No cut	100.0	100.0							
1	base: 0 lepton	98.8 ± 1.41	99.96 ± 0.03	1.01	0.83	0	0.99 ± 0.01	1.0 ± 0.0	1.01	0.83
2	base: MET > 160	95.9 ± 1.38	97.02 ± 0.24	1.01	0.8	1	0.97 ± 0.01	0.97 ± 0.0	1.0	−0.0
3	base: $p_T(j_1) > 130$	95.8 ± 1.38	97.02 ± 0.24	1.01	0.87	2	1.0 ± 0.01	1.0 ± 0.0	1.0	0.07
4	base: $p_T(j_2) > 60$	95.2 ± 1.38	96.96 ± 0.24	1.02	1.26	3	0.99 ± 0.01	1.0 ± 0.0	1.01	0.39
5	$p_T(j_3) > 60$	75.7 ± 1.23	93.02 ± 0.36	1.23	13.51	4	0.8 ± 0.01	0.96 ± 0.0	1.21	12.21
6	B base: $\Delta\phi(j_i, MET) > 0.4$	66.2 ± 1.15	77.58 ± 0.59	1.17	8.8	5	0.87 ± 0.02	0.83 ± 0.01	0.95	−2.46
7	BM: $MET/m_{eff}(3j) > 0.3$	31.8 ± 0.8	50.7 ± 0.71	1.59	17.73	6	0.48 ± 0.01	0.65 ± 0.01	1.36	11.46
8	BM: m_{eff}(inc) > 1800	22.8 ± 0.68	45.48 ± 0.7	1.99	23.25	7	0.72 ± 0.02	0.9 ± 0.01	1.25	7.1

Table 1: The cut-flow table for B tight signal region: $\tilde{q}\tilde{q}$ direct (1612, 37).

- ATOM automatically generates cut-flow tables and checks the efficiencies between ATOM and experimental collaborations.
- If significant deviation is found, it provides warnings.

Automated Validation

1. sakurai@Kazukis-MacBook-Pro: ~/atom/Atom-validation/Analyses/ATLAS_2013_CONF_2013_047 (zsh)

ATLAS_2013_CONF_2013_047: GQdirect_1612-37

#	cut name	eff_Exp	eff_Atom	Atom/Exp	(Atom-Exp)/Err	#/?	R_Exp	R_Atom	Atom/Exp	(Atom-Exp)/Err
0	No cut	100.0	100.0							
1	base: 0 lepton	98.8 +- 1.41	99.96 +- 0.03	1.01	0.83	0	0.99 +- 0.01	1.0 +- 0.0	1.01	0.83
2	base: MET > 160	95.9 +- 1.38	97.02 +- 0.24	1.01	0.8	1	0.97 +- 0.01	0.97 +- 0.0	1.0	-0.0
3	base: pTj1 > 130	95.8 +- 1.38	97.02 +- 0.24	1.01	0.87	2	1.0 +- 0.01	1.0 +- 0.0	1.0	0.07
4	base: pTj2 > 60	95.2 +- 1.38	96.96 +- 0.24	1.02	1.26	3	0.99 +- 0.01	1.0 +- 0.0	1.01	0.39
5	pTj3 > 60	75.7 +- 1.23	93.02 +- 0.36	1.23	13.51	4	0.8 +- 0.01	0.96 +- 0.0	1.21	12.21
6	B base: dphi_min_23 > 0.4	66.2 +- 1.15	77.58 +- 0.59	[illegible]	8.8	5	0.87 +- 0.02	0.83 +- 0.01	[illegible]	-2.46
7	BM: MET/meff_3j > 0.3	31.8 +- 0.8	50.7 +- 0.71	1.59	17.73	6	0.48 +- 0.01	0.65 +- 0.01	1.36	11.46
8	BM: meff_inc > 1800	22.8 +- 0.68	45.48 +- 0.7	1.99	23.25	7	0.72 +- 0.02	0.9 +- 0.01	[illegible]	7.1

0.1 $\bar{q}\tilde{g}$ direct (1612, 37): (ATLAS_CONF_2013_047)

- Process: $pp \to \tilde{q}\tilde{g} \to (q\tilde{\chi}_1^0)(qq\tilde{\chi}_1^0)$.
- Mass: $m_{\tilde{g}} = 1612$ GeV, $m_{\tilde{q}} = 1548$ GeV, $m_{\tilde{\chi}_1^0} = 37$ GeV.
- The number of events: $5 \cdot 10^5$.
- Event Generator: MadGraph 5 and Pythia 6. The MLM merging is used with the shower-k_T scheme implemented in MadGraph 5 and Pythia 6, where we take xqcut = qcut = $M_{SUSY}/4$ with MSUSY being the mass of the heavier SUSY particles in the production.

#	cut name	ϵ_{Exp}	ϵ_{Atom}	$\frac{Atom}{Exp}$	$\frac{(Exp-Atom)}{Error}$	#/?	R_{Exp}	R_{Atom}	$\frac{Atom}{Exp}$	$\frac{(Exp-Atom)}{Error}$
0	No cut	100.0	100.0							
1	base: 0 lepton	98.8 ± 1.41	99.96 ± 0.03	1.01	0.83	0	0.99 ± 0.01	1.0 ± 0.0	1.01	0.83
2	base: MET > 160	95.9 ± 1.38	97.02 ± 0.24	1.01	0.8	1	0.97 ± 0.01	0.97 ± 0.0	1.0	−0.0
3	base: $p_T(j_1) > 130$	95.8 ± 1.38	97.02 ± 0.24	1.01	0.87	2	1.0 ± 0.01	1.0 ± 0.0	1.0	0.07
4	base: $p_T(j_2) > 60$	95.2 ± 1.38	96.96 ± 0.24	1.02	1.26	3	0.99 ± 0.01	1.0 ± 0.0	1.01	0.39
5	$p_T(j_3) > 60$	75.7 ± 1.23	93.02 ± 0.36	1.23	13.51	4	0.8 ± 0.01	0.96 ± 0.0	1.21	12.21
6	B base: $\Delta\phi(j_i, MET) > 0.4$	66.2 ± 1.15	77.58 ± 0.59	1.17	8.8	5	0.87 ± 0.02	[illegible]	[illegible]	[illegible]
7	BM: MET/$m_{eff}(3j) > 0.3$	[illegible]	[illegible]	1.59	17.73	6	0.48 ± 0.01	0.65 ± 0.01	1.36	11.46
8	BM: m_{eff}(inc) > 1800	22.8 ± 0.68	45.48 ± 0.7	1.99	23.25	7	0.72 ± 0.02	0.9 ± 0.01	1.25	7.1

Table 1: The cut-flow table for B tight signal region: $\bar{q}\tilde{g}$ direct (1612, 37).

- ATOM automatically generates cut-flow tables and checks the efficiencies between ATOM and experimental collaborations.
- If significant deviation is found, it provides warnings.

can easily catch anomaly

Coding in Atom

ATLAS-CONF-2013-093

Contents

1 Introduction

Supersymmetry (SUSY) [1–9] provides an extension that solves the hierarchy problem [10–13] by introdu

ATLAS_CONF_2013_093.cc

```
void initLocal() {

      ✦ JET DEFINITION
      ✦ TIGHT ELECTRON DEFINITION
      ✦ LOOSE ELECTRON DEFINITION
                ⋮
}
/// Perform the per-event analysis
bool analyzeLocal(const Event& event, const double weight) {

                ⋮

    if( jets.size() >= 4 ){
        _effh.PassEvent("Njet >= 4");
    }else{ vetoEvent; }

    if( jets[0].momentum().pT() > 100 ){
        _effh.PassEvent("pT(j1) > 100");
    }else{ vetoEvent; }
                ⋮
}
```

✦ JET DEFINITION

```
RangeSelector jetrange =
    RangeSelector(RangeSelector::TRANSVERSE_MOMENTUM, 20., 8000.) &
    RangeSelector(RangeSelector::PSEUDO_RAPIDITY, -4.5, 4.5);
//                                                                  radius
JetFinalState jets_Base = jetBase(base, muDetRange, FastJets::ANTIKT,    0.4, hadRange, jetrange);
jets_Base.setFSSmearing  ( dp.jetSim( "Smear_TopoJet_ATLAS" ) );
jets_Base.setFSEfficiency( dp.jetEff( "Jet_ATLAS" ) );
```

```
void initLocal() {

      ✦ JET DEFINITION
      ✦ TIGHT ELECTRON DEFINITION
      ✦ LOOSE ELECTRON DEFINITION
                    ⋮
}
/// Perform the per-event analysis
bool analyzeLocal(const Event& event, const double weight) {
                    ⋮
    if( jets.size() >= 4 ){
        _effh.PassEvent("Njet >= 4");
    }else{ vetoEvent; }

    if( jets[0].momentum().pT() > 100 ){
        _effh.PassEvent("pT(j1) > 100");
    }else{ vetoEvent; }
                    ⋮
}
```

✦ JET DEFINITION

$p_T > 20\,\mathrm{GeV},\ |\eta| < 4.5$

anti-kT, ΔR=0.4 (by Fastjet)

```
RangeSelector jetrange =
    RangeSelector(RangeSelector::TRANSVERSE_MOMENTUM, 20., 8000.) &
    RangeSelector(RangeSelector::PSEUDO_RAPIDITY, -4.5, 4.5);
//                                                              radius
JetFinalState jets_Base = jetBase(base, muDetRange, FastJets::ANTIKT,    0.4, hadRange, jetrange);
jets_Base.setFSSmearing  ( dp.jetSim( "Smear_TopoJet_ATLAS" ) );
jets_Base.setFSEfficiency( dp.jetEff( "Jet_ATLAS" ) );
```

```
void initLocal() {

      ✦ JET DEFINITION
      ✦ TIGHT ELECTRON DEFINITION
      ✦ LOOSE ELECTRON DEFINITION
                 ⋮
}
/// Perform the per-event analysis
bool analyzeLocal(const Event& event, const double weight) {
                 ⋮

    if( jets.size() >= 4 ){
        _effh.PassEvent("Njet >= 4");
    }else{ vetoEvent; }

    if( jets[0].momentum().pT() > 100 ){
        _effh.PassEvent("pT(j1) > 100");
    }else{ vetoEvent; }
                 ⋮
}
```

✦ JET DEFINITION

$p_T > 20\,\mathrm{GeV},\ |\eta| < 4.5$

anti-kT, ΔR=0.4 (by Fastjet)

```
RangeSelector jetrange =
    RangeSelector(RangeSelector::TRANSVERSE_MOMENTUM, 20., 8000.) &
    RangeSelector(RangeSelector::PSEUDO_RAPIDITY, -4.5, 4.5);
//
                                                                  radius
JetFinalState jets_Base = jetBase(base, muDetRange, FastJets::ANTIKT,     0.4, hadRange, jetrange);
jets_Base.setFSSmearing  ( dp.jetSim( "Smear_TopoJet_ATLAS" ) );
jets_Base.setFSEfficiency( dp.jetEff( "Jet_ATLAS" ) );
```

Smear_TopoJet_ATLAS.yaml ×

```
Name: Smear_TopoJet_ATLAS
Tag: ATLAS
Description: topojet
Comment: table
Reference: XXX
Smearing:
    Type: Interpolation
    IsEtaSymmetric: True
    Interpolation:
        Type: PredefinedMode3
        EtaBound: 4.0
        EtaBinContent:
            - BinStart: 0.0
              BinContent:
                  [ [ -2, 9.47621618775420З ]
                  , [ -1, -0.16939888048822812
                  , [ 0, 1.096643215740863e-2 ]
                  , [ 1, -1.147146295333292e-5
                  , [ 2, 1.9289334367006085e-8
                  , [ 3, -1.5000987275723775e-1
            - BinStart: 0.75
```

ATLAS-CONF-2013-004

Table 5: Summary of the *in situ* LCW+JES jet energy scale systematic uncertainties for different p_T^{jet} and $|\eta|$ values for anti-k_t jets with $R = 0.4$. These values do not include pile-up, flavour or topology uncertainties.

$|\eta|$ region	Fractional JES uncertainty				
	p_T^{jet} = 20 GeV	p_T^{jet} = 40 GeV	p_T^{jet} = 200 GeV	p_T^{jet} = 800 GeV	p_T^{jet} = 1.5 TeV
$|\eta|$ = 0.1	2.4%	1.2%	0.8%	1.3%	3.2%
$|\eta|$ = 0.5	2.5%	1.2%	0.8%	1.3%	3.2%
$|\eta|$ = 1.0	2.6%	1.4%	1.1%	1.3%	3.2%
$|\eta|$ = 1.5	3.1%	2.1%	1.7%	1.4%	3.3%
$|\eta|$ = 2.0	3.9%	2.9%	2.6%	1.8%	
$|\eta|$ = 2.5	4.6%	3.9%	3.4%		
$|\eta|$ = 3.0	5.2%	4.6%	3.9%		
$|\eta|$ = 3.5	5.8%	5.2%	4.5%		
$|\eta|$ = 4.0	6.2%	5.5%	5.1%		

✦ TIGHT ELECTRONS

$p_T > 25\,\mathrm{GeV},\ |\eta| < 2.47$

```
// prepare for tight electrons
RangeSelector ele_range =
    RangeSelector(RangeSelector::TRANSVERSE_MOMENTUM, 25., 3000.) &
    RangeSelector(RangeSelector::PSEUDO_RAPIDITY, -2.47, 2.47);
IsoElectron ele_smear(ele_range);
ele_smear.setIso(TRACK_ISO_PT, 0.3,  0.01, 0.16, 0.0, CALO_ALL);
ele_smear.setIso(CALO_ISO_ET,  0.3,  0.01, 0.18, 0.0, CALO_ALL);
ele_smear.setVariableThreshold(0.0);
ele_smear.setFSSmearing  ( dp.electronSim( "Smear_Electron_ATLAS" ) );
ele_smear.setFSEfficiency( dp.electronEff( "Electron_Tight_ATLAS" ) );
```

✦ TIGHT ELECTRONS

$p_T > 25\,\text{GeV}, \;\; |\eta| < 2.47$

```
// prepare for tight electrons
RangeSelector ele_range =
    RangeSelector(RangeSelector::TRANSVERSE_MOMENTUM, 25., 3000.) &
    RangeSelector(RangeSelector::PSEUDO_RAPIDITY, -2.47, 2.47);
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ele_smear.setIso(TRACK_ISO_PT, 0.3,  0.01, 0.16, 0.0, CALO_ALL);
ele_smear.setIso(CALO_ISO_ET,  0.3,  0.01, 0.18, 0.0, CALO_ALL);
ele_smear.setVariableThreshold(0.0);
ele_smear.setFSSmearing  ( dp.electronSim( "Smear_Electron_ATLAS" ) );
ele_smear.setFSEfficiency( dp.electronEff( "Electron_Tight_ATLAS" ) );
```
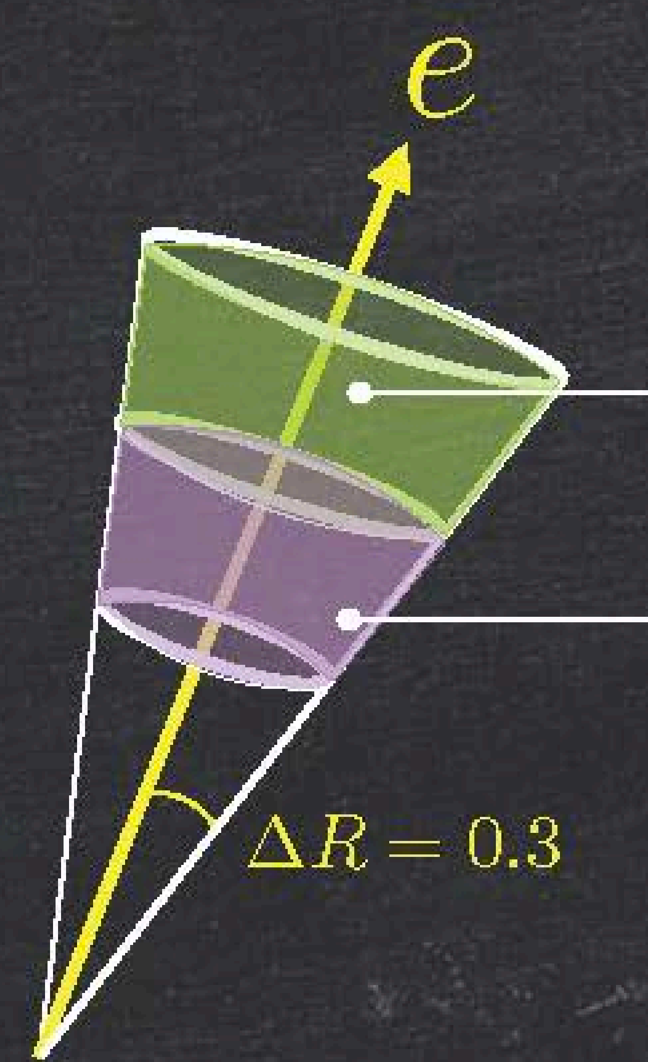

track
calorimeter
isolation



$\sum_{i}^{\text{CAL}} E_T^i < 0.18 \cdot p_T^e$

$\sum_{i}^{\text{track}} p_T^i < 0.16 \cdot p_T^e$

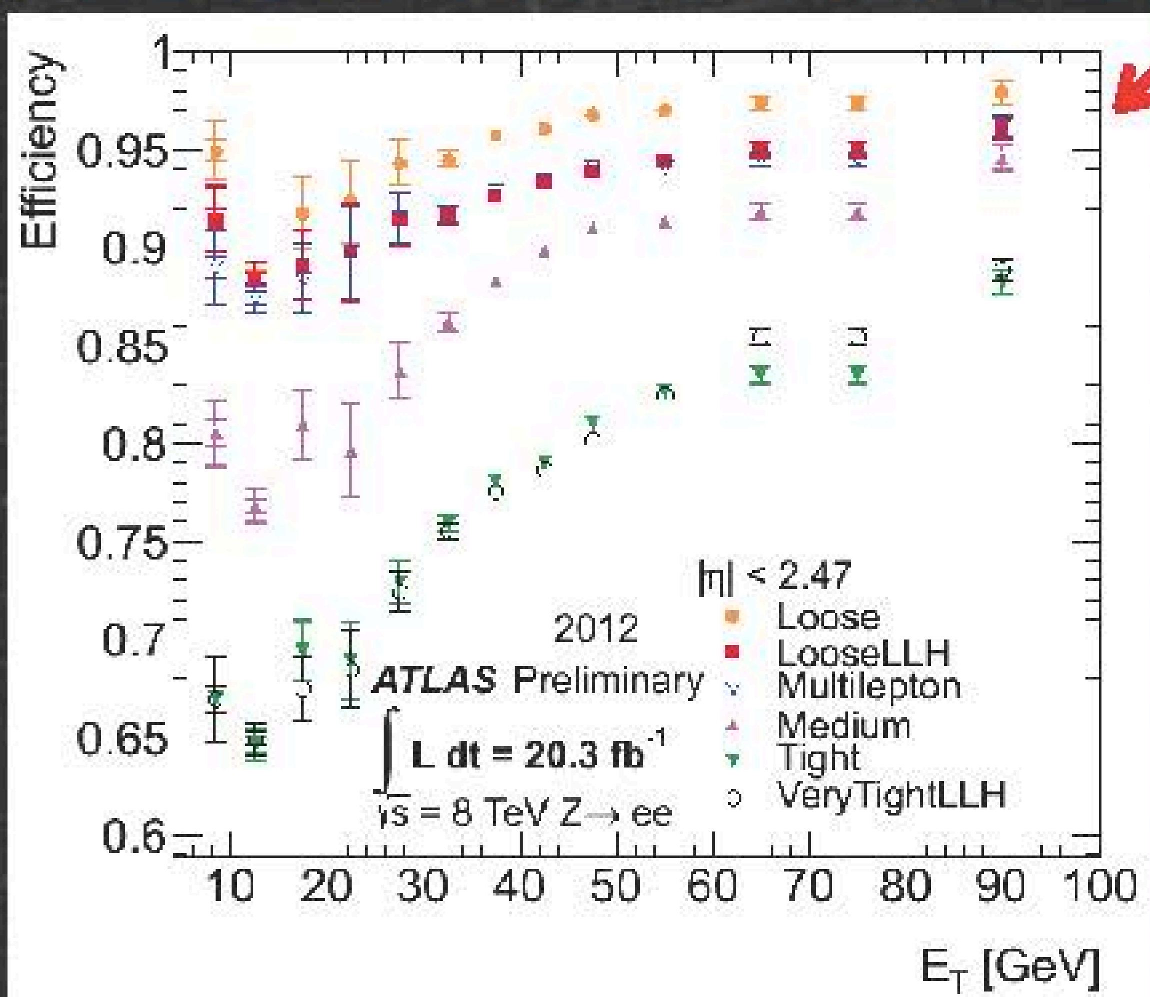
✦ TIGHT ELECTRONS

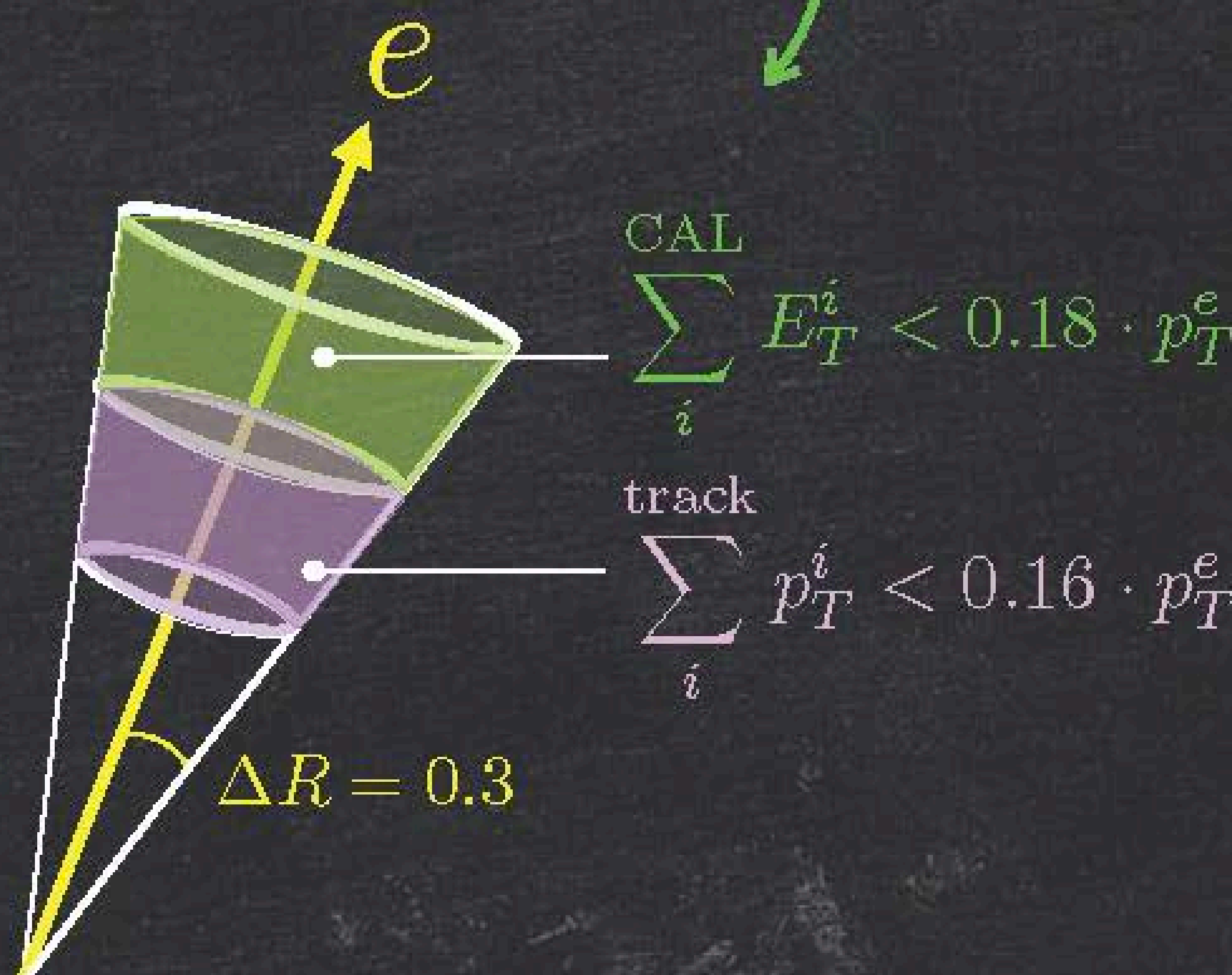
$p_T > 25\,\mathrm{GeV},\ |\eta| < 2.47$

```
// prepare for tight electrons
RangeSelector ele_range =
    RangeSelector(RangeSelector::TRANSVERSE_MOMENTUM, 25., 3000.) &
    RangeSelector(RangeSelector::PSEUDO_RAPIDITY, -2.47, 2.47);
IsoElectron ele_smear(ele_range);
ele_smear.setIso(TRACK_ISO_PT, 0.3,  0.01, 0.16, 0.0, CALO_ALL);
ele_smear.setIso(CALO_ISO_ET,  0.3,  0.01, 0.18, 0.0, CALO_ALL);
ele_smear.setVariableThreshold(0.0);
ele_smear.setFSSmearing  ( dp.electronSim( "Smear_Electron_ATLAS" ) );
ele_smear.setFSEfficiency( dp.electronEff( "Electron_Tight_ATLAS" ) );
```

track calorimeter isolation

reconstruction efficiencies





Similar Projects

- There are several programs/ideas on the market

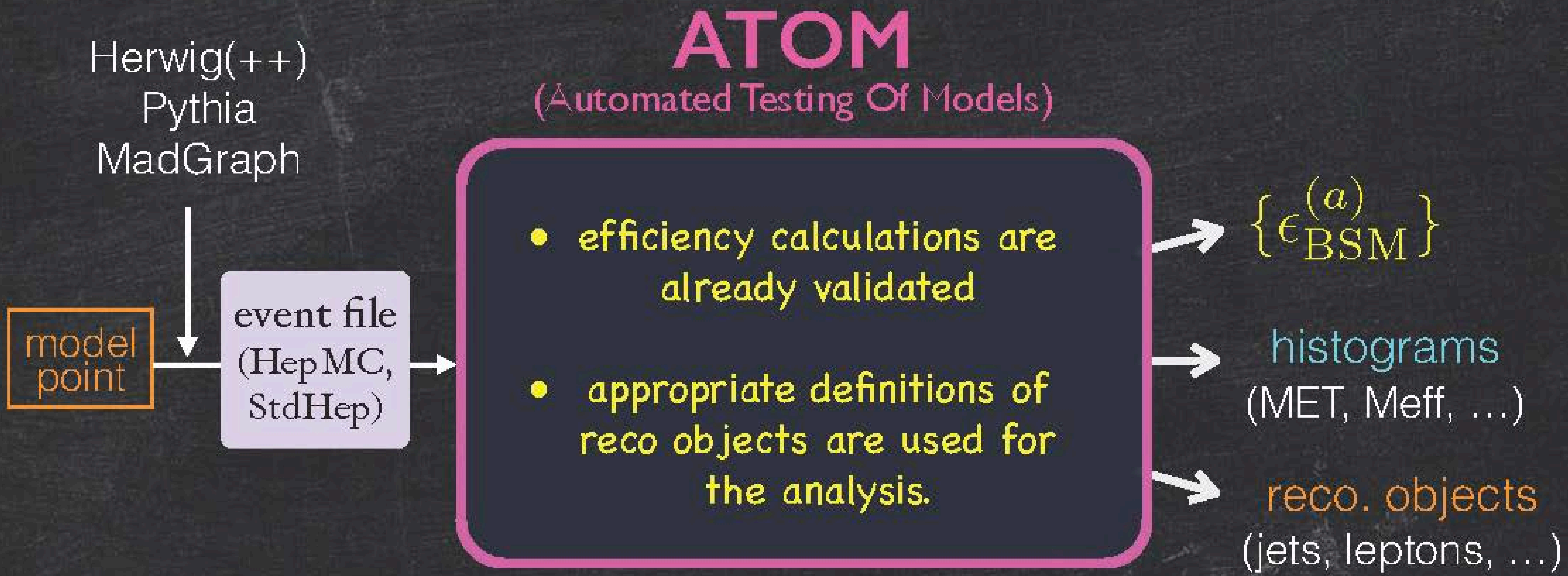
MadAnalysis 5: a general event analysis code E.Conte, B.Fuks, G.Serret, 2012

CheckMATE: a tool to test a generic BSM point agains ATLAS/CMS results

M.Drees, H.Dreiner, J.S.Kim, D.Schmeier, J.Tattersall, 2013

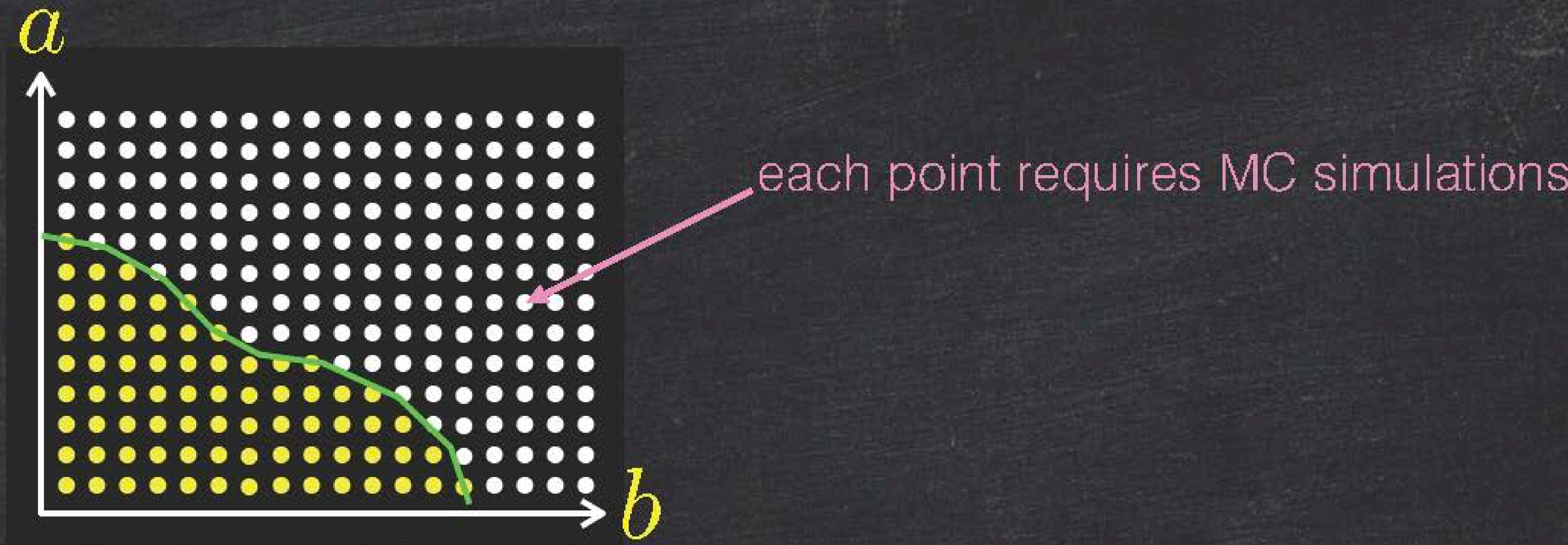
ATOM Summary

- ATOM is a tool to calculate efficiencies of various signal regions from a given event sample.
- Various BSM searches are available with appropriate detector objects definitions.
- All analyses are validated.



Fastlim motivation

- In the standard procedure, testing model points requires time consuming MC simulations. This is problematic when performing parameter scans.

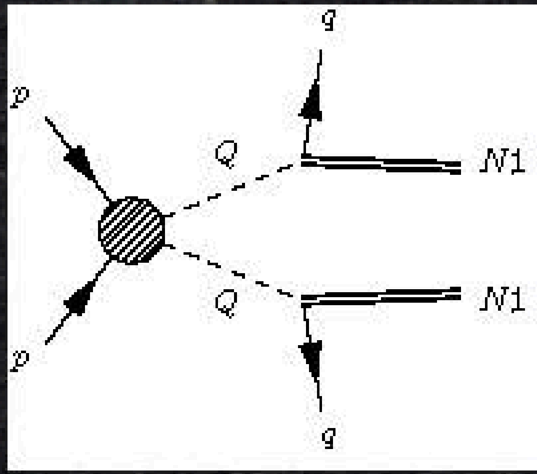


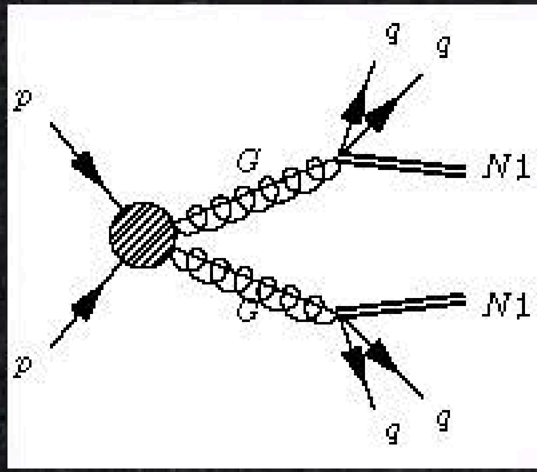
It is desirable to have a fast model testing method

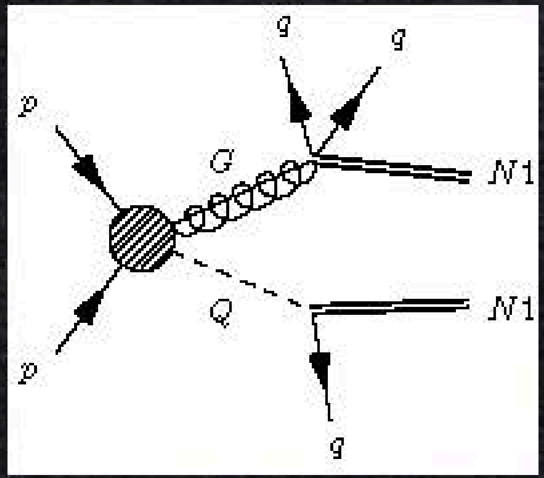
N_{BSM} de/reconstruction

$Q = \tilde{q}$
$G = \tilde{g}$
$N1 = \tilde{\chi}_1^0$

$$N^{(a)}_{\mathrm{BSM}} = \begin{cases} N^{(a)}_{\mathrm{QqN1:QqN1}} \\ + \\ N^{(a)}_{\mathrm{GqqN1:GqqN1}} \\ + \\ N^{(a)}_{\mathrm{GqqN1:QqN1}} \\ \vdots \end{cases}$$







N_{BSM} de/reconstruction

$Q = \tilde{q}$
$G = \tilde{g}$
$N1 = \tilde{\chi}_1^0$

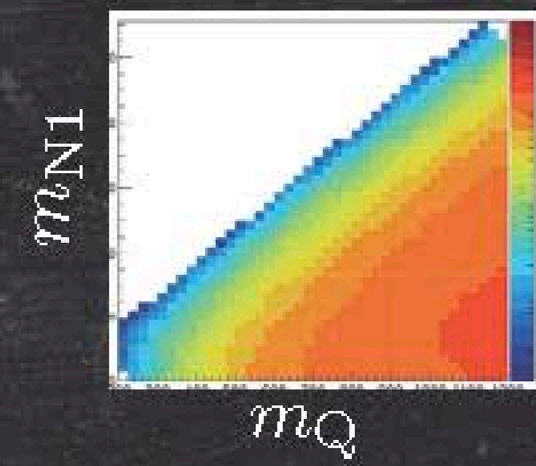
depends *only* on 2 or 3 BSM particle masses

$$N^{(a)}_{\rm BSM} = \begin{cases} N^{(a)}_{\rm QqN1:QqN1} = \epsilon^{(a)}_{\rm QqN1:QqN1}(m_{\rm Q}, m_{\rm N1}) \cdot \sigma_{\rm QQ} \cdot BR \cdot \mathcal{L} \\ + \\ N^{(a)}_{\rm GqqN1:GqqN1} = \epsilon^{(a)}_{\rm GqqN1:GqqN1}(m_{\rm G}, m_{\rm N1}) \cdot \sigma_{\rm GG} \cdot BR \cdot \mathcal{L} \\ + \\ N^{(a)}_{\rm GqqN1:QqN1} = \epsilon^{(a)}_{\rm GqqN1:QqN1}(m_{\rm G}, m_{\rm Q}, m_{\rm N1}) \cdot \sigma_{\rm GQ} \cdot BR \cdot \mathcal{L} \\ \vdots \end{cases}$$

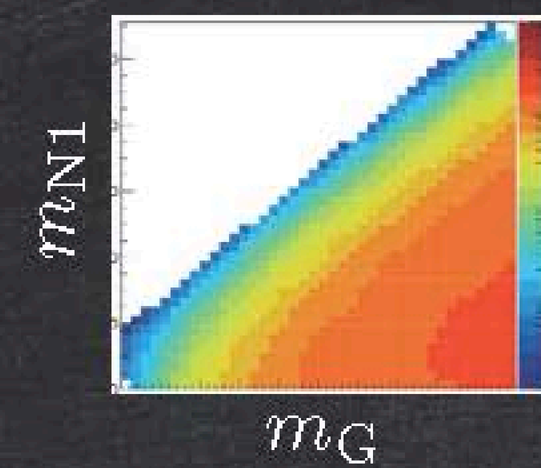
N_{BSM} de/reconstruction

$\mathrm{Q} = \tilde{q}$
$\mathrm{G} = \tilde{g}$
$\mathrm{N1} = \tilde{\chi}_1^0$

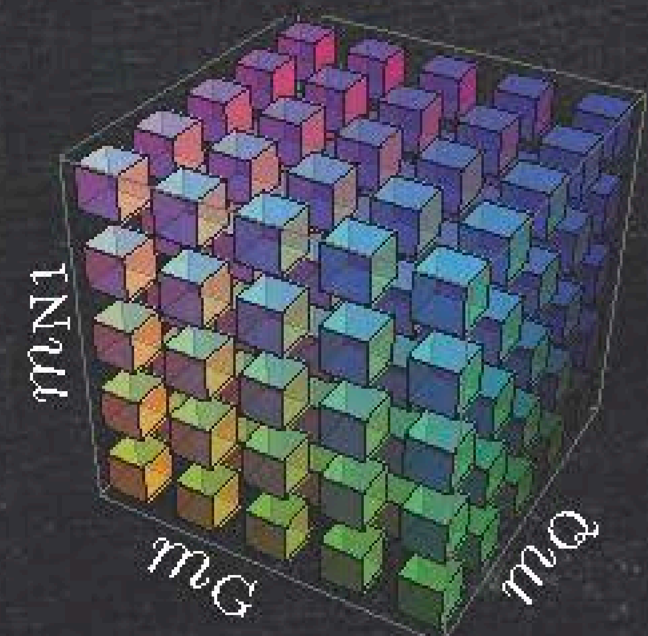
$$N^{(a)}_{\mathrm{BSM}} = \begin{cases} N^{(a)}_{\mathrm{QqN1:QqN1}} = \\ + \\ N^{(a)}_{\mathrm{GqqN1:GqqN1}} = \\ + \\ N^{(a)}_{\mathrm{GqqN1:QqN1}} = \\ \vdots \end{cases}$$



$$\sigma_{\mathrm{QQ}} \cdot BR \cdot \mathcal{L}$$



$$\sigma_{\mathrm{GG}} \cdot BR \cdot \mathcal{L}$$



$$\sigma_{\mathrm{GQ}} \cdot BR \cdot \mathcal{L}$$

http://fastlim.web.cern.ch/fastlim/

Fastlim

Papucci, KS, Weiler, Zeune 1402.0492

cross section tables

m_Q	m_G	σ
300	300	87.94
300	350	34.98
...		

efficiency tables

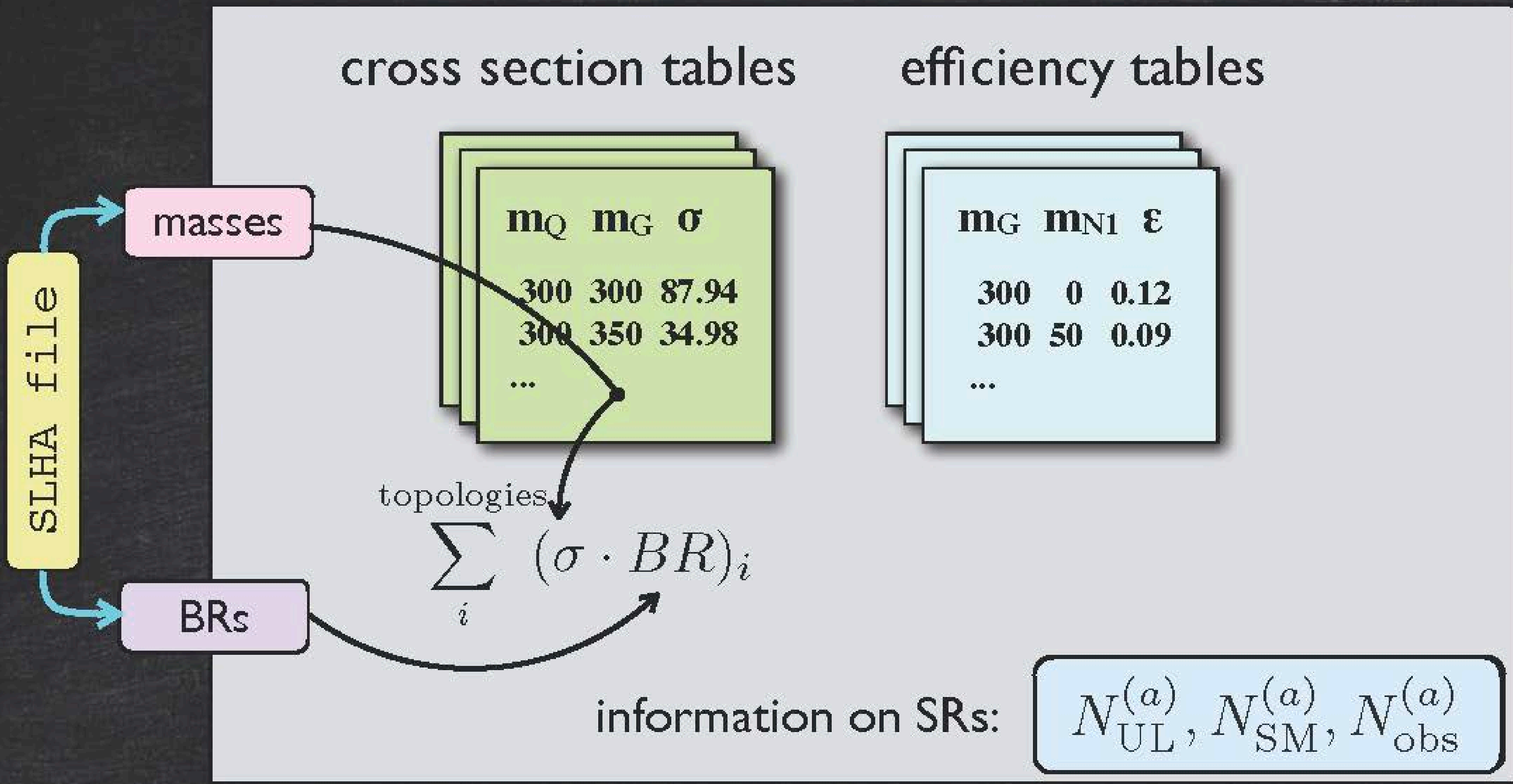
m_G	m_{N1}	ε
300	0	0.12
300	50	0.09
...		

information on SRs: $N_{\rm UL}^{(a)}, N_{\rm SM}^{(a)}, N_{\rm obs}^{(a)}$

http://fastlim.web.cern.ch/fastlim/

Fastlim

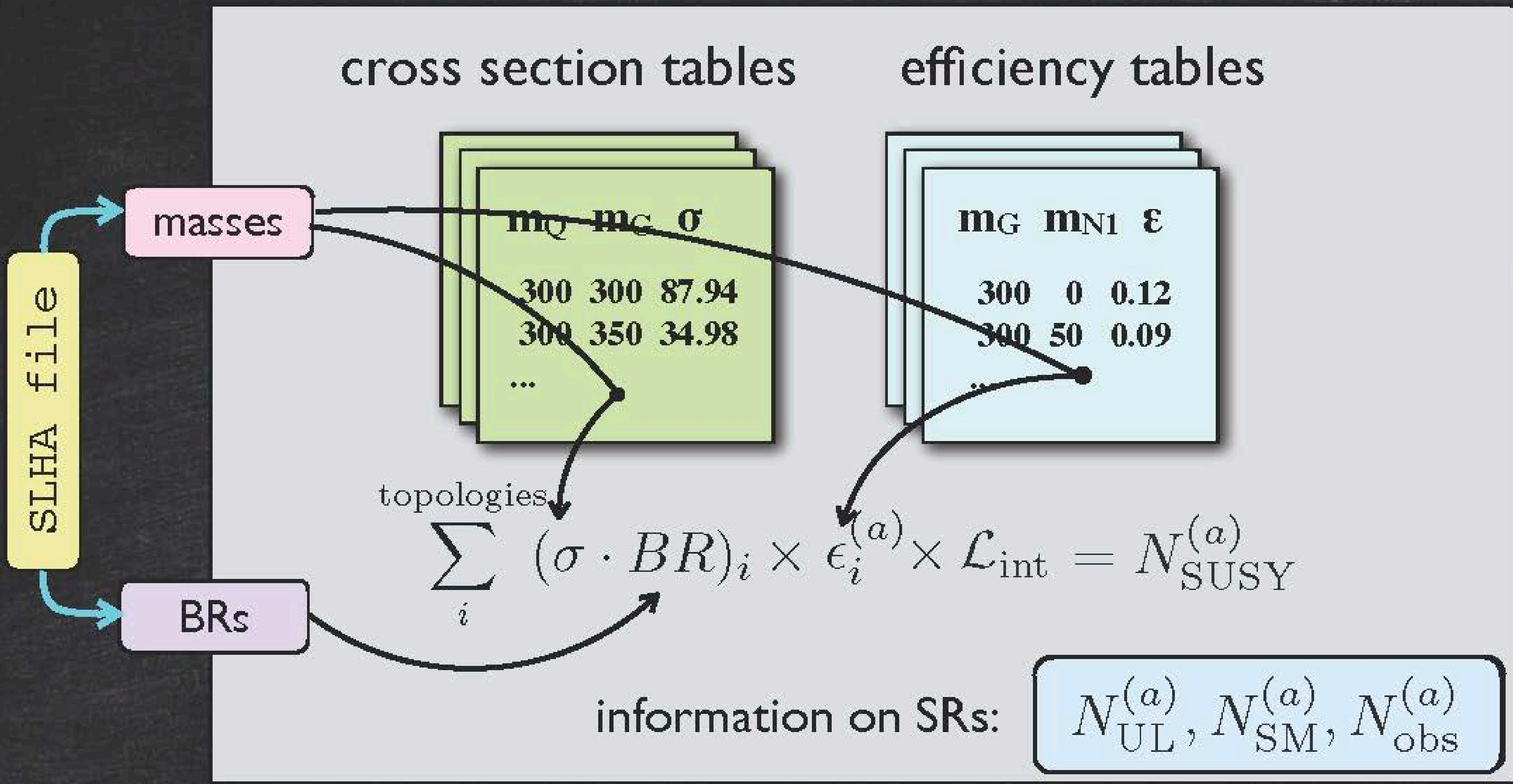
Papucci, KS, Weiler, Zeune 1402.0492



http://fastlim.web.cern.ch/fastlim/

Fastlim

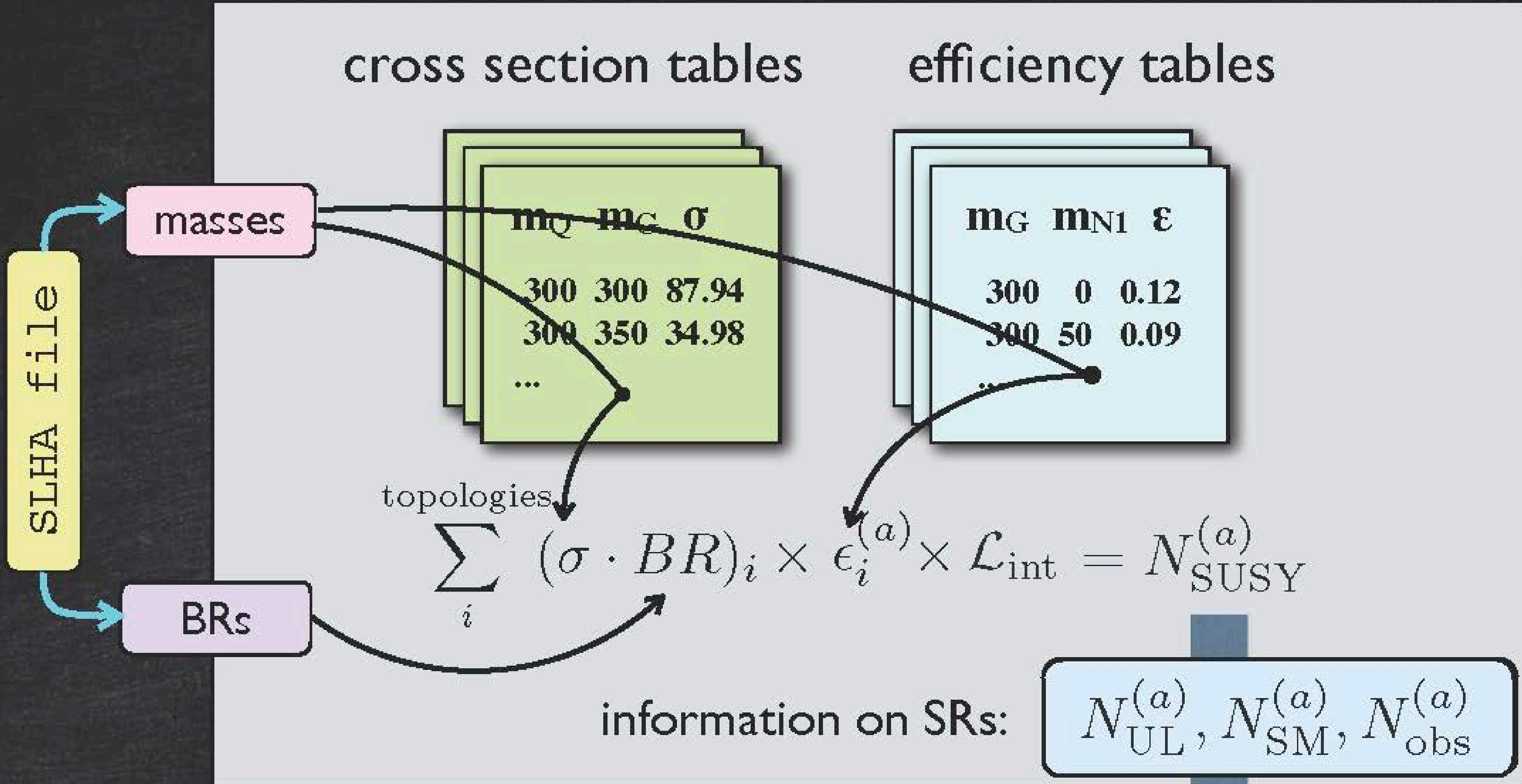
Papucci, KS, Weiler, Zeune 1402.0492



http://fastlim.web.cern.ch/fastlim/

Fastlim

Papucci, KS, Weiler, Zeune 1402.0492

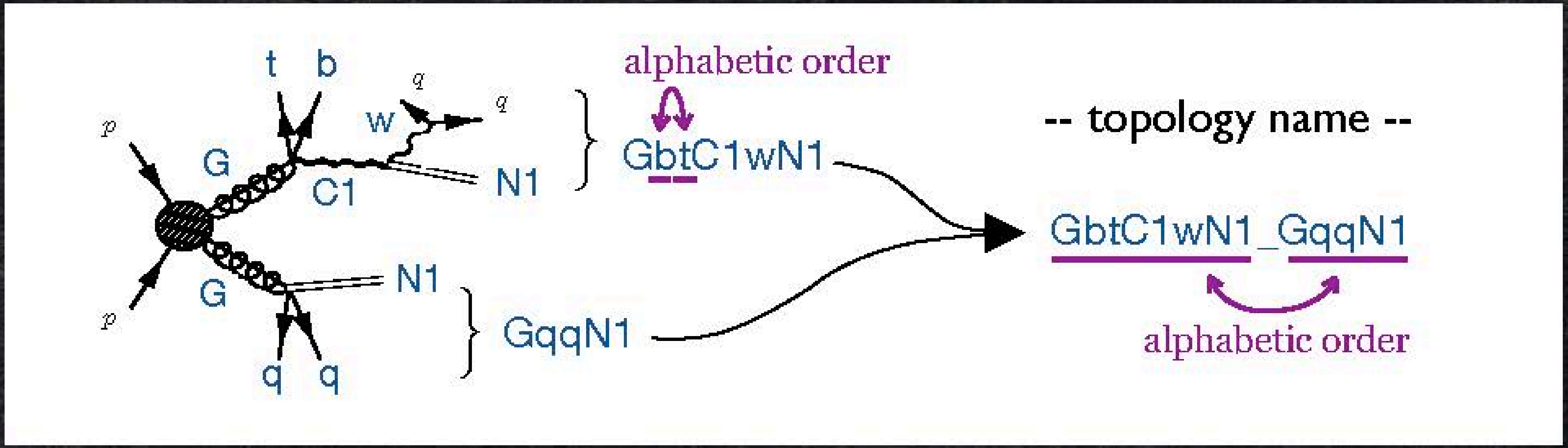


No MC sim. required

output: $N_{\rm SUSY}^{(a)}/N_{\rm UL}^{(a)}, CL_s^{(a)}$

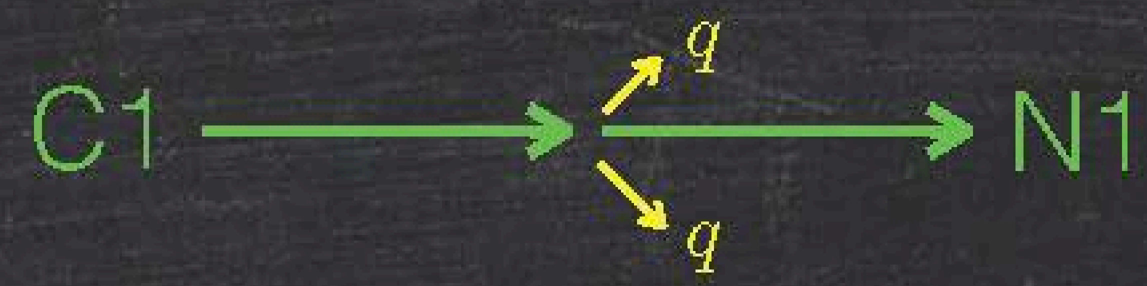
Naming topologies

SM	g	gam, z, w, h	q	t	b	e, m, ta	n
BSM	G	N1,...,N4, C1,C2	Q	T1, T2	B1, B2	E, M, TAU	NU, NUT



Truncation of soft decays

$$m_{\mathrm{C1}} \simeq m_{\mathrm{N1}}$$



very soft and do not affect efficiencies

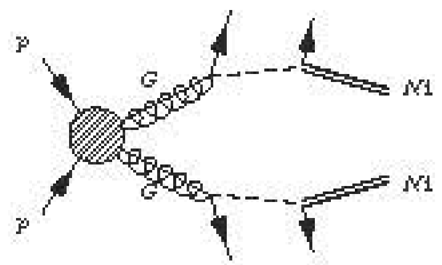
G→btC1→qqN1 ⇒ GbtN1

- note: this introduces topologies as if EM charge is not conserved.

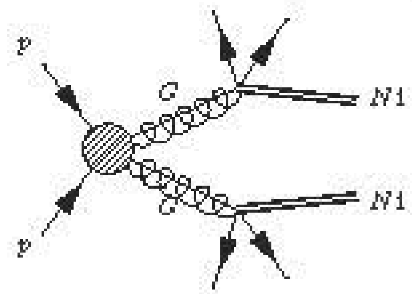
useful for wino and higgsino scenarios

Fastlim 1.0

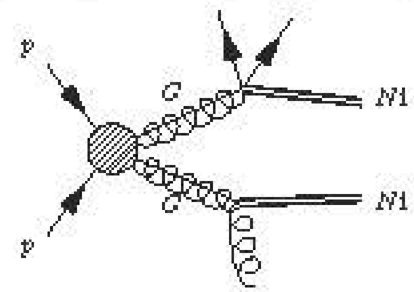
topologies in Fastlim 1.0



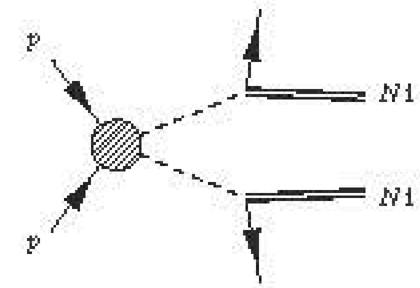
GbB1bN1_GbB1bN1
GbB1bN1_GbB1tN1
GbB1tN1_GbB1tN1
GtT1bN1_GtT1bN1
GtT1bN1_GtT1tN1
GtT1tN1_GtT1tN1
(GbB2bN1_GbB2bN1)
(GbB2bN1_GbB2tN1)
(GbB2tN1_GbB2tN1)
(GtT2bN1_GtT2bN1)
(GtT2bN1_GtT2tN1)
(GtT2tN1_GtT2tN1)
[GbB1bN1_GbB2bN1]
[GbB1bN1_GbB2tN1]
[GbB1tN1_GbB2bN1]
[GbB1tN1_GbB2tN1]
[GtT1bN1_GtT2bN1]
[GtT1bN1_GtT2tN1]
[GtT1tN1_GtT2bN1]
[GtT1tN1_GtT2tN1]



GbbN1_GbbN1
GbbN1_GbtN1
GbbN1_GttN1
GbbN1_GqqN1
GbtN1_GbtN1
GbtN1_GttN1
GbtN1_GqqN1
GttN1_GttN1
GttN1_GqqN1
GqqN1_GqqN1



GbbN1_GgN1
GbtN1_GgN1
GgN1_GgN1
GgN1_GttN1
GgN1_GqqN1



T1bN1_T1bN1
T1bN1_T1tN1
T1tN1_T1tN1
(B1bN1_B1bN1)
(B1bN1_B1tN1)
(B1tN1_B1tN1)
(B2bN1_B2bN1)
(B2bN1_B2tN1)
(B2tN1_B2tN1)
(T2bN1_T2bN1)
(T2bN1_T2tN1)
(T2tN1_T2tN1)

not all topologies are implemented

↓

the result may be underestimated but at least conservative

Fastlim 1.0

available analyses

Name	Short description	E_{CM}	$\mathcal{L}_{int}$	# SRs
ATLAS_CONF_2013_024	0 lepton + (2 b-)jets + MET [Heavy stop]	8	20.5	3
ATLAS_CONF_2013_035	3 leptons + MET [EW production]	8	20.7	6
ATLAS_CONF_2013_037	1 lepton + 4(1 b-)jets + MET [Medium/heavy stop]	8	20.7	5
ATLAS_CONF_2013_047	0 leptons + 2-6 jets + MET [squarks & gluinos]	8	20.3	10
ATLAS_CONF_2013_048	2 leptons (+ jets) + MET [Medium stop]	8	20.3	4
ATLAS_CONF_2013_049	2 leptons + MET [EW production]	8	20.3	9
ATLAS_CONF_2013_053	0 leptons + 2 b-jets + MET [Sbottom/stop]	8	20.1	6
ATLAS_CONF_2013_054	0 leptons + $\geq$ 7-10 jets + MET [squarks & gluinos]	8	20.3	19
ATLAS_CONF_2013_061	0-1 leptons + $\geq$ 3 b-jets + MET [3rd gen. squarks]	8	20.1	9
ATLAS_CONF_2013_062	1-2 leptons + 3-6 jets + MET [squarks & gluinos]	8	20.3	13
ATLAS_CONF_2013_093	1 lepton + bb(H) + Etmiss [EW production]	8	20.3	2

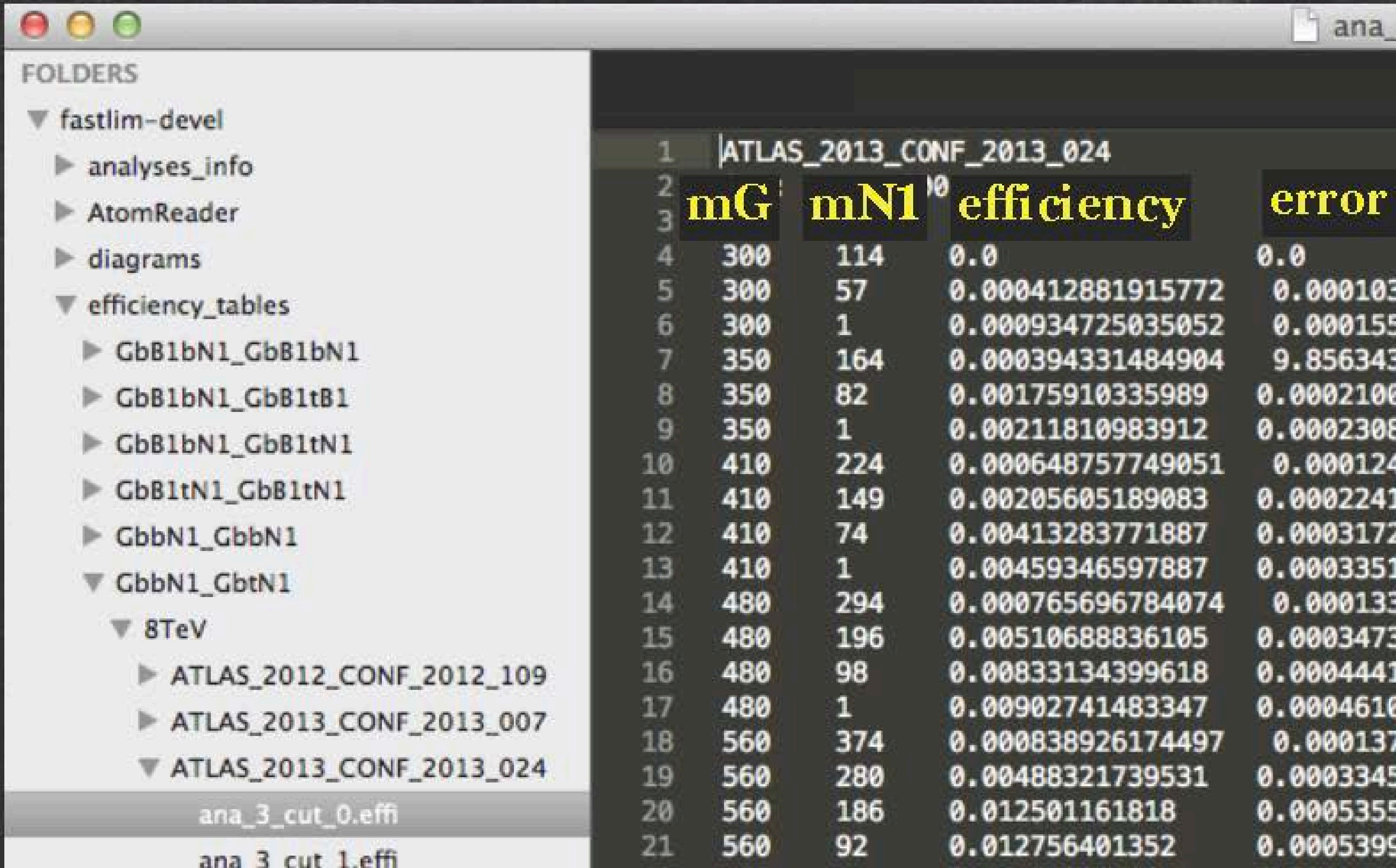
- Most 2013 ATLAS analyses are implemented (CMS analyses will be implemented soon).
- Event generation was done using MadGraph 5. The sample include up to extra 1 parton emission at ME level, matched to parton shower using MLM scheme.
- ATOM is used for efficiency estimation.

Efficiency tables

- efficiency tables are standard text file.
- should be given for each signal region and each topology
- any 3rd party's efficiency tables can be easily incorporated.

global coordinating effort to generate efficiency maps and share

https://indico.cern.ch/event/272303/



Effi

- efficiency tables are standa
- should be given for each si
- any 3rd party's efficiency ta

global coordinating effort to generate efficiency maps and share

https://indico.cern.ch/event/272303/

can include efficiency maps on HepData very easily.

Please provide more maps!

The Durham HepData Project

REACTION DATABASE • DATA REVIEWS • PDF PLOTTER

Reaction Database Full Record Display

View short record or as: input, plain text, AIDA, PyROOT, YODA, ROOT, mpl, ScaVis or MarcXML

AAD 2012 — Search for squarks and gluinos with the ATLAS detector in final states with jets and missing transverse momentum using 4.7 fb^-1 of sqrt(s) = 7 TeV proton-proton collision data

Experiment: CERN-LHC-ATLAS (ATLAS)
Preprinted as **CERN-PH-EP-2012-195**
Archived as: ARXIV:1208.0949
Record in: INSPIRE
Rivet Analysis: ATLAS_2012_I1125961

CERN-LHC. Data from proton-proton interactions at a centre-of-mass energy of 7 TeV with a final state consisting of jets and missing transverse momentum and no high-pT electron or muons are interpreted in a number of SUSY model, listed in the table below.

The table below provides links to the following information for each of the SUSY models

Nevt/Xsec	Number of Monte Carlo events generated The Total SUSY production cross section
AccEffUnc:	Signal Acceptance (truth level) Efficiency (reconstruction level) Uncertainty on signal efficiencies due to detector effects and ISR
CLs	Observed and expected 95% CLs of signal models
SLHA	SLHA files from the analyses
xsUL	Combined and inidividual signal level upper limits on the effective cross sections
Exclusion	The exclusion plot contours as presented in the figures

Model	Nevt/Xsec	AccEffUnc	CLs	SLHA	xsUL	Exclusion
CMSSM/MSUGRA, tan beta=10, A_0=0, mu0	select	select	select	select		select
compressed SUSY (baseline)	select	select	select	select		select
compressed SUSY, (heavy EW gauginos)	select	select	select	select		select
compSUSY_HSQ	select	select	select	select		select
MSSM squark-gluino-neutralino model, mLSP=0	select	select	select	select	select	select
MSSM squark-gluino-neutralino model, mLSP=195 GeV	select	select	select	select	select	select
MSSM squark-gluino-neutralino model, mLSP=395 GeV	select	select	select	select	select	select
gluino-gluino simplified model, direct decays	select	select	select	select	select	select
squark-antisquark simplified model, direct decays	select	select	select	select	select	select
gluino-gluino simplified model, intermediate chargino, vs mLSP	select	select	select	select	select	select
gluino-gluino simplified model, intermediate chargino, vs mChargino	select	select	select	select	select	select
squark-antisquark simplified model, intermediate chargino, vs mLSP	select	select	select	select	select	select
squark-antisquark simplified model, intermediate chargino, vs mChargino	select	select	select	select	select	select

Fastlim demo

Fastlim Summary

- Fastlim computes N_{BSM}/N_{UL} from a given model file immediately without performing MC simulation.
- Only implemented topologies are considered ⇒ the limit may be (significantly) underestimated though it is at least conservative.
- Application is limited in SUSY-like models

Application

for experimentalists: - for various quick checks:

- quick implementation of a new analysis
- when designing a new search, check and make sure the existing searches are not sensitive to the target region to be searched for

no excess in data: - can study constraints on the BSM parameter space (look for blind spots in the current analyses coverage)

excess in data: - can study which new physics models can fit the observed excess

Application

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Natural SUSY

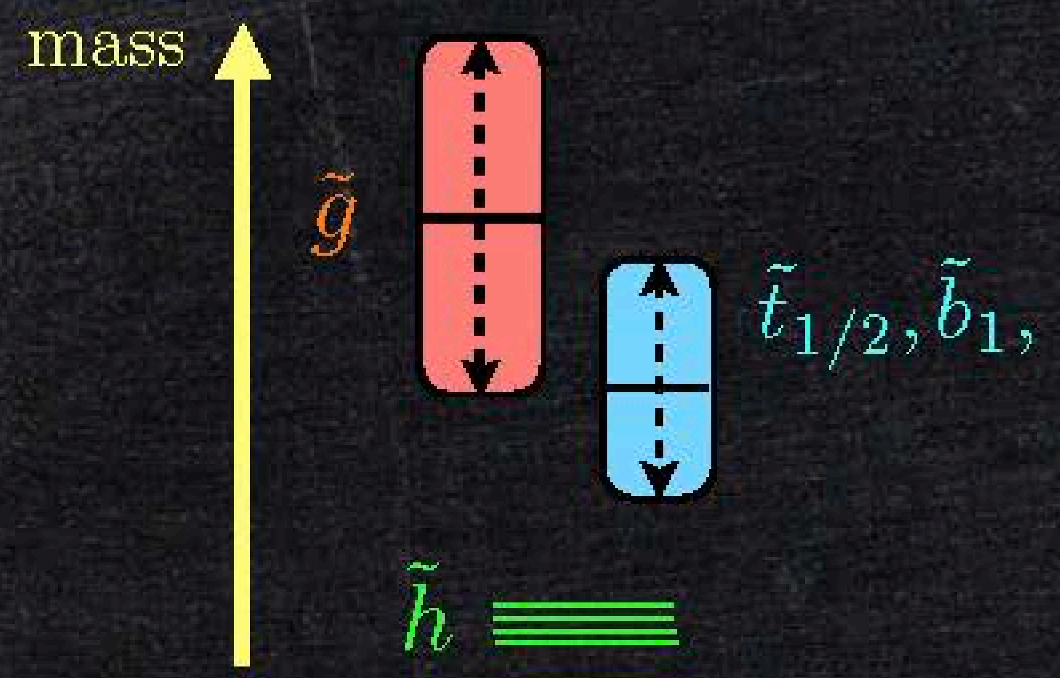
- Natural SUSY contains a minimum particle content that makes the EWSB natural.

$$-\frac{m_Z^2}{2} \simeq |\mu|^2 + m_{H_u}^2(\Lambda) + \Delta m_{H_u}^2$$

μ is higgsino mass: higgsino is lightest

stop 1 loop correction to Δm_{Hu}^2: stop is very light

gluino 2-loop correction to Δm_{Hu}^2: gluino is light



- Only a few particles are accessible at the LHC

⇒ nice playground for Fastlim 1.0

M_{Q3} vs μ

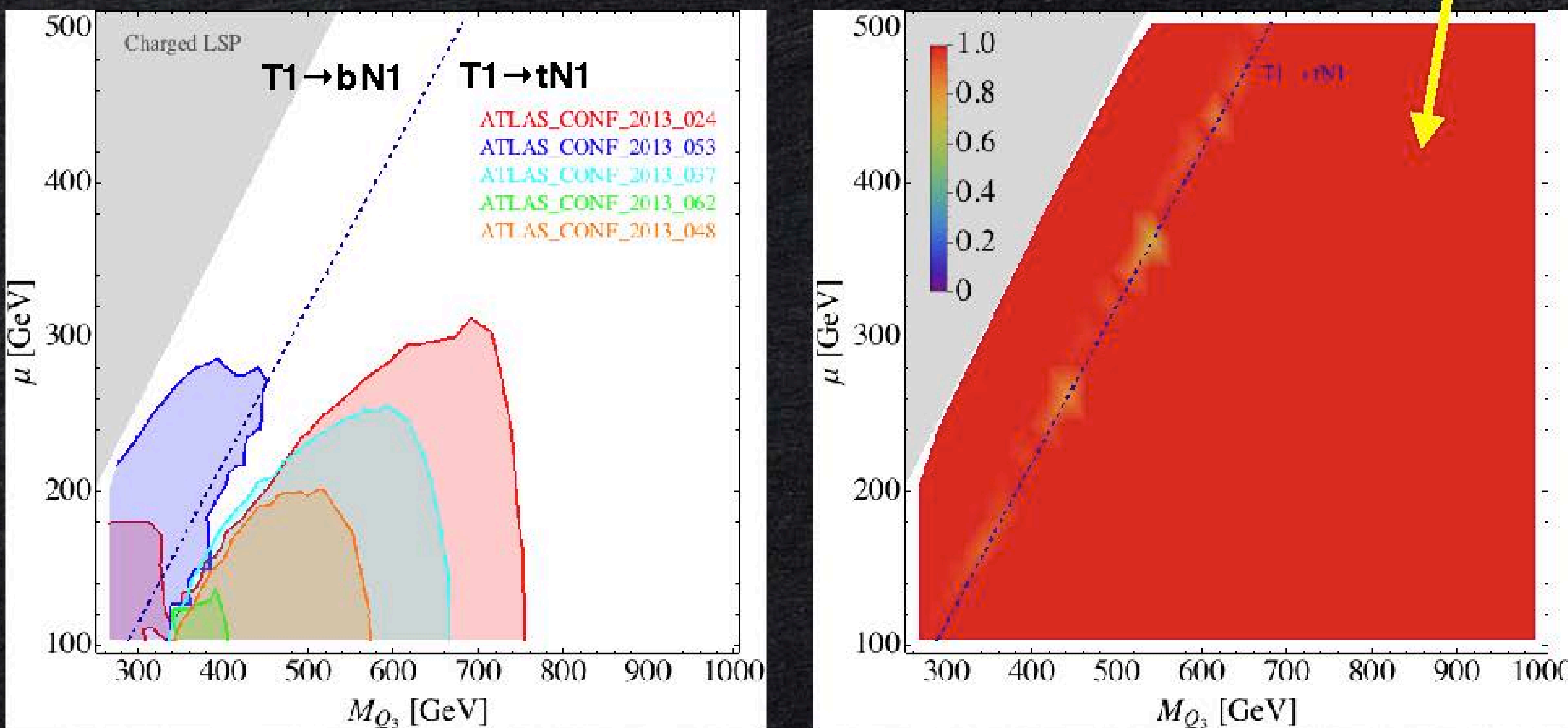
$$\mathcal{L} \supset y_t \cdot t_R \widetilde{Q}_3 \widetilde{H}_u + y_b \cdot b_R \widetilde{Q}_3 \widetilde{H}_d$$

$$\text{coverage} = \frac{\sigma^{\text{implimented}}}{\sigma_{\text{tot}}}$$

$$\begin{cases} \text{T1} \to t\,\text{N1} \\ \text{B1} \to t\,\text{C1}\ (\text{C1} \to \text{N1}) \end{cases}$$

good coverage

$\tan\beta = 10$



M_{Q3} vs μ

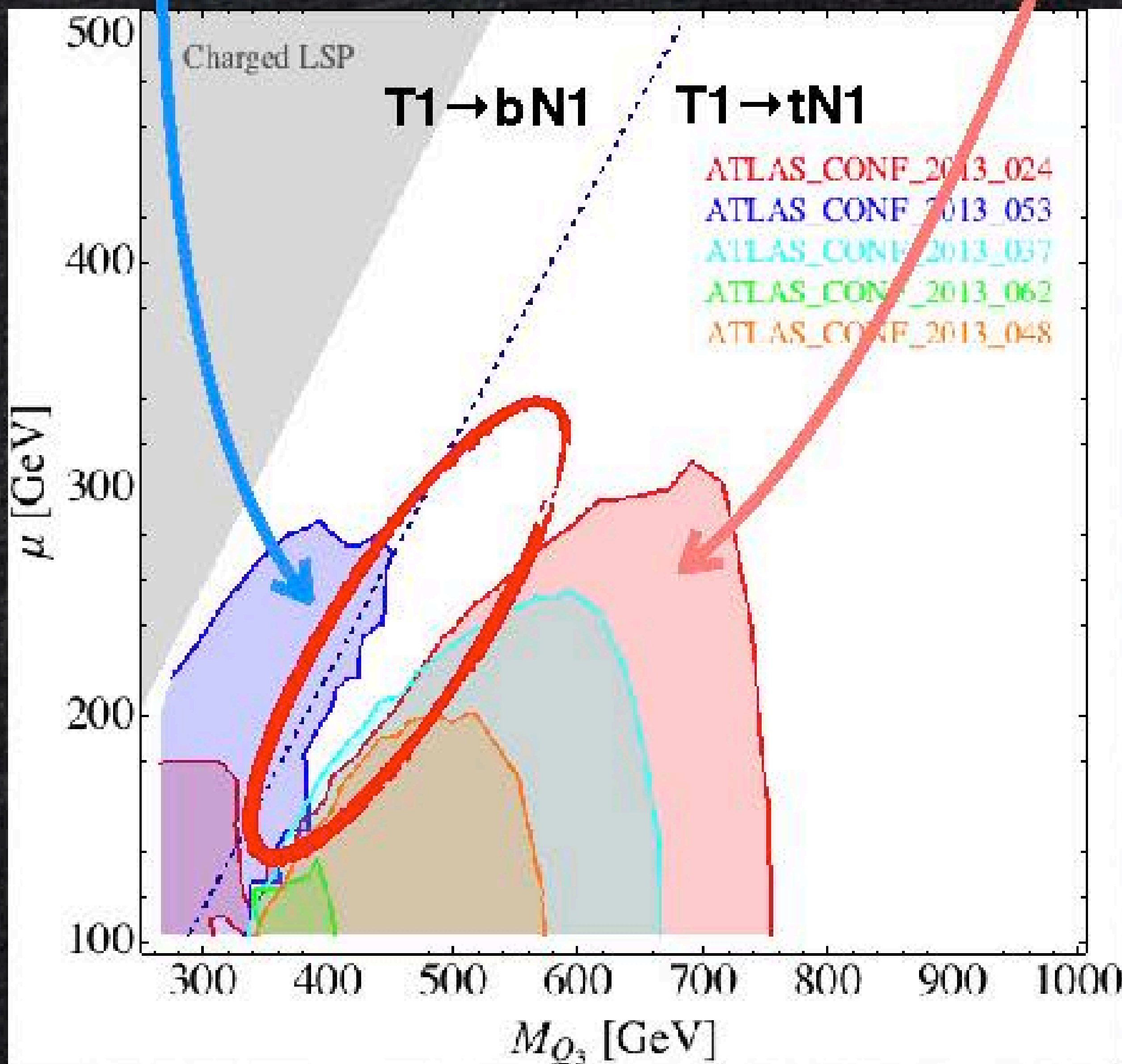
$$\text{coverage} = \frac{\sigma^{\text{implimented}}}{\sigma_{\text{tot}}}$$

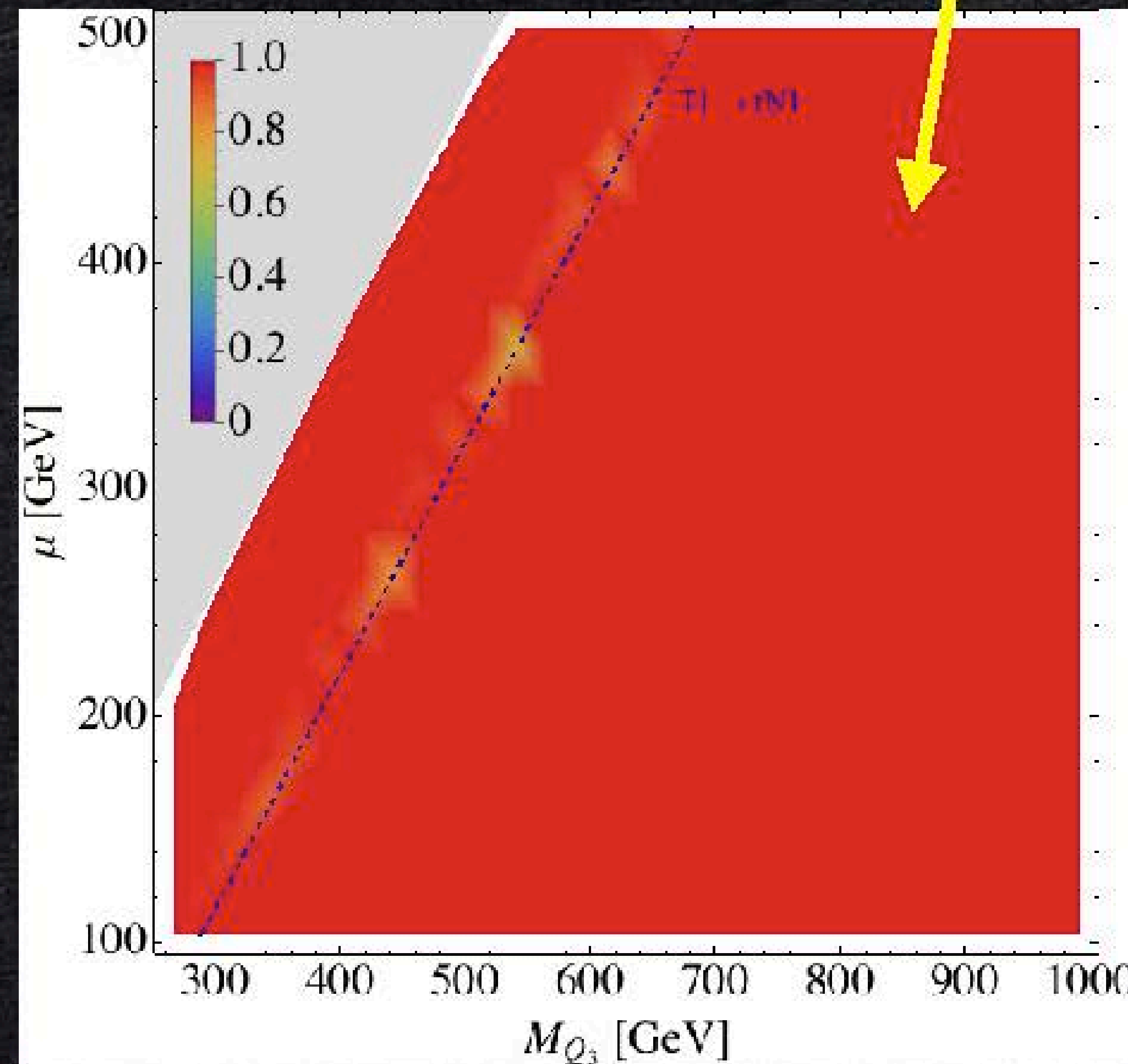
for B1→bN1 topology

designed for T1→tN1 topology

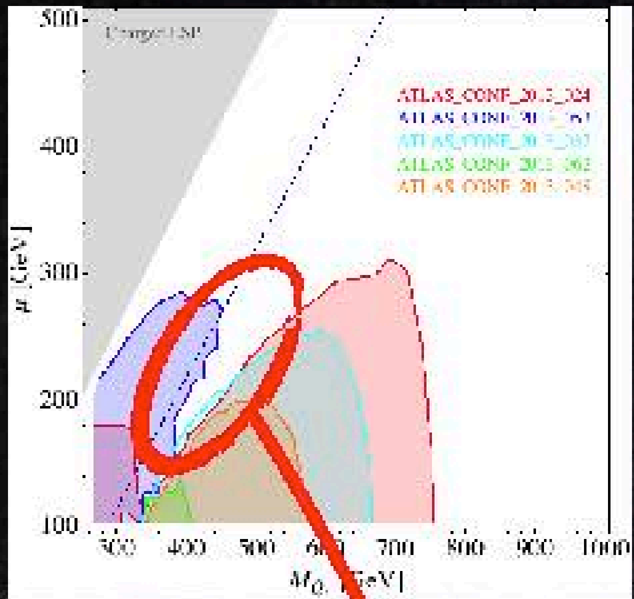
good coverage

$\tan\beta = 10$





M_{Q3} vs tanβ

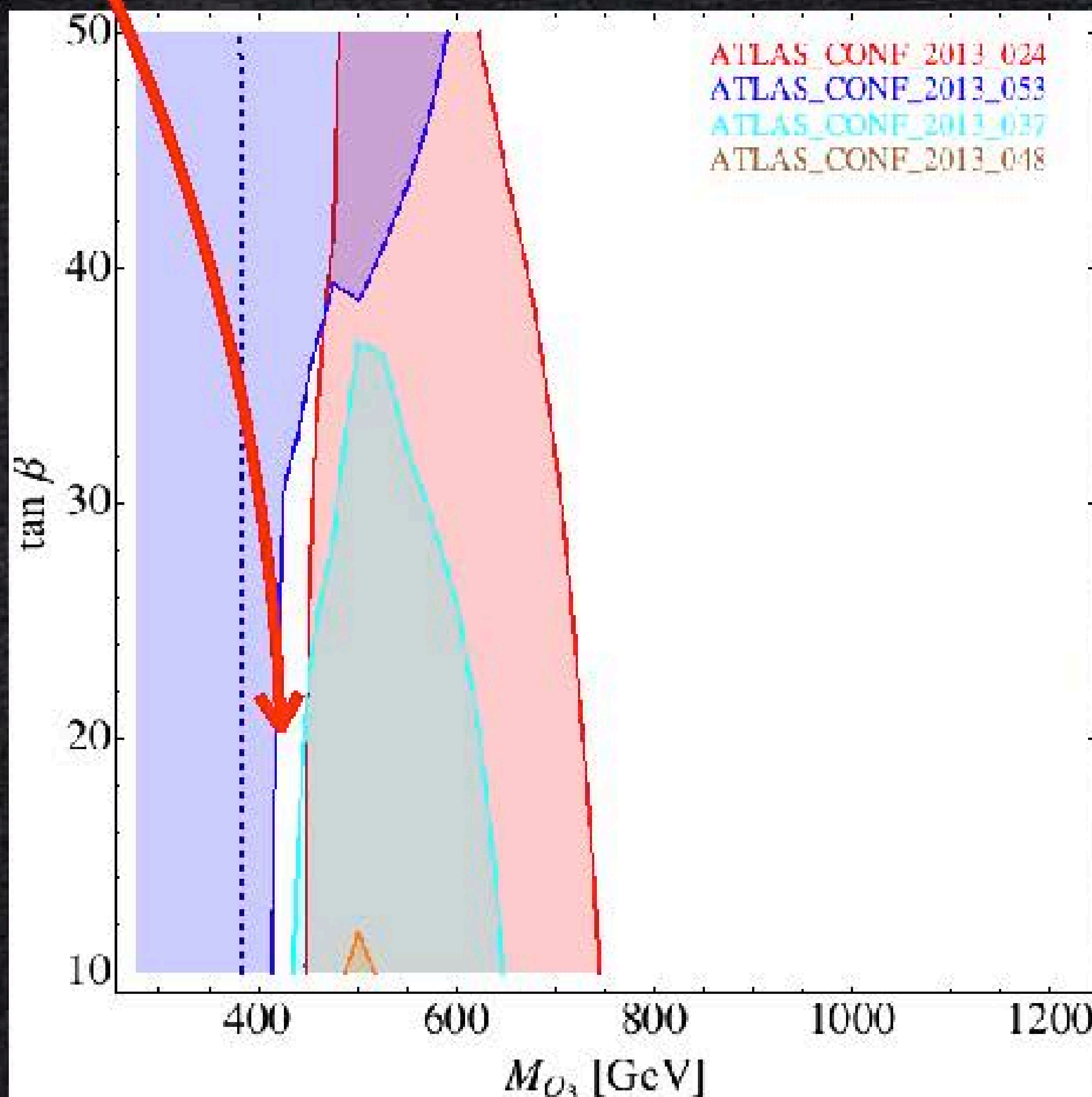


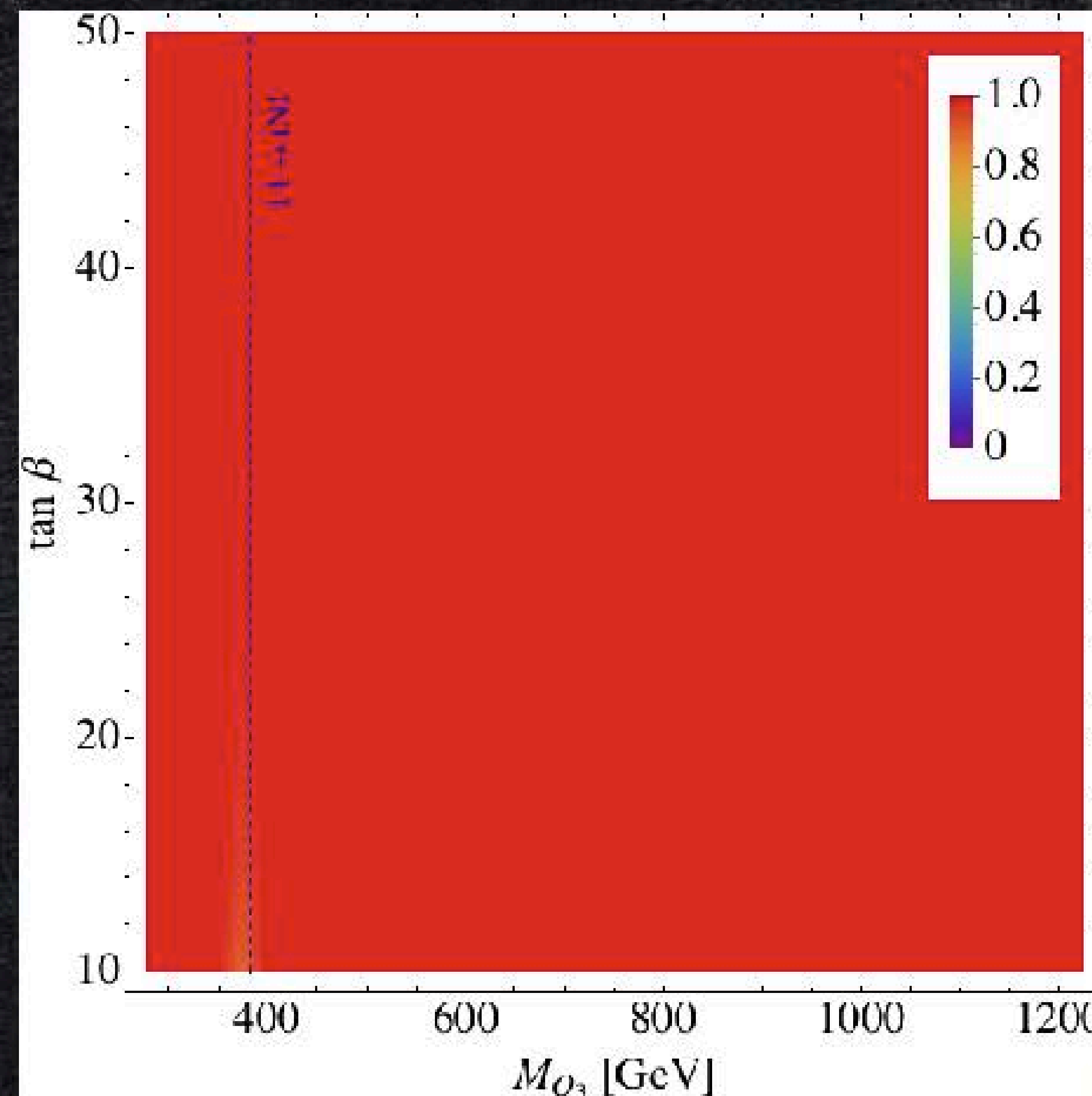
$$\mathcal{L} \supset y_t \cdot t_R \widetilde{Q}_3 \widetilde{H}_u + y_b \cdot b_R \widetilde{Q}_3 \widetilde{H}_d$$

tanβ enhancement

$$\begin{cases} \mathrm{T1} \to b\,\mathrm{C1}\ (\mathrm{C1} \to \mathrm{N1}) \\ \mathrm{B1} \to b\,\mathrm{N1} \end{cases}$$

$\mu = 200\text{GeV}$





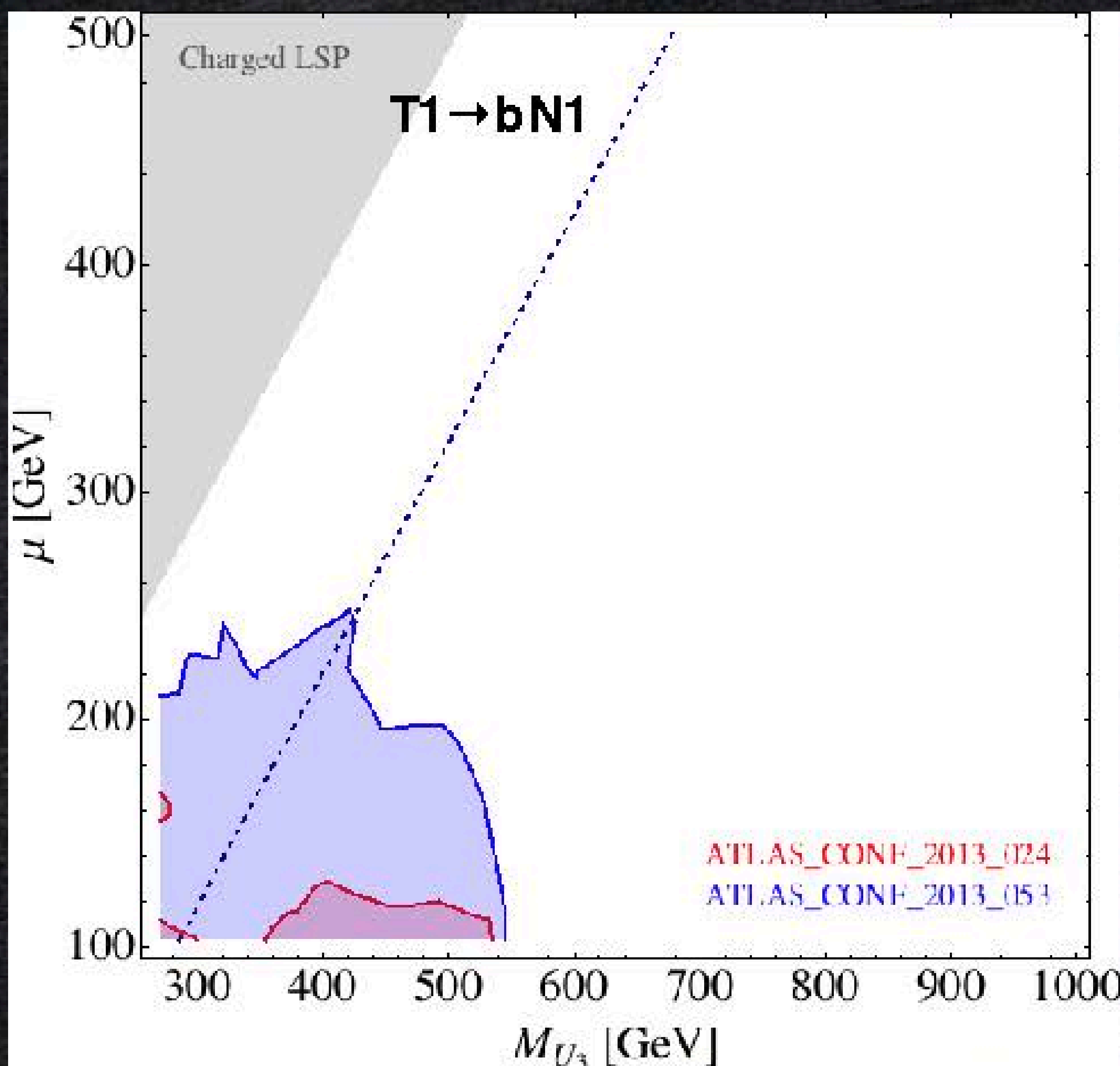
M_{U3} vs μ

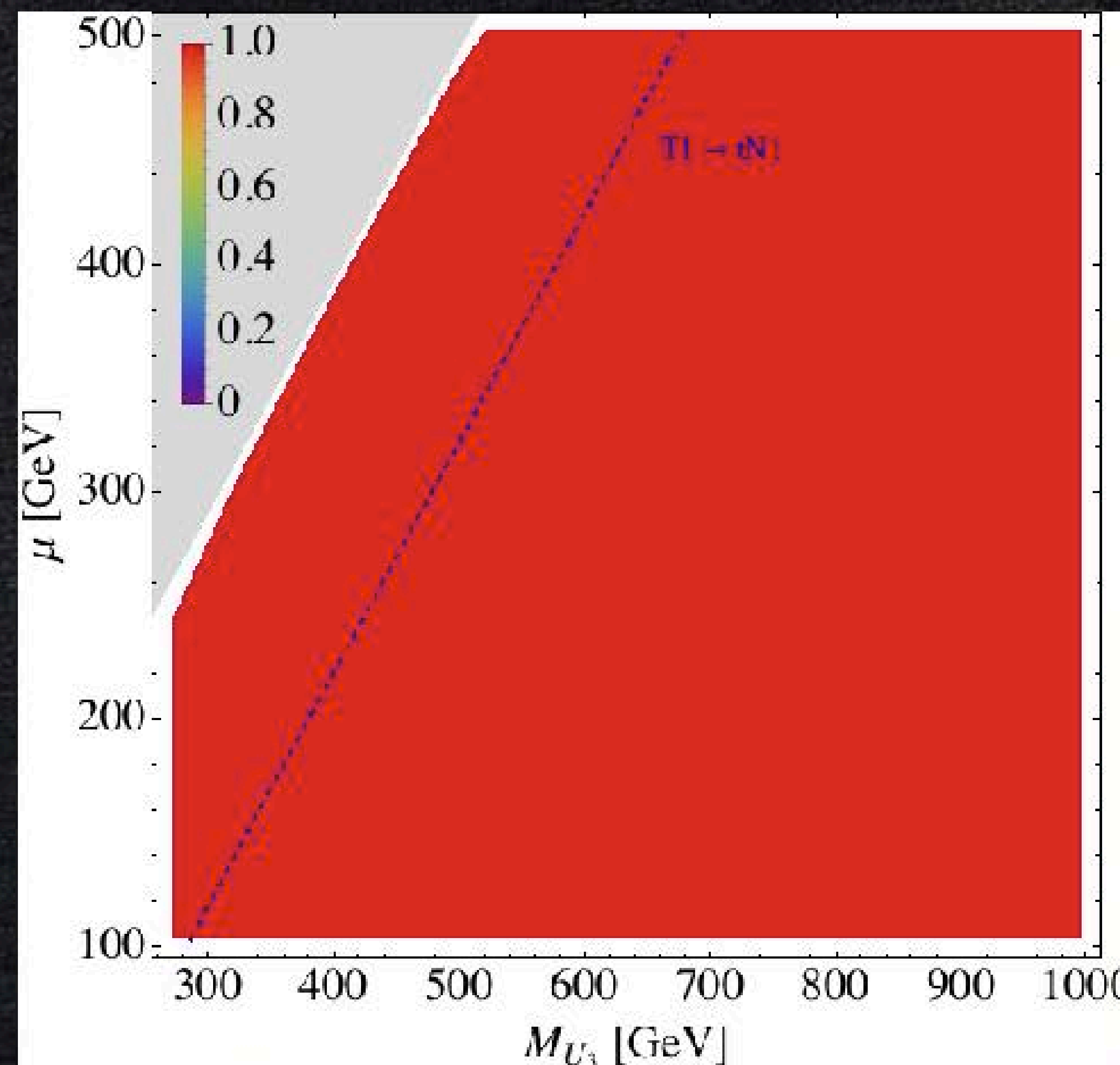
$$\mathcal{L} \supset y_t \cdot \widetilde{t}_R Q_3 \widetilde{H}_u$$

$\mathrm{BR(T1bN1\_T1tN1)} > \mathrm{BR(T1bN1\_T1bN1)} > \mathrm{BR(T1tN1\_T1tN1)}$

asymmetric topology

$\tan\beta = 10$





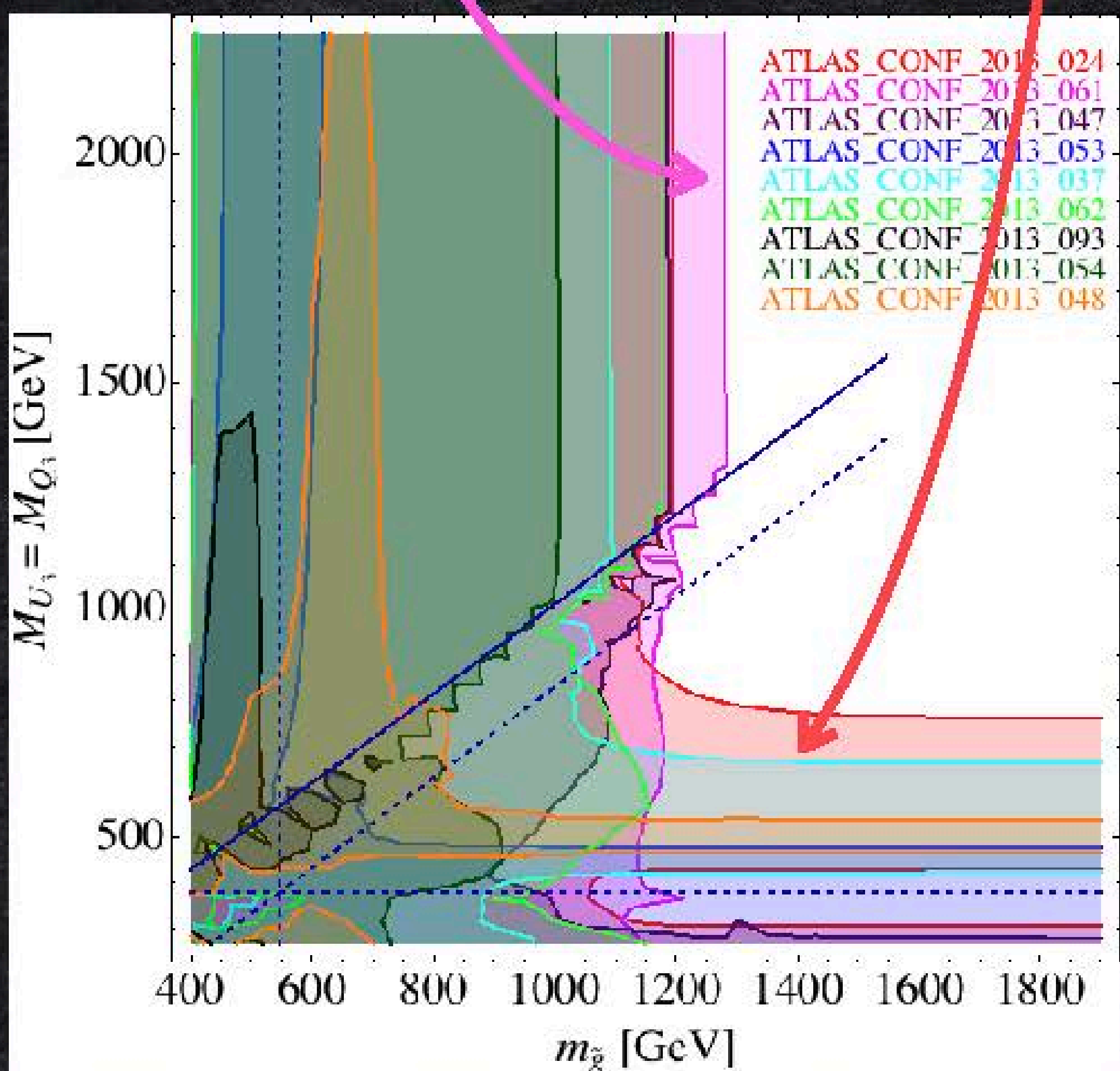
M_G vs M_{Q3}

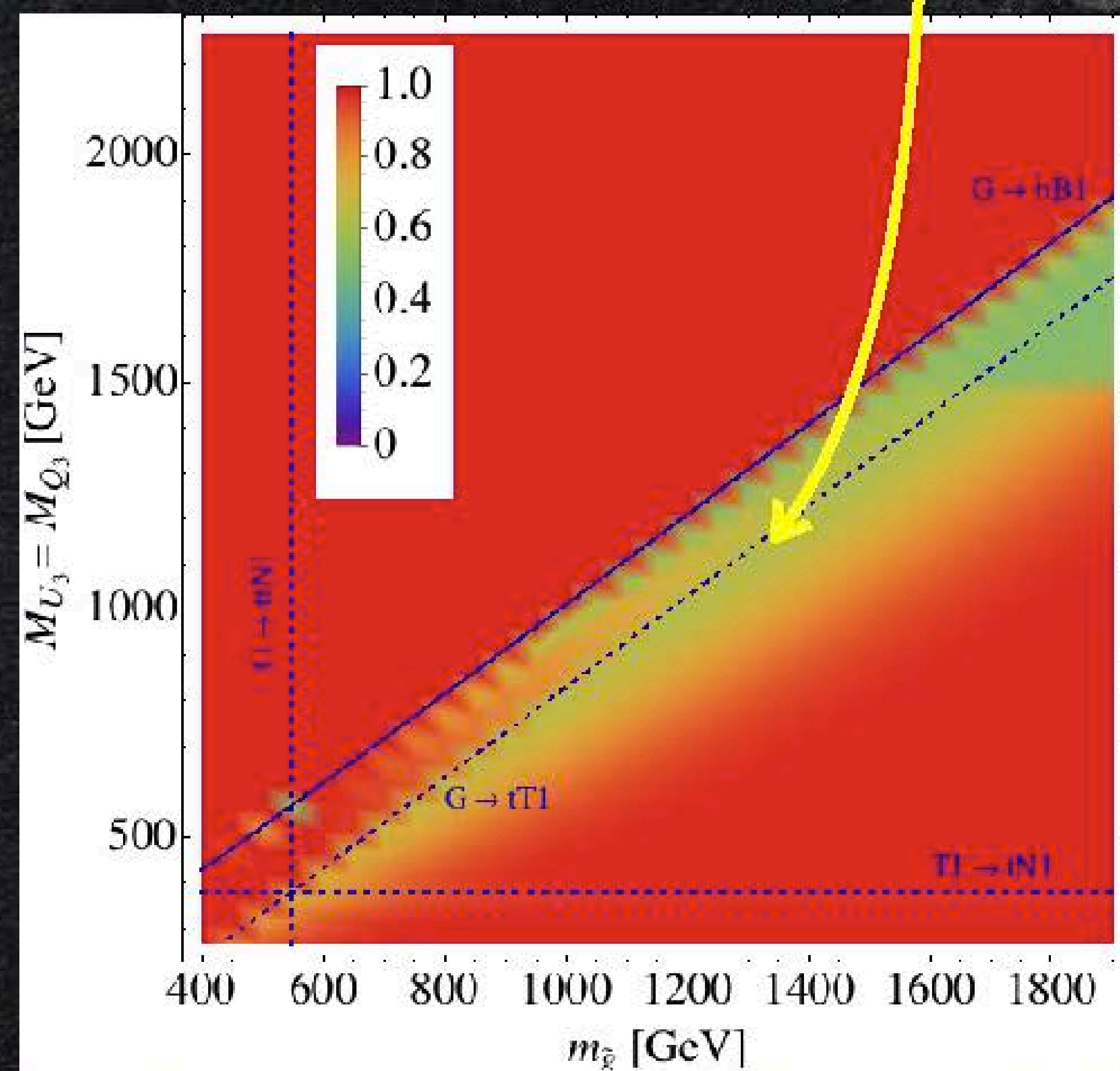
designed for G→ffN1

for T1→tN1

T1→qqB1 via W* &
GtT1tN1_GbB1bN1 (4D)

$\mu = 200\text{GeV}$



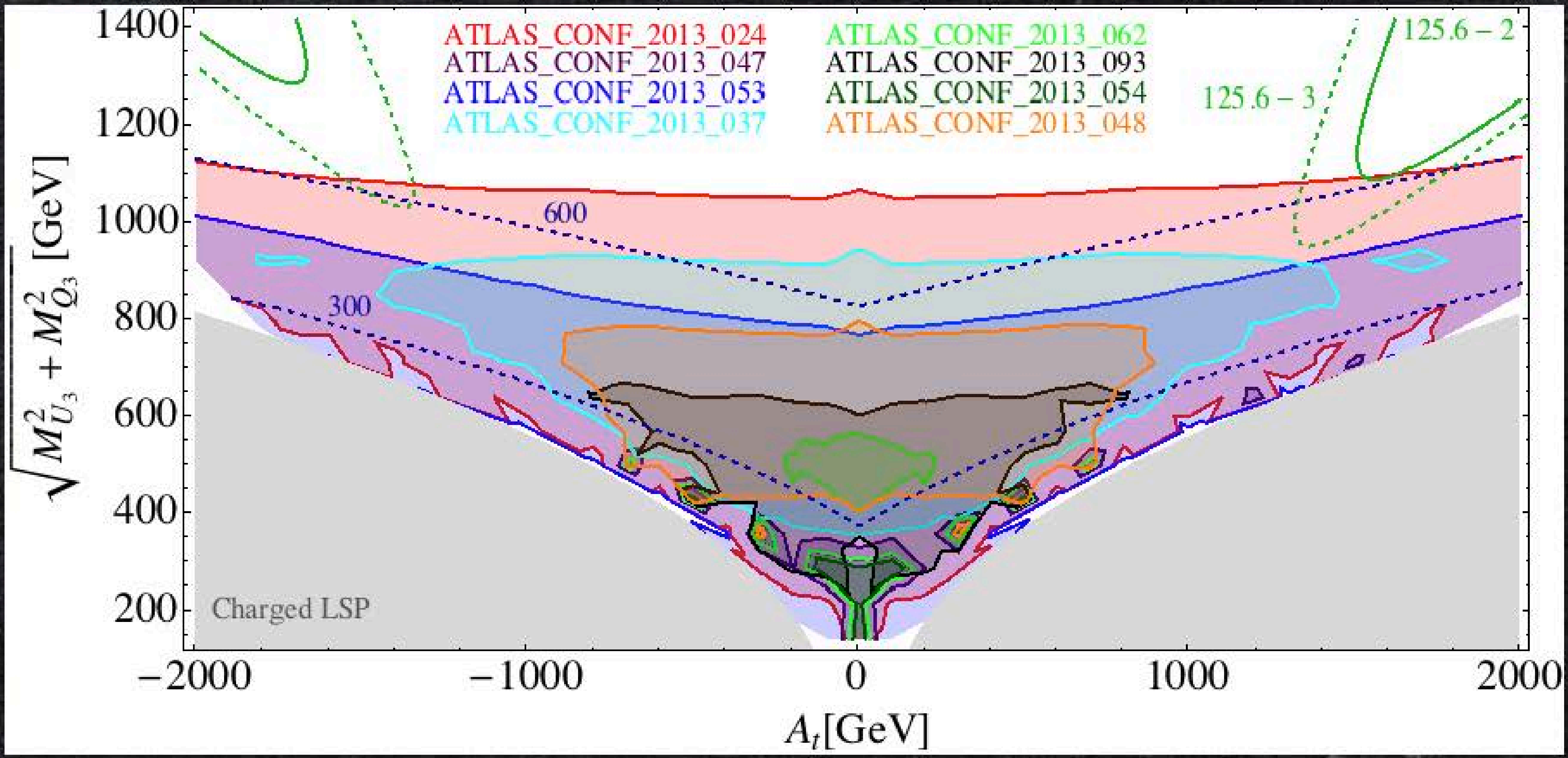


A_t vs $M_{Q,U3}$

- distance from the origin is sensitive to the fine-tuning

$$\Delta m_{H_u}^2 \simeq -\frac{3y_t^2}{8\pi^2}(M_{U_3}^2 + M_{Q_3}^2 + A_t^2)\ln\left(\frac{\Lambda}{m_{\tilde{t}}}\right)$$

$\mu = 100\text{GeV},\ M_{Q_3} = M_{U_3}$



Application

for experimentalists: - for various quick checks:

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excess in data: - can study which new physics models can fit the observed excess

Small but interesting excesses in data

Study	SR	Obs	Exp	SM s.d.
ATLAS W^+W^- (7 TeV) [5]	Combined	1325	1219 ± 87	1.1-σ
CMS W^+W^- (7 TeV) [7]	Combined	1134	1076 ± 62	0.8-σ
CMS W^+W^- (8 TeV) [6]	Combined	1111	986 ± 60	1.8-σ
ATLAS Higgs [27]	WW CR	3297	3110 ± 186	0.9-σ
	Higgs SR	3615	3288 ± 220	1.4-σ
ATLAS $\tilde{q}$ and $\tilde{g}$ (1-2 ℓ) [23]	Di-muon	7	1.7 ± 1	2.5-σ
ATLAS Electroweak (3 ℓ) [24]	SR0τa01	36	23 ± 4	2.1-σ
	SR0τa06	13	6.6 ± 1.9	1.9-σ
	SR0τa10	24	16.4 ± 2.4	1.6-σ

2 lepton mode (ATLAS/CMS W^+W^-, ATLAS Higgs, ATLAS $\tilde{q}$ and $\tilde{g}$)

3 lepton mode (ATLAS Electroweak)

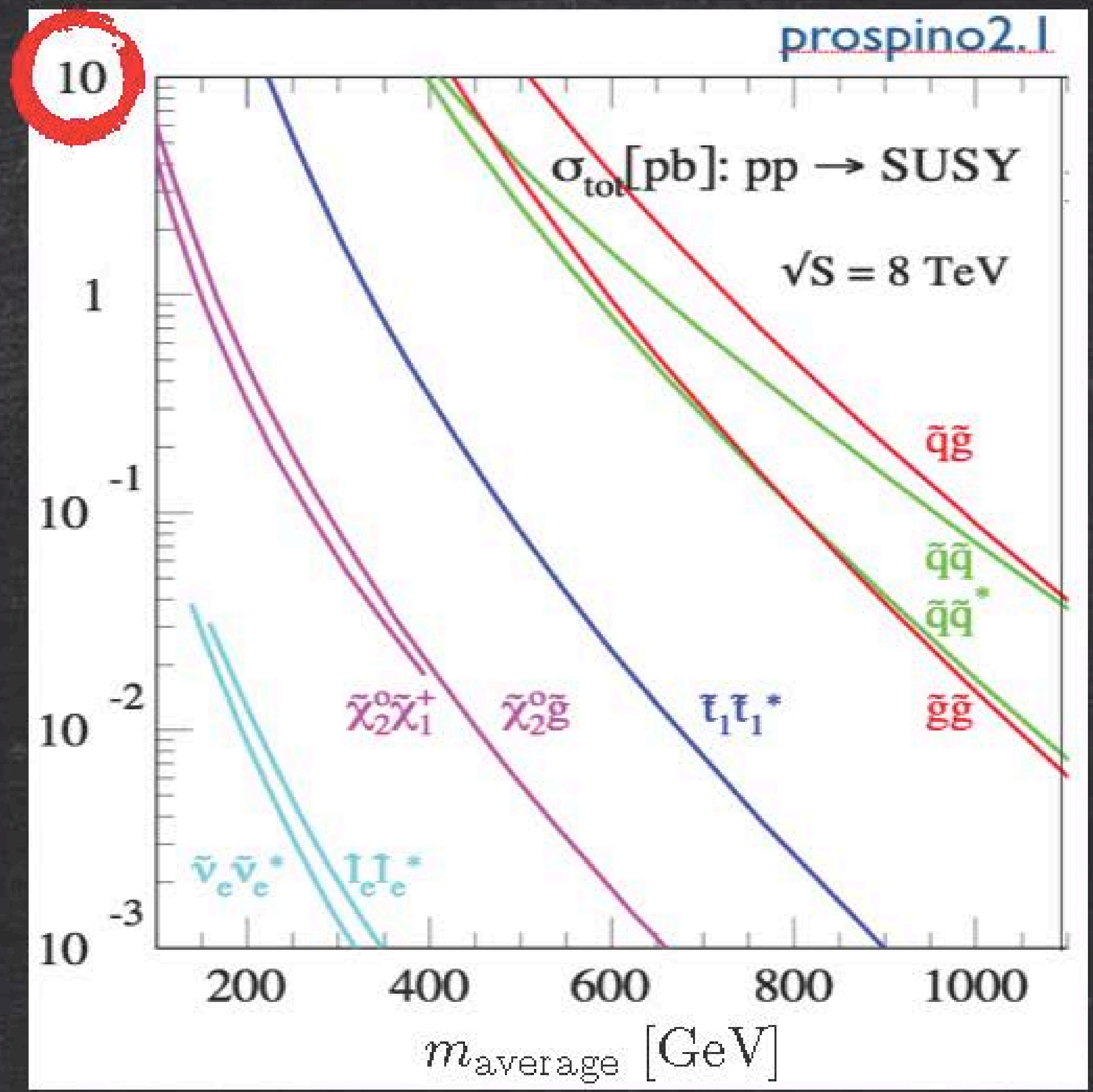
Can we explain these excesses by BSM?

[CMS-12-005: *WW* 8TeV]

SM prediction: $\sigma = 57.3 \pm 2$ pb

CMS observed: $\sigma = 69.9 \pm 2.8\,(\text{stat}) \pm 5.6\,(\text{syst}) \pm 3.1\,(\text{lumi})$ pb

➡ needs extra 10 pb



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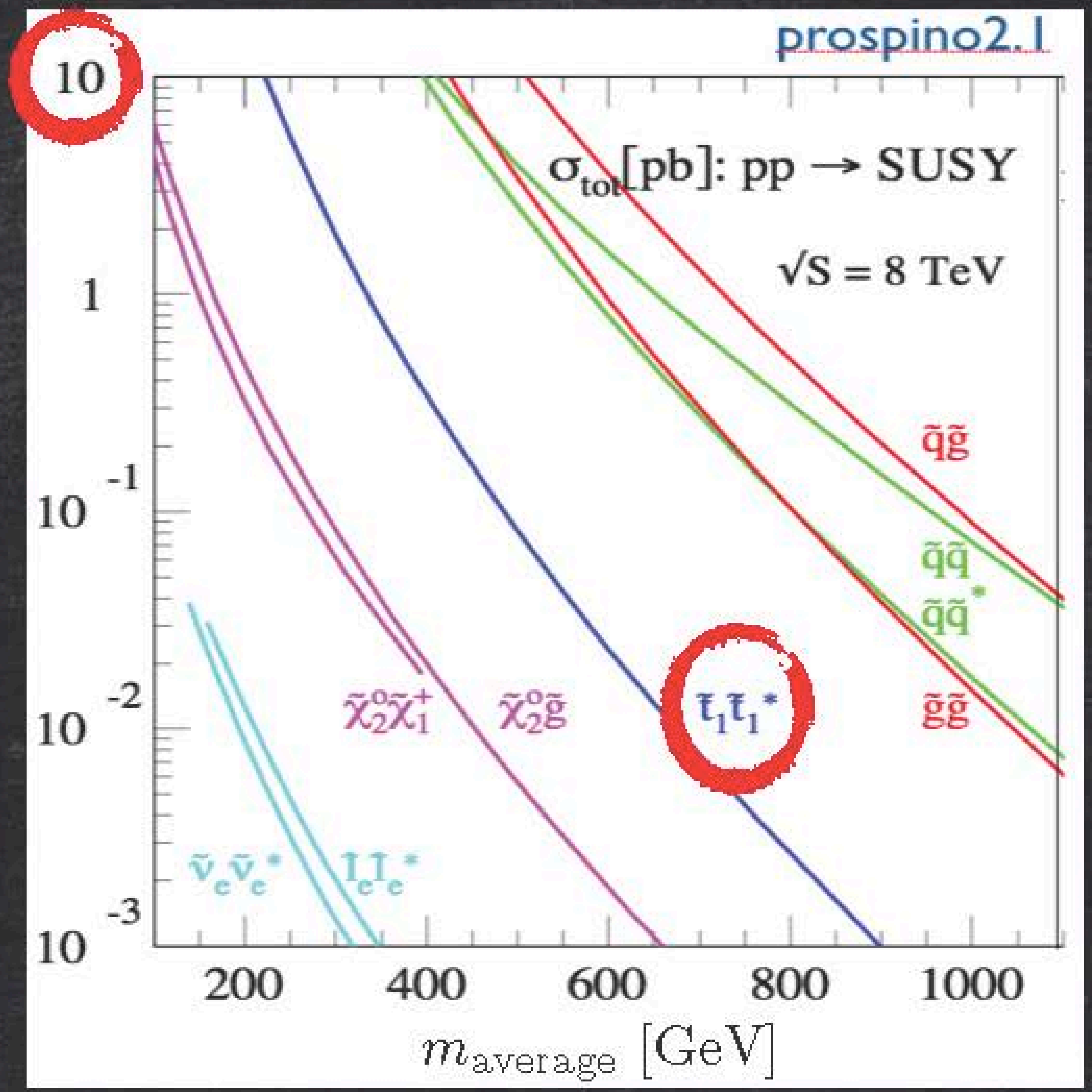
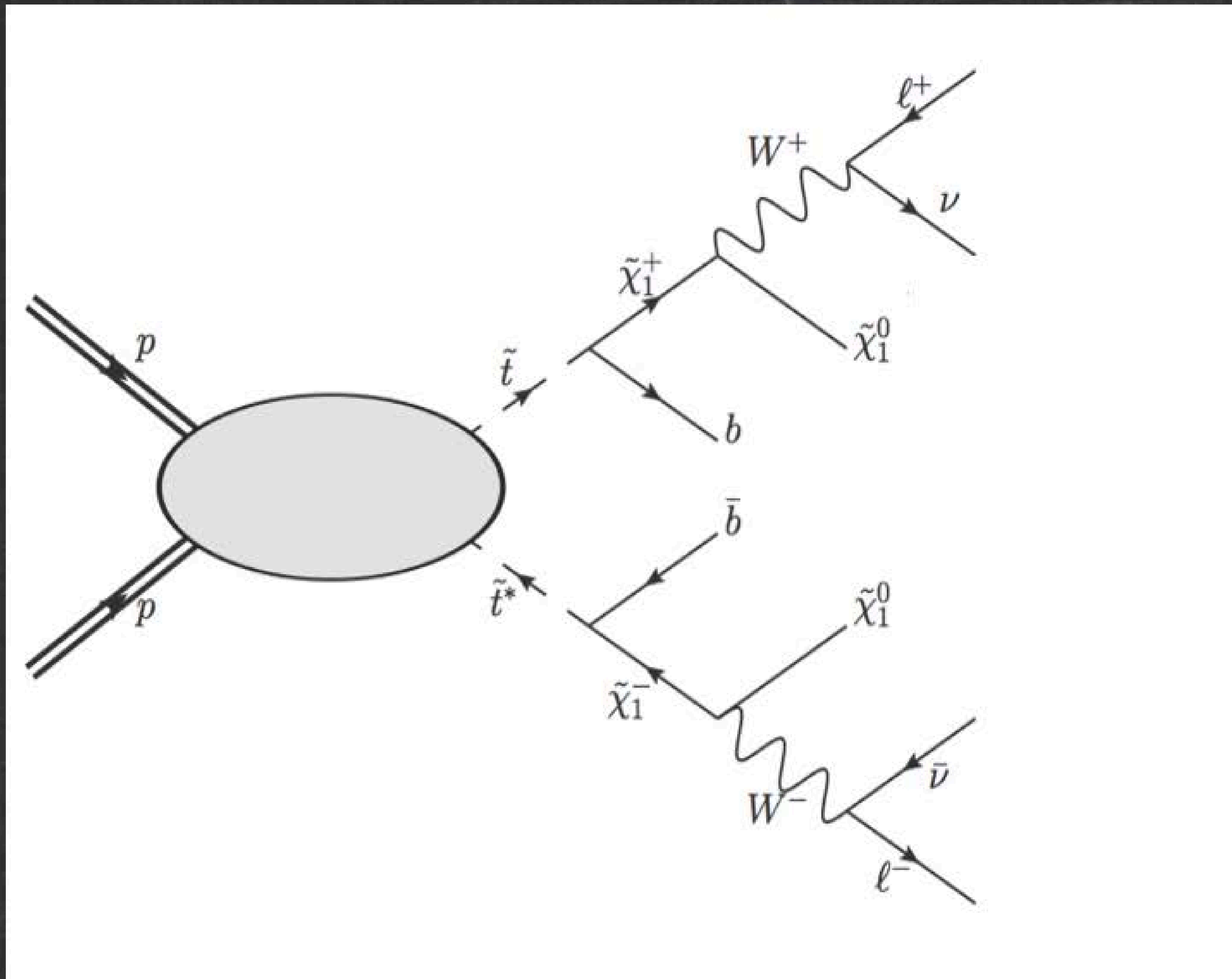
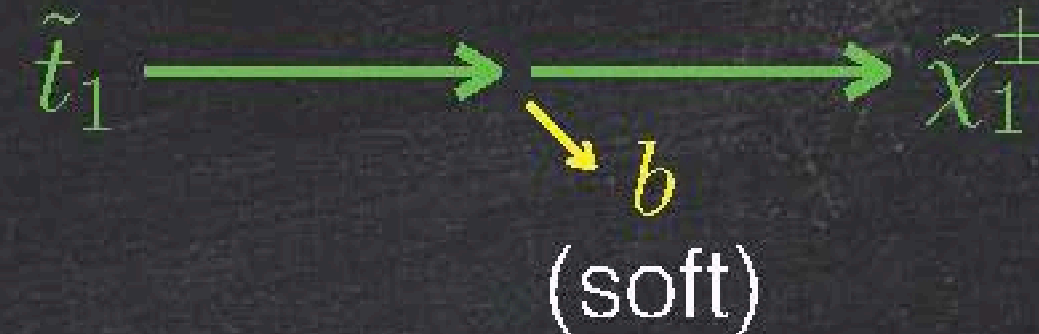


T1-C1(N2)-N1 model

- 2 lepton channel

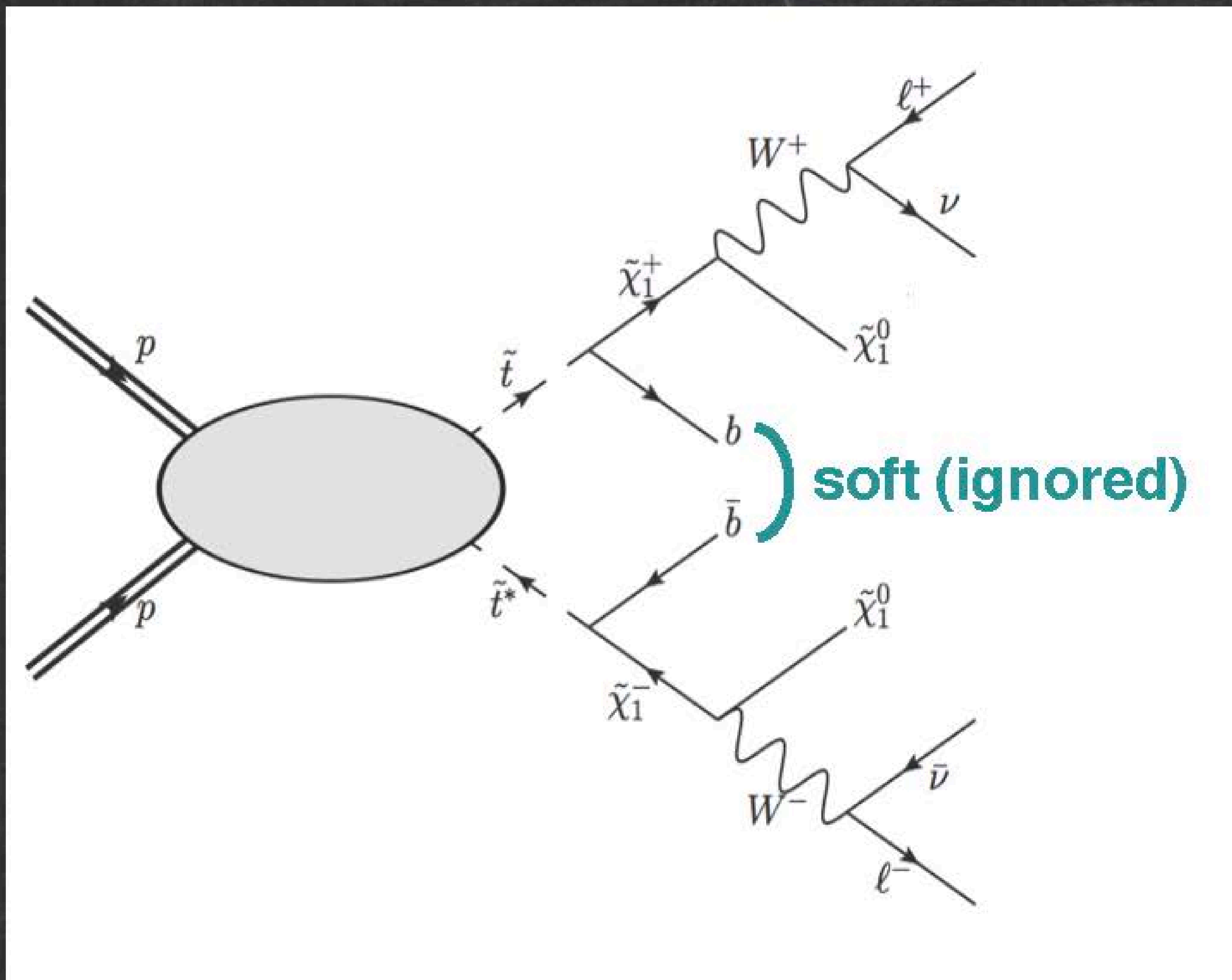


$$m_{\tilde{t}_1} - m_{\tilde{\chi}_1^\pm} = 7\,\mathrm{GeV}$$

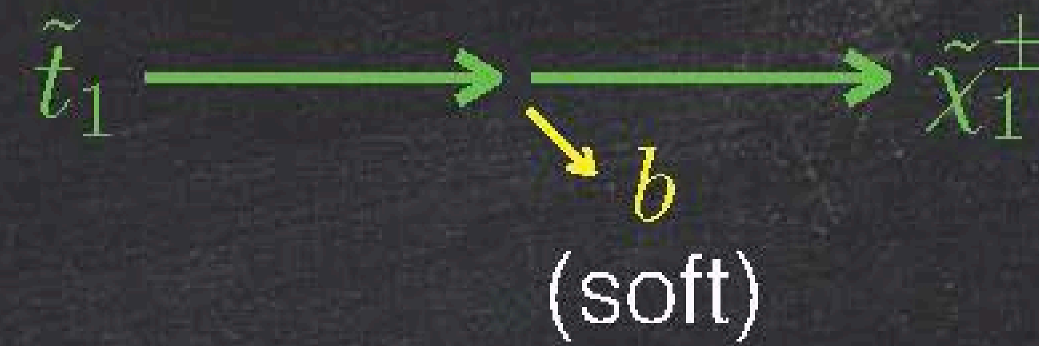


T1-C1(N2)-N1 model

- 2 lepton channel

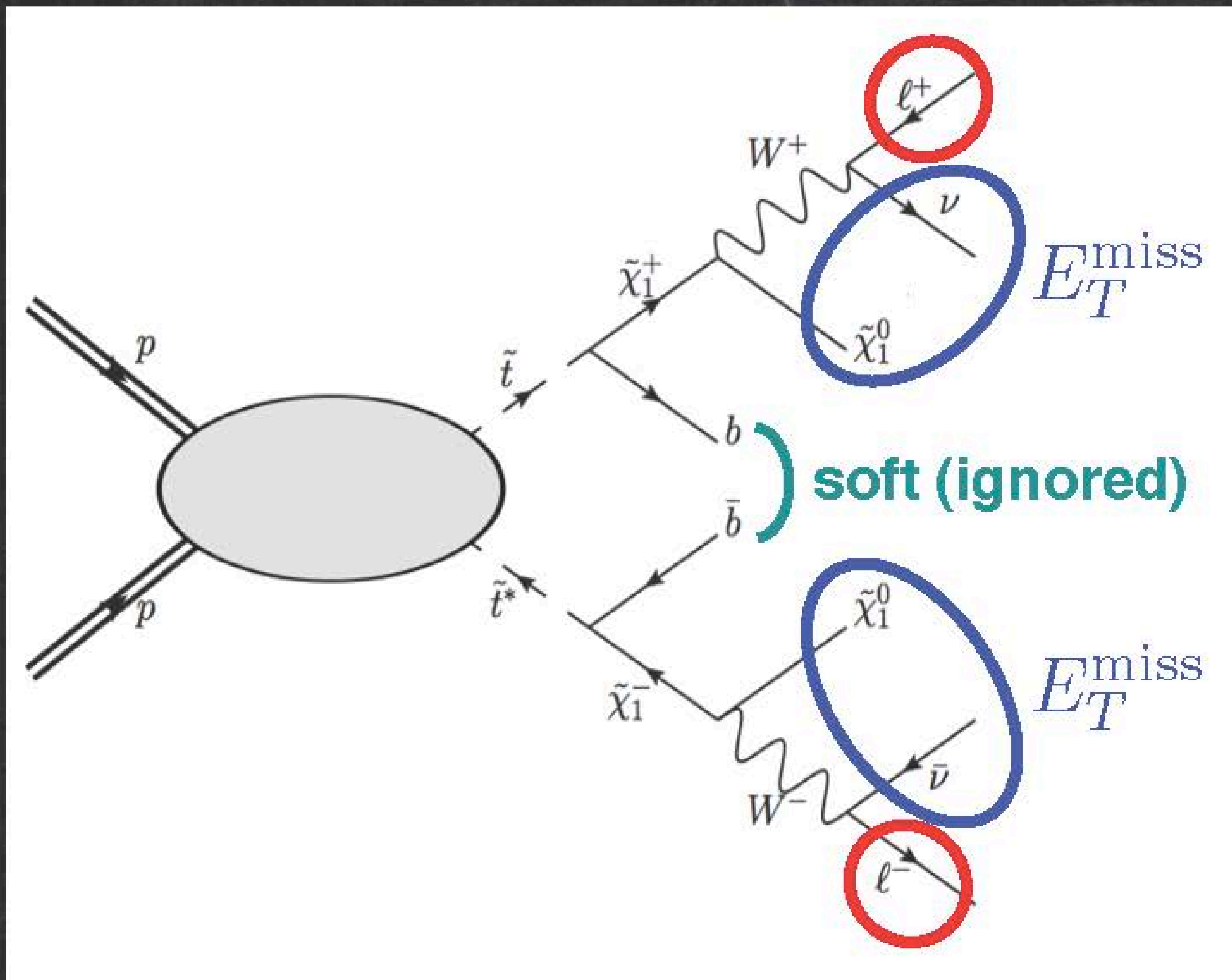


$$m_{\tilde{t}_1} - m_{\tilde{\chi}_1^\pm} = 7\,\mathrm{GeV}$$

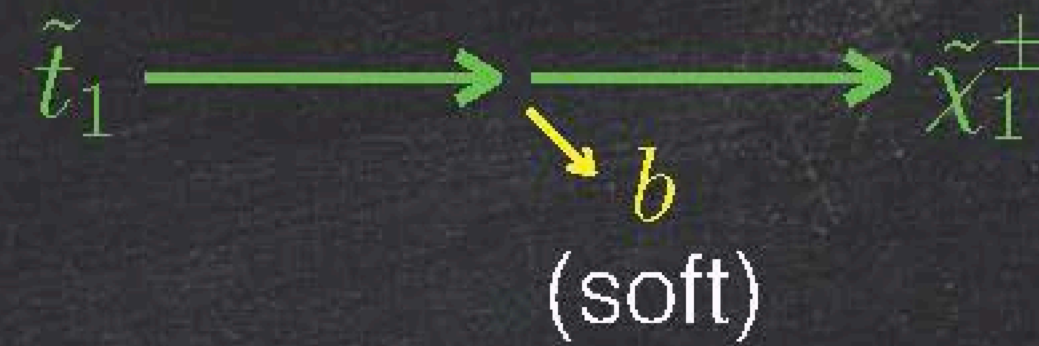


T1-C1(N2)-N1 model

- 2 lepton channel

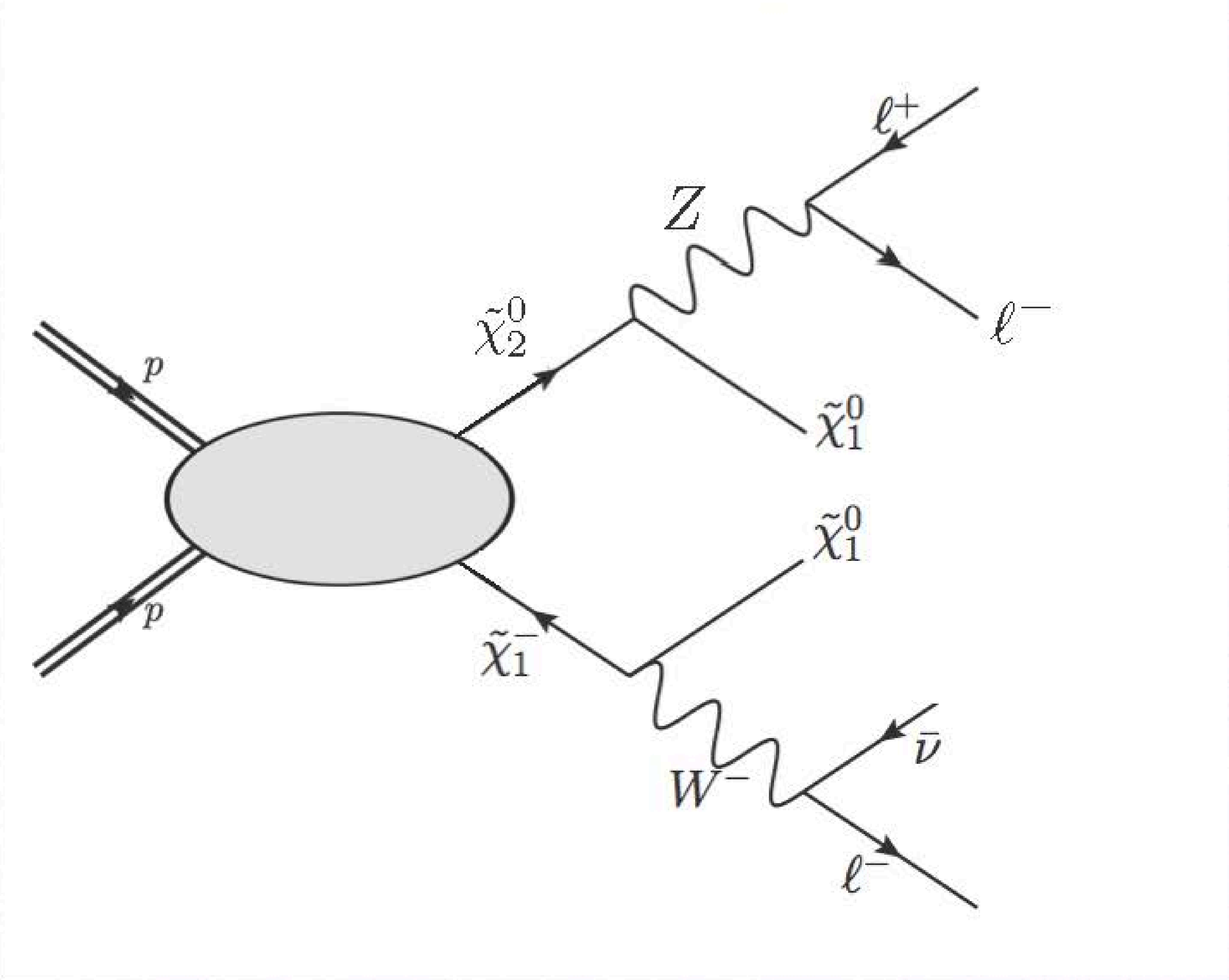


$$m_{\tilde{t}_1} - m_{\tilde{\chi}_1^\pm} = 7\,\mathrm{GeV}$$



T1-C1(N2)-N1 model

- 3 lepton channel

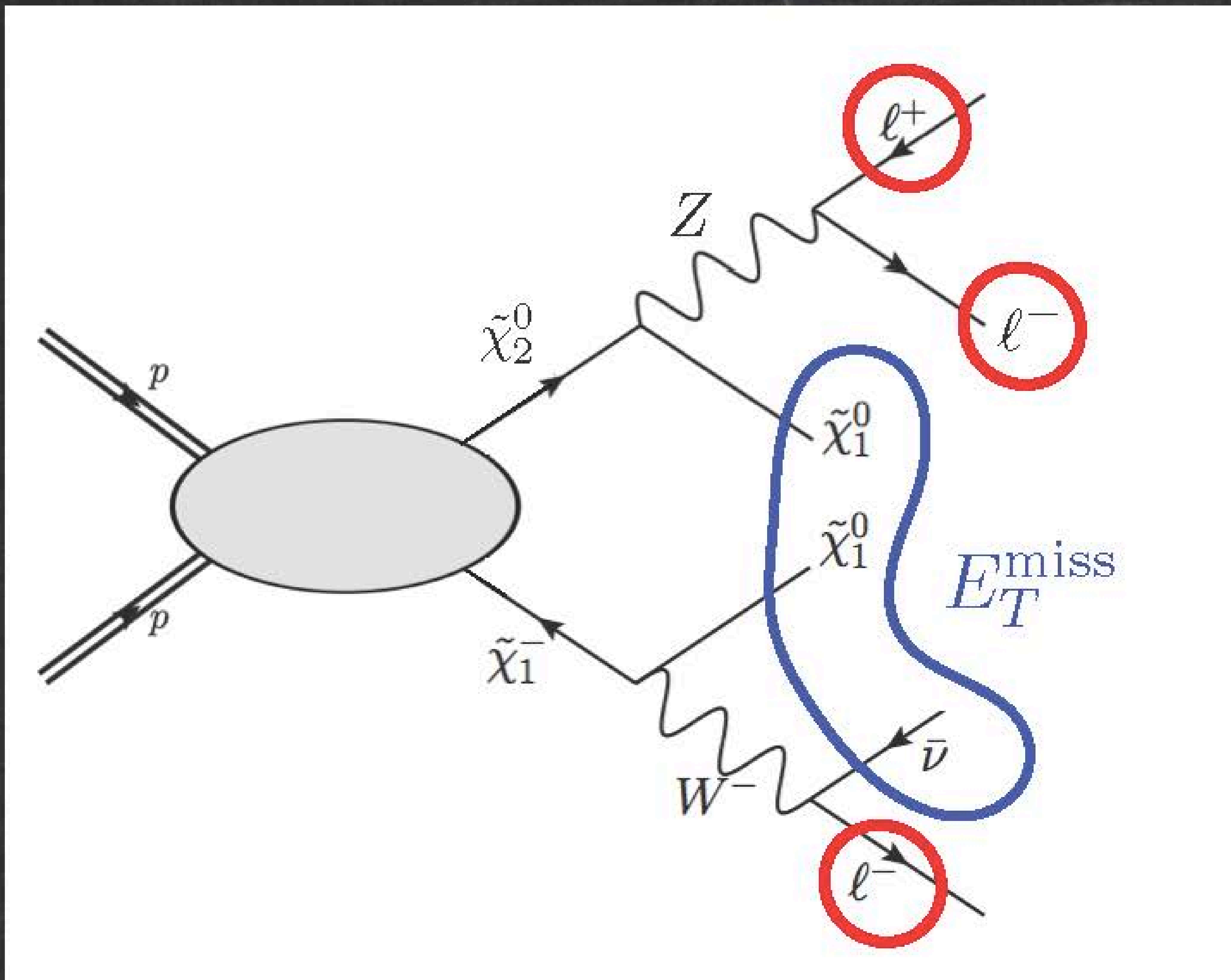


$$m_{\tilde{t}_1} - m_{\tilde{\chi}_1^\pm} = 7\,\mathrm{GeV}$$

$$m_{\tilde{\chi}_2^0} \simeq m_{\tilde{\chi}_1^\pm}$$

T1-C1(N2)-N1 model

- 3 lepton channel



$$m_{\tilde{t}_1} - m_{\tilde{\chi}_1^\pm} = 7\,\mathrm{GeV}$$

$$m_{\tilde{\chi}_2^0} \simeq m_{\tilde{\chi}_1^\pm}$$

Analyses

- excess in data

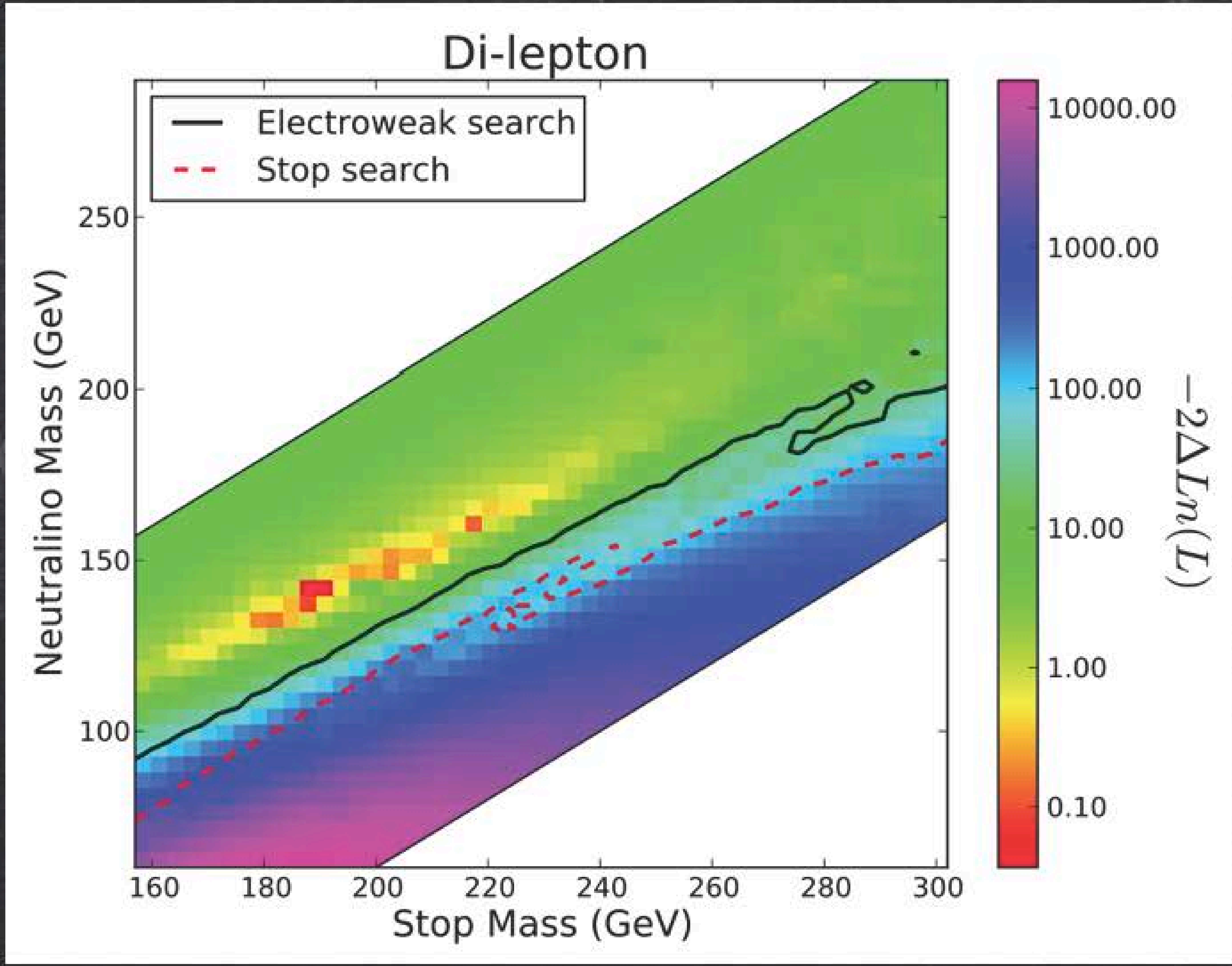
Description	$\sqrt{s}$ [TeV]	Luminosity [fb^{-1}]	Number of SR
ATLAS W^+W^-	7	4.6	1
CMS W^+W^-	7	4.9	1
CMS W^+W^-	8	3.5	1
ATLAS Higgs	8	20.7	2
ATLAS Electroweak (2 ℓ)	8	20.3	13
ATLAS $\tilde{q}$ and $\tilde{g}$ (1-2 ℓ)	8	20.1	19
ATLAS $\tilde{q}$ and $\tilde{g}$ razor (2 ℓ)	8	20.3	6
ATLAS Electroweak (3 ℓ)	8	20.3	20
ATLAS $\tilde{t}$ (1 ℓ)	8	20.7	8
ATLAS $\tilde{t}$ (2 ℓ)	8	20.3	12
CMS $W^\pm Z^0$	8	19.6	4
ATLAS $W^\pm Z^0$	8	13.0	4

$$\ln L(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) = \sum_a^{\{\text{SRs}\}} \ln P(N_{\text{Data}}^{(a)} | N_{\text{SM}}^{(a)} + N_{\text{BSM}}^{(a)}(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}))$$

$$P(n|\lambda) = \frac{\lambda^n e^{-\lambda}}{n!}$$

Di-lepton fit

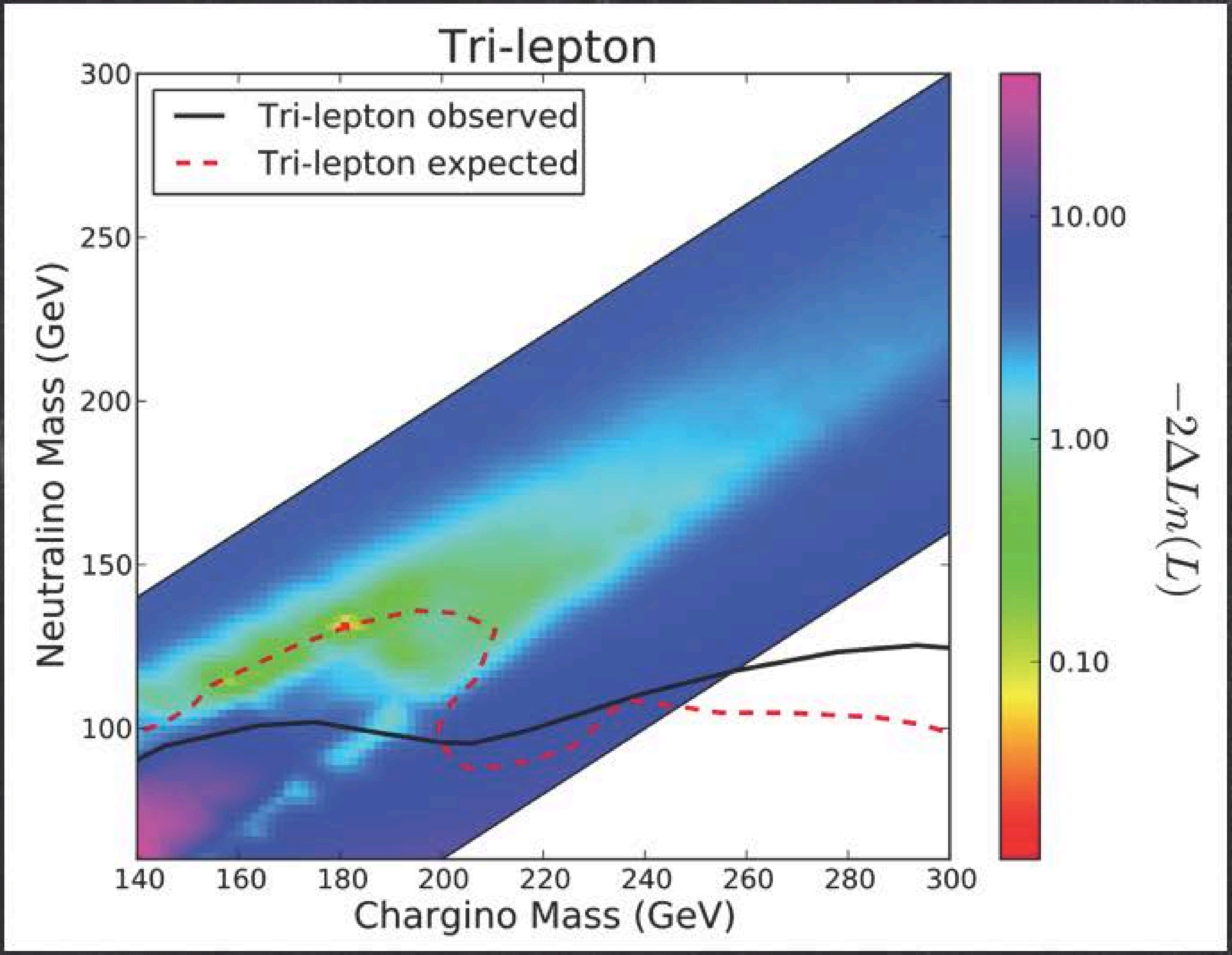
J-S.Kim, K.Rolbiecki, KS, J. Tattersall [1406.0858]



$$2\Delta \ln L(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) = 2\left[\ln L(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) - \ln L_{\min}\right]$$

Tri-lepton fit

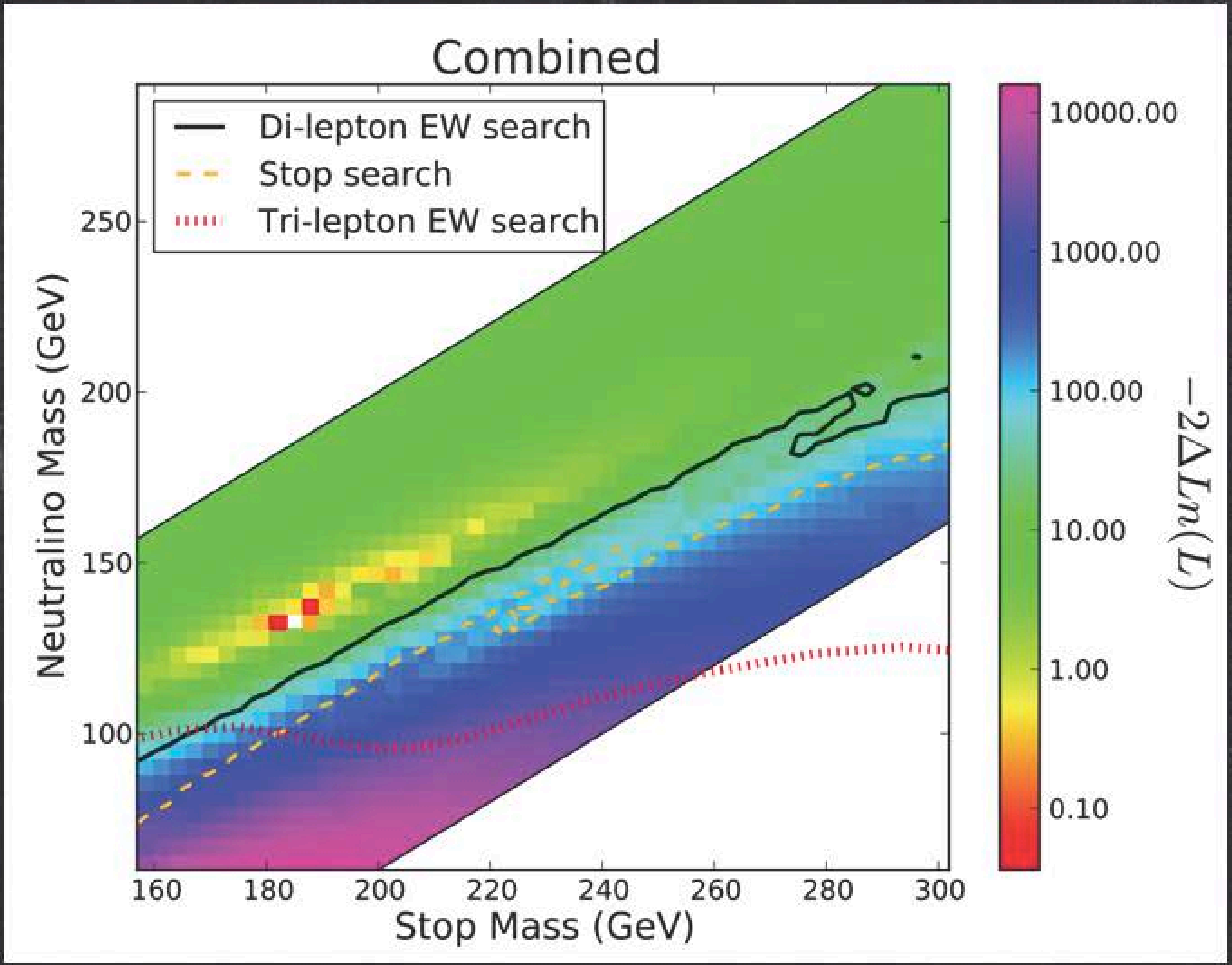
J-S.Kim, K.Rolbiecki, KS, J. Tattersall [1406.0858]



$$2\Delta \ln L(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) = 2\left[\ln L(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) - \ln L_{\min}\right]$$

Combined

J-S.Kim, K.Rolbiecki, KS, J. Tattersall [1406.0858]



$$2\Delta \ln L(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) = 2\left[\ln L(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0}) - \ln L_{\min}\right]$$

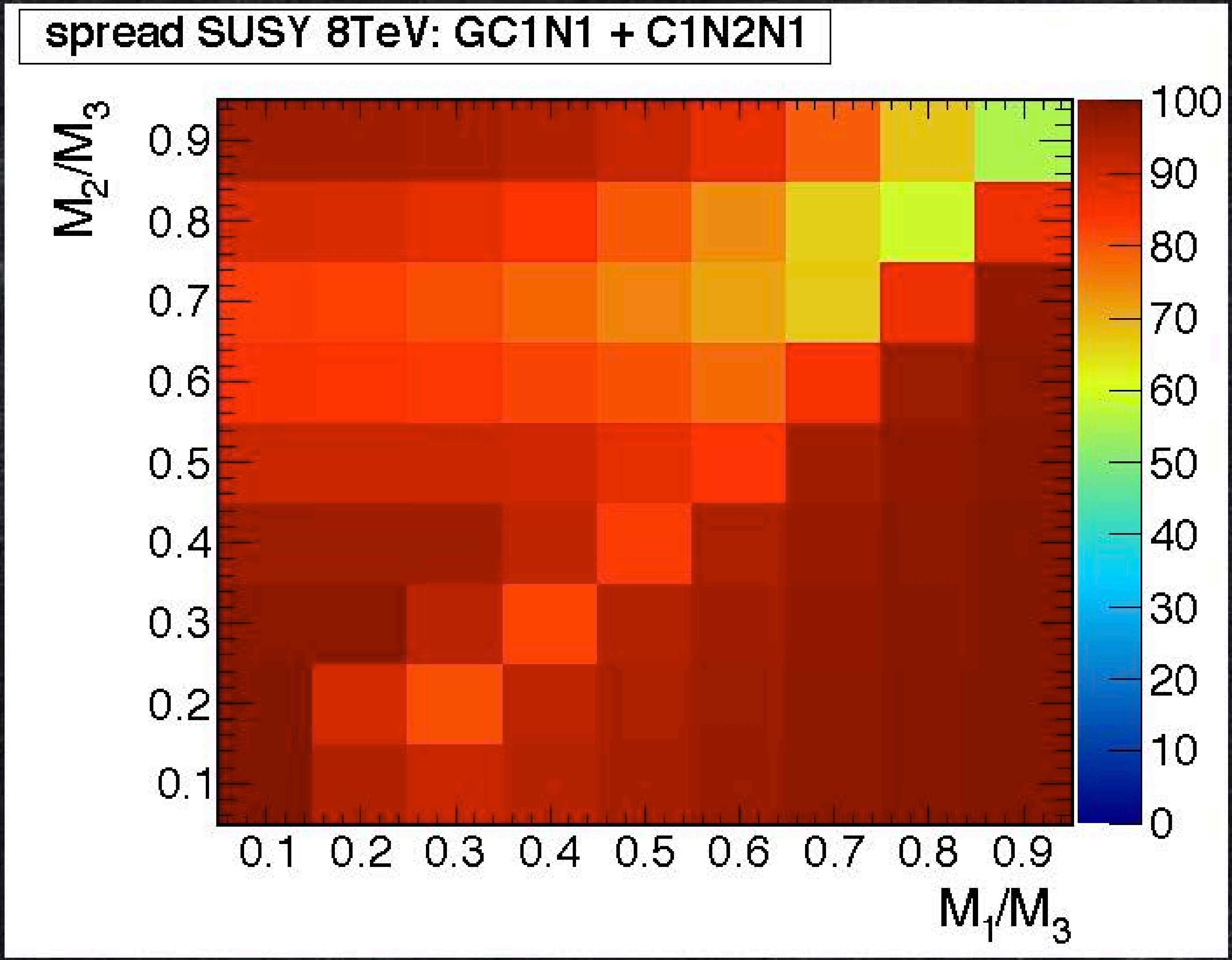
Summary

	input	output	application	limit	speed
ATOM:	event file	efficiency	any	full	normal
Fastlim:	model file	N	SUSY-like	conservative	fast

There are useful tools, let's test your model

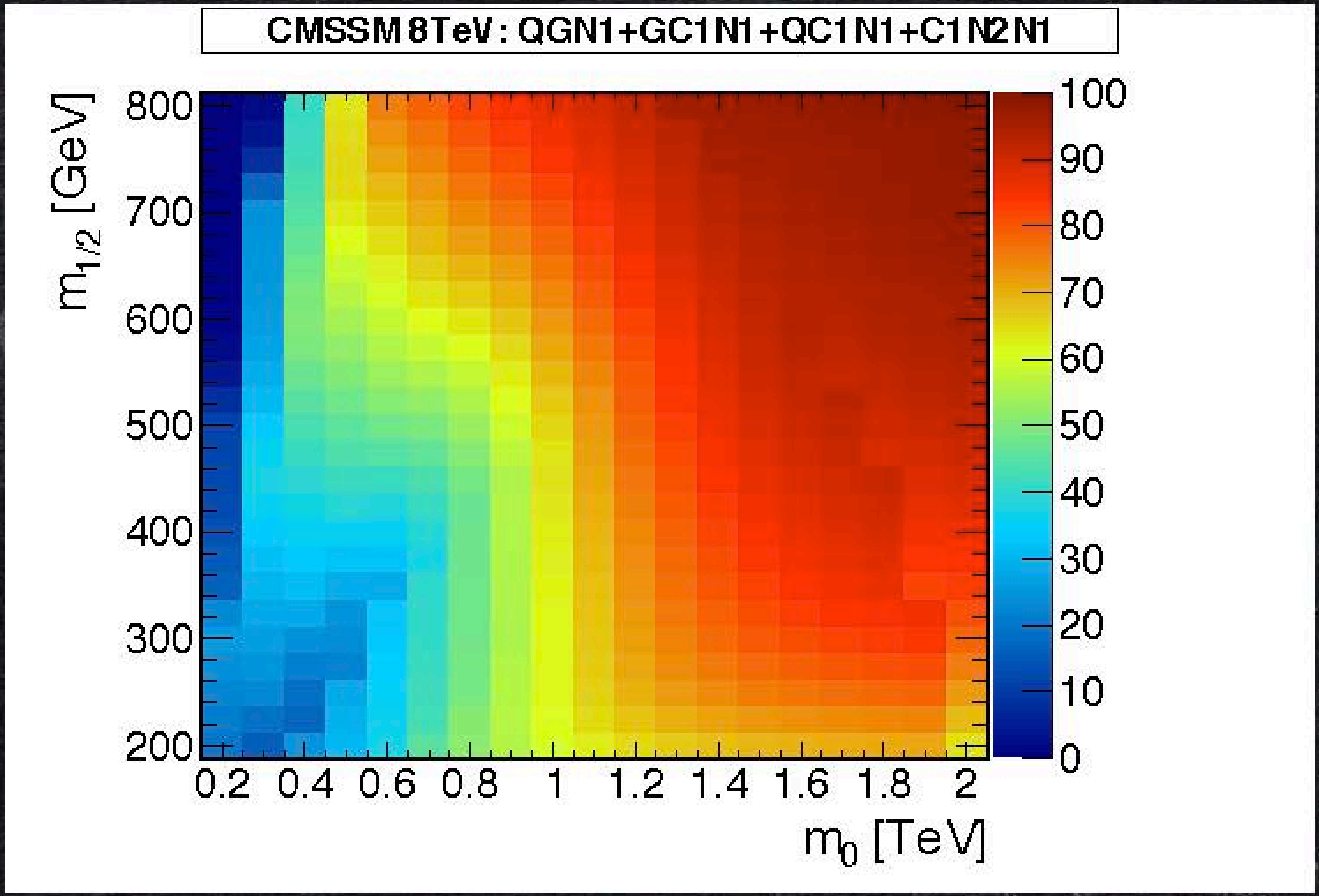
Backup

Split SUSY



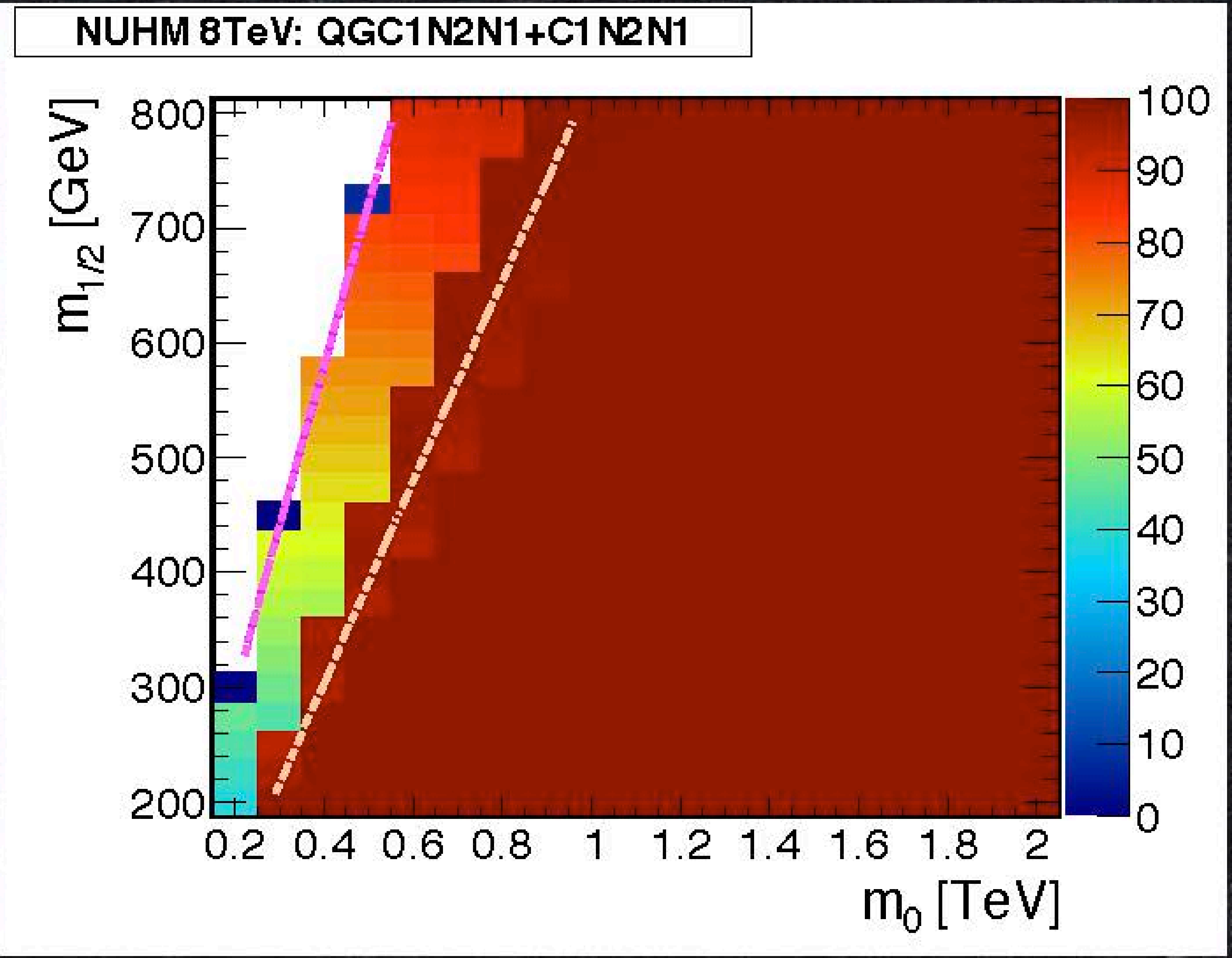
spread SUSY 8TeV: GC1N1 + C1N2N1
M_2/M_3
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
M_1/M_3
100 %
90
80
70
60
50
40
30
20
10
0

CMSSM

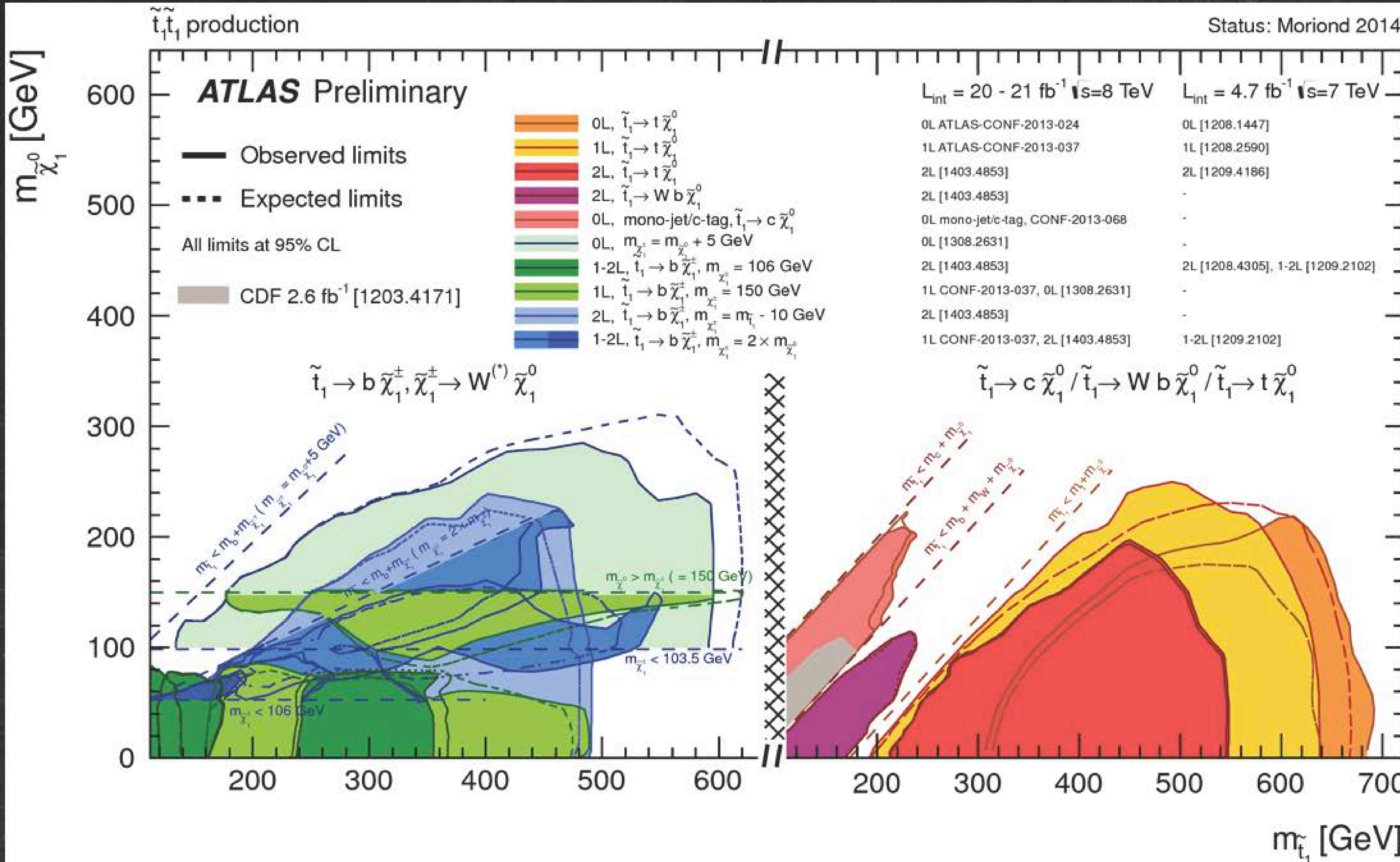


CMSSM 8TeV : QGN1+GC1N1+QC1N1+C1N2N1
m_{1/2} [GeV]
800
700
600
500
400
300
200
0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
m_0 [TeV]
100
90
80
70
60
50
40
30
20
10
0

NUHM



NUHM 8TeV: QGC1N2N1+C1N2N1
m1/2 [GeV]
800
700
600
500
400
300
200
0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
m0 [TeV]
100
90
80
70
60
50
40
30
20
10
0



$\tilde{t}_1\tilde{t}_1$ production
Status: Moriond 2014
ATLAS Preliminary
Observed limits
Expected limits
All limits at 95% CL
CDF 2.6 fb^{-1} [1203.4171]
L_{int} = 20 - 21 fb^{-1} $\sqrt{s}$=8 TeV
L_{int} = 4.7 fb^{-1} $\sqrt{s}$=7 TeV
0L, $\tilde{t}_1 \to t\,\tilde{\chi}_1^0$ — 0L ATLAS-CONF-2013-024 — 0L [1208.1447]
1L, $\tilde{t}_1 \to t\,\tilde{\chi}_1^0$ — 1L ATLAS-CONF-2013-037 — 1L [1208.2590]
2L, $\tilde{t}_1 \to t\,\tilde{\chi}_1^0$ — 2L [1403.4853] — 2L [1209.4186]
2L, $\tilde{t}_1 \to W\,b\,\tilde{\chi}_1^0$ — 2L [1403.4853] — -
0L, mono-jet/c-tag, $\tilde{t}_1 \to c\,\tilde{\chi}_1^0$ — 0L mono-jet/c-tag, CONF-2013-068 — -
0L, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0}$ + 5 GeV — 0L [1308.2631] — -
1-2L, $\tilde{t}_1 \to b\,\tilde{\chi}_1^\pm$, $m_{\tilde{\chi}_1^\pm}$ = 106 GeV — 2L [1403.4853] — 2L [1208.4305], 1-2L [1209.2102]
1L, $\tilde{t}_1 \to b\,\tilde{\chi}_1^\pm$, $m_{\tilde{\chi}_1^\pm}$ = 150 GeV — 1L CONF-2013-037, 0L [1308.2631] — -
2L, $\tilde{t}_1 \to b\,\tilde{\chi}_1^\pm$, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{t}_1}$ - 10 GeV — 2L [1403.4853] — -
1-2L, $\tilde{t}_1 \to b\,\tilde{\chi}_1^\pm$, $m_{\tilde{\chi}_1^\pm} = 2 \times m_{\tilde{\chi}_1^0}$ — 1L CONF-2013-037, 2L [1403.4853] — 1-2L [1209.2102]
$\tilde{t}_1 \to b\,\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \to W^{(*)}\,\tilde{\chi}_1^0$
$\tilde{t}_1 \to c\,\tilde{\chi}_1^0\,/\,\tilde{t}_1 \to W\,b\,\tilde{\chi}_1^0\,/\,\tilde{t}_1 \to t\,\tilde{\chi}_1^0$
$m_{\tilde{\chi}_1^0} > m_{\tilde{\chi}_1^\pm}$ (= 150 GeV)
$m_{\tilde{\chi}_1^\pm}$ < 103.5 GeV
$m_{\tilde{\chi}_1^\pm}$ < 106 GeV
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{t}_1}$ [GeV]

SModelS

Sabine Kraml, *et.al*, 2013

- SModelS is a tool to automatically check the simplified model constraints on a given BSM model.