ATOM/Fastlim

Recasting LHC constraints on new physics models

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In collaboration with:

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SUSY 2014 @ Manchester, 21/7/2014

Introduction

- ATLAS and CMS have performed many BSM searches.

— Constraints —

- CMSSM
- GMSB
- a simplified model
- a simplified model
- …

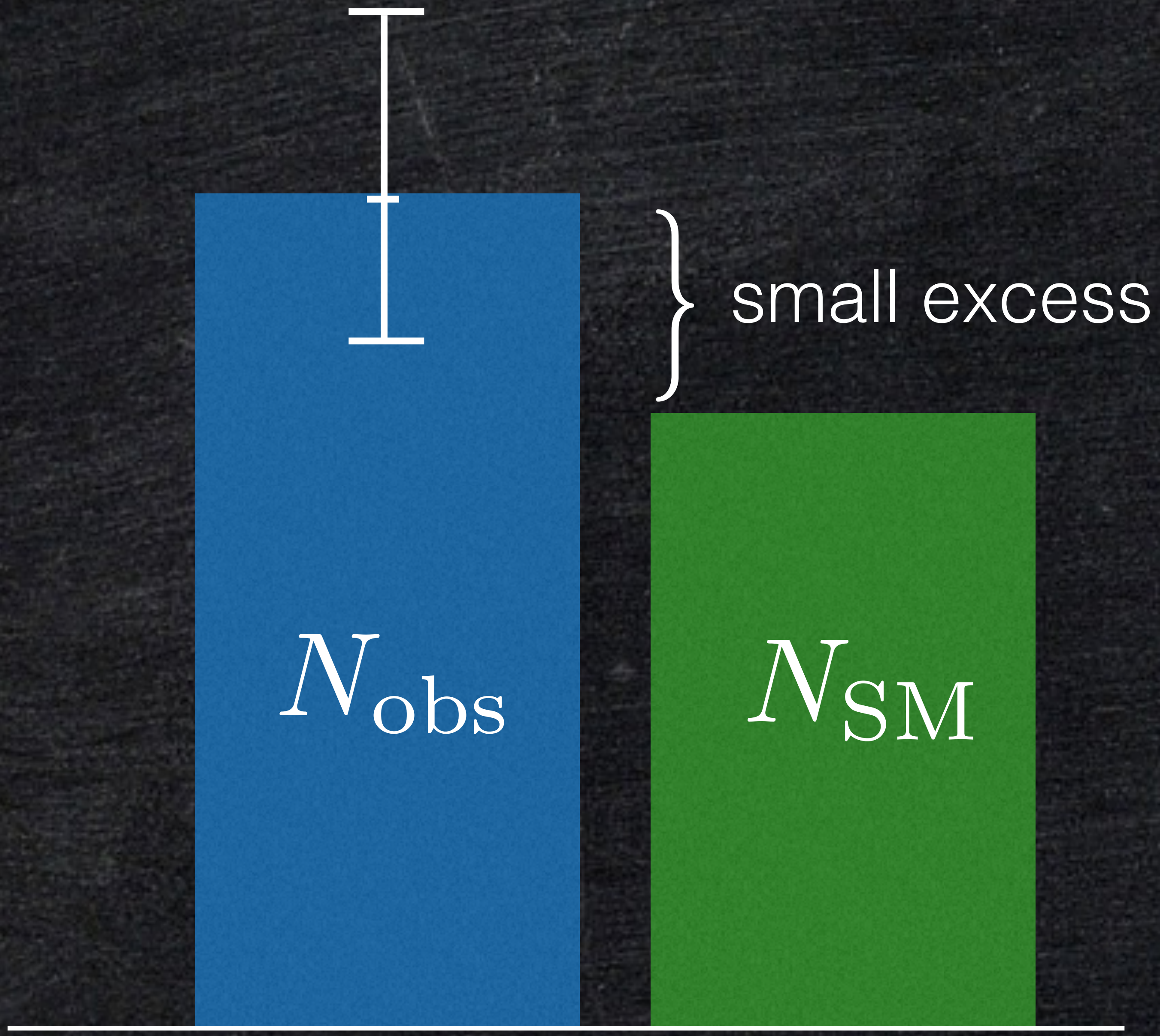
— Excesses (small) —

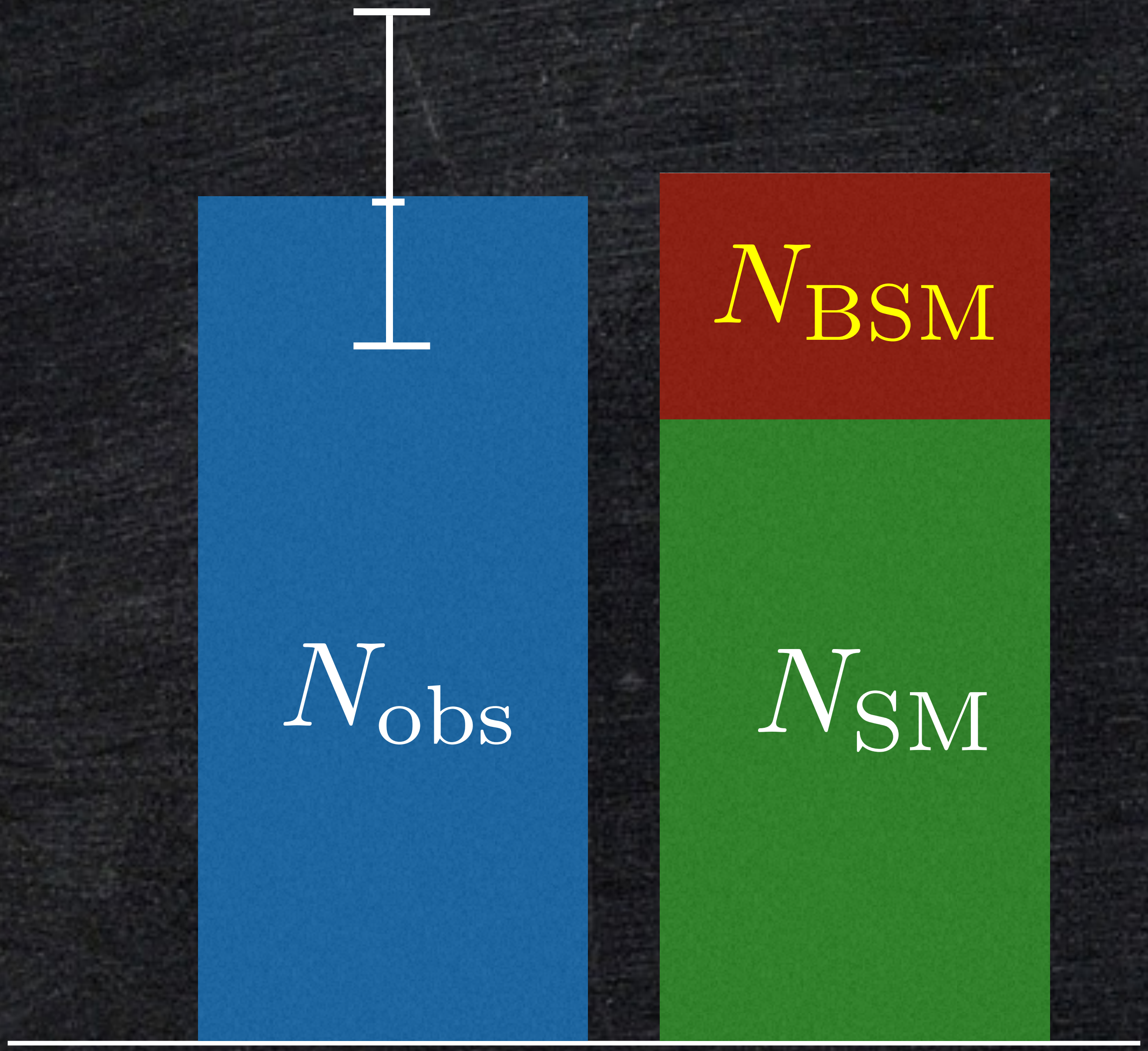
- WW cross section
- Leptoquark search
- LFV Higgs
- SUSY trilepton
- …

✤ Constraints on the other models?

✤ Which models can fit the excesses without violating the agreement found in the other channels.

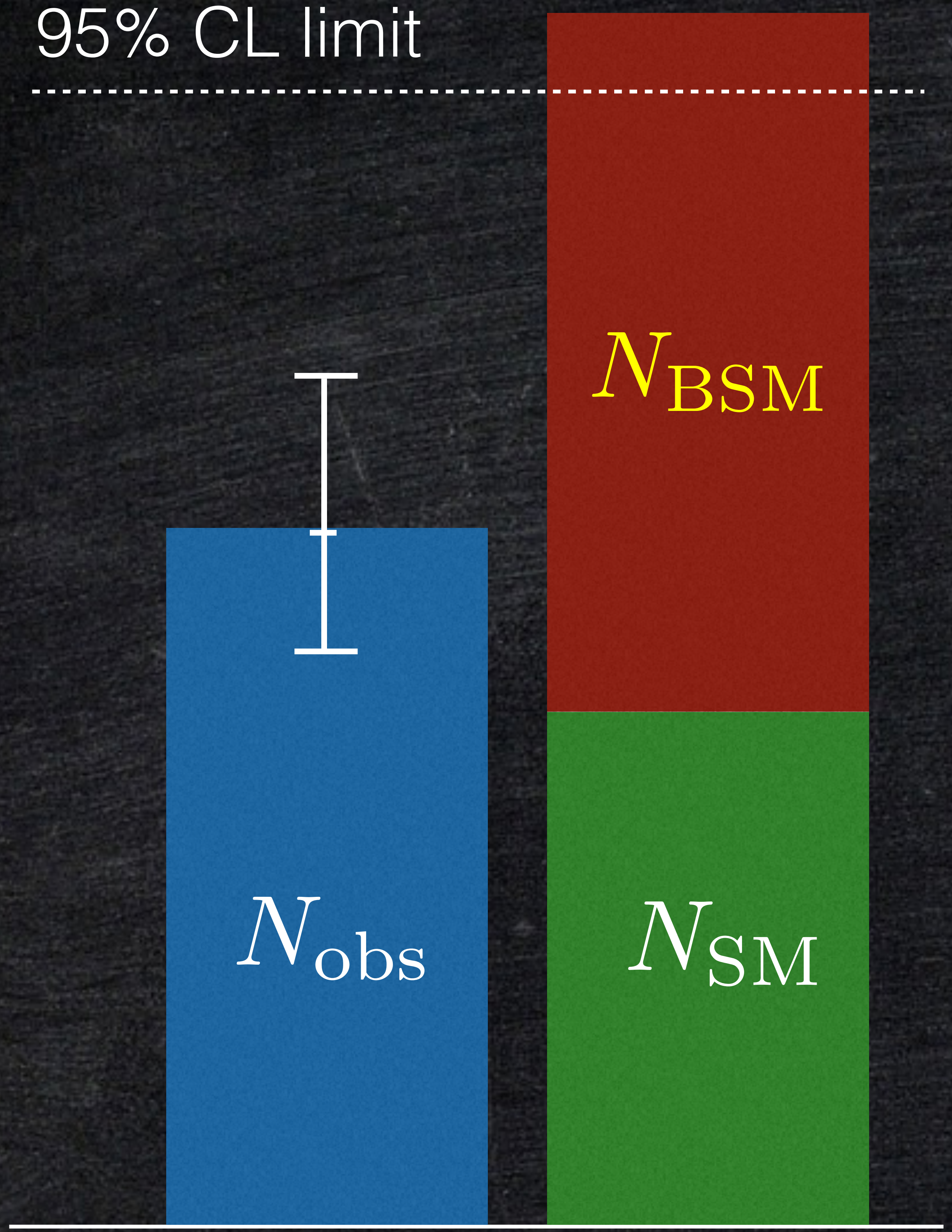
In the cut and count based measurements, one compares the # of predicted events with the # of observed events.





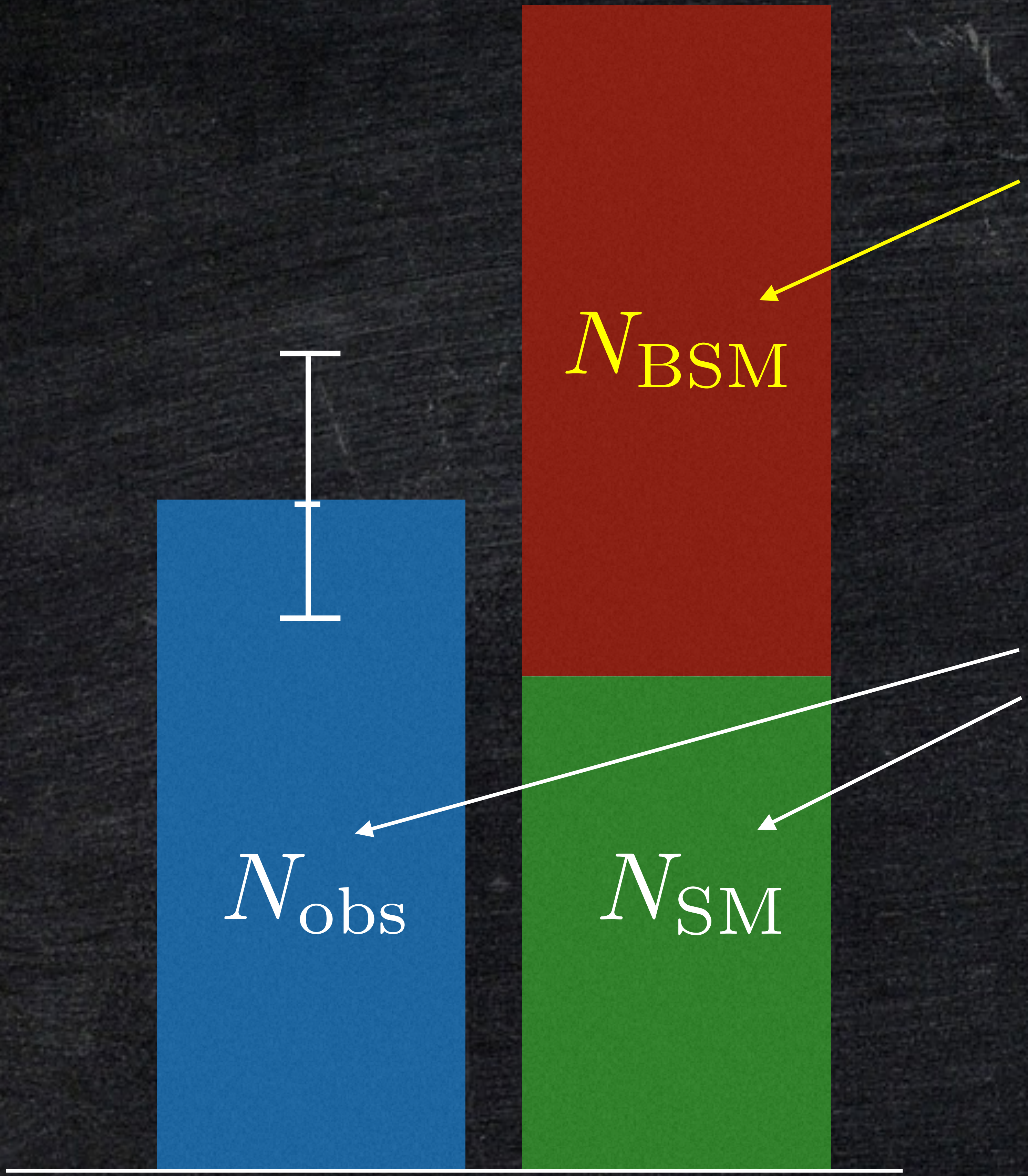
In the cut and count based measurements, one compares the # of predicted events with the # of observed events.

- If the size of the BSM events is just enough to fit the excess, the BSM model point is *favoured* by data.



In the cut and count based measurements, one compares the # of predicted events with the # of observed events.

- If the size of the BSM events is just enough to fit the excess, the BSM model point is *favoured* by data.
- If the size of the BSM events is too large, the BSM point is *excluded*.



We need to compute it for the model to be tested

These are provided by experiments

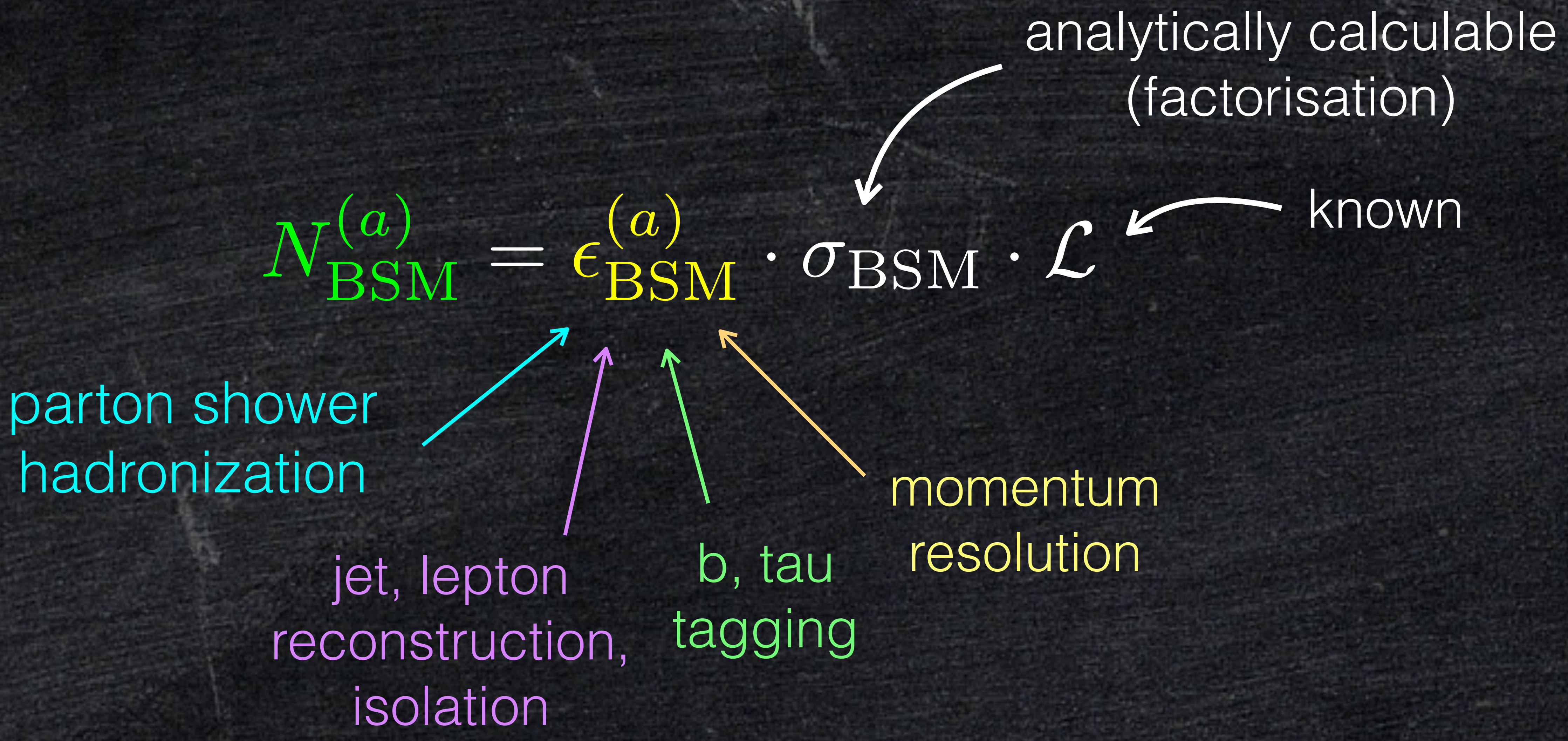
How to calculate N_{BSM}?

analytically calculable
(factorisation)

known

$$N_{\mathrm{BSM}}^{(a)} = \epsilon_{\mathrm{BSM}}^{(a)} \cdot \sigma_{\mathrm{BSM}} \cdot \mathcal{L}$$

How to calculate N$_{\mathrm{BSM}}$?



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

analytically calculable
(factorisation)

known

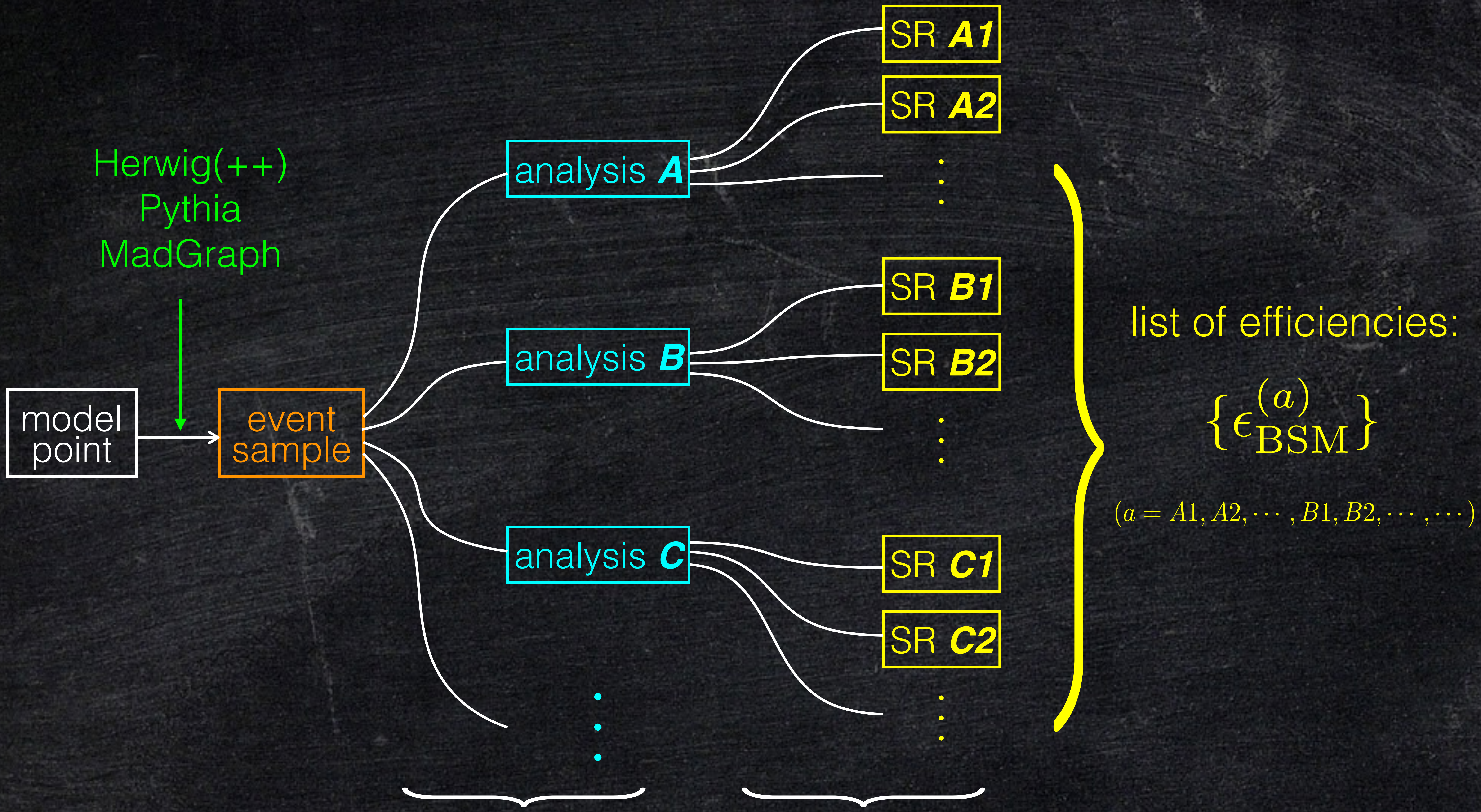
parton shower
hadronization

jet, lepton
reconstruction,
isolation

b, tau
tagging

momentum
resolution

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



model point

Herwig(++)
Pythia
MadGraph

event sample

analysis ***A***

analysis ***B***

analysis ***C***

SR ***A1***

SR ***A2***

SR ***B1***

SR ***B2***

SR ***C1***

SR ***C2***

list of efficiencies:

$$\{\epsilon^{(a)}_{\mathrm{BSM}}\}$$

$(a = A1, A2, \cdots, B1, B2, \cdots, \cdots)$

Detector simulation

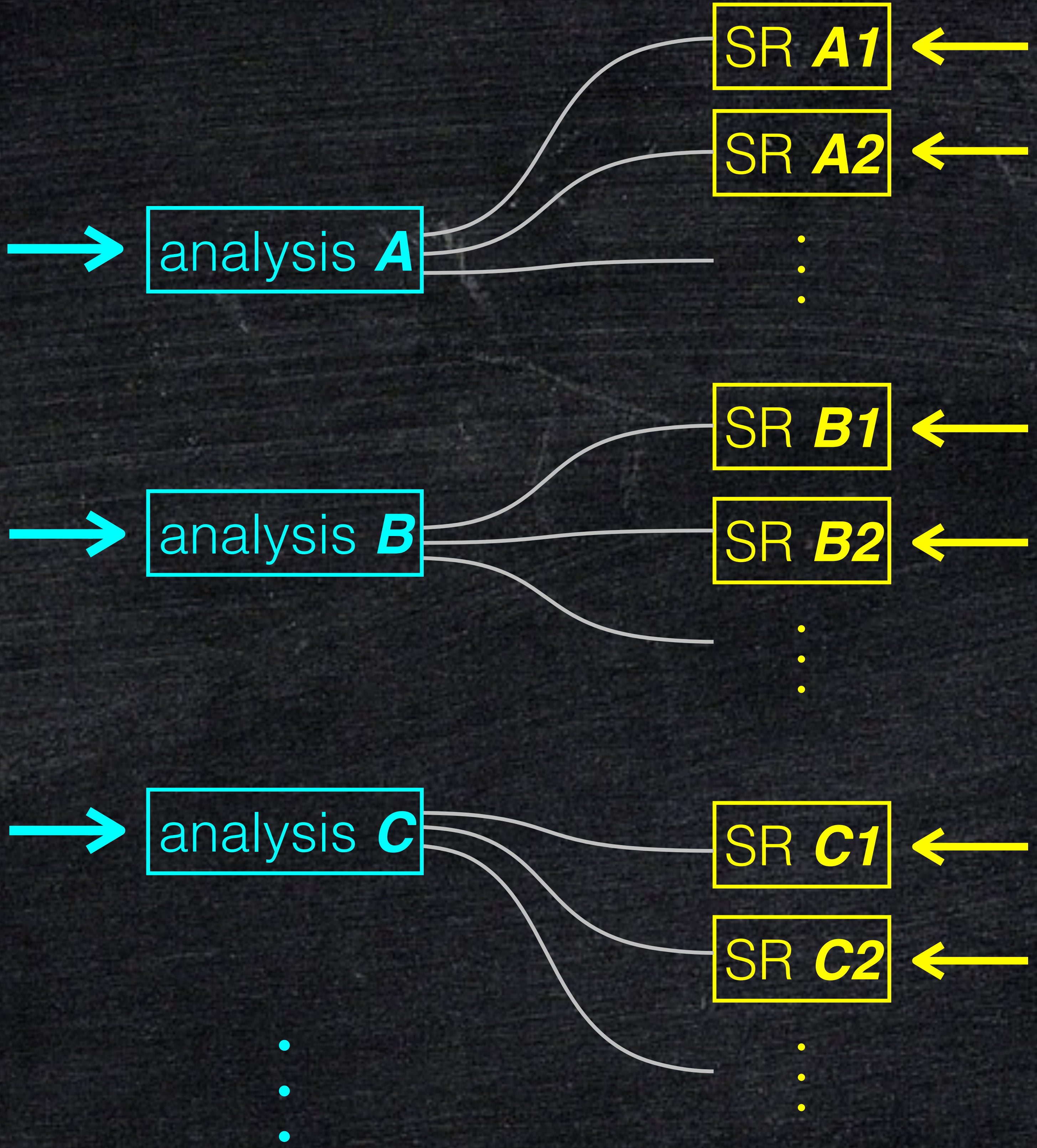
Delphes, PGS, ...

Efficiency estimation

in-house C++, python codes

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

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



analysis ***A***

SR ***A1***

SR ***A2***

⋮

analysis ***B***

SR ***B1***

SR ***B2***

⋮

analysis ***C***

SR ***C1***

SR ***C2***

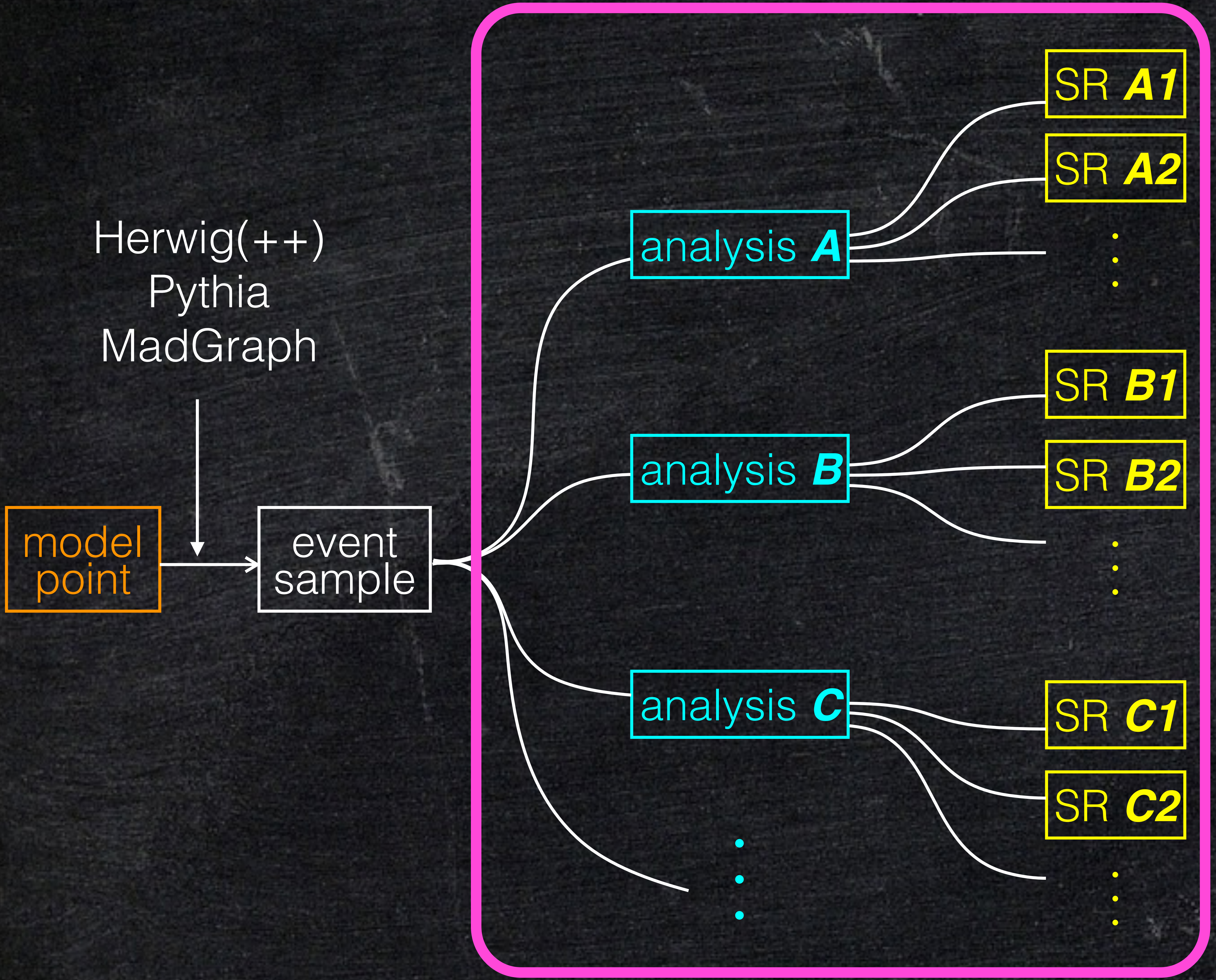
⋮

⋮

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

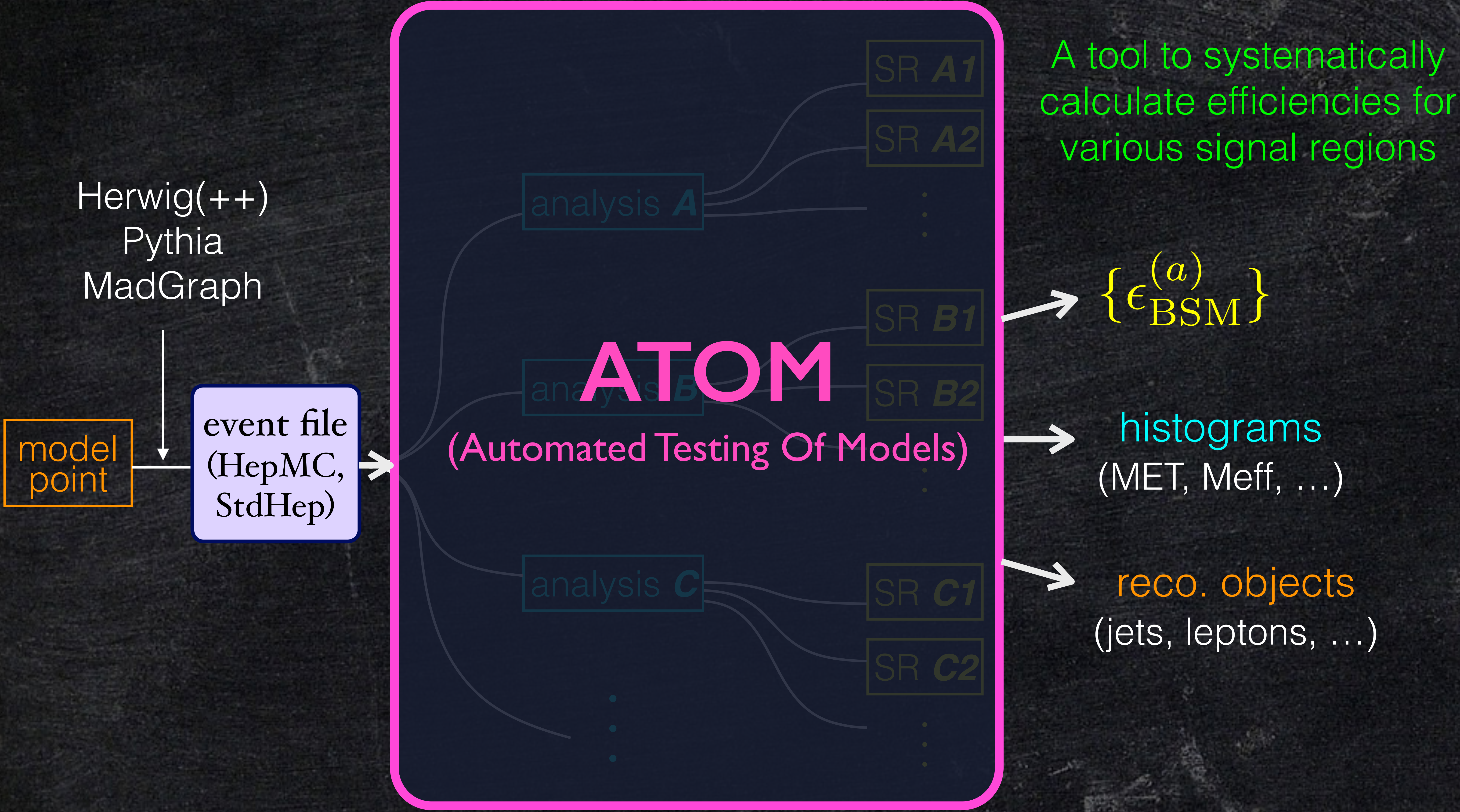
The procedure becomes cumbersome if multiple analyse are considered



A tool to systematically calculate efficiencies for various signal regions

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

A tool to systematically calculate efficiencies for various signal regions



Herwig(++)
Pythia
MadGraph

model point

event file (HepMC, StdHep)

ATOM

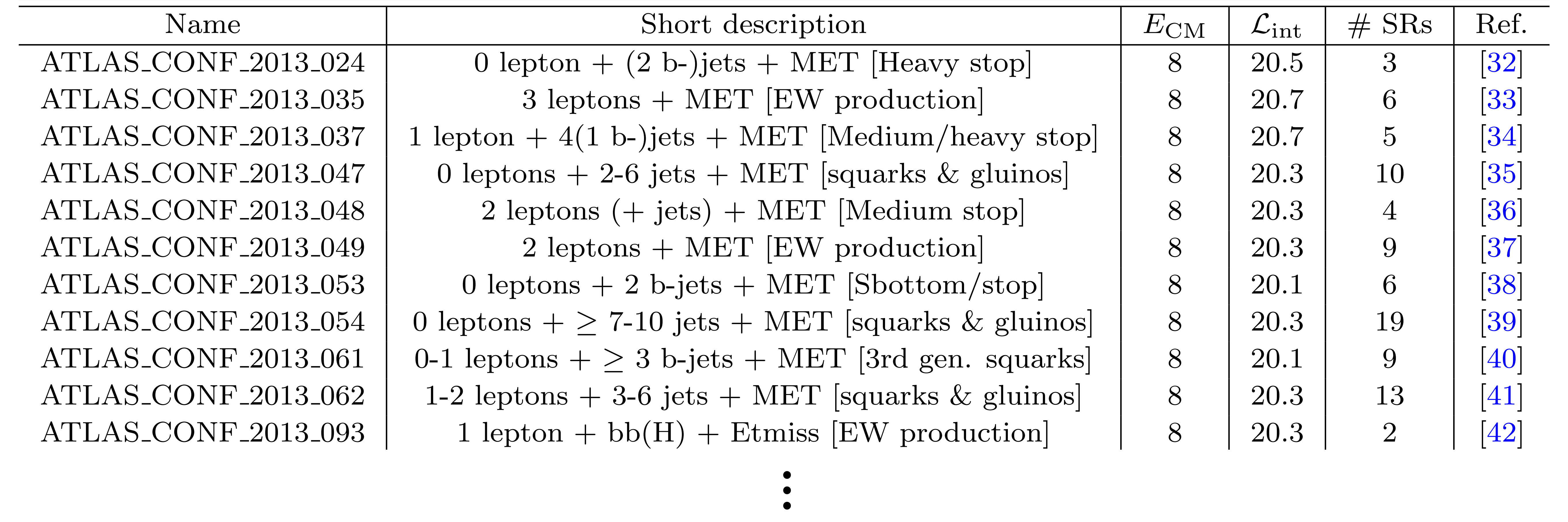
(Automated Testing Of Models)

$\{\epsilon^{(a)}_{\rm BSM}\}$

histograms
(MET, Meff, ...)

reco. objects
(jets, leptons, ...)

Analyses in ATOM



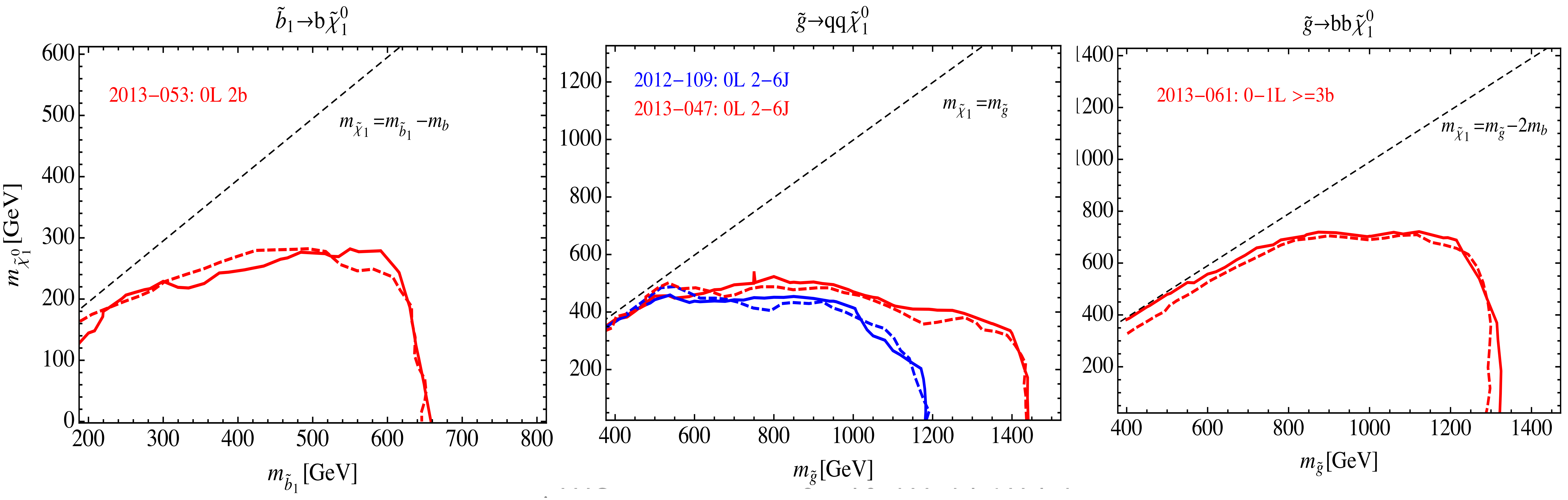
Name	Short description	E_{CM}	$\mathcal{L}_{\text{int}}$	# SRs	Ref.
ATLAS_CONF_2013_024	0 lepton + (2 b-)jets + MET [Heavy stop]	8	20.5	3	[32]
ATLAS_CONF_2013_035	3 leptons + MET [EW production]	8	20.7	6	[33]
ATLAS_CONF_2013_037	1 lepton + 4(1 b-)jets + MET [Medium/heavy stop]	8	20.7	5	[34]
ATLAS_CONF_2013_047	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.



Validation

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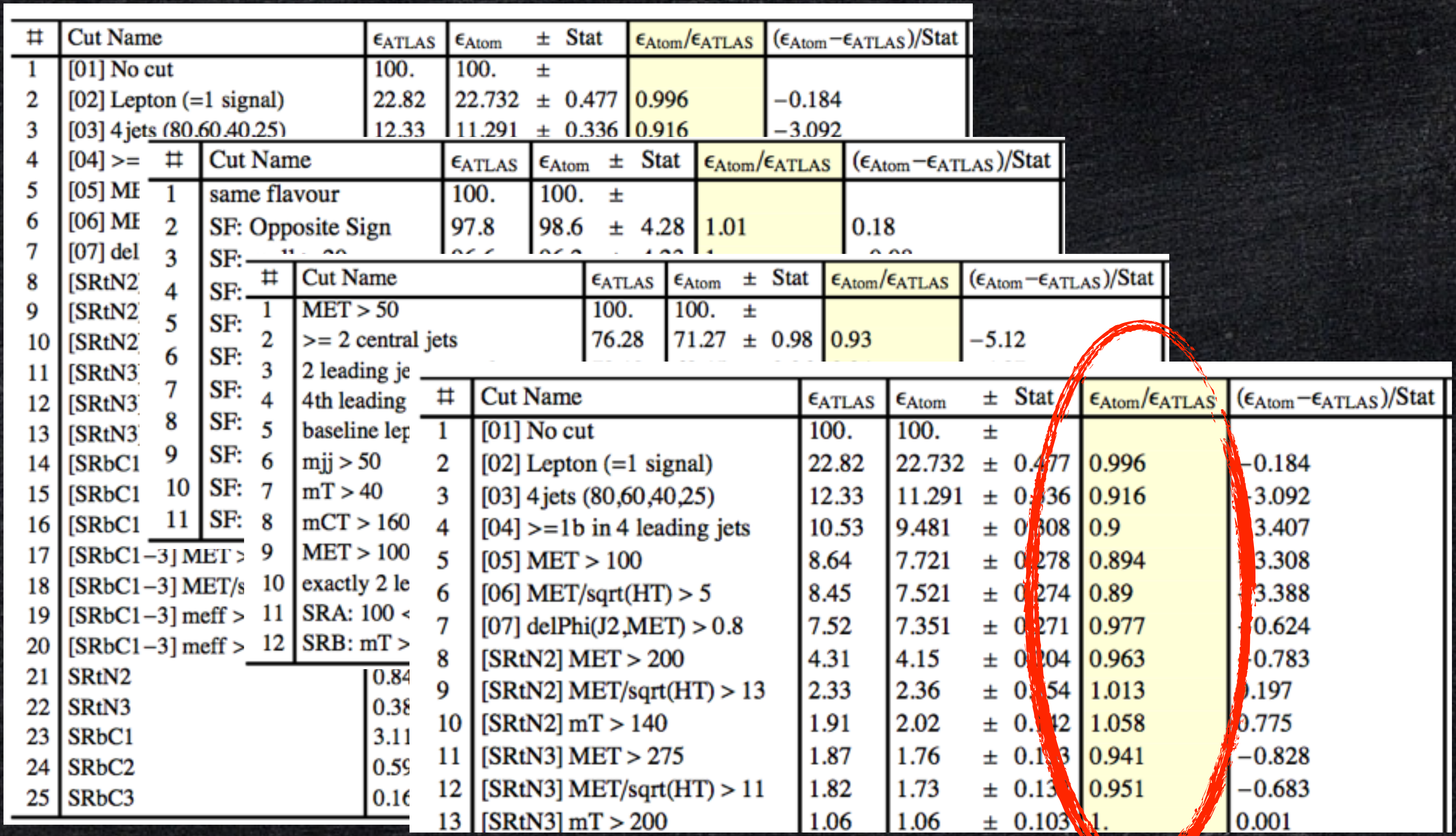


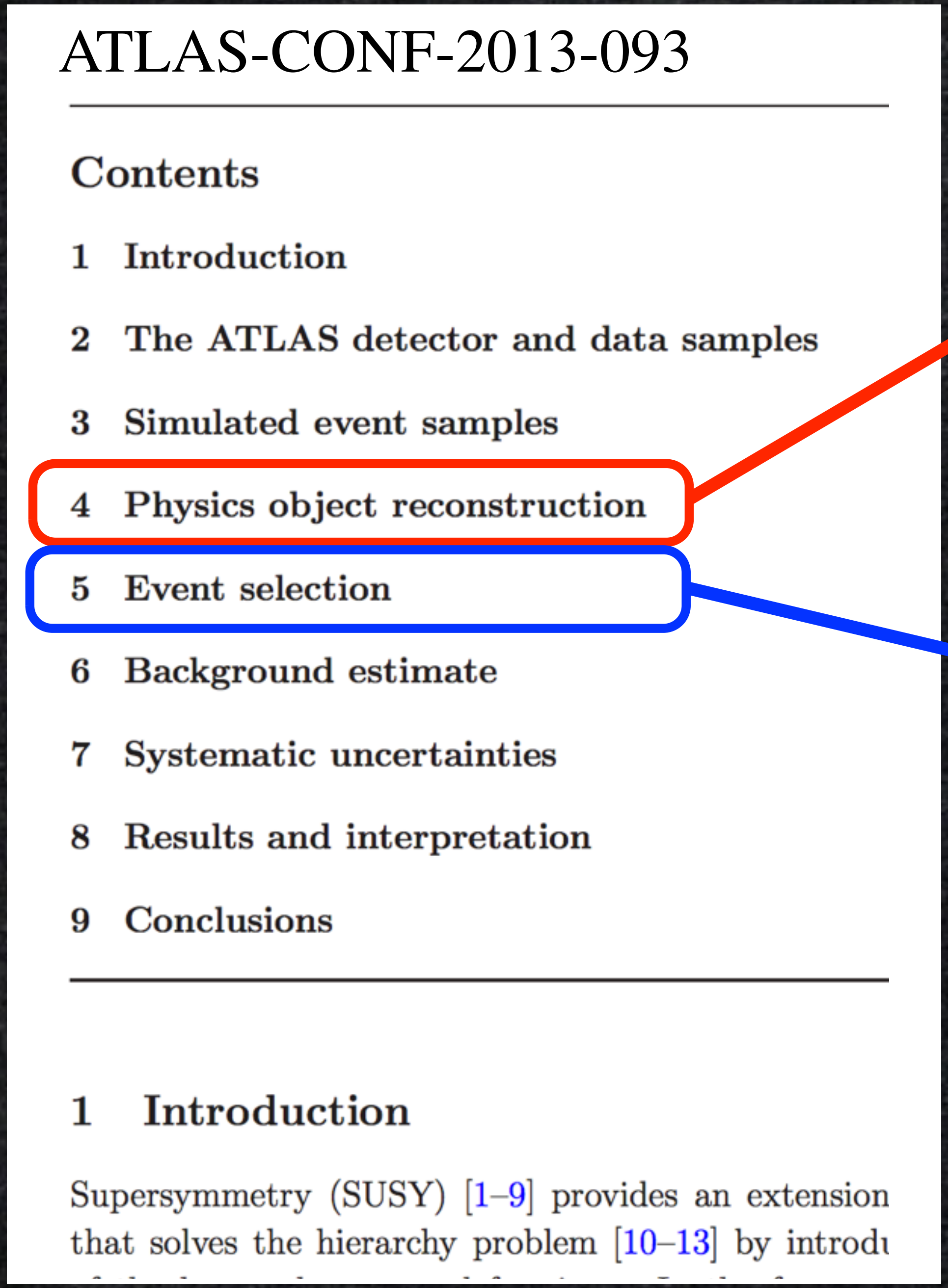
#	Cut Name	$\epsilon_{\rm ATLAS}$	$\epsilon_{\rm Atom}$	±	Stat	$\epsilon_{\rm Atom}/\epsilon_{\rm ATLAS}$	$(\epsilon_{\rm Atom}-\epsilon_{\rm ATLAS})$/Stat
1	[01] No cut	100.	100.	±			
2	[02] Lepton (=1 signal)	22.82	22.732	±	0.477	0.996	−0.184
3	[03] 4jets (80,60,40,25)	12.33	11.291	±	0.336	0.916	−3.092
4	[04] >=						
5	[05] ME						
6	[06] ME						
7	[07] del						
8	[SRtN2						
9	[SRtN2						
10	[SRtN2						
11	[SRtN3						
12	[SRtN3						
13	[SRtN3						
14	[SRbC1						
15	[SRbC1						
16	[SRbC1						
17	[SRbC1−3] MET >						
18	[SRbC1−3] MET/s						
19	[SRbC1−3] meff >						
20	[SRbC1−3] meff >						
21	SRtN2	0.84					
22	SRtN3	0.38					
23	SRbC1	3.11					
24	SRbC2	0.59					
25	SRbC3	0.16					

#	Cut Name	$\epsilon_{\rm ATLAS}$	$\epsilon_{\rm Atom}$	±	Stat	$\epsilon_{\rm Atom}/\epsilon_{\rm ATLAS}$	$(\epsilon_{\rm Atom}-\epsilon_{\rm ATLAS})$/Stat
1	same flavour	100.	100.	±			
2	SF: Opposite Sign	97.8	98.6	±	4.28	1.01	0.18
3	SF:						
4	SF:						
5	SF:						
6	SF:						
7	SF:						
8	SF:						
9	SF:						
10	SF:						
11	SF:						

#	Cut Name	$\epsilon_{\rm ATLAS}$	$\epsilon_{\rm Atom}$	±	Stat	$\epsilon_{\rm Atom}/\epsilon_{\rm ATLAS}$	$(\epsilon_{\rm Atom}-\epsilon_{\rm ATLAS})$/Stat
1	MET > 50	100.	100.	±			
2	>= 2 central jets	76.28	71.27	±	0.98	0.93	−5.12
3	2 leading je						
4	4th leading						
5	baseline lep						
6	mjj > 50						
7	mT > 40						
8	mCT > 160						
9	MET > 100						
10	exactly 2 le						
11	SRA: 100 <						
12	SRB: mT >						

#	Cut Name	$\epsilon_{\rm ATLAS}$	$\epsilon_{\rm Atom}$	±	Stat	$\epsilon_{\rm Atom}/\epsilon_{\rm ATLAS}$	$(\epsilon_{\rm Atom}-\epsilon_{\rm ATLAS})$/Stat
1	[01] No cut	100.	100.	±			
2	[02] Lepton (=1 signal)	22.82	22.732	±	0.477	0.996	−0.184
3	[03] 4jets (80,60,40,25)	12.33	11.291	±	0.336	0.916	−3.092
4	[04] >=1b in 4 leading jets	10.53	9.481	±	0.308	0.9	−3.407
5	[05] MET > 100	8.64	7.721	±	0.278	0.894	−3.308
6	[06] MET/sqrt(HT) > 5	8.45	7.521	±	0.274	0.89	−3.388
7	[07] delPhi(J2,MET) > 0.8	7.52	7.351	±	0.271	0.977	−0.624
8	[SRtN2] MET > 200	4.31	4.15	±	0.204	0.963	−0.783
9	[SRtN2] MET/sqrt(HT) > 13	2.33	2.36	±	0.[illegible]54	1.013	0.197
10	[SRtN2] mT > 140	1.91	2.02	±	0.[illegible]42	1.058	0.775
11	[SRtN3] MET > 275	1.87	1.76	±	0.1[illegible]3	0.941	−0.828
12	[SRtN3] MET/sqrt(HT) > 11	1.82	1.73	±	0.13[illegible]	0.951	−0.683
13	[SRtN3] mT > 200	1.06	1.06	±	0.103	1.	0.001

Coding in Atom



ATLAS-CONF-2013-093

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1 Introduction

2 The ATLAS detector and data samples

3 Simulated event samples

4 Physics object reconstruction

5 Event selection

6 Background estimate

7 Systematic uncertainties

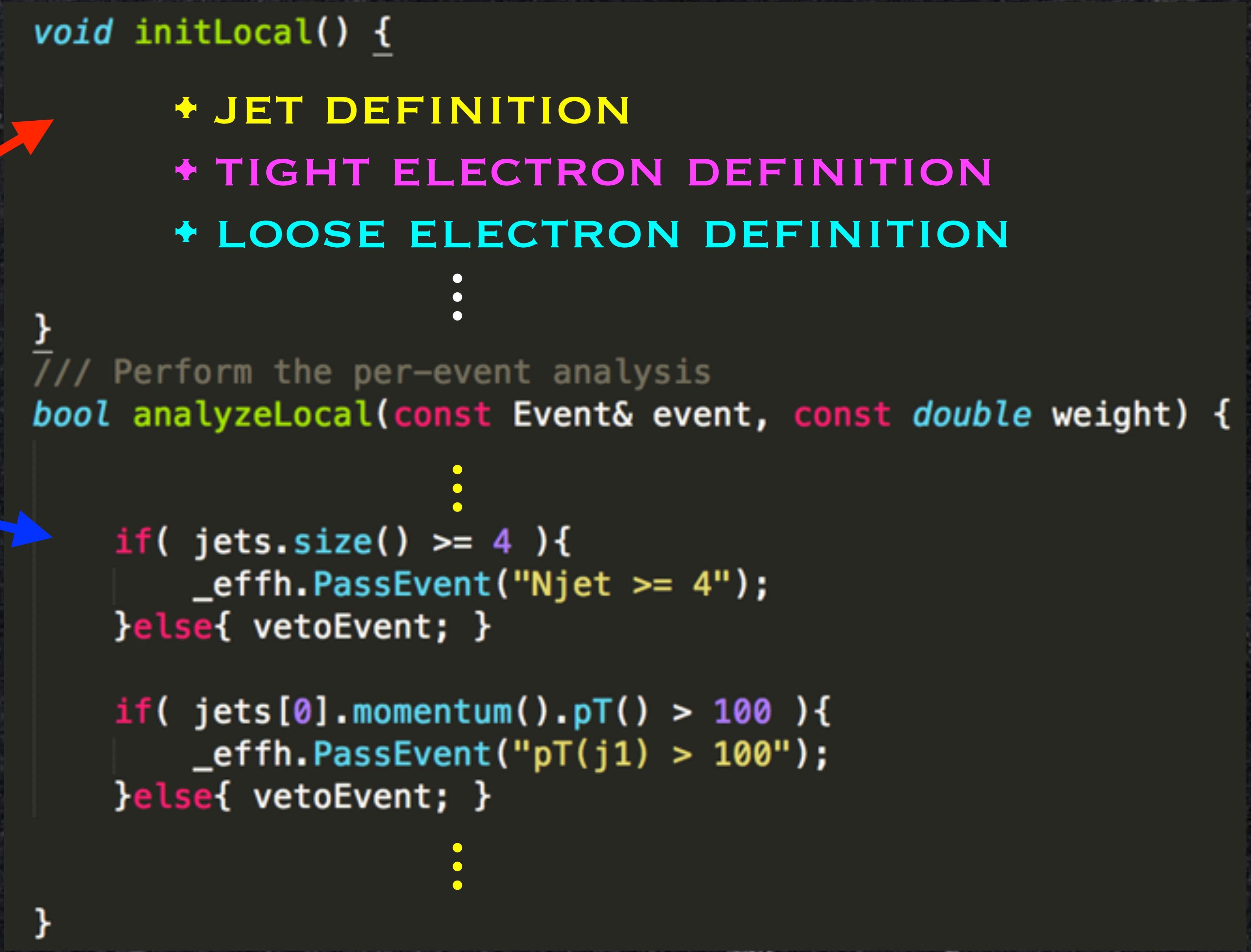
8 Results and interpretation

9 Conclusions

1 Introduction

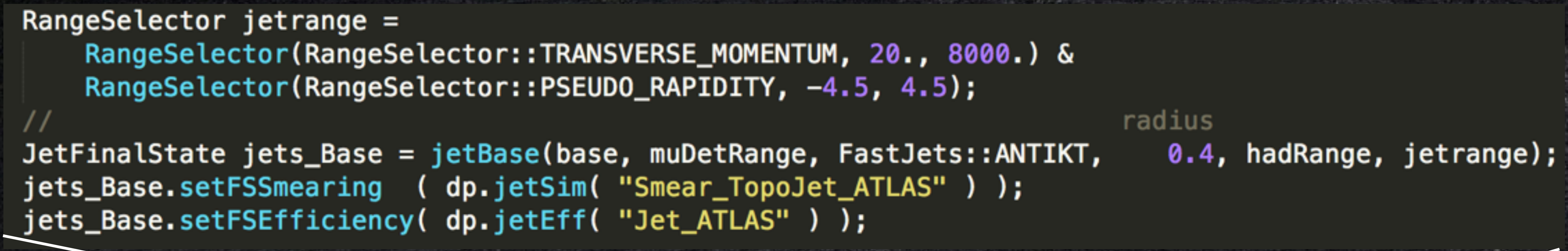
Supersymmetry (SUSY) [1–9] provides an extension that solves the hierarchy problem [10–13] by introdu

ATLAS_CONF_2013_093.cc

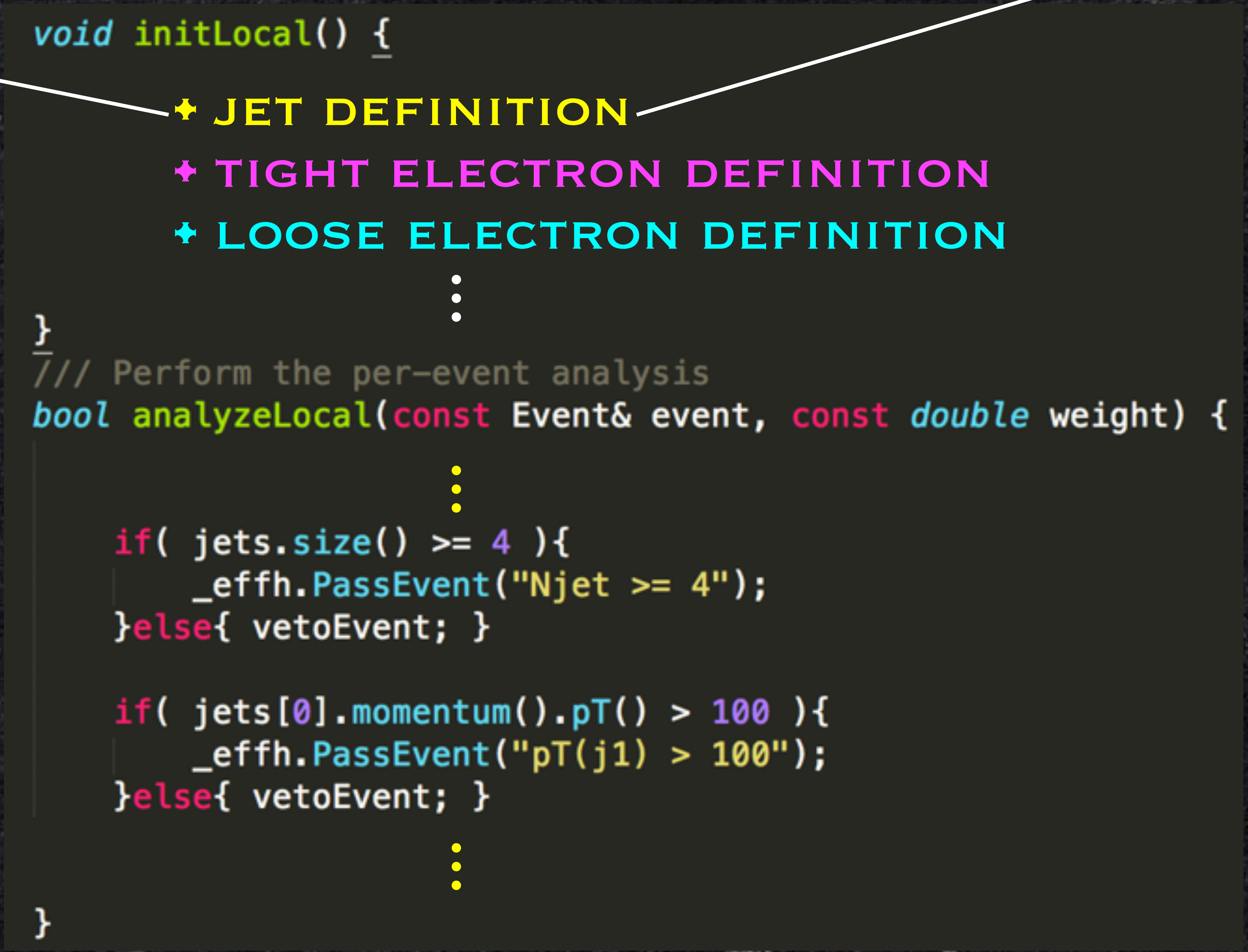


```
void initLocal() {

        ✦ 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() {
```

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⋮

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```

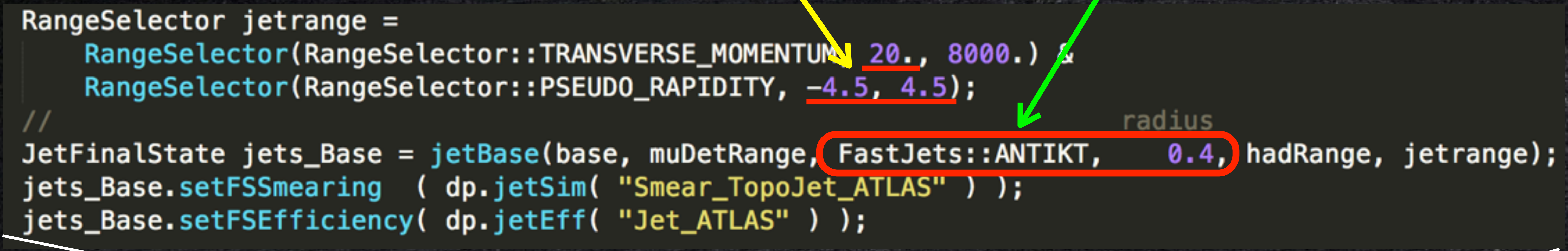
⋮

```
}
```

✦ JET DEFINITION

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

anti-kT, ΔR=0.4 (by Fastjet)



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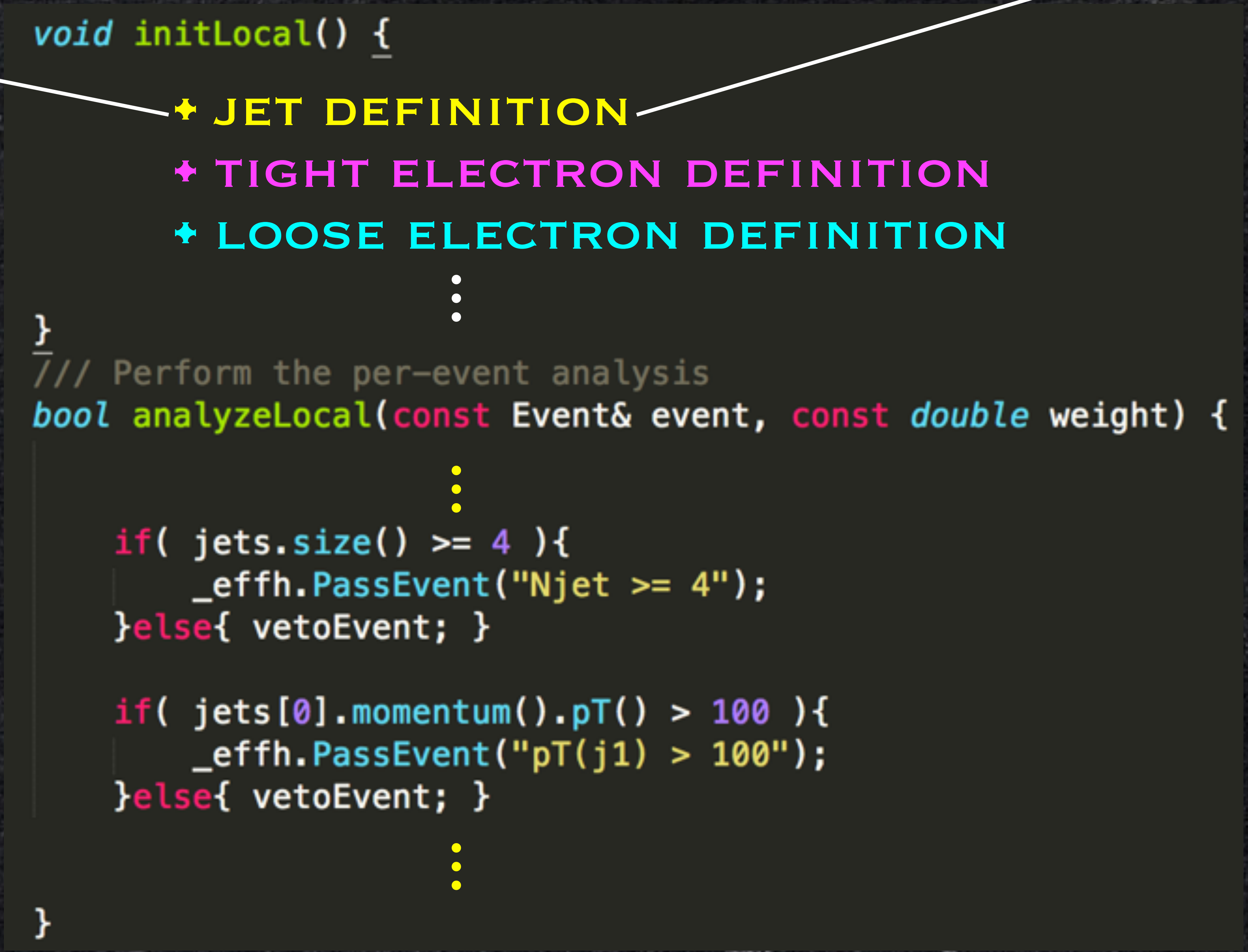
    RangeSelector(RangeSelector::PSEUDO_RAPIDITY, -4.5, 4.5);
//
JetFinalState jets_Base = jetBase(base, muDetRange, FastJets::ANTIKT,     0.4, hadRange, jetrange);
jets_Base.setFSSmearing  ( dp.jetSim( "Smear_TopoJet_ATLAS" ) );
jets_Base.setFSEfficiency( dp.jetEff( "Jet_ATLAS" ) );
```



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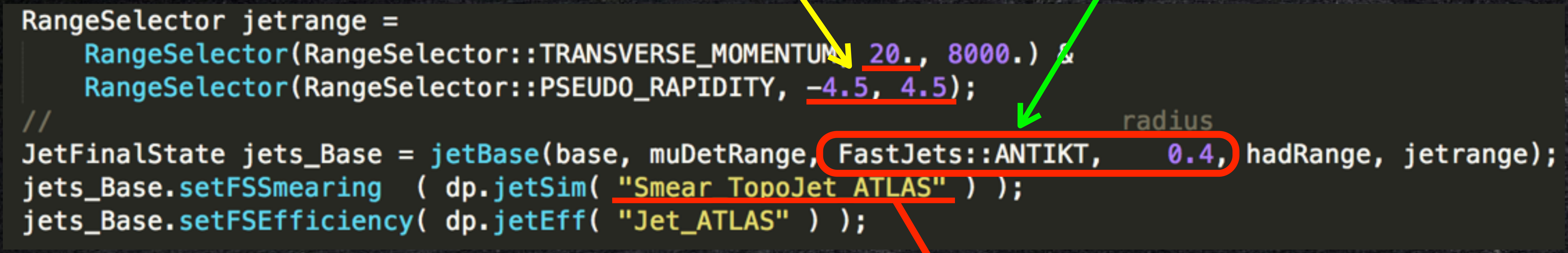

```
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//                                                                      radius
JetFinalState jets_Base = jetBase(base, muDetRange, FastJets::ANTIKT,     0.4, hadRange, jetrange);
jets_Base.setFSSmearing  ( dp.jetSim( "Smear_TopoJet_ATLAS" ) );
jets_Base.setFSEfficiency( dp.jetEff( "Jet_ATLAS" ) );
```

ATLAS-CONF-2013-004

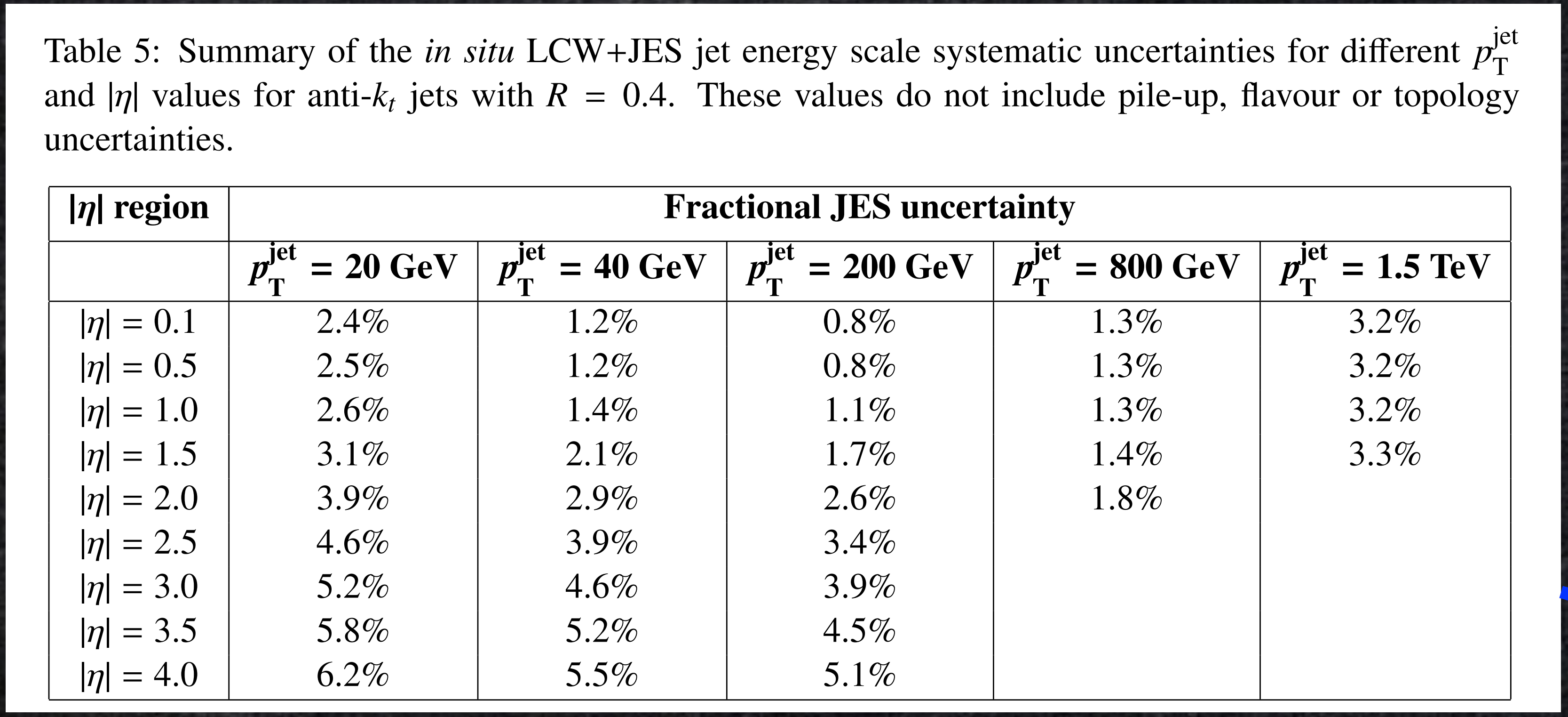
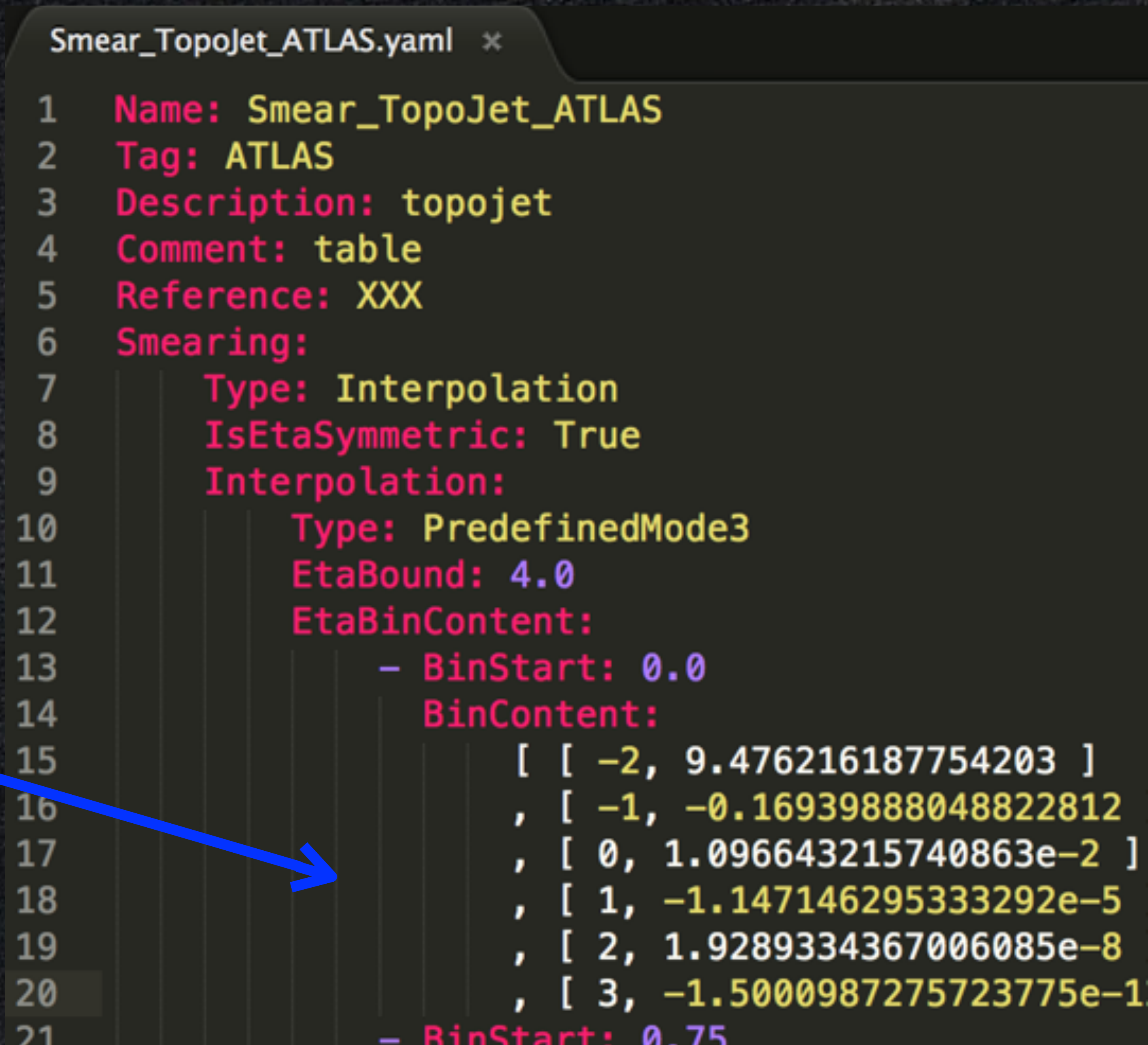


Table 5: Summary of the *in situ* LCW+JES jet energy scale systematic uncertainties for different p_T^{jet} and $|\eta|$ values for anti-k_t jets with $R = 0.4$. These values do not include pile-up, flavour or topology uncertainties.

$\|\eta\|$ 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%		

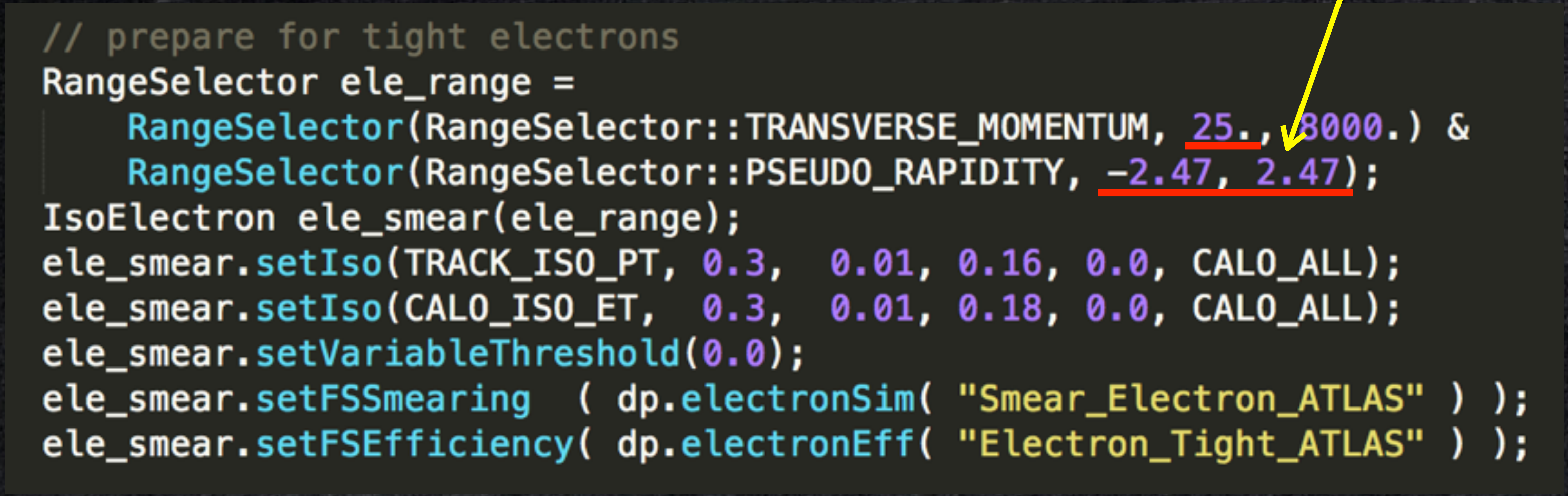


Smear_TopoJet_ATLAS.yaml ×

```
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, 9.476216187754203 ]
                  , [ -1, -0.16939888048822812
                  , [ 0, 1.096643215740863e-2 ]
                  , [ 1, -1.147146295333292e-5
                  , [ 2, 1.9289334367006085e-8
                  , [ 3, -1.5000987275723775e-1
            - BinStart: 0.75
```

✦ TIGHT ELECTRONS

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



```
// prepare for tight electrons
RangeSelector ele_range =
    RangeSelector(RangeSelector::TRANSVERSE_MOMENTUM, 25., 8000.) &
    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" ) );
```

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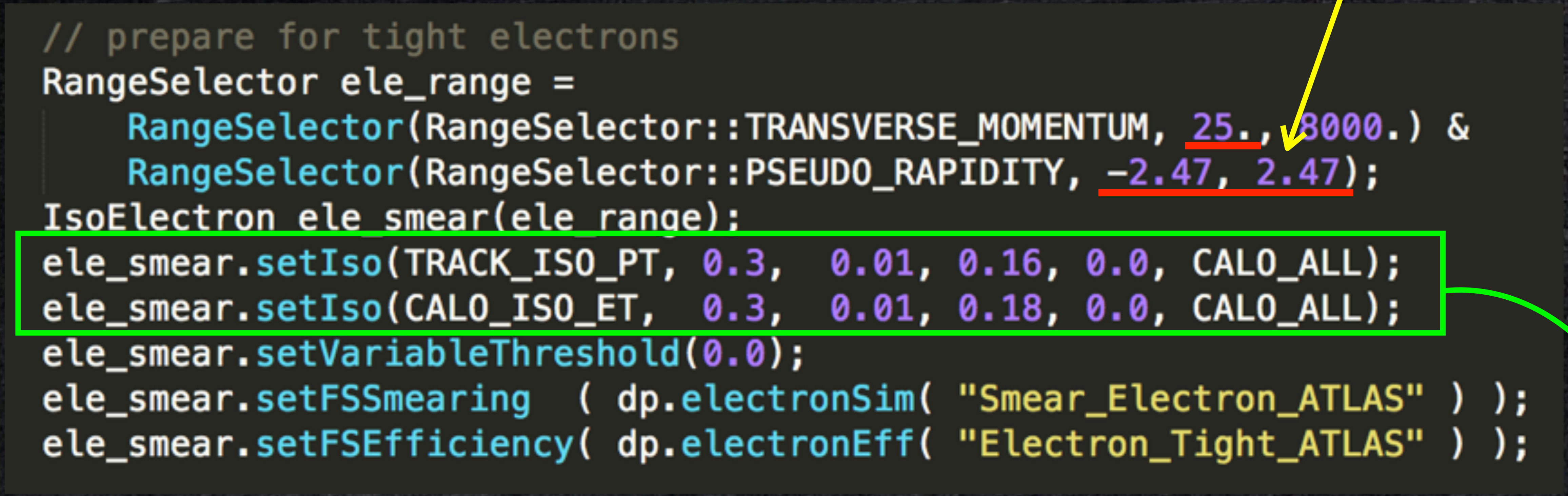

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    RangeSelector(RangeSelector::PSEUDO_RAPIDITY, -2.47, 2.47);
IsoElectron ele_smear(ele_range);
ele_smear.setIso(TRACK_ISO_PT, 0.3,  0.01, 0.16, 0.0, CALO_ALL);
ele_smear.setIso(CALO_ISO_ET,  0.3,  0.01, 0.18, 0.0, CALO_ALL);
ele_smear.setVariableThreshold(0.0);
ele_smear.setFSSmearing  ( dp.electronSim( "Smear_Electron_ATLAS" ) );
ele_smear.setFSEfficiency( dp.electronEff( "Electron_Tight_ATLAS" ) );
```
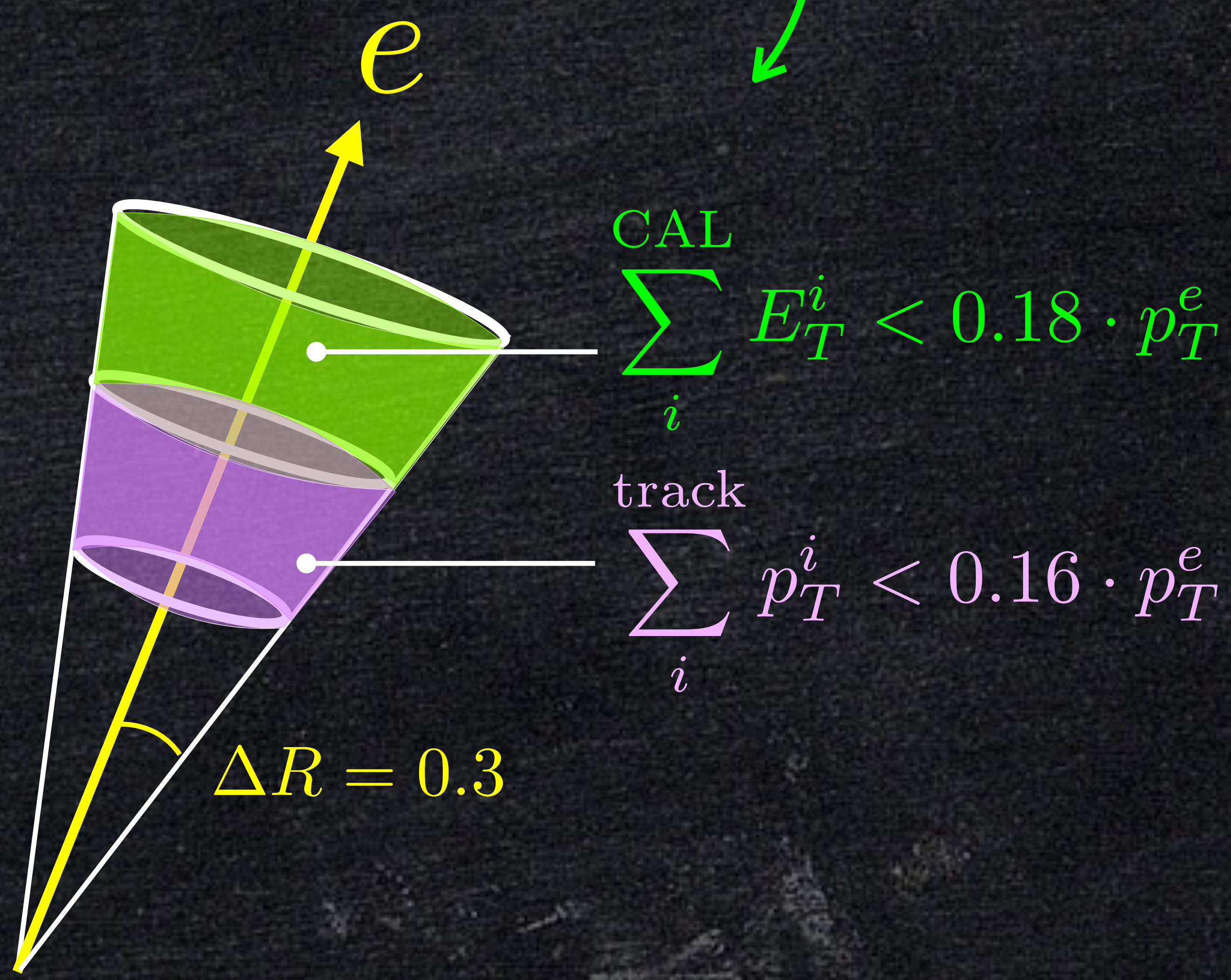

track
calorimeter
isolation



$$\sum_i^{\mathrm{CAL}} E_T^i < 0.18 \cdot p_T^e$$

$$\sum_i^{\mathrm{track}} p_T^i < 0.16 \cdot p_T^e$$

✦ TIGHT ELECTRONS

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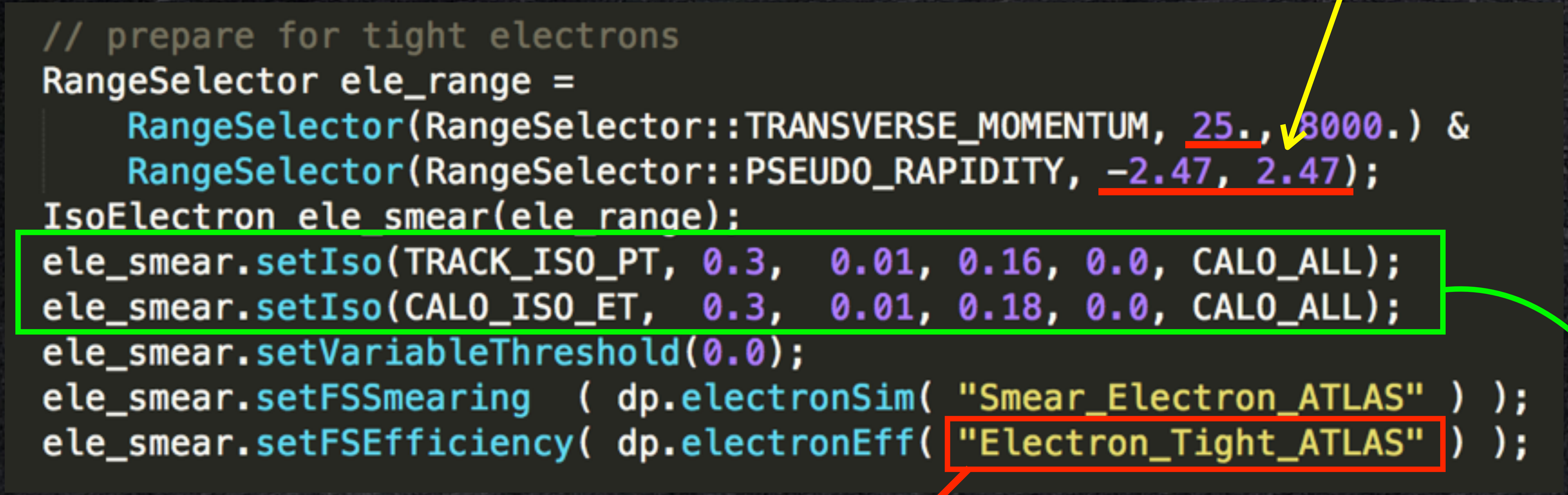
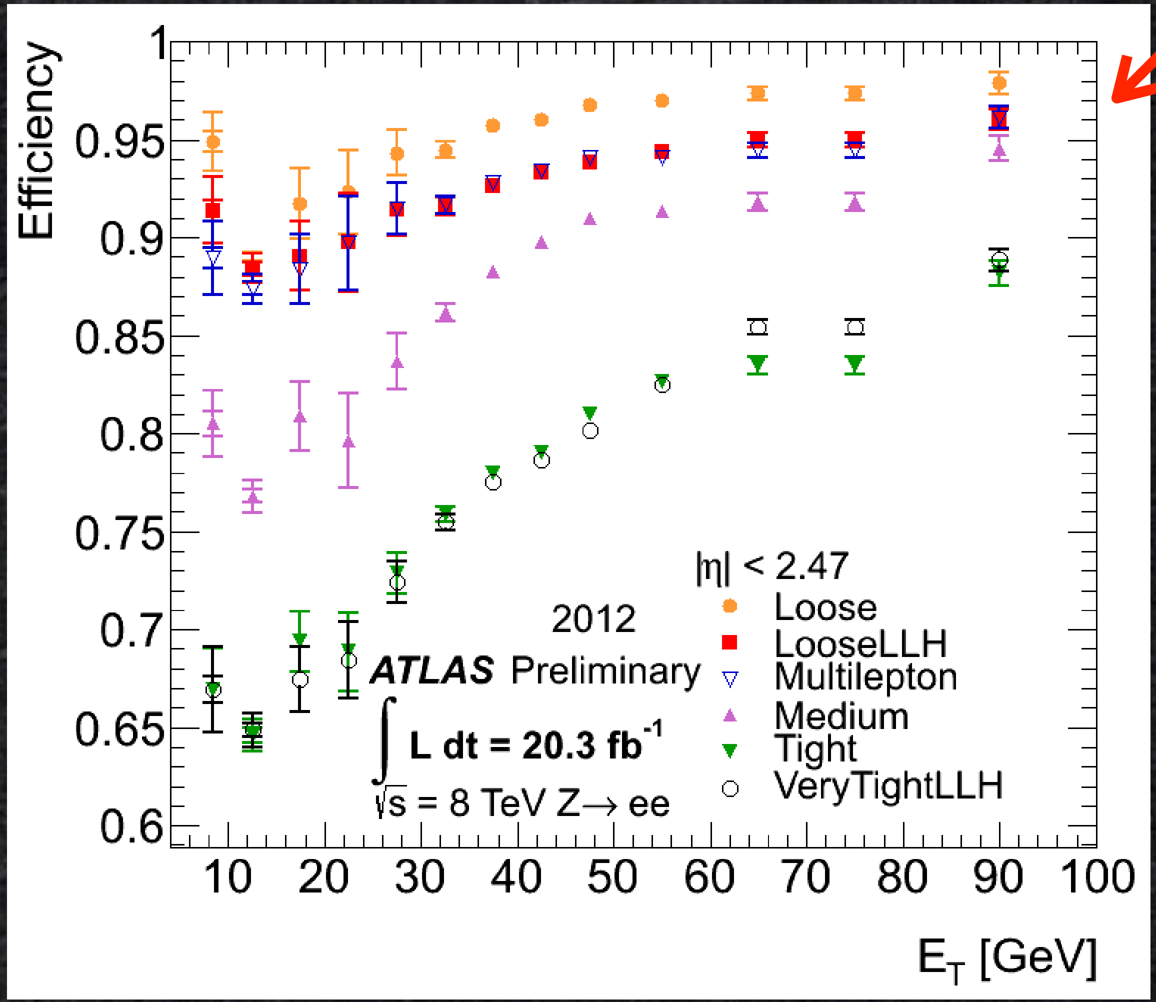
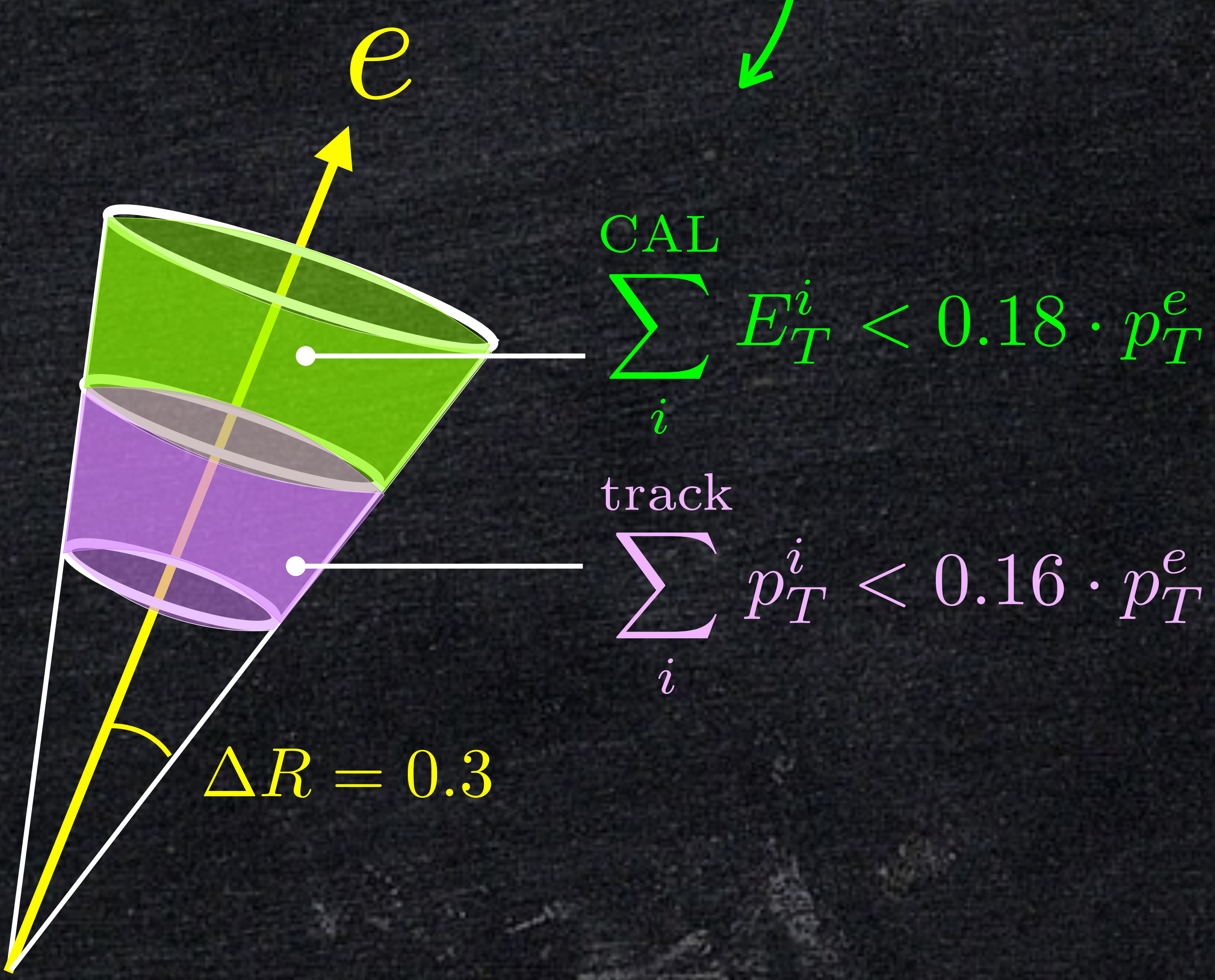


```
// prepare for tight electrons
RangeSelector ele_range =
    RangeSelector(RangeSelector::TRANSVERSE_MOMENTUM, 25., 8000.) &
    RangeSelector(RangeSelector::PSEUDO_RAPIDITY, -2.47, 2.47);
IsoElectron ele_smear(ele_range);
ele_smear.setIso(TRACK_ISO_PT, 0.3,  0.01, 0.16, 0.0, CALO_ALL);
ele_smear.setIso(CALO_ISO_ET,  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

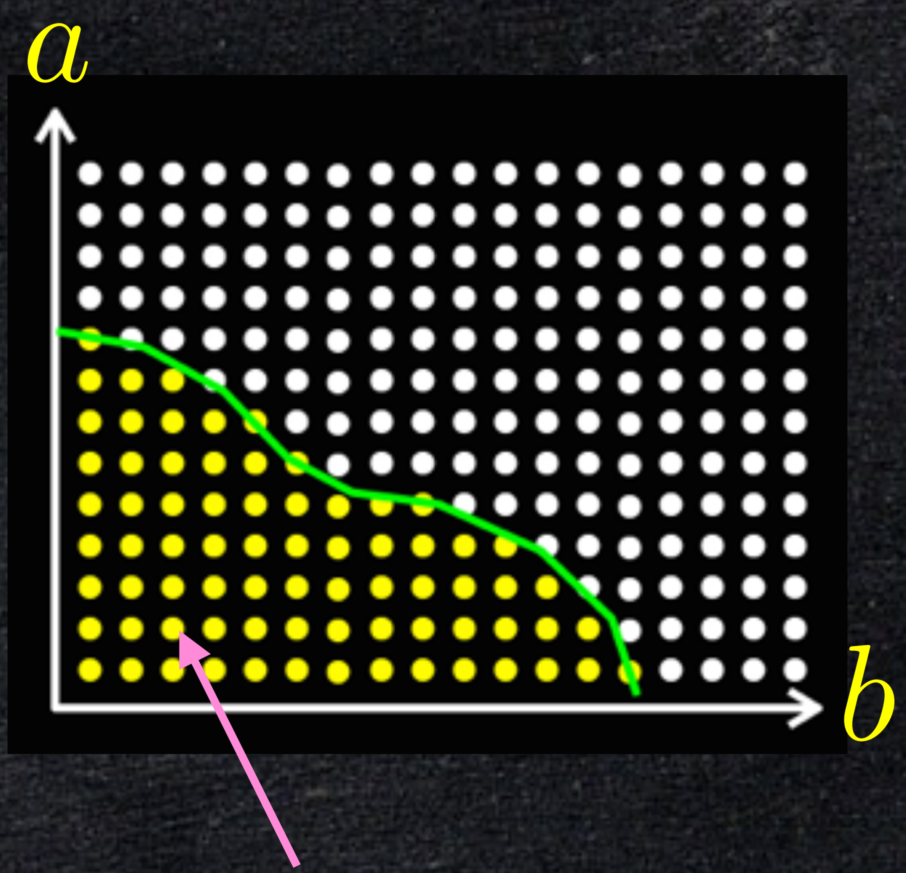
reconstruction efficiencies





Faster model testing (with approximation)

- ATOM provides a model independent and efficient method to test BSM models.
- ATOM requires event files for inputs. However, event generation is generally time consuming and computationally expensive.
- It would be useful if we could develop an approximate method for testing BSM models without event generation.



each point requires MC simulations

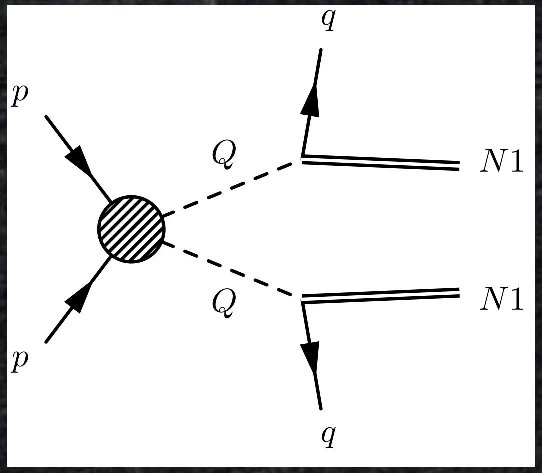
N_{BSM} de/reconstruction

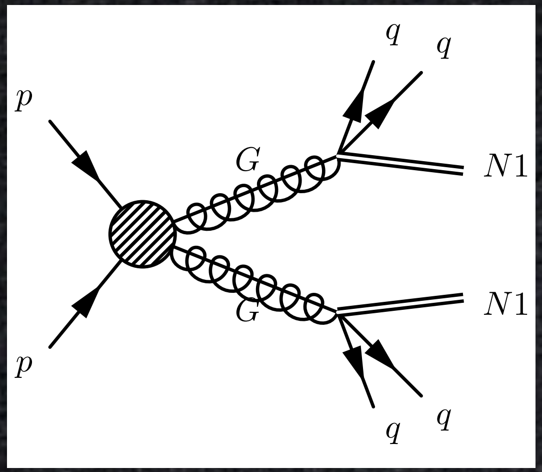
$\text{Q} = \tilde{q}$

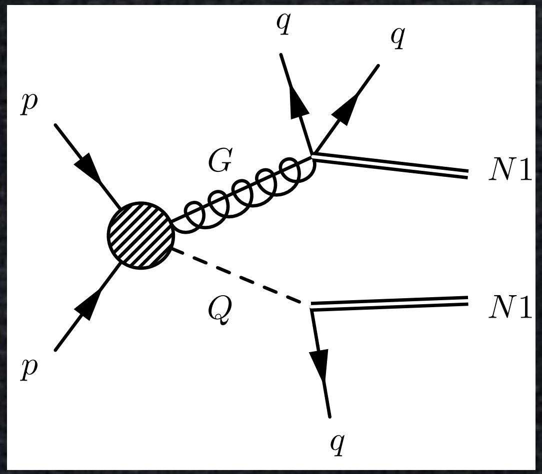
$\text{G} = \tilde{g}$

$\text{N1} = \tilde{\chi}_1^0$

$$N^{(a)}_{\text{BSM}} = \left\{ \begin{array}{c} N^{(a)}_{\text{QqN1:QqN1}} \\ + \\ N^{(a)}_{\text{GqqN1:GqqN1}} \\ + \\ N^{(a)}_{\text{GqqN1:QqN1}} \\ \vdots \end{array} \right.$$







N_{BSM} de/reconstruction

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

depends *only* on 2 or 3 BSM particle masses

$$N^{(a)}_{\mathrm{BSM}} = \left\{ \begin{array}{l} N^{(a)}_{\mathrm{QqN1:QqN1}} = \epsilon^{(a)}_{\mathrm{QqN1:QqN1}}(m_{\mathrm{Q}}, m_{\mathrm{N1}}) \cdot \sigma_{\mathrm{QQ}} \cdot BR \cdot \mathcal{L} \\ \quad + \\ N^{(a)}_{\mathrm{GqqN1:GqqN1}} = \epsilon^{(a)}_{\mathrm{GqqN1:GqqN1}}(m_{\mathrm{G}}, m_{\mathrm{N1}}) \cdot \sigma_{\mathrm{GG}} \cdot BR \cdot \mathcal{L} \\ \quad + \\ N^{(a)}_{\mathrm{GqqN1:QqN1}} = \epsilon^{(a)}_{\mathrm{GqqN1:QqN1}}(m_{\mathrm{G}}, m_{\mathrm{Q}}, m_{\mathrm{N1}}) \cdot \sigma_{\mathrm{GQ}} \cdot BR \cdot \mathcal{L} \\ \quad \vdots \end{array} \right.$$

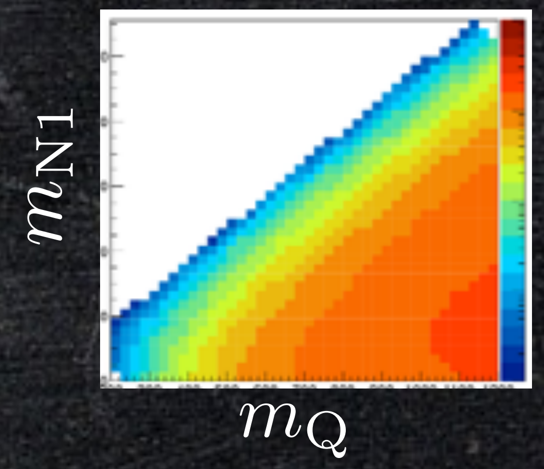
N_{BSM} de/reconstruction

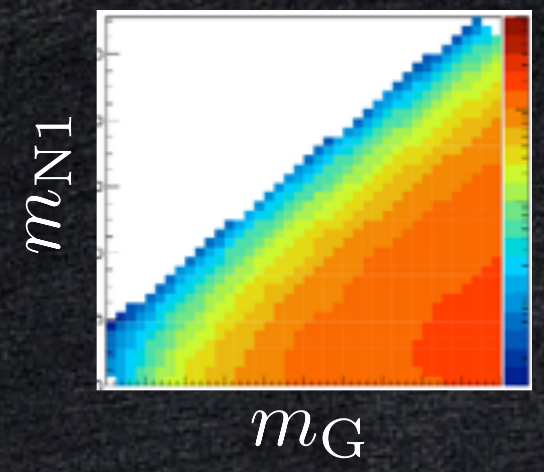
$\mathrm{Q} = \tilde{q}$

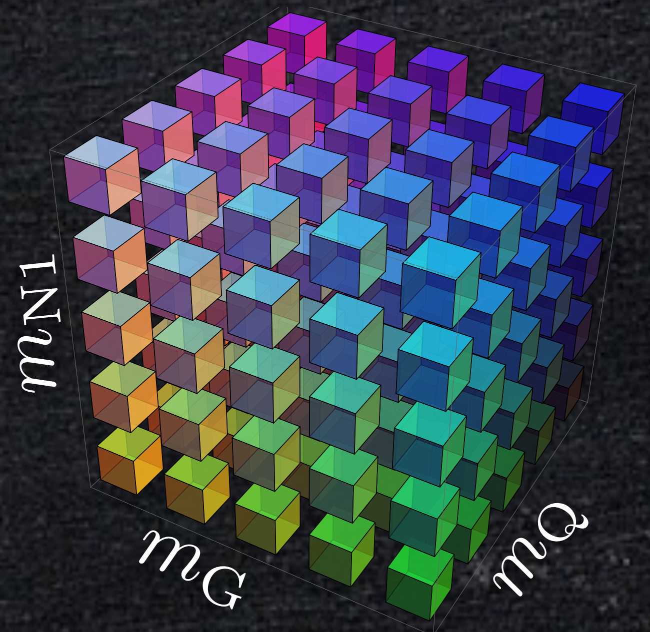
$\mathrm{G} = \tilde{g}$

$\mathrm{N1} = \tilde{\chi}_1^0$

$$N^{(a)}_{\mathrm{BSM}} = \begin{cases} N^{(a)}_{\mathrm{QqN1:QqN1}} = & \sigma_{\mathrm{QQ}} \cdot BR \cdot \mathcal{L} \\ + & \\ N^{(a)}_{\mathrm{GqqN1:GqqN1}} = & \sigma_{\mathrm{GG}} \cdot BR \cdot \mathcal{L} \\ + & \\ N^{(a)}_{\mathrm{GqqN1:QqN1}} = & \sigma_{\mathrm{GQ}} \cdot BR \cdot \mathcal{L} \\ \vdots & \end{cases}$$







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

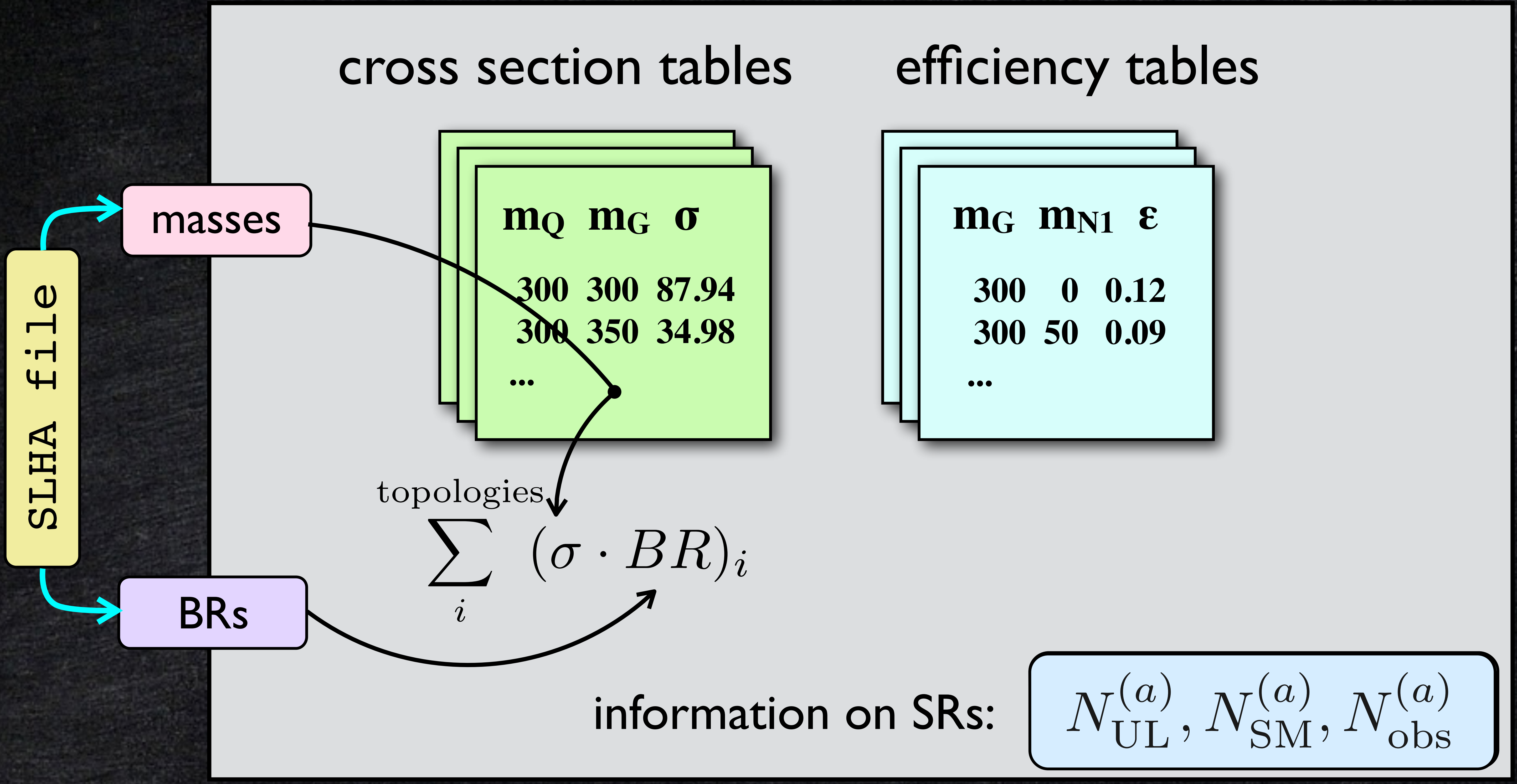
m_G	m_{N1}	ε
300	0	0.12
300	50	0.09
...		

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

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

Fastlim

Papucci, KS, Weiler, Zeune 1402.0492



SLHA file

masses

BRs

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
...		

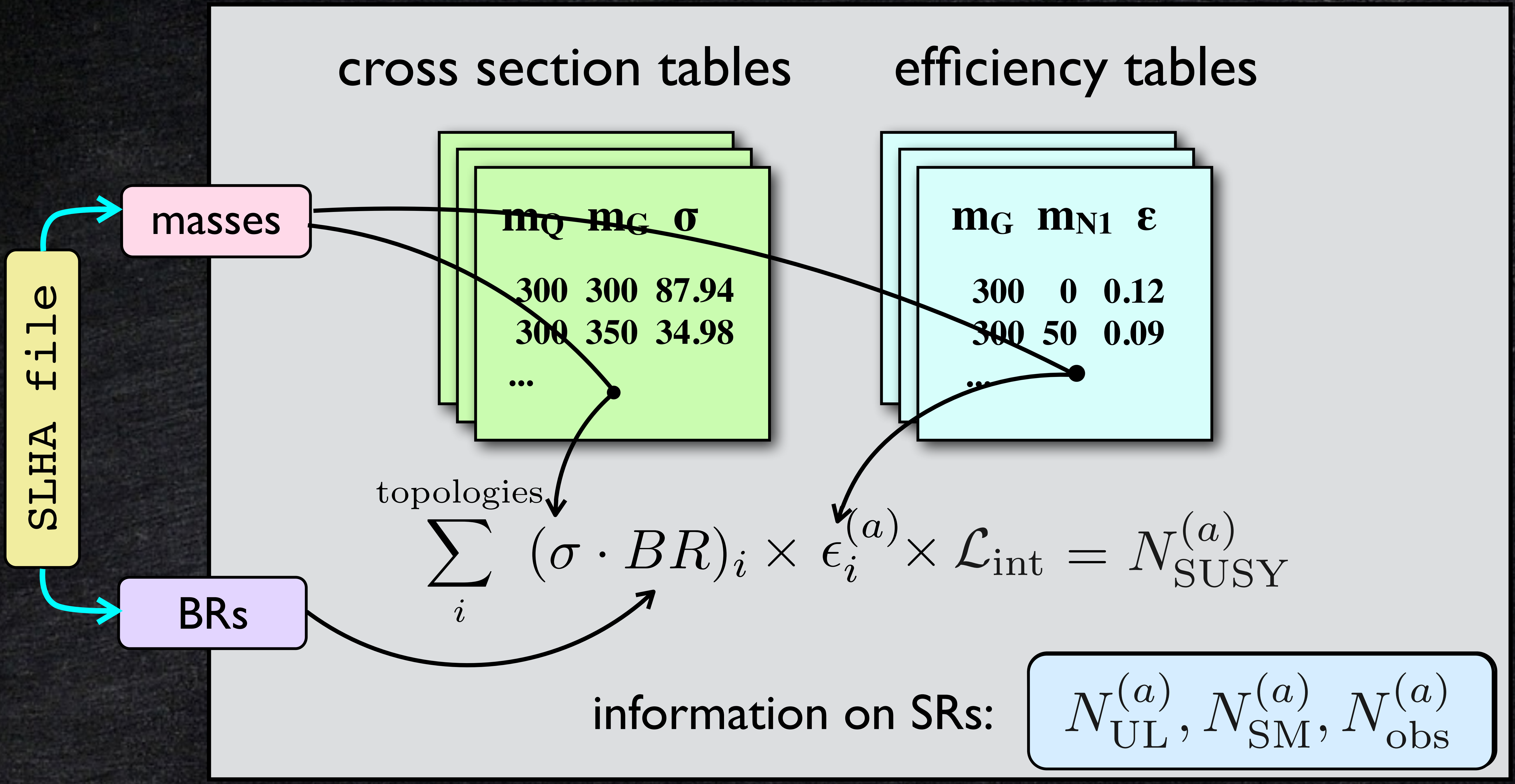
$$\sum_{i}^{\text{topologies}} (\sigma \cdot BR)_i$$

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

Fastlim

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

Papucci, KS, Weiler, Zeune 1402.0492



SLHA file

masses

BRs

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
...		

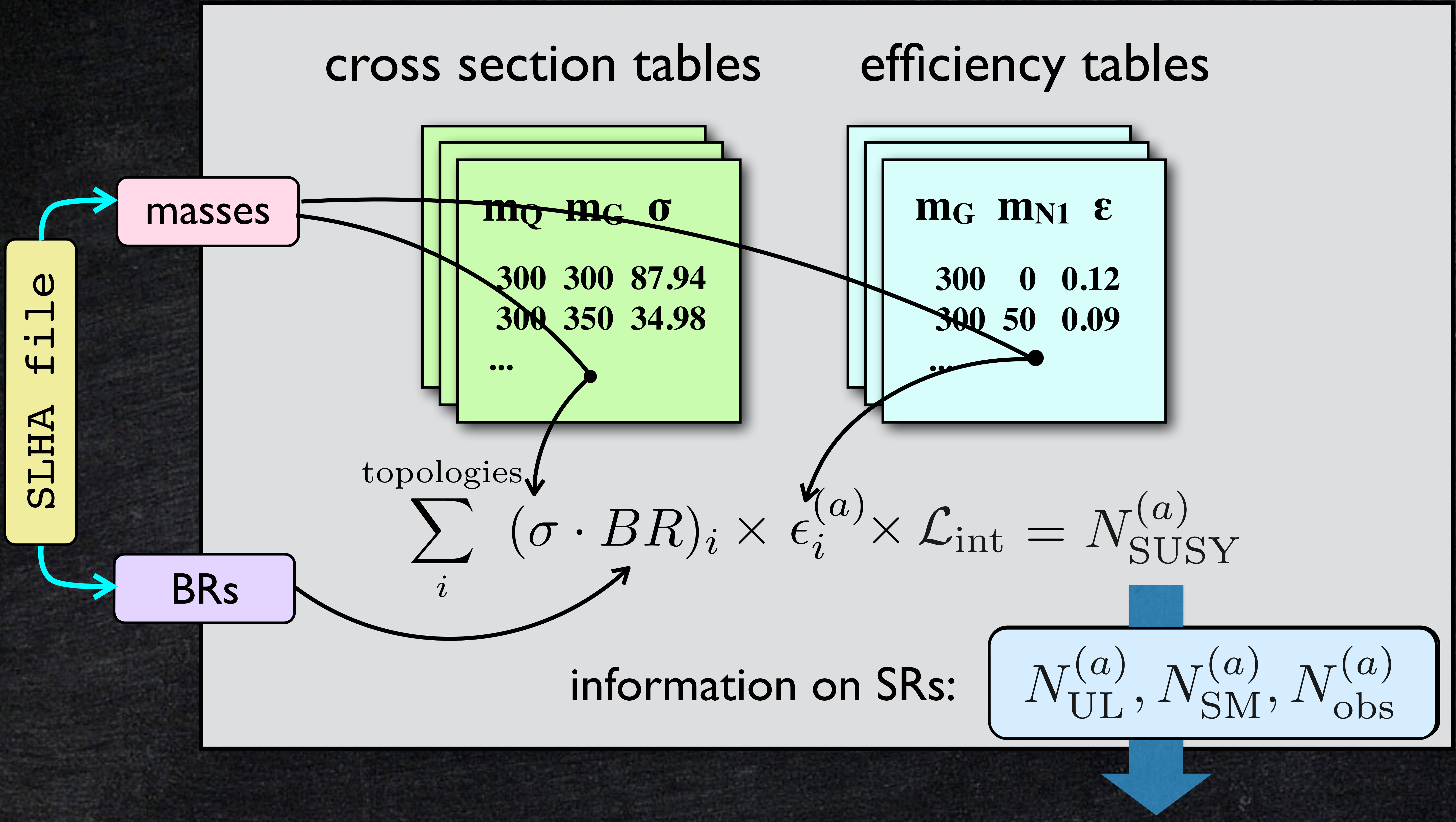
$$\sum_{i}^{\text{topologies}} (\sigma \cdot BR)_i \times \epsilon_i^{(a)} \times \mathcal{L}_{\text{int}} = N_{\text{SUSY}}^{(a)}$$

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

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

Fastlim

Papucci, KS, Weiler,
Zeune 1402.0492



SLHA file

masses

BRs

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
...		

$$\sum_{i}^{\text{topologies}} (\sigma \cdot BR)_i \times \epsilon_i^{(a)} \times \mathcal{L}_{\rm int} = N^{(a)}_{\rm SUSY}$$

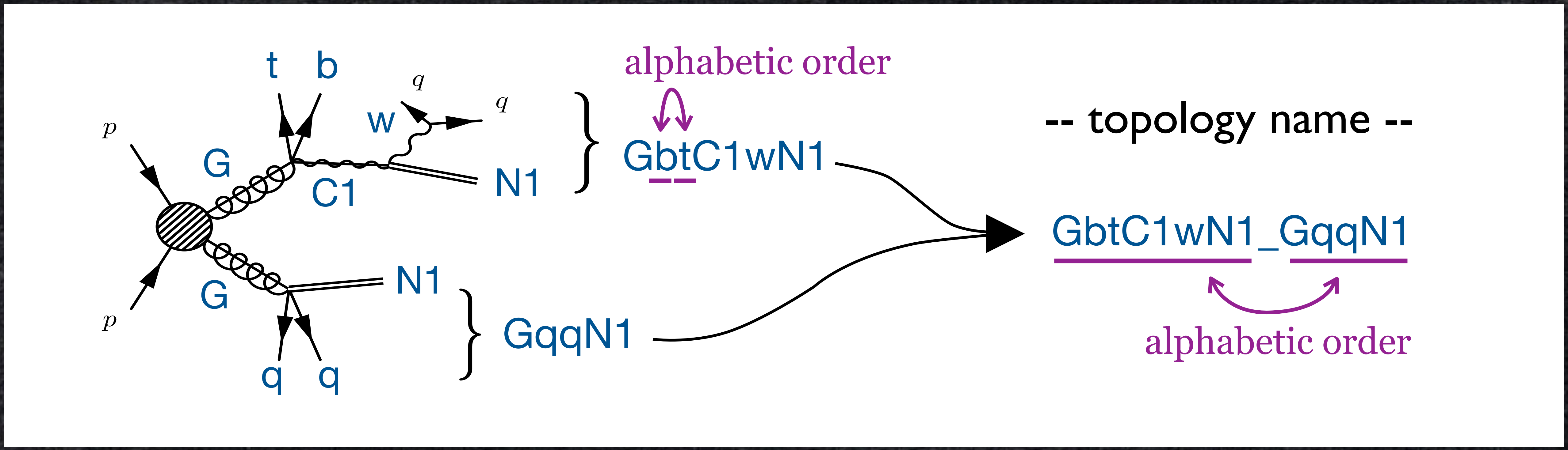
information on SRs: $N^{(a)}_{\rm UL}, N^{(a)}_{\rm SM}, N^{(a)}_{\rm obs}$

No MC sim. required

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

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



alphabetic order

GbtC1wN1

GqqN1

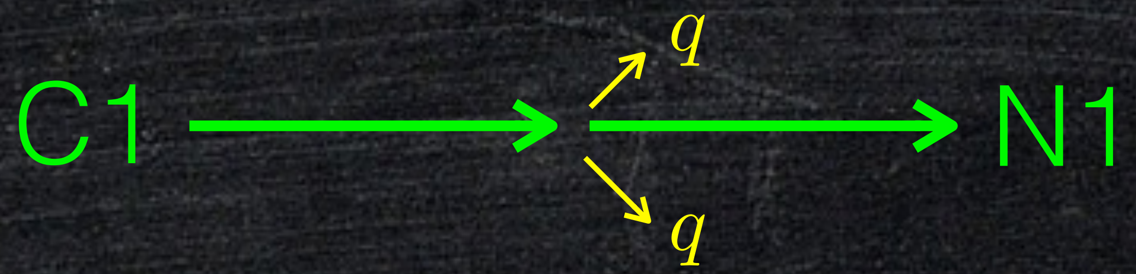
-- topology name --

GbtC1wN1_GqqN1

alphabetic order

Truncation of soft decays

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



very soft and do not affect efficiencies

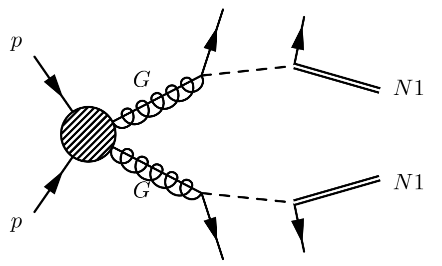
G→btC1→qqN1 ⇨ GbtN1

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

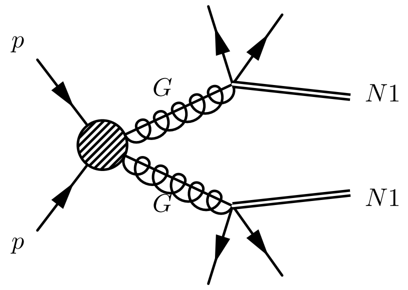
useful for wino and higgsino scenarios

Implemented topologies

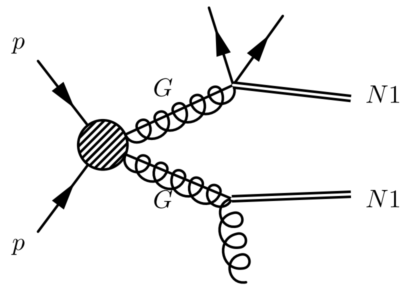
topologies in Fastlim 1.0



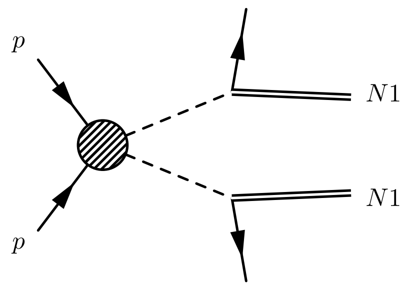
GbB1bN1_GbB1bN1
GbB1bN1_GbB1tN1
GbB1tN1_GbB1tN1
GtT1bN1_GtT1bN1
GtT1bN1_GtT1tN1
GtT1tN1_GtT1tN1
(GbB2bN1_GbB2bN1)
(GbB2bN1_GbB2tN1)
(GbB2tN1_GbB2tN1)
(GtT2bN1_GtT2bN1)
(GtT2bN1_GtT2tN1)
(GtT2tN1_GtT2tN1)
[GbB1bN1_GbB2bN1]
[GbB1bN1_GbB2tN1]
[GbB1tN1_GbB2bN1]
[GbB1tN1_GbB2tN1]
[GtT1bN1_GtT2bN1]
[GtT1bN1_GtT2tN1]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

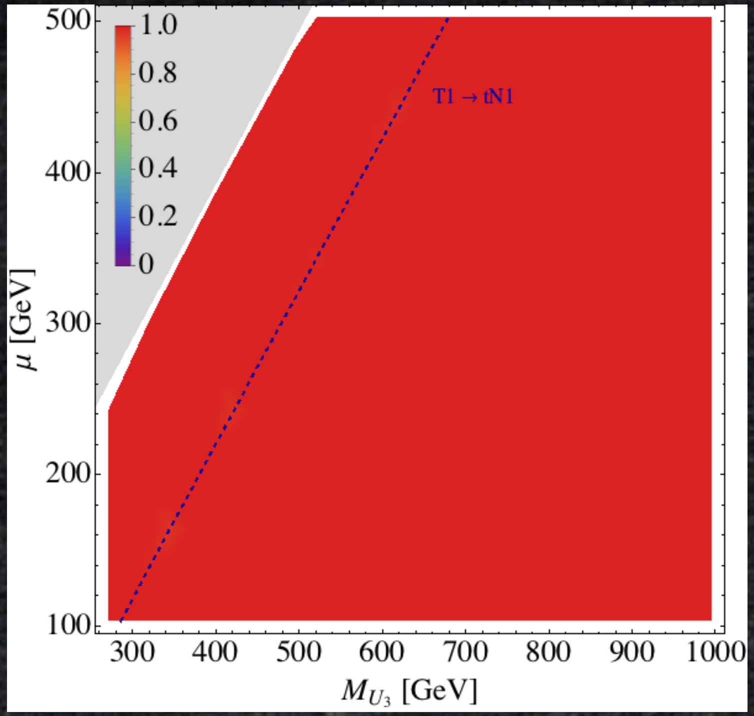
↓

the result may be underestimated but at least conservative

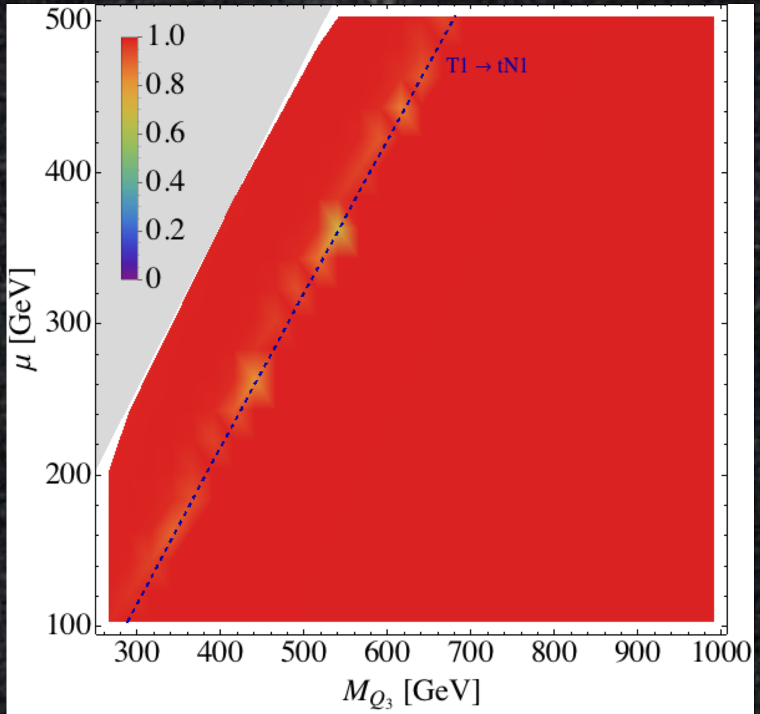
Coverage

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

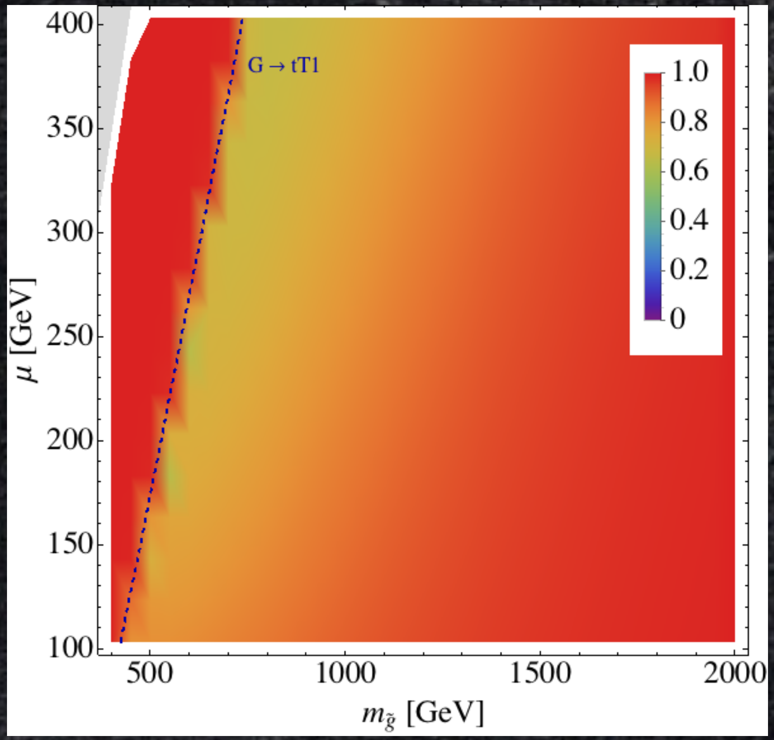
M_{U_3} vs. μ



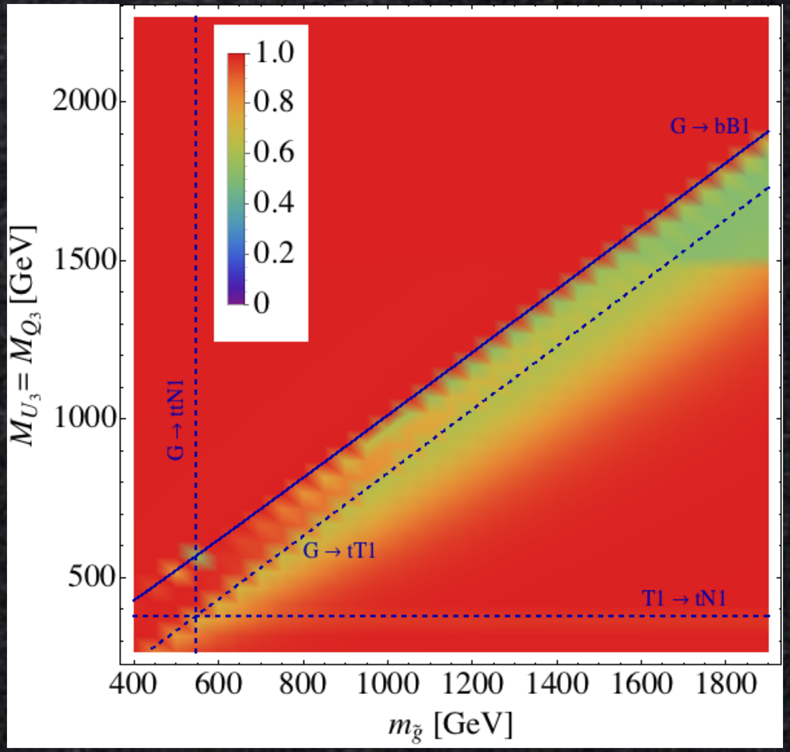
M_{Q_3} vs. μ



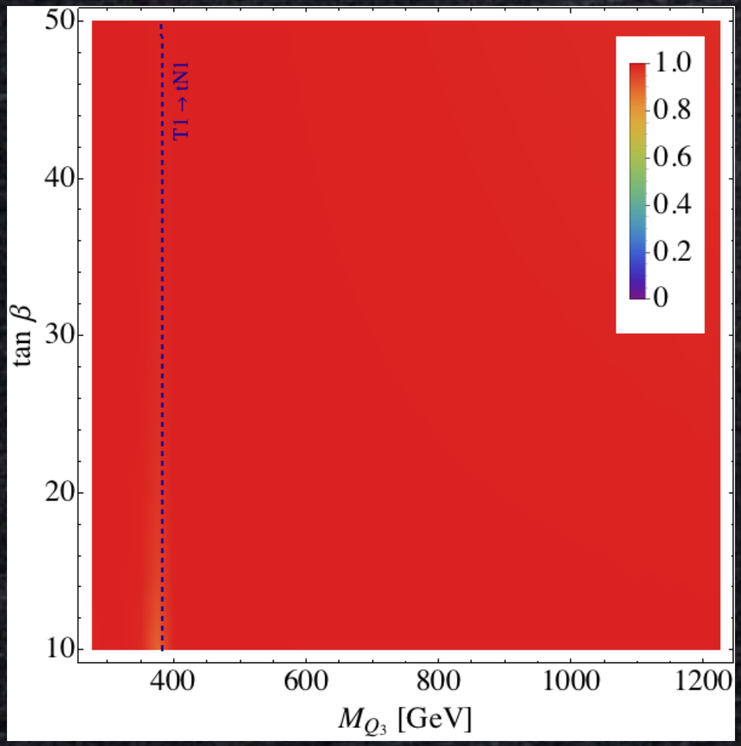
$M_{\tilde{g}}$ vs. μ



$M_{\tilde{g}}$ vs. $M_{U_3} (= M_{Q_3})$



M_{Q_3} vs. $\tan\beta$



Overall, very good coverage

The main deficit come from

GtT1tN1_GbB1bN1

T1->qqB1

Implemented analyses

analyses in Fastlim-1.0

Name	Short description	$E_{\rm CM}$	$\mathcal{L}_{\rm int}$	# 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

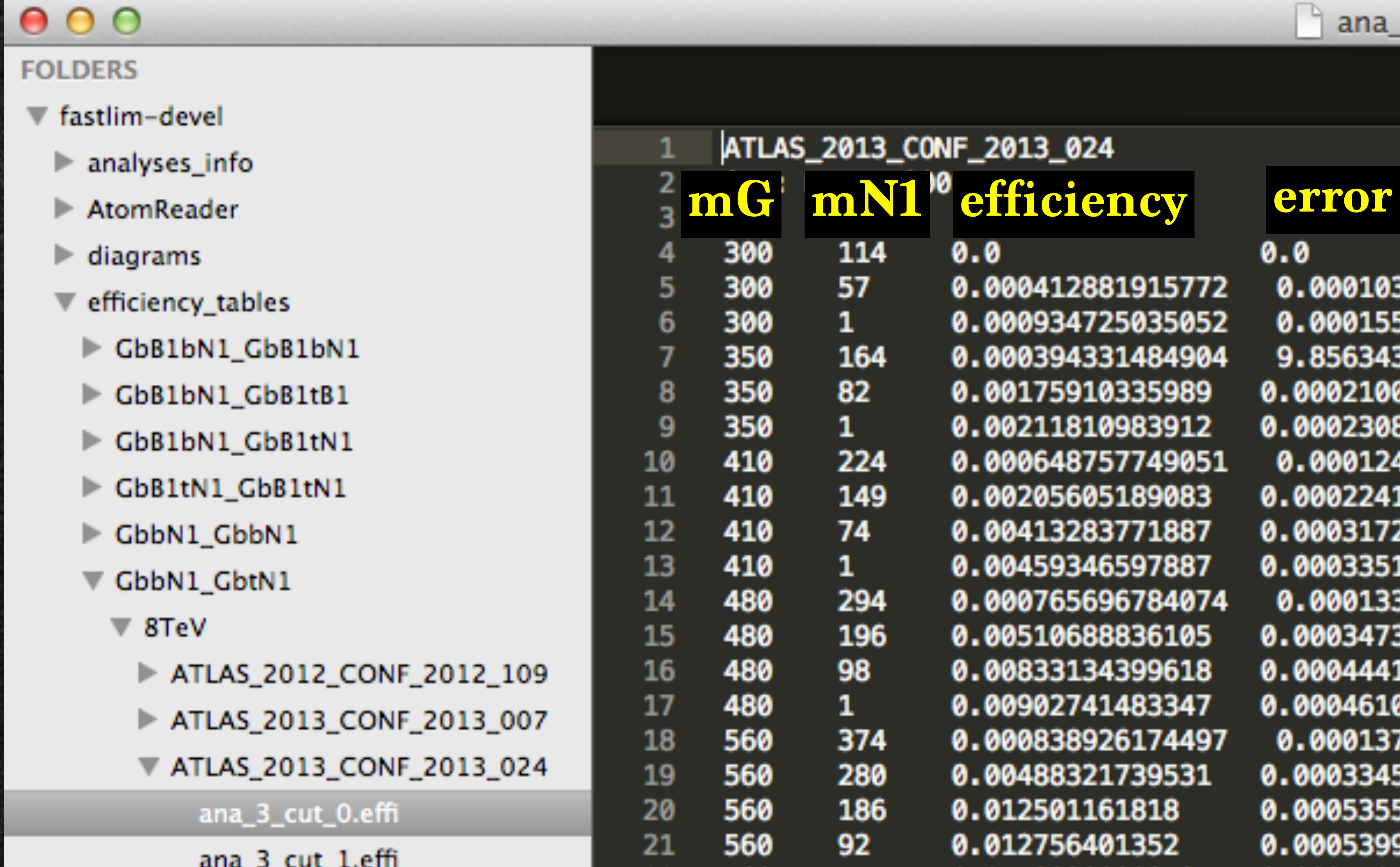
- Most 2013 ATLAS analyses are implemented (CMS analyses will be implemented soon).
- Event generation was done using MadGraph 5. The sample include up to extra 1 parton emission at ME level, matched to parton shower using MLM scheme.
- ATOM is used for efficiency estimation.

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/



- fastlim-devel
  - analyses_info
  - AtomReader
  - diagrams
  - efficiency_tables
    - GbB1bN1_GbB1bN1
    - GbB1bN1_GbB1tB1
    - GbB1bN1_GbB1tN1
    - GbB1tN1_GbB1tN1
    - GbbN1_GbbN1
    - GbbN1_GbtN1
      - 8TeV
        - ATLAS_2012_CONF_2012_109
        - ATLAS_2013_CONF_2013_007
        - ATLAS_2013_CONF_2013_024
          - ana_3_cut_0.effi
          - ana_3_cut_1.effi

ATLAS_2013_CONF_2013_024

mG	mN1	efficiency	error
300	114	0.0	0.0
300	57	0.000412881915772	0.000103
300	1	0.000934725035052	0.000155
350	164	0.000394331484904	9.856343
350	82	0.00175910335989	0.0002100
350	1	0.00211810983912	0.0002308
410	224	0.000648757749051	0.000124
410	149	0.00205605189083	0.0002241
410	74	0.00413283771887	0.0003172
410	1	0.00459346597887	0.0003351
480	294	0.000765696784074	0.000133
480	196	0.00510688836105	0.0003473
480	98	0.00833134399618	0.0004441
480	1	0.00902741483347	0.0004610
560	374	0.000838926174497	0.000137
560	280	0.00488321739531	0.0003345
560	186	0.012501161818	0.0005355
560	92	0.012756401352	0.0005399

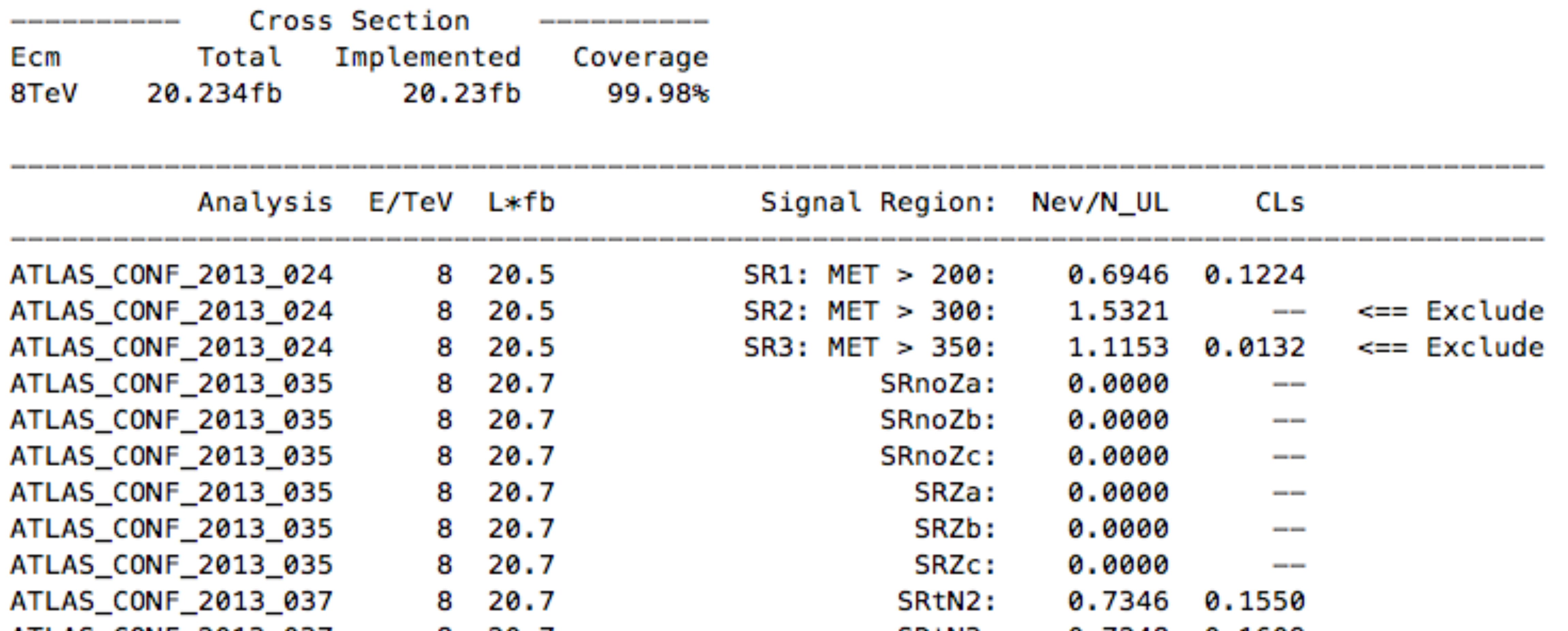
How to use?

① download the program from: http://fastlim.web.cern.ch/fastlim/

② untar and enter the fastlim-1.0 directory

③ type (assuming the input file name is input.slha):

```
./fastlim  input.slha
```



```
----------      Cross Section     ----------
Ecm          Total   Implemented    Coverage
8TeV      20.234fb       20.23fb      99.98%


------------------------------------------------------------------------------------------
           Analysis  E/TeV  L*fb               Signal Region:  Nev/N_UL     CLs
------------------------------------------------------------------------------------------
ATLAS_CONF_2013_024      8  20.5            SR1: MET > 200:     0.6946   0.1224
ATLAS_CONF_2013_024      8  20.5            SR2: MET > 300:     1.5321       --   <== Exclude
ATLAS_CONF_2013_024      8  20.5            SR3: MET > 350:     1.1153   0.0132   <== Exclude
ATLAS_CONF_2013_035      8  20.7                    SRnoZa:     0.0000       --
ATLAS_CONF_2013_035      8  20.7                    SRnoZb:     0.0000       --
ATLAS_CONF_2013_035      8  20.7                    SRnoZc:     0.0000       --
ATLAS_CONF_2013_035      8  20.7                      SRZa:     0.0000       --
ATLAS_CONF_2013_035      8  20.7                      SRZb:     0.0000       --
ATLAS_CONF_2013_035      8  20.7                      SRZc:     0.0000       --
ATLAS_CONF_2013_037      8  20.7                     SRtN2:     0.7346   0.1550
```

Summary

- One can test any model confronting with the existing ATLAS/CMS analyses using **ATOM** and **Fastlim**.
- In this way, one can derive the constraints and can fit the excesses.
  => Rolbiecki's talk on Tuesday, for a concrete example.
- ATOM takes event files as inputs and works for any BSM models. (Soon to be public)
- Fastlim takes SLHA files as inputs and runs very fast. (Already public, download from http://fastlim.web.cern.ch/fastlim)

Backup

Natural SUSY

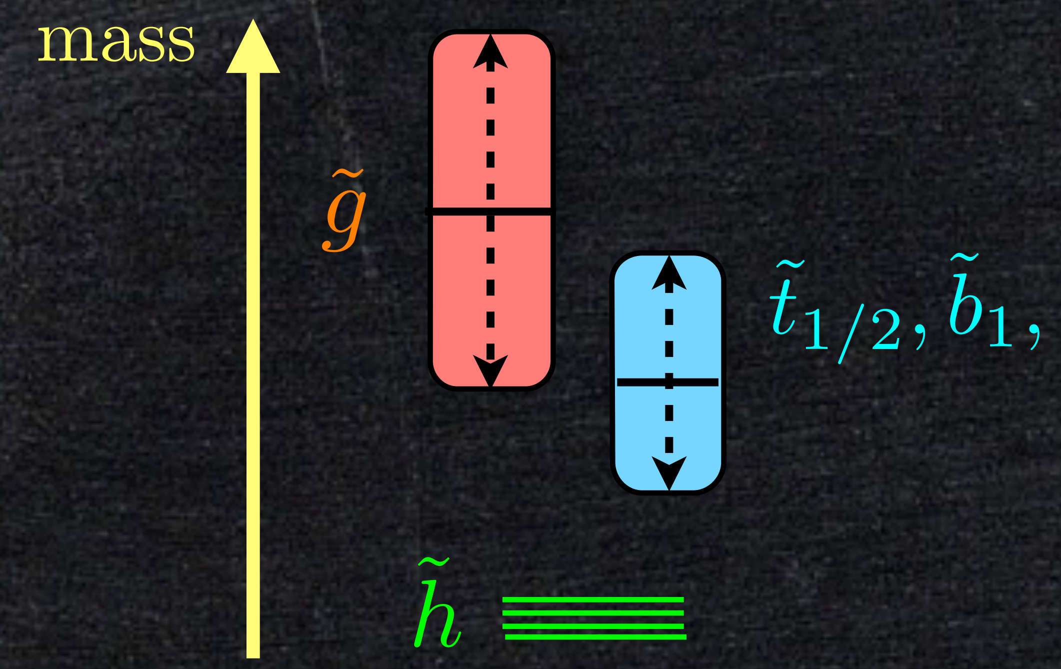
- Natural SUSY contains a minimum particle content that makes the EWSB natural.

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

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

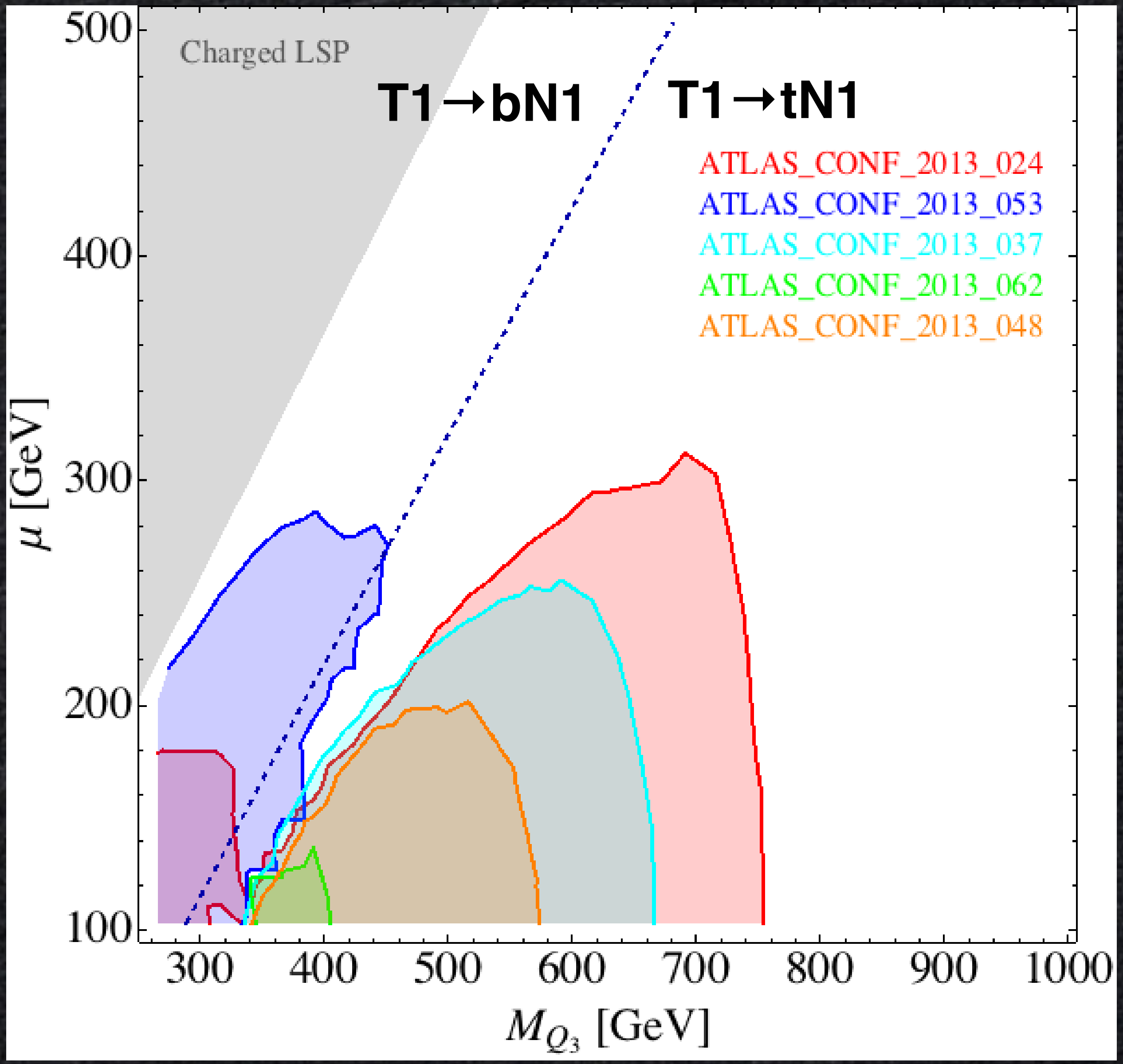
M_{Q3} vs μ

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

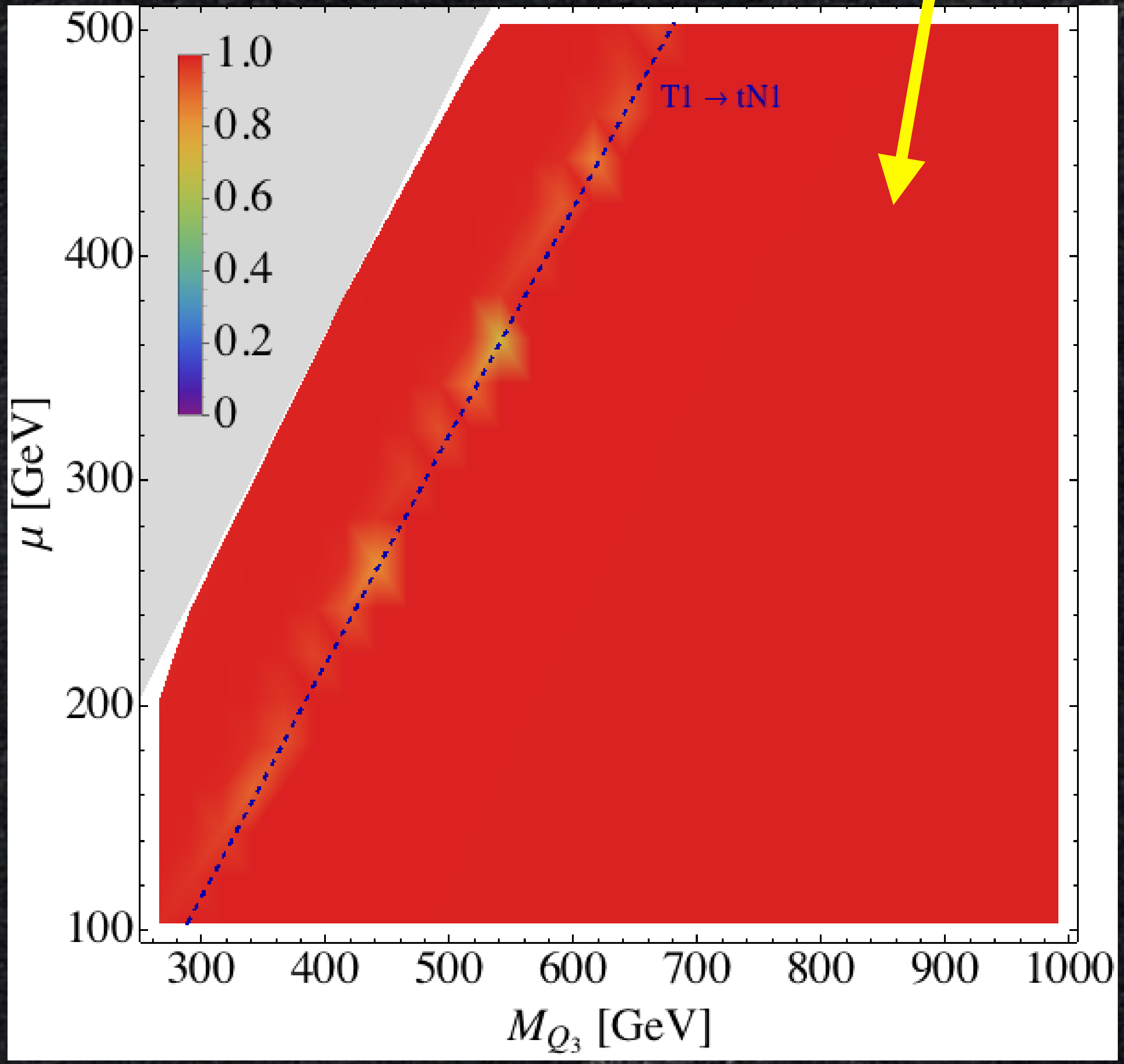
$$\text{coverage} = \frac{\sigma^{\text{implimented}}}{\sigma_{\text{tot}}}$$

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

$\tan\beta = 10$



good coverage



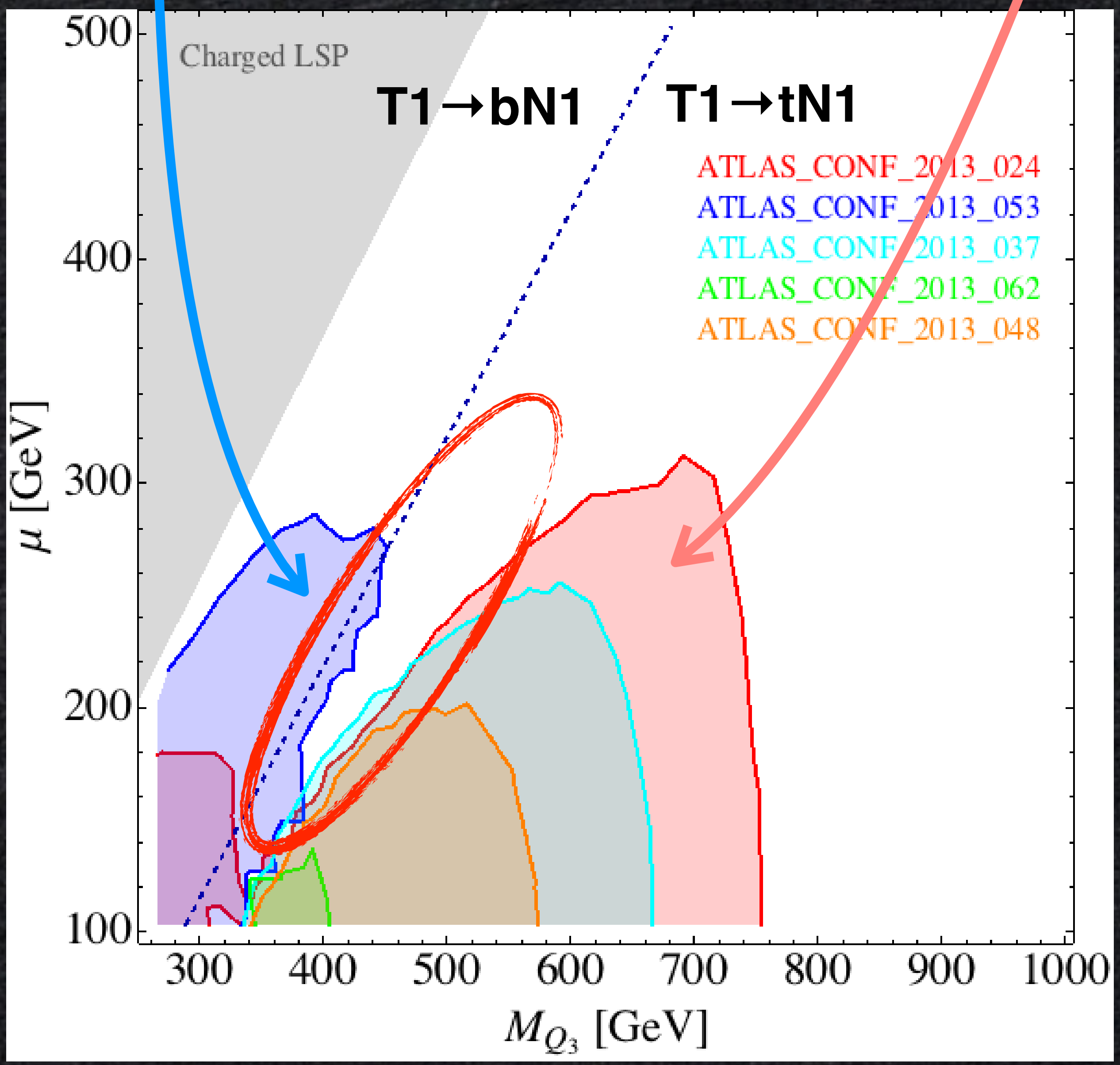
M_{Q3} vs μ

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

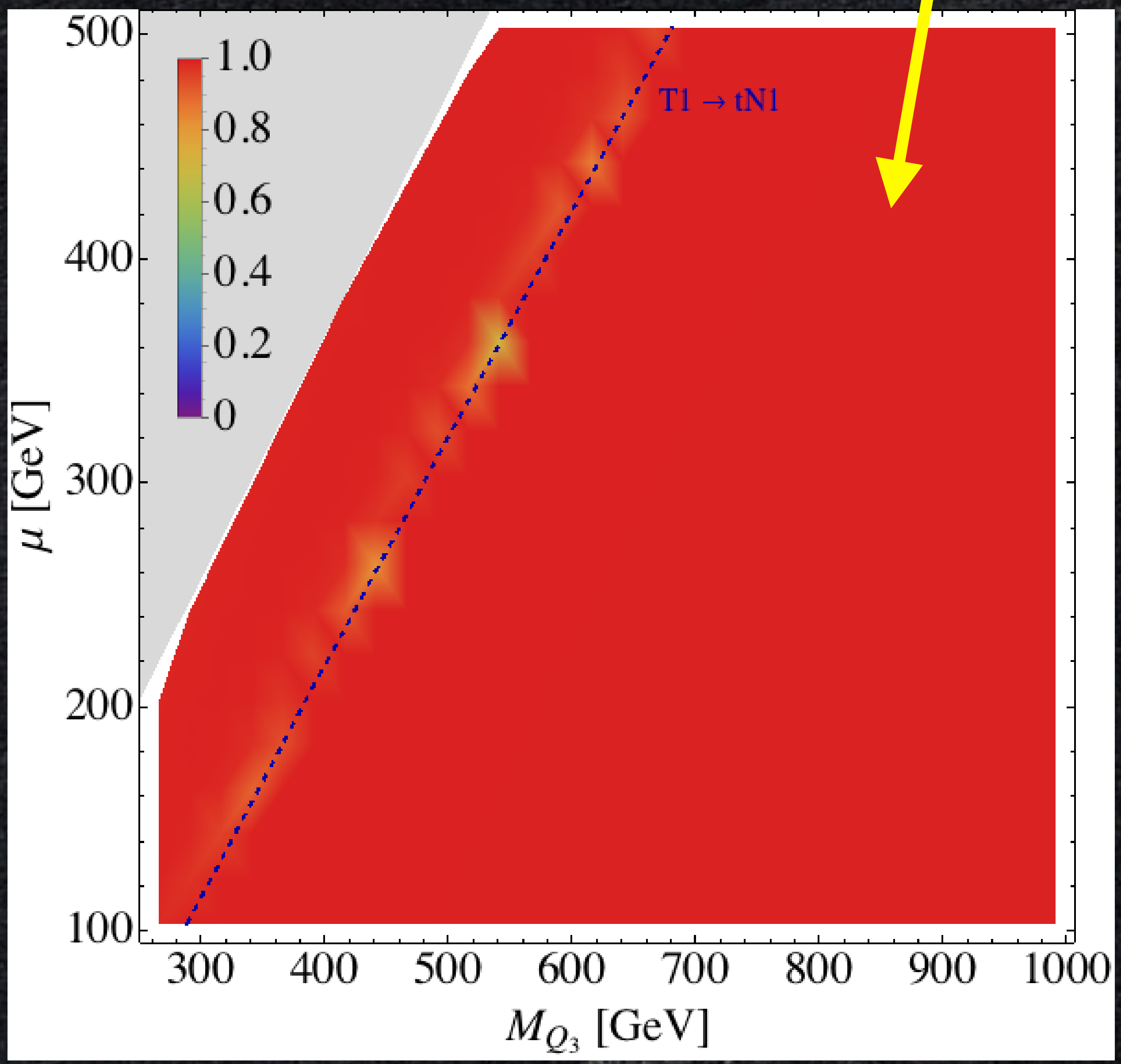
for B1→bN1 topology

designed for T1→tN1 topology

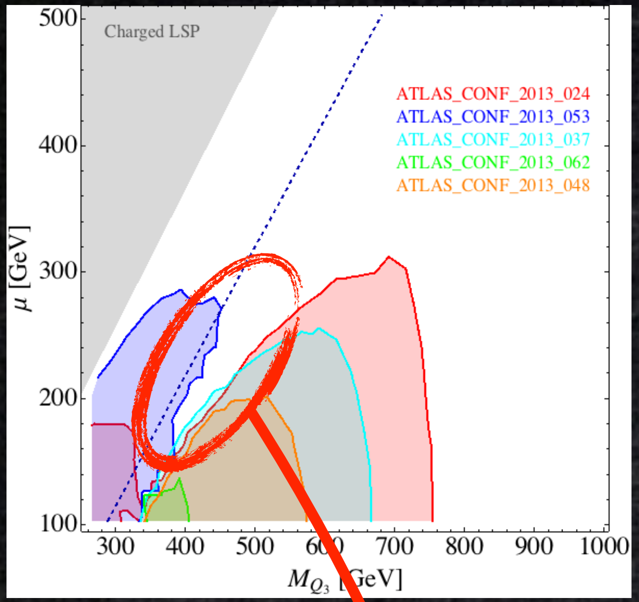
$\tan\beta = 10$



good coverage



M_{Q3} vs tanβ

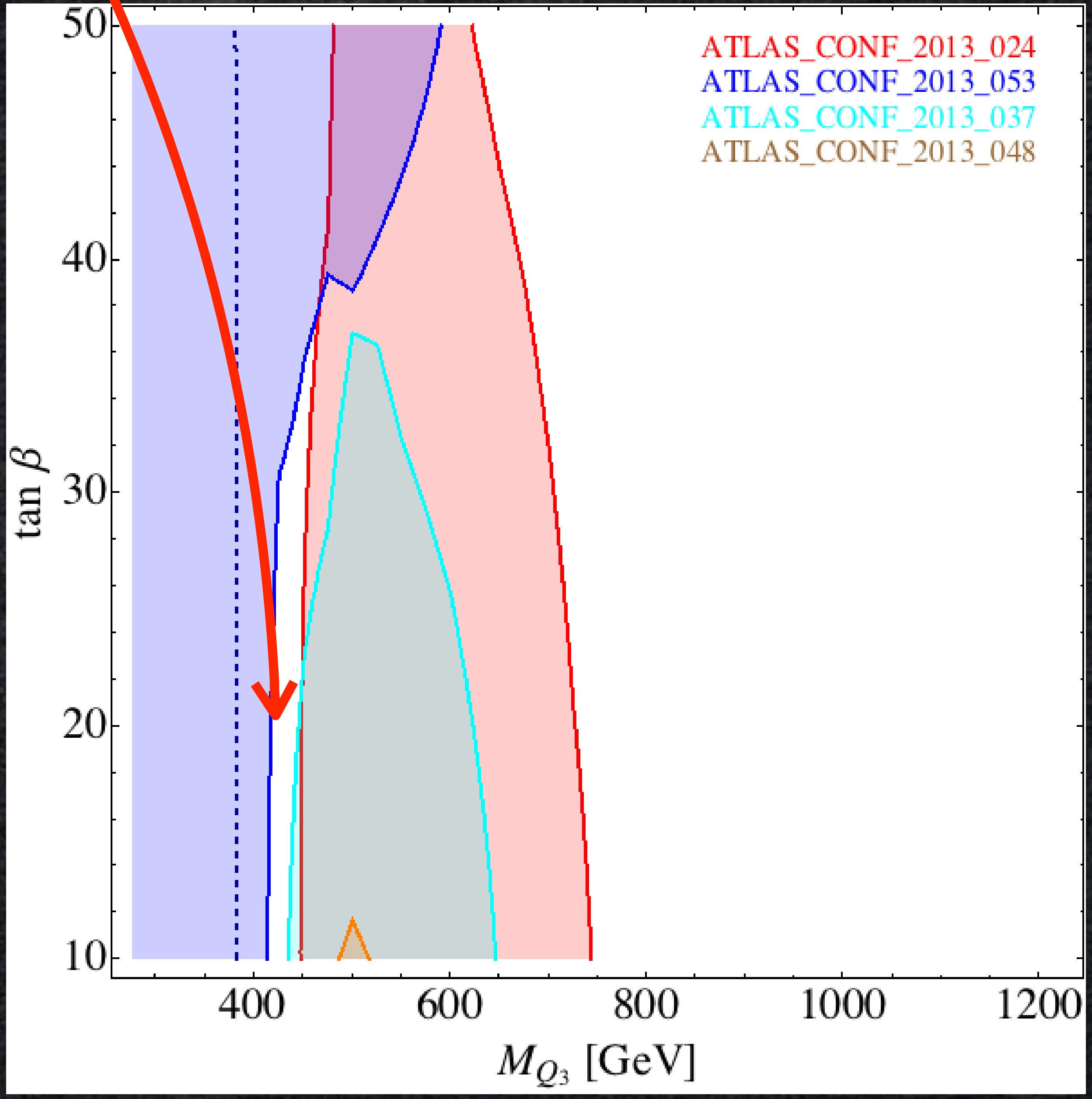


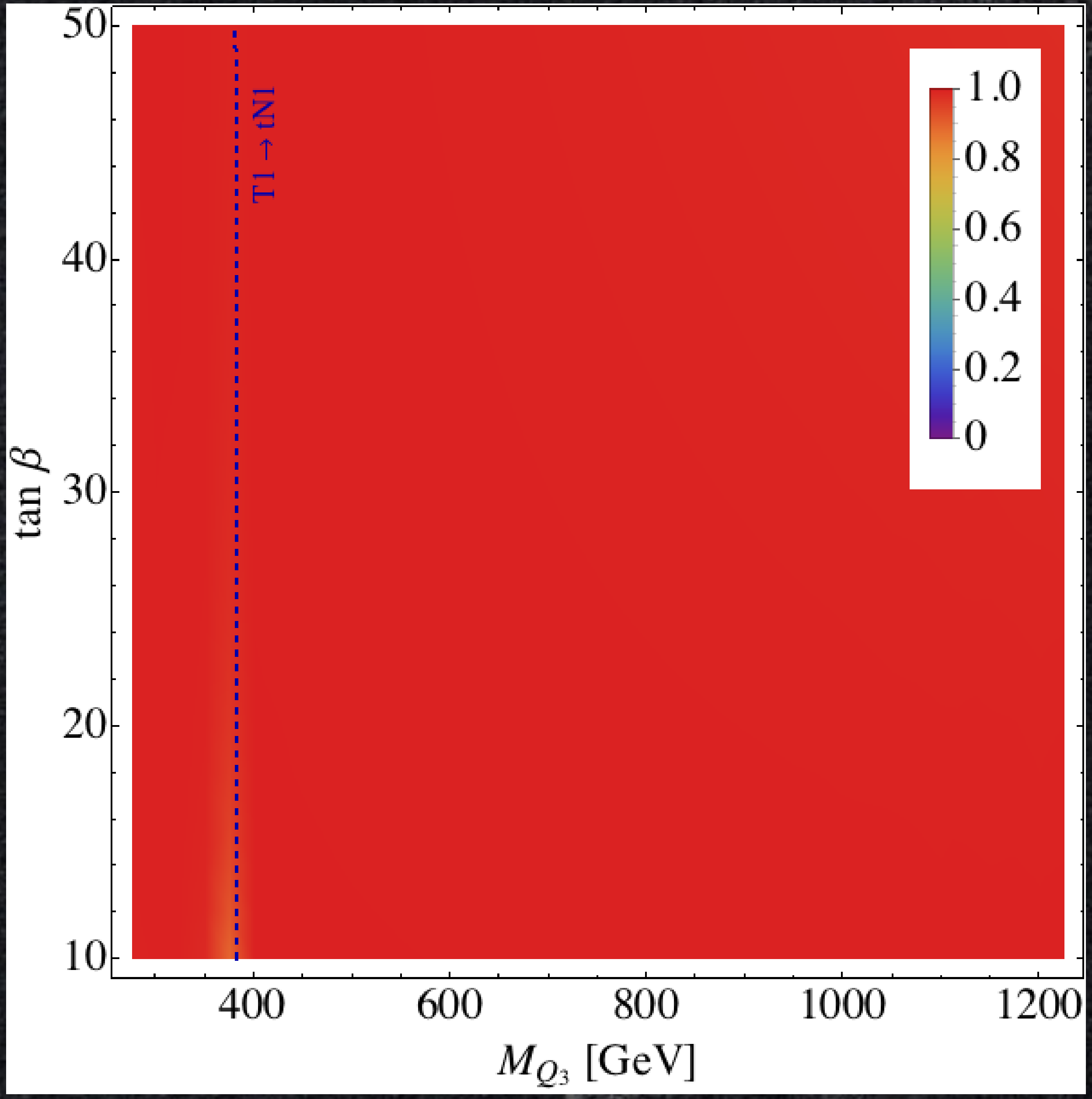
$$\mathcal{L} \supset y_t \cdot t_R \widetilde{Q}_3 \widetilde{H}_u + \underline{y_b} \cdot b_R \widetilde{Q}_3 \widetilde{H}_d$$

tanβ enhancement

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

$\mu = 200\text{GeV}$





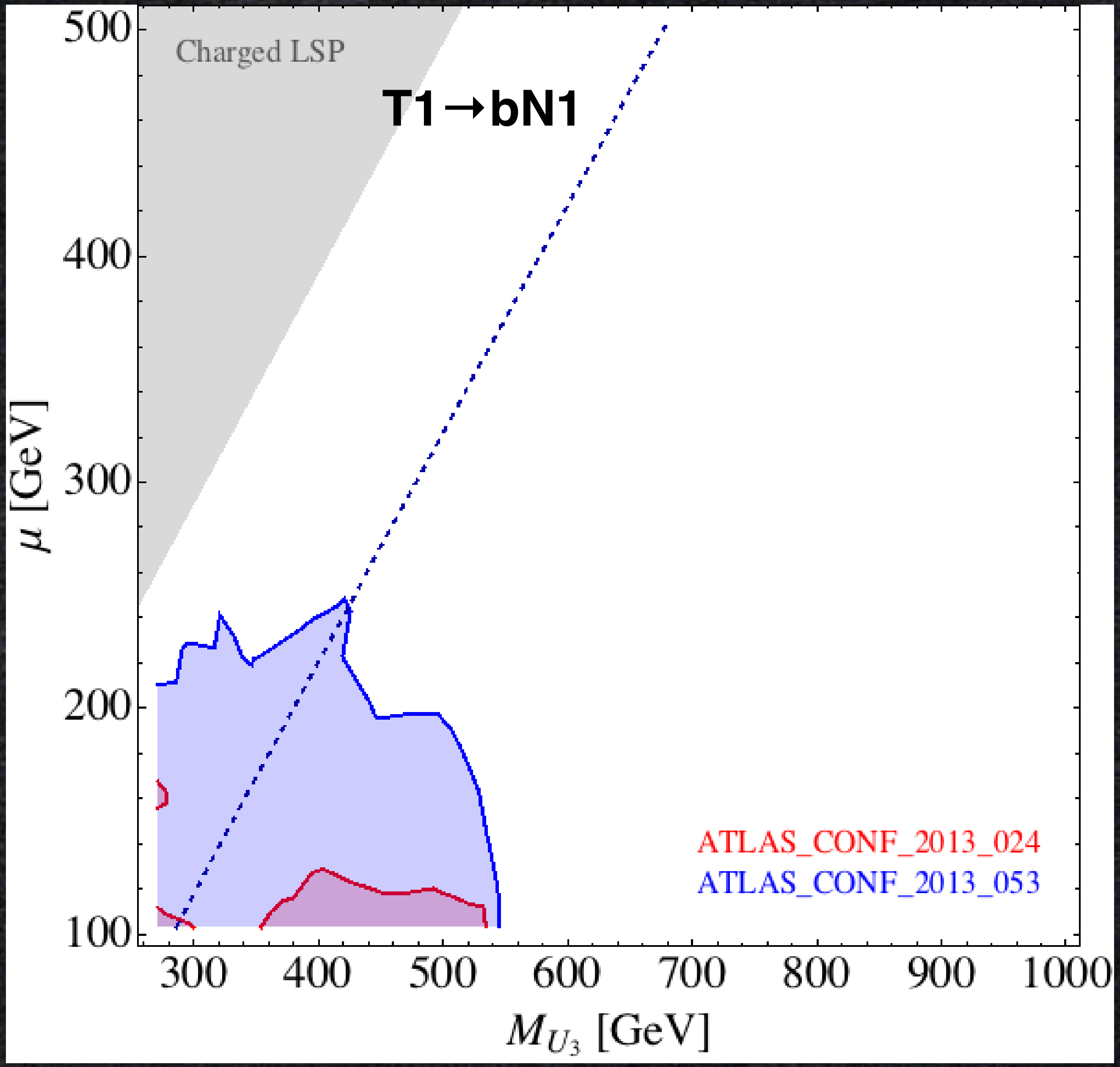
M_{U3} vs μ

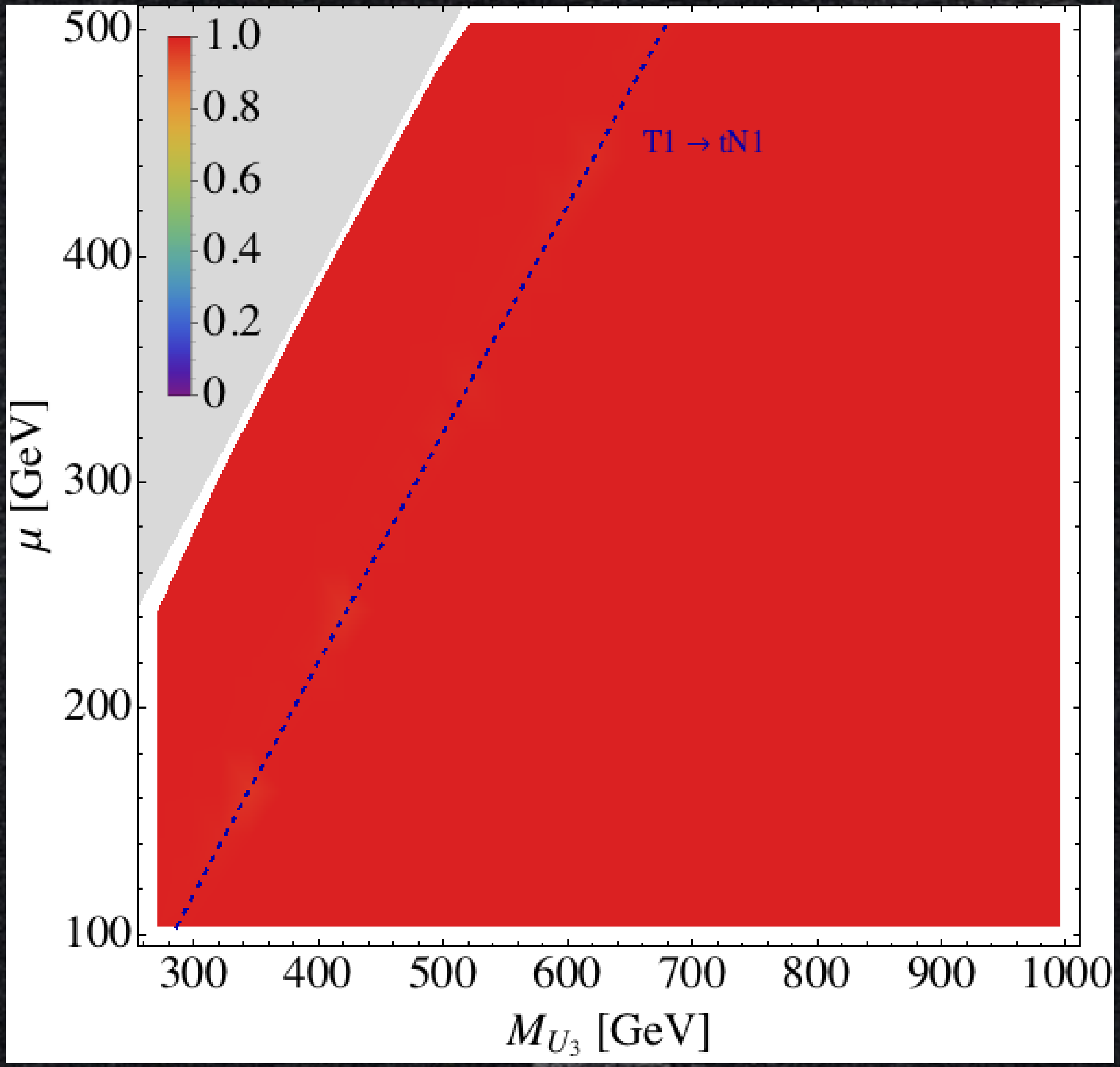
$$\mathcal{L} \supset y_t \cdot \widetilde{t}_R Q_3 \widetilde{H}_u$$

BR(T1bN1_T1tN1) > BR(T1bN1_T1bN1) > BR(T1tN1_T1tN1)

asymmetric topology

$\tan\beta = 10$





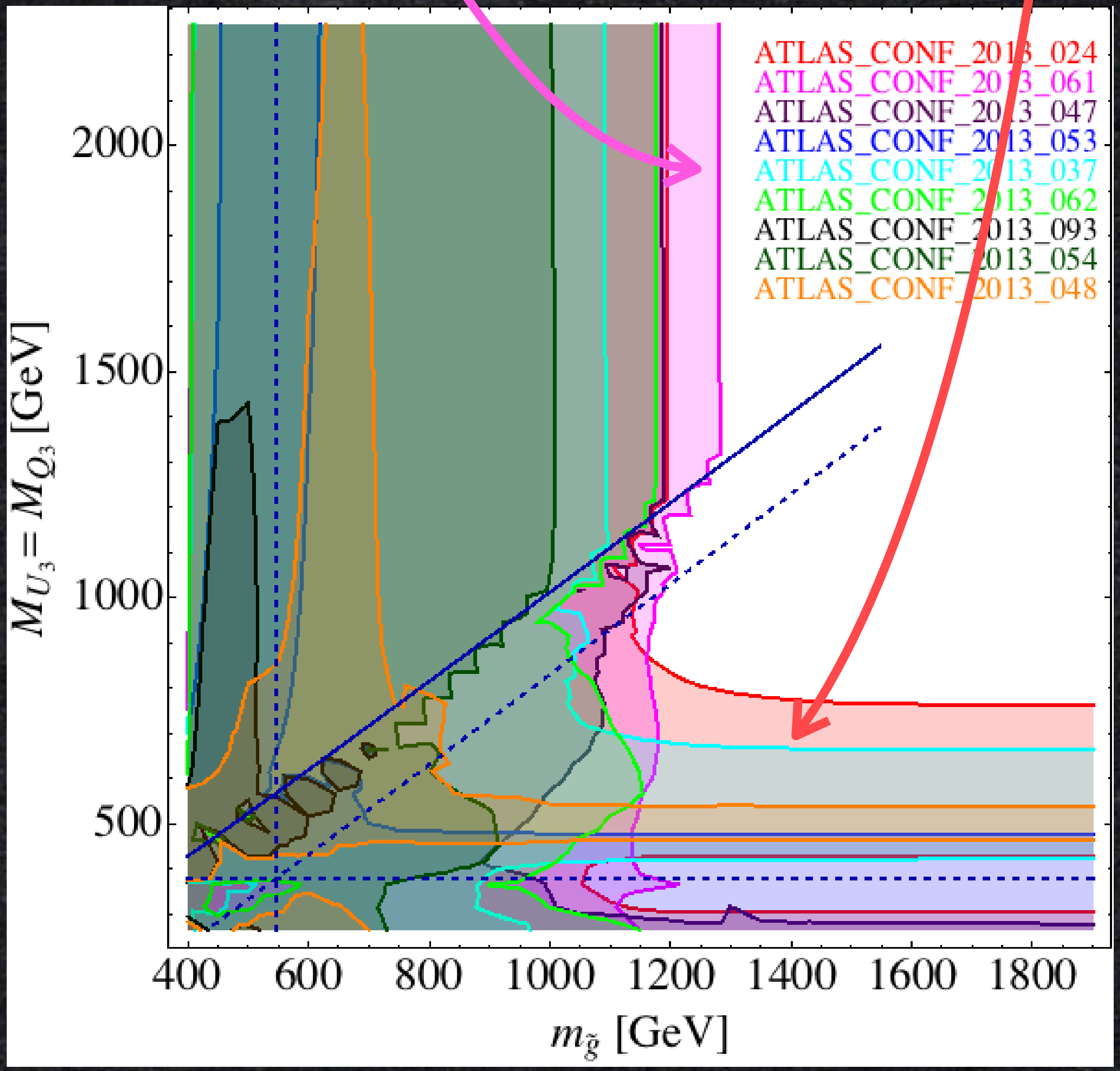
M_G vs M_{Q3}

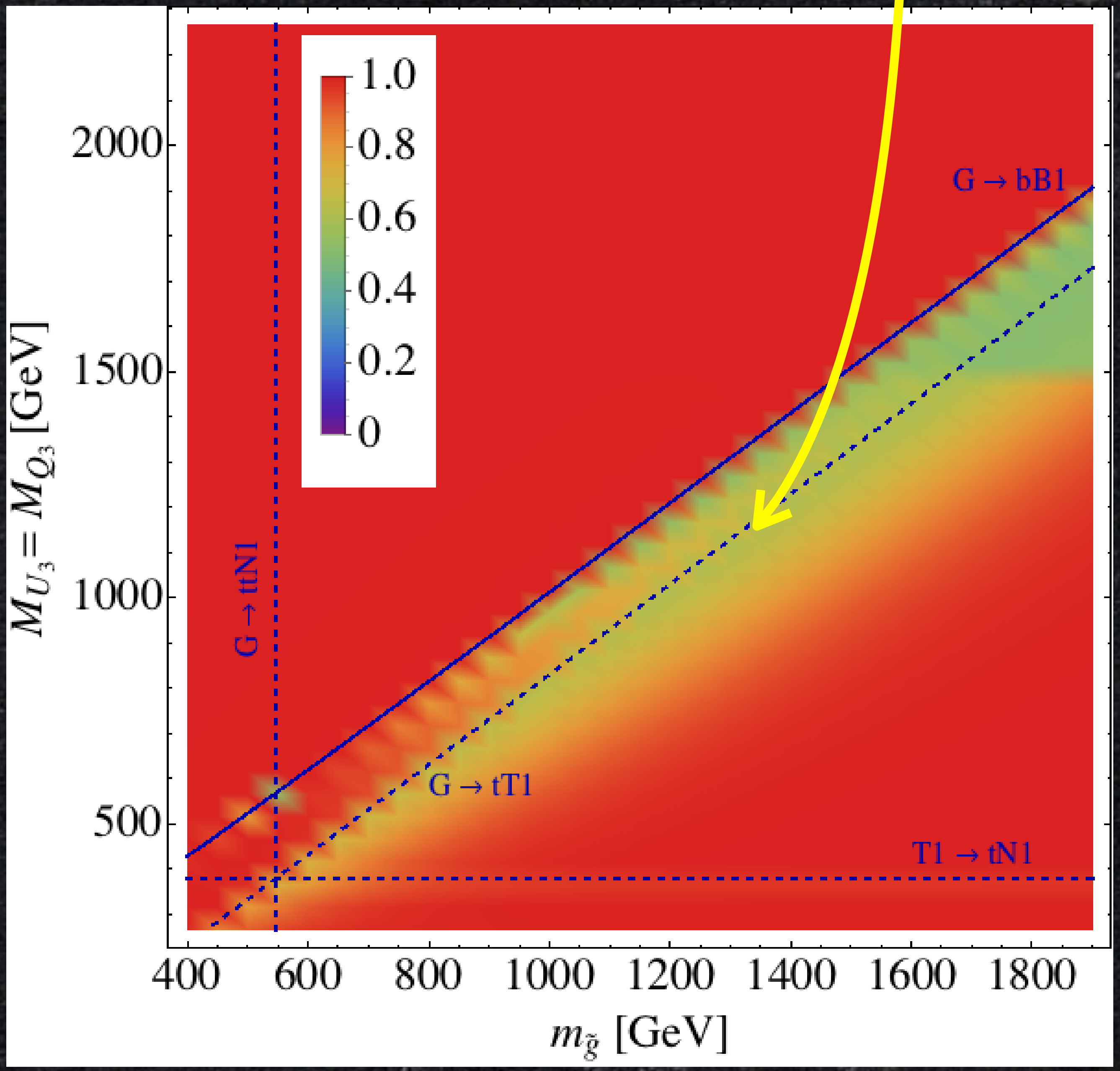
designed for G→ffN1

for T1→tN1

T1→qqB1 via W* &
GtT1tN1_GbB1bN1 (4D)

$\mu = 200\text{GeV}$



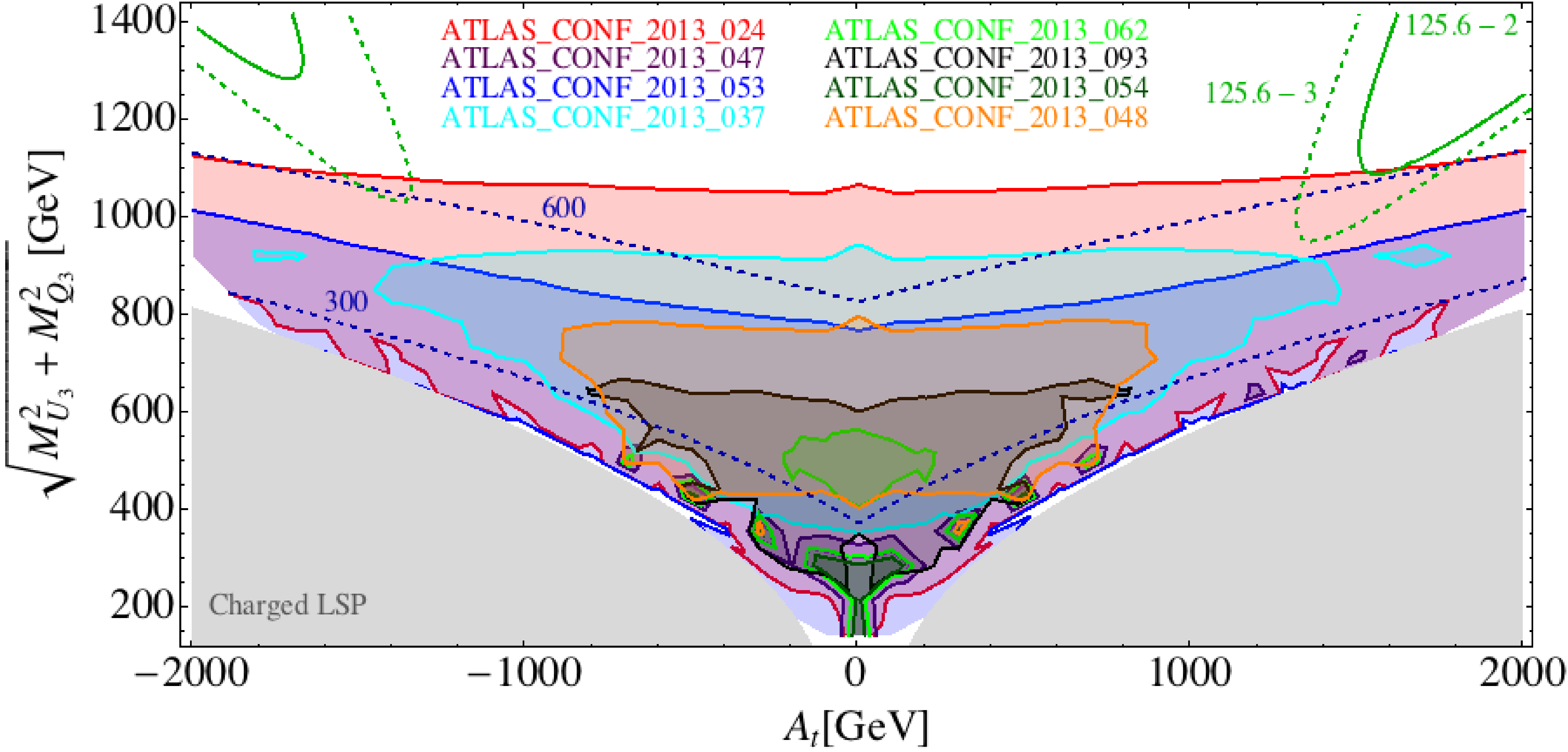


A_t vs $M_{Q,U3}$

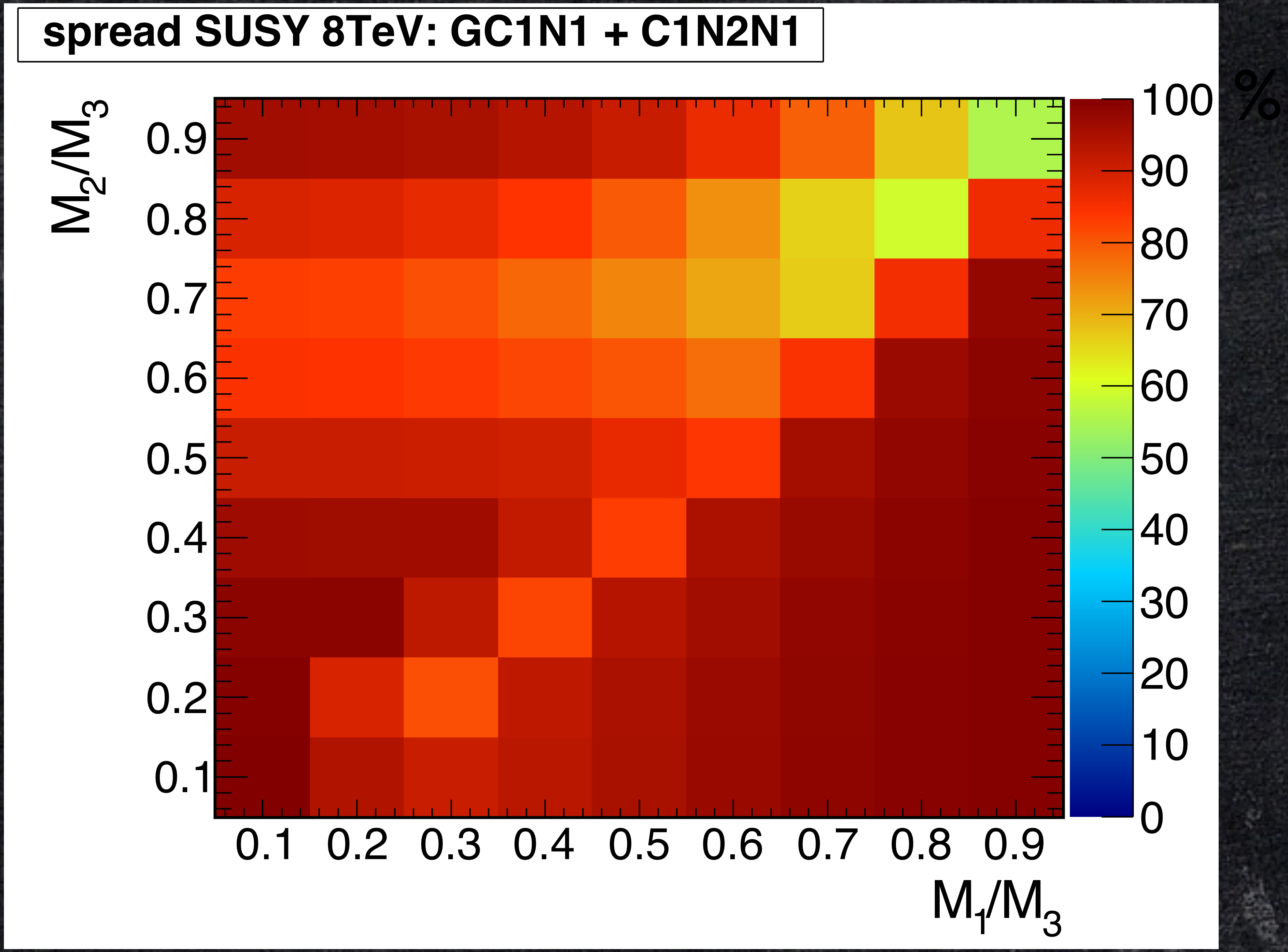
- distance from the origin is sensitive to the fine-tuning

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

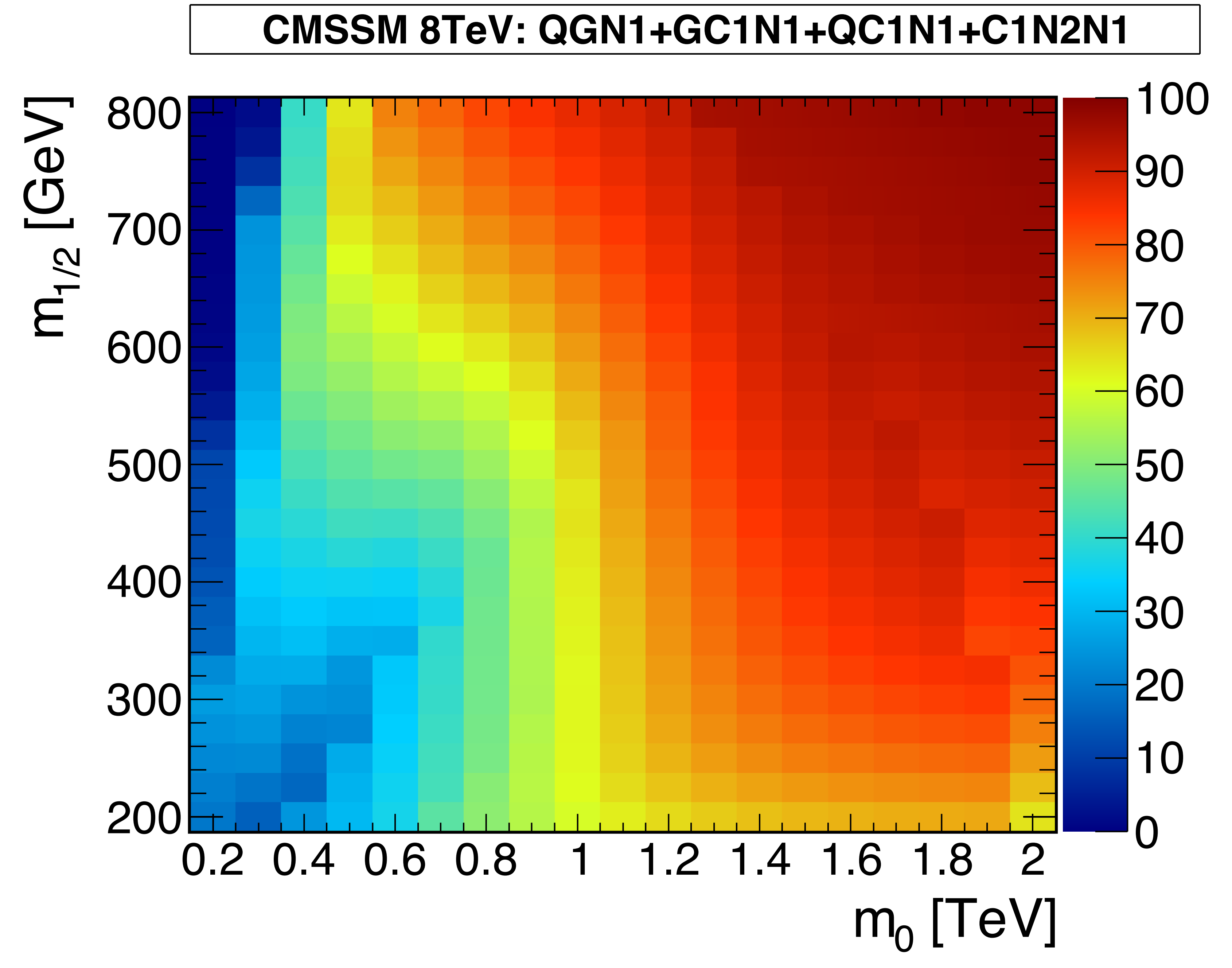
$\mu = 100\text{GeV},\ M_{Q_3} = M_{U_3}$



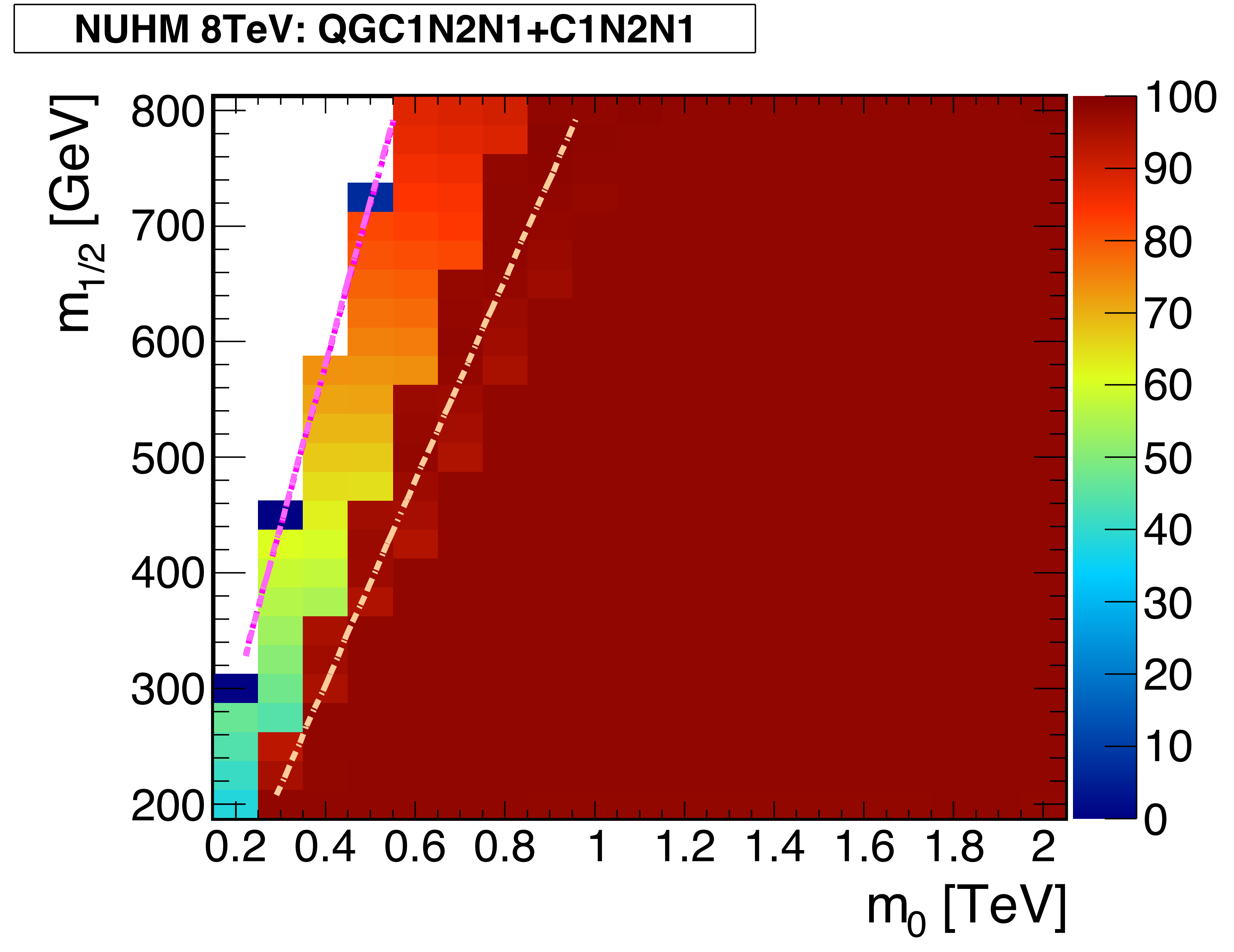
Split SUSY


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
%

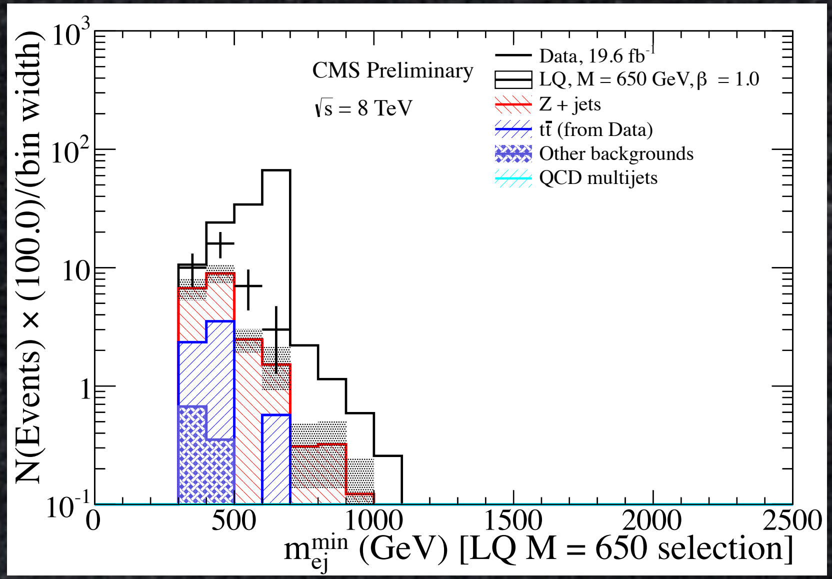
CMSSM

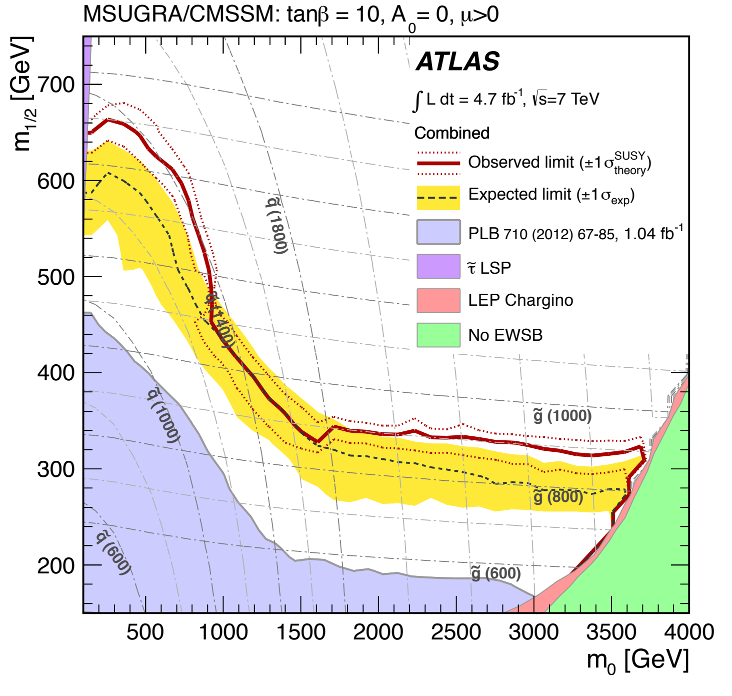

CMSSM 8TeV: QGN1+GC1N1+QC1N1+C1N2N1
$m_{1/2}$ [GeV]
800
700
600
500
400
300
200
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
m_0 [TeV]
100
90
80
70
60
50
40
30
20
10
0

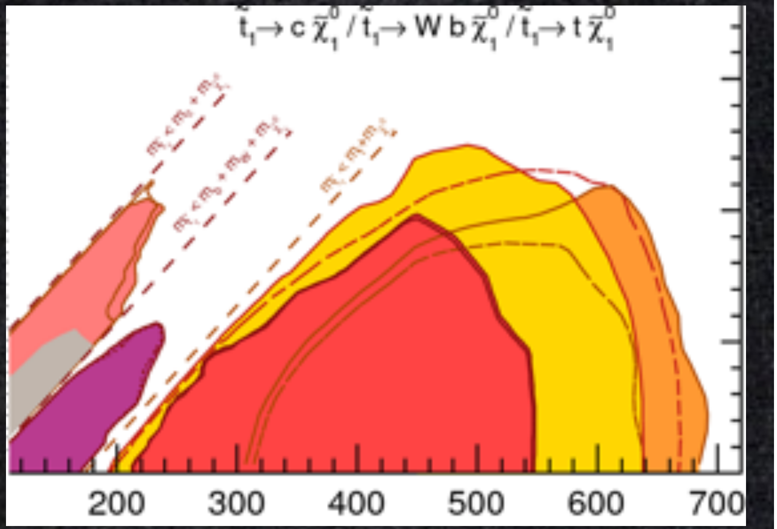
NUHM

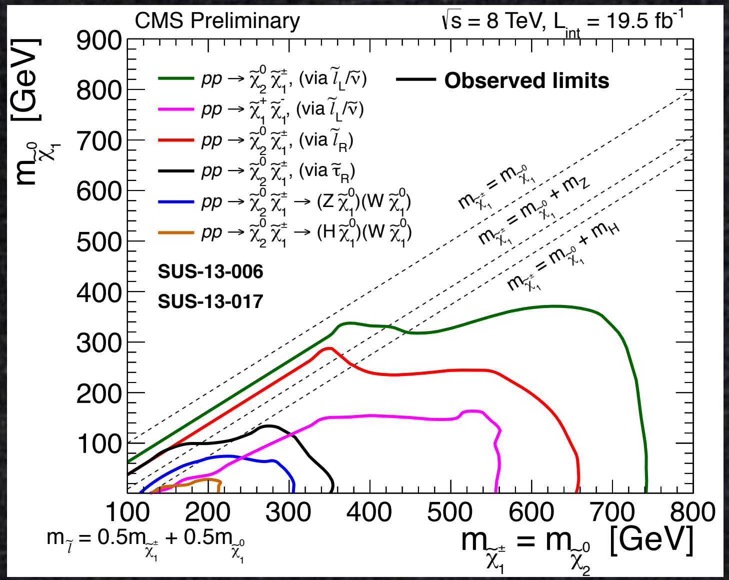

NUHM 8TeV: QGC1N2N1+C1N2N1
m_{1/2} [GeV]
800
700
600
500
400
300
200
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
m_0 [TeV]
100
90
80
70
60
50
40
30
20
10
0

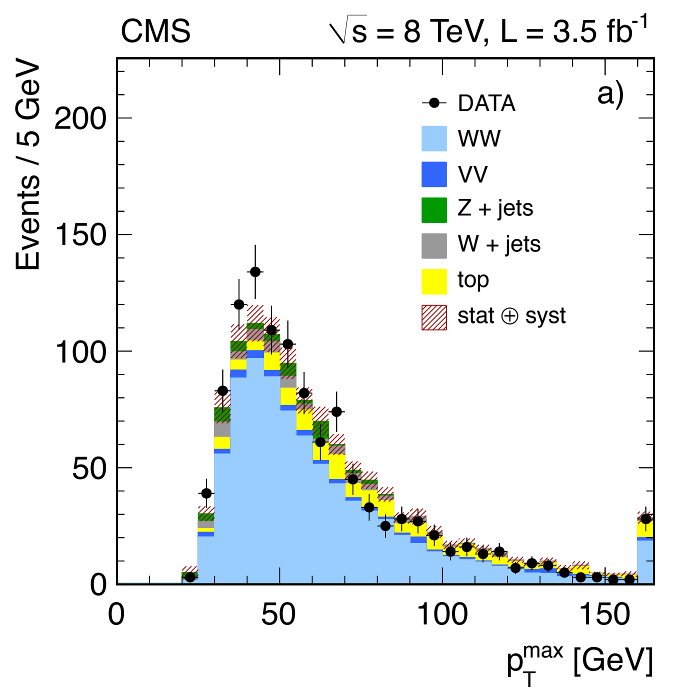
Introduction

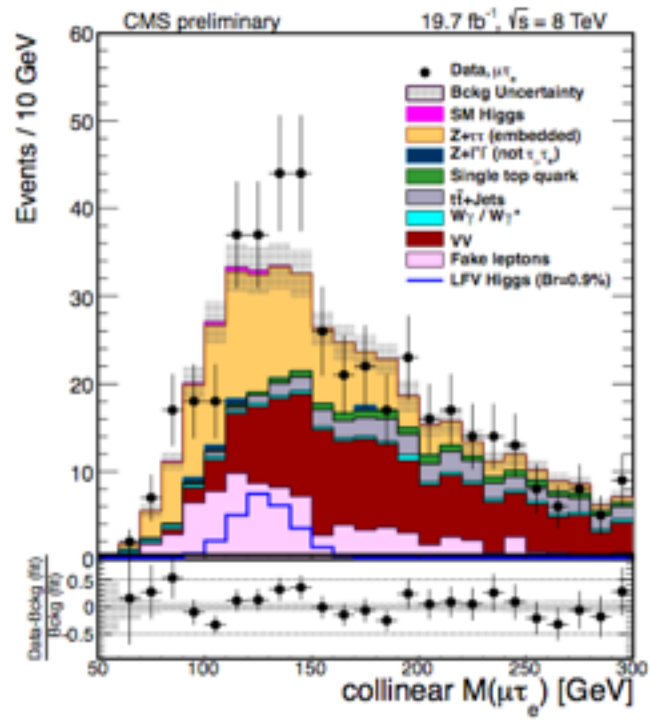


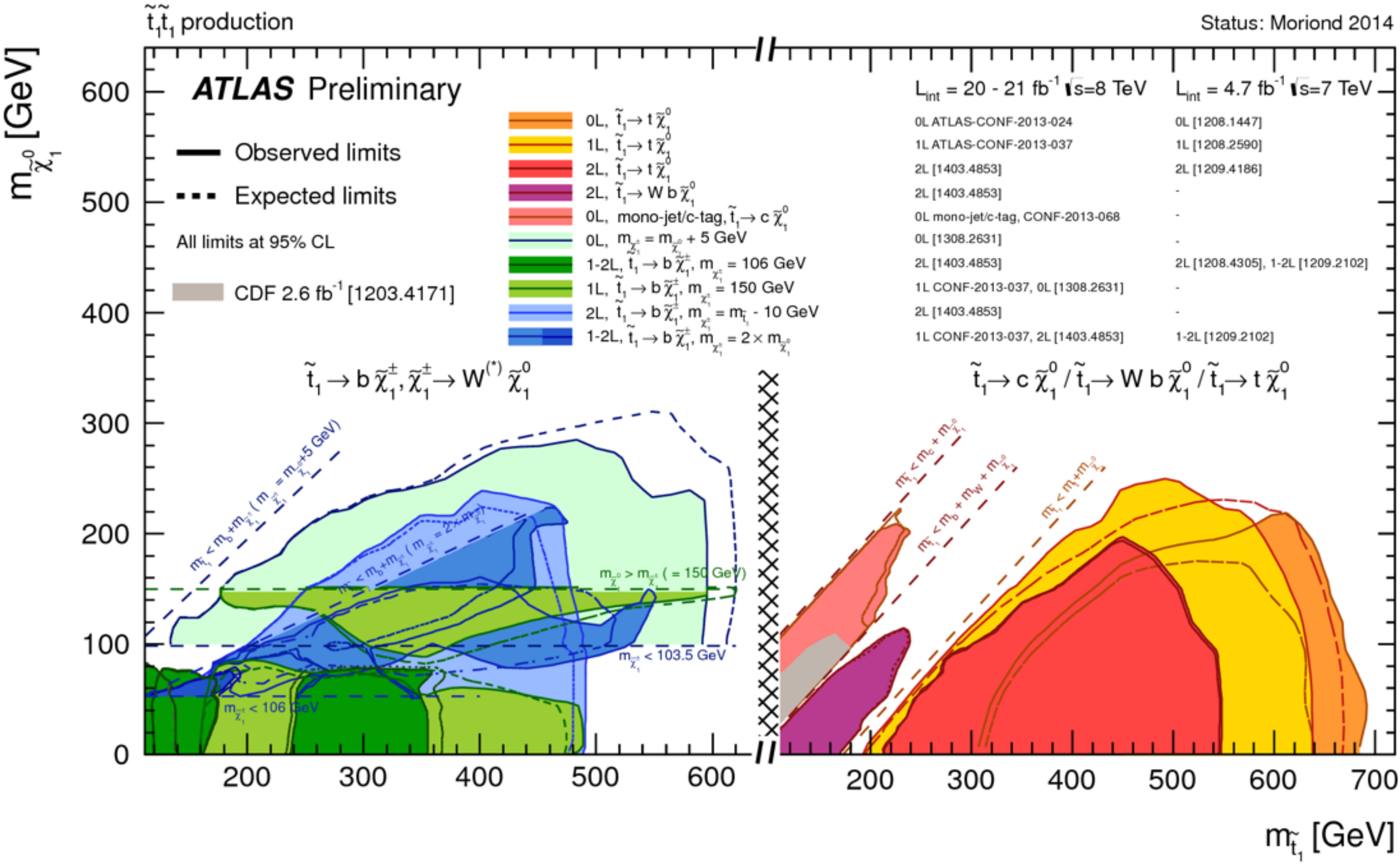










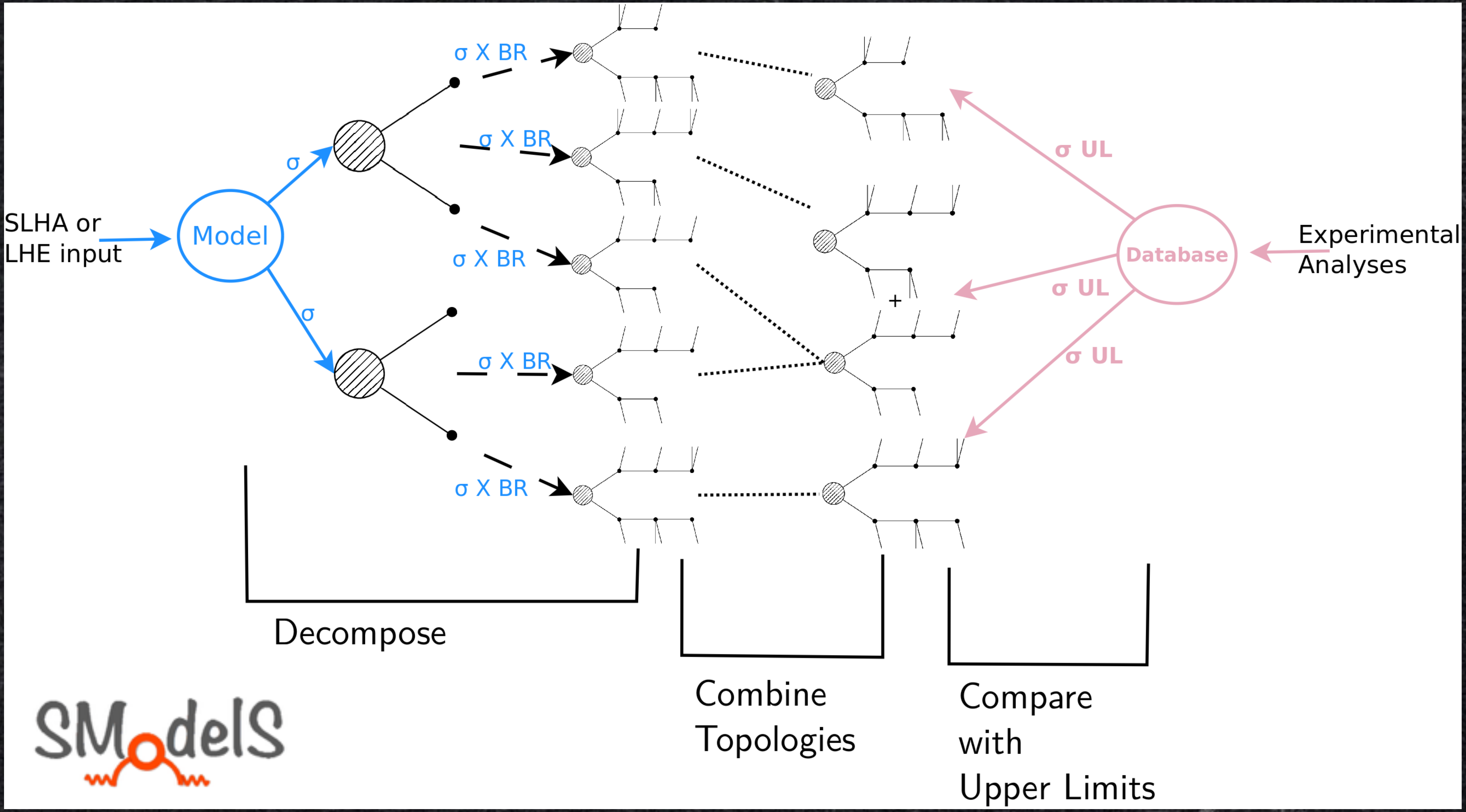


$\tilde{t}_1\tilde{t}_1$ production
Status: Moriond 2014
ATLAS Preliminary
Observed limits
Expected limits
All limits at 95% CL
CDF 2.6 fb^{-1} [1203.4171]
0L, $\tilde{t}_1 \to t\,\tilde{\chi}_1^0$
1L, $\tilde{t}_1 \to t\,\tilde{\chi}_1^0$
2L, $\tilde{t}_1 \to t\,\tilde{\chi}_1^0$
2L, $\tilde{t}_1 \to W\,b\,\tilde{\chi}_1^0$
0L, mono-jet/c-tag, $\tilde{t}_1 \to c\,\tilde{\chi}_1^0$
0L, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0} + 5$ GeV
1-2L, $\tilde{t}_1 \to b\,\tilde{\chi}_1^\pm$, $m_{\tilde{\chi}_1^\pm} = 106$ GeV
1L, $\tilde{t}_1 \to b\,\tilde{\chi}_1^\pm$, $m_{\tilde{\chi}_1^\pm} = 150$ GeV
2L, $\tilde{t}_1 \to b\,\tilde{\chi}_1^\pm$, $m_{\tilde{\chi}_1^\pm} = m_{\tilde{t}_1} - 10$ GeV
1-2L, $\tilde{t}_1 \to b\,\tilde{\chi}_1^\pm$, $m_{\tilde{\chi}_1^\pm} = 2 \times m_{\tilde{\chi}_1^0}$
L_{int} = 20 - 21 fb^{-1} $\sqrt{s}$=8 TeV
0L ATLAS-CONF-2013-024
1L ATLAS-CONF-2013-037
2L [1403.4853]
2L [1403.4853]
0L mono-jet/c-tag, CONF-2013-068
0L [1308.2631]
2L [1403.4853]
1L CONF-2013-037, 0L [1308.2631]
2L [1403.4853]
1L CONF-2013-037, 2L [1403.4853]
L_{int} = 4.7 fb^{-1} $\sqrt{s}$=7 TeV
0L [1208.1447]
1L [1208.2590]
2L [1209.4186]
-
-
-
2L [1208.4305], 1-2L [1209.2102]
-
-
1-2L [1209.2102]
$\tilde{t}_1 \to b\,\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \to W^{(*)}\,\tilde{\chi}_1^0$
$\tilde{t}_1 \to c\,\tilde{\chi}_1^0$ / $\tilde{t}_1 \to W\,b\,\tilde{\chi}_1^0$ / $\tilde{t}_1 \to t\,\tilde{\chi}_1^0$
$m_{\tilde{t}_1} < m_b + m_{\tilde{\chi}_1^\pm}$ ($m_{\tilde{\chi}_1^\pm} = m_{\tilde{\chi}_1^0}$+5 GeV)
$m_{\tilde{t}_1} < m_b + m_{\tilde{\chi}_1^\pm}$ ($m_{\tilde{\chi}_1^\pm} = 2 \times m_{\tilde{\chi}_1^0}$)
$m_{\tilde{\chi}_1^0} > m_{\tilde{\chi}_1^\pm}$ (= 150 GeV)
$m_{\tilde{\chi}_1^\pm}$ < 103.5 GeV
$m_{\tilde{\chi}_1^\pm}$ < 106 GeV
$m_{\tilde{t}_1} < m_c + m_{\tilde{\chi}_1^0}$
$m_{\tilde{t}_1} < m_b + m_W + m_{\tilde{\chi}_1^0}$
$m_{\tilde{t}_1} < m_t + m_{\tilde{\chi}_1^0}$
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{t}_1}$ [GeV]
0
100
200
300
400
500
600
200
300
400
500
600
200
300
400
500
600
700

SModelS

Sabine Kraml, *et.al*, 2013

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



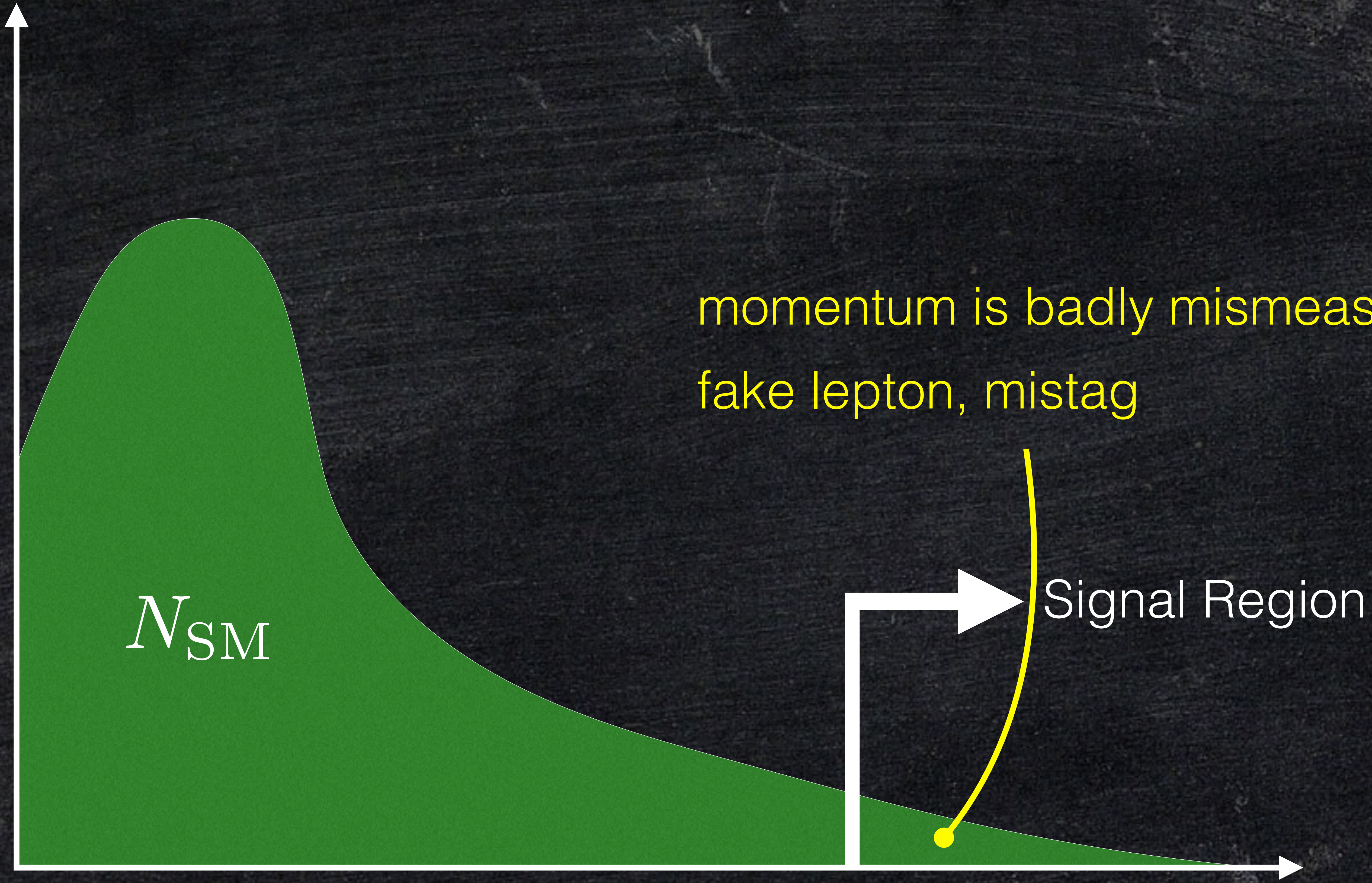
Fitting Excesses

Excesses

Analysis	√s	lumi	SR	Exp	Obs	s.d.
ATLAS WW	7	4.6	comb	1219 ± 87	1325	~1σ
CMS WW	7	4.9	comb	1076 ± 62	1134	~1σ
CMS WW	8	5.3	comb	986 ± 60	1111	~2σ
ATLAS Higgs WW	8	20.7	WW CR	3110 ± 220	3296	~1σ
ATLAS 1-2 lep + jets	8	20.1	dimuon	1.9 ± 1.8	7	~2.5σ
ATLAS trilepton	8	20.3	SR0τa01	23 ± 6.2	36	~2σ
			SR0τa06	6.6 ± 3.2	13	~2σ
			SR0τa10	16.4 ± 4.7	24	~1.5σ

Analysis	√s	lumi	SR	Exp	Obs	s.d.
ATLAS 1-2 lep + jets	7	4.6	comb	1219 ± 87	1325	~1σ
ATLAS 2lep razor	7	4.9	comb	1076 ± 62	1134	~1σ
ATLAS trilepton	8	5.3	comb	986 ± 60	1111	~2σ

ϵ_{BG}: estimation is harder

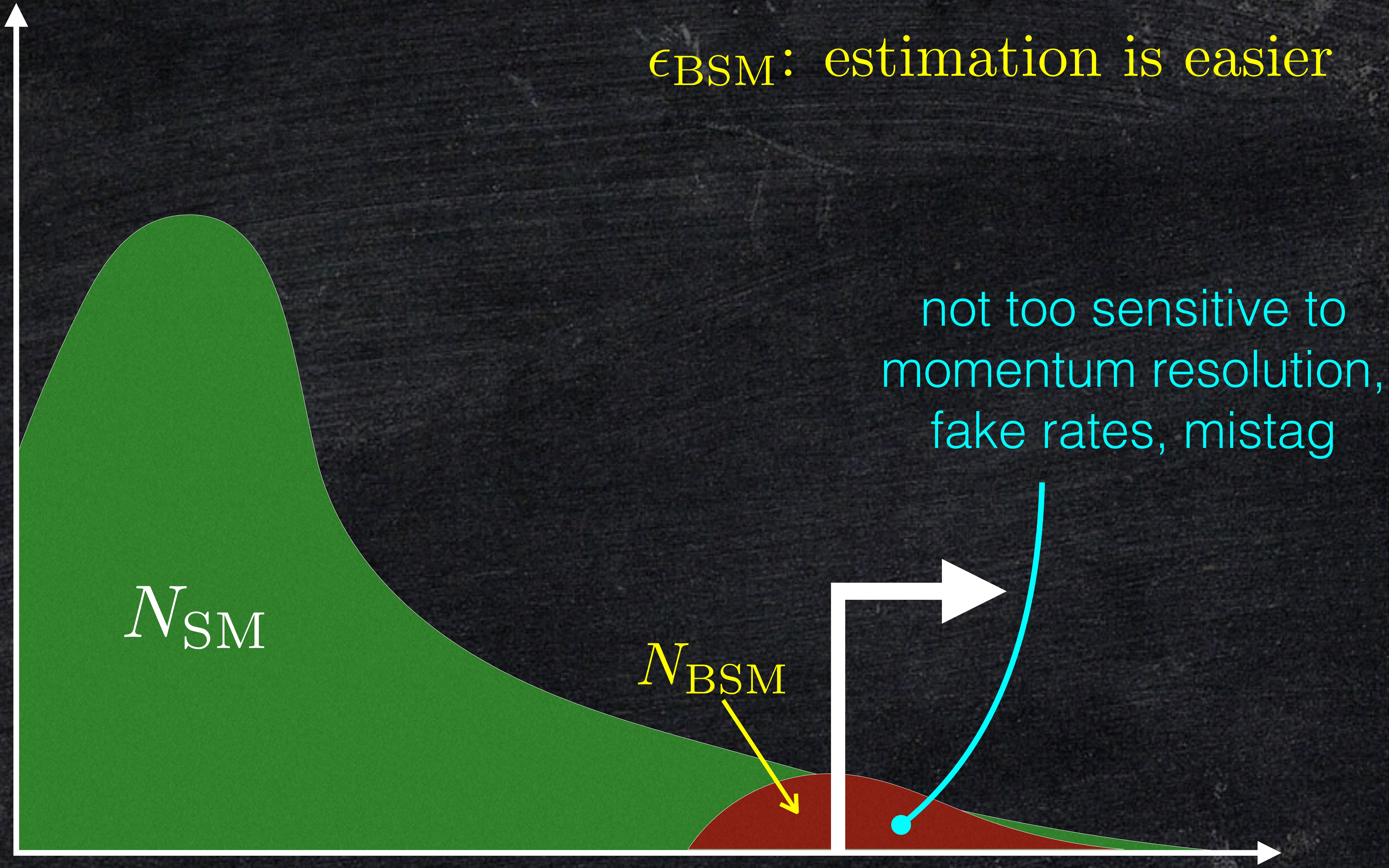


momentum is badly mismeasured

fake lepton, mistag

ϵ_{BG}: estimation is harder

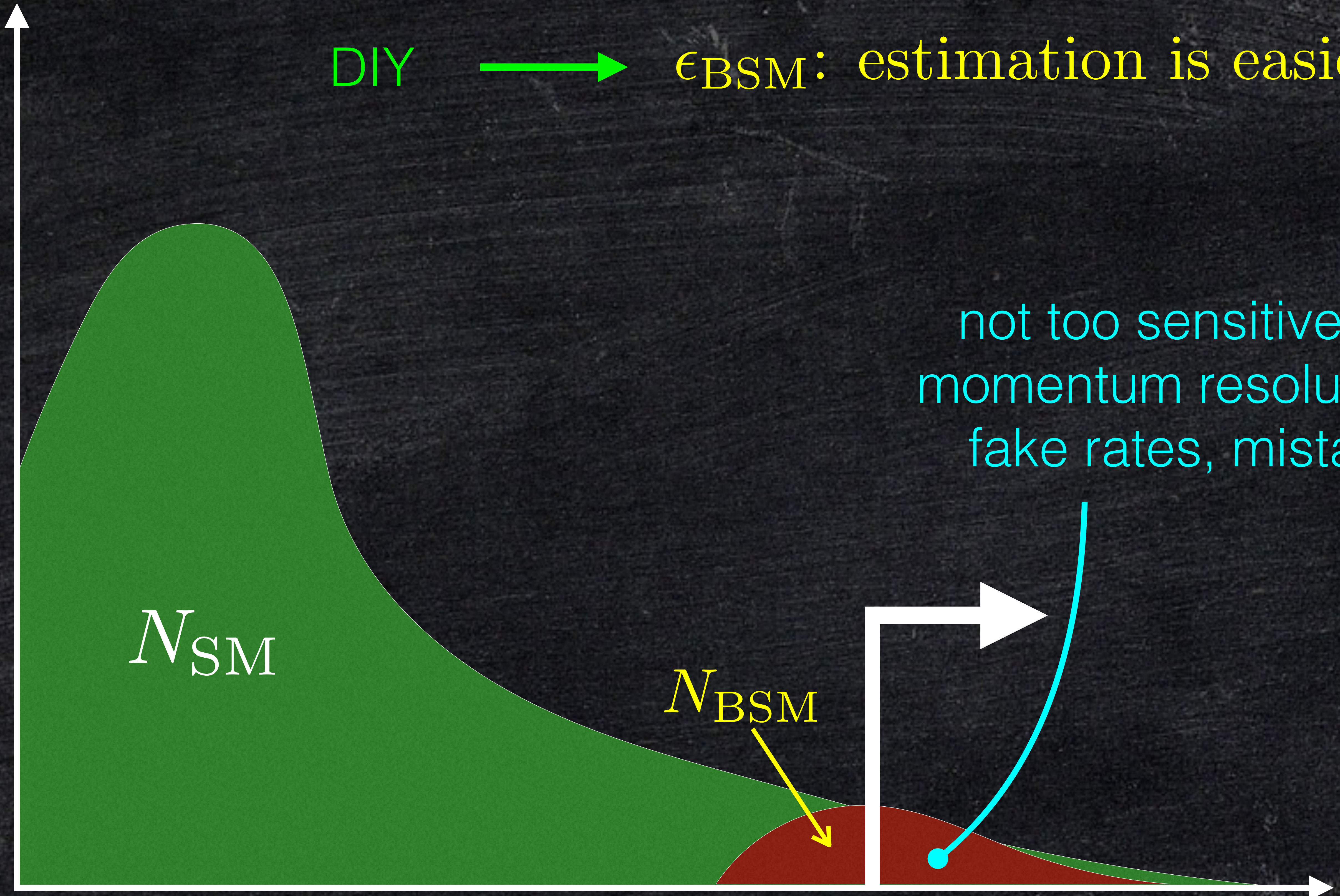
ϵ_{BSM}: estimation is easier



not too sensitive to
momentum resolution,
fake rates, mistag

use ATLAS/CMS estimation → ϵ_{BG}: estimation is harder

DIY → ϵ_{BSM}: estimation is easier



not too sensitive to momentum resolution, fake rates, mistag