SUSY MC and formats for reporting results

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on behalf of **ATLAS** and **CMS**

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Thank you to input from Ana Ovcharova, Nadja Strobbe, Tomasso Lari, & Iacopo Vivarelli !

Introduction and Overview

Supersymmetry provides a framework to investigate a ***broad class of models*** *with a diverse phenomenology*

Many of the investigated final states are **not unique to SUSY** - what unifies these searches is the motivation, simulation, and cross-section calculations

Today: SUSY Models

Run II SUSY Simulation

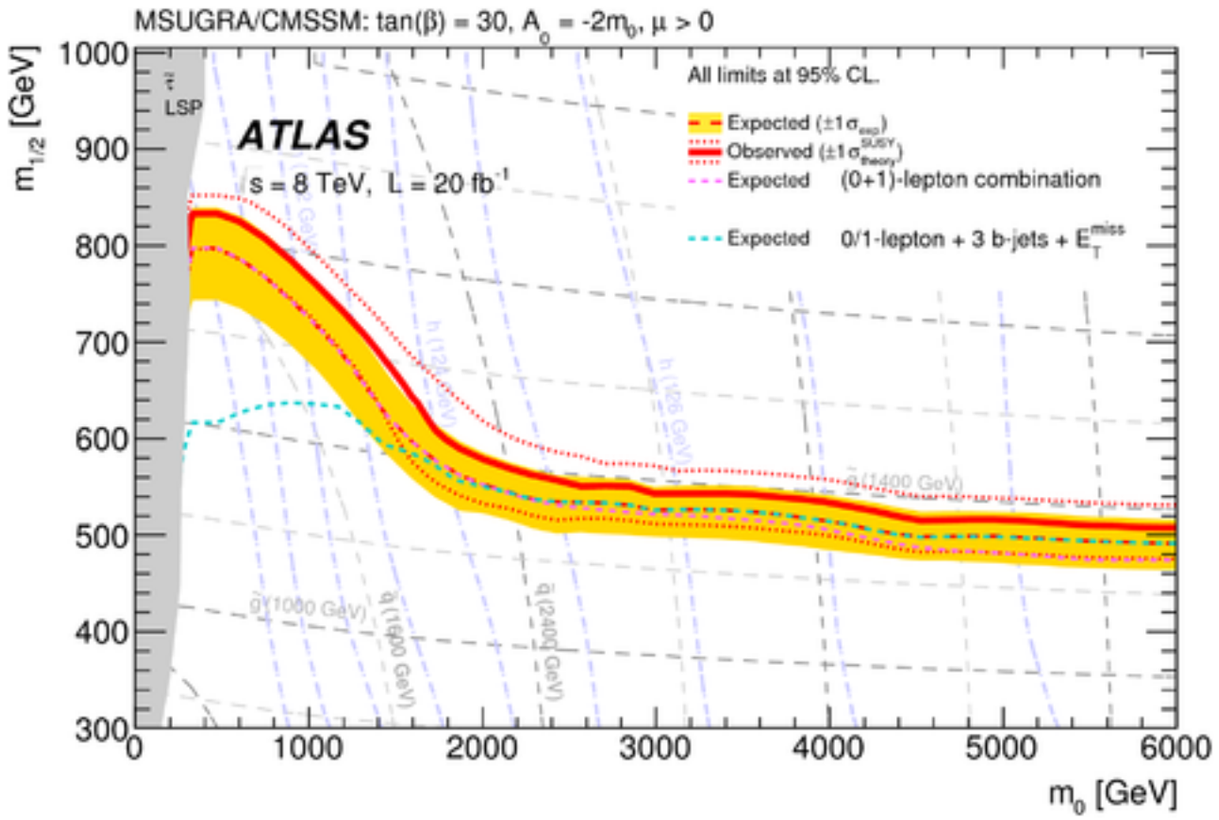
Presentation and Preservation of Results

SUSY Models: Two Approaches

Complete models

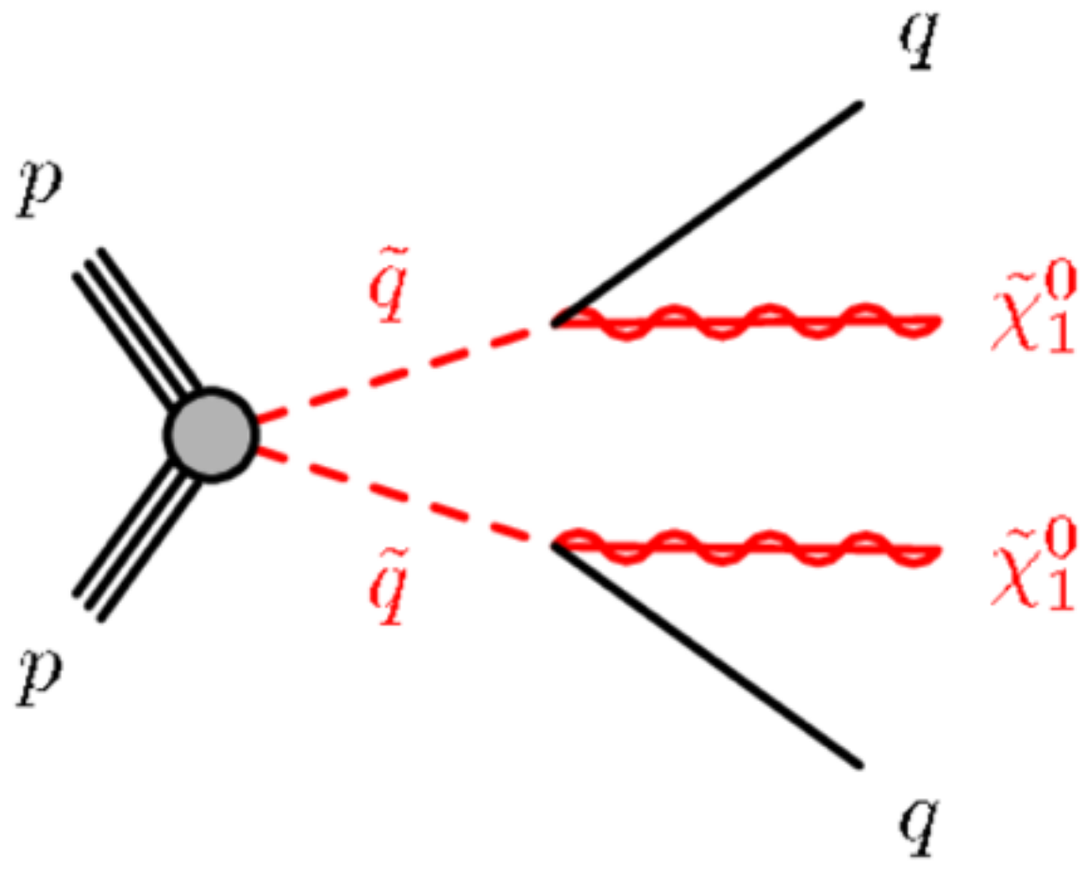
Specify parameters that determine the entire SUSY model

e.g. cMSSM, pMSSM



Simplified models

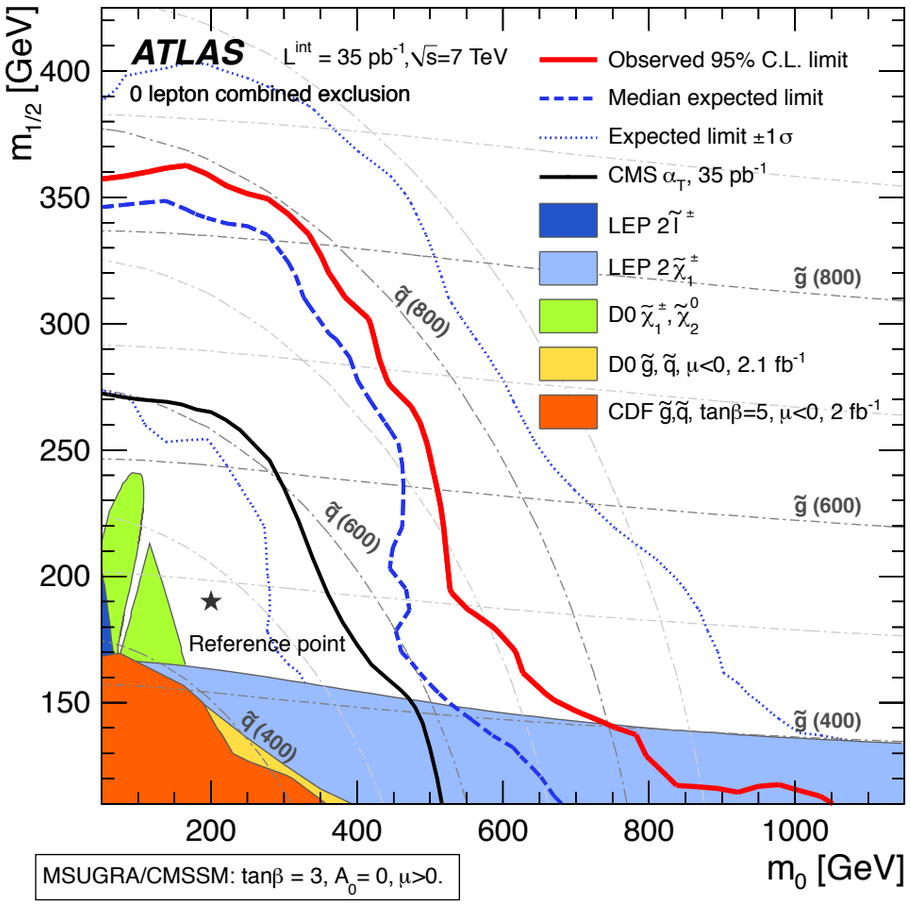
Specify a small number of SUSY degrees of freedom that would participate in LHC-scale physics



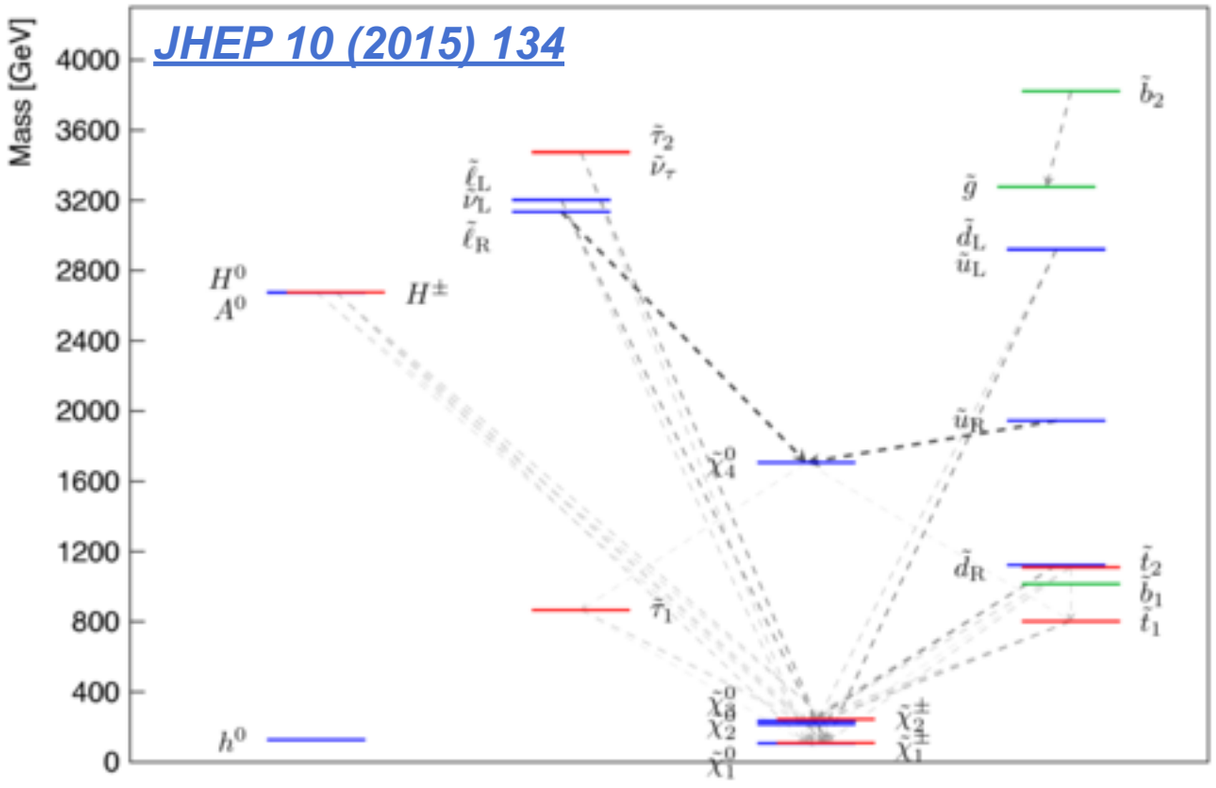
Electroweak scale: pMSSM

Specified by 19 weak-scale parameters

Very popular for large-scale scans of ‘realistic models’ from ATLAS/CMS



Complete models



GUT-scale: cMSSM

Specified by 5 parameters

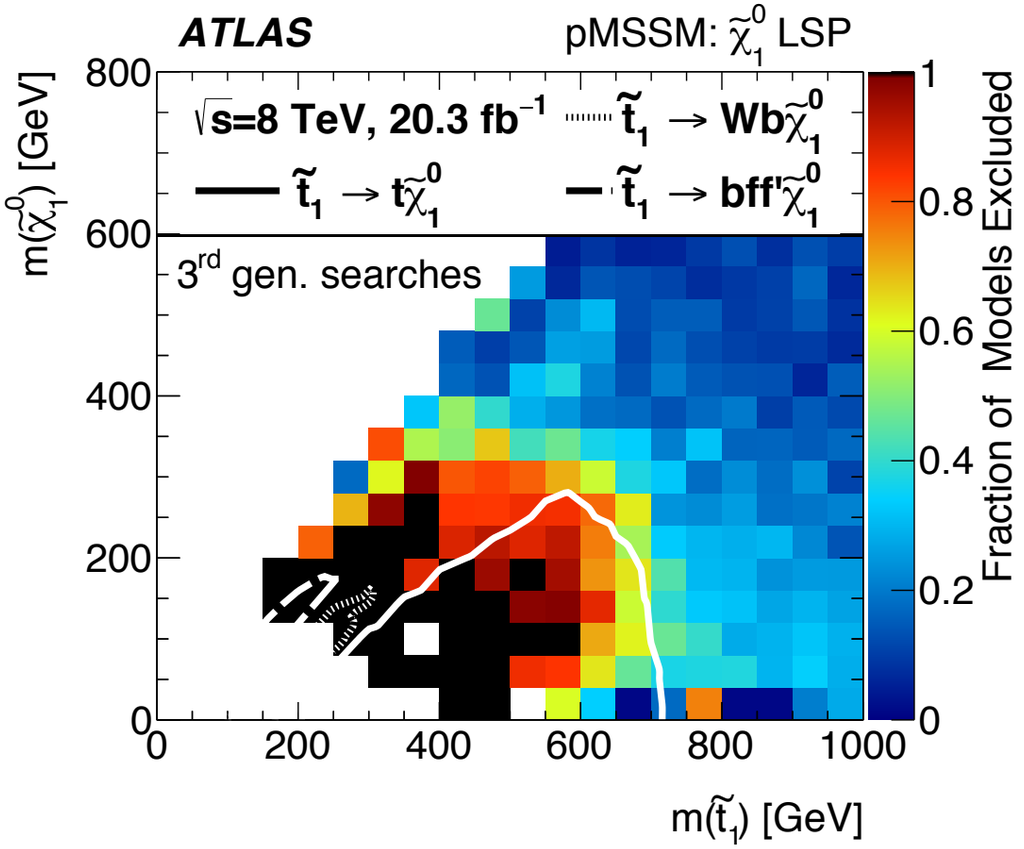
An early Run I favorite; there is very little effort now to interpret search results in these frameworks (not used at yet with the 2015 data)

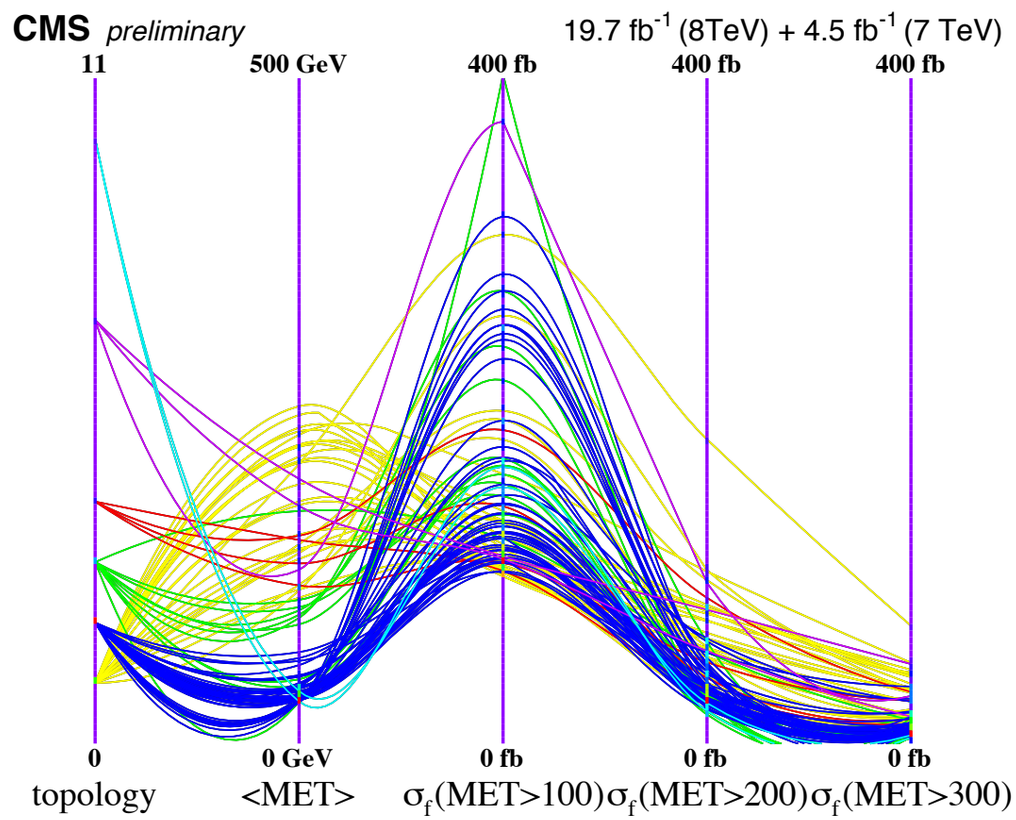
pMSSM Simulation *Run I Legacy*

Both **ATLAS** and **CMS** have performed large pMSSM scans

JHEP 10 (2015) 134 CMS PAS SUS-15-010

Complicated scans, model calculations, low-energy constraints, etc. (deserves its own talk!)





We are doing a great job with simplified models, but there are gaps - largely from long decay chains.

Simplified Models

inclusive squarks and gluinos

biggest gains with the 2015 data

3rd generation

motivated by naturalness

electroweak

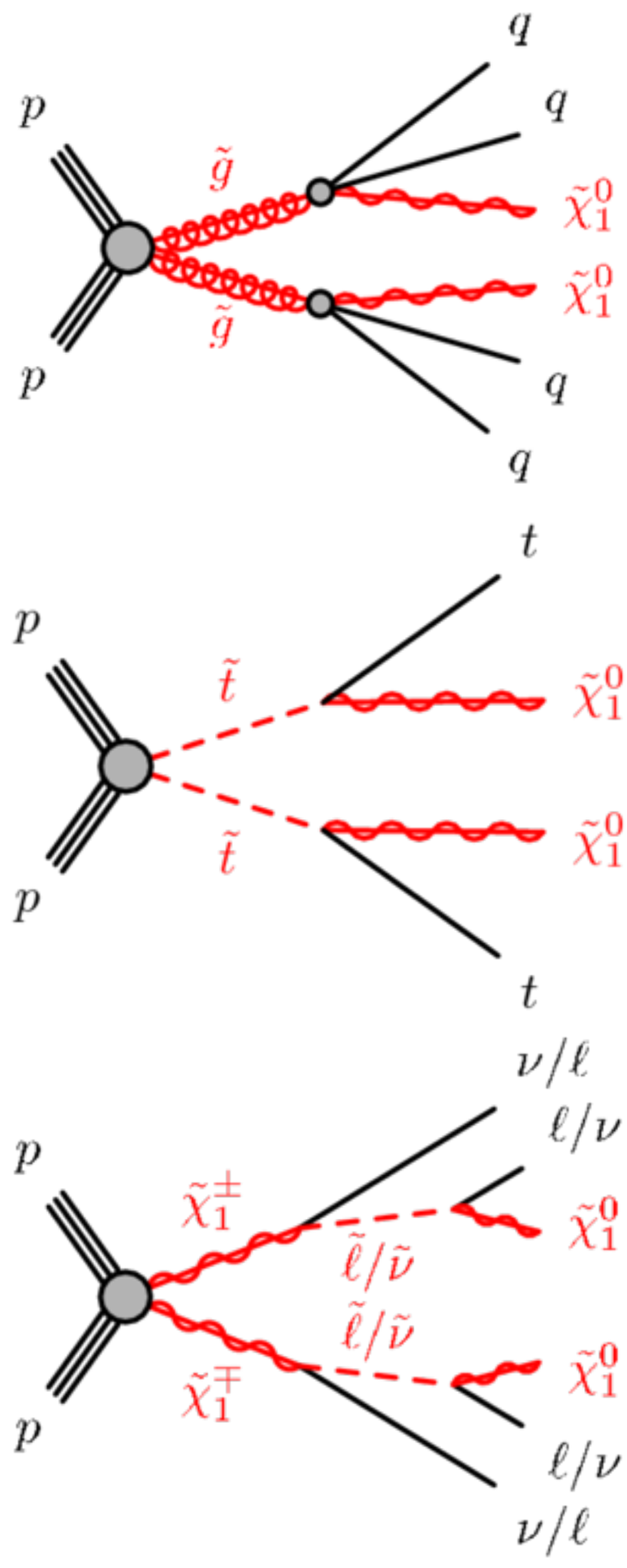
strong constraints from LEP

long-lived

*e.g. R-hadrons**

RPV

often little or no MET



cross-section

*this is SUSY in ATLAS but Exotica in CMS

Simplified Model Simulation

(Amazingly,) both **ATLAS** and **CMS** use the ~same simulation setup in Run II.

MadGraph + Pythia 8

```
import model mssm
p p > X X(~) @1
add process p p > X X(~) j @2
add process p p > X X(~) j j @3
```

X = go, t1, etc.

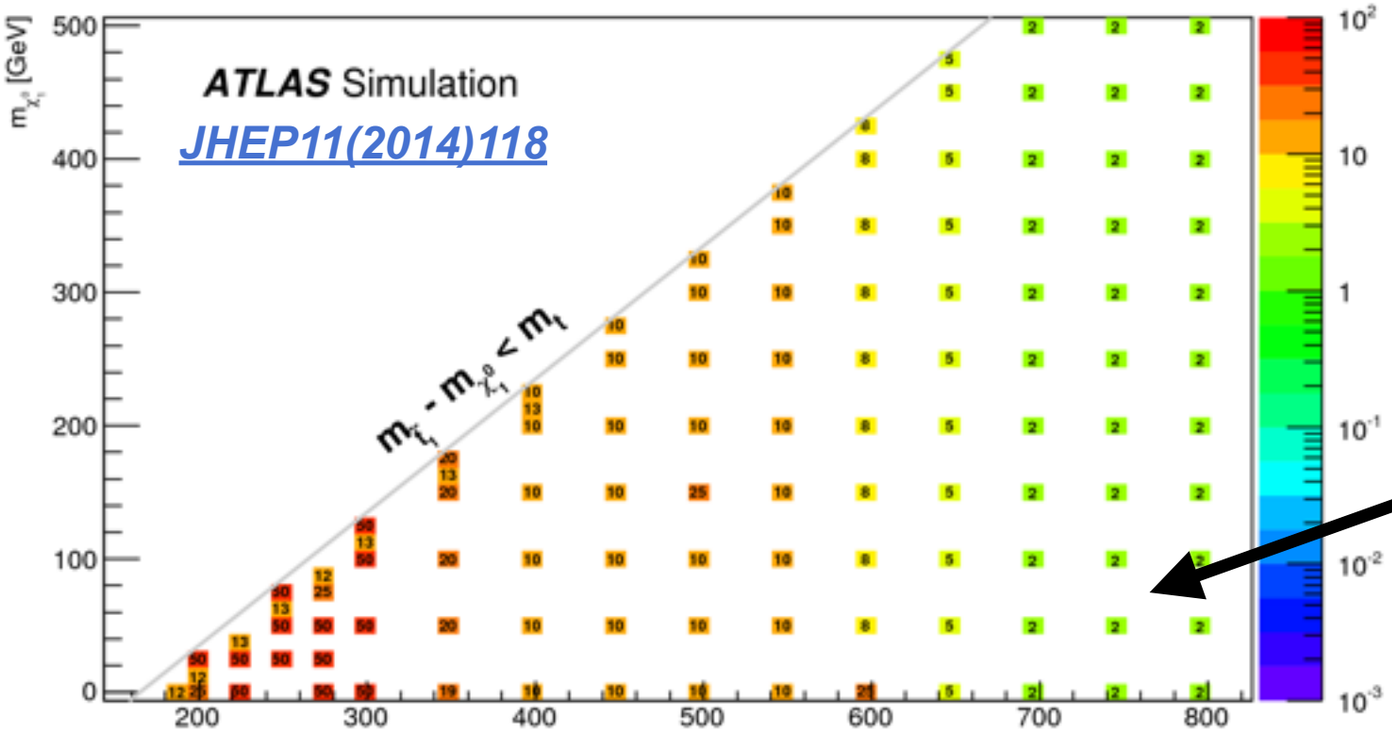
MadGraph only produces the first SUSY particle - **decays are all handled by Pythia**

NLO+NLL cross-sections from SUSY LHC cross-section WG

Simplified Model Simulation *Technicalities*

	ATLAS	CMS
ME Generator	MadGraph	MadGraph
Extra Partons	2	2
Fragmentation	Pythia 8	Pythia 8
PDF	NNPDF2.3 LO	NNPDF2.3 LO
Pythia Tune	Monash Variant (A14)	Monash Variant (CUETP8M1)
Afterburner	EvtGen	N/A
Typical Number of Events	O(10k)	O(100k)
Typical Grid Granularity	varies, but generally coarse	varies, but generally fine

Simplified Model Simulation



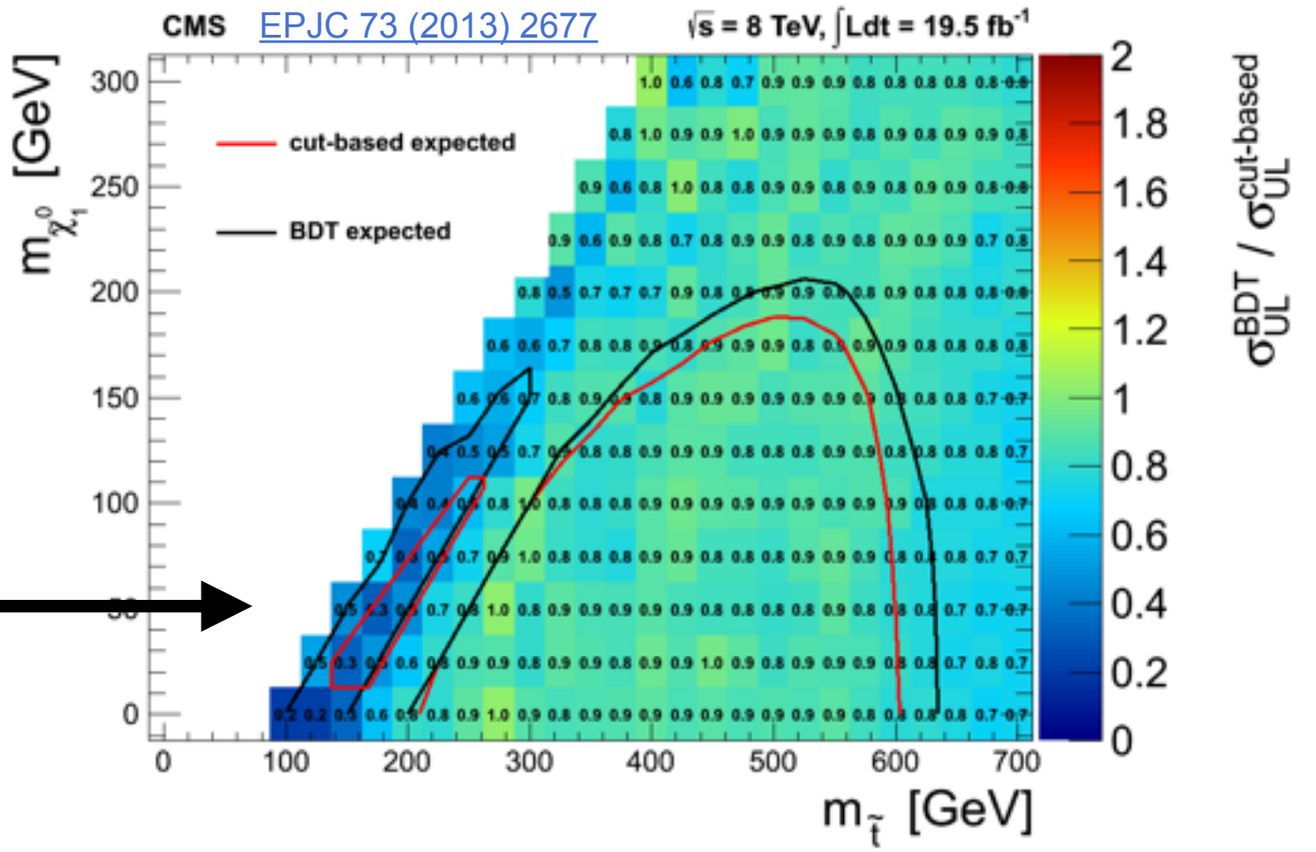
Example grid:
direct stop search

~5% acceptance

~3% MC stat uncert.

More events needed at low mass where the acceptance drops

Higher model density (more on this later)



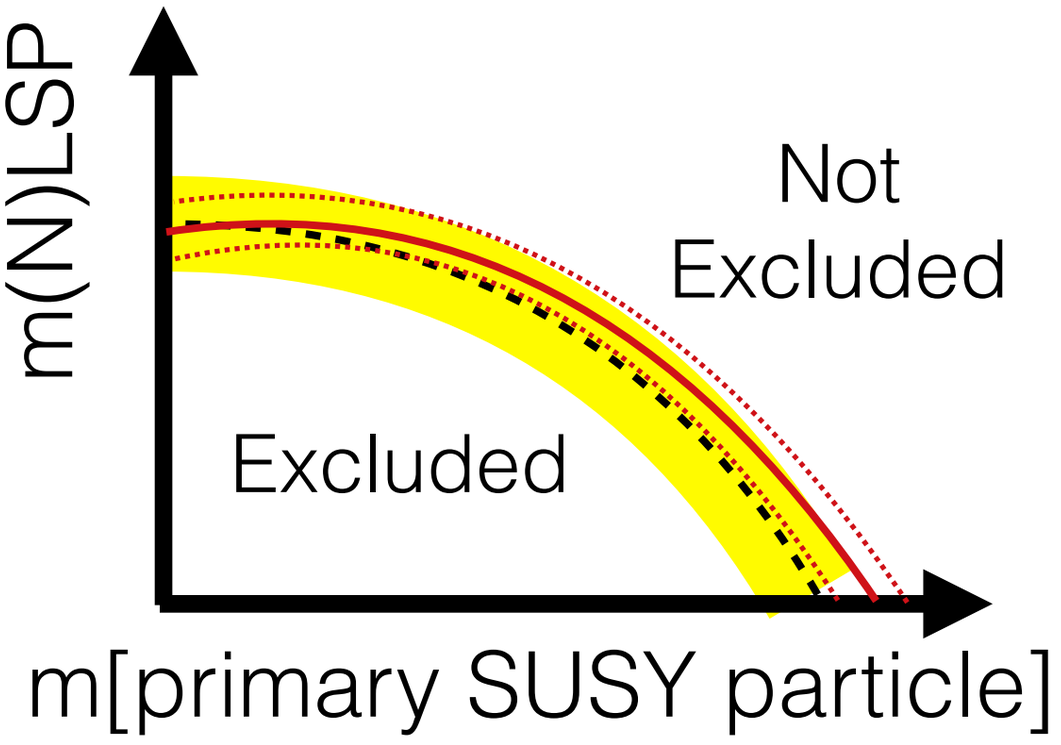
Theory Systematic Uncertainties

…and where they go in the bands

Cross-section uncertainties from factorization/ renormalization scale as well as PDF variations

ATLAS: use uncertainties from LHC XS WG (1407.5066)

CMS: 10% for PDF (based on 100 NNPDF variations), independent fact. and ren. scales, ISR modeling (next slide)



Line: Observed Limit
Band: Signal **xs** Theory Uncertainties

Line: Expected Limit
Band: All other Uncertainties

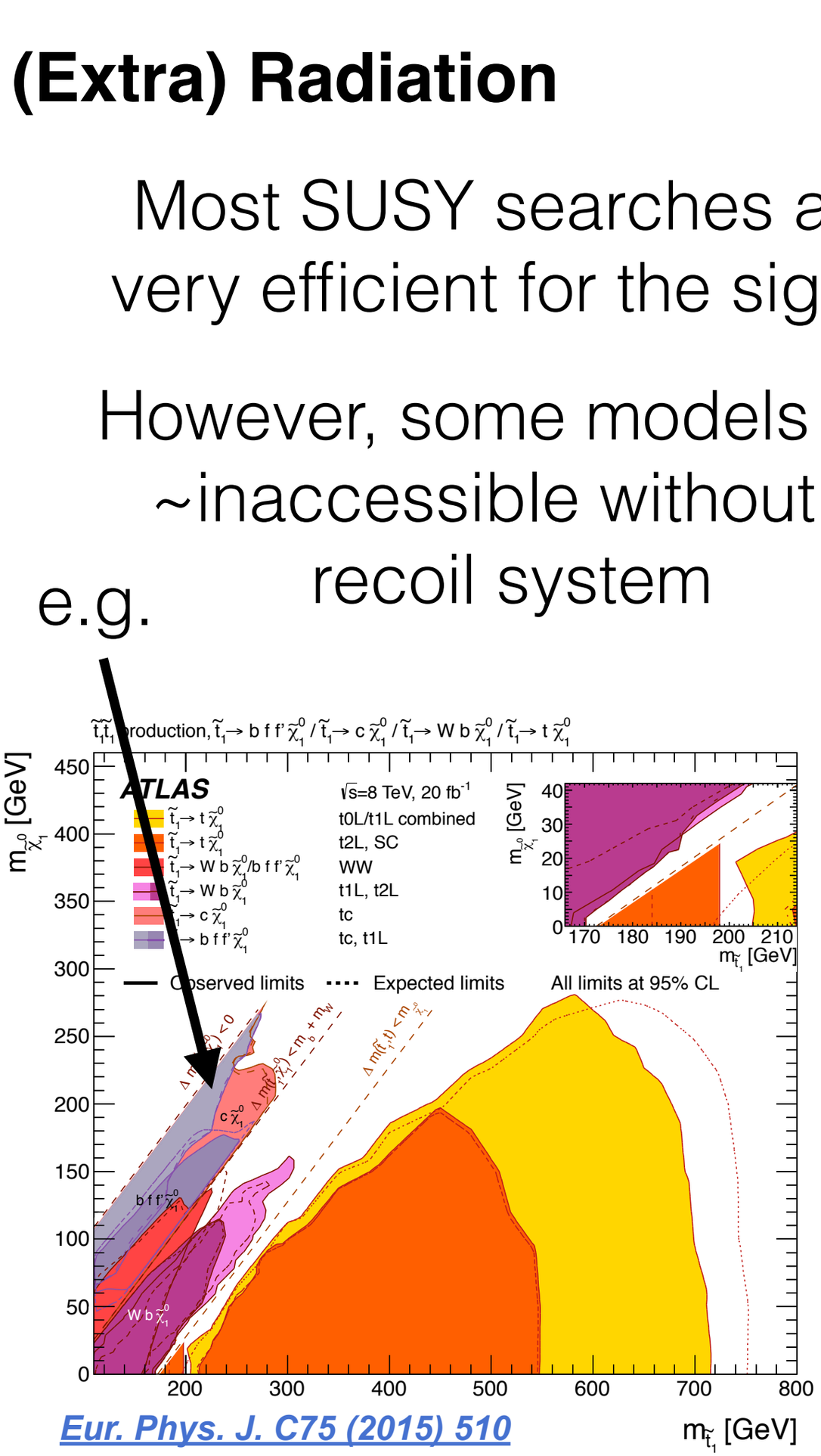
Limit: $CL_s < 0.05$ (not exactly 95% confidence)

(Extra) Radiation

Most SUSY searches are very efficient for the signal

However, some models are ~inaccessible without a recoil system

e.g.



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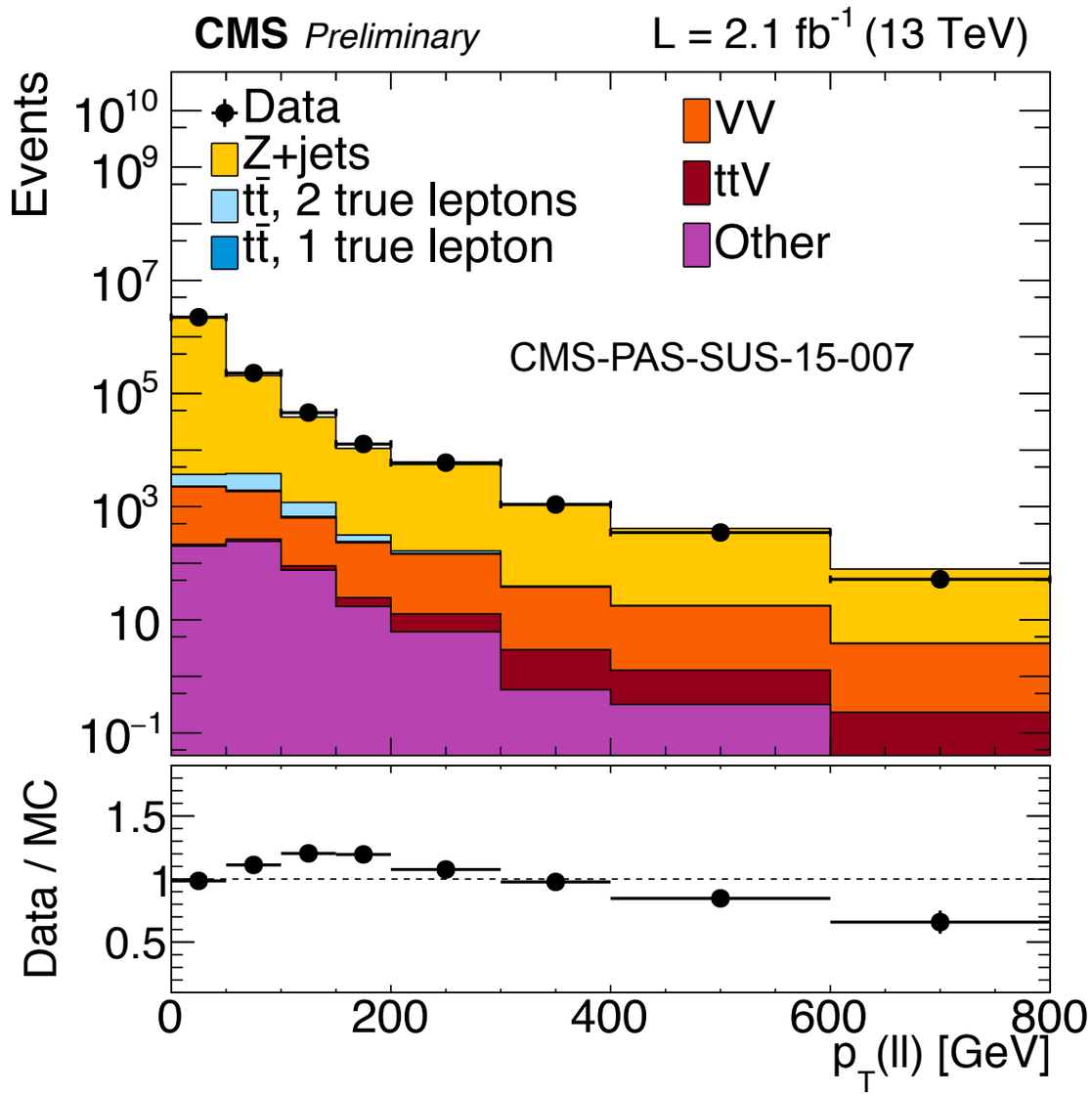


ATLAS: Vary ISR/FSR in Pythia for sensitive models/selections only

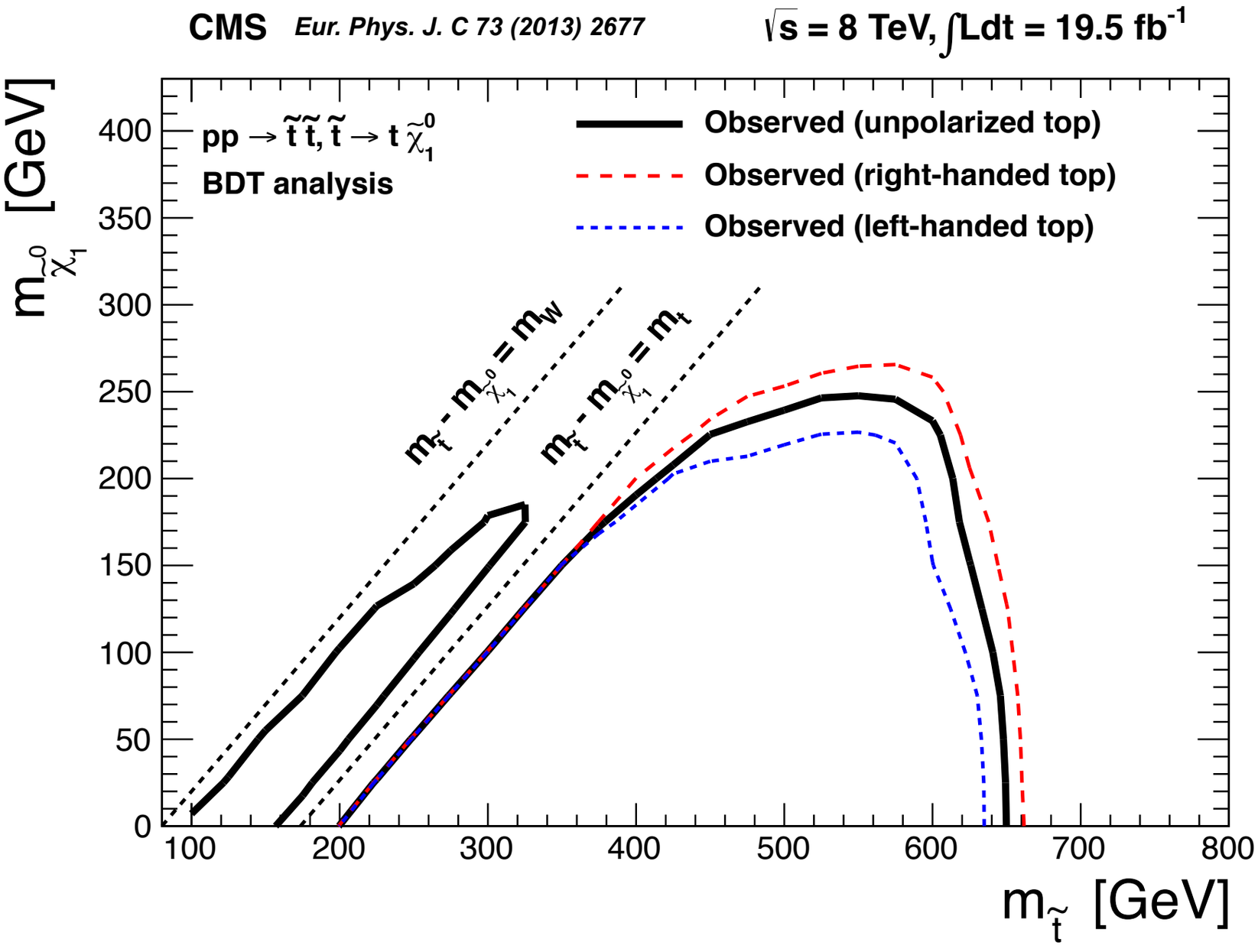
CMS: (Re-weight*) and take the uncertainty from Z+recoil and ttbar+recoil measurements

*Run I only

Polarization

Both **ATLAS** and **CMS** use unpolarized decay and then re-weight after-the-fact (not the case for ATLAS in Run I)

Inspired by Phys. Rev. D 88, 095018 (2013) and is used for decays involving stops and charginos.



Saving Generation Time: Matrix Element Calculations

In **ATLAS**, every model is generated ‘On-the-fly’:

MadGraph → LHE → Pythia is run all in one job and LHE files are not saved.

However, in **CMS**, generation happens in two steps, so that LHE files can be re-used:

1) Run MadGraph for a given primary SUSY process (e.g. p p > go go)

2) For all subsequent decays with the same primary SUSY masses, re-use the LHE files from (1)

Saving Generation Time: Detector Sim *Generator Filters*

Obvious observation:

While SUSY searches are generally efficient for signal, they are highly inefficient for the background.

Consequence:

Most background events are not used in studies based on signal-like selections.

Both ATLAS and CMS use ME level generator filters

e.g. 1L, 2L (for signal and background) as well as H_T, $p_T(V)$, np, flavor filters for the background (e.g. W+jets)

Saving Generation Time: Detector Sim *Generator Filters*

ATLAS has a system of (MET and H_T) generator filters, applied after Pythia 8, but before any detector simulation.

e.g. 4M 1L ttbar MET > 200 sample with ~1% filter efficiency

= effectively 400M events! (about 90% of events with a tight MET cut come from this filtered sample)

(only works for Powheg, aMC@NLO which are relatively fast - does not work for Sherpa (gen time ~ fast sim time))

Truth Definitions

We (and you) rely heavily on particle-level objects systematic uncertainties, acceptance, etc.

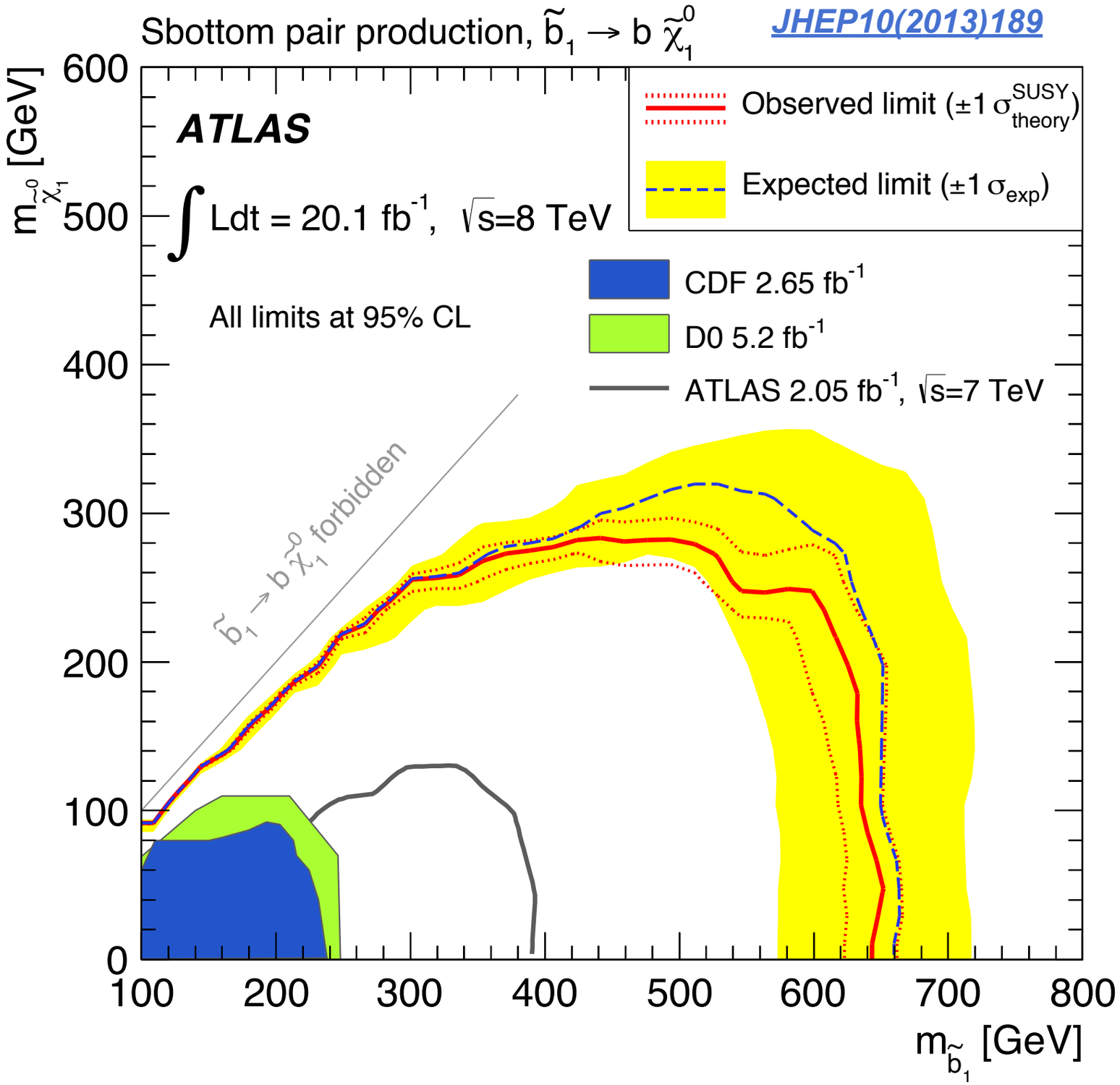
The definitions are very similar between **ATLAS** and **CMS**, and likely for SUSY searches the subtle differences are not important.

CMS: truth jets include all status 1 particles except for neutrinos; for leptons we have centrally computed flags which indicate whether a lepton is prompt in a generator independent manner (i.e. no use of hard scatter information, require that lepton does not come from hadron/tau decay or photon conversion); there is currently no central recommendation for dressed leptons.

For the ATLAS definition, see Appendix A: http://arxiv.org/pdf/1403.4853v1.pdf

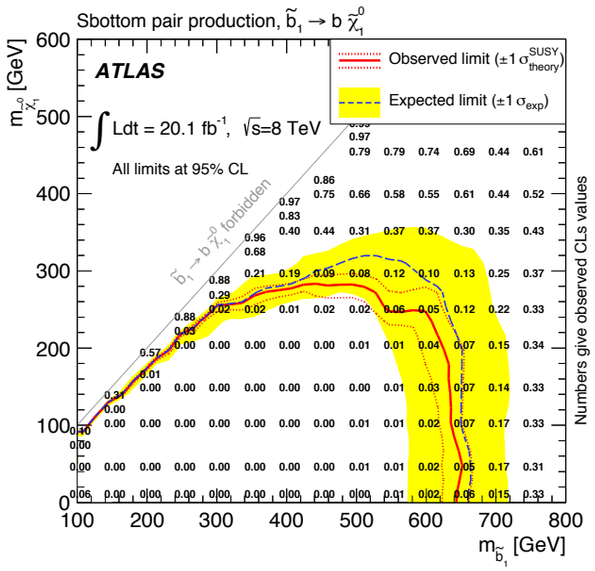
Presentation of results

ATLAS

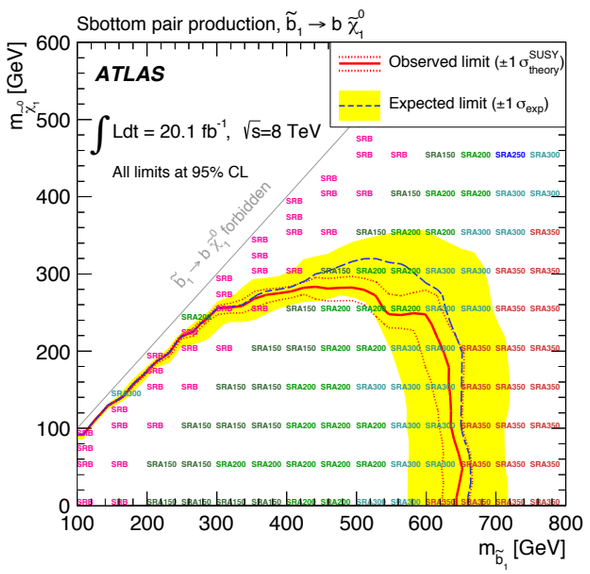


Repo for plots and tables: HepData

example: Run I sbottom search

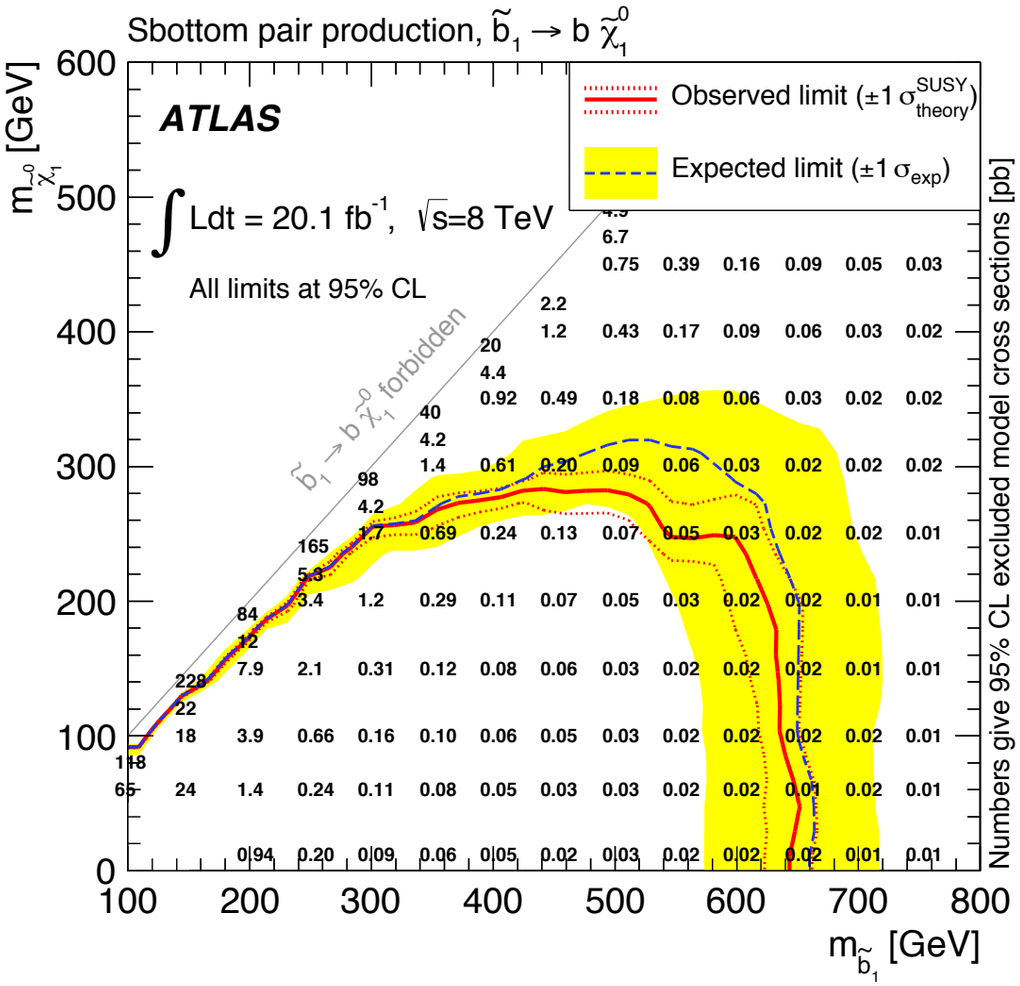


(the actual CL_s map always comes along with the results as well as the best SR)



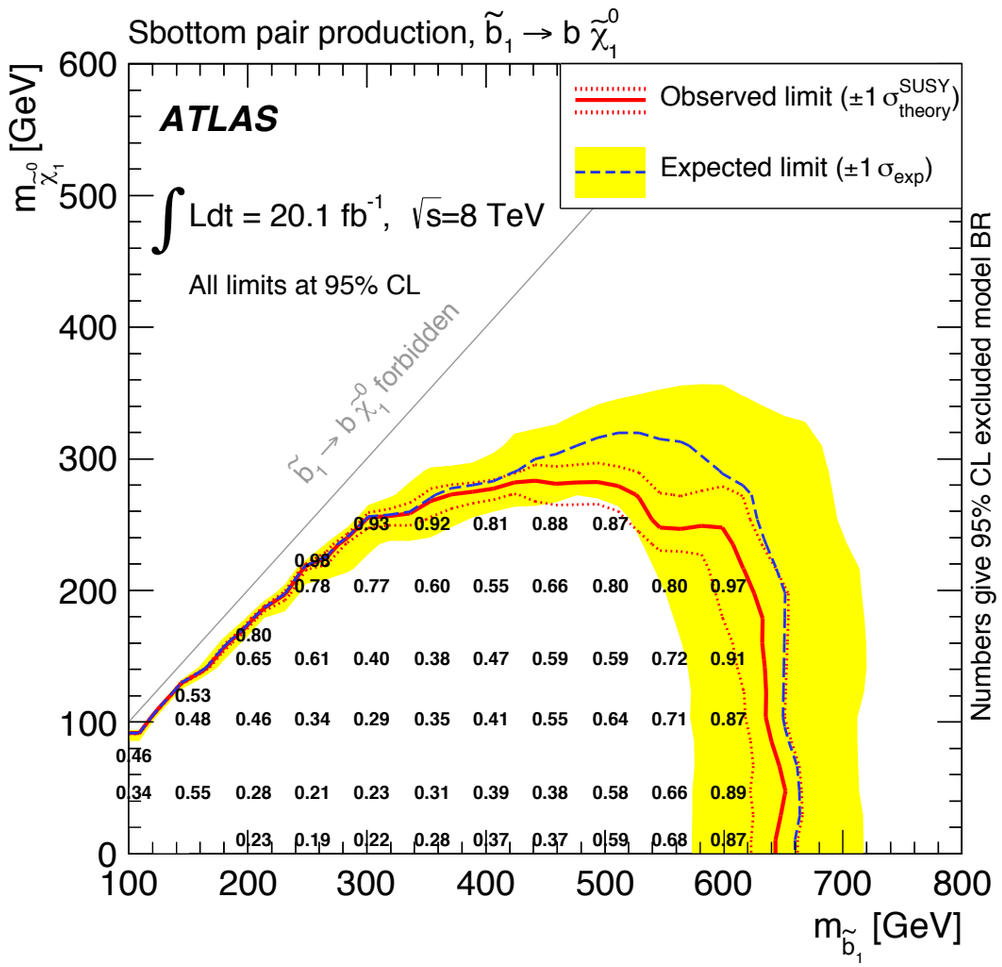
Presentation of results

ATLAS



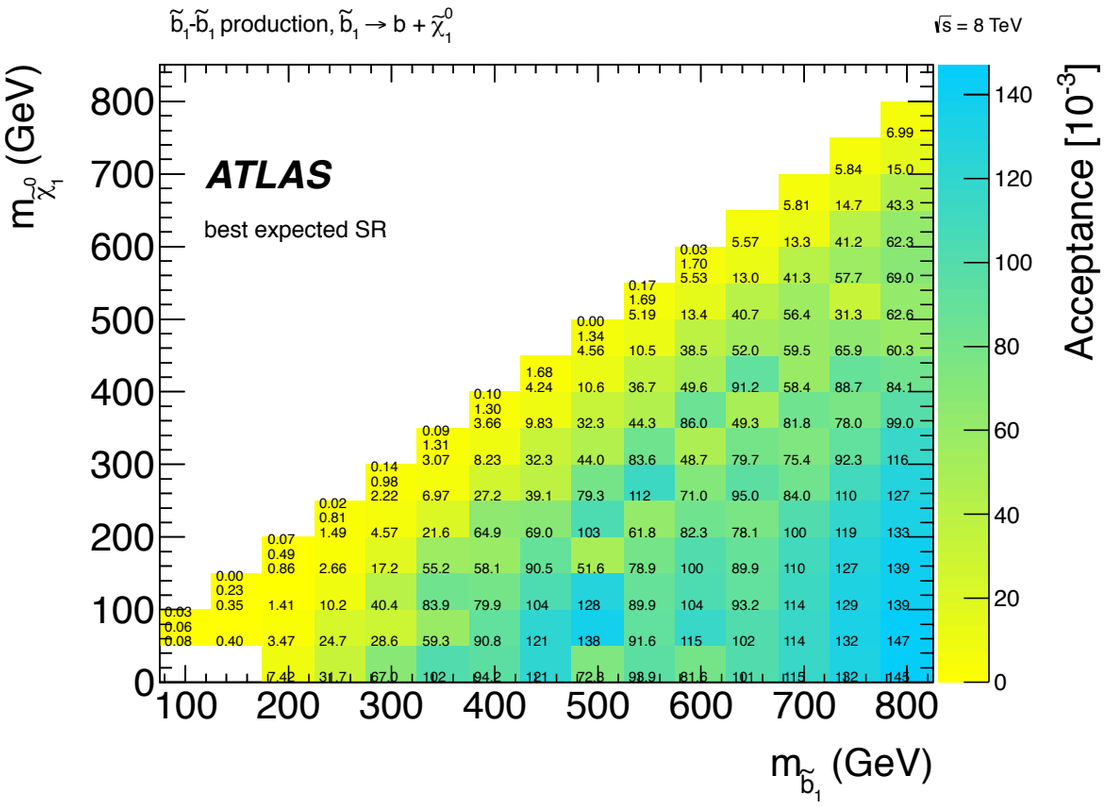
If your model had the same pheno, but different cross-section

If you had the same model, but different BR



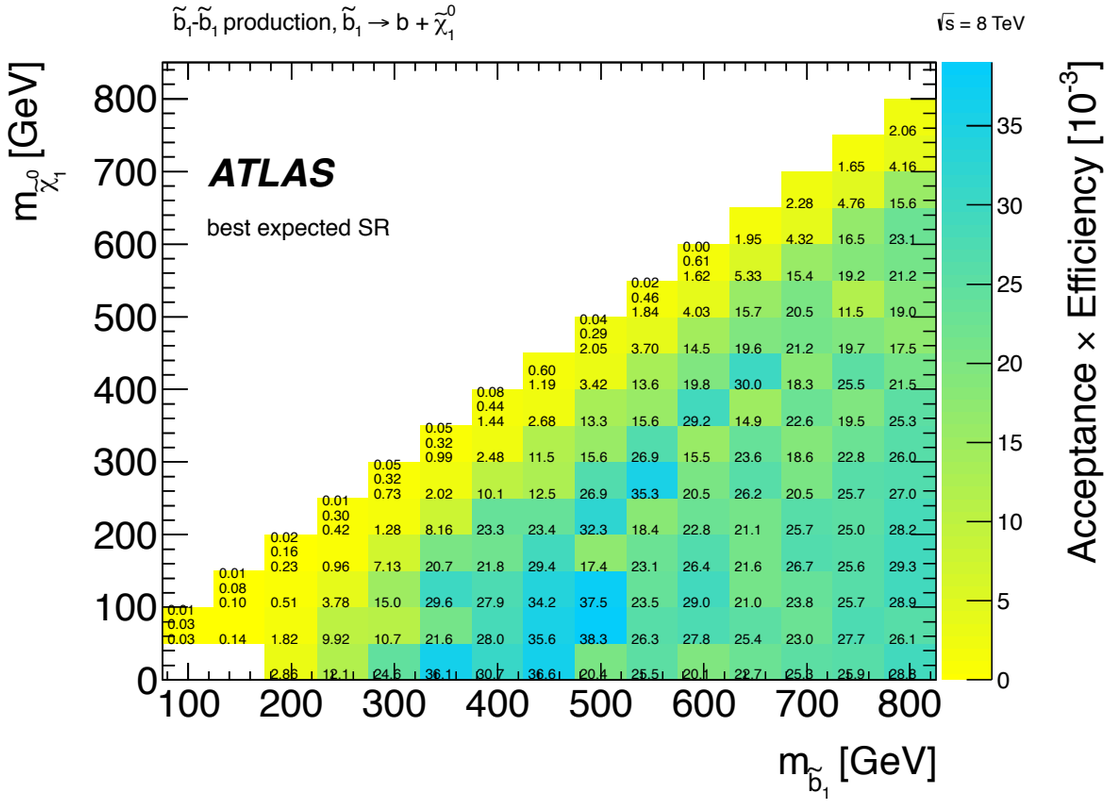
Presentation of results

ATLAS



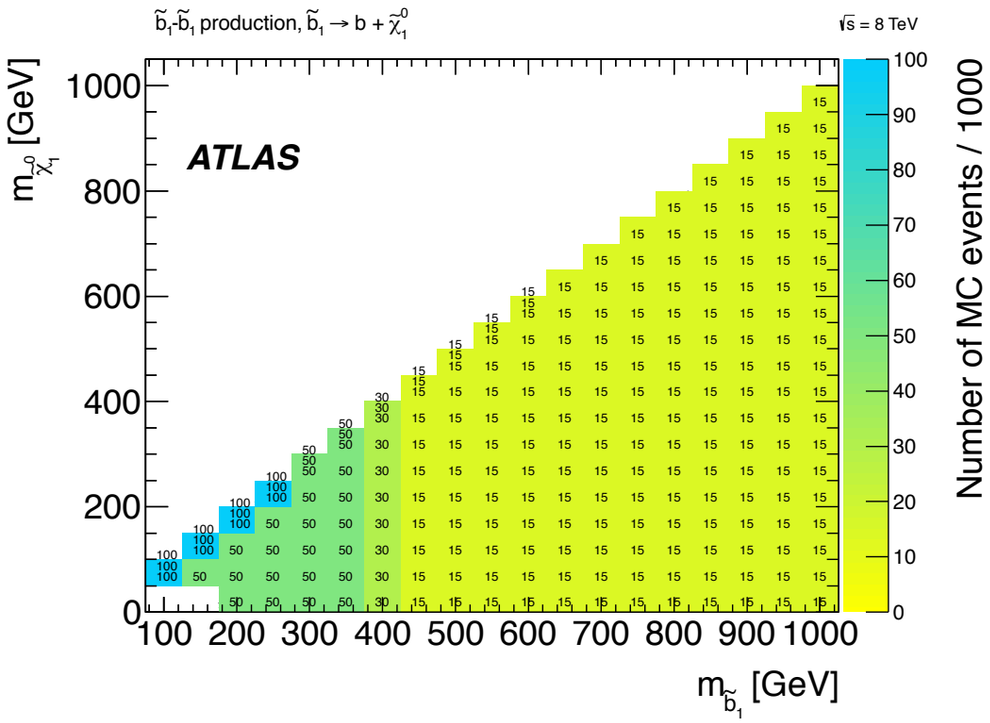
Acceptance based on truth-level objects

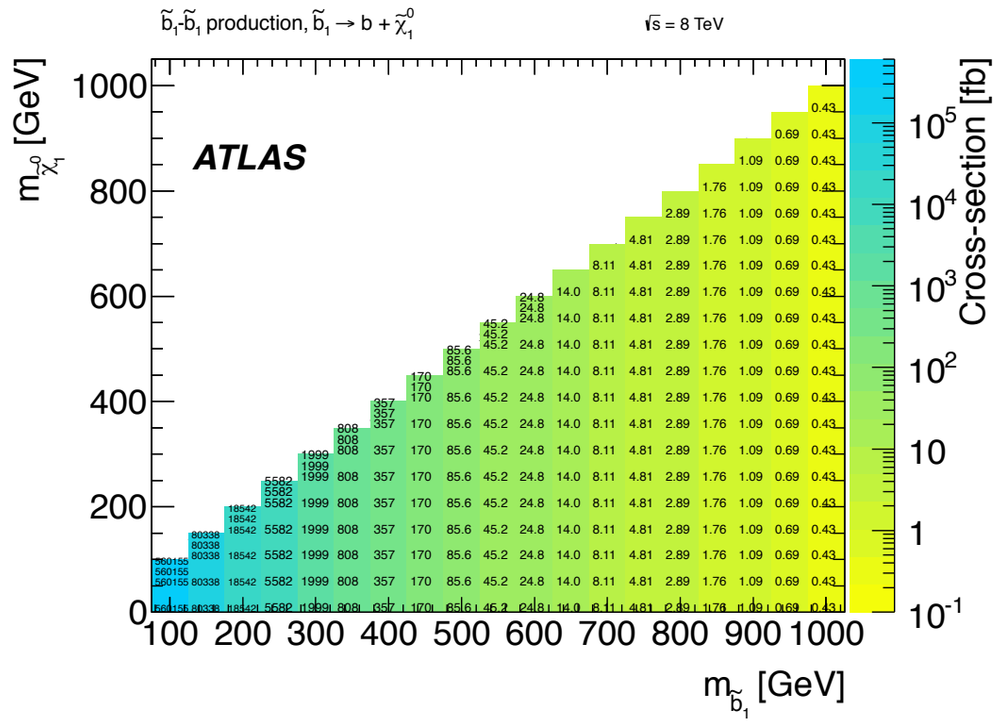
Acceptance based on reco-level objects

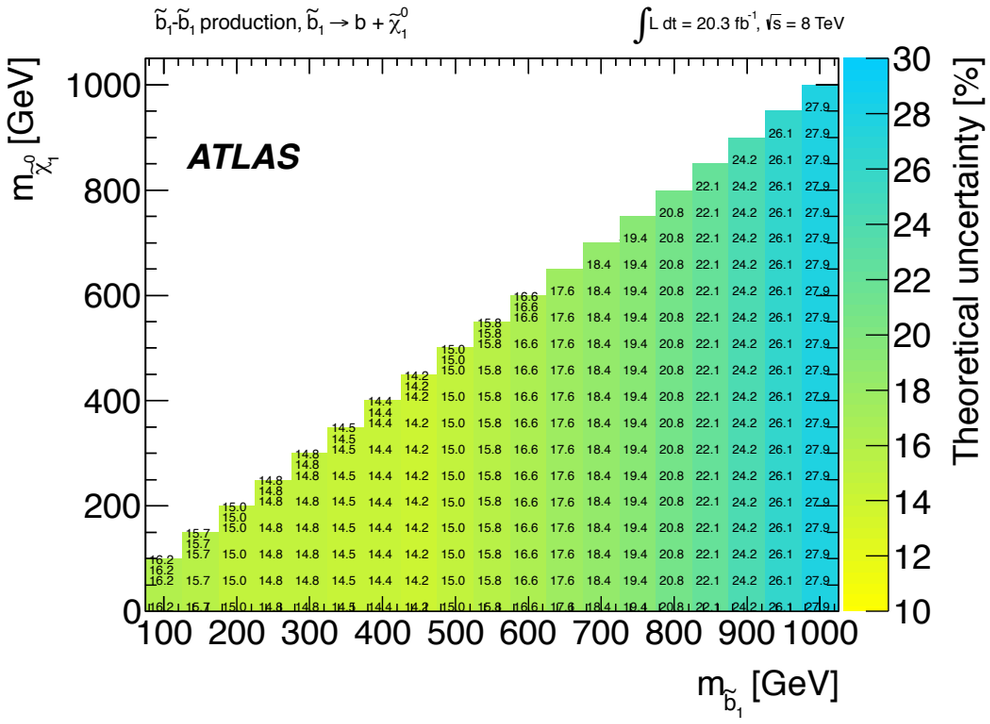


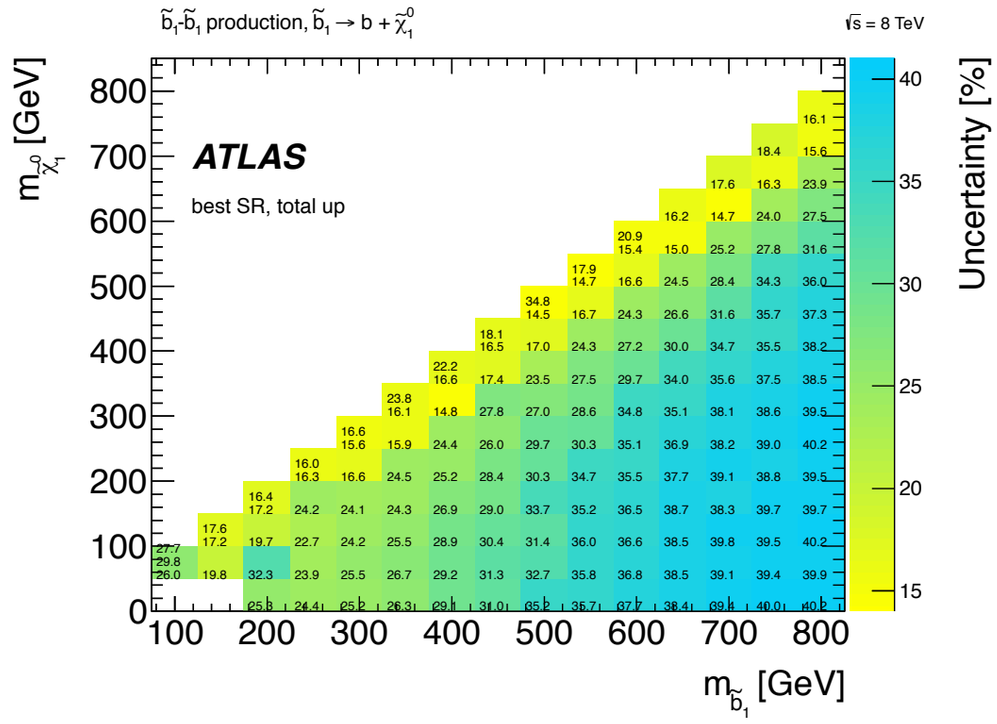
Presentation of results

ATLAS









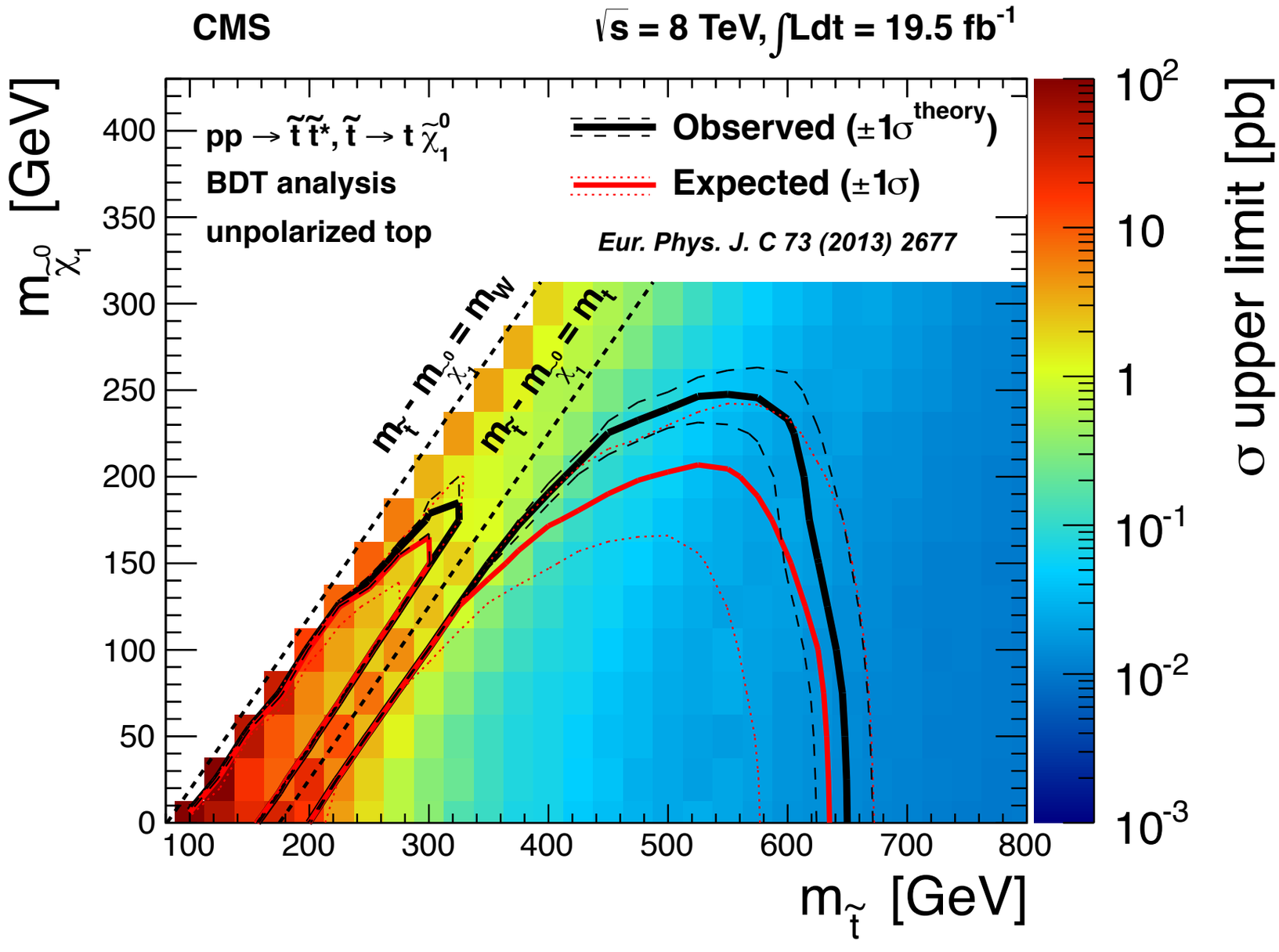
Other useful information

Presentation of results

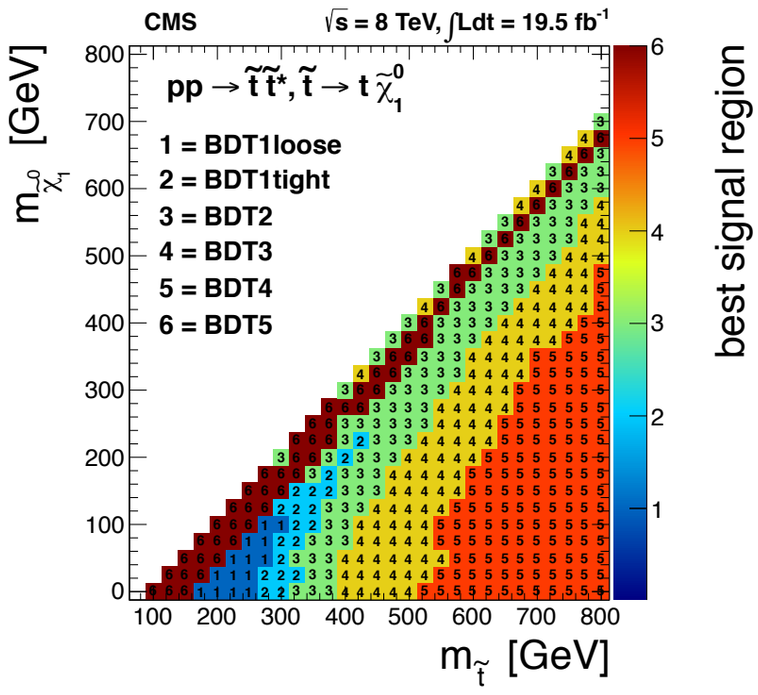
CMS

example: Run I
stop 1L search

Less standardized than ATLAS with sometimes more and sometimes less information



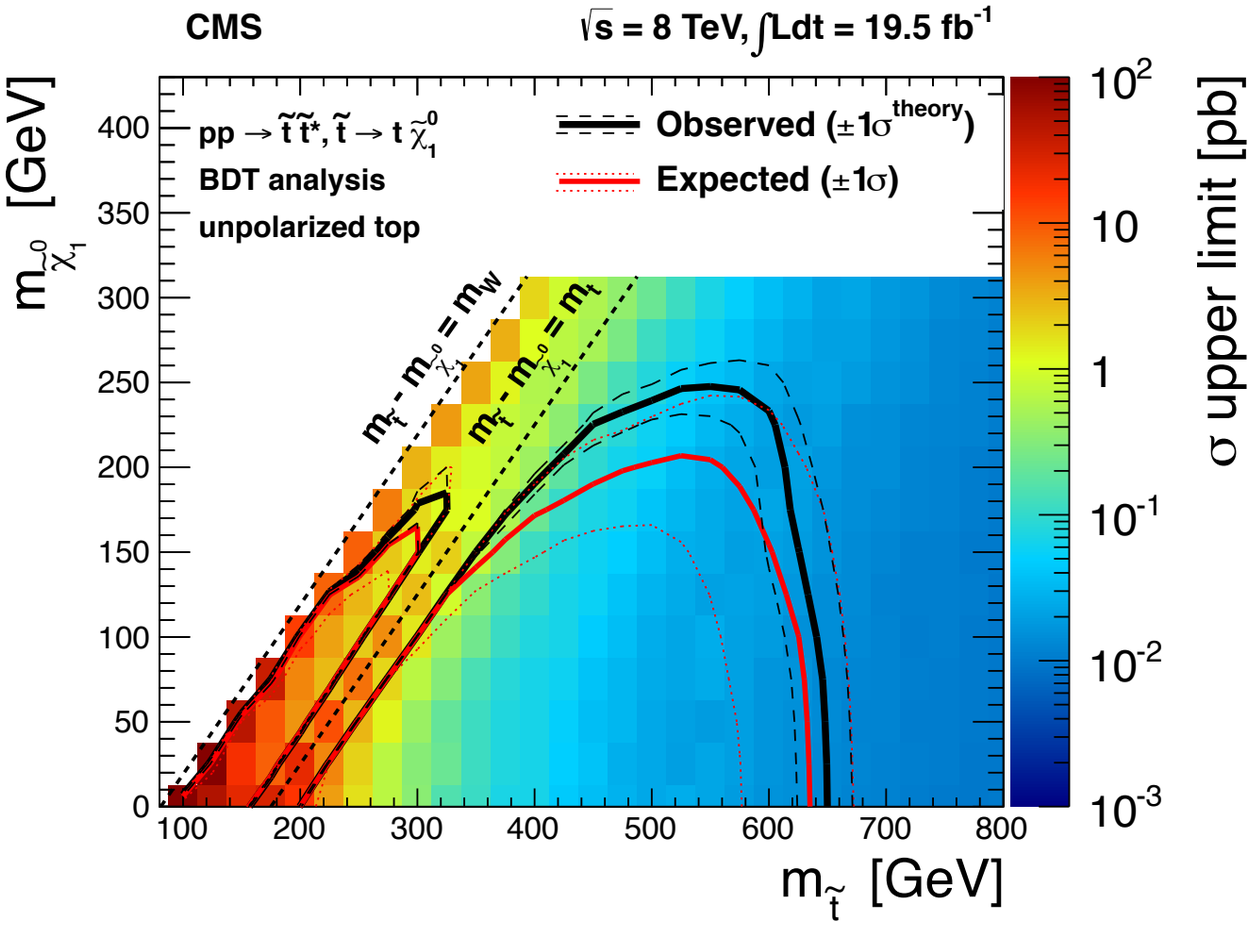
Cross-section upper limit usually combined with main limits plot



Always get the most sensitive SR map

Repo for plots and tables:
CMS public twiki (ROOT files)

Presentation of results CMS

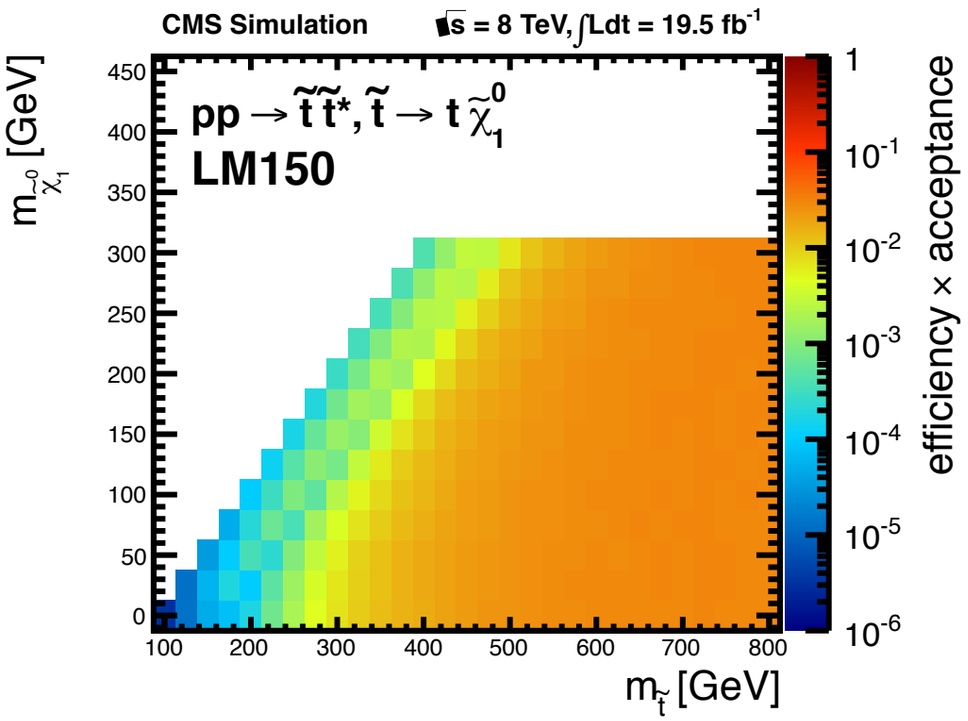


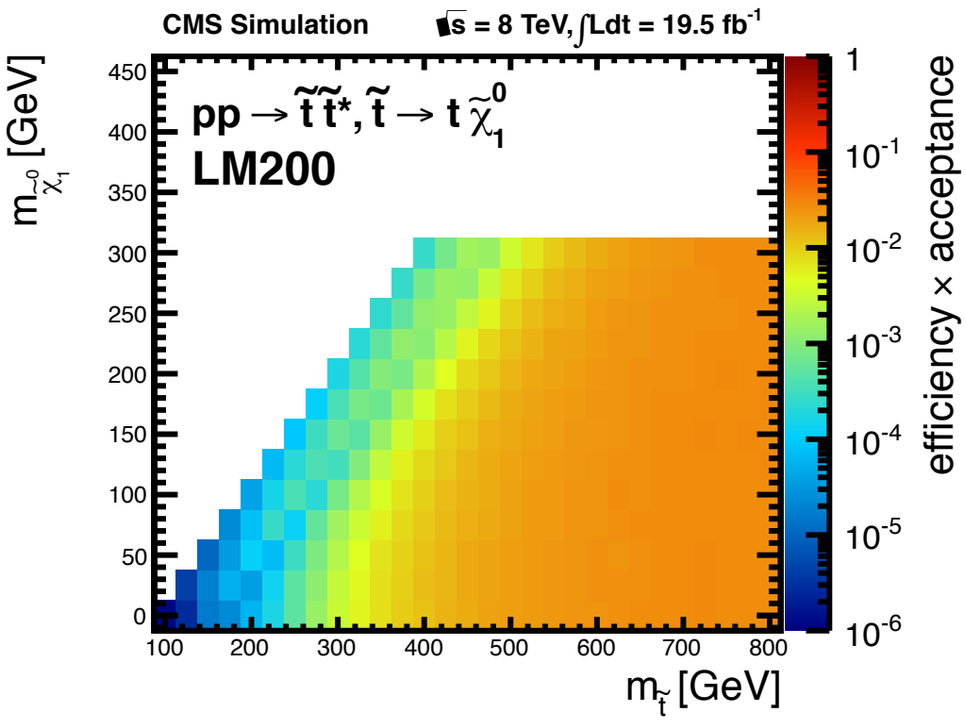
(same plot as previous page)

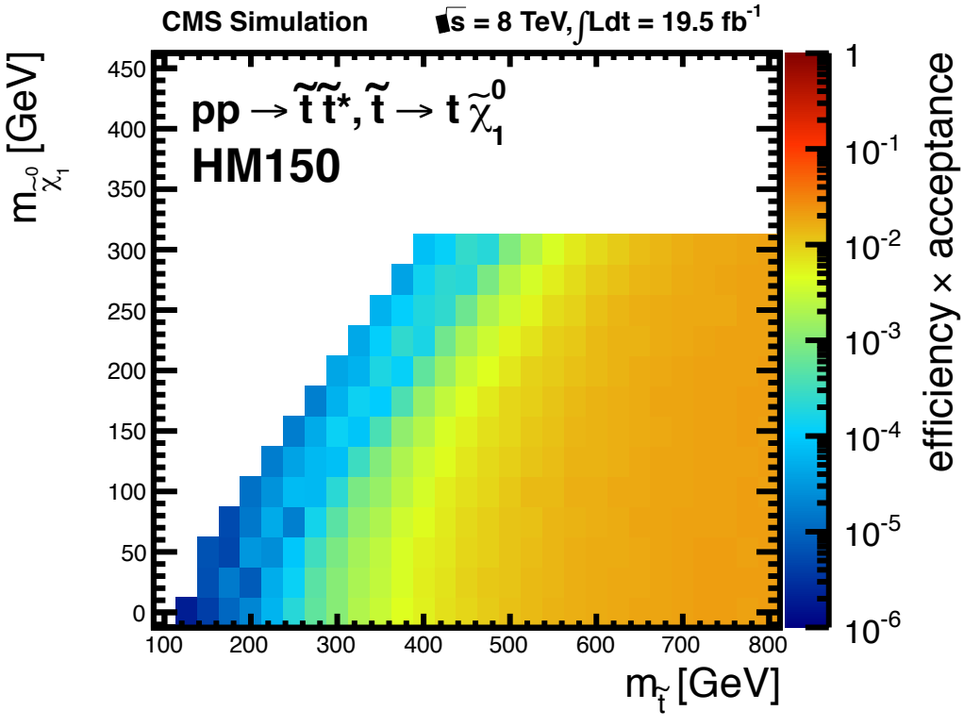
If your model had the same pheno, but different cross-section

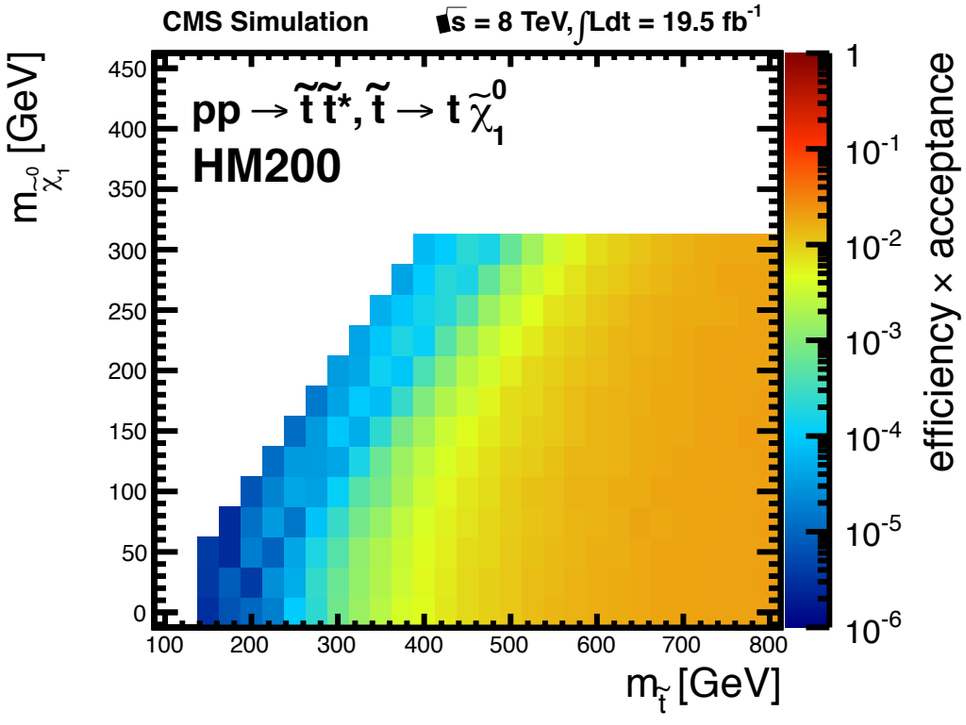
If you had the same model, but different BR

Presentation of results CMS





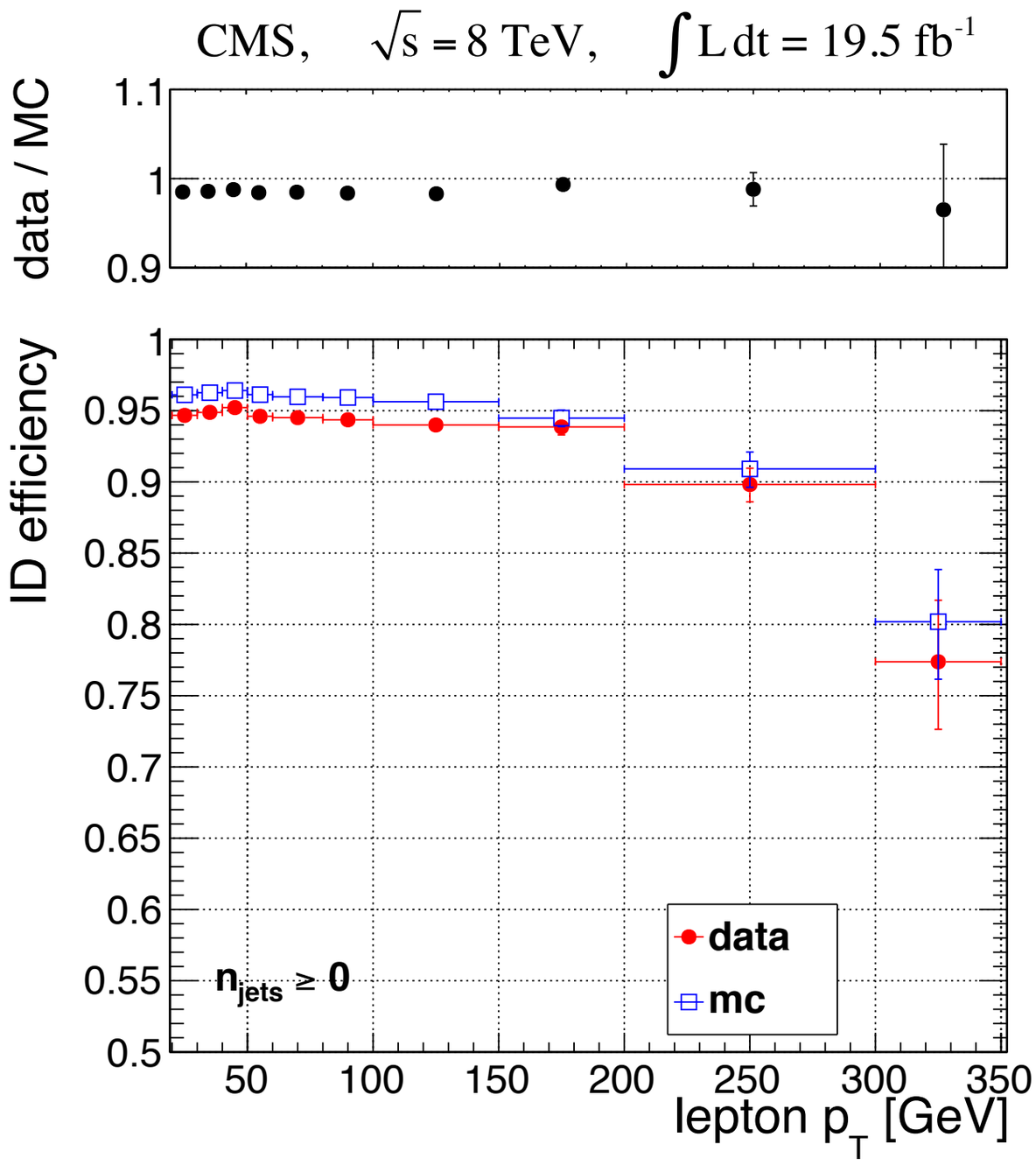


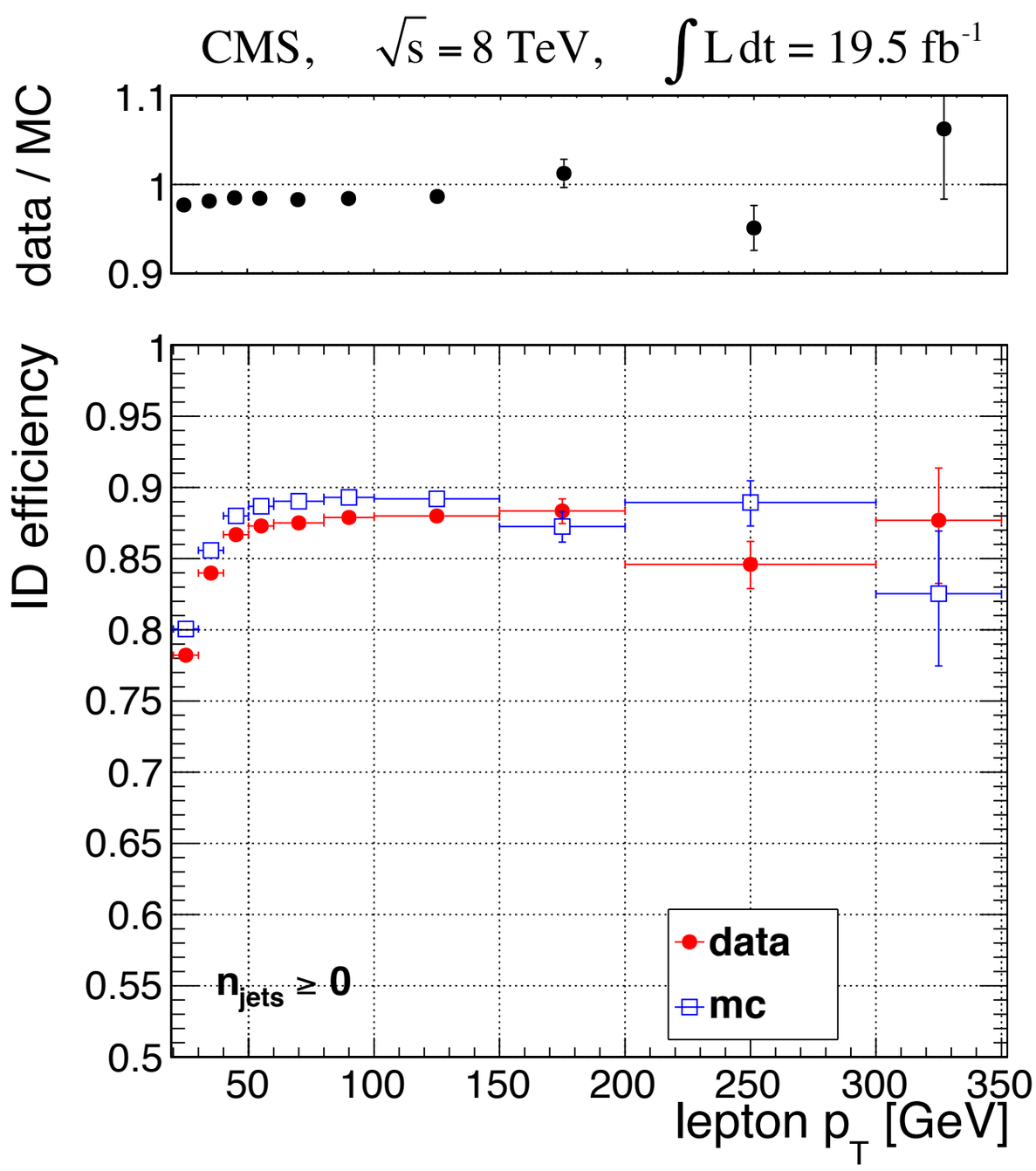


Acceptance based on reco-level objects

Presentation of results

CMS





Other useful information

Future outlook

ATLAS and CMS (mostly) agree on simulation

As we push further into the new energy frontier,
we will have key questions to answer:

When/where do we need more precise simulation?

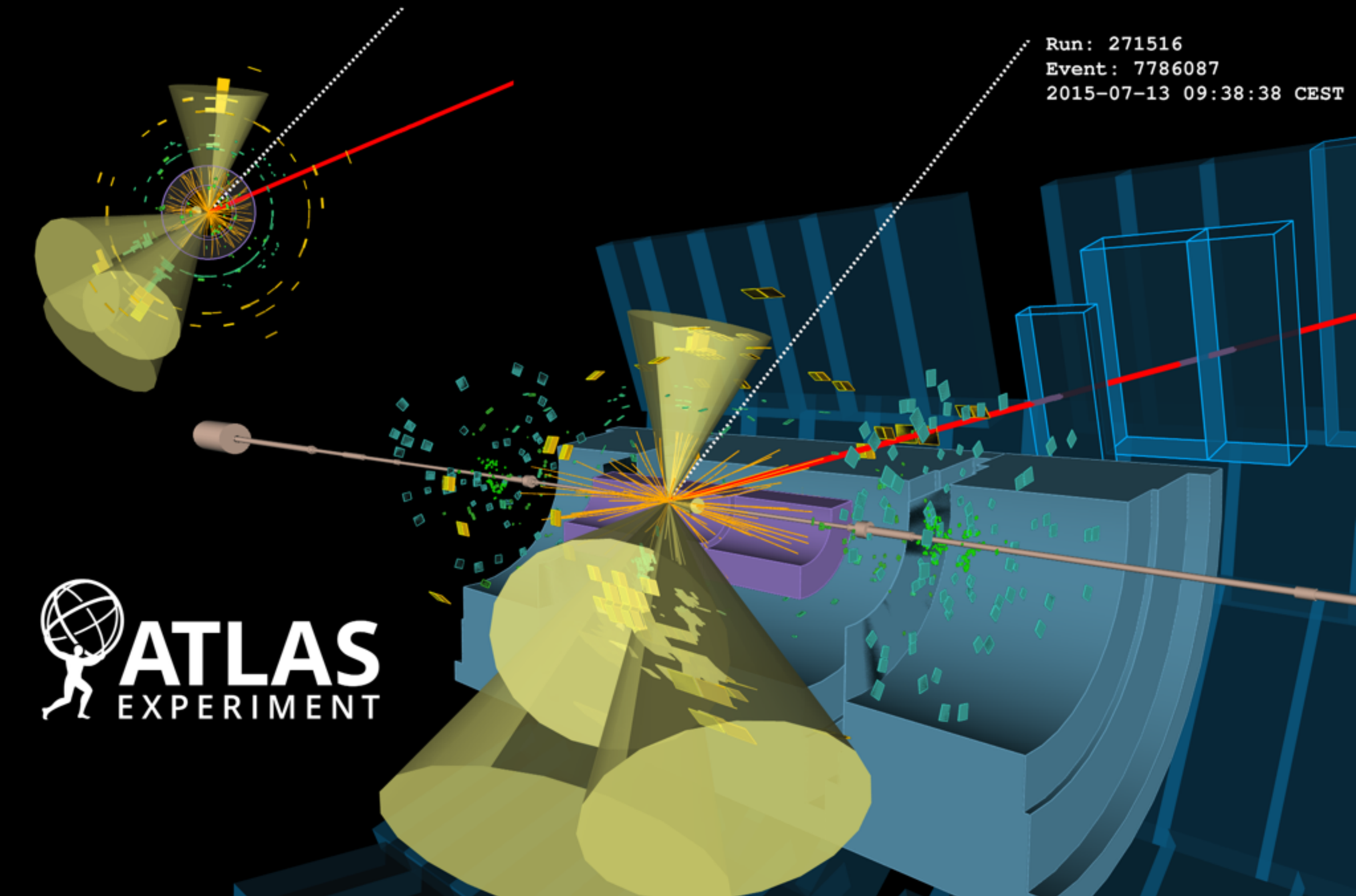
Compressed spectra? 3- and 4-body decays? When ISR jets are involved? When background looks just like signal?

How can we save disk space and CPU time?

Recycling events, filters, etc.

2015 was a great kickoff to hopefully an exciting investigation of the unexplored at the 13 TeV!

The unexplored? (600 GeV large R jet with m_{jet} ~180 GeV and MET ~ 500 GeV)



Backup

Eur. Phys. J. C 73 (2013) 2677