Recasting and reinterpreting LHC searches with MadAnalysis5.

Dipan Sengupta

LPSC, Grenoble

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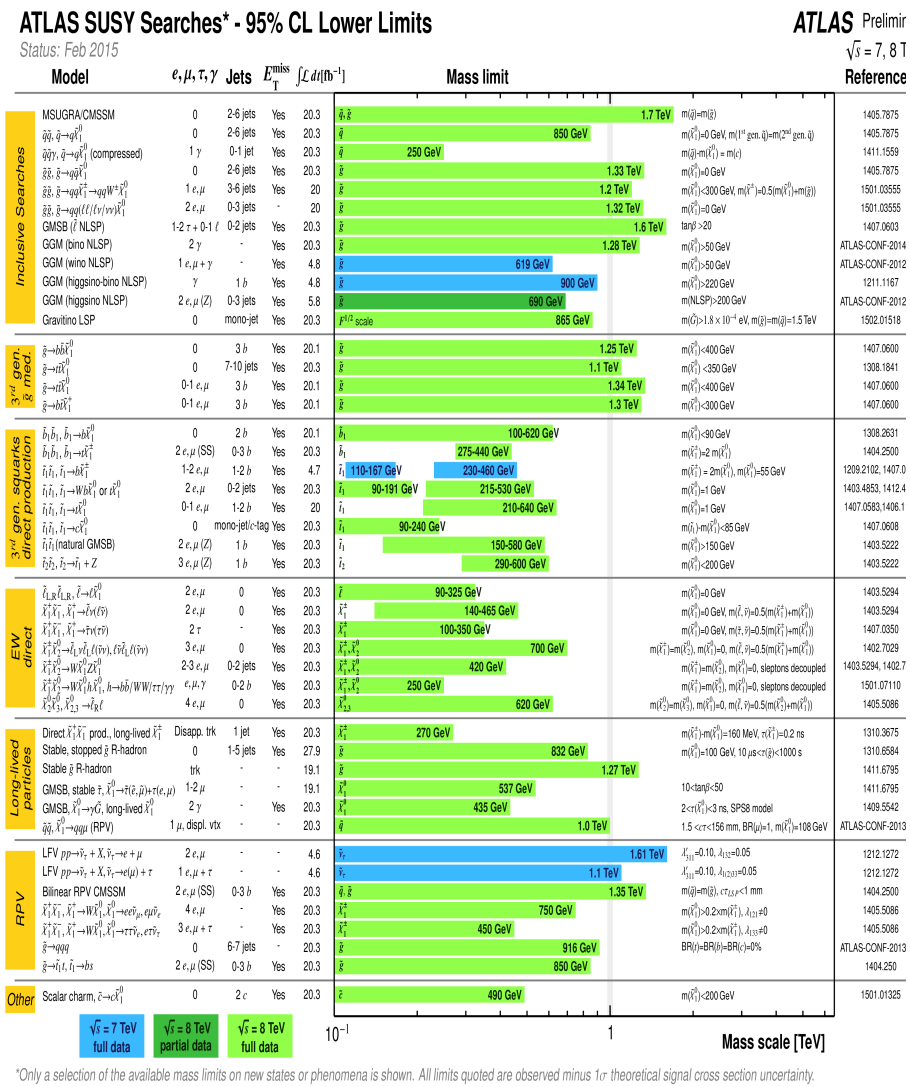
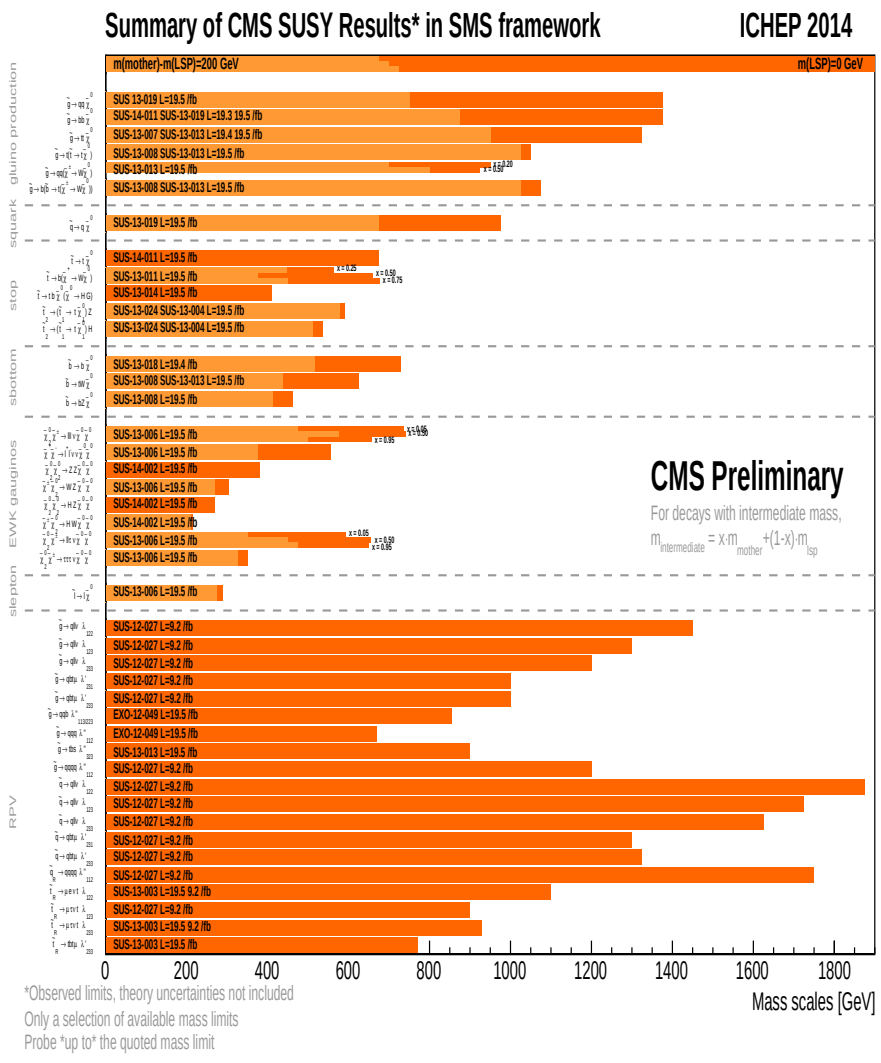
The need for recasting and reinterpretation.

At the end of run I at the LHC a lot of experimental searches have probed new physics, in particular SUSY.



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

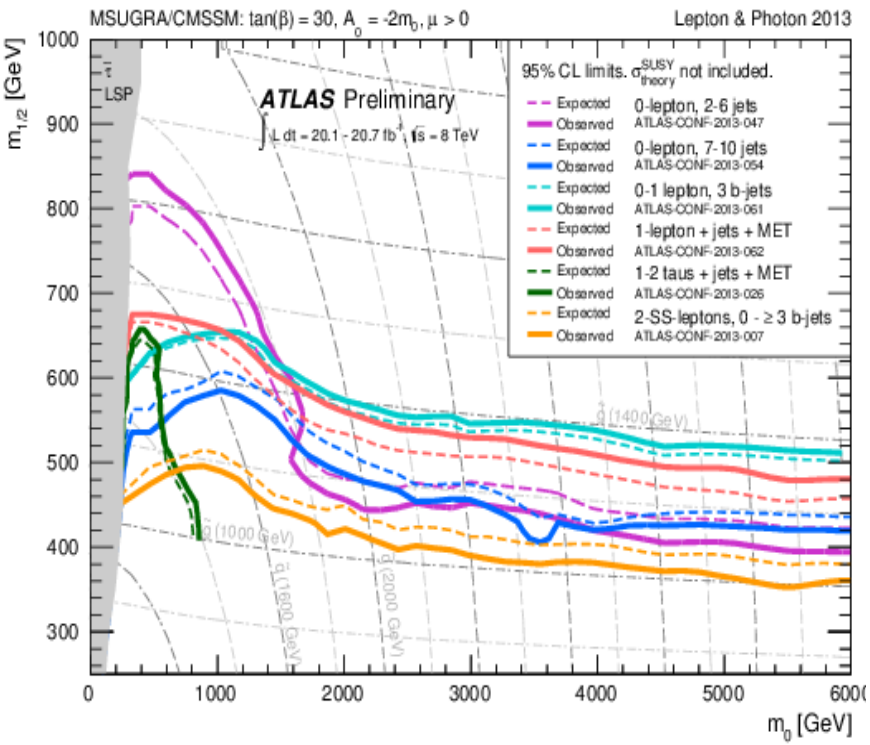


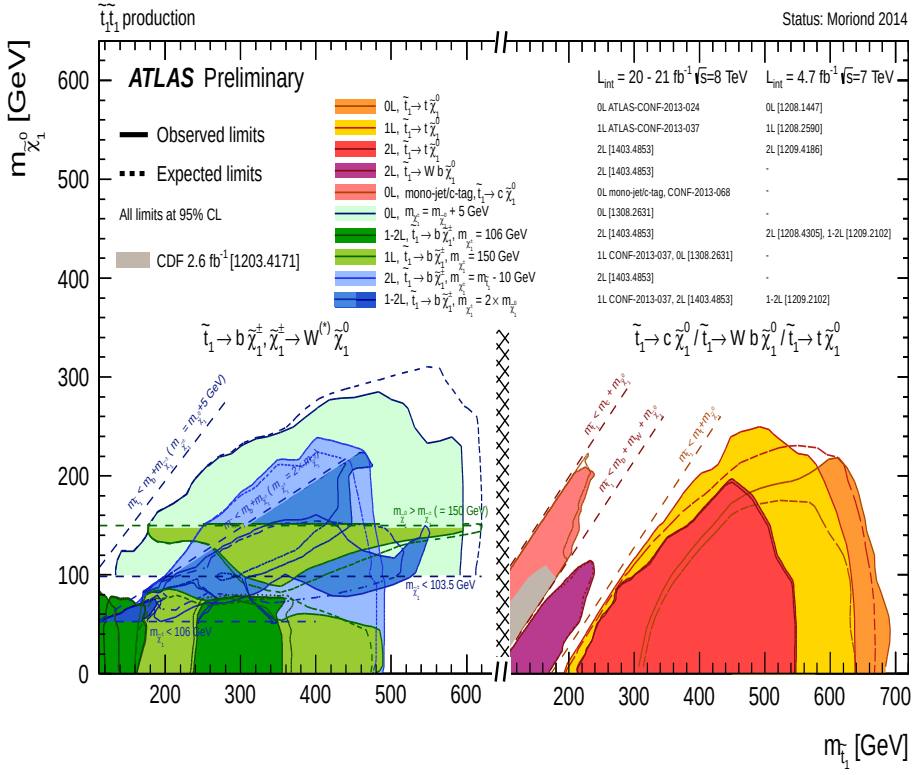
*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe *up to* the quoted mass limit

However, one can ask : Can these searches be used to cover more real estate in BSM physics ?

The need for recasting and reinterpretation.

Two classes of SUSY searches are considered by the experimental collaboration, full model and SMS scenarios.





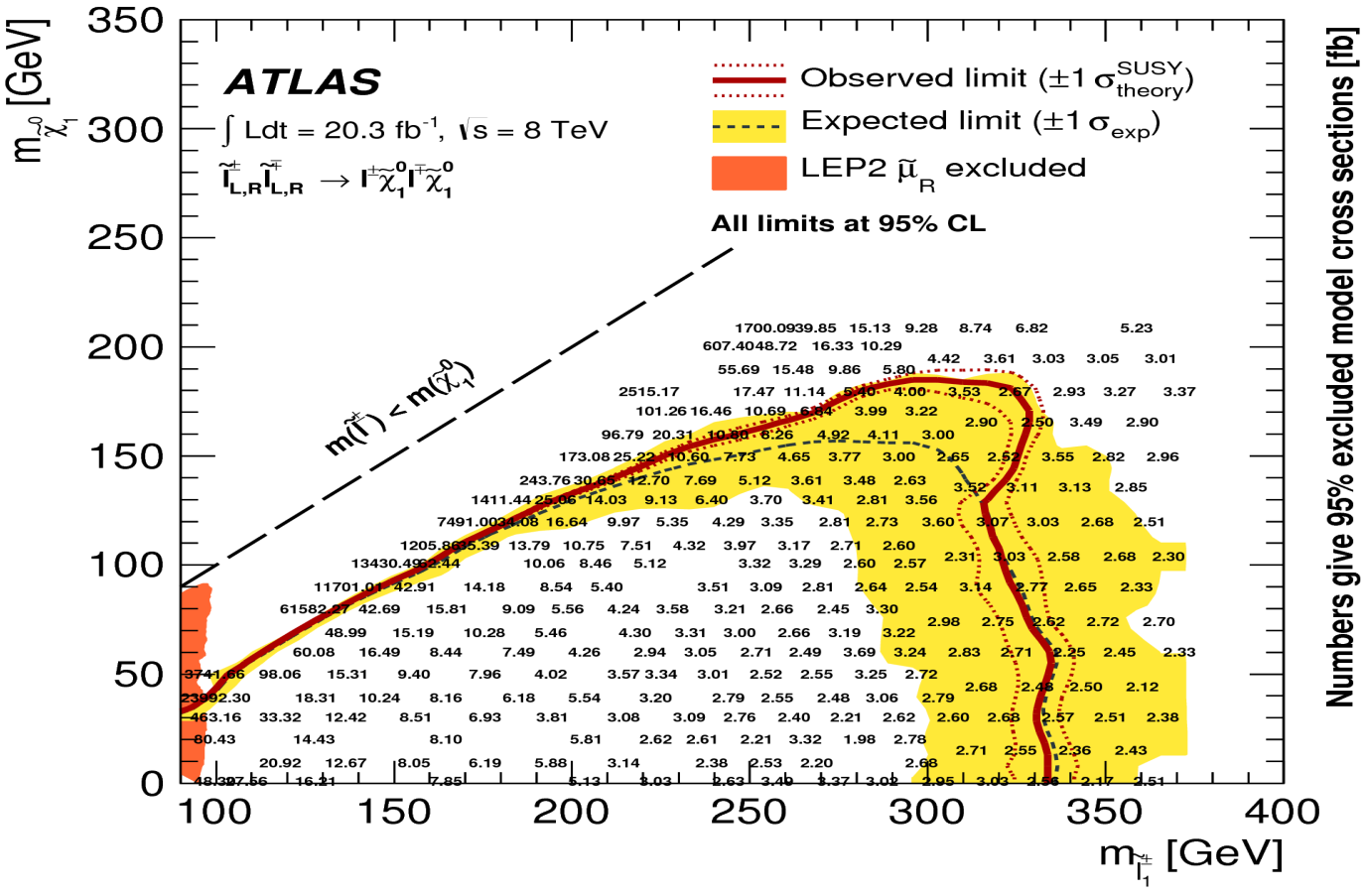
- A generic new physics search has n-leptons + m-jets + i-photons + $\not{p}_T$ optimized for the target model.
- Most simplified model searches at LHC are done with strong assumptions on the spectrum.
- However these searches can be reinterpreted in a wide variety of models.

Reinterpretation of BSM searches

Two ways of reinterpreting LHC searches :

- SMS approach :
  1. SModels : [Kraml et al, 1312.4175]
  2. Fastlim : [Papucci et al, 1402.0492]
  3. XQCAT : Barducci et al [1405,0737]
- Recast approach :
  1. Checkmate : Drees et al, [1312.2591]
  2. ATOM : [Kim et al, to appear ?]
  3. LHC-PAD in MadAnalysis5 [DS,Dumont,Fuks, Kraml et al, arxiv:1407,3208]

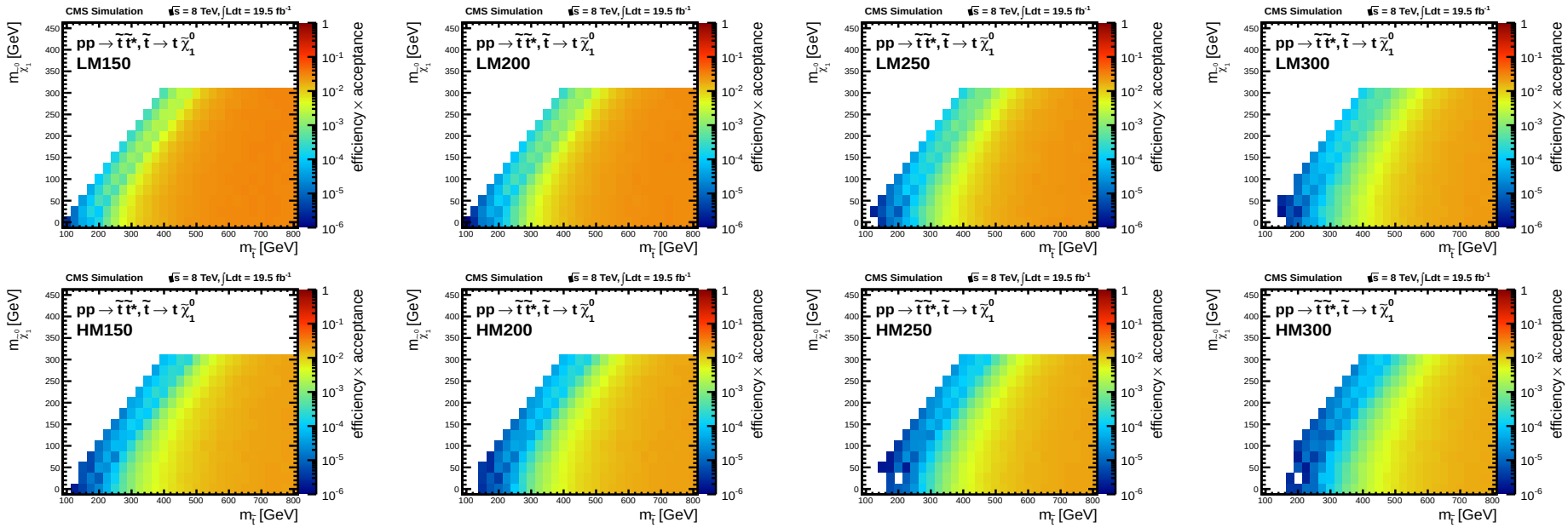
Reinterpretation of BSM searches.



- Experimental collaborations give a 95 % confidence level upper limit on model cross section
- Makes it possible to decompose a model into $\sigma \times \mathrm{BR}$ and compare it to ATLAS and CMS results.
- Therefore decompose a model into simplified topologies . (more than 50 ATLAS and CMS SUSY searches)
  SModelS: Kraml et al. arXiv:1312.4175(`http://smodels.hephy.at`)

Reinterpreting BSM searches

Alternatively, use acceptance $\times$ efficiency maps instead of 95 % confidence level bounds on model cross section.



- For every signal region in an LHC analyses, $n_s = \Sigma_i \sigma_i \times (\text{Acceptance} \times \text{efficiency})_i \times \mathcal{L}$ for every simplified model.

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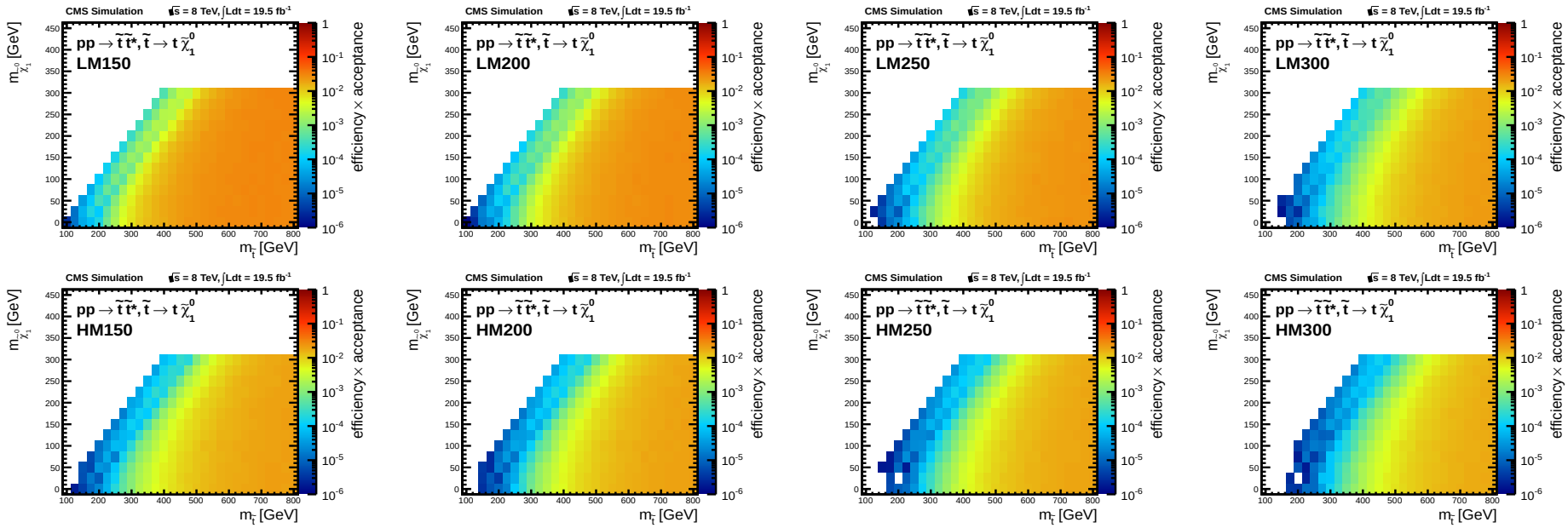

- For every signal region in an LHC analyses, $\mathrm{n_s} = \Sigma_\mathrm{i}\sigma_\mathrm{i} \times (\mathrm{Acceptance} \times \mathrm{efficiency})_\mathrm{i} \times \mathcal{L}$ for every simplified model.
- Problem : One needs to have these maps for every simplifed model for all regions.
- This is the FastLim approach. [1402.0492] (10 ATLAS SUSY searches at 8 TeV)

The need for recasting LHC analyses

- The SMS approach although extremely useful is limited
  1. Simplified models do not cover all possible scenarios.
  2. A new model may not be decomposable in a simplified scenario.
  3. The need to reinterpret LHC results in all kinds of new physics models.
  4. To have a repository of LHC analyses for future use for the whole community.

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- Checkmate : A repository of analyses that can be used to constrain generic models.
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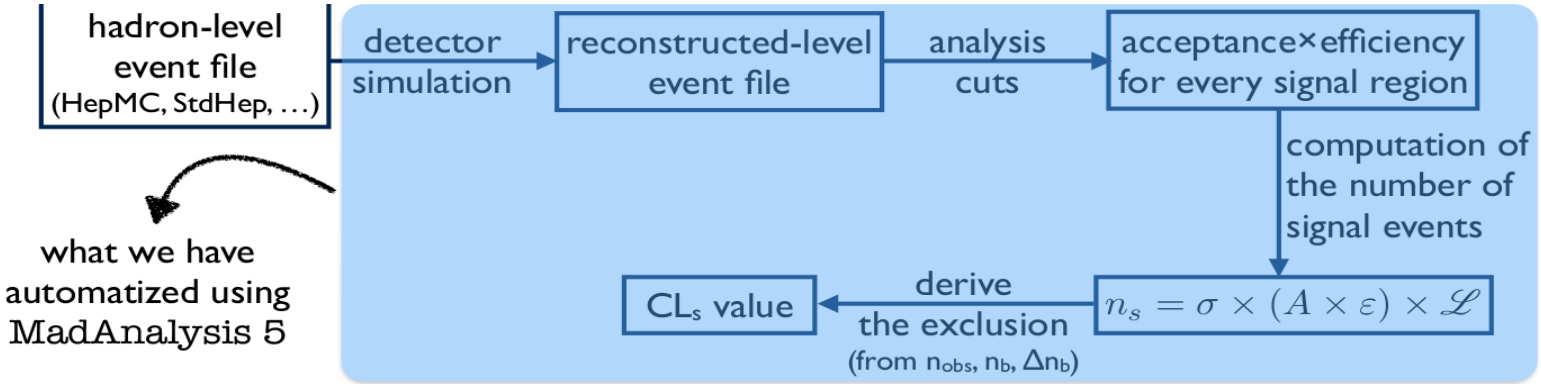
- MadAnalysis5 : A user friendly public analysis database in the MadAnalysis5 framework based on monte carlo events.
  Conte, Fuks, Serret, arXiv :1206.1599
  Conte, Fuks, arXiv: 1309.7831
  Conte, Dumont, Fuks, Wymant, arXiv: 1405.3982

The scope of MadAnalysis5

1. MadAnalysis5
   - A public analysis database of validated LHC Analyses.
   - User friendly, out of the box installation, flexible.
   - Sophistication : Parton level (lhe,LHCO), hadron level(stdhep,hepmc), Detector simulated(Root).
2. Normal Mode :
   - Command line mode on a python shell.
   - Simple commands to calculate relevant variables.
   - Outputs in HTML, latex and pdf format.
3. Expert Mode :
   - Allows us to recast LHC analyses in the SampleAnalyzer framework.
   - One has to write simple c++ codes and use root files to recast an analyses.

The working principle of MadAnalysis5

For every analysis we follow the following steps:



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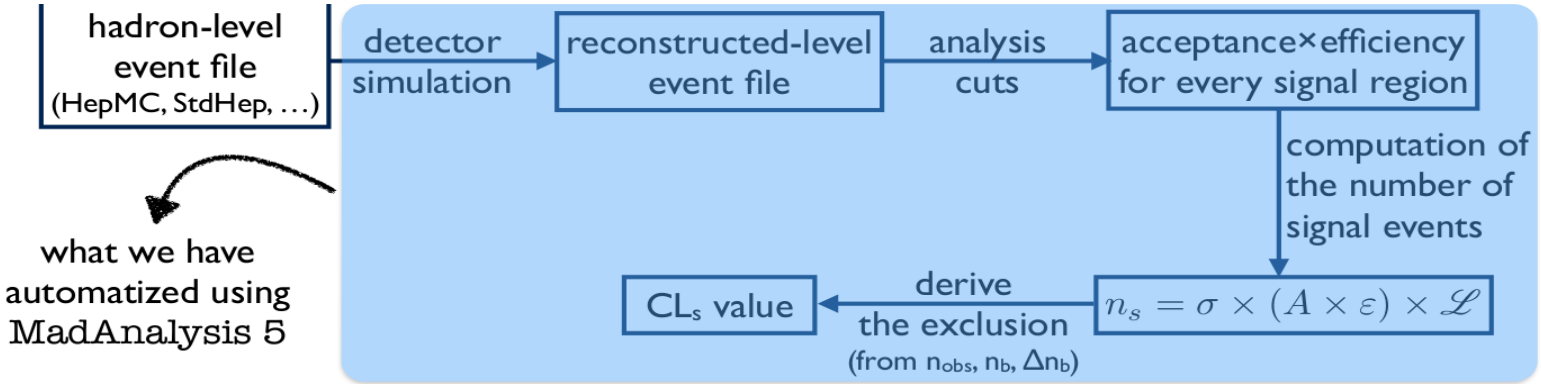
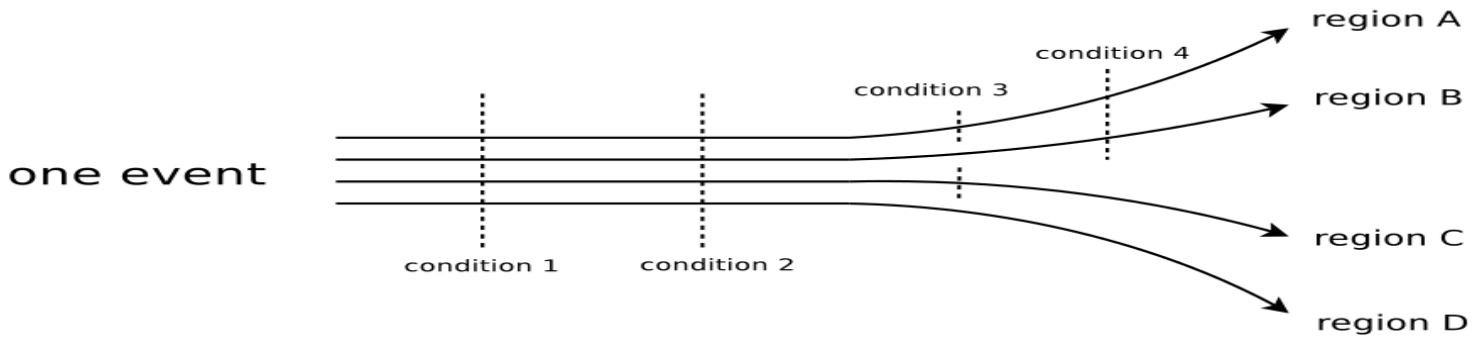


MadAnalysis5 follows a modular approach to handling cuts:



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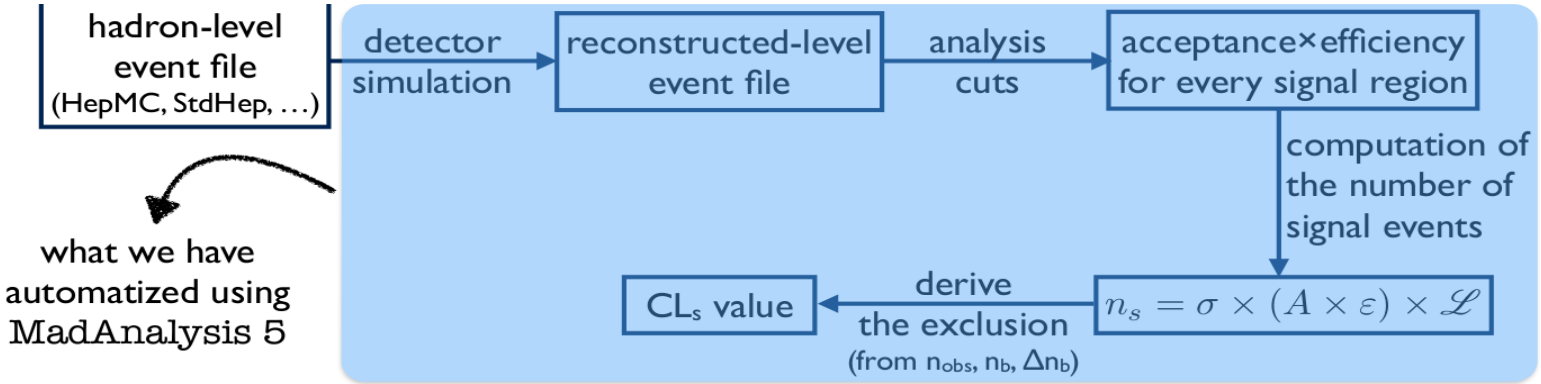

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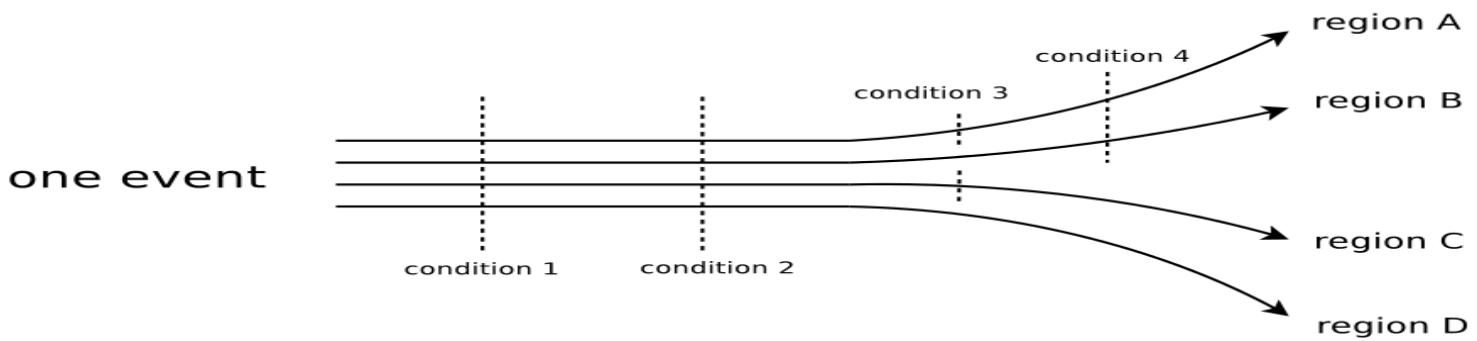


Features

- Efficient algorithm to evaluate each cut condition only once and apply to all surviving signal region.
- Support for several analysis at the same time.
- Ready to use kinematic variables ($\mathrm{M_{T2}}, \alpha_{\mathrm{T}}, \mathrm{H_T}$ ...)

The scope of validation in MadAnalysis5

- A full experimental analysis takes into account real detector effects, object identification with detector efficiency.
- Additionally underlying events, pile up, misidentification of objects are highly detector specific.
- In a fastsim one can only model all of the above to some degree of accuracy.
- We call an analysis validated only if the cutflow is within 20 % of the official.

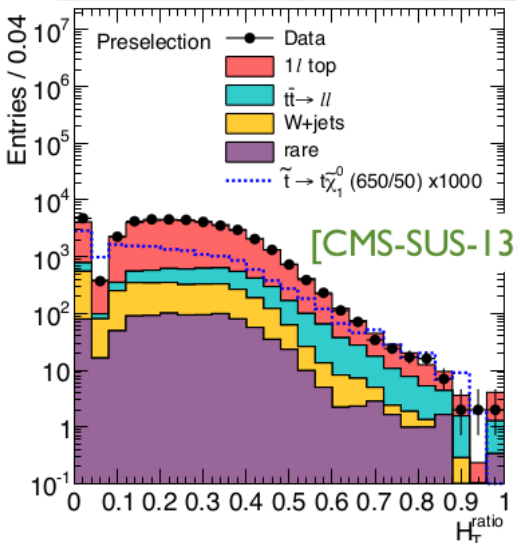
- The need for proper validation material is of primary requirement.
- Cut flows, Histograms, and additionally the lhe event file and/or the monte carlo settings.

cutflows

$(m_{\tilde{\ell}}, m_{\tilde{\chi}_1^0})$	$(191, 90)$ GeV	
Lepton flavour	e^+e^-	$\mu^+\mu^-$
Two signal leptons	135.4	147.8
Jet veto	60.5	64.7
Z Veto	55.7	60.0
SR-m_{T2}^{90}	21.8	21.7
SR-m_{T2}^{120}	8.0	8.5
SR-m_{T2}^{150}	0.6	1.1

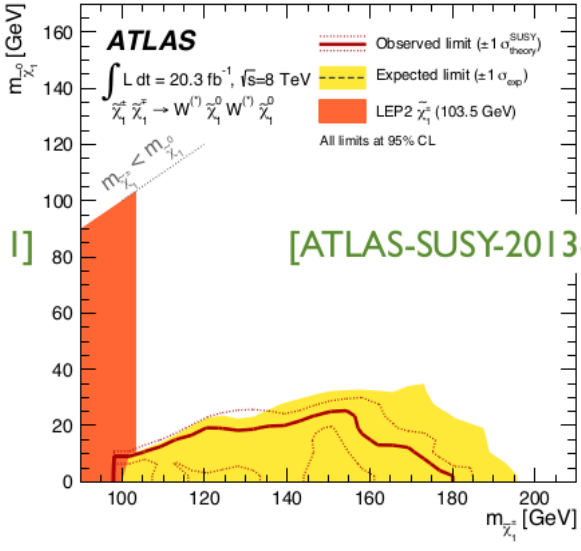
[ATLAS-SUSY-2013-11]

histograms of kinematic quantities



[CMS-SUS-13-011]

limit plots

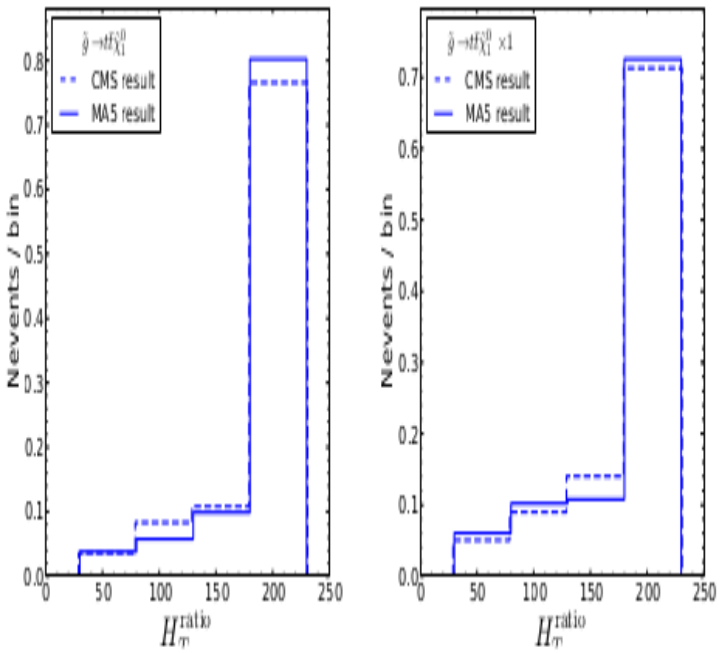


[ATLAS-SUSY-2013-11]

A validated CMS analysis : CMS-SUS-PAS-016

- The analysis targets gluino search in $\tilde{g} \to t\bar{t}\chi_1^0$ in $l^+l^- + 2\,b-jets + jets + \not{p}_T$ channel.
- We received lhe files + Cut-flows+ histograms as validation material from the CMS collaboration Big Thumbs Up!.

cut	$m_{\tilde{\chi}_1^0} = 275$ GeV		$m_{\tilde{\chi}_1^0} = 525$ GeV	
	CMS result	MA5 result	CMS result	MA5 result
$2\ell + \geq 2$jets	9.8 ± 0.2	9.0	9.5 ± 0.2	8.9
$+ E_T^{miss} > 180$ GeV	7.5	7.3	6.6	6.4
$+ n_j > 4$	6.2	6.5	5.4	5.7
$+ n_b > 2$	2.6	3.1	2.3	2.6
$+ \lvert\eta\rvert_{j1} < 1$	2.2	2.7	2.0	2.1
$+ \lvert\eta\rvert_{j1} < 1$	1.9	2.3	1.6	1.7



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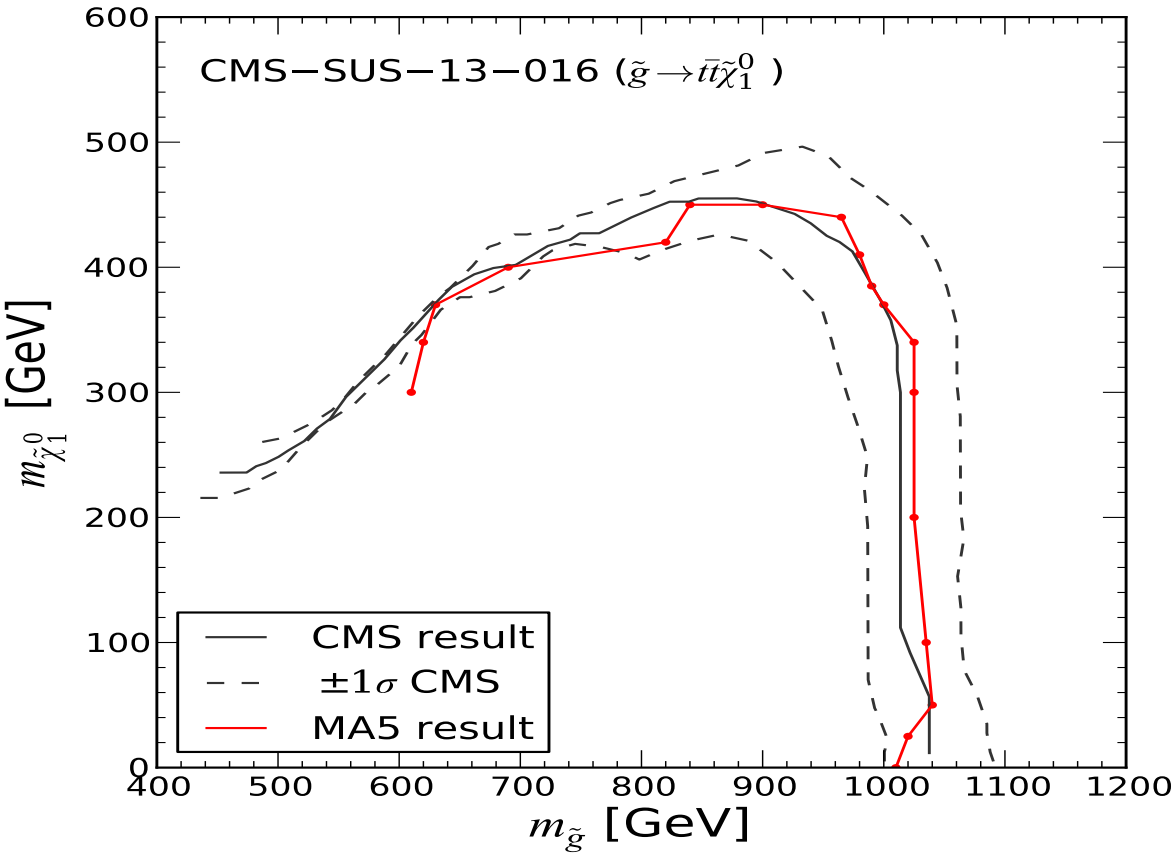
The exclusion curve



The public analysis database (MA5-PAD)

- The creation of a public analysis database is well under way.
- The detailed instructions on the installation and usage of MadAnalysis5 and the LHC Pad is documented in `http://madanalysis.irmp.ucl.ac.be/wiki/PhysicsAnalysisDatabase`.

ATLAS analyses, 8 TeV

Analysis	Short Description	Implemented by	Code	Validation note	Status
ATLAS-SUSY-2013-05 (published)	stop/sbottom search: 0 leptons + 2 b-jets	G. Chalons	Inspire	PDF (figures)	done
ATLAS-SUSY-2013-11 (published)	EWK-inos, 2 leptons + MET	B. Dumont	Inspire	PDF (source)	done
ATLAS-HIGG-2013-03 (published)	ZH->ll+invisible	B. Dumont	Inspire	PDF (source)	done
ATLAS-EXOT-2014-06 (published)	mono-photons + MET	D. Barducci	Inspire	PDF	done

Delphes card for ATLAS-SUSY-2013-05
Delphes card for ATLAS-SUSY-2013-11

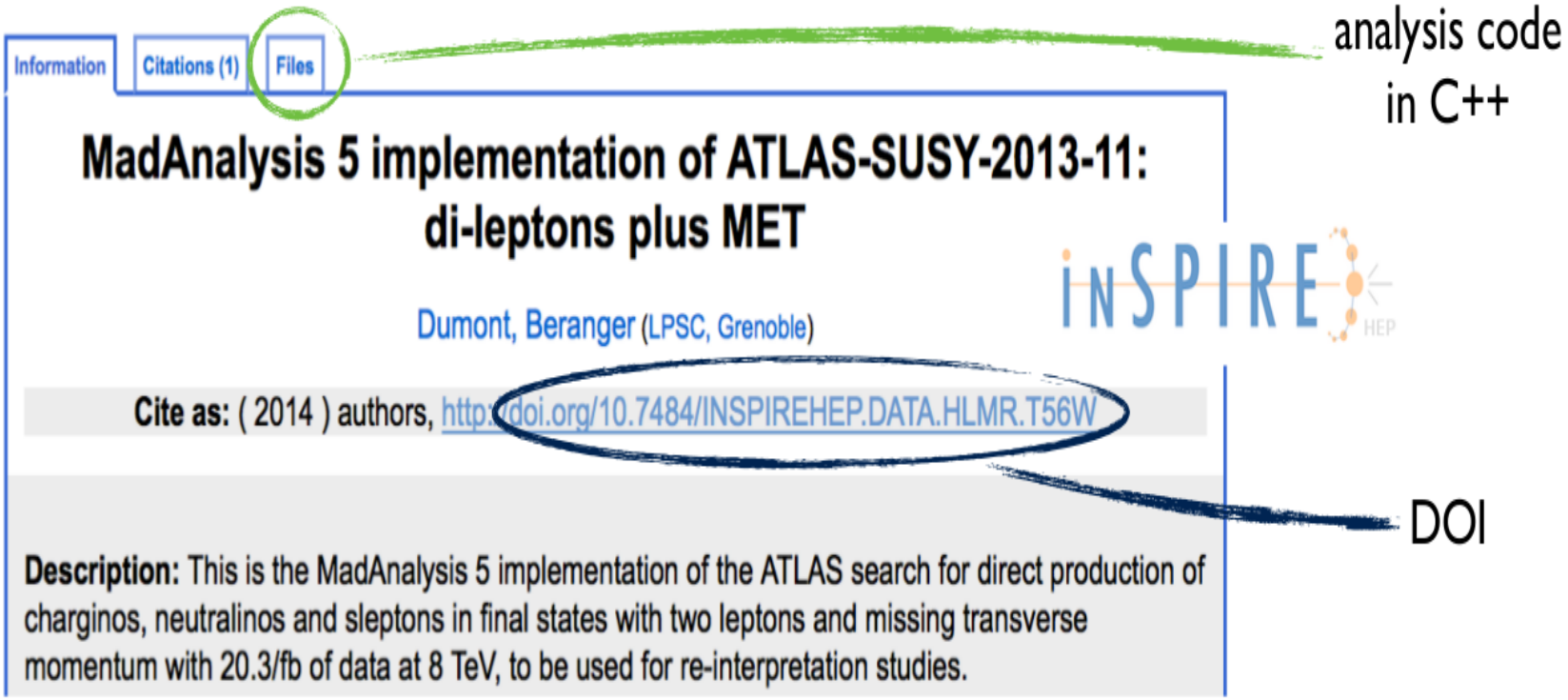
CMS analyses, 8 TeV

Analysis	Short Description	Implemented by	Code	Validation note	Status
CMS-SUS-13-011 (published)	stop search in the single lepton mode	B. Dumont, B. Fuks, C. Wymant	Inspire [1]	PDF (source)	done
CMS-SUS-13-012 (published)	gluino/squark search in jet multiplicity and missing energy	S. Bein, D. Sengupta	Inspire	PDF (source)	done
CMS-SUS-13-016 (PAS)	search for gluinos using OS dileptons and b-jets	D. Sengupta, S. Kulkarni	Inspire	PDF (source)	done

More validated analysis on it's way.
Slow and tedious process.

MA5-PAD : Publication policy

- Every validated analysis comes with the recast code on an INSPIRE page with a DOI.
- This way any one who has validated an analysis can be part of the database and cited accordingly.



MA5-PAD : Exclusion limits

- Additionally we provide a statistical tool : exclusion − CLs.py to derive confidence levels.
- It calculates the exclusion in the CLs prescription with $n_S, n_b, n_{obs}, \Delta n_b$.
- It requires $n_b, n_{obs}, \Delta n_b$ from the experimental analysis.
- For analyses with multiple signal regions, it selects the best expected signal for exclusion.

XML .info file
(provided on INSPIRE
along with the analysis code)

```
<analysis id="atlas_susy_2013_11">
 <lumi>20.3</lumi> <!-- in fb^-1 -->

 <region type="signal" id="MT2-90 emu">
   <nobs>21</nobs>
   <nb>23.3</nb>
   <deltanb>3.7</deltanb>
 </region>

 ... ... ...

</analysis>
```

```
lpsc-32-1.in2p3.fr:> ./exclusion_CLs.py atlas_susy_2013_11 run_872.list 0 0.04
The best expected signal region is "WWb ee;WWb mumu".
It has: nobs = 26, nb = 30.2 \pm 3.5, nsignal = 33.79.

This signal is excluded at the 100.0% CL (CLs=0.0).
```

Reinterpretation studies using the MA5-PAD

- A number of reinterpretation studies are currently on the way encompassing a wide variety of models.
- Probing top-philic sgluons with LHC Run I data. L. Bleck et al. arXiv:1501.075180.
- Dilepton constraints in the Inert Doublet Model from Run 1 of the LHC . G.Belanger et al. arXiv:1503.07367 (B.Dumont's talk).

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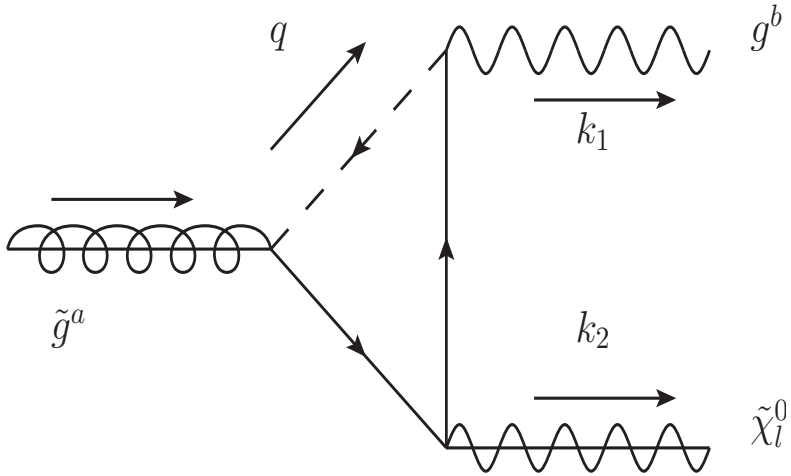
- Constraining the radiative gluino decay $\tilde{g} \to g\chi_1^0$ at LHC. (with G. Chalons (in progress))
- This decay has hitherto not been constrained by LHC searches.
- The decay is generally dominant for small mass gaps between $\tilde{g}$ and χ_1^0.
- It is important from a lot of physics scenarios, including gluino co-annhilation. (J. Ellis, K. Olive, arXiv: 1503.07142)



Constraining the radiative gluino decay

Important analyses that can be important to constrain this decay

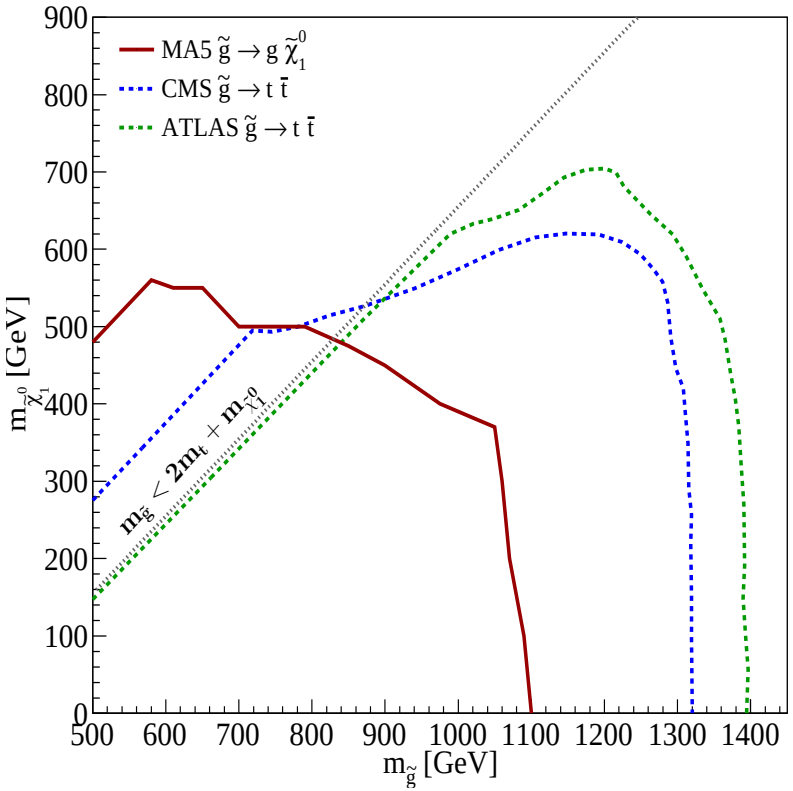
- The ATLAS monojet study : $\tilde{\mathrm{t}}_1 \rightarrow \mathrm{c}\chi_1^0$. (arXv:1407.0608)
  Status: Validated , exclusion curve to be made.

- The ATLAS 0 leptons + 2-6 jets + $\not{p}_{\mathrm{T}}$study. (arXiv:1405.7875)

- The CMS 0 lepton + 3-8 jets + $\not{p}_{\mathrm{T}}$ study. (CMS-PAS-SUS-012)

Reinterpretation studies using the MA5-PAD : Constraining the radiative gluino decay

- We already have some constraints from the validated CMS multi-jet (0 lepton + 3-8 jets + $\not{p}_{\mathrm{T}}$ study) (CMS-SUS-PAS-012) study in a simplified model scenario.



Conclusion

- We propose to create a public analysis database within the framework of MadAnalysis5.
- Simple c++ codes to be written to recast an analysis.
- Requires a community wide effort to make it successful
- Benefits include constraining new models, filling up blind spots, motivating new search strategies at the all important Run-II of LHC.
- It is also vitally important for experimentalists and theorists to exchange ideas and fill up the gaps in understanding from both perspectives.