Towards a public analysis database
for LHC new physics searches using MadAnalysis 5

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In collaboration with
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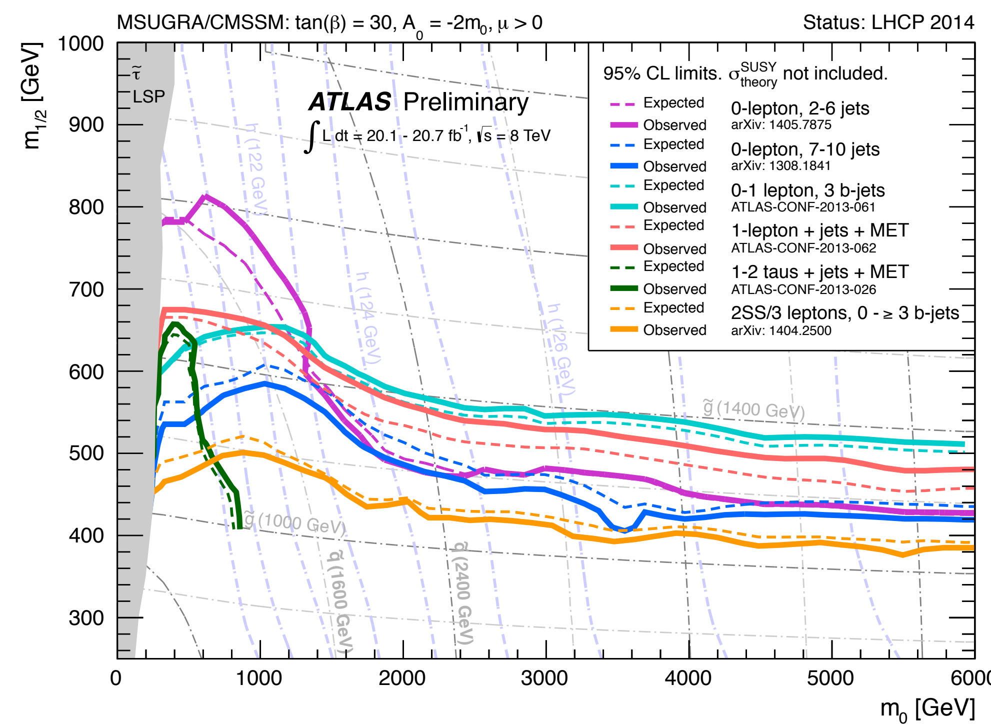
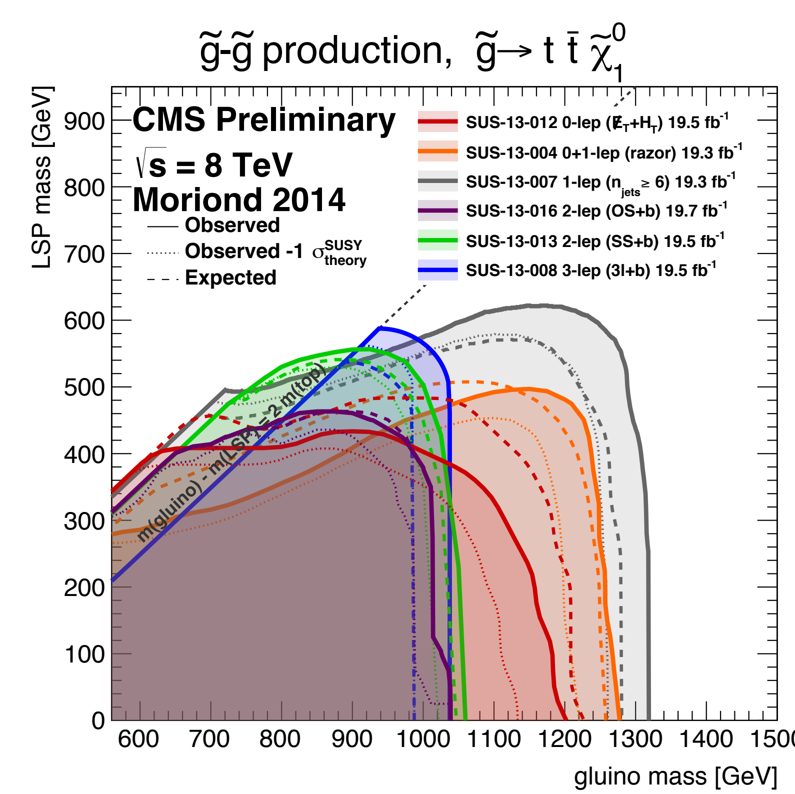
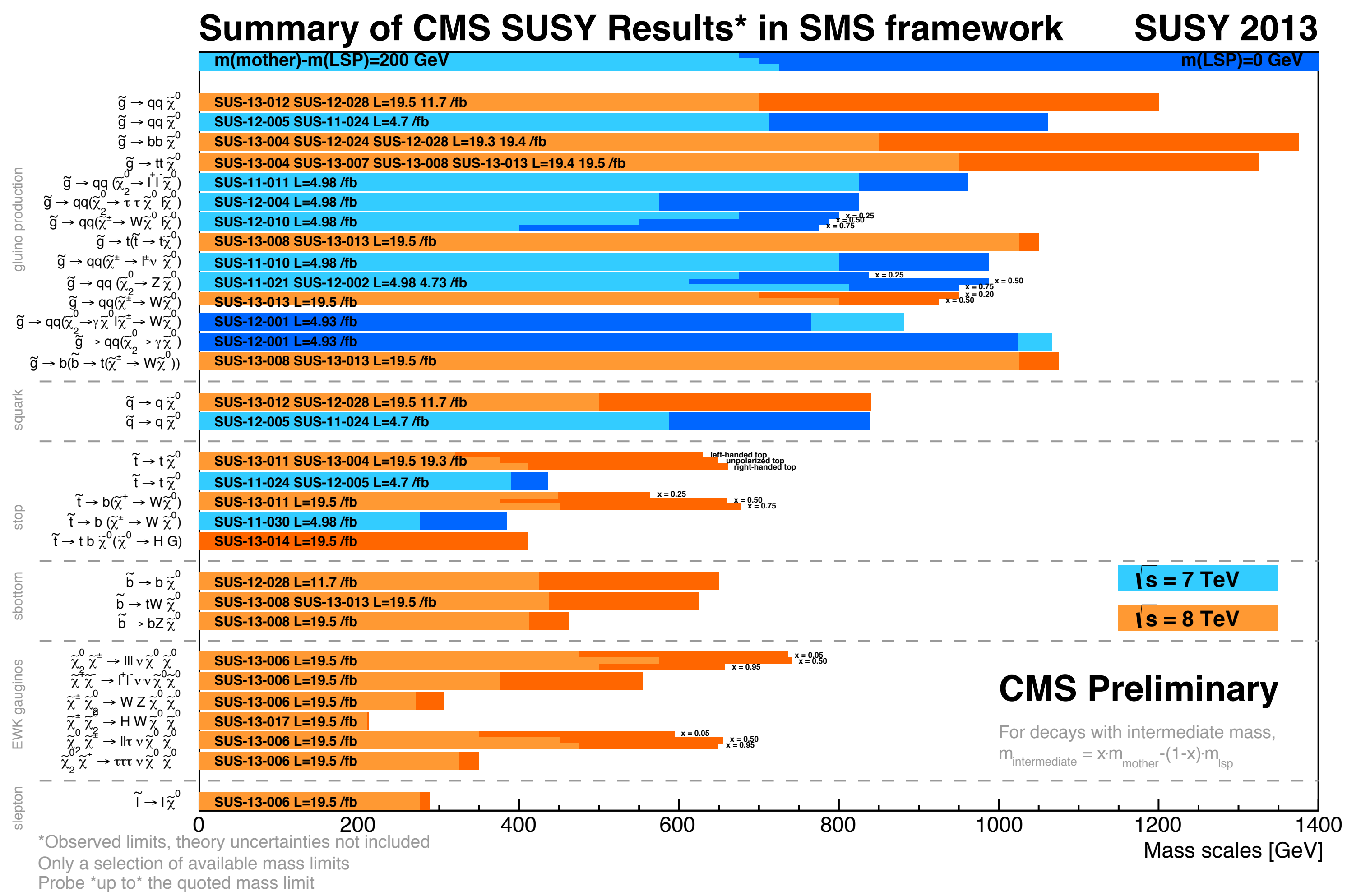
The need for interpretation studies

- ATLAS and CMS perform searches for new physics in many different channels.
- The collaborations typically interpret their results within constrained models, e.g. the CMSSM, or within topology-based "Simplified Model Spectra" (SMSs).
- However, constrained models and SMSs always have specific assumptions built in (mass ratios, branching fractions, etc).
- SUSY (and BSM in general) has much larger variety of signatures.
- Need to interpret LHC results in the contexts of all kinds of models of new physics; crucial if we are to unravel the correct theory and determine its parameters ⇨ community-wide effort !





- Current SUSY limits depend a lot (by 200-600 GeV) on the assumptions on the mass spectrum, and disappear for small mass splittings, m_{LSP}>600 GeV, etc.



- Need to be able to interpret the experimental results in a large variety of scenarios, test all kinds of models, beyond the MSSM and beyond SUSY.
  E.g. could use EW-ino or slepton searches to constrain inert-Higgs dark matter

Interpretation tools

- Several groups have been developing their private codes for recasting BSM searches
- A number of public tools have become available recently
    - CheckMATE confronts simulated events of any model to LHC results; currently has 8 ATLAS and 1 CMS SUSY analyses implemented [Drees et al., 1312.2591]
    - SModelS decomposes the spectrum of any BSM scenario into SMS topologies, and compares it to the cross section upper limits from more than 50 ATLAS and CMS simplified-model results [SK et al., 1312.4175]
      → talk by Suchita Kulkarni
    - Fastlim reconstructs the visible cross sections from pre-calculated efficiency tables and cross section tables for simplified event topologies, currently taking into account 11 ATLAS analyses [Papucci et al., 1402.0492]
    - XQCAT determines the exclusion confidence level for heavy extra quarks based on efficiency maps, CMS search for top partners plus 2 SUSY searches at 8 TeV. [Barducci et al., 1405.0737]

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- These tools are extremely valuable. However, they are maintained by just a handful of people. Staying up to date with new exp. results can be difficult.
- SMS approach particularly useful for vast surveys, but has its limitations

The difficulty of recasting with fastsim

Non-collaboration members do not have access to the experimental data, nor the Monte Carlo (MC) event set simulated with an official collaboration detector simulation.

Therefore, the implementation and validation of ATLAS and CMS analyses for re-interpretation of the experimental results in general contexts is a tedious task, even more so as the information given in the experimental papers is often incomplete.

Les Houches Recommendations

[arXiv:1203.2489]

"The community should identify, develop and adopt a common platform to store analysis databases, collecting object definitions, cuts, and all other information, including well-encapsulated functions, necessary to reproduce or use the results of the analyses [...]"

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“The tools needed to provide extended experimental information will require some dedicated efforts in terms of resources and manpower, to be supported by both the experimental and the theory communities.”

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We think it would be of great value for the whole community to have a database of LHC analyses based on fast simulation.

→ we propose to create such a database using the MadAnalysis 5 framework

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- Validated analysis codes, easy to check and to use for everybody.
- Can serve for the interpretation of the LHC results in a large variety of models.
- Convenient way of documentation; helps long-term preservation of the analyses performed by ATLAS and CMS.
- Modular approach, easy to extend, everybody who implements and validates an existing ATLAS or CMS analysis can publish it within this framework.
- Provides feedback to the experiments about documentation and use of their results. (The ease with which an experimental analysis can be implemented and validated may actually serve as a useful check for the experimental collaborations for the quality of their documentation.)

What is MadAnalysis 5 ?

E. Conte, B. Fuks, G. Serret, arXiv:1206.1599
E. Conte, B. Fuks, arXiv:1309.7831

- Public framework for analyzing Monte Carlo events
- different levels of sophistication: partonic, hadronic, detector reconstructed
- input formats: StdHep, HepMC, LHE, LHCO, Delphes ROOT files
- user-friendly, flexible and fast
- normal mode: intuitive commands typed in the Python interface
  human-readable output: HTML and LaTeX
- expert mode: C++/ROOT programming within the SampleAnalyzer framework
- powerful tool, well-suited for phenomenological studies for particle colliders

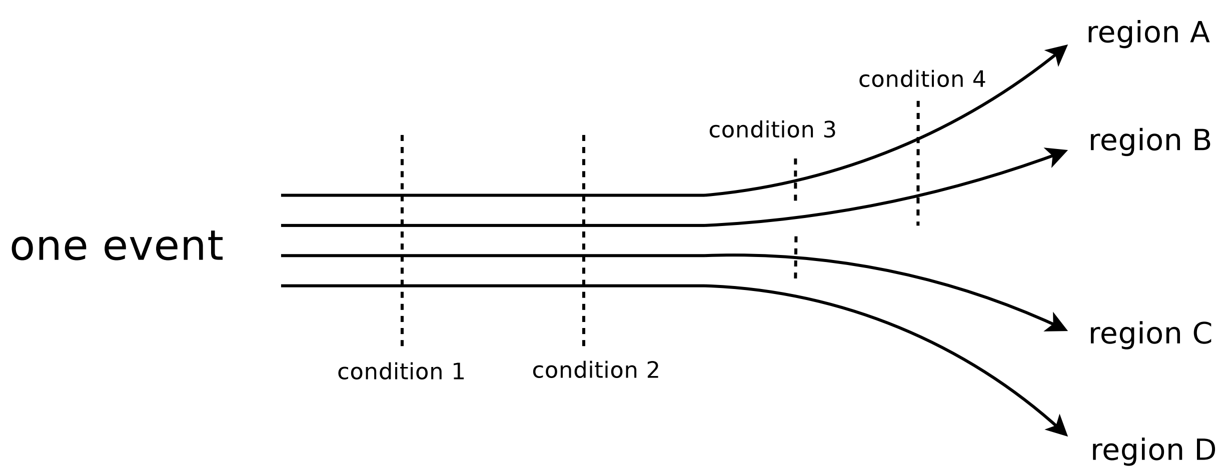
https://madanalysis.irmp.ucl.ac.be

Recasting LHC analyses with MadAnalysis 5

E. Conte, B. Dumont, B. Fuks, C. Wymant
arXiv:1405.3982

- MadAnalysis 5 was recently extended to include an efficient treatment of different signal regions in the same analysis

- New optimized handling of cuts and histograms



- Every cut is evaluated only once and applied to all relevant signal regions simultaneously

```
string SRForMet150Cut[] = {
  "Stop->b+chargino,LowDeltaM,MET>150",
  "Stop->b+chargino,HighDeltaM,MET>150",
Manager()->AddCut("MET>150GeV",SRForMet150Cut);
```

Conventional nesting of conditions is not efficient:

```
count the event in region D
if (condition 3)
{
  count the event in region C
  if (condition 4)
  {
    count the event in region A
  }
}
if (condition 4)
{
  count the event in region B
}
```

Similar for histograms

Analysis implementation and validation

1. Read and understand the experimental paper

2. Write the C++ analyzer code for MadAnalysis 5

3. The difficult part: get missing information from the experimental collaboration. Needed, but not always publicly available, are:

   - efficiencies for trigger, electron, muons, b-tagging, event cleaning, ... treatment of ISR, jet energy scale } p_T dependence
   - exact configuration of MC tools (versions, run card settings)
   - benchmark points: SLHA or LHE files
   - cut flows for the benchmark points
   - expected final number of events in each signal region

4. Digitize the histograms from the experimental paper
   (stupid work; direct numerical form would be highly welcome → HepData, Twiki !)

5. Produce your own cut flows and histograms and compare, iterate until reasonable agreement is achieved

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EPJC 73 (2013) 2677
arXiv:1308.1586

CMS example: SUS-13-011 (leptonic stop search)

- Search for stops in the single lepton final state, 19.5 fb^{-1} at 8 TeV
- Targets stop → t+neutralino and stop → b+chargino decays (higgsino scenario)
- Two types of signal regions characterized by stop-LSP mass difference (low ΔM, high ΔM)

	$\tilde{t} \to t\tilde{\chi}_1^0$			$\tilde{t} \to b\tilde{\chi}^+$		
		Cut-based			Cut-based	
Selection	BDT	Low ΔM	High ΔM	BDT	Low ΔM	High ΔM
E_T^{miss} (GeV)	yes	$>$ 150, 200, 250, 300	$>$ 150, 200, 250, 300	yes	$>$ 100, 150, 200, 250	$>$ 100, 150, 200, 250
M_{T2}^W (GeV)	yes		$>$200	yes		$>$200
min $\Delta\phi$	yes	$>$0.8	$>$0.8	yes	$>$0.8	$>$0.8
H_T^{ratio}	yes			yes		
Hadronic top χ^2	(on-shell top)	$<$5	$<$5			
Leading b-tagged jet p_T (GeV)	(off-shell top)			yes		$>$100
$\Delta R(\ell$,leading b-tagged jet)				yes		
Lepton p_T (GeV)				(off shell W)		

C++ code available on CMS Twiki page

- Generally very well documented, all MC tools specified, validation material OK
- Missing pieces: details on benchmark points, exact lepton efficiencies

→ provided upon request !

Search for direct top squark pair production in the single lepton final state at $\sqrt{s}$ = 8 TeV (SUS-13-011)

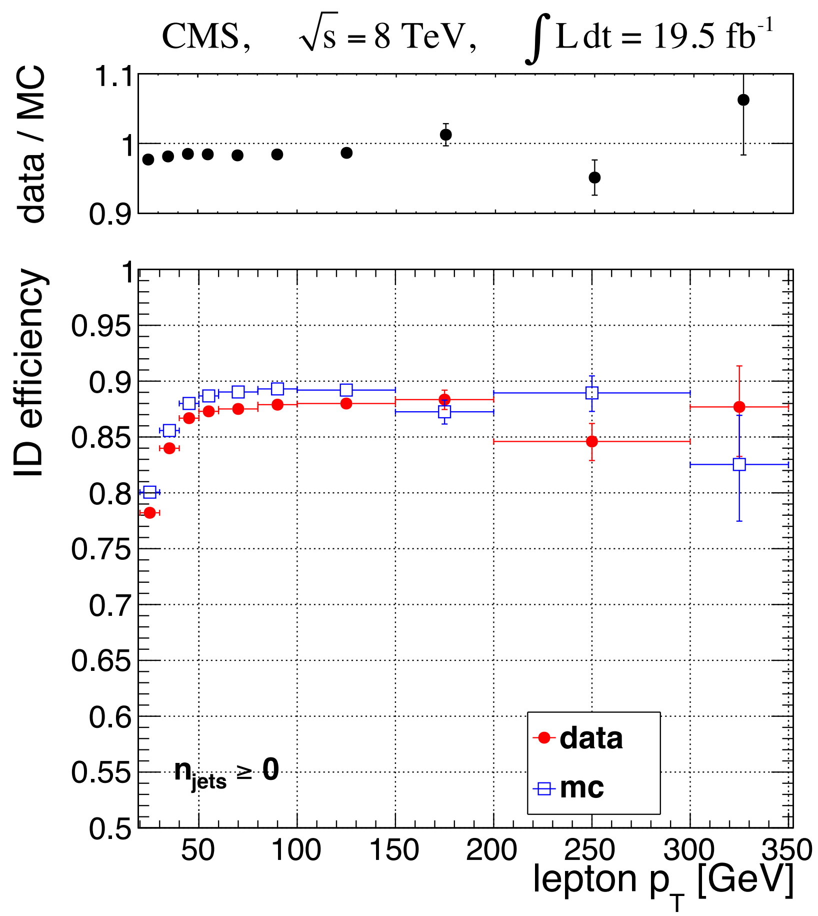
Contents:

CMS very unbureaucratically provided us LHE files for the benchmark points, efficiencies, and cut flows

CMS-SUS-13-011: additional material to aid ....

The single electron trigger efficiency. Uncertainties are statistical.

p_T range [GeV]	$\|\eta\| < 1.5$	$1.5 < \|\eta\| < 2.1$
20 - 22	0.00 ± 0.000	0.00 ± 0.000
22 - 24	0.00 ± 0.000	0.00 ± 0.000
24 - 26	0.00 ± 0.000	0.03 ± 0.001
26 - 28	0.07 ± 0.001	0.22 ± 0.002
28 - 30	0.57 ± 0.001	0.52 ± 0.002
30 - 32	0.85 ± 0.001	0.65 ± 0.002
32 - 34	0.88 ± 0.001	0.70 ± 0.002
34 - 36	0.89 ± 0.000	0.72 ± 0.001
36 - 38	0.91 ± 0.000	0.74 ± 0.001
38 - 40	0.92 ± 0.000	0.75 ± 0.001
40 - 50	0.94 ± 0.000	0.77 ± 0.001
50 - 60	0.95 ± 0.000	0.79 ± 0.001
60 - 80	0.96 ± 0.000	0.79 ± 0.002
80 - 100	0.96 ± 0.001	0.80 ± 0.005
100 - 150	0.97 ± 0.001	0.82 ± 0.006
150 - 200	0.97 ± 0.002	0.83 ± 0.014
>200	0.97 ± 0.003	0.85 ± 0.020



Summary of yields for the $\tilde{t} \to t\tilde{\chi}_1^0$ model with $m_{\tilde{t}} = 650$ GeV and $m_{\tilde{\chi}_1^0} = 50$ GeV. No trigger efficiency or ISR reweighting is applied. In the first block of the table, the first row shows the yield after requiring at least one analysis lepton, at least 4 jets, and MET > 50 GeV. In each subsequent row, the preselection requirements are added one at a time. In the second block of the table the low-mass (LM) signal region yields are indicated. In the third block the high-mass (HM) signal region yields are indicated. The number after LM or HM indicates the MET requirement. The latter results may be compared to the signal yields in Table 4 of http://arxiv.org/pdf/1308.1586.pdf but they are slightly higher ($\sim 10-20\%$) because the trigger and ISR weights are not applied. All uncertainties are statistical only. The bold entry indicates the signal region with the best sensitivity, i.e., the signal region used for limit-setting.

$\ell + \geq 4$ jets + MET>50	31.6 ± 0.3
+ MET>100	29.7 ± 0.3
+ nb ≥ 1	25.2 ± 0.2
+ iso-track veto	21.0 ± 0.2
+ tau-veto	20.6 ± 0.2
+ min-dphi	17.8 ± 0.2
+ chi2	11.9 ± 0.2
+ MT>120	9.6 ± 0.1
LM150	9.1 ± 0.1
LM200	8.2 ± 0.1
LM250	7.1 ± 0.1
LM300	5.7 ± 0.1
HM150	5.5 ± 0.1
HM200	5.4 ± 0.1
HM250	4.9 ± 0.1
HM300	**4.2 ± 0.1**

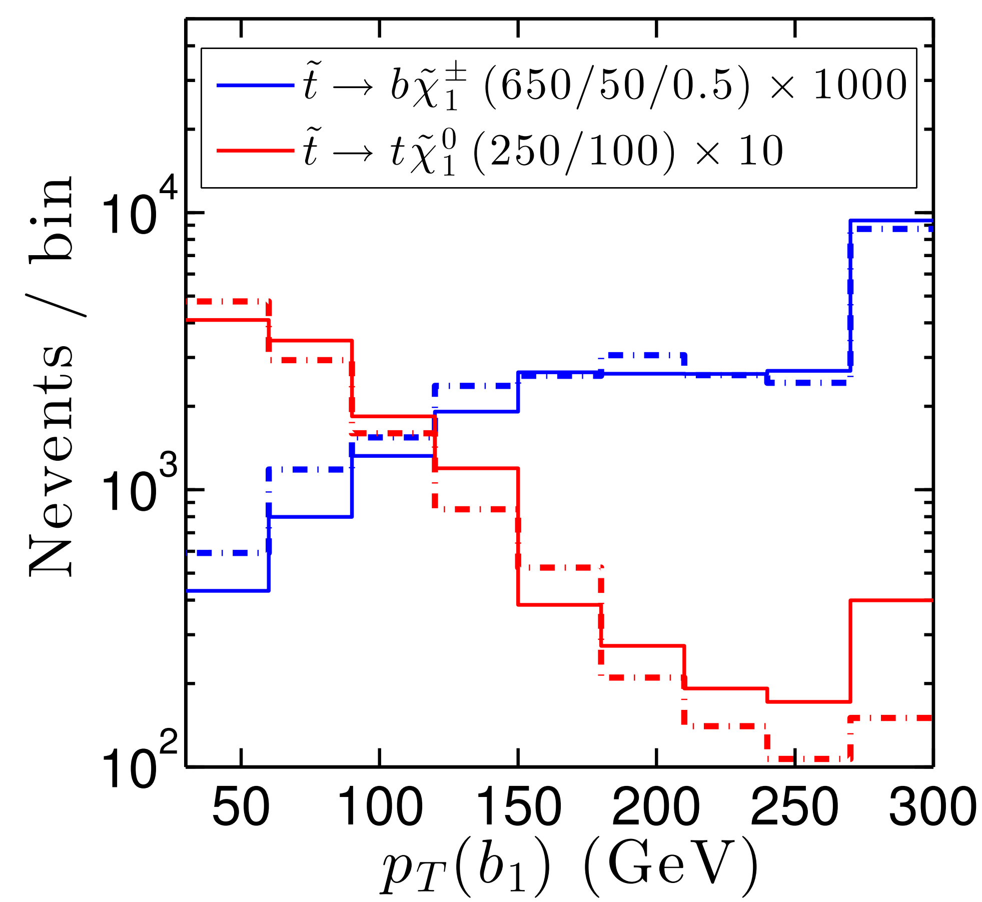
Plus several distributions available for validation.
Only remaining wish: digitized plots

CMS-SUS-13-011: validation

benchmark point	CMS result	MA 5 result
$\tilde{t} \to b\tilde{\chi}_1^{\pm}$, low ΔM, $E_T^{\rm miss} > 150$ GeV		
(250/50/0.5)	157 ± 9.9	141.2
(250/50/0.75)	399 ± 18	366.8
$\tilde{t} \to b\tilde{\chi}_1^{\pm}$, high ΔM, $E_T^{\rm miss} > 150$ GeV		
(450/50/0.25)	23 ± 2.3	23.4
$\tilde{t} \to b\tilde{\chi}_1^{\pm}$, high ΔM, $E_T^{\rm miss} > 250$ GeV		
(600/100/0.5)	6.1 ± 0.5	5.4
(650/50/0.5)	6.7 ± 0.4	5.8
(650/50/0.75)	6.3 ± 0.4	5.7

benchmark point	CMS result	MA 5 result
$\tilde{t} \to t\tilde{\chi}_1^0$, low ΔM, $E_T^{\rm miss} > 150$ GeV		
(250/50)	108 ± 3.7	100.1
$\tilde{t} \to t\tilde{\chi}_1^0$, high ΔM, $E_T^{\rm miss} > 300$ GeV		
(650/50)	3.7 ± 0.1	3.6

$$m_{\tilde{\chi}_1^{\pm}} = x \cdot m_{\tilde{t}_1} + (1-x) m_{\tilde{\chi}_1^0}$$



$\tilde{t} \to t\tilde{\chi}_1^0$ model

cut	$m_{\tilde{t}_1} = 650$ GeV CMS result	$m_{\tilde{t}_1} = 650$ GeV MA 5 result	$m_{\tilde{t}_1} = 250$ GeV CMS result	$m_{\tilde{t}_1} = 250$ GeV MA 5 result
$1\ell + \geq 4$jets $+ E_T^{\rm miss} > 50$	31.6 ± 0.3	29.0	8033.0 ± 38.7	7365.0
$+ E_T^{\rm miss} > 100$ GeV	29.7 ± 0.3	27.3	4059.2 ± 27.5	3787.2
$+ n_b \geq 1$	25.2 ± 0.2	23.8	3380.1 ± 25.1	3166.0
+ iso-track veto	21.0 ± 0.2	19.8	2770.0 ± 22.7	2601.4
+ tau veto	20.6 ± 0.2	19.4	2683.1 ± 22.4	2557.2
$+ \Delta\phi_{\rm min} > 0.8$	17.8 ± 0.2	16.7	2019.1 ± 19.4	2021.3
+ hadronic $\chi^2 < 5$	11.9 ± 0.2	9.8	1375.9 ± 16.0	1092.0
$+ M_T > 120$ GeV	9.6 ± 0.1	7.9	355.1 ± 8.1	261.3
high ΔM, $E_T^{\rm miss} > 300$ GeV	4.2 ± 0.1	3.9	—	—
low ΔM, $E_T^{\rm miss} > 150$ GeV	—	—	124.0 ± 4.8	107.9

without trigger efficiency or ISR reweighting

~10-20% agreement,
quite good for fastsim

JHEP 1310 (2013) 189
arXiv:1308.2631

ATLAS example: stop/sbottom, 0l2b+MET

Description	Signal Regions	
	SRA	SRB
Event cleaning	Common to all SR	
Lepton veto	No e/μ after overlap removal with $p_T > 7(6)$ GeV for $e(\mu)$	
E_T^{miss}	> 150 GeV	> 250 GeV
Leading jet $p_T(j_1)$	> 130 GeV	> 150 GeV
Second jet $p_T(j_2)$	> 50 GeV,	> 30 GeV
Third jet $p_T(j_3)$	veto if > 50 GeV	> 30 GeV
$\Delta\phi(p_T^{miss}, j_1)$	-	> 2.5
b-tagging	leading 2 jets ($p_T > 50$ GeV, $\|\eta\| < 2.5$)	2nd- and 3rd-leading jets ($p_T > 30$ GeV, $\|\eta\| < 2.5$)
	$n_{b\text{-jets}} = 2$	
$\Delta\phi_{min}$	> 0.4	> 0.4
$E_T^{miss}/m_{eff}(k)$	$E_T^{miss}/m_{eff}(2) > 0.25$	$E_T^{miss}/m_{eff}(3) > 0.25$
m_{CT}	> 150, 200, 250, 300, 350 GeV	-
$H_{T,3}$	-	< 50 GeV
m_{bb}	> 200 GeV	-

public code available

- Search for stops and sbottoms in the 0 lepton + 2 b-jets final state with large MET
- Two signal regions optimized for high and low ΔM
- Analysis well documented for physics, but not so well for recasting purposes
- Upon request obtained cut flows as well as SLHA files and some missing details on MC settings.
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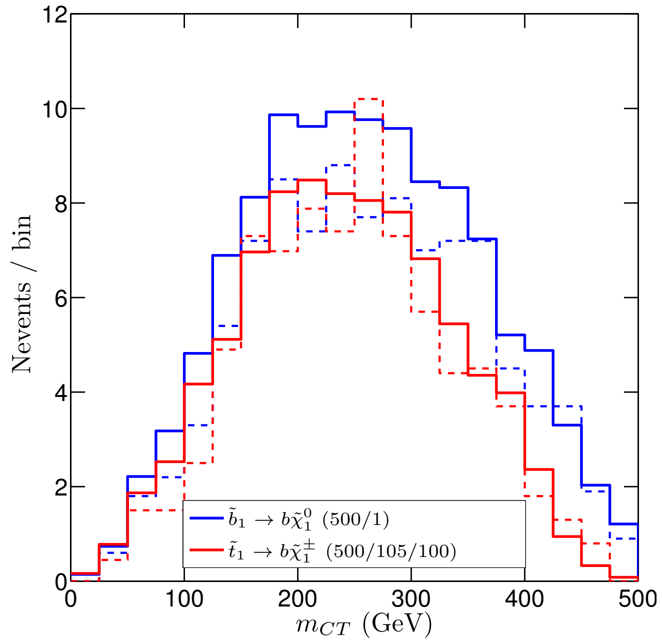
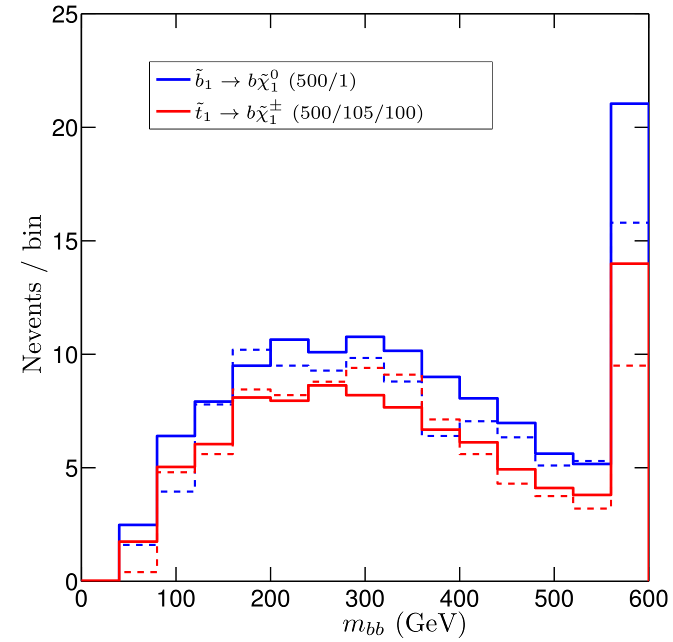
- In general, it is difficult for us to get necessary additional information from ATLAS; less fruitful interaction than with CMS.
  → We would very much like to improve this.

ATLAS 0 lepton + 2b: validation for SRA



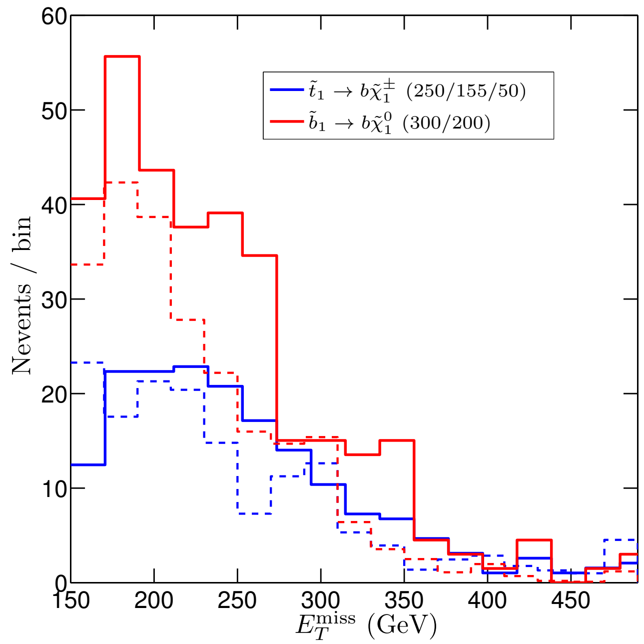


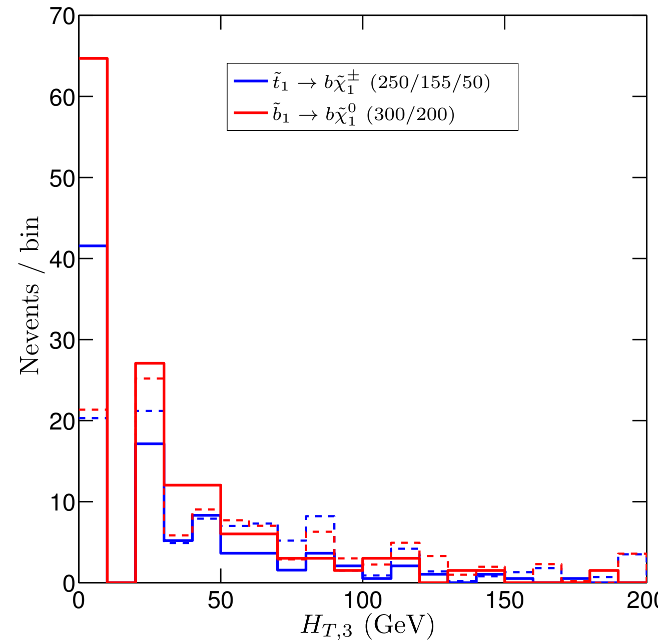
solid: MA5 result
dashed: ATLAS result

cut	$m_{\tilde{b}_1} = 500$ GeV ATLAS result	$m_{\tilde{b}_1} = 500$ GeV MA 5 result	$m_{\tilde{t}_1} = 500$ GeV ATLAS result	$m_{\tilde{t}_1} = 500$ GeV MA 5 result
$E_T^{miss} > 80$ GeV filter	1606.0	1628.2	1632.0	1585.2
+ Lepton veto	1505.0	1223.5	1061.0	863.2
+ $E_T^{miss} > 150$ GeV	1323.0	1052.2	859.0	696.3
+ Jet Selection	119.0	142.3	39.0	47.6
+ $M_{bb} > 200$ GeV	96.0	116.5	32.0	38.8
+ $M_{CT} > 150$ GeV	82.0	97.5	26.8	31.7
+ $M_{CT} > 200$ GeV	67.0	80.7	20.2	24.5
+ $M_{CT} > 250$ GeV	51.0	60.8	13.2	16.6
+ $M_{CT} > 300$ GeV	35.0	42.3	7.7	9.2

good agreement (~20%)

ATLAS 0 lepton + 2b: validation for SRB





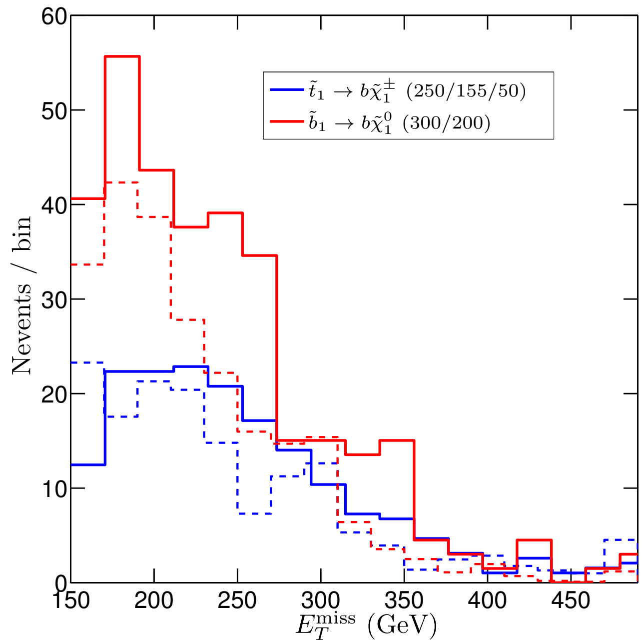
solid: MA5 result
dashed: ATLAS result

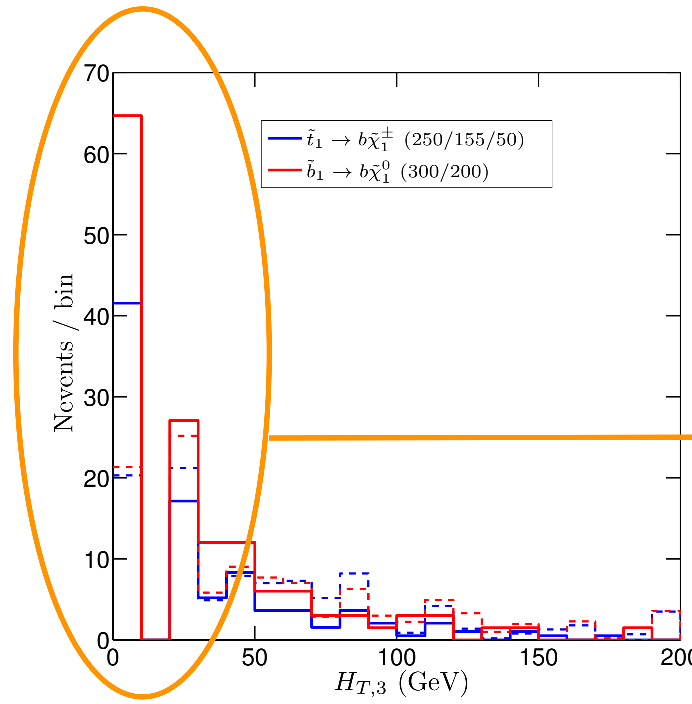
$(m_{\tilde{b}_1}, m_{\tilde{\chi}_1^0}) = (350, 320)$ GeV $\quad$ $(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0}) = (500, 420, 400)$ GeV

cut	$m_{\tilde{b}_1} = 350$ GeV		$m_{\tilde{t}_1} = 500$ GeV	
	ATLAS result	MA 5 result	ATLAS result	MA 5 result
$E_T^{miss} > 80$ GeV filter	6221.0	5963.7	1329.0	1117.9
+ Lepton veto	4069.0	4450.4	669.0	702.9
+ $E_T^{miss} > 250$ GeV	757.0	724.5	93.0	86.8
+ Jet Selection	7.9	7.5	6.2	5.7
+ $H_{T,3} < 50$ GeV	5.2	6.6	3.0	4.6

agreement less good than for SRA but still reasonable (30-50%)

ATLAS 0 lepton + 2b: validation for SRB





solid: MA5 result
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first bin factor 2-3 too high;
not enough hadronic activity

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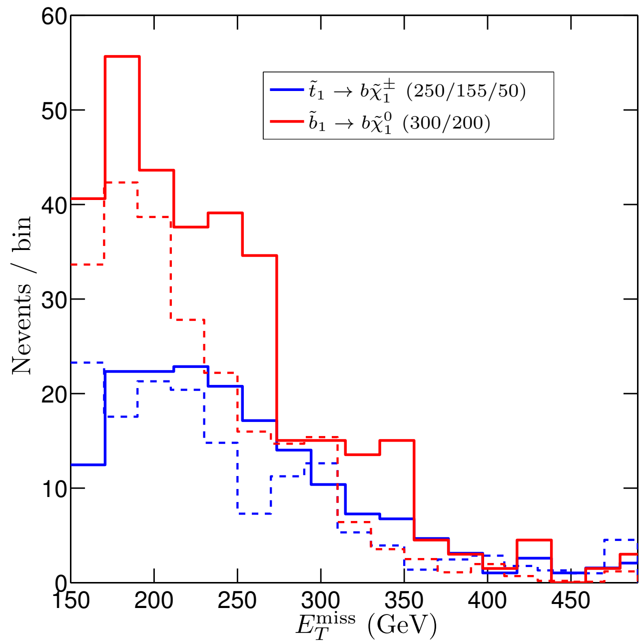
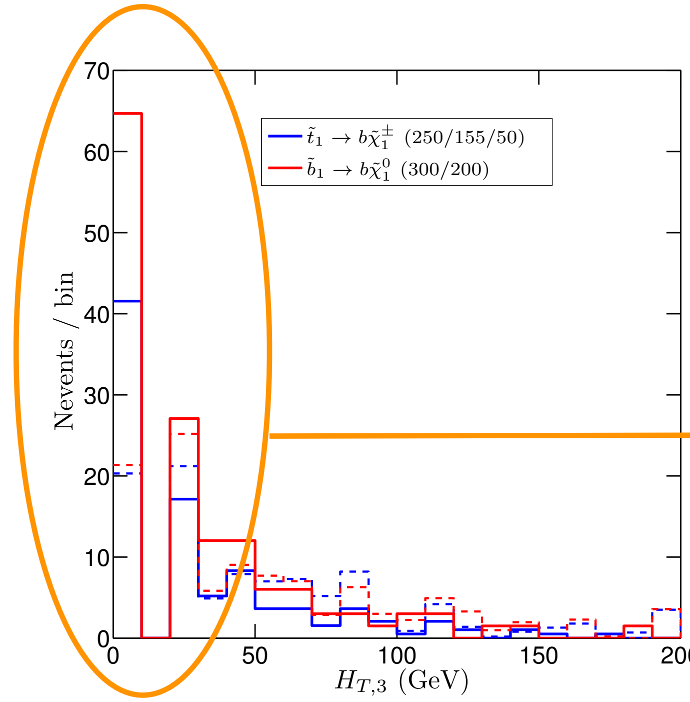
cut	$m_{\tilde{b}_1} = 350$ GeV ATLAS result	$m_{\tilde{b}_1} = 350$ GeV MA 5 result	$m_{\tilde{t}_1} = 500$ GeV ATLAS result	$m_{\tilde{t}_1} = 500$ GeV MA 5 result
$E_T^{miss} > 80$ GeV filter	6221.0	5963.7	1329.0	1117.9
+ Lepton veto	4069.0	4450.4	669.0	702.9
+ $E_T^{miss} > 250$ GeV	757.0	724.5	93.0	86.8
+ Jet Selection	7.9	7.5	6.2	5.7
+ $H_{T,3} < 50$ GeV	5.2	6.6	3.0	4.6

agreement less good than for SRA but still reasonable (30-50%)

ATLAS 0 lepton + 2b: validation for SRB





solid: MA5 result
dashed: ATLAS result

first bin factor 2-3 too high; not enough hadronic activity

$(m_{\tilde{b}_1}, m_{\tilde{\chi}_1^0}) = (350, 320)$ GeV $(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0}) = (500, 420, 400)$ GeV

	$m_{\tilde{b}_1} = 350$ GeV		$m_{\tilde{t}_1} = 500$ GeV	
cut	ATLAS result	MA 5 result	ATLAS result	MA 5 result
$E_T^{\rm miss} > 80$ GeV filter	6221.0	5963.7	1329.0	1117.9
+ Lepton veto	4069.0	4450.4	669.0	702.9
+ $E_T^{\rm miss} > 250$ GeV	757.0	724.5	93.0	86.8
+ Jet Selection	7.9	7.5	6.2	5.7
+ $H_{T,3} < 50$ GeV	5.2	6.6	3.0	4.6

trigger efficiencies would be helpful

agreement less good than for SRA but still reasonable (30-50%)

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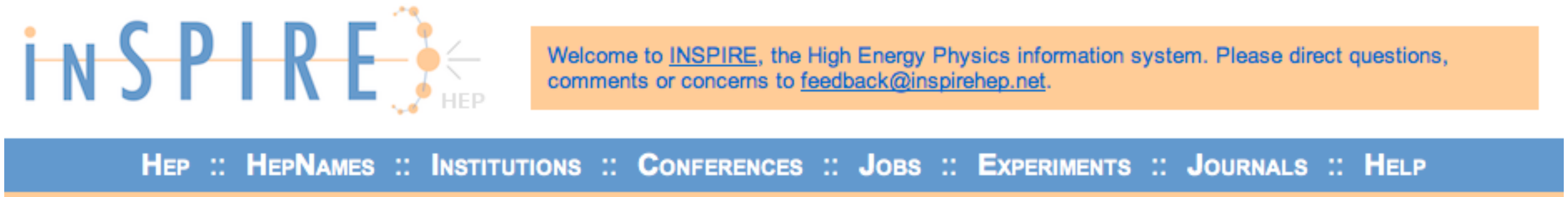

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MadAnalysis 5 implementation of CMS-SUS-13-011: search for stops in the single lepton final state at 8 TeV

Dumont, Beranger (LPSC, Grenoble); Fuks, Benjamin (CERN); Wymant, Chris (Annecy, LAPTH)

Description: This is the MadAnalysis 5 implementation of the CMS search for top-squark pair production in the single lepton final state with 19.5/fb at 8 TeV, to be used for re-interpretation studies. The C++ code contains extensive comments and can thus easily be used as a template for implementing other analyses.

Note: This analysis requires MINUIT libraries. Therefore, the line <LIBFLAGS += -lMinuit> should be added to the Makefile of the Build/ directory before compilation. More information how to use this code as well as a detailed validation summary are available at http://madanalysis.irmp.ucl.ac.be/wiki/PhysicsAnalysisDatabase

Cite as: Dumont, B., Fuks, B., Wymant, C. (2014) MadAnalysis 5 implementation of CMS-SUS-13-011: search for stops in the single lepton final state at 8 TeV. doi: 10.7484/INSPIREHEP.DATA.LR5T.2RR3

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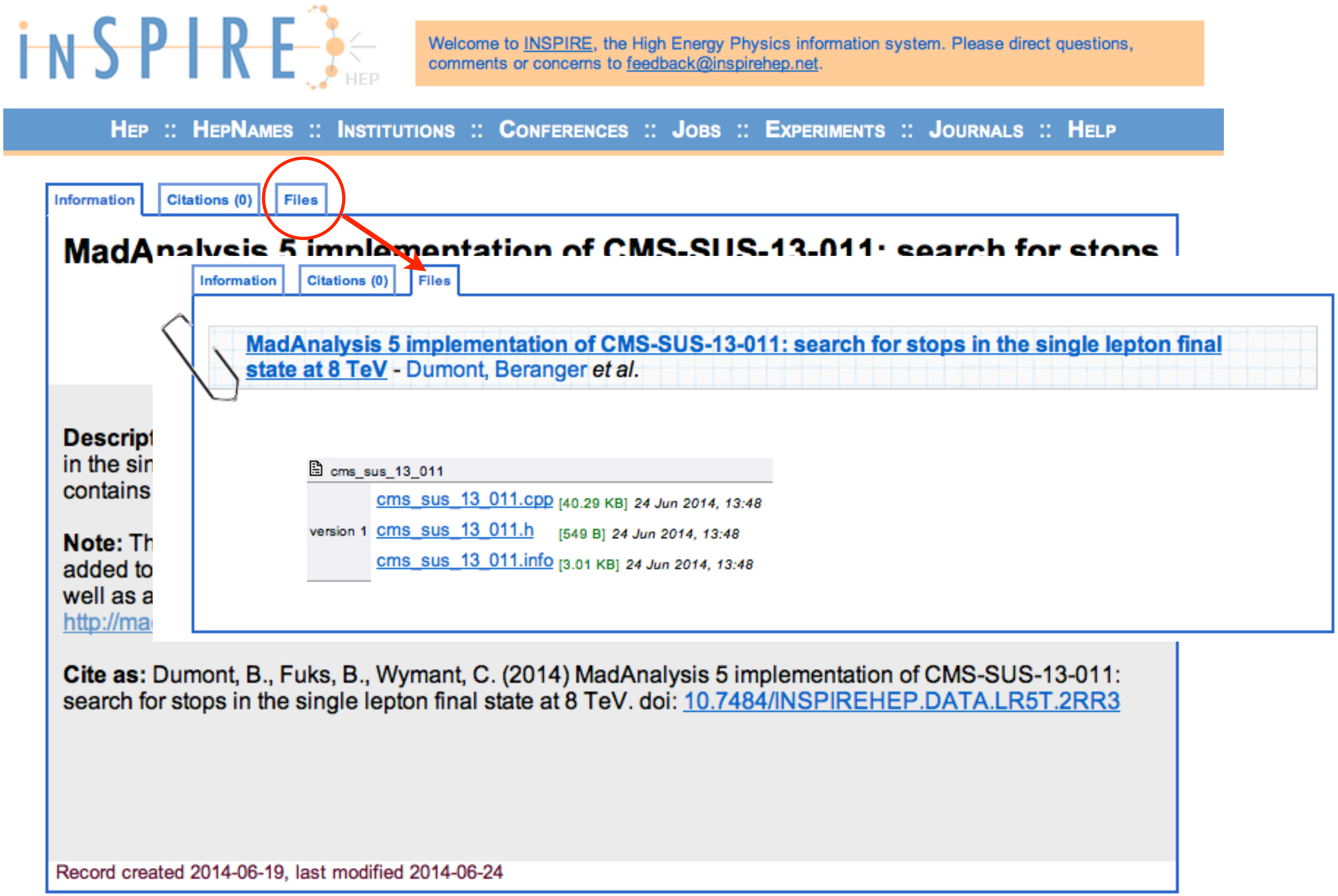

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MadAnalysis 5 implementation of ATLAS-SUSY-2013-05

Chalons, Guillaume (LPSC, Grenoble)

Description: This is the MadAnalysis 5 implementation of the ATLAS search for third-generation squarks in final states with 0-leptons and two b -jets, with 20.1/fb at 8 TeV, to be used for re-interpretation studies.

Note: Information how to use this code as well as a detailed validation summary are available at http://madanalysis.irmp.ucl.ac.be/wiki/PhysicsAnalysisDatabase

Cite as: Chalons, G. (2014) MadAnalysis 5 implementation of ATLAS-SUSY-2013-05. doi: 10.7484/INSPIREHEP.DATA.Z4ML.3W67

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each recasted analysis gets a DOI (digital document identifier)
and is individually searchable and citable

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MadAnalysis 5 physics analysis database

Available Analyses

!! please properly cite the DOIs of all the re-implementation codes you are using !!

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	done
ATLAS-SUSY-2013-11 (published)	EWK-inos, 2 leptons + MET	B. Dumont	t.b.a.	PDF	validation in progress

CMS analyses, 8 TeV

Delphes card for these analyses

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	done
CMS-SUS-13-012 (published)	gluino/squark search in jet multiplicity and missing energy	S. Bein, D. Sengupta	t.b.a.	PDF	ok, move to v1.1.11
CMS-SUS-13-016 (PAS)	search for gluinos using OS dileptons and b-jets	D. Sengupta, S. Kulkarni	t.b.a.	PDF	done

Conclusions

- We propose to create a public database of LHC analyses for BSM searches using the MadAnalysis 5 framework

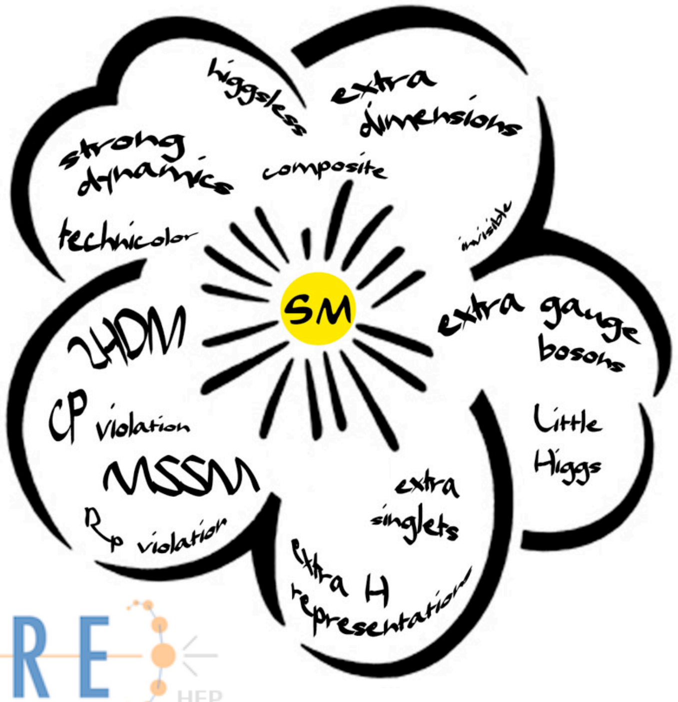
- Implemented and validated several cut-based ATLAS and CMS SUSY searches; more in preparation (MVA-based analyses can also be implemented in principle if final MVA is provided)

- C++ analysis codes published via INSPIRE → each implementation obtains a digital objet identifier (DOI) and is individually citable.

- It is important for the legacy of the LHC that its experimental results can be used by the whole HEP community. We hope that our project contributes to this aim. Everybody welcome to contribute his/her recast code!

- However, this can only succeed if more information is provided by the experimental collaborations on their analyses. We plea for a more open communication and exchange of information between EXP and TH/users.

  → Les Houches Recommendations



Thanks to

- ATLAS: Jamie Boyd, Marie-Helene Genest, Monica d'Onofrio
  CMS: Alessandro Gaz, Benjamin Hooberman, Christian Sander, Frank Würthwein
  for providing additional information beyond the analysis papers/Twiki pages
- Inspire people: Sunje Dallmeier-Tiessen, Salvatore Mele and Laura Rueda Garcia for setting up a system for publishing ‘datasets’ (incl. computer codes) via Inspire
- The Les Houches Physics at TeV Colliders 2013 workshop where this project originated, and the LabEx Enigmass for various financial support