Recast of LHC analyses: motivations, tools & results

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Top LHC France
4-5 May 2017 @ Marseille

Outlines

1. Motivations
2. Recasting with CheckMate & MadAnalysis5
3. Recasting with Rivet & derived tools
4. Reinterpreting simplified models
5. Required inputs
6. Summary

1. **Motivations**
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BSM researches @ LHC

Two kind of researches in the top sector:

- Standard Model measurement + reinterpretation in terms of New Physics
  Ex: ttZ-ttW with reinterpretation in terms of Wilson coefficients, …

- Direct search of BSM
  → Several benchmarks are chosen for showing the performance the analysis
  Ex: SUSY analysis, VLQ research, …

Difficulty to be exhaustive in interpretation:

- testing all the existing models
- covering all the parameter space of a given model
- testing all the new models which could be conceived after the analysis

→ We must be able to launch an existing analysis, **tomorrow or in few years,** with a **different signal** benchmark and to compute a limit.

Recasting strategy

How to recast the analysis?

Method 1

- Experimentalists keep and maintain their code internally.
- Phenomenologists ask to the authors to test a new model

→ Need manpower, time consuming

Method 2

- Use a framework which :
  - Captures the analysis code, the data, …
  - Allows people to upload they own MC samples
  - Launch automatically the codes and store results

→ **RECAST** project

Method 3

- Experimentalists provide all useful information to phenomenologists.
- Developing an external code which mimics the analysis results.

→ Approximations but much faster (useful for scan over parameter-space)

→ Identification of topologies or region not tested by experimentalists

→ Feedback to experimentalists

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recast

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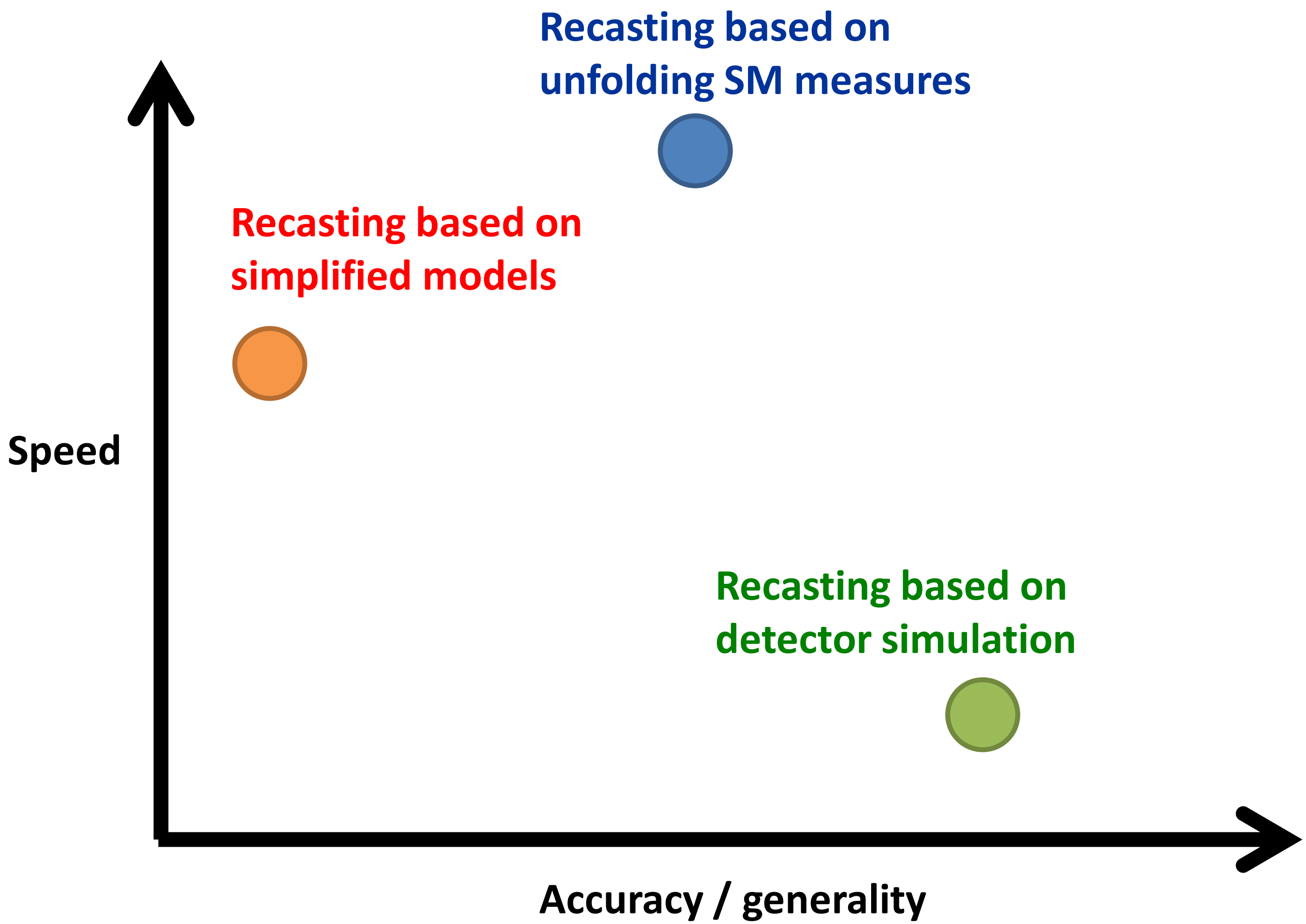
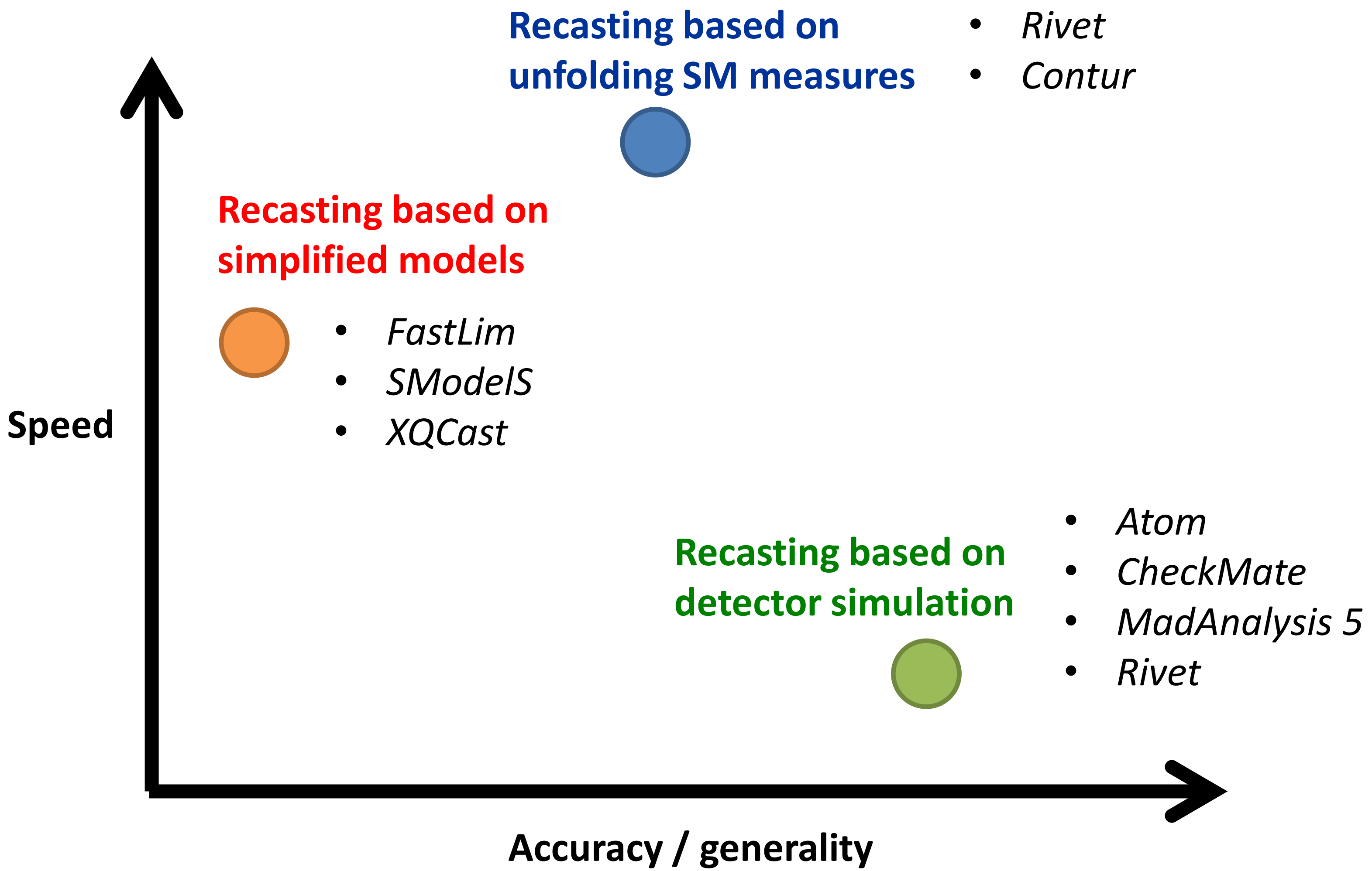
Recasting tools



Recasting tools



The talk is only devoted to public tools.

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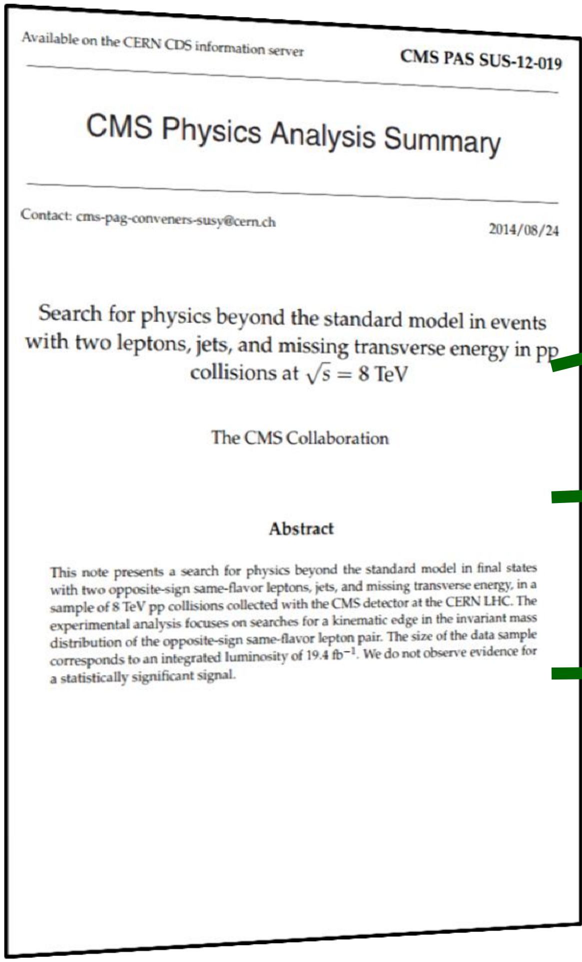
Strategy of CheckMate & MadAnalysis 5



Available on the CERN CDS information server — CMS PAS SUS-12-019

CMS Physics Analysis Summary

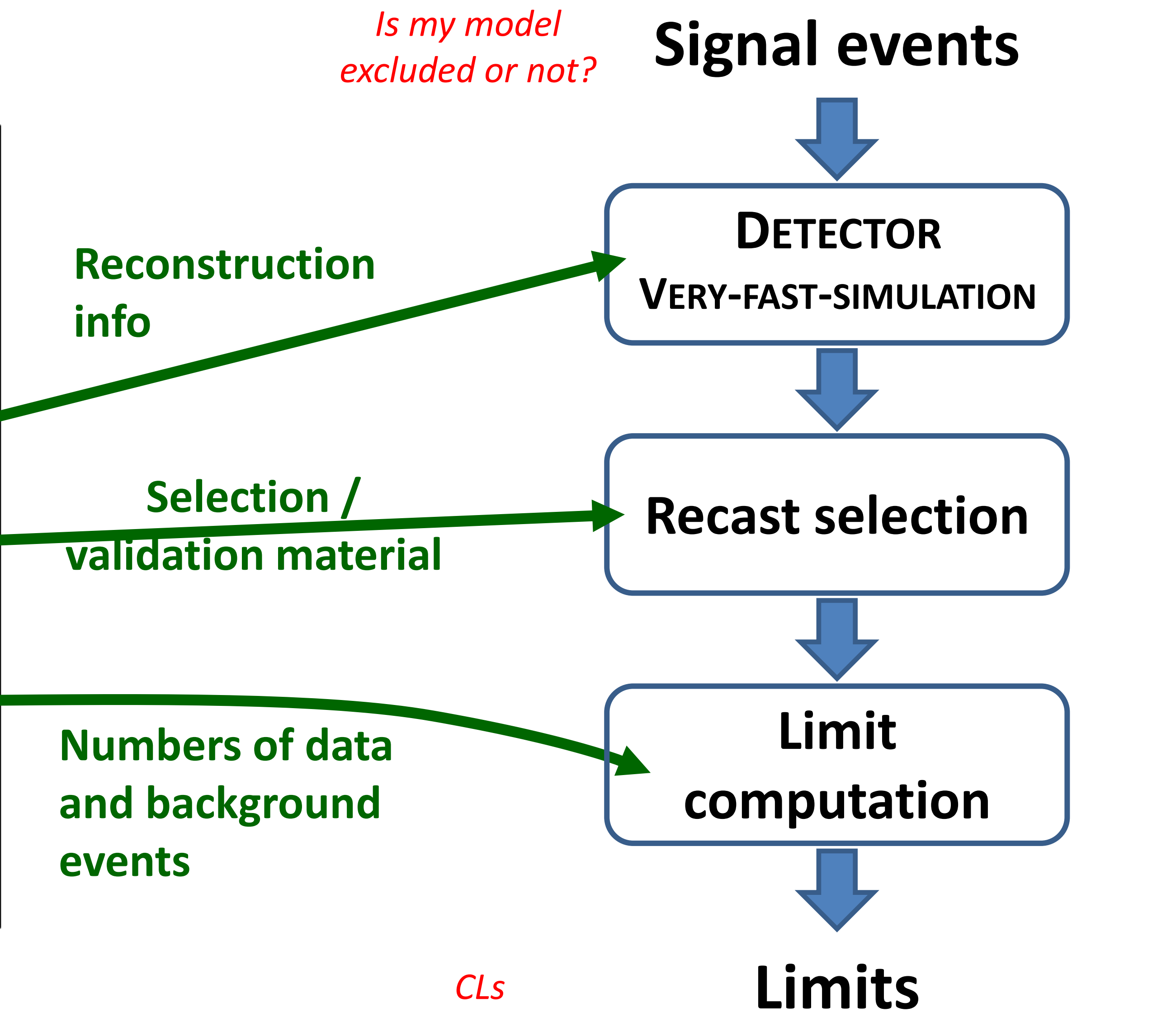
Contact: cms-pag-conveners-susy@cern.ch — 2014/08/24

Search for physics beyond the standard model in events with two leptons, jets, and missing transverse energy in pp collisions at $\sqrt{s} = 8$ TeV

The CMS Collaboration

Abstract

This note presents a search for physics beyond the standard model in final states with two opposite-sign same-flavor leptons, jets, and missing transverse energy, in a sample of 8 TeV pp collisions collected with the CMS detector at the CERN LHC. The experimental analysis focuses on searches for a kinematic edge in the invariant mass distribution of the opposite-sign same-flavor lepton pair. The size of the data sample corresponds to an integrated luminosity of 19.4 fb^{-1}. We do not observe evidence for a statistically significant signal.



Very-Fast-Simulation package: Delphes

- **Public package for collider generic detector:**

  ATLAS, CMS, detectors for ILC or FCC, …

DELPHES
fast simulation

- **Very-Fast-Simulation = parametric simulation**
  - Algorithm : track propagation, calorimeter tower, energy-flow
  - Smearing/Efficiency from public results (b-tagging for instance)
  - Pile-up simulation

- **Very flexible tool:**
  - Detector description = configuration card (tcl language)
  - Possibility to add new modules for extension
  - → Development of public or private " tunes " of Delphes

- **Difficulties of the simulation to:**
  - Reproduce the trigger selection
  - Generate fakes (electron, photon)
  - Deal with the distribution deal of some observables (ex: MET)
  - Deal with exotic topology (ex: long-lived particle)

CheckMate & MadAnalysis5: a brief overview

Designed for recasting:

- Choose the objects of interest
- Filter objects
- Check event vetoes
- Check various signal region criteria
- Count number of input events that fall into each signal region

Tune of Delphes:

- Big improvement of ATLAS simulation
- Add isolation flags
- Add object definition flags

Multipurpose tool:

- Monte-Carlo validation
- Phenomenological analysis with 2 levels:
    - Intuitive metalanguage
    - C++ development
- Recasting with the Physics Data Base

Tune of Delphes:

- Small improvement of CMS simulation
- Isolation defined at the analysis level
- Provides more « MC truth info »
- Produces compact and generic ROOT files → avoids as much as possible from launching Delphes

List of recast analyses

CHECKMATE

Exp	$\sqrt{s}$	Already validated	Not yet validated
ATLAS	7 TeV	0	1
	8 TeV	21	10
	13 TeV	12	2
	HL 14 TeV	6	0
CMS	7 TeV	0	1
	8 TeV	6	4
	13 TeV	0	1
	HL 14 TeV	0	0

MadAnalysis 5

Exp	$\sqrt{s}$	Already validated	Not yet validated
ATLAS	8 TeV	8	0
	13 TeV	2	0
CMS	8 TeV	9	1
	13 TeV	0	0

List of recast Top analyses

CheckMATE

ATLAS-SUSY-2013-05	stop/sbottom search: 0 leptons + 2 b-jets
ATLAS-SUSY-2013-19	Top-squark pair with 2 leptons
ATLAS-SUSY-2013-08	Top squark pair with a Z boson, b-jets and MET
ATLAS-CONF - 2014-056	Top squark in the all-hadronic $t\bar{t}$ + MET
ATLAS-CONF -2016-013	Vector-like top quark pairs
ATLAS-CONF -2016-050	Top squarks with one isolated lepton, jets and MET
CMS-B2G-14-004	Dark matter + $t\bar{t}$

MadAnalysis 5

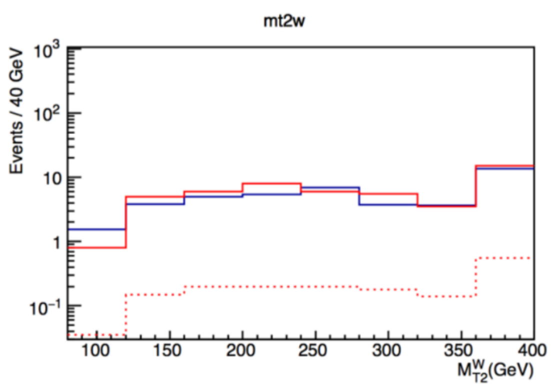
ATLAS-SUSY-2013-05	stop/sbottom search: 0 leptons + 2 b-jets
CMS-SUS-13-011	stop search in the single lepton mode
CMS-SUS-14-001	third-generation squarks in fully hadronic final states (top-tag)
CMS-B2G-12-022	T5/3 top partners in same-sign dilepton channel
CMS-B2G-12-022	monotops
CMS-B2G-14-004	Dark matter + $t\bar{t}$

Recasting validation: CMS-B2G-14-004

CHECKMATE

- Validation note

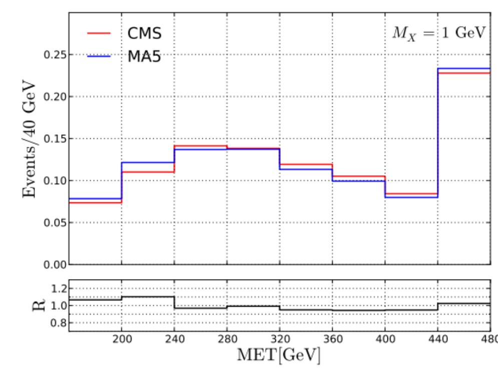
Signal Region	SR	
Process	$pp \to \bar{t}t\bar{\chi}\chi$	
Source	CMS	CheckMATE-1.2.2 (40,000 events)
M_χ(GeV)	Signal efficiency (%) (±stat)	Signal efficiency (%)
1	1.01±0.02	1.10
10	1.01±0.02	1.19
50	1.20±0.02	1.31



MADAnalysis 5

- Validation note
- MadGraph cards for signal benchmark

	Selection step	CMS	ϵ_i^{CMS}	MA5	ϵ_i^{MA5}	δ_i^{rel}
0	Nominal	224510		224510		
1	Preselection			15468.5	0.069	
2	$\not{E}_T > 320$ GeV	4220.8		4579.8	0.296	
3	$M_T > 160$ GeV	3390.1	0.803	3648.2	0.797	0.75%
4	$\Delta\Phi(j_{1,2}, \not{E}_T) > 1.2$	2963.5	0.874	3124.3	0.856	2.06%
5	$M_{T2}^W > 200$ GeV	2267.6	0.765	2403	0.769	-0.52%



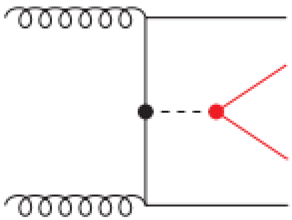
Example of recasting

Extract from: C. Arina et al, *A comprehensive approach to dark matter studies: exploration of simplified top-philic models*, JHEP04(2015)029, arXiv:1605.09242v1

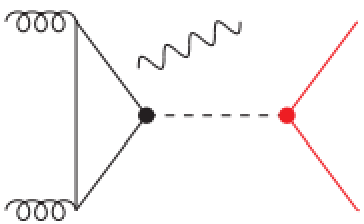
Simplified top-philic dark matter model
→ Fermionic dark matter candidate X
→ Scalar mediator Y_0

$$\mathcal{L}_{t,X}^{Y_0} = -\left(g_t \frac{y_t}{\sqrt{2}} \bar{t}t + g_X \bar{X}X\right) Y_0$$

2 relevant topologies with large MET signature at collider experiments



tt + MET



X + MET
avec X=Z,j,H

4 recast analyses

- CMS-B2G-14-004: tt + MET
- CMS-EXO-12-048: monojet
- CMS-EXO-12-054: mono-Z
- ATLAS-EXOT-2014-20 mono-Higgs

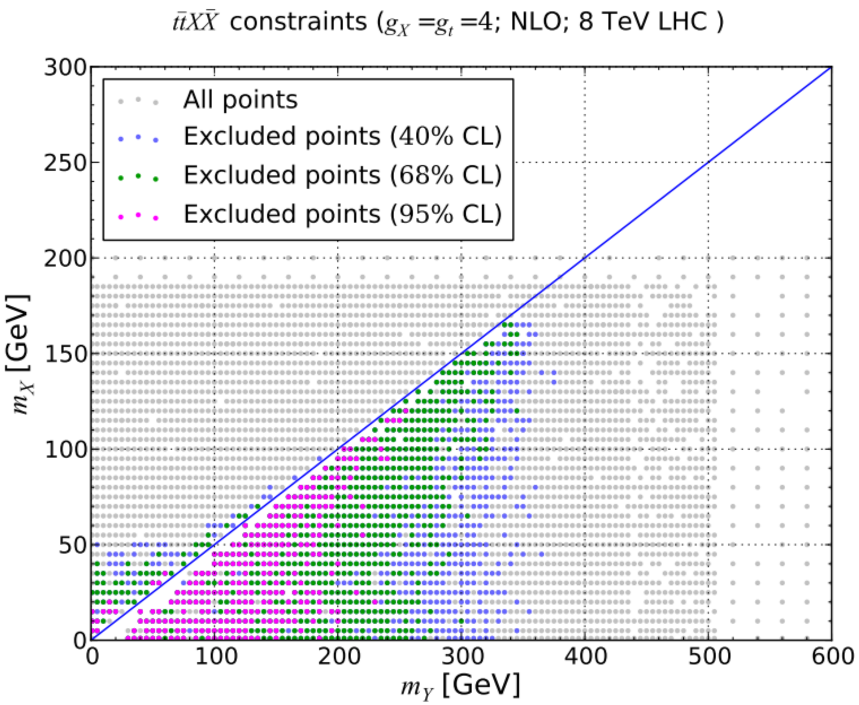
MADAnalysis 5

Home made recasting

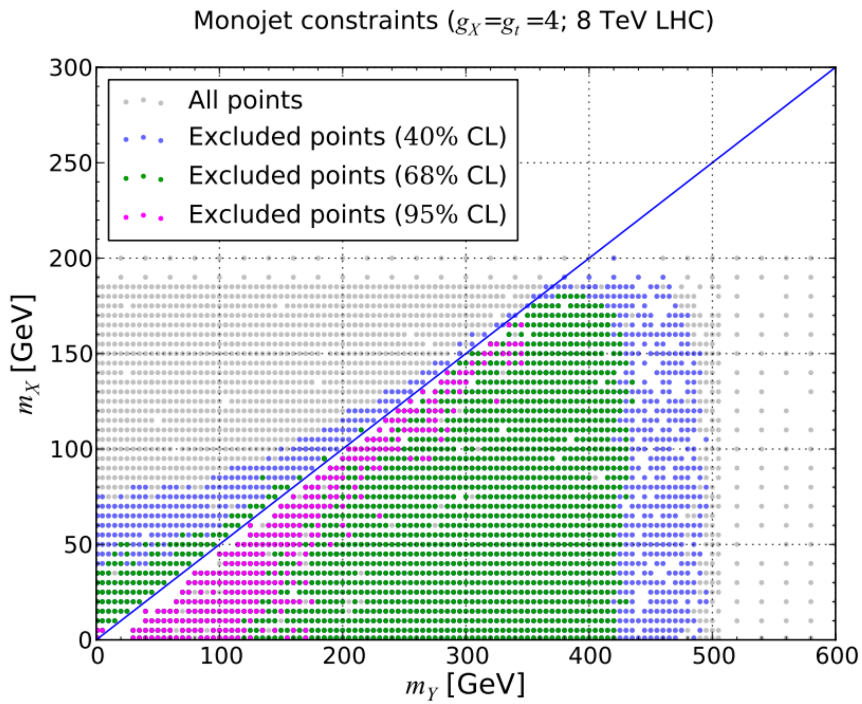
Example of recasting

Extract from: C. Arina et al, *A comprehensive approach to dark matter studies: exploration of simplified top-philic models*, JHEP04(2015)029, arXiv:1605.09242v1

Results with the 2 MadAnalysis-recast analyses:



$t\bar{t}$ + XX



Monojet+XX

Tools based on machine learning algorithm

- Getting LHC constraints could be time consuming (wrt low-energy or cosmological constraints).
- For instance: scanning over parameter space of a SUSY-like model

→ Machine learning algorithm could be used to scan in a clever way.

SUSY-AI

- Scan over MSSM or NMSSM parameter-space with a **random forest**
- Algorithm validated with ATLAS pMSSM-? study (arXiv:1508.06608)
- Using CHECKMATE-recast analyses

→ 5000 predictions / CPU seconds

ScyNet = Susy Calculating Yields NET

- Scan over SUSY parameter-space with a **neural network**
- Using CHECKMATE-recast analyses
- Figure of merit = LHC χ^2 obtained in few seconds

→ Could complete a global fit with FITTINO

Still a private tool

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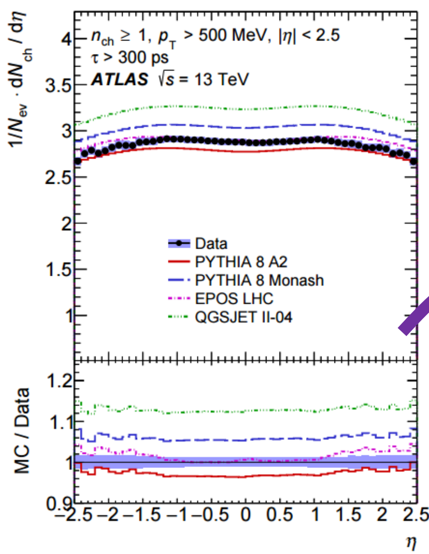
Rivet for SM

RIVET = Robust Independent Validation of Experiment and Theory

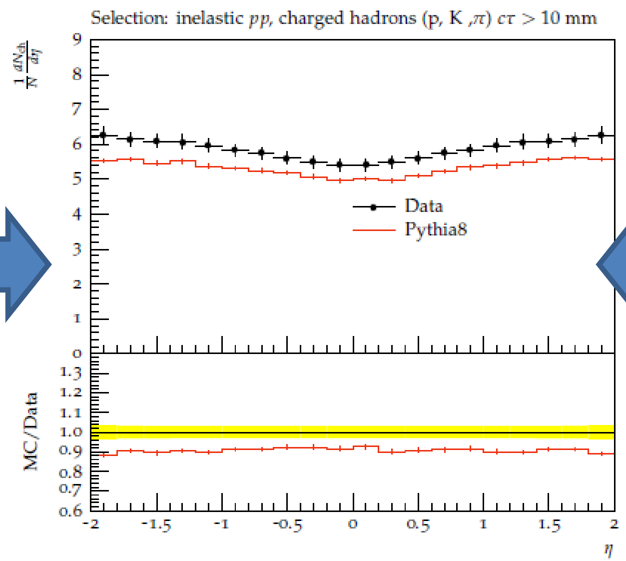
- **Initial goal of RIVET:** validation of MC generation/simulation/tuning
- Standalone program or library (which could be encapsulated into a collaboration framework)
- **Strategy:**



unfolding

unfolded data on **HepData**

ATLAS/CMS collaborations



MC Generation

Phenomenologists

Rivet for SM

Has become the LHC standard for archiving measurements in electroweak, top & Higgs

→ 230 LHC analysis among a total of 427 *(54 are pure MC, and some double/triple-counting)*

ATLAS EXPERIMENT – Public Results

Rivet analysis for top results

List of currently available Rivet routines from top results
(click to access the result page with links to the Rivet pages)

7 TeV results:

- Jet veto measurement (arXiv:1203.5015)
- Jet shapes in ttbar events (arXiv:1307.5749)
- ttbar+jets (arXiv:1407.0891)
- Differential ttbar cross-section, particle-level variables (arXiv:1502.05923)

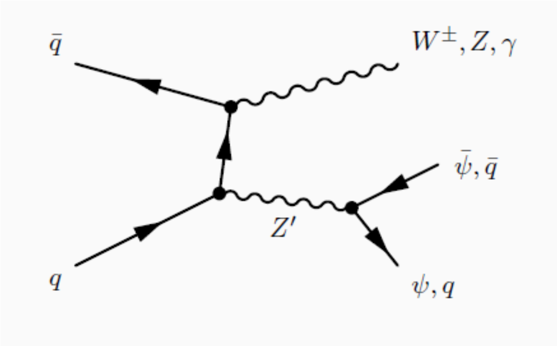
8 TeV results:

- Colour flow measurement (arXiv:1506.05629)
- Differential ttbar cross-section of highly boosted top quarks as a function of top pT (arXiv:1510.03818).
- Fiducial cross-sections for ttbar production with one or two additional b-jets (arXiv:1508.06868).
- Measurement of the production cross-section of a single top quark in association with a W boson (arXiv:1510.03752).
- Measurements of top-quark pair differential cross-sections in the lepton+jets channel (arXiv:1511.04716)

Contur

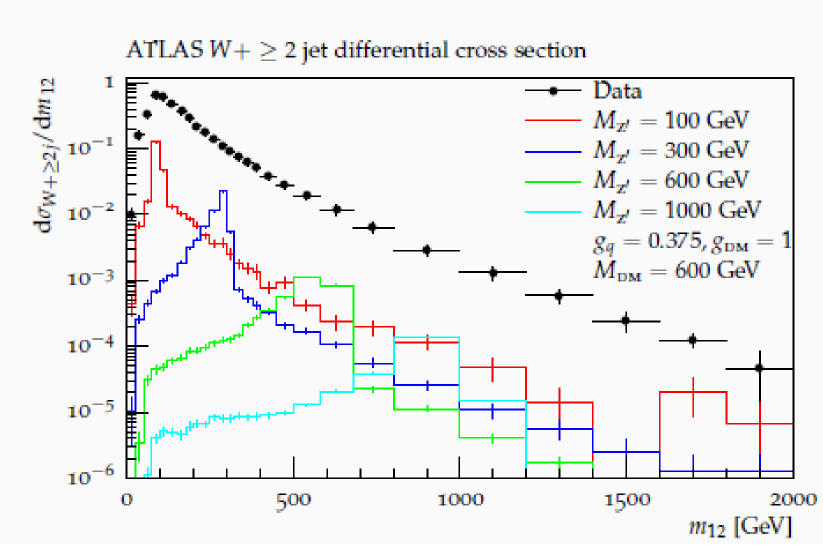
CONTUR = Constraints on new theories using Rivet
→ use unfolded fiducial cross section measurements
→ tool chain: FeynRules →Herwig 7 → RIVET

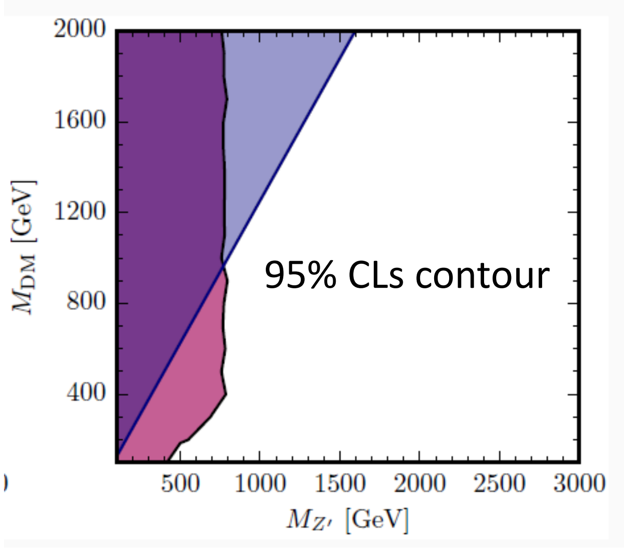
Still a private tool



Example of results: simple DM models
4 parameters : $M_{Z'}$, M_{DM}, $g_{Z'}$, g_{DM}
→ Constraints from EW measures (JHEP07(2013)032)

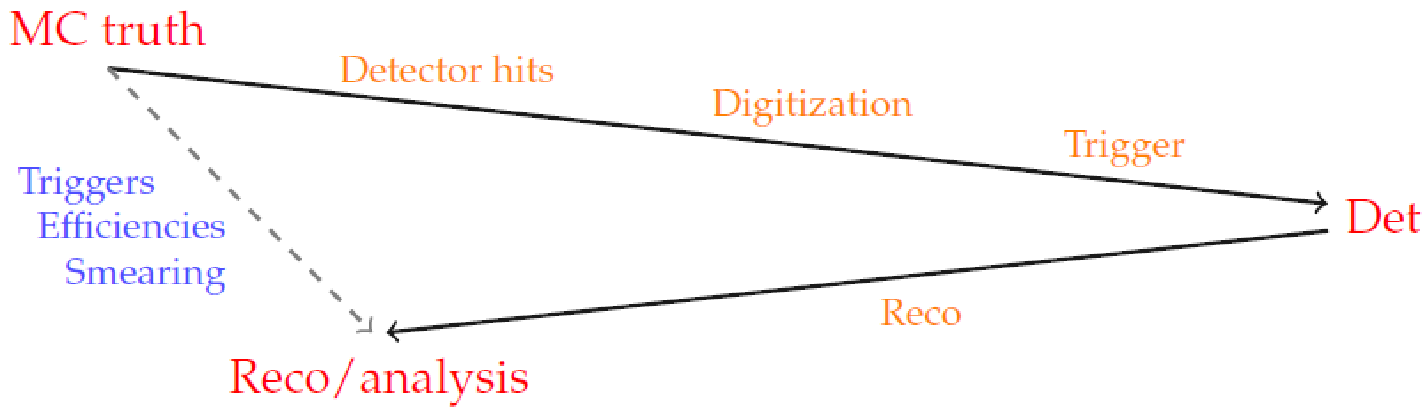
ATLAS W+Jet 7TeV





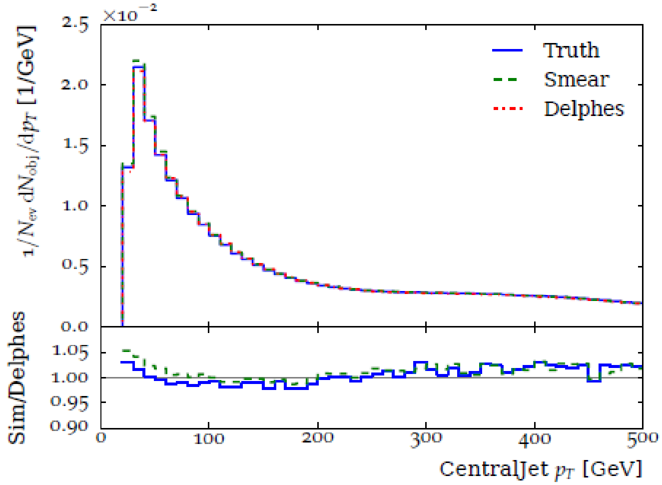
Rivet for BSM

Since release 2.5, RIVET is able to deal with BSM recasting
→ Use efficiencies and smearing for modeling the detector response

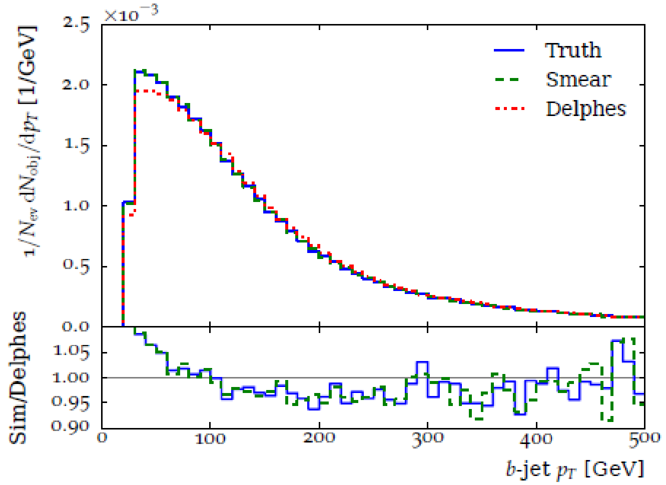


Gain of time wrt fast sim because the reco reverses almost all detector effects

central-jet PT



b-jet PT



Rivet for BSM

Status: development on-going and release imminent

- Start coding up selected recent ATLAS & CMS search analyses
  - ATLAS:
    - ICHEP 2016 3-lepton & same-sign 2-lepton, 1-lepton + jets, 1-lepton + jets, jets + MET
    - 2015 jets + MET and monojet
  - CMS:
    - ICHEP 2016 jets + MET
    - 8 TeV α_T + b-jets

  → Partially validated

- Rivet tutorials dedicate to new BSM feature are planned for July @ CERN

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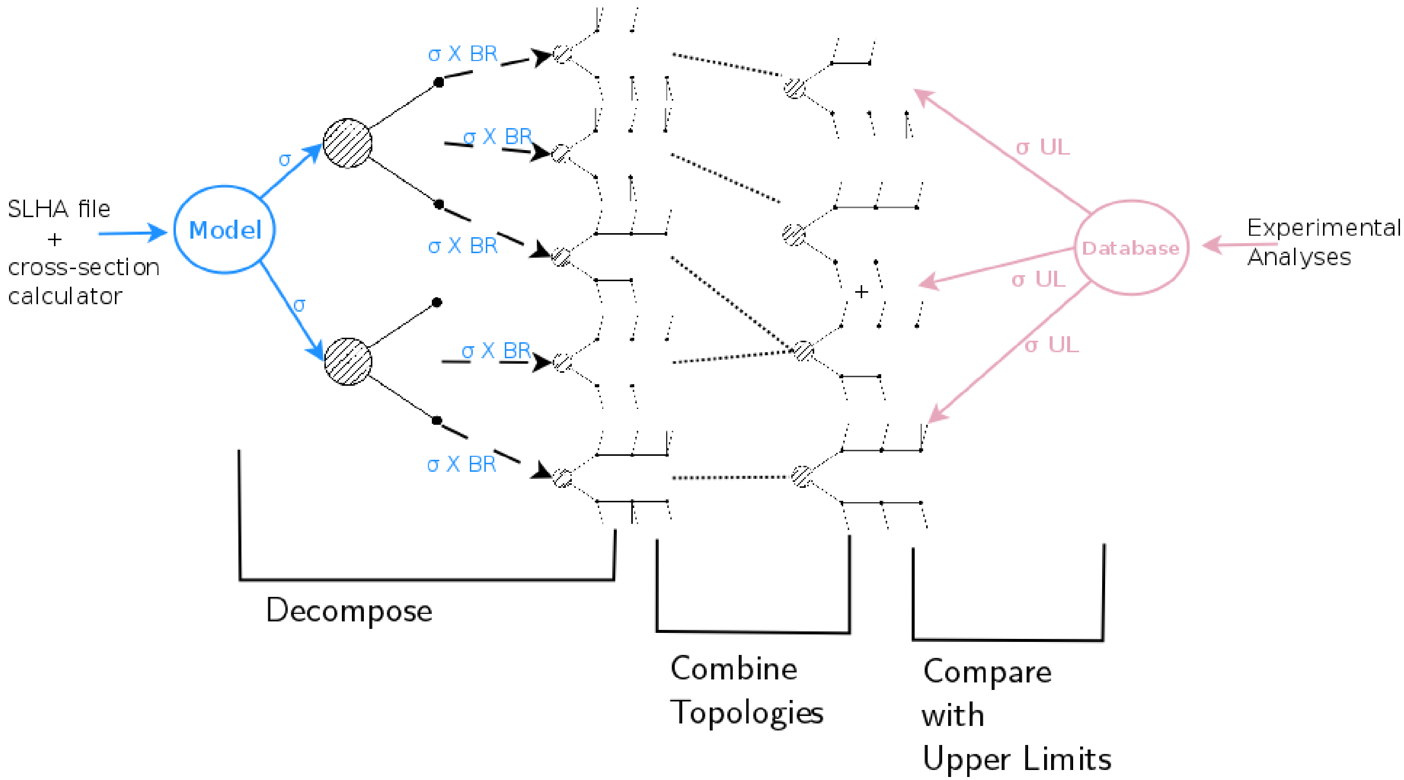
SModelS

- For generic BSM models with Z2 symmetry
- From experimental inputs:
  - Upper limit
  - Map efficiencies

test models without MC simulation



SModelS

A huge database of experimental SMS results!

ATLAS

14 publications + 16 CONF notes

Experimental Result	$\sqrt{s}$	lumi	data type
ATLAS-CONF-2012-105	8	5.8	upperLimit
ATLAS-CONF-2012-166	8	13.0	upperLimit
ATLAS-CONF-2013-001	8	12.8	upperLimit
ATLAS-CONF-2013-007	8	20.7	upperLimit
...	...	...	...
ATLAS-SUSY-2013-14	8	20.3	upperLimit
ATLAS-SUSY-2013-15	8	20.3	efficiencyMap
ATLAS-SUSY-2013-15	8	20.3	upperLimit
ATLAS-SUSY-2013-16	8	20.1	efficiencyMap
ATLAS-SUSY-2013-16	8	20.1	upperLimit
ATLAS-SUSY-2013-18	8	20.1	efficiencyMap
ATLAS-SUSY-2013-18	8	20.1	upperLimit
ATLAS-SUSY-2013-19	8	20.3	upperLimit
ATLAS-SUSY-2013-23	8	20.3	upperLimit
ATLAS-SUSY-2014-03	8	20.3	efficiencyMap
ATLAS-SUSY-2015-09	13	3.2	upperLimit

CMS

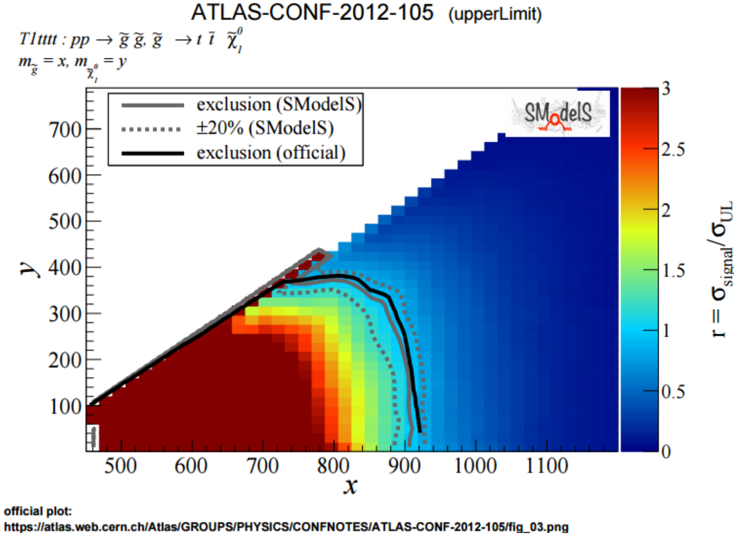
12 publications + 7 PAS

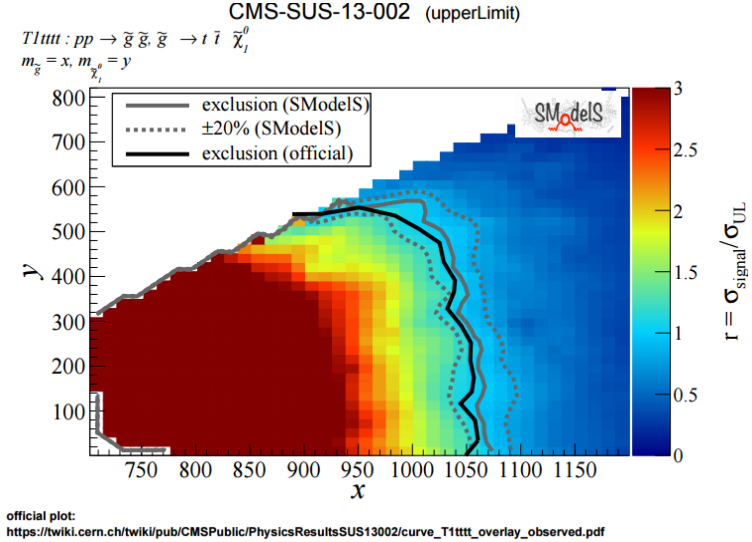
Experimental Result	$\sqrt{s}$	lumi	data type
CMS-SUS-12-024	8	19.4	efficiencyMap
CMS-SUS-12-024	8	19.4	upperLimit
CMS-SUS-12-028	8	11.7	upperLimit
CMS-SUS-13-002	8	19.5	upperLimit
CMS-SUS-13-004	8	19.3	upperLimit
CMS-SUS-13-006	8	19.5	upperLimit
CMS-SUS-13-007	8	19.3	efficiencyMap
CMS-SUS-13-007	8	19.3	upperLimit
CMS-SUS-13-011	8	19.5	efficiencyMap
CMS-SUS-13-011	8	19.5	upperLimit
CMS-SUS-13-012	8	19.5	efficiencyMap
CMS-SUS-13-012	8	19.5	upperLimit
CMS-SUS-13-015	8	19.4	efficiencyMap
CMS-SUS-13-015	8	19.4	upperLimit
CMS-SUS-13-019	8	19.5	upperLimit
...	...	...	...
CMS-SUS-PAS-13-016	8	19.7	upperLimit
CMS-SUS-PAS-13-018	8	19.4	upperLimit
CMS-SUS-PAS-15-002	13	2.2	upperLimit

Collaboration with FASTLIM community for map efficiencies

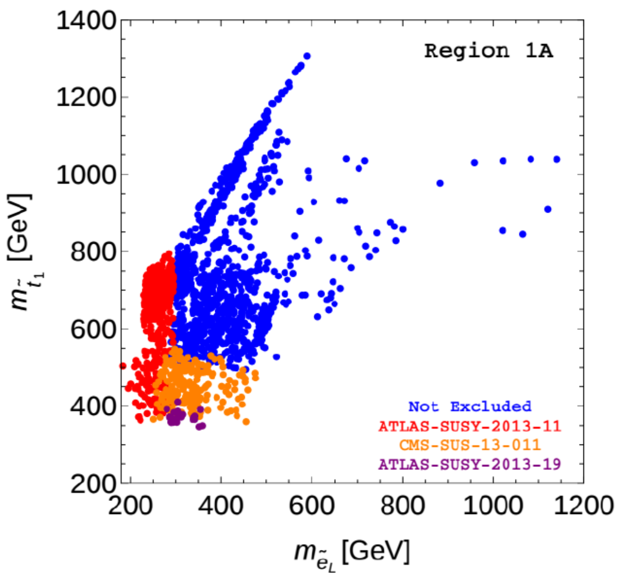
SModelS

Validation:





Example of results:



NMSSM constraints

D. Barducci et al, JHEP 1601 (2016) 050

Fastlim

Fastlim

- Restricted currently to the MSSM
- Same strategy than SModelS based on efficiency maps

List of analyses:

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

Validation done with a private detector-simulation-like recasting tool: ATOM

Fastlim

Fastlim

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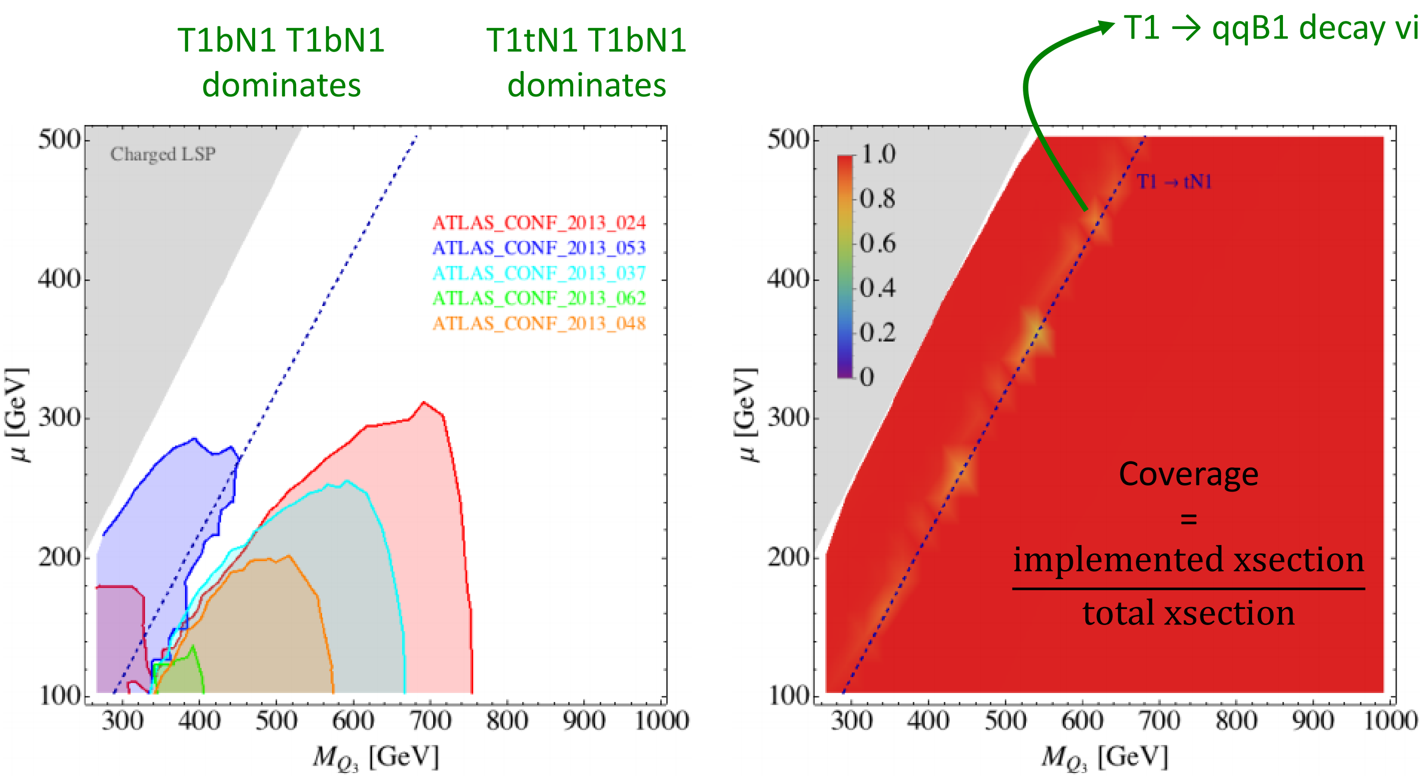
Examples of results: natural susy models



$m_{\tilde{g}} = MU_3 = MD_3 = 3$ TeV,
$\tan\beta = 10$,
$X_t = A_t - \mu \cot\beta = 0$

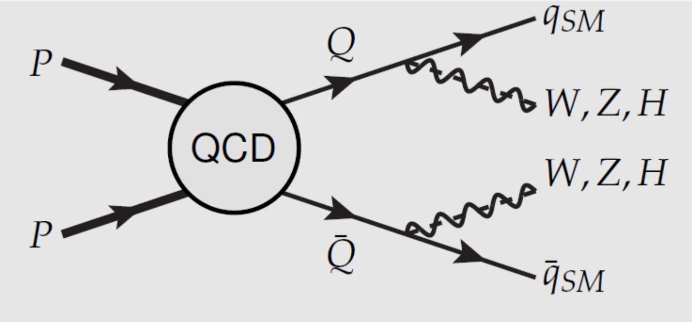
arXiv:1402.0492v1

XQCAT

XQCAT = eXtra Quark Combined Analysis Tool

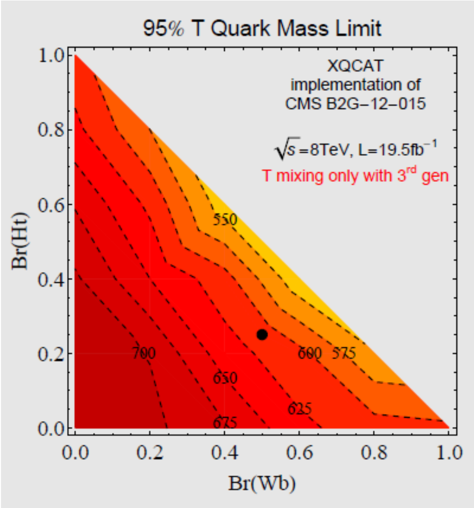
Designed for heavy extra quarks and based on efficiency maps

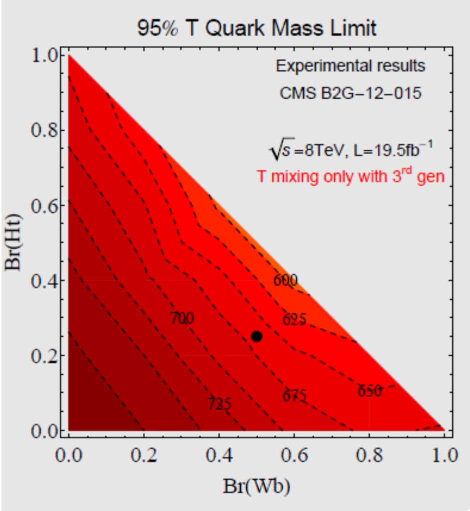
- Reinterpreting in terms of pair-production of VLQ in the NWA



$$N_S = L_{exp} \sum_Q \sigma_{QCD}(m_Q) \sum_{ij} BR_i(Q) BR_j(\bar{Q}) \epsilon_{ij}$$

- Validation:



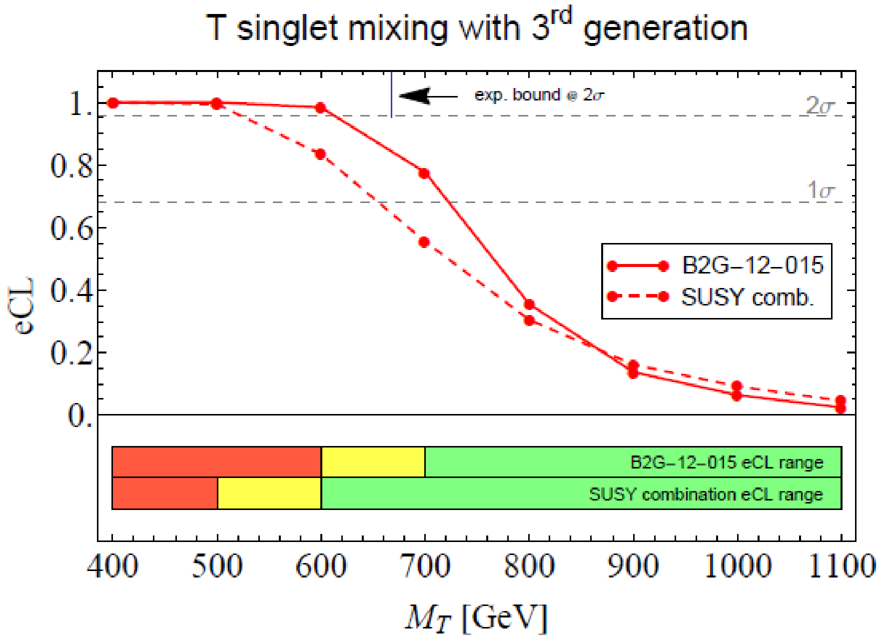


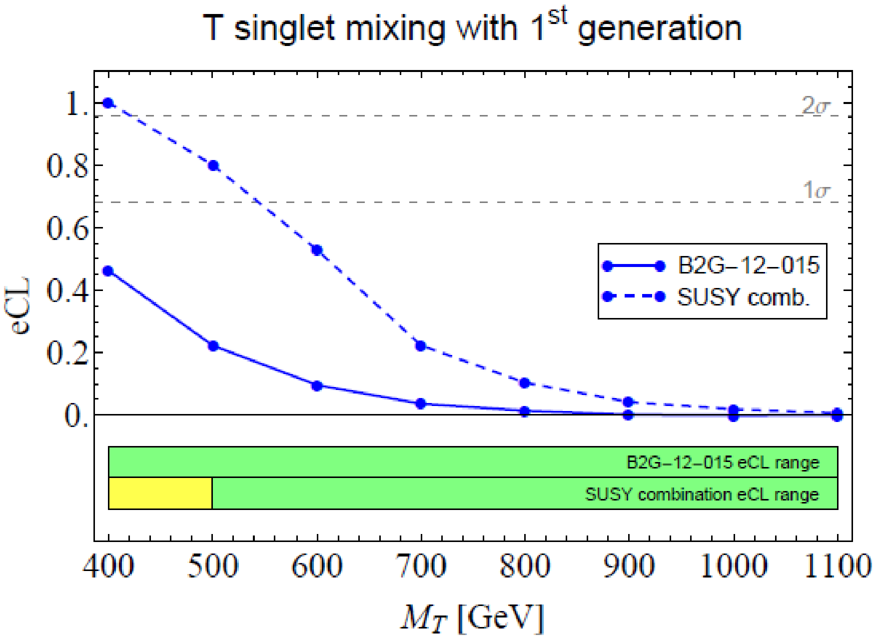
Reproduction of CMS 95% CL bounds within 50-60 GeV in the whole BR range

XQCAT

Example of results:

Combining VLQ direct research (BG2-12-015)
+ SUSY combination @ 7 & 8 TeV (αT, monolepton, SS dilepton, OS dileptons)
(arXiv:1304.2185)





$$BR(Zq) = BR(Hq) = 25\% \qquad BR(Wq) = 50\%$$

1. Motivations
2. Recasting with CheckMate & MadAnalysis5
3. Recasting with Rivet & derived tools
4. Reinterpreting simplified models
5. **Required inputs**
6. Summary

What we need for recasting one analysis?

S. KRAMEL et al, *Les Houches Recommendations for the Presentation of LHC Results*, arXiv:1203.2489v2

- **Clear description of the selection in the paper:**
  - Definition of the reconstructed objects
  - Each step of the selection
  - Source code of specific and sophisticated of observables (SUSY transverse observable)

- **Clear description of the results:**
  - Crucial numbers
  - Final likelihood expression

- **Detector modeling:**
  - Resolution & efficiency plots for reconstruction of exotic objects, trigger?
  - Efficiency maps

- **Materials for validation:**
  - Cut-flow chart
  - Description of the signal benchmarks and its generation (the best is to have the LHE files)
  - Plots of key observables

- **Analysis combination?**

Support for describing an analysis

- **Service for storing information:**
  - INSPIRE
  - HEPDATA

- **Description of the analysis could be achieved by a universal metalanguage:**
  - MADANALYSIS5 metalanguage: intuitive but too much simple
  - AEACUS & RHADAMANTHUS: advanced metalanguage but not enough
  - Framework-independent language:

    Towards an analysis description accord for the LHC (arXiv:1605.02684)

    LHADA (Les Houches Analysis Description Accord for the LHC) in development

- **All-in-one service:** RECAST project (still in development)

1. Motivations

2. Recasting with CheckMate & MadAnalysis5

3. Recasting with Rivet & derived tools

4. Reinterpreting simplified models

5. Required inputs

6. Summary

Summary

- **Importance of recasting for:**
  - Preserving LHC analyses
  - Identifying holes in the ATLAS/CMS research program

- **Public recasting tools:**
  - Constraints from SM measurements: **RIVET**
  - Based on simplified models: **SMODELS**, **FASTLIM**, **XQCAT**
  - Based on detector simulation/smearing:
    - **CHECKMATE**, **MADANALYSIS5** + **SUSY-AI**
    - Incoming tools: **RIVET** for BSM

Private tools:
- **Contur**
- ***ATOM*, *GAMBIT*** *and* **SCYNET**

- **ATLAS/CMS collaborations contribute to the recasting efforts by providing more and more useful infos. What are the next steps?**
  - A common language such as **LHADA**?
  - Extension of the well-known **RIVET** format to the BSM?
  - Use **RECAST** service?

- **Join the effort?**

  https://twiki.cern.ch/twiki/bin/view/LHCPhysics/InterpretingLHCresults

List of discussed tools & projects

Name	Public / Private	Home site	Reference
Aeacus & RHADAManTHUS	Public	http://joelwalker.net/code/	
ATOM	Private	http://fastlim.web.cern.ch/fastlim/	See Fastlim papers currently
CheckMate	Public	https://checkmate.hepforge.org/	arXiv:1312.2591, arXiv:1611.09856
Contur	Private	https://contur.hepforge.org/	arXiv:1606.05296
Fastlim	Public	http://fastlim.web.cern.ch/fastlim/	arXiv:1402.40492 , EPJC74 (2014) 11
Gambit	Private	http://www.mn.uio.no/fysikk/english/research/projects/gambit/	
HepData	Public	https://hepdata.net/	arXiv:1704.05473
Inspire	Public	https://inspirehep.net	
LHADA	Public	https://indico.cern.ch/event/572170/	arXiv:1605.02684, section 16 & 17

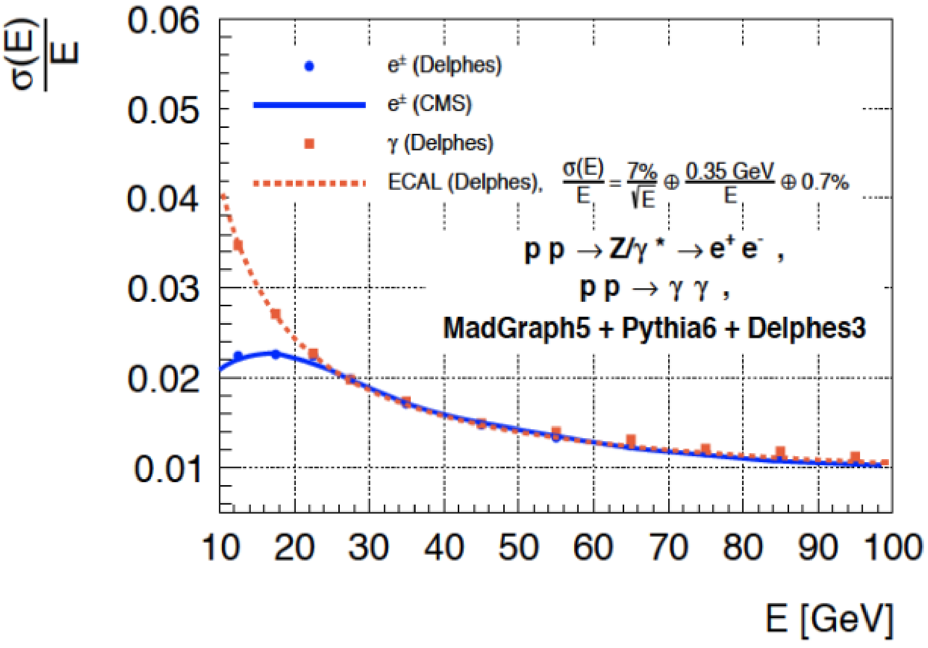
List of discussed tools & projects

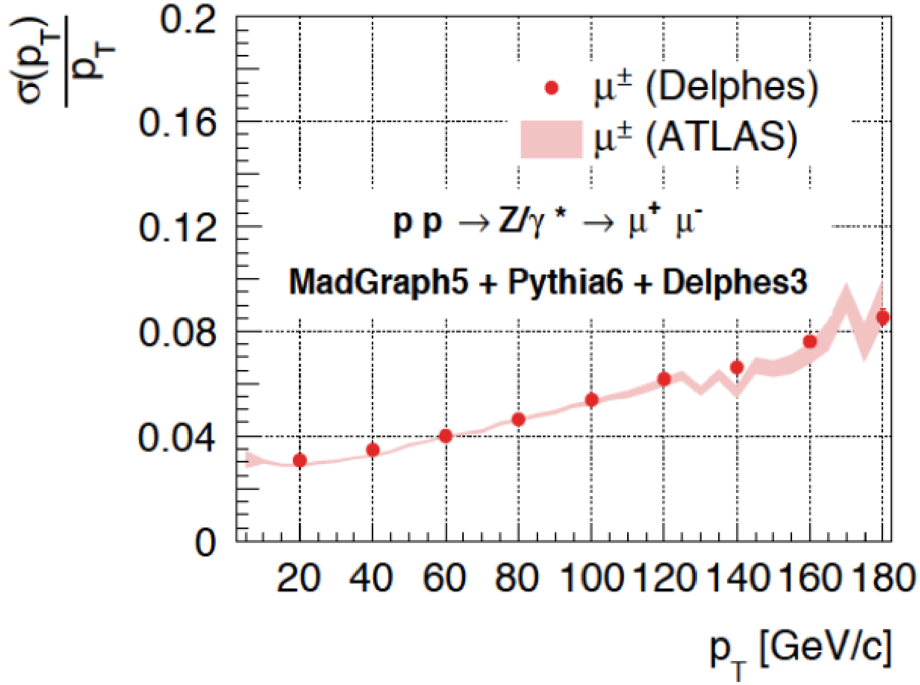
Name	Public / Private	Home site	Reference
MadAnalysis5	Public	https://launchpad.net/madanalysis5	arXiv:1206.1599, arXiv:1405.3982, arXiv:1407.3278
Recast	Public	http://recast.perimeterinstitute.ca/ https://github.com/recast-hep	arXiv:1010.2506
Rivet	Public	http://rivet.hepforge.org/	arXiv:1003.0694
ScyNET	Private		arXiv:1703.01309
SModelS	Public	http://smodels.hephy.at/wiki	arXiv:1701.06586, arXiv:1312.4175
Susy-AI	Public	http://susyai.hepforge.org/	arXiv: 1605.02797
XQCAT	Public	https://launchpad.net/xqcat	JHEP 1412 (2014) 080,arXiv:1405.0737, arXiv:1409:3116

Back-up slides

Very-Fast-Simulation package: Delphes

- Validation for ATLAS & CMS





Other related tools

ATOM = Automated Testing Of Models

Atom

- Forked from Rivet
- Detector simulation: transfert functions between particle-objects and detector-objects
- Associated to the public package FastLim for limits
- Under development

Still a private tool

Gambit

GAMBIT = Global and Modular BSM Inference Tool

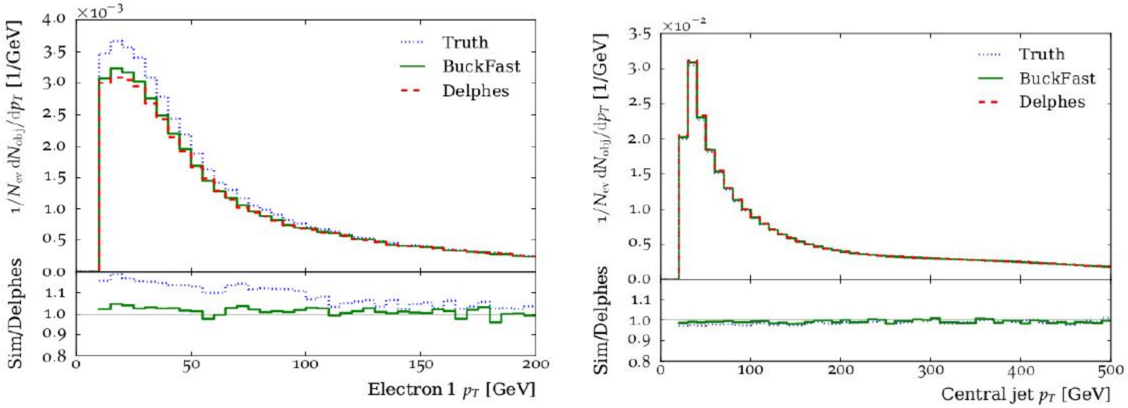
Goal: global statistical fit from different sources of data (frequentists & bayesian):

- Low physics,
- Astrophysics,
- Colliders, …

Still a private tool

Module devoted to LHC analyses: CollisionBit

- Generation with parallelised Pythia
  Detector effects: **BuckFast** (efficiencies/smearing) or Delphes
- Multithread (OpenMP) available with BuckFast



Gambit

- First release will contain implementations of (8 TeV):

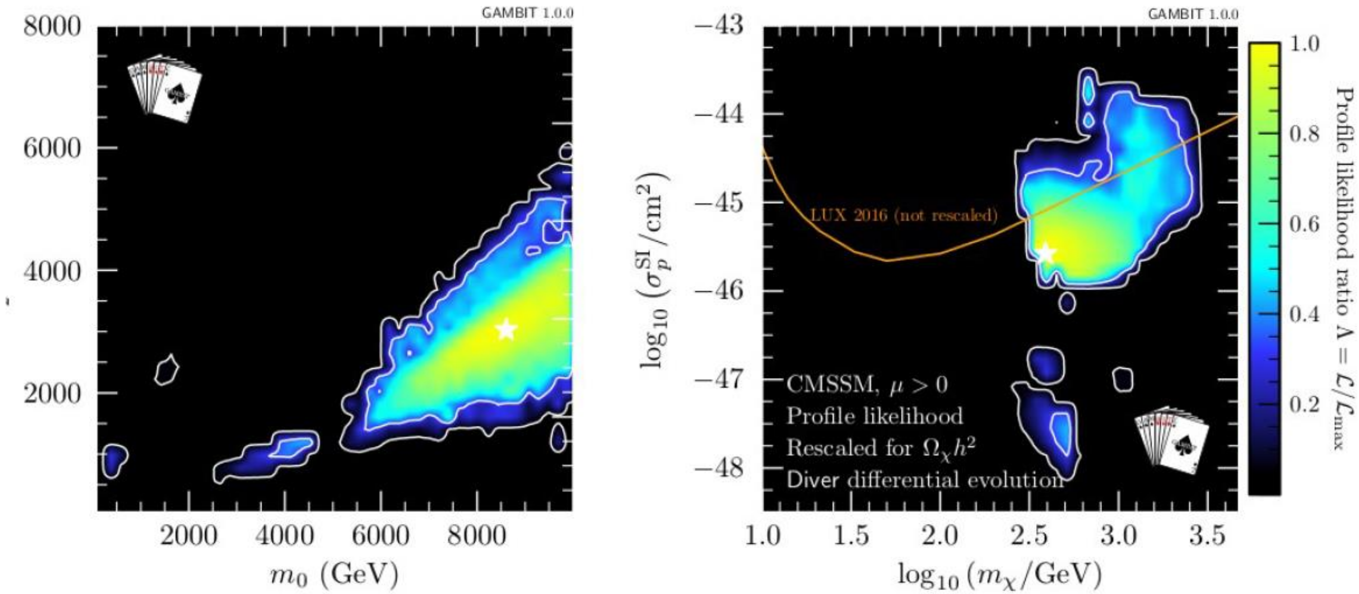
  - ATLAS SUSY searches (0 lep, 0-1-2 lep stop, b jets plus MET, 2 lep EW, 3 lep EW)
  - CMS DM searches (top pair plus MET, mono-b, mono-jet)
  - CMS multilepton SUSY search
  - good coverage for SUSY and DM effective field theory

Cut	ATLAS	GAMBIT	Ratio
$E_{\mathrm{T}}^{\mathrm{miss}}$ + jet p_{T} cuts	89.6%	91.0%	1.02
$\Delta\phi_{\mathrm{min}} > 0.4$	81.0%	82.5%	1.02
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}} > 15\,\mathrm{GeV}^{-1/2}$	56.0%	56.8%	1.01
$m_{\mathrm{eff}}^{\mathrm{incl}} > 1600\,\mathrm{GeV}$	31.6%	33.4%	1.06

ATLAS 0 lepton cutflow performance, with **BuckFast**

Gambit

Use of Gambit : ongoing



CMSSM
(also NUHM1 and NUHM2)

- m_0, $m_{\frac{1}{2}}$, A_0, $\tan\beta$ + 5 nuisances
- H/A^0 funnel, $\chi^\pm$ co-annihilation, $\tilde{\tau}$ co-annihilation, $\tilde{t}$ co-annihilation
- Includes LUX 2016, Panda-X + direct simulation of all relevant LHC Run 1 limits. Run 2 coming soon.

The tool will be public when the 9 expected papers will be released.

nMSSM benchmarks

Region	1A		1B	
$\tan\beta$	6.6	10	6	8
λ	0.33	0.53	0.49	0.52
μ	240	400	350	430
m_0	0	1080	4040	4800
$M_{1/2}$	630	1200	280	440
A_0	-1700	50	6700	7900
A_λ	1400	6000	7000	7900
ξ_F	10	100	$-1.5{\cdot}10^4$	$-1.4{\cdot}10^4$
ξ_S	$-6{\cdot}10^4$	$2{\cdot}10^4$	$-1.9{\cdot}10^7$	$-1.6{\cdot}10^7$
M_1	270	520	110	190
M_2	500	950	200	340
$m_{\tilde{q}}$	1300	2400	> 3000	
$m_{\tilde{t}_1}$	350	1300	1050	1900
$m_{\tilde{l}}$	180	1100	> 3000	
$m_{\tilde{g}}$	1450	2600	780	1250