From new physics simulations to the recasting of LHC results

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LPTHE Paris / UPMC Paris VI

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Outline

1. When new physics meets Monte Carlo simulations
2. New physics simulations with Monte Carlo event generators
3. Interpretation of LHC results and recasting the experimental searches
4. Conclusions - summary

Standard Model simulations at the LHC: the status

✦ The need for better simulation tools has spurred a very intense activity

- ✤ Automated matrix element generation (MADGRAPH5, *etc.*)
- ✤ Higher-order computations (aMC@NLO, *etc.*)
- ✤ Parton showering and hadronization (PYTHIA, HERWIG, *etc.*)
- ✤ Matrix element - parton showering matching
- ✤ Merging techniques (MLM, CKKW, FxFx, UNLOPS, *etc.*)

✦ Standard Model simulations

- ✤ All processes relevant for LHC physics can be simulated with a very good precision
- ✤ This precision will even improve within the next few years (electroweak corrections, *etc.*)

Standard Model simulations are under good control
What about new physics?

New physics simulations at the LHC: the challenge

- The challenges with respect to new physics simulations are of a different nature
  - Theoretically, we are still in the dark
    - ★ No sign of new physics
    - ★ All measurements are Standard-Model-like
  - There is not any leading new physics candidate theory
    - ★ Plethora of models to implement in the tools

- New physics is a standard in many tools today
  - Prospective phenomenological studies
  - Experimental searches (signal generation)
  - Recasting of current results

Topics of this lecture

Outline

1. When new physics meets Monte Carlo simulations
2. **New physics simulations with Monte Carlo event generators**
3. Interpretation of LHC results and recasting the experimental searches
4. Conclusions - summary

New physics implementations in Monte Carlo tools (I)

- How to implement a new physics model in a Monte Carlo program?
  - Model definition: particles, parameters & vertices (≡ Lagrangian)
  - To be translated in a programming language, following some conventions, *etc.*
  - Tedious, time-consuming, error prone (and no-brainer)
  - Iterations for all considered tools and models (high level of redundancy)
  - Beware of the restrictions of each tool (Lorentz structures, color structures)
  - Validation is tricky

$$\mathcal{L} = \frac{\bar{c}_H}{2v^2}\partial^\mu\left[\Phi^\dagger\Phi\right]\partial_\mu\left[\Phi^\dagger\Phi\right] \longrightarrow$$

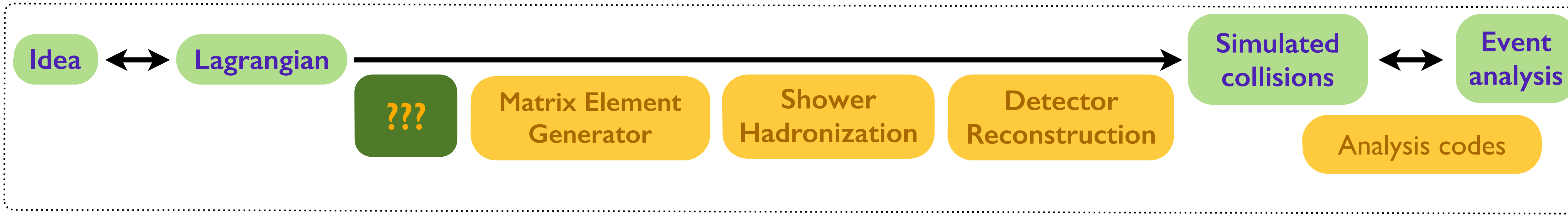
```
H = Particle(pdg_code = 25,
             name = 'H',
             antiname = 'H',
             spin = 1,
             color = 1,
             mass = Param.MH,
             width = Param.WH,
             texname = 'H',
             antitexname = 'H',
             charge = 0,
             GhostNumber = 0,
             LeptonNumber = 0,
             Y = 0)
```

$+ \ldots$

New physics implementations in Monte Carlo tools (2)

✦ A comprehensive approach to Monte Carlo simulations

[Christensen, de Aquino, Degrande, Duhr, BF, Herquet, Maltoni & Schumann (EPJC'11)]



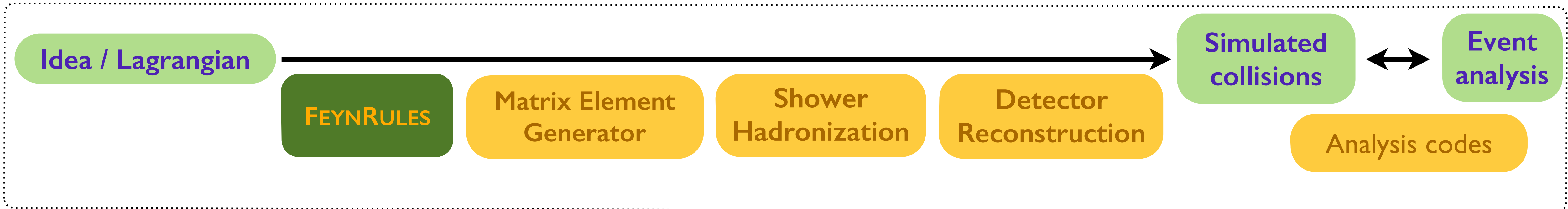
✦ How to streamline the chain from the model Lagrangian to analyzed simulated collisions

- ✤ Connect the physics (Lagrangians) to simulated LHC collisions: need for an efficient framework
  - ★ … where any new physics model can be implemented
  - ★ … where any new physics model can be tested against data
  - ★ … easy to validate, to maintain
  - ★ … easily integrable in the above chain

See talk from C. Duhr: FEYNRULES plays that role

New physics simulations: other challenges

✦ A comprehensive approach to Monte Carlo simulations



✦ Implementation of any new physics theory in Monte Carlo tools is straightforward

✦ Other challenge 1: cascade-decays

- Beyond the Standard Model theories involve lots of new particles
- These particles can decay into each other
- Large multiplicity final states

✦ Other challenge 2: QCD radiation simulation

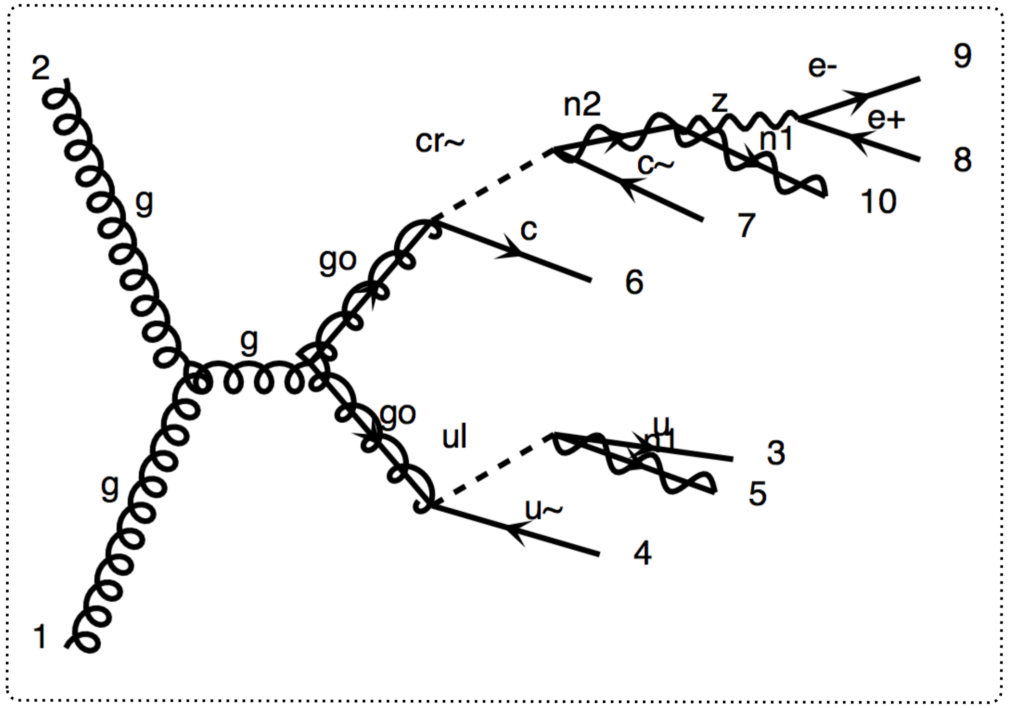
See talks from A. Papaefstathiou and S. Prestel

- Merging matrix elements with different final state jet multiplicity (including parton showering)
- More accurate description of jet-related observables

New physics simulations: cascade decays (I)

✦ Concrete models

- ✤ Many new states to be supplemented to the Standard Model
- ✤ Usually pair-produced
- ✤ Further cascade-decaying into each other
- ✤ The lightest new state can be stable (and a dark matter candidate)



Is the simulation of 2 to N processes (with N large) a problem?

✦ The issue is the computing time

- ✤ Matrix element generation is possible
- ✤ Computationally challenging
- ✤ Practically useless: only diagrams with intermediate resonances usually dominate

New physics simulations: cascade decays (2)

✦ Production and decay processes are factorized

- ✤ Propagators can be seen as sums of products of external wave functions

  Example: $$\mathcal{M} \sim j_1^\mu \left[g_{\mu\nu} - \frac{p_\mu p_\nu}{p^2} \right] j_2^\nu = \sum_\lambda \underbrace{j_1^\mu \varepsilon_\mu^*(\lambda)}_{\mathcal{M}_{\rm prod}(\lambda)} \underbrace{\varepsilon_\nu(\lambda) j_2^\nu}_{\mathcal{M}_{\rm dec}(\lambda)}$$

- ✤ Case 1: loss of spin correlations
  - ★ Helicity sums performed independently at the production and decay levels
  - ★ Example:

$$\sum_\lambda \underbrace{j_1^\mu \varepsilon_\mu^*(\lambda)}_{\mathcal{M}_{\rm prod}(\lambda)} \sum_{\lambda'} \underbrace{\varepsilon_\nu(\lambda') j_2^\nu}_{\mathcal{M}_{\rm dec}(\lambda')}$$

PYTHIA 6 [Sjostrand, Mrenna, Skands (JHEP '06)]

- ✤ Case 2: including spin correlations
  - ★ Helicity sums performed after accounting for production and decays
  - ★ Example:

$$\sum_\lambda \underbrace{j_1^\mu \varepsilon_\mu^*(\lambda)}_{\mathcal{M}_{\rm prod}(\lambda)} \underbrace{\varepsilon_\nu(\lambda) j_2^\nu}_{\mathcal{M}_{\rm dec}(\lambda)}$$

HERWIG [Richardson (JHEP '01)]

MADSPIN [Artoisenet, Frederix, Mattelaer, Rietkerk (JHEP '13)]

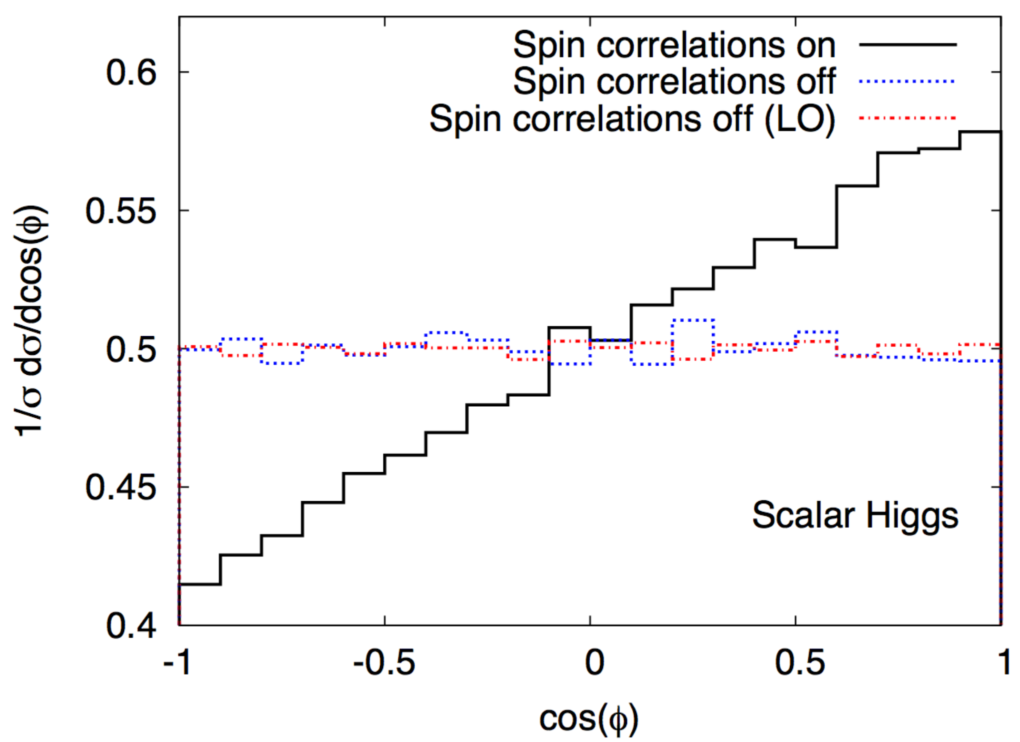
PYTHIA 8 [Sjostrand, Mrenna, Skands (CPC '08)]

SHERPA [Höche, Kuttimalai, Schumann, Siegert (EPJC '15)]

- ✤ Off-shell effects are lost (as a result of the factorization)
  - ★ Resonance mass smearing: partial recovery [Frixione, Laenen, Motylinksi, Webber (JHEP '07)]

New physics simulations: cascade decays (3)

✦ Is a correct decay handling important: yes!



MADSPIN
$t\bar{t}H$ production @ NLOQCD
[LHC8, dileptonic $t\bar{t}$ decay]

See talk from H.S. Shao for information on NLO simulations

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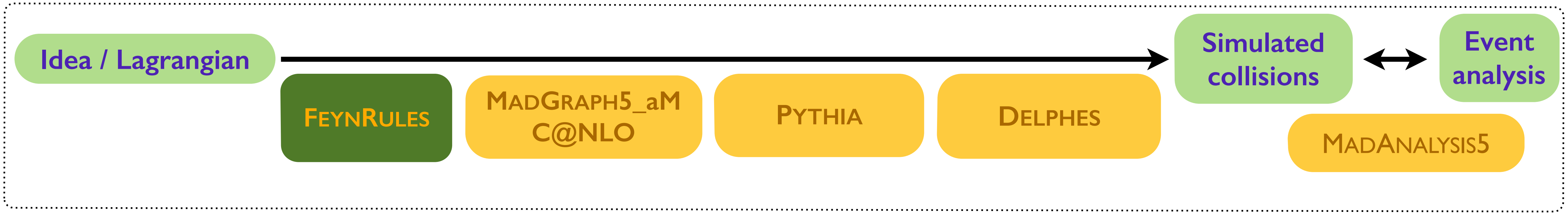
New physics simulations so far

✦ A comprehensive approach to Monte Carlo simulations (using our framework this time)



✦ Works very well at the leading order in QCD and can work at the next-to-leading order

Let's reverse the chain…

Reinterpreting LHC physics analyses (I)

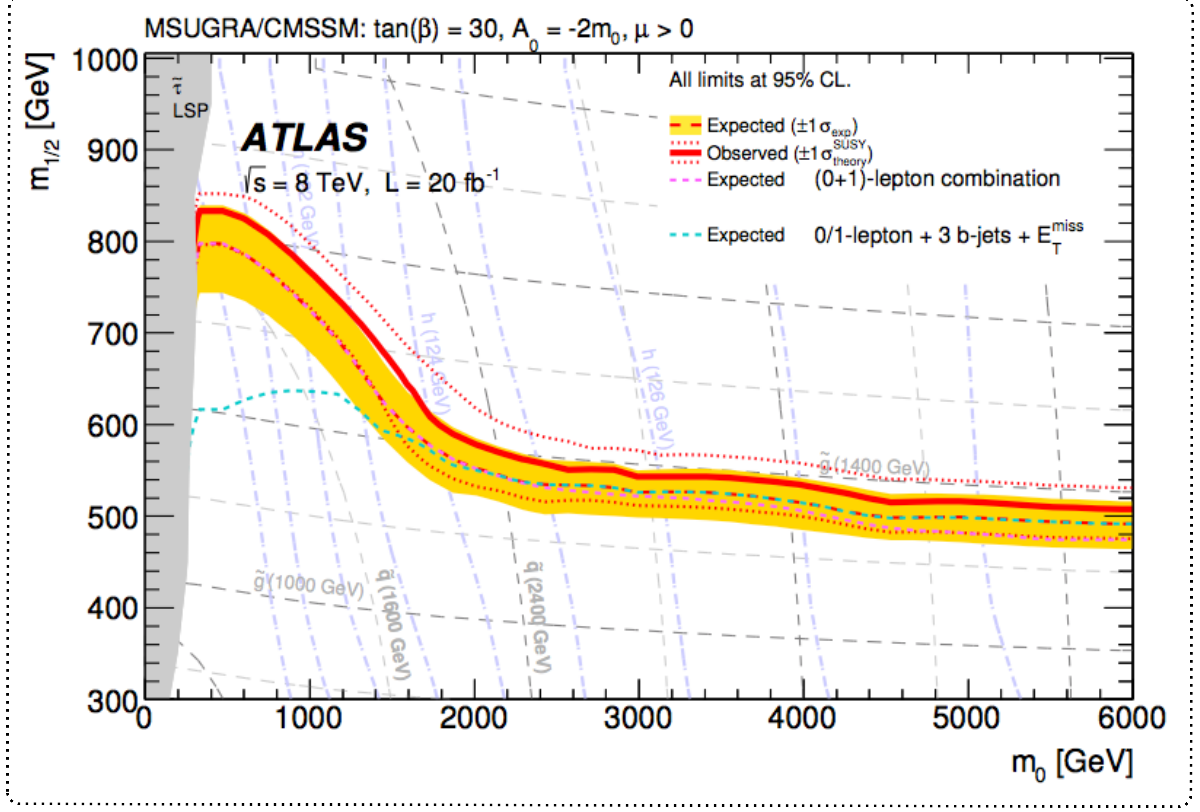
- Exploit the full potential of the LHC (for new physics)
  - Priority #1 of the European strategy for particle physics
  - Designing new analyses to probe new ideas — Prospectives for new physics (based on MC simulations)
  - Recasting LHC analyses to study models not experimentally considered — The LHC legacy

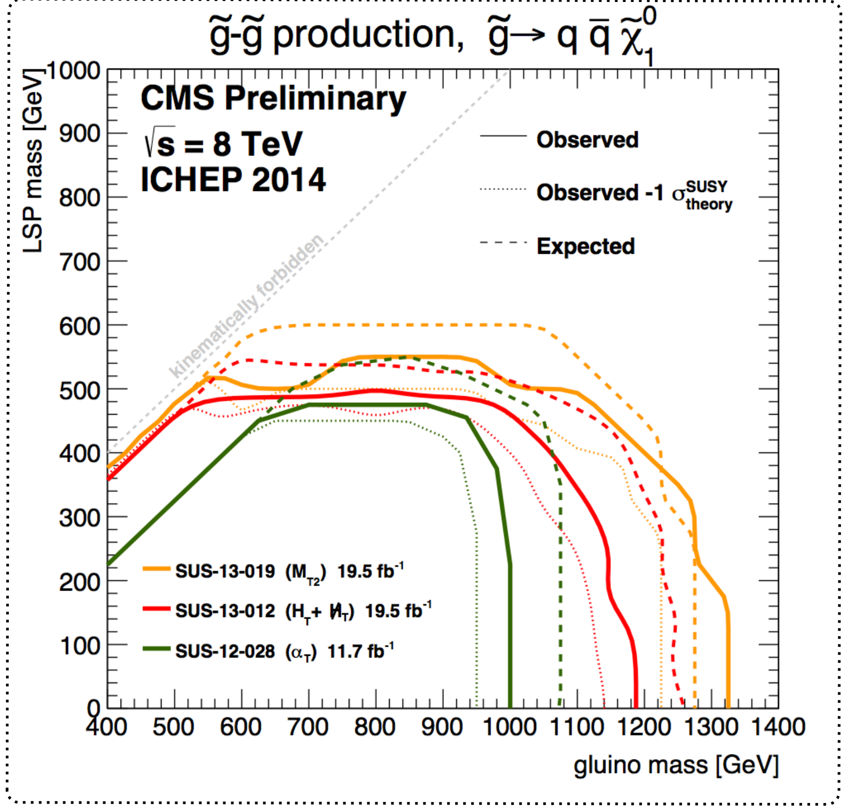
- LHC data has been collected with significant human and financial efforts
  - Important for on-going analyses (within popular theoretical contexts of today)
  - Important for future opportunities (within future scientific contexts)
- Data preservation in high-energy physics is mandatory [Kogler, South & Steder (JPCS'12)]
  - Studies are on-going and go beyond raw data (ICFA DPHEP Study Group)

- Related tools need to be supported by the entire community [Kraml *et al.* (EPJC'12)]
  - Both theorists and experimentalists
  - Allowing for the reinterpretation of the LHC analysis results

Reinterpreting LHC physics analyses (2)

- ✦ The LHC has been built as a discovery machine
  - ✤ There are many ATLAS and CMS searches for new physics
  - ✤ Interpretation within popular frameworks and simplified models



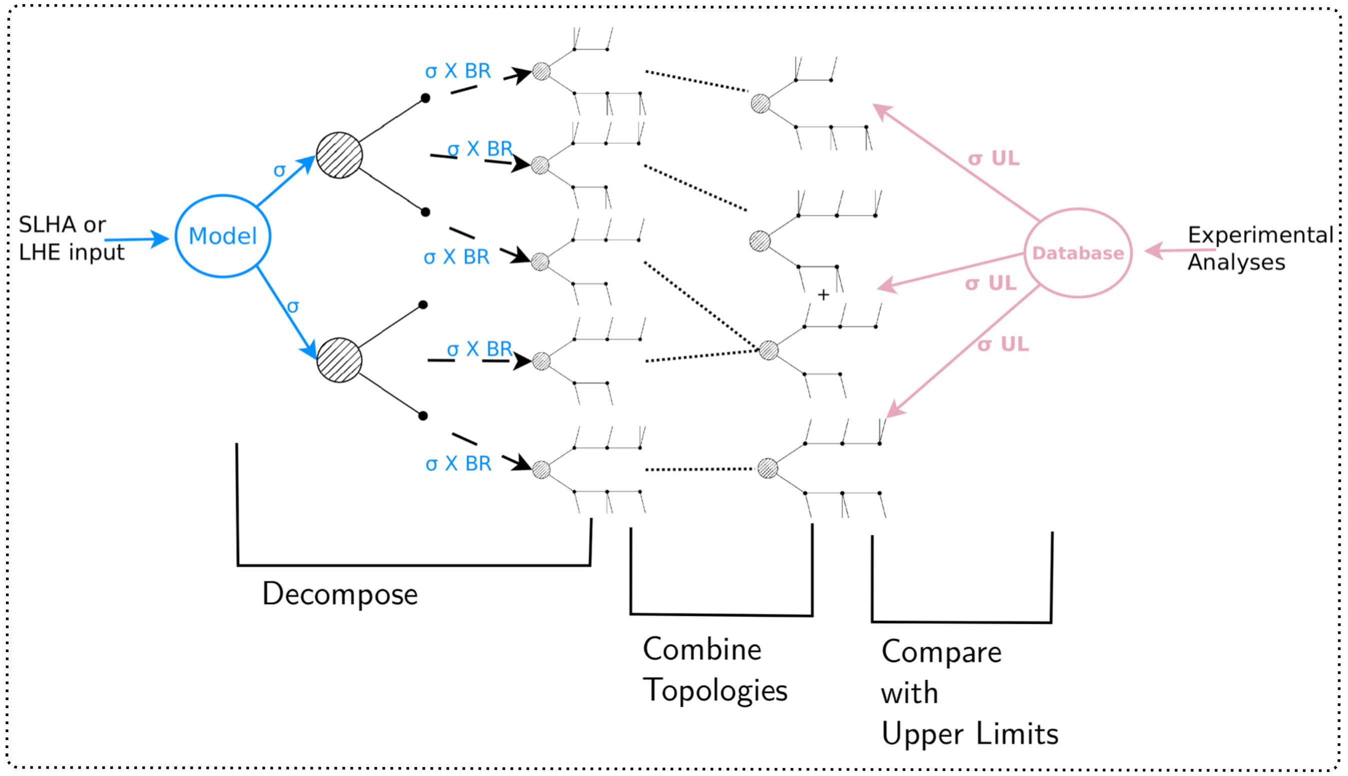


- ✦ Theorists need to reinterpret the results for all kinds of models [Community-wide effort]
- ✦ The simplified model spectrum (SMS) approach is fast and powerful, but limited
  - ✤ Too conservative (final state topologies, different kinematics, *etc.*)
  - ✤ Considered decay patterns and assumptions rarely realized (many channels, *etc.*)
  - ✤ Works however not too bad in many cases for a fair estimate of constraints

The SMS approach for LHC result reinterpretations (I)

✦ The SMS-based reinterpretation framework

- ✤ All signatures of a given theory are decomposed according to those of the SMS searches
- ✤ Fiducial cross sections are calculated on the basis of public efficiency maps
- ✤ Comparisons to published upper bounds are made



✦ Basic features

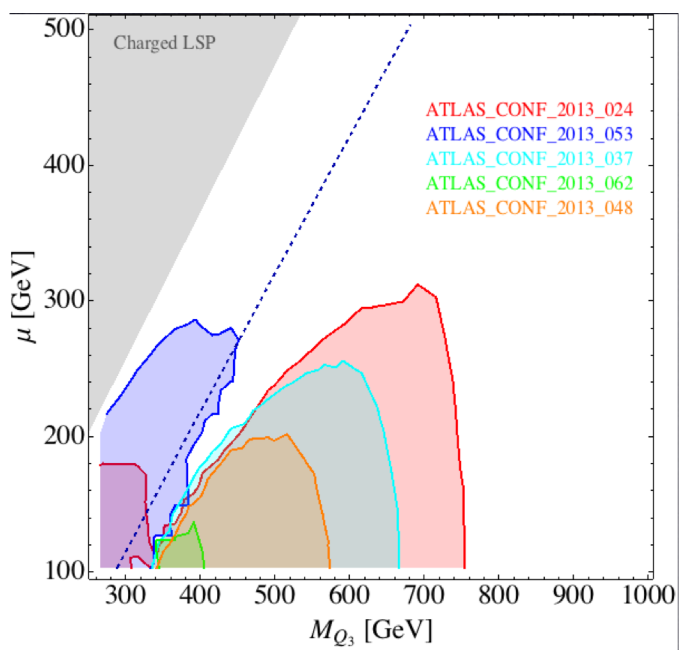
- ✤ Extremely fast
- ✤ Moderately accurate and general
  - ★Kinematical configurations often not close to the SMS ones
  - ★Multistep or asymmetric decays

The SMS approach for LHC result reinterpretations (2)

✦ Existing tools

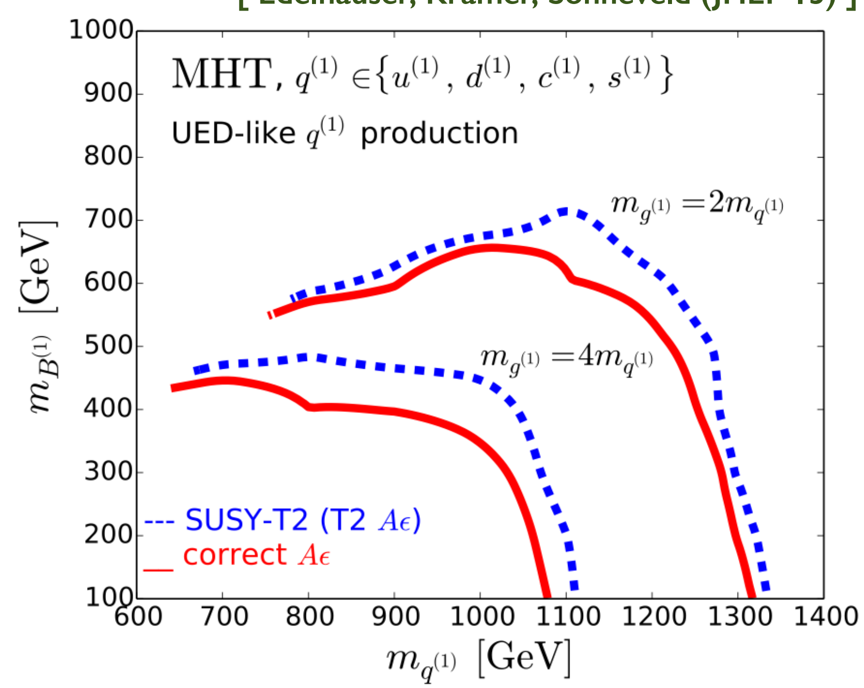
- ✤ FASTLIM: 11 ATLAS analyses [Papucci, Sakurai, Weiler & Zeune (EPJC'14)]
- ✤ SMODELS: 13 ATLAS and 13 CMS analyses [Kraml, Kulkarni, Laa, Lessa, Magerl, Proschofsky-Spindler & Waltenberger (EPJC'14)]
- ✤ XQCAT: 7 CMS analyses [Barducci, Belyaev, Buchkremer, Marrouche, Moretti, Panizzi (CPC'15)]

✦ Examples



MSSM reinterpretations with FASTLIM

[Edelhäuser, Krämer, Sonneveld (JHEP'15)]



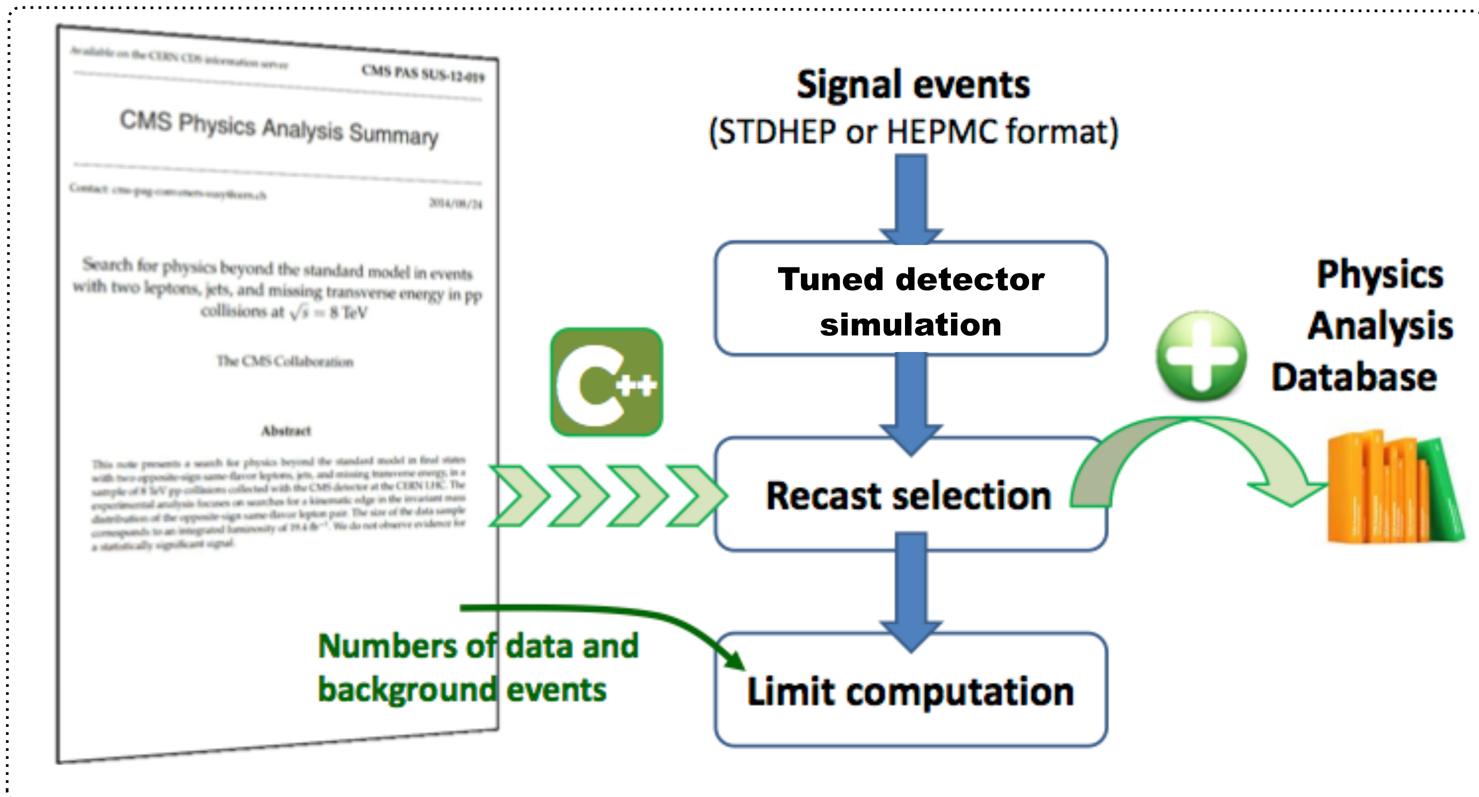
Limitations (using SMODELS): SUSY *versus* UED

Beyond the SMS approach

✦ There are plethora of new physics realizations that deserve to be studied

- ✤ The simplified model approach is often not sufficient (e.g., different topologies)
- ✤ Need to rely on a (public) detector simulation closely mimicking ATLAS and CMS simulations
- ✤ Need for a (public) framework where LHC analyses can be easily implemented

✦ Recasting strategy



✤ 2 options for detector simulation

- ★ DELPHES/PGS-like (resolutions, efficiencies, *etc.*)
- ★ RIVET-like (transfer functions)

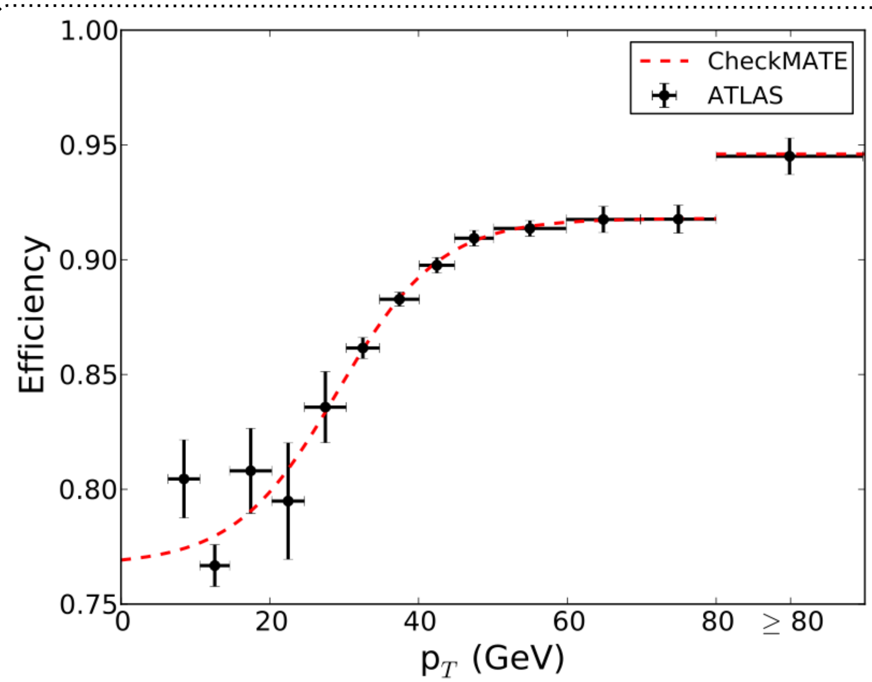
Topic of this talk (uses our tools)

Detector modeling with DELPHES

See talk from M. Selvaggi

✦ Detector simulation with DELPHES 3 [de Favereau, Delaere, Demin, Giammanco, Lemaître, Mertens & Selvaggi (JHEP'14)]

- Starts from hadron-level Monte Carlo information
- Derive calorimetric and track information; object reconstruction is then necessary
  - ★ Close to what actually happens
- DELPHES is modular ➢ extra modules and tuning can be added / included
  - ★ Extra information on lepton isolation or track information; skimming of the output files. *etc.*



Medium electron efficiency in CHECKMATE

```
module Efficiency ElectronEfficiency {
  set InputArray ElectronEnergySmearing/electrons
  set OutputArray electrons

  # efficiency formula for electrons
  # medium efficiency from a fit to ATLAS medium electron efficiencies
  set EfficiencyFormula {
      (pt < 90.) * ((1.65892e-11)*pt^6 + \
                    (-5.71108e-09)*pt^5 + \
                    (8.08921e-07)*pt^4 + \
                    (-5.88213e-05)*pt^3 + \
                    (0.00219812)*pt^2 + \
                    (-0.0345875)*pt + 0.968282) + \
      (pt >= 90.) * 0.945514}
}
```

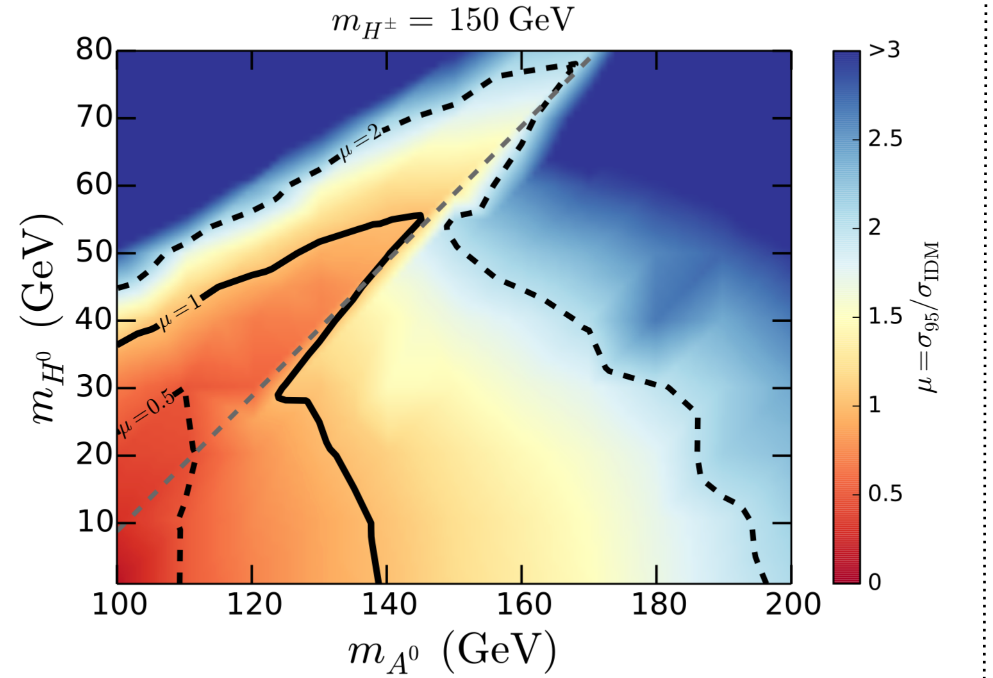
Corresponding implementation in MADANALYSIS 5

Current existing programs

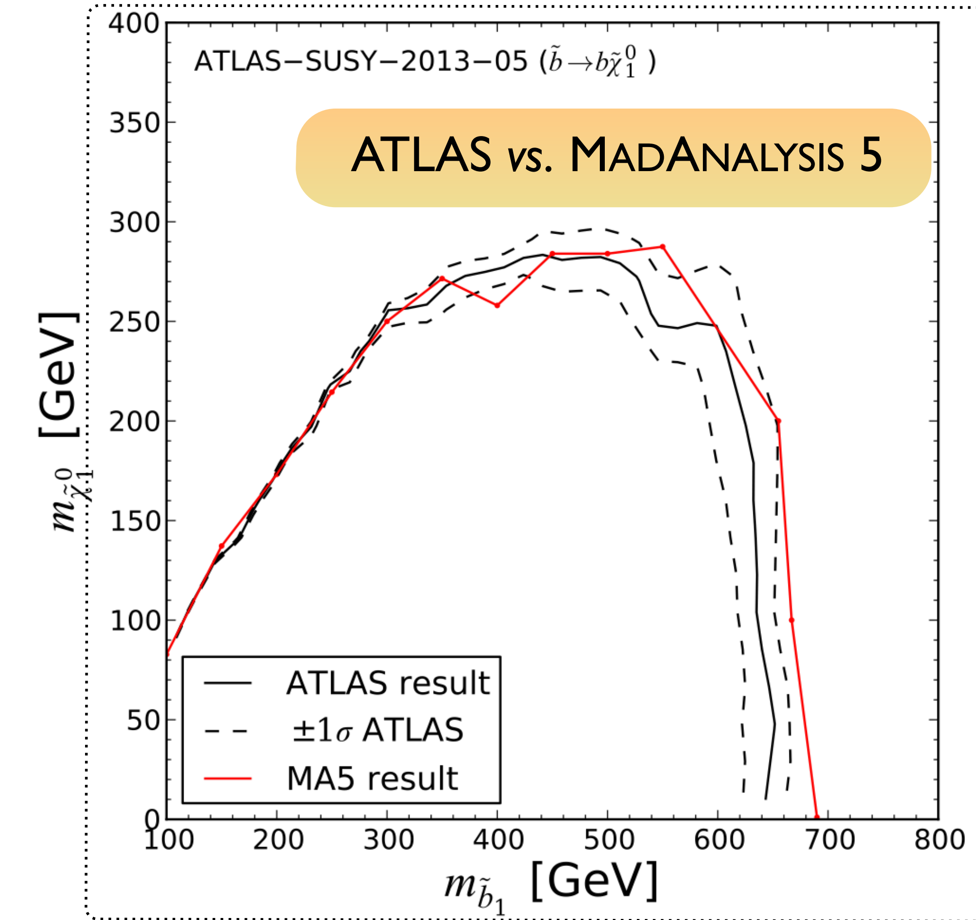
- ✦ Two public programs using DELPHES (soon cross-compatible)
  - ✤ CHECKMATE: 19 validated analyses [Drees, Dreiner, Schmeier, Tattersall & Kim (CPC'14)]
  - ✤ MADANALYSIS 5: 15 validated analyses [Conte, BF & Serret (CPC'12); Conte, Dumont, BF & Wymant (EPJC'14)] [Dumont, BF, Kraml *et al.* (EPJC'15)]
- ✦ One private program (that could be obtained on request) based on RIVET
  - ✤ ATOM: 15 validated analyses [Kim, Papucci, Sakurai & Weiler]

✦ Examples

[Belanger, Dumont, Goudelis, Herrmann, Kraml, Sengupta (PRD'15)]

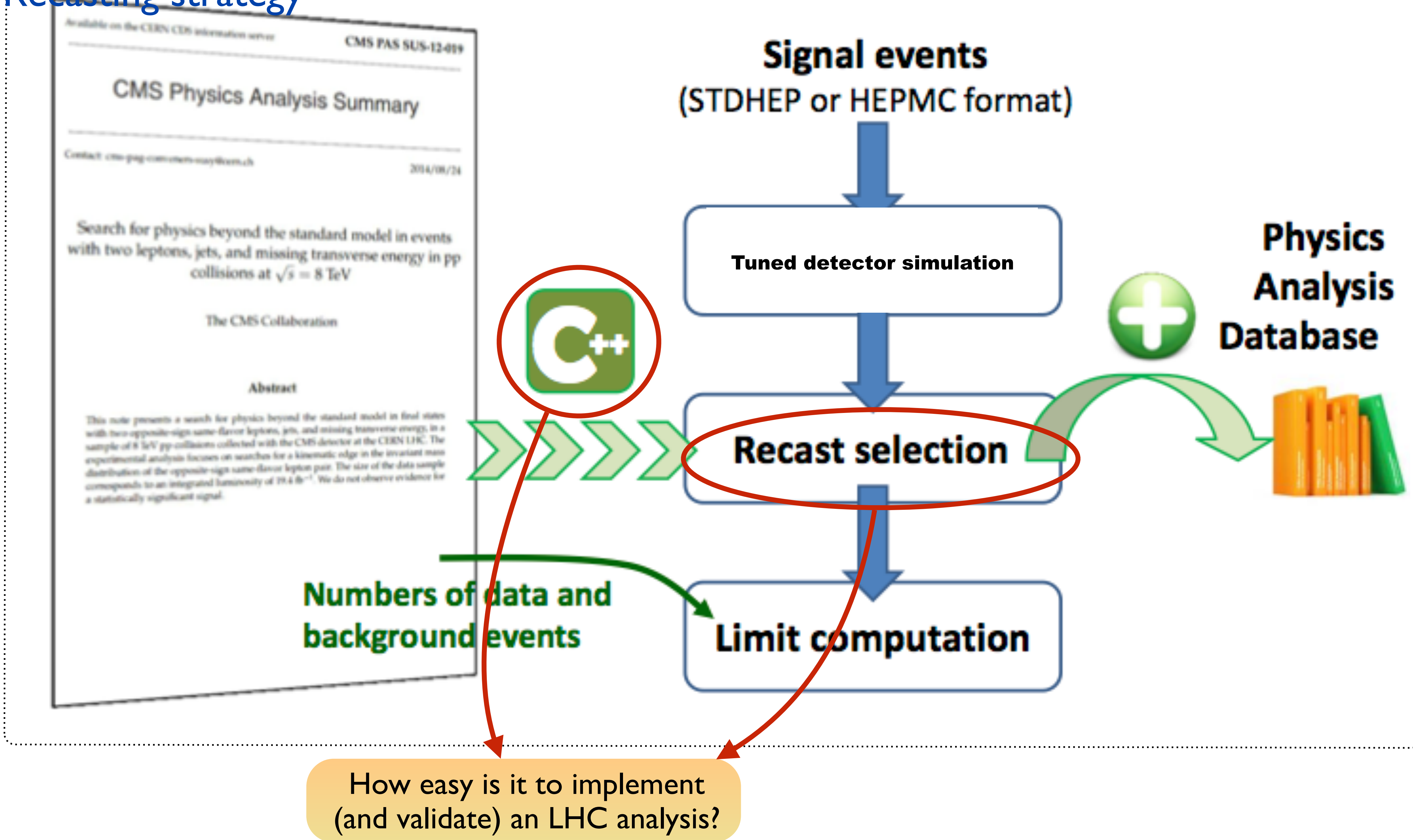


Constraining the inert Higgs doublet model with SUSY searches and MADANALYSIS 5



Reimplementing new physics analyses: challenges

✦ Recasting strategy



Implementing a new analysis in a recasting tool

- Picking up an experimental publication
  - Reading
  - Understanding

✅ Relatively easy

- Writing the analysis code in the tool internal language

✅ Relatively easy

- Getting the information missing from the publication for a proper validation
  - Efficiencies (trigger, electrons, muons, b-tagging, JES, *etc.*)
    - ★ Including p_T and/or η dependence
    - ★ Accurate information
  - Detailed cutflows for some well-defined benchmark scenarios
    - ★ Exact definition of the benchmarks (SLHA spectra)
    - ★ Event generation information (cards, tunes, LHE files if possible)
  - Expected number of events in each region and cross sections
  - Digitized histograms (e.g., on HEPDATA)

⚠️ Essential
❌ Often difficult!

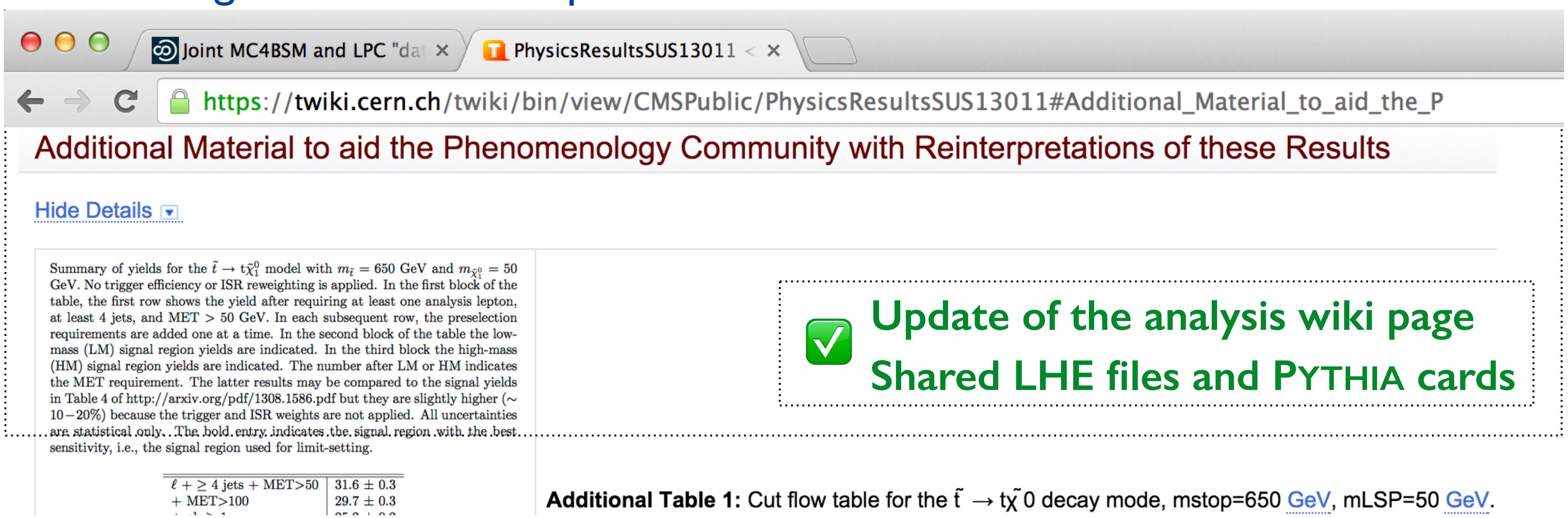
- Comparing tools and real life

Example 1: CMS-SUS-13-11 (stops with one lepton)

- Missing information for the validation
  - Efficiencies
  - Cutflows and Monte Carlo information for given benchmarks

✅ Discussions with CMS needed

- All missing information was provided



✅ Update of the analysis wiki page
Shared LHE files and PYTHIA cards

Example 2: ATLAS-EXO-2014-04 (monophotons)

- ✦ Missing information
  - ✤ Crack in the detector: no photons in the [1.37-1.52] η-range
  - ✤ Tight photon requirements

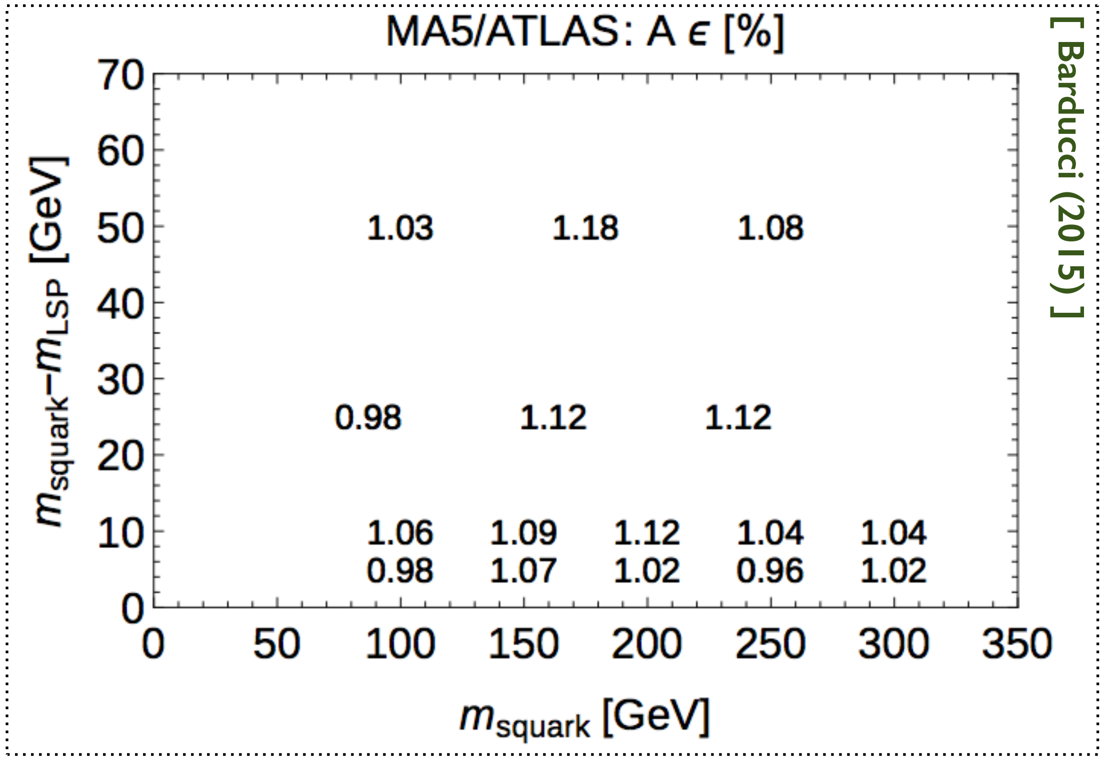
✅ Discussions with ATLAS needed

✅ In ATLAS-COM-PHYS-2014-542

- ✦ Event generation for the test benchmarks
  - ✤ Monte Carlo information (cards, tunes, *etc.*)

✅ Kindly provided by ATLAS

Very good results
(ratio of efficiencies)



Example 3: When things are borderline…

- ATLAS-EXOT-2014-04 (monophotons)
  - Effects non-reproducible with DELPHES (cleaning cuts, triggers, good vertexing)
- ATLAS-SUS-2013-09 (stops in the dilepton channel)
  - Information on effects non-reproducible with DELPHES lost (student has quit physics)

Efficiencies computed by hand
Maybe model-dependent

Very good results
(for a SUSY benchmark)

Cut	ATLAS	Rel. decr.	MA5 (ul ul~)	Rel. decr.
Nominal	9989		9989	
a. Trigger	8582		?	
b. Good Vertex	8574			
c. Cleaning cuts	8213			
0. $E_T^{\rm miss} > 150$ GeV	4131		4384	
1. 1 loose γ, $p_T > 125$ GeV, $\lvert\eta\rvert < 2.37$	2645	−36.0	2637	−39.8
2. Tight leading γ with $\lvert\eta\rvert < 1.37$	2068	−21.8	2052	−22.2
3. Isolated leading γ	1898	−8.2	1856	−9.6
4. $\Delta\phi(\gamma^{\rm leading}, E_T^{\rm miss}) > 0.4$	1887	−0.6	1840	−0.8
5. $N_{\rm jet} \leq 1$ and $\Delta\phi(jet, E_T^{\rm miss}) > 0.4$	1219	−35.4	1234	−33.0
6. Lepton veto	1188	−2.5	1233	−0.1

Example 4: sometimes…

✦ Missing or incomplete validation information

✤ CMS-SUS-12-028 (α_T)
- ★ No cutflows; no answers from CMS to requests

❌ Dead end!

✤ CMS-SUS-13-007 (1 lepton+b-jets+met)
- ★ Semi-official validation material provided (that cannot be used in the public validation)
- ★ No cutflows
- ★ Messy definition of the benchmark points

⚠ We'll do our best…

✦ Missing or incomplete analysis information

⚠ Too vague!

✤ ATLAS-EXOT-2013-10 (monolepton)
- ★ The average trigger efficiency is 80%–90% in the muon channel"
- ★ 80% of the muons are reconstructed with most of the loss coming from…
- ★ No precise information on signal event generation
- ★ No signal distributions on HEPDATA

Unfortunately: many more examples!

A wishlist from theorists to experimentalists - part I

- Analysis description
  - Clear description of the selections, including their sequence
    - A tabulated form would be appreciable (possibly on the analysis wiki pages)
  - Efficiencies for physics (electrons, muons, jets, taus, b-tagging, mistagging rates, *etc*.)
    - Including p_T and η dependence
    - Or a reference with the information
  - Efficiencies for triggers, event cleaning, *etc.*
    - Effects that cannot be modeled in our fast simulation
  - Digitized figures
    - Missing in particular the performance results (reading off log-scale histograms…)
    - ROOT format, text format, *etc*.
  - Special variables (*e.g.*, the CMS razor)
    - Providing snippets of code would be highly appreciated
    - Some variables have different definitions in different analyses (e.g., asymmetric M_{T2})

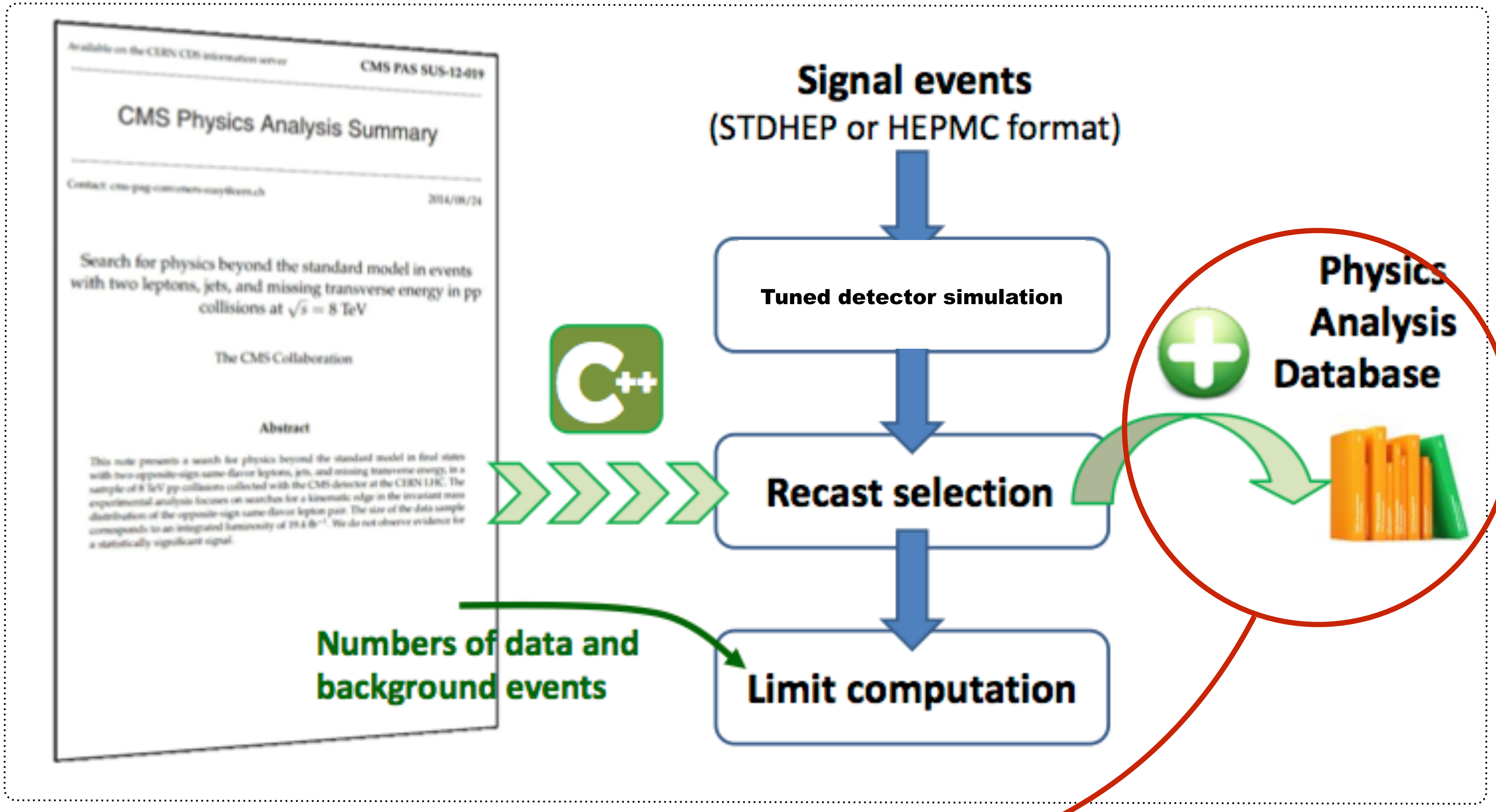
A wishlist from theorists to experimentalists - part 2

✦ Validation material ➢ quality of the reinterpretation

- ✤ Benchmark scenarios
  - ★ Spectra and decay tables (under an SLHA-form)
  - ★ Several scenarios are appreciable
  - ★ Publicly available on the wiki pages or HEPDATA
- ✤ Monte Carlo tools configuration
  - ★ Cards, tunes, merging information, *etc*.
  - ★ Better, the CMS way: LHE files with shower inputs (no new source of discrepancies)
  - ★ Publicly available on the wiki pages or HEPDATA
- ✤ Detailed cutflows for the benchmarks, with the correct selection ordering
  - ★ Including each step of the (pre)selection
  - ★ For several benchmarks
  - ★ The more steps are available, the better (even the preselection, the cleaning, *etc*.) (pin-down the differences in our machinery, in the fastsim *vs.* CMS-ATLAS simulation)
- ✤ Kinematical distributions at different steps of the selection
  - ★ Extra cross-check of our machinery

The LHC legacy (I)

✦ Recasting strategy



How to store recasted analyses?
Part of the LHC legacy

The Physics Analysis Database (PAD) of MADANALYSIS

[Dumont, BF, Kraml *et al.* (EPJC '15)]

✦ A database with MADANALYSIS 5 implementations of LHC analyses has been initiated

- http://madanalysis.irmp.ucl.ac.be/wiki/PhysicsAnalysisDatabase
- Easy to install (*install PAD*)

Analysis	Short Description	Implemented by	Code	Validation note
ATLAS-SUSY-2013-05 (published)	stop/sbottom search: 0 leptons + 2 b-jets	G. Chalons	Inspire	PDF (figures)
ATLAS-SUSY-2013-11 (published)	EWK-inos, 2 leptons + MET	B. Dumont	Inspire	PDF (source)
ATLAS-HIGG-2013-03 (published)	ZH->ll+invisible	B. Dumont	Inspire	PDF (source)
ATLAS-EXOT-2014-06 (published)	mono-photons + MET	D. Barducci	Inspire	PDF MadGraph cards
ATLAS-SUSY-2014-10 (published)	2 leptons + jets + MET	B. Dumont	Inspire	PDF (source)
ATLAS-SUSY-2013-21 (published)	0 leptons + mono-jet/c-jets + MET	G. Chalons, D. Sengupta	Inspire	PDF (source)
ATLAS-SUSY-2013-02 (published)	0 leptons + 2-6 jets + MET	G. Chalons, D. Sengupta	Inspire	PDF

Delphes card for ATLAS-SUSY-2013-05, ATLAS-SUSY-2013-21 and ATLAS-EXOT-2014-06
Delphes card for ATLAS-SUSY-2013-11, ATLAS-SUSY-2013-02 and ATLAS-HIGG-2013-03
Delphes card for ATLAS-SUSY-2014-10

DELPHES cards

Code from INSPIRE

Validation notes (cutflows, distributions)

Analysis	Short Description	Implemented by	Code	Validation note
CMS-SUS-13-011 (published)	stop search in the single lepton mode	B. Dumont, B. Fuks, C. Wymant	Inspire [1]	PDF (source)
CMS-SUS-13-012 (published)	gluino/squark search in jet multiplicity and missing energy	S. Bein, D. Sengupta	Inspire	PDF (source)
CMS-SUS-13-016 (PAS)	search for gluinos using OS dileptons and b-jets	D. Sengupta, S. Kulkarni	Inspire	PDF (source)
CMS-SUS-14-001 (published)	Searches for third-generation squarks in fully hadronic final states (monojet analysis)	S. Sharma, S. Pandey	Inspire	PDF
CMS-B2G-12-012 (published)	T5/3 top partners in same-sign dilepton channel	D. Barducci, C. Delaunay	Inspire	PDF (source), cards

Delphes card for the MA5tune analyses

DELPHES cards

The LHC legacy: data preservation

[Dumont, BF, Kraml *et al.* (EPJC '15)]

- Implementation of LHC analyses can be uploaded on INSPIRE
  - DOI are assigned: can be cited, searched for, *etc.*
  - Used by MADANALYSIS 5 only at the moment

Files are versioned, can be downloaded

Information | Citations (3) | Files

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

DOI and citations

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

Cite as: (2014) authors, http://doi.org/10.7484/INSPIREHEP.DATA.LR5T.2RR3

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

This dataset complements the following publication:
Toward a public analysis database for LHC new physics searches using MADANALYSIS 5

Record added 2014-06-19, last modified 2014-07-17

A stop simplified model: the recasting episode

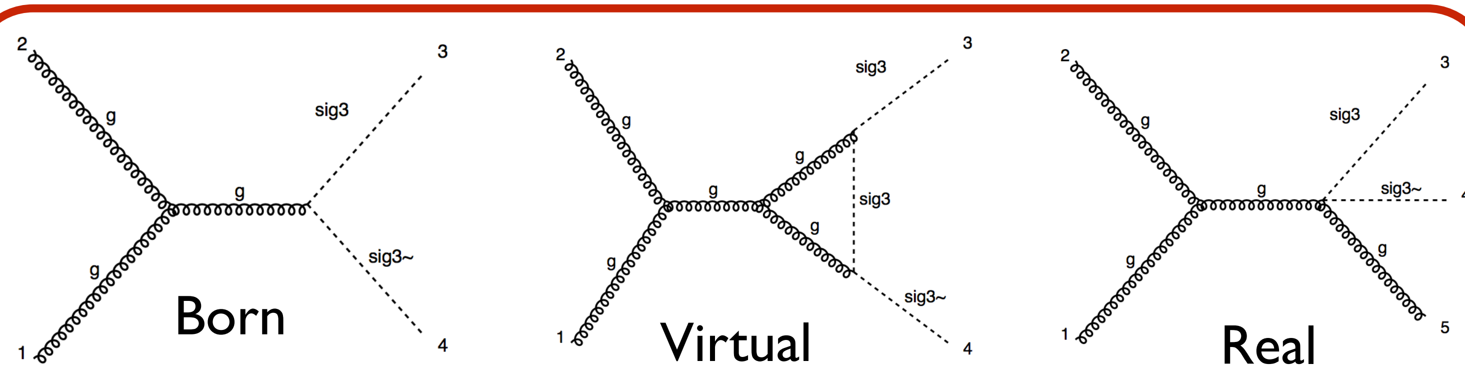
✦ The stop (σ_3) / bino (χ) model

$$\mathcal{L}_3 = D_\mu \sigma_3^\dagger D^\mu \sigma_3 - m_3^2 \sigma_3^\dagger \sigma_3 + \frac{i}{2}\bar{\chi}\partial\!\!\!/\chi - \frac{1}{2} m_\chi \bar{\chi}\chi + \Big[\sigma_3 \bar{t}(\tilde{g}_L P_L + \tilde{g}_R P_R)\chi + \text{h.c.}\Big]$$

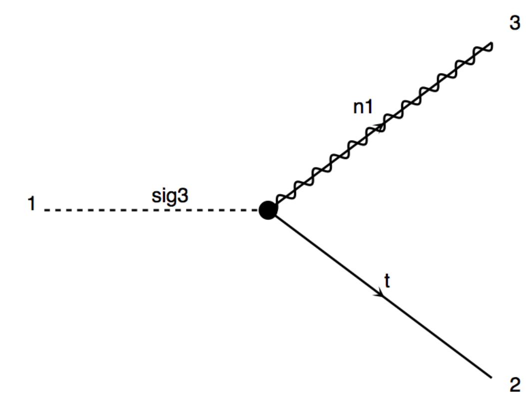
Production — Decay

- ✤ One scalar field in the fundamental representation (σ_3)
- ✤ One gauge-singlet Majorana fermion (χ) coupling the stop to the top

✦ Representative Feynman diagrams (yielding a top-antitop plus missing energy signature)



Production (possibly at NLO)



Recasting of the CMS analysis

The CMS-SUS-13-011 analysis: recasting and simulations

- The CMS study relies on leading order simulation and MLM merging
  - Simulated signal: $p\,p \to \tilde{t}\,\tilde{t}^* + 0,1,2$ jets at the leading order
  - Parton showering: PYTHIA 6 with the Z2 tune [Field (APPB '11)]
- Analysis
  - Selection of top-antitop plus missing energy final states yielding a single lepton signature
  - One single lepton and 4 jets (mainly issued from the stop-antistop system decay)
  - Large missing energy
  - At least one *b*-jet
  - Top reconstruction quality
  - Transverse variable constraints

- Observation
  - The selection does not really depend on the extra jets
    - The main hadronic activity comes from the decay products
  - The limit should be agnostic of the merging

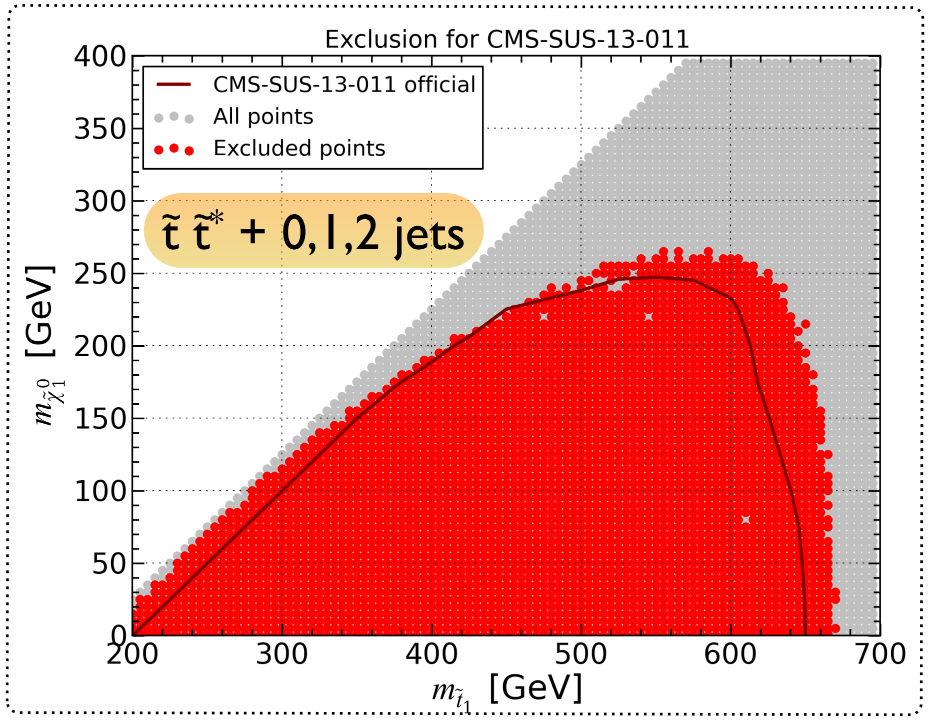
The CMS-SUS-13-011 analysis: multijet merging

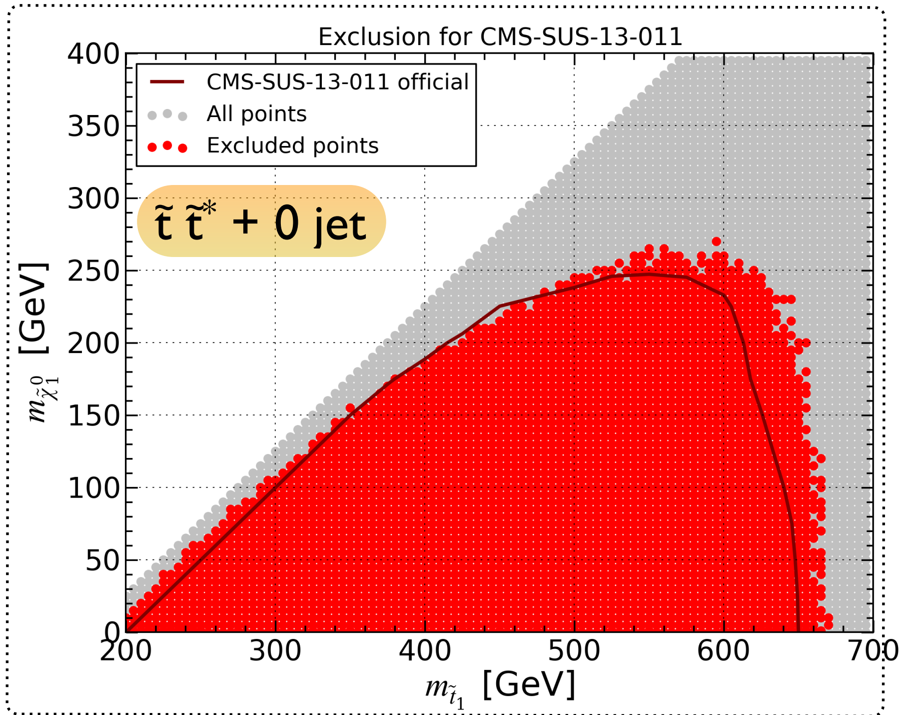
- ✦ Relies on leading order simulation and MLM merging
  - ✤ Simulated signal: $p\, p \to \tilde{t}\, \tilde{t}^* + 0,1,2$ jets at the leading order; PYTHIA 6 with the Z2 tune
- ✦ Observation
  - ✤ The selection does not really depend on the extra jets
  - ✤ The limit should be agnostic of the merging

- ✦ Verification with MADANALYSIS 5

[Ambrogi, Conte, BF, Kulkarni & Molter (in preparation)]

  - ✤ Good agreement of the exclusion at the 20 GeV level
  - ✤ The limit does not depend on the merging





The CMS-SUS-13-011 analysis: modern tools effects

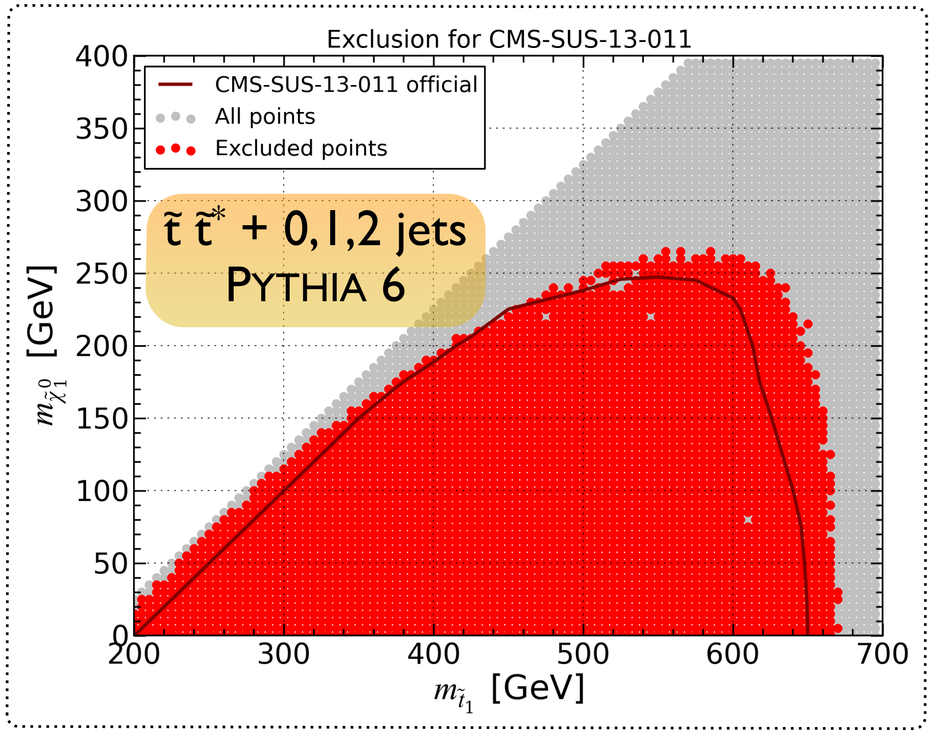
✦ Moving towards more modern tools

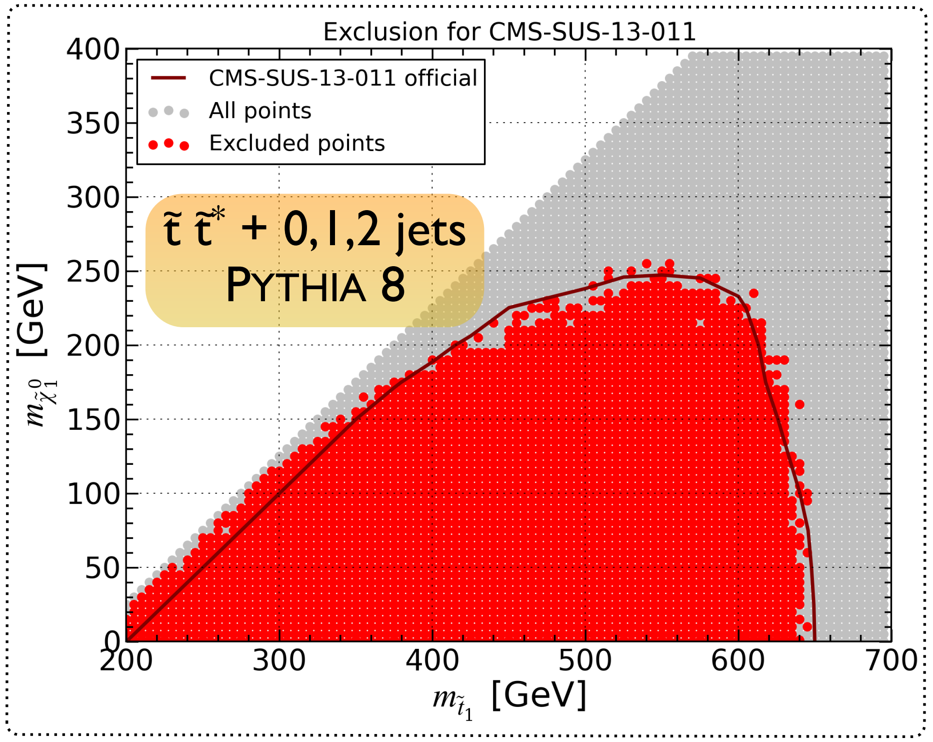
- ✤ Simulated signal: p p → $\tilde{t}\,\tilde{t}^*$ + 0 jet at the next-to-leading order in QCD
- ✤ Parton-showering, hadronization, underlying event: PYTHIA 8 with the MONASH tune

[Skands, Carrazza & Rojo (EPJC '14)]

✦ How are the limits changing (using MADANALYSIS 5)? [Ambrogi, Conte, BF, Kulkarni & Molter (in preparation)]

- ✤ Limits stable at the 20-40 GeV level (better agreement with the official limit…)
- ✤ Origins of the differences: a PYTHIA effect! Effect on the CMS numbers?





The CMS-SUS-13-011 analysis: merging and NLO

✦ Adding FxFx NLO merging

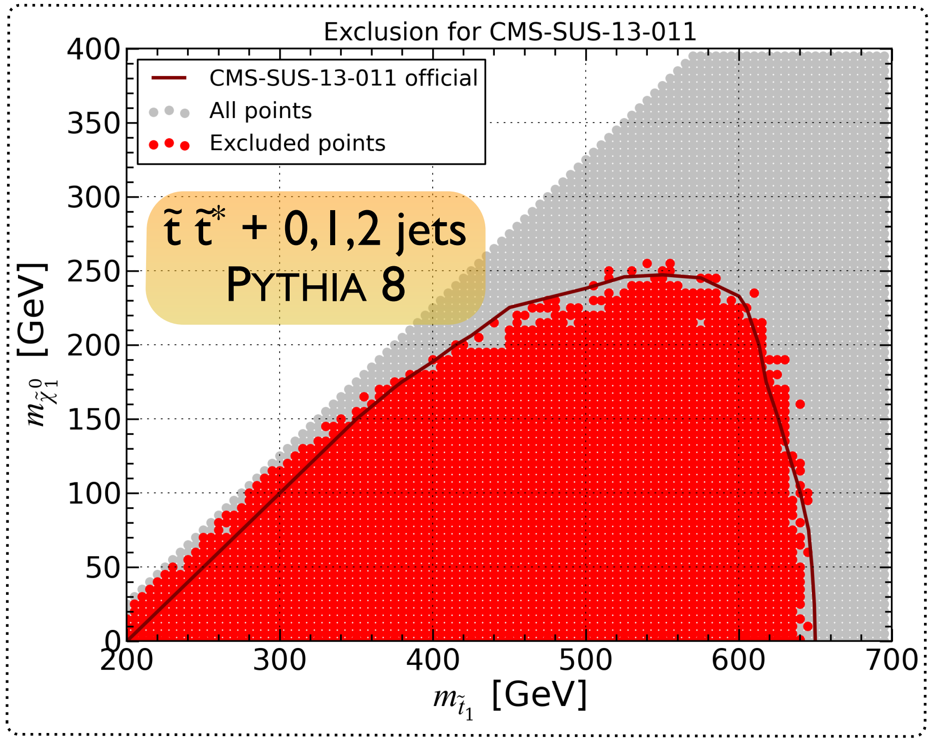
- Simulated signal: p p → $\tilde{t}\,\tilde{t}^*$ + 0,1 jets at the next-to-leading order in QCD
- Parton-showering, hadronization, underlying event: PYTHIA 8 with the MONASH tune

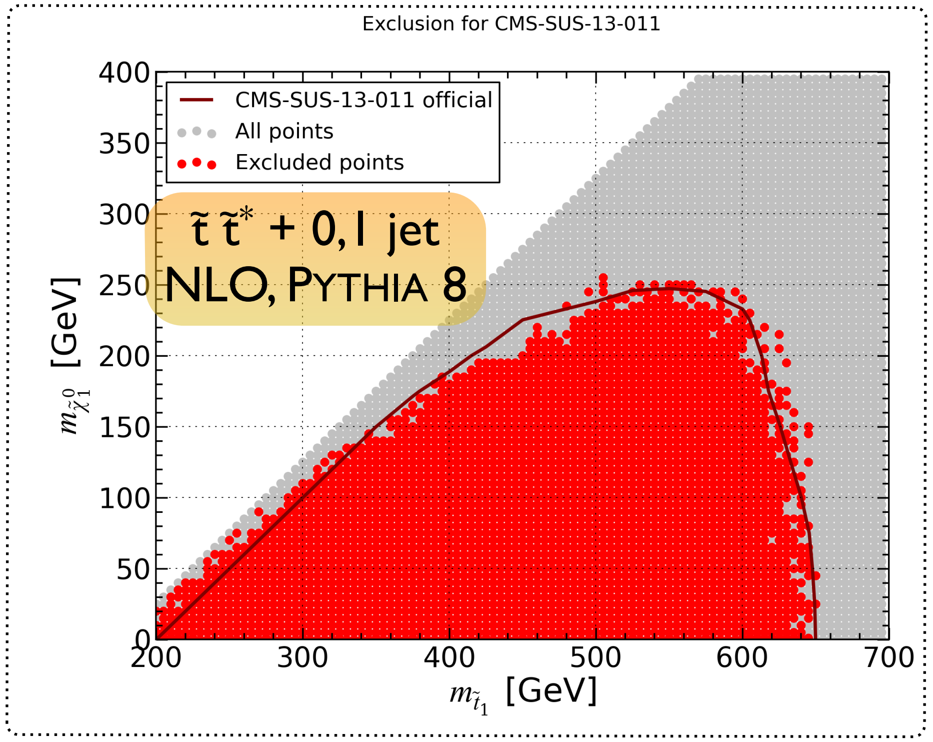
[Skands, Carrazza & Rojo (EPJC '14)]

✦ How are the limits changing (using MADANALYSIS 5)

[Ambrogi, Conte, BF, Kulkarni & Molter (in preparation)]

- Stable constraints (due to the many jets already there at the LO)





Outline

1. When new physics meets Monte Carlo simulations

2. New physics simulations with Monte Carlo event generators

3. Interpretation of LHC results and recasting the experimental searches

4. **Conclusions - summary**

Summary

✦ Lots of effort have been invested in new physics simulations during the last decade

- Streamlining the link between models and events
- Multipartonic matrix element merging
- Cascade decays
- Next-to-leading order corrections
- Techniques are (and will be) used for signal simulations both by theorists and experimentalists

✦ The LHC legacy

- It is crucial to be able to reinterpret the LHC results in any theoretical context
- This is a very active field of the last few years: several tools are now ready to be used
- **Reproducibility** is the ability of an entire experiment to be reproduced, possibly by an independent (pheno) study