Validating your recast analysis

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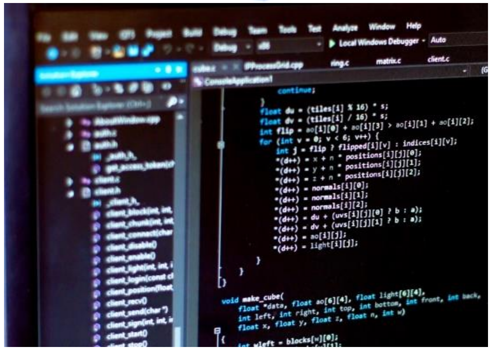
The second MadAnalysis 5 workshop on LHC recasting @ Korea
13-20 February 2020

Introduction

- **Why the validation procedure?**
  - Possible bugs in the implementation of recast analysis?
  - Bad understanding of the selection from the reading of the paper?
  - Does the level of realism of the detection simulation suit?

- **How to validate?**



Results produced with the recast analysis

comparison

Public results from the ATLAS or CMS analysis

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

Submitted to: Eur. Phys. J. C

CERN-EP-2019-106
13th November 2019

arXiv:1908.08215v1 [hep-ex] 22 Aug 2019

Search for electroweak production of charginos and sleptons decaying into final states with two leptons and missing transverse momentum in $\sqrt{s} = 13$ TeV pp collisions using the ATLAS detector

The ATLAS Collaboration

Are the discrepancies negligible in the context of the phenomenogical reinterpretation?

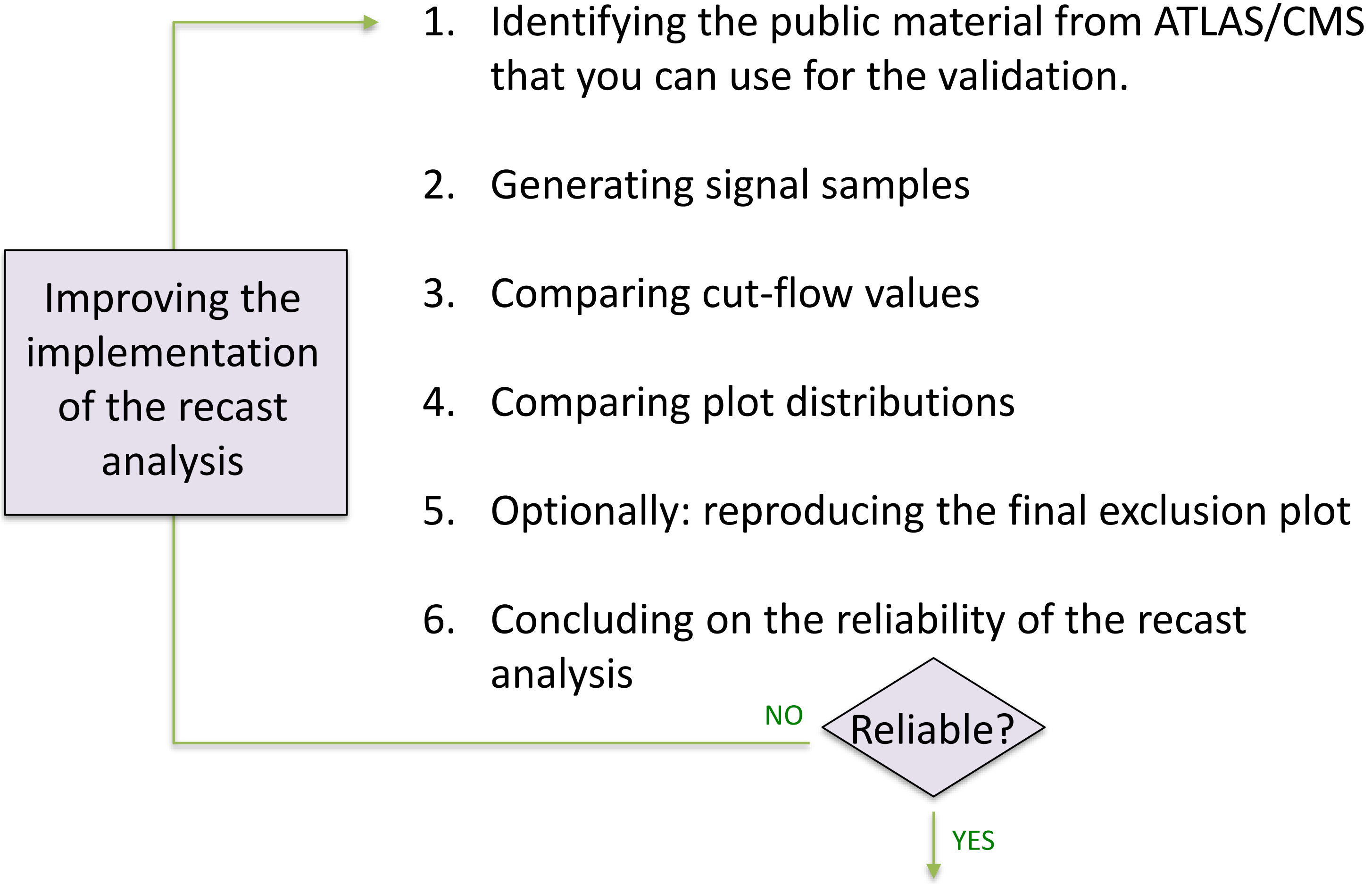
Introduction

The validation procedure in 6 steps:

1. Identifying the public material from ATLAS/CMS that you can use for the validation.
2. Generating signal samples
3. Comparing cut-flow values
4. Comparing plot distributions
5. Optionally: reproducing the final exclusion plot
6. Concluding on the reliability of the recast analysis

Introduction

The validation procedure in 6 steps:



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6. Concluding on the reliability of the recast analysis

Reliable?

NO

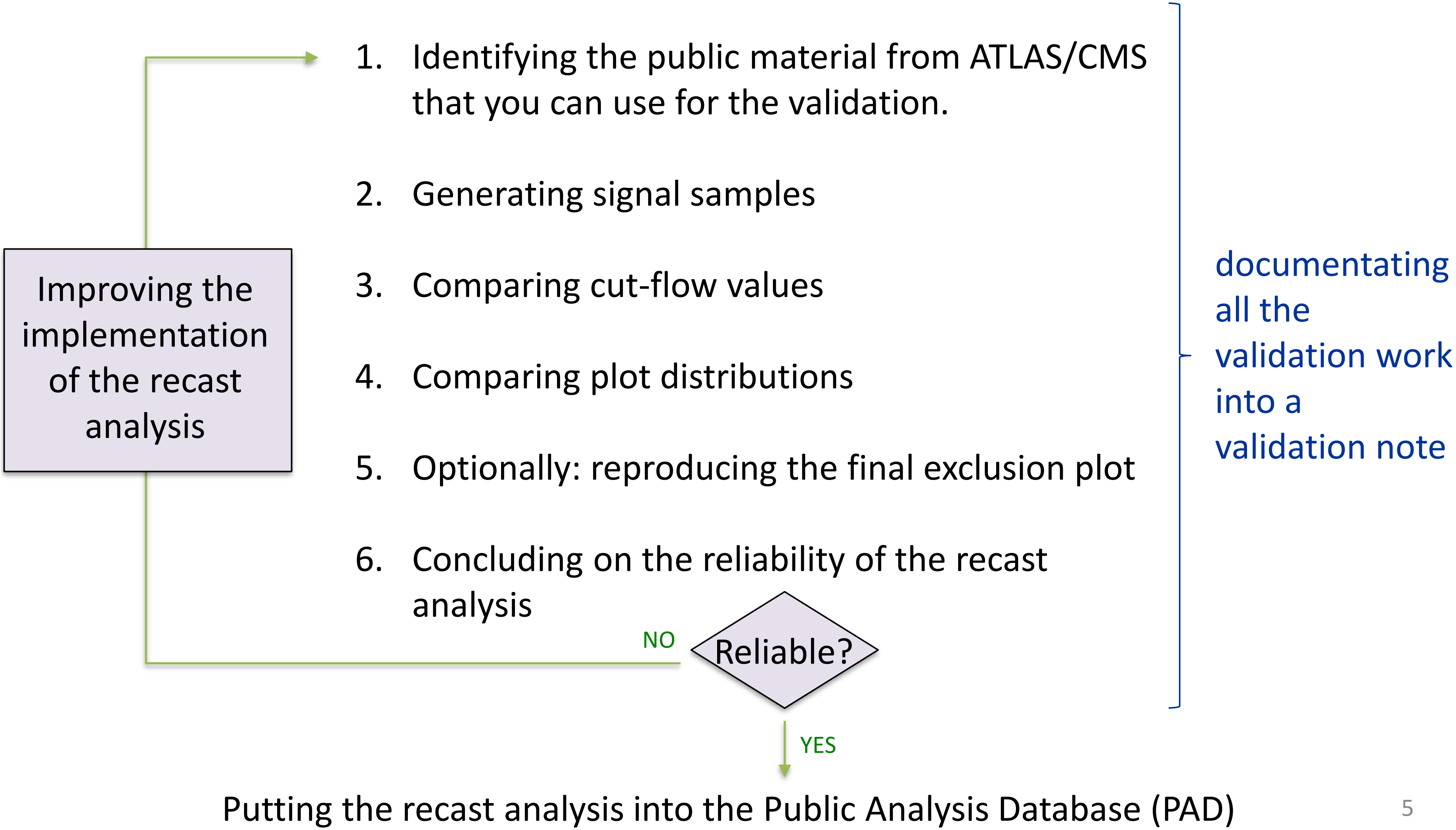
Improving the implementation of the recast analysis

YES

Putting the recast analysis into the Public Analysis Database (PAD)

Introduction

The validation procedure in 6 steps:



1. Identifying the public material from ATLAS/CMS that you can use for the validation.
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Improving the implementation of the recast analysis

Reliable?

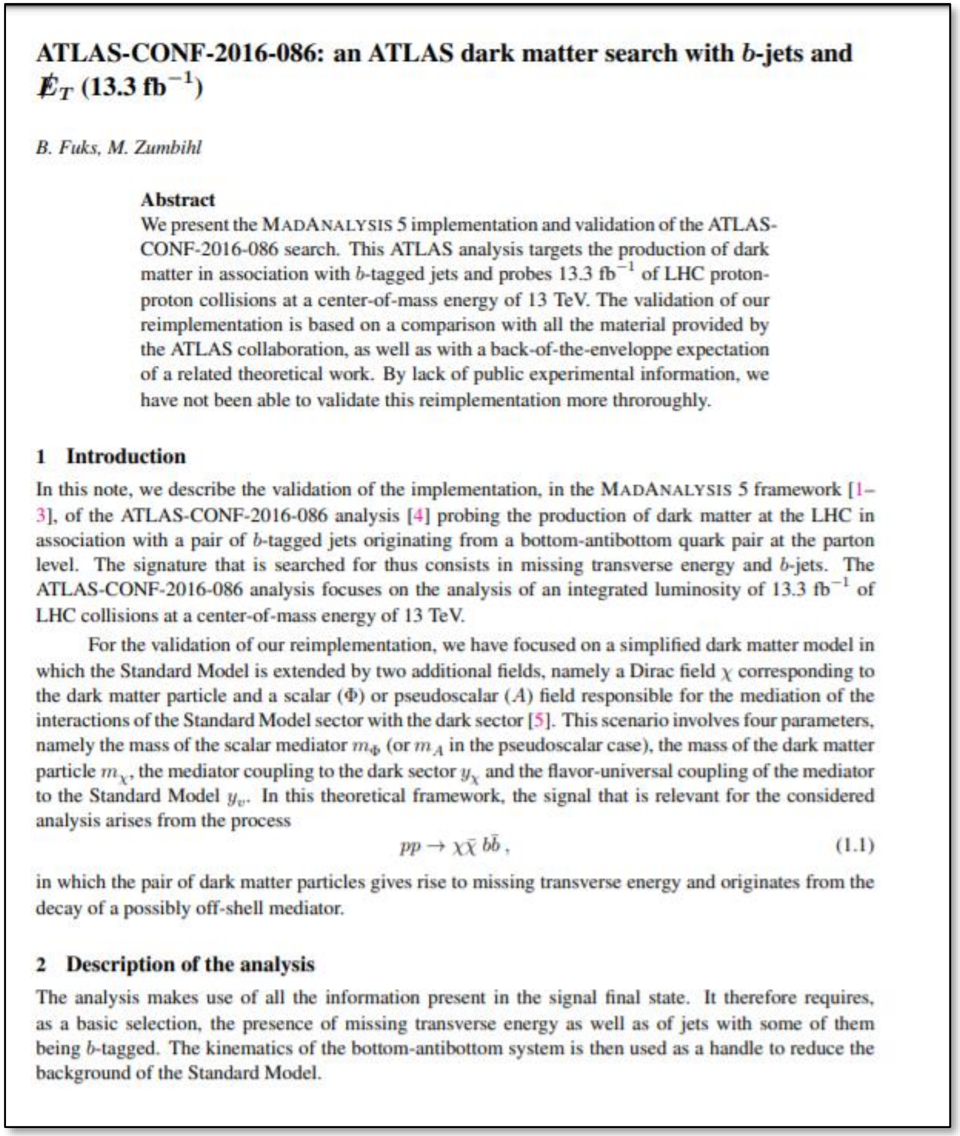
NO

YES

documentating all the validation work into a validation note

Putting the recast analysis into the Public Analysis Database (PAD)

Writing the validation note



ATLAS-CONF-2016-086: an ATLAS dark matter search with b-jets and $\not\!\!E_T$ (13.3 fb^{-1})

B. Fuks, M. Zumbihl

Abstract

We present the MADANALYSIS 5 implementation and validation of the ATLAS-CONF-2016-086 search. This ATLAS analysis targets the production of dark matter in association with b-tagged jets and probes 13.3 fb^{-1} of LHC proton-proton collisions at a center-of-mass energy of 13 TeV. The validation of our reimplementation is based on a comparison with all the material provided by the ATLAS collaboration, as well as with a back-of-the-enveloppe expectation of a related theoretical work. By lack of public experimental information, we have not been able to validate this reimplementation more throroughly.

1 Introduction

In this note, we describe the validation of the implementation, in the MADANALYSIS 5 framework [1–3], of the ATLAS-CONF-2016-086 analysis [4] probing the production of dark matter at the LHC in association with a pair of b-tagged jets originating from a bottom-antibottom quark pair at the parton level. The signature that is searched for thus consists in missing transverse energy and b-jets. The ATLAS-CONF-2016-086 analysis focuses on the analysis of an integrated luminosity of 13.3 fb^{-1} of LHC collisions at a center-of-mass energy of 13 TeV.

For the validation of our reimplementation, we have focused on a simplified dark matter model in which the Standard Model is extended by two additional fields, namely a Dirac field χ corresponding to the dark matter particle and a scalar (Φ) or pseudoscalar (A) field responsible for the mediation of the interactions of the Standard Model sector with the dark sector [5]. This scenario involves four parameters, namely the mass of the scalar mediator m_Φ (or m_A in the pseudoscalar case), the mass of the dark matter particle m_χ, the mediator coupling to the dark sector y_χ and the flavor-universal coupling of the mediator to the Standard Model y_v. In this theoretical framework, the signal that is relevant for the considered analysis arises from the process

$$pp \to \chi\bar{\chi}\, b\bar{b}\,, \tag{1.1}$$

in which the pair of dark matter particles gives rise to missing transverse energy and originates from the decay of a possibly off-shell mediator.

2 Description of the analysis

The analysis makes use of all the information present in the signal final state. It therefore requires, as a basic selection, the presence of missing transverse energy as well as of jets with some of them being b-tagged. The kinematics of the bottom-antibottom system is then used as a handle to reduce the background of the Standard Model.

- Starting writing the document at the beginning of the validation procedure and filling it gradually.
- Format: LATEX.
- A template is imposed.

Example: validation note of the ATLAS-CONF-2016-086
https://madanalysis.irmp.ucl.ac.be/raw-attachment/wiki/PublicAnalysisDatabase/validation_atlas_conf_2016_086.pdf

Writing the validation note

- **Content of the validation note and application to the recast of the analysis ATLAS-SUSY-2018-32**

Validation of the MadAnalysis 5 implementation of ATLAS-SUSY-2018-32

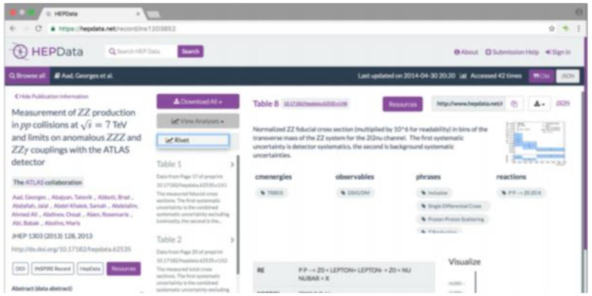
1. *Introduction*
2. *Description of the selection*
3. *Signal generation*
4. *Comparison with the official results (cut-flow charts and plots)*
5. *Exclusion limit plot with MadAnalysis 5 (optional)*
6. *Summary and conclusion on the reliability of the recast analysis*
7. *All the mandatory and useful references*

1. Public material for validation

Where can I find the public ATLAS/CMS material for the validation my implementation?

- In the paper of the analysis
  - *Signal sample description*
  - *Cut-flow charts with signal samples*
  - *Plots with signal samples*
  - *Final exclusion limit plot*

- In the official ATLAS/CMS page devoted to the analysis:
  - *Complementary plots/tables*
  - *Numerical data: ROOT files or HepData*



Measurement of ZZ production in pp collisions at $\sqrt{s} = 7$ TeV and limits on anomalous ZZZ and $ZZ\gamma$ couplings with the ATLAS detector

The ATLAS collaboration

JHEP 1303 (2013) 128, 2013

http://dx.doi.org/10.17182/hepdata.62535

Normalized ZZ fiducial cross section (multiplied by 10^6 for readability) in bins of the transverse mass of the ZZ system for the 2l2nu channel. The first systematic uncertainty is detector systematics, the second is background systematic uncertainties.

- ATLAS/CMS code from githup

- Information or data provided by the authors of the ATLAS/CMS analysis with the agreement of the ATLAS/CMS working-group conveners.
  → PLEASE DO NOT CONTACT THEM BY YOURSELF. ASK TO THE TUTORS FIRST.

- ~~Validation note or recast implementation from RIVET or Check-Mate communities.~~

1. Public material for validation

Example of ATLAS-SUSY-2018-32

- In the paper of the analysis [arXiv:1908.08215]
  - *Signal sample description* [see section 4]
  - *Cut-flow charts with signal samples* [no]
  - *Plots with signal samples* [MT2 and MET distributions in figures 2. 3 and 6]
  - *Exclusion limit plot* [figures 7 and 8]

- In the official ATLAS/CMS page devoted to the analysis: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/SUSY-2018-32/
  - *Complementary plots/tables*
    - *Cut-flow charts with signal samples* [Tables 5. 6 and 7]
    - *Plots:* signal efficiencies and acceptances
  - *Numerical data: ROOT files or HepData* [no]

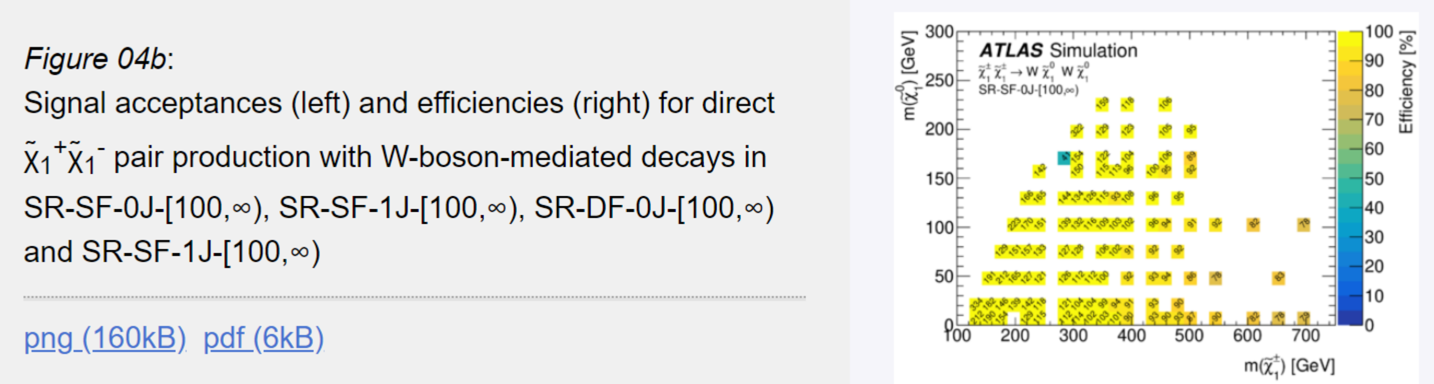


Figure 04b:

Signal acceptances (left) and efficiencies (right) for direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ pair production with W-boson-mediated decays in SR-SF-0J-[100,∞), SR-SF-1J-[100,∞), SR-DF-0J-[100,∞) and SR-SF-1J-[100,∞)

png (160kB) pdf (6kB)

2. Generating signal samples

- For comparing your results with the official ones. you need to use the **same Monte-Carlo samples** (ME generation + shower) and then to apply your detector simulation on them.

- **Where can you find Monte-Carlo signal samples?**

You are lucky!

- *The samples are available on a public plateform.*
- *ATLAS/CMS conveners have accepted to give you the samples.*

You are jinxed!

You need to reproduce them by yourself.

- **2 kinds of samples are used in the analyses:**

signal samples

background samples

2. Generating signal samples

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- **2 kinds of samples are used in the analyses:**

signal samples

~~background samples~~

Validation is done with signal samples only.
→ partial validation!

To not try to reproduce background samples: no time and no CPU for that.

2. Generating signal samples

For generating samples. be particulary careful to:

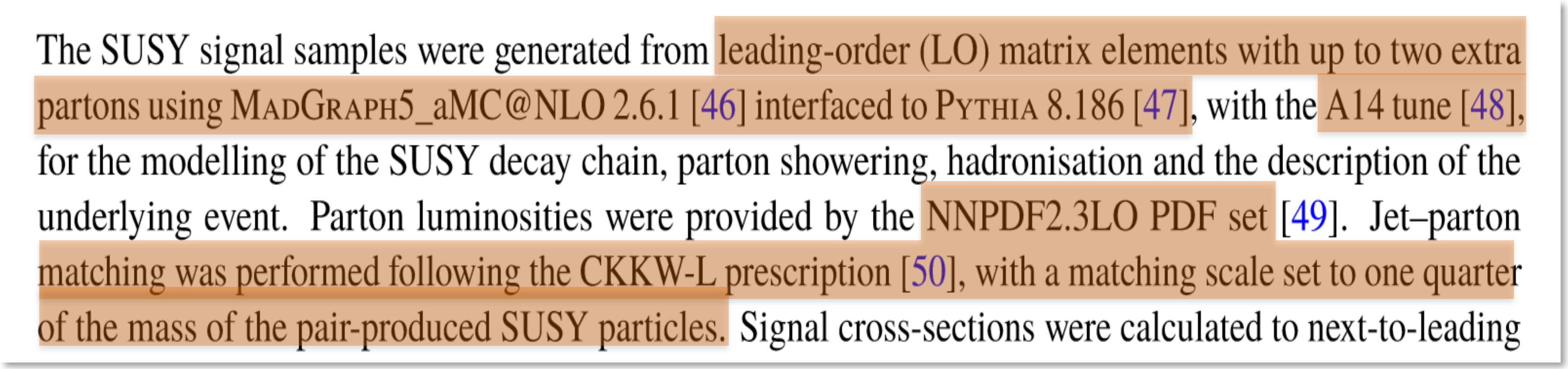
- *Theoretical model (UFO models / hardcoded one)*
- *Content of your event*
  (physics processes. fixed-order perturbative QCD. …)
- *Number of events to generate*
- *ME generation program*
- *Shower program*
- *ME/PS merging/matching scheme*
- *PDF*
- *Monte-Carlo tuning*
  (mainly for the UE description)

Most of these information should be found in the paper.

To not forget to normalize your samples to the cross-section given in the paper.

2. Generating signal samples

Example of ATLAS-SUSY-2018-32:



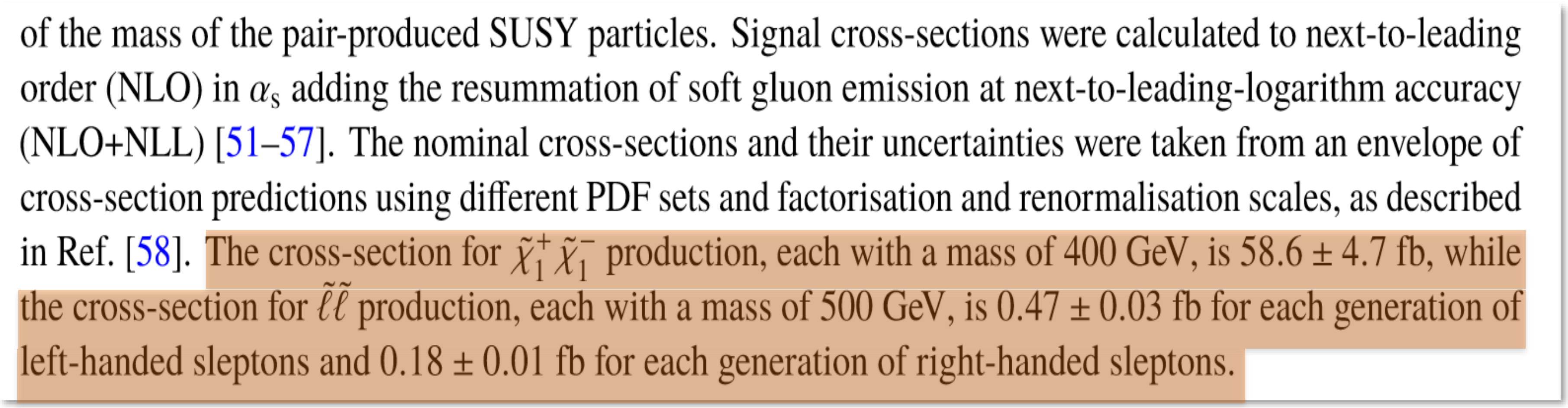
The SUSY signal samples were generated from leading-order (LO) matrix elements with up to two extra partons using MadGraph5_aMC@NLO 2.6.1 [46] interfaced to Pythia 8.186 [47], with the A14 tune [48], for the modelling of the SUSY decay chain, parton showering, hadronisation and the description of the underlying event. Parton luminosities were provided by the NNPDF2.3LO PDF set [49]. Jet–parton matching was performed following the CKKW-L prescription [50], with a matching scale set to one quarter of the mass of the pair-produced SUSY particles. Signal cross-sections were calculated to next-to-leading

Comments:

- Do not take exactly the same versions for the MG_aMC@NLO and Pythia software.
- Theoretical model = simplifed models. How to find that?
  → Possibility here to take a SUSY model for describing the process and to normalize the samples to the proper cross-section.
- Number of events to generate???

2. Generating signal samples

Example of ATLAS-SUSY-2018-32:



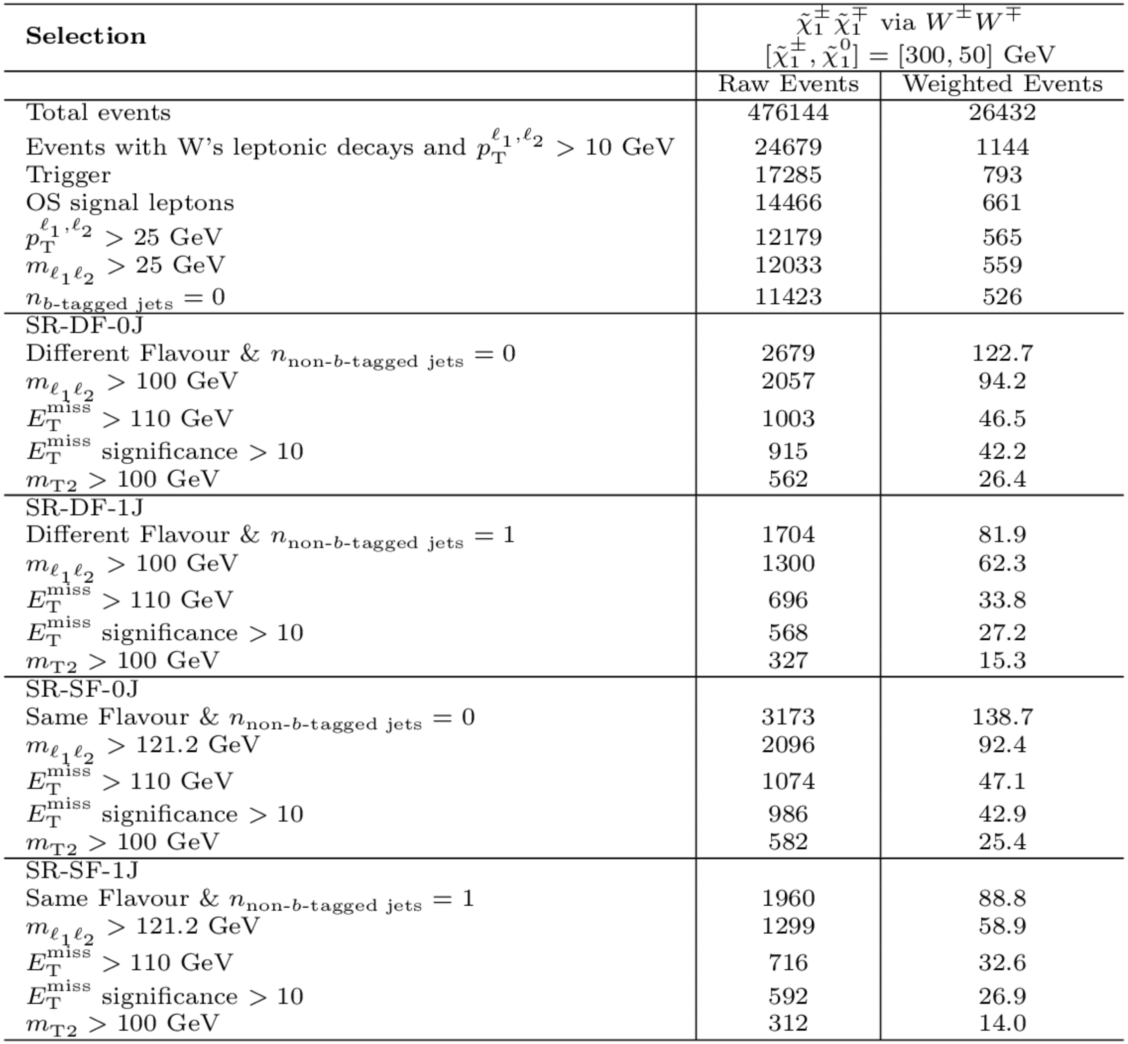
of the mass of the pair-produced SUSY particles. Signal cross-sections were calculated to next-to-leading order (NLO) in α_s adding the resummation of soft gluon emission at next-to-leading-logarithm accuracy (NLO+NLL) [51–57]. The nominal cross-sections and their uncertainties were taken from an envelope of cross-section predictions using different PDF sets and factorisation and renormalisation scales, as described in Ref. [58]. The cross-section for $\tilde{\chi}_1^+\tilde{\chi}_1^-$ production, each with a mass of 400 GeV, is 58.6 ± 4.7 fb, while the cross-section for $\tilde{\ell}\tilde{\ell}$ production, each with a mass of 500 GeV, is 0.47 ± 0.03 fb for each generation of left-handed sleptons and 0.18 ± 0.01 fb for each generation of right-handed sleptons.

Comments:

- Cross-sections values for normalizing the samples

3. Comparing cut-flow values

Example of ATLAS-SUSY-2018-32:



Selection	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ via $W^{\pm}W^{\mp}$ $[\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^{0}] = [300, 50]$ GeV	
	Raw Events	Weighted Events
Total events	476144	26432
Events with W's leptonic decays and $p_{\mathrm{T}}^{\ell_1,\ell_2} > 10$ GeV	24679	1144
Trigger	17285	793
OS signal leptons	14466	661
$p_{\mathrm{T}}^{\ell_1,\ell_2} > 25$ GeV	12179	565
$m_{\ell_1\ell_2} > 25$ GeV	12033	559
$n_{b\text{-tagged jets}} = 0$	11423	526
SR-DF-0J		
Different Flavour & $n_{\text{non-}b\text{-tagged jets}} = 0$	2679	122.7
$m_{\ell_1\ell_2} > 100$ GeV	2057	94.2
$E_{\mathrm{T}}^{\mathrm{miss}} > 110$ GeV	1003	46.5
$E_{\mathrm{T}}^{\mathrm{miss}}$ significance > 10	915	42.2
$m_{\mathrm{T2}} > 100$ GeV	562	26.4
SR-DF-1J		
Different Flavour & $n_{\text{non-}b\text{-tagged jets}} = 1$	1704	81.9
$m_{\ell_1\ell_2} > 100$ GeV	1300	62.3
$E_{\mathrm{T}}^{\mathrm{miss}} > 110$ GeV	696	33.8
$E_{\mathrm{T}}^{\mathrm{miss}}$ significance > 10	568	27.2
$m_{\mathrm{T2}} > 100$ GeV	327	15.3
SR-SF-0J		
Same Flavour & $n_{\text{non-}b\text{-tagged jets}} = 0$	3173	138.7
$m_{\ell_1\ell_2} > 121.2$ GeV	2096	92.4
$E_{\mathrm{T}}^{\mathrm{miss}} > 110$ GeV	1074	47.1
$E_{\mathrm{T}}^{\mathrm{miss}}$ significance > 10	986	42.9
$m_{\mathrm{T2}} > 100$ GeV	582	25.4
SR-SF-1J		
Same Flavour & $n_{\text{non-}b\text{-tagged jets}} = 1$	1960	88.8
$m_{\ell_1\ell_2} > 121.2$ GeV	1299	58.9
$E_{\mathrm{T}}^{\mathrm{miss}} > 110$ GeV	716	32.6
$E_{\mathrm{T}}^{\mathrm{miss}}$ significance > 10	592	26.9
$m_{\mathrm{T2}} > 100$ GeV	312	14.0

- **Reference:** Table 5
- **Useful part:** signal samples
- **Goal:**
  - Comparison cut-by-cut
  - One cut-flow for each signal region

3. Comparing cut-flow values

Advised presentation of the comparison results
Example: CMS-SUS-16-039

Selection criteria	CMS		MadAnalysis 5		Relative error	
	Events	Efficiency	Events	Efficiency	on Events	on Efficiency
3 tight e. μ. τ	18.06	-	18.06	-	0.0%	-
4th lepton	18.03	99.8%	18.06	100.0%	0.2%	0.2%
conversion & low-mass veto	17.79	98.7%	17.88	99.0%	0.5%	0.3%
b-jet veto	17.47	98.2%	17.51	97.9%	0.2%	-0.3%
MET > 50 GeV	16.98	97.2%	17.05	97.4%	0.4%	0.2%
MT > 100 GeV	12.74	75.0%	13.07	76.7%	2.6%	2.2%
Mll > 75 GeV	11.71	91.9%	12.61	96.5%	7.7%	5.0%

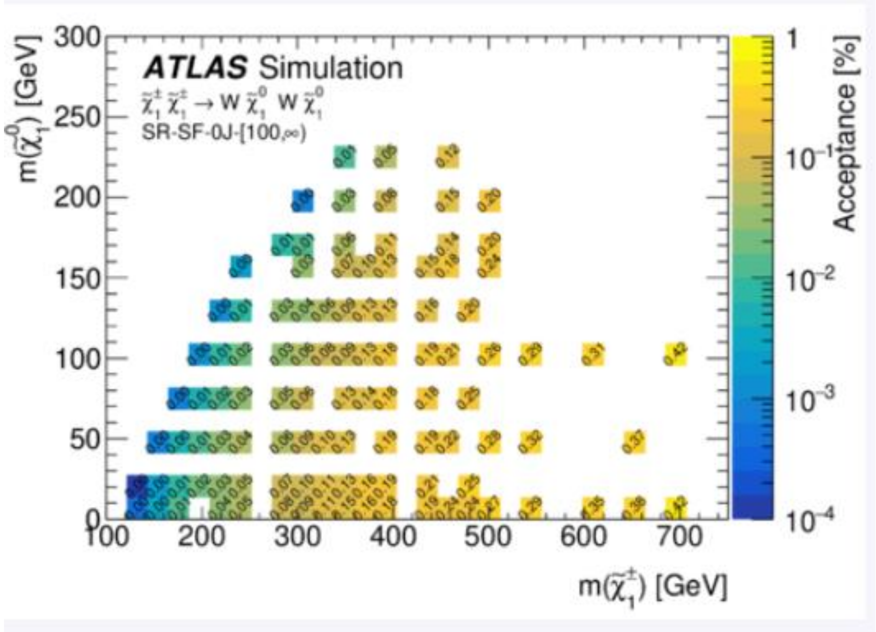
Nb of events = $\mathcal{L}^{int} \cdot \sigma$
≠ Nb of generated events

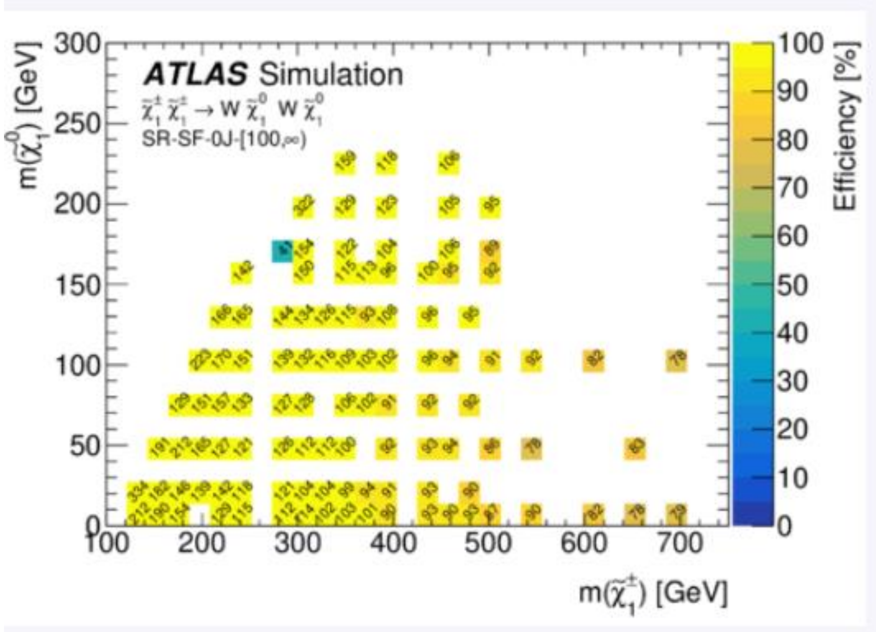
Cumulative
efficiency

Reasonable disagreement
(less than 20%)

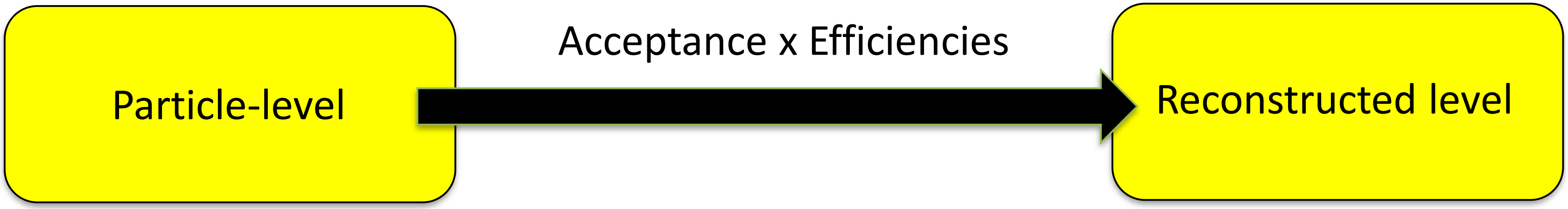
3. Acceptances & efficiencies?

The ATLAS collaboration (in particular in the SUSY working-group) provides also some tables of "Acceptances" and "Efficiencies". Example of ATLAS-SUSY-2018-32:





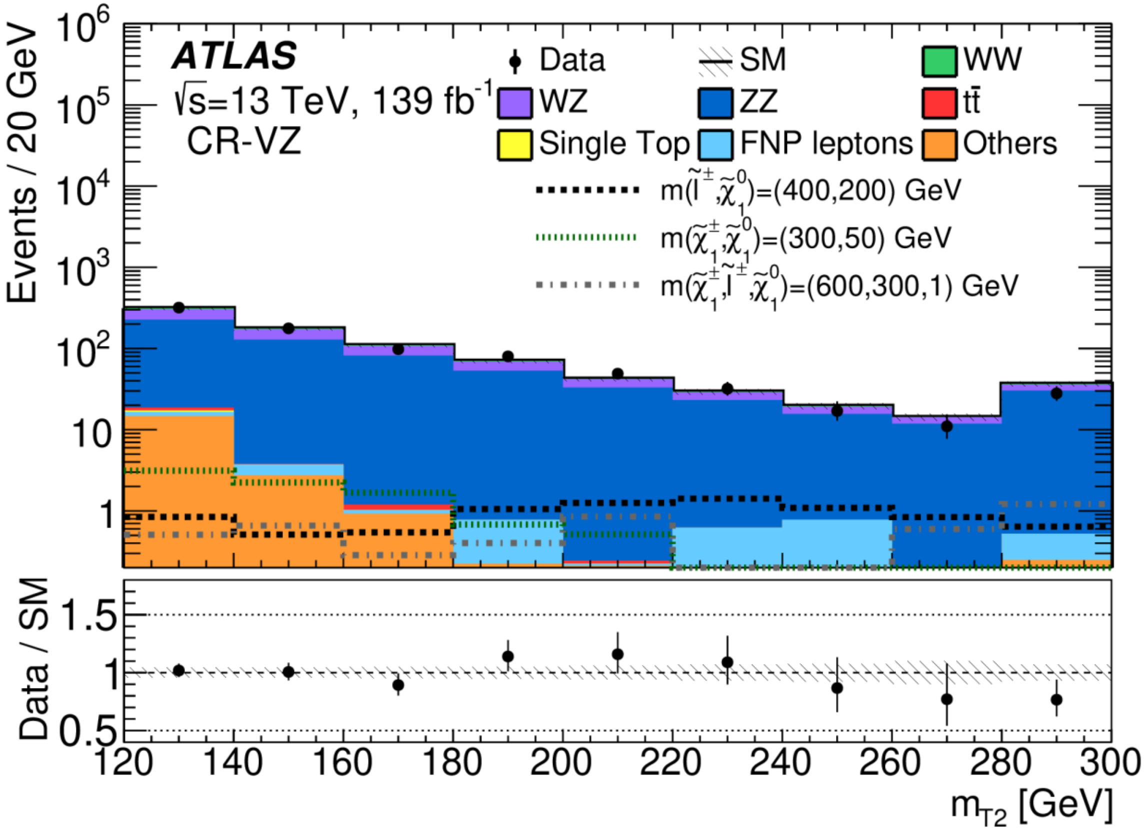
This data are used for "parametric simulation" strategy. More details in ATL-PHYS-PUB-2015-013.



Irrelevant for us (except for sanity check)

4. Comparing plot distributions

Example of ATLAS-SUSY-2018-32:



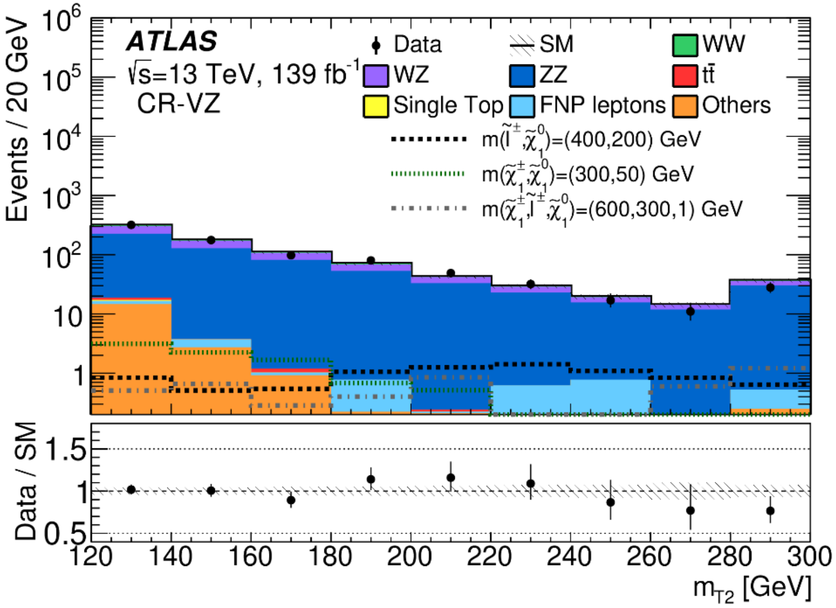
- **Reference:** Table 2a
- **Useful part:** signal samples
- **Goals:**
  - Superimpose on a same plot the official signal distribution and the the recast signal distributions.

4. Comparing plot distributions

Advertisement page

How to extract data from this plot?

- **Plot available on HepData?**
- **Only the image?**



→ WebPlotDigitizer

4. Comparing plot distributions

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https://apps.automeris.io/wpd/

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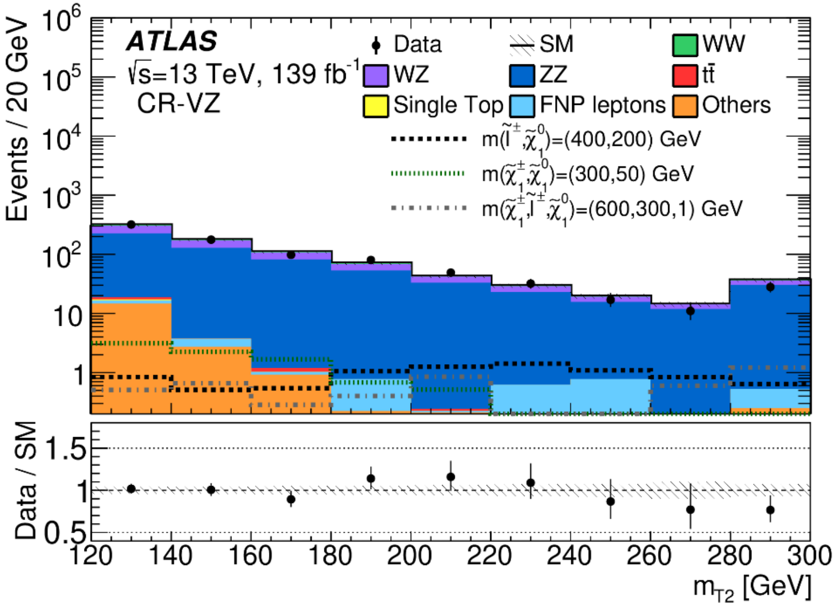

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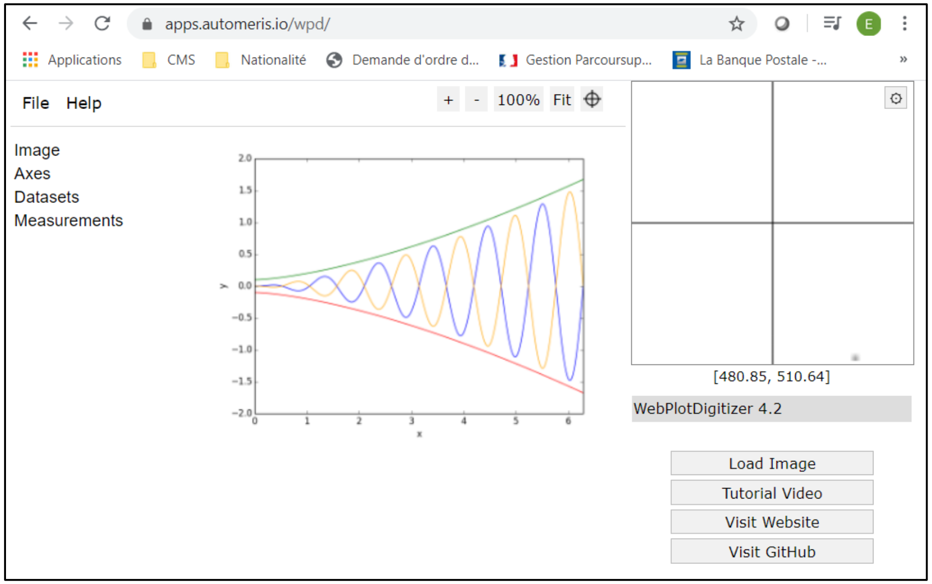
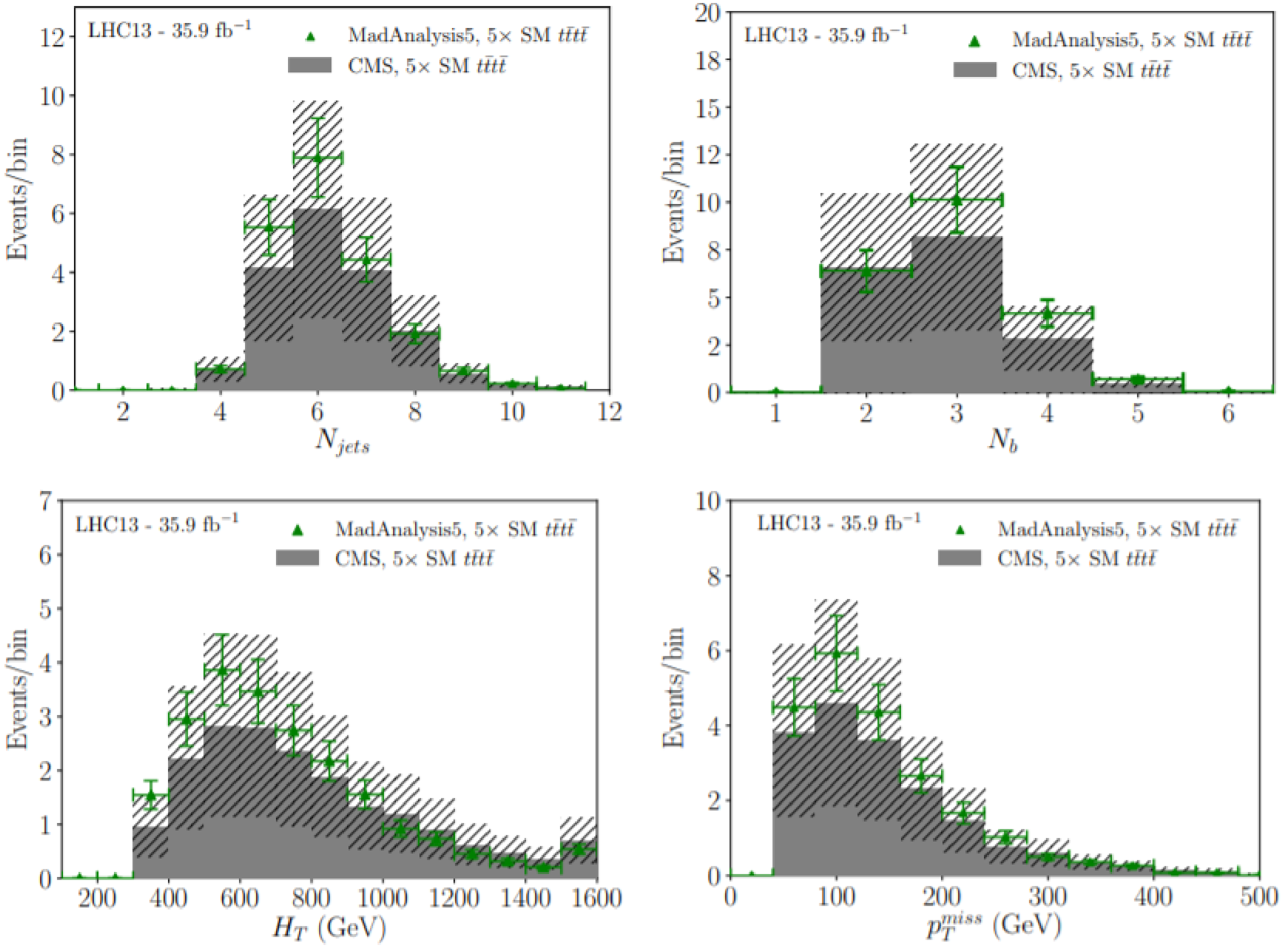


- Loading the image.
- Adding a calibration for the axes of type 2D-XY plot.
  - Setting the axes boundaries by placing points X1, X2, Y1, Y2
  - Setting the log scale if necessary.

4. Comparing plot distributions

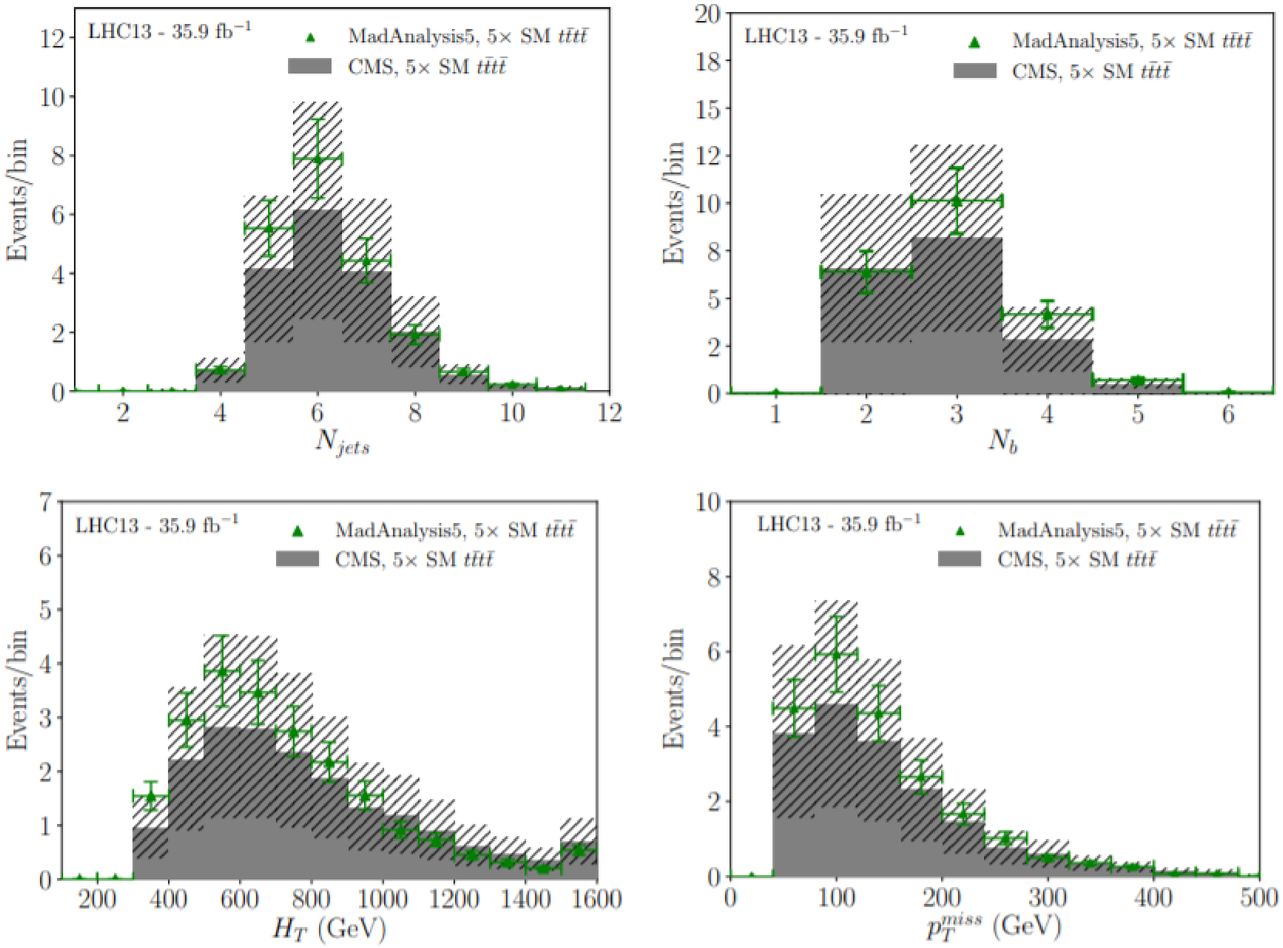
Advised presentation of the comparison results
Example: CMS-TOP-17-009



- Statistical uncertainty for MA5 sample
- Statistical + systematics uncertainties for CMS sample

4. Comparing plot distributions

Advised presentation of the comparison results
Example: CMS-TOP-17-009



Reasonable disagreement ?

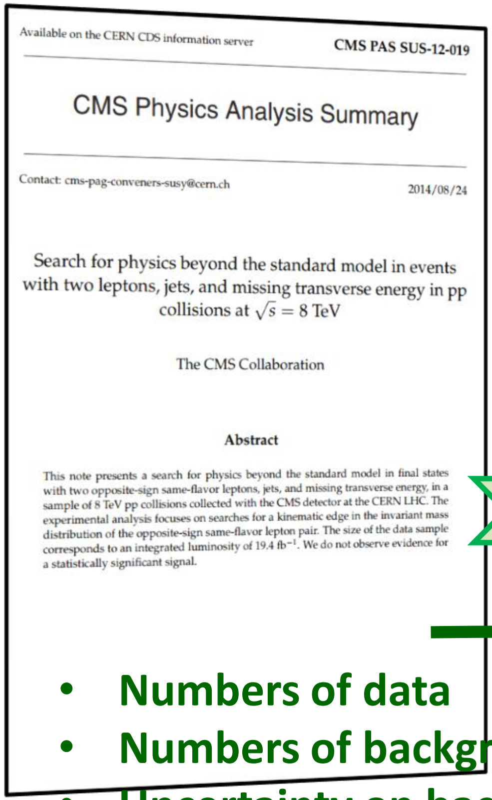
- Need to investigate bin-by-bin.
- It seems OK.
- **Possible improvement:** plot MA5/CMS ratio and see if there is a trend.

5. The final exclusion plot

- **Goal:** testing the MadAnalysis 5 way to get an exclusion limit on the signal model and comparing the results to the official ones.

This step is optional because it is time-consuming.

- **Reminder about the MadAnalysis5 strategy:**



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

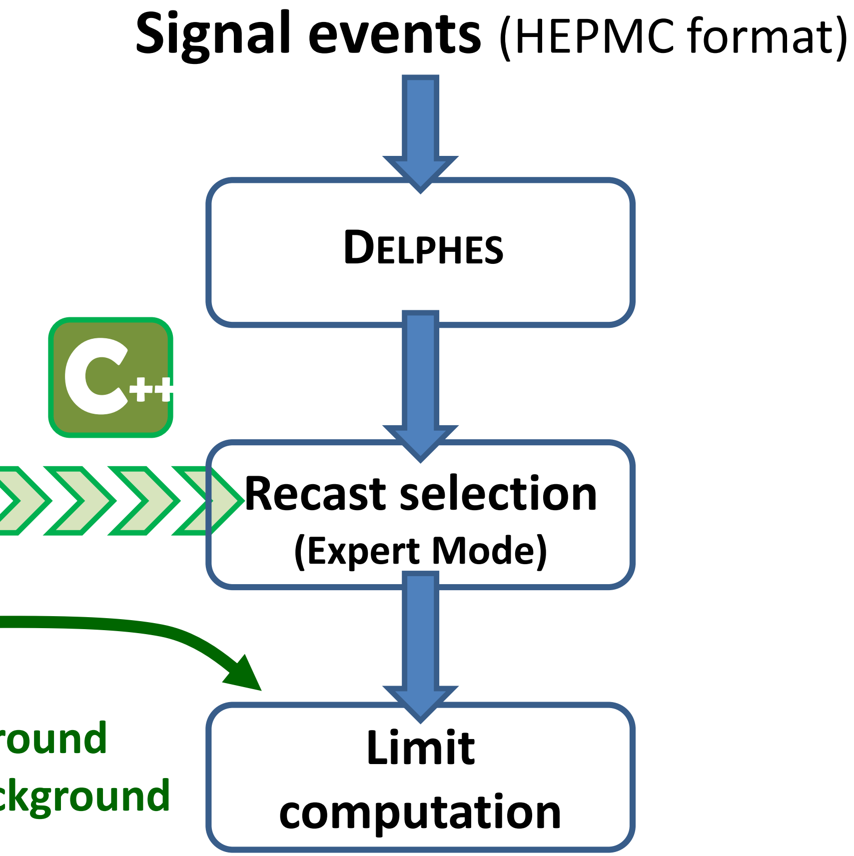
Search for physics beyond the standard model in events with two leptons, jets, and missing transverse energy in pp collisions at $\sqrt{s} = 8$ TeV

The CMS Collaboration

Abstract

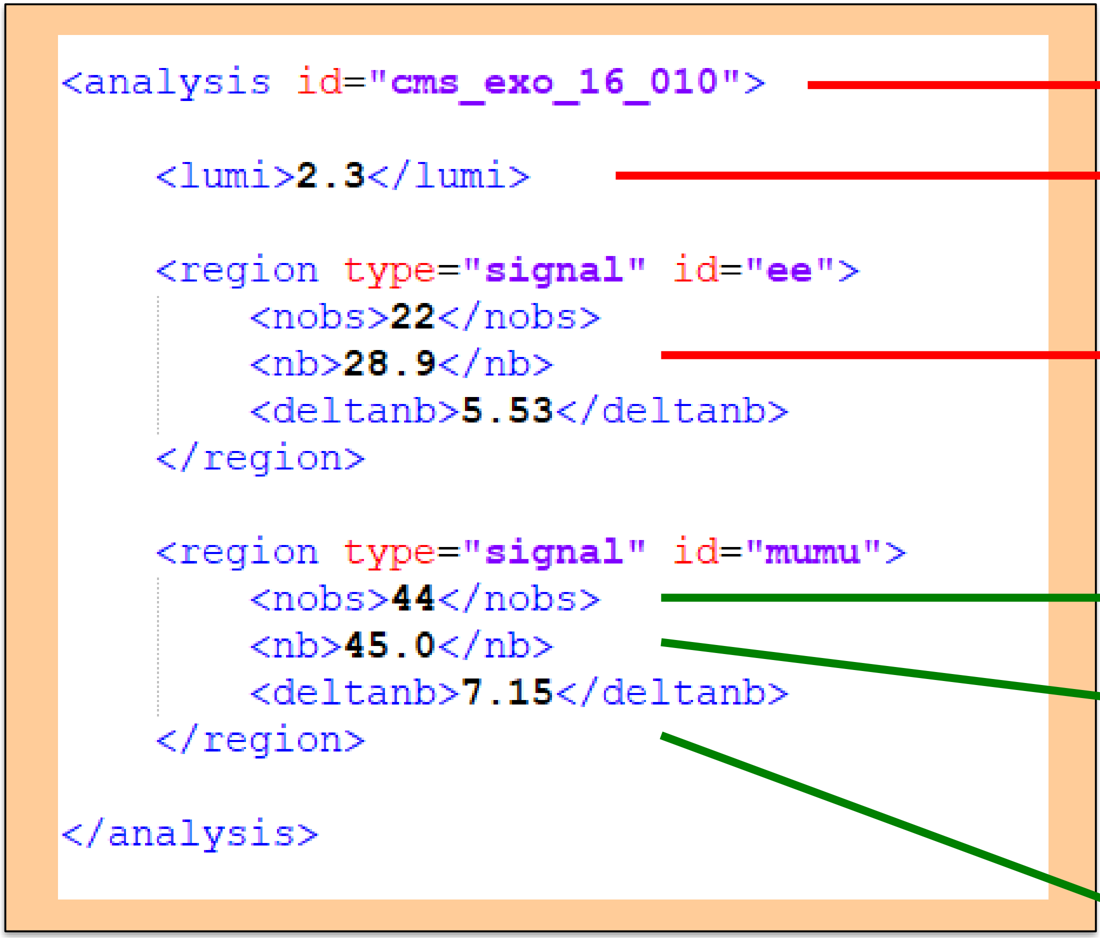
This note presents a search for physics beyond the standard model in final states with two opposite-sign same-flavor leptons, jets, and missing transverse energy, in a sample of 8 TeV pp collisions collected with the CMS detector at the CERN LHC. The experimental analysis focuses on searches for a kinematic 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.

- Numbers of data
- Numbers of background
- Uncertainty on background



5. The final exclusion plot

- **The info file (*.info) gathers statistical information extracted from the official analysis**



```
<analysis id="cms_exo_16_010">

    <lumi>2.3</lumi>

    <region type="signal" id="ee">
        <nobs>22</nobs>
        <nb>28.9</nb>
        <deltanb>5.53</deltanb>
    </region>

    <region type="signal" id="mumu">
        <nobs>44</nobs>
        <nb>45.0</nb>
        <deltanb>7.15</deltanb>
    </region>

</analysis>
```

Name of your analysis

Integrated luminosity (fb^{-1})

One block per signal region

Number of observed data events in the signal region

Number of estimated background events in the signal region

Statistical uncertainty @ 1σ on the number of background events

5. The final exclusion plot

- **Computing of the observed cross-section excluded @ CLs=95%**
- Extracting the values of $\mathcal{L}$. n_{obs}. n_b and Δn_b from the info file.
- Launching the recast analysis on the top of your signal sample and getting the number of signal surviving after the selection: $n_s = \mathcal{L} \cdot \epsilon_s \cdot \sigma_s$
- Generating N (= 100.000 by default) toy experiments where the expected number of background events N_b is randomly chosen assuming a Gaussian distribution $(n_b. \Delta n_b)$.

calculating p_b

  - The actual number of background events $\widehat{N}_b$ is randomly chosen according to a Poisson distrib mean N_b.
  - p_b = fraction of toy Monte-Carlo $\widehat{N}_b < n_{obs}$

calculating p_{b+s}

  - The actual number of signal+background events $\widehat{N}_s + \widehat{N}_b$ is randomly chosen according to a Poisson distrib mean $N_s + N_\mathrm{b}$.
  - p_{b+s} = fraction of toy Monte-Carlo $\widehat{N}_s + \widehat{N}_b < n_{obs}$

- The observed cross-section excluded is obtained by setting σ_s free and imposing a CLs = 95% (computed with p_b and p_{b+s})

5. The final exclusion plot

- **Computing of the expected cross-section excluded @ CLs=95%**

Same recipe than before but n_{obs} is replaced by n_b in the computation of $\boldsymbol{p_b}$ and $\boldsymbol{p_{b+s}}$

- **Case of an analysis with several signal regions**

The recipe is applied for each signal region.
Then MadAnalysis 5 selects **the most constraining signal region**.

5. The final exclusion plot

Example of the recast analysis ATLAS-SUSY-2013-05

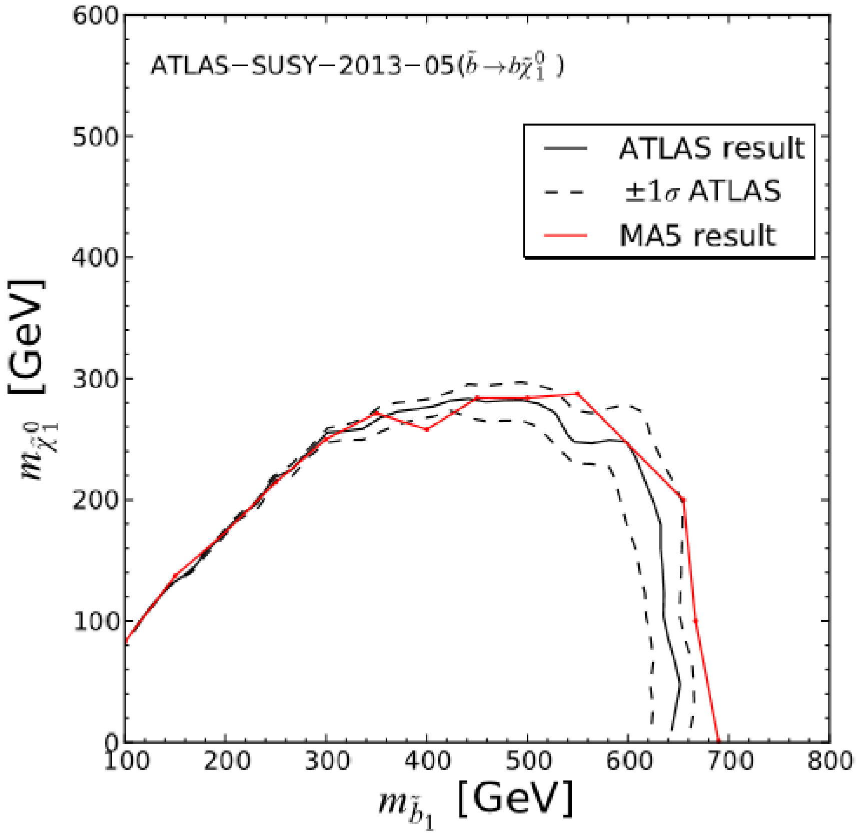
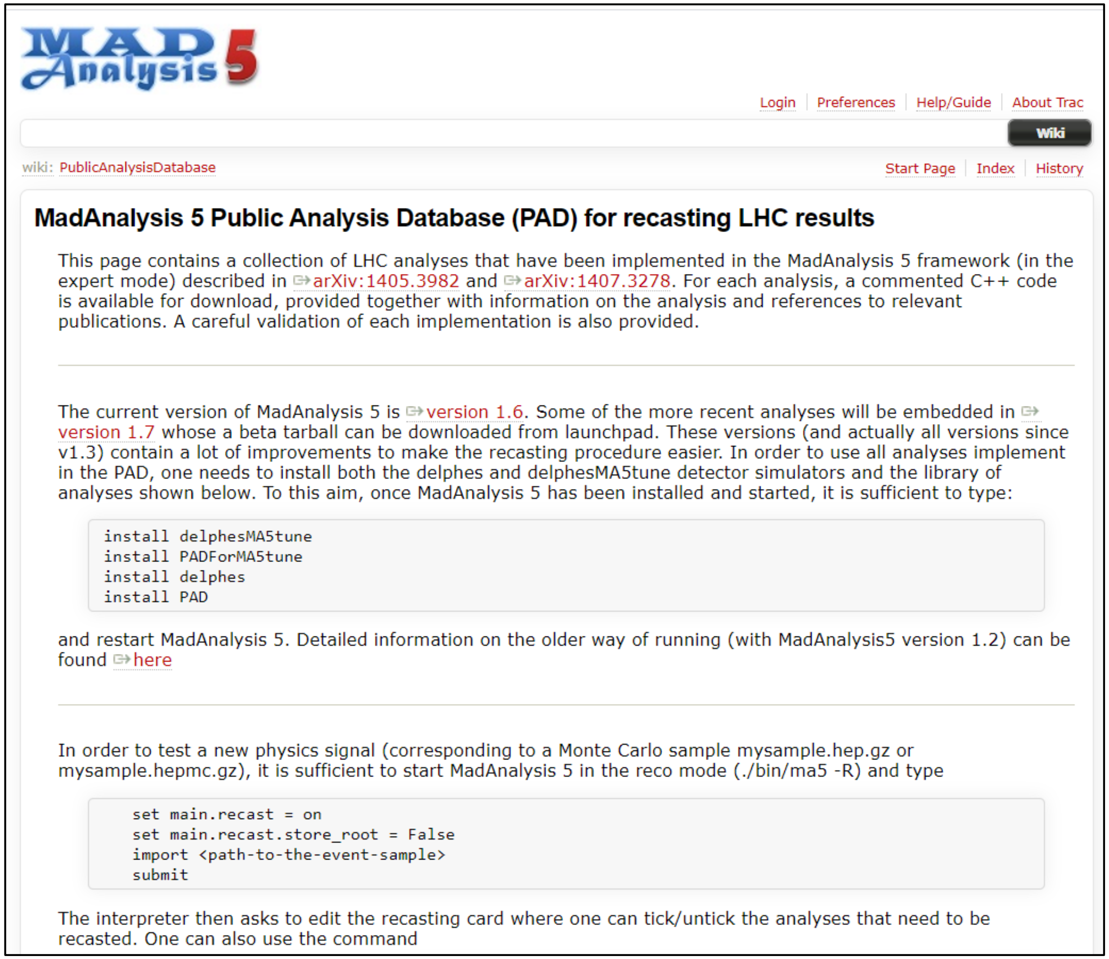


Figure 3: Comparison between the observed exclusion limit provided by ATLAS for the sbottom scenario against the recasted MA5 analysis. The black lines correspond respectively to the ATLAS result (the dashed lines correspond to the $\pm 1\sigma$ theory uncertainty) and the red one to the MA5 one.

Including the analysis in the PAD

Public Analysis Database (PAD) of MadAnalysis 5:
http://madanalysis.irmp.ucl.ac.be/wiki/PublicAnalysisDatabase



MadAnalysis 5 Public Analysis Database (PAD) for recasting LHC results

This page contains a collection of LHC analyses that have been implemented in the MadAnalysis 5 framework (in the expert mode) described in arXiv:1405.3982 and arXiv:1407.3278. For each analysis, a commented C++ code is available for download, provided together with information on the analysis and references to relevant publications. A careful validation of each implementation is also provided.

The current version of MadAnalysis 5 is version 1.6. Some of the more recent analyses will be embedded in version 1.7 whose a beta tarball can be downloaded from launchpad. These versions (and actually all versions since v1.3) contain a lot of improvements to make the recasting procedure easier. In order to use all analyses implement in the PAD, one needs to install both the delphes and delphesMA5tune detector simulators and the library of analyses shown below. To this aim, once MadAnalysis 5 has been installed and started, it is sufficient to type:

```
install delphesMA5tune
install PADForMA5tune
install delphes
install PAD
```

and restart MadAnalysis 5. Detailed information on the older way of running (with MadAnalysis5 version 1.2) can be found here

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In order to test a new physics signal (corresponding to a Monte Carlo sample mysample.hep.gz or mysample.hepmc.gz), it is sufficient to start MadAnalysis 5 in the reco mode (./bin/ma5 -R) and type

```
   set main.recast = on
   set main.recast.store_root = False
   import <path-to-the-event-sample>
   submit
```

The interpreter then asks to edit the recasting card where one can tick/untick the analyses that need to be recasted. One can also use the command

Congratulations!

At this step. your analyis is validated.

Including the analysis in the PAD

Recipe for including your analysis in the PAD:

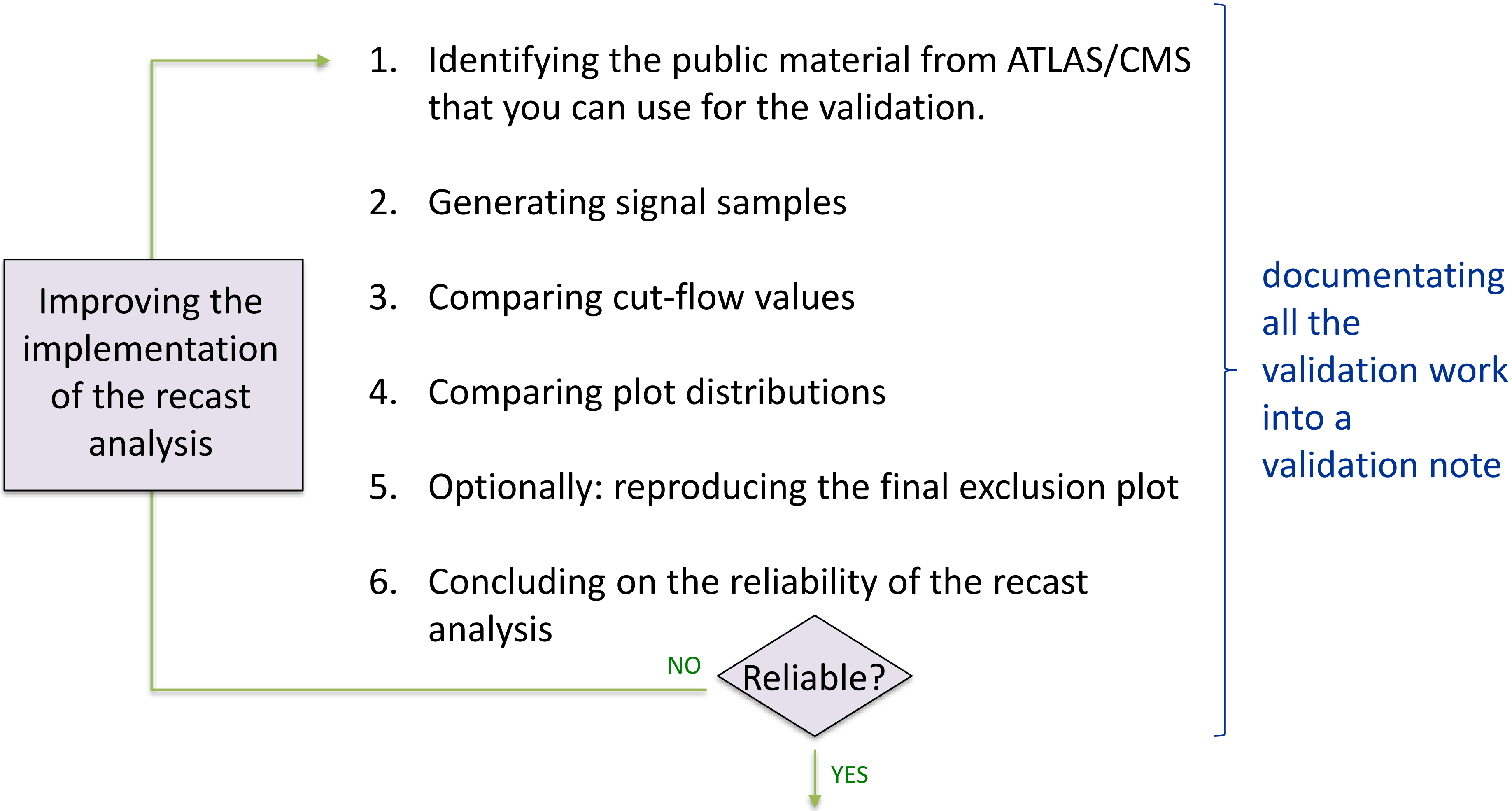
- Contact the MA5 team (ma5team@iphc.cnrs.fr) for putting your analysis in the PAD

- Attach to your email the following documents:
  - The code of the recast analysis (.cpp & .h).
  - The configuration file for the Delphes simulation of the detector.
  - The info file = XML-formated file contained the number of observed data events and of background events for each signal region.
  - The validation note (latex source).
  - Optionally: the cards for signal generation.

- Specify any special features of your code. For instance: the package dependencies.

Summary

The validation procedure in 6 steps:



1. Identifying the public material from ATLAS/CMS that you can use for the validation.
2. Generating signal samples
3. Comparing cut-flow values
4. Comparing plot distributions
5. Optionally: reproducing the final exclusion plot
6. Concluding on the reliability of the recast analysis

Reliable?

NO

Improving the implementation of the recast analysis

YES

documentating all the validation work into a validation note

Putting the recast analysis into the Public Analysis Database (PAD)