Designing and recasting LHC analyses with MadAnalysis 5

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What is MadAnalysis 5?

MadAnalysis 5 is a public program that allows high-energy physicists (theorists and experimentalists) to efficiently design and recast LHC analyses. Phenomenologists can, in this way, investigate their favorite models, and determine whether the LHC is sensitive to a given signature by either conceiving a novel analysis or by recasting existing CMS or ATLAS studies.

Natively associated with MadGraph 5, MadAnalysis 5 is now able to read the output of any Monte Carlo generator (at leading order or next-to-leading order QCD accuracy). Analyzing event samples consists in histogramming distributions of observables, applying some selection cuts and building a cut-flow chart. All results are summarized into a HTML, PS or PDF report.

According to the wishes of the user, MadAnalysis 5 can process the events before analyzing them. In particular, a jet-clustering algorithm or a detector simulation can be used effortlessly. Besides processed events can be saved in output files.

Main concepts

A unique framework

The MadAnalysis 5 package **[1]** allows one to design/recast in a same way phenomenological investigations at any step of the generation (parton, hadron and reconstructed object level), for any file format (STDHEP, HEPMC, LHE, LHCO, ROOT).

User-friendly

The user designs her/his analysis by interacting with a Python console. Settings and analyses can be written with the help of a metalanguage designed to be intuitive. Tab completion and in-line help facilitate the life of the user.

Efficient

The Python console exports the analysis encoded using the MadAnalysis 5 metalanguage to a dedicated C++ program readily to be compiled and executed.

Flexible

MadAnalysis 5 is shipped with a series of common built-in observables that includes sophisticated variables such as α_T or M_{T2}. Operations between four-momenta are also available. For more complicated selections, the user can directly write the analysis in C++ (the so-called ***expert mode***) and design her/his own observables.

Multi-interface

MadAnalysis 5 is interfaced to several packages: Gzip, Root, FastJet, FastJet-Contrib, Delphes. Installation of these packages can be done easily from the Python console. It is also distributed with Delphes-MA5tune, a modified version of Delphes.

Program summary

Current release: MadAnalysis 5 v1.1.12
Platforms: Unix, Linux, Mac OS X
Programming language: Python, C++
Requirements: Gcc, Python, Make, Root
Software License: GNU General Public License
Official web-site: https://launchpad.net/madanalysis5
Tutorials: https://madanalysis.irmp.ucl.ac.be/wiki/tutorials
Physics Analysis Database:
https://madanalysis.irmp.ucl.ac.be/wiki/PhysicsAnalysisDatabase

References

[1] E. Conte, B. Fuks, G. Serret, CPC 184 (2013) 222
[2] E. Conte, B. Dumont *et al*, *submitted to EPJC,* arXiv:1405.3982
[3] M. Cacciari, G.P. Salam, G. Soyez, EPJC 72 (2012) 1896
[4] J. De Favereau *et al*, JHEP 02 (2014) 057
[5] B. Dumont, B. Fuks *et al*, *submitted to EPJC,* arXiv:1407.3278
[6] A. Buckley, J. Butterworth *et al*, CPC 184 (2013) 2803
[7] A. Alloul, M. Frank, B. Fuks *et al*, JHEP 1310 (2013) 033

Acknowledgments

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Analysis design based on the MadAnalysis 5 metalanguage

User side: the metalanguage

```
import DrellYan*.lhe as dy
import ttbar_semilep*.lhe as tt
import ttbar_dilep*.lhe as tt
```

optional

```
set detector.fastsim.package = fastjet
set detector.fastsim.algo = kt
set detector.fastim.bjet.efficiency = 0.5
```

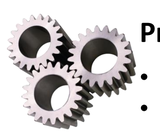
```
plot MET
plot M(mu+ mu-)
plot PT(j[1]) # the hardest jet

select 70 < M(mu+ mu-) < 110
define mu = mu+ mu-
select (mu) PT > 25
reject N(mu)< 2
```

optional

```
set main.outputfile = output.lhco
```

Behind the scene

Reading signal and background event files
Supporting any event file formats
(STDHEP, HEPMC, LHE, LHCO, ROOT)



Processing data
- Detector simulation
- Predefined analyses

Analyzing data
- Filling histograms
- Selection cuts

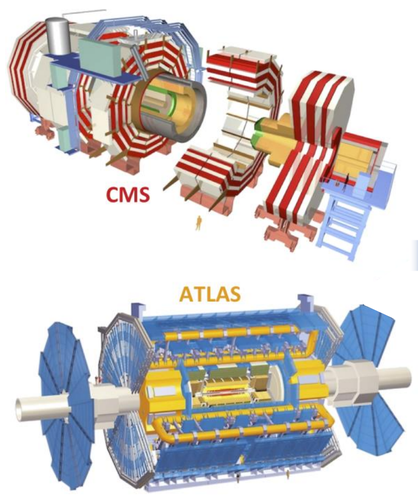
Storing events into output files
LHE, LHCO, ROOT file formats

Report Generator
three possible "graphical drivers": Root, Matplotlib or Gnuplot

available in the next release

Analysis report HTML or PDF
- histograms
- selection efficiencies
- figures of merit

Three available packages devoted to detector fast-simulation



Tunable simulation based on FastJet

Any of the jet-clustering algorithms included in the FastJet package **[3]** can be applied to the content of an hadron-level event. Options allow to switch on one or several detector effects applied on physics objects: efficiency, resolution, mis-identification.

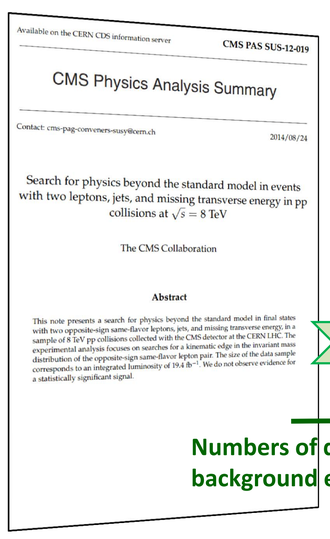
Delphes 3

MadAnalysis 5 is interfaced to Delphes 3 **[4]**. This public package offers the most realistic description of the ATLAS and the CMS detectors, including pile-up effects.

Delphes-MA5tune

This package is a modified release of Delphes 3, providing new observables and optimizing the output file. The main improvement deals with lepton (tracker/calorimeter/particle flow) isolation which is tuned and can be accounted for at the analysis level.

Recasting an existing ATLAS or CMS analysis with the MadAnalysis 5 *expert mode* [2]


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

CMS Physics Analysis Summary

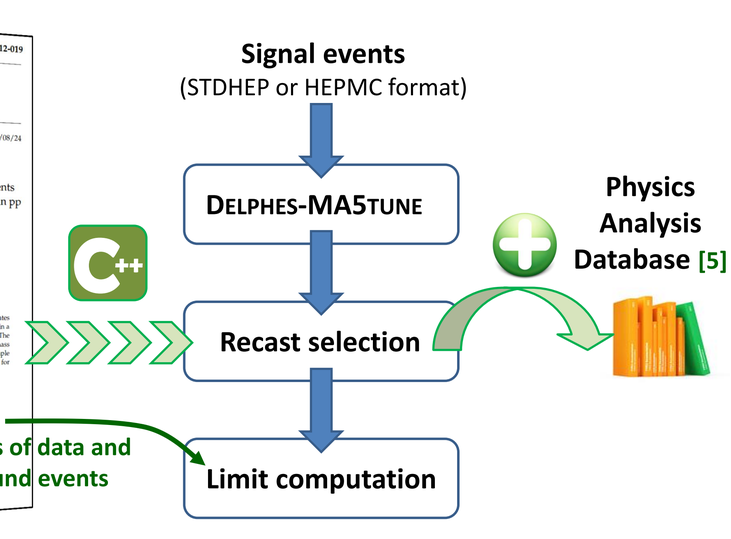
Contact: cms-pag-conveners-susy@cern.ch — 2014/08/24

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.



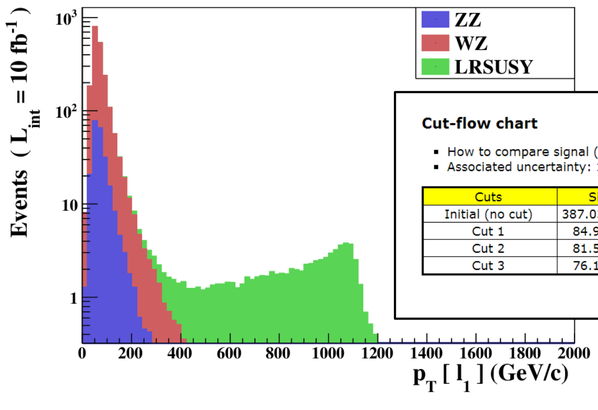
The flexibility of the *expert mode* (= writing the selection in C++) allows one to take into account any cut-based ATLAS or CMS analysis. Developer-friendly, it provides a large collection of high-energy-physics-oriented functions, services allowing one, for instance, to produce cut-flow charts and/or histograms. Analyses with multiple sub-analysis (or signal/control regions) can also be addressed.

Features:
- Complementary to the Rivet approach **[6]**.
- Efforts to improve the content and the realism of detector simulation packages.
- Helping the experimentalists to interpret their results by highlighting relevant theoretical models.
- Identification of possible topologies not scrutinized by the LHC experiments.

Examples of results

Investigating a LR-SUSY multileptonic signature for the 2015 LHC data [7]

Signal = W'production @ a Left-Right Supersymmetric (LR-SUSY) model
Background = Standard Model production of dibosons



Selection:
1. more than 3 charged leptons,
2. highest lepton P_T > 200 GeV,
3. $\not{E}_T$ > 50 GeV

Cut-flow chart

- How to compare signal (S) and background (B): S/B.
- Associated uncertainty: 1./(B**2)*sqrt(B**2*ES**2+S**2*EB**2).

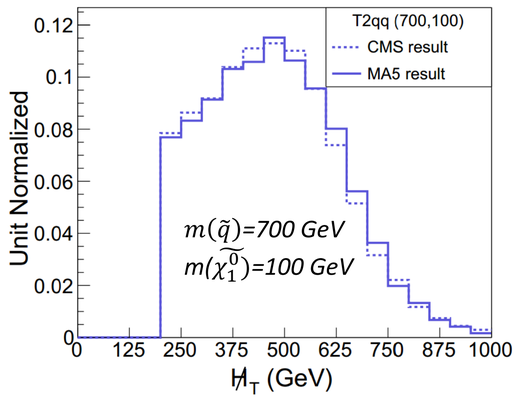
Cuts	Signal (S)	Background (B)	S vs B
Initial (no cut)	387.033 +/- 0.584	2029.72 +/- 1.44	0.190683 +/- 0.000318
Cut 1	84.95 +/- 8.14	2029.72 +/- 1.44	0.04185 +/- 0.00401
Cut 2	81.56 +/- 8.02	26.09 +/- 5.08	3.126 +/- 0.681
Cut 3	76.19 +/- 7.82	19.45 +/- 4.39	3.92 +/- 0.97

Signal and Background comparison

Extracted from a MadAnalysis 5 report

Recasting of a SUSY multijet analysis [5]

Comparison between the CMS (CMS-SUS-13-012 analysis) and MadAnalysis 5 results for the $\not{H}_T$ distribution (vector sum of the jet transverse momenta) for the "T2qq" simplified model.



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