Analysis and reinterpretation with MadAnalysis 5

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Outlines

1. What is MadAnalysis 5?
2. Software architecture
3. Plotting histograms
4. Defining a simple selection
5. Applying recast analyses
6. Epilogue

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1. **What is MadAnalysis 5?**
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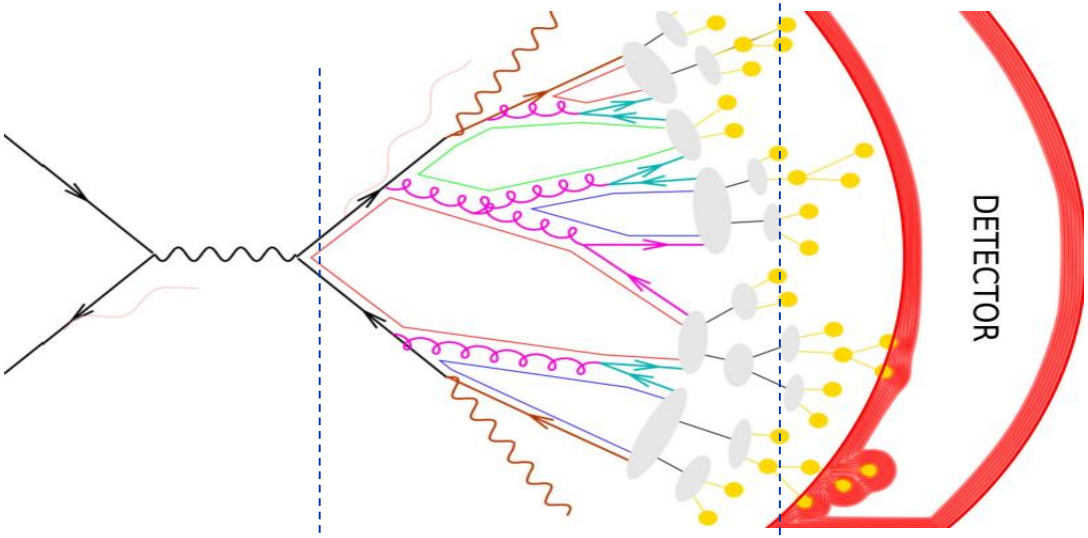
1. What is MadAnalysis 5?

The primary goal of MadAnalysis 5: analyzing generated & simulated samples



Parton level — LHE files

Hadron level — STDHEP/HEPMC files

Reconstructed objects level — LHCO, ROOT files

Relevant features of design

- ☑ User-friendly
- ☑ Flexible
- ☑ Efficient
- ☑ Easy to maintain

A unique framework : MadAnalysis 5

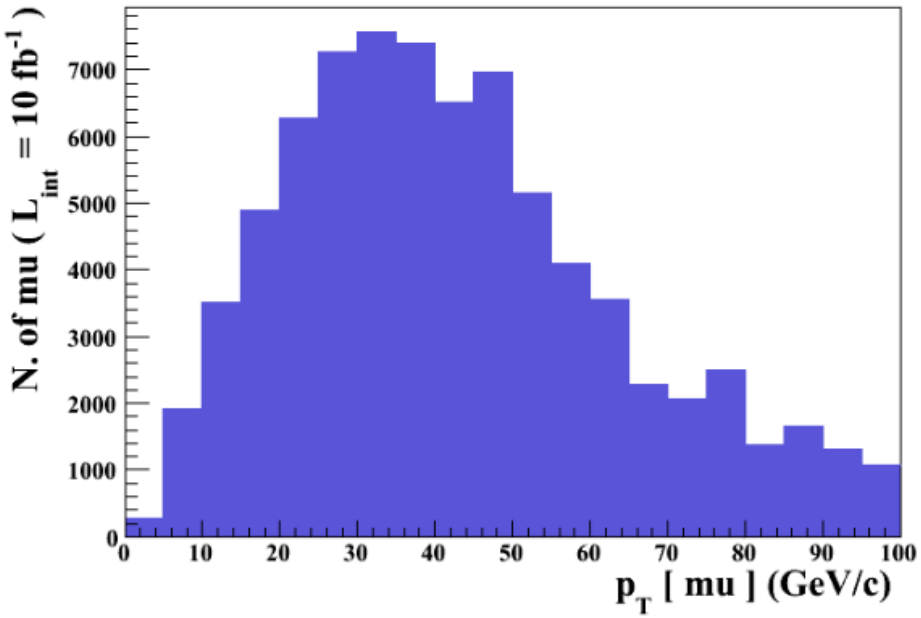
1. What is MadAnalysis 5?

Example of basic features:

- Reading of signal and background event files
- Production of histograms for different distributions.
- Definition of various selection cuts on the input samples.
- Results of the analysis summed up by a S/B-like ratio table.
- Dumping results in a smart report (PDF, DVI or HTML)

Dataset	Integral	Entries / events	Mean	RMS	Underflow	Overflow
defaultset	82747	0.752	42.8177	21.36	0.0	1.296

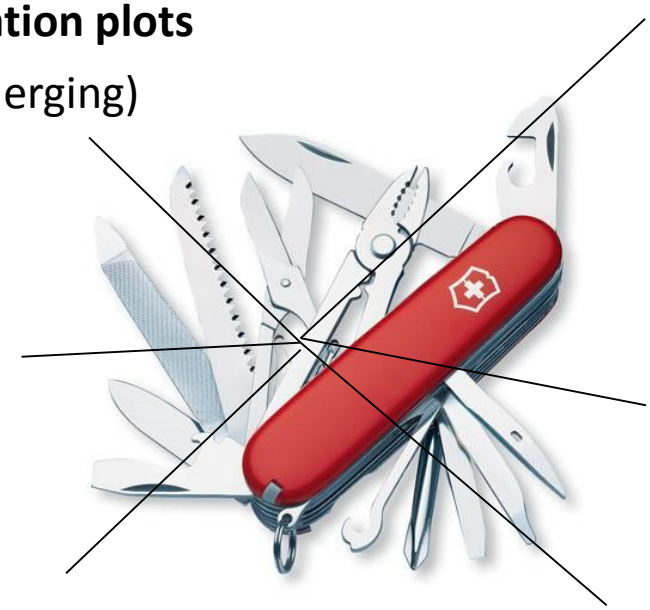
Statistics table



1. What is MadAnalysis 5?

But MadAnalysis 5 can do other things for you:

- Producing special plots such as **ME/PS merging validation plots** (see talk devoted to merging)
- **Writing** the events in another data format.



- Applying **a jet-clustering algorithm** to your hadronic events
- Designing a sophisticated analysis in the **expert mode**
- Applying a **fast-simulation detector (Delphes or home-made)** to your hadronic events
- **Recasting an existed analysis** and **computing a limit** to a BSM signal

Outlines

1. What is MadAnalysis 5?
2. **Software architecture**
3. Plotting histograms
4. Defining a simple selection
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2. Software architecture

Scope:

Defining an analysis with a dedicated metalanguage

Reading of signal and background event files

Supporting any event file format
(STDHEP, HEPMC, LHE, LHCO, ROOT)

optional

Processing data

- Clustering
- Fast-simulation

Analyzing data

- Selection cuts
- Filling histograms

Analysis report

histograms,
selection efficiencies,
S/B-like ratio table

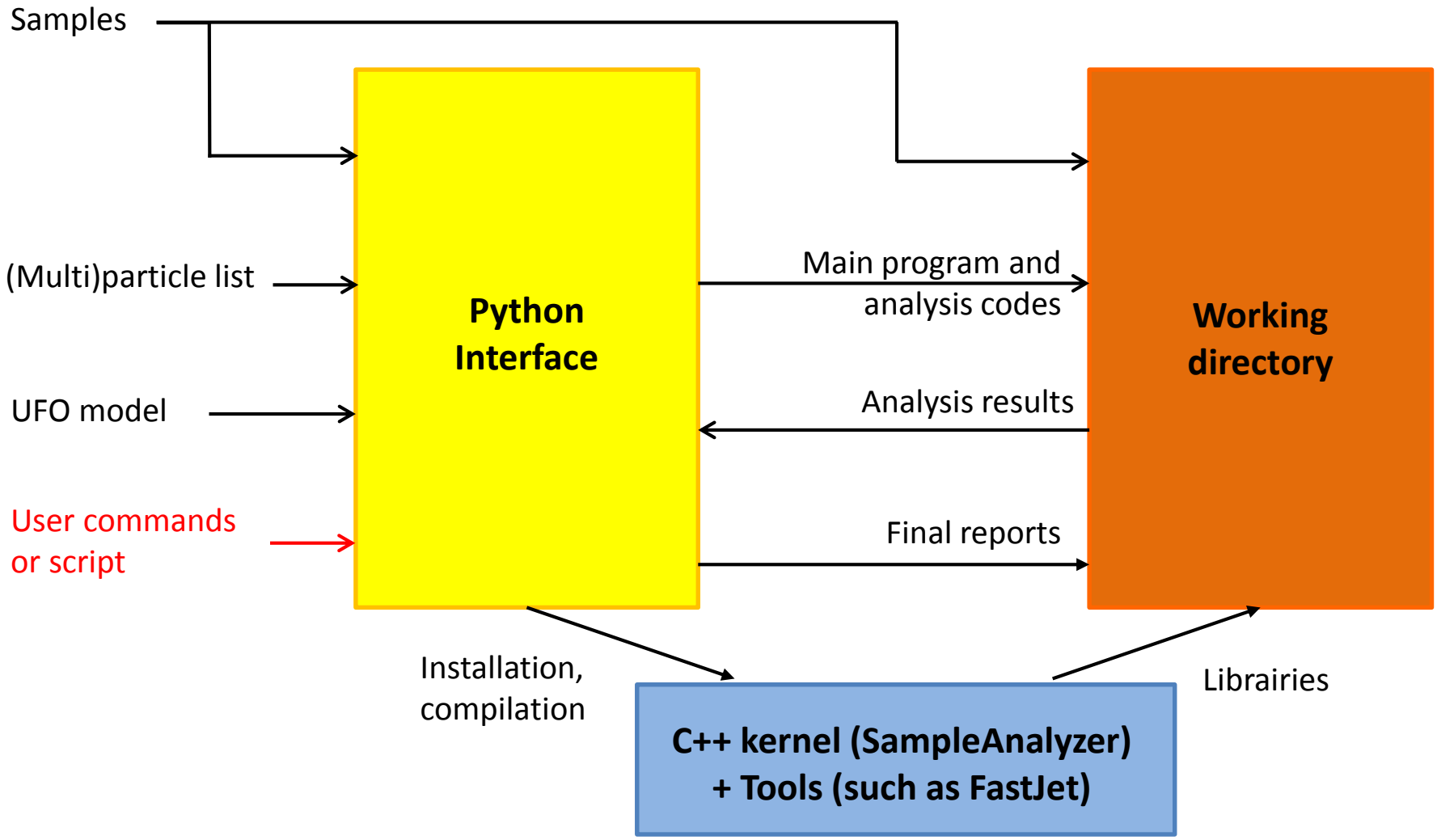
optional

Storing events into output files

LHE and LHCO file formats

2. Software architecture

Software architecture

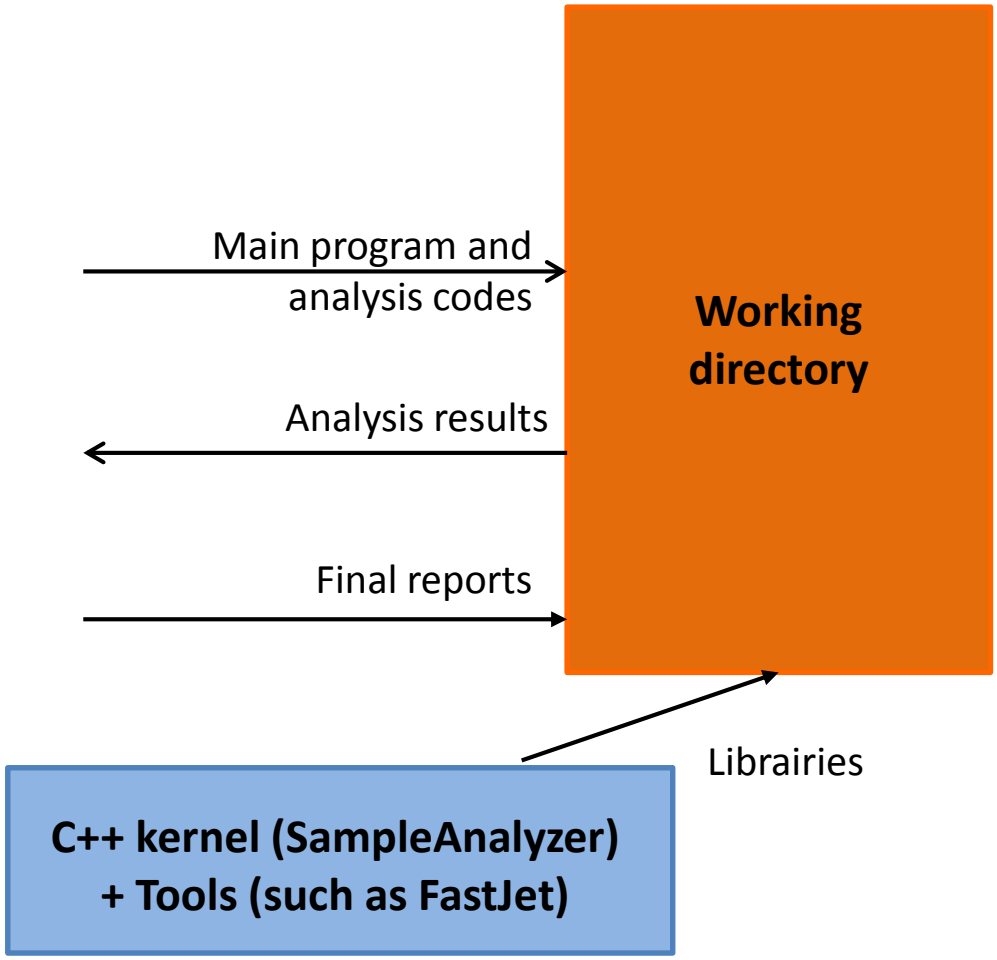


2. Software architecture

Software architecture

MadAnalysis has an **expert mode** (developer-friendly) :

- C++ programming within the SampleAnalyzer framework.
- The Python interface creates a blank analysis as a starting point.



2. Software architecture

Two ways of using MadAnalysis

Normal mode

= user-friendly

- Based on a Python console
- Analysis definition is based on a intuitive meta-language
- Plots & chart-flow automatically done
- Transparent interface to known HEP programs

Expert mode

= developer-friendly

- Writing your analysis in C++ language
- Facilitated development due to general services, physics library, program interfaces
- Analysis results are dumped into text files

2. Software architecture

How to install MadAnalysis 5?

- **1st way:** downloading the package from the webpage: https://launchpad.net/madanalysis5
- **2nd way:** installing from MG_aMC@NLO console:

```
mg5> install MadAnalysis5
```

The program will be stored in the folder `HEPTools/MadAnalysis5`

Requirements

Mandatory packages
g++
Python v>2.6 (not 3)
Makefile

Optional packages
Delphes
FastJet
Zlib
PDFLatex
Latex

Graphical driver

For histogramming, there are 3 possibilities:

- ROOT (version > 5.27)
- MatPlotlib (version > 1.0.1)
- None

Outlines

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3. **Plotting histograms**
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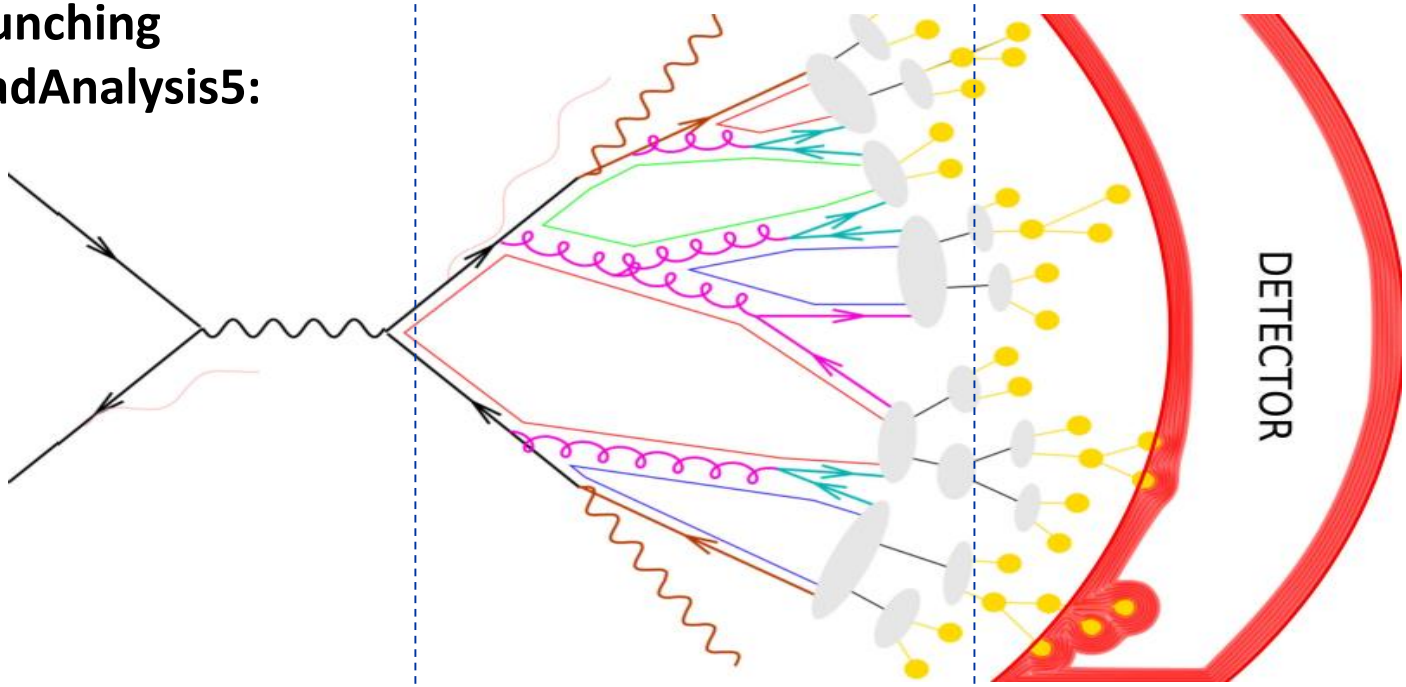
3. Plotting histograms

Launching MadAnalysis5:



Parton level	Hadron level	Reconstructed objects level
LHE files	STDHEP/HEPMC files	LHCO, ROOT files
`./bin/ma5`	`./bin/ma5 -H`	`./bin/ma5 -R`

3. Plotting histograms

The console

```
ma5>
```

Very similar to the MG_aMC@NLO one:

- Inline help. Just type **`help`**
- Autocompletion with tabulation key
- History of the commands
- Possibility to launch shell commands by starting with **`!`**
- Multiline command separating by **`;`**
- Allowing comments starting with **`#`**
- Colored logger with several levels of criticality
- alternative to interactive interface: scripts

How to quit?

- Just type **`quit`**

3. Plotting histograms

Defining new particles and multiparticles

Particles are defined by **labels**, which could point to one or several **PDG-id**.

SM and MSSM labels are automatically loaded at the starting of MadAnalysis.

- Defining your own particle labels:

```
ma5> define mu = mu+ mu-
```

or

```
ma5> define mu = +13 -13
```

- The user can import the labels from a UFO model:

```
ma5> import MyModel_UFO
```

- Display the list of particles and multiparticles:

```
ma5>display_particles
MA5: a b b1 b1~ b2 b2~ b~ c cl cl~ cr cr~ c~ d dl dl~ […]
ma5>display_multiparticles
MA5: hadronic invisible j l+ l- p vl vl~
```

3. Plotting histograms

Defining new particles and multiparticles

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```

two special multiparticles related to MET and hadronic activity.

- Display the list of particles and multiparticles:

```
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MA5: a b b1 b1~ b2 b2~ b~ c cl cl~ cr cr~ c~ d dl dl~ […]
ma5>display_multiparticles
MA5: hadronic invisible j l+ l- p vl vl~
```

3. Plotting histograms

Importing a dataset

- For MadAnalysis, a **dataset** is a collection of samples which will be merged.
- Supported format: LHE, STDHEP, HEPMC, LHCO, ROOT
- Wildcards are allowed → several files can be imported at the same time

- Importing samples without specifying a dataset name [default set]

```
ma5> import tt*.lhe
```

- Importing samples by specifying the dataset name

```
ma5> import tt*.lhe as ttbar
ma5> import Wj*.lhe as Wjets
```

3. Plotting histograms

Defining an analysis: plots

Histograms

- Observable can be related to the event or the properties of a particle
- Plethora of observables: **N, E, ET, M, MT, P, PT, PX, PY, PZ, THETA, ETA, …, ALPHAT**
- Including sophisticated observables: **ALPHAT, MT2, MT2W**

```
ma5> plot MET
ma5> plot PT(mu)
```

```
ma5> plot M(mu+ mu-)
```

More options are available:

- Specifying the histogram binning

```
ma5> plot MET 100 0 1000
```

- Specifying other options

```
ma5> plot PT(mu) [logY]
ma5> plot MET 100 0 1000 [normalize2one]
```

3. Plotting histograms

Some global information of your analysis

```
ma5>display main
MA5:  **********************************
MA5:              main program
MA5:  **********************************
MA5:  currentdir = /grid_mnt/home/econte/MA5/v1.6/v1.6beta
MA5:  graphic renderer = root
MA5:  histogram normalization mode = lumi_weight
MA5:  integrated luminosity = 10 fb^{-1}
MA5:  output file = none
MA5:  figure of merit (fom) - formula num 4: S/sqrt(S+B)
MA5:  **********************************
MA5:  File extension readable in this session: .lhe .hep .hepmc [..]
MA5:  File extension NOT readable in this session: .root .lhco [..]
MA5:  **********************************
MA5:  fast-simulation package : none
MA5:  isolation algorithm : cone
MA5:   + cone radius = 0.5
MA5:  **********************************
MA5:  recasting mode: off
MA5:  **********************************
```

3. Plotting histograms

Change global information of your analysis

- **Integrated luminosity**

```
ma5> set main.lumi=1000
```

- **Normalization of plots**

```
ma5> set main.normalize =
lumi    lumi_weight    none
```

- **Stacking method of plots**

```
ma5>set main.stacking_method =
normalize2one    stack    superimpose
```

- **Choice of the graphical render**

```
ma5> set main.graphic_render =
matplotlib      none   root
```

3. Plotting histograms

Launching the analysis:

This can be done by the command **submit**

- Creating a working directory (with a default name if no name is specified)
- Compiling the C++ job
- Launching the analysis over the different samples contained in the datasets

```
* SampleAnalyzer 2.0 for MadAnalysis 5 - Welcome.
* Option choices: selecting analysis = 'MadAnalysis5job'.
* Extracting the following sample files:
* 1/4  ~/samples/ttbar_sl_1.lhe.gz
    => file size : 107.09 Mo
    => sample produced by MadGraph.
    => progress [======================>          ]
```

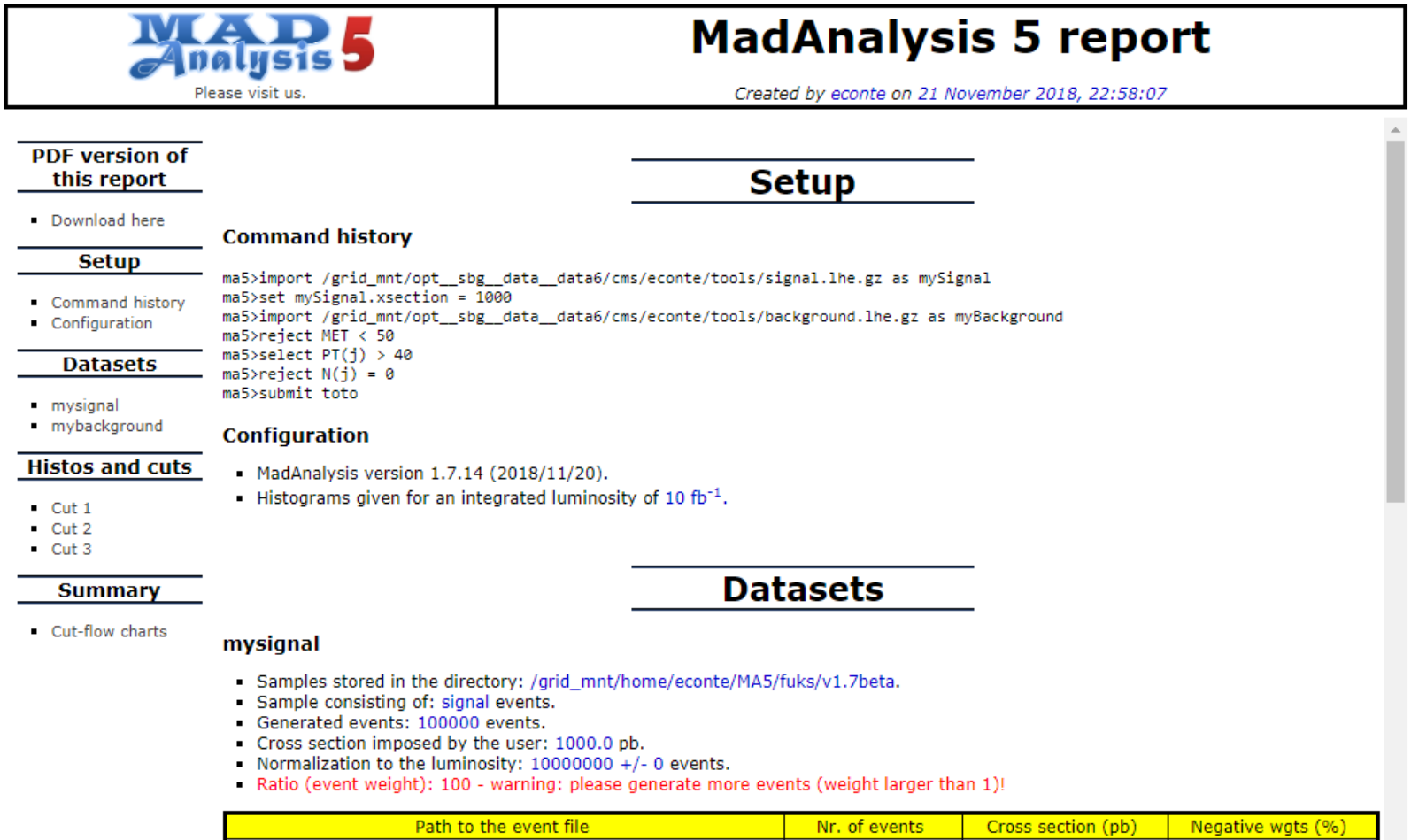
If you modify, after the submission, the analysis or the layout of the plots , the results can be updated in an optimized way by the command **resubmit**.

3. Plotting histograms

Opening a generated report:

The command **open** displays the HTML report of the last job created.

Reports in PDF and DVI format are also available.



MadAnalysis 5 report

Created by econte on 21 November 2018, 22:58:07

Please visit us.

PDF version of this report
- Download here

Setup
- Command history
- Configuration

Datasets
- mysignal
- mybackground

Histos and cuts
- Cut 1
- Cut 2
- Cut 3

Summary
- Cut-flow charts

Setup

Command history

```
ma5>import /grid_mnt/opt__sbg__data__data6/cms/econte/tools/signal.lhe.gz as mySignal
ma5>set mySignal.xsection = 1000
ma5>import /grid_mnt/opt__sbg__data__data6/cms/econte/tools/background.lhe.gz as myBackground
ma5>reject MET < 50
ma5>select PT(j) > 40
ma5>reject N(j) = 0
ma5>submit toto
```

Configuration
- MadAnalysis version 1.7.14 (2018/11/20).
- Histograms given for an integrated luminosity of 10 fb^{-1}.

Datasets

mysignal
- Samples stored in the directory: /grid_mnt/home/econte/MA5/fuks/v1.7beta.
- Sample consisting of: signal events.
- Generated events: 100000 events.
- Cross section imposed by the user: 1000.0 pb.
- Normalization to the luminosity: 10000000 +/- 0 events.
- Ratio (event weight): 100 - warning: please generate more events (weight larger than 1)!

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)

3. Plotting histograms

Opening a generated report: Details on sample information

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
mg5_merged.hep.gz	5116	162.0	0.0

Path to the event file	Nr. of events	Cross section (pb)	Negative wgts (%)
amcatnlo.hw.hep.gz	9993	313	8.4

- By default, MadAnalysis5 takes into account the **event-weights** contained in the samples. If no event-weights are available, there are set to one.

- MadAnalysis5 handles **negative event-weights** produced by NLO generators and propagates them properly into the uncertainties calculation.

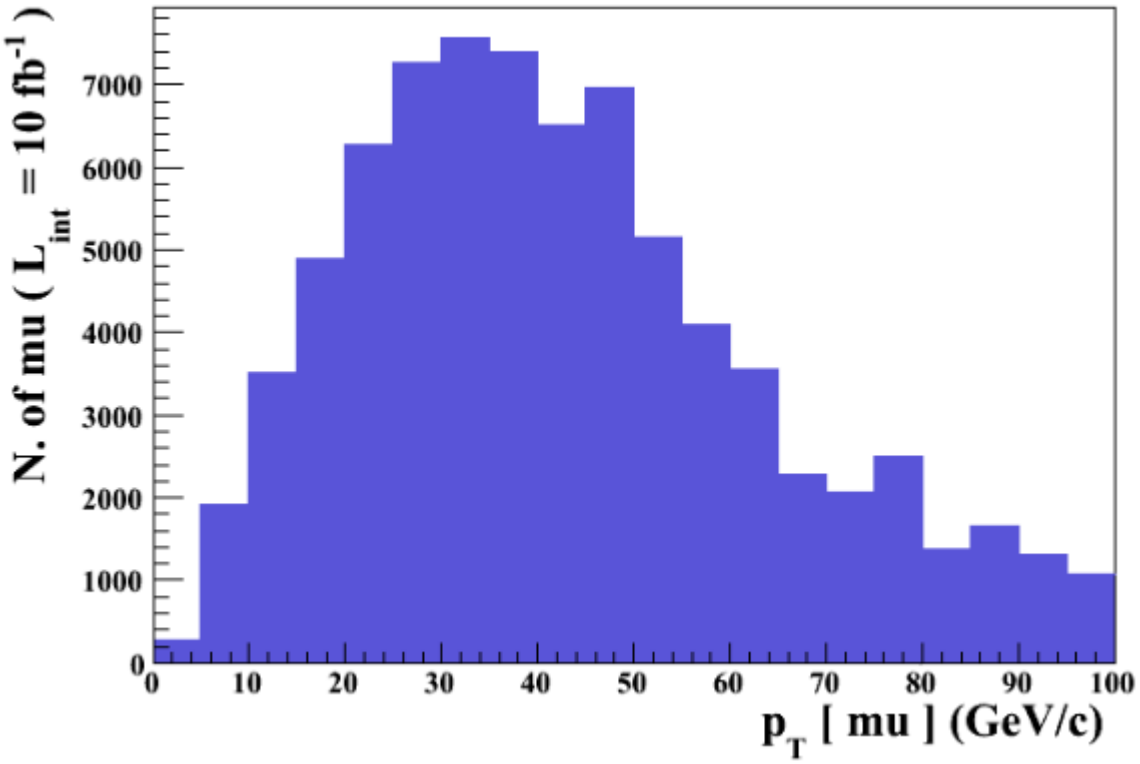
3. Plotting histograms

Opening a generated report:

Details on histogramming

Dataset	Integral	Entries / events	Mean	RMS	Underflow	Overflow
defaultset	82747	0.752	42.8177	21.36	0.0	1.296

Statistics table



- the cross section of the sample is automatically extracted from the sample
- Integrated luminosity is by default 10 fb^{-1}. This value can be set by the user:

```
ma5> set main.lumi =
```

3. Plotting histograms

Accessing histogram scripts

- **When you launch an analysis, MadAnalysis 5 will save the histograms in scripts:**
  - A C++ script for ROOT
  - A Python script for Matplotlib

  → Easy to tune your figures before publishing

This script can be found in the folder: <analysis folder>/Histos/selection_*

Displaying the histograms can be done with ROOT or Matplotlib
(if you have installed them) :

```
bash> root selection_0.C
```

```
bash> python selection_0.py
```

3. Plotting histograms

MadAnalysis 5

MG_aMC@NLO

arXiv:1405.0301 [hep-ph]

- **Installing MadAnalysis 5 from MG_aMC@NLO console**

```
MG_aMC@NLO> install MadAnalysis
```

- **Defining the physics process and launching the generation**

```
The following switches determine which programs are run:
/-------------------------------------------------------------------------------------\
|  1. Choose the shower/hadronization program:          shower = Not installed     |
|  2. Choose the detector simulation program:         detector = Not installed     |
|  3. Run an analysis package on the events generated: analysis = MADANALYSIS_5    |
|  4. Decay particles with the MadSpin module:         madspin = OFF               |
|  5. Add weights to events for different model hypothesis: reweight = OFF         |
\-------------------------------------------------------------------------------------/
```

3. Plotting histograms

```
Do you want to edit a card (press enter to bypass editing)?
/-----------------------------------------------------------\
|  1. param                : param_card.dat                 |
|  2. run                  : run_card.dat                   |
|  3. madanalysis5_parton  : madanalysis5_parton_card.dat   |
|  4. madanalysis5_hadron  : madanalysis5_hadron_card.dat   |
\-----------------------------------------------------------/
```

MadAnalysis5 interface

Generation of a default analysis card tuned for the final state produced *(here a dilepton pair production)*

```
# Multiparticle definition
define vl = 12 14 16
define vl~ = -16 -14 -12
define invisible = ve ve~ vm vm~ vt vt~ vl vl~

# Histogram drawer (options: matplotlib or root)
set main.graphic_render = root

# Global event variables
plot THT   40 0 500 [logY]
plot MET   40 0 500 [logY]
plot SQRTS 40 0 500 [logY]
# PT and ETA distributions of all particles
plot  PT(e-[1]) 40 0  500 [logY]
plot ETA(e-[1]) 40 -10 10 [logY]
plot  PT(e+[1]) 40 0  500 [logY]
plot ETA(e+[1]) 40 -10 10 [logY]
# Invariant-mass distributions
plot M(e-[1] e+[1]) 40 0  500 [logY ]
# Angular distance distributions
plot DELTAR(e-[1],e+[1]) 40 0 10 [logY ]
```

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4. Defining a simple selection

Importing datasets

- Possibility to tag datasets as **signal** or **background**.

```
ma5> set ttbar.type = signal
ma5> set Wjets.type = background
```

Change the FOM (figure of merit)

- **Figure of merit (FOM) formula**

```
ma5> set main.fom.formula = 1
```

1 = S/B, 2=S/sqrt(B) , 3=S/(S+B), 4=S/sqrt(S+B), 5=S/sqrt(S+B+xB^2)

```
ma5> set main.fom.x = 0.1
```

4. Defining a simple selection

Defining an analysis: cuts

2 equivalent commands are available:

- **Select:** keep an event if a criterion is satisfied
- **Reject:** remove an event if a criterion is satisfied

- **Cuts : selecting / rejecting events**

```
ma5> reject MHT < 50
ma5> select N(mu) >= 2
```

- **Cuts : selecting / rejecting a particle or a combination**

```
ma5> select (mu) PT > 50
ma5> select 80 < M (mu+ mu-) < 100
```

4. Defining a simple selection

Signal regions

- Defining a signal region:

```
ma5> define_region S1
ma5> define_region S2
```

- Applying a cut selection in a given signal region

```
ma5> select N(b)=1 {S1}
ma5> select N(b)=2 {S2}
ma5> select N(j)>0 {S1 S2}
ma5> select N(mu)>0
```

- Display all defined signal regions and the corresponding selection cuts:

```
ma5> display_regions
MA5:  ****** List of defined regions *****
MA5:  > Region 1: S1
MA5:   ** Cut - 1: select N ( b ) = 1.0
MA5:   ** Cut - 2: select N ( j ) > 0.0
MA5:   ** Cut - 3: select N ( mu+ ) > 0.0
MA5:  > Region 2: S2
MA5:   ** Cut - 1: select N ( b ) = 2.0
MA5:   ** Cut - 2: select N ( j ) > 0.0
MA5:   ** Cut - 3: select N ( mu+ ) > 0.0
MA5:  ************************************
```

4. Defining a simple selection

Results displayed in the report

Cut 1

*** Cut: reject MET < 50.0**

Dataset	Events kept: K	Rejected events: R	Efficiency: K / (K + R)	Cumul. efficiency: K / Initial
mysignal	293578 +/- 507	635437 +/- 681	0.316010 +/- 0.000482	0.316010 +/- 0.000482
mybackground	6019047 +/- 19855	40968053 +/- 134259	1.28e-01 +/- 4.88e-05	1.28e-01 +/- 4.88e-05

. . .

Summary

Cut-flow charts

- How to compare signal (S) and background (B): S/sqrt(S+B).
- Object definition selections are indicated in cyan.
- Reject and select are indicated by 'REJ' and 'SEL' respectively

Cuts	Signal (S)	Background (B)	S vs B
Initial (no cut)	929016 +/- 750	46987100 +/- 153962	134.209 +/- 0.241
REJ: MET < 50.0	293578 +/- 507	6019047 +/- 19855	116.847 +/- 0.269
SEL: PT (j) > 50.0	274264 +/- 492	6019047 +/- 19855	109.328 +/- 0.258

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5. Applying recast LHC analyses

Intensive search of BSM is ongoing at the LHC:

- Looking for promising signatures (SMS, bottom-up approach, …)
- Setting limits

→ Several benchmarks are chosen for showing the performance the analysis

Ex: SUSY analysis, VLQ research, …

Difficulty to be exhaustive in interpretation:

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

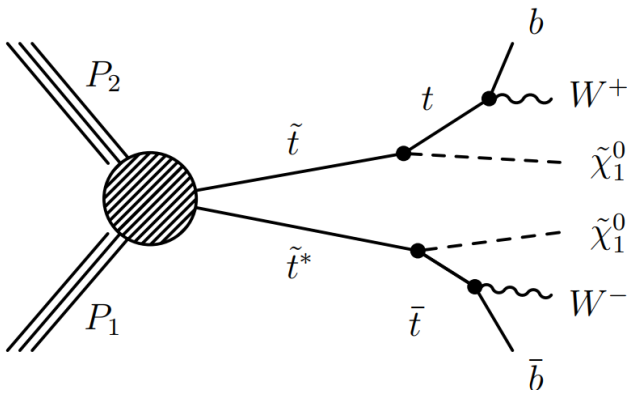
→ We must be able to launch an existing analysis, **tomorrow or in few years,** with a **different signal** benchmark and to compute a limit.

5. Applying recast LHC analyses

How to reinterpret LHC results?

Based on Simplified Models

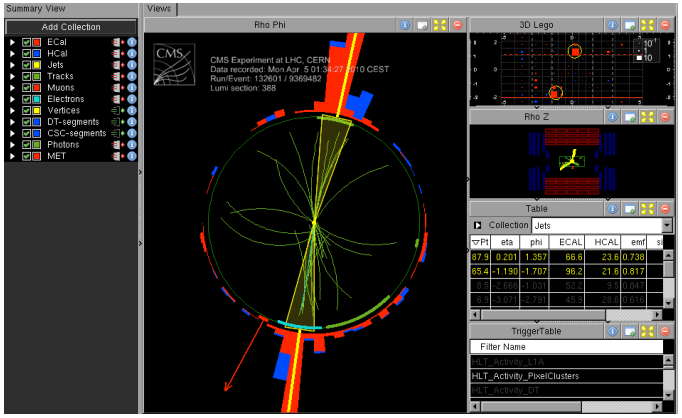
T2tt



- Work with event topology
- Properties are reduced to mass spectrum, xsection and BR

Extremely fast
Moderately accurate / general

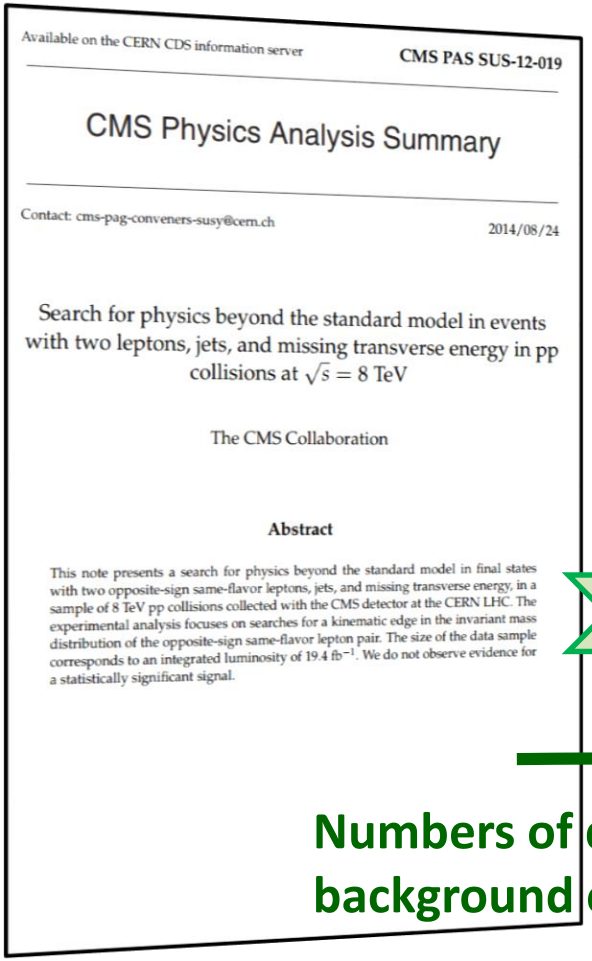
Based on Detector simulation



- Mimicking simulation + reconstruction + selection acheived by CMS or ATLAS
- « Very-fast » simulation

Very-Fast
Accurate / general

5. Applying recast LHC analyses


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.

Signal events

(STDHEP or HEPMC format)

DELPHES / DELPHESMA5TUNE

Recast selection
(Expert Mode)

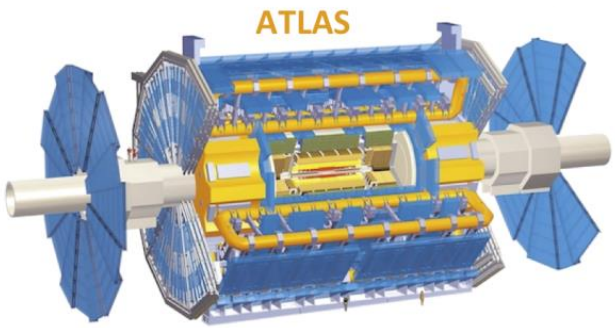
Limit computation

Numbers of data and background events

Physics Analysis Database

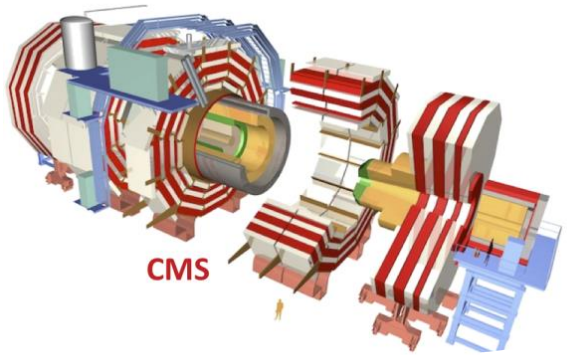
Eur.Phys.J. C74 (2014) 3103

5. Applying recast LHC analyses



Detector

very-fast-simulation



old way

Delphes MA5-Tune

Special tuning of the Delphes 3.0 package provided by MadAnalysis 5

- Reducing the ROOT size.
- Lepton & photon isolation done @ analysis level.
- More realistic parametrization of the b-tagging(mis-)efficiency @ analysis level.
- More info on generated particles.

new way

from MA5 v1.2

Delphes + MA5 card

Official Delphes release using special CMS/ATLAS detector cards provided by MadAnalysis 5

- Most of the features implemented in the official Delphes release.
- Other features are encapsulated into external Delphes modules (such as displaced leptons)
- Lepton & photon isolation always done @ analysis level **+ improvement**.

5. Applying recast LHC analyses

A database with MadAnalysis 5 implementations of LHC analyses
https://madanalysis.irmp.ucl.ac.be/wiki/PublicAnalysisDatabase

B. Dumont et al, Eur. Phys. J. C75 (2015) 56

ATLAS analyses, 13 TeV

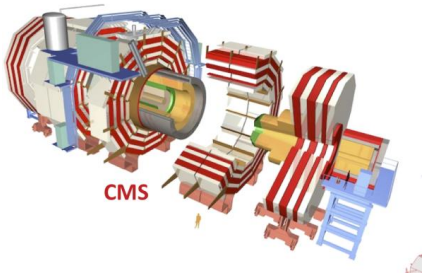
Analysis	Short Description	Implemented by	Code	Validation note	Version
ATLAS-SUSY-2015-06	Multijet + missing transverse momentum	S. Banerjee, B. Fuks, B. Zaldivar	Inspire	PDF	v1.3/Delphes3
ATLAS-SUSY-2016-07	Multijet + missing transverse momentum (36.1 fb-1)	G. Chalons, H. Reyes-Gonzalez	Inspire	PDF Pythia files	v1.7/Delphes3
ATLAS-EXOT-2015-03	Monojet (3.2 fb-1)	D. Sengupta	Inspire	PDF	v1.3/Delphes3
ATLAS-EXOT-2016-25	Mono-Higgs (36.1 fb-1)	S. Jeon, Y. Kang, G. Lee, C. Yu	Inspire	PDF	v1.6/Delphes3
ATLAS-EXOT-2016-27	Monojet (36.2 fb-1)	D. Sengupta	Inspire	PDF	v1.6/Delphes3
ATLAS-EXOT-2016-32	Monophoton (36.1 fb-1)	S. Baek, T.H. Jung	Inspire	PDF	v1.6/Delphes3
ATLAS-CONF-2016-086	b-pair + missing transverse momentum	B. Fuks & M. Zumbihl	Inspire	PDF	v1.6/Delphes3

+ analyses @ 8 TeV

5. Applying recast LHC analyses

A database with MadAnalysis 5 implementations of LHC analyses
https://madanalysis.irmp.ucl.ac.be/wiki/PublicAnalysisDatabase

B. Dumont et al, Eur. Phys. J. C75 (2015) 56



CMS analyses, 13 TeV

Analysis	Short Description	Implemented by	Code	Validation note	Version
CMS-SUS-16-033	Supersymmetry in the multijet plus missing energy channel (35.9 fb-1)	F. Ambrogi and J. Sonneveld	Inspire	PDF	v1.7/Delphes3
CMS-SUS-16-039	Electroweakinos in the SS2L, 3L and 4L channels (35.9 fb-1)	B. Fuks and S. Mondal	Inspire	PDF	v1.7/Delphes3
CMS-SUS-16-052	SUSY in the 1l + jets channel (36 fb-1)	D. Sengupta	Inspire	PDF	v1.6/Delphes3
CMS-SUS-17-001	Stops in the OS dilepton mode (35.9 fb-1)	S.-M. Choi, S. Jeong, D.-W. Kang, J. Li *et al.*	Inspire	PDF	v1.6/Delphes3
CMS-EXO-16-010	Mono-Z-boson (2.3 fb-1)	B. Fuks	Inspire	PDF	v1.6/Delphes3
CMS-EXO-16-012	Mono-Higgs (2.3 fb-1)	S. Ahn, J. Park, W. Zhang	Inspire	PDF	v1.6/Delphes3
CMS-EXO-16-022	Long-lived leptons (2.6 fb-1)	J. Chang	Inspire	PDF	v1.6_tracks/Delphes3 [1]
CMS-TOP-17-009	SM four-top analysis (35.9 fb-1)	L. Darmé and B. Fuks	Inspire	PDF	v1.7/Delphes3

+ analyses @ 8 TeV

5. Applying recast LHC analyses

Normal mode with the PYTHON console

- **Installing the required framework within MadAnalysis 5.**
  - → All available analyses are automatically downloaded from the PAD.
  - → 3 options: only Delphes-based analyses, only DelphesMA5tune-based analyses, or both.

```
ma5>install PAD
```

and/or

```
ma5>install PADForMA5tune
```

- **Importing your signal samples**
- **Activating the recasting mode**

```
ma5>set main.recast = on
```

- **Launching the processing**

```
ma5>submit
MA5: Would you like to edit the recasting Card ? (Y/N)
```

5. Applying recast LHC analyses

Recasting card: only 'ON' / 'OFF' to be changed

```
# AnalysisName              PADType     Switch      DelphesCard
cms_top_17_009               v1.2         on     delphes_card_cms_top_17_009.tcl        # CMS   - 13 TeV - 4 top anal
CMS_EXO_16_012_2gamma        v1.2         on     delphes_card_cms_exo_16_012.tcl        # CMS   - 13 TeV - Mono-Higgs
cms_sus_17_001               v1.2         on     delphes_card_cms_exo_16_010.tcl        # CMS   - 13 TeV - stops in t
CMS_SUS_16_052               v1.2         on     delphes_card_cms_SUS_16_052.tcl        # CMS   - 13 TeV - SUSY 1 lep
ATLAS_SUSY_16_07             v1.2         on     delphes_card_ATLAS_1604_07773.tcl      # ATLAS - 13 TeV - Multijet +
ATLAS_EXOT_2016_32           v1.2         on     delphes_card_atlas_2016_32.tcl         # ATLAS - 13 TeV - Monophoton
ATLAS_EXOT_2016_25           v1.2         on     delphes_card_atlas_2016_25.tcl         # ATLAS - 13 TeV - Mono-Higgs
ATLAS_1711_03301             v1.2         on     delphes_card_ATLAS_1711_03301.tcl      # ATLAS - 13 TeV - Monojet (3
ATLAS_CONF_2016_086          v1.2         on     delphes_card_ATLAS_CONF_2016_086.tcl   # ATLAS - 13 TeV - Dark matte
```

Illustrative output

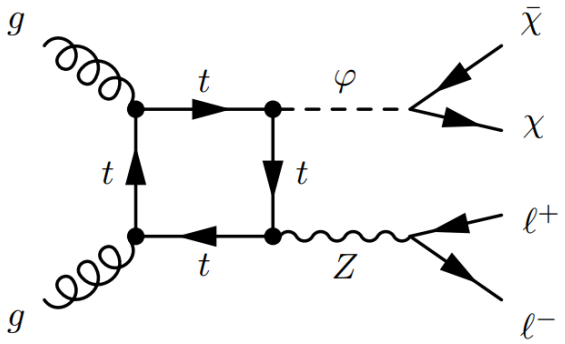
```
# dataset     analysis name       signal region     sig95(exp)      sig95(obs)   ||   efficiency    stat. unc.    syst
defaultset    ATLAS_1604_07773        EM1           4.8706612       5.1880773    ||   0.0529692     0.0341248     0.00
defaultset    ATLAS_1604_07773        EM2           2.3853053       1.8139249    ||   0.0694817     0.0387413     0.00
defaultset    ATLAS_1604_07773        EM3           1.0788100       0.6677819    ||   0.1020777     0.0461277     0.00
defaultset    ATLAS_1604_07773        EM4           0.2632191       0.3037660    ||   0.3445360     0.0724050     0.00
defaultset    ATLAS_1604_07773        EM5           0.2899671       0.4168377    ||   0.1198082     0.0494776     0.00
```

5. Applying recast LHC analyses

Example: top-philic dark model

- **Model**

simplified dark matter model where dark matter couples dominantly via a scalar mediator to top quarks

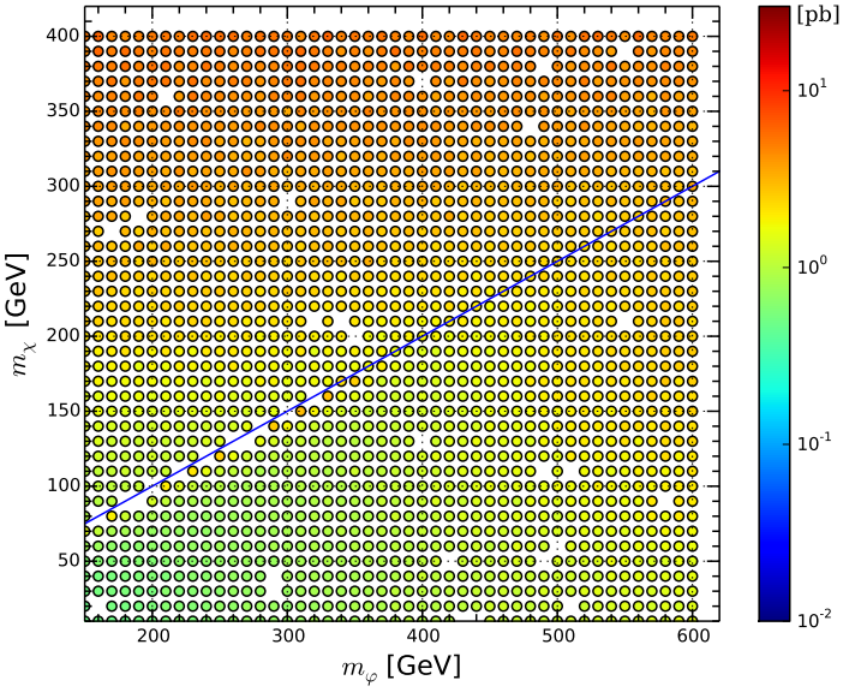


- **Recast analysis**

CMS-EXO-16-010 mono-Z analysis

2.3 fb−1 of LHC data

cross section excluded at the 95% confidence level in the plane (mϕ, mχ)



new physics couplings are set to arbitrary values

Outlines

1. What is MadAnalysis 5?
2. Software architecture
3. Plotting histograms
4. Defining a simple selection
5. Applying recast LHC analyses
6. **Epilogue**

6. Epilogue

Validation

Validation is mandatory when a new version of MadAnalysis must be released.

- Several MadAnalysis configurations are tested (presence of optional packages + release of ROOT).
- A huge collection of tests is launched on each configuration. Corresponding MadAnalysis output (reports or samples) are stored in a private database.
- Validation is performed by comparing test-by-test the results between the new and the previous MadAnalysis results.
  - Comparing numbers
  - Comparing plots

6. Epilogue

Validation

Validation success is summarized in a web page.

Validation MadAnalysis 5

Date of HTML creation: 02/06/2014

Author: Eric Conte

Versions: root-5.34.10/v1.1.10beta_v1.1.11beta/no_options/plots

Number	Scripts' description	Matching (%)	Comparison log files	Scripts v1.1.10beta	Scripts v1.1.11beta	MA5 output log v1.1.10beta	MA5 output log v1.1.11beta
0	testing all observables with Plot and 0 particle	100	plot_0part.log	plot_0part.ma5	plot_0part.ma5	plot_0part.ma5.log	plot_0part.ma5.log
1	testing all observables with Plot and 0 particle	100	plot_0part_H.log	plot_0part_H.ma5	plot_0part_H.ma5	plot_0part_H.ma5.log	plot_0part_H.ma5.log
2	testing all observables with Plot and 0 particle	100	plot_0part_R.log	plot_0part_R.ma5	plot_0part_R.ma5	plot_0part_R.ma5.log	plot_0part_R.ma5.log
3	testing all observables with Plot and 1 particle	100	plot_1part.log	plot_1part.ma5	plot_1part.ma5	plot_1part.ma5.log	plot_1part.ma5.log
4	testing all observables with Plot and 1 particle	100	plot_1part_H.log	plot_1part_H.ma5	plot_1part_H.ma5	plot_1part_H.ma5.log	plot_1part_H.ma5.log
5	testing all observables with Plot and 1 particle	100	plot_1part_R.log	plot_1part_R.ma5	plot_1part_R.ma5	plot_1part_R.ma5.log	plot_1part_R.ma5.log
6	testing all observables with Plot and 1 particle	100	plot_2parts.log	plot_2parts.ma5	plot_2parts.ma5	plot_2parts.ma5.log	plot_2parts.ma5.log
7	testing all observables with Plot and 1 particle	79	plot_2parts_H.log	plot_2parts_H.ma5	plot_2parts_H.ma5	plot_2parts_H.ma5.log	plot_2parts_H.ma5.log
8	testing all observables with Plot and 1 particle	100	plot_2parts_R.log	plot_2parts_R.ma5	plot_2parts_R.ma5	plot_2parts_R.ma5.log	plot_2parts_R.ma5.log
9	testing all observables with Plot and 3 particles	100	plot_3parts.log	plot_3parts.ma5	plot_3parts.ma5	plot_3parts.ma5.log	plot_3parts.ma5.log
10	testing all observables with Plot and 3 particles (HADRON mode)	100	plot_3parts_H.log	plot_3parts_H.ma5	plot_3parts_H.ma5	plot_3parts_H.ma5.log	plot_3parts_H.ma5.log

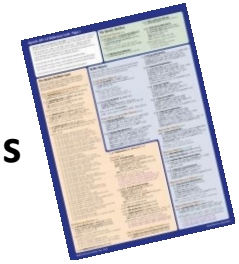
6. Epilogue

Documentation

Tutorials

- *Targeting both the normal mode & expert mode.*
- *More tutorials are expected in the next months.*
- https://madanalysis.irmp.ucl.ac.be/wiki/tutorials

Reference cards



- *A reminder of all instructions for the normal and expert mode*
- *Produced for each release of MadAnalysis 5 (since v1.6)*
- https://madanalysis.irmp.ucl.ac.be/wiki/WikiStart

Website

- *Questions / answers with the contributors*
- https://launchpad.net/madanalysis5

User-guide

- *"Confronting new physics theories to LHC data with MadAnalysis 5" (September 2018),* arXiv:1808.00480 [hep-ph]
- *Older papers are quite out of date.*

6. Epilogue

Not covered by this talk

- MadAnalysis 5 home-made detector simulation
- ME/PS merging validation plot from HEP/HEPMC samples
- Expert mode
- How to write a recast LHC analysis and to implement it to the PAD?

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https://launchpad.net/madanalysis5
Comput. Phys. Commun. 184 (2013) 222

6. Epilogue

Summary

- MadAnalysis 5 = a **unique framework** with two ways to use it :
  - **Normal mode:** python interface with intuitive commands.
  - **Expert mode:** requiring programming skills (C++, ROOT).

- MadAnalysis 5 is designed to be **user-friendly**:
  - Installation and compilation of libraries behind the scene
  - Intuitive meta-language: not complete but enough for simple cases

- MadAnalysis 5 is also a tool for **LHC reinterpretation**:
  - The PAD = collection of **VALIDATED** recast analyses from ATLAS and CMS
  - Easy to get the limit on cross-section for a process describing by a new model

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Comput. Phys. Commun. 184 (2013) 222