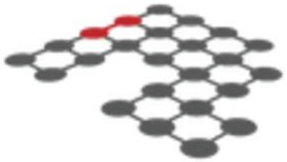

MadAnalysis 5

Version 1.6 & Beyond

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INR Terascale
13-15 December 2017 @ Marseille (France)

Outlines

1. Reminder: what is MadAnalysis 5?
2. Configuration of MadAnalysis 5
3. Signal regions in the normal mode
4. MadAnalysis embedded in MG_aMC@NLO
5. Feedback of the first MA5 school
6. Tune of Delphes & Long-Lived Particle (LLP)

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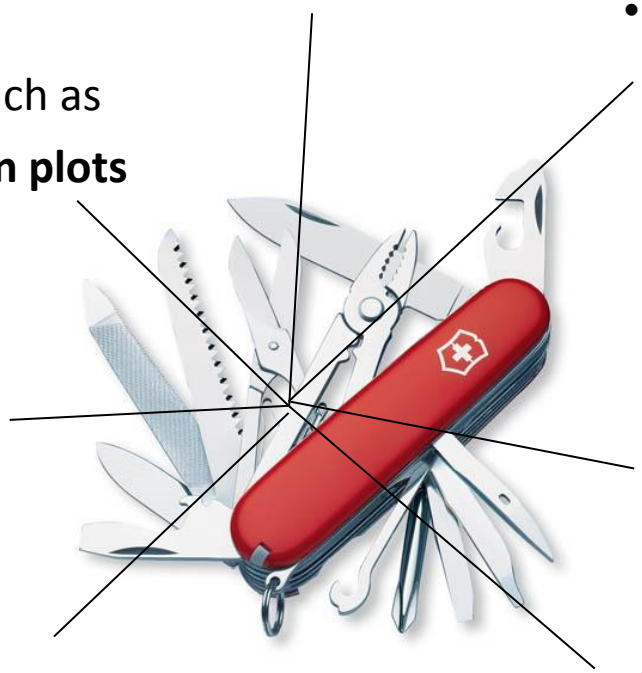
1. What is MadAnalysis 5?

MadAnalysis 5: a multi-purpose tool

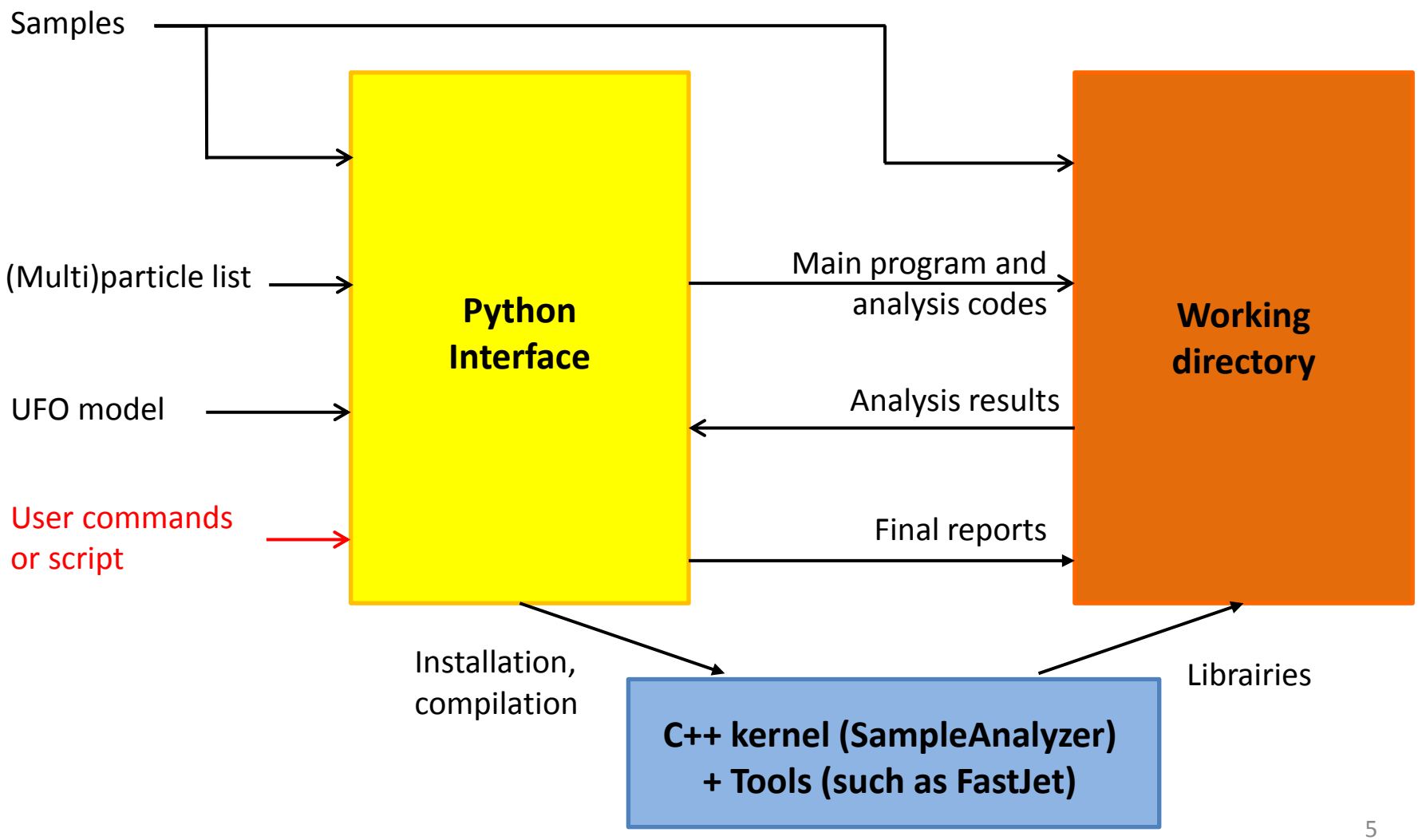
- **Histogramming and selection** in the normal mode
- **Writing** the events in another data format.
- Producing special plots such as **ME/PS merging validation plots**



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

1. What is MadAnalysis 5?

Software architecture



1. What is MadAnalysis 5?

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 SAF files

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2. Configuration of MadAnalysis 5

Required packages

Only 3 dependencies

Mandatory packages
GNU GCC g++
Python
GNU Makefile

Optional packages

Optional packages	Relative functions
FastJet	Jet clustering
Delphes	Fast detector simulation
Zlib	Reading zip files
SciPy	Statistics package for recasting

→ If the package is not found, the corresponding function is disable.

→ Easy to install with the command “install”

```
ma5>install <program name>
```

<program name> = fastjet, delphes, zlib

2. Configuration of MadAnalysis 5

Graphical driver

- **For histogramming, there are 3 possibilities:**
  - ROOT (version > 5.27)
  - MatPlotlib (version > 1.0.1)
  - None

MadAnalysis 5 chooses at the beginning of the session the best program

- **Command for changing the graphical renderer:**

```
ma5>set main.graphic_render = <program name>
```

<program name> = root, matplotlib or none

- **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_*

2. Configuration of MadAnalysis 5

Installation card

- More options in the configuration file: **madanalysis/input/installation_options.dat**

```
# ----GENERAL----
# tmp_dir = /tmp/toto/
# download_dir = /Users/fuks/Desktop/tmp
# webaccess_veto = 0 # 0=No, 1=Yes

# -----ROOT-----
# root_veto     = 0 # 0=No, 1=Yes
# root_bin_path = /home/toto/root/bin

# -----MATPLOTLIB-----
#matplotlib_veto = 0 # 0=No, 1=Yes

# -----DELPHES-----
# delphes_veto     = 0 # 0=No, 1=Yes
# delphes_includes = /Users/fuks/Work/tools/madanalysis/bzr/v1.3beta/tools/RE_delphes/
# delphes_libs     = /Users/fuks/Work/tools/madanalysis/bzr/v1.3beta/tools/RE_delphes/

# -----DELPHESMA5TUNE-----
# delphesMA5tune_veto     = 0 # 0=No, 1=Yes
# delphesMA5tune_includes = /home/toto/delphesMA5tune/include
# delphesMA5tune_libs     = /home/toto/delphesMA5tune/lib

# -----ZLIB-----
# zlib_veto     = 0 # 0=No, 1=Yes
# zlib_includes = /usr/include
# zlib_libs = /usr/lib

# -----FASTJET-----
# fastjet_veto     = 0 # 0=No, 1=Yes
```

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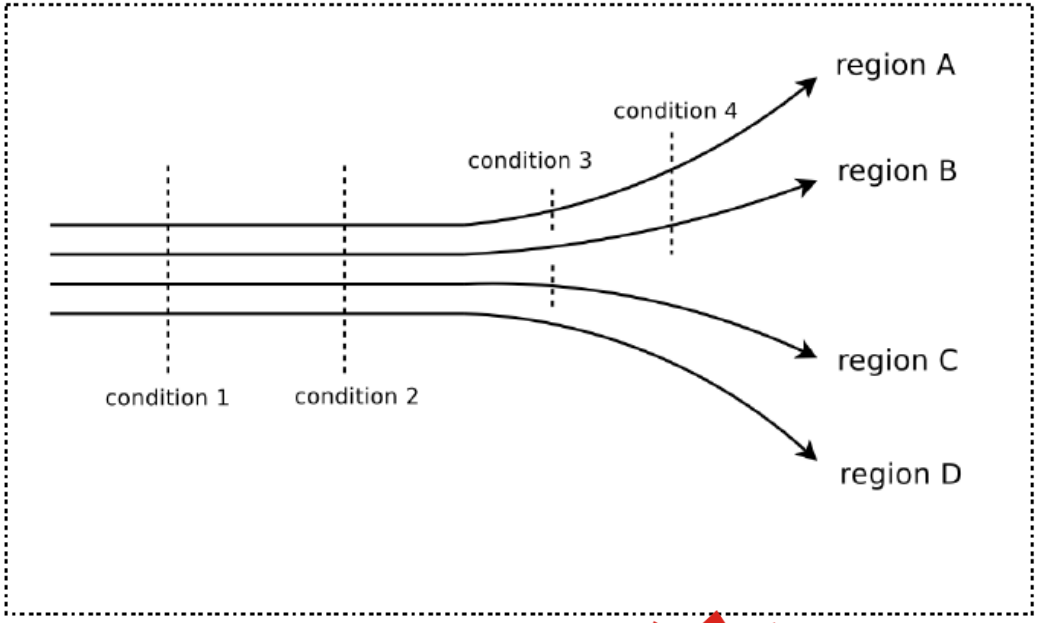
3. Signal regions

Signal regions

- Already implemented in the **expert mode**
  very useful for recasting ATLAS/CMS analyses



- Implemented now in the **normal mode**

NEW

3. 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:  ************************************
```

3. Signal regions

MADAnalysis 5
Please visit us.

MadAnalysis 5 report

Created by econte on 12 December 2017, 15:26:09

PDF version of this report

- Download here

Setup

- Command history
- Configuration

Datasets

- defaultset

Histos and cuts

- Cut 1
- Cut 2
- Cut 3
- Cut 4

Summary

- Cut-flow charts

Cut 2

*** Cut: select N (b) = 2.0**

*** Regions:** S2

Region: "S2"				
Dataset	Events kept: K	Rejected events: R	Efficiency: K / (K + R)	Cumul. efficiency: K / Initial
defaultset	0.0 +/- 0.0	109999 +/- 789	0.0 +/- 0.0	0.0 +/- 0.0

Cut 3

*** Cut: select N (j) > 0.0**

*** Regions:** S1, S2

Region: "S1"				
Dataset	Events kept: K	Rejected events: R	Efficiency: K / (K + R)	Cumul. efficiency: K / Initial
defaultset	100795 +/- 729	0.0 +/- 0.0	1.0	0.916325 +/- 0.000835

Region: "S2"				
Dataset	Events kept: K	Rejected events: R	Efficiency: K / (K + R)	Cumul. efficiency: K / Initial
defaultset	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0	0.0 +/- 0.0

3. Signal regions

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

Region: "S1"			
Cuts	Signal (S)	Background (B)	S vs B
Initial (no cut)	109999 +/- 789		
SEL: N (b) = 1.0	100795 +/- 729		
SEL: N (j) > 0.0	100795 +/- 729		
SEL: N (mu) > 0.0	34660 +/- 292		

Region: "S2"			
Cuts	Signal (S)	Background (B)	S vs B
Initial (no cut)	109999 +/- 789		
SEL: N (b) = 2.0	0.0 +/- 0.0		
SEL: N (j) > 0.0	0.0 +/- 0.0		
SEL: N (mu) > 0.0	0.0 +/- 0.0		

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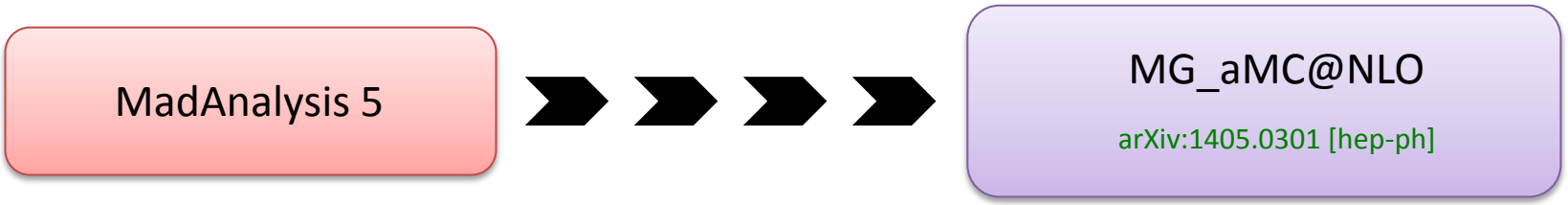
4. Embedded in MG_aMC@NLO

Collaboration work between MadGraph and MadAnalysis authors



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

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

→ strongly advised

- **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          |
\-------------------------------------------------------------------------------------/
```

4. Embedded in MG_aMC@NLO

```
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 ]
```

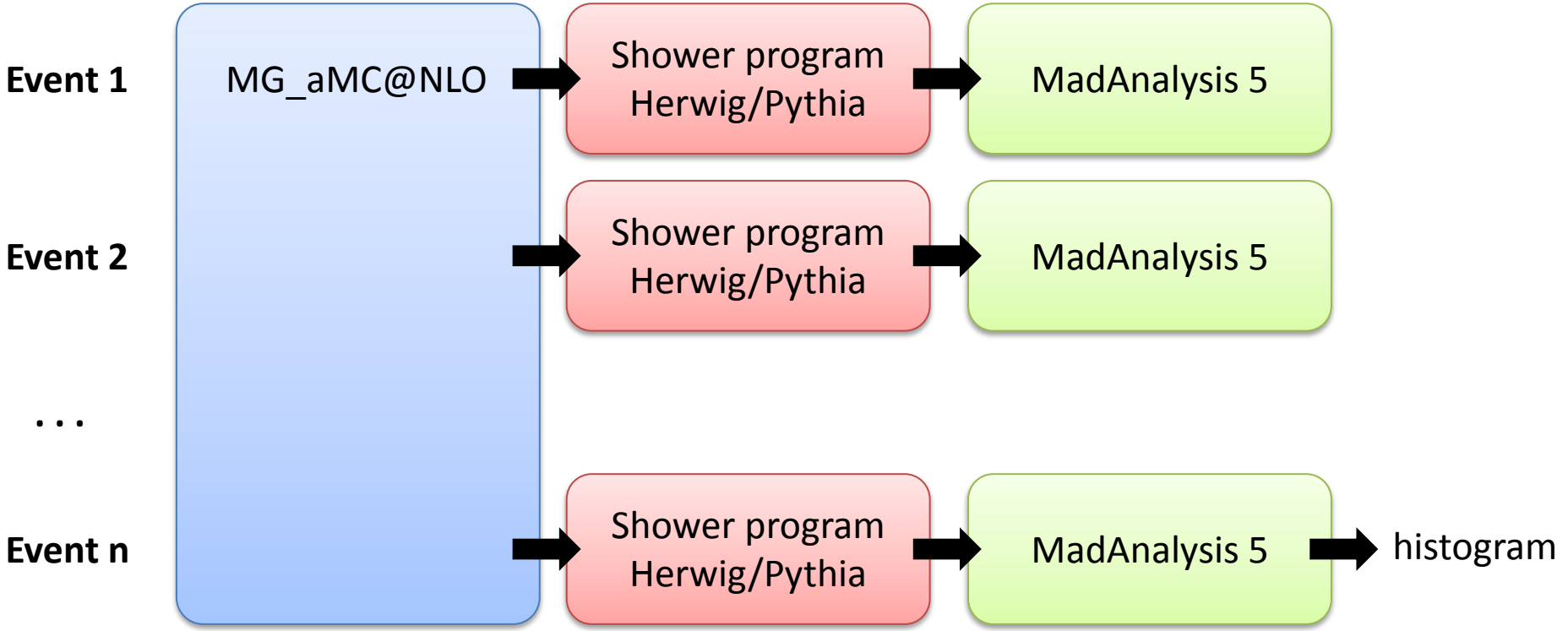
4. Embedded in MG_aMC@NLO

```
INFO: Running MadAnalysis5 [arXiv:1206.1599]
INFO: Parton input file considered:
INFO:   --> /MG5_aMC_v2_5_1/eric/Events/run_01/unweighted_events.lhe.gz
INFO: MadAnalysis5 now running the 'analysis1' analysis...
INFO: Follow Madanalysis5 run with the following command in a separate terminal:
INFO:   tail -f /MG5_aMC_v2_5_1/eric/Events/run_01/tag_1_MA5_analysis1.log
INFO: MadAnalysis5 successfully completed the analysis 'analysis1'. Reported results are placed in:
INFO:   --> /MG5_aMC_v2_5_1/eric/Events/run_01/tag_1_MA5_parton_analysis_analysis1.pdf
INFO: Finished MA5 analyses.
```

4. Embedded in MG_aMC@NLO

The FIFO mode

Goal: avoiding from storing super-heavy HEP or HEPMC data file
Beta version currently. Only available at LO QCD & for Pythia8
→ Just modify the file **pythia8_card.dat**



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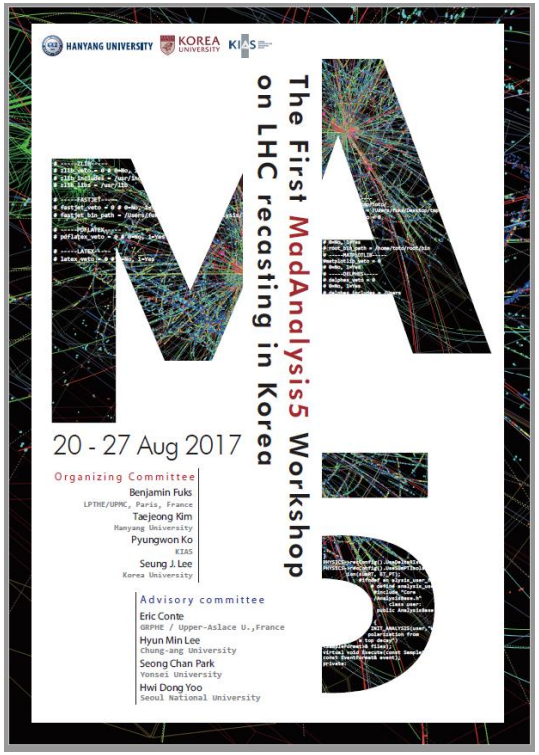
5. Feedback of the 1rst MA5 school



- Devoted to PhD students, postdocs, junior researchers or motivated people.
- The program includes both lectures and practical hands-on sessions on the reimplementation of an LHC analysis in the MA5 framework.
- Working groups of 5-6 people that will work together: one recast analysis per group.

- Big success: ~50 participants. Good results and happy students!
- Validated recast analyses will enter the Public Analysis Database.

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6. Tune of Delphes & LLP

Detector simulation based on Delphes:

2 ways

Using official cards of Delphes

DELPHES
fast simulation

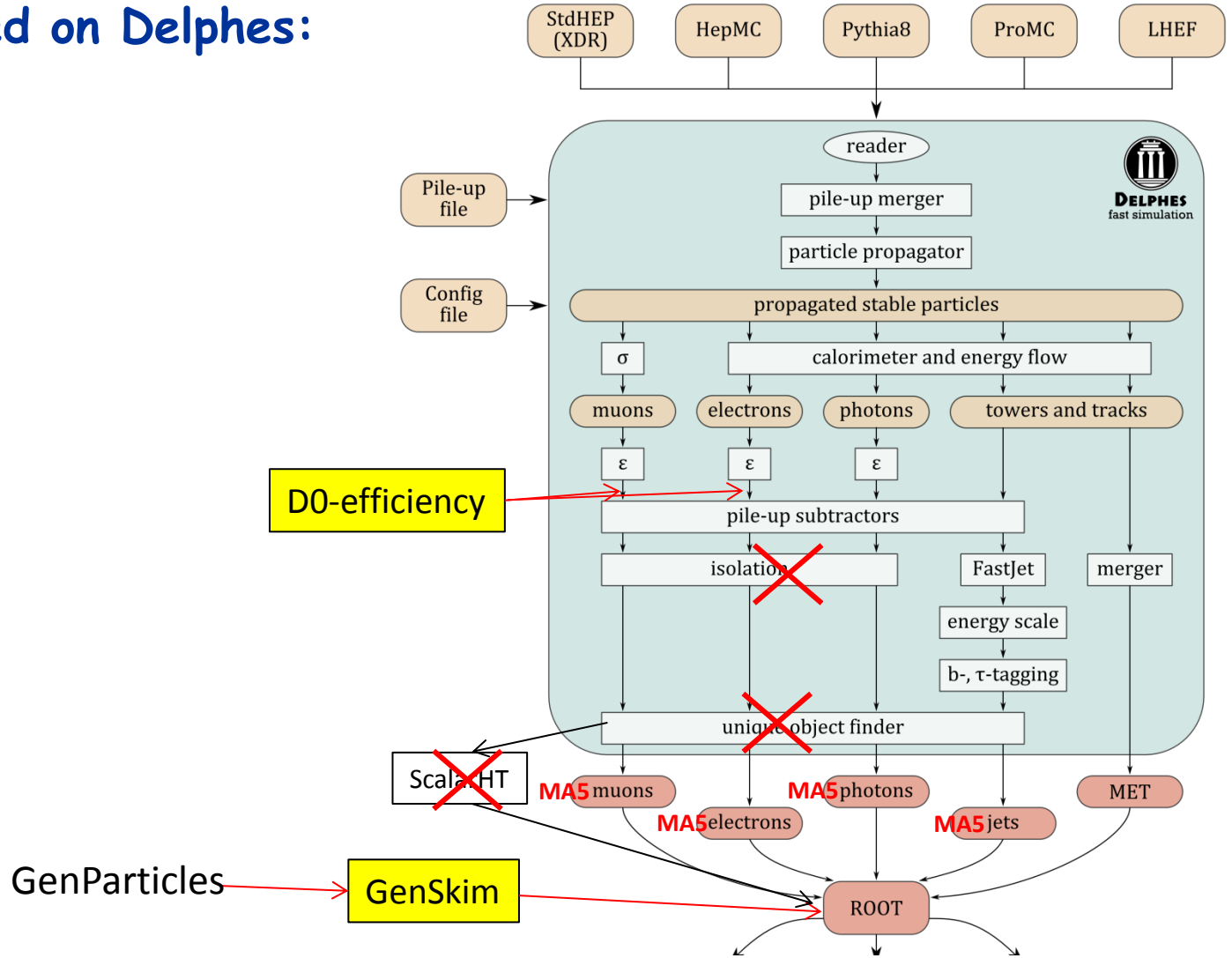
Using MA5-tune cards of Delphes

- Reducing the size of Delphes ROOT file
- Isolation @ analysis level
- Displaced tracks **[new]**

DELPHES
fast simulation

6. Tune of Delphes & LLP

Detector simulation based on Delphes:



6. Tune of Delphes & LLP

Delphes and Long-lived particles

- **The official card CMS and ATLAS does not suit LLP.**
  - If the LLP decays into charged particles in the tracker volume, the corresponding tracks are properly propagated.
  - Only the LLP decay products enter the simulation. *Example: if the LLP decays in the muon chamber, the possible interaction of LLP with the tracker and the calorimeter is ignored.*
  - Particles coming from the LLP decay are treated as prompt particles. Classical efficiency and resolution are applied to these objects.
- **But some options are available for LLP analyses:**
  - The module PARTICLEPROGATOR can be set in order to handle properly LLP which decay outside the detector volume. In this case, the LLP will be considered as MET.
  - Two complementary Delphes modules could be interesting for LLP analyses:
    - TRACKSMEARING: smearing the track momentum according to the d0 and dz parameters
    - VERTEXFINDERDA4D: determine the vertices from tracks using deterministic annealing and timing information

6. Tune of Delphes & LLP

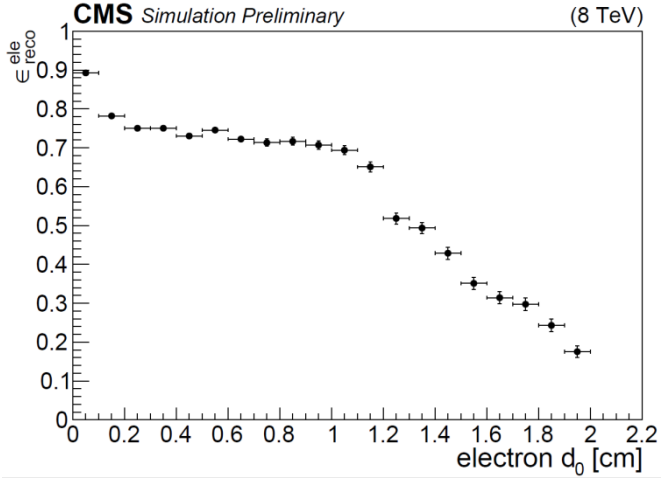
Special tune devoted to displaced leptons in MA5:

→ Special package devoted to LLP decaying in leptons

https://madanalysis.irmp.ucl.ac.be/wiki/MA5LongLivedParticle

- If the LLP decays in the tracker volume, the proper efficiency is applied to displaced tracks by a new module MA5EfficiencyD0 (using parametrization of the CMS detector)

https://twiki.cern.ch/twiki/bin/view/CMSPublic/DisplacedSusyParametrisationStudyForUser




```
set EfficiencyFormula {
(d0<=20) * (-5.06107e-7 * d0**6 +
0.0000272756 * d0**5 - 0.00049321 *
d0**4 + 0.00287189 * d0**3 + 0.00522007
* d0**2 -0.0917957 * d0 + 0.924921) +
(d0>20) * (0.00) }
```

- If the LLP decays outside the tracker volume, the LLP is ignored by the simulation.

✓ Technique validated by the recasting of the analysis CMS-EXO-16-022.
✓ Results of this recast (and its validation note) will be public soon.

6. Tune of Delphes & LLP

Other implementations are possible in Delphes+MA5:

- **Ongoing development:** simulating the B-field on charged LLP
- **Examples of possible future developments:**
  - Displaced jets:
    Delphes must provided more information on jet shape.
    A new module must be created for clustering secondary vertices based on the displaced tracks matched to jets.
  - Displaced vertices:
    To addition to the new module devoted to Displaced jets, a simple vertexing algorithm must be implemented.

Collaboration work with **Michele Selvaggi** of the Delphes team

BUT Delphes development is not enough
→ experimental inputs (efficiencies and resolutions) are essential.

Could we expect a realistic simulation with Delphes?
no trigger simulation and no simulation of fakes

Summary

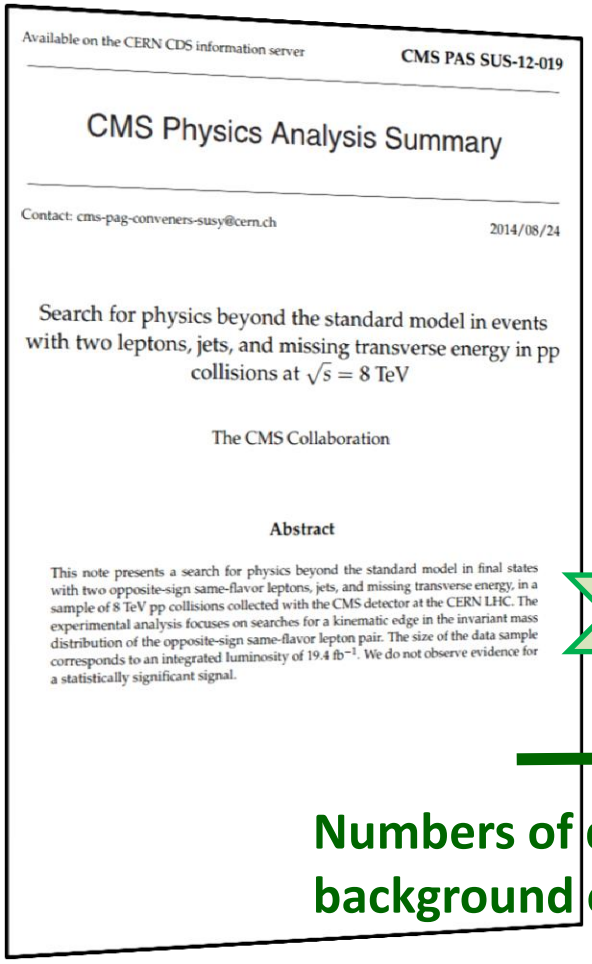
MadAnalysis 5 release: 1.6

- **A multi-purpose tool:**
  - Validating Monte Carlo production (in particle ME/PS merging conf)
  - Performing a phenomenological analysis
  - Applying a detector simulation on hadronic events
  - Applying recast analyses to a benchmark with the PAD (Physics Analysis Database) : ~ 23 recast analyses but more soon with the results of the 1rst MA5 school in Korea.
- **News:**
  - Defining signal regions in the normal mode
  - Improving the MA5 tune of Delphes for handling displaced leptons
  - New documentation available soon
- **Next developments:**
  - Multi-weights (theoretical systematics)
  - New modules for Long-Lived Particles

Backup slides

1. What is MadAnalysis 5?

MadAnalysis recasting way


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