Status (MA5 v1.5) & developments

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(Re)interpreting the results of new physics searches at the LHC
12-14 December 2016 @ CERN

Outlines

1. Reminder: what is MadAnalysis 5?

2. New core functionalities (v1.4 & v1.5)

3. MadAnalysis embedded in MG_aMC@NLO

4. Status of the Physics Analysis Database

5. Ongoing and expected developments

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**

- Designing a sophisticated analysis in the **expert mode**

- Applying **a jet-clustering algorithm** to your hadronic events

- Applying a **fast-simulation detector (Delphes)** to your hadronic events

- **Recasting an existed analysis** and **computing a limit** to a BSM signal

4
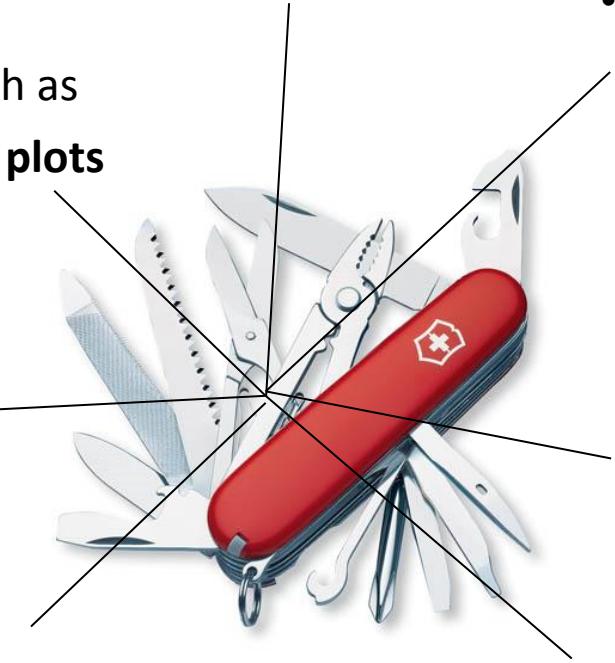
What is MadAnalysis 5?

Software architecture

Samples

(Multi)particle list

Python Interface

UFO model

User commands or script

Main program and analysis codes

Analysis results

Final reports

Working directory

Installation, compilation

C++ kernel (SampleAnalyzer) + Tools (such as FastJet)

Librairies
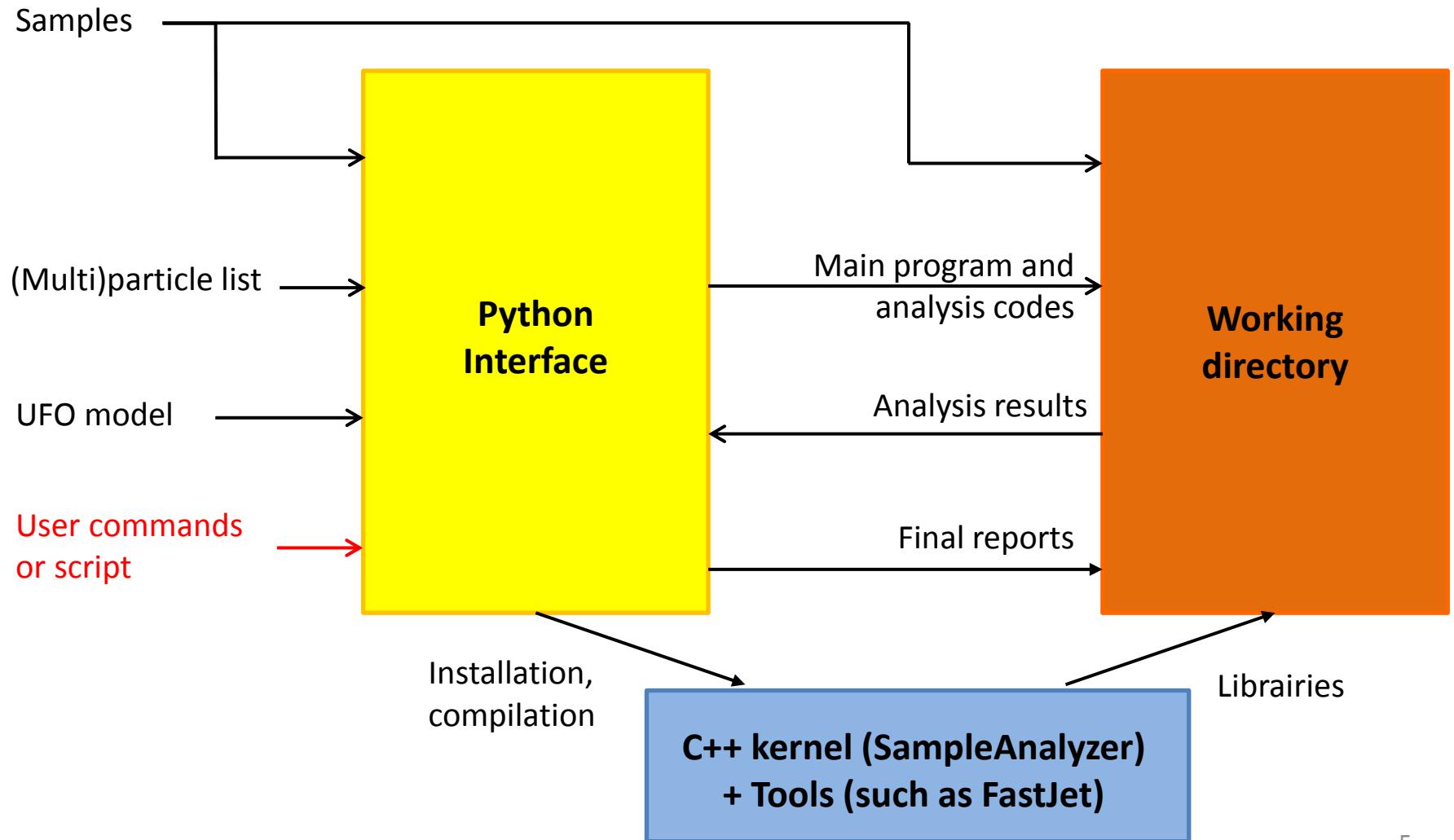
What is MadAnalysis 5?

Two ways of using MadAnalysis

Normal mode	Expert mode
= user-friendly	**= developer-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

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

MadAnalysis recasting way

Signal events
(STDHEP or HEPMC format)

DELPHES / DELPHESMA5TUNE

Recast selection (Expert Mode)

Physics Analysis Database

Numbers of data and background events

Limit computation
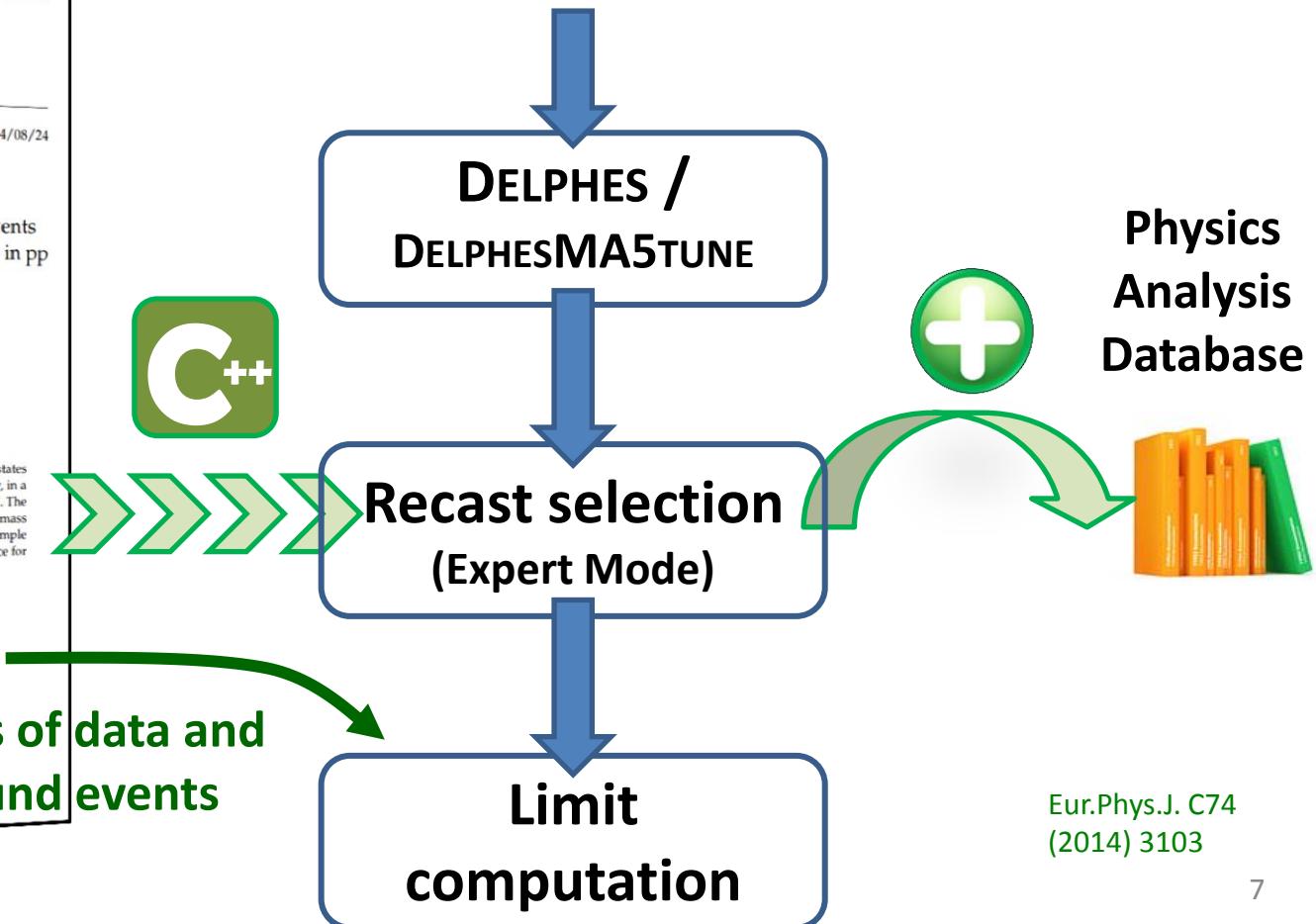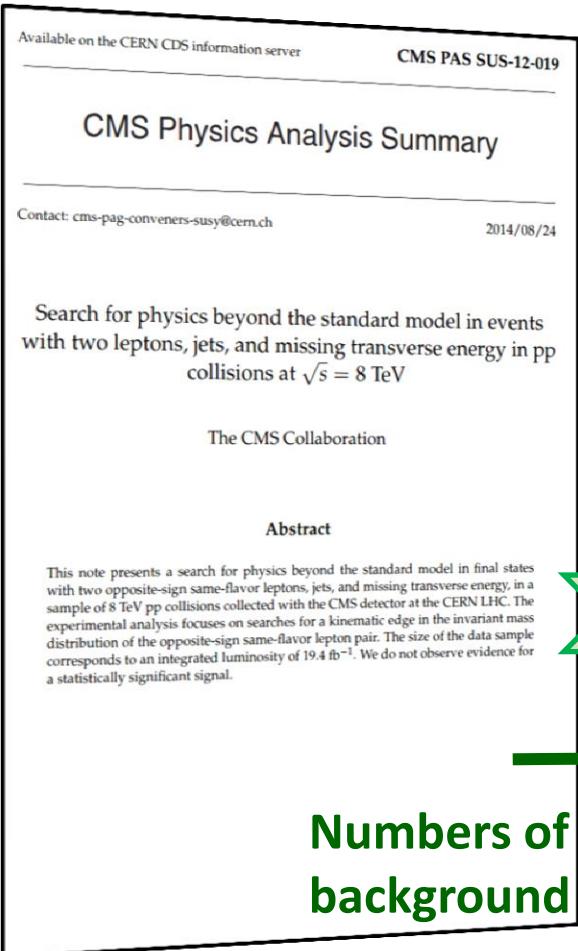
Eur.Phys.J. C74 (2014) 3103

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Reducing the number of dependencies

Mandatory packages
g++
Python
Makefile
pyROOT
ROOT
NumPy
SciPy (limit calculation)
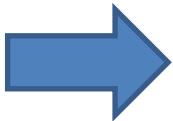
previous releases → **since 1.4**

Mandatory packages
g++
Python
Makefile

→ Easier to install MadAnalysis 5.

→ ROOT becomes an optional package but still required for Delphes & DelphesMA5tune packages (and therefore for the recasting mode).

→ MadAnalysis owns its proper geometry library and can be linked to other program for producing plots.

2. New core functionalities

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
```

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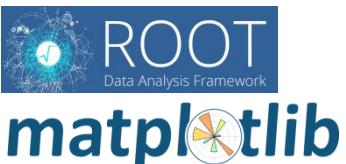
- **Command for changing the graphical renderer:**

```
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_*

3. Embedded in MG_aMC@NLO

Collaboration work between MadGraph and MadAnalysis authors
Special thank to Olivier & Valentin!

MadAnalysis 5 ▶▶▶▶ MG_aMC@NLO

arXiv:1405.0301 [hep-ph]

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

3. 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 ]
```

3. 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.
```

3. 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**
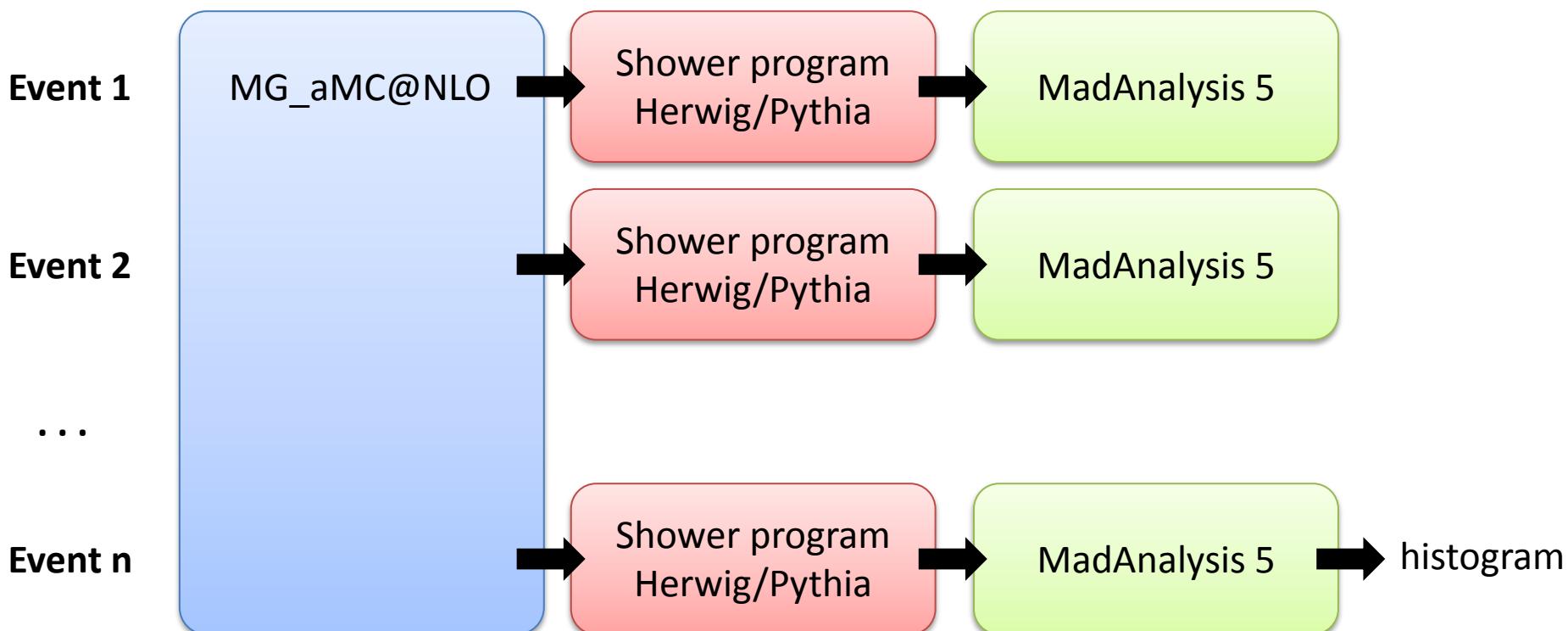
Event 1	MG_aMC@NLO	Shower program Herwig/Pythia	MadAnalysis 5	
Event 2		Shower program Herwig/Pythia	MadAnalysis 5	
...				
Event n		Shower program Herwig/Pythia	MadAnalysis 5	histogram

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4. Status of the PAD

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-EXOT-2015-03	monojet + missing transverse energy	D. Sengupta	⇨ Inspire	⇨ PDF	v1.3/Delphes3
⇨ ATLAS-SUSY-2015-06	jets + missing transverse momentum		⇨ Inspire	⇨ PDF	v1.3/Delphes3

ATLAS analyses, 8 TeV

Analysis	Short Description	Implemented by	Code	Validation note	Version
⇨ ATLAS-SUSY-2013-05 (published)	stop/sbottom search: 0 leptons + 2 b-jets	G. Chalons	⇨ Inspire	⇨ PDF ⇨ (figures)	MA5tune
⇨ ATLAS-SUSY-2013-11 (published)	EWK-inos, 2 leptons + MET	B. Dumont	⇨ Inspire	⇨ PDF ⇨ (source)	MA5tune
⇨ ATLAS-HIGG-2013-03 (published)	ZH->ll+invisible	B. Dumont	⇨ Inspire	⇨ PDF ⇨ (source)	MA5tune
⇨ ATLAS-EXOT-2014-06 (published)	mono-photons + MET	D. Barducci	⇨ MA5tune ⇨ v1.2/Delphes3	⇨ PDF ⇨ MadGraph cards	MA5tune + v1.2/Delphes3
⇨ ATLAS-SUSY-2014-10 (published)	2 leptons + jets + MET	B. Dumont	⇨ Inspire	⇨ PDF ⇨ (source)	MA5tune
⇨ ATLAS-SUSY-2013-21 (published)	0 leptons + mono-jet/c-jets + MET	G. Chalons, D. Sengupta	⇨ Inspire	⇨ PDF ⇨ (source)	MA5tune
⇨ ATLAS-SUSY-2013-02 (published)	0 leptons + 2-6 jets + MET	G. Chalons, D. Sengupta	⇨ Inspire	⇨ PDF	MA5tune
⇨ ATLAS-SUSY-2013-04 (published)	0 leptons + >6 jets + MET	B. Fuks, M. Blanke, I. Galon	⇨ Inspire	⇨ PDF	MA5tune

Big work achieved by the PAD collaboration

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, 8 TeV

Analysis	Short Description	Implemented by	Code	Validation note	Version
⇨ CMS-SUS-13-011 (published)	stop search in the single lepton mode	B. Dumont, B. Fuks, C. Wymant	⇨ Inspire [1]	⇨ PDF ⇨ (source)	MA5tune
⇨ CMS-SUS-13-012 (published)	gluino/squark search in jet multiplicity and missing energy	S. Bein, D. Sengupta	⇨ Inspire	⇨ PDF ⇨ (source)	MA5tune
⇨ CMS-SUS-13-016 (PAS)	search for gluinos using OS dileptons and b-jets	D. Sengupta, S. Kulkarni	⇨ Inspire	⇨ PDF ⇨ (source)	MA5tune
⇨ CMS-SUS-14-001 (published)	Third-generation squarks in fully hadronic final states (monojet analysis)	S. Sharma, S. Pandey	⇨ Inspire	⇨ PDF	MA5tune
⇨ CMS-SUS-14-001 (published)	Third-generation squarks in fully hadronic final states (top-tag analysis)	S. Bein, P. Atmasiddha, S. Sharma	⇨ Inspire	⇨ PDF	MA5tune
⇨ CMS-B2G-12-012 (published)	T5/3 top partners in same-sign dilepton channel	D. Barducci, C. Delaunay	⇨ Inspire	⇨ PDF ⇨ (source), ⇨ cards	v1.2/Delphes3
⇨ CMS-B2G-12-022 (published)	Monotops	J. Guo, E. Conte, B. Fuks	To appear	To appear	v1.2/Delphes3
⇨ CMS-B2G-14-004 (published)	Dark matter with top quark pairs (single lepton)	B. Fuks and A. Martini	⇨ Inspire	⇨ PDF ⇨ MadGraph cards	v1.2/Delphes3
⇨ CMS-EXO-12-047 (published)	Monophoton	J. Guo, E. Conte, B. Fuks	⇨ Inspire	⇨ PDF ⇨ Pythia script	v1.2/Delphes3
⇨ CMS-EXO-12-048 (published)	Monojet	J. Guo, E. Conte, B. Fuks	⇨ Inspire	⇨ PDF ⇨ MadGraph cards	v1.2/Delphes3

Big work achieved by the PAD collaboration

- **Installing the required framework within MadAnalysis 5.**

  Normal mode with the PYTHON console

  → All available analyses are automatically downloaded from the PAD.
  → 3 options: only Delphes-based analyses, only DelphesMA5tune-based analyses, or both.

```
ma5>install PADForMA5tune
```
and/or
```
ma5>install PAD
```

- **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)
```

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

```
# AnalysisName              PADType    Switch    DelphesCard
atlas_susy_2013_04          v1.1       off      delphes_card_atlas_sus_2013_04.tcl          # ATLAS - multijet + met
atlas_sus_13_05             v1.1       on       delphes_card_atlas_sus_2013_05.tcl          # ATLAS - stop/sbottom - 0 lepton + 2 bjets + met
atlas_susy_2013_11          v1.1       off      delphes_card_atlas_sus_2013_11.tcl          # ATLAS - ewkinos - 2 leptons + met
atlas_susy_2013_21          v1.1       off      delphes_card_atlas_sus_2013_05.tcl          # ATLAS - monojet
atlas_susy_2014_10          v1.1       off      delphes_card_atlas_sus_2014_10.tcl          # ATLAS - squark-gluino - 2 leptons + jets + met
atlas_1405_7875             v1.1       off      delphes_card_atlas_sus_2013_11.tcl          # ATLAS - squark-gluino - 0 leptons + 2-6 jets + met
atlas_higg_2013_03          v1.1       off      delphes_card_atlas_sus_2013_11.tcl          # ATLAS - ZH to invisible + 2 leptons
cms_sus_13_012              v1.1       off      delphes_card_cms_standard.tcl               # CMS   - squark-gluino - MET/MHT
cms_sus_13_016              v1.1       off      delphes_card_cms_standard.tcl               # CMS   - gluinos - 2 leptons + bjets + met
cms_sus_14_001_TopTag       v1.1       on       delphes_card_cms_sus14004.tcl               # CMS   - stop - the top tagging channel
cms_sus_14_001_monojet      v1.1       off      delphes_card_cms_standard.tcl               # CMS   - stop - the monojet channel
cms_sus_13_011              v1.1       on       delphes_card_cms_standard.tcl               # CMS   - stop - 1 lepton + bjets + met
ATLAS_EXOT_2014_06          v1.2       off      delphes_card_atlas_sus_2013_05_pad.tcl      # ATLAS - monophoton
cms_exo_12_047              v1.2       off      delphes_card_cms_b2g_12_012.tcl             # CMS   - monophoton
cms_exo_12_048              v1.2       off      delphes_card_cms_b2g_12_012.tcl             # CMS   - monojet
cms_b2g_14_004              v1.2       off      delphes_card_cms_b2g_14_004.tcl             # CMS   - Dark matter production with a ttbar pair
cms_b2g_12_022              v1.2       off      delphes_card_cms_b2g_14_004.tcl             # CMS   - Monotop search
CMS_B2G_12_012              v1.2       off      delphes_card_cms_b2g_12_012.tcl             # CMS   - T5/3 partners in the SSDL channel
```

Illustrative output (beware of low statistics for the example)

# analysis name	signal region	sig95(exp)	sig95(obs)	||	efficiency	stat. unc
cms_sus_13_011	Stop->T+neutralino, LowDeltaM, MET>200	0.3301365	0.2651069	||	0.0070623	0.0083740
cms_sus_13_011	Stop->T+neutralino, LowDeltaM, MET>250	-1	-1	||	0.0000000	0.0000000
cms_sus_13_011	Stop->T+neutralino, LowDeltaM, MET>300	-1	-1	||	0.0000000	0.0000000
cms_sus_13_011	Stop->T+neutralino, HighDeltaM, MET>150	-1	-1	||	0.0000000	0.0000000
cms_sus_13_011	Stop->T+neutralino, HighDeltaM, MET>200	-1	-1	||	0.0000000	0.0000000
cms_sus_13_011	Stop->T+neutralino, HighDeltaM, MET>250	-1	-1	||	0.0000000	0.0000000
cms_sus_13_011	Stop->T+neutralino, HighDeltaM, MET>300	-1	-1	||	0.0000000	0.0000000
cms_sus_13_011	Stop->b+chargino, LowDeltaM, MET>100	2.9531986	2.7750373	||	0.0070623	0.0083740
cms_sus_13_011	Stop->b+chargino, LowDeltaM, MET>150	1.1270604	0.8966912	||	0.0070623	0.0083740
cms_sus_13_011	Stop->b+chargino, LowDeltaM, MET>200	0.4476290	0.3246151	||	0.0070623	0.0083740
cms_sus_13_011	Stop->b+chargino, LowDeltaM, MET>250	-1	-1	||	0.0000000	0.0000000

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5. Ongoing developments

Technical developments

- **Taking into account the multi-weights samples**
  - *Several motivations: PDF choice, scale choice, BSM model scenario, …*
  - *Read the multi-weights and compute the combination*
  - *Produce automatically plots with a band*

- **Extending the meta-language for the normal mode**
  - *Multi-analysis will be available in the normal mode*

- **Report Generator for the expert mode**
  - *Produce plots and cut-flow chart from the produced SAF files*
  - *A configuration card to edit for changing general setting (ex: luminosity, …)*

- **New graphical drivers**
  Currently the plots are produced by using Root or Matplotlib.
  Other formats are expected : Gnuplot, D3 (Data Driven Document), …

Documentation

Tutorials

- *The first tutorial are available & validated for MA5 v1.5.*
- *Targeting both the normal mode & expert mode.*
- *More tutorials are expected in the next months.*
- https://madanalysis.irmp.ucl.ac.be/wiki/tutorials

Reference card

- *A reminder of MA5 in only one sheet of paper.*
- *To be appeared soon.*

Website

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

User-guide

- *Available ones are quite out of date.*
- *A new user-guide should be released.*

More recast analyses...

current release: 1.5 (12 December 2016)

- **A multi-purpose tool, in particular for reinterpretation:**

  - Recast analyses are stored on the **PAD (Physics Analysis Database)**
    ~ 20 recast LHC8 analyses ; ~ 2 LHC13 analyses ; more soon

  - All the recast analyses can be applied on a given signal
    in order to determine if this signal is excluded or not.

- **News:**

  - Now MADANALYSIS 5 is fully interfaced to MG_aMC@NLO.

  - Its installation is simplified by reducing the number of dependencies.

  - Plots can be produced by ROOT or MATPLOTLIB.

- **Next developments:**

  - Multi-weights (theoretical systematics)

  - Extending the metalanguage

  - Improving the documentation