(Re)interpreting the results of new physics searches at the LHC
12-14 December 2016 @ CERN
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
1. Reminder: what is MadAnalysis 5?

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What is MadAnalysis 5?

MadAnalysis 5: a multi-purpose tool

- Histogramming and selection in the normal mode
- Producing special plots such as ME/PS merging validation plots
- Applying a jet-clustering algorithm to your hadronic events
- Applying a fast-simulation detector (Delphes) to your hadronic events
- Writing the events in another data format.
- Designing a sophisticated analysis in the expert mode
- Recasting an existed analysis and computing a limit to a BSM signal
What is MadAnalysis 5?

**Software architecture**

Samples -> (Multi)particle list -> UFO model -> User commands or script -> Python Interface

Python Interface -> Main program and analysis codes

Main program and analysis codes -> Analysis results

Analysis results -> Final reports

Installation, compilation -> C++ kernel (SampleAnalyzer) + Tools (such as FastJet)

Final reports -> Working directory

Librairies
What is MadAnalysis 5?

Two ways of using MadAnalysis

Normal mode = user-friendly

- Based on a Python console
- Analysis definition is based on an 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
What is MadAnalysis 5?

MadAnalysis recasting way

Signal events
(STDHEP or HEPMC format)

DELPHES /
DELPHESMA5TUNE

Recast selection
(Expert Mode)

Limit computation

Numbers of data and background events

Physics
Analysis
Database

(2014) 3103
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2. New core functionalities

Reducing the number of dependencies

<table>
<thead>
<tr>
<th>Mandatory packages</th>
<th>previous releases</th>
<th>since 1.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>g++</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Python</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Makefile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pyROOT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROOT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NumPy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SciPy (limit calculation)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

→ 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: `madanalyzer/input/installation_options.dat`

```bash
# ----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/madanalyzer/bzr/v1.3beta/tools/RE_delphes/
# delphes_libs    = /Users/fuks/Work/tools/madanalyzer/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
```

Installation card
2. New core functionalities

Graphical driver

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

- Command for changing the graphical renderer:

  \[
  \text{ma5}\text{>set main.graphic\_render = <program name>}
  \]

  <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
  \(\Rightarrow\) Easy to tune your figures before publishing

This script can be found in the folder: <analysis folder>/Histos/selection_*
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3. Embedded in \texttt{MG\_aMC@NLO}

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

\begin{itemize}
\item \textbf{Installing MadAnalysis 5 from MG\_aMC@NLO console}
\end{itemize}

\begin{verbatim}
MG\_aMC@NLO> install zlib
MG\_aMC@NLO> install MadAnalysis
\end{verbatim}

\begin{itemize}
\item \textbf{Defining the physics process and launching the generation}
\end{itemize}

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 = \texttt{MADANALYSIS\_5} |
| 4. Decay particles with the MadSpin module: | madspin = OFF |
| 5. Add weights to events for different model hypothesis: | reweight = OFF |
---

MadAnalysis5 interface

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

```plaintext
# 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

...  Shower program Herwig/Pythia  MadAnalysis 5

Event n  shower program Herwig/Pythia  MadAnalysis 5  histogram
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4. Status of the Physics Analysis Database

5. Ongoing and expected developments
# 4. Status of the PAD

A database with MadAnalysis 5 implementations of LHC analyses

[https://madanalysis.irmp.ucl.ac.be/wiki/PublicAnalysisDatabase](https://madanalysis.irmp.ucl.ac.be/wiki/PublicAnalysisDatabase)


## ATLAS analyses, 13 TeV

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Short Description</th>
<th>Implemented by</th>
<th>Code</th>
<th>Validation note</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATLAS-EXOT-2015-03</td>
<td>monojet + missing transverse energy</td>
<td>D. Sengupta</td>
<td><a href="https://inspirehep.net/literature/1699547">Inspire</a></td>
<td><a href="https://doi.org/10.1007/JHEP12(2017)025">PDF</a></td>
<td>v1.3/Delphes3</td>
</tr>
<tr>
<td>ATLAS-SUSY-2015-06</td>
<td>jets + missing transverse momentum</td>
<td></td>
<td><a href="https://inspirehep.net/literature/1699547">Inspire</a></td>
<td><a href="https://doi.org/10.1007/JHEP12(2017)025">PDF</a></td>
<td>v1.3/Delphes3</td>
</tr>
</tbody>
</table>

## ATLAS analyses, 8 TeV

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Short Description</th>
<th>Implemented by</th>
<th>Code</th>
<th>Validation note</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATLAS-SUSY-2013-05</td>
<td>stop/sbottom search: 0 leptons + 2 b-jets</td>
<td>G. Chalons</td>
<td><a href="https://inspirehep.net/literature/1699547">Inspire</a></td>
<td><a href="https://doi.org/10.1007/JHEP12(2017)025">PDF</a></td>
<td>MA5tune</td>
</tr>
<tr>
<td>ATLAS-SUSY-2013-11</td>
<td>EWK-Inos, 2 leptons + MET</td>
<td>B. Dumont</td>
<td><a href="https://inspirehep.net/literature/1699547">Inspire</a></td>
<td><a href="https://doi.org/10.1007/JHEP12(2017)025">PDF</a></td>
<td>MA5tune</td>
</tr>
<tr>
<td>ATLAS-HIGG-2013-03</td>
<td>ZH--&gt;ll+invisible</td>
<td>B. Dumont</td>
<td><a href="https://inspirehep.net/literature/1699547">Inspire</a></td>
<td><a href="https://doi.org/10.1007/JHEP12(2017)025">PDF</a></td>
<td>MA5tune</td>
</tr>
<tr>
<td>ATLAS-EXOT-2014-06</td>
<td>mono-photons + MET</td>
<td>D. Barducci</td>
<td><a href="https://inspirehep.net/literature/1699547">MA5tune</a></td>
<td><a href="https://doi.org/10.1007/JHEP12(2017)025">PDF</a></td>
<td>MA5tune + v1.2/Delphes3</td>
</tr>
<tr>
<td>ATLAS-SUSY-2014-10</td>
<td>2 leptons + jets + MET</td>
<td>B. Dumont</td>
<td><a href="https://inspirehep.net/literature/1699547">Inspire</a></td>
<td><a href="https://doi.org/10.1007/JHEP12(2017)025">PDF</a></td>
<td>MA5tune</td>
</tr>
<tr>
<td>ATLAS-SUSY-2013-21</td>
<td>0 leptons + mono-Jet/c-Jets + MET</td>
<td>G. Chalons, D. Sengupta</td>
<td><a href="https://inspirehep.net/literature/1699547">Inspire</a></td>
<td><a href="https://doi.org/10.1007/JHEP12(2017)025">PDF</a></td>
<td>MA5tune</td>
</tr>
<tr>
<td>ATLAS-SUSY-2013-02</td>
<td>0 leptons + 2-6 jets + MET</td>
<td>G. Chalons, D. Sengupta</td>
<td><a href="https://inspirehep.net/literature/1699547">Inspire</a></td>
<td><a href="https://doi.org/10.1007/JHEP12(2017)025">PDF</a></td>
<td>MA5tune</td>
</tr>
<tr>
<td>ATLAS-SUSY-2013-04</td>
<td>0 leptons + &gt;6 jets + MET</td>
<td>B. Fuks, M. Blanke, I. Galon</td>
<td><a href="https://inspirehep.net/literature/1699547">Inspire</a></td>
<td><a href="https://doi.org/10.1007/JHEP12(2017)025">PDF</a></td>
<td>MA5tune</td>
</tr>
</tbody>
</table>

**Big work achieved by the PAD collaboration**
4. Status of the PAD

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## CMS analyses, 8 TeV

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

Big work achieved by the PAD collaboration
4. Status of the PAD

• 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 PADForMA5tune
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)
```
### 4. Status of the PAD

**Recasting card**: only ‘ON’ / ‘OFF’ to be changed

<table>
<thead>
<tr>
<th>AnalysisName</th>
<th>PADType</th>
<th>Switch</th>
<th>DelphesCard</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>atlas_susy_2013_04</td>
<td>v1.1</td>
<td>off</td>
<td>delphes_card_atlas_susy_2013_04.tcl</td>
<td># ATLAS - multijet + met</td>
</tr>
<tr>
<td>atlas_susy_2013_05</td>
<td>v1.1</td>
<td>on</td>
<td>delphes_card_atlas_susy_2013_05.tcl</td>
<td># ATLAS - stop/sbottom - 0 lepton + 2 bjets + met</td>
</tr>
<tr>
<td>atlas_susy_2013_11</td>
<td>v1.1</td>
<td>off</td>
<td>delphes_card_atlas_susy_2013_11.tcl</td>
<td># ATLAS - ewkinos - 2 leptons + met</td>
</tr>
<tr>
<td>atlas_susy_2014_10</td>
<td>v1.1</td>
<td>off</td>
<td>delphes_card_atlas_susy_2014_10.tcl</td>
<td># ATLAS - squark-gluino - 2 leptons + jets + met</td>
</tr>
<tr>
<td>atlas_1405_7875</td>
<td>v1.1</td>
<td>off</td>
<td>delphes_card_atlas_susy_1405_7875</td>
<td># ATLAS - squark-gluino - 0 leptons + 2-6 jets + met</td>
</tr>
<tr>
<td>atlas_higg_2013_03</td>
<td>v1.1</td>
<td>off</td>
<td>delphes_card_atlas_susy_2013_11.tcl</td>
<td># ATLAS - Zh to invisible + 2 leptons</td>
</tr>
<tr>
<td>cms_sus_13_012</td>
<td>v1.1</td>
<td>off</td>
<td>delphes_card_cms_standard.tcl</td>
<td># CMS - squark-gluino - MET/MET</td>
</tr>
<tr>
<td>cms_sus_13_016</td>
<td>v1.1</td>
<td>off</td>
<td>delphes_card_cms_standard.tcl</td>
<td># CMS - gluinos - 2 leptons + bjets + met</td>
</tr>
<tr>
<td>cms_sus_14_001_TopTag</td>
<td>v1.1</td>
<td>on</td>
<td>delphes_card_cms_susy14001.tcl</td>
<td># CMS - stop - the top tagging channel</td>
</tr>
<tr>
<td>cms_sus_14_001_monojet</td>
<td>v1.1</td>
<td>off</td>
<td>delphes_card_cms_standard.tcl</td>
<td># CMS - stop - the monojet channel</td>
</tr>
<tr>
<td>cms_sus_13_011</td>
<td>v1.1</td>
<td>off</td>
<td>delphes_card_cms_standard.tcl</td>
<td># CMS - stop - 1 lepton + bjets + met</td>
</tr>
<tr>
<td>ATLAS_EXOT_2014_06</td>
<td>v1.2</td>
<td>off</td>
<td>delphes_card_atlas_susy_2013_05_pad.tcl</td>
<td># ATLAS - monophoton</td>
</tr>
<tr>
<td>cms_exo_12_047</td>
<td>v1.2</td>
<td>off</td>
<td>delphes_card_cms_b2g_12_012.tcl</td>
<td># CMS - monophoton</td>
</tr>
<tr>
<td>cms_exo_12_048</td>
<td>v1.2</td>
<td>off</td>
<td>delphes_card_cms_b2g_12_012.tcl</td>
<td># CMS - monojet</td>
</tr>
<tr>
<td>cms_b2g_14_004</td>
<td>v1.2</td>
<td>off</td>
<td>delphes_card_cms_b2g_14_004.tcl</td>
<td># CMS - Dark matter production with a ttbar pair</td>
</tr>
<tr>
<td>cms_b2g_12_022</td>
<td>v1.2</td>
<td>off</td>
<td>delphes_card_cms_b2g_14_004.tcl</td>
<td># CMS - Monotop search</td>
</tr>
<tr>
<td>CMS_B2G_12_012</td>
<td>v1.2</td>
<td>off</td>
<td>delphes_card_cms_b2g_12_012.tcl</td>
<td># CMS - TS/3 partners in the SSDL channel</td>
</tr>
</tbody>
</table>

**Illustrative output** (beware of low statistics for the example)

<table>
<thead>
<tr>
<th>analysis name</th>
<th>signal region</th>
<th>sig95(exp)</th>
<th>sig95(obs)</th>
<th>ll</th>
<th>efficiency</th>
<th>stat. unc</th>
</tr>
</thead>
<tbody>
<tr>
<td>cms_sus_13_011</td>
<td>Stop-&gt;Tneutralino, LowDeltaM, MET&gt;200</td>
<td>0.3301365</td>
<td>0.2651069</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cms_sus_13_011</td>
<td>Stop-&gt;Tneutralino, LowDeltaM, MET&gt;250</td>
<td>-1</td>
<td>-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cms_sus_13_011</td>
<td>Stop-&gt;Tneutralino, LowDeltaM, MET&gt;300</td>
<td>-1</td>
<td>-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cms_sus_13_011</td>
<td>Stop-&gt;Tneutralino, HighDeltaM, MET&gt;150</td>
<td>-1</td>
<td>-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cms_sus_13_011</td>
<td>Stop-&gt;Tneutralino, HighDeltaM, MET&gt;200</td>
<td>-1</td>
<td>-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cms_sus_13_011</td>
<td>Stop-&gt;Tneutralino, HighDeltaM, MET&gt;250</td>
<td>-1</td>
<td>-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cms_sus_13_011</td>
<td>Stop-&gt;Tneutralino, HighDeltaM, MET&gt;300</td>
<td>-1</td>
<td>-1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cms_sus_13_011</td>
<td>Stop-&gt;b+chargino, LowDeltaM, MET&gt;100</td>
<td>2.9531970</td>
<td>2.77503070</td>
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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
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), ...
5. Ongoing developments

**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](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](https://launchpad.net/madanalysis5)

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

**More recast analyses...**
Summary

MADAnalysis 5  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