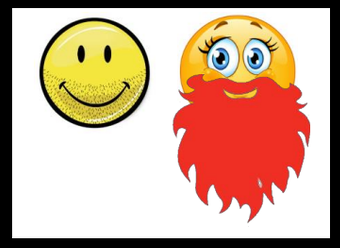

Collider phenomenology and LHC recasting made easy with MADANALYSIS 5

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LPTHE - CNRS - UPMC

In collaboration with Eric Conte (GRPHE Colmar)

The 10th Monte Carlo tools for BSM workshop

20-24 July 2016

Outline

New physics at the LHC (and beyond)

✦ The quest for physics beyond the Standard Model has started!

✤ How to get hints of new physics at the LHC?
- ★ Confront data to the Standard Model expectation
- ★ Observe unexplained deviations at a good confidence level

✤ Nature of non standard effects?
- ★ Fitting deviations by new physics signals
- ★ Designing new analyses to probe new ideas
- ★ Reinterpretation of data in possibly different theoretical frameworks
- ★ Leading order Monte Carlo tools and techniques do a proper job

Predictions for specific models, signal and background analysis

Confronting models to LHC data

✤ Final words on the nature of new physics
- ★ Accurate measurements of the model parameters
- ★ The most precise predictions are mandatory

Many other talks from this workshop

MadAnalysis 5 in a nutshell

[Conte, BF, Serret (CPC '13); Conte, Dumont, BF, Wymant (EPJC '14)]

What is MadAnalysis 5?

- A framework for phenomenological analyses
- Any level of sophistication: partonic, hadronic, detector, reconstructed
- Several input format: StdHep, HepMC, Lhe, Lhco, Root (from Delphes)
- User-friendly, flexible and fast
- Interfaces to other HEP packages (ROOT, detector simulation, jet clustering, *etc.)*

Normal pythonic mode

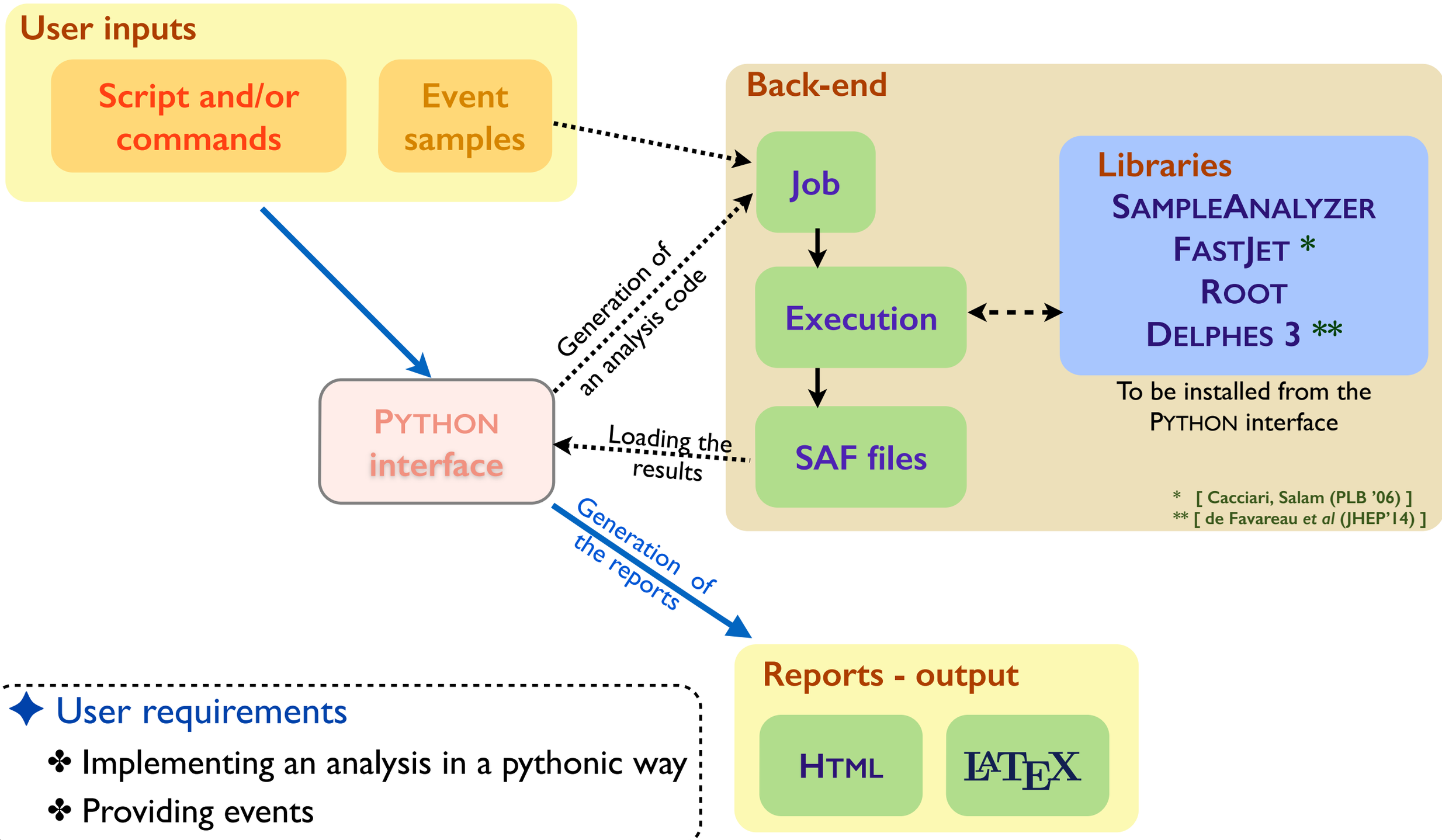
- Intuitive commands typed in a Python interface
- Analysis performed behind the scenes (a C++ black box)
- Human readable output: Html and LaTeX

Expert mode

- C++ programming within the SampleAnalyzer framework (the MadAnalysis 5 core)

The (normal) user-friendly mode

[Conte, BF, Serret (CPC '13); Conte, Dumont, BF, Wymant (EPJC '14)]



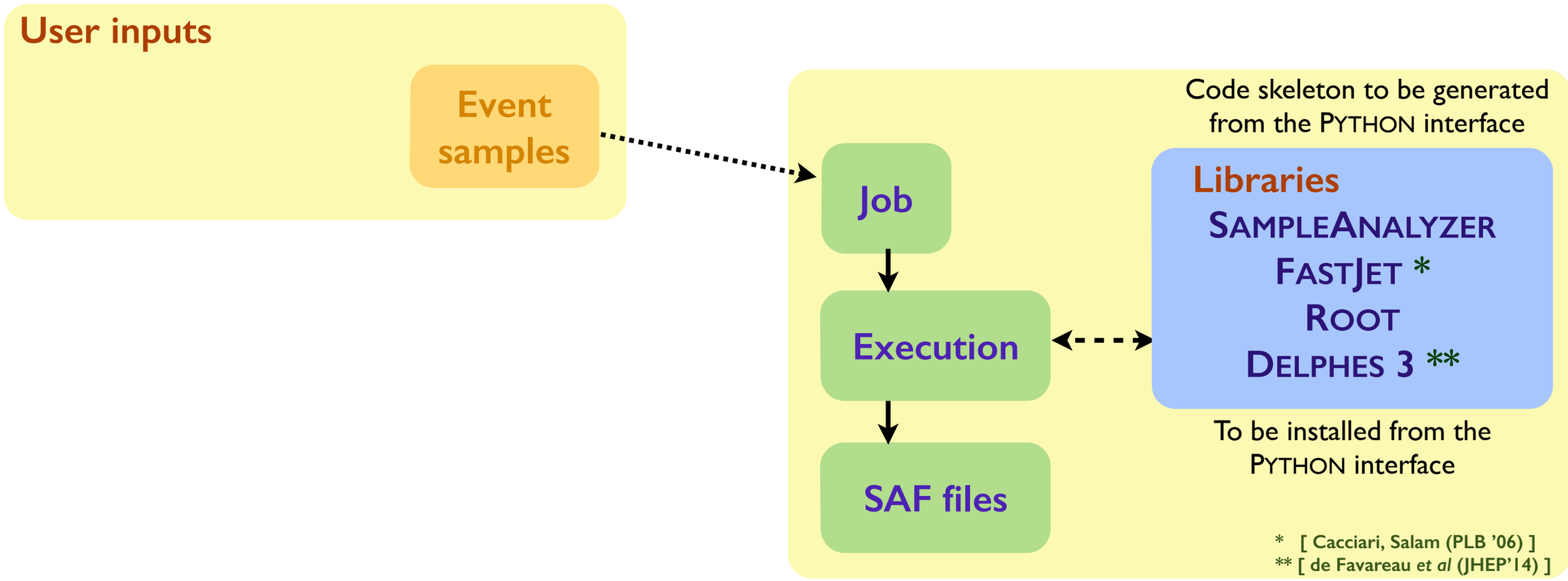
* [Cacciari, Salam (PLB '06)]
** [de Favareau *et al* (JHEP'14)]

✦ User requirements

- ✤ Implementing an analysis in a pythonic way
- ✤ Providing events

The expert (developer-friendly) mode

[Conte, BF, Serret (CPC '13); Conte, Dumont, BF, Wymant (EPJC '14)]



✦ User requirements

- ✤ Implementing an analysis in C++: the analysis skeleton is automatically generated
- ✤ Providing events
- ✤ Treatment of the output

Getting started...

Installation

- Download: launchpad.net/madanalysis5
- Current version: MADANALYSIS5 v1.4
- Starting the code: bin/ma5

```
**************************************************************
*                                                            *
*      W E L C O M E  to  M A D A N A L Y S I S  5           *
*                                                            *
*                                                            *
*   MA5 release : 1.4                          2016/07/20    *
*                                                            *
*         Comput. Phys. Commun. 184 (2013) 222-256           *
*             Eur. Phys. J. C74 (2014) 3103                  *
*                                                            *
*   The MadAnalysis Development Team - Please visit us at    *
*             https://launchpad.net/madanalysis5             *
*                                                            *
*                 Type 'help' for in-line help.              *
*                                                            *
**************************************************************
```

Requirements

New in v1.4

- PYTHON 2.6 or more recent (but not the 3.X series)
- The GNU GCC compiler
- The NUMPY PYTHON library

```
MA5: Platform: Darwin 13.4.0 [MAC/OSX mode]
MA5: Reading user settings ...
MA5: Checking mandatory packages:
MA5:       - Python                        [OK]
MA5:       - GNU GCC g++                   [OK]
MA5:       - GNU Make                      [OK]
```

Presence tested on startup

Optional packages

Prior to version v1.4

- Problems with the PYROOT / ROOT libraries for a significant number of users
- Compilation issues
- Nightmares with Mac OS (partially fixed with v1.3)

Solution with version v1.4

- PYROOT not needed anymore
- ROOT libraries optional
- MATPLOTLIB can be used instead

```
MA5: Checking optional packages devoted to histogramming:
MA5:       - Root                       [OK]
MA5:       - Matplotlib                 [OK]
MA5:       - pdflatex                   [OK]
MA5:       - latex                      [OK]
MA5: Package used for graphical rendering: Root
```

- Histograming:
  - ★ With ROOT or MATPLOTLIB if present; C++ / PYTHON files always generated
  - ★ Easy selection the graphical package to use:

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

  - ★ SAF (text) output always present
- Recasting mode: ROOT must be there (to be able to used DELPHES)

New in v1.4

Other optional packages

- ZLIB headers and libraries (g-zipped files)
- LATEX, PDFLATEX, DVIPDF (LaTeX reports)
- FASTJET (jet reconstruction)
- DELPHES (detector simulation)

```
MA5: Checking optional packages devoted to data processing:
MA5:       - Zlib                       [OK]
MA5:       - FastJet                    [OK]
MA5:       - Root                       [OK]
MA5:       - Delphes                    [OK]
MA5:       - Delphes-MA5tune            [DEACTIVATED]
```

Outline

Collider phenomenology with MADANALYSIS 5

Getting lost?

- In-line help: the tab key
- Auto-completion

```
ma5>help

Documented commands (type help <topic>):
========================================
EOF                 display_multiparticles  history  quit     resubmit  swap
define              display_particles       import   reject   select
define_region       display_regions         install  remove   set
display             exit                    open     reset    shell
display_datasets    help                    plot     restart  submit
```

```
ma5>import samples/ttbar.lhe.gz as ttbar
MA5:    -> Storing the file 'ttbar.lhe.gz' in the dataset 'ttbar'.
ma5>import samples/dy.lhe.gz as dy
MA5:    -> Storing the file 'dy.lhe.gz' in the dataset 'dy'.
ma5>set dy.type = signal
ma5>set ttbar.type = background
```

Events

- Event samples collected as datasets

Particle/multiparticle identification

- Labels can be linked to PDG codes
- PDG codes are default

```
ma5>define lep = e+ e- mu+ mu- ta+ ta-
ma5>define ww = 24 -24
ma5>define top = 6
ma5>define antitop = -6
```

```
ma5>select (j) ABSETA < 2.5
ma5>select (e) PT > 10
ma5>reject (e) DELTAR(j) < 0.4
ma5>select MET > 100
ma5>select N(j) > 2
ma5>plot PT(j[1]) 100 0 50 [logY]
ma5>plot THT 200 0 1000 [logY]
```

Analysis tools: cuts, object definition, plots

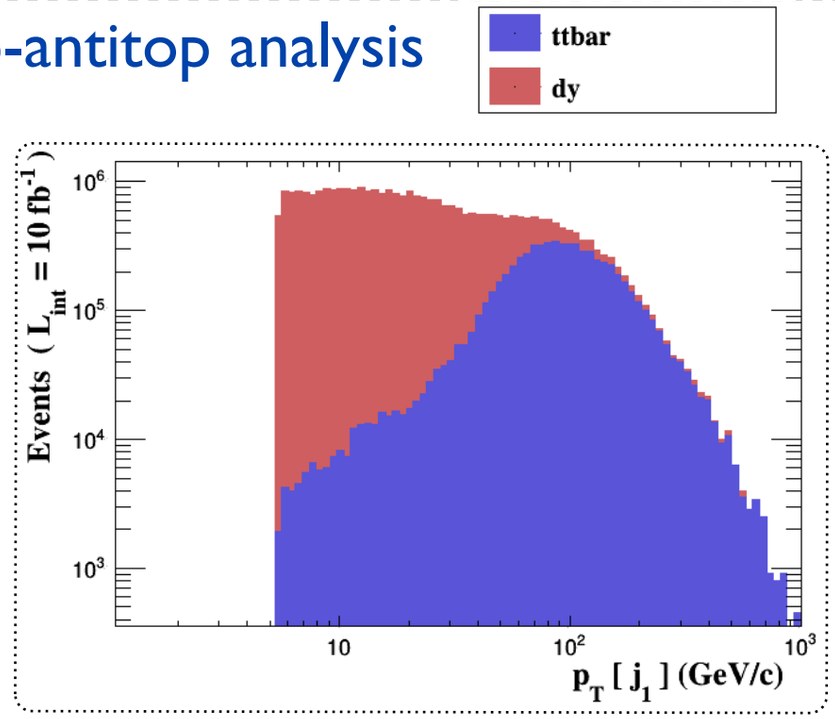
- Cuts: the select/reject commands
- Histograms: the plot command

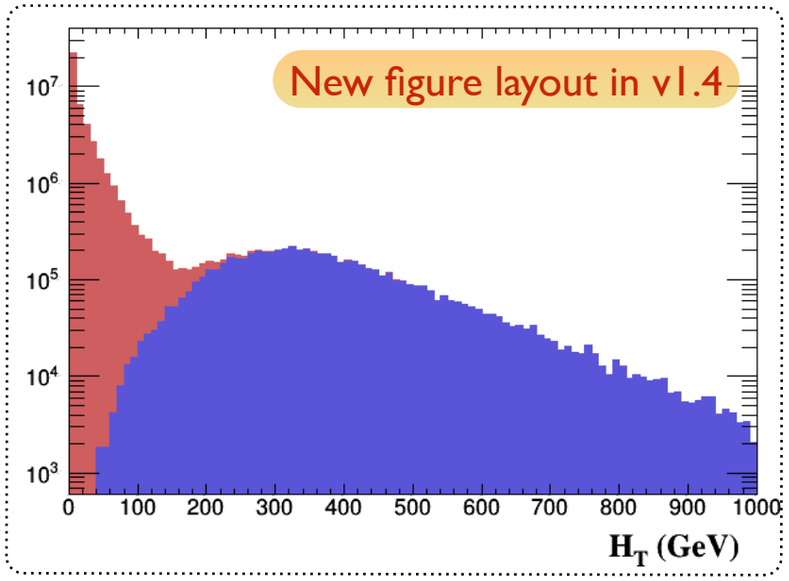
More information: tutorial

Example

✦ Simple Drell-Yan *vs.* top-antitop analysis

```
import samples/ttbar.lhe.gz as ttbar
import samples/dy.lhe.gz as dy
set dy.type = background
set dy.xsection =  4195.
set ttbar.xsection = 679.5
plot PT(j[1]) 100 1 1000 [logX logY]
define l = l+ l-
reject (l) DELTAR(j)<0.4
reject (l) PT<10
plot N(l) 5 0 5 [logY]
plot THT 100 0 1000 [logY]
select THT>50
submit
```





Cut: select THT > 50.0

Dataset	Events kept: K	Rejected events: R	Efficiency: K / (K + R)	Cumul. efficiency: K / Initial
ttbar	6793161.6 +/- 42.9	1838.4 +/- 42.9	1.00e+00 +/- 6.31e-06	1.00e+00 +/- 6.31e-06
dy	4600743 +/- 2023	37349256 +/- 2023	1.10e-01 +/- 4.82e-05	1.10e-01 +/- 4.82e-05

Cut-flow chart

Cuts	Signal (S)	Background (B)	S vs B
Initial (no cut)	6795000	41950000	973
Cut 1	6795000	41950000	973
Cut 2	6795000	41950000	973
Cut 3	6793161.6 +/- 42.9	4600743 +/- 2023	2012.499 +/- 0.179

More information: tutorial

Reconstructing showered/hadronized event files

✦ The output of a parton shower code is non-practical for an analysis

- ✤ It contains many (many many) hadrons ➢ large event files, hard to read
- ✤ Jets rather than individual hadrons are desired ➢ reconstruction

✦ Jet reconstruction with FASTJET

More information: tutorial

- ✤ FASTJET is interfaced to MADANALYSIS 5
- ✤ Automatic detection; if not present: `ma5>install fastjet`
- ✤ Easy to use; b-tagging and tau-tagging modules available

```
ma5>set main.fastsim.package = fastjet
ma5>set main.fastsim.algorithm = antikt
ma5>set main.fastsim.radius = 0.5
ma5>import samples/ZZ.hepmc.gz
MA5:    -> Storing the file 'ZZ.hepmc.gz' in the dataset 'defaultset'.
ma5>set main.outputfile = rec_zz.lhe.gz
```

- ✤ Output: LHE or LHCO file with jets, leptons, missing energy, *etc.* (can be further used for analysis)

✦ Event reconstruction with DELPHES (ROOT is mandatory)

More information: tutorial

- ✤ DELPHES (with special MA5TUNE detector cards) is interfaced to MADANALYSIS 5
- ✤ Can be installed easily: `ma5>install delphes`
- ✤ Easy to use

```
ma5>set main.fastsim.package = delphes
ma5>set main.fastsim.detector = cms-ma5tune
```

- ✤ Output: DELPHES ROOT file with all reconstructed objects (can be further used)

Outline

Reinterpreting LHC physics analyses (1)

✦ Exploit the full potential of the LHC (for new physics)

- ✤ Priority #1 of the European strategy for particle physics
- ✤ Designing new analyses to probe new ideas — Prospectives (based on MC simulations)
- ✤ Recasting LHC analyses to study models not considered — The LHC legacy

✦ LHC data has been collected with significant human and financial efforts

- ✤ Important for on-going analyses (within popular theoretical contexts of today)
- ✤ Important for future opportunities (within future scientific contexts)

✦ Data preservation in high-energy physics is mandatory [Kogler, South & Steder (JPCS'12)]

- ✤ Studies are on-going and go beyond raw data (ICFA DPHEP Study Group)

✦ Related tools need to be supported by the entire community [Kraml *et al.* (EPJC'12)]

- ✤ Both theorists and experimentalists
- ✤ Allowing for the reinterpretation of the LHC analysis results

Recasting in MADANALYSIS 5

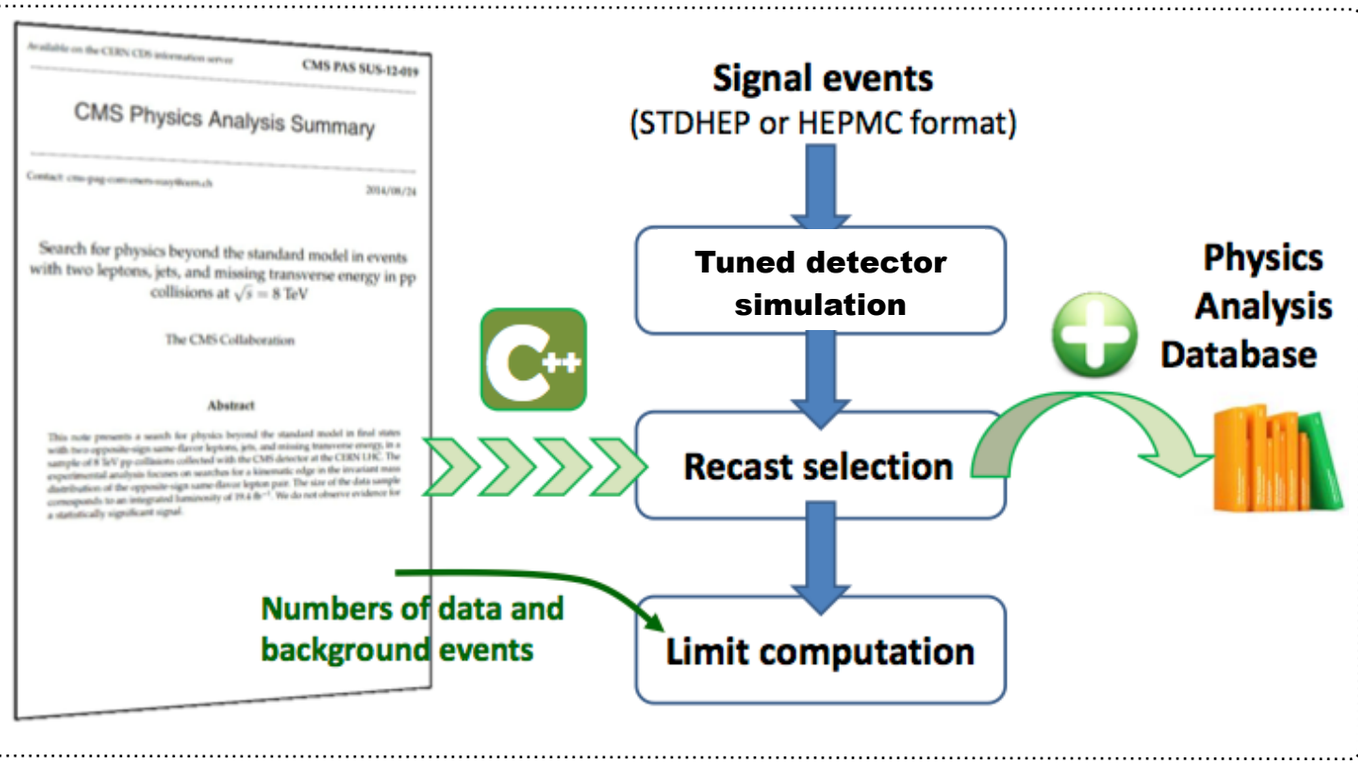
[Conte, Dumont, BF, Wymant (EPJC '14); Dumont, BF, Kraml *et al.* (EPJC '15)]

✦ There are plethora of new physics realizations that deserve to be studied

✤ Our choice: rely on a public detector simulator mimicking the ATLAS-CMS simulations

✤ Need for a (public) framework where LHC analyses can be easily implemented

✦ The recasting strategy in MADANALYSIS 5



✤ 2 options for detector effects

★ DELPHES/PGS-like (resolutions, efficiencies, *etc.*)

★ RIVET-like (transfer functions)

Recasting made easy with MADANALYSIS 5 (1)

Confronting a BSM signal to LHC analyses is straightforward

More information: tutorial

- Starting point: a showered/hadronized event file
- Installation of the detector simulators: DELPHES and DELPHESMA5TUNE
- Installation of the analysis libraries: PAD and PADFORMA5TUNE

```
install delphes
install delphesMA5tune
install PAD
install PADForMA5tune
```

- Recasting is then reduced to selecting the analyses of interest

```
ma5>set main.recast = on
ma5>import samples/stops.hep.gz
MA5:    -> Storing the file 'stops.hep.gz' in the dataset 'defaultset'.
ma5>submit
MA5:    Creating folder 'ANALYSIS_0'...
MA5: Would you like to edit the recasting Card ? (Y/N)
Answer:
```

New from v1.3

Snippet of the recasting card (only on/off switches to be set by the user)

- O(20) 8 TeV ATLAS and CMS analyses; 2 13 TeV ATLAS analyses

```
cms_sus_13_012              v1.1    on    delphes_card_cms_standard.tcl          # CMS   - 8 TeV - squark-gluino - MET/MHT
cms_sus_13_016              v1.1    on    delphes_card_cms_standard.tcl          # CMS   - 8 TeV - gluinos - 2 leptons + bjets + met
cms_sus_14_001_TopTag       v1.1    on    delphes_card_cms_sus14004.tcl          # CMS   - 8 TeV - stop - the top tagging channel
cms_sus_14_001_monojet      v1.1    on    delphes_card_cms_standard.tcl          # CMS   - 8 TeV - stop - the monojet channel
cms_sus_13_011              v1.1    on    delphes_card_cms_standard.tcl          # CMS   - 8 TeV - stop - 1 lepton + bjets + met
ATLAS_1604_07773            v1.2    on    delphes_card_ATLAS_1604_07773.tcl      # ATLAS - 13 TeV - monojet
ATLAS_EXOT_2014_06          v1.2    on    delphes_card_atlas_sus_2013_05_pad.tcl # ATLAS - 8 TeV - monophoton
cms_exo_12_047              v1.2    on    delphes_card_cms_b2g_12_012.tcl        # CMS   - 8 TeV - monophoton
cms_exo_12_048              v1.2    on    delphes_card_cms_b2g_12_012.tcl        # CMS   - 8 TeV - monojet
cms_b2g_14_004              v1.2    on    delphes_card_cms_b2g_14_004.tcl        # CMS   - 8 TeV - Dark matter production with a ttbar pair
cms_b2g_12_022              v1.2    on    delphes_card_cms_b2g_14_004.tcl        # CMS   - 8 TeV - Monotop search
```

Recasting made easy with MadAnalysis 5 (2)

[Conte, BF, Serret (CPC '13); Conte, Dumont, BF, Wymant (EPJC '14)]

✦ Snippet of the output file (example: low statistics ➢ lots of '-1' in the example)

- ✤ CLs if a signal cross section is provided
- ✤ Cross sections excluded at the 95% CL

# dataset name	analysis name	signal region	sig95(exp)	sig95(obs)		efficiency	stat. unc.	syst. unc.	tot. unc.
defaultset	ATLAS_1604_07773	EM1	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	ATLAS_1604_07773	EM2	8.3188058	6.2969151	||	0.0200000	0.0140000	0.0000000	0.0140000
defaultset	ATLAS_1604_07773	EM3	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	ATLAS_1604_07773	EM4	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	ATLAS_1604_07773	EM5	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	ATLAS_1604_07773	EM6	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	ATLAS_1604_07773	EM7	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	ATLAS_1604_07773	IM1	29.1514003	26.4878808	||	0.0200000	0.0140000	0.0000000	0.0140000
defaultset	ATLAS_1604_07773	IM2	17.8723953	14.4968326	||	0.0200000	0.0140000	0.0000000	0.0140000
defaultset	ATLAS_1604_07773	IM3	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	ATLAS_1604_07773	IM4	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	ATLAS_1604_07773	IM5	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	ATLAS_1604_07773	IM6	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	8j50, 0 bjet	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	8j50, 1 bjet	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	8j50, >=2 bjets	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	9j50, 0 bjet	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	9j50, 1 bjet	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	9j50, >=2 bjets	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	>=10j50	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	7j80, 0 bjet	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	7j80, 1 bjet	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	7j80, >=2 bjets	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	>=8j80, 0 bjet	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	>=8j80, 1 bjet	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	atlas_susy_2013_04	>=8j80, >=2 bjets	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	cms_sus_13_011	Stop->T+neutralino, LowDeltaM, MET>150	0.7520585	0.6472155	||	0.0070623	0.0083740	0.0000000	0.0083740
defaultset	cms_sus_13_011	Stop->T+neutralino, LowDeltaM, MET>200	0.3329506	0.2662354	||	0.0070623	0.0083740	0.0000000	0.0083740
defaultset	cms_sus_13_011	Stop->T+neutralino, LowDeltaM, MET>250	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	cms_sus_13_011	Stop->T+neutralino, LowDeltaM, MET>300	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	cms_sus_13_011	Stop->T+neutralino, HighDeltaM, MET>150	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	cms_sus_13_011	Stop->T+neutralino, HighDeltaM, MET>200	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	cms_sus_13_011	Stop->T+neutralino, HighDeltaM, MET>250	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	cms_sus_13_011	Stop->T+neutralino, HighDeltaM, MET>300	-1	-1	||	0.0000000	0.0000000	0.0000000	0.0000000
defaultset	cms_sus_13_011	Stop->b+chargino, LowDeltaM, MET>100	2.9459611	2.7846696	||	0.0070623	0.0083740	0.0000000	0.0083740
defaultset	cms_sus_13_011	Stop->b+chargino, LowDeltaM, MET>150	1.1201228	0.8983135	||	0.0070623	0.0083740	0.0000000	0.0083740
defaultset	cms_sus_13_011	Stop->b+chargino, LowDeltaM, MET>200	0.4486195	0.3241250	||	0.0070623	0.0083740	0.0000000	0.0083740

Reimplementing new physics LHC searches

✦ The MADANALYSIS 5 way for recasting an LHC search
- ✤ Use of the expert mode of the program as a framework
- ✤ Use of DELPHES 3 for detector simulation (with dedicated detector descriptions)

✦ Validation of the reimplementations
- ✤ Built-in differences: DELPHES *versus* ATLAS and CMS detector simulations
- ✤ Comparison of cut-flows, kinematical distributions for specific benchmarks
- ✤ Aiming for a 20%/30%-level agreement

✦ Complications: incomplete experimental documentation
- ✤ The material is better and better
- ✤ Loss of months in exchanges with ATLAS and CMS
- ✤ Sometimes dead ends

Implementing a new analysis in MADANALYSIS 5

✦ Picking up an experimental publication
- ✤ Reading
- ✤ Understanding

✅ Relatively easy

✦ Writing the analysis code in the tool internal language ✅ Relatively easy

✦ Getting the information missing from the publication for a proper validation
- ✤ Efficiencies (trigger, electrons, muons, b-tagging, JES, *etc.*)
  - ★ Including p_T and/or η dependence
  - ★ Accurate information
- ✤ Detailed cutflows for some well-defined benchmark scenarios
  - ★ Exact definition of the benchmarks (spectra)
  - ★ Event generation information (cards, tunes, *etc.*)
- ✤ Expected number of events in each region and cross sections
- ✤ Digitized histograms (*e.g.*, on HEPDATA)

⚠ Essential
✗ Often difficult!

✦ Comparing theory tools and real life

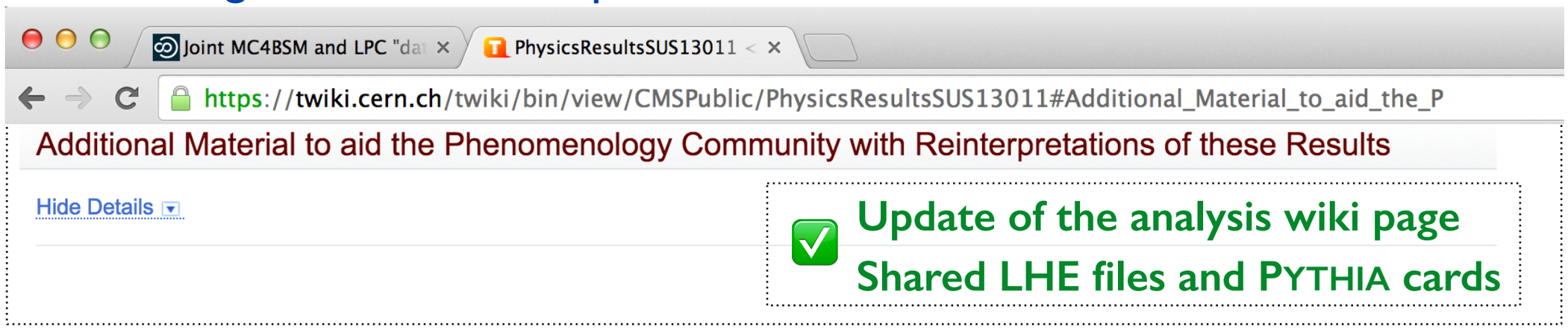
Example 1: CMS-SUS-13-11 (stops with one lepton)

Missing information for the validation

- Efficiencies
- Cutflows and Monte Carlo information for given benchmarks

✅ Discussions with CMS needed

All missing information was provided



✅ Update of the analysis wiki page
✅ Shared LHE files and PYTHIA cards

Validation

Cut	MadAnalysis 5	CMS
At least one lepton, four jets and 100 GeV of missing transverse energy	31.4	29.7
At least one b-tagged jet	27.1	25.2
No extra loosely-isolated lepton or track	22.5	21.0
No hadronic tau	22.0	20.6
Angular separation between the missing momentum and the two hardest jets	18.9	17.8
Hadronic top quark reconstruction	12.7	11.9
The transverse mass M_T (defined in the text) is larger than 120 GeV	10.4	9.6
At least 300 GeV of missing transverse energy and $M_{T2}^W > 200$ GeV	5.1	4.2

[Dumont, BF, Wymant (2014)]

Example 2: ATLAS-EXO-2014-04 (monophoton)

✦ Missing information

✤ Crack in the detector: no photons in the [1.37-1.52] η-range

✤ Tight photon requirements

✅ Discussions with ATLAS needed

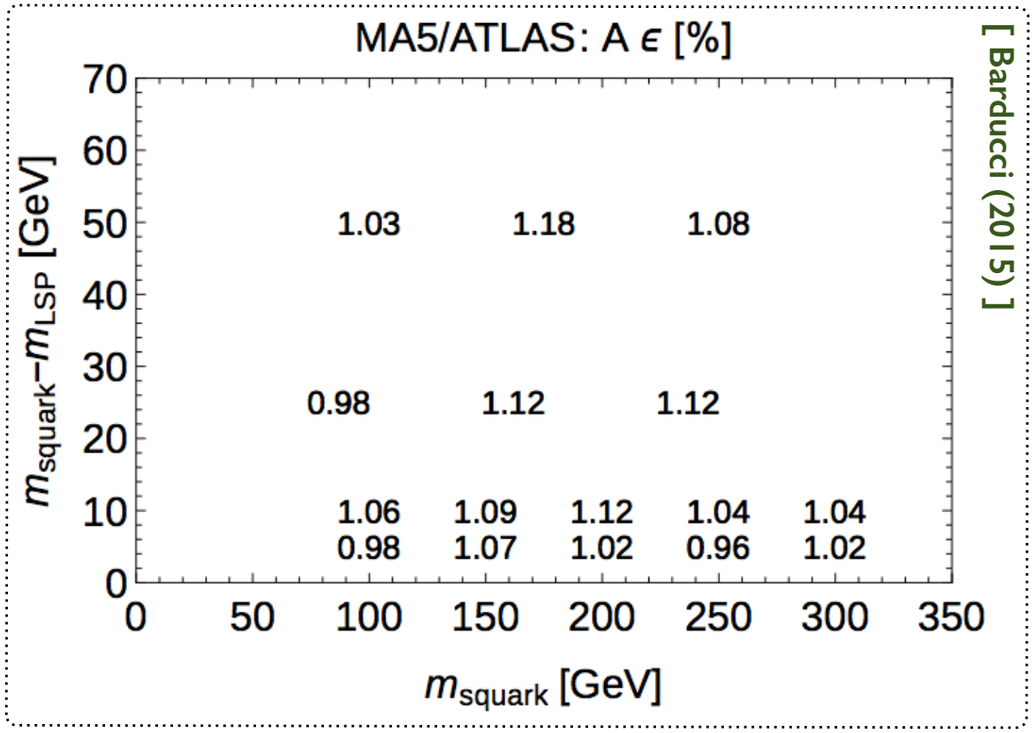
✅ In ATLAS-COM-PHYS-2014-542

✦ Event generation for the test benchmarks

✤ Monte Carlo information (cards, tunes, *etc.*)

✅ Kindly provided by ATLAS

Very good results
(ratio of efficiencies)



The Public Analysis Database (PAD) of MadAnalysis

[Dumont, BF, Kraml *et al.* (EPJC '15)]

- A database with MadAnalysis 5 implementations of LHC analyses exists
  - http://madanalysis.irmp.ucl.ac.be/wiki/PublicAnalysisDatabase
- Snippet of the webpage

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

Delphes card for ATLAS-EXOT-2015-03

Dedicated DELPHES cards

Code from INSPIRE

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-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

Validation information (cutflows, distributions, *etc.*)

- Can be automatically installed within MadAnalysis 5

MADANALYSIS 5 analyses on INSPIRE

[Dumont, BF, Kraml *et al.* (EPJC '15)]

✦ MADANALYSIS 5Implementation of LHC analyses can be uploaded on INSPIRE

- ✤ DOI are assigned: can be cited, searched for, *etc.*
- ✤ Versioning

Codes can now be cited in papers

Files are versioned, can be downloaded

Information | Citations (1) | Files

MadAnalysis5 implementation of the CMS monojet search (EXO-12-048)

Guo,Jun; Conte, Eric; Fuks, Benjamin

Description: This is the MadAnalysis5 implementation of the CMS search for monojet systems. This search targets events featuring a single hard jet produced in association with missing energy.

Note: Information on how to use this code as well as a detailed validation summary are available at http://madanalysis.irmp.ucl.ac.be/wiki/PublicAnalysisDatabase. The CMS analysis is documented at https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO12048.

Cite as: Guo, J., Conte, E., Fuks, B. (2016). MadAnalysis5 implementation of the CMS monojet search (EXO-12-048). doi: 10.7484/INSPIREHEP.DATA.JAN2.UNDA

DOI to be cited in papers

Record added 2016-01-06, last modified 2016-07-15

Importance of the NLO effects: the stop-pair case

[Ambrogi, Conte, BF, Kulkarni & Molter (*in prep.*)]

✦ Two types of simulation for the signal (NLO+NLL normalization)

1. Simulated signal *à la* CMS: p p → $\tilde{t}\,\tilde{t}^*$ + 0,1,2 jets @LO; PYTHIA 8 with the MONASH tune
2. Simulated signal: p p → $\tilde{t}\,\tilde{t}^*$ + 0 jet @NLO; PYTHIA 8 with the MONASH tune

✦ Analysis: single-leptonic (plus MET) decay of the stop pair (CMS-SUS-13-011)

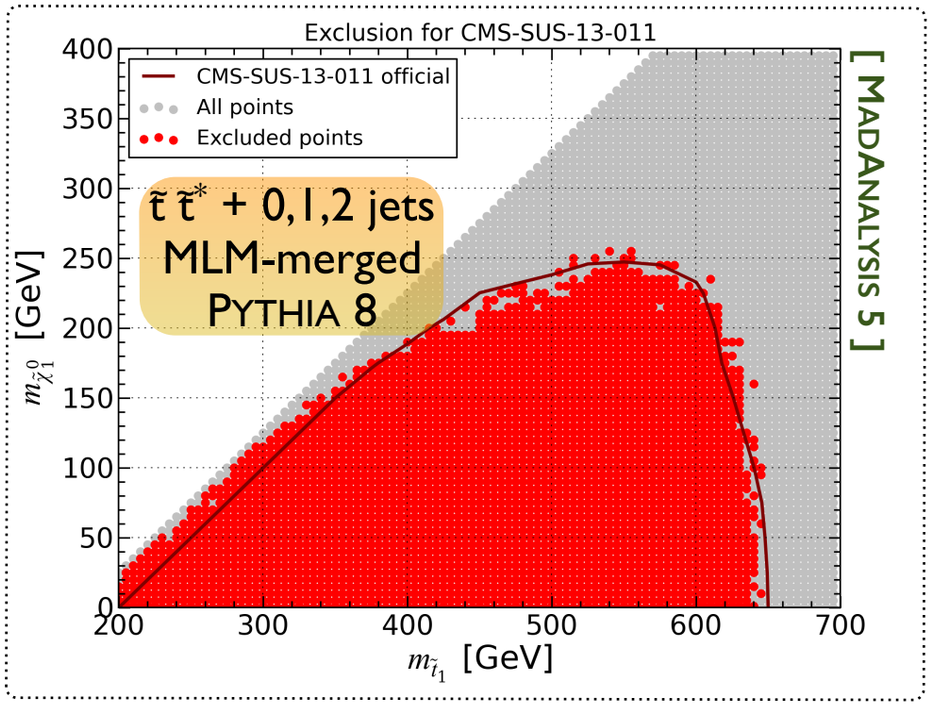
✤ Jet selection: 4 jets (mainly issued from the stop-antistop system decay)

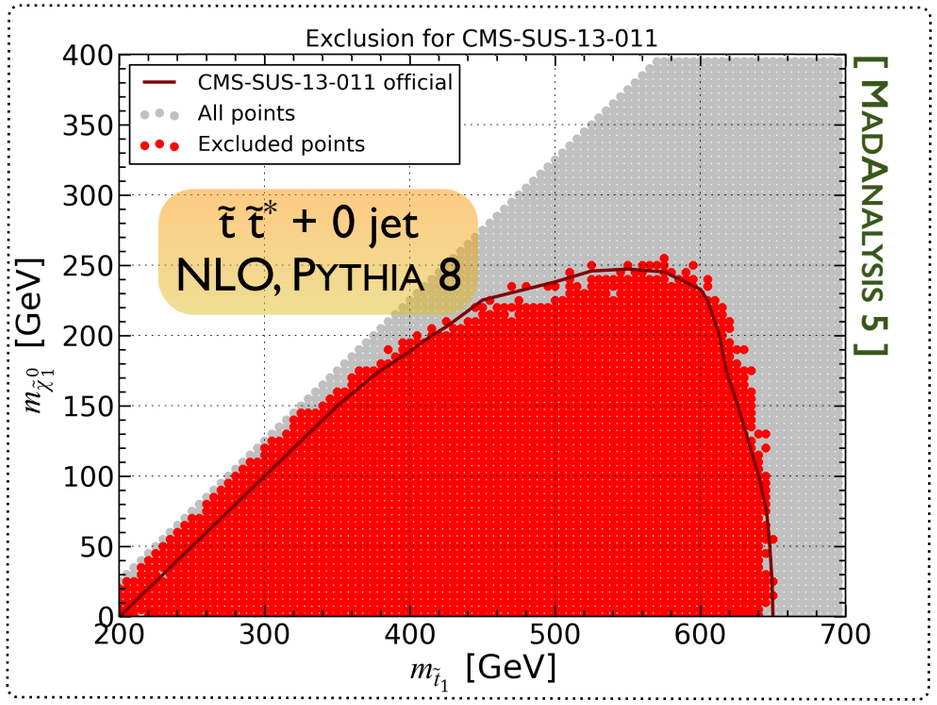
✦ Are the limits changing according to the simulation details?

✤ Not really (due to the many jets already there at LO)

✤ May be different for jet-dependent analyses (monojets, *etc.*)

✤ How do the theoretical uncertainties on the limit change?





NLO effects on a CLs: top-philic dark matter (1)

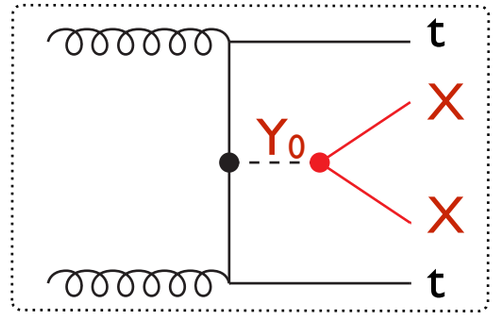
[Arina, Backovic, Conte, BF, Guo *et al.* (1605.09242)]

✦ A simplified model for top-philic dark matter

[BF & Martini (2016)]

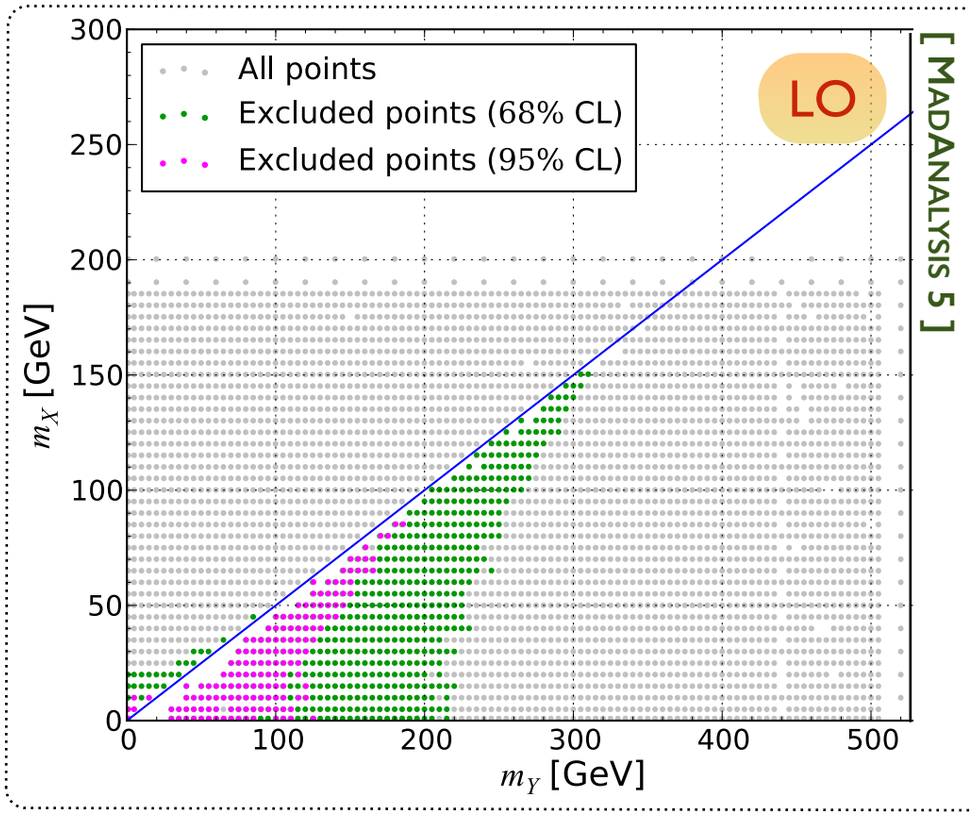
- ✤ A dark sector with a fermionic dark matter candidate X
- ✤ A (scalar) mediator Y_0 linking the dark sector and the top

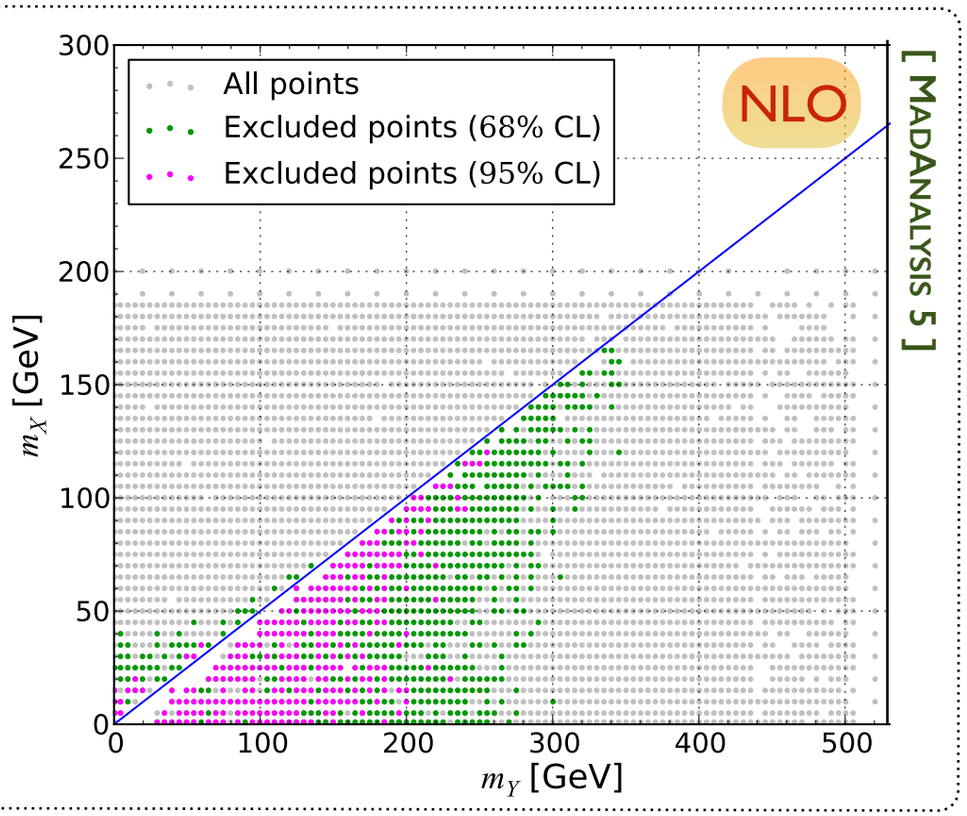
$$\mathcal{L}_{t,X}^{Y_0} = -\left(g_t \frac{y_t}{\sqrt{2}} \bar{t}t + g_X \bar{X}X\right) Y_0$$



- ✤ Could be probed with tt+MET events (CMS-B2G-14-004)

✦ For central scales: mild (but visible) NLO effects on the exclusions





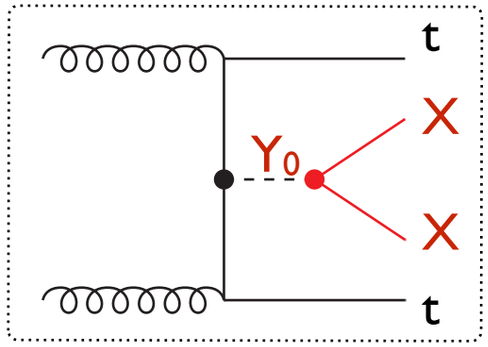
- ✤ How is the picture changing when including scale variations?

NLO effects on a CLs: top-philic dark matter (2)

[Arina, Backovic, Conte, BF, Guo *et al.* (1605.09242)]

✦ There are theoretical uncertainties on a CLs number

	(m_Y, m_X)	$\sigma_{\rm LO}$ [pb]	$\mathrm{CL}_{\rm LO}$ [%]	$\sigma_{\rm NLO}$ [pb]	$\mathrm{CL}_{\rm NLO}$ [%]
I	(150, 25) GeV	$0.658^{+34.9\%}_{-24.0\%}$	$98.7^{+0.8\%}_{-13.0\%}$	$0.773^{+6.1\%}_{-10.1\%}$	$95.0^{+2.7\%}_{-0.4\%}$
II	(40, 30) GeV	$0.776^{+34.2\%}_{-24.1\%}$	$74.7^{+19.7\%}_{-17.7\%}$	$0.926^{+5.7\%}_{-10.4\%}$	$84.2^{+0.4\%}_{-14.4\%}$
III	(240, 100) GeV	$0.187^{+37.1\%}_{-24.4\%}$	$91.6^{+6.4\%}_{-18.1\%}$	$0.216^{+6.7\%}_{-11.4\%}$	$86.5^{+8.6\%}_{-5.5\%}$



✤ An excluded point (95% CL) may not be excluded when accounting for uncertainties

✤ The CLs number can increase / decrease at NLO

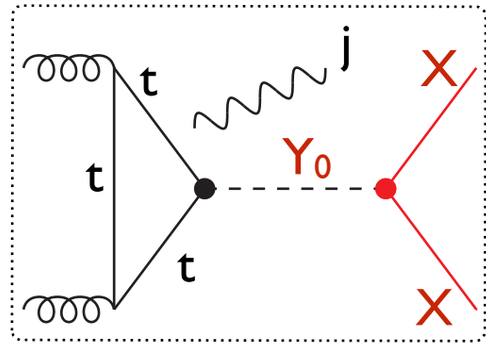
✤ The error band is reduced

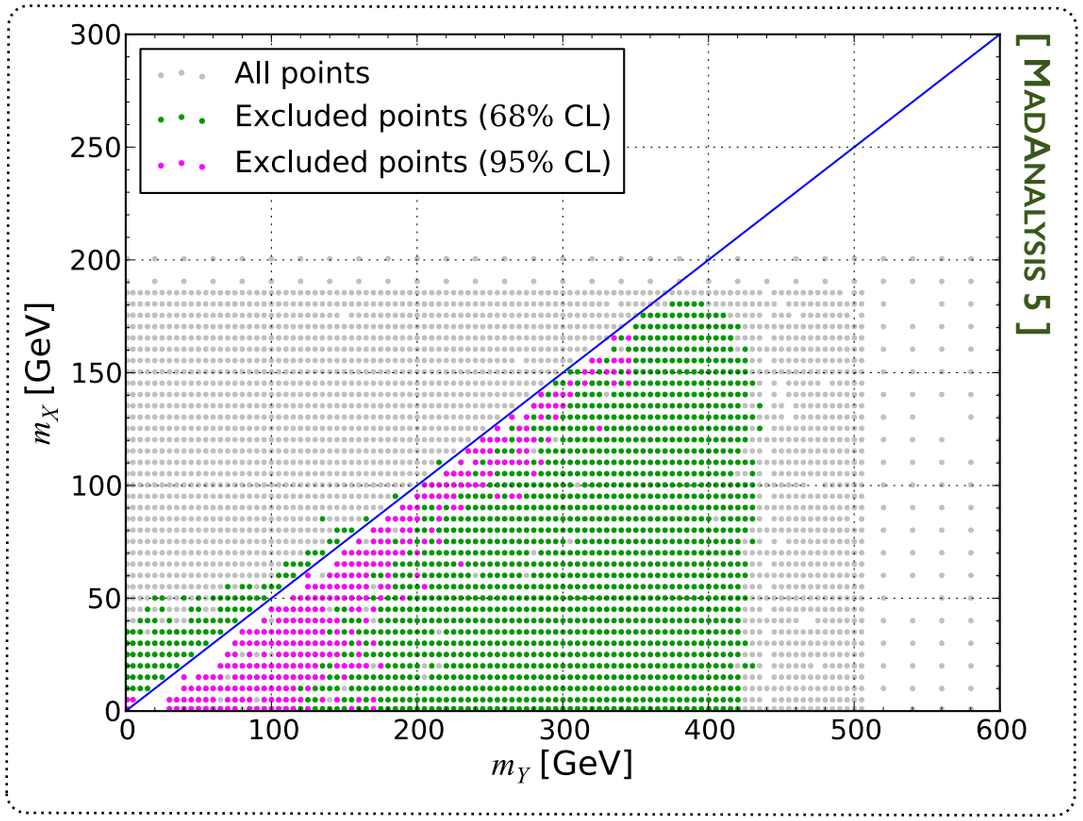
Loop-induced processes can also be studied

[Arina, Backovic, Conte, BF, Guo *et al.* (1605.09242)]

✦ Monojet probes

- ✤ The monojet cross section rapidly falls with the mediator mass
- ✤ Mediator width effects important (for the 95%CL exclusions)
- ✤ CMS-EXO-12-048 [Conte, BF & Guo (2016)]





Outline

Future: full embedding in MADGRAPH5_aMC@NLO

- Full streamlining of the simulation chain (after all, MAD is MAD)
  - Hard-scattering process inputted in MG5_aMC (and that's all!)
  - Shower/hadronization driven by MG5_aMC
  - Parton-level analysis (with MADANALYSIS 5)
  - Several reconstructions of the showered/hadronized events
    - ★ Using the FASTJET interface of MADANALYSIS 5
    - ★ Using the DELPHES interface of MADANALYSIS 5
  - Reconstructed-level analyses (with MADANALYSIS 5)
  - Recasting (with MADANALYSIS 5)
  - No storage of large HEPMC or ROOT file

```
The following switches determine which programs are run:
 1 Choose the shower/hadronization program:                          shower = PYTHIA8
 2 Choose the detector simulation program:                         detector = OFF
 3 Decay particles with the MadSpin module:                         madspin = OFF
 4 Add weights to the events based on changing model parameters:     reweight = Not available (requires NumPy)
 5 Run MadAnalysis5 on the events generated:                    madanalysis5 = PARTON+HADRON
  Either type the switch number (1 to 5) to change its setting,
  Set any switch explicitly (e.g. type 'madspin=ON' at the prompt)
  Type 'help' for the list of all valid option
  Type '0', 'auto', 'done' or just press enter when you are done.
 [0, auto, done, pythia, pgs, pythia=ON, pythia=OFF, pgs=ON, pgs=OFF, shower=OFF, ... ][60s to answer]
```

```
Do you want to edit a card (press enter to bypass editing)?
  1 / param      : param_card.dat
  2 / run        : run_card.dat
  3 / pythia8    : pythia8_card.dat
  4 / madanalysis5_parton : madanalysis5_parton_card.dat
  5 / madanalysis5_hadron : madanalysis5_hadron_card.dat
```

Summary

✦ MADANALYSIS 5:

- ✤ A framework for collider phenomenology (parton, hadron & reco level)
- ✤ User-friendly by means of its PYTHON interface
- ✤ Flexible thanks to its C++ kernel
- ✤ Interfaced to several HEP packages

http://launchpad.net/madanalysis5

✦ Two modes of the code

- ✤ PYTHONIC: intuitive commands typed in a PYTHON interface
  - ★ Analyses performed behind the scenes
  - ★ Human readable reports as output
- ✤ C++: programming in the SAMPLEANALYZER framework (the MADANALYSIS 5 core)

✦ The LHC legacy

http://madanalysis.irmp.ucl.ac.be/wiki/PublicAnalysisDatabase

- ✤ Crucial to be able to reinterpret the LHC results in any theoretical context
- ✤ MADANALYSIS 5 has been actively developed along these lines
  - ★ User-friendly way to confront any MC-simulated BSM signal to LHC results
- ✤ **Reproducibility** is the ability of an entire experiment to be reproduced (possibly by an independent theoretical study)