Phenomenological investigations with

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2015 MadGraph school on Collider Phenomenology
November 23-27 @ Shanghai

Outlines

1. Reminder: what is MadAnalysis 5?

2. Launching MadAnalysis 5

3. Writing an analysis step-by-step

4. Behind the scene

5. Extra: applying Fast-Jet on hadronic events

Outlines

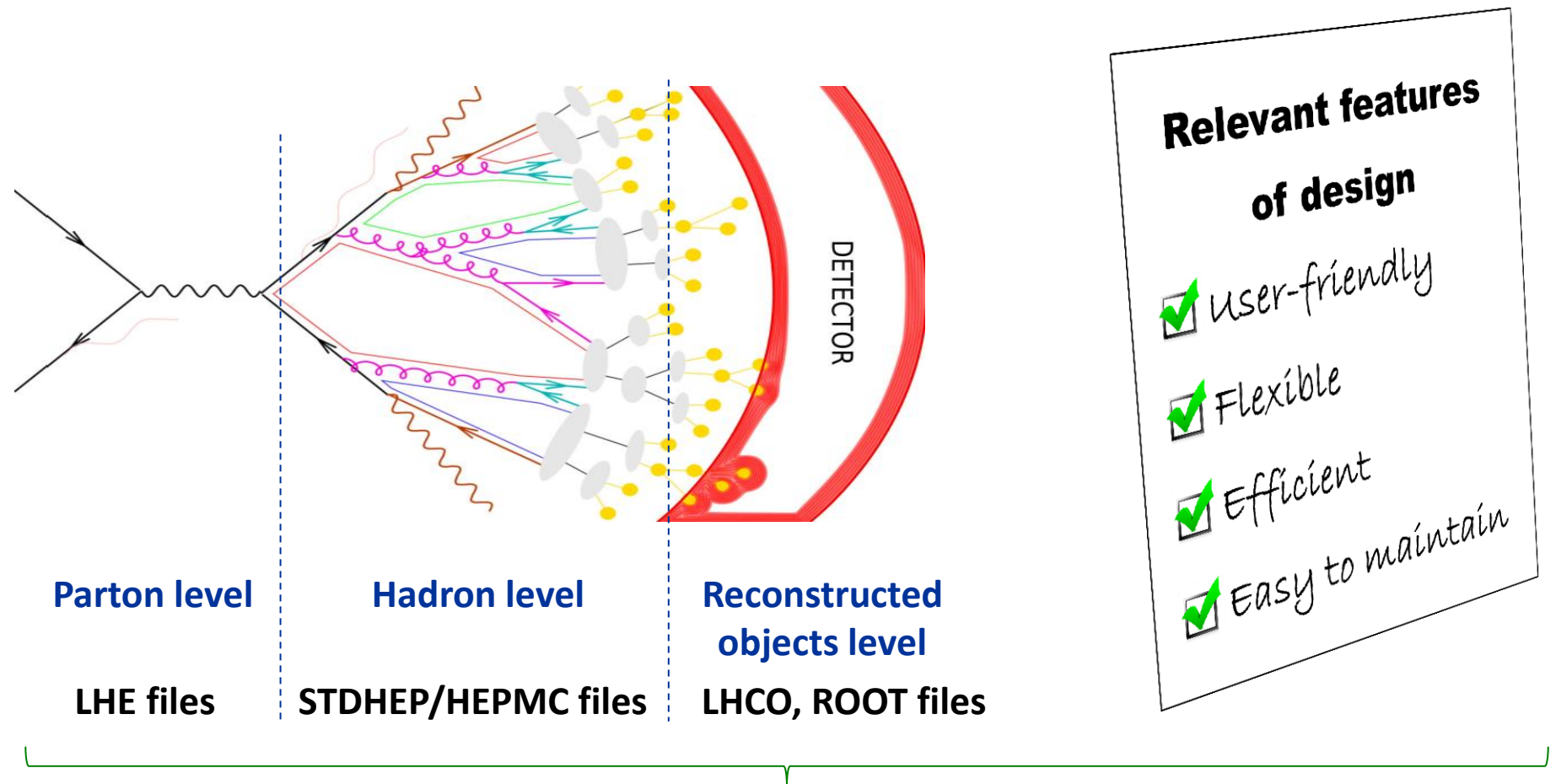1. **Reminder: what is MadAnalysis 5?**

What is MadAnalysis 5?

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

Parton level   **Hadron level**   **Reconstructed objects level**

DETECTOR

LHE files   STDHEP/HEPMC files   LHCO, ROOT files

Relevant features of design

✔ User-friendly

✔ Flexible

✔ Efficient

✔ Easy to maintain

**A unique framework : MadAnalysis 5**

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)

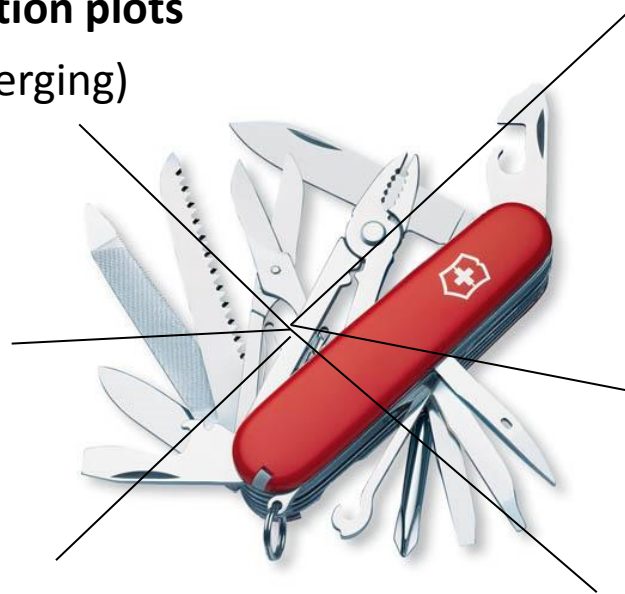| Dataset	Integral	Entries / events	Mean	RMS	Underflow	Overflow
defaultset	82747	0.752	42.8177	21.36	0.0	1.296

Statistics table
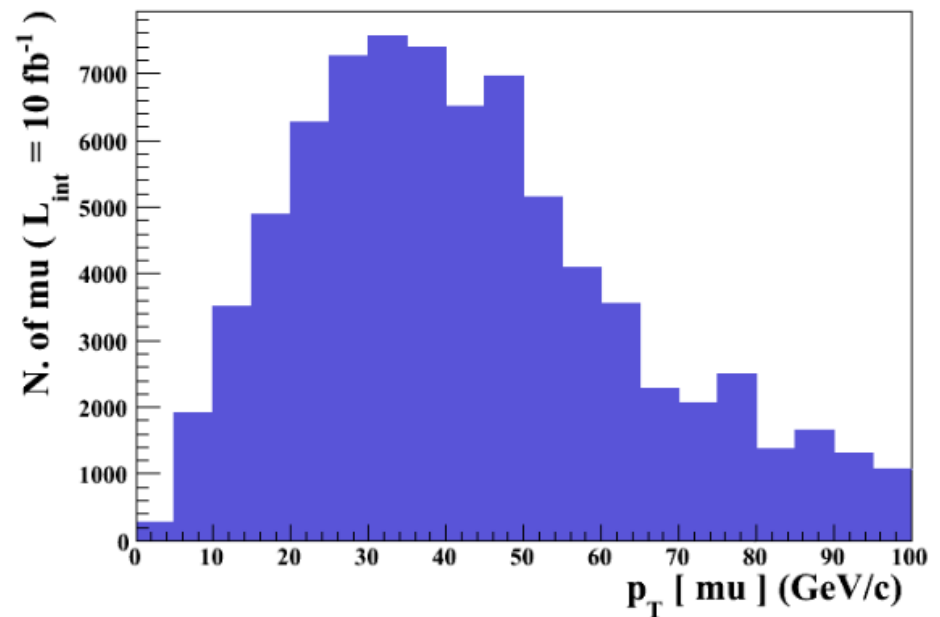
What is MadAnalysis 5?

But MadAnalysis 5 can do other things for you:

- Producing special plots such as **ME/PS merging validation plots** (see talk devoted to merging)

- 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

Outlines
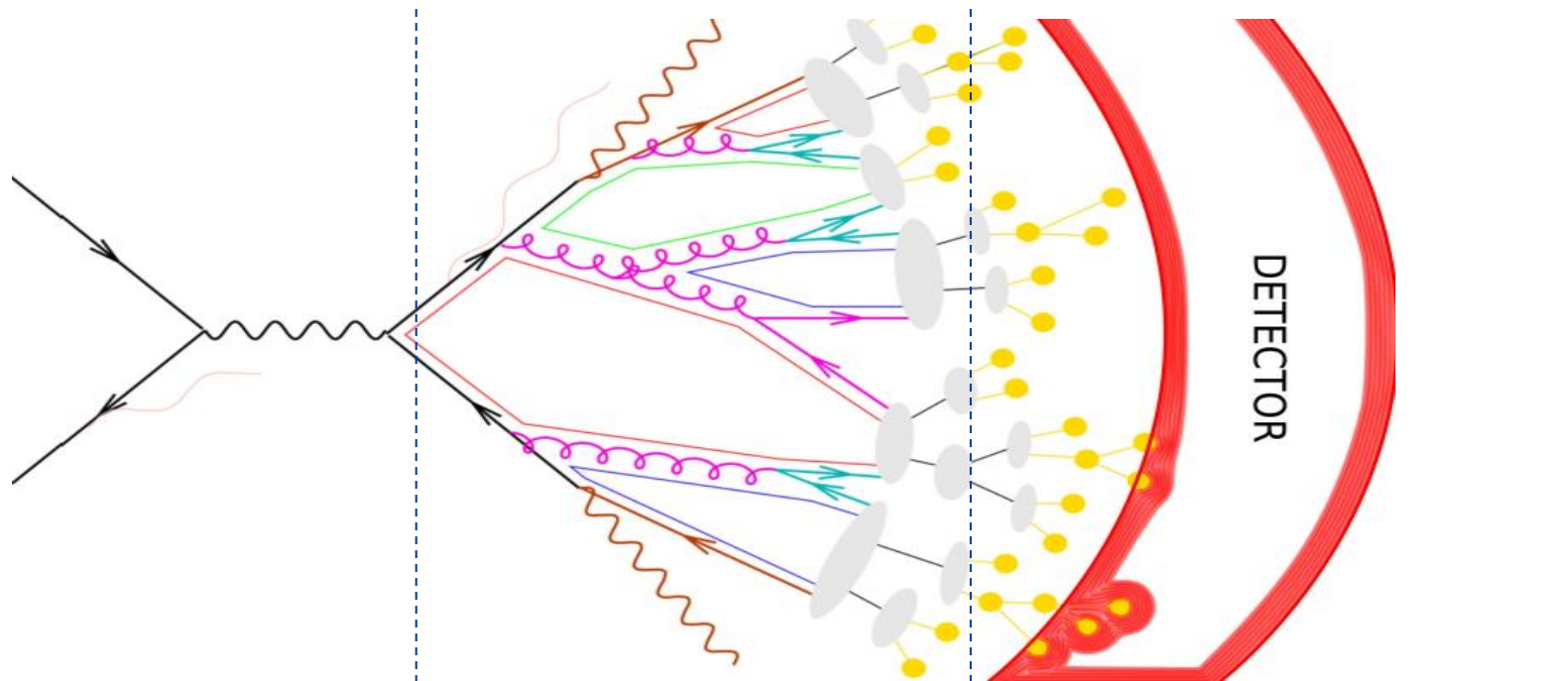
2. Launching MadAnalysis 5

Parton level	Hadron level	Reconstructed objects level
LHE files	STDHEP/HEPMC files	LHCO, ROOT files

Launching MadAnalysis5: ./bin/ma5 ./bin/ma5 -H ./bin/ma5 -R

For the tutorial:
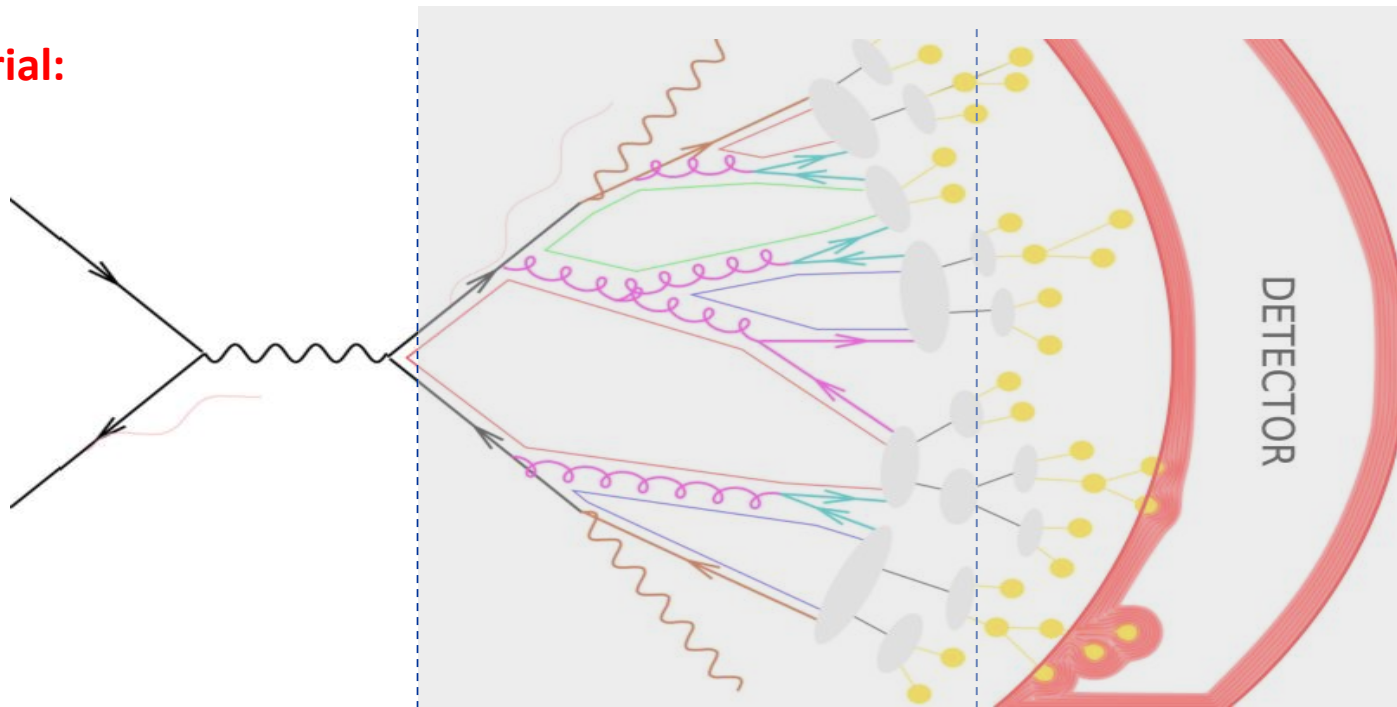
Parton level	Hadron level	Reconstructed objects level
LHE files	STDHEP/HEPMC files	LHCO, ROOT files

Launching MadAnalysis5: `./bin/ma5` | `./bin/ma5 -H` | `./bin/ma5 -R`

The MadAnalysis 5 console


```
Platform: Linux 2.6.18-348.12.1.el5 [Linux mode]
Reading user settings ...
Checking mandatory packages:
    - python                     [OK]
    - python library: numpy      [OK]
    - g++                        [OK]
    - GNU Make                   [OK]
    - Root                       [OK]
    - PyRoot libraries           [OK]
Checking optional packages:
    - pdflatex                   [OK]
    - latex                      [OK]
    - dvipdf                     [OK]
    - zlib                       [OK]
    - FastJet                    [OK]
    - Delphes                    [OK]
    - Delphes-MA5tune            [OK]
Checking the MadAnalysis library:
  => MadAnalysis libraries found.
  => MadAnalysis test program works.
*************************************************************
MadGraph 5 NOT found:
  => Particle labels from input/particles_name_default.txt
  => 87 particles successfully exported.
  => Multiparticle labels from
madanalysis/input/multiparticles_default.txt
  => Creation of the label 'invisible' (-> missing energy).
  => Creation of the label 'hadronic' (-> jet energy).
  => 8 multiparticles successfully exported.

ma5>_
```

2. Launching MadAnalysis 5

Compilation and other software tricks behind the scene = physicist-friendly

- **Inspection of your system:**
  - Autodetection of the required packages (g++, root,numpy)
  - Autodetection of the optional packages (zlib, delphes, fastjet, …)
  - Autodetection of MadGraph if it is installed.

- First time you used MadAnalysis: **compilation of the core libraries**

- Users could bypass or force a step of the MadAnalysis recipe
  →**configuration file** *madanalysis/ inputs/user_installation.dat*

```
Platform: Linux 2.6.18-348.12.1.el5 [Linux mode]
Reading user settings ...
Checking mandatory packages:
    - python                        [OK]
    - python library: numpy         [OK]
    - g++                           [OK]
    - GNU Make                      [OK]
    - Root                          [OK]
    - PyRoot libraries              [OK]
Checking optional packages:
    - pdflatex                      [OK]
    - latex                         [OK]
    - dvipdf                        [OK]
    - zlib                          [OK]
    - FastJet                       [OK]
    - Delphes                       [OK]
    - Delphes-MA5tune               [OK]
Checking the MadAnalysis library:
  => MadAnalysis libraries found.
  => MadAnalysis test program works.
```

Optional libraries could be installed quickly from the console with the command **install**

11

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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.
- The user can define his own labels :

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

Importing datasets

- For MadAnalysis, a **dataset** is a collection of samples which will be merged.
- All sample files are stored in a dataset.

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

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

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

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

3. First analysis step-by-step

Defining an analysis: plots and/or cuts

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. First analysis step-by-step

Defining an analysis: plots and/or cuts

- **<u>Cuts</u> : selecting / rejecting events**

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

- **<u>Cuts</u> : selecting / rejecting a particle or a combination**

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

Defining an analysis: plots and/or cuts

Several options or syntaxes allow to extend the potential of MadAnalysis.
Some examples:

- Selecting a particle according to its rank in energy (or to other observables)

```
ma5> plot PT(mu+[1])
```

- By default, a combination is interpreted as the vector sum of momenta.
  This interpretation can be changed by adding a prefix to the observable label.
  For instance : vPT, sPT, dsPT, dvPT, rPT

```
ma5> plot sPT(mu+[1] mu+[2])
```

- Selecting a particle according to its history (requirements on mother, grand-mother …)

```
ma5> plot PT(mu+ < w+ < t~)
```

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**.

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.

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
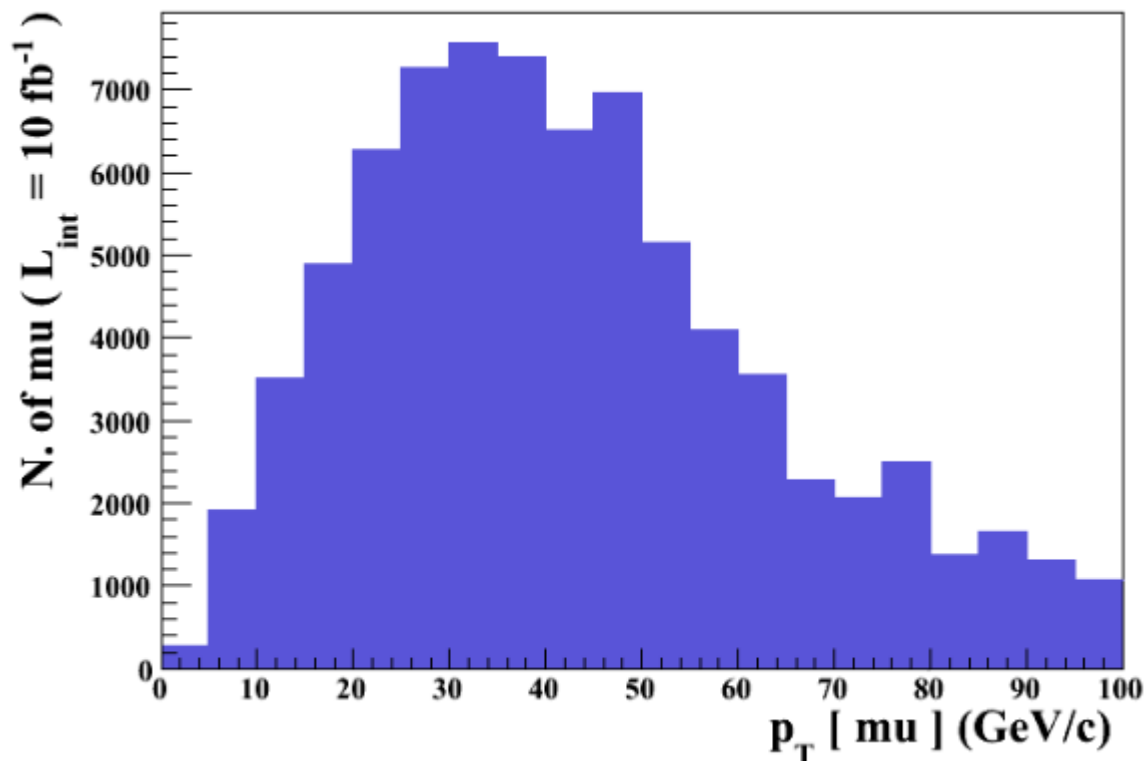
- the cross section of the sample is automatically extracted from the sample

- Integrated luminosity is by default 10 fb^{-1}. This value can be set by the user:
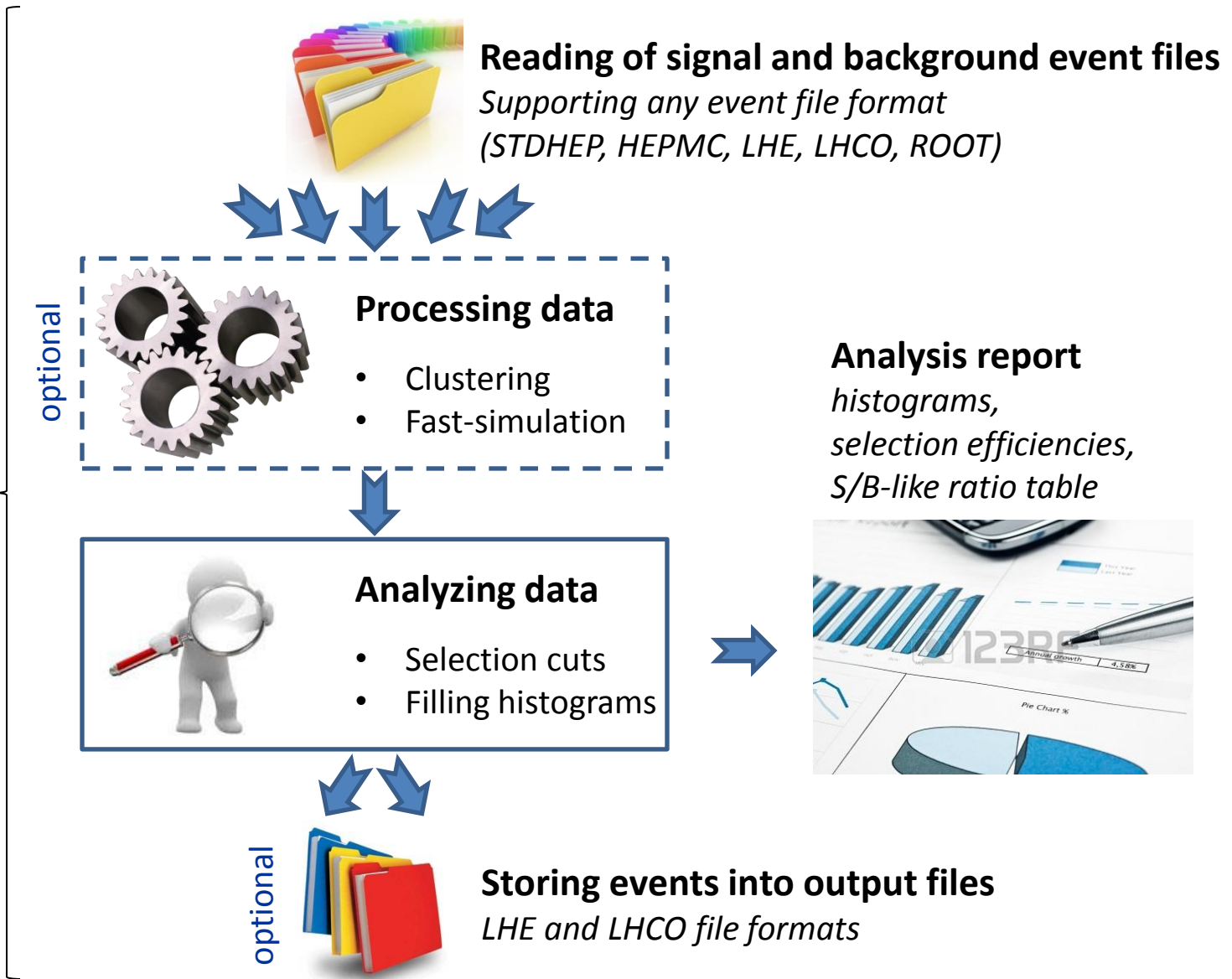
```
ma5> set main.lumi =
```

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4. **Behind the scene**

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Scope:

Reading of signal and background event files
Supporting any event file format
(STDHEP, HEPMC, LHE, LHCO, ROOT)

**Defining
an analysis
with a
dedicated
metalanguage**

optional

Processing data

- Clustering
- Fast-simulation

Analysis report
*histograms,
selection efficiencies,
S/B-like ratio table*

Analyzing data

- Selection cuts
- Filling histograms

optional

Storing events into output files
LHE and LHCO file formats

21

Samples

(Multi)particle list

Python Interface

UFO model

User commands or script

Main program and analysis codes

Working directory

Analysis results

Final reports

Installation, compilation
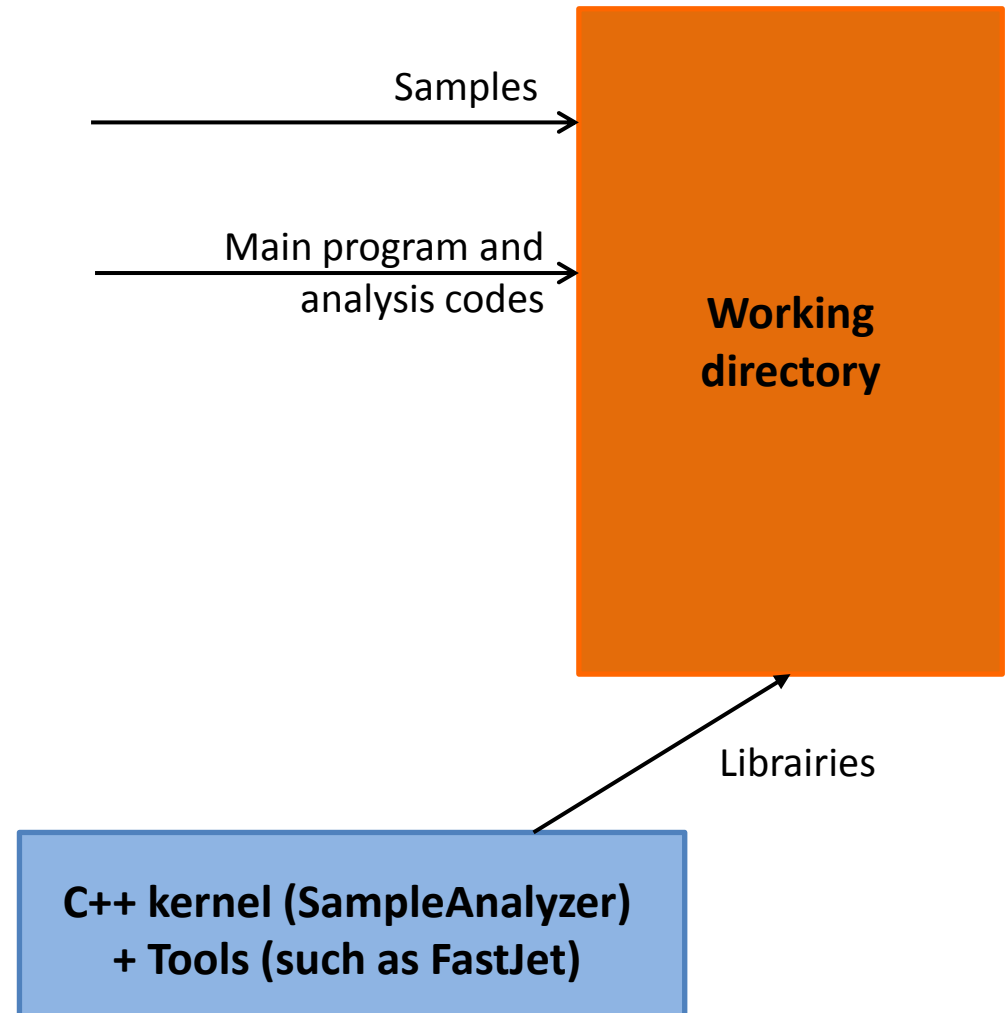
Librairies

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

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

- C++ programming within the SampleAnalyzer framework.

- The Python interface creates a blank analysis as a starting point.

  `./bin/ma5 -e`

Samples →

Main program and analysis codes →

Working directory

Librairies

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

23

Outlines

Hadronic events

Reconstructed events
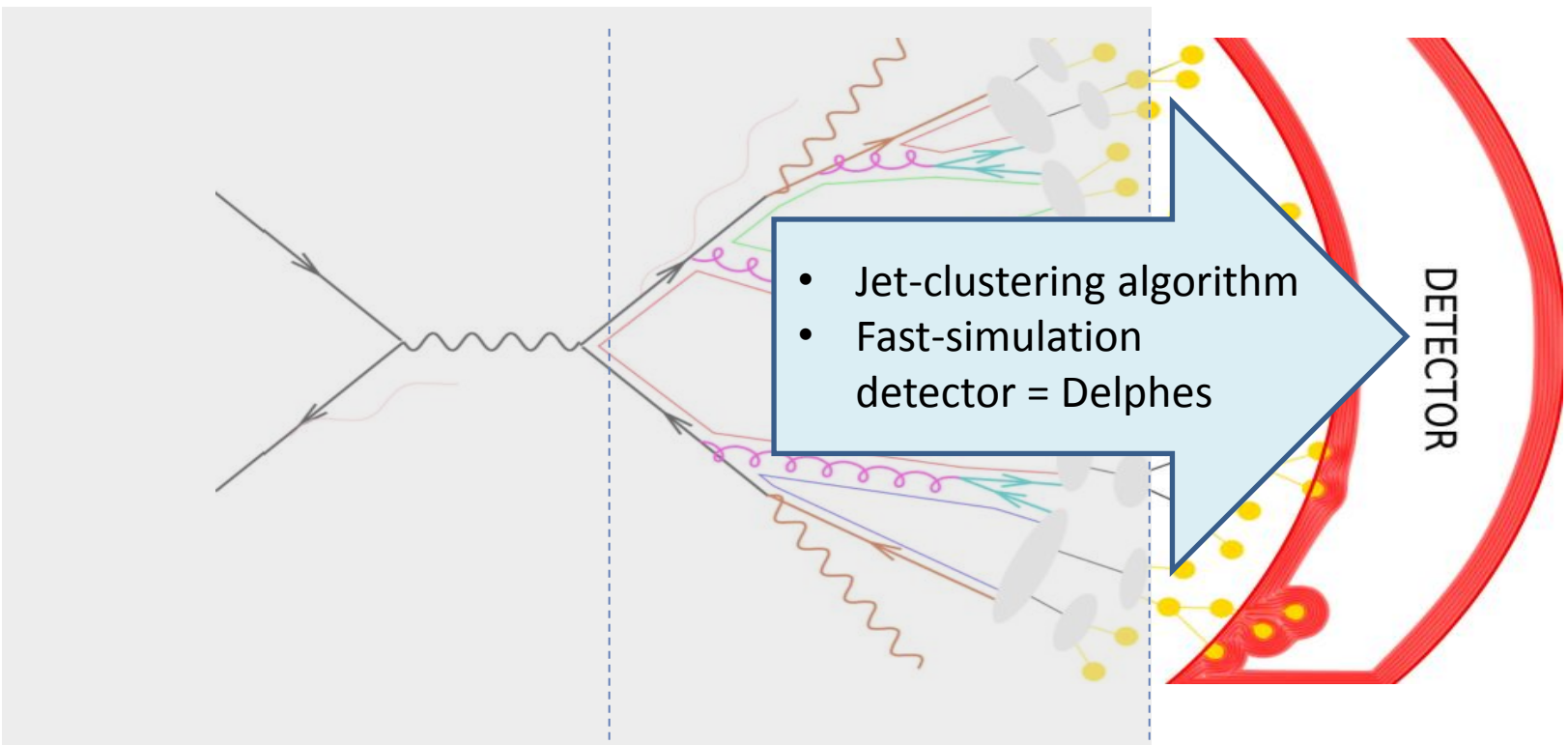
- Jet-clustering algorithm
- Fast-simulation detector = Delphes

DETECTOR

Parton level	**Hadron level**	**Reconstructed objects level**
LHE files	STDHEP/HEPMC files	LHCO, ROOT files

Launching MadAnalysis5:

`./bin/ma5`   `./bin/ma5 -H`   `./bin/ma5 -R`

25

5. Extra

Jet clustering algorithms:

- Need to install **FastJet** and interface it to MadAnalysis
  → just one command line:

```
ma5>  install fastjet
```

- Large selection of jet algorithms

```
ma5> set main.clustering.algorithm =

antikt   cdfjetclu   genkt   kt   siscone
cambridge   cdfmidpoint   gridjet none
```

- Adopting a jet algorithm → new options (**algorithm** & **object-identification** parameters)

```
ma5>  set  main.clustering.algorithm  =  antikt
ma5>  set  main.clustering.ptmin   =  5
ma5>  set  main.clustering.radius   =  1
ma5>  set  main.clustering.bjet.efficiency  =  0.5
```

- Possibility to save the clustered events in to a "simplified" LHE (and LHCO format soon)

```
ma5>  set  main.outputfile = "mysample.lhe.gz"
```

More info?
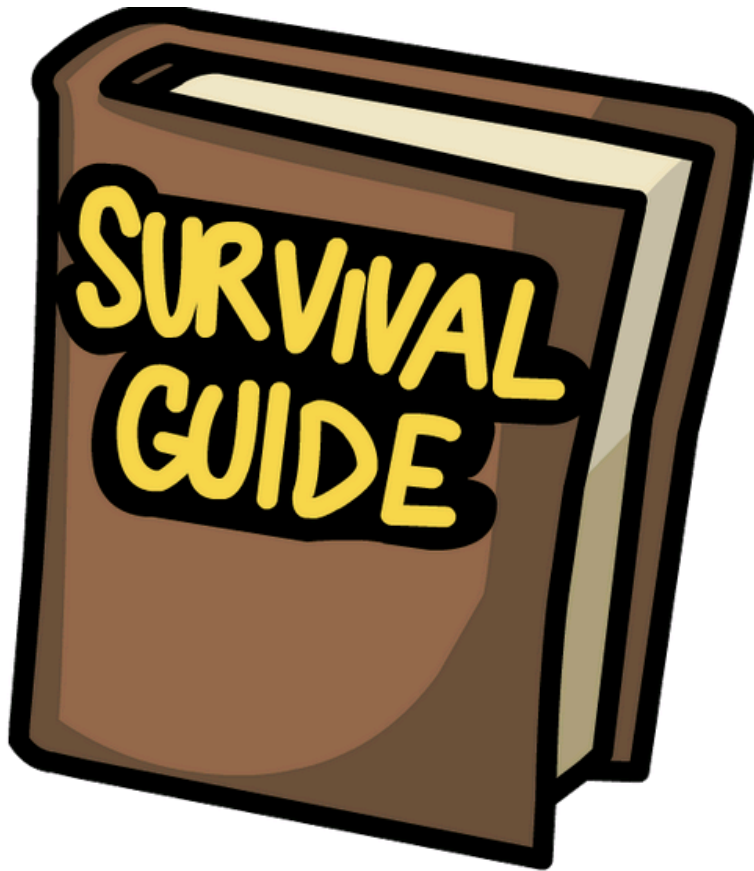
Manual and user guides

- **Comput. Phys. Commun. 184 (2013) 222-256 arXiv:1206.1599**

- **Eur.Phys.J. C74 (2014) 10, 3103 arXiv:1405.3982**

For questions, suggestion or bug report, please contact us with the launchpad framework:
https://bugs.launchpad.net/madanalysis5