A brief intro to MadGraph, Pythia, Delphes and MadAnalysis

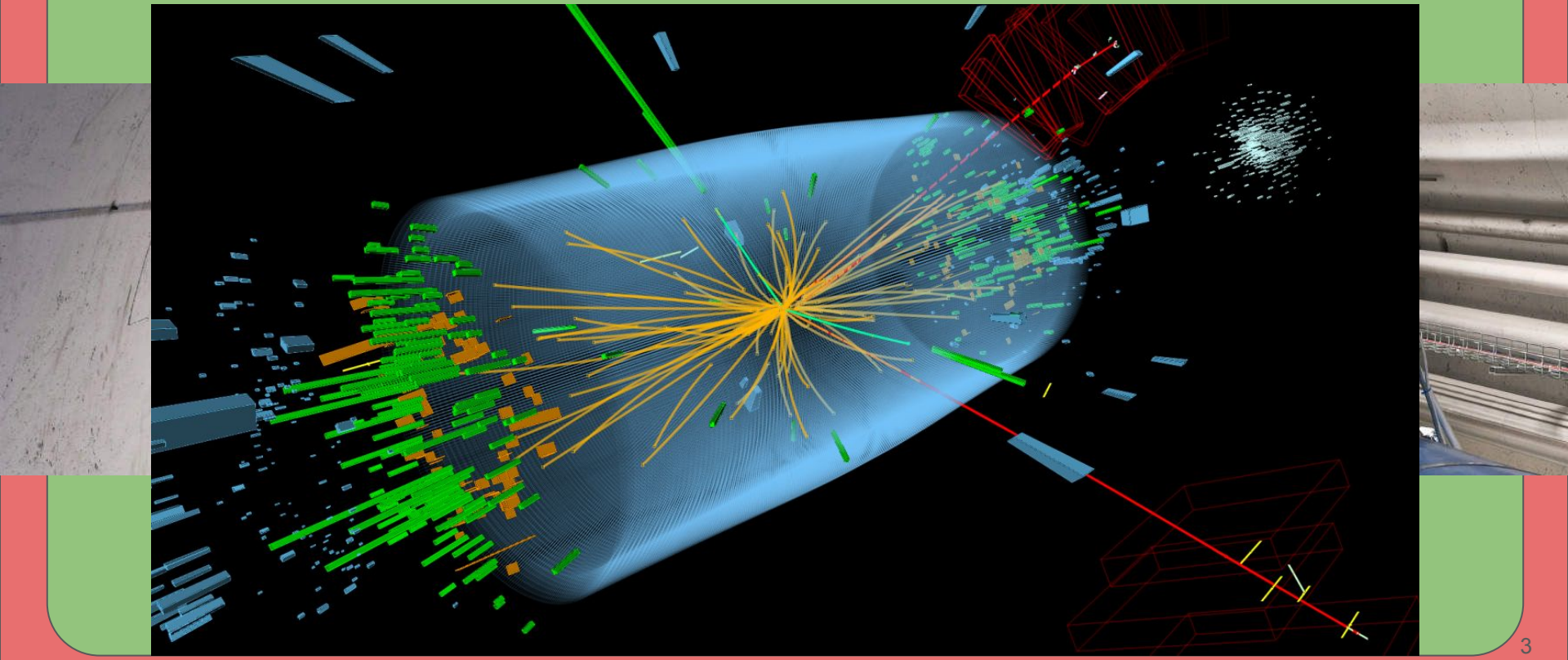
José Ruiz

VII Uniandes Particle Physics School - Dec 5 2022

UNIVERSIDAD
DE ANTIOQUIA

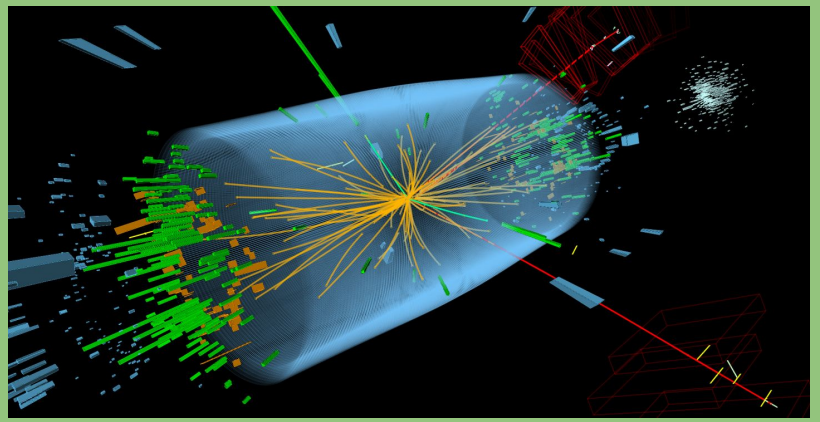
How to model particle physics collisions?

How to model particle physics collisions?

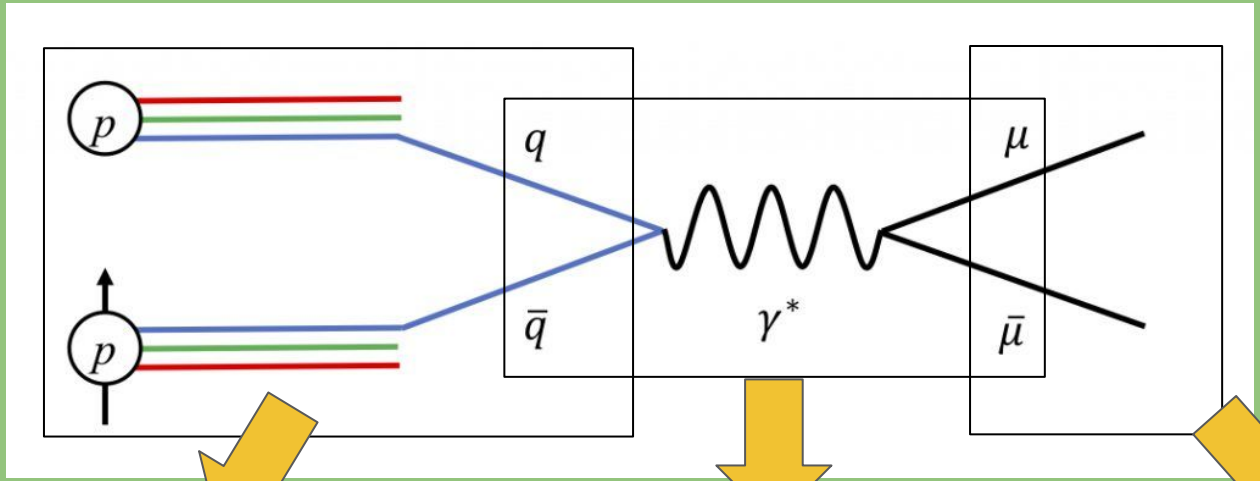


How to model particle physics collisions?

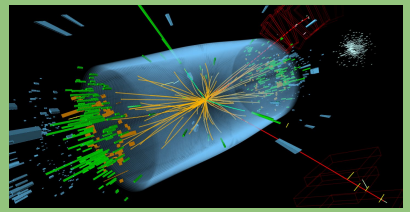
Particle Physics Model (like the SM)

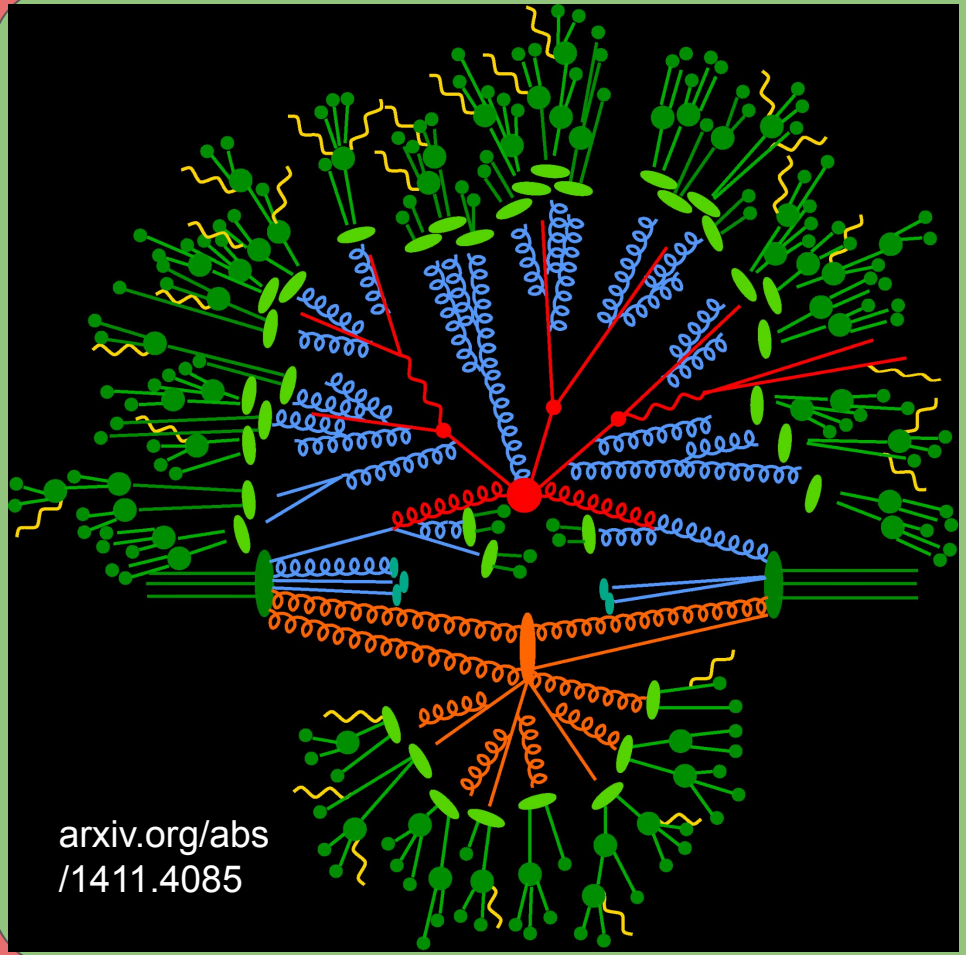


How to model particle physics collisions?

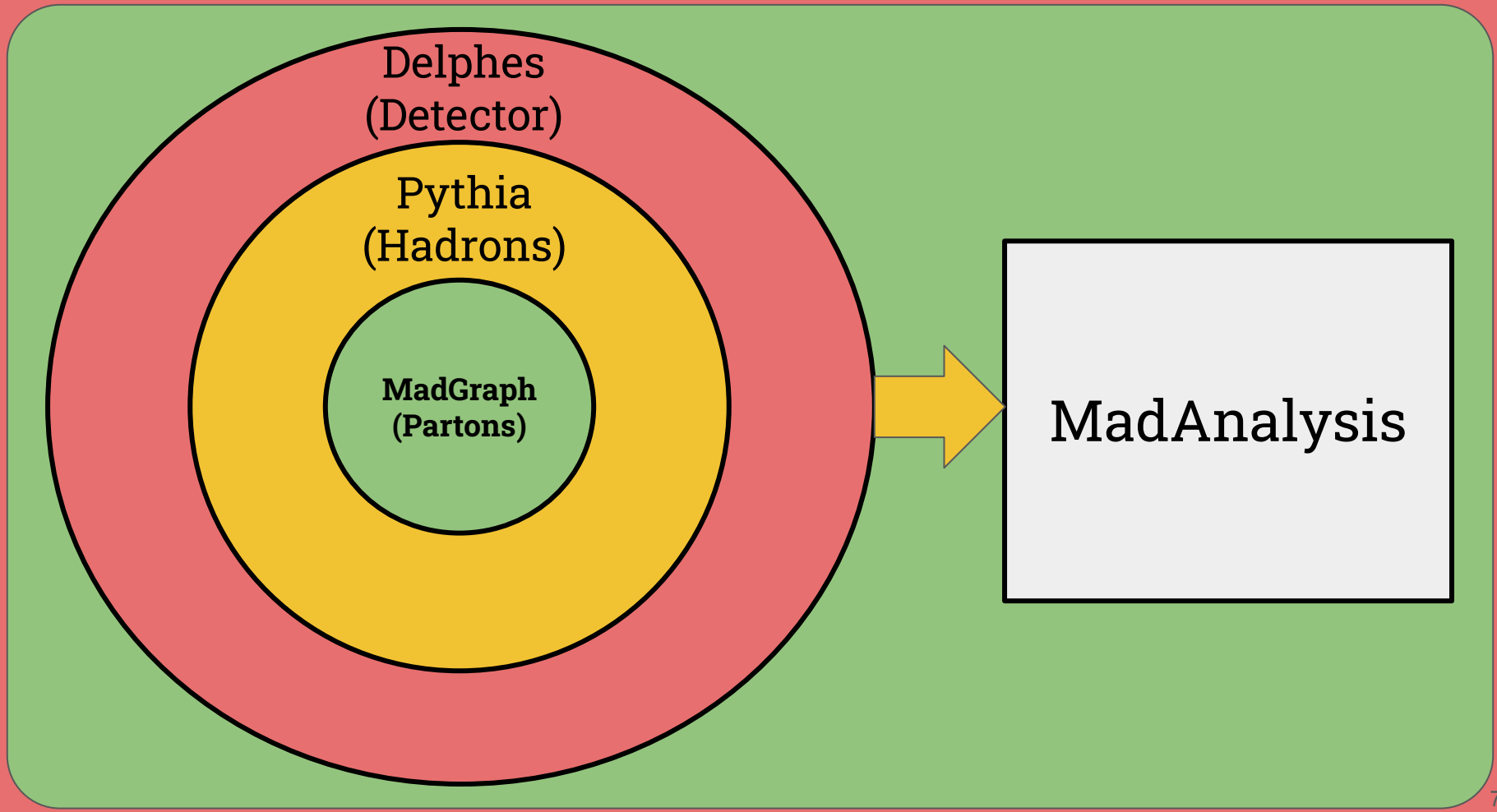


Particle Physics Model (like the SM)





- hard scatter – matrix elements from first principles - incoming partons from parton-distribution functions (PDFs)
- radiative corrections – resumming logarithms to all orders
- multiple parton interactions – additional interactions between proton remnants
- hadronisation – going colourless
- hadron decays – from excited states to final-state particles
- photon radiation – QED corrections


Delphes
(Detector)
Pythia
(Hadrons)
MadGraph
(Partons)
MadAnalysis

A note on detector simulation

Geant 4

- Particles-Matter interactions simulation.
- Real detectors as CMS or ATLAS.
- Only doable by the collaborations.

Delphes

- Detector emulation.
- Parametric functions to describe the detector response to particles.
- Main tool at pheno studies.

Comput. Implementation of models

FeynRules

- https://feynrules.irmp.ucl.ac.be/
- For MG we need the UFO format.
- SM implementation, tested and used by big collaborations.
- BSM implementation.
  - Common models: https://feynrules.irmp.ucl.ac.be/wiki/ModelDatabaseMainPage
  - New models (Needs Mathematica).

How to get the tools

- Root: https://root.cern/install/

- MadGraph: https://launchpad.net/mg5amcnlo
- Pythia8: https://pythia.org/
- Delphes: https://cp3.irmp.ucl.ac.be/projects/delphes
- MadAnalysis: https://launchpad.net/madanalysis5

It is easier to work with the Pythia and Delphes versions that come integrated in MadGraph.

Let’s code: First steps

tar -zxvf MG5_aMC_v3.4.1.tar.gz
cd MG5_aMC_v3_4_1/
./bin/mg5_aMC

install pythia8
install Delphes
install MadAnalysis5

Our first process: Drell-Yan

```
MG5_aMC>define p = p b b~

MG5_aMC>define j = j b b~

MG5_aMC>generate p p > mu+ mu-

MG5_aMC>output DYToMuMu

MG5_aMC>exit
```

Configuring the production

cd DYToMuMu/

ls Cards/

- me5_configuration.txt
- run_card.dat
- param_card.dat
- pythia8_card_default.dat
- delphes_card_default.dat

me5 Card

```
# automatic_html_opening = True

#! Default Running mode
#!  0: single machine/ 1: cluster / 2: multicore
# run_mode = 2

#! Nb_core to use (None = all) This is use only for multicore run
#!  This correspond also to the number core used for code
compilation for cluster mode
# nb_core = None
```

Run Card

```
10000 = nevents ! Number of unweighted events requested
0   = iseed   ! rnd seed (0=assigned automatically=default))

6500.0     = ebeam1  ! beam 1 total energy in GeV
6500.0     = ebeam2  ! beam 2 total energy in GeV

20.0  = ptl       ! minimum pt for the charged leptons

50.0   = mmll    ! min invariant mass of l+l- (same flavour) lepton pair

False  = use_syst      ! Enable systematics studies
```

Param Card

```
###################################
## INFORMATION FOR MASS
###################################
Block mass
    5 4.700000e+00 # MB
    6 1.730000e+02 # MT
   15 1.777000e+00 # MTA
   23 9.118800e+01 # MZ
   25 1.250000e+02 # MH
```

Pythia and Delphes Card

- Modify Pythia card only if you need to do something very specific: Matching/Merging, special configuration on hadron decays.

- Delphes card comes by default as CMS card, however you have examples for other experiments:
  - delphes_card_ATLAS.dat (in Cards directory)
  - https://github.com/delphes/delphes/tree/master/cards

Launch the production

./bin/madevent
DYToMuMu>launch

>shower=Pythia8
>detector=Delphes

[enter, enter]

Results

Cross-section:
=== Results Summary for run: run_01 tag: tag_1 ===

Cross-section : 659.4 +- 3.011 pb
Nb of events : 10000

ls Events/run_01/
unweighted_events.lhe.gz (Partonic events)
tag_1_pythia8_events.hepmc.gz (Hadronic events)
tag_1_delphes_events.root (Detector events)
run_01_tag_1_banner.txt (Full config content)

Simple exploration with MadAnalysis

```
cd madanalysis5/
python3 ./bin/ma5

ma5>import
/home/jose/PhenoTools/MG5_aMC_v3_4_1/DYToMuMu/Events/run_01/unweighted_even
ts.lhe.gz
ma5>plot PT(mu+) 20 0 200 #bins xmin xmax
ma5>plot PT(mu-) 20 0 200
ma5>plot ETA(mu+) 50 -2.5 2.5
ma5>plot ETA(mu-) 50 -2.5 2.5
ma5>plot PHI(mu+) 64 -3.2 3.2
ma5>plot PHI(mu-) 64 -3.2 3.2
ma5>plot M(mu+ mu-) 24 30 150
ma5>submit DYToMuMuFull #To produce the output with the results
```

Simple selection with MadAnalysis

```
cd madanalysis5/
python3 ./bin/ma5

ma5>import
/home/jose/PhenoTools/MG5_aMC_v3_4_1/DYToMuMu/Events/run_0
1/unweighted_events.lhe.gz
ma5>define mu = mu+ mu- #Define multiparticle
ma5>select (mu) PT>40 #Select events with muons with a PT>40 GeV
ma5>plot M(mu+ mu-) 24 30 150
ma5>submit SimpleSelectionDYToMuMu
```

Generating events for BSM

1. Get your UFO.
2. cp -r EFTcb_UFO models/

```
import model EFTcb_UFO
define p = p b b~
define j = j b b~
define Tau = ta- ta+
define ntau = vt vt~
generate p p > tau ntau NP==1
output EFT_dinamical_study_v2
```

This is just an intro!

1. Much more things can be done.
2. Generation with additional jets require an special configuration called Matching/Merging: https://arxiv.org/pdf/1405.0301.pdf
3. Generating big samples in clusters.
4. Calculating decays and Branching ratios.
5. MadAnalysis reco normal mode and expert mode.
6. MC samples at NLO!!!

Thanks!!!

josed.ruiz@udea.edu.co