

Madgraph Tutorial

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Introduction

MadGraph is a framework that provides elements for the SM and BSM Phenomenology about the computation of cross-section, generations of events, Matrix Element and detector response, etc. For further information you can look into it. [1, MadGraph].

1 Download

You can download the latest version of Madgraph from it's website. [1, MadGraph]. Or you can simply download from this link https://launchpad.net/mg5amcnlo/2.0/2.7.x/+download/MG5_aMC_v2.7.2.tar.gz

2 Installation

Now, in order to install the madgraph open a terminal where you have download the madgraph .tar file. Once, you have open the terminal then follow the steps. Follow the Figure 1 Madgraph. For the installation of Madgraph we have the pre-requisite of the root cern and python2.7.

3 Madgraph tutorial

We have to look into it's tutorial.

Now, open the madgraph terminal follow the Figure 1 Madgraph.

3.1 Exploring the Model

By default the model is Standard model (SM). In order to see the particles in the current SM model write:

display particles

It's shows current model contains 17 particles. In this model all particles have the same name as the SM except of the photon it's symbol is **a** instead of γ .

In order to see the particles properties write following command like:

display particles h

It's shows the properties of Higgs like name, charge, spin, pdg_code, line etc. similarly, for the other particles just write **display particles particlename**.

3.2 Multiparticles

In order to define the multi-particles for saving the lot of typing in the channel. You can define the multiparticles like:

display multiparticles

It's shows the multi-particles like the jet, proton, leptons, lepton-neutrinos. You can define your own multiparticles like:

define v=w+ w- z a

It's define the multi-particle of electro-weak bosons.

Similarly, you can define the jets including the b-quarks in the jet. like:

define j=j b b~

3.3 Interactions

In order to see the number of interaction or vertices in the current model. Type the command:

display interactions

This will show current model contains 56 interactions in SM model. In order to come out from this interactions view press **q** and press ENTER.

3.4 Generating a Process

To generate a collision process like PP collision goes to di-leptons:

generate p p > l+ l-

This is a Drell-Yan process in which di-leptons produce from a Z boson or photon decay. This process contains the 8 process with 16 diagrams. In order to display the diagrams of that process write the following command

and press ENTER.

display diagrams

In these diagrams you can see that there are two mediators photon (**a**) and Z boson. In order to exclude anyone of the mediator from the diagrams write the following command like:

generate p p > l+ l- /a

After this Write the command **display diagrams** and press ENTER. In these diagrams you can see that photon mediator are excluded from the diagrams, and only Z boson mediator is left.

3.5 Decay process

In order to generate a decay process there are a number of intermediate particles in the channel. Here, for the decaying particles we use the parenthesis in order to locate the decaying particles in the brackets. Like:

generate p p > z h , z > vl vl~ , (h > z l+ l- , z > l+ l-)

In above example, here higgs boson production associated with Z boson, where Z boson decays to neutrinos and Higgs boson decays to four leptons.

3.6 Packages Installation

After, the installation of the Madgraph we have to install other package inside the Madgraph on the terminal of Madgraph for the parton shower, detector response, and for events analysis, etc. Follow the Figure 2 Packages Installation. Packages:

install pythia8 [2]

install Delphes [3]

install pythia-pgs [4]

install MadAnalysis5 [5]

install ExRootAnalysis

After the installation of the packages it shows the successfully install in the directory of HEPTools in the Madgraph directory. In order to exit from the madgraph just enter exit and press.

4 Simulation of channels

In this section, we will see the simulation of different channels, calculate their cross-section, draw Feynman diagrams at a certain centre-of-mass energy at TeV scale.

5 tWZ Channel

In tWZ channel, here top quark is associated with di-boson. The final state contain three leptons along with one neutrino(MET) coming from the decays of top into W^+ boson along with b-jet, and from the decays of Z boson. Now write a decay channel on madgraph terminal. First open the madgraph terminal. Follow the Figure 1 Madgraph.

generate g b > t w- z , (t > b w+ , w+ > e+ ve), (z > e+ e-), (w- > u~ d)

Follow the Figure 3 for twz region.

When it's done now save the output into a folder for that purpose do the following step and press Enter:

output regiontwz

It's save outputs in the folder name **regiontwz** in madgraph directory. Now, in order to launch process for parton shower and detector response and events reconstruction do the following step and press Enter:

launch regiontwz

There show a view like Figure 4 for packages. There are different packages pythia8, Delphes, MadAnalysis5, In order to enable package like for pythia8 for parton shower/hadronization **Press 1** and Enter. This will enable pythia8. For detector response we use the Delphes. In order to enable this **Press 2** and Enter. This will enable Delphes. And MadAnalysis5 use for analysis package it's already enabled. Now, finally **Press 0** and Enter. It will show the cards like run card, parameter,pythia8,Delphes and MadAnalysis5 Figure 5.Now to run this process you have to **Press 0** and Enter. The output will show on your default browser like Mozilla FireFox. The competition of process will take time and output will show like Figure 6. You can see cross-section, collider energy, parton and hadron information are save in output.

In order to see output information you have to click on anyone MA5analysis1 and MA5analysis2_BasicReco. To see on madgraph terminal process is completed successfully.

You can see your outputs in your folder in which you have save your outputs, for this go back to the madgraph directory. And open **regiontwz** folder. You have to open file **crossx.html** in this file you can same information which you have seen in Mozilla FireFox.Figure 7 crossx.html.

All outputs are save in folder **run_1** you can jump into this folder, from regiontwz/Events/run_1. Here you can see output about your channel. Figure 8 run_1.

Similarly, you can try other channels:

generate g g > t~ t z, (z > e- e+), (t~ > w- b~ , w- > d u~), (t > b w+, w+ > e+ ve)

5.1 Tutorials

I mentioned here, some useful links about madgraph tutorials. [6, Madgraph5], [7], [8]

References

- [1] MadGraph, <https://launchpad.net/mg5amcnlo>
- [2] An Introduction to PYTHIA 8.2, <https://arxiv.org/abs/1410.3012>
- [3] DELPHES 3, A modular framework for fast simulation of a generic collider experiment, <https://arxiv.org/abs/1307.6346>
- [4] PYTHIA 6.4 Physics and Manual, <https://arxiv.org/abs/hep-ph/0603175>
- [5] MadAnalysis 5, a user-friendly framework for collider phenomenology, <https://arxiv.org/abs/1206.1599>
- [6] MadGraph 5 : Going Beyond, <https://arxiv.org/abs/1106.0522>
- [7] The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations, <https://arxiv.org/abs/1405.0301>
- [8] MadGrapg Twiki Pages, <https://twiki.cern.ch/twiki/bin/view/Main/UnitsHiggsTutorial2016>

```

muhammadfarooq@atlas-VirtualBox: ~/Downloads/MG5_aMC_v2_7_2
muhammadfarooq@atlas-VirtualBox:~/Downloads$ tar -xvf MG5_aMC_v2.7.2.tar.gz
muhammadfarooq@atlas-VirtualBox:~/Downloads$ cd MG5_aMC_v2_7_2/
muhammadfarooq@atlas-VirtualBox:~/Downloads/MG5_aMC_v2_7_2$ python2.7 ./bin/mg5_aMC

```

Figure 1: Madgraph installation

```

muhammadfarooq@atlas-VirtualBox: ~/montecarlo/MG5_aMC_v2_7_2
MG5_aMC> set fastjet /PATH/TO/fastjet-config
MG5_aMC> set lhapdf /PATH/TO/lhapdf-config
MG5_aMC>install pythia8

```

Figure 2: packages installation

```

Activities  Terminal  23:07 جمعرات
muhammadfarooq@atlas-VirtualBox: ~/Downloads/MG5_aMC_v2_7_2

File Edit View Search Terminal Help
* The MadGraph5_aMC@NLO Development Team - Find us at *
* https://server06.fynu.ucl.ac.be/projects/madgraph *
* and *
* http://amcatnlo.web.cern.ch/amcatnlo/ *
* *
* Type 'help' for in-line help. *
* Type 'tutorial' to learn how MG5 works *
* Type 'tutorial aMCatNLO' to learn how aMC@NLO works *
* Type 'tutorial MadLoop' to learn how MadLoop works *
* *
*****
load MG5 configuration from input/mg5_configuration.txt
fastjet-config does not seem to correspond to a valid fastjet-config executable (v3+). We will use fjcore instead.
Please set the 'fastjet' variable to the full (absolute) /PATH/TO/fastjet-config (including fastjet-config).
MG5_aMC> set fastjet /PATH/TO/fastjet-config

set lhapdf to /home/muhammadfarooq/Downloads/MG5_aMC_v2_7_2/HEPTools/lhapdf6/bin/lhapdf-config
Using default text editor "vi". Set another one in ./input/mg5_configuration.txt
Using default eps viewer "evince". Set another one in ./input/mg5_configuration.txt
Using default web browser "firefox". Set another one in ./input/mg5_configuration.txt
Loading default model: sm
INFO: Restrict model sm with file models/sm/restrict_default.dat .
INFO: Run "set stdout_level DEBUG" before import for more information.
INFO: Change particles name to pass to MG5 convention
Defined multiparticle p = g u c d s u~ c~ d~ s~
Defined multiparticle j = g u c d s u~ c~ d~ s~
Defined multiparticle l+ = e+ mu+
Defined multiparticle l- = e- mu-
Defined multiparticle vl = ve vm vt
Defined multiparticle vl~ = ve~ vm~ vt~
Defined multiparticle all = g u c d s u~ c~ d~ s~ a ve vm vt e- mu- ve~ vm~ vt~ e+ mu+ t b t~ b~ z w+ h w- ta- ta+
MG5_aMC>generate g b > t w- z , (t > b w+ , w+ > e+ ve), (z > e+ e-), (w- > u- d)[]

```

Figure 3: twz channel

```

Activities  Terminal  15:21 جمعرات
muhammadfarooq@atlas-VirtualBox: ~/Downloads/MG5_aMC_v2_7_2

File Edit View Search Terminal Help
* * * * *
* * * * 5 * * * *
* * * * *
*
VERSION 2.7.2          2020-03-17
*
* The MadGraph5_aMC@NLO Development Team - Find us at *
* https://server06.fynu.ucl.ac.be/projects/madgraph *
* *
* Type 'help' for in-line help. *
* *
*****
INFO: load configuration from /home/muhammadfarooq/Downloads/MG5_aMC_v2_7_2/twz/Cards/me5_configuration.txt
INFO: load configuration from /home/muhammadfarooq/Downloads/MG5_aMC_v2_7_2/input/mg5_configuration.txt
INFO: load configuration from /home/muhammadfarooq/Downloads/MG5_aMC_v2_7_2/twz/Cards/me5_configuration.txt
Using default text editor "vi". Set another one in ./input/mg5_configuration.txt
generate_events run_01
The following switches determine which programs are run:
/===== Description =====|===== values =====|== other options ==\
| 1. Choose the shower/hadronization program | shower = OFF | Pythia8 | |
| 2. Choose the detector simulation program | detector = OFF | Delphes |
| 3. Choose an analysis package (plot/convert) | analysis = MadAnalysis5 | OFF |
| 4. Decay onshell particles | madspin = OFF | ON|onshell |
| 5. Add weights to events for new hypp. | reweight = OFF | ON |
\=====|
Either type the switch number (1 to 5) to change its setting,
Set any switch explicitly (e.g. type 'shower=Pythia8' at the prompt)
Type 'help' for the list of all valid option
Type '0', 'auto', 'done' or just press enter when you are done.[60s to answer]
>

```

Figure 4: Packages selection


```

Activities Terminal 15:22 جمعرات
muhammadfarooq@atlas-VirtualBox: ~/Downloads/MG5_aMC_v2_7_2

>2
The following switches determine which programs are run:
/===== Description =====|===== values =====|== other options ==\
| 1. Choose the shower/hadronization program | shower = Pythia8 | OFF | |
| 2. Choose the detector simulation program | detector = Delphes | OFF |
| 3. Choose an analysis package (plot/convert) | analysis = MadAnalysis5 | OFF |
| 4. Decay onshell particles | madspin = OFF | ON|onshell |
| 5. Add weights to events for new hypp. | reweight = OFF | ON |
\=====|=====|=====|
Either type the switch number (1 to 5) to change its setting,
Set any switch explicitly (e.g. type 'shower=OFF' 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
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. delphes : delphes_card.dat |
| 5. madanalysis5_parton : madanalysis5_parton_card.dat |
| 6. madanalysis5_hadron : madanalysis5_hadron_card.dat |
\-----/
you can also
- enter the path to a valid card or banner.
- use the 'set' command to modify a parameter directly.
The set option works only for param_card and run_card.
Type 'help set' for more information on this command.
- call an external program (ASperGE/MadWidth/...).
Type 'help' for the list of available command
[0, done, 1, param, 2, run, 3, pythia8, 4, enter path, ... ][90s to answer]
>0

```

Figure 5: cards

Activities Firefox Web Browser 23:47 جمعرات

Online Event Generation - Mozilla Firefox

Inbox (3,680) - 2714befa x Problem loading page x Online Event Generation x New Tab x Online Event Generation x +

file:///home/muhammadfarooq/Downloads/MG5_aMC_v2_7_2/regiontwz/crossx.html

Results in the sm for $g b > t w^- z$, ($t > b w^+$, $w^+ > e^+ \nu_e$), ($z > e^+ e^-$), ...

Available Results

Run	Collider	Banner	Cross section (pb)	Events	Data	Output	Action
run_01	p p 6500.0 x 6500.0 GeV	tag_1	3.416e-05 ± 9.8e-08	10000	parton madevent	LHE MA5_report_analysis1	remove run launch detector simulation
					pythia8	LOG HEPMC	remove run launch detector simulation
					delphes	LOG rootfile	remove run
					hadron MA5	analysis2_BasicReco	

[Main Page](#)

Figure 6: Main page

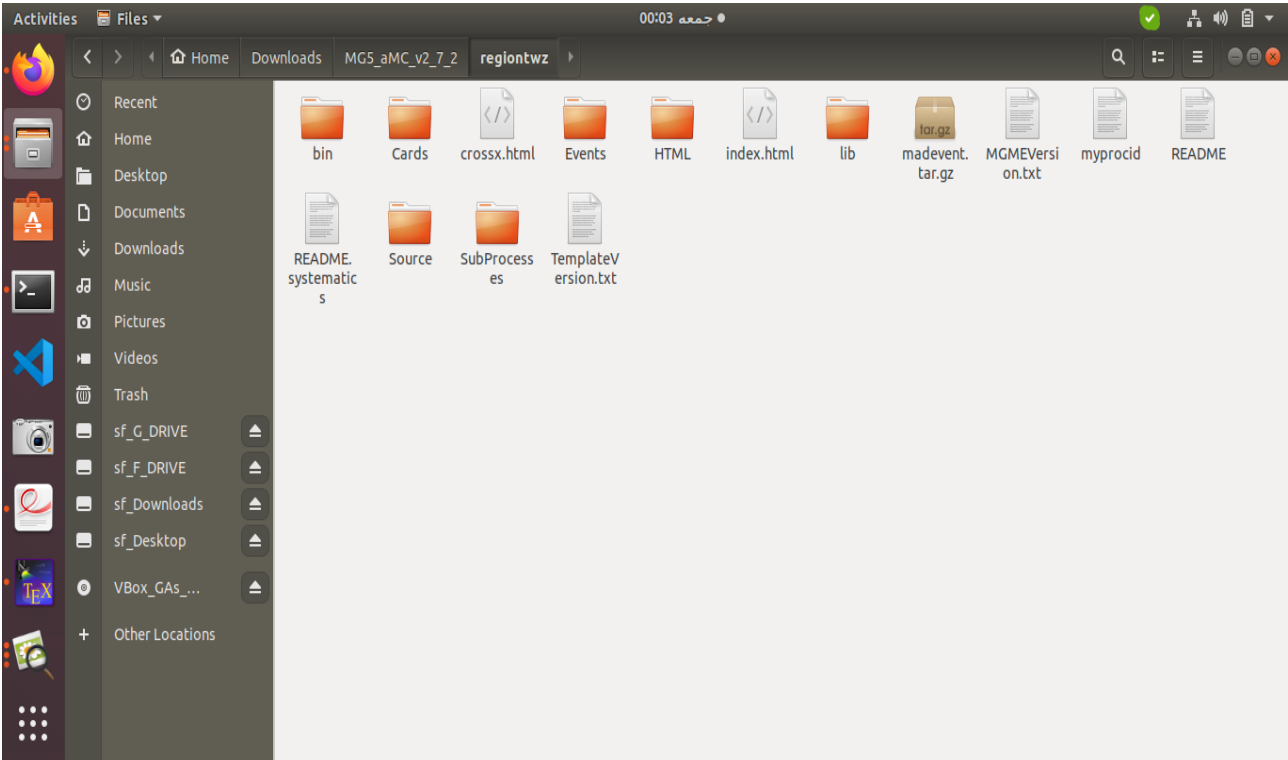


Figure 7: crossx.html

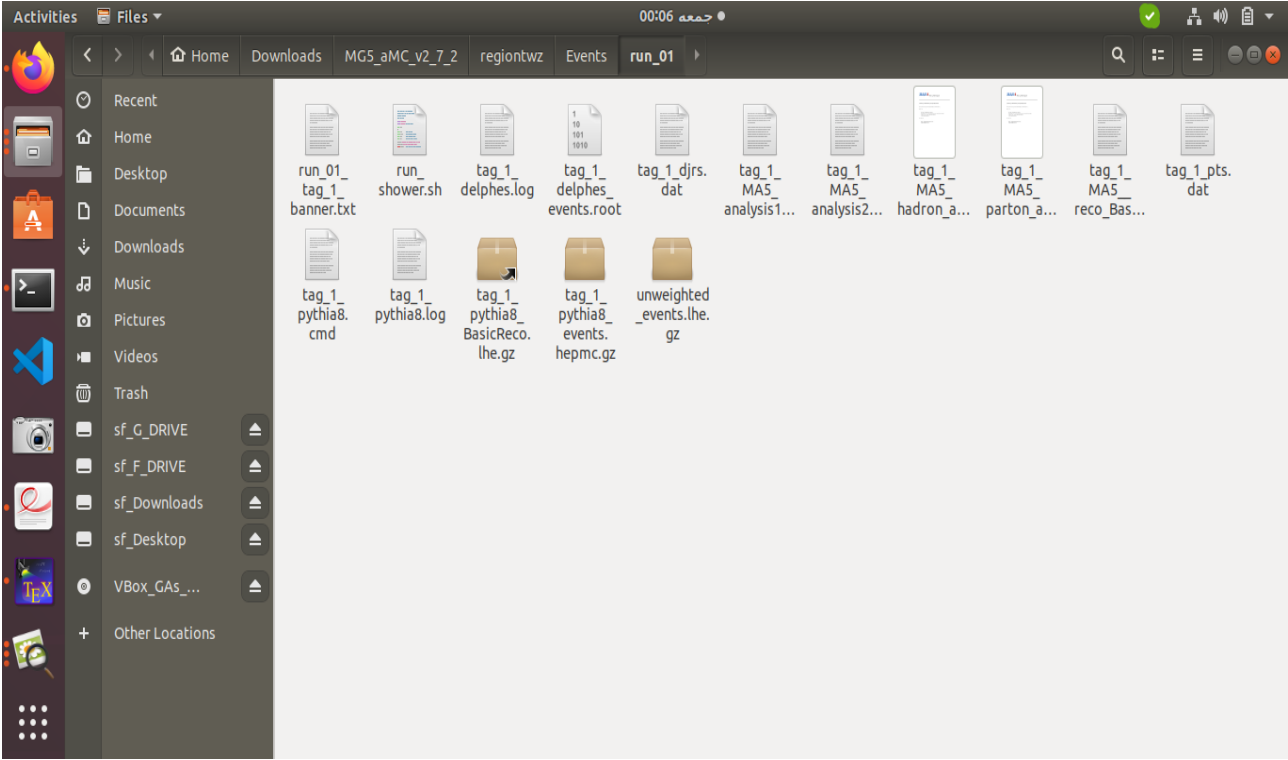


Figure 8: run_1