

ICS2025 Tutorial; requirements

- Laptop PC (with internet connection)
- Terminal (for shell operation)
- Basic knowledge of shell commands;
e.g. `pwd`, `mkdir`, `cd`, `cp`, `mv`, `rm`, `tar`, `less`, `more`, ...
- python 3.7 (or higher)
- gfortran/gcc 4.6 or higher
- matplotlib (or ROOT) [for MadAnalysis5]
- Mathematica [only for those who want to learn FeynRules]

MadGraph5_aMC@NLO; start-up

- Download **MG5_aMC_vX.Y.Z.tar.gz** (v2.9.22) from the MadGraph5_aMC@NLO launchpad: <https://launchpad.net/mg5amcnlo>
- At your working directory in a terminal, untar:
\$ tar zxvf MG5_aMC_X.Y.Z.tar.gz
- Go into the MG5aMC directory:
\$ cd MG5_aMC_vX_Y_Z/
- Start MG5aMC:
\$./bin/mg5_aMC

MG5aMC; first try

- After the MG5aMC logo, your terminal should have **MG5_aMC>** prompt. Please try:
 - **MG5_aMC>** generate p p > t t~
 - **MG5_aMC>** output
 - **MG5_aMC>** launch
- Please ignore a few questions from MG5aMC by just pushing the "Enter" key, then after a few minutes, you should get in your browser (.../MG5_aMC_vX_Y_Z/PROC_sm_0/crossx.html) like

Results in the sm for p p > t t~

Available Results

Run	Collider	Banner	Cross section (pb)	Events	Data	Output	Action
run_01	pp 6500.0 x 6500.0 GeV	tag_1	505.8 ± 0.73	10000	parton madevent	LHE	<input type="button" value="remove run"/> <input type="button" value="launch detector simulation"/>

- Now you are ready to do some simulations for the LHC and the ILC!

MG5aMC; install other tools

Please also try to install other tools as

- For plots:
`MG5_aMC> install MadAnalysis5`
- For parton-shower and hadronization:
`MG5_aMC> install pythia8`

MG5aMC; main 4 steps

- MG5_aMC> import model **MODEL** (e.g. 2HDM)
- MG5_aMC> generate **PROCESS** (e.g. $p p \rightarrow t t^{\sim}$)
- MG5_aMC> output (**my_process**)
- MG5_aMC> launch
- MG5_aMC> launch
- MG5_aMC> ...

MG5aMC; tips

- Use auto-completion by “tab (tab)”.
- MG5_aMC> help
- MG5_aMC> help **COMMAND** (e.g. generate)
- MG5_aMC> tutorial

The image shows two overlapping browser windows. The foreground window is at `answers.launchpad.net` and displays the 'Ask a question' page for MadGraph5_aMC@NLO. The page includes a navigation menu with 'Overview', 'Code', 'Bugs', 'Blueprints', 'Translations', and 'Answers'. A large red text overlay reads: "One can directly communicate with the developers via Launchpad (ask questions, report bugs, etc)." The page content includes a text area for a question, a language dropdown set to 'English (en)*', and a 'Continue' button. The background window is at `launchpad.net` and shows the main project page with a 'Log Out' button and a 'Subscribe to bug mail' button.

One can directly communicate with the developers via Launchpad (ask questions, report bugs, etc).

EX-1.1; warm up (top quark pair production)

- Top-pair production at the LHC:
`MG5_aMC> generate p p > t t~`

Questions?

- Which partonic subprocesses contribute ?
- How the Feynman diagrams look like ?

`MG5_aMC> display diagrams`

To Remember

$$\sum_{a,b} \int dx_1 dx_2 d\Phi_{\text{FS}} f_a(x_1, \mu_F) f_b(x_2, \mu_F) \hat{\sigma}_{ab \rightarrow X}(\hat{S}, \mu_F, \mu_R)$$

Phase-space integral Parton density functions Parton-level cross section

- PDF: content of the proton
 - ➔ Define the physics/processes that will dominate on your accelerator
- LO: good for shape
- NLO/NNLO: Reduce scale uncertainty
- Computation are inclusive (+ any jet) due to renormalization/factorization scale

EX-1.2; warm up (top quark pair production)

- Top-pair production at the LHC:
MG5_aMC> generate p p > t t~

Questions?

- How much the cross sections are at 7TeV (= Run-1), 13TeV (= Run-2), and 13.6TeV (= Run-3) at the LHC ?
- How much the cross section is if $m_t = 170\text{GeV}$?

MG5_aMC> output my_toppair (name it as you like)

MG5_aMC> open index.html (check the diagrams)

MG5_aMC> launch (modify run_card/param_card)

→ alternative way in the next page

EX-1.2; warm up (top quark pair production)

- Top-pair production at the LHC:
MG5_aMC> generate p p > t t~

Questions?

- How much the cross sections are at 7TeV (= Run-1), 13TeV (= Run-2), and 13.6TeV (= Run-3) at the LHC ?
- How much the cross section is if $m_t = 170\text{GeV}$?

MG5_aMC> output my_toppair (name it as you like)

MG5_aMC> open index.html (check the diagrams)

MG5_aMC> launch -n run1

> set ebeam 7000/2

> set mt 170

One can “set” the parameters without editing the cards.
→ useful for scripting

EX-1.3; warm up (top quark pair production)

- Top-pair production at the LHC:
MG5_aMC> generate p p > t t~

Questions?

- Are b-quarks included in the initial state ? (check the diagrams)
- How can we include them ? and How much do they contribute to the cross section ?

```
MG5_aMC> display multiparticles
```

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

```
MG5_aMC> generate ...; output ...; launch
```

→ better solution in the next page

EX-1.3; warm up (top quark pair production)

- Top-pair production at the LHC:
MG5_aMC> generate p p > t t~

Questions?

- Are b-quarks included in the initial state ? (check the diagrams)
- How can we include them ? and How much do they contribute to the cross section ?

```
MG5_aMC> import model sm-no_b_mass (SM w/ mb=0)
```

```
MG5_aMC> display multiparticles
```

```
MG5_aMC> generate ...; output ...; launch
```

4-flavor scheme → 5-flavor scheme

EX-1.4; warm up (top quark pair production)

- Top-pair production at the LHC:
MG5_aMC> generate p p > t t~

Questions?

- How can we calculate for Tevatron (= p p~ collider) ?
- How much the cross section is at 2TeV Tevatron ?
Which subprocesses contribute to the cross section ?
Compare to the 2TeV LHC result ?

```
MG5_aMC> generate p p~ > t t~  
MG5_aMC> display multiparticles  
MG5_aMC> launch (modify run_card)
```

EX-1.5; warm up (top quark pair production)

- Top-pair production at the LHC:

```
MG5_aMC> generate p p > t t~
```

Questions?

- Are diagrams with photon(a)/Z included ?
- How can we include them ? How much are the cross sections with each command below different ?

```
MG5_aMC> display particles a (check what is “a”)
```

```
MG5_aMC> generate p p > t t~
```

```
MG5_aMC> generate p p > t t~ QCD=0
```

```
MG5_aMC> generate p p > t t~ QED=0
```

```
MG5_aMC> generate p p > t t~ QED=99 (or QED<=99)
```

Solution

EX-1.5; warm up (top quark pair production)

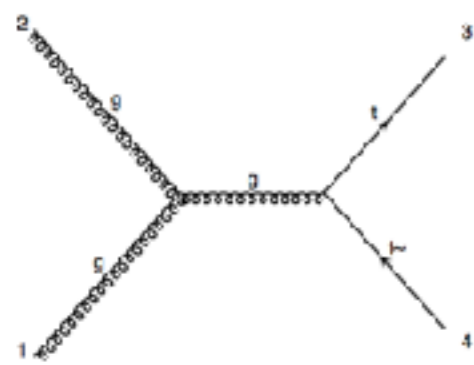


diagram 1 **QCD=2, QED=0**

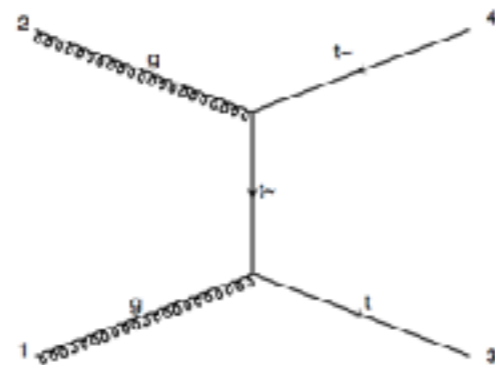


diagram 2 **QCD=2, QED=0**

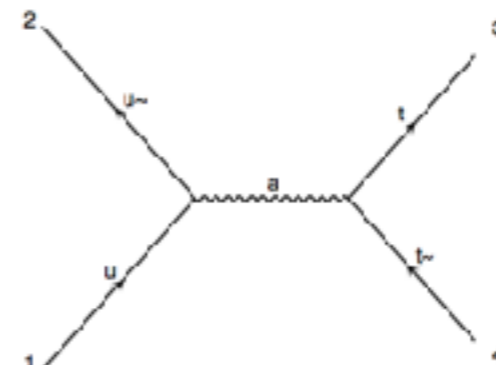


diagram 1 **QCD=0, QED=2**



diagram 2 **QCD=2, QED=0**

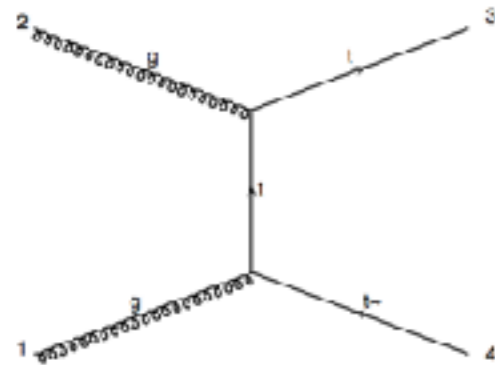


diagram 3 **QCD=2, QED=0**

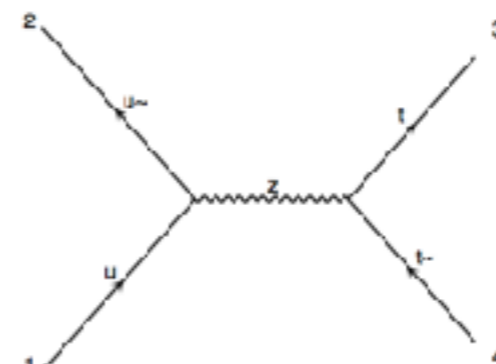


diagram 3 **QCD=0, QED=2**

QCD
only

	Cross-Section ↓
/P1_gg_ttx	<u>441.7</u>
/P1_qq_ttx	<u>64.04</u>

QCD
+
QED

	Cross-Section ↓
/P1_gg_ttx	<u>441.7</u>
/P1_qq_ttx	<u>64.06</u>

EX-1.6; warm up (top quark pair production)

- Top-pair production at the LHC:
`MG5_aMC> generate p p > t t~`

Questions?

- Check the energy dependence of the cross section from 1 TeV up to 100 TeV ?

Open a text file (mg5test.txt) and put the commands inside.
`./bin/mg5_aMC mg5test.txt`

- Check the top-quark mass dependence ($170 \text{ GeV} < m_t < 180 \text{ GeV}$) at the 14 TeV-LHC ?

`> set mt scan:[170+i for i in range (0,11)]`