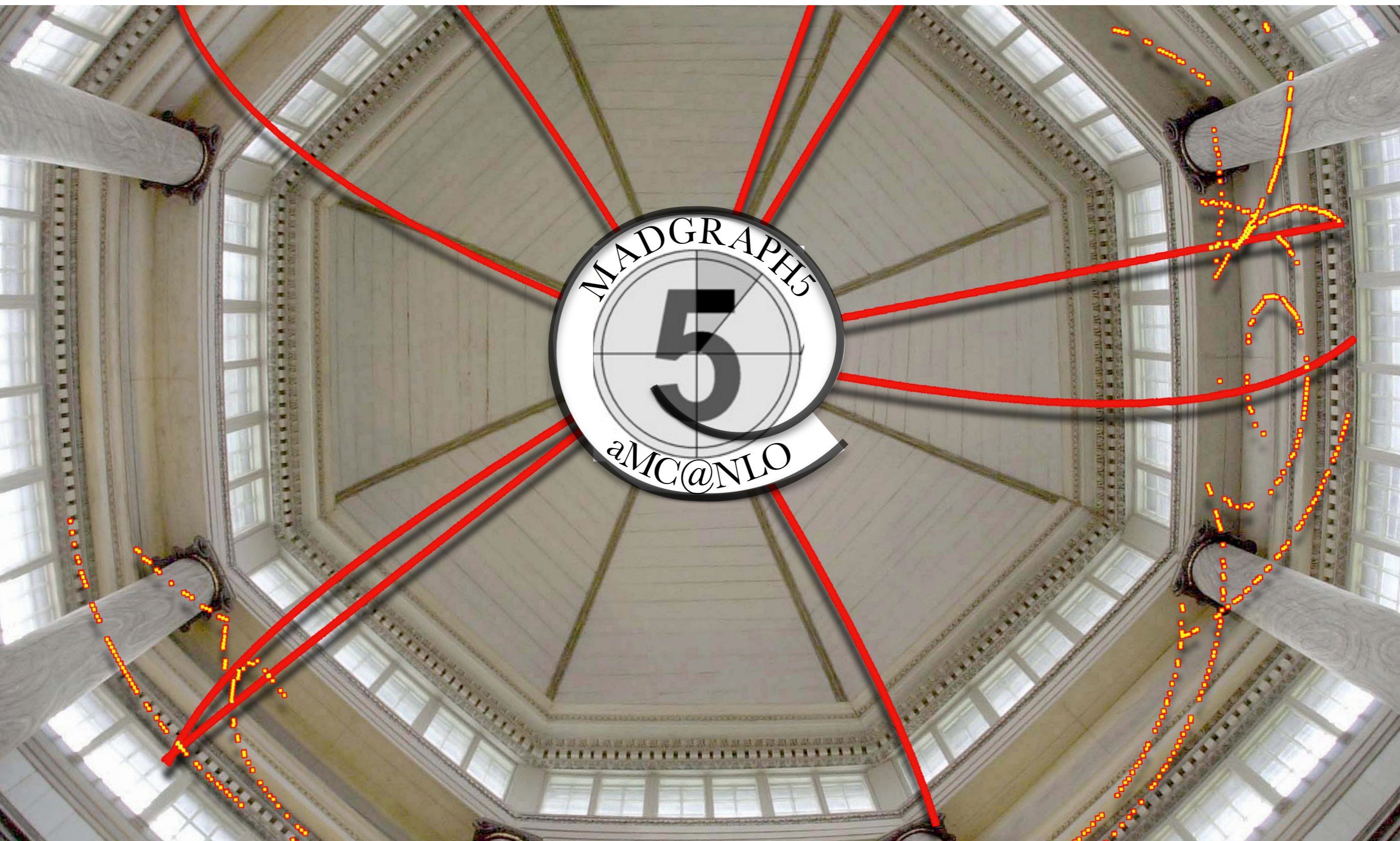


MadGraph5_aMC@NLO

Olivier Mattelaer

IPPP/Durham



- A Python **framework** that handles tree-level, one-loop, LO and NLO, LO+PS, NLO+PS and merged calculations.

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- A Python **framework** that handles tree-level, one-loop, LO and NLO, LO+PS, NLO+PS and merged calculations.
- MadGraph5 and MadLoop generate **tree-level** and **one loop** matrix-element.
- Several outputs are possible, both as **standalone** (to be used in native or independent applications) or as a **full-fledged codes** that generate events (MadEvent at LO, aMC@NLO at NLO).
- Full **BSM** support at LO, starts at NLO.

- Mass production in MadGraph5
- aMC@NLO
- Conclusion

Event Generation

- MadGraph5
- aMC@NLO
- ...

SLOW

Shower/ Hadronization

- Pythia
- Herwig
- ...

FAST

Full Simulation

- ATLAS
- CMS
- DELPHES
- ...

VERY SLOW

- We need method to minimize the amount of time use in Full Sim -> minimize number of events

Phase-space

- Events with a probability

$$\vec{p}_1 \rightarrow P_1$$

$$\vec{p}_2 \rightarrow P_2$$

$$\vec{p}_3 \rightarrow P_3$$

...

Phase-space

- Events with a probability

$$\vec{p}_1 \rightarrow P_1$$

$$\vec{p}_2 \rightarrow P_2$$

$$\vec{p}_3 \rightarrow P_3$$

...

Unweighting

- Select a sub-sample

$$\vec{p}_1 \rightarrow 1$$

~~$$\vec{p}_2 \rightarrow P_2$$~~

$$\vec{p}_3 \rightarrow 1$$

$$P_{keep_i} = \frac{P_i}{\max_j(P_j)}$$

Phase-space

- Events with a probability

$$\vec{p}_1 \rightarrow P_1$$

$$\vec{p}_2 \rightarrow P_2$$

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...

Second Theory

- Events with a probability

$$\vec{p}_1 \rightarrow \tilde{P}_1$$

$$\vec{p}_2 \rightarrow \tilde{P}_2$$

$$\vec{p}_3 \rightarrow \tilde{P}_3$$

...

Unweighting

- Select a sub-sample

$$\vec{p}_1 \rightarrow 1$$

~~$$\vec{p}_2 \rightarrow P_2$$~~

$$\vec{p}_3 \rightarrow 1$$

$$P_{keep_i} = \frac{P_i}{\max_j(P_j)}$$

Phase-space

- Events with a probability

$$\vec{p}_1 \rightarrow P_1$$

$$\vec{p}_2 \rightarrow P_2$$

$$\vec{p}_3 \rightarrow P_3$$

...

Second Theory

- Events with a probability

$$\vec{p}_1 \rightarrow \tilde{P}_1$$

$$\vec{p}_2 \rightarrow \tilde{P}_2$$

$$\vec{p}_3 \rightarrow \tilde{P}_3$$

...

Unweighting

- Select a sub-sample

$$\begin{array}{l} \vec{p}_1 \rightarrow 1 \rightarrow \frac{\tilde{P}_1}{P_1} \\ \cancel{\vec{p}_2} \\ \vec{p}_3 \rightarrow 1 \rightarrow \frac{\tilde{P}_3}{P_3} \end{array}$$

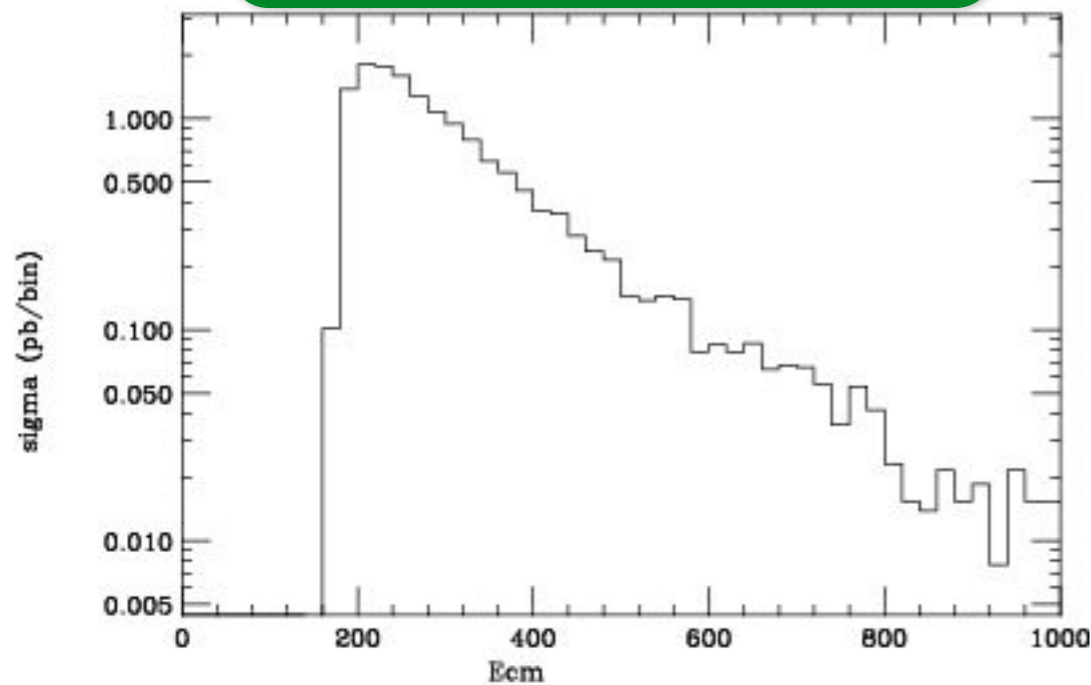
$$P_{keep_i} = \frac{P_i}{\max_j(P_j)}$$

- Idea: use one (un)weighted generations and associate additional weights from different hypothesis.

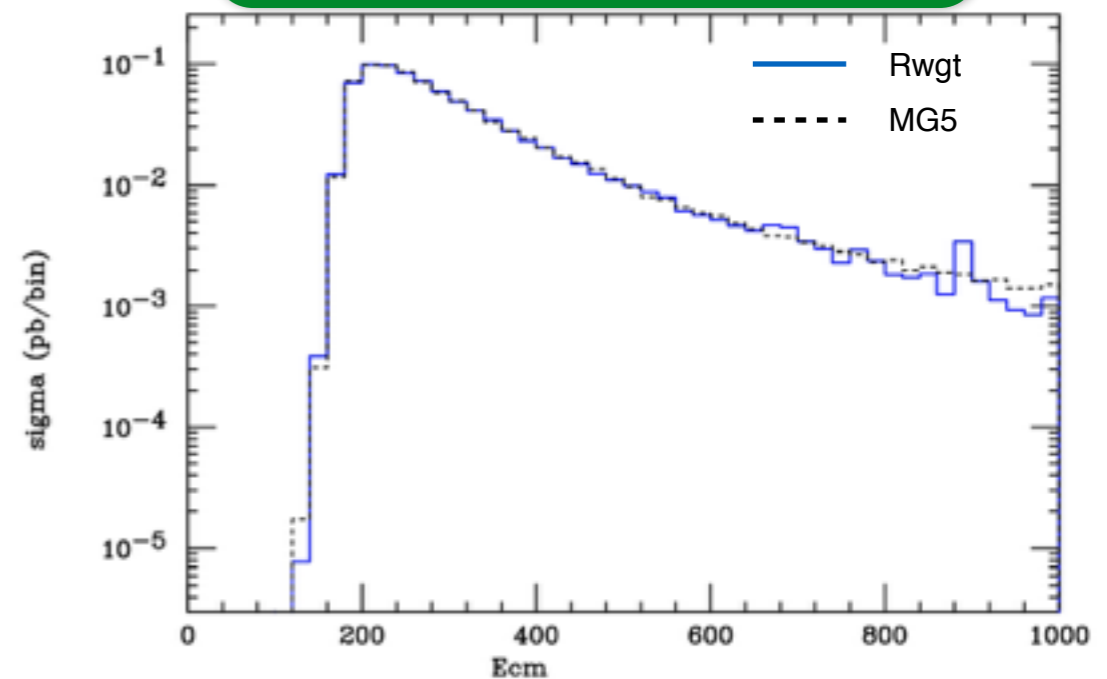
$$W_{new} = \frac{|M_{new}|^2}{|M_{old}|^2} * W_{old}$$

- Can be run on the flight inside MG5

Original



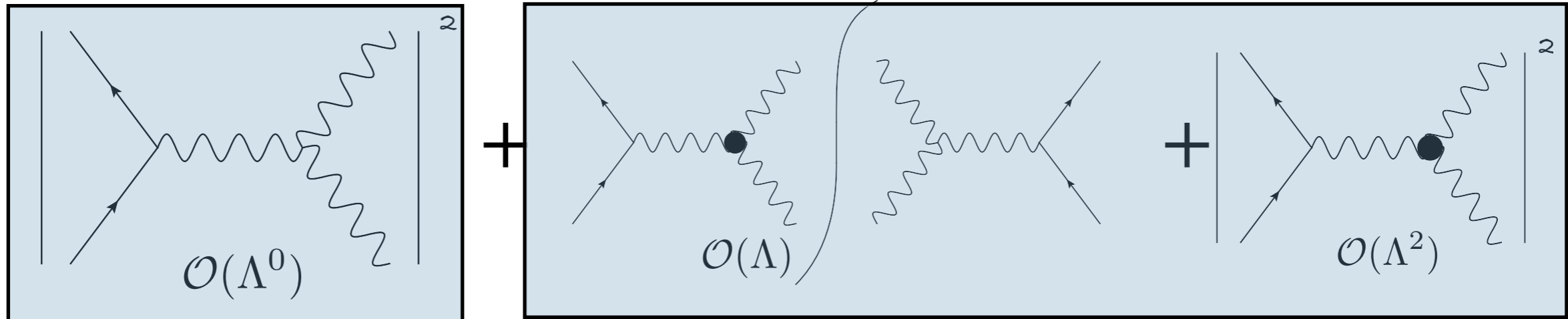
Reweighted



1405.0301/1404.7129

- This is **NOT** a 1D histogram re-weighting
 - This is a Fully differential re-weighting
- This assume that the **Phase-Space** is the same
 - **Bad** for scan over mass
 - **Good** for scan over coupling
- Output in LHEF version 3 format

Motivation:



SM

Model independent
Dominant

BSM

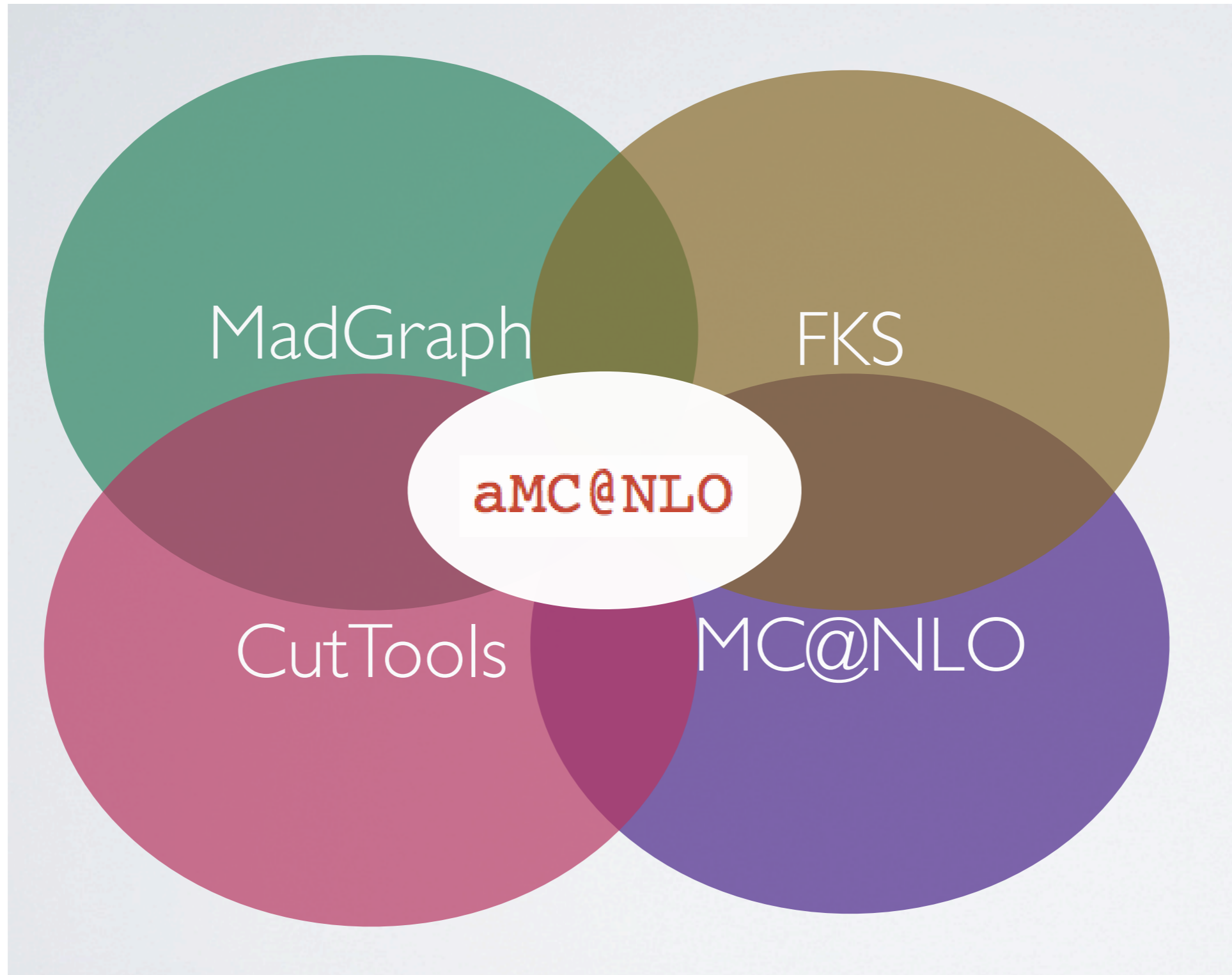
Model dependent
Sub-Dominant

Idea:

- Compute them separately
- Have a new syntax for such selection ($NP^2=$)

Status:

- Release this week



- Why automation?
 - Time: Don't have to wait for a theorist!
 - Robust: Easier to test, to trust

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- Why **automation**?
 - Time: Don't have to wait for a theorist!
 - Robust: Easier to test, to trust
- Why **NLO**?
 - Reliable prediction of the total rate
 - Reduction of the theoretical uncertainty
- Why **matched to the PS**?
 - Matching cure some fix-order ill behaved observables

- Is it **Really** automatic?

- 1) Download the code

MadGraph5_aMC@NLO Generator

Overview Code Bugs Blueprints Translations Answers

Registered 2009-09-15 by [Michel Herquet](#)

MadGraph5_aMC@NLO is a framework that aims at providing all the elements necessary for SM and BSM phenomenology, such as the computations of cross sections, the generation of hard events and their matching with event generators, and the use of a variety of tools relevant to event manipulation and analysis. Processes can be simulated to LO accuracy for any user-defined Lagrangian, and the NLO accuracy in the case of QCD corrections to SM processes. Matrix elements at the tree- and one-loop-level can also be obtained.

MadGraph5_aMC@NLO is the new version of both MadGraph5 and aMC@NLO that unifies the LO and NLO lines of development of automated tools within the MadGraph family. It therefore supersedes all the MadGraph5 1.5.x versions and all the beta versions of aMC@NLO.

The standard reference for the use of the code is: J. Alwall et al, "The automated computation of tree-level and next-to-leading order differential cross sections, and their matching to parton shower simulations", arXiv:1405.0301 [hep-ph]. A more complete list of references can be found here: http://amcatnlo.web.cern.ch/amcatnlo/list_refs.htm

Download:

The latest stable release can be downloaded as a tar.gz package (see the right of this page), or through the Bazaar versioning system, using bazaar branch [lp:madgraph5](#)

Installation:

MadGraph5_aMC@NLO needs Python version 2.6 or 2.7 ; gfortran/gcc 4.6 or higher is required for NLO calculations/simulations.

Getting started:

Run bin/mg5_aMC and type "help" to learn how to run MadGraph5_aMC@NLO using the command interface, or run the interactive quick-start tutorial by typing "tutorial". Some third-party packages can be installed using the MG5_aMC shell command "install". LO generation can also be done directly online at: <http://madgraph.phys.ucl.ac.be> or <http://madgraph.hep.uiuc.edu>

[Change branding](#)

[Home page](#) [Wiki](#)

Project information

Maintainer: [MadTeam](#)

Also known as: [madgraph5](#)

Series and milestones

2.0

[View full history](#)

Downloads

Latest version is 2.1.0

MG5_aMC_v2.1.2.tar.gz [Download](#)

Released on 2014-02-21

[All downloads](#)

Announcements

Official Release of MadGraph5_aMC@NLO on 2013-12-16

we would like to announce the public release of the new code MadGraph5_aMC@NLO

[aMC@NLO in MadGraph5 on 2012-11-08](#)

- You can enter **ANY** process!
 - ➔ add [QCD] for NLO functionalities
 - ❑ generate $p p > t t^{\sim}$ [QCD]
 - ❑ generate $p p > e^+ e^- \mu^+ \mu^-$ [QCD]
 - ❑ generate $p p > w^+ w^- j j$ [QCD]

```

MG5>generate p p > t t~ [QCD]
Switching from interface MG5 to aMC@NLO
The default sm model does not allow to generate loop processes. MG5 now loads 'loop_sm' instead.
  import model loop_sm
INFO: load particles
INFO: load vertices
INFO: Restrict model loop_sm with file models/loop_sm/restrict_default.dat .
INFO: Run "set stdout_level DEBUG" before import for more information.
INFO: Change particles name to pass to MG5 convention
Kept definitions of multiparticles l- / j / vl / l+ / p / vl~ unchanged
Defined multiparticle all = g gh gh~ d u s c d~ u~ s~ c~ a ve vm vt e- mu- ve~ vm~ vt~ e+ mu+ b t b~ t~ z w+ h w- ta- ta+
INFO: Generating FKS-subtracted matrix elements for born process: g g > t t~ [ QCD ]
INFO: Generating FKS-subtracted matrix elements for born process: u u~ > t t~ [ QCD ]
INFO: Generating FKS-subtracted matrix elements for born process: c c~ > t t~ [ QCD ]
INFO: Generating FKS-subtracted matrix elements for born process: d d~ > t t~ [ QCD ]
INFO: Generating FKS-subtracted matrix elements for born process: s s~ > t t~ [ QCD ]
INFO: Generating FKS-subtracted matrix elements for born process: u~ u > t t~ [ QCD ]
INFO: Generating FKS-subtracted matrix elements for born process: c~ c > t t~ [ QCD ]
INFO: Generating FKS-subtracted matrix elements for born process: d~ d > t t~ [ QCD ]
INFO: Generating FKS-subtracted matrix elements for born process: s~ s > t t~ [ QCD ]
INFO: Generating virtual matrix elements using MadLoop:
INFO: Generating virtual matrix element with MadLoop for process: g g > t t~ [ QCD ]
INFO: Generating virtual matrix element with MadLoop for process: u u~ > t t~ [ QCD ]
INFO: Generating virtual matrix element with MadLoop for process: c c~ > t t~ [ QCD ]
INFO: Generating virtual matrix element with MadLoop for process: d d~ > t t~ [ QCD ]
INFO: Generating virtual matrix element with MadLoop for process: s s~ > t t~ [ QCD ]
INFO: Generating virtual matrix element with MadLoop for process: u~ u > t t~ [ QCD ]
INFO: Generating virtual matrix element with MadLoop for process: c~ c > t t~ [ QCD ]
INFO: Generating virtual matrix element with MadLoop for process: d~ d > t t~ [ QCD ]
INFO: Generating virtual matrix element with MadLoop for process: s~ s > t t~ [ QCD ]
INFO: Generated 9 subprocesses with 136 real emission diagrams, 11 born diagrams and 157 virtual diagrams
aMC@NLO>

```

- Create your aMC@NLO code
 - ➔ output PATH
- Run it:
 - ➔ launch [PATH]

- Create your aMC@NLO code
 - ➔ output PATH
- Run it:
 - ➔ launch [PATH]

First Question:

The following switches determine which operations are executed:

- | | |
|---|-----------------|
| 1 Perturbative order of the calculation: | order=NLO |
| 2 Fixed order (no event generation and no MC@[N]LO matching): | fixed_order=OFF |
| 3 Shower the generated events: | shower=ON |
| 4 Decay particles with the MadSpin module: | madspin=OFF |

Either type the switch number (1 to 4) to change its default setting,
or set any switch explicitly (e.g. type 'order=L0' at the prompt)

Type '0', 'auto', 'done' or just press enter when you are done.

[0, 1, 2, 3, 4, auto, done, order=L0, order=NLO, ...][60s to answer]

>[timer stopped]



- Create your aMC@NLO code
 - ➔ output PATH
- Run it:
 - ➔ launch [PATH]

Second Question:

```

INFO: will run in mode: aMC@NLO
Do you want to edit a card (press enter to bypass editing)?
 1 / param      : param_card.dat
 2 / run        : run_card.dat
 3 / madspin    : madspin_card.dat
 4 / shower     : shower_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.
[_0, done, 1, param, 2, run, 3, madspin, 4, enter path, ... ][60s to answer]
> █

```



```
INFO: For gauge cancellation, the width of 't' has been set to zero.
INFO: Using built-in libraries for PDFs
INFO: Compiling source...
INFO:      ...done, continuing with P* directories
INFO: Compiling directories...
INFO: Compiling on 8 cores
INFO:   Compiling P0_gg_ttx...
INFO:   Compiling P0_uux_ttx...
INFO:   Compiling P0_uxu_ttx...
INFO:     P0_uux_ttx done.
INFO:     P0_uxu_ttx done.
INFO:     P0_gg_ttx done.
INFO: Checking test output:
INFO: P0_gg_ttx
INFO:   Result for test_ME:
INFO:     Passed.
INFO:   Result for test_MC:
INFO:     Passed.
INFO:   Result for check_poles:
INFO:     Poles successfully cancel for 20 points over 20 (tolerance=1.0e-05)
INFO: P0_uux_ttx
INFO:   Result for test_ME:
INFO:     Passed.
INFO:   Result for test_MC:
INFO:     Passed.
INFO:   Result for check_poles:
INFO:     Poles successfully cancel for 20 points over 20 (tolerance=1.0e-05)
INFO: P0_uxu_ttx
INFO:   Result for test_ME:
INFO:     Passed.
INFO:   Result for test_MC:
INFO:     Passed.
INFO:   Result for check_poles:
INFO:     Poles successfully cancel for 20 points over 20 (tolerance=1.0e-05)
```

Compilation

Check Poles cancelation

```

INFO: Starting run
INFO: Using 8 cores
INFO: Cleaning previous results
INFO: Doing NLO matched to parton shower
INFO: Setting up grid
INFO: Idle: 2, Running: 8, Completed: 0 [ current time: 22h58 ]
INFO: Idle: 1, Running: 8, Completed: 1 [ 7.1s ]
INFO: Idle: 0, Running: 8, Completed: 2 [ 7.2s ]
INFO: Idle: 0, Running: 7, Completed: 3 [ 13.6s ]
INFO: Idle: 0, Running: 6, Completed: 4 [ 21s ]
INFO: Idle: 0, Running: 5, Completed: 5 [ 21s ]
INFO: Idle: 0, Running: 4, Completed: 6 [ 1m 5s ]
INFO: Idle: 0, Running: 3, Completed: 7 [ 1m 5s ]
INFO: Idle: 0, Running: 2, Completed: 8 [ 6m 38s ]
INFO: Idle: 0, Running: 1, Completed: 9 [ 6m 43s ]
INFO: Idle: 0, Running: 0, Completed: 10 [ 6m 52s ]
INFO: Determining the number of unweighted events per channel

```

Intermediate results:

Random seed: 33

Total cross-section: 1.775e+02 +- 2.1e+00 pb

Total abs(cross-section): 2.633e+02 +- 1.6e+00 pb

INFO: Computing upper envelope

```

INFO: Idle: 2, Running: 8, Completed: 0 [ current time: 23h05 ]
INFO: Idle: 1, Running: 8, Completed: 1 [ 8.7s ]
INFO: Idle: 0, Running: 8, Completed: 2 [ 8.9s ]
INFO: Idle: 0, Running: 7, Completed: 3 [ 16.3s ]
INFO: Idle: 0, Running: 6, Completed: 4 [ 25.7s ]
INFO: Idle: 0, Running: 5, Completed: 5 [ 25.7s ]
INFO: Idle: 0, Running: 4, Completed: 6 [ 1m 16s ]
INFO: Idle: 0, Running: 3, Completed: 7 [ 1m 18s ]
INFO: Idle: 0, Running: 2, Completed: 8 [ 6m 38s ]
INFO: Idle: 0, Running: 1, Completed: 9 [ 6m 46s ]
INFO: Idle: 0, Running: 0, Completed: 10 [ 7m 4s ]
INFO: Updating the number of unweighted events per channel

```

Intermediate results:

Random seed: 33

Total cross-section: 1.770e+02 +- 1.7e+00 pb

Total abs(cross-section): 2.630e+02 +- 1.2e+00 pb

INFO: Generating events

```

INFO: Idle: 2, Running: 8, Completed: 0 [ current time: 23h12 ]
INFO: Idle: 1, Running: 8, Completed: 1 [ 0.52s ]
INFO: Idle: 0, Running: 8, Completed: 2 [ 0.71s ]
INFO: Idle: 0, Running: 7, Completed: 3 [ 1.7s ]
INFO: Idle: 0, Running: 6, Completed: 4 [ 1.8s ]
INFO: Idle: 0, Running: 5, Completed: 5 [ 3.9s ]
INFO: Idle: 0, Running: 4, Completed: 6 [ 14.5s ]
INFO: Idle: 0, Running: 3, Completed: 7 [ 19.7s ]
INFO: Idle: 0, Running: 2, Completed: 8 [ 21.4s ]
INFO: Idle: 0, Running: 1, Completed: 9 [ 31.7s ]
INFO: Idle: 0, Running: 0, Completed: 10 [ 36.4s ]
INFO: Doing reweight

```

INFO: Doing reweight

INFO: Idle: 0, Running: 4, Completed: 6 [current time: 23h13]

INFO: Idle: 0, Running: 3, Completed: 7 [0.51s]

INFO: Idle: 0, Running: 2, Completed: 8 [0.53s]

INFO: Idle: 0, Running: 1, Completed: 9 [1.6s]

INFO: Idle: 0, Running: 0, Completed: 10 [1.8s]

INFO: Collecting events

INFO:

Summary:

Process $p p > t t \sim$ [QCD]

Run at p-p collider (6500 + 6500 GeV)

Total cross-section: 6.843e+02 +- 4.1e+00 pb

Ren. and fac. scale uncertainty: +10.4% -12.1%

Number of events generated: 10000

Parton shower: HERWIG6

Fraction of negative weights: 20

Total running time : 1m 41s

Process	Syntax	Cross section (pb)	
		LO 13 TeV	NLO 13 TeV
c.1 $pp \rightarrow W^+W^-W^+(4f)$	$p p \rightarrow w^+ w^- w^+$	$1.307 \pm 0.003 \cdot 10^{-1}$	$2.109 \pm 0.006 \cdot 10^{-1}$
c.2 $pp \rightarrow ZW^+W^-(4f)$	$p p \rightarrow z w^+ w^-$	$9.658 \pm 0.065 \cdot 10^{-2}$	$1.679 \pm 0.005 \cdot 10^{-1}$
c.3 $pp \rightarrow ZZW^+$	$p p \rightarrow z z w^+$	$2.996 \pm 0.036 \cdot 10^{-2}$	$5.550 \pm 0.020 \cdot 10^{-2}$
c.4 $pp \rightarrow ZZZ$	$p p \rightarrow z z z$	$1.985 \pm 0.002 \cdot 10^{-2}$	$1.417 \pm 0.005 \cdot 10^{-2}$
c.5 $pp \rightarrow \gamma W^+W^-(4f)$	$p p \rightarrow \gamma w^+ w^-$	$1.427 \pm 0.011 \cdot 10^{-1}$	$2.581 \pm 0.008 \cdot 10^{-1}$
c.6 $pp \rightarrow \gamma\gamma W^+$	$p p \rightarrow \gamma \gamma w^+$	$2.681 \pm 0.007 \cdot 10^{-2}$	$8.251 \pm 0.032 \cdot 10^{-2}$
c.7 $pp \rightarrow \gamma\gamma W^+$	$p p \rightarrow \gamma \gamma w^+$	$4.994 \pm 0.011 \cdot 10^{-2}$	$1.117 \pm 0.004 \cdot 10^{-1}$
c.8 $pp \rightarrow \gamma ZZ$	$p p \rightarrow \gamma z z$	$2.320 \pm 0.005 \cdot 10^{-2}$	$3.118 \pm 0.012 \cdot 10^{-2}$
c.9 $pp \rightarrow \gamma\gamma Z$	$p p \rightarrow \gamma \gamma z$	$3.078 \pm 0.007 \cdot 10^{-2}$	$4.634 \pm 0.020 \cdot 10^{-2}$
c.10 $pp \rightarrow \gamma\gamma\gamma$	$p p \rightarrow \gamma \gamma \gamma$	$1.309 \pm 0.003 \cdot 10^{-2}$	$3.441 \pm 0.012 \cdot 10^{-2}$

Process	Syntax	Cross section (pb)	
		LO 13 TeV	NLO 13 TeV
c.11 $pp \rightarrow W^+W^-W^+(4f)$	$p p \rightarrow w^+ w^- w^+$	$1.307 \pm 0.003 \cdot 10^{-1}$	$2.109 \pm 0.006 \cdot 10^{-1}$
c.12 $pp \rightarrow ZW^+W^-(4f)$	$p p \rightarrow z w^+ w^-$	$9.658 \pm 0.065 \cdot 10^{-2}$	$1.679 \pm 0.005 \cdot 10^{-1}$
c.13 $pp \rightarrow ZZW^+$	$p p \rightarrow z z w^+$	$2.996 \pm 0.036 \cdot 10^{-2}$	$5.550 \pm 0.020 \cdot 10^{-2}$
c.14 $pp \rightarrow ZZZ$	$p p \rightarrow z z z$	$1.985 \pm 0.002 \cdot 10^{-2}$	$1.417 \pm 0.005 \cdot 10^{-2}$
c.15 $pp \rightarrow \gamma W^+W^-(4f)$	$p p \rightarrow \gamma w^+ w^-$	$1.427 \pm 0.011 \cdot 10^{-1}$	$2.581 \pm 0.008 \cdot 10^{-1}$
c.16 $pp \rightarrow \gamma\gamma W^+$	$p p \rightarrow \gamma \gamma w^+$	$2.681 \pm 0.007 \cdot 10^{-2}$	$8.251 \pm 0.032 \cdot 10^{-2}$
c.17 $pp \rightarrow \gamma\gamma W^+$	$p p \rightarrow \gamma \gamma w^+$	$4.994 \pm 0.011 \cdot 10^{-2}$	$1.117 \pm 0.004 \cdot 10^{-1}$
c.18 $pp \rightarrow \gamma ZZ$	$p p \rightarrow \gamma z z$	$2.320 \pm 0.005 \cdot 10^{-2}$	$3.118 \pm 0.012 \cdot 10^{-2}$
c.19 $pp \rightarrow \gamma\gamma Z$	$p p \rightarrow \gamma \gamma z$	$3.078 \pm 0.007 \cdot 10^{-2}$	$4.634 \pm 0.020 \cdot 10^{-2}$
c.20 $pp \rightarrow \gamma\gamma\gamma$	$p p \rightarrow \gamma \gamma \gamma$	$1.309 \pm 0.003 \cdot 10^{-2}$	$3.441 \pm 0.012 \cdot 10^{-2}$

Process	Syntax	Cross section (pb)	
		LO 1 TeV	NLO 1 TeV
j.1 $e^+e^- \rightarrow t\bar{t}H$	$e^+ e^- \rightarrow t \bar{t} h$	$2.018 \pm 0.003 \cdot 10^{-3}$	$1.911 \pm 0.006 \cdot 10^{-3}$
j.2 $e^+e^- \rightarrow t\bar{t}Hj$	$e^+ e^- \rightarrow t \bar{t} h j$	$2.533 \pm 0.003 \cdot 10^{-4}$	$2.658 \pm 0.009 \cdot 10^{-4}$
j.3 $e^+e^- \rightarrow t\bar{t}Hjj$	$e^+ e^- \rightarrow t \bar{t} h j j$	$2.663 \pm 0.004 \cdot 10^{-5}$	$3.278 \pm 0.011 \cdot 10^{-5}$
j.4 $e^+e^- \rightarrow t\bar{t}H\gamma$	$e^+ e^- \rightarrow t \bar{t} h \gamma$	$1.270 \pm 0.002 \cdot 10^{-2}$	$1.335 \pm 0.007 \cdot 10^{-2}$
j.5 $e^+e^- \rightarrow t\bar{t}H\gamma j$	$e^+ e^- \rightarrow t \bar{t} h \gamma j$	$2.355 \pm 0.002 \cdot 10^{-3}$	$2.617 \pm 0.010 \cdot 10^{-3}$
j.6 $e^+e^- \rightarrow t\bar{t}H\gamma jj$	$e^+ e^- \rightarrow t \bar{t} h \gamma j j$	$3.103 \pm 0.005 \cdot 10^{-4}$	$4.002 \pm 0.021 \cdot 10^{-4}$
j.7 $e^+e^- \rightarrow t\bar{t}HZ$	$e^+ e^- \rightarrow t \bar{t} h z$	$4.612 \pm 0.006 \cdot 10^{-4}$	$4.919 \pm 0.014 \cdot 10^{-4}$
j.8 $e^+e^- \rightarrow t\bar{t}Zj$	$e^+ e^- \rightarrow t \bar{t} h z j$	$6.059 \pm 0.006 \cdot 10^{-4}$	$6.940 \pm 0.028 \cdot 10^{-4}$
j.9 $e^+e^- \rightarrow t\bar{t}Zjj$	$e^+ e^- \rightarrow t \bar{t} h z j j$	$6.351 \pm 0.028 \cdot 10^{-5}$	$8.439 \pm 0.051 \cdot 10^{-5}$
j.10 $e^+e^- \rightarrow t\bar{t}W^+W^-jj$	$e^+ e^- \rightarrow t \bar{t} w^+ w^- j j$	$2.400 \pm 0.004 \cdot 10^{-7}$	$3.723 \pm 0.012 \cdot 10^{-7}$

Process	Syntax	Cross section (pb)	
		LO 1 TeV	NLO 1 TeV
L.1 $e^+e^- \rightarrow jj$	$e^+ e^- \rightarrow j j$	$6.223 \pm 0.005 \cdot 10^{-1}$	$6.389 \pm 0.013 \cdot 10^{-1}$
L.2 $e^+e^- \rightarrow jjj$	$e^+ e^- \rightarrow j j j$	$3.491 \pm 0.002 \cdot 10^{-1}$	$3.166 \pm 0.019 \cdot 10^{-1}$
L.3 $e^+e^- \rightarrow jjjj$	$e^+ e^- \rightarrow j j j j$	$1.047 \pm 0.001 \cdot 10^{-1}$	$1.050 \pm 0.006 \cdot 10^{-1}$
L.4 $e^+e^- \rightarrow jjjjj$	$e^+ e^- \rightarrow j j j j j$	$2.211 \pm 0.006 \cdot 10^{-2}$	$2.771 \pm 0.021 \cdot 10^{-2}$

Process	Syntax	Cross section (pb)	
		LO 1 TeV	NLO 1 TeV
L.11 $e^+e^- \rightarrow b\bar{b}$	$e^+ e^- \rightarrow b \bar{b}$	$0.198 \pm 0.004 \cdot 10^{-2}$	$0.282 \pm 0.031 \cdot 10^{-2}$
L.12 $e^+e^- \rightarrow b\bar{b}j$	$e^+ e^- \rightarrow b \bar{b} j$	$5.029 \pm 0.003 \cdot 10^{-2}$	$4.826 \pm 0.026 \cdot 10^{-2}$
L.13 $e^+e^- \rightarrow b\bar{b}jj$	$e^+ e^- \rightarrow b \bar{b} j j$	$1.821 \pm 0.001 \cdot 10^{-1}$	$1.817 \pm 0.009 \cdot 10^{-1}$
L.14 $e^+e^- \rightarrow b\bar{b}jjj$	$e^+ e^- \rightarrow b \bar{b} j j j$	$3.641 \pm 0.009 \cdot 10^{-3}$	$4.936 \pm 0.038 \cdot 10^{-3}$
L.15 $e^+e^- \rightarrow b\bar{b}bb$	$e^+ e^- \rightarrow b \bar{b} b \bar{b}$	$1.644 \pm 0.003 \cdot 10^{-1}$	$3.691 \pm 0.017 \cdot 10^{-1}$
L.16 $e^+e^- \rightarrow b\bar{b}bbj$	$e^+ e^- \rightarrow b \bar{b} b \bar{b} j$	$7.660 \pm 0.022 \cdot 10^{-2}$	$1.537 \pm 0.011 \cdot 10^{-1}$
L.17 $e^+e^- \rightarrow t\bar{t}bb$	$e^+ e^- \rightarrow t \bar{t} b \bar{b}$	$1.819 \pm 0.003 \cdot 10^{-4}$	$2.923 \pm 0.011 \cdot 10^{-4}$
L.18 $e^+e^- \rightarrow t\bar{t}bbj$	$e^+ e^- \rightarrow t \bar{t} b \bar{b} j$	$4.045 \pm 0.011 \cdot 10^{-8}$	$7.019 \pm 0.052 \cdot 10^{-8}$

Process	Syntax	Cross section (pb)	
		LO 13 TeV	NLO 13 TeV
L1 $pp \rightarrow t\bar{t}$ (s-channel)	$p p \rightarrow t \bar{t}$	$1.320 \pm 0.001 \cdot 10^2$	$1.560 \pm 0.005 \cdot 10^2$
L2 $pp \rightarrow t\bar{t}j$ (s-channel)	$p p \rightarrow t \bar{t} j$	$6.956 \pm 0.014 \cdot 10^{-1}$	$1.017 \pm 0.003 \cdot 10^0$
L3 $pp \rightarrow t\bar{t}jj$ (s-channel)	$p p \rightarrow t \bar{t} j j$	$6.967 \pm 0.007 \cdot 10^{-1}$	$6.903 \pm 0.021 \cdot 10^{-1}$
L4 $pp \rightarrow t\bar{t}j$ (s-channel, 4f)	$p p \rightarrow t \bar{t} j$	$1.093 \pm 0.006 \cdot 10^0$	$1.319 \pm 0.003 \cdot 10^0$
L5 $pp \rightarrow t\bar{t}jj$ (s-channel, 4f)	$p p \rightarrow t \bar{t} j j$	$6.293 \pm 0.006 \cdot 10^{-1}$	$8.612 \pm 0.025 \cdot 10^{-1}$
L6 $pp \rightarrow t\bar{t}jZ$ (s-channel, 4f)	$p p \rightarrow t \bar{t} j z$	$3.534 \pm 0.002 \cdot 10^{-1}$	$5.637 \pm 0.014 \cdot 10^{-1}$

hundreds of processes

Process	Syntax	Cross section (pb)	
		LO 13 TeV	NLO 13 TeV
b.1 $pp \rightarrow H$ (Loop improved)	$p p \rightarrow h$	$1.772 \pm 0.006 \cdot 10^{-2}$	$2.743 \pm 0.008 \cdot 10^{-2}$
b.2 $pp \rightarrow Hjj$ (VBF)	$p p \rightarrow h j j$	$4.303 \pm 0.010 \cdot 10^{-2}$	$6.820 \pm 0.026 \cdot 10^{-2}$
b.3 $pp \rightarrow HWW^+$	$p p \rightarrow h w^+$	$4.303 \pm 0.010 \cdot 10^{-2}$	$6.820 \pm 0.026 \cdot 10^{-2}$
b.4 $pp \rightarrow HWW^+$	$p p \rightarrow h w^+$	$1.922 \pm 0.002 \cdot 10^{-1}$	$2.218 \pm 0.009 \cdot 10^{-1}$
b.5 $pp \rightarrow HWW^+\gamma$	$p p \rightarrow h w^+ \gamma$	$1.952 \pm 0.004 \cdot 10^{-1}$	$2.247 \pm 0.007 \cdot 10^{-1}$
b.6 $pp \rightarrow HZZ$	$p p \rightarrow h z z$	$2.391 \pm 0.007 \cdot 10^{-1}$	$3.130 \pm 0.008 \cdot 10^{-1}$
b.7 $pp \rightarrow HZZ\gamma$	$p p \rightarrow h z z \gamma$	$1.311 \pm 0.001 \cdot 10^{-1}$	$1.394 \pm 0.006 \cdot 10^{-1}$
b.8 $pp \rightarrow HZZ\gamma\gamma$	$p p \rightarrow h z z \gamma \gamma$	$1.307 \pm 0.003 \cdot 10^{-1}$	$1.604 \pm 0.005 \cdot 10^{-1}$
b.9 $pp \rightarrow HZZZ$	$p p \rightarrow h z z z$	$2.309 \pm 0.005 \cdot 10^{-1}$	$2.754 \pm 0.009 \cdot 10^{-1}$
b.10 $pp \rightarrow HZZW^+$	$p p \rightarrow h z z w^+$	$3.708 \pm 0.013 \cdot 10^{-1}$	$4.904 \pm 0.009 \cdot 10^{-1}$
b.11 $pp \rightarrow HZZW^+W^-(4f)$	$p p \rightarrow h z z w^+ w^-$	$7.514 \pm 0.070 \cdot 10^{-2}$	$9.308 \pm 0.030 \cdot 10^{-2}$
b.12 $pp \rightarrow HZZ\gamma$	$p p \rightarrow h z z \gamma$	$6.756 \pm 0.007 \cdot 10^{-1}$	$7.305 \pm 0.021 \cdot 10^{-1}$
b.13 $pp \rightarrow HZZj$	$p p \rightarrow h z z j$	$1.891 \pm 0.009 \cdot 10^{-1}$	$2.441 \pm 0.009 \cdot 10^{-1}$
b.14 $pp \rightarrow HZZ\gamma\gamma$	$p p \rightarrow h z z \gamma \gamma$	$7.849 \pm 0.022 \cdot 10^{-2}$	$1.094 \pm 0.012 \cdot 10^{-1}$

Process	Syntax	Cross section (pb)	
		LO 13 TeV	NLO 13 TeV
g.1 $pp \rightarrow H$ (HEFT)	$p p \rightarrow h$	$1.000 \pm 0.003 \cdot 10^0$	$3.261 \pm 0.010 \cdot 10^0$
g.2 $pp \rightarrow Hj$ (HEFT)	$p p \rightarrow h j$	$8.367 \pm 0.033 \cdot 10^0$	$1.422 \pm 0.006 \cdot 10^1$
g.3 $pp \rightarrow Hjj$ (HEFT)	$p p \rightarrow h j j$	$3.030 \pm 0.007 \cdot 10^0$	$5.724 \pm 0.030 \cdot 10^0$
g.4 $pp \rightarrow Hjj$ (VBF)	$p p \rightarrow h j j$	$1.987 \pm 0.002 \cdot 10^0$	$1.900 \pm 0.006 \cdot 10^0$
g.5 $pp \rightarrow Hjjj$ (VBF)	$p p \rightarrow h j j j$	$2.824 \pm 0.005 \cdot 10^{-1}$	$3.685 \pm 0.010 \cdot 10^{-1}$

Process	Syntax	Cross section (pb)	
		LO 13 TeV	NLO 13 TeV
e.1 $pp \rightarrow W^+b\bar{b}$ (4f)	$p p \rightarrow w^+ b \bar{b}$	$3.074 \pm 0.002 \cdot 10^2$	$8.162 \pm 0.031 \cdot 10^2$
e.2 $pp \rightarrow Zb\bar{b}$ (4f)	$p p \rightarrow z b \bar{b}$	$6.993 \pm 0.003 \cdot 10^2$	$1.235 \pm 0.004 \cdot 10^3$
e.3 $pp \rightarrow \gamma b\bar{b}$ (4f)	$p p \rightarrow \gamma b \bar{b}$	$1.731 \pm 0.001 \cdot 10^3$	$4.171 \pm 0.015 \cdot 10^3$
e.4 $pp \rightarrow W^+b\bar{b}j$ (4f)	$p p \rightarrow w^+ b \bar{b} j$	$1.863 \pm 0.003 \cdot 10^2$	$3.957 \pm 0.013 \cdot 10^2$
e.5 $pp \rightarrow Zb\bar{b}j$ (4f)	$p p \rightarrow z b \bar{b} j$	$1.601 \pm 0.001 \cdot 10^3$	$2.895 \pm 0.009 \cdot 10^3$
e.6 $pp \rightarrow \gamma b\bar{b}j$ (4f)	$p p \rightarrow \gamma b \bar{b} j$	$7.812 \pm 0.017 \cdot 10^2$	$1.234 \pm 0.004 \cdot 10^3$
e.7 $pp \rightarrow t\bar{t}W^+$	$p p \rightarrow t \bar{t} w^+$	$3.777 \pm 0.003 \cdot 10^{-1}$	$5.602 \pm 0.021 \cdot 10^{-1}$
e.8 $pp \rightarrow t\bar{t}Z$	$p p \rightarrow t \bar{t} z$	$5.373 \pm 0.004 \cdot 10^{-1}$	$7.598 \pm 0.036 \cdot 10^{-1}$
e.9 $pp \rightarrow t\bar{t}\gamma$	$p p \rightarrow t \bar{t} \gamma$	$1.304 \pm 0.001 \cdot 10^0$	$1.744 \pm 0.005 \cdot 10^0$
e.10 $pp \rightarrow t\bar{t}W^+j$	$p p \rightarrow t \bar{t} w^+ j$	$2.352 \pm 0.002 \cdot 10^{-1}$	$3.494 \pm 0.011 \cdot 10^{-1}$
e.11 $pp \rightarrow t\bar{t}Zj$	$p p \rightarrow t \bar{t} z j$	$3.953 \pm 0.004 \cdot 10^{-1}$	$5.074 \pm 0.016 \cdot 10^{-1}$
e.12 $pp \rightarrow t\bar{t}\gamma j$	$p p \rightarrow t \bar{t} \gamma j$	$8.726 \pm 0.010 \cdot 10^{-1}$	$1.135 \pm 0.004 \cdot 10^0$
e.13 $pp \rightarrow t\bar{t}W^+W^-(4f)$	$p p \rightarrow t \bar{t} w^+ w^-$	$6.875 \pm 0.006 \cdot 10^{-3}$	$9.904 \pm 0.026 \cdot 10^{-3}$
e.14 $pp \rightarrow t\bar{t}W^+Z$	$p p \rightarrow t \bar{t} w^+ z$	$2.401 \pm 0.002 \cdot 10^{-3}$	$3.525 \pm 0.010 \cdot 10^{-3}$
e.15 $pp \rightarrow t\bar{t}W^+\gamma$	$p p \rightarrow t \bar{t} w^+ \gamma$	$2.718 \pm 0.003 \cdot 10^{-3}$	$3.927 \pm 0.013 \cdot 10^{-3}$
e.16 $pp \rightarrow t\bar{t}ZZ$	$p p \rightarrow t \bar{t} z z$	$1.319 \pm 0.011 \cdot 10^{-3}$	$1.840 \pm 0.007 \cdot 10^{-3}$
e.17 $pp \rightarrow t\bar{t}Z\gamma$	$p p \rightarrow t \bar{t} z \gamma$	$2.548 \pm 0.003 \cdot 10^{-3}$	$3.548 \pm 0.012 \cdot 10^{-3}$
e.18 $pp \rightarrow t\bar{t}\gamma\gamma$	$p p \rightarrow t \bar{t} \gamma \gamma$	$3.272 \pm 0.006 \cdot 10^{-3}$	$4.402 \pm 0.015 \cdot 10^{-3}$

Process	Syntax	Cross section (pb)	
		LO 13 TeV	NLO 13 TeV
c.21 $pp \rightarrow W^+W^-W^+W^-(4f)$	$p p \rightarrow w^+ w^- w^+ w^-$	$5.721 \pm 0.014 \cdot 10^{-4}$	$9.509 \pm 0.035 \cdot 10^{-4}$
c.22 $pp \rightarrow W^+W^-W^+Z(4f)$	$p p \rightarrow w^+ w^- w^+ z$	$6.291 \pm 0.076 \cdot 10^{-4}$	$1.188 \pm 0.004 \cdot 10^{-3}$
c.23 $pp \rightarrow W^+W^-W^+\gamma(4f)$	$p p \rightarrow w^+ w^- w^+ \gamma$	$8.115 \pm 0.064 \cdot 10^{-4}$	$1.546 \pm 0.005 \cdot 10^{-3}$
c.24 $pp \rightarrow W^+W^-ZZ(4f)$	$p p \rightarrow w^+ w^- z z$	$4.320 \pm 0.013 \cdot 10^{-4}$	$7.107 \pm 0.020 \cdot 10^{-4}$
c.25 $pp \rightarrow W^+W^-Z\gamma(4f)$	$p p \rightarrow w^+ w^- z \gamma$	$8.403 \pm 0.016 \cdot 10^{-4}$	$1.483 \pm 0.004 \cdot 10^{-3}$
c.26 $pp \rightarrow W^+W^-\gamma\gamma(4f)$	$p p \rightarrow w^+ w^- \gamma \gamma$	$5.196 \pm 0.012 \cdot 10^{-4}$	$9.381 \pm 0.032 \cdot 10^{-4}$
c.27 $pp \rightarrow W^+W^-ZZZ(4f)$	$p p \rightarrow w^+ w^- z z z$	$5.862 \pm 0.010 \cdot 10^{-5}$	$1.240 \pm 0.004 \cdot 10^{-4}$
c.28 $pp \rightarrow W^+W^-ZZ\gamma(4f)$	$p p \rightarrow w^+ w^- z z \gamma$	$1.148 \pm 0.003 \cdot 10^{-4}$	$2.545 \pm 0.008 \cdot 10^{-4}$
c.29 $pp \rightarrow W^+W^-\gamma\gamma\gamma(4f)$	$p p \rightarrow w^+ w^- \gamma \gamma \gamma$	$1.054 \pm 0.014 \cdot 10^{-4}$	$3.033 \pm 0.010 \cdot 10^{-4}$
c.30 $pp \rightarrow W^+W^-\gamma\gamma Z(4f)$	$p p \rightarrow w^+ w^- \gamma \gamma z$	$3.030 \pm 0.013 \cdot 10^{-4}$	$1.246 \pm 0.005 \cdot 10^{-4}$
c.31 $pp \rightarrow ZZZZ$	$p p \rightarrow z z z z$	$1.980 \pm 0.002 \cdot 10^{-5}$	$2.029 \pm 0.008 \cdot 10^{-5}$
c.32 $pp \rightarrow ZZZ\gamma$	$p p \rightarrow z z z \gamma$	$3.945 \pm 0.007 \cdot 10^{-5}$	$5.274 \pm 0.016 \cdot 10^{-5}$
c.33 $pp \rightarrow ZZZ\gamma\gamma$	$p p \rightarrow z z z \gamma \gamma$	$5.543 \pm 0.017 \cdot 10^{-5}$	$7.538 \pm 0.032 \cdot 10^{-5}$
c.34			

- Only NLO in QCD (Electroweak well in progress)
- Mainly the SM
 - Tools for creating NLO-UFO
 - 2HDM is under validation
- Support for Merging at NLO
 - FxFx (Herwig6)
 - FxFx (Pythia8 -> Friday release)
 - UnLops (Pythia8 -> Friday release)

- How to handle the decay of particle?

- WISH-LIST:

- ➔ For a sample of events include the decay of unstable final states particles.
- ➔ Keep full spin correlations and finite width effect
- ➔ Keep unweighted events
- ➔ Decay LO accurate

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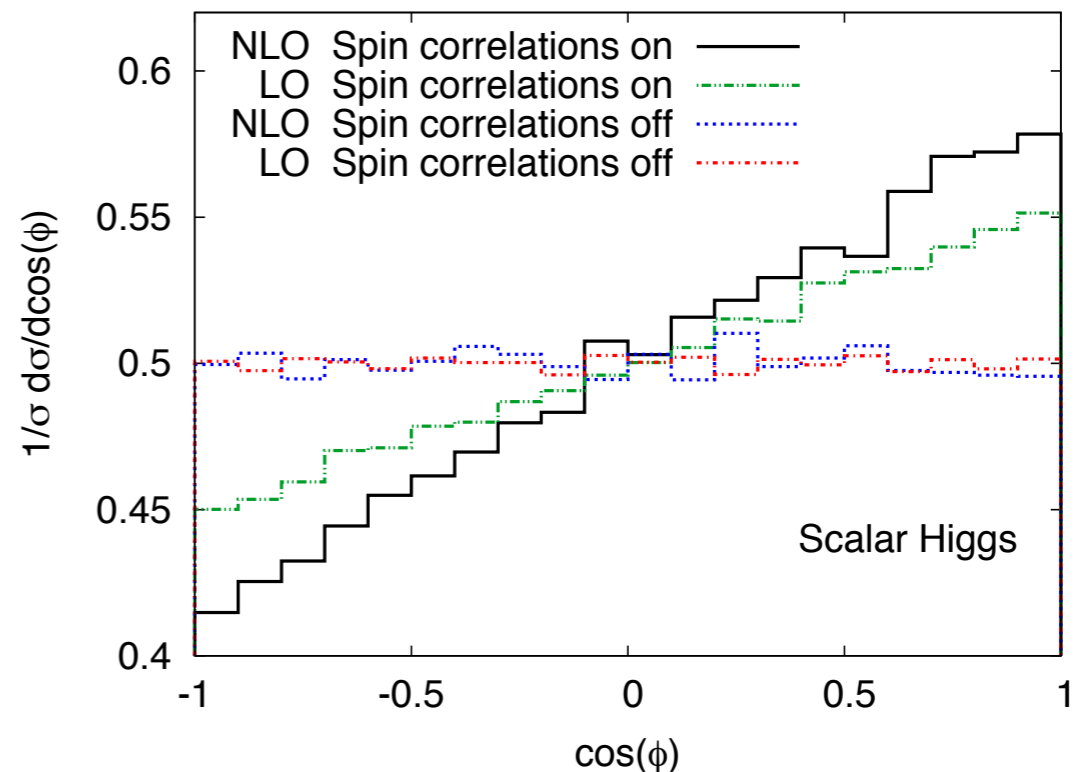
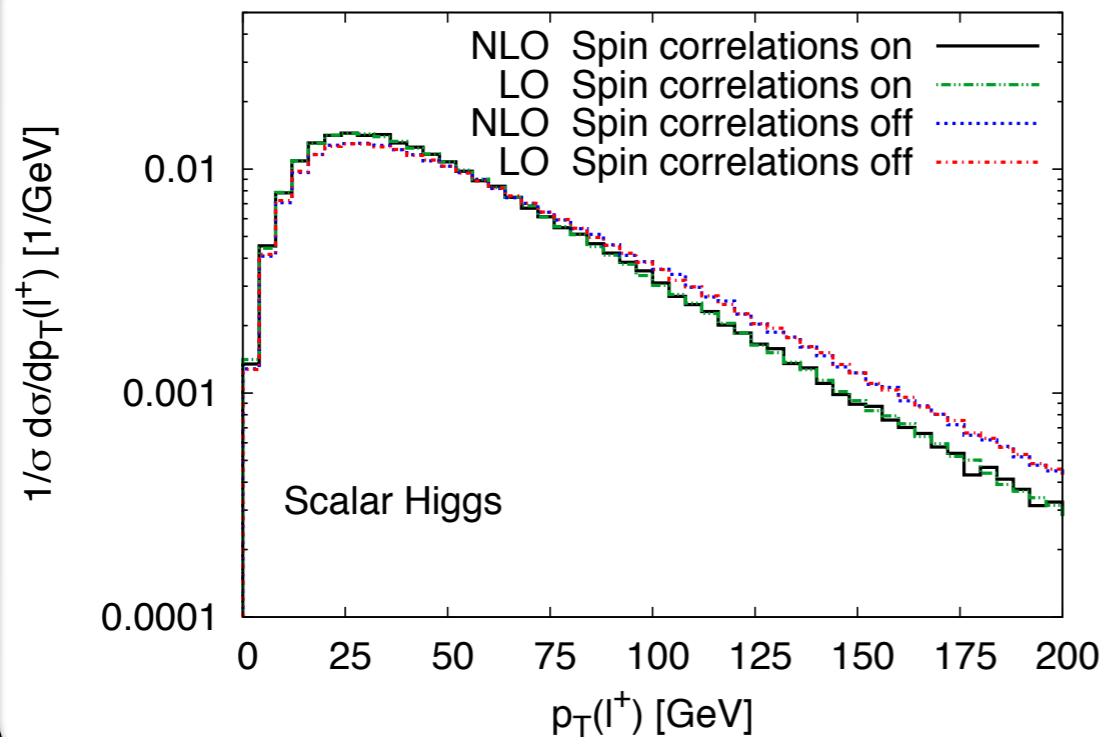
- Can be done via ME re-weighting

[Frixione, Leenen, Motylinski, Webber (2007)]

- Fully automatic

- ➔ Fully integrated in MG5 [LO and NLO]

- ➔ Can do BSM decay (from SM production)



Conclusion

Madgraph5:

- Various Method for Mass production @LO
 - ➔ ME re-weighting
 - ➔ Non Definite Matrix-Element

aMC@NLO:

- Fully automatic tool for NLO computation
 - ➔ Cross-section (like MCFM)
 - ➔ Generation of Events (matched to PS)
- Decay with full-spin correlation (MadSpin)