MadGraph5_aMC@NLO

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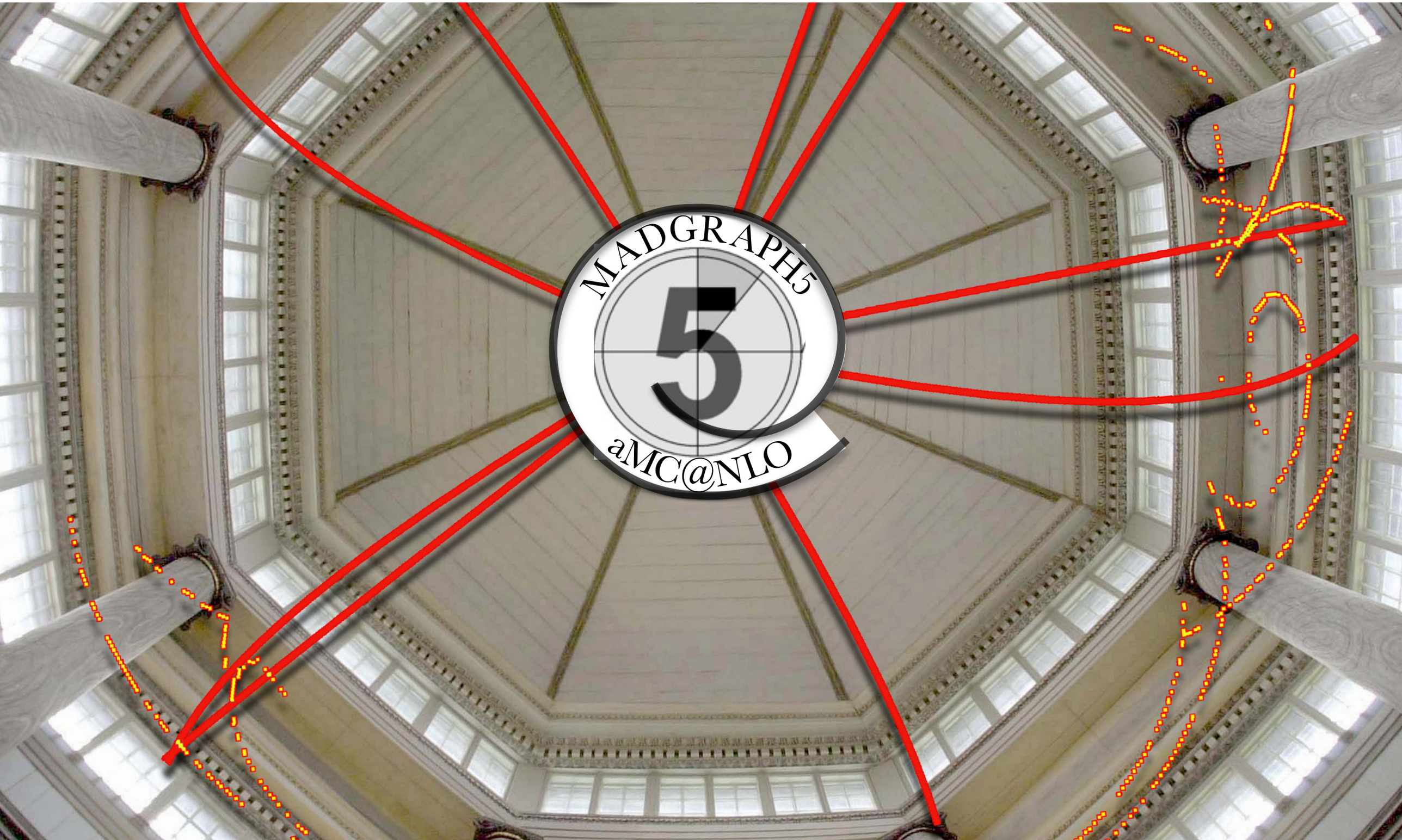

What is MG5_aMC?

- 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.

Plan

- 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

ME Reweighting

Phase-space

- Events with a probability

$$\vec{p}_1 \rightarrow P_1$$
$$\vec{p}_2 \rightarrow P_2$$
$$\vec{p}_3 \rightarrow P_3$$
$$\dots$$

ME Reweighting

Phase-space

- Events with a probability

$$\vec{p}_1 \to P_1$$
$$\vec{p}_2 \to P_2$$
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$$\dots$$

Unweighting

- Select a sub-sample

$$\vec{p}_1 \to 1$$
$$\cancel{\vec{p}_2}$$
$$\vec{p}_3 \to 1$$

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

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Second Theory

- Events with a probability

$$\vec{p}_1 \to \tilde{P}_1$$
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Unweighting

- Select a sub-sample

$$\vec{p}_1 \to 1 \to \frac{\tilde{P}_1}{P_1}$$
$$\cancel{\vec{p}_2}$$
$$\vec{p}_3 \to 1 \to \frac{\tilde{P}_3}{P_3}$$

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

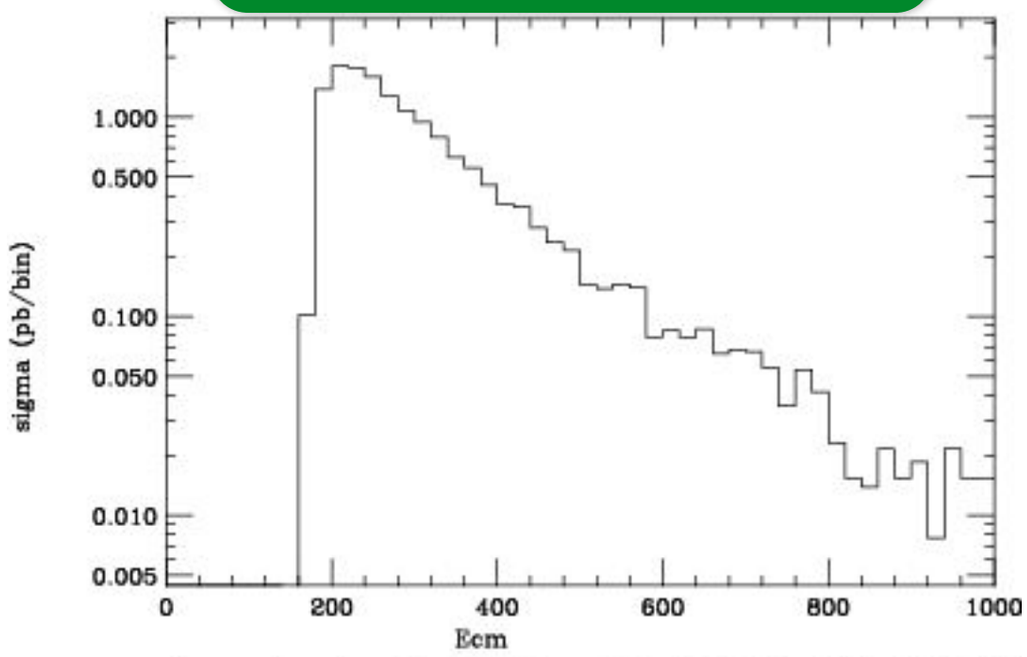
ME-Reweighting

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

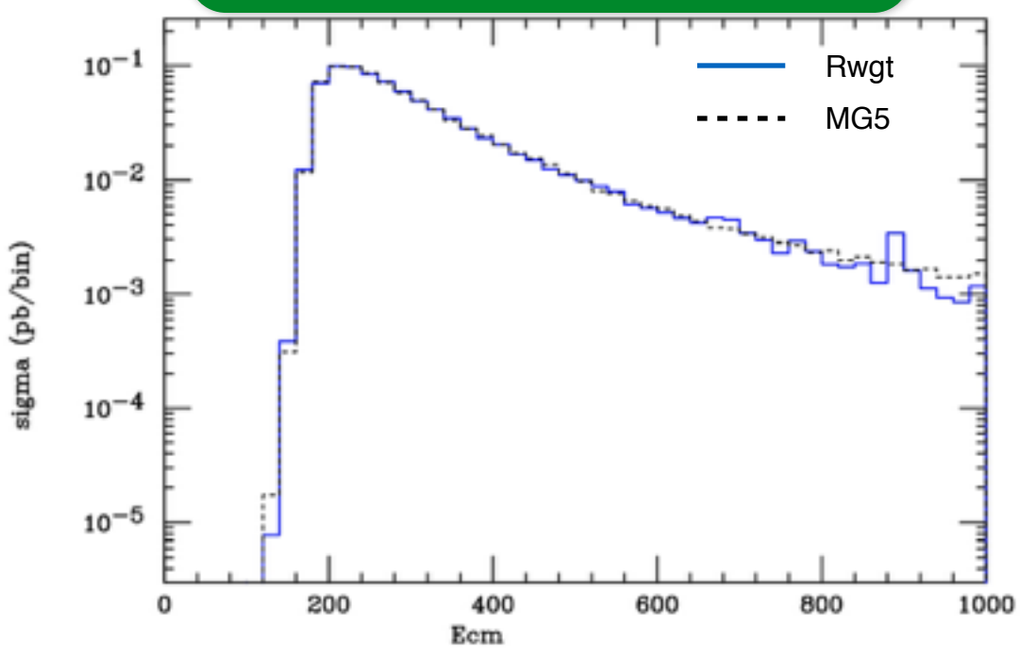
$$W_{new} = \frac{|M_{new}|^2}{|M_{old}|^2} * W_{old}$$

- Can be run on the flight inside MG5

Original



Reweighted



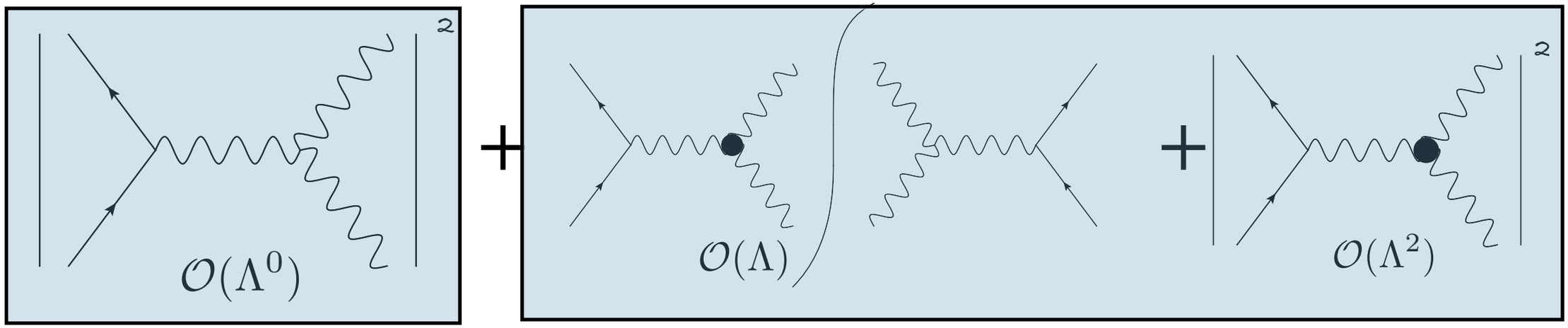
1405.0301/1404.7129

Remark

- 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

Non Definite positive

Motivation:



SM
Model independent
Dominant

BSM
Model dependent
Sub-Dominant

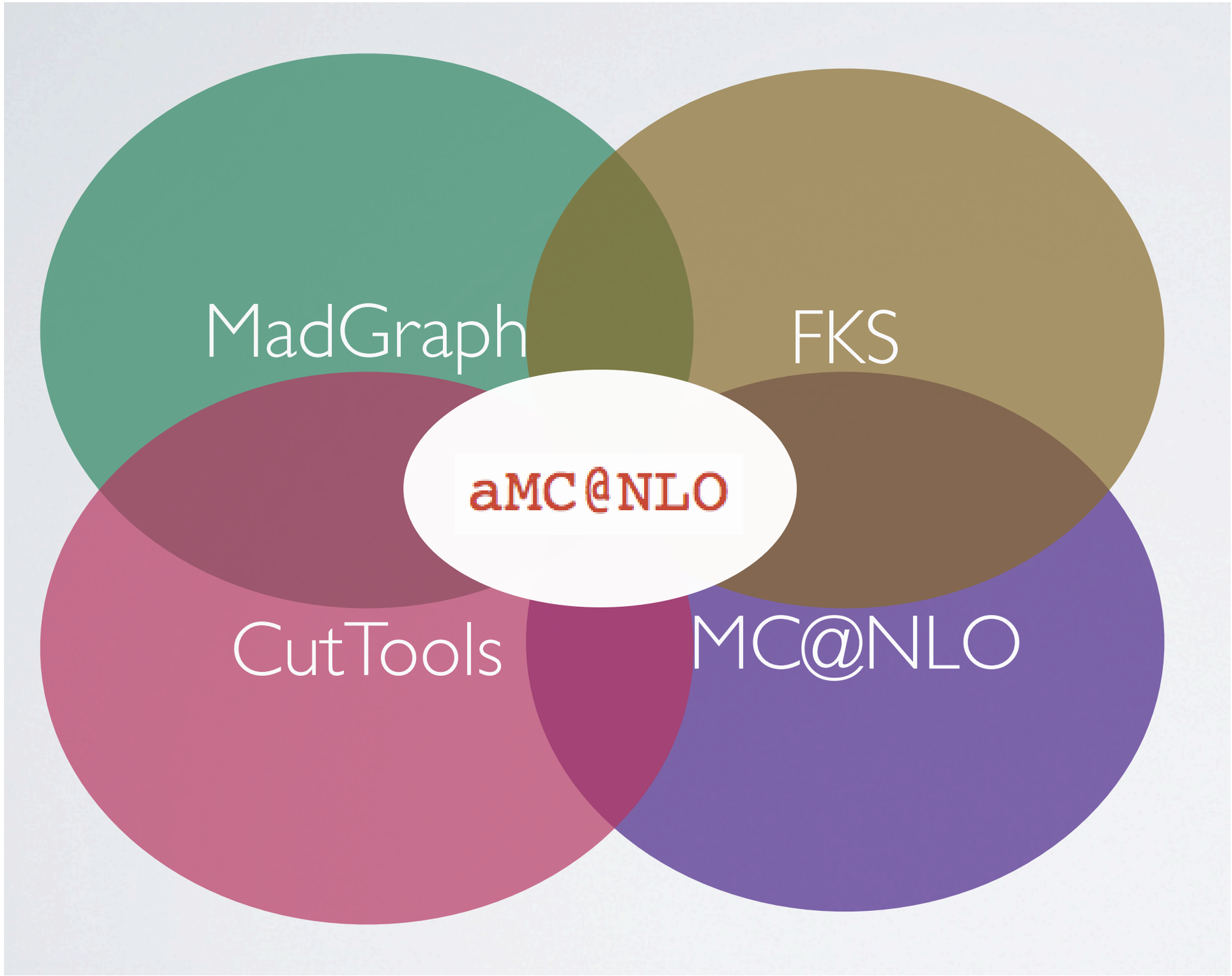
Idea:

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

Status:

- Release this week

aMC@NLO



aMC@NLO

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

aMC@NLO

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- Why NLO?
  - ➡Reliable prediction of the total rate
  - ➡Reduction of the theoretical uncertainty

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- Why NLO?
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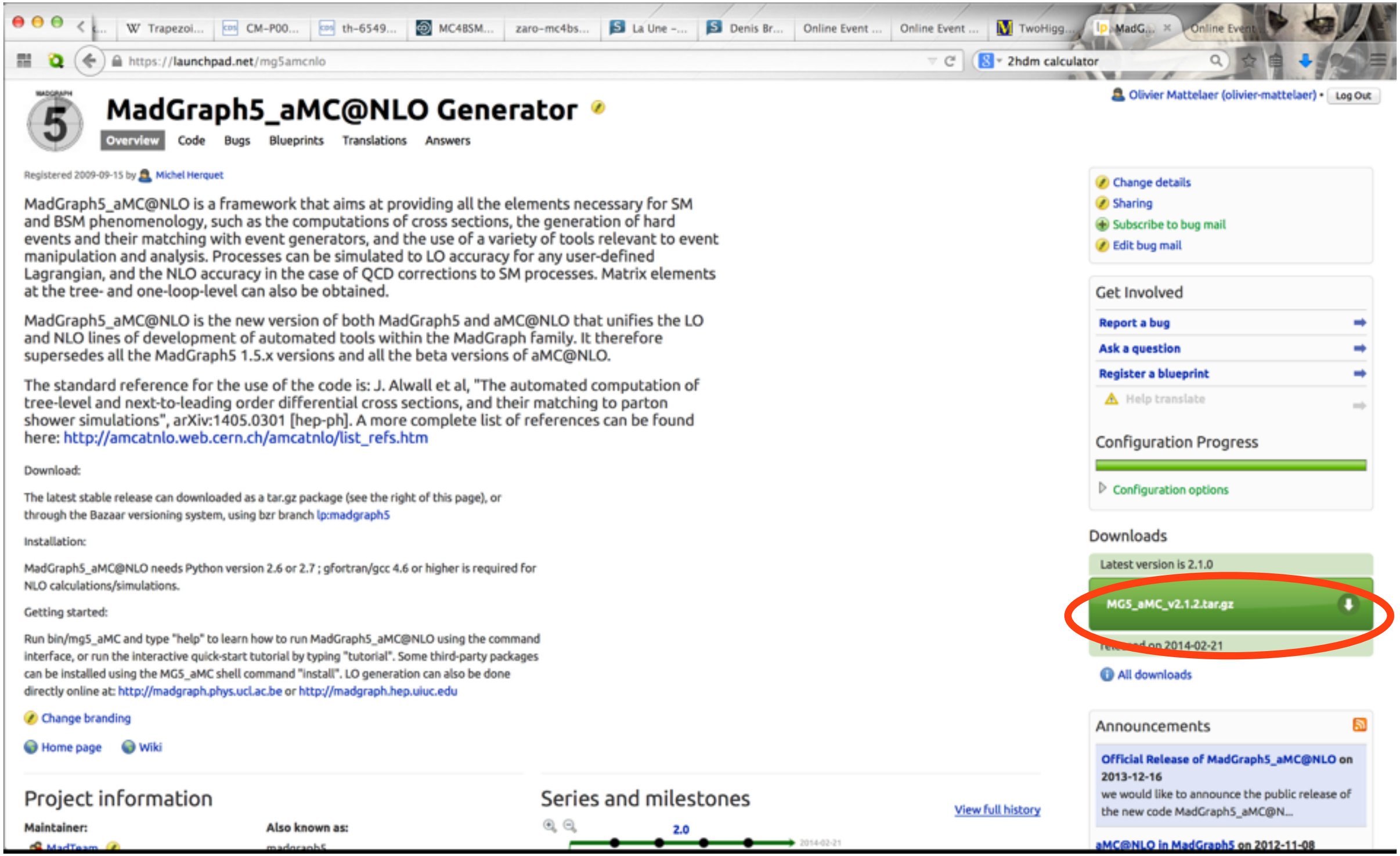
  - ➡Reduction of the theoretical uncertainty
- Why matched to the PS?
  - ➡Matching cure some fix-order ill behaved observables

DEMO

- Is it Really automatic?

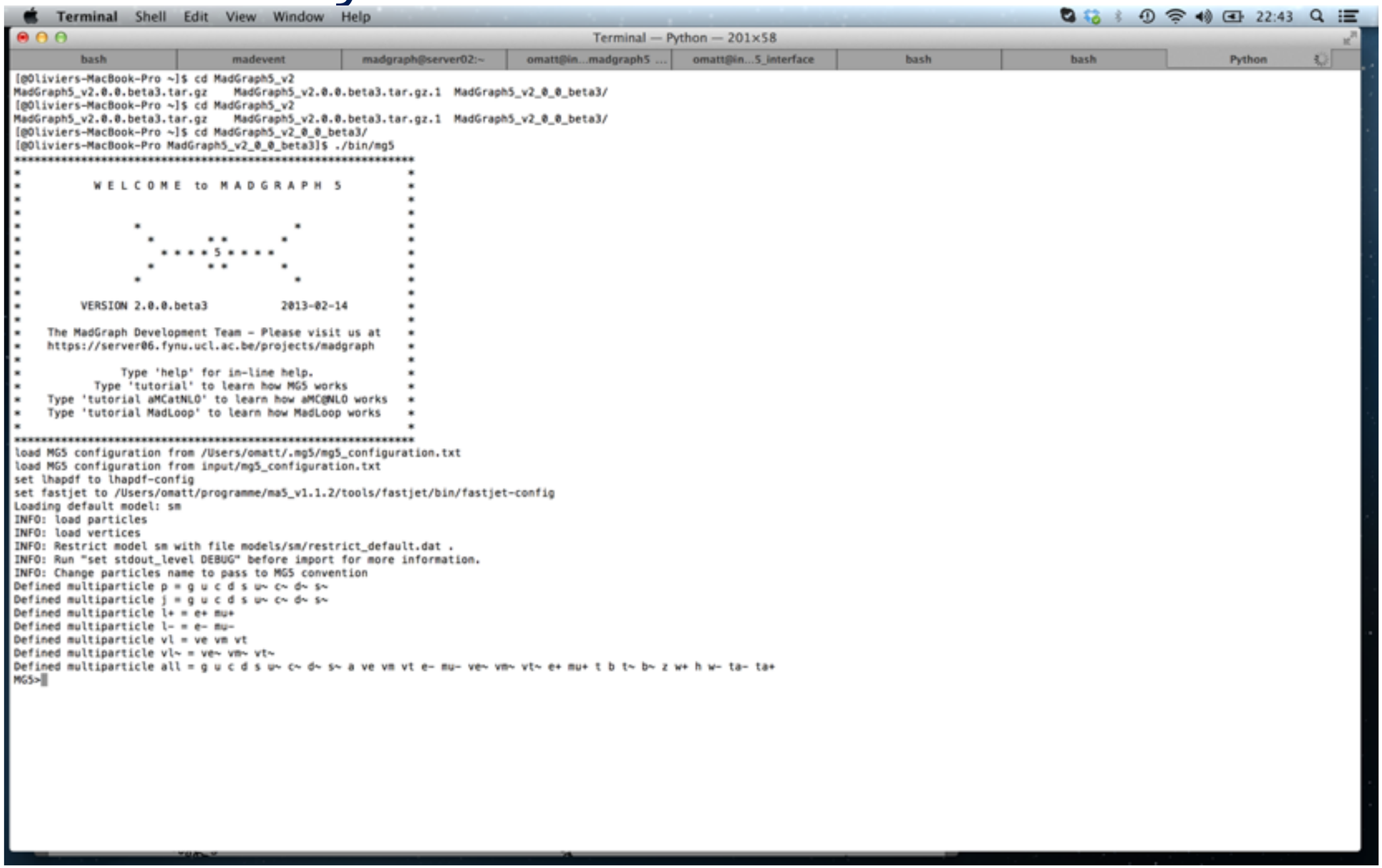
DEMO

- 1) Download the code



DEMO

- launch the code [./bin/mg5_aMC]
  - ➡Exactly like MG5 !!!



DEMO

- You can enter ANY process!
  - ➡add [QCD] for NLO functionalities
    - generate p p > t t~ [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:

```
aMC@NLO>launch
INFO: ************************************************************
*                                                          *
*         W E L C O M E  to  M A D G R A P H  5            *
*                     a M C @ N L O                        *
*                                                          *
*                *                       *                 *
*                  *      * *      *                      *
*                    * * * * 5 * * * *                     *
*                  *      * *      *                      *
*                *                       *                 *
*                                                          *
*          VERSION 2.0.0.beta3           2013-02-14        *
*                                                          *
*    The MadGraph Development Team - Please visit us at    *
*                  http://amcatnlo.cern.ch                 *
*                                                          *
*               Type 'help' for in-line help.              *
*                                                          *
************************************************************
INFO: load configuration from /Users/omatt/.mg5/mg5_configuration.txt
INFO: load configuration from /Users/omatt/MadGraph5_v2_0_0_beta3/PROCNLO_loop_sm_0/Cards/amcatnlo_configuration.txt
INFO: load configuration from /Users/omatt/MadGraph5_v2_0_0_beta3/input/mg5_configuration.txt
INFO: load configuration from /Users/omatt/MadGraph5_v2_0_0_beta3/PROCNLO_loop_sm_0/Cards/amcatnlo_configuration.txt
set group_subprocesses Auto
set ignore_six_quark_processes False
set loop_optimized_output True
set gauge unitary
set complex_mass_scheme False
launch auto
Which programs do you want to run?
  0 / auto       : NLO event generation and -if cards exist- shower and madspin.
  1 / NLO        : Fixed order NLO calculation (no event generation).
  2 / aMC@NLO    : NLO event generation (include running the shower).
  3 / noshower   : NLO event generation (without running the shower).
  4 / LO         : Fixed order LO calculation (no event generation).
  5 / aMC@LO     : LO event generation (include running the shower).
  6 / noshowerLO : LO event generation (without running the shower).
+10 / +madspin   : Add decays with MadSpin (before the shower).
 [0, auto, 1, NLO, 2, aMC@NLO, 12, aMC@NLO+madspin, 3, ... ][60s to answer]
>
```

- 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=LO' at the prompt)
  Type '0', 'auto', 'done' or just press enter when you are done.
 [0, 1, 2, 3, 4, auto, done, order=LO, 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.
```

Compilation

```
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)
```

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~ [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
      Parto[illegible] HERWIG6
      [illegible]raction of negative weights:    20
      Total running time :  1m 41s
```

hundreds of processes

Status of aMC@NLO

- 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)

MadSpin

- 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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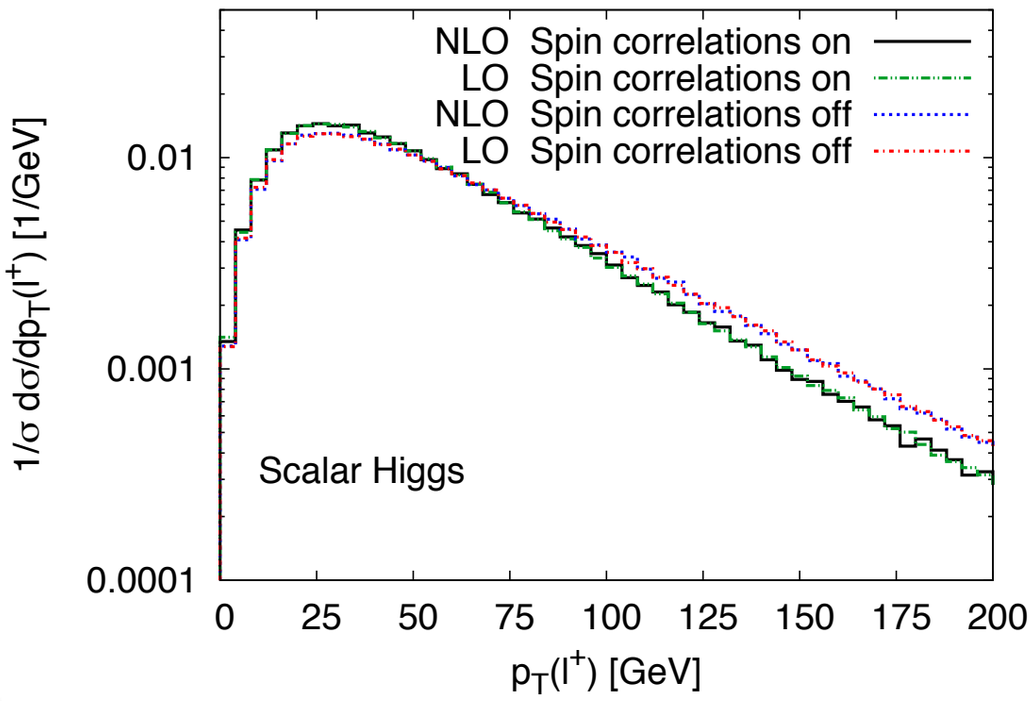
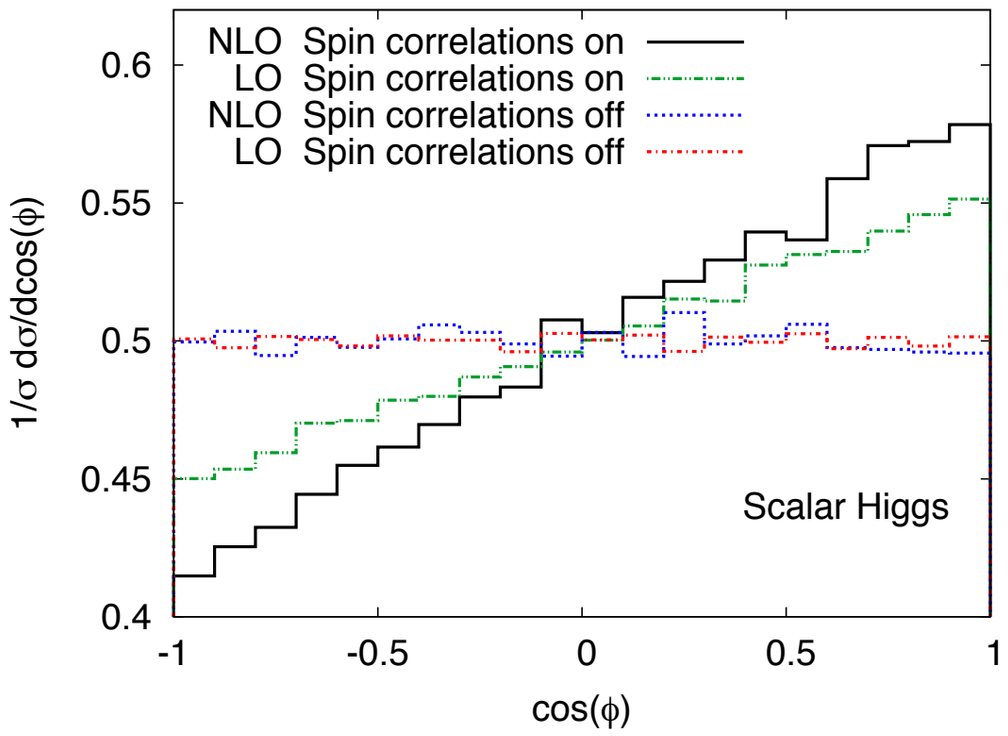
- Can be done via ME re-weighting

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

MadSpin

- 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)