aMC@NLO

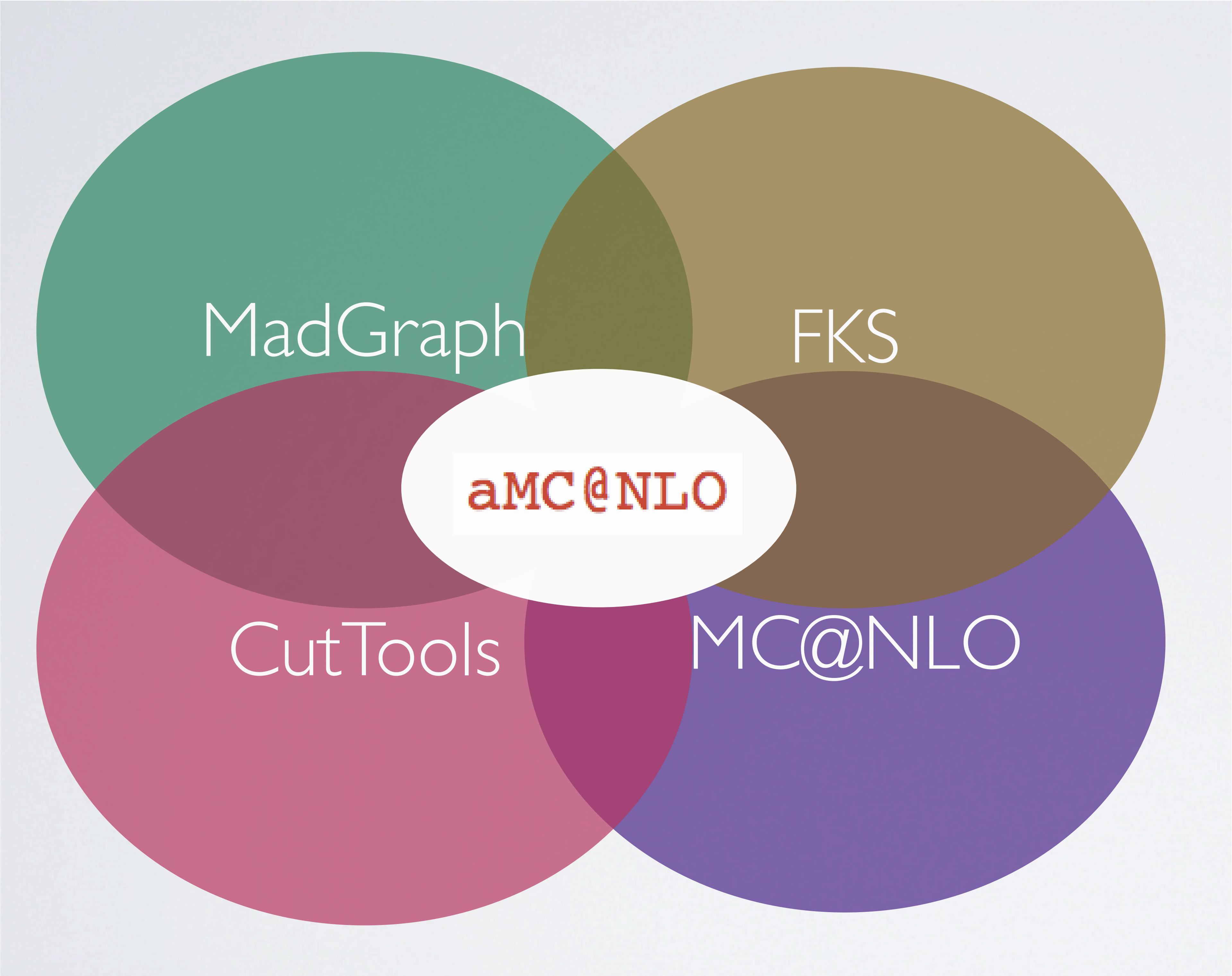
Olivier Mattelaer
University of Illinois at Urbana-Champaign

for the MadGraph/aMC@NLO team
Full list of contributors:
http://amcatnlo.web.cern.ch/amcatnlo/people.htm

Plan of the Talk

- aMC@NLO
  - ➡ MadLoop
  - ➡ MadFKS
  - ➡ NLO+PS
- DEMO
- MadSpin (decay of unstable particles)
- Work in progress
- Conclusion

aMC@NLO: A Joint Venture



aMC@NLO

- Why automation?
  - ➡ Time: Less tools, means more time for physics
  - ➡ Robust: Easier to test, to trust
  - ➡ Easy: One framework/tool to learn

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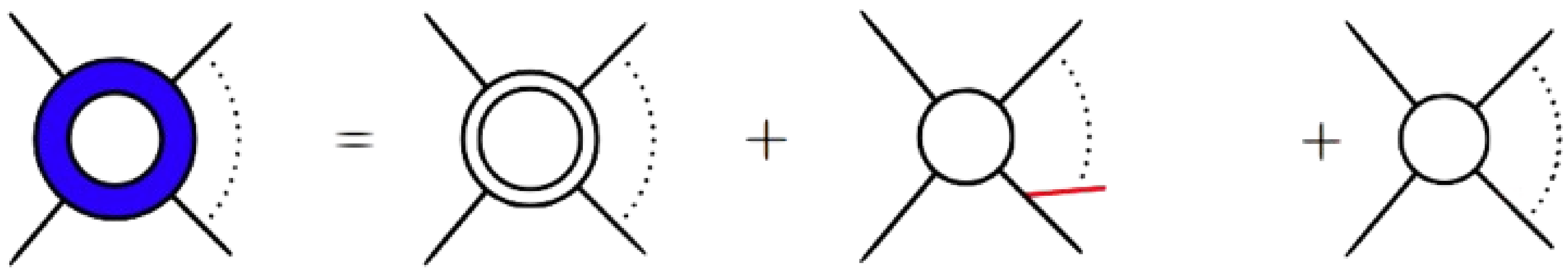
- Why NLO?
  - ➡ Reliable prediction of the total rate
  - ➡ Reduction of the theoretical uncertainty
- Why matched to the PS?
  - ➡ Parton are not an detector observables
  - ➡ Matching cure some fix-order ill behaved observables

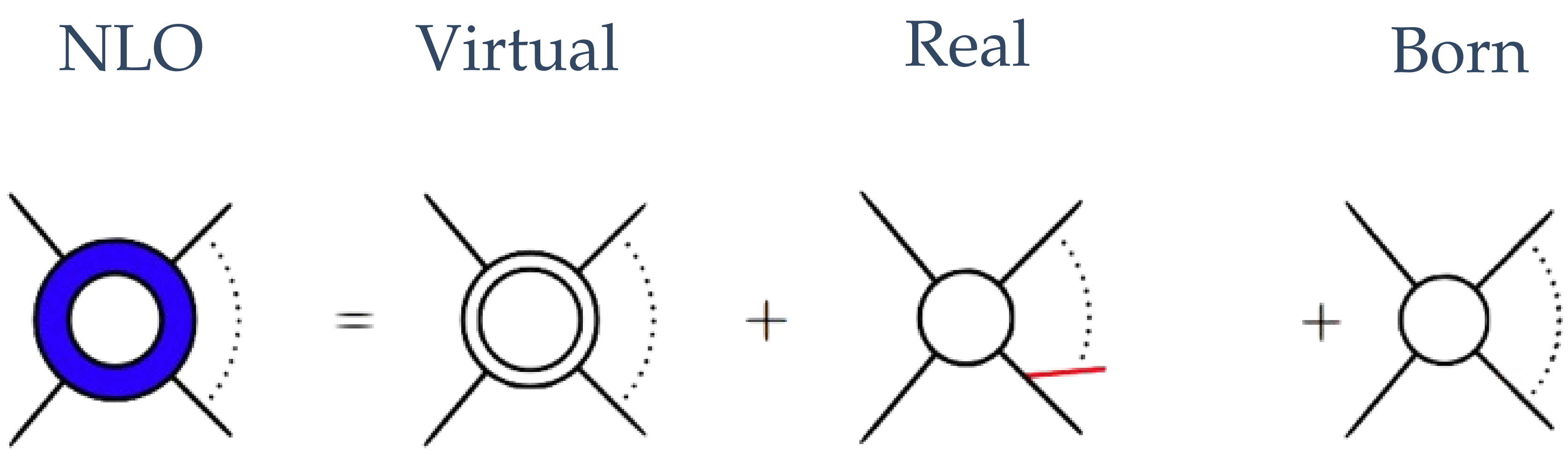
NLO Basics

NLO Virtual Real Born



$$\sigma^{NLO} = \int_m d^{(d)}\sigma^V + \int_{m+1} d^{(d)}\sigma^R + \int_m d^{(4)}\sigma^B$$

NLO Basics

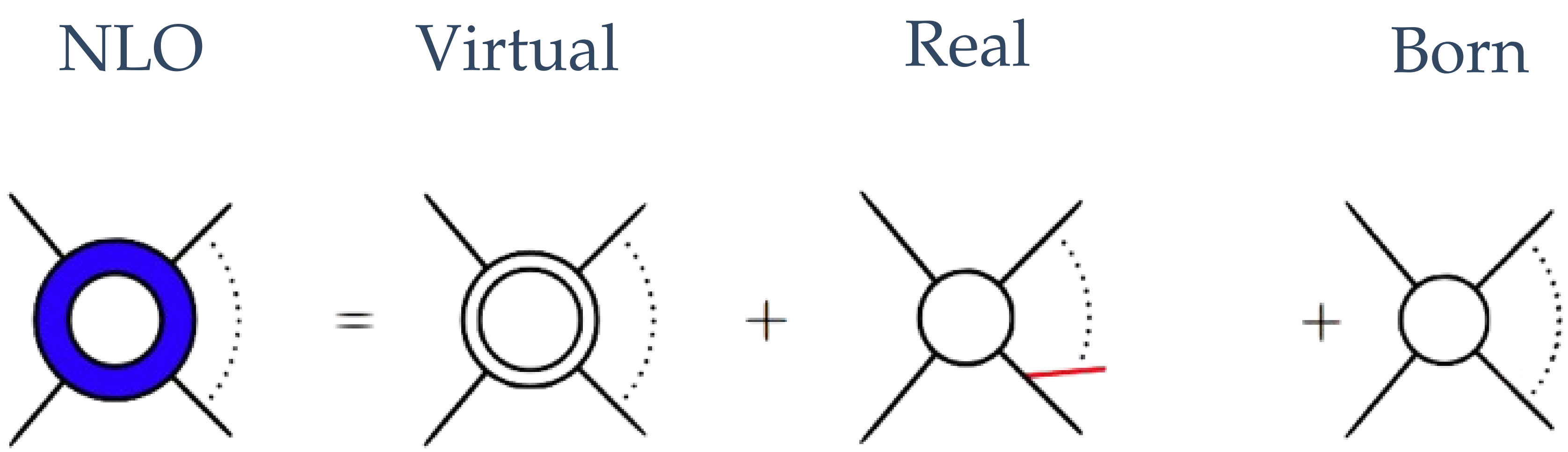


$$\sigma^{NLO} = \int_m d^{(d)}\sigma^V + \int_{m+1} d^{(d)}\sigma^R + \int_m d^{(4)}\sigma^B$$

Need to deal with singularities

$$\sigma^{NLO} = \int_m d^{(d)}(\sigma^V + \int_1 d\phi_1 C) + \int_{m+1} d^{(d)}(\sigma^R - C) + \int_m d^{(4)}\sigma^B$$

NLO Basics



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MadLoop MadFKS MadGraph

MADLOOP

The virtual

The OPP Method

- Reduce the Amplitudes at the Integrand level.

$$
\begin{aligned}
N(l) = & \sum_{i_0<i_1<i_2<i_3}^{m-1} \left[d_{i_0i_1i_2i_3} + \tilde{d}_{i_0i_1i_2i_3}(l)\right] \prod_{i\neq i_0,i_1,i_2,i_3}^{m-1} D_i \\
& + \sum_{i_0<i_1<i_2}^{m-1} \left[c_{i_0i_1i_2} + \tilde{c}_{i_0i_1i_2}(l)\right] \prod_{i\neq i_0,i_1,i_2}^{m-1} D_i \\
& + \sum_{i_0<i_1}^{m-1} \left[b_{i_0i_1} + \tilde{b}_{i_0i_1}(l)\right] \prod_{i\neq i_0,i_1}^{m-1} D_i \\
& + \sum_{i_0}^{m-1} \left[a_{i_0} + \tilde{a}_{i_0}(l)\right] \prod_{i\neq i_0}^{m-1} D_i \\
& + \tilde{P}(l) \prod_{i}^{m-1} D_i
\end{aligned}
$$

- Feed CutTools with loop numerator and obtain the coefficients (including R1 Term)
- Add R2 counter-terms.

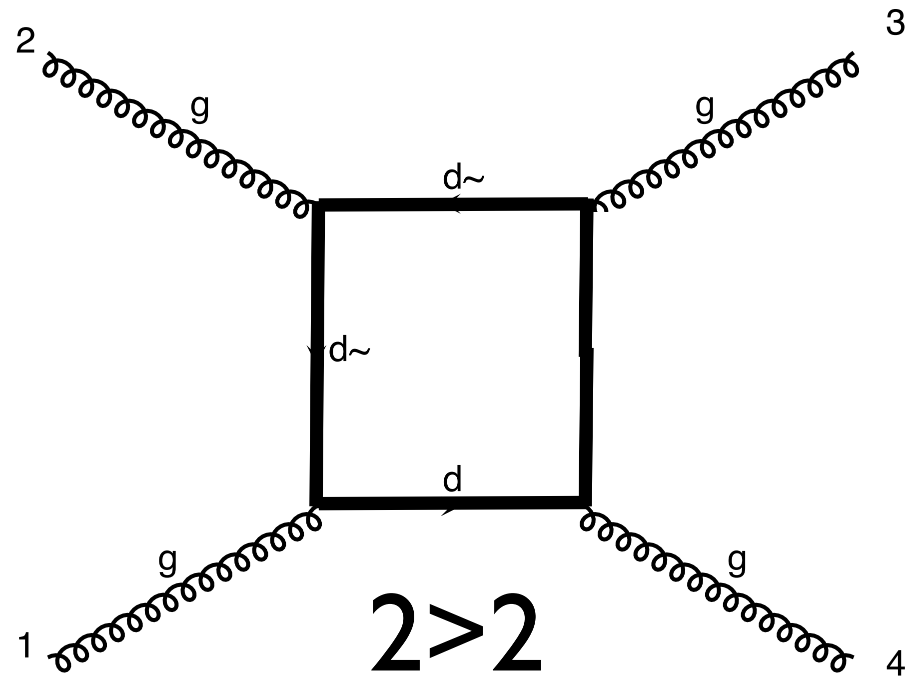
[Ossola, Papadopoulos, Pittau 2006]

OPP in a nutshell

- In OPP reduction we reduce the system at the integrand level.
- We can solve the system numerically: we only need a numerical function of the (numerator of) integrand. We can set-up a system of linear equations by choosing specific values for the loop momentum l, depending on the kinematics of the event
- OPP reduction is implemented in CutTools (publicly available). Given the integrand, CutTools provides all the coefficients in front of the scalar integrals and the R1 term
- The OPP reduction leads to numerical unstabilities whose origins are not well under control. Require quadruple precision.
- Analytic information is needed for the R2 term, but can be compute once and for all for a given model [See C. Degrande Talk]

MADLOOP

- Diagram Generation
  - ➡ Generate diagrams with 2 extra particles
  - ➡ Need to filter result
- Evaluation of the Numerator:
  - ➡ OpenLoops techniques



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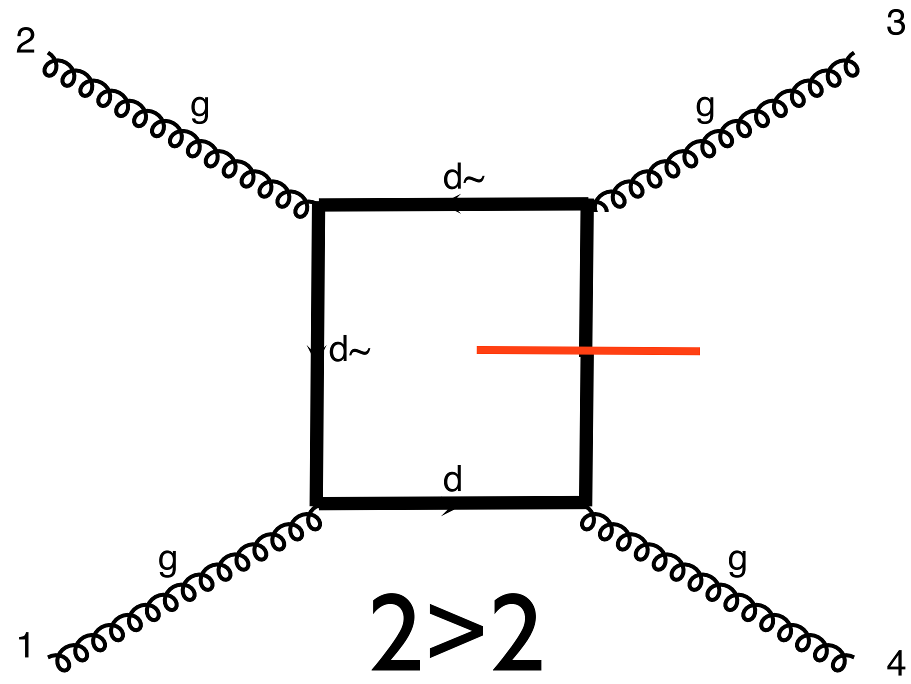

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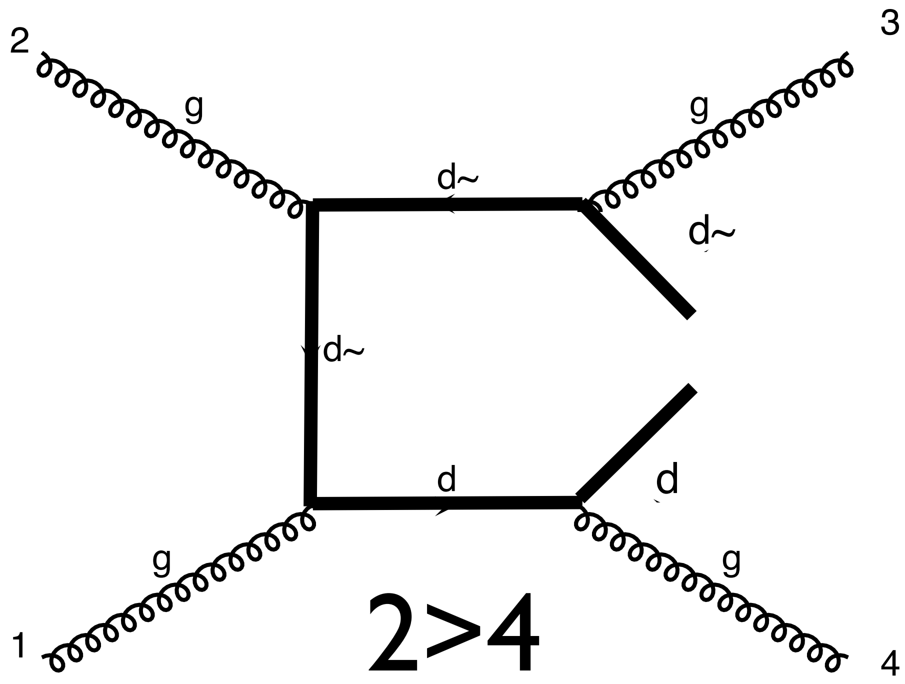

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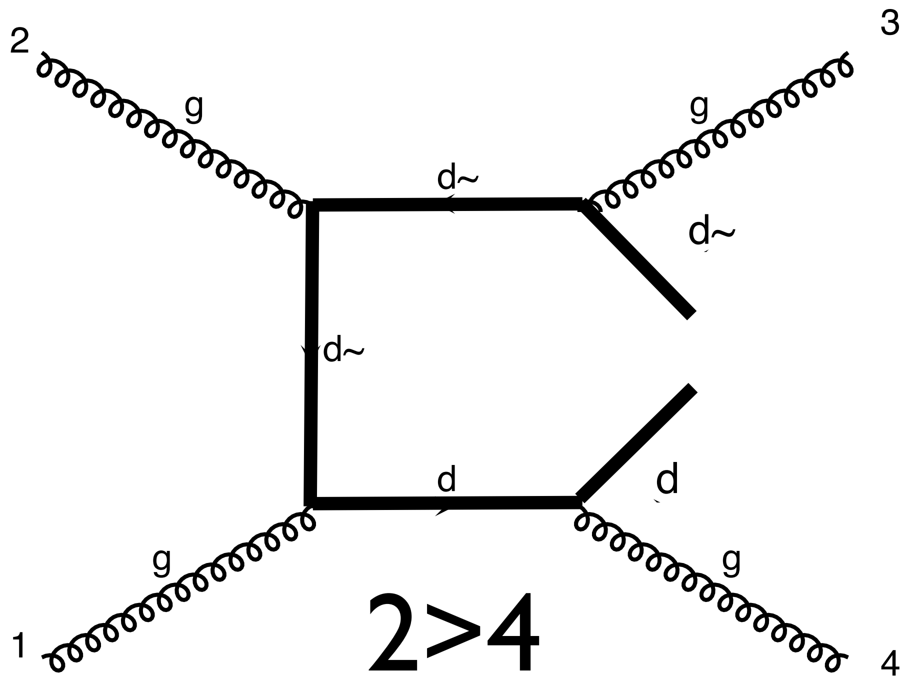

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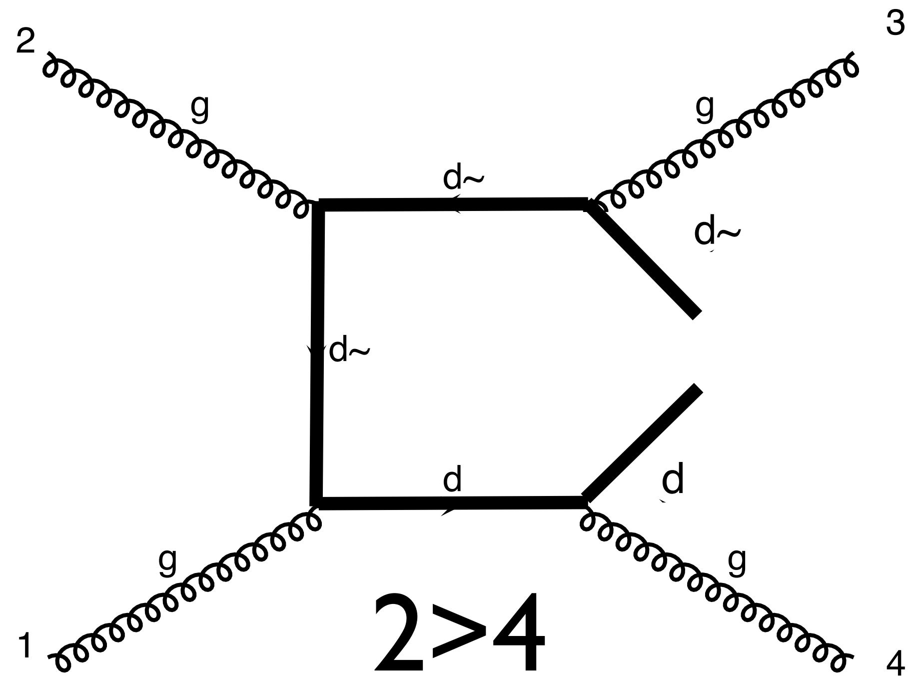
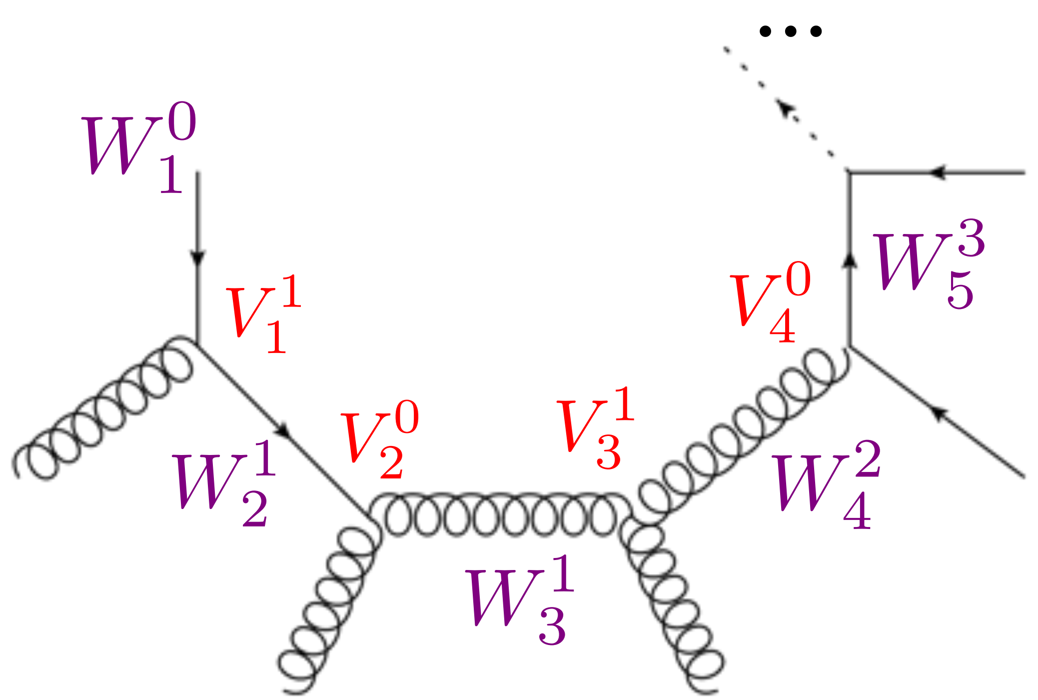


- Diagram Generation
  - ➡ Generate diagrams with 2 extra particles
  - ➡ Need to filter result
- Evaluation of the Numerator:
  - ➡ OpenLoops techniques [S. Pozzorini & al.(2011)]

$$\mathcal{N}(l^\mu) = \sum_{r=0}^{r_{max}} C^{(r)}_{\mu_0\mu_1\cdots\mu_r} l^{\mu_0} l^{\mu_1} \dots l^{\mu_r}$$



[See F. Cascioli Talk]

MADFKS

The real

FKS substraction

- Find parton pairs *i*, *j* that can give collinear singularities
- Split the phase space into regions with one collinear singularities
- Integrate them independently
  - ➡ with an adhoc PS parameterization
  - ➡ can be run in parallel
- # of contributions ~ n^2

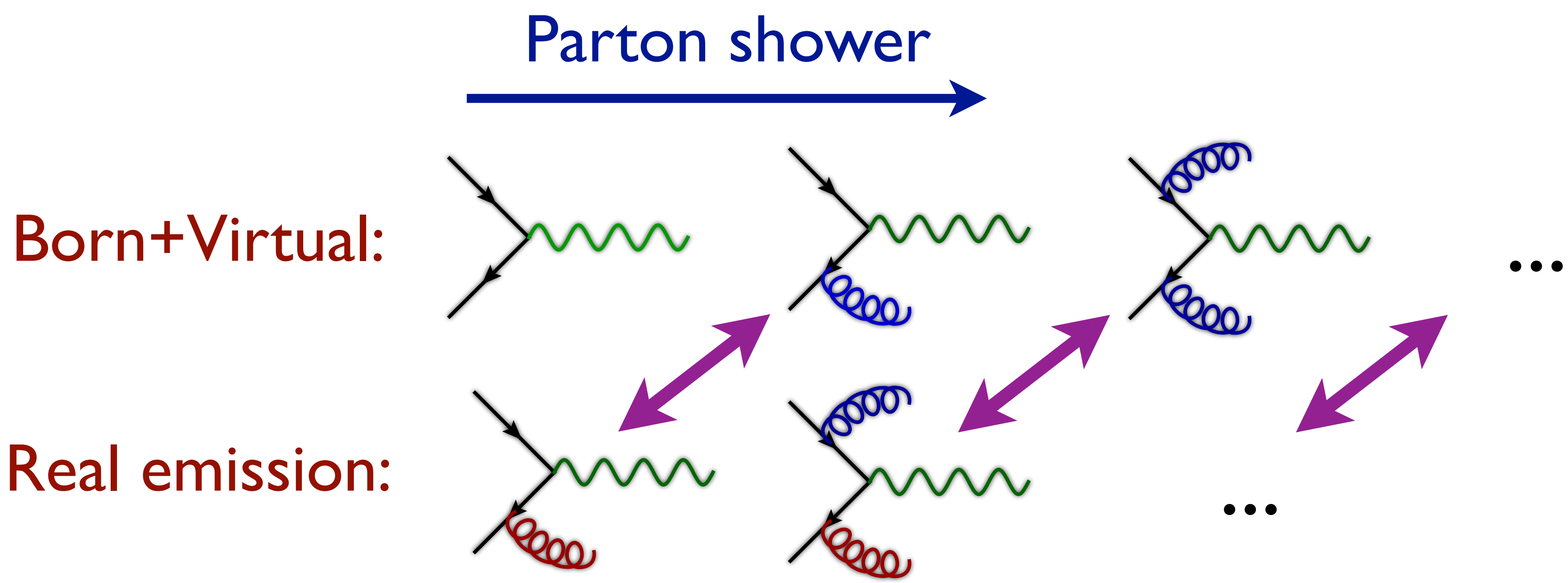
More details in F. Caola Talk

[S. Frixione, Z Kunst, A Signer (1995)]

MC@NLO

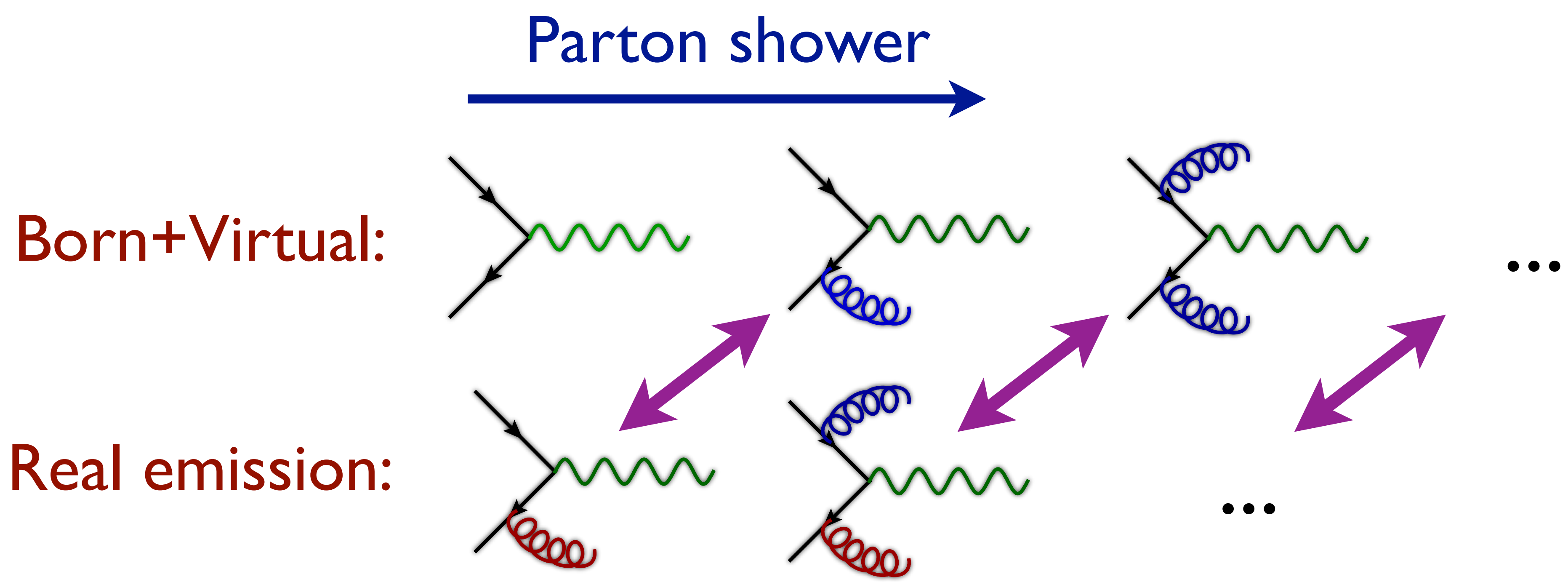
Matching to the shower

Sources of double counting



- There is double counting between the real emission matrix elements and the parton shower: the extra radiation can come from the matrix elements or the parton shower
- There is also an overlap between the virtual

MC@NLO procedure



$$\frac{d\sigma_{\mathrm{NLOwPS}}}{dO} = \left[d\Phi_m \left(B + \int_{\mathrm{loop}} V + \int d\Phi_1 MC \right) \right] I_{\mathrm{MC}}^{(m)}(O)$$

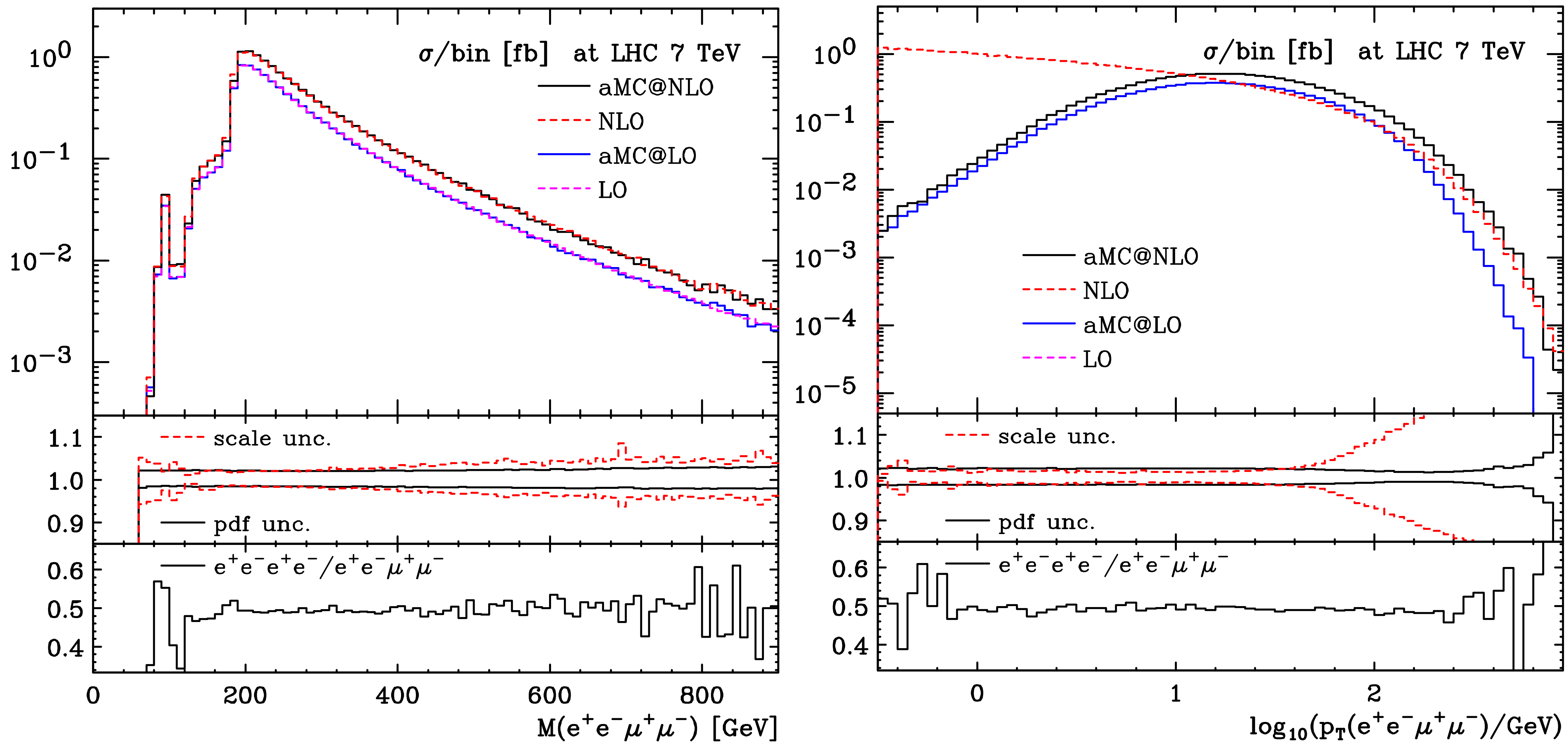
$$+ \left[d\Phi_{m+1} (R - MC) \right] I_{\mathrm{MC}}^{(m+1)}(O)$$

- Double counting is explicitly removed by including the “shower subtraction terms”

MC@NLO properties

- Good features of including the subtraction counter terms
  1. **Double counting avoided**: The rate expanded at NLO coincides with the total NLO cross section
  2. **Smooth matching**: MC@NLO coincides (in shape) with the parton shower in the soft/collinear region, while it agrees with the NLO in the hard region
  3. **Stability**: weights associated to different multiplicities are separately finite. The *MC* term has the same infrared behavior as the real emission (there is a subtlety for the soft divergence)
- Not so nice feature (for the developer):
  1. **Parton shower dependence**: the form of the *MC* terms depends on what the parton shower does exactly. Need special subtraction terms for each parton shower to which we want to match

Four-lepton production



- 4-lepton invariant mass is almost insensitive to parton shower effects. 4-lepton transverse momenta is extremely sensitive

[Frederix, Frixione, Hirschi, maltoni, Pittau & Torrielli (2011)]

results

- Errors are the MC integration uncertainty only
- Cuts on jets, γ*/Z decay products and photons, but no cuts on b quarks (their mass regulates the IR singularities)
- Efficient handling of exceptional phase-space points: their uncertainty always at least two orders of magnitude smaller than the integration uncertainty
- Running time: two weeks on ~150 node cluster leading to rather small integration uncertainties

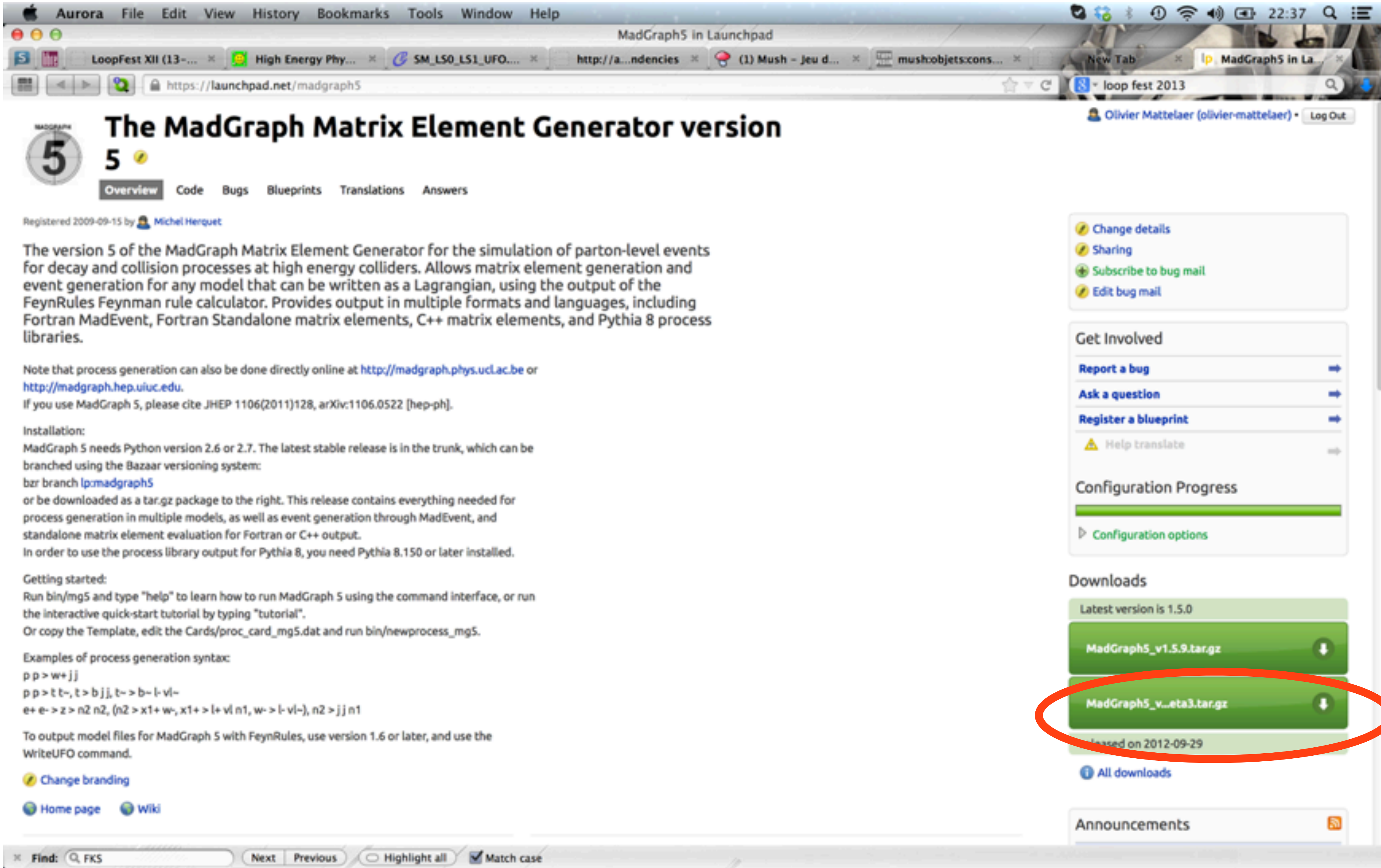
	Process	μ	n_{lf}	Cross section (pb) LO	NLO
a.1	$pp \to t\bar{t}$	m_{top}	5	123.76 ± 0.05	162.08 ± 0.12
a.2	$pp \to tj$	m_{top}	5	34.78 ± 0.03	41.03 ± 0.07
a.3	$pp \to tjj$	m_{top}	5	11.851 ± 0.006	13.71 ± 0.02
a.4	$pp \to t\bar{b}j$	$m_{top}/4$	4	25.62 ± 0.01	30.96 ± 0.06
a.5	$pp \to t\bar{b}jj$	$m_{top}/4$	4	8.195 ± 0.002	8.91 ± 0.01
b.1	$pp \to (W^+ \to)e^+\nu_e$	m_W	5	5072.5 ± 2.9	6146.2 ± 9.8
b.2	$pp \to (W^+ \to)e^+\nu_e\, j$	m_W	5	828.4 ± 0.8	1065.3 ± 1.8
b.3	$pp \to (W^+ \to)e^+\nu_e\, jj$	m_W	5	298.8 ± 0.4	300.3 ± 0.6
b.4	$pp \to (\gamma^*/Z \to)e^+e^-$	m_Z	5	1007.0 ± 0.1	1170.0 ± 2.4
b.5	$pp \to (\gamma^*/Z \to)e^+e^-\, j$	m_Z	5	156.11 ± 0.03	203.0 ± 0.2
b.6	$pp \to (\gamma^*/Z \to)e^+e^-\, jj$	m_Z	5	54.24 ± 0.02	56.69 ± 0.07
c.1	$pp \to (W^+ \to)e^+\nu_e b\bar{b}$	$m_W + 2m_b$	4	11.557 ± 0.005	22.95 ± 0.07
c.2	$pp \to (W^+ \to)e^+\nu_e t\bar{t}$	$m_W + 2m_{top}$	5	0.009415 ± 0.000003	0.01159 ± 0.00001
c.3	$pp \to (\gamma^*/Z \to)e^+e^- b\bar{b}$	$m_Z + 2m_b$	4	9.459 ± 0.004	15.31 ± 0.03
c.4	$pp \to (\gamma^*/Z \to)e^+e^- t\bar{t}$	$m_Z + 2m_{top}$	5	0.0035131 ± 0.0000004	0.004876 ± 0.000002
c.5	$pp \to \gamma t\bar{t}$	$2m_{top}$	5	0.2906 ± 0.0001	0.4169 ± 0.0003
d.1	$pp \to W^+W^-$	$2m_W$	4	29.976 ± 0.004	43.92 ± 0.03
d.2	$pp \to W^+W^-\, j$	$2m_W$	4	11.613 ± 0.002	15.174 ± 0.008
d.3	$pp \to W^+W^+\, jj$	$2m_W$	4	0.07048 ± 0.00004	0.1377 ± 0.0005
e.1	$pp \to HW^+$	$m_W + m_H$	5	0.3428 ± 0.0003	0.4455 ± 0.0003
e.2	$pp \to HW^+\, j$	$m_W + m_H$	5	0.1223 ± 0.0001	0.1501 ± 0.0002
e.3	$pp \to HZ$	$m_Z + m_H$	5	0.2781 ± 0.0001	0.3659 ± 0.0002
e.4	$pp \to HZ\, j$	$m_Z + m_H$	5	0.0988 ± 0.0001	0.1237 ± 0.0001
e.5	$pp \to Ht\bar{t}$	$m_{top} + m_H$	5	0.08896 ± 0.00001	0.09869 ± 0.00003
e.6	$pp \to Hb\bar{b}$	$m_b + m_H$	4	0.16510 ± 0.00009	0.2099 ± 0.0006
e.7	$pp \to Hjj$	m_H	5	1.104 ± 0.002	1.036 ± 0.002

DEMO

Is it really automatic?

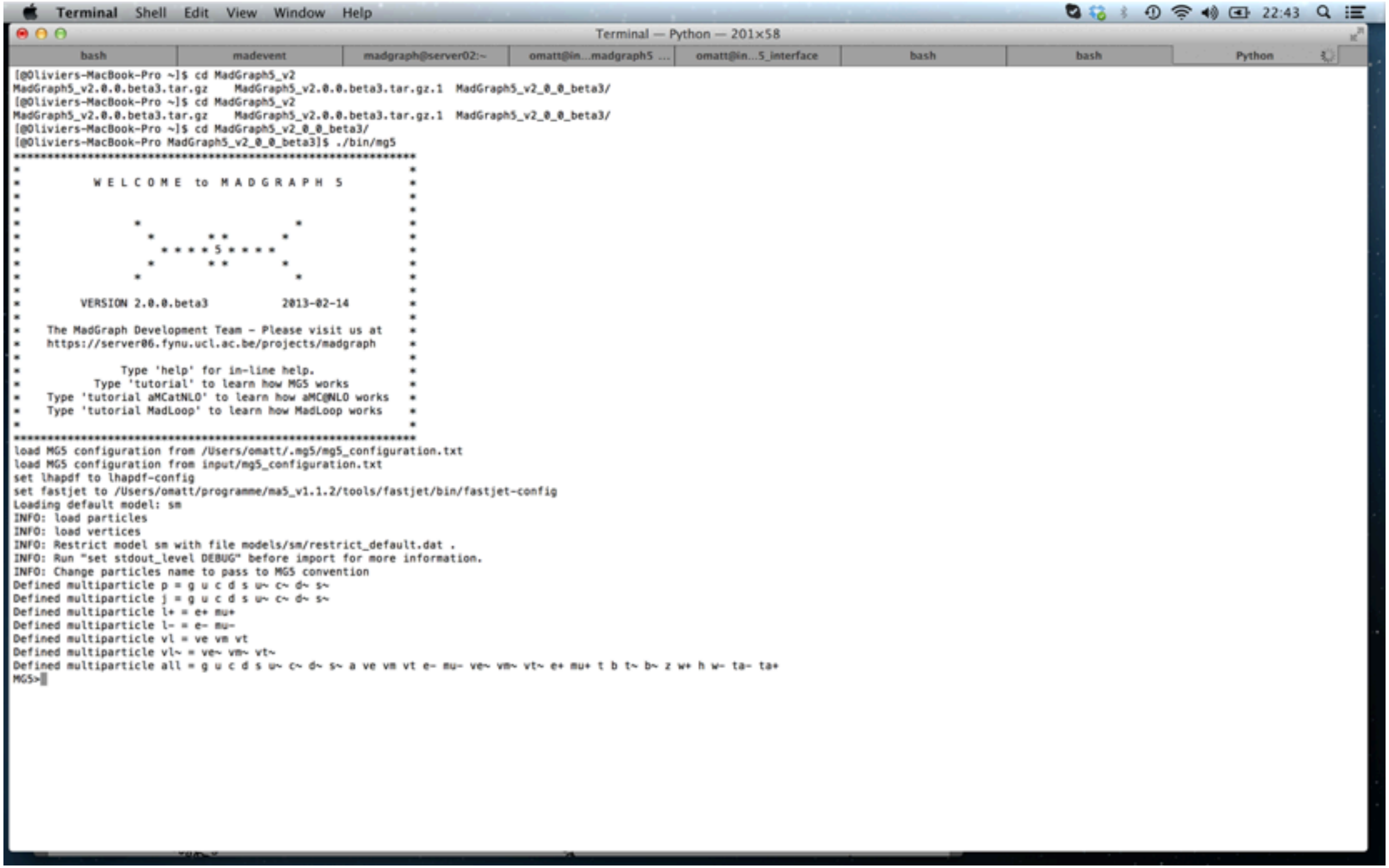
DEMO

- 1) Download the code



DEMO

- launch the code [./bin/mg5]
  - ➡ Exactly like MG5 !!!



- 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+ 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]

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```
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
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First Question:

```
Which programs do you want to run?
  0 / auto       : NLO event generation and -if cards exist- shower and madspin.
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  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]

Second Question:

```
Do you want to edit one cards (press enter to bypass editing)?
  1 / param      : param_card.dat
  2 / run        : run_card.dat
  3 / 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, shower, enter path][60s to answer]
>
```

- The code runs:

```
INFO: For gauge cancellation, the width of 't' has been set to zero.
```

- The code runs:

```
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

- The code runs:

```
INFO: For gauge cancellation, the width of 't' has been set to zero.
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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
```

Integration

```
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
```

Events Generation

```
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:
```

Unweight Events

```
      Summary:
      Process p p > t t~ [QCD]
      Run at p-p collider (4000 + 4000 GeV)
      Total cross-section: 1.770e+02 +- 1.7e+00 pb
      Ren. and fac. scale uncertainty: +13.5% -13.0%
      Number of events generated: 10000
      Parton shower to be used: HERWIG6
      Fraction of negative weights: 0.16
      Total running time :  15m 42s
```

Main Results

```
INFO: The /Users/omatt/MadGraph5_v2_0_0_beta3/PROCNLO_loop_sm_0/Events/run_01/events.lhe.gz file has been generated.
```

```
decay_events -from_cards
INFO:    Prepairing MCatNLO run
INFO:    Compiling MCatNLO for HERWIG6...
INFO:                  ... done
INFO: Running MCatNLO in /Users/omatt/MadGraph5_v2_0_0_beta3/PROCNLO_loop_sm_0/MCatNLO/RUN_HERWIG6_1 (this may take some time)...
gzip: /Users/omatt/MadGraph5_v2_0_0_beta3/PROCNLO_loop_sm_0/Events/run_01/events_HERWIG6_0.hep has 1 other link  -- unchanged
INFO: The file /Users/omatt/MadGraph5_v2_0_0_beta3/PROCNLO_loop_sm_0/Events/run_01/events_HERWIG6_0.hep.gz has been generated.
```

The Shower

DEMO

Is it really automatic?

DEMO

Is it really automatic?

As much as LO!

MadSpin

Decay with Full Spin correlation

[P. Artoisenet, R. Frederix, OM, R. RietKerk (2012)]

MadSpin

- WISH-LIST:
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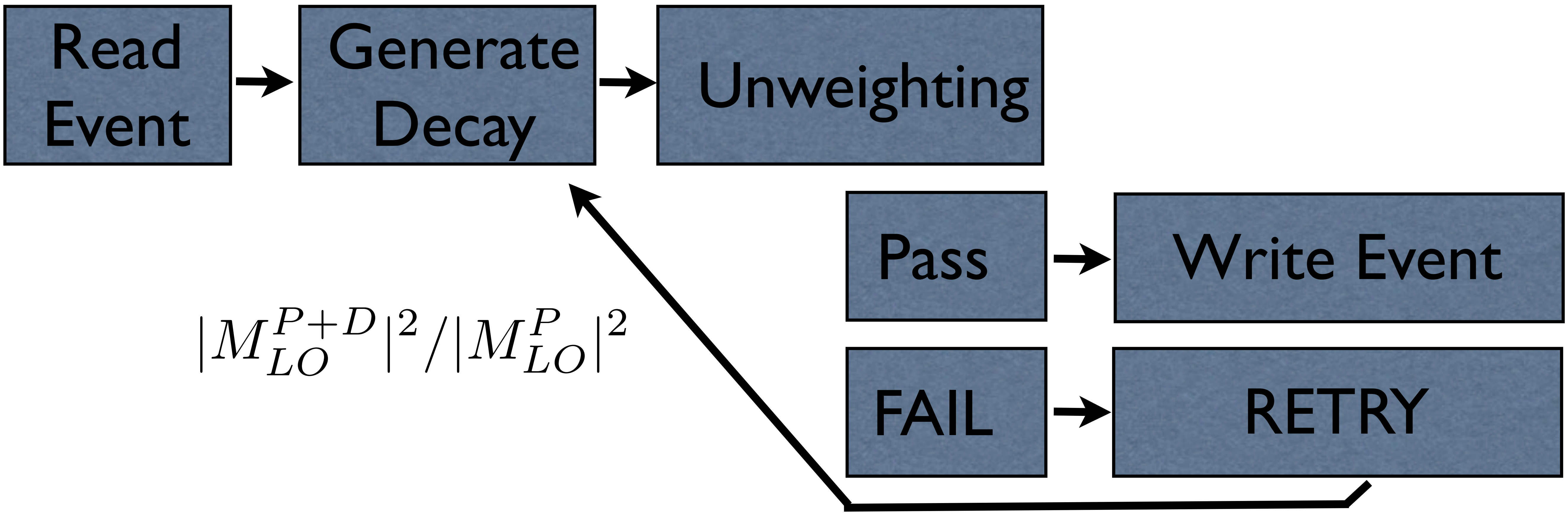
- Solution:

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



MadSpin

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  - ➡ Fully integrated in MG5 [LO and NLO]
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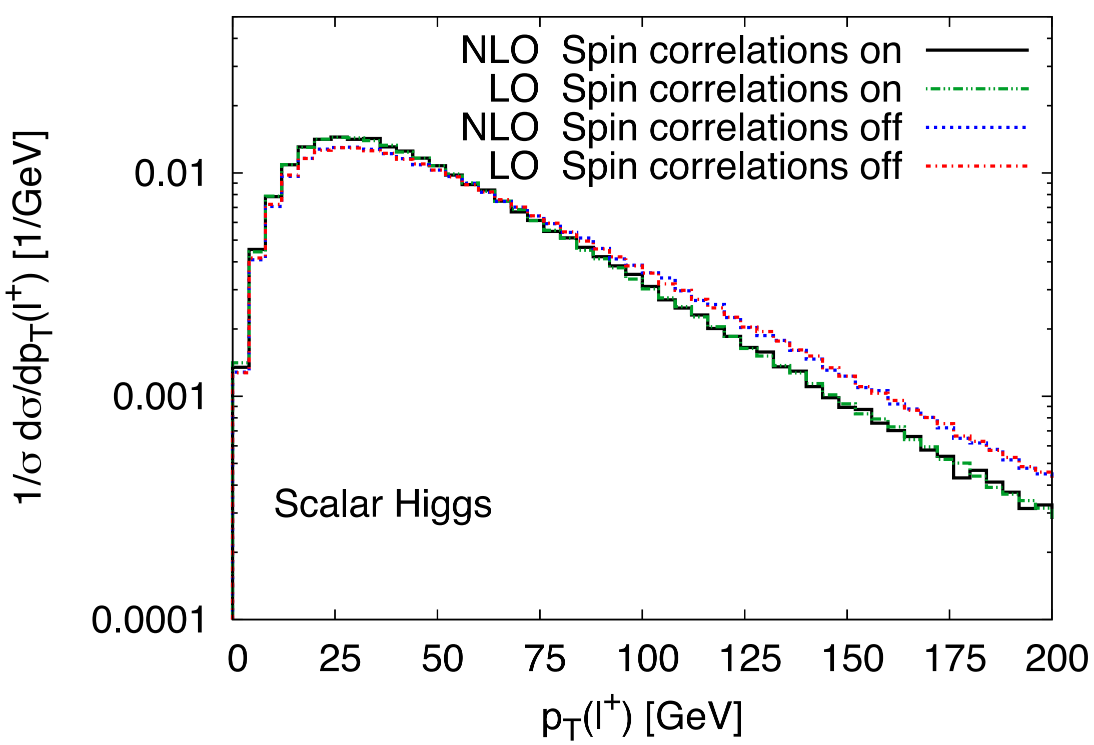

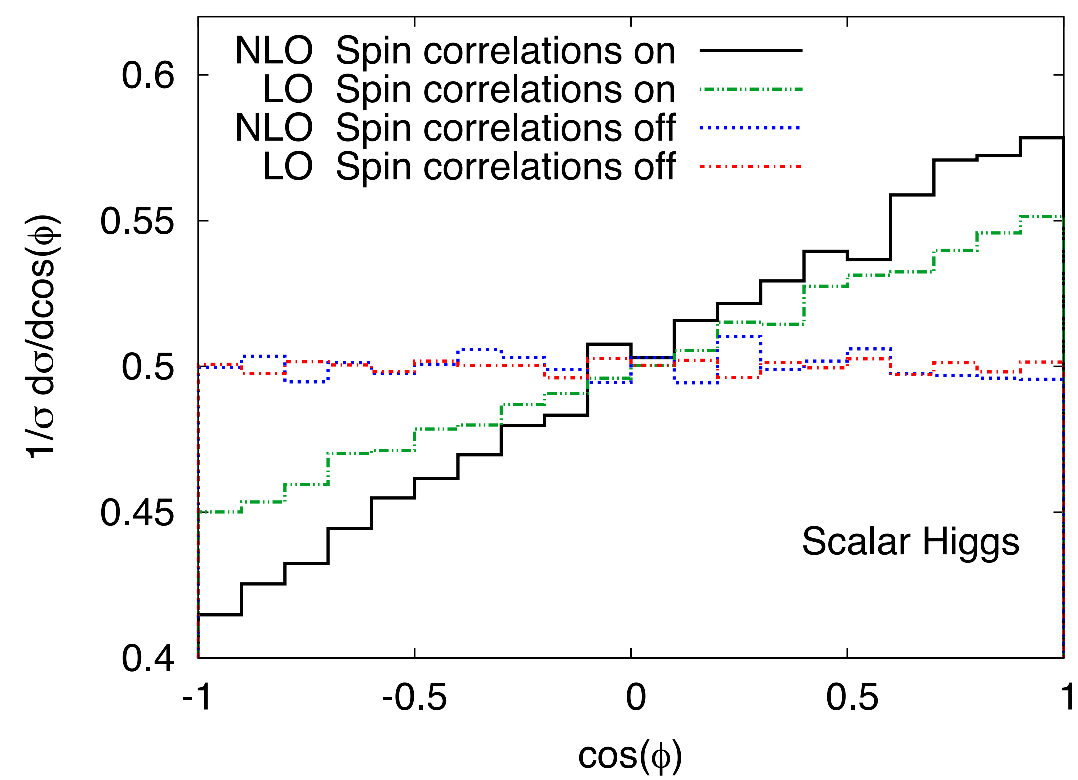

Work in Progress in aMC@NLO

What to expect in the future

Perspectives

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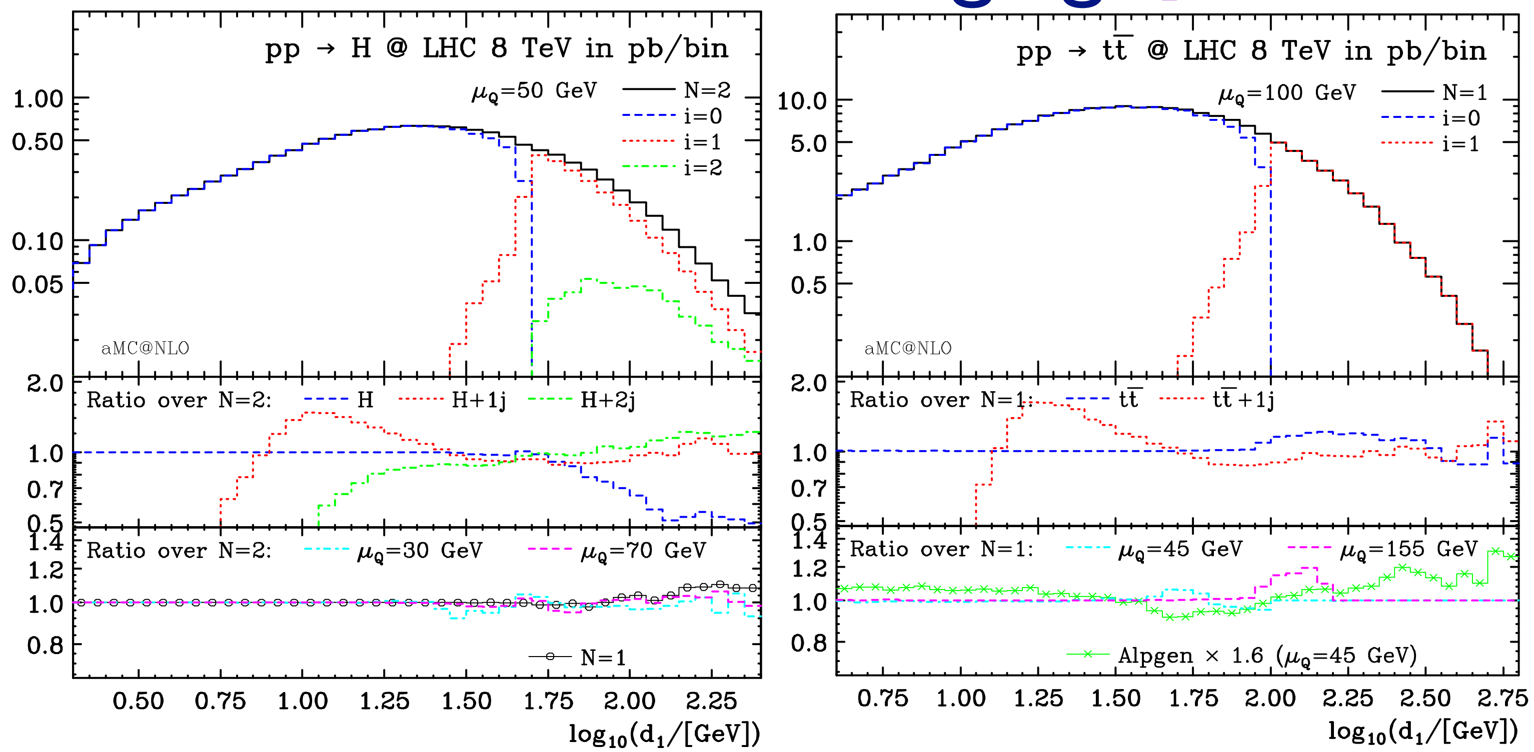

$0 \to 1$ rates in H^0 and $t\bar{t}$ production

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- Full automation of FxFx merging [R. Frederix, S. Frixione (2012)]
- Automation of loop-induced processes
- Interface to Pythia8
- Complex mass scheme

Conclusion

- aMC@NLO is
  - ➡ public
  - ➡ automatic
  - ➡ flexible
- MadSpin
  - ➡ decay with full spin correlations
  - ➡ keep finite width effect
- This is only the beginning of this Tool!

	Process	μ	n_{lf}	Cross section (pb) LO	NLO
a.1	$pp \to t\bar{t}$	m_{top}	5	123.76 ± 0.05	162.08 ± 0.12
a.2	$pp \to tj$	m_{top}	5	34.78 ± 0.03	41.03 ± 0.07
a.3	$pp \to tjj$	m_{top}	5	11.851 ± 0.006	13.71 ± 0.02
a.4	$pp \to t\bar{b}j$	$m_{top}/4$	4	25.62 ± 0.01	30.96 ± 0.06
a.5	$pp \to t\bar{b}jj$	$m_{top}/4$	4	8.195 ± 0.002	8.91 ± 0.01
b.1	$pp \to (W^+ \to)e^+\nu_e$	m_W	5	5072.5 ± 2.9	6146.2 ± 9.8
b.2	$pp \to (W^+ \to)e^+\nu_e\, j$	m_W	5	828.4 ± 0.8	1065.3 ± 1.8
b.3	$pp \to (W^+ \to)e^+\nu_e\, jj$	m_W	5	298.8 ± 0.4	300.3 ± 0.6
b.4	$pp \to (\gamma^*/Z \to)e^+e^-$	m_Z	5	1007.0 ± 0.1	1170.0 ± 2.4
b.5	$pp \to (\gamma^*/Z \to)e^+e^-\, j$	m_Z	5	156.11 ± 0.03	203.0 ± 0.2
b.6	$pp \to (\gamma^*/Z \to)e^+e^-\, jj$	m_Z	5	54.24 ± 0.02	56.69 ± 0.07
c.1	$pp \to (W^+ \to)e^+\nu_e b\bar{b}$	$m_W + 2m_b$	4	11.557 ± 0.005	22.95 ± 0.07
c.2	$pp \to (W^+ \to)e^+\nu_e t\bar{t}$	$m_W + 2m_{top}$	5	0.009415 ± 0.000003	0.01159 ± 0.00001
c.3	$pp \to (\gamma^*/Z \to)e^+e^- b\bar{b}$	$m_Z + 2m_b$	4	9.459 ± 0.004	15.31 ± 0.03
c.4	$pp \to (\gamma^*/Z \to)e^+e^- t\bar{t}$	$m_Z + 2m_{top}$	5	0.0035131 ± 0.0000004	0.004876 ± 0.000002
c.5	$pp \to \gamma t\bar{t}$	$2m_{top}$	5	0.2906 ± 0.0001	0.4169 ± 0.0003
d.1	$pp \to W^+W^-$	$2m_W$	4	29.976 ± 0.004	43.92 ± 0.03
d.2	$pp \to W^+W^-\, j$	$2m_W$	4	11.613 ± 0.002	15.174 ± 0.008
d.3	$pp \to W^+W^+\, jj$	$2m_W$	4	0.07048 ± 0.00004	0.1377 ± 0.0005
e.1	$pp \to HW^+$	$m_W + m_H$	5	0.3428 ± 0.0003	0.4455 ± 0.0003
e.2	$pp \to HW^+\, j$	$m_W + m_H$	5	0.1223 ± 0.0001	0.1501 ± 0.0002
e.3	$pp \to HZ$	$m_Z + m_H$	5	0.2781 ± 0.0001	0.3659 ± 0.0002
e.4	$pp \to HZ\, j$	$m_Z + m_H$	5	0.0988 ± 0.0001	0.1237 ± 0.0001
e.5	$pp \to Ht\bar{t}$	$m_{top} + m_H$	5	0.08896 ± 0.00001	0.09869 ± 0.00003
e.6	$pp \to Hb\bar{b}$	$m_b + m_H$	4	0.16510 ± 0.00009	0.2099 ± 0.0006
e.7	$pp \to Hjj$	m_H	5	1.104 ± 0.002	1.036 ± 0.002