MadGraph 5 – The All-New Matrix Element generator for Everything

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Fermilab Theory Seminar, March 31, 2011

The LHC is on track!

but where are we heading...?

What will be needed for the LHC?

NLO

Exp-TH communication

Very exotic models

Exotic models

Effective theories

DECAY CHAINS

MATRIX ELEMENTS

Advanced analysis techniques

Multi-jet samples

Cluster/Grid computing

Merging ME/PS

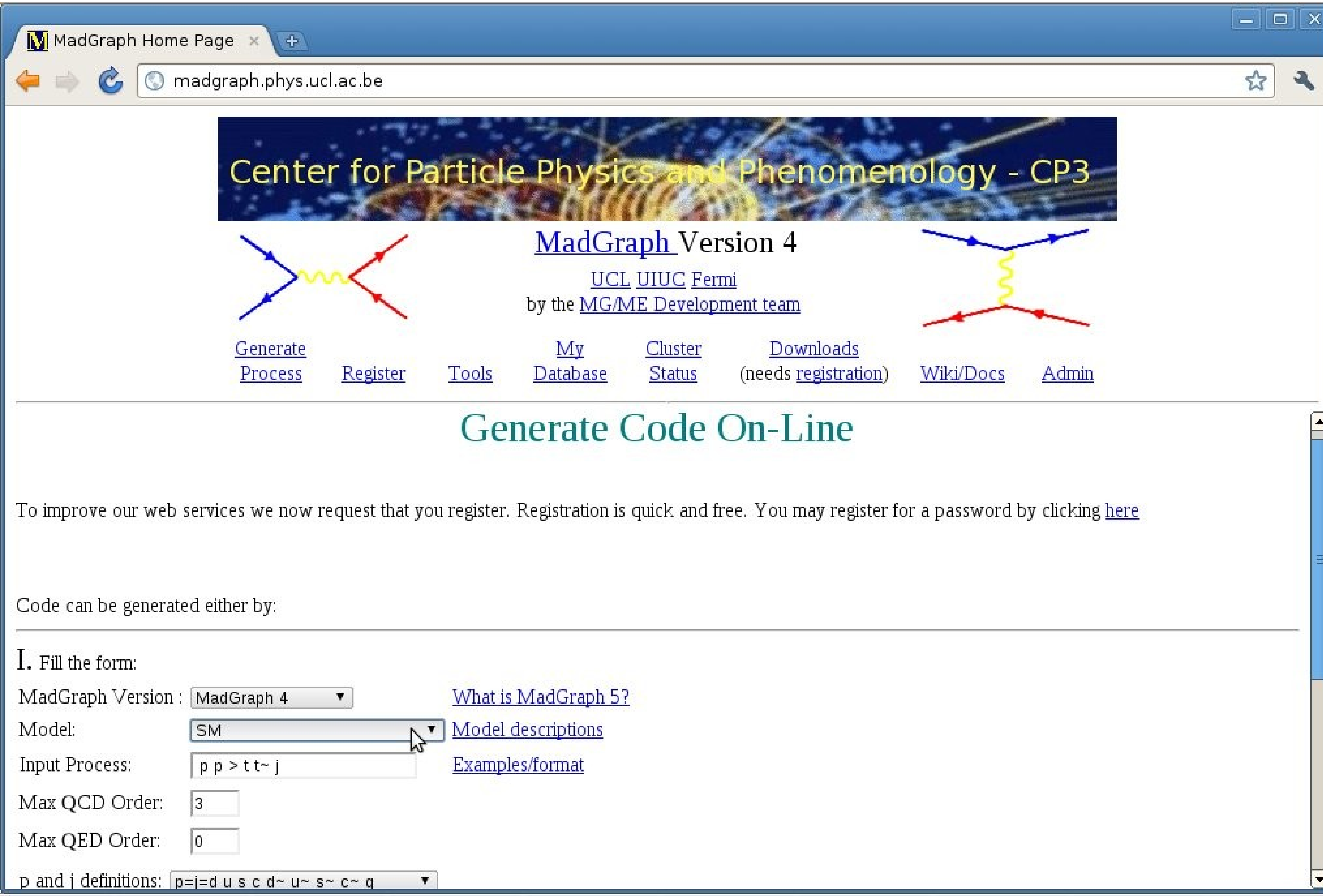
DECAY PACKAGES

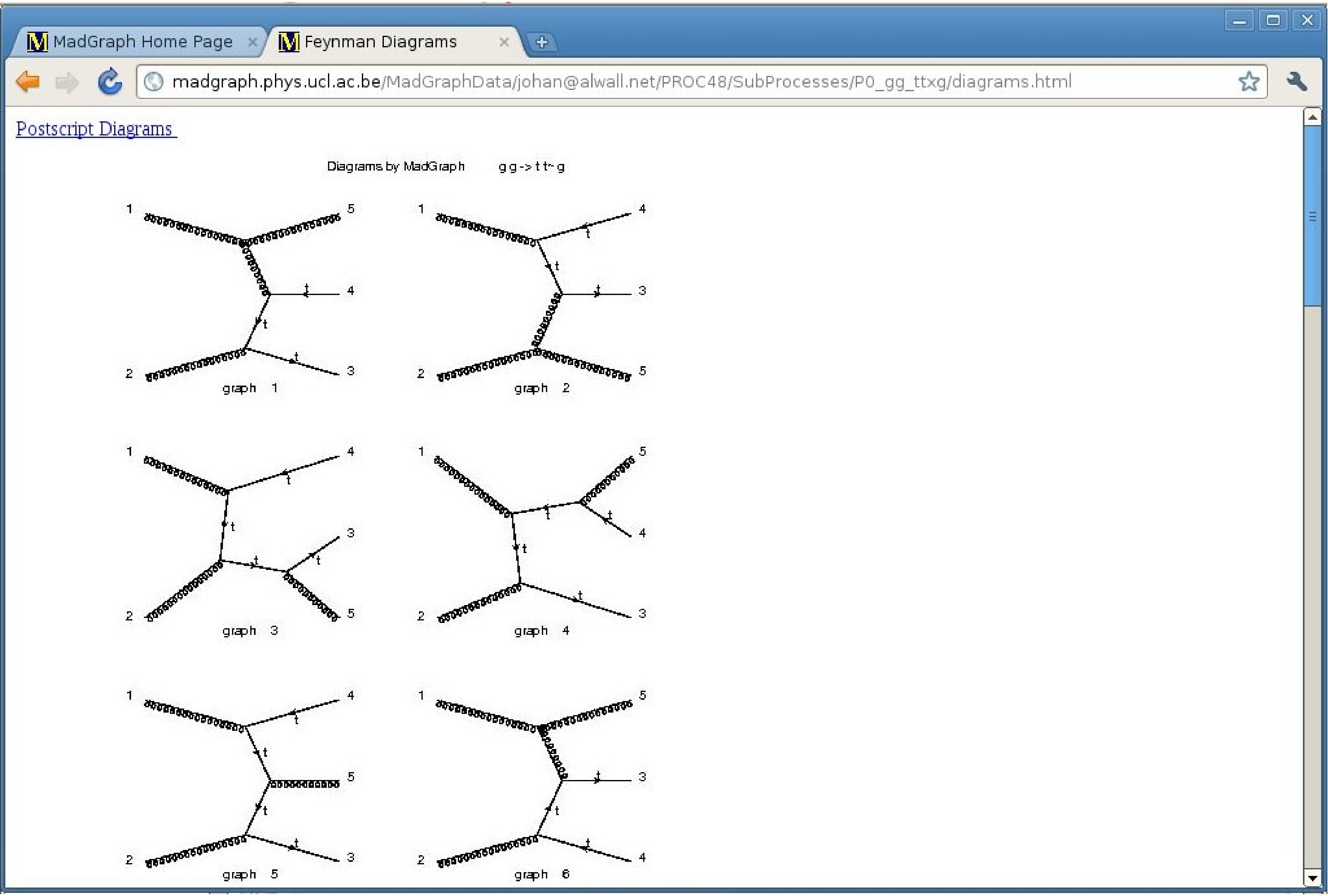
Testing / robustness

User friendliness

MadGraph/MadEvent 4

- One of the most widely used automatized matrix element generators
  - Specify any process using simple syntax
  - > 1500 registered users (+ CDF/D0/CMS/ATLAS/...)
- Originally written by Tim Stelzer in 1994
- Phase space integrator/event generator MadEvent by F. Maltoni and T. Stelzer in 2002
- MadGraph/MadEvent v. 4 in 2006


MadGraph Home Page
madgraph.phys.ucl.ac.be
Center for Particle Physics and Phenomenology - CP3
MadGraph Version 4
UCL UIUC Fermi
by the MG/ME Development team
Generate Process
Register
Tools
My Database
Cluster Status
Downloads (needs registration)
Wiki/Docs
Admin
Generate Code On-Line
To improve our web services we now request that you register. Registration is quick and free. You may register for a password by clicking here
Code can be generated either by:
I. Fill the form:
MadGraph Version : MadGraph 4
What is MadGraph 5?
Model: SM
Model descriptions
Input Process: p p > t t~ j
Examples/format
Max QCD Order: 3
Max QED Order: 0
p and j definitions: p=j=d u s c d~ u~ s~ c~ g


MadGraph Home Page
Feynman Diagrams
madgraph.phys.ucl.ac.be/MadGraphData/johan@alwall.net/PROC48/SubProcesses/P0_gg_ttxg/diagrams.html
Postscript Diagrams
Diagrams by MadGraph g g -> t t~ g
graph 1
graph 2
graph 3
graph 4
graph 5
graph 6

MadGraph Home Page | Online Event Genera...

madgraph.phys.ucl.ac.be/MadGraphData//johan@alwall.net/PROC48/HTML/crossx.html

Results for p p > t t~ j in the sm

Available Results

Links	Events		Tag	Run	Collider	Cross section (pb)	Events	
results plots banner	Parton-level	LHE rootfile	fermi	run_01	p p 7000 x 7000 GeV	.60019E+03	10000	Remove run
	Hadron-level (Pythia)	STDHEP LHE rootfile (LHE)						Remove Pythia
	Reco. Objects. (PGS)	LHCO rootfile						Remove PGS

Main Page

Why new MadGraph?

- First version of core code from 1994
  - Never intended for the present variety of use cases and periferal tools
- Written in Fortran 77
  - Fixed array sizes
  - No recursion
  - Difficult to modularize, modify or extend (no OO, dynamic libraries,...)
- Becoming a roadblock for new developments

MadGraph 5

- Development started November 2009
  - First public full MG functionality version in May 2010
  - Release version 1.0.0 upcoming (including revamped MadEvent and much much more)
- Programming language: Python
  - (Very) high level, modern programming language
  - Easy to learn/write/maintain/extend/structure/...
- Modular program structure
  - Central collection of tools for any matrix element-based implementations
- New algorithms for every part of the code
  - Diagram generation, color, decay chains, ...

Speed benchmarks

Full MadEvent subprocess directory output, including diagram drawing

Computer: Sony Vaio TZ

Process	MadGraph 4	MadGraph 5	Subprocesses	Diagrams
$pp \to jjj$	29.0 s	54.4 s	34	307
$pp \to jjl^+l^-$	341 s	258 s	108	1216
$pp \to jjje^+e^-$	1151 s	654 s	141	9012
$u\bar{u} \to e^+e^-e^+e^-e^+e^-$	772 s	175 s	1	3474
$gg \to ggggg$	2788 s	1049 s	1	7245
$pp \to jj(W^+ \to l^+\nu_l)$	146 s	70 s	82	304
$pp \to t\bar{t}$+full decays	5640 s	22 s	27	45
$pp \to \tilde{q}/\tilde{g}\,\tilde{q}/\tilde{g}$	222 s	286 s	313	475
7 particle decay chain	383 s	5.2 s	1	6
$gg \to (\tilde{g} \to u\bar{u}\tilde{\chi}_1^0)(\tilde{g} \to u\bar{u}\tilde{\chi}_1^0)$	70 s	5.5 s	1	48
$pp \to (\tilde{g} \to jj\tilde{\chi}_1^0)(\tilde{g} \to jj\tilde{\chi}_1^0)$	$\gg$ 1 year	551 s	144	11008

$$gg \to (\tilde{g} \to u(\bar{\tilde{u}}_l \to \bar{u}(\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0)))(\tilde{g} \to u\hat{\bar{\tilde{d}}}\tilde{\chi}_1^-)$$

Speed of ME calculation

Computer: Sony Vaio TZ

Process	Amplitudes	Wavefunctions		Run time	
		MG 4	MG 5	MG 4	MG 5
$u\bar{u} \to e^+e^-$	2	6	6	$< 6\mu s$	$< 6\mu s$
$u\bar{u} \to e^+e^-e^+e^-$	48	62	32	0.22 ms	0.14 ms
$u\bar{u} \to e^+e^-e^+e^-e^+e^-$	3474	3194	301	46.5 ms	19.0 ms
$u\bar{u} \to d\bar{d}$	1	5	5	$< 4\mu s$	$< 4\mu s$
$u\bar{u} \to d\bar{d}g$	5	11	11	27 μs	27 μs
$u\bar{u} \to d\bar{d}gg$	38	47	29	0.42 ms	0.31 ms
$u\bar{u} \to d\bar{d}ggg$	393	355	122	10.8 ms	6.75 ms
$u\bar{u} \to u\bar{u}gg$	76	84	40	1.24 ms	0.80 ms
$u\bar{u} \to u\bar{u}ggg$	786	682	174	35.7 ms	17.2 ms
$u\bar{u} \to d\bar{d}d\bar{d}$	14	28	19	84 μs	83 μs
$u\bar{u} \to d\bar{d}d\bar{d}g$	132	178	65	1.88 ms	1.15 ms
$u\bar{u} \to d\bar{d}d\bar{d}gg$	1590	1782	286	141 ms	34.4 ms
$u\bar{u} \to d\bar{d}d\bar{d}d\bar{d}$	612	758	141	42.5 ms	6.6 ms

Speed of ME calculation

Computer: Sony Vaio TZ

Factor ~10 less function calls
→ factor ~2.5 speed improvement!

Process	Amplitudes	Wavefunctions		Run time	
		MG 4	MG 5	MG 4	MG 5
$u\bar{u} \to e^+e^-$	[illegible]	[illegible]	[illegible]	[illegible]	$< 6\mu s$
$u\bar{u} \to e^+e^-e^+e^-$	48	62	32	0.22 ms	0.14 ms
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Test suite

Unit (= method) tests, Acceptance tests and Parallel tests

```
[alwall@alwall-laptop madgraph5] python tests/test_manager.py
...
Test a complete decay chain process gp>jg,j>jjj,j>jjj ... ok
Test a complete decay chain process pp>jj,j>jj with QED=2, QCD=2 ... ok
Test the functions for checking equal decay chains ... ok
Test the HelasMultiProcess with the processes uu~>uu~ ... ok
Setting up and testing pp > nj based on multiparticle lists, ... ok
Test decay chain with majorana particles e+e->n1n1 ... ok
Test a multistage decay g g > d d~, d > g d, d~ > g d~, g > u u~ g ... ok
Test error raising in HelasWavefunction __init__, get and set ... ok
Test filters for wavefunction properties ... ok
Test the color basis building for uu~ > aggg (3! elements) ... ok
Test the color flow decomposition of various color strings ... ok
Test the colorize function for uu~ > gg ... ok
Test the colorize function for uu~ > ggg ... ok
Test the Nc power restriction during color basis building ... ok
Test index fixing for immutable color string ... ok
----------------------------------------------------------------------
Ran 415 tests in 34.098s
```

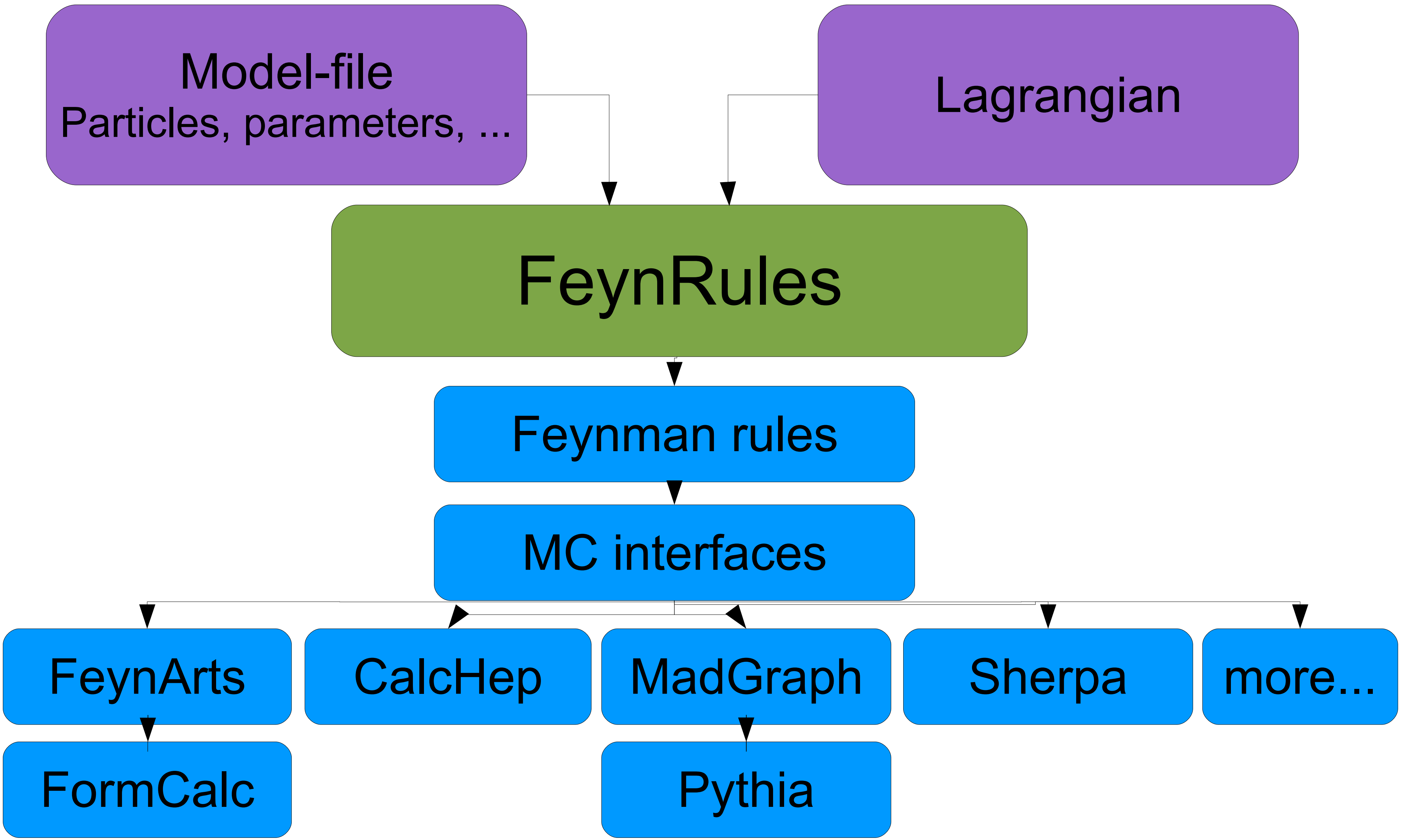
~30500 lines of tests, cf. ~29000 lines of code in MadGraph 5

The big news

- Automatic writing of HELAS routines for vertices with any Lorentz structure
- Effective vertices with any number of particles (including multi-fermion vertices)
- New color structures (color sextets and ε^{ijk})
- Checks to validate model implementations
- Output of C++ matrix elements for Pythia 8
- New, compact organization of subprocesses and integration channels in MadEvent
- Really user-friendly command line interface

Sidenote: FeynRules

[Christiansen, Duhr, arXiv:0806.4194]



Automatic HELAS routines

with P. de Aquino, C. Duhr, W. Link

- Universal FeynRules Output (UFO)
  - Includes color and Lorentz structure
  - Allows for complete specification of effective/non-renormalizable vertices
  - Allows for automatic output of model parameter calculations for any model and language
- Automatic Language-independent Output of Helicity Amplitudes (ALOHA)
  - Automatic generation the necessary helicity amplitude code for any new model (including effective theories, multi-fermion vertices,...) in Fortran/C++/Python/...

Universal FeynRules Output (UFO)

particles.py:

```
G = Particle(pdg_code = 21,
         name = 'G',
         antiname = 'G',
         spin = 3,
         color = 8,
         mass = 'ZERO',
         width = 'ZERO',
         texname = 'G',
         antitexname = 'G',
         line = 'curly',
         charge = 0,
         LeptonNumber = 0,
         GhostNumber = 0)
```

lorentz.py:

```
VVV1 = Lorentz(name = 'VVV1',
         spins = [ 3, 3, 3 ],
         Structure =
                 'P(3,1)*Metric(1,2) -
                 P(3,2)*Metric(1,2) -
                 P(2,1)*Metric(1,3) +
                 P(2,3)*Metric(1,3) +
                 P(1,2)*Metric(2,3) -
                 P(1,3)*Metric(2,3)')
```

couplings.py:

```
GC_4 = Coupling(name = 'GC_4',
         value = '-G',
         order = {'QCD':1})
```

vertices.py:

```
V_2 = Vertex(name = 'V_2',
         particles = [ P.G, P.G, P.G ],
         color = [ 'f(1,2,3)' ],
         lorentz = [ L.VVV1 ],
         couplings = {(0,0):C.GC_4})
```

ALOHA output

Fortran

```
      SUBROUTINE VVV1_0(V1,V2,V3,C,VERTEX)
      IMPLICIT NONE
      DOUBLE COMPLEX V1(6)
      DOUBLE COMPLEX V2(6)
      DOUBLE COMPLEX V3(6)
      DOUBLE COMPLEX C
      DOUBLE COMPLEX VERTEX
      DOUBLE PRECISION P2(0:3),P3(0:3),P1(0:3)

      P2(0) =  DBLE(V2(5))
      P2(1) =  DBLE(V2(6))
      P2(2) =  DIMAG(V2(6))
      P2(3) =  DIMAG(V2(5))
      P3(0) =  DBLE(V3(5))
      P3(1) =  DBLE(V3(6))
      P3(2) =  DIMAG(V3(6))
      P3(3) =  DIMAG(V3(5))
      P1(0) =  DBLE(V1(5))
      P1(1) =  DBLE(V1(6))
      P1(2) =  DIMAG(V1(6))
      P1(3) =  DIMAG(V1(5))

VERTEX = C*( (V3(1)*( (V1(1)*( (V2(2)*( (0, -1)*P1(1)+(0, 1)
     $ *P3(1)))+( (V2(3)*( (0, -1)*P1(2)+(0, 1)*P3(2)))+(V2(4)*( (0,
     $ -1)*P1(3)+(0, 1)*P3(3))))))+( (V2(1)*( (V1(2)*( (0, 1)*P2(1)
     $ +(0, -1)*P3(1)))+( (V1(3)*( (0, 1)*P2(2)+(0, -1)*P3(2)))
     $ +(V1(4)*( (0, 1)*P2(3)+(0, -1)*P3(3))))))+( (P1(0)*( (0, 1)
     $ *(V2(2)*V1(2))+(0, 1)*(V2(3)*V1(3))+(0, 1)*(V2(4)*V1(4))))
     ...
```

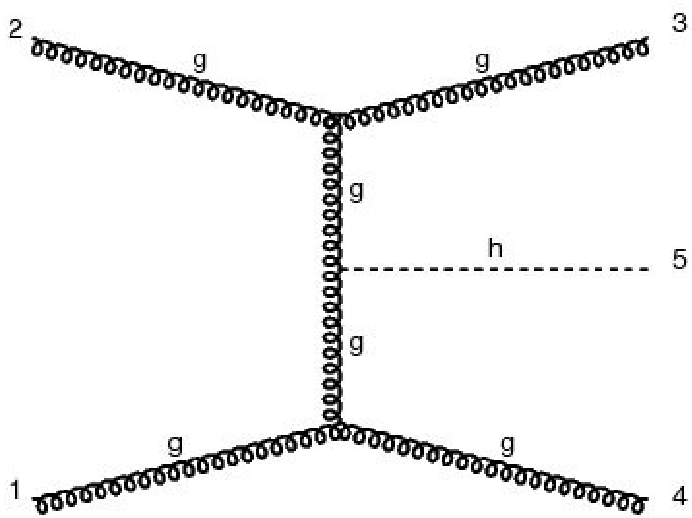
ALOHA output

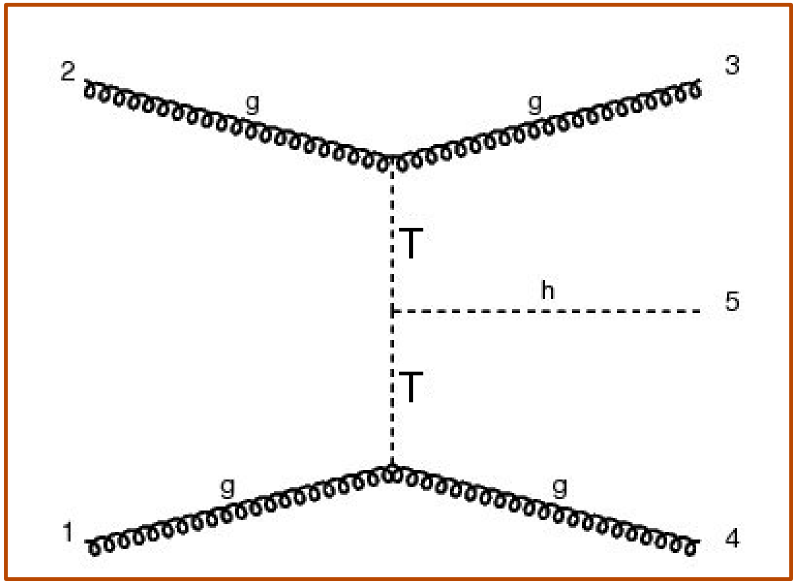
C++

```
void VVV1_0(complex<double> V1[], complex<double> V2[], complex<double> V3[],
   complex<double> C, complex<double> & vertex)
{
  double P2[4], P3[4], P1[4];
  P2[0] = V2[4].real();
  P2[1] = V2[5].real();
  P2[2] = V2[5].imag();
  P2[3] = V2[4].imag();
  P3[0] = V3[4].real();
  P3[1] = V3[5].real();
  P3[2] = V3[5].imag();
  P3[3] = V3[4].imag();
  P1[0] = V1[4].real();
  P1[1] = V1[5].real();
  P1[2] = V1[5].imag();
  P1[3] = V1[4].imag();
  vertex = C * ((V3[0] * ((V1[0] * ((V2[1] * (complex<double> (0., -1.) * P1[1]
     + complex<double> (0., 1.) * P3[1])) + ((V2[2] * (complex<double> (0.,
     -1.) * P1[2] + complex<double> (0., 1.) * P3[2])) + (V2[3] *
     (complex<double> (0., -1.) * P1[3] + complex<double> (0., 1.) *
     P3[3]))))) + ((V2[0] * ((V1[1] * (complex<double> (0., 1.) * P2[1] +
     complex<double> (0., -1.) * P3[1])) + ((V1[2] * (complex<double> (0., 1.)
     * P2[2] + complex<double> (0., -1.) * P3[2])) + (V1[3] * (complex<double>
     (0., 1.) * P2[3] + complex<double> (0., -1.) * P3[3]))))) + ((P1[0] *
     (complex<double> (0., 1.) * (V2[1] * V1[1]) + complex<double> (0., 1.) *
     (V2[2] * V1[2]) + complex<double> (0., 1.) * (V2[3] * V1[3]))) + (P2[0] *
     (complex<double> (0., -1.) * (V2[1] * V1[1]) + complex<double> (0., -1.)
     * (V2[2] * V1[2]) + complex<double> (0., -1.) * (V2[3] * V1[3])))))) +
     ...
```

Multi-particle vertices

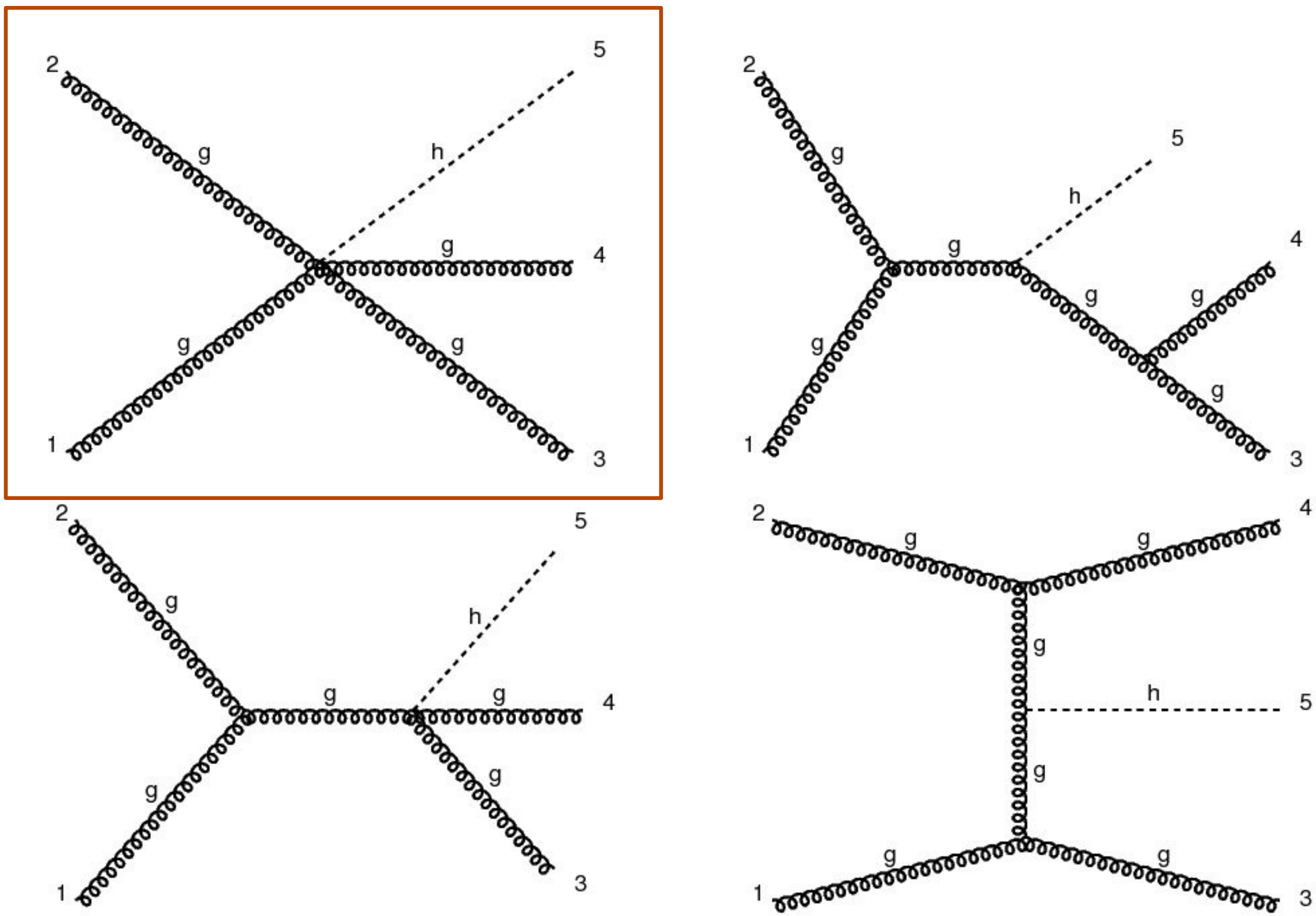
- Higgs effective couplings to gluons (through top loop)
  - From non-commutativity of QCD, get H + 2-, 3- and 4-gluon vertices
  - In MG4: 5-particle vertex handled by using non-propagating tensor particles





Effective multi-particle vertices

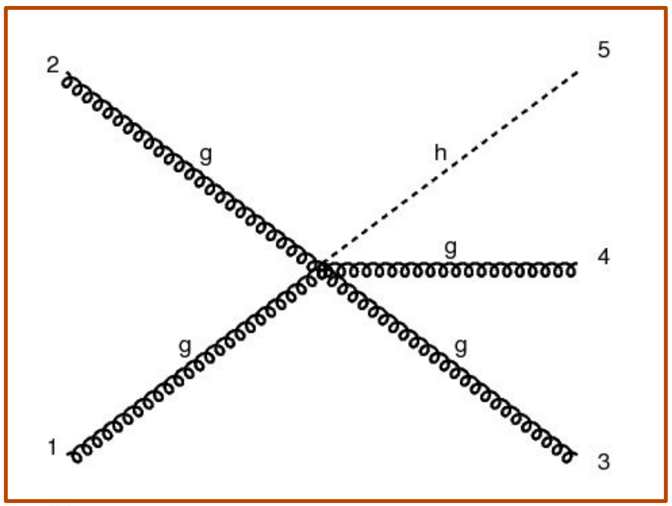
- In MG5: Use 5-particle vertex directly!

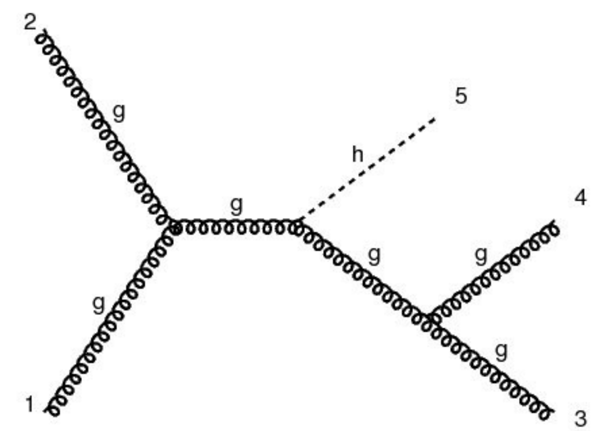


(Thoroughly tested against MG4)

Effective multi-particle vertices

- In MG5: Use 5-particle vertex directly!





lorentz.py

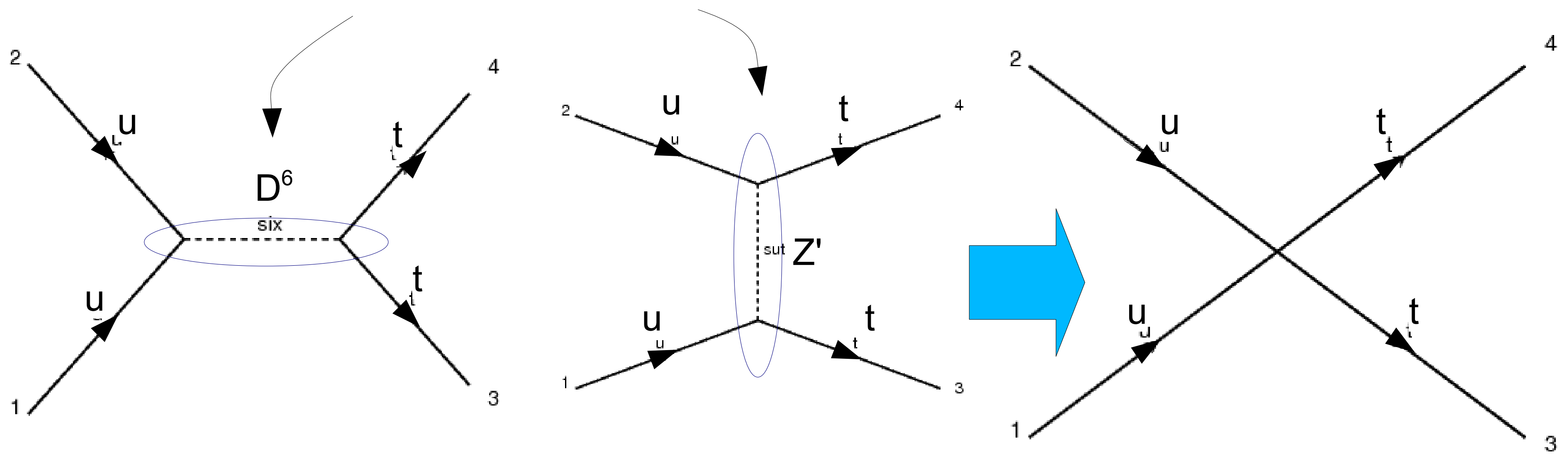
```
VVVVS1 = Lorentz(name = 'VVVVS1',
             spins = [ 3, 3, 3, 3, 1 ],
             structure = 'Metric(1,4)*Metric(2,3) - Metric(1,3)*Metric(2,4)')

VVVVS2 = Lorentz(name = 'VVVVS2',
             spins = [ 3, 3, 3, 3, 1 ],
             structure = 'Metric(1,4)*Metric(2,3) - Metric(1,2)*Metric(3,4)')

VVVVS3 = Lorentz(name = 'VVVVS3',
             spins = [ 3, 3, 3, 3, 1 ],
             structure = 'Metric(1,3)*Metric(2,4) - Metric(1,2)*Metric(3,4)')
```

Multi-fermion vertices

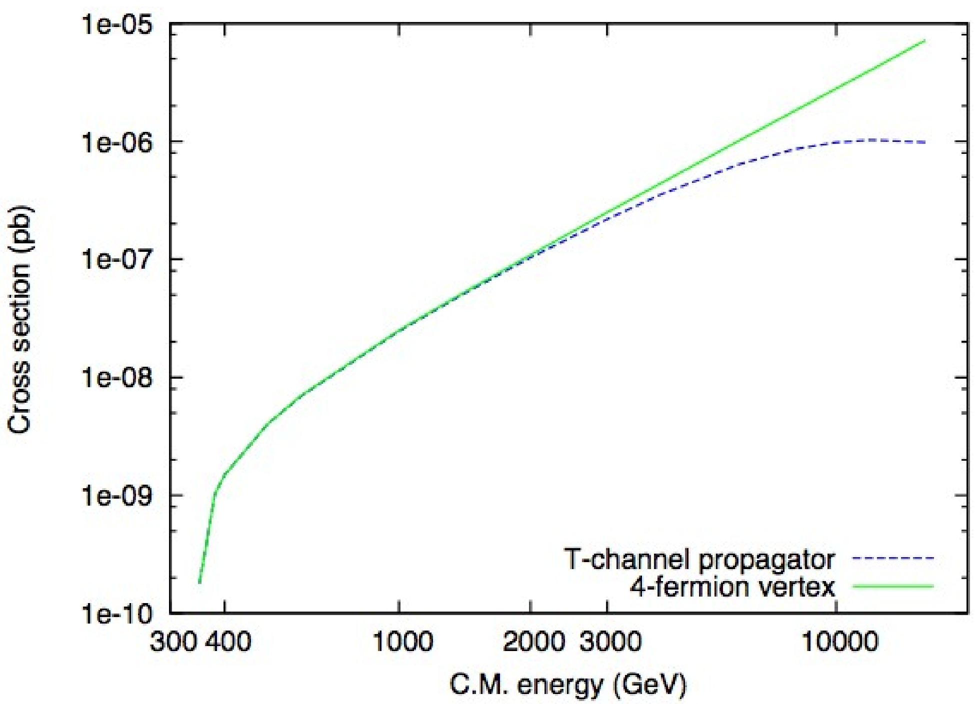
- Extra difficulty in multi-fermion vertices: Fermion flow
  - Using convention based on particle ordering as IOIOIO... (incoming-outgoing)
  - Example: $\bar{u}\ \bar{u}\ t\ t \neq \bar{u}\ t\ \bar{u}\ t$ (from MG point of view*)



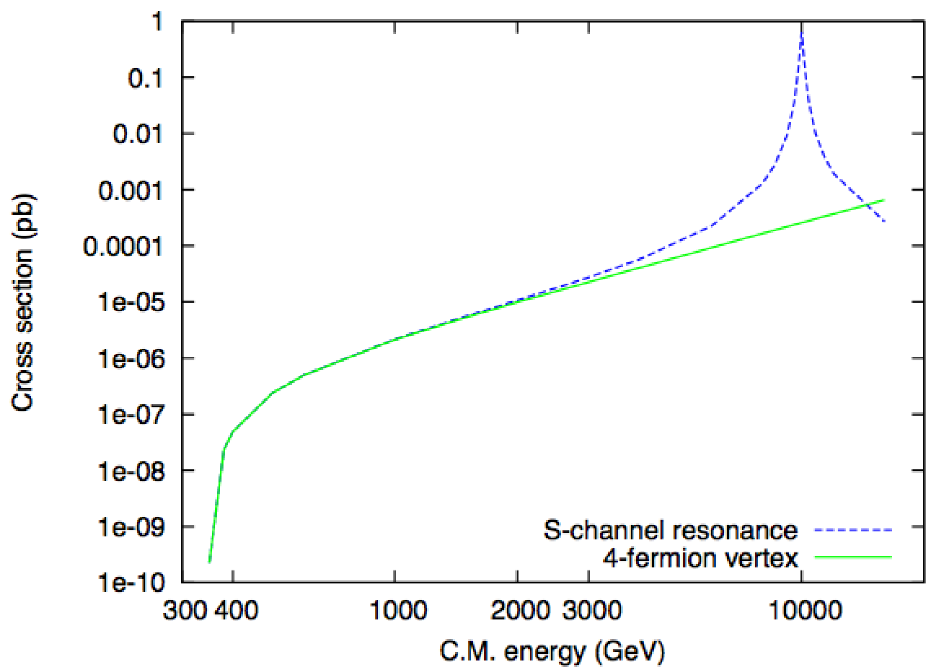
* Can interchange using Fierz identities

Multi-fermion vertices

Comparisons between explicit propagators and 4-fermion vertex



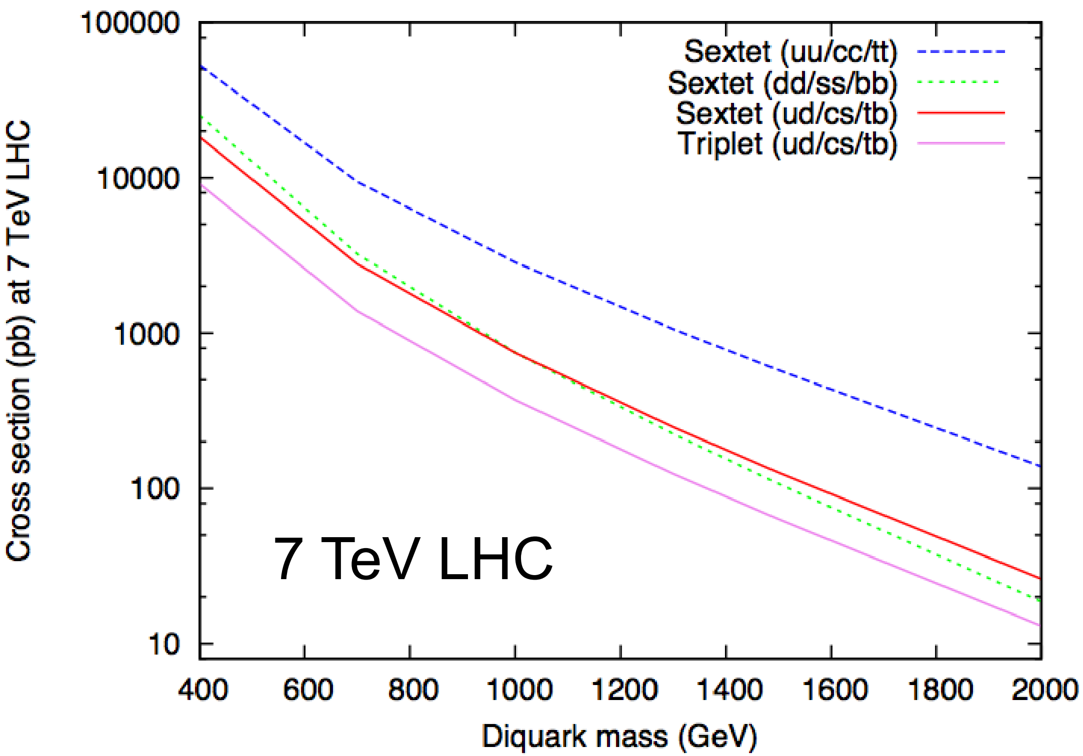
t-channel u u > t t



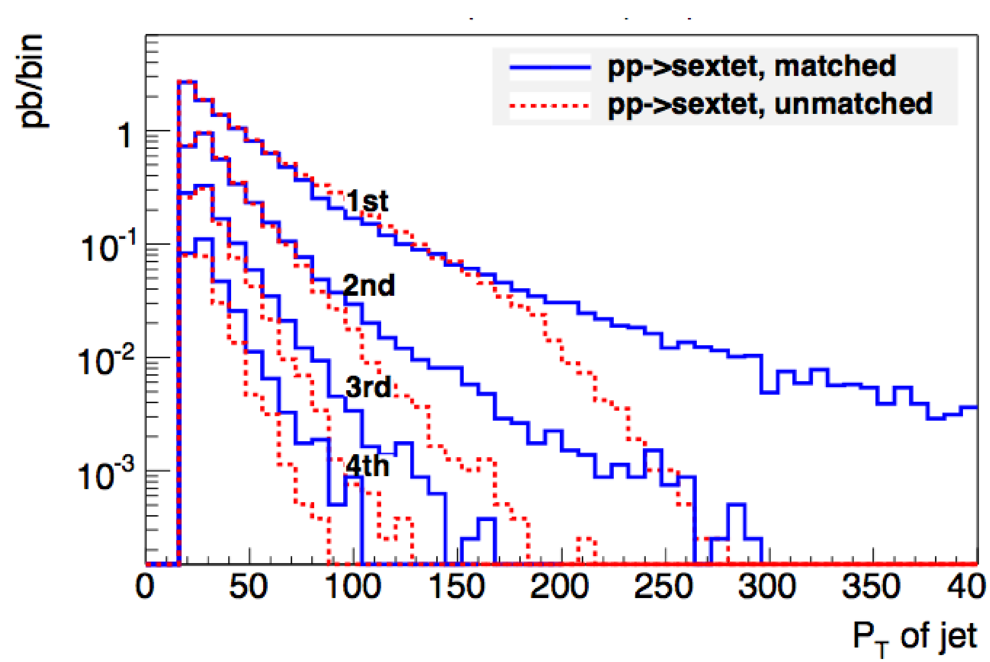
s-channel u u > t t

New color structures

- Implementation of diquark models q q > D
- Require 3 x 3 = 6 + $\bar{3}$, i.e. color sextet or ε^{ijk}
- Important also for RPV SUSY



Diquark cross sections with coupling 0.01



Jet p_T:s, fully matched
pp → D + 0,1,2 jets

Pythia 8 matrix elements

Sigma_sm_qq_ttx.h

- Automatic generation of Pythia 8 processes by MadGraph 5
- Creates process library of .h and .cc files in format used by Pythia, together with example main file
- Run as standard internal Pythia process
- Allows using Pythia for any (2→1,2,3) process in any model at the push of a key!

```
#include "SigmaProcess.h"
#include "Parameters_sm.h"
using namespace std;
namespace Pythia8
{
//==========================================
// A class for calculating the matrix elements for
// Process: u u~ > t t~ QED=0 @1
// Process: c c~ > t t~ QED=0 @1
// Process: d d~ > t t~ QED=0 @1
// Process: s s~ > t t~ QED=0 @1
//--------------------------------------------------------------------

class Sigma_sm_qq_ttx : public Sigma2Process
{  public:

   // Constructor.
   Sigma_sm_qq_ttx() {}
  // Initialize process.
   virtual void initProc();
   // Calculate flavour-independent parts of cross section.
   virtual void sigmaKin();
   // Evaluate sigmaHat(sHat).
   virtual double sigmaHat();
   // Select flavour, colour and anticolour.
   virtual void setIdColAcol();

...
```

Process	MG5-Pythia (mb)	Pythia (mb)	Rel. difference
g g > g g	5.92E-001	5.92E-001	0.0000
g g >q qbar	1.54E-002	1.55E-002	0.0036
g q > g q	3.22E-001	3.22E-001	0.0003
q qbar > g g	3.87E-004	3.85E-004	0.0018
q q > q q	3.24E-002	3.22E-002	0.0026
g g > b bbar	3.61E-003	3.59E-003	0.0026
(q q > b bbar	7.67E-005	7.90E-005	0.0149)
g g > t tbar	5.38E-007	5.38E-007	0.0003
q qbar > t tbar	8.15E-008	8.29E-008	0.0086
q b> t q' (t-channel)	1.97E-007	1.83E-007	0.0364
q qbar' > t b (s-channel)	8.71E-009	8.47E-009	0.0137
q g > q gamma	1.82E-004	1.82E-004	0.0008
q qbar > g gamma	1.26E-005	1.28E-005	0.0063
q qbar > gamma gamma	8.55E-008	8.58E-008	0.0019
g g > gluino gluino	4.55E-009	4.55E-009	0.0000
q qbar > gluino gluino	2.02E-010	2.03E-010	0.0037

MG5 multiparton processes

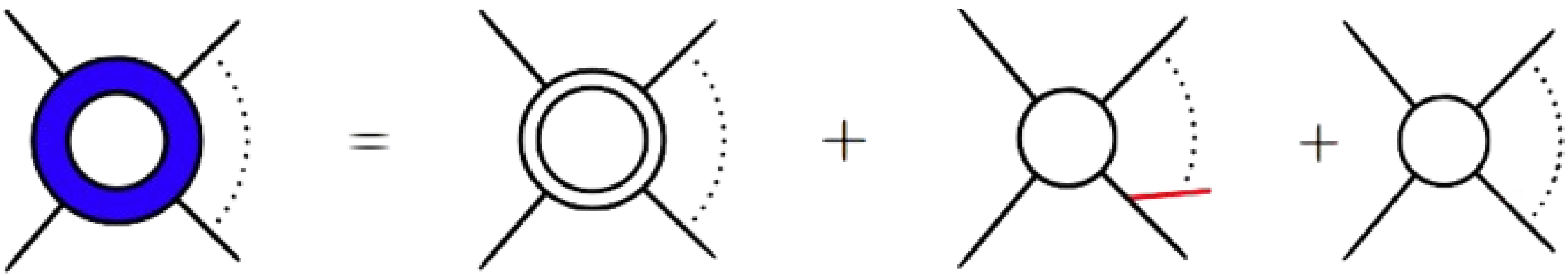
- New scheme for organizing MadEvent processes
  - Combine all processes and channels with same pole structures
  - p p → l^+l^- j j j: 5 subprocess directories, 368 integration channels (factor 11 fewer than MG/ME4)
    p p → W j j j j: factor 15 fewer channels than MG/ME4
  - Optimizations to phase space integration → reduced phase space integration time by factor 3
- Ongoing: Multi-parton matrix element evaluation by recursion relations
  - Should allow up to W/Z+6 jets
  - Challenge: MadEvent-style phase space integration

MG5 multiparton processes

Process	Subprocess directories		Channels for survey		Directory size	
	ME 4	ME 5	ME 4	ME 5	ME 4	ME 5
$pp \to W^+j$	6	2	12	4	79 MB	35 MB
$pp \to W^+jj$	41	4	138	29	438 MB	64 MB
$pp \to W^+jjj$	73	5	1164	184	842 MB	110 MB
$pp \to W^+jjjj$	296	7	15029	1327	3.8 GB	352 MB
$pp \to l^+l^-j$	12	2	48	8	149 MB	44 MB
$pp \to l^+l^-jj$	54	4	586	58	612 MB	83 MB
$pp \to l^+l^-jjj$	86	5	5408	368	1.2 GB	151 MB
$pp \to l^+l^-jjjj$	235	7	63114	2500	5.3 GB	662MB
$pp \to t\bar{t}$	3	2	5	4	49 MB	39 MB
$pp \to t\bar{t}j$	7	3	45	25	97 MB	56 MB
$pp \to t\bar{t}jj$	22	5	417	188	274 MB	98 MB
$pp \to t\bar{t}jjj$	34	6	3816	1300	620 MB	209 MB

MadGraph@NLO

NLO | Virtual | Real | Born



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

MadGraph@NLO

[Frederix, Gehrmann, Greiner;
Frederix, Frixione, Maltoni, Stelzer]

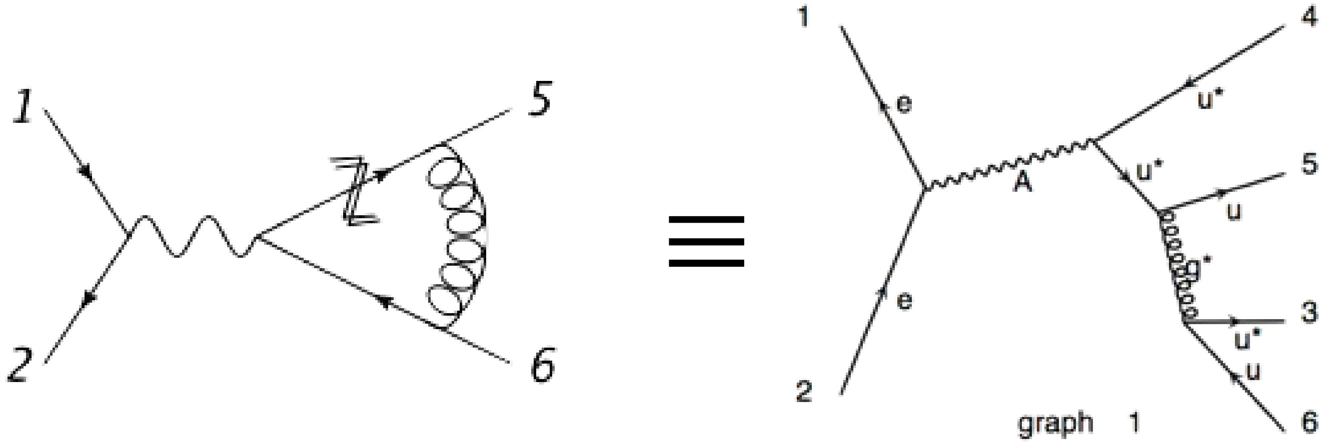
- Real contributions:
  - MadDipole: Catani-Seymour dipole substraction scheme, including integrated dipoles
  - MadFKS: Frixione-Kunszt-Signer substraction scheme (used for MC@NLO and POWHEG implementations). Including phase space integration for complete NLO calculation (with loop corrections from any package through Binoth-LH accord)
- Both: Handles both SM and BSM processes, and massless and massive external particles

MadGraph@NLO

- MadNLO virtuals

[Hirschi, Frederix, Frixione, Garzelli, Maltoni, Pittau arXiv:1103.0621]

  - Uses MadGraph to generate amplitudes for n+2 process, build loop amplitude using CutTools (OPP technique, by Ossola, Papadopoulos, Pittau)
  - Any SM process already possible, NLO for any BSM model in principle possible (see next point)
  - Work to automatize generation of necessary “R2” and UV counter terms for any model yet to be started



MadGraph@NLO

	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

[Hirschi, Frederix, Frixione, Garzelli, Maltoni, Pittau arXiv:1103.0621]

MadGraph@NLO

- Automatic MC@NLO [Frederix, Frixione, Torrielli]
  - Inclusion of counterterms for parton shower allows automatization of MC@NLO within the MadFKS framework
  - Work recently started, very promising results so far
- Move to MadGraph 5 [J.A., Frederix, Hirschi, Zaro]
  - Work started March 2011 (JA + V. Hirschi)
  - Huge optimizations, more straightforward implementations
  - Take advantage of upcoming improvements in matrix element speed (recursion relations)
  - Improved/facilitated organization of produced code
  - Full BSM functionality of MG5

FAQ

- "Do I need to learn Python now?"
  - Not unless you want to make additions to the core code of MadGraph. The standard MadGraph output is still Fortran (or C++), and MadEvent works as before.
- "Can I use jet matching with my favorite new physics model?"
  - Yes you can! Matching between MadEvent and Pythia works as before, for any model.
- "Can I use my old MadGraph models with MG5?"
  - Yes you can! MadGraph 5 is fully backward compatible for both models and cards.

FAQ (cont.)

- "Will there be a MadEvent in Python?"
  - No, MadEvent stays Fortran, but is continuously developed to make optimal use of new functionality of MadGraph 5.
- "Where can I get all this amazing stuff?"
  - At https://launchpad.net/madgraph5
    (or simply google for MadGraph 5)
  - Release (as tar ball) and development code (using the Bazaar versioning system)

Conclusions

- MadGraph 5 is now a full-fledged replacement for older MadGraph versions, with important and unprecedented improvements in all directions.
- MadGraph 5 v. 0.7 available, 1.0.0 (including new MadEvent) released in the coming days
- Stay tuned for more exciting stuff in the near future (more NLO, fast multijet, BSM decay package, FeynRules developments, …)

Don't miss upcoming MadGraph developer workshop at Fermilab (May 3-6, 2011)

Backup slides

Process checks

Suite of powerful checks on internal consistency of model implementation (including UFO/ALOHA/MG5) internally in MG5

- Generation of ME using multiple different orders of the wavefunction calls
- Gauge invariance for massless vector bosons
- Lorentz boost invariance of ME

Decay chains

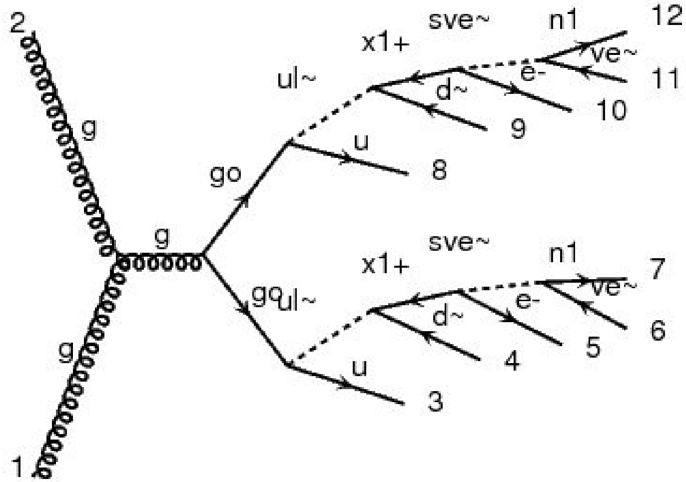


diagram 1

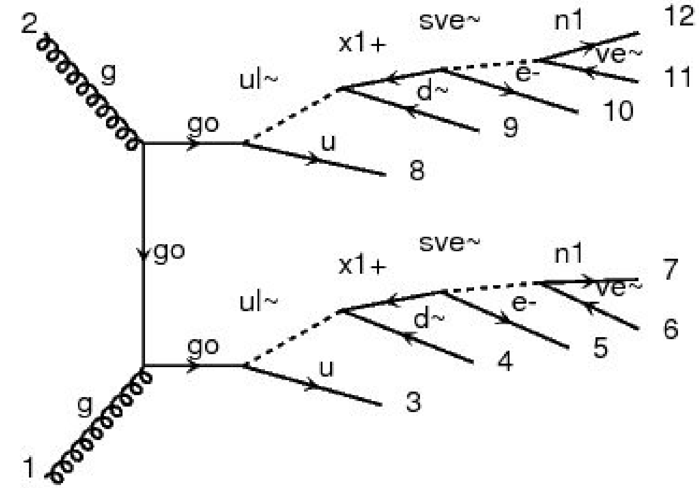


diagram 2

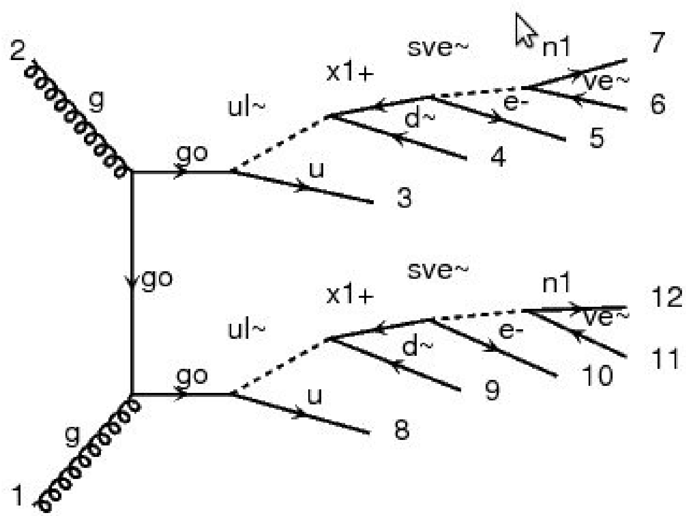


diagram 3

Process: g g > go go
  Decay: go > u ul~
    Decay: ul~ > d~ x1-
      Decay: x1- > e- sve~
        Decay: sve~ > ve~ n1
  Decay: go > u ul~
    Decay: ul~ > d~ x1-
      Decay: x1- > e- sve~
        Decay: sve~ > ve~ n1
(10 FS particles. Generation time: 5 s)