LHC Phenomenology with Madgraph

Tutorials

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Standard Model

- **Good News! $SU(3)xSU_L(2)xU(1)$**
  - Most successful theory in physics!
  - Tested over 30 orders of magnitude!
    - (photon mass < 10^{-18} eV , Tevatron > 10^{12} eV)

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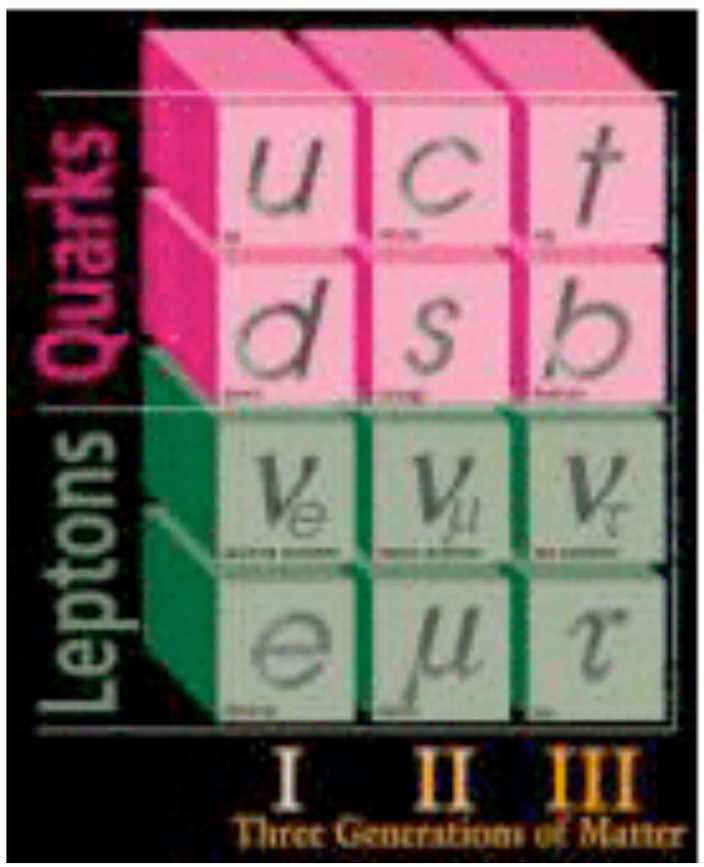

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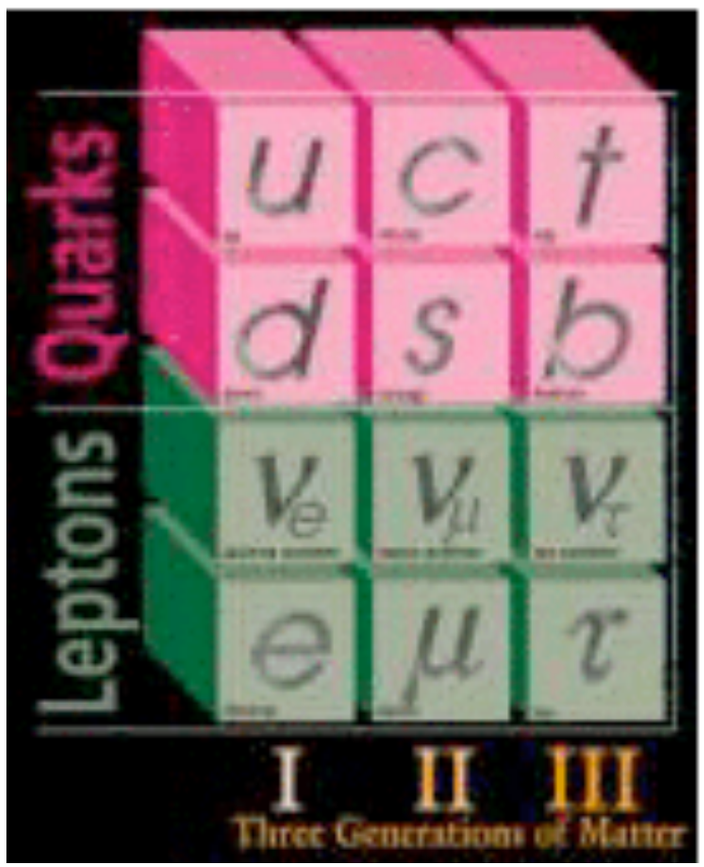

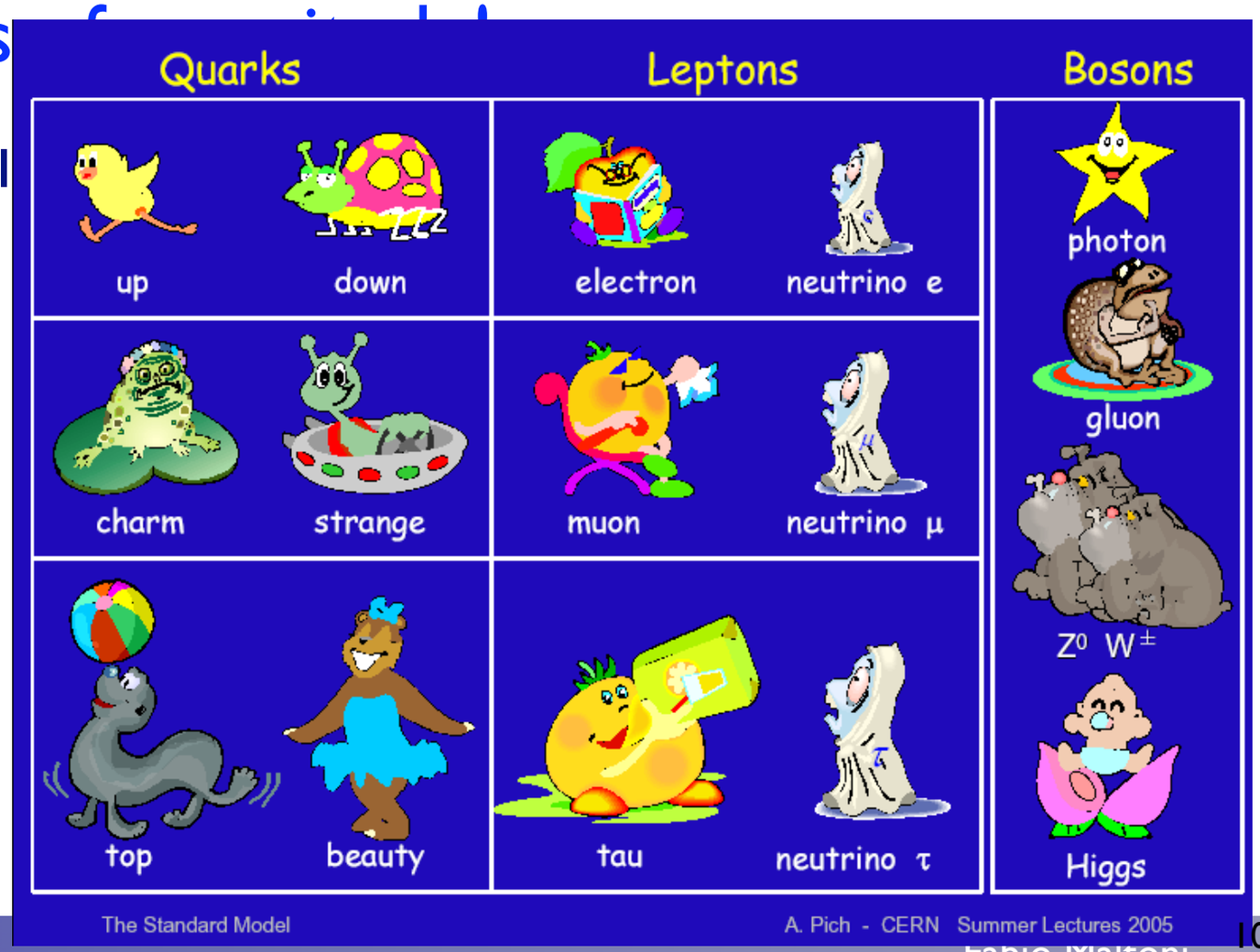

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$$\mathcal{L}_{\mathrm{QCD}} = -\frac{1}{2}\,\mathrm{Tr}\left(\mathbf{G}^{\mu\nu}\,\mathbf{G}_{\mu\nu}\right) + \bar{\mathbf{q}}\left[i\,\gamma^{\mu}\,\mathbf{D}_{\mu} - m_q\right]\mathbf{q}$$

$$= -\frac{1}{4}\left(\partial^{\mu}G_a^{\nu} - \partial^{\nu}G_a^{\mu}\right)\left(\partial_{\mu}G_{\nu}^{a} - \partial_{\nu}G_{\mu}^{a}\right) + \sum_q \bar{q}_{\alpha}\left[i\,\gamma^{\mu}\partial_{\mu} - m_q\right]q_{\alpha}$$

$$+ \frac{1}{2}\sum_q g_s\left[\bar{q}_{\alpha}\,(\lambda^{a})_{\alpha\beta}\,\gamma^{\mu}q_{\beta}\right]G_{\mu}^{a}$$

$$- \frac{1}{2}\,g_s\,f_{abc}\,(\partial_{\mu}G_{\nu}^{a} - \partial_{\nu}G_{\mu}^{a})\,G_b^{\mu}\,G_c^{\nu} - \frac{1}{4}\,g_s^{2}\,f_{abc}\,f_{ade}\,G_b^{\mu}\,G_c^{\nu}\,G_{\mu}^{d}\,G$$

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$$\mathcal{L}_{QCD} = -\frac{1}{2}\mathrm{Tr}\left(\mathbf{G}^{\mu\nu}\,\mathbf{G}\right)$$

$$= -\frac{1}{4}\left(\partial^{\mu}G^{\nu}_{a} - \partial^{\nu}G^{\mu}_{a}\right)\left(\partial_{\mu}G^{}_{\nu}\right.$$

$$+ \frac{1}{2}\sum_{q} g_s\,\left[\overline{q}_{\alpha}\,(\lambda^{a})_{\alpha\beta}\,\gamma^{\mu}q_{\beta}\right]$$

$$- \frac{1}{2}g_s\,f_{abc}\,(\partial_{\mu}G^{a}_{\nu} - \partial_{\nu}G^{a}_{\mu})$$

$$\mathbf{W}_{\mu\nu} \equiv \frac{i}{g}\left[\mathbf{D}_{\mu},\mathbf{D}_{\nu}\right] \equiv \frac{\vec{\sigma}}{2}\cdot\vec{W}_{\mu\nu} \;\rightarrow\; \mathbf{U}_{\mathrm{L}}\,\mathbf{W}_{\mu\nu}\,\mathbf{U}_{\mathrm{L}}^{\dagger} \qquad ; \qquad B_{\mu\nu} \equiv \partial_{\mu}B_{\nu} - \partial_{\nu}B_{\mu} \;\rightarrow\; B_{\mu\nu}$$

$$W^{i}_{\mu\nu} = \partial_{\mu}W^{i}_{\nu} - \partial_{\nu}W^{i}_{\mu} + g\,\varepsilon^{ijk}\,W^{j}_{\mu}W^{k}_{\nu}$$

$$\mathcal{L}_{K} = -\frac{1}{4}B_{\mu\nu}\,B^{\mu\nu} - \frac{1}{2}\mathrm{Tr}\left(\mathbf{W}_{\mu\nu}\,\mathbf{W}^{\mu\nu}\right) = -\frac{1}{4}B_{\mu\nu}\,B^{\mu\nu} - \frac{1}{4}\vec{W}_{\mu\nu}\,\vec{W}_{\mu\nu} = \mathcal{L}_{\mathrm{kin}} + \mathcal{L}_{3} + \mathcal{L}_{4}$$

$$\mathcal{L}_{3} = -ie\cot\theta_{W}\left\{\left(\partial^{\mu}W^{\nu} - \partial^{\nu}W^{\mu}\right)W^{\dagger}_{\mu}Z_{\nu} - \left(\partial^{\mu}W^{\nu\dagger} - \partial^{\nu}W^{\mu\dagger}\right)W_{\mu}Z_{\nu} + W_{\mu}W^{\dagger}_{\nu}\left(\partial^{\mu}Z^{\nu} - \partial^{\nu}Z^{\mu}\right)\right\}$$

$$-ie\left\{\left(\partial^{\mu}W^{\nu} - \partial^{\nu}W^{\mu}\right)W^{\dagger}_{\mu}A_{\nu} - \left(\partial^{\mu}W^{\nu\dagger} - \partial^{\nu}W^{\mu\dagger}\right)W_{\mu}A_{\nu} + W_{\mu}W^{\dagger}_{\nu}\left(\partial^{\mu}A^{\nu} - \partial^{\nu}A^{\mu}\right)\right\}$$

$$\mathcal{L}_{4} = -\frac{e^{2}}{2\sin^{2}\theta_{W}}\left\{\left(W^{\dagger}_{\mu}W^{\mu}\right)^{2} - W^{\dagger}_{\mu}W^{\mu\dagger}W_{\nu}W^{\nu}\right\} - e^{2}\cot^{2}\theta_{W}\left\{W^{\dagger}_{\mu}W^{\mu}Z_{\nu}Z^{\nu} - W^{\dagger}_{\mu}Z^{\mu}W_{\nu}Z^{\nu}\right\}$$

$$-e^{2}\cot\theta_{W}\left\{2W^{\dagger}_{\mu}W^{\mu}Z_{\nu}A^{\nu} - W^{\dagger}_{\mu}Z^{\mu}W_{\nu}A^{\nu} - W^{\dagger}_{\mu}A^{\mu}W_{\nu}Z^{\nu}\right\} - e^{2}\left\{W^{\dagger}_{\mu}W^{\mu}A_{\nu}A^{\nu} - W^{\dagger}_{\mu}A^{\mu}W_{\nu}A^{\nu}\right\}$$

Predictions from SM

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- Cross Section:

$$\sigma = \frac{1}{2s}\int |M|^2 \, d\Phi$$

$$M = \left\langle \mu^+\mu^- \left| T\left(e^{-i\int H_I dt}\right) e^+e^- \right\rangle \right.$$

  - Can't solve exactly because interactions change wave functions!

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$$M \approx \left\langle \mu^+\mu^- \left| H_{\text{int}} \right| e^+e^- \right\rangle + \frac{1}{2}\left\langle \mu^+\mu^- \left| H_{\text{int}}^2 \right| e^+e^- \right\rangle + \ldots$$

Example: $e^+e^- \rightarrow \mu^+\mu^-$

- Scattering cross section

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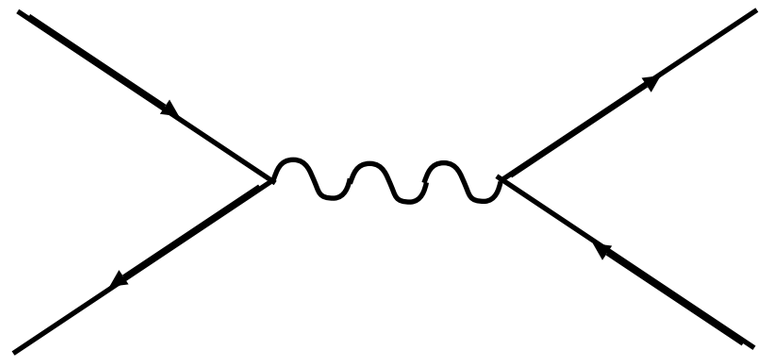

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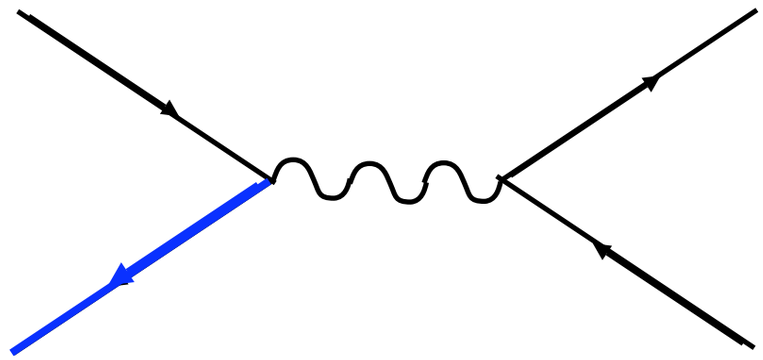

$$M \approx \overline{v}(e^+)$$

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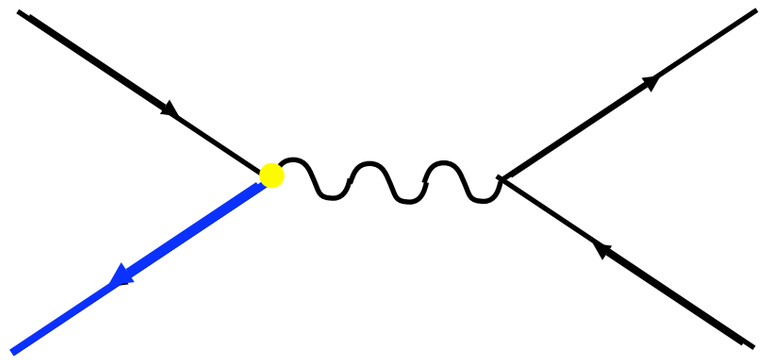

$$M \approx \bar{v}(e^+)\ (-iq\gamma^{\mu})$$

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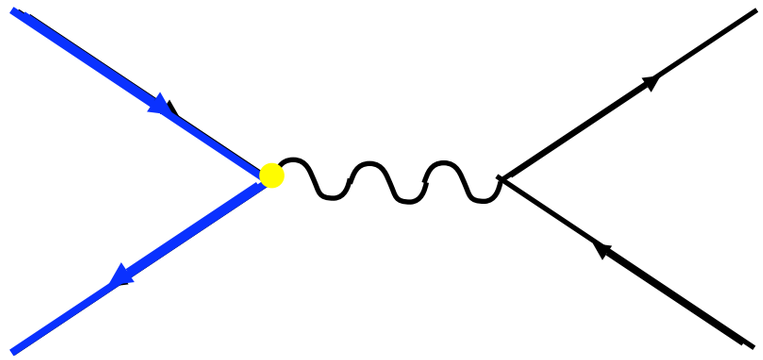

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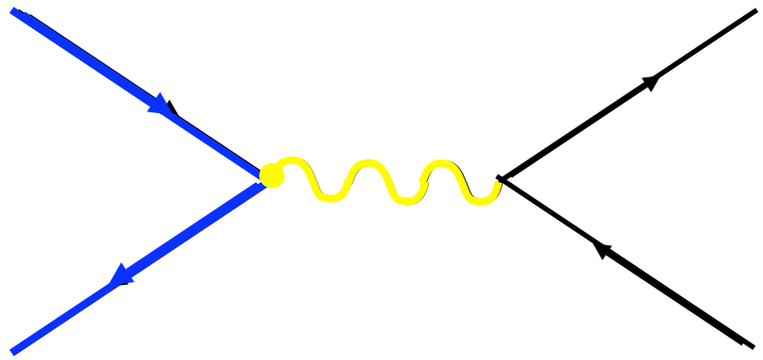

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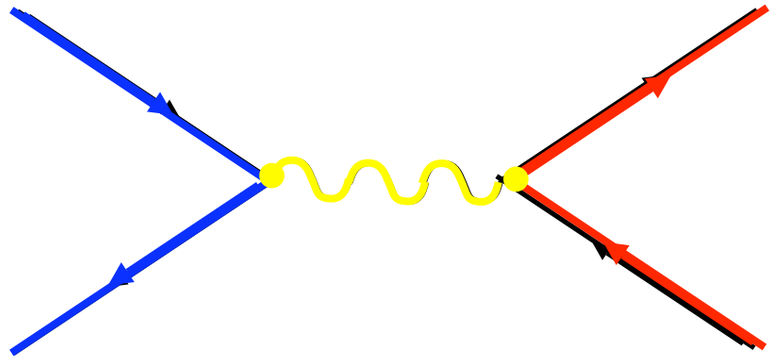

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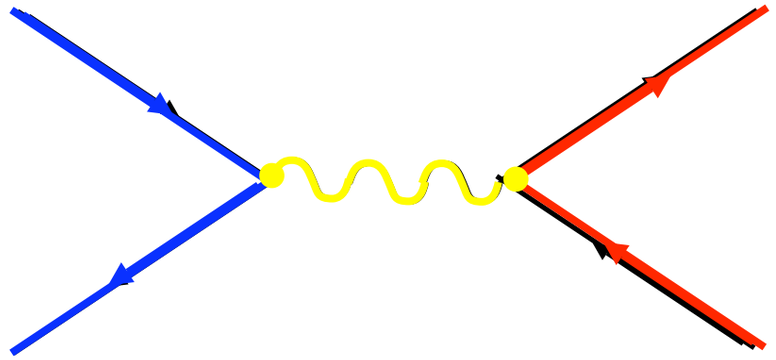

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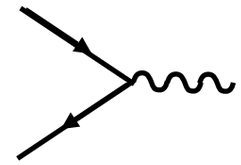
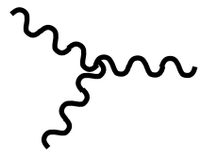
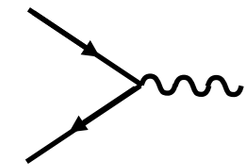
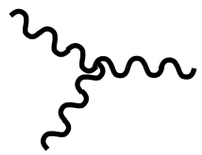
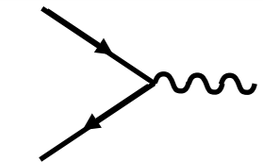
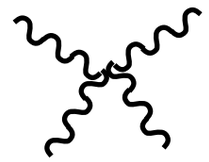
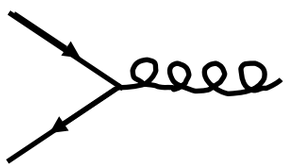
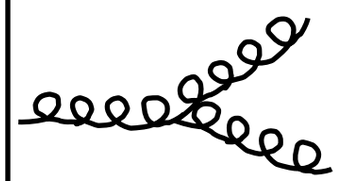
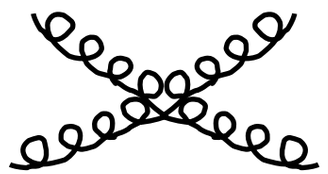
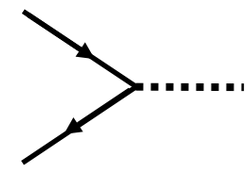
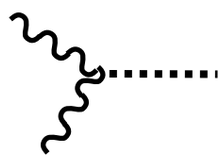
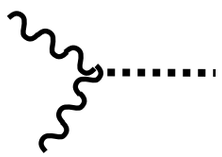
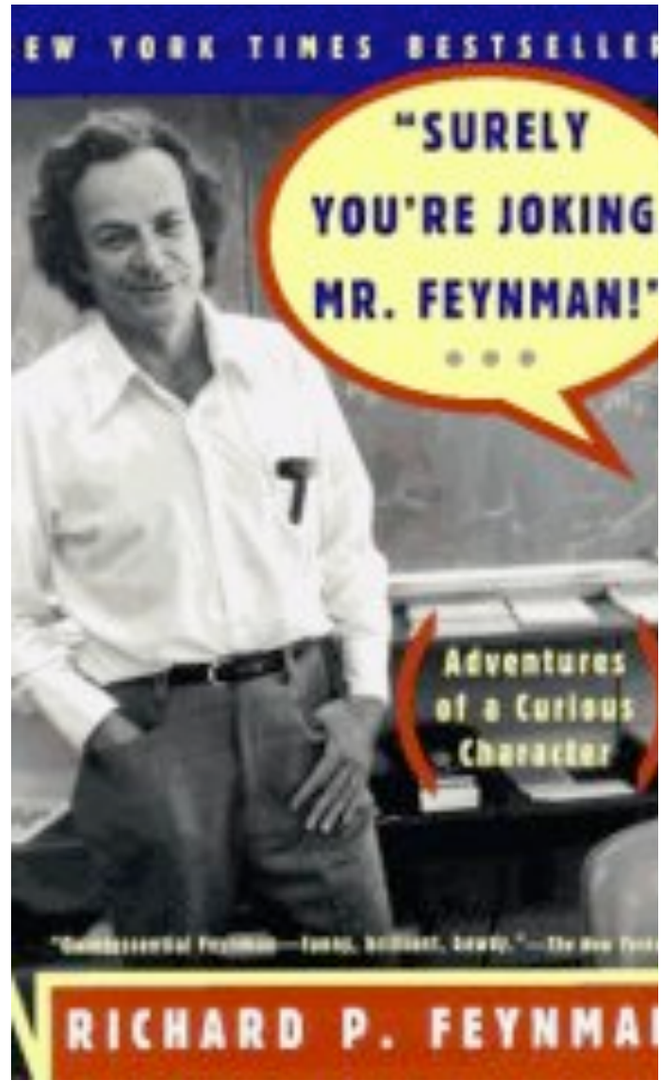
Feynman Rules!

γ	**QED**	 $q\bar{q}\gamma \quad l^-l^+\gamma$	 $W^+W^-\gamma$	
Z	**QED**	 $q\bar{q}Z \quad l\bar{l}Z$	 W^+W^-Z	
W+-	**QED**	 $q\bar{q}'W \quad l\nu W$		 $WWWW$
g	**QCD**	 $q\bar{q}g$	 ggg	 $gggg$
h	**QED (m)**	 $q\bar{q}h \quad l\bar{l}h$	 W^+W^-h	 ZZh



Partial list from SM

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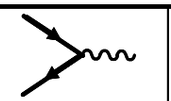
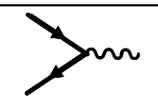
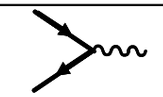
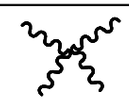
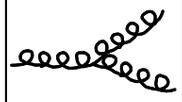
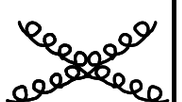
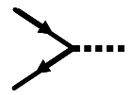
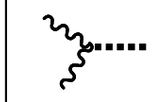
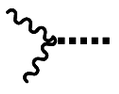
γ ∿∿	**QED**	 $q\bar{q}\gamma$ $l^-l^+\gamma$	 $W^+W^-\gamma$	
Z ∿∿	**QED**	 $q\bar{q}Z$ $l\bar{l}Z$	 W^+W^-Z	
W ∿∿	**QED**	 $q\bar{q}'W$ $l\nu W$		 $WWWW$
g ∿∿	**QCD**	 $q\bar{q}g$	 ggg	 $gggg$
h ·····	**QED (m)**	 $q\bar{q}h$ $l\bar{l}h$	 W^+W^-h	 ZZh

Feynman Rules!

- These are basic building blocks, combine to form "allowed" diagrams
  - e.g. u u~ > t t~

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g ∿∿	**QCD**	$q\bar{q}g$	ggg	$gggg$
h ·····	**QED (m)**	$q\bar{q}h$ $l\bar{l}h$	W^+W^-h	ZZh

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g ∿∿	**QCD**	$q\bar{q}g$	ggg	$gggg$
h ·····	**QED (m)**	$q\bar{q}h$ $l\bar{l}h$	W^+W^-h	ZZh

Feynman Rules!

- These are basic building blocks, combine to form "allowed" diagrams
  - e.g. u u~ > t t~

γ ∿∿	**QED**	$q\bar{q}\gamma$ $l^-l^+\gamma$	$W^+W^-\gamma$	
Z ∿∿	**QED**	$q\bar{q}Z$ $l\bar{l}Z$	W^+W^-Z	
W ∿∿	**QED**	$q\bar{q}'W$ $l\nu W$		$WWWW$
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- Determine "order" for each diagram

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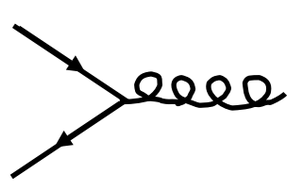

γ	QED	$q\bar{q}\gamma$ $l^-l^+\gamma$	$W^+W^-\gamma$	
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W	QED	$q\bar{q}'W$ $l\nu W$		$WWWW$
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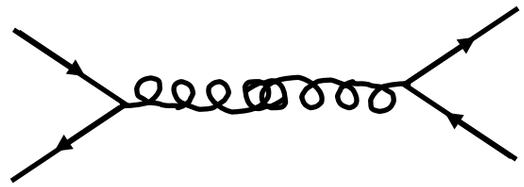

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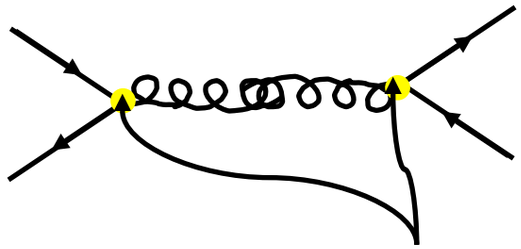

Order is QCD^2

γ ~~~	QED	$q\bar{q}\gamma$ $l^-l^+\gamma$	$W^+W^-\gamma$	
Z ~~~	QED	$q\bar{q}Z$ $l\bar{l}Z$	W^+W^-Z	
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- Draw Feynman diagrams:
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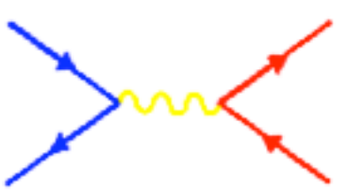
MadGraph on the Web

This material is based upon work supported by the National Science Foundation under Grant No. 0426272.
Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation

http://madgraph.hep.uiuc.edu/

http://madgraph.phys.ucl.ac.be/

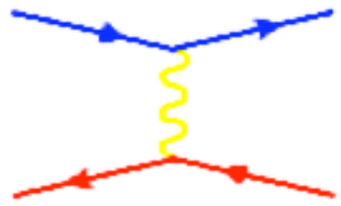
http://madgraph.roma2.infn.it/



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

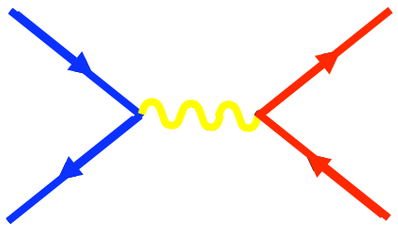
Three medium size clusters public access (+private clusters). ~1500 registered users.

Showroom

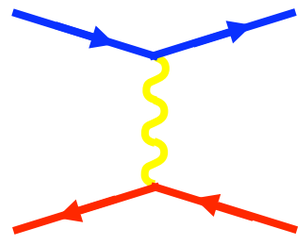
Movie 1

Movie 2

http://madgraph.uiuc.edu



MadGraph



MadGraph

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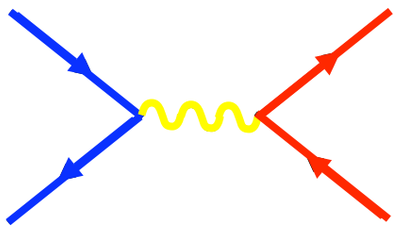

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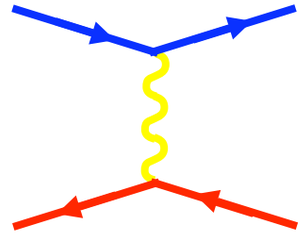

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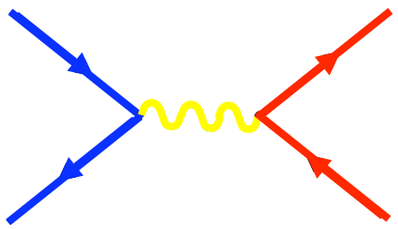

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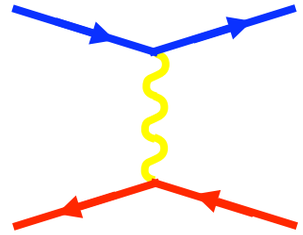

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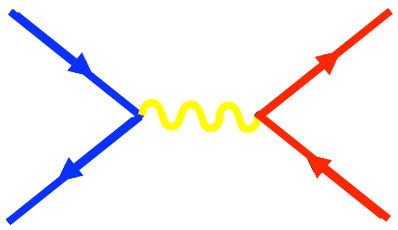

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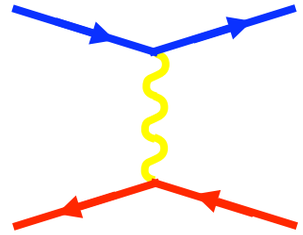

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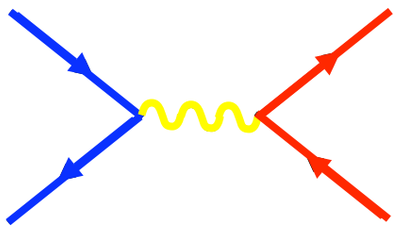

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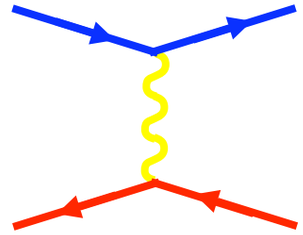

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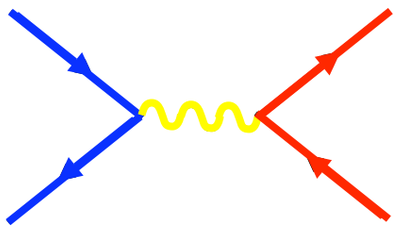

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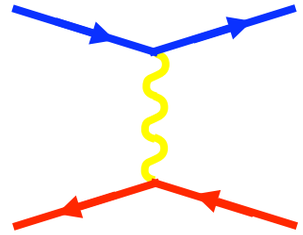

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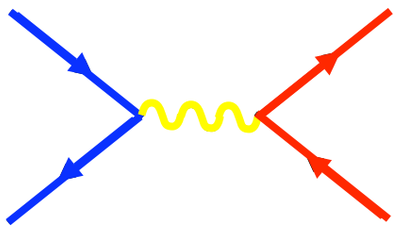
  - Self-Contained Fortran Code for |M|^2



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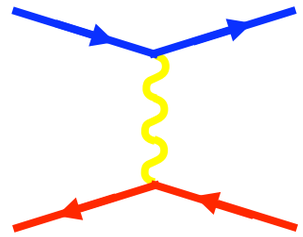

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```
 SUBROUTINE SMATRIX(P1,ANS)
C
C Generated by MadGraph II Version 3.83. Updated 06/13/05
C RETURNS AMPLITUDE SQUARED SUMMED/AVG OVER COLORS
C AND HELICITIES
C FOR THE POINT IN PHASE SPACE P(0:3,NEXTERNAL)
C
C FOR PROCESS : g g -> t t~ b b~
C
C Crossing   1 is g g -> t t~ b b~
      IMPLICIT NONE
C
C CONSTANTS
C
      Include "genps.inc"
      INTEGER              NCOMB,     NCROSS
      PARAMETER (          NCOMB=  64, NCROSS=  1)
      INTEGER    THEL
      PARAMETER (THEL=NCOMB*NCROSS)
C
C ARGUMENTS
C
      REAL*8 P1(0:3,NEXTERNAL),ANS(NCROSS)
C
```

- MadGraph Returns:
  - Feynman diagrams
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How do I generate the diagrams?

How do I generate the diagrams?

1. Generate the topologies

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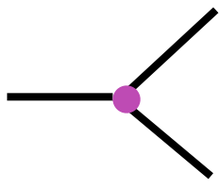

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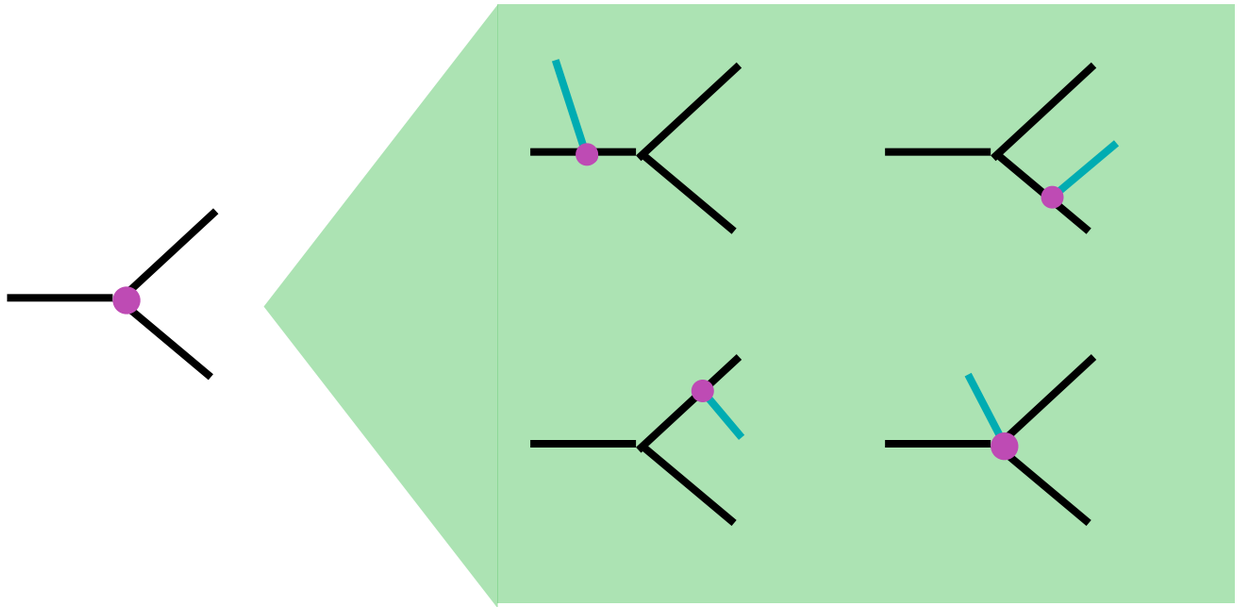

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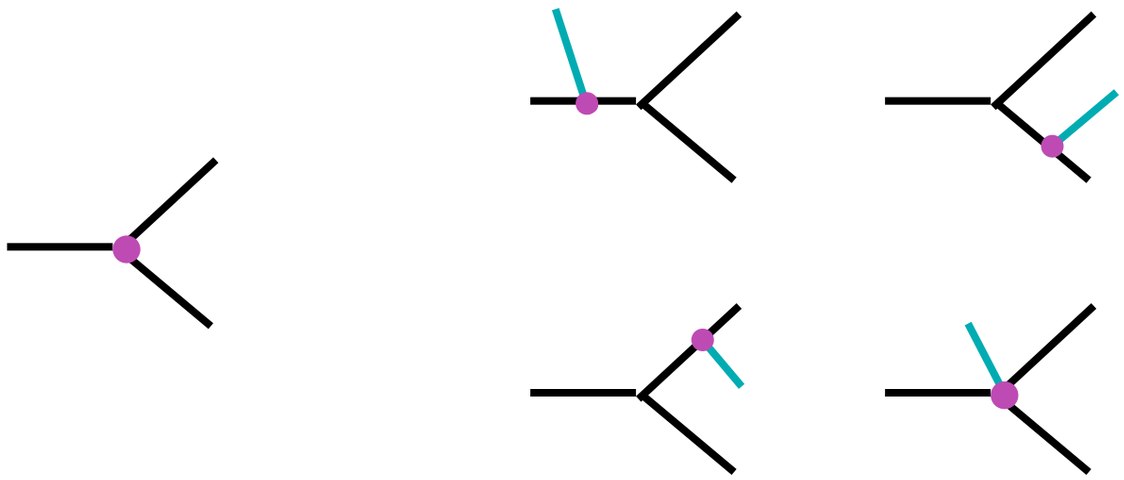

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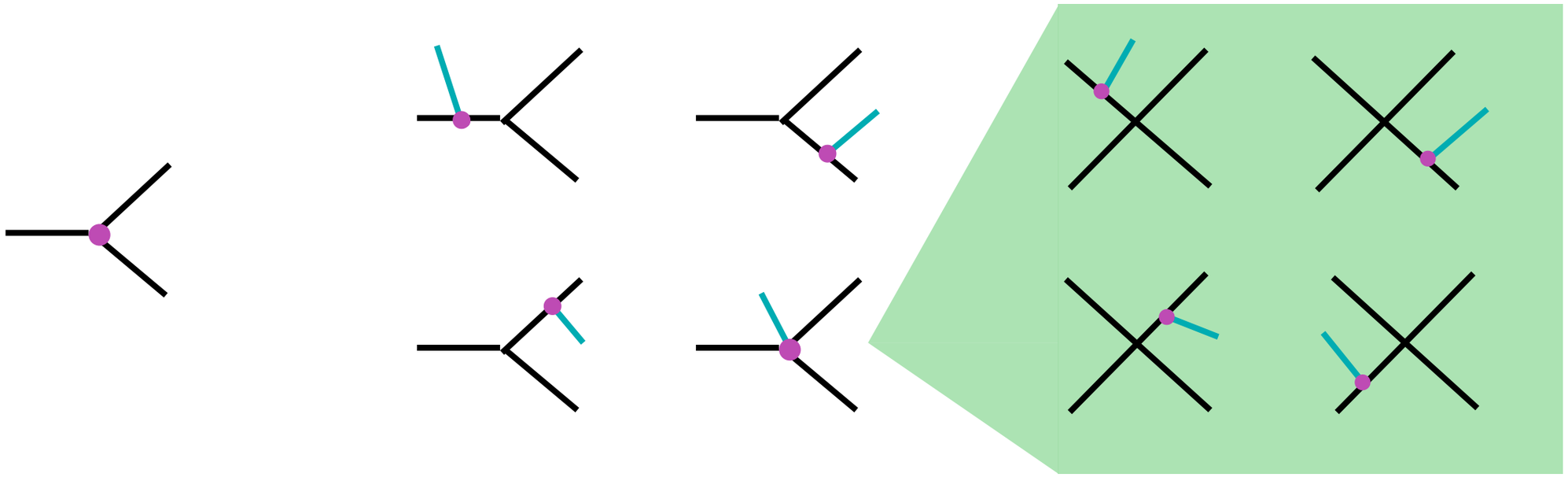

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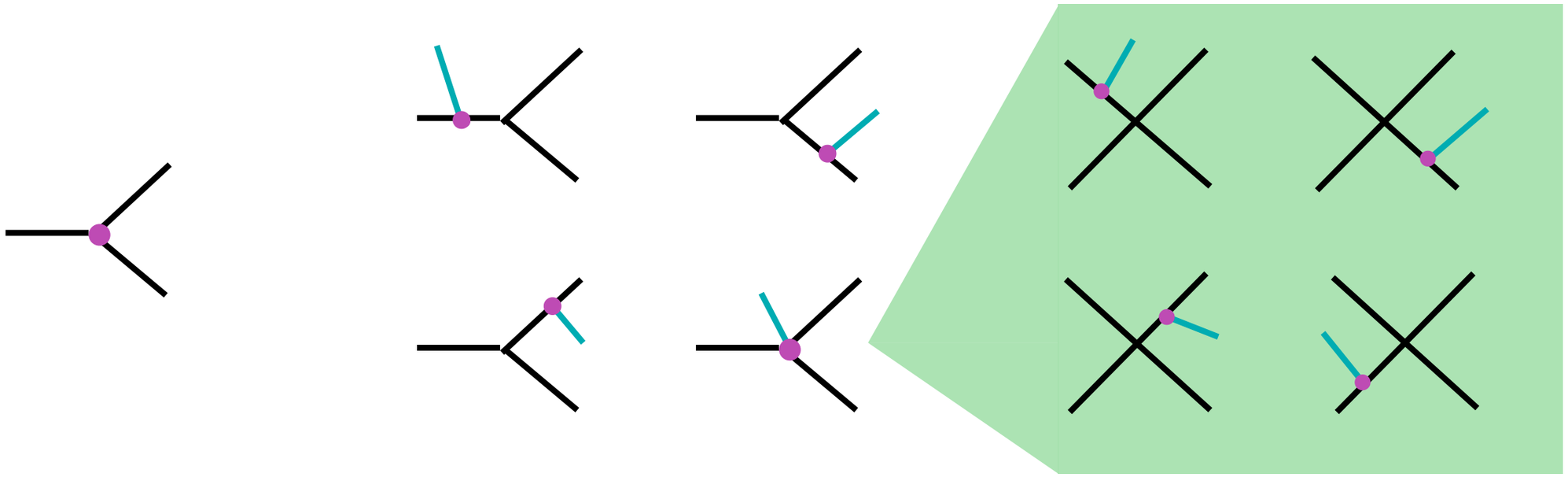

2. Dress the topologies with particles starting from the external particles and checking the existence of the corresponding verteces.

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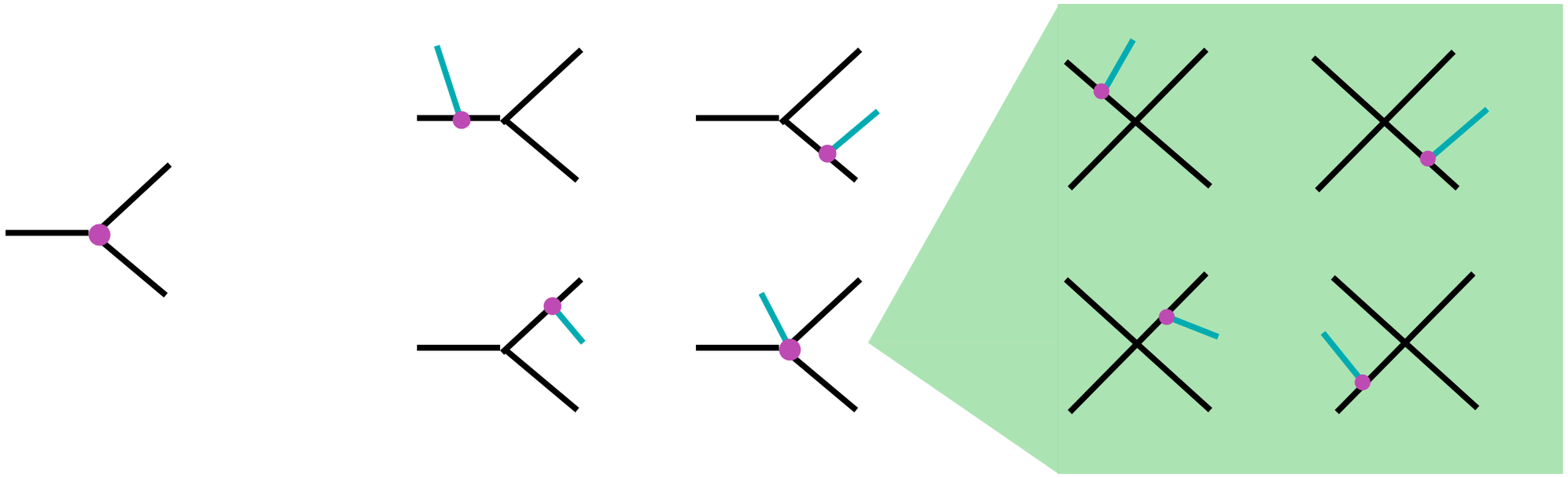

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3. Write out a code based on the HELAS library.

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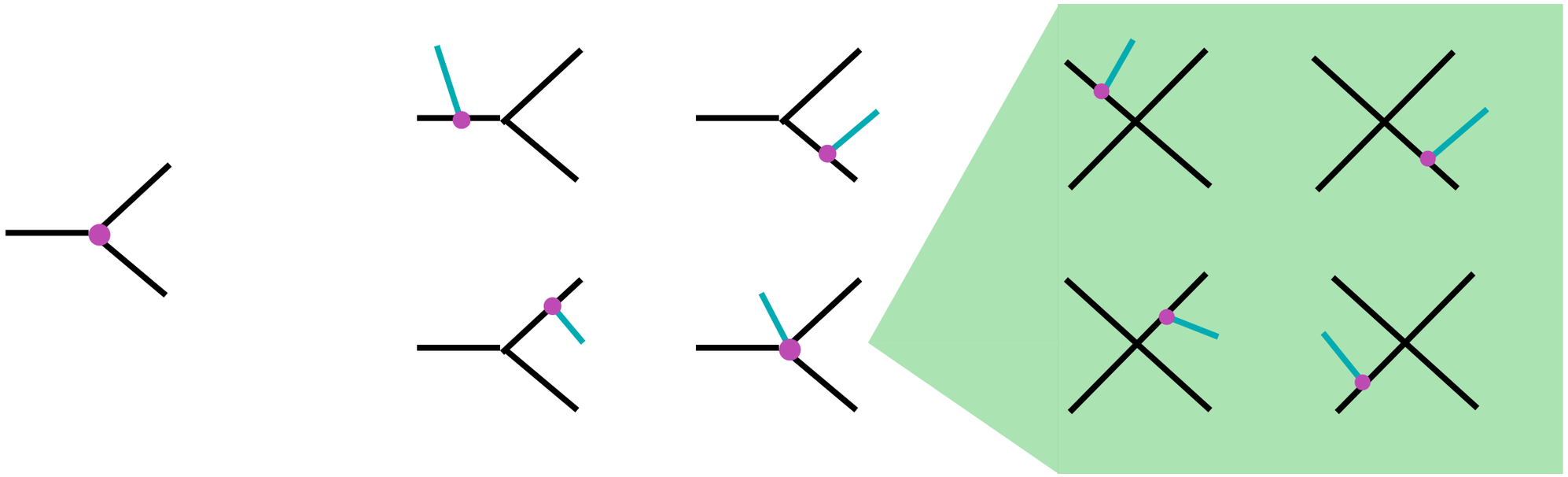

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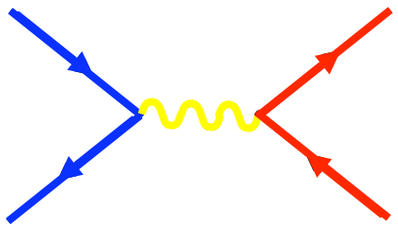
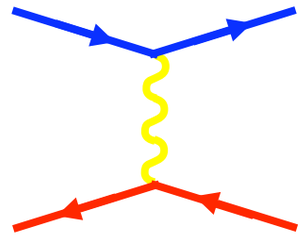
"Only" a book-keeping problem!

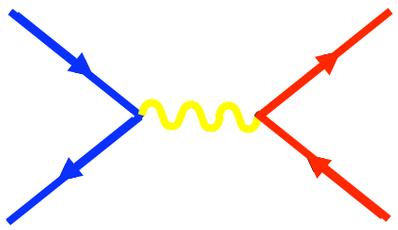
Exercises

- List processes for signal pp > h > tt~bb~
  - e.g. uu~ > h > tt~ bb~
- List process for background pp > ttbb
  - e.g. uu~ > tt~bb~
- List process for reducible background pp>ttjj
  - e.g. uu~ > tt~gg



MadGraph





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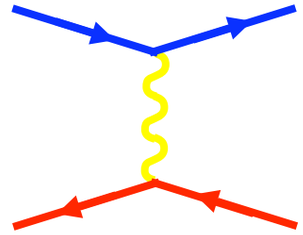
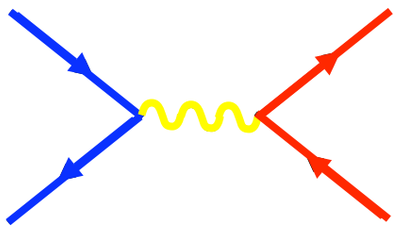


- User Requests:



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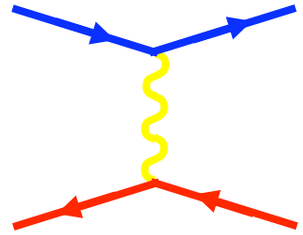

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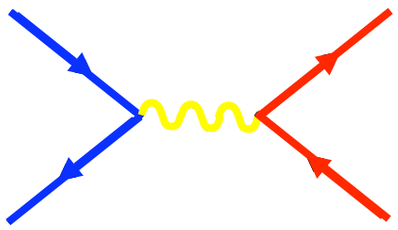

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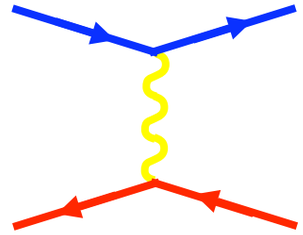

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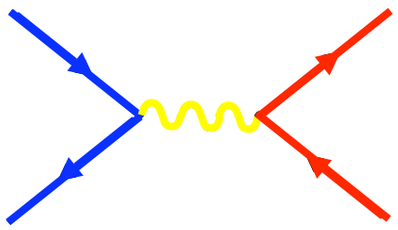

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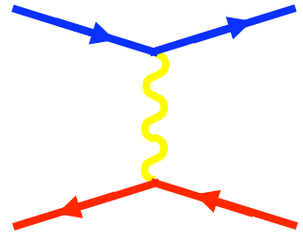

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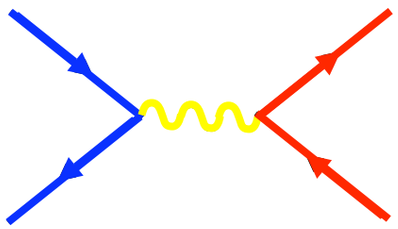

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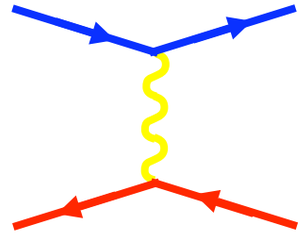

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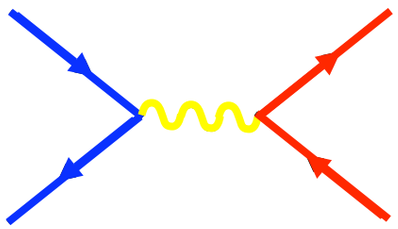

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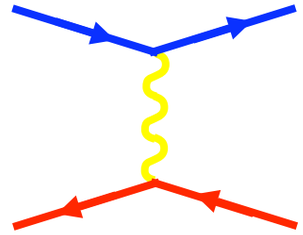

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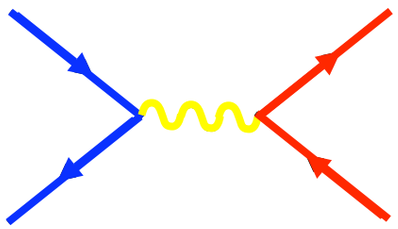
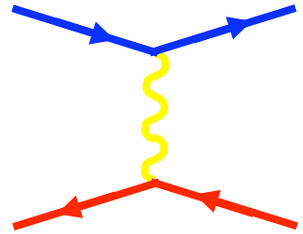
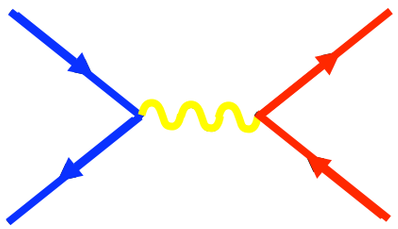


MadGraph

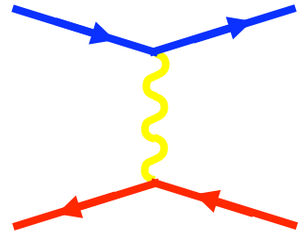


- User Requests:
  - pp -> bb~tt~
  - QCD Order = 4
  - QED Order =0

- MadGraph Returns:
  - Feynman diagrams
  - Fortran Code for |M|^2



MadGraph



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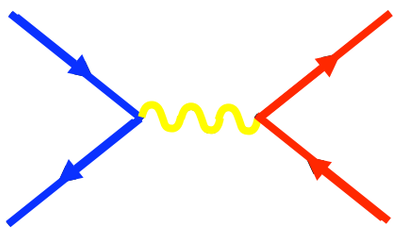
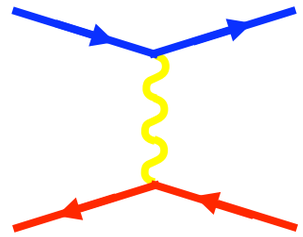
  - Summed over all sub processes w/ pdf



MadGraph



- User Requests:
  - pp -> bb~tt~
  - QCD Order = 4
  - QED Order =0

```
DOUBLE PRECISION FUNCTION DSIG(PP,WGT)
C *************************************************
C Generated by MadGraph II Version 3.83. Updated 06/13/05
C     RETURNS DIFFERENTIAL CROSS SECTION
C     Input:
C           pp    4 momentum of external particles
C           wgt   weight from Monte Carlo
C     Output:
C           Amplitude squared and summed
C *************************************************

      ----------------------------------

      IPROC=IPROC+1      ! u u~ -> t t~ b b~
      PD(IPROC)=PD(IPROC-1) + u1 * ub2
      IPROC=IPROC+1      ! d d~ -> t t~ b b~
      PD(IPROC)=PD(IPROC-1) + d1 * db2
      IPROC=IPROC+1      ! s s~ -> t t~ b b~
      PD(IPROC)=PD(IPROC-1) + s1 * sb2
      IPROC=IPROC+1      ! c c~ -> t t~ b b~
      PD(IPROC)=PD(IPROC-1) + c1 * cb2
      CALL SMATRIX(PP,DSIGUU)

      dsig = pd(iproc)*conv*dsiguu
```

- MadGraph Returns:
  - Feynman diagrams
  - Fortran Code for |M|^2
  - Summed over all sub processes w/ pdf

Models in MadGraph

Models in MadGraph

Previously:

- Standard Model
  (Higgs & backgrounds)

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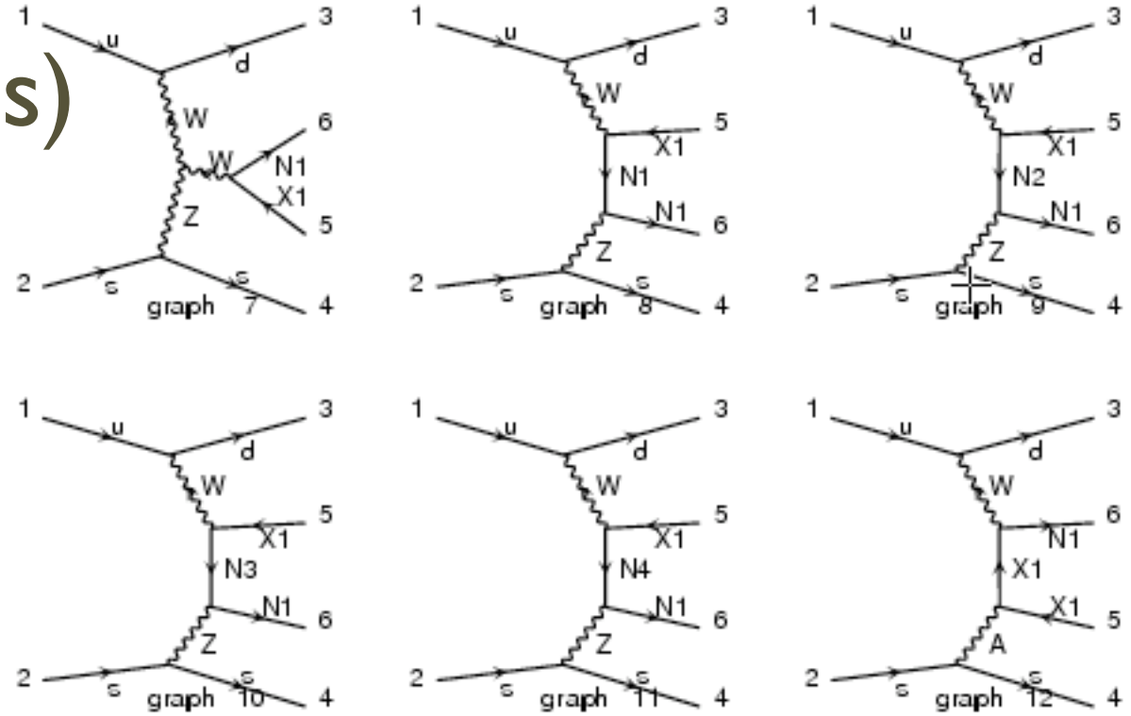
New models:

- MSSM



Models in MadGraph

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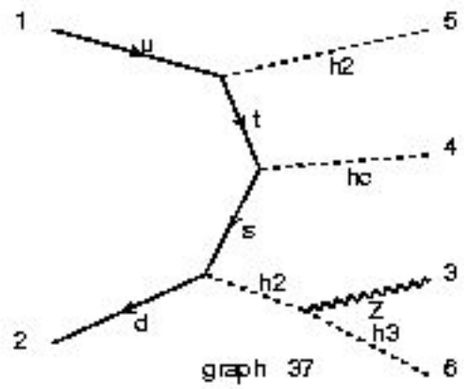
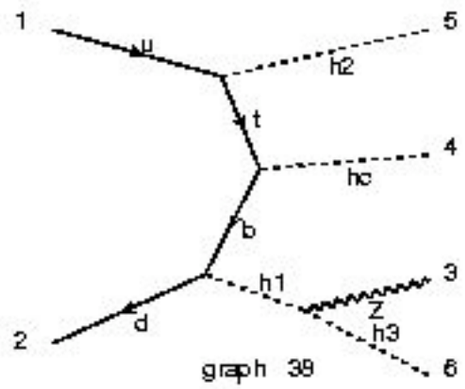
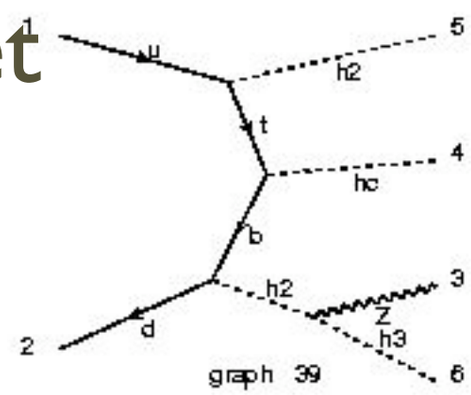
New models:

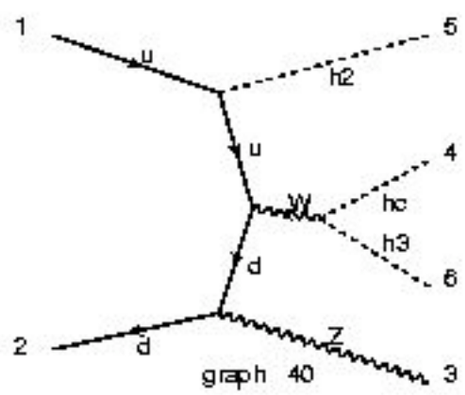
- MSSM

- General 2 Higgs Doublet Model (including CPV)









Models in MadGraph

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New models:

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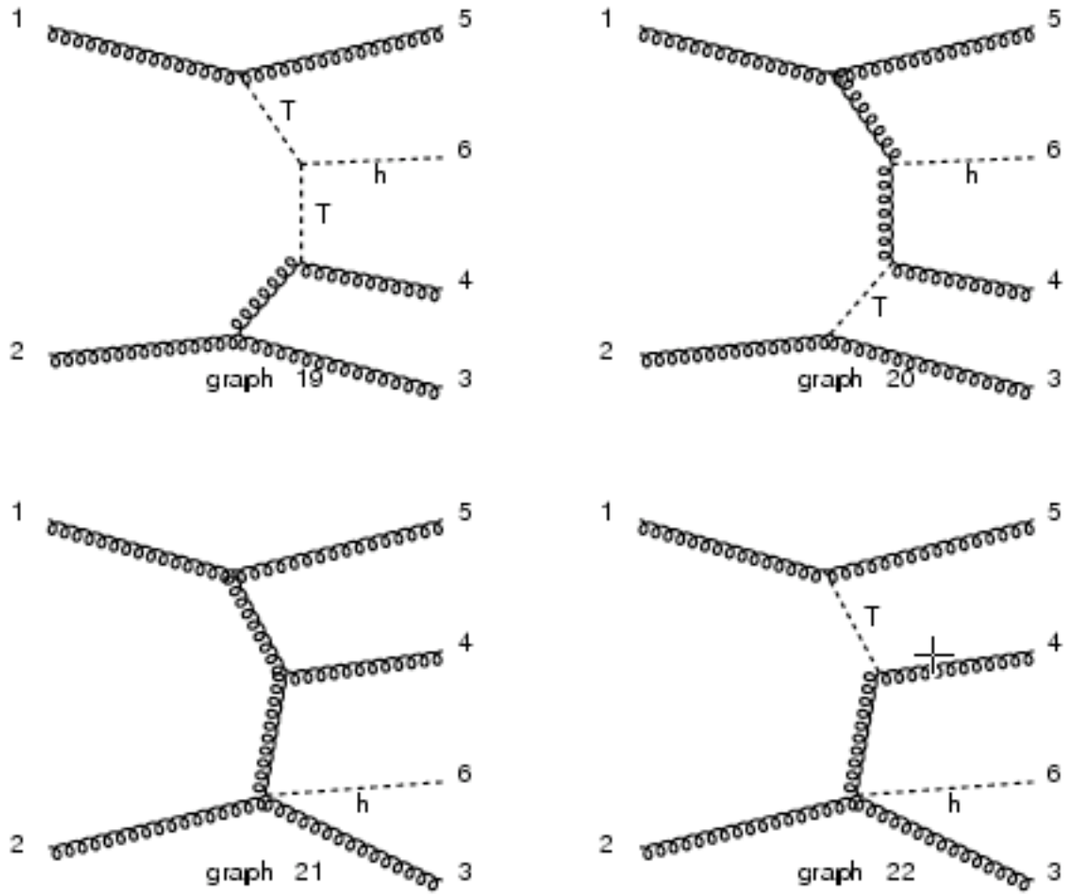
- General 2 Higgs Doublet Model (including CPV)
- Higgs EFT



Models in MadGraph

Previously:

- Standard Model
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New models:

- MSSM

- General 2 Higgs Doublet Model (including CPV)

- Higgs EFT

- General framework for user-defined models

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```
#Name anti_Name  Spin    Linetype Mass Width Color Label Mod
#xxx   xxxx      SFV      WSDC     str  str   STO    str   PDG

#
# Quarks
#

d       d~        F        S      ZERO  ZERO    T     d     1
u       u~        F        S      ZERO  ZERO    T     u     2
s       s~        F        S      ZERO  ZERO    T     s     3
c       c~        F        S      ZERO  ZERO    T     c     4
b       b~        F        S      BMASS ZERO    T     b     5
t       t~        F        S      TMASS TWIDTH  T     t     6
```

particles.dat

Models in MadGraph

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New models:

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- General 2 Higgs Dc Model (including Cl

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particles.dat

```
#Name anti_Name  Spin    Linetype Mass Width Color Label Mod
#xxx   xxxx      SFV      WSDC     str  str   STO    str   PDG

#
# Quarks
#

d       d~        F        S      ZERO  ZERO    T     d     1
u       u~        F        S      ZERO  ZERO    T     u     2
s       s~        F        S      ZERO  ZERO    T     s     3
c       c~        F        S      ZERO  ZERO    T     c     4
b       b~        F        S      BMASS ZERO    T     b     5
t       t~        F        S      TMASS TWIDTH  T     t     6
```

interactions.dat

```
#
# QCD interactions
#

d d g GG QCD
u u g GG QCD
s s g GG QCD
c c g GG QCD
b b g GG QCD
t t g GG QCD

g g g G  QCD
```

[J. Alwall et al., arXiv:0706.2334]

- The new web generation:

[J. Alwall et al., arXiv:0706.2334]

  - User requests a process (Ex. pp>tt~jjj) and corresponding code is generated on the fly.
  - User inputs model/parameters/cuts, and code runs in parallel on modest farms.
  - MG/ME Returns cross section, plots, parton-level events.

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  - Reduces overhead to getting results
  - Events can easily be shared/stored
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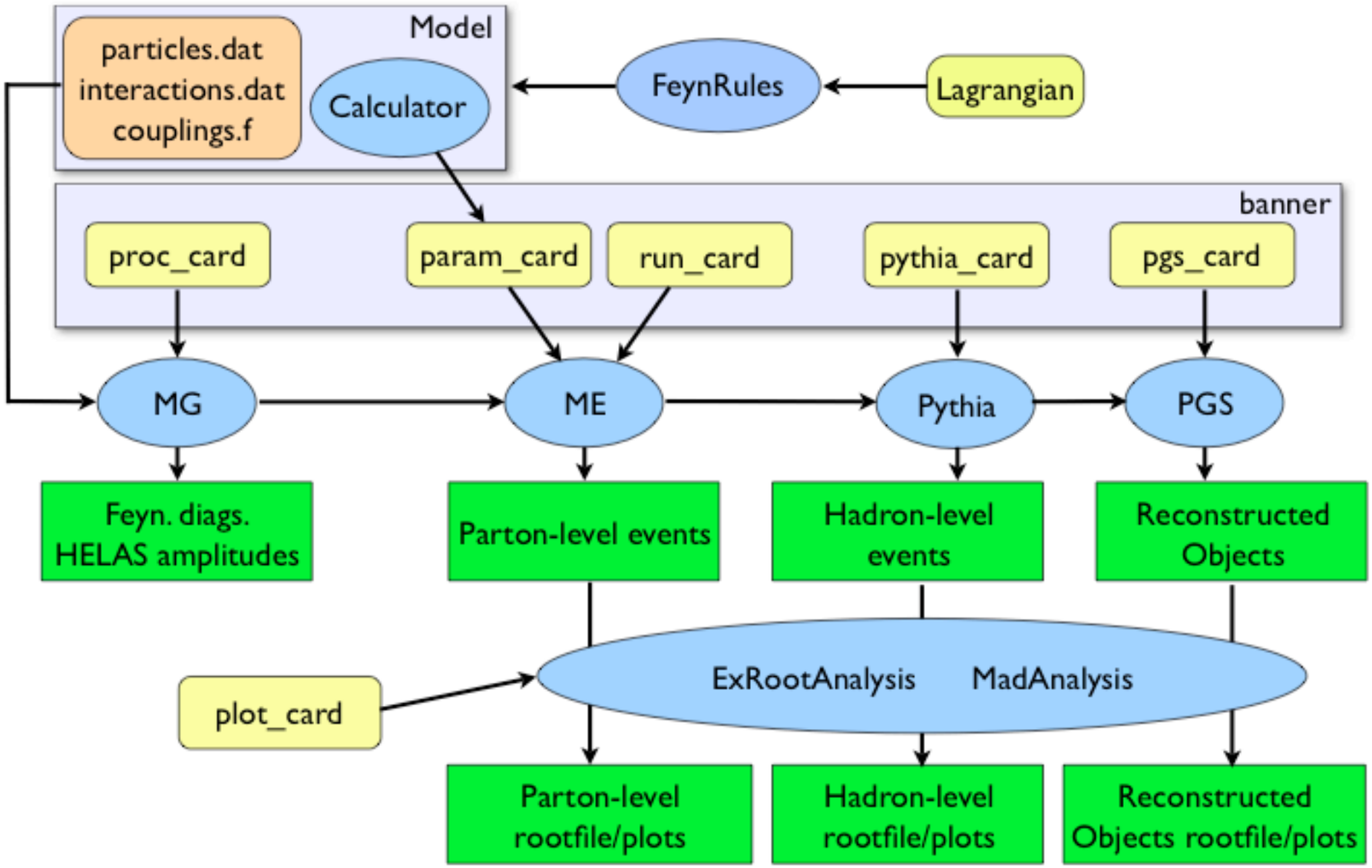
- Advantages:
  - Reduces overhead to getting results
  - Events can easily be shared/stored
  - Quick response to user requests and to new ideas!
- Limitations:
  - Optimization on single procs limited by generality
  - Tree-level amplitudes based on Feynman diagrams

MadGraph/MadEvent v4

[J. Alwall et al., arXiv:0706.2334]

- Personal web databases
- Complete simulation on the web: MadEvent → Pythia → PGS
- Multi-processes in single code & generation
- Cross section and decay width calculations
- Standalone version for theorists
- New complete models : SM, HEFT, MSSM,2HDM,UED,ADD
- USRMOD & interface to FeynRules: New Models implementation
- Les Houches Accord (LHEF) for parton-level event files and Les Houches Accord 2 for model parameters
- Merging w/ Parton Showers (k_T a la MLM) w/ Pythia

FlowChart


Model
particles.dat
interactions.dat
couplings.f
Calculator
FeynRules
Lagrangian
banner
proc_card
param_card
run_card
pythia_card
pgs_card
MG
ME
Pythia
PGS
Feyn. diags.
HELAS amplitudes
Parton-level events
Hadron-level
events
Reconstructed
Objects
plot_card
ExRootAnalysis
MadAnalysis
Parton-level
rootfile/plots
Hadron-level
rootfile/plots
Reconstructed
Objects rootfile/plots

Let's plug ... & play!

1. t tbar production: pp>tt~>bb~mu+ e- ve~ vm.
2. t tbar + Higgs : pp>h>tt~bb~ (QCD=2,QED=2). Generate the background pp>tt~bb~ (QCD=99,QED=0) and put a min cut on the m(bb)=100 GeV.
3. Single top + Higgs: pp>tHj (QCD=0, QED=3,j=gudsc, p=gudscb). Show that there is a large negative interference between the diagrams.
4. gg>h: pp>h>mu+ e- ve~ vm (HEFT,QED). Generate the background, pp>W+W-> mu+ e- ve~ vm/h (QCD=0,QED=4). Use different Higgs masses (mh=120,mh=170). Identify a smart discriminating variable among those plotted automatically.

MadGraph advanced features

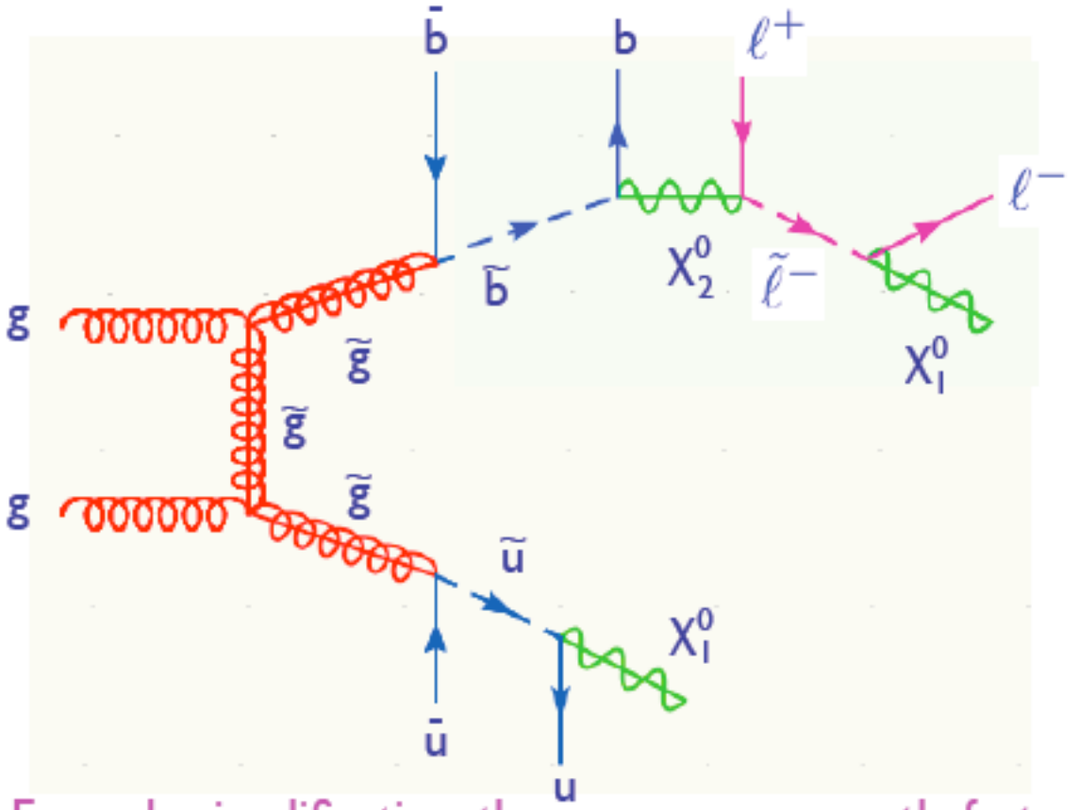
- Latest information available at the Wiki page
- Examples : decay rates, multiprocesses, decay chains,..
- Tools and Calculators
- Full expert/developer's package downloadable
- Standalone
- MadWeight
- New physics models : FeynRules and USERMOD

Let's play advanced!

Decay chains

[Alwall and Stelzer,2007]

```
gg >(go>u~(ul > u n1 ))(go>b~(b1>(b(n2>mu+(mul- >mu- n1)))))
```



In this case:

1. Full matrix element is obtained which includes correlations between production and decays.
2. Spin of the intermediate states is kept.
3. One can go beyond 1→2 decays.
4. Resonances have BW.
5. Non-resonant contributions can be systematically included only where relevant.

Example simplification: the process can exactly factorized in

```
gg >(go>u~ul)(go>b~b1)
```

where the squarks can be decayed at the event level, for example by BRIDGE

[Maede and Reece,2007]

```
ul > u n1
b1 > b(n2>mu+(mul- >mu- n1))
```

Multi-processes

http://madgraph.phys.ucl.ac.be/EXAMPLES/Cards/proc_card_2.dat

http://madgraph.phys.ucl.ac.be/EXAMPLES/Cards/proc_card_2.dat

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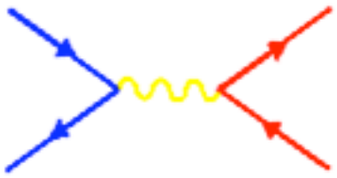
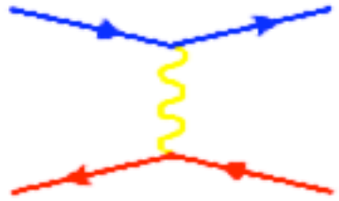
```
#*************************************************************
#-------------------------------------------------------------*
# Process(es) requested : mg2 input                           *
#-------------------------------------------------------------*
# Begin PROCESS # This is TAG. Do not modify this line

pp>h>tt~bb~ @1     # First Process: signal for tt~h
QCD=2              # Max QCD couplings
QED=2              # Max QED couplings
end_coup           # no more couplings for this proc

pp>tt~bb~   @2     # Second Process: QCD background tt~bb~
QCD=99             # Max QCD couplings
QED=0              # Max QED couplings
end_coup           # no more couplings for this proc

pp>tt~bb~/h @3     # First Process: EW background  tt~bb~
QCD=2              # Max QCD couplings
QED=2              # Max QED couplings
end_coup           # no more couplings for this proc

done               # Write 'done' to tell MG to stop

# End PROCESS  # This is TAG. Do not modify this line
#-------------------------------------------------------------*
# Model information                                           *
```

Web tools



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

Online MadGraph/MadEvent related tools

Calculators

Plotting Interface (ExRootAnalysis)

Plotting Interface (MadAnalysis)

Decay Interface

MadGraph Standalone

- "Naked" Matrix elements can be also generated to be EXPORTED to any other ME MC or used in higher order computations.
- Matrix elements can be tested point-by-point in phase space AUTOMATICALLY for ANY process.
- Model and parameters are included in a small library (easy to compare different model implementations).

http://cp3wks05.fynu.ucl.ac.be/twiki/bin/view/Software/StandAlone

Installing the MG/ME & analysis routines:

1. Get the full thing:

wget http://madgraph.phys.ucl.ac.be/Downloads/MG_ME_V4.2.11.tar.gz;
tar zxvf MG_ME_V4.2.11.tar.gz;
cd MG_ME_V4.2.11

2. Get a very simple LHE and LHCO event analyzer:

wget http://madgraph.phys.ucl.ac.be/Downloads/MadAnalysis_V1.0.7.tar.gz;
tar zxvf MadAnalysis_V1.0.7.tar.gz

3. make

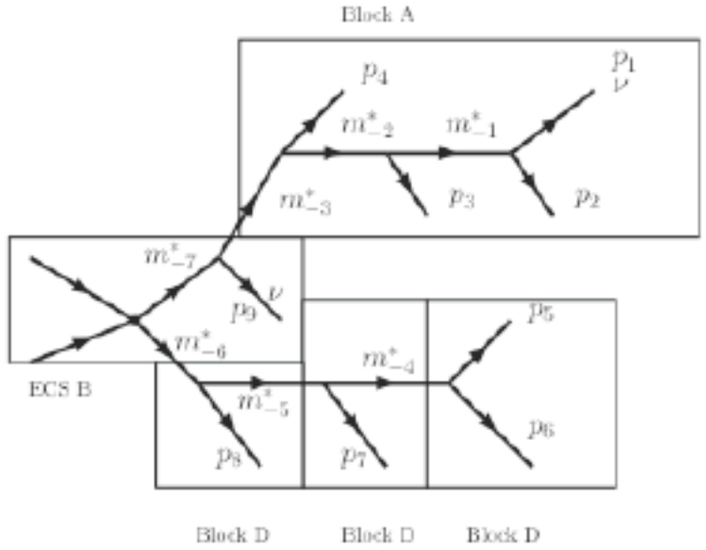
4. Install topdrawer :

cd MadAnalysis; wget http://madgraph.phys.ucl.ac.be/Downloads/td.tgz

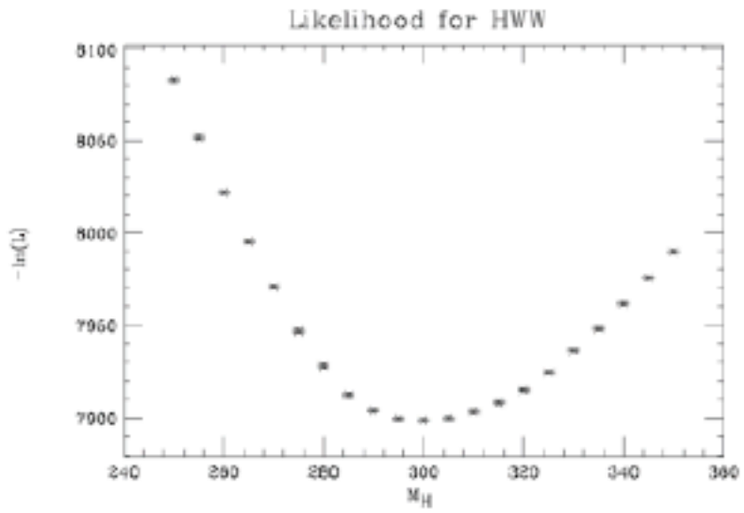
Matrix element methods

[Artoisenet, Lemaitre, FM, Mattelaer]

- Tool to find matrix element weight of experimental events for (almost) any process in any model.



Phase space integration using automatic change of variables to align with peaks



Find likelihood for model parameters (here Higgs mass in $h \to WW$)

http://cp3wks05.fynu.ucl.ac.be/twiki/bin/view/Software/MadWeight

code available on demand

A look into the future

MadGraph 5 : alpha version coming soon!

Automatic NLOwPS in SM and BSM....

A look into the future

MadGraph 5 : alpha version coming soon!

Main points:

* New Matrix Element generator engine in Python
* Full flexibility for New Physics implementation through FeynRules
* Loops... NLO computations for SM and BSM!

Automatic NLOwPS in SM and BSM....

Thanks and enjoy!!!