Preforming a collider study using HEP tools

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contents

- Motivation
- B-L extension of the standard model

“ *seesaw mechanism*”

-FeynRules/LanHEP

-ME-Generators

-HF-Generators

-LHE formate

-ROOT

-Conclusion

What is “a collider study” and how do you “perform” one?

A “collider study” is generating an appropriate simulation of a particle collider and analyzing the generated events, using appropriate Monte Carlo tools.

So, Why MC simulation??

1. Compare theory to experiment
2. Compare predicted particle properties to measured properties:

mass mX, charge qX, spin sX, lifetime τX / decay width ΓX , branching ratios BR(X → ...),

production crosssections- σ(X, ...)

Compare model’s σ theo to measured σ exp.
Theory should be predictive and map to physical observables.
Colliders bring their own complications...

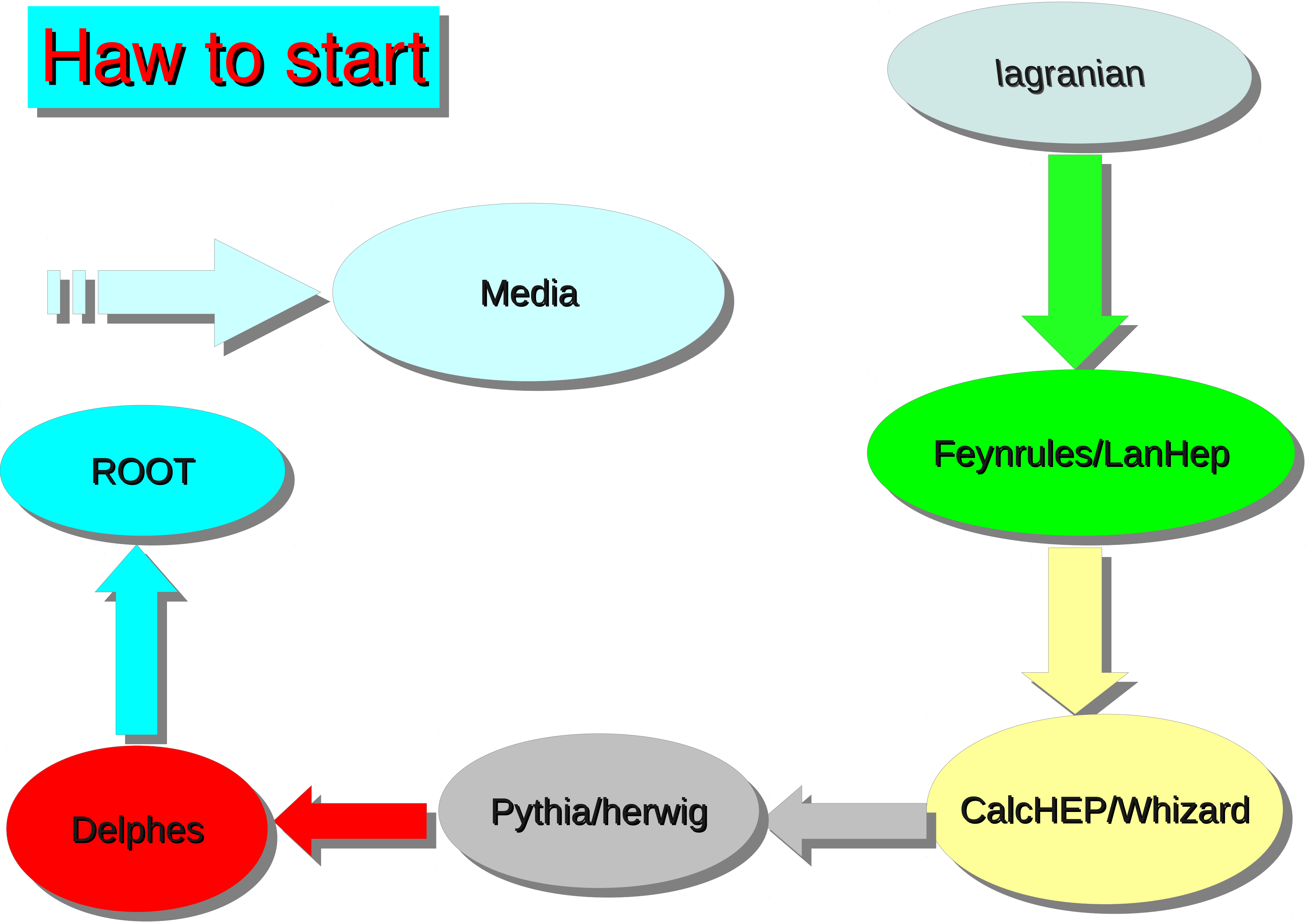
multiparticle phase spaces.

kinematic cuts :

- ➔ *Real detectors do not cover full solid angle .*
- ➔ *Real detectors do not trigger on arbitrarily soft particles.*
- ➔ *Often want to remove backgrounds with typical kinematic cut.*

invisible particles “ Neutrinos , Dark matter”.

Haw to start



lagranian

Feynrules/LanHep

CalcHEP/Whizard

Pythia/herwig

Delphes

ROOT

Media

B – L Extension of the SM

The fact that neutrinos are massive indicates that the Standard Model (SM) requires extension. B − L extension of the SM, which is based on the gauge group

SU (3)C × SU (2)L × U (1)Y × U (1)B−L .

This model provides a natural explanation for the presence of three right-handed neutrinos in addition to an extra gauge boson and a new scalar Higgs.

The invariance of the lagrangian under this gauge symmetry implies the existence of a new gauge boson (beyond the SM ones) “Z`”.

Also in order to ensure that U(1)B−L is anomaly free, three SM singlet fermions must be introduced .These singlet fermions are usually called right-handed neutrinos.

This model contains one singlet complex scaler field “X” that can spontaneously break the U(1)B−L symmetry and one doublet “φ “ to break the SU(2)L × U(1)Y symmetry down to U(1)em .

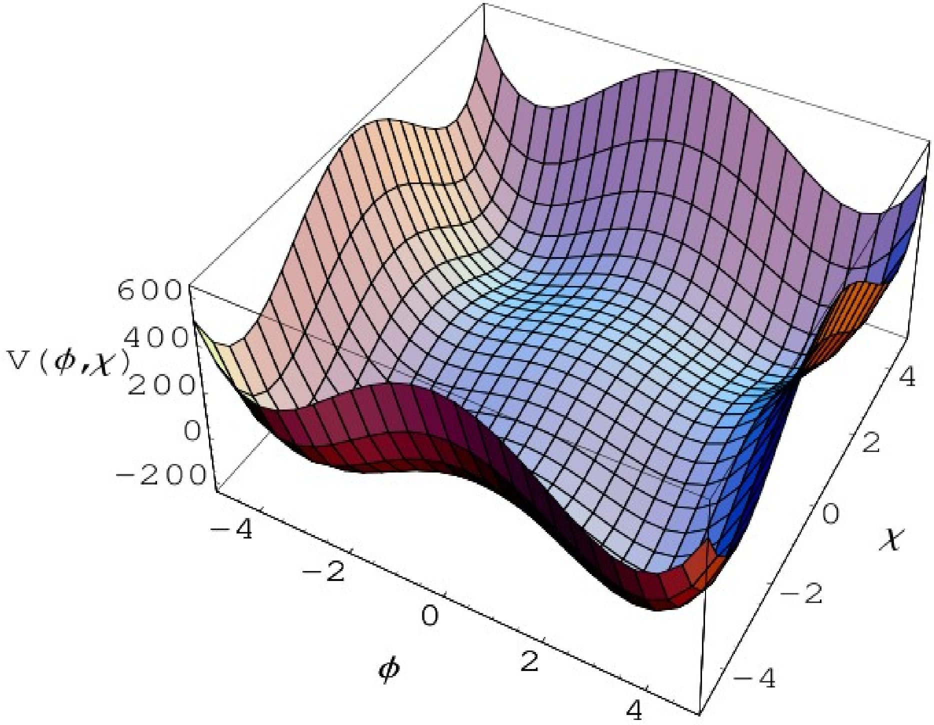
$$\begin{aligned}\mathcal{L}_{B-L} &= -\frac{1}{4}C_{\mu\nu}C^{\mu\nu} + i\,\bar{l}D_\mu\gamma^\mu l + i\,\bar{e}_R D_\mu\gamma^\mu e_R + i\,\bar{\nu}_R D_\mu\gamma^\mu\nu_R + (D^\mu\phi)(D_\mu\phi)\\ &+ (D^\mu\chi)(D_\mu\chi) - V(\phi,\chi) - \Big(\lambda_e\bar{l}\phi e_R + \lambda_\nu\bar{l}\tilde{\phi}\nu_R + \frac{1}{2}\lambda_{\nu_R}\bar{\nu^c}_R\chi\nu_R + h.c.\Big),\end{aligned}$$

The electroweak symmetry breaking and Higgs potential

$$\begin{aligned}V(\phi,\chi) &= m_1^2\phi^\dagger\phi + m_2^2\chi^\dagger\chi + \lambda_1(\phi^\dagger\phi)^2 + \lambda_2(\chi^\dagger\chi)^2\\ &+ \lambda_3(\chi^\dagger\chi)(\phi^\dagger\phi),\end{aligned}$$

As in the usual Higgs mechanism of the SM, the vevs “v” and “v ’” can not be emerged unless negative squared masses, m2 < 0 and m2 < 0, are assumed.

$$v^2 = \frac{4\lambda_2 m_1^2 - 2\lambda_3 m_2^2}{\lambda_3^2 - 4\lambda_1\lambda_2}, \qquad v'^2 = \frac{-2(m_1^2 + \lambda_1 v^2)}{\lambda_3}.$$



After the symmetry breaking the new gauge field acqires mass

MZ ′ /g ″ > 6 TeV.

The high energy experimental searches for an extra neutral gauge boson impose lower bounds on this mass.The CDF limit leads to MZ ′ > O(600 − 800) GeV

MZ ′ /g ″ > 6 TeV.

Scalar Masses

To find the scalar masses, we must expand the potential around the minima , the unitary gauge :

$$\phi(x) \equiv \begin{pmatrix} 0 \\ \frac{v+h(x)}{\sqrt{2}} \end{pmatrix}, \qquad \chi(x) \equiv \frac{v' + h'(x)}{\sqrt{2}}.$$

Now the potential bcomes :

$$\begin{aligned} V(h,h') &= \lambda_1 v^2 h^2 + \lambda_2 v'^2 h'^2 + \lambda_3 h h' v v' \\ &+ \frac{\lambda_3}{2}(v' h^2 h' + v h h'^2) + \lambda_1 v h^3 + \lambda_2 v' h'^3 + \frac{\lambda_1}{4} h^4 + \frac{\lambda_2}{4} h'^4. \end{aligned}$$

The first three terms form the squared mass matrix for h and h′

$$\frac{1}{2} M^2(h,h') = \begin{pmatrix} h & h' \end{pmatrix} \begin{pmatrix} \lambda_1 v^2 & \frac{\lambda_3}{2} v v' \\ \frac{\lambda_3}{2} v v' & \lambda_2 v'^2 \end{pmatrix} \begin{pmatrix} h \\ h' \end{pmatrix}.$$

To acquir masses to the new scalars , one has to diagonlalize the mass matrix

$$\begin{pmatrix} \phi_1 \\ \phi_2 \end{pmatrix} = \begin{pmatrix} c_\theta & -s_\theta \\ s_\theta & c_\theta \end{pmatrix} \begin{pmatrix} h \\ h' \end{pmatrix}$$

New mass eign states

$$m^2_{\phi_1,\phi_2} = \lambda_1 v^2 + \lambda_2 v'^2 \mp \sqrt{(\lambda_1 v^2 - \lambda_2 v'^2)^2 + \lambda_3^2 v^2 v'^2}.$$

$$\tan 2\theta = \frac{|\lambda_3| v v'}{\lambda_1 v^2 - \lambda_2 v'^2}.$$

Neutrino Masses

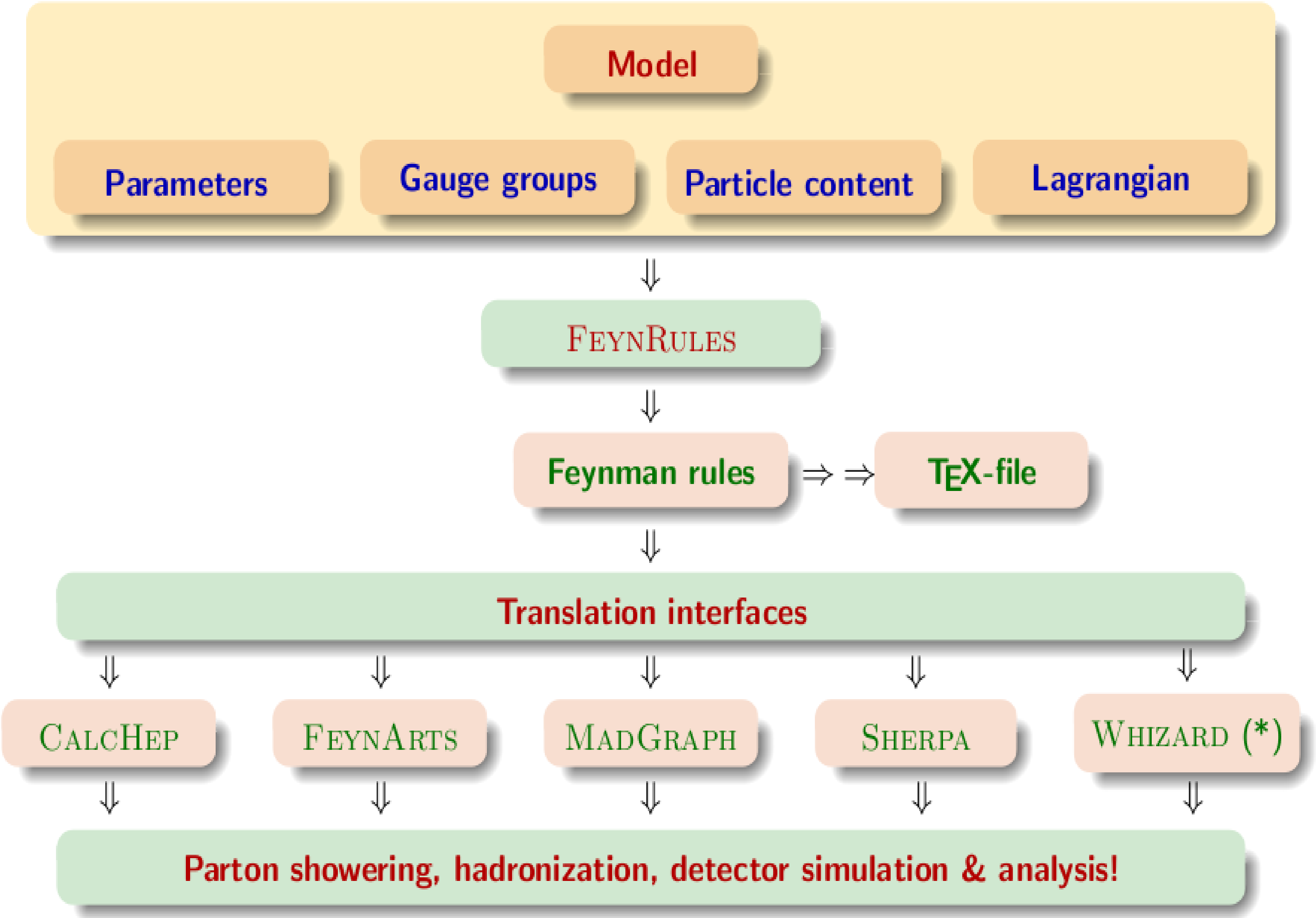
After $U(1)_{B-L}$ symmetry breaking, we know that the field χ can be shifted around its minima as : $\chi = \frac{1}{\sqrt{2}}(h'+v')$, so the Yukawa interaction term: $\frac{1}{2} y_M \, \overline{(\nu_R)^c} \chi \nu_R$ leads, as usual, to right handed neutrino mass: $M_R = \frac{1}{2\sqrt{2}} y_M \, v'$. Also after the electroweak symmetry breaking, the field ϕ can be shifted around its minima as:

$$\phi = \begin{pmatrix} 0 \\ \frac{h+v}{\sqrt{2}} \end{pmatrix}$$

the term $y_\nu \overline{\ell_L} \tilde{\phi} \nu_R$ implies Dirac neutrino mass term : $m_D = \frac{1}{\sqrt{2}} y_\nu \, v$. mass matrix of the left and RH neutrino is given by

$$\begin{pmatrix} 0 & m_D \\ m_D^T & M_R \end{pmatrix}.$$

Automatic generation of Feynman rules



Model

Parameters

Gauge groups

Particle content

Lagrangian

⇓

FEYNRULES

⇓

Feynman rules ⇒ ⇒ TEX-file

⇓

Translation interfaces

⇓ ⇓ ⇓ ⇓ ⇓

CALCHEP

FEYNARTS

MADGRAPH

SHERPA

WHIZARD (*)

⇓ ⇓ ⇓ ⇓ ⇓

Parton showering, hadronization, detector simulation & analysis!

Features of FeynRules

- FeynRules is a new package based on Mathematica.
- FeynRules is not tied to any existing Feynman diagram calculator.
- The generic model format of FeynRules is suitable to be translated to any other format.
- Calchep/Comphep , Sherpa , MadGraph ,UFO and recently whizard
- The underlying Mathematica structure allows a ‘theorist-friendly’ environment, which makes the package useful as a sandbox to develop a new model.
- Generating Hermitian conjugate terms allow to simplify model description.
- Superpotential can be used for supersymmetric theories.
- The built in commands easy the usage of FeynRules (left,right,del,proj,Fs,.....).

- Note ,, FeynRules doesn't diagonalize the mass matrices .

Haw to implement a new model

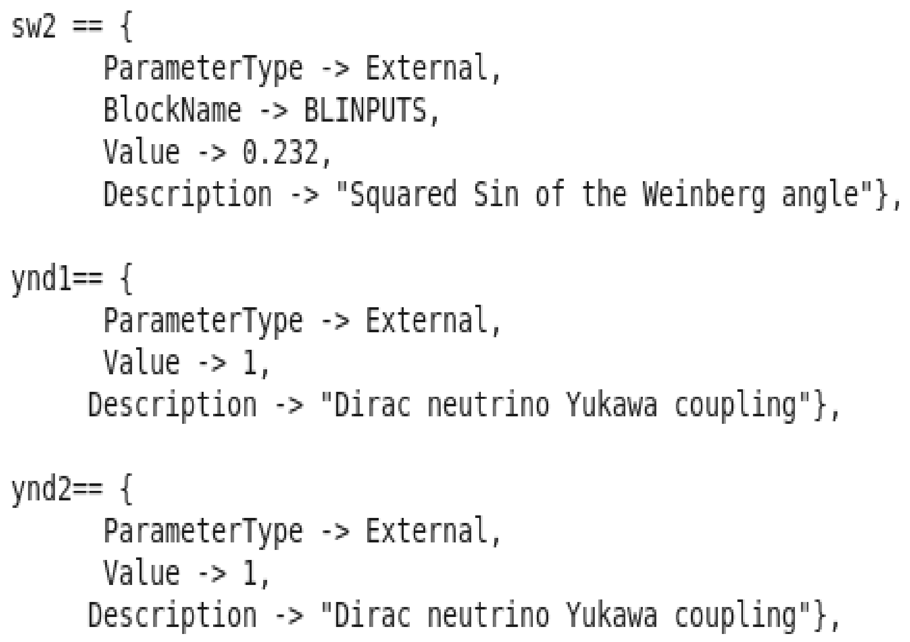
At the level of Feynman diagram calculations, a new model consists of the following:

(1) a set of quantum fields.
(2) a set of parameters.
(3) a Lagrangian of the model.

In order to implement such a new model in a program that calculates Feynman diagrams, this information must be entered in a format appropriate for the respective program. Each program has its own format making this a tedious and error prone process. FeynRules solves this problem by allowing the user to write their model in a generic “FeynRules” format and then run a Feyn-Rules interface that translates this format into the format appropriate for the Feynman diagram calculation program of choice. To do this, the user creates a FeynRules model file containing the essential model information and then run FeynRules for a specific Feynman diagram calculators .

Parameters Declaration

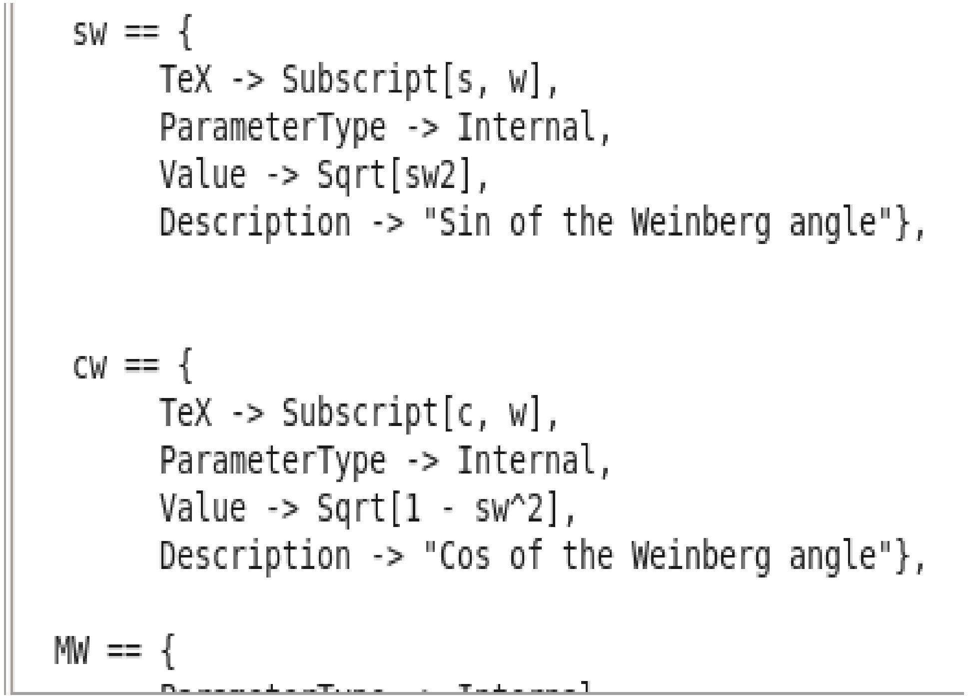
A model also contains many parameters such as coupling constants, mixing angles, masses, gauge charges, etc.
Parameter declaration consists of two types :
(1) External: This is an independent parameter and is given by a numerical value (the strong coupling αs = 0.118).
(2) Internal: This is a dependent parameters and is specified in terms of the other parametrs (cos θW = MW /MZ).



```
sw2 == {
      ParameterType -> External,
      BlockName -> BLINPUTS,
      Value -> 0.232,
      Description -> "Squared Sin of the Weinberg angle"},

ynd1== {
      ParameterType -> External,
      Value -> 1,
     Description -> "Dirac neutrino Yukawa coupling"},

ynd2== {
      ParameterType -> External,
      Value -> 1,
     Description -> "Dirac neutrino Yukawa coupling"},
```



```
 sw == {
      TeX -> Subscript[s, w],
      ParameterType -> Internal,
      Value -> Sqrt[sw2],
      Description -> "Sin of the Weinberg angle"},

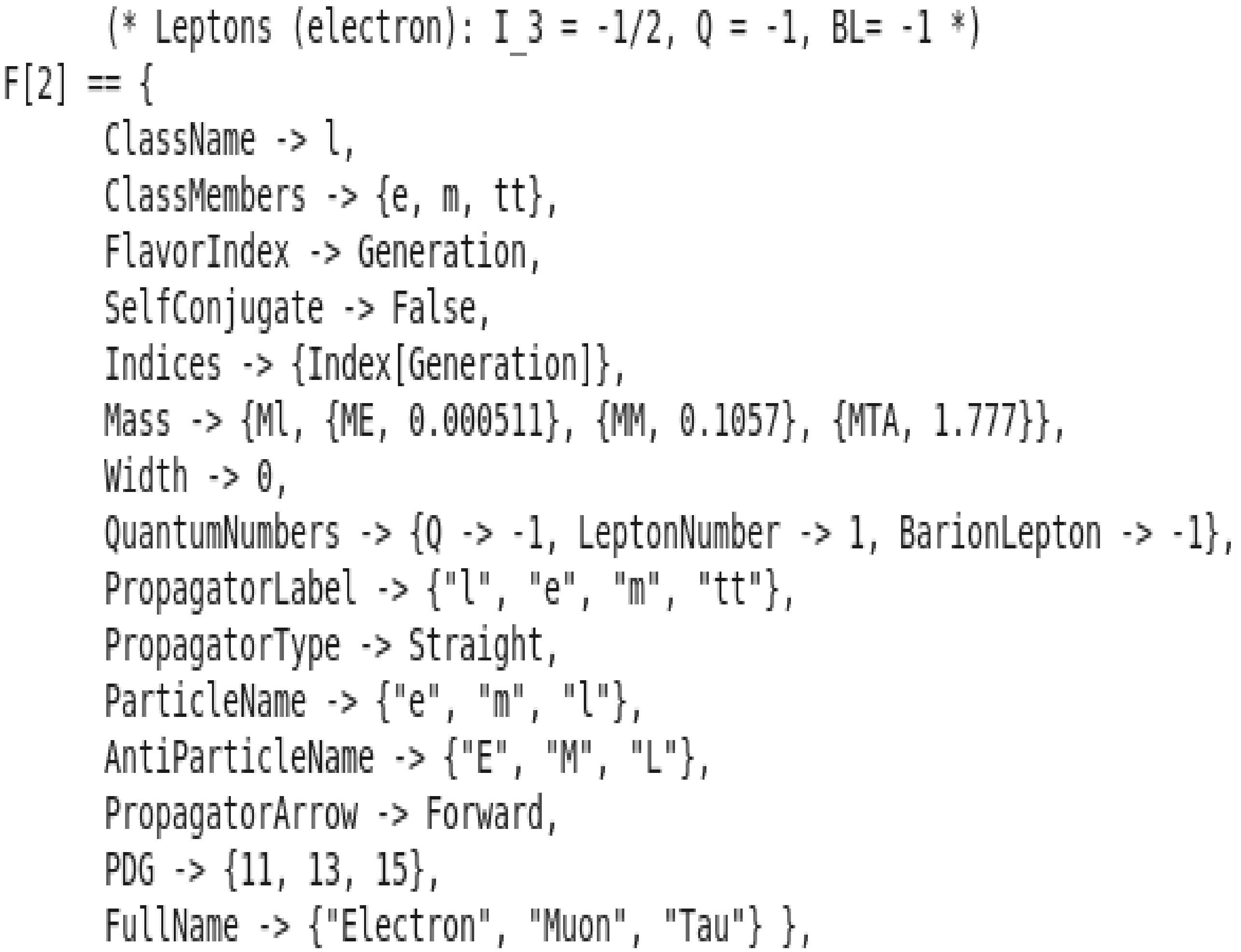

 cw == {
      TeX -> Subscript[c, w],
      ParameterType -> Internal,
      Value -> Sqrt[1 - sw^2],
      Description -> "Cos of the Weinberg angle"},

MW == {
```

Particles Declaration

The declaration of the particle classes in the model file follows similar lines as the parameters and devided into :

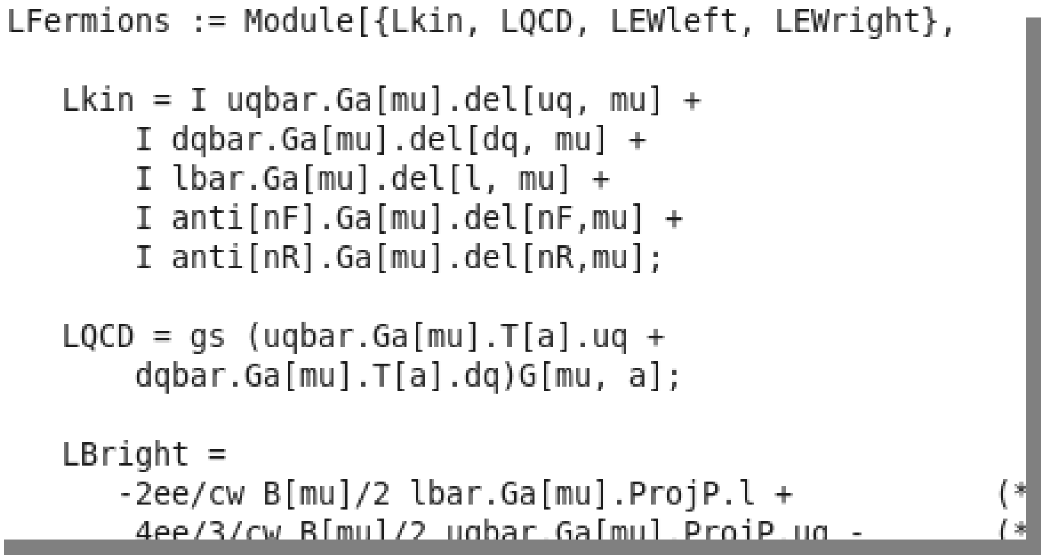
- $\mathcal{S}$ -> Scalar field
- $\mathcal{F}$ -> Fermions
- $\mathcal{V}$ -> Vector field
- $\mathcal{T}$ -> Spin 2 field
- $\mathcal{U}$ -> Ghost field



```
      (* Leptons (electron): I_3 = -1/2, Q = -1, BL= -1 *)
F[2] == {
      ClassName -> l,
      ClassMembers -> {e, m, tt},
      FlavorIndex -> Generation,
      SelfConjugate -> False,
      Indices -> {Index[Generation]},
      Mass -> {Ml, {ME, 0.000511}, {MM, 0.1057}, {MTA, 1.777}},
      Width -> 0,
      QuantumNumbers -> {Q -> -1, LeptonNumber -> 1, BarionLepton -> -1},
      PropagatorLabel -> {"l", "e", "m", "tt"},
      PropagatorType -> Straight,
      ParticleName -> {"e", "m", "l"},
      AntiParticleName -> {"E", "M", "L"},
      PropagatorArrow -> Forward,
      PDG -> {11, 13, 15},
      FullName -> {"Electron", "Muon", "Tau"} },
```

Lagrangian Declaration

Each new model is specified by a Lagrangian, which contains all the information about the interactions among the particles in the model. FeynRules introduced built in commands to facilitates the Lagrangian implementation. Also, you can divided the Lagrangian into terms and sumed it again .

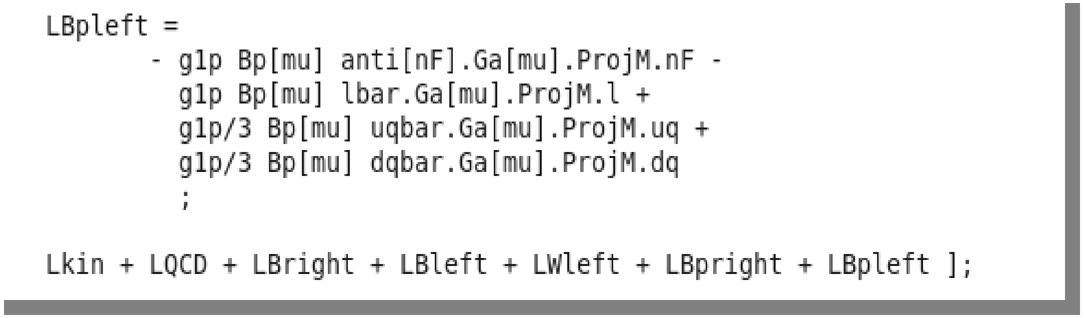


```
LFermions := Module[{Lkin, LQCD, LEWleft, LEWright},

   Lkin = I uqbar.Ga[mu].del[uq, mu] +
       I dqbar.Ga[mu].del[dq, mu] +
       I lbar.Ga[mu].del[l, mu] +
       I anti[nF].Ga[mu].del[nF,mu] +
       I anti[nR].Ga[mu].del[nR,mu];

   LQCD = gs (uqbar.Ga[mu].T[a].uq +
       dqbar.Ga[mu].T[a].dq)G[mu, a];

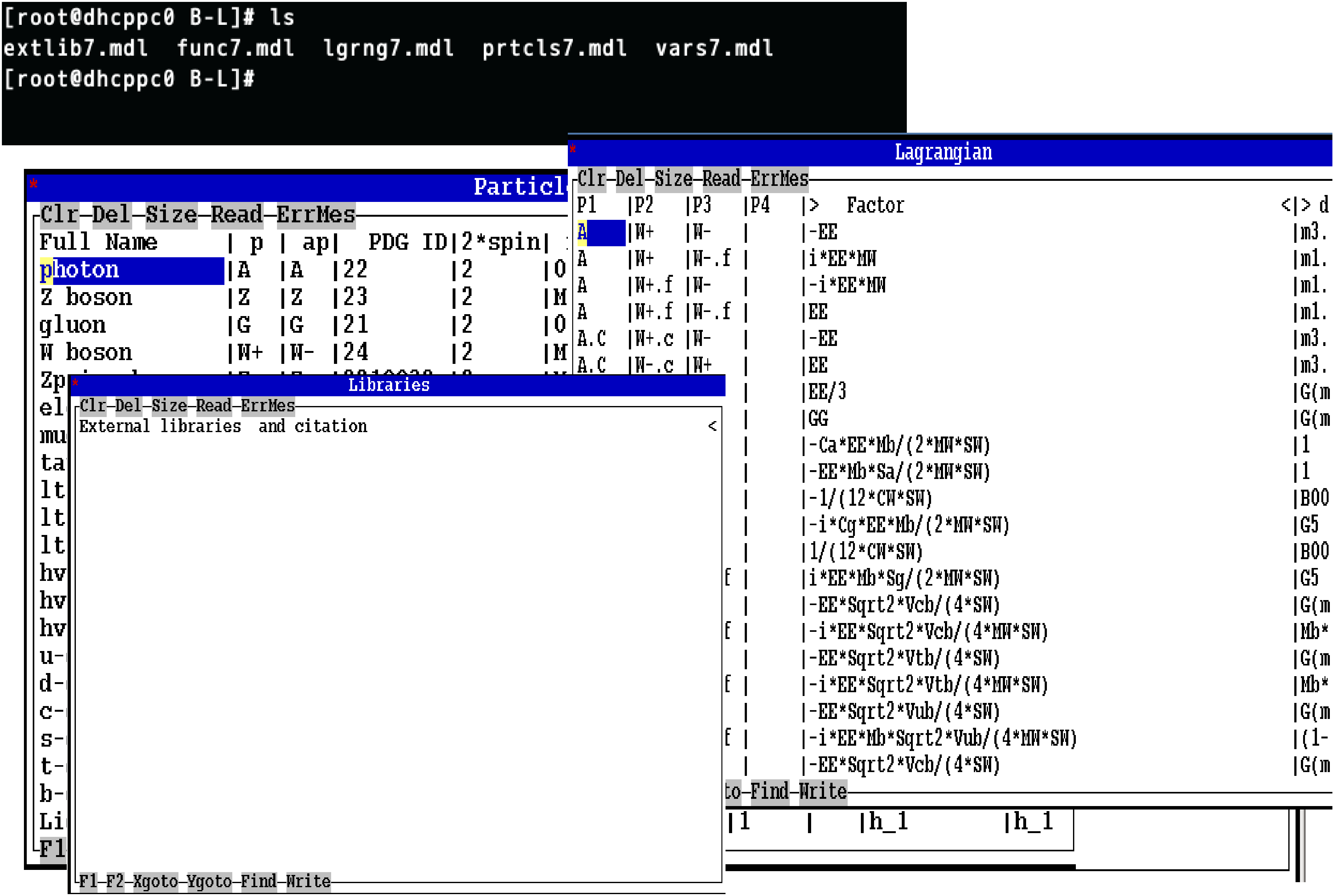
   LBright =
      -2ee/cw B[mu]/2 lbar.Ga[mu].ProjP.l +          (*
       4ee/3/cw B[mu]/2 uqbar.Ga[mu].ProjP.uq -       (*
```



```
LBpleft =
       - g1p Bp[mu] anti[nF].Ga[mu].ProjM.nF -
         g1p Bp[mu] lbar.Ga[mu].ProjM.l +
         g1p/3 Bp[mu] uqbar.Ga[mu].ProjM.uq +
         g1p/3 Bp[mu] dqbar.Ga[mu].ProjM.dq
         ;

Lkin + LQCD + LBright + LBleft + LWleft + LBpright + LBpleft ];
```

For CalcHEP FeynRules produces 5 files



```
[root@dhcppc0 B-L]# ls
extlib7.mdl  func7.mdl  lgrng7.mdl  prtcls7.mdl  vars7.mdl
[root@dhcppc0 B-L]#
```

```
Particl
Clr-Del-Size-Read-ErrMes
Full Name           | p | ap|  PDG ID|2*spin|
photon              |A  |A  |22      |2     |0
Z boson             |Z  |Z  |23      |2     |M
gluon               |G  |G  |21      |2     |0
W boson             |W+ |W- |24      |2     |M
Zp
el
mu
ta
lt
lt
lt
hv
hv
hv
u-
d-
c-
s-
t-
b-
Li
F1
```

```
Libraries
Clr-Del-Size-Read-ErrMes
External libraries  and citation                                <






F1-F2-Xgoto-Ygoto-Find-Write
```

```
Lagrangian
Clr-Del-Size-Read-ErrMes
P1    |P2    |P3    |P4    |>   Factor                          <|> d
A     |W+    |W-    |      |-EE                                 |m3.
A     |W+    |W-.f  |      |i*EE*MW                             |m1.
A     |W+.f  |W-    |      |-i*EE*MW                            |m1.
A     |W+.f  |W-.f  |      |EE                                  |m1.
A.C   |W+.c  |W-    |      |-EE                                 |m3.
A.C   |W-.c  |W+    |      |EE                                  |m3.
                    |      |EE/3                                |G(m
                    |      |GG                                  |G(m
                    |      |-Ca*EE*Mb/(2*MW*SW)                 |1
                    |      |-EE*Mb*Sa/(2*MW*SW)                 |1
                    |      |-1/(12*CW*SW)                       |B00
                    |      |-i*Cg*EE*Mb/(2*MW*SW)               |G5
                    |      |1/(12*CW*SW)                        |B00
                   f|      |i*EE*Mb*Sg/(2*MW*SW)                |G5
                    |      |-EE*Sqrt2*Vcb/(4*SW)                |G(m
                   f|      |-i*EE*Sqrt2*Vcb/(4*MW*SW)           |Mb*
                    |      |-EE*Sqrt2*Vtb/(4*SW)                |G(m
                   f|      |-i*EE*Sqrt2*Vtb/(4*MW*SW)           |Mb*
                    |      |-EE*Sqrt2*Vub/(4*SW)                |G(m
                   f|      |-i*EE*Mb*Sqrt2*Vub/(4*MW*SW)        |(1-
                    |      |-EE*Sqrt2*Vcb/(4*SW)                |G(m
to-Find-Write
|1       |     |h_1          |h_1
```

ME Generators

CalcHEP

CalcHEP (Calculations in High Energy Physics) is a package for the automatic evaluation of production cross sections and decay widths in elementary particle physics. In general CalcHEP divided into two main sessions :

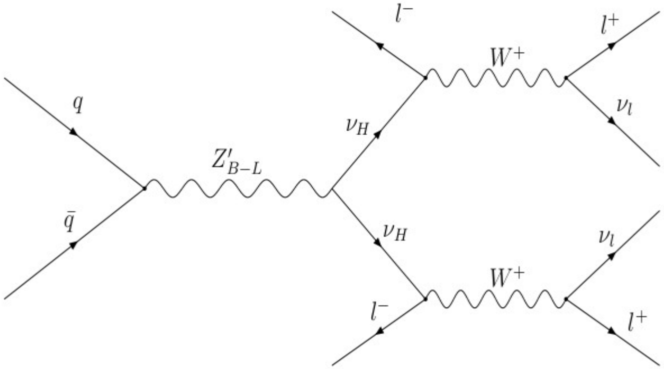
1- Symbolic session
2- Numerical session

Limitation of CalcHEP

- Tree-level processes
- no spin information for outgoing particles
- Limit on number of external legs (involved particles)and number of diagrams

2->6 , 1->7 ,, 100-200 diagram

Symbolic session



Menu 3

Parameters

Constraints

Particles

Libraries
RENAME
CHECK MODEL

Menu 1

SELECT MODEL

IMPORT OF MODELS

FILE SEARCH/LIST

Menu 2

Enter Process

Force Unit gauge = *OFF*

Edit Model

Numerical Evaluations
=====================

Delete model

Menu 5

Enter processes: p,p -> W+,2*x
composite p consists of: u,U,d,D
Exclude diagrams with: A
Exclude X-particles: G

Menu 4

Parameters

All Constraints

Masses,Widths,Br

Menu 8

C-code(for num calc)
C-compiler
Edit linker
REDUCE code
MATHEMATICA code
FORM code
Enter new process

Menu 7

View squared diagrams

Symbolic calculation

Make&Launch n_calchep

REDUCE program

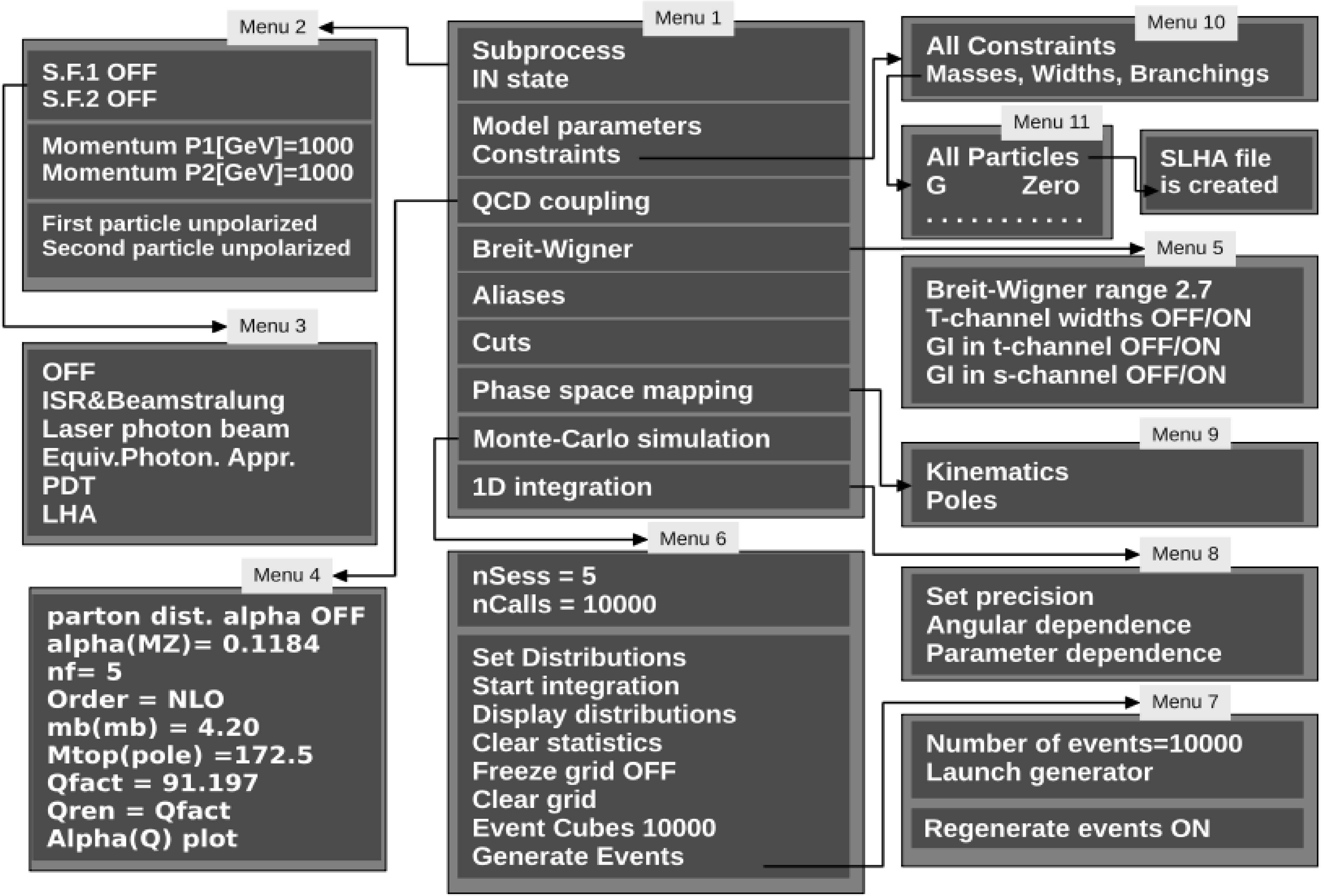
Menu 6

View diagrams

Square diagrams

Write down processes

Numerical session



Menu 1

Subprocess
IN state

Model parameters
Constraints

QCD coupling

Breit-Wigner

Aliases

Cuts

Phase space mapping

Monte-Carlo simulation

1D integration

Menu 2

S.F.1 OFF
S.F.2 OFF

Momentum P1[GeV]=1000
Momentum P2[GeV]=1000

First particle unpolarized
Second particle unpolarized

Menu 3

OFF
ISR&Beamstralung
Laser photon beam
Equiv.Photon. Appr.
PDT
LHA

Menu 4

parton dist. alpha OFF
alpha(MZ)= 0.1184
nf= 5
Order = NLO
mb(mb) = 4.20
Mtop(pole) =172.5
Qfact = 91.197
Qren = Qfact
Alpha(Q) plot

Menu 6

nSess = 5
nCalls = 10000

Set Distributions
Start integration
Display distributions
Clear statistics
Freeze grid OFF
Clear grid
Event Cubes 10000
Generate Events

Menu 10

All Constraints
Masses, Widths, Branchings

Menu 11

All Particles
G Zero
. . . .

SLHA file
is created

Menu 5

Breit-Wigner range 2.7
T-channel widths OFF/ON
GI in t-channel OFF/ON
GI in s-channel OFF/ON

Menu 9

Kinematics
Poles

Menu 8

Set precision
Angular dependence
Parameter dependence

Menu 7

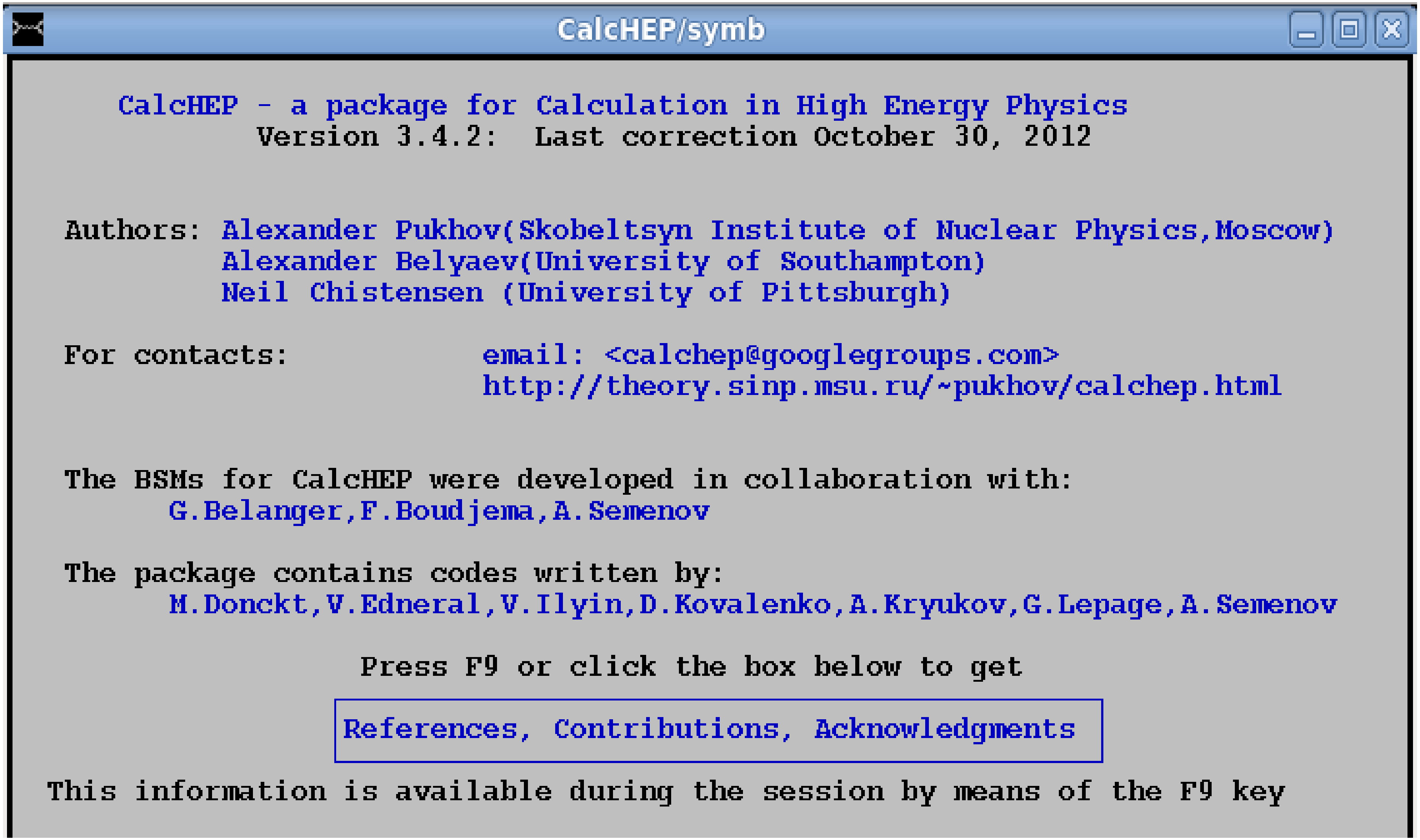
Number of events=10000
Launch generator

Regenerate events ON

Calchep divided into three modes :

1-Interactive mode

Which links the X11 library to CalcHEP for better use of GUI



```
    CalcHEP - a package for Calculation in High Energy Physics
            Version 3.4.2:  Last correction October 30, 2012


 Authors: Alexander Pukhov(Skobeltsyn Institute of Nuclear Physics,Moscow)
          Alexander Belyaev(University of Southampton)
          Neil Chistensen (University of Pittsburgh)

 For contacts:               email: <calchep@googlegroups.com>
                             http://theory.sinp.msu.ru/~pukhov/calchep.html


 The BSMs for CalcHEP were developed in collaboration with:
       G.Belanger,F.Boudjema,A.Semenov

 The package contains codes written by:
       M.Donckt,V.Edneral,V.Ilyin,D.Kovalenko,A.Kryukov,G.Lepage,A.Semenov

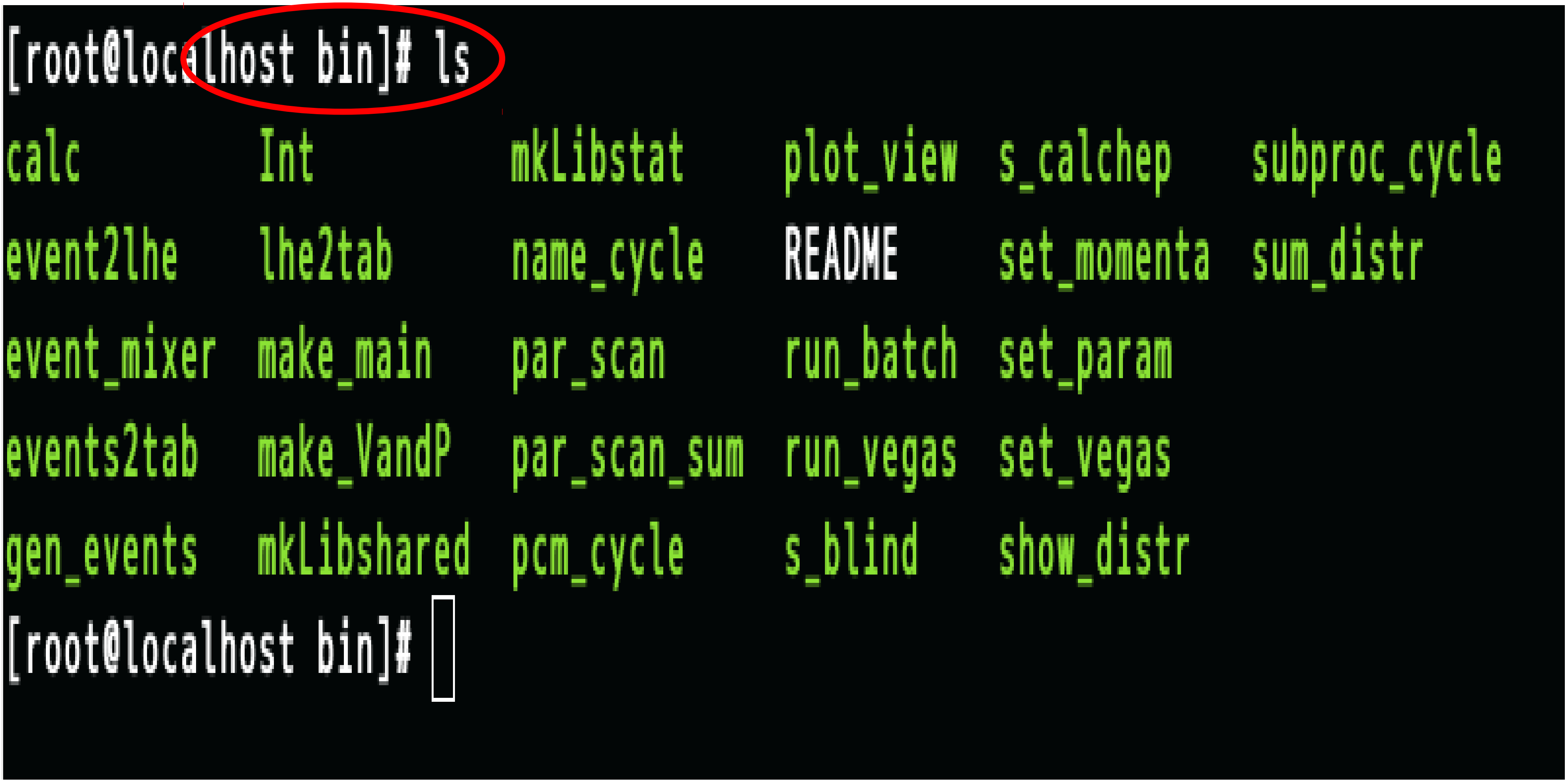
                   Press F9 or click the box below to get

                  References, Contributions, Acknowledgments

 This information is available during the session by means of the F9 key
```

2- Blind mode

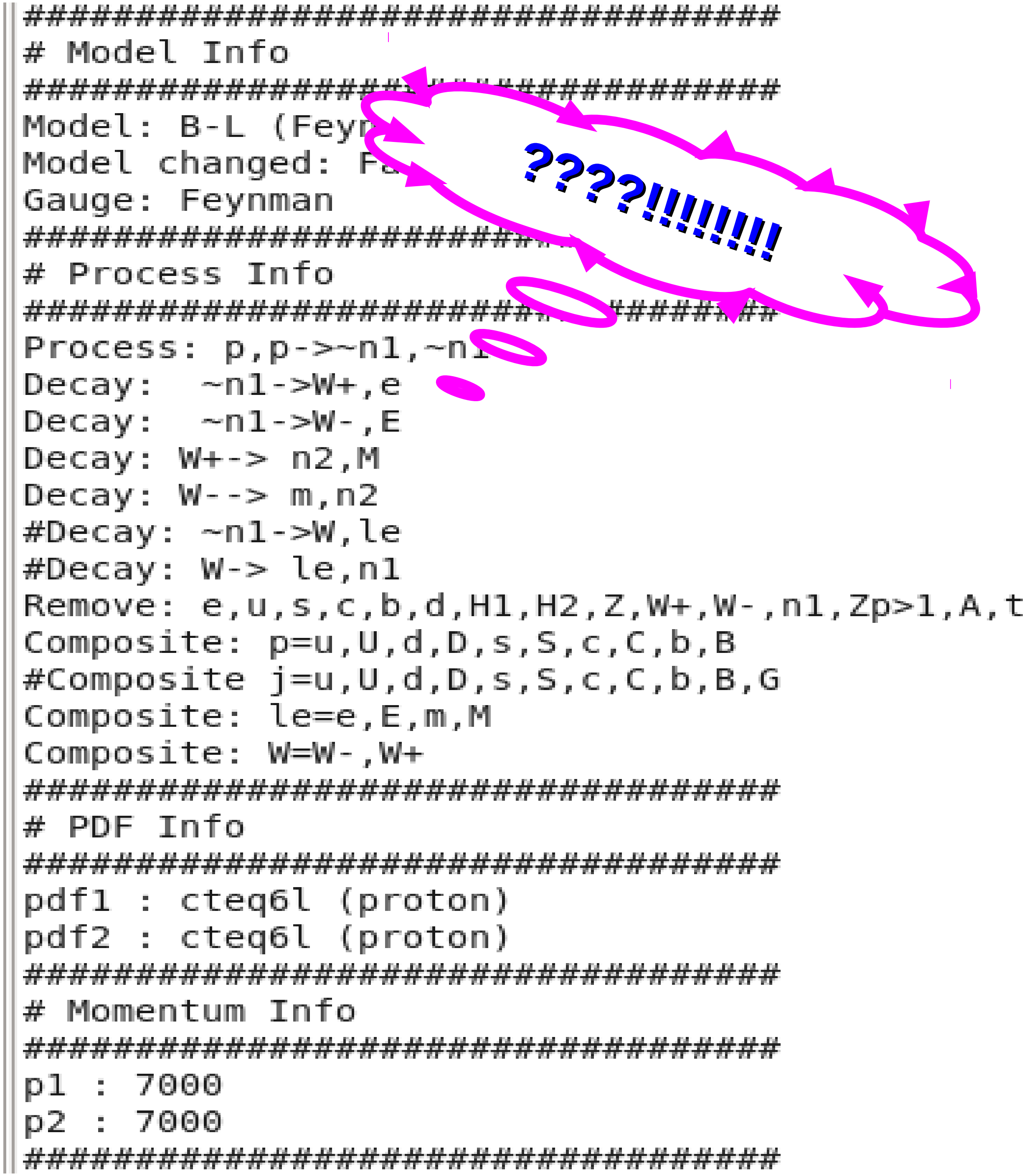
Which allows the user to run CalcHEP individual script by hand



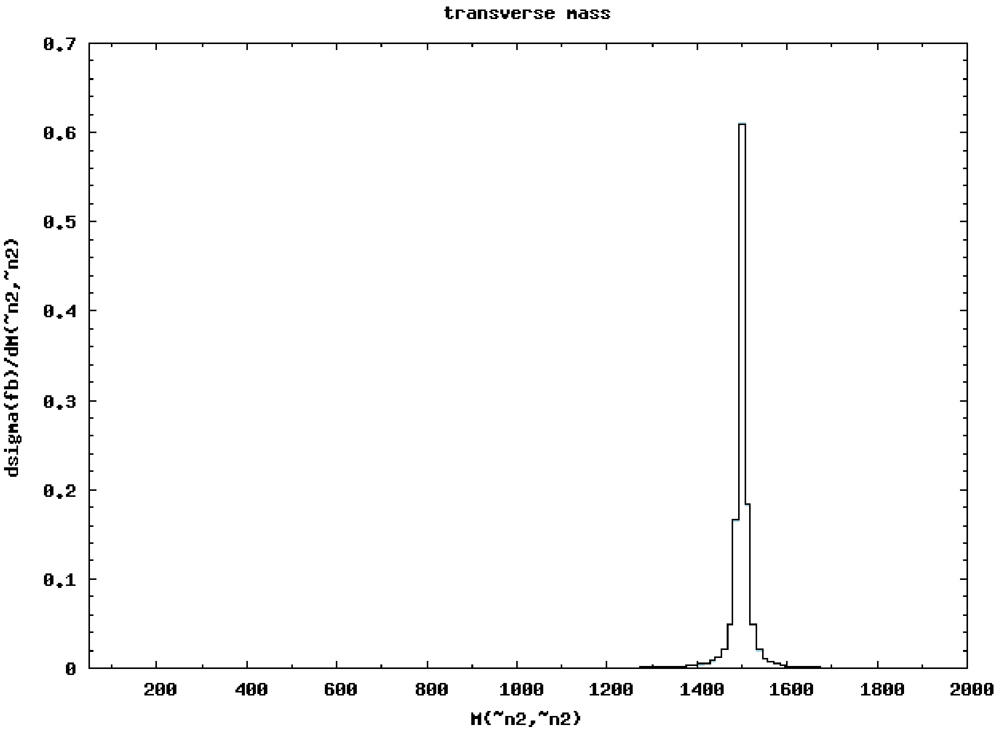
```
[root@localhost bin]# ls
calc         Int          mkLibstat     plot_view  s_calchep    subproc_cycle
event2lhe    lhe2tab      name_cycle    README     set_momenta  sum_distr
event_mixer  make_main    par_scan      run_batch  set_param
events2tab   make_VandP   par_scan_sum  run_vegas  set_vegas
gen_events   mkLibshared  pcm_cycle     s_blind    show_distr
[root@localhost bin]# 
```

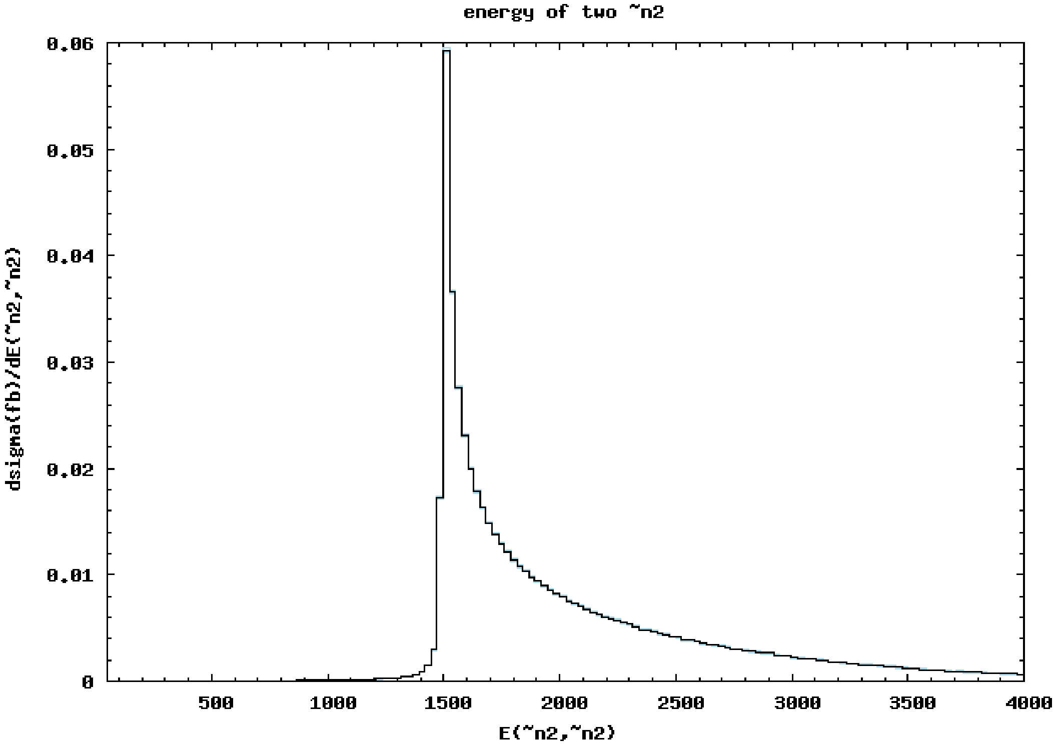
Note : you have to run this scripts from result directory

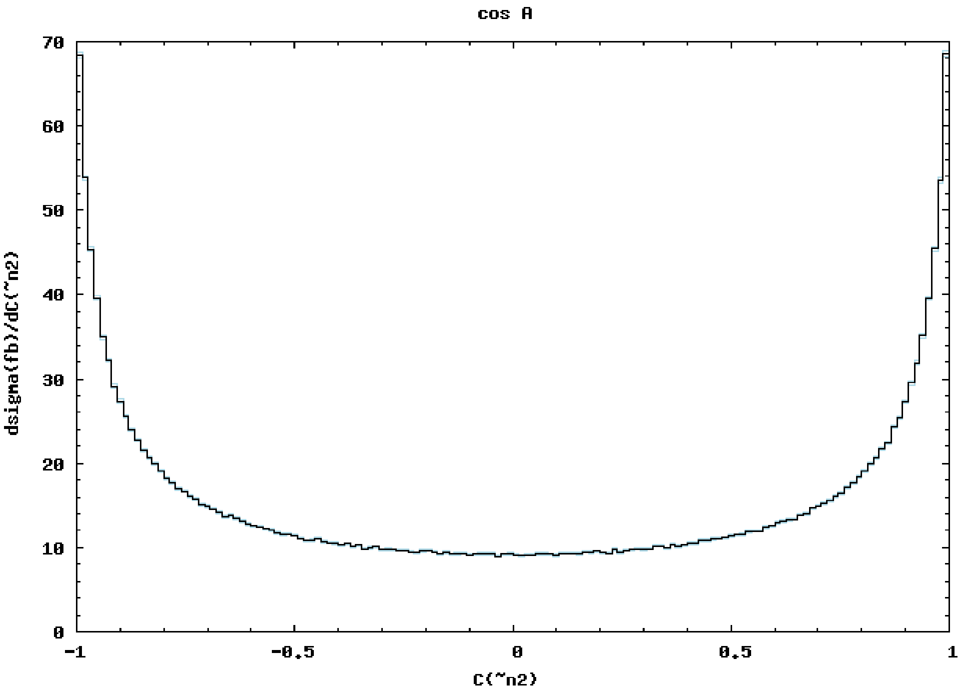
3- Batch mode



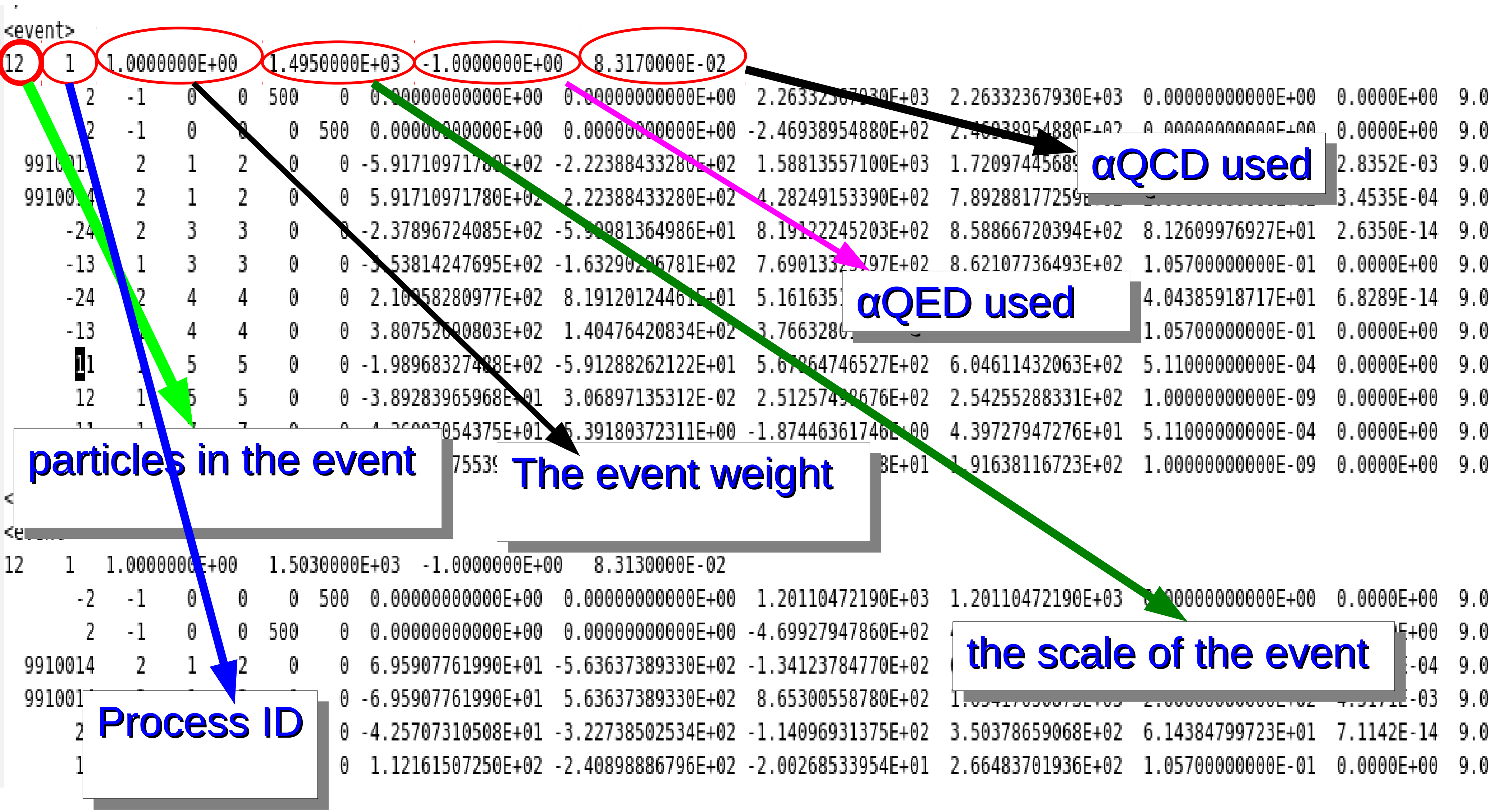
```
###################################
# Model Info
###################################
Model: B-L (Feyn
Model changed: Fa
Gauge: Feynman
#########################
# Process Info
###################################
Process: p,p->~n1,~n1
Decay:  ~n1->W+,e
Decay:  ~n1->W-,E
Decay: W+-> n2,M
Decay: W--> m,n2
#Decay: ~n1->W,le
#Decay: W-> le,n1
Remove: e,u,s,c,b,d,H1,H2,Z,W+,W-,n1,Zp>1,A,t
Composite: p=u,U,d,D,s,S,c,C,b,B
#Composite j=u,U,d,D,s,S,c,C,b,B,G
Composite: le=e,E,m,M
Composite: W=W-,W+
###################################
# PDF Info
###################################
pdf1 : cteq6l (proton)
pdf2 : cteq6l (proton)
###################################
# Momentum Info
###################################
p1 : 7000
p2 : 7000
###################################
```


transverse mass
dsigma(fb)/dM(~n2,~n2)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
200
400
600
800
1000
1200
1400
1600
1800
2000
M(~n2,~n2)


energy of two ~n2
dsigma(fb)/dE(~n2,~n2)
0.06
0.05
0.04
0.03
0.02
0.01
0
500
1000
1500
2000
2500
3000
3500
4000
E(~n2,~n2)


cos A
dsigma(fb)/dC(~n2)
70
60
50
40
30
20
10
0
-1
-0.5
0
0.5
1
C(~n2)

The out put of the CalcHEP **output.lhe**



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       2    -1     0     0     0   500  0.00000000000E+00  0.00000000000E+00 -2.46938954880E+02  2.46938954880E+02  0.00000000000E+00  0.0000E+00  9.0
 9910014     2     1     2     0     0 -5.91710971780E+02 -2.22388433280E+02  1.58813557100E+03  1.72097445689                     2.8352E-03  9.0
 9910014     2     1     2     0     0  5.91710971780E+02  2.22388433280E+02  4.28249153390E+02  7.89288177259                     3.4535E-04  9.0
     -24     2     3     3     0     0 -2.37896724085E+02 -5.90981364986E+01  8.19122245203E+02  8.58866720394E+02  8.12609976927E+01  2.6350E-14  9.0
     -13     1     3     3     0     0 -3.53814247695E+02 -1.63290206781E+02  7.69013323797E+02  8.62107736493E+02  1.05700000000E-01  0.0000E+00  9.0
     -24     2     4     4     0     0  2.10958280977E+02  8.19120124461E+01  5.161635                             4.04385918717E+01  6.8289E-14  9.0
     -13     1     4     4     0     0  3.80752690803E+02  1.40476420834E+02  3.766328                             1.05700000000E-01  0.0000E+00  9.0
      11     1     5     5     0     0 -1.98968327488E+02 -5.91288262122E+01  5.67864746527E+02  6.04611432063E+02  5.11000000000E-04  0.0000E+00  9.0
      12     1     5     5     0     0 -3.89283965968E+01  3.06897135312E-02  2.51257498676E+02  2.54255288331E+02  1.00000000000E-09  0.0000E+00  9.0
      11     1     7     7     0     0  4.36007054375E+01  5.39180372311E+00 -1.87446361746E+00  4.39727947276E+01  5.11000000000E-04  0.0000E+00  9.0
                                            75539                                       8E+01  1.91638116723E+02  1.00000000000E-09  0.0000E+00  9.0
<
<e
12     1   1.0000000E+00   1.5030000E+03  -1.0000000E+00   8.3130000E-02
      -2    -1     0     0     0   500  0.00000000000E+00  0.00000000000E+00  1.20110472190E+03  1.20110472190E+03  0.00000000000E+00  0.0000E+00  9.0
       2    -1     0     0   500     0  0.00000000000E+00  0.00000000000E+00 -4.69927947860E+02                                        E+00  9.0
 9910014     2     1     2     0     0  6.95907761990E+01 -5.63637389330E+02 -1.34123784770E+02                                        -04  9.0
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       2                              0 -4.25707310508E+01 -3.22738502534E+02 -1.14096931375E+02  3.50378659068E+02  6.14384799723E+01  7.1142E-14  9.0
       1                              0  1.12161507250E+02 -2.40898886796E+02 -2.00268533954E+01  2.66483701936E+02  1.05700000000E-01  0.0000E+00  9.0
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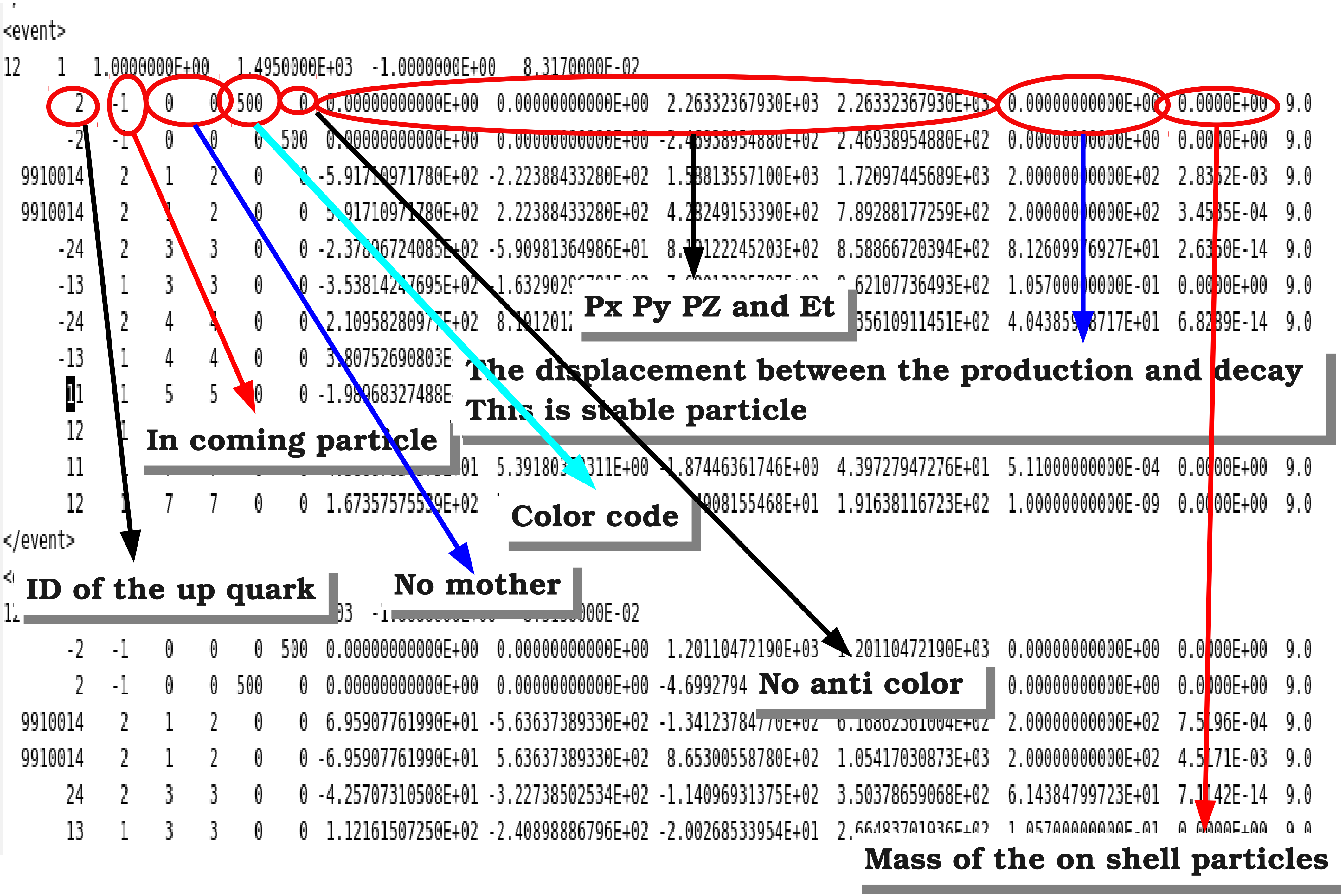

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       2   -1    0    0  500    0  0.00000000000E+00  0.00000000000E+00  2.26332367930E+03  2.26332367930E+03  0.00000000000E+00  0.0000E+00  9.0
      -2   -1    0    0    0  500  0.00000000000E+00  0.00000000000E+00 -2.46938954880E+02  2.46938954880E+02  0.00000000000E+00  0.0000E+00  9.0
  9910014    2    1    2    0    0 -5.91710971780E+02 -2.22388433280E+02  1.58813557100E+03  1.72097445689E+03  2.00000000000E+02  2.8352E-03  9.0
  9910014    2    1    2    0    0  5.91710971780E+02  2.22388433280E+02  4.28249153390E+02  7.89288177259E+02  2.00000000000E+02  3.4585E-04  9.0
     -24    2    3    3    0    0 -2.37806724085E+02 -5.90981364986E+01  8.10122245203E+02  8.58866720394E+02  8.12609976927E+01  2.6360E-14  9.0
     -13    1    3    3    0    0 -3.53814247695E+02 -1.632902                              62107736493E+02  1.05700000000E-01  0.0000E+00  9.0
     -24    2    4    4    0    0  2.10958280977E+02  8.191201                              35610911451E+02  4.04385978717E+01  6.8289E-14  9.0
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      11    1    5    5    0    0 -1.98968327488E
      12    1
      11    1                                   01  5.39180  311E+00 -1.87446361746E+00  4.39727947276E+01  5.11000000000E-04  0.0000E+00  9.0
      12    1    7    7    0    0  1.67357575539E+02                      908155468E+01  1.91638116723E+02  1.00000000000E-09  0.0000E+00  9.0
</event>
<
12                                 03  -1.                   00E-02
      -2   -1    0    0    0  500  0.00000000000E+00  0.00000000000E+00  1.20110472190E+03  1.20110472190E+03  0.00000000000E+00  0.0000E+00  9.0
       2   -1    0    0  500    0  0.00000000000E+00  0.00000000000E+00 -4.6992794                             0.00000000000E+00  0.0000E+00  9.0
  9910014    2    1    2    0    0  6.95907761990E+01 -5.63637389330E+02 -1.34123784770E+02  6.16862361004E+02  2.00000000000E+02  7.5196E-04  9.0
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      24    2    3    3    0    0 -4.25707310508E+01 -3.22738502534E+02 -1.14096931375E+02  3.50378659068E+02  6.14384799723E+01  7.1142E-14  9.0
      13    1    3    3    0    0  1.12161507250E+02 -2.40898886796E+02 -2.00268533954E+01  2.66483701936E+02  1.05700000000E-01  0.0000E+00  9.0
```

Px Py PZ and Et

The displacement between the production and decay
This is stable particle

In coming particle

Color code

ID of the up quark

No mother

No anti color

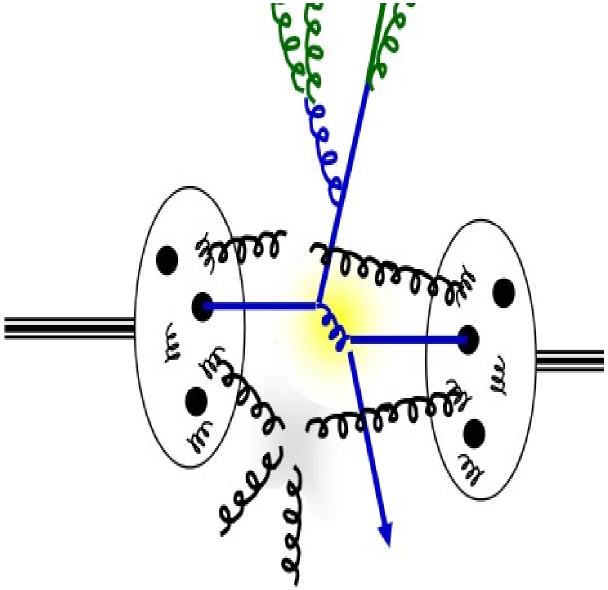
Mass of the on shell particles

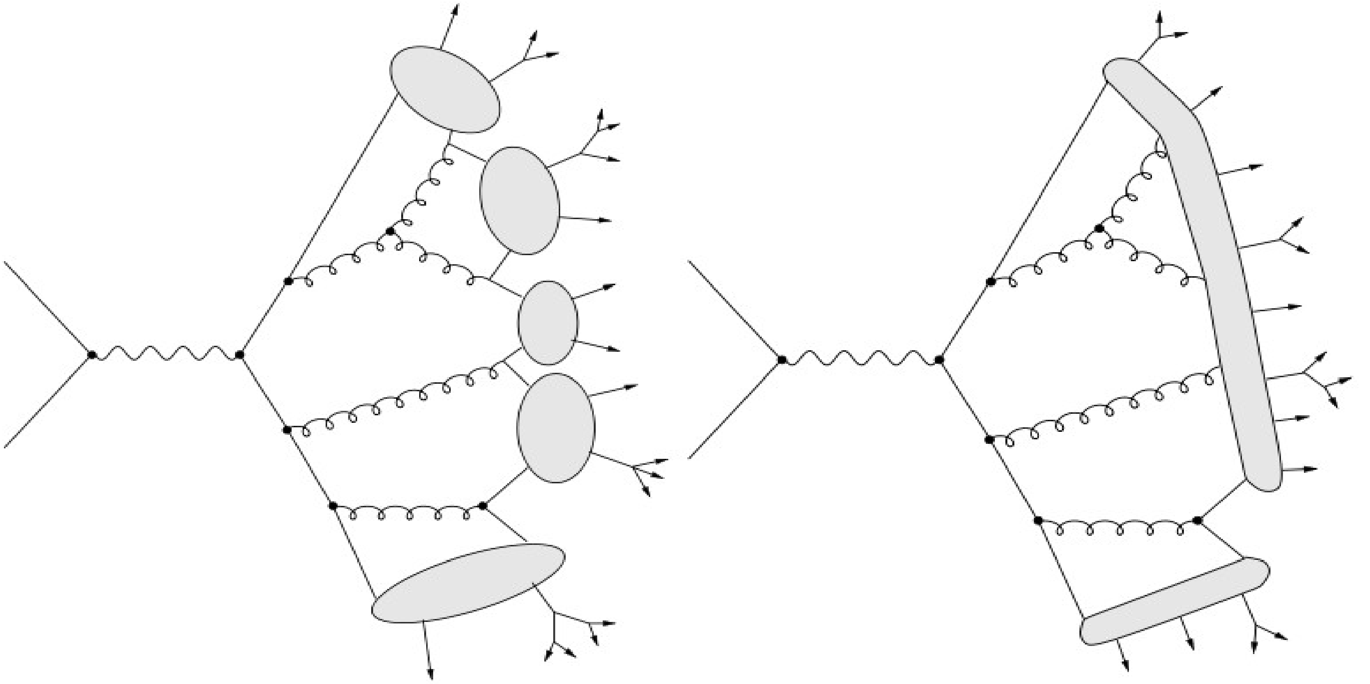
HF Generators

PYHTIA

Two common blocks are used to link pythia with ME generators

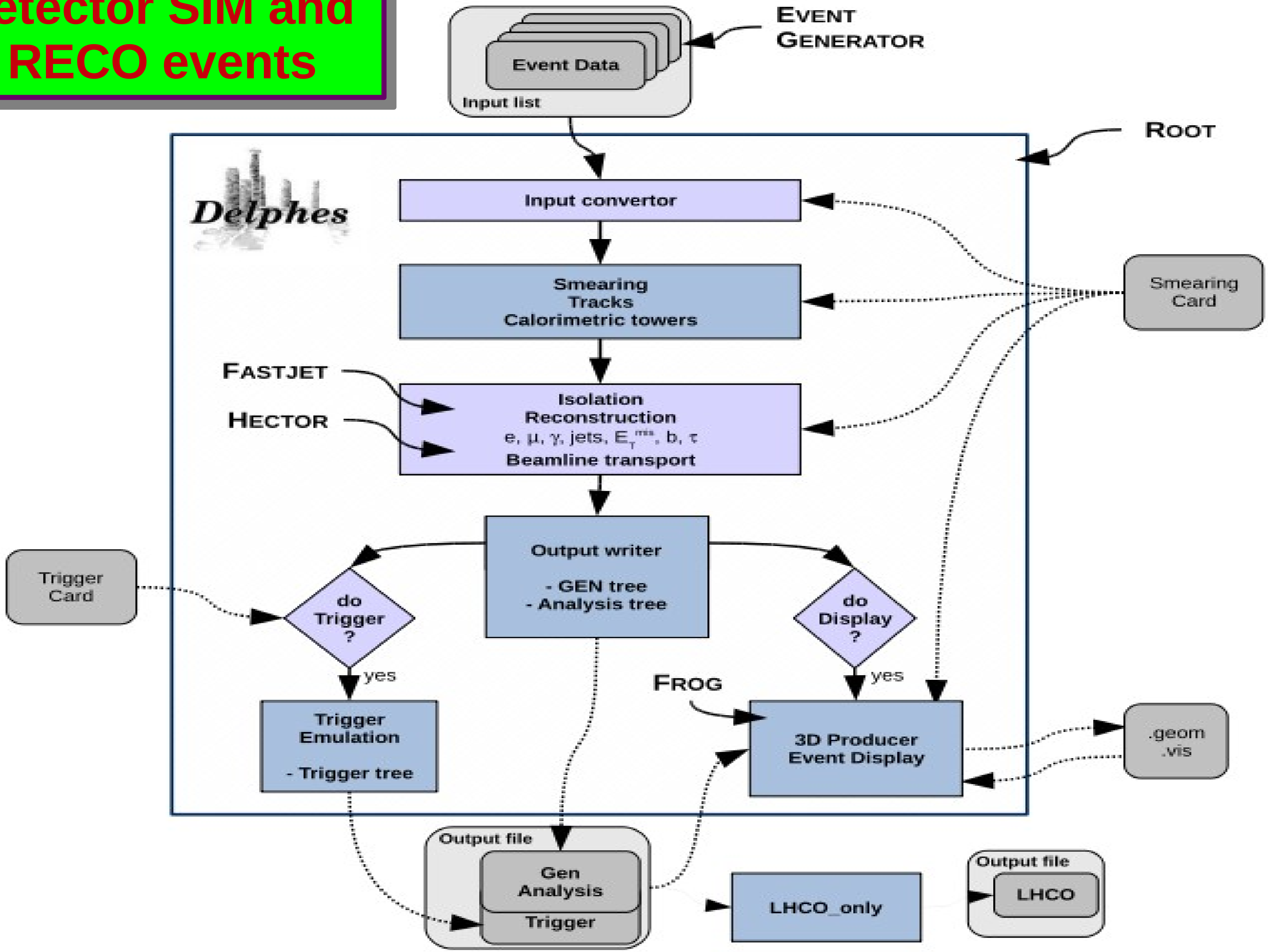
1-UPINT **2-UPEVENT**





Cluster and string hadronization models.

Detector SIM and RECO events



ROOT → **Sooooooon**

Conclusion

While the right handed neutrino interacts with SM gauge bosons only when, a very small mixing with the left handed one occurs .It be of O(-6), which affect the total cross section.Introducing a new See-Saw mechanism

“Inverse See-Saw”

where mixing factor O(0.1), So we expect the total cross section to increases by three time of magnitude , which means we then have a very predictive signal ....