Practical introduction to CalcHEP and HEPMDB

/High Energy Physics Model Database/

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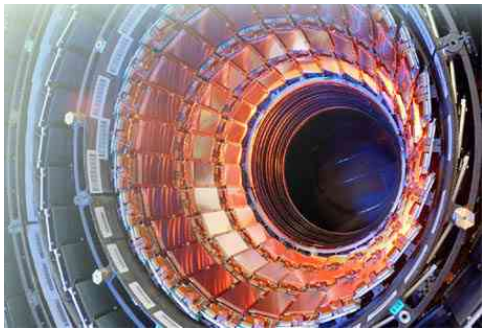
Calculations for Modern and Future Colliders

5th Helmholtz International Summer School – Workshop
Dubna International Advanced School of Theoretical Physics
July 23 - August 2, 2012, Dubna, Russia



OUTLINE

- ***CalcHEP***
  - ***models and symbolic session***
  - ***numerical session and kinematical distributions***
  - ***event generation***
  - ***CalcHEP Batch Interface and tutorial***

    arXiv:1207.6082

- ***High Energy Physics Model Database (HEPMDB)***
  - ***pre-History of HEPMDB and its idea***
  - ***HEPMD, present status and tutorial***
  - ***Future plans***

    arXiv:1203.1488 **(the last section of the Les Houches 2011 proceedings)**

Web pages & contacts

- ***The WEB page of CalcHEP***
  http://theory.npi.msu.su/~pukhov/calchep.html

- ***The HEPMDB page***
  http://hepmdb.soton.ac.uk

- ***e-mails***
  calchep@googlegroups.com
  hepmdb@soton.ac.uk
  a.belyaev@soton.ac.uk

CalcHEP

CalcHEP

was born as a CompHEP in 1989: MGU-89-63/140

- ***Author(s)***
  - ***Alexander Pukhov, AB, Neil Christensen***

    (AB and Neil Christensen have joined the project in 2009)
    http://theory.npi.msu.su/~pukhov/calchep.html
- ***Idea***
  - ***The effective study of HEP phenomenology passing at high level of automation from your favorite model to physical observables such as decay width, branching ratios, cross sections kinematic distributions, parton-level events, ...***
- ***Analogous packages*** ***(matrix element generators)***
  http://www.ippp.dur.ac.uk/montecarlo/BSM/
  - ***CompHEP (Boos et al)***
  - ***MadGraph/MadEvent (Maltoni, Stelzer)***
  - ***Grace/Helas (Fujimoto et al)***
  - ***FeynArts/FeynCalc/FormCalc (Hahn et al)***
  - ***WHIZARD,O'mega (Moretti, Ohl, Reuter)***
  - ***Sherpa (Krauss et al)***

Features/Limitations of CalcHEP

- ***Can evaluate any decay and scattering processes within any (user defined) model!***

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- ***Tree-level processes***
- ***Squared Matrix Element calculation***
  - ***no spin information for outgoing particles – spin averaged amplitude***

Features/Limitations of CalcHEP

- ***Can evaluate any decay and scattering processes within any (user defined) model!***

- ***Tree-level processes***
- ***Squared Matrix Element calculation***
  - ***no spin information for outgoing particles – spin averaged amplitude***
- ***Limit on number of external legs (involved particles) and number of diagrams***
  - ***official limit – 8 , unofficial – none***
  - ***limit is set from the practical point of view:***
    - **2 → 6 (1→7) set the essential time/memory limit**
    - **number of diagrams ~ 500 set the disk space and the time limit**

http://theory.npi.msu.su/~pukhov/calchep.html

CalcHEP - a package for calculation of Feynman diagrams and integration over multi-particle phase space.

Authors - Alexander Pukhov, Alexander Belyaev, Neil Christensen

The main idea in CalcHEP was to enable one to go directly from the Lagrangian to the cross sections and distributions effectively, with the high level of automation. The package can be compiled on any Unix platform.

General information
Main facilities , Old Versions , Acknowledgments News&Bugs

Manual
calchep_man_3.3.6.pdf (manual for version 3.3.6, July 19, 2012)
HEP computer tools (Lecture by Alexander Belyaev)
See also: Dan Green, High Pt physics at hadron colliders (Cambrige University Press)

Codes download.
Licence Installation References&Contributions
CalcHEP code for UNIX: version 3.4.0 (July 26, 2012)

Models:
MSSM(24.06.2011) NMSSM23(07.05.2011) CPVMSSM(03.05.2012) LeptoQuarks
Universal Extra Dimension Models: 5DSM 6DSM SUSY models for CompHEP By A.Semenov

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Relative packages on Web:
Packages for model generation: LanHEP FeynRules
RGE and spectrum calculation: SuSpect Isajet SoftSUSY SPheno CPsuperH NMHDecay
Particle widths in MSSM: SDECAY HDECAY
Parton showers: PYTHIA

Email contact: **calchep@googlegroups.com**

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manual is updated!

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new version and writeup!
arXiv:1207.6082

Models:
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Quick start with CalcHEP: practical notes on the installation

- ***Download code, read manual and compile***
  http://theory.npi.msu.su/~pukhov/calchep.html
  - **tar -zxvf calchep_3.*x.x*.tgz**
  - **cd calchep_3.*x.x***
  - **make**

    the current version is 3.*x.x* = 3.4.0
- **Create work directory**
  - **From calchep_3.*x.x* directory (e.g. ../calc_work)**

  ./mkUsrDir *../calc_work*
- **Supported operating system**
  - **Linux, IRIX, IRIX64, HP-UX, OSF1, SunOS, Darwin, CYGWIN**

    (see *getFlags* file)

Exercise#1: Install CalcHEP

Starting CalcHEP

- **cd ../calc_work**

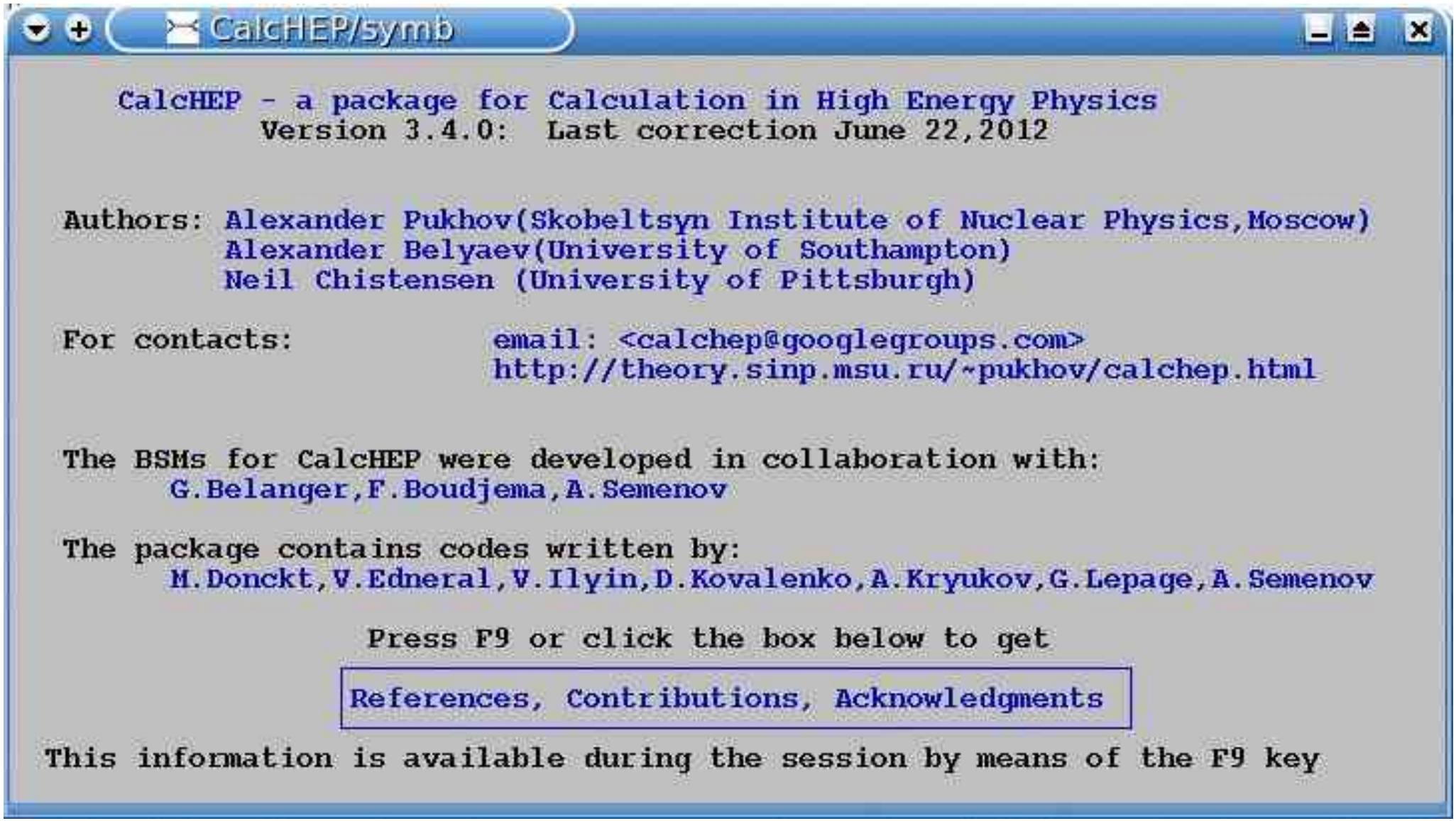
- ***Files:***

bin -> ..... /calchep_3.x.x/bin
calchep
calchep_batch
calchep.ini
models/
results/
tmp/

- ***Start:***

./calchep

Starting CalcHEP



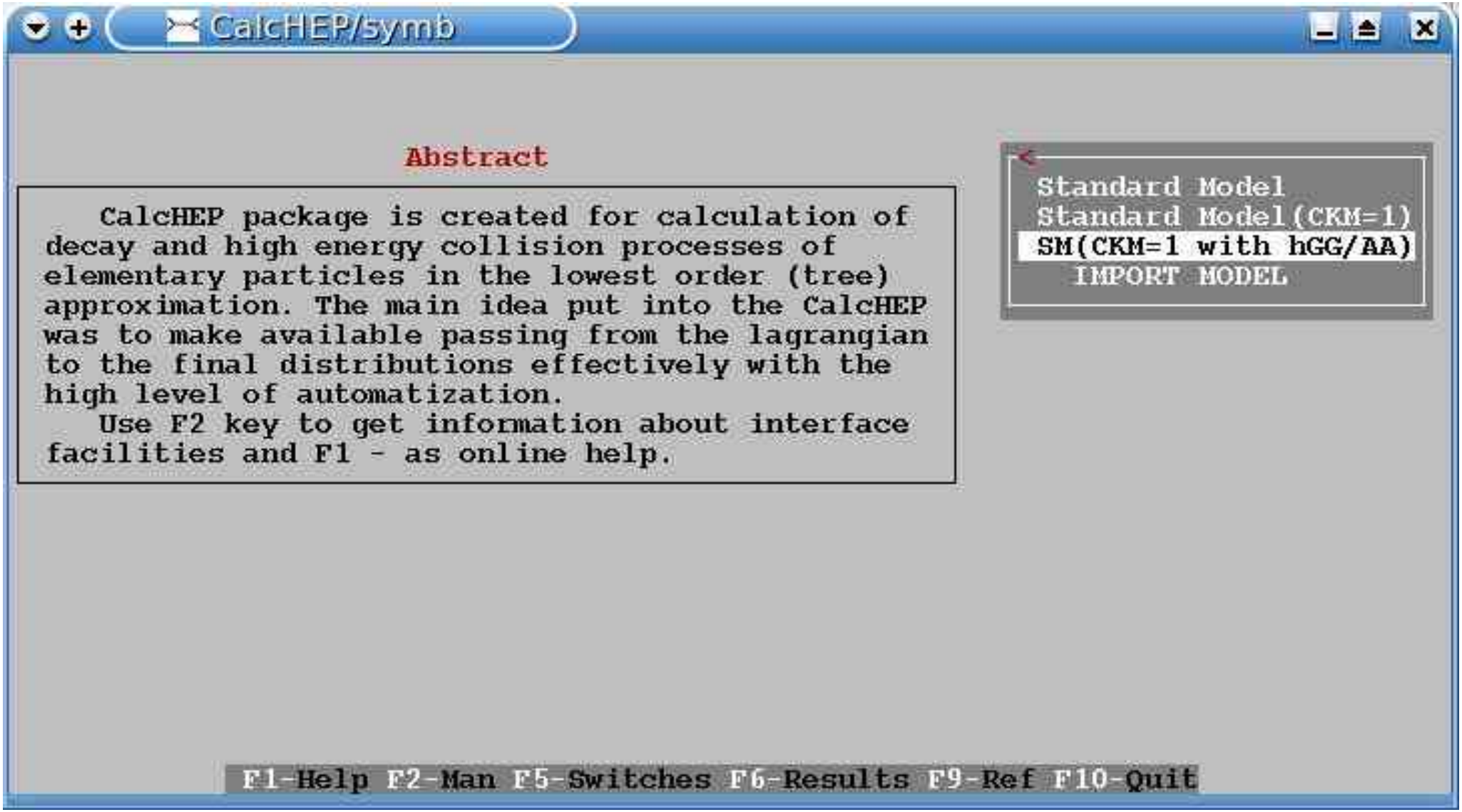
Principle KEYS for CalcHEPs GUI

Enter menu selection (forward)

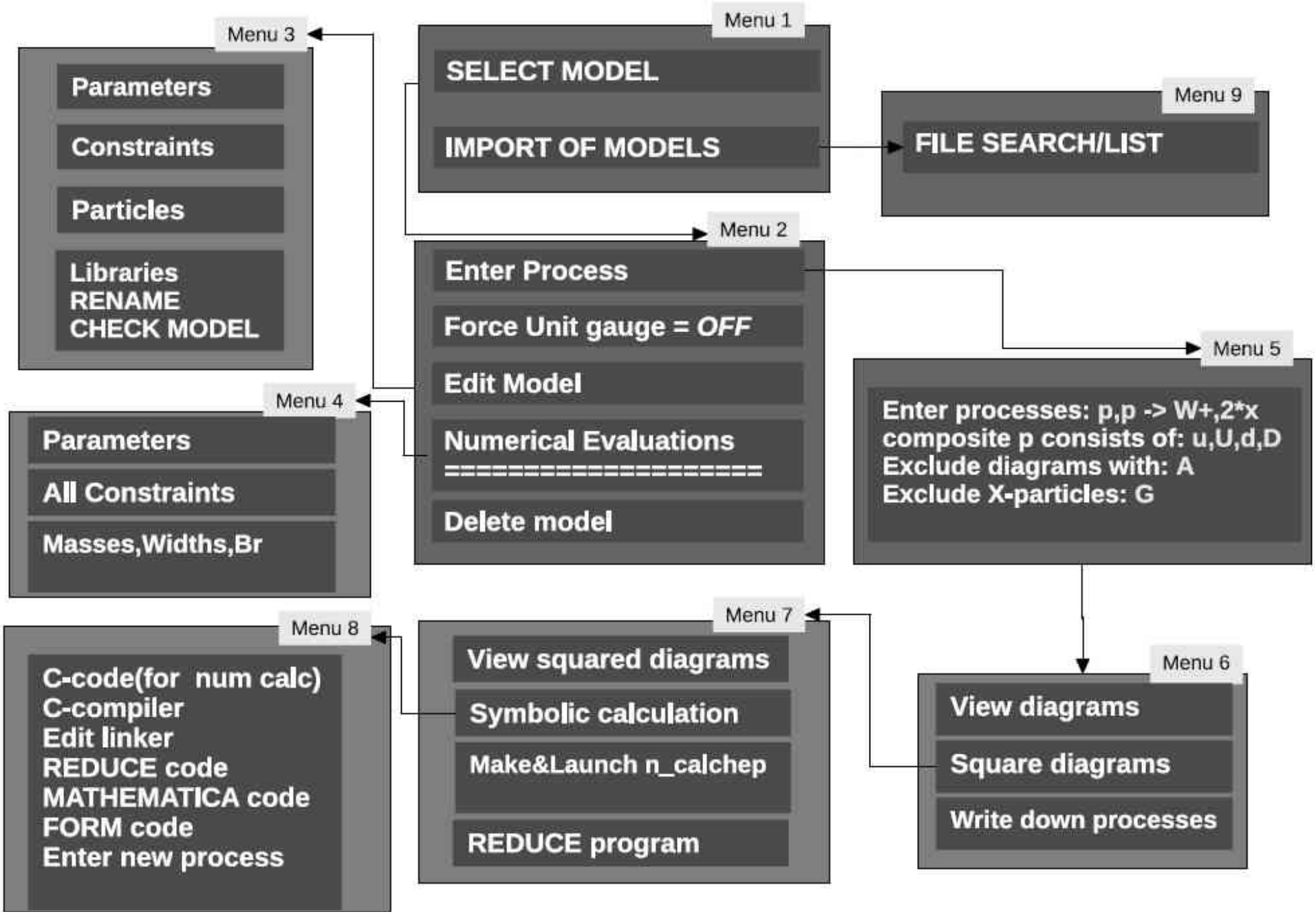
Exit menu selection (back)

Help!

Starting CalcHEP



CalcHEP menu structure: symbolic part



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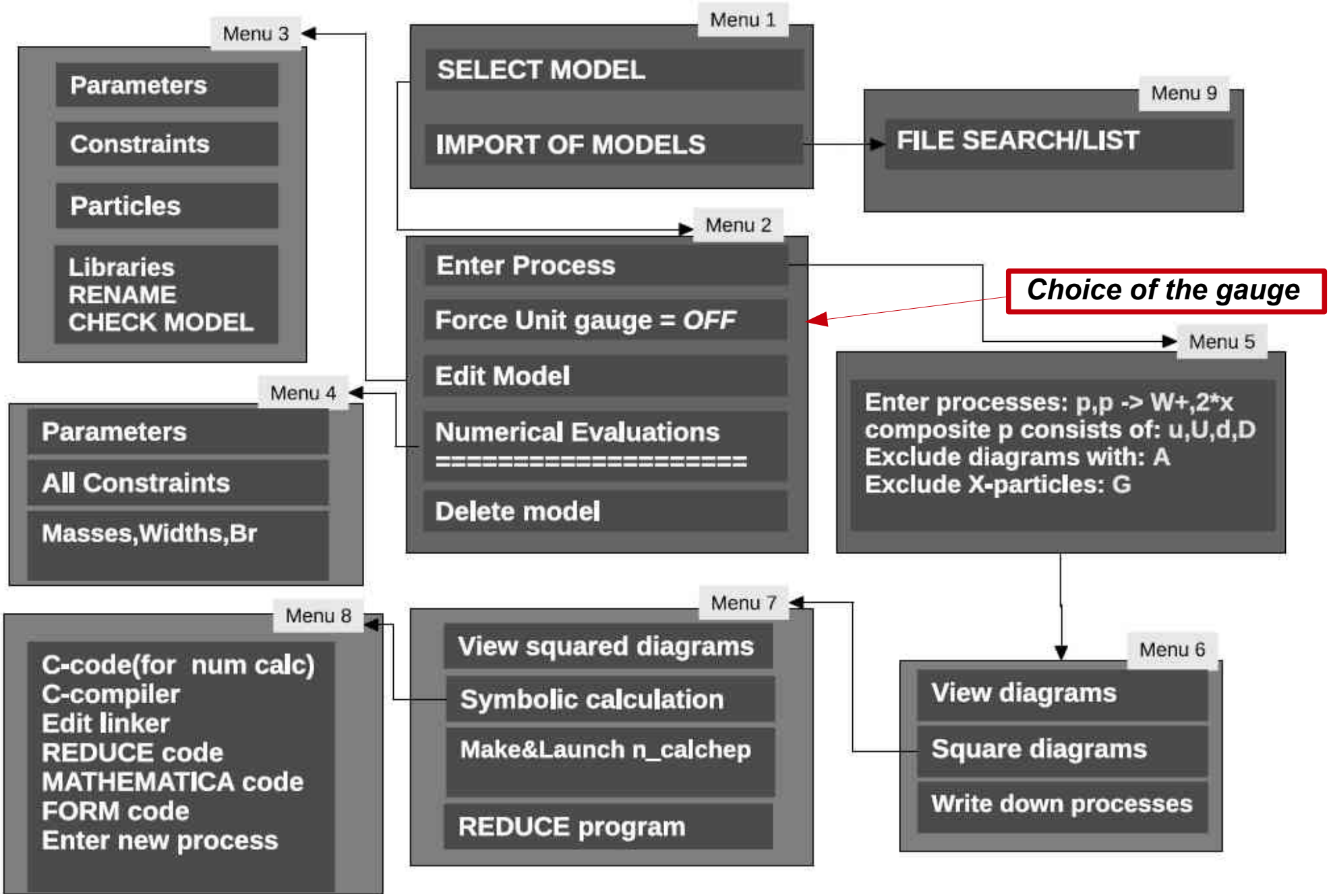
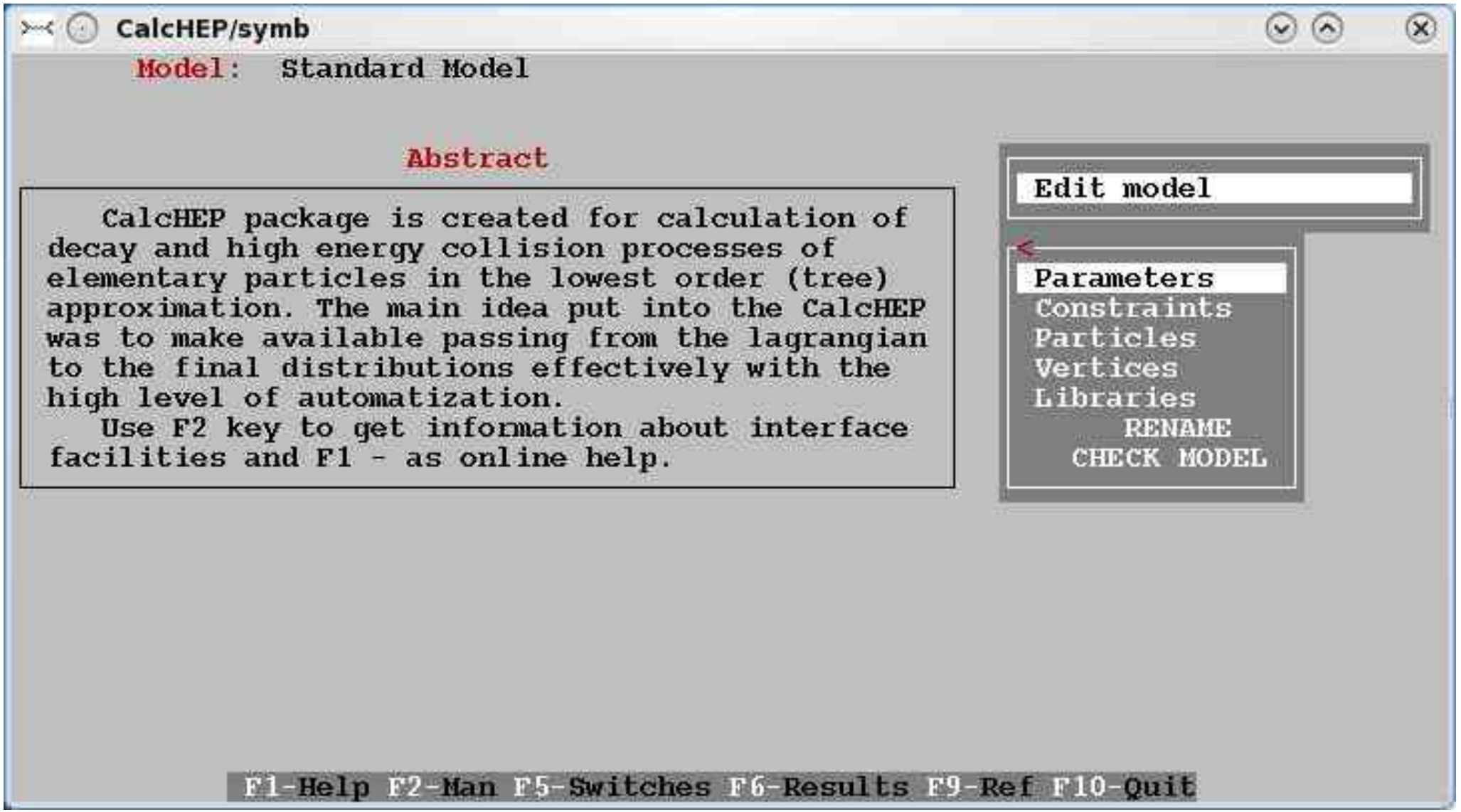


Model Structure

Parameters ***Constraints***
Particles ***Vertices***



Particles: prtcl*xx*.mdl (spins 0,1/2,1,3/2,2)

CalcHEP/symb

Particles

Clr Del Size Read ErrMes

Full name	A	A+	number	2*spin	mass	width	color	aux	>LaTex(A)<	>LaTeX(A+)
gluon	G	G	21	2	0	0	8	G	g	g
photon	A	A	22	2	0	0	1	G	\gamma	\gamma
Z-boson	Z	Z	23	2	MZ	wZ	1	G	Z	Z
W-boson	W+	W-	24	2	MW	wW	1	G	W^+	W^-
Higgs	h	h	25	0	Mh	!wh	1		h	h
electron	e	E	11	1	0	0	1		e^-	e^+
e-neutrino	ne	Ne	12	1	0	0	1	L	\nu_e	\bar{\nu}_e
muon	m	M	13	1	Mm	0	1		\mu^-	\mu^+
m-neutrino	nm	Nm	14	1	0	0	1	L	\nu_\mu	\bar{\nu}_\mu
tau-lepton	l	L	15	1	Ml	0	1		\tau^-	\tau^-
t-neutrino	nl	Nl	16	1	0	0	1	L	\nu_\tau	\bar{\nu}_\tau
d-quark	d	D	1	1	0	0	3		d	\bar{d}
u-quark	u	U	2	1	0	0	3		u	\bar{u}
s-quark	s	S	3	1	Ms	0	3		s	\bar{s}
c-quark	c	C	4	1	Mc	0	3		c	\bar{c}
b-quark	b	B	5	1	Mb	0	3		b	\bar{b}
t-quark	t	T	6	1	Mt	wt	3		t	\bar{t}

F1 F2 Xgoto Ygoto Find Write

Particles: prtcl*xx*.mdl

CalcHEP/symb

Particles

Clr Del Size Read ErrMes

Full name	A	A+	number	2*spin	mass	width	color	aux	>LaTex(A)<	>LaTeX(A+)
gluon	G	G	21	2	0	0	8	G	g	g
photon	A	A	22	2	0	0	1	G	\gamma	\gamma
Z-boson	Z	Z	23	2	MZ	wZ	1	G	Z	Z
W-boson	W+	W-	24	2	MW	wW	1	G	W^+	W^-
Higgs	h	h	25	0	Mh	!wh	1		h	h
electron	e	E	11	1	0	0	1		e^-	e^+
e-neutrino	ne	Ne	12	1	0	0	1	L	\nu_e	\bar{\nu}_e
muon	m	M	13	1	Mm	0	1		\mu^-	\mu^+
m-neutrino	nm	Nm	14	1	0	0	1	L	\nu_\mu	\bar{\nu}_\mu
tau-lepton	l	L	15	1	Ml	0	1		\tau^-	\tau^-
t-neutrino	nl	Nl	16	1	0	0	1	L	\nu_\tau	\bar{\nu}_\tau
d-quark	d	D	1	1	0	0	3		d	\bar{d}
u-quark	u	U	2	1	0	0	3		u	\bar{u}
s-quark	s	S	3	1	Ms	0	3		s	\bar{s}
c-quark	c	C	4	1	Mc	0	3		c	\bar{c}
b-quark	b	B	5	1	Mb	0	3		b	\bar{b}
t-quark	t	T	6	1	Mt	wt	3		t	\bar{t}

F1 F2 Xgoto Ygoto Find Write

Higgs boson width will be calculated `on the fly`

Independent parameters: vars*xx*.mdl

CalcHEP/symb

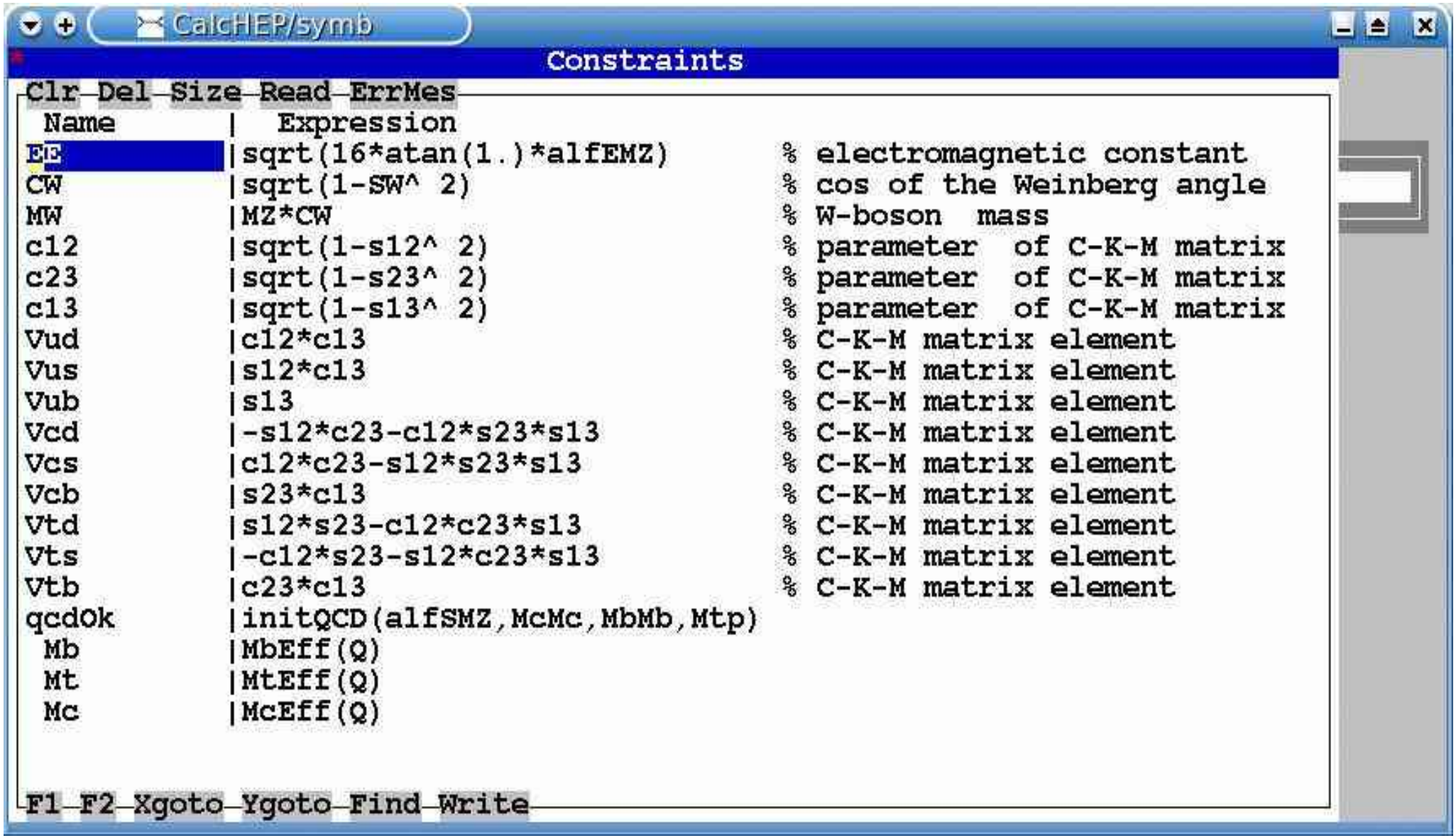
Parameters 1

Clr Del Size Read ErrMes

Name	Value	> Comment
alfEMZ	0.0078180608	MS-BAR electromagnetic alpha(MZ)
alfSMZ	0.1172	Srtong alpha(MZ) for running mass calculation
Q	100	scale for running mass calculation
GG	1.238	Running Strong coupling. The given value doesn't matter.
SW	0.481	MS-BAR sine of the electroweak mixing angle
s12	0.221	Parameter of C-K-M matrix (PDG96)
s23	0.041	Parameter of C-K-M matrix (PDG96)
s13	0.0035	Parameter of C-K-M matrix (PDG96)
Mm	0.1057	muon mass
Ml	1.777	tau-lepton mass
McMc	1.2	Mc(Mc)
Ms	0	s-quark mass (pole mass, PDG96)
MbMb	4.25	Mb(Mb)
Mtp	175	t-quark pole mass
MZ	91.187	Z-boson mass
Mh	120	higgs mass
wt	1.59	t-quark width (tree level 1->2x)
wZ	2.49444	Z-boson width (tree level 1->2x)
wW	2.08895	W-boson width (tree level 1->2x)

F1 F2 Xgoto Ygoto Find Write

Dependent parameters(constraints): funcxx.mdl



Feynman rules: lgrng*xx*.mdl

CalcHEP/symb

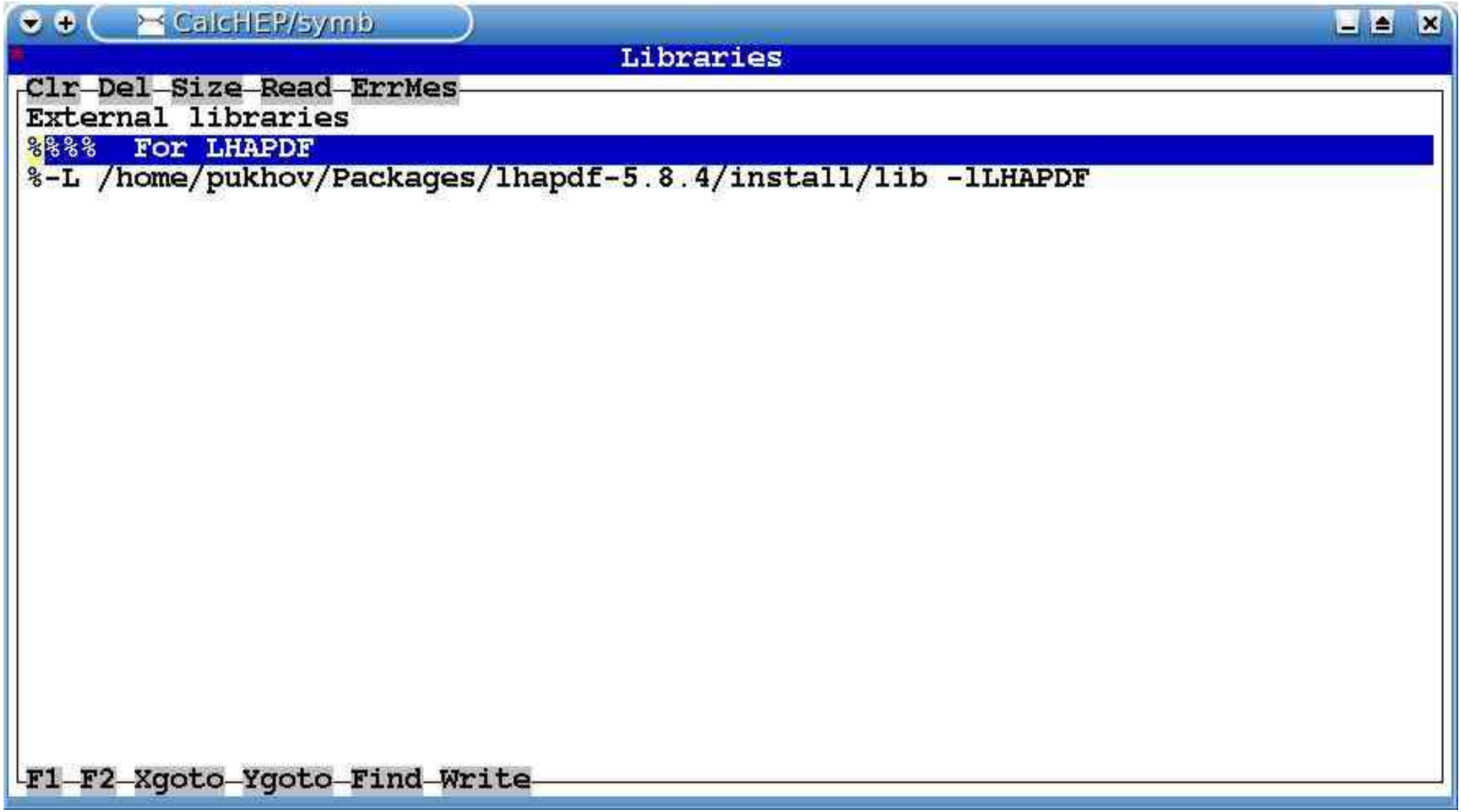
Vertices

Clr Del Size Read ErrMes

A1	A2	A3	A4	> Factor <	> Lorentz part
h	W+	W-		EE*MW/SW	m2.m3
h	Z	Z		EE/(SW*CW^ 2)*MW	m2.m3
h	h	h		-(3/2)*EE*Mh^ 2/(MW*SW)	1
h	h	h	h	(-3/4)*(EE*Mh/(MW*SW))^ 2	1
h	h	Z	Z	(1/2)*(EE/(SW*CW))^ 2	m3.m4
h	h	W+	W-	(1/2)*(EE/SW)^ 2	m3.m4
M	m	h		-EE*Mm/(2*MW*SW)	1
L	l	h		-EE*Ml /(2*MW*SW)	1
C	c	h		-EE*Mc/(2*MW*SW)	1
S	s	h		-EE*Ms/(2*MW*SW)	1
B	b	h		-EE*Mb/(2*MW*SW)	1
T	t	h		-EE*Mt /(2*MW*SW)	1
E	e	A		-EE	G(m3)
M	m	A		-EE	G(m3)
L	l	A		-EE	G(m3)
Ne	e	W+		EE/(2*Sqrt2*SW)	G(m3)*(1-G5)
Nm	m	W+		EE/(2*Sqrt2*SW)	G(m3)*(1-G5)
Nl	l	W+		EE/(2*Sqrt2*SW)	G(m3)*(1-G5)
E	ne	W-		EE/(2*Sqrt2*SW)	G(m3)*(1-G5)
M	nm	W-		EE/(2*Sqrt2*SW)	G(m3)*(1-G5)
L	nl	W-		EE/(2*Sqrt2*SW)	G(m3)*(1-G5)

F1 F2 Xgoto Ygoto Find Write

External Libraries: extlib*xx*.mdl



Details of symbolic session

- ***the input syntax:*** `P1[,P2] -> P3,P4 [,,...,[N*x]]`

- ***hadron/composite particle scattering***

  'p,p->W+,b,B'

  unknown particle are assumed to be composite:

  'p' consists of u,U,d,D,s,S,c,C,b,B,G

- ***wild cards/names for outgoing particles***

  'H -> 2*x'

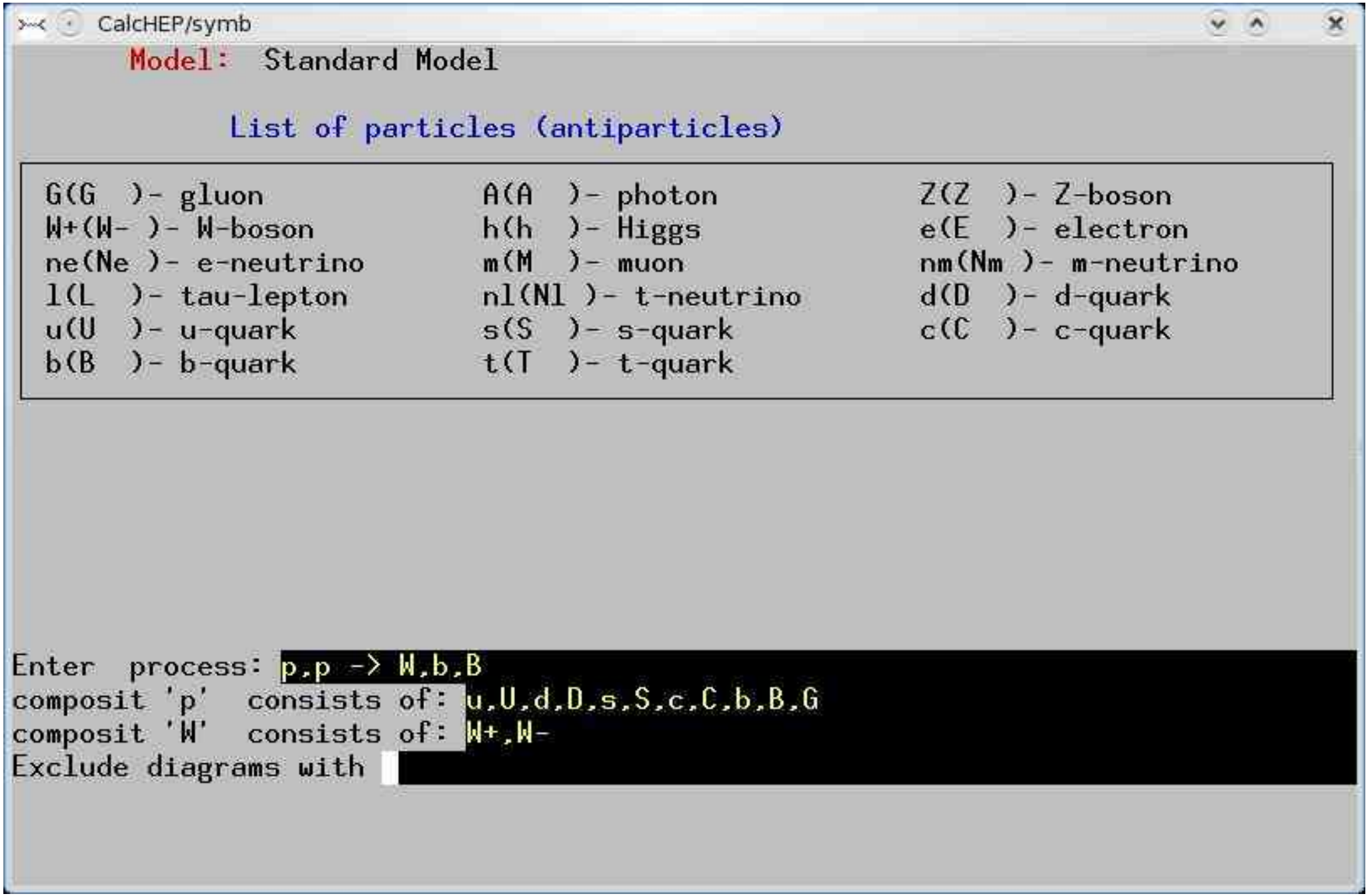
- ***intermediate particles can be non-trivially excluded***

  'W+ > 2, A>1, Z>3'

Exercise#2

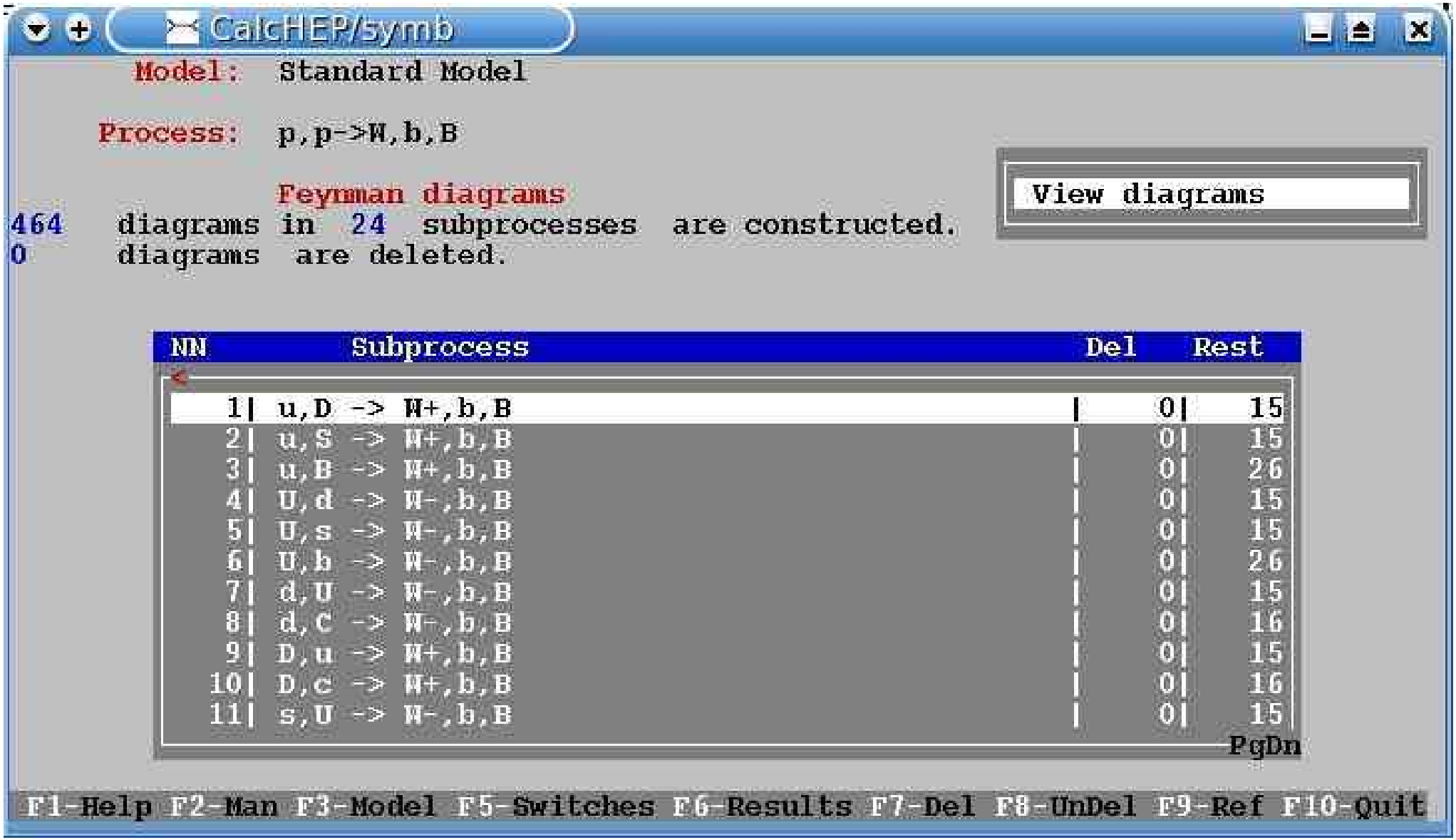
calculate SM Higgs boson Decay width and branching ratios as a function of Higgs boson mass

Symbolic session (1)

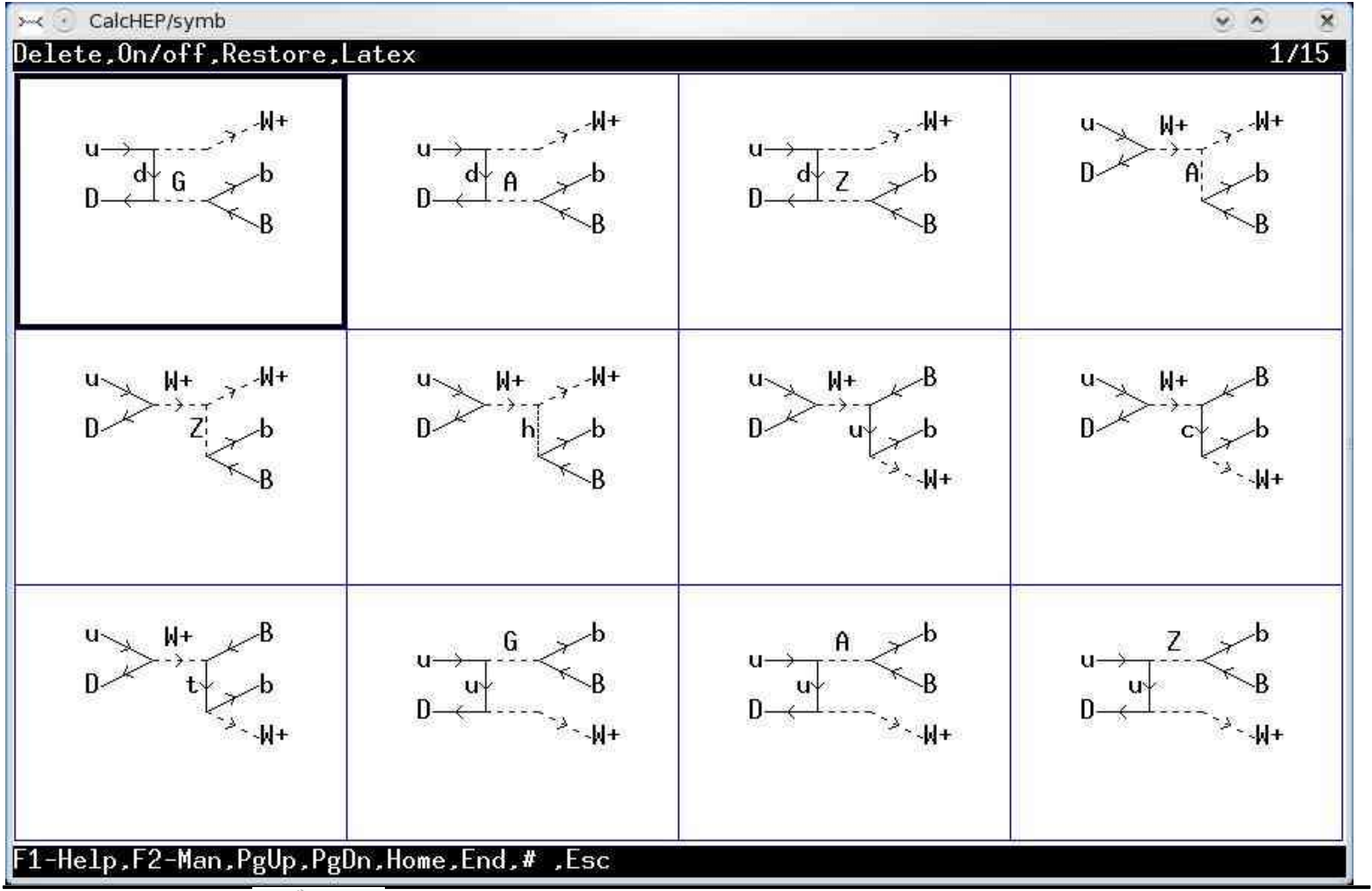


Symbolic session (2)

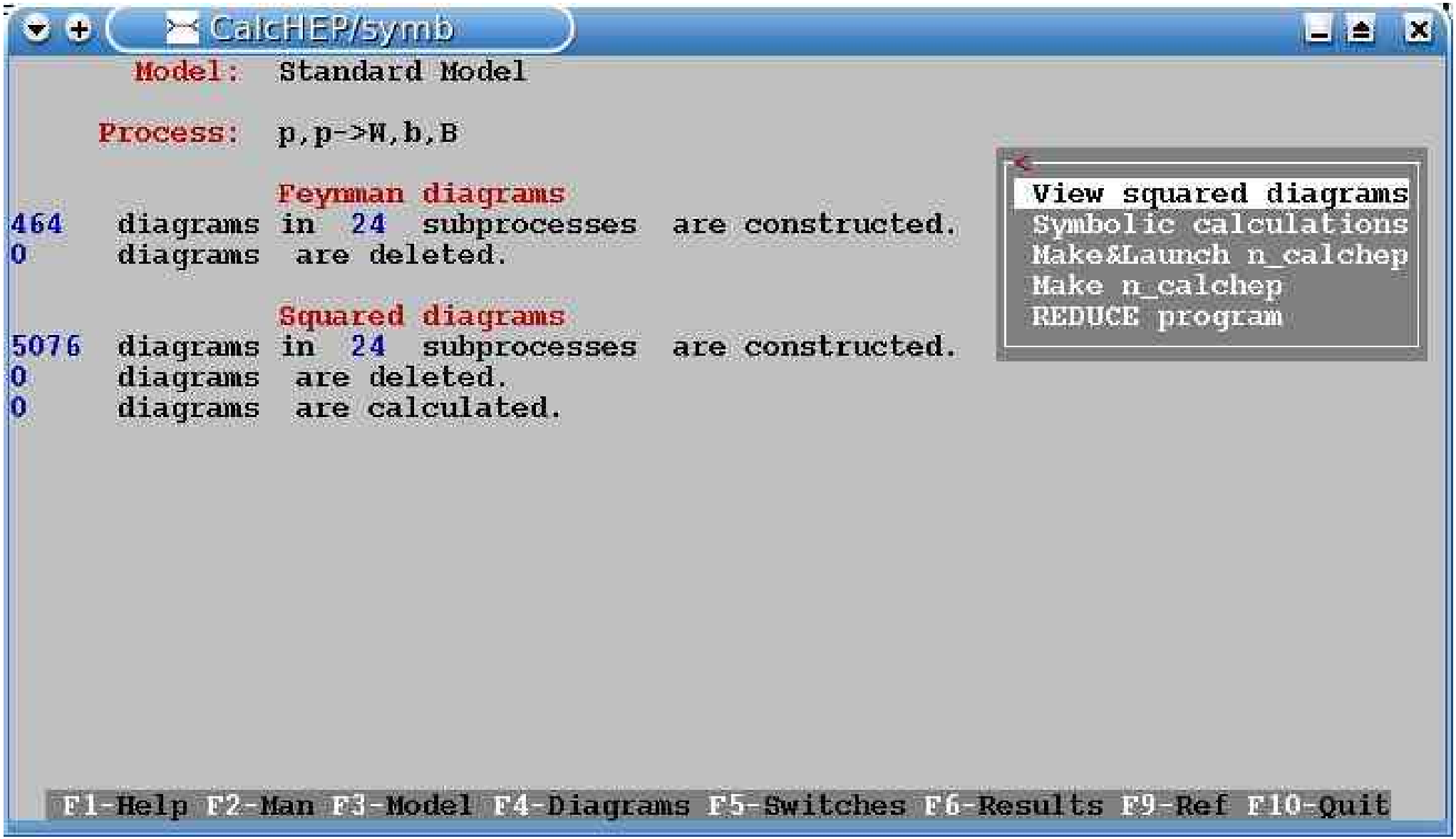
Symbolic session (3)



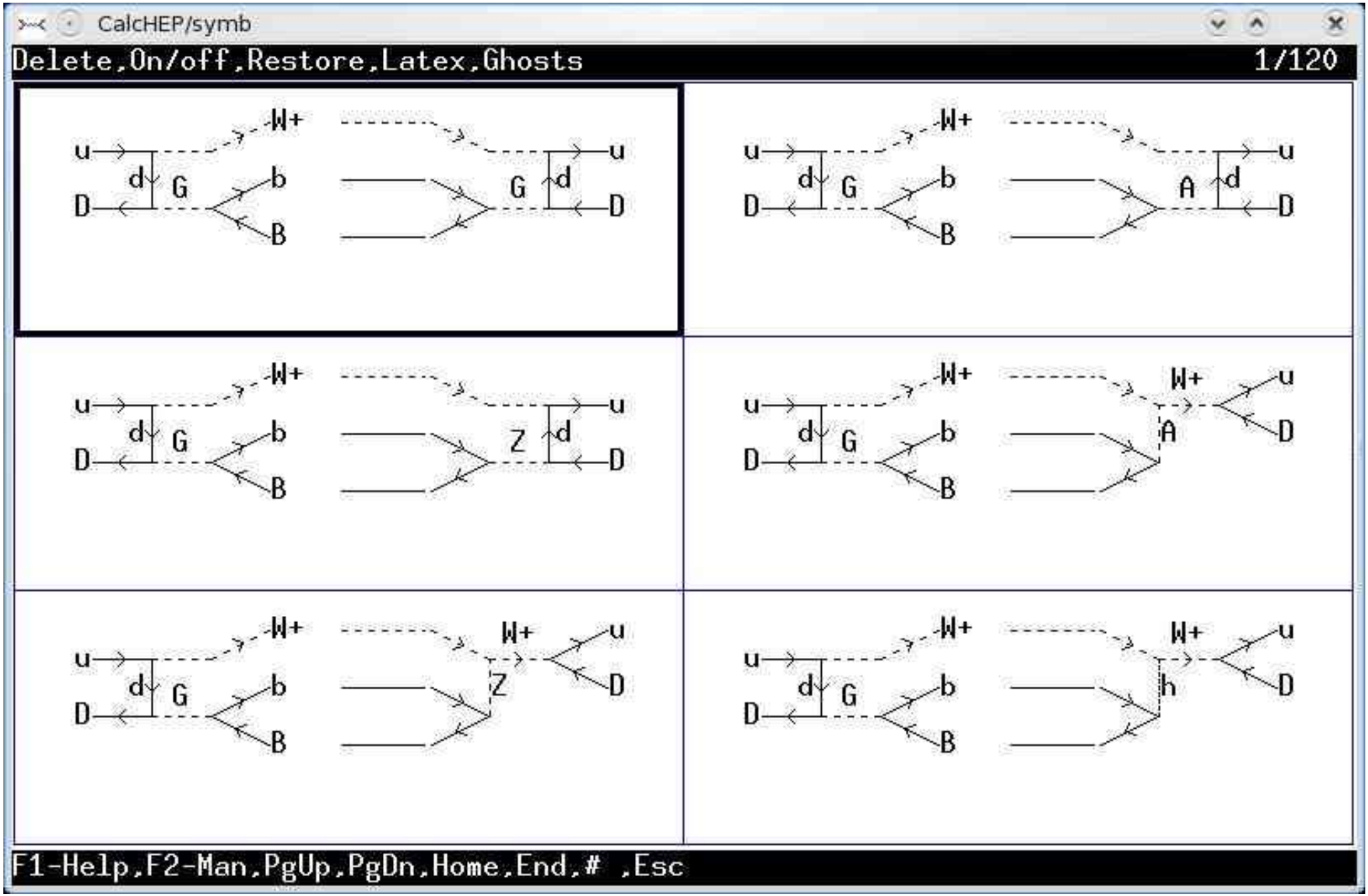
Symbolic session (4)



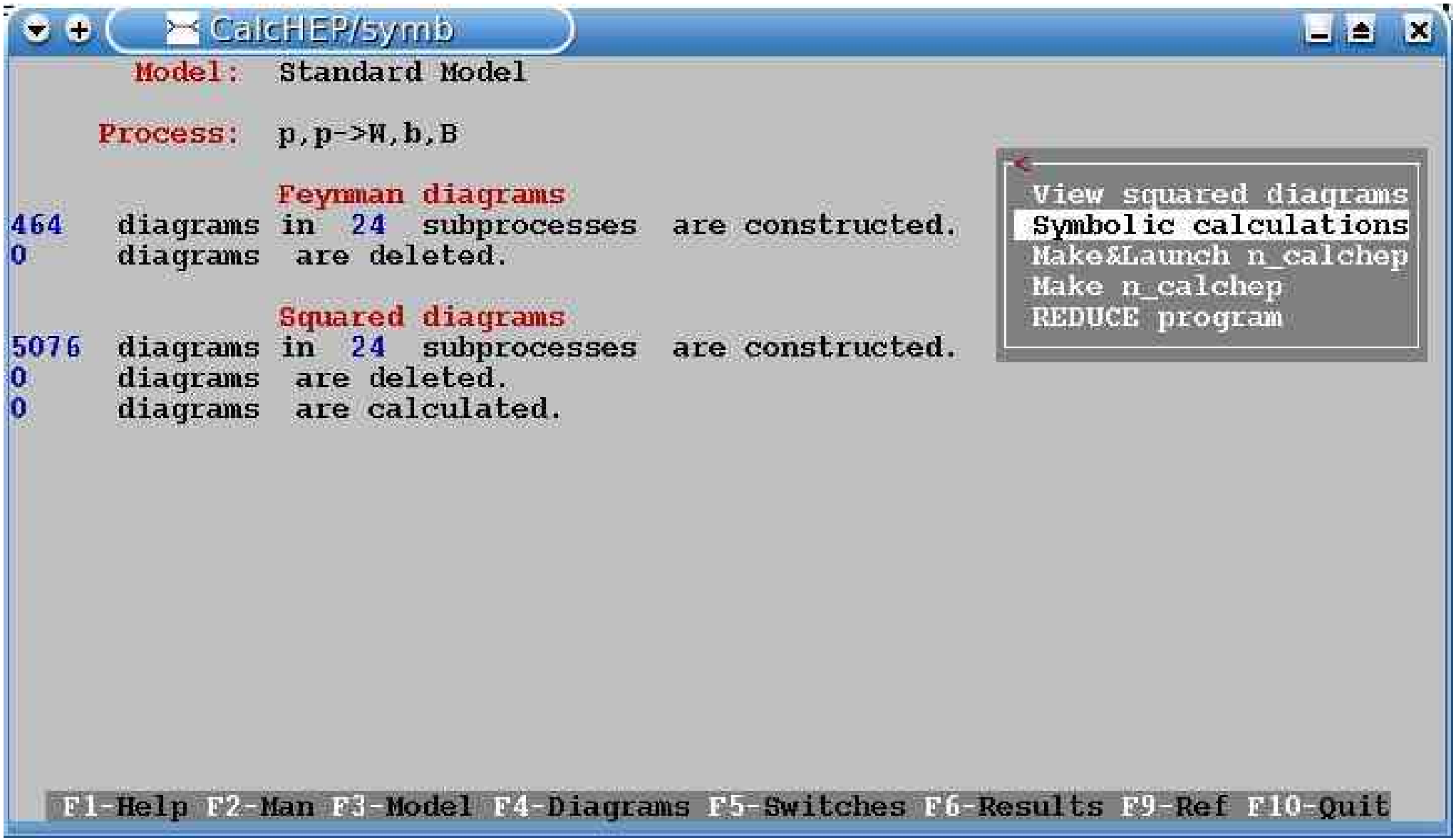
Symbolic session (5)



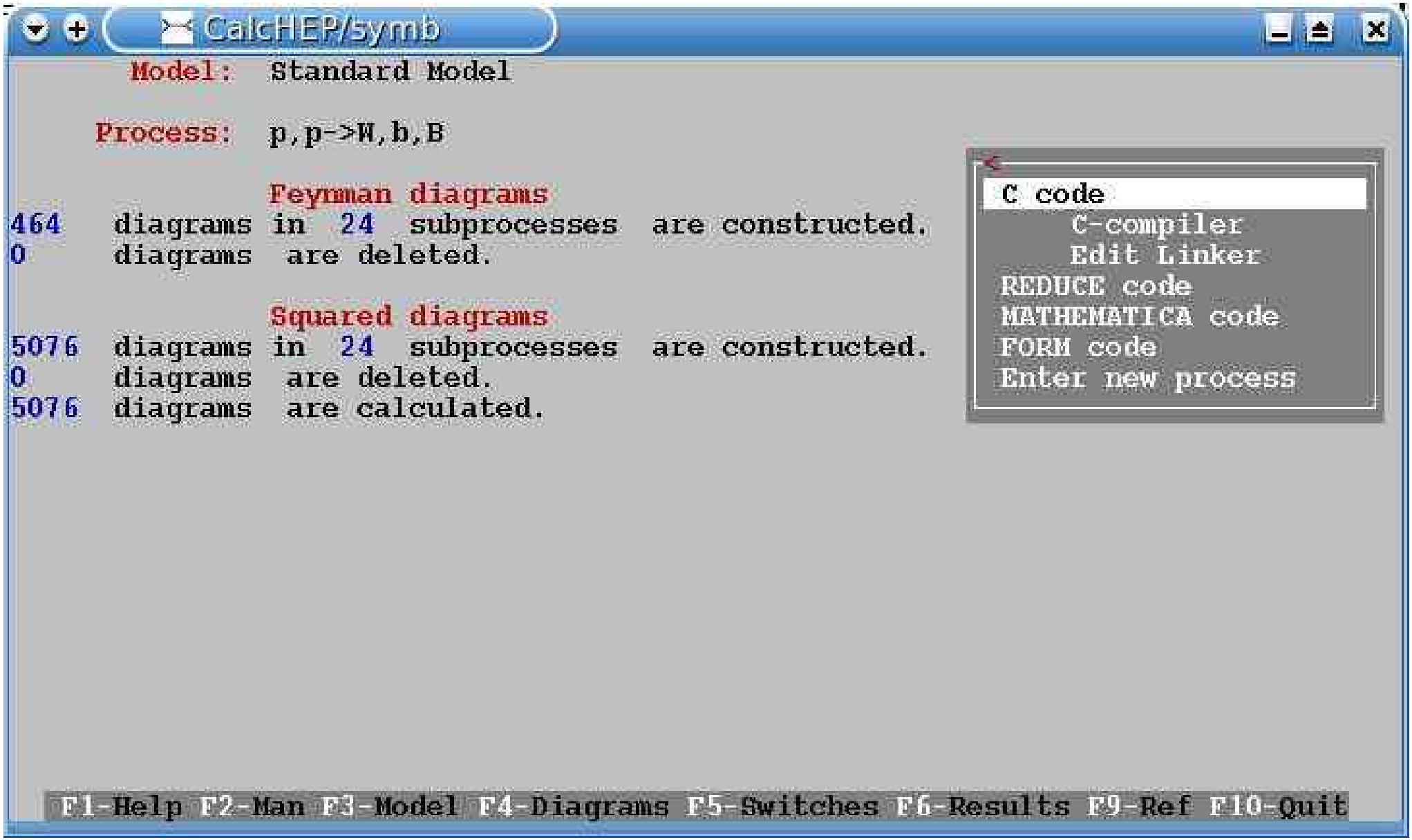
Symbolic session (6)



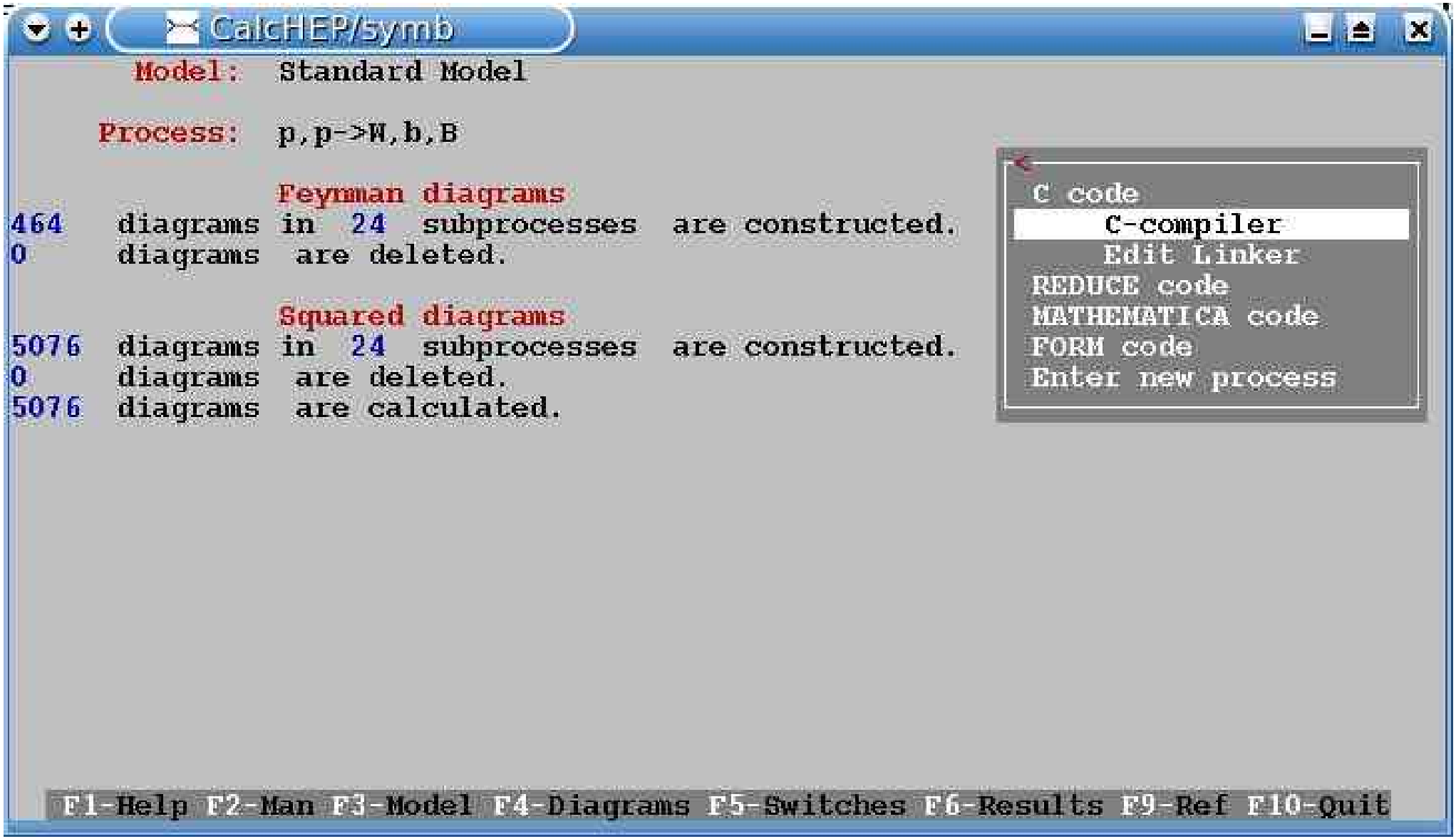
Symbolic session (7)



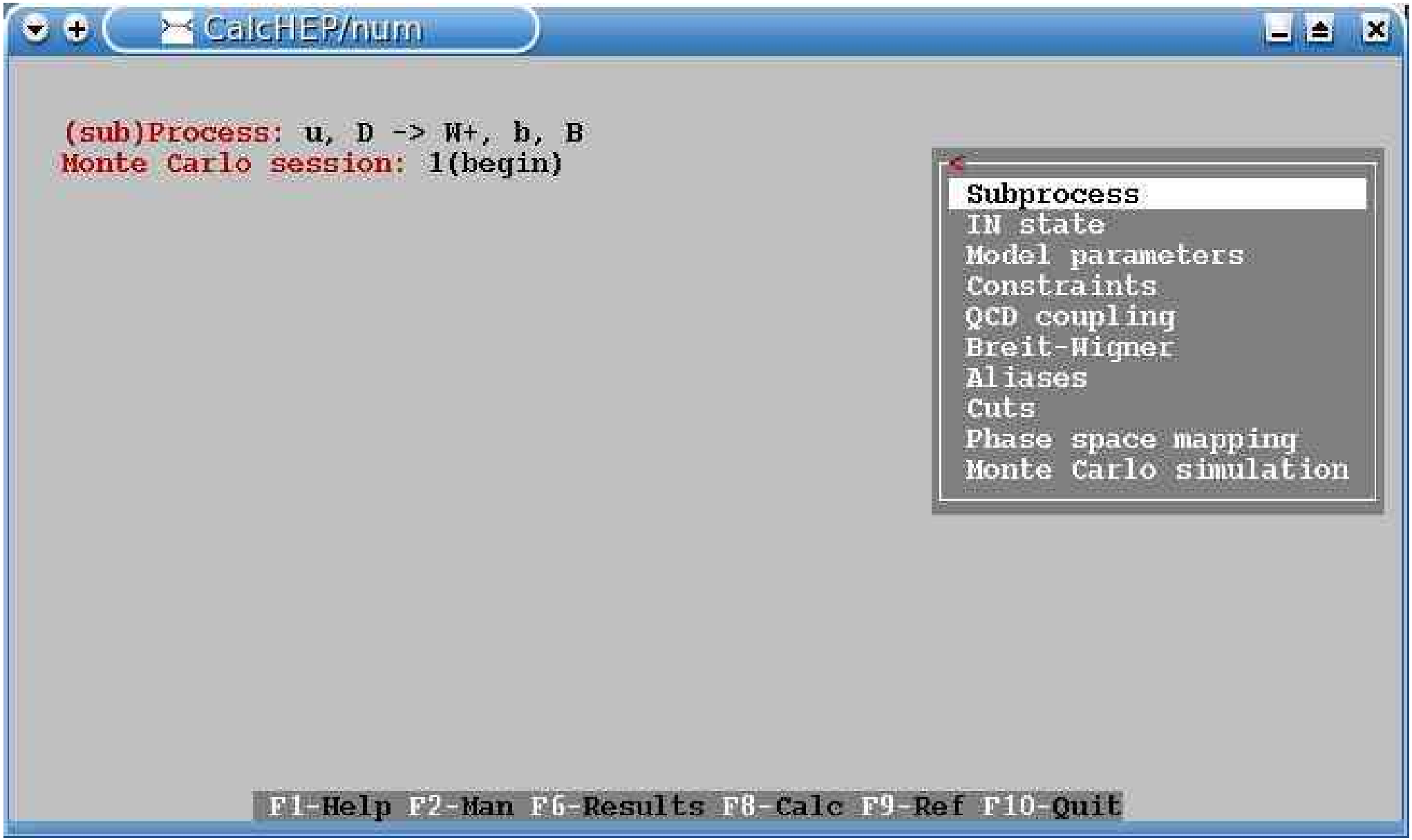
Symbolic session (8)



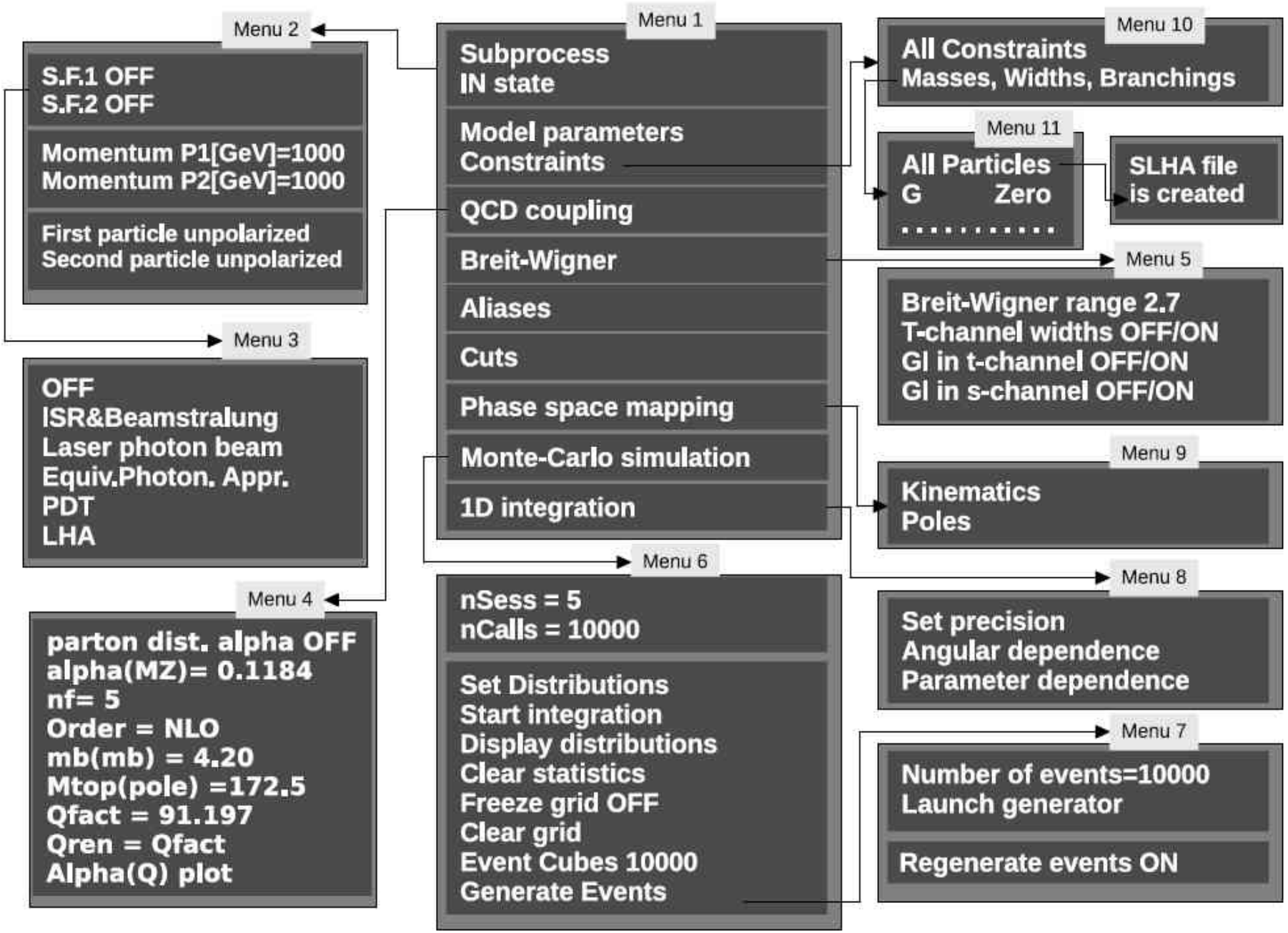
Symbolic session (9)



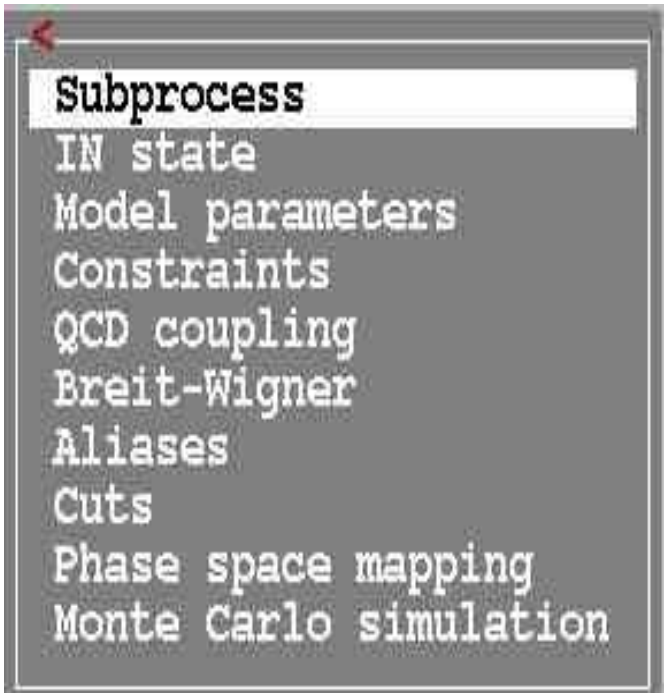
Numerical part of CalcHEP

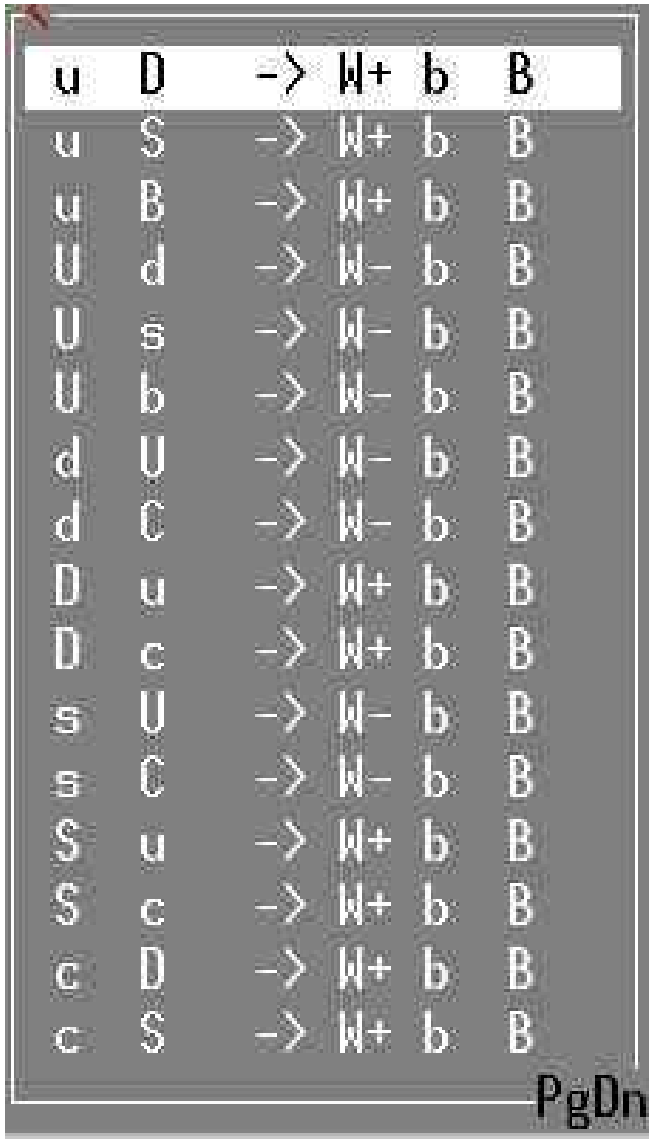


Menu structure of the numerical part



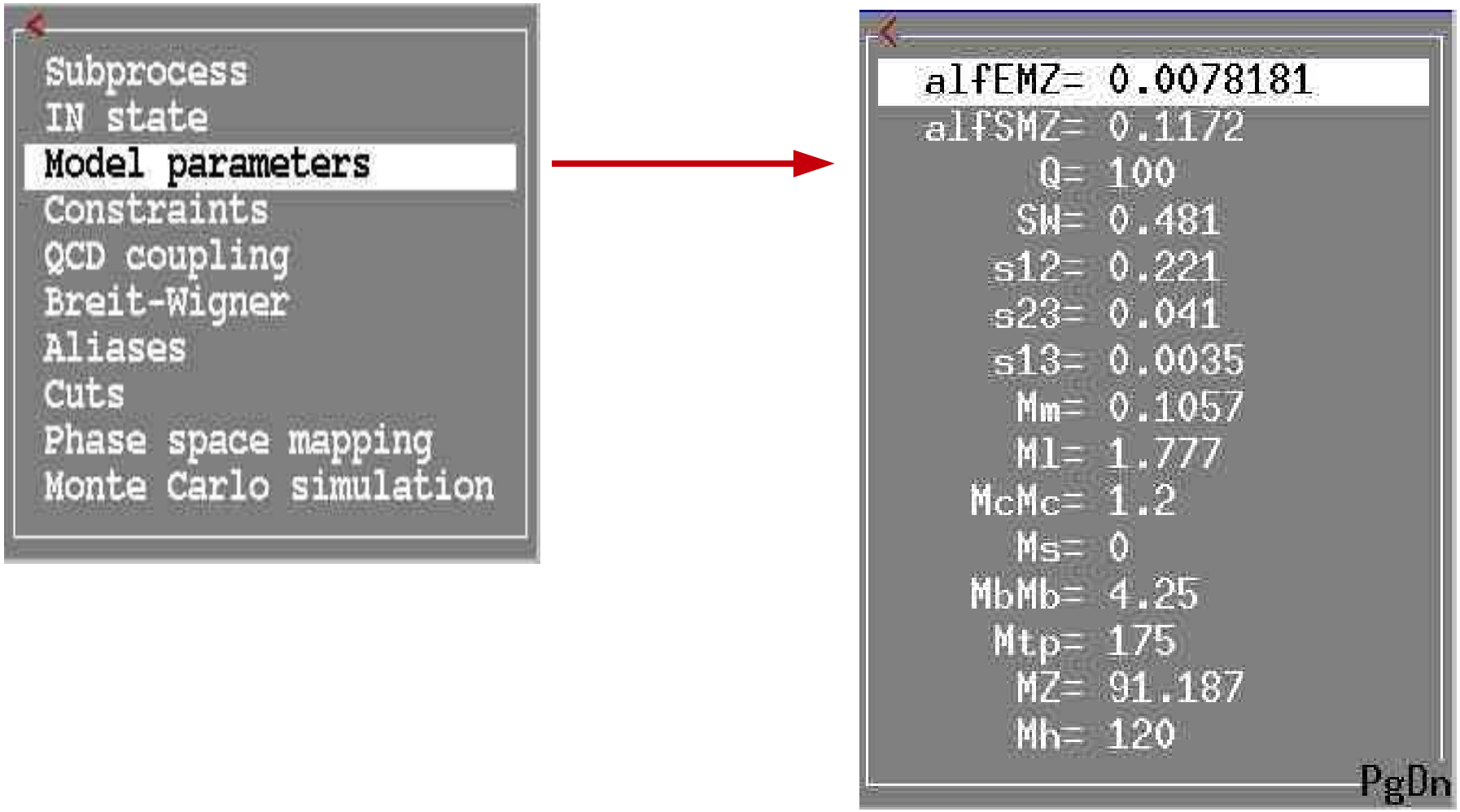
subprocess menu



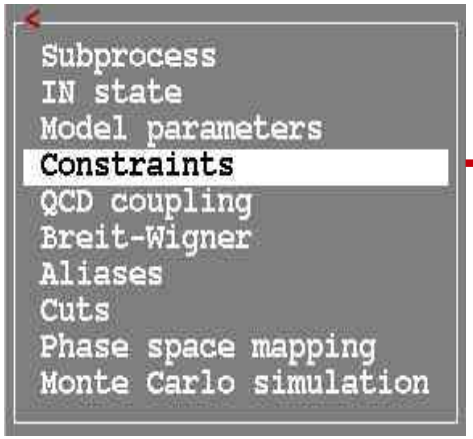


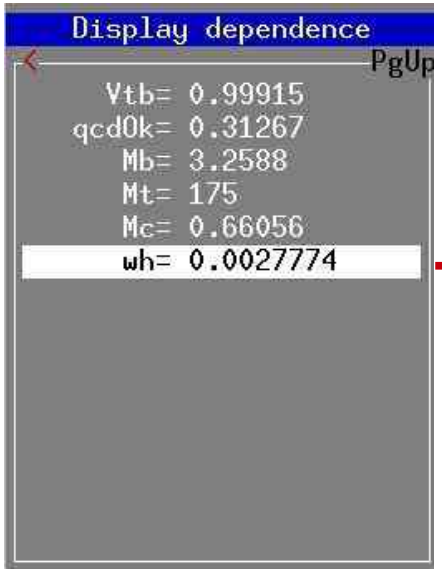
control of the initial states and parton density functions

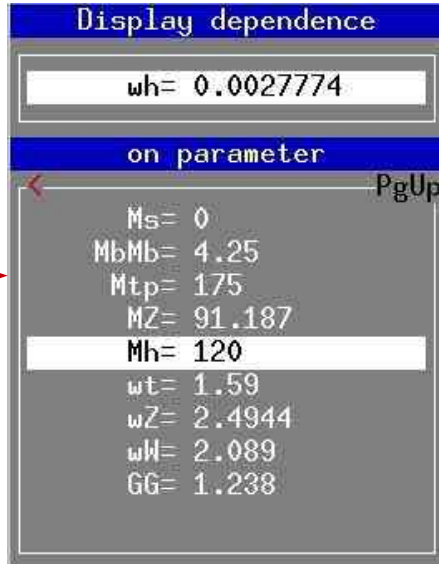
model parameters

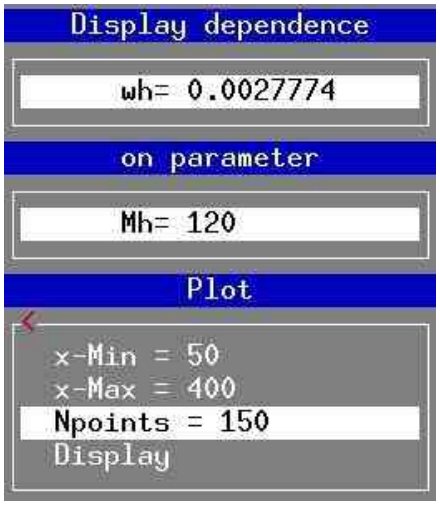


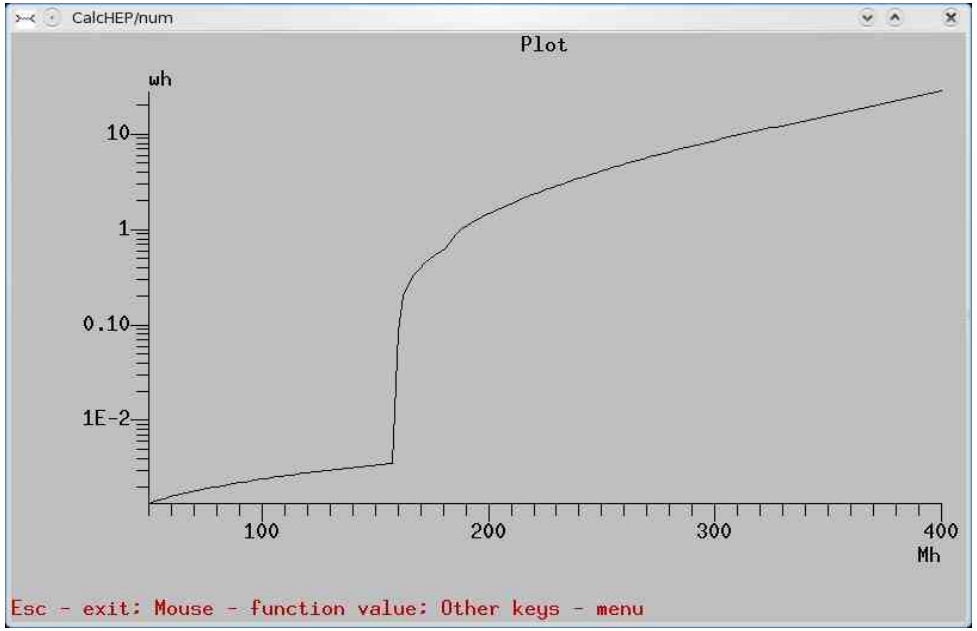
dependent parameters



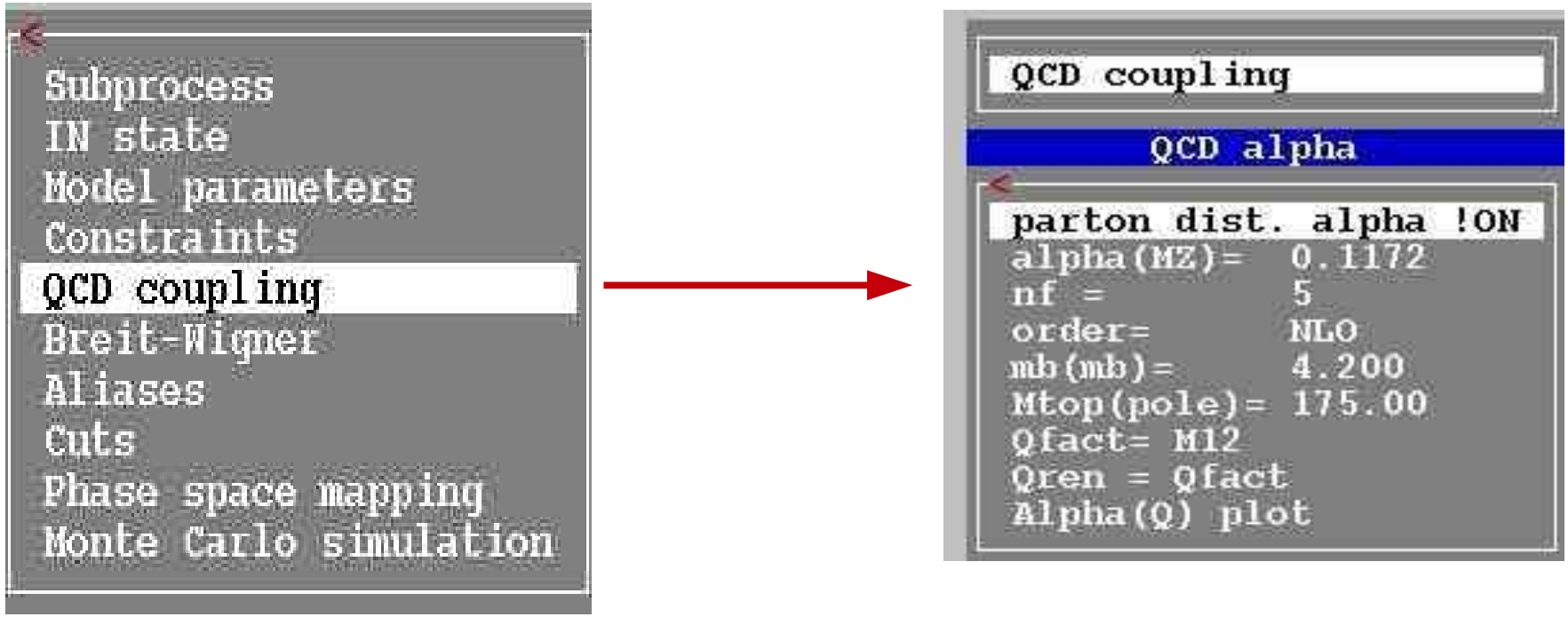




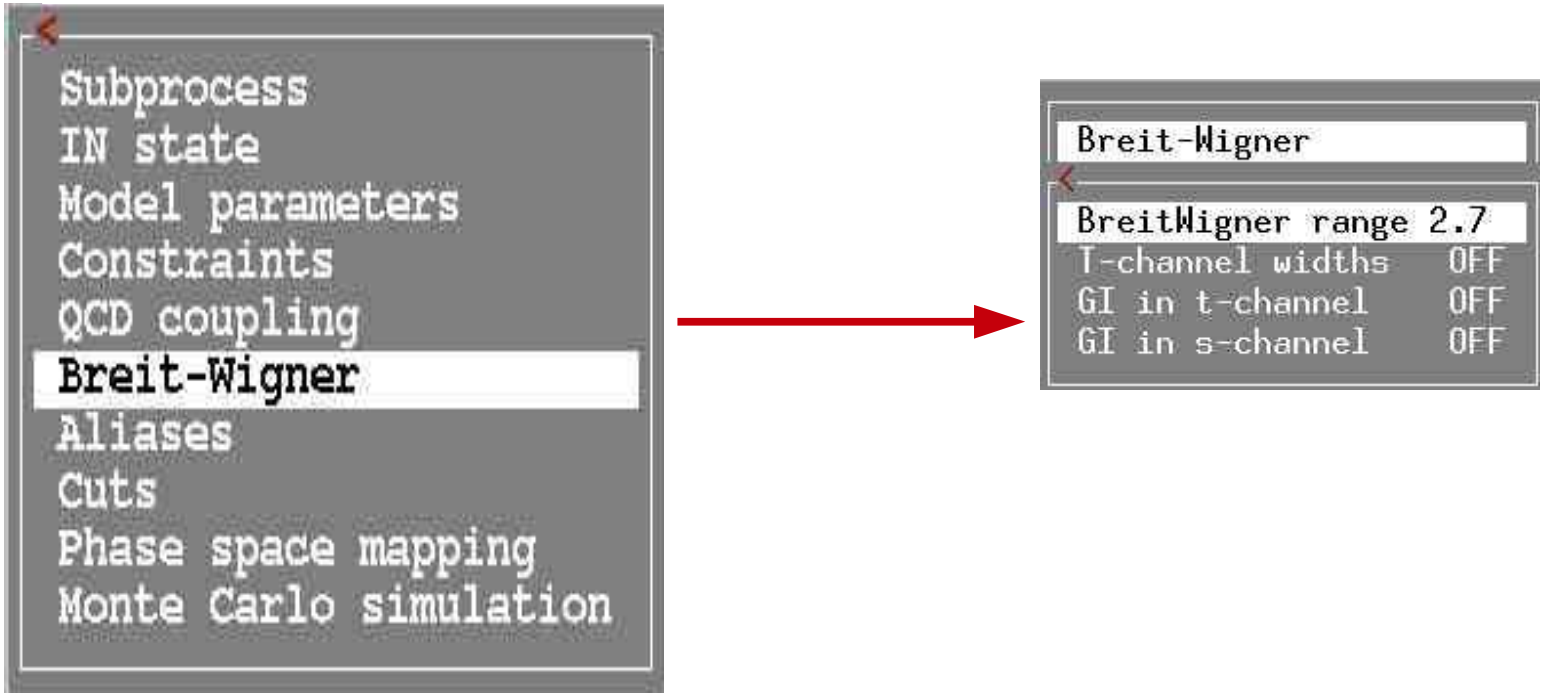




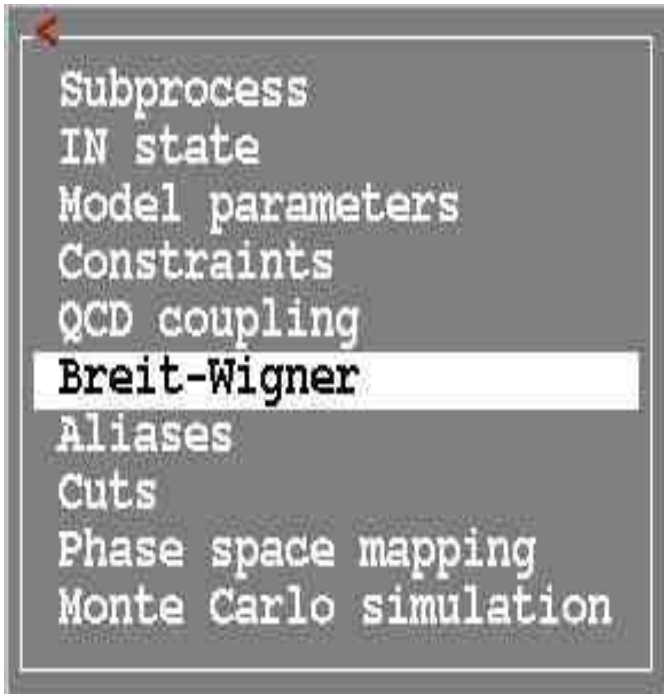
QCD coupling and the scale



control of resonances



control of resonances



F1

n_width_1

This menu sets value R which defines range of implementation of Breit-Wigner formula. Namely it is used in the region where

|p^2-m^2|< R*m*w

For region

|p^2-m^2|> sqrt(R^2+1)*m*w

we use zero width propagator. In the intermediate region constant propagator interpolates both formulas.

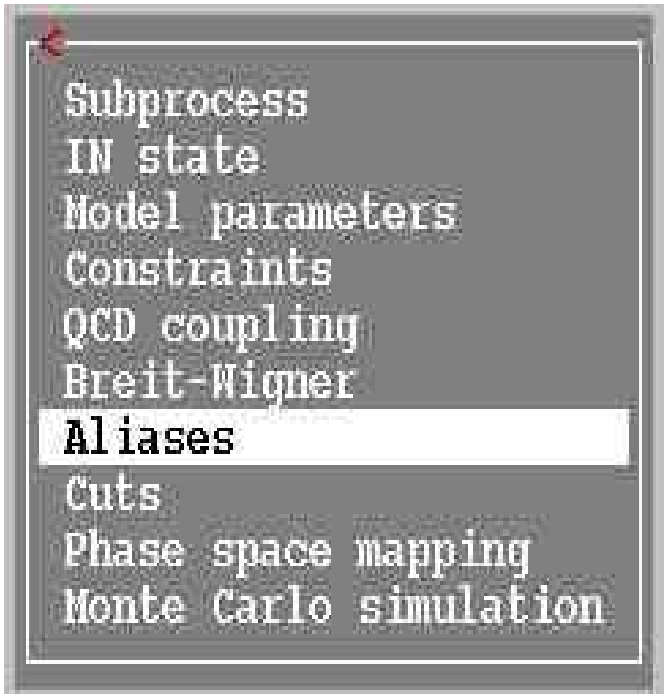
In general Breit-Wigner leads to breaking of gauge invariance. In its turn it can lead to the lost of diagram cancellation. From the other side just in the point p^2=m^2 the contribution of pole

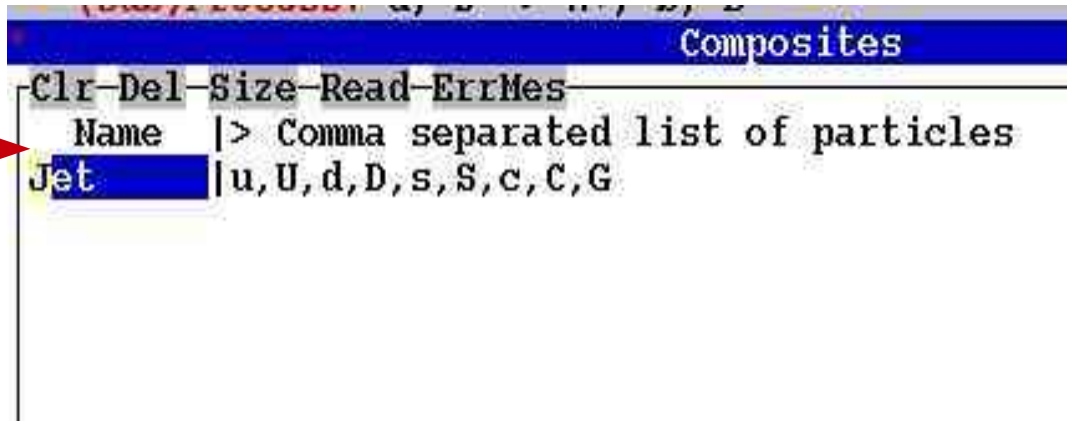
diagram have to be gauge invariant. Thus at this

pont cancellation between pole and non-pole diagra ms
is not expected. We assume that close to pole the problem also is not so serious. But far from the p ole
we ignore width and restore gauge invariance.

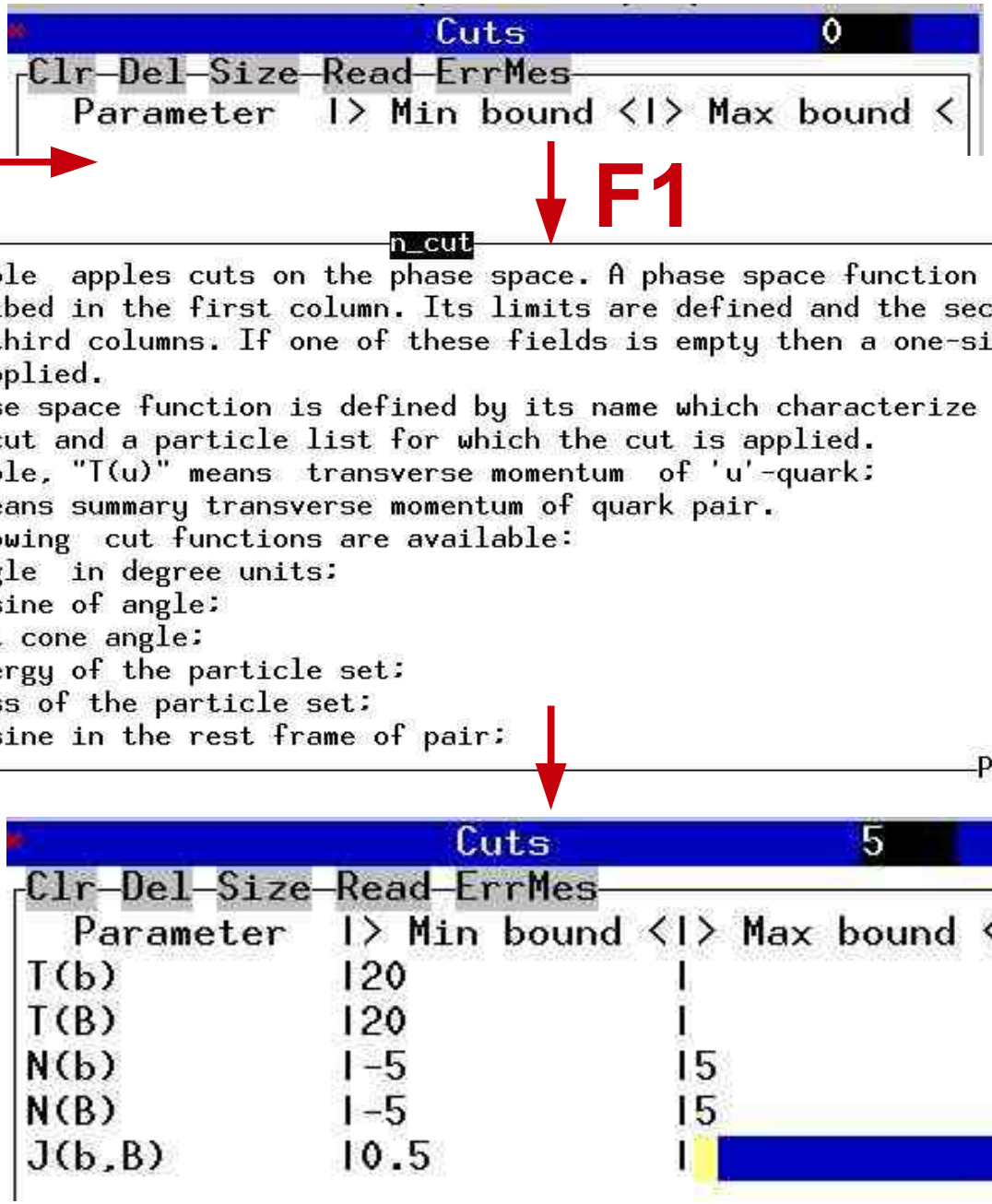
setting kinematical cuts

Aliases

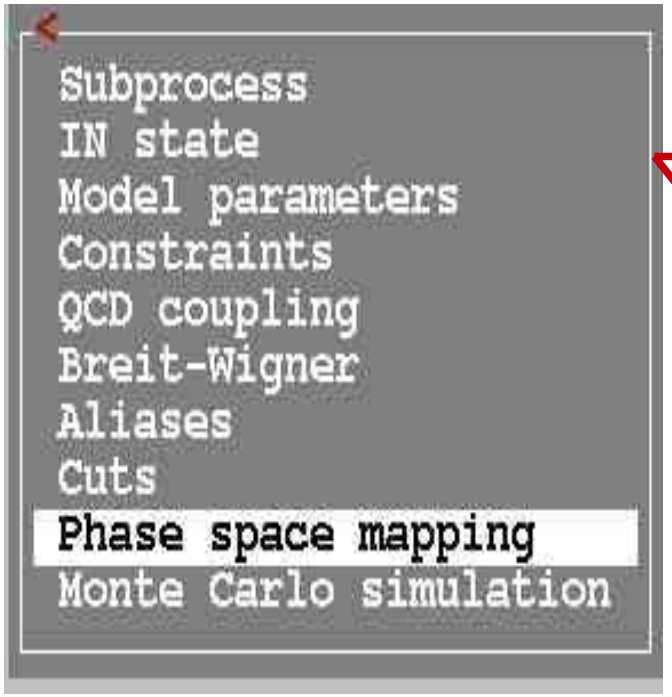

Subprocess
IN state
Model parameters
Constraints
QCD coupling
Breit-Wigner
Aliases
Cuts
Phase space mapping
Monte Carlo simulation

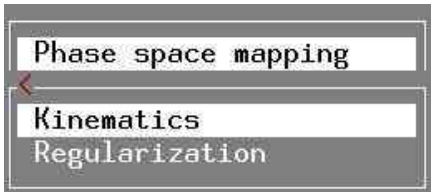

Composites
Clr-Del-Size-Read-ErrMes
Name |> Comma separated list of particles
Jet |u,U,d,D,s,S,c,C,G

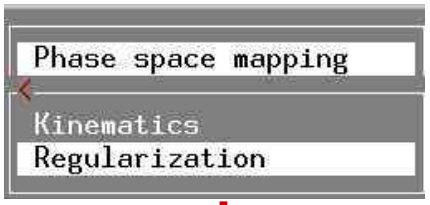
setting kinematical cuts

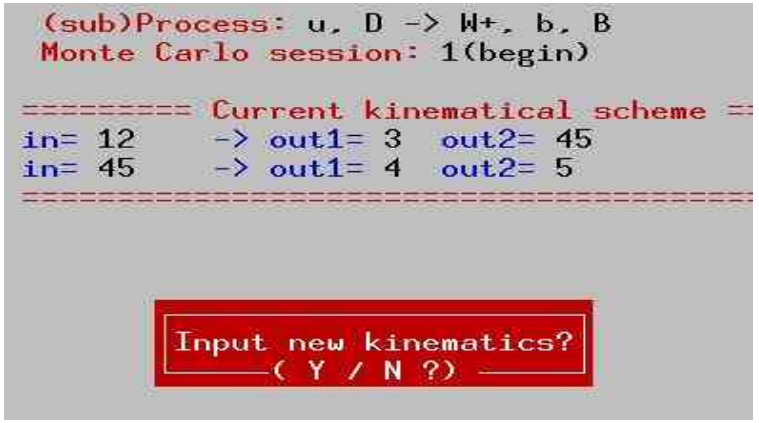


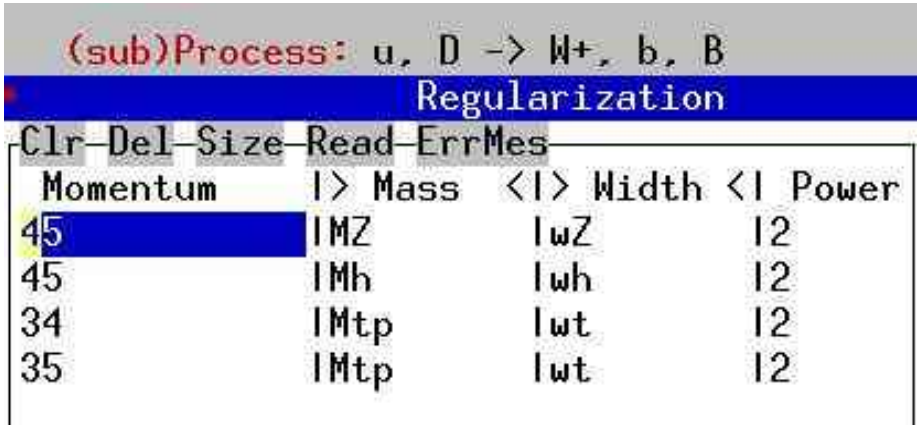
phase-space mapping











integration over the phase space

```
Subprocess
IN state
Model parameters
Constraints
QCD coupling
Breit-Wigner
Aliases
Cuts
Phase space mapping
Monte Carlo simulation
```

```
Monte Carlo simulation
nSess  = 5
nCalls = 10000
Set  Distributions
*Start integration
Display Distributions
Clear statistic
Freeze grid          OFF
Clear  grid
Event Cubes 10000
Generate Events
```

Distributions

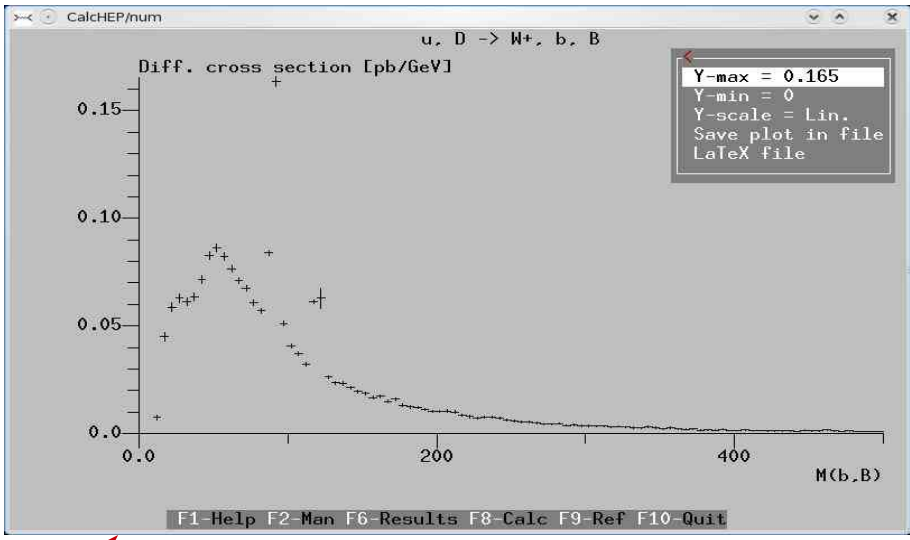
Clr Del Size Read ErrMes					
Parameter_1 |>	Min_1	<|>	Max_1	<|Parameter_2|>	Min_2	<|>	Max_2
T(b)	0		200				
T(B)	0		200				
N(b)	-5		5				
N(B)	-5		5				
M(b,B)	0		500				
M(W+,b)	0		500				
T(b)	0		500	M(b,B)	0		500

```
nSess  = 5
nCalls = 10000
Set  Distributions
*Start integration
Display Distributions
Clear statistic
Freeze grid          OFF
Clear  grid
Event Cubes 10000
Generate Events
```

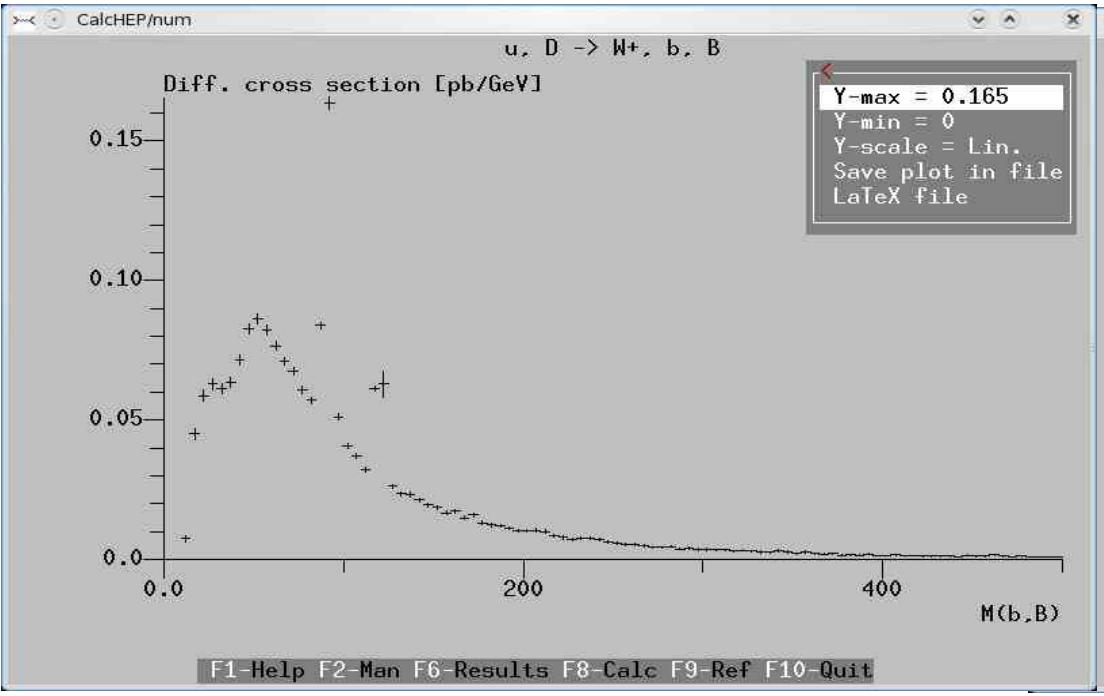
```
(sub)Process: u, D -> W+, b, B
Monte Carlo session: 2(continue)
```

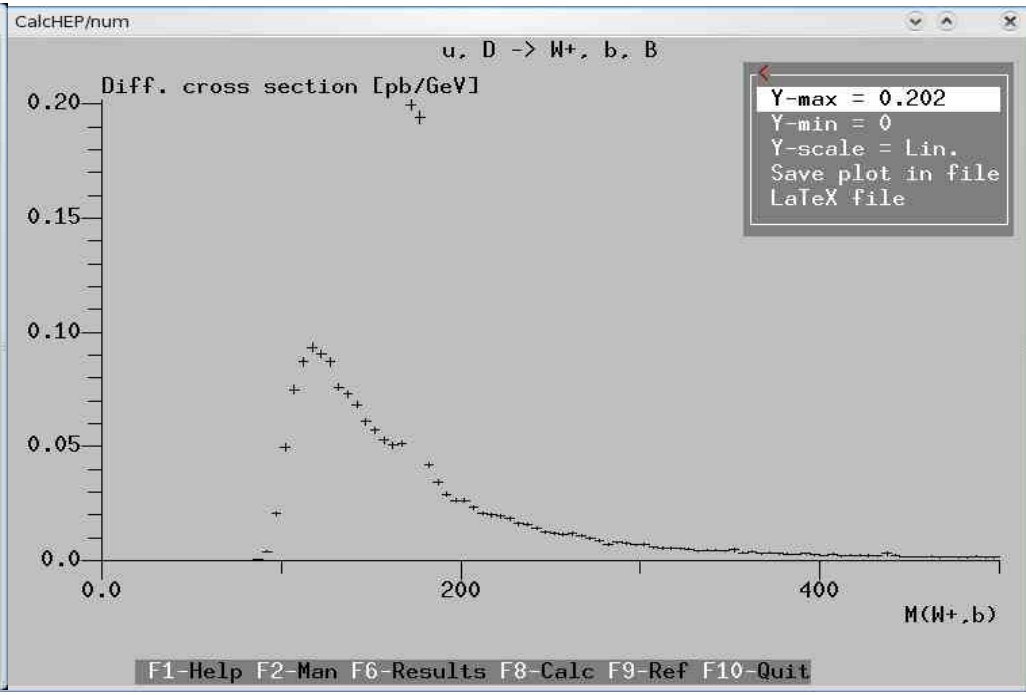
#IT	Cross section [pb]	Error %
6	9.5931E+00	7.10E-01
7	9.5686E+00	6.79E-01
8	9.5669E+00	6.82E-01
9	9.6892E+00	7.93E-01
10	9.6267E+00	7.51E-01
1	9.7757E+00	7.32E-01
clear statistics.		
2	9.6557E+00	6.82E-01
3	9.7464E+00	1.38E+00
4	9.6945E+00	1.05E+00
5	9.7032E+00	7.68E-01
< >	9.7095E+00	3.74E-01

```
nSess  = 5
nCalls = 10000
Set  Distributions
*Start integration
Display Distributions
Clear statistic
Freeze grid          OFF
Clear  grid
Event Cubes 10000
Generate Events
```



Resulting M_{bb} and M_{Wtb} kinematical distributions



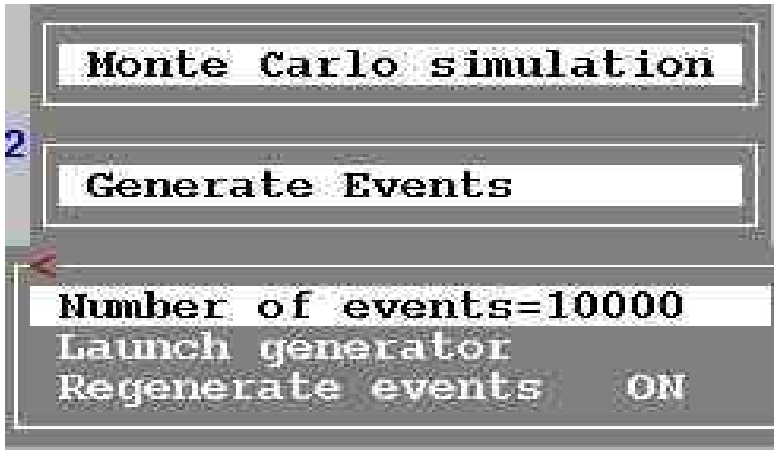


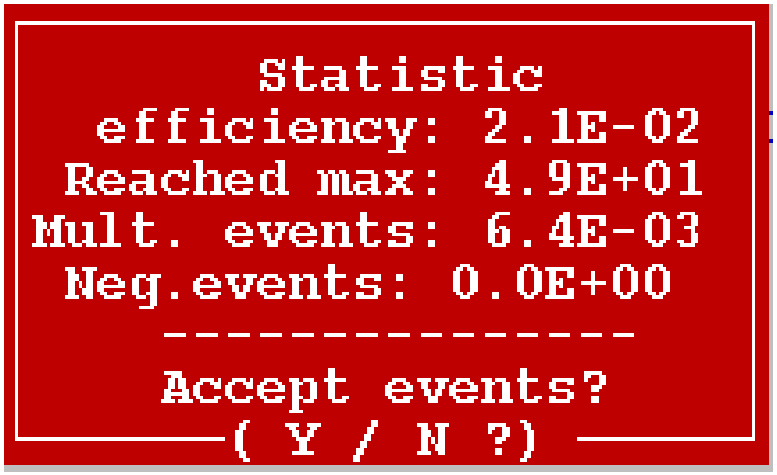
Exercise#3

1. Calculate WbB production rates at the LHC for PT b-jet > 20 GeV, b-Jet separation > 0.5, max pseudorapidity < 3

2. Plot bb- and Wb invariant mass distributions for PT b-jet > 20 GeV and PT b-jet > 40 GeV

events generations





GUI gives user a full control of details of symbolic/numerical session. To sum over the sub-processes one should use scripts

there are several scripts which run various loops to facilitate calculation

- ***cycle over subprocesses***
  - ***exit from the numerical session***
  - **cd results**
  - **../bin/subproc_cycle** ***lumi nmax***

requires 2 parameters:

1. luminosity

2. max number of events per process

e.g.

../bin/subproc_cycle 1000 100000

You should run it from results dir where the n_calchep binary is!

running subproc_cycle for SM model

```
 ../bin/subproc_cycle 100 1000
#Subprocess 1 ( u, D -> W+, b, B ) Cross section = 3.7118E+00 , 1000 events
#Subprocess 2 ( u, S -> W+, b, B ) Cross section = 1.4038E-01 , 1000 events
#Subprocess 3 ( u, B -> W+, b, B ) Cross section = 6.5581E-05 , 6 events
#Subprocess 4 ( U, d -> W-, b, B ) Cross section = 2.0071E+00 , 1000 events
#Subprocess 5 ( U, s -> W-, b, B ) Cross section = 2.3631E-02 , 1000 events
#Subprocess 6 ( U, b -> W-, b, B ) Cross section = 8.5102E-06 , 0 events
#Subprocess 7 ( d, U -> W-, b, B ) Cross section = 1.9329E+00 , 1000 events
#Subprocess 8 ( d, C -> W-, b, B ) Cross section = 6.1994E-02 , 1000 events
#Subprocess 9 ( D, u -> W+, b, B ) Cross section = 3.7528E+00 , 1000 events
#Subprocess 10 ( D, c -> W+, b, B ) Cross section = 2.1220E-02 , 1000 events
#Subprocess 11 ( s, U -> W-, b, B ) Cross section = 2.6142E-02 , 1000 events
#Subprocess 12 ( s, C -> W-, b, B ) Cross section = 2.4726E-01 , 1000 events
#Subprocess 13 ( S, u -> W+, b, B ) Cross section = 1.4176E-01 , 1000 events
#Subprocess 14 ( S, c -> W+, b, B ) Cross section = 2.4992E-01 , 1000 events
#Subprocess 15 ( c, D -> W+, b, B ) Cross section = 2.1041E-02 , 1000 events
#Subprocess 16 ( c, S -> W+, b, B ) Cross section = 2.4806E-01 , 1000 events
#Subprocess 17 ( c, B -> W+, b, B ) Cross section = 4.9244E-04 , 49 events
#Subprocess 18 ( C, d -> W-, b, B ) Cross section = 6.0969E-02 , 1000 events
#Subprocess 19 ( C, s -> W-, b, B ) Cross section = 2.5407E-01 , 1000 events
#Subprocess 20 ( C, b -> W-, b, B ) Cross section = 4.9473E-04 , 49 events
#Subprocess 21 ( b, U -> W-, b, B ) Cross section = 8.3331E-06 , 0 events
#Subprocess 22 ( b, C -> W-, b, B ) Cross section = 4.9524E-04 , 49 events
#Subprocess 23 ( B, u -> W+, b, B ) Cross section = 6.3592E-05 , 6 events
#Subprocess 24 ( B, c -> W+, b, B ) Cross section = 5.0576E-04 , 50 events
Total Cross Section 12.90318118 [pb]
see details in prt_29 - prt_52 files
```

running subproc_cycle for SM CKM=1 model

```
../bin/subproc_cycle 100 1000
#Subprocess 1 ( u, D -> W+, b, B ) Cross section = 3.9103E+00 , 1000 events
#Subprocess 2 ( U, d -> W-, b, B ) Cross section = 2.0301E+00 , 1000 events
#Subprocess 3 ( d, U -> W-, b, B ) Cross section = 2.0992E+00 , 1000 events
#Subprocess 4 ( D, u -> W+, b, B ) Cross section = 3.9088E+00 , 1000 events
#Subprocess 5 ( s, C -> W-, b, B ) Cross section = 2.6165E-01 , 1000 events
#Subprocess 6 ( S, c -> W+, b, B ) Cross section = 2.6151E-01 , 1000 events
#Subprocess 7 ( c, S -> W+, b, B ) Cross section = 2.6073E-01 , 1000 events
#Subprocess 8 ( C, s -> W-, b, B ) Cross section = 2.5592E-01 , 1000 events
Total Cross Section 12.98821 [pb]
see details in prt_37 - prt_44 files
```

Accessing your results

- *results are stored in "results" directory*
- *output files:*
  - n_calchep — *numerical module*
  - prt_*nn* — *protocol*
  - distr_*nn_mm* — *summed distributions*
  - distr_*nn* — *individual distribution*
  - events_*nn.txt* — *events file*
  - list_prc.txt — *list of processes*
  - qnumbers — *qnumbers – PYTHIA input with new prt definitions*
  - session.dat — *current session status – format is similar to* prt_*nn* *one*
- *for every new process the "results" directory is offered to be renamed or removed*

protocol prt_*nn*

```
    CalcHEP kinematics module
 The session parameters:

#Subprocess 1 ( u, D -> W+, b, B )
#Session_number 1
#Initial_state  inP1=7.000000E+03  inP2=7.000000E+03
 Polarizations= { 0.000000E+00  0.000000E+00 }
  StrFun1="PDT:cteq6m(proton)" 2212
  StrFun2="PDT:cteq6m(proton)" 2212

#Physical_Parameters
    alfEMZ = 7.8180609999999E-03
    alfSMZ = 1.1720000000000E-01
.........................................
.........................................
#Cuts
*** Table ***
 Cuts
  Parameter   |> Min bound <|> Max bound <|
T(b)          |20           |
T(B)          |20           |
.........................................
.........................................
#Regularization
*** Table ***
 Regularization
 Momentum     |> Mass  <|> Width <| Power|
45            |MZ       |wZ       |2
45            |Mh       |wh       |2
.........................................
.........................................
#END
=====================================
 #IT   Cross section [pb]  Error %    nCall    chi**2
  1      2.0373E+00       3.30E+01    20000
  2      8.6164E+00       2.86E+01    20000
.........................................
.........................................
```

useful scripts for numerical session

see calchep_x.x.x/bin/ directory and README file!

- ***subproc_cycle*** ***../bin/subproc_cycle 1000 100000***
- ***sum_distr*** ***../bin/sum_distr distr_2 distr_3 > distr_sum***
- ***show_distr*** ***../bin/show_distr distr_sum***
- ***plot_view*** ***../bin/plot_view < tab_1.txt***
- ***events2tab***
- ***gen_events***
- ***name_cycle***
- ***pcm_cycle***

Exercise#4
learn how to use:
1) gen_events
2) events2tab
3) plot_view

scripts for numerical session

- ***events2tab***

Parameters:
1- name of variable,
2- minimum limit,
3- maximum limit,
4- number of bins(<=300).
File with events must be passed to input.

```
../bin/events2tab "T(b)" 1 100 200 < events_1.txt >tab.txt
../bin/tab_view < tab.txt
```

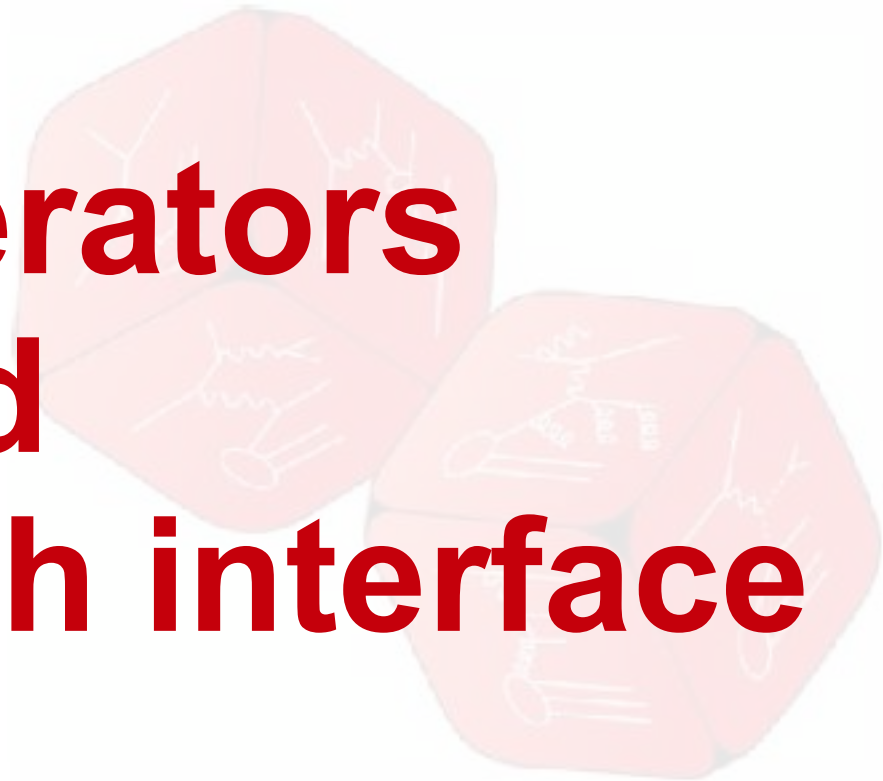
- ***name_cycle***

1: Name of parameter
2: Initial value
3: Step
4: Number of steps

```
../bin/name_cycle Mh 100 10 11
```

scripts above became a part of calchep_batch interface – to be discussed below

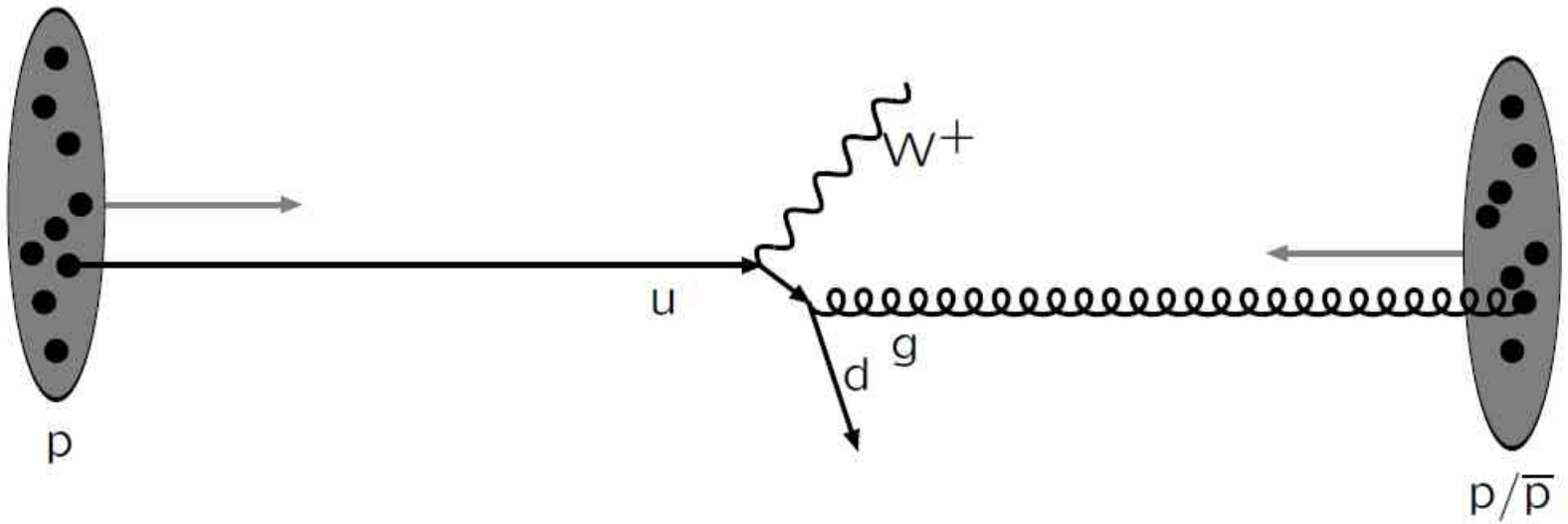
MC generators and CalcHEP batch interface



Event Structure

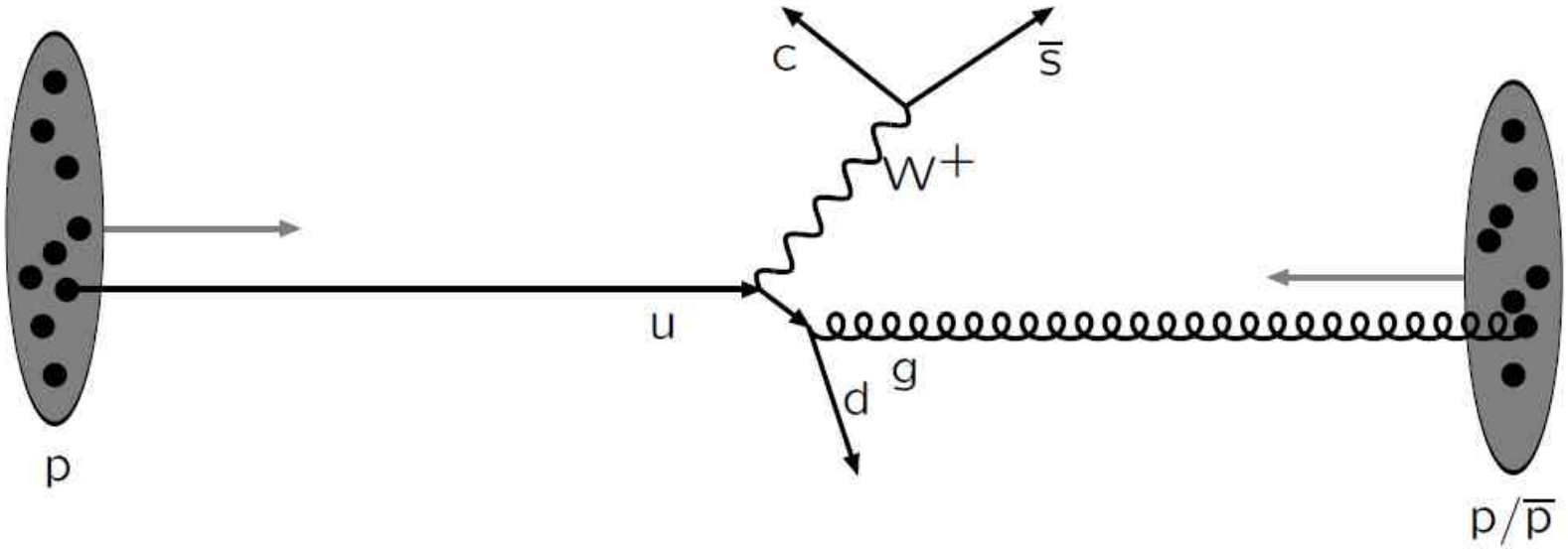
Incoming beams: parton densities

Event Structure



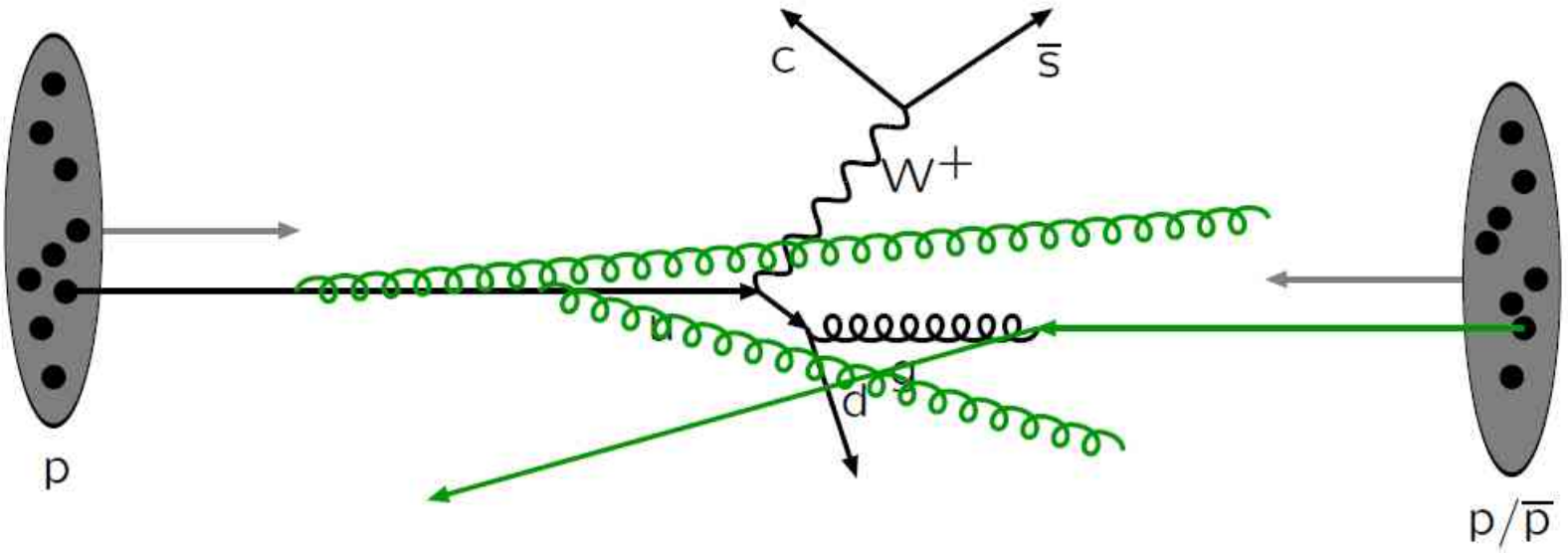
Hard subprocess: described by matrix elements

Event Structure



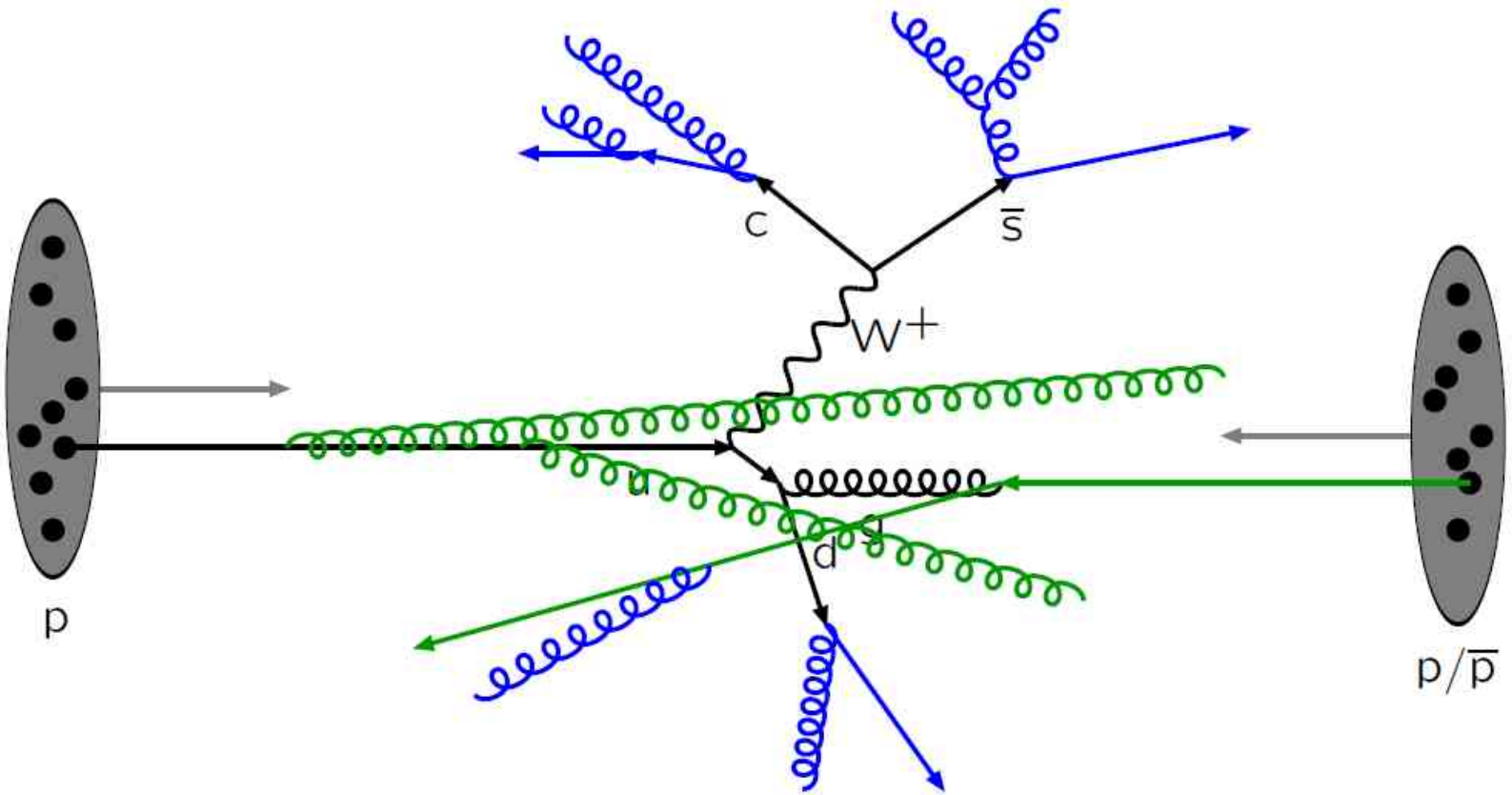
Resonance decays: correlated with hard subprocess

Event Structure



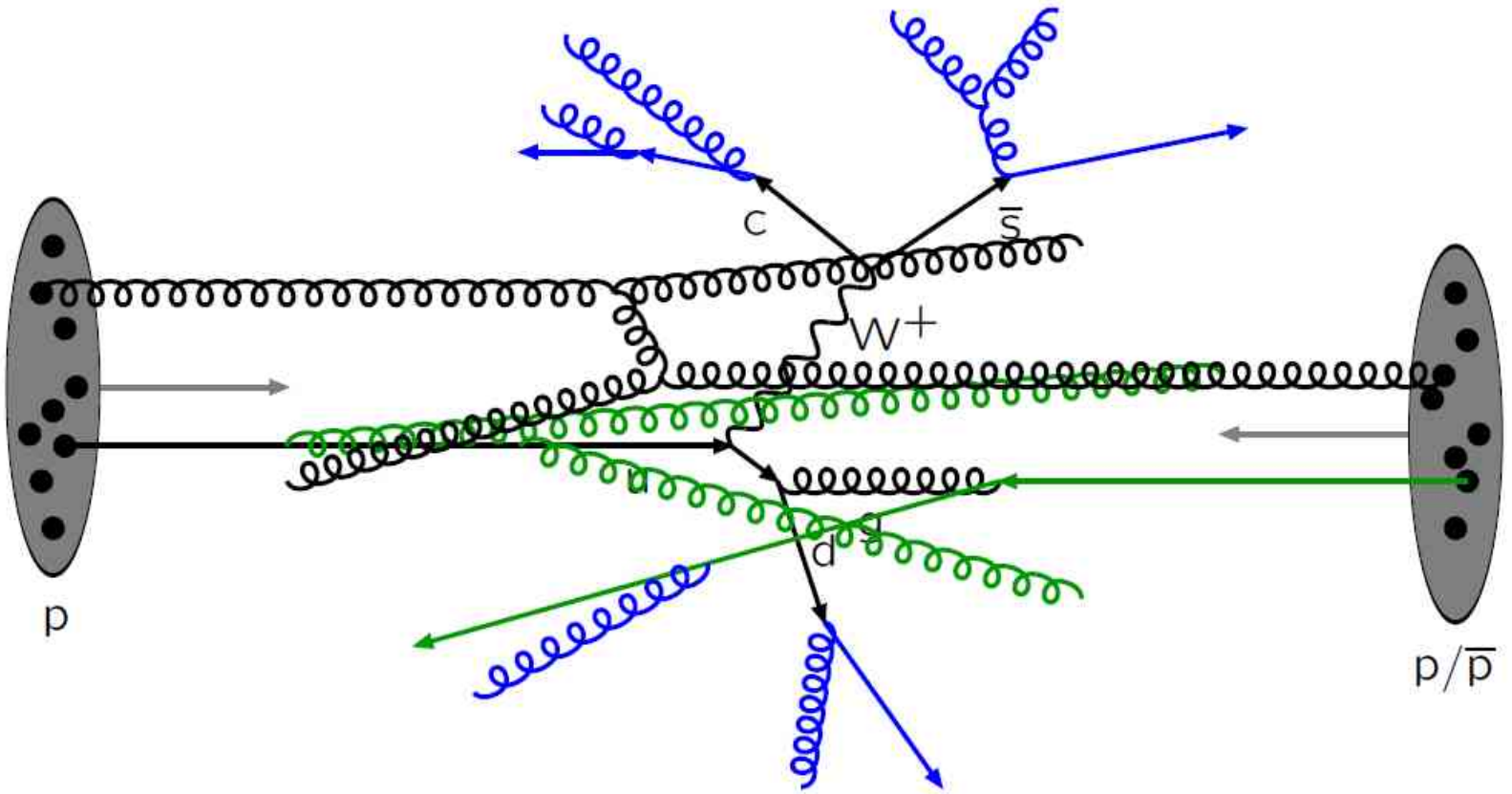
Initial-state radiation: spacelike parton showers

Event Structure



Final-state radiation: timelike parton showers

Event Structure



Multiple parton–parton interactions . . .

We need Events in LHE format to talk to MC generators!

- **bin/event_mixer** ***Luminosity[1/fb] nevents event_dirs***

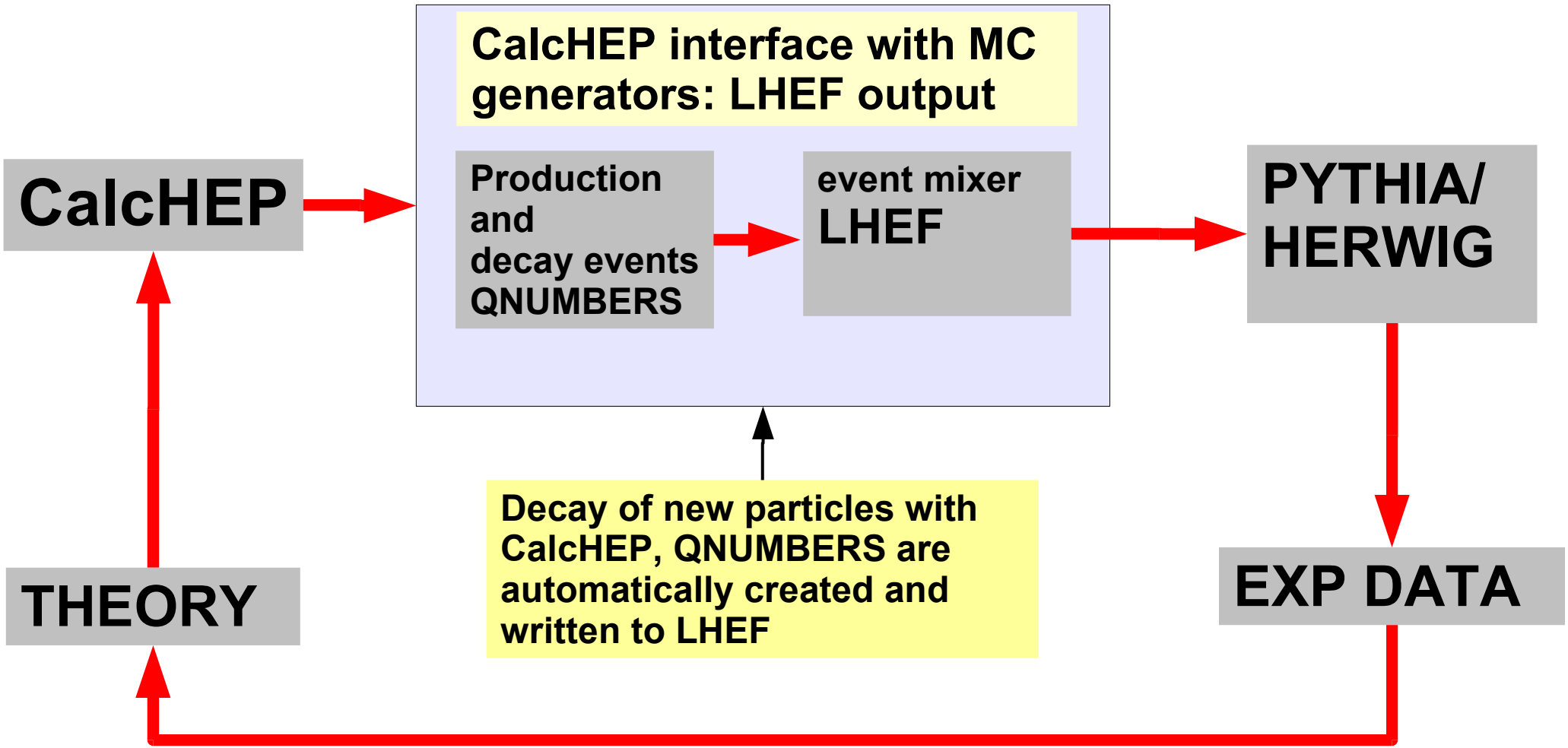
mixes subprocesses and connects scattering and decay events

```
bin/event_mixer  10 1000 pp_wbb w_2x
9.327E+00  -total cross section[pb]
3265     -maximum number of events
```

- ***the output is*** **event_mixer.lhe** ***file***

```
<LesHouchesEvents version="1.0">
<!--
File generated with CalcHEP-PYTHIA interface
-->
<header>
<slha>
</slha>
</header>
<init>
  2212  2212  7.00000006860E+03  7.00000006860E+03    -1    -1    -1    -1     3     1
  1.16593335502E+01  0.00000000000E+00  1.00000000000E+00   1
</init>
<event>
 7    1   1.0000000E+00   2.8420000E+02  -1.0000000E+00  -1.0000000E+00
       -3   -1    0    0    0  501  0.00000000000E+00  0.00000000000E+00  1.54424456520E+02
        4   -1    0    0  500    0  0.00000000000E+00  0.00000000000E+00 -1.30792414700E+02
       24    2    1    2    0    0 -9.99292465447E+01 -1.63668803915E+01 -6.48692987742E+01
        5    1    1    2  500    0  7.34149473360E+01  2.15593961832E+01  4.23390519202E+01
       -5    1    1    2    0  501  2.65142992097E+01 -5.19251579179E+00  4.61622886720E+01
      -11    1    3    3    0    0 -7.19345413730E+01  7.47572186340E-01 -8.03452022142E+01
       12    1    3    3    0    0 -2.79947051718E+01 -1.71144525779E+01  1.54759034400E+01
</event>
```

Present Status of the CalcHEP



CalcHEP batch interface: results from CalcHEP in one shot

- calchep_batch batch_file

```
./calchep_batch batch_file

calchep_batch version 0.146

Processing batch:
Progress information can be found in the html directory.
Simply open the following link in your browser:
file:///home/belyaev/tmp/tutorial/calc_work/html/index.html
You can also view textual progress reports in
/home/belyaev/tmp/tutorial/calc_work/html/index.txt
         and the other .txt files in the html directory.
Events will be stored in the Events directory.
```

CalcHEP batch interface: example of the batch file

Main Features

- Batch file
- Process library
- Runs
- Combines decays
- Parallelization
- HTML progress

batch_file

```
Model:          Standard Model(CKM=1)
Model changed:  False
Gauge:          Feynman
```

```
Process:    p,p->W,b,B
Decay:      W->ll,nn

Composite:  p=u,U,d,D,s,S,c,C,b,B,G
Composite:  W=W+,W-
Composite:  ll=e,E,m,M,l,L
Composite:  nn=ne,Ne,nm,Nm,nl,Nl
```

CalcHEP batch interface: monitoring the progress

file:///home/belyaev/tmp/tutorial/calc_work/html/index.h

Home
Symbolic Results
Numerical Results
Events Library
Process Library
Help

Thank you for using CalcHEP!
Please cite arXiv:1207.6082

CalcHEP Batch Details

Standard Model(CKM=1)

Generating Events

		Finished Time(hr)
Symbolic	12/12	0.01
σ	3/3	0.07
Events	2/3	0.01

CalcHEP batch interface: monitoring details of the symbolic section

file:///home/belyaev/tmp/tutorial/calc work/html/index.ht

Home
Symbolic Results
Numerical Results
Events Library
Process Library
Help

Thank you for using CalcHEP!
Please cite arXiv:1207.6082

Symbolic Sessions

Standard Model(CKM=1)

Processes	Lib	PID	Time(hr)
u,D->W+,b,B	✓		
U,d->W-,b,B	✓		
d,U->W-,b,B	✓		
D,u->W+,b,B	✓		
s,C->W-,b,B	✓		
S,c->W+,b,B	✓		
c,S->W+,b,B	✓	24571	0.00
C,s->W-,b,B	✓	24575	0.00
W+->E,ne	✓	25201	0.00
W+->M,nm	✓	25205	0.00
W-->e,Ne	✓	25339	0.00
W-->m,Nm	✓	25343	0.00
Widths	✓	25477	0.00

CalcHEP batch interface: monitoring results of the numerical session

file:///home/belyaev/tmp/tutorial/calc work/html/index.ht

Numerical Sessions

Home
Symbolic Results
Numerical Results
Events Library
Process Library
Help

Thank you for using CalcHEP!
Please cite arXiv:1207.6082

Standard Model(CKM=1)

Done!

Scans	σ (fb)	Running	Finished	Time (hr)	N events
Mh=120	984.9	0/13	13/13	0.01	1000
Mh=125	970	0/13	13/13	0.01	1000
Mh=130	965.5	0/13	13/13	0.01	1000
				0.03	

CalcHEP batch interface: details of the numerical session

file:///home/belyaev/tmp/tutorial/calc_work/html/index.h

Standard Model(CKM=1)

Home
Symbolic Results
Numerical Results
Events Library
Process Library
Help

Thank you for using CalcHEP!
Please cite arXiv:1207.6082

Done!

Processes	σ (fb)	Δσ (%)	PID	Time (hr)	N events	Details
u,D->W+,b,B	1319.3	0.46	28597	0.00	382/382	prt_1 session.dat
U,d->W-,b,B	715.68	0.47	28601	0.00	221/221	prt_1 session.dat
d,U->W-,b,B	714.79	0.48	28638	0.00	221/221	prt_1 session.dat
D,u->W+,b,B	1336.1	0.66	28642	0.00	386/386	prt_1 session.dat
s,C->W-,b,B	86.063	0.41	28678	0.00	39/39	prt_1 session.dat
S,c->W+,b,B	86.641	0.4	28682	0.00	39/39	prt_1 session.dat
c,S->W+,b,B	86.338	0.37	28718	0.00	39/39	prt_1 session.dat
C,s->W-,b,B	86.574	0.38	28722	0.00	39/39	prt_1 session.dat
Total	4431.5					

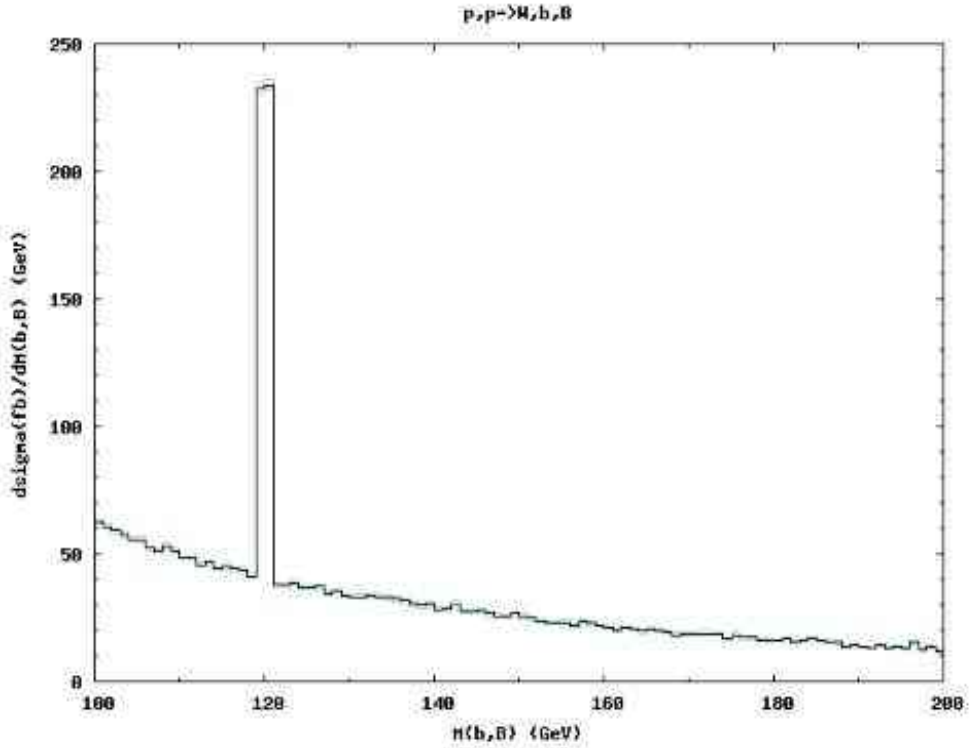
Decays	Γ (GeV)	ΔΓ (%)	PID	Time (hr)	N events	Details
W+->E,ne	0.22349	4.5 x10^{-05}	28758	0.00	5098/5100	prt_1 session.dat

CalcHEP batch interface: numerical results and distributions

file:///home/belyaev/tmp/tutorial/calchep_work/html/index.ht

Widths		PID	Time (hr)	Details
Widths		28838	0.00	session.dat
Total	984.9		0.01	1000/1000

Distributions



gnuplot should be installed to make the plots with the batch interface!

Skeleton of the main program to use .lhe file in PYTHIA generator

```
      IMPLICIT DOUBLE PRECISION(A-H, O-Z)
      IMPLICIT INTEGER(I-N)

      integer MSTP,MSTI
      COMMON/PYPARS/MSTP(200),PARP(200),MSTI(200),PARI(200)

      integer I,J,K,lun1,lun2,LHA

      mstp(161)=lun2
      mstp(162)=lun2
      NEV=10
      IMSS(21)=lun2

      OPEN(lun2, FILE='lhe˙file.lhe',STATUS='UNKNOWN',
     &     FORM='FORMATTED')

      CALL PYINIT('USER',' ',' ',0d0)
      DO 200 NVT=1,NEV
      CALL PYEVNT

C...  Insert your analysis here

200   CONTINUE
100   CALL PYSTAT(1)
      CLOSE(lun2)
      END
```

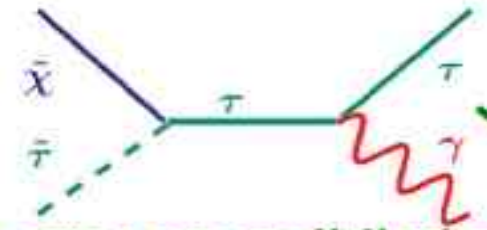
Examples of the CalcHEP application

Dark matter relic density – IsaRed and MicrOmegas

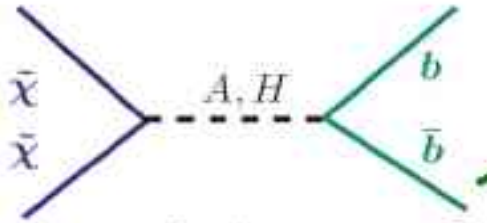
Neutralino relic density in mSUGRA

most of the parameter space is ruled out! $\Omega h^2 \gg 1$

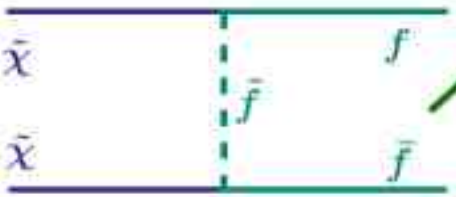
special regions with high σ_A *are required to get* $0.094 < \Omega h^2 < 0.129$

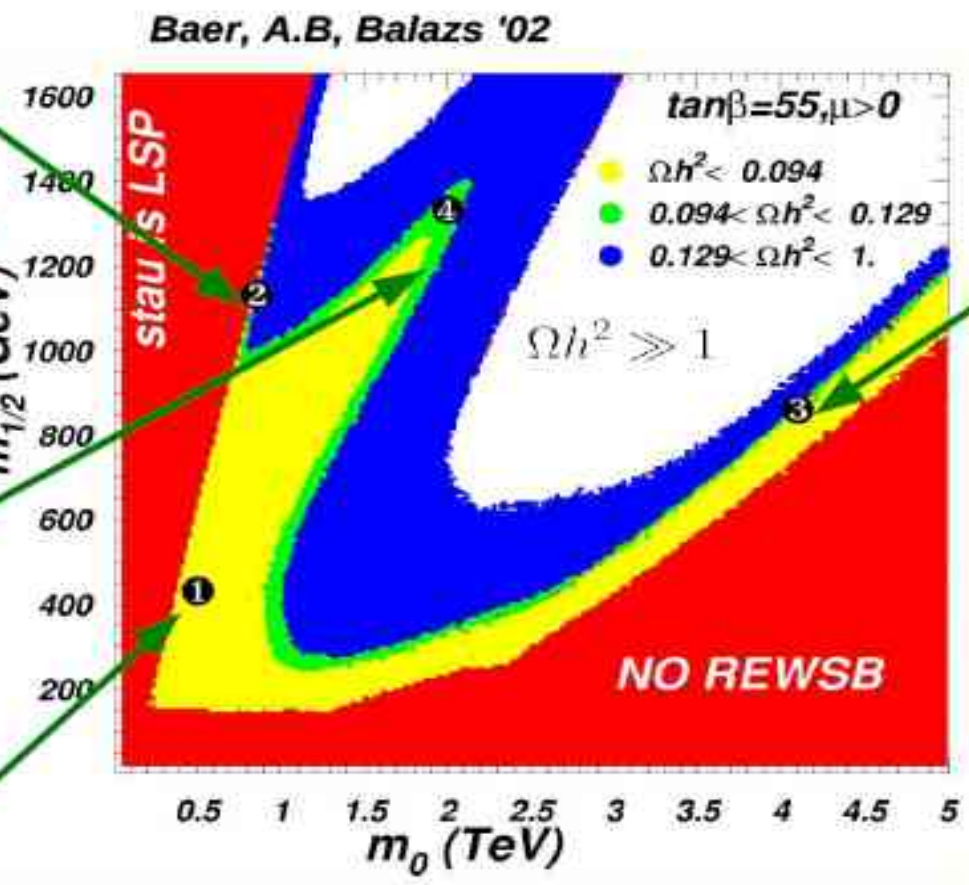


2. stau coannihilation:
degenerate χ *and stau*

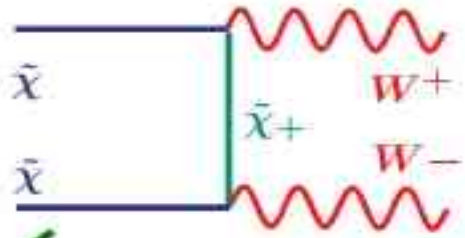


4. funnel: *(large tanβ)*
annihilation via A, H





1. bulk region: *light sfermions*



3. focus point:
mixed neutralino, low μ, importance of higgsino-wino component

$\mu^2 + M_Z^2/2 \approx -\varepsilon m_0^2 + 2m_{1/2}^2$

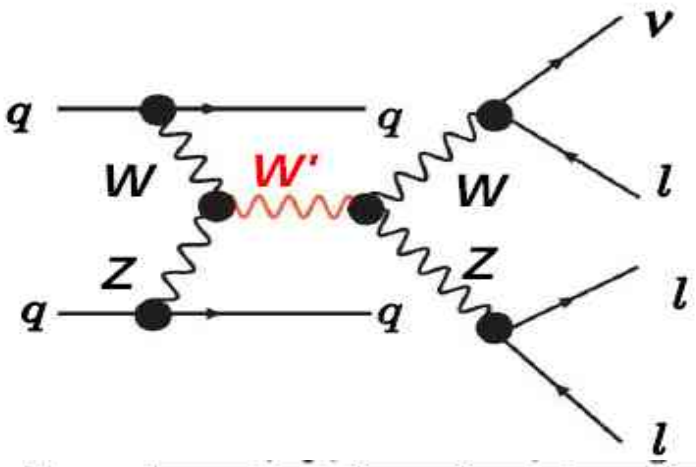
additional regions:
Z/h annihilation
stop coannihilation

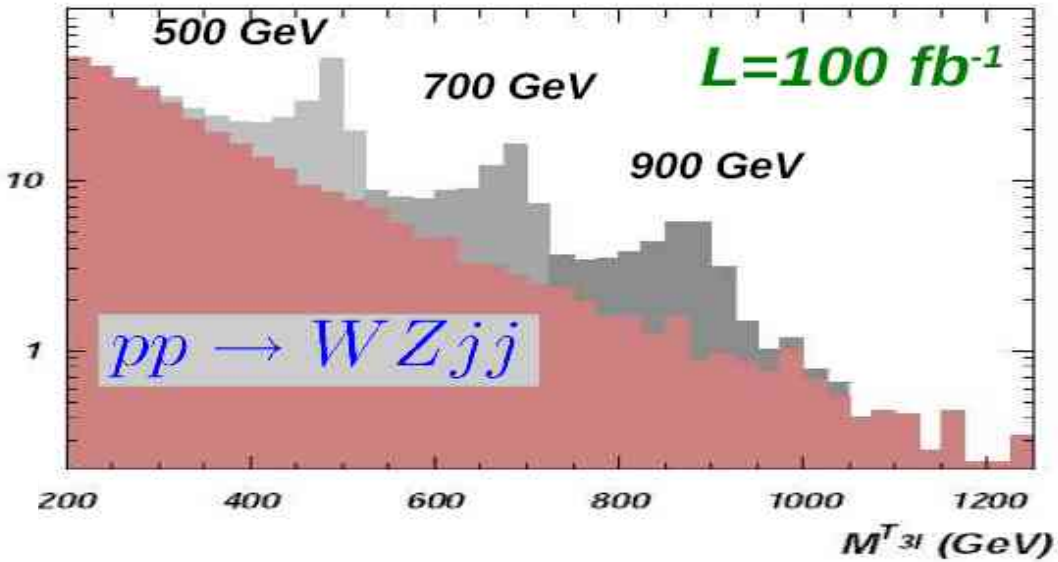
W' 3-lepton signatures from 3-site Higgsless model

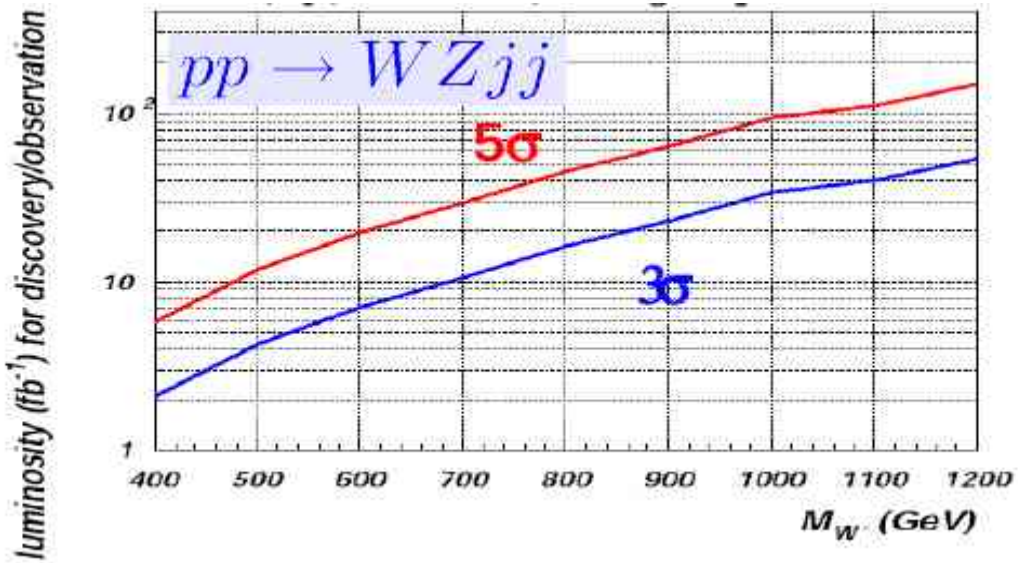
- **CMS: W' 3-lepton signatures from 3-site Higgsless model**

LHC reach for WZ->W' process

[AB, Chivukula, Christensen, He, Kuang, Pukhov, Qi, Simmons, Zhang '07]



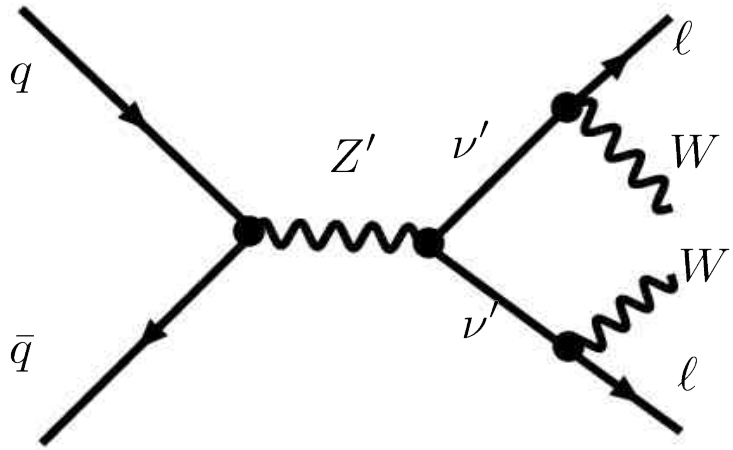


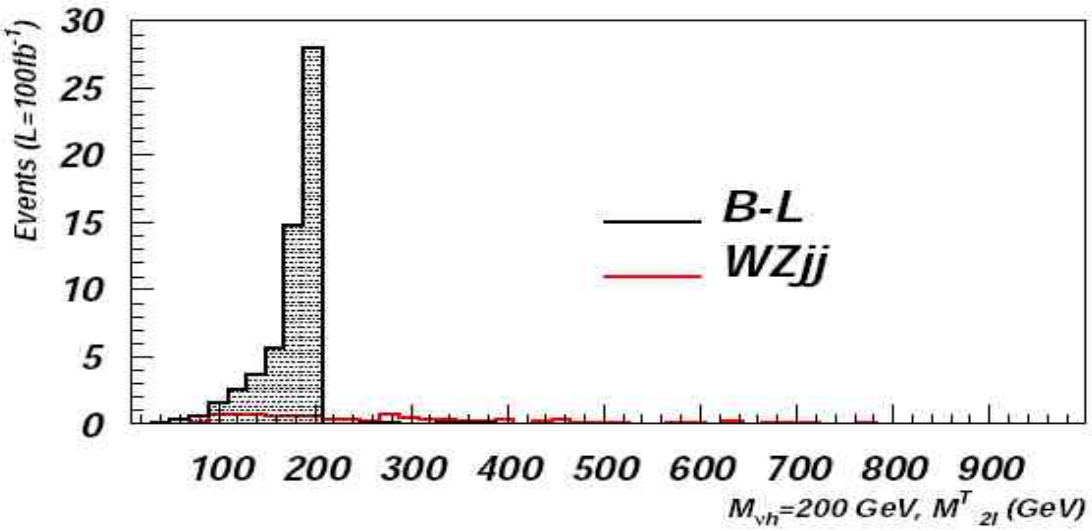


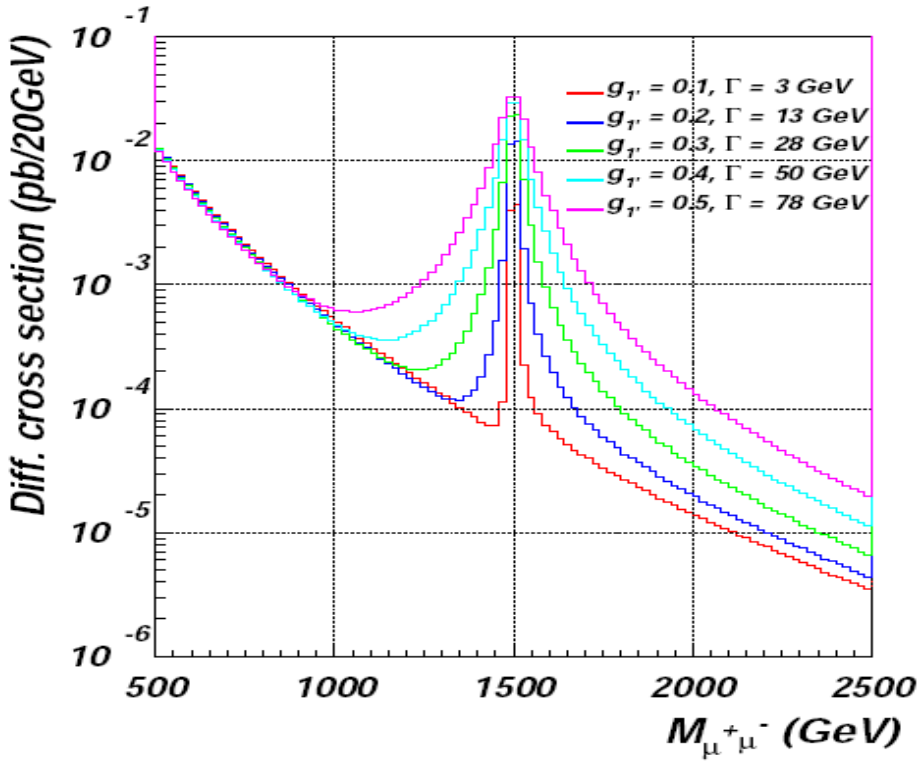
B-L extension of SM

Extra U(1)' : Z', heavy long leaving neutrino

(in collaboration with S. Moretti, L. Basso, C. Shepherd)

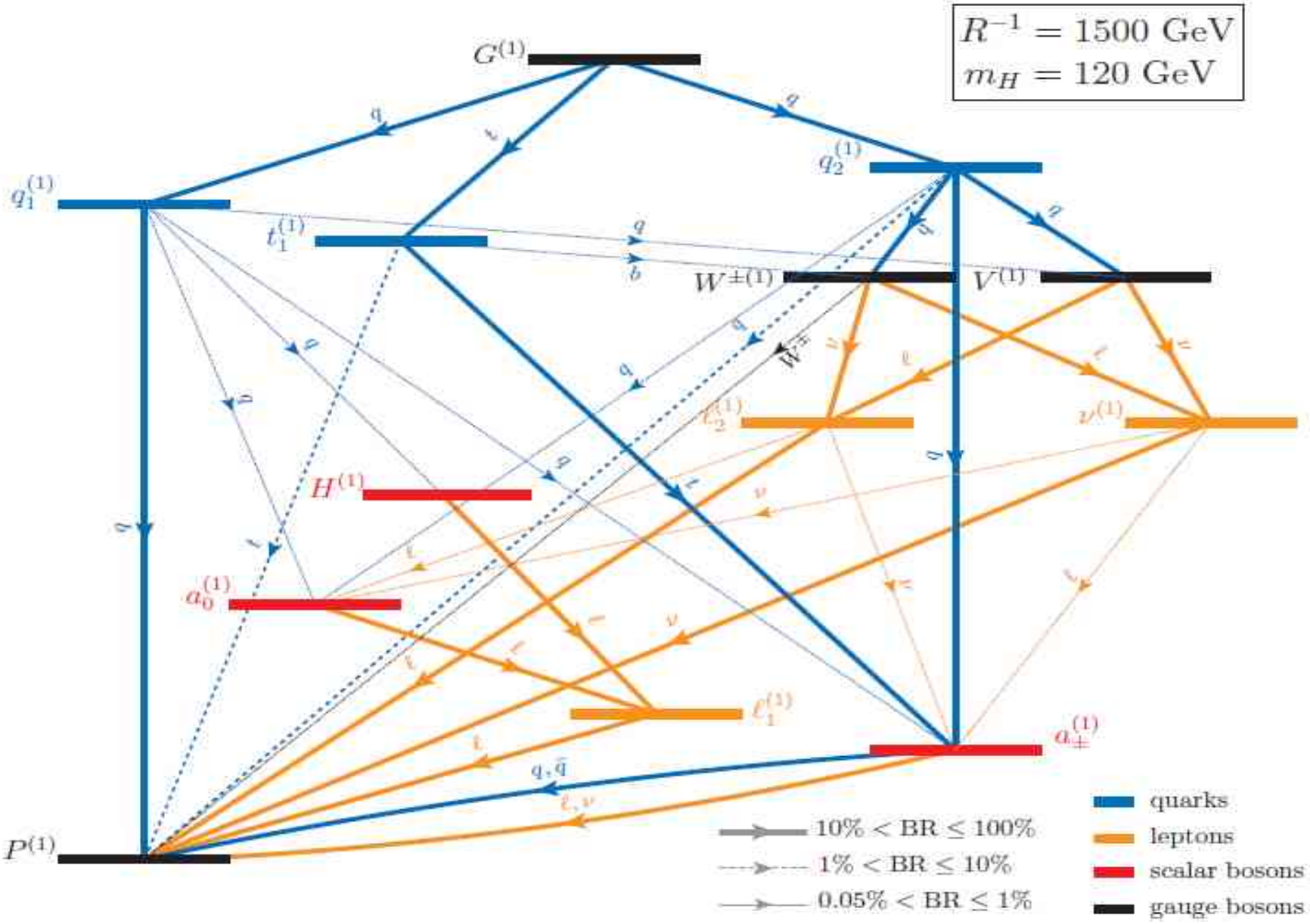






Universal Extra Dimensions

In collaboration with M.Brown, J.M. Moreno, C. Papineau



Universal Extra Dimensions

- **Set up of the production and decay processes with the calchep_batch**

```
Process: p,p->y2,y2
Process: p,p->y3,y3
Process: p,p->y2,y3

Decay: y1->2*x
Decay: y2->2*x
Decay: y3->2*x
Decay: y4->2*x
Decay: y5->2*x
Decay: y6->2*x
Decay: y7->2*x
Decay: y8->2*x

Composite: p=u,U,d,D,s,S,c,C,b,B,G
Composite: y1=~G_1
Composite: y2=~d1_1,~u1_1,~s1_1,~c1_1,~b1_1,~t1_1,~d2_1,~u2_1,~s2_1,~c2_1,~b2_1,~t2_1
Composite: y3=~D1_1,~U1_1,~S1_1,~C1_1,~B1_1,~T1_1,~D2_1,~U2_1,~S2_1,~C2_1,~B2_1,~T2_1
Composite: y4=Z,W+,W-,t,T,H
Composite: y5=~P_1,~V_1,~W+_1,~W-_1
Composite: y6=~e1_1,~e2_1,~n1_1,~mu1_1,~mu2_1,~n2_1,~tau1_1,~tau2_1,~n3_1
Composite: y7=~E1_1,~E2_1,~N1_1,~Mu1_1,~Mu2_1,~N2_1,~Tau1_1,~Tau2_1,~N3_1
Composite: y8=~H_1,~a0_1,~a+_1,~a-_1
```

- **Scan in 2D space with the calchep_batch**

```
################################################
#  Run Info                                    #
#  Masses and Energies are in GeV              #
#  More than one run can be specified at       #
#     the same time.                           #
################################################
Run parameter: invR
Run begin:     600
Run step size: 200
Run n steps:   4
Run parameter: nL
Run begin:     10
Run step size: 10
Run n steps:   4
```

Results from calchep_batch

Home
Symbolic Results
Numerical Results
Events Library
Process Library
Help

Thank you for using CalcHEP!
Please cite
arXiv:0000.0000

CalcHEP Batch Details

MUED-Chloe-2KK

Done!

	Finished	Time(hr)
Symbolic	6498/6498	0.00
σ	4/4	3.29
Events	4/4	7.30

Results from calchep_batch

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Symbolic Sessions

MUED-Chloe-2KK

Processes	Lib PID Time(hr)
u,u->~u1_1,~u1_1	✓
u,u->~u1_1,~u2_1	✓
u,u->~u2_1,~u2_1	✓
u,d->~d1_1,~u1_1	✓
u,d->~d1_1,~c1_1	✓
u,d->~d1_1,~t1_1	✓
u,d->~d1_1,~u2_1	✓
u,d->~d1_1,~c2_1	✓

.....~ 6k subprocesses .....

~a-_1->N1,~e2_1	✓
~a-_1->N1,~e1_1	✓
~a-_1->H,~W-_1	✓
~a-_1->Z,~W-_1	✓
~a-_1->A,~W-_1	✓
~a-_1->W-,~V_1	✓
~a-_1->W-,~P_1	✓
Widths	✓

Results from calchep_batch

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Numerical Sessions

MUED-Chloe-2KK

Done!

Runs	σ (fb)	Running	Finished	Time (hr)	N events
invR=600 LR=40	5126	0/6499	6499/6499	20.68	50000
invR=800 LR=40	809.2	0/6499	6499/6499	28.52	50000
invR=1000 LR=40	151.2	0/6499	6499/6499	24.66	50000
invR=1200 LR=40	30.29	0/6499	6499/6499	21.86	50000
				95.72	

Results from calchep_batch

Numerical Sessions

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Process Library
Help

Thank you for using CalcHEP!
Please cite
arXiv:0000.0000

MUED-Chloe-2KK

Done!

Processes	σ (fb)	PID	Time (hr)	N events	Details
u,u->~u1_1,~u1_1	497.36	19766	0.00	5196/5196	prt_1 session.dat
u,u->~u1_1,~u2_1	696.28	19769	0.00	7202/7202	prt_1 session.dat
u,u->~u2_1,~u2_1	550.46	19775	0.00	5734/5734	prt_1 session.dat
u,d->~d1_1,~u1_1	212.45	19781	0.00	2297/2297	prt_1 session.dat

.....~ 6k subprocesses .....

~a-_1->N1,~e1_1	1.3688 x10^{-14}	14954	0.00	255000/254999	prt_1 session.dat
~a-_1->H,~W-_1	0	14991	0.00	0/254999	prt_1 session.dat
~a-_1->Z,~W-_1	0	15098	0.00	0/254999	prt_1 session.dat
~a-_1->A,~W-_1	0	15172	0.00	0/254999	prt_1 session.dat
~a-_1->W-,~V_1	0	18314	0.00	0/254999	prt_1 session.dat
~a-_1->W-,~P_1	0	18320	0.00	0/254999	prt_1 session.dat

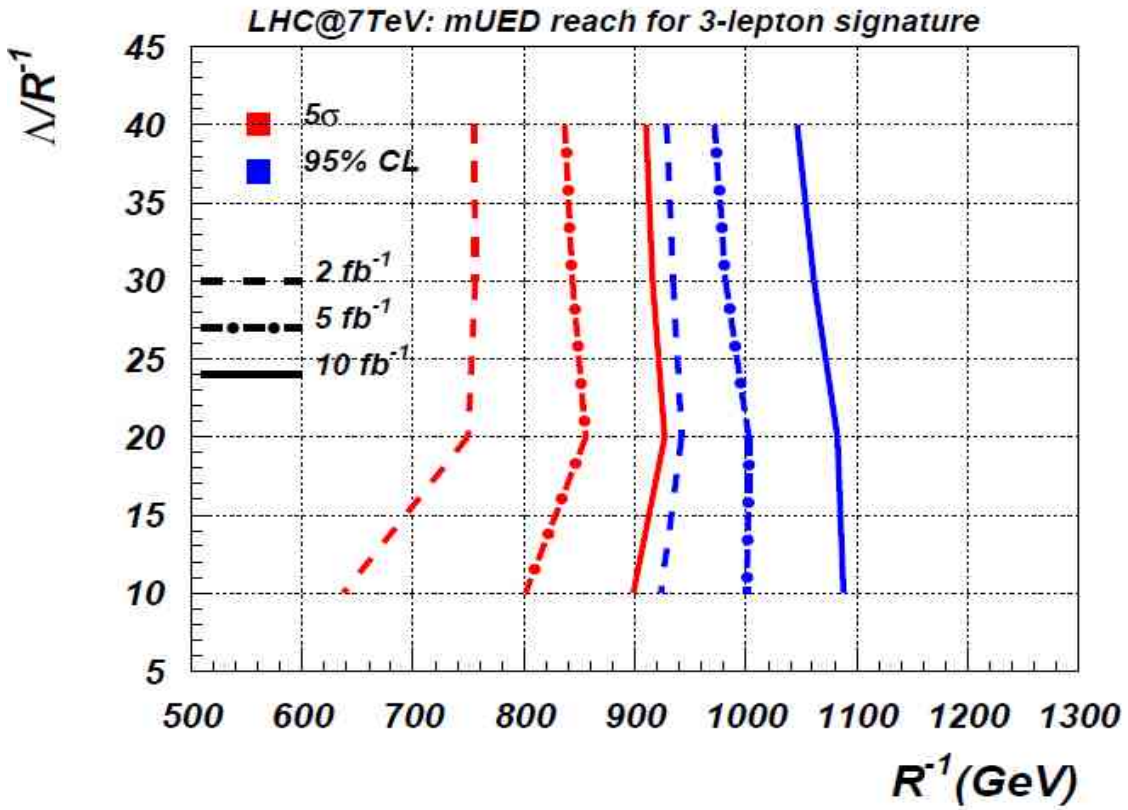
Widths		PID	Time (hr)	Details
Widths		18342	0.00	session.dat
Total	5126		20.68	

Results from calchep_batch

CalcHEP Events Library

Home
Symbolic Results
Numerical Results
Events Library
Process Library

Date	LHE	plain Ntuple
Tue Mar 27 23:06:39 2012	Q1Q1_MH120_8tev-invR1000LR40.lhe	
Wed Mar 28 00:32:40 2012	Q1Q1_MH120_8tev-invR1200LR40.lhe	
Tue Mar 27 19:42:27 2012	Q1Q1_MH120_8tev-invR600LR40.lhe	
Tue Mar 27 21:34:29 2012	Q1Q1_MH120_8tev-invR800LR40.lhe	



Some highlights of the CalcHEP

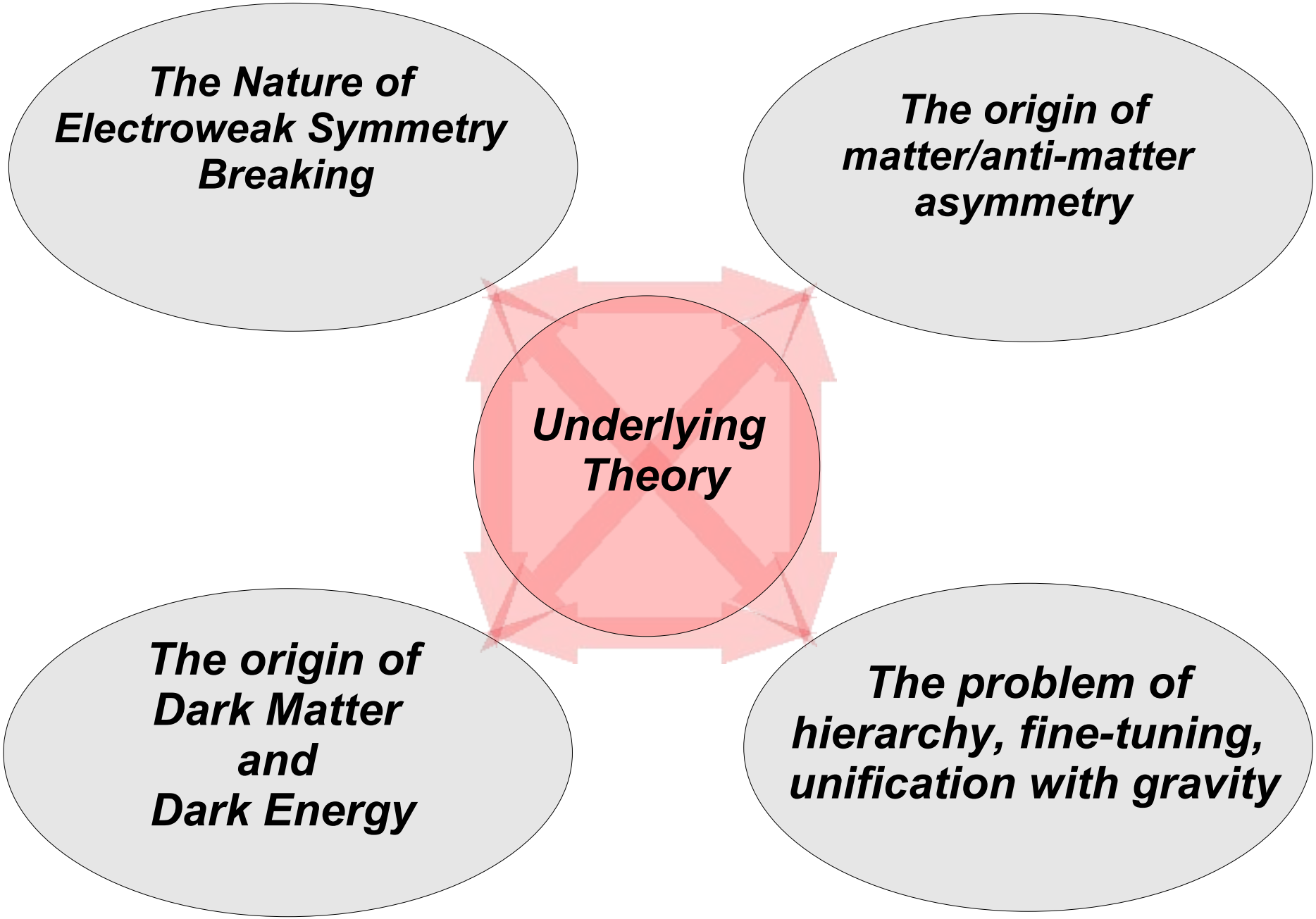
- Convenient graphical interface
- Calculates particle widths 'on the fly'
- Allows to edit diagrams as well as squared diagrams – important for the dedicated interference studies
- Easy to modify an existing model (GUI) or to implement the new one (LanHEP, FeynRules)
- Powerful batch interface – connects numerous production and decay processes
- Allows to perform multidimensional scan of the the parameter space and produce LHE files in one run
- Adopted to HPC cluster (installed at HEPMDB – next lecture)
- Many more – see an updated manual

Outlook

- ME matching: for 1,2,..3 jets ME's
- Connection production and decay without loss of the polarization info
- Helicity amplitude method is on the way
- Possiblity to link to GoSam - CalcHEP@NLO is under discussion

HEPMDB

What underlying theory should explain?



Promising candidates for underlying theory

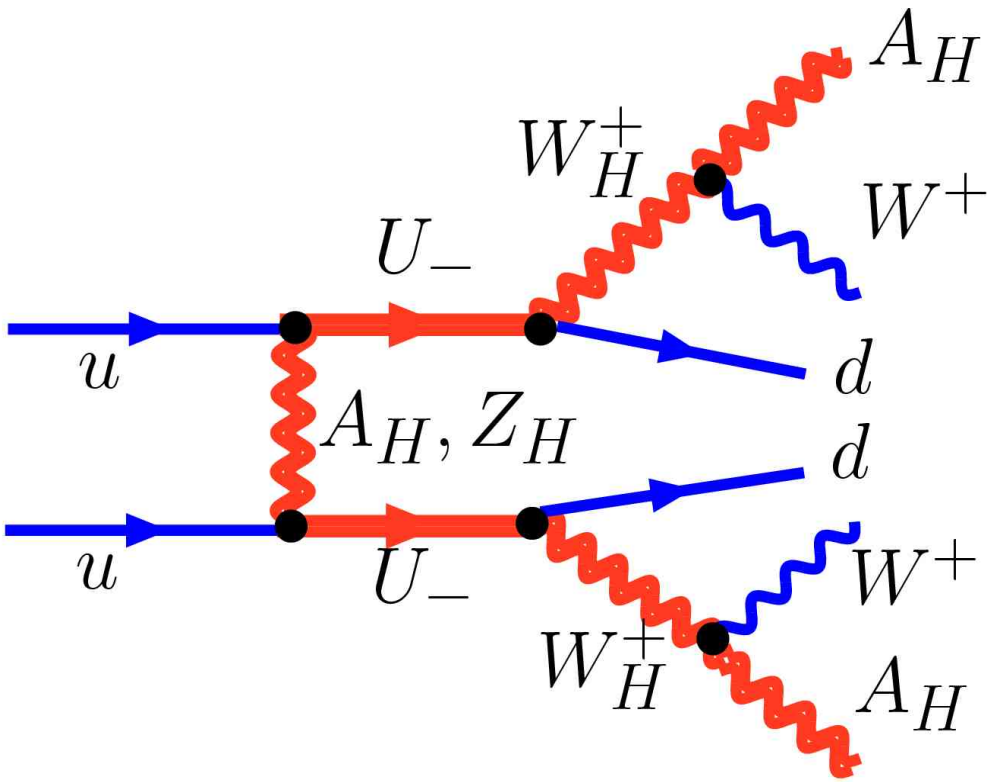
- ***Supersymmetry:***
  - ***cMSSM, MSSM, NMSSM, E_6SSM, ...***
- ***Walking Technicolor***
- ***Extradimensional Models:***
  - ***Universal and Warp extra dimensions***

.....

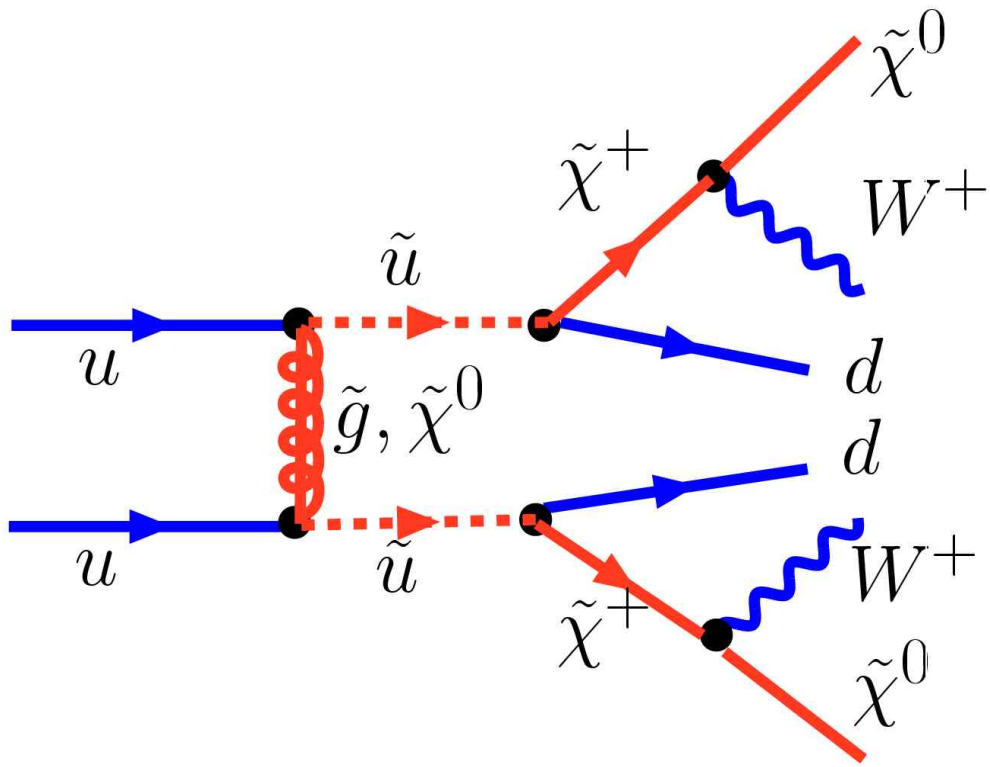
.....

.....

Signatures could look alike

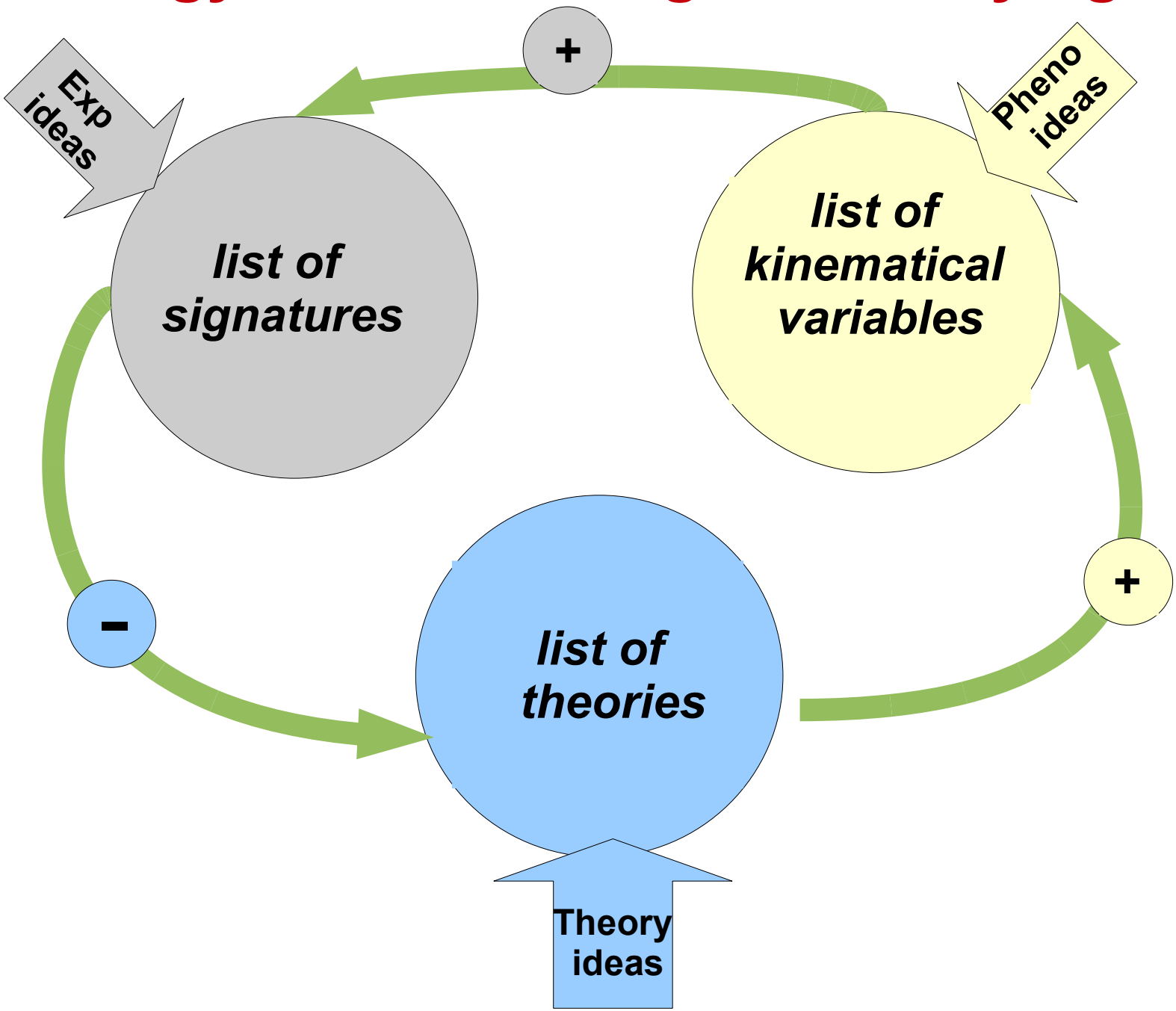


LHT

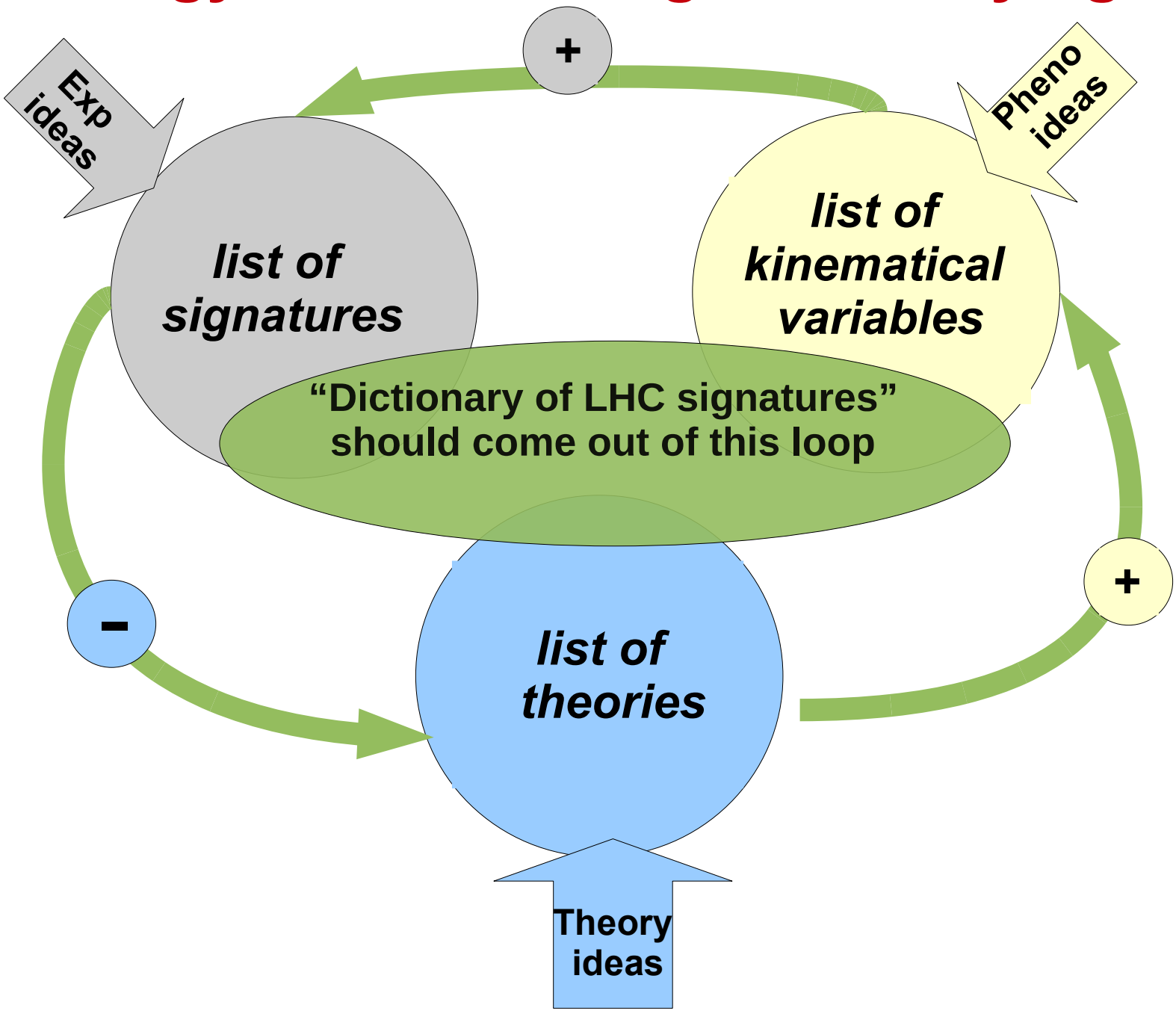


SUSY

The strategy for delineating of underlying theory



The strategy for delineating of underlying theory



First Steps towards "Dictionary"

AB, Asesh Datta, A. De Roeck Rohini Godbole, Bruce Mellado, Andreas Nyffeler, Chara Petridou, D.P. Roy, Pramana 72:229-238,2009. e-Print: arXiv:0806.2838 [hep-ph]

Variables		SUSY (MSSM)	LHT	UED
Spin		heavy partners differ in spin by 1/2	heavy partners have the same spin, no heavy gluon	heavy partners have the same spin
Higher level modes		NO heavy partners	NO heavy partners	YES heavy partners
$N_{l^+l^+}/N_{l^-l^-}$		$R_{SUSY} < R_{LHT}$	R_{LHT}	$R_{UED} \simeq R_{LHT}$
SS leptons rates		from several channels: SS heavy fermions, Majorana fermions	only from SS heavy fermions	only from SS heavy fermions
$R = \frac{N(\not{E}_T + jets)}{N(l's + \not{E}_T + \text{jets})}$		R_{SUSY}	$R_{\text{LHT}} < R_{\text{SUSY}}$	R_{UED} to be studied
b-jet multiplicity		enhanced (FP)	not enhanced	not enhanced
Single heavy top		NO	YES	YES via KK2 decay
polarization effects	$tt + \not{E}_T$	to be studied	to be studied	to be studied
	$\tau\tau + \not{E}_T$	to be studied	to be studied	to be studied
Direct DM detection rate		high (FP) low (coann)	low (Bino-like LTP)	typically low for γ_1(5D) DM [22] typically high for γ_H(6D) DM [22]

It was realised that
“Dictionary of the LHC Signatures”
in the form of various tables is not enough to accommodate all models and their signatures

It was realised that
"Dictionary of the LHC Signatures"
in the form of various tables is not enough to accommodate all models and their signatures

We need dictionary in the form of the Model Database and their Signatures

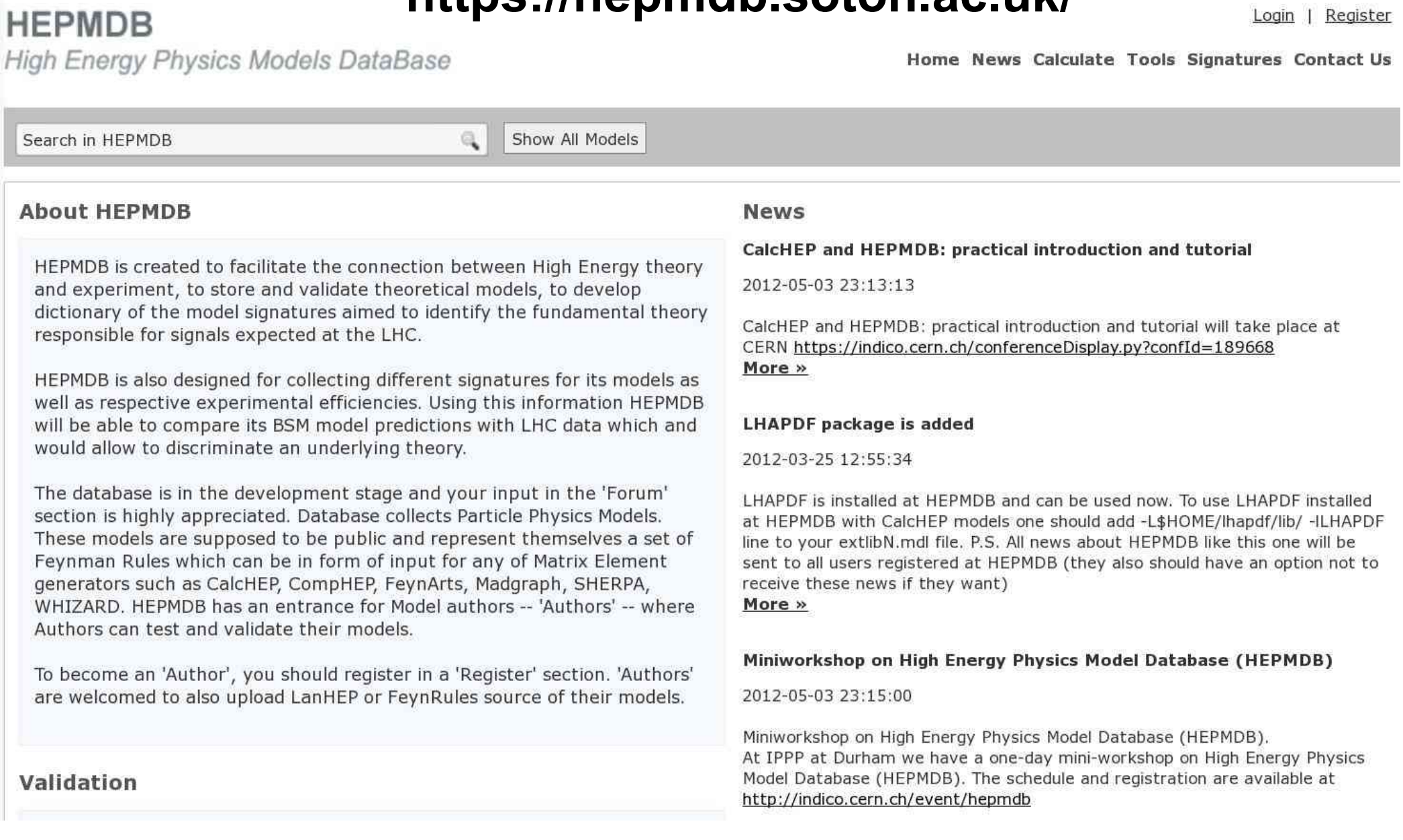
It was realised that "Dictionary of the LHC Signatures" in the form of various tables is not enough to accommodate all models and their signatures

We need dictionary in the form of the Model Database and their Signatures

High Energy Physics Model Database [HEPMDB]

High Energy Physics Model Database

https://hepmdb.soton.ac.uk/



High Energy Physics Model Database

- **Developed at Southampton with support from IPPP, Durham**
  as a result of ideas discussed in the context of the "Dictionary of LHC signatures", at the FeynRules workshop (April, 2010) and at the Mini-Workshop on Dynamical Symmetry Breaking models and tools (July 2010)
- **Further developed at the Les Houches Workshop, June 2011**

High Energy Physics Model Database – HEPMDB. Towards decoding of the underlying theory at the LHC.

arXiv:1203.1488 (the last section of the Les Houches 2011 proceedings)

Maksym Bondarenko[1], Alexander Belyaev[1,2], Lorenzo Basso[1,2,3], Edward Boos[4], Vyacheslav Bunichev[4], R. Sekhar Chivukula[5], Neil D. Christensen[6], Simon Cox[7], Albert De Roeck[8], Stefano Moretti[1,2], Alexander Pukhov[4], Sezen Sekmen[8], Andrei Semenov[9], Elizabeth H. Simmons[5], Claire Shepherd-Themistocleous[2], Christian Speckner[3]

Abstract

We present here the first stage of development of the High Energy Physics Model Data-Base (HEPMDB) which is already a convenient centralized storage environment for HEP models, and can accommodate, via web interface to the HPC cluster, the validation of models, evaluation of LHC predictions and event generation-simulation chain. The ultimate goal of HEPMDB is perform an effective LHC data interpretation isolating the most successful theory for explaining the LHC observations.

Aims of the HEPMDB (1)

- *to collect HEP models for various multipurpose Matrix Element (ME) generators like CalcHEP, CompHEP, FeynArts, MadGraph/MadEvent, AMEGIC ++/COMIX within SHERPA and WHIZARD.*
  Under "HEP models" we denote the set of particles, Feynman rules and parameters written in the format specific for a given package
- *to collect models' sources which can be used in the HEPMDB to generate HEP models for various ME generators using FeynRules or LanHEP which automate the process of generating Feynman Rules, particle spectra, etc..*
  For the moment, FeynRules supports formats for CompHEP, CalcHEP, FeynArts, GoSam, MadGraph/MadEvent, SHERPA and WHIZARD Currently LanHEP works with CalcHEP, CompHEP, FeynArts and GoSam. Also, the latest LanHEP version 3.15 has an option under testing of outputting the model in UFO format which provides a way to interface it with MadGraph/MadEvent
- to allows users upload their models and perform evaluation of HEP processes and event generation for their own models using the full power of the High Performance Computing (HPC) cluster behind the HEPMDB.
  This is one of the very powerful features of the HEPMDB: it provides a web interface to various ME generators which can then also be run directly on the HPC cluster. This way, users can preform calculations for any model from HEPMDB avoiding problems related to installing the actual software, which can sometimes be quite cumbersome

Aims of HEPMDB (2)

- to plot and document various kinematical distributions from generated events in the LHE format
- to allow to compare predictions from models generated from LanHEP and FeynRules
- to collect predictions and specific features of various models in the form of database of signatures and perform comparison of various model predictions with experimental data (to be developed)

  There are a lot of different aspects related to this problem. This task includes a comprehensive development of a database of signatures as well as development of the format of presentation of these signatures. This format will be consistent with the format which will be used by the experimentalists for the presentation of the LHC data, discussed in the context of the "Les Houches Recommendations for the Presentation of LHC Results" activity.
- to trace the history of the model modifications, and makes available all the versions of the model

  Through this application, we stress the importance of reproducibility of the results coming from HEPMDB or from a particular model downloaded from HEPMDB.

Sounding similar but qualitatively different related projects

- “Database of Numerical HEP scattering cross sections”
  http://durpdg.dur.ac.uk/HEPDATA/REAC
  collects various particle scattering process which are connected to experimental searches of different reactions

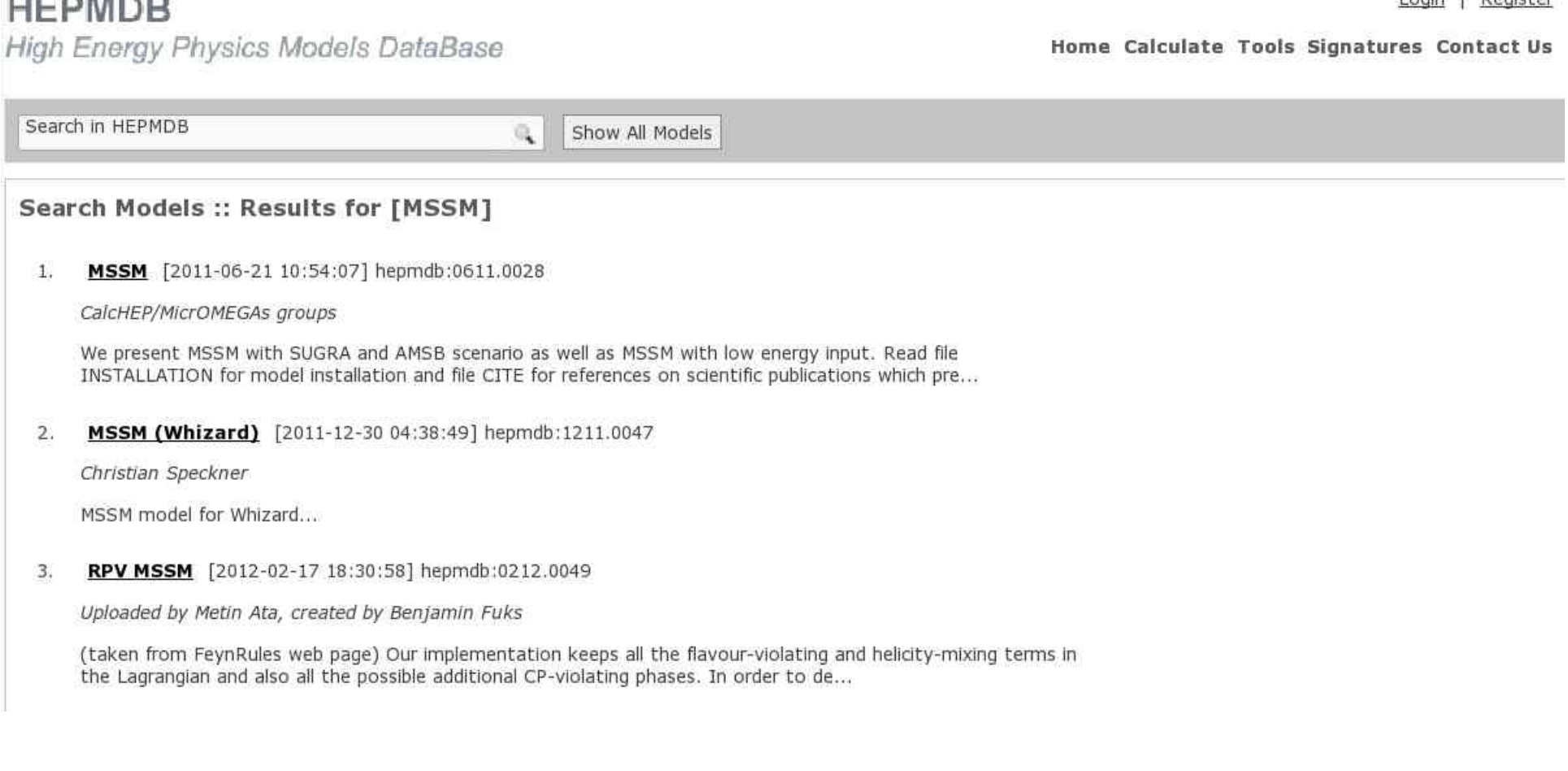
- “Signatures of New Physics at the LHC” web-site
  http://www.lhcnewphysics.org/
  collects various BSM signatures, their classification and related papers

- FeynRules and models database
  http://feynrules.irmp.ucl.ac.be
  collects various models implemented into FeynRules and have an effective way to validate them

- **HEPMDB can effectively collaborate with all projects above!**

The current status of HEPMDB (1)

- Allows to search and download an existing HEP model. The search engine checks patterns in the fields:
  Model, Authors, References, Abstract, Signatures and Information



The current status of HEPMDB (2)

- one can upload a new model (upon user registration). The model can be uploaded in the format of any ME generator. Also, a user can upload the model source in FeynRules or LanHEP formats, allows to keep model privately!

Model : MSSM

http://hepmdb.soton.ac.uk/hepmdb:0611.0028

Authors

CalcHEP/MicrOMEGAs groups

Added By

Alexander Belyaev

References

G.~Belanger, F.~Boudjema, A.~Pukhov and A.~Semenov, Comput. Phys. Commun. 174, 577 (2006)[arXiv:hep-ph/0405253]
A.~Djouadi, J.~L.~Kneur and G.~Moultaka, arXiv:hep-ph/0211331

Abstract

Updated MSSM model for CalcHEP is uploaded (bug for SC constant in the file with dependences is corrected)

Information

We present MSSM with SUGRA and AMSB scenario as well as MSSM with low energy input. Read file INSTALLATION for model installation and file CITE for references on scientific publications which present realization of the model.

Tools

CalcHEP [model]

Model History

2011-12-02 15:01:19
2011-10-14 13:40:10

Download Model File | Validate Model on HPCx | Edit Model

Reviews

The current status of HEPMDB (3)

- allows to the evaluate cross sections for user-defined processes for the chosen model and produce a respective LHE file with generated parton-level events. This file is becomes available for download once the process is finished (user will receive an e-mail notification on this)
  Currently, the HEPMDB allows the user to perform these calculations (using the HPC) for CalcHEP, WHIZARD and MadGRAPH 5
- produces ntuple files and allows to plot various kinematical distributions
- allows to update/add features and respective signatures specific to each model.
  These features and signatures can be used in the future to distinguish the model from others and connect it to the LHC signatures.
- keeps track of the model changes, providing reproducibility for the results obtained with previous versions of the models uploaded to HEPMDB
- allows to collect feedback/remarks on particular model from users in Review section

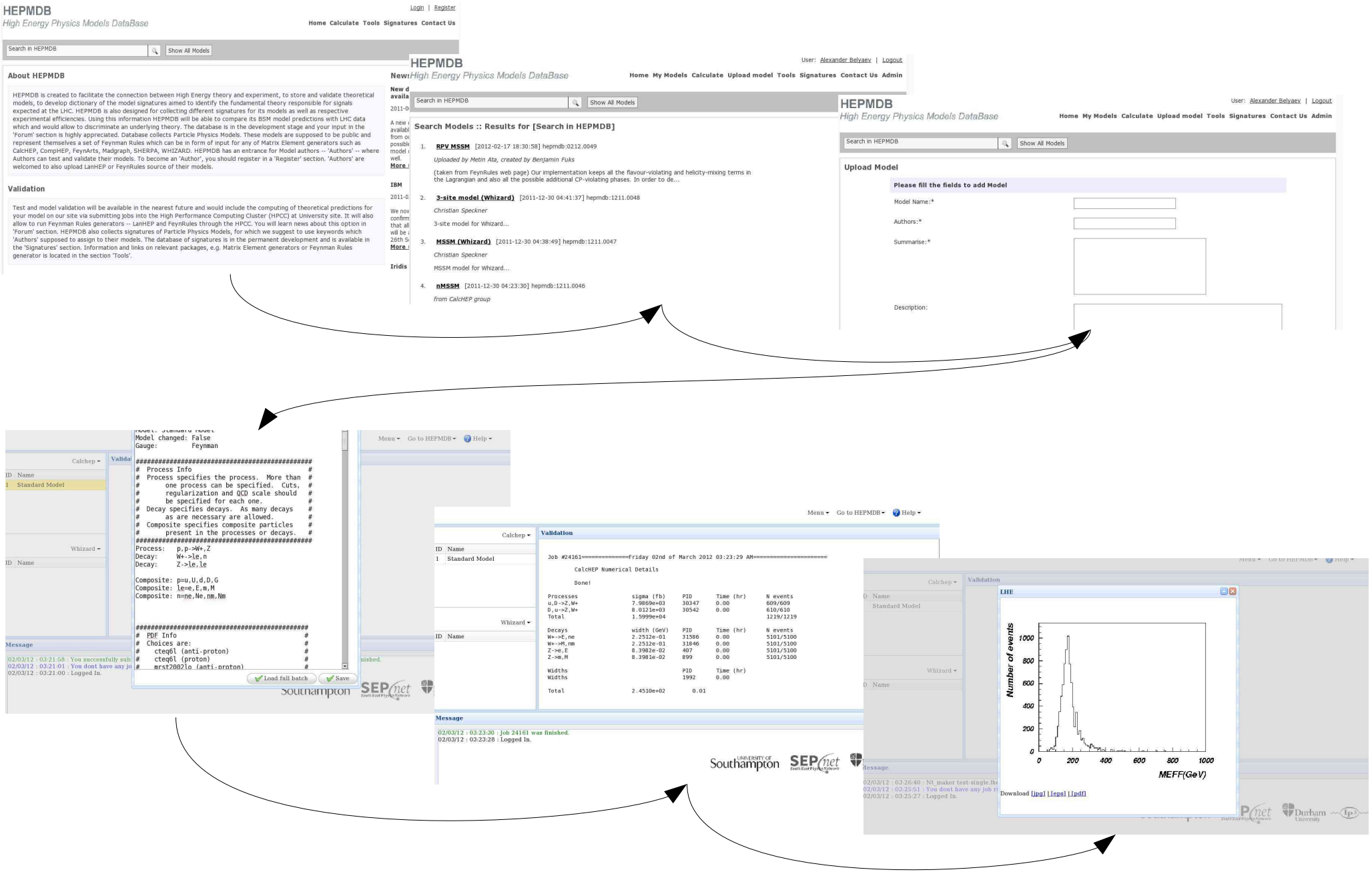
Future prospects for HEPMDB (months scale)

- The LanHEP and FeynRules packages will be added to provide model generation from model sources
- CompHEP package will be added.
- A systematic model validation process will be started and the respective pages will be added.
- The possibility to study events beyond the parton level will be carefully considered, up to detector simulation.
  One concrete possibility would be the chain
  LHE events -> HEPMC events -> FASTSIM events (ROOT format)
  For the FASTSIM package, Delphes seems a promising candidate.
- The structure of the database of signatures will be extended to deal with correlated signatures (i.e., whereby multiple signatures, or lacks thereof, must be accounted for simultaneously)

Future prospects for HEPMDB (~year time scale)

- we plan to install the MicrOMEGAs package for evaluation of the dark matter relic density as well as to provide a possibility for scans of various model parameter spaces.
- Author of other packages/models are welcome to install/upload them
- the format for model predictions consistent with the format for presentation of the LHC data by experimentalists is planned.
- The question about including automatic tools for NLO evaluations is under discussion and will be developed further at the later stages of HEPMDB development.

Tutorial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Validation
Search Models :: Results for [Search in HEPMDB]
Upload Model
Please fill the fields to add Model
Model Name:*
Authors:*
Summarise:*
Description:
Validation
Message
LHE
Number of events
MEFF(GeV)

Tutorial

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About HEPMDB

HEPMDB is created to facilitate the connection between High Energy theory and experiment, to store and validate theoretical models, to develop dictionary of the model signatures aimed to identify the fundamental theory responsible for signals expected at the LHC.

HEPMDB is also designed for collecting different signatures for its models as well as respective experimental efficiencies. Using this information HEPMDB will be able to compare its BSM model predictions with LHC data which and would allow to discriminate an underlying theory.

The database is in the development stage and your input in the 'Forum' section is highly appreciated. Database collects Particle Physics Models. These models are supposed to be public and represent themselves a set of Feynman Rules which can be in form of input for any of Matrix Element generators such as CalcHEP, CompHEP, FeynArts, Madgraph, SHERPA, WHIZARD. HEPMDB has an entrance for Model authors -- 'Authors' -- where Authors can test and validate their models.

News

We suffered a failure of the Iridis cooling system earlier this morning

2012-07-10 18:52:13

We suffered a failure of the Iridis cooling system earlier this morning, which led to temperatures in the data centre rising very rapidly. We do not expect to be able o resume a batch service until after lunch.
More »

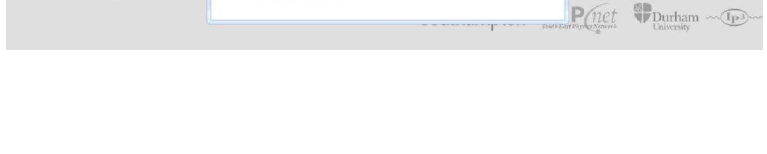
CalcHEP and HEPMDB: practical introduction and tutorial

2012-05-03 23:13:13

CalcHEP and HEPMDB: practical introduction and tutorial will take place at CERN https://indico.cern.ch/conferenceDisplay.py?confId=189668
More »

LHAPDF package is added

2012-03-25 12:55:34



Tutorial

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Search Models :: Results for [MSSM]

1. **MSSM** [2011-06-21 10:54:07] hepmdb:0611.0028

   CalcHEP/MicrOMEGAs groups

   We present MSSM with SUGRA and AMSB scenario as well as MSSM with low energy input. Read file INSTALLATION for model installation and file CITE for references on scientific publications which pre...

2. **MSSM with bilinear R-Parity violation** [2011-11-17 20:00:51] hepmdb:1111.0036

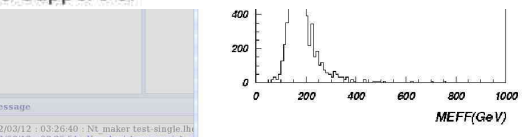
   Florian Staub

   The MSSM with bilinear R-Parity violating terms in the superpotential and for the soft-breaking terms. Model files created by SARAH 3.1.0 Support of SLHA+ functionality to read spectrum files...

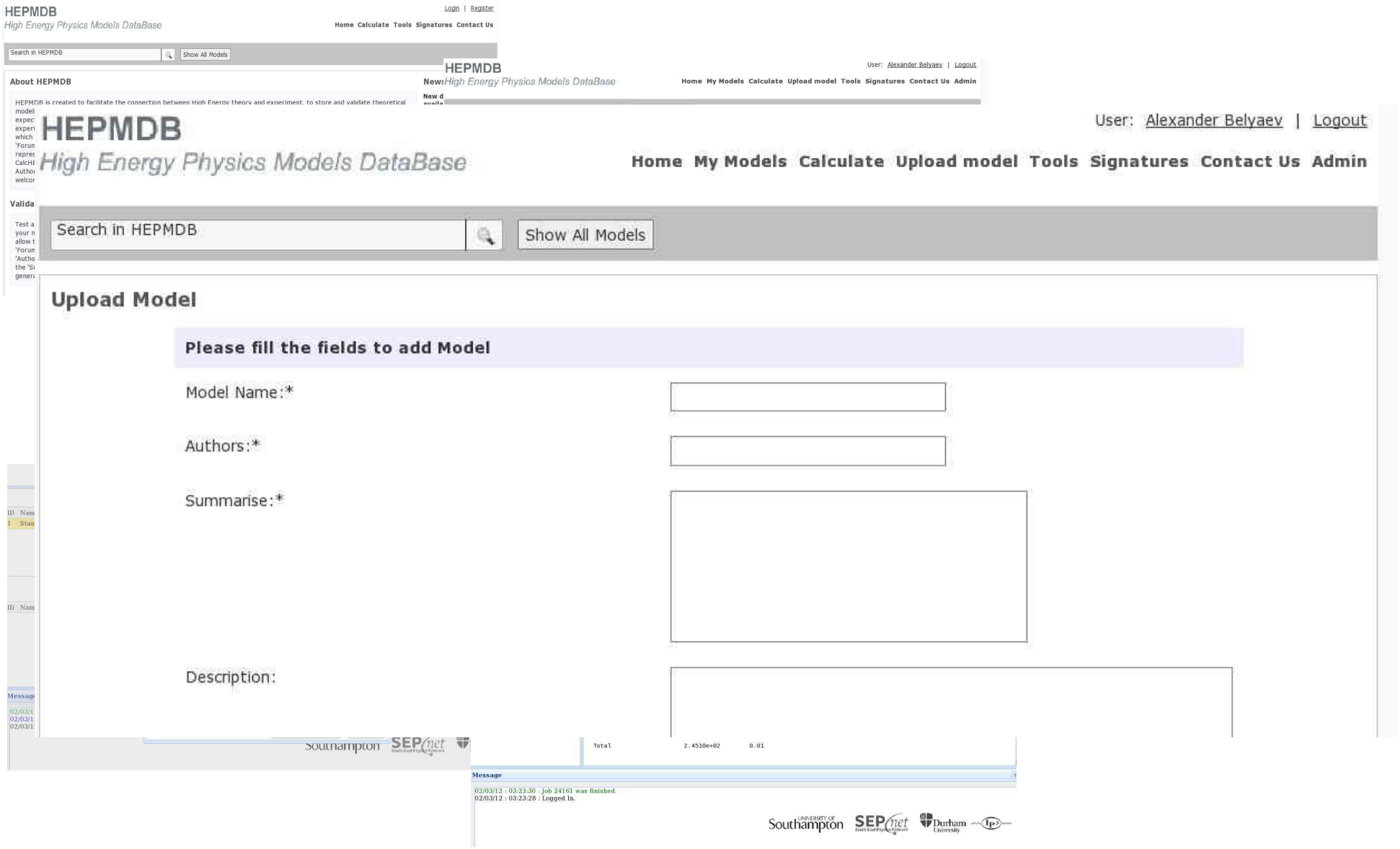
3. **TMSSM** [2011-11-17 20:06:23] hepmdb:1111.0037

   Florian Staub

   Triplet extended MSSM (including possibility of flavor violation) Model files created by SARAH 3.1.0 Support of



Tutorial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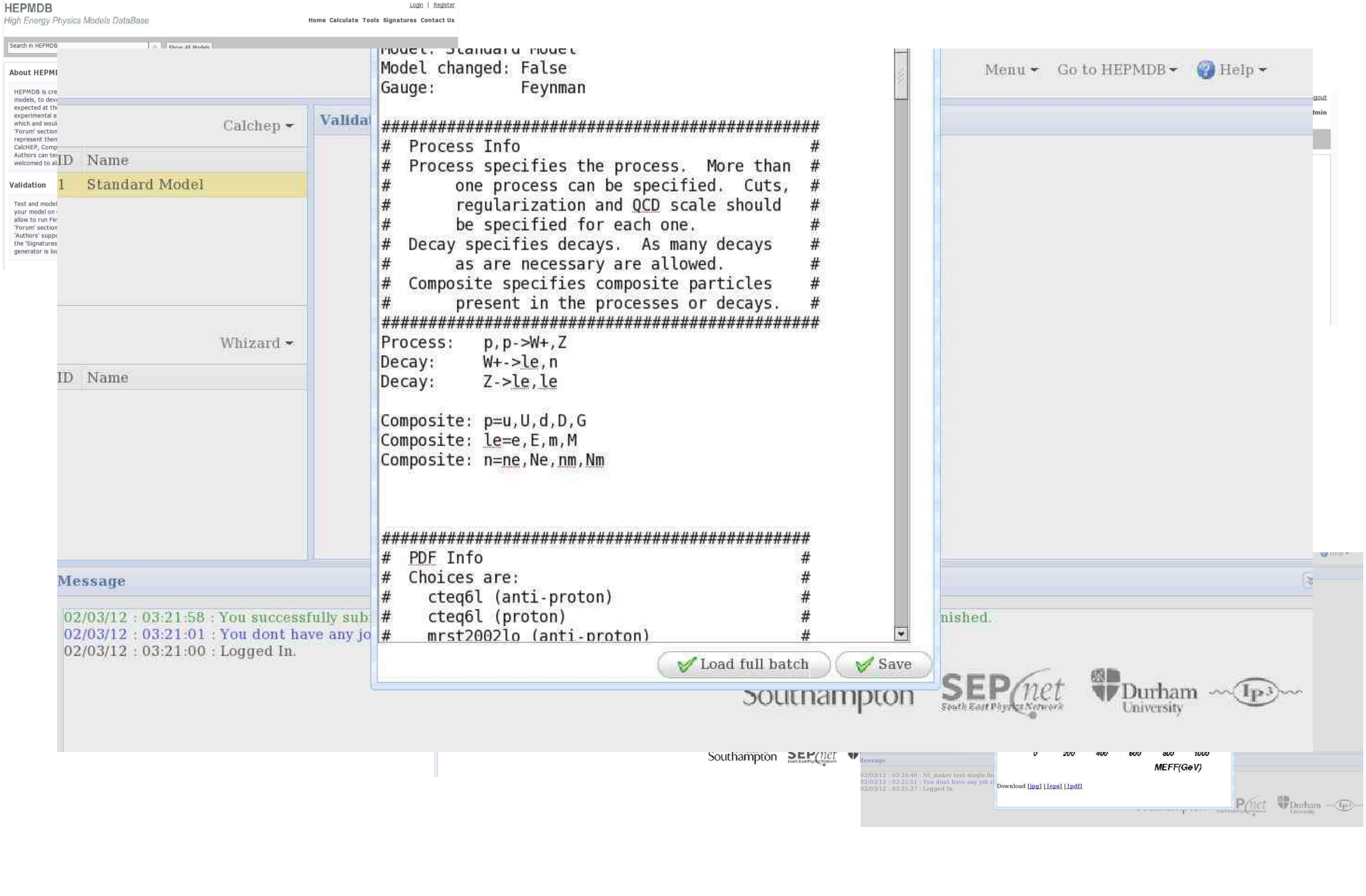
Please fill the fields to add Model
Model Name:*
Authors:*
Summarise:*
Description:
Total 2.4510e+02 0.01
Message
02/03/12 : 03:23:30 : Job 24161 was finished.
02/03/12 : 03:23:28 : Logged In.
Southampton
SEPnet
Durham University

Tutorial


HEPMDB
High Energy Physics Models DataBase
Model changed: False
Gauge: Feynman
Process: p,p->W+,Z
Decay: W+->le,n
Decay: Z->le,le
Composite: p=u,U,d,D,G
Composite: le=e,E,m,M
Composite: n=ne,Ne,nm,Nm
PDF Info
Choices are:
cteq6l (anti-proton)
cteq6l (proton)
Load full batch
Save
Menu
Go to HEPMDB
Help
Calchep
Whizard
Standard Model
Message
02/03/12 : 03:21:58 : You successfully sub
02/03/12 : 03:21:01 : You dont have any jo
02/03/12 : 03:21:00 : Logged In.
Southampton
SEPnet
Durham University
MEFF(GeV)

Batch file in details(1)

```
################################################
#  batch_file for CalcHEP                      #
#  It has to be launched via                   #
#          ./calchep_batch batch_file          #
#  Lines beginning with # are ignored.         #
################################################

################################################
#  Model Info                                  #
#  Model is the exact model name.              #
#  Model changed specifies whether a change    #
#       was made to the model files.  Changes  #
#       to the numerical values of external    #
#       parameters is ok.  Other changes       #
#       require that the process library be    #
#       recreated.  Values are True or False.  #
#  Gauge specifies gauge.  Choices are         #
#       Feynman or unitary.                    #
################################################
Model:         Standard Model(CKM=1)
Model changed: False
Gauge:         Feynman

################################################
#  Process Info                                #
#  Process specifies the process.  More than   #
#       one process can be specified.  Cuts,   #
#       regularization and QCD scale should    #
#       be specified for each one.             #
#  Decay specifies decays.  As many decays     #
#       as are necessary are allowed.          #
#  Composite specifies composite particles     #
#       present in the processes or decays.    #
################################################
Process:   p,p->W,b,B
Decay:     W->le,n
```

```
Composite: p=u,U,d,D,s,S,c,C,b,B,G
Composite: W=W+,W-
Composite: le=e,E,m,M
Composite: n=ne,Ne,nm,Nm
Composite: jet=u,U,d,D,s,S,c,C,b,B,G



################################################
#  PDF Info                                    #
#  Choices are:                                #
#    cteq6l (anti-proton)                      #
#    cteq6l (proton)                           #
#    mrst2002lo (anti-proton)                  #
#    mrst2002lo (proton)                       #
#    cteq6m (anti-proton)                      #
#    cteq6m (proton)                           #
#    cteq5m (anti-proton)                      #
#    cteq5m (proton)                           #
#    mrst2002nlo (anti-proton)                 #
#    mrst2002nlo (proton)                      #
#    ISR                                       #
#    ISR & Beamstrahlung                       #
#    Equiv. Photon                             #
#    Laser photons                             #
#    Proton Photon                             #
#    OFF                                      #
#                                               #
#  ISR and Beamstrahlung are only available     #
#    for electrons and positrons, while the     #
#    others are available for protons and       #
#    antiprotons.                               #
#    Default pdf: OFF                          #
#  Bunch x+y sizes (nm)                         #
#    Ignored unless ISR & Beam chosen.          #
#    Default: 560                               #
#  Bunch length (mm)                            #
#    Ignored unless ISR & Beam chosen.          #
```

Batch file in details(2)

```
#    Default: 0.4                                  #
#  Number of particles                             #
#    Ignored unless ISR & Beam chosen.             #
#    Default: 2E+10                                #
#  Default Beamstrahlung parameters                #
#    correspond roughly with ILC.                  #
#                                                  #
#  Equiv. Photon, Laser photons and                #
#    Proton Photon are available for               #
#    photons.                                      #
#    Default pdf: OFF                             #
#  Photon particle                                 #
#    Ignored unless Equiv. Photon chosen.          #
#    Choices are: mu^-,e^-,e^+,mu^+                #
#    Default: e^+                                  #
#  |Q|max                                          #
#    Ignored unless Equiv. Photon chosen.          #
#    Default: 100                                  #
#  Incoming particle mass                          #
#    Ignored unless Proton Photon chosen.          #
#    Default: 0.938                                #
#  Incoming particle charge                        #
#    Ignored unless Proton Photon chosen.          #
#    Choices are: 1,-1                             #
#    Default: 1                                    #
#  |Q^2|max                                        #
#    Ignored unless Proton Photon chosen.          #
#    Default: 2                                    #
#  Pt cut of outgoing proton                       #
#    Ignored unless Proton Photon chosen.          #
#    Default: 0.1                                  #
################################################
pdf1:      cteq6l (proton)
pdf2:      cteq6l (proton)
```

```
#Bunch x+y sizes (nm)      : 202500
#Bunch length (mm)         : 10
#Number of particles       : 5E+11

#Photon particle           : e^-
#|Q|max                    : 250
#Incoming particle mass    : 0.938
#Incoming particle charge  : -1
#|Q^2|max                  : 2.0
#Pt cut of outgoing proton : 0.15

################################################
#  Momentum Info                               #
#    in GeV                                    #
################################################
p1:        4000
p2:        4000

################################################
#  Parameter Info                              #
#  Masses and Energies are in GeV              #
################################################
#Parameter: EE=0.31

################################################
#  Run Info                                    #
#  Masses and Energies are in GeV              #
#  More than one run can be specified at       #
#     the same time.                           #
################################################
Run parameter: Mh
Run begin:     120
Run step size: 5
Run n steps:   3
```

Batch file in details(3)

```
################################################
#  QCD Running Info                            #
#  As in the gui:                              #
#  parton dist. alpha                          #
#     default: ON                              #
#  alpha(MZ)                                   #
#     default: 0.1172                          #
#  alpha nf                                    #
#     default: 5                               #
#  alpha order                                 #
#     choices: LO, NLO, NNLO                   #
#     default: NLO                             #
#  mb(mb)                                      #
#     default: 4.2                             #
#  Mtop(pole)                                  #
#     default: 175                             #
#  alpha Q                                     #
#     Must be in terms of the final state      #
#     particles.                               #
#     default: M12                             #
#     :n: specifies which process.             #
#     : means to apply to all processes.       #
################################################
#parton dist. alpha: ON
#alpha(MZ):          0.118
#alpha nf:           5
#alpha order:        NLO
#mb(mb):             4
#Mtop(pole):         174

#alpha Q :1:         M34
#alpha Q :2:         M45
alpha Q :           M45
```

```
################################################
#  Cut Info                                    #
#  Must be in terms of the (production mode)   #
#     final state particles.                   #
#     :n: specifies which process.             #
#     : means to apply to all processes.       #
################################################

Cut parameter:    M(b,B)
Cut invert:       False
Cut min:          100
Cut max:

Cut parameter:    J(jet,jet)
Cut invert:       False
Cut min:          0.5
Cut max:

Cut parameter:    T(jet)
Cut invert:       False
Cut min:          20
Cut max:

Cut parameter:    N(jet)
Cut invert:       False
Cut min:          -2.5
Cut max:          2.5



################################################
#  Kinematics Info                             #
#  Must be exactly as in CH.                   #
#     Comment out to use the CH defaults.      #
#     :n: specifies which process.             #
#     : means to apply to all processes.       #
################################################
```

Batch file in details(4)

```
#Kinematics :1:    12 -> 34 , 56
#Kinematics :1:    34 -> 3 , 4
#Kinematics :1:    56 -> 5 , 6

Kinematics :      12 -> 3, 45
Kinematics :      45 -> 4 , 5



################################################
#  Regularization Info                         #
#  Must be in terms of the final state         #
#     particles.                               #
#     :n: specifies which process.             #
#     : means to apply to all processes.       #
################################################
Regularization momentum:1: 45
Regularization mass:1:     Mh
Regularization width:1:    wh
Regularization power:1:    2


################################################
#  Distribution Info                           #
#  Only 1 dimensional distributions are        #
#     currently supported.                     #
#  Dist n bins should be one of:               #
#     300, 150, 100, 75, 60, 50, 30, 25,       #
#     20, 15, 12, 10, 6, 5, 4, 3, 2            #
#  Dist title and Dist x-title should be       #
#     plain text.                              #
################################################
Dist parameter:    M(b,B)
Dist min:          100
Dist max:          200
Dist n bins:       100
Dist title:        p,p->W,b,B
Dist x-title:      M(b,B) (GeV)
```

```
Dist parameter:    M(W,jet)
Dist min:          100
Dist max:          200
Dist n bins:       100
Dist title:        p,p->W,b,B
Dist x-title:      M(W,jet) (GeV)

################################################
#  Events Generation                           #
#  Number of events determines how many        #
#       events to produce for each run.        #
#  Filename is the name used for the event     #
#       files.  If no parameter is run over    #
#       then, -Single.lhe is appended.  If     #
#       a parameter is run over then its       #
#       value will be appended as in           #
#       pp-WW-MW400.lhe.                       #
#  NTuple determines whether PAW ntuples       #
#       are created.  This only works if       #
#       nt_maker is properly compiled and      #
#       in the bin directory.                  #
#       Choices are True or False.             #
#  Cleanup determines whether the              #
#       individual event files are removed     #
#       after they are combined.               #
#       Default: True                          #
################################################
Number of events (per run step): 1000
Filename:                        test
NTuple:                          False
Cleanup:                         False
```

Batch file in details(5)

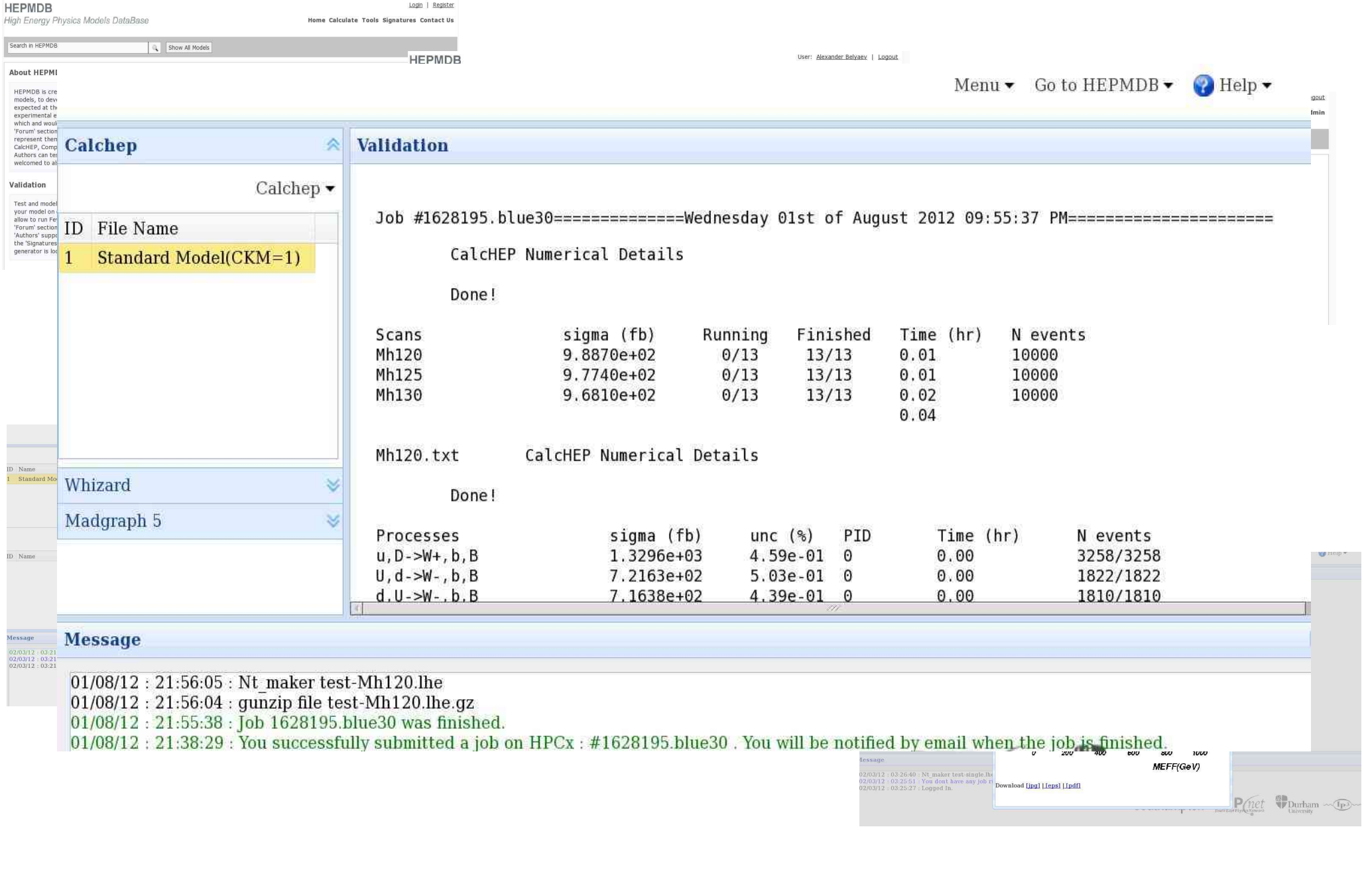
```
################################################
#  Parallelization Info                        #
#  Parallelization method choices:             #
#      local                                   #
#      pbs                                     #
#  Que can be left blank if not required       #
#      on your pbs cluster.                    #
#  Walltime should be the number               #
#      of hours necessary for each job.        #
#      Leave blank if your pbs cluster does    #
#      not require this and will let a         #
#      job run until it is finished.           #
#  Memory is the amount of memory required     #
#      for each job in gb.  Leave blank        #
#      if not required on your cluster.        #
#  email is only used on the pbs cluster       #
#      if you want it to inform you of         #
#      problems. email is currently ignored.   #
#  sleep time determines how often the         #
#      script updates (in seconds)             #
#      while waiting for processes to finish.  #
#  nice level is used for the CH jobs in       #
#      local mode and combining events in      #
#      all modes.                              #
#      default: 19                             #
################################################
Parallelization method:      local
#Que:                         brody_main
#Walltime:                    0.15
#Memory:                      1
#email:                       name@address
Max number of cpus:          2
sleep time:                  3
nice level :                 19
```

```
################################################
#  Vegas                                       #
#  The variables are the same as in the gui.   #
#  If commented out, the default values        #
#      are used.                               #
#                                              #
#  nSess_1 : number of the 1st sessions        #
#     default: 5                               #
#  nCalls_1 : number of calls per 1st sessions#
#     default: 10000                           #
#  nSess_2 : number of the 2nd sessions        #
#     default: 0                               #
#  nCalls_2 : number of calls per 2nd sessions#
#     default: 10000                           #
################################################
nSess_1:   5
nCalls_1:  100000
nSess_2:   5
nCalls_2:  100000


################################################
#  Event Generator                             #
#  The variables are the same as in the gui.   #
#  If commented out, the default values        #
#      are used.                               #
#                                              #
#  sub-cubes:                                  #
#     default: 1000                            #
#  random search:                              #
#     default: 100                             #
#  simplex search:                             #
#     default: 50                              #
#                                              #
#  MAX*N: integer to multiply max by           #
#     default: 2                               #
#  find new MAX:                               #
#     default: 100                             #
################################################
#sub-cubes:      100000
#random search:  100
#simplex search: 50

#MAX*N:          2
#find new MAX:   100
```

Tutorial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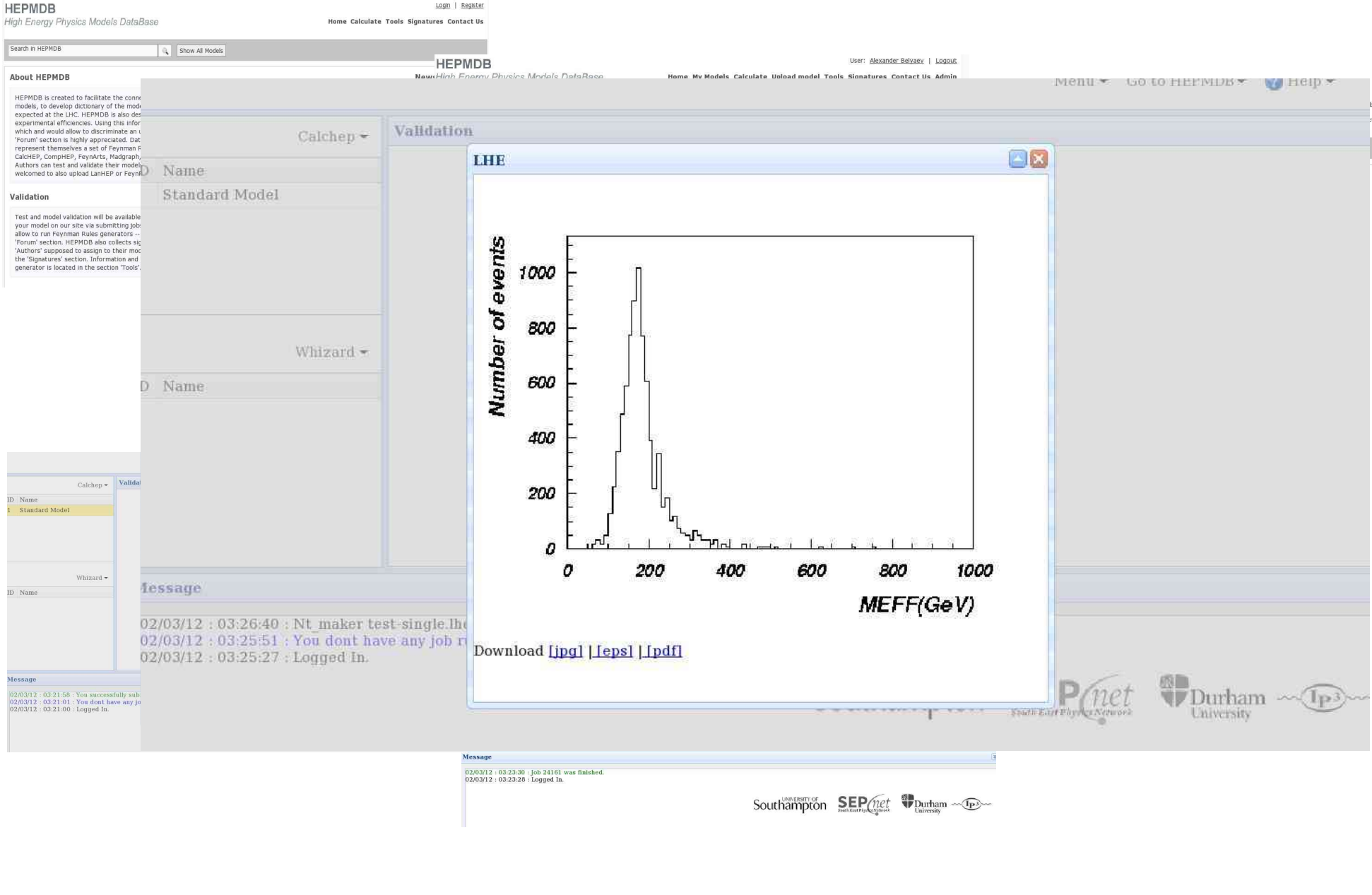
Go to HEPMDB
Help
Calchep
Calchep
ID File Name
1 Standard Model(CKM=1)
Whizard
Madgraph 5
Validation
Job #1628195.blue30==========Wednesday 01st of August 2012 09:55:37 PM==========
CalcHEP Numerical Details
Done!
Scans sigma (fb) Running Finished Time (hr) N events
Mh120 9.8870e+02 0/13 13/13 0.01 10000
Mh125 9.7740e+02 0/13 13/13 0.01 10000
Mh130 9.6810e+02 0/13 13/13 0.02 10000
0.04
Mh120.txt CalcHEP Numerical Details
Done!
Processes sigma (fb) unc (%) PID Time (hr) N events
u,D->W+,b,B 1.3296e+03 4.59e-01 0 0.00 3258/3258
U,d->W-,b,B 7.2163e+02 5.03e-01 0 0.00 1822/1822
d,U->W-,b,B 7.1638e+02 4.39e-01 0 0.00 1810/1810
Message
01/08/12 : 21:56:05 : Nt_maker test-Mh120.lhe
01/08/12 : 21:56:04 : gunzip file test-Mh120.lhe.gz
01/08/12 : 21:55:38 : Job 1628195.blue30 was finished.
01/08/12 : 21:38:29 : You successfully submitted a job on HPCx : #1628195.blue30 . You will be notified by email when the job is finished.
MEFF(GeV)

Tutorial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Show All Models
About HEPMDB
Validation
Calchep
Whizard
Name
Standard Model
Validation
Message
02/03/12 : 03:26:40 : Nt_maker test-single.lhe
02/03/12 : 03:25:51 : You dont have any job r
02/03/12 : 03:25:27 : Logged In.
LHE
Number of events
1000
800
600
400
200
0
0
200
400
600
800
1000
MEFF(GeV)
Download [jpg] | [eps] | [pdf]
02/03/12 : 03:23:30 : Job 24161 was finished.
02/03/12 : 03:23:28 : Logged In.
Durham University

Example of models created for CalcHEP

- **SM + extensions**
  - SM
  - B-L symmetric Z' with heavy Majorana neutrinos
  - SM + Z'
  - general 2 Higgs doublet model
  - 4th generation
  - Excited fermions
  - Model with contact interactions
  - Standard Model + anomalous gauge boson couplings
  - Model of strongly int EW sector
    (5 & 6 dim operators involving Sigma field)
- **SUSY**
  - constraint MSSM
  - general MSSM, with 124 free parameters
  - NMSSM
  - RPVMSSM
  - left-right symmetric MSSM
  - MSSM with CP violation
  - E6MSSM
- **Extra dimensions**
  - 5D UED with 2KK layers
  - 6D UED with 2KK layers
  - ADD = ADD
  - RS = Randall Sundrum
- **Leptoquarks**
  - Complete LQ model
    SU(3)xSU(1)xU(1) vector&scalar
- **Technicolor & Higgsless**
  - Minimal walking technicolor
  - TC with DM
  - 3-site model
  - Hidden Local symmetry model
  - 4SM = general 4-site model
- **Little Higgs**
  - Littlest higgs model with T-parity
  - LHT + T-parity violation

Models at FeynRules web-site

Standard Model	The SM implementation of FeynRules, included into the distribution of the FeynRules package.
Simple extensions of the SM (10)	Several models based on the SM that include one or more additional particles, like a 4th generation, a second Higgs doublet or additional colored scalars.
Supersymmetric Models (4)	Various supersymmetric extensions of the SM, including the MSSM, the NMSSM and many more.
Extra-dimensional Models (4)	Extensions of the SM including KK excitations of the SM particles.
Strongly coupled and effective field theories (4)	Including Technicolor, Little Higgs, as well as SM higher-dimensional operators.
Miscellaneous (0)	

Remarks on collecting models at HEPMDB

- *there are numerous model implementations exist (FeynRules team, LanHEP/CalcHEP/CompHEP teams, private implementations)*
- *they are highly complementary and useful*
- *HEPMDB is the natural place to accommodate all of them (also allows to keep model privately, controlled by Public/Private option On/Off!)*

Summary on HEPMDB

- HEPMDB is already a convenient centralized storage environment for HEP models. Via web interface to the HPC cluster (12 cores per user) it allows to evaluate the LHC predictions and event generation-simulation chain

- Your relevant packages can be installed at HEPMDB!

- we hope that starting from the present stage, HEPMDB development will be boosted further via involvement of the HEP community
  (via direct involvement into HEPMDB, via various projects involving HEPMDB, via numerous comments/requests for HEPMDB features)

- we hope also that in the near future the HEPMDB will become a powerful tool for isolation of the most successful theory for explaining the LHC data