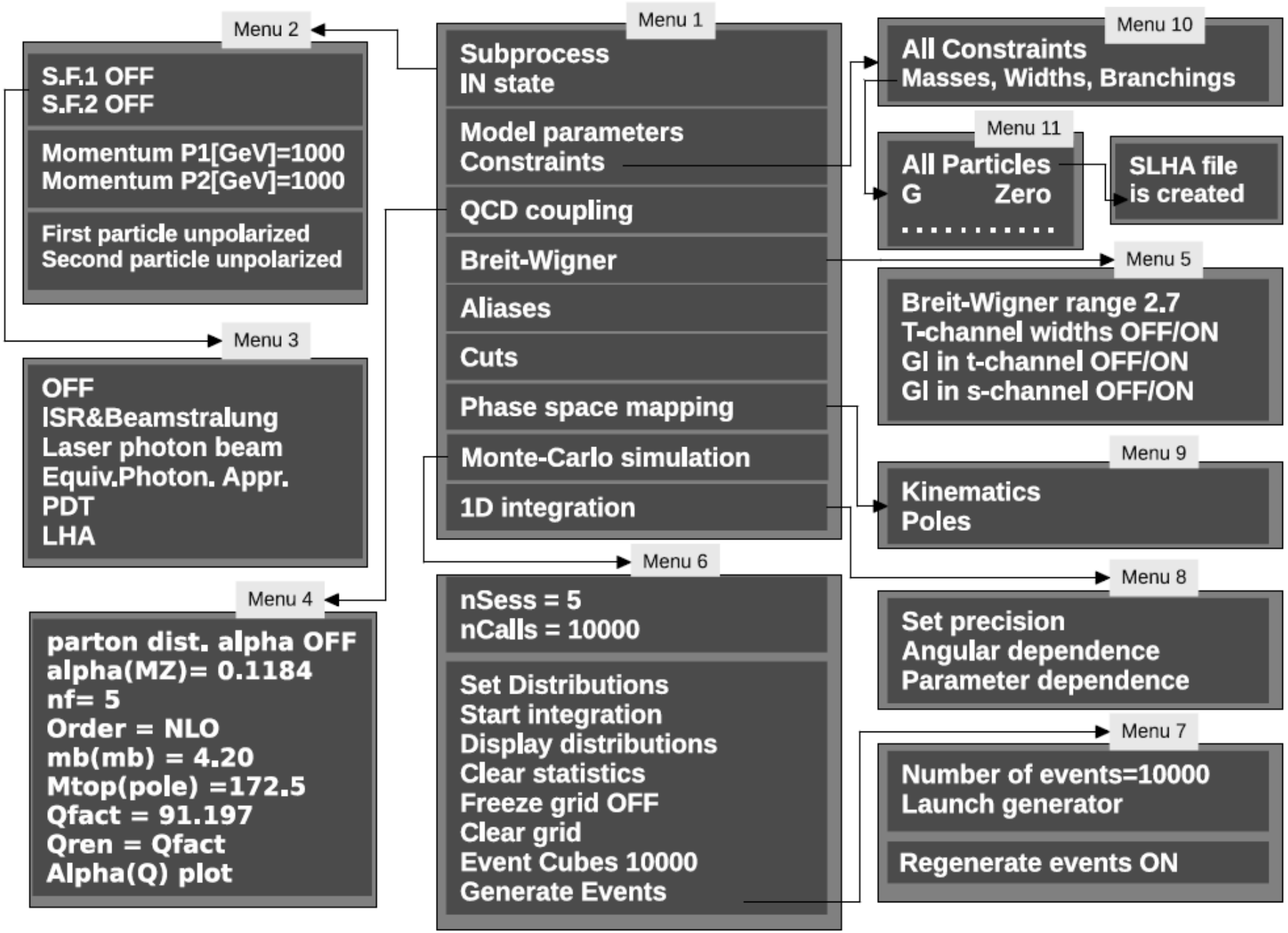
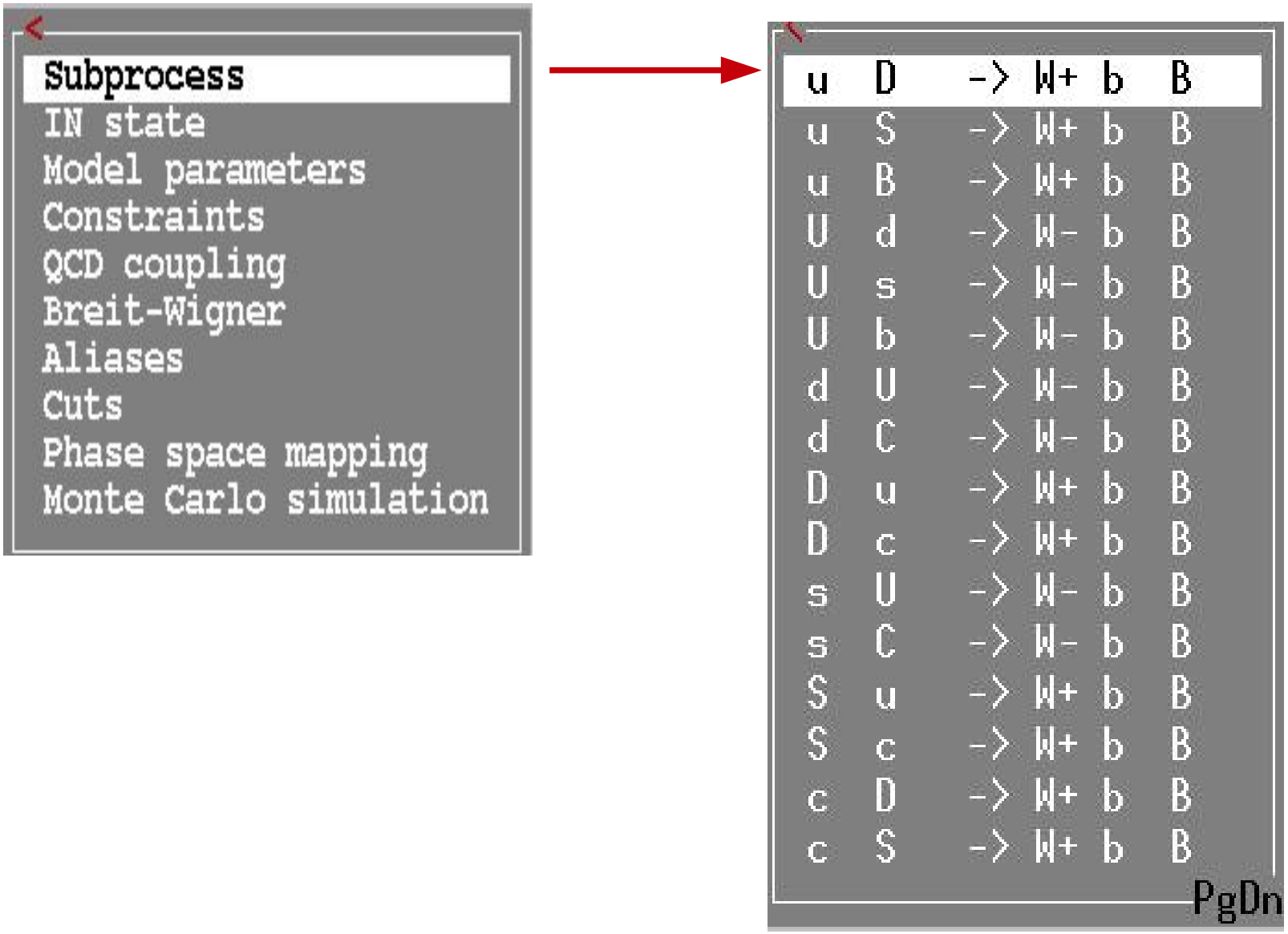
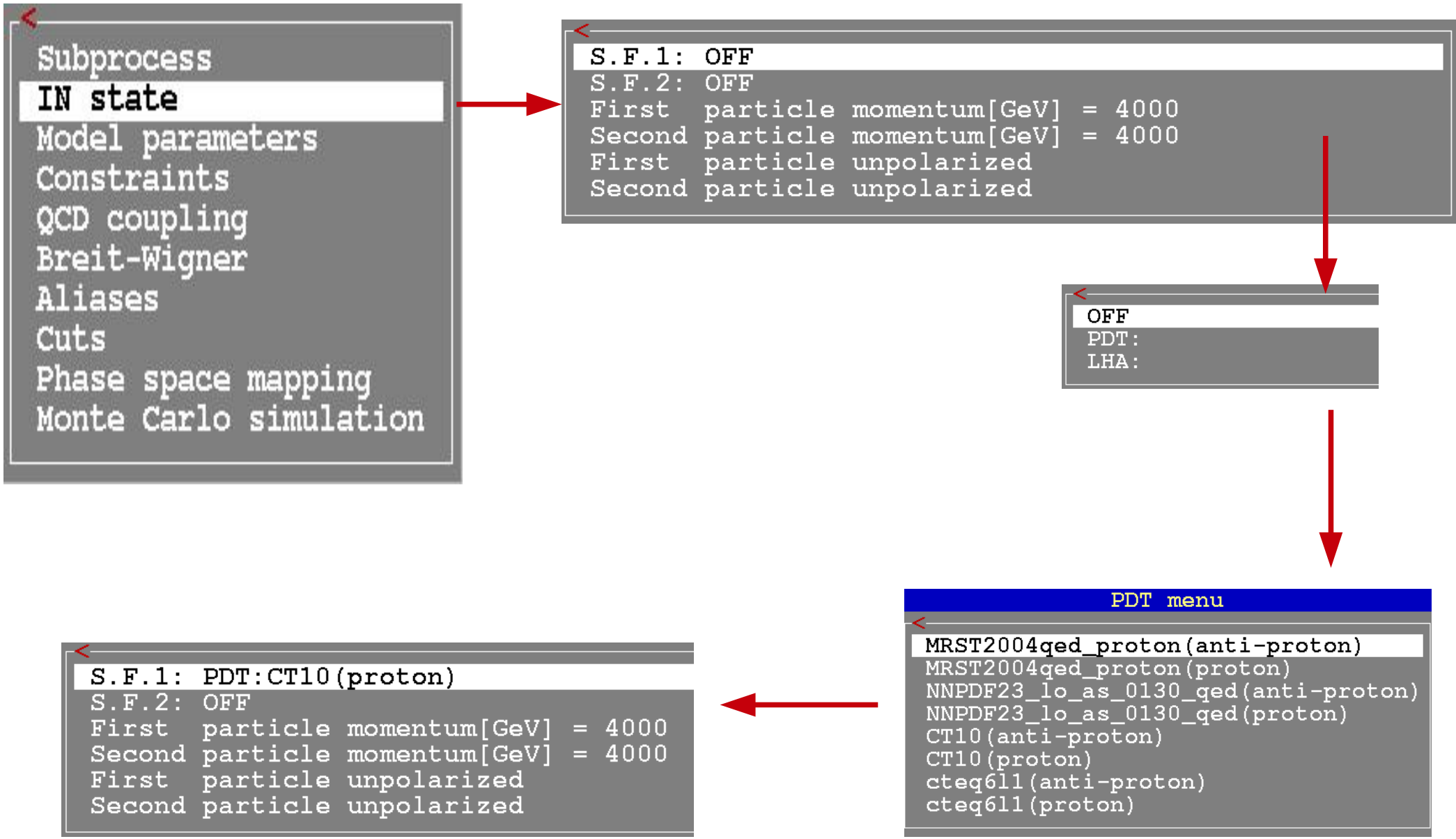
Menu structure of the numerical part



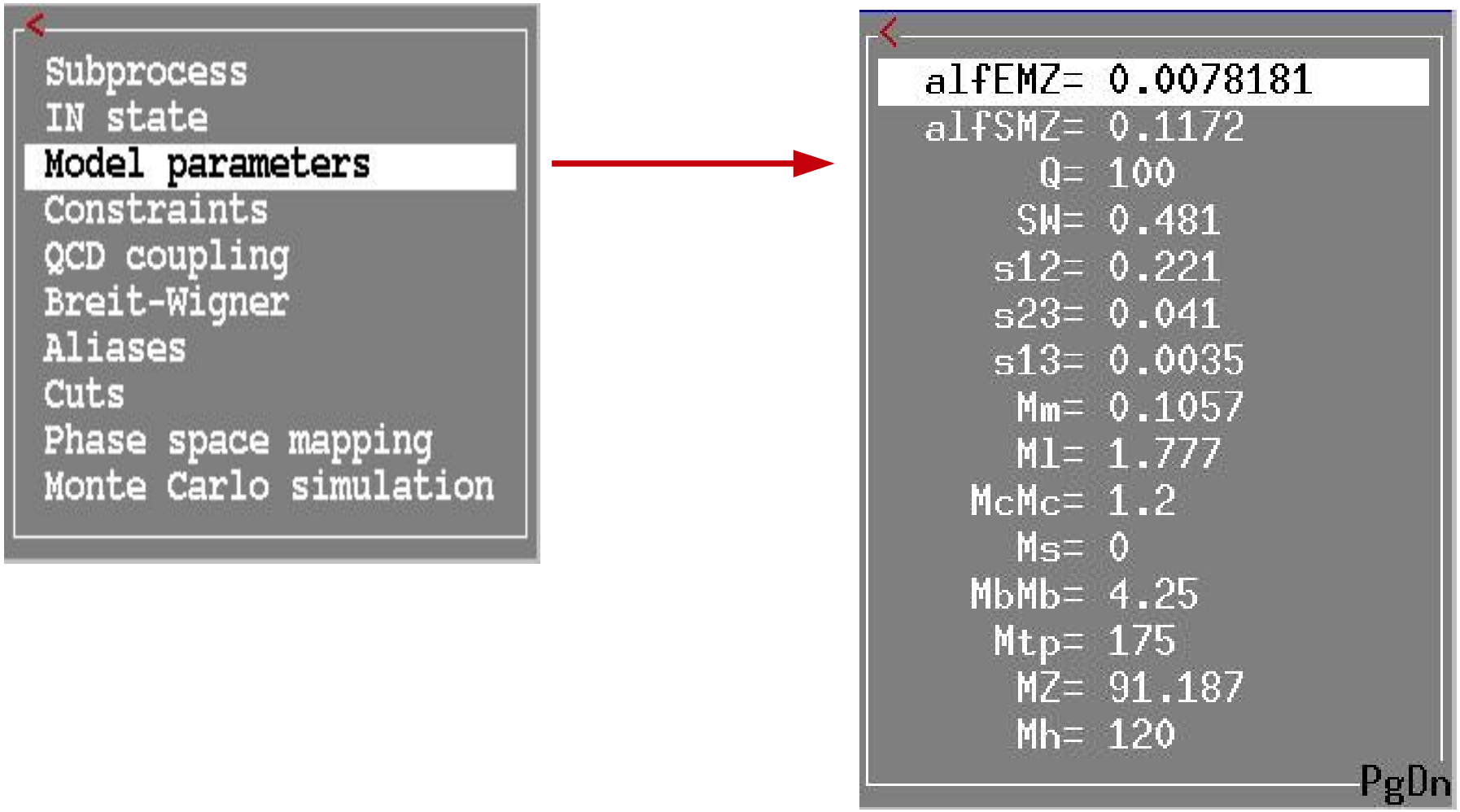
subprocess menu



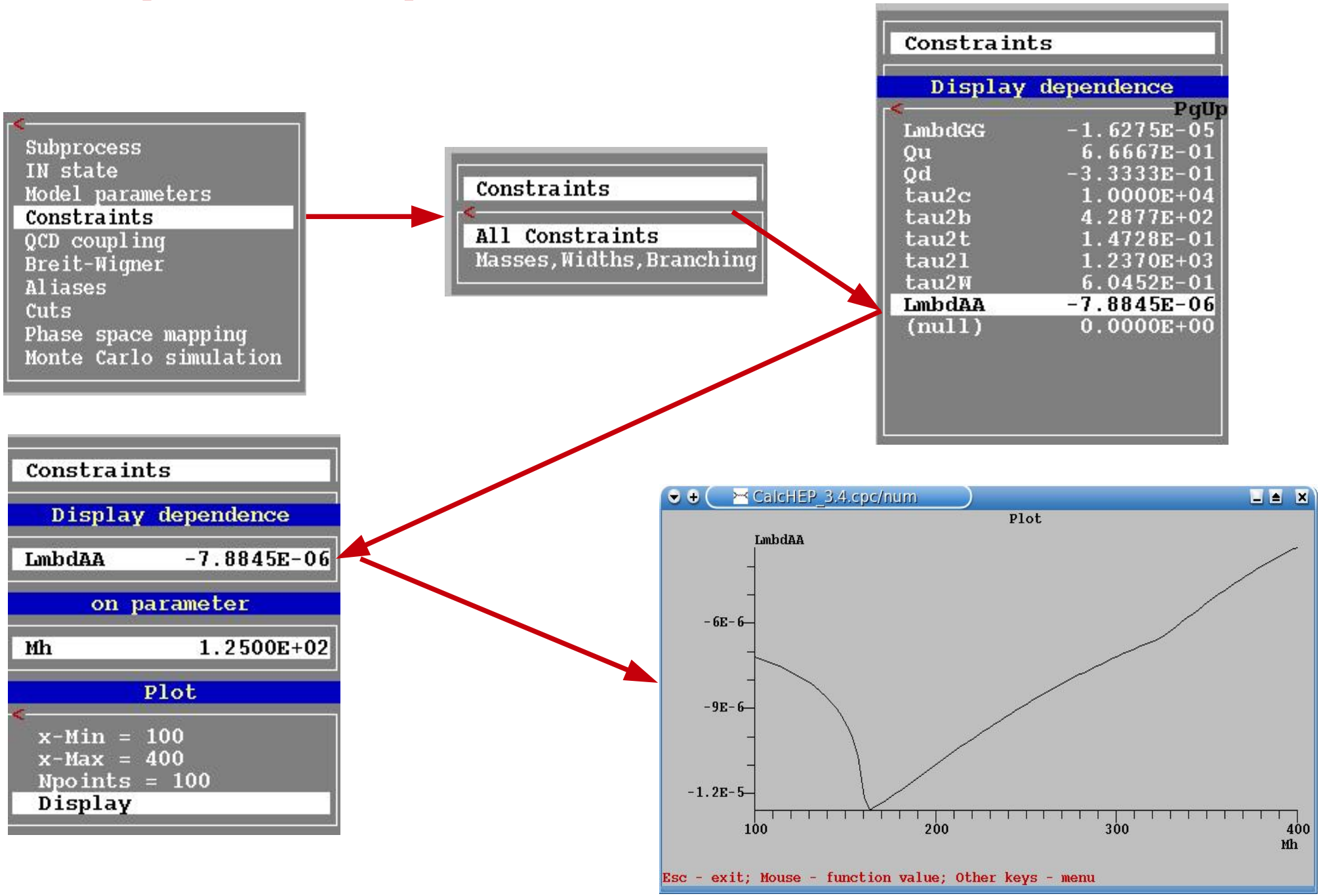
control of the initial states and parton density functions



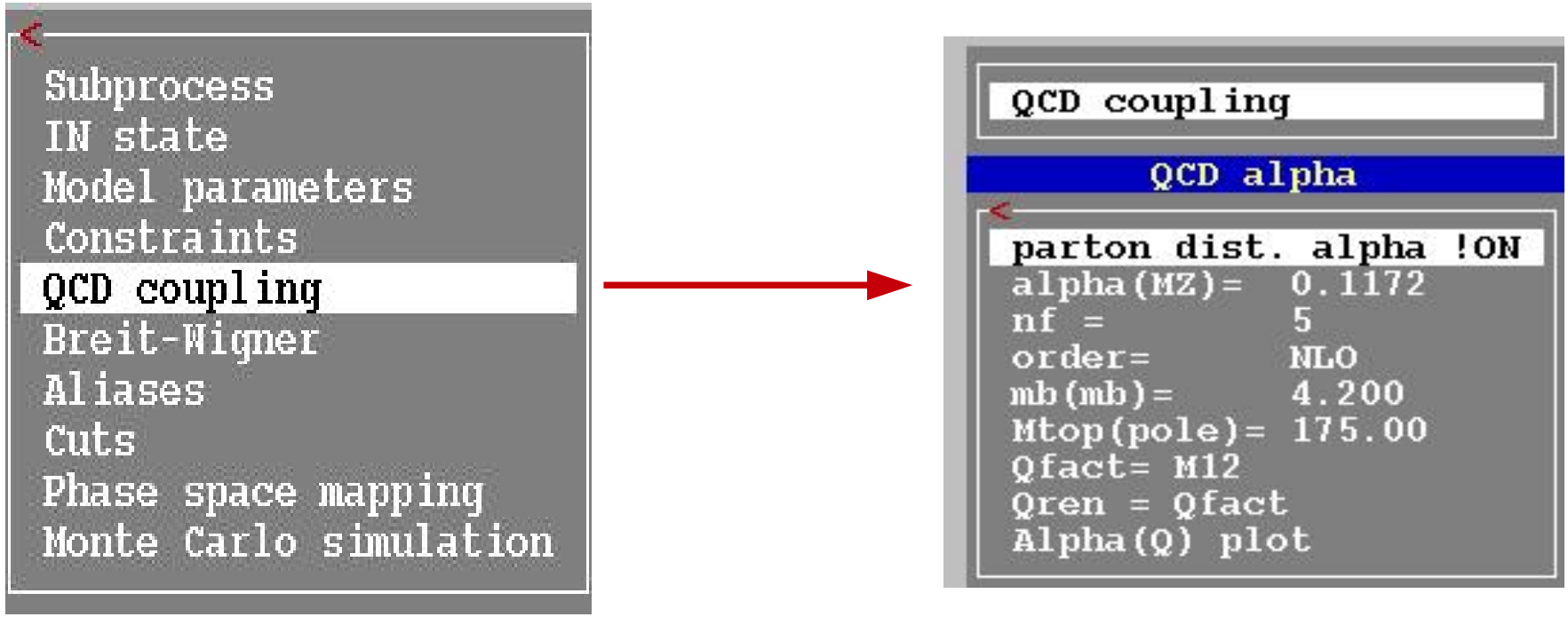
model parameters



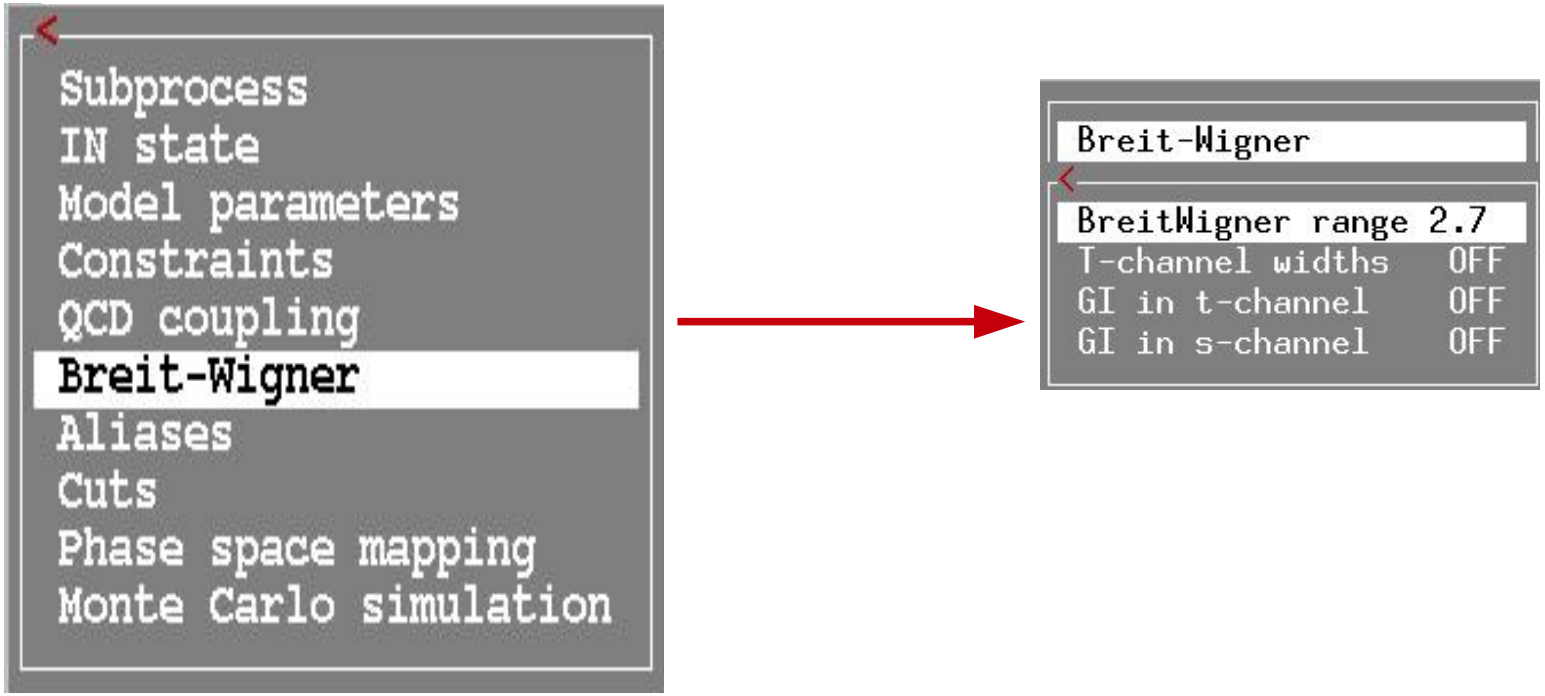
dependent parameters (SM CKM=1 with hGG/AA)



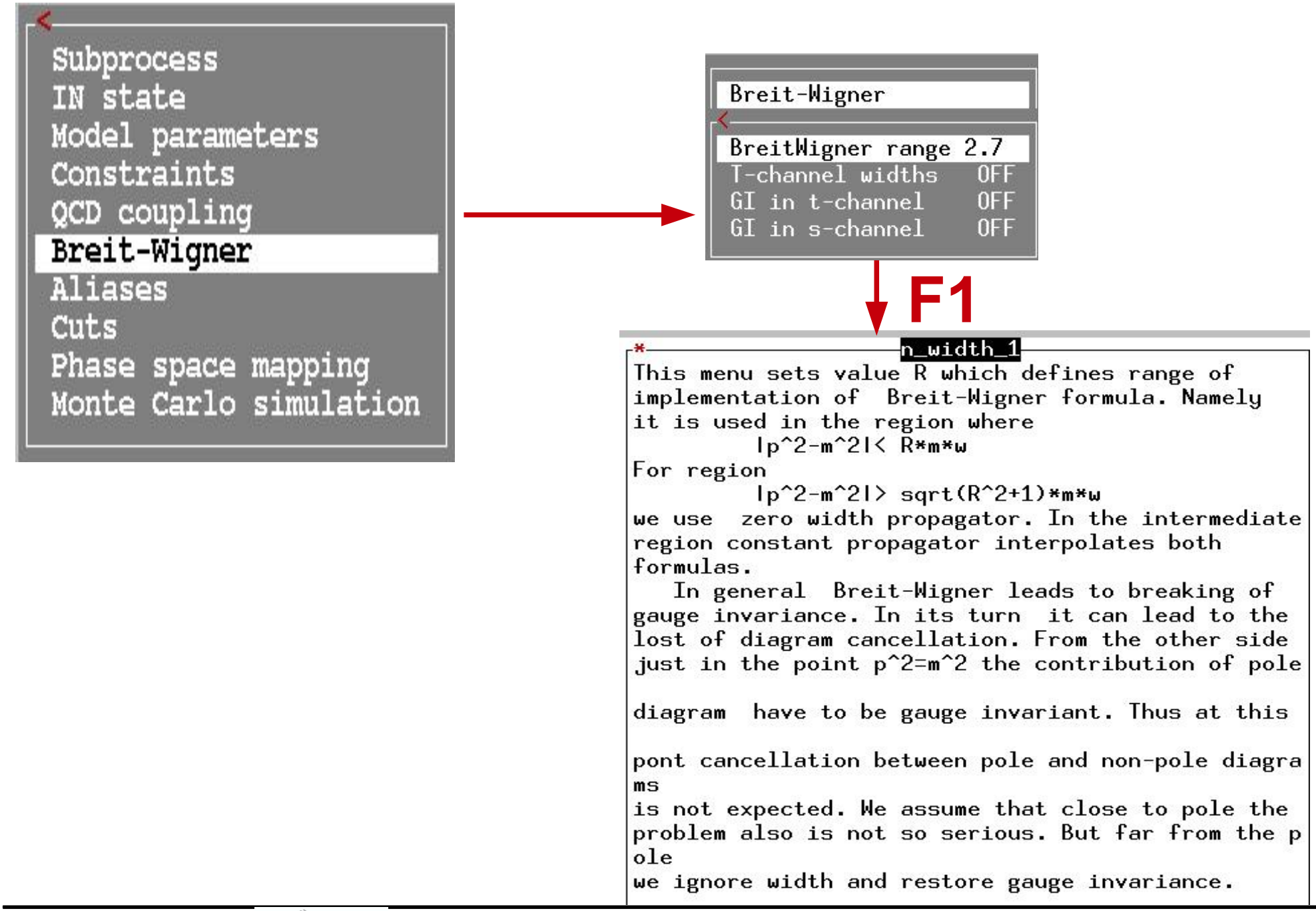
QCD coupling and the scale



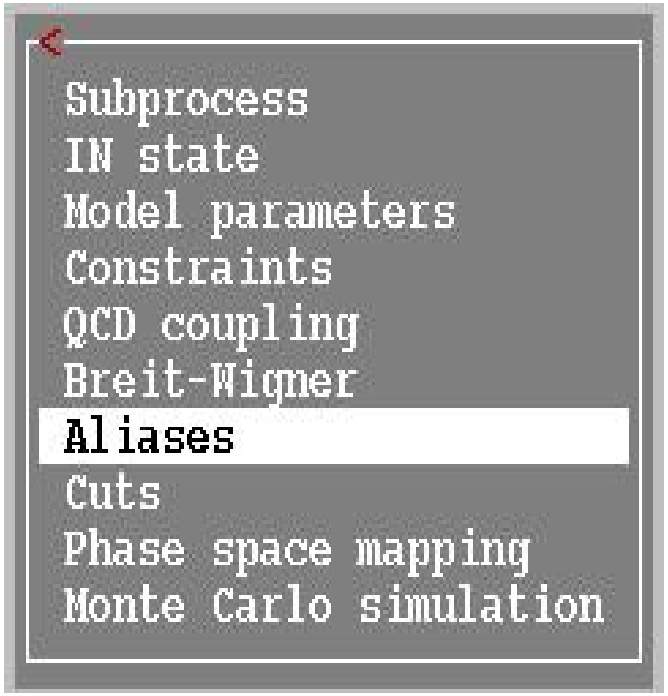
control of resonances

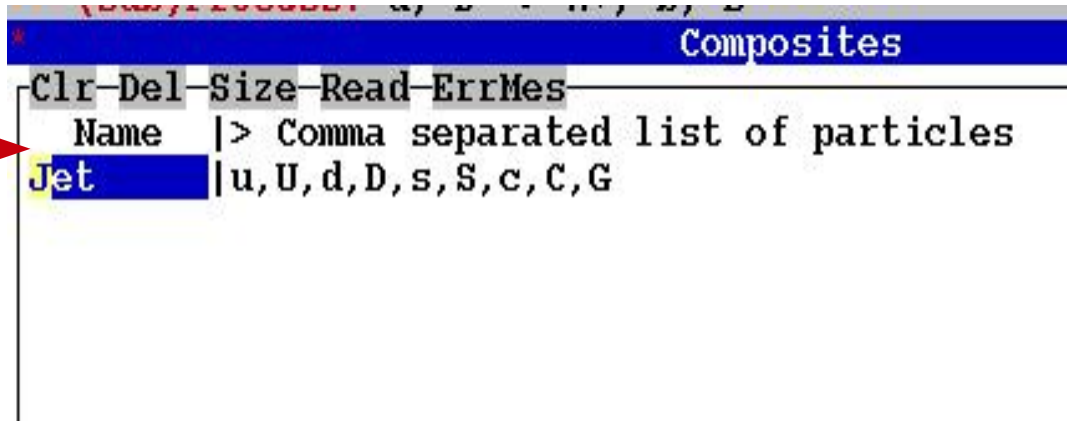


control of resonances

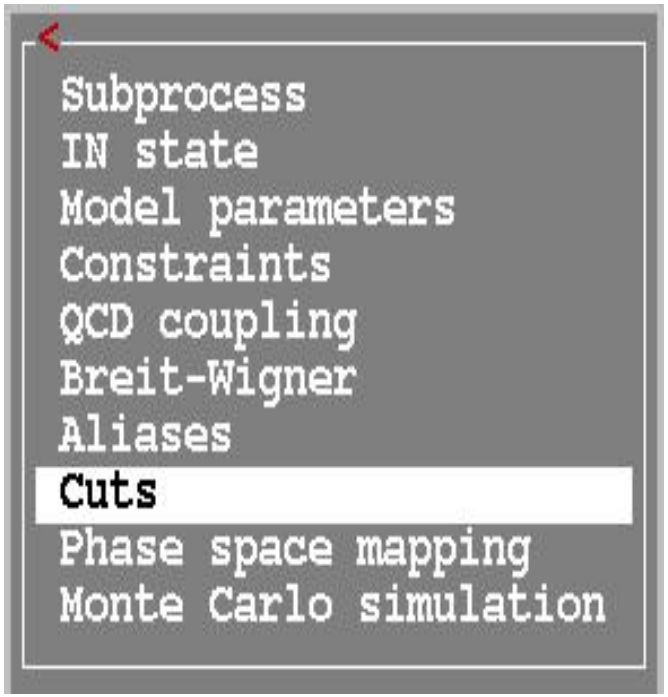


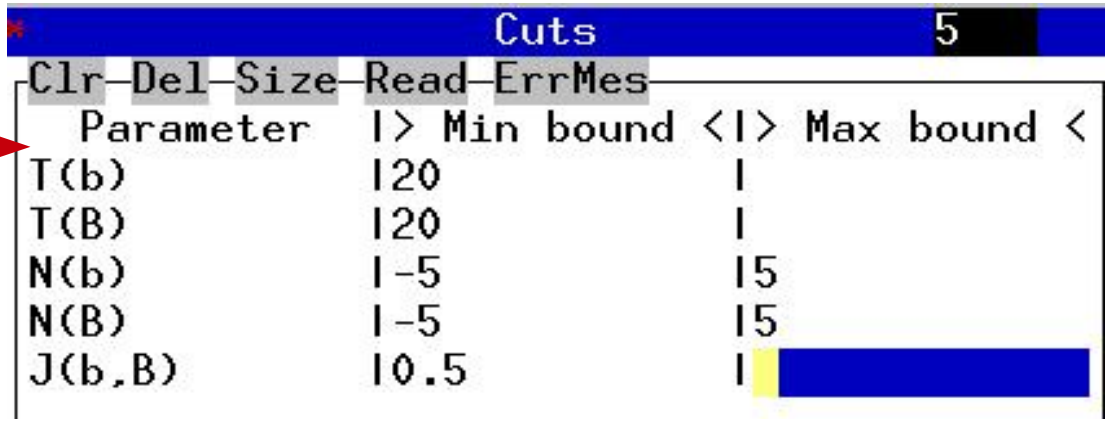
Aliases


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

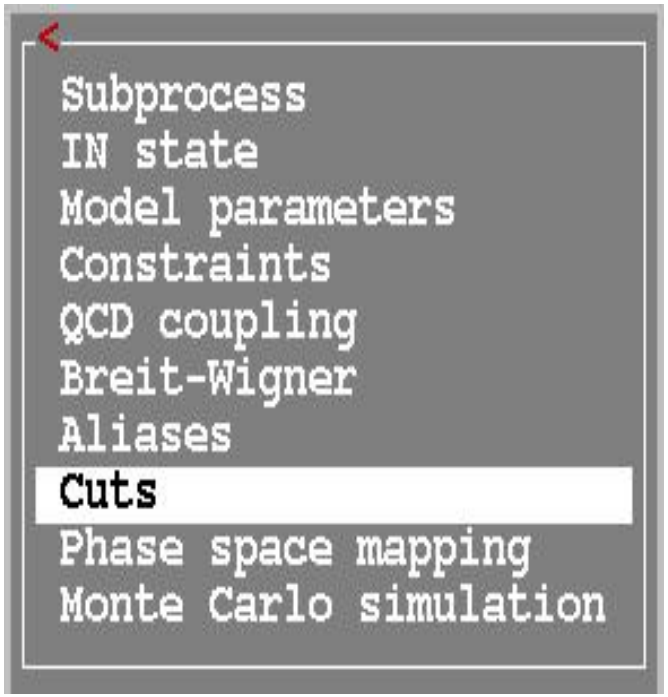

Composites
Clr-Del-Size-Read-ErrMes
Name |> Comma separated list of particles
Jet |u,U,d,D,s,S,c,C,G

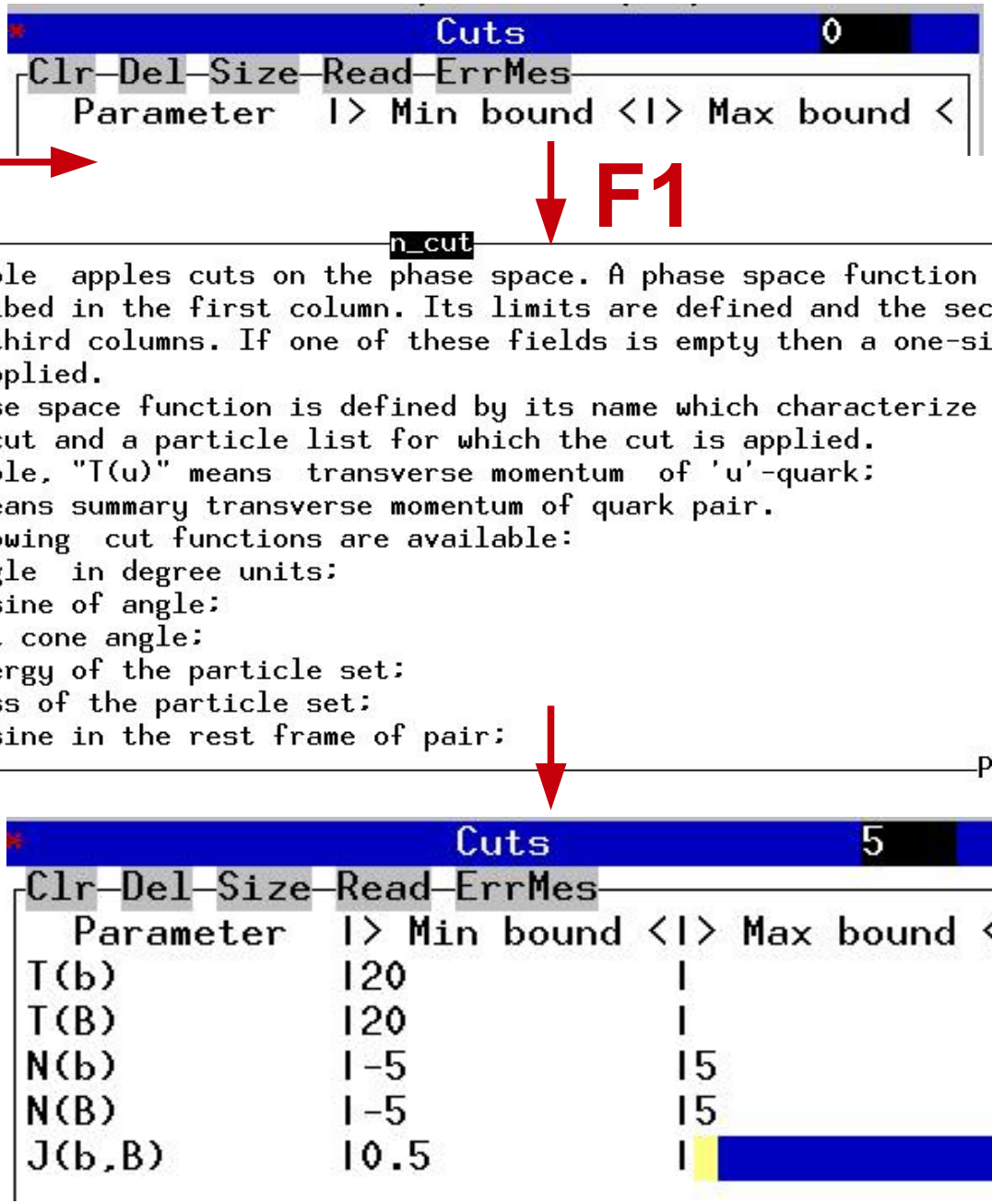
setting kinematical cuts



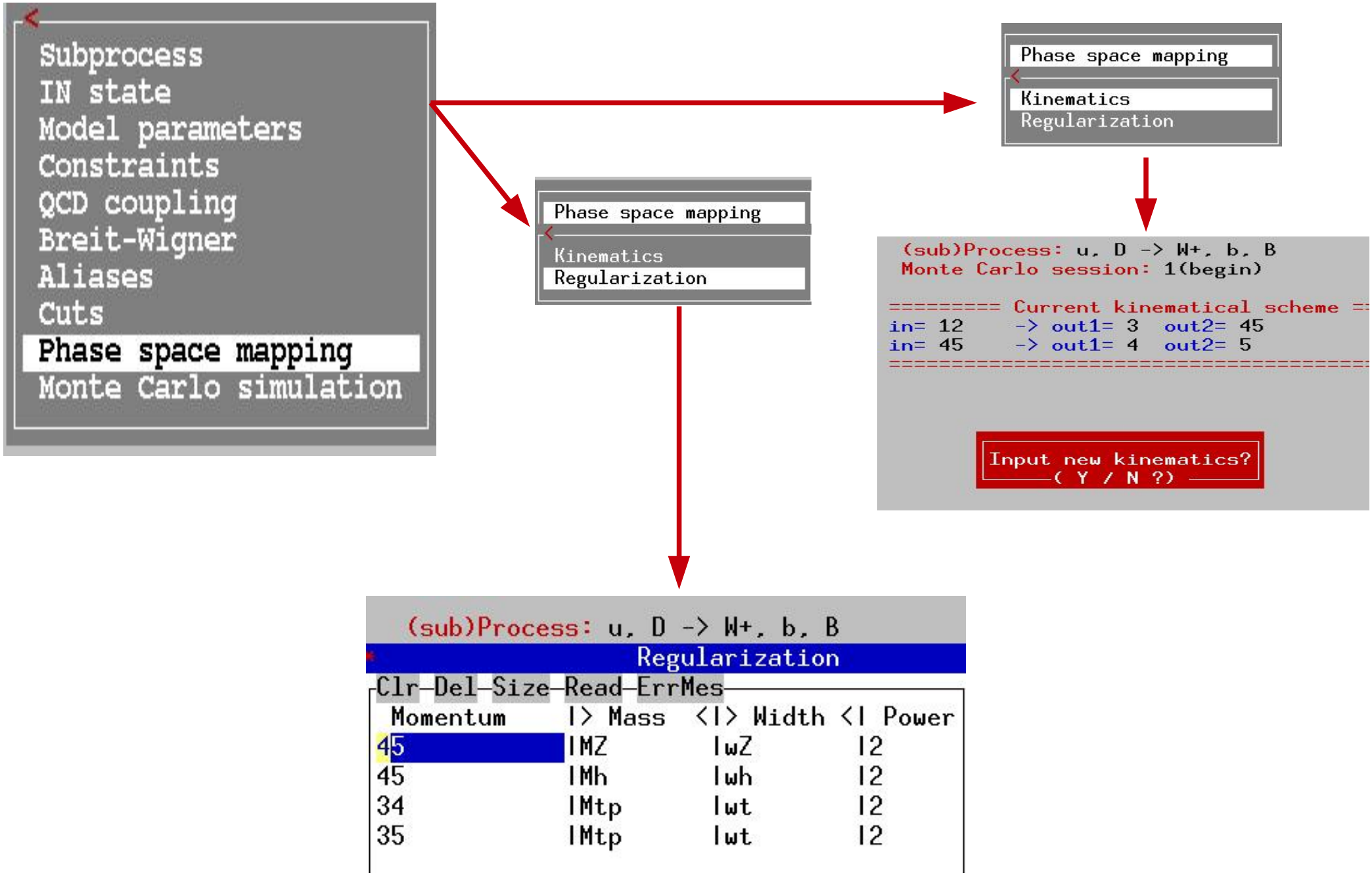


setting kinematical cuts





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

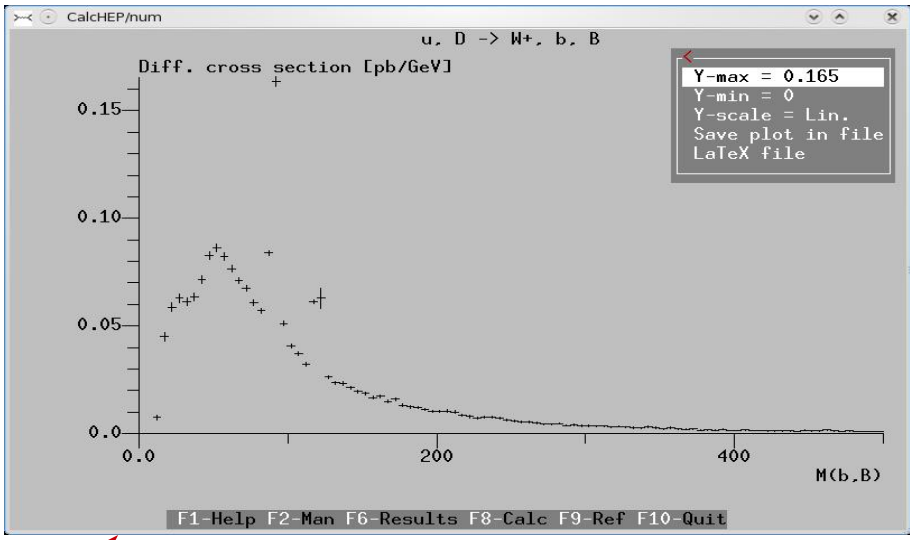
Parameter_1	I> Min_1	<I> Max_1	<IParameter_2	I> Min_2	<I> Max_2
T(b)	0	200			
T(B)	0	200			
N(b)	-5	5			
N(B)	-5	5			
M(b,B)	0	500			
M(W+,b)	0	500			
T(b)	0	500	M(b,B)	0	500

```
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)
```

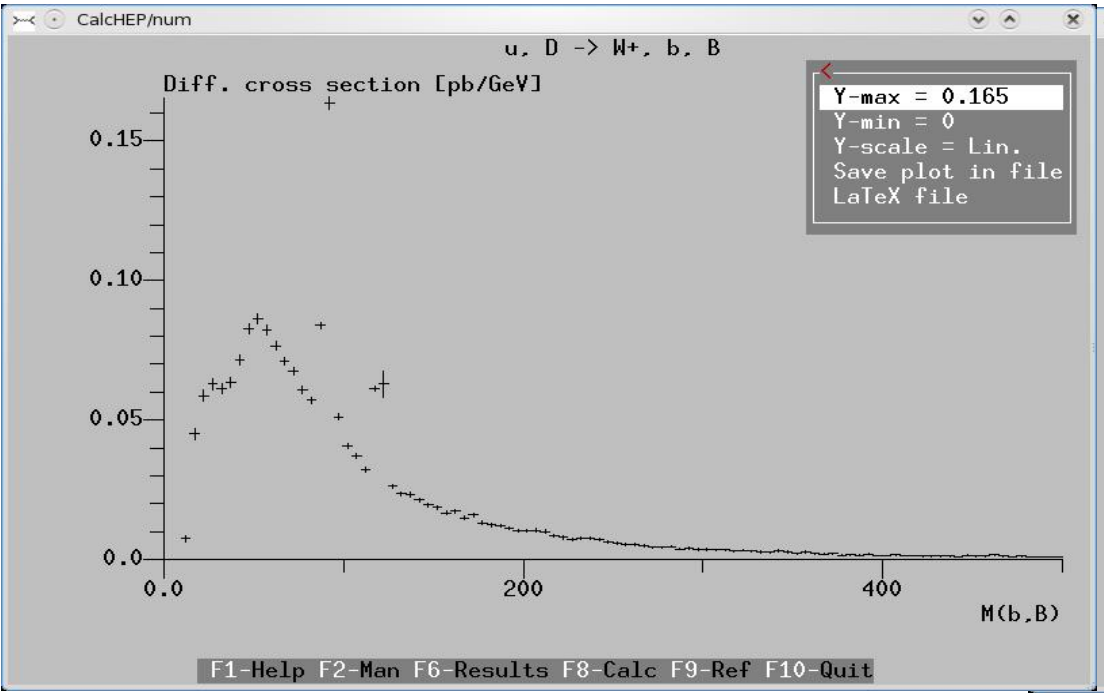
#IT	Cross section [pb]	Error %
6	9.5931E+00	7.10E-01
7	9.5686E+00	6.79E-01
8	9.5669E+00	6.82E-01
9	9.6892E+00	7.93E-01
10	9.6267E+00	7.51E-01
1	9.7757E+00	7.32E-01
clear statistics.		
2	9.6557E+00	6.82E-01
3	9.7464E+00	1.38E+00
4	9.6945E+00	1.05E+00
5	9.7032E+00	7.68E-01
< >	9.7095E+00	3.74E-01

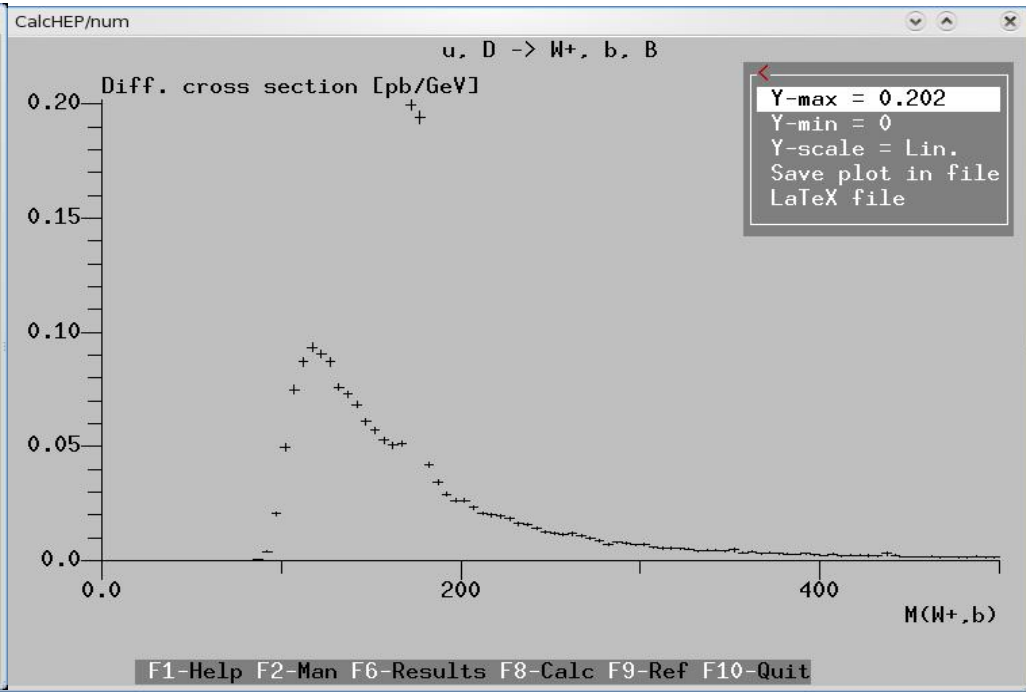
```
nSess  = 5
nCalls = 10000
Set  Distributions
*Start integration
Display Distributions
Clear statistic
Freeze grid          OFF
Clear  grid
Event Cubes 10000
Generate Events
```



The accuracy and the stability of the cross section indicate that you can trust your results

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

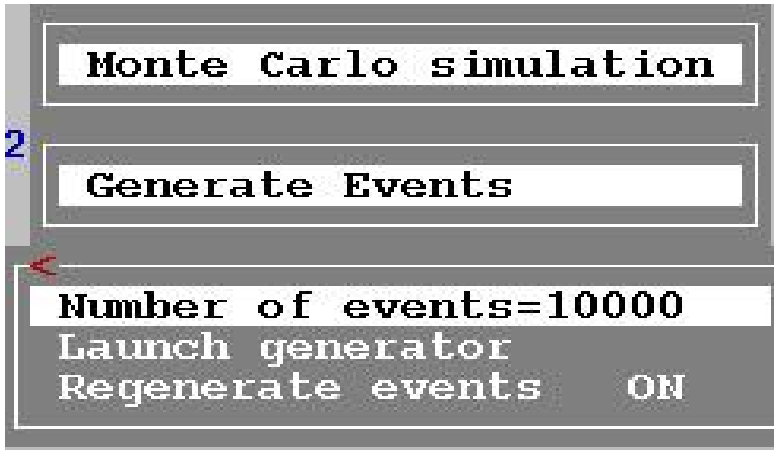


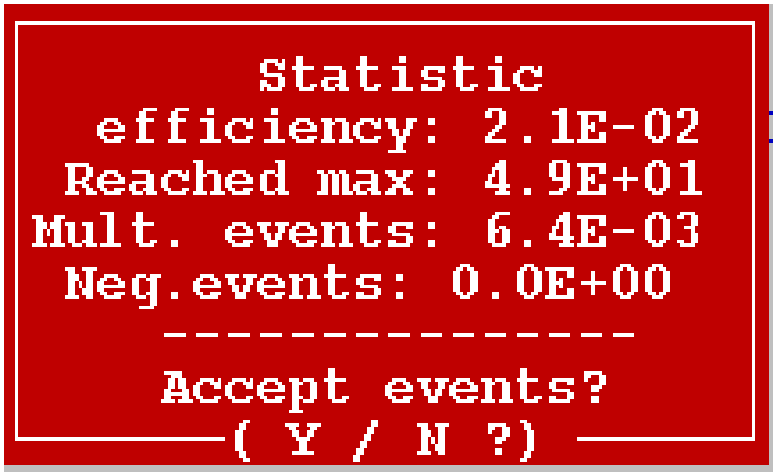


ex#4

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





File with events in the native CalcHEP format

events_1.txt - /home/belyaev/Dropbox/hep_tools/calchep/calc_work/pp_Wbb_example/

File Edit Search Preferences Shell Macro Windows Help

/home/belyaev/Dropbox/hep_tools/calchep/calc_work/pp_Wbb_example/events_1.txt 243603 bytes L: 1 C: 0

```
#CalcHEP  3.4.cpc
#Type 2 -> 3
#Initial_state
  P1_3=4.000000E+03  P2_3=-4.000000E+03
  StrFun1="PDT:cteq6m(proton)" 2212
  StrFun2="PDT:cteq6m(proton)" 2212
#PROCESS   2(u) -1(D) -> 24(W+) 5(b) -5(B)
#MASSES  0.0000000000E+00 0.0000000000E+00 8.0385000000E+01 3.2414139578E+00 3.2414139578E+00
#Cross_section(Width) 6.473084E+01
#Number_of_events       1000
#Events       P1_3 [Gev]         P2_3 [Gev]         P3_1 [Gev]         P3_2 [Gev]         P3_3 [Gev]         P4
       1   7.0828325272E+02 -3.8182148276E+00 -5.8685533663E+00  2.4810106784E+00  6.8128552155E+02  1.995
       1   1.5237718262E+02 -2.5952742306E+01  1.1734367441E+01 -2.1669699291E+01  5.6645397996E+01  4.499
       1   7.2370755716E+02 -3.3186893665E+00 -3.4449322581E+00 -5.1815667765E+00  5.8508268207E+02 -3.584
       1   2.6295673814E+02 -1.1370528114E+01  8.9463043464E+00 -3.4258266547E+00  2.2732569389E+02 -9.675
       1   5.7099697940E+02 -3.3943984194E+01  7.2879879961E+00 -2.3531627752E+01  1.9857446272E+01 -8.750
       1   3.6709401207E+02 -2.4124155464E+01 -4.8101350483E+00  6.6698730251E+01  2.0295672218E+02 -4.597
       1   3.7196555447E+01 -4.1553021555E+02 -3.1735918986E+00  2.8330641675E-01 -6.6745521993E+00  4.343
       1   4.0543944850E+01 -1.1104274125E+02 -8.2903700266E+00 -4.3292277920E+00 -9.0241583360E-01  6.562
       1   4.0084952687E+02 -1.0215920577E+01  1.1427574950E+01  2.6016502364E+00  3.8645254998E+02 -4.666
       1   2.2620009412E+01 -1.2387066011E+02 -5.0869818859E+00  1.1389105773E+01 -7.1200204784E+01  1.176
       1   7.2046251695E+02 -2.1091178466E+01 -1.4887347954E+01  8.1292985197E+01  5.8742582956E+02 -5.134
       1   6.8661185459E+01 -8.3534206530E+01 -5.5091602956E+00 -1.7099072377E+01  4.1559702536E+01  2.604
       1   1.5145483971E+03 -3.1164597600E+00 -7.8325298677E+00  3.6606202670E+01  1.2782056265E+03  1.074
```

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 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
```

- **bunch of events_*nn.txt* *event files are created,***
  so how do we combine them?

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

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

mixes subprocesses and connects production 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>
```

Accessing all 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
- lhe2tab
- gen_events
- name_cycle
- pcm_cycle
- par_scan

ex#5
produce LHE file
and use lhe2tab
to produce
distributions

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 – will be discussed below

the most general scan with

par_scan

- Usage:
  $CALCHEP/bin/par_scan < data_file

- Data file structure:

```
# Comments following the '#' symbol
par_name_1  par_name_2 ...   par_name_N & fun_name_1  fun_name_2 ...
  val11       val12    ....    val1N
  val21       val12    ....    val1N
.........................
```

- where par_name_i present free parameters of the models. Among them one also can write momenta of incoming particles as momentum1 and momentum2.
- fun_name_i is the name of constrained parameter which will be presented in output file
- Output file has the same structure as input plus calculated numerical values for constrained parameters, and an additional column for evaluated cross section with statistical error
- If you are not interested in the prt_# files you can clean it using
  $CALCHEP/bin/par_scan clean < data_file

CalcHEP batch interface

CalcHEP batch interface: all results in one shot

```
Model:          Standard Model(CKM=1)
Model changed: False
Gauge:          Feynman
#######################################
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
#######################################
pdf1:       cteq6l (proton)
pdf2:       cteq6l (proton)
#######################################
p1:         4000
p2:         4000
#######################################
Run parameter: Mh
Run begin:     120
Run step size: 5
Run n steps:   3
#######################################
alpha Q :              M45
#######################################
Cut parameter:    M(b,B)
Cut invert:       False
Cut min:          100
#######################################
```

```
#######################################
Kinematics :      12 -> 3, 45
Kinematics :      45 -> 4 , 5
Regularization momentum:1: 45
Regularization mass:1:     Mh
Regularization width:1:    wh
Regularization power:1:    2
#######################################
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)
#######################################
Number of events (per run step): 1000
Filename:                        test
#######################################
Parallelization method:      local
Max number of cpus:          2
sleep time:                  3
#######################################
nSess_1:   5
nCalls_1:  100000
nSess_2:   5
nCalls_2:  100000
```

CalcHEP batch interface: running and monitoring

```
sasha:~/calchep/work> ./calchep_batch

Main usage: "./calchep_batch batch_file_name"
    An example batch file  can be seen in:
    file:///home/belyaev/calchep/calchep_last/utile/batch_file

Help files can be created with the command:
    "./calchep_batch -help".

The files and directories created by the batch script can
    be removed with the command: "./calchep_batch -clean".
    This will remove the Events, Processes and html directories.
```

```
sasha:~/calchep/work> ./calchep_batch batch_file

calchep_batch version 1.38

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

CalcHEP batch interface: monitoring the progress

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)

Done!

	Finished	Time(hr)
Symbolic	12/12	0.00
σ	3/3	0.03
Events	3/3	0.01

CalcHEP batch interface:
monitoring details of the symbolic section

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	Removes	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	✓			
C,s->W-,b,B	✓			
W+->E,ne	✓			
W+->M,nm	✓			
W-->e,Ne	✓			
W-->m,Nm	✓			
Widths	✓			

CalcHEP batch interface: monitoring results of the numerical session

Home
Symbolic Results
Numerical Results
Events Library
Process Library
Help

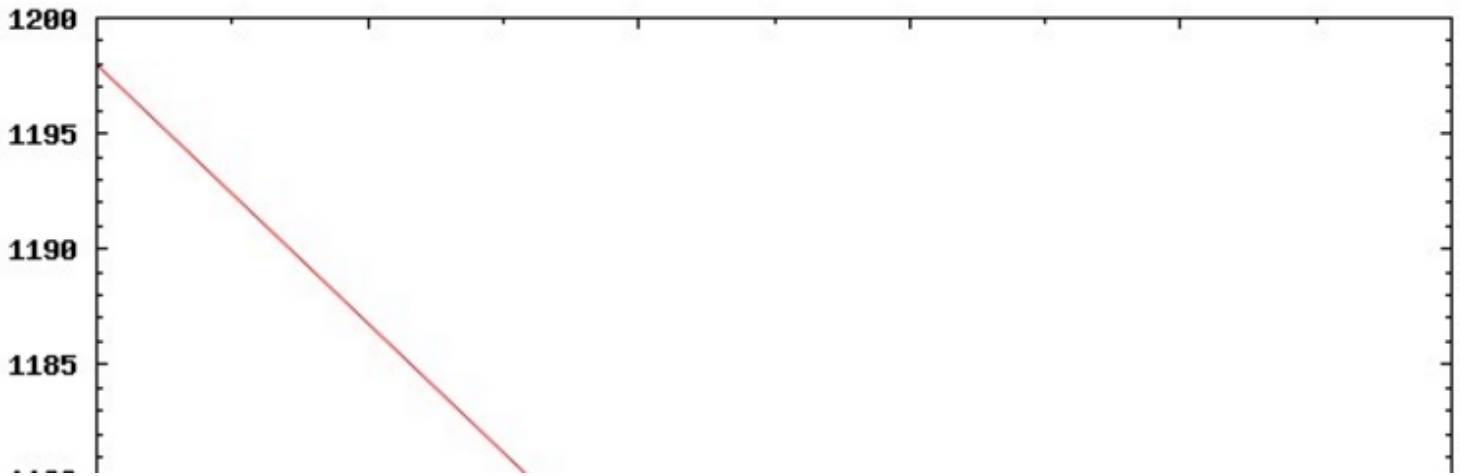
Thank you for using CalcHEP!
Please cite arXiv:1207.6082

Numerical Sessions

Standard Model(CKM=1)

Done!

Scans	σ (fb)	Running	Finished	Time (hr)	N events
Mh=120	1198	0/13	13/13	0.01	1000
Mh=125	1170	0/13	13/13	0.01	1000
Mh=130	1157	0/13	13/13	0.01	1000
				0.03	



CalcHEP batch interface: details of the numerical session

Home
Symbolic Results
Numerical Results
Events Library
Process Library
Help

Thank you for using CalcHEP!
Please cite arXiv:1207.6082

Numerical Sessions

Standard Model(CKM=1)

Done!

Processes	σ (fb)	Δσ (%)	PID	Time (hr)	N events	Details	
u,D->W+,b,B	1582.1	0.53	28919	0.00	383/382	prt_1	session.dat
U,d->W-,b,B	837.97	0.41	28923	0.00	218/217	prt_1	session.dat
d,U->W-,b,B	838.94	0.49	28928	0.00	218/217	prt_1	session.dat
D,u->W+,b,B	1621.4	2.7	28935	0.00	390/389	prt_1	session.dat
s,C->W-,b,B	111.07	0.41	28942	0.00	41/40	prt_1	session.dat
S,c->W+,b,B	111.15	0.38	28947	0.00	41/40	prt_1	session.dat
c,S->W+,b,B	111.5	0.46	28955	0.00	41/40	prt_1	session.dat
C,s->W-,b,B	111.76	0.41	28962	0.00	41/40	prt_1	session.dat
Total	5325.9	0.85					

Decays	Γ (GeV)	ΔΓ (%)	PID	Time (hr)	N events	Details	
W+->E,ne	0.23493	0	29144	0.00	5099/5100	prt_1	session.dat
W+->M,nm	0.23493	0	29148	0.00	5099/5100	prt_1	session.dat

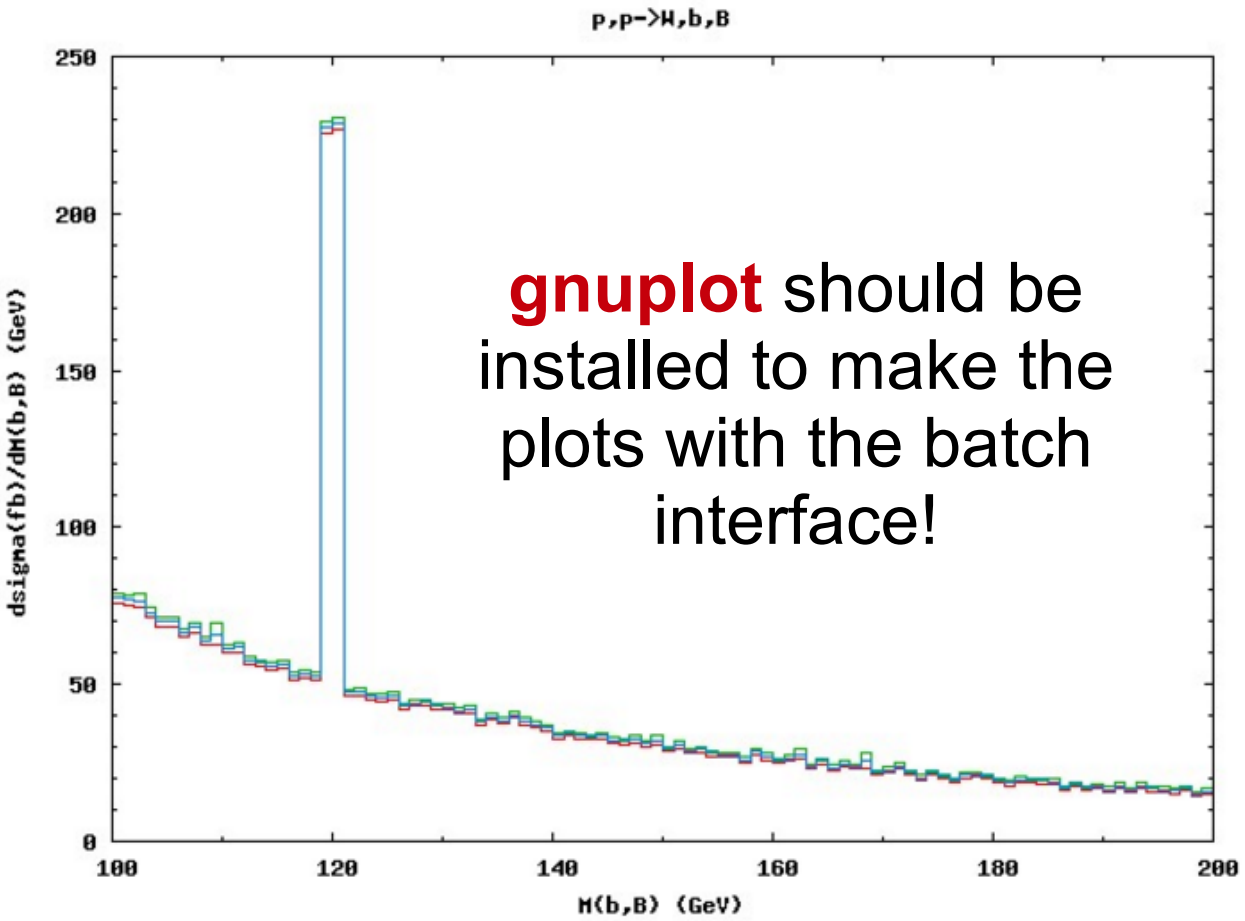
CalcHEP batch interface:
numerical results and distributions

Home
Symbolic Results
Numerical Results
Events Library
Process Library
Help

Thank you for using CalcHEP!
Please cite arXiv:1207.6082

Widths		PID	Time (hr)	Details
Widths		29167	0.00	session.dat
Total	1198		0.01	1000/1000

Distributions



ex#6: *using calchep_batch evaluate complete cross section for pp-> Wbb process with the same cuts as for ex#4*

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

CalcHEP batch interface:
access to your results

- results are located in **batch_results** folder
- ***.lhe.gz** : LHE event files
- ***.jpg** : figures
- ***.distr** : files with distributions which cab be used to re-produce plots using **$CALCHEP/bin/show_distr**
- ***.tgz** : zipped html folder with all numerical details, .txt and .html files of the batch run

CalcHEP batch interface:
some additional features/tricks

- see https://answers.launchpad.net/calchep
  for many “tricky” questions/answers
- scanning over the collider energy

  Run parameter: rtS
  Run begin: 7
  Run step size: 1
  Run n steps: 2

  p1: 1000*rtS/2
  p2: 1000*rtS/2

  rtS here is some “fake” parameter
- you can use “fake” parameter only if you define it as a loop parameter
  - It can be used in the cut statement (assigning cut to the symbol)
  - It can be assigned to the parameter model – this way you can run use complicated scan

CalcHEP interface to MC generators via Events in the LHE format