

# CALCHEP

Introduction to CalcHep  
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June 2020

# Where to get information ?

- Web Page: <https://theory.sinp.msu.ru/~pukhov/calchep.html>
- More detailed Tutorial (Alexander Belyaev):  
[https://indico.cern.ch/event/656211/contributions/2756825/attachments/1547486/2429259/calchep\\_tools\\_bootcamp\\_belyaev.pdf](https://indico.cern.ch/event/656211/contributions/2756825/attachments/1547486/2429259/calchep_tools_bootcamp_belyaev.pdf)
- Models BSM (HEPMDB):  
<https://hepmdb.soton.ac.uk/>  
Many models available! (need registration)

# Installation I

Any Linux distribution (Here I'll assume Ubuntu 18.04 )

1. Install cernlib (not essential, but we will need it later)

```
sudo apt-get install -y cernlib
```

2. Install library libx11-dev

```
sudo apt-get install -y libx11-dev
```

3. Download, unzip and compile the code

```
tar -zxvf calchep_3.x.x.tgz  
cd calchep_3.x.x.tgz  
make
```

# Installation II

4. Create a directory for CalcHep working sessions

```
./mkWORKDir <path>/<directory_name>
```

It is possible to create many working directories in different locations.

5. Check the working directory: `ls`

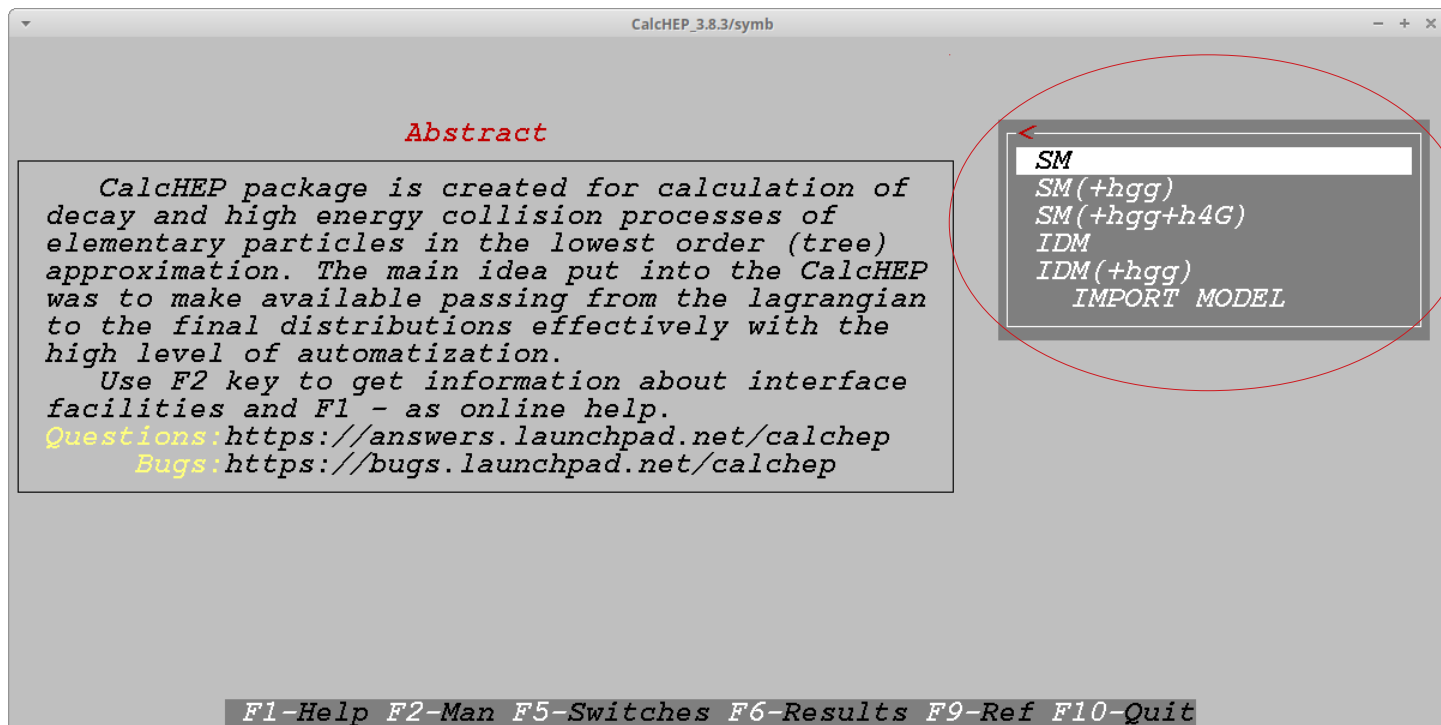
```
batch_results  
bin  
calchep  
calchep_batch  
models  
results
```

The executables are marked as green.

# Starting CalcHep

From the working directory, do:

```
./calchep &
```



The screenshot shows the CalcHEP 3.8.3/symb interface. On the left, there is a text box titled "Abstract" containing the following text:

*CalcHEP package is created for calculation of decay and high energy collision processes of elementary particles in the lowest order (tree) approximation. The main idea put into the CalcHEP was to make available passing from the lagrangian to the final distributions effectively with the high level of automatization.*

*Use F2 key to get information about interface facilities and F1 - as online help.*

*Questions: <https://answers.launchpad.net/calchep>*

*Bugs: <https://bugs.launchpad.net/calchep>*

On the right, a list of models is displayed, with "SM" selected and highlighted. The list includes:

- SM
- SM(+hgg)
- SM(+hgg+h4G)
- IDM
- IDM(+hgg)
- IMPORT MODEL

At the bottom of the window, a status bar shows the following keyboard shortcuts: F1-Help F2-Man F5-Switches F6-Results F9-Ref F10-Quit

**Models**

# Starting CalcHep

Terminal - asevedo@nepomuceno: ~/programs/calchep38/models

File Edit View Terminal Tabs Help

```
(base) asevedo@nepomuceno:~/programs/calchep38/models$ ls
extlib1.mdl  extlib4.mdl  func3.mdl  lgrng1.mdl  lgrng4.mdl  prtcls2.mdl  prtcls5.mdl  vars3.mdl
extlib2.mdl  func1.mdl    func4.mdl  lgrng2.mdl  lgrng5.mdl  prtcls3.mdl  vars1.mdl    vars4.mdl
extlib3.mdl  func2.mdl    func5.mdl  lgrng3.mdl  prtcls1.mdl  prtcls4.mdl  vars2.mdl    vars5.mdl
(base) asevedo@nepomuceno:~/programs/calchep38/models$
```

```
SM
SM(+hgg)
SM(+hgg+h4G)
IDM
IDM(+hgg)
IMPORT MODEL
```

ts F9-Ref F10-Quit

# Initial Menu

The screenshot shows the CalcHEP 3.8.3/symb interface. At the top, a dropdown menu is set to "Model: SM", with a red arrow pointing to it. Below this, the word "Abstract" is displayed in red. A large text box contains the following text:

*CalcHEP package is created for calculation of decay and high energy collision processes of elementary particles in the lowest order (tree) approximation. The main idea put into the CalcHEP was to make available passing from the lagrangian to the final distributions effectively with the high level of automatization.*

*Use F2 key to get information about interface facilities and F1 - as online help.*

*Questions: <https://answers.launchpad.net/calchep>*

*Bugs: <https://bugs.launchpad.net/calchep>*

To the right, a menu box is open, showing the following options:

- Enter Process
- Force Unit.Gauge= OFF
- Edit model (with a red arrow pointing to it)
- Numerical Evaluation
- =====
- Delete model

At the bottom of the window, a status bar displays the following keyboard shortcuts: *F1-Help F2-Man F5-Switches F6-Results F9-Ref F10-Quit*

# Models Structure

*Model:* SM

## *Abstract*

*CalcHEP package is created for calculation of decay and high energy collision processes of elementary particles in the lowest order (tree) approximation. The main idea put into the CalcHEP was to make available passing from the lagrangian to the final distributions effectively with the high level of automatization.*

*Use F2 key to get information about interface facilities and F1 - as online help.*

*Questions:* <https://answers.launchpad.net/calchep>

*Bugs:* <https://bugs.launchpad.net/calchep>

*Edit model*

*Variables*

*Constraints*

*Particles*

*Lagrangian*

*Libraries*

*RENAME*

*CHECK MODEL*

*F1-Help F2-Man F5-Switches F6-Results F9-Ref*



# Variables

CalcHEP 3.8.3/symb

Clr	Del	Size	Read	ErrMes	
Name	/	Value	/>	Comment	<
EE	/	0.31333	/>	Electromagnetic coupling constant ( $\leftrightarrow 1/128$ )	<
GG	/	1.117	/>	Strong coupling constant (Z point) (PDG-94)	
SW	/	0.474	/>	sin of the Weinberg angle 0.474 - "on-shell", 4	
Q	/	100	/>	Scale of effective running masses	
MW	/	80.385	/>	W boson mass	
Mtp	/	172.5	/>	Top quark pole mass	
McMc	/	1.23	/>	Mc(Mc) MS-BAR	
MbMb	/	4.25	/>	Mb(Mb) MS-BAR	
alphaSMZ	/	0.1184	/>	Strong alpha(MZ)	
Ml	/	1.777	/>	mass of tau-lepton	
Mh	/	125	/>	mass of Higgs	

F1 F2 Xgoto Ygoto Find Write

# Constraints

```
CalcHEP 3.8.3/symb
Constraints
Clr Del Size Read ErrMes
Name /> Expression
CW /sqrt(1-SW^2) % cos of the Weinberg angle
GF /EE^2/(2*SW*MW)^2/Sqrt2 % experimental value 1.166E-5 [1/GeV^2]
MZ /MW/CW % Z boson mass
LamQCD /initQCD5(alphaSMZ, McMc, MbMb, Mtp)
Mb /MbEff(Q)
Mc /McEff(Q)
Ms /MqEff(0.096, Q) % s-quark effective mass via 2MeV running one
B00000 /1-2*SW^2
B00001 /1-4*SW^2+4*SW^4
F1 F2 Xgoto Ygoto Find Write
```

# Particles

CalcHEP\_3.8.3/symb

Particles

Clr	Del	Size	Read	ErrMes							
Full	Name	/ P	/ aP	number	/spin2	/mass	/width	/color	/aux	LaTeX(A)	
photon		/A	/A	122	12	10	10	11	/G	/A	
Z boson		/Z	/Z	123	12	/MZ	/!wZ	11	/G	/Z	
gluon		/G	/G	121	12	10	10	18	/G	/G	
W boson		/W+	/W-	124	12	/MW	/!wW	11	/G	/W^+	
neutrino		/ne	/Ne	112	11	10	10	11	/L	/\nu^e	
electron		/e	/E	111	11	10	10	11	/	/e	
mu-neutrino		/nm	/Nm	114	11	10	10	11	/L	/\nu^\mu	
muon		/m	/M	113	11	10	10	11	/	/\mu	
tau-neutrino		/nl	/Nl	116	11	10	10	11	/L	/\nu^\tau	
tau-lepton		/l	/L	115	11	/Ml	10	11	/	/\tau	
u-quark		/u	/U	12	11	10	10	13	/	/u	
d-quark		/d	/D	11	11	10	10	13	/	/d	
c-quark		/c	/C	14	11	/Mc	10	13	/	/c	
s-quark		/s	/S	13	11	/Ms	10	13	/	/s	
t-quark		/t	/T	16	11	/Mtp	/!wt	13	/	/t	
b-quark		/b	/B	15	11	/Mb	10	13	/	/b	
Higgs		/h	/h	125	10	/Mh	/!wh	11	/	/h	

F1 F2 Xgoto Ygoto Find Write

Width automatically calculated.

# Lagrangian

CalcHEP\_3.8.3/symb

Lagrangian 29

Clr	Del	Size	Read	ErrMes		</>	d
P1	/P2	/P3	/P4	/>	Factor		
C	/c	/h	/	/-EE*Mc/(2*MW*SW)		/1	
C	/s	/W+	/	/EE*Sqrt2/(4*SW)		/G(m	
C	/s	/W+.f	/	/-i*EE*Sqrt2/(4*MW*SW)		/Ms*	
D	/d	/A	/	/-EE/3		/G(m	
D	/d	/G	/	/GG		/G(m	
D	/d	/Z	/	/EE/(12*CW*SW)		/4*S	
D	/u	/W-	/	/EE*Sqrt2/(4*SW)		/G(m	
E	/e	/A	/	/-EE		/G(m	
E	/e	/Z	/	/EE/(4*CW*SW)		/4*S	
E	/ne	/W-	/	/EE*Sqrt2/(4*SW)		/G(m	
G	/G	/G	/	/GG		/m2.	
G.C	/G.c	/G	/	/GG		/m3.	
L	/l	/A	/	/-EE		/G(m	
L	/l	/Z	/	/EE/(4*CW*SW)		/4*S	
L	/l	/Z.f	/	/i*EE*M1/(2*MW*SW)		/G5	
L	/l	/h	/	/-EE*M1/(2*MW*SW)		/1	
L	/nl	/W-	/	/EE*Sqrt2/(4*SW)		/G(m	
L	/nl	/W-.f	/	/i*EE*M1*Sqrt2/(4*MW*SW)		/ (1-	
M	/m	/A	/	/-EE		/G(m	
M	/m	/Z	/	/EE/(4*CW*SW)		/4*S	
M	/nm	/W-	/	/EE*Sqrt2/(4*SW)		/G(m	

$$L = \frac{e}{\sin \theta_W \cos \theta_W} J_Z^\mu Z_\mu$$

F1 F2 Xgoto Ygoto Find Write

# Libraries

CalcHEP\_3.8.3/symb

*Libraries*

1

~~Clr Del Size Read ErrMes~~

*External libraries and function prototypes*

`% -L $HOME/LHAPDF6/lib -lLHAPDF`

It can be used to link with LHAPDFs sets

~~F1 F2 Xgoto Ygoto Find Write~~

# Enter Process

```
CalcHEP_3.8.3/symb
Model: SM

List of particles (antiparticles)

A(A ) - photon
W+(W- ) - W boson
nm(Nm ) - mu-neutrino
l(L ) - tau-lepton
c(C ) - c-quark
b(B ) - b-quark

Z(Z ) - Z boson
ne(Ne ) - neutrino
m(M ) - muon
u(U ) - u-quark
s(S ) - s-quark
h(h ) - Higgs

G(G ) - gluon
e(E ) - electron
nl(Nl ) - tau-neutrino
d(D ) - d-quark
t(T ) - t-quark

Enter process: p,p -> m,M
composite 'p' consists of: u,U,d,D,c,C,b,B,s,S,G
Exclude diagrams with
```

# Enter Process

```
CalcHEP_3.8.3/symb  
  
Model: SM  
  
Process: p,p -> m,M  
  
Feynman diagrams  
20 diagrams in 10 subprocesses are constructed.  
0 diagrams are deleted.
```

< View diagrams  
Square diagrams  
Write down processes

F1-Help F2-Man F3-Model F5-Switches F6-Results F9-Ref F10-Quit

# Enter Process

CalcHEP\_3.8.3/symb

*Model:* SM

*Process:* p,p -> m,M

*Feynman diagrams*

View diagrams

20 diagrams in 10 subprocesses are constructed.  
0 diagrams are deleted.

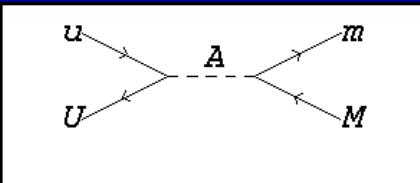
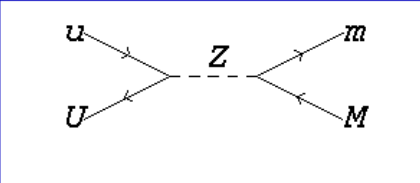
NN	Subprocess	Del	Rest
1/	u,U -> m,M	/	0/ 2
2/	U,u -> m,M	/	0/ 2
3/	d,D -> m,M	/	0/ 2
4/	D,d -> m,M	/	0/ 2
5/	c,C -> m,M	/	0/ 2
6/	C,c -> m,M	/	0/ 2
7/	b,B -> m,M	/	0/ 2
8/	B,b -> m,M	/	0/ 2
9/	s,S -> m,M	/	0/ 2
10/	S,s -> m,M	/	0/ 2



# Enter Process

CalcHEP 3.8.3/symb

Delete, On/off, Restore, Latex 1/2

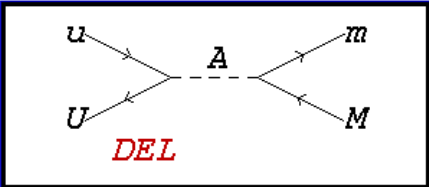
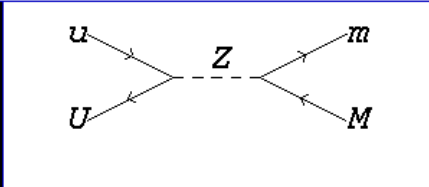
			

F1-Help, F2-Man, PgUp, PgDn, Home, End, # , Esc

# Enter Process

CalcHEP\_3.8.3/symb

Delete, On/off, Restore, Latex 1/2

 <p><i>DEL</i></p>			

F1-Help, F2-Man, PgUp, PgDn, Home, End, #, Esc

# Square Diagrams

CalcHEP\_3.8.3/symb

*Model:* SM

*Process:*  $p, p \rightarrow m, M$

*Feynman diagrams*

20 diagrams in 10 subprocesses are constructed.  
0 diagrams are deleted.

View diagrams

Square diagrams

Write down processes

F1-Help F2-Man F3-Model F5-Switches F6-Results F9-Ref F10-Quit

# Symbolic Calculation

CalcHEP\_3.8.3/symb

*Model:* SM

*Process:* p,p -> m,M

*Feynman diagrams*

20 diagrams in 10 subprocesses are constructed.  
0 diagrams are deleted.

*Squared diagrams*

30 diagrams in 10 subprocesses are constructed.  
0 diagrams are deleted.  
30 diagrams are calculated.

<  
View squared diagrams  
Symbolic calculations  
Make&Launch n\_calchep  
Make n\_calchep  
REDUCE program

# Symbolic Calculation

CalcHEP\_3.8.3/symb

*Model:* SM

*Process:* p,p -> m,M

*Feynman diagrams*

20 diagrams in 10 subprocesses are constructed.  
0 diagrams are deleted.

*Squared diagrams*

30 diagrams in 10 subprocesses are constructed.  
0 diagrams are deleted.  
30 diagrams are calculated.

C code

C-compiler

Edit Linker

REDUCE code

MATHEMATICA code

FORM code

Enter new process

# Numerical Calculation

CalcHEP\_3.8.3/num

*(sub)Process: u, U -> m, M*  
*Monte Carlo session: 1(begin)*

*#IT Cross section[pb] Error[%] nCall Eff. chi^2*

## Subprocess

*IN state*  
*Model parameters*  
*Constraints*  
*QCD alpha & scales*  
*Breit-Wigner*  
*Aliases*  
*Cuts*  
*Phase space mapping*  
*Monte Carlo simulation*  
*1D integration*

# Numerical Calculation

```
CalcHEP_3.8.3/num
```

*(sub)Process: u, U -> m, M*  
*Monte Carlo session: 1(begin)*

*#IT Cross section[pb] Error[%] nCall Eff. chi^2(begin)*

<i>u U</i>	<i>-&gt;</i>	<i>m M</i>
<i>U u</i>	<i>-&gt;</i>	<i>m M</i>
<i>d D</i>	<i>-&gt;</i>	<i>m M</i>
<i>D d</i>	<i>-&gt;</i>	<i>m M</i>
<i>c C</i>	<i>-&gt;</i>	<i>m M</i>
<i>C c</i>	<i>-&gt;</i>	<i>m M</i>
<i>b B</i>	<i>-&gt;</i>	<i>m M</i>
<i>B b</i>	<i>-&gt;</i>	<i>m M</i>
<i>s S</i>	<i>-&gt;</i>	<i>m M</i>
<i>S s</i>	<i>-&gt;</i>	<i>m M</i>

*F1-Help F2-Man F5-Options F6-Results F8-Calc F9-Ref*

# Numerical Calculation

```
CalcHEP_3.8.3/num  
  
(sub)Process: u, U -> m, M  
Monte Carlo session: 1(begin)  
  
#IT Cross section[pb] E <  
S.F.1: OFF  
S.F.2: OFF  
First particle momentum[GeV] = 6500  
Second particle momentum[GeV] = 6500  
First particle unpolarized  
Second particle unpolarized  
  
F1-Help F2-Man F5-Options F6-Results F7-Plot F8-Calc F9-Ref
```



# Numerical Calculation

CalcHEP\_3.8.3/num

*(sub)Process: u, U -> m, M*  
*Monte Carlo session: 1(begin)*

*#IT Cross section[pb] E*

*IN state*

*S.F.1: OFF*

*PDT menu*

- cteq611(anti-proton)*
- cteq611(proton)*
- NNPDF23\_lo\_as\_0130\_qed(anti-proton)*
- NNPDF23\_lo\_as\_0130\_qed(proton)*
- MRST2004qed\_proton(anti-proton)*
- MRST2004qed\_proton(proton)*
- CT10(anti-proton)*
- CT10(proton)*

*F1-Help F2-Man F5-Options F6-Results F8-Calc F9-Ref*

LHAPDF will show up here

# Numerical Calculation

```
(sub)Process: u, U -> m, M  
Monte Carlo session: 1(begin)
```

```
#IT Cross section[pb] Error[%] nCall Eff. chi^2
```

You can change the parameters of your model that will be used in the calculations.

```
Model parameters  
Change parameter
```

```
READ_FROM_FILE  
EE 3.1333E-01  
SW 4.7400E-01  
Q 1.0000E+02  
MW 8.0385E+01  
Mtp 1.7250E+02  
McMc 1.2300E+00  
MbMb 4.2500E+00  
alphaSMZ 1.1840E-01  
Ml 1.7770E+00  
Mh 1.2500E+02
```

# Numerical Calculation

CalcHEP\_3.8.3/num

```
(sub)Process: u, U -> m, M
```

Parameter	Min bound	Max bound
$T(p^*)$	50	
$e(m)$	15	
$M(m, M)$	15	

Click on "F1" below for help.

*chi<sup>2</sup>*

Cuts

Masses, Widths, Branching

F1 F2 Xgoto Ygoto Find Write

# Numerical Calculation

```
CalcHEP_3.8.3/num  
  
(sub)Process: u, U -> m, M  
Monte Carlo session: 1(begin)  
  
#IT Cross section[pb] Error[%] nCall Eff. chi^2  
  
Phase space mapping  
Kinematics  
Regularization  
  
Crucial for more than 2 particles in  
the final state!  
  
F1-Help F2-Man F5-Options F6-Results F8-Calc F9-Ref F10-Quit
```

# Numerical Calculation

```
CalcHEP_3.8.3/num
```

```
(sub)Process: u, U -> m, M  
Monte Carlo session: 1(begin)
```

```
=====  
in= 12    -> out1= 3  out2= 4  
=====
```

```
Input new kinematics?  
_____( Y / N ?) _____
```

2

Phase space mapping

Kinematics

# Numerical Calculation

Consider the process  $pp \rightarrow ZZ \rightarrow 4e$

CalcHEP\_3.8.3/num

```
(sub)Process: u, U -> e, e, E, E
Monte Carlo session: 1

===== Current kinematical scheme =====
in= 12   -> out1= 3   out2= 456
in= 456  -> out1= 4   out2= 56
in= 56   -> out1= 5   out2= 6
=====
```

Input new kinematics?  
\_\_\_\_\_( Y / N ? )\_\_\_\_

Phase space mapping

2 Kinematics

# Numerical Calculation

Consider the process  $pp \rightarrow ZZ \rightarrow 4e$

```
CalcHEP_3.8.3/num
```

```
(sub)Process: u, U -> e, e, E, E  
Monte Carlo session: 1
```

```
=====  
Current kinematical scheme  
=====  
in= 12   -> out1= 35 out2= 46  
in= 35   -> out1= 3  out2= 5  
in= 46   -> out1= 4  out2= 6  
=====
```

```
Input new kinematics?  
_____( Y / N ? )____
```

2

Phase space mapping

Kinematics

# Numerical Calculation

CalcHEP\_3.8.3/num

*(sub)Process: u, U -> e, e, E, E*

\* **Regularization 2**

Clr	Del	Size	Read	ErrMes	
Momentum	/>	Mass	</>	Width </	Power
35	/MZ		/wZ		/2
46	/MZ		/wZ		/2

Eff.  $\chi^2$

Phase space mapping

Regularization

F1 F2 Xgoto Ygoto Find Write



# Numerical Calculation

CalcHEP\_3.8.3/num

*(sub)Process: u, U -> m, M*  
*Monte Carlo session: 1(begin)*

*#IT Cross section[pb] Error[%] nCall Eff. chi^2*

*Subprocess*  
*IN state*  
*Model parameters*  
*Constraints*  
*QCD alpha & scales*  
*Breit-Wigner*  
*Aliases*  
*Cuts*  
*Phase space mapping*  
***Monte Carlo simulation***  
*1D integration*

*F1-Help F2-Man F5-Options F6-Results F8-Calc F9-Ref F10-Quit*

# Numerical Calculation

```
CalcHEP_3.8.3/num
```

```
(sub)Process: u, U -> m, M  
Monte Carlo session: 1(begin)
```

```
#IT Cross section[pb] Error[%] nCall Eff. chi^2 <
```

```
Monte Carlo simulation
```

```
nSess = 5  
nCalls = 100000  
Set Distributions  
*Start integration  
Display Distributions  
Clear statistic  
Freeze grid OFF  
Clear grid
```

```
F1-Help F2-Man F5-Options F6-Results F8-Calc F9-Ref F10-Quit
```

# Numerical Calculation

CalcHEP\_3.8.3/num

```
(sub)Process: u, U -> m, M  
Monte Carlo session: 1(begin)
```

```
#IT Cross section[pb] Error[%] nCall Eff. chi^2
```

Monte Carlo simulation

nSess = 5

Enter new value 20

# Numerical Calculation

CalcHEP\_3.8.3/num

*(sub)Process: u, U -> m, M*

*Distributions*

1

~~Clr~~ ~~Del~~ ~~Size~~ ~~Read~~ ~~ErrMes~~

Parameter\_1 /> Min\_1 </> Max\_1 </Parameter\_2/> Min\_2 </> Max\_2 <

**T(m)** /10 /100 / / /

M(m,M) /70 /100 / / /

mulation

ions

~~F1~~ ~~F2~~ ~~Xgoto~~ ~~Ygoto~~ ~~Find~~ ~~Write~~

# Numerical Calculation

CalcHEP\_3.8.3/num

```
(sub)Process: u, U -> m, M  
Monte Carlo session: 1(begin)
```

```
#IT Cross section[pb] Error[%] nCall Eff. chi^2
```

Monte Carlo simulation

```
nSess = 20  
nCalls = 100000  
Set Distributions  
*Start integration  
Display Distributions  
Clear statistic  
Freeze grid OFF  
Clear grid
```

F1-Help F2-Man F5-Options F6-Results F8-Calc F9-Ref F10-Quit

# Numerical Calculation

```
CalcHEP_3.8.3/num
```

*(sub)Process: u, U -> m, M*  
*Monte Carlo session: 2(begin)*

#IT	Cross section[pb]	Error[%]	nCall	Eff.	chi <sup>2</sup>
< >	6.3974E+03	1.51E+00	1478520		4E+01
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX					
3	5.2482E+03	2.29E+01	98568		
4	7.4957E+03	2.69E+00	98568		
5	7.4874E+03	1.79E-01	98568		
6	7.4831E+03	1.34E-01	98568		
7	7.4821E+03	1.25E-01	98568		
8	7.4770E+03	1.08E-01	98568		
9	7.4572E+03	1.04E-01	98568		
10	7.4504E+03	1.02E-01	98568		
11	7.4197E+03	1.09E-01	98568		
12	7.3795E+03	9.81E-02	98568		
13	7.2874E+03	1.12E-01	98568		
14	7.1917E+03	8.96E-02	98568		
15	7.1671E+03	7.79E-02	98568		
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX					

Monte Carlo simulation

Start integration

Integration is over  
Press any key

# Numerical Calculation

CalcHEP\_3.8.3/num

*(sub)Process: u, U -> m, M*  
*Monte Carlo session: 1(continue)*

#IT	Cross section[pb]	Error[%]	nCall	Eff.	chi <sup>2</sup>
4	1.2073E-04	5.98E-06	100000		
5	1.2073E-04	6.01E-06	100000		
6	1.2073E-04	5.95E-06	100000		
7	1.2073E-04	5.86E-06	100000		
8	1.2073E-04	5.93E-06	100000		
9	1.2073E-04	5.94E-06	100000		
10	1.2073E-04	5.94E-06	100000		
11	1.2073E-04	5.92E-06	100000		
12	1.2073E-04	5.95E-06	100000		
13	1.2073E-04	5.98E-06	100000		
14	1.2073E-04	5.97E-06	100000		
15	1.2073E-04	5.89E-06	100000		
< >	1.2073E-04	1.54E-06	1500000		0.7
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX					
3	1.2073E-04	5.97E-06	100000		

Monte Carlo simulation

Display Distributions

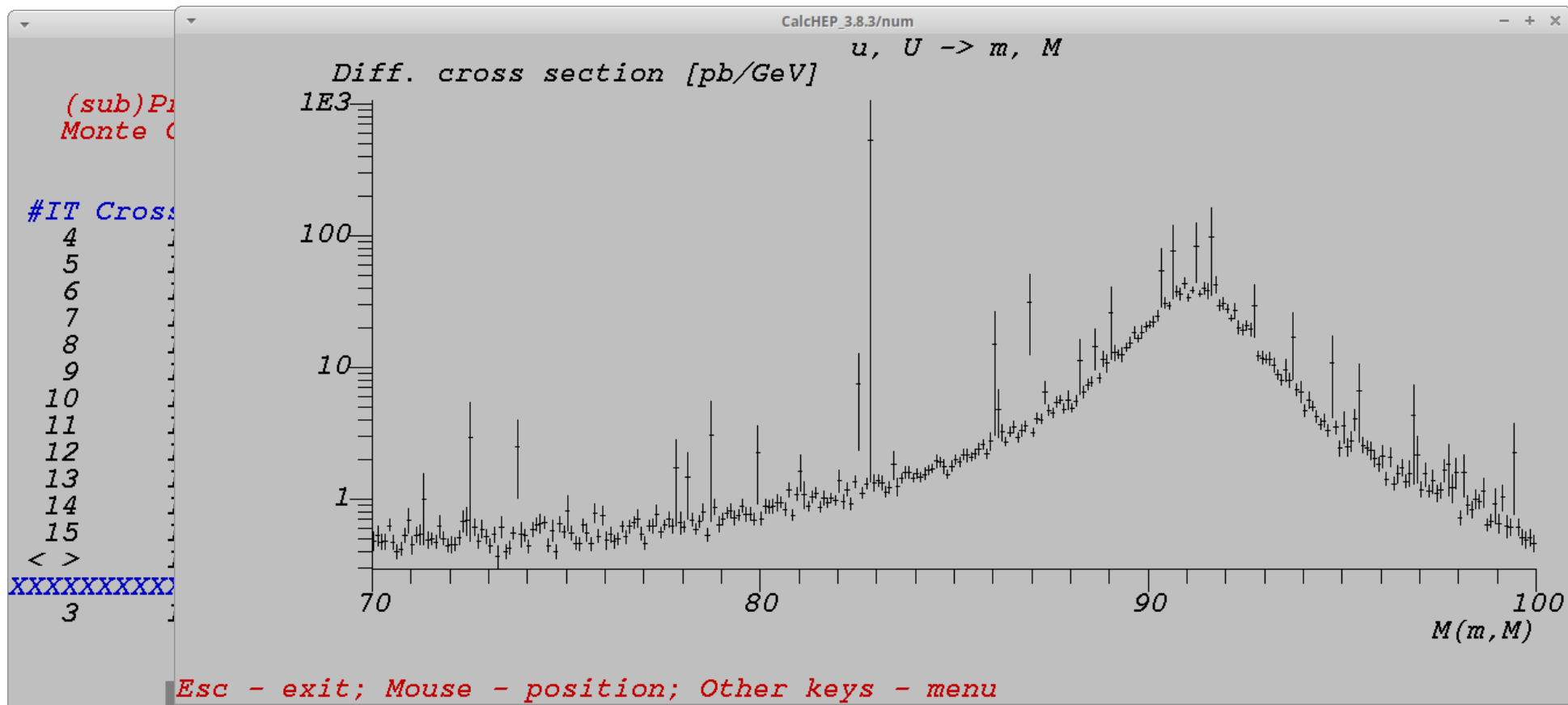
Distributions

T(m)

M(m, M)

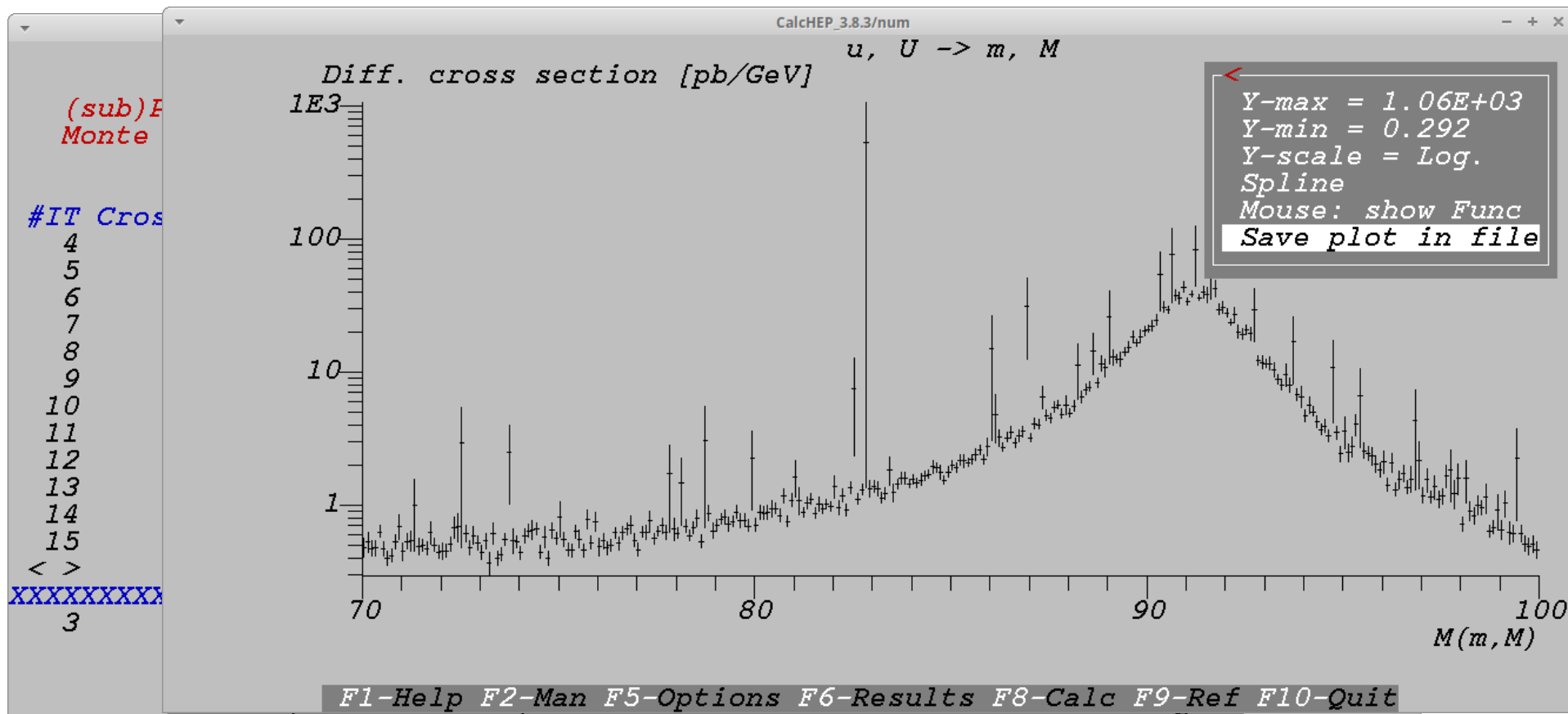
F1-Help F2-Man F5-Options F6-Results F8-Calc F9-Ref F10-Quit

# Numerical Calculation

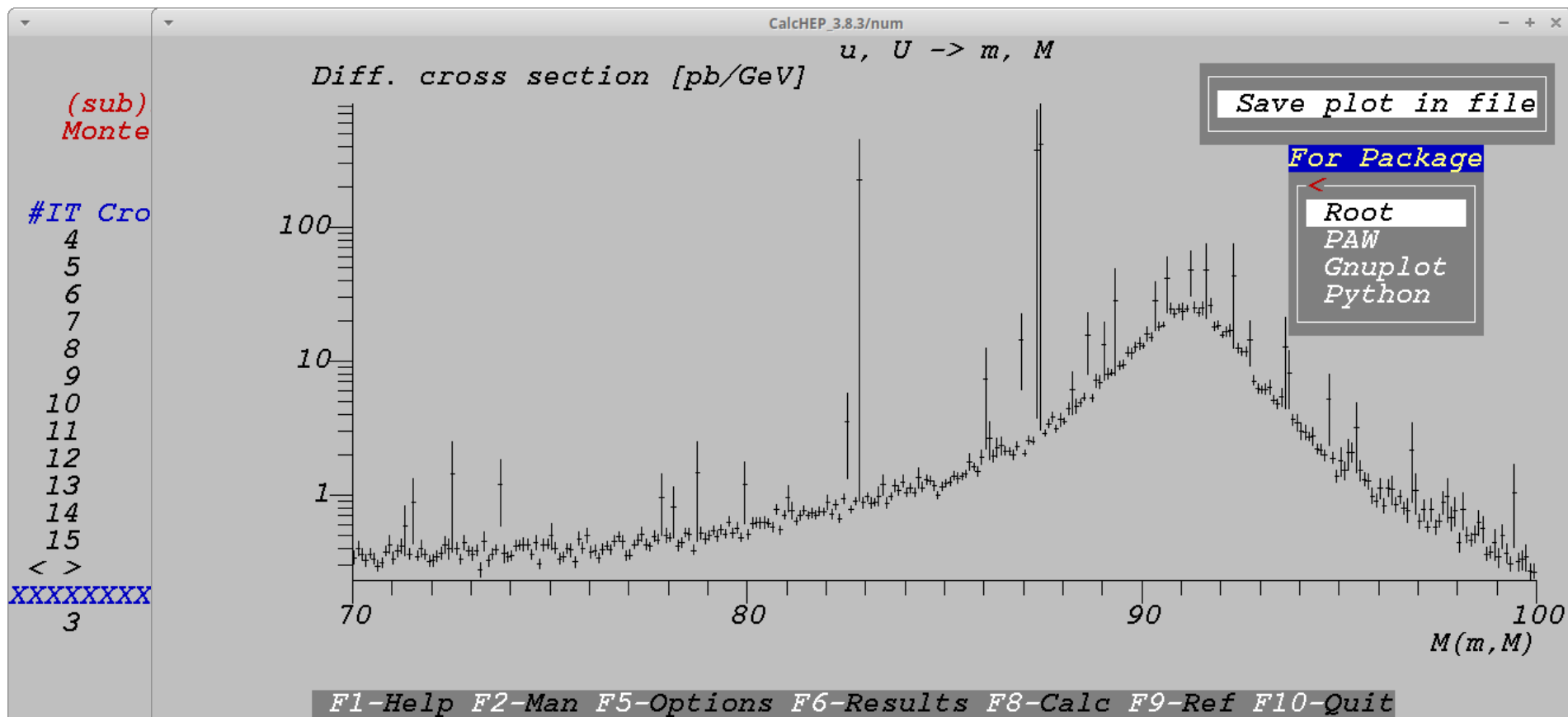




# Numerical Calculation



# Numerical Calculation



# Numerical Calculation

CalcHEP\_3.8.3/num

(sub)Process: u, U -> m, M  
Monte Carlo session: 2(continue)

#IT	Cross section[pb]	Error[%]	nCall	Eff.	chi^2
57	6.8992E+03	7.73E-02	98568	1.6E-01	
58	6.8858E+03	7.68E-02	98568	1.6E-01	
59	6.8865E+03	7.79E-02	98568	1.6E-01	
60	6.8850E+03	8.41E-02	98568	1.6E-01	
61	6.9507E+03	1.08E+00	98568	1.6E-01	
62	6.8889E+03	7.77E-02	98568	1.6E-01	
63	6.8885E+03	9.41E-02	98568	1.6E-01	
64	6.8860E+03	7.66E-02	98568	1.6E-01	
65	6.8824E+03	7.73E-02	98568	1.6E-01	
66	6.8953E+03	1.93E-01	98568	1.6E-01	
67	6.8869E+03	7.72E-02	98568	1.6E-01	
68	6.8935E+03	7.79E-02	98568	1.6E-01	
69	7.1767E+03	4.14E+00	98568	1.4E-01	
70	6.8923E+03	7.68E-02	98568	1.4E-01	
< >	7.0174E+03	9.01E-01	6899760	1.4E-01	5

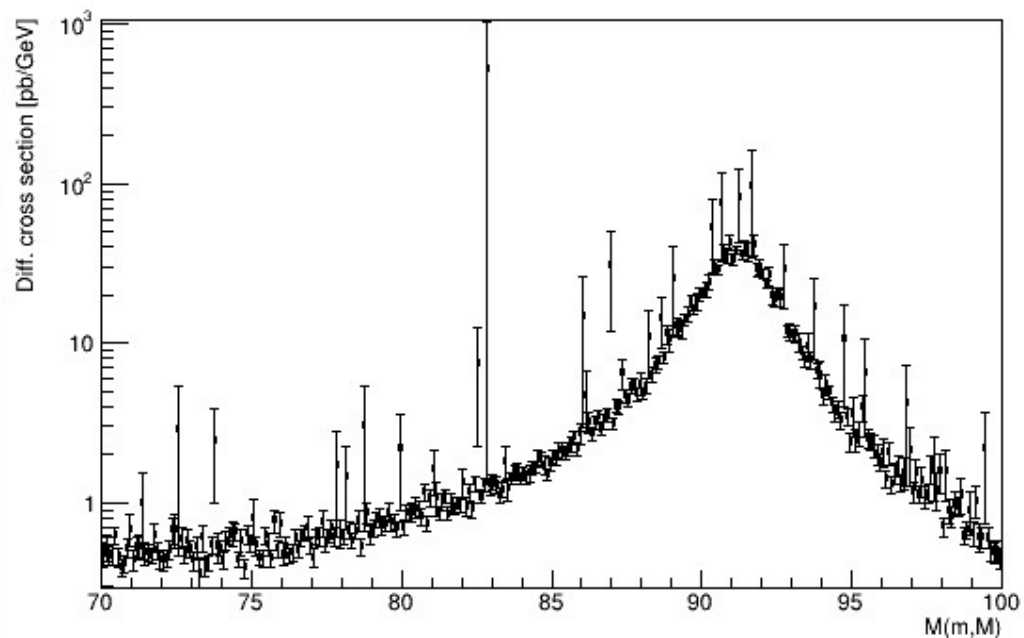
Monte Carlo simulation

```
nSess = 20
nCalls = 100000
Set Distributions
*Start integration
Display Distributions
Clear statistic
Freeze grid      ON
Clear grid
Event Cubes 9702
Num. of events=100
Generate Events
```

F1-Help F2-Man F5-Options F6-Results F8-Calc F9-Ref F10-Quit

# Numerical Calculation – Results

```
Terminal - asevedo@nepomuceno: ~/programs/calchep38/results
File Edit View Terminal Tabs Help
(base) asevedo@nepomuceno:~/programs/calchep38/results$ ls
autoprot.h  distr_2      ld2.a  lib_0.a  plot_1.tab  plot_2.tab  scale.c
aux         events_2.txt ld3.a  n_calchep  plot_2.C    prt_1       scale.so
distr_1     EXTLIBsh    ld4.a  plot_1.py  plot_2.pdf  prt_2       session.dat
(base) asevedo@nepomuceno:~/programs/calchep38/results$ root -l
root [0] .x plot_2.
Error in <TApplication::ExecuteFile>: macro plot_2. not found in path ./home/asevedo/macros
root [1] .x plot_2.C
Info in <TCanvas::Print>: pdf file plot_2.pdf has been created
root [2] █
```



Useful for validation

# Numerical Calculation

CalcHEP\_3.8.3/num

*(sub)Process: u, U -> W+, W-*  
*Monte Carlo session: 1(begin)*

*#IT Cross section[pb] Error[%] nCall Eff. chi^2*

*Subprocess*  
*IN state*  
*Model parameters*  
*Constraints*  
*QCD alpha & scales*  
*Breit-Wigner*  
*Aliases*  
*Cuts*  
*Phase space mapping*  
*Monte Carlo simulation*  
*1D integration*

*F1-Help F2-Man F5-Options F6-Results F8-Calc F9-Ref F10-Quit*

# Numerical Calculation

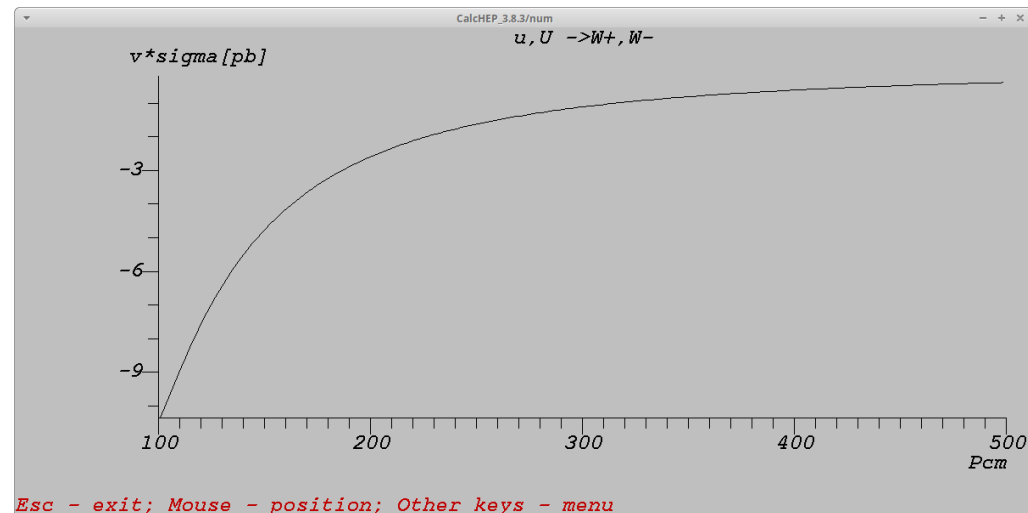
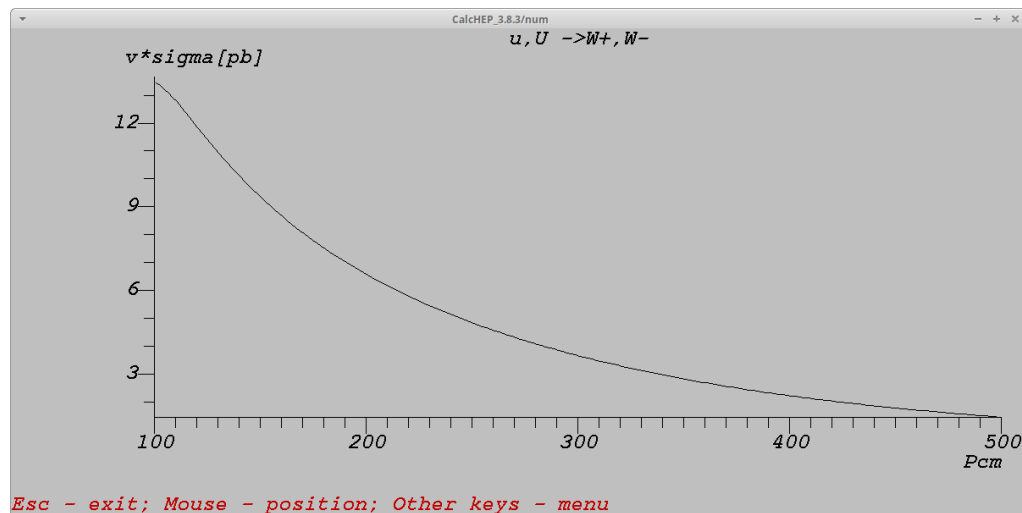
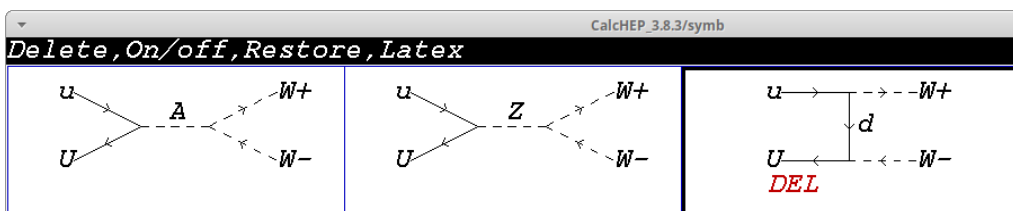
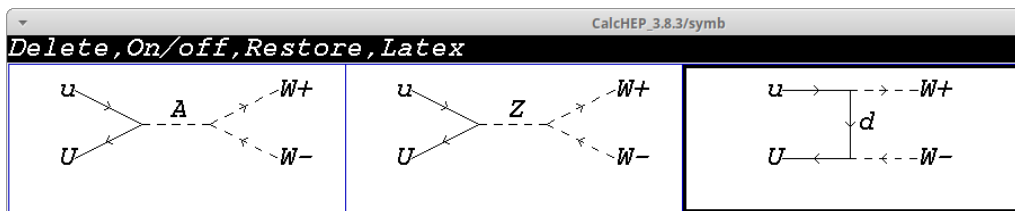
```
CalcHEP_3.8.3/num

(sub)Process: u, U -> W+, W-
P(c.m.s.)    : 6500.000000 [GeV]
Cos(p1,p3): min=-0.999000      max= 0.999000
Cross Section: -0.00117309 [pb]
#IT Cross section[pb] Error[%] nCall   Eff.   chi^2

Change parameter
Set precision
Cos13(min) = -0.999000
Cos13(max) = 0.999000
Angular dependence
Parameter dependence
sigma*v plots

F1-Help F2-Man F5-Options F6-Results F8-Calc F9-Ref F10-Quit
```

# Numerical Calculation



Always check the unitarity of your model!

# Decays

CalcHEP\_3.8.3/symb

Model: SM

List of particles (antiparticles)

A(A )- photon	Z(Z )- Z boson	G(G )- gluon
W+(W- )- W boson	ne(Ne )- neutrino	e(E )- electron
nm(Nm )- mu-neutrino	m(M )- muon	nl(Nl )- tau-neutrino
l(L )- tau-lepton	u(U )- u-quark	d(D )- d-quark
c(C )- c-quark	s(S )- s-quark	t(T )- t-quark
b(B )- b-quark	h(h )- Higgs	

Enter process: **Z->2\*X**

Exclude diagrams with

Exclude X-particles



# Batch Calculation

The CalcHep GUI is very useful to understand and validate your model, but obviously it is not effective for “production mode”. What if you want to calculate cross-sections and generate thousands of events considering different model parameters (for instance, varying the mass of a resonance) ?

For this task, CalcHep has a very powerful **batch mode calculation**. From a single batch file, we can set all the parameters needed to perform the calculations. The progress of the calculations can be check via a html file.

# Batch File

```
#####  
# Model Info  
#####
```

```
Model:      B-L (Full fast)  
Model changed: False  
Gauge:      Unitary
```

```
#####  
# Process Info                                     #  
#####
```

```
Process:  p,p->m,M  
Composite: p=u,U,d,D,s,S,c,C,b,B,G  
Remove:  Z,A,H1,H2
```

```
# PDF Info  
#pdf1:    LHA:cteq6ll.LHpdf:0:1  
#pdf2:    LHA:cteq6ll.LHpdf:0:1
```

```
pdf1:     cteq6l1 (proton)  
pdf2:     cteq6l1 (proton)
```

```
# Momentum Info in GeV
```

```
p1:       6500  
p2:       6500
```

```
# Parameter Info  
# Masses and Energies are in GeV  
#Parameter: EE=0.31  
#Parameter: MZp=5000
```

# Batch File

```
# Run Info                                     #  
# Masses and Energies are in GeV  
# More than one run can be specified at  
# the same time.
```

```
Run parameter: MZp  
Run begin:    1000  
Run step size: 500  
Run n steps:  3
```

```
#Run parameter: g1p  
#Run begin:    0.2  
#Run step size: 0.1  
#Run n steps:  10
```

```
##### QCD Running Info  
#####  
#####  
#parton dist. alpha: ON  
#alpha(MZ):      0.118  
#alpha Q :1:     M34  
#alpha Q :2:     M45  
alpha Q :        M12
```

# Batch File

## #Cuts info

Cut parameter: n(m)

Cut invert: False

Cut min: -100

Cut max: 100

Cut parameter: n(M)

Cut invert: False

Cut min: -100

Cut max: 100

Cut parameter: M(m,M)

Cut invert: False

Cut min: 50

Cut max:

## # Kinematics and Regularization

Kinematics : 12 -> 3,4

Regularization momentum: 34

Regularization mass: MZp

Regularization width: wZp

Regularization power: 2

# Batch File

#Distribution

#Need gnplot installed

Dist parameter: M(m,M)

Dist min: 400

Dist max: 3000

Dist n bins: 150

Dist title: p,p->m,M

Dist x-title: M(m,M) (GeV)

# Event generation and Vegas

Number of events (per run step): **1000**

Filename: **zprime\_mm\_events**

NTuple: **True**

#Vegas

nSess\_1: 20

nCalls\_1: 100000

nSess\_2: 20

nCalls\_2: 100000

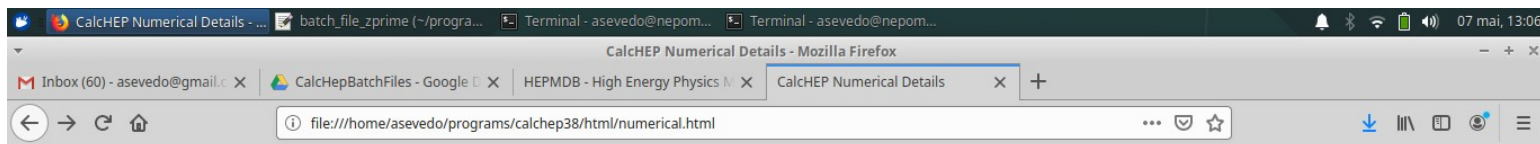
Run you batch file: `./calchep_batch batch_file`

# Batch Results

```
Terminal - asevedo@nepomuceno: ~/programs/calchep38/html
File Edit View Terminal Tabs Help
(base) asevedo@nepomuceno:~/programs/calchep38$ ls
batch_file_zprime  bin      calchep_batch  Events  models  results
batch_results     calchep  calchep.ini    html    Processes tmp
(base) asevedo@nepomuceno:~/programs/calchep38$ cd html/
(base) asevedo@nepomuceno:~/programs/calchep38/html$ ls
events.html  index.html  library.html  numerical.html  request.html  style.css  symbolic.txt
help         index.txt  m7           numerical.txt   runs          symbolic.html
(base) asevedo@nepomuceno:~/programs/calchep38/html$
```

In your work directory, you will find the “html” folder, where you can find “numerical.html” file.

# Batch Results



## Numerical Sessions

Home  
Symbolic Results  
Numerical Results  
Events Library  
Process Library  
Help

Thank you for  
using CalCHEP!  
Please cite  
arXiv:1207.6082

### B-L (Full fast)

#### Calculating Cross Sections

Scans	$\sigma$ (fb)	Running	Finished	Time (hr)	N events			
MZp=1000	76.464	0/10	10/10	0.05		0/10	10/10	0.05
MZp=1500	12.353	0/10	10/10	0.05		0/10	10/10	0.05
MZp=2000	2.862	1/10	6/10	0.03		1/10	6/10	0.03
				0.14				



Remember to clear your web browser cache if the plots are not updating properly. Also, remember to refresh your browser if you started a new run.

# Batch Results

```
Terminal - asevedo@nepomuceno: ~/programs/calchep38/batch_results
File Edit View Terminal Tabs Help Rotate
(base) asevedo@nepomuceno:~/programs/calchep38$ ls
batch_file zprime bin calchep_batch Events models results
batch_results calchep calchep.ini html Processes tmp
(base) asevedo@nepomuceno:~/programs/calchep38$ cd html/
(base) asevedo@nepomuceno:~/programs/calchep38/html$ ls
events.html index.html library.html numerical.html request.html style.css symbolic.txt
help index.txt m7 numerical.txt runs symbolic.html
(base) asevedo@nepomuceno:~/programs/calchep38/html$ cd ..
(base) asevedo@nepomuceno:~/programs/calchep38$ ls
batch_file zprime bin calchep_batch Events models results
batch_results calchep calchep.ini html Processes tmp
(base) asevedo@nepomuceno:~/programs/calchep38$ cd batch_results/
(base) asevedo@nepomuceno:~/programs/calchep38/batch_results$ ls
events.txt zprime_mm_events-MZp1000-1.nt zprime_mm_events-MZp1500.lhe.gz
plot_1.tab zprime_mm_events-MZp1000.distr zprime_mm_events-MZp2000-1.nt
tmp zprime_mm_events-MZp1000.lhe.gz zprime_mm_events-MZp2000.distr
zprime_mm_events zprime_mm_events-MZp1500-1.nt zprime_mm_events-MZp2000.lhe.gz
zprime_mm_events-cs.dat zprime_mm_events-MZp1500.distr
(base) asevedo@nepomuceno:~/programs/calchep38/batch_results$
```



# Batch Results

```
Terminal - asevedo@nepomuceno: ~/programs/calchep38/batch_results
File Edit View Terminal Tabs Help
(base) asevedo@nepomuceno:~/programs/calchep38$ ls
batch_file zprime bin calchep_batch Events models results
batch_results calchep calchep.ini html Processes tmp
(base) asevedo@nepomuceno:~/programs/calchep38$ cd html/
(base) asevedo@nepomuceno:~/programs/calchep38/html$ ls
events.html index.html library.html numerical.html request.html style.css
help index.txt m7 numerical.txt runs symbolic.
(base) asevedo@nepomuceno:~/programs/calchep38/html$ cd ..
(base) asevedo@nepomuceno:~/programs/calchep38$ ls
batch_file zprime bin calchep_batch Events models results
batch_results calchep calchep.ini html Processes tmp
(base) asevedo@nepomuceno:~/programs/calchep38$ cd batch_results/
(base) asevedo@nepomuceno:~/programs/calchep38/batch_results$ ls
events.txt zprime_mm_events-MZp1000-1.nt zprime_mm_events-MZp
plot_1.tab zprime_mm_events-MZp1000.distr zprime_mm_events-MZp
tmp zprime_mm_events-MZp1000.lhe.gz zprime_mm_events-MZp
zprime_mm_events zprime_mm_events-MZp1500-1.nt zprime_mm_events-MZp2000.lhe.gz
zprime_mm_events-cs.dat zprime_mm_events-MZp1500.distr
(base) asevedo@nepomuceno:~/programs/calchep38/batch_results$
```

**zprime\_mm\_events-cs.dat** – xsec as a function of the running parameter ( $Z'$  mass) .

**zprime\_mm\_events-Mzp\*.lhe.gz** – Event file (LHE format)

**zprime\_mm\_events-Mzp\*.nt** – PAW ntuple

# Analyze Event File

In order to produce the PAW ntuple file, we need the “nt\_maker” script in the \$CALCHEP/“bin” directory (see backup slides on how to produce it).

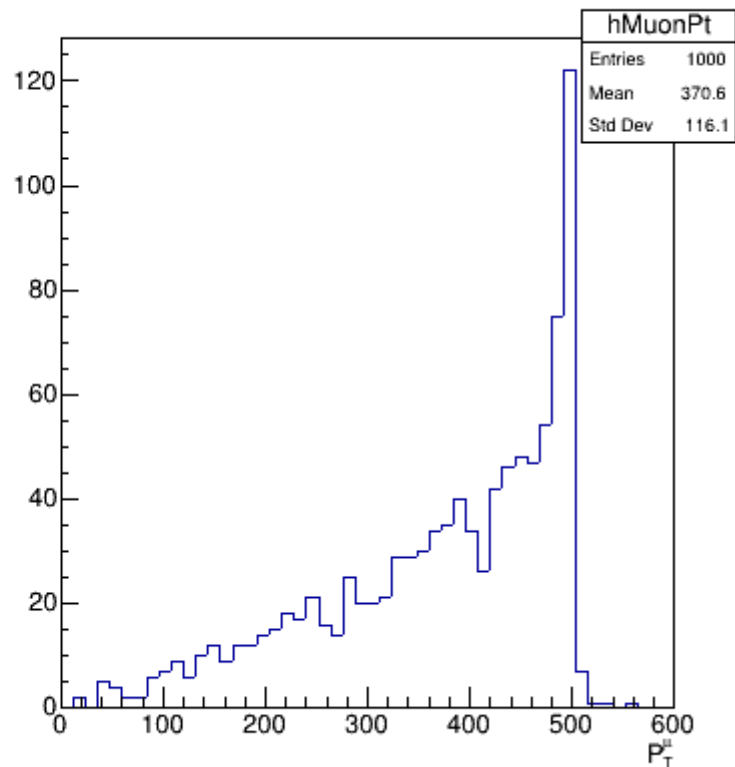
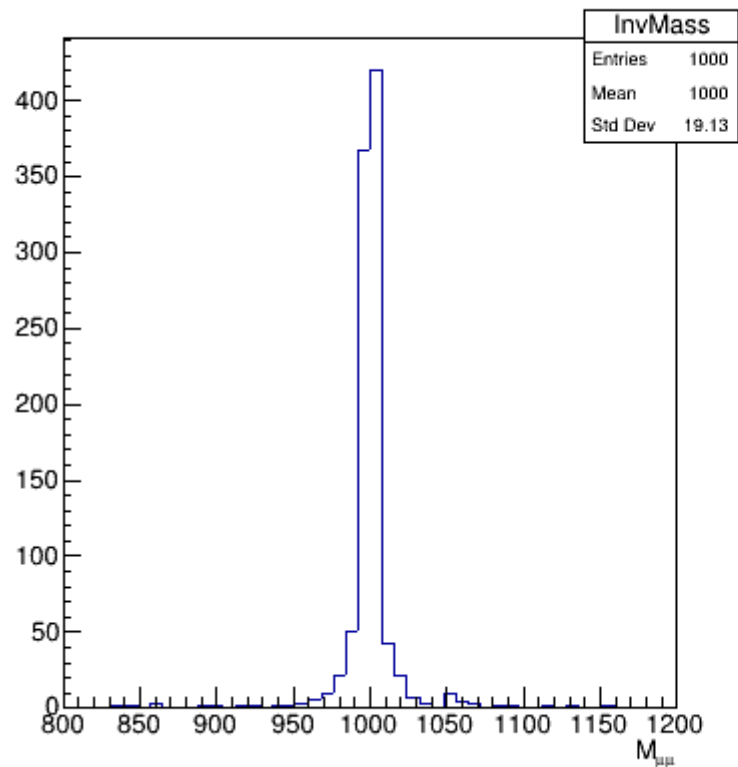
We can use h2root to convert PAW hbook to a ROOT file:

```
h2root zprime_mm_events-MZp1000-1.nt zprime_mm_Mzp1000.root
```

The root file has the Xsec and the four-momenta of the particles. It can be analyzed using the ROOT **TLorentzVector** class (see example attached).

The LHE file can also be read with a Python script. See backup slides for details.

# Analyze Event File - Example



# Try Yourself!

1. Download the model “Minimal Zp models” from HEPMDB
2. Put the model files in the “models” directory (do not forget to rename the files!)
3. Calculate the cross-section for the various sub-process of the process  $pp \rightarrow Z' \rightarrow \mu^+ \mu^-$ . Remove the contributions from the photon and Z bosons and from the scalars H1 and H2 in order to estimate the contribution from Z' only.
4. Check unitary (using 1D integration option to plot Xsec versus center-of-mass energy).
5. Check how the Z' width vary with its mass.
6. Calculate the Xsec for the above process using different Z' mass in batch mode. Generate events.
7. Using the root ntuple from the LHE event file, plot individual muons pseudorapidity, transverse momentum, muon pair rapidity and muon pair invariant mass.

# Getting Help

- Visit CalcHep web page (see slide 2)
- Browse through many Q&A in “Questions for CalcHEP”:  
<https://answers.launchpad.net/calchep>
- Ask the most powerful answering machine in the world (Google)
- You can also ask me: asevedo@gmail.com

# Backup Slide I

Producing the script “nt\_maker” when compile CalcHep

1. Assuming that you have version 3.8.3, go to directory **calchep\_3.8.3/c\_source/mix\_events** and open the file “MakeFile”.
2. Include the path to the CERN library files. Example:  
CERN=/usr/lib/x86\_64-linux-gnu/
3. Compile CalcHep (see slide 3). The script will be in “bin” directory.

# Backup Slide II

We can use Python to read a LHE Event file. There is a Python module for that.

Check the link below:

<https://pypi.org/project/lhereader/>

# Backup Slide III

We can use LanHep to implement models in CalcHep. Check this video tutorial:

[https://www.youtube.com/watch?v=3dydCI44ZYE&feature=youtu.be&fbclid=IwAR2IHSVfv9TLxWVxdXVockJuXJpySgNMkrw\\_Z757v7YSU\\_h71eu\\_0QBgMwE](https://www.youtube.com/watch?v=3dydCI44ZYE&feature=youtu.be&fbclid=IwAR2IHSVfv9TLxWVxdXVockJuXJpySgNMkrw_Z757v7YSU_h71eu_0QBgMwE)