CALCHEP, COMPHEP

Tutorial
and Introduction

Comphep – Main Page

CompHEP

- News
- Overview
- Screen shots
- Downloads
- Community contributions
- Community model library
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- License
- **Restricted area**

Documentation

- Installation guide
- MAC OS installation
- CompHEP-3.3 Manual
- CompHEP-3.3 Manual (pdf)
- The Bibliography. History.

User support

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Useful Links

Trace: » overview

Main facilities of CompHEP

Table of Contents

- Main facilities of CompHEP
- CompHEP Models.
- LanHEP overview
- CompHEP-Pythia interface

CompHEP is a package for automatic calculations of elementary particle decays and collision processes in the lowest order of perturbation theory (the tree level approximation). The main idea behind the program is to make calculations and data manipulations from Lagrangians to final distributions with a high level of automation. There are several packages created to solve the problem in a similar way: FeynArts/FeynCalc, GRACE, HELAS, MadGraph. CompHEP is a GUI computer system with context help. A user makes all manupulations by means of graphical menus.

The notations used in CompHEP are very similar to those used in particle physics.

CompHEP is based on an idea of the physical model. ComHEP Models are very simular to physical models in high energy physics, like Standards Model or MSSM. The present version of the program has several built-in physical models (see later). Two of them are versions of the Standard Model (SU(3)xSU(2)xU(1)) in the unitary and t'Hooft - Feynman gauges. Users can change particle content of a model, interaction vertices, and other model parameters. It is also possible to create a new model of particle interaction.

The present version does not take into account separate polarization states of particles. All results are presented with averaged initial and summed final polarization states.

The CompHEP package consists of two parts, symbolic and numerical programs. The symbolic part is written in the C programming language. It produces C codes for squared matrix elements, and they are used in the numerical calculation later on.

The symbolic part of CompHEP has the following possibilities:

- select a process by specifying incoming and outgoing particles for the decays of $1 \rightarrow 2, \ldots ,1 \rightarrow 5$ types and the collisions of $2 \rightarrow 2, \ldots , 2 \rightarrow 6$ types;
- generate Feynman diagrams, display them, and create the corresponding LATEX output;
- exclude some diagrams;
- generate and display squared Feynman diagrams;

CalcHEP – Main Page

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_2.3.5(ps.gz) (137 pages, 445KB, March 18, 2005)

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 2.5.4 (July 10 , 2009) version 2.5.5 (version for testing)

Models:

MSSM(04.08.2006) NMSSM CPVMSSM(04.08.2006) 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

Downloads and Users Manual

CompHEP- a package for evaluation of Feynman diagrams and integration over multi-particle phase space

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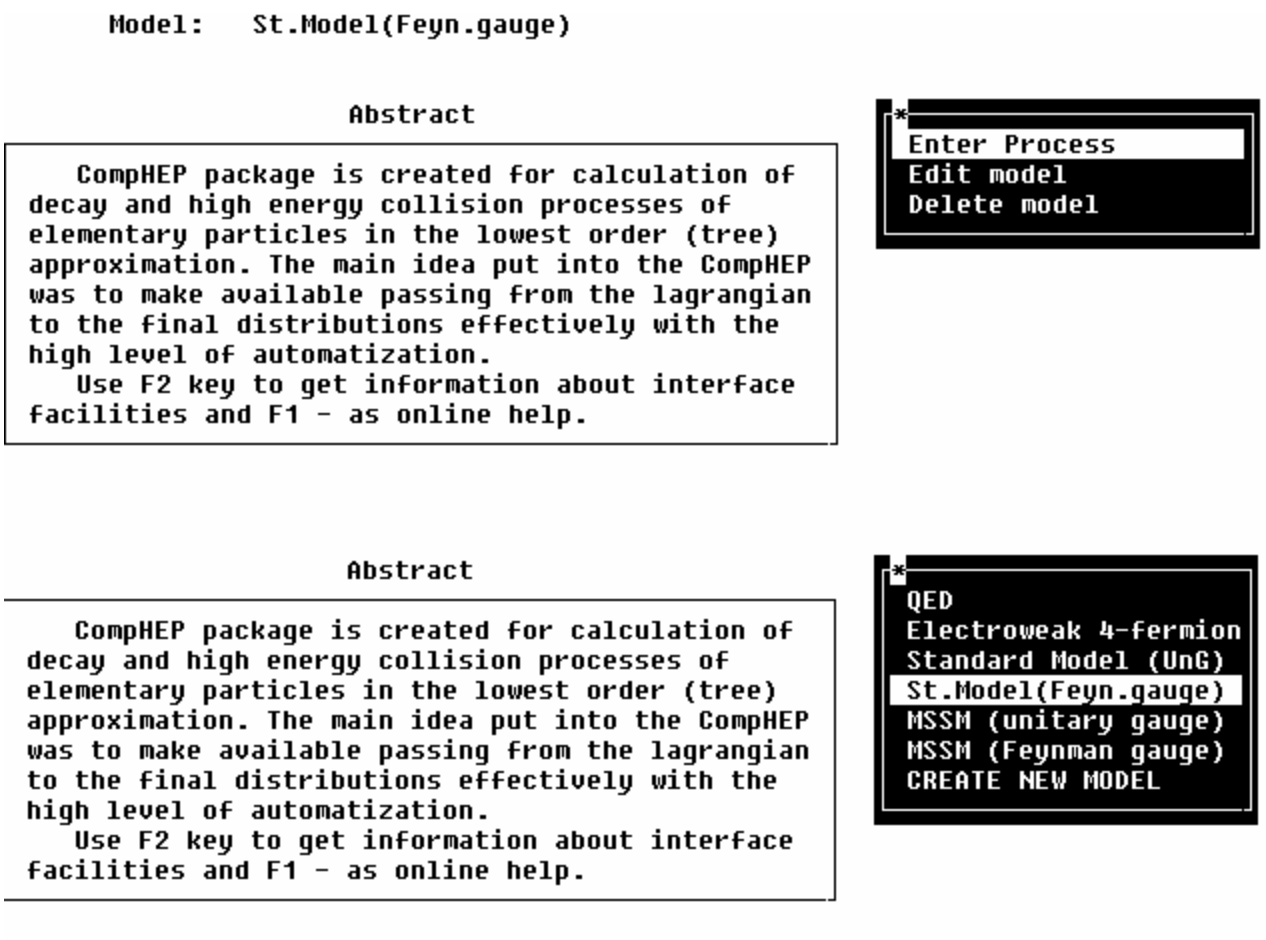
User's manual for version 33

Preprint INP-MSU 98-41/542

Navigate with arrows and escape

Model Choice and Edits



Edit - Parameters

Self-evident – GeV units

Parameters

Clr-Rest-Del-New-Size

Name	Value	> Comment
EE	0.31223	Elementary charge (alpha=1/128.9, on-shell, MZ point, PDG96)
GG	1.238	Strong coupling (LEP/SLD average alphas=0.122, PDG96)
SW	0.4730	sine of the electroweak mixing angle (PDG96)
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
Mt	1.777	tau-lepton mass (PDG96)
Mc	1.420	c-quark mass (pole mass, PDG96)
Ms	0.200	s-quark mass (pole mass, PDG96)
Mb	4.620	b-quark mass (pole mass, PDG96)
Mtop	175	t-quark mass (pole mass)
MZ	91.1884	Z-boson mass (PDG96)
MH	200	higgs mass
wtop	1.7524	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)
wH	0.004244	Higgs width (tree level 1->2x)
Mp	0.94	proton mass

Edit – Particles in the Model

Clr–Rest–Del–New–Size

Full name	A	A+	2*spin	mass	width	color	aux	>LaTex(A)<	>LaTeX(A+) <
photon	A	A	2	0	0	1	G	\gamma	\gamma
gluon	G	G	2	0	0	8	G	g	g
electron	e1	E1	1	0	0	1		e	\bar{e}
e-neutrino	n1	N1	1	0	0	1	L	\nu_e	\bar{\nu}_e
muon	e2	E2	1	Mm	0	1		\mu	\bar{\mu}
m-neutrino	n2	N2	1	0	0	1	L	\nu_\mu	\bar{\nu}_\mu
tau-lepton	e3	E3	1	Mt	0	1		\tau	\bar{\tau}
t-neutrino	n3	N3	1	0	0	1	L	\nu_\tau	\bar{\nu}_\tau
u-quark	u	U	1	0	0	3		u	\bar{u}
d-quark	d	D	1	0	0	3		d	\bar{d}
c-quark	c	C	1	Mc	0	3		c	\bar{c}
s-quark	s	S	1	Ms	0	3		s	\bar{s}
t-quark	t	T	1	Mtop	wtop	3		t	\bar{t}
b-quark	b	B	1	Mb	0	3		b	\bar{b}
Higgs	H	H	0	MH	wH	1		H	H
W-boson	W+	W-	2	MW	wW	1	G	W^+	W^-
Z-boson	Z	Z	2	MZ	wZ	1	G	Z	Z

CALCHEP is a tree level, 2 -> 2 or 3 or 4 calculational model. There is no underlying event and no hadronization of partons. There are no loops – can add, e.g. a Hgg vertex, however

Edit - Vertices

Clr-Rest-Del-New-Size

A1	A2	A3	A4	> Factor	<| > Lorentz part
G	G	G		GG	m1.m2*(p1-p2).m3+m2.m3*(p2-p3).m1+m3.m1*(p3-p1).m2
G	G	G.t		GG/Sqrt2	m1.M3*m2.m3-m1.m3*m2.M3
W+	W-	A		-EE	m1.m2*(p1-p2).m3+m2.m3*(p2-p3).m1+m3.m1*(p3-p1).m2
W+	W-	Z		-EE*CW/SW	m1.m2*(p1-p2).m3+m2.m3*(p2-p3).m1+m3.m1*(p3-p1).m2
W+	W-	Z	Z	-(EE*CW/SW)**2	2*m1.m2*m3.m4-m1.m3*m2.m4-m1.m4*m2.m3
W+	W+	W-	W-	(EE/SW)**2	2*m1.m2*m3.m4-m1.m3*m2.m4-m1.m4*m2.m3
W+	W-	A	Z	-EE**2*CW/SW	2*m1.m2*m3.m4-m1.m3*m2.m4-m1.m4*m2.m3
W+	W-	A	A	-EE**2	2*m1.m2*m3.m4-m1.m3*m2.m4-m1.m4*m2.m3
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
E2	e2	H		-EE*Mm/(2*MW*SW)	1
E3	e3	H		-EE*Mt/(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*Mtop/(2*MW*SW)	1
E1	e1	A		-EE	G(m3)
E2	e2	A		-EE	G(m3)
E3	e3	A		-EE	G(m3)
N1	e1	W+		EE/(2*Sqrt2*SW)	G(m3)*(1-G5)
N2	e2	W+		EE/(2*Sqrt2*SW)	G(m3)*(1-G5)
N3	e3	W+		EE/(2*Sqrt2*SW)	G(m3)*(1-G5)
E1	n1	W-		EE/(2*Sqrt2*SW)	G(m3)*(1-G5)
E2	n2	W-		EE/(2*Sqrt2*SW)	G(m3)*(1-G5)
E3	n3	W-		EE/(2*Sqrt2*SW)	G(m3)*(1-G5)
E1	e1	Z		-EE/(4*SW*CW)	G(m3)*(1-G5)-4*(SW**2)*G(m3)
E2	e2	Z		-EE/(4*SW*CW)	G(m3)*(1-G5)-4*(SW**2)*G(m3)
E3	e3	Z		-EE/(4*SW*CW)	G(m3)*(1-G5)-4*(SW**2)*G(m3)
N1	n1	Z		EE/(4*SW*CW)	G(m3)*(1-G5)
N2	n2	Z		EE/(4*SW*CW)	G(m3)*(1-G5)
N3	n3	Z		EE/(4*SW*CW)	G(m3)*(1-G5)
U	u	A		(2/3)*EE	G(m3)
D	d	A		(-1/3)*EE	G(m3)
C	c	A		(2/3)*EE	G(m3)
S	s	A		(-1/3)*EE	G(m3)
B	b	A		(-1/3)*EE	G(m3)

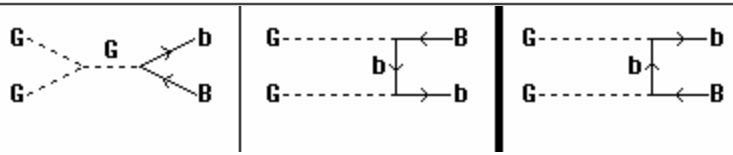
Can add interactions or remove them – models can be edited

Define a Process

```
Model:   St.Model(Feyn.gauge)

        List of particles (antiparticles)

A(A  )- photon          G(G  )- gluon          e1(E1 )- electron
n1(N1 )- e-neutrino     e2(E2 )- muon          n2(N2 )- m-neutrino
e3(E3 )- tau-lepton     n3(N3 )- t-neutrino    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
W+(W- )- W-boson        Z(Z  )- Z-boson
```




```
Enter  process: G,G->b,B

     Model:   St.Model(Feyn.gauge)

   Process:  G,G->b,B

             Feynman diagrams
3     diagrams in  1   subprocesses  are constructed.
0     diagrams  are deleted.
```

Squaring
View diagrams

```
*                    s squa 2
  This function allows you:
1. to view a set of amplitude diagrams;
2. to edit this set by removing unwanted diagrams
   in order to simplify the calculation;
3. to create a LaTeX file with graphical diagram
   pictures.
```

Can be 2 -> 2 or 2 -> 3. Can be exclusive or inclusive (e.g. 2*x)

Can view Feynman diagrams. Can select which set of diagrams is calculated

Square Diagrams

```
       Model:   St.Model(Feyn.gauge)

     Process:  G,G->b,B

               Feynman diagrams
3     diagrams in  1   subprocesses  are constructed.
0     diagrams  are deleted.

               Squared diagrams
6     diagrams in  1   subprocesses  are constructed.
0     diagrams  are deleted.
0     diagrams  are calculated.
```

```
*
View squared diagrams
Symbolic calculations
REDUCE program
Make n_comphep_c
Make n_comphep_f
```

```
(sub)Process: G, G -> b, B
```

```
*
Subprocess
IN state
Model parameters
QCD scale
Breit-Wigner
Cuts
Kinematics
Regularization
Vegas
Simpson
```

```
Monte Carlo session:
```

The program computes an explicit matrix element (symbolic) which it squares and averages over initial spins. However, it retains the spin in the final state – as opposed to Pythia.

Simpson – Fundamental 2 -> 2 Only

```
(sub)Process: G, G -> b, B

Monte Carlo session:
```

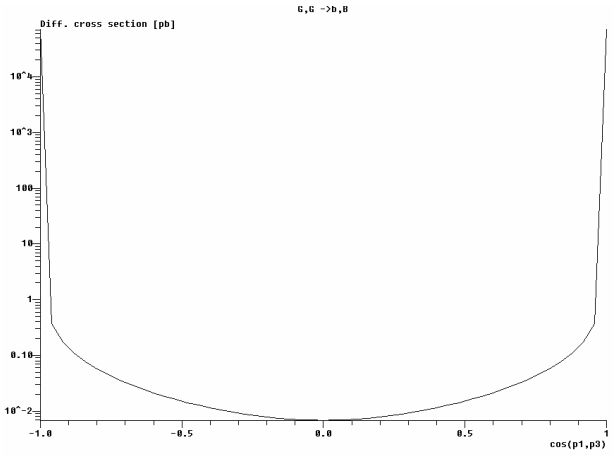
```
IN state
S.F.1: CTEQ4m (  Proton )
S.F.2: CTEQ4m (  Proton )
First  particle momentum[GeV] = 7000
Second particle momentum[GeV] = 7000
```

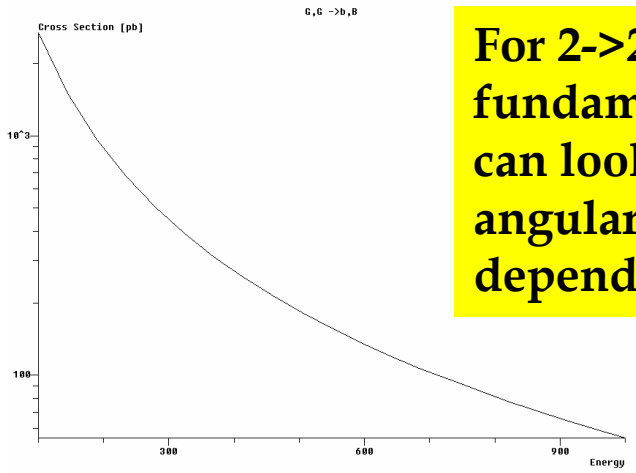
Can choose a few PDF. Can thus compare PDF dependence

```
(sub)Process: G, G -> b, B

Energy       :  14000.000143 [GeV]
Cos(p1,p3): min=-1.000000          max= 1.000000
Cross Section:  0.442003 [pb]
```

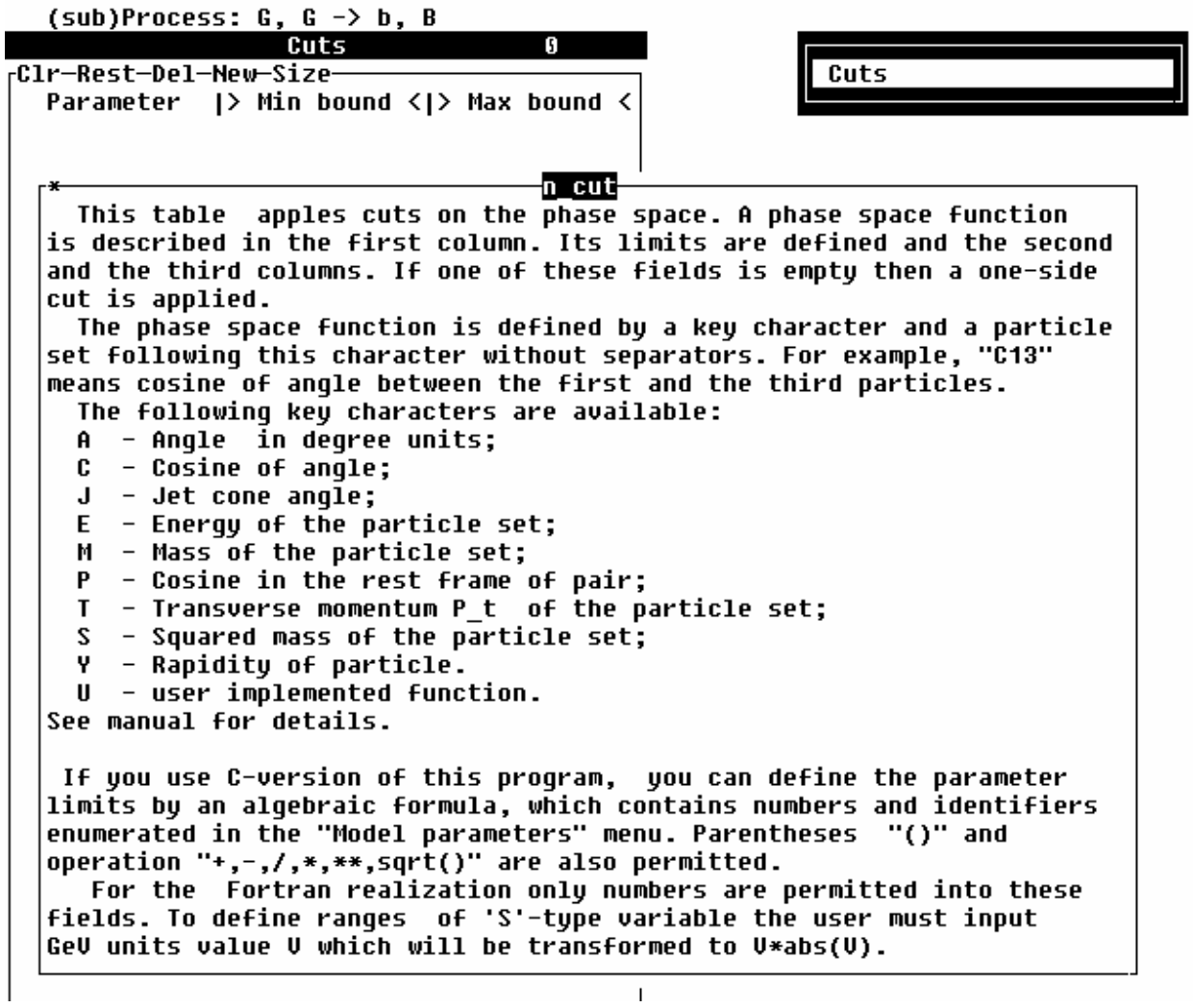
```
Set precision
Angular dependence
Parameter dependence
```





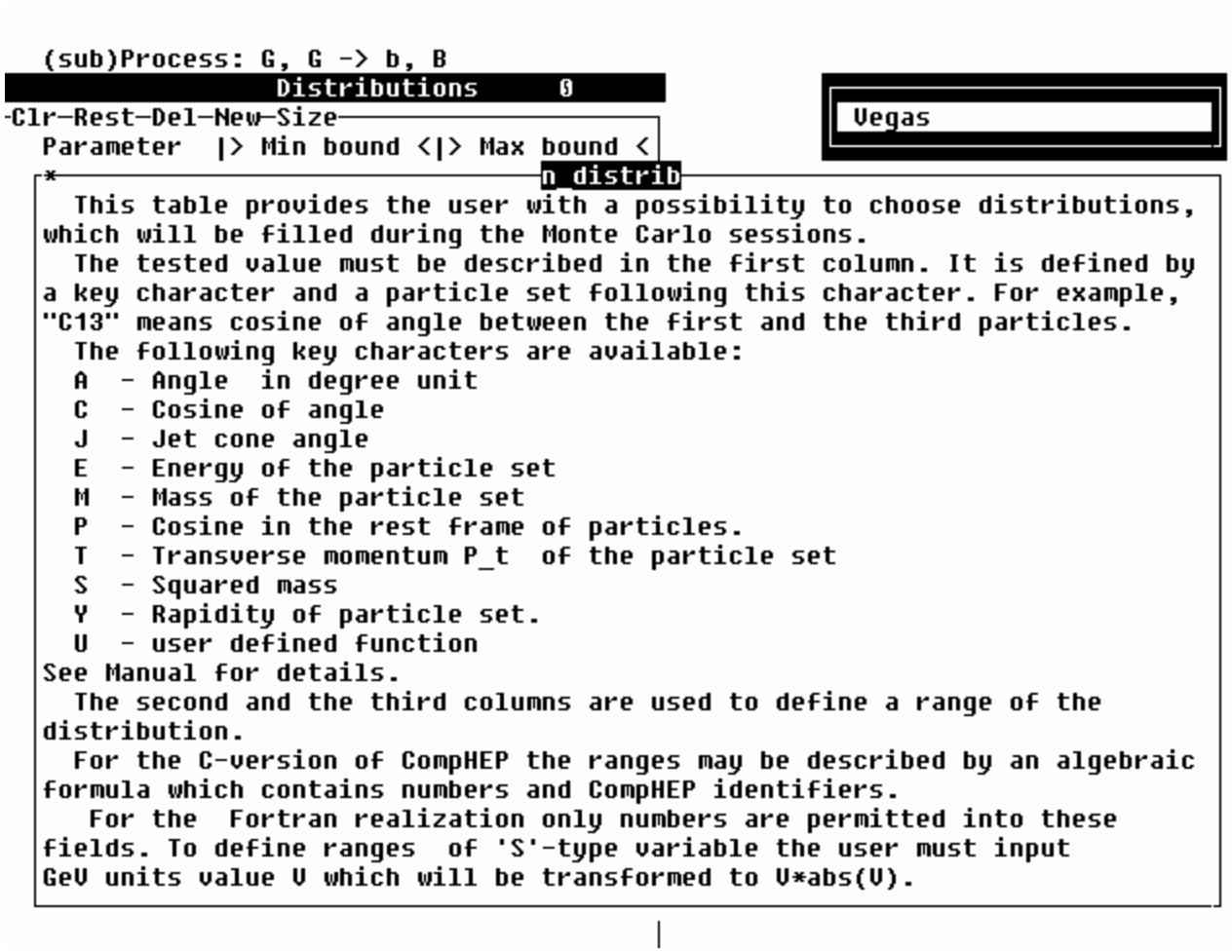
For 2->2 fundamental can look at angular and s dependence

Phase Space - Cuts



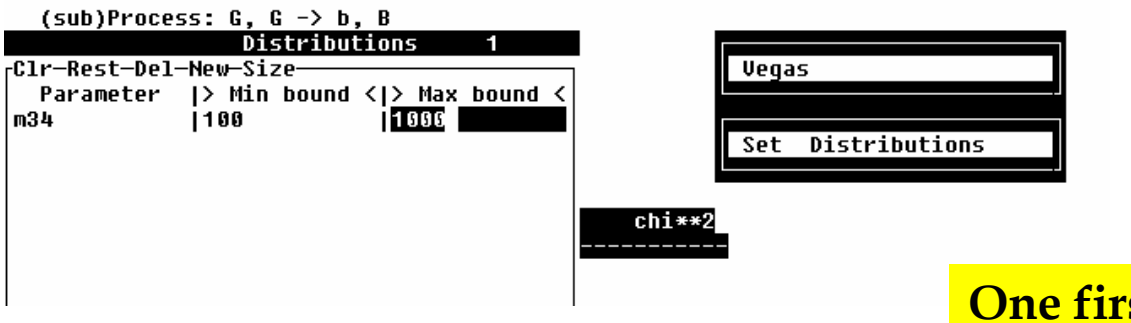
Cuts can be set on several parameters for a single final state parton or on combinations of final state partons.

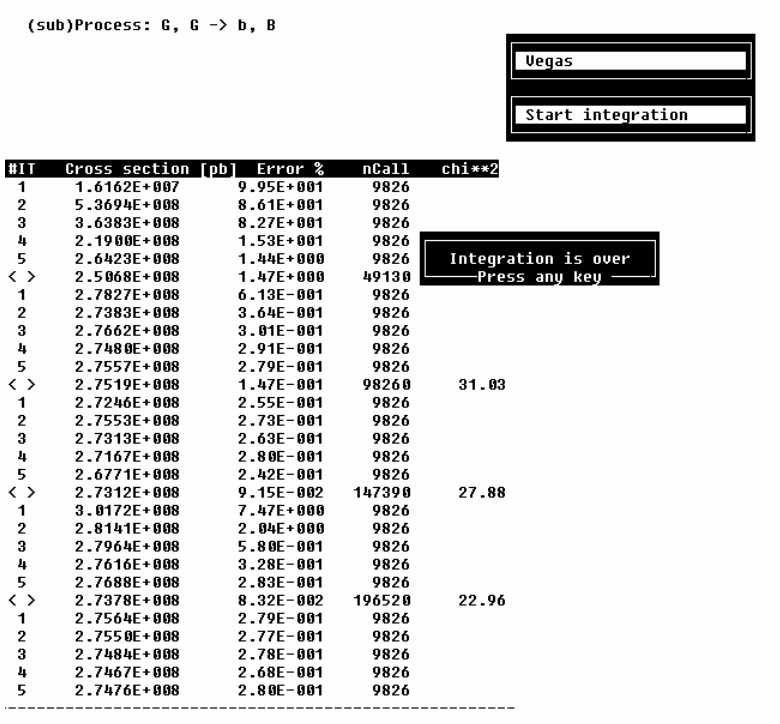
Vegas – Phase Space Integration



As with cuts, histos of single kinematic variables can be displayed

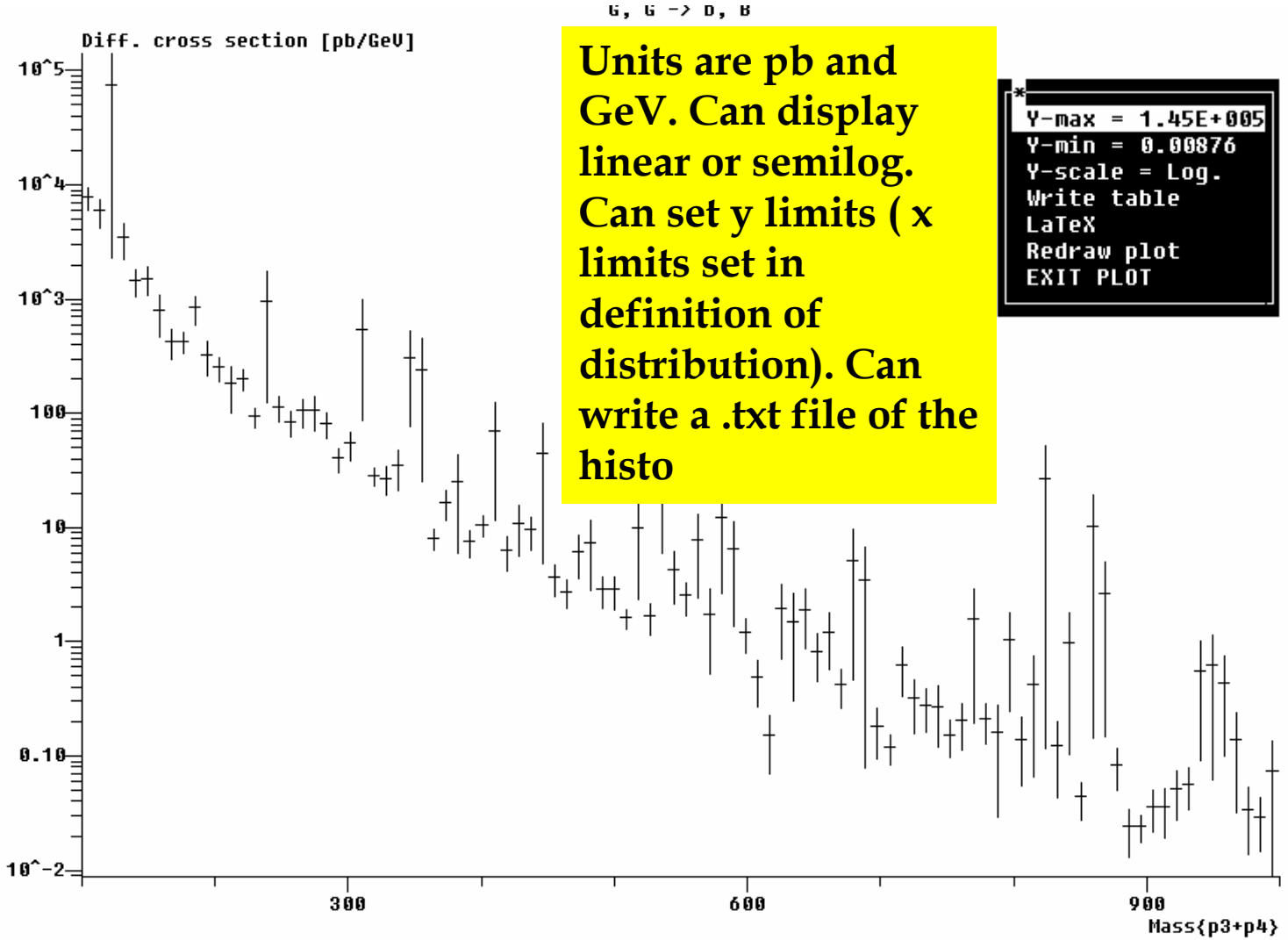
Vegas – Gives Chisq





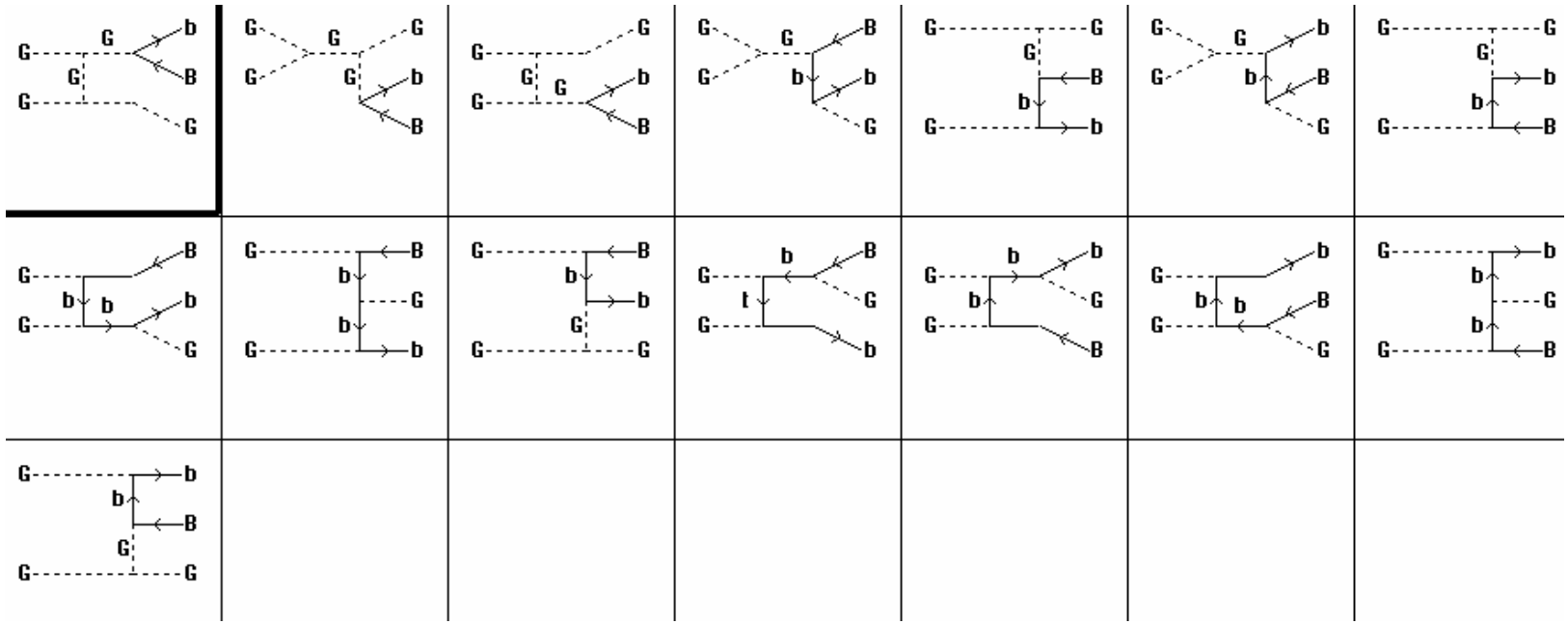
One first sets distributions. They can be cleared. Chisq should be reasonable for the Vegas integration

Kinematic Histograms



Units are pb and GeV. Can display linear or semilog. Can set y limits (x limits set in definition of distribution). Can write a .txt file of the histo

Options – 2 -> 3



Will do up to 2 -> 5 but the calculation becomes dramatically slower. However, 2 -> 3 is perfectly feasible. Useful for ISR/FSR exploration.

Options – Inclusive Final State

```
      Model:   St.Model(Feyn.gauge)

    Process:  G,G->2*x

              Feynman diagrams
20    diagrams in  7   subprocesses  are constructed.
0     diagrams  are deleted.
```

View diagrams

NN	Subprocess	Del	Rest
1	G,G -> b,B	0	3
2	G,G -> t,T	0	3
3	G,G -> s,S	0	3
4	G,G -> c,C	0	3
5	G,G -> d,D	0	3
6	G,G -> u,U	0	3
7	G,G -> G,G	0	2

Useful option if you want to see what Feynman diagrams might contribute to a final state. Also can be used to get branching fractions. Will do 1 -> 2 or 3 but not 2 -> 1. Must explicitly decay a single particle final state.

Option – MSSM SUSY

Clr-Rest-Del-New-Size

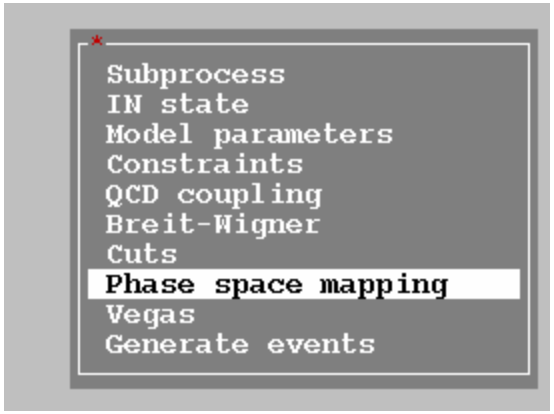
Full name	P	aP	2*spin	mass	width	color	aux
photon	A	A	2	0	0	1	
Z boson	Z	Z	2	MZ	wZ	1	
W boson	W+	W-	2	MW	wW	1	
gluon	G	G	2	0	0	8	G
neutrino	n1	N1	1	0	0	1	L
electron	e1	E1	1	0	0	1	
mu-neutrino	n2	N2	1	0	0	1	L
muon	e2	E2	1	Mm	0	1	
tau-neutrino	n3	N3	1	0	0	1	L
tau-lepton	e3	E3	1	Mt	0	1	
u-quark	u	U	1	0	0	3	
d-quark	d	D	1	0	0	3	
c-quark	c	C	1	Mc	0	3	
s-quark	s	S	1	Ms	0	3	
t-quark	t	T	1	Mtop	wtop	3	
b-quark	b	B	1	Mb	0	3	
Light Higgs	h	h	0	Mh	wh	1	
Heavy higgs	H	H	0	MHH	wHh	1	
CP-odd Higgs	H3	H3	0	MH3	wH3	1	
Charged Higgs	H+	H-	0	MHc	wHc	1	
chargino 1	~1+	~1-	1	MC1	wC1	1	
chargino 2	~2+	~2-	1	MC2	wC2	1	
neutralino 1	~o1	~o1	1	MNE1	0	1	
neutralino 2	~o2	~o2	1	MNE2	wNE2	1	
neutralino 3	~o3	~o3	1	MNE3	wNE3	1	
neutralino 4	~o4	~o4	1	MNE4	wNE4	1	
gluino	~g	~g	1	MSG	wSG	8	
1st selectron	~e1	~E1	0	MSe1	wSe1	1	
2nd selectron	~e4	~E4	0	MSe2	wSe2	1	
1st smuon	~e2	~E2	0	MSmu1	wSmu1	1	
2nd smuon	~e5	~E5	0	MSmu2	wSmu2	1	
1st stau	~e3	~E3	0	MStau1	wStau1	1	
2nd stau	~e6	~E6	0	MStau2	wStau2	1	
e-sneutrino	~n1	~N1	0	MSne	wSne	1	
m-sneutrino	~n2	~N2	0	MSnmu	wSnmu	1	
t-sneutrino	~n3	~N3	0	MSntau	wSntau	1	
u-squark 1	~u1	~U1	0	MSu1	wSu1	3	
u-squark 2	~u2	~U2	0	MSu2	wSu2	3	
d-squark 1	~d1	~D1	0	MSd1	wSd1	3	
d-squark 2	~d2	~D2	0	MSd2	wSd2	3	

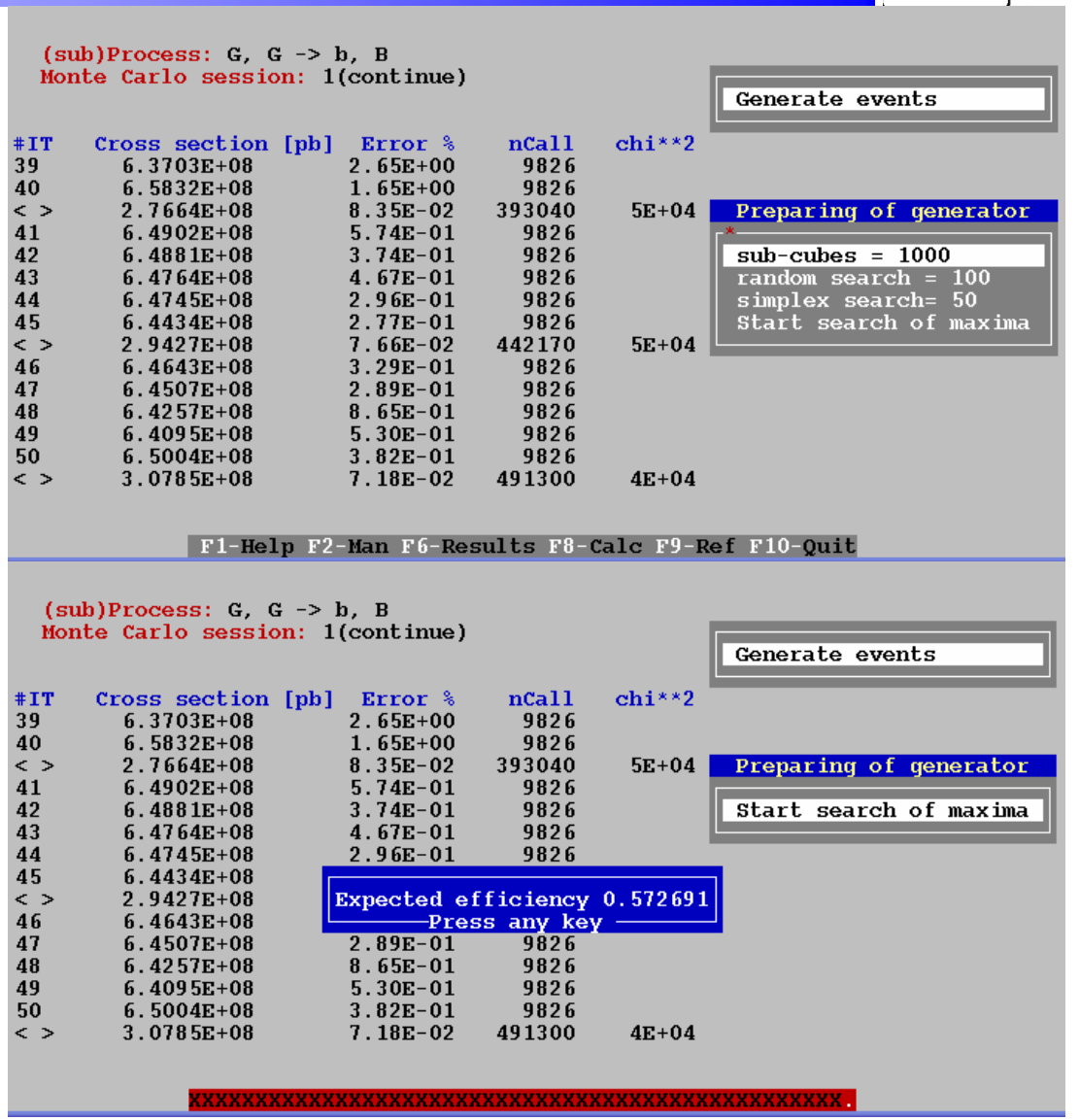
F1-F2-Top-Bottom-GoTo-Find-fAgain-Zoom-ErrMes

Recovery

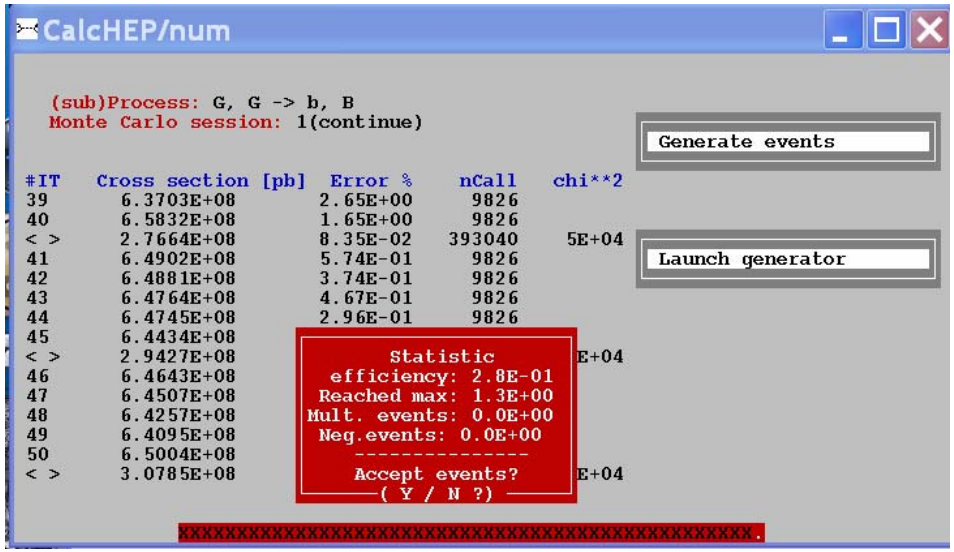
- Note – if you have to close the program it will write a file called “Lock”. You have to remove that before it will start again
- Note – there is a users manual that you can download

Calchep – Extra Options





Events Written to .txt




```
#CalcHEP version 2.4.5
#Type 2 -> 2
#Initial_state
  P1_3=7.000000E+03  P2_3=-7.000000E+03
  StrFun1="PDT:cteq6m(proton)" 2212
  StrFun2="PDT:cteq6m(proton)" 2212
#PROCESS   21(G) 21(G) -> 5(b) -5(B)
#MASSES  0.0000000000E+00 0.0000000000E+00 3.2588068426E+00 3.2588068426E+00
#Cross_section(Width) 3.078488E+08
#Number_of_events      10000
#Events       P1_3 [Gev]        P2_3 [Gev]        P3_1 [Gev]        P3_2 [Gev]
        P3_3 [Gev]        P4_1 [Gev]        P4_2 [Gev]        P4_3 [Gev]     Q
CD SCALE    Color chains
       1   1.3764960889E+02 -8.9776629178E-02  3.7283619312E-01 -6.3385642785E
-01  9.0215087212E+01 -3.7283619312E-01  6.3385642785E-01  4.7344745053E+01|
7.031E+00   (1 3)(2 1)(4 2)
       1   9.9266035217E+02 -3.0020905529E-02 -1.1565788952E+00 -1.7567405805E
+00  1.4703850373E+02  1.1565788952E+00  1.7567405805E+00  8.4559182753E+02|
1.092E+01   (1 2)(2 3)(4 1)
       1   1.4408153285E-01 -3.3324326523E+02  2.3750798640E-02  4.4122540313E
-01 -3.1327343162E+02 -2.3750798640E-02 -4.4122540313E-01 -1.9825752082E+01|
1.386E+01   (1 2)(2 3)(4 1)
```

Can then use PYTHIA to hadronize final state partons.