



# CALCHEP, COMPHEP



## Tutorial and Introduction



# Comphep – Main Page



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## Documentation

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

## User support

- FAQ
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## Useful links

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## 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 manipulations 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. CompHEP Models are very similar to physical models in high energy physics, like Standard 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 ( $SU(3) \times SU(2) \times U(1)$ ) 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  $1 \rightarrow 2, \dots, 1 \rightarrow 5$  types and the collisions of  $2 \rightarrow 2, \dots, 2 \rightarrow 6$  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* (Cambridge 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](#)

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



arXiv:hep-ph/9908288 v2 11 Feb 2000

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

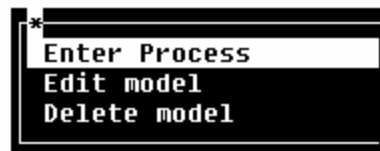


Model: `St.Model(Feyn.gauge)`

## Abstract

CompHEP 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 CompHEP was to make available passing from the lagrangian to the final distributions effectively with the high level of automatization.

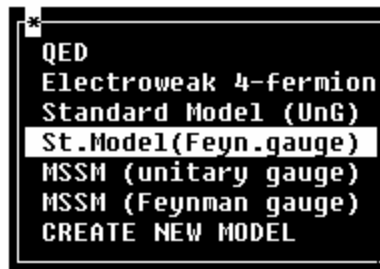
Use F2 key to get information about interface facilities and F1 - as online help.



## Abstract

CompHEP 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 CompHEP 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.





# 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
G	G	G			GG	<> Lorentz part
G	G	G.t			GG/Sqrt2	m1.m2*(p1-p2).m3+m2.m3*(p2-p3).m1+m3.m1*(p3-p1).m2
W+	W-	A			-EE	m1.M3*m2.m3-m1.m3*m2.M3
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	m1.m2*(p1-p2).m3+m2.m3*(p2-p3).m1+m3.m1*(p3-p1).m2
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





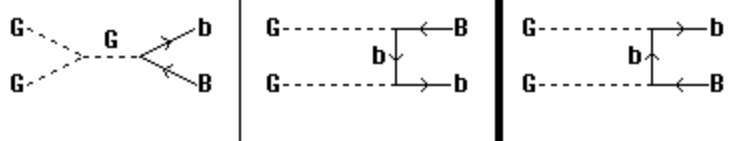
# Define a Process



```
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	



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

```
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

```
* 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.
```



# 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
```

```
Monte Carlo session:
```

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

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

```

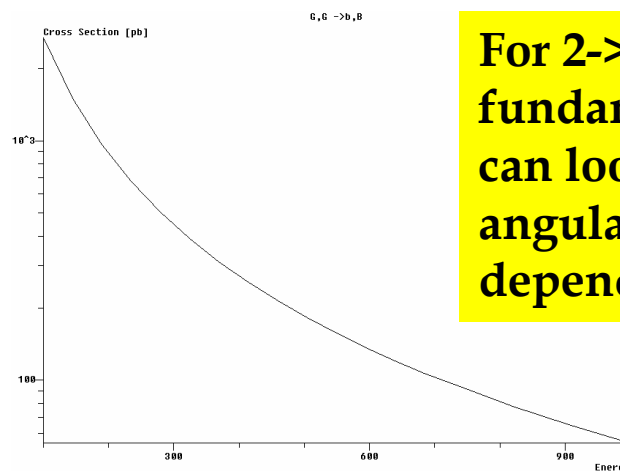
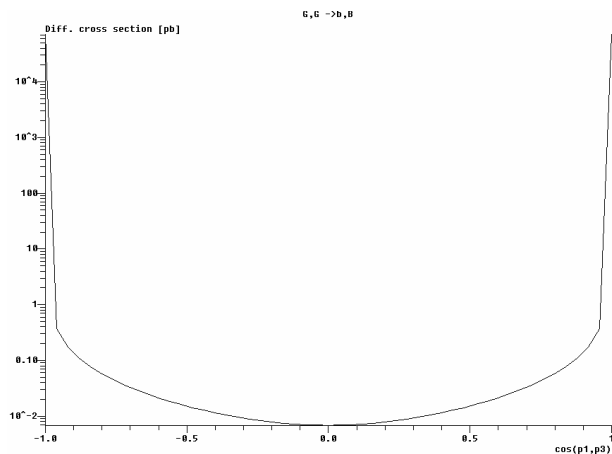
Energy      : 14000.000143 [GeV]
Cos(p1,p3): min=-1.000000      max= 1.000000
Cross Section: 0.442003 [pb]
-----

```

```

*
Set precision
Angular dependence
Parameter dependence

```



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



# Phase Space - Cuts



```
(sub)Process: G, G -> b, B
Cuts 0
Clr-Rest-Del-New-Size
Parameter |> Min bound <|> Max bound <
n cut
```

\* This table applies cuts on the phase space. A phase space function is described in the first column. Its limits are defined in the second and the third columns. If one of these fields is empty then a one-side cut is applied.

The phase space function is defined by a key character and a particle set following this character without separators. For example, "C13" means cosine of angle between the first and the third particles.

The following key characters are available:

- A - Angle in degree units;
- C - Cosine of angle;
- J - Jet cone angle;
- E - Energy of the particle set;
- M - Mass of the particle set;
- P - Cosine in the rest frame of pair;
- T - Transverse momentum  $P_t$  of the particle set;
- S - Squared mass of the particle set;
- Y - Rapidity of particle.
- U - user implemented function.

See manual for details.

If you use C-version of this program, you can define the parameter limits by an algebraic formula, which contains numbers and identifiers enumerated in the "Model parameters" menu. Parentheses "(" and operation "+,-,/,\*,\*\*,sqrt()" are also permitted.

For the Fortran realization only numbers are permitted into these fields. To define ranges of 'S'-type variable the user must input GeV units value U which will be transformed to  $U*abs(U)$ .

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



# Vegas – Phase Space Integration



```
(sub)Process: G, G -> b, B
Distributions 0
-Clr-Rest-Del-New-Size
Parameter |> Min bound <|> Max bound <
n distrib
*
This table provides the user with a possibility to choose distributions,
which will be filled during the Monte Carlo sessions.
The tested value must be described in the first column. It is defined by
a key character and a particle set following this character. For example,
"C13" means cosine of angle between the first and the third particles.
The following key characters are available:
A - Angle in degree unit
C - Cosine of angle
J - Jet cone angle
E - Energy of the particle set
M - Mass of the particle set
P - Cosine in the rest frame of particles.
T - Transverse momentum P_t of the particle set
S - Squared mass
Y - Rapidity of particle set.
U - user defined function
See Manual for details.
The second and the third columns are used to define a range of the
distribution.
For the C-version of CompHEP the ranges may be described by an algebraic
formula which contains numbers and CompHEP identifiers.
For the Fortran realization only numbers are permitted into these
fields. To define ranges of 'S'-type variable the user must input
GeV units value U which will be transformed to U*abs(U).
```

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



# Vegas – Gives Chisq



```
(sub)Process: G, G -> b, B
Distributions 1
Clr-Rest-Del-New-Size
Parameter |> Min bound <|> Max bound <
n34      |100      |1000
```

Vegas

Set Distributions

chi\*\*2

-----

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

Vegas

Start integration

#IT	Cross section [pb]	Error %	nCall	chi**2
1	1.6162E+007	9.95E+001	9826	
2	5.3694E+008	8.61E+001	9826	
3	3.6383E+008	8.27E+001	9826	
4	2.1900E+008	1.53E+001	9826	
5	2.6423E+008	1.44E+000	9826	
< >	2.5068E+008	1.47E+000	49130	
1	2.7827E+008	6.13E-001	9826	
2	2.7383E+008	3.64E-001	9826	
3	2.7662E+008	3.01E-001	9826	
4	2.7480E+008	2.91E-001	9826	
5	2.7557E+008	2.79E-001	9826	
< >	2.7519E+008	1.47E-001	98260	31.03
1	2.7246E+008	2.55E-001	9826	
2	2.7553E+008	2.73E-001	9826	
3	2.7313E+008	2.63E-001	9826	
4	2.7167E+008	2.80E-001	9826	
5	2.6771E+008	2.42E-001	9826	
< >	2.7312E+008	9.15E-002	147390	27.88
1	3.0172E+008	7.47E+000	9826	
2	2.8141E+008	2.04E+000	9826	
3	2.7964E+008	5.80E-001	9826	
4	2.7616E+008	3.28E-001	9826	
5	2.7688E+008	2.83E-001	9826	
< >	2.7378E+008	8.32E-002	196520	22.96
1	2.7564E+008	2.79E-001	9826	
2	2.7550E+008	2.77E-001	9826	
3	2.7484E+008	2.78E-001	9826	
4	2.7467E+008	2.68E-001	9826	
5	2.7476E+008	2.80E-001	9826	

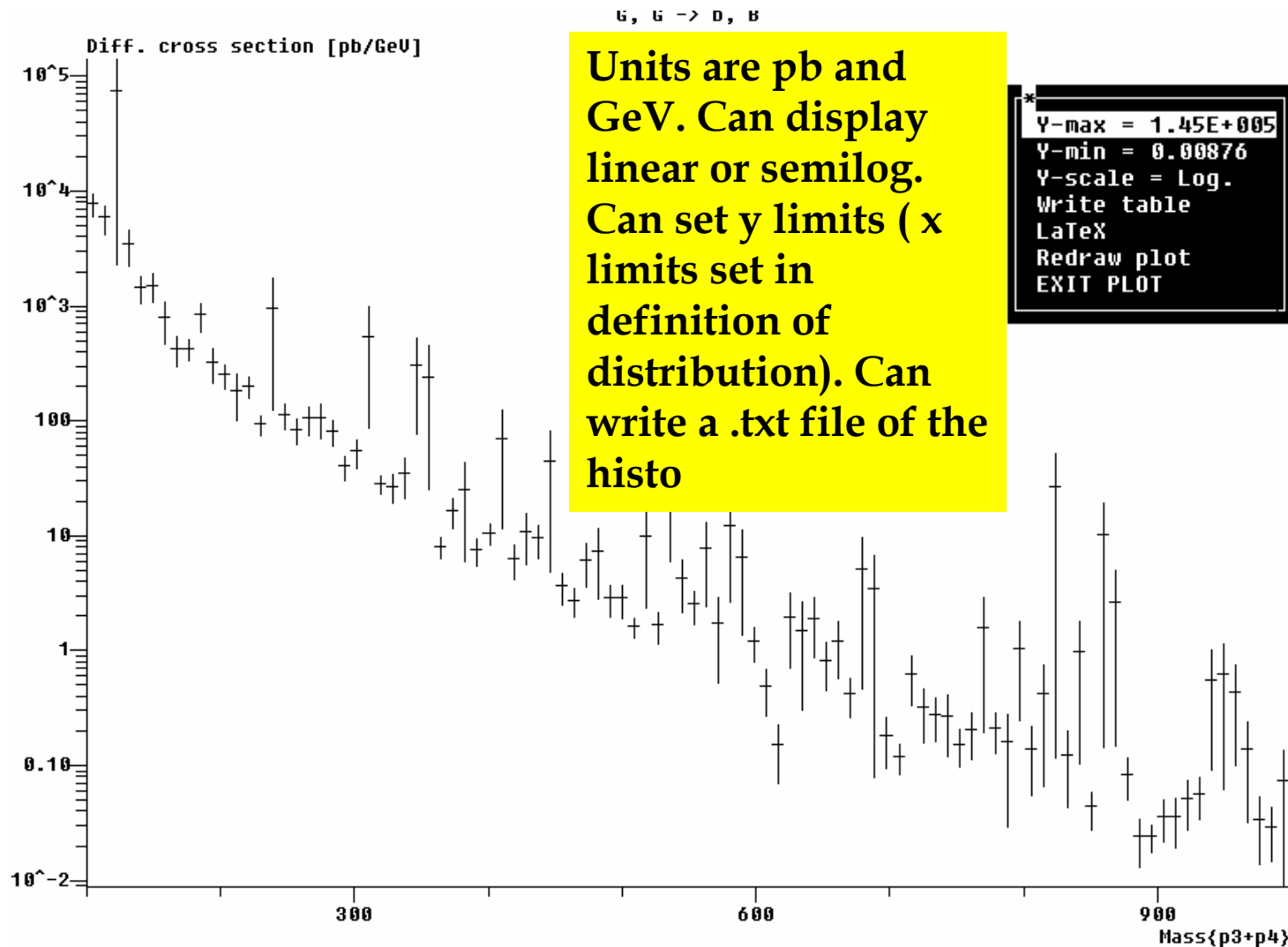
Integration is over

Press any key

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

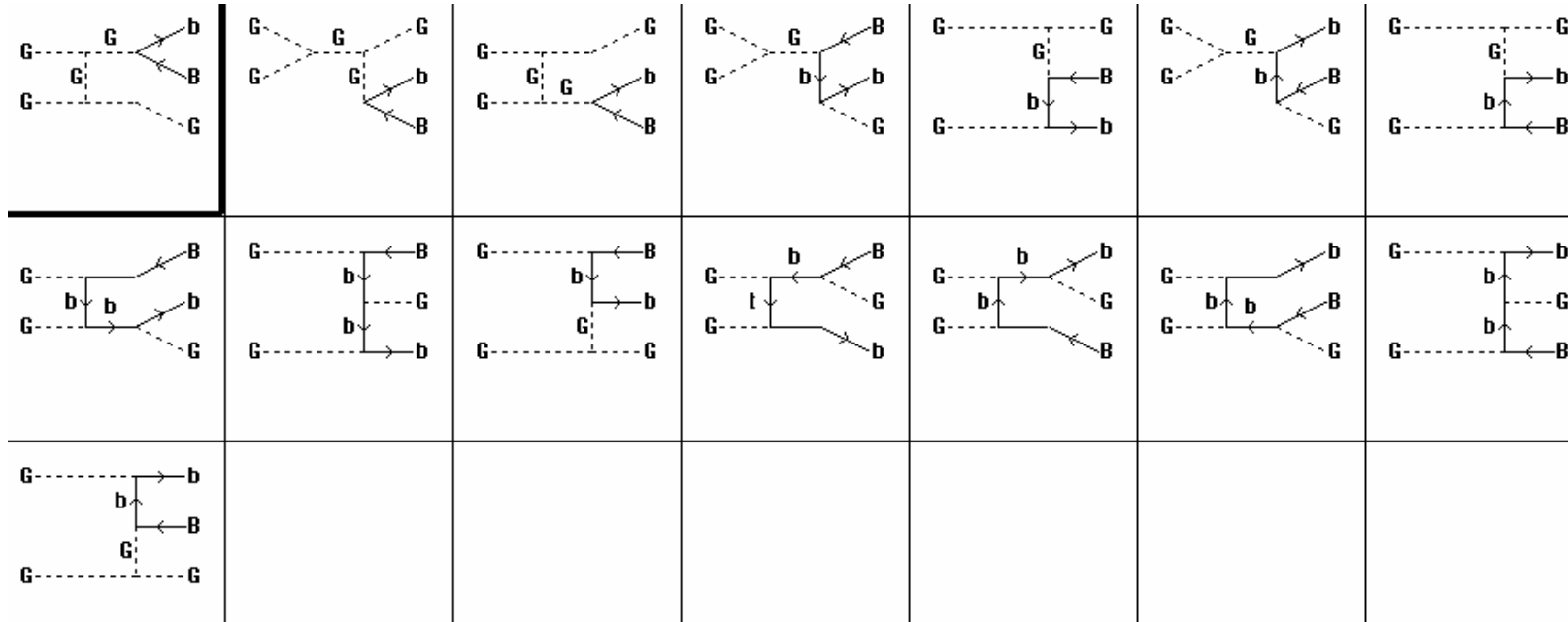


# Kinematic Histograms





# 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



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	MSnu	wSnu	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	



# 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



- \* Subprocess
- IN state
- Model parameters
- Constraints
- QCD coupling
- Breit-Wigner
- Cuts
- Phase space mapping**
- Vegas
- Generate events

```
(sub)Process: G, G -> b, B
Monte Carlo session: 1(continue)
```

#IT	Cross section [pb]	Error %	nCall	chi**2
39	6.3703E+08	2.65E+00	9826	
40	6.5832E+08	1.65E+00	9826	
< >	2.7664E+08	8.35E-02	393040	5E+04
41	6.4902E+08	5.74E-01	9826	
42	6.4881E+08	3.74E-01	9826	
43	6.4764E+08	4.67E-01	9826	
44	6.4745E+08	2.96E-01	9826	
45	6.4434E+08	2.77E-01	9826	
< >	2.9427E+08	7.66E-02	442170	5E+04
46	6.4643E+08	3.29E-01	9826	
47	6.4507E+08	2.89E-01	9826	
48	6.4257E+08	8.65E-01	9826	
49	6.4095E+08	5.30E-01	9826	
50	6.5004E+08	3.82E-01	9826	
< >	3.0785E+08	7.18E-02	491300	4E+04

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

Generate events

Preparing of generator

```
*
sub-cubes = 1000
random search = 100
simplex search= 50
Start search of maxima
```

```
(sub)Process: G, G -> b, B
Monte Carlo session: 1(continue)
```

#IT	Cross section [pb]	Error %	nCall	chi**2
39	6.3703E+08	2.65E+00	9826	
40	6.5832E+08	1.65E+00	9826	
< >	2.7664E+08	8.35E-02	393040	5E+04
41	6.4902E+08	5.74E-01	9826	
42	6.4881E+08	3.74E-01	9826	
43	6.4764E+08	4.67E-01	9826	
44	6.4745E+08	2.96E-01	9826	
45	6.4434E+08	2.77E-01	9826	
< >	2.9427E+08	7.66E-02	442170	5E+04
46	6.4643E+08	3.29E-01	9826	
47	6.4507E+08	2.89E-01	9826	
48	6.4257E+08	8.65E-01	9826	
49	6.4095E+08	5.30E-01	9826	
50	6.5004E+08	3.82E-01	9826	
< >	3.0785E+08	7.18E-02	491300	4E+04

Expected efficiency 0.572691  
Press any key

XX

Generate events

Preparing of generator

Start search of maxima



# Events Written to .txt



CalcHEP/num

(sub)Process: G, G -> b, B  
 Monte Carlo session: 1(continue)

Generate events

#IT	Cross section [pb]	Error %	nCall	chi**2
39	6.3703E+08	2.65E+00	9826	
40	6.5832E+08	1.65E+00	9826	
< >	2.7664E+08	8.35E-02	393040	5E+04
41	6.4902E+08	5.74E-01	9826	
42	6.4881E+08	3.74E-01	9826	
43	6.4764E+08	4.67E-01	9826	
44	6.4745E+08	2.96E-01	9826	
45	6.4434E+08			
< >	2.9427E+08			E+04
46	6.4643E+08			
47	6.4507E+08			
48	6.4257E+08			
49	6.4095E+08			
50	6.5004E+08			
< >	3.0785E+08			E+04

Launch generator

Statistic  
 efficiency: 2.8E-01  
 Reached max: 1.3E+00  
 Mult. events: 0.0E+00  
 Neg. events: 0.0E+00  
 -----  
 Accept events?  
 ( Y / N ? )

XX

Can then use PYTHIA to hadronize final state partons.

```

*
#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)

```