

# Practical introduction to **CalcHEP and HEPMDB** */High Energy Physics Model Database/*

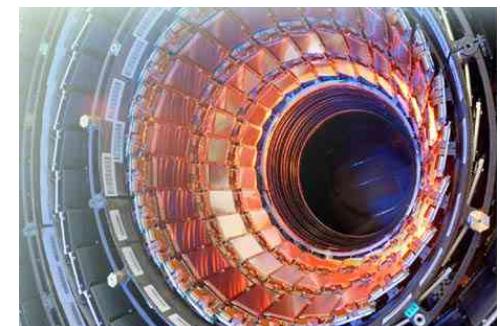
Alexander Belyaev



Southampton University & Rutherford Appleton LAB

***Calculations for Modern and Future Colliders***

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



# OUTLINE

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

**arXiv:1207.6082**
- **High Energy Physics Model Database (HEPMDB)**
  - *pre-History of HEPMDB and its idea*
  - *HEPMDB, present status and tutorial*
  - *Future plans*

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

# Web pages & contacts

- *The WEB page of CalcHEP*  
***<http://theory.npi.msu.su/~pukhov/calchep.html>***
- *The HEPMDB page*  
***<http://hepmdb.soton.ac.uk>***
- **e-mails**  
***[calchep@googlegroups.com](mailto:calchep@googlegroups.com)***  
***[hepmdb@soton.ac.uk](mailto:hepmdb@soton.ac.uk)***  
***[a.belyaev@soton.ac.uk](mailto:a.belyaev@soton.ac.uk)***

# CalcHEP

# CalcHEP

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

- **Author(s)**

- **Alexander Pukhov, AB, Neil Christensen**

(AB and Neil Christensen have joined the project in 2009)

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

- **Idea**

- **The effective study of HEP phenomenology passing at high level of automation from your favorite model to physical observables such as decay width, branching ratios, cross sections kinematic distributions, parton-level events, ...**

- **Analogous packages (matrix element generators)**

<http://www.ippp.dur.ac.uk/montecarlo/BSM/>

- **CompHEP (Boos et al)**
  - **MadGraph/MadEvent (Maltoni, Stelzer)**
  - **Grace/Helas (Fujimoto et al)**
  - **FeynArts/FeynCalc/FormCalc (Hahn et al)**
  - **WHIZARD,O'mega (Moretti, Ohl, Reuter)**
  - **Sherpa (Krauss et al)**

# Features/Limitations of CalcHEP

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

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

# Features/Limitations of CalcHEP

- *Can evaluate any decay and scattering processes within any (user defined) model!*
- *Tree-level processes*
- *Squared Matrix Element calculation*
  - *no spin information for outgoing particles – spin averaged amplitude*
- *Limit on number of external legs (involved particles) and number of diagrams*
  - *official limit – 8 , unofficial – none*
  - *limit is set from the practical point of view:*
    - $2 \rightarrow 6$  ( $1 \rightarrow 7$ ) set the essential time/memory limit
    - number of diagrams  $\sim 500$  set the disk space and the time limit

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

**Authors - Alexander Pukhov, Alexander Belyaev, Neil Christensen**

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

General information

- [Main facilities](#)
  - [Old Versions](#)
  - [Acknowledgments](#)
  - [News&Bugs](#)
- 

Manual

- [calchep\\_man\\_3.3.6.pdf](#) (manual for version 3.3.6, July 19, 2012)
- [HEP computer tools](#) (Lecture by Alexander Belyaev)

See also: Dan Green, High Pt physics at hadron colliders (Cambridge University Press)

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Codes download.

- [Licence](#)
  - [Installation](#)
  - [References&Contributions](#)
- CalcHEP code for UNIX: • [version 3.4.0](#) (July 26, 2012)
- 

Models:

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

Relative packages on Web:

- Packages for model generation: • [LanHEP](#) • [FeynRules](#)
- RGE and spectrum calculation: • [SuSpect](#) • [Isajet](#) • [SoftSUSY](#) • [SPheno](#) • [CPsuperH](#) • [NMHDecay](#)
- Particle widths in MSSM: • [SDECAY](#) • [HDECAY](#)
- Parton showers: • [PYTHIA](#)
- 

Email contact: [calchep@googlegroups.com](mailto:calchep@googlegroups.com)

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- [HET computer tools](#) (Lecture by Alexander Belyaev)

See also: Dan Green, High Pt physics at hadron colliders (Cambridge University Press)

**manual is updated!**

Codes download.

- [Licence](#)
- [Installation](#)
- [References&Contributions](#)

CalcHEP code for UNIX: • [version 3.4.0](#) (July 26, 2012)

**new version and  
writeup!**

**arXiv:1207.6082**

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- [CPVMSSM\(03.05.2012\)](#)

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Particle widths in MSSM: • [SDECAY](#) • [HDECAY](#)

Parton showers: • [PYTHIA](#)

Email contact: [calcheep@googlegroups.com](mailto:calcheep@googlegroups.com)

# Quick start with CalcHEP: practical notes on the installation

- **Download code, read manual and compile**  
***<http://theory.npi.msu.su/~pukhov/calchept.html>***
  - ➔ tar -zxvf calchept\_3.x.x.tgz
  - ➔ cd calchept\_3.x.x
  - ➔ make

the current version is 3.x.x = **3.4.0**
- **Create work directory**
  - ➔ From **calchept\_3.x.x** directory (e.g. **../calc\_work**)  
**./mkUsrDir ..//calc\_work**
- **Supported operating system**
  - ➔ Linux, IRIX, IRIX64, HP-UX, OSF1, SunOS, Darwin, CYGWIN  
(see **getFlags** file)

**Exercise#1:** Install CalcHEP

# Starting CalcHEP

- `cd .../calc_work`
- ***Files:***  
*bin* -> ..... /calchep\_3.x.x/bin  
***calchep***  
***calchep\_batch***  
***calchep.ini***  
***models/***  
***results/***  
***tmp/***
- ***Start:***  
***./calchep***

# Starting CalcHEP

CalcHEP/symb

**CalcHEP - a package for Calculation in High Energy Physics**  
Version 3.4.0: Last correction June 22, 2012

**Authors:** Alexander Pukhov (Skobeltsyn Institute of Nuclear Physics, Moscow)  
Alexander Belyaev (University of Southampton)  
Neil Chistensen (University of Pittsburgh)

**For contacts:** email: <[calchep@googlegroups.com](mailto:calchep@googlegroups.com)>  
<http://theory.sinp.msu.ru/~pukhov/calchep.html>

The BSMs for CalcHEP were developed in collaboration with:  
G. Belanger, F. Boudjema, A. Semenov

The package contains codes written by:  
M. Donckert, V. Edneral, V. Ilyin, D. Kovalenko, A. Kryukov, G. Lepage, A. Semenov

Press F9 or click the box below to get

[References](#), [Contributions](#), [Acknowledgments](#)

This information is available during the session by means of the F9 key

# Principle KEYS for CalcHEPs GUI



**Enter menu  
selection  
(forward)**

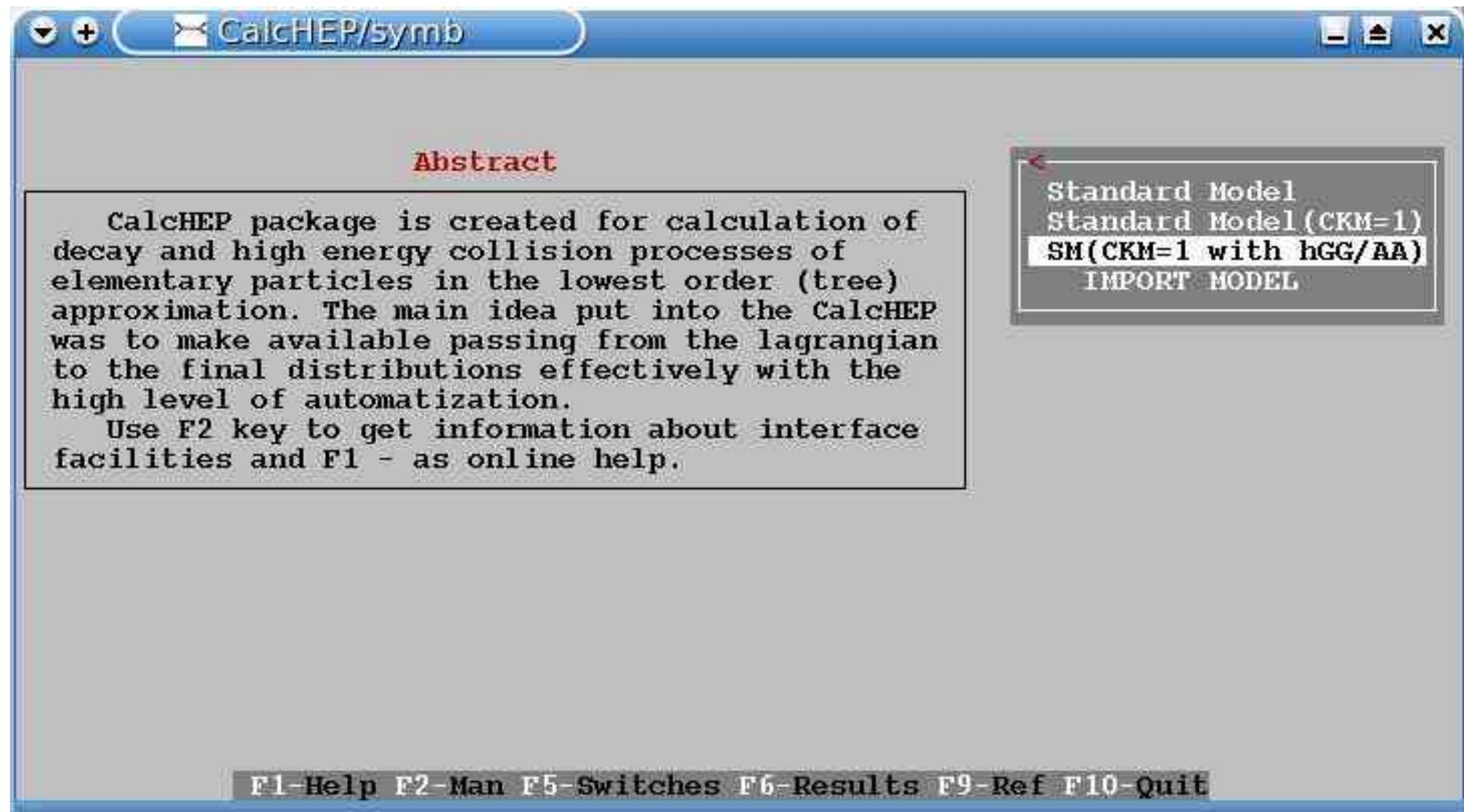


**Exit menu  
selection  
(back)**

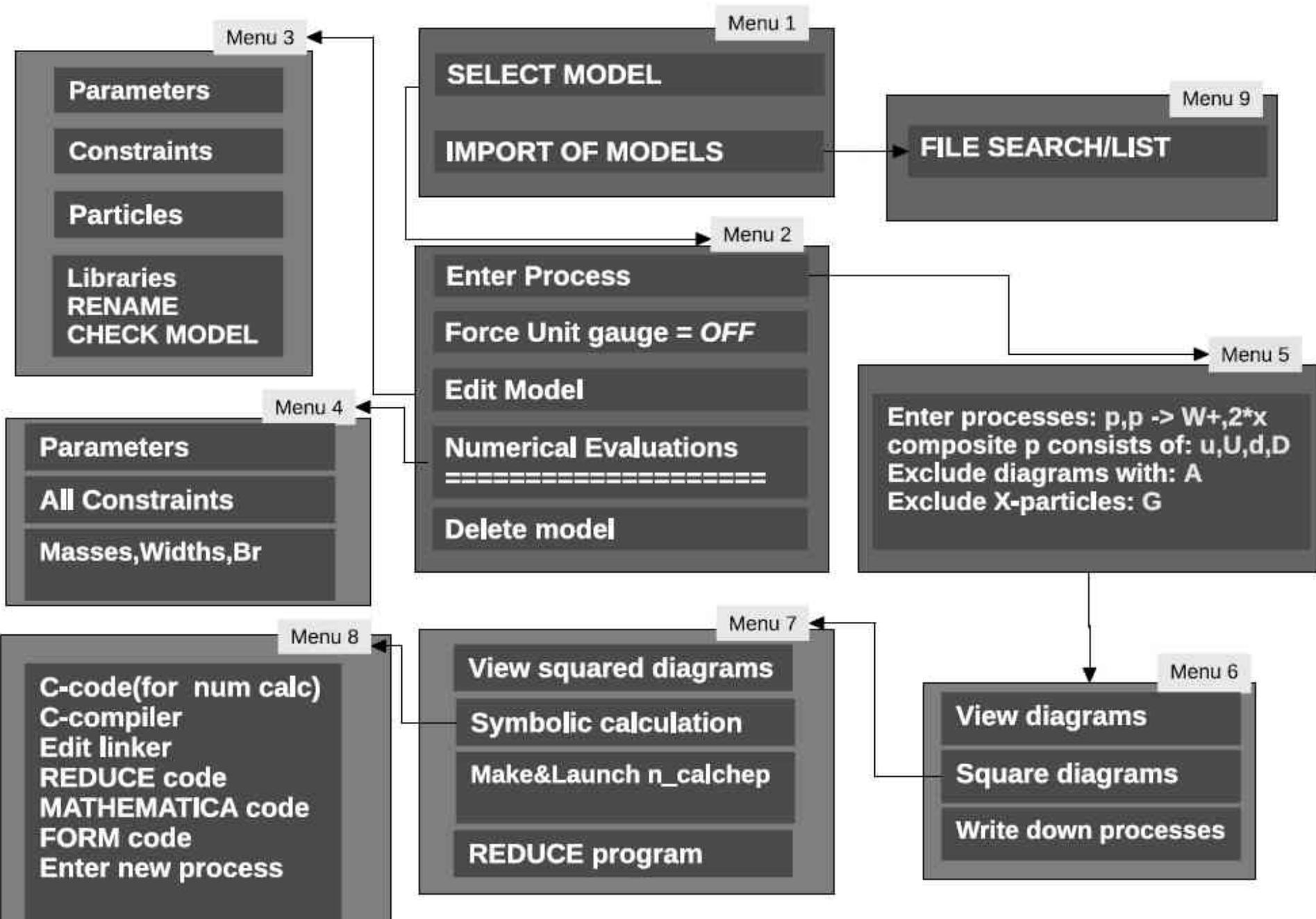


**Help!**

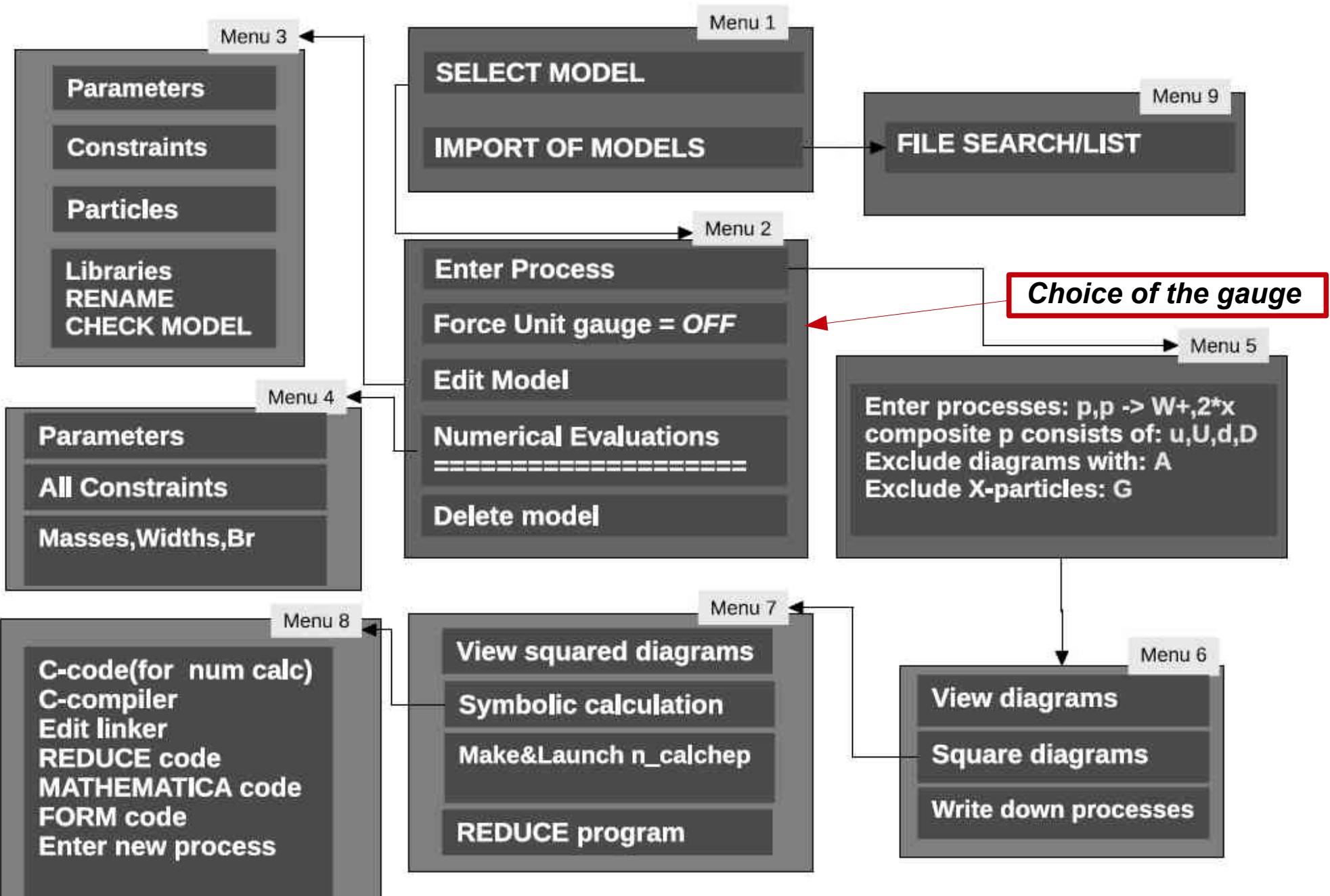
# Starting CalcHEP



# CalcHEP menu structure: symbolic part



# CalcHEP menu structure: symbolic part



# Model Structure

*Parameters  
Particles*

*Constraints  
Vertices*

The screenshot shows the CalcHEP/symb interface. At the top, it says "Model: Standard Model". Below that, the word "Abstract" is highlighted in red. The main text area contains the following 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.

To the right, a dropdown menu titled "Edit model" is open, showing the following options:

- Parameters
- Constraints
- Particles
- Vertices
- Libraries
- RENAME
- CHECK MODEL

At the bottom of the window, there is a menu bar with the following items:

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

# Particles: prtclxx.mdl (spins 0,1/2,1,3/2,2)

CalcHEP/symb

Particles

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

F1 F2 Xgoto Ygoto Find Write

# Particles: prtclxx.mdl

CalcHEP/symb

Particles

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

Higgs boson width will be calculated 'on the fly'

F1 F2 X goto Y goto Find Write

# Independent parameters: varsxx.mdl

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

# Dependent parameters(constraints): funcxx.mdl

CalcHEP/Symb Constraints

Clr	Del	Size	Read	ErrMes	Expression	Comments	
					Name		
					EEm	sqrt(16*atan(1.)*alfEMZ)	% electromagnetic constant
					CW	sqrt(1-SW^ 2)	% cos of the Weinberg angle
					MW	MZ*CW	% W-boson mass
					c12	sqrt(1-s12^ 2)	% parameter of C-K-M matrix
					c23	sqrt(1-s23^ 2)	% parameter of C-K-M matrix
					c13	sqrt(1-s13^ 2)	% parameter of C-K-M matrix
					Vud	c12*c13	% C-K-M matrix element
					Vus	s12*c13	% C-K-M matrix element
					Vub	s13	% C-K-M matrix element
					Vcd	-s12*c23-c12*s23*s13	% C-K-M matrix element
					Vcs	c12*c23-s12*s23*s13	% C-K-M matrix element
					Vcb	s23*c13	% C-K-M matrix element
					Vtd	s12*s23-c12*c23*s13	% C-K-M matrix element
					Vts	-c12*s23-s12*c23*s13	% C-K-M matrix element
					Vtb	c23*c13	% C-K-M matrix element
					qcdOk	initQCD(alfSMZ,McMc,MbMb,Mtp)	
					Mb	MbEff(Q)	
					Mt	MtEff(Q)	
					Mc	McEff(Q)	

F1 F2 Xgoto Ygoto Find Write

# Feynman rules: lgrngxx.mdl

CalcHEP/symb

Vertices							
Clr	Del	Size	Read	ErrMes	>	Factor	<   > Lorentz part
A1					>		
h	W+	W-				EE * MW / SW	m2 . m3
h	Z	Z				EE / ( SW * CW ^ 2 ) * MW	m2 . m3
h	h	h				- (3/2) * EE * Mh ^ 2 / (MW * SW)	1
h	h	h	h			(-3/4) * (EE * Mh / (MW * SW)) ^ 2	1
h	h	Z	Z			(1/2) * (EE / (SW * CW)) ^ 2	m3 . m4
h	h	W+	W-			(1/2) * (EE / SW) ^ 2	m3 . m4
M	m	h				-EE * Mn / (2 * MW * SW)	1
L	l	h				-EE * Ml / (2 * MW * SW)	1
C	c	h				-EE * Mc / (2 * MW * SW)	1
S	s	h				-EE * Ms / (2 * MW * SW)	1
B	b	h				-EE * Mb / (2 * MW * SW)	1
T	t	h				-EE * Mt / (2 * MW * SW)	1
E	e	A				-EE	G(m3 )
M	m	A				-EE	G(m3 )
L	l	A				-EE	G(m3 )
Ne	e	W+				EE / (2 * Sqrt2 * SW)	G(m3 ) * (1-G5)
Nm	m	W+				EE / (2 * Sqrt2 * SW)	G(m3 ) * (1-G5)
Nl	l	W+				EE / (2 * Sqrt2 * SW)	G(m3 ) * (1-G5)
E	ne	W-				EE / (2 * Sqrt2 * SW)	G(m3 ) * (1-G5)
M	nm	W-				EE / (2 * Sqrt2 * SW)	G(m3 ) * (1-G5)
L	nl	W-				EE / (2 * Sqrt2 * SW)	G(m3 ) * (1-G5)
F1-F2-Xgoto-Ygoto-Find-Write							

# External Libraries: extlibxx.mdl

The screenshot shows the CalcHEP/Symb software interface. The title bar reads "CalcHEP/Symb". The main window has a blue header bar with the title "Libraries". Below the header, there is a menu bar with items: Clr, Del, Size, Read, ErrMes. Underneath the menu bar, the text "External libraries" is displayed. A command line input field contains the following text:  
%% %% For LHAPDF  
%-L /home/pukhov/Packages/lhapdf-5.8.4/install/lib -lLHAPDF

# Details of symbolic session

- **the input syntax:**  $P1 [ , P2] \rightarrow P3, P4 [ , , \dots, [N^*x]]$
- **hadron/composite particle scattering**  
 $'p, p \rightarrow W+, b, B'$   
**unknown particle are assumed to be composite:**  
**'p' consists of**  $u, U, d, D, s, S, c, C, b, B, G$
- **wild cards/names for outgoing particles**  
 $'H \rightarrow 2^*x'$
- **intermediate particles can be non-trivially excluded**  
 $'W+ > 2, A > 1, Z > 3'$

## Exercise#2

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

# Symbolic session (1)

CalcHEP/symb

Model: Standard Model

List of particles (antiparticles)

$G(G^-)$ - gluon	$A(A^-)$ - photon	$Z(Z^-)$ - Z-boson
$W^+(W^-)$ - W-boson	$h(h^-)$ - Higgs	$e(E^-)$ - electron
$\nu_e(\bar{\nu}_e)$ - e-neutrino	$\nu_\mu(\bar{\nu}_\mu)$ - muon	$\nu_m(\bar{\nu}_m)$ - m-neutrino
$\tau(L^-)$ - tau-lepton	$\nu_\tau(\bar{\nu}_\tau)$ - t-neutrino	$d(D^-)$ - d-quark
$u(U^-)$ - u-quark	$s(S^-)$ - s-quark	$c(C^-)$ - c-quark
$b(B^-)$ - b-quark	$t(T^-)$ - t-quark	

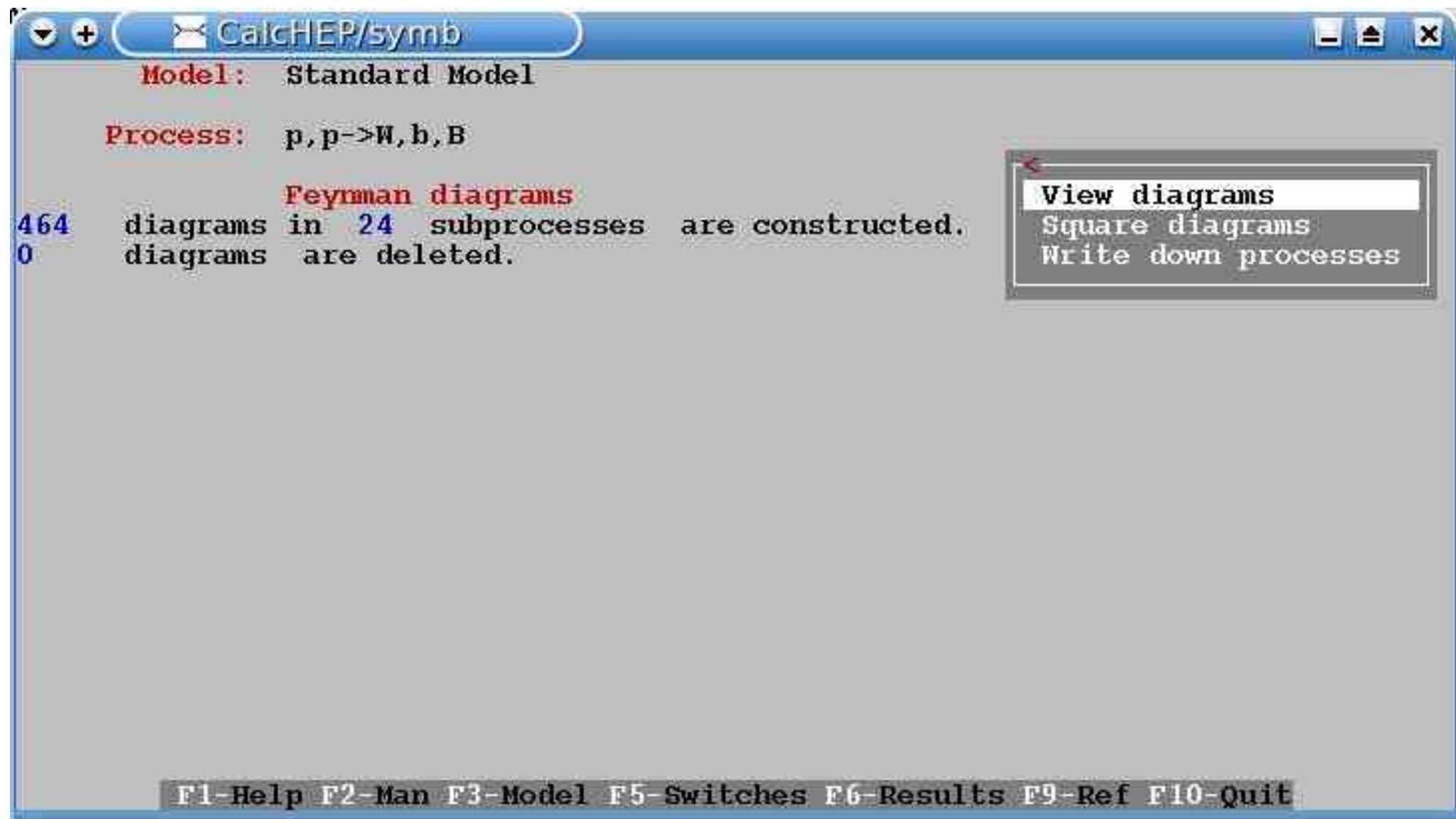
Enter process:  $p.p \rightarrow W.b.B$

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

composit 'W' consists of: W+,W-

Exclude diagrams with [ ]

# Symbolic session (2)



# Symbolic session (3)

CalcHEP/Symb

Model: Standard Model

Process:  $p, p \rightarrow W, b, B$

Feynman diagrams

464 diagrams in 24 subprocesses are constructed.  
0 diagrams are deleted.

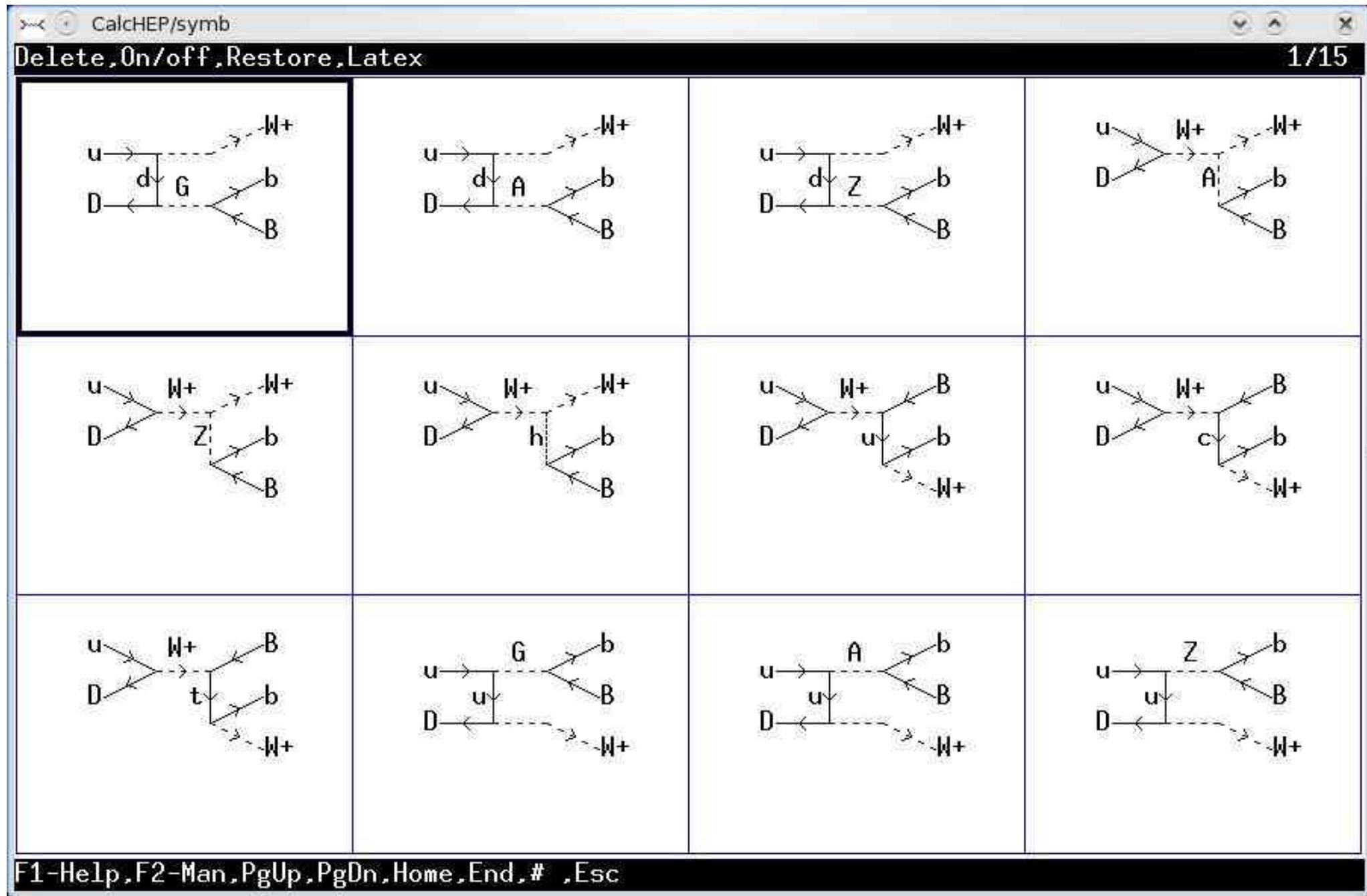
View diagrams

NN	Subprocess	Del	Rest
1	$u, D \rightarrow W^+, b, B$	0	15
2	$u, S \rightarrow W^+, b, B$	0	15
3	$u, B \rightarrow W^+, b, B$	0	26
4	$U, d \rightarrow W^-, b, B$	0	15
5	$H, S \rightarrow W^-, b, B$	0	15
6	$U, b \rightarrow W^-, b, B$	0	26
7	$d, U \rightarrow W^-, b, B$	0	15
8	$d, C \rightarrow W^-, b, B$	0	16
9	$D, u \rightarrow W^+, b, B$	0	15
10	$D, C \rightarrow W^+, b, B$	0	16
11	$S, U \rightarrow W^-, b, B$	0	15

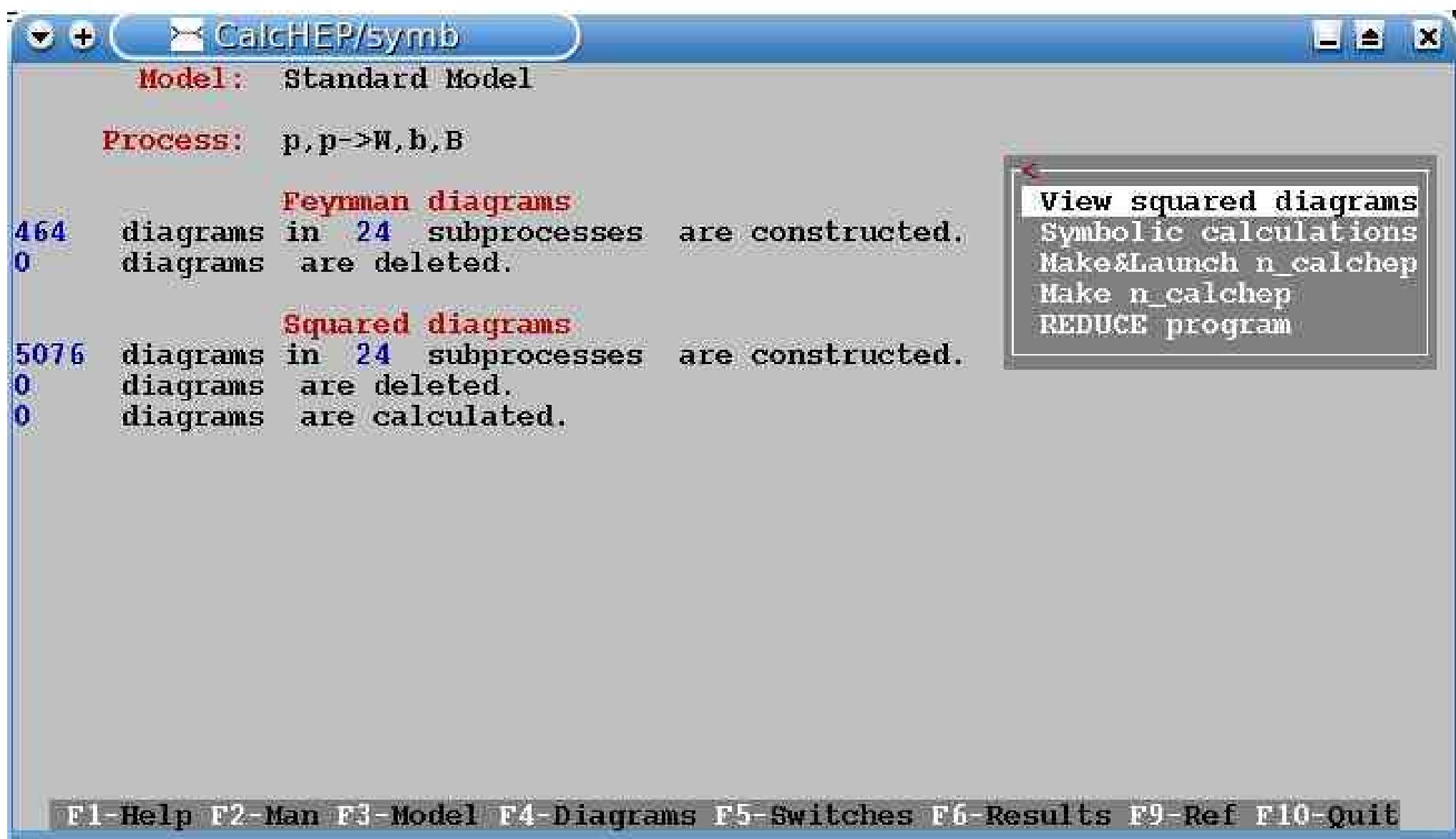
PgDn

F1-Help F2-Man F3-Model F5-Switches F6-Results F7-Del F8-UnDel F9-Ref F10-Quit

# Symbolic session (4)



# Symbolic session (5)



F1-Help F2-Man F3-Model F4-Diagrams F5-Switches F6-Results F9-Ref F10-Quit

# Symbolic session (6)

CalcHEP/symb

Delete, On/off, Restore, Latex, Ghosts 1/120

The image displays six Feynman diagrams arranged in a 3x2 grid, each representing a different particle interaction. The diagrams are generated by CalcHEP and show various particle flows and interactions.

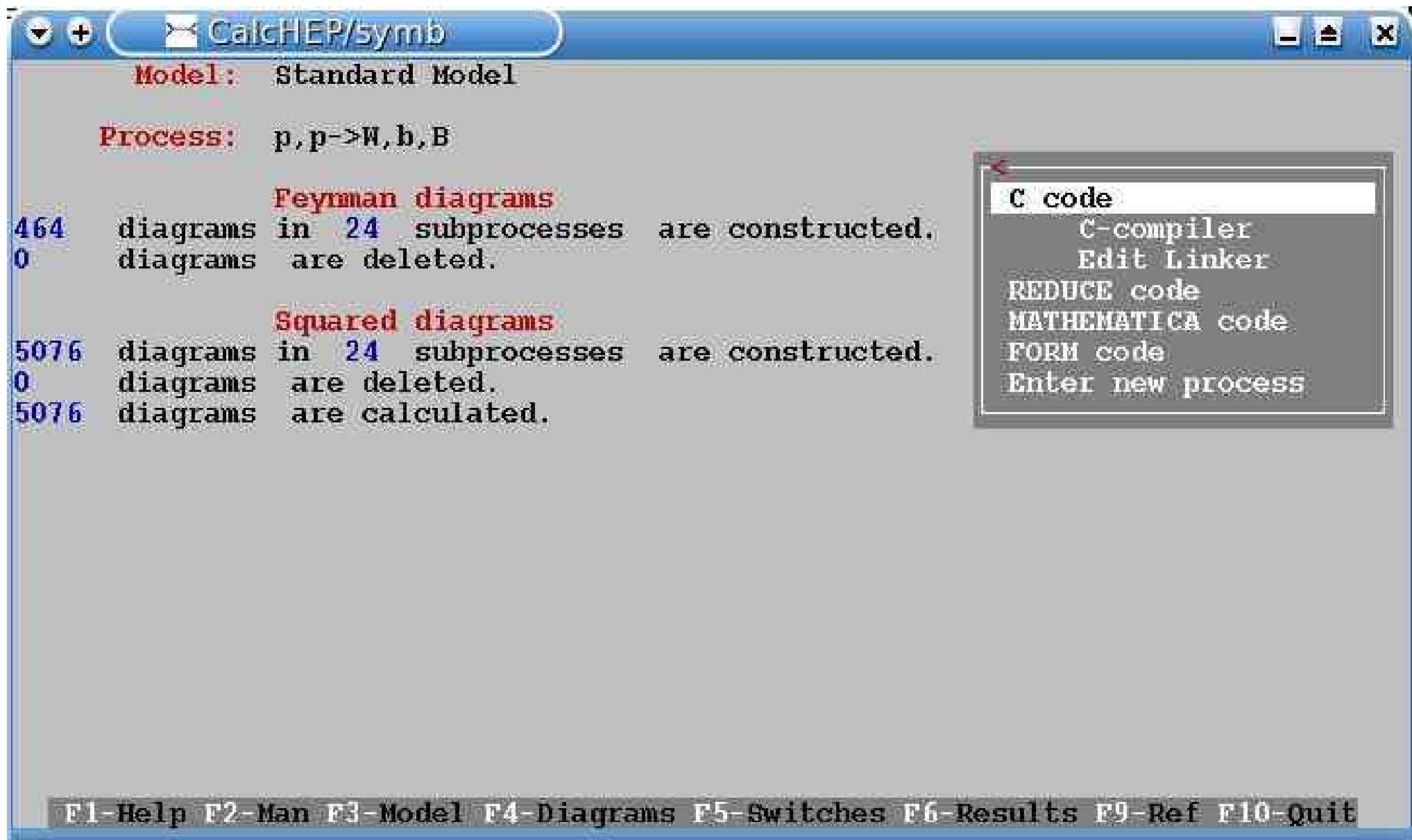
- Top Left:** An incoming  $W^+$  boson interacts with a gluon ( $G$ ) to produce a  $u$  quark and a  $D$  quark. The  $u$  quark then interacts with a  $b$  quark to form a  $u\bar{d}$  meson, which decays into a  $D$  meson. The  $D$  meson then interacts with a  $b$  quark to form a  $u\bar{d}$  meson, which decays into a  $u$  quark.
- Top Right:** An incoming  $W^+$  boson interacts with a gluon ( $G$ ) to produce a  $u$  quark and a  $D$  quark. The  $u$  quark then interacts with a  $d$  quark to form a  $u\bar{d}$  meson, which decays into a  $A$  boson. The  $A$  boson then interacts with a  $D$  quark to form a  $u\bar{d}$  meson, which decays into a  $u$  quark.
- Middle Left:** An incoming  $W^+$  boson interacts with a gluon ( $G$ ) to produce a  $u$  quark and a  $D$  quark. The  $u$  quark then interacts with a  $b$  quark to form a  $u\bar{d}$  meson, which decays into a  $Z$  boson. The  $Z$  boson then interacts with a  $D$  quark to form a  $u\bar{d}$  meson, which decays into a  $u$  quark.
- Middle Right:** An incoming  $W^+$  boson interacts with a gluon ( $G$ ) to produce a  $u$  quark and a  $D$  quark. The  $u$  quark then interacts with a  $b$  quark to form a  $u\bar{d}$  meson, which decays into an  $A$  boson. The  $A$  boson then interacts with a  $D$  quark to form a  $u\bar{d}$  meson, which decays into a  $u$  quark.
- Bottom Left:** An incoming  $W^+$  boson interacts with a gluon ( $G$ ) to produce a  $u$  quark and a  $D$  quark. The  $u$  quark then interacts with a  $b$  quark to form a  $u\bar{d}$  meson, which decays into a  $Z$  boson. The  $Z$  boson then interacts with a  $D$  quark to form a  $u\bar{d}$  meson, which decays into a  $u$  quark.
- Bottom Right:** An incoming  $W^+$  boson interacts with a gluon ( $G$ ) to produce a  $u$  quark and a  $D$  quark. The  $u$  quark then interacts with a  $b$  quark to form a  $u\bar{d}$  meson, which decays into an  $h$  boson. The  $h$  boson then interacts with a  $D$  quark to form a  $u\bar{d}$  meson, which decays into a  $u$  quark.

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

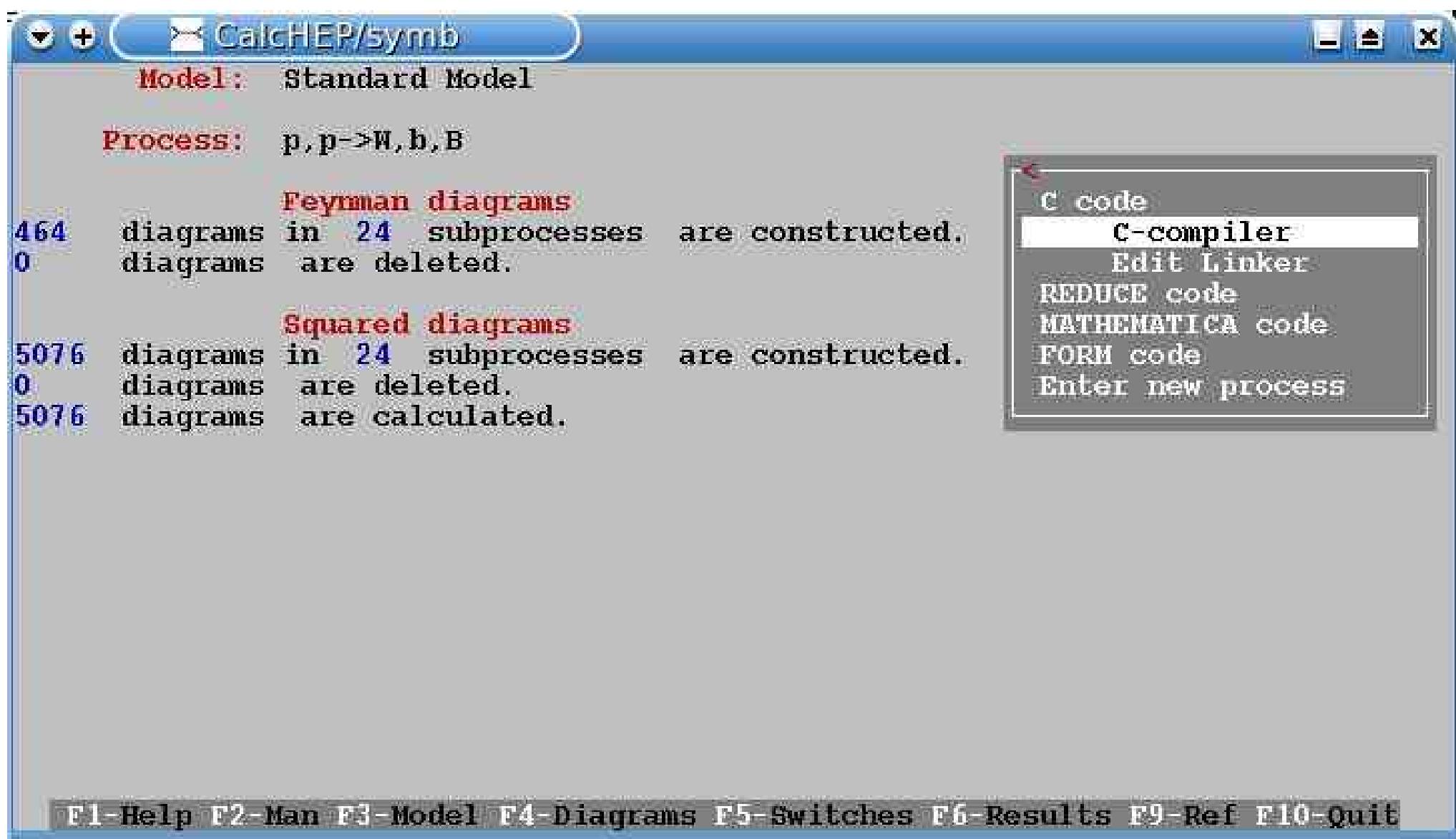
# Symbolic session (7)



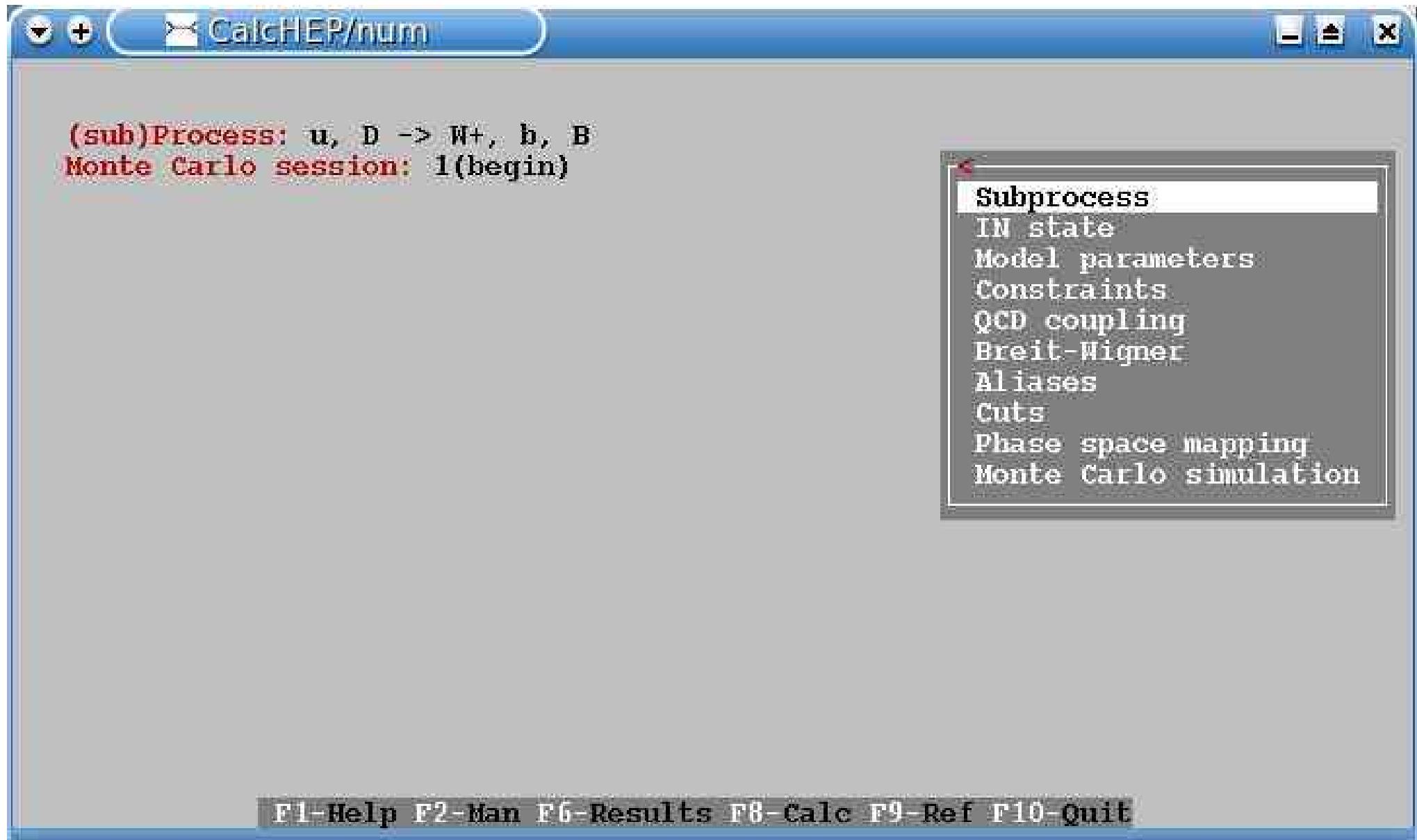
# Symbolic session (8)



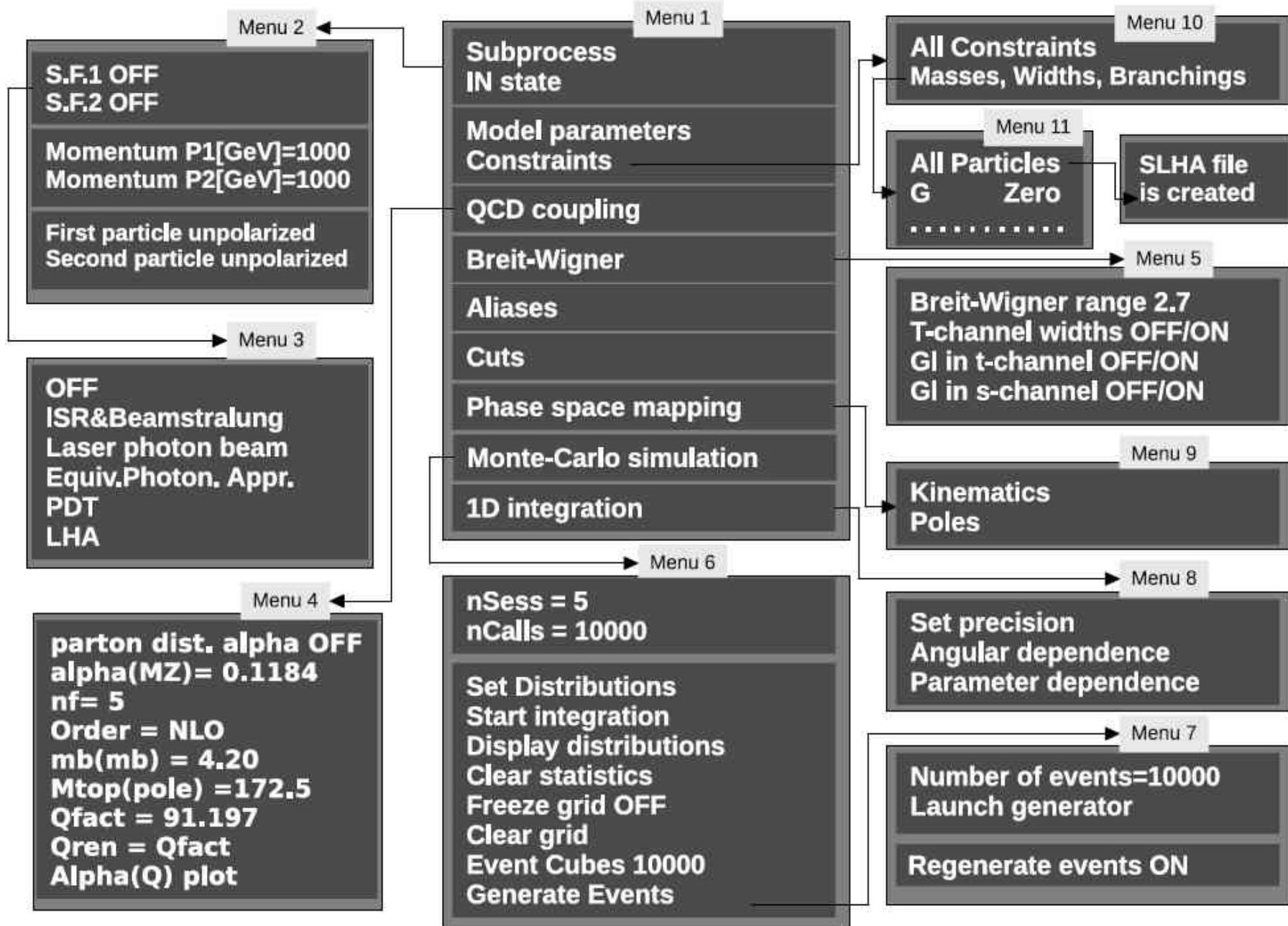
# Symbolic session (9)



# Numerical part of CalcHEP



# Menu structure of the numerical part



# subprocess menu

The image shows a screenshot of the CalcHEP software interface. On the left, there is a vertical menu bar with the title "Subprocess" at the top. Below it, the following items are listed:

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

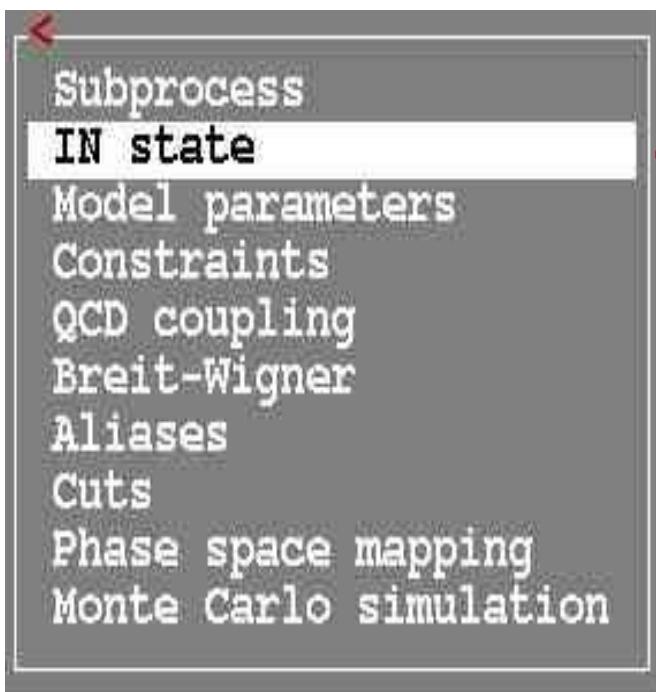
A red arrow points from the "Subprocess" menu item to a list of subprocesses on the right. This list is presented in a table-like format with columns for quarks (u, D), a blank column, a reaction arrow ( $\rightarrow$ ), and three leptons (W+, b, B). The rows show various combinations of quarks and leptons:

u	D		$\rightarrow$	W+	b	B
u	s		$\rightarrow$	W+	b	B
u	d		$\rightarrow$	W+	b	B
u	u	d	$\rightarrow$	W-	b	B
u	u	d	$\rightarrow$	W-	b	B
u	u	s	$\rightarrow$	W-	b	B
u	u	s	$\rightarrow$	W-	b	B
u	u	u	$\rightarrow$	W-	b	B
u	u	u	$\rightarrow$	W-	b	B
d	d	u	$\rightarrow$	W-	b	B
d	d	u	$\rightarrow$	W-	b	B
D	u	u	$\rightarrow$	W+	b	B
D	u	u	$\rightarrow$	W+	b	B
D	s	u	$\rightarrow$	W+	b	B
D	s	u	$\rightarrow$	W+	b	B
s	u	u	$\rightarrow$	W-	b	B
s	u	u	$\rightarrow$	W-	b	B
s	c	u	$\rightarrow$	W+	b	B
s	c	u	$\rightarrow$	W+	b	B
c	d	u	$\rightarrow$	W+	b	B
c	d	u	$\rightarrow$	W+	b	B
c	s	u	$\rightarrow$	W+	b	B
c	s	u	$\rightarrow$	W+	b	B

A red arrow points from the "Subprocess" menu item to the first row of the table.

PgDn

# control of the initial states and parton density functions

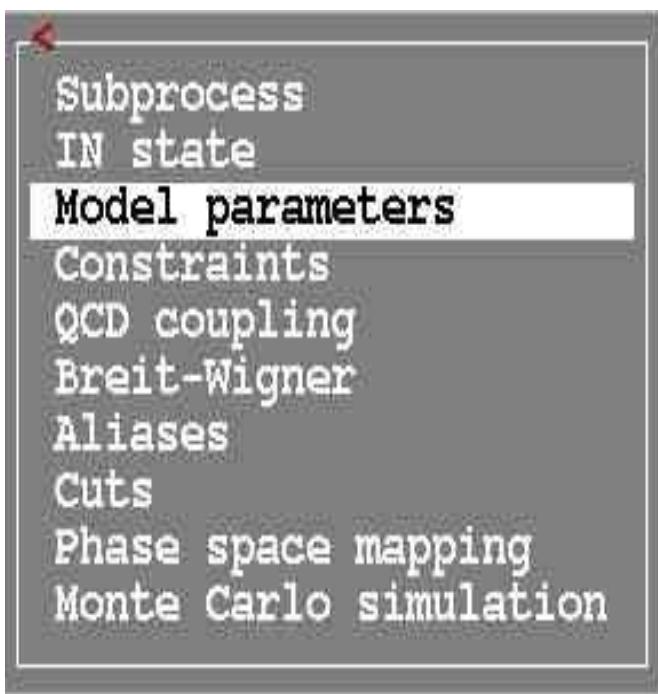


```
S.F.1: OFF
S.F.2: OFF
First particle momentum[GeV] = 7000
Second particle momentum[GeV] = 7000
First particle unpolarized
Second particle unpolarized
```

```
PDT:cteq6m(anti-proton)
PDT:cteq6m(proton)
PDT:cteq6l(anti-proton)
PDT:cteq6l(proton)
PDT:CTEQ5M(anti-proton)
PDT:CTEQ5M(proton)
PDT:mrst2002nlo(anti-proton)
PDT:mrst2002nlo(proton)
PDT:mrst2002lo(anti-proton)
PDT:mrst2002lo(proton)
```

```
S.F.1: PDT:cteq6m(proton)
S.F.2: OFF
First particle momentum[GeV] = 7000
Second particle momentum[GeV] = 7000
First particle unpolarized
Second particle unpolarized
```

# model parameters



The screenshot shows a list of model parameters and their values:

- $\alpha_{fEMZ} = 0.0078181$
- $\alpha_{fSMZ} = 0.1172$
- $Q = 100$
- $S_W = 0.481$
- $s_{12} = 0.221$
- $s_{23} = 0.041$
- $s_{13} = 0.0035$
- $M_m = 0.1057$
- $M_l = 1.777$
- $M_{McM} = 1.2$
- $M_S = 0$
- $M_b M_b = 4.25$
- $M_{tp} = 175$
- $M_Z = 91.187$
- $M_h = 120$

PgDn

# dependent parameters

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

Display dependence

```
Vtb= 0.99915  
qcd0k= 0.31267  
Mb= 3.2588  
Mt= 175  
Mc= 0.66056  
wh= 0.0027774
```

Display dependence

```
wh= 0.0027774
```

on parameter

```
Ms= 0  
MbMb= 4.25  
Mtp= 175  
MZ= 91.187  
Mh= 120  
wt= 1.59  
wZ= 2.4944  
wW= 2.089  
GG= 1.238
```

Display dependence

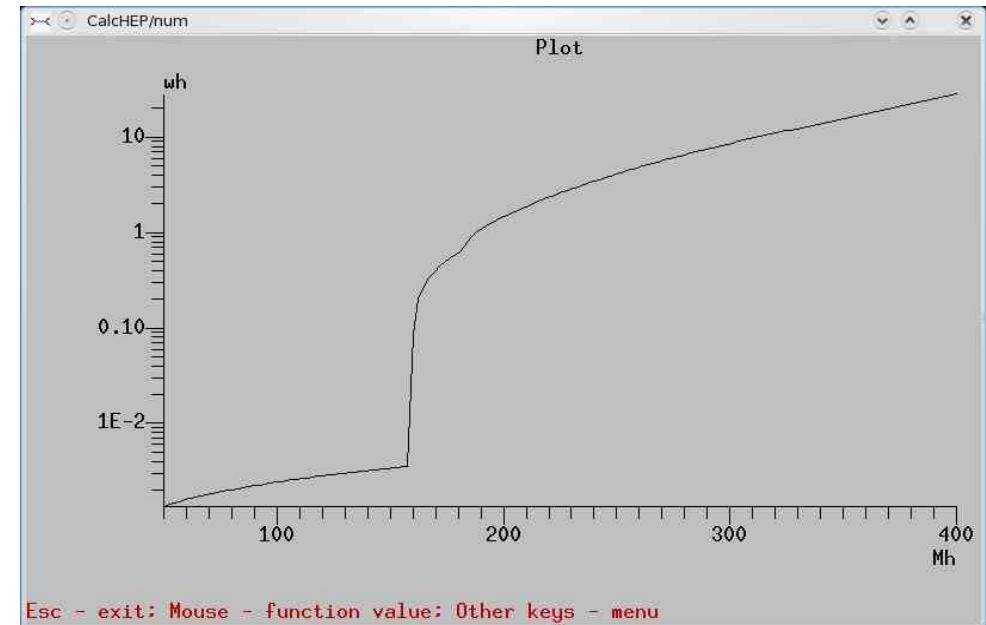
```
wh= 0.0027774
```

on parameter

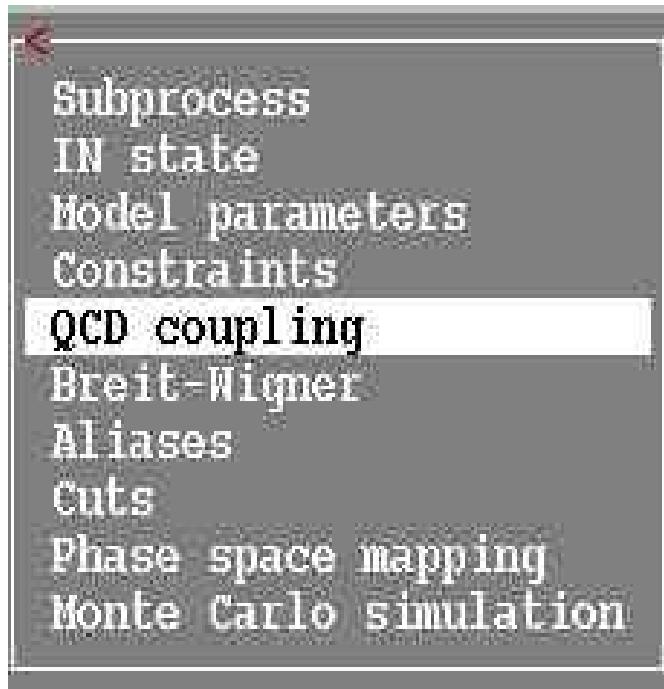
```
Mh= 120
```

Plot

```
x-Min = 50  
x-Max = 400  
Npoints = 150  
Display
```



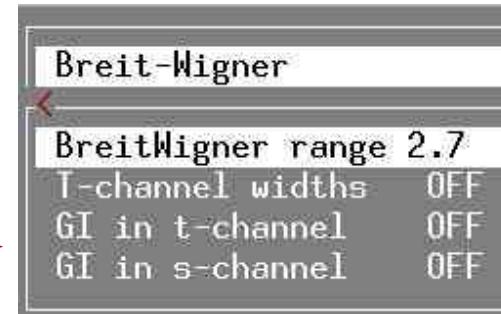
# QCD coupling and the scale



The screenshot shows the 'QCD coupling' section of the parameter list in the CalcHEP software. The list includes:

- parton dist. alpha !ON
- alpha(MZ) = 0.1172
- nf = 5
- order = NLO
- mb(mb) = 4.200
- Mtop(pole) = 175.00
- Qfact = M12
- Qren = Qfact
- alpha(Q) plot

# control of resonances



# control of resonances



A red arrow points from the "Breit-Wigner" item in the sidebar to the "Breit-Wigner range 2.7" section of the configuration window.

**Breit-Wigner**

BreitWigner range 2.7

T-channel widths	OFF
GI in t-channel	OFF
GI in s-channel	OFF

**F1**

\* n\_width\_1

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

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

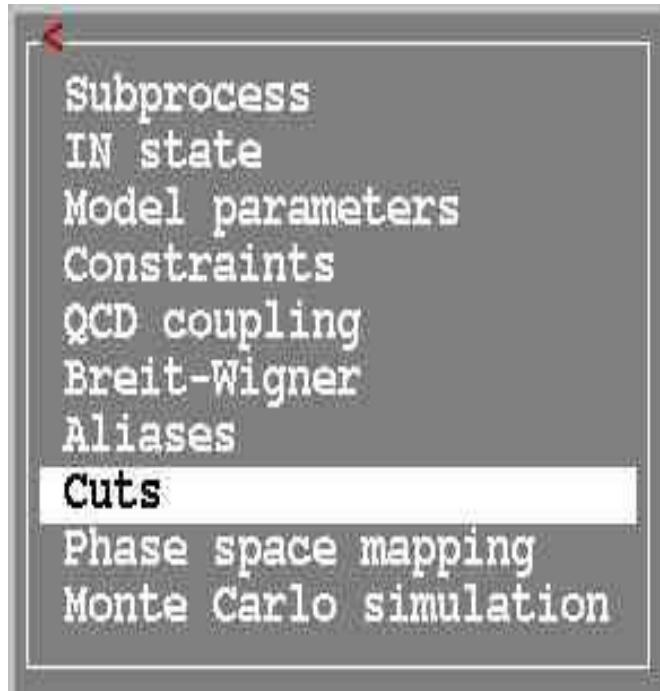
For region

$$|p^2-m^2| > \sqrt{R^2+1}*m*w$$

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

In general Breit-Wigner leads to breaking of gauge invariance. In its turn it can lead to the lost of diagram cancellation. From the other side just in the point  $p^2=m^2$  the contribution of pole diagram have to be gauge invariant. Thus at this point cancellation between pole and non-pole diagrams is not expected. We assume that close to pole the problem also is not so serious. But far from the pole we ignore width and restore gauge invariance.

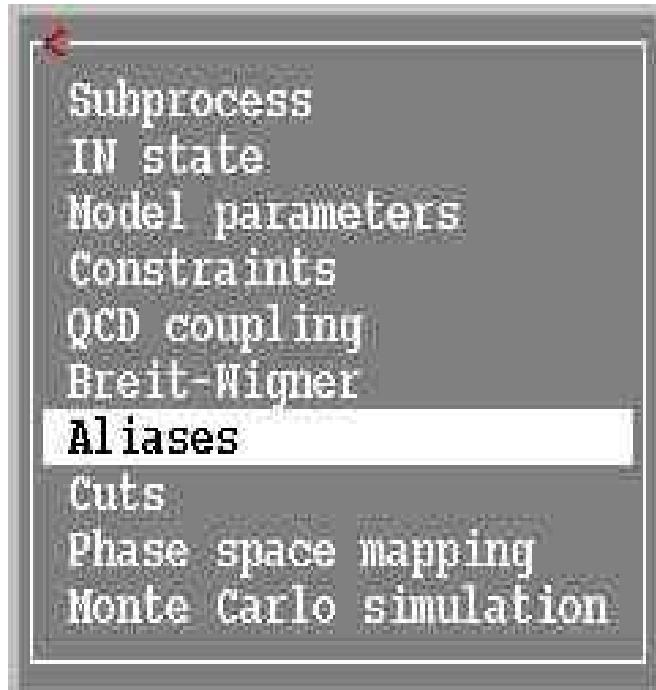
# setting kinematical cuts



A red arrow points from the 'Cuts' option in the sidebar to this window. The window title is 'Cuts' and has a number '5' in the top right corner. It contains a table with the following data:

Parameter	Clr-Del-Size	Read-ErrMes
T(b)	120	
T(B)	120	
N(b)	1-5	15
N(B)	1-5	15
J(b,B)	10.5	1

# Aliases



A screenshot of the HEPMDB interface, specifically the 'Composites' section. The table has columns for Name and Description. The 'Name' column contains 'Clr', 'Del', 'Size', 'Read', and 'ErrMes'. The 'Description' column contains a placeholder 'Comma separated list of particles'. Below this is a table row for 'Jet' with the value '|u,U,d,D,s,S,c,C,G'. A red arrow points from the 'Aliases' menu in the CalcHEP screenshot to the 'Jet' row in the HEPMDB screenshot.

Name	Comma separated list of particles
Jet	u,U,d,D,s,S,c,C,G

# setting kinematical cuts

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

0

Clr-Del-Size-Read-ErrMes

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 its name which characterizes type of cut and a particle list for which the cut is applied. For example, "T(u)" means transverse momentum of 'u'-quark; T(u,D) means summary transverse momentum of quark pair.

The following cut functions 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;

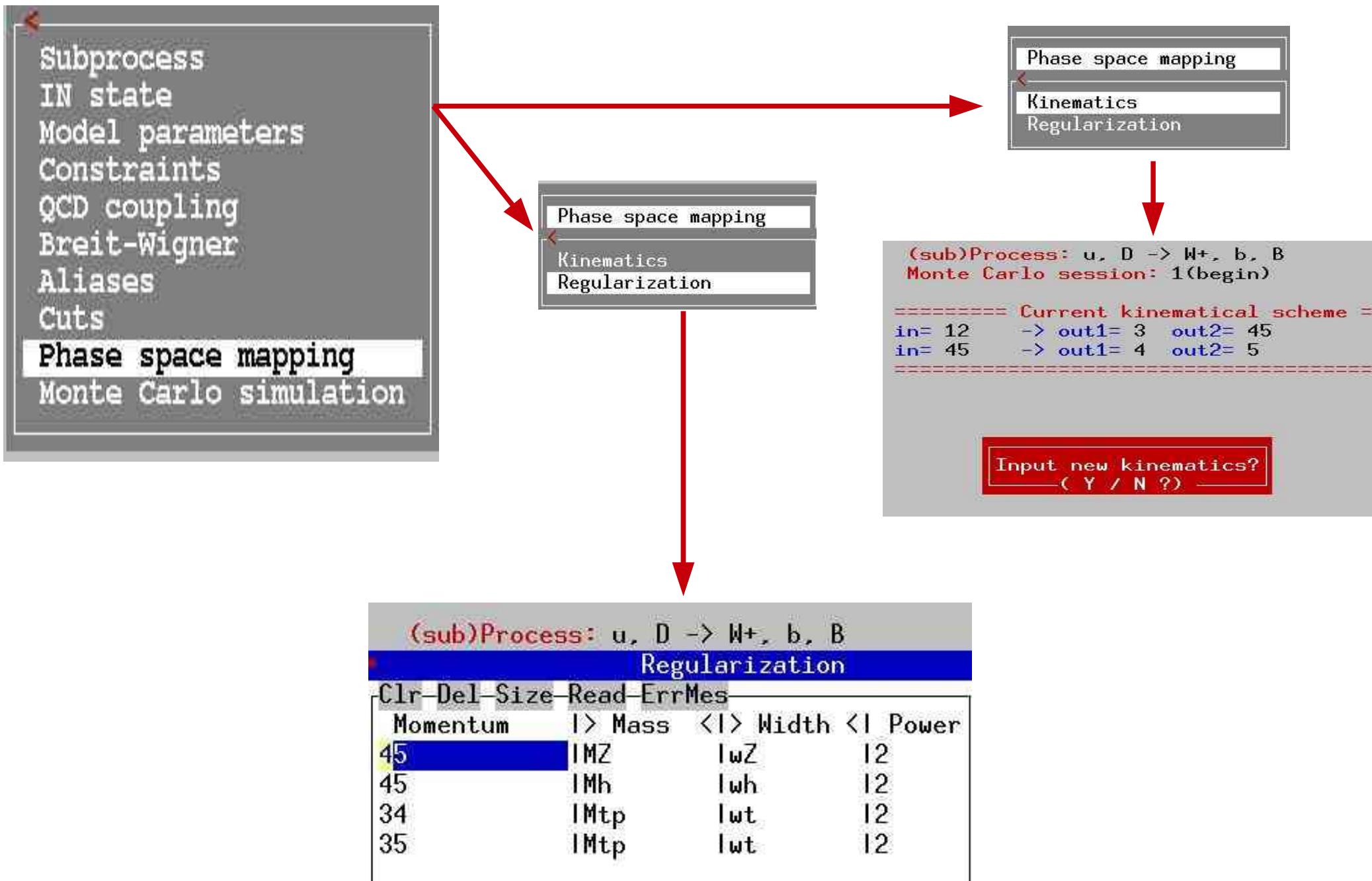
PgDn

5

Clr-Del-Size-Read-ErrMes

Parameter	> Min bound < > Max bound <
T(b)	120
T(B)	120
N(b)	-5
N(B)	-5
J(b,B)	10.5

# 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

(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

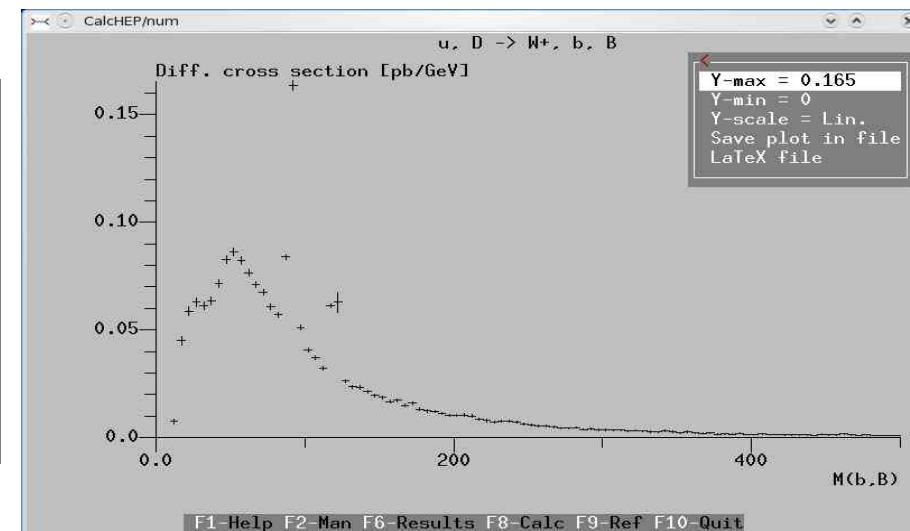
Monte Carlo simulation

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

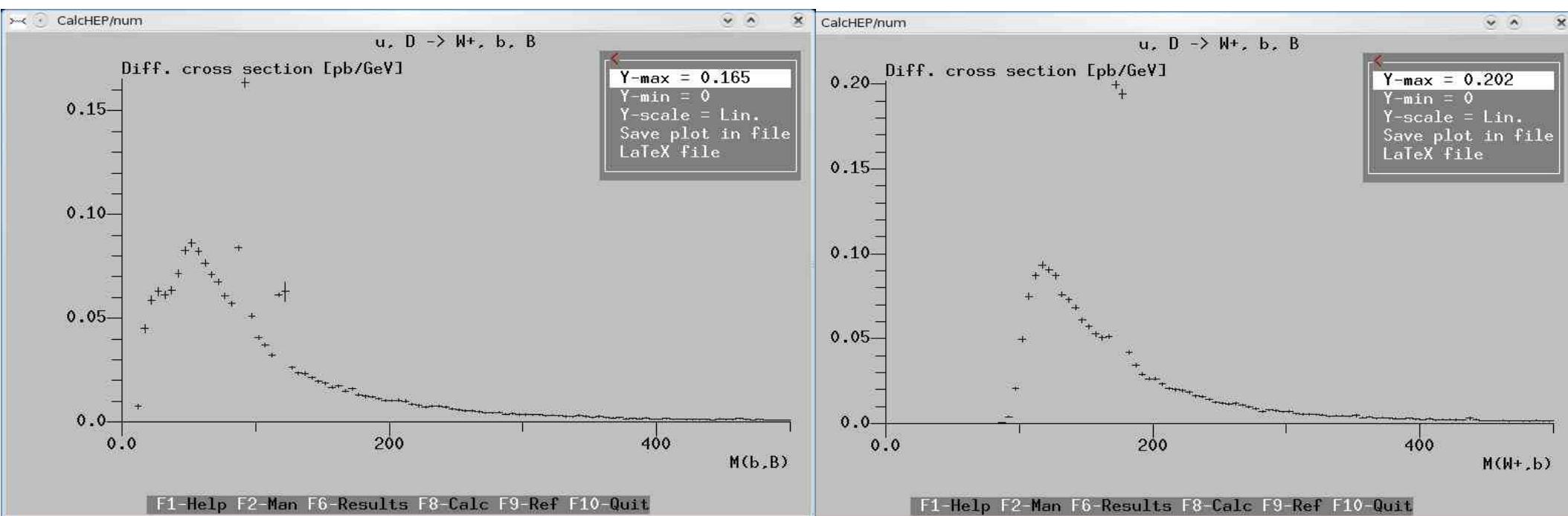
```
nSess = 5
nCalls = 10000
Set Distributions
*Start integration
Display Distributions
Clear statistic
Freeze grid      OFF
Clear grid
Event Cubes 10000
Generate Events
```

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

	Clr	Del	Size	Read	ErrMes									
						Parameter_11>	Min_1	< >	Max_1	< >	Parameter_21>	Min_2	< >	Max_2
T(b)	10					I(b)	10	< >	1200					
T(B)	10					T(B)	10	< >	1200					
N(b)	1-5					N(b)	1-5	< >	15					
N(B)	1-5					N(B)	1-5	< >	15					
M(b,B)	10					M(b,B)	10	< >	1500					
M(W+,b)	10					M(W+,b)	10	< >	1500					
T(b)	10					T(b)	10	< >	1500		M(b,B)	10	< >	1500



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



## Exercise#3

1. Calculate  $WbB$  production rates at the LHC for  $PT$   $b$ -jet  $> 20$  GeV,  $b$ -Jet separation  $> 0.5$ , max pseudorapidity  $< 3$
2. Plot  $bb$ - and  $Wb$  invariant mass distributions for  $PT$   $b$ -jet  $> 20$  GeV and  $PT$   $b$ -jet  $> 40$  GeV

# events generations

```
Monte Carlo simulation  
  
nSess = 5  
ncalls = 10000  
Set Distributions  
*Start integration  
Display Distributions  
Clear statistic  
Freeze grid      ON  
Clear grid  
Event cubes 10000  
Generate Events
```



```
Monte Carlo simulation  
2  
Generate Events  
  
Number of events=10000  
Launch generator  
Regenerate events   ON
```

Statistic  
efficiency: 2.1E-02  
Reached max: 4.9E+01  
Mult. events: 6.4E-03  
Neg. events: 0.0E+00  
-----  
Accept events?  
( Y / N ? )

**GUI gives user a full control of details  
of symbolic/numerical session.**

**To sum over the sub-processes one should use scripts**

*there are several scripts which run various loops to facilitate calculation*

► **cycle over subprocesses**

- *exit from the numerical session*
- **cd results**
- **..../bin/subproc\_cycle *lumi nmax***

**requires 2 parameters:**

**1. luminosity**

**2. max number of events per process**

**e.g.**

**..../bin/subproc\_cycle 1000 100000**

**You should run it from results dir where the *n\_calchep* binary is!**

# running subproc\_cycle for SM model

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

# running subproc\_cycle for SM CKM=1 model

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

# Accessing your results

- **results are stored in “*results*” directory**
- **output files:**
  - ▶ **n\_calchep**      *numerical module*
  - ▶ **prt\_nn**      *protocol*
  - ▶ **distr\_nn\_mm**      *summed distributions*
  - ▶ **distr\_nn**      *individual distribution*
  - ▶ **events\_nn.txt**      *events file*
  - ▶ **list\_prc.txt**      *list of processes*
  - ▶ **qnumbers**      *qnumbers – PYTHIA input with new prt definitions*
  - ▶ **session.dat**      *current session status – format is similar to prt\_nn one*
- **for every new process the “*results*” directory is offered to be renamed or removed**

## protocol prt\_nn

```
CalcHEP kinematics module
The session parameters:

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

#Physical_Parameters
    alfEMZ = 7.818060999999999E-03
    alfSMZ = 1.172000000000000E-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 **calchept\_x.x.x/bin/ directory and README file!**

- **subproc\_cycle**                   `..../bin/subproc_cycle 1000 100000`
- **sum\_distr**                      `..../bin/sum_distr distr_2 distr_3 > distr_sum`
- **show\_distr**                     `..../bin/show_distr distr_sum`
- **plot\_view**                       `..../bin/plot_view < tab_1.txt`
- **events2tab**
- **gen\_events**
- **name\_cycle**
- **pcm\_cycle**

## **Exercise#4**

*learn how to use:*

- 1) `gen_events`
- 2) `events2tab`
- 3) `plot_view`

# scripts for numerical session

- **events2tab**

*Parameters:*

- 1- *name of variable,*
- 2- *minimum limit,*
- 3- *maximum limit,*
- 4- *number of bins(<=300).*

*File with events must be passed to input.*

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

- **name\_cycle**

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

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

*scripts above became a part of calchep\_batch interface – to be discussed below*

# MC generators and CalcHEP batch interface

...because Einstein was wrong: God does throw dice!

Quantum mechanics: amplitudes  $\Rightarrow$  probabilities

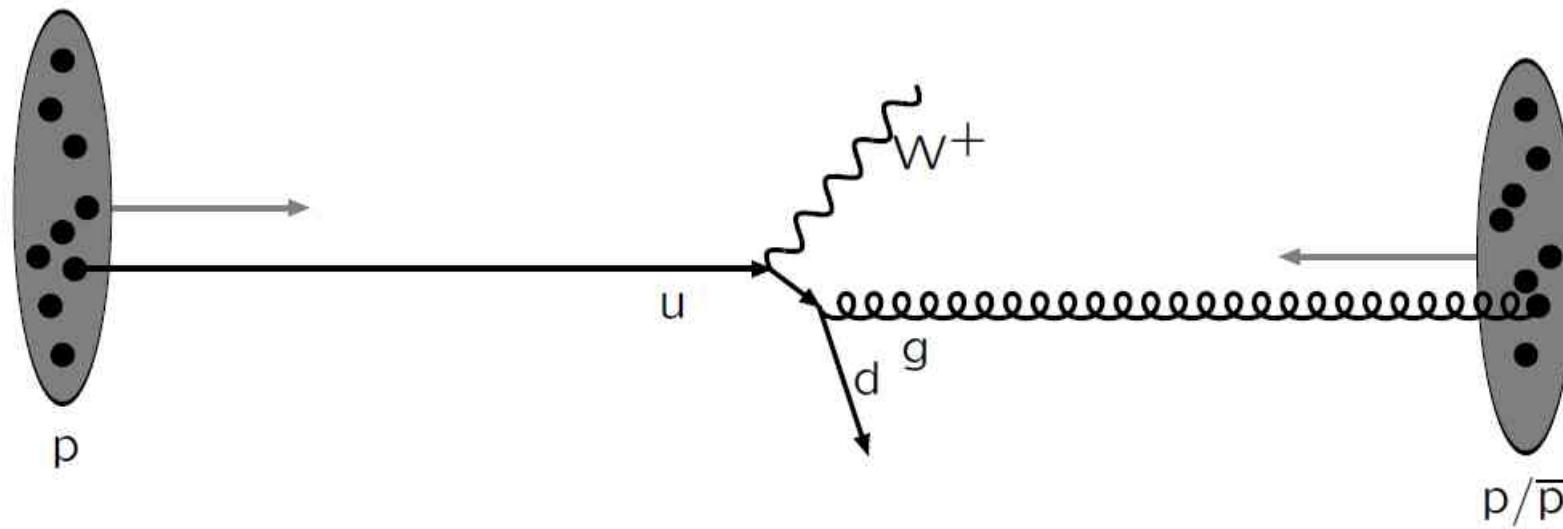
Anything that possibly can happen, will (but more or less often)

# Event Structure



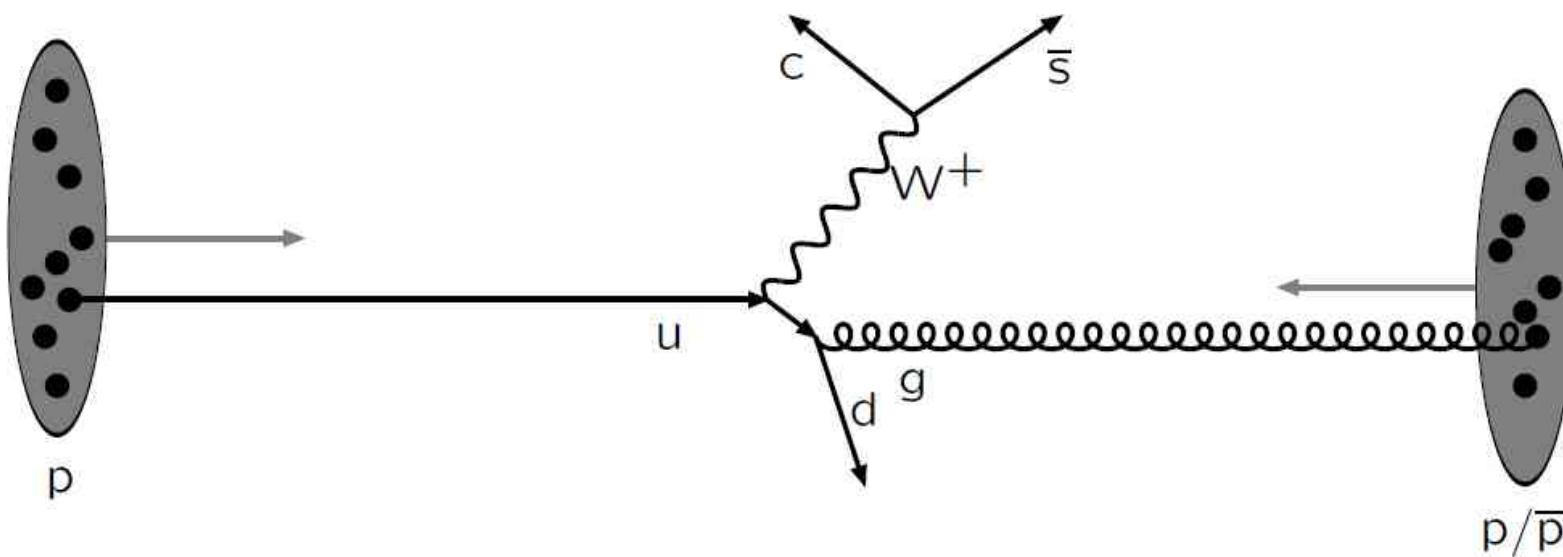
Incoming beams: parton densities

# Event Structure



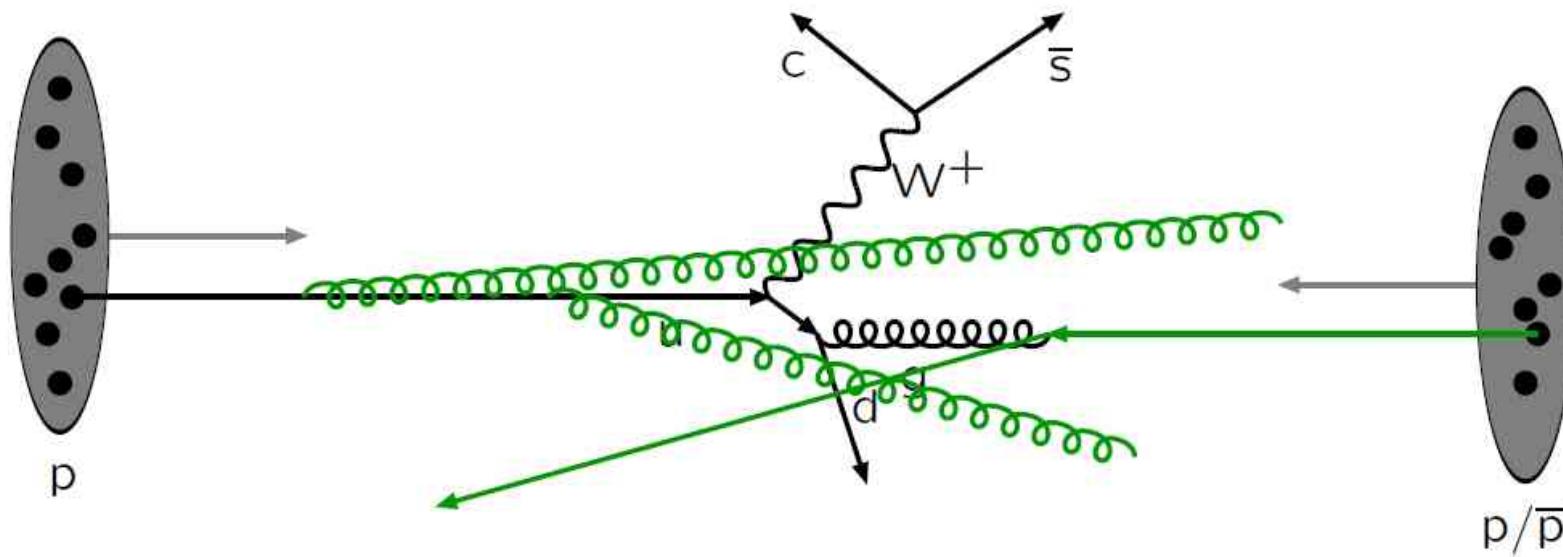
Hard subprocess: described by matrix elements

# Event Structure



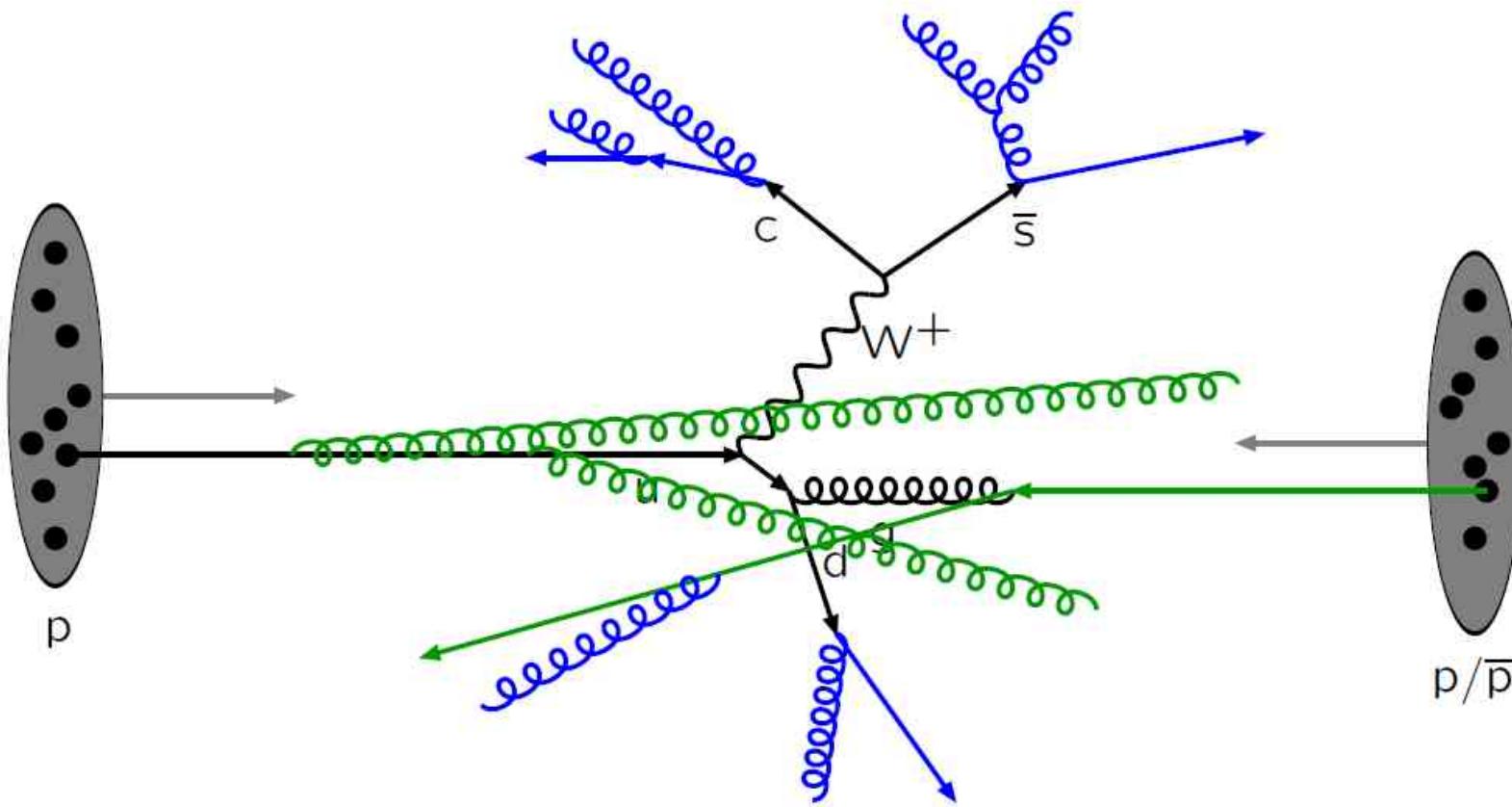
Resonance decays: correlated with hard subprocess

# Event Structure



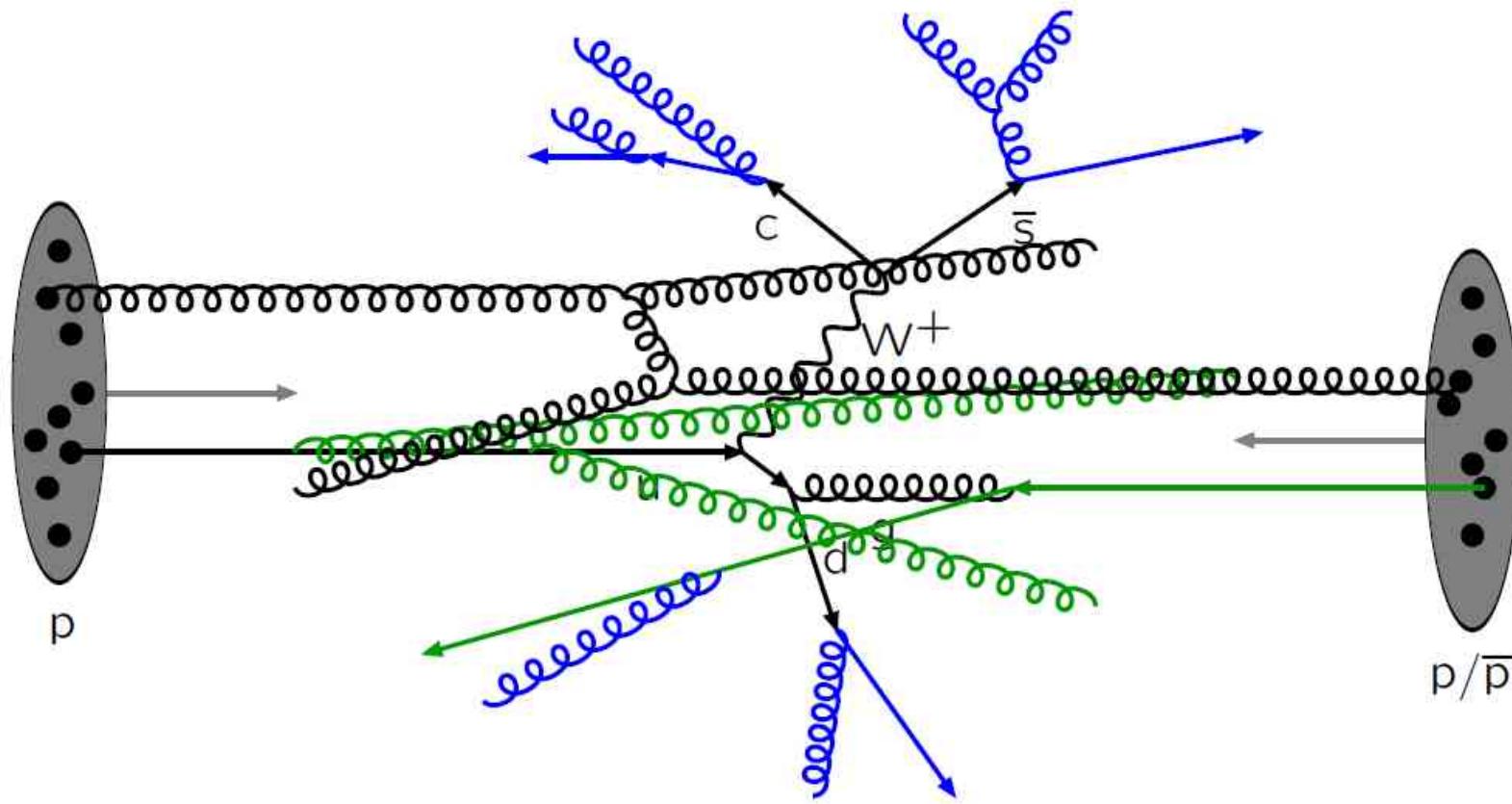
Initial-state radiation: spacelike parton showers

# Event Structure



Final-state radiation: timelike parton showers

# Event Structure



Multiple parton–parton interactions ...

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

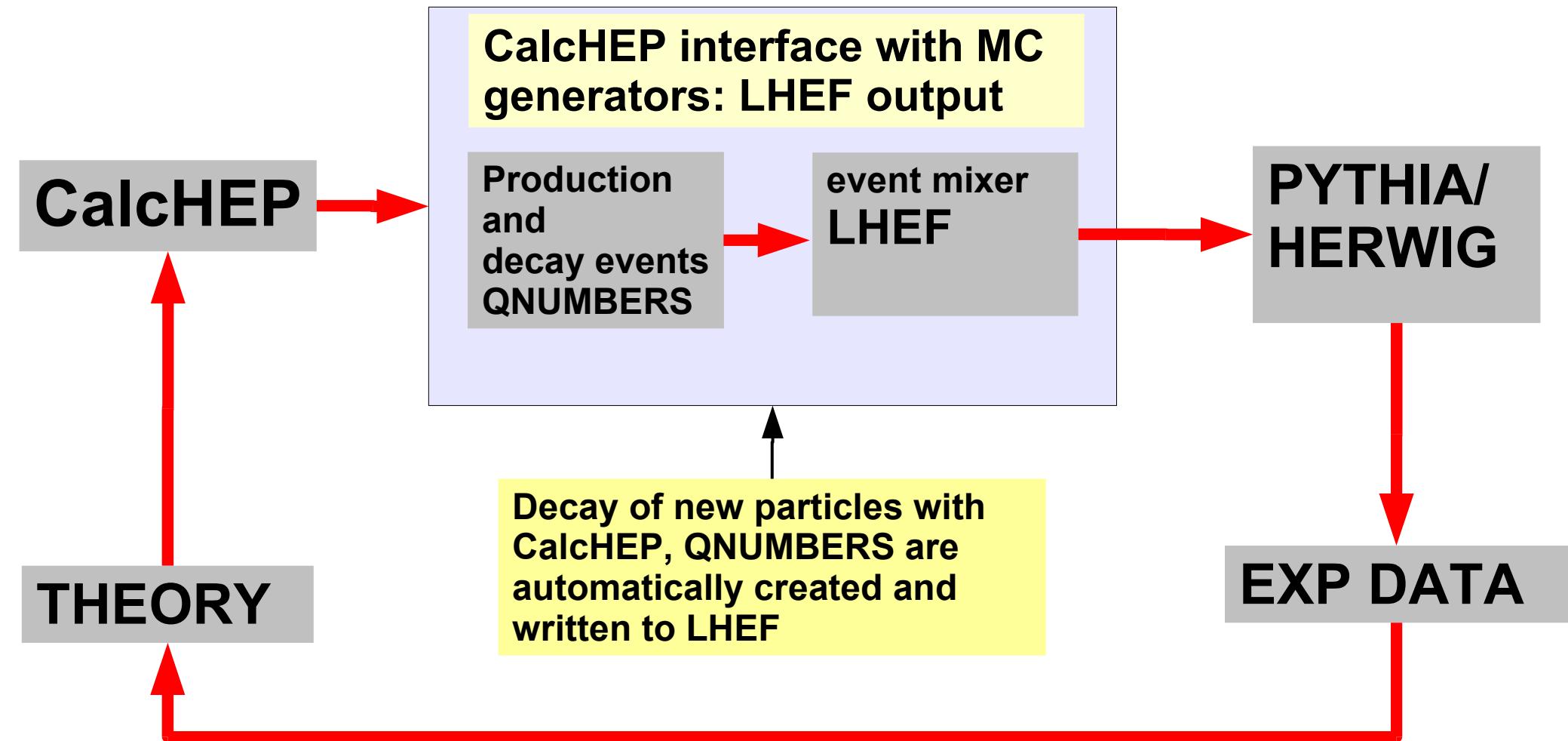
- **bin/event\_mixer** *Luminosity[1/fb] nevents event\_dirs*  
mixes subprocesses and connects scattering and decay events

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

- **the output is event\_mixer.lhe file**

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

# Present Status of the CalcHEP



# CalcHEP batch interface: results from CalcHEP in one shot

- `calcheep_batch batch_file`

```
./calcheep_batch batch_file
```

```
calcheep_batch version 0.146
```

```
Processing batch:
```

```
Progress information can be found in the html directory.
```

```
Simply open the following link in your browser:
```

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

```
You can also view textual progress reports in
```

```
/home/belyaev/tmp/tutorial/calc_work/html/index.txt
```

```
and the other .txt files in the html directory.
```

```
Events will be stored in the Events directory.
```

# CalCHEP batch interface: example of the batch file

## Main Features

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

## batch\_file

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

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

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

# CalcHEP batch interface: monitoring the progress

`file:///home/belyaev/tmn/tutorial/calc_work/html/index.html`

## CalcHEP Batch Details

Home  
Symbolic Results  
Numerical Results  
Events Library  
Process Library  
Help

Thank you for  
using CalcHEP!  
Please cite  
arXiv:1207.6082

### Standard Model(CKM=1)

#### Generating Events

	Finished Time(hr)
Symbolic	12/12 0.01
$\sigma$	3/3 0.07
Events	2/3 0.01

# CalcHEP batch interface: monitoring details of the symbolic section

*file:///home/belyaev/tmp/tutorial/calc\_work/html/index.html*

## Symbolic Sessions

### Standard Model(CKM=1)

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

Home  
Symbolic Results  
Numerical Results  
Events Library  
Process Library  
Help

Thank you for  
using CalcHEP!  
Please cite  
arXiv:1207.6082

# CalcHEP batch interface: monitoring results of the numerical session

*file:///home/belyaev/tmp/tutorial/calc\_work/html/index.html*

## Numerical Sessions

Home  
Symbolic Results  
Numerical Results  
Events Library  
Process Library  
Help

Thank you for  
using CalcHEP!  
Please cite  
[arXiv:1207.6082](https://arxiv.org/abs/1207.6082)

### Standard Model(CKM=1)

Done!

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

# CalcHEP batch interface: details of the numerical session

file:///home/belyaev/tmp/tutorial/cole\_work/html/index.html

## Standard Model(CKM=1)

Home  
Symbolic Results  
Numerical Results  
Events Library  
Process Library  
Help

Thank you for  
using CalcHEP!  
Please cite  
arXiv:1207.6082

Done!

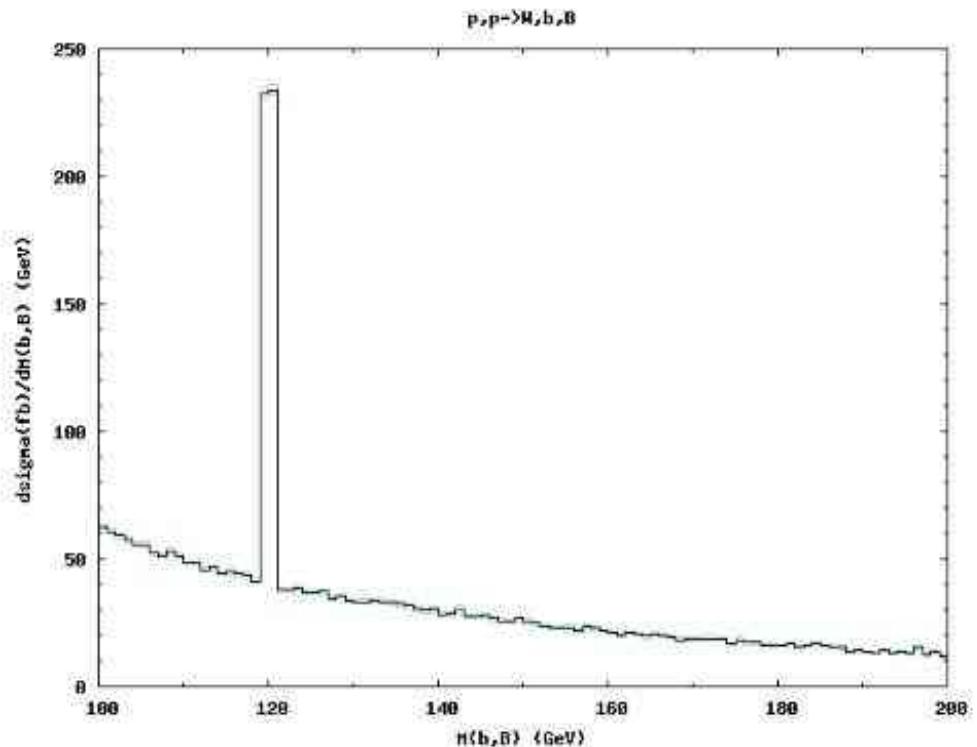
Processes	$\sigma$ (fb)	$\Delta\sigma$ (%)	PID	Time (hr)	N events	Details
u,D->W+,b,B	1319.3	0.46	28597	0.00	382/382	prt_1 session.dat
U,d->W-,b,B	715.68	0.47	28601	0.00	221/221	prt_1 session.dat
d,U->W-,b,B	714.79	0.48	28638	0.00	221/221	prt_1 session.dat
D,u->W+,b,B	1336.1	0.66	28642	0.00	386/386	prt_1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

Decays	$\Gamma$ (GeV)	$\Delta\Gamma$ (%)	PID	Time (hr)	N events	Details
W+->E,ne	0.22349	4.5	28758	0.00	5098/5100	prt_1 session.dat

# CalcHEP batch interface: numerical results and distributions

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

## Distributions



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

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

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

```
IMPLICIT INTEGER(I-N)
```

```
integer MSTP,MSTI
```

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

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

```
mstp(161)=lun2
```

```
mstp(162)=lun2
```

```
NEV=10
```

```
IMSS(21)=lun2
```

```
OPEN(lun2, FILE='lhefile.lhe',STATUS='UNKNOWN',  
& FORM='FORMATTED')
```

```
CALL PYINIT('USER',' ',' ',0d0)
```

```
DO 200 NVT=1,NEV
```

```
CALL PYEVNT
```

C... Insert your analysis here

```
200  CONTINUE
```

```
100  CALL PYSTAT(1)
```

```
CLOSE(lun2)
```

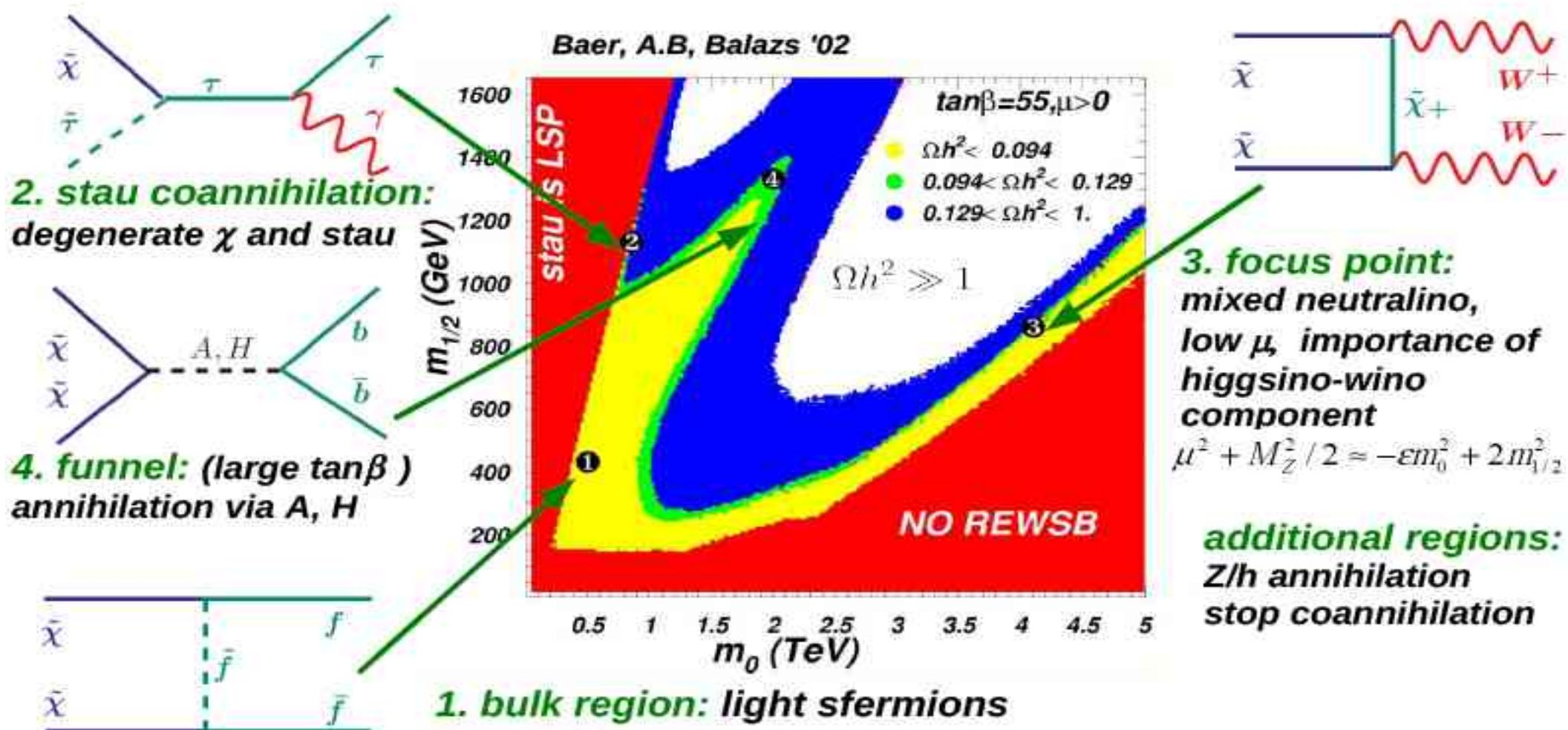
```
END
```

# Examples of the CalcHEP application

# Dark matter relic density – IsaRed and MicrOmegas

## Neutralino relic density in mSUGRA

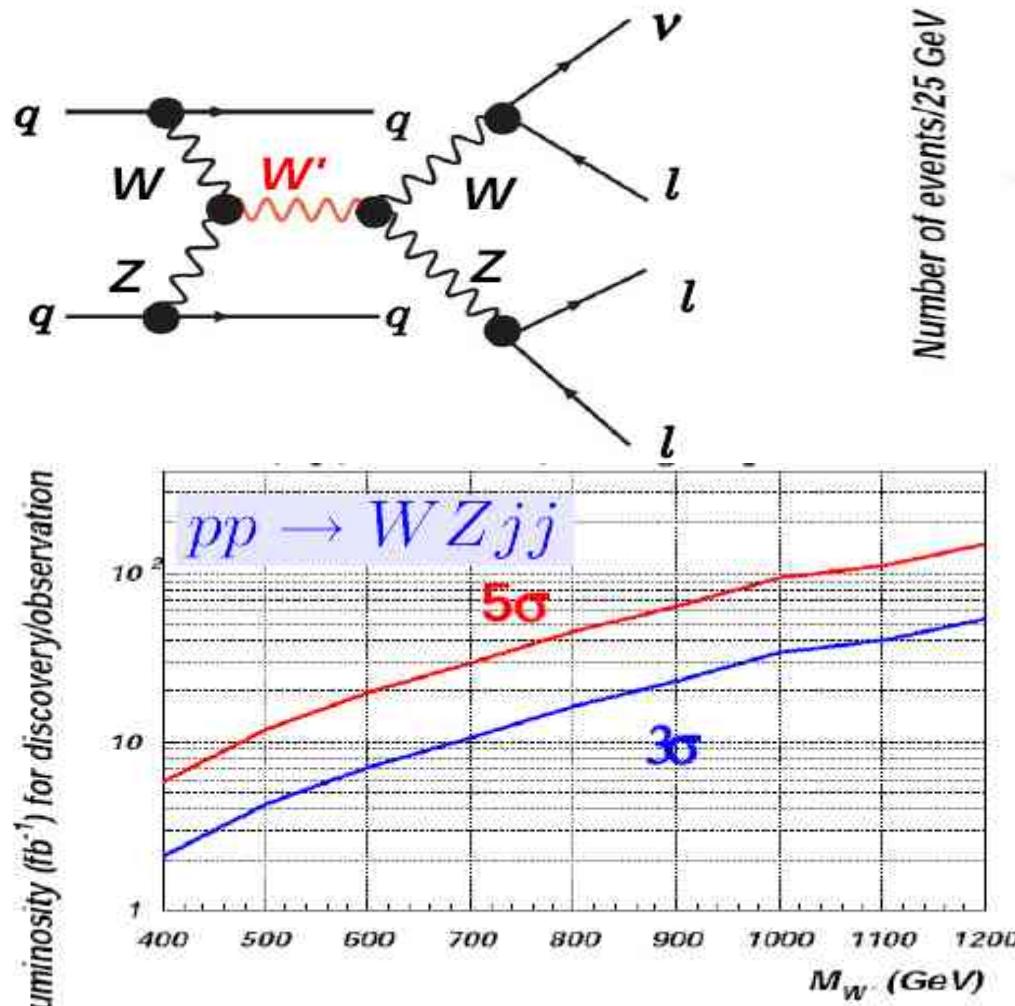
*most of the parameter space is ruled out!  $\Omega h^2 \gg 1$*   
*special regions with high  $\sigma_A$  are required to get  $0.094 < \Omega h^2 < 0.129$*



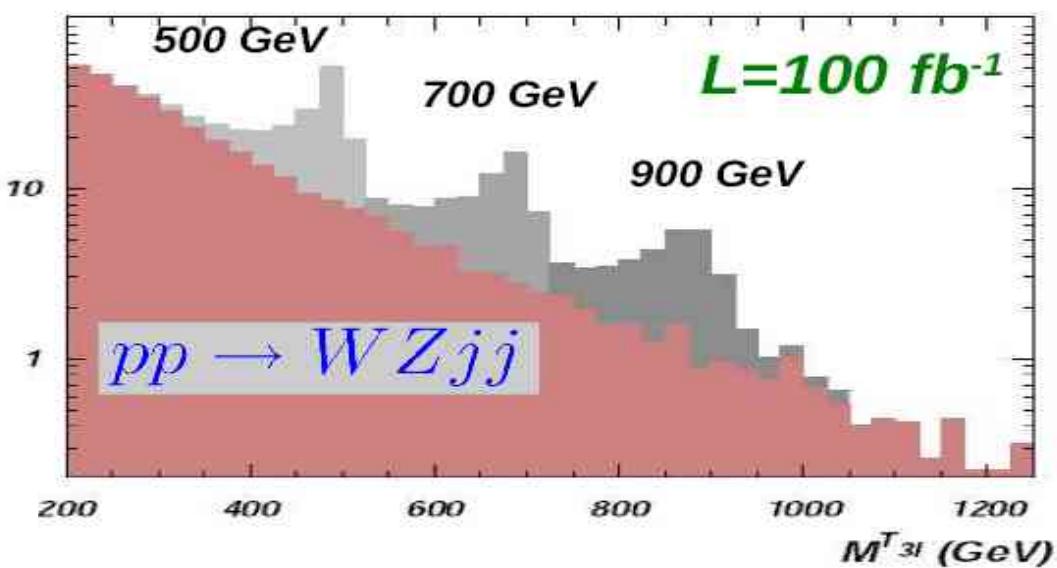
# $W'$ 3-lepton signatures from 3-site Higgsless model

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

LHC reach for  $WZ \rightarrow W'$  process



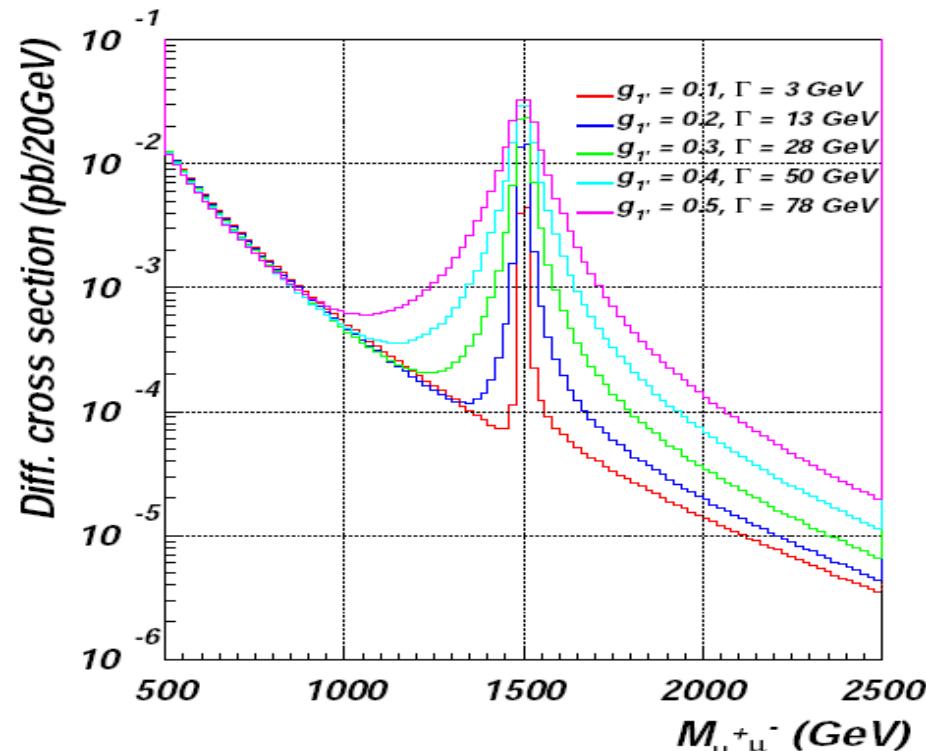
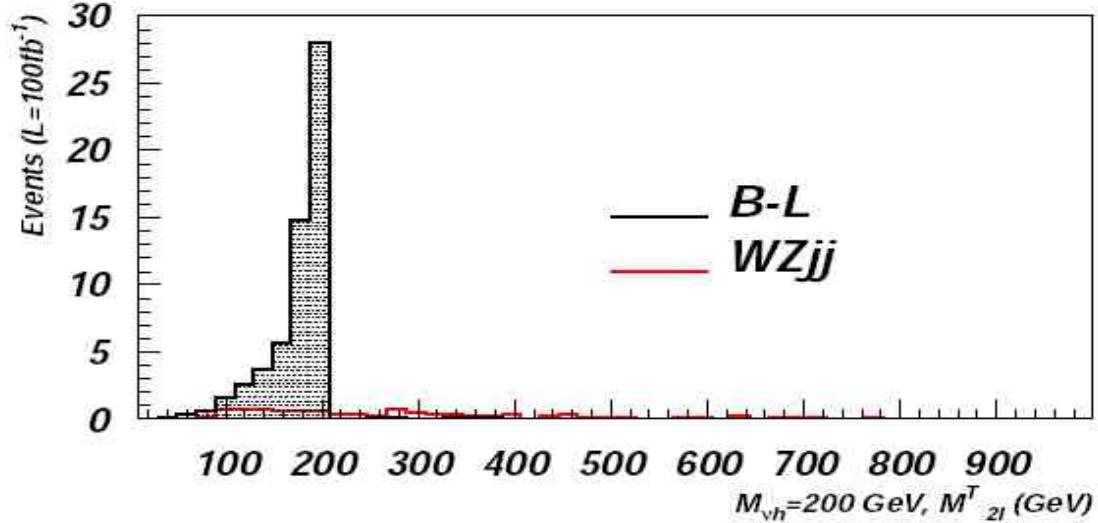
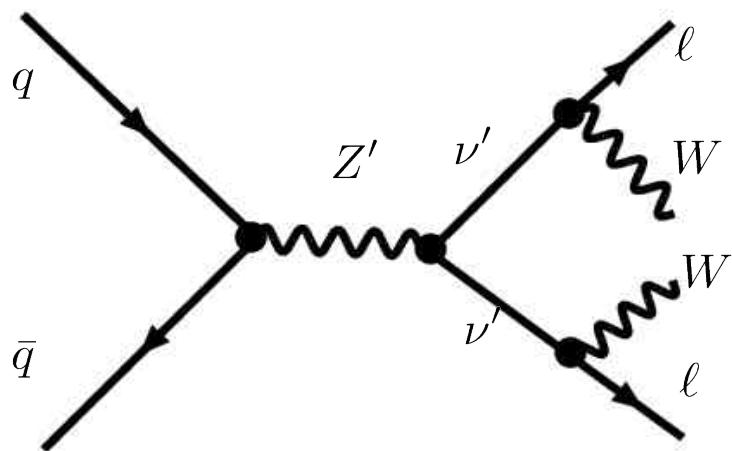
[AB, Chivukula, Christensen, He, Kuang, Pukhov, Qi, Simmons, Zhang '07]



# B-L extension of SM

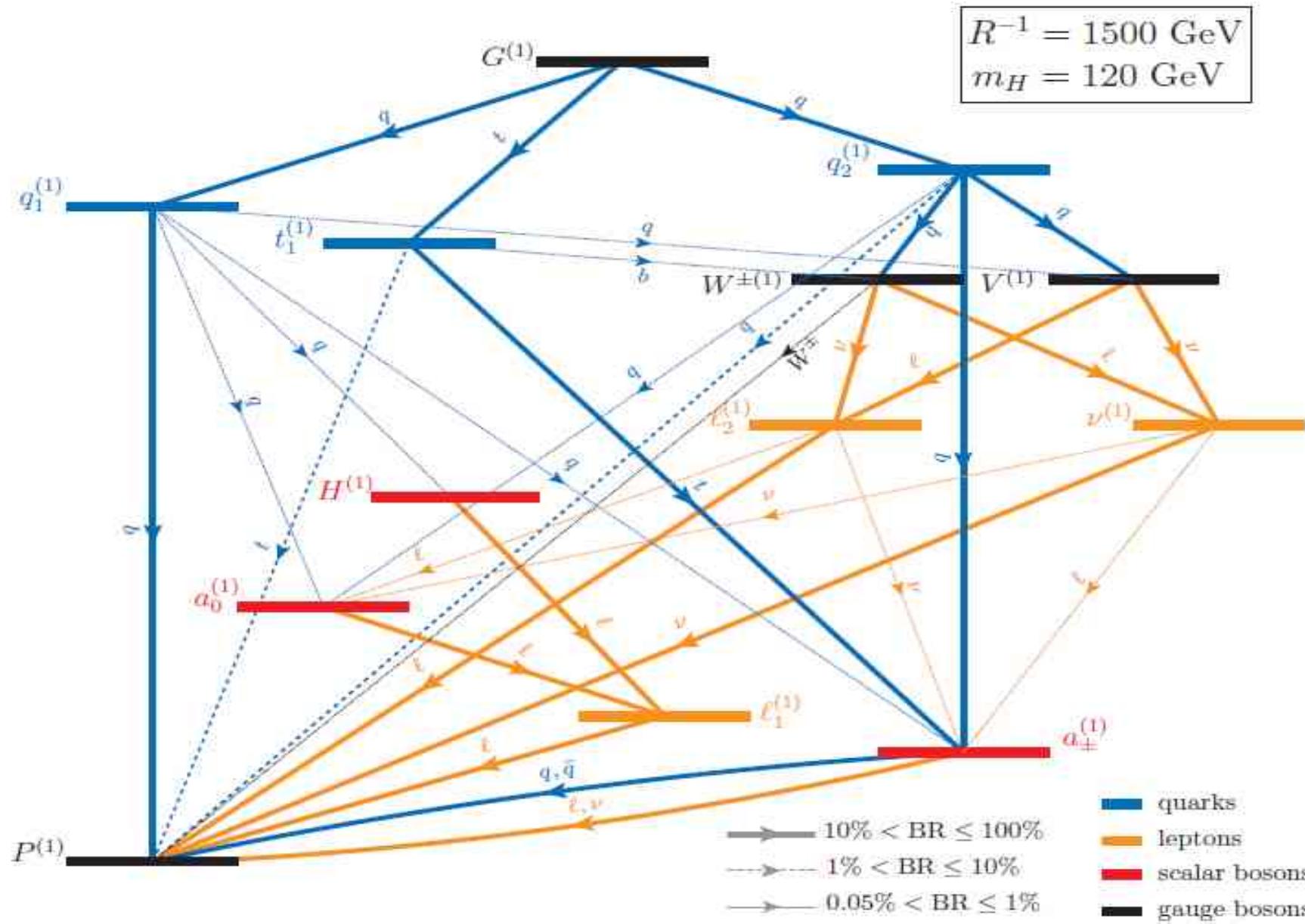
Extra U(1)': Z', heavy long leaving neutrino

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



# Universal Extra Dimensions

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



# Universal Extra Dimensions

- Set up of the production and decay processes with the calchep\_batch

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

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

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

- Scan in 2D space with the calchep\_batch

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

# Results from calchep\_batch

## CalcHEP Batch Details

[Home](#)  
[Symbolic Results](#)  
[Numerical Results](#)  
[Events Library](#)  
[Process Library](#)  
[Help](#)

Thank you for  
using CalcHEP!  
Please cite  
arXiv:0000.0000

### MUED-Chloe-2KK

**Done!**

	<b>Finished</b>	<b>Time(hr)</b>
Symbolic	6498/6498	0.00
$\sigma$	4/4	3.29
Events	4/4	7.30

# Results from calchep\_batch

## Symbolic Sessions

[Home](#)  
[Symbolic Results](#)  
[Numerical Results](#)  
[Events Library](#)  
[Process Library](#)  
[Help](#)

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### MUED-Chloe-2KK

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

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

-a_1->N1,~e2_1	✓
-a_1->N1,~e1_1	✓
-a_1->H,~W_1	✓
-a_1->Z,~W_1	✓
-a_1->A,~W_1	✓
-a_1->W,~V_1	✓
-a_1->W,~P_1	✓
Widths	✓

# Results from calchep\_batch

## Numerical Sessions

[Home](#)  
[Symbolic Results](#)  
[Numerical Results](#)  
[Events Library](#)  
[Process Library](#)  
[Help](#)

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arXiv:0000.0000

### MUED-Chloe-2KK

Done!

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

# Results from calchep\_batch

## Numerical Sessions

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Symbolic Results  
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Help

Thank you for  
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arXiv:0000.0000

### MUED-Chloe-2KK

Done!

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

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

~a_-1->N1,~e1_1	1.3688 $\times 10^{-14}$	14954	0.00	255000/254999	prt_1 session.dat
~a_-1->H,~W_-1	0	14991	0.00	0/254999	prt_1 session.dat
~a_-1->Z,~W_-1	0	15098	0.00	0/254999	prt_1 session.dat
~a_-1->A,~W_-1	0	15172	0.00	0/254999	prt_1 session.dat
~a_-1->W,~V_-1	0	18314	0.00	0/254999	prt_1 session.dat
~a_-1->W,~P_-1	0	18320	0.00	0/254999	prt_1 session.dat

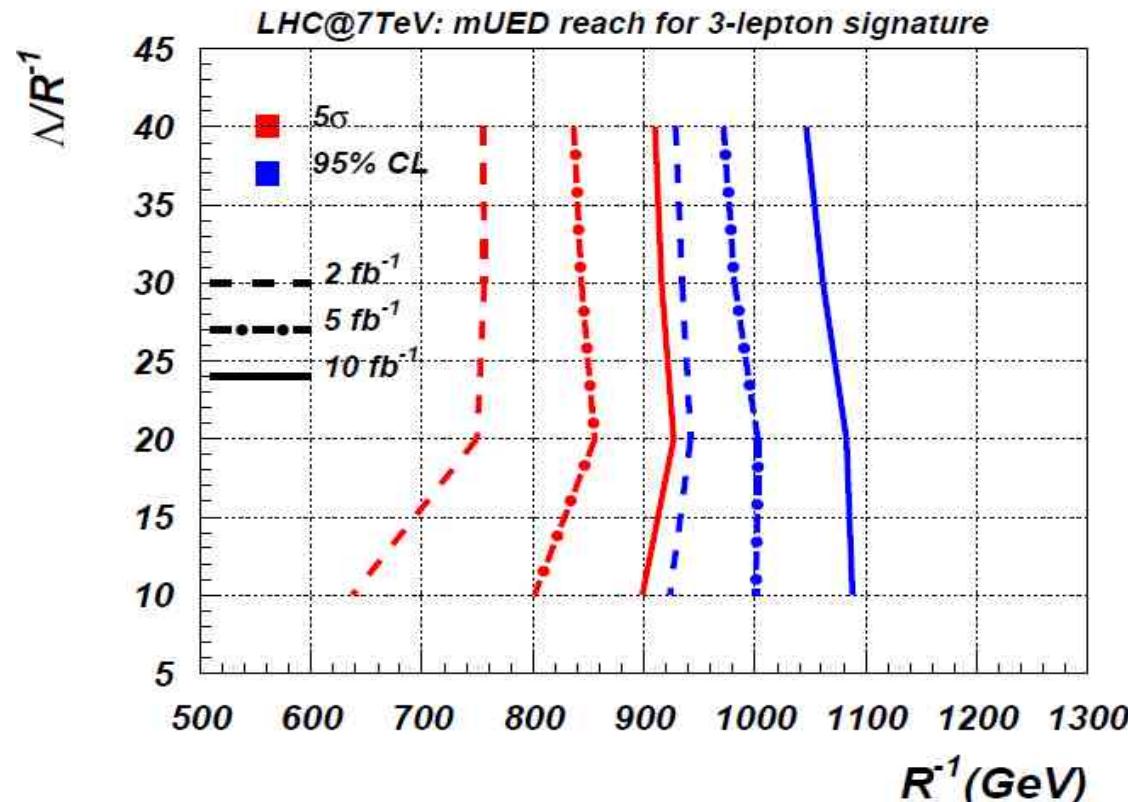
Widths	PID	Time (hr)	Details
Widths	18342	0.00	session.dat
Total	5126	20.68	

# Results from calchep\_batch

## CalcHEP Events Library

Home  
Symbolic Results  
Numerical Results  
Events Library  
Process Library

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



# Some highlights of the CalcHEP

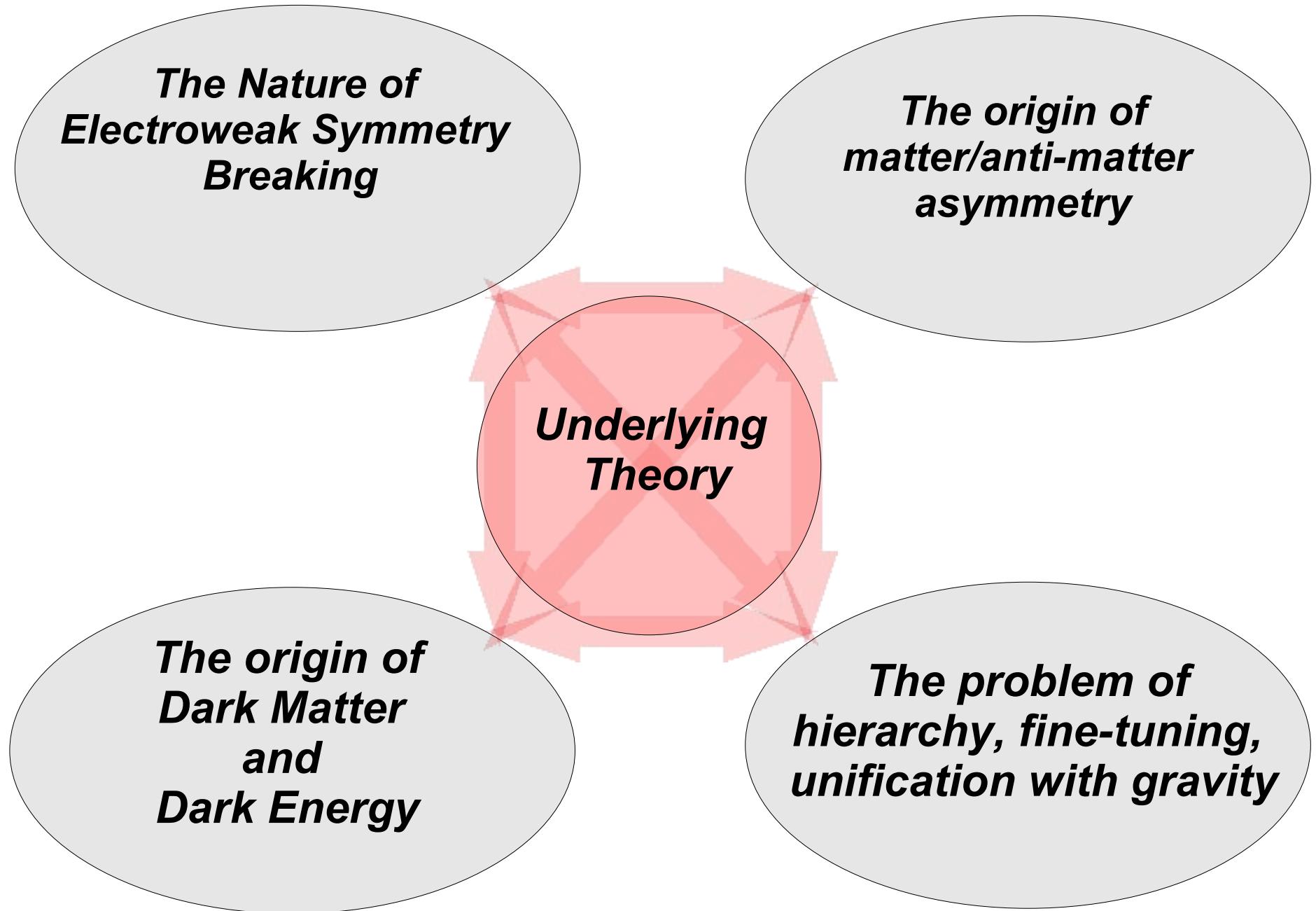
- Convenient graphical interface
- Calculates particle widths 'on the fly'
- Allows to edit diagrams as well as squared diagrams – important for the dedicated interference studies
- Easy to modify an existing model (GUI) or to implement the new one (LanHEP, FeynRules)
- Powerful batch interface – connects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

## Outlook

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

# HEPMDB

# What underlying theory should explain?

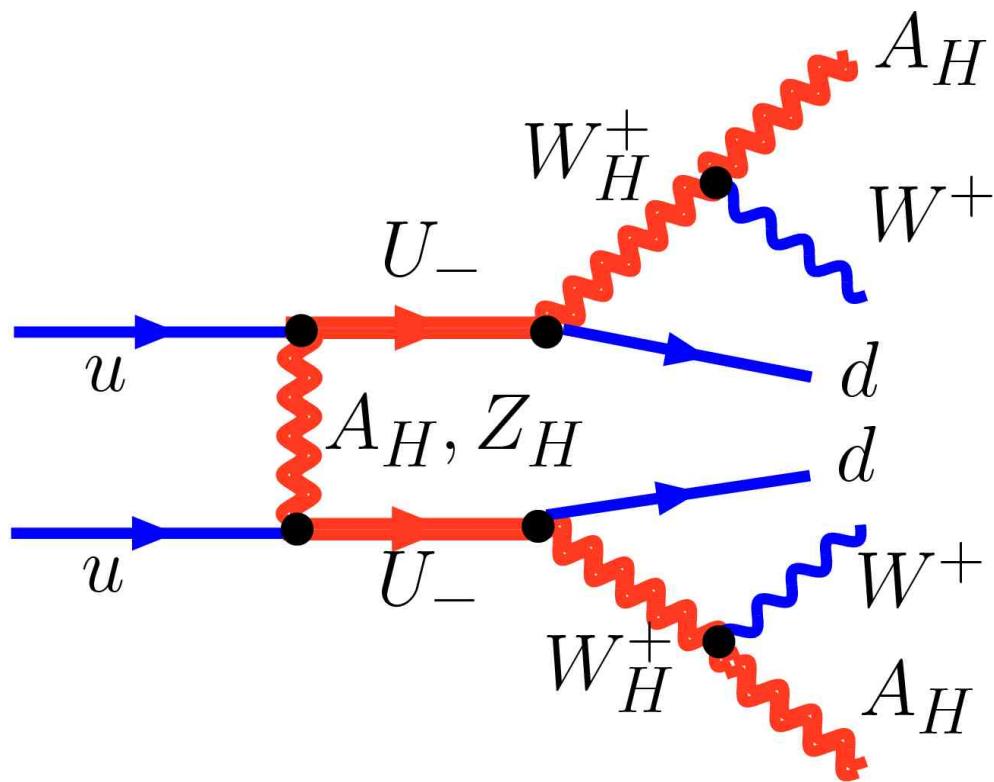


# Promising candidates for underlying theory

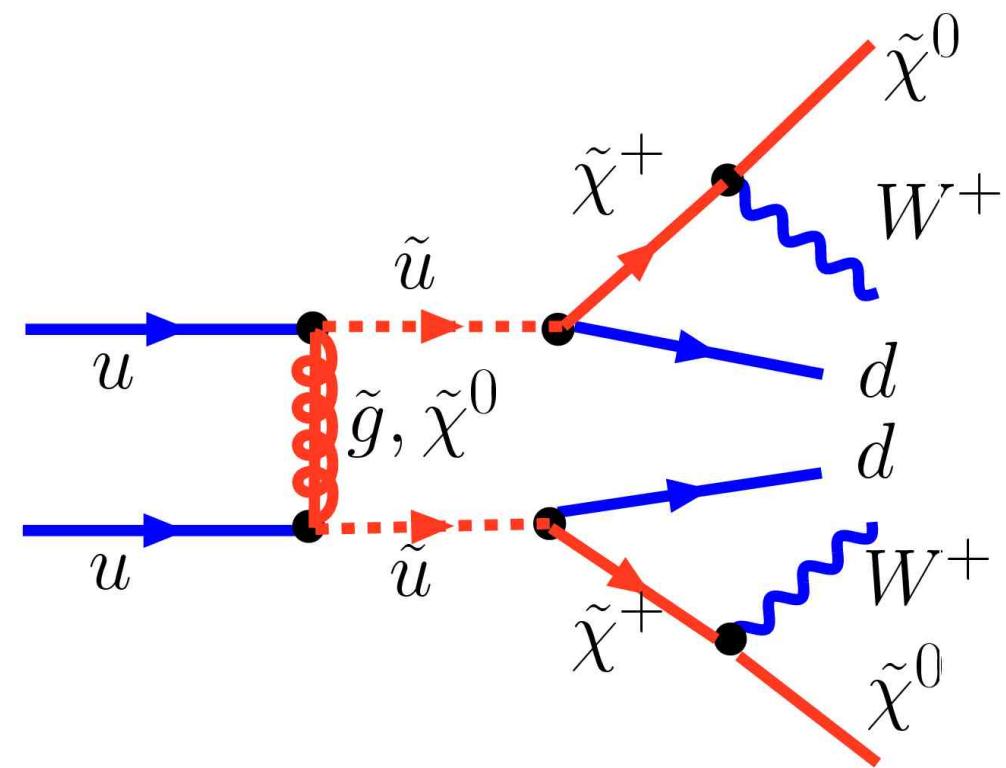
- ***Supersymmetry:***
  - ***cMSSM, MSSM, NMSSM,  $E_6$ SSM, ...***
- ***Walking Technicolor***
- ***Extradimensional Models:***
  - ***Universal and Warp extra dimensions***



# Signatures could look alike

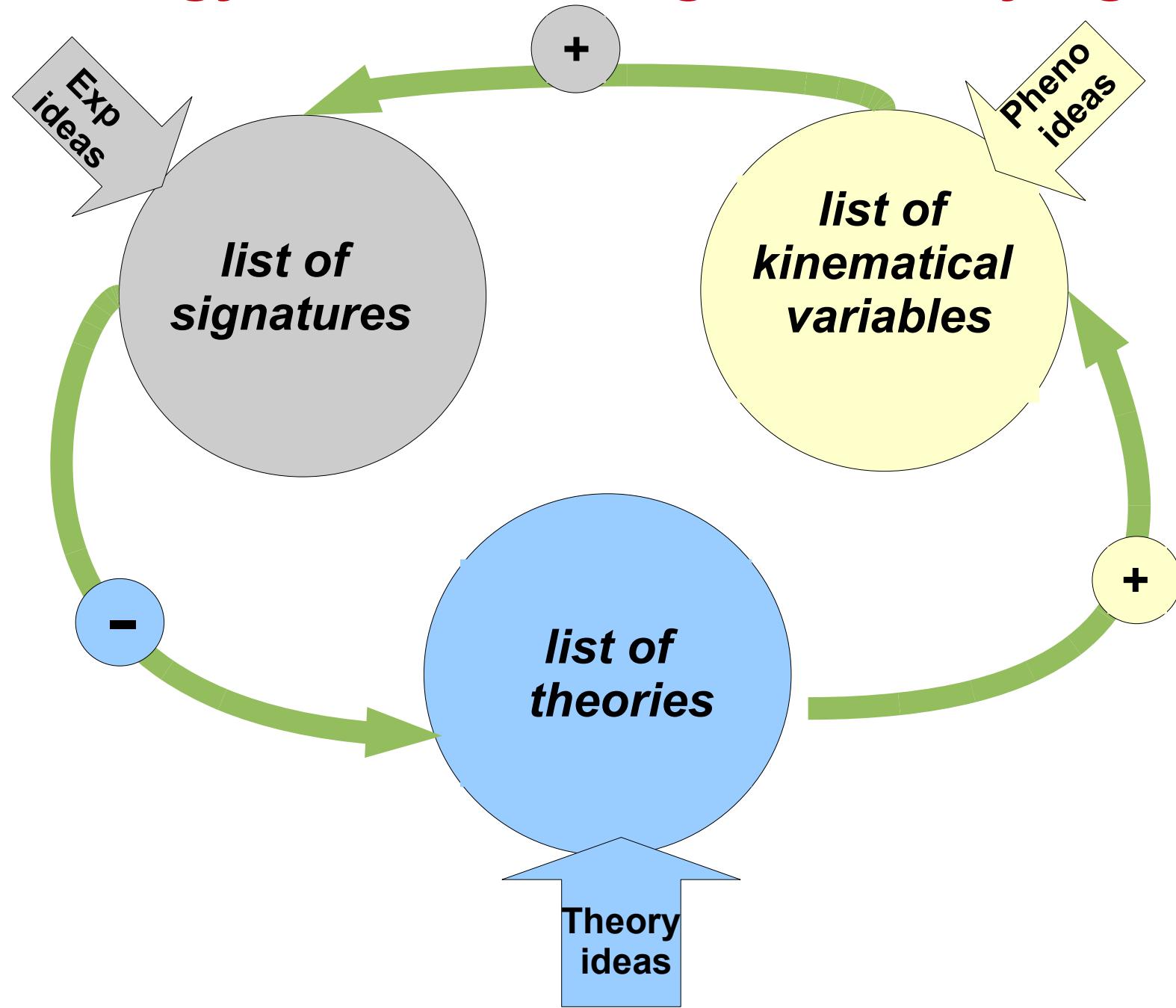


LHT

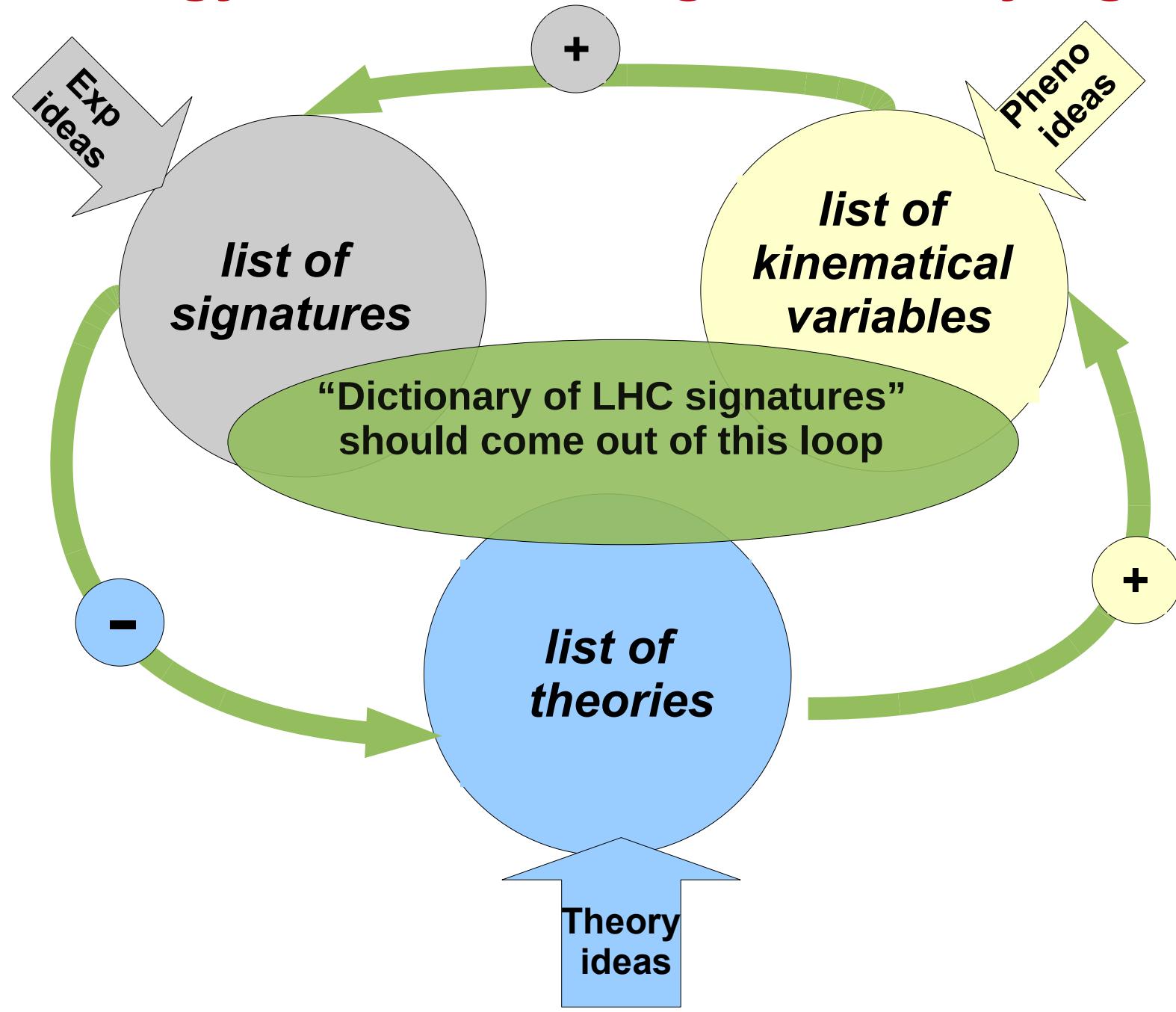


SUSY

# The strategy for delineating of underlying theory



# The strategy for delineating of underlying theory



# First Steps towards “Dictionary”

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

Variables	SUSY (MSSM)	LHT	UED
Spin	heavy partners differ in spin by 1/2	heavy partners have the same spin, no heavy gluon	heavy partners have the same spin
Higher level modes	NO heavy partners	NO heavy partners	YES heavy partners
$N_{l+l+}/N_{l-l-}$	$R_{\text{SUSY}} < R_{\text{LHT}}$	$R_{\text{LHT}}$	$R_{\text{UED}} \simeq R_{\text{LHT}}$
SS leptons rates	from several channels: SS heavy fermions, Majorana fermions	only from SS heavy fermions	only from SS heavy fermions
$R = \frac{N(\cancel{E}_T + \text{jets})}{N(l' s + \cancel{E}_T + \text{jets})}$	$R_{\text{SUSY}}$	$R_{\text{LHT}} < R_{\text{SUSY}}$	$R_{\text{UED}}$ to be studied
b-jet multiplicity	enhanced (FP)	not enhanced	not enhanced
Single heavy top	NO	YES	YES via KK2 decay
polarization effects	$t\bar{t} + \cancel{E}_T$ $\tau\tau + \cancel{E}_T$	to be studied to be studied	to be studied to be studied
Direct DM detection rate	high (FP) low (coann)	low (Bino-like LTP)	typically low for $\gamma_1(5\text{D})$ DM [22] typically high for $\gamma_H(6\text{D})$ DM [22]

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

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

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

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

**High Energy Physics Model Database  
[HEPMDB]**

# High Energy Physics Model Database

## <https://hepmdb.soton.ac.uk/>

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HEPMDB

High Energy Physics Models DataBase

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Search in HEPMDB



Show All Models

## About HEPMDB

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

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

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

To become an 'Author', you should register in a 'Register' section. 'Authors' are welcomed to also upload LanHEP or FeynRules source of their models.

## Validation

## News

### **CalcHEP and HEPMDB: practical introduction and tutorial**

2012-05-03 23:13:13

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

[More »](#)

### **LHAPDF package is added**

2012-03-25 12:55:34

LHAPDF is installed at HEPMDB and can be used now. To use LHAPDF installed at HEPMDB with CalcHEP models one should add -L\$HOME/lhapdf/lib/ -ILHAPDF line to your extlibN.mdl file. P.S. All news about HEPMDB like this one will be sent to all users registered at HEPMDB (they also should have an option not to receive these news if they want)

[More »](#)

### **Miniworkshop on High Energy Physics Model Database (HEPMDB)**

2012-05-03 23:15:00

Miniworkshop on High Energy Physics Model Database (HEPMDB). At IPPP at Durham we have a one-day mini-workshop on High Energy Physics Model Database (HEPMDB). The schedule and registration are available at <http://indico.cern.ch/event/hepmdb>

# High Energy Physics Model Database

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

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

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

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

### Abstract

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

# Aims of the HEPMDB (1)

- *to collect HEP models for various multipurpose Matrix Element (ME) generators like CalcHEP, CompHEP, FeynArts, MadGraph/MadEvent, AMEGIC ++/COMIX within SHERPA and WHIZARD.*

*Under “HEP models” we denote the set of particles, Feynman rules and parameters written in the format specific for a given package*

- *to collect models’ sources which can be used in the HEPMDB to generate HEP models for various ME generators using FeynRules or LanHEP which automate the process of generating Feynman Rules, particle spectra, etc..*

*For the moment, FeynRules supports formats for CompHEP, CalcHEP, FeynArts, GoSam, MadGraph/MadEvent, SHERPA and WHIZARD. Currently LanHEP works with CalcHEP, CompHEP, FeynArts and GoSam. Also, the latest LanHEP version 3.15 has an option under testing of outputting the model in UFO format which provides a way to interface it with MadGraph/MadEvent*

- *to allows users upload their models and perform evaluation of HEP processes and event generation for their own models using the full power of the High Performance Computing (HPC) cluster behind the HEPMDB.*

*This is one of the very powerful features of the HEPMDB: it provides a web interface to various ME generators which can then also be run directly on the HPC cluster. This way, users can preform calculations for any model from HEPMDB avoiding problems related to installing the actual software, which can sometimes be quite cumbersome*

# Aims of HEPMDB (2)

- to plot and document various kinematical distributions from generated events in the LHE format
- to allow to compare predictions from models generated from LanHEP and FeynRules
- to collect predictions and specific features of various models in the form of database of signatures and perform comparison of various model predictions with experimental data (to be developed)  
*There are a lot of different aspects related to this problem. This task includes a comprehensive development of a database of signatures as well as development of the format of presentation of these signatures. This format will be consistent with the format which will be used by the experimentalists for the presentation of the LHC data, discussed in the context of the “Les Houches Recommendations for the Presentation of LHC Results” activity.*
- to trace the history of the model modifications, and makes available all the versions of the model  
*Through this application, we stress the importance of reproducibility of the results coming from HEPMDB or from a particular model downloaded from HEPMDB.*

# Sounding similar but qualitatively different related projects

- “Database of Numerical HEP scattering cross sections”  
<http://durpdg.dur.ac.uk/HEPDATA/REAC>  
collects various particle scattering process which are connected to experimental searches of different reactions
- “Signatures of New Physics at the LHC” web-site  
<http://www.lhcnewphysics.org/>  
collects various BSM signatures, their classification and related papers
- FeynRules and models database  
<http://feynrules.irmp.ucl.ac.be>  
collects various models implemented into FeynRules and have an effective way to validate them
- **HEPMDB can effectively collaborate with all projects above!**

# The current status of HEPMDB (1)

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

Search in HEPMDB  Show All Models

---

**Search Models :: Results for [MSSM]**

- MSSM** [2011-06-21 10:54:07] hepmdb:0611.0028  
*CalcHEP/MicrOMEGAs groups*  
We present MSSM with SUGRA and AMSB scenario as well as MSSM with low energy input. Read file INSTALLATION for model installation and file CITE for references on scientific publications which pre...
- MSSM (Whizard)** [2011-12-30 04:38:49] hepmdb:1211.0047  
*Christian Speckner*  
MSSM model for Whizard...
- RPV MSSM** [2012-02-17 18:30:58] hepmdb:0212.0049  
*Uploaded by Metin Ata, created by Benjamin Fuks*  
(taken from FeynRules web page) Our implementation keeps all the flavour-violating and helicity-mixing terms in the Lagrangian and also all the possible additional CP-violating phases. In order to de...

# The current status of HEPMDB (2)

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

Model : MSSM

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

## Authors

CalcHEP/MicrOMEGAs groups

## Added By

Alexander Belyaev

## References

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

## Abstract

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

## Information

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

## Tools

CalcHEP [model]

## Model History

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

[Download Model File](#)

[Validate Model on HPCx](#)

[Edit Model](#)

## Reviews

# The current status of HEPMDB (3)

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

# Future prospects for HEPMDB (months scale)

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

# Future prospects for HEPMDB (~year time scale)

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

# Tutorial

HEPMDB

High Energy Physics Models DataBase

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About HEPMDB

HEPMDB is created to facilitate the connection between High Energy theory and experiment, to store and validate theoretical models, to develop dictionary of the model signatures aimed to identify the fundamental theory responsible for signals expected at the LHC. HEPMDB is also designed for collecting different signatures for its models as well as respective experimental efficiencies. Using this information HEPMDB will be able to compare its BSM model predictions with LHC data which will allow to disentangle underlying theory. The database is in the development stage and your input is the "Forum". The database is highly transparent. Published code is freely available. Models and their codes are stored in public and represent them as a set of Feynman Rules code that can be in form of input for any of Matrix Element generators such as CalcHEP, CompHEP, FeynArts, Madgraph, SHERPA, WHIZARD. HEPMDB has an entrance for Model authors - 'Authors' where Authors can test and validate their models. To become an 'Author', you should register in a 'Register' section. 'Authors' are welcomed to also upload LanHEP or FeynRules source of their models.

Validation

Test and model validation will be available in the nearest future and would include the computing of theoretical predictions for your model on our site via submitting jobs into the High Performance Computing Cluster (HPC) at University site. It will also allow to run Feynman Rules generators - LanHEP and FeynRules through the HPC. You will learn news about this option in 'Forum' section. HEPMDB also collects signatures of Particle Physics Models, for which we suggest to use keywords which 'Authors' supposed to assign to their models. The database of signatures is in the permanent development and is available in the 'Signatures' section. Information and links on relevant packages, e.g. Matrix Element generators or Feynman Rules generator is located in the section 'Tools'.

HEPMDB

New: High Energy Physics Models DataBase

Home My Models Calculate Upload model Tools Signatures Contact Us Admin

User: Alexander Belyaev | Logout

Search in HEPMDB

Show All Models

2011-0

A new is available from or possibly

model is well

More...

IBM

2011-0

We now confirm

that all will be i

26th Si

More...

Iridis

We now confirm

that all will be i

26th Si

More...

RPV MSSM [2012-02-17 18:30:58] hepmdb:0212.0049

Uploaded by Metin Ata, created by Benjamin Fuks

(taken from FeynRules web page) Our implementation keeps all the flavour-violating and helicity-mixing terms in the Lagrangian and also all the possible additional CP-violating phases. In order to do...

2. 3-site model (Whizard) [2011-12-30 04:41:37] hepmdb:1211.0048

Christian Speckner

3-site model for Whizard...

3. MSSM (Whizard) [2011-12-30 04:38:49] hepmdb:1211.0047

Christian Speckner

MSSM model for Whizard...

4. nMSSM [2011-12-30 04:23:30] hepmdb:1211.0046

from CalcHEP group

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High Energy Physics Models DataBase

User: Alexander Belyaev | Logout

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Upload Model

Please fill the fields to add Model

Model Name:\*

Authors:\*

Summarise:\*

Description:

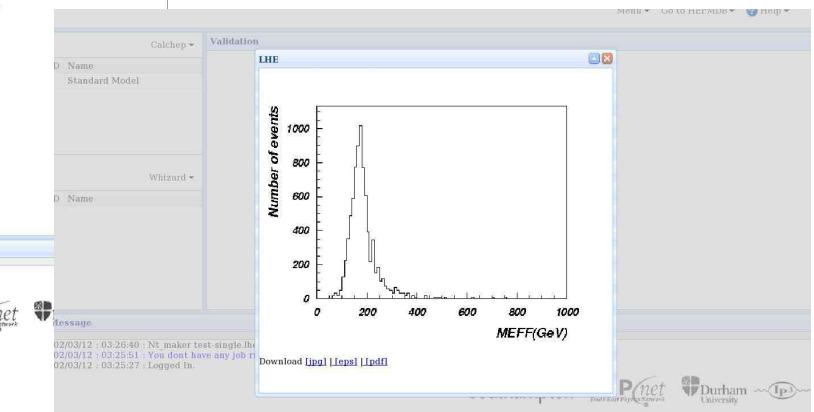
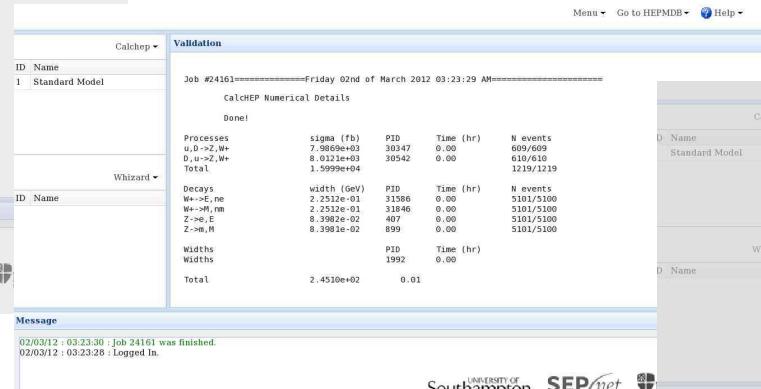
Model changed: False  
Gauge: Feynman

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

Composite: ps=U,D,d,D,G
Composite: le=e,E,s,M
Composite: n=ne,Ne,ns,Mn

#####
# PDF Info
# Choices are:
# cteq6l (anti-proton)
# cteq6l (proton)
# mst2002lo (anti-proton)
#
Message
02/03/12 : 03:21:58 : You successfully sub
02/03/12 : 03:21:01 : You dont have any jo
02/03/12 : 03:21:00 : Logged In.

Load full batch Save
SEPnet
South East Physics Network
```



# Tutorial

## HEPMDB

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## About HEPMDB

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

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

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

## News

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

2012-07-10 18:52:13

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

[More »](#)

### CalcHEP and HEPMDB: practical introduction and tutorial

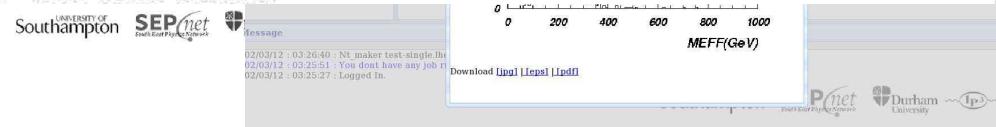
2012-05-03 23:13:13

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

[More »](#)

### LHAPDF package is added

2012-03-25 12:55:34



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About HEPMDB

HEPMDB is created to f...  
models, to develop dict...  
expected at the LHC. Hi...  
experimental efficiency  
which and would allow to  
"For authors is highly  
represent them. Have a  
CalcHEP, CompHEP, Fey...  
Authors can test and va...  
welcomed to also uploa...

Validation

Test and model validatio...  
your model on our site s...  
allow to run Feynman Ru...  
'Forum' section, HEPMD...  
'Authors' supposed to a...  
the 'Signatures' section...  
generator is located in t...

## HEPMDB

### High Energy Physics Models DataBase

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Show All Models

## Search Models :: Results for [MSSM]

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

*CalcHEP/MicrOMEGAs groups*

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

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

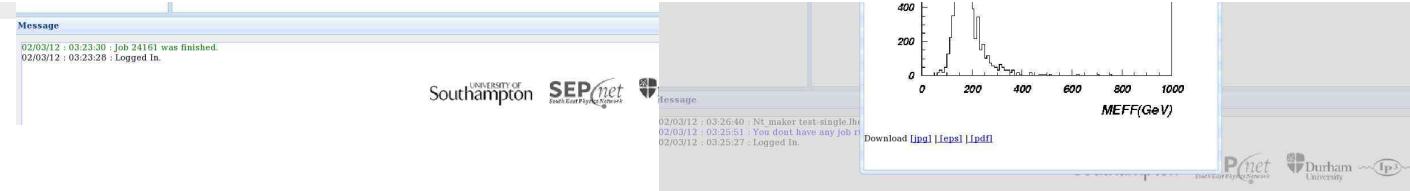
*Florian Staub*

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

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

*Florian Staub*

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



# Tutorial

HEPMDB  
High Energy Physics Models DataBase

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About HEPMDB

HEPMDB is created to facilitate the connection between High-Energy theory and experiment: to store and validate theoretical model

experiments which are represented by CalcHEP

and welcome to the High Energy Physics Models DataBase

HEPMDB

High Energy Physics Models DataBase

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HEPMDB  
New: High Energy Physics Models DataBase

User: Alexander Belyaev | Logout  
Home My Models Calculate Upload model Tools Signatures Contact Us Admin

User: Alexander Belyaev | Logout

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Show All Models

## Upload Model

Please fill the fields to add Model

Model Name:\*

Authors:\*

Summarise:\*

Description:



UNIVERSITY OF Southampton SEPnet Durham University ~IP~

# Tutorial

HEPMDB  
High Energy Physics Models DataBase

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Search in HEPMDB

About HEPMI

HEPMDB is created to store models, to develop them and to expect at the experimental results which and when they will be observed. It also represents them. CalCHEP, Comp Authors can test and welcome to all.

ID	Name
1	Standard Model

Test and model your model on, allow to run Fe, 'Forum' section, 'Authors' support the 'Signatures' generator is located here.

Calchep ▾

Validation

Whizard ▾

ID Name

Message

02/03/12 : 03:21:58 : You successfully submitted your job.  
02/03/12 : 03:21:01 : You don't have any job.  
02/03/12 : 03:21:00 : Logged In.

Model: Standard Model  
Model changed: False  
Gauge: Feynman

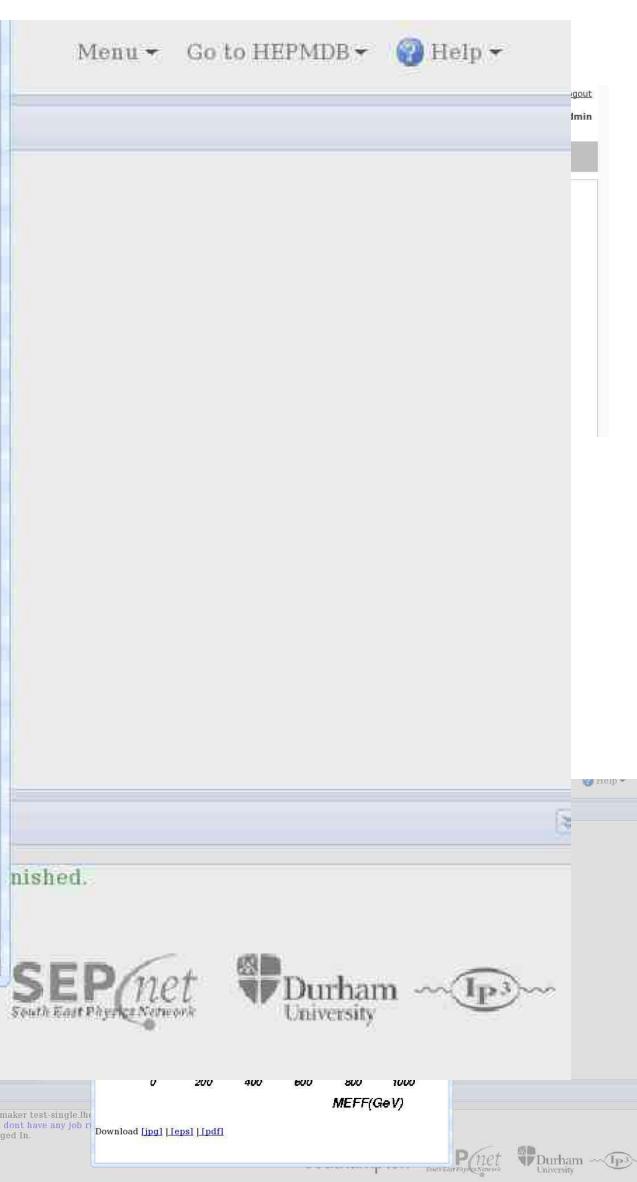
```
#####
# Process Info
# Process specifies the process. More than one process can be specified. Cuts, regularization and QCD scale should be specified for each one.
# Decay specifies decays. As many decays as are necessary are allowed.
# Composite specifies composite particles present in the processes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

Composite: p=u, U, d, D, G
Composite: le=e, E, m, M
Composite: n=n, Ne, nm, Nm
```

#####
# PDF Info
# Choices are:
# cteq6l (anti-proton)
# cteq6l (proton)
# mrst2002lo (anti-proton)

Load full batch  Save

SOUTHAMPTON



# Batch file in details(1)

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

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

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

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

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

# Batch file in details(2)

```
# Default: 0.4          #
# Number of particles   #
# Ignored unless ISR & Beam chosen. #
# Default: 2E+10        #
# Default Beamstrahlung parameters #
# correspond roughly with ILC.    #
#                                     #
# Equiv. Photon, Laser photons and #
# Proton Photon are available for #
# photons.                      #
# Default pdf: OFF            #
# Photon particle           #
# Ignored unless Equiv. Photon chosen. #
# Choices are: mu^-,e^-,e^+,mu^+ #
# Default: e^+              #
# |Q1|max                 #
# Ignored unless Equiv. Photon chosen. #
# Default: 100              #
# Incoming particle mass      #
# Ignored unless Proton Photon chosen. #
# Default: 0.938             #
# Incoming particle charge     #
# Ignored unless Proton Photon chosen. #
# Choices are: 1,-1           #
# Default: 1                  #
# |Q^2|1max                #
# Ignored unless Proton Photon chosen. #
# Default: 2                  #
# Pt cut of outgoing proton    #
# Ignored unless Proton Photon chosen. #
# Default: 0.1                #
#####
pdf1:      cteq6l (proton)
pdf2:      cteq6l (proton)

#Bunch x+y sizes (nm) : 202500
#Bunch length (mm)   : 10
#Number of particles : 5E+11
#Photon particle      : e^- 
#|Q1|max               : 250
#Incoming particle mass: 0.938
#Incoming particle charge: -1
#|Q^2|1max             : 2.0
#Pt cut of outgoing proton: 0.15
#####
# Momentum Info          #
# in GeV                 #
#####
p1:      4000
p2:      4000
#####
# Parameter Info          #
# Masses and Energies are in GeV #
#####
#Parameter: EE=0.31
#####
# Run Info                #
# Masses and Energies are in GeV #
# More than one run can be specified at #
# the same time.             #
#####
Run parameter: Mh
Run begin:   120
Run step size: 5
Run n steps:  3
```

# Batch file in details(3)

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

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

```
#####
# Cut Info                  #
# Must be in terms of the (production mode) #
#   final state particles.                   #
#   :n: specifies which process.           #
#   : means to apply to all processes.      #
#####
Cut parameter: M(b,B)
Cut invert: False
Cut min: 100
Cut max:

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

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

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

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

# Batch file in details(4)

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

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

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

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

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

```
#####
# Events Generation          #
# Number of events determines how many    #
# events to produce for each run.         #
# Filename is the name used for the event #
# files. If no parameter is run over     #
# then, -Single.lhe is appended. If       #
# a parameter is run over then its       #
# value will be appended as in          #
# pp-WW-MM400.lhe.                      #
# NTuple determines whether PAW ntuples   #
# are created. This only works if        #
# nt_maker is properly compiled and      #
# in the bin directory.                 #
# Choices are True or False.            #
# Cleanup determines whether the         #
# individual event files are removed    #
# after they are combined.              #
# Default: True.                      #
#####
Number of events (per run step): 1000
Filename: test
NTuple: False
Cleanup: False
```

# Batch file in details(5)

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

Parallelization method:      local
#Que:                      brody_main
#Walltime:                  0.15
#Memory:                    1
#email:                     name@address
Max number of cpus:          2
sleep time:                 3
nice level :                19
```

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

nSess_1: 5
nCalls_1: 100000
nSess_2: 5
nCalls_2: 100000

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

#sub-cubes: 100000
#random search: 100
#simplex search: 50

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

# Tutorial

HEPMDB  
High Energy Physics Models DataBase

Login | Register  
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Search in HEPMDB Show All Models

About HEPMI  
HEPMDB is created by the experimentalists who want to represent their CalcHEP, Comp. Authors can tell us about it.

Calchep Validation Calchep ▾

ID	File Name
1	Standard Model(CKM=1)

Test and model on allow to run the 'Forum' section 'Authors' supports the 'Signatures' generator is located in the sidebar.

ID Name  
1 Standard Model

Whizard

Madgraph 5

Message  
02/03/12 : 03:21  
02/03/12 : 03:21  
02/03/12 : 03:21

Validation Job #1628195.blue30=====Wednesday 01st of August 2012 09:55:37 PM=====

CalcHEP Numerical Details

Done!

Scans	sigma (fb)	Running	Finished	Time (hr)	N events
Mh120	9.8870e+02	0/13	13/13	0.01	10000
Mh125	9.7740e+02	0/13	13/13	0.01	10000
Mh130	9.6810e+02	0/13	13/13	0.02	10000

Mh120.txt CalcHEP Numerical Details

Done!

Processes	sigma (fb)	unc (%)	PID	Time (hr)	N events
u, D->W+, b, B	1.3296e+03	4.59e-01	0	0.00	3258/3258
U, d->W-, b, B	7.2163e+02	5.03e-01	0	0.00	1822/1822
d, U->W-, b, B	7.1638e+02	4.39e-01	0	0.00	1810/1810

Message  
01/08/12 : 21:56:05 : Nt\_maker test-Mh120.lhe  
01/08/12 : 21:56:04 : gunzip file test-Mh120.lhe.gz  
01/08/12 : 21:55:38 : Job 1628195.blue30 was finished.  
01/08/12 : 21:38:29 : You successfully submitted a job on HPCx : #1628195.blue30 . You will be notified by email when the job is finished.

Message  
02/03/12 : 03:26:40 : Nt\_maker test-single.lhe  
02/03/12 : 03:25:51 : You don't have any job(s)  
02/03/12 : 03:25:27 : Logged In.

Download [jpg] [eps] [pdf]

MEFF(GeV)

Pnet Durham University IP

# Tutorial

HEPMDB  
High Energy Physics Models DataBase

Search in HEPMDb

Show All Models

Login | Register

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About HEPMDb

HEPMDB is created to facilitate the communication of models, to develop dictionary of the models expected at the LHC. HEPMDb is also designed to experimental efficiencies. Using this information and we will allow to disseminate the "FeynRules" generator is highly appreciated, but represent them as a set of Feynman's CalcHEP, CompHEP, FeynArts, Madgraph. Authors can test and validate their models, welcomed to also upload LanHEP or FeynRules.

Validation

Test and model validation will be available on your model on our site via submitting jobs to run FeynRules generators - "Forum" section. HEPMDb also collects site "Authors" supposed to assign to their models the "Signatures" section. Information about the generator is located in the section "Tools".

Name:  
Standard Model

Name:  
Whizard

Name:

Calchep Validation

ID Name  
1 Standard Model

Whizard

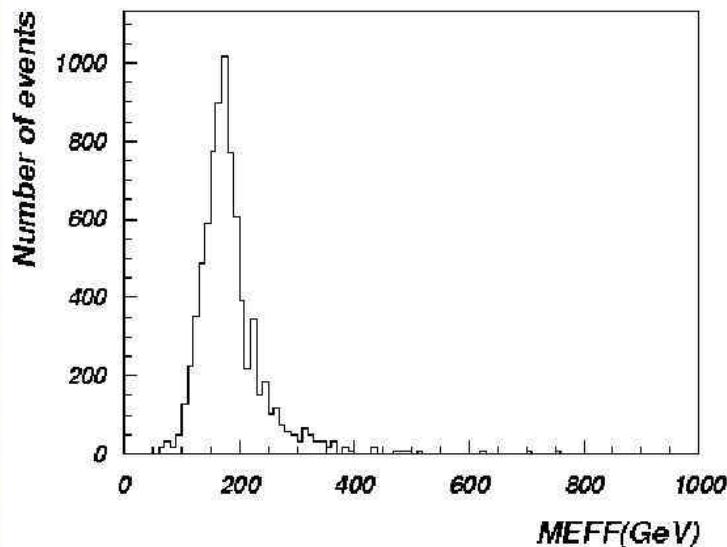
ID Name

Message

02/03/12 : 03:26:40 : Nt\_maker test-single.lhe  
02/03/12 : 03:25:51 : You dont have any job running.  
02/03/12 : 03:25:27 : Logged In.

Message  
02/03/12 : 03:21:58 : You successfully submitted your job.  
02/03/12 : 03:21:01 : You dont have any job running.  
02/03/12 : 03:21:00 : Logged In.

LHE



Download [\[jpg\]](#) [\[eps\]](#) [\[pdf\]](#)



Message

02/03/12 : 03:23:30 : job 24161 was finished.  
02/03/12 : 03:23:28 : Logged In.

UNIVERSITY OF Southampton SEPnet Durham University IP3

# *Example of models created for CalcHEP*

- **SM + extensions**

- SM
- B-L symmetric Z' with heavy Majorana neutrinos
- SM + Z'
- general 2 Higgs doublet model
- 4th generation
- Excited fermions
- Model with contact interactions
- Standard Model + anomalous gauge boson couplings
- Model of strongly int EW sector  
(5 & 6 dim operators involving Sigma field)

- **SUSY**

- constraint MSSM
- general MSSM, with 124 free parameters
- NMSSM
- RPVMSSM
- left-right symmetric MSSM
- MSSM with CP violation
- E6MSSM

- **Extra dimensions**

- 5D UED with 2KK layers
- 6D UED with 2KK layers
- ADD = ADD
- RS = Randall Sundrum

- **Leptoquarks**

- Complete LQ model  
SU(3)xSU(1)xU(1) vector&scalar

- **Technicolor & Higgsless**

- Minimal walking technicolor
- TC with DM
- 3-site model
- Hidden Local symmetry model
- 4SM = general 4-site model

- **Little Higgs**

- Littlest higgs model with T-parity
- LHT + T-parity violation

# *Models at FeynRules web-site*

---

## Standard Model

The SM implementation of FeynRules, included into the distribution of the FeynRules package.

---

## Simple extensions of the SM (10)

Several models based on the SM that include one or more additional particles, like a 4th generation, a second Higgs doublet or additional colored scalars.

---

## Supersymmetric Models (4)

Various supersymmetric extensions of the SM, including the MSSM, the NMSSM and many more.

---

## Extra-dimensional Models (4)

Extensions of the SM including KK excitations of the SM particles.

---

## Strongly coupled and effective field theories (4)

Including Technicolor, Little Higgs, as well as SM higher-dimensional operators.

---

## Miscellaneous (0)

# Remarks on collecting models at HEPMDB

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

# Summary on HEPMDB

- HEPMDB is already a convenient centralized storage environment for HEP models. Via web interface to the HPC cluster (12 cores per user) it allows to evaluate the LHC predictions and event generation-simulation chain
- Your relevant packages can be installed at HEPMDB!
- we hope that starting from the present stage, HEPMDB development will be boosted further via involvement of the HEP community  
(via direct involvement into HEPMDB, via various projects involving HEPMDB, via numerous comments/requests for HEPMDB features)
- we hope also that in the near future the HEPMDB will become a powerful tool for isolation of the most successful theory for explaining the LHC data