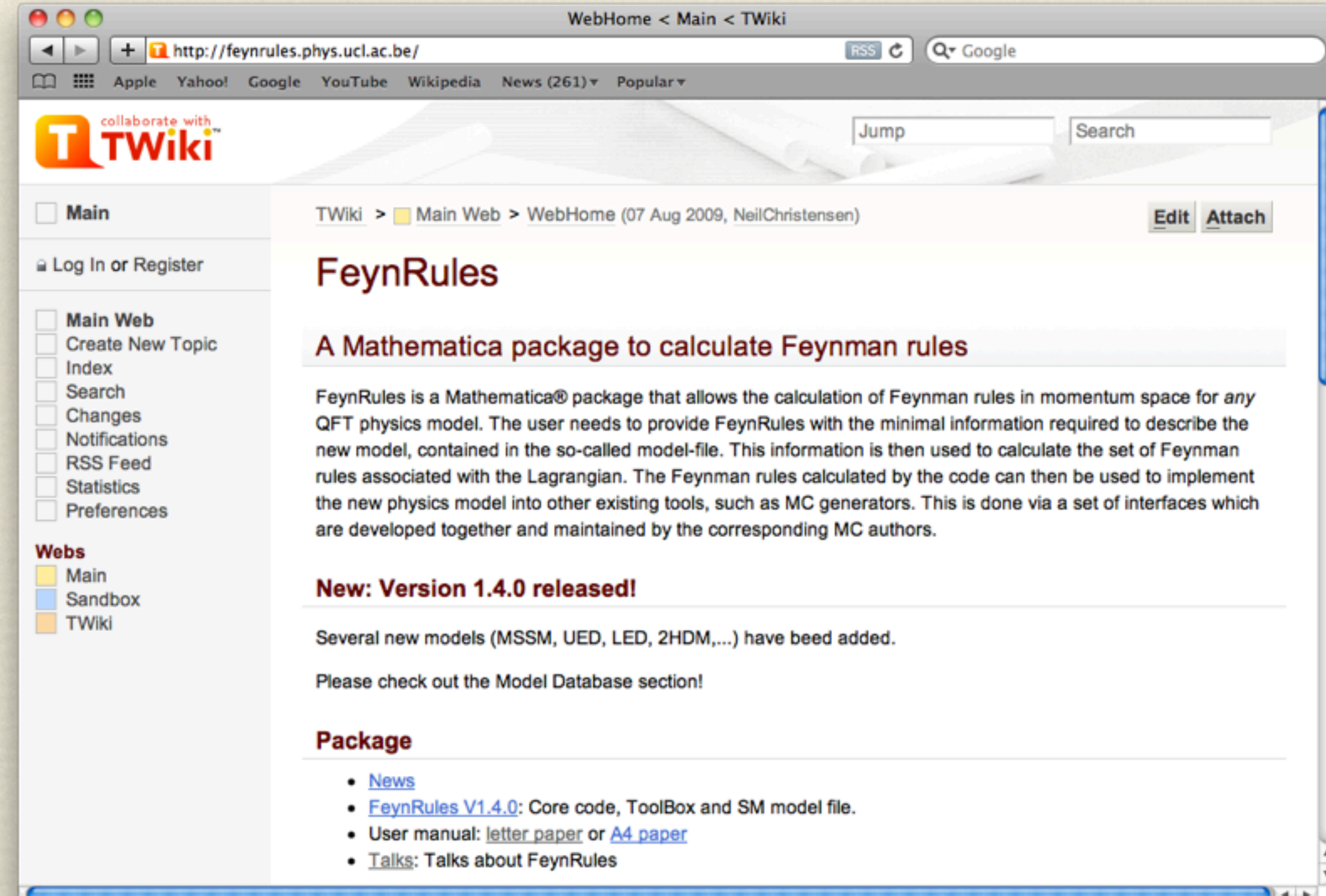
BSM
with
FeynRules

Neil Christensen
University of Wisconsin - Madison

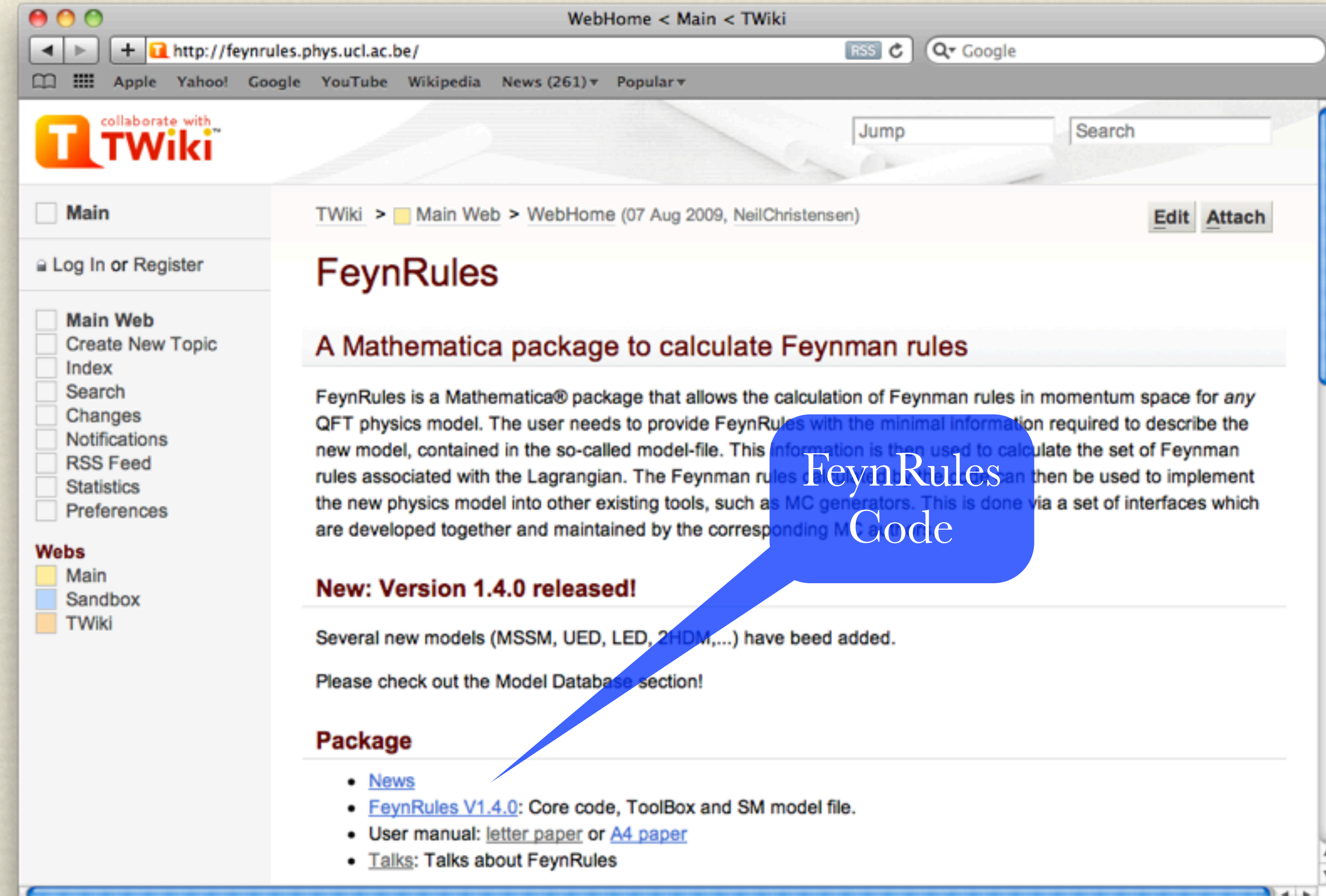
Links

- This tutorial:
  - http://www.hep.wisc.edu/~neil/Research/talks/2009-10-29.pdf
- FeynRules:
  - http://feynrules.phys.ucl.ac.be
- CalcHEP:
  - http://theory.sinp.msu.ru/~pukhov/calchep.html
- MadGraph:
  - http://madgraph.hep.uiuc.edu/

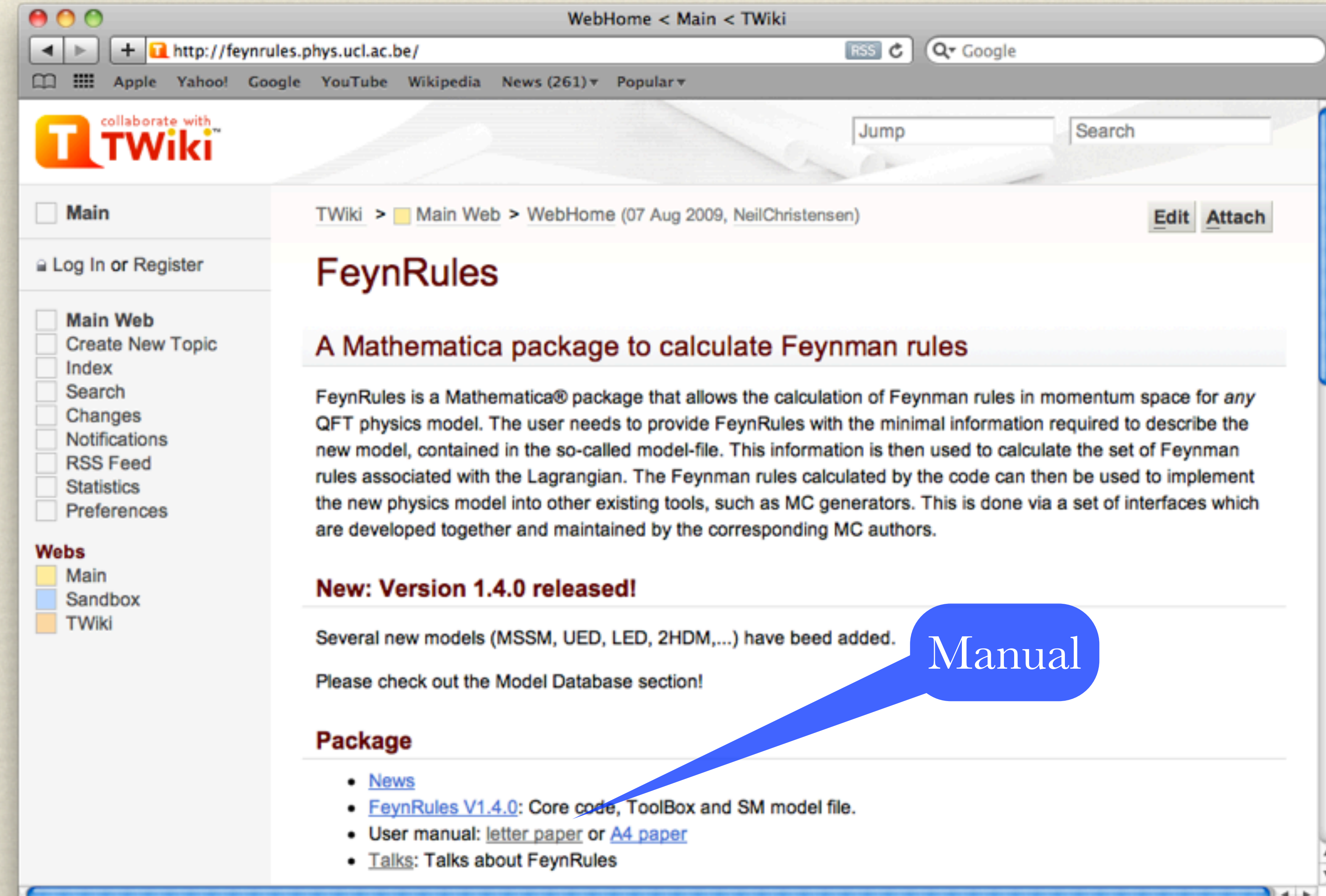
Download FeynRules



Download FeynRules



Download FeynRules



Prepare FeynRules

- Setup FeynRules directory:
  - cd
  - mkdir physics/FeynRules
  - cp Downloads/FeynRules1.4.0.tar.gz physics/FeynRules/FeynRules1.4.0.tar.gz
- Unpack FeynRules:
  - cd physics/FeynRules
  - tar xvzf FeynRules1.4.0.tar.gz
- Setup model directory:
  - mkdir Models
  - mkdir Models/SMpS
  - cp FeynRules1.4.0/Models/SM/SM.fr Models/SMpS/SMpS.fr
- Open model file in your favorite text editor:
  - cd Models
  - emacs SMpS.fr &

SMpS.fr

```
(***************************************************************************************)
(******                    This is the FeynRules mod-file for the Standard model          ******)
(******                                                                                   ******)
(******     Authors: N. Christensen, C. Duhr                                              ******)
(******                                                                                   ******)
(****** Choose whether Feynman gauge is desired.                                          ******)
(****** If set to False, unitary gauge is assumed.                                          ****)
(****** Feynman gauge is especially useful for CalcHEP/CompHEP where the calculation is 10-100 times faster. ***)
(****** Feynman gauge is not supported in MadGraph and Sherpa.                              ****)
(***************************************************************************************)

M$ModelName = "Standard_Model";


M$Information = {Authors -> {"N. Christensen", "C. Duhr"},
             Version -> "1.0",
             Date -> "02. 06. 2009",
             Institutions -> {"Michigan State University", "Universite catholique de Louvain (CP3)"},
             Emails -> {"neil@pa.msu.edu", "claude.duhr@uclouvain.be"},
             URLs -> "http://feynrules.phys.ucl.ac.be/view/Main/StandardModel"};

FeynmanGauge = False;


(******* Index definitions ********)

IndexRange[ Index[Generation] ] = Range[3]
```

-:-- SMpS.fr   Top (27,42)   (Fundamental)

Modify Model Info

```
(******************************************************************************************)
(******                  This is the FeynRules mod-file for the Standard model       ******)
(******                                                                              ******)
(******     Authors: N. Christensen, C. Duhr                                         ******)
(******                                                                              ******)
(****** Choose whether Feynman gauge is desired.                                     ******)
(****** If set to False, unitary gauge is assumed.                                     ****)
(****** Feynman gauge is especially useful for CalcHEP/CompHEP where the calculation is 10-100 times faster. ***)
(****** Feynman gauge is not supported in MadGraph and Sherpa.                         ****)
(******************************************************************************************)

M$ModelName = "Standard_Model";


M$Information = {Authors -> {"N. Christensen", "C. Duhr"},
        Version -> "1.0",
        Date -> "02. 06. 2009",
        Institutions -> {"Michigan State University", "Universite catholique de Louvain (CP3)"},

        Emails -> {"neil@pa.msu.edu", "claude.duhr@uclouvain.be"},
        URLs -> "http://feynrules.phys.ucl.ac.be/view/Main/StandardModel"};

FeynmanGauge = False;
```

Modify Model Info

```
(**********************************************************************************************)
(******                    This is the FeynRules mod-file for the Standard model                ******)
(******                                                                                          ******)
(******     Authors: N. Christensen, C. Duhr, N. Christensen                                     ******)
(******                                                                                          ******)
(****** Choose whether Feynman gauge is desired.                                                 ******)
(****** If set to False, unitary gauge is assumed.                                                 ****)
(****** Feynman gauge is especially useful for CalcHEP/CompHEP where the calculation is 10-100 times faster. ***)
(****** Feynman gauge is not supported in MadGraph and Sherpa.                                     ****)
(**********************************************************************************************)

M$ModelName = "Standard_Model_plus_Scalar";


M$Information = {Authors -> {"N. Christensen", "C. Duhr",”N. Christensen”},
        Version -> "1.0",
        Date -> "10/29/2009",
        Institutions -> {"Michigan State University", "Universite catholique de Louvain (CP3)",
                         "University of Wisconsin-Madison"},
        Emails -> {"neil@pa.msu.edu", "claude.duhr@uclouvain.be","neil@hep.wisc.edu"},
        URLs -> "url of your model"};

FeynmanGauge = False;
```

Add New Scalar Field

```
(************ Scalar Fields **********)
S[1] == {
    ClassName -> H,
    SelfConjugate -> True,

    ...},
S[2] == {
       ...},
S[3] == {
       ...}

}
```

Add New Scalar Field

```
(************ Scalar Fields **********)
S[1] == {
    ClassName -> H,
    SelfConjugate -> True,
    Unphysical -> True,
    ...},
S[2] == {
      ...},
S[3] == {
      ...},
S[4] == {
    ClassName -> S,
    SelfConjugate -> True,
    Unphysical -> True}
}
```

Add New Lagrangian Terms I

(********************* Higgs Lagrangian terms*****************************)

...

(**************** Yukawa Lagrangian************************)

Add New Lagrangian Terms I

(********************* Higgs Lagrangian terms******************************)

...

```
LScalar = 1/2 del[S,mu] del[S,mu] - \[Lambda]S ( v^2/2 + muS*S - Phibar.Phi )^2
```

(**************** Yukawa Lagrangian************************)

Add New Lagrangian Terms II

```
(*********Total SM Lagrangian*******)
LSM := LGauge + LHiggs + LFermions + LYukawa  + LGhost;
```

Add New Lagrangian Terms II

```
(*********Total SM Lagrangian*******)
LSM := LGauge + LHiggs + LFermions + LYukawa  + LGhost;

LSMpS := LSM + LScalar;
```

Add Parameters

```
\[Lambda] == {


            ...},
muH == {
            ...},
```

Add Parameters

```
\[Lambda] == {
        ParameterType -> External,
        Value -> 0.2,
        ...},
muH == {
        ...},
\[Lambda]S == {
        ParameterType -> External,
        Value -> 0.2,
        ParameterName -> lamS},
muS == {
        ParameterType -> External,
        Value -> 400},
```

Start FeynRules

```
$FeynRulesPath = "~/physics/FeynRules/FeynRules1.4.0";
SetDirectory[$FeynRulesPath];
<< FeynRules`;
```

Start FeynRules

Untitled-2

```
In[1]:= $FeynRulesPath = "~/physics/FeynRules/FeynRules1.4.0";
        SetDirectory[$FeynRulesPath];
        << FeynRules`;

 - FeynRules -

Version: 1.4.0

Authors: C. Duhr, N. Christensen, B. Fuks


Please cite: arXiv:0806.4194

http://feynrules.phys.ucl.ac.be


The FeynRules palette can be opened using the command FRPalette[].
```

100%

Load Model

```
ModelDir = "~/physics/FeynRules/Models/SMpS";
SetDirectory[ModelDir];
LoadModel["SMpS.fr"]
```

Load Model

Untitled-2

```
In[4]:= ModelDir = "~/physics/FeynRules/Models/SMpS";
        SetDirectory[ModelDir];
        LoadModel["SMpS.fr"]

This model implementation was created by
N. Christensen
C. Duhr
N. Christensen
Model Version: 1.0
url of your model
For more information, type ModelInformation[].

   - Loading particle classes.
   - Loading gauge group classes.
   - Loading parameter classes.

Model Standard_Model_plus_Scalar loaded.
```

100%

Get Mass Terms

```
GetMassTerms[LHiggs + LScalar ,
    SelectParticles -> {{H, H}, {H, S}, {S, S}} ]
```

Get Mass Terms

Untitled-1

In[7]:=
```
Simplify[GetMassTerms[LHiggs + LScalar /. muH → √λ v,
  SelectParticles → {{H, H}, {H, S}, {S, S}}]]
```

```
Selecting specified field content.
  Warning! Only mass eigenstates should be selected!
```

Out[7]= $-\mathrm{muS}^2\, S^2\, \lambda S + 2\, H\, \mathrm{muS}\, S\, v\, \lambda S - H^2\, v^2\, (\lambda + \lambda S)$

In[8]:=
```
M2 = {{2 (λ + λS) v², -2 λS muS v}, {-2 λS muS v, 2 λS muS²}}; MatrixForm[M2]
```

Out[8]//MatrixForm=

$$\begin{pmatrix} 2\, v^2\, (\lambda + \lambda S) & -2\, \mathrm{muS}\, v\, \lambda S \\ -2\, \mathrm{muS}\, v\, \lambda S & 2\, \mathrm{muS}^2\, \lambda S \end{pmatrix}$$

100%

Get Masses and Eigenvectors

```
Eigenvalues[M2]
Eigenvectors[M2]
```

Get Masses and Eigenvectors

Untitled-1

In[9]:= `Eigenvalues[M2]`

Out[9]=
$$\left\{\frac{1}{2}\left(2 v^2 \lambda + 2\, \text{muS}^2\, \lambda S + 2 v^2\, \lambda S - \sqrt{-16\, \text{muS}^2\, v^2\, \lambda\, \lambda S + \left(-2 v^2 \lambda - 2\, \text{muS}^2\, \lambda S - 2 v^2\, \lambda S\right)^2}\right),\right.$$
$$\left.\frac{1}{2}\left(2 v^2 \lambda + 2\, \text{muS}^2\, \lambda S + 2 v^2\, \lambda S + \sqrt{-16\, \text{muS}^2\, v^2\, \lambda\, \lambda S + \left(-2 v^2 \lambda - 2\, \text{muS}^2\, \lambda S - 2 v^2\, \lambda S\right)^2}\right)\right\}$$

In[10]:= `Eigenvectors[M2]`

Out[10]=
$$\left\{\left\{-\frac{v^2 \lambda - \text{muS}^2\, \lambda S + v^2\, \lambda S - \frac{1}{2}\sqrt{-16\, \text{muS}^2\, v^2\, \lambda\, \lambda S + \left(-2 v^2 \lambda - 2\, \text{muS}^2\, \lambda S - 2 v^2\, \lambda S\right)^2}}{2\, \text{muS}\, v\, \lambda S}, 1\right\},\right.$$
$$\left.\left\{-\frac{v^2 \lambda - \text{muS}^2\, \lambda S + v^2\, \lambda S + \frac{1}{2}\sqrt{-16\, \text{muS}^2\, v^2\, \lambda\, \lambda S + \left(-2 v^2 \lambda - 2\, \text{muS}^2\, \lambda S - 2 v^2\, \lambda S\right)^2}}{2\, \text{muS}\, v\, \lambda S}, 1\right\}\right\}$$

100%

Add Masses

Copy and Paste

```
muS == {
        ...},
```

Add Masses

Copy and Paste

```
muS == {
        ...},

mh1 == {
        ParameterType -> Internal,
        Value -> ...},

mh2 == {
        ParameterType -> Internal,
        Value -> ...},
```

Add Masses

Copy and Paste

SMpS.fr

SMpS-1.fr 1 | SM.fr 2 | SMpS.fr 3

```
      ParameterType -> External,
      Value -> 0.2,
      ParameterName -> lamS},

 muS == {
      ParameterType -> External,
      Value -> 400},

mh1 == {
      ParameterType -> Internal,
      Value -> Sqrt[1/2 (2 v^2 \[Lambda] + 2 muS^2 \[Lambda]S + 2 v^2 \[Lambda]S -
                  Sqrt[-16 muS^2 v^2 \[Lambda] \[Lambda]S + (-2 v^2 \[Lambda] -
                  2 muS^2 \[Lambda]S - 2 v^2 \[Lambda]S)^2]) ]
      },

mh2 == {
      ParameterType -> Internal,
      Value -> Sqrt[ 1/2 (2 v^2 \[Lambda] + 2 muS^2 \[Lambda]S + 2 v^2 \[Lambda]S +
                     Sqrt[-16 muS^2 v^2 \[Lambda] \[Lambda]S + (-2 v^2 \[Lambda] -
                     2 muS^2 \[Lambda]S - 2 v^2 \[Lambda]S)^2]) ]
      },
```

-:-- SMpS.fr 28% (219,14) (Fundamental)

Add Rotation Parameters

Copy and Paste

mh2 == {
...},

Add Rotation Parameters

Copy and Paste

```
mh2 == {
        ...},
sS0 == {
        ParameterType -> Internal,
        Value -> ...},
sSN == {
        ParameterType -> Internal,
        Value -> Sqrt[1+sS0^2]},
sS == {
        ParameterType -> Internal,
        Value -> sS0/sSN},
cS == {
        ParameterType -> Internal,
        Value -> Sqrt[1-sS^2],
        Definition -> Sqrt[1-sS^2]},
```

Add Rotation Parameters

Copy and Paste

SMpS.fr

SMpS-1.fr | SM.fr | SMpS.fr

```
  sS0 == {
        ParameterType -> Internal,
        Value -> (v^2 \[Lambda] - muS^2 \[Lambda]S + v^2 \[Lambda]S - Sqrt[-4 muS^2 v^2 \[Lamb
da] \[Lambda]S + (-v^2 \[Lambda] - muS^2 \[Lambda]S - v^2 \[Lambda]S)^2])/(2 muS v \[Lambda]S
)
        },
  sSN == {
        ParameterType -> Internal,
        Value -> Sqrt[1+sS0^2]},

  sS == {
        ParameterType -> Internal,
        Value -> sS0/sSN,
        Description->"Sine of rotation angle from gauge basis to mass basis in scalar sector."
},

  cS == {
        ParameterType -> Internal,
        Value -> Sqrt[1-sS^2],
        Definition -> Sqrt[1-sS^2]},
```

-:-- SMpS.fr 31% (244,9) (Fundamental)

Add Mass-Eigenstate Fields

```
S[4] == {
        ...},
}
```

Add Mass-Eigenstate Fields

```
S[4] == {
         ...},
S[5] == {
        ClassName -> h1,
        SelfConjugate -> True,
        Mass -> {mh1, Internal},
        Width -> wh1,
        PDG -> 6000001},
S[6] == {
        ClassName -> h2,
        SelfConjugate -> True,
        Mass -> {mh2, Internal},
        Width -> wh2,
        PDG -> 6000002}
}
```

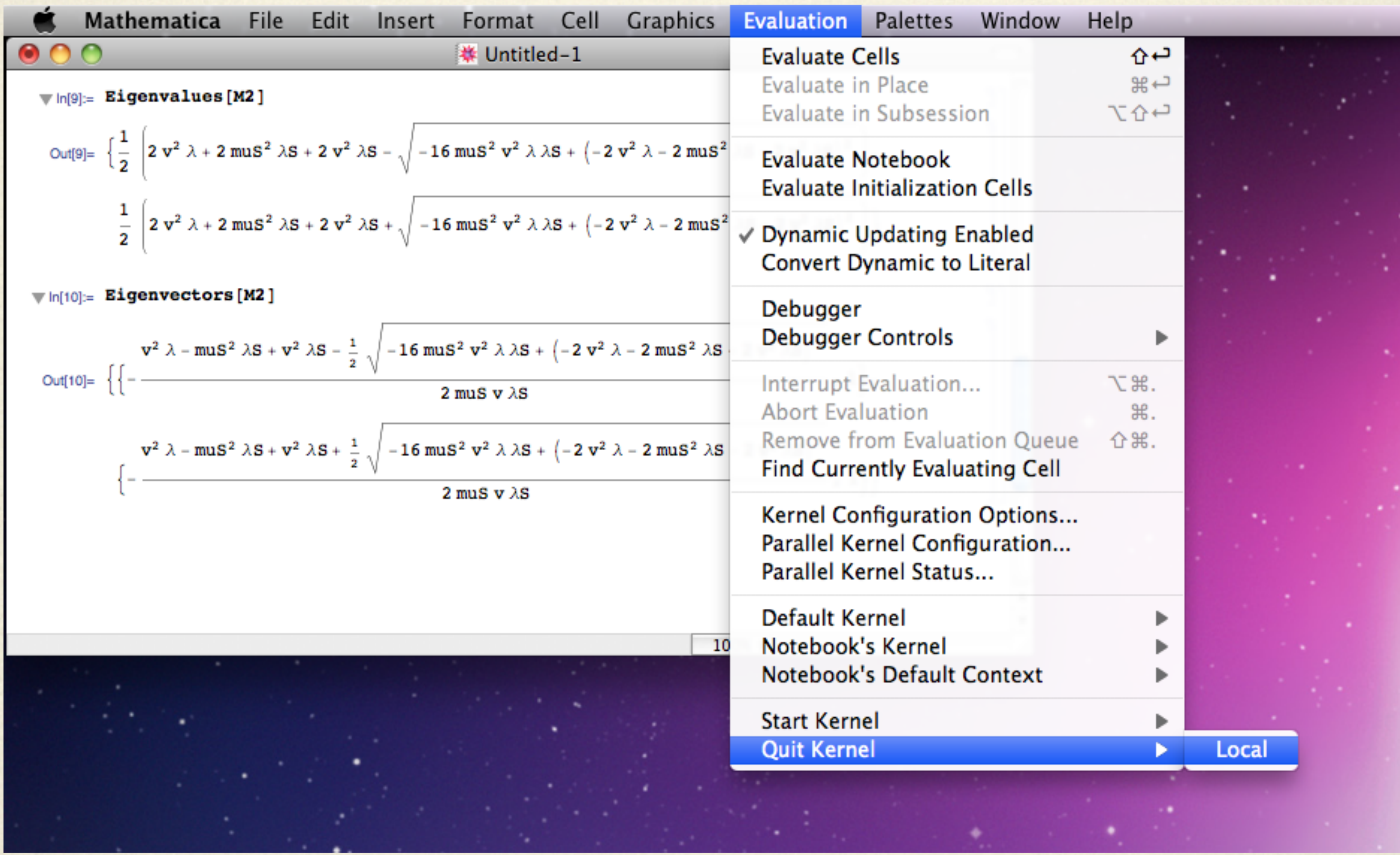
Transform Fields

```
S[1] == {
        ClassName -> H,
        SelfConjugate -> True,
        Unphysical -> True,

        ...},
S[2] == {
        ...},
S[3] == {
        ...},
S[4] == {
        ClassName -> S,
        SelfConjugate -> True,
        Unphysical -> True,
                                  },
```

Transform Fields

```
S[1] == {
      ClassName -> H,
      SelfConjugate -> True,
      Unphysical -> True,
      Definitions -> {H -> - sS h1 + cS h2},
      ...},
S[2] == {
      ...},
S[3] == {
      ...},
S[4] == {
      ClassName -> S,
      SelfConjugate -> True,
      Unphysical -> True,
      Definitions -> {S -> cS h1 + sS h2}},
```

Quit Mathematica Kernel



Start FeynRules

Untitled-2

```
In[1]:= $FeynRulesPath = "~/physics/FeynRules/FeynRules1.4.0";
        SetDirectory[$FeynRulesPath];
        << FeynRules`;

 – FeynRules –

Version: 1.4.0

Authors: C. Duhr, N. Christensen, B. Fuks


Please cite: arXiv:0806.4194

http://feynrules.phys.ucl.ac.be


The FeynRules palette can be opened using the command FRPalette[].
```

100%

Load Model

Untitled-2

```
In[4]:= ModelDir = "~/physics/FeynRules/Models/SMpS";
        SetDirectory[ModelDir];
        LoadModel["SMpS.fr"]

This model implementation was created by

N. Christensen

C. Duhr

N. Christensen

Model Version: 1.0

url of your model

For more information, type ModelInformation[].


   - Loading particle classes.

   - Loading gauge group classes.

   - Loading parameter classes.


Model Standard_Model_plus_Scalar loaded.
```

100%

Check Masses

CheckMassSpectrum[LHiggs + LScalar]

Check Masses

Untitled-1

In[7]:= `CheckMassSpectrum[LHiggs + LScalar]`

```
Expanding flavors...
All mass terms are diagonal.
Expanding flavors...
Getting mass spectrum.
Checking for less then 0.1% agreement with model file values.
```

Out[7]//TableForm=

Particle	Analytic value	Numerical value	Model-file value
h2	$\sqrt{2}\sqrt{-\frac{1}{2}\, cS^2 \mu^2 + \frac{3}{2}\, cS^2 v^2 \lambda + muS^2\, sS^2\, \lambda S - 2\, cS\, muS\, sS\, v\, \lambda S + cS^2 v^2 \lambda S}$	310.483	310.483
h1	$\sqrt{2}\sqrt{-\frac{1}{2}\, \mu^2 sS^2 + \frac{3}{2}\, sS^2 v^2 \lambda + cS^2\, muS^2\, \lambda S + 2\, cS\, muS\, sS\, v\, \lambda S + sS^2 v^2 \lambda S}$	126.883	126.883
W	$\frac{1}{2}\sqrt{\frac{e^2 v^2}{s_w^2}}$	79.8252	79.8252
Z	$\sqrt{2}\sqrt{\frac{e^2 v^2}{4} + \frac{c_w^2 e^2 v^2}{8 s_w^2} + \frac{e^2 s_w^2 v^2}{8 c_w^2}}$	91.188	91.188

100%

Generate Feynman Rules

```
FeynmanRules[LSMpS];
```

Generate Feynman Rules

Untitled-1

```
In[8]:= FeynmanRules[LSMpS];
Starting Feynman rule calculation.
Expanding indices...
Collecting the different structures that enter the vertex...
Found 42 possible non zero vertices.
Start calculating vertices...
42 vertices obtained.
(* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *)
Vertex 1
Particle 1 : Scalar , h2
Particle 2 : Scalar , h2
Particle 3 : Scalar , h2
Particle 4 : Scalar , h2
Vertex:
-6 i cS^4 λ - 6 i cS^4 λS
(* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *)
Vertex 2
Particle 1 : Scalar , h1
```

100%

Generate Feynman Rules

Untitled-1

(* *)

Vertex 2

Particle 1 : Scalar , h1

Particle 2 : Scalar , h2

Particle 3 : Scalar , h2

Particle 4 : Scalar , h2

Vertex:

$6\, i\, cS^3\, sS\, \lambda + 6\, i\, cS^3\, sS\, \lambda S$

(* *)

Vertex 3

Particle 1 : Scalar , h1

Particle 2 : Scalar , h1

Particle 3 : Scalar , h2

Particle 4 : Scalar , h2

Vertex:

$-6\, i\, cS^2\, sS^2\, \lambda - 6\, i\, cS^2\, sS^2\, \lambda S$

(* *)

Vertex 4

Particle 1 : Scalar , h1

Particle 2 : Scalar , h1

100%

Generate Feynman Rules

Untitled-1

```
(* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *)
Vertex 14
Particle 1 : Scalar , h2
Particle 2 : Scalar , h2
Particle 3 : Vector , W
Particle 4 : Vector , W†
Vertex:
```

$$\frac{i\, cS^2\, e^2\, \eta_{\mu_3,\mu_4}}{2\, s_w^2}$$

```
(* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *)
Vertex 15
Particle 1 : Scalar , h1
Particle 2 : Scalar , h2
Particle 3 : Vector , W
Particle 4 : Vector , W†
Vertex:
```

$$-\frac{i\, cS\, e^2\, sS\, \eta_{\mu_3,\mu_4}}{2\, s_w^2}$$

100%

Generate Feynman Rules

Untitled-1

```
(* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *)
Vertex 25
Particle 1 : Scalar , h2
Particle 2 : Dirac , uq†
Particle 3 : Dirac , uq
Vertex:
```

$$-\frac{i\,\mathrm{cS}\,\delta_{i_2,i_3}\,\delta_{f_2,f_3}\,\delta_{s_2,s_3}\,\left(y^u\right)_{f_2}}{\sqrt{2}}$$

```
(* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *)
Vertex 26
Particle 1 : Scalar , h1
Particle 2 : Dirac , uq†
Particle 3 : Dirac , uq
Vertex:
```

$$\frac{i\,\mathrm{sS}\,\delta_{i_2,i_3}\,\delta_{f_2,f_3}\,\delta_{s_2,s_3}\,\left(y^u\right)_{f_2}}{\sqrt{2}}$$

```
(* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *)
Vertex 27
```

100%

Generate CalcHEP Files

```
FeynmanGauge = True;
SetDirectory[ModelDir];
WriteCHOutput[LSMpS]
```

Generate CalcHEP Files

Untitled-1

```
In[9]:= FeynmanGauge = True;
        SetDirectory[ModelDir];
        WriteCHOutput[LSMpS, MaxExpressionLength → 200]

  - - - FeynRules interface to CalcHep - - -

 Authors: N. Christensen, C. Duhr

 Writing files to
    /Users/neil/physics/FeynRules/Models/SMpS/Standard_Model_plus_Scalar-CH.

 Writing particles file 'prtcls1.mdl'.

 Writing external parameter file 'vars1.mdl'.

 Writing internal parameter file 'func1.mdl'.

 Calculating Feynman rules for L1
 Starting Feynman rule calculation for L1.
 Neglecting all terms with more than 4 particles.
 Expanding indices...
 Expanding flavors...
 Collecting the different structures that enter the vertex...
```

100%

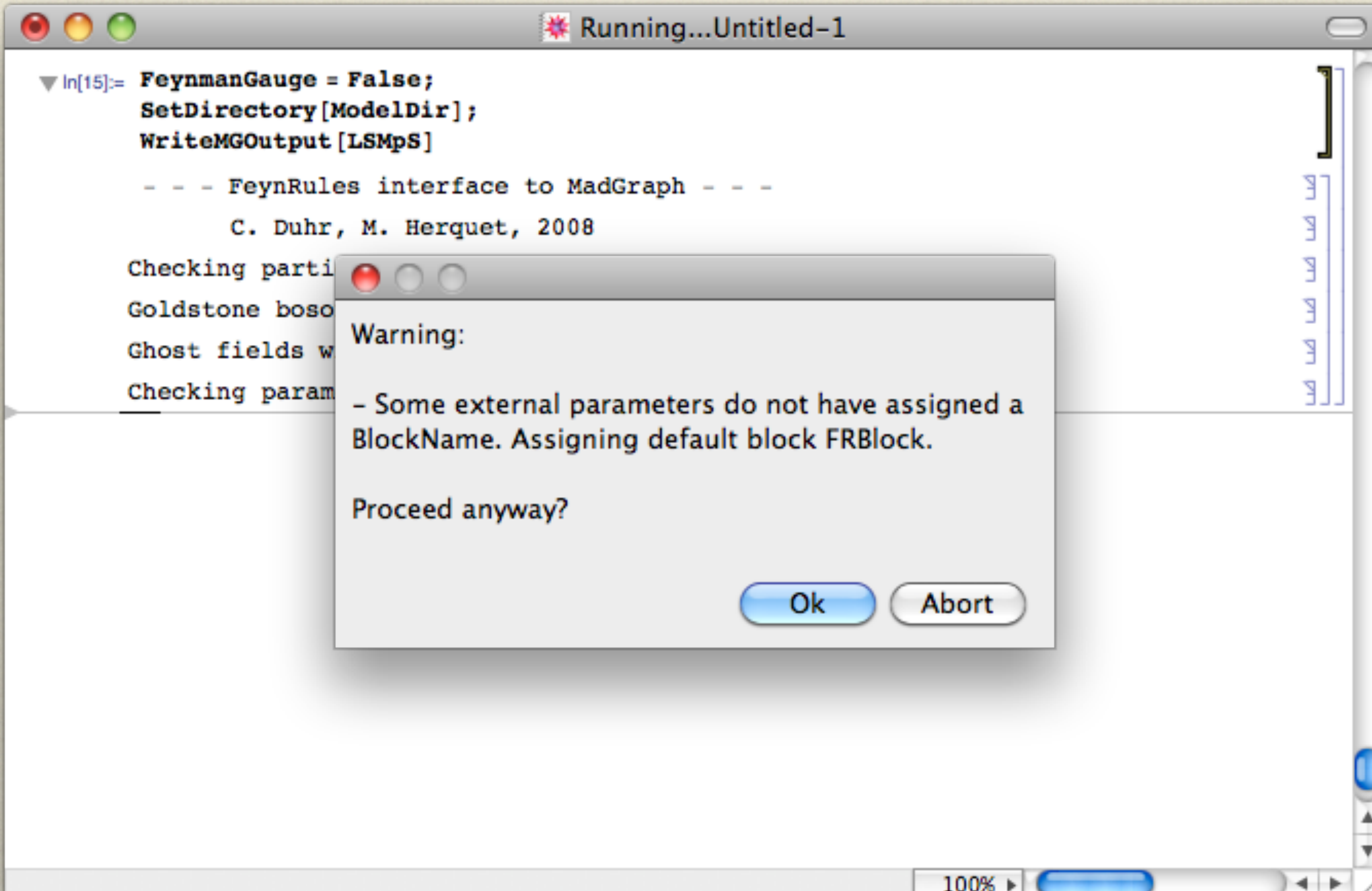
Generate CalcHEP Files

```
Writing internal parameter file 'func1.mdl'.

Calculating Feynman rules for L1
Starting Feynman rule calculation for L1.
Neglecting all terms with more than 4 particles.
Expanding indices...
Expanding flavors...
Collecting the different structures that enter the vertex...
Found 201 possible non zero vertices.
Start calculating vertices...

201 vertices obtained.

Writing Vertices file 'lgrng1.mdl'
and appending variable file 'func1.mdl',
   particle file 'prtcls1.mdl' and variable file 'vars1.mdl'.

Done in 0.16min!
```

Generate MadGraph Files

```
FeynmanGauge = False;
SetDirectory[ModelDir];
WriteMGOutput[LSMpS]
```

Generate MadGraph Files



Generate MadGraph Files

Untitled-1

```
In[15]:= FeynmanGauge = False;
         SetDirectory[ModelDir];
         WriteMGOutput[LSMpS]

   - - - FeynRules interface to MadGraph - - -
         C. Duhr, M. Herquet, 2008
  Checking particle list...
  Goldstone bosons will be ignored.
  Ghost fields will be ignored.
  Checking parameter list...

  Calculating Feynman rules for Lagrangian number 1
  Starting Feynman rule calculation.
  Expanding indices...
  Expanding flavors...
  Collecting the different structures that enter the vertex...
  Found 96 possible non zero vertices.
  Start calculating vertices...

  96 vertices obtained.
  Merging vertices...
```

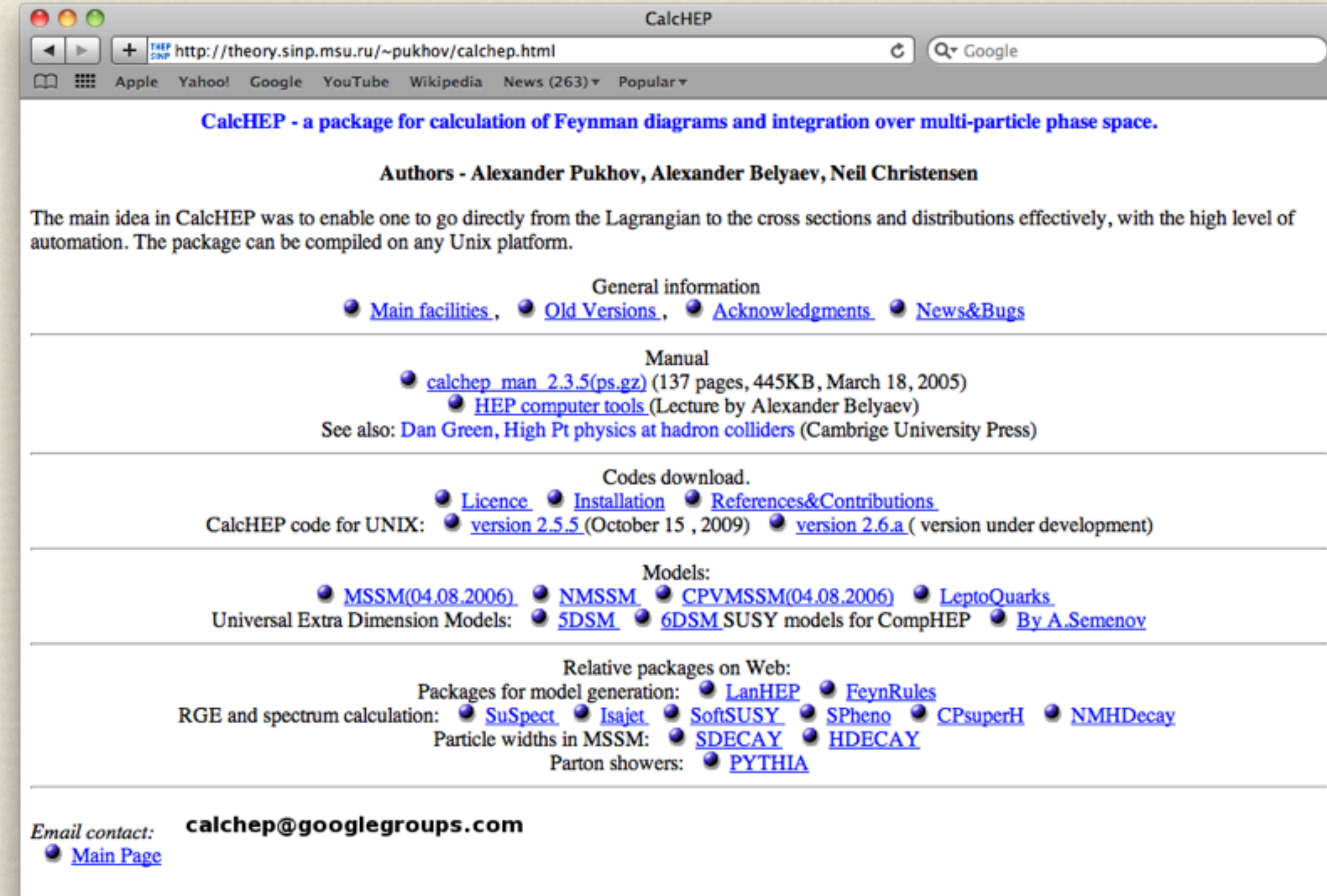
100%

Generate MadGraph Files

Untitled-1

```
Calculating Feynman rules for Lagrangian number 1
Starting Feynman rule calculation.
Expanding indices...
Expanding flavors...
Collecting the different structures that enter the vertex...
Found 96 possible non zero vertices.
Start calculating vertices...

96 vertices obtained.
Merging vertices...

    Converting vertices to MG format
Getting color structures.
    Getting HELAS structures: 96/96 .

    MG Output obtained for Standard_Model_plus_Scalar
MG / ME output written on Standard_Model_plus_Scalar_MG
```

Download CalcHEP


CalcHEP

http://theory.sinp.msu.ru/~pukhov/calchep.html

Google

Apple Yahoo! Google YouTube Wikipedia News (263) Popular

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

Authors - Alexander Pukhov, Alexander Belyaev, Neil Christensen

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

General information
- Main facilities, • Old Versions, • Acknowledgments • News&Bugs

Manual
- calchep_man_2.3.5(ps.gz) (137 pages, 445KB, March 18, 2005)
- HEP computer tools (Lecture by Alexander Belyaev)

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

Codes download.
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CalcHEP code for UNIX: • version 2.5.5 (October 15 , 2009) • version 2.6.a (version under development)

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RGE and spectrum calculation: • SuSpect • Isajet • SoftSUSY • SPheno • CPsuperH • NMHDecay

Particle widths in MSSM: • SDECAY • HDECAY

Parton showers: • PYTHIA

Email contact: **calchep@googlegroups.com**
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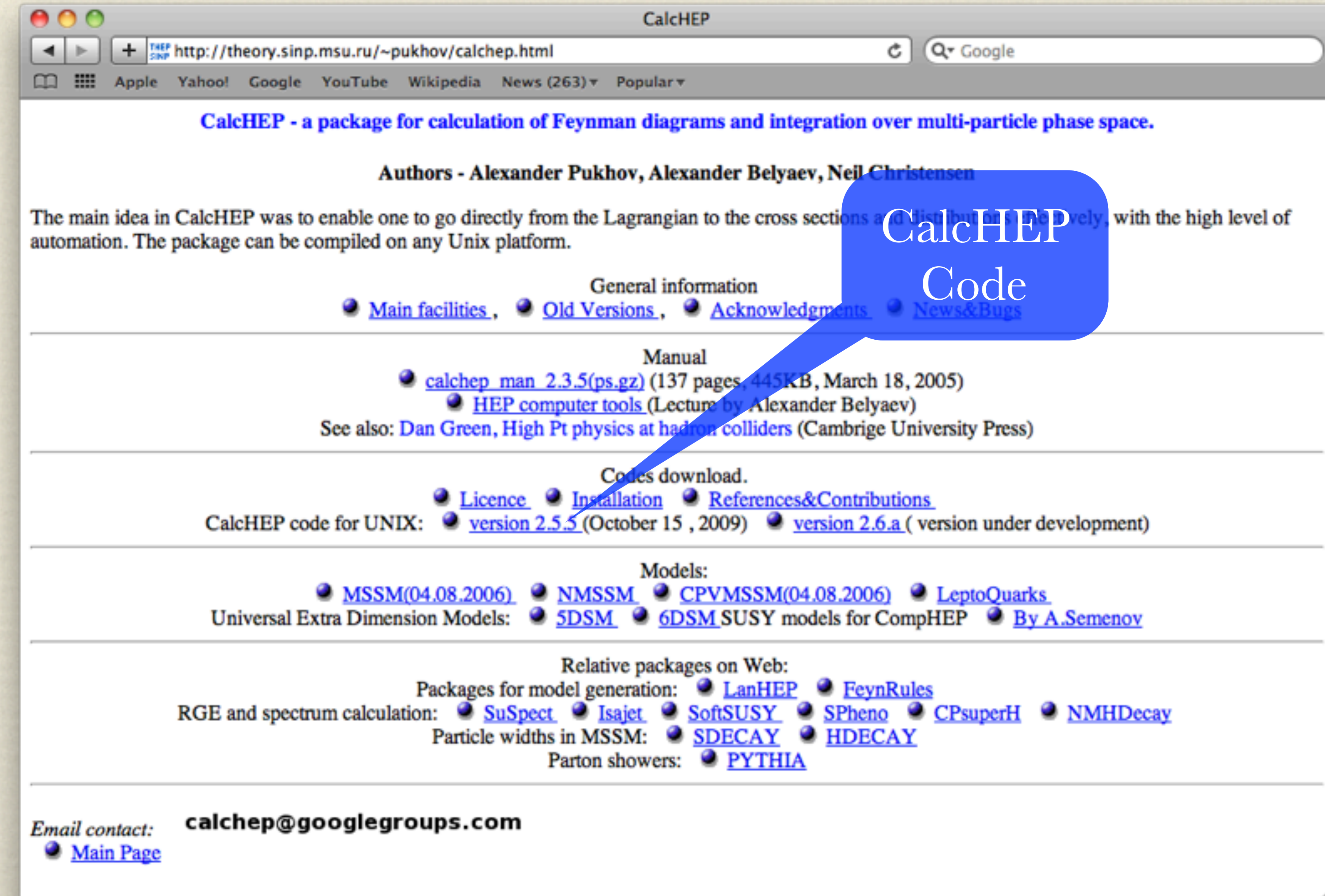

CalcHEP - a package for calculation of Feynman diagrams and integration over multi-particle phase space.

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 respectively, with the high level of automation. The package can be compiled on any Unix platform.

General information
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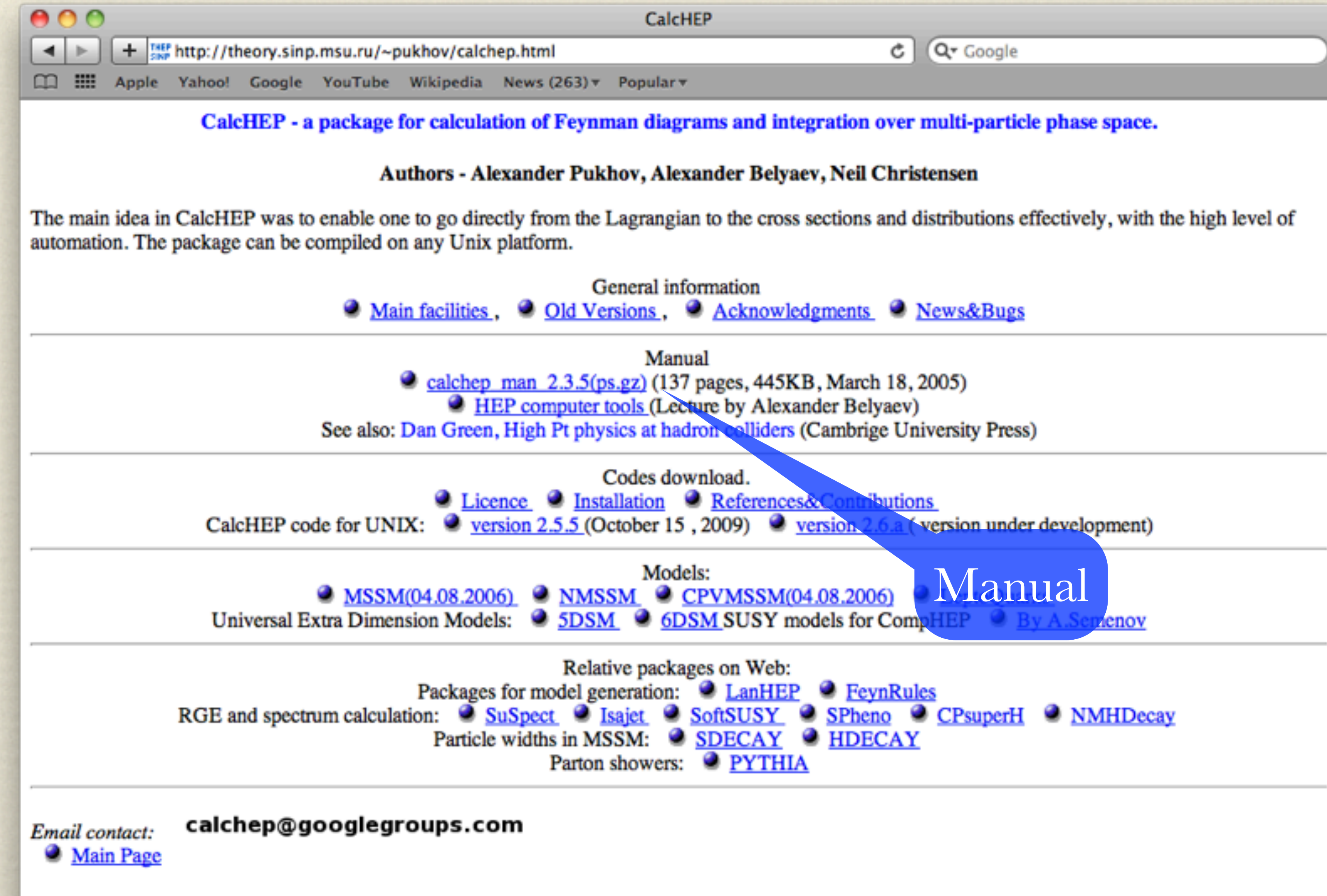

CalcHEP

http://theory.sinp.msu.ru/~pukhov/calchep.html

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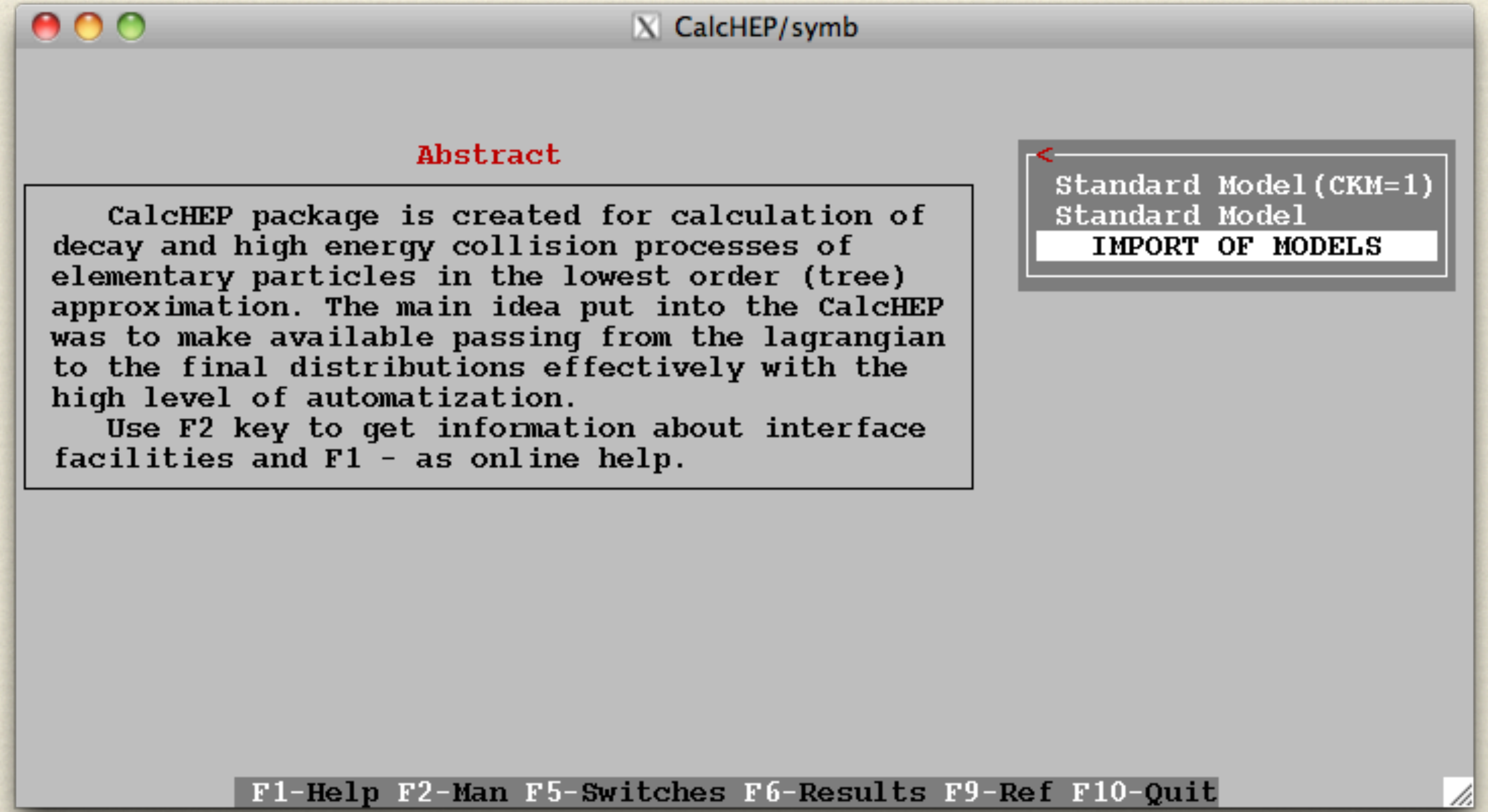
Main Page

Prepare CalcHEP

- Setup CalcHEP directory:
  - cd
  - mkdir physics/CalcHEP
  - cp Downloads/calchep_2.5.5.tar.gz physics/CalcHEP/calchep_2.5.5.tar.gz
- Compile CalcHEP:
  - cd physics/CalcHEP
  - tar xvzf calchep_2.5.5.tar.gz
  - cd calchep_2.5.5
  - make
- Start CalcHEP:
  - ./mkUsrDir ../ch_2.5.5
  - cd ../ch_2.5.5
  - ./calchep &

Import FR Model



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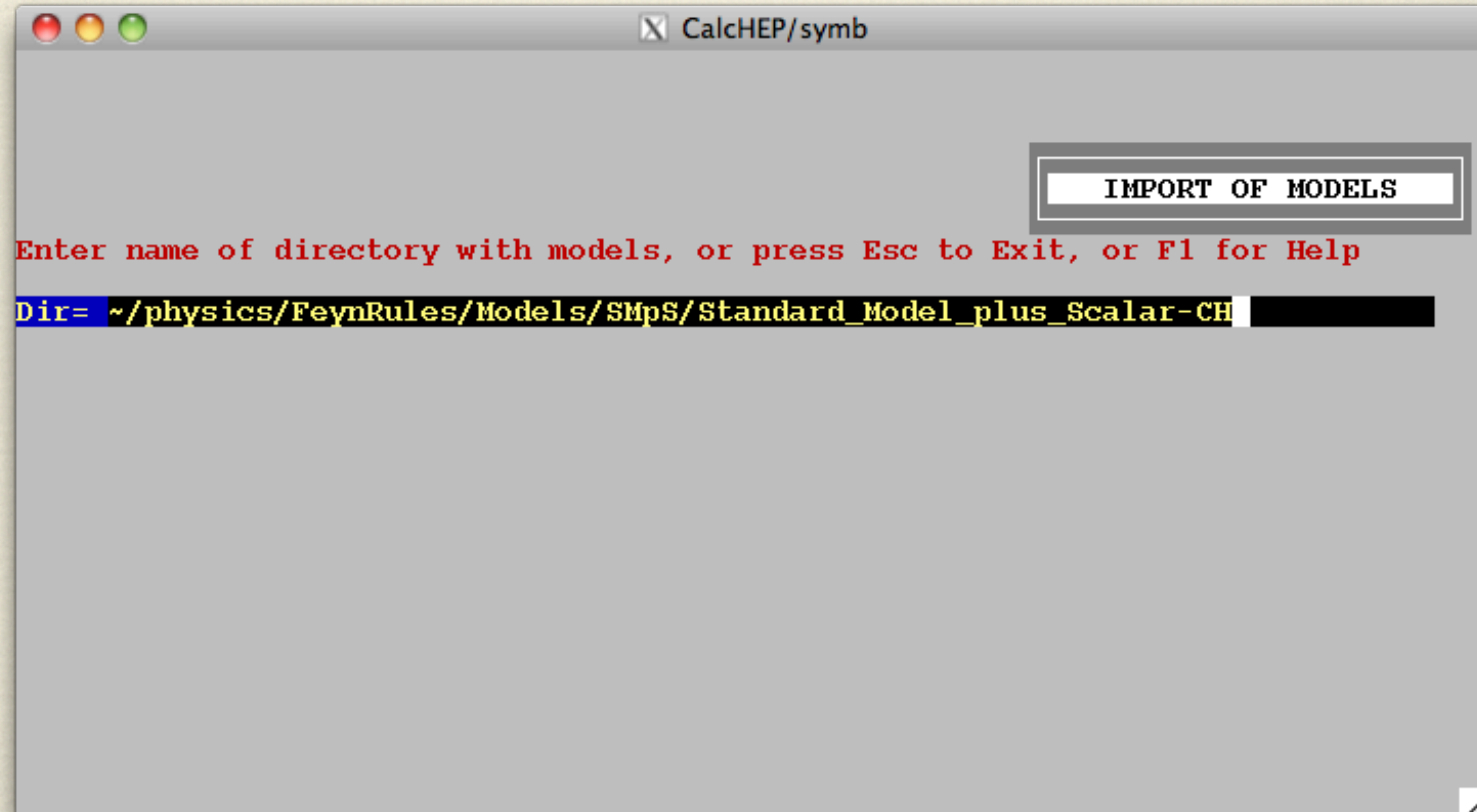

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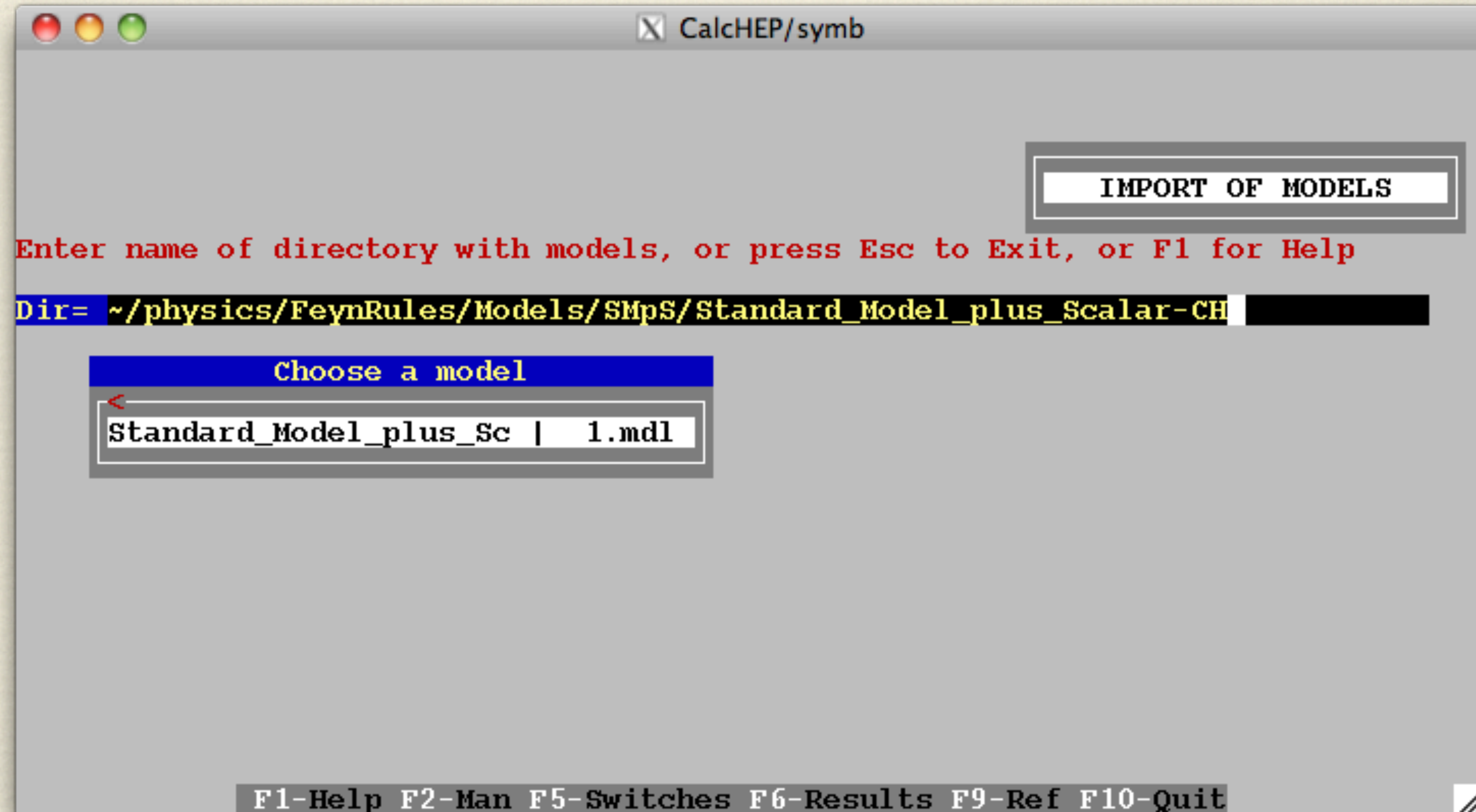

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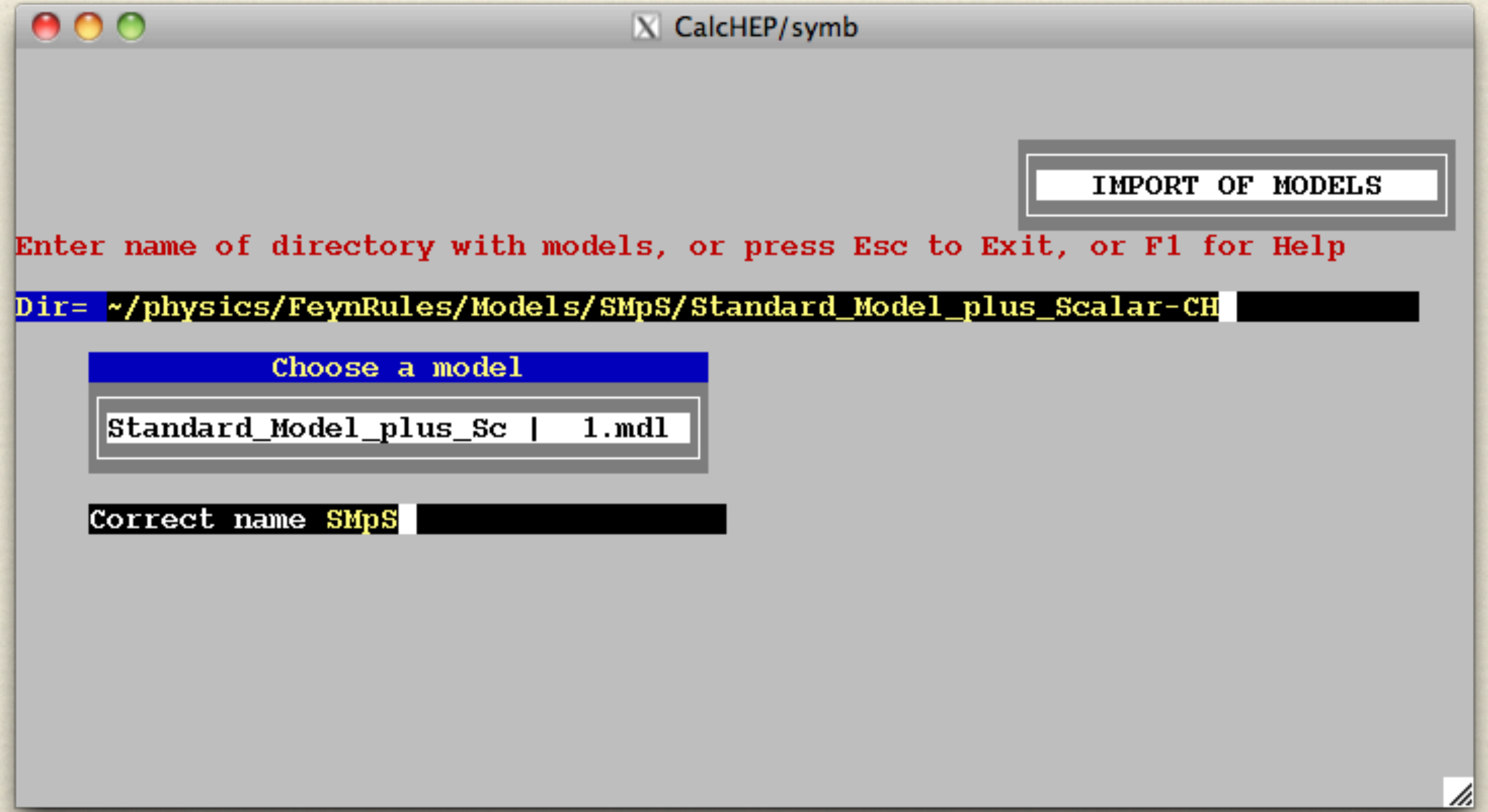

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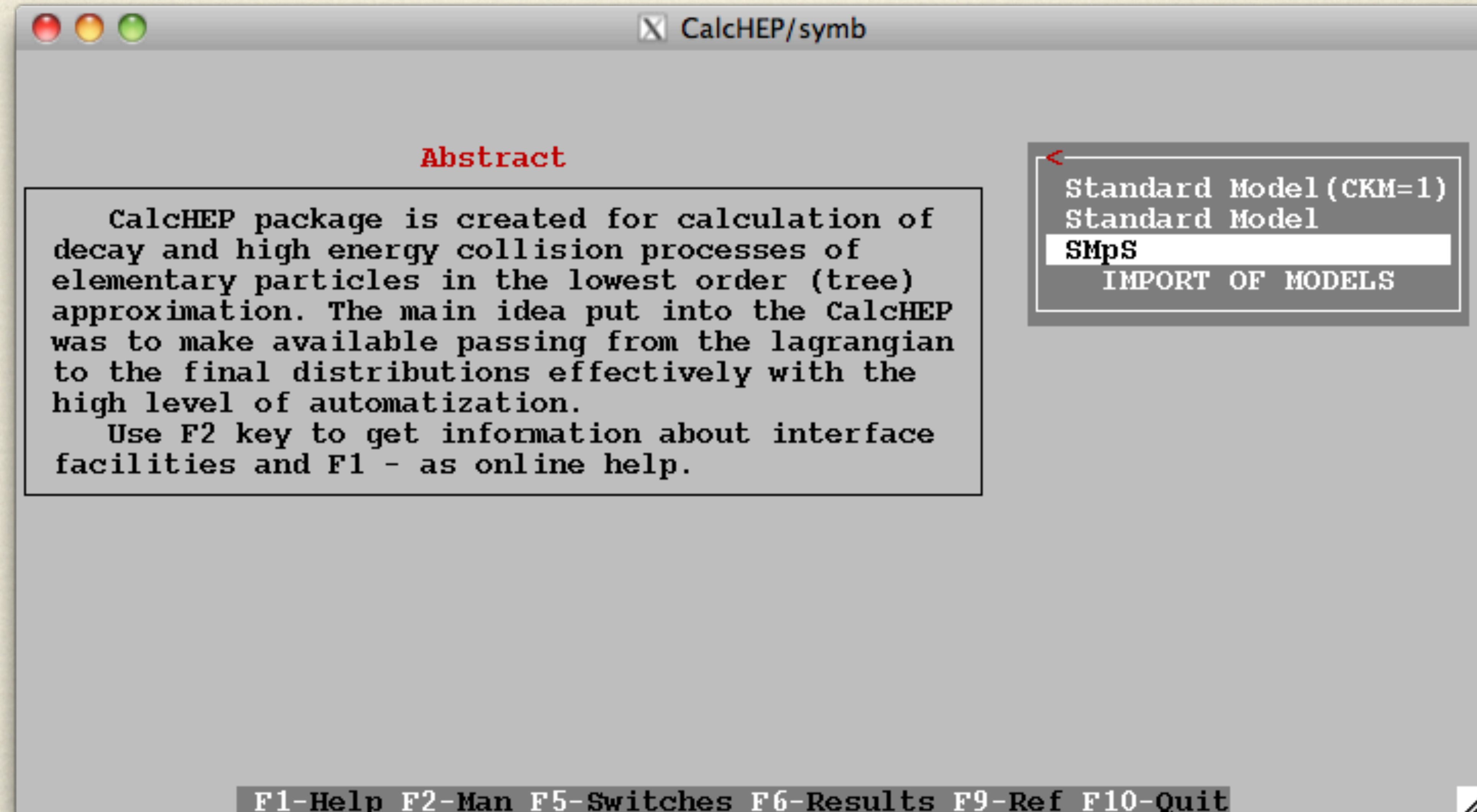

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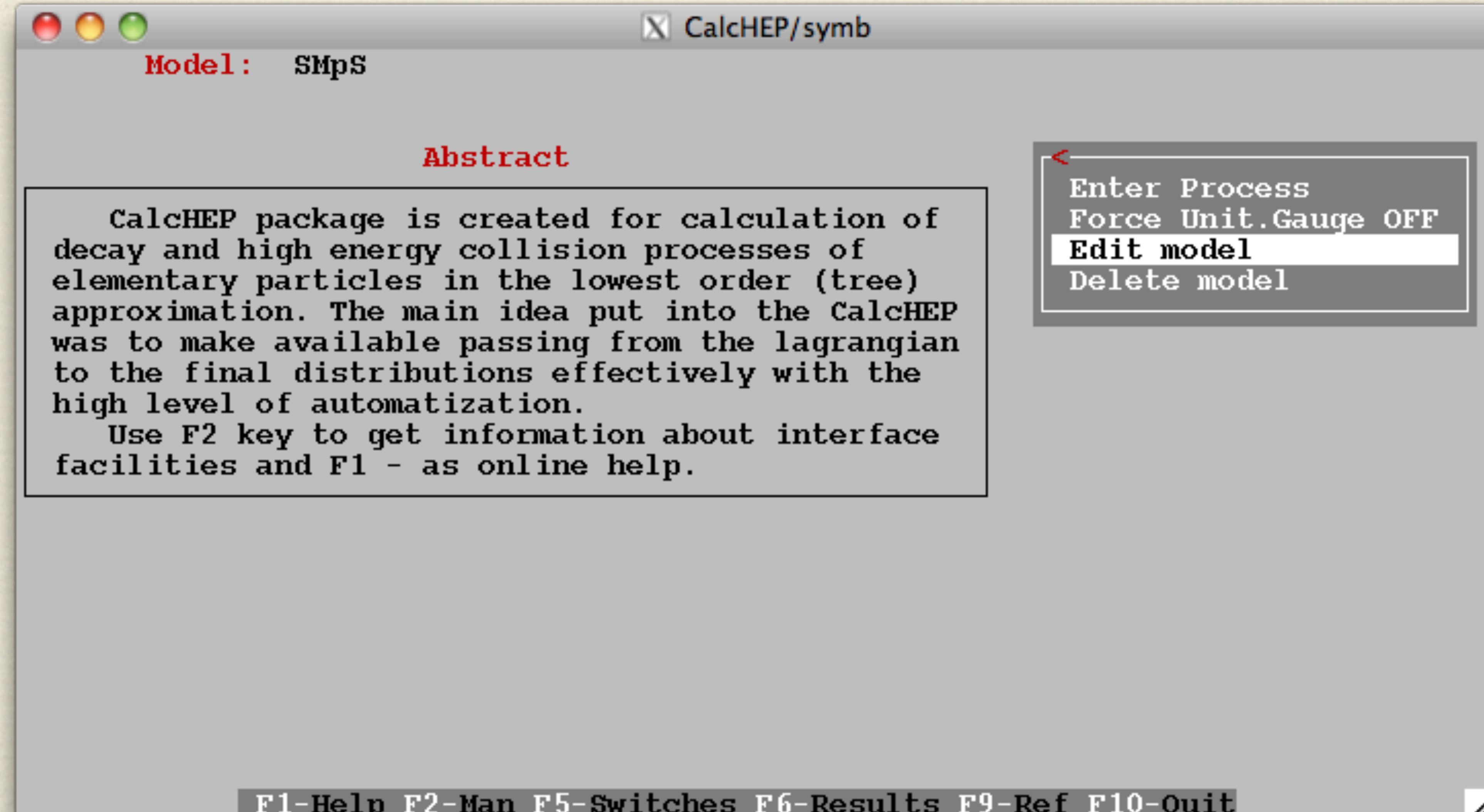

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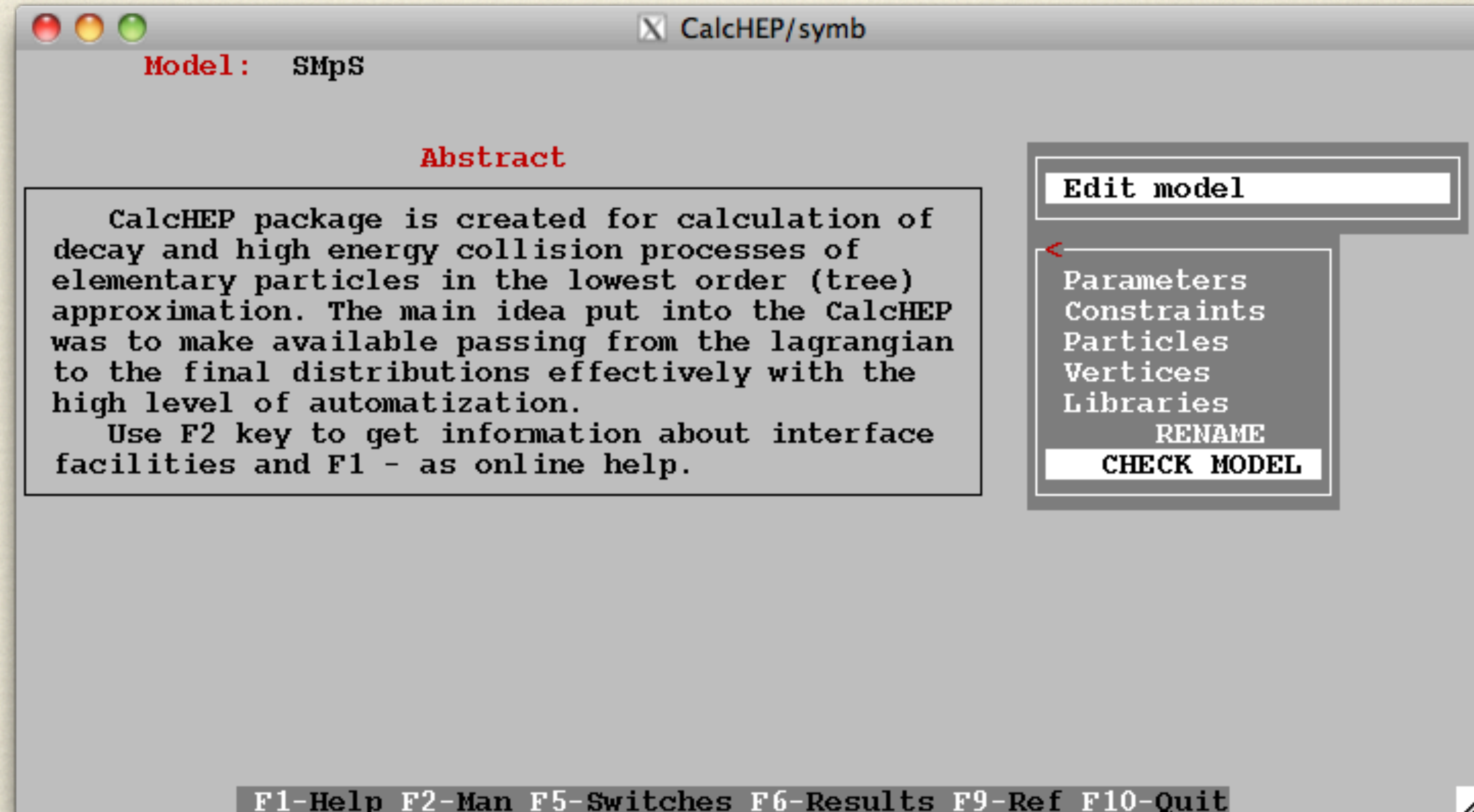

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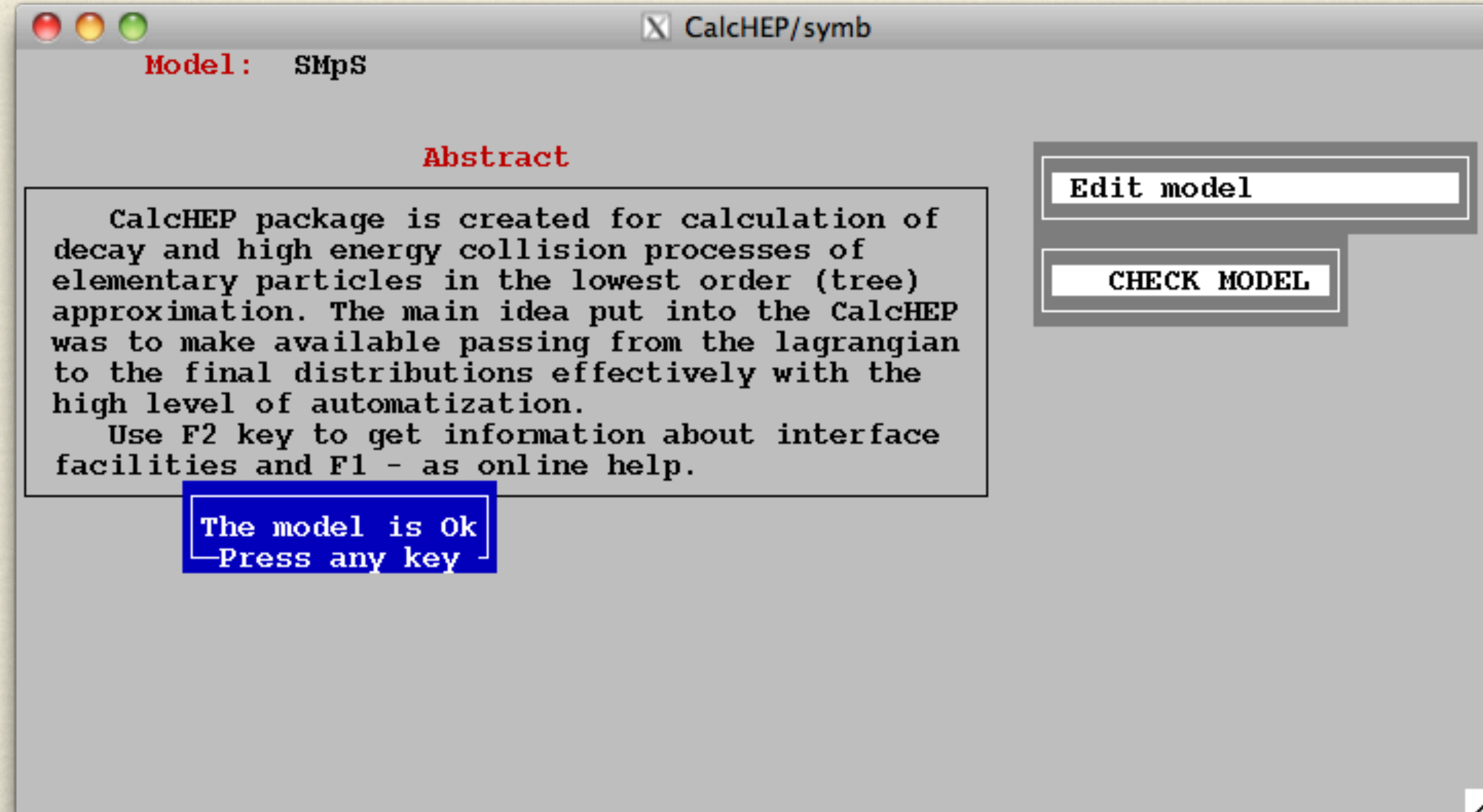

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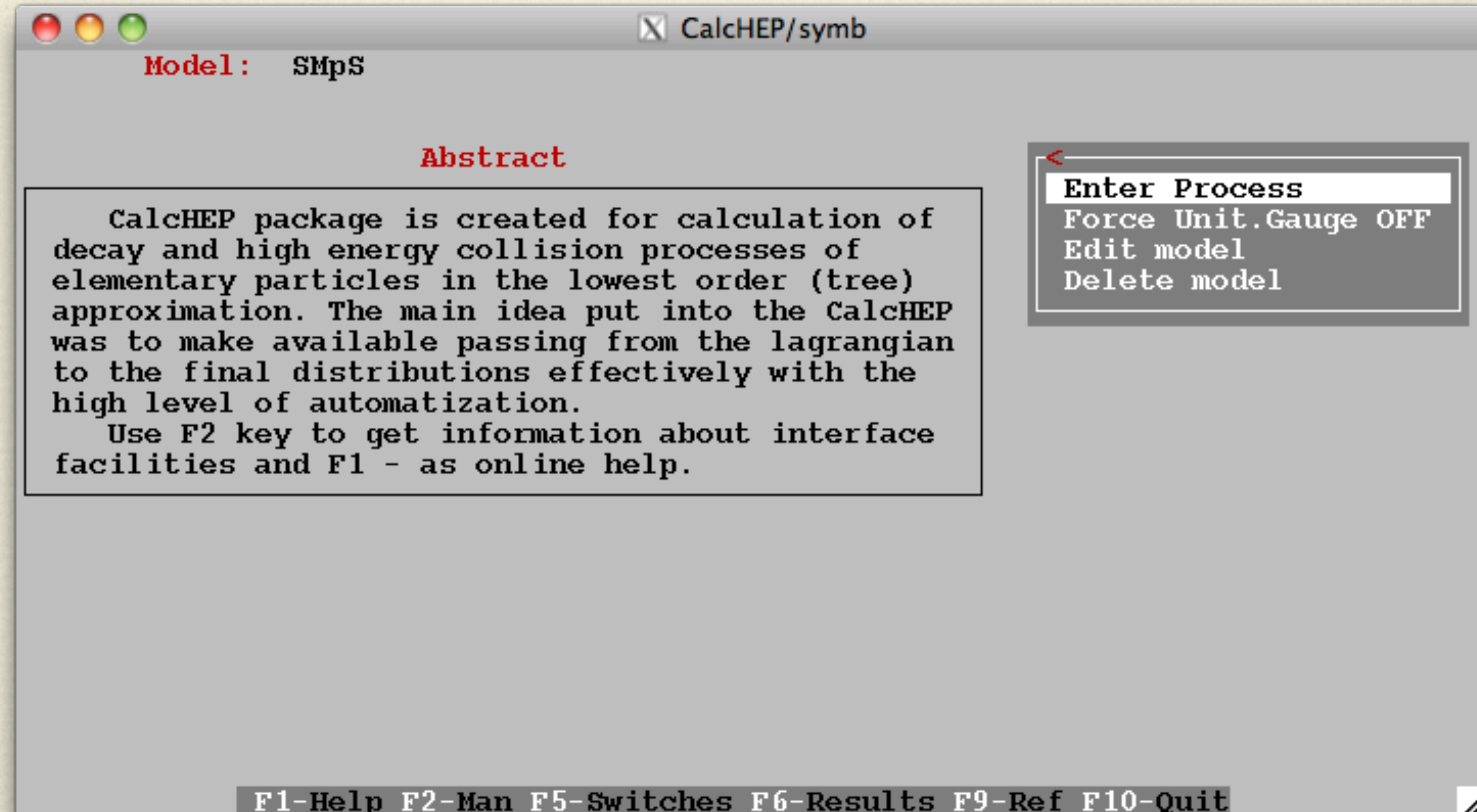

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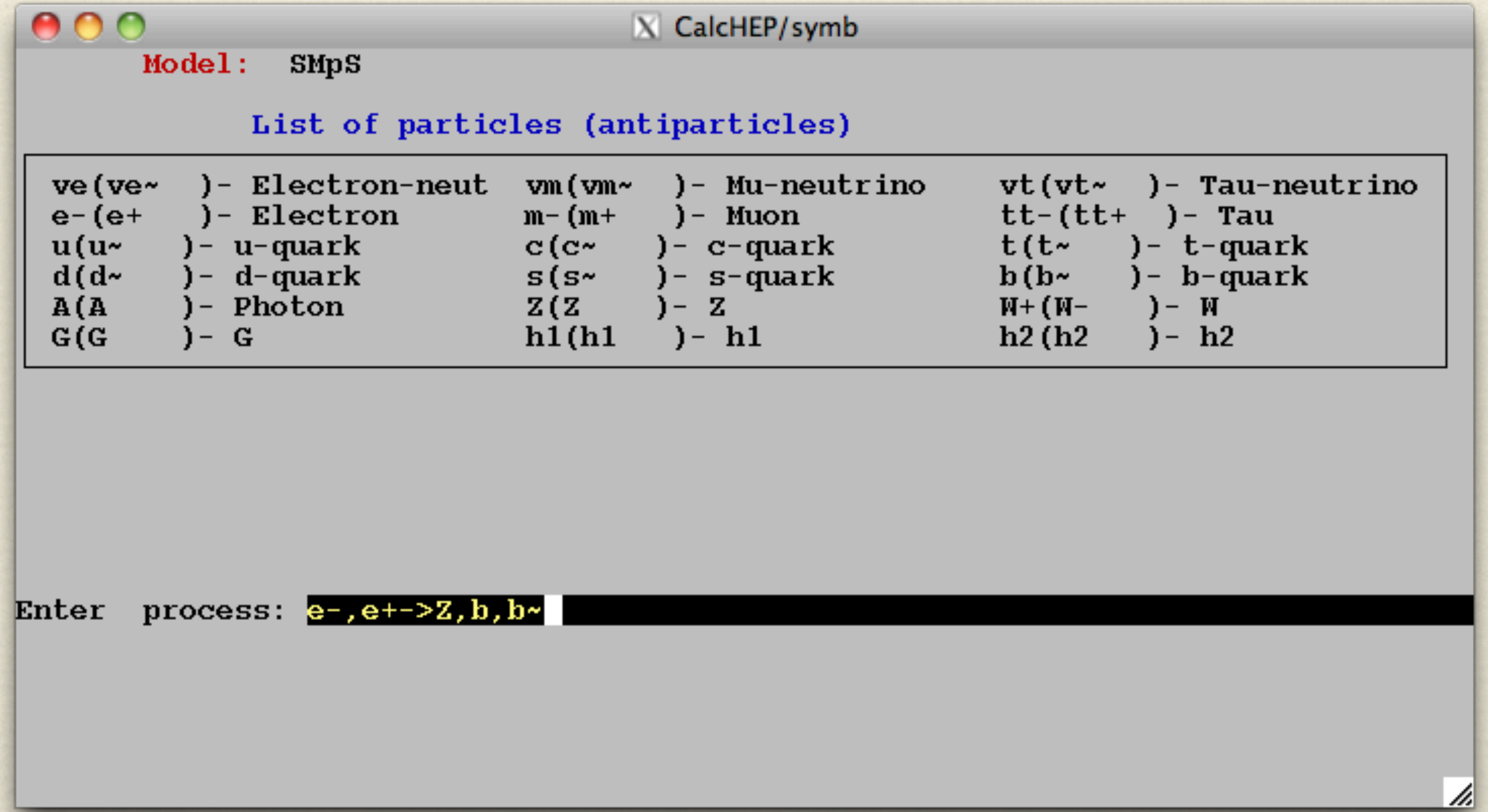

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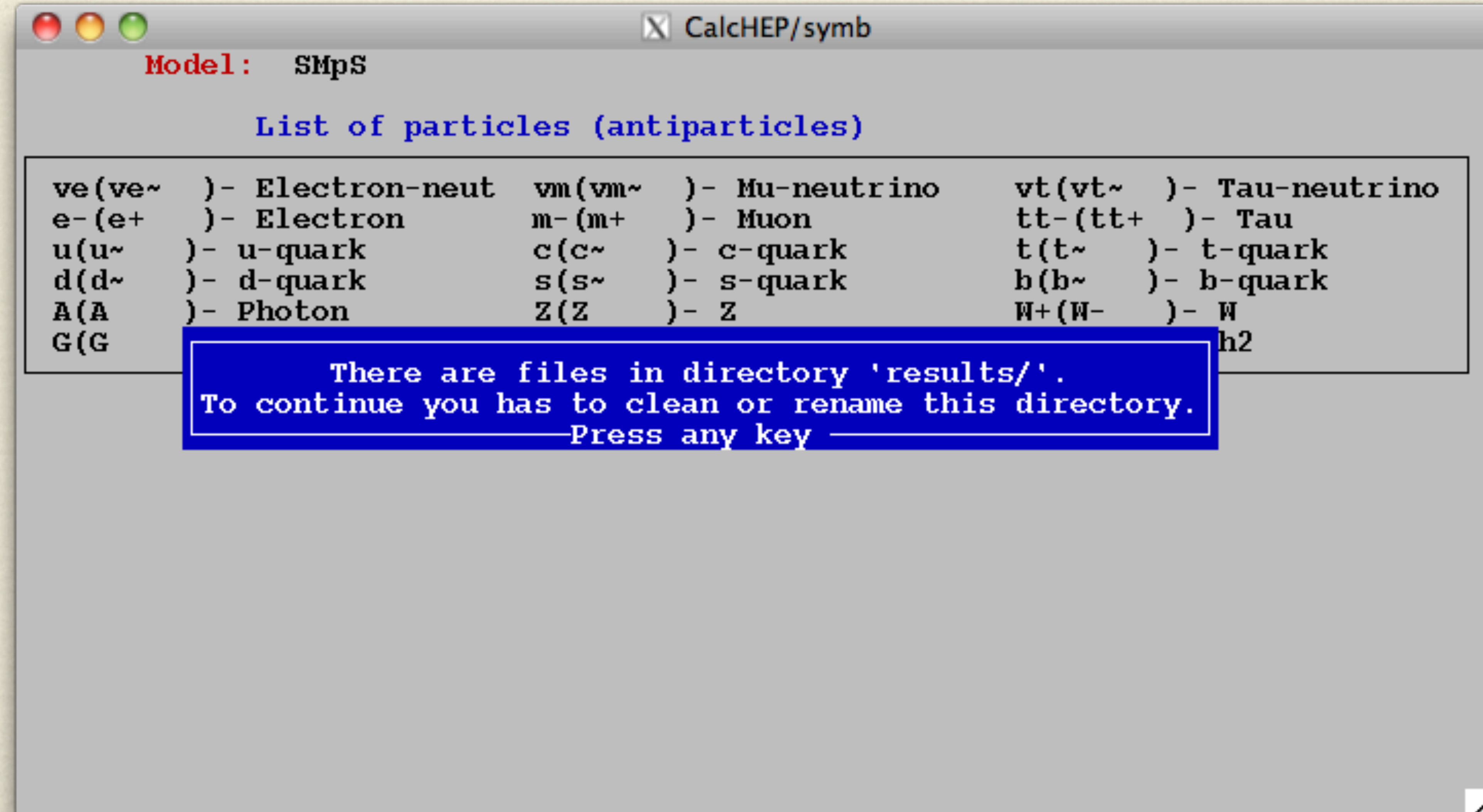

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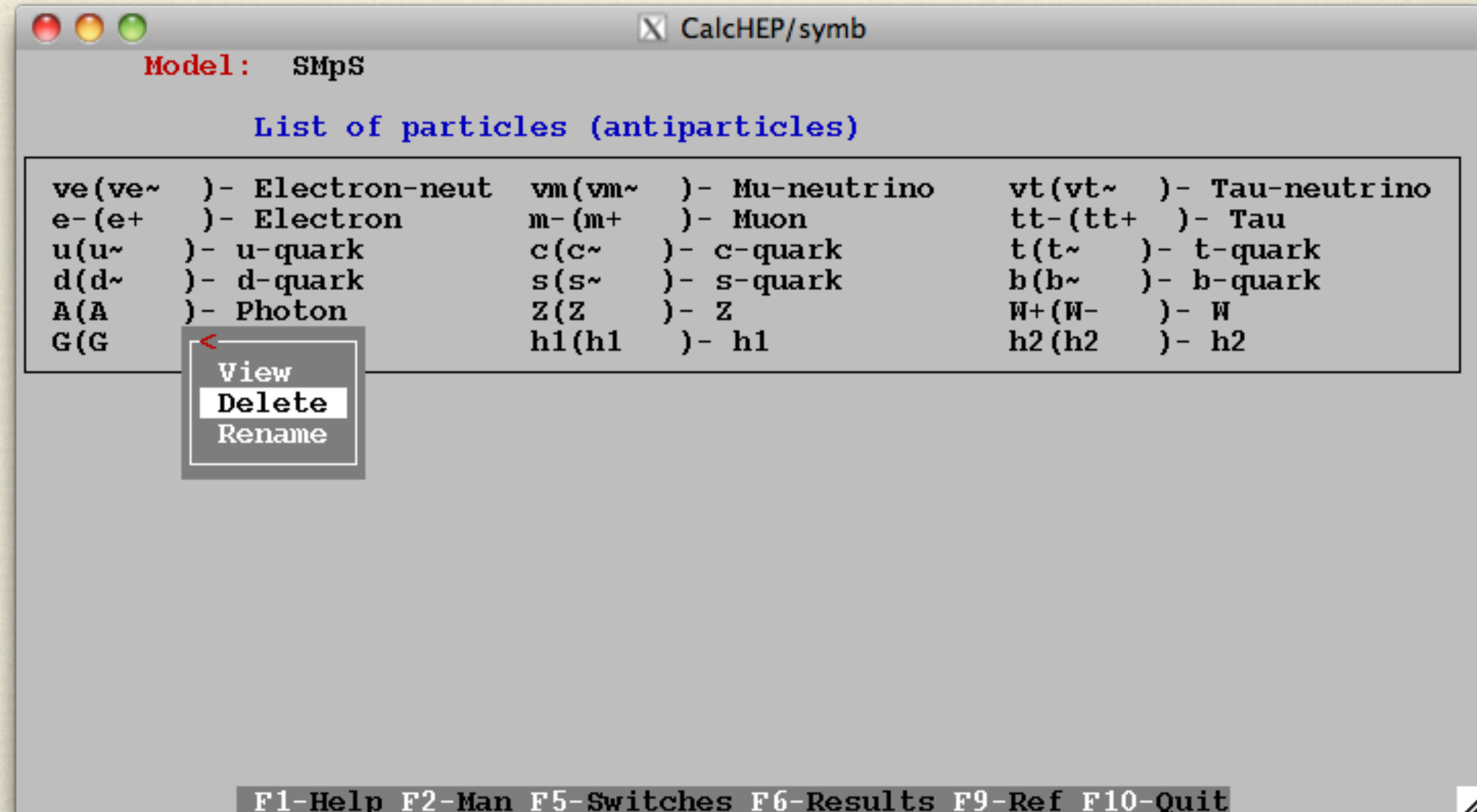

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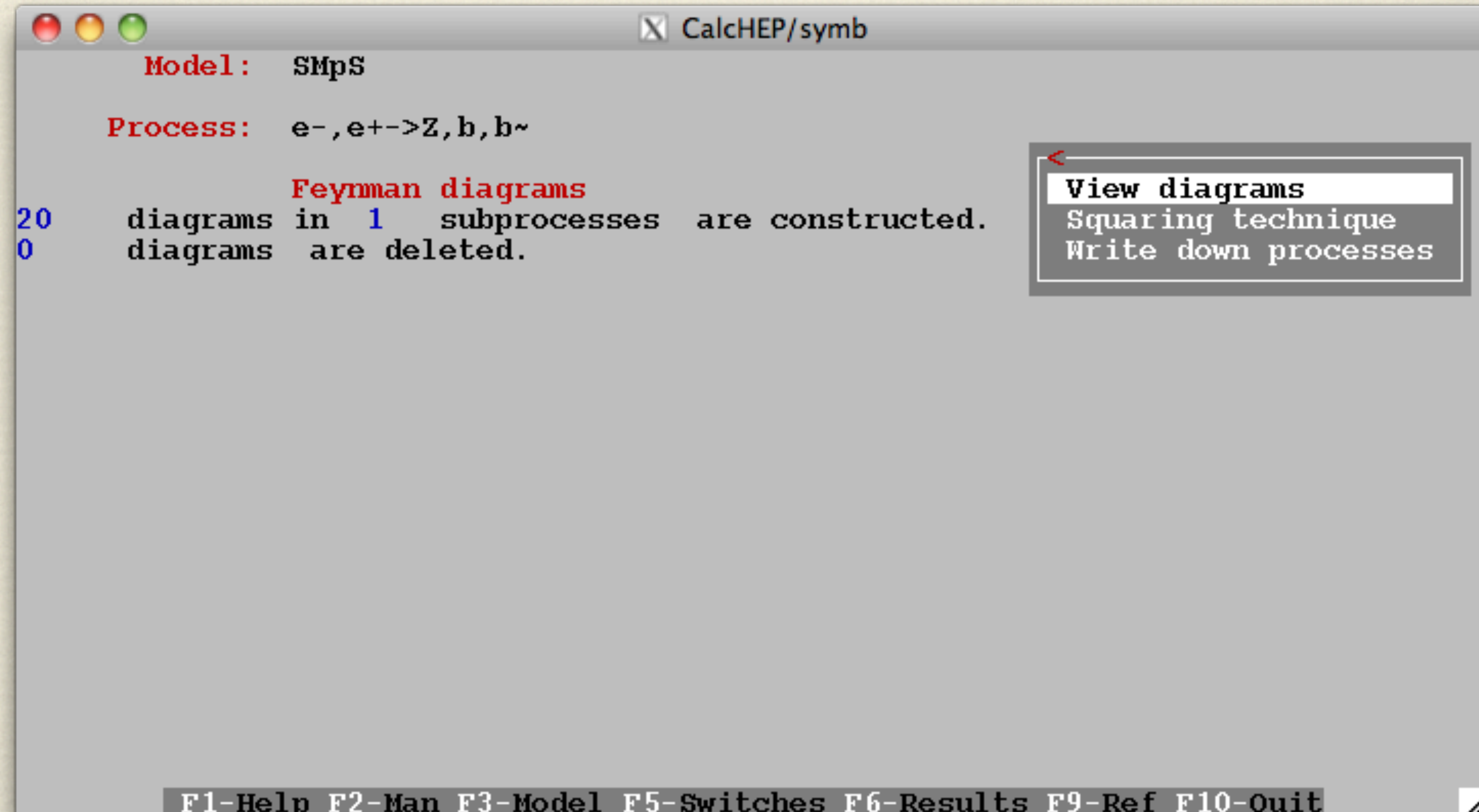

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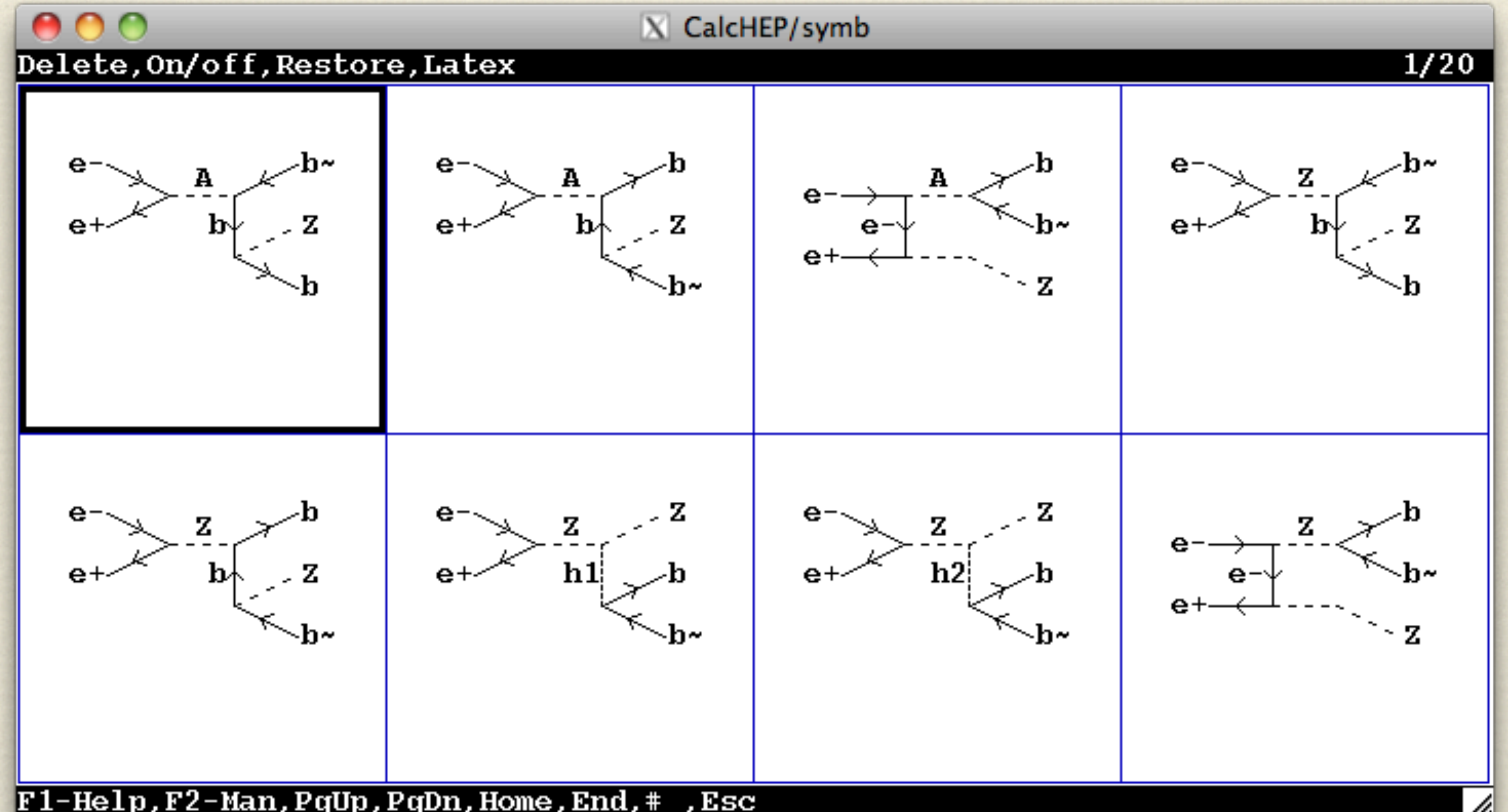

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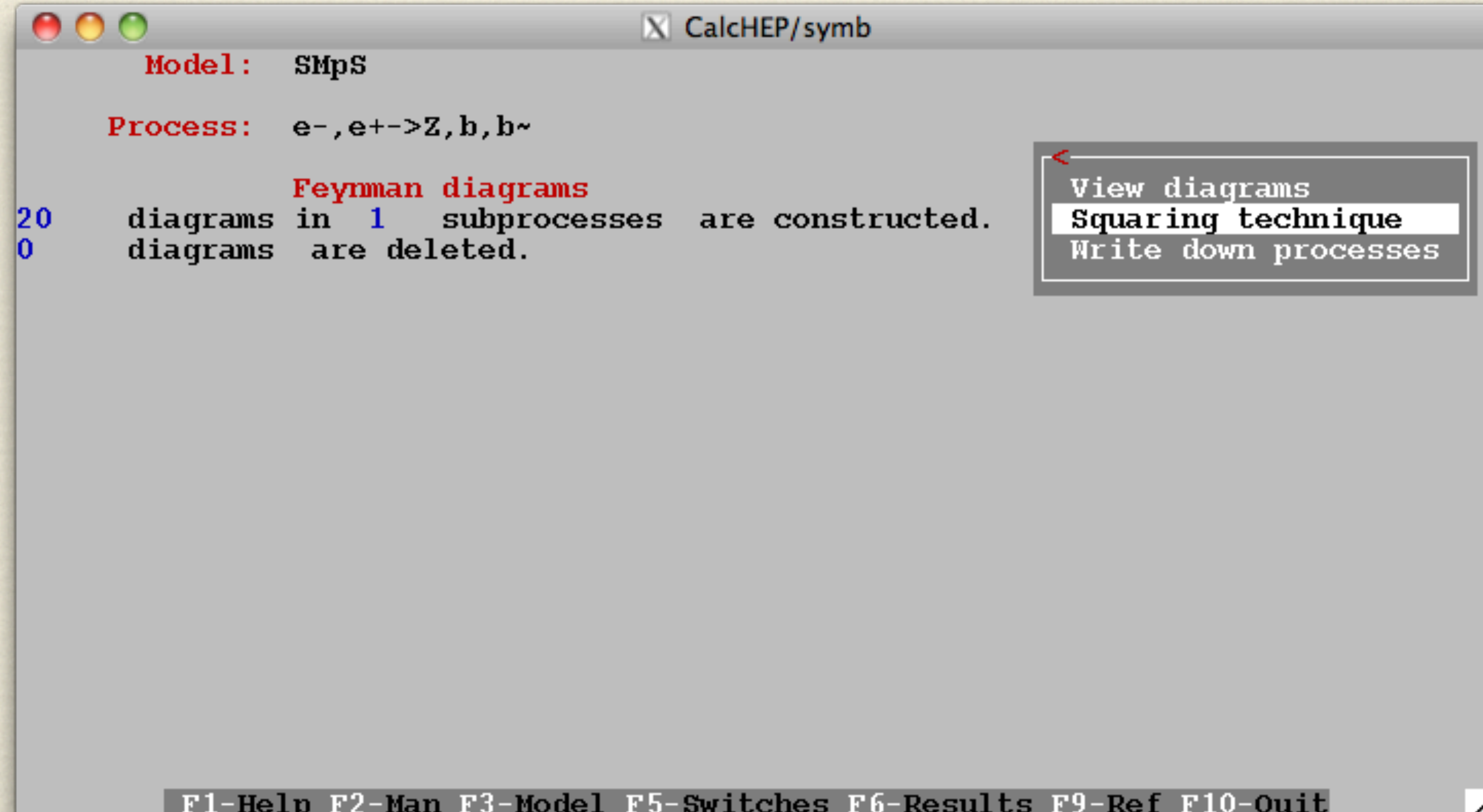

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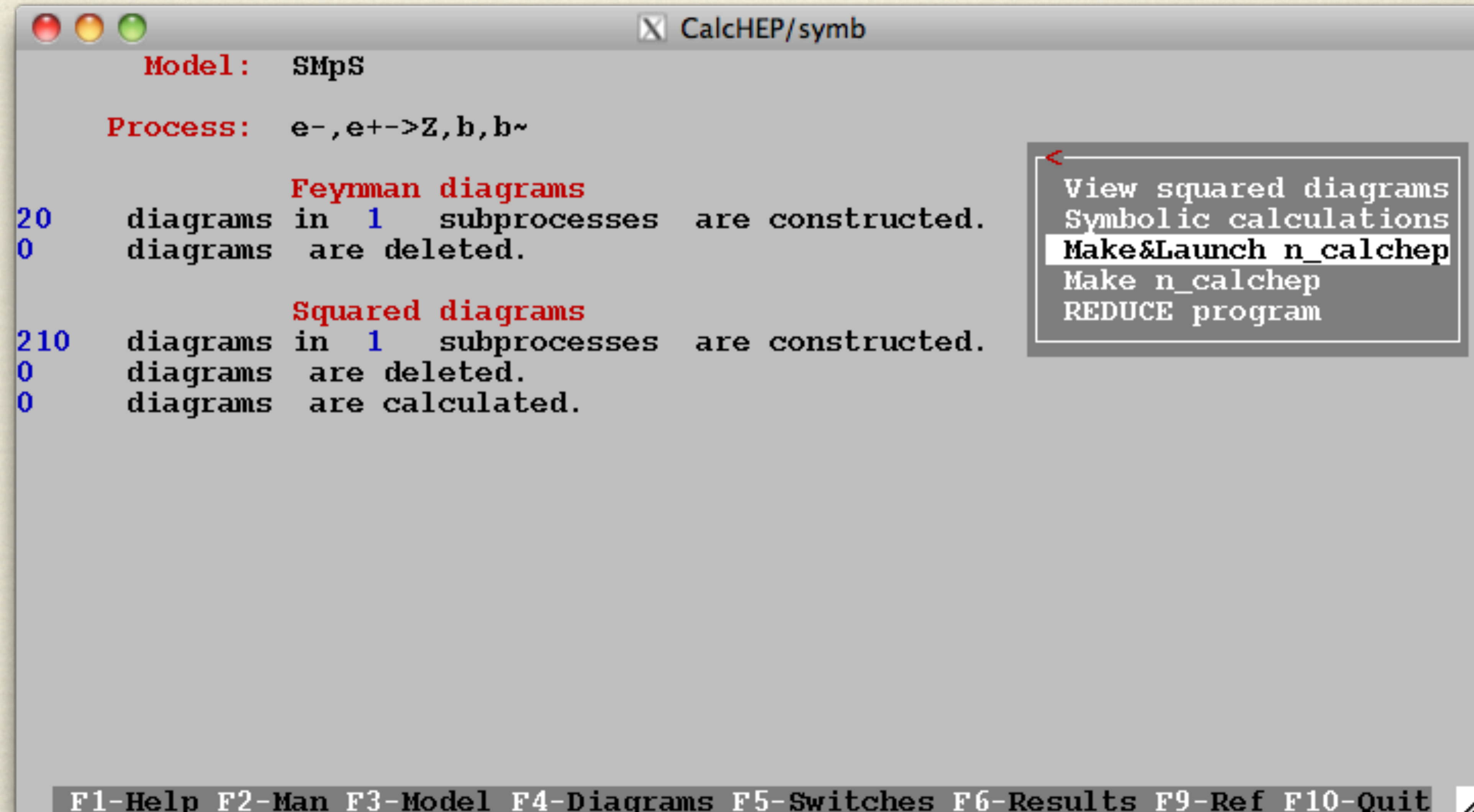

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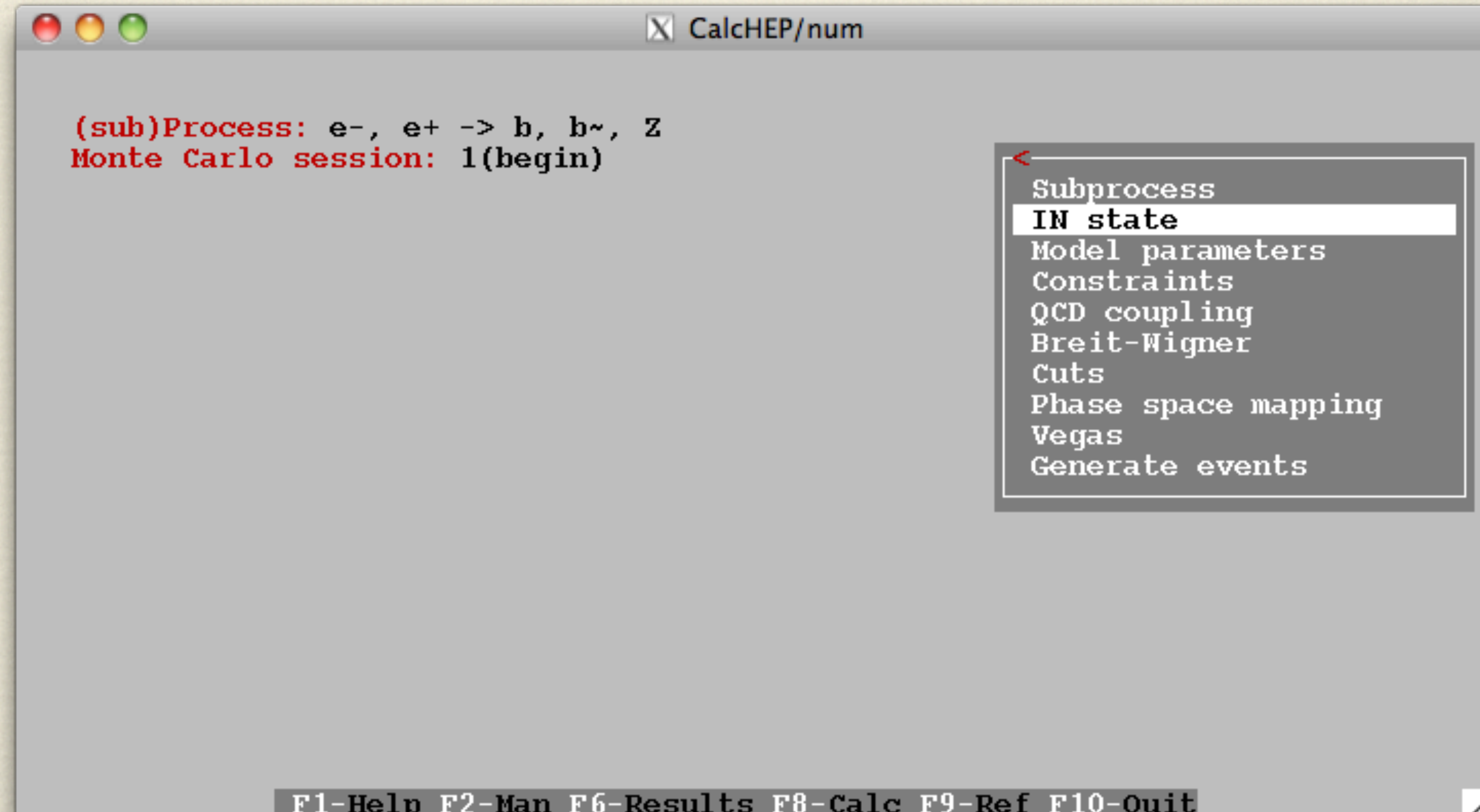

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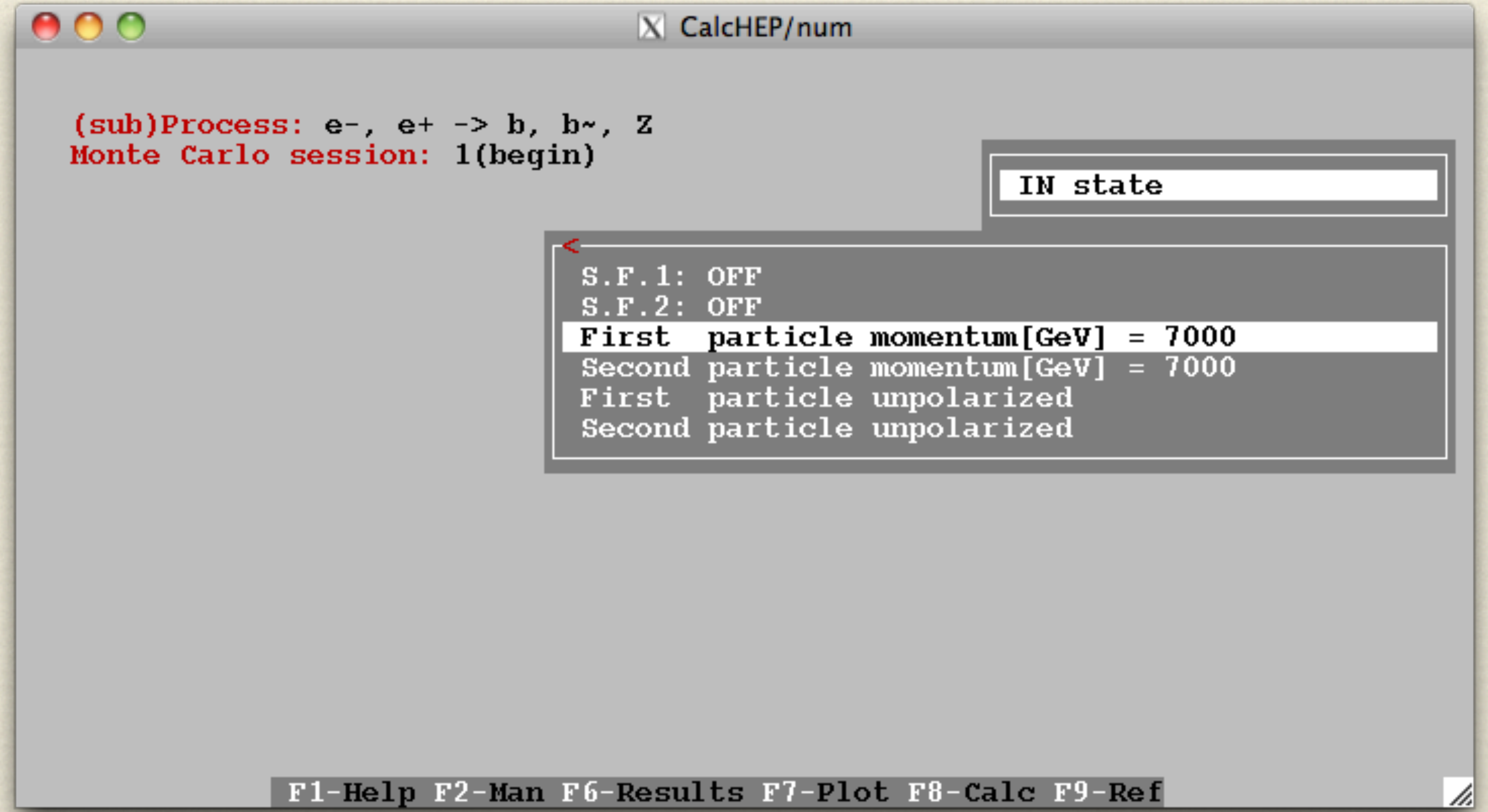

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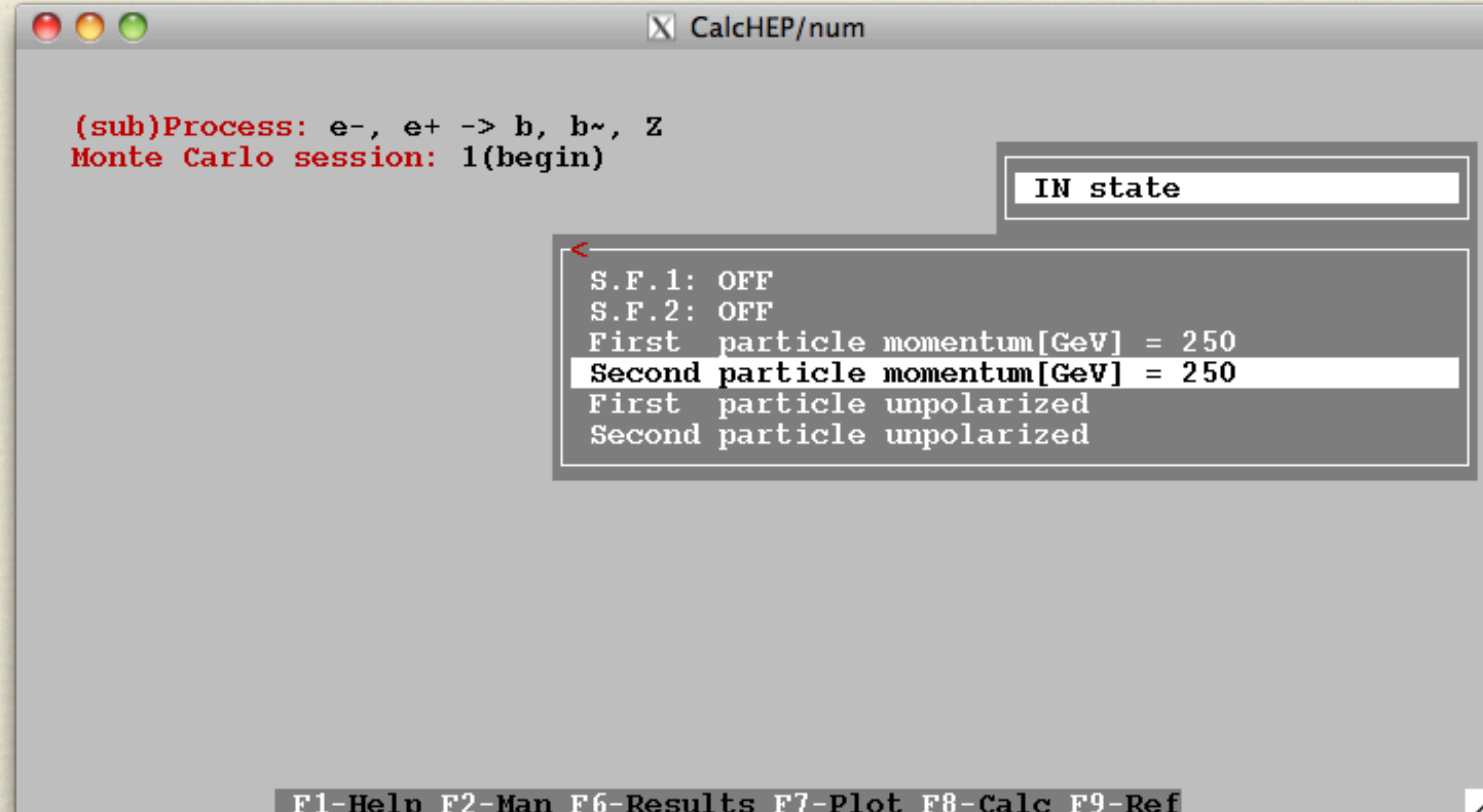

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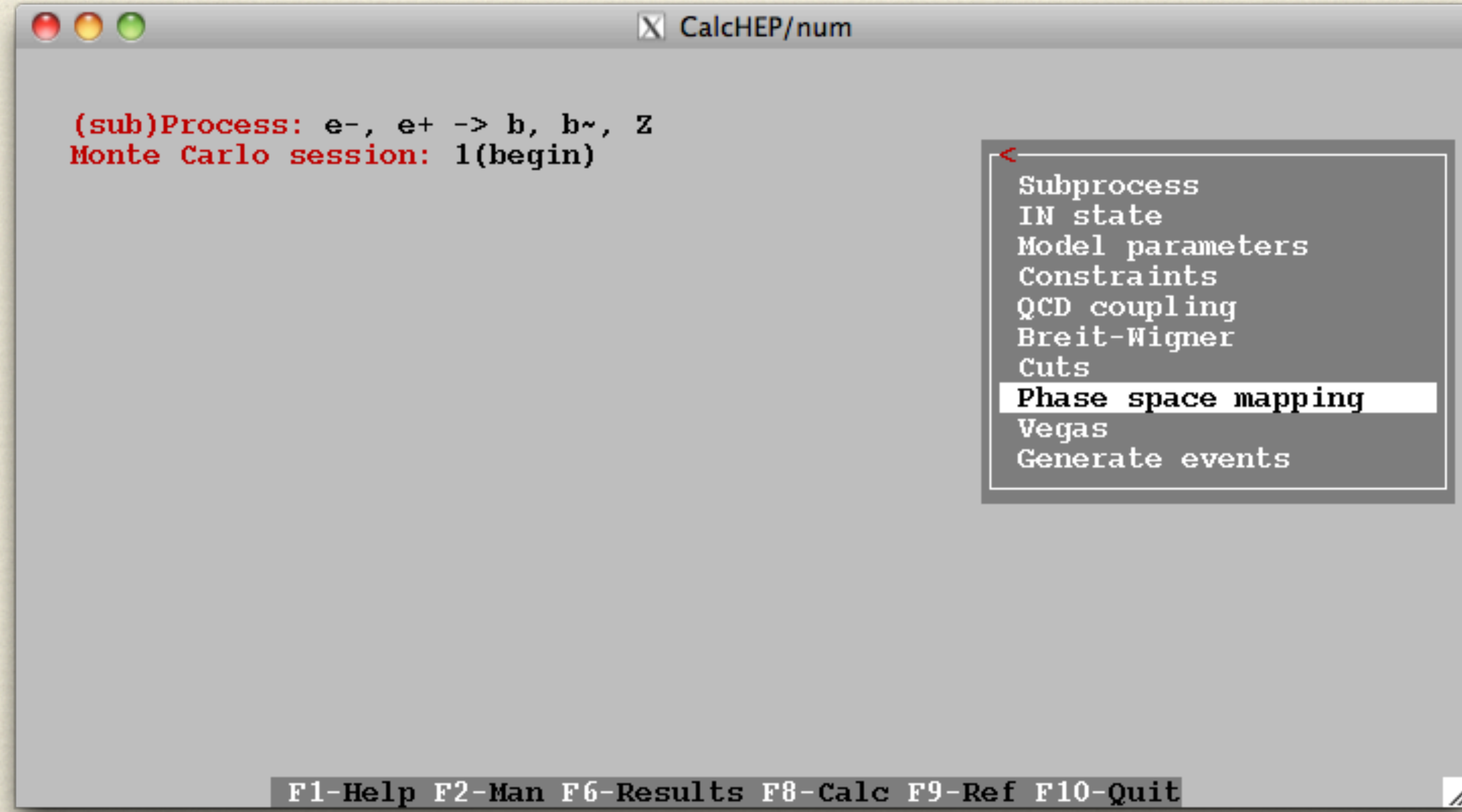

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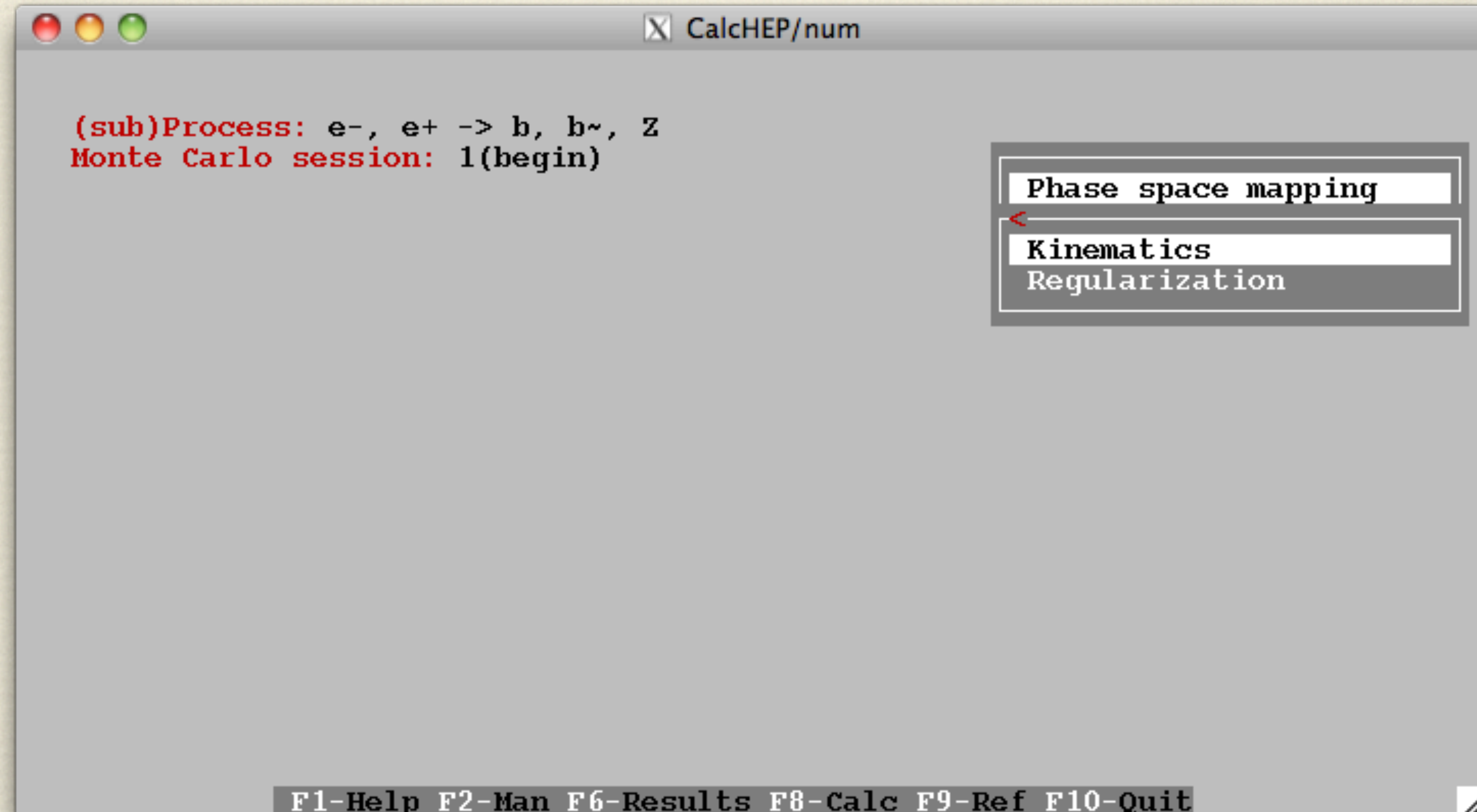

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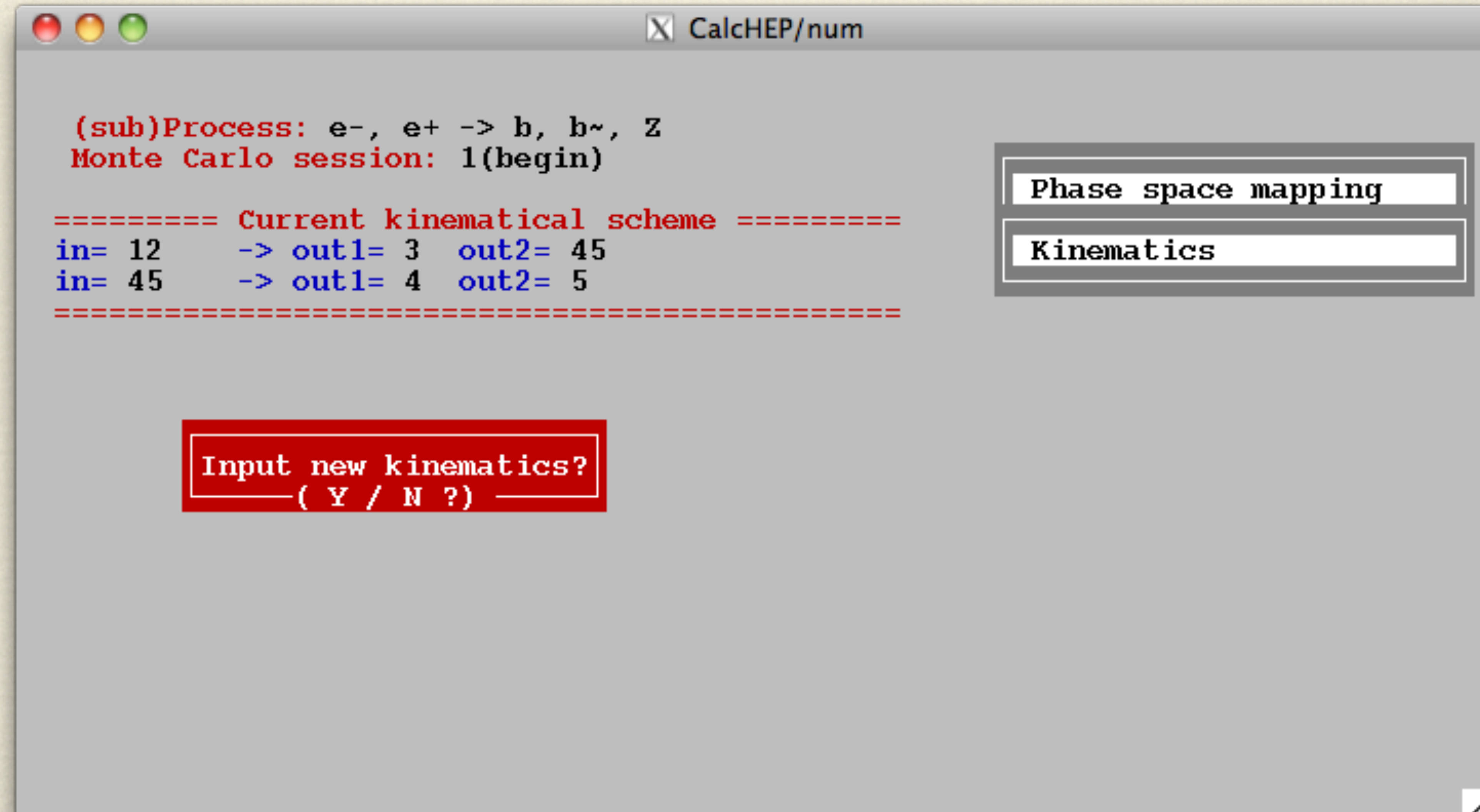

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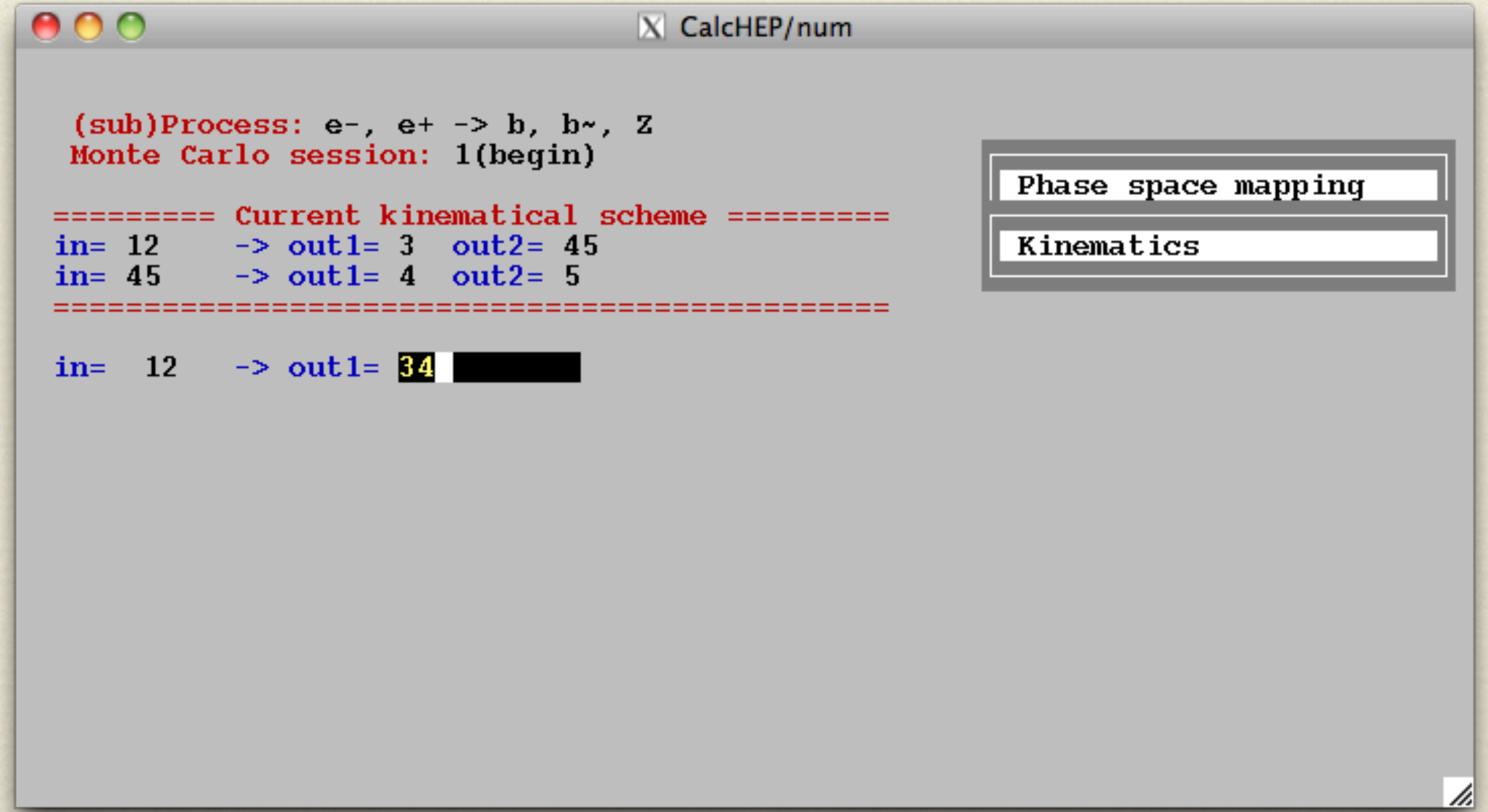

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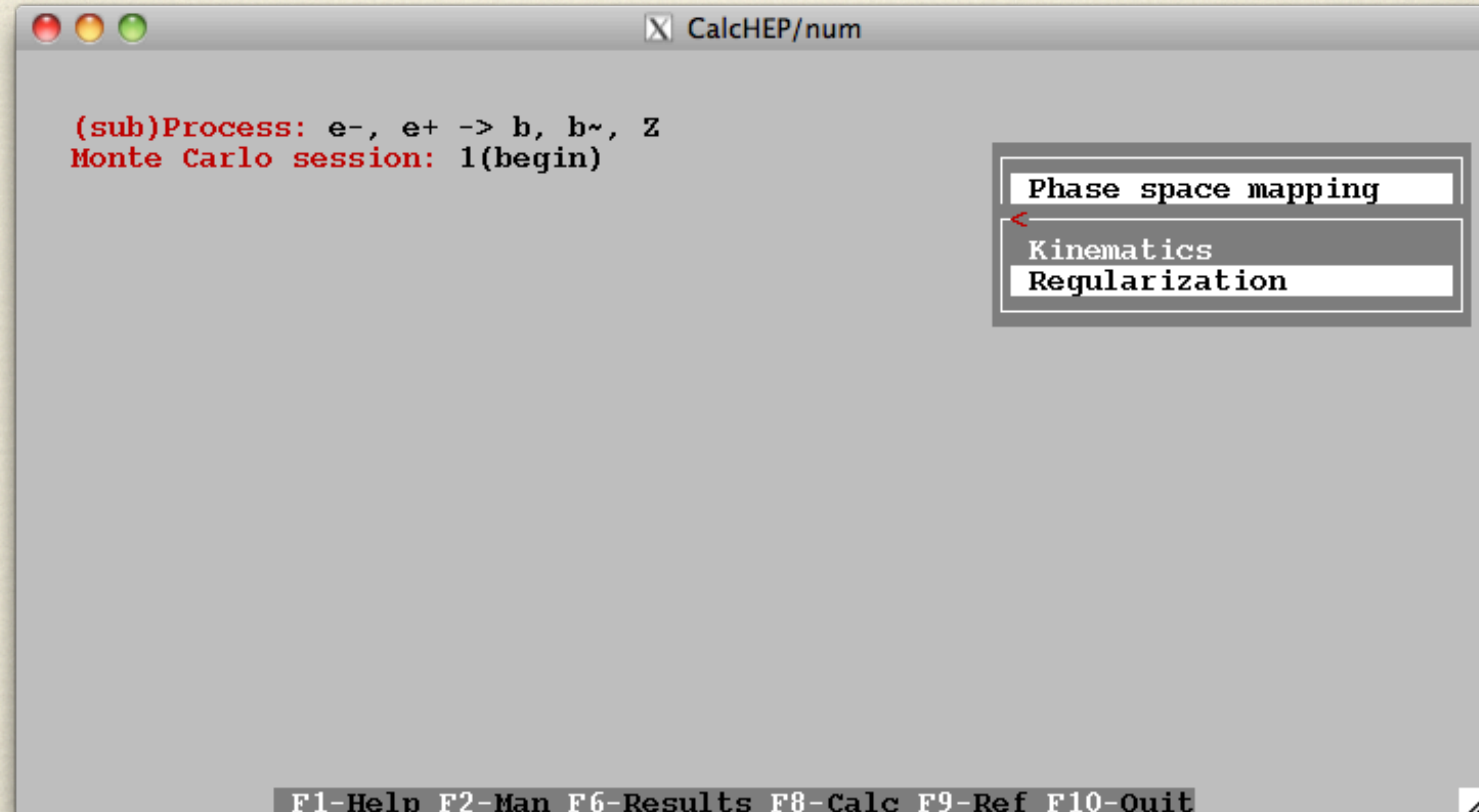

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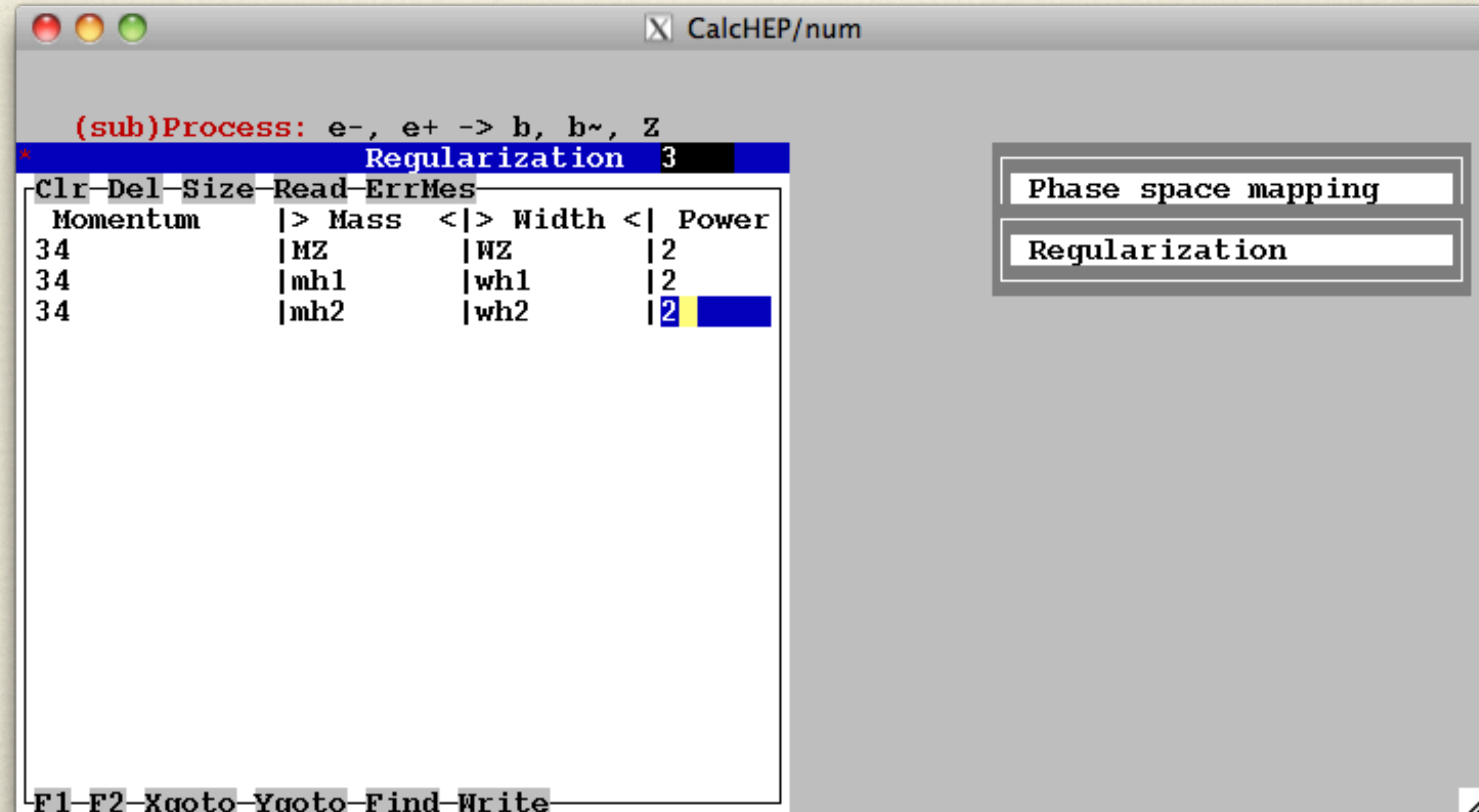

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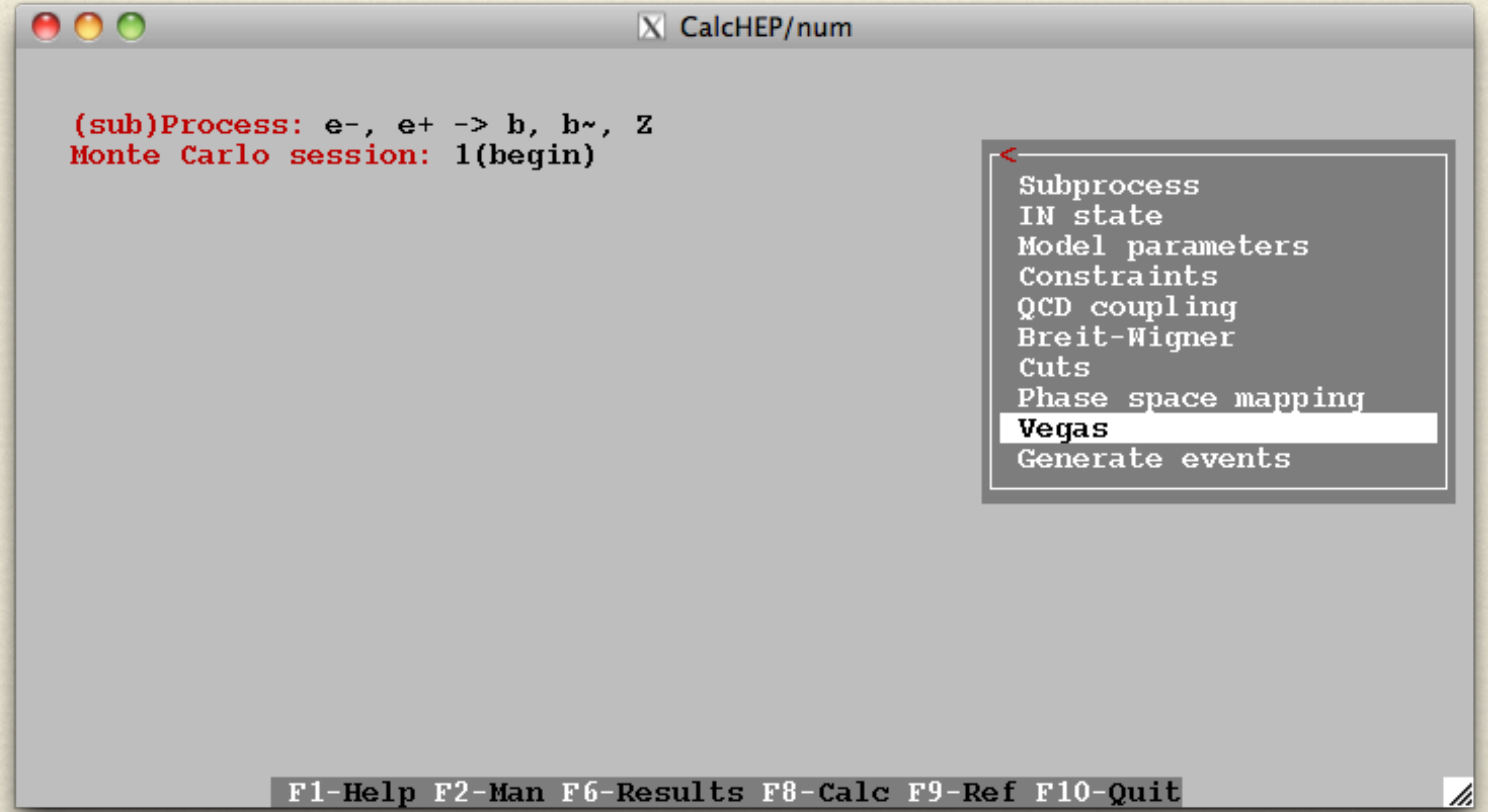

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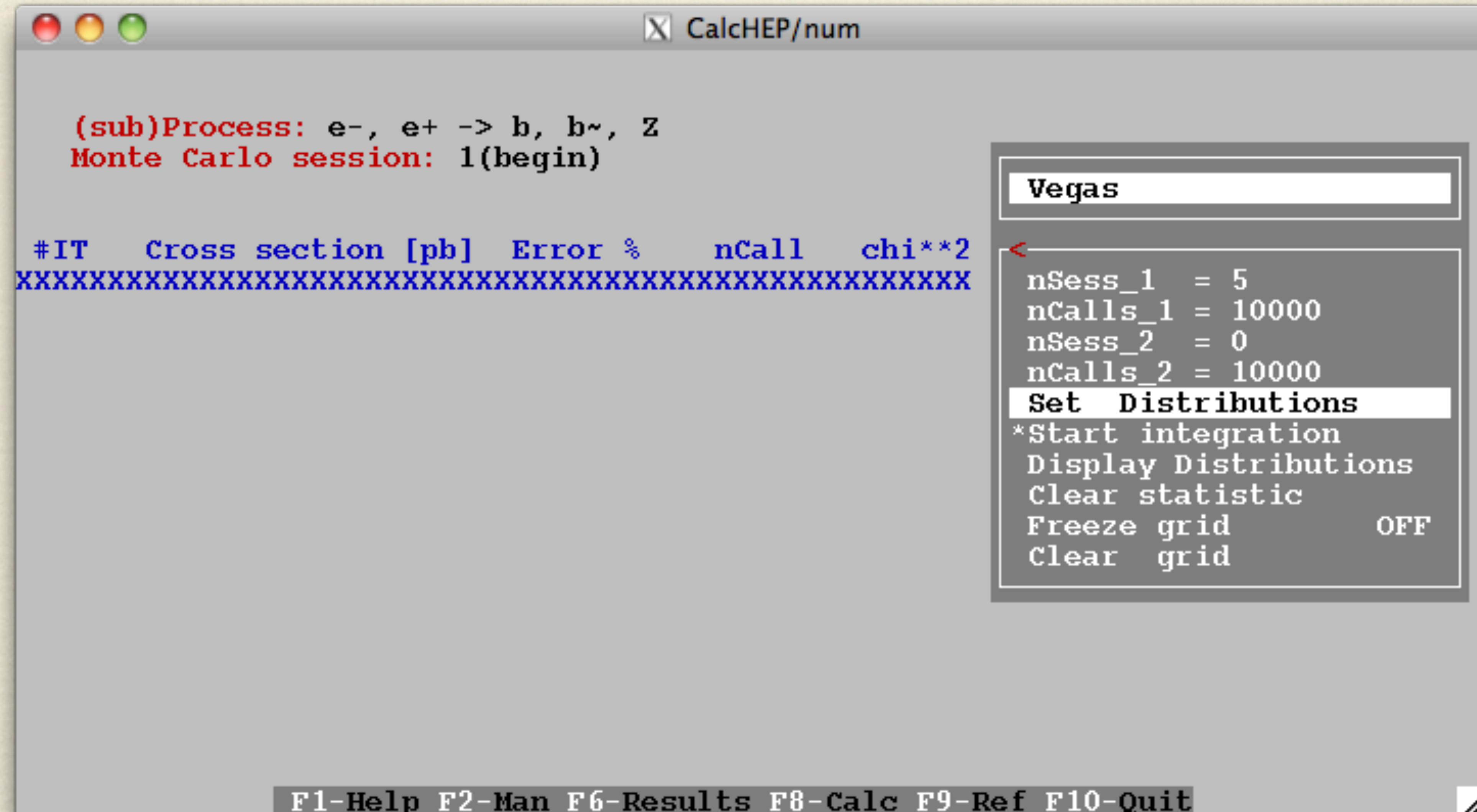

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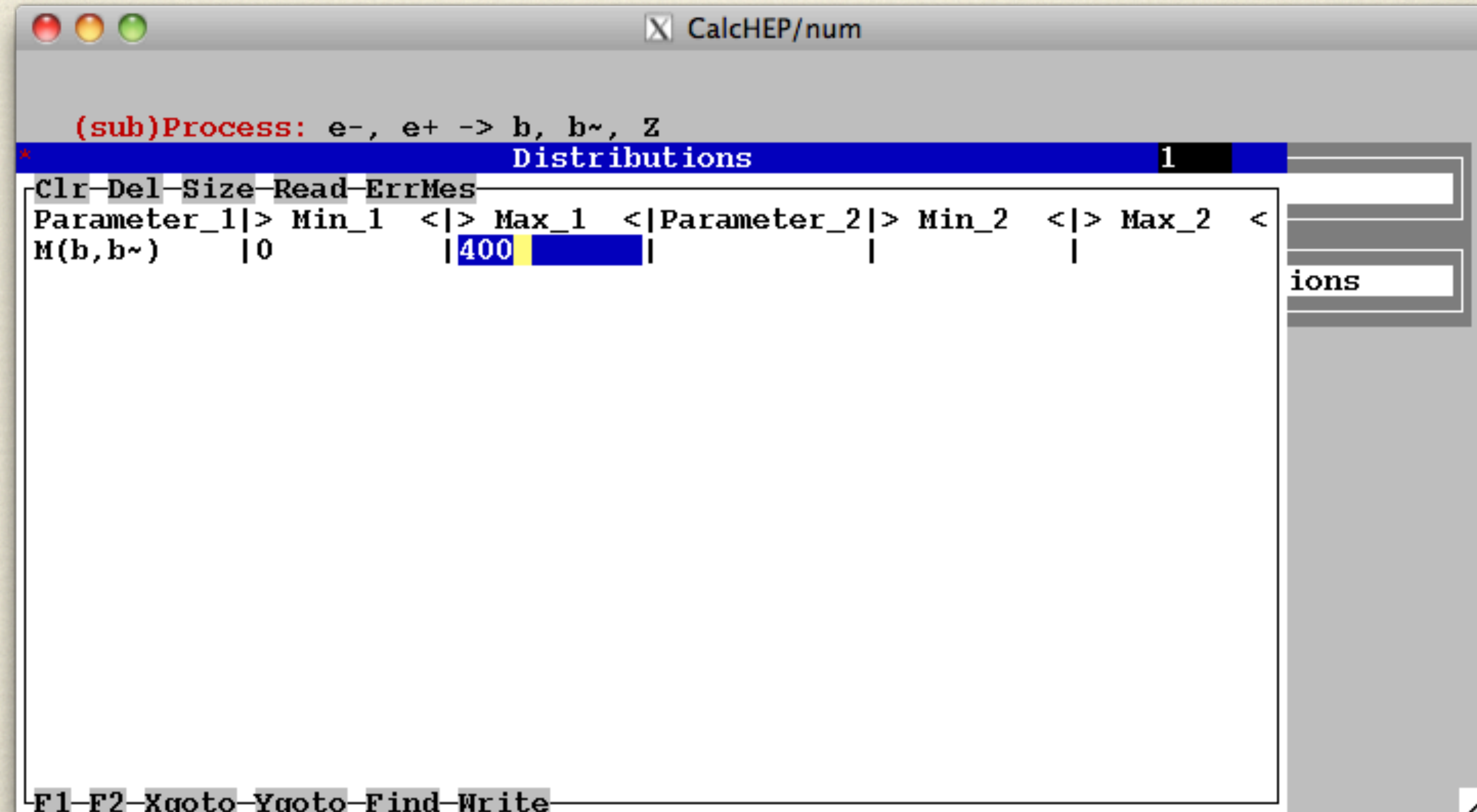

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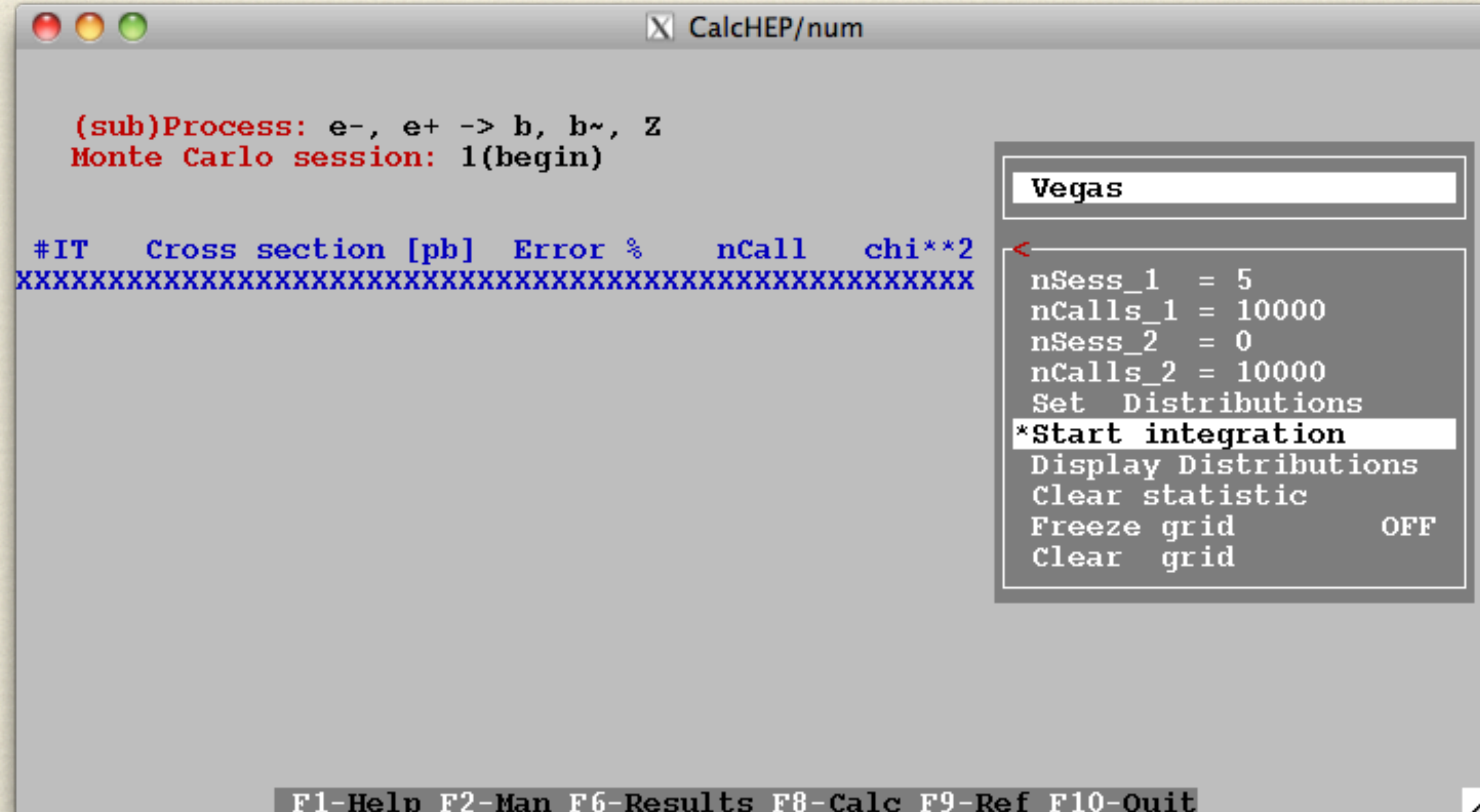

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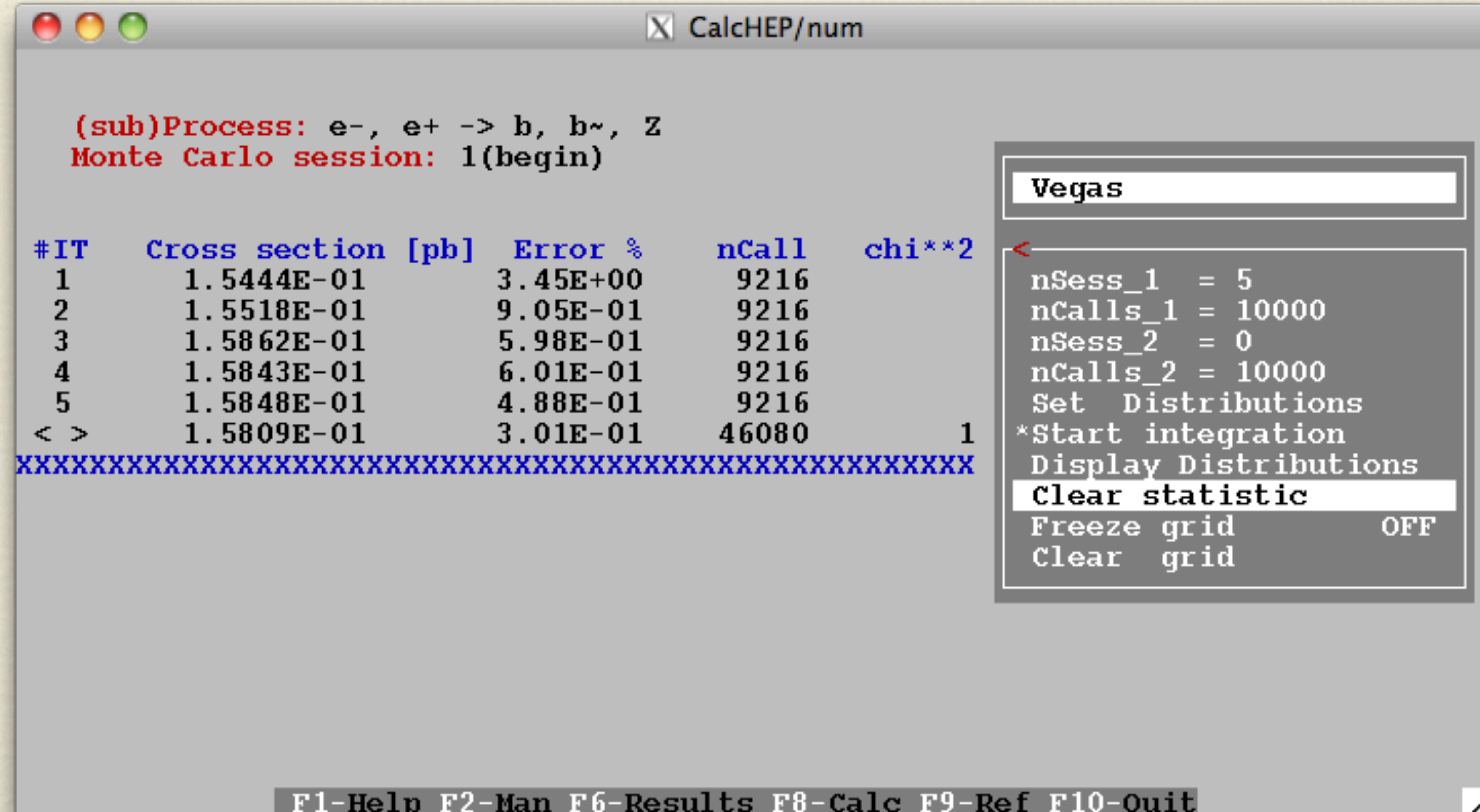

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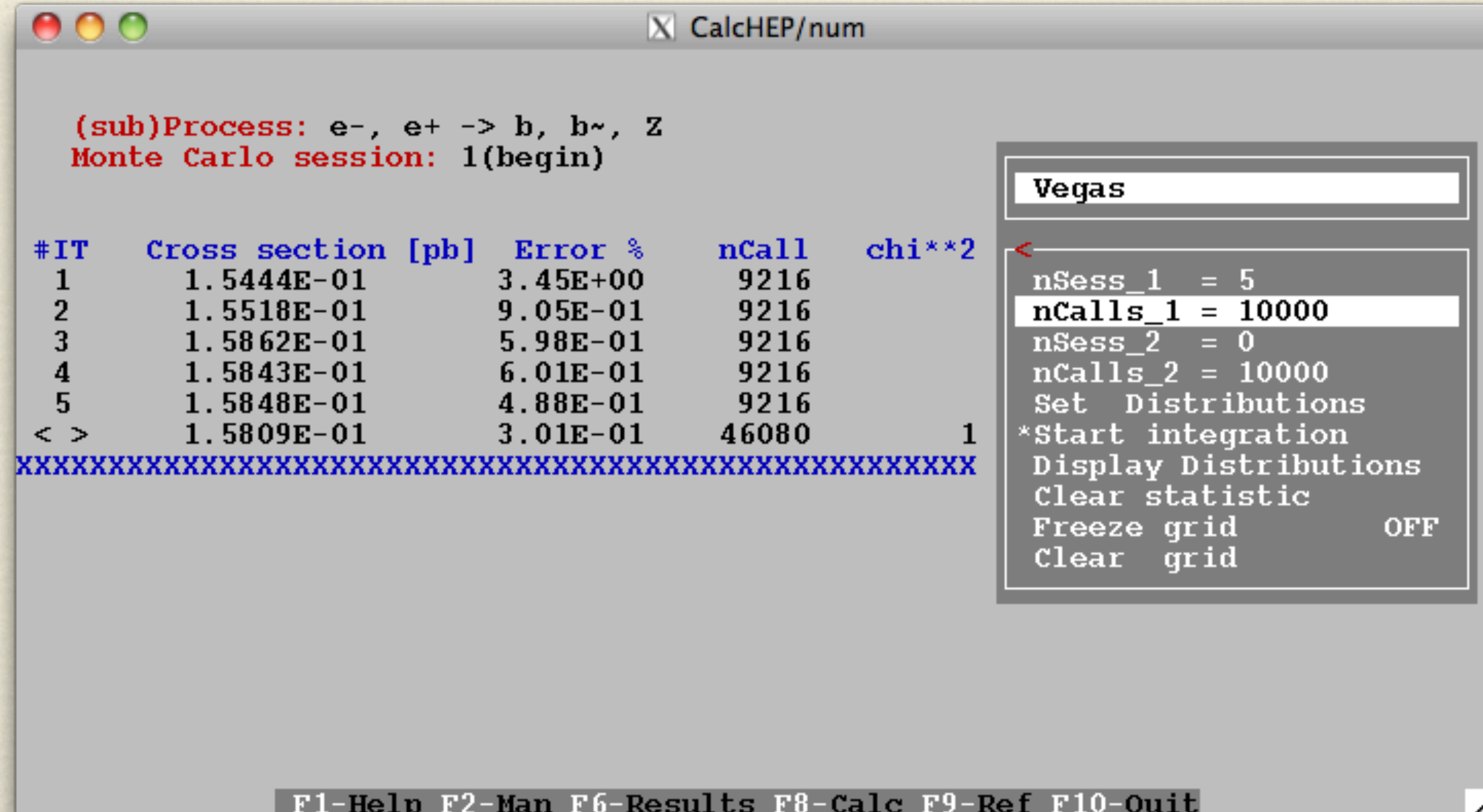

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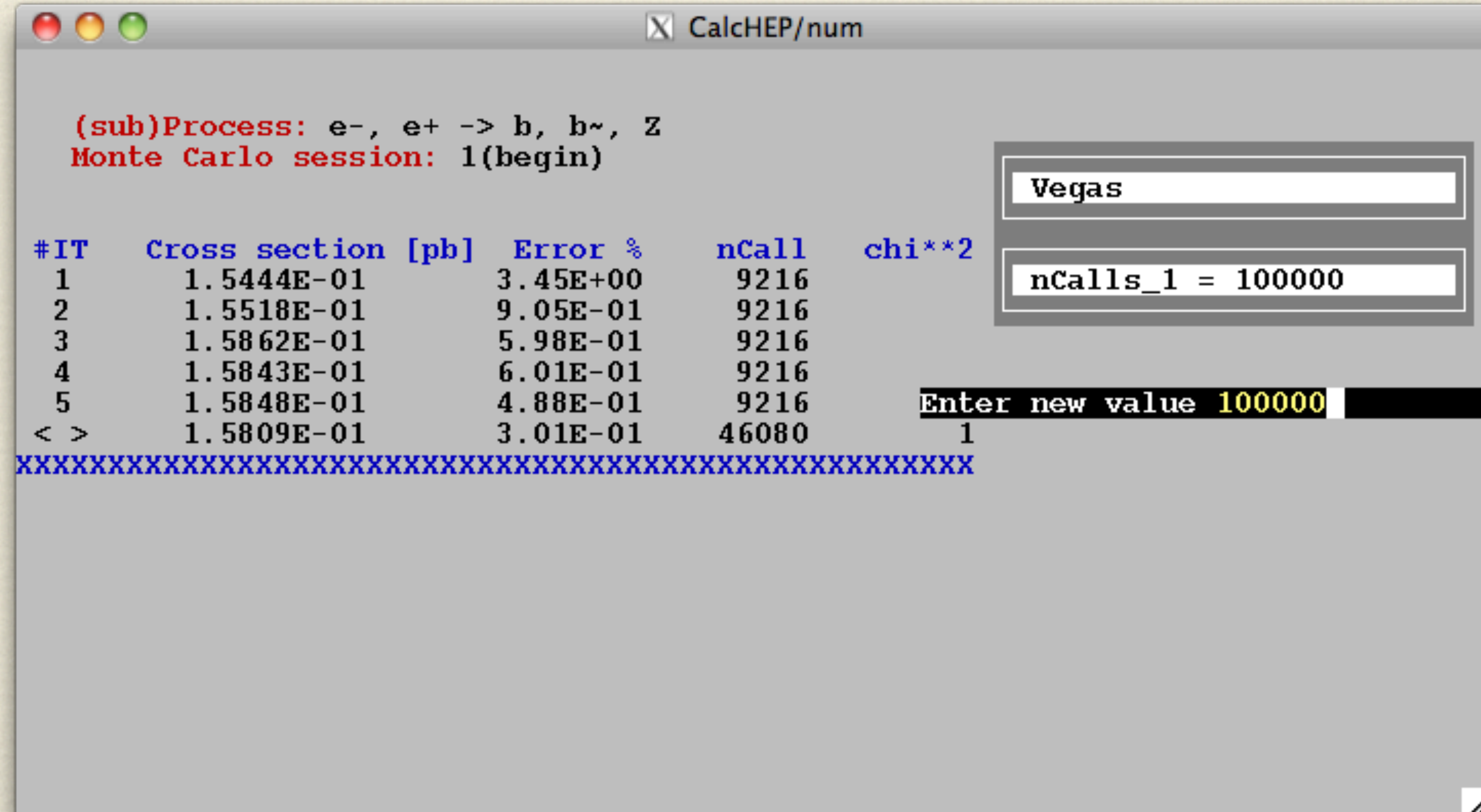

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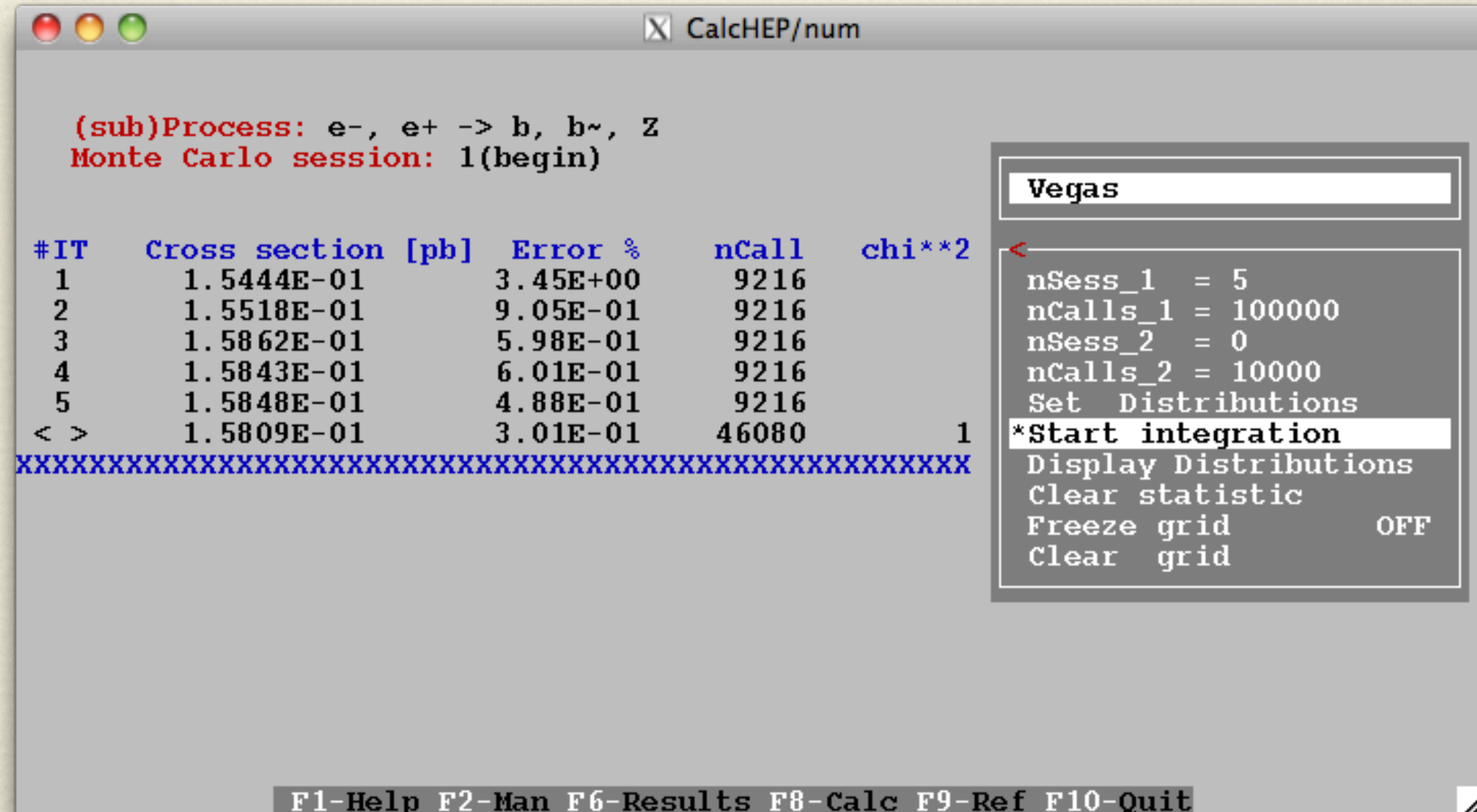

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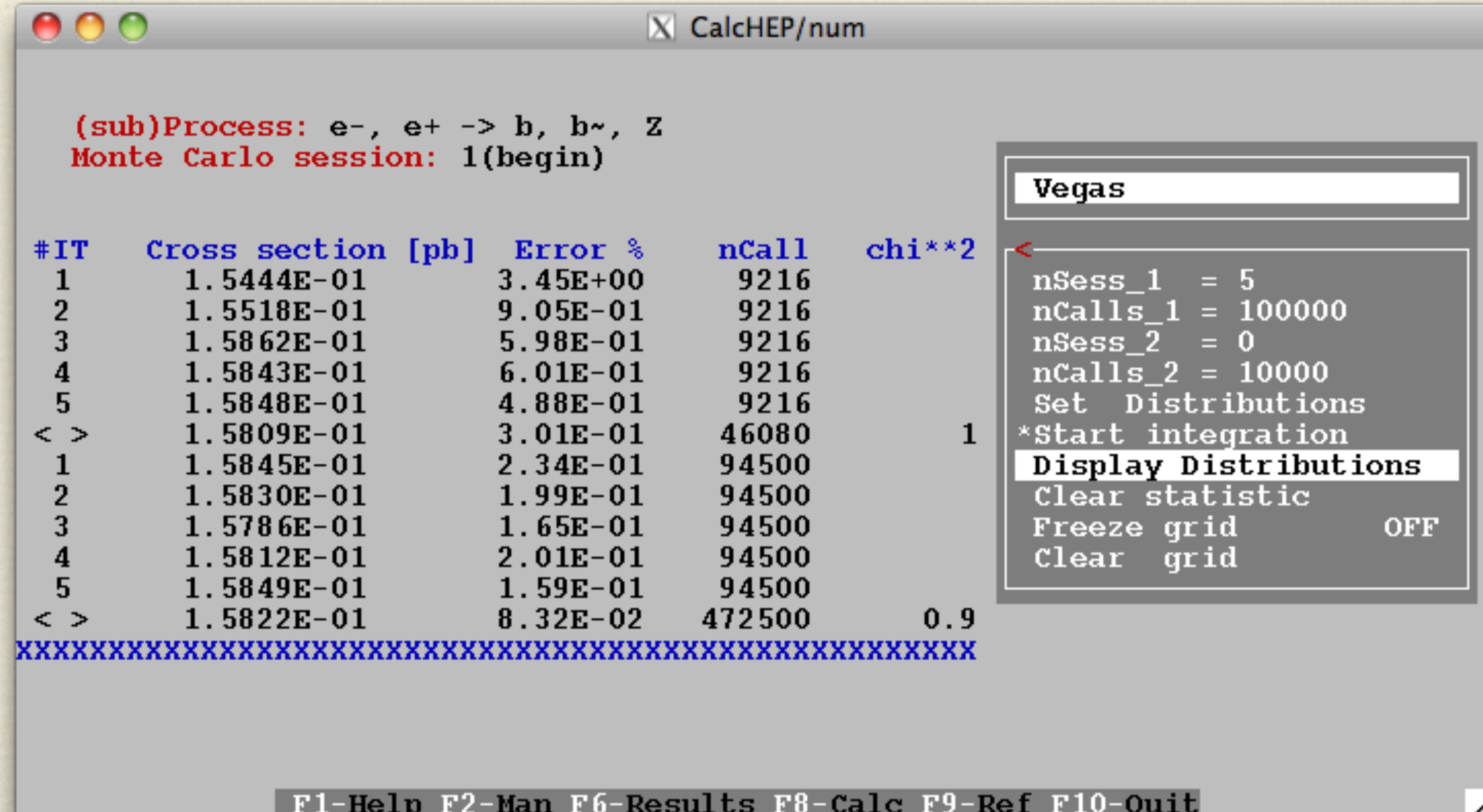

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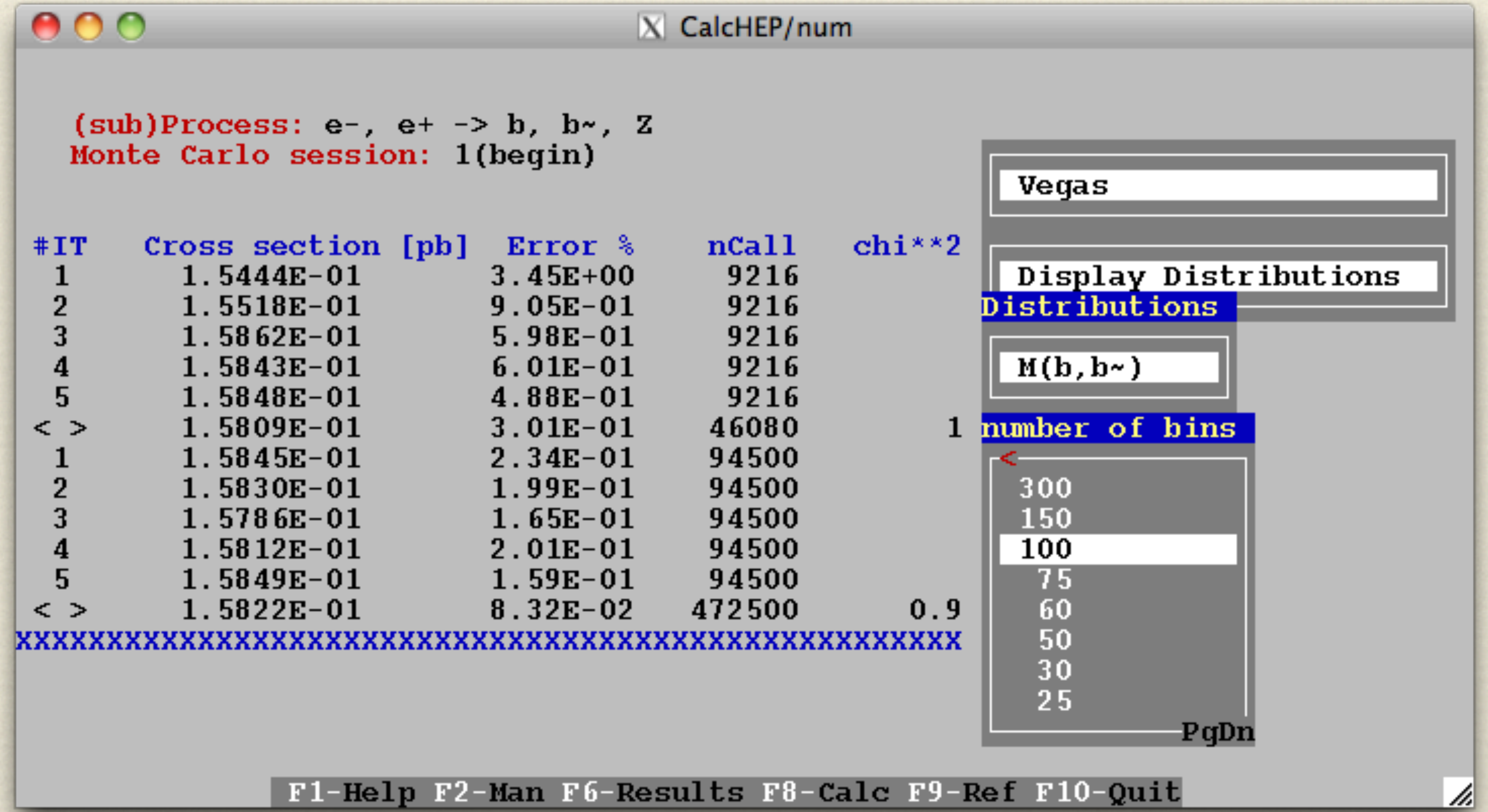

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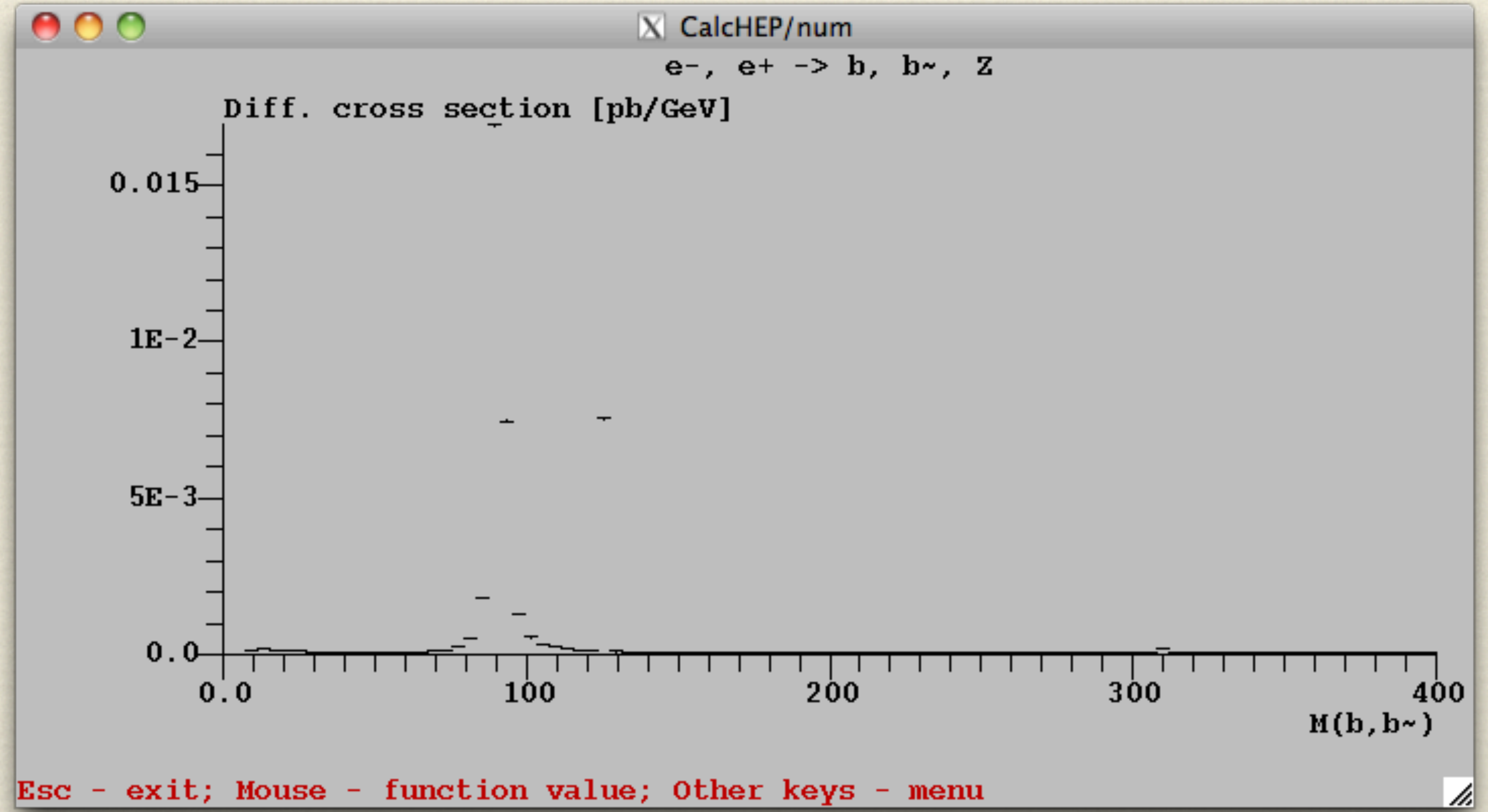

Done Early?

- Make mh1 & mh2 the external parameters:
  - Set mh1 & mh2 to be external.
  - Set \[Lambda] and muH to be internal.
  - Set their values to be formulas in terms of mh1 & mh2.
- Add other allowed lagrangian terms.
- Start implementing your favorite unimplemented model!