# Physics 214 UCSD/225a UCSB

## Lecture 16

- Intro to comphep
  - Why numeric calculations?
  - Simple Example.
  - A few pitfalls
- Comments to final
- Common mistake on HW

# What we have learned:
## *The big picture*

- Express cross sections in terms of lorentz invariant Matrix Element
- Compute leading order matrix elements
- Understand how to proceed from parton collisions to hadron collisions

***Now it's time to make our life a little easier by introducing computational tools instead of pencil and paper.***

# Getting Oriented

- Computing leading order processes
  - Comphep
    - http://comphep.sinp.msu.ru
  - MADGraph
    - http://madgraph.hep.uiuc.edu/
  - I will talk about the first today, and the second next quarter.
- Compute NLO processes
  - MCFM
    - http://mcfm.fnal.gov/
  - MC@NLO
    - http://www.hep.phy.cam.ac.uk/theory/webber/MCatNLO/
  - We will learn about these next quarter.
- All of the above require hadronization to be done by Pythia/Herwig etc.

# Comphep

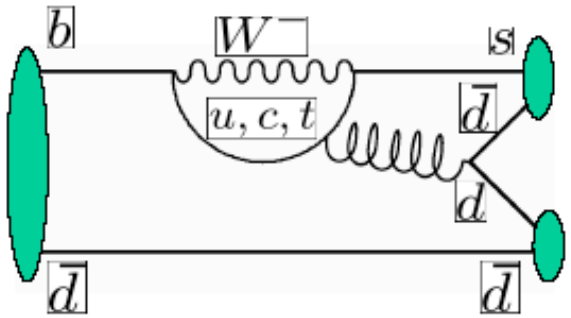
- A computer program that allows you to do some simple calculations at leading order in perturbation theory.
- Why is it needed?
  - Experimental observables in Hadron collider physics are difficult to calculate because this requires pdf's.
  - Programs like comphep (madgraph, etc.) allow you to specify a process, calculate its cross section, plot a few simple kinematic variables, or generate the "hard collision events".
  - This is crucial to get a quick look at something.
- However, we will see that it's easy to make mistakes!

# Comphep Resources

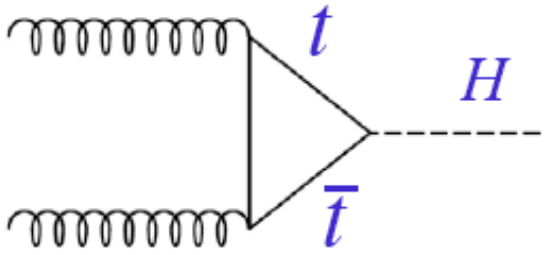
- The web site:
  - http://comphep.sinp.msu.ru/
- A tutorial by Jeff Richman:
  - http://comphep.sinp.msu.ru/tutorials
- The complete manual:
  - http://theory.sinp.msu.ru/comphep_html/tutorial/node1.html
- I will use all of the above, as well as running the actual code, in todays lecture.

# Comphep Limitations

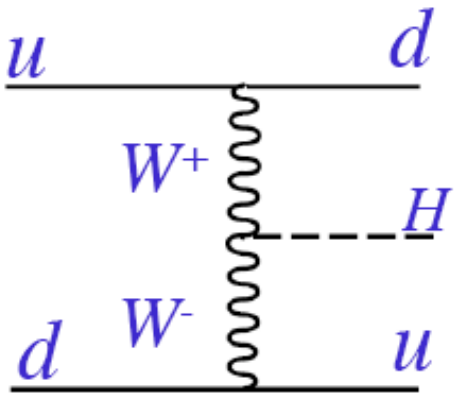
- No hadronic bound states (mesons, baryons) and no hadronization of quarks and gluons into jets
- No loop/box diagrams
- All processes are averaged over allowed initial-state spin polarizations and summed over final-state polarizations.
- No neutrino oscillations
- CompHEP can be used to compute quasi-inclusive processes (e.g., $H \rightarrow 2^*x$), but it is awkward to perform truly inclusive calculations.




*No, No*




*No*



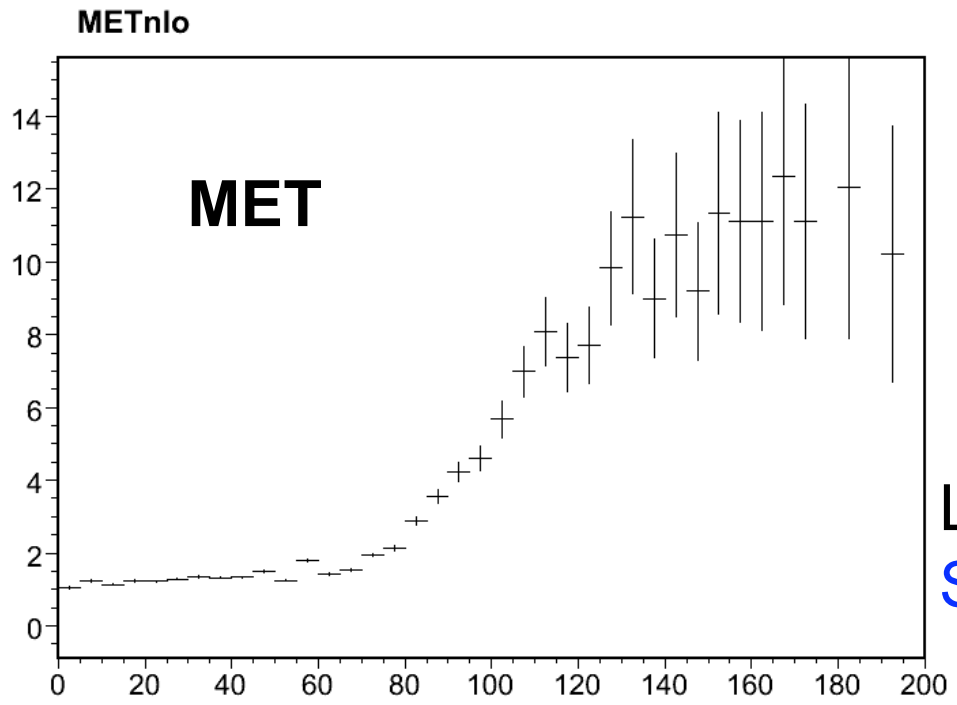

*Yes*

# NLO vs LO cross sections

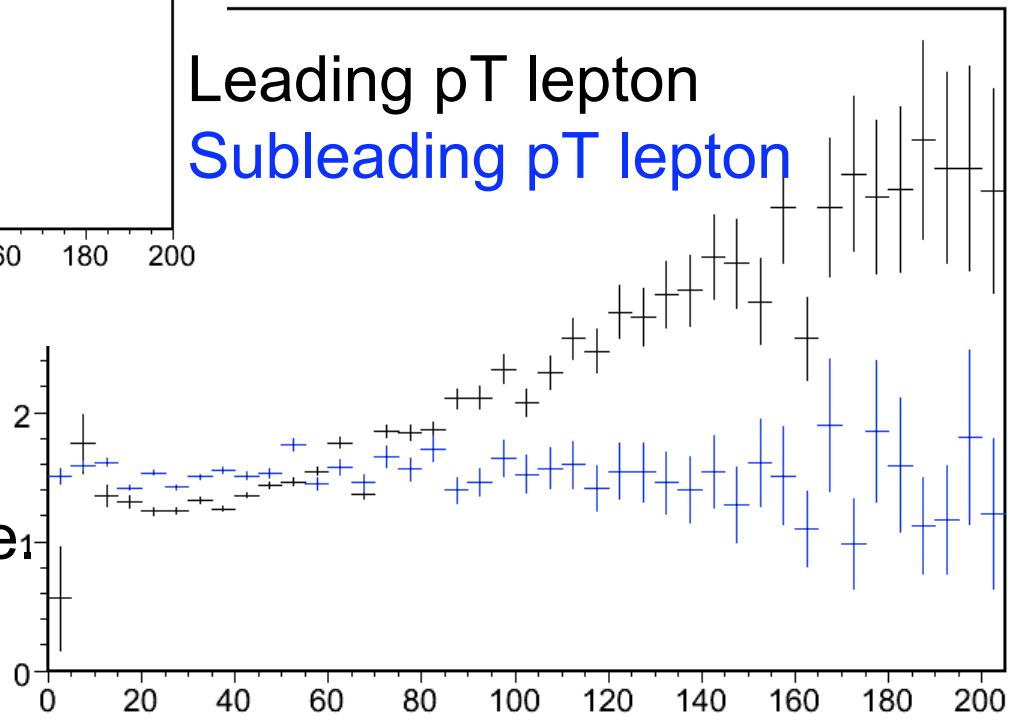
| Process | Tevatron | LHC | |
|---|---|---|---|
| | NLO (LO) | NLO (LO) | all numbers are pb and were obtained with mcfm 5.1 |
| WW | 11.8(8.9) | 110(72.7) | |
| WZ | 3.5(2.56) | 22.9+18.2(16.8+10.1) | zero width approximation |
| WZ | 4.6(3.4) | 29.0+22.5(21.7+13.6) | mZ .ge. 16GeV and including Zgamma interference et al. |
| ZZ | 1.38(1.06) | 14.4(10.6) | zero width aproximation |
| ZZ | 2.036(1.562) | 18.9(14.1) | mZ .ge. 16GeV and including Zgamma interference et al. |
| H -> WW | 0.236(0.098) | 25.4(10.8) | |
| DY | | 118(149nb) | mZ .ge. 16GeV and including Zgamma interference et al. |
| DY | | 56(50nb) | zero width approximation |

*All of this was done with MCFM by fkw.*
*This is only an illustration.*
*Chances are some of the details are wrong.*
*(e.g. ZZ mll > 16GeV is wrong in MCFM.)*

# NLO/LO for WW->lnulnu at LHC




At LO pT of WW system is zero. NLO can provide pT boost to system to “fold” the neutrinos in same direction.

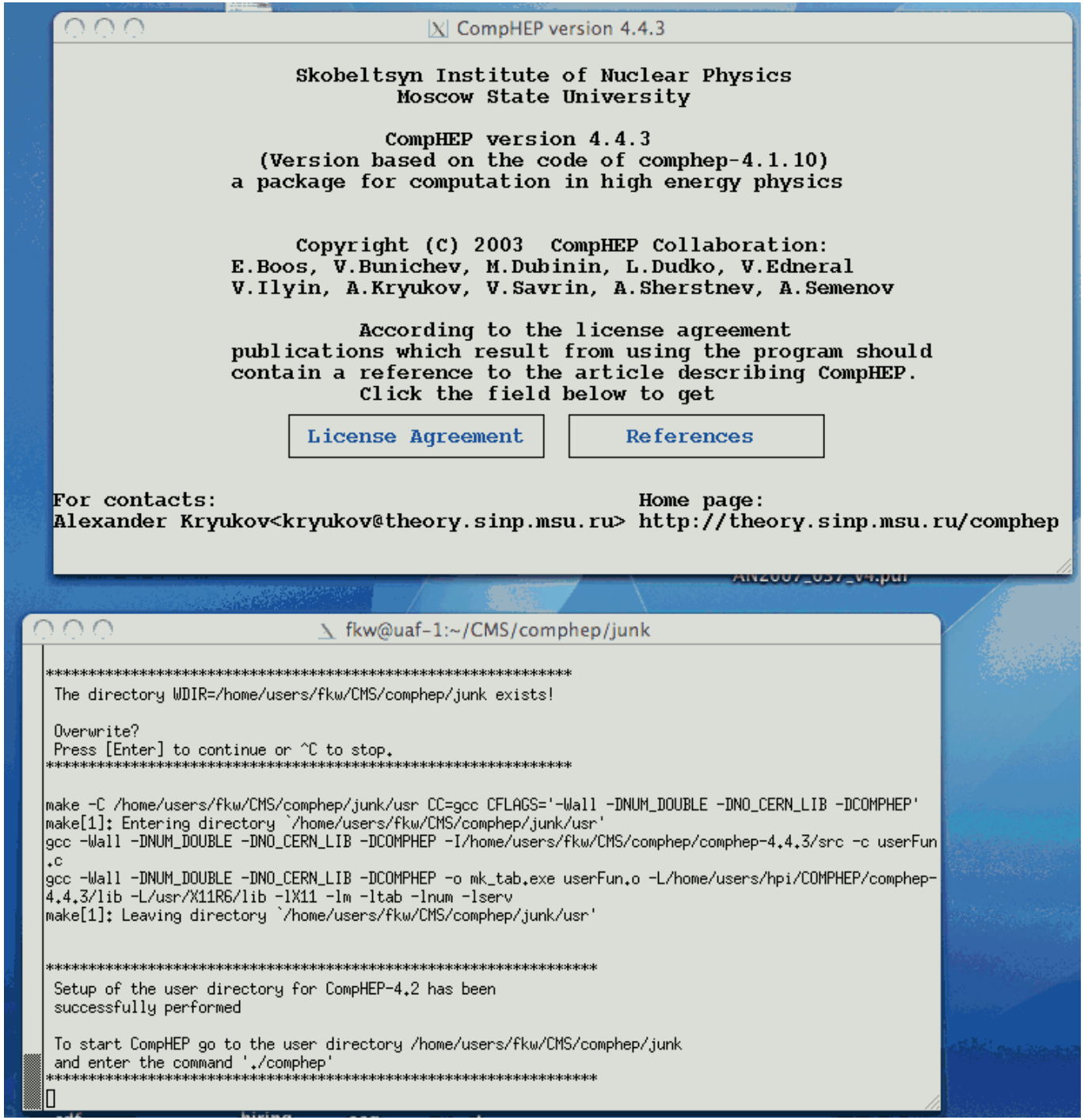



Be careful!
There are corners of phase space where NLO/LO is large.

*MCFM was used here.*

# Linux Installation

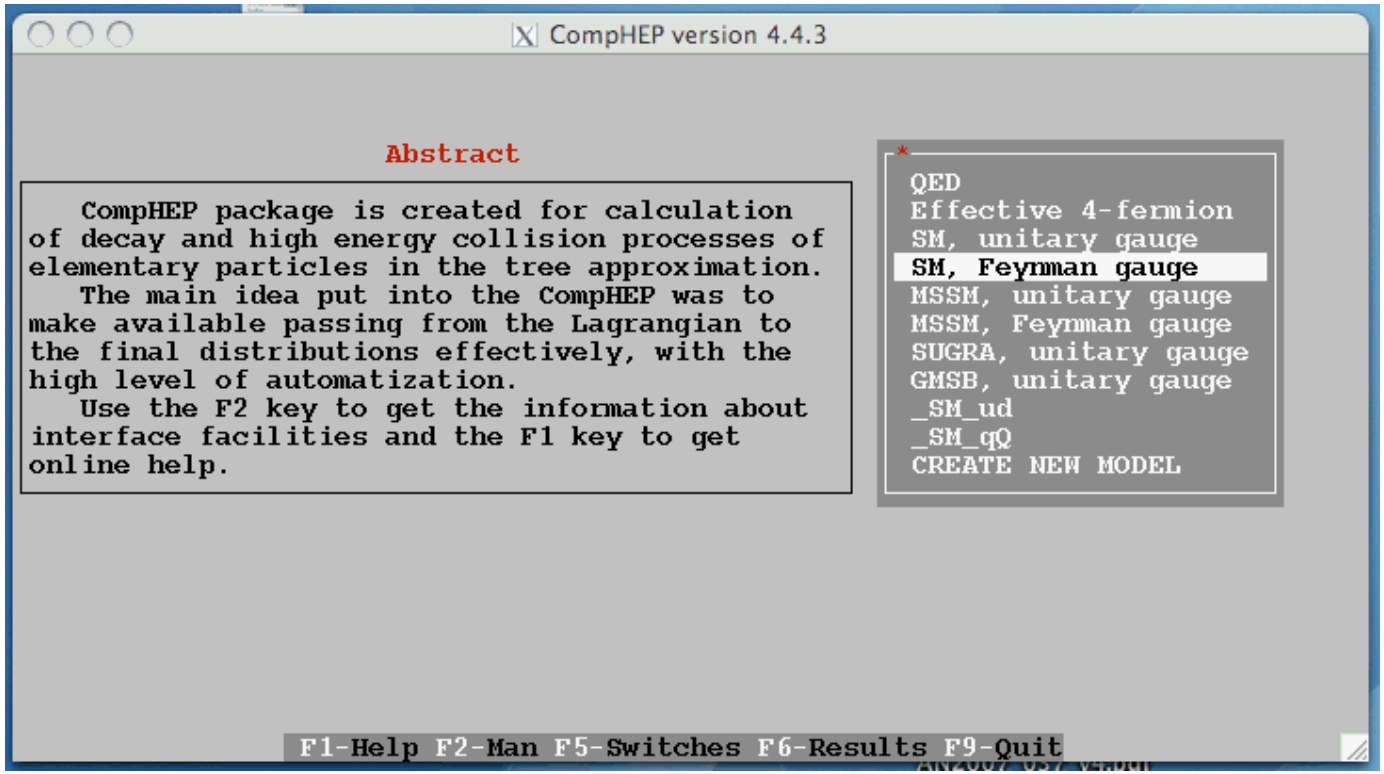
- **Installation of CompHEP**
  - **download archive file (comphep-4.4.3.tgz) to your directory**
  - **/home/richman/CompHEPSource**
  - **tar xzvf comphep-4.4.3.tgz**
  - **creates directory with name comphep-4.4.3**
  - **cd comphep-4.4.3**
  - **./configure**
    - Note: the configure script looks for CERNLIB. You may need to change the CERNLIB environment variable to point to the appropriate directory. CERNLIB is needed only for SUSY models.
  - **make**
  - **make setup WDIR=/home/richman/MyCompHEPWorkDir**
- **Running CompHEP**
  - **cd ~/MyCompHEPWorkDir**
  - **./comphep &**




Click anywhere to move on.

# *Main Screen for Comphep*

Here is where you decide on the broad physics model.

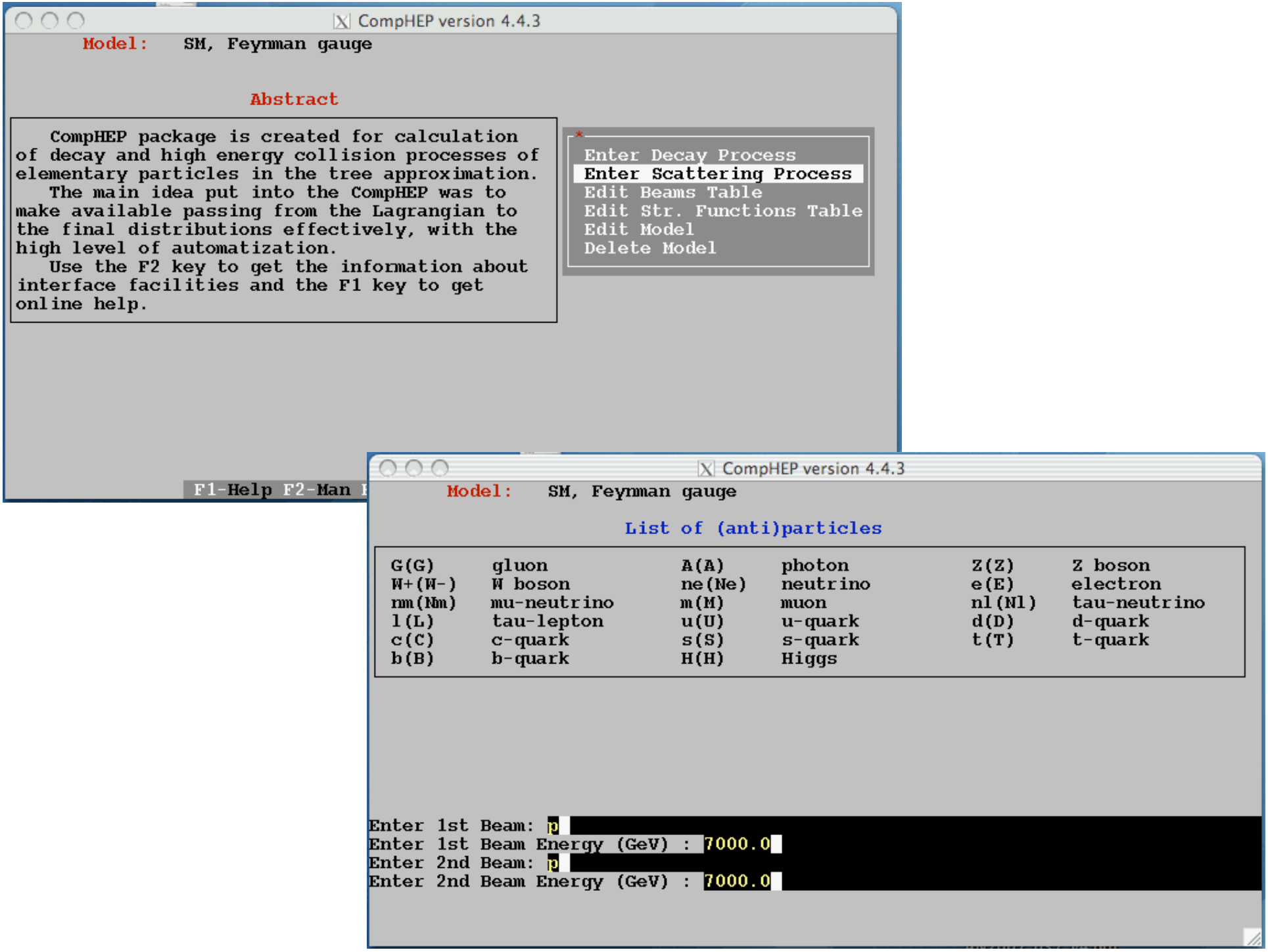



Before we proceed, let's get oriented.

# Outline of Procedure

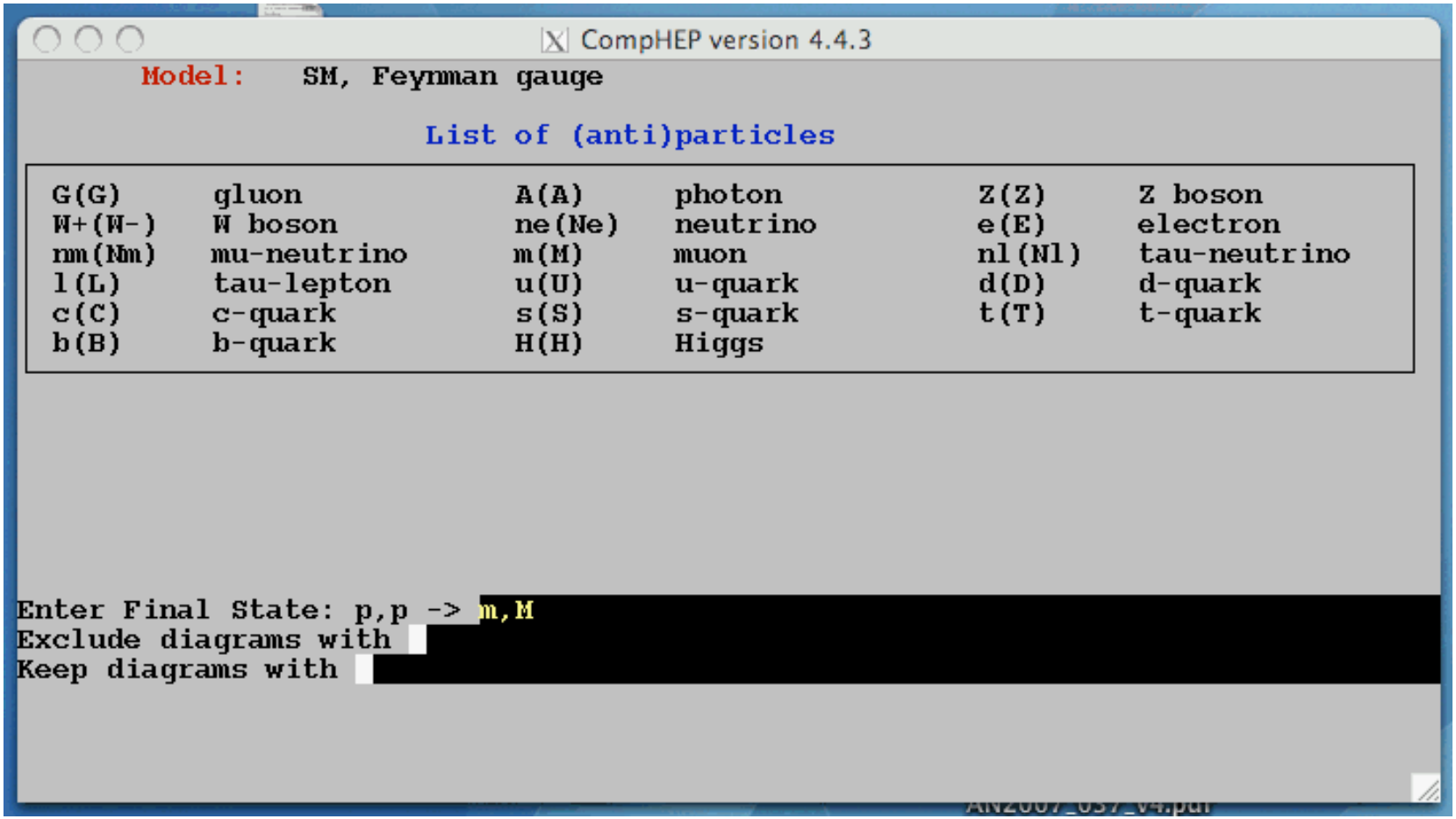
1. Specify decay or scattering process
2. View Diagrams; can write Latex code; can Delete selected diagrams; Exit (escape key)
3. Square Diagrams (can View and escape)
4. Symbolic calculation
5. Write results
6. C code
7. C-Compiler (hit return in separate window after complete)
8. Go to new window for numerical calculations
9. Select subprocess if applicable
10. Define cuts if desired
11. Vegas (or Simpson if applicable)
12. Set distributions and ranges if desired
13. Integrate ($X^2<1$ for numerically consistent results)
14. View distributions
15. Generate events if desired

In the following I have prepared screen shots for your reference, just in case I fail miserably doing this in class in real time.

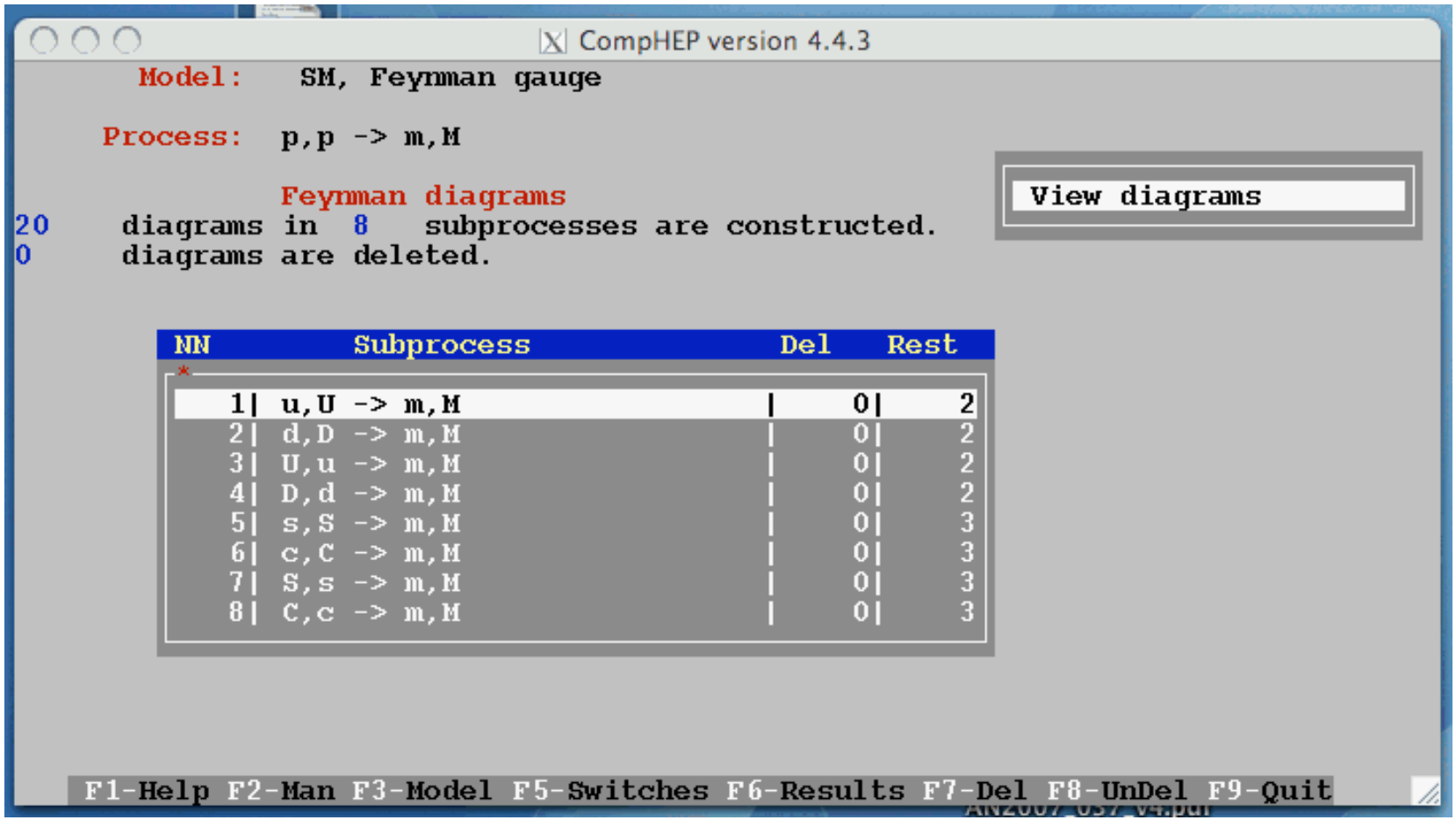

CompHEP version 4.4.3
Model: SM, Feynman gauge
Abstract
CompHEP package is created for calculation of decay and high energy collision processes of elementary particles in the tree approximation.
The main idea put into the CompHEP was to make available passing from the Lagrangian to the final distributions effectively, with the high level of automatization.
Use the F2 key to get the information about interface facilities and the F1 key to get online help.
Enter Decay Process
Enter Scattering Process
Edit Beams Table
Edit Str. Functions Table
Edit Model
Delete Model
F1-Help F2-Man
CompHEP version 4.4.3
Model: SM, Feynman gauge
List of (anti)particles
G(G) gluon
A(A) photon
Z(Z) Z boson
W+(W-) W boson
ne(Ne) neutrino
e(E) electron
nm(Nm) mu-neutrino
m(M) muon
nl(Nl) tau-neutrino
l(L) tau-lepton
u(U) u-quark
d(D) d-quark
c(C) c-quark
s(S) s-quark
t(T) t-quark
b(B) b-quark
H(H) Higgs
Enter 1st Beam: p
Enter 1st Beam Energy (GeV) : 7000.0
Enter 2nd Beam: p
Enter 2nd Beam Energy (GeV) : 7000.0

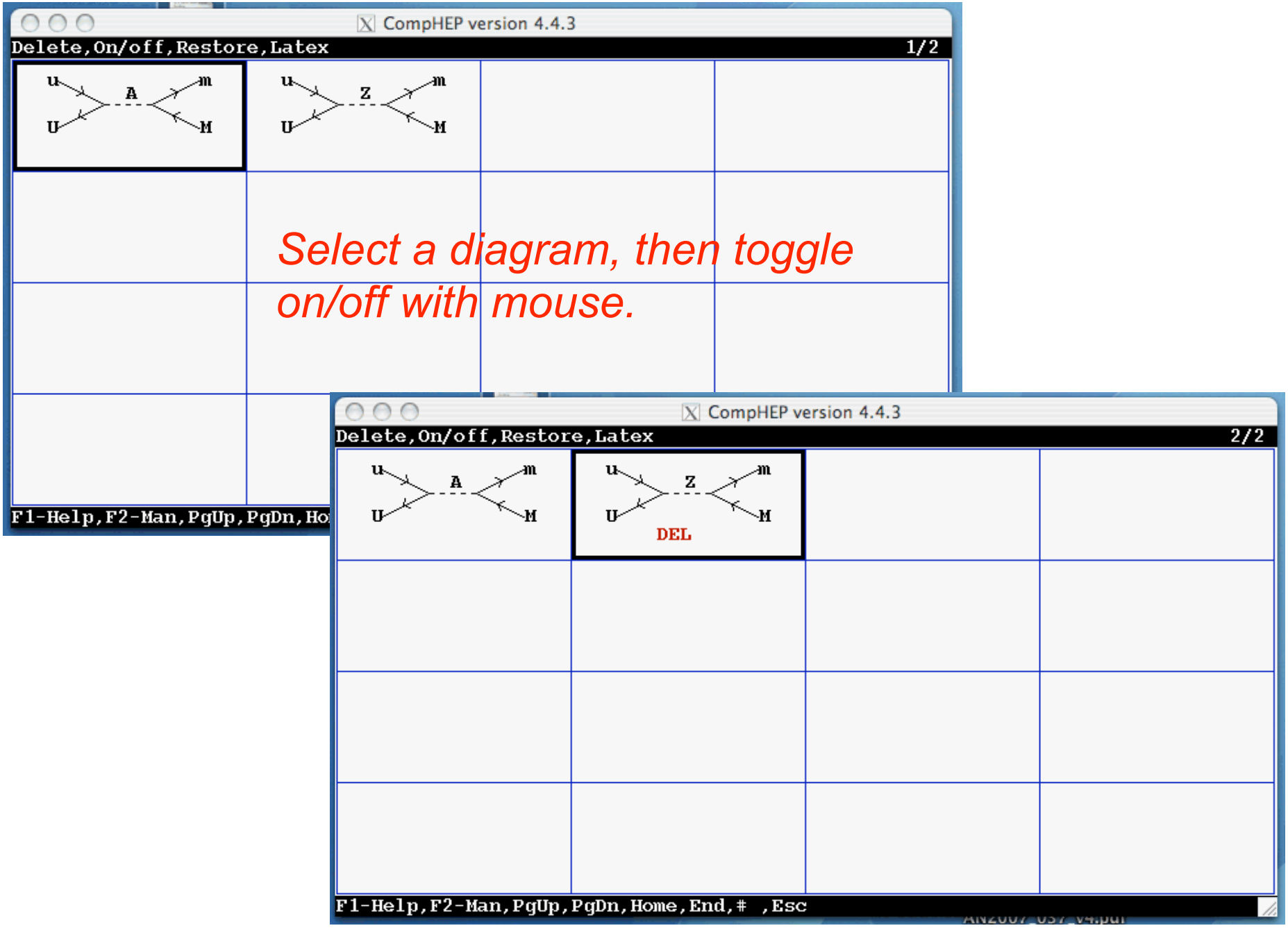
It’s sometimes sufficient to just pick partons instead of protons.

# *Selecting final state and excluding diagrams.*



# View and select diagrams by subprocess




CompHEP version 4.4.3
Delete,On/off,Restore,Latex
1/2
u
A
m
U
M
u
Z
m
U
M
Select a diagram, then toggle on/off with mouse.
F1-Help,F2-Man,PgUp,PgDn,Ho
CompHEP version 4.4.3
Delete,On/off,Restore,Latex
2/2
u
A
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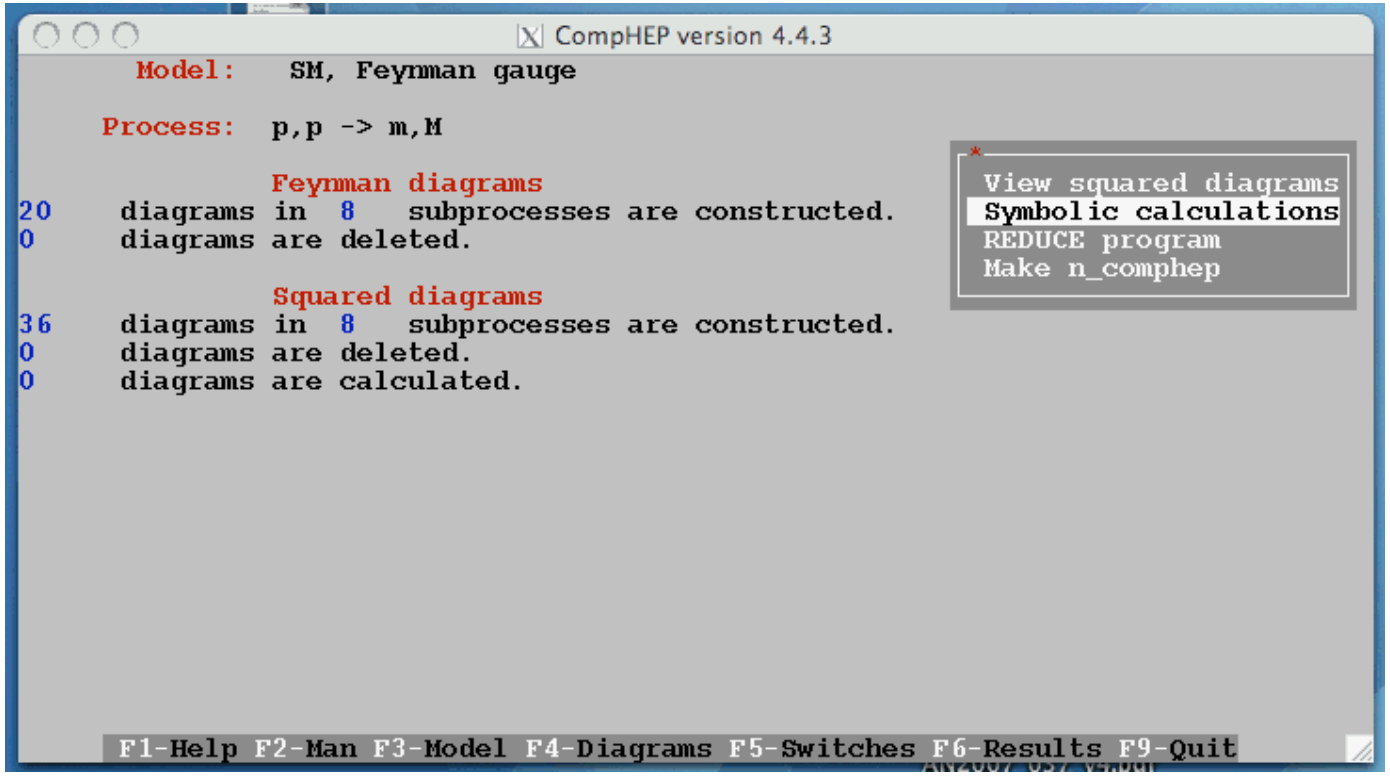
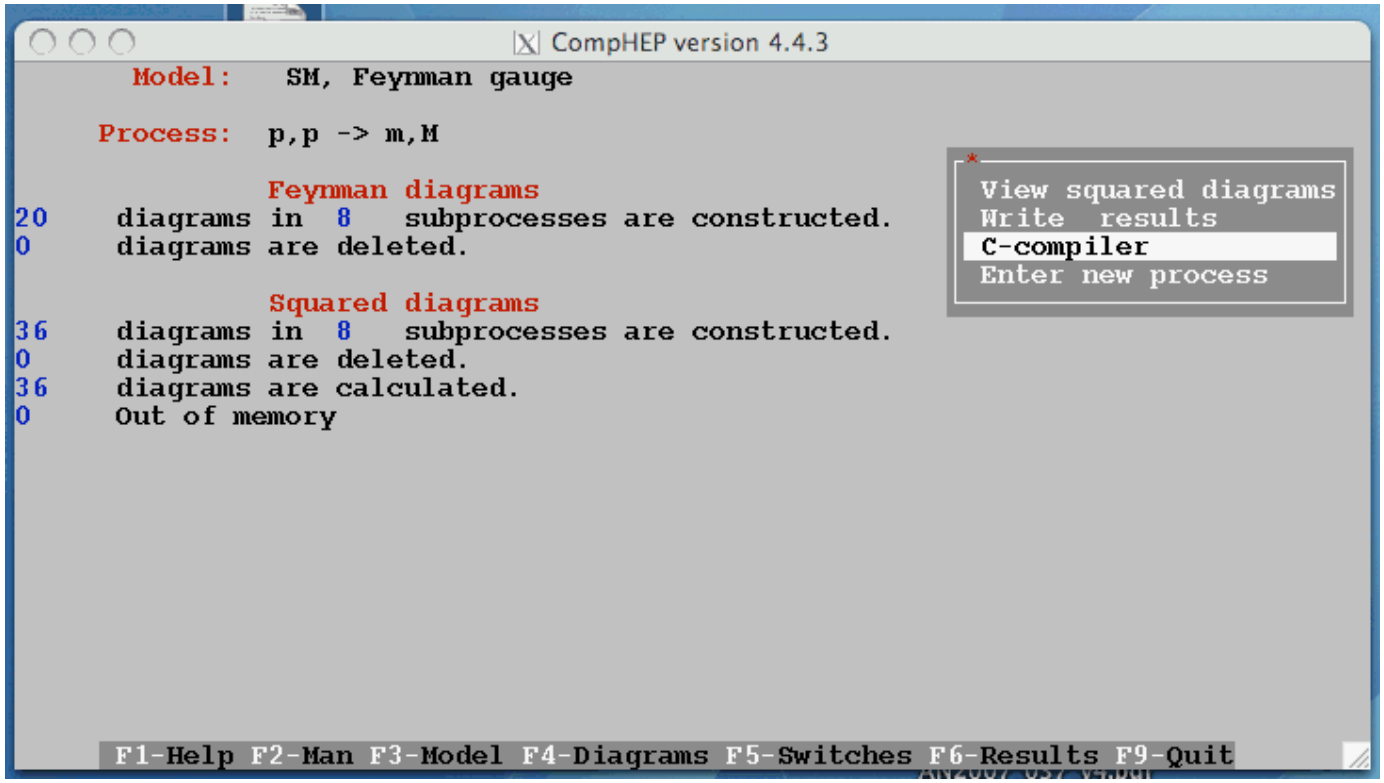
DEL
F1-Help,F2-Man,PgUp,PgDn,Home,End,# ,Esc

# Now calculate the diagrams

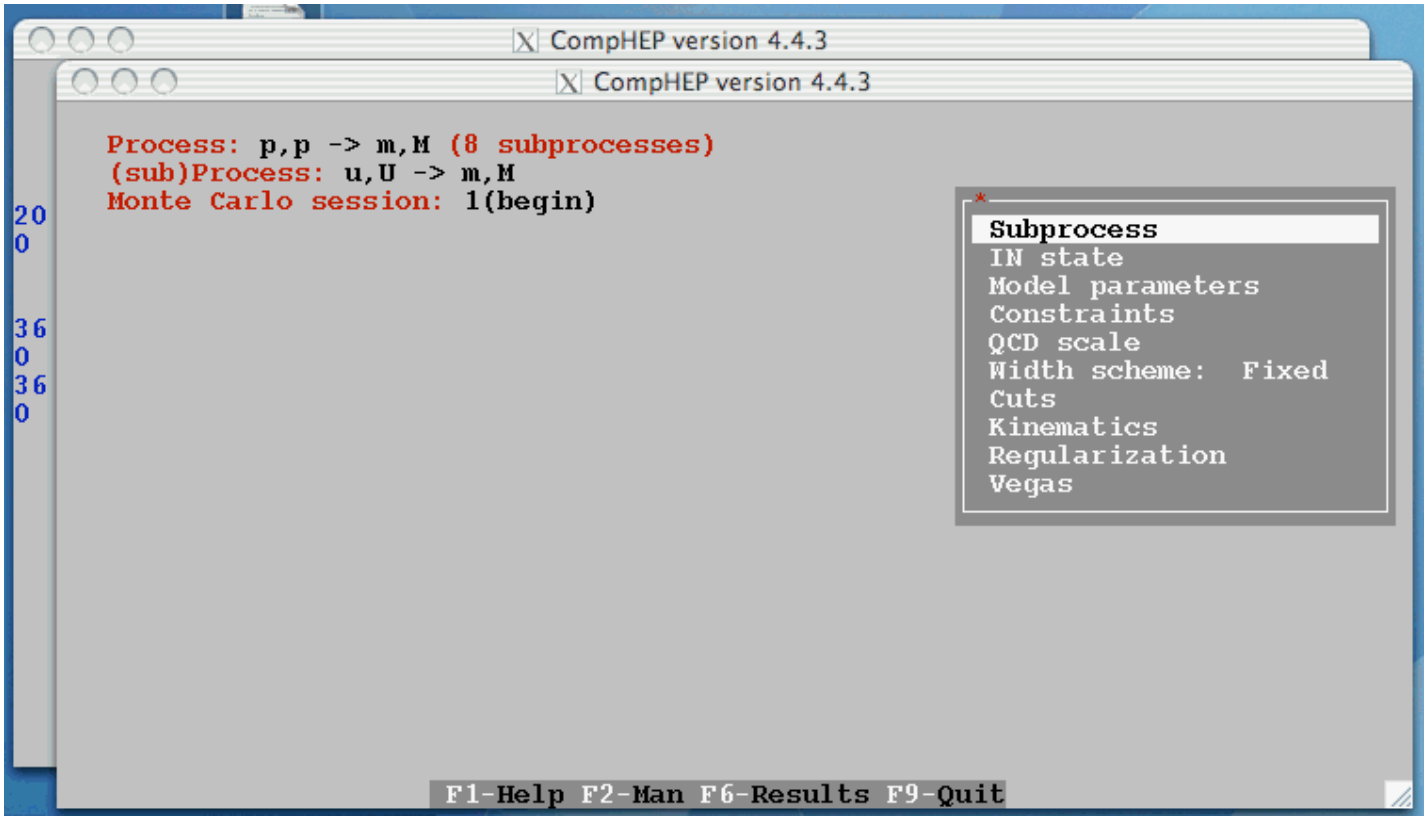


Now write results, and then compile.



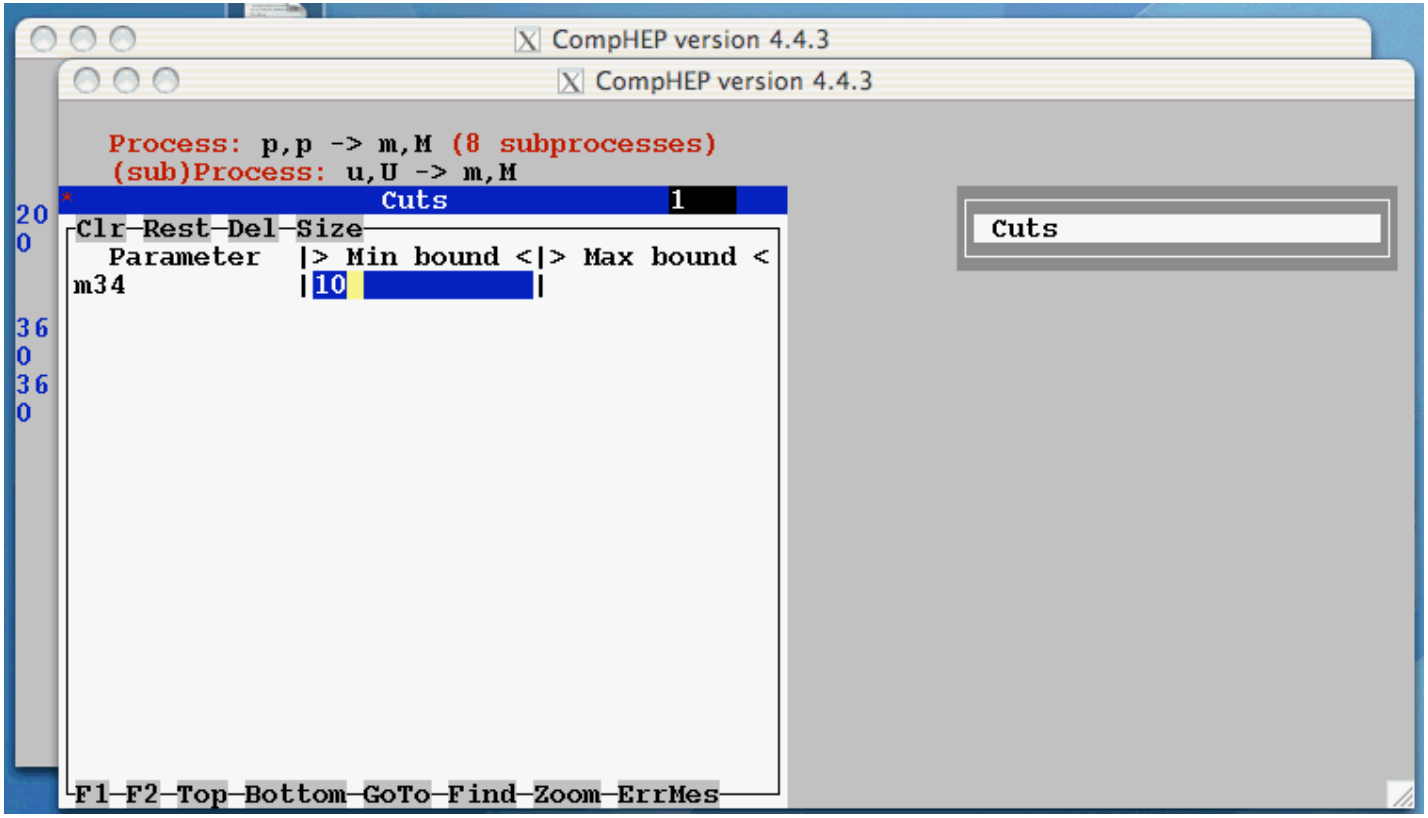

At this point a new window pops up, and you can see compilation/linking happen. Once done, you press enter In that window, and a new screen appears …

Here you can select subprocess to calculate, and define cuts, before you move on to Vegas.




Note: One of the annoying features is that I am unable to calculate the sum of several subprocesses. If you figure out how, let me know!

Cuts are often important for convergence, and to stay away from divergencies, or zero in on the part of phase space you care about.




The cryptic keys that are built in are explained on p.37f of the manual.

You can use this to define cuts and plots.

For more see manual.

### 3.3.5 Phase space functions

There is a special set of phase space functions which may be used to construct cuts and distributions in the framework of CompHEP. The general notation looks like

*(Key Character)(momentum set).*

A set of momenta is represented as a set of digits. Any digit corresponds to a momentum number. For example, *C13* means a cosine of the angle between momenta $\mathbf{p_1}$ and $\mathbf{p_3}$. The momenta are assigned to particles according to their sequence in the process name.

Below we list the available key characters and explain the meaning of the corresponding physical functions.

A - angle in degree units.

C - cosine of angle.

J - jet cone angle. The jet cone angle $J_{ij}$ is defined as $\sqrt{\Delta y^2 + \Delta\varphi^2}$, where $\Delta y$ is the pseudo-rapidity difference and $\Delta\varphi$ is the azimuth angle difference for momenta $\mathbf{p_i}$ and $\mathbf{p_j}$.

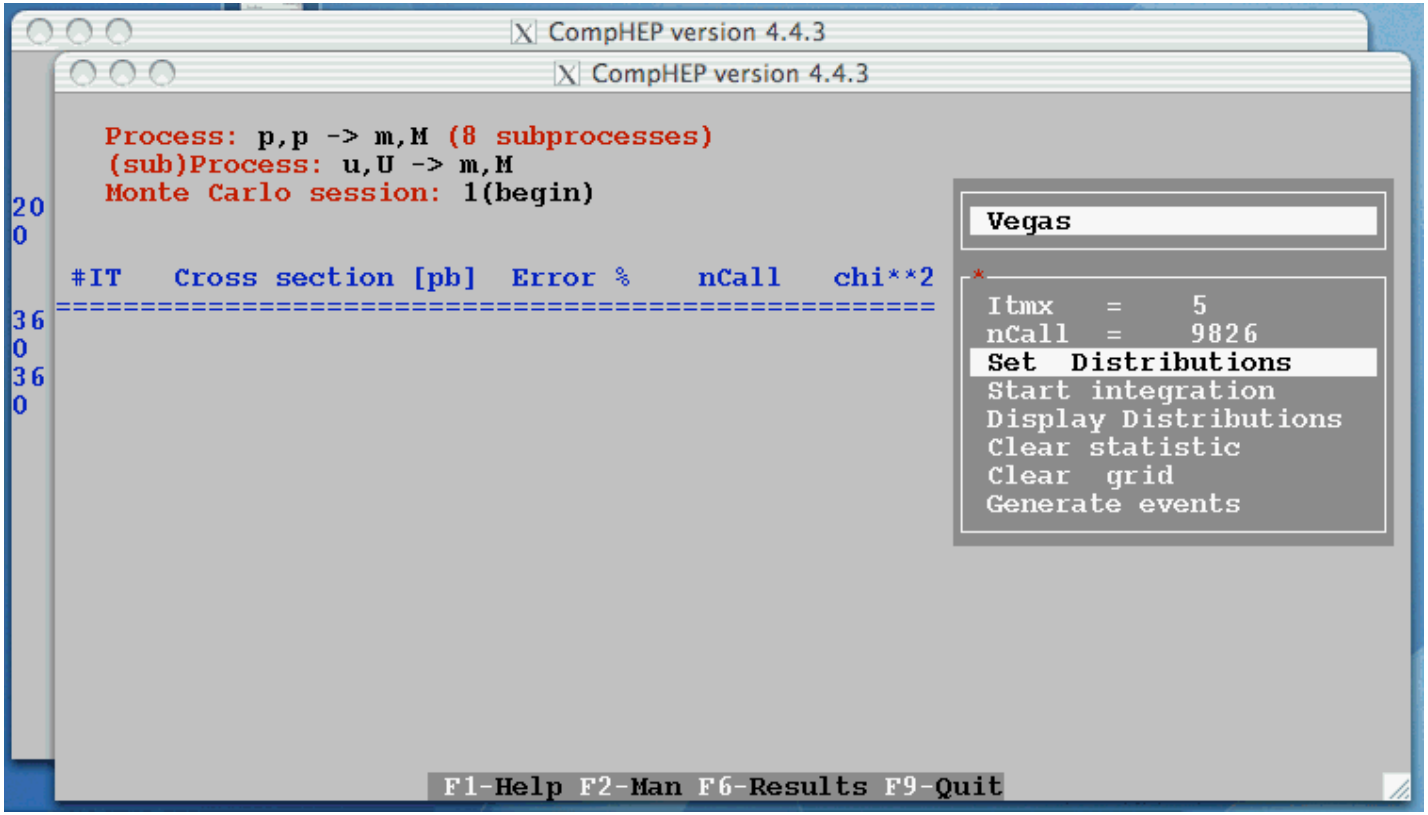
E - energy of the particle set.

M - mass of the particle set.

P - cosine in the rest frame of pair. *Pij* is defined as follows: we imply a boost in the direction of $\mathbf{p_i} + \mathbf{p_j}$ to get the rest frame of the pair. Then *P* is a cosine of angle between the transformed $\mathbf{p_i}$ and the direction of boost.

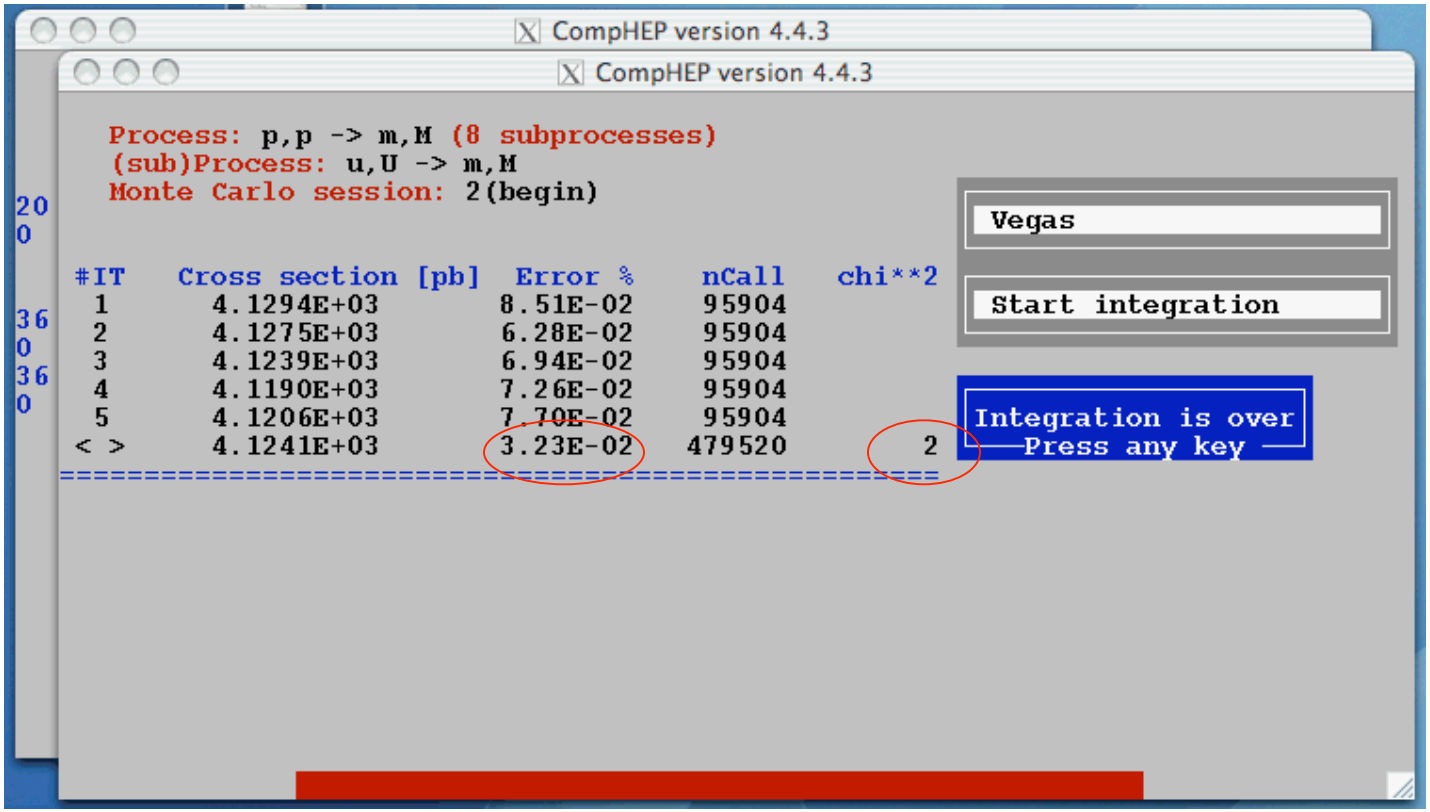
T - transverse momentum of the particle set.

Next set the distributions you want to look at BEFORE doing the Vegas integration.



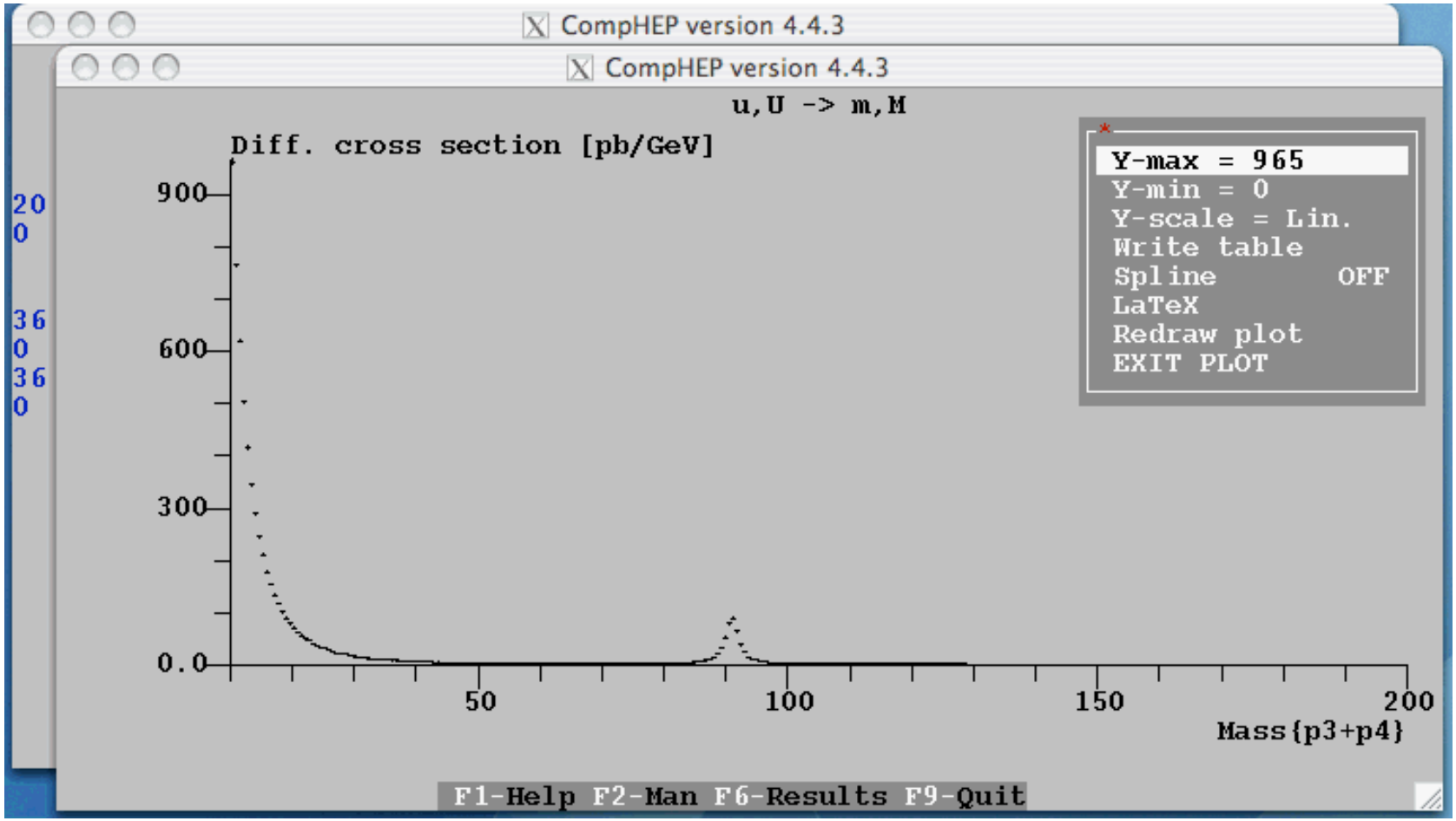

Then “start integration”.

# Result of an integration:




You want a chi**2 less than 1 before you believe your integration.
You may also want to a certain precision. You have two handles:
Restart the integration (go out of vegas, and back in).
Increase ncall and/or itmx.

# Display a successful integration

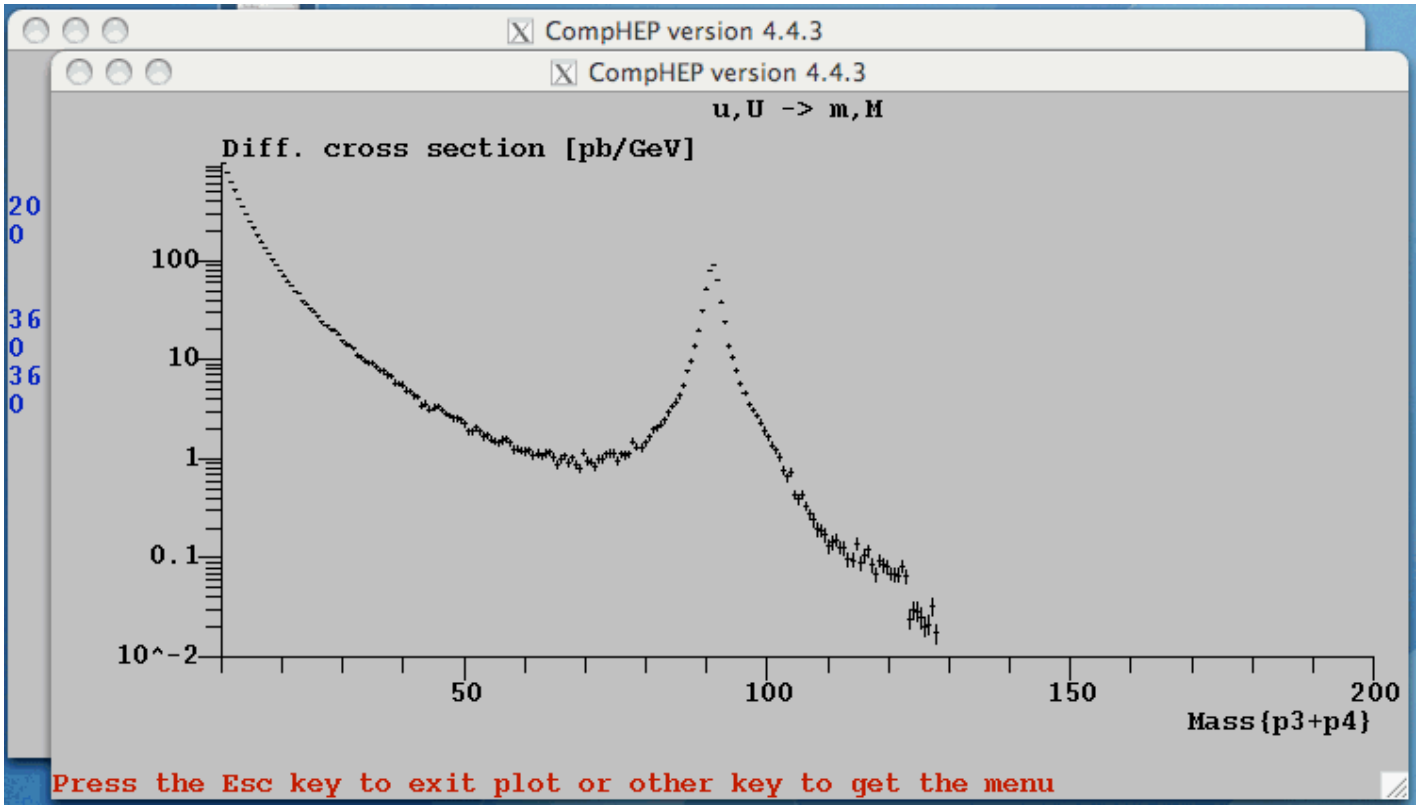


# Getting fooled by comphep

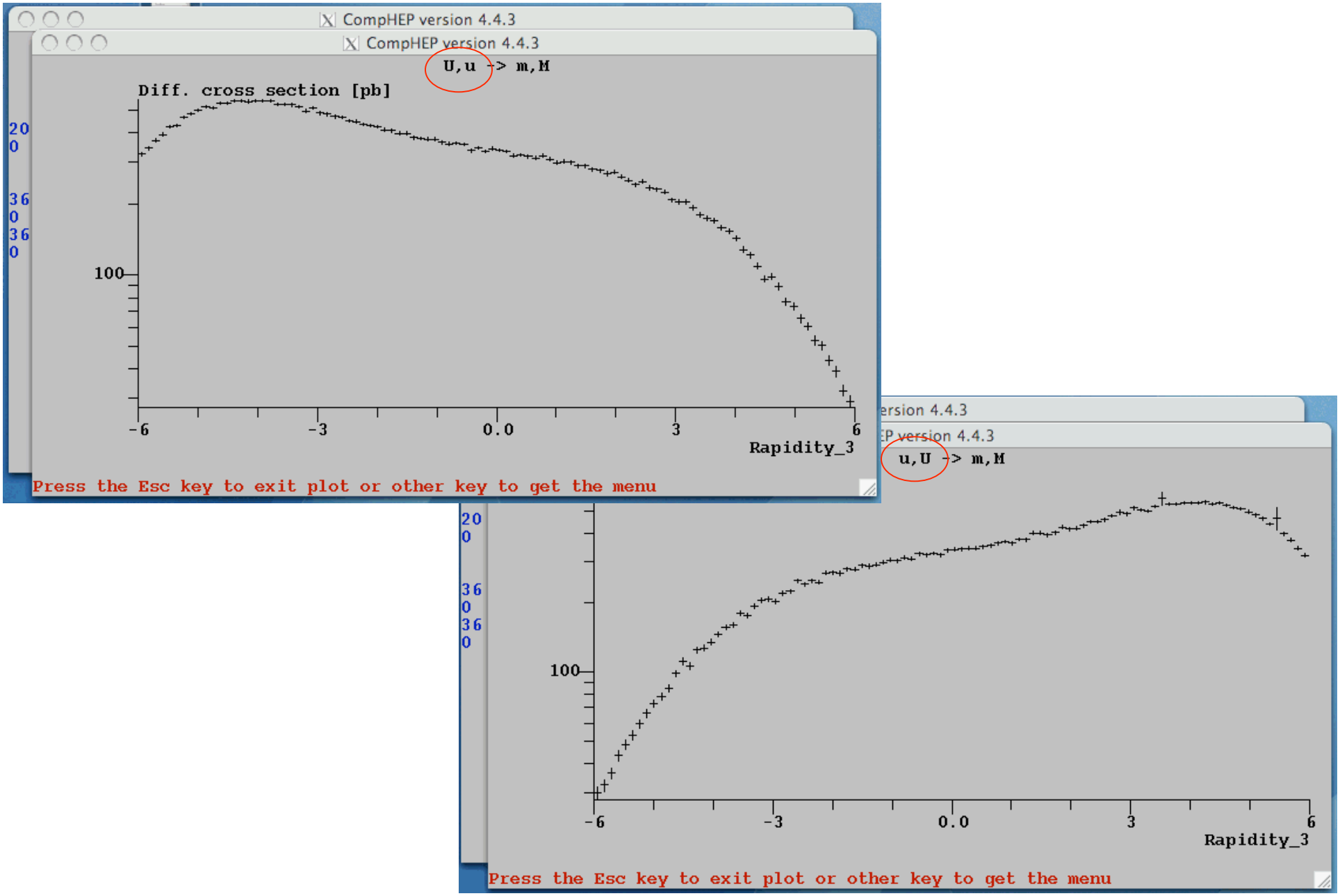
- Make sure that your integration propperly converged -> watch your chisquare !!!
- Remember that you calculate one parton level process at a time, while nature produces the sum of all !!!

Let’s look at these two screw-ups in turn!

This integration didn’t converge:

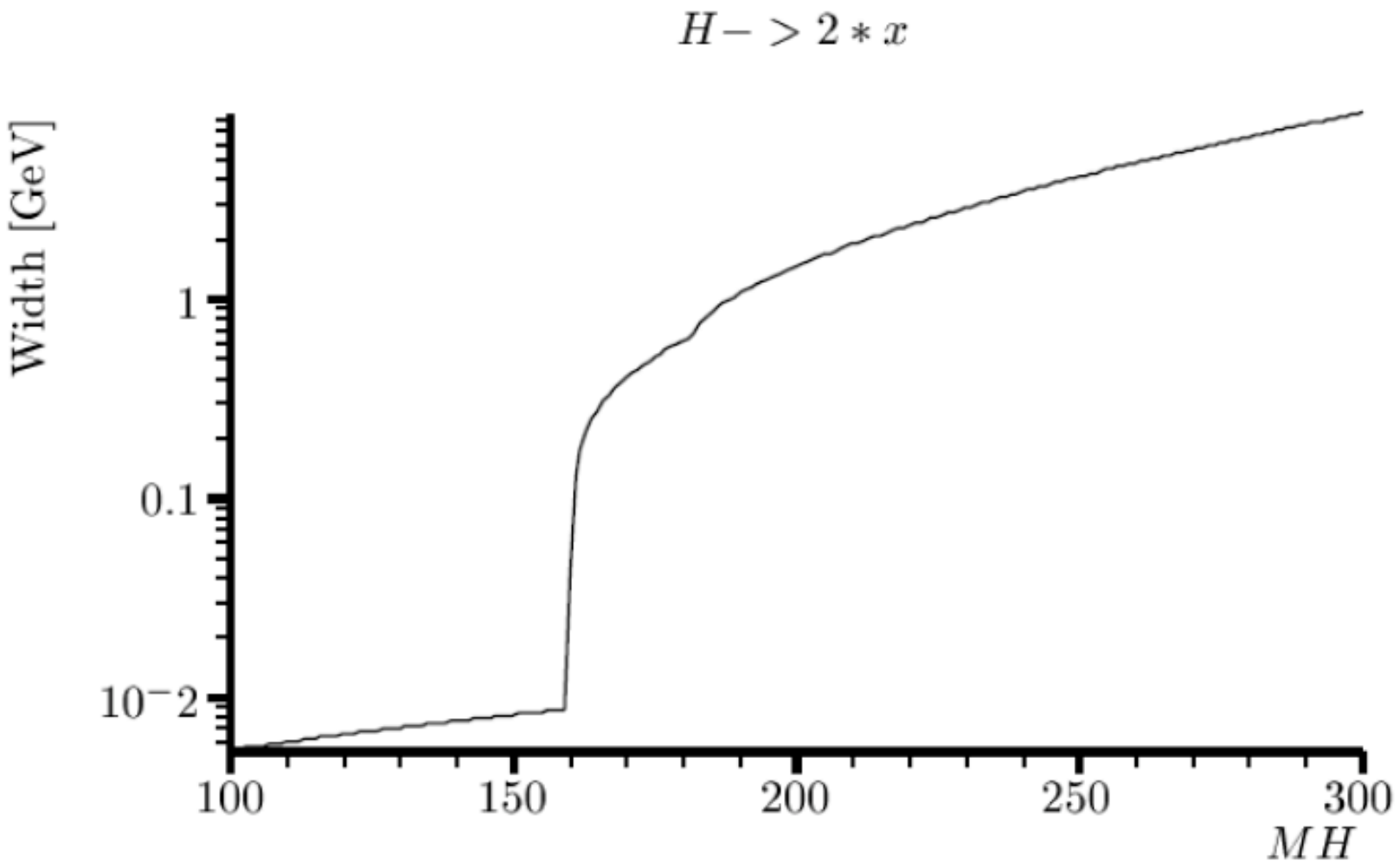


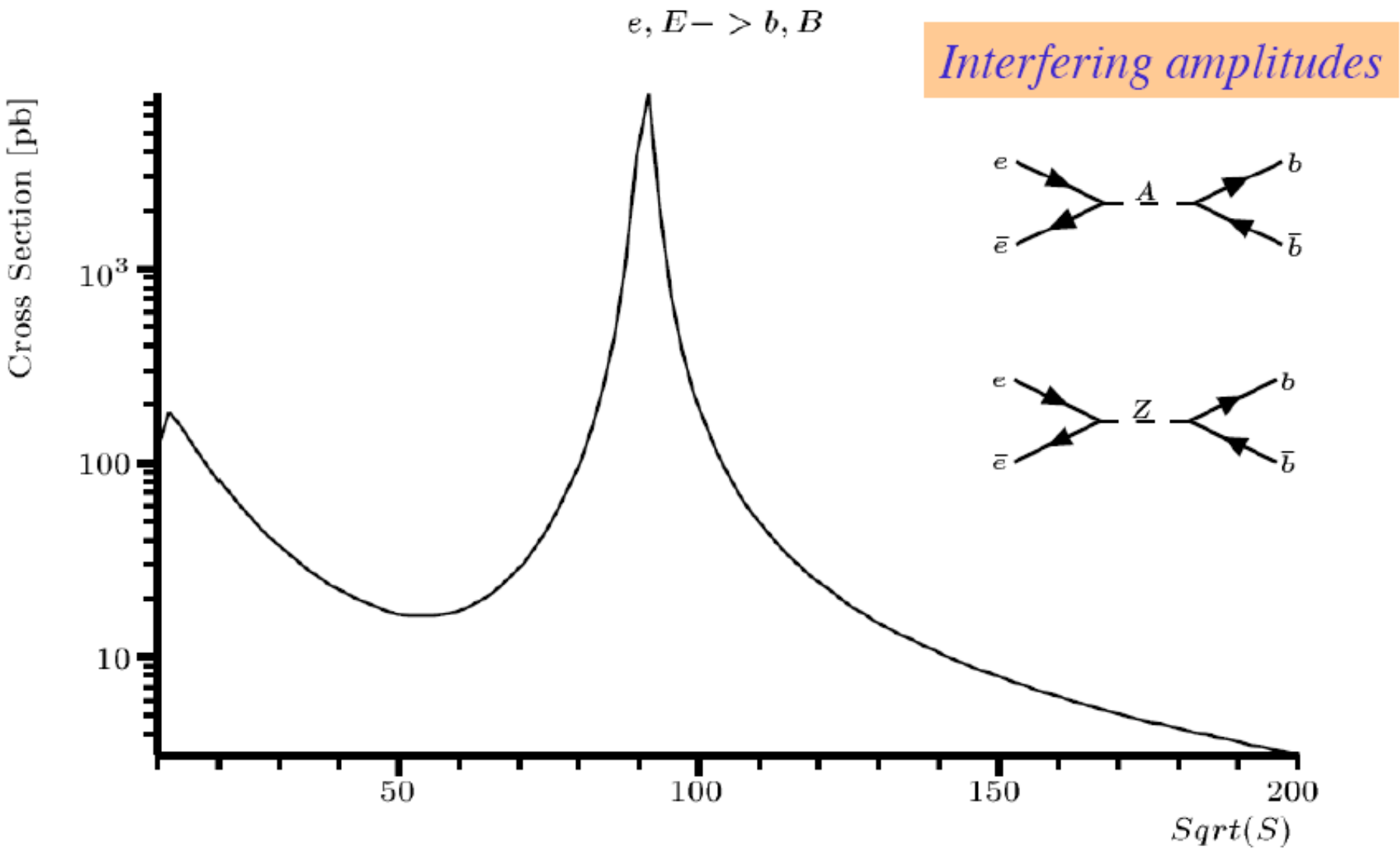
# Remember to add subprocesses !!!

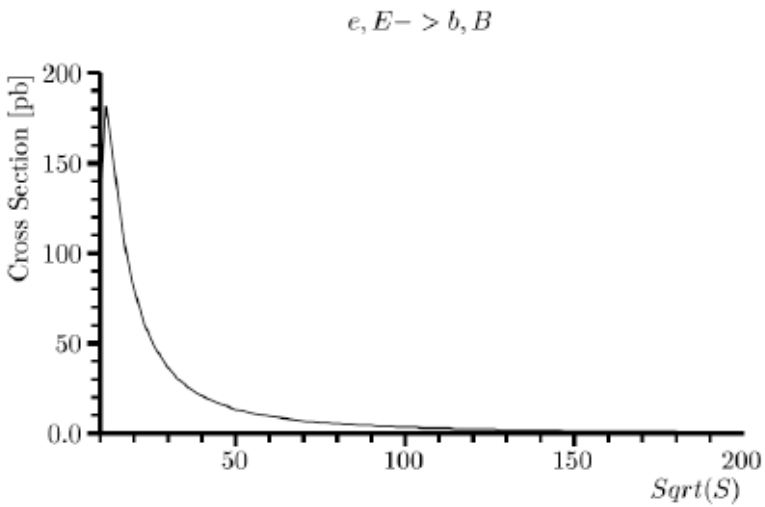


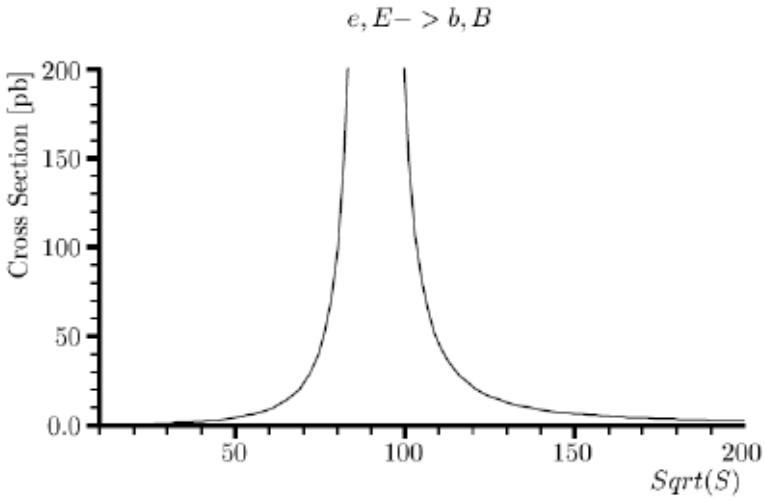
# Same more examples

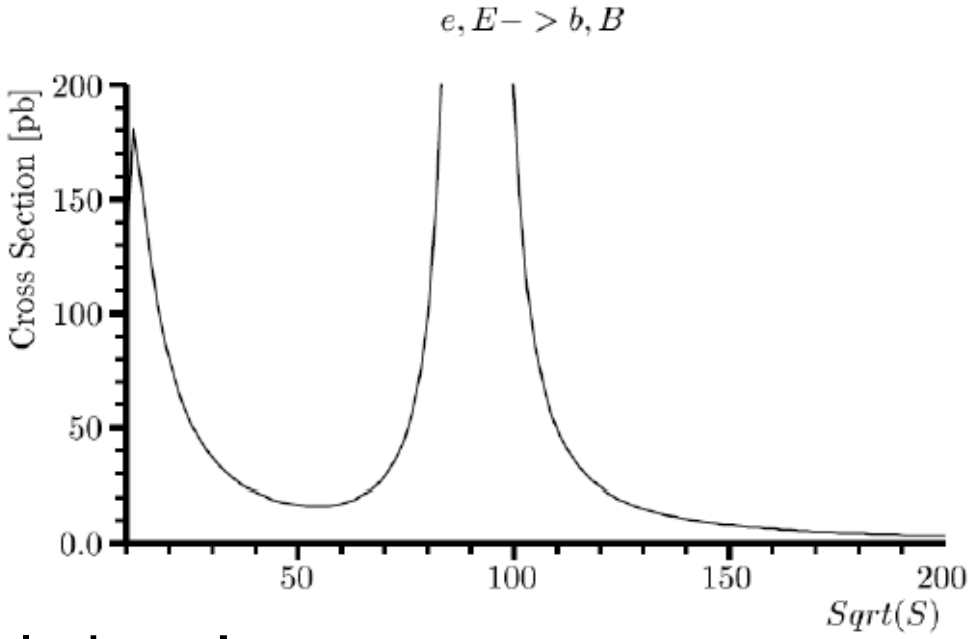
- Width of standard model higgs
  - We'll discuss this in some detail next quarter.
- e+ e- -> b bbar scattering
  - You explored this on final exam.


$H- > 2 * x$
Width [GeV]
1
0.1
$10^-2$
100
150
200
250
300
$MH$


$e, E- > b, B$
Cross Section [pb]
$10^3$
100
10
50
100
150
200
$Sqrt(S)$
Interfering amplitudes
e
$\bar{e}$
A
b
$\bar{b}$
e
$\bar{e}$
Z
b
$\bar{b}$



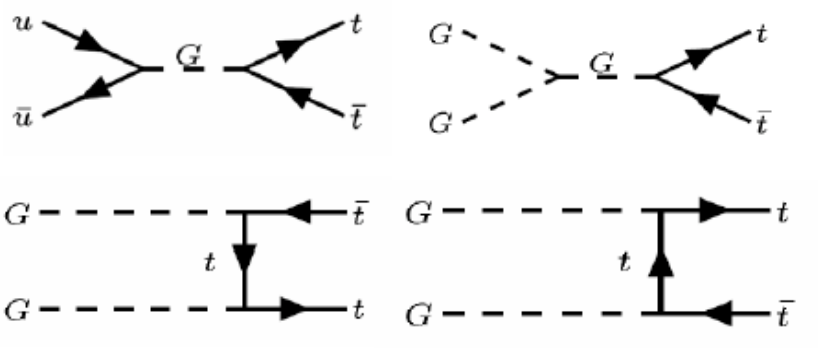



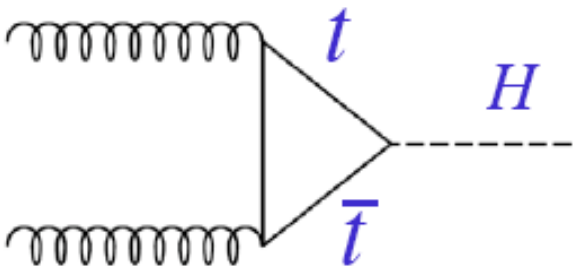



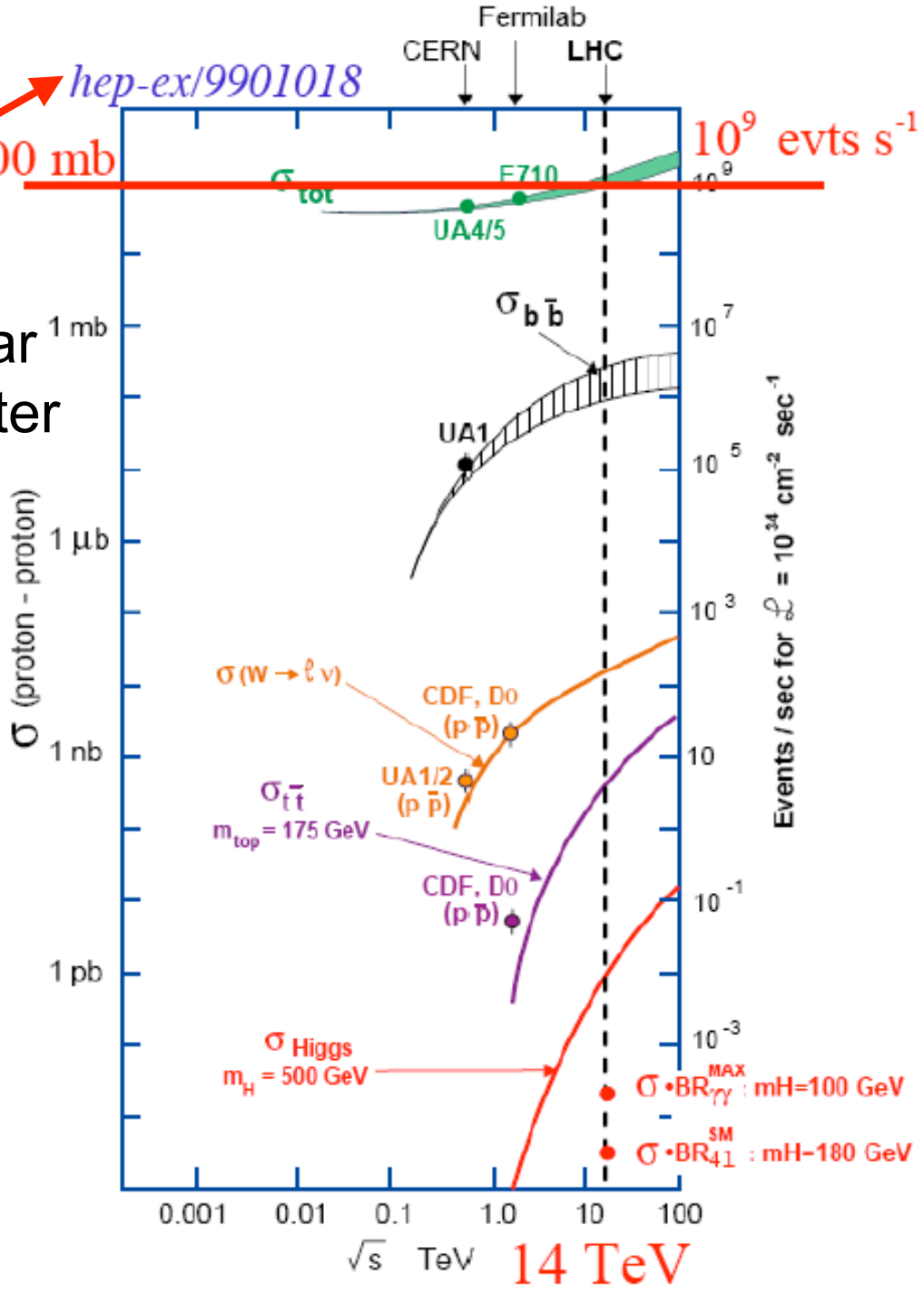

Note: linear scale here!

Taken from Jeff Richman's Tutorial who took it from

It shows nicely how H and ttbar production increase much faster with sqrt(s) than W and Z.



# Confusion about Multiple Scattering

- Several of you calculated ms as if the tracker was a SOLID solid state device.
  - Instead, it's mostly air !!!

$$\frac{\sigma(p_T)}{p_T} = \frac{0.05}{BL}\sqrt{\frac{1.43L}{X_0}}$$

This L is NOT
The size of the tracker!

This L is the size of
The tracker.

*My apologies for confusing you!*