

Physics 214 UCSD/225a UCSB

Lecture 16

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

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>
 - I will talk about this today.
 - MADGraph
 - <http://madgraph.hep.uiuc.edu/>
- Compute NLO processes
 - MCFM
 - <http://mcfm.fnal.gov/>
 - MC@NLO
 - <http://www.hep.phy.cam.ac.uk/theory/webber/MCatNLO/>
 - Prospino
 - <http://www.thphys.uni-heidelberg.de/~plehn/prospino/>
- Hadronization done by Pythia/Herwig in all cases

Locally:

On the uaf at UCSD T2 center we have many of the generators installed in my home directory.

~fkw/generators

Those of you who have access, feel free to poke around there, and ask me how to use the stuff that's there.

Comphep

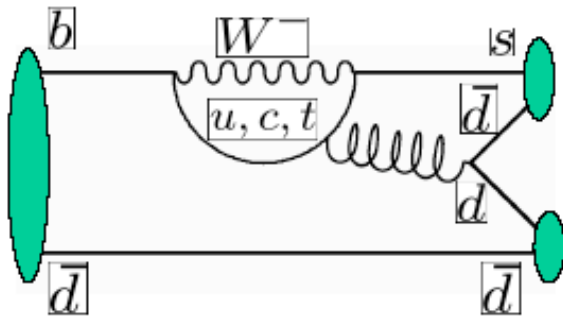
- A computer program that allows you to do some simple calculations at leading order in perturbation theory.
- Why is it needed?
 - Experimental observables in Hadron collider physics are difficult to calculate because this requires pdf's.
 - Programs like comphep (madgraph, etc.) allow you to specify 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, and develop intuition.
- However, we will see that it's easy to make mistakes!

Comphep Resources

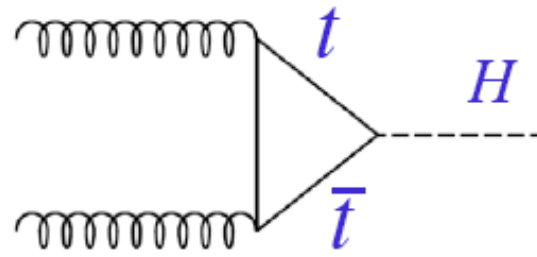
- The web site:
 - <http://comphep.sinp.msu.ru/>
- A tutorial by Jeff Richman:
 - <http://comphep.sinp.msu.ru/tutorials>
- The complete manual:
 - http://theory.sinp.msu.ru/comphep_html/tutorial/note1.html
- I will use all of the above, as well as running the actual code, in today's lecture.

Comphep Limitations

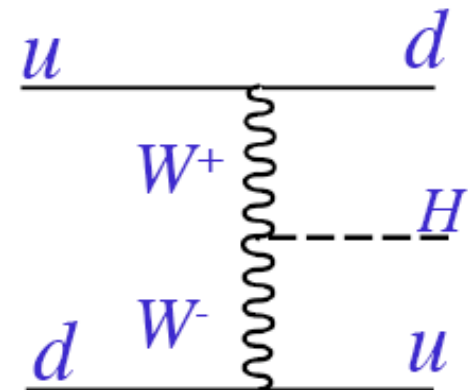
- No hadronic bound states (mesons, baryons) and no hadronization of quarks and gluons into jets
- No loop/box diagrams
- All processes are averaged over allowed initial-state spin polarizations and summed over final-state polarizations.
- No neutrino oscillations
- CompHEP can be used to compute quasi-inclusive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

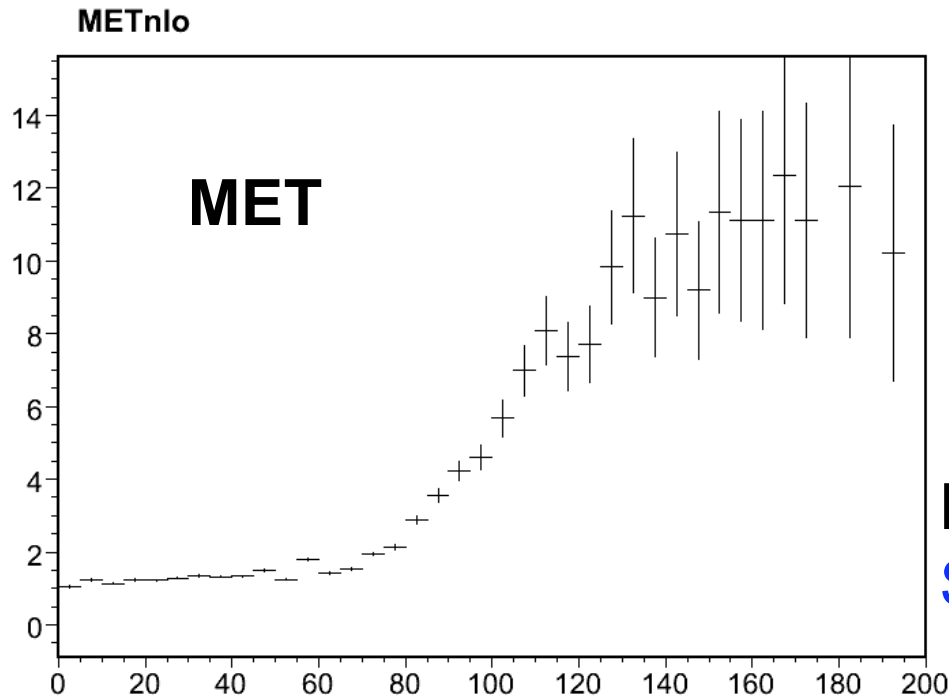
All of this was done with MCFM by fkw.

This is only an illustration.

Chances are some of the details are wrong.

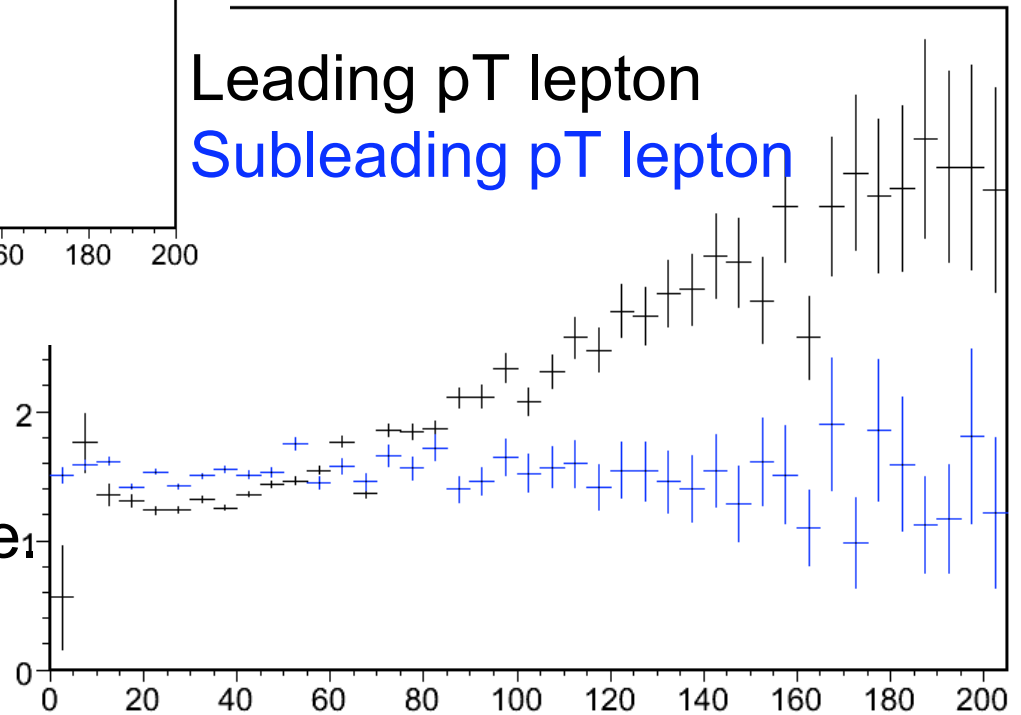
(e.g. ZZ mll > 16GeV is wrong in MCFM.)

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.

Leading pT lepton
Subleading pT lepton



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

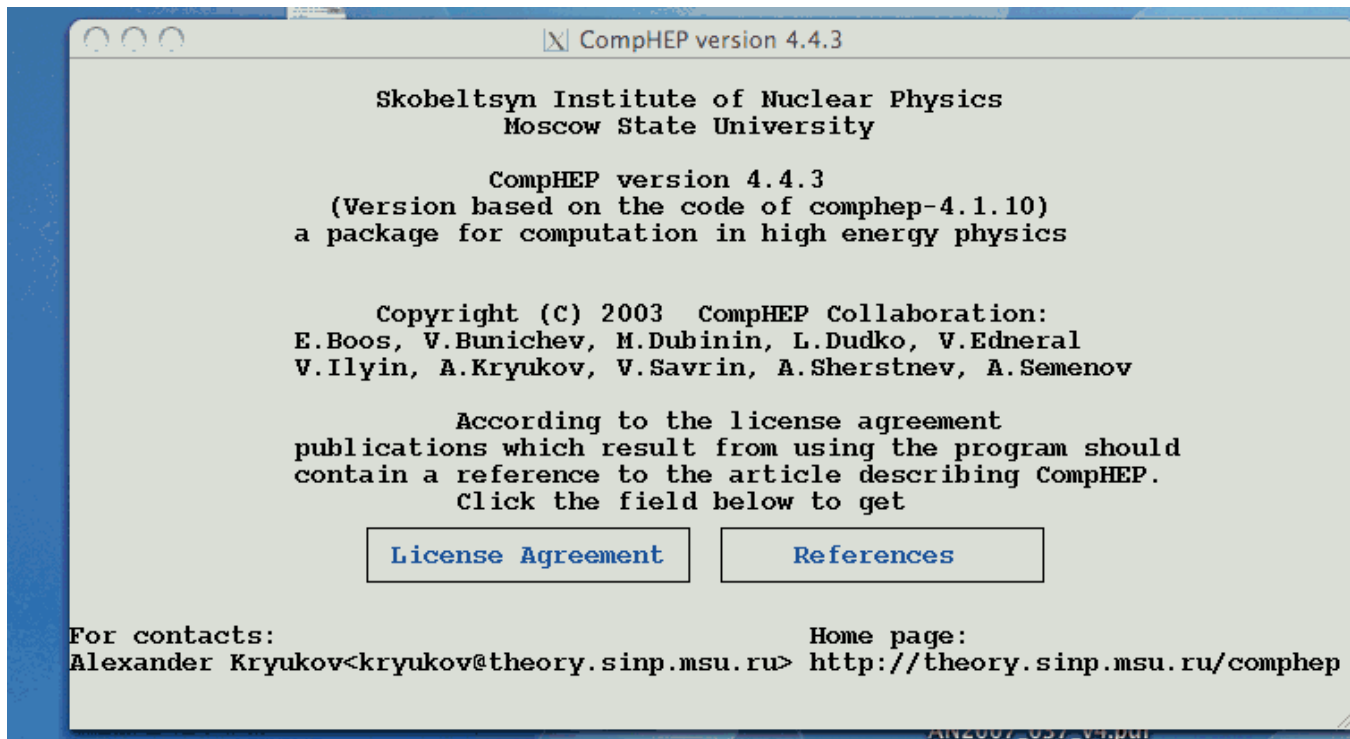
- ↳ cd ~/MyCompHEPWorkDir

- ↳ ./comphep &

Locally:

I put a tgz file at:

<http://physics.ucsd.edu/students/courses/fall09/physics214/finalExamComphep.tgz>

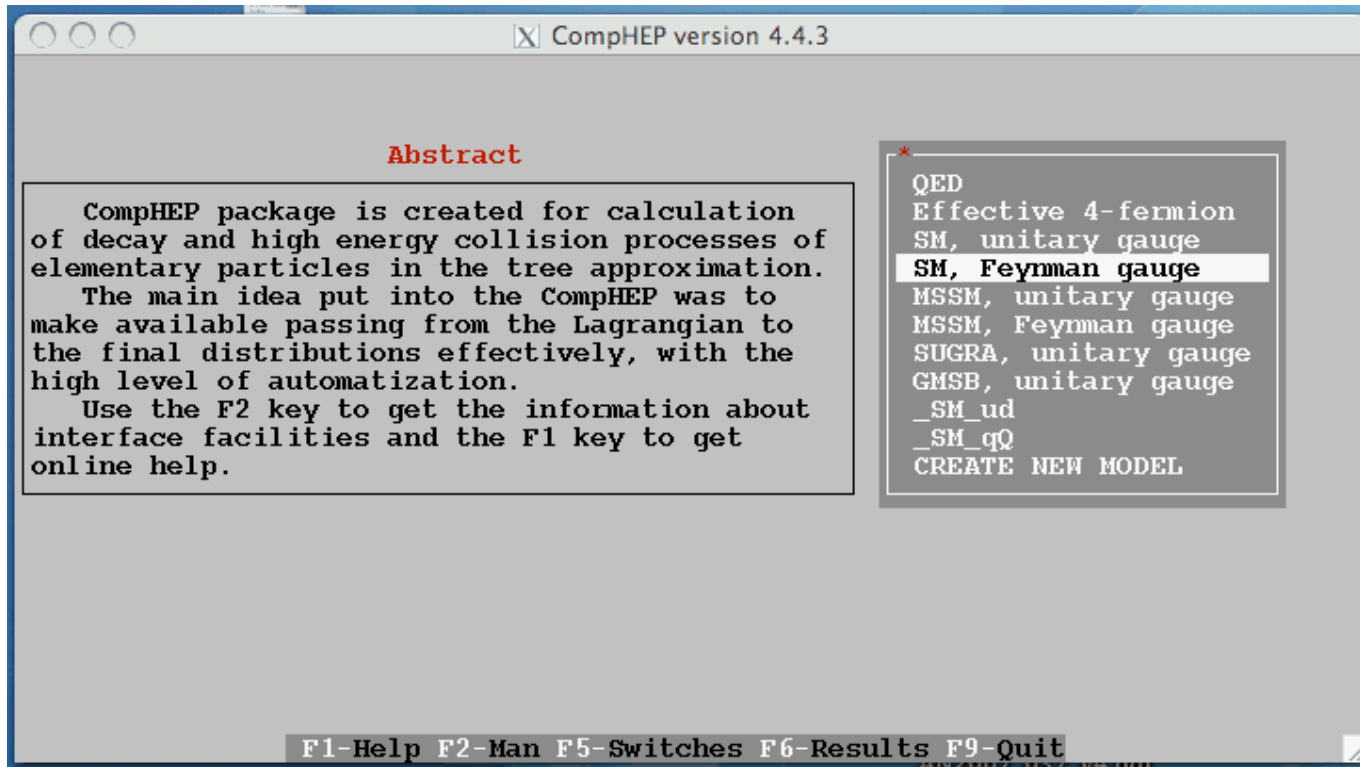


Click anywhere
to move on.

This is the first page that pops up after starting comphep.
The next page is what you get after you click anywhere,
other than “License Agreement” or “References” on this page.

Main Screen for Comphep

Here is where you decide on the broad physics model.

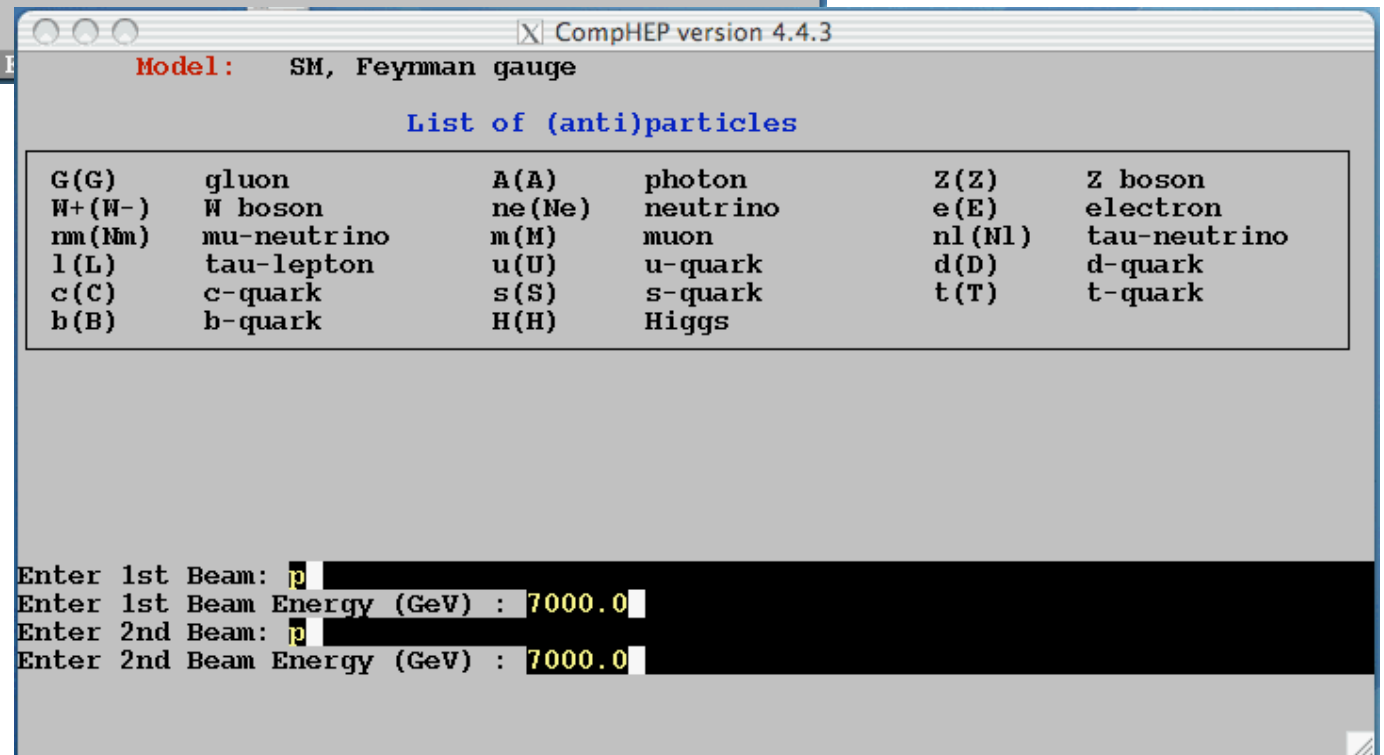
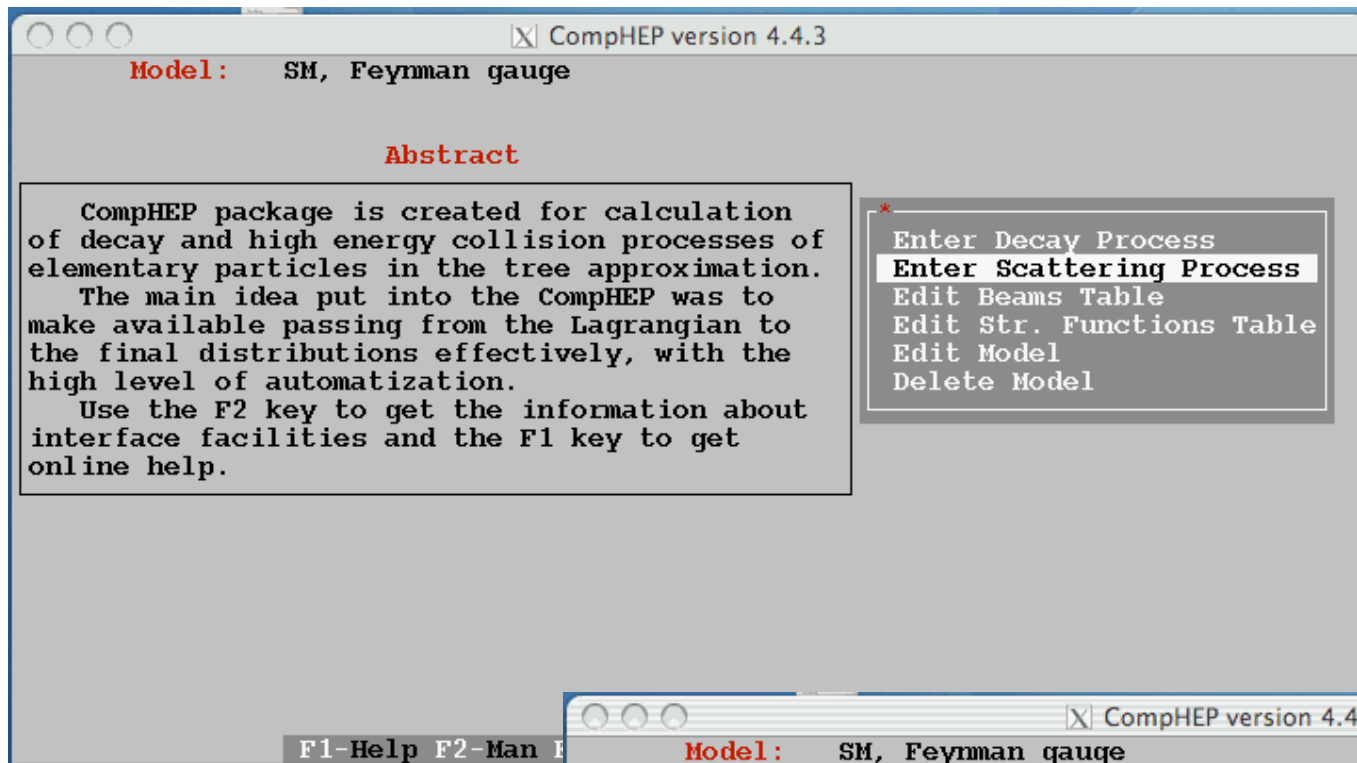


Before we proceed, let's get oriented.

Outline of Procedure

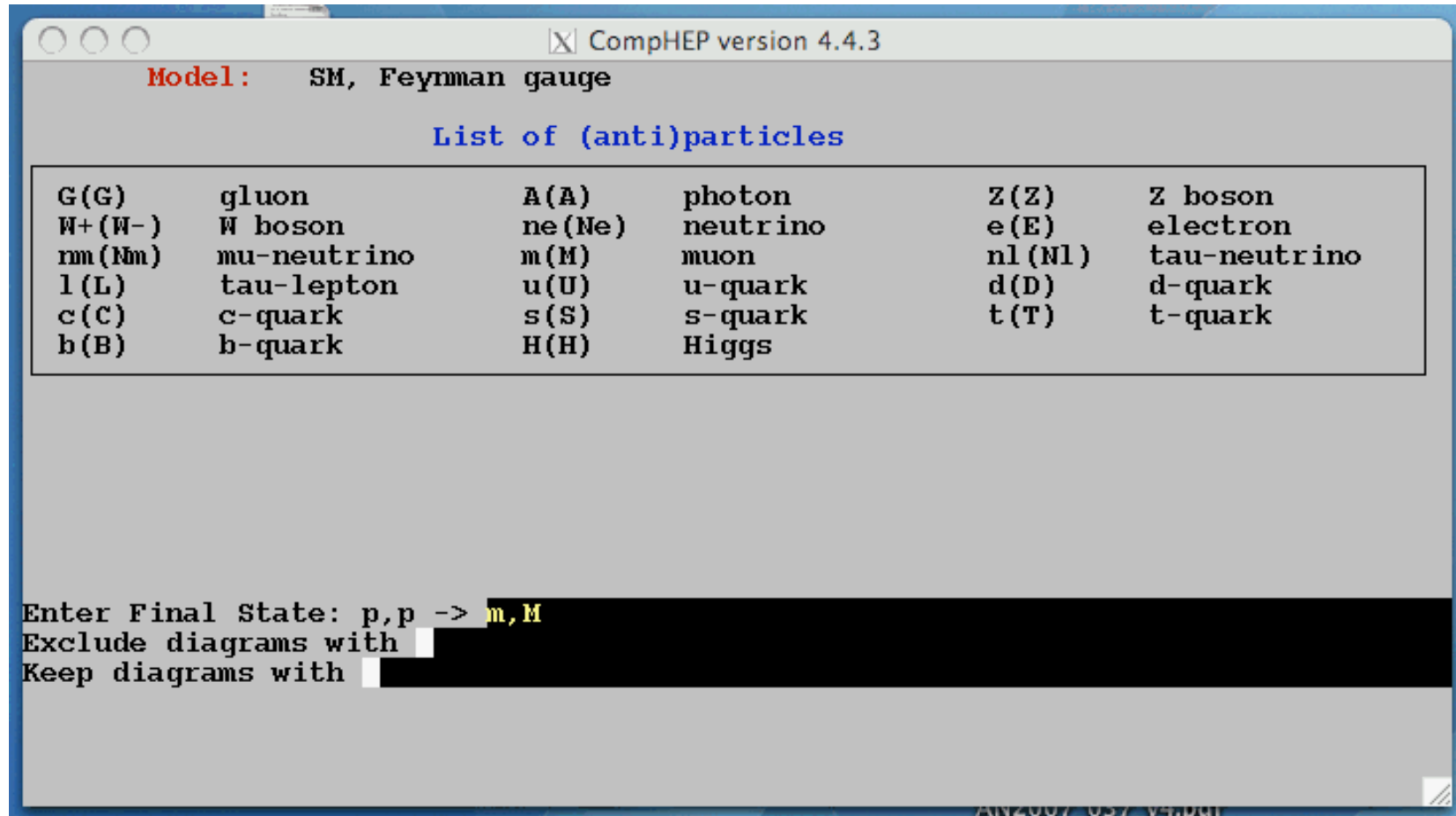
1. Specify decay or scattering process
2. View Diagrams; can write Latex code; can Delete selected diagrams, Exit (escape key)
3. Square Diagrams (can View and escape)
4. Symbolic calculation
5. Write results
6. C code
7. C-Compiler (hit return in separate window after complete)
8. Go to new window for 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.

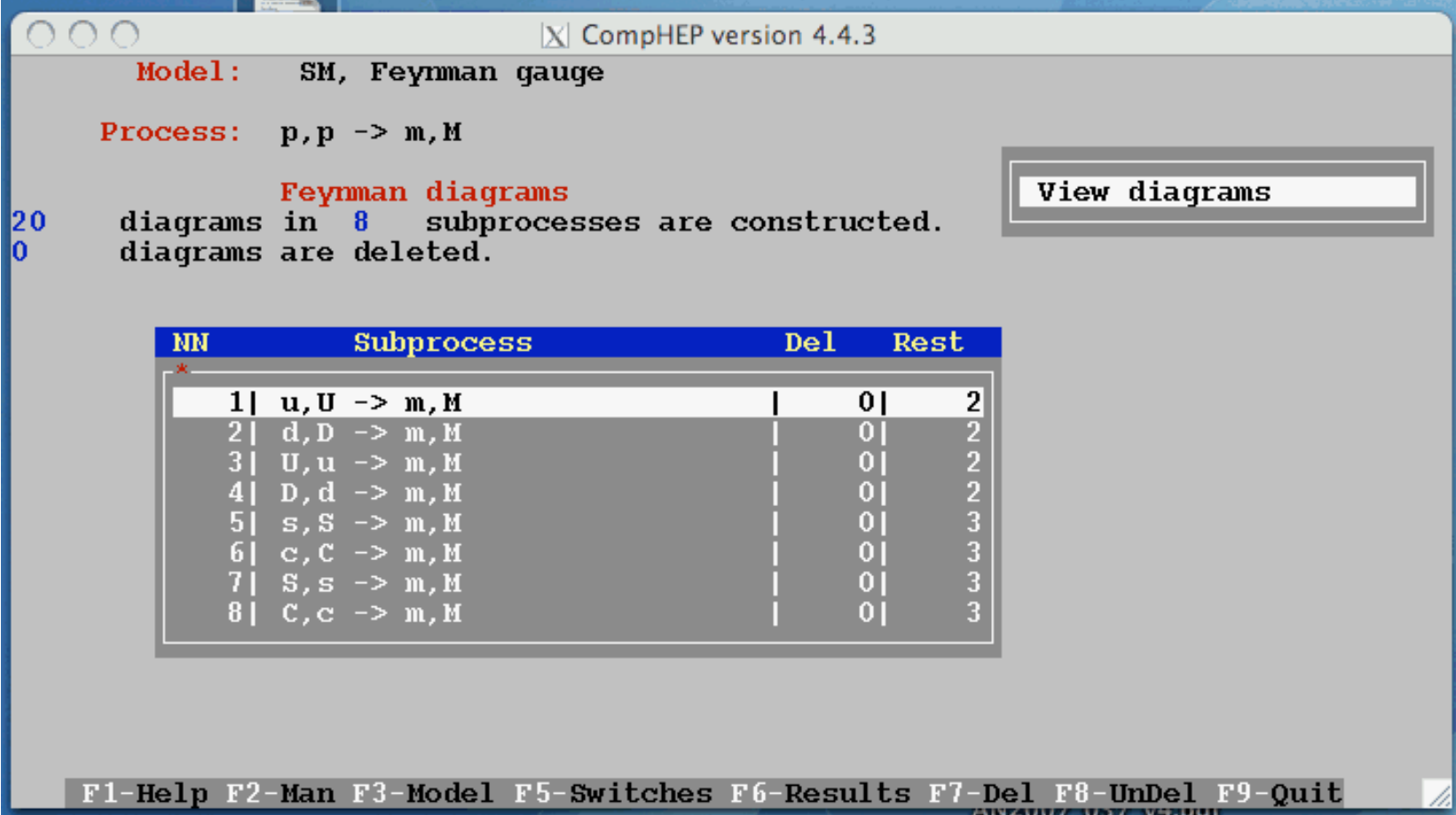


It's sometimes sufficient to just pick partons instead of protons.

Selecting final state and excluding diagrams.



View and select diagrams by subprocess



CompHEP version 4.4.3

Model: SM, Feynman gauge

Process: p,p -> m,M

Feynman diagrams

20 diagrams in 8 subprocesses are constructed.
0 diagrams are deleted.

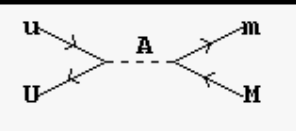
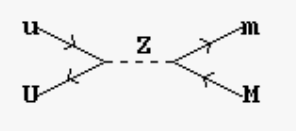
View diagrams

NN	Subprocess	Del	Rest
1	u,U -> m,M	0	2
2	d,D -> m,M	0	2
3	U,u -> m,M	0	2
4	D,d -> m,M	0	2
5	s,S -> m,M	0	3
6	c,C -> m,M	0	3
7	S,s -> m,M	0	3
8	C,c -> m,M	0	3

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

CompHEP version 4.4.3

Delete, On/off, Restore, Latex 1/2

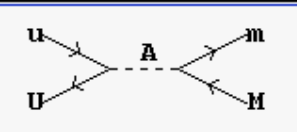
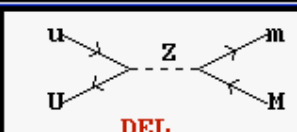
			

Select a diagram, then toggle on/off with mouse.

F1-Help, F2-Man, PgUp, PgDn, Ho

CompHEP version 4.4.3

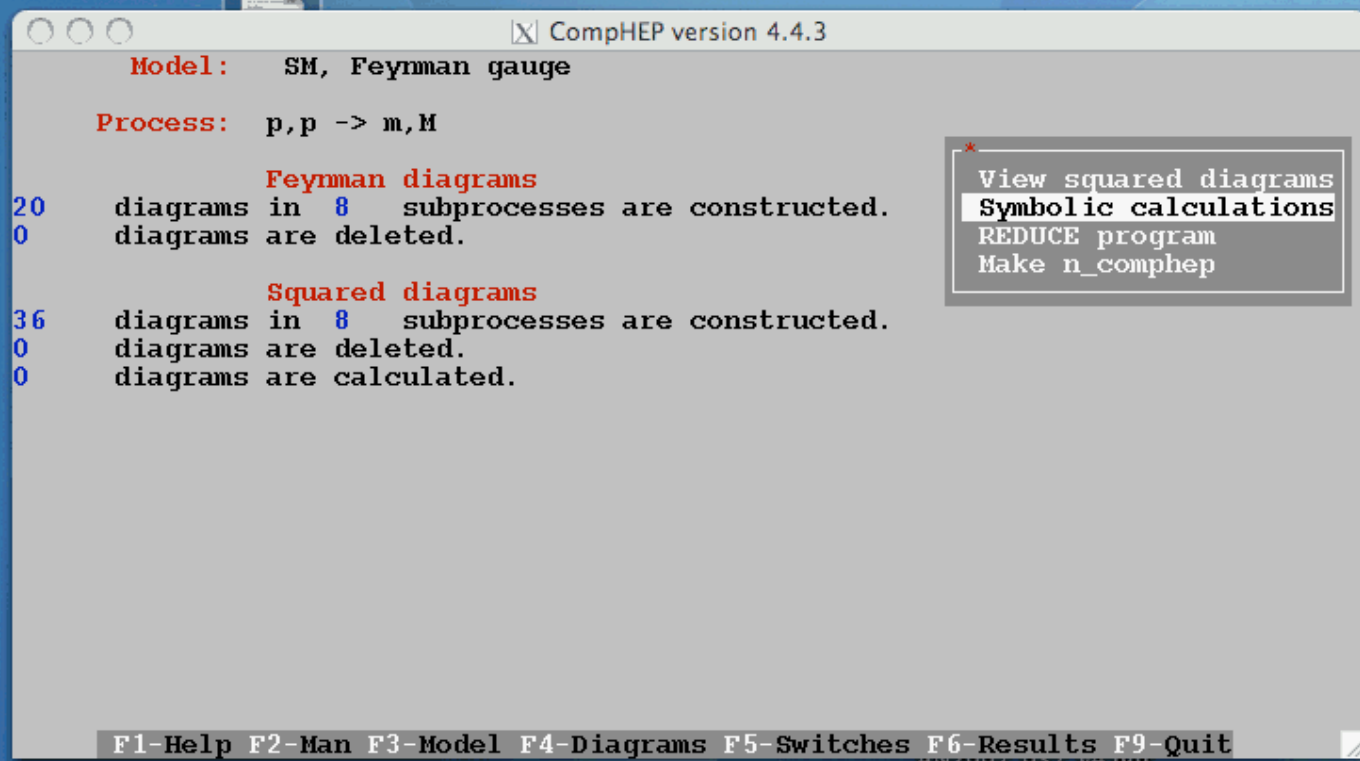
Delete, On/off, Restore, Latex 2/2

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

AN2007_057_v4.ppt

Now calculate the diagrams

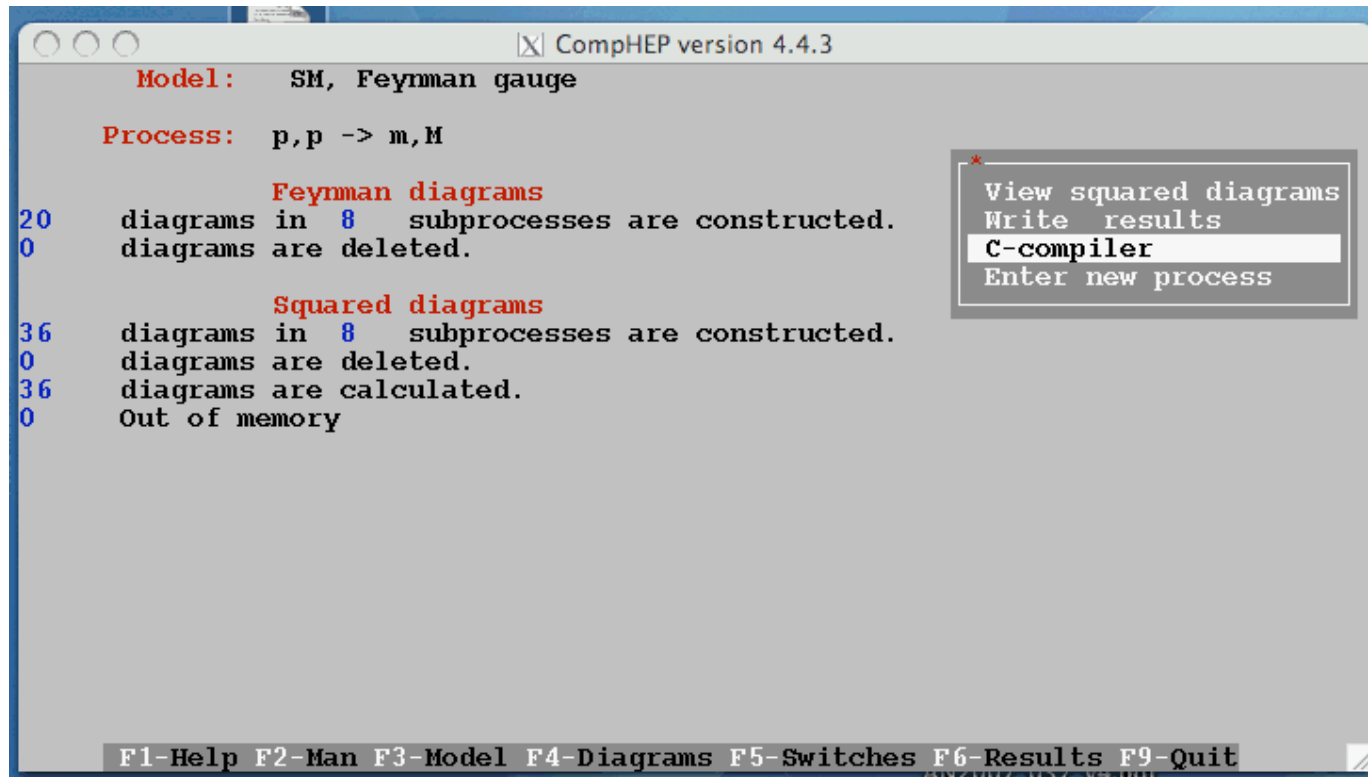


```
CompHEP version 4.4.3
Model: SM, Feynman gauge
Process: p,p -> m,M
Feynman diagrams
20 diagrams in 8 subprocesses are constructed.
0 diagrams are deleted.
Squared diagrams
36 diagrams in 8 subprocesses are constructed.
0 diagrams are deleted.
0 diagrams are calculated.
```

View squared diagrams
Symbolic calculations
REDUCE program
Make n_comphep

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

Now write results, and then compile.



```
CompHEP version 4.4.3
Model: SM, Feynman gauge
Process: p,p -> m,M

Feynman diagrams
20 diagrams in 8 subprocesses are constructed.
0 diagrams are deleted.

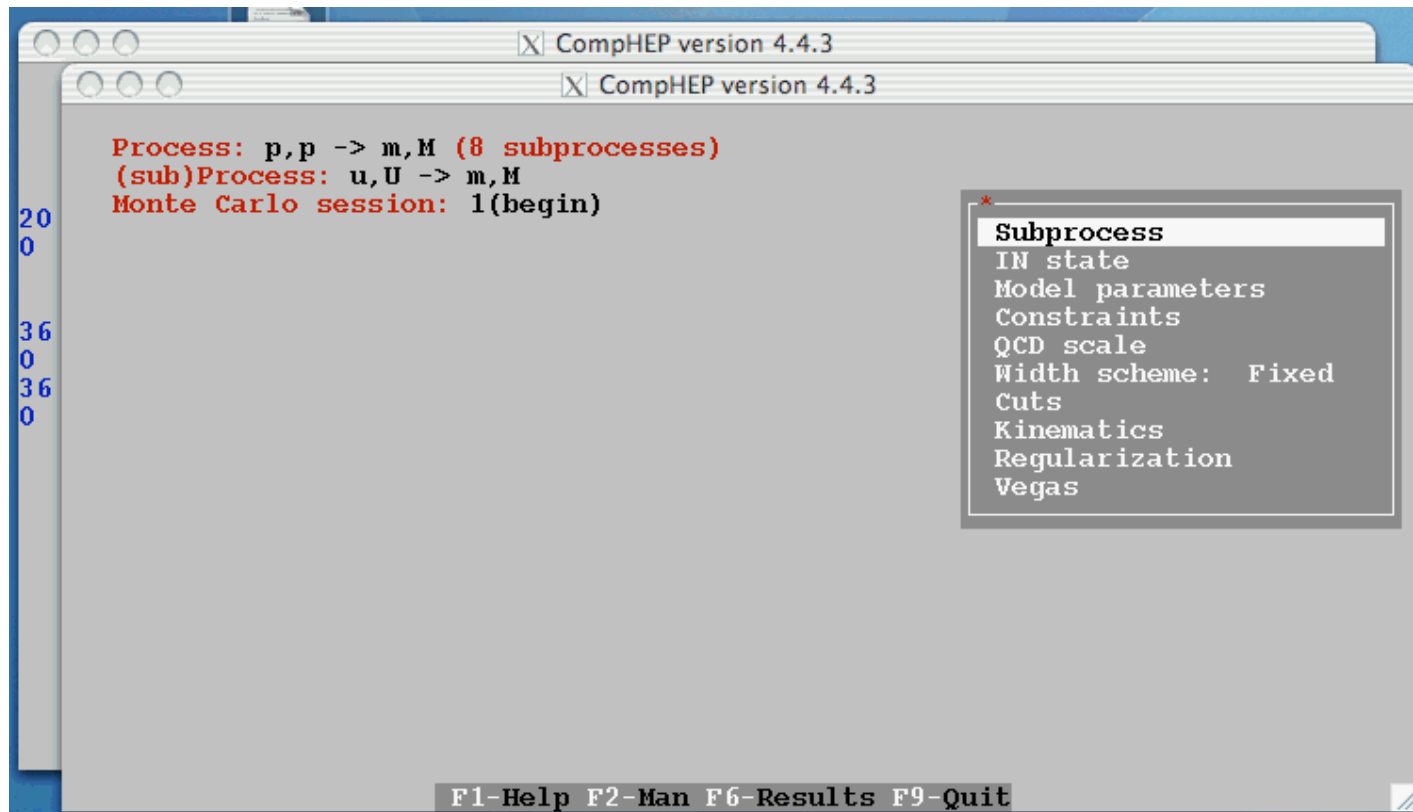
Squared diagrams
36 diagrams in 8 subprocesses are constructed.
0 diagrams are deleted.
36 diagrams are calculated.
0 Out of memory

View squared diagrams
Write results
C-compiler
Enter new process

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

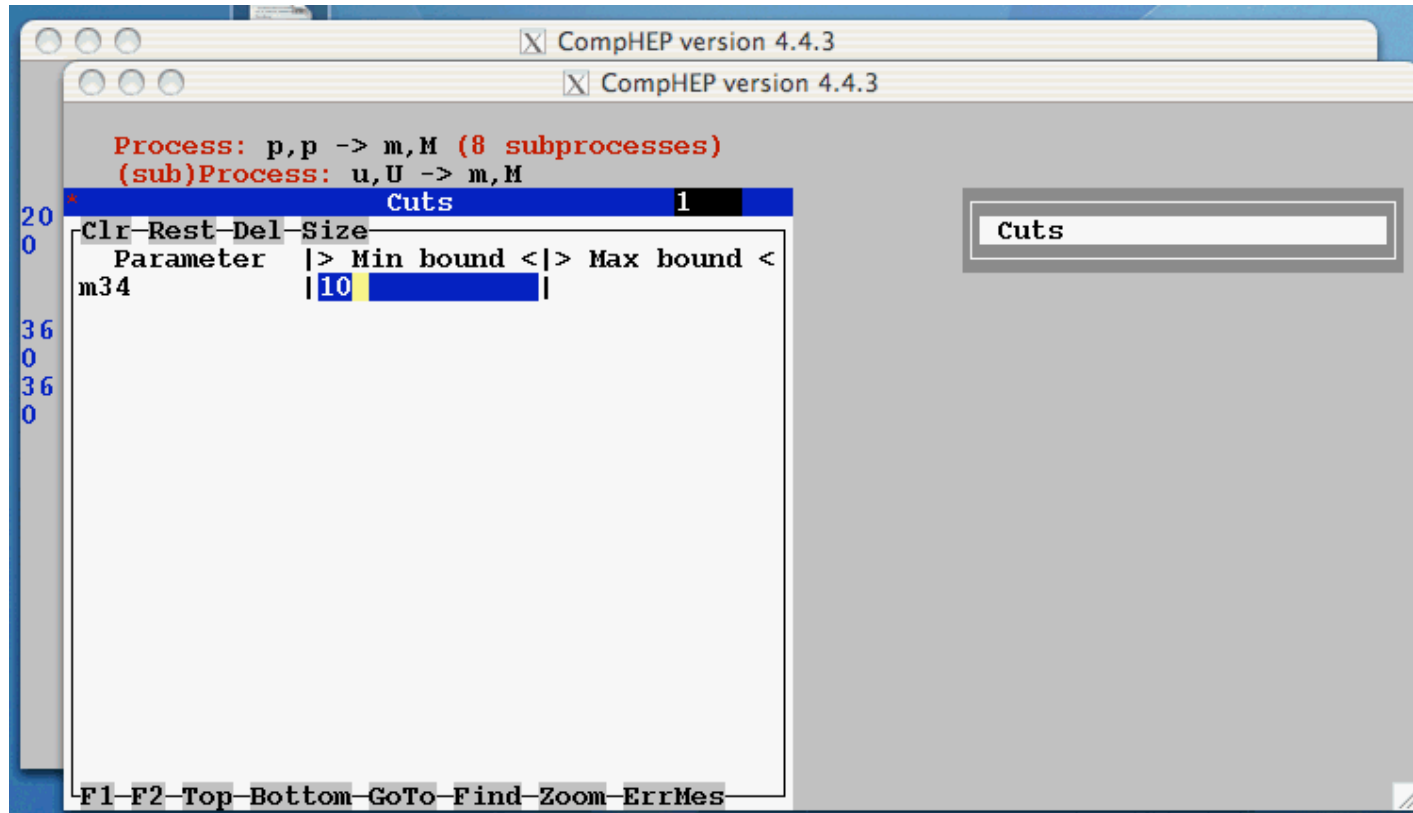
At this point a new window pops up, and you can see compilation/linking happen. Once done, you press enter In that window, and a new screen appears ...

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.

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 Δy 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.

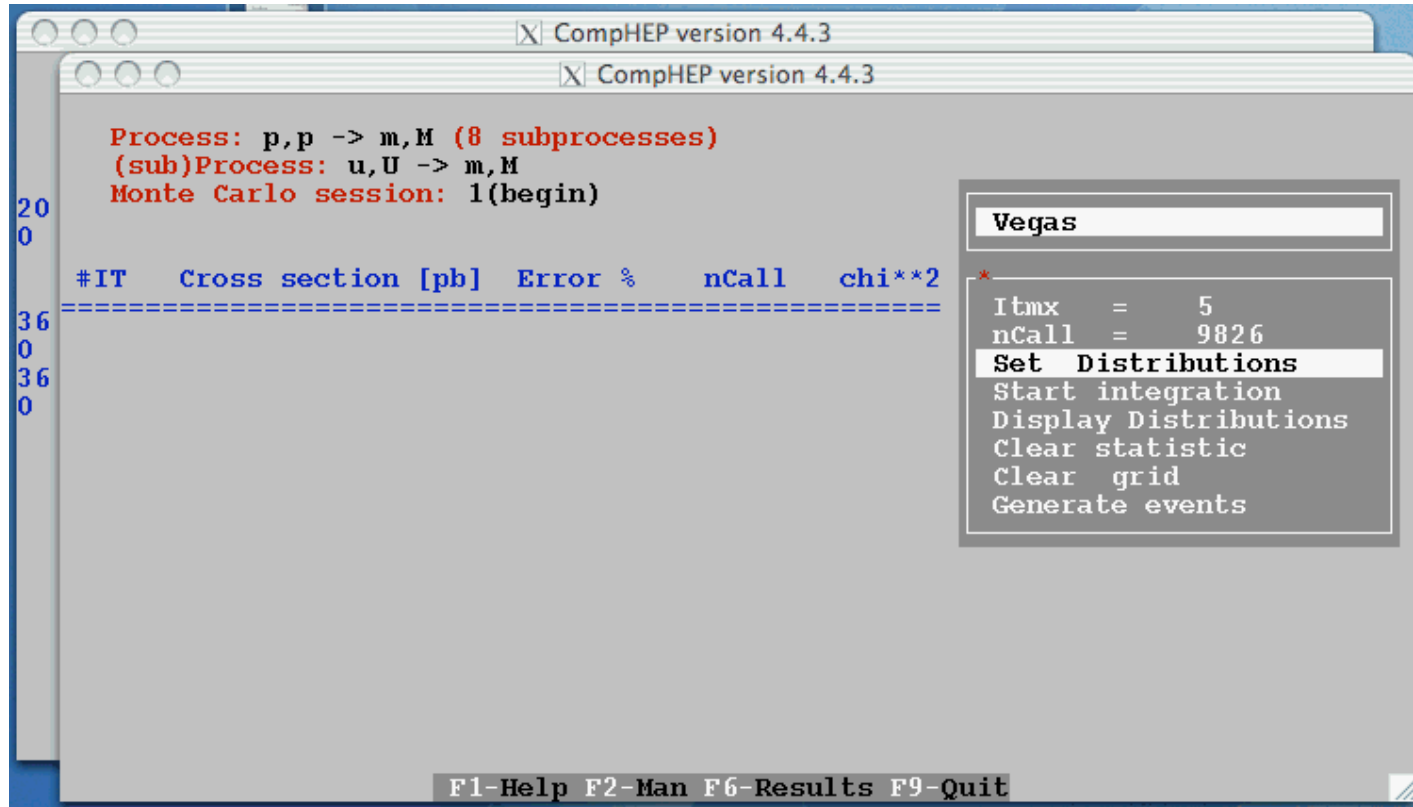
P - cosine in the rest frame of pair. P_{ij} is defined as follows: we imply a boost in the direction of $\mathbf{p}_i + \mathbf{p}_j$ to get the rest frame of the pair. Then P is a cosine of angle between the transformed \mathbf{p}_i and the direction of boost.

T - transverse momentum of the particle set.

You can use this to define cuts and plots.

For more see manual.

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



The screenshot shows the CompHEP version 4.4.3 interface. The main window displays the following text:

```
Process: p,p -> m,M (8 subprocesses)
(sub)Process: u,U -> m,M
Monte Carlo session: 1(begin)
```

Below this, a table header is shown:

#IT	Cross section [pb]	Error %	nCall	chi**2
-----	--------------------	---------	-------	--------

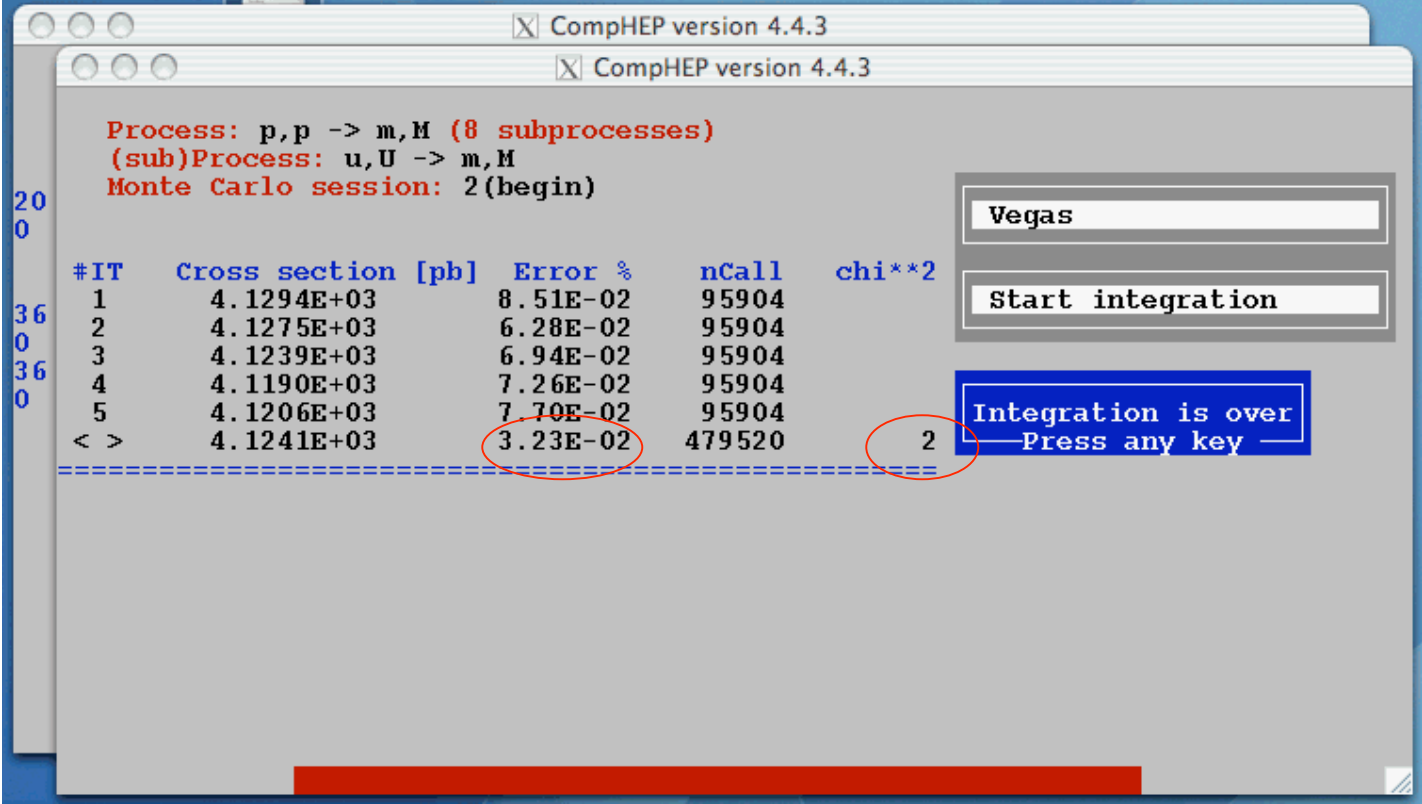
The table is currently empty. To the right of the terminal window, a menu titled "Vegas" is open, showing the following options:

- Itmx = 5
- nCall = 9826
- Set Distributions**
- Start integration
- Display Distributions
- Clear statistic
- Clear grid
- Generate events

At the bottom of the window, a status bar indicates: F1-Help F2-Man F6-Results F9-Quit

Then “start integration”.

Result of an integration:



Process: p,p -> m,M (8 subprocesses)
(sub)Process: u,U -> m,M
Monte Carlo session: 2(begin)

#IT	Cross section [pb]	Error %	nCall	chi**2
1	4.1294E+03	8.51E-02	95904	
2	4.1275E+03	6.28E-02	95904	
3	4.1239E+03	6.94E-02	95904	
4	4.1190E+03	7.26E-02	95904	
5	4.1206E+03	7.70E-02	95904	
< >	4.1241E+03	3.23E-02	479520	2

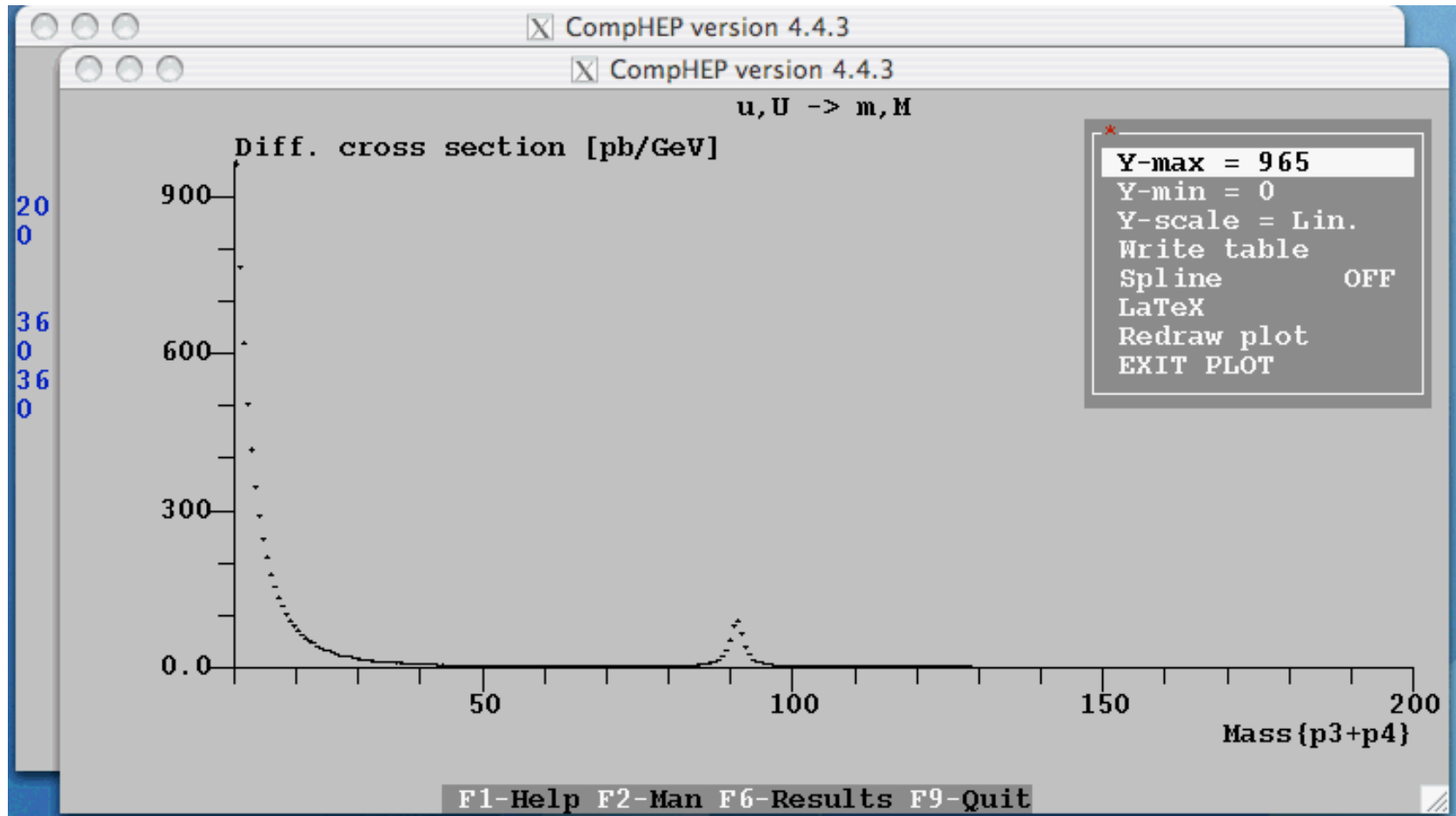
Vegas

Start integration

Integration is over
Press any key

You want a χ^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

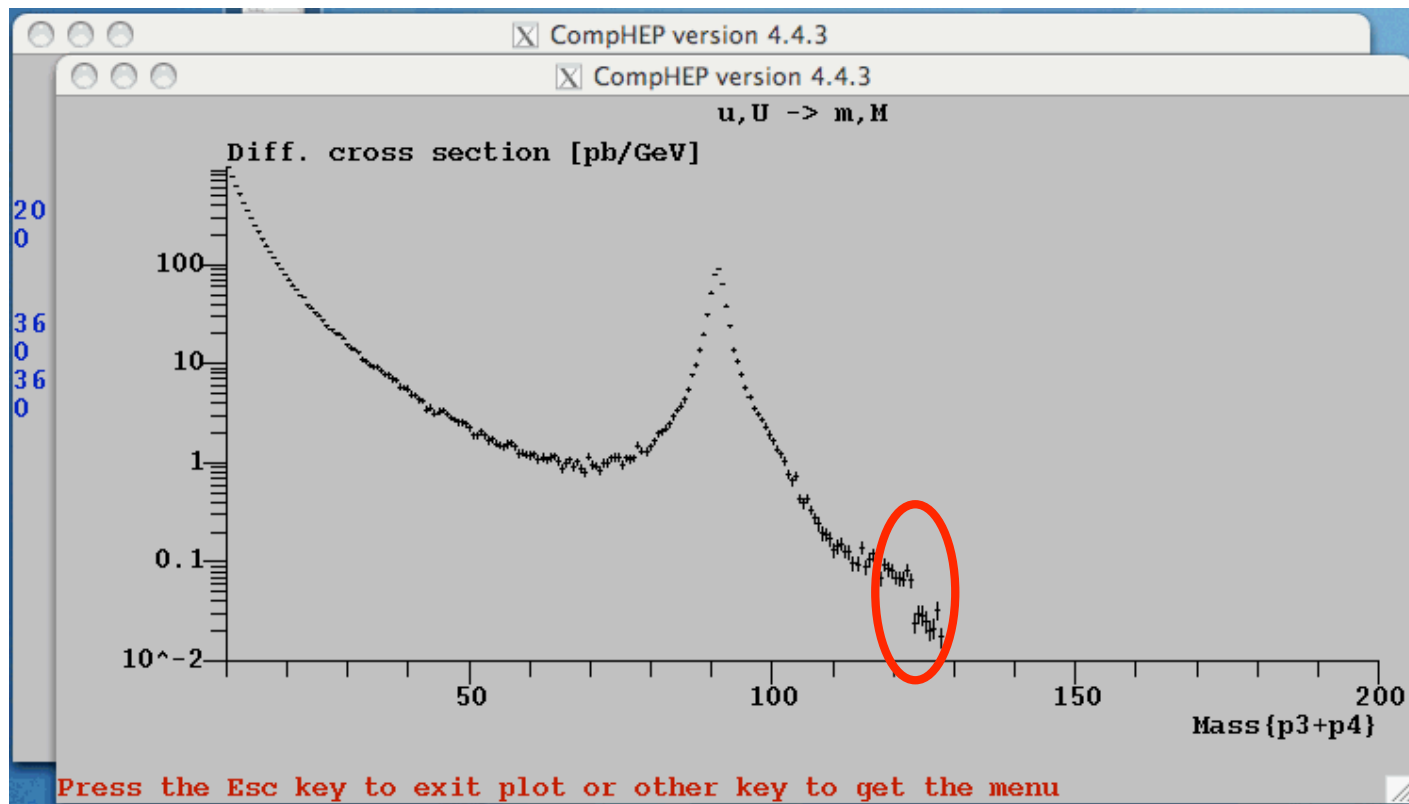


Getting fooled by comphep

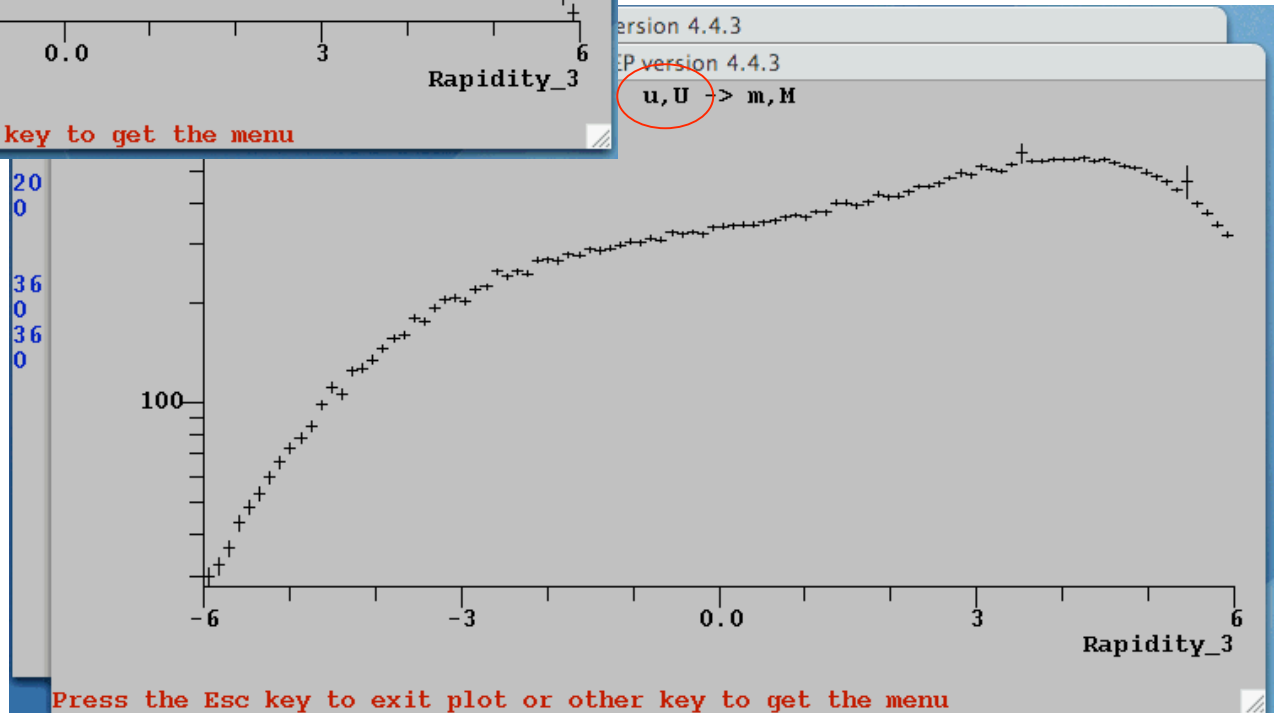
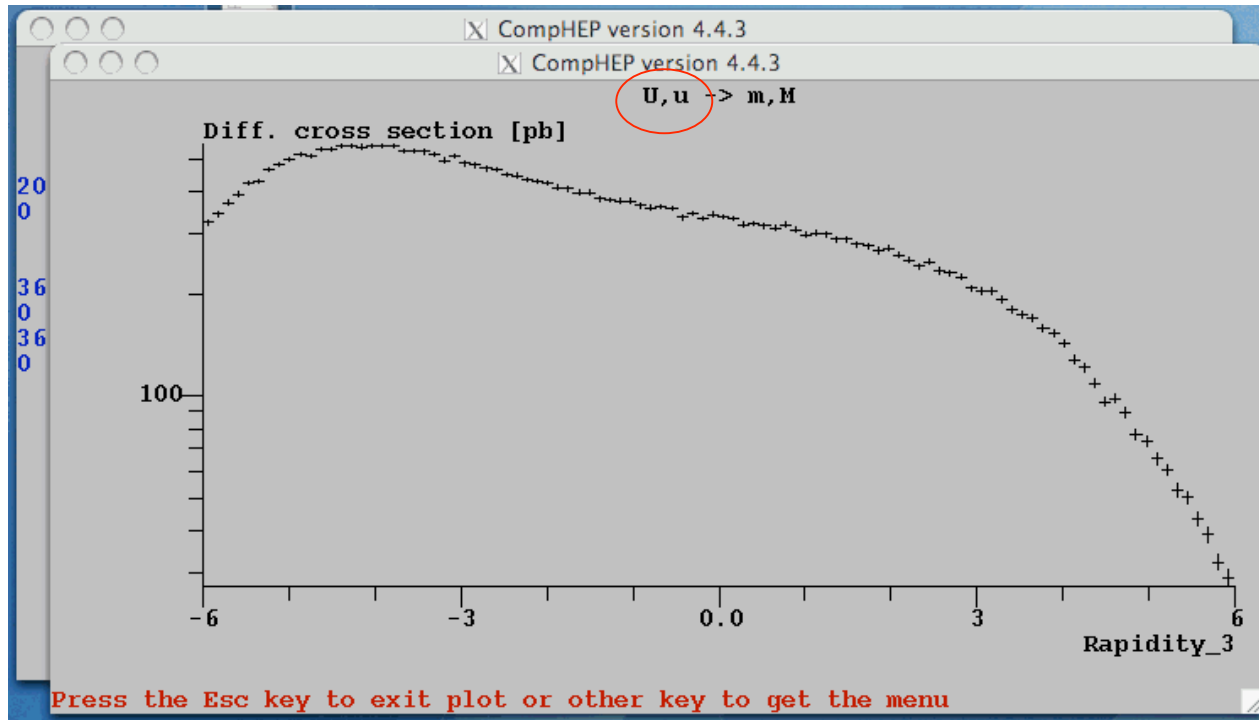
- Make sure that your integration properly converged -> watch your chisquare !!!
- Remember that you calculate one parton level process at a time, while nature produces the sum of all !!!

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

This integration didn't converge:



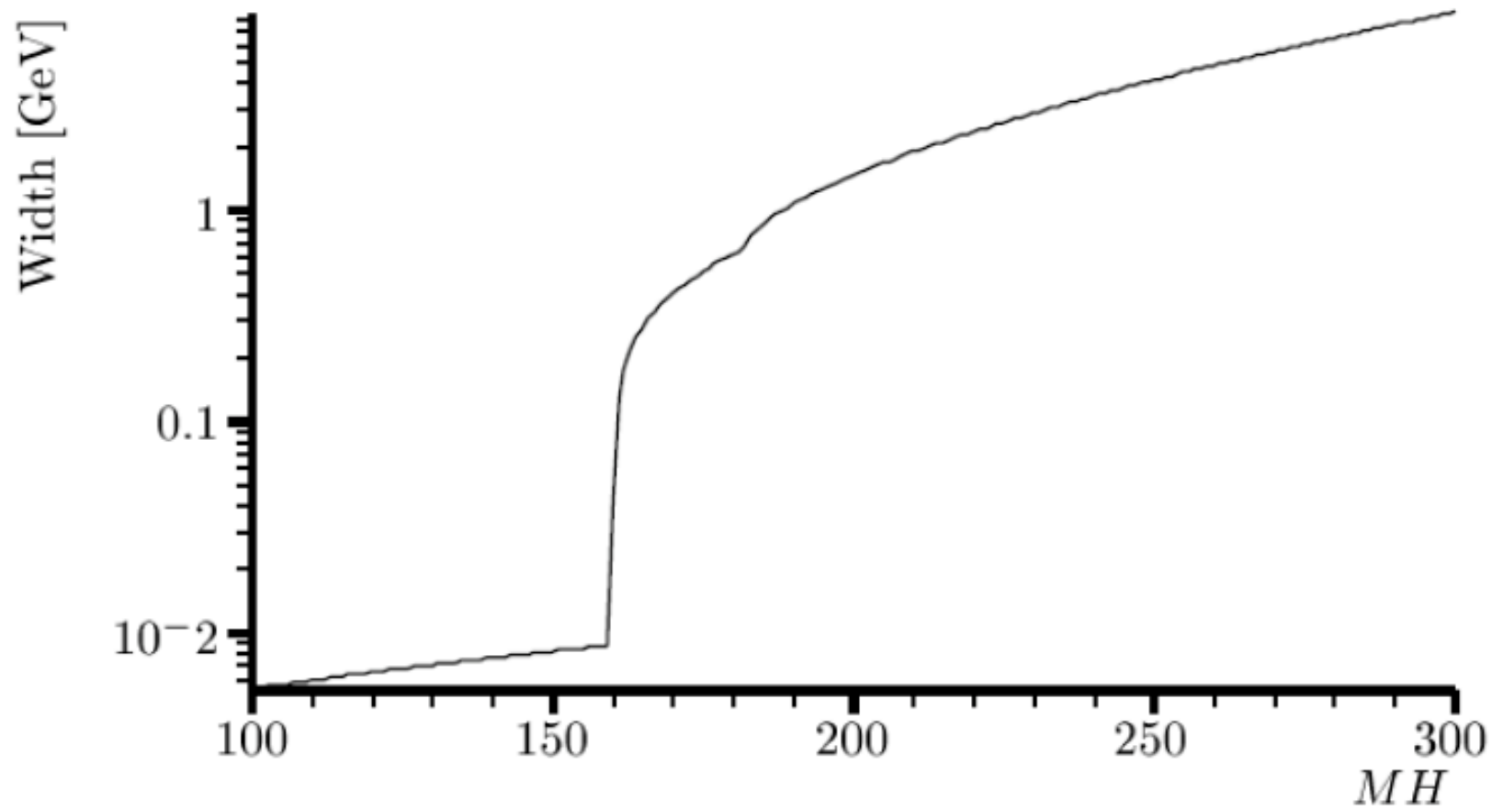
Remember to add subprocesses !!!



Some more examples

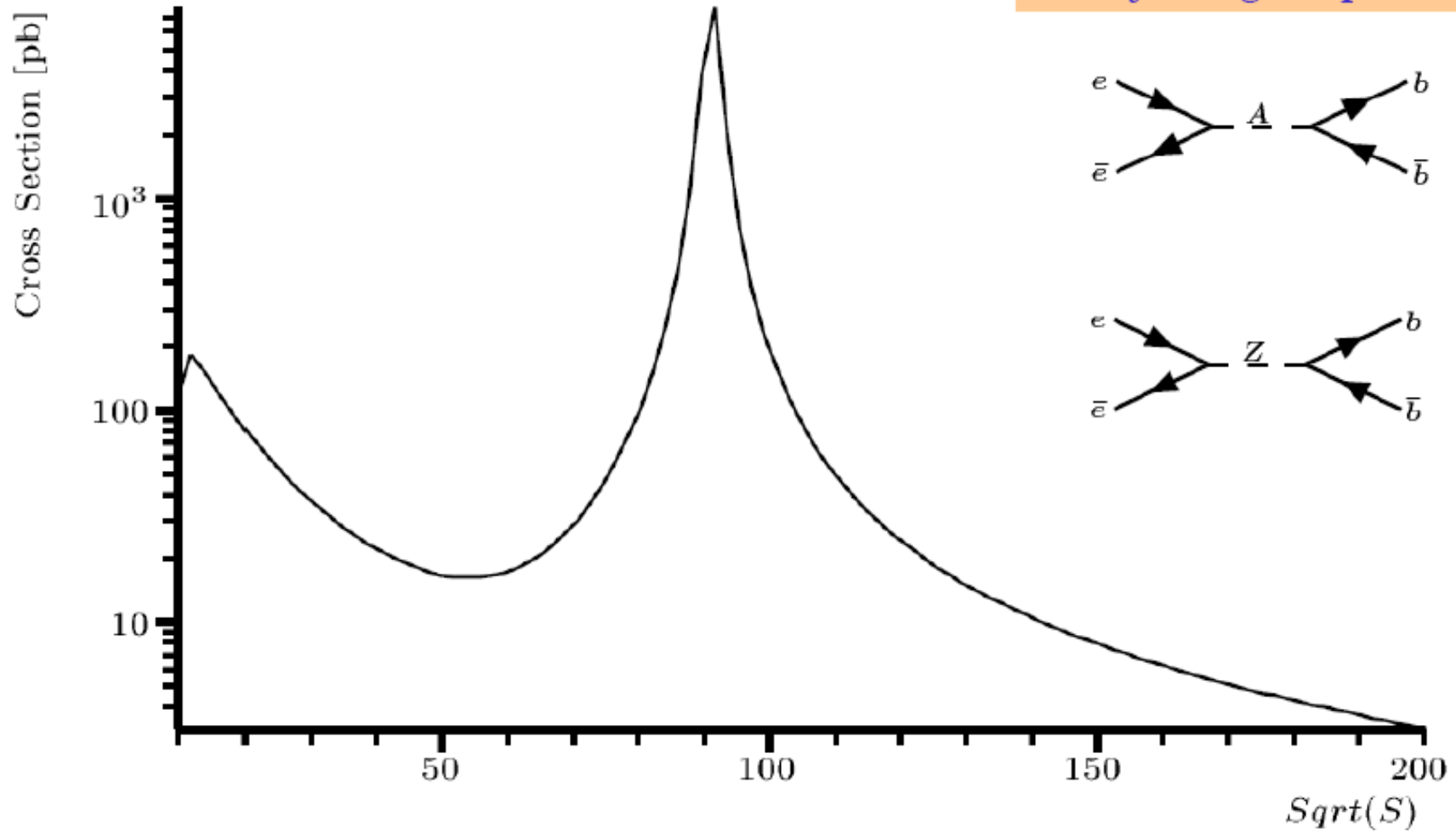
- Width of standard model higgs
 - We'll discuss this in some detail next quarter.
- $e^+ e^- \rightarrow b \bar{b}$ scattering
 - You explored this on homework.

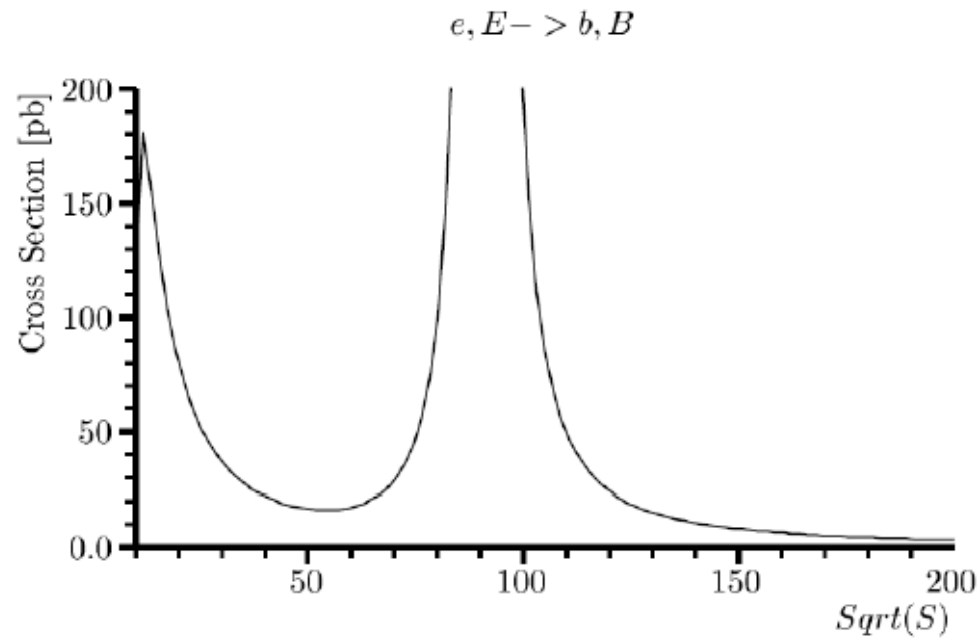
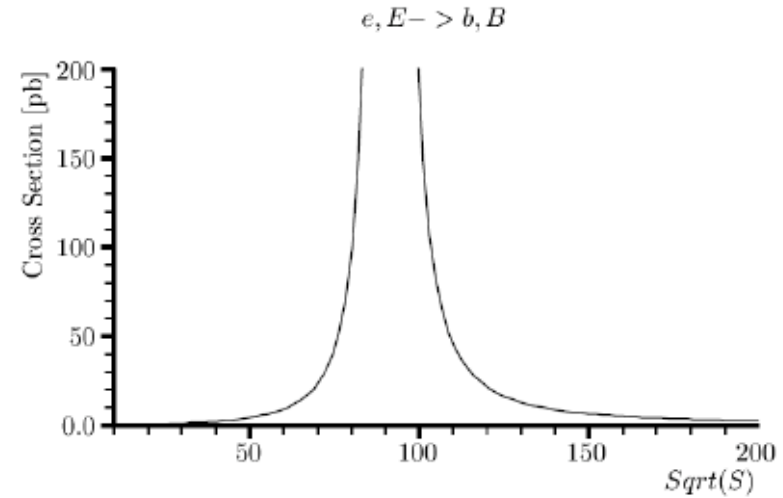
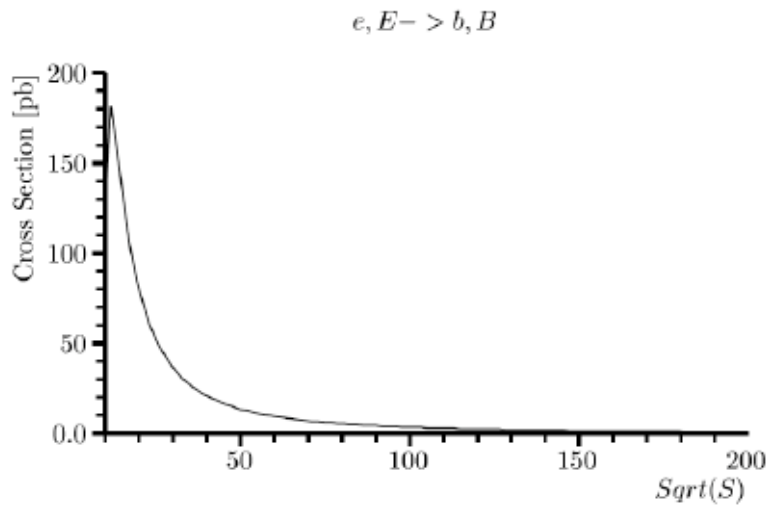
$$H \rightarrow 2 * x$$



$e, E- \rightarrow b, B$

Interfering amplitudes



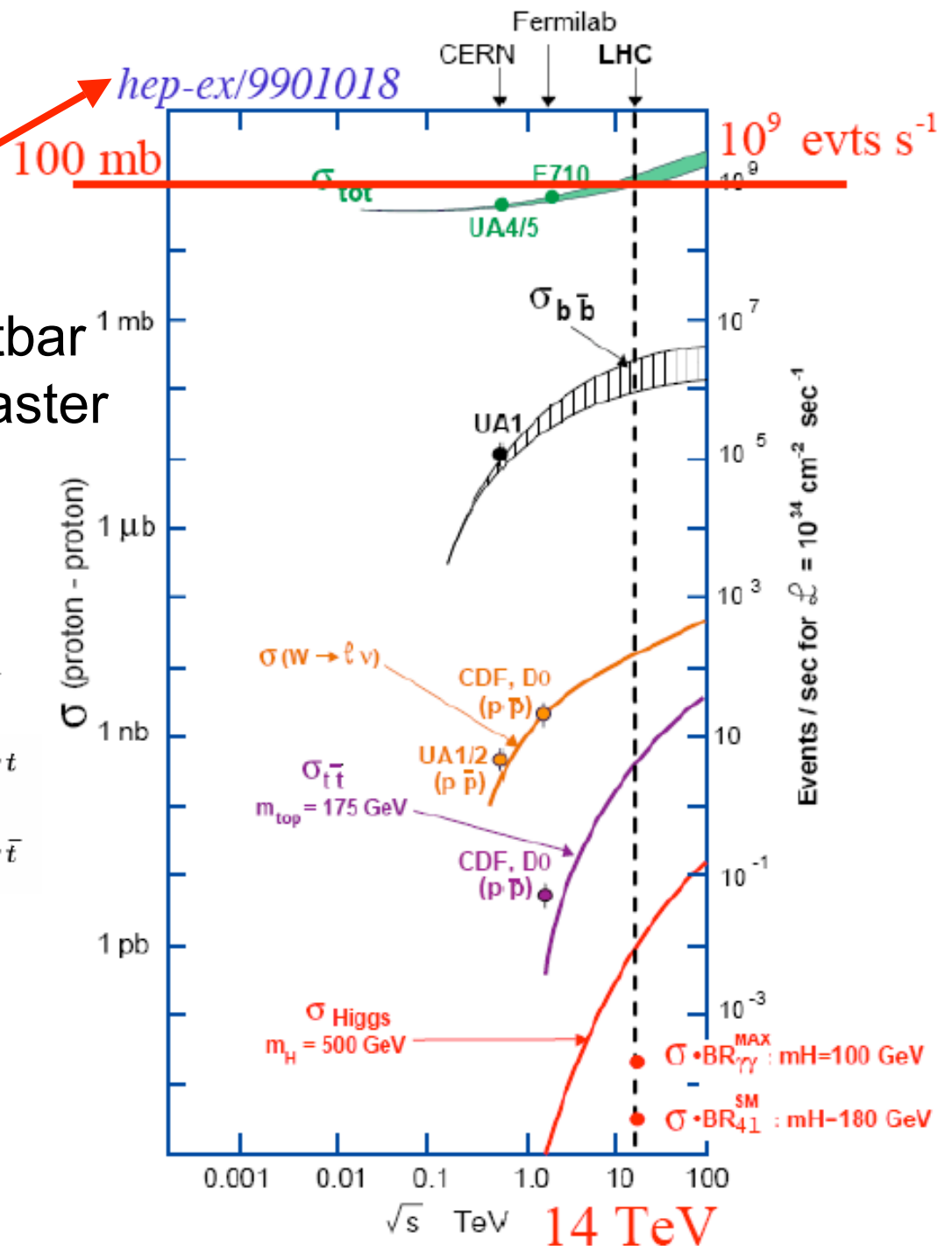
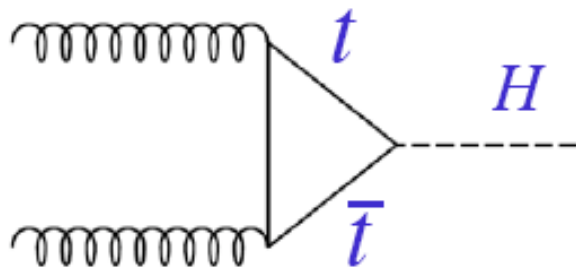
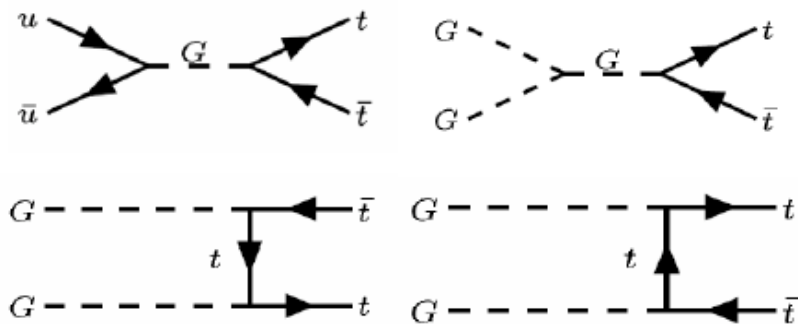


Note: linear scale here!

Good luck on Final!

Taken from Jeff Richman's Tutorial who took it from hep-ex/9901018

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 the size of
The tracker.

This L is NOT
The size of the tracker!

My apologies for confusing you!