Simulations and MLM Matching with MadGraph + Pythia

Tutorial

Johan Alwall

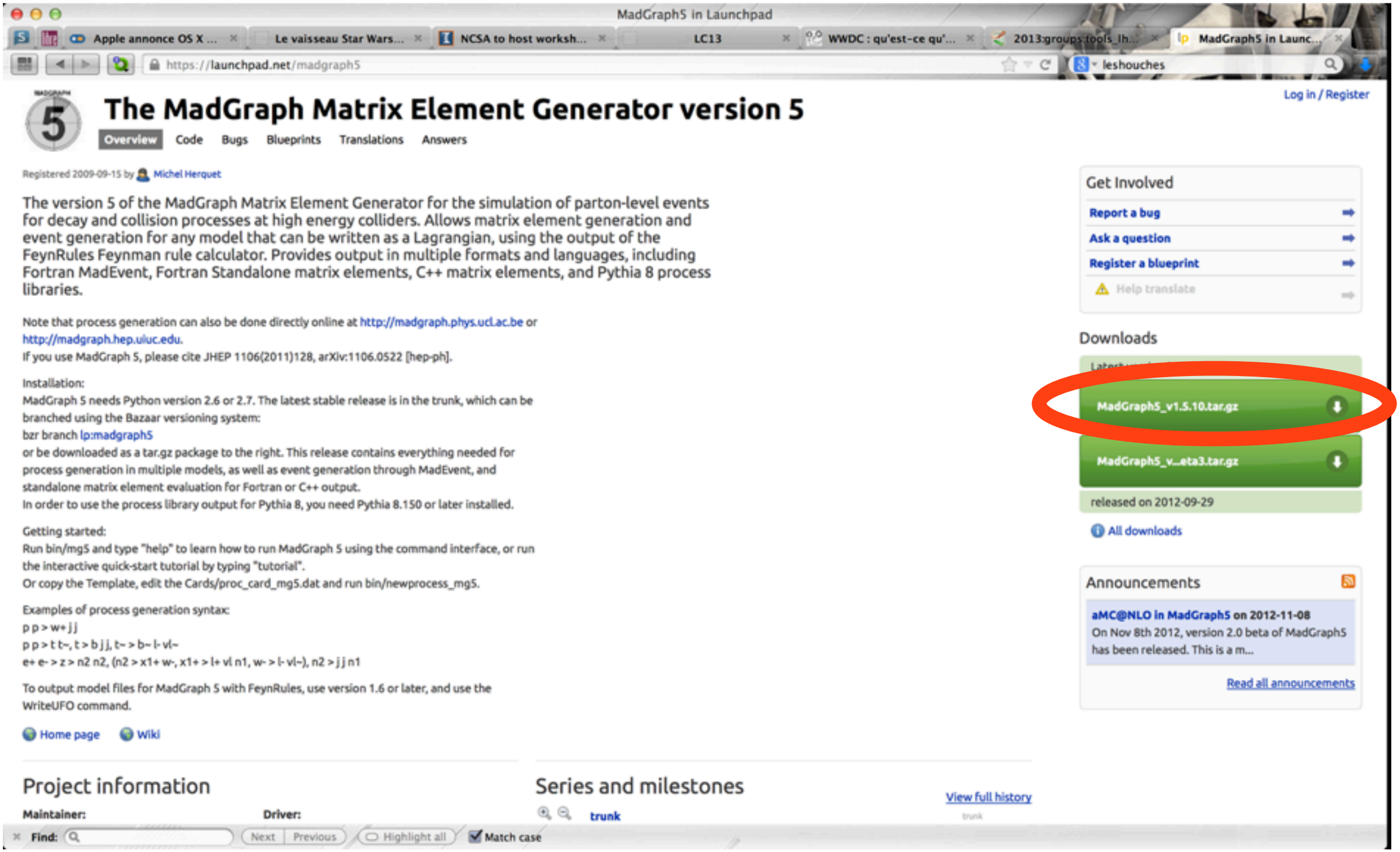
Plan for the tutorial

Total time: 4 h

1. Installation and introduction to MadGraph 5 (Exercise I, 20 min)
2. Useful syntax examples and distributions (Exercise II-V, 40 min)
3. MLM matching with MadGraph+Pythia (Exercise VI, 3 h)

Exercise I: Install MadGraph 5!

- https://launchpad.net/madgraph5
  - ➡ 1.5.10
  - ➡ 2.0.0.beta3 -> (NLO available !)
- untar it (tar -xzpvf TUTO_model.tgz)
- launch it ($ ./bin/mg5)
- learn it!
  - ➡ Type tutorial and follow instructions


MadGraph5 in Launchpad
Apple annonce OS X ...
Le vaisseau Star Wars...
NCSA to host worksh...
LC13
WWDC : qu'est-ce qu'...
2013:groups:tools_lh...
MadGraph5 in Launc...
https://launchpad.net/madgraph5
leshouches
Log in / Register
The MadGraph Matrix Element Generator version 5
Overview
Code
Bugs
Blueprints
Translations
Answers
Registered 2009-09-15 by Michel Herquet
The version 5 of the MadGraph Matrix Element Generator for the simulation of parton-level events for decay and collision processes at high energy colliders. Allows matrix element generation and event generation for any model that can be written as a Lagrangian, using the output of the FeynRules Feynman rule calculator. Provides output in multiple formats and languages, including Fortran MadEvent, Fortran Standalone matrix elements, C++ matrix elements, and Pythia 8 process libraries.
Note that process generation can also be done directly online at http://madgraph.phys.ucl.ac.be or http://madgraph.hep.uiuc.edu.
If you use MadGraph 5, please cite JHEP 1106(2011)128, arXiv:1106.0522 [hep-ph].
Installation:
MadGraph 5 needs Python version 2.6 or 2.7. The latest stable release is in the trunk, which can be branched using the Bazaar versioning system:
bzr branch lp:madgraph5
or be downloaded as a tar.gz package to the right. This release contains everything needed for process generation in multiple models, as well as event generation through MadEvent, and standalone matrix element evaluation for Fortran or C++ output.
In order to use the process library output for Pythia 8, you need Pythia 8.150 or later installed.
Getting started:
Run bin/mg5 and type "help" to learn how to run MadGraph 5 using the command interface, or run the interactive quick-start tutorial by typing "tutorial".
Or copy the Template, edit the Cards/proc_card_mg5.dat and run bin/newprocess_mg5.
Examples of process generation syntax:
p p > w+ j j
p p > t t~, t > b j j, t~ > b~ l- vl~
e+ e- > z > n2 n2, (n2 > x1+ w-, x1+ > l+ vl n1, w- > l- vl~), n2 > j j n1
To output model files for MadGraph 5 with FeynRules, use version 1.6 or later, and use the WriteUFO command.
Home page
Wiki
Get Involved
Report a bug
Ask a question
Register a blueprint
Help translate
Downloads
MadGraph5_v1.5.10.tar.gz
MadGraph5_v...eta3.tar.gz
released on 2012-09-29
All downloads
Announcements
aMC@NLO in MadGraph5 on 2012-11-08
On Nov 8th 2012, version 2.0 beta of MadGraph5 has been released. This is a m...
Read all announcements
Project information
Maintainer:
Driver:
Series and milestones
View full history
trunk
Find:
Next
Previous
Highlight all
Match case

Where to find help?

- Ask me/the tutors/other students!
- Use the command "help" / "help XXX"
  - ➡ "help" gives you the next command that you want to do.
- Launchpad:
  - ➡ https://answers.launchpad.net/madgraph5
  - ➡ FAQ: https://answers.launchpad.net/madgraph5/+faqs

What are those cards?

- Read the cards and identify what they do
  - ➡ param_card: model parameters
  - ➡ run_card: beam/run parameters and cuts
- https://answers.launchpad.net/madgraph5/+faq/2014

Exercise II: Cards Meaning

- How do you change
  - ➡ top mass
  - ➡ top width
  - ➡ W mass
  - ➡ beam energy
  - ➡ pt cut on the lepton

Exercise III: Syntax

- What's the meaning of the order QED/QCD
- What's the difference between
  - ➡ p p > t t~
  - ➡ p p > t t~ QED=2
  - ➡ p p > t t~ QED=0

Exercise IV: Syntax

- Generate the cross-section and the distribution (invariant mass) for
  - ➡ p p > e+ e-
  - ➡ p p > z, z > e+ e-
  - ➡ p p > e+ e- $ z
  - ➡ p p > e+ e- / z

Hint :To plot automatically distributions:
mg5> install MadAnalysis

Exercise V: Automation

- Compute the cross-section for the top pair production for 3 different mass points.
  - ➡ Do NOT use the interactive interface
    - hint: you can edit the param_card/run_card via the "set" command [After the launch]
    - hint: All commands [including answers to questions] can be put in a file. (run ./bin/mg5 PATH_TO_FILE)

Let's start

Exercises

1. Follow the built-in tutorial (type "tutorial" in mg5 shell)
2. Understand the cards
3. compare (diagram and cross-section)
   - ➡ p p > t t~
   - ➡ p p > t t~ QED=0
   - ➡ p p > t t~ QED=2
4. compare (distributions)
   - ➡ p p > e+ e-
   - ➡ p p > z, z > e+ e-
   - ➡ p p > e+ e- $ z
   - ➡ p p > e+ e- / z
5. compute the cross-section
   p p > t t~
   - ➡ for Mtop between 160 to 180 GeV
   - ➡ Do not use the interface!

Solutions

Exercise II: Cards Meaning

- How do you change
  - ➡ top mass
  - ➡ top width
  - ➡ W mass
  - ➡ beam energy
  - ➡ pt cut on the lepton

Param_card

Run_card

- top mass

```
###################################
## INFORMATION FOR MASS
###################################
Block mass
    6 1.730000e+02 # MT
   23 9.118800e+01 # MZ
   25 1.200000e+02 # MH
## Dependent parameters, given by model restrictions.
## Those values should be edited following the
## analytical expression. MG5 ignores those values
## but they are important for interfacing the output of MG5
## to external program such as Pythia.
  1 0.000000 # d : 0.0
  2 0.000000 # u : 0.0
  3 0.000000 # s : 0.0
  4 0.000000 # c : 0.0
  11 0.000000 # e- : 0.0
  12 0.000000 # ve : 0.0
  13 0.000000 # mu- : 0.0
  14 0.000000 # vm : 0.0
  16 0.000000 # vt : 0.0
  21 0.000000 # g : 0.0
  22 0.000000 # a : 0.0
  24 80.419002 # w+ : cmath.sqrt(MZ__exp__2/2. + cmath.sqrt(MZ__exp__4/4. - (aEW*cmath.pi*MZ__exp__2)/(Gf*sqrt__2)))
```

- W mass

```
####################################
## INFORMATION FOR MASS
####################################
Block mass
    5 4.700000e+00 # MB
    6 1.730000e+02 # MT
   15 1.777000e+00 # MTA
   23 9.118800e+01 # MZ
   25 1.200000e+02 # MH
## Dependent parameters, given by model restrictions.
## Those values should be edited following the
## analytical expression. MG5 ignores those values
## but they are important for interfacing the output of MG5
## to external program such as Pythia.
  1 0.000000 # d : 0.0
  2 0.000000 # u : 0.0
  3 0.000000 # s : 0.0
  4 0.000000 # c : 0.0
 11 0.000000 # e- : 0.0
 12 0.000000 # ve : 0.0
 13 0.000000 # mu- : 0.0
 14 0.000000 # vm : 0.0
 16 0.000000 # vt : 0.0
 21 0.000000 # g : 0.0
 22 0.000000 # a : 0.0
 24 80.419002 # w+ : cmath.sqrt(MZ__exp__2/2. + cmath.sqrt(MZ__exp__4/4. - (aEW*cmath.pi*MZ__exp__2)/(Gf*sqrt__2)))
```

W Mass is an internal parameter!

MG5 doesn't use this entry!

So you need to change MZ or Gf or alpha_EW

Exercise III: Syntax

- What's the meaning of the order QED/QCD
- What's the difference between
  - ➡ p p > t t~
  - ➡ p p > t t~ QED=2
  - ➡ p p > t t~ QED=0

- What's the meaning of the order QED/QCD
  - ➡ By default MG5 takes the lowest order in QED!
  - ➡ p p > t t~ => p p > t t~ QED=0
  - ➡ p p > t t~ QED=2
    - additional diagrams (photon/z exchange)

p p > t t~

Cross section (pb)
555 ± 0.84

p p > t t~ QED=2

Cross section (pb)
555.8 ± 0.91

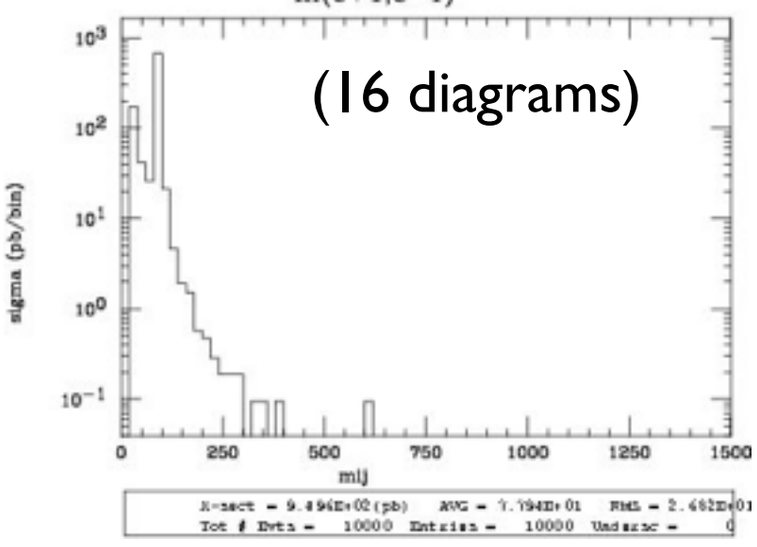
No significant QED contribution

Exercise IV: Distributions

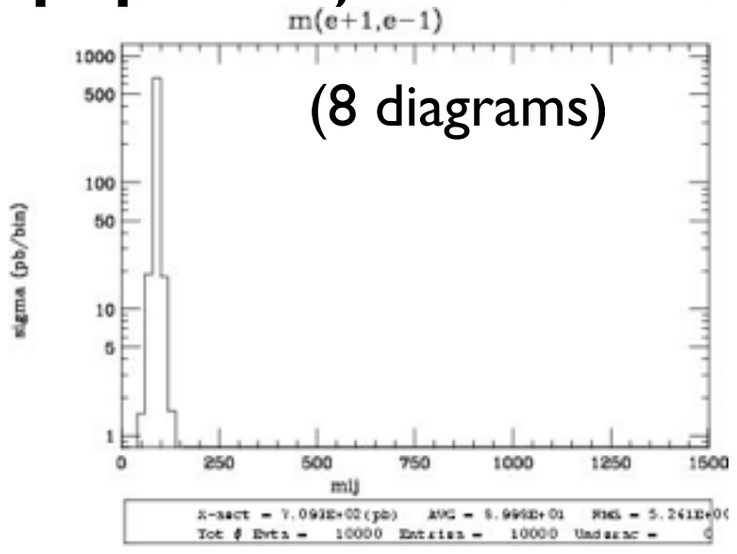
- Generate the cross-section and the distribution (invariant mass) for
  - ➡ p p > e+ e-
  - ➡ p p > z, z > e+ e-
  - ➡ p p > e+ e- $ z
  - ➡ p p > e+ e- / z

Hint : To have automatic distributions:
mg5> install MadAnalysis

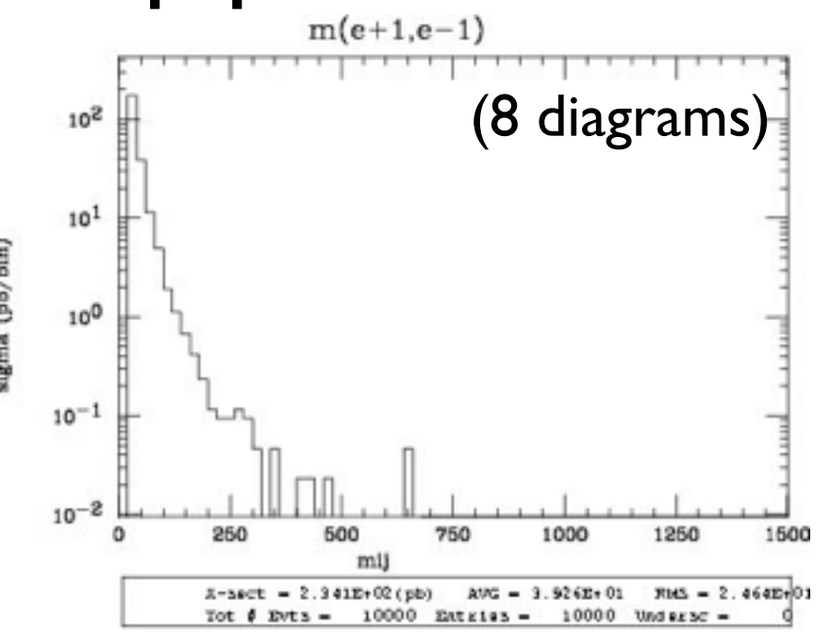
p p > e+ e-



p p >z , z > e+ e-

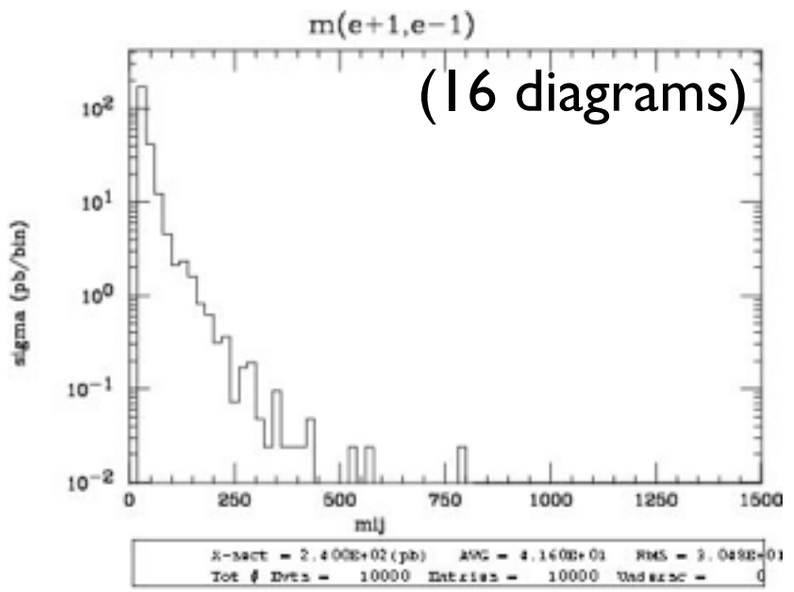


p p > e+ e- /z



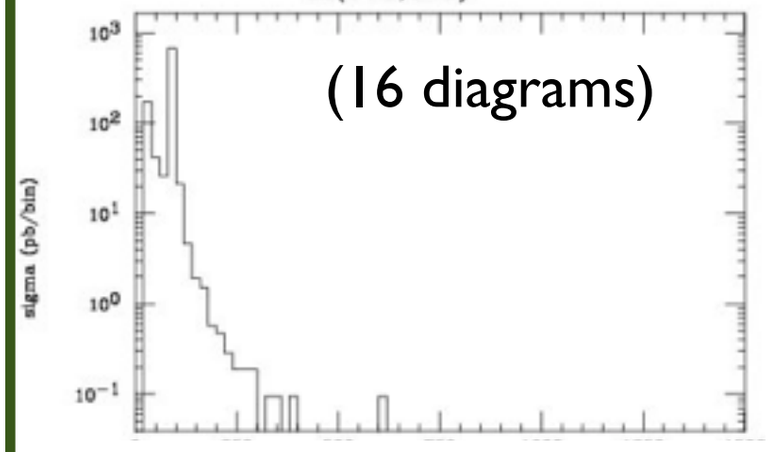
No Z

p p > e+ e- $ z



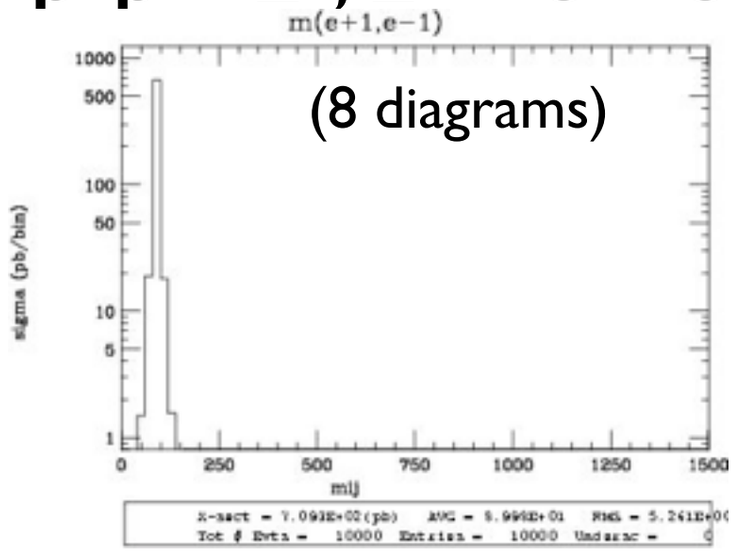
Z- onshell veto

p p > e+ e-

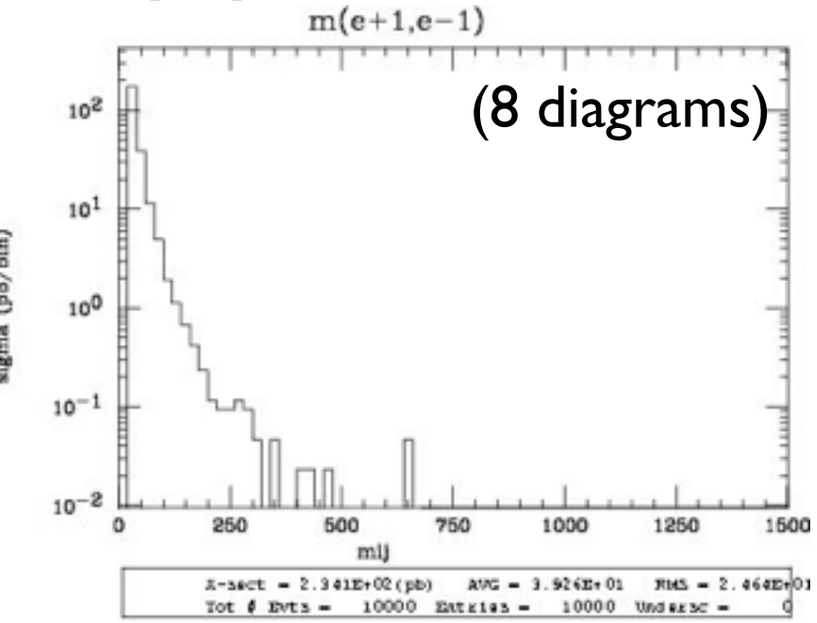


Correct Distribution

p p >z , z > e+ e-

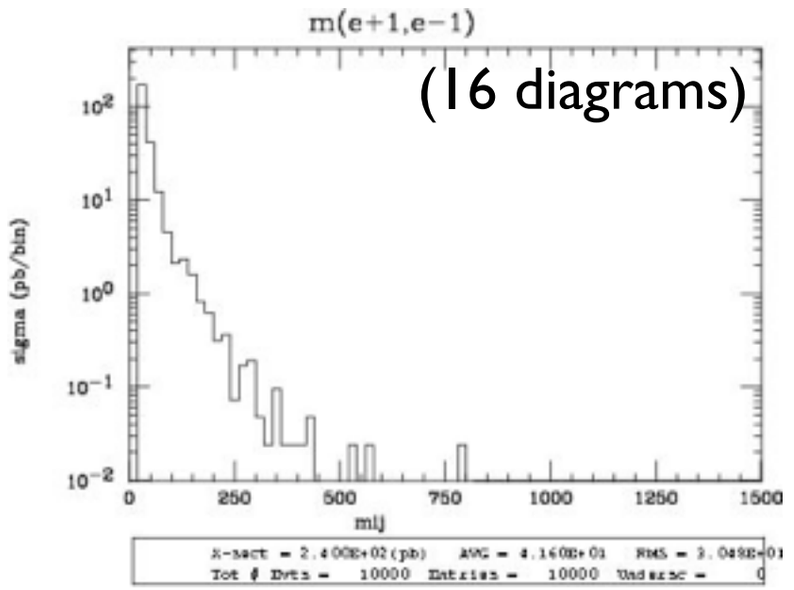


p p > e+ e- /z



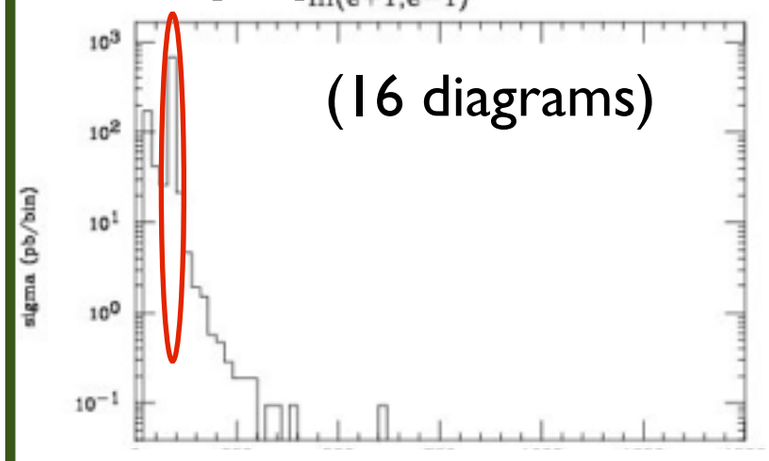
No Z

p p > e+ e- $ z



Z- onshell veto

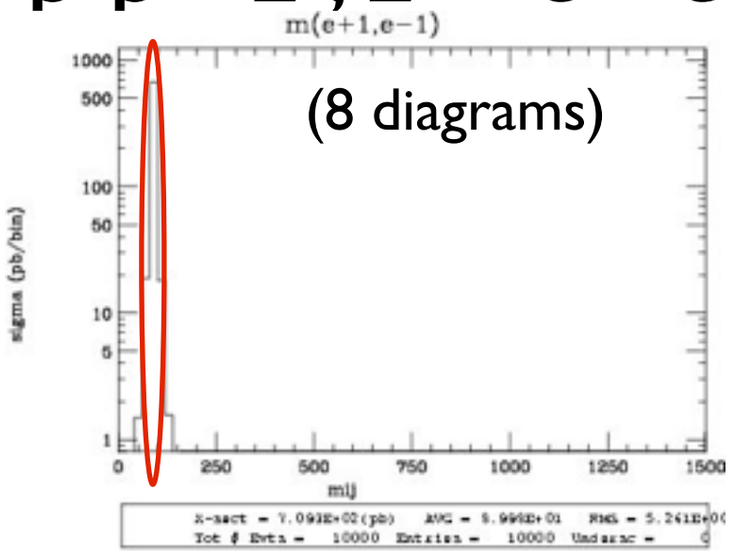
p p > e+ e-



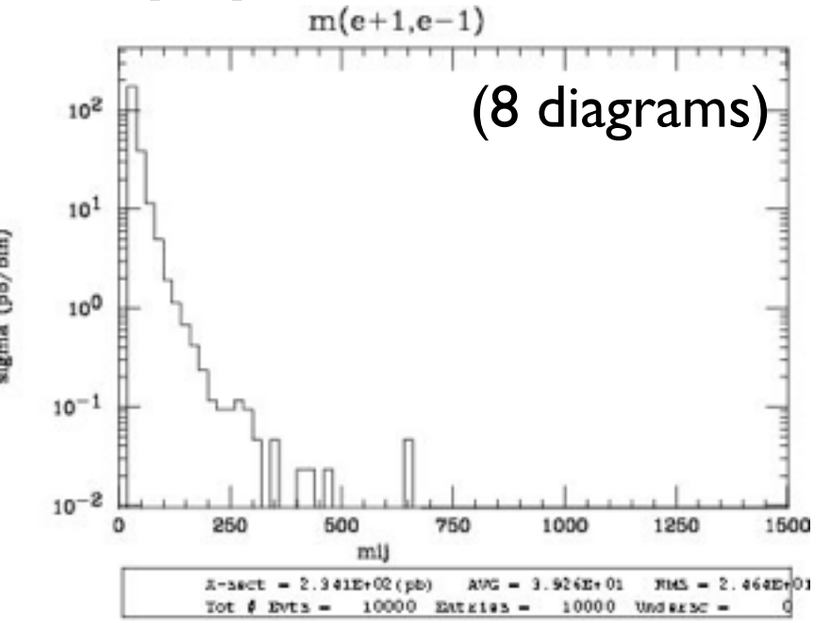
Correct Distribution

Z Peak

p p >z , z > e+ e-



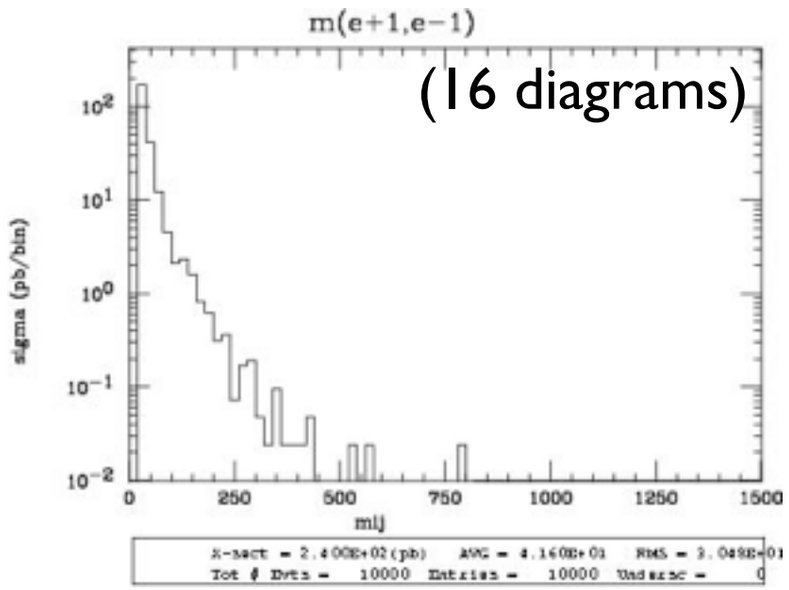
p p > e+ e- /z



No Z

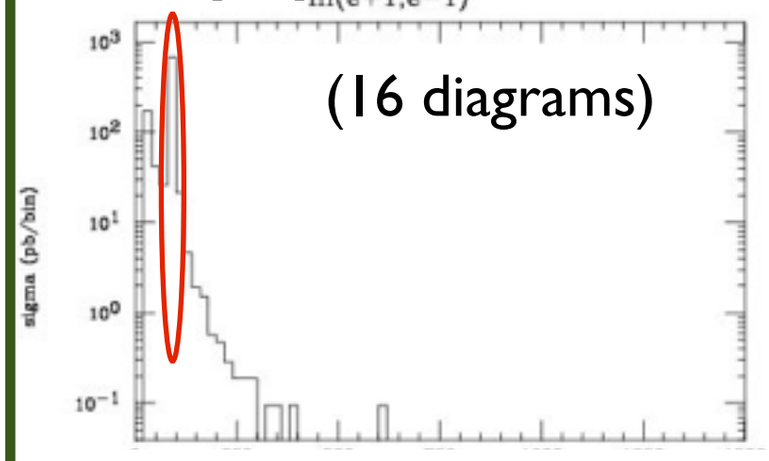
NO Z Peak

p p > e+ e- $ z



Z- onshell veto

p p > e+ e-



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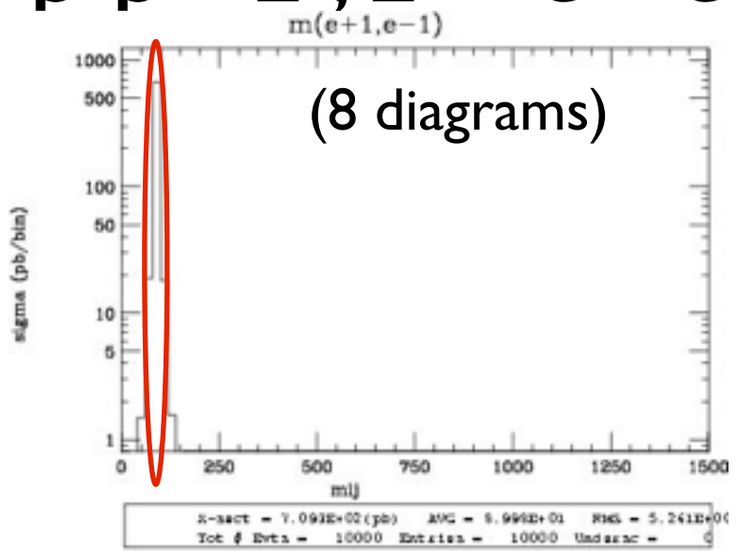
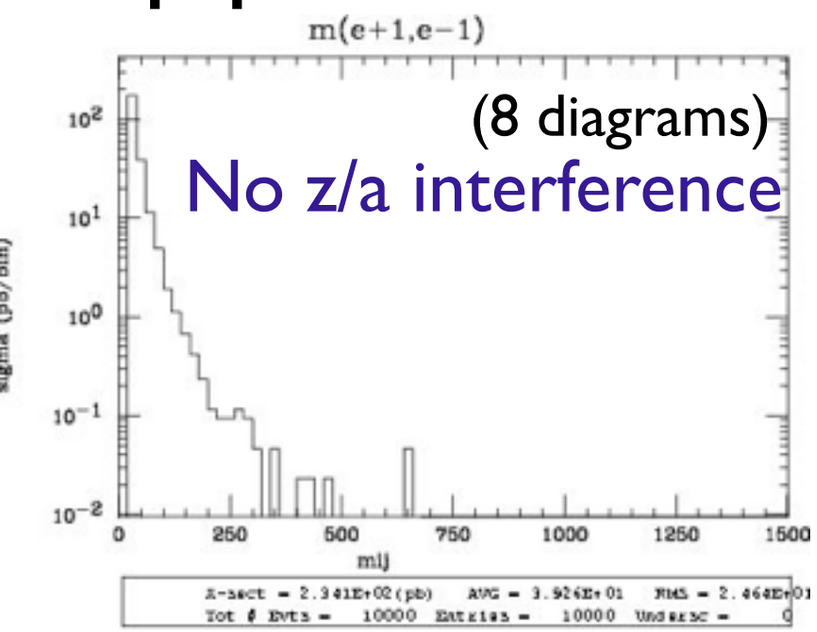


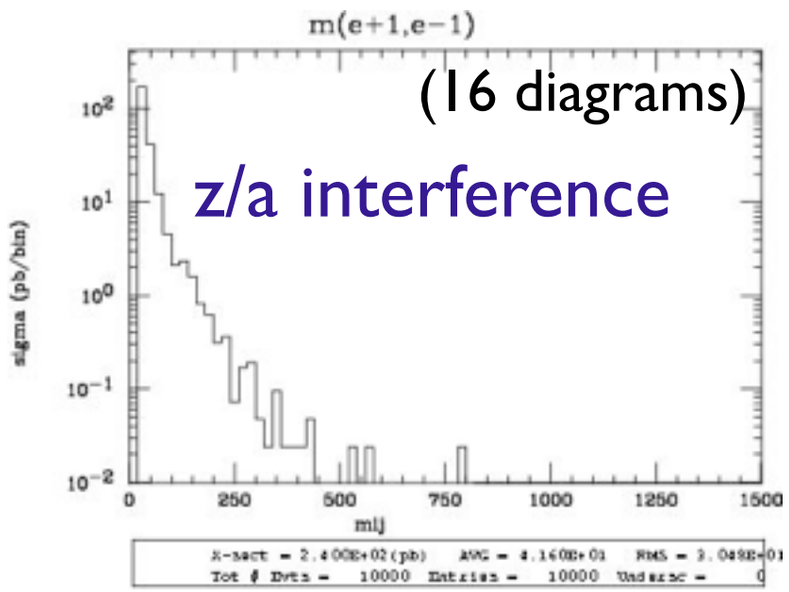
p p > e+ e- /z



No Z

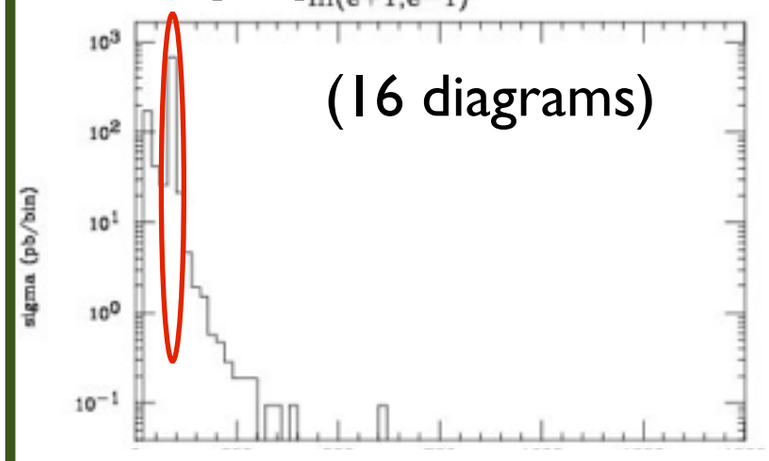
NO Z Peak

p p > e+ e- $ z



Z- onshell veto

p p > e+ e-



Correct Distribution

Z Peak

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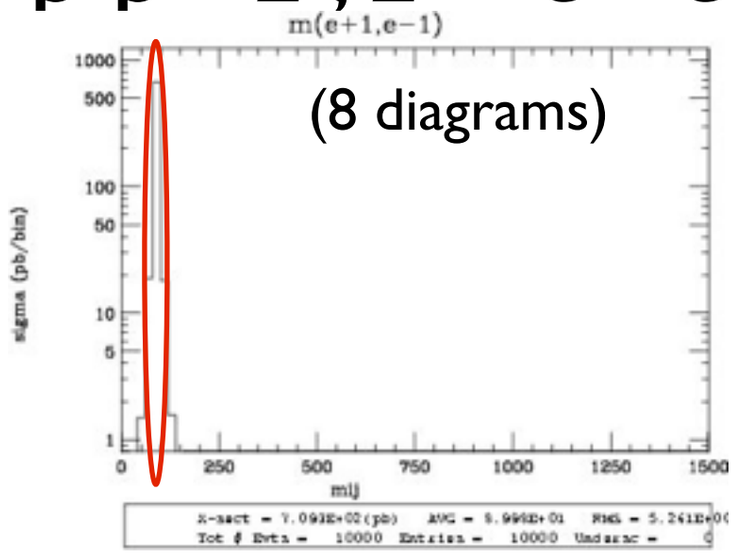
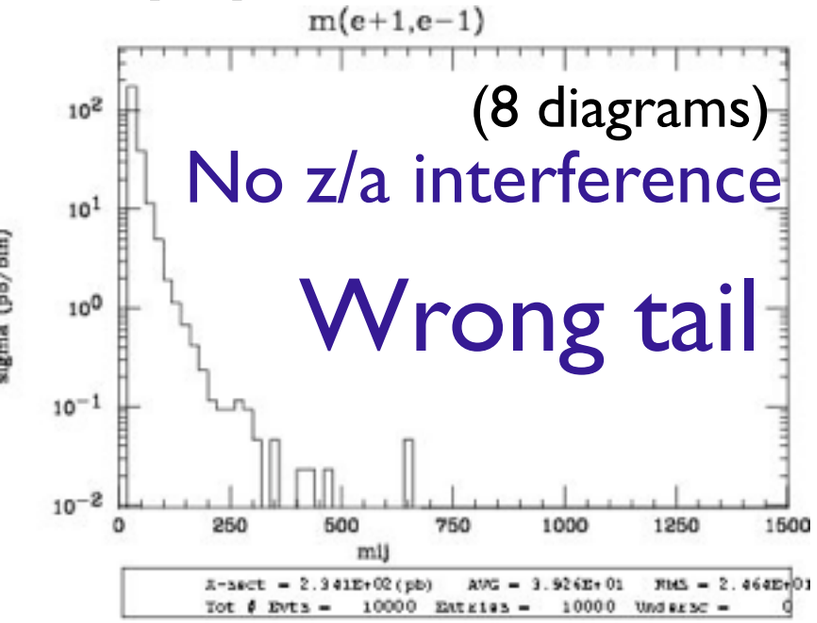


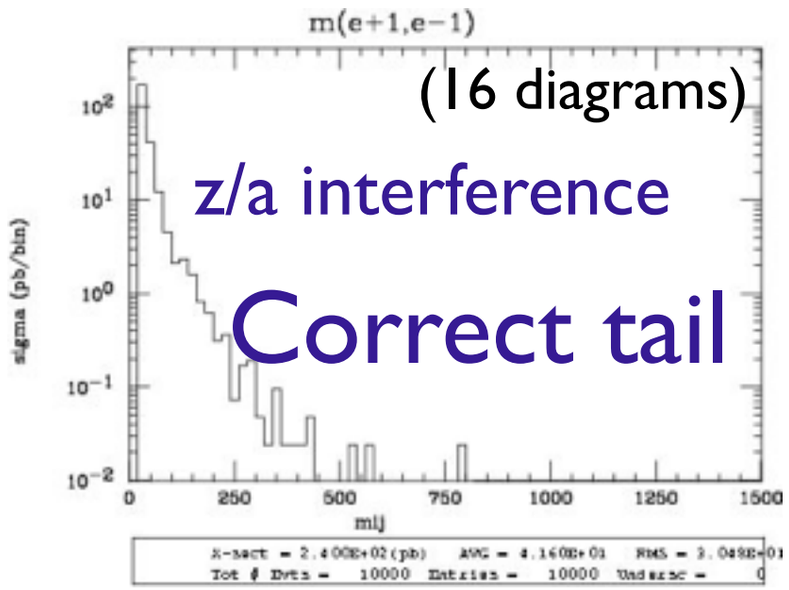
p p > e+ e- /z



No Z

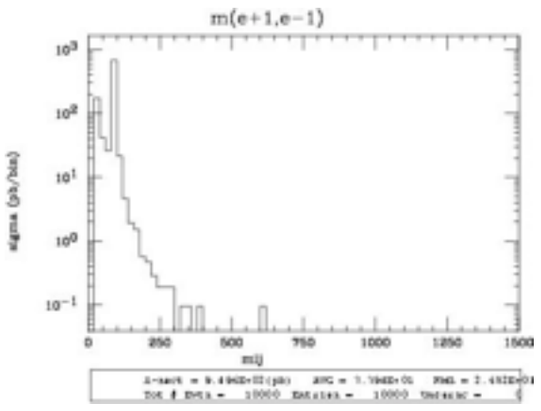
NO Z Peak

p p > e+ e- $ z



Z- onshell veto

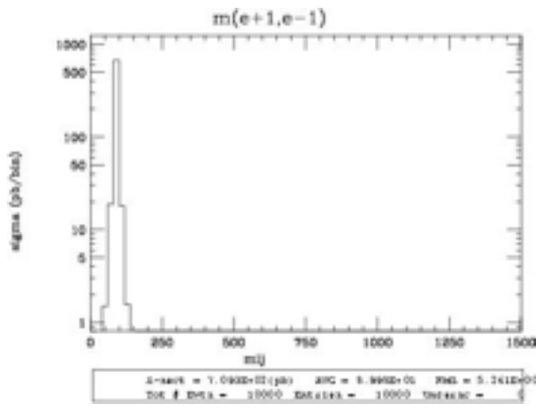
p p > e+ e-



(16 diagrams)

=

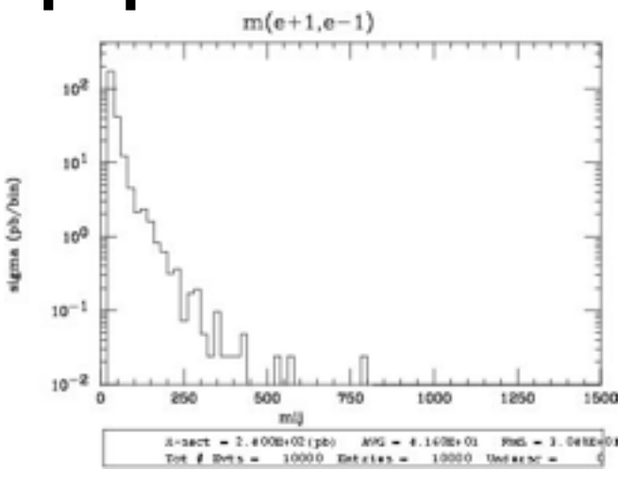
p p >z , z > e+ e-



(8 diagrams)

+

p p > e+ e- $ z



(16 diagrams)

Onshell cut: BW_cut

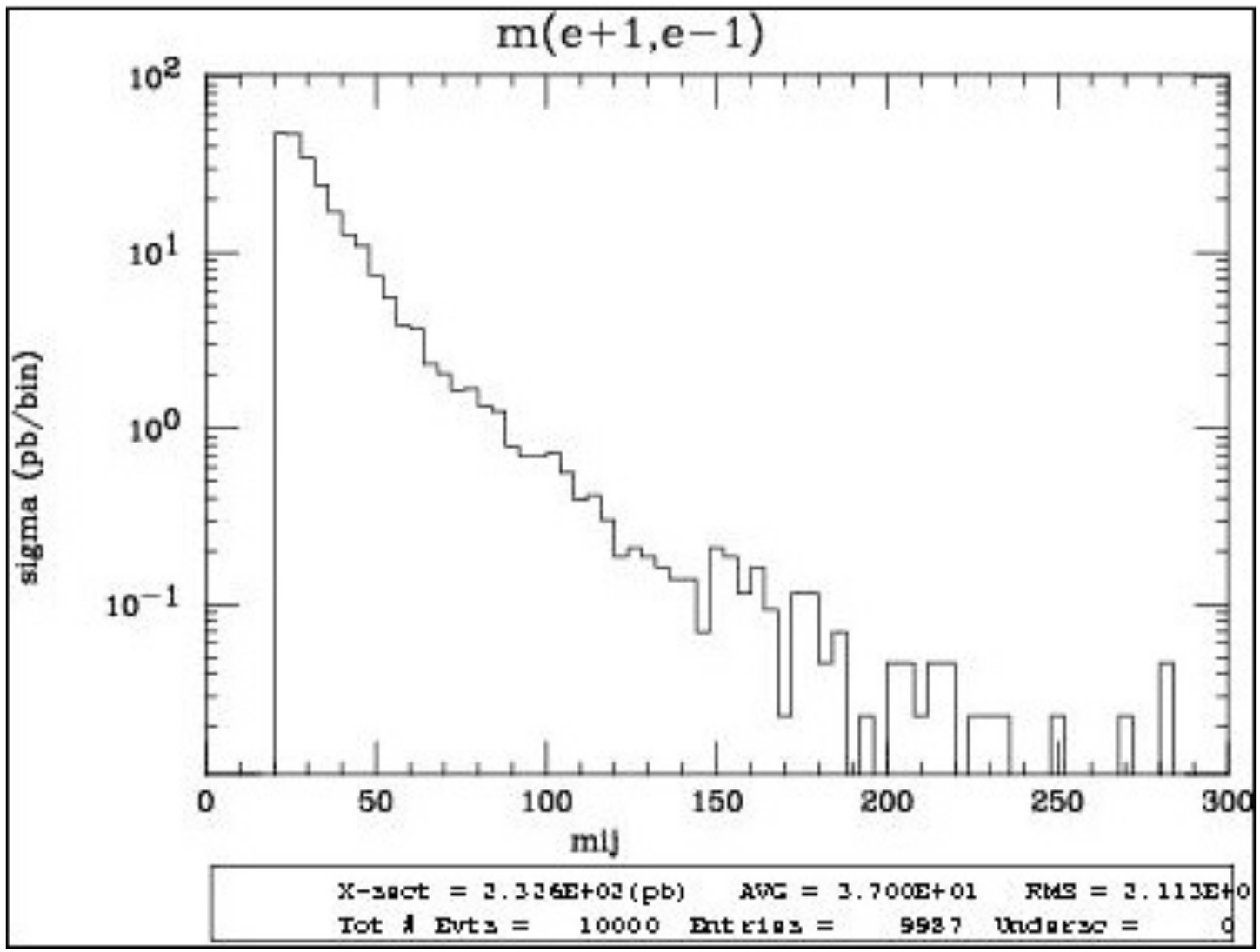
$$|M^* - M| < BW_{cut} * \Gamma$$

- The physical distribution is (very close to) sum of the two other one.
- The "$" forbids the Z to be onshell but the photon invariant mass can be at MZ.
- The "/" is to be avoided if possible since this might lead to violation of gauge invariance.

WARNING

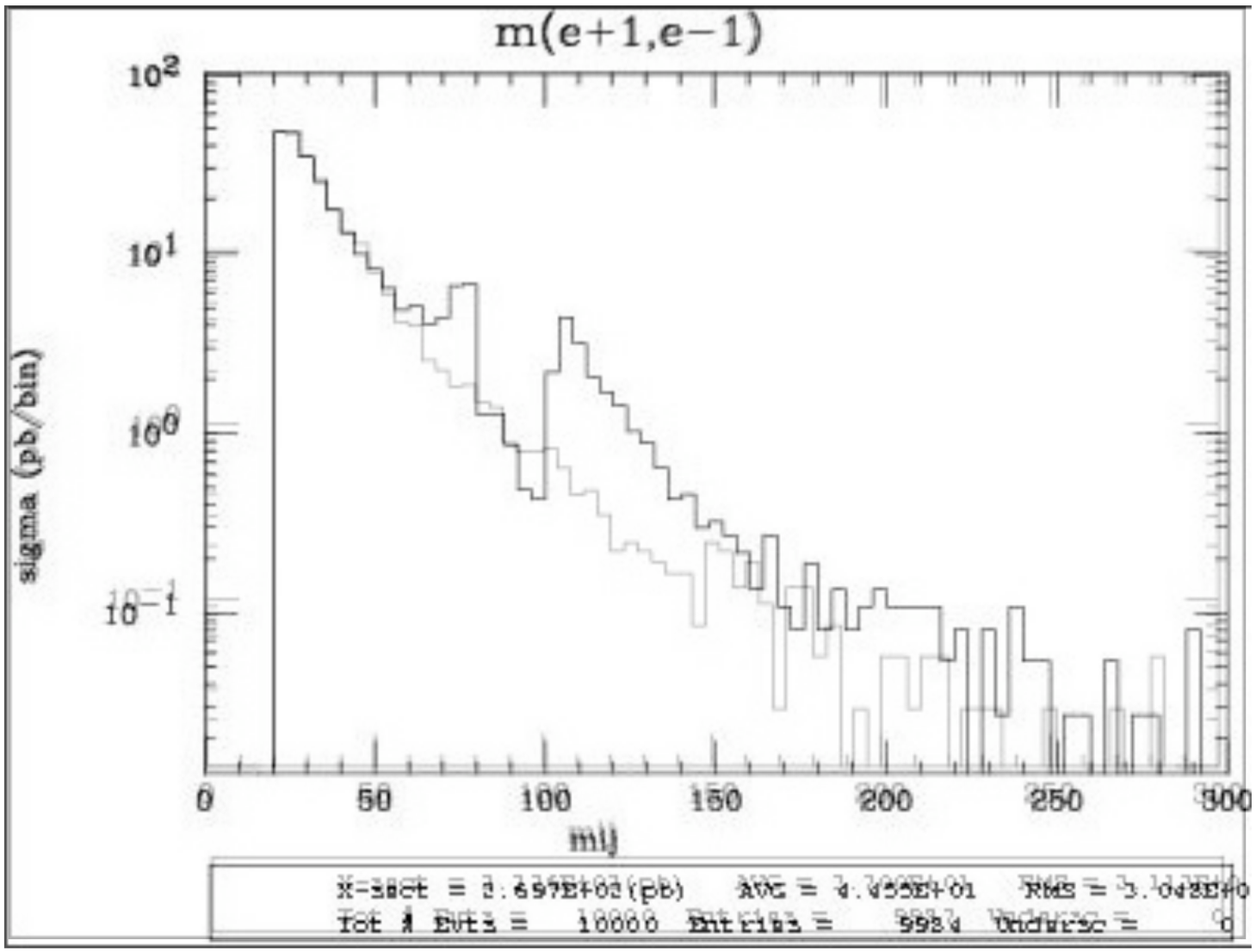
- NEXT SLIDE is generated with bw_cut =5
- This is TOO SMALL to be meaningful (the default value 15 used in previous plot is better)
- This was done to illustrate more in detail how the "$" syntax works.

p p > e+ e- / Z

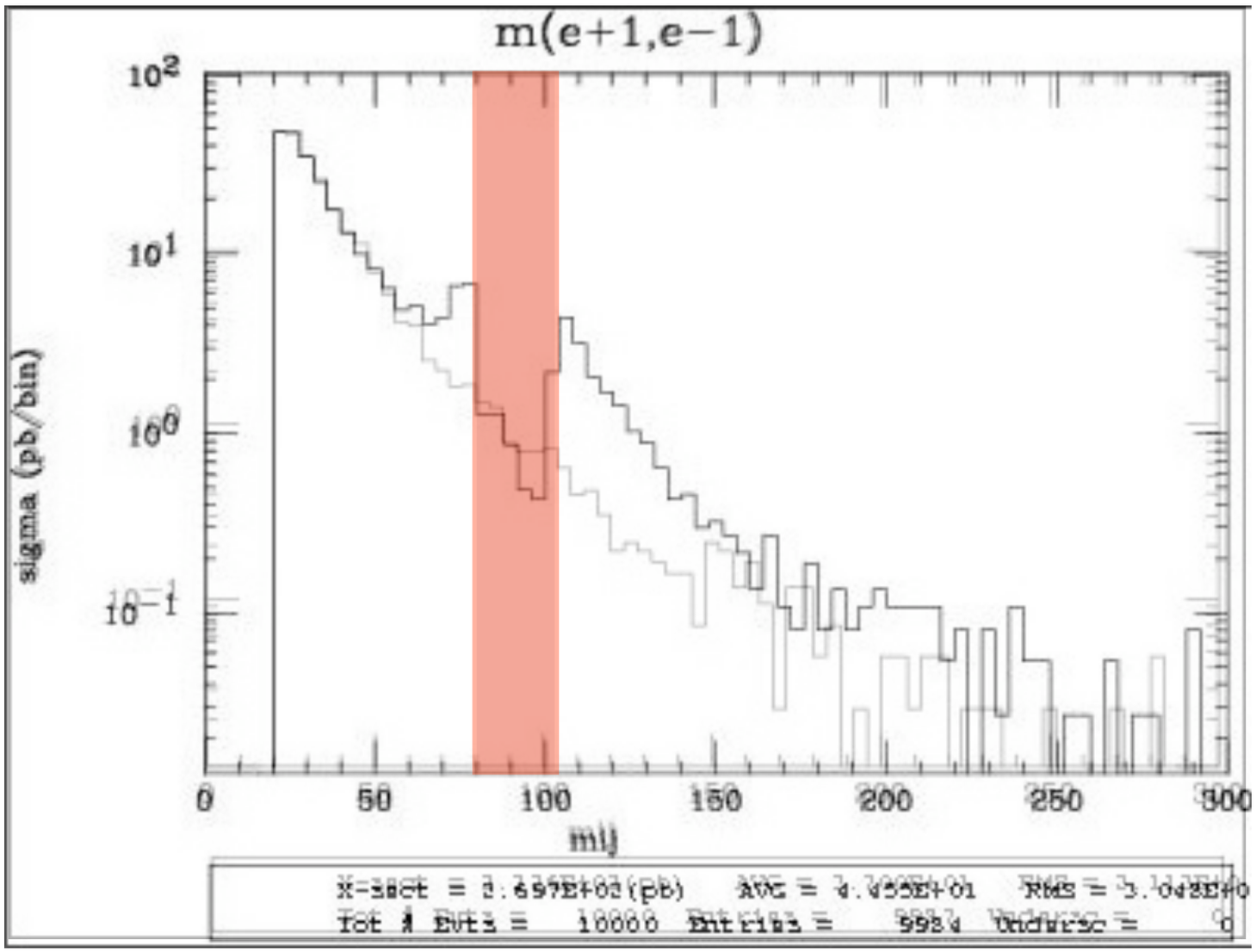

m(e+1,e−1)
sigma (pb/bin)
10^2
10^1
10^0
10^{-1}
0
50
100
150
200
250
300
mij
X-sect = 2.326E+02(pb) AVG = 3.700E+01 RMS = 2.113E+0
Tot # Evts = 10000 Entries = 9987 Undersc = 0

p p > e+ e- / Z

adding p p > e+ e- $ Z



p p > e+ e- / Z



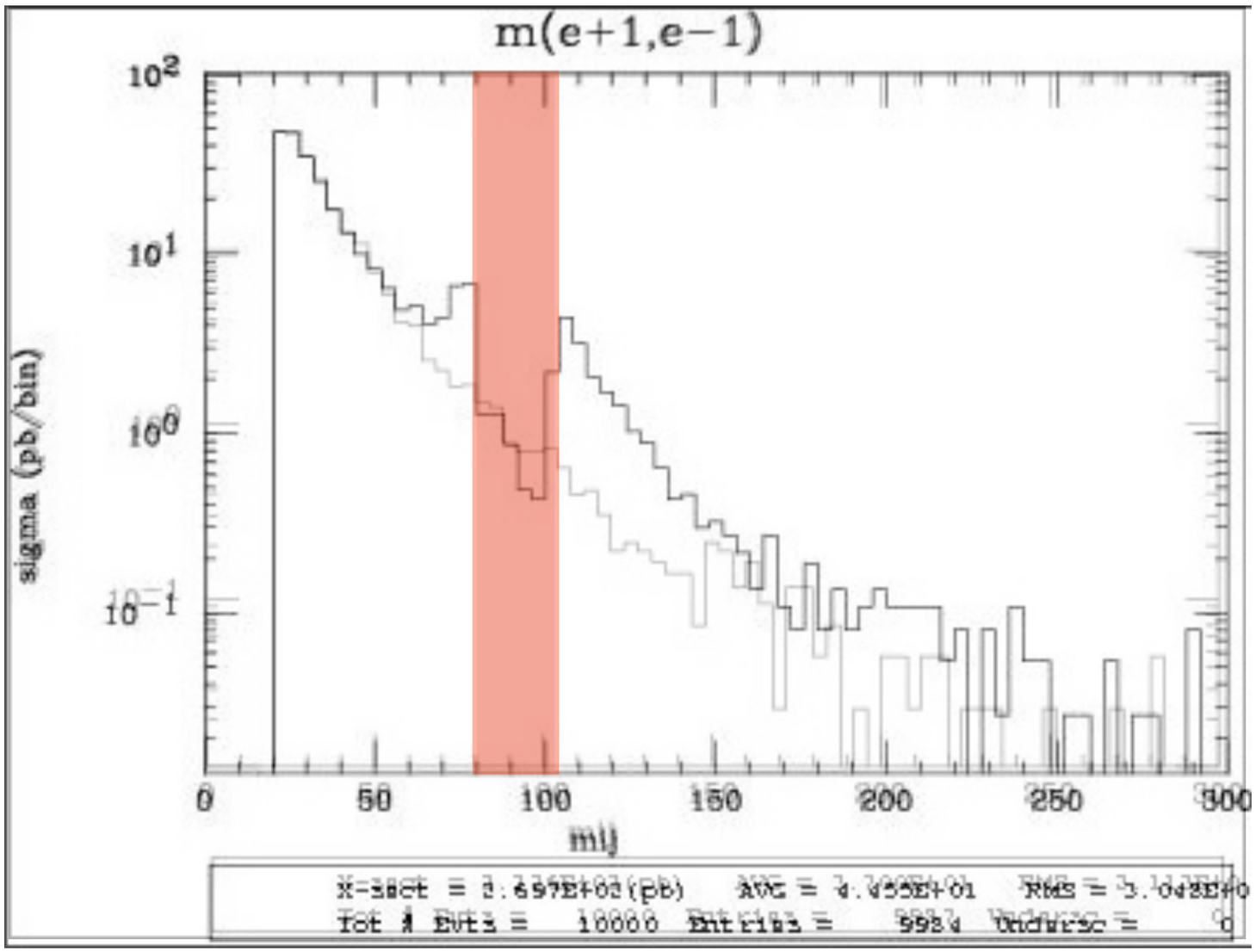
adding p p > e+ e- $ Z

- Z onshell veto

5 times width area

p p > e+ e- / Z

adding p p > e+ e- $ Z

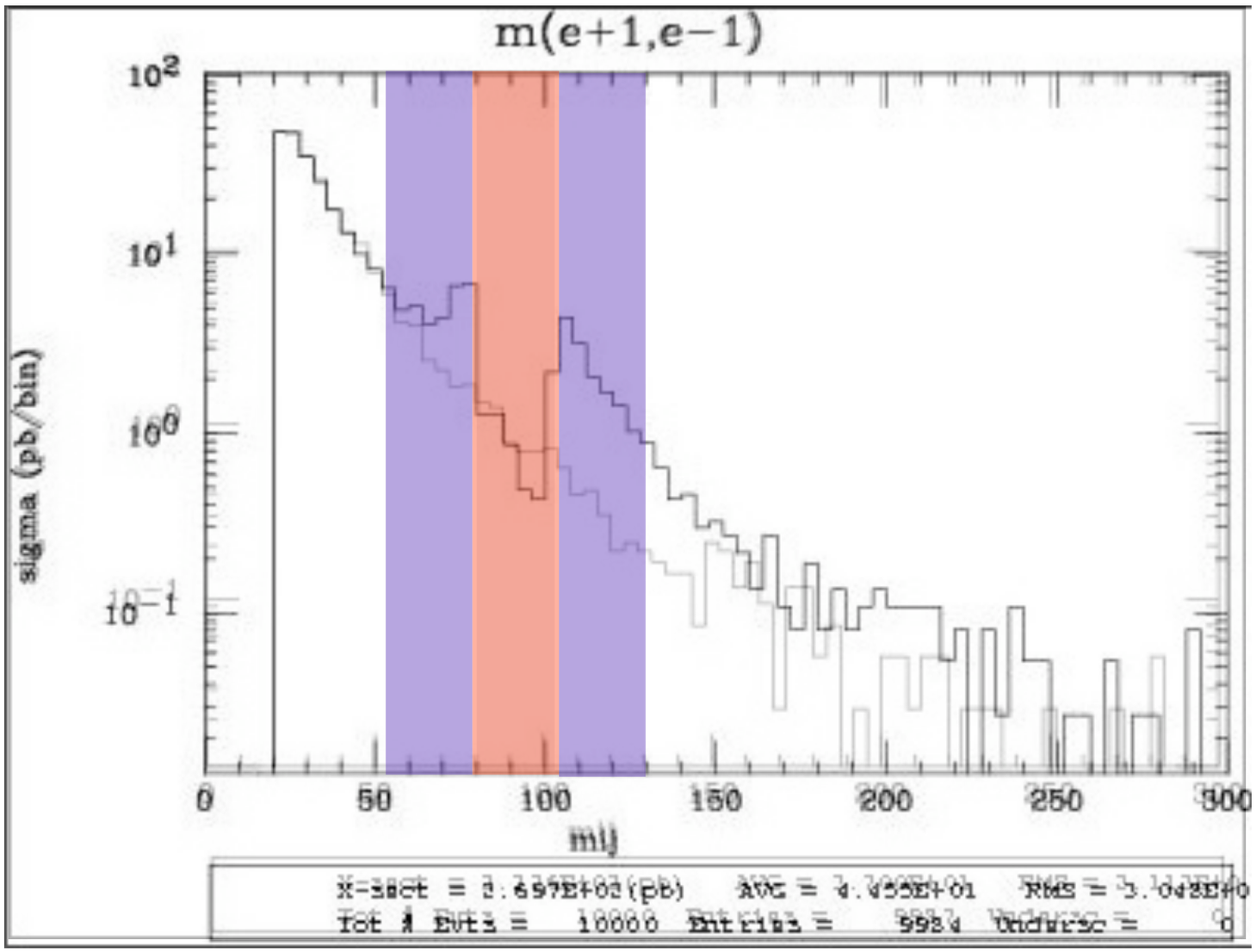


- Z onshell veto
- In veto area only photon contribution

5 times width area

p p > e+ e- / Z

adding p p > e+ e- $ Z

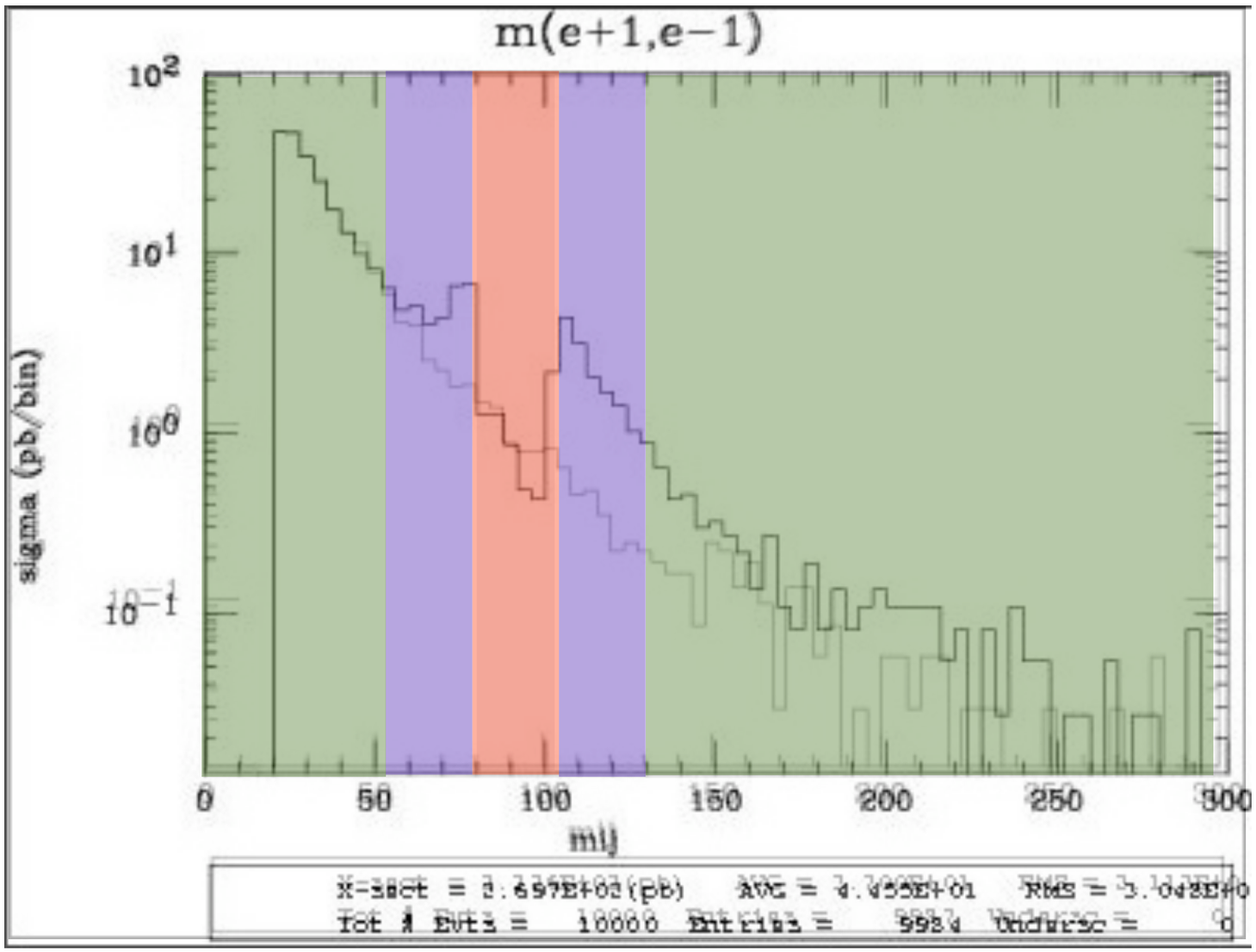


- Z onshell veto
- In veto area only photon contribution
- area sensitive to z-peak

5 times width area

15 times width area

p p > e+ e- / Z



5 times width area

15 times width area

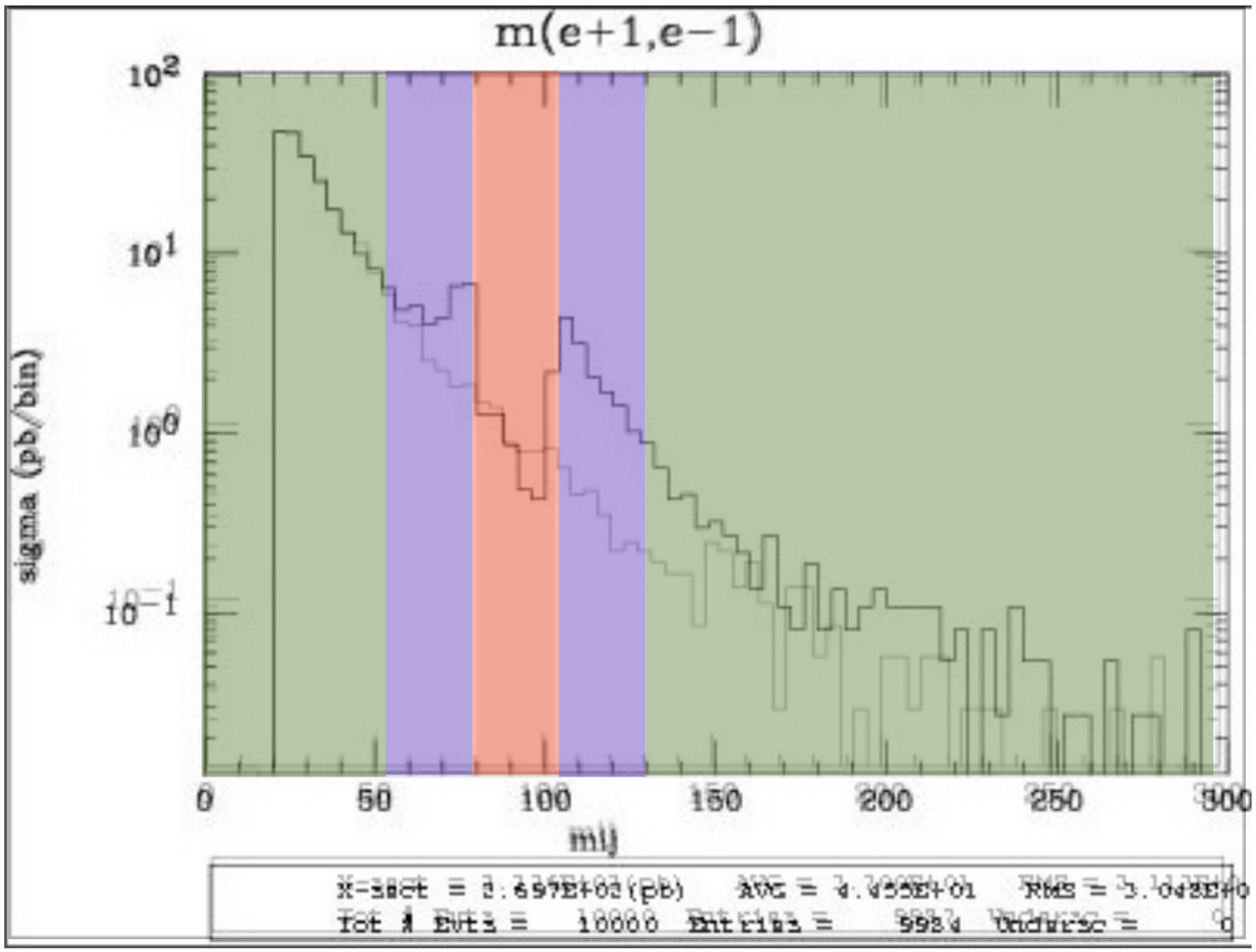
>15 times width area

adding p p > e+ e- $ Z

- Z onshell veto
- In veto area only photon contribution
- area sensitive to z-peak
- very off-shell Z, the difference between the curve is due to interference which are need to be KEPT in simulation.

p p > e+ e- / Z

adding p p > e+ e- $ Z



- Z onshell veto
- In veto area only photon contribution
- area sensitive to z-peak
- very off-shell Z, the difference between the curve is due to interference which are need to be KEPT in simulation.

5 times width area

15 times width area

>15 times width area

The "$" splits the sample in BG/peak area

- The syntaxes
  - ➡ p p > z > e+ e- (ask one S-channel z)
  - ➡ p p > e+ e- / z (forbids any z)
  - ➡ p p > e+ e- $$ z (forbids any z in s-channel)
- ARE NOT GAUGE INVARIANT !
- removes diagram interference.
- can provide unphysical distributions.

- The syntaxes
  - ➡ p p > z > e+ e- (ask one S-channel z)
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  - ➡ p p > e+ e- $$ z (forbids any z in s-channel)
- ARE NOT GAUGE INVARIANT !
- removes diagram interference.
- can provide unphysical distributions.

Avoid those as far as possible!

- The syntaxes
  - ➡ p p > z > e+ e- (ask one S-channel z)
  - ➡ p p > e+ e- / z (forbids any z)
  - ➡ p p > e+ e- $$ z (forbids any z in s-channel)
- ARE NOT GAUGE INVARIANT !
- removes diagram interference.
- can provide unphysical distributions.

Avoid those as far as possible!

Check physical meaning and gauge/Lorentz invariance if you do.

- The syntaxes
  - p p > z, z > e+ e- (on-shell z decaying)
  - p p > e+ e- $ z (forbids s-channel z to be on-shell)
- are linked to cut $|M^* - M| < BW_{cut} * \Gamma$
- are safer to use
- Prefer those syntaxes to the ones on previous slides

Exercise V: Automation

- Look at the cross-section for the previous process for 3 different mass points.
  - ➡ hint: you can edit the param_card/run_card via the "set" command [After the launch]
  - ➡ hint: All command [including answer to question] can be put in a file.

Exercise V: Automation

- File content:

```
import model sm
generate p p > t t~
output
launch
set mt 160
set wt Auto
done
launch
set mt 165
set wt Auto
launch
set mt 170
set wt Auto
launch
set mt 175
set wt Auto
launch
set mt 180
set wt Auto
launch
set mt 185
set wt Auto
```

- Run it by:
  - ./bin/mg5 PATH
    - (smarter than ./bin/mg5 < PATH)
- If an answer to a question is not present: Default is taken automatically

Exercise VI: MLM Matching with MG + Pythia

Choose one of the following two exercises:

1. Generate p p > w+ with 0 jets, 0,1 jets and 0,1,2 jets
   (Each on different computers - use the most powerful computer for 0,1,2 jets)
   a. Generate 20,000 events for a couple of different xqcut values (e.g., xqcut = 10, 20, 40, 80, 150).
   b. Compare the distributions (before and after Pythia) and cross sections (before and after Pythia) between the different processes, and between the different xqcut values.
   c. Summarize: How many jets do we need to simulate? What is a good xqcut value? How are the distributions affected?
2. Matched squark production (p p > ur ur~ + 0,1 jets)
   a. Run with and without "$ go" - how does the result change?
   b. With "$ go", do the exercises a.-c. under 1.
      What is a good choice for matching scale?