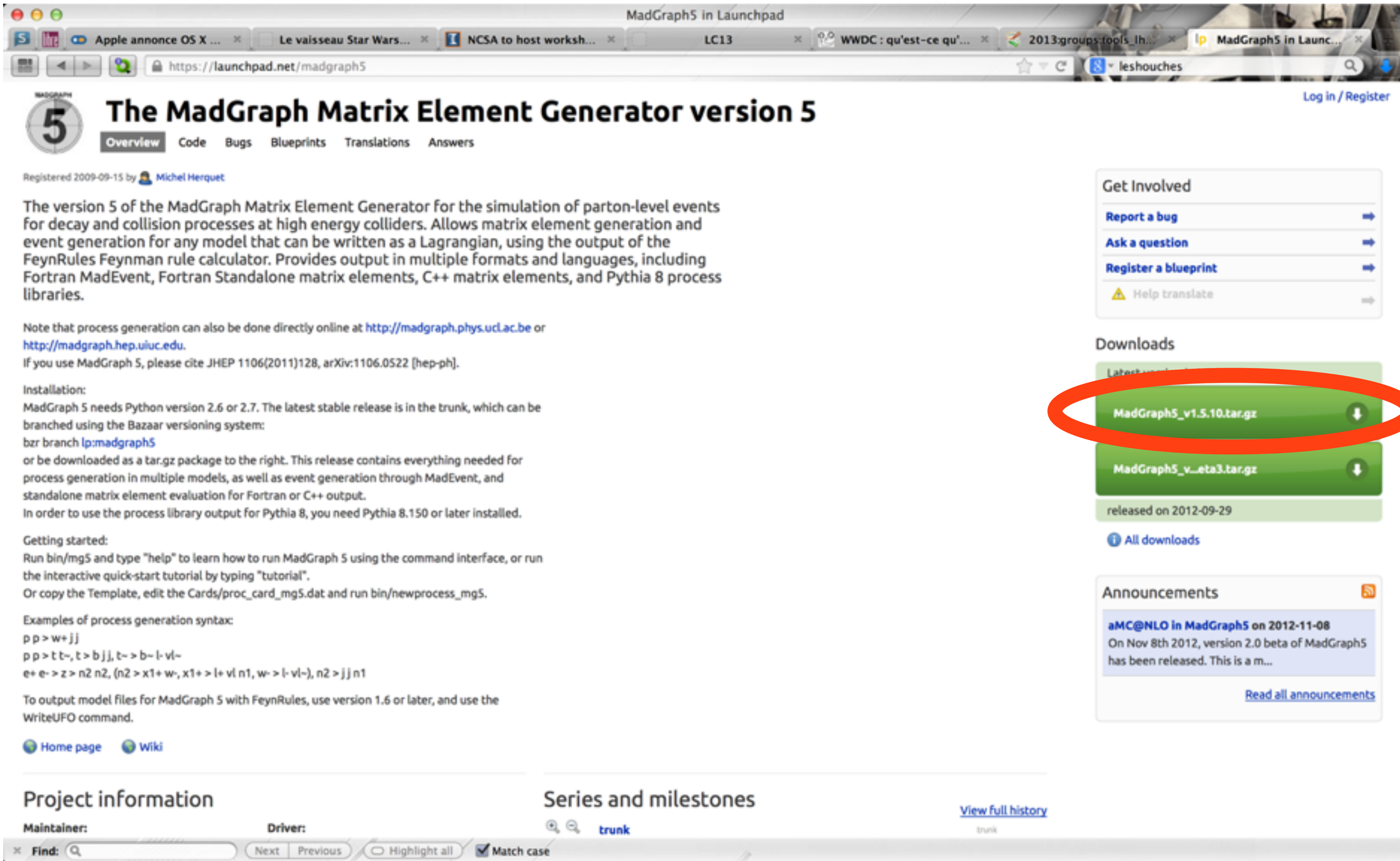
Learning MG5_aMC

Exercise 0: Install MadGraph 5!

- https://launchpad.net/madgraph5
- untar it (tar -xzpvf MG5_aMC_v2.3.3.tgz)
- launch it ($ ./bin/mg5)
- learn it!
  - ➡ Type tutorial and follow instructions
- Download those slides!

Install



MadGraph5 in Launchpad

https://launchpad.net/madgraph5

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
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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

Where to find help?

- Ask me, any other tutor.
- Use the command "help" / "help XXX"
  - ➡ "help" tell you the next command that you need to do.
- Launchpad:
  - ➡ https://answers.launchpad.net/madgraph5
  - ➡ FAQ: https://answers.launchpad.net/madgraph5/+faqs

Exercise 1: 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

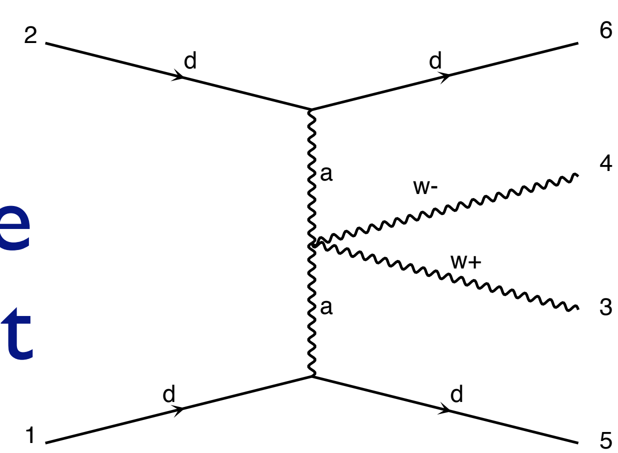
Exercise II: Cards Meaning

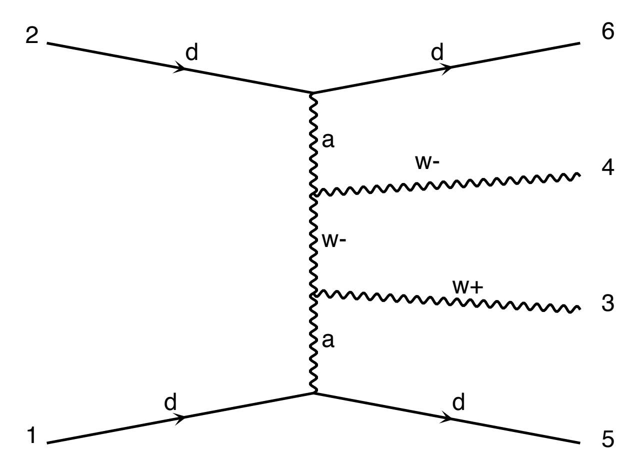
- How do you change
  - ➡ top mass
  - ➡ top width
  - ➡ W mass
  - ➡ beam energy
  - ➡ pt cut on the lepton

Exercise II : 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
  - ➡ p p > t t~ QCD=0
  - ➡ p p > t t~ QED<=2
  - ➡ p p > t t~ QCD^2==2
- Compute the cross-section for each of those and check the diagram

- Generate VBF process
- check that you have the diagram that you want





Exercise III: 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

- Use the invariant mass distribution to determine the meaning of each syntax.

Exercise IV: Automation/Width

- 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 command [including answer to question] can be put in a file. (run ./bin/mg5 PATH_TO_FILE)
  - ➡ Remember to change the value of the width
    - ✦ "set width 6 Auto" works
    - ✦ cross-check that it indeed returns the correct width

Examples

File:

```
import model EWDim6
generate p p > z z
ouput TUTO_DIM6
launch
  set nevents 5000
  set MZ 100
```

How to Run:

```
./bin/mg5_amc PATH
```

Exercise V: Decay Chain

- Generate p p > t t~ h, fully decayed (fully leptonic decay for the top)
  - ➡ Using the decay-chain formalism
  - ➡ Using MadSpin
- Compare cross-section
  - ➡ which one is the correct one?
  - ➡ Why are they different?
- Compare the shape.

Exercise VI: Re-Weighting

- Use the EWDim6 Model
- Generate 50k events for p p > w+ w- QED<=2
  - First for the SM hypothesis
  - use the reweighing method for Owww operator with coupling 0.1, 1, 10, 100
  - Make the same computation in MadGraph
  - Compare.

- Redo the computation of all the cross-section with the re-weigthing method but starting from the cwww=100 sample.
- Compare

Solution Learning MG5_aMC

Exercise I: Cards Meaning

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

Param_card (top mass, top width, W mass)

Run_card (beam energy, pt cut on the lepton)

- 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 #
  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 didn't use this value!

So you need to change MZ or Gf or alpha_EW

Exercise II: 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
  - ➡ p p > t t~ QCD^2==2
  - ➡ p p > t t~ QCD=0
  - ➡ p p > t t~ QED<=2
  - ➡ p p > t t~ QCD^2==2

Solution I : Syntax

- 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

- QED<=2 is the SAME as QED=2
  - ➡ quite often source of confusion since most of the people use the = syntax
- QCD^2==2
  - ➡ returns the interference between the QCD and the QED diagram

Cross section (pb)
5.455e-17 ± 4.7e-19 ± systematics

Solution I Syntax

- generate p p > w+ w- j j
  - ➡ 76 processes
  - ➡ 1432 diagrams
  - ➡ None of them are VBF

- generate p p > w+ w- j j QED = 2
  - ➡ 76 processes
  - ➡ 1432 diagrams
  - ➡ None of them are VBF

- generate p p > w+ w- j j QED = 4
  - ➡ 76 processes
  - ➡ 5332 diagrams
  - ➡ VBF present! + those not VBF

- generate p p > w+ w- j j QCD = 0
  - ➡ 60 processes
  - ➡ 3900 diagrams
  - ➡ VBF present!

- generate p p > w+ w- j j QCD = 2
  - ➡ 76 processes
  - ➡ 5332 diagrams

- generate p p > w+ w- j j QCD = 4
  - ➡ 76 processes
  - ➡ 5332 diagrams

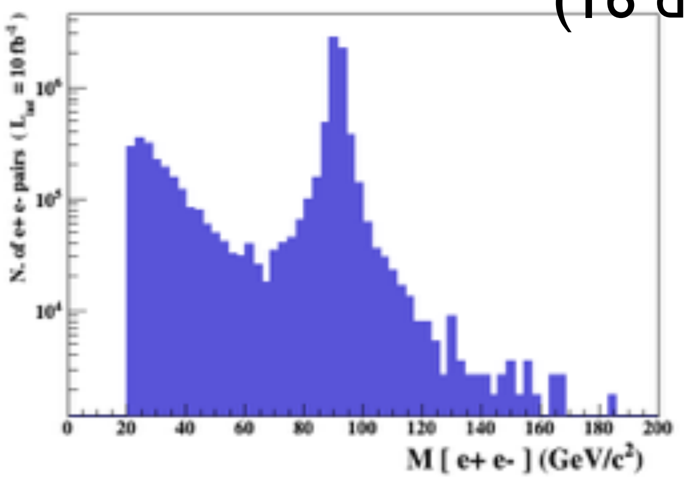
Exercise III: Syntax

- 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

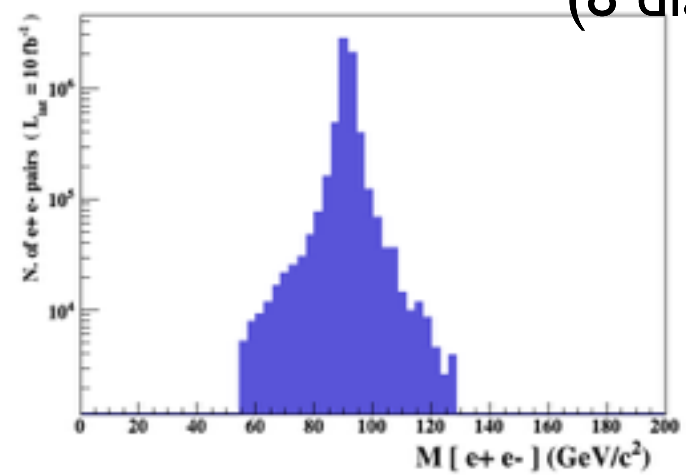
Hint :To have automatic distributions:

mg5> install MadAnalysis

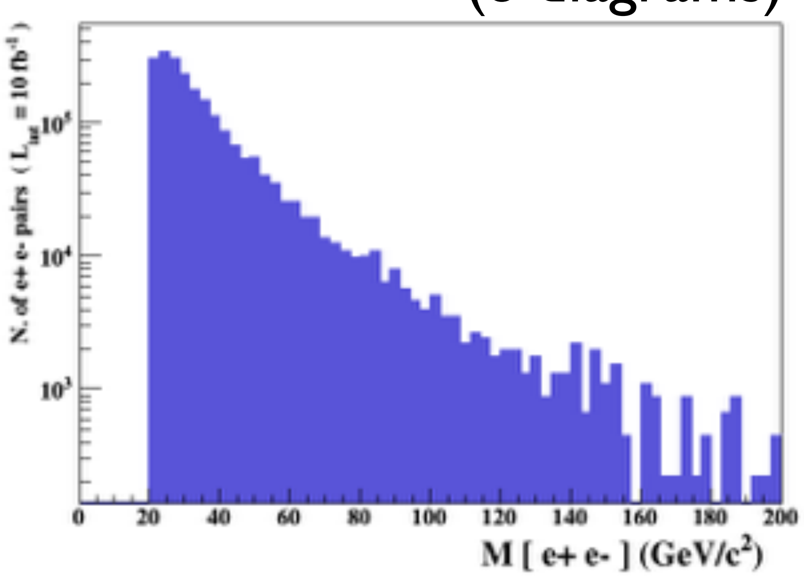
p p > e+ e-
(16 diagrams)



p p >z , z > e+ e-
(8 diagrams)

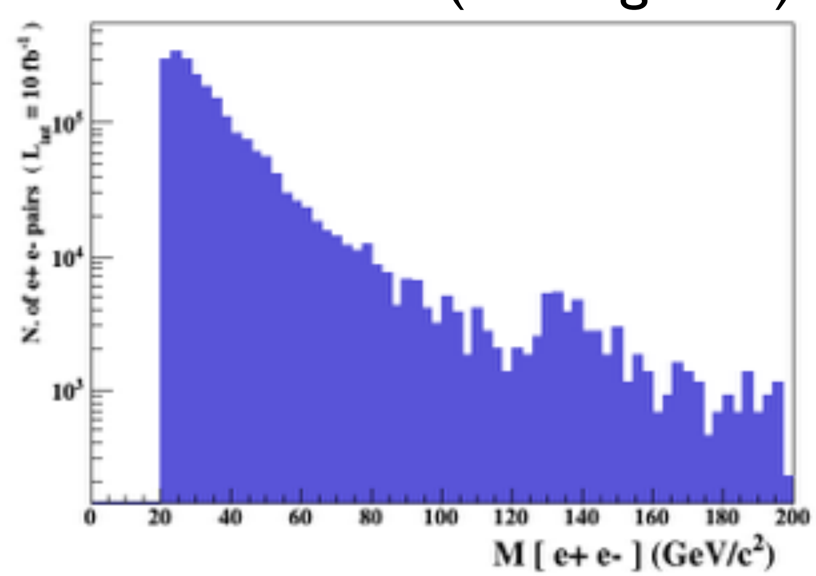


p p > e+ e- /z
(8 diagrams)



No Z

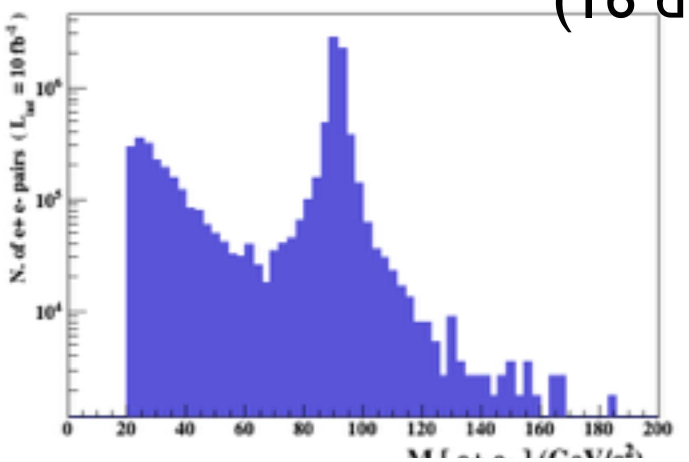
p p > e+ e- $ z
(16 diagrams)



Z- onshell veto

p p > e+ e-

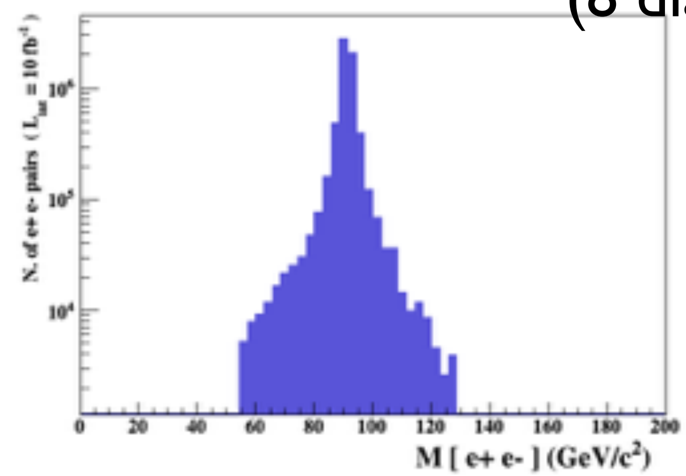
(16 diagrams)



Correct Distribution

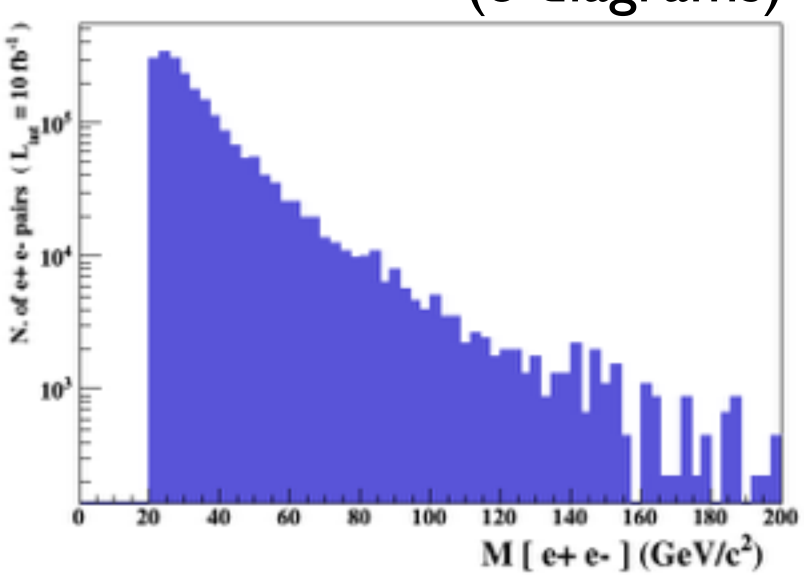
p p >z , z > e+ e-

(8 diagrams)



p p > e+ e- /z

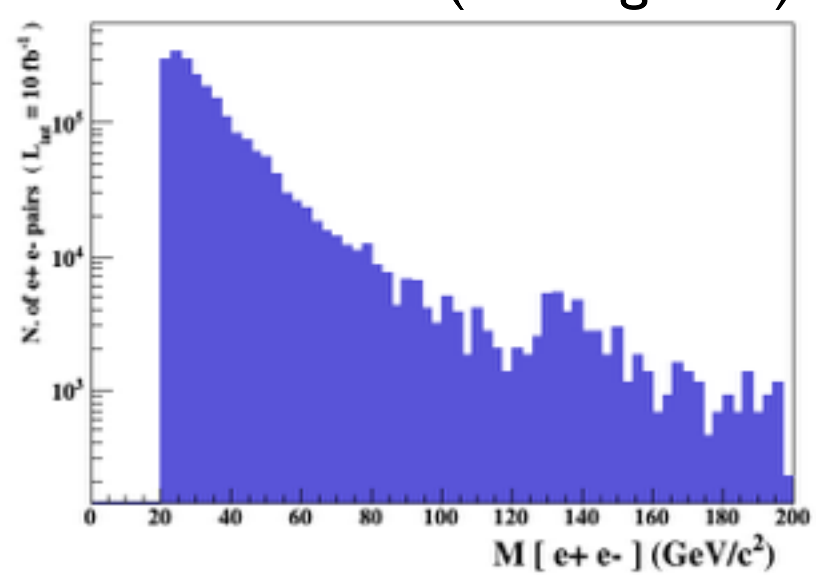
(8 diagrams)



No Z

p p > e+ e- $ z

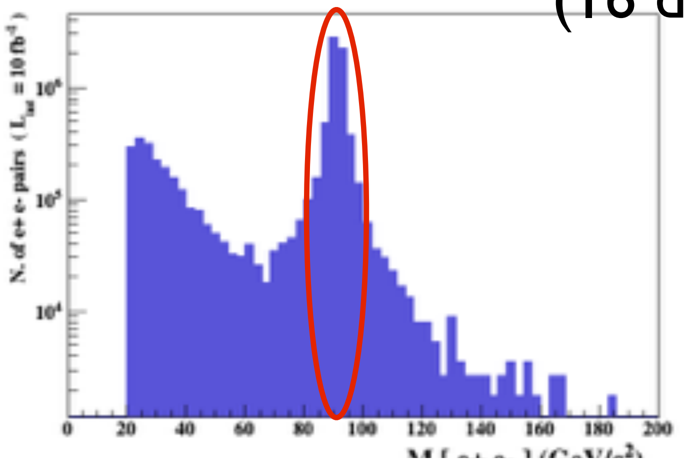
(16 diagrams)



Z- onshell veto

p p > e+ e-

(16 diagrams)

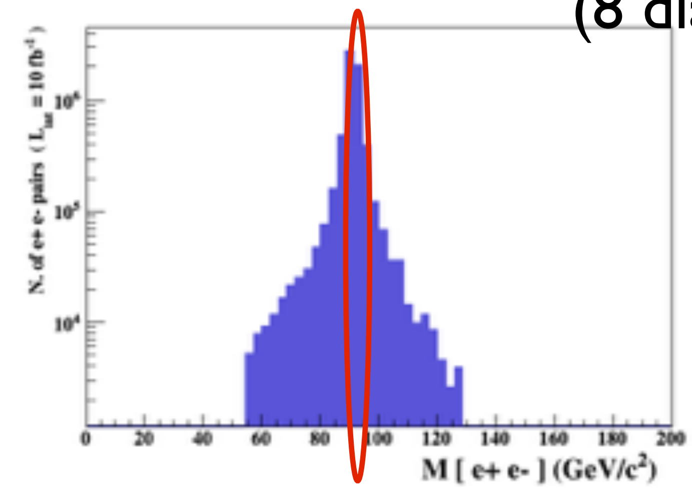


Correct Distribution

Z Peak

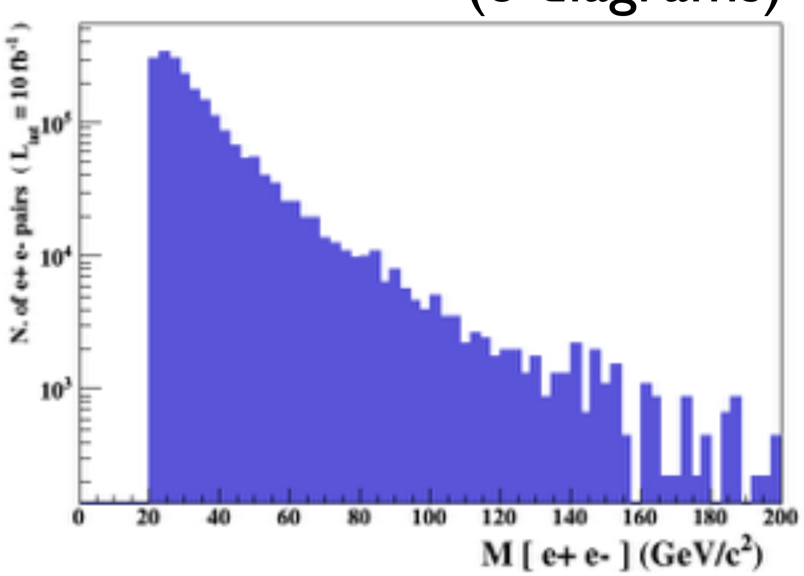
p p >z , z > e+ e-

(8 diagrams)



p p > e+ e- /z

(8 diagrams)

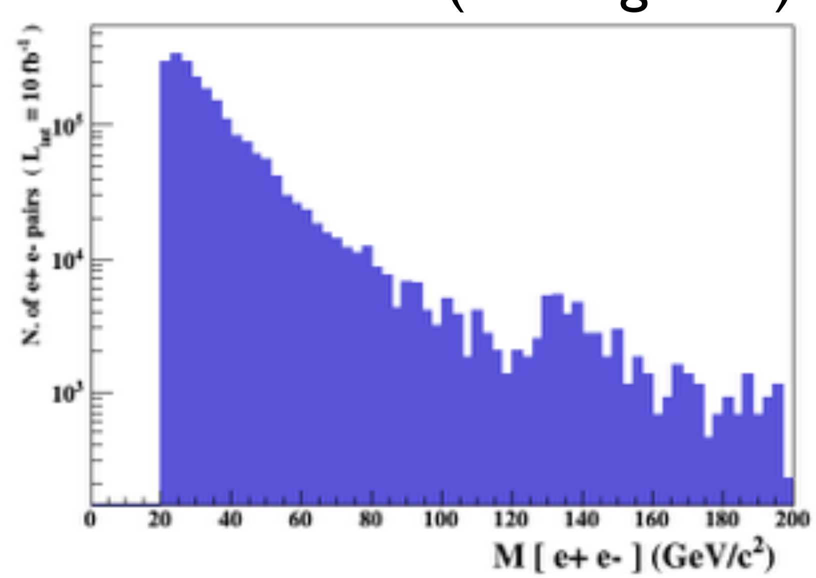


No Z

NO Z Peak

p p > e+ e- $ z

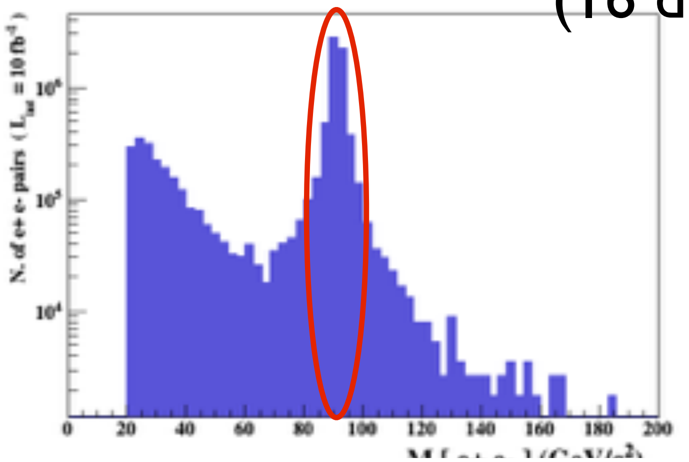
(16 diagrams)



Z- onshell veto

p p > e+ e-

(16 diagrams)

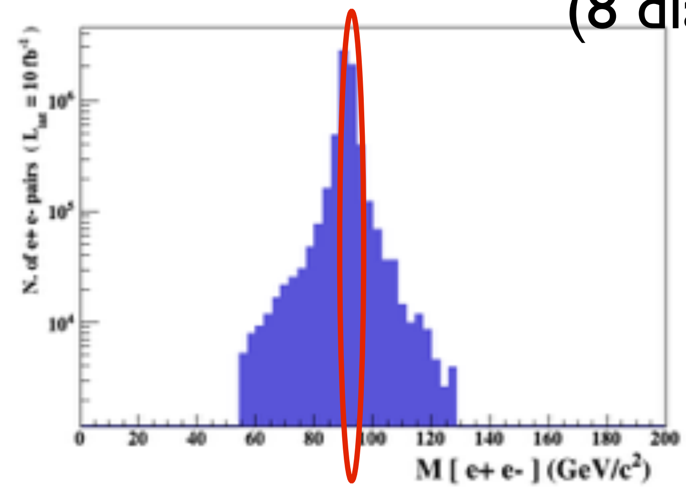


Correct Distribution

Z Peak

p p >z , z > e+ e-

(8 diagrams)

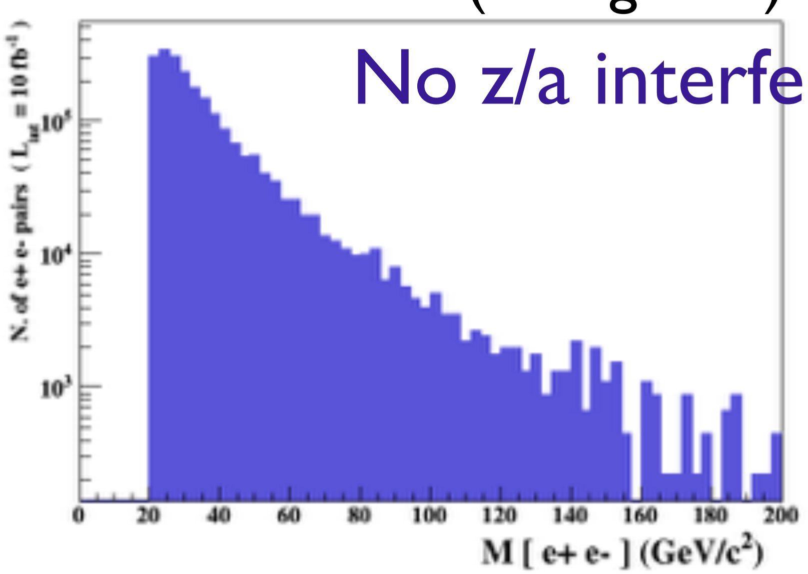


p p > e+ e- /z

(8 diagrams)

NO Z Peak

No z/a interference

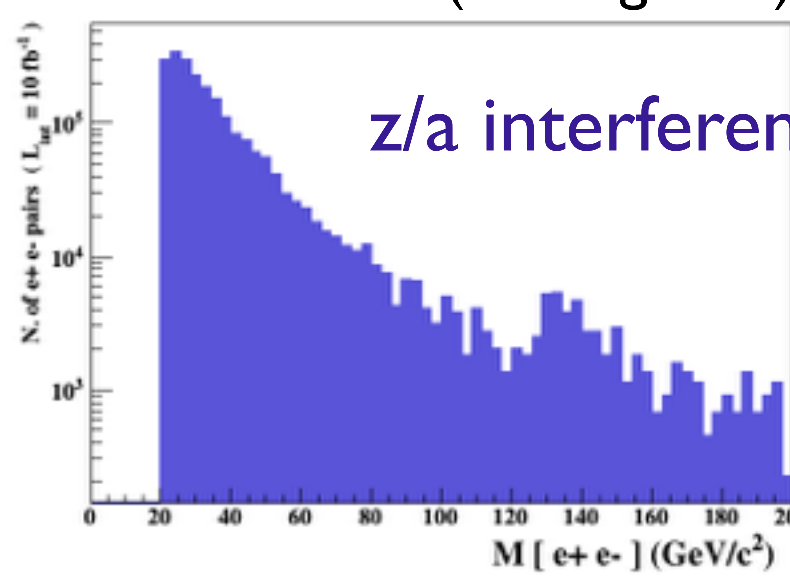


No Z

p p > e+ e- $ z

(16 diagrams)

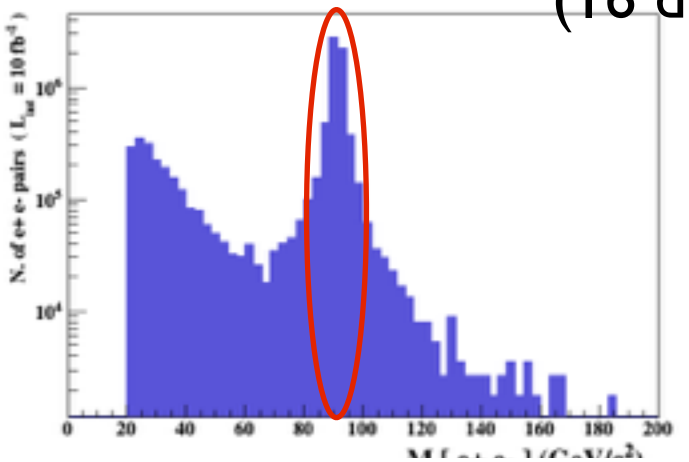
z/a interference



Z- onshell veto

p p > e+ e-

(16 diagrams)

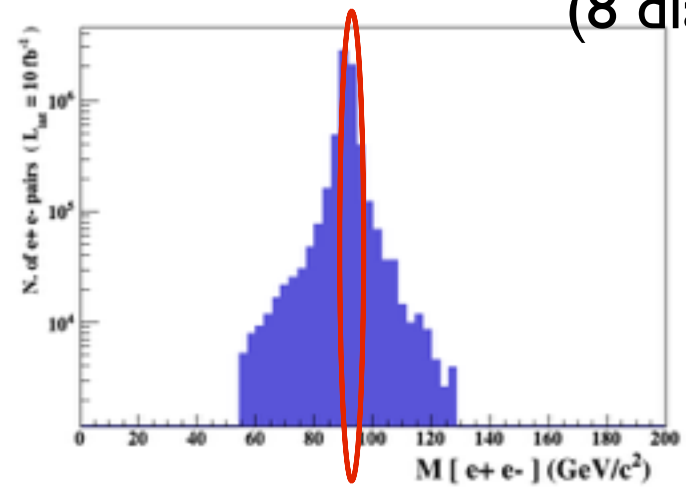


Correct Distribution

Z Peak

p p >z , z > e+ e-

(8 diagrams)



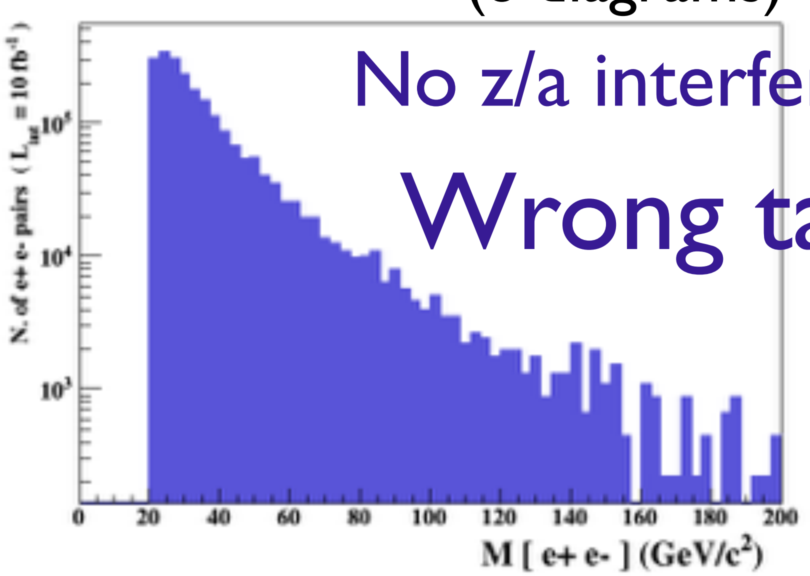
p p > e+ e- /z

(8 diagrams)

NO Z Peak

No z/a interference

Wrong tail



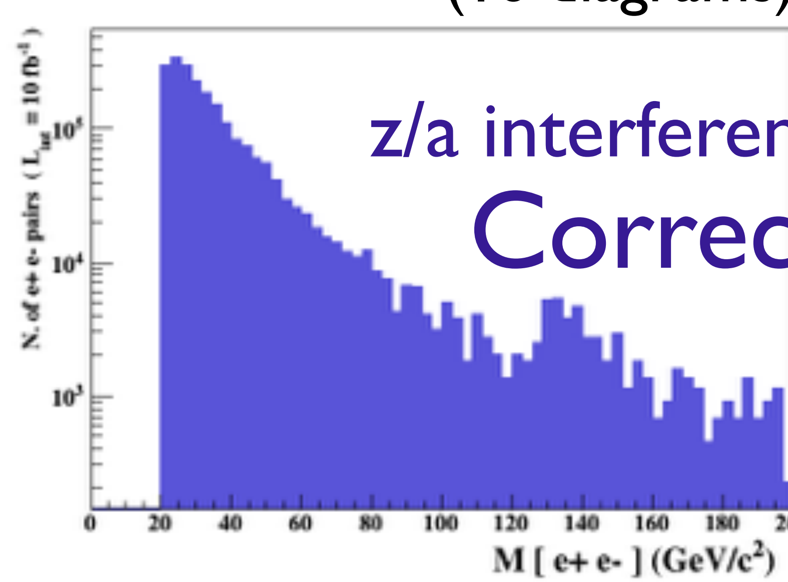
No Z

p p > e+ e- $ z

(16 diagrams)

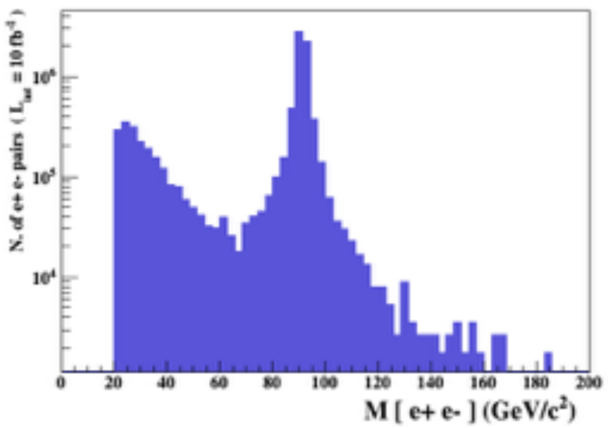
z/a interference

Correct tail



Z- onshell veto

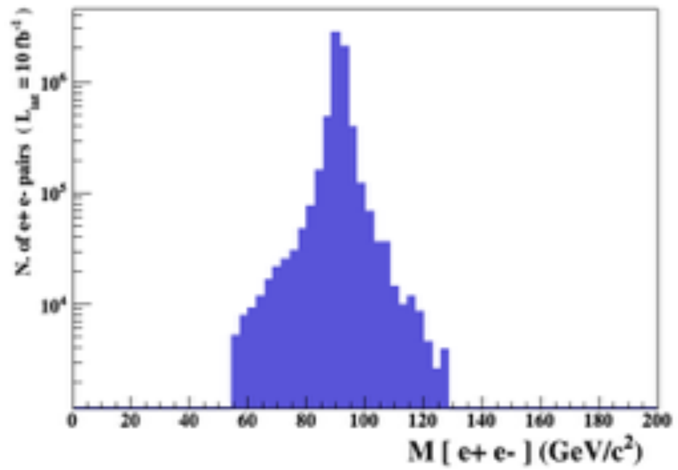
p p > e+ e-



(16 diagrams)

=

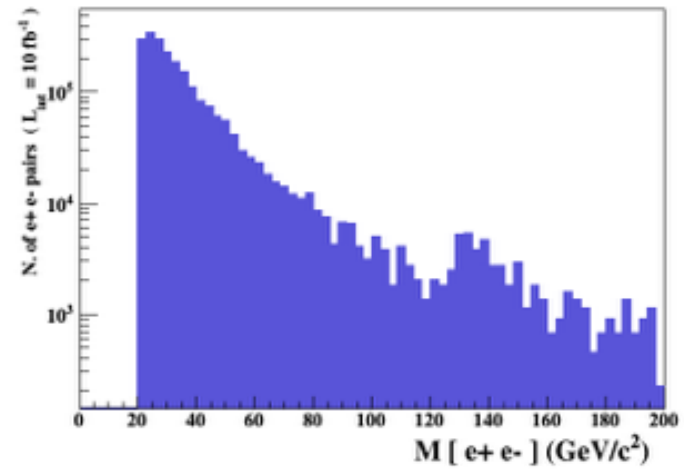
p p >z , z > e+ e-



(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) exact sum of the two other one.
- The "$" forbids the Z to be onshell but the photon invariant mass can be at MZ (i.e. on shell substraction).
- The "/" is to be avoid if possible since this leads to violation of gauge invariance.

WARNING

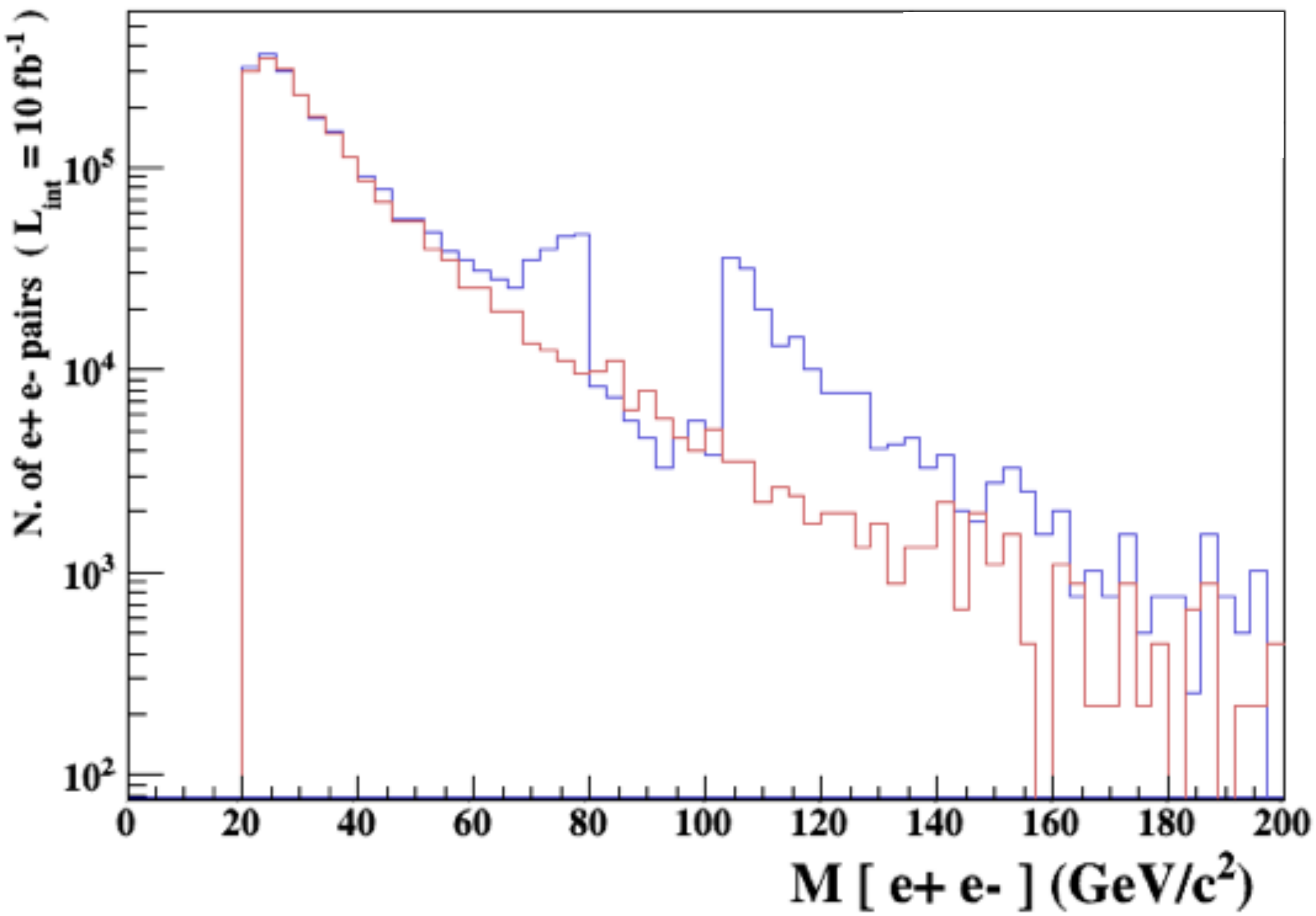
- NEXT SLIDE is generated with bw_cut =5
- This is TOO SMALL to have a physical meaning (15 the default value used in previous plot is better)
- This was done to illustrate more in detail how the "$" syntax works.

See previous slide warning

p p > e+ e- / Z

(red curve)

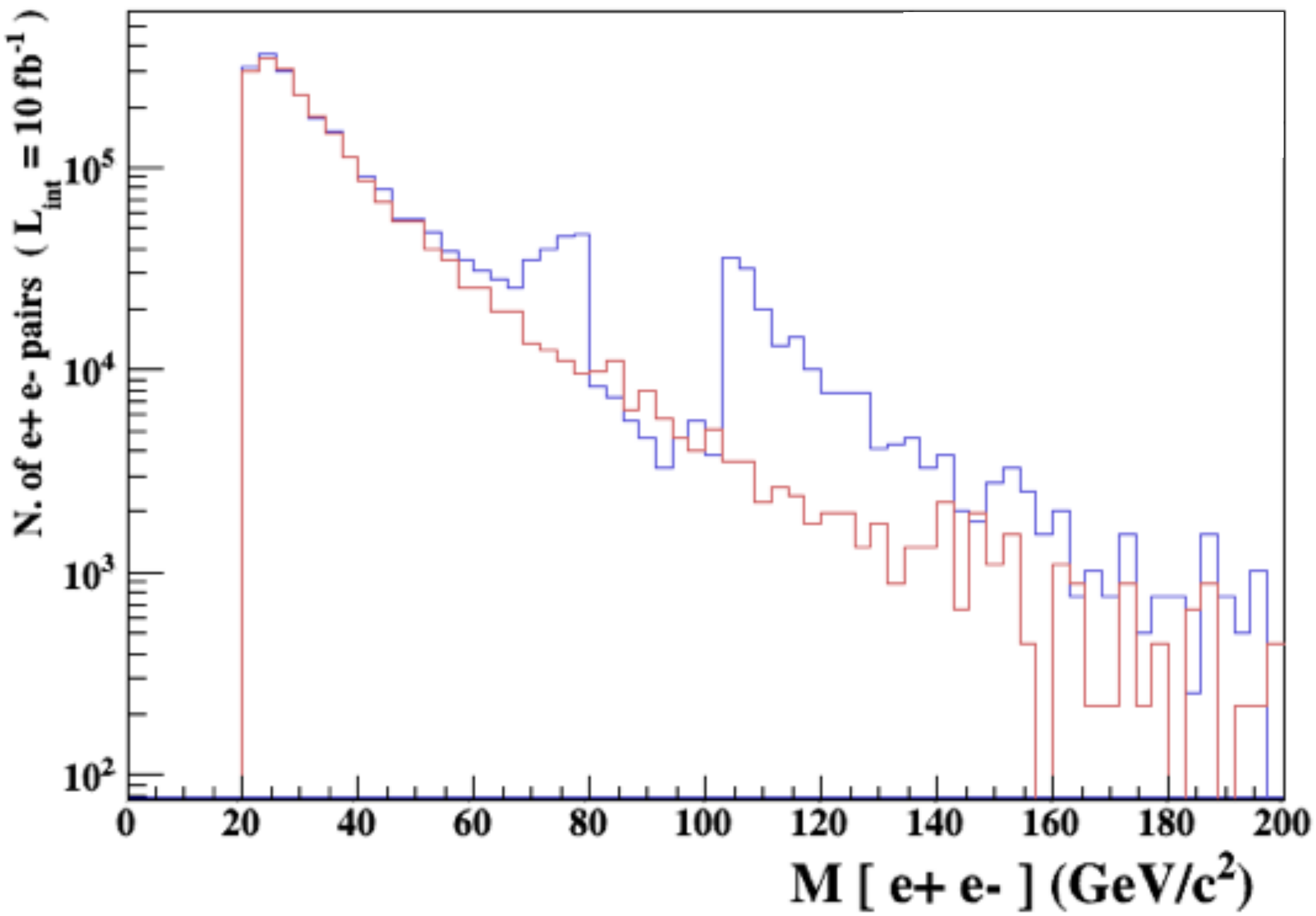
(blue curve)



See previous slide warning

p p > e+ e- / Z
(red curve)

adding p p > e+ e- $ Z
(blue curve)



See previous slide warning

p p > e+ e- / Z
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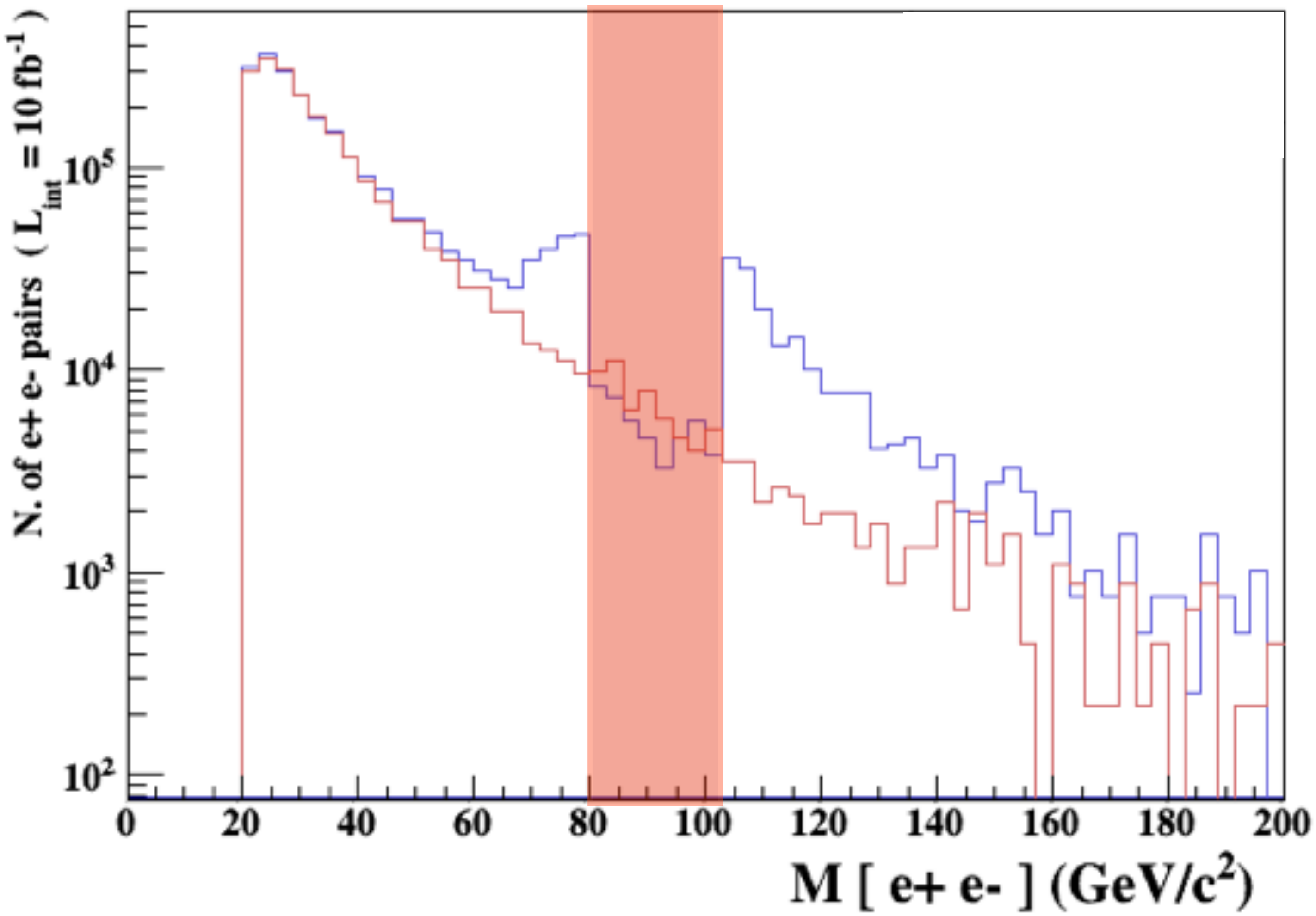
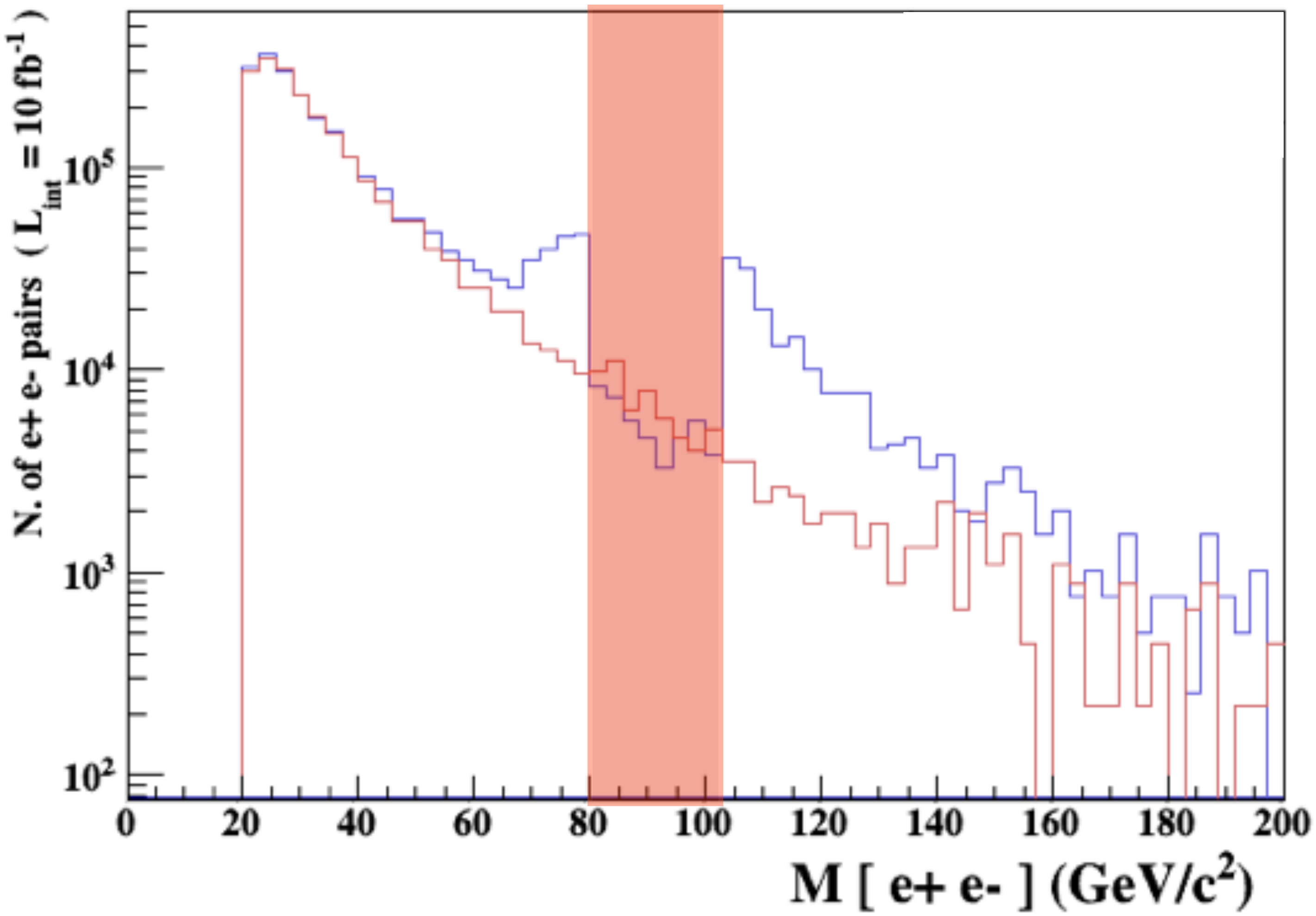


- Z onshell veto

5 times width area

See previous slide warning

p p > e+ e- / Z (red curve) adding p p > e+ e- $ Z (blue curve)



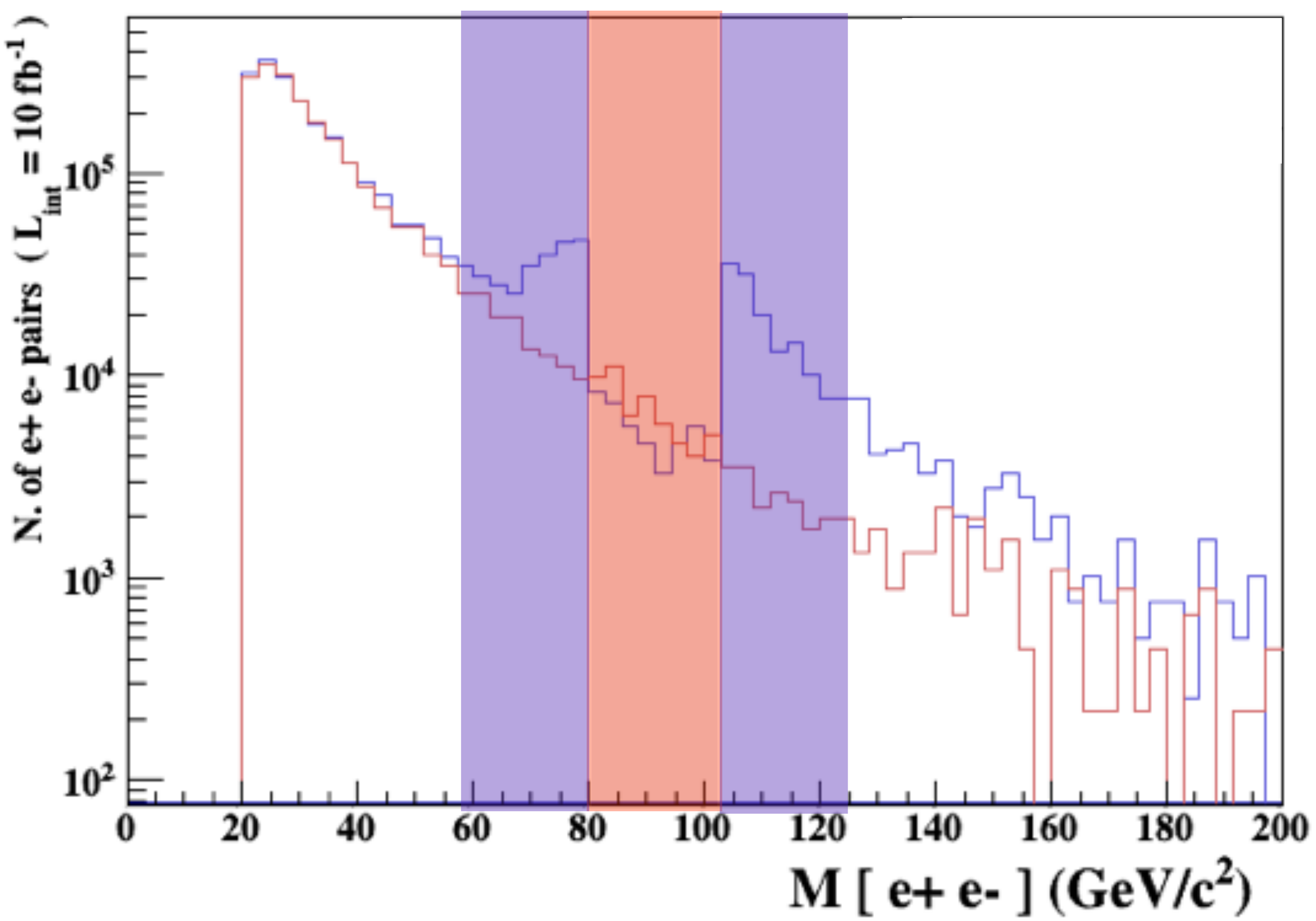
- Z onshell veto
- In veto area only photon contribution

5 times width area

See previous slide warning

p p > e+ e- / Z (red curve)

adding p p > e+ e- $ Z (blue curve)



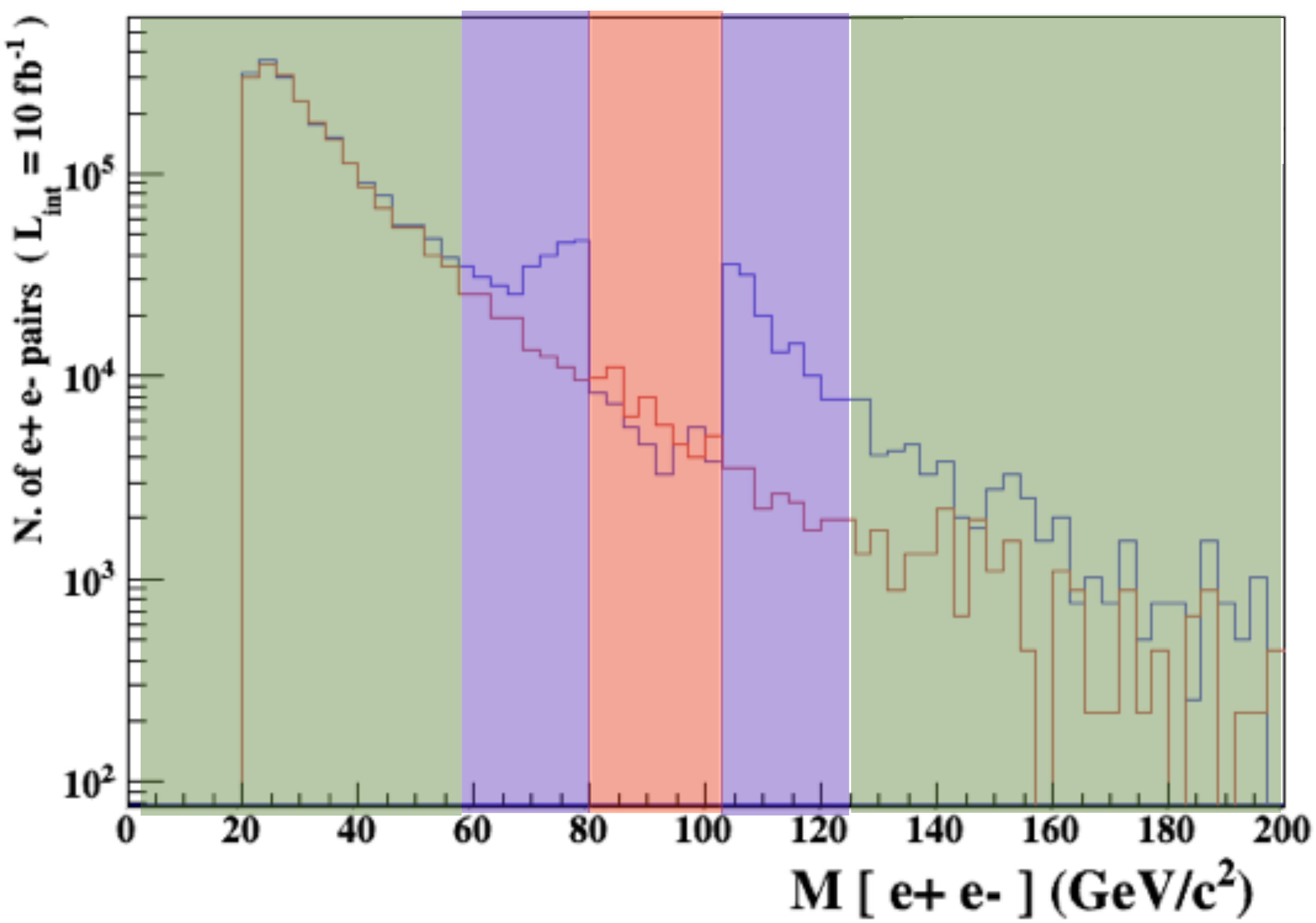
- Z onshell veto
- In veto area only photon contribution
- area sensitive to z-peak

5 times width area

15 times width area

See previous slide warning

p p > e+ e- / Z (red curve) adding p p > e+ e- $ Z (blue curve)



- 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

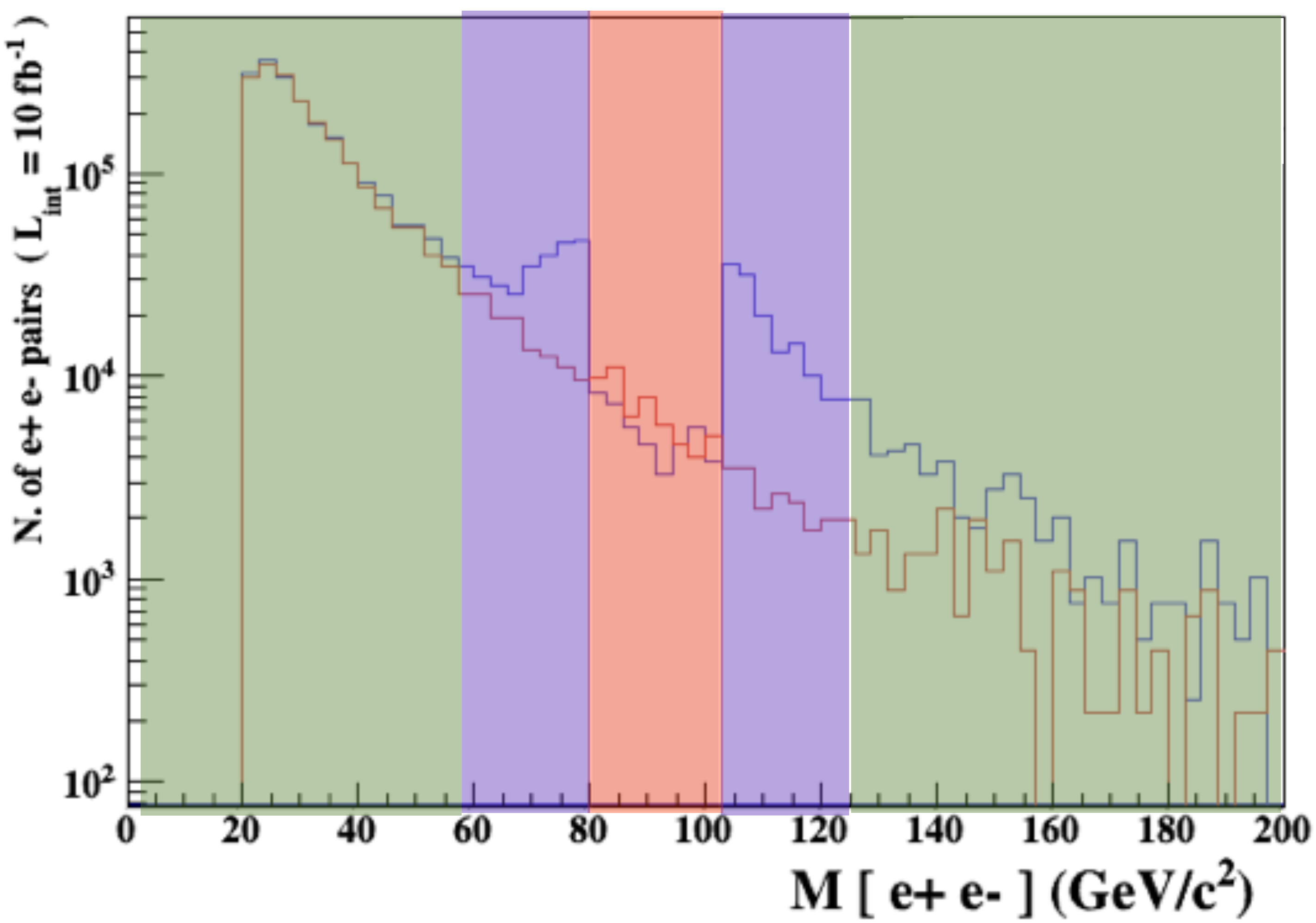
15 times width area

>15 times width area

See previous slide warning

p p > e+ e- / Z (red curve)

adding p p > e+ e- $ Z (blue curve)



- 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 "$" implements on-shell subtraction

- Syntax Like
  - 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 !
  - ➡ forgets diagram interference.
  - ➡ can provides un-physical distributions.
- Syntax Like
  - 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 on-shell cut $|M^* - M| < BW_{cut} * \Gamma$
  - ➡ are typically safer

Exercise IV: 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 V: Automation NEW!

- parameter scan can be done in a even simpler way:
  - ➡ import model sm
  - ➡ output
  - ➡ launch
  - ➡ set mt scan:[160,165,170,175,180,185]
  - ➡ set wt Auto
- run it like previous method (./bin/mg5_aMC PATH)
- new in version 2.3.3
- summary file: Events/scan_run_[01-06].txt

#run_name	mass#6	cross(pb)
run_01	160	726.434
run_02	165	628.235
run_03	170	548.591
run_04	175	448.413
run_05	180	418.303
run_06	185	368.538

Exercise V: Decay

MadSpin

- generate p p > t t~ h

MadSpin Card

- ➡ decay t > w+ b, w+ > e+ ve
- ➡ decay t~ >w- b~, w- > e- ve~
- ➡ decay h > b b~

```
2m18.214s
0.004707
```

MadGraph

- generate p p > t t~ h, (t > w+ b, w+ > e+ ve), (t~ >w- b~, w- > e- ve~), h > b b~

```
9m30.806s
```

0.003014

Different here because of cut (not cut should be applied since 2.3.0)

Exercise VI Reweighting

No Reweighting

```
import model EWdim6
generate p p > w+ w- QED<=2
output
launch
set dim6 1 scan:[0,0.1,1,10,100]
set dim6 2 0
set dim6 3 0
set dim6 4 0
set dim6 5 0
```

Exercise VI Reweighting

Reweighting

```
import model EWdim6
generate p p > w+ w-
QED<=2
output
launch
set dim6 1 0
set d
set d
set d
```

```
INFO: 2 : 161.299882802 +- 6911.38505257 pb
INFO: 3 : 9583.30793192 +- 66448360.5422 pb
INFO: 4 : 950108.957709 +- 6.61855586502e+11 pb
INFO: 5 : 94985922.3841 +- 6.61593143551e+15 pb
INFO: 6 : 9583.30793192 +- 66448360.5422 pb
```

Reweig

```
launch
set dim6 1 0.1
launch
set dim6 1 1
launch
set dim6 1 10
launch
set dim6 1 100
```

Exercise VI Reweighting

No Reweighting

Reweighting

```
INFO: 2 : 161.299882802 +- 6911.38505257 pb
INFO: 3 : 9583.30793192 +- 66448360.5422 pb
INFO: 4 : 950108.957709 +- 6.61855586502e+11 pb
INFO: 5 : 94985922.3841 +- 6.61593143551e+15 pb
INFO: 6 : 9583.30793192 +- 66448360.5422 pb
```