

# Tutorial

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# Learning MG5\_aMC

# Where to find help?

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- Ask us
- 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>

# Minimal tutorial

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- Launch the code (`./bin/mg5_aMC`)
- Type tutorial
  - ➔ Follow instructions

# What are those cards?

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- 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

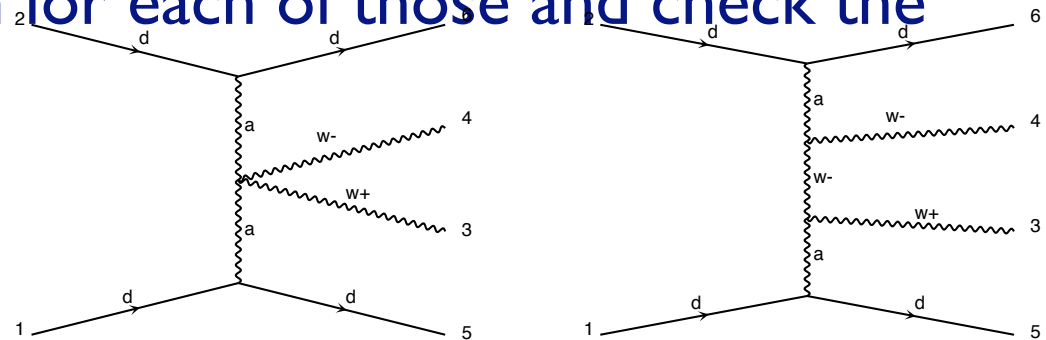
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- How do you change
  - ➔ top mass
  - ➔ top width
  - ➔  $W$  mass
  - ➔ beam energy
  - ➔ pt cut on the lepton

# Exercise II : Syntax

- What's the meaning of the order  $\frac{\alpha_s}{\alpha} \frac{d\sigma}{d\Omega} \gg t \bar{t}$  QCD=0
  - $\frac{\alpha_s}{\alpha} \frac{d\sigma}{d\Omega} \gg t \bar{t}$  QED<=2
- What's the difference between
  - $\frac{\alpha_s}{\alpha} \frac{d\sigma}{d\Omega} \gg t \bar{t}$  QCD^2==2
  - $\frac{\alpha_s}{\alpha} \frac{d\sigma}{d\Omega} \gg t \bar{t}$
  - $\frac{\alpha_s}{\alpha} \frac{d\sigma}{d\Omega} \gg t \bar{t}$  QED=2
  - $\frac{\alpha_s}{\alpha} \frac{d\sigma}{d\Omega} \gg t \bar{t}$  QED=0

- Compute the cross-section for each of those and check the diagram



- Generate VBF process

# Exercise III: Syntax

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- Generate the cross-section and the distribution (invariant mass) for
  - ➔  $pp \rightarrow e^+ e^-$
  - ➔  $pp \rightarrow z, z \rightarrow e^+ e^-$
  - ➔  $pp \rightarrow e^+ e^- \gamma z$
  - ➔  $pp \rightarrow e^+ e^- / z$

**Hint** : To plot automatically distributions:  
`mg5> install MadAnalysis`

- Use the invariant mass distribution to determine the



# 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)

## Examples

File:

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

How to Run: `./bin/mg5_amc PATH`

# Exercise V: Decay Chain

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- Generate  $p p \rightarrow t t^* h$ , 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.

# Solution Learning MG5\_aMC

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# 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  
5 1.730000e+02 # MT  
6 1.730000e+02 # MT  
7 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)))
```

```

#####
## 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 III: Syntax

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- What's the meaning of the order QED/QCD
- What's the difference between
  - $p p \rightarrow t t^{\sim}$
  - $p p \rightarrow t t^{\sim} \text{ QED}=2$
  - $p p \rightarrow t t^{\sim} \text{ QED}=0$
  - $p p \rightarrow t t^{\sim} \text{ QCD}^2=2$

# Solution I : Syntax

- What's the meaning of the order QED/QCD
  - By default MG5 takes the lowest order in QED!
  - $p p > t t^{\sim} \Rightarrow p p > t t^{\sim} \text{ QED}=0$
  - $p p > t t^{\sim} \text{ QED}=2$ 
    - additional diagrams (photon/z exchange)

$p p > t t^{\sim}$

Cross section (pb)
<u><math>555 \pm 0.84</math></u>

$p p > t t^{\sim} \text{ QED}=2$

Cross section (pb)
<u><math>555.8 \pm 0.91</math></u>

**No significant QED contribution**



- $\text{QED}^{\leq 2}$  is the SAME as  $\text{QED}^2$

→ quite often source of confusion since most of the people use the = syntax

- $\text{QCD}^2=2$

→ returns the interference between the QCD and the QED diagram

Cross section (pb)
<u><math>5.455\text{e-}17 \pm 4.7\text{e-}19 \pm \text{systematics}</math></u>

# Solution I Syntax

- generate  $p p > w^+ w^- j j$   
→ 76 processes

- 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
  - 1432 diagrams
  - None of them are VBF
  - 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

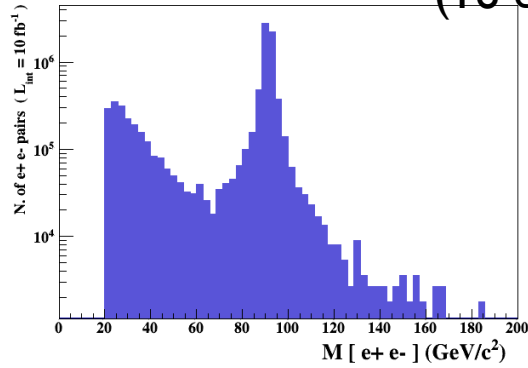
# Exercise IV: Syntax

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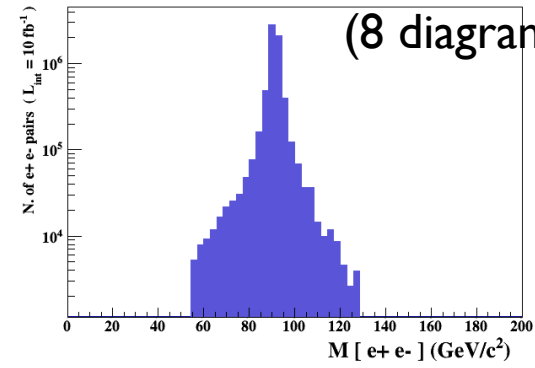
- Generate the cross-section and the distribution (invariant mass) for
  - ➔  $pp \rightarrow e^+ e^-$
  - ➔  $pp \rightarrow z, z \rightarrow e^+ e^-$
  - ➔  $pp \rightarrow e^+ e^- \otimes z$
  - ➔  $pp \rightarrow e^+ e^- / z$

**Hint** :To have automatic distributions:  
`mg5> install MadAnalysis`

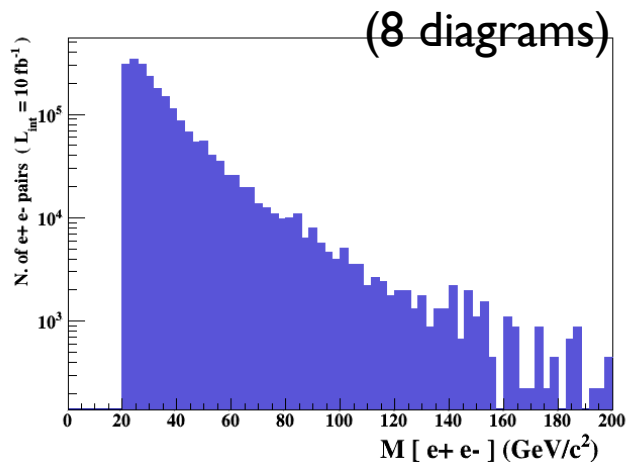
$pp \rightarrow e^+ e^-$   
(16 diagrams)



$pp \rightarrow z, z \rightarrow e^+ e^-$   
(8 diagrams)

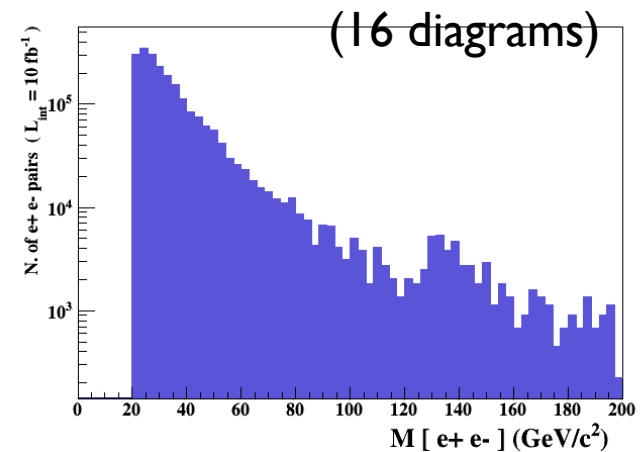


$pp \rightarrow e^+ e^- / z$



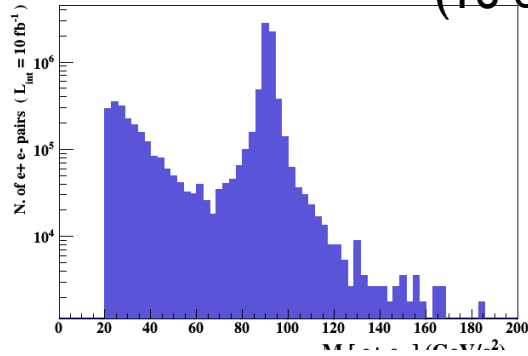
No Z

$pp \rightarrow e^+ e^- \cancel{z}$



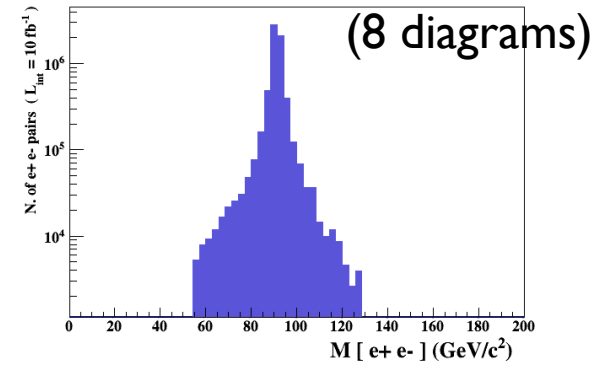
Z- onshell veto

$pp \rightarrow e^+ e^-$   
(16 diagrams)

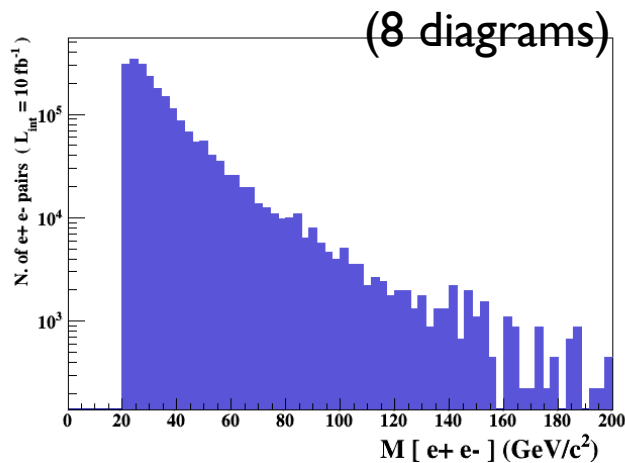


Correct Distribution

$pp \rightarrow z, z \rightarrow e^+ e^-$

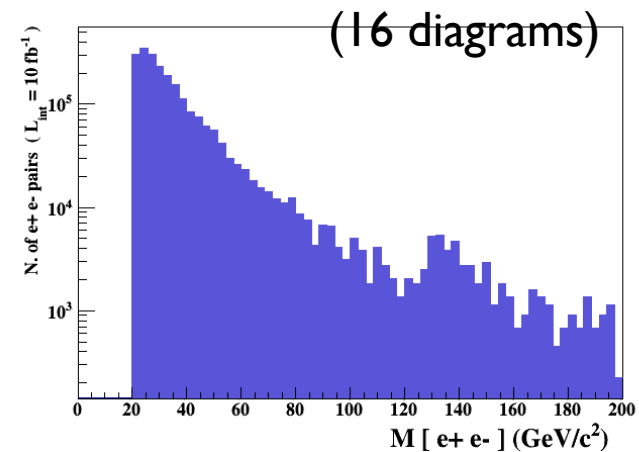


$pp \rightarrow e^+ e^- / z$

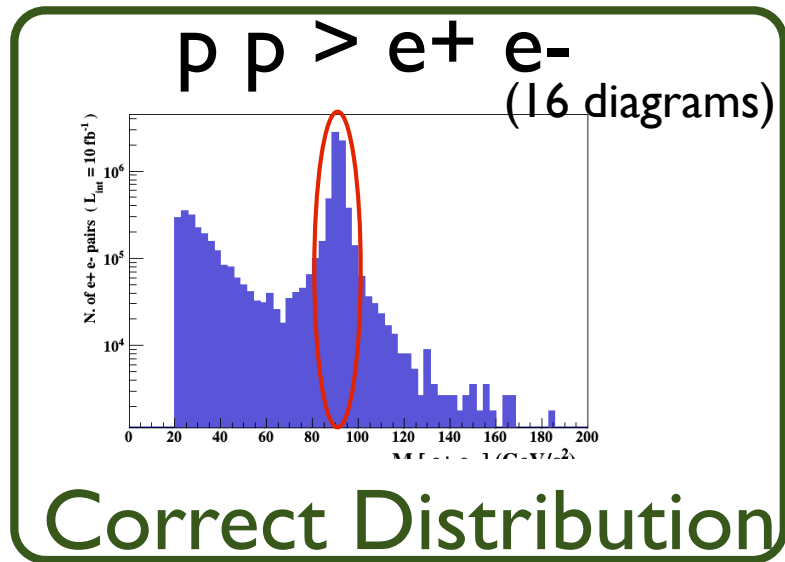


No Z

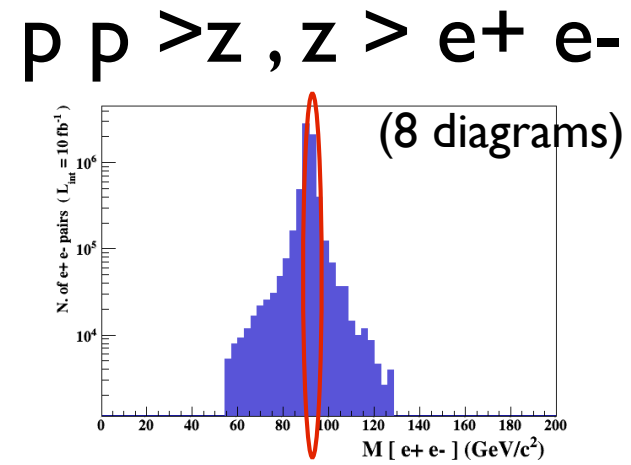
$pp \rightarrow e^+ e^- \cancel{z}$



Z- onshell veto

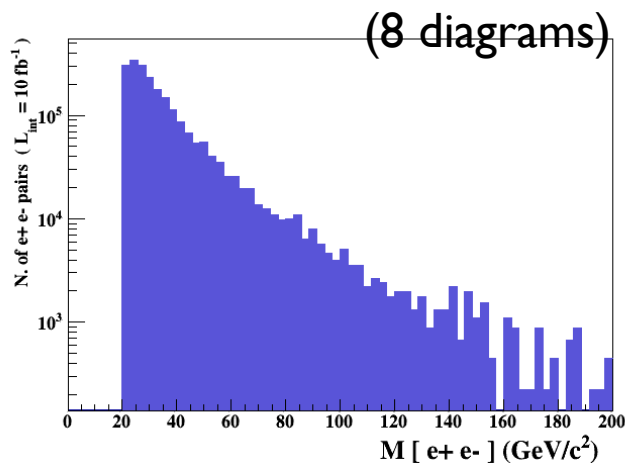


**Z Peak**

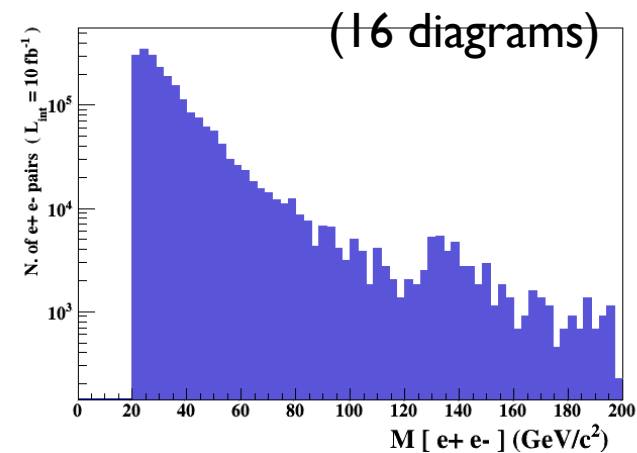


$pp \rightarrow e^+ e^- / z$

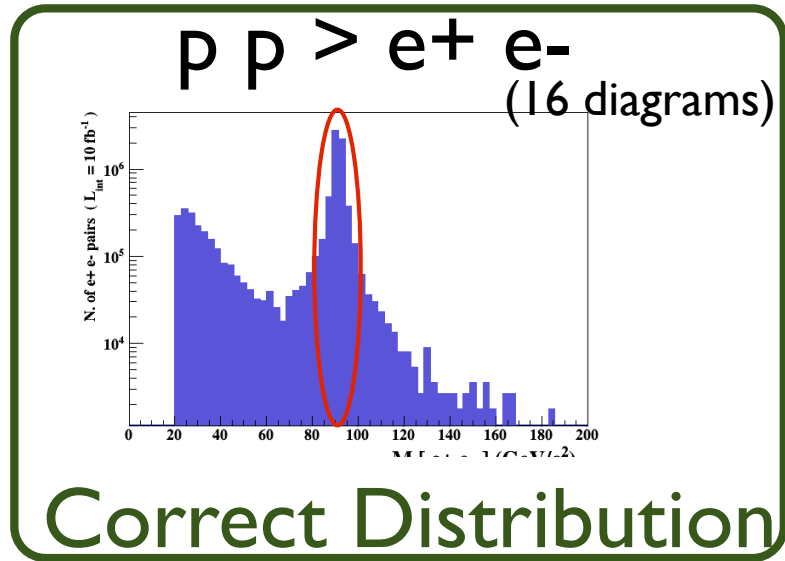
**NO Z Peak**



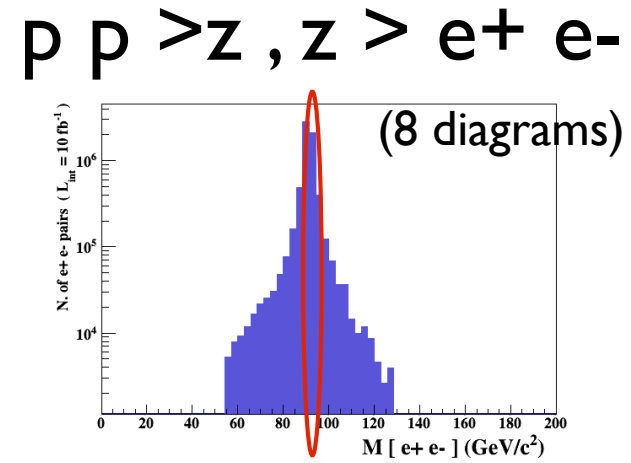
**No Z**



**Z- onshell veto**

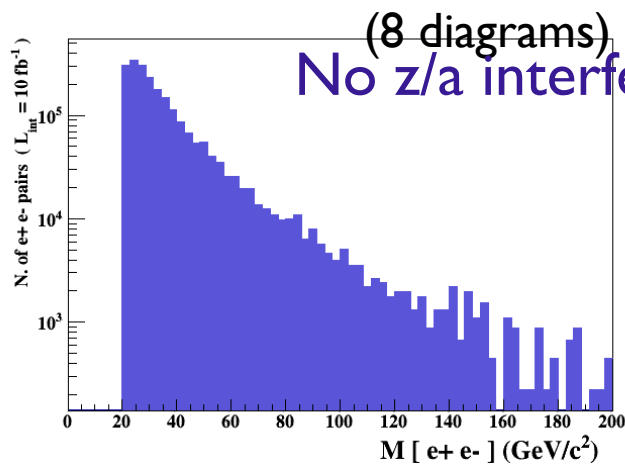


**Z Peak**



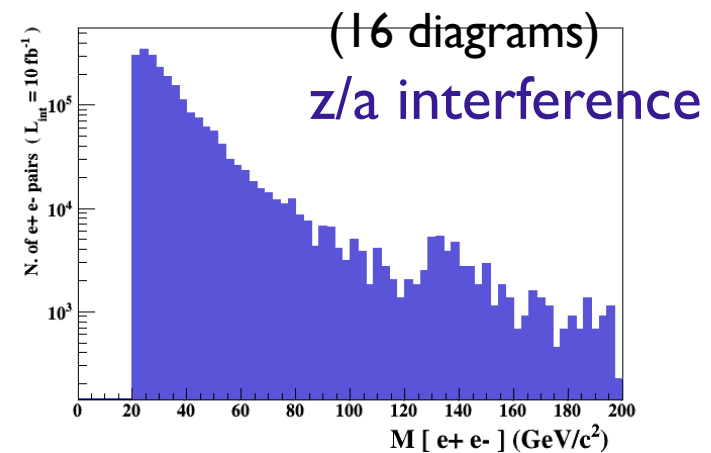
$pp \rightarrow e^+ e^- / z$

**NO Z Peak**

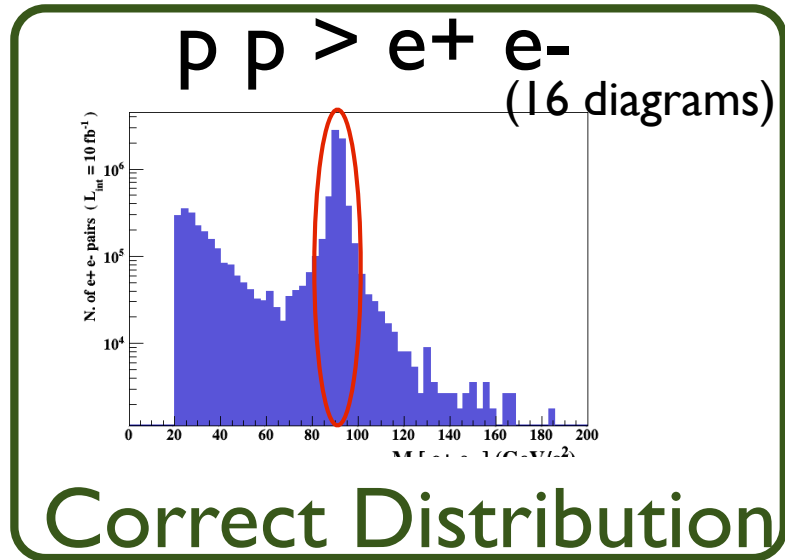


**No Z**

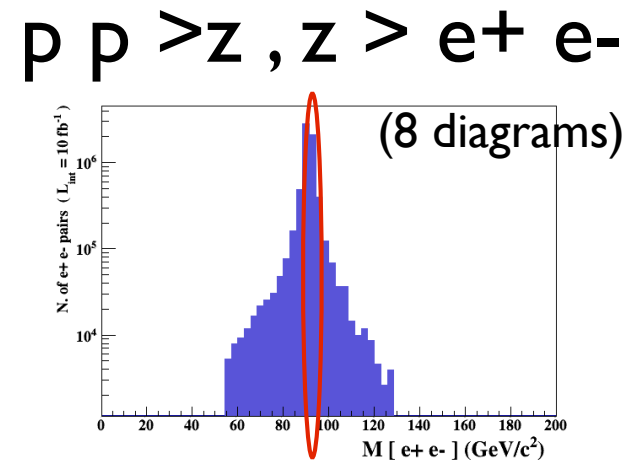
$pp \rightarrow e^+ e^- \text{ } z$



**Z- onshell veto**

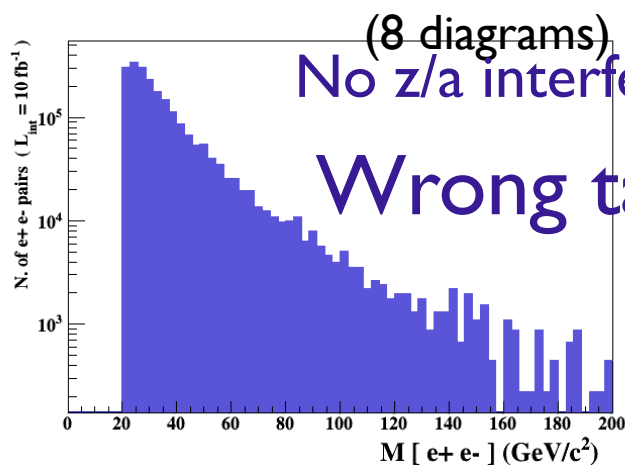


**Z Peak**



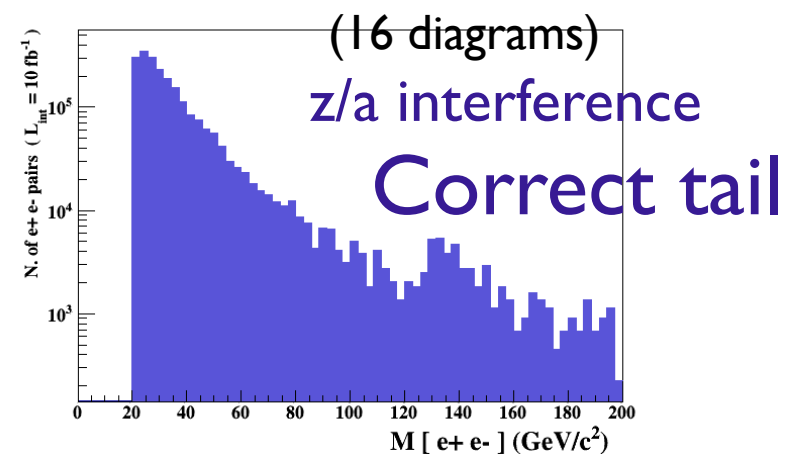
$pp \rightarrow e^+ e^- / z$

$pp \rightarrow e^+ e^- \text{ } z$



**NO Z Peak**

**No Z**



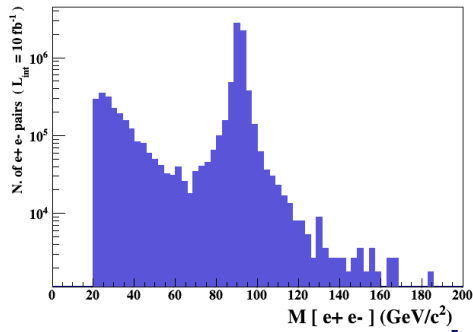
**Z- onshell veto**



~~$pp \rightarrow e^+ e^-$~~

~~$pp \rightarrow z, z \rightarrow e^+ e^-$~~

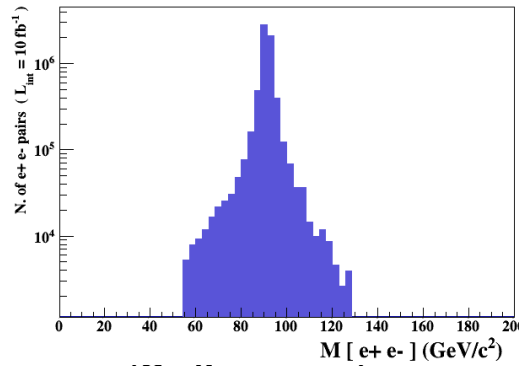
~~$pp \rightarrow e^+ e^- \cancel{z}$~~



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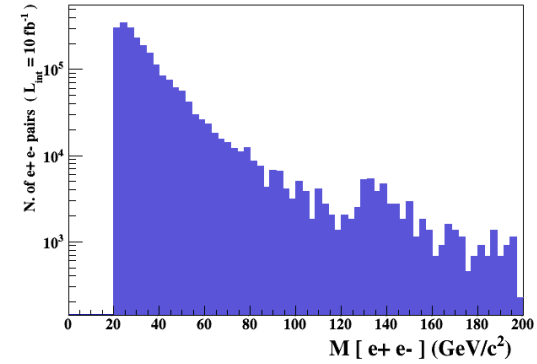
(16 diagrams) two other one.



(8 diagrams)

+

se to)



(16 diagrams)

### Onshell cut: BW\_cut

- The “\$” forbids the Z to be onshell but the photon invariant mass can be at MZ (i.e. on shell subtraction).

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

- The “/” is to be avoid if possible since this leads to violation of gauge invariance.

# WARNING

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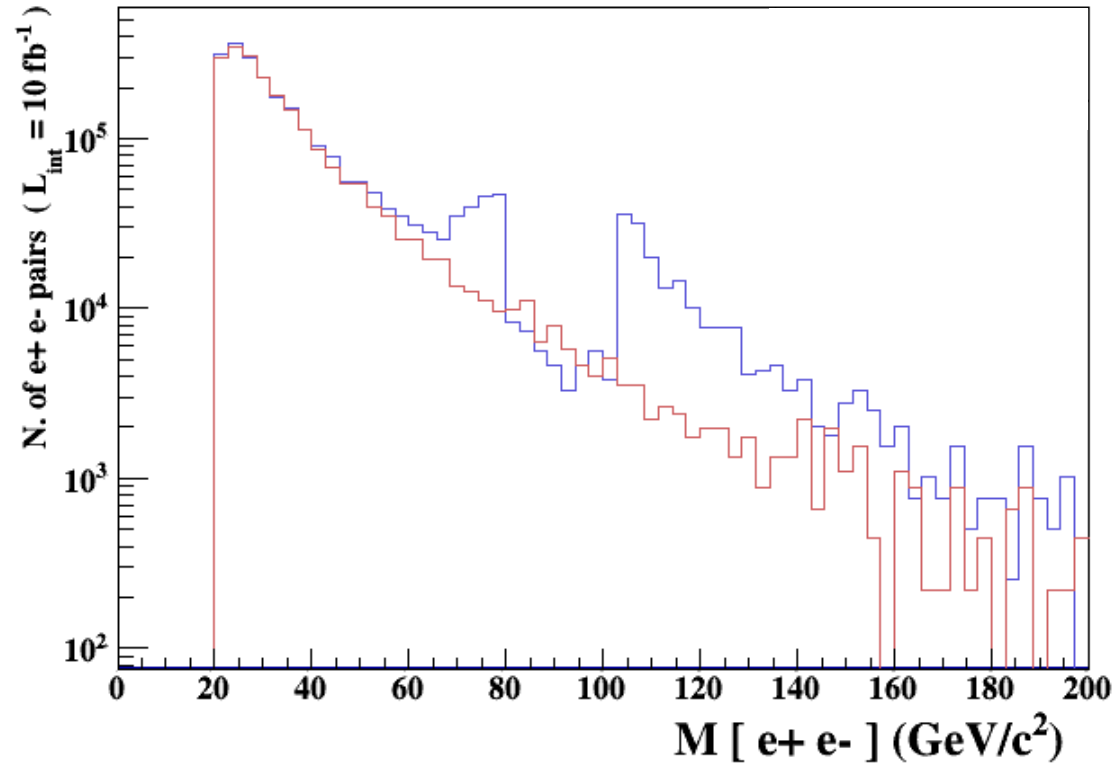
- NEXT SLIDE is generated with `bw_cut = 5`
- This is **TOO SMALL** to have a physical meaning (15 the default value used in previous plot is better)
- This was done to **illustrate** more in detail how the “\$” syntax works.

See previous slide warning  
& explanation

$$p p \rightarrow e^+ e^- / Z$$

(red curve)

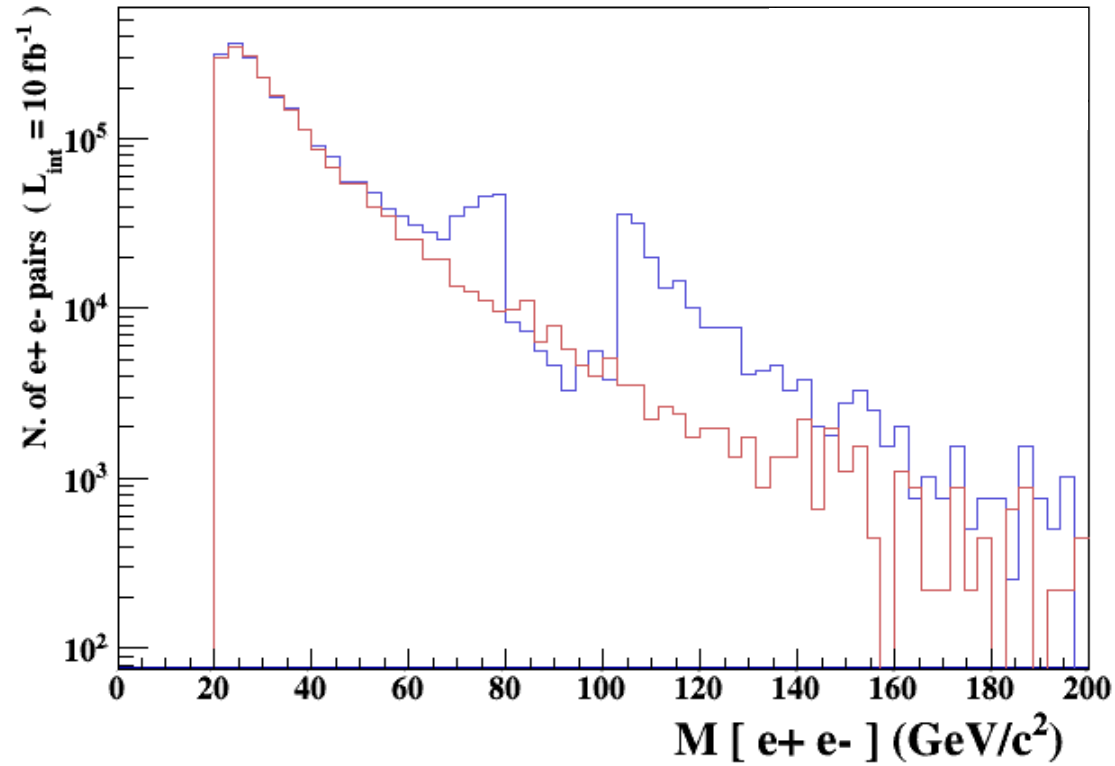
(blue curve)



See previous slide warning  
\$ explanation

$p p \rightarrow e^+ e^- / Z$   
(red curve)

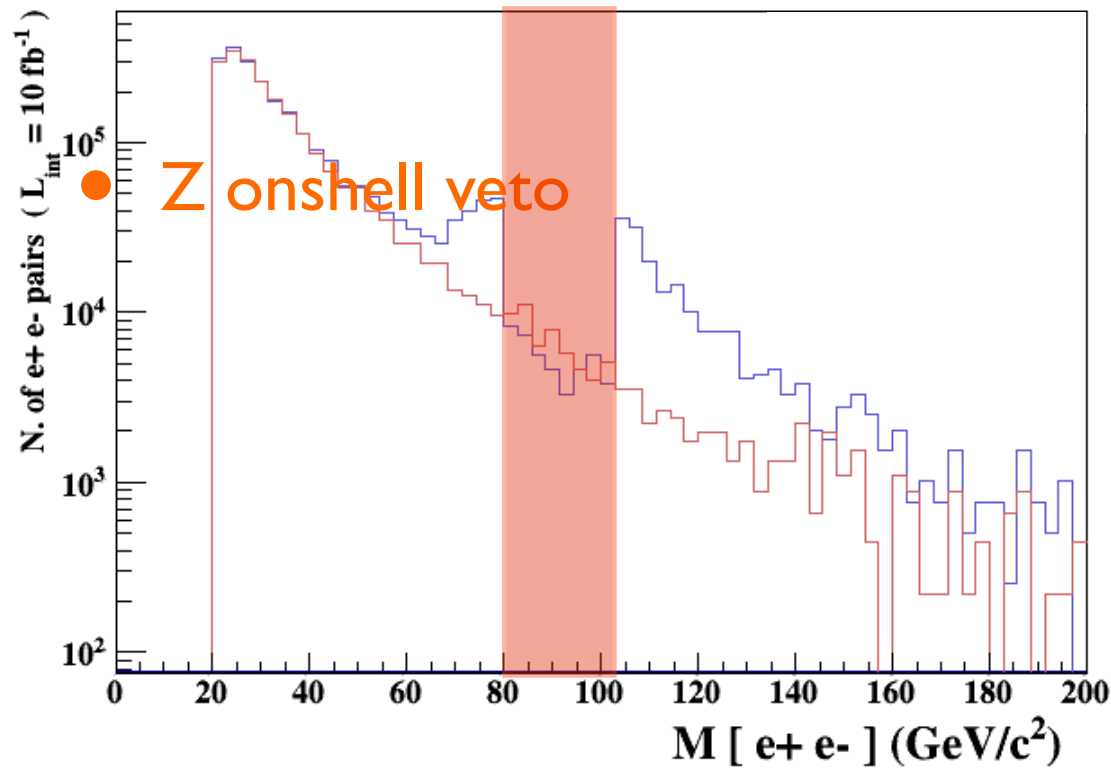
adding  $p p \rightarrow e^+ e^- Z$   
(blue curve)



See previous slide warning  
\$ explanation

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

adding  $p p > e^+ e^- \text{ } \$ Z$   
(blue curve)

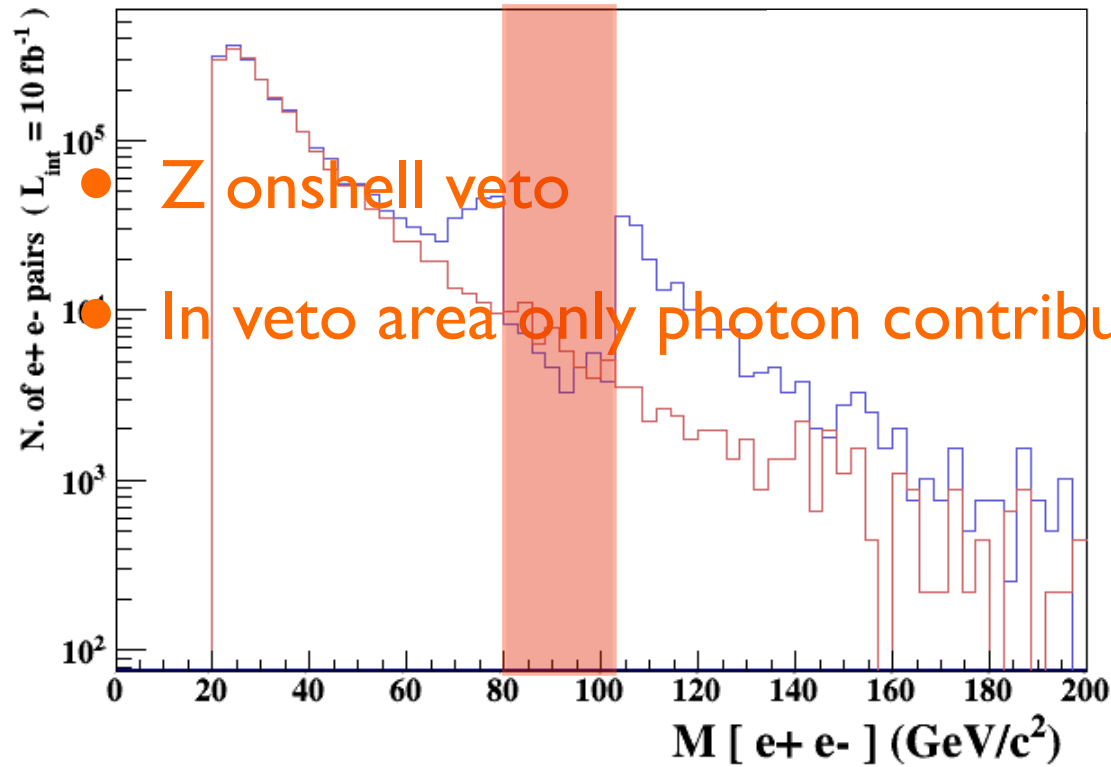


5 times width area

See previous slide warning  
\$ explanation

$p p \rightarrow e^+ e^- / Z$   
(red curve)

adding  $p p \rightarrow e^+ e^- \text{ } Z$   
(blue curve)

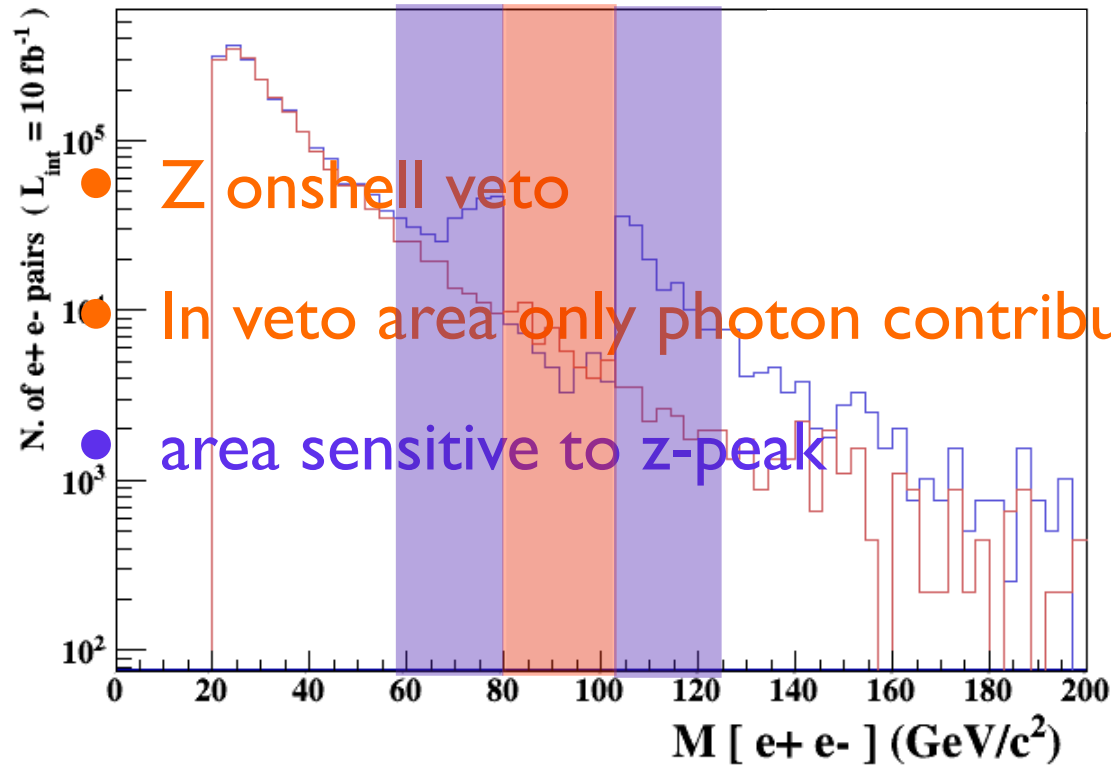


5 times width area

See previous slide warning  
\$ explanation

$p p \rightarrow e^+ e^- / Z$   
(red curve)

adding  $p p \rightarrow e^+ e^- Z$   
(blue curve)



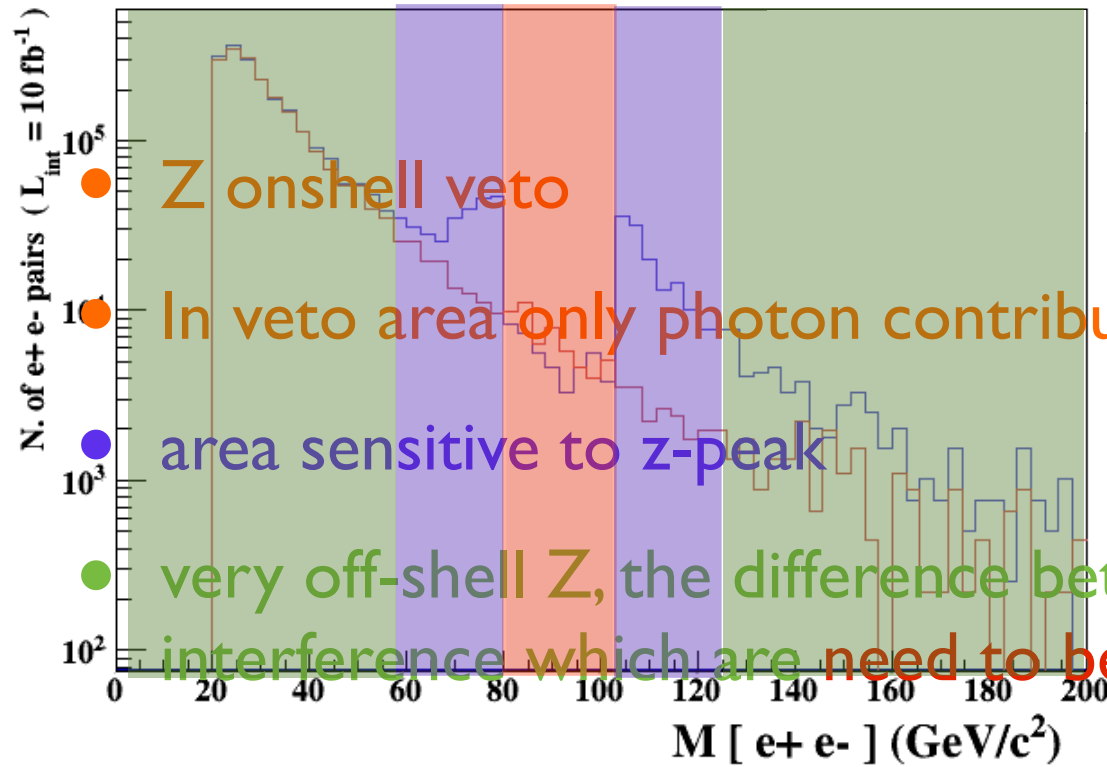
5 times width area

15 times width area

See previous slide warning  
\$ explanation

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

adding  $p p > e^+ e^- \text{ } \$ Z$   
(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



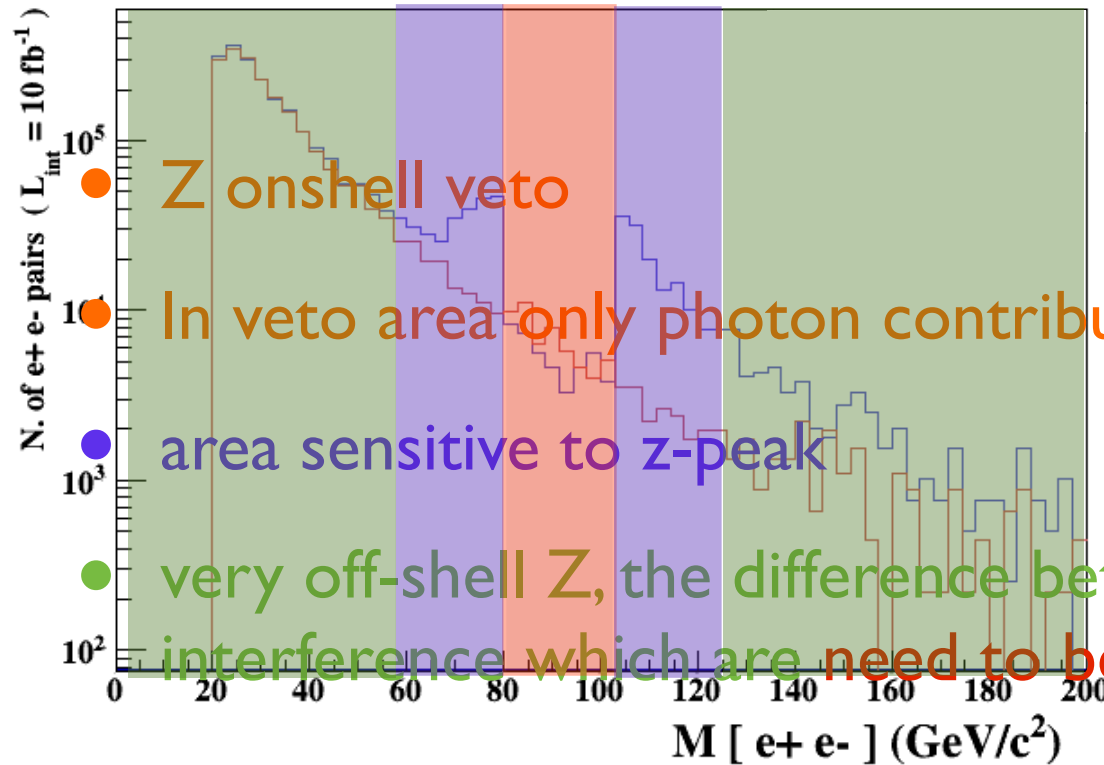
See previous slide warning  
\$ explanation

$p p > e^+ e^- / Z$

(red curve)

adding  $p p > e^+ e^- \$ Z$

(blue curve)



5 times width area

15 times width area

>15 times width area

The “\$” can be use to split the sample in BG/SG area

---

- Syntax Like

- $p p \rightarrow z \rightarrow e^+ e^-$

(ask one S-channel z)

- $p p \rightarrow e^+ e^- / z$

(forbids any z)

- $p p \rightarrow e^+ e^- \$\$ z$

(forbids any z in s-channel)

- ARE NOT GAUGE INVARIANT !
- forgets diagram interference.
- can provides un-physical distributions.

---

- Syntax Like

- $p p > z > e^+ e^-$

(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 provide un-physical distributions.

# Avoid Those as much as possible!

---

- 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 provide un-physical distributions

# Avoid Those as much as possible!

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

- Syntax like
  - $p p > z, z > e^+ e^-$  (on-shell  $z$  decaying)
  - $p p > e^+ e^- \text{ \$ } z$  (forbids s-channel  $z$  to be on-shell)
- Are linked to cut  $|M^* - M| < BW_{cut} * \Gamma$
- Are more safer to use
- Prefer those syntax to the previous slides one

# 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

```
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: Decay

## MadSpin

- generate  $p p \rightarrow t \bar{t} h$

MadSpin Card

→ decay  $t \rightarrow w^+ b, w^+ \rightarrow e^+ \nu_e$

→ decay  $\bar{t} \rightarrow w^- \bar{b}, w^- \rightarrow e^- \bar{\nu}_e$

→ decay  $h \rightarrow b \bar{b}$

2m18.214s

0.004707

## MadGraph

- generate  $p p \rightarrow t \bar{t} h, (t \rightarrow w^+ b, w^+ \rightarrow e^+ \nu_e), (\bar{t} \rightarrow w^- \bar{b}, w^- \rightarrow e^- \bar{\nu}_e), h \rightarrow b \bar{b}$

9m30.806s

0.003014

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