

Solution

- 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.
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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

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

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

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

Cross section (pb)
<u>555 ± 0.84</u>

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

Cross section (pb)
<u>555.8 ± 0.91</u>

No significant QED contribution

- generate $p p \rightarrow w^+ w^- j j$
 - ➔ 76 processes
 - ➔ 1432 diagrams
 - ➔ None of them are VBF

- generate $p p \rightarrow w^+ w^- j j$ QED = 2
 - ➔ 76 processes
 - ➔ 1432 diagrams
 - ➔ None of them are VBF

- generate $p p \rightarrow w^+ w^- j j$ QED = 4
 - ➔ 76 processes
 - ➔ 5332 diagrams
 - ➔ VBF present! + those not VBF

- generate $p p \rightarrow w^+ w^- j j$ QCD = 0
 - ➔ 60 processes
 - ➔ 3900 diagrams
 - ➔ VBF present!

- generate $p p \rightarrow w^+ w^- j j$ QCD = 2
 - ➔ 76 processes
 - ➔ 5332 diagrams

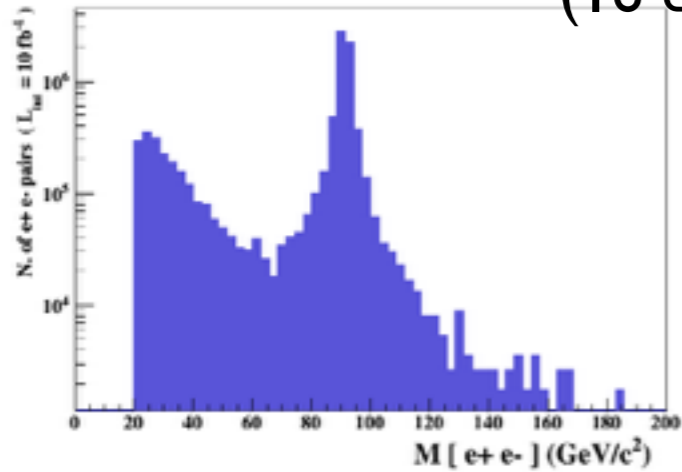
- generate $p p \rightarrow w^+ w^- j j$ QCD = 4
 - ➔ 76 processes
 - ➔ 5332 diagrams

Exercise IV: Syntax

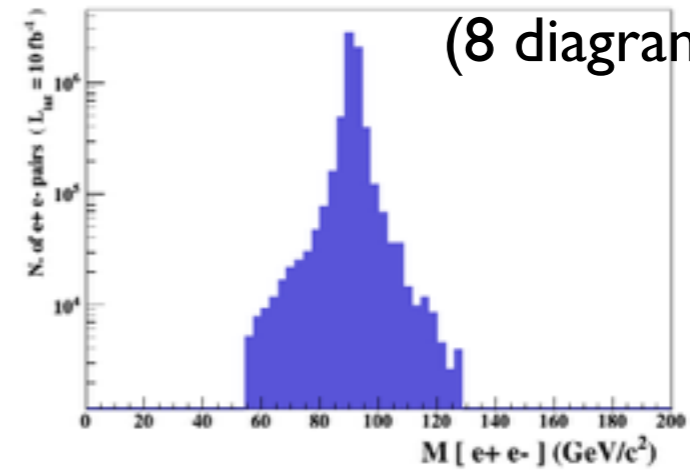
- Generate the cross-section and the distribution (invariant mass) for
 - ➔ $pp \rightarrow e^+ e^-$
 - ➔ $pp \rightarrow z, z \rightarrow e^+ e^-$
 - ➔ $pp \rightarrow e^+ e^- \gamma z$
 - ➔ $pp \rightarrow e^+ e^- / z$

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

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

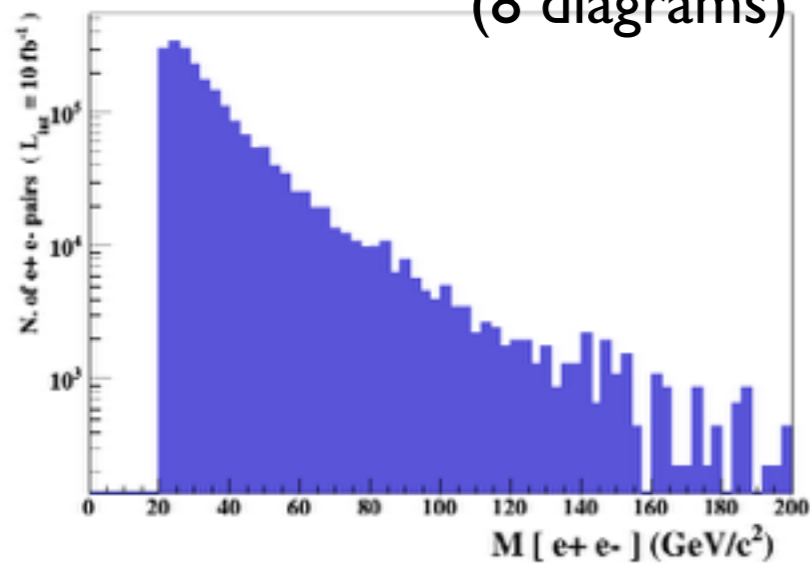


$pp \rightarrow z, z \rightarrow e^+ e^-$
(8 diagrams)



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

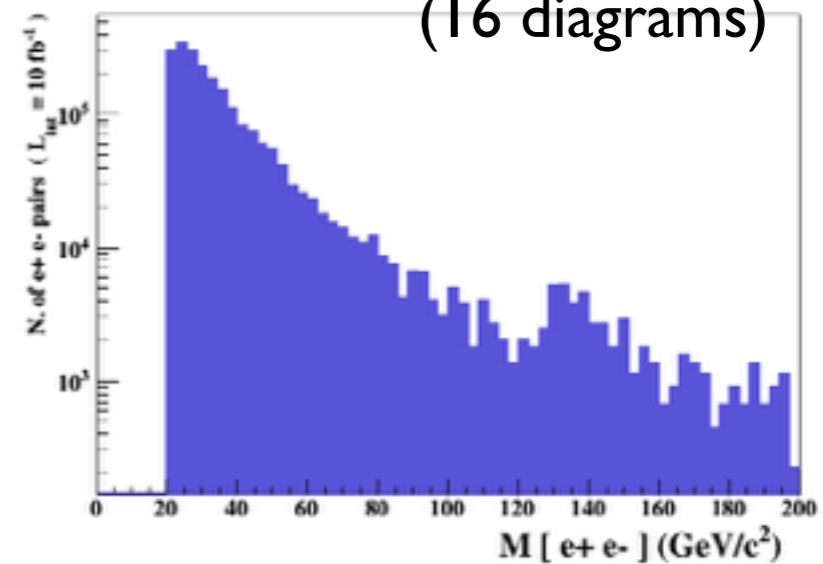
(8 diagrams)



No Z

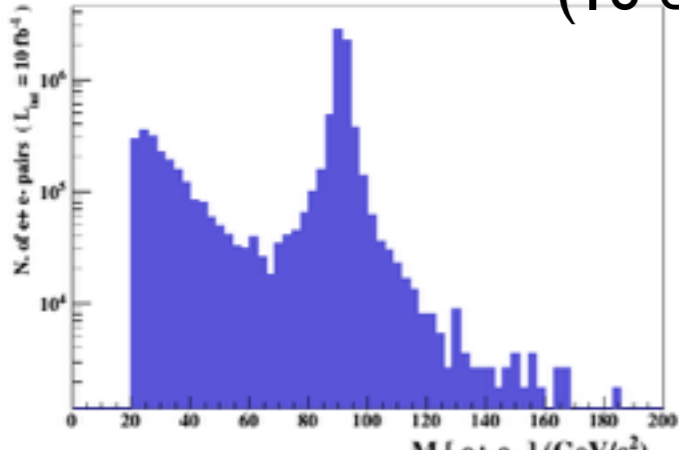
$pp \rightarrow e^+ e^- \cancel{z}$

(16 diagrams)



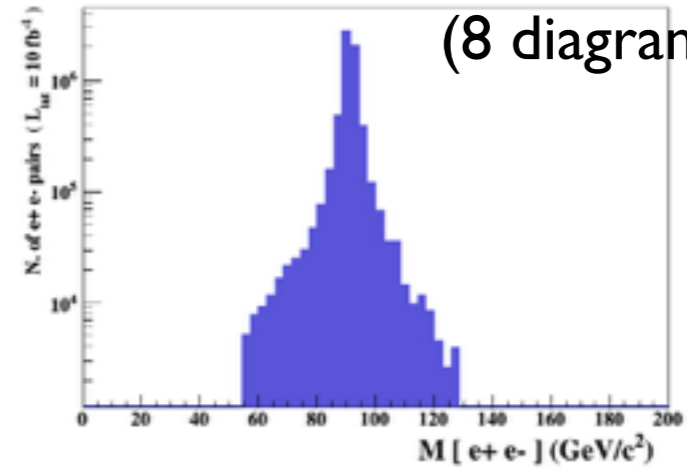
Z- onshell veto

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



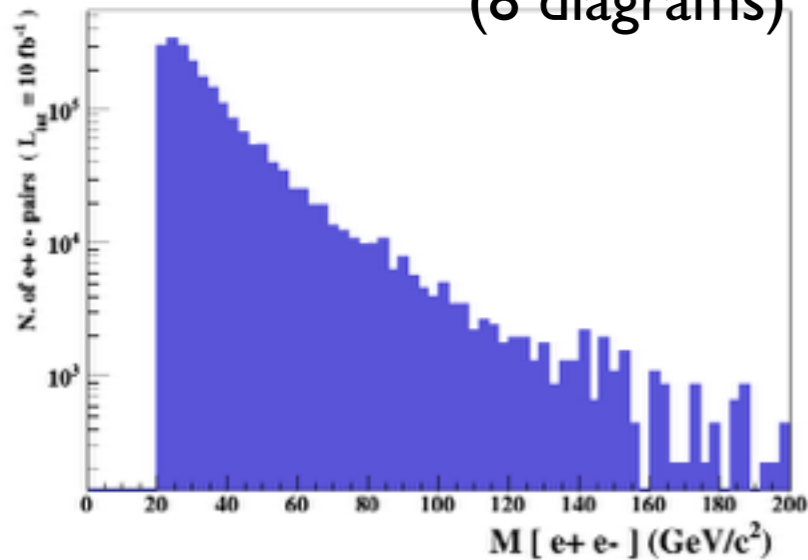
Correct Distribution

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



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

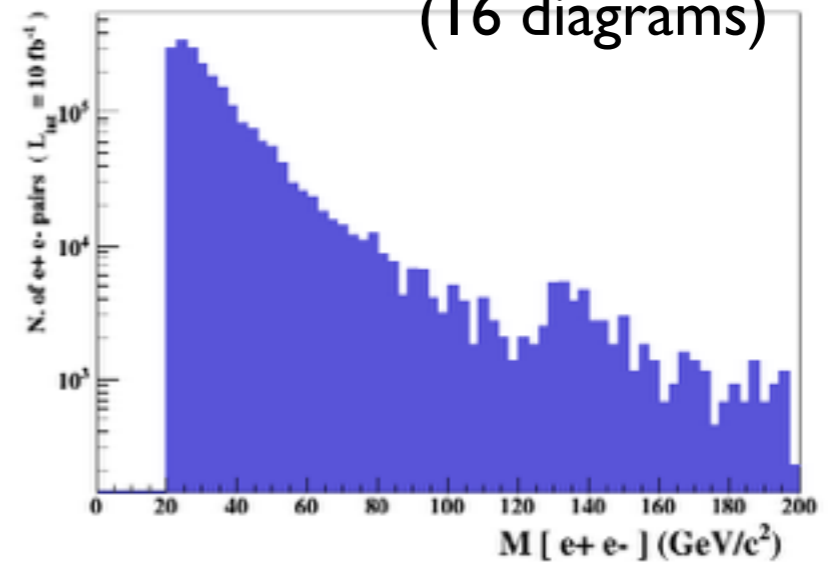
(8 diagrams)



No Z

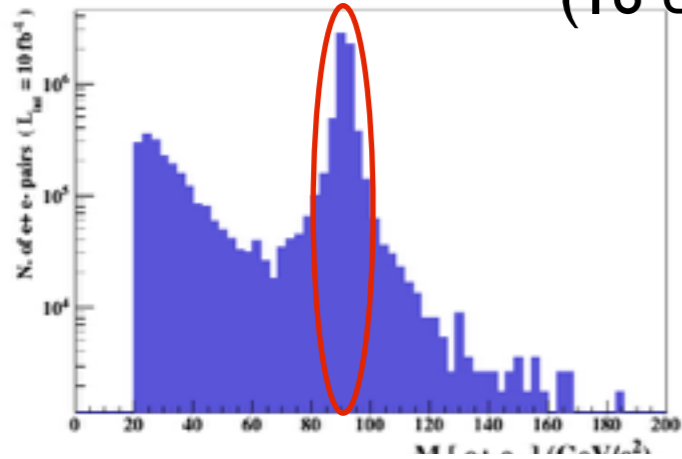
$p p \rightarrow e^+ e^- \& z$

(16 diagrams)



Z- onshell veto

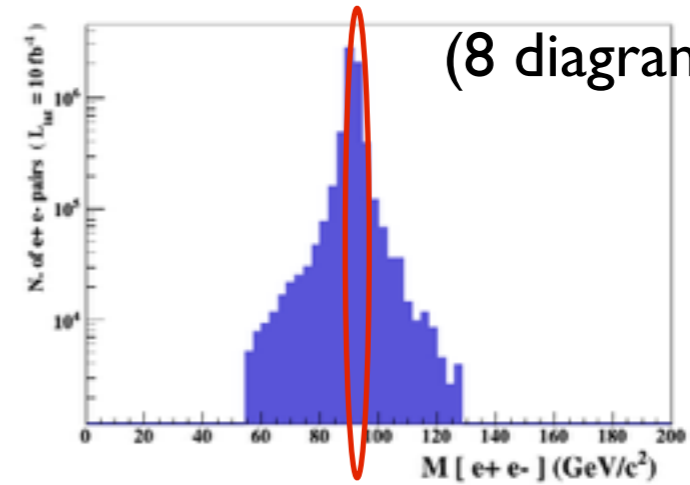
$p p \rightarrow e^+ e^-$
(16 diagrams)



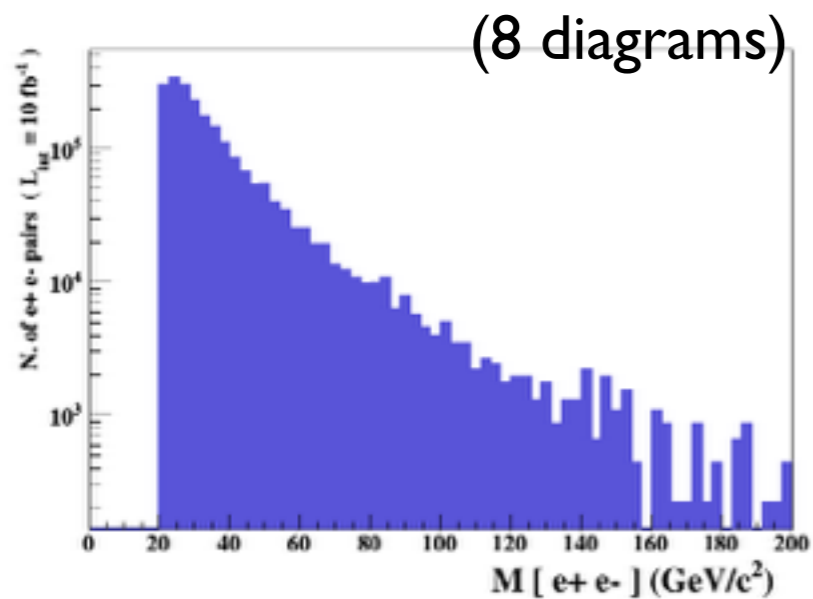
Correct Distribution

Z Peak

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



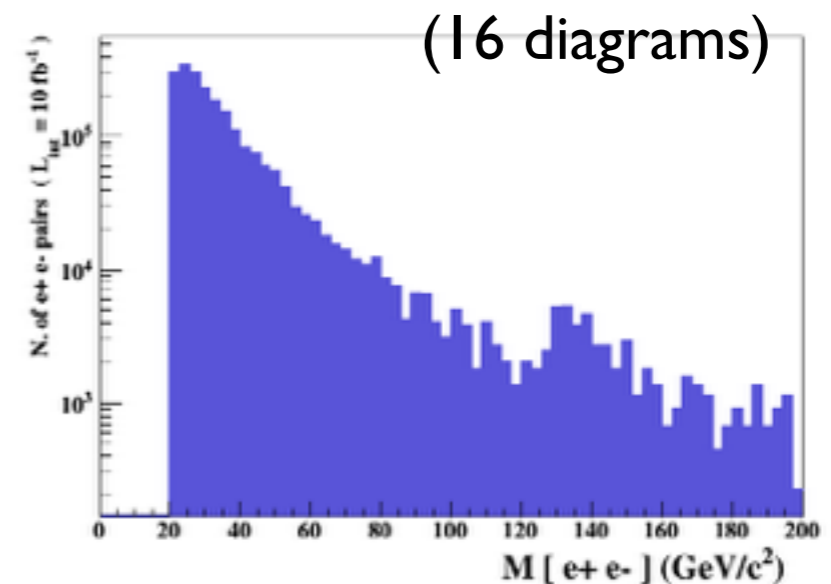
$p p \rightarrow e^+ e^- / z$



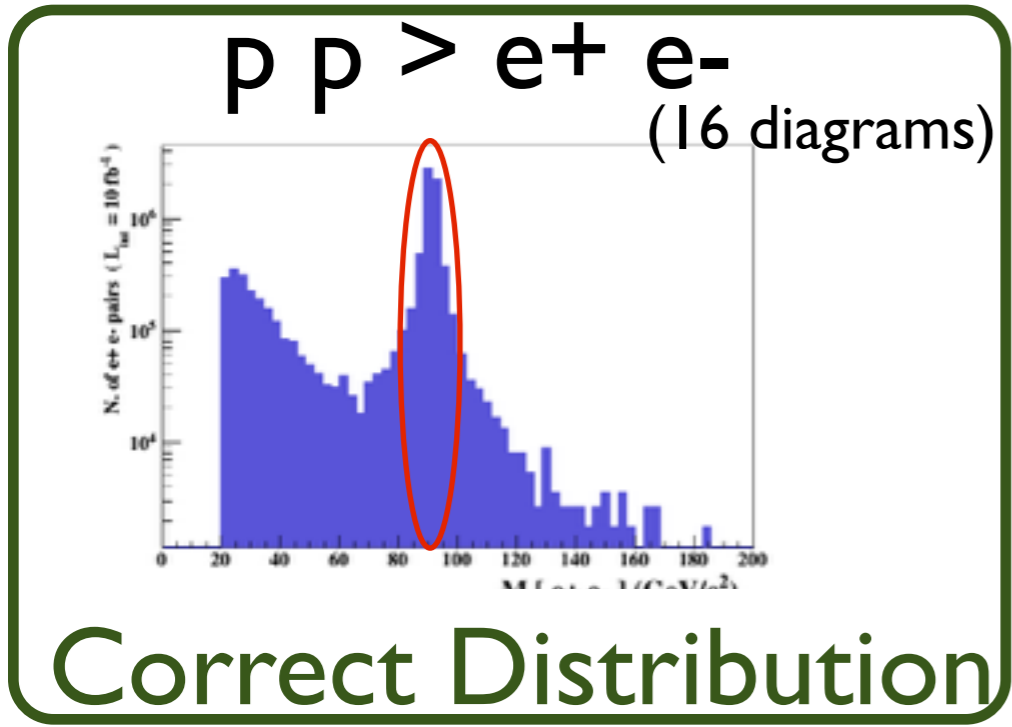
No Z

NO Z Peak

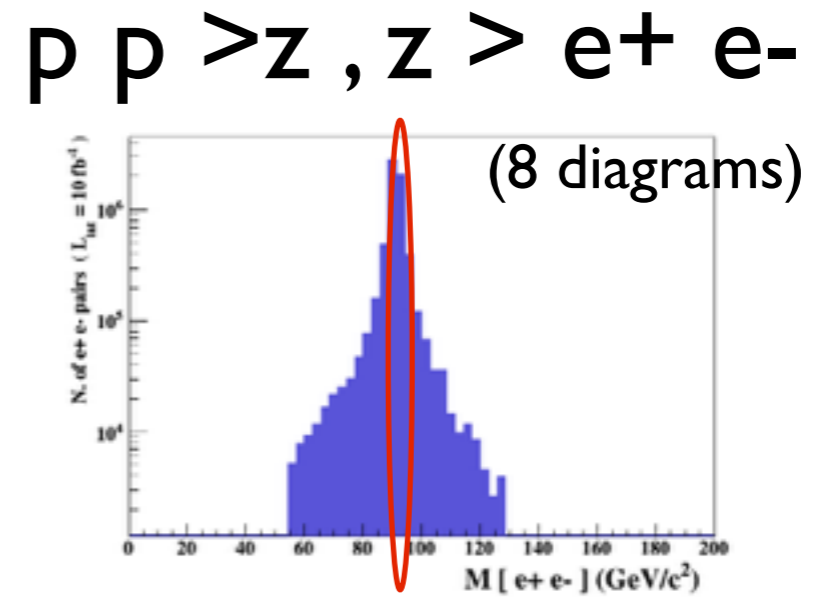
$p p \rightarrow e^+ e^- \cancel{z}$



Z- onshell veto

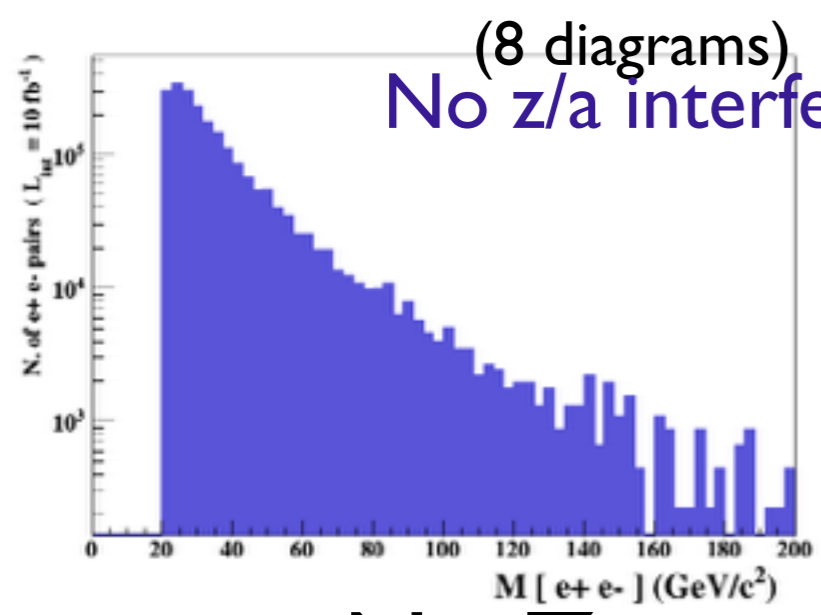


Z Peak

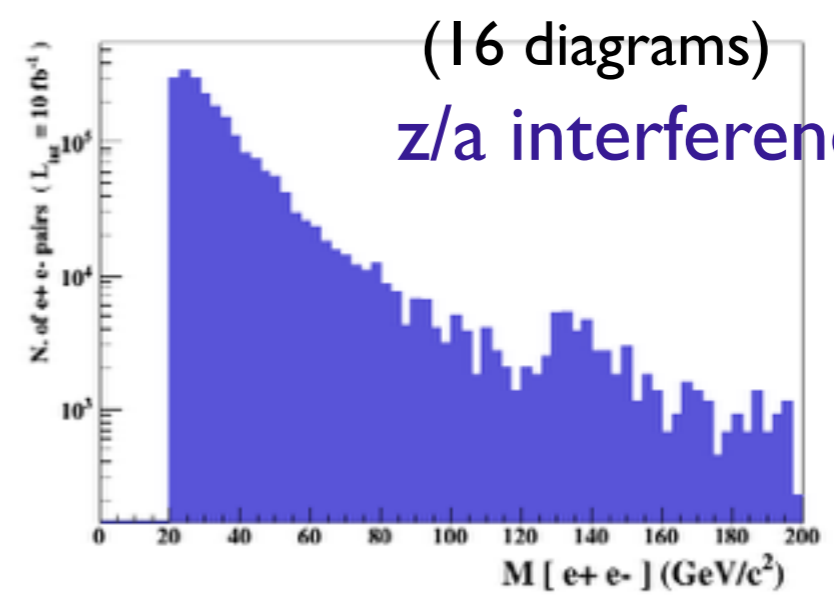


$p p \rightarrow e^+ e^- / z$

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

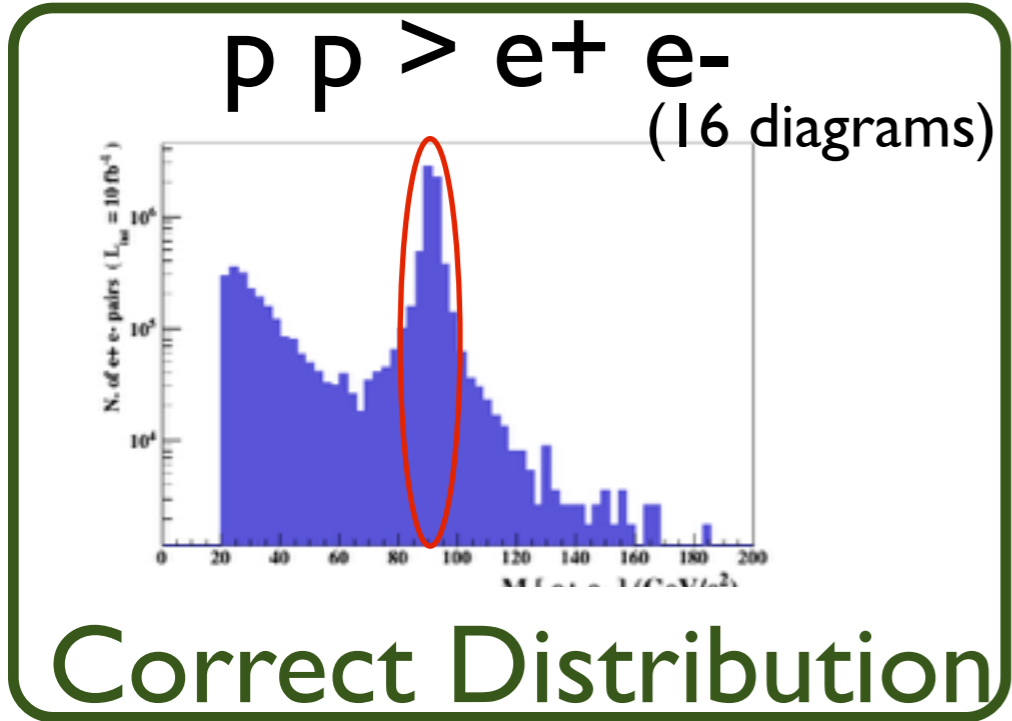


NO Z Peak

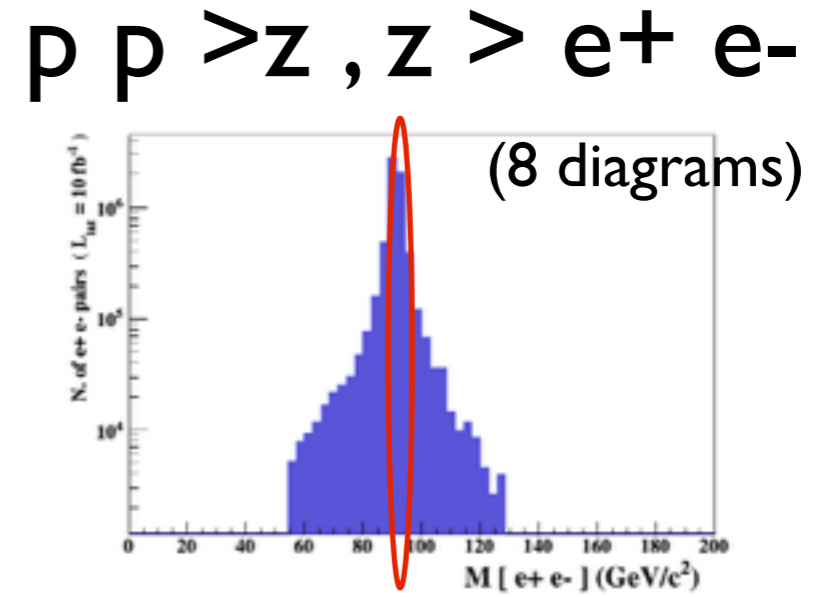


No Z

Z- onshell veto

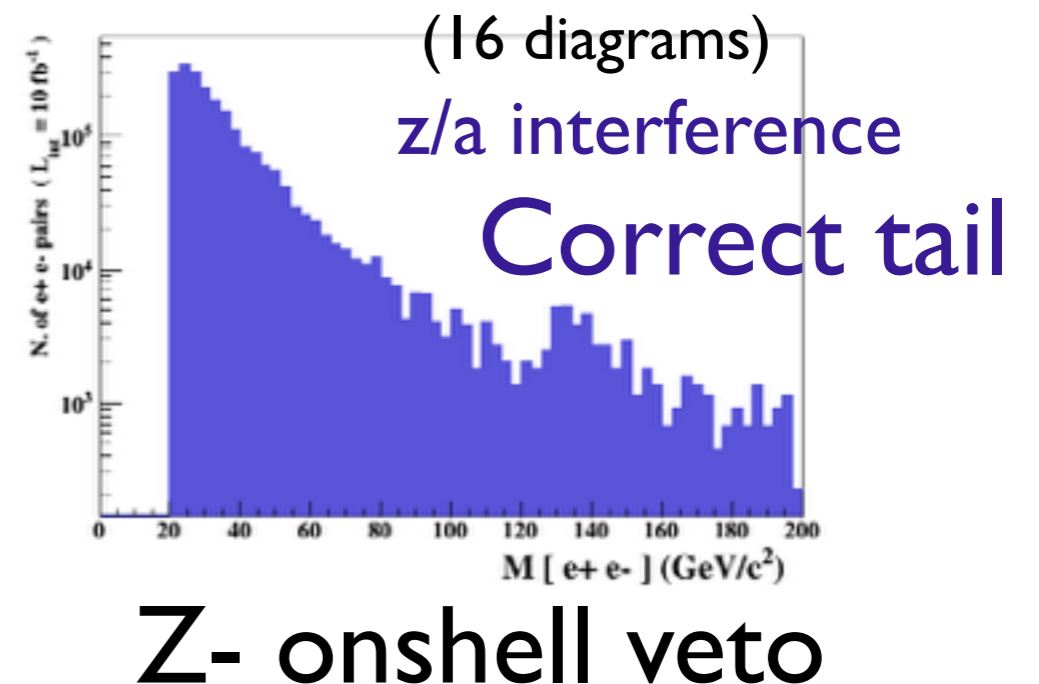


Z Peak



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

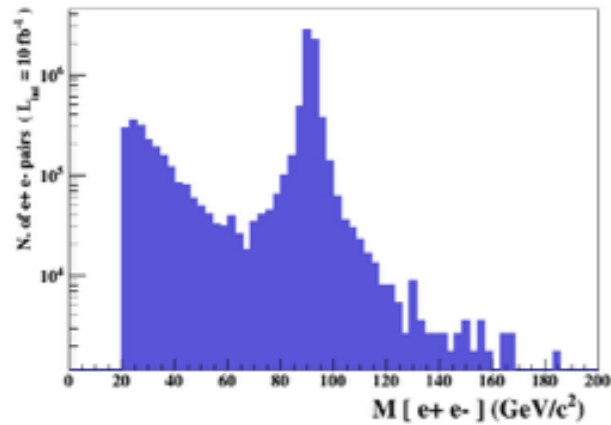
$pp \rightarrow e^+ e^- \text{ } \cancel{z}$



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

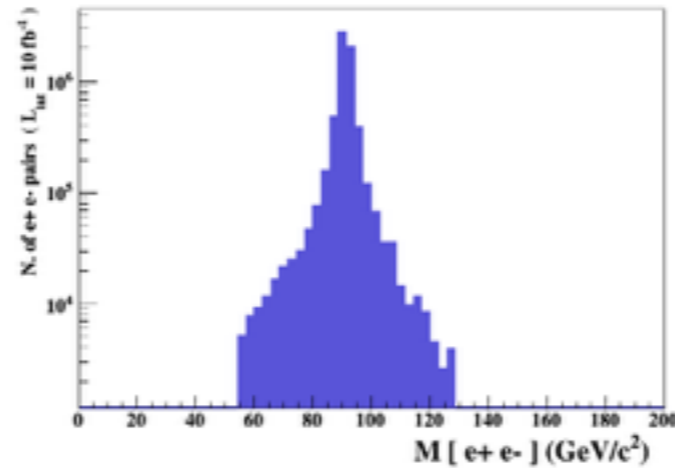
$p p \rightarrow Z, Z \rightarrow e^+ e^-$

$p p \rightarrow e^+ e^- \text{ } \$ \text{ } Z$



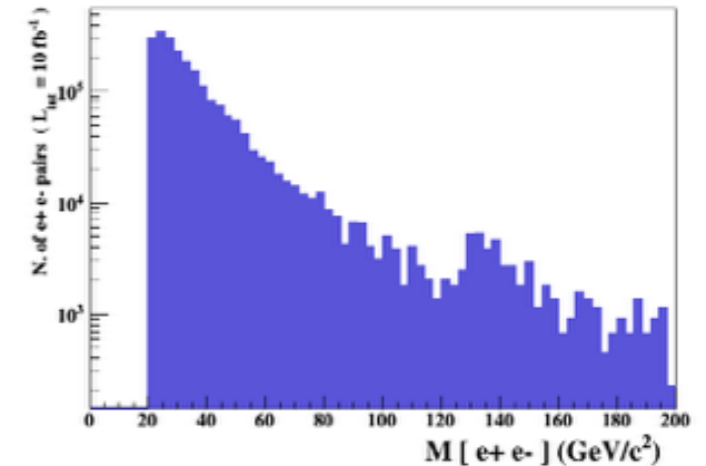
(16 diagrams)

=



(8 diagrams)

+



(16 diagrams)

Onshell cut: BW_cut

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

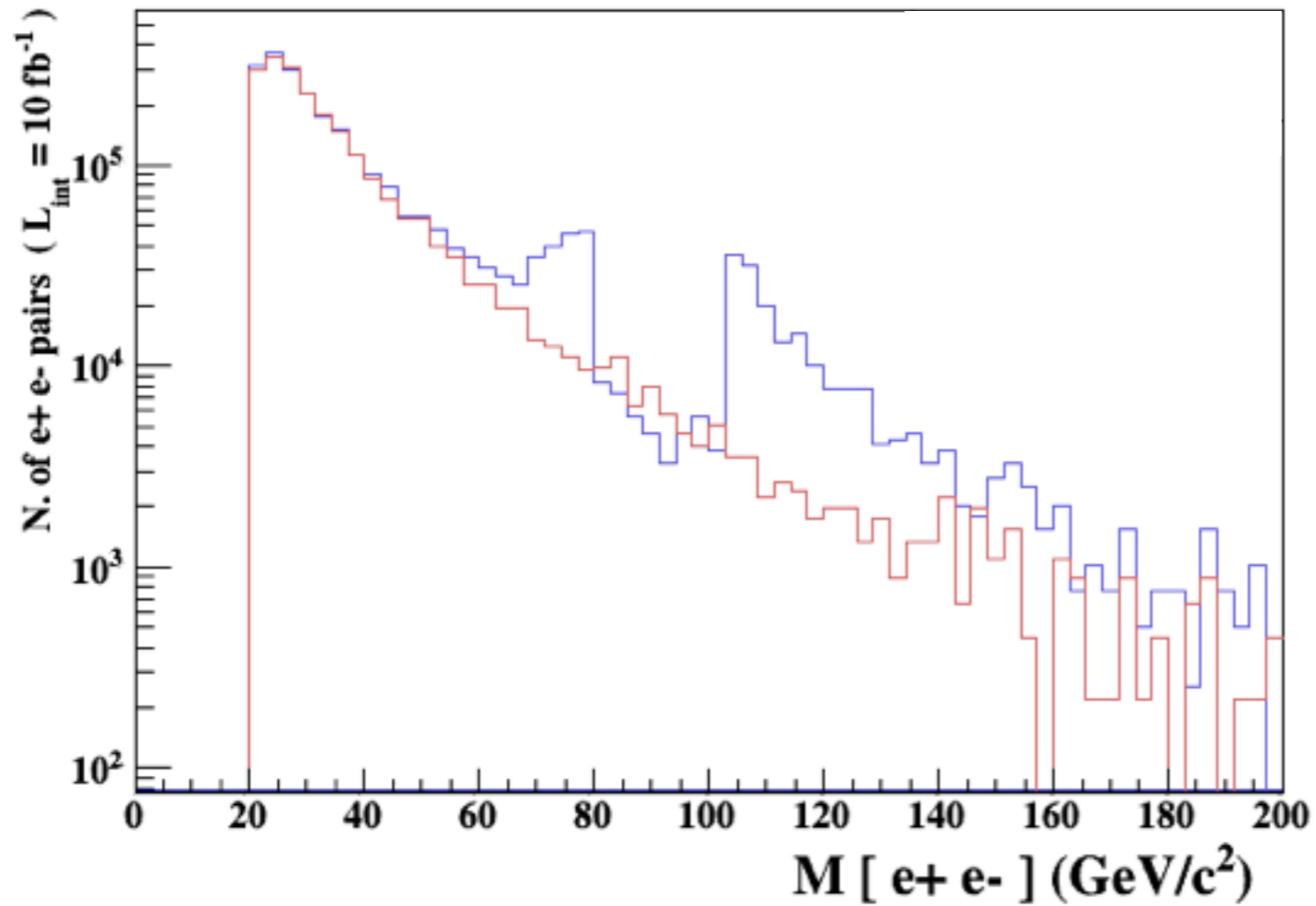
- The Physical distribution is (very close to) exact sum of the two other one.
- The “\$” forbids the Z to be onshell but the photon invariant mass can be at MZ (i.e. on shell subtraction).
- The “/” is to be avoid if possible since this leads to violation of gauge invariance.

- 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.

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

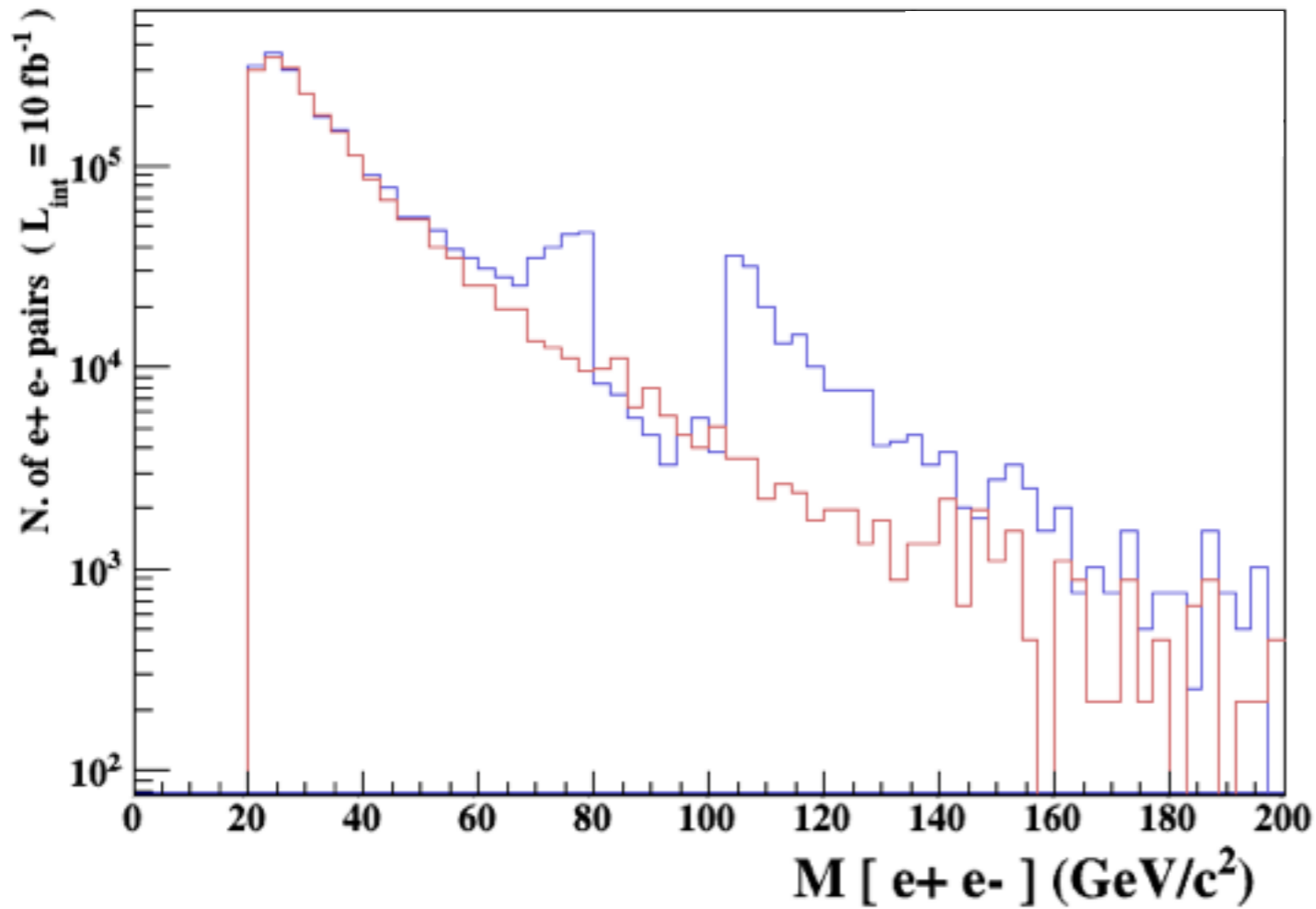
(red curve)

(blue curve)



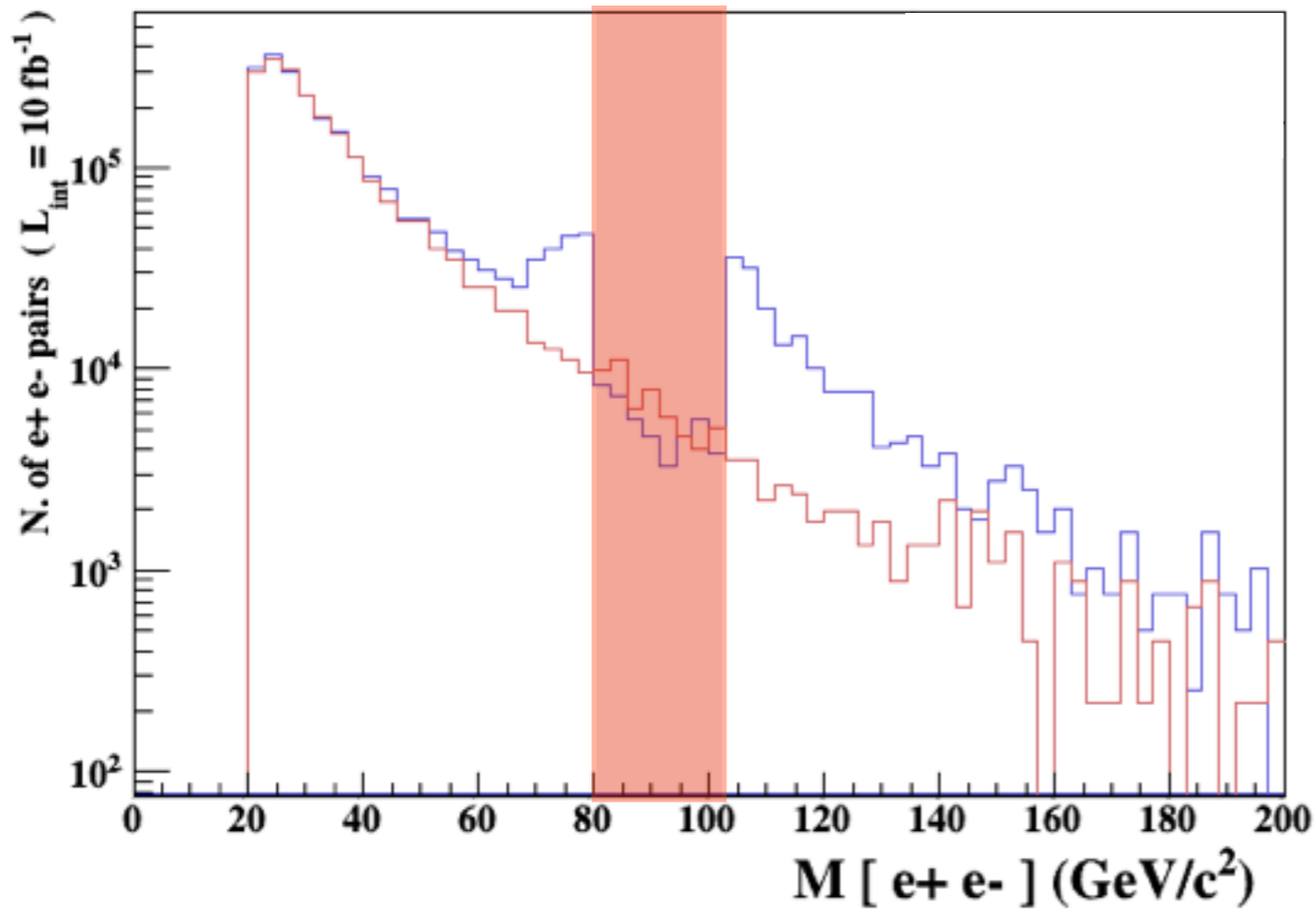
$p p > e^+ e^- / Z$
(red curve)

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



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

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

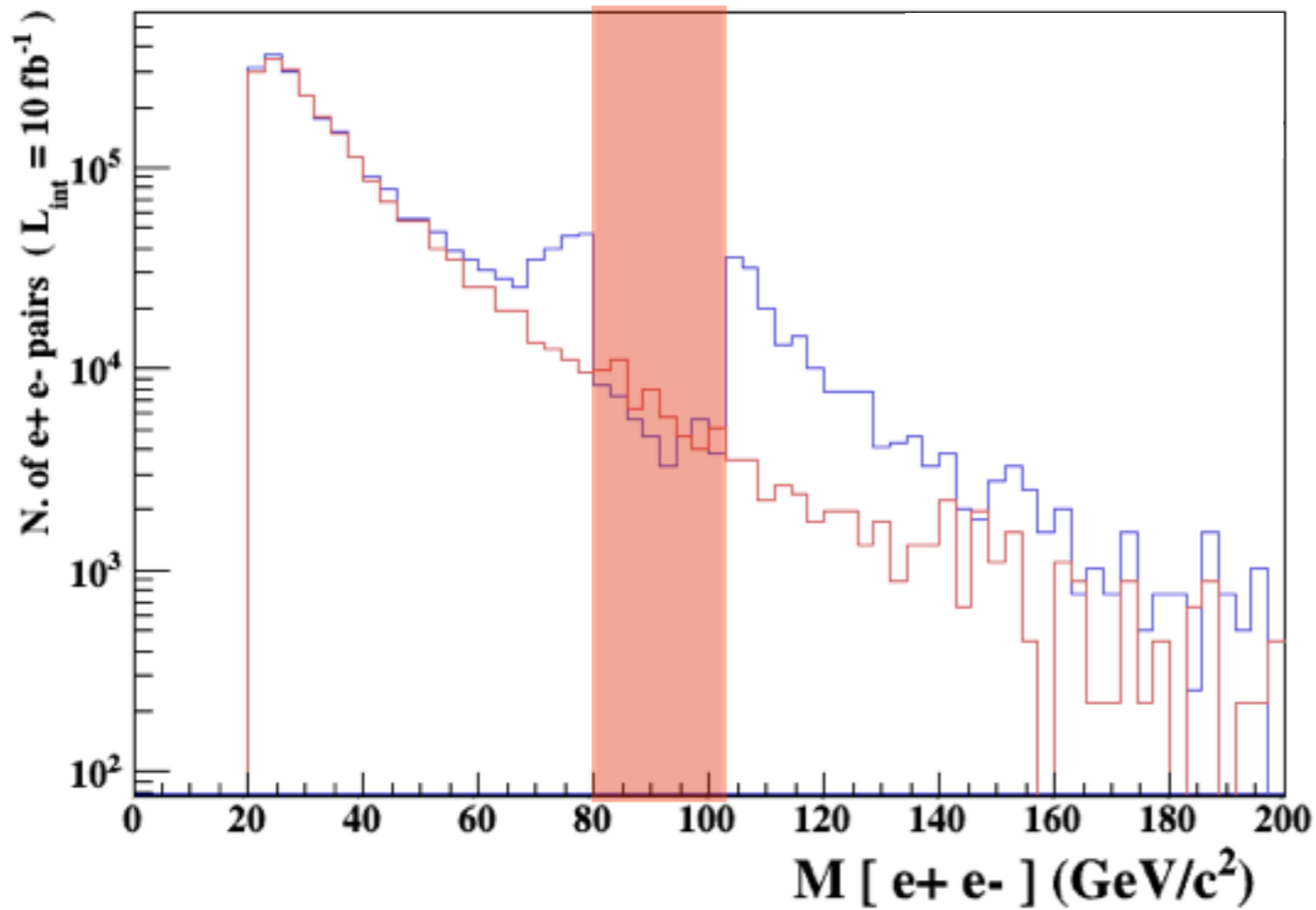


- Z onshell veto

5 times width area

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

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

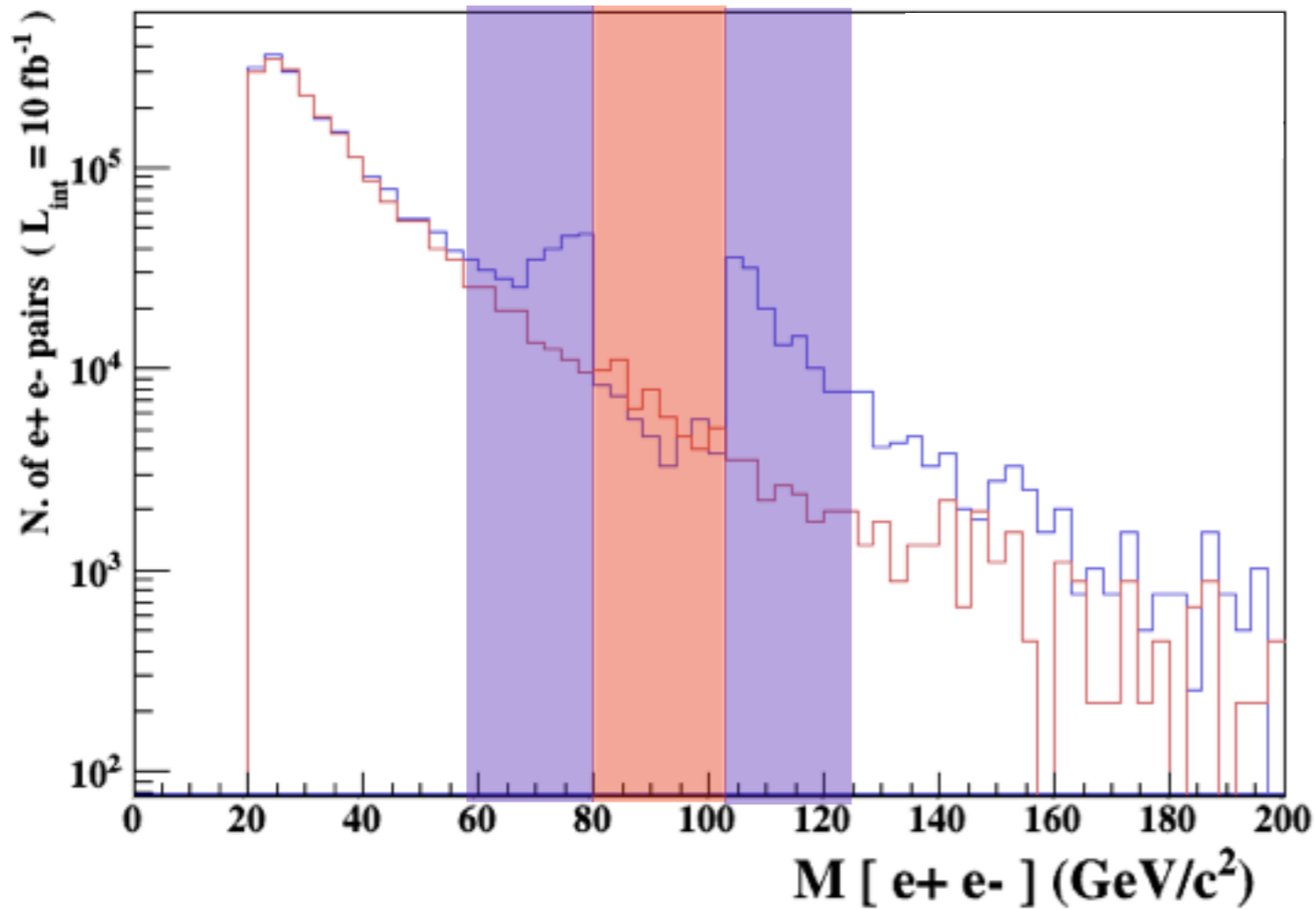


- Z onshell veto
- In veto area only photon contribution

5 times width area

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

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



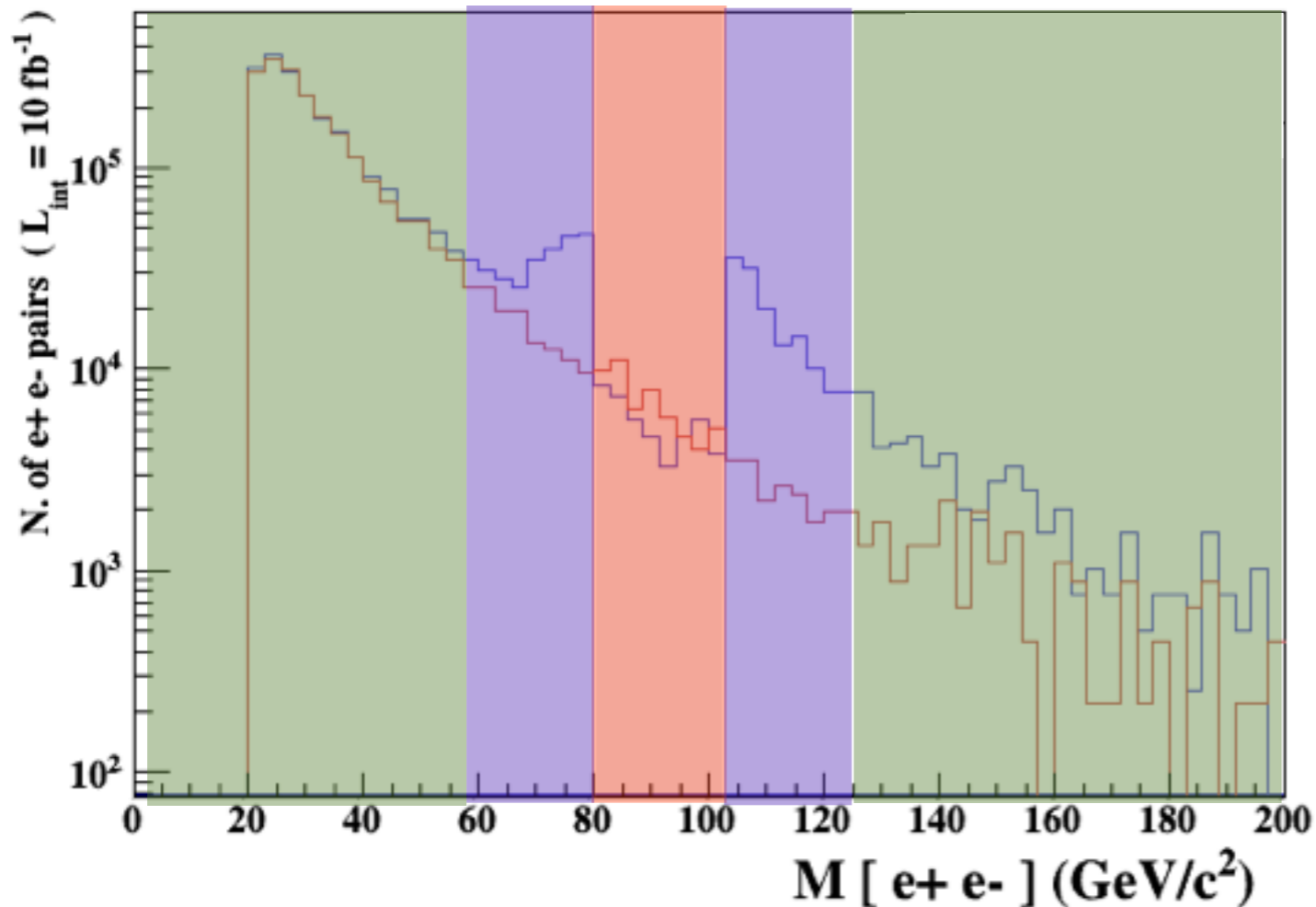
- Z onshell veto
- In veto area only photon contribution
- area sensitive to z-peak

5 times width area

15 times width area

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

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

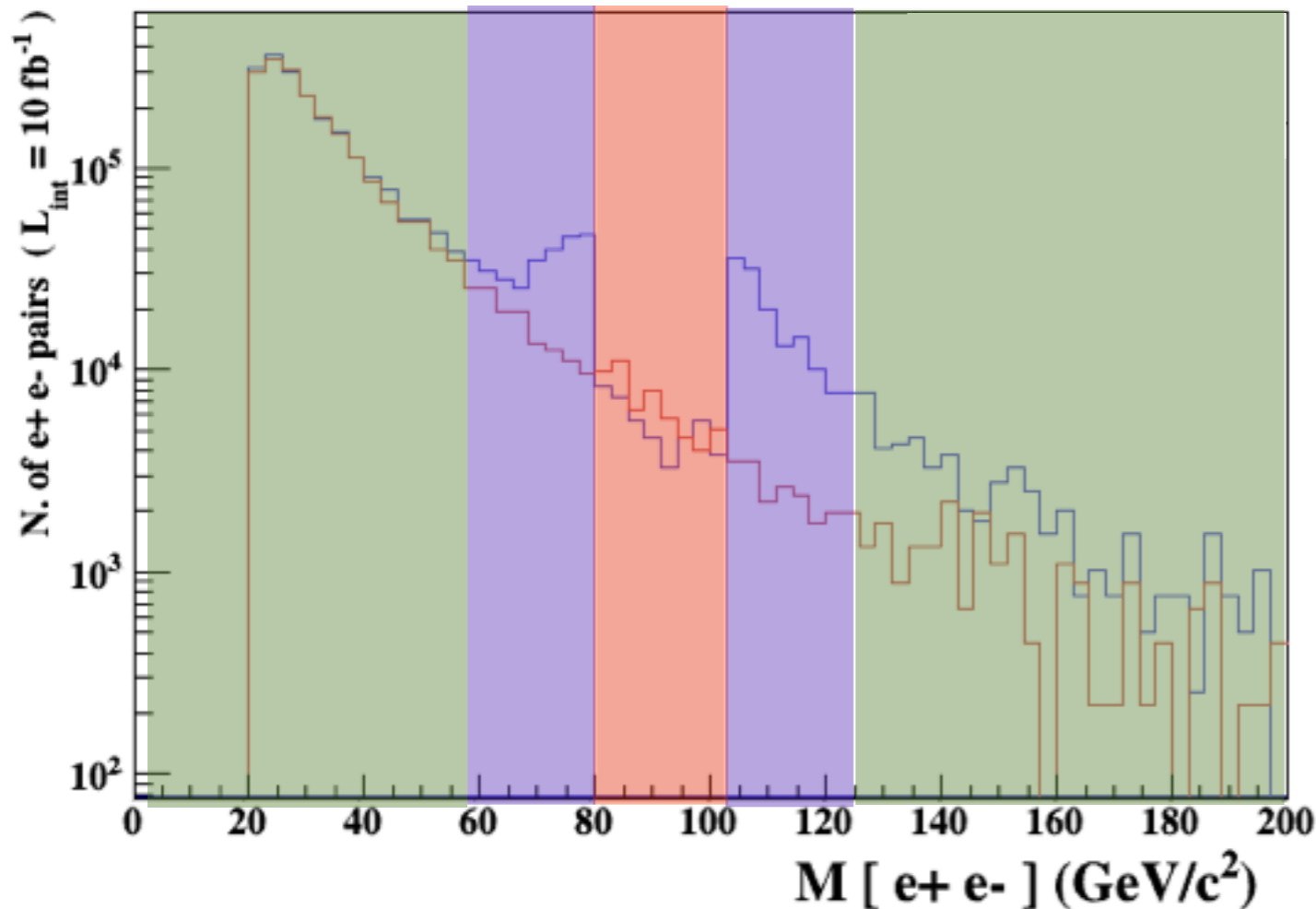
5 times width area

15 times width area

> 15 times width area

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

adding $p p \rightarrow e^+ e^- \$ Z$
(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 “\$” can be use to split the sample in BG/SG area

- 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

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

(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.

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 provides un-physical distributions.

Avoid Those as much as possible!

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

- Syntax like
 - $p p \rightarrow z, z \rightarrow e^+ e^-$ (on-shell z decaying)
 - $p p \rightarrow e^+ e^- \cancel{z}$ (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

- 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.

- 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

MadSpin

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

MadSpin Card

```

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

2m18.214s

0.004707 pb

MadGraph

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

9m30.806s

0.003014 pb

Cross-section is different because MadGraph has cut on the final states that MadSpin do not have. Since the 2.3 the default is no cut for particle coming from decay. This corresponds to cut_decays parameter in the run_card