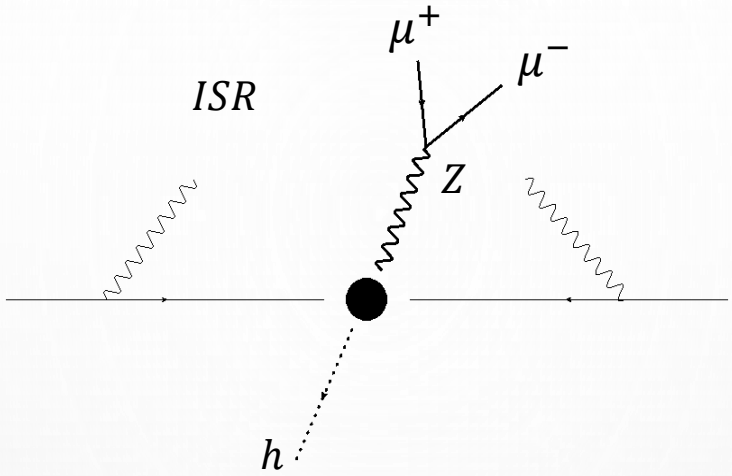
# Searching for a Higgs-like scalar using $e^+ + e^- \rightarrow Z + h \rightarrow \mu^+ + \mu^- + h$ channel

YAN WANG

ILD GROUP MEETING

2017-05-24



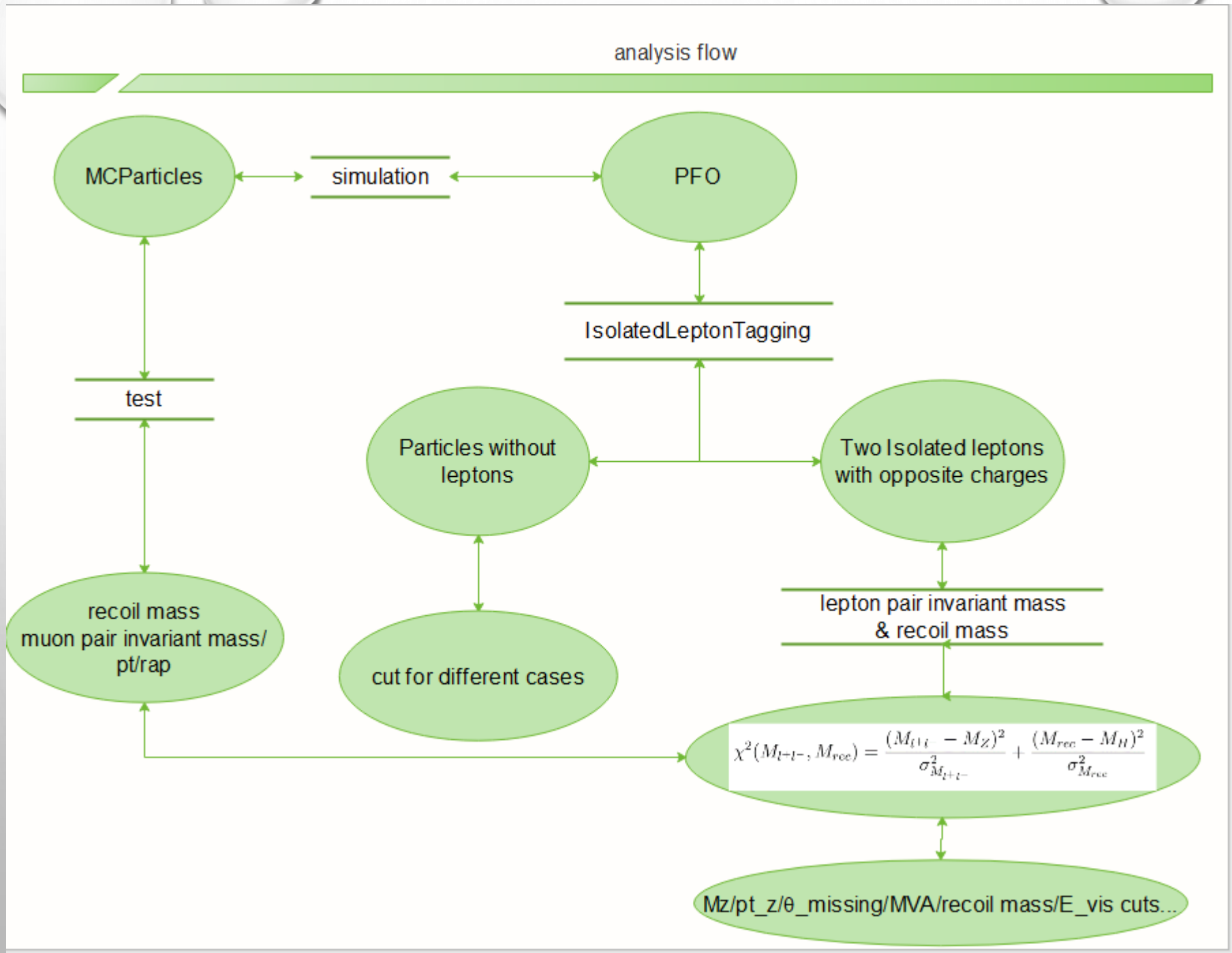

1. $h$ is a higgs-like particle, its mass can be lighter than the SM Higgs.
2. This kind of scalar, which can still escape the constrains from LEP results, exists in many models --- by adding Higgs scalar singlets and/or doublets to the SM Higgs part with the very small coupling. ( A. Belyaev, etc.. Phys.Rev.D 81 095006)
3. We choose $M_h = 10, 30, 50, 70, 90, 115$ GeV.

Signal: $e^+ + e^- \rightarrow Z + h$, with $Z \rightarrow \mu^+ + \mu^-$,

$h$ decays profile do not differ much from the SM higgs.

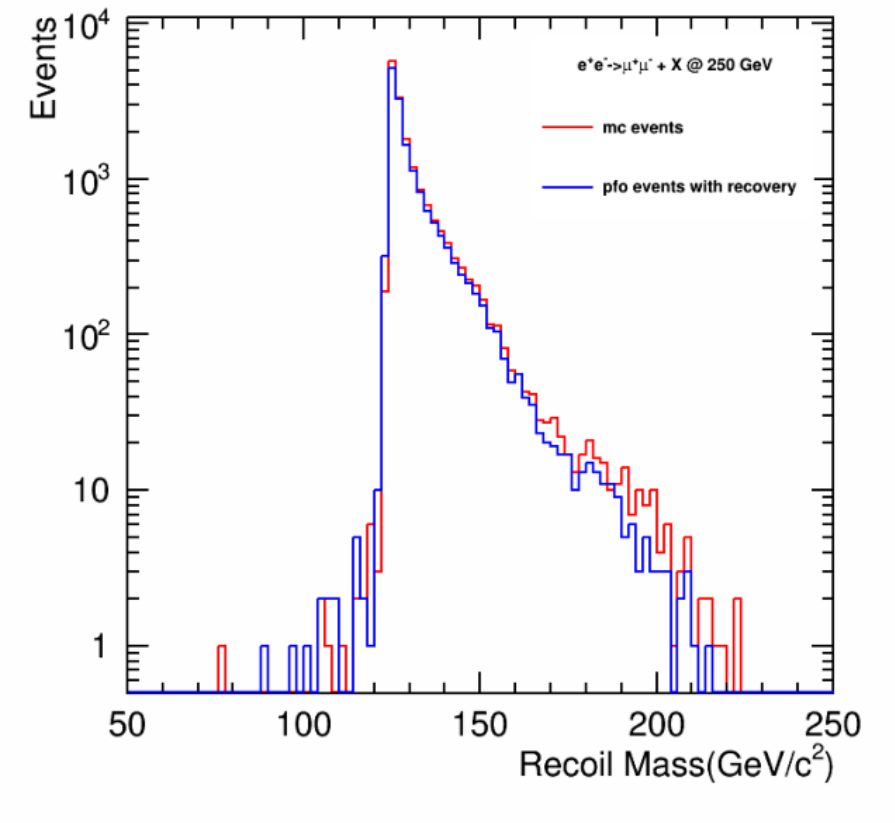
SM Background:

- 2-lepton: 2- $ZZ/\gamma\gamma$ pair with $\mathrm{Z}/\gamma^* \rightarrow \mu^+\mu^-$ and $\mathrm{Z}/\gamma^* \rightarrow \nu\nu$
- 2-lepton: $WW$ pair with both $W \rightarrow \mu\nu_\mu$
- 4-lepton: $ZZ/\gamma\gamma$ pair with $\mathrm{Z}/\gamma^* \rightarrow \mu^+\mu^-$ and $\mathrm{Z}/\gamma^* \rightarrow \mu^+\mu^-/e^+e^-$
- 4-fermion, semi-lepton: $ZZ/WW$ with $\mathrm{Z} \rightarrow \mu^+\mu^-, \mathrm{Z} \rightarrow qq$ or $W \rightarrow \mu\nu_\mu, W \rightarrow qq$
- 4-fermion, hadronic: $ZZ/WW \rightarrow 4q$

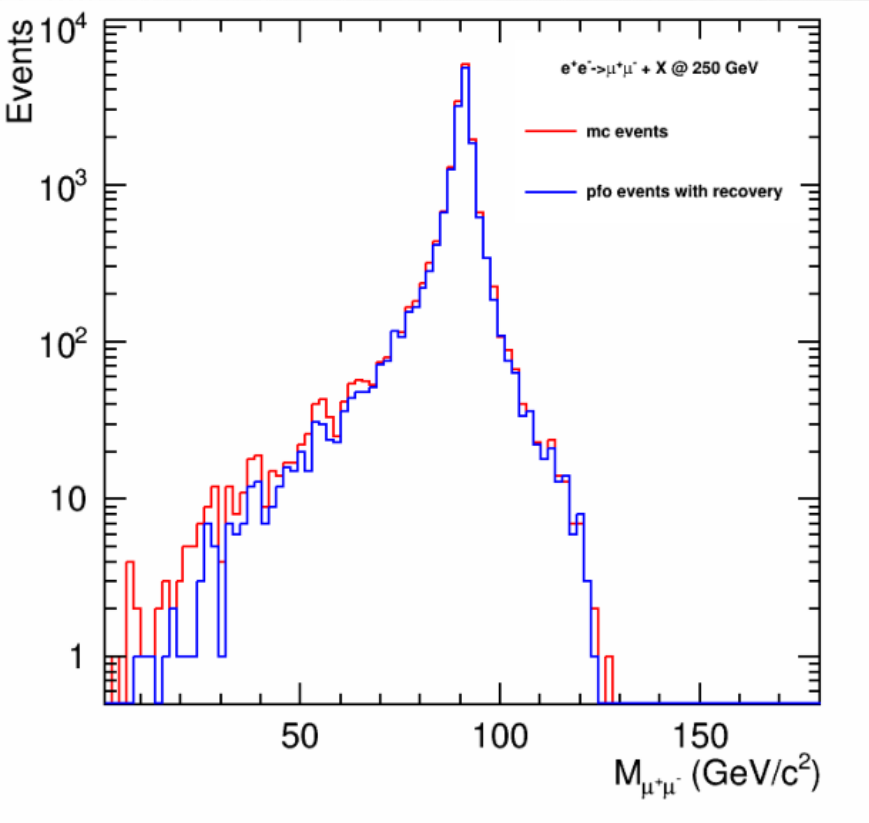

analysis flow
MCParticles
simulation
PFO
IsolatedLeptonTagging
test
Particles without leptons
Two Isolated leptons with opposite charges
recoil mass
muon pair invariant mass/
pt/rap
cut for different cases
lepton pair invariant mass
& recoil mass
$\chi^2(M_{l^+l^-}, M_{rec}) = \frac{(M_{l^+l^-} - M_Z)^2}{\sigma^2_{M_{l^+l^-}}} + \frac{(M_{rec} - M_H)^2}{\sigma^2_{M_{rec}}}$
Mz/pt_z/θ_missing/MVA/recoil mass/E_vis cuts...

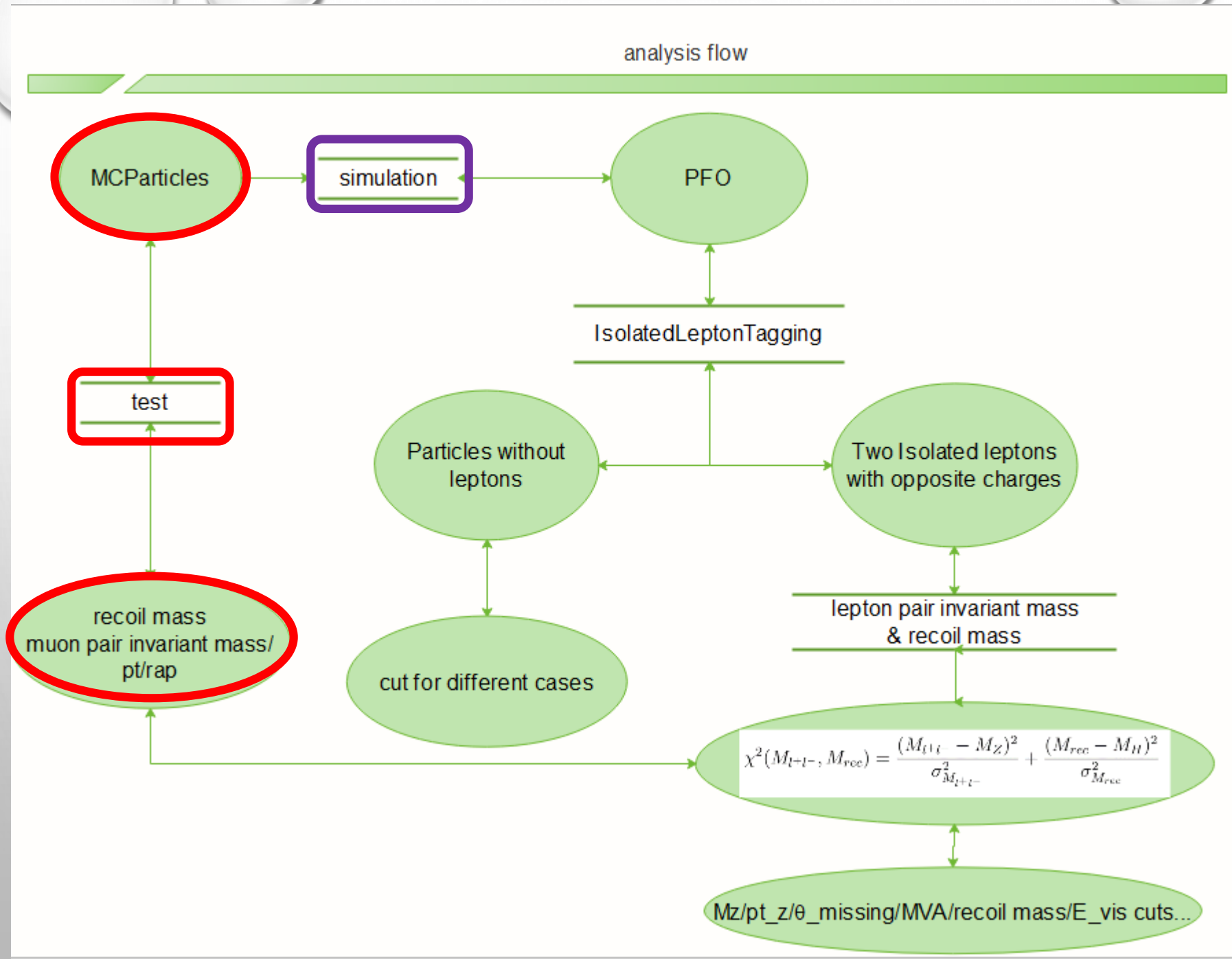
# Part of results for 125 GeV higgs

Recoil mass




Reconstructed Z mass

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Mz/pt_z/θ_missing/MVA/recoil mass/E_vis cuts...

# Need full-simulated MC samples

- Whizard-1.95 + Pythia-6.4
- Whizard setting:

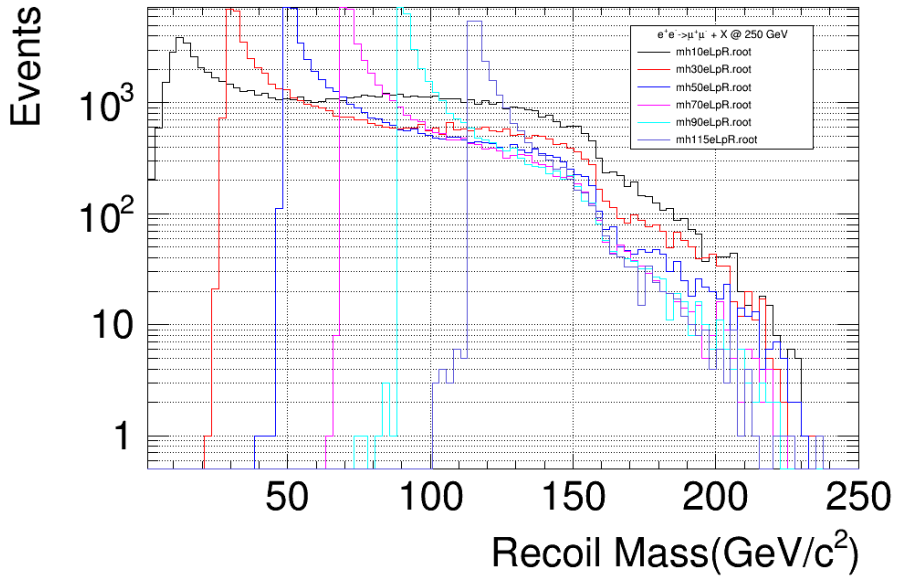
following the 250 GeV ILC DBD higgs events configuration

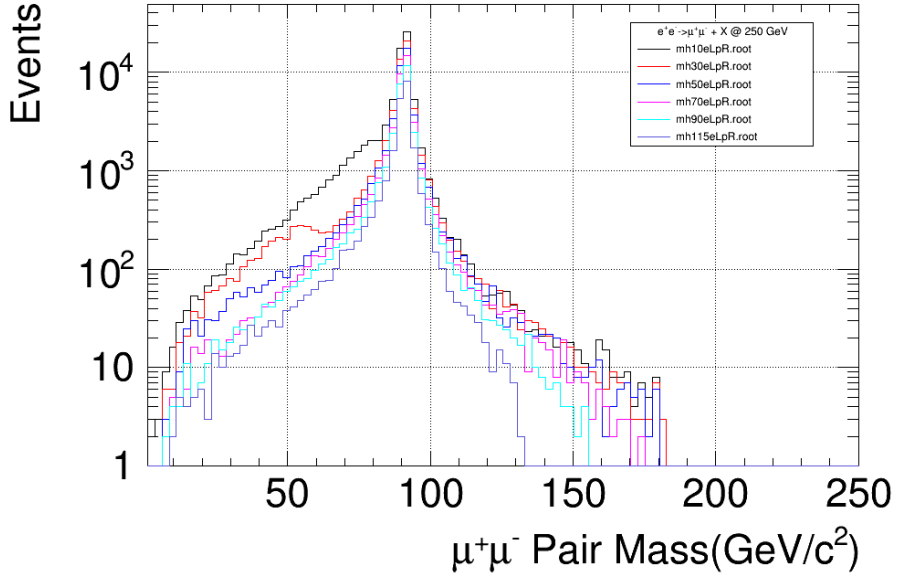
- ILCSoft v01-17-11

| events | $m_h$ GeV | events number ($\mathcal{L} = 1000 fb^{-1}$) |
|---|---|---|
| mh115-eLpR | 115 | 17211 |
| mh115-eRpL | 115 | 10977 |
| mh90-eLpR | 90 | 30982 |
| mh90-eRpL | 90 | 19845 |
| mh70-eLpR | 70 | 38645 |
| mh70-eRpL | 70 | 24686 |
| mh50-eLpR | 50 | 46425 |
| mh50-eRpL | 50 | 29690 |
| mh30-eLpR | 30 | 56503 |
| mh30-eRpL | 30 | 35848 |
| mh10-eLpR | 10 | 79027 |
| mh10-eRpL | 10 | 50415 |
| total | | 440254 |

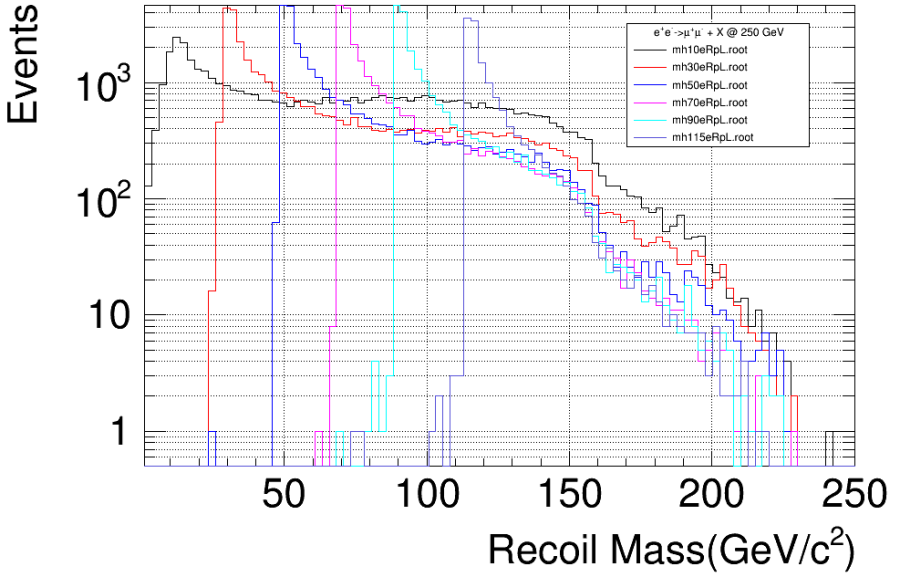
# MC results: compare the polarization

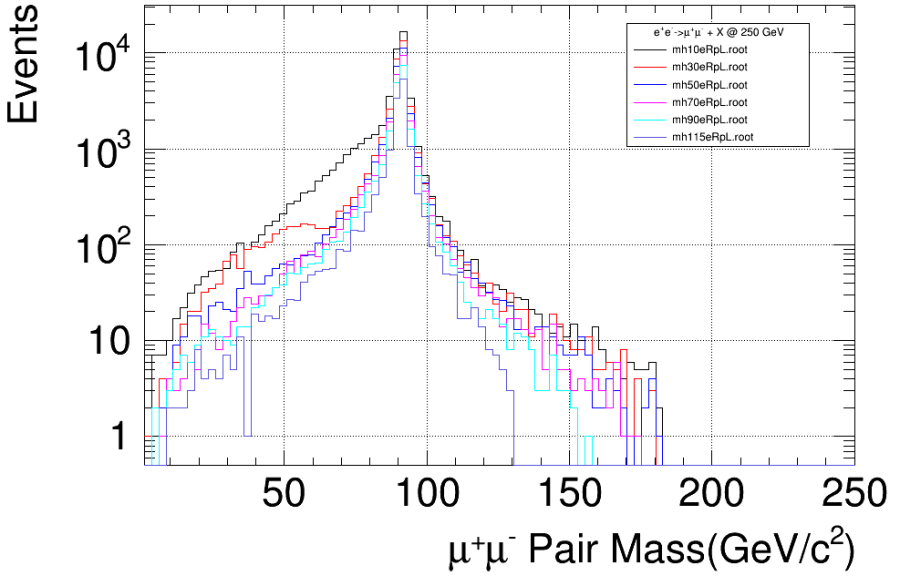
## eLpR



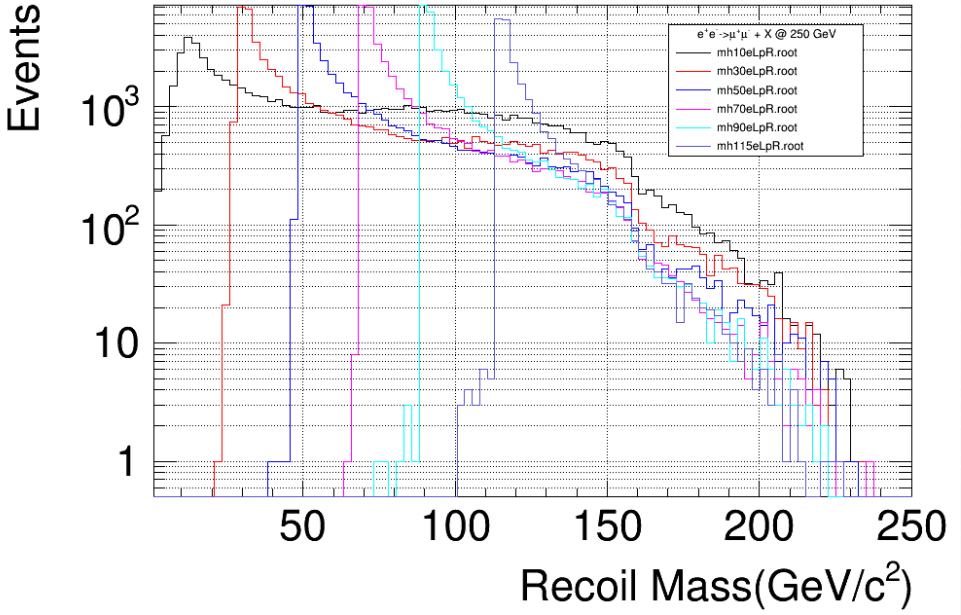




## eRpL



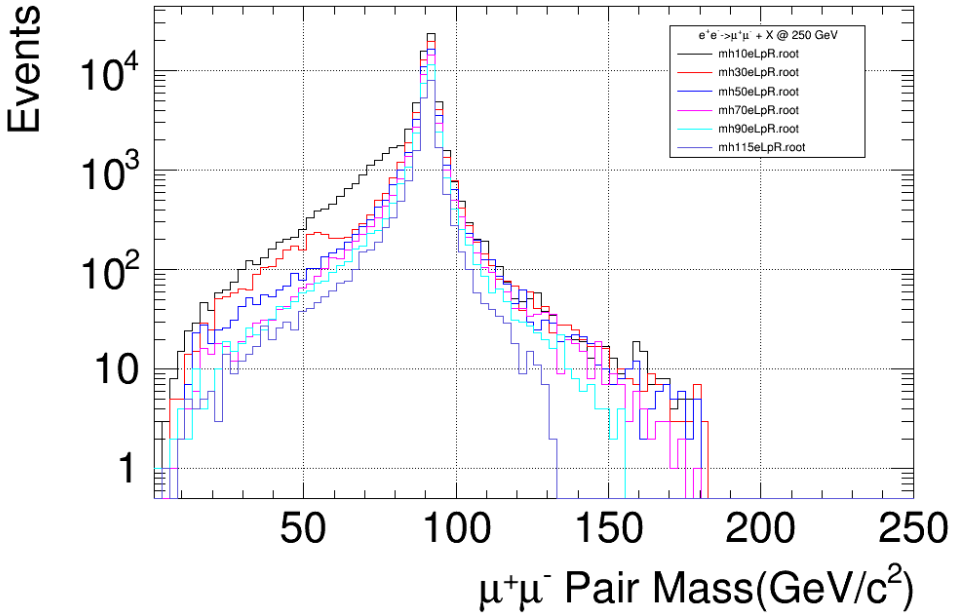



# Recoil mass

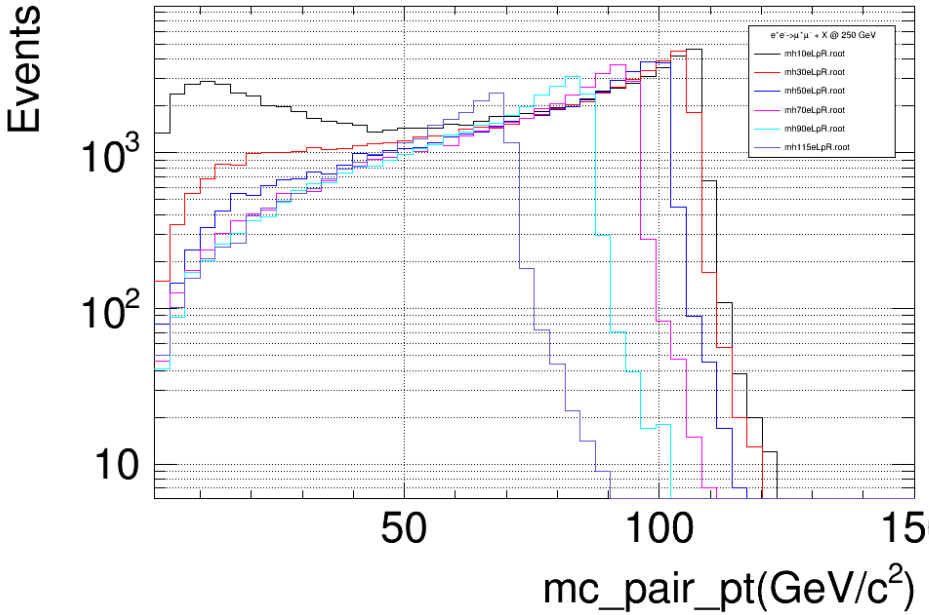



# MC results

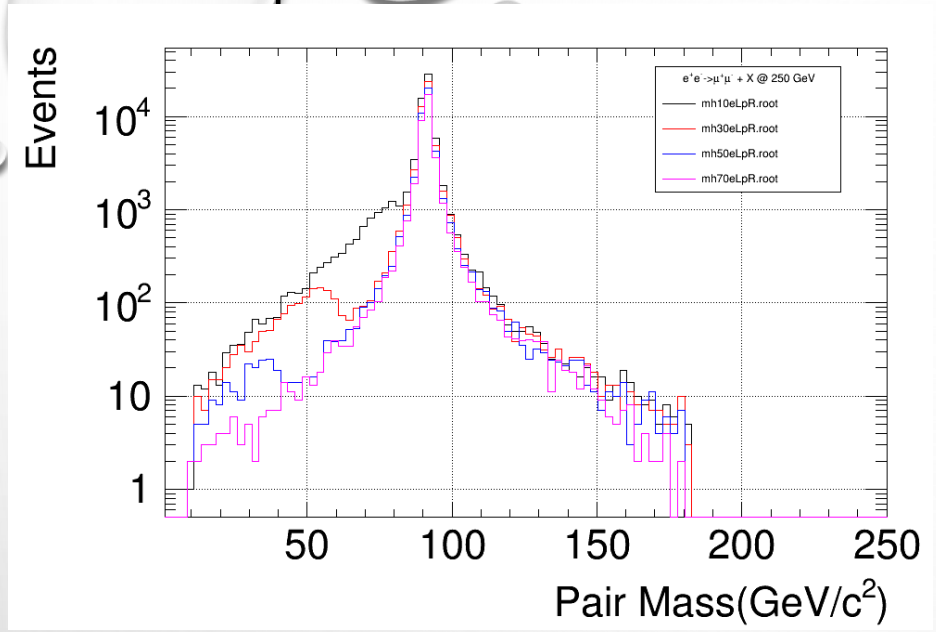
## Reconstructed Z mass

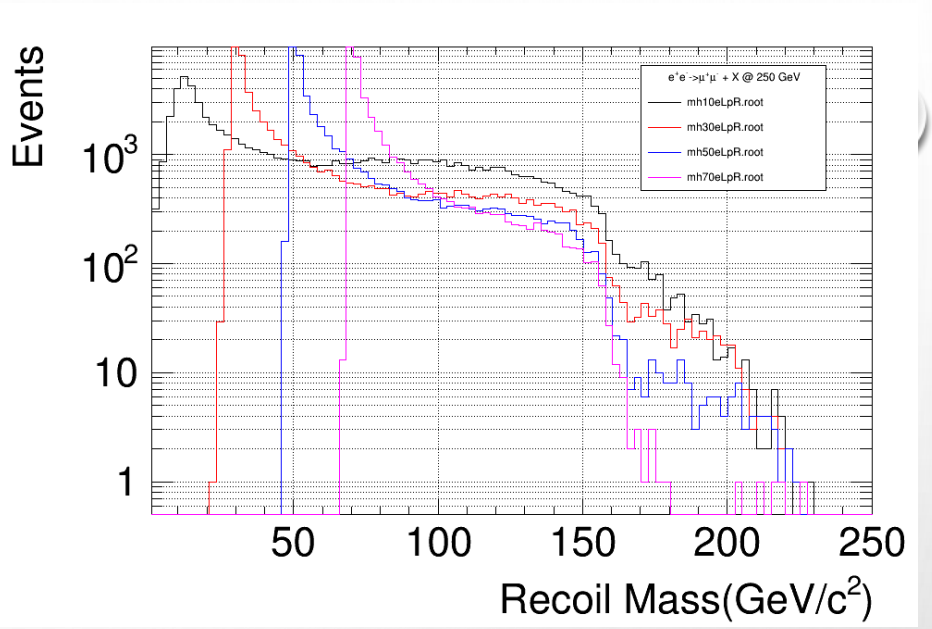



## Reconstructed Z pt

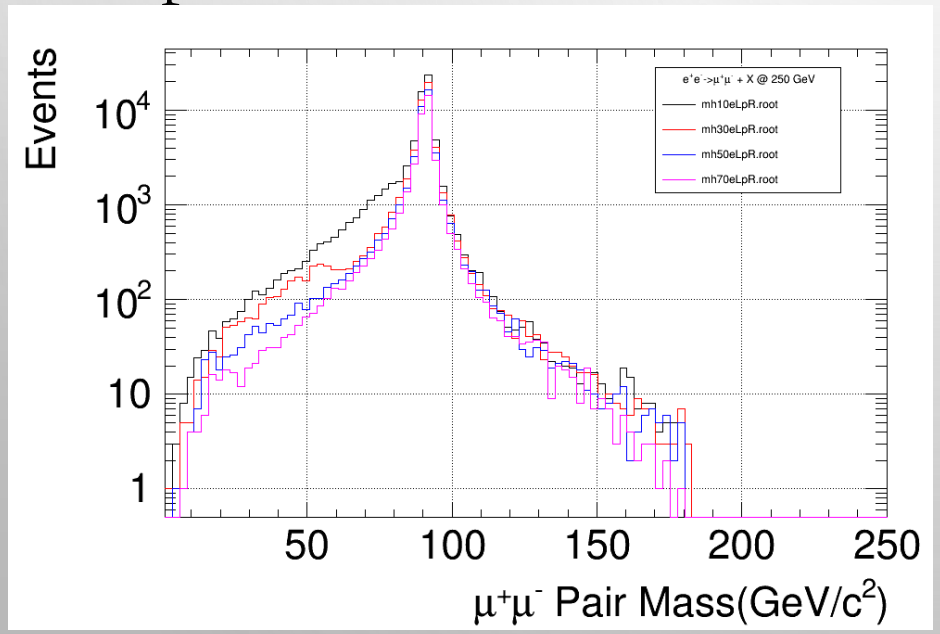


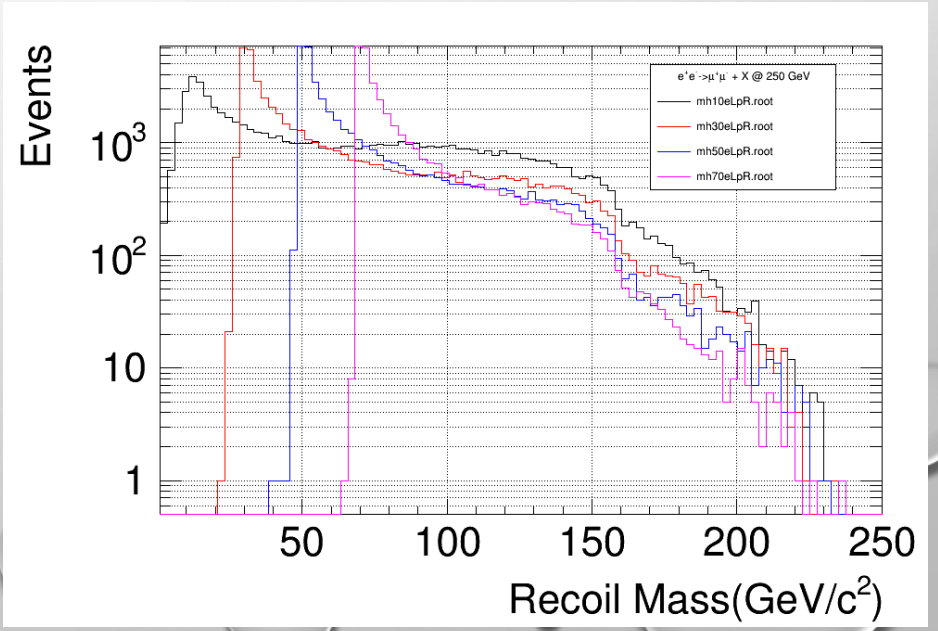
# without parton shower

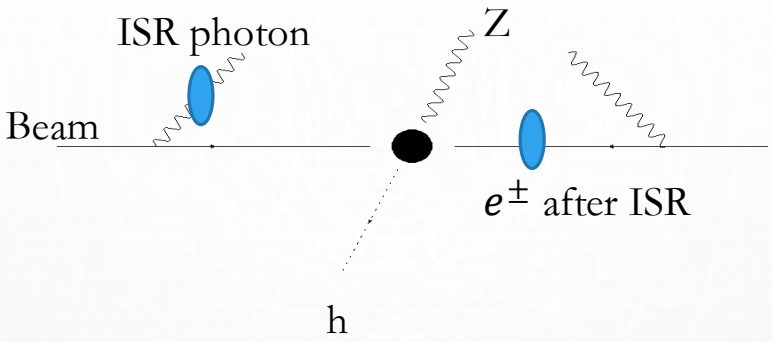



# with parton shower

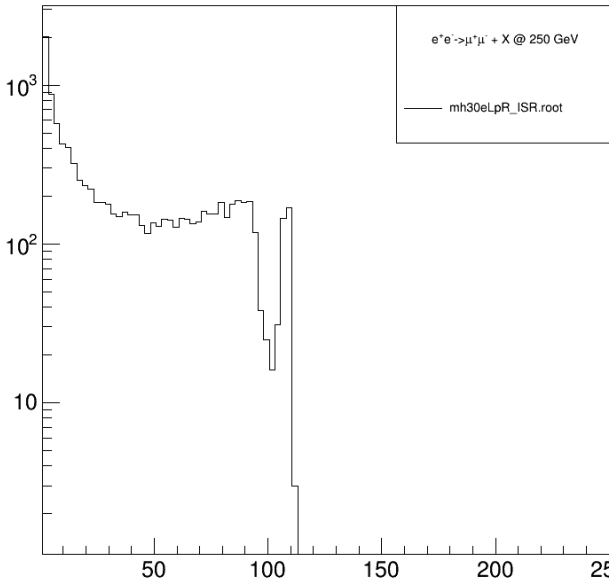


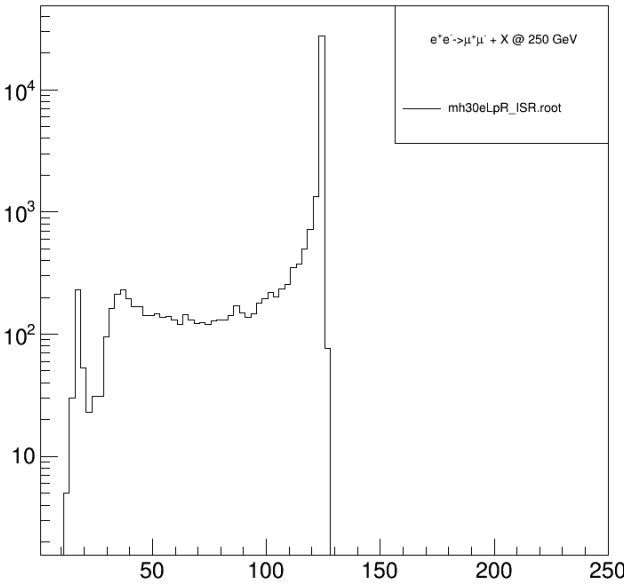



Take $m_h = 30\ GeV$ for example.

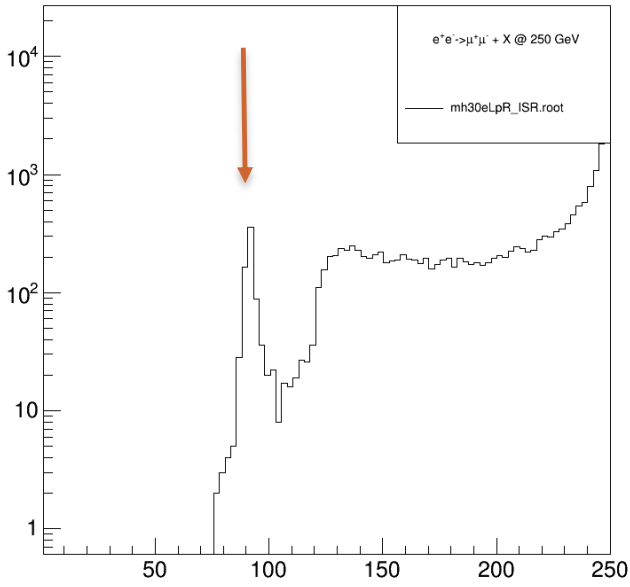
91 GeV



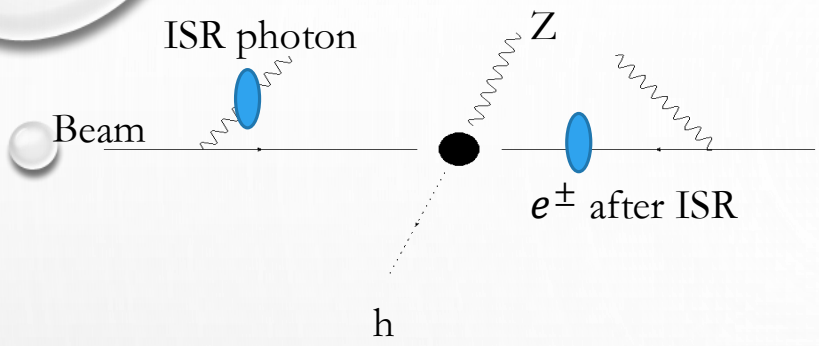

ISR photon energy



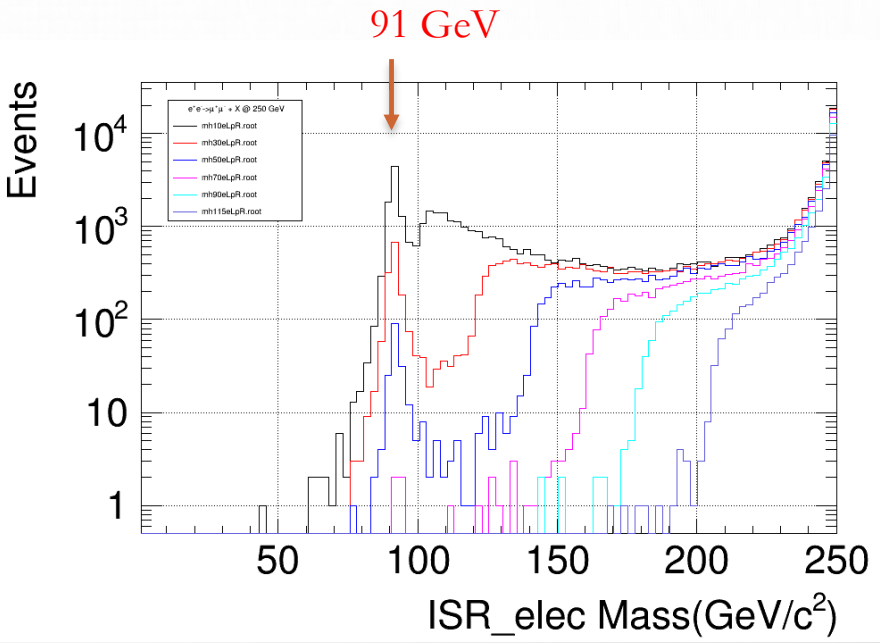

$e^-/e^+$ energy after ISR

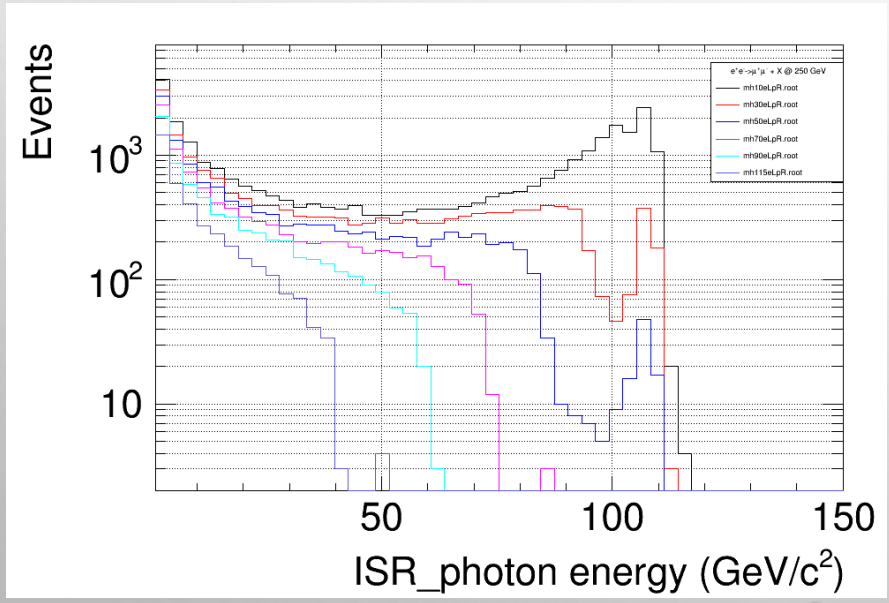



Invariant mass of $e^-e^+$

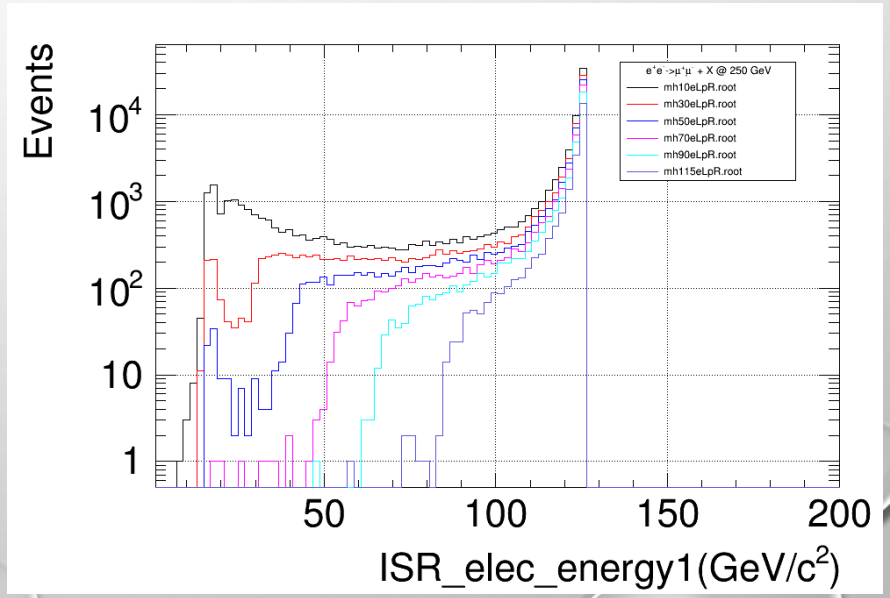



Invariant mass of $e^-e^+$



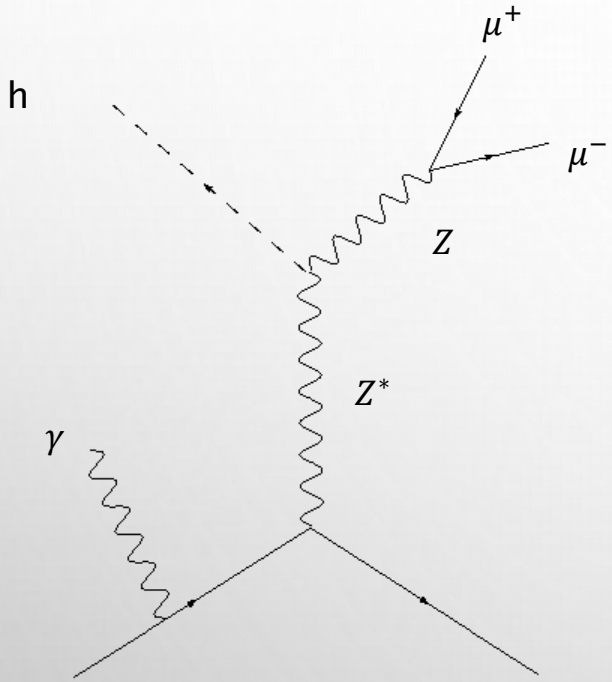




ISR photon energy

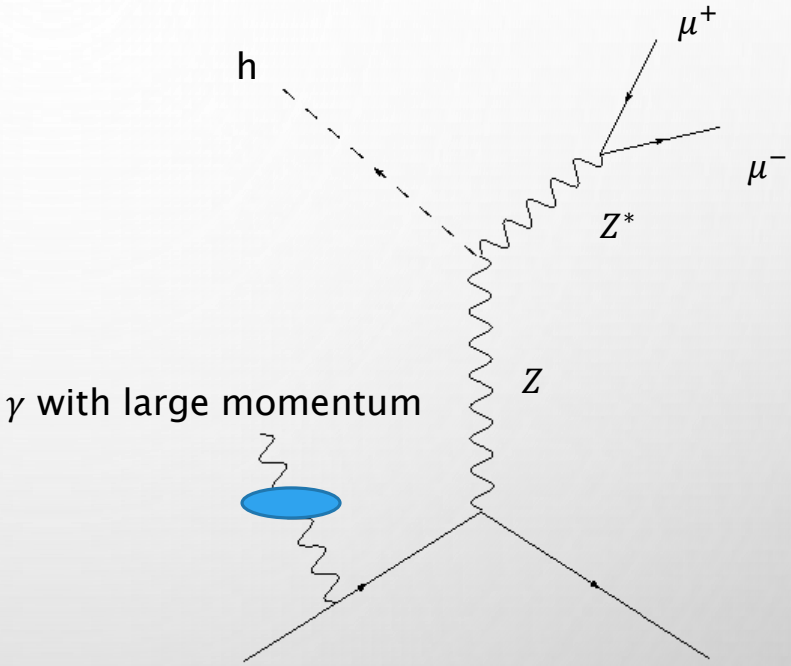


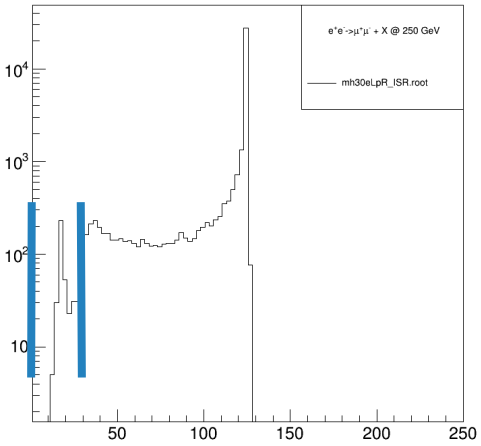

$e^-/e^+$ energy after ISR

general




For low higgs mass

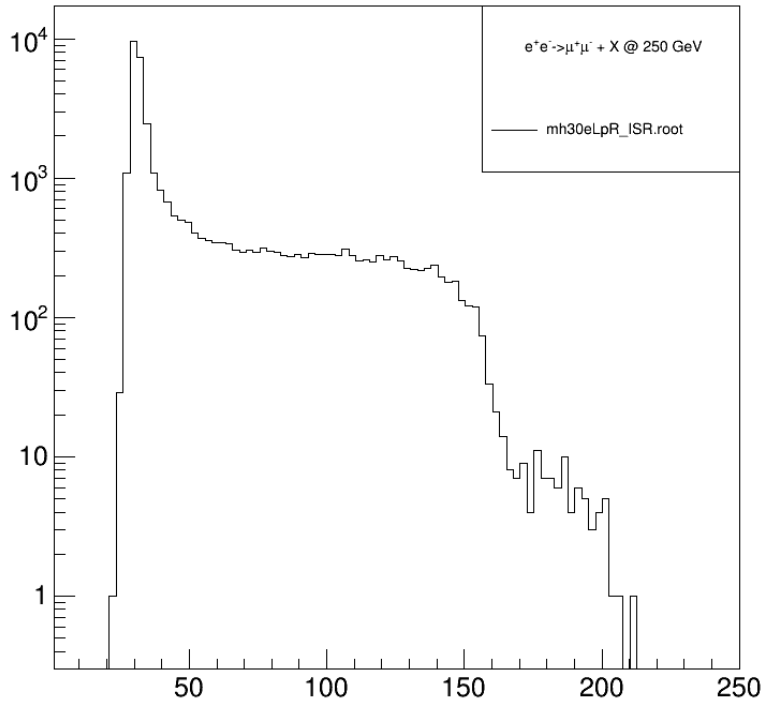




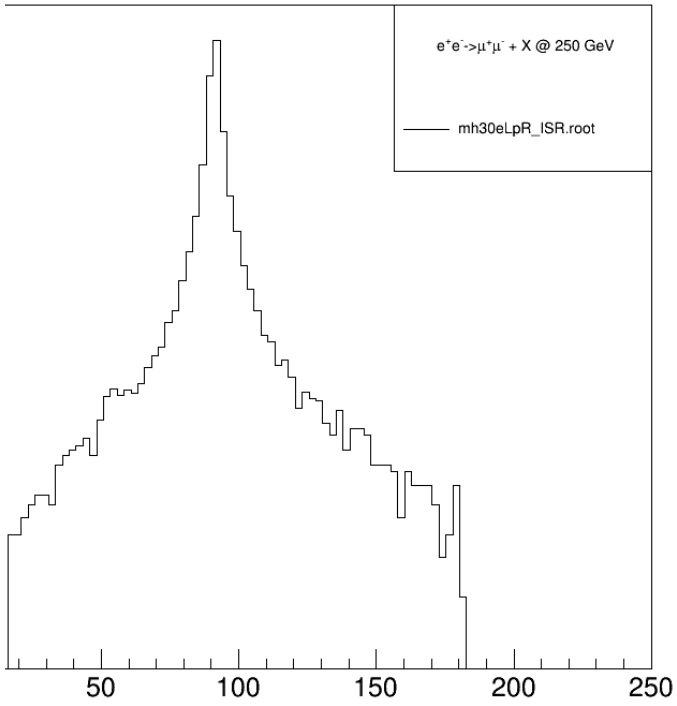

Cut on $e^-/e^+$ energy after ISR

# After cuts

Recoil mass

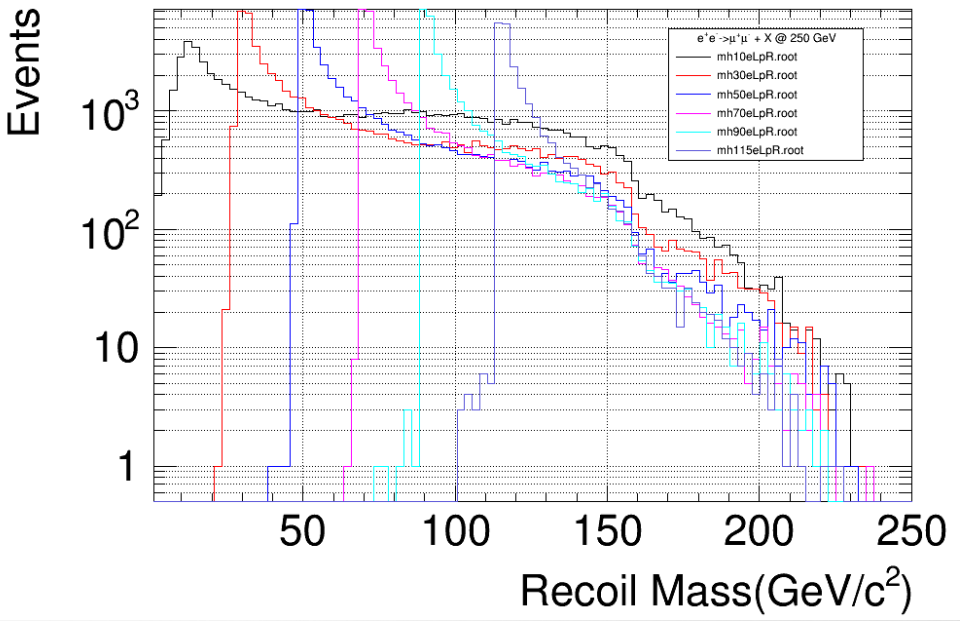



Reconstructed Z mass

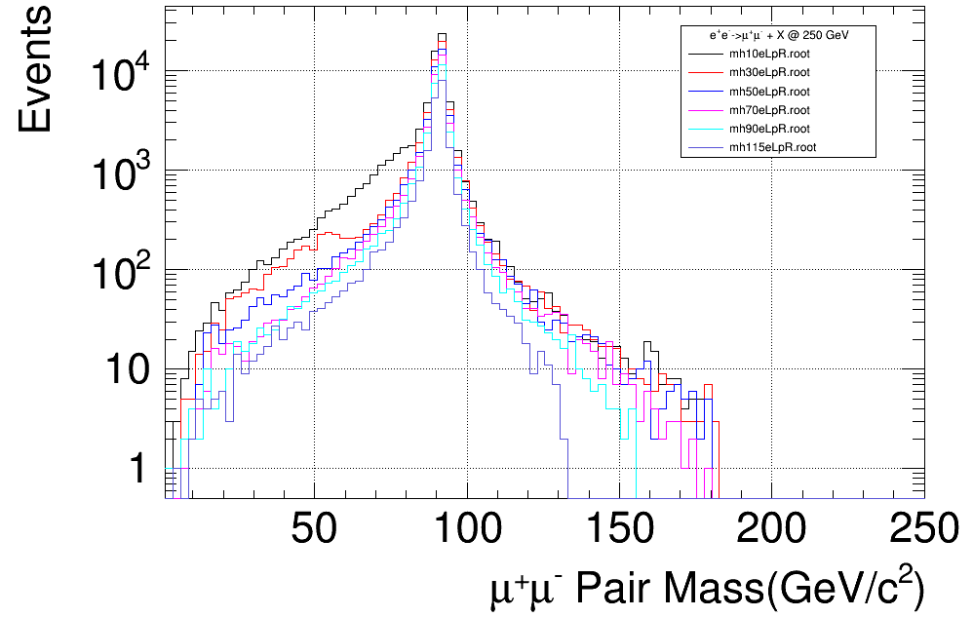


# MC results

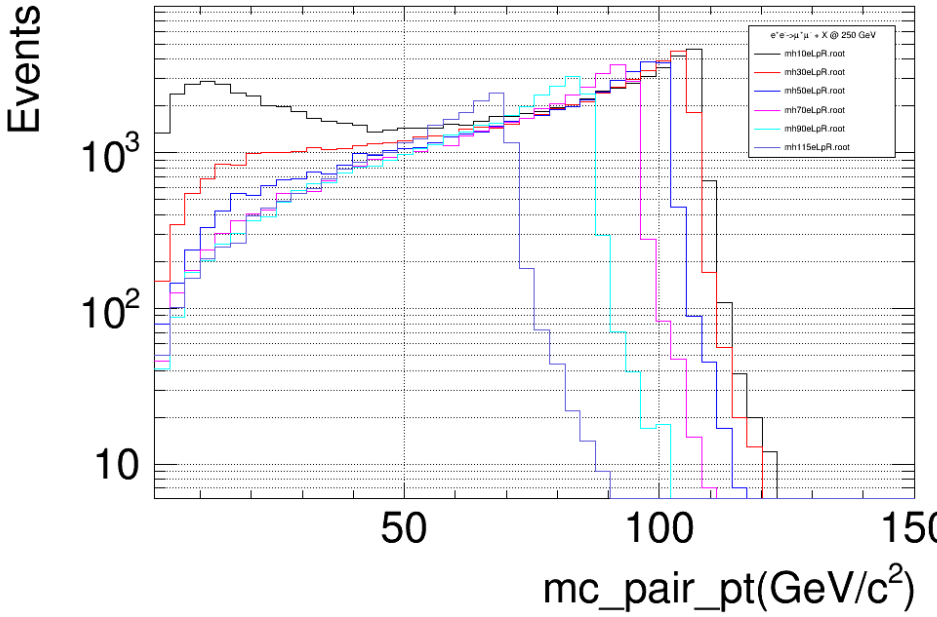
Recoil mass




Reconstructed Z mass



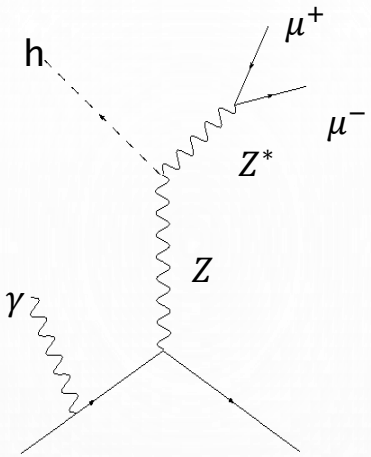

Reconstructed Z pt



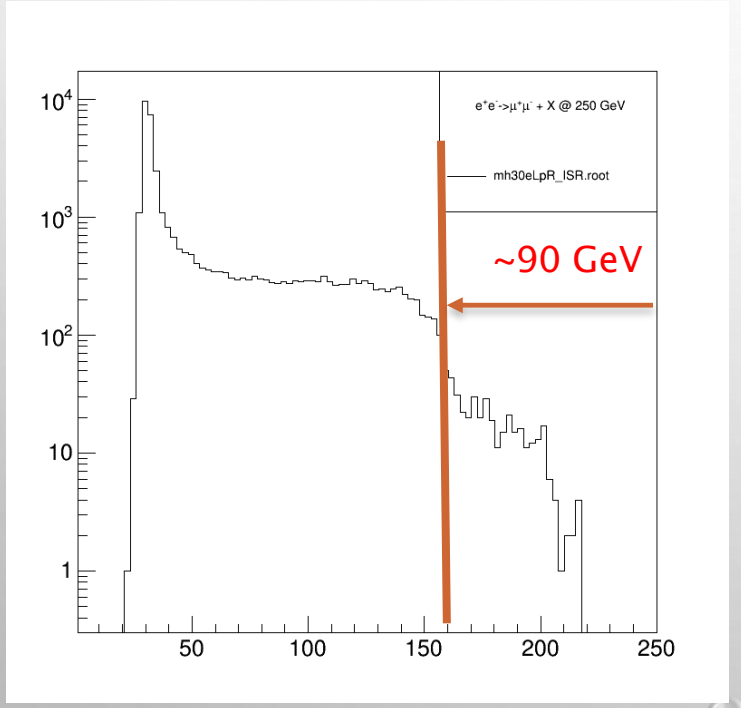
# Conclusion

- We generated $e^+ + e^- \rightarrow Z + h \rightarrow \mu^+ + \mu^- + h$ processes, where higgs masses are set to be 10,30,50,70,90,115 GeV.
- The total number of events, which needs to be simulated, are about 440,000.
- When higgs mass is small, there are some new effects.
- Study the background events distribution, and how to reject background events efficiently for different higgs mass.

# THANKS




Recoil mass

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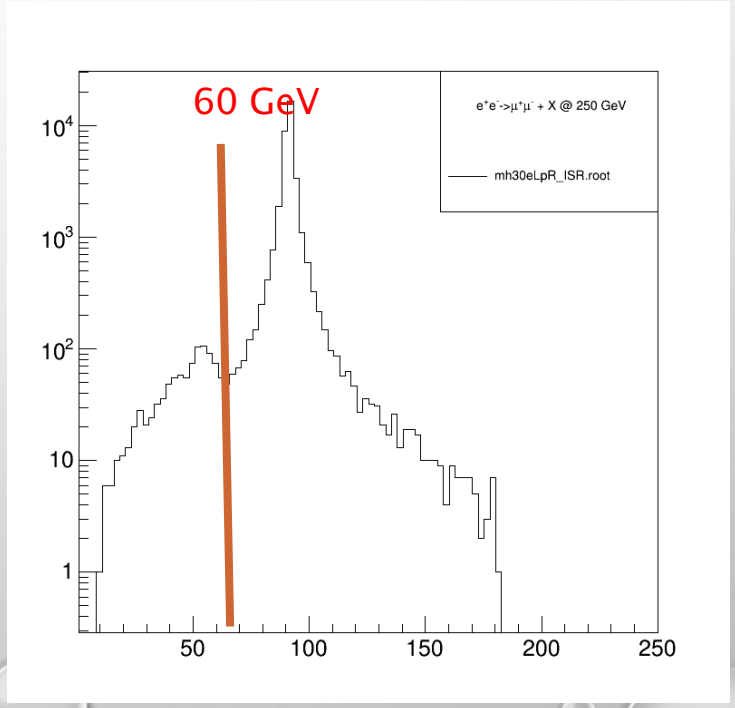


$M_h$ =30 Ge