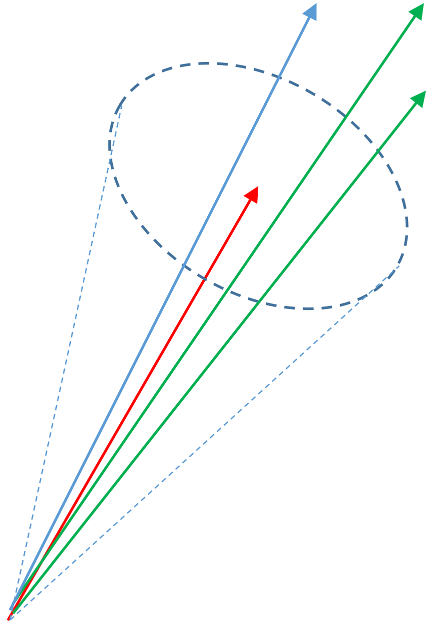
Analysis status of $Z(\to ee)H(Z\to\nu\nu, Z^*\to qq)$ (part-I. 2019-11-22)

“Cone” around the lepton (electron)

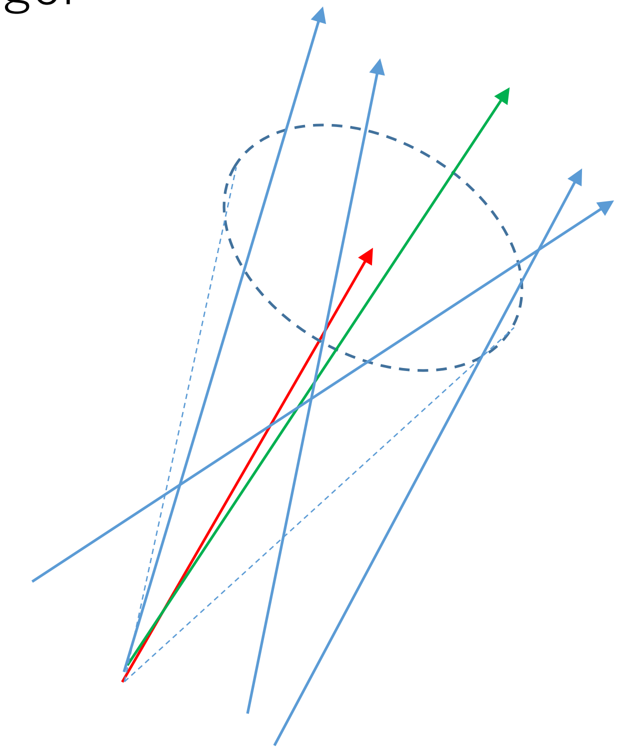
N(pfo) within the cone : smaller ⟷ larger

Average of the angle between lepton and the others: smaller ⟷ larger

cone angle is $\cos\theta > 0.98$ (~ 11 degree)



⟺

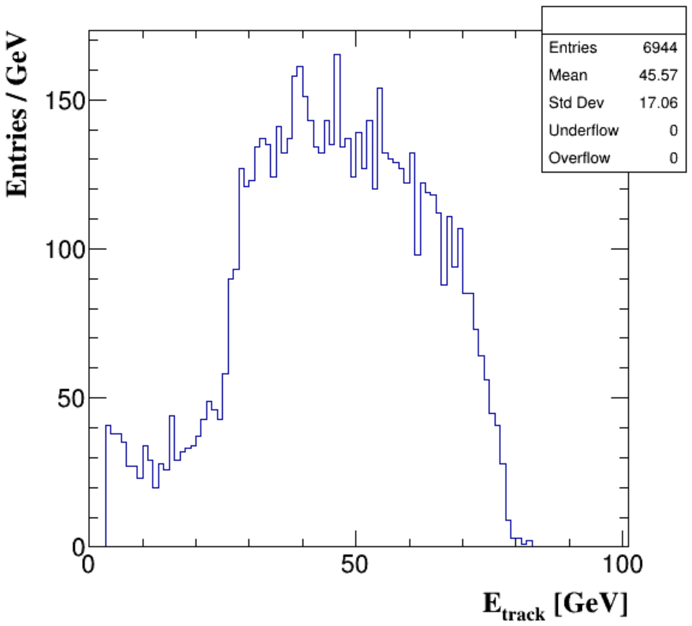


Pattern I. “Isolated” Electron (red),
neutral particles (green)
are emitted close to the electron axis

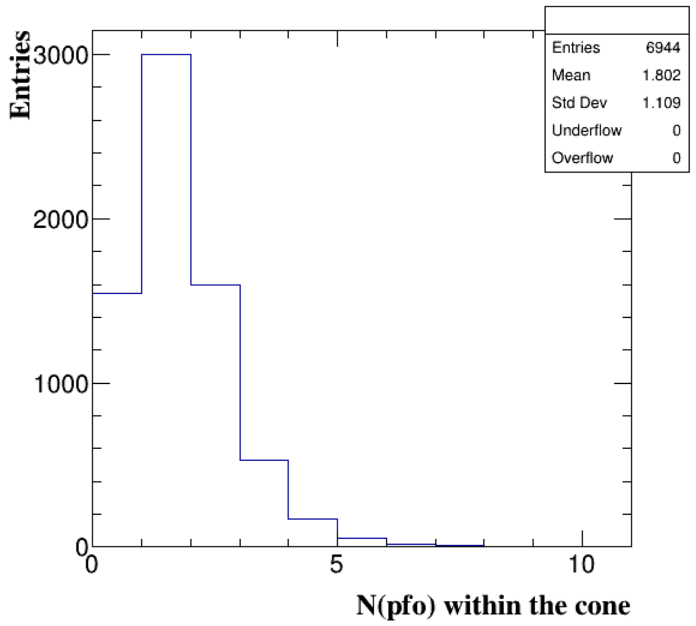
Pattern II. “non-Isolated” Electron (red),
neutral particles (green)
are emitted close to the electron axis
but there are others

$Z(\to ee)H(\to ZZ^* \to \nu\nu\nu\nu)$

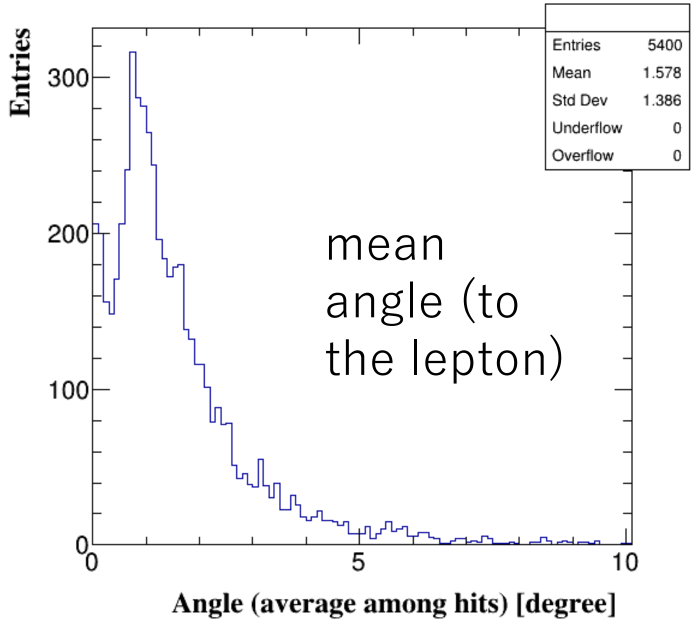
As in the past, check with a reference channel



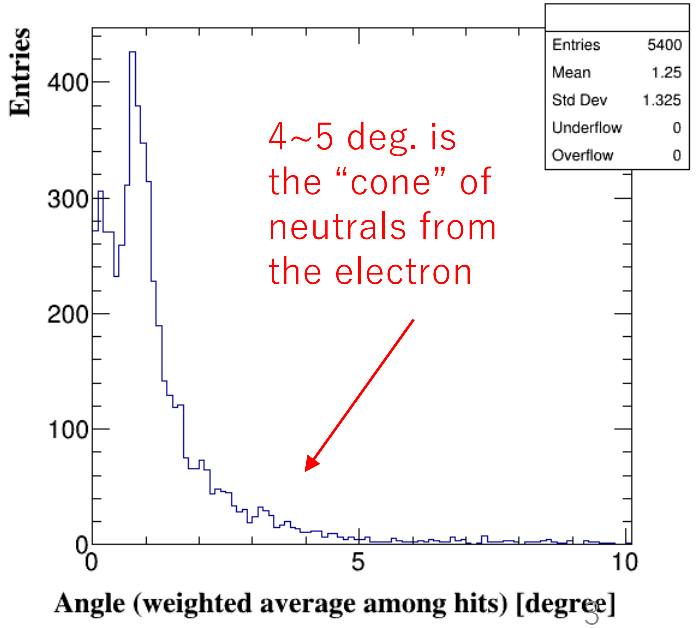
E(lepton) : for reference purpose



Number of pfo within the cone

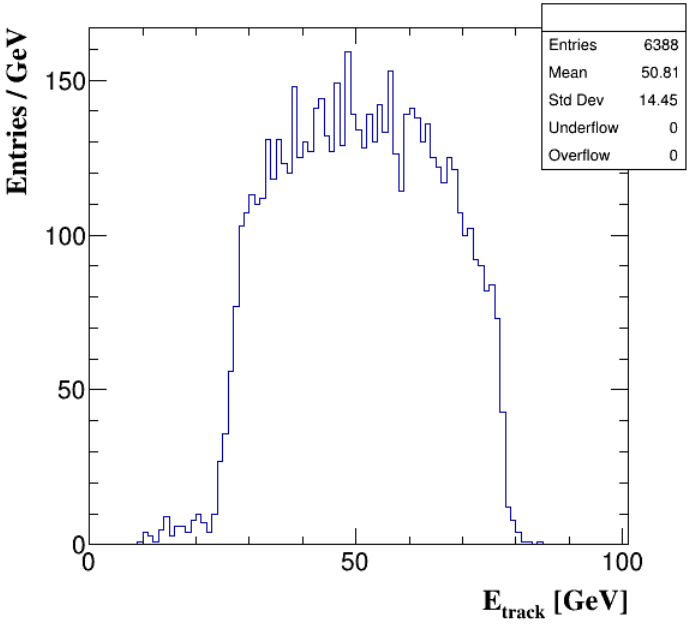


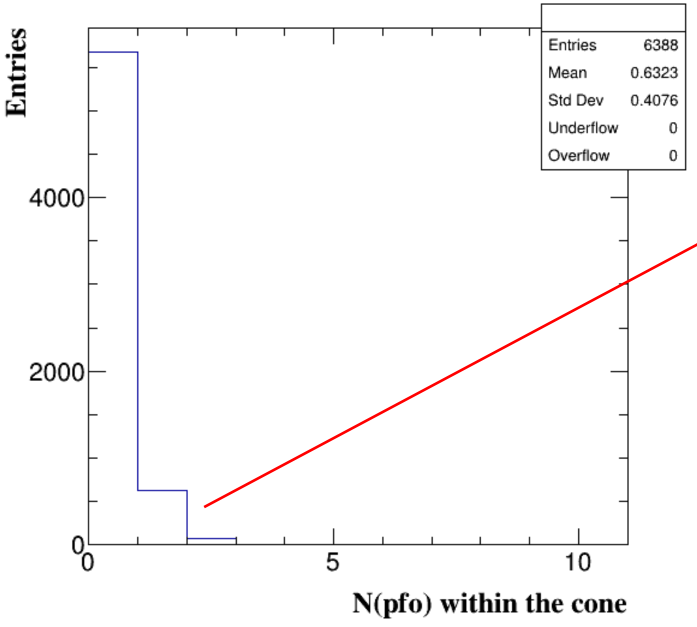
mean angle (to the lepton)



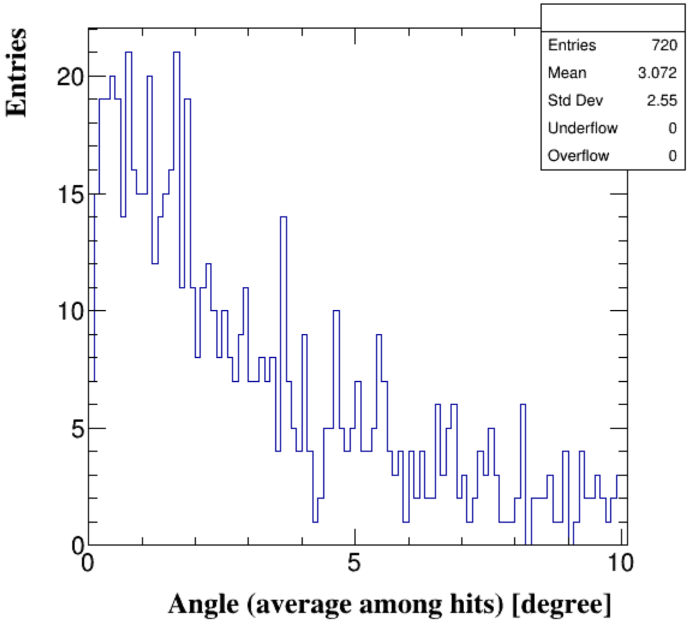
4~5 deg. is the "cone" of neutrals from the electron

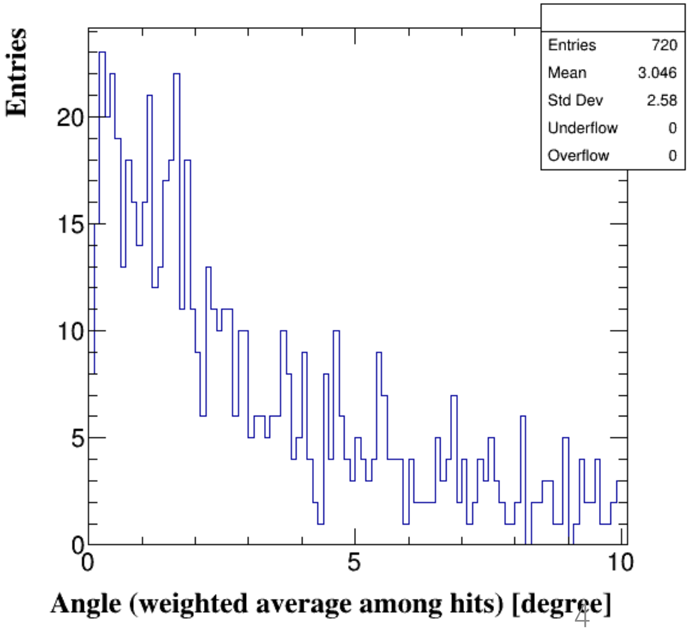
Z(→μμ)H(→ZZ*→νννν)





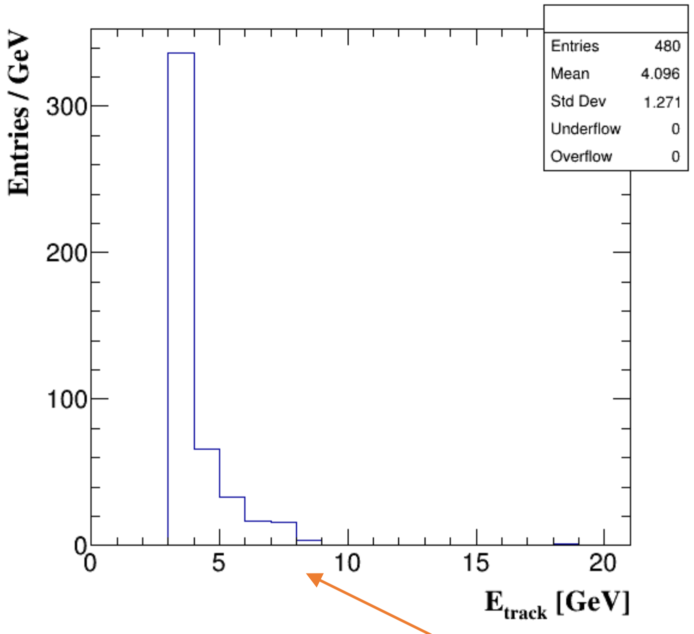
statistics
is low

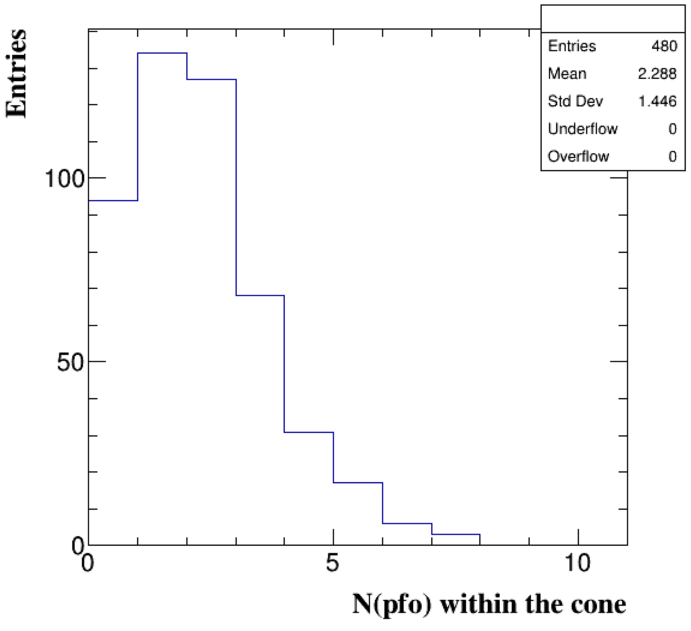


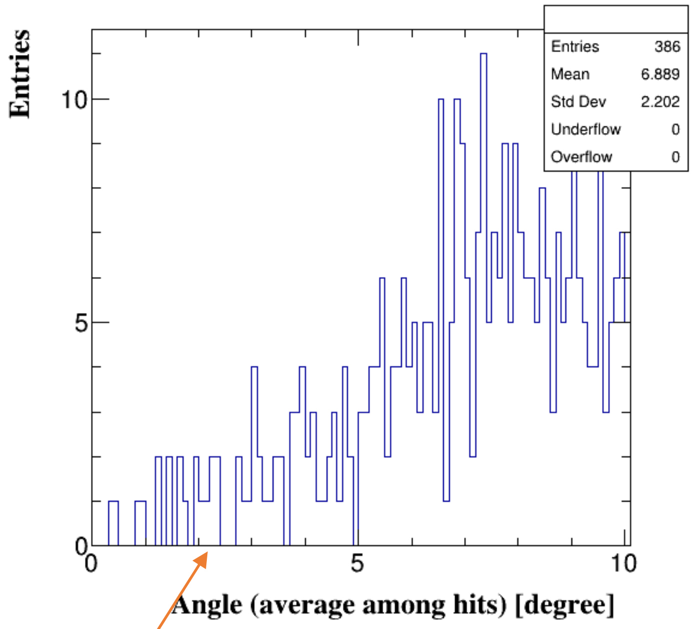


$Z(\rightarrow\nu\nu)H(\rightarrow WW\rightarrow qqqq)$

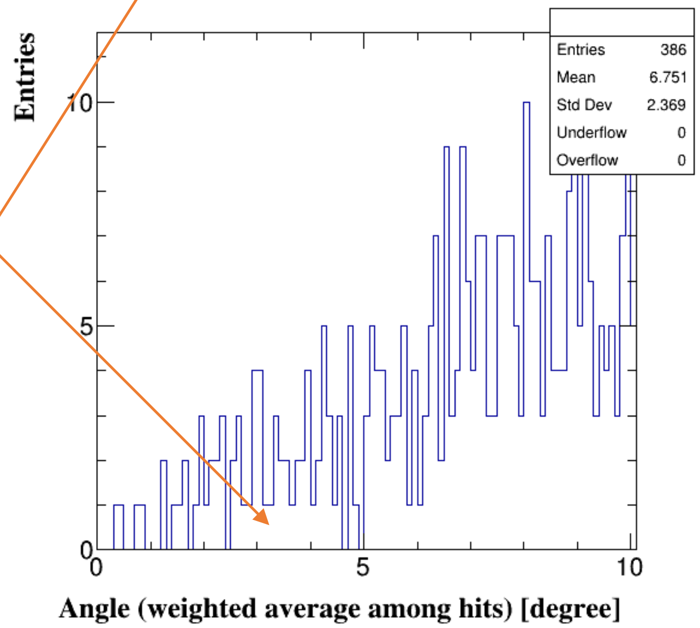
E(cone)/E(track) < 0.7 is applied, therefore, somehow "isolated-electron"-like events are already selected.





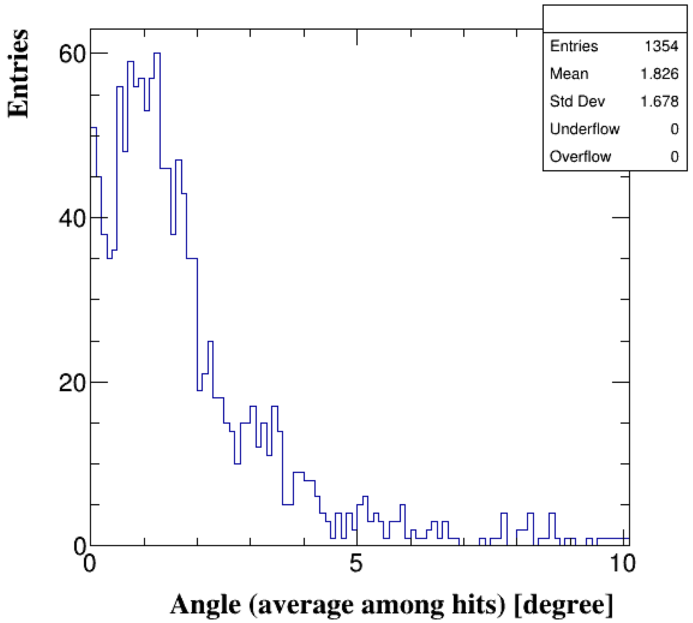


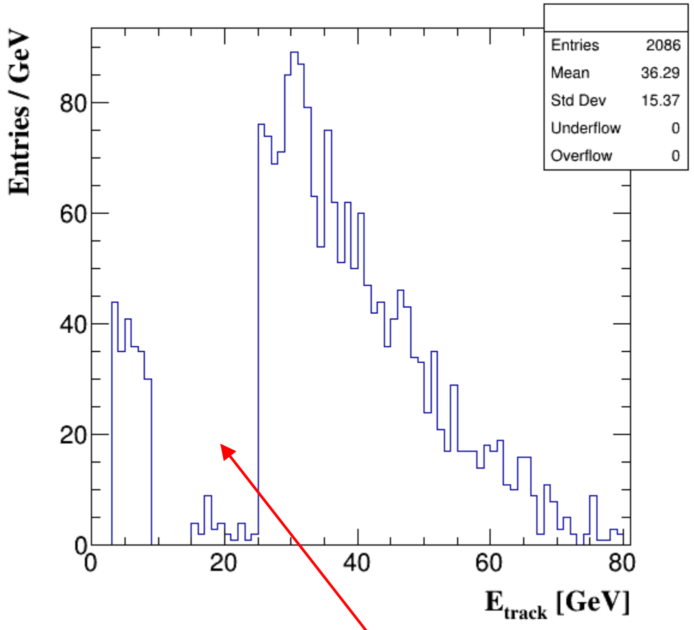
this is different from previous

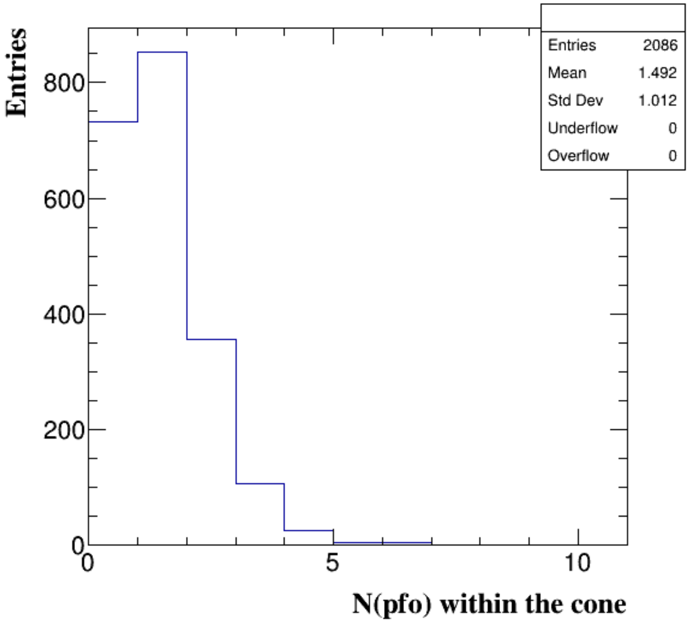


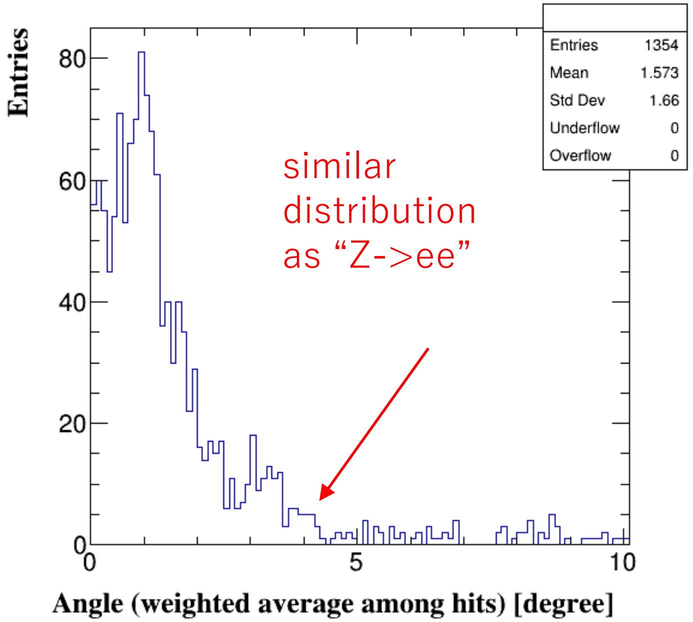
Most of electrons has energy lower than 10 GeV ,
(be care about the statistics above)

Z(→νν)H(→WW→eνeν)









This gap is not understood yet.
But what we can naturally guess is that analysis of H->ZZ*->qqee could be difficult due to electron energy

Z(->ee)H(Z->νν, Z*->qq)

2019-12-27

Pre-selection

IsolatedleptonFinder

- “Use lepton PID” ON
- “Rectangle-Isolation” ON
- “Polynomial-Isolation” ON

    - E(cone)/E(lepton) < 0.7

Higgs2zz

- N(e+)==1, N(e-)==1,
- N(lepton) == 2
- N(jets)==2

    - same as “muon”

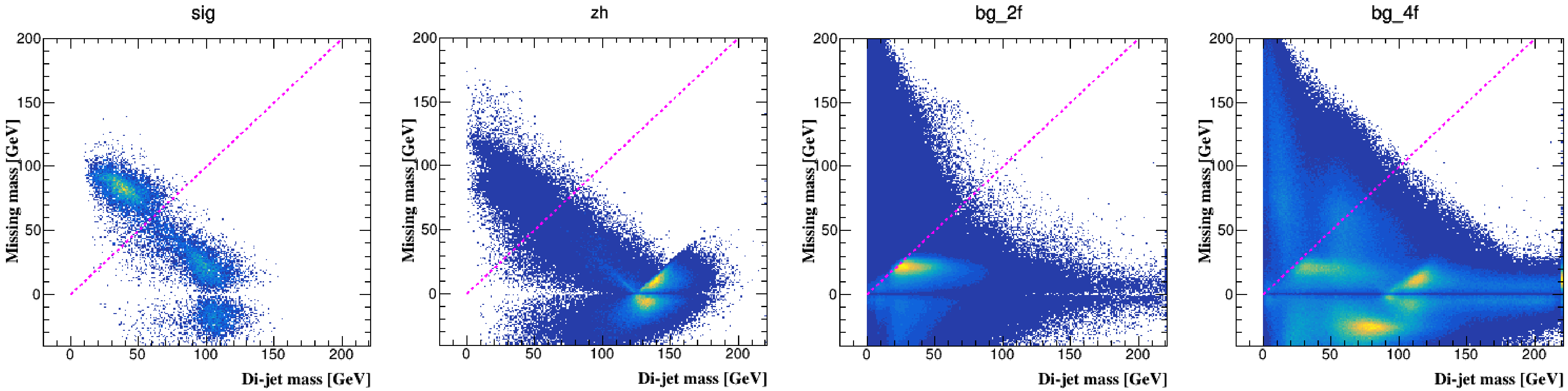
```
-bash-4.1$ ./submit.sh 1.4.2
run mumuHzz
plot pictures and save results
Plot information...
scale for signal is 0.010008768
name                     scale               final
e1e1h_ww                 0.08456             12
nnh_zz                   0.06832             26
ww_sl0tauq               1.10899434445       14
sze_l0tau                1.10888554561       33
sw_sl0qq                 1.10891173157       37


cut                      llhzz     zh        2f           4f
Raw events               1000      1140511   801811977    107203890
Pre-selection            501       22058     40351084     2873260
Signal or not            166       21885     40351084     2873260
missingM > M(dijet)      75        637       2333507      478833
M(dimuon)                71        525       339622       114862
RecM(dimuon)             68        481       170873       56389
N(pfo)                   68        210       30694        13149
Pt(total visible)        65        200       21614        11630
Min angle                46        155       427          1693
Missing Mass & M(dijets) 35        69        254          491
Single jet               33        62        26           384
RecM(dijet) not qqhzz    32        61        6            282
VisM not vvhzz           26        48        0            95
-bash-4.1$
```

$N(pfo)\_e^{+/-} < 6$

(weighted) Averaged angle_$e^{+/-}$ < 3.5 degree

Event selection - I.

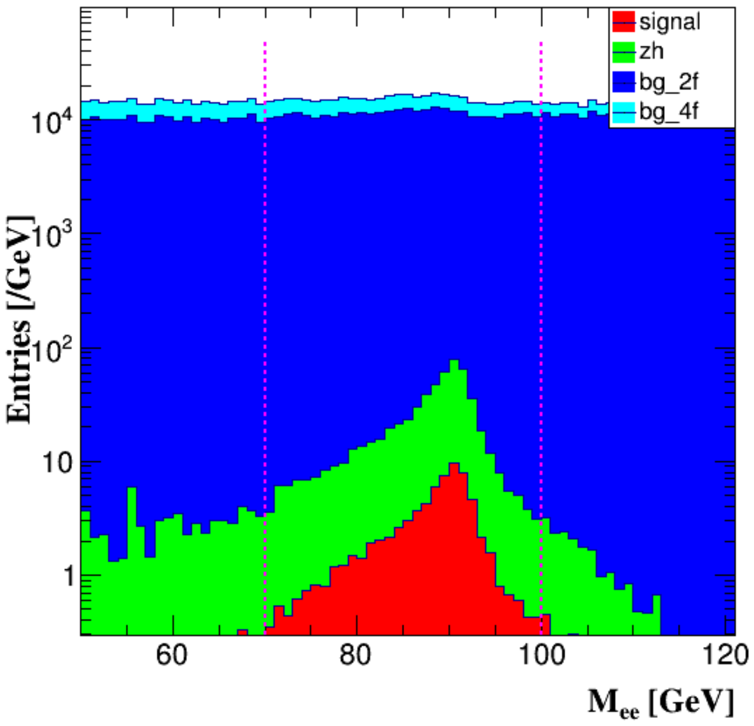
Same as before
(2019/12/19)



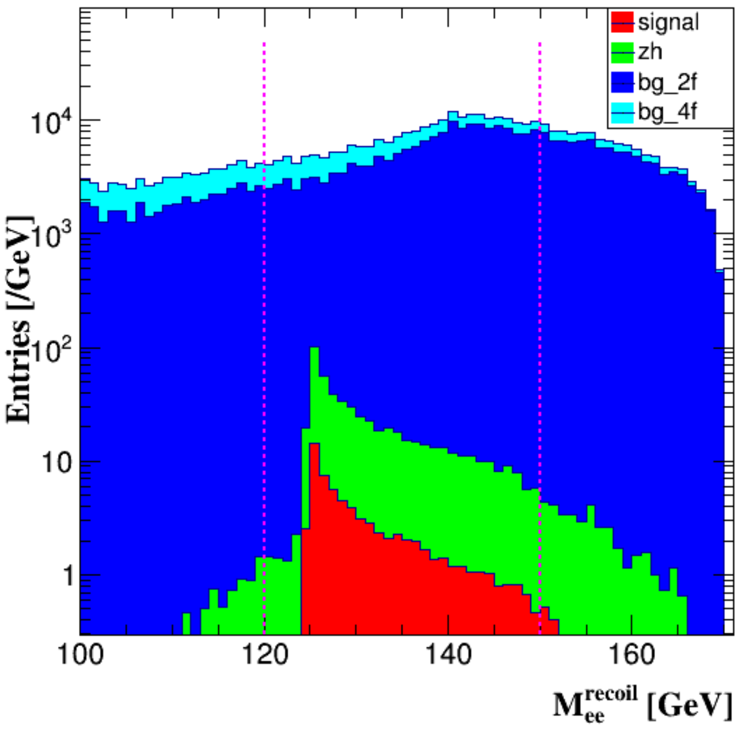
・ Distribution before cut, “Missing mass > Di-jet Mass” is applied
Because of reduction of background events (from 12/16), the some structures can be seen now.

Event selection - II.

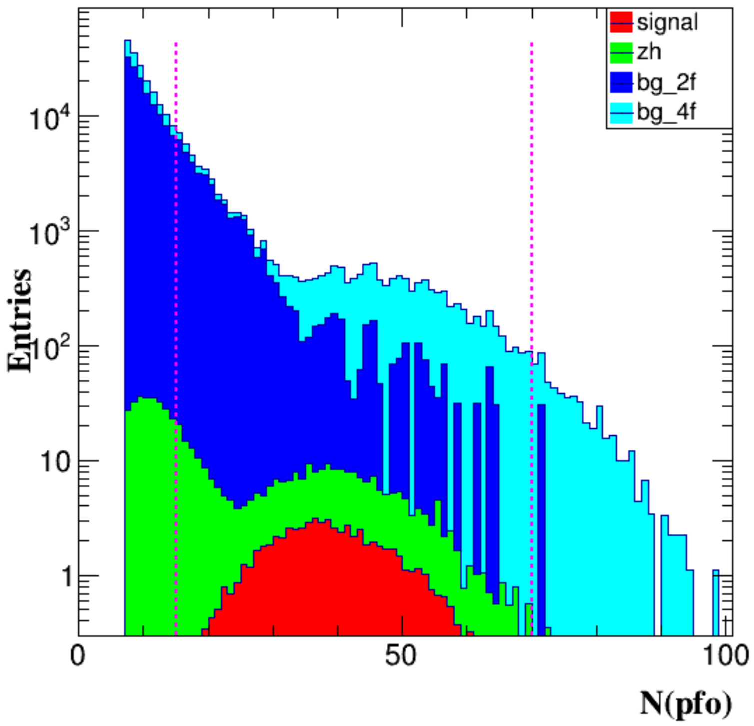
Same as before (2019/12/19)



70 < M(ee) < 100



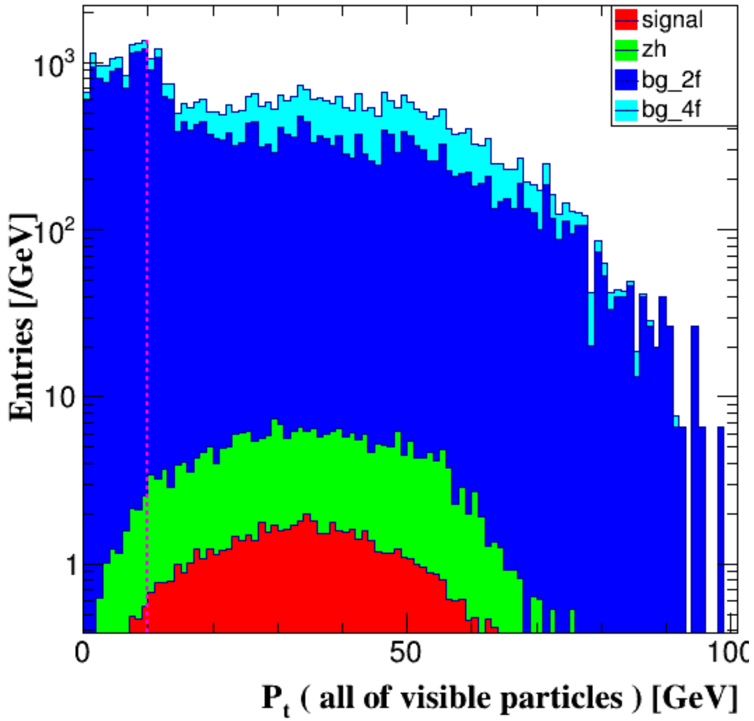
120 < Recoil M(ee) < 160

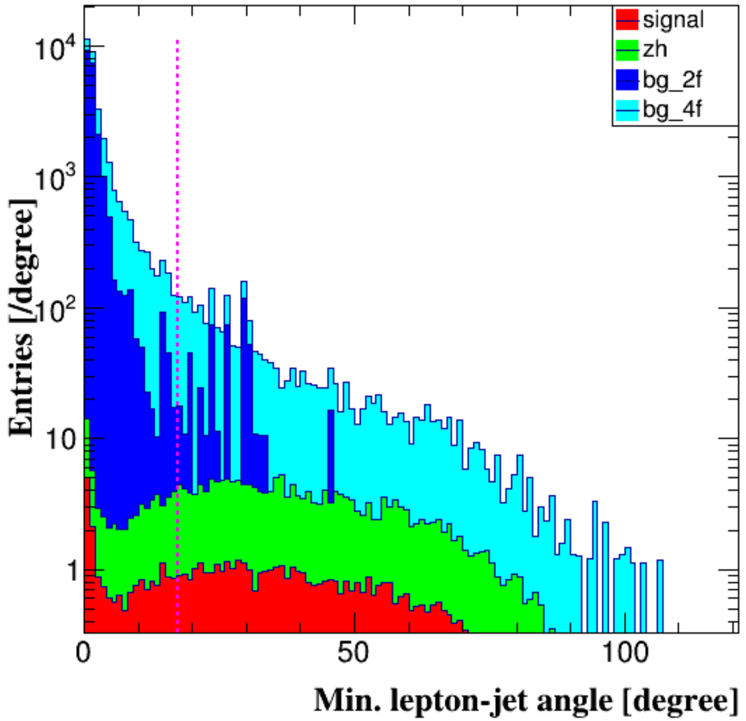


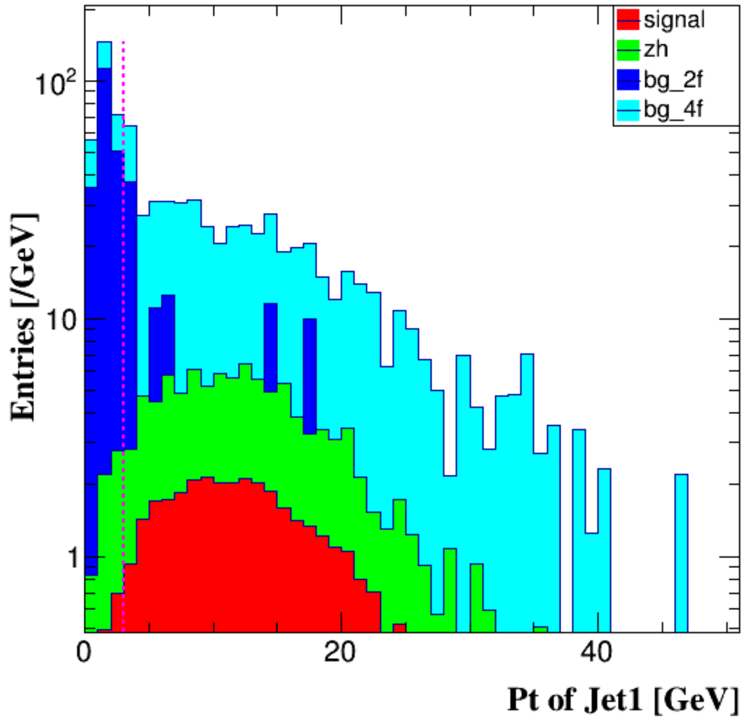
70> N(pfo) >15

Event selection - III.

Same as before
(2019/12/19)







Pt(total visible) > 10

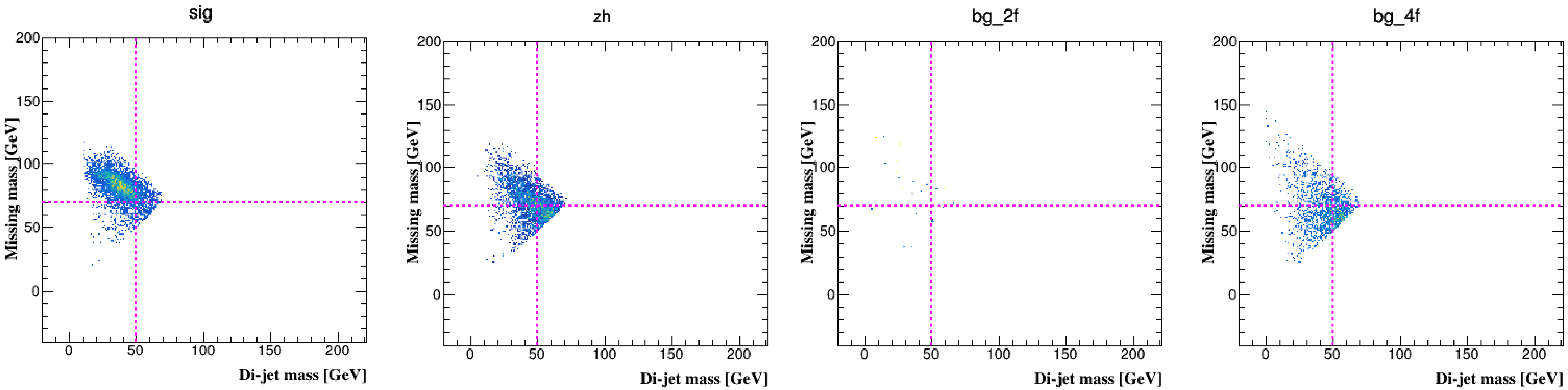
Min. angle > 17.2

Pt(jet1) > 3

Event selection - IV.

Same as before (2019/12/19)

Signal & 4fermion bg has similar distribution

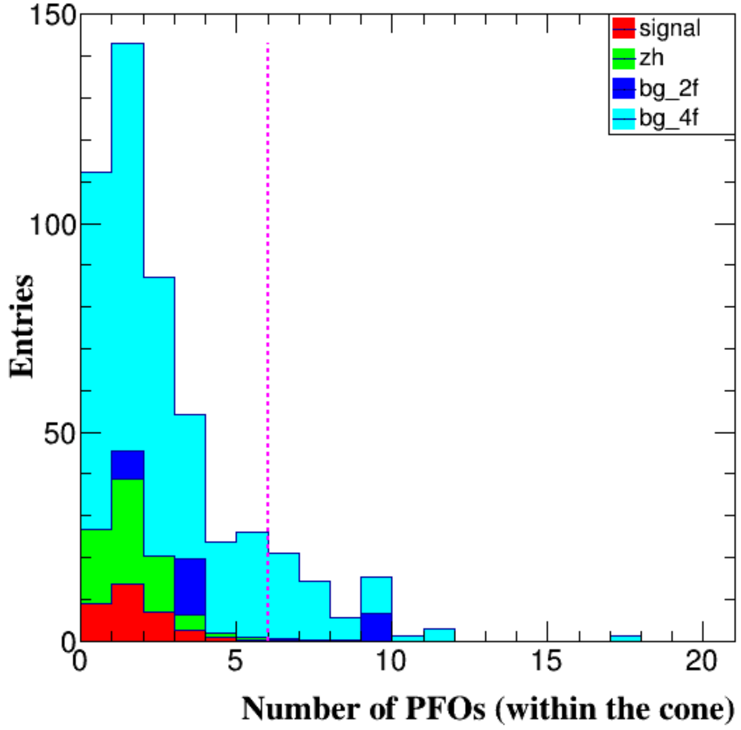


Missing Mass > 70 GeV & M(dijet) < 50 GeV

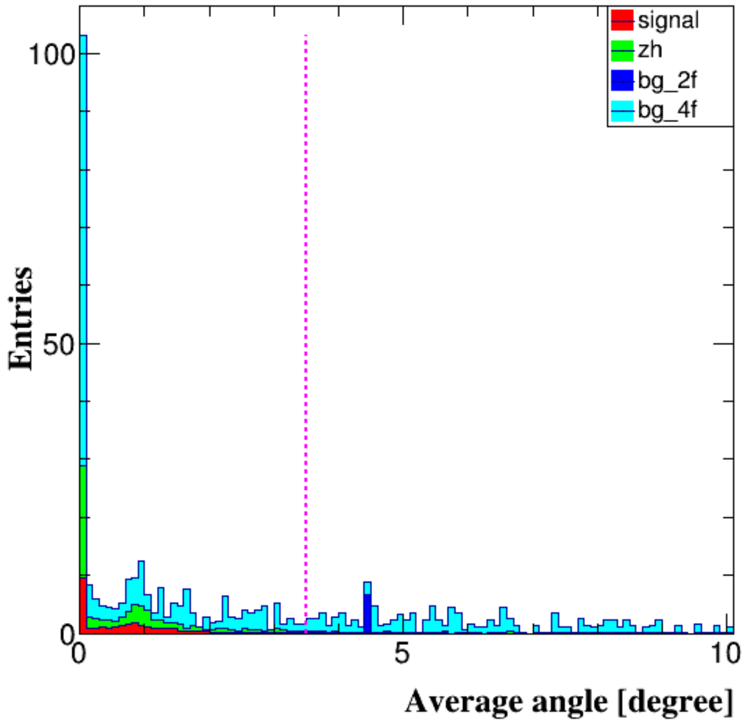
Original one (muon channel) is Missing Mass > 80 & M(dijet) < 35, but can reduce signal much

Event selection - V.

Newly added two cuts
probably, 2D plot, such as, N(pfo)_e+ vs N(pfo)_e-
would be easier to see the discrimination. (shown in part II.)

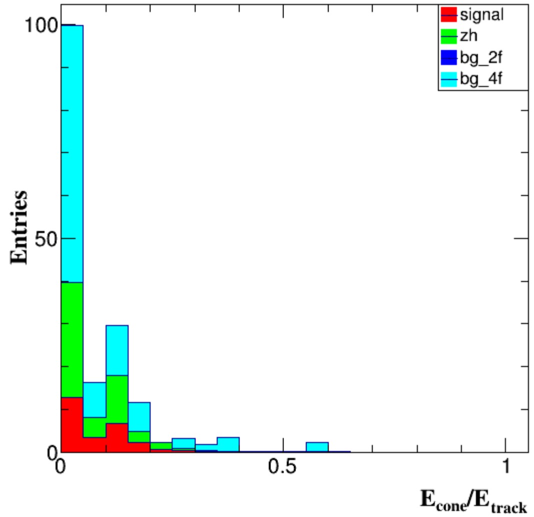


N(pfo) with in the Cone < 6
(for both e^+/e^-)



Energy weighted average angle < 3.5
(for both e^+/e^-)

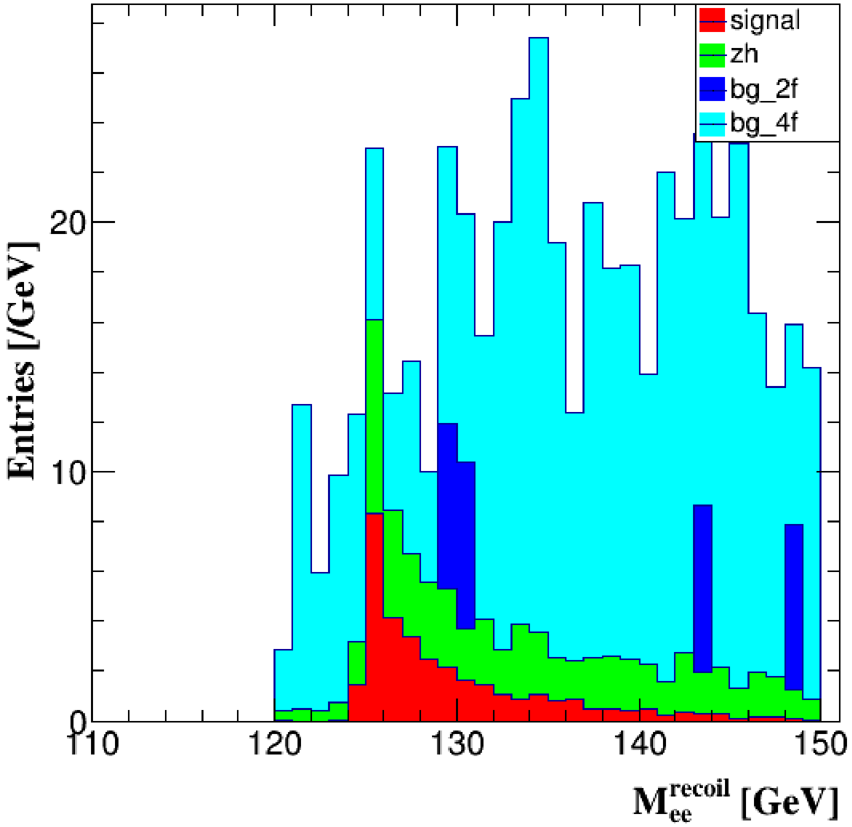
Reference : E(Cone)/E(lepton), after all of cuts



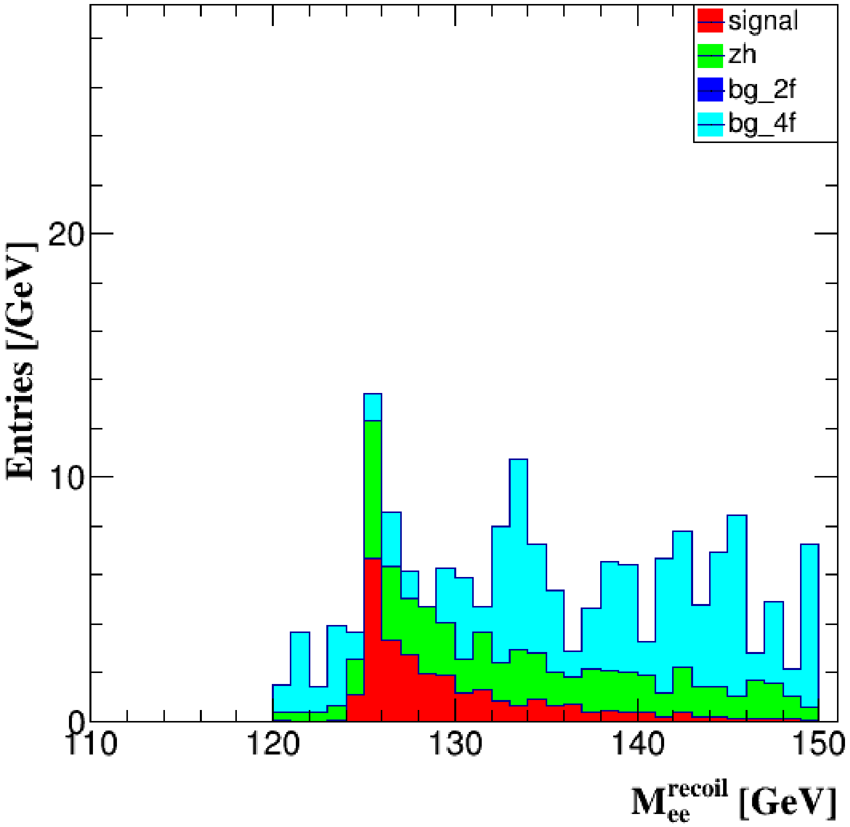
From the result at this stage,
E(cone)/E(lepton) < 0.5
is also acceptable.

Final distributions

Recoil mass distribution
@ 2019-12-19



Recoil mass distribution
with additional two cuts
@ 2019-12-22(27)

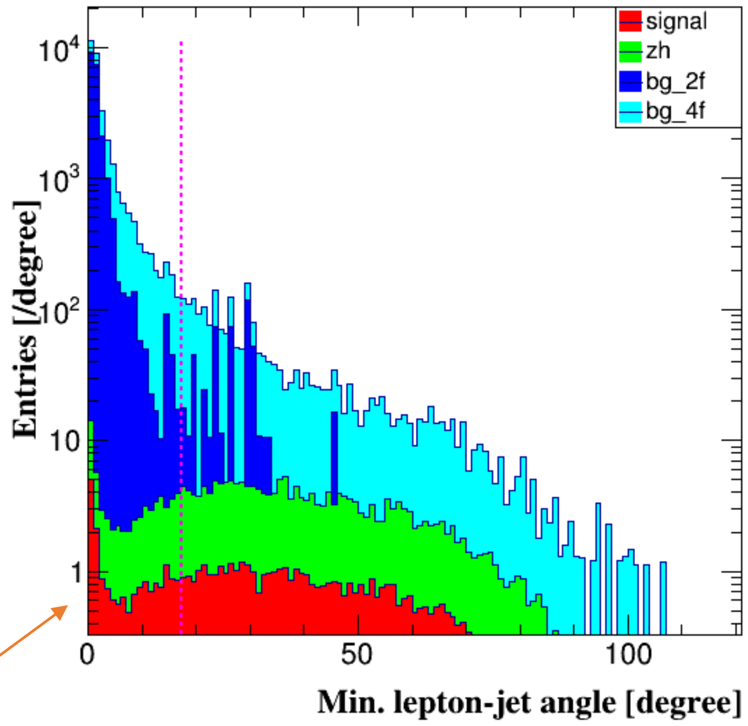


Analysis status of Z(->ee)H(Z->$\nu\nu$, Z*->qq) (part-II. 2019-11-27~30)

Trial : protection around isolated lepton

One question from the beginning. Why, at the distribution of minimum angle between lepton<->jet, there is a peak around zero degree (for signal) ?

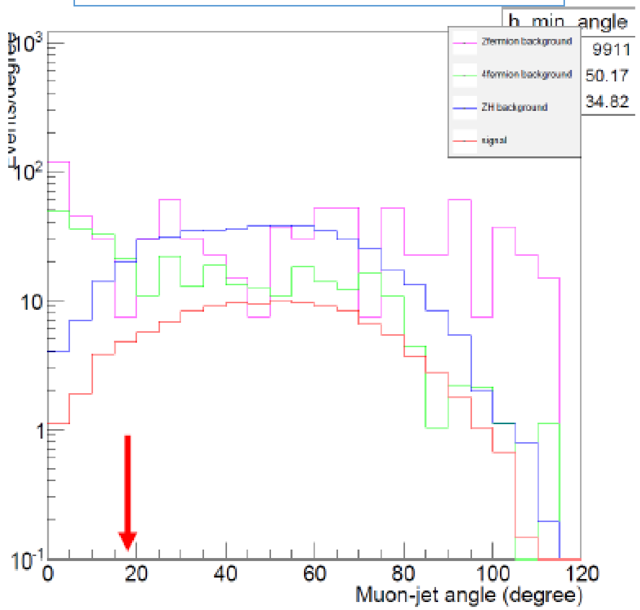
the next consideration is that, is there any way to recover that ? since we loose the signal with this angle cut (than muon channel)



peak ?

angle > 17.2

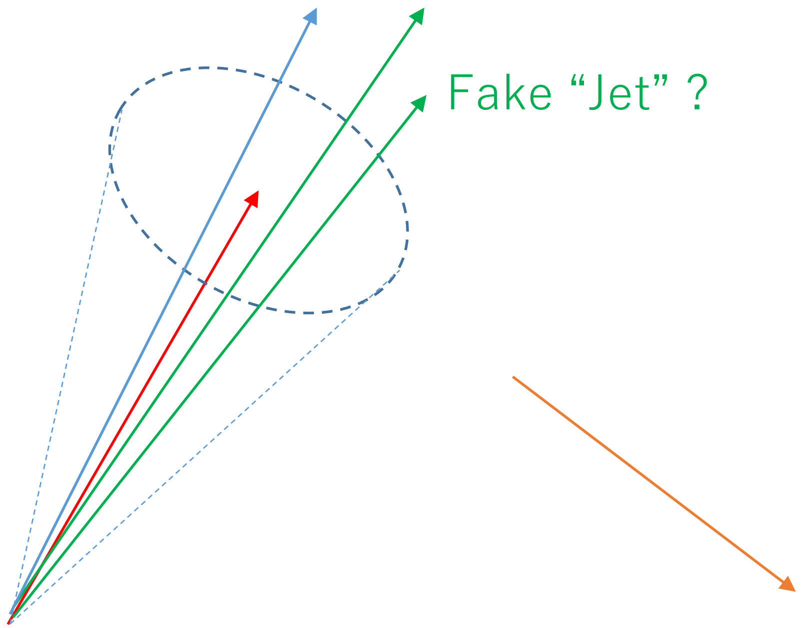
Min angle (lepton⇔jet)



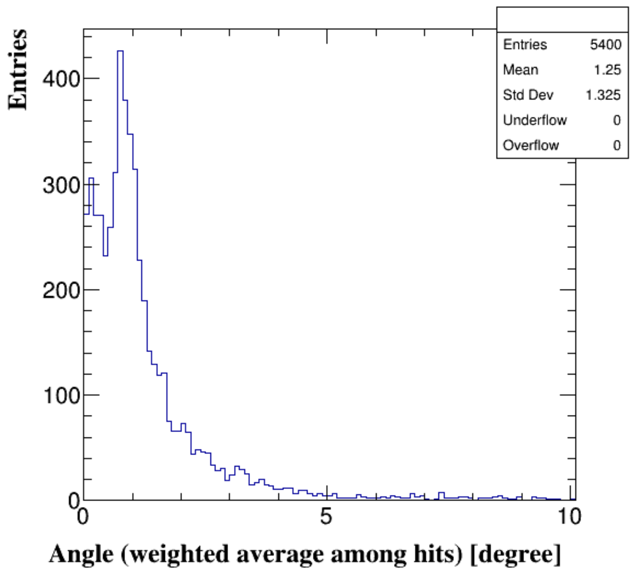
Z->μμ, ZZ*->ννqq

Trial : protection around isolated lepton

-- My consideration is that associated particles around the selected electron, is forming a jet by jet-clustering.



the same histogram as shown in page 3



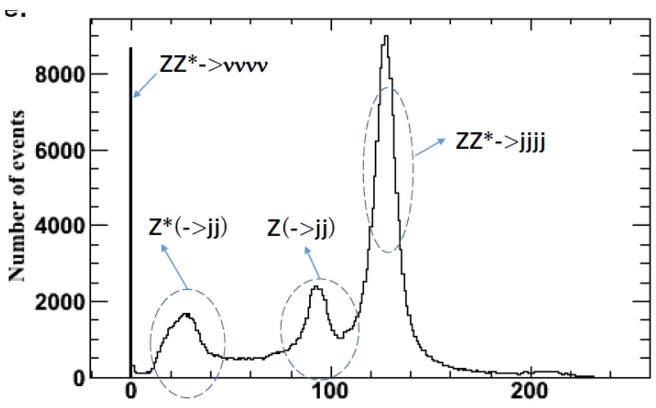
As a trial, neutral particles around the electron within cosθ = 0.998 (= ~3.6 degree) are not sent to the collection which will be clustered into two jets by the Fastjet.

The value, 0.998, is the one I found in a reference from the ILC , at there, photons within 0.998 is kept away from clustering. Also, I have compared the histogram above, though it is the distribution from averaged angle.

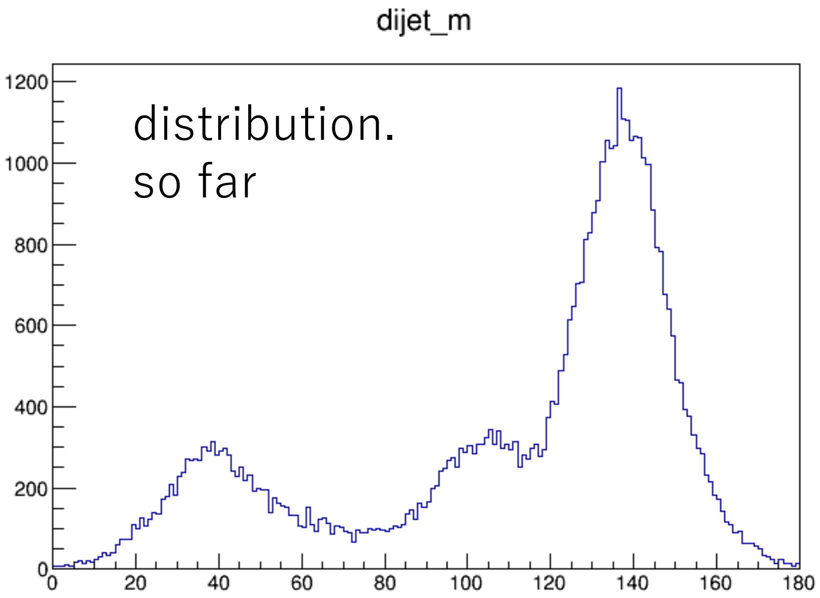
Comparison of dijet invariant mass

・ After this procedure, the dijet mass distribution (for the signal) changes as follows.

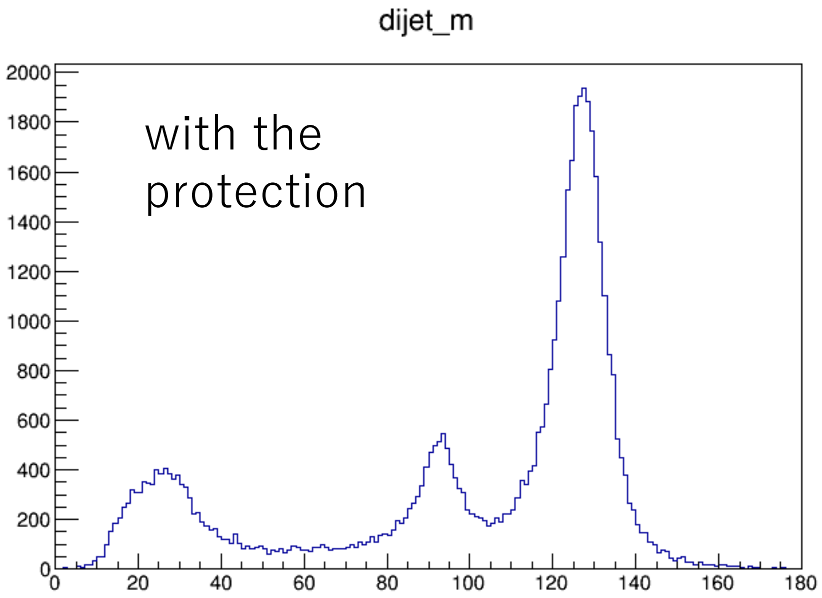
-- note that, the event number is slightly different, 50136<-->49597,
probably, there are events which can not makes two jets for
this procedure.



Ref: muon channel



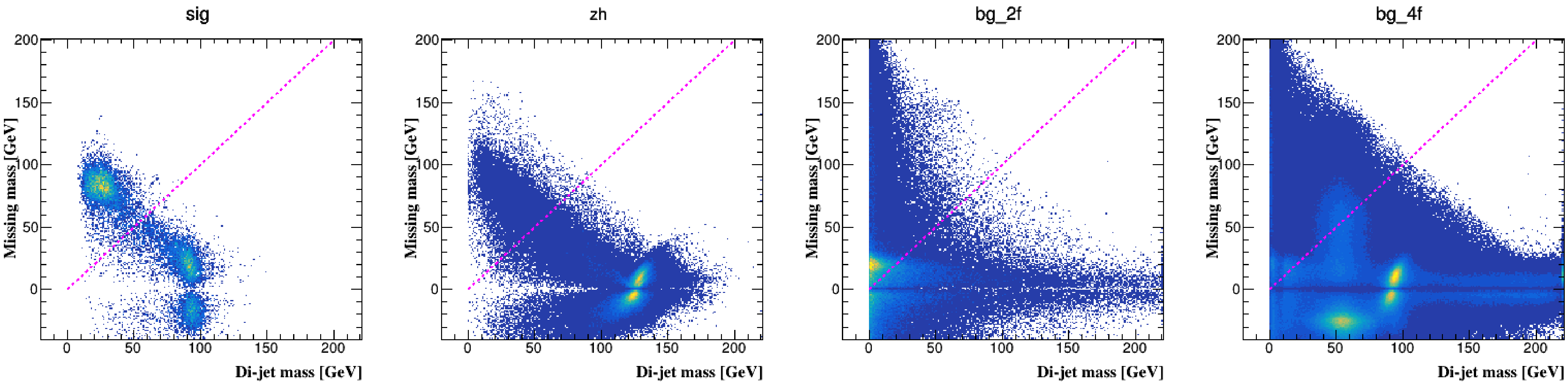
Invariant mass from di-jet [GeV]



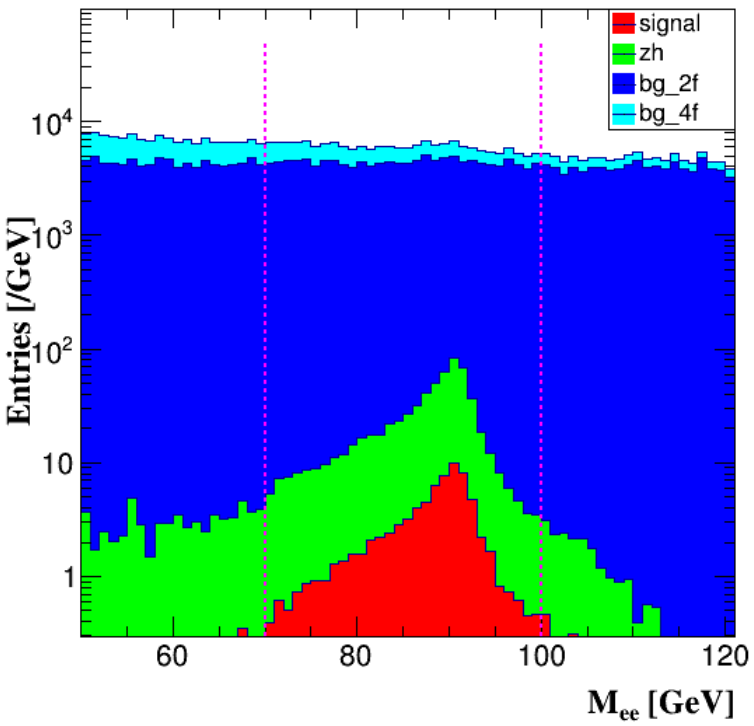
Invariant mass from di-jet [GeV]

Dijet invariant mass distribution is much like the muon channel !

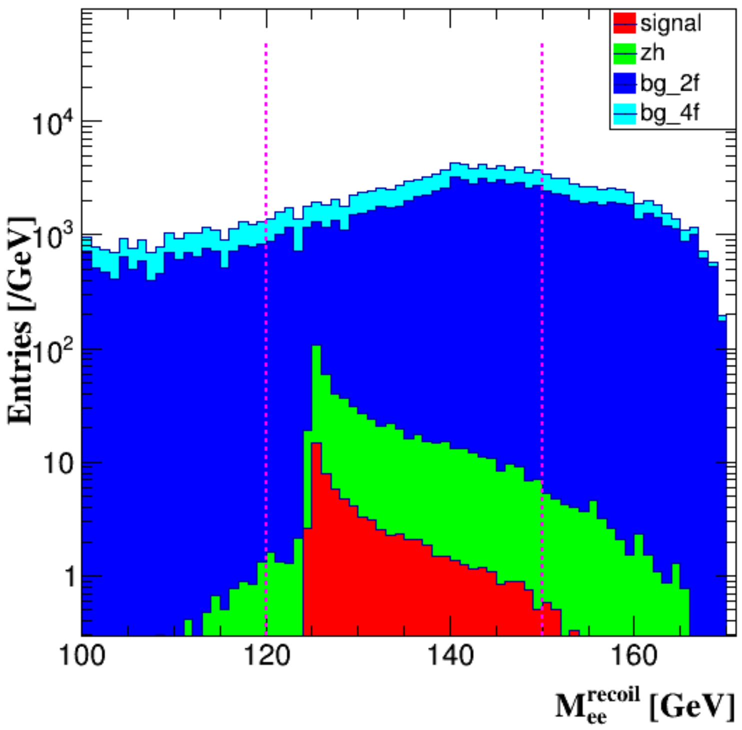
Repeat the cut procedure



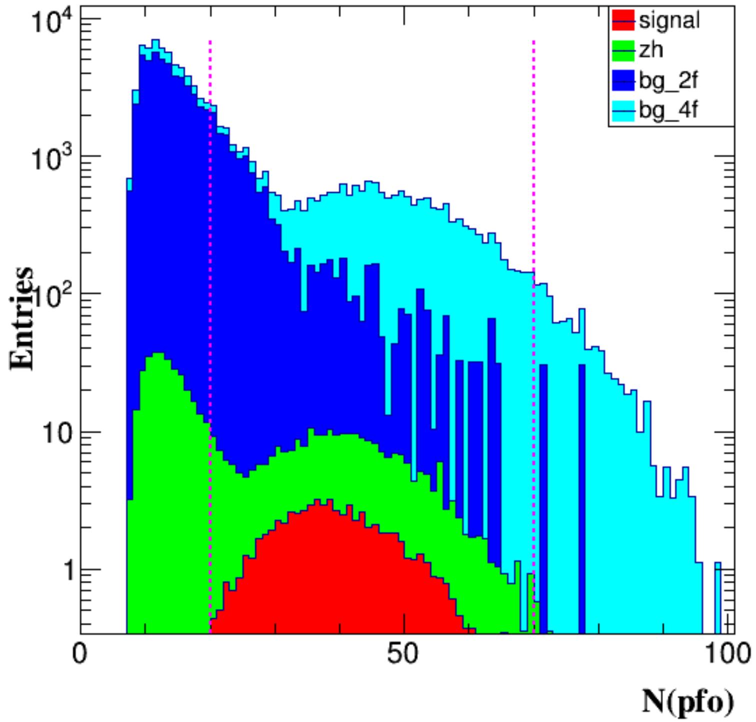
Repeat the cut procedure



70 < M(ee) < 100



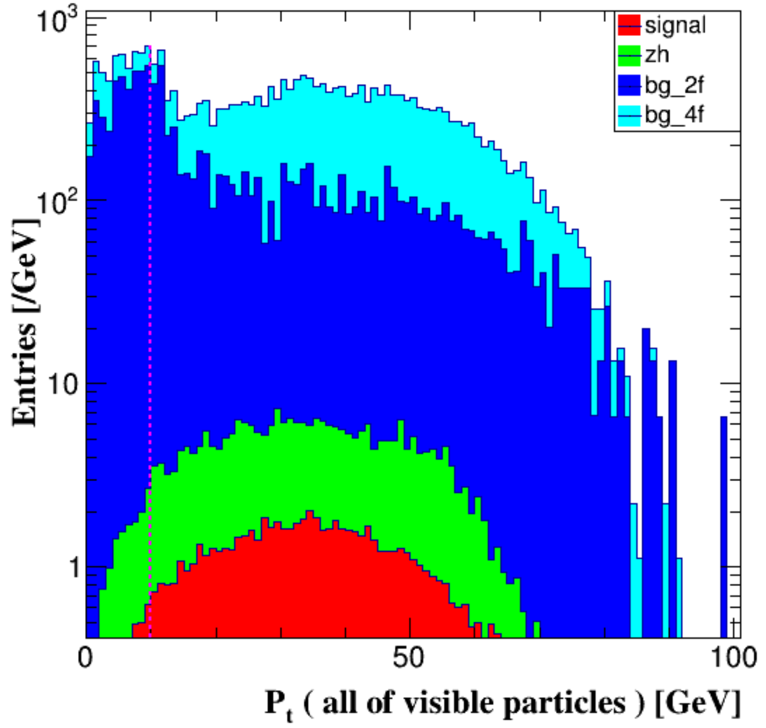
120 < Recoil M(ee) < 150



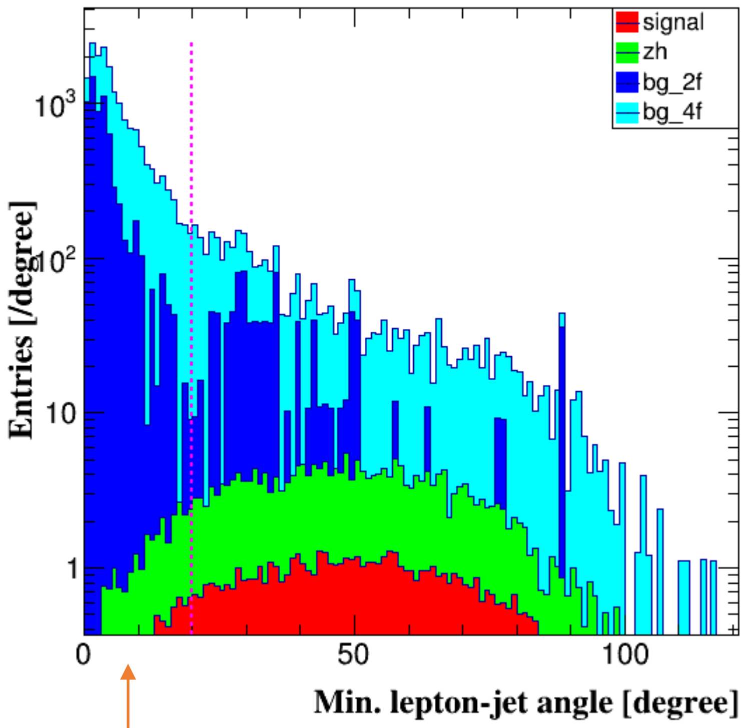
70> N(pfo) >20

this value is changed from 15 to 20 ,
since it was bit loose, and also has effects to cut tau-related background, with this trial

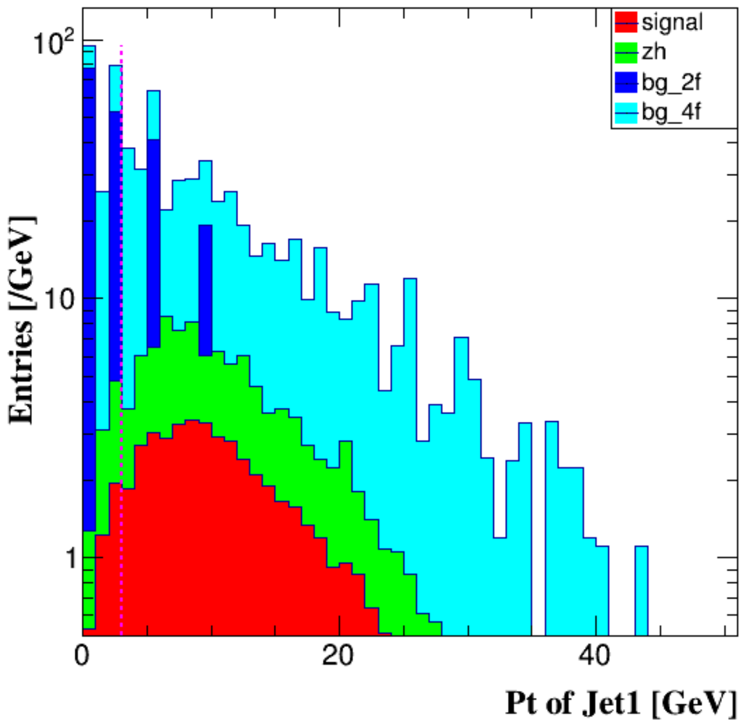
Repeat the cut procedure



Pt(total visible) > 10



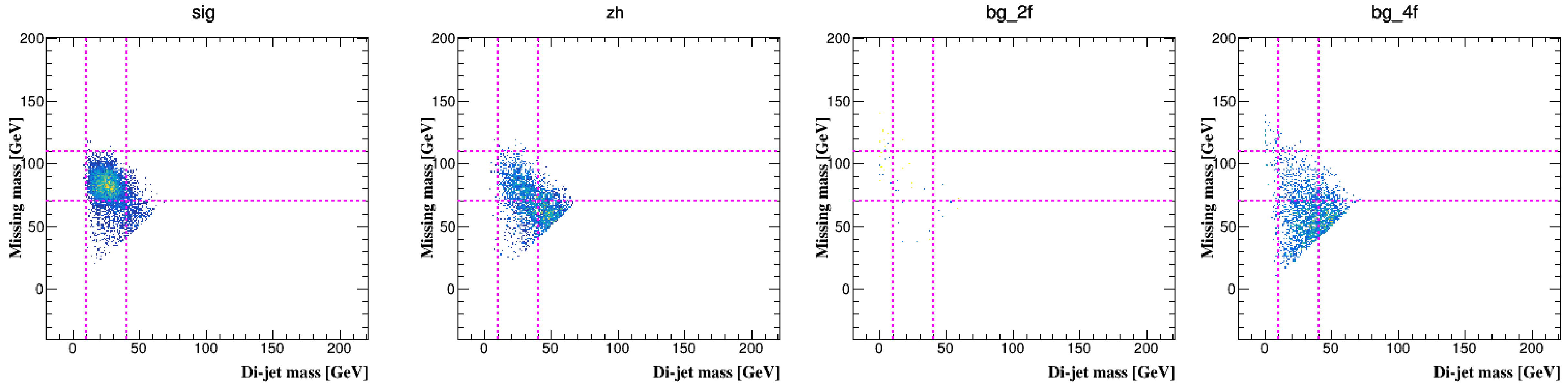
Min. angle > 20



Pt(jet1) > 3

now the peak is disappeared. The cut value is change from 17.2 to 20

Repeat the cut procedure

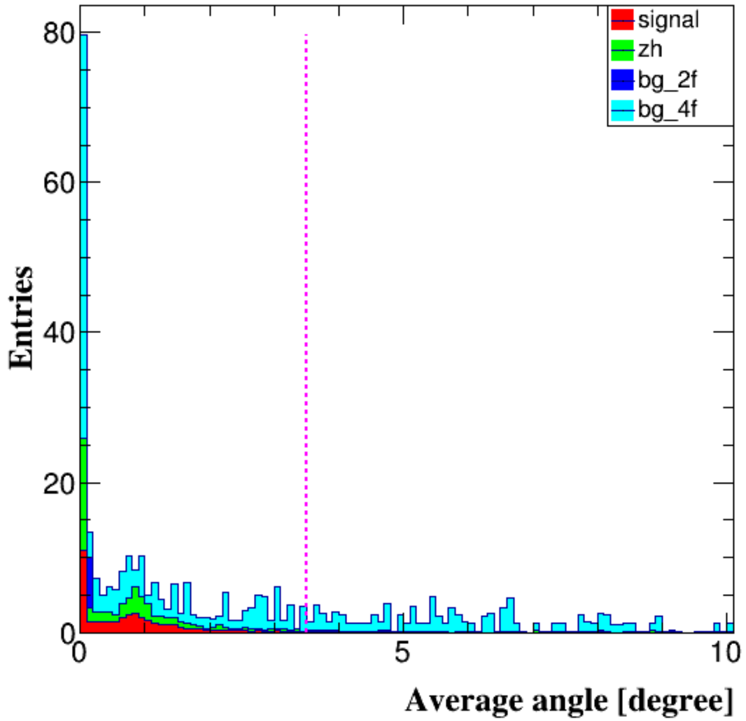


Missing Mass > 70 GeV & M(dijet) < 40 GeV (because of a shift of dijet mass)

\+

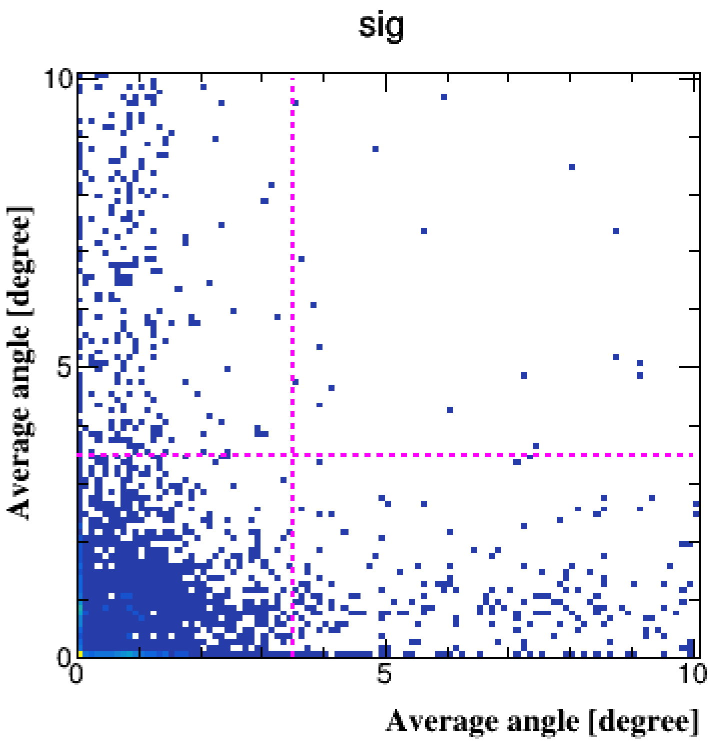
additional , (though not so much effect) Missing Mass < 110 GeV & M(dijet) > 10 GeV

Repeat the cut procedure



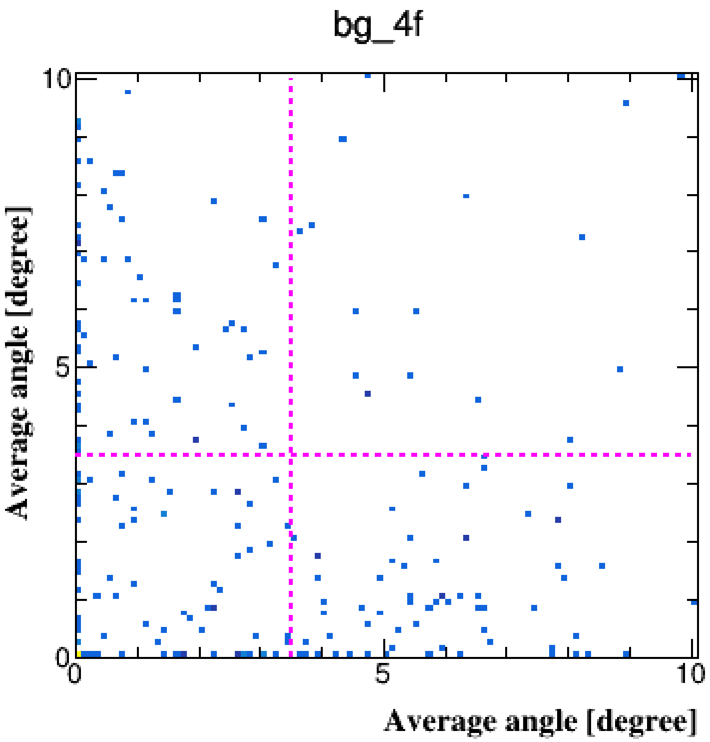
Energy weighted average angle < **3.5**
(for both e^+/e^-)

OR



X-axis : for lepton plus

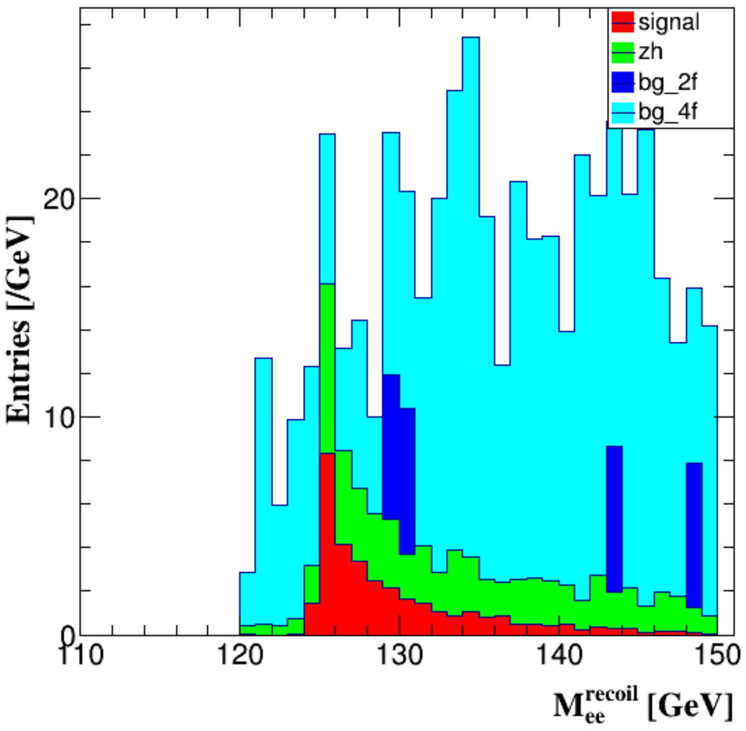
Y-axis : for lepton plus



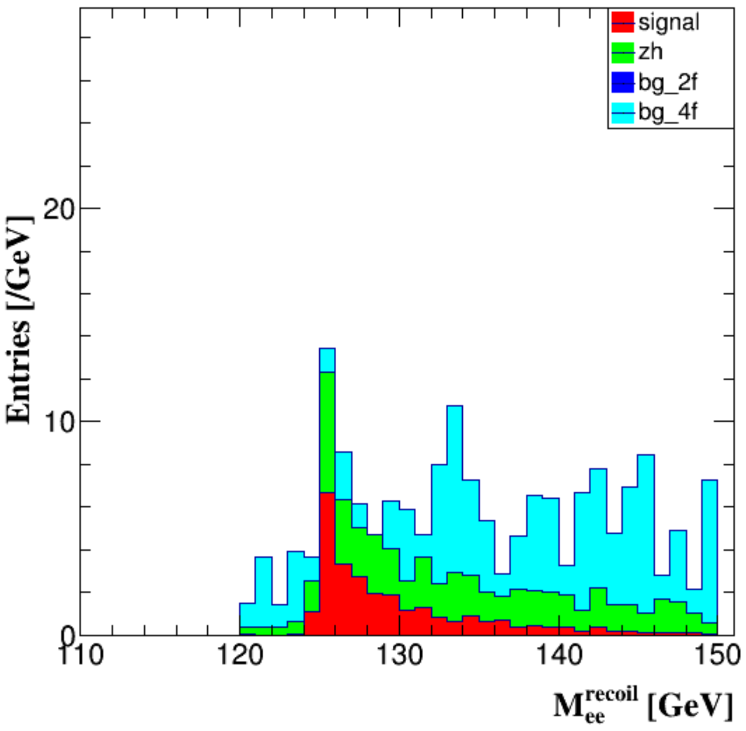
for 4f background, this cut reduce the number

Final distributions

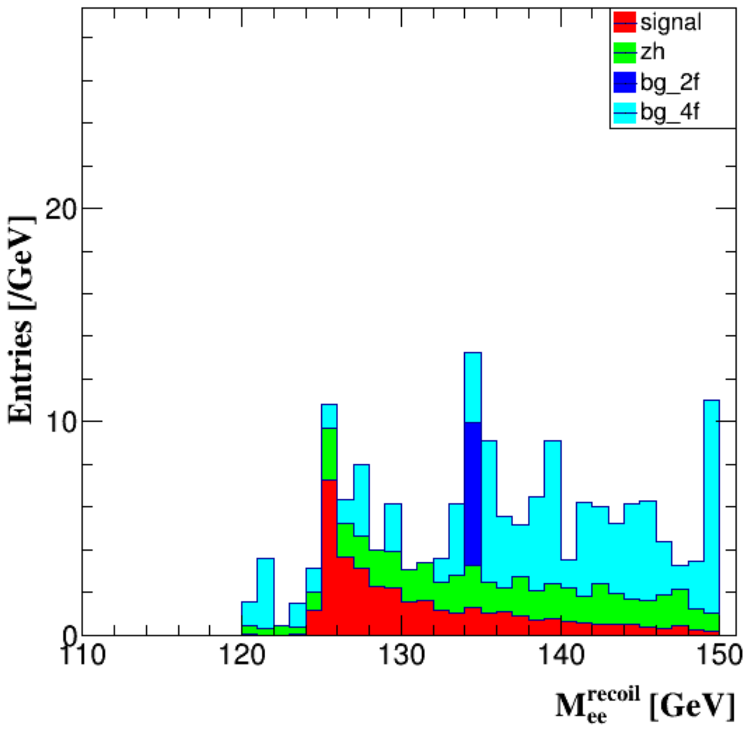
Recoil mass distribution
@ 2019-12-19



Recoil mass distribution
with additional two cuts
@ 2019-12-22(27)



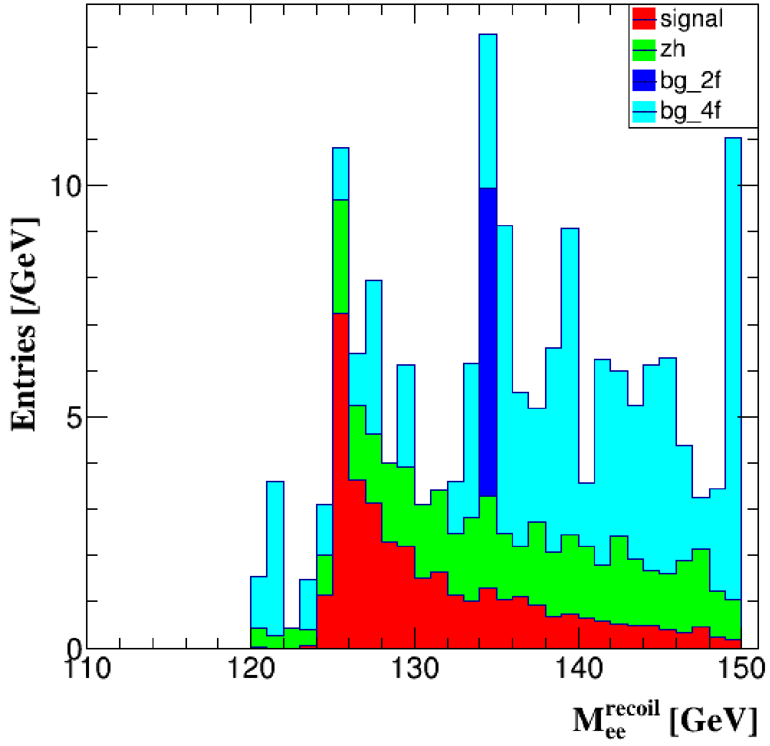
Recoil mass distribution
with the protection
around the electron
(from the trial)



Almost the same level, with a little higher signal yield

Final statistics

$$\frac{\sqrt{S+B}}{S} = \frac{\sqrt{36+40+6+83}}{36} \times 100 = 35.7\%$$




```
-bash-4.1$ ./submit.sh 1.4.2
run mumuHzz
plot pictures and save results
Plot information...
scale for signal is 0.010407936
name                    scale                   final
nnh_zz                  0.06832                 29
ww_sl0tauq              1.10899434445           18
sze_l0tau               1.10888554561           15
sw_sl0qq                1.10891173157           36


cut                     llhzz         zh             2f             4f
Raw events              1040          1140511        801811977      107203890
Pre-selection           516           21926          4281022        2122134
Signal or not           173           21753          4281022        2122134
missingM > M(dijet)     83            682            1404074        291557
M(dimuon)               78            569            130834         49100
RecM(dimuon)            75            519            59658          25578
N(pfo)                  73            204            11169          14977
Pt(total visible)       70            193            7246           13365
Min angle               63            174            835            2608
Missing Mass & M(dijets) 49           60             171            428
Single jet              44            51             13             323
RecM(dijet) not qqhzz   43            51             6              236
VisM not vvhzz          36            40             6              83
-bash-4.1$
```

Replacement of the cross section (μμH->eeH) is also incorporated. (but it is a small change)

http://cepcsoft.ihep.ac.cn/guides/Generation/docs/ExistingSamples/#240-gev

Short summary

- Regarding the analysis status of Z(->ee)H(Z->$\nu\nu$, Z*->qq)

-- Using, the number of pfo in the cone ($\cos\theta > 0.98$) and the energy weight averaged angle , 4-fermion background, is reduced .

-- As a further trial, to prevent associate particles with the electron from forming a jet, neutral particles around the electron ($\cos\theta > 0.998$) is kept away from jet clustering.

-- dijet invariant mass looks natural

-- Estimating the very rough precision from the stat,
it is ~35.7 % (then, probably,,, it would be ~34(?)% with fitting .)

-- Can we do further optimization and/or reduction of backgrounds ?

-- Take a look of vvHZZ*(Z->ee, Z*->qq) would be worth to do.