Higgs recoil mass study using ZH->qqH @ 250 GeV ILC

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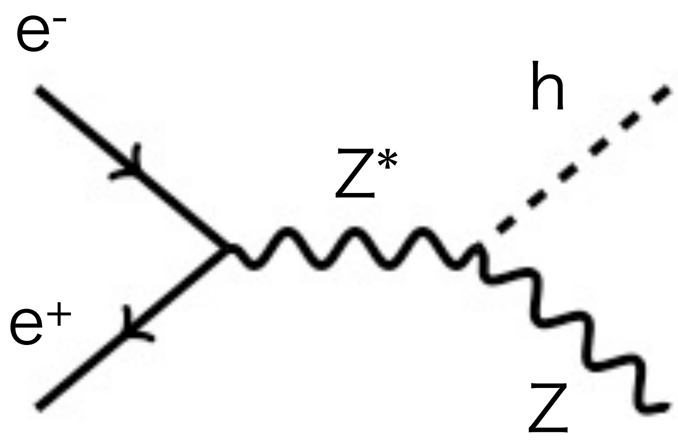
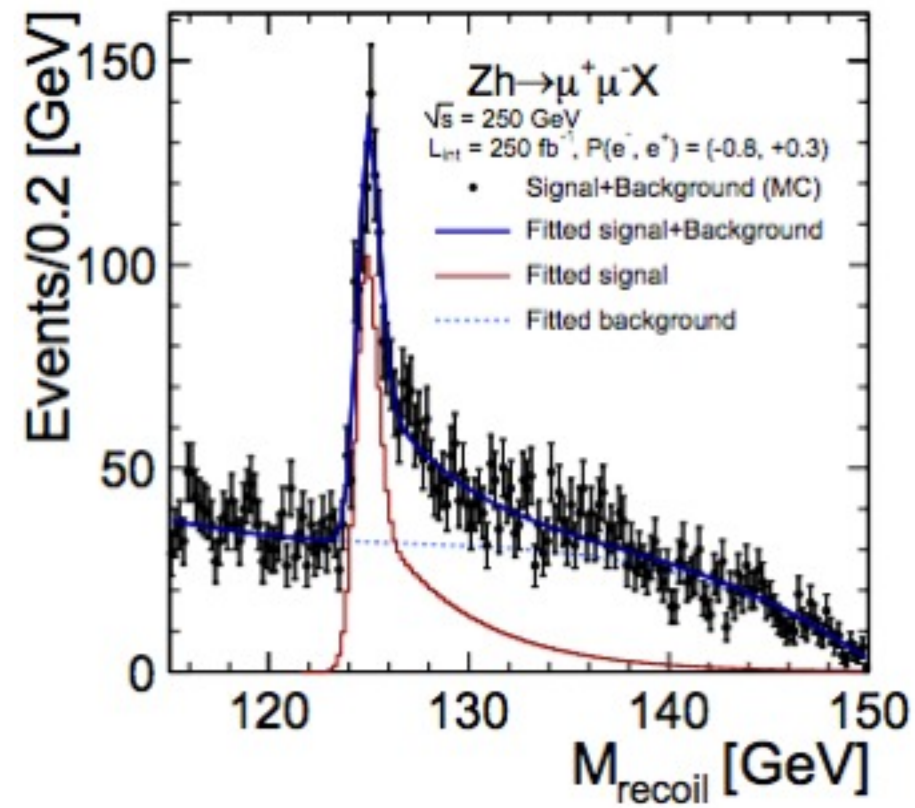
qqH channel



At lepton collider, we can measure Higgs without looking Higgs directly.
-> Model Independent search

In recoil mass study, leptonic channel such as Z -> e^+e^-, mu^+mu^- has very good signal/background ratio.
But, the branching ratio of Z -> leptonic is ~3.5% for each generation.



In contrast, the branching ratio of **Z -> hadronic is ~70%**.
However, analysis is difficult due to a large amount of BG.

dataset and method (ILD full simulation)

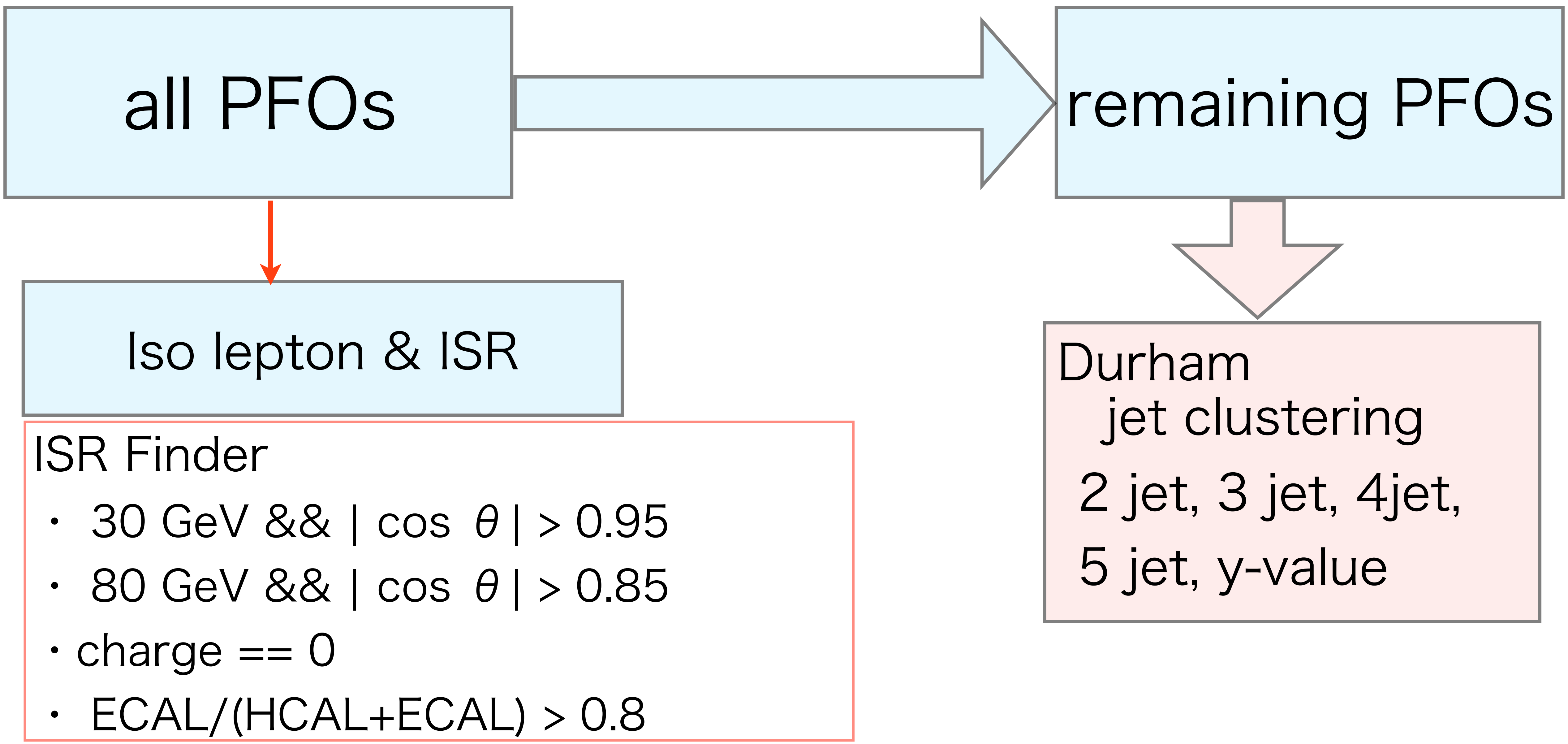
- All DBD sample was used.

  signal qqH ,

  main background (ZZ/WW->hadronic, 2f_hadronic)

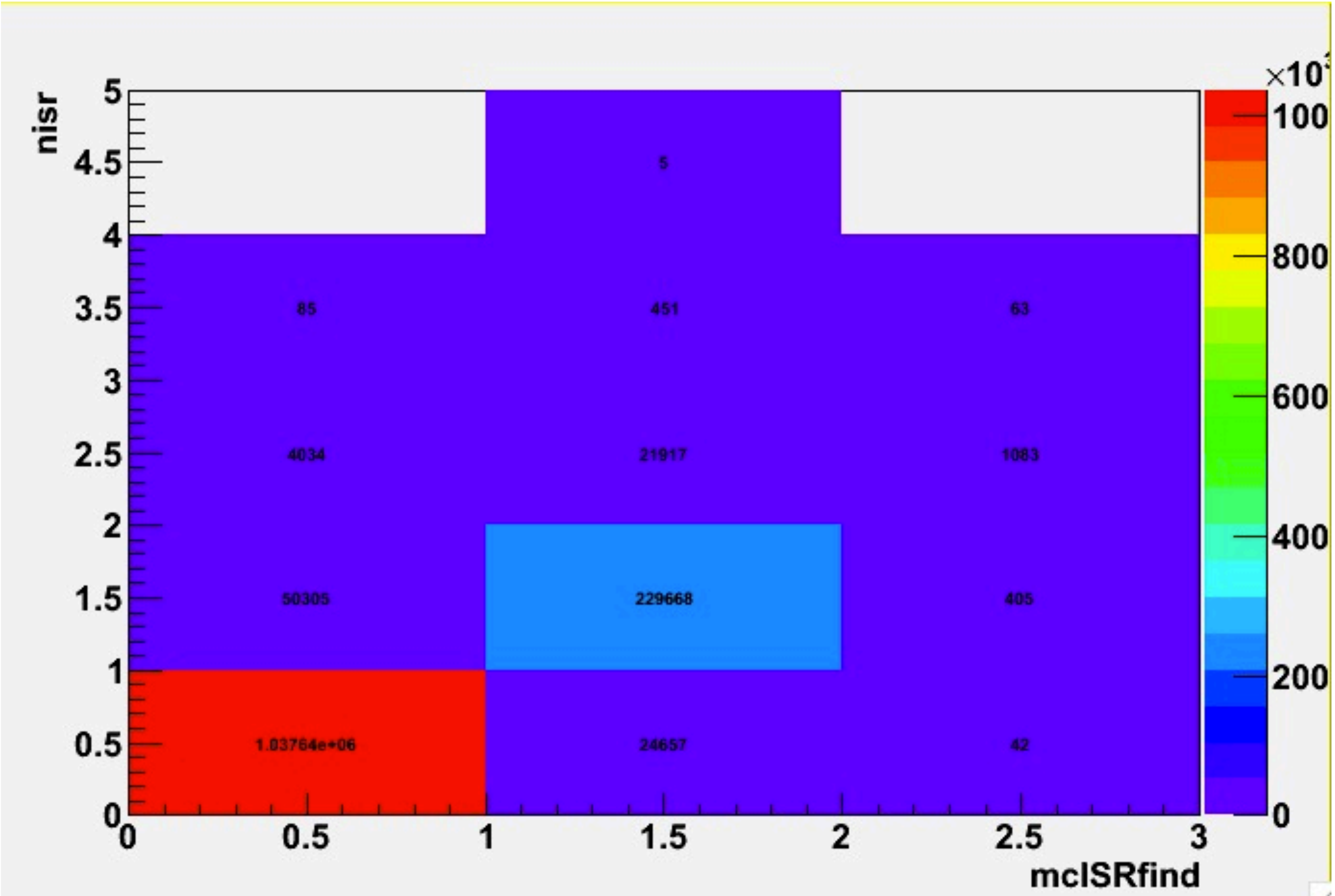
250GeV 250fb^{-1} (+0.8,-0.3),(-0.8+0.3)

- Jet Clustering (with Durham method)



ISR finder

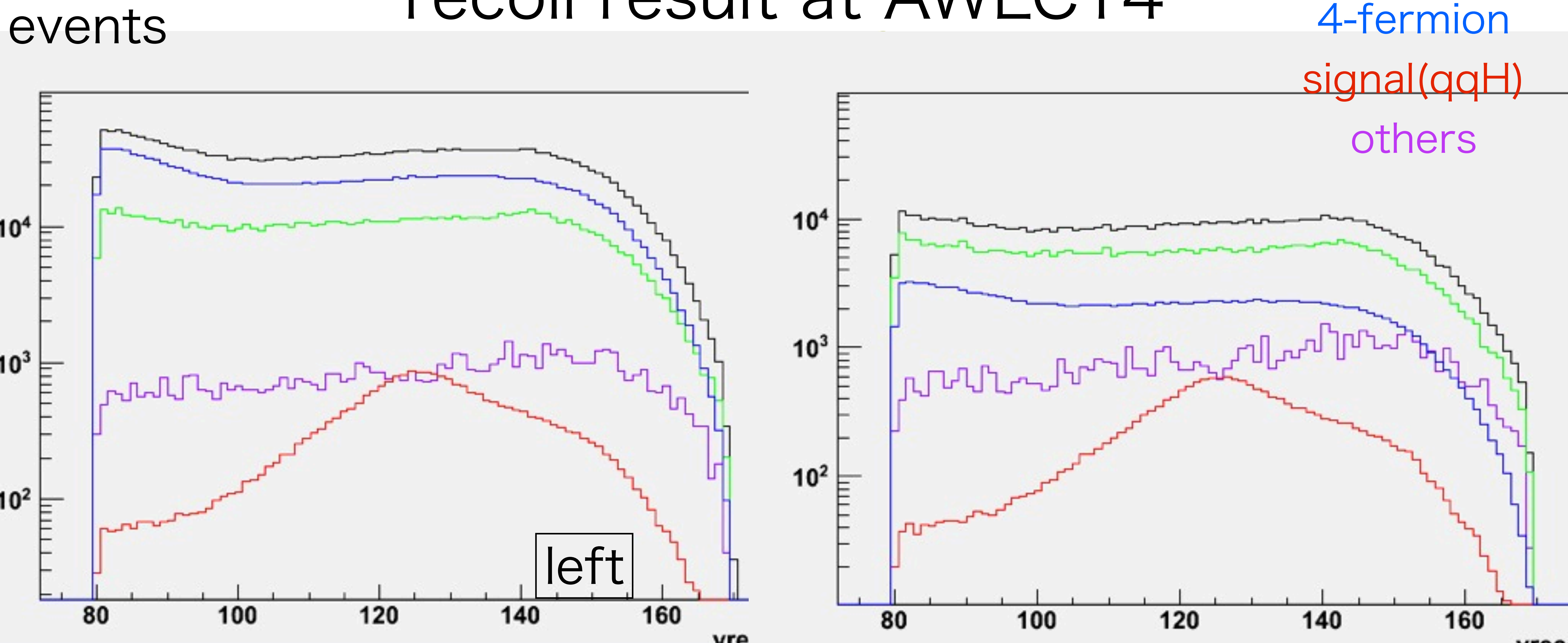
- For 2 fermion events, its efficiency is 90%, and its purity is around 80%.



Cuts so far (until AWLC14)

- BOX cut using 4 jet clustering
  (81:101) for ZZ, (70:90) for WW
- mass cut using 2 jet clustering
  (70:110) for semi lepton background
- mass selection using y value clustering
  within (76:106)
- jet pT > 20
- recoil mass cut (110:150)

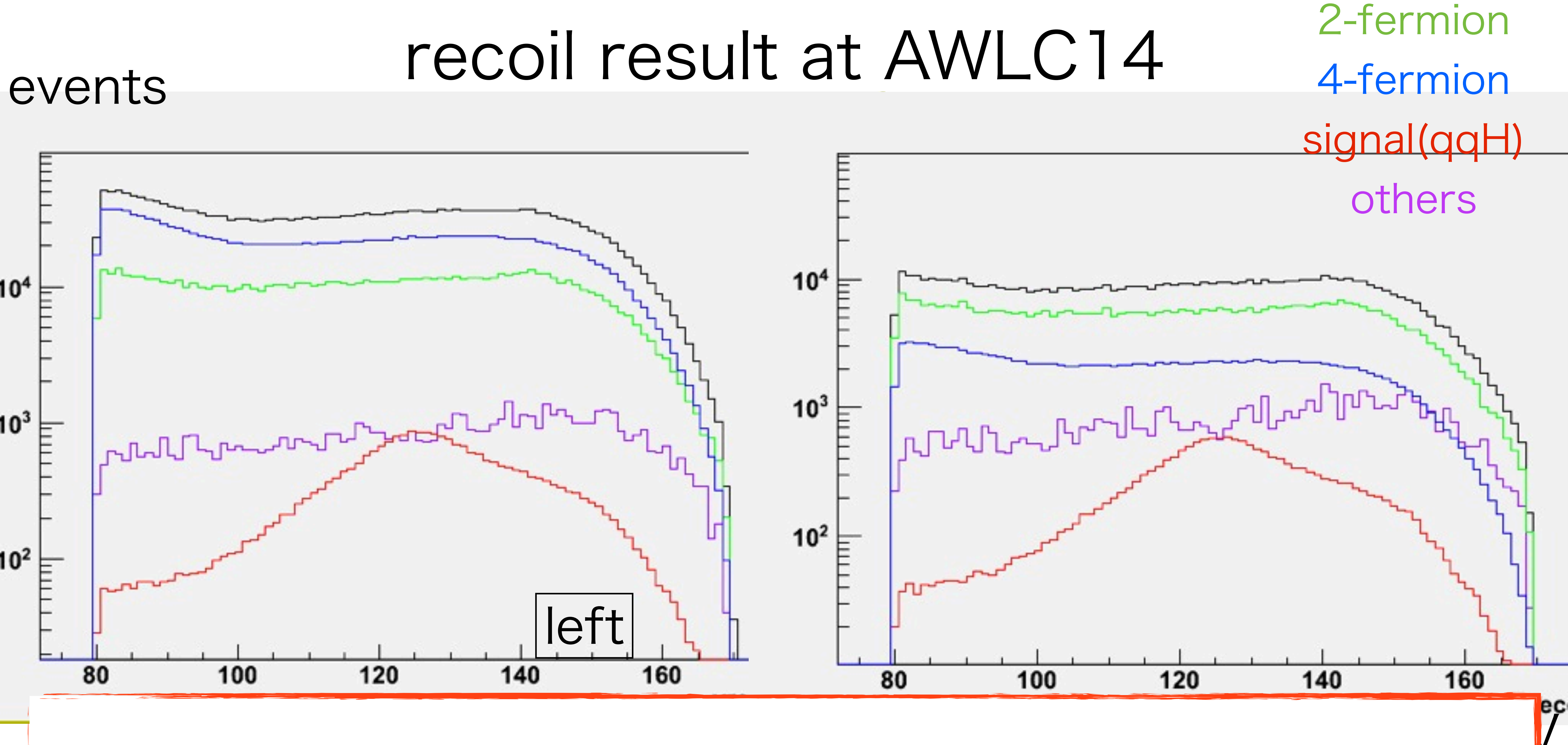
recoil result at AWLC14



significance in (110,150)

polarization	significance	$\Delta\sigma/\sigma$
left (-0.8, +0.3)	17.7σ	5.6%
right (+0.8, -0.3)	25.2σ	4.0%

recoil result at AWLC14



There are a lot of background events after cuts.

cut table (AWLC14)

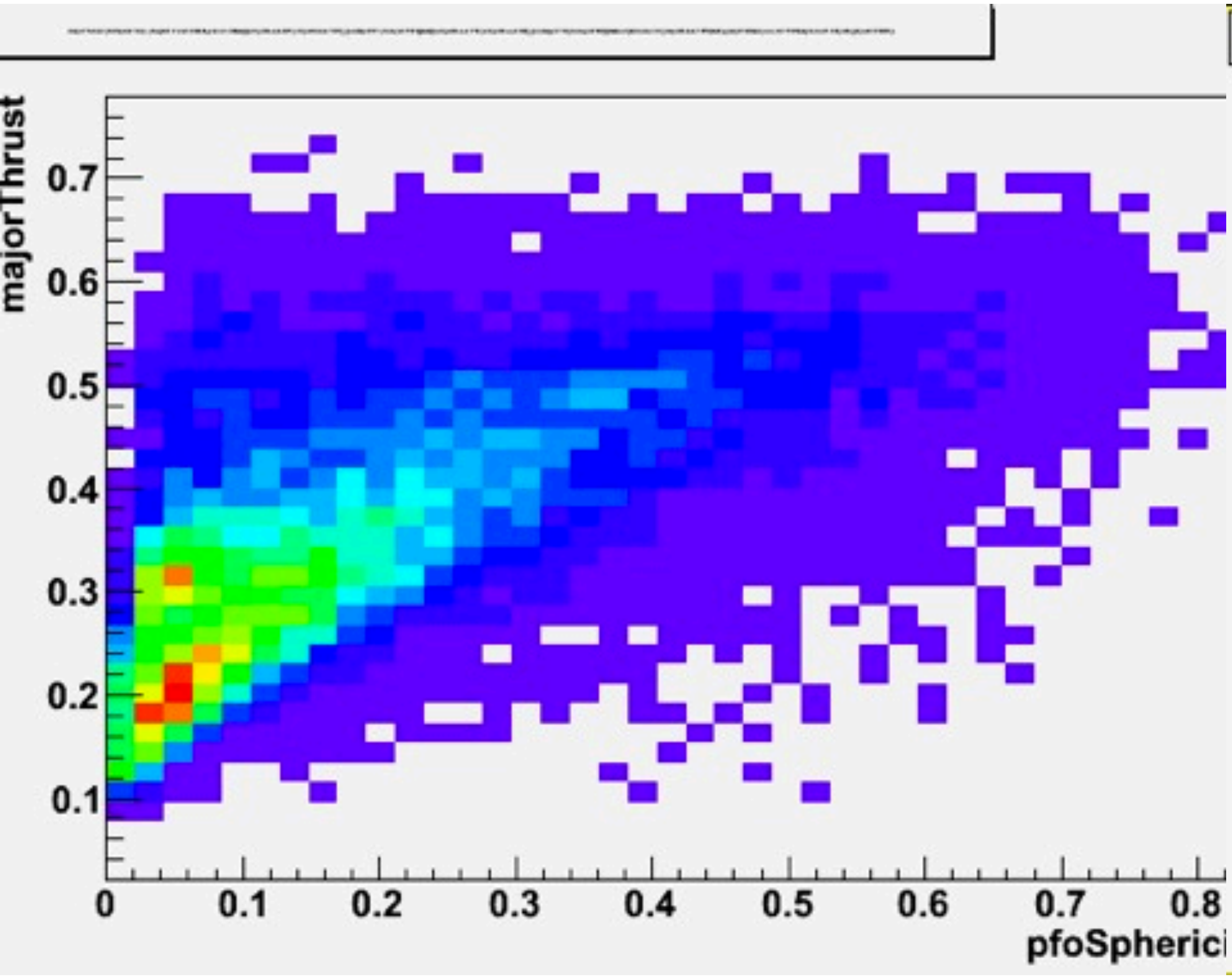
cut	qqH	4f_had	4f_other	2f_had	2f_other	other (aa,1f, so on)
no	100%	100%	100%	100%	100%	100%
box	89.9%	64.1%	52.8%	39.5%	83.9%	90.6%
z pt	78.4%	56.4%	33.6%	22.4%	29.4%	1.8%
y dijet mass	60.5%	51.4%	19.8%	14.5%	4.1%	0.4%
recoil	46.7%	15.8%	6.6%	2.5%	1.1%	0.2%

New cuts

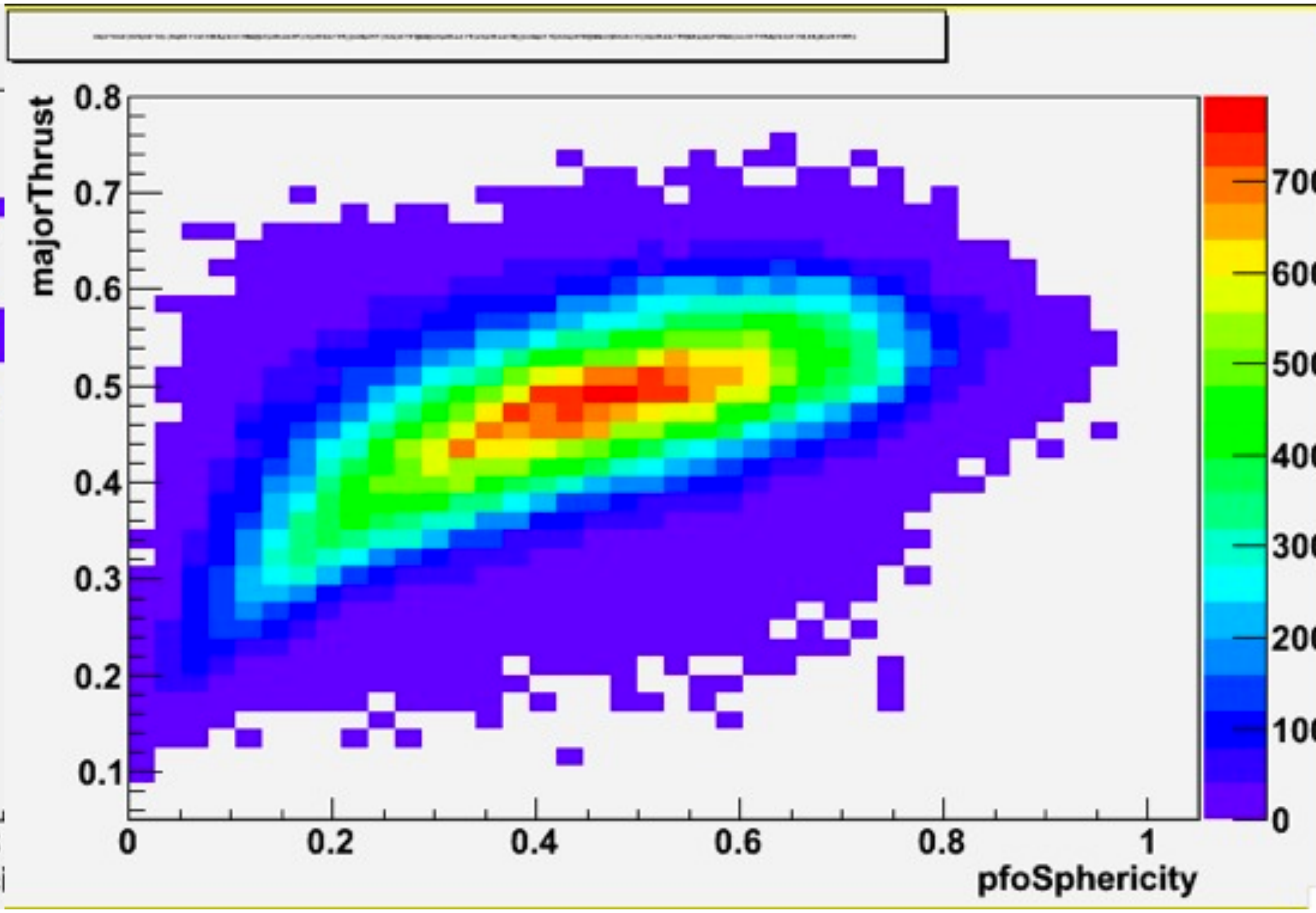
- Sphericity > 0.2
- Thrust
  major Thrust value > 0.3 , minor Thrust value > 0.1

- Both cuts mainly target the 2 fermion background.
  It can reduce 2 jet like event effectively.

major Thrust and Sphericity



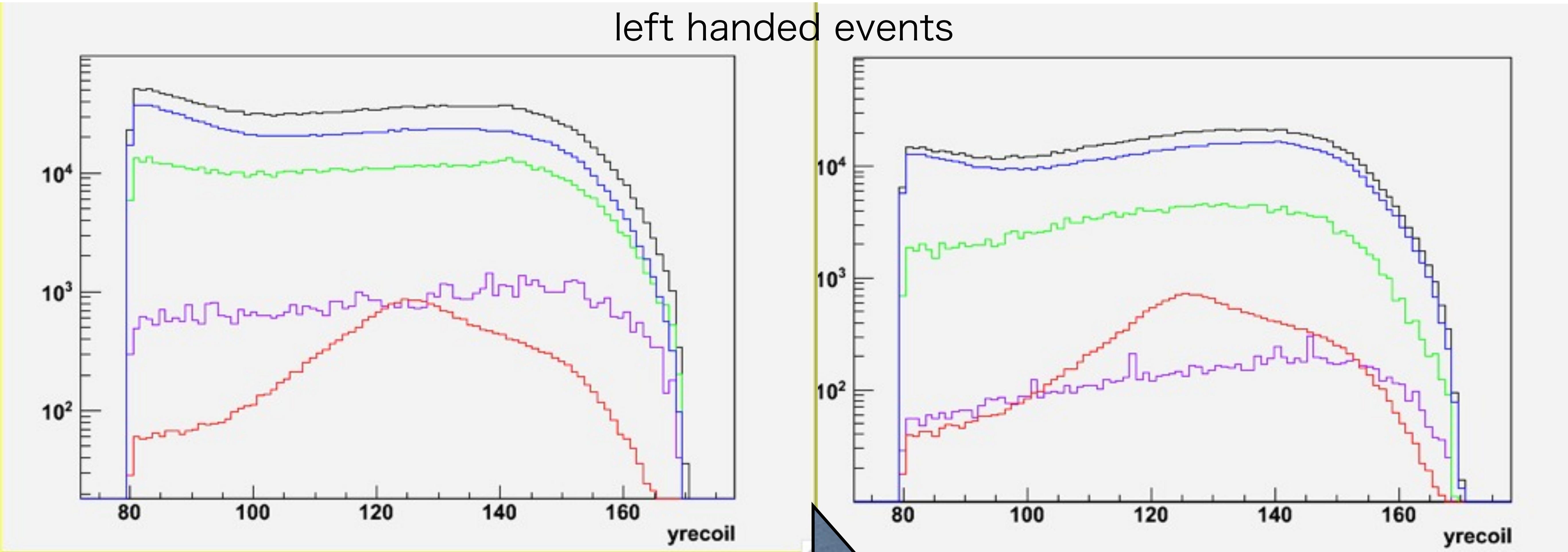
2 fermion (after cut at AWLC14)



higgs (after cut at AWLC14)

- After applying cut at AWLC14, signal and 2 fermion background are well separated.

applying Sphericity and Thrust cut

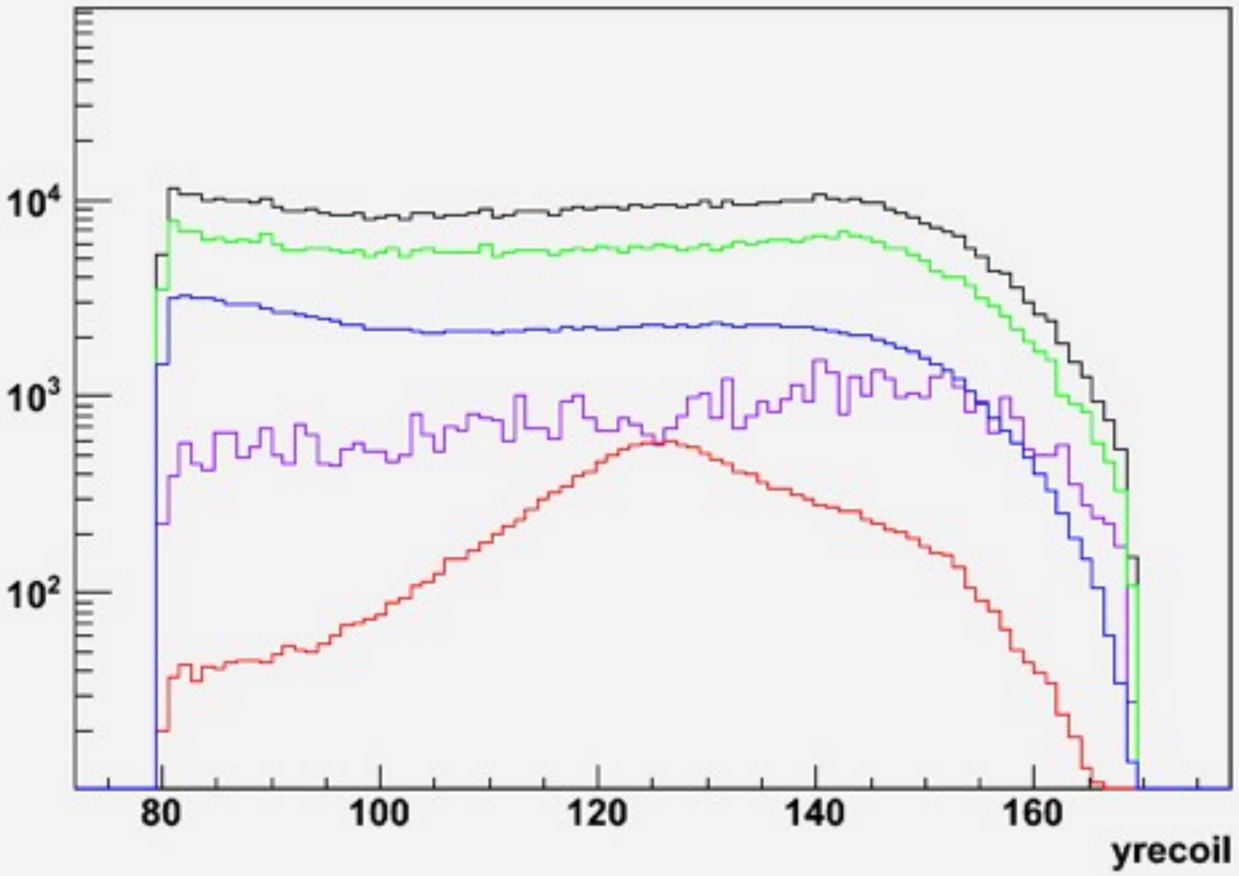


before Thrust & Sphericity cut   after Thrust & Sphericity cut

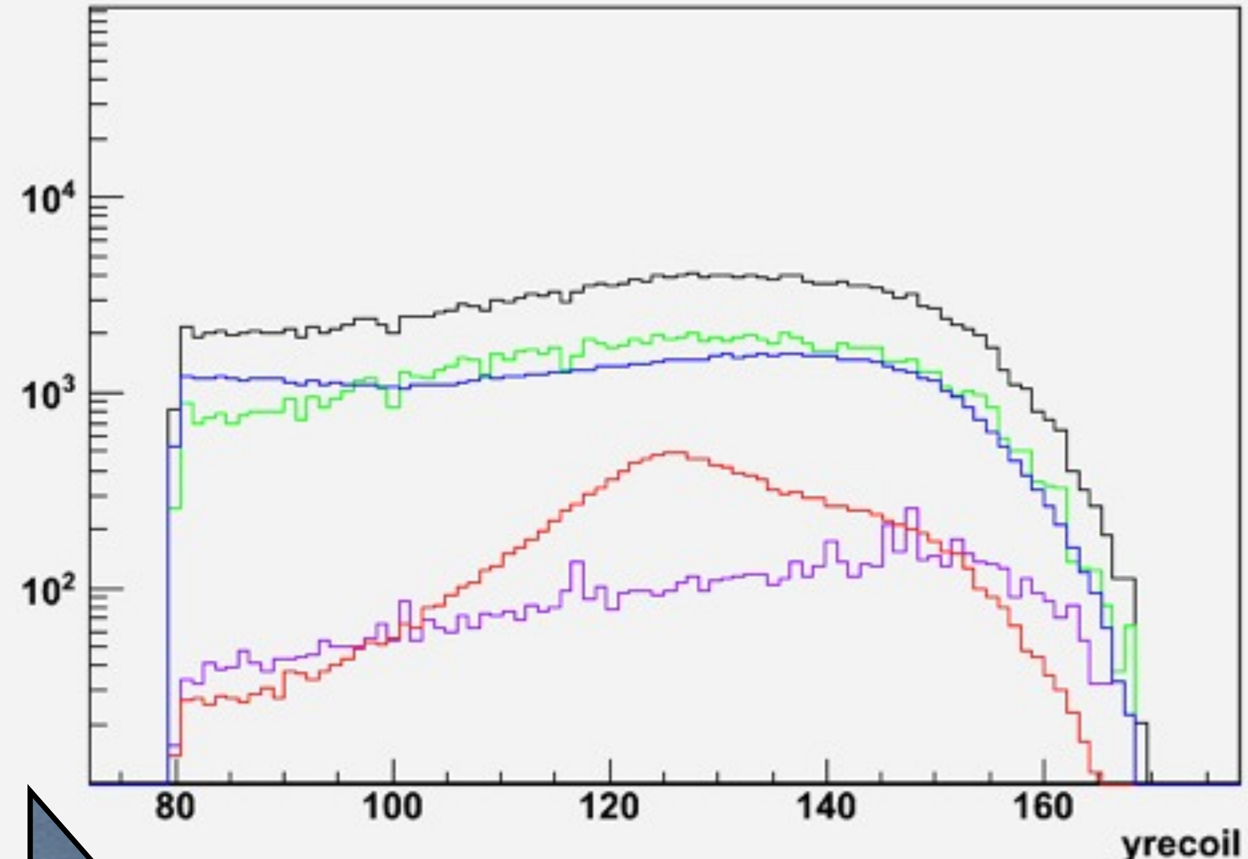
- After Thrust and Sphericity cut, backgrounds reduced by about 1 of magnitude, and signals spoiled by 15%.

applying Sphericity and Thrust cut

left handed events



before Thrust & Sphericity cut



after Thrust & Sphericity cut

polarization	significance	$\Delta\sigma/\sigma$
left (-0.8, +0.3)	20.5σ	4.8% (-0.8%)
right (+0.8, -0.3)	31.1σ	3.2% (-0.8%)

Cut table with new cut

cuts	qqH(549K)	4f(9.3M)	2f(5.6M)	other(37.9M)
left	490,370	6,255,904	16,267,218	21,274,095
right	331,118	798,363	10,355,564	21,274,095
box	82.7%	83.9%	99.0%	99.9%
z pt	70.6%	60.9%	30.3%	2.4%
y dijet	54.7%	36.2%	10.0%	0.7%
recoil	43.1%	10.8%	2.7%	0.3%
sphericity	39.1%	6.7%	0.7%	0.2%
thrust	36.9%	5.2%	0.4%	0.05%

Summary and Prospects

summary

- Using Sphericity and Thrust cuts, 2 fermion background is well suppressed, but 4 fermion background is still alive.
- Significance is improved.
  If we can reduce 4 fermion background, there is still some room for improvement.
- Higgs decay mode must be affected by these cuts,
  so we need to categorize the events and to optimize cut for each mode.

prospects

- Use MVA? to reduce 4 fermion background
- Cut optimization using categories (no lepton, 1 lepton… etc)
- We need tau finder for categorize.

backup

strategy for resolving efficiency issue -1

To resolve efficiency inconsistent issue, we will categorize events using

- the number of jets (2, 3, 4, and >= 5)
- the number of isolated lepton (0, 1, and >= 2)

$$\mathrm{N}^i = \sum_n \sigma_{\mathrm{tot}} \cdot \mathrm{BR}_n \cdot \theta_n^i \cdot \epsilon_n^i$$

$$\mathrm{n} = (\mathrm{b}, \mathrm{W}, \mathrm{g}, \tau, ...)$$

N^i is a number of events in category i, σ_{tot} is total cross section,

BR_n is Higgs decay branching ratio, θ_n^i is fraction in category i,

ϵ_n^i is cut efficiency for category i.

If the cut efficiency of each decay mode can be assumed to be the same as ϵ^i($=\bar{\epsilon}_n^i$).

$$\frac{\mathrm{N}^i}{\epsilon^i} = \sigma_{\mathrm{tot}} \sum_n \mathrm{BR}_n \cdot \theta_n^i$$

Then we can get

$$\sum_i \frac{\mathrm{N}^i}{\epsilon^i} = \sigma_{\mathrm{tot}} \sum_n \sum_i \mathrm{BR}_n \cdot \theta_n^i = \sigma_{\mathrm{tot}}$$

strategy for resolving efficiency issue -2

If the cut efficiency is not exactly the same,
we should consider the systematic effect caused by the difference.

$$\delta\epsilon_n^i = \epsilon_n^i - \epsilon^i$$

And the cross section is

$$\sigma_{\mathrm{tot}} = \frac{\sum_i \frac{\mathrm{N}^i}{\epsilon^i}}{1 + \sum_n \sum_i \mathrm{BR}_n \cdot \theta_n^i \cdot \frac{\delta\epsilon_n^i}{\epsilon^i}}$$

We want to keep systematic uncertainty is less than 1 % to do model independent analysis.

If we don't assume any models, we should keep $\theta_n^i \cdot \frac{\delta\epsilon_n^i}{\epsilon^i}$ << 1 %.

If we can assume SM like higgs, we should keep $\mathrm{BR}_n \cdot \theta_n^i \cdot \frac{\delta\epsilon_n^i}{\epsilon^i}$ << 1 %.