Higgs recoil mass study in qqH channel @ 250GeV ILC

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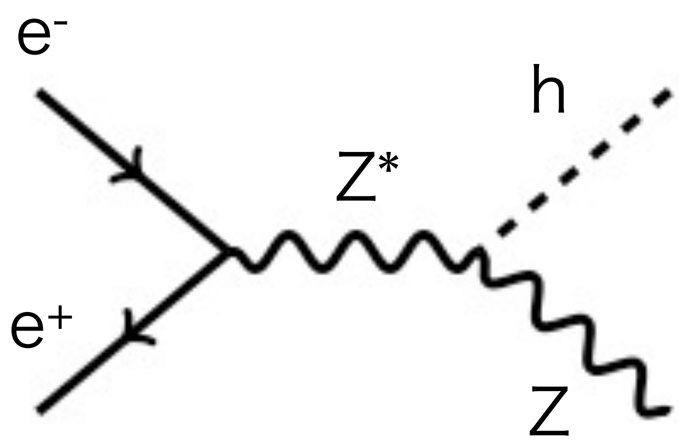
Outline

- What is “recoil mass” ?
- Why “qqH” ?
- background estimation, cut optimization
  - Method
  - Result
- signal efficiency and significance with “cut”
- Summary & Next step

What is recoil mass ?



The typical higgs production mode at ILC is “higgs-strahlung”.

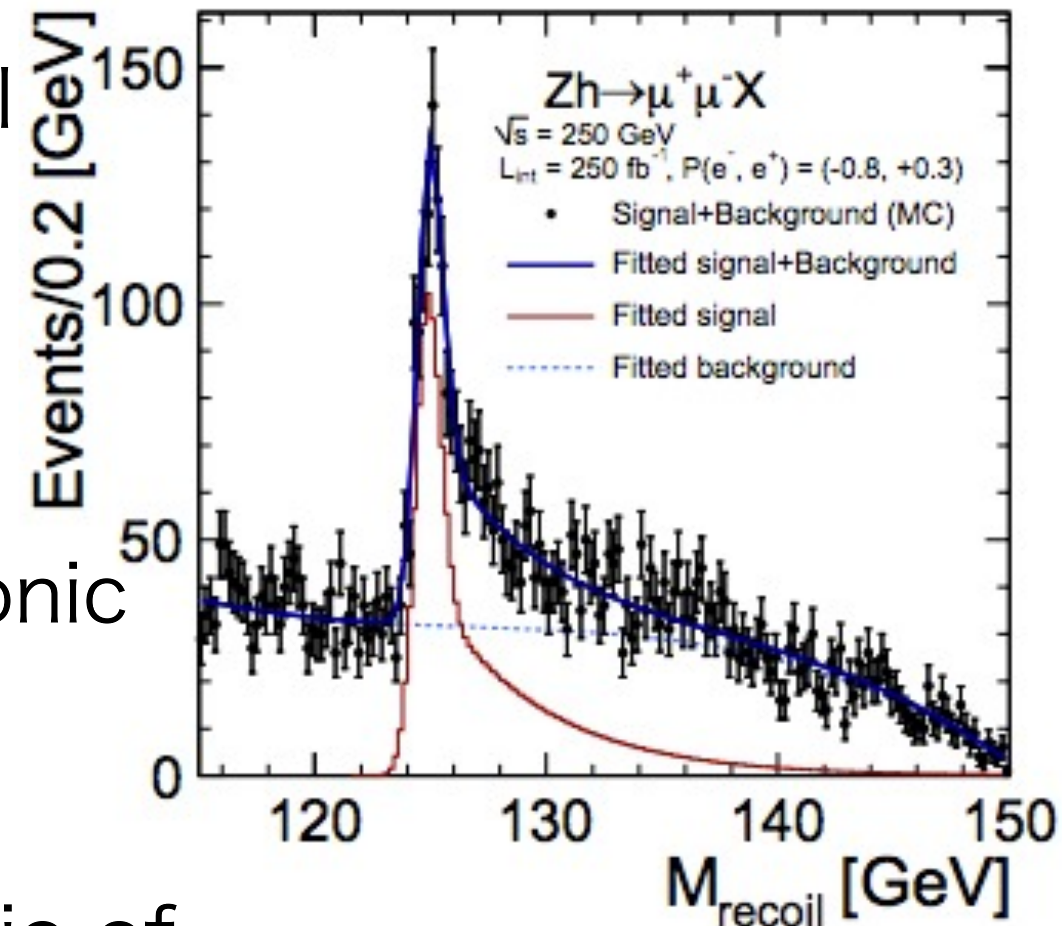
In this channel, we don’t have to look any higgs because we can use four momentum conservation.

$$m^2_{\mathrm{recoil}} = (\sqrt{s} - E_Z)^2 - \mid \vec{p}_Z \mid^2$$

(Initial 4-momentum of e^+e^- collision is well determined.)

To use four momentum conservation, we should reconstruct Z mass as well as possible.

Why qqH ?



In recoil mass study, leptonic channel such as Z -> e^+e^-, mu^+mu^- has very good signal/back-ground ratio.

BUT, the branching ratio of Z -> leptonic is ~3.5% for each generation.

On the other hand, the branching ratio of

Z -> hadronic is ~70%.

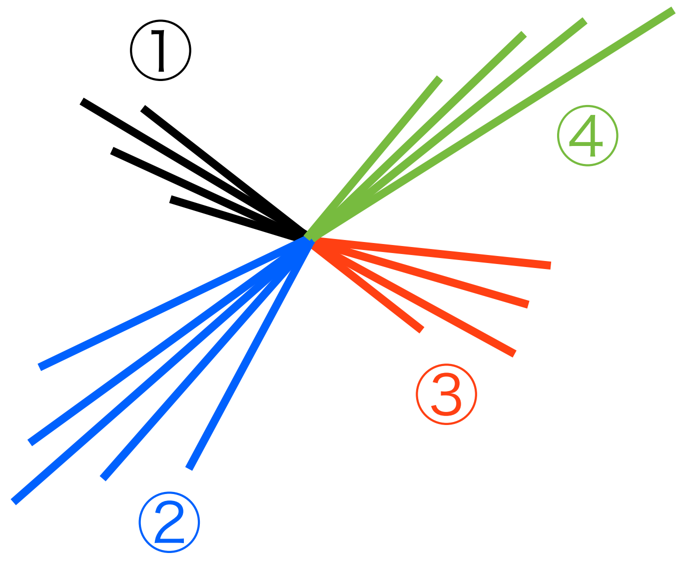
This is the big motivation for qqH study.
Fortunately, detector performance, JER ~3.5% with PFA, support this qqH study. (ex. ZZ,WW separation)

Event list

- The recoil higgs mass against Z->hadronic with DBD sample.
- Polarization both (-0.8,0.3) and (0.8,-0.3) are used.
- for background estimation,
  at first we used only ZZ->4q and WW->4q to decide cut box,
  and then we added all kind of background.

DBD sample is created with mixed final states,
so we select from qqqq events with flavors consistent to ZZ/WW event
that two MC di-jet mass within 10 GeV from Z mass for ZZ events
and two MC di-jet mass within 10 GeV from W mass for WW events.

reconstruction for background rejection



1.Forced 4-jets clustering for each event.

2.Reconstruct every pair of jets.
(1-2,1-3,1-4,2-3,2-4,3-4)

3.Record the pair which is the
nearest to Z mass as horizontal axis. (ex. 2-3)

4.Reconstruct the rest pair. (ex. 1-4)

5.Record the rest pair mass as vertical axis.

6.Repeat 2-5 for every event.

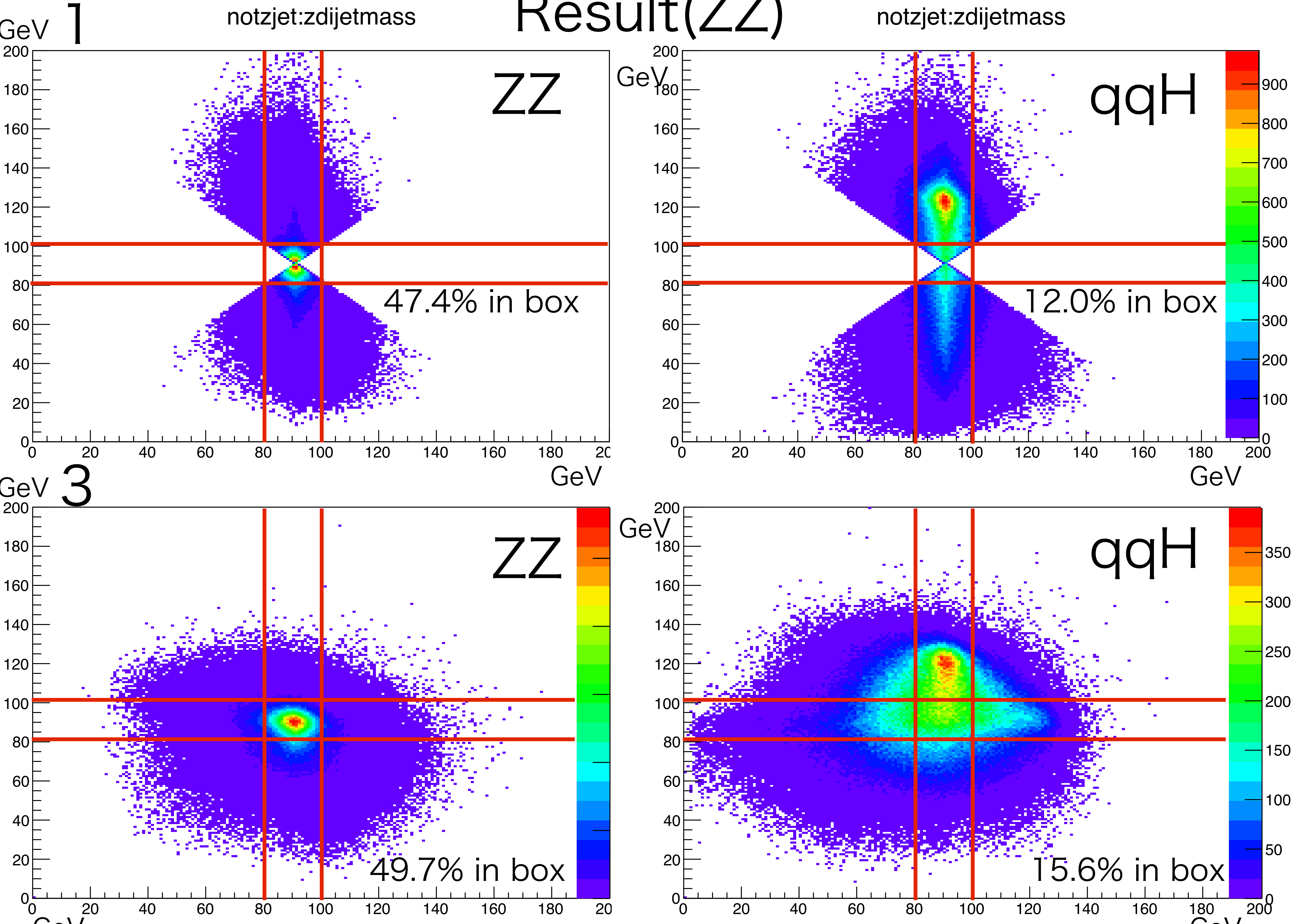
Comparison of jet pairings

- We checked three types of jet pairing,
  - 1. select minimum (Z/W mass - di-jet mass)^2 from every pair (same method as previous slide)
  - 2. select minimum (Z/W mass - di-jet mass)^2 from pairs (1-2,1-3,1-4)
  - 3. select minimum (Z/W mass - di-jet mass)^2 + (Z/W mass - restjetmass)^2 from every pair
  - Set the rejection box at (81-101,81-101) for ZZ and (70-90,70-90) for WW

	ZZ(WW)	qqH,Z(qqH,W)
1	47.4% (56.9%)	12.0% (9.2%)
2	49.8% (57.1%)	13.7% (10.6%)
3	49.7% (63.9%)	15.6% (11.7%)

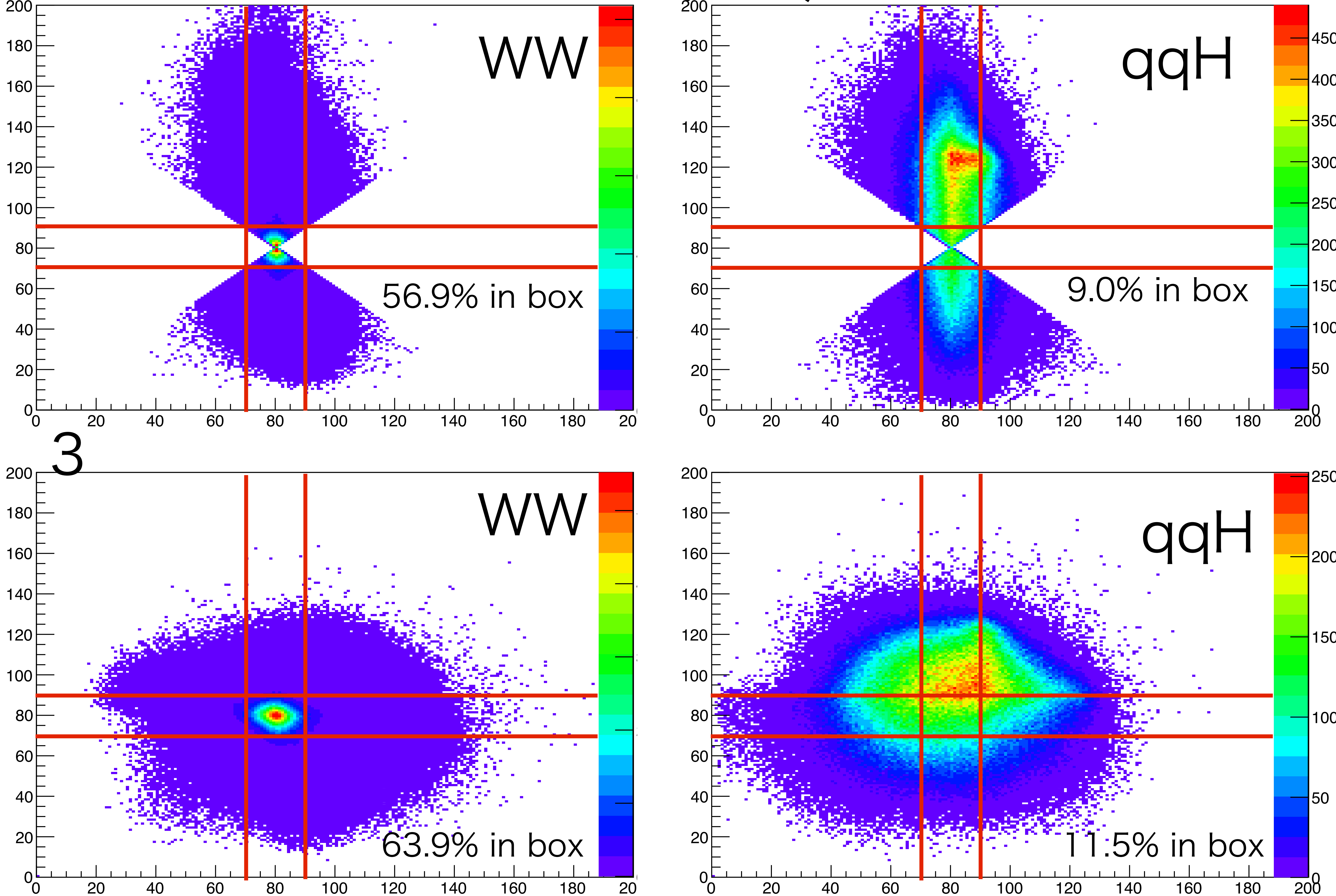
Adopt 1. for the following analysis

Result(ZZ)


1
notzjet:zdijetmass
ZZ
47.4% in box
qqH
12.0% in box
3
ZZ
49.7% in box
qqH
15.6% in box
GeV

Result(WW)

1 notwjet:wdijetmass notwjet:wdijetmass



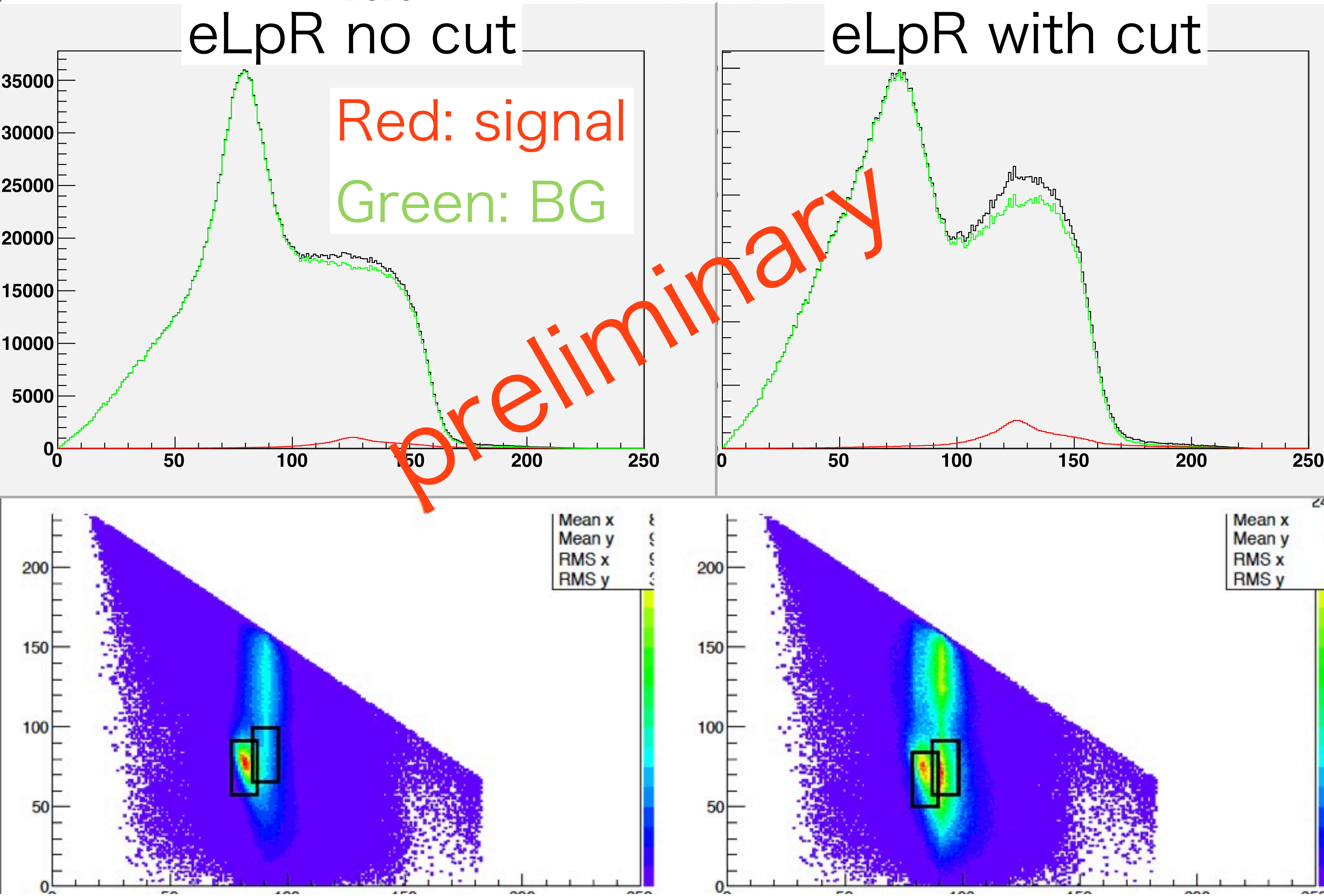
reconstruction for recoil mass

- Apply the rejection box to reduce WW/ZZ background (as shown in previous slide)
- We used "**y-value clustering**" to study higgs recoil mass.

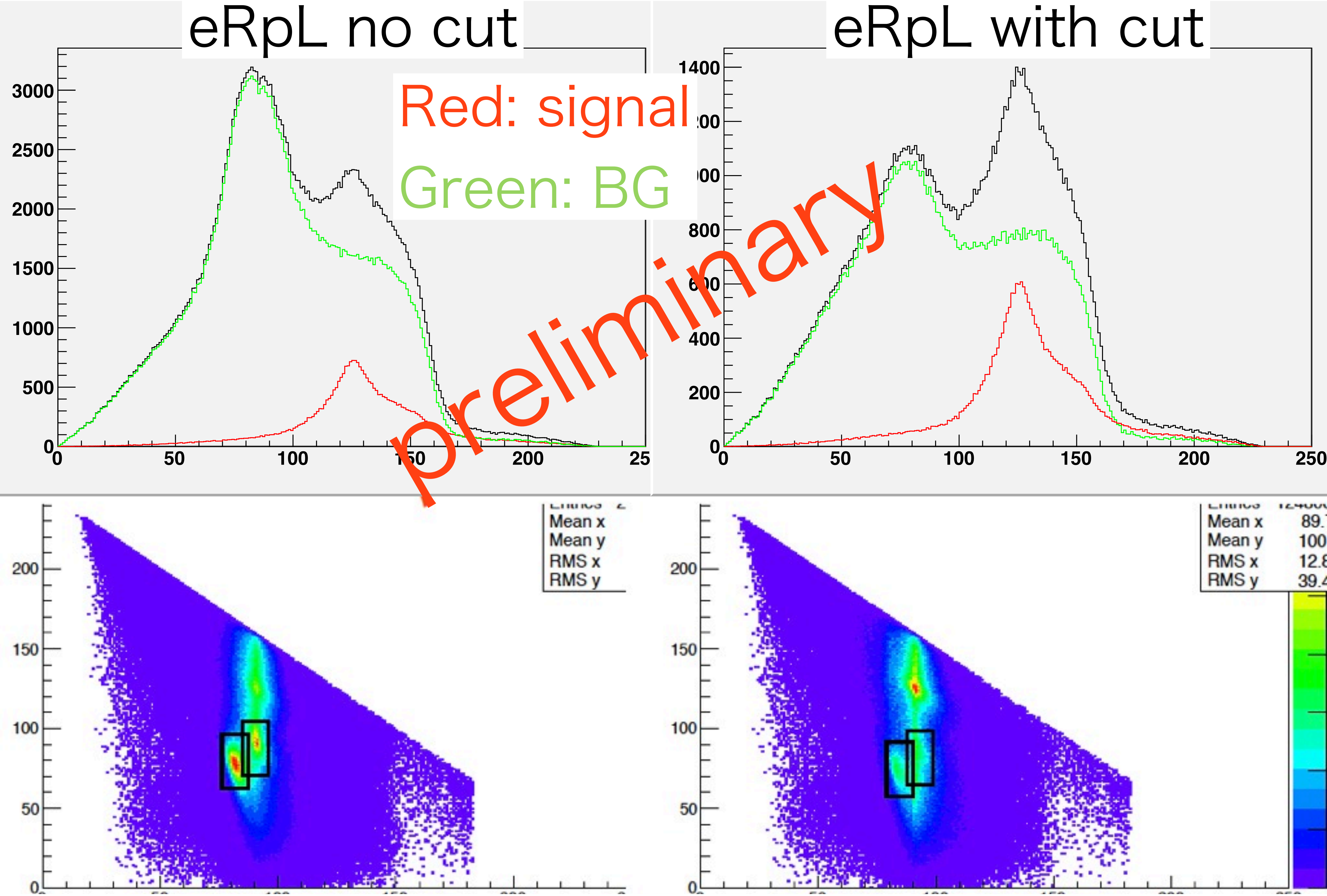
$$y = \frac{2\min(E_i^2, E_j^2)(1 - \cos\theta_{ij})}{Q^2}$$

in this time, y-threshold fixed to 0.005

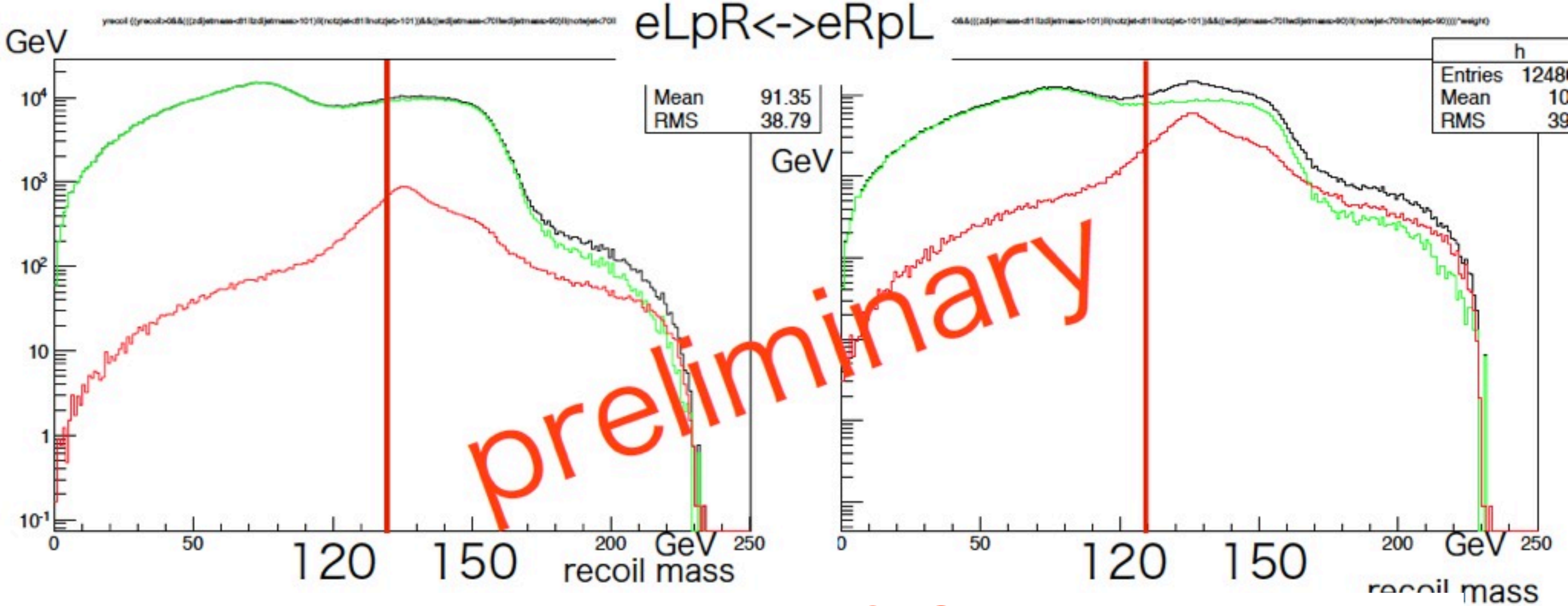
Higgs recoil mass with "cut"



Higgs recoil mass with “cut”



Significance with cut



recoil > 110 GeV

	qqH	ZZ/WW	significance
eLpR	30,591	359,167	49.0 σ
eRpL	20,663	36,931	86.1 σ

Signal efficiency with recoil cut

recoil>110GeV

decay mode	counts	ZZ cut	WW cut	both cut	recoil cut	(%)
qqH all eLpR	46,401	41,109	42,437	38,002	30,591	65.9%
qqH all eRpL	31,345	27,774	28,663	25,677	20,663	65.9%
H -> bb eLpR	25,733	22,829	23,760	21,270	17,430	67.7%
H -> bb eRpL	17,282	15,322	15,931	14,259	11,689	67.6%
H -> WW eLpR	10,656	9,292	9,584	8,467	6,879	64.6%
H -> WW eRpL	7,235	6,314	6,518	5,764	4,676	64.6%
H -> ZZ eLpR	1,379	1,211	1,268	1,129	928	67.3%
H -> ZZ eRpL	941	824	870	774	635	67.5%
H -> $\gamma\gamma$ eLpR	172	161	161	152	104	60.5%
H -> $\gamma\gamma$ eRpL	123	113	113	106	74	60.2%
ZZ eLpR	145,395	83,539	124,460	72,681	30,715	21.1%
ZZ eRpL	67,614	39,379	57,478	34,109	13,752	20.3%
WW eLpR	1,779,638	1,563,115	815,083	733,107	247,157	13.9%
WW eRpL	123,359	108,108	55,721	49,977	17,356	14.1%

preliminary

more cuts

- to add the other background, we set more cut step

E_{jet} >10 GeV (to reduce small jets)

jetPt > 20 GeV (to reduce back to back Z)

76 GeV < dijetmass(y-fix) <106 GeV

recoil mass > 110 GeV

- Isolated lepton are identified and eliminated before jet clustering.

4-jet clustering
y-fix clustering(0.005)

with more cuts

E-jet>10

	qqH eLpR	qqH eRpL	ZZ eLpR	ZZ eRpL	WW eLpR	WW eRpL
no cut	46,339	31,312	145,359	67,602	1,779,793	123,370
Z box cut [81:101]	41,272	27,898	83,701	39,451	1,563,621	108,147
W box cut [70:90]	42,508	28,707	124,433	57,474	818,306	55,935
both box cut	38,269	25,858	72,826	34,177	736,311	50,197
z-jet Pt > 20(GeV)	33,412	22,583	64,486	30,042	655,008	44,851
z-jet mass [76:106]	25,469	17,221	52,644	24,548	590,090	40,595
recoil mass cut > 110	21,254	14,382	20,710	9,126	187,848	13,322
%	45.9%	45.9%	14.2%	13.5%	10.6%	10.8%

preliminary

4-jet clustering
y-fix clustering(0.005)

with more cuts

E-jet>10

	qqH eLpR	qqH eRpL	ZZ eLpR	ZZ eRpL	WW eLpR	WW eRpL
no cut	46,339	31,312	145,359	67,602	1,779,793	123,370
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recoil mass cut >	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22
%	45.9%	45.9%	14.2%	13.5%	10.6%	10.8%

preliminary

dijetmass(y-fix) kills too large number of signals
jet pairing and/or clustering does not work well

4-jet clustering
y-fix clustering(0.005)

with more cuts

E-jet>10

	qqH eLpR	qqH eRpL	ZZ eLpR	ZZ eRpL	WW eLpR	WW eRpL
no cut	46,339	31,312	145,359	67,602	1,779,793	123,370
Z box cut [81:101]	41,272	27,898	83,701	39,451	1,563,621	108,147
						35
b						97
z-je						51
[76:106]	25,469	17,221	52,644	24,548	590,090	40,595
recoil mass cut >						22
%	45.9%	45.9%	14.2%	13.5%	10.6%	10.8%

We need to optimize
jet pairing and/or clustering
much more

dijetmass(y-fix) kills too large number of signals
jet pairing and/or clustering does not work well

add other background

- add the other backgrounds (leptonic,semi leptonic,etc…)
- apply same cut step.

- We checked total cut efficiency for background, and signal significance with all background.

left handed

	2f Z bhabha	2f Z leptonic	2f Z hadronic	4f ZZ leptonic	4f ZZ semi lep	4f ZZ hadronic	4f WW leptonic	4f WW semi lep	4f WW hadronic	4f W leptonic	4f W semi lep
w/o cut	105,628	11,898	144,223	5,529	132,579	145,359	13,223	916,602	1.78E+06	34,200	484,915
w/ cut	5,041	213	285	498	24,595	20,710	1,074	148,168	187,848	3,702	66,450
	4f Zee leptonic	4f Zee semi lep	4f Z/W leptonic	4f Znunu leptonic	4f Znunu semi lep	1f_3f	aa_2f	aa_minijet			
w/o cut	8,658	29,819	6,316	2,353	40,860	658,808	563,486	30,779			
w/ cut	497	5,787	545	139	7,729	2,927	564	30			

preliminary

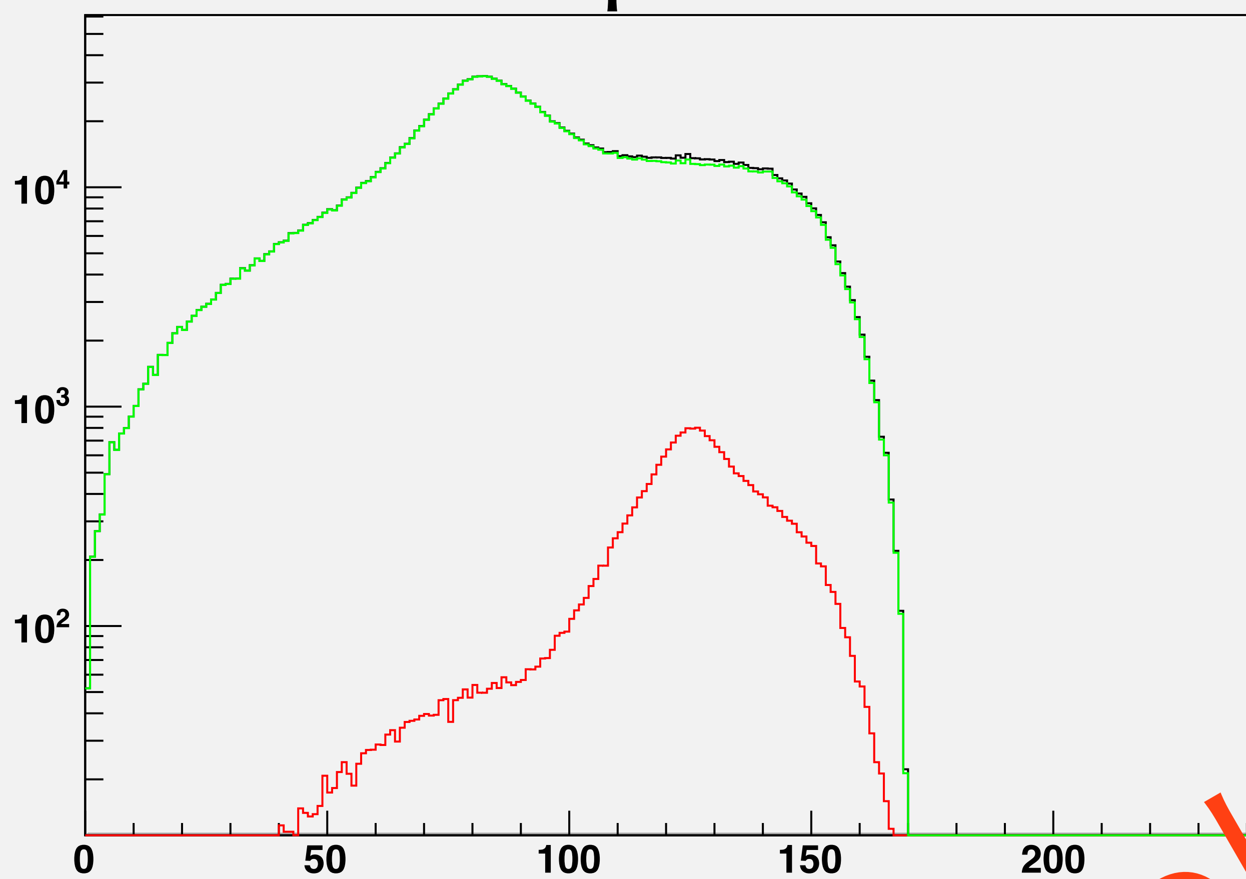
right handed

	2f Z bhabha	2f Z leptonic	2f Z hadronic	4f ZZ leptonic	4f ZZ semi lep	4f ZZ hadronic	4f WW leptonic	4f WW semi lep	4f WW hadronic	4f W leptonic	4f W semi lep
w/o cut	72,570	9,833	145,337	3,251	65,572	67,602	893	62,801	125,370	2,345	35,907
w/ cut	3,214	210	2,908	284	11,382	9,126	73	10,310	13,322	254	5,468
	4f Zee leptonic	4f Zee semi lep	4f Z/W leptonic	4f Znunu leptonic	4f Znunu semi lep	1f_3f	aa_2f	aa_minijet			
w/o cut	7,157	17,482	618	1,219	18,231	793,232	563,486	30,779			
w/ cut	353	3,242	46	75	3,143	2,933	564	30			

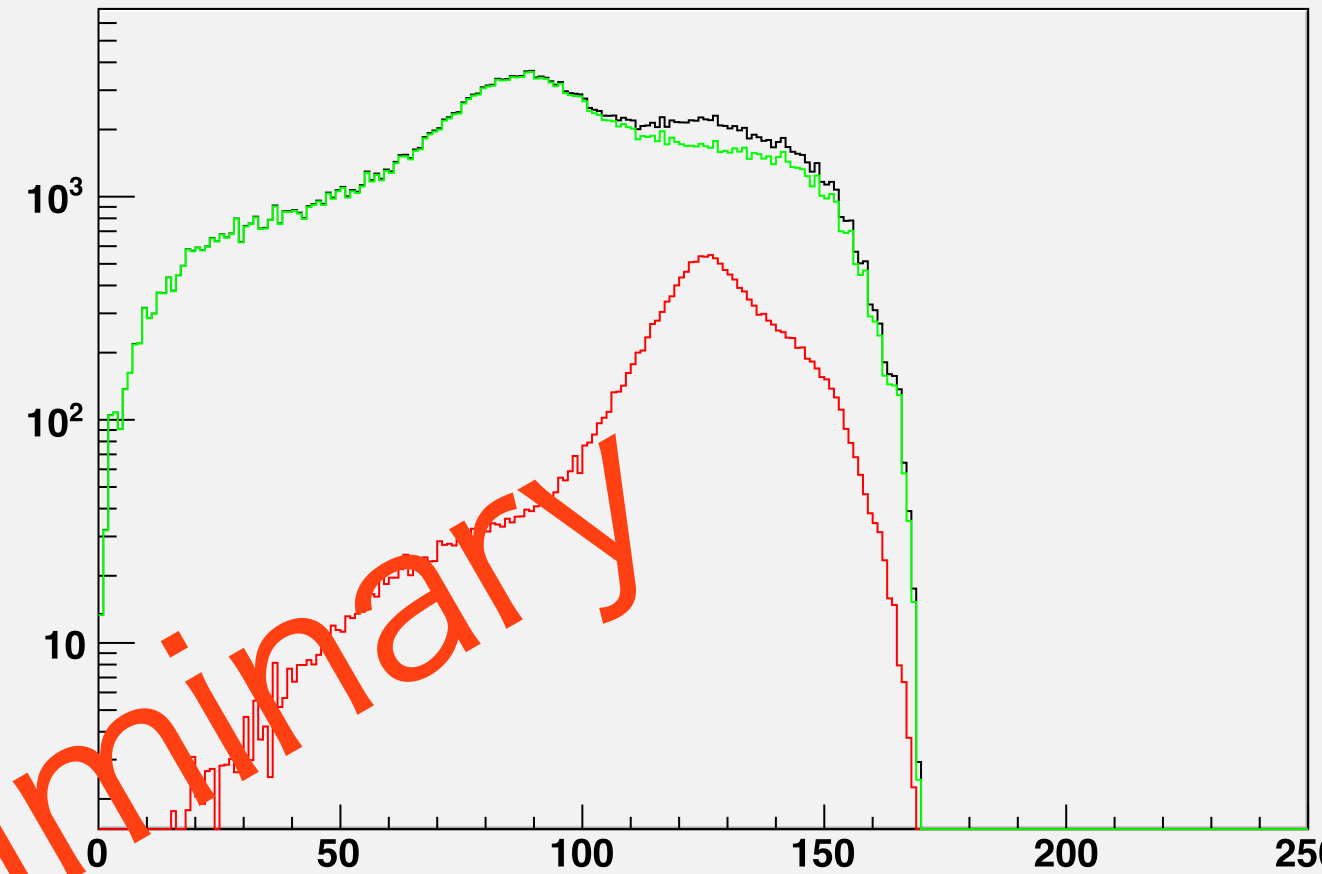
preliminary

significance with all background

eLpR



eRpL



recoil > 110GeV

	qqH	BG	significance
eLpR	21,254	544,575	28.3 σ
eRpL	14,382	71,857	49.0 σ

Summary & Next step

- We are studying higgs recoil mass using qqH channel at 250GeV ILC.
- BG study using forced 4-jets clustering.
  - ZZ reduced ~50.0%, WW reduced ~60.0%.
    (ZZ reduced ~80%, WW reduced 85% with recoil cut)
- Recoil mass study using y-value clustering. (y fixed 0.005)
  - Signal efficiency with box cut ~66%.
    with all cut ~ 46%
  - Higgs recoil mass is clearly separated from BG.
  - The next step -> optimize jet pairing with y-value.
    consider more appropriate cut.

- back up