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

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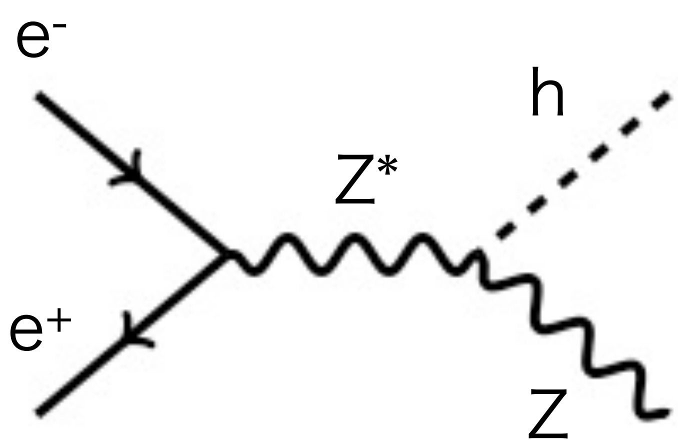
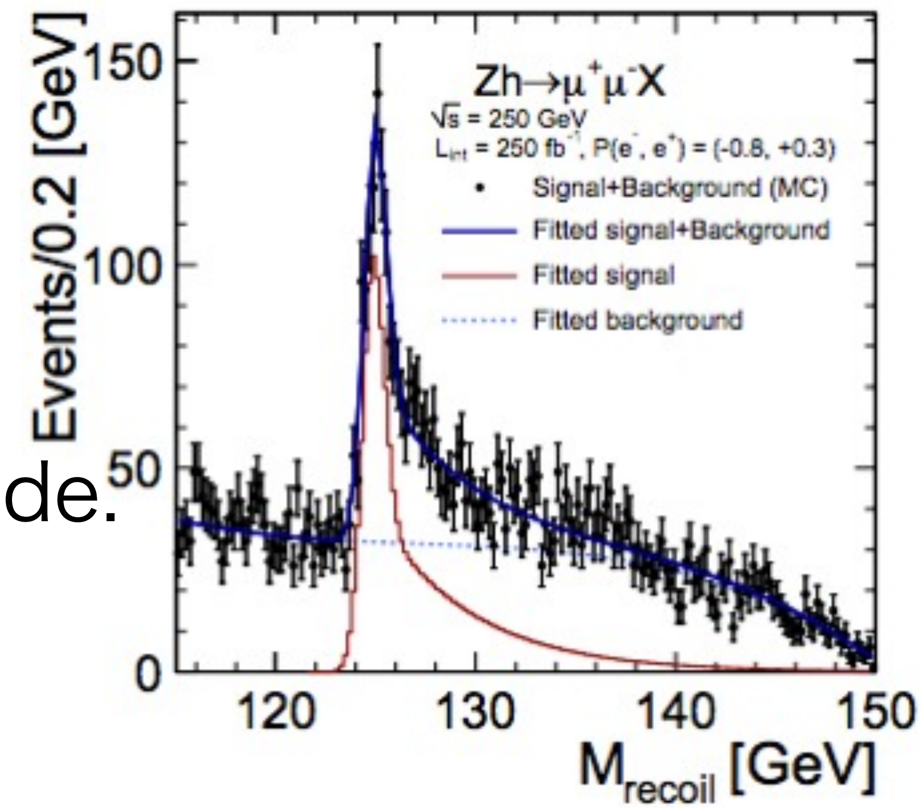
Reminder : Why qqH channel?



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



Since four momentum conservation of electron-positron collider,
We should not assume any higgs decay mode.
-> Model independent.

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

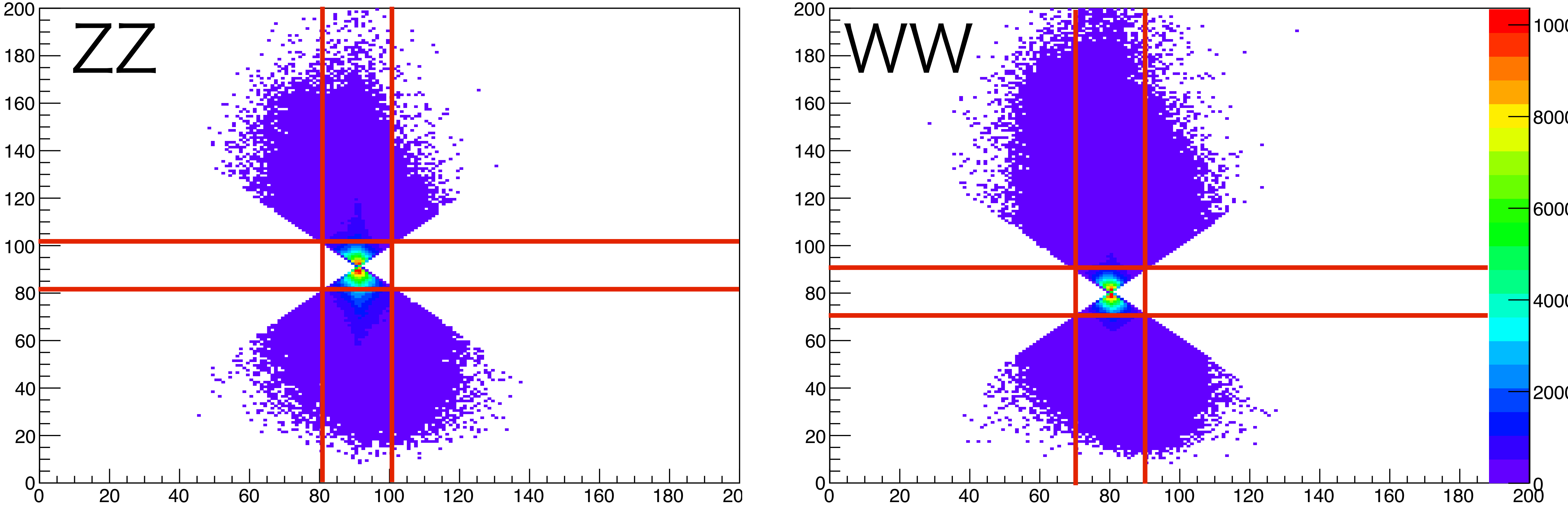
On the other hand, the branching ratio of

Z -> hadronic is ~70%.

Reminder : Background estimation

We did forced 4-jet clustering to cut the background of ZZ/WW.
(using DBD samples)

And we decided the cut box as (81,101) for ZZ, (70,90) for WW.



After cut, ZZ reduced 50% and WW reduced 60%.

Then, we did y-value clustering to do recoil mass study.

$$y = \frac{2\min(E_i^2, E_j^2)(1 - \cos\theta_{ij})}{Q^2} = 0.005$$

Reminder : The result so far

As another cut step, we used these variables.

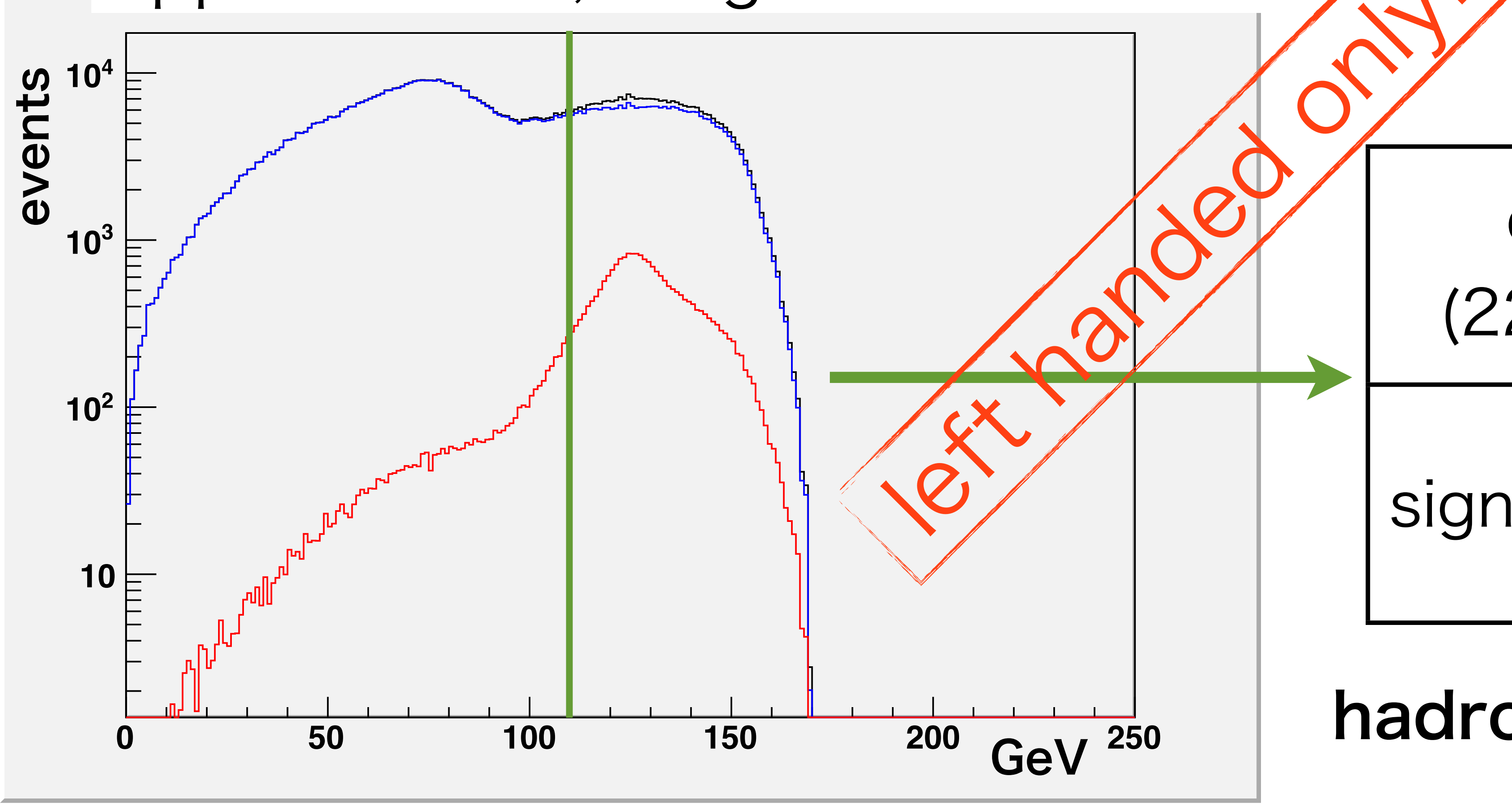
E_{jet} >10 GeV (to reduce small jets)

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

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

recoil mass > 110 GeV

Applied all cut, we got...



qqH (22,669)	ZZ/WW (266,091)
significance	42.2 σ

hadronic background only

Remain issues - 1

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Iso lepton = 0
not weighted

mode	before	ZZ	WW	ZZWW	recoil	efficiency
H->all (67.4%)	330,638 (100%)	291,100 (88.0%)	302,489 (91.5%)	269,117 (81.4%)	220,989	66.8% ±0.1%
H->bb (61.0%)	179,303 (100%)	158,164 (88.2%)	165,144 (92.1%)	146,994 (82.0%)	122,912	68.5% ±0.1%
H->WW (77.7%)	67,472 (100%)	58,192 (86.2%)	61,388 (91.0%)	53,571 (79.4%)	43,518	64.5% ±0.2%
H->gg (79.6%)	38,095 (100%)	34,561 (90.7%)	35,364 (92.8%)	32,316 (84.8%)	24,563	64.5% ±0.2%
H->$\tau\tau$ (73.9%)	24,495 (100%)	21,230 (86.7%)	20,997 (85.7%)	18,590 (75.9%)	15,940	65.1% ±0.3%
H->ZZ (69.4%)	9,724 (100%)	8,375 (86.1%)	8,898 (94.4%)	7,792 (80.1%)	6,557	67.4% ±0.5%
H->cc (70.3%)	9,830 (100%)	8,983 (91.4%)	9,100 (92.6%)	8,363 (85.1%)	6,387	65.0% ±0.5%
H->$\gamma\gamma$ (77.1%)	1,510 (100%)	1,400 (92.7%)	1,400 (92.7%)	1,306 (86.5%)	979	64.8% ±1.2%

Efficiency is not consistent with each mode... bb/gg/cc is strange!

Remain issues - 1

Iso lepton = 0
not weighted

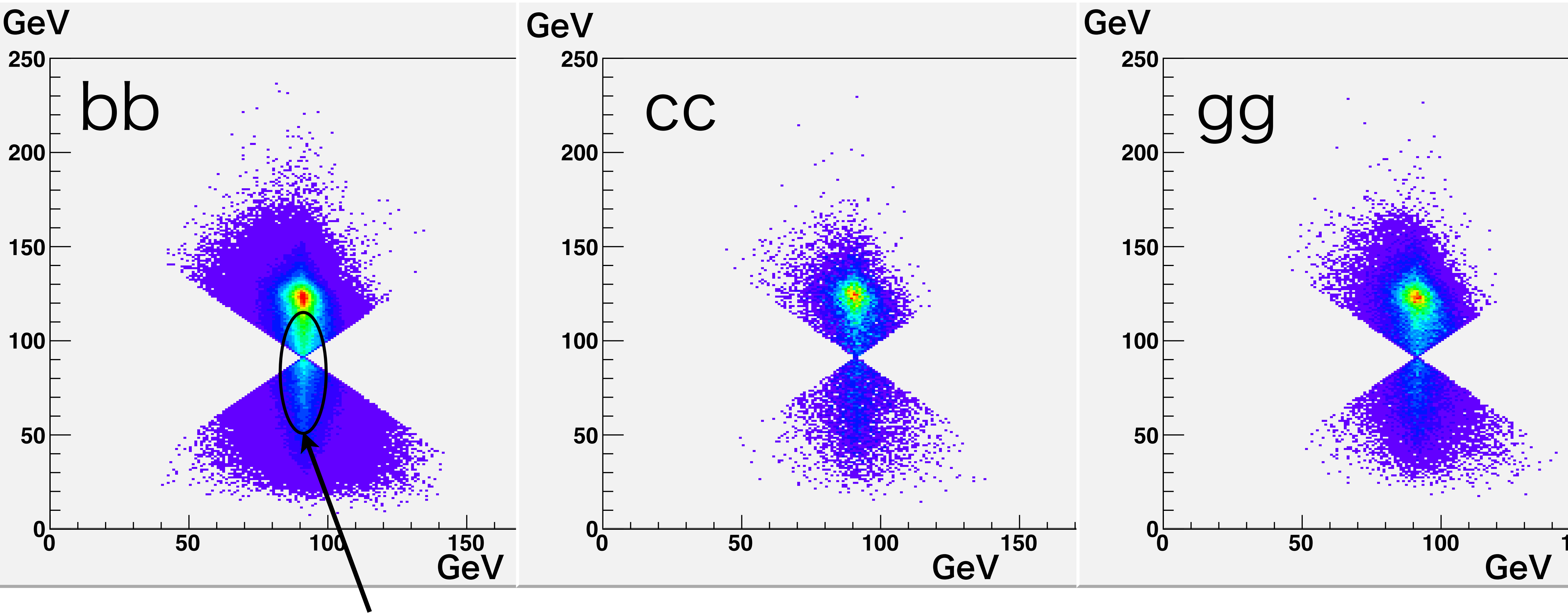
mode	before	ZZ	WW	ZZWW	recoil	efficiency
H->a						66.8% ±0.1%
H->b						68.5% ±0.1%
H->W						64.5% ±0.2%
H->g						64.5% ±0.2%
H->τ						65.1% ±0.3%
H->Z						67.4% ±0.5%
H->c						65.0% ±0.5%
H->γ						64.8% ±1.2%

These three modes can assume
4 jet and no Iso lepton.
But very large inconsistent
between bb and gg/cc.

Efficiency is not consistent with each mode... bb/gg/cc is strange!

Efficiency investigation

The comparison of 4-jet clustering these three modes (bb/cc/gg)

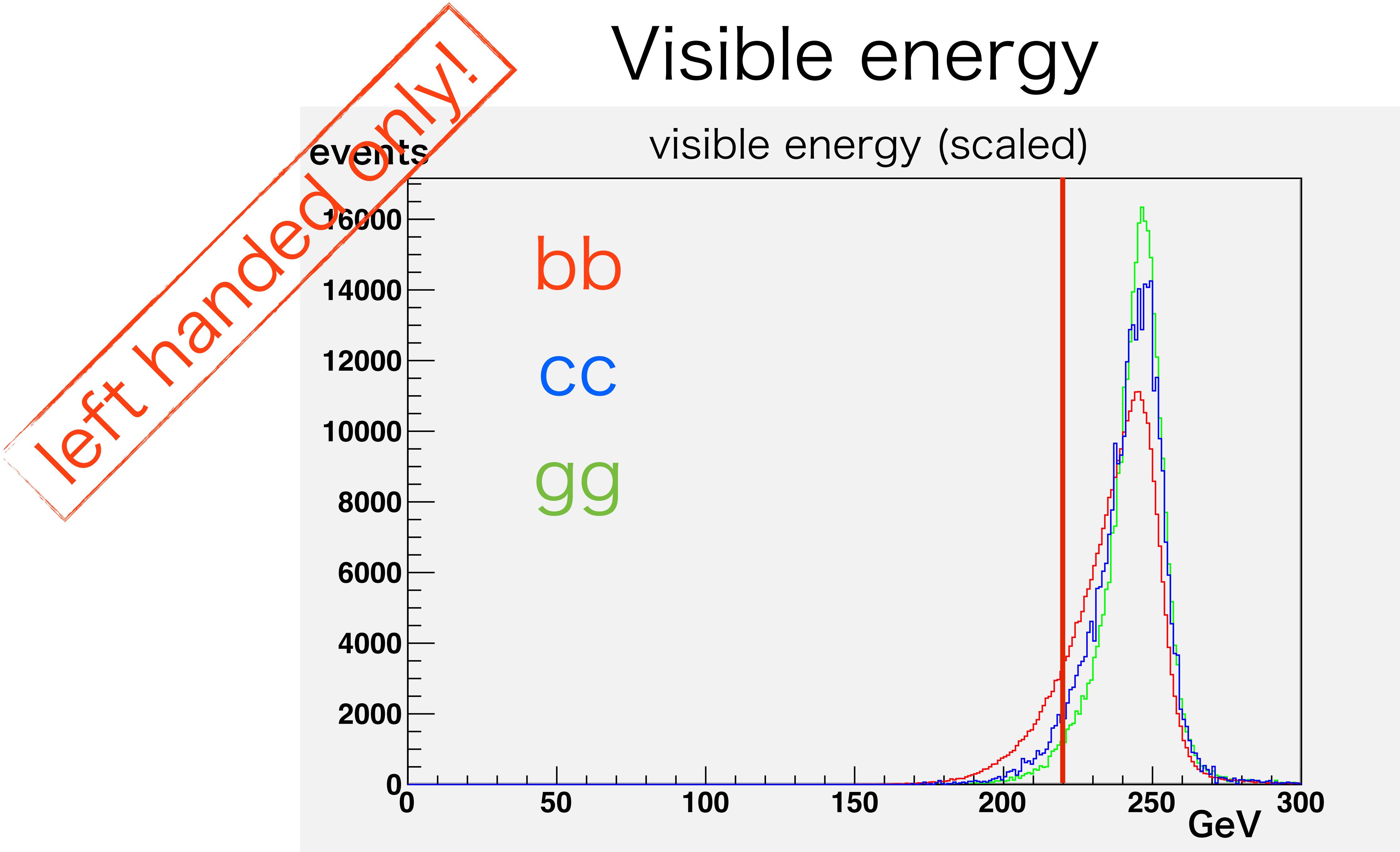


Slightly long tail to lower side is observed only in bb mode.

It might be caused neutrino emission from b-quark decay process?

We looked the plot of the result from visible energy.

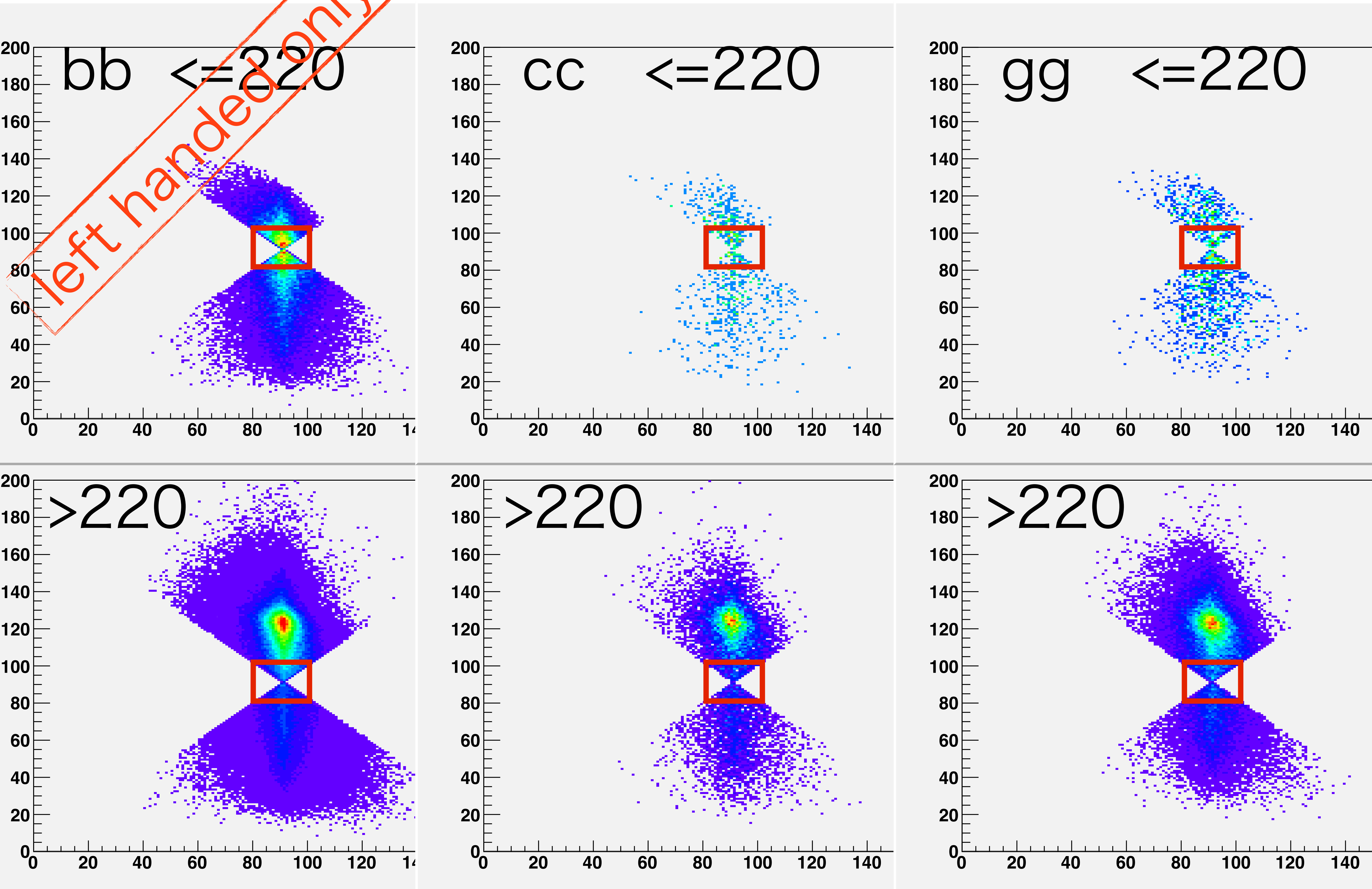
Visible energy



bb mode has a larger missing energy than the other two mode.

We should set visible energy cut for 4 jet clustering…

4 jet mass (visible >220 or <=220)



visible energy > 220

Efficiency (again)

Iso lepton = 0
not weighted

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mode	before	ZZ	WW	ZZWW	recoil	efficiency
H->all (48.2%)	263,500 (100%)	237,277 (90.6%)	245,216 (93.2%)	222,250 (84.9%)	180,471	68.5% ±0.1%
H->bb (54.0%)	158,766 (100%)	144,512 (91.3%)	147,660 (93.1%)	135,179 (85.5%)	112,895	71.1% ±0.1%
H->WW (55.6%)	47,904 (100%)	41,410 (86.4%)	44,727 (93.4%)	39,002 (81.4%)	31,013	64.7% ±0.2%
H->gg (77.6%)	37,133 (100%)	33,793 (91.0%)	34,544 (93.0%)	31,655 (85.2%)	24,033	64.7% ±0.2%
H->$\tau\tau$ (8.5%)	2,833 (100%)	2,321 (81.9%)	2,624 (92.6%)	2,174 (76.7%)	1,507	53.2% ±0.8%
H->ZZ (42.5%)	5,948 (100%)	5,160 (86.8%)	5,532 (93.0%)	4,847 (81.5%)	3,885	65.3% ±0.5%
H->cc (67.1%)	9,376 (100%)	8,648 (92.2%)	8,700 (92.8%)	8,067 (86.0%)	6,168	65.8% ±0.4%
H->$\gamma\gamma$ (68.2%)	1,337 (100%)	1,243 (93.0%)	1,237 (92.5%)	1,155 (86.4%)	841	62.9% ±1.2%

visible energy > 220

Efficiency (again)

Iso lepton = 0 not weighted

mode	before	ZZ	WW	ZZWW	recoil	efficiency
H->a (48.2						68.5% ±0.1%
H->b (54.0						71.1% ±0.1%
H->W (55.6						64.7% ±0.2%
H->g (77.6						64.7% ±0.2%
H->τ (8.5						53.2% ±0.8%
H->Z (42.5						65.3% ±0.5%
H->c (67.1						65.8% ±0.4%
H->γ (68.2						62.9% ±1.2%

Still there is an disagreement with bb/cc/gg mode after all cut…

However…

visible energy > 220

Efficiency (again)

Iso lepton = 0
not weighted

mode	before	ZZ	WW	ZZWW	recoil	efficiency
			16 %)	222,250 (84.9%)	180,471	68.5% ±0.1%
			60 %)	135,179 (85.5%)	112,895	71.1% ±0.1%
			7 %)	39,002 (81.4%)	31,013	64.7% ±0.2%
			4 %)	31,655 (85.2%)	24,033	64.7% ±0.2%
			4 %)	2,174 (76.7%)	1,507	53.2% ±0.8%
			2 %)	4,847 (81.5%)	3,885	65.3% ±0.5%
			0 %)	8,067 (86.0%)	6,168	65.8% ±0.4%
(68.2%)	(100%)	(93.0%)	7 (92.5%)	1,155 (86.4%)	841	62.9% ±1.2%

Before recoil cut, these three modes efficiency is almost same.
(within 1%)
-> 4jet 0lepton cut is optimized?

visible energy > 220

Efficiency (again)

Iso lepton = 0
not weighted

mode	before	ZZ	WW	ZZWW	recoil	efficiency
H->all (48.2%)						
H->bb (54.0%)						
H->WW (55.6%)						
H->gg (77.6%)						
H->$\tau\tau$ (8.5%)						
H->ZZ (42.5%)						
H->cc (67.1%)						
H->$\gamma\gamma$ (68.2%)						

But this cut (visible energy>220) killed almost all H->$\tau\tau$ event...
we will try **tau tagging.**

Categories

Now we plan to categorize higgs decay mode using
- the number of jets (2, 3, 4, and more than 5)
- the number of Iso lepton (0, 1, and more than 2)
- visible energy (more/less than 220 or 230)

Try to find optimal cut to reduce efficiency disagreement for each category.

applying optimal cut for each category.

Combine the result of each category.

We can make final decision of optimal cut.

Remain issues - 2

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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
105,628	11,898	144,223	5,529	132,579	145,359	13,223	916,602	1,779,793	34,200	484,915
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			
8,658	29,819	6,316	2,353	40,860	658,808	563,486	30,779			
497	5,787	545	139	7,729	2,927	564	30			

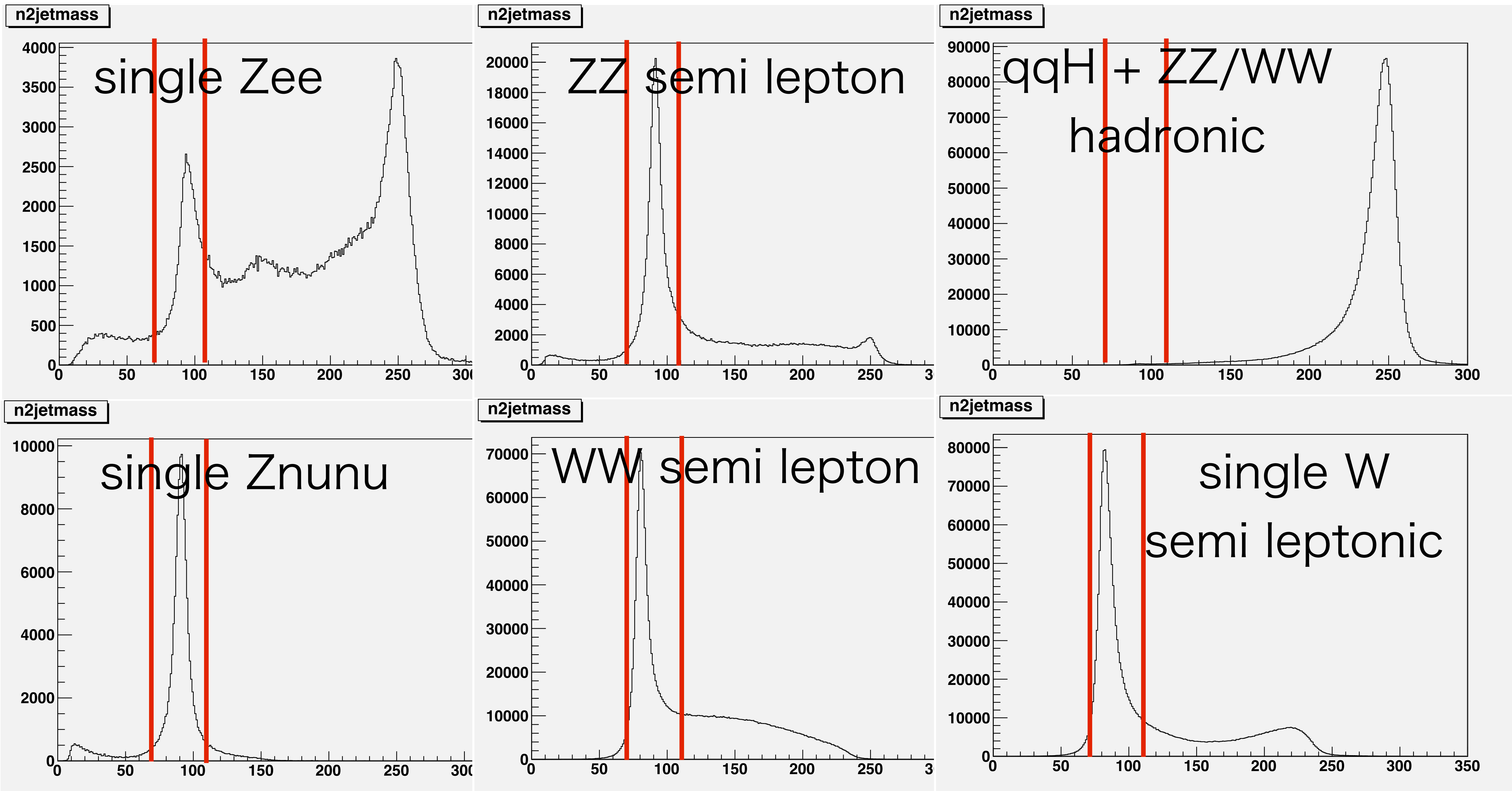
After all cut step, there is still a large number of semi-leptonic background.

We need another cut to reduce these event.

2-jet clustering

To cut semi leptonic background, we tried 2-jet clustering.

ZZ->llqq (l = e, μ) , ZZ->$\nu\nu$qq, WW->lνqq (l = e , μ)



Cut box is (70,110)

The result of 2-jet mass cut

	4f Zee semi lep	4f ZZ semi lep	4f Znunu semi lep	4f WW semi lep	4f W semi lep
before cut	78,394	372,315	138,970	1,047,659	564,745
after cut	5,022	28,675	3,368	226,443	97,007
%	6.4%	7.7%	2.4%	21.6%	17.2%

for ZZ, this cut is very useful !
for WW, this cut is not so much useful !

Here we should do **tau tagging** to decide more optimal cut for WW semi leptonic decay.

Summary and Prospects

- We tried investigation about disagreement of efficiency.
  -> Since b-quark emits neutrino in their decay process,
  there is missing energy. => visible energy cut (good)
  -> Tau problem => should do **tau tagging**.
  -> Recoil mass cut has also disagreement, should be investigate.
  -> categorize the decay and optimize the cut for each category.

- 2-jet clustering is promising to reduce semi-leptonic background…
  -> for ZZ, it is OK.
  -> for WW, it is not powerful enough. first we try **tau tagging** !