Higgs recoil mass study

ILC Physics Meeting
2/27/2015

Jacqueline Yan (Univ. of Tokyo)

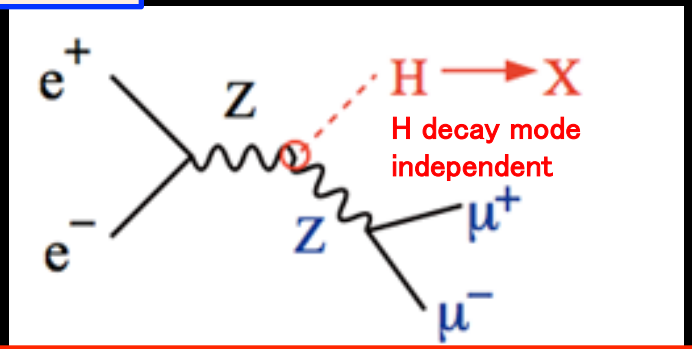
This week : Improvement of ZH recoil studies

- Remove acoplanarity cut
- implement likelihood cut at end of final selection

ILC sample used in analysis

chanel	mh	ECM	L	Spin polarization	Detector simulation
e+e→Zh->μμh	125 GeV	350 GeV	333 fb-1	P(e-,e+) = (-0.8,+0.3) (+0.8,-0.3)	Full ILD (ILD_01_v05 DBD ver.)

signal Pe2e2h_.eL.pR / Pe2e2h._eR.pL

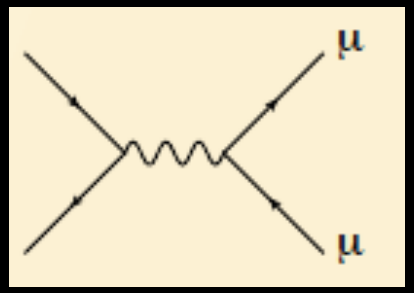


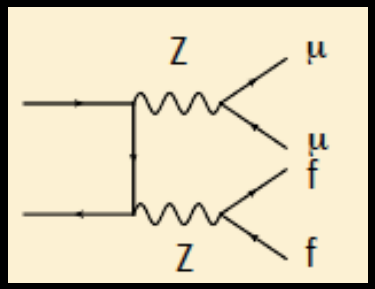
$$M_X^2 = (p_{CM} - (p_{\mu^+} + p_{\mu^-}))^2$$

Higgs recoil against di-lepton (μ μ) system

BG :
all 2f, 4f, 6f processes

major BG after event selection:
2f_Z_l (μ μ), 4f_WWsl , 4f_ZZ_sl (μ μ ff, μ μ ν ν)





event selection

Cut values optimized in terms of signal efficiency and $\Delta\sigma/\sigma$

Muon Selection

- reject neutrals
- P_total > 5 GeV
- E_cluster / P_total < 0.5
- cos(track angle) < 0.98 & |D0/δD0| < 5

Best muon pair candidate Selection

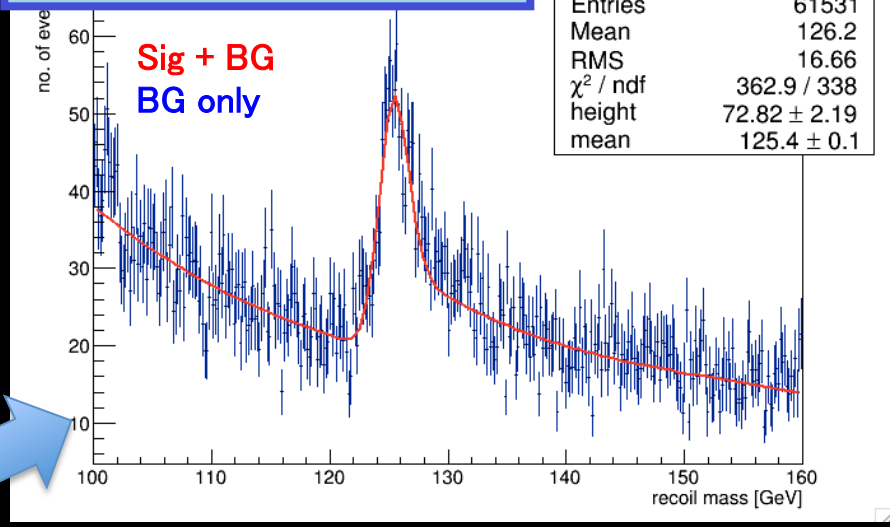
- **opposite charge**
- **invariant mass closest to Z mass**

Final Selection

- 84 GeV < M_inv < 98 GeV
- 10 GeV < pT_mumu < 140 GeV
- dptbal = |pT_mumu – pTγ_max| > 10 GeV
- ~~acoplanarity < 3~~
- |cos(θ_Zpro)| < 0.91

120 GeV < Mrecoil < 140 GeV

recoil mass fitting



- Signal: GPET
- BG: 3rd order polynomial

definition

- M_inv : invariant mass of 2 muons
- pT_mumu : pT of reconstructed muons
- pTγ_max : pT of most energetic photon
- θ_Zpro = Z production angle

Newest Final result:

ECM =350 GeV

- **Eff_sig= 46.1+/- 0.5%**
- S/B = 0.48

This week's investigations:

- Is acoplanarity cut necessary? *redundant ??*
- Is pt_bal cut necessary?

  photon maybe from Higgs decay products e.g. Hadronization → π → $\gamma\ \gamma$

  → cause mode dependent bias ?

What I discovered ……

❖ Pt_bal cut is apparently a good idea !!

Significant effect on BG reduction esp. 2f_Z_leptonic ($\mu\ \mu$)

almost no reduction in signal

❖ Acoplanarity cut should be removed

no longer effective after other selection steps

It simply lowers signal efficiency a waste !!!

Details coming up !!!

Later, we will observe these results in terms of

- number of signal and BG events
- cross section measurement precision

But first,

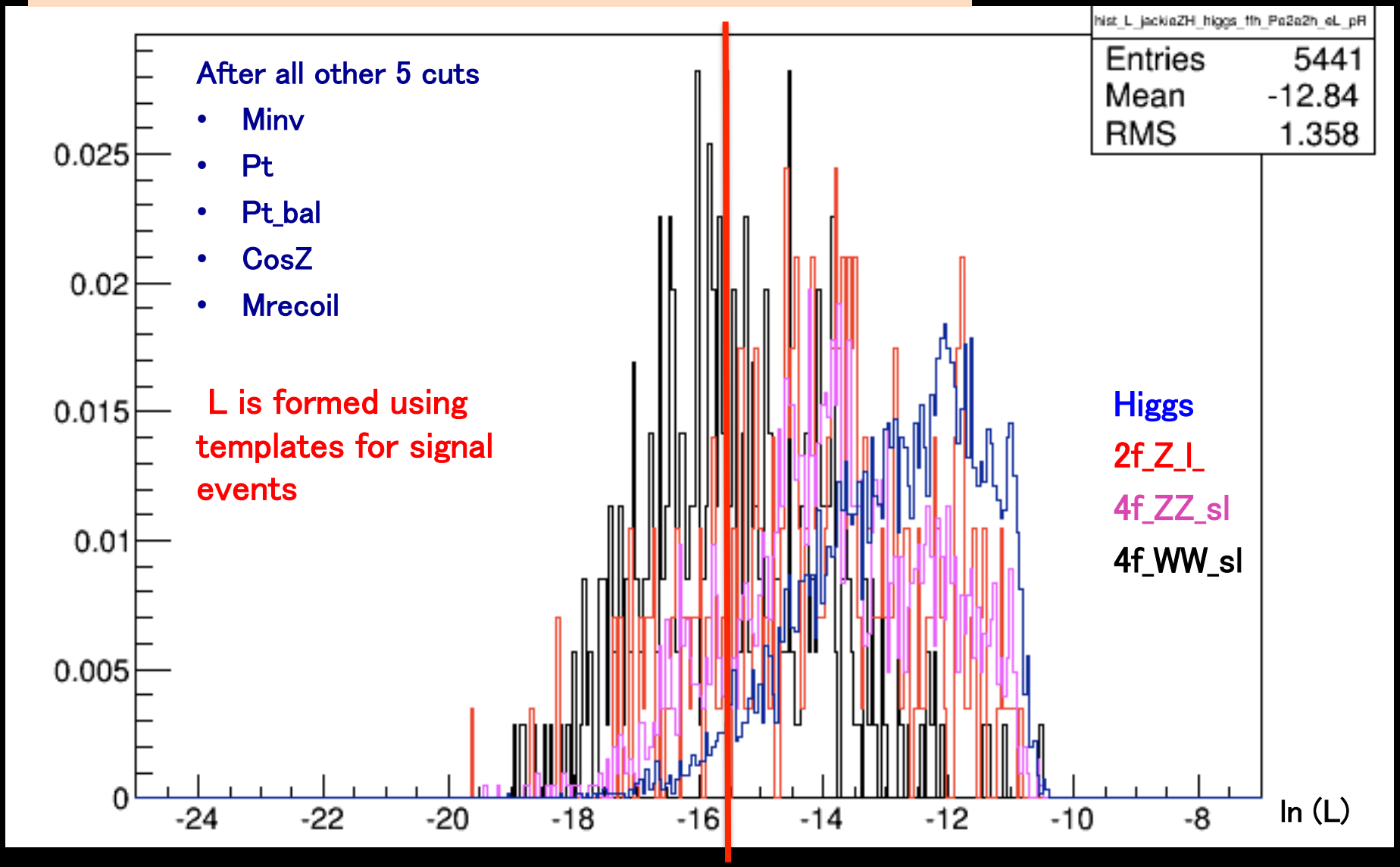
to tell some good news ……

Likelihood cut was successfully implemented

- Effective for reducing BG
- improved xsec precision
- (maybe also reduce M_recoil fit bias ??)

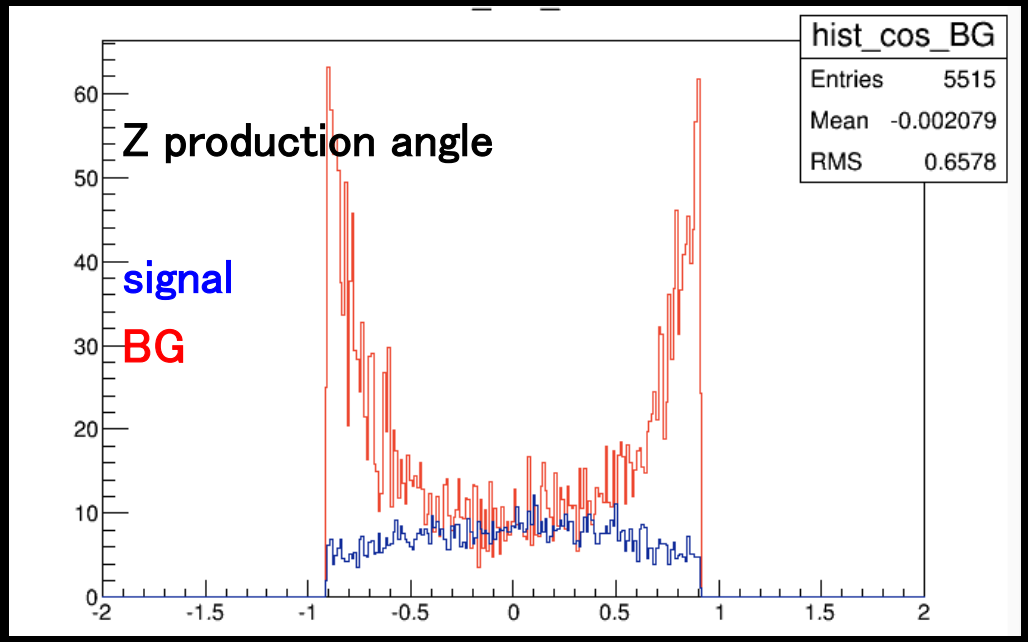
from here on, acop cut is removed and pt_bal cut is included

Likelihood function: L = P(M_inv) * P(Pt) * P(CosZ)

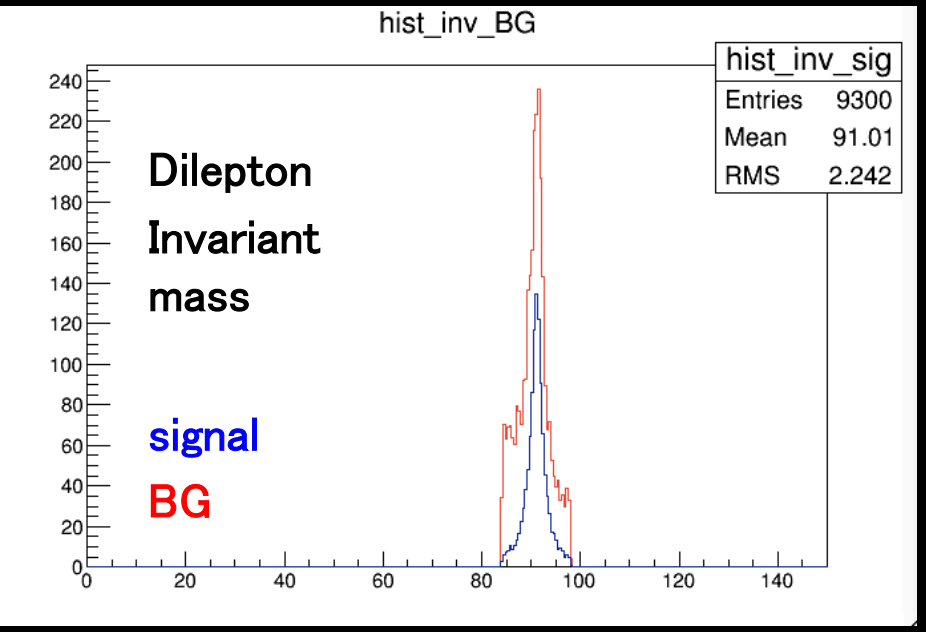


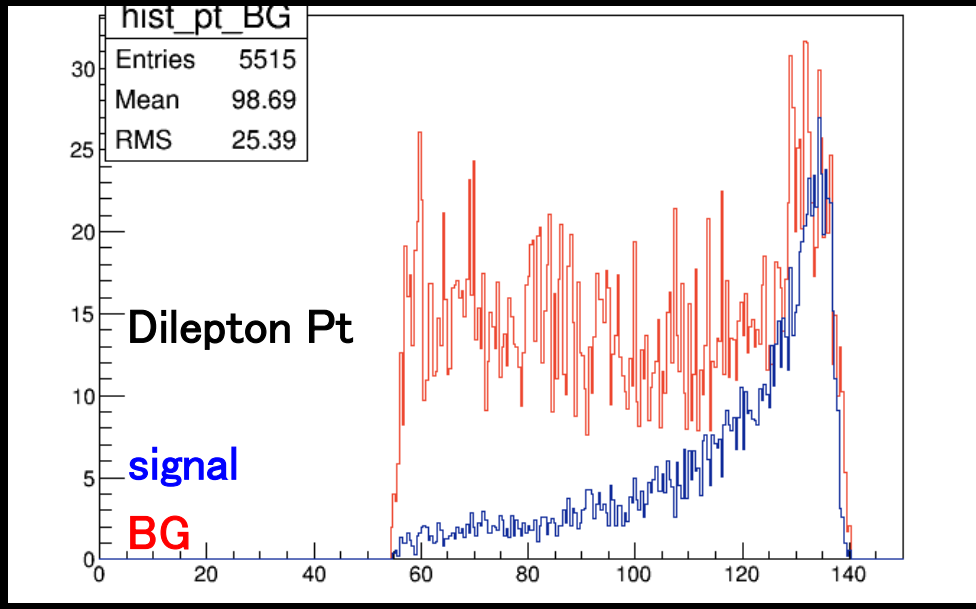
optimized likelihood cut 15 – 16

Finally decided on ln(L) > −15.5



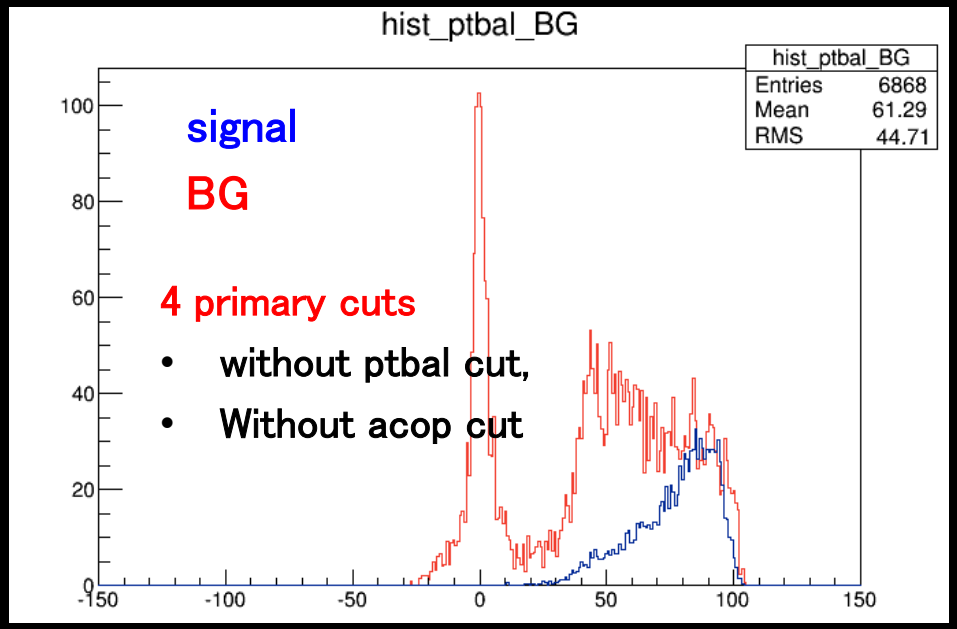
formed using templates
for signal events

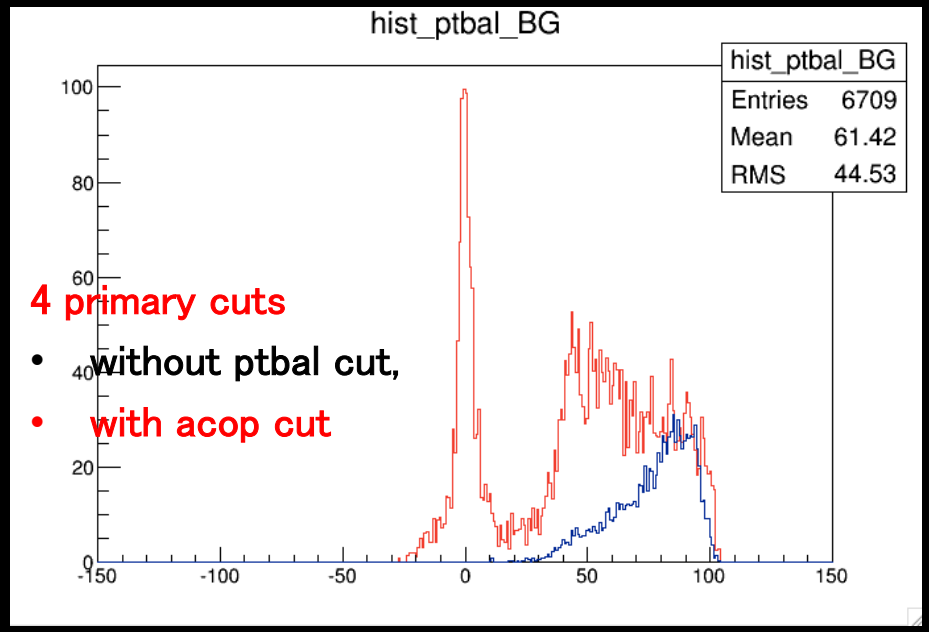


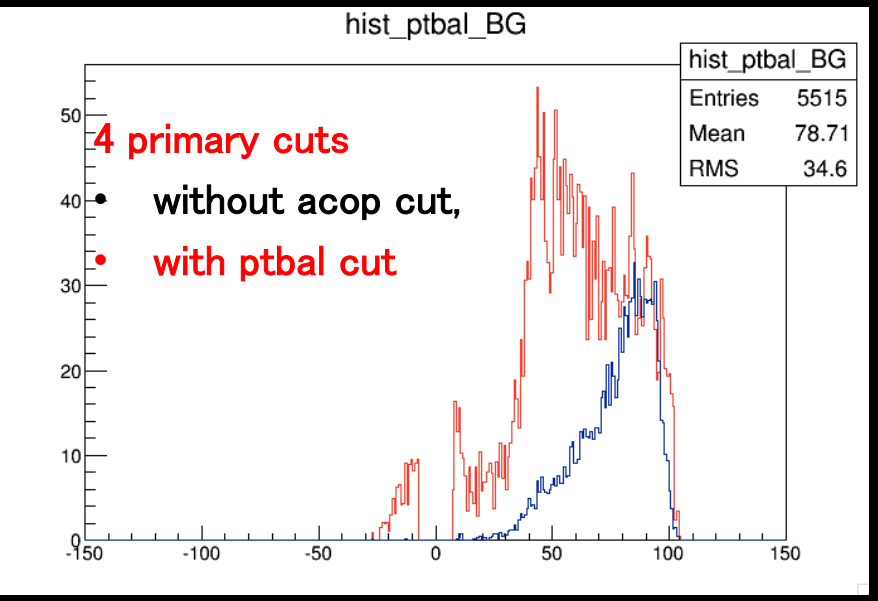


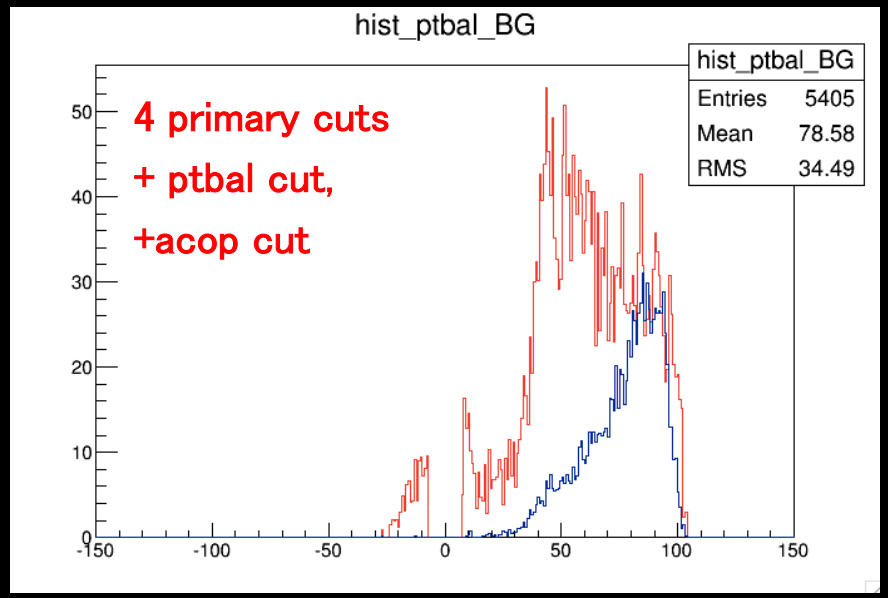
Acop > 3
|dpt_bal| > 10 GeV

Comparing Pt_bal distributions:
Large amount of 2f_Z_leptonic BG removed, no signal loss



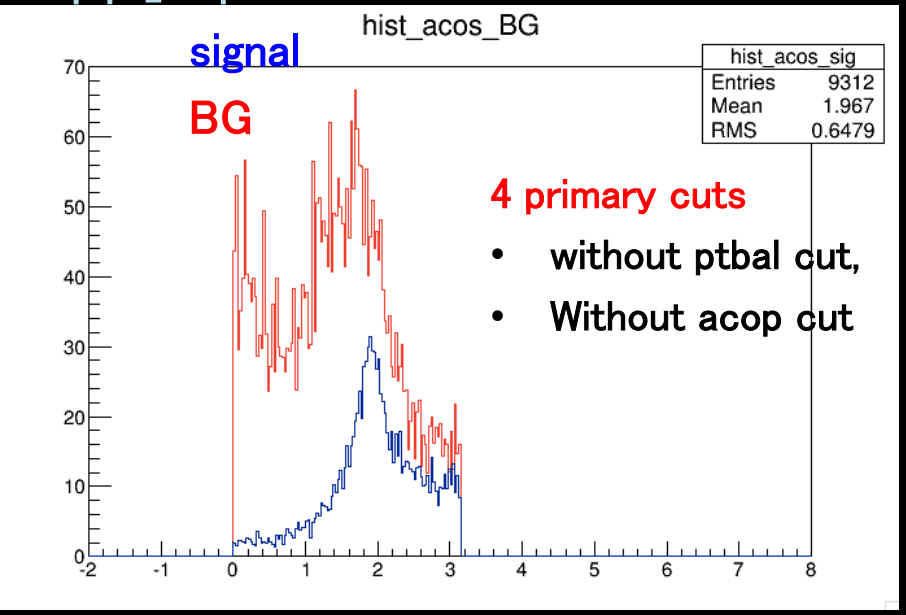


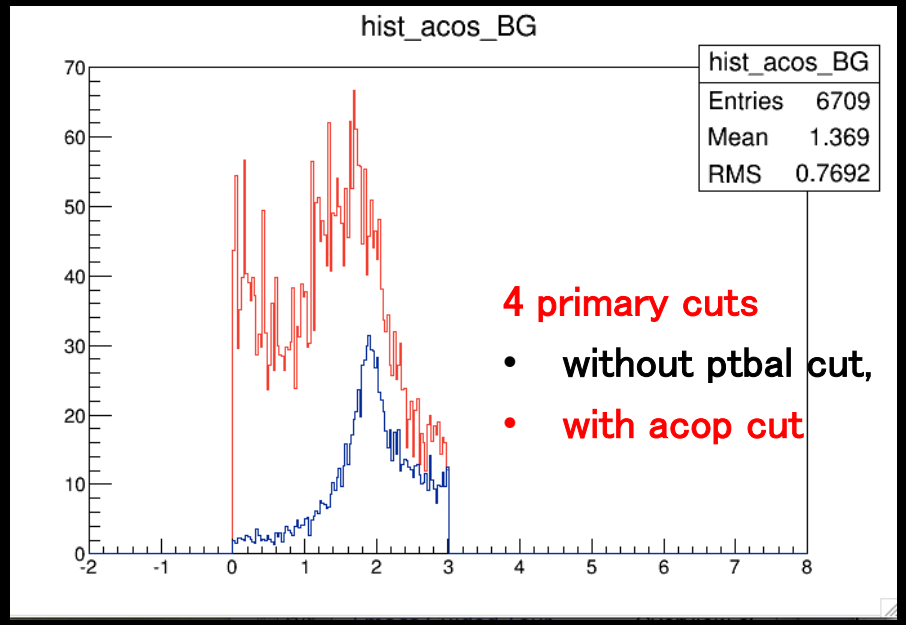




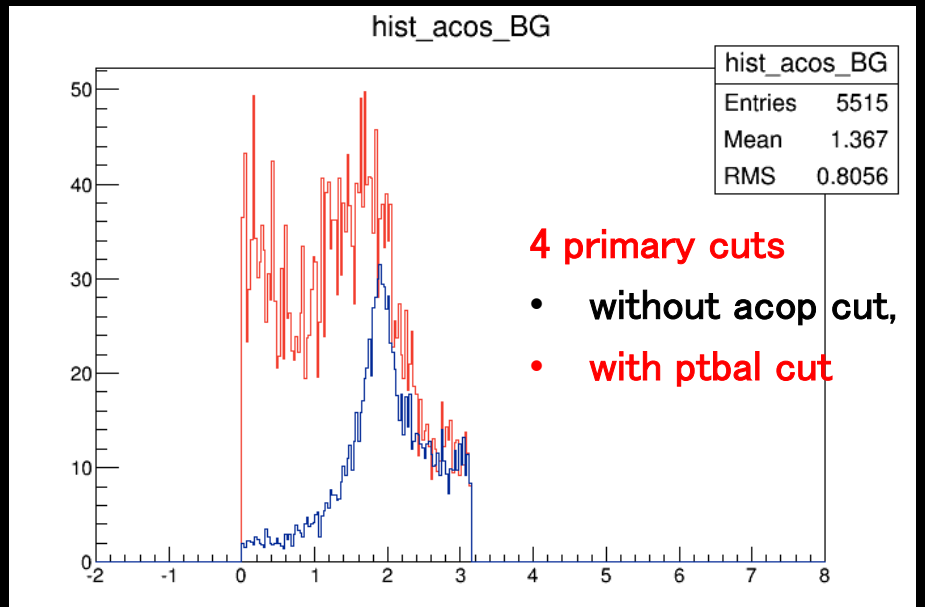
Acop < 3
|dpt_bal| > 10 GeV

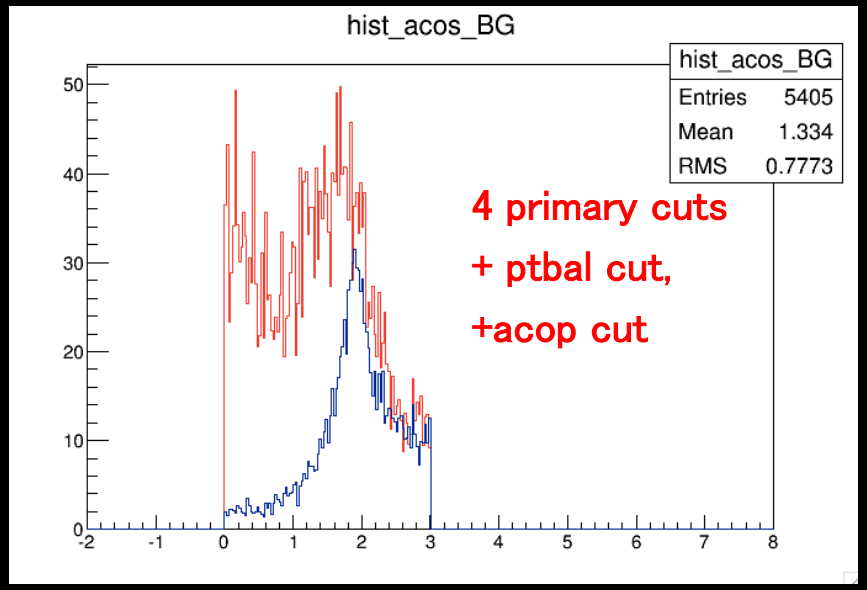
Comparing acoplanarity distributions:





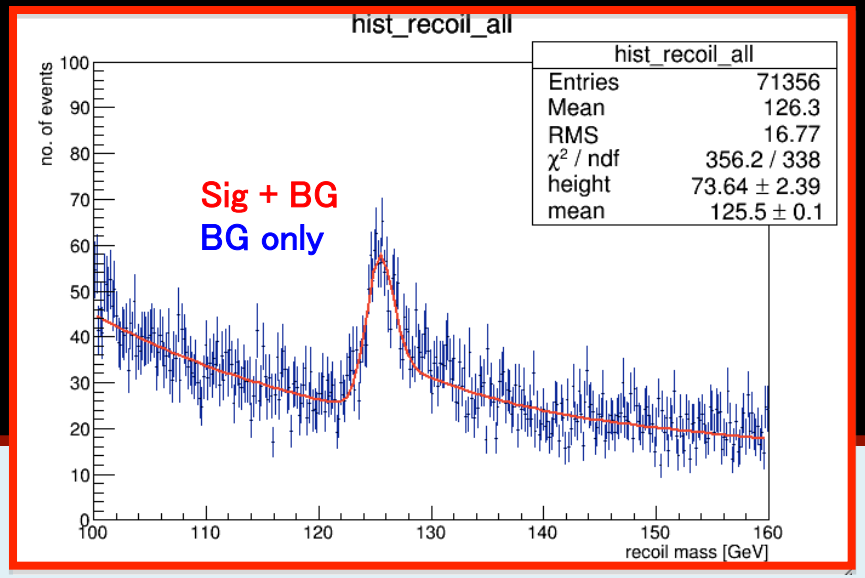
No outstanding difference : only cut off this little region of BG (Acop > 3)





recoil mass fitting method

Fit range: 100–160 GeV



1st step:

- Fit only signal with GPET float all 5 pars
- Fit only BG: 3rd order polynomial

2nd step :

fit Sig + BG : only float height and mean

fix others from step 1

◆ **SIGNAL: GPET:** 5 parameters :

$$\frac{N}{\sqrt{\pi}\sigma}\exp\left\{-\frac{1}{2}\left(\frac{x-x_{mean}}{\sigma}\right)^2\right\} \qquad \left(\frac{x-x_{mean}}{\sigma}\le k\right)$$

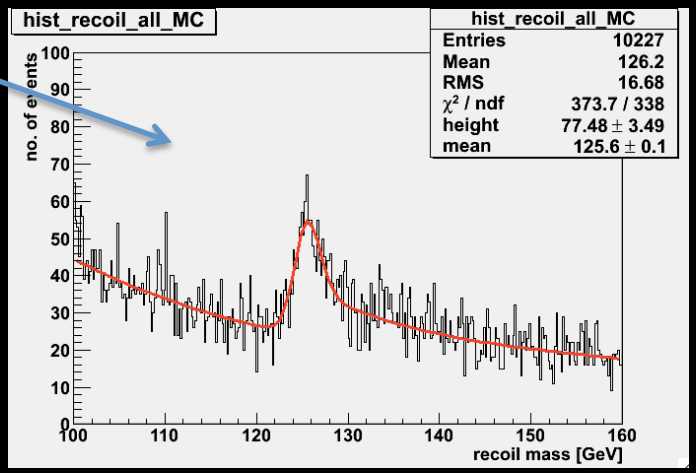
Gaus (left-side) ,

$$\frac{N}{\sqrt{\pi}\sigma}\left[b\cdot\exp\left\{-\frac{1}{2}\left(\frac{x-x_{mean}}{\sigma}\right)^2\right\}+(1-b)\exp\left\{-k\left(\frac{x-x_{mean}}{\sigma}\right)\right\}\exp\left(k^2/2\right)\right] \qquad \left(\frac{x-x_{mean}}{\sigma}\ge k\right)$$

Gaus + expo (right side)

Toy MC study

Toy MC 10000 seeds



goal: test quality of fitting method

in terms of M_h、 xsec etc……

method:

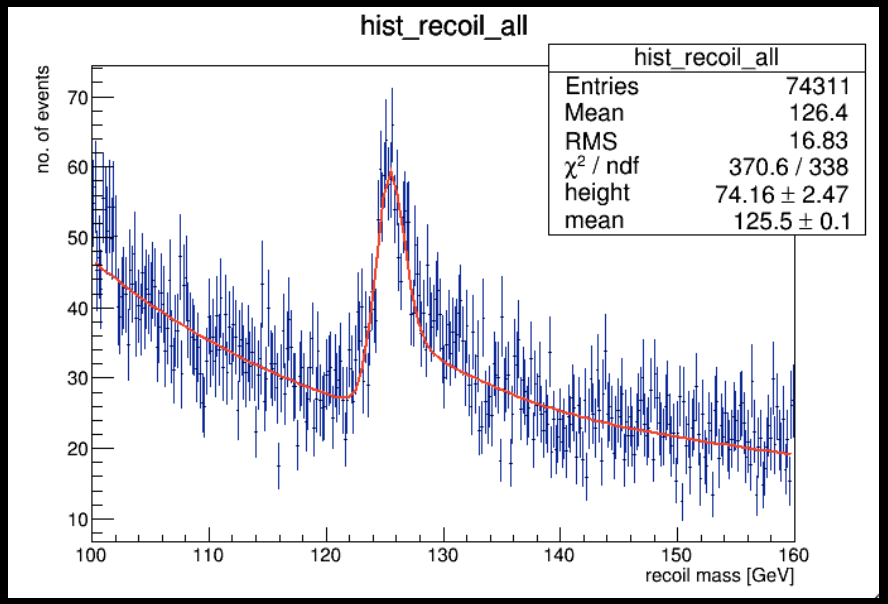
generate MC events according to fittied "real" data

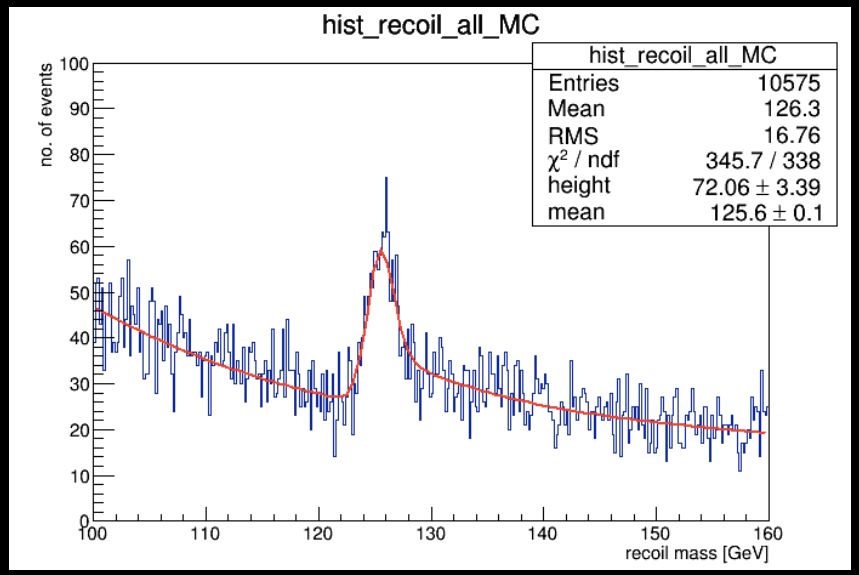
(Poisson)

fit MC hist with same GPET function → get Nsig, xsec

w/o likelihood cut

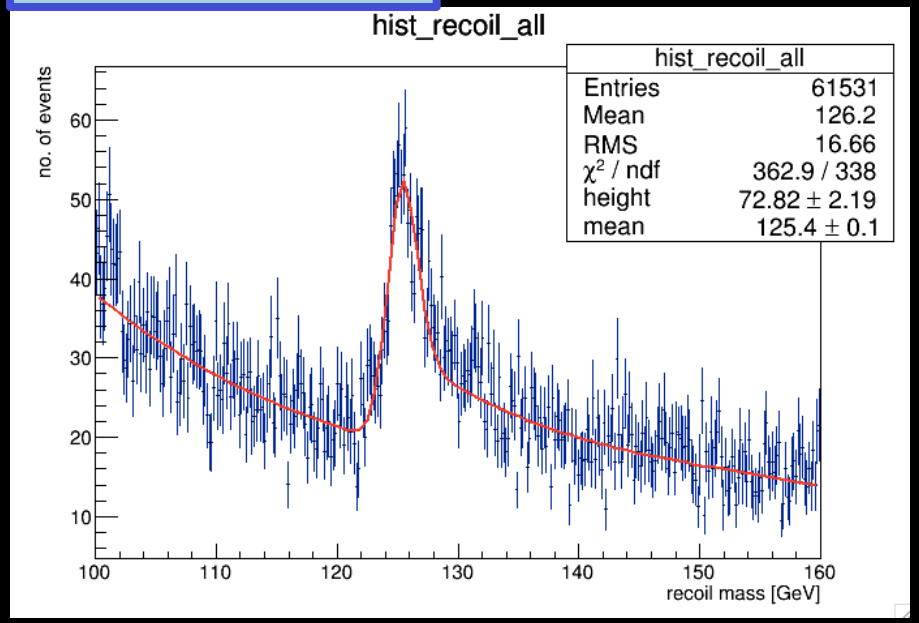
Fit range: 100–160 GeV

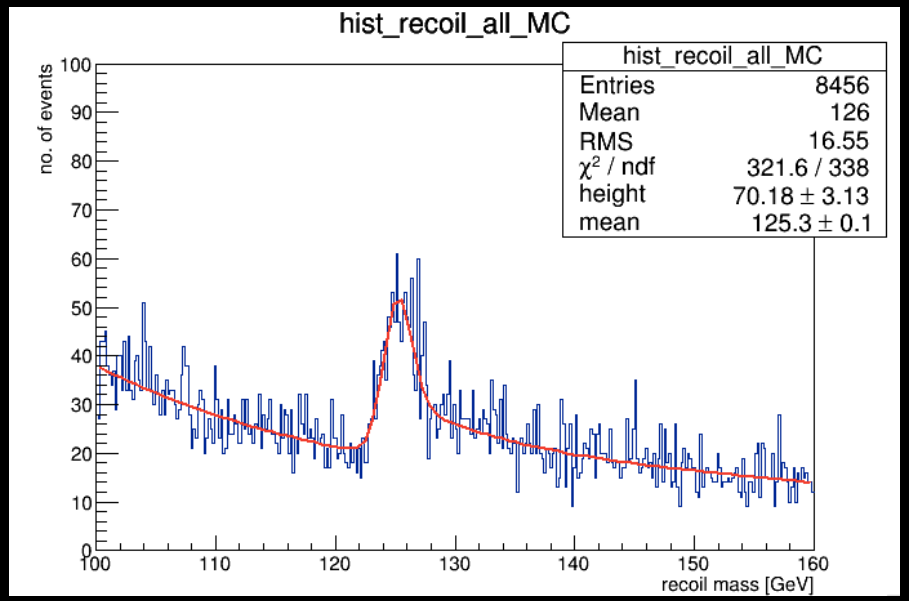


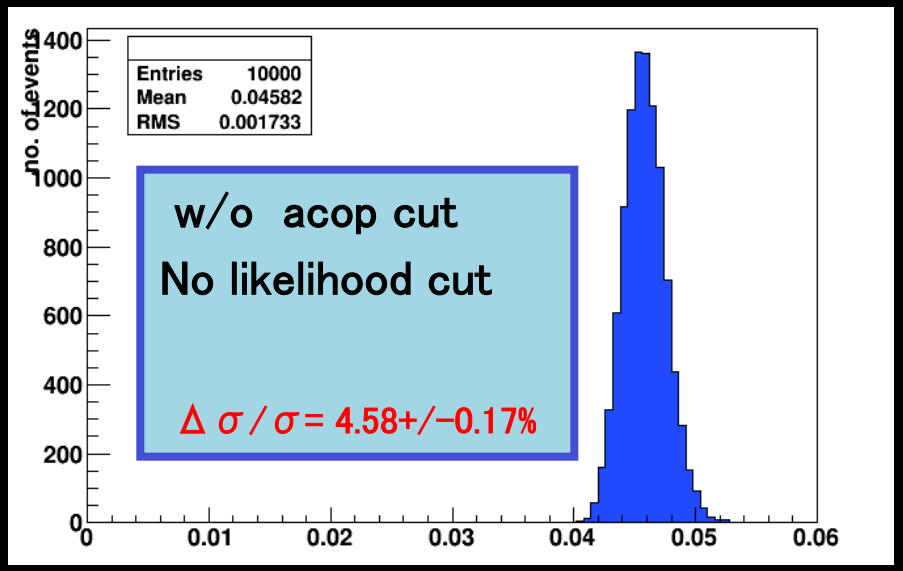


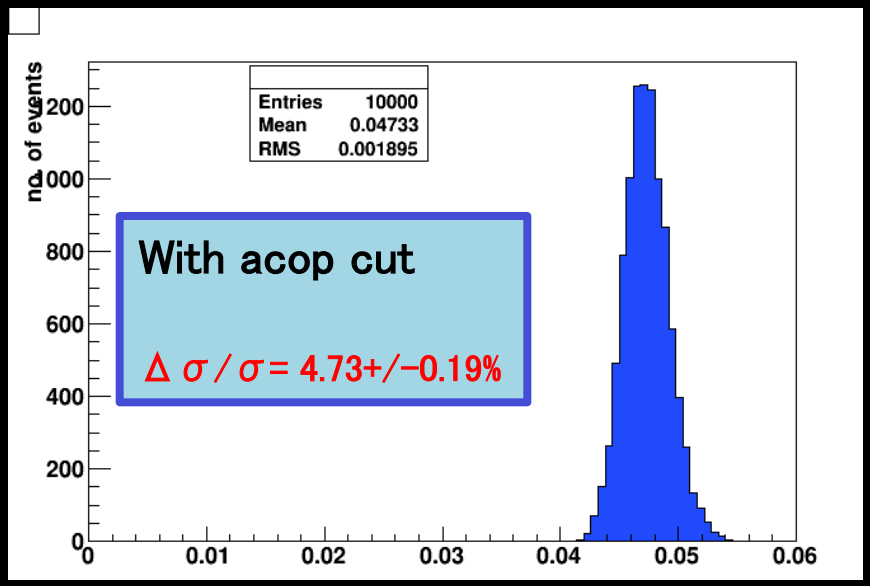
With Likelihood cut

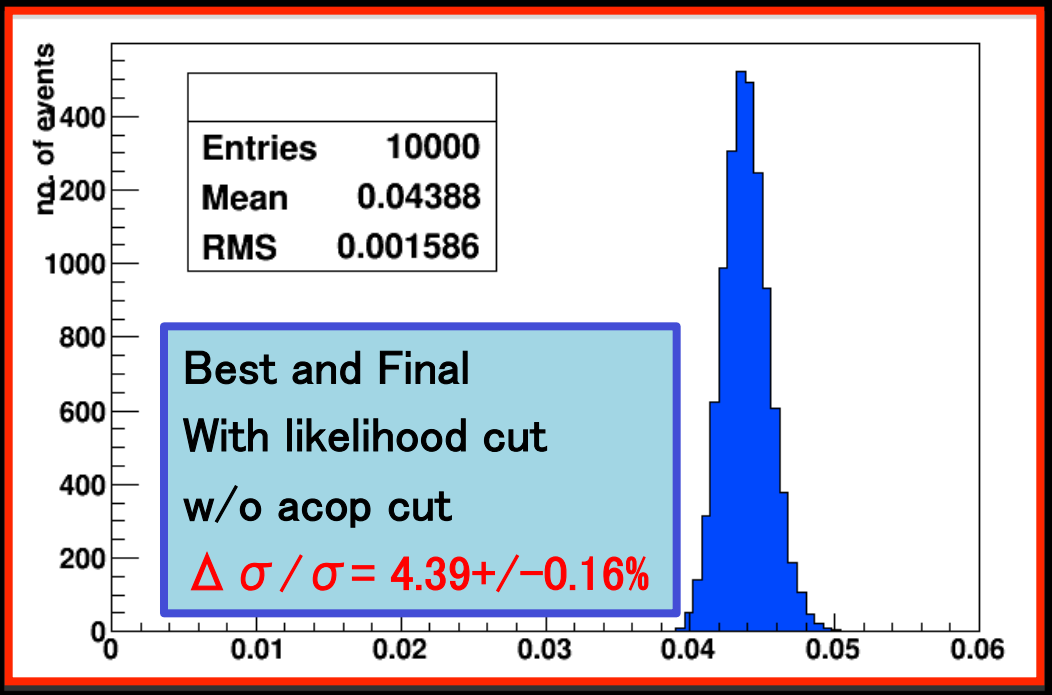
Slight reduction in bias of recoil mass fitting (?)











Result of Toy MC

Xsec error the best so far due to likelihood cut

～ 8 % improvement

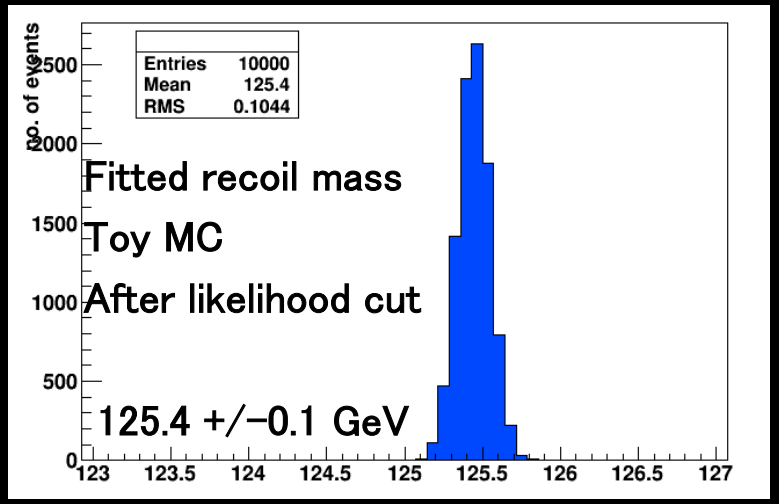
(about 2 sigma)

condition: (ln(L) > −15.5)

Comparison of results

cuts	(both eLpR and eRpL) Nsig	Nbg	S/B ratio	sig eff	Δσ/σMC)	(only eLpR) 2f_Z_l	4f_WW_sl	4f_ZZ_sl
Primary cuts	1102	3691	0.30	48.2+/−0.05%		1.05E3 (0.050%)	504 (0.019%)	1.13E3 (0.62%)
Primary +acop	1049	3608	0.29	45.8+/−0.5%		1.02E3 (0.048%)	504 (0.019%)	1.11E3 (0.61%)
Primary +ptbal	1101	2872	0.38	48.1+/−0.5%	4.58+/−0.17%	280 (0.013%)	504 (0.019%)	1.13E3 (0.62%)
Primary + ptbal+acop	1048	2818	0.37	45.8+/−0.5%	4.73+/−0.19%	271 (0.013%)	504 (0.019%)	1.10E3 (0.60%)
after likelihood cut								
Primary + ptbal + ln(L)>−16	1079	2405	0.45	47.2+/−0.5%	4.56+/−0.17%	243 (0.011%)	315 (0.011%)	1.01E3 (0.55%)
Primary + ptbal + ln(L)>−15.5	1056	2189	0.48	46.1+/−0.5%	4.39+/−0.16%	225 (0.011%)	241 (0.009%)	950 (0.52%)

Xsec（from reconstructed data）： 6.9+/−0.2 fb



Location of data for each process after each selection step
/home/ilc/jackie/jackieZHProcessornew/data/CutOp/

- Evt_350_L155.dat : # of events
- EvtRate_350_L155.dat : # displayed in % w.r.t. raw #

Conclusion

(1) Pt_bal cut is tested to be effective

- Significant effect on BG reduction esp. 2f_Z_leptonic (μ μ)
- almost no reduction in signal

(2) Acoplanarity is removed

→ signal efficiency improved

(3) Implemented likelihood cut

- Effective for reducing BG , improve xsec precision, (maybe also reduce M_recoil fit bias ??)
- xsec error (4.39%) and S/B ratio (48%) the best so far

Next step:

Further check of Pt_bal cut

- Require γ and μ μ is back to back
- require lower energy boundary on γ

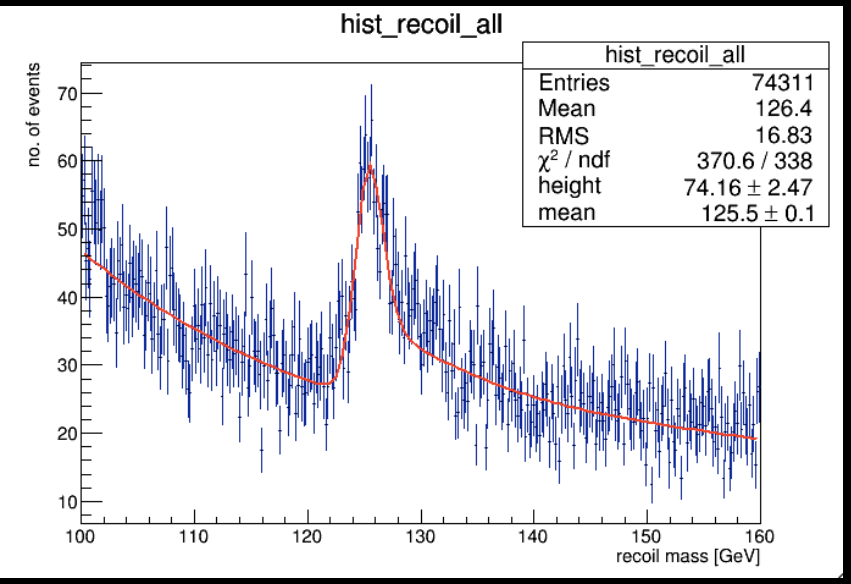
Optimize likelihood cut

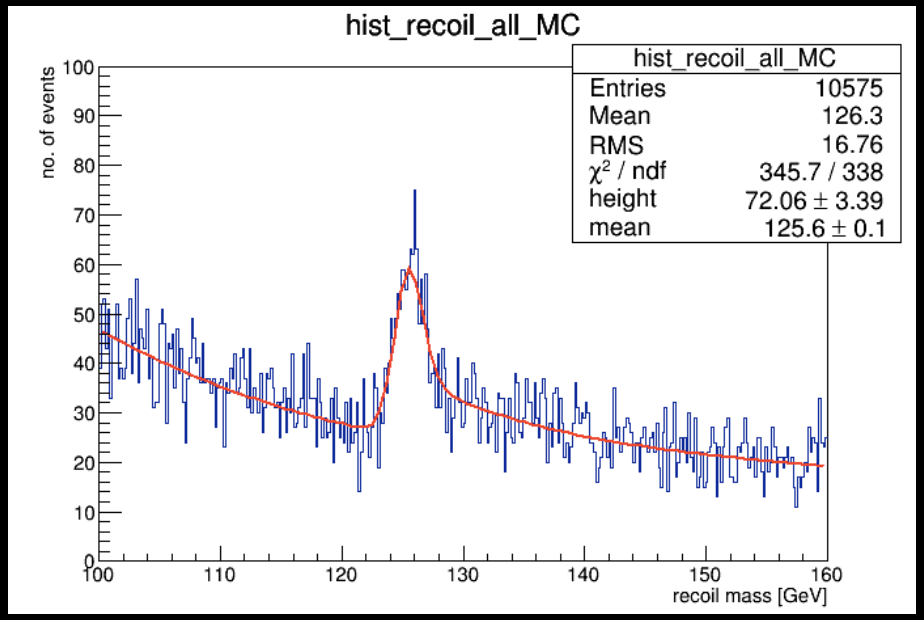
- Use pt_bal cut also ? is pt cut necessary ? What is best cut threshold ??

BACKUP

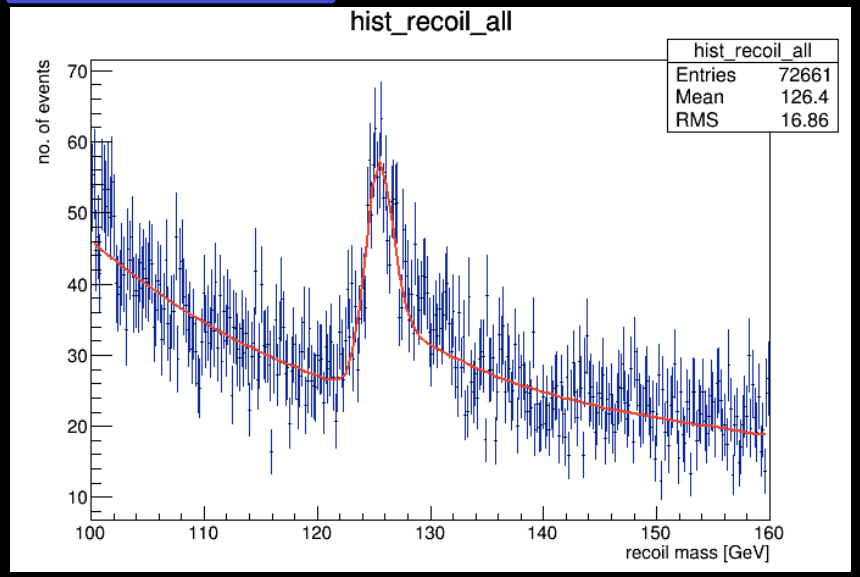
w/o acop cut

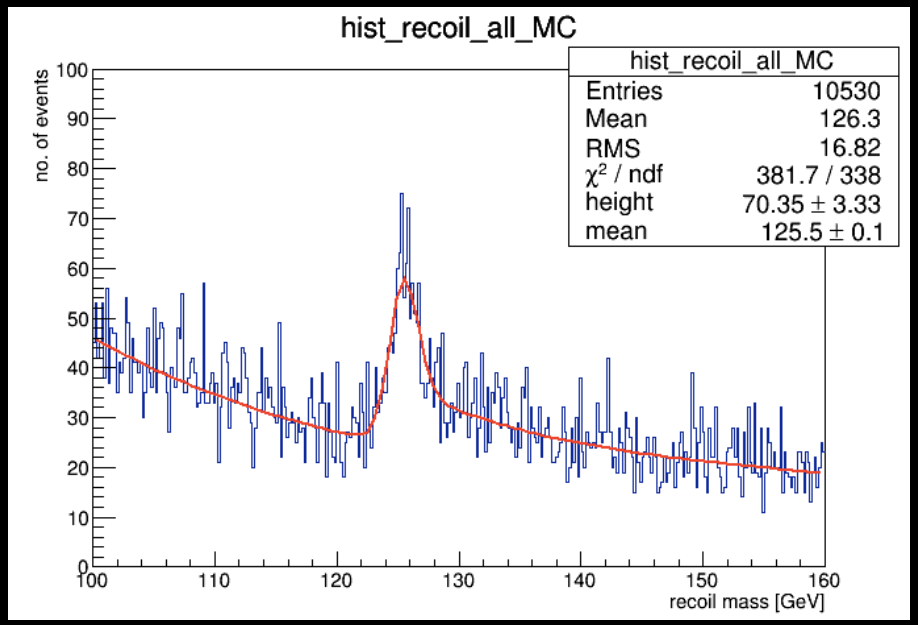
Fit range: 100-160 GeV



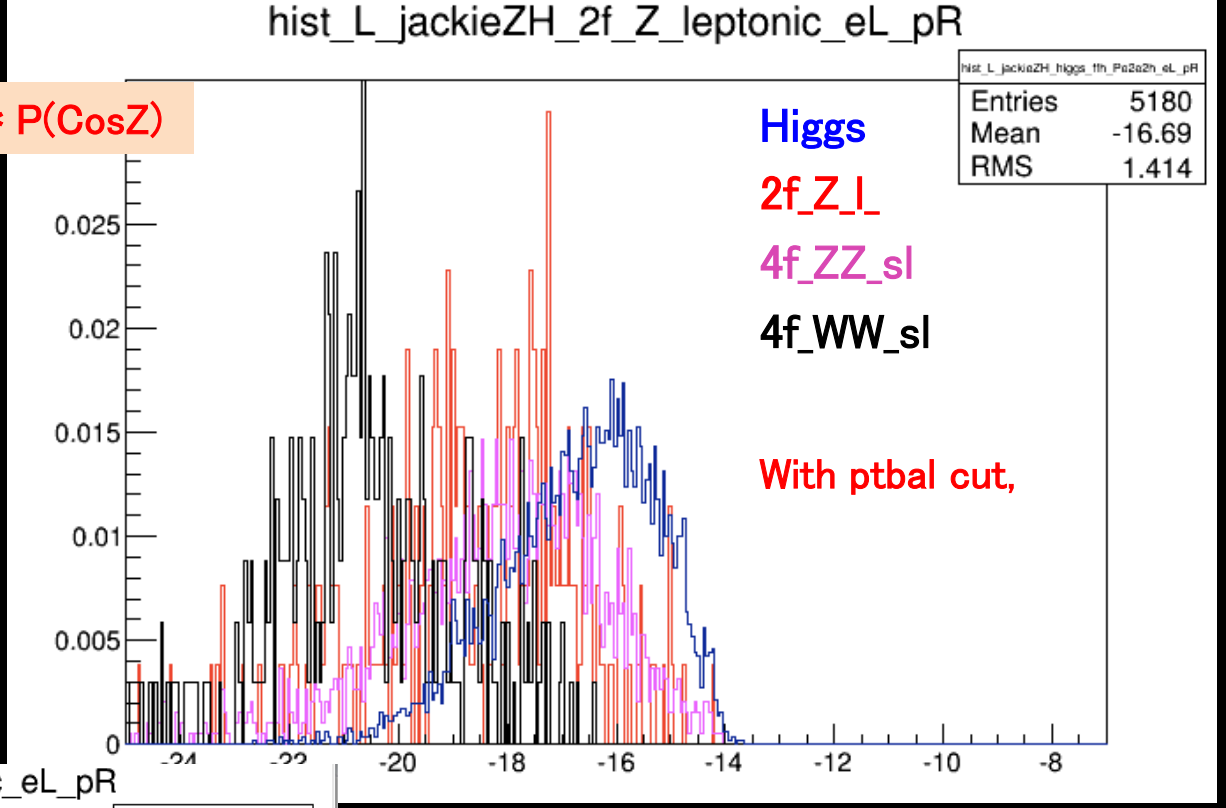


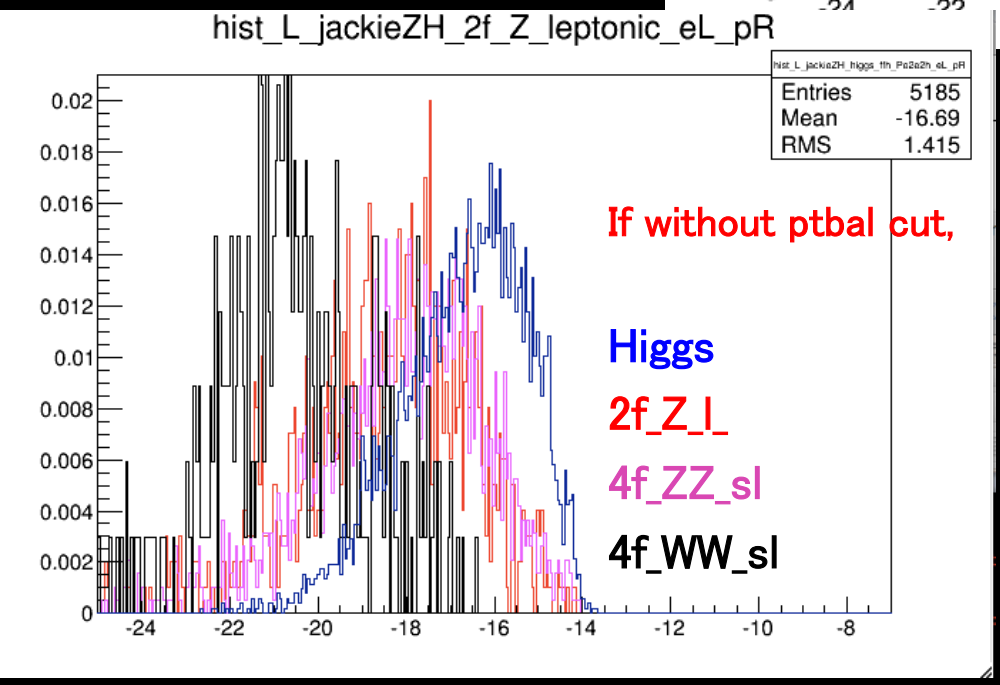
With acop cut





L = P(M_inv) * P(Acop)* P(M_rec) * P(CosZ)

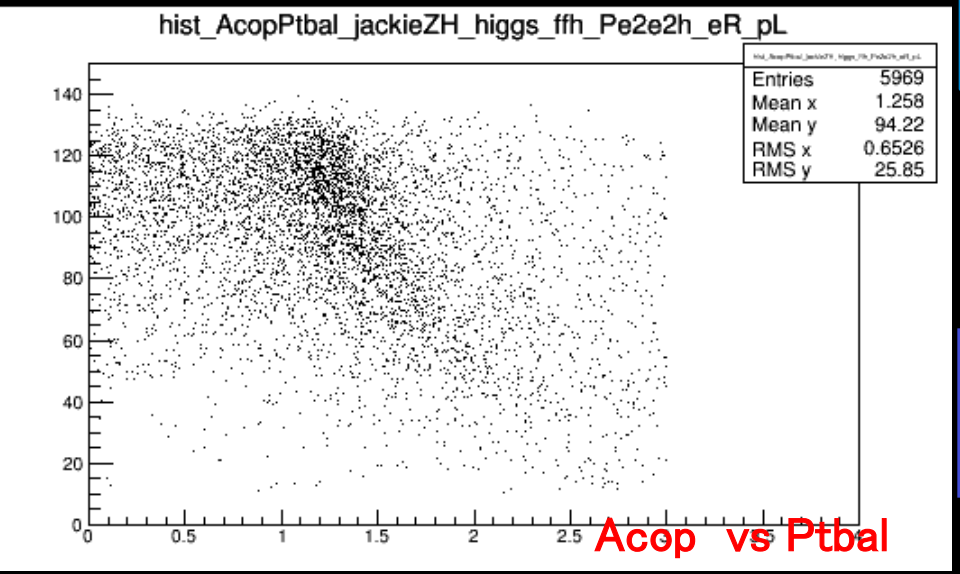




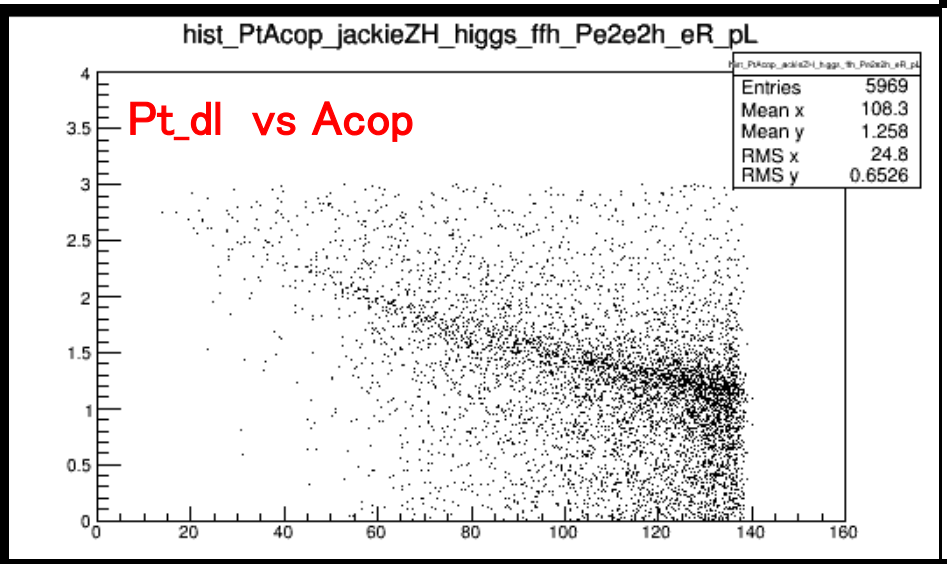
selection of parameters for use in Likelihood cut

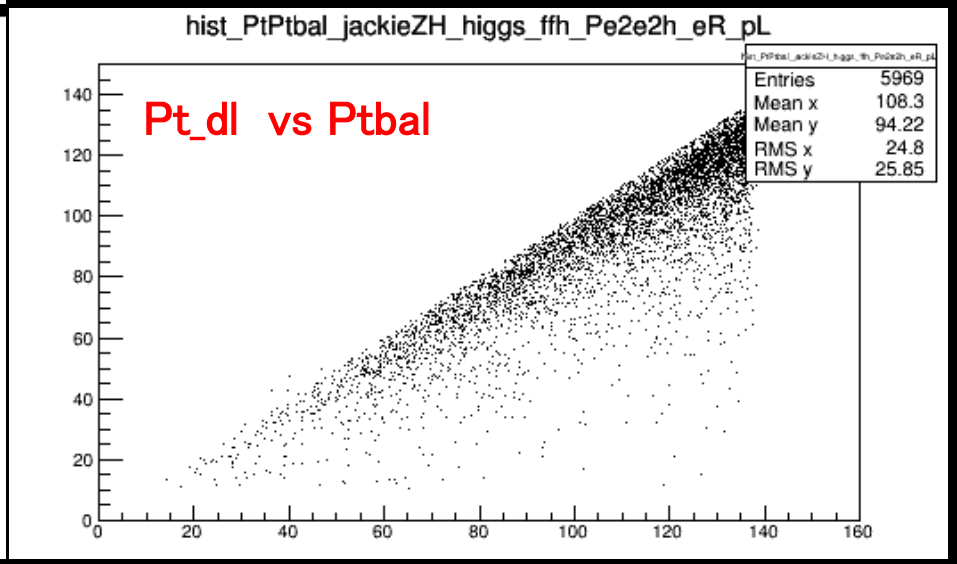
- 84 GeV < M_inv < 98 GeV
- 10 GeV < pT_mumu < 140 GeV
- dptbal = |pT_mumu – pTγ_max| > 10 GeV
- coplanarity < 3
- |cos(θ_Zpro)| < 0.91

120 GeV < Mrecoil < 140 GeV

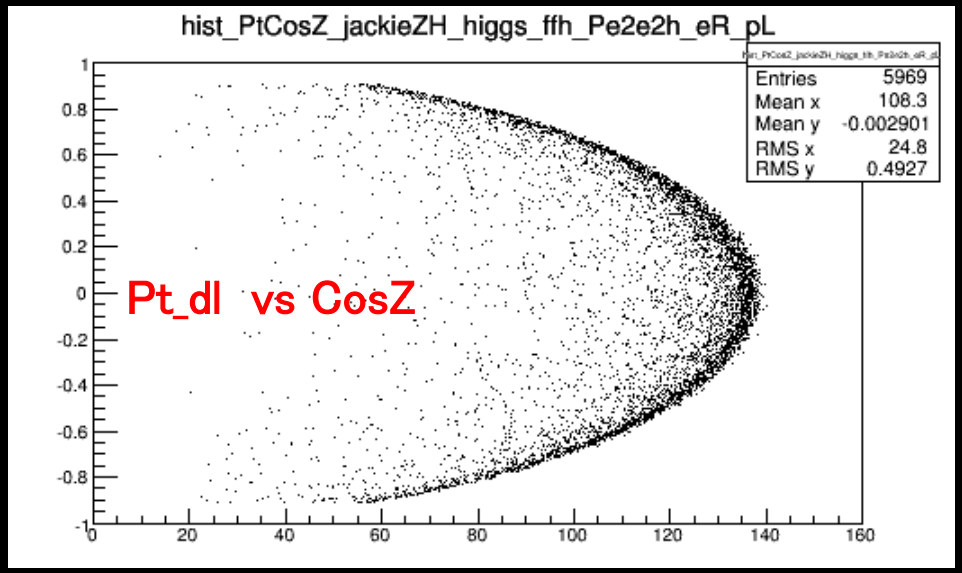


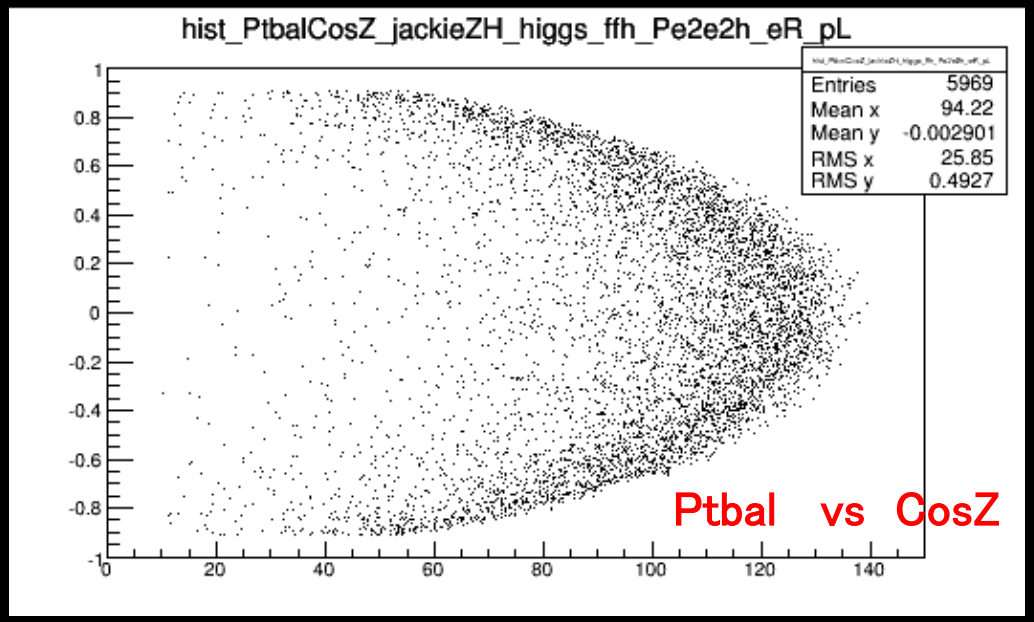
Parameters showing correlation: not good for likelihood cut (?)



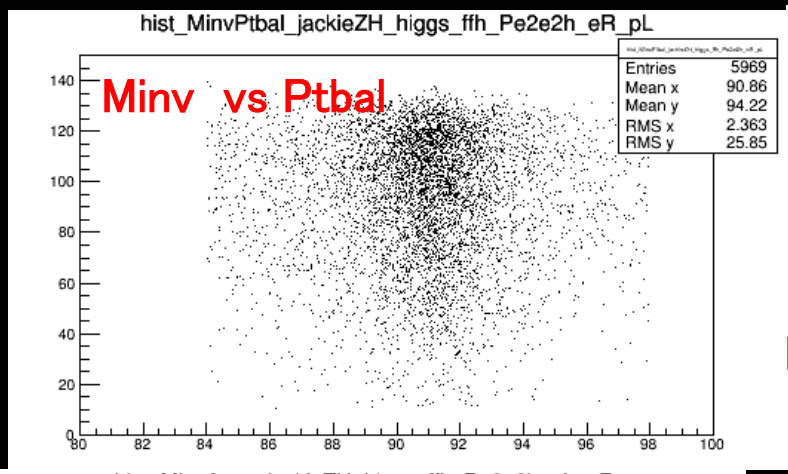


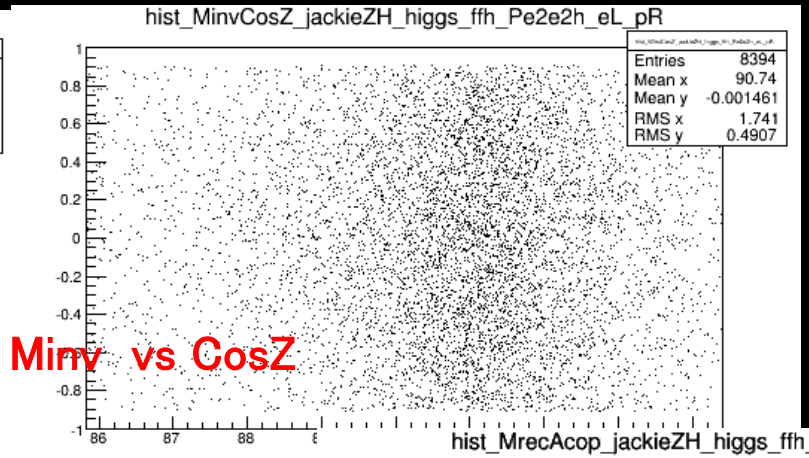
Parameters showing correlation: not good for likelihood cut (?)

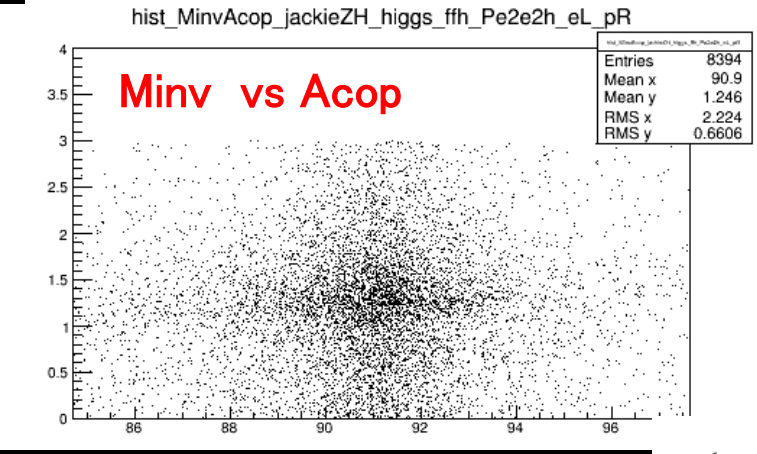


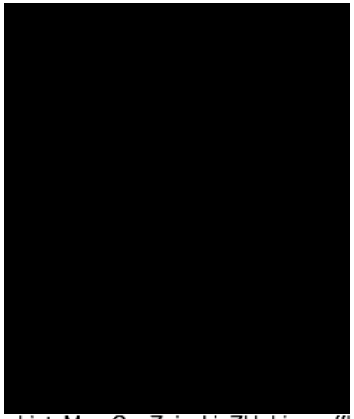


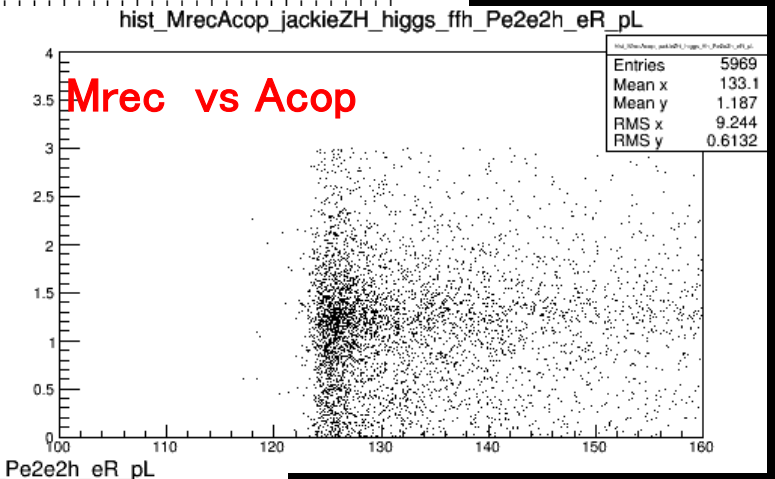
Parameters with no apparent correlation: good for likelihood cut (?)

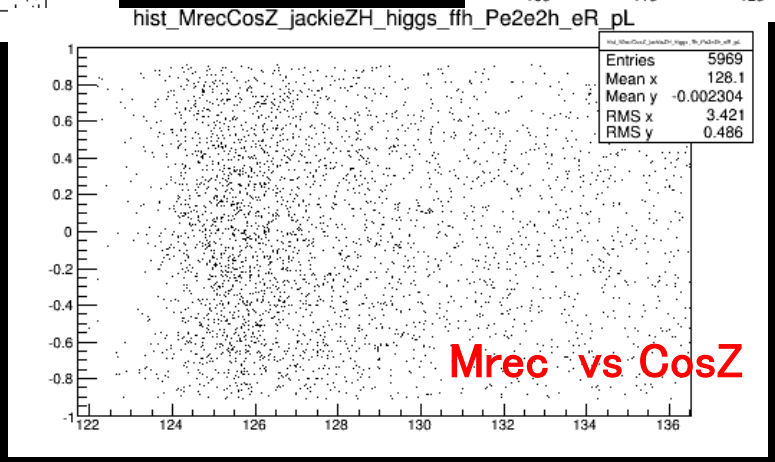


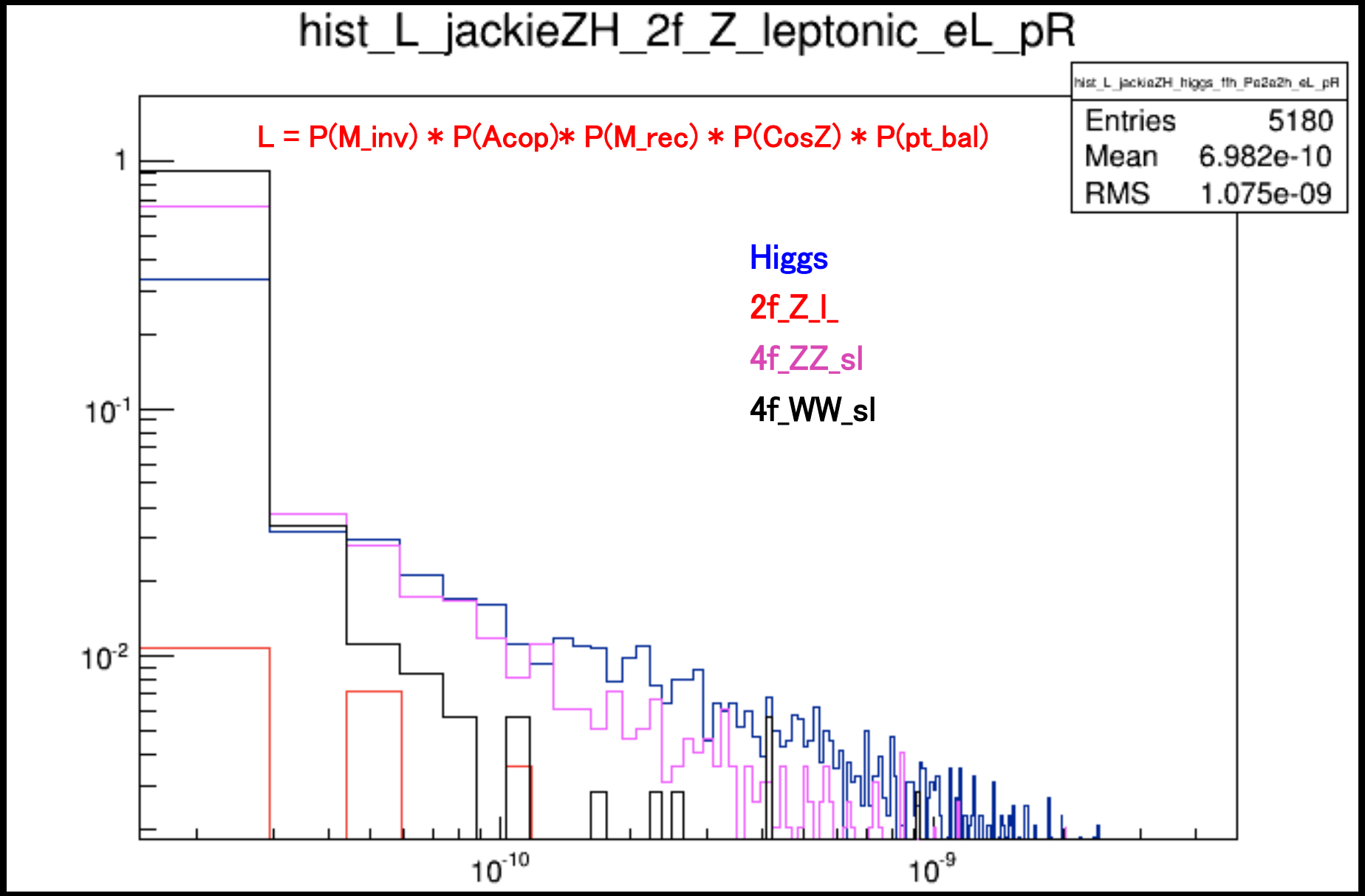


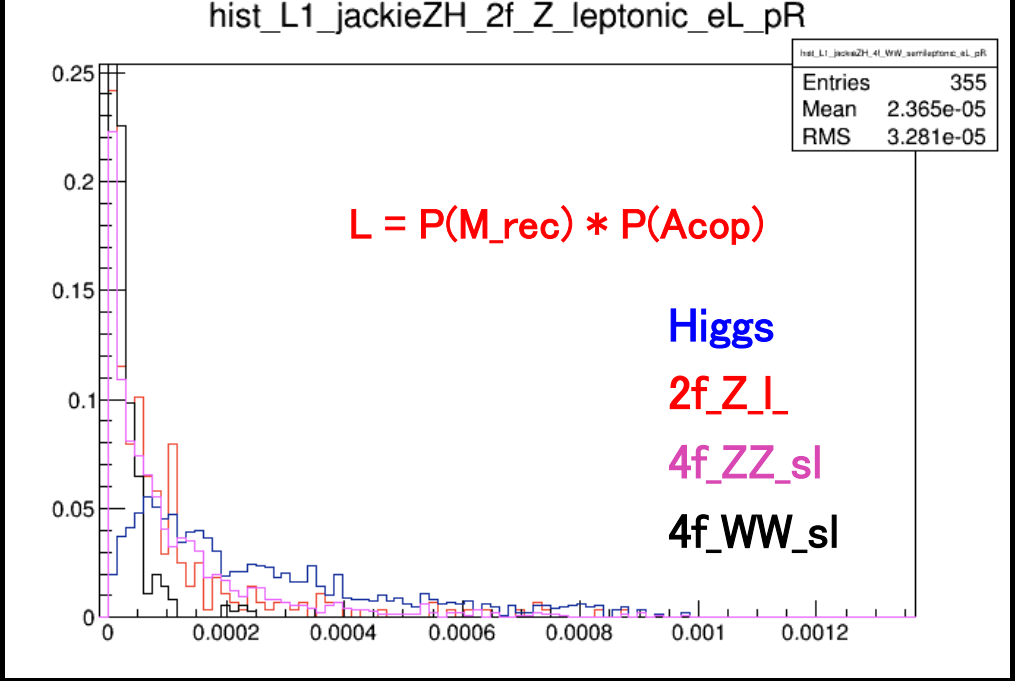


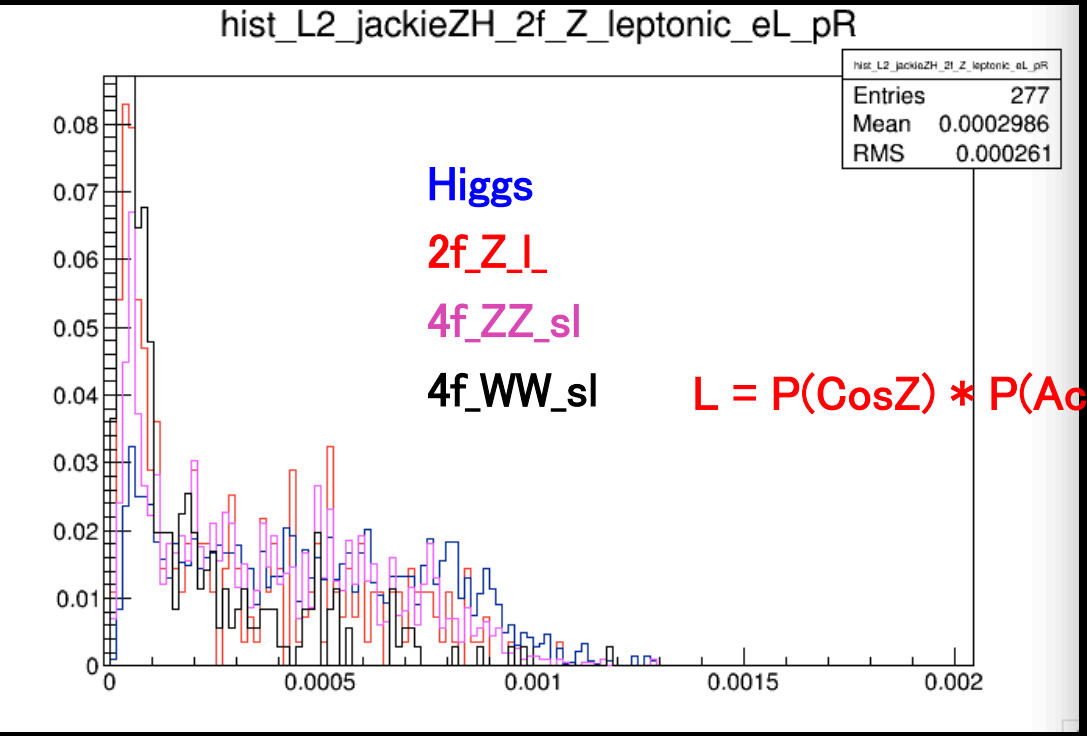


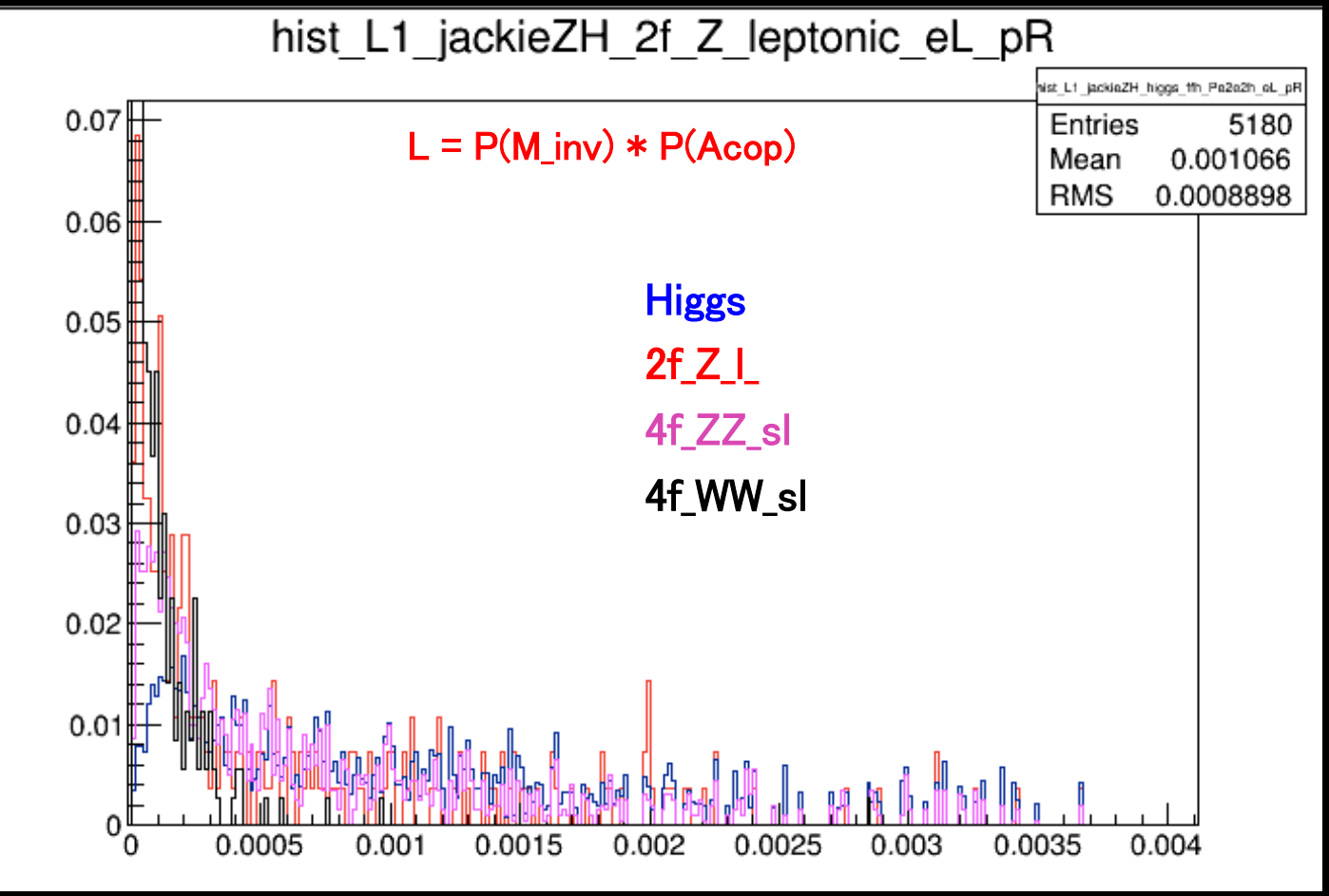


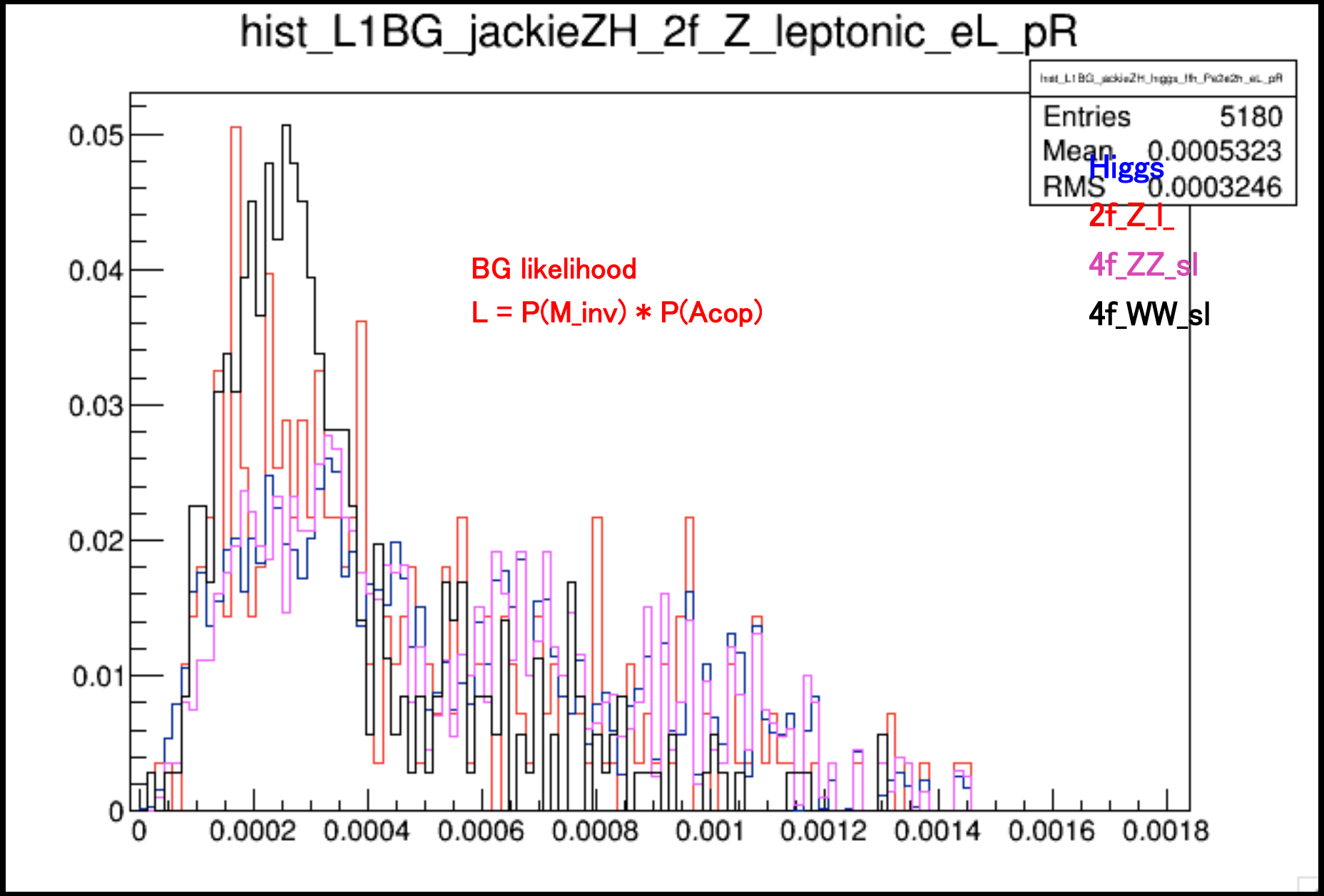



hist_L_jackieZH_2f_Z_leptonic_eL_pR
hist_L_jackieZH_higgs_ffh_Pa2a2h_eL_pR
Entries 5180
Mean 6.982e-10
RMS 1.075e-09
L = P(M_inv) * P(Acop)* P(M_rec) * P(CosZ) * P(pt_bal)
Higgs
2f_Z_l_
4f_ZZ_sl
4f_WW_sl
1
10^-1
10^-2
10^-10
10^-9


hist_L1_jackieZH_2f_Z_leptonic_eL_pR
Entries 355
Mean 2.365e-05
RMS 3.281e-05
L = P(M_rec) * P(Acop)
Higgs
2f_Z_l_
4f_ZZ_sl
4f_WW_sl
0.25
0.2
0.15
0.1
0.05
0
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012


hist_L2_jackieZH_2f_Z_leptonic_eL_pR
Entries 277
Mean 0.0002986
RMS 0.000261
Higgs
2f_Z_l_
4f_ZZ_sl
4f_WW_sl
L = P(CosZ) * P(Acop)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.0005
0.001
0.0015
0.002


hist_L1_jackieZH_2f_Z_leptonic_eL_pR
hist_L1_jackieZH_higgs_tfh_Pe2e2h_eL_pR
Entries 5180
Mean 0.001066
RMS 0.0008898
L = P(M_inv) * P(Acop)
Higgs
2f_Z_l_
4f_ZZ_sl
4f_WW_sl
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.0005
0.001
0.0015
0.002
0.0025
0.003
0.0035
0.004


hist_L1BG_jackieZH_2f_Z_leptonic_eL_pR
Entries 5180
Mean 0.0005323
RMS 0.0003246
Higgs
2f_Z_l_
4f_ZZ_sl
4f_WW_sl
BG likelihood
L = P(M_inv) * P(Acop)
0.05
0.04
0.03
0.02
0.01
0
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
0.0018

断面積測定の精度の評価　：　異なるECMとビーム偏極の比較　NEW

ECM	Pol	ε	Δσ/σ	xsec [fb]	Nsig	significance
350 GeV	(−0.8,+0.3)	47.7+/−0.5%	4.9+/−0.2%	6.71+/−0.34	1092+/−55	17.7
	(+0.8,−0.3)	47.8+/−0.5%	5.0+/−0.2%	4.53+/−0.26	720+/−41	17.8
250 GeV	(−0.8,+0.3)	66.4+/−0.5%	3.6+/−0.1%	10.52+/−0.38	1747+/−64	21.7
	(+0.8,−0.3)	64.4+/−0.5%	3.3+/−0.1%	8.68+/−0.30	1398+/−48	22.7

注）この表の　fitting範囲は115−150 GeV　（AWLC14 @ Fermilabより）
現在350 GeV のみ範囲を広げて、　Δσ/σが 4.7 +/− 0.2 % へ改善した

比較#1:　ECM =350 GeV ←→　ECM = 250 GeV :

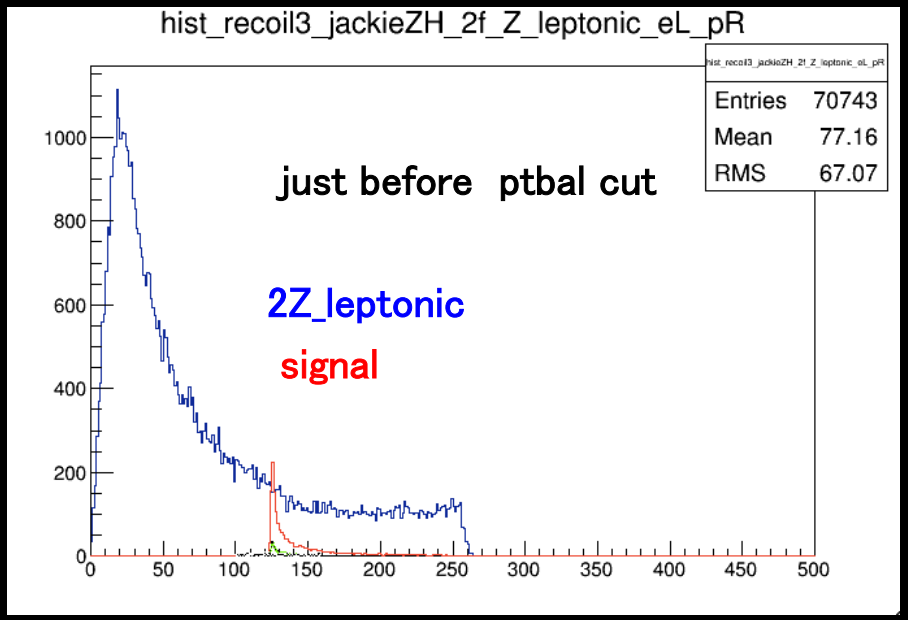
ECM= 250 GeVの方がΔσ/σ　と Mh 精度　が良い　　*μの運動量測定の分解能は低いPTほど良い*

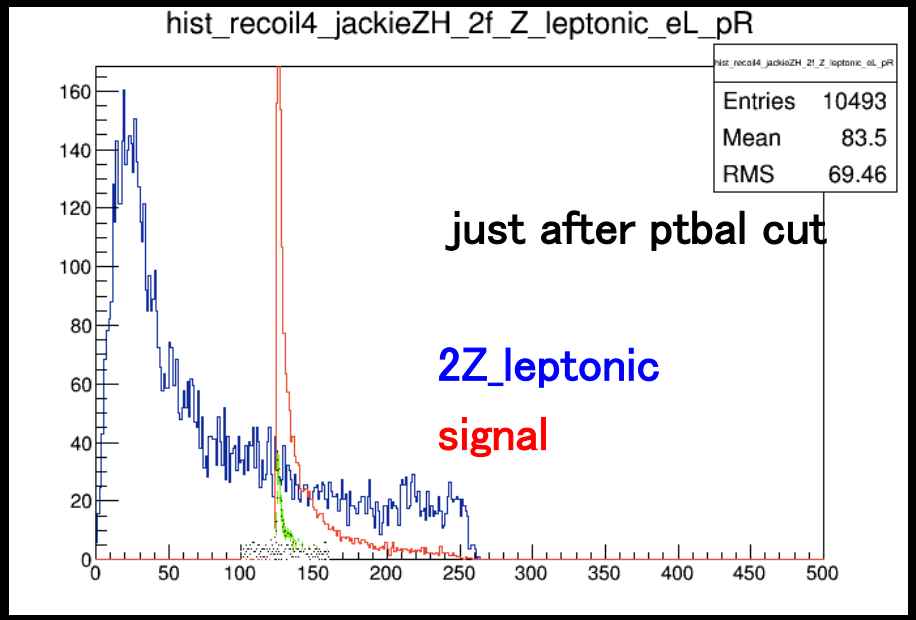
比較#2:　Pol: (−0.8,+0.3) ←→ (+0.8, −0.3) :

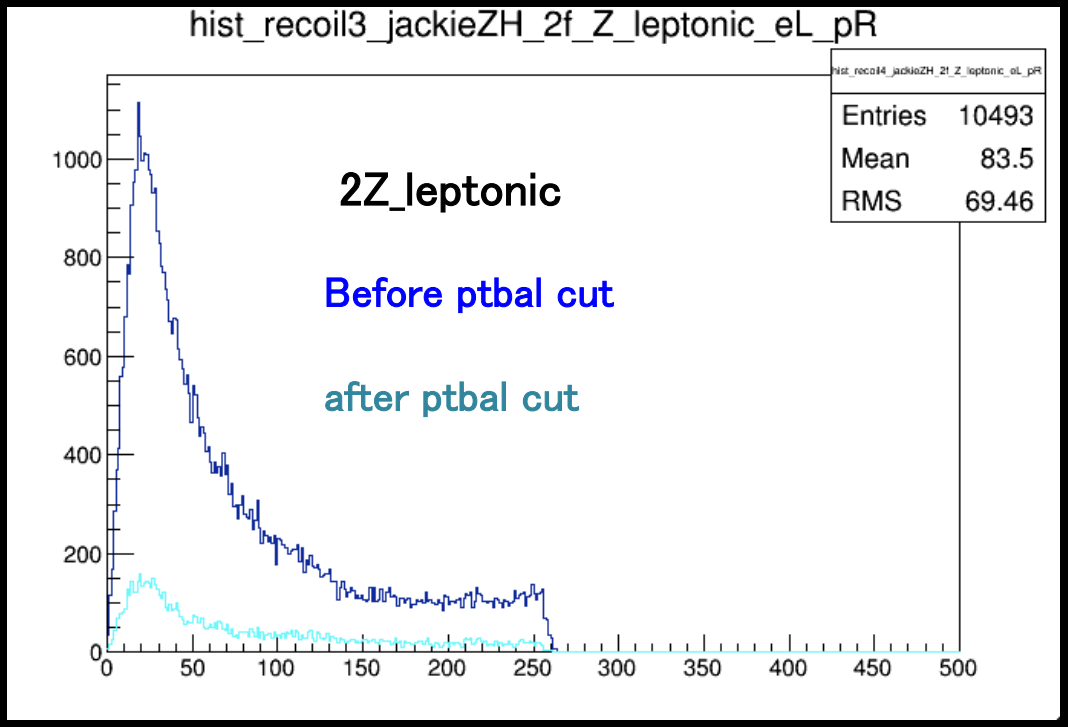
- 異なる偏極の間でΔσ/σに大きな差がなさそう
- (+0.8, −0.3) :　統計が少ないが、S/B がずっと高い :　WW BGが顕著に抑制

注意）先行studyとの色んな違い:

- assumed L　(350, 250 GeV) = (333 , 250 fb-1)　vs　RDR: (300 fb-1, 188 fb-1)
- このstudy : ALL　2f, 4f, 6f BGs (whizard generator)　vs　only WW, ZZ (pythia generator ?)


hist_recoil3_jackieZH_2f_Z_leptonic_eL_pR
Entries 70743
Mean 77.16
RMS 67.07
just before ptbal cut
2Z_leptonic
signal

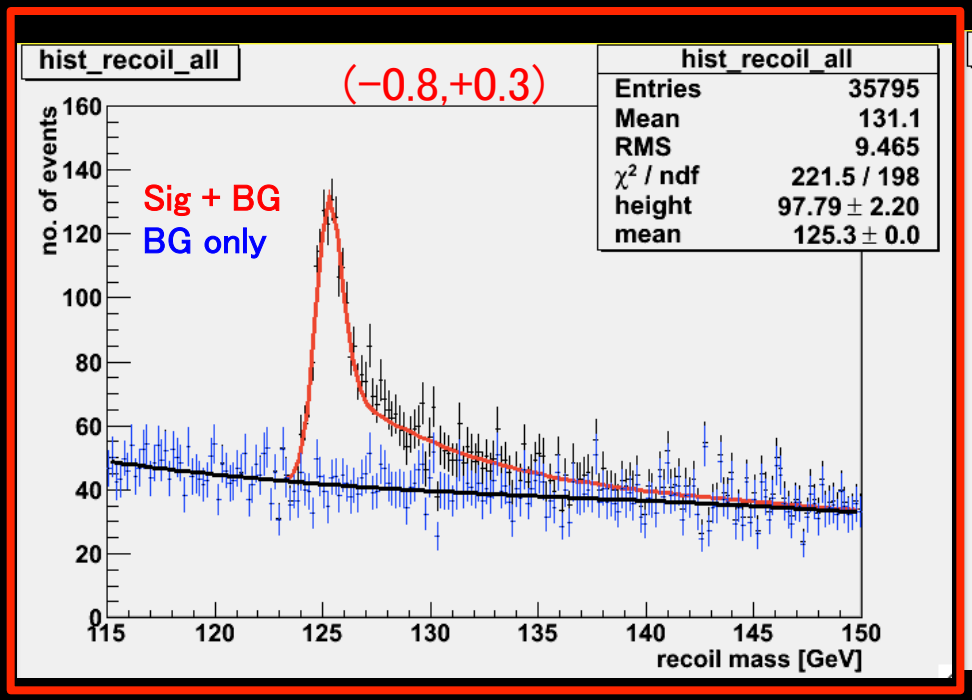

hist_recoil4_jackieZH_2f_Z_leptonic_eL_pR
Entries 10493
Mean 83.5
RMS 69.46
just after ptbal cut
2Z_leptonic
signal

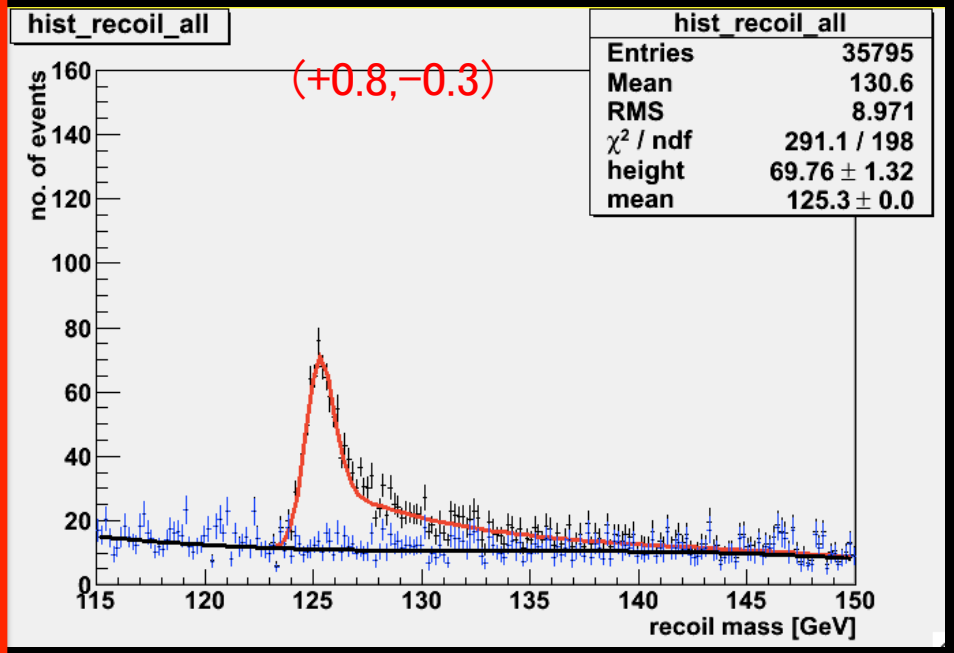

hist_recoil3_jackieZH_2f_Z_leptonic_eL_pR
Entries 10493
Mean 83.5
RMS 69.46
2Z_leptonic
Before ptbal cut
after ptbal cut

results for sqrt(s) =250 GeV , L = 250 fb−1

evaluated using Toy MC generated from fitted function shapes

250 GeV	ε	Δ σ / σ	xsec	Nsig	S/N	significance
(−0.8,+0.3)	66.4+/−0.5%	3.6+/−0.1%	10.52+/−0.38	1747+/−64	0.37	21.7
(+0.8,−0.3)	64.4+/−0.5%	3.3+/−0.1%	8.68+/−0.30	1398+/−48	0.81	22.7





Signal sample:

Pe2e2h_.eL.pR & Pe2e2h._eR.pL

relevant BG process for Zmumu

- 4f_ZZ_leptonic
- 4f_ZZ_semileptonic
- 2f_Z_leptonic
- 4f_WW_leptonic
- 4f_WW_semileptonic
- 4fSingleZee_leptonic
- 4fSingleZnunu_leptonic
- 4f_ZZWWMix_leptonic
- 6f backgrounds (sqrt(s)=350 GeV)