Higgs Recoil Mass Study at ECM=350 GeV and 250 GeV

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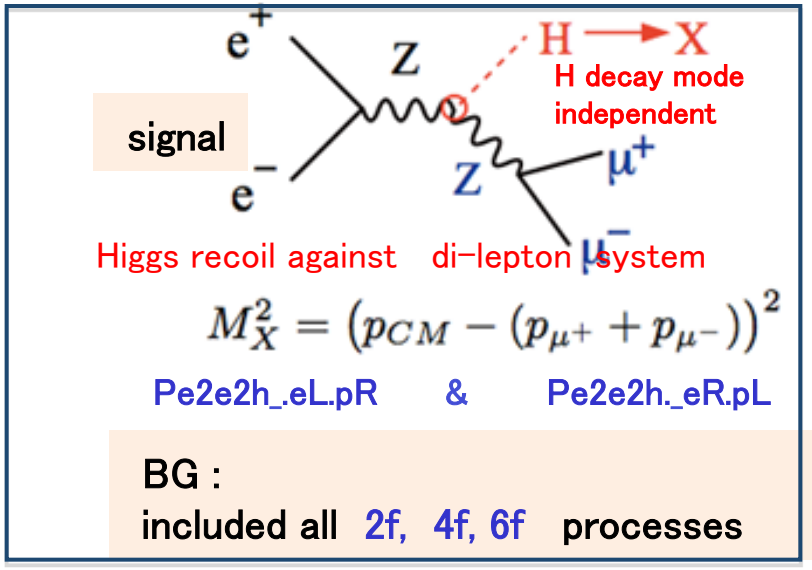
recoil mass study using e+e- → ZH → μ+μ-H
ECM = 350 GeV as well as ECM= 250 GeV,



Goal:

- precise measurement of Higgs cross section σ_H
- contribute to the decision for ILC run scenario

Many physics become important at Ec.m.s.= 350 GeV

ILC sample used in analysis

chanel	mh	ECM	L	Spin polarization	Detector simulation
e+e→Zh->μμh	125 GeV	350 GeV 250 GeV	333 fb-1 250 fb-1	P(e-,e+) = (-0.8,+0.3) (+0.8,-0.3)	Full ILD (ILD_01_v05 DBD ver.)

Layout of this Talk

- Evaluation of data analysis performance
  cross section error, signal efficiency, significance, S/N ratio, ect……
- Comparison with sqrt(s)=250 GeV
- Compare alternative polarization scenarios
- Summary & Plans

Muon Candidate Selection

using conditions on

- charge,
- E_cluster / P_total < 0.5
- isolation (small cone energy)
- cos(track angle) < 0.98 & |D0/δD0| < 5

Best Z Candidate Selection

2 muon candidates with **opposite charge**

choose pair **with invariant mass closest to Z mass**

Final Selection

ECM=350 GeV, (-0.8,+0.3)

- **73 GeV < M_inv < 120 GeV**
- **10 GeV < pT_mumu < 140 GeV**
- **dptbal > 10 GeV**
- **Ebal < 230 GeV**
- **|cos(θ_Zpro)| < 0.9**
- **120 GeV < Mrecoil < 140 GeV**
- **Likelihood cut**

Data Selection Method

Experimented with various cut threshold to achieve highest sig eff and S/N raio

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
- **dptbal = Pt_dl − Pt_γ**
- Ebal = Eγ + E_dl

Results after selection

ECM=350 GeV, (-0.8,+0.3)

- Sig efficiency = 51 %
- S/B = 0.63, significance = 21.3

similar optimized for sqrt(s)=250 GeV and other polarization secenarios

recoil mass fitting method

1st step:

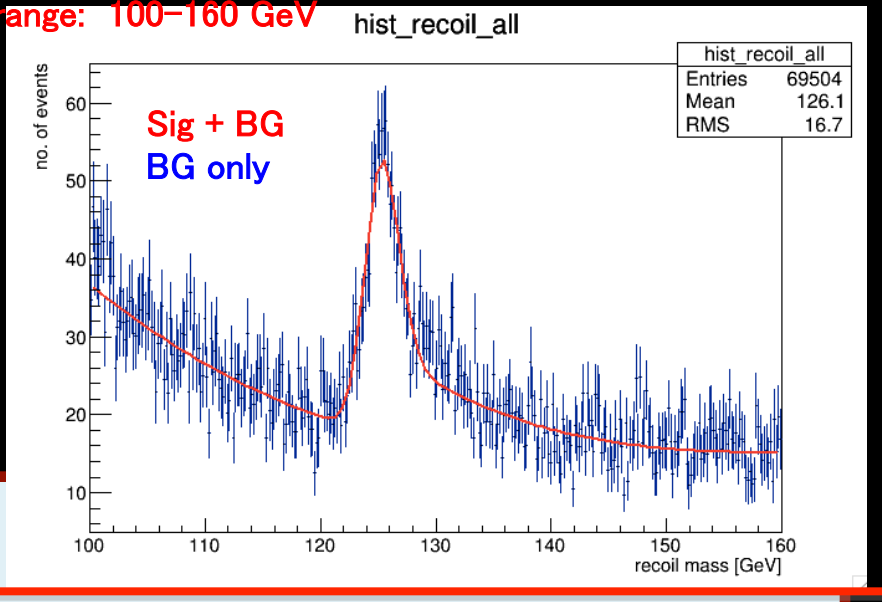
- Fit only signal with GPET float all 5 pars
- Fit only BG: 3rd order polynomial

2nd step :

fit Sig + BG : only float height and mean

fix others from step 1

Fit range: 100–160 GeV



◆ **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

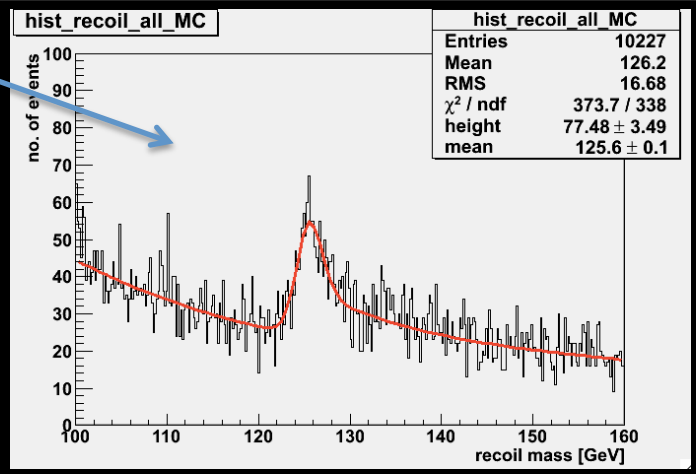
in terms of M_h、 xsec etc……

method:

generate MC events according to fitted “real” data

(Poisson distr.)

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



Compare ECM=350 GeV and ECM= 250 GeV , polarization (−0.8,+0.3) and (+0.8, −0.3)

Evaluated xsec error and validity of fitting using Toy MC generated from these fitted function shapes

	Nsig	Nbg	S/B ratio	significance	sig eff (before Mrec)	Δσ/σ(MC)
Ecm=350 GeV						
(−0.8,+0.3)	1171	1865	0.63	21.3	51% (82%)	3.98%
(+0.8,−0.3)	807	716	1.13	20.7	52% (82%)	4.40%
Nsig and Nbg in Mrecoil 120−140 GeV						
Ecm=250 GeV						
(−0.8,+0.3)	1703	3815	0.45	22.9	65% (76%)	3.31%
(+0.8,−0.3)	1178	1185	0.99	24.2	67% (76%)	3.49%

◆ ECM= 250 GeV (w.r.t. 350 GeV)

higher statistics, sharper recoil mass peak → 17 % better xsec precision

may need more optimization of analysis method to suppress BG

◆ for (+0.8, −0.3) : S/B much higher:

- WW BGs significantly suppressed , other major BGs less also
- however statistics is lower → cause for slightly worse xsec precision ?

Compare with results from AWLC2014 (Fermilab)

	S/B ratio	significance	sig eff	Δσ/σ(MC)	improvement
Ecm=350 GeV					
(−0.8,+0.3)	0.63	21.3	51%	4.0%	18.8%
(+0.8,−0.3)	1.13	20.7	52%	4.4%	12.0%
Ecm=250 GeV					
(−0.8,+0.3)	0.45	22.9	65%	3.3%	8.1%
(+0.8,−0.3)	0.99	24.2	67%	3.5%	−6.1%

Current April, 2015

AWLC14: May, 2014

	S/B ratio	significance	sig eff	Δσ/σ(MC)
Ecm=350 GeV				
(−0.8,+0.3)	0.40	17.7	48%	4.9%
(+0.8,−0.3)	0.75	17.8	48%	5.0%
Ecm=250 GeV				
(−0.8,+0.3)	0.37	21.7	66%	3.6%
(+0.8,−0.3)	0.81	22.7	64%	3.3%

Key improvement points

- Use of Likelihood cut
- Isolated lepton finder in processor (thanks to Junping-san)
  → removes all 4f_WW_sl BG
- Use info of cone energy around most energetic gamma
  → cut 2f_Z BG using dptbal = pt_dl − pt_γ while preventing bias on signal

Relative results

	Nsig	Nbg	S/B	sig eff	xsec err
Ecm=350 GeV (−0.8,+0.3)	0.69	0.49	1.41	0.98	1.2
Ecm=250 GeV (−0.8,+0.3)	1	1	1	1	1
Ecm=350 GeV (+0.8,−0.3)	0.69	0.6	1.13	0.97	1.26
Ecm=250 GeV (+0.8,−0.3)	1	1	1	1	1

ECM = 350 GeV vs 250 GeV

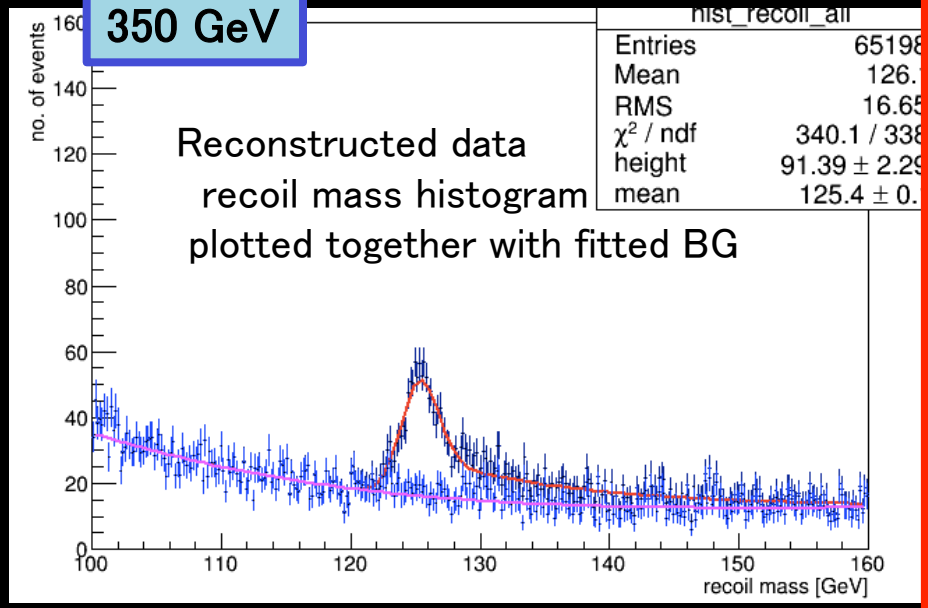
- xsec error is 17% better for 250 GeV
- Sig. eff almost same

Comparing polarization

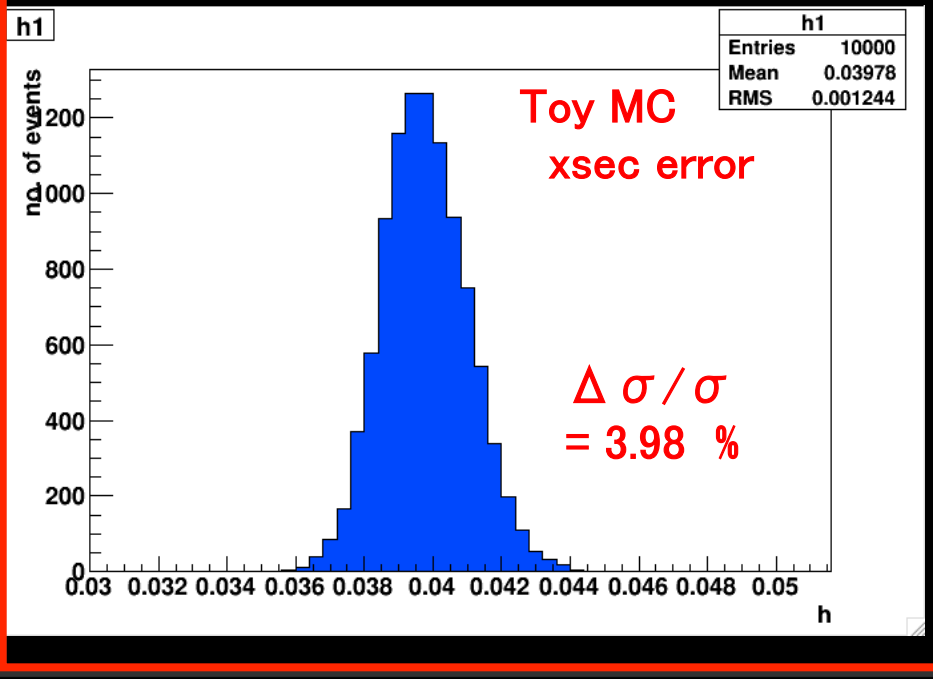
	Nsig	Nbg	S/B	sig eff	xsec err
Ecm=350 GeV (−0.8,+0.3)	1	1	1	1	1
(+0.8,−0.3)	0.69	0.38	1.80	1.02	1.11
Ecm=250 GeV (−0.8,+0.3)	1	1	1	1	1
(+0.8,−0.3)	0.69	0.31	2.23	1.03	1.05

- xsec error is 10% better for left pol
- Sig. eff almost same

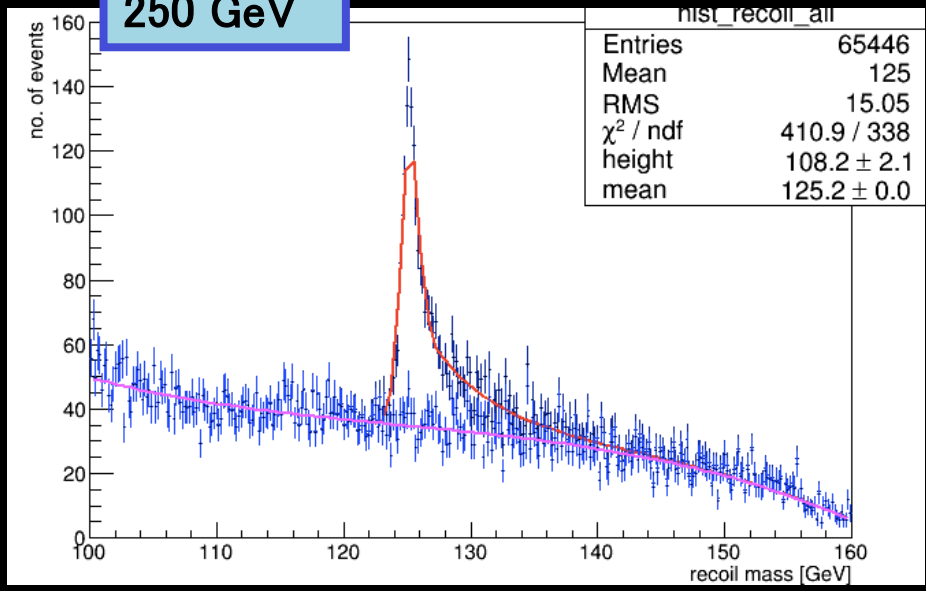
350 GeV

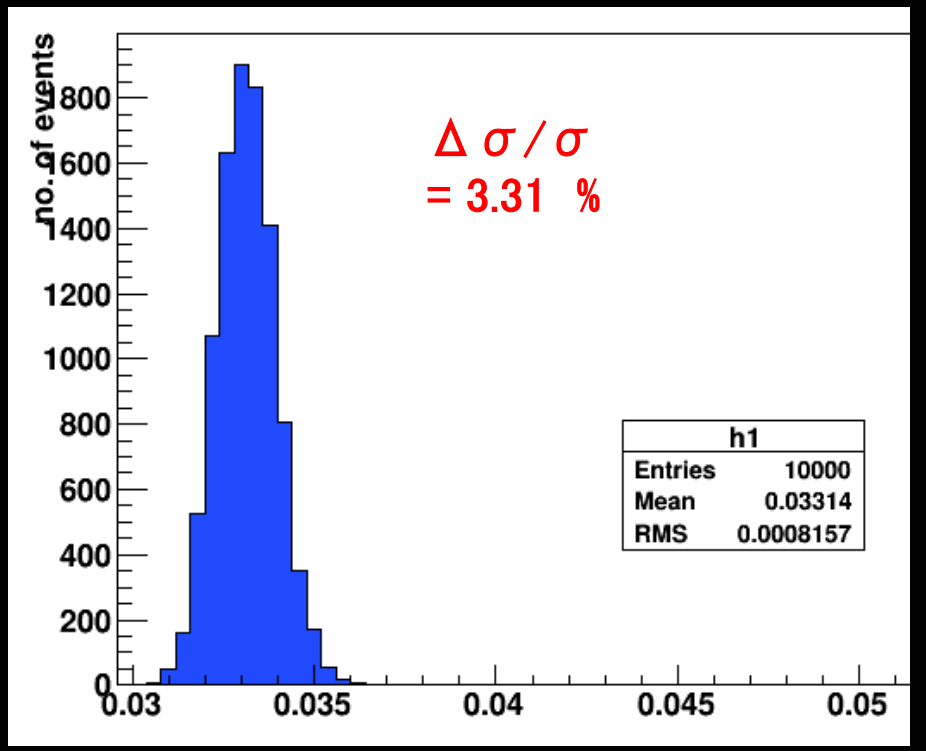


Reconstructed data
recoil mass histogram
plotted together with fitted BG



250 GeV

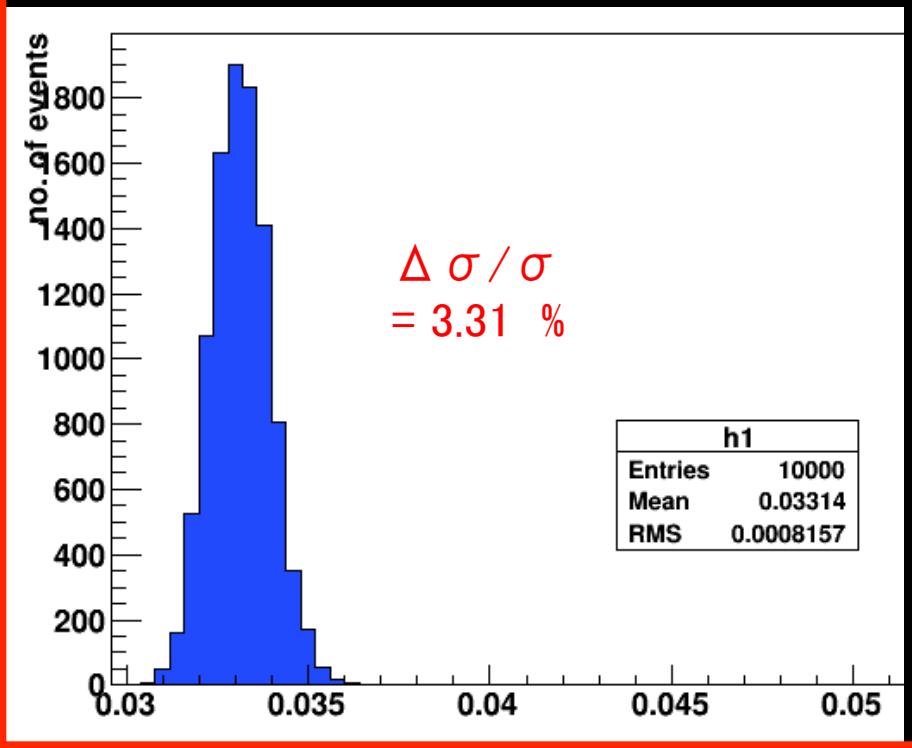




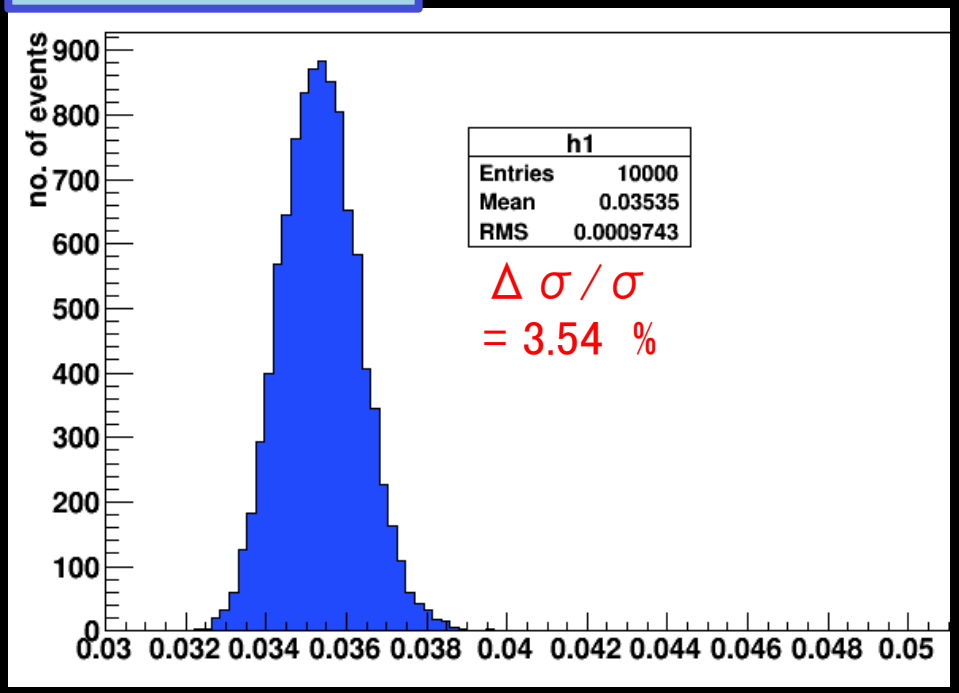
Toy MC study results
xsec error

about 7 % worse if we float BG
(pessimistic scenario)

250 GeV, fix BG



250 GeV, float BG



dominant BG after final selection (Mrec 120–140 GeV + Likelihood cut)

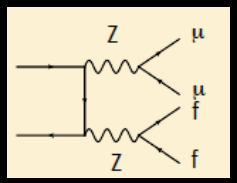
4f_ZZ_semileptonic : 991 *can't do anything*

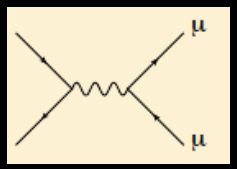
4f_ZZWWMix_leptonic: 320

vs

Higgs: 1171

	original		after Minv, pt		after dptbal		final	
P1: (−0.8,+0.3)								
P2: (+0.8,−0.3)	P1	P2	P1	P2	P1	P2	P1	P2
signal	2288	1543	2004	1355	1983	1339	1171	808
4f_ZZ_sl	188125	99900	16922	8051	16614	7883	991	416
4f_ZZWWMix_l	541187	35527	19325	1573	18024	1485	320	42
2f_Z_l	2227000	1757000	85335	57319	13182	8819	79	59





number of events after each selection step is in

/ home/ ilc / jackie / jackieZHProcessornew / data /

350 GeV: outputD1_350GeVP1.dat (−0.8, + 0.3), outputD1_350GeVP2.dat (+0.8, − 0.3)

250 GeV: outputD1_250GeVP1.dat (−0.8, + 0.3), outputD1_250GeVP2.dat (+0.8, − 0.3)

Note) These will continue to be optimized in days to come

Summary

Higgs recoil study using **e+e- → ZH → μ+μ-H** @ **ECM =350 GeV**, L = 333 fb-1

Goal: **contribute to deciding ILC run scenario and detector design optimization**

- **optimization of data selection method**
- compared with **Ec.m.s. = 250 GeV and different polarization scenarios : (-0.8, 0.3) vs (+ 0.8, -0.3)**

< Preliminary results >

350 GeV: **(-0.8, +0.3) Δσ / σ = 4.0 % , ε_sig～50%**
(+0.8, -0.3) Δσ / σ = 4.4 % ,

250 GeV: **(-0.8, +0.3) Δσ / σ = 3.3 % , ε_sig ～ 65%**
(+0.8, -0.3) Δσ / σ = 3.5 %

- **ECM= 250 GeV has better Δσ/σ by 17% w.r.t. ECM=350 GeV**
- (+0.8, -0.3) has better S/B , but lower statistics, 5-10% worse Δσ/ σ

significant improvements w.r.t. AWLC14 (@Fermilab May 2014) :
xsec precision better by ～ 19 % (350 GeV, (-0.8, + 0.3)

Plans

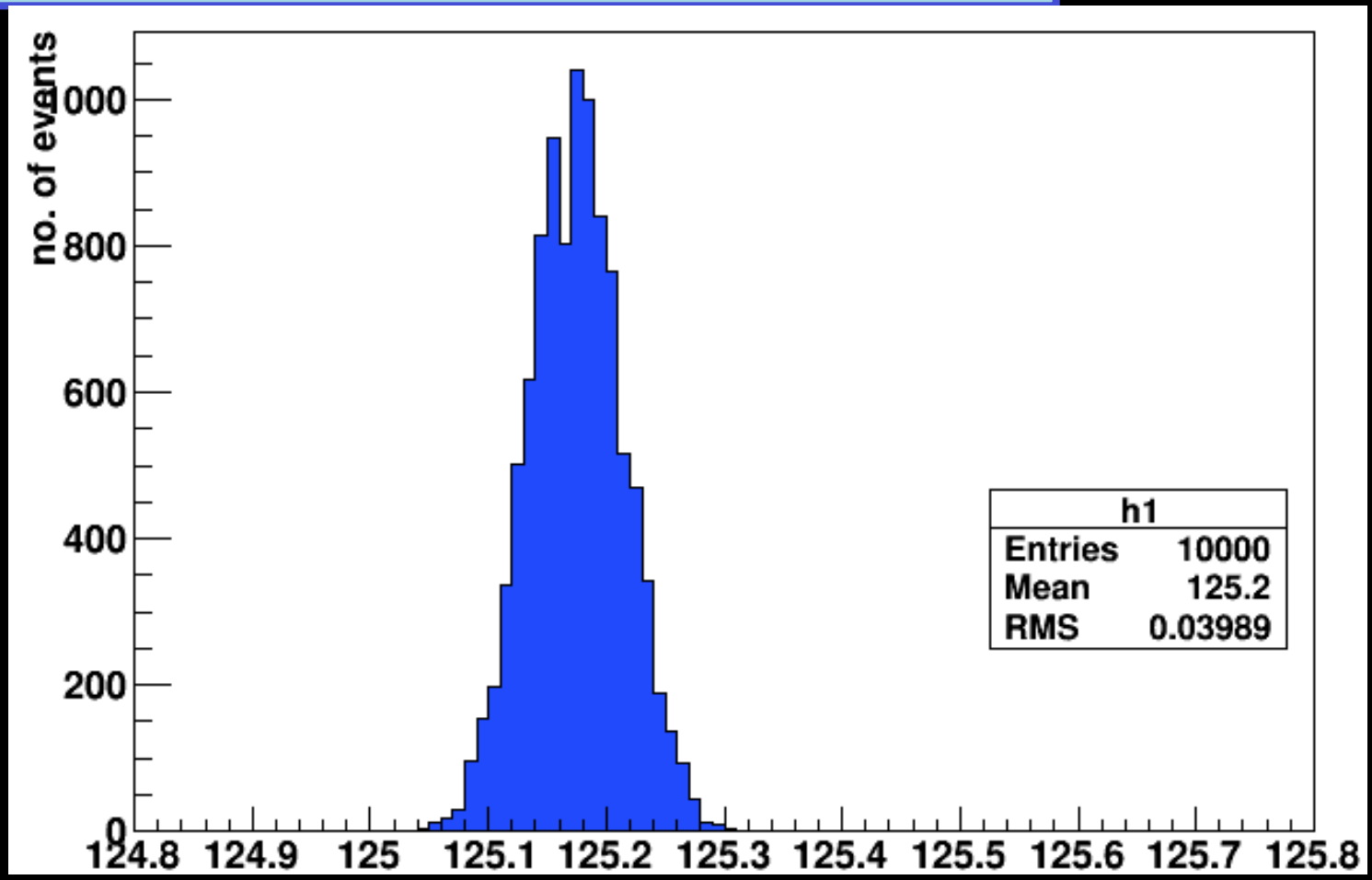
- the goal is always to cut more BG without losing too much signal
  especially must minimize bias on signal (cause of mode dependence)
- **implement similar methods to Zee channel**
  so we can get a more reliable comparison of ECM = 250 GeV vs 350 GeV

BACKUP

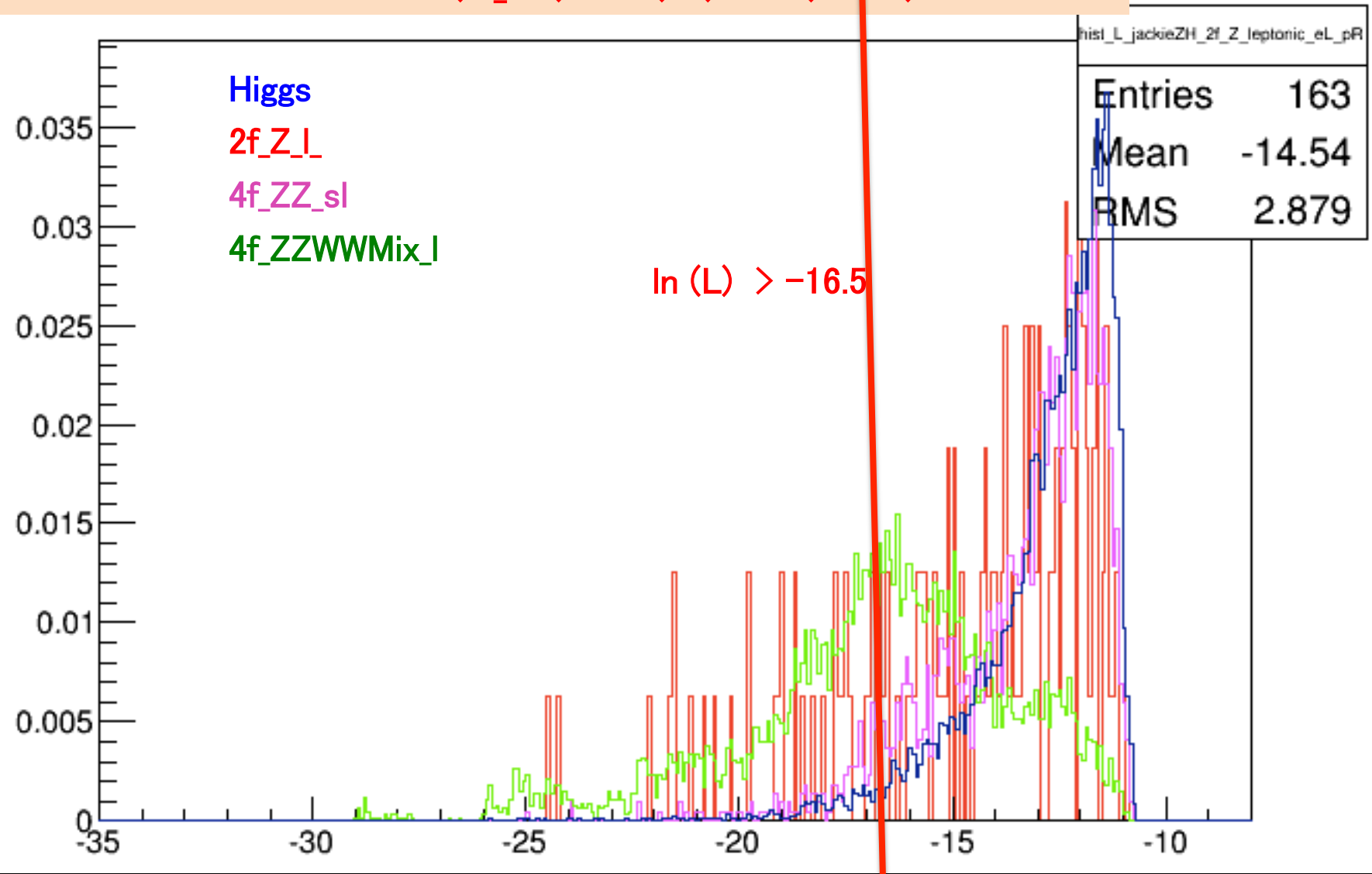
ECM = 350 GeV

Toy MC : fitted Higgs recoil mass

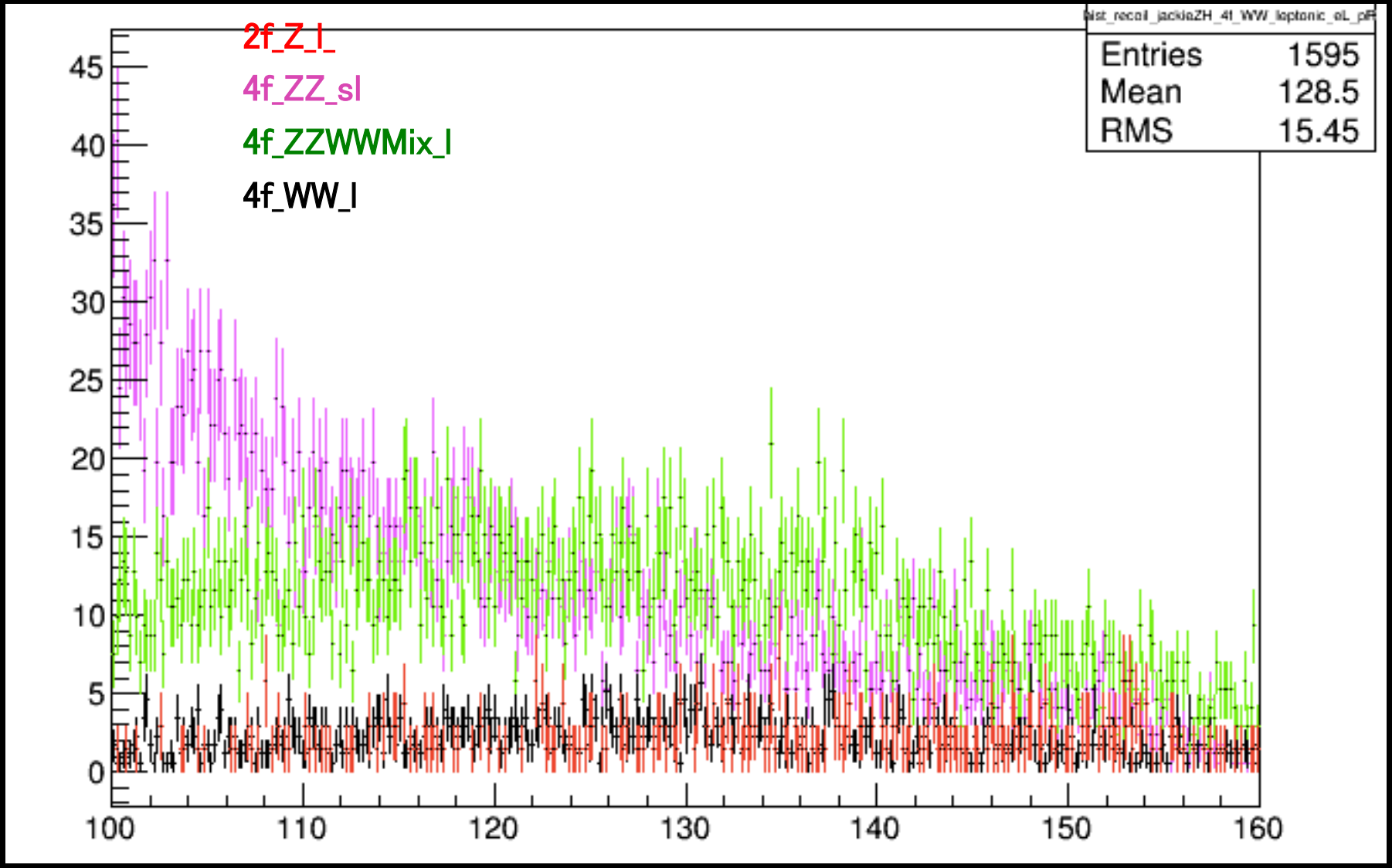
125.2 GeV



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



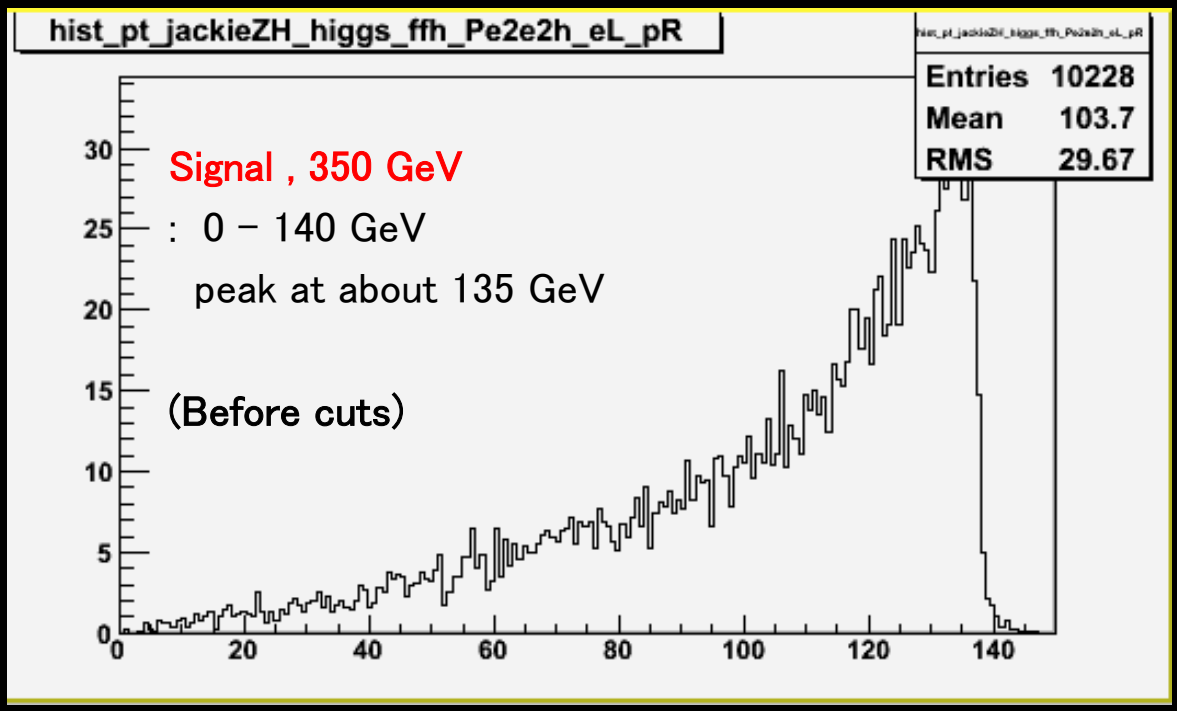
BG Recoil Mass

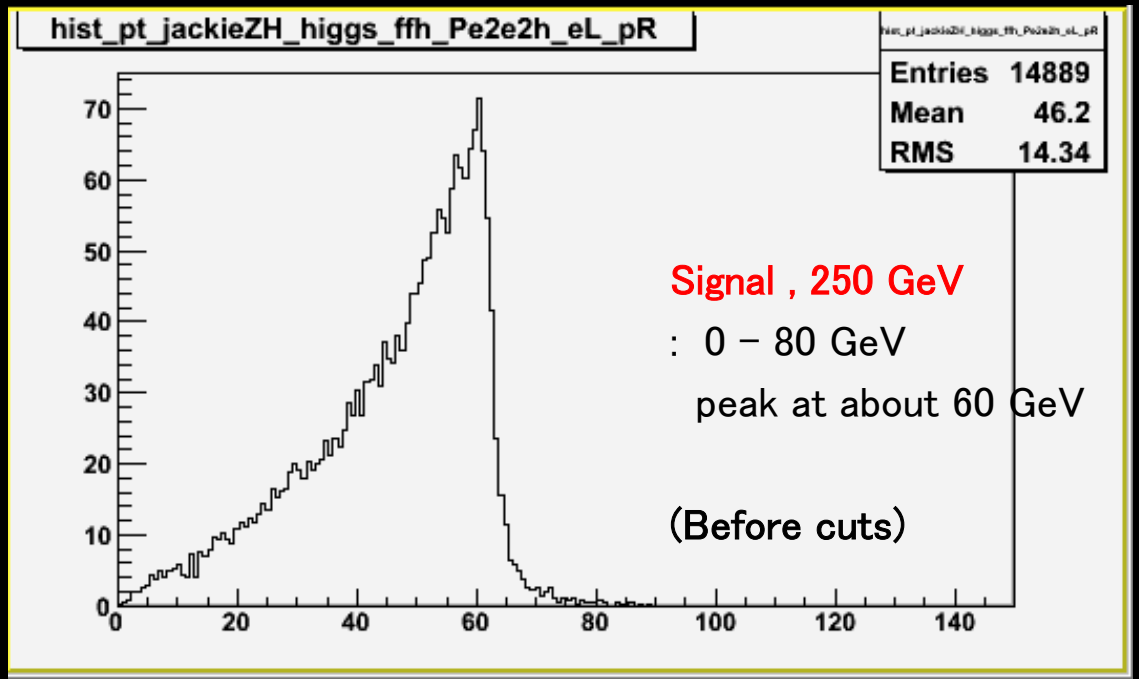


dilepton PT, 350 GeV

do cut :

10 GeV< pT_dl < 140 GeV



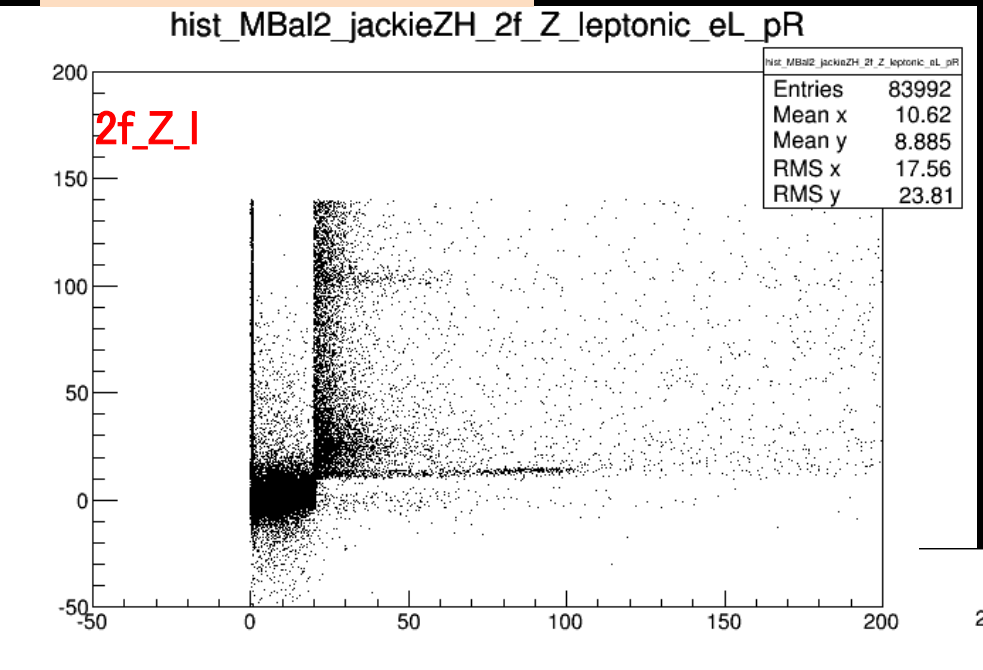


2D distr. Of

X: Econe_γ

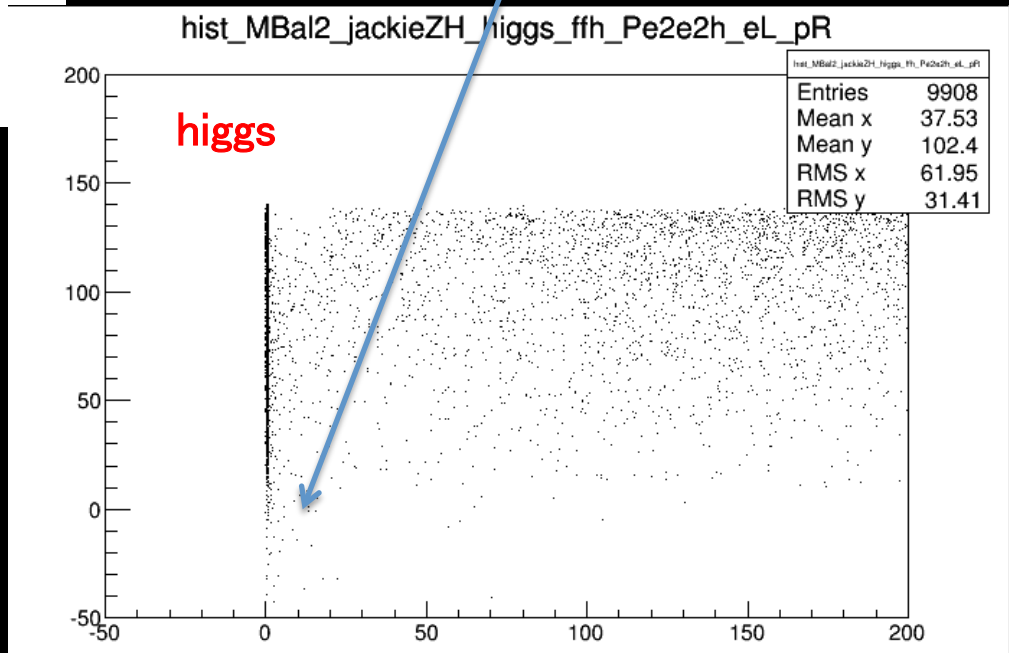
Y: dptabl

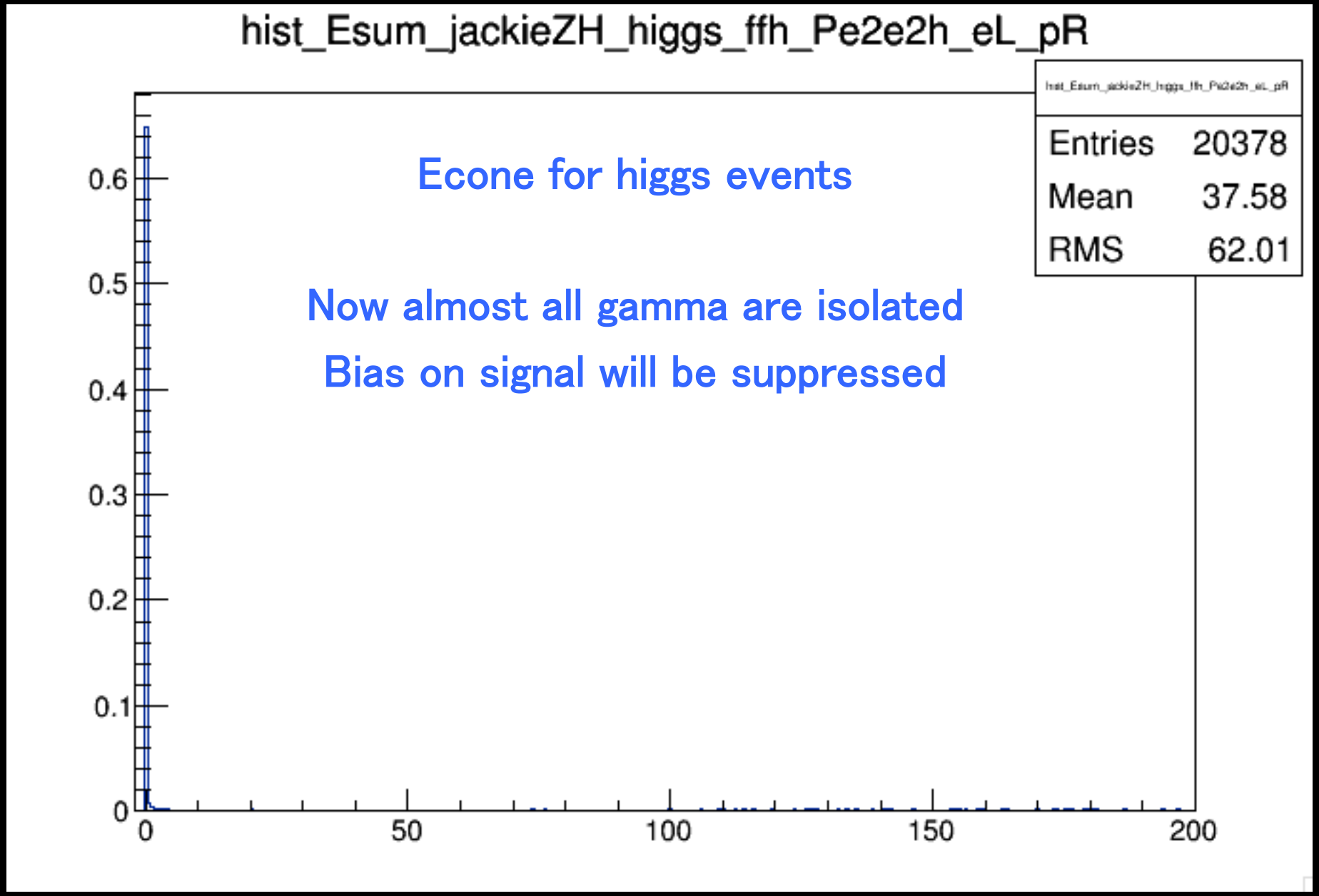
New: corrected condition for selecting photons (EcalE/Etot > 0.9)

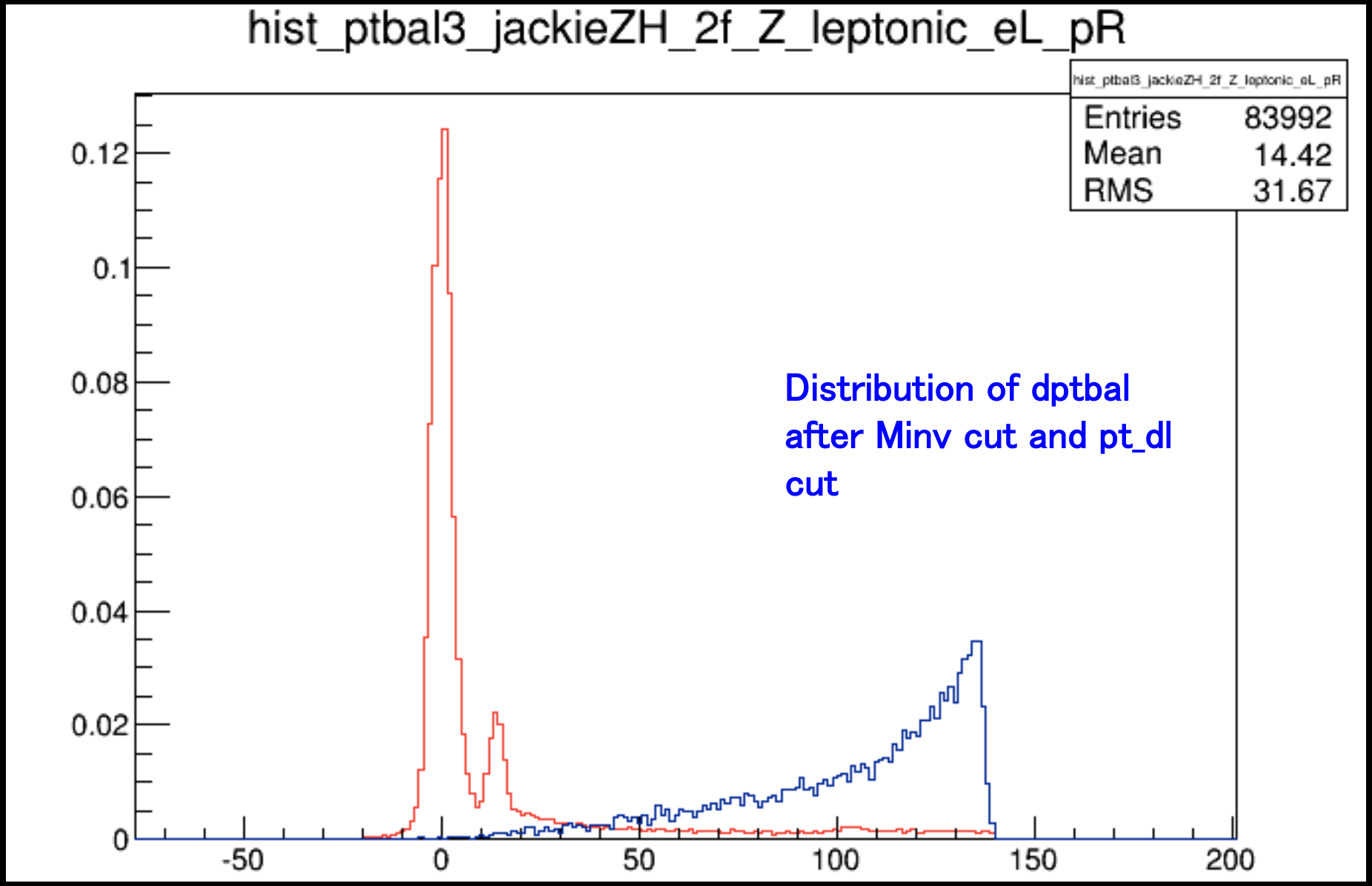


It seems that most higgs events that have dptbal < 10 GeV are isolated (i.e. small Econe)

so it may be OK to cut these events




hist_Esum_jackieZH_higgs_ffh_Pe2e2h_eL_pR
Econe for higgs events
Now almost all gamma are isolated
Bias on signal will be suppressed
Entries 20378
Mean 37.58
RMS 62.01
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200


hist_ptbal3_jackieZH_2f_Z_leptonic_eL_pR
hist_ptbal3_jackieZH_2f_Z_leptonic_eL_pR
Entries 83992
Mean 14.42
RMS 31.67
0.12
0.1
0.08
0.06
0.04
0.02
0
-50
0
50
100
150
200
Distribution of dptbal after Minv cut and pt_dl cut

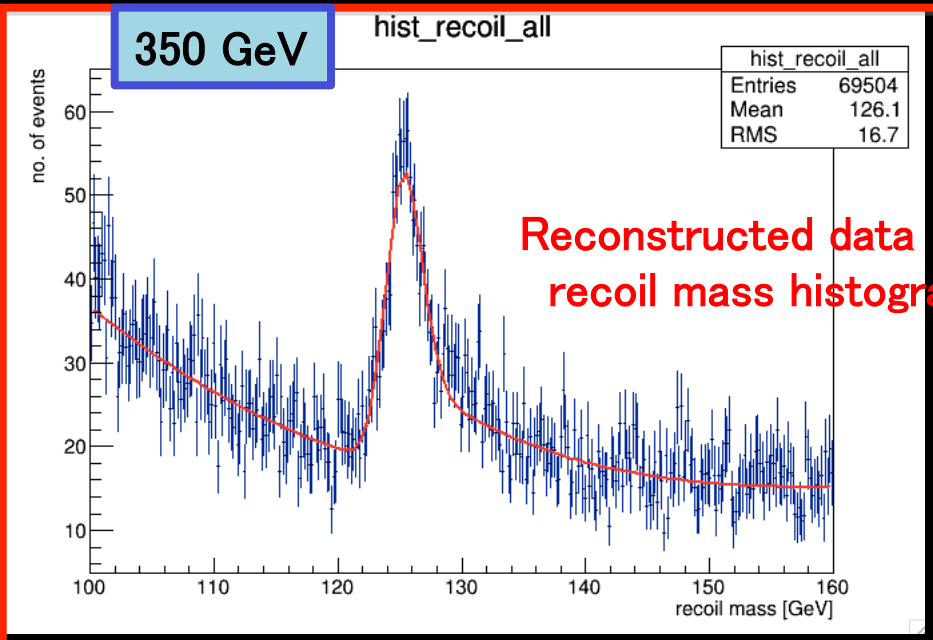
Pe2e2h_.eL.pR & Pe2e2h._eR.pL

- 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)

note that difference from past studies maybe sue to:

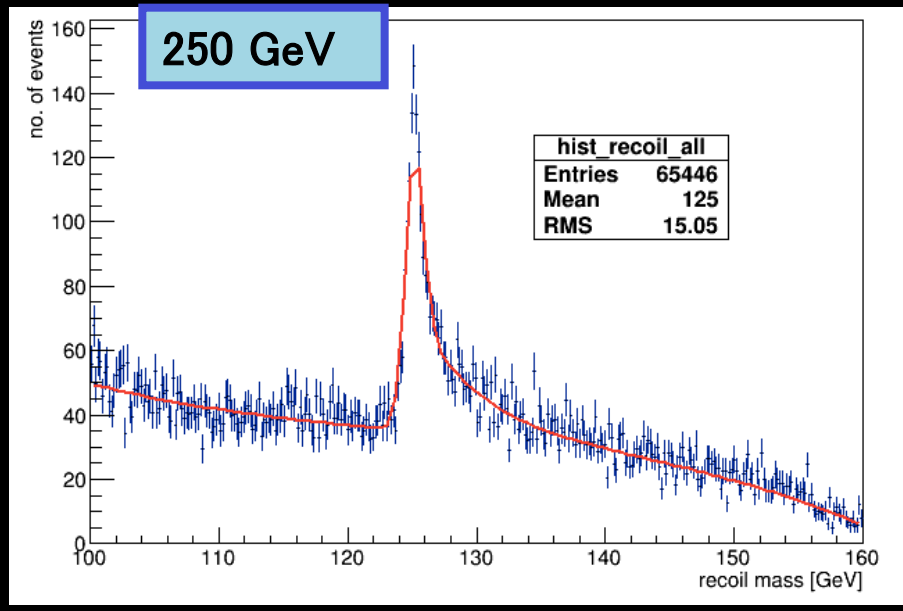
- assumed L (350, 250 GeV) = (333 , 250 fb-1) vs RDR: (300 fb-1, 188 fb-1)
- this analysis include all 2f, 4f, 6f BGs (whizard generator) vs only WW, ZZ (pythia generator ?)

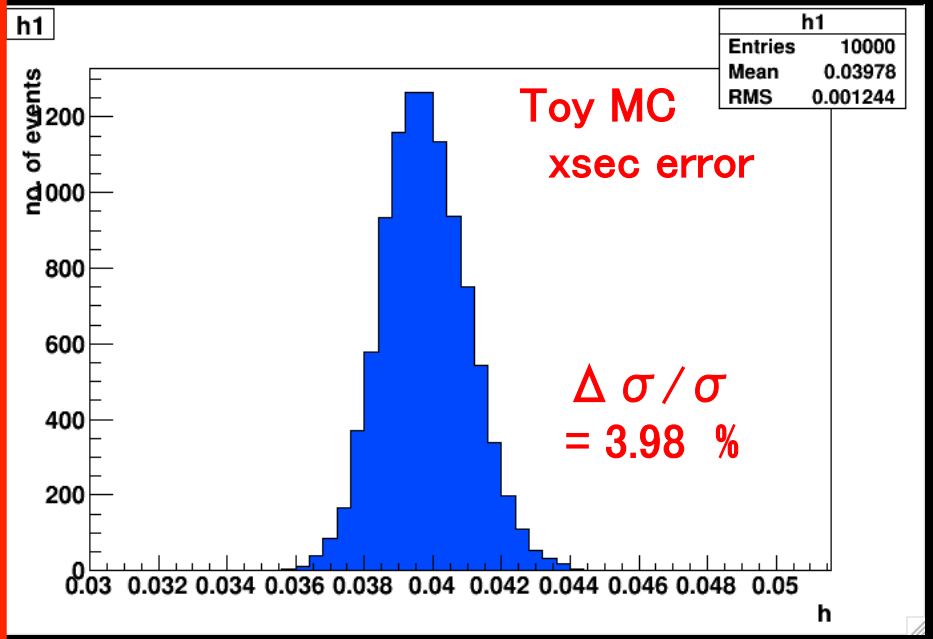
350 GeV



Reconstructed data
recoil mass histogram

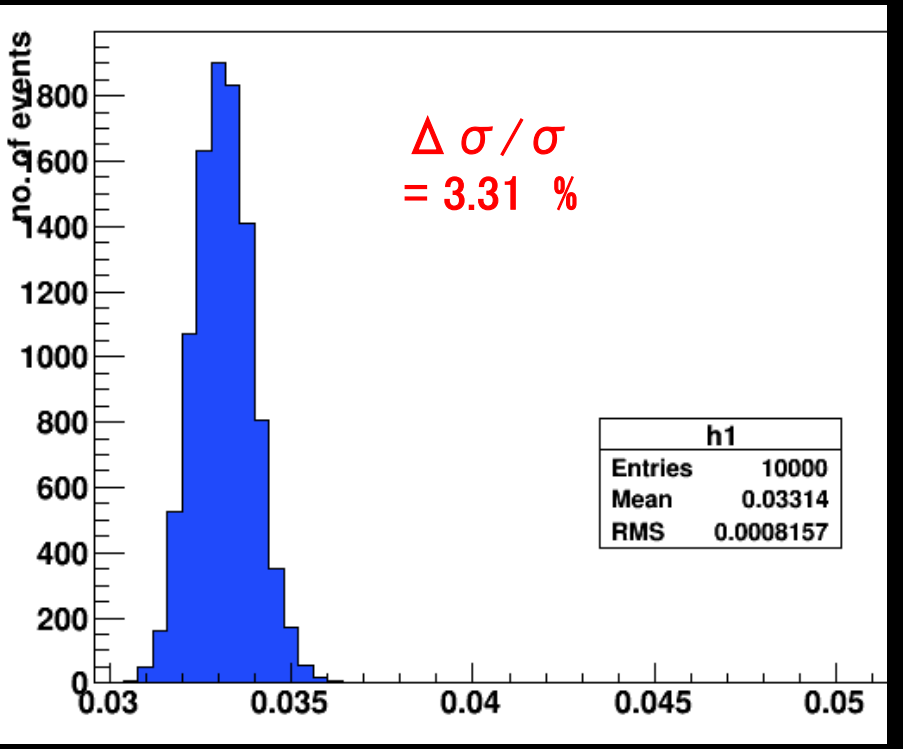
250 GeV





Toy MC
xsec error

$\Delta\sigma/\sigma$
= 3.98 %



$\Delta\sigma/\sigma$
= 3.31 %