Higgs Recoil Mass Study

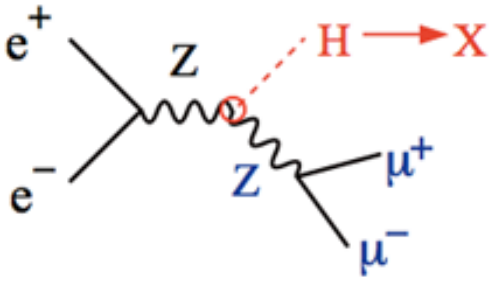
Apr 11 , 2014

Jacqueline Yan

Komamiya Lab, Univ. of Tokyo

recoil mass study using e+e- → Zh → μ+μ-h
Ec.m.s. = 250 GeV, L = 250 fb-1
Ec.m.s. = 350 GeV, L = 333 fb-1

polarization:
(e−, e+) = (− 0.8, + 0.3)



Goal:

precise measurement of

- Higgs mass
- cross section σ_H : $N = \sigma * L * \varepsilon$

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

What's new this week

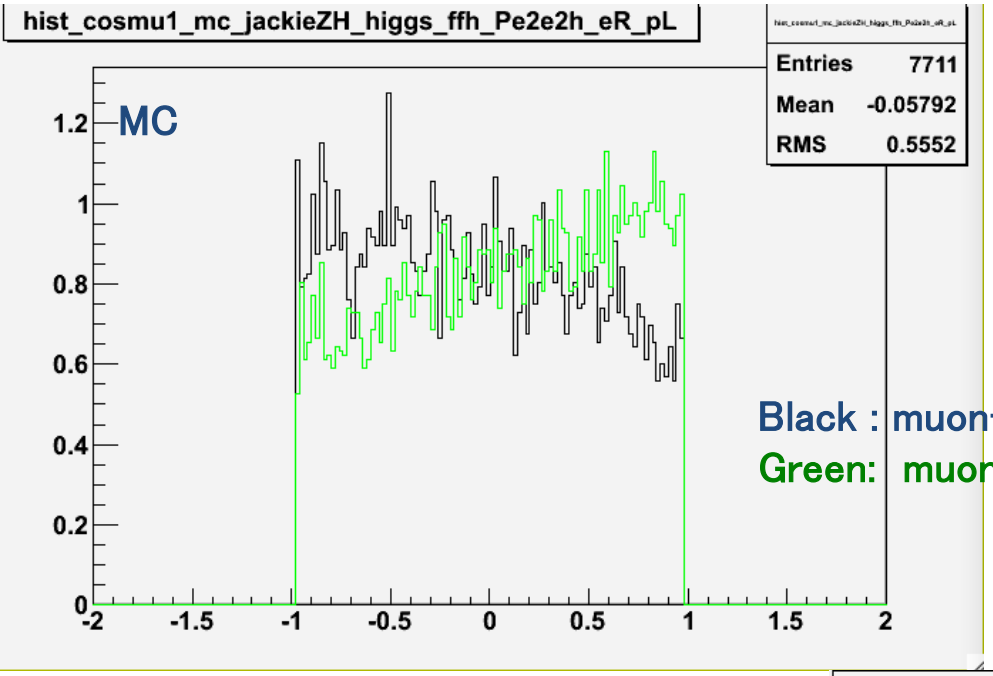
study using MC particle "truth"

- observe cut efficiency
- observe muon track angle

fitting with weighted bins → use fitted results

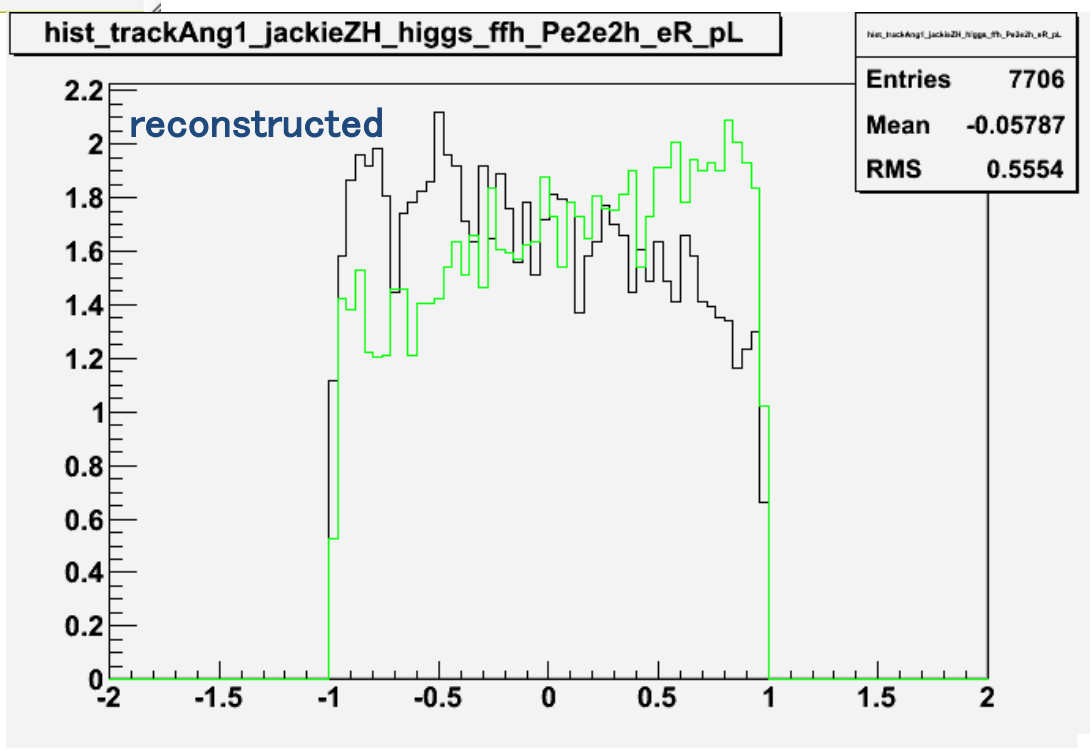
- What is best recoil mass range for fitting ?

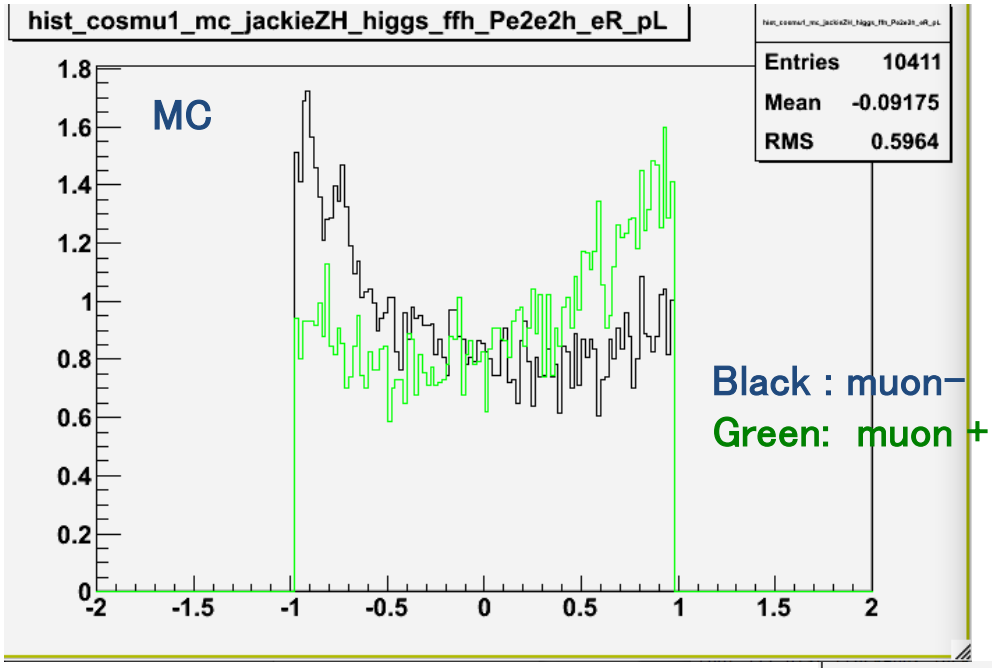
Study using MC particles



Muon track angle

sqrt(s) = 350 GeV

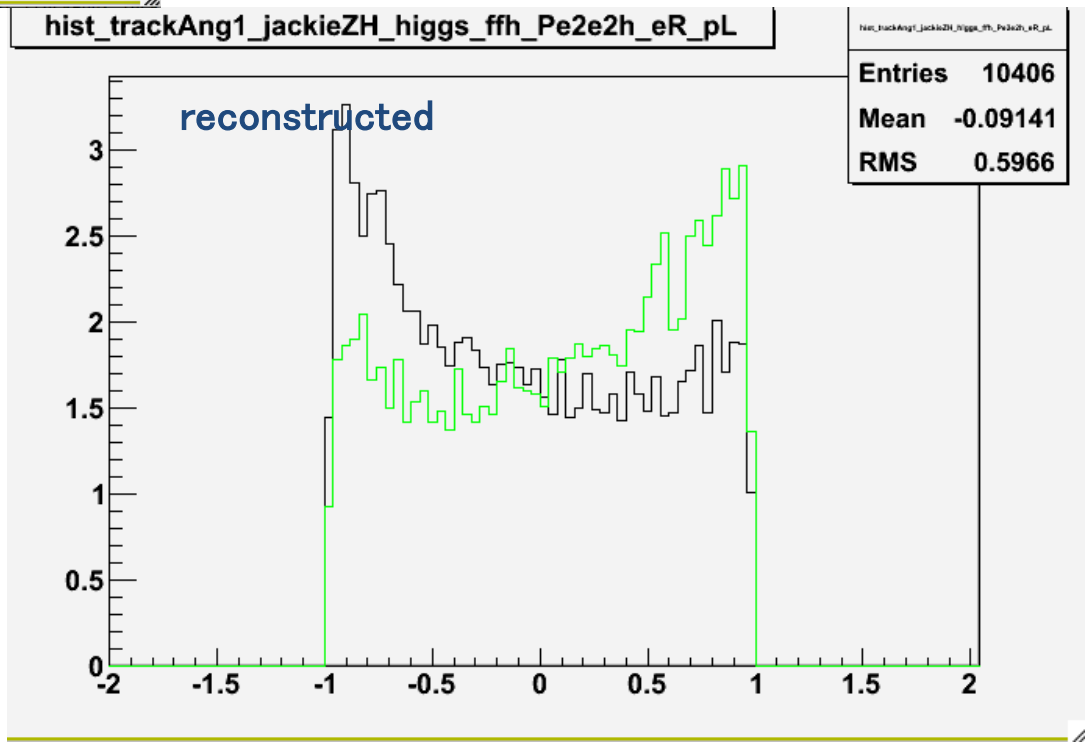




more forward/ asymmetrical than 350 GeV

Muon track angle

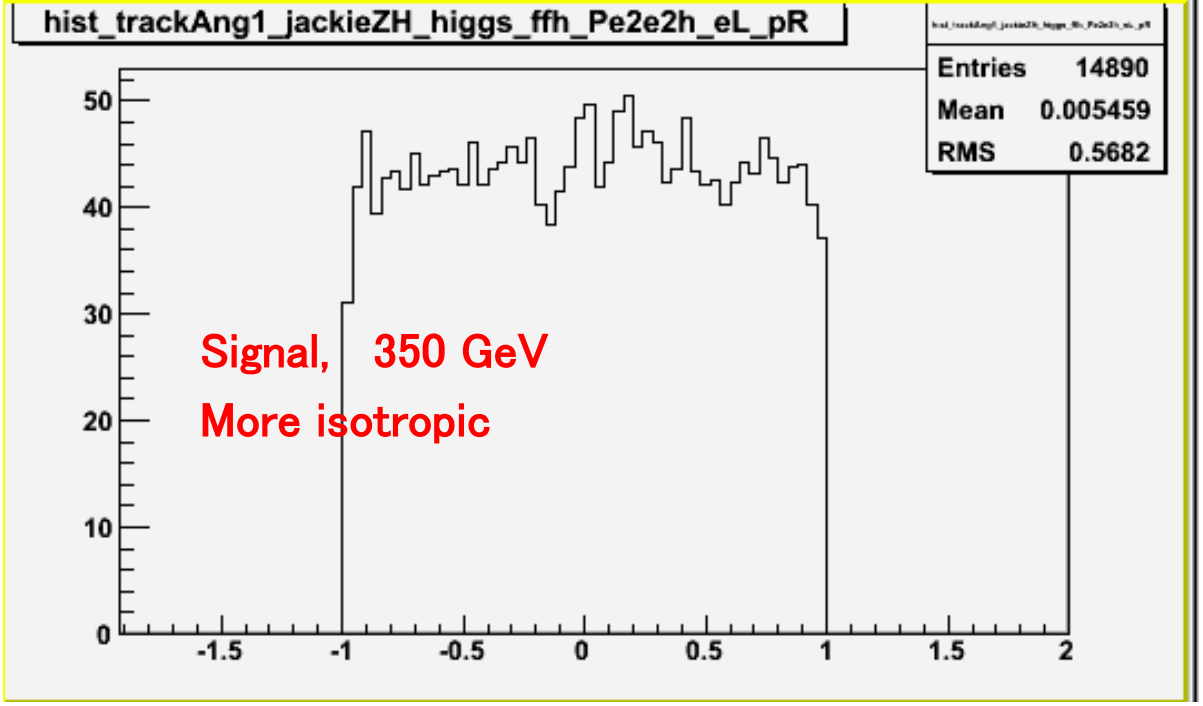
sqrt(s) = 250 GeV



Cos(track angle), 350 GeV

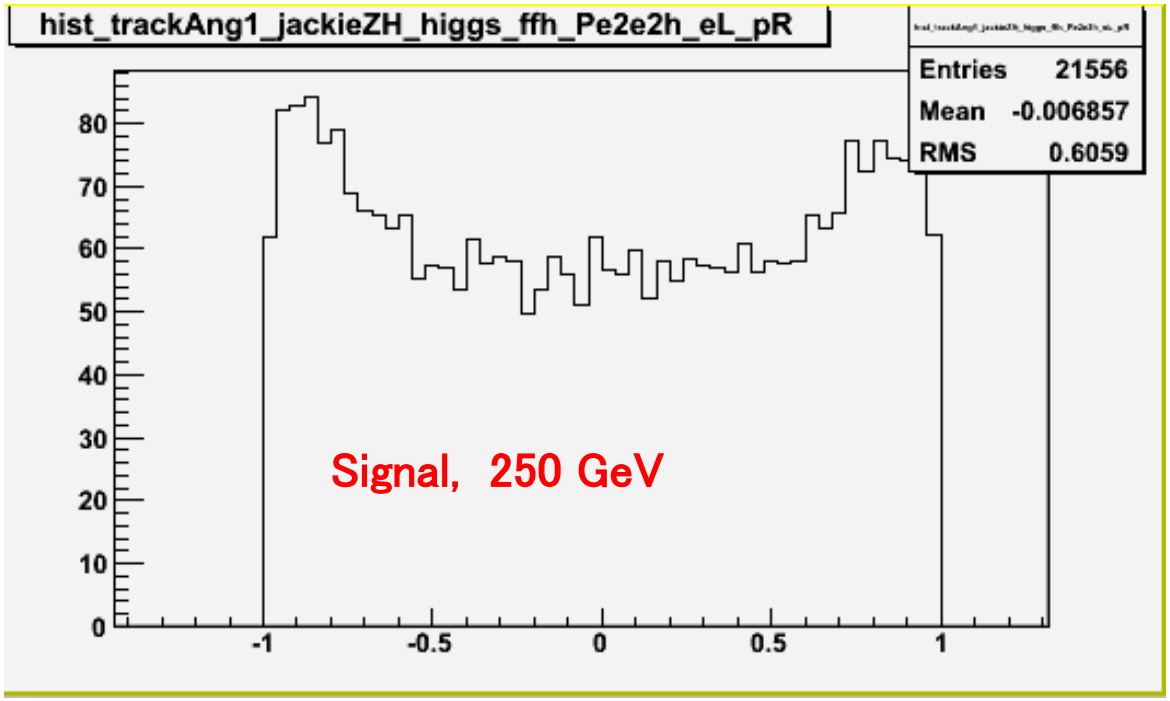
do cut

cos(trackAngle) < 0.98



do cut :

cos(trackAngle) < 0.98



- **preliminary comparison of cut efficiency between MC truth and reconstructed for 350 GeV**

  for now, just observe signal and dominant BGs

Rec

cut	signal	eff	4f_ZZ_sl	eff	2f_Z_l	eff
raw	2288	100%	188087	100.00%	2226361	100.00%
only best mu pair	2214	97%	25217	13.41%	329581	14.80%
cos(trackAng)<0.98	2202	96%	19906	10.58%	305146	13.71%
84 <M_inv <98	1824	80%	5314	2.83%	94671	4.25%
10 <P_Tdl<140	1817	79%	5198	2.76%	26063	1.17%
copl < 3	1790	78%	4853	2.58%	22766	1.02%
cos(θ Z)<0.91	1707	75%	3672	1.95%	10765	0.48%
120 GeV <M_rec <140 GeV	1089	48%	1133	0.60%	1050	0.05%

signal efficiency and BG cut is slightly better for MC (?), but mostly similar

MC

cut	signal	eff	4f_ZZ_sl	eff	2f_Z_l	eff
raw	2288	100%	188087	100.00%	2226361	100.00%
only best mu pair	2288	100%	26219	13.94%	417982	18.77%
cos(trackAng)<0.98	2208	97%	17385	9.24%	306297	13.76%
84 <M_inv <98	1981	87%	5115	2.72%	102691	4.61%
10 <P_Tdl<140	1945	85%	5006	2.66%	24539	1.10%
copl < 3	1945	85%	4691	2.49%	24539	1.10%
cos(θ Z)<0.91	1852	81%	3599	1.91%	11813	0.53%
120 GeV <M_rec <140 GeV	1256	55%	1056	0.56%	986	0.04%

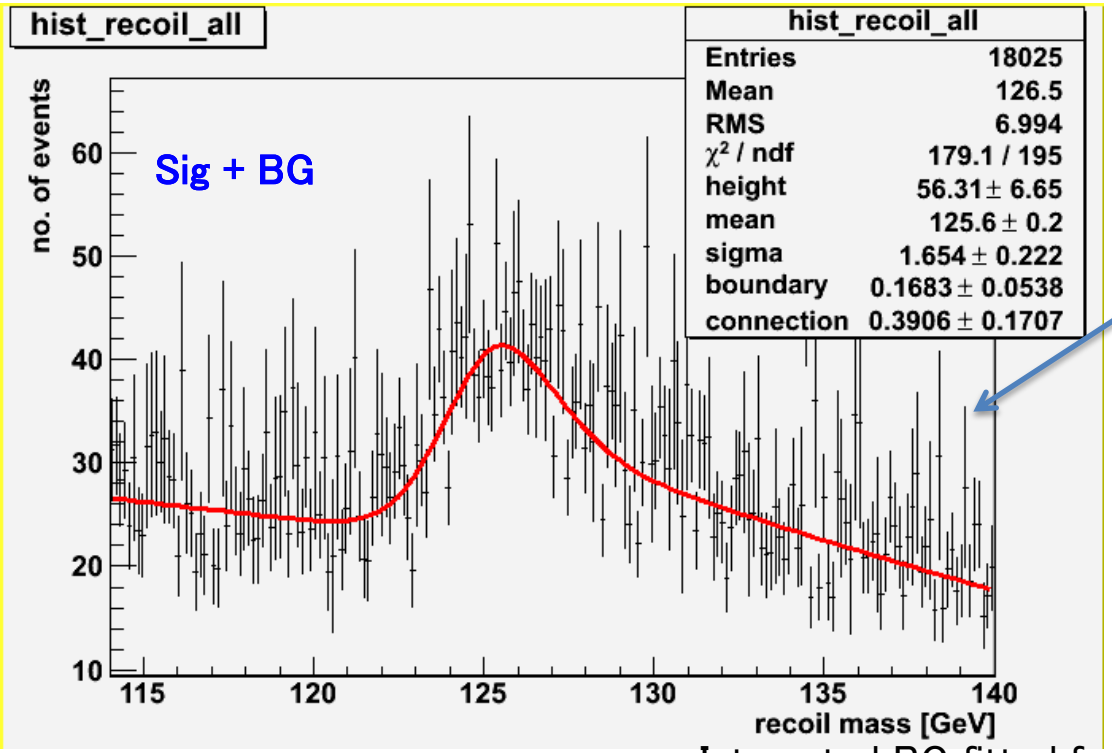
Results for 350 GeV

Tried to fit in wider range

[114- 140 GeV] → Changed to [115 - 150 GeV]

Tried widening recoil mass window

[123- 135 GeV] → Changed to [120 - 140 GeV]



new fitting: using weighted bins

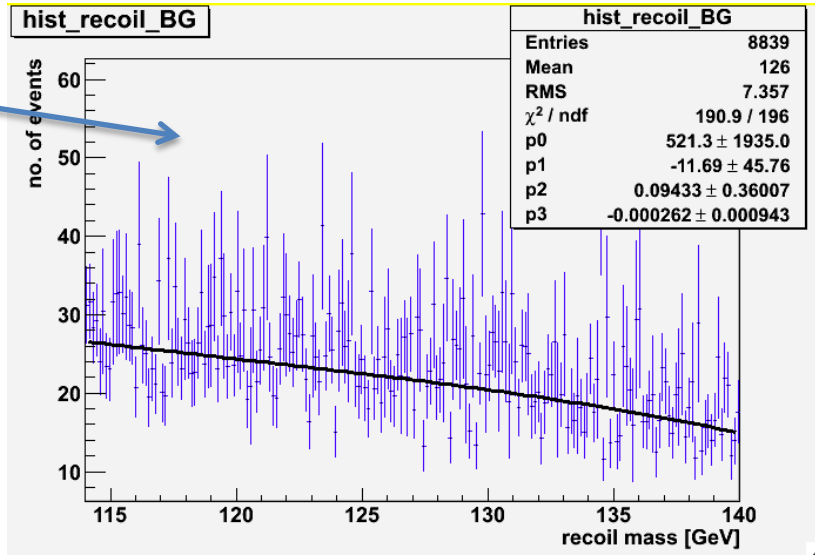
Integrated fitted func in （120 – 140 GeV)

Nsig = 1115

(error is 133 ? = relative error of fitted height ?)

Integrated BG fitted func in （120 – 140 GeV)

- Nbg= 3100
- S/BG = 1115 /3100 = 0.36
- significance = 17.2

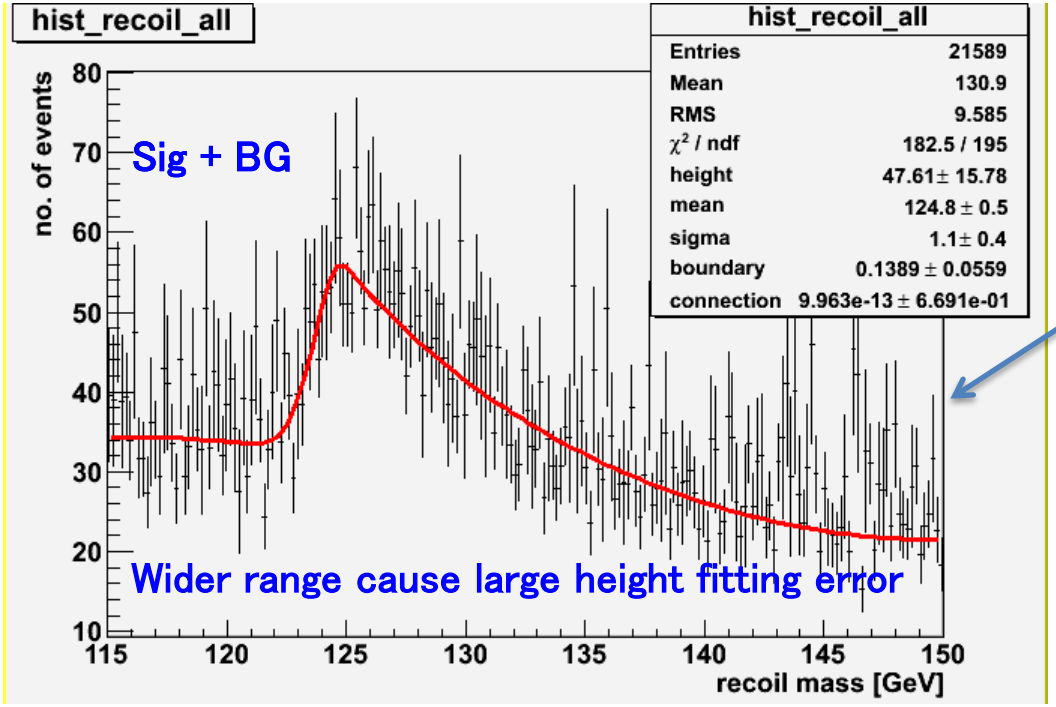


Result from counting under histogram

- <n> = 1125 +/- 24
- **<ε> = 47.4 +/- 0.5 %**
- **<n>/sqrt(<n>+<B>) = 16.0**
- <n>/<B>=0.31

Δσmeas> / <σmeas> = 6.3 %

9.3 % if consider BG uncertainty



new fitting: using weighted bins

Fitting in range **115-150 GeV**

Wider range !!

Integrated fitted func in (120 – 140 GeV)

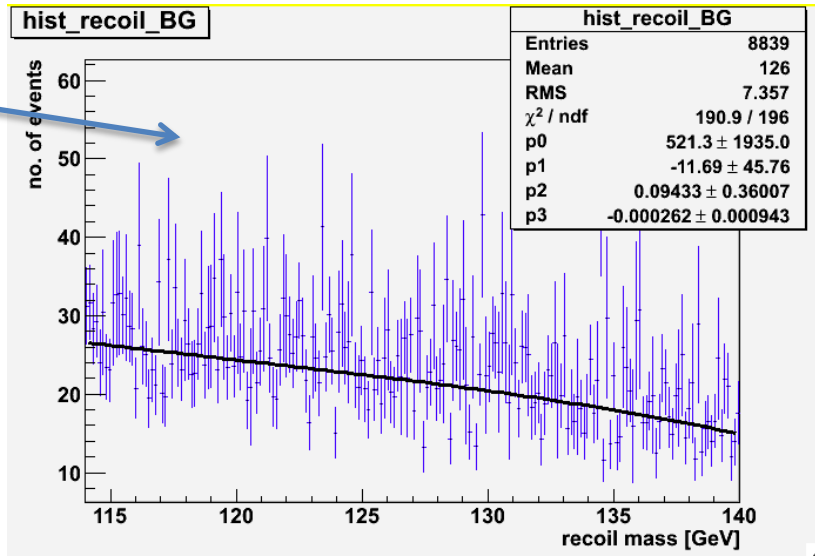
Nsig = 1145

Integrated BG fitted func in (120 – 140 GeV)

Nbg= 3255

S/BG = 1145 /3255 = 0.35

significance = 17.3

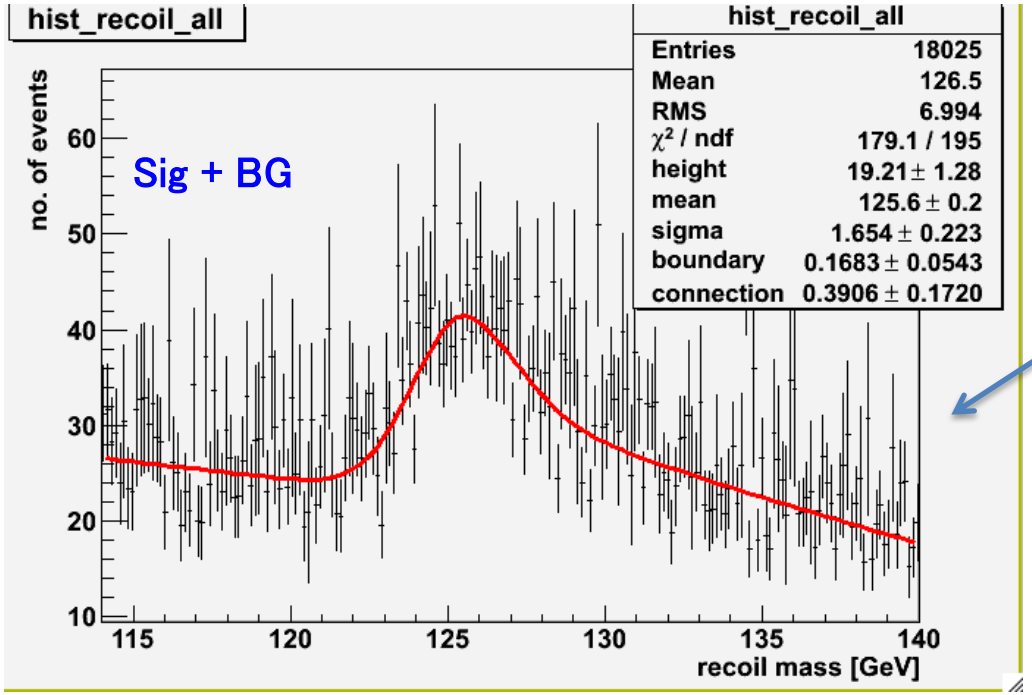


Result from counting under histogram

- <n> = 1125 +/- 24
- **<ε> = 47.4 +/- 0.5 %**
- **<n>/sqrt(<n>+<B>) = 16.0**
- <n>/<B>=0.31

Δσmeas> / <σmeas> = 6.3 %

9.3 % if consider BG uncertainty



new fitting: using weighted bins

Before fixing overall factor of 1/sigma

Integrated fitted func in (120 – 140 GeV)

Nsig = 1115

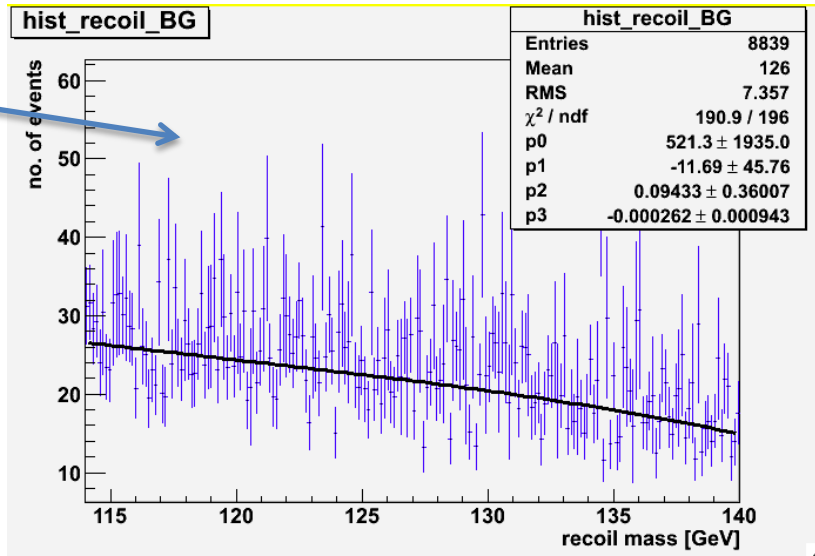
(error is 74 ? 6.7%
= relative error of fitted height ?)

Integrated BG fitted func in (120 – 140 GeV)

Nbg= 3100

•S/BG = 1115 /3100 = 0.36

• significance = 17.2



Result from counting under histogram

- <n> = 1125 +/- 24
- **<ε> = 47.4 +/- 0.5 %**
- **<n>/sqrt(<n>+<B>) = 16.0**
- <n>/<B>=0.31

Δσmeas> / <σmeas> = 6.3 %
9.3 % if consider BG uncertainty

Tried to widen recoil mass cut window

sqrt(s) = 350 GeV L = 333 fb-1

M_recoil: 123 – 135 GeV

<n> = 923 +/- 23

<ε> = 40.4 +/- 0.5 %

<n>/sqrt(<n>+<B>) = 16.6

<n>/<B>=0.42

Δσmeas> / <σmeas> = 6.0 %

8.8 % if consider BG uncertainty

M_recoil: 120 – 140 GeV

<n> = 1125 +/- 24

<ε> = 47.4 +/- 0.5 %

<n>/sqrt(<n>+<B>) = 16.0

<n>/<B>=0.31

Δσmeas> / <σmeas> = 6.3 %

9.3 % if consider BG uncertainty

If I just count inside histogram :

- signal eff iciency is increased by widening recoil mass cut window
- But S/N is worse

S/N and significance is better when I use fitted results

Next : I need to do double loop fitting (leave only mean and height as free parameters)

Data selection : 123 – 135 GeV

Sqrt(s)= 350 GeV

with all 6f BG included, whizard events (no NRQCD correction?)

cut	signal	eff	BG_all	eff	S/B	S/sqrt(S+B)
raw	2288	100%	6242481	100.00%	0.0004	0.92
only best mu pair	2202	96%	689050	11.04%	0.0032	2.65
ΔD0/D0 < 5	2190	96%	610653	9.78%	0.0036	2.80
cos(trackAng)<0.98	2161	94%	543876	8.71%	0.0040	2.92
84 <M_inv <98	1791	78%	115244	1.85%	0.0155	5.24
10 <P_Tdl<140	1786	78%	46855	0.75%	0.0381	8.10
copl < 3	1759	77%	41849	0.67%	0.042	8.42
cos(θZ)<0.91	1677	73%	25623	0.41%	0.065	10.15
123 GeV <M_rec <135GeV	924	40%	2188	0.04%	0.422	16.57

Signal efficiency 40 %

S/N → 0.42

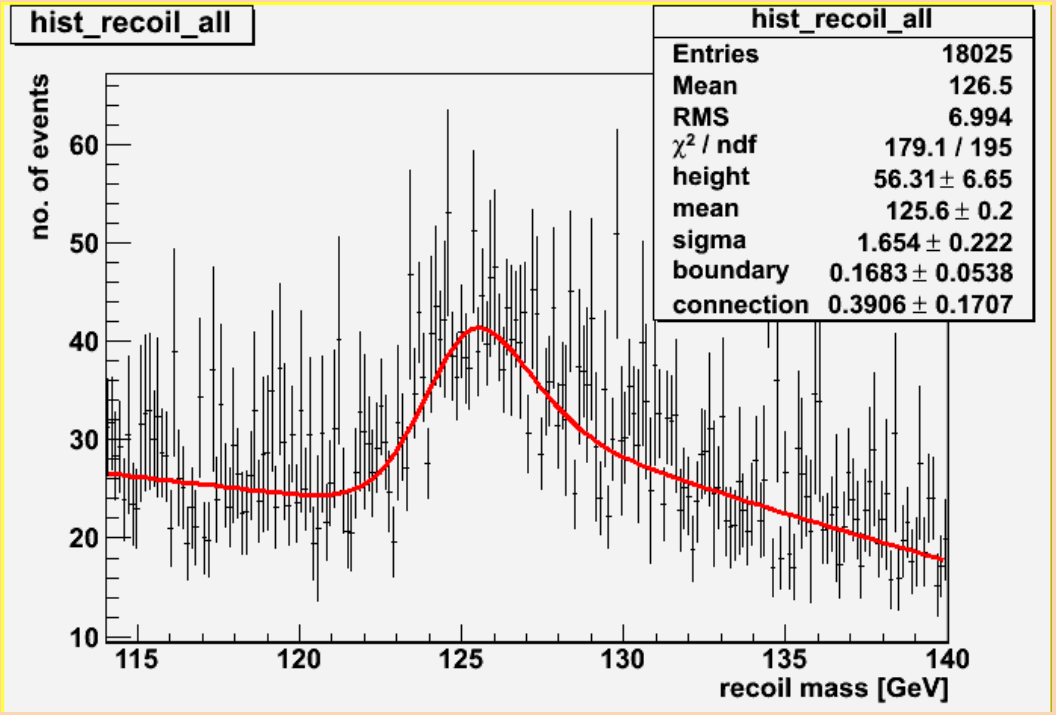
Significance ~16.6

cut	4f_ZZ_l	4f_ZZ_sl	2f_Z_l	4f_WW_l	4f_WW_sl	4fSingleZe_l	4fSingleZnn_l	4f_ZZWWMix_l	6f
raw	19632	188087	2226358	226193	2715937	243879	43056	541352	37989
only best mu pair	4231	20482	349026	25340	145897	37121	8924	94303	3726
ΔD0/D0 < 5	3969	17431	330450	10706	112044	36560	8760	88832	1901
cos(trackAng)<0.98	3574	15647	296010	9227	101276	24582	7880	83874	1806
84 <M_inv <98	1512	4950	93061	912	4469	1367	3042	5769	162
10 <P_Tdl<140	1293	4836	25448	901	4456	1280	2967	5518	156
copl < 3	1200	4520	22234	808	3842	1174	2736	5191	144
cos(θZ)<0.91	855	3450	10501	644	2613	809	2299	4319	133
123 GeV <M_rec <135GeV	149	704	634	18	300	58	108	216	0

BACKUP

recoil mass

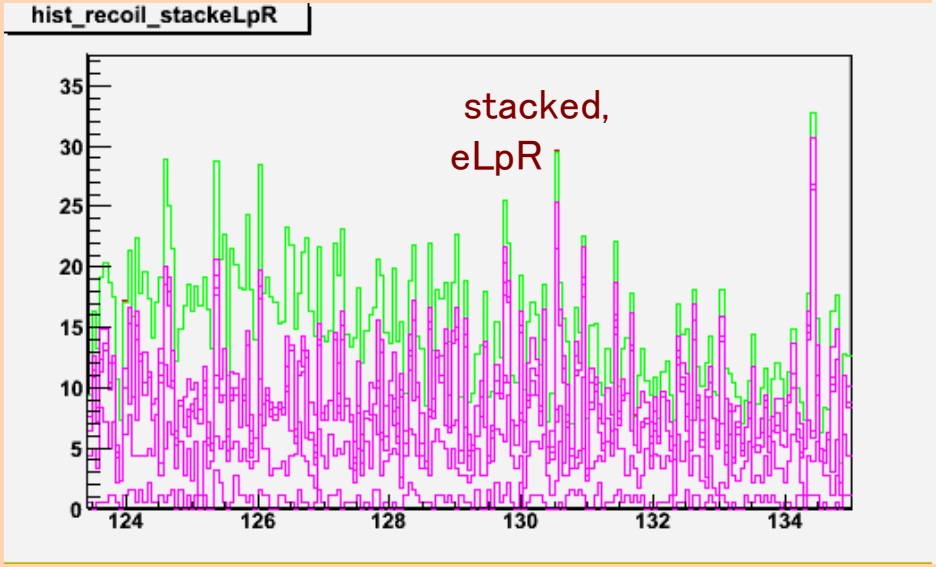
after implementing all cuts

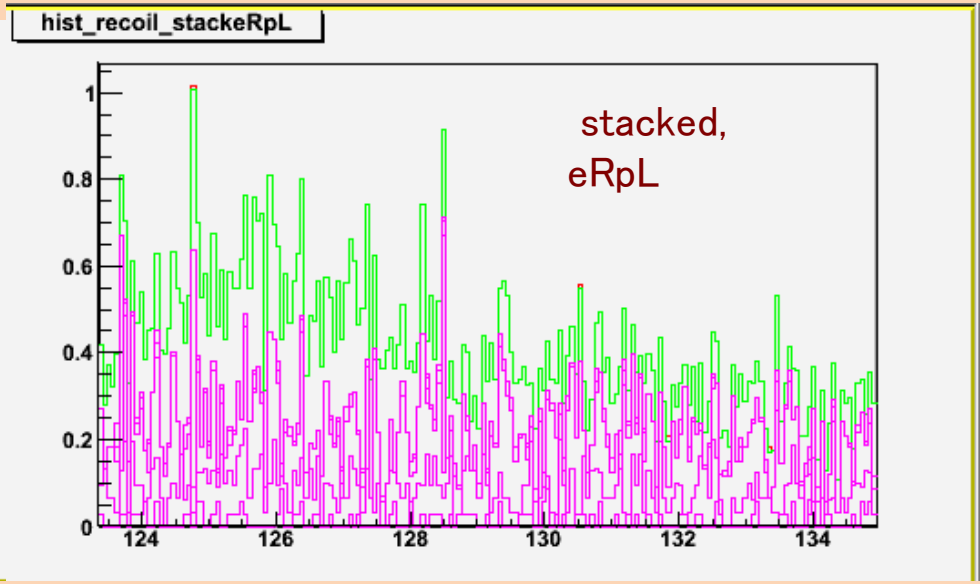


fitted **recoil mass** :

Mh =125.6 +/− 0.3 GeV

calculate recoil mass with correction for 14 mrad beam crossing angle





Results for 250 GeV

efficiency problem resolved

Muon Selection

- reject neutrals
- Ptot > 5 GeV
- small E_cluster / P_total < 0.5
- opposite charge

Wider cut window

- **Best track selection**
  - cos(track angle) < 0.98
  - |D0/δD0| < 5

Best Z Candidate Selection

2 mu candidates with **opposite charge**

if several possibilities :

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

Final Selection for 250 GeV

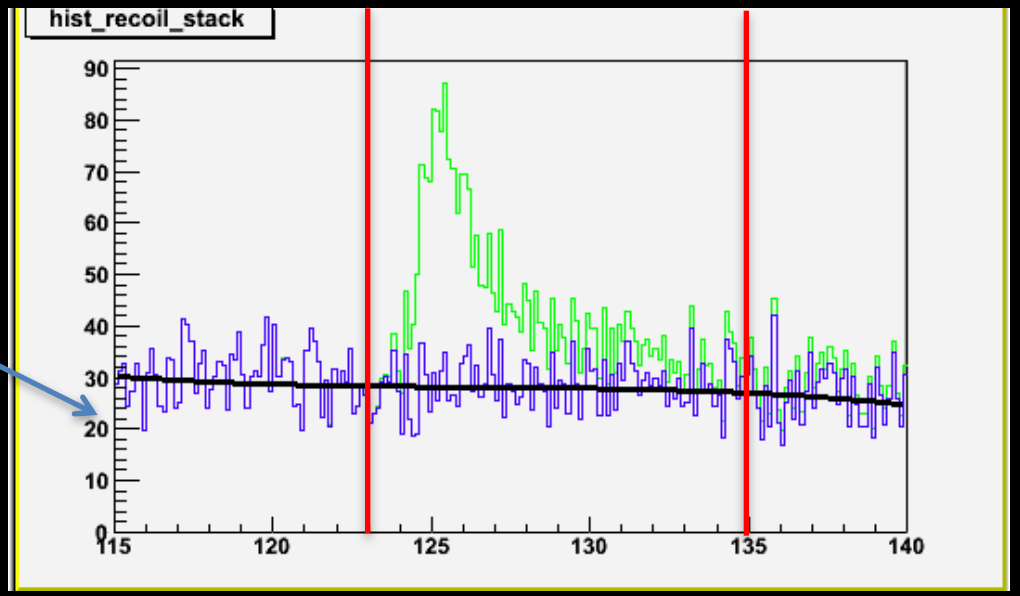
analysis after filling root files

- **84 GeV < M_mumu < 98 GeV**
- 10 GeV < pT_mumu < 70 GeV
- |cos(θ_Zpro)| < 0.91 (Z production angle)
- **123 GeV < Mrecoil < 135 GeV**

Moved to last

Evaluate data selection efficiency in within range of 123 – 135 GeV

calculate recoil mass with correction for 14 mrad beam crossing angle



This Week ‘s updated results : 250 GeV

Calculation of Error of σmeas

- Case#1: ignore uncertainty of <B> i.e. MC statistics
- Case#2: taking into account uncertainty of ε and <B> *is this necessary ?*

Usual signal samples (1000 fb−1)

<n> = 1598 +/- 25

<ε> = 61.4 +/- 0.4 %

<n>/sqrt(<n>+<B>) = 21.2
<n>/<B>=0.39

If Case#1
Δσmeas> / <σmeas> = 4.7 %

If Case#2
Δσmeas> / <σmeas> = 6.4%

NEW: Sqrt(s)= 250 GeV

After fixing efficiency problem

I had been counting eberything only in 123 – 135 GeV region sorry !!!

cut	signal	eff	BG_all	eff	S/B	S/sqrt(S+B)
raw	2605	100%	6923287	100.00%	0.0004	0.99
only best mu pair	2519	97%	1767237	25.53%	0.0014	1.89
ΔD0/D0 < 5	2504	96%	1683552	24.32%	0.0015	1.93
cos(trackAng)<0.98	2446	94%	1571532	22.70%	0.0016	1.95
84 <M_inv <98	2110	81%	506279	7.31%	0.0042	2.96
10 <P_Tdl<70	2073	80%	113512	1.64%	0.0183	6.10
cos(θZ)<0.91	1945	75%	50111	0.72%	0.004	0.99
123 GeV <M_rec <135Ge	1598	61%	4108	0.06%	0.389	21.15

Signal efficiency 61 %

S/N → 0.39

Significance ~21.2

cut	4f_ZZ_l	4f_ZZ_sl	2f_Z_l	4f_WW_l	4f_WW_sl	4fSingleZee	4fSingleZn	4f_ZZWWMix_l
raw	23972	214232	3248465	228894	2771978	167469	28534	239742
only best mu pair	12235	48144	1394970	33608	125335	29953	7262	115732
ΔD0/D0 < 5	11997	45974	1365080	14489	96125	29554	7150	113183
cos(trackAng)<0.98	11104	42140	1279342	13403	90499	20132	6488	108423
84 <M_inv <98	5673	19101	465555	1605	1299	1942	2539	8566
10 <P_Tdl<70	3363	13273	84497	1438	1143	1438	1934	6426
cos(θZ)<0.91	2067	9652	28439	1231	951	862	1521	5388
123 GeV <M_rec <135Ge	178	749	1584	264	157	92	209	875

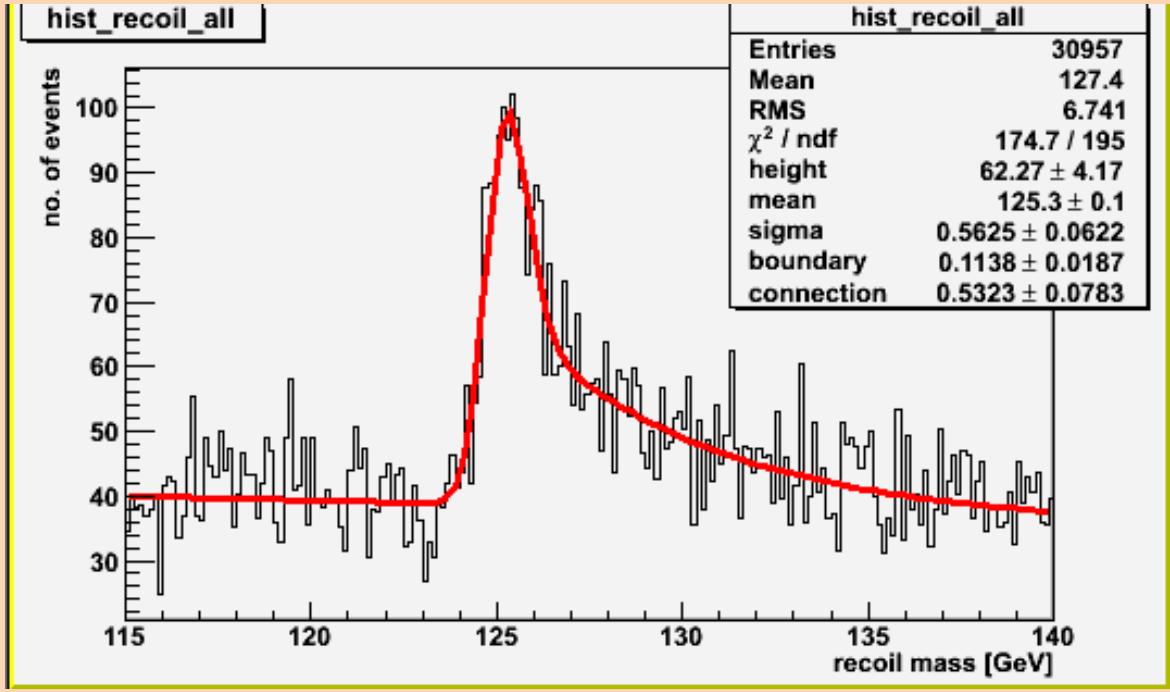
recoil mass

after implementing all cuts

fitted **recoil mass** :

Mh =125.3 GeV +/− 70 MeV

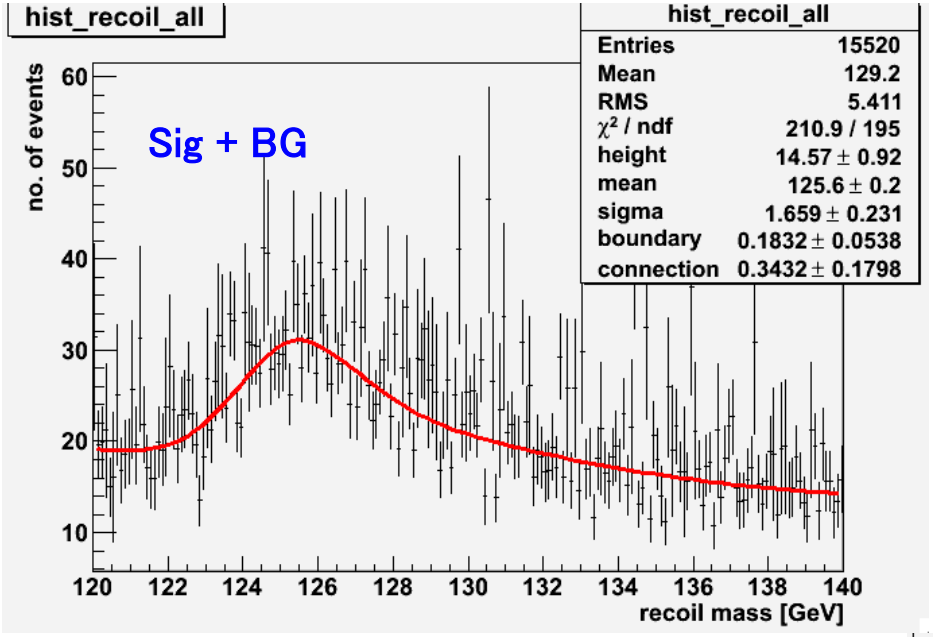
calculate recoil mass with correction for 14 mrad beam crossing angle



- **BG: 3rd order polynomial**
- **signal : GPET:** 5 parameters : Gaus (left−side) , Gaus + expo (right side)

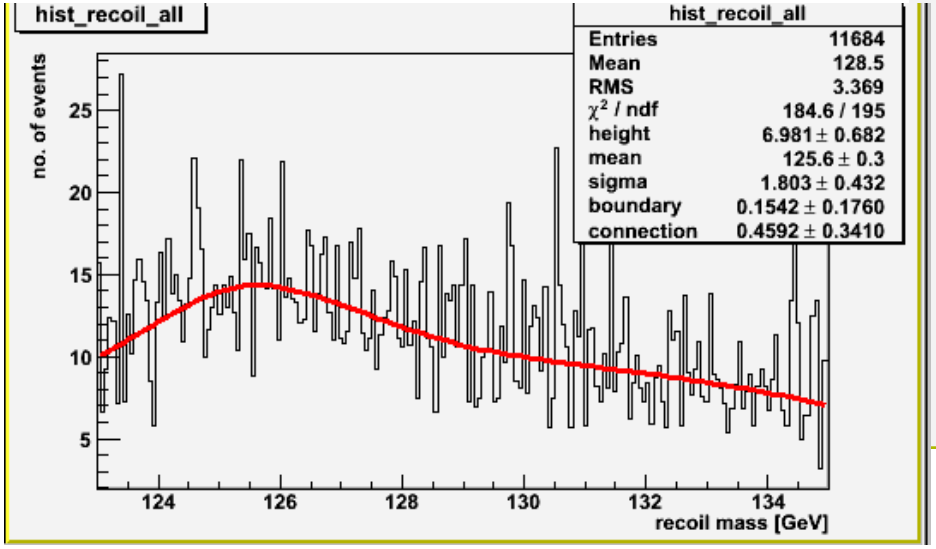
$$N\exp\left[-\frac{1}{2}\left(\frac{x-x_{mean}}{s}\right)^2\right] \quad \left(\frac{x-x_{mean}}{s}\right) \le k$$

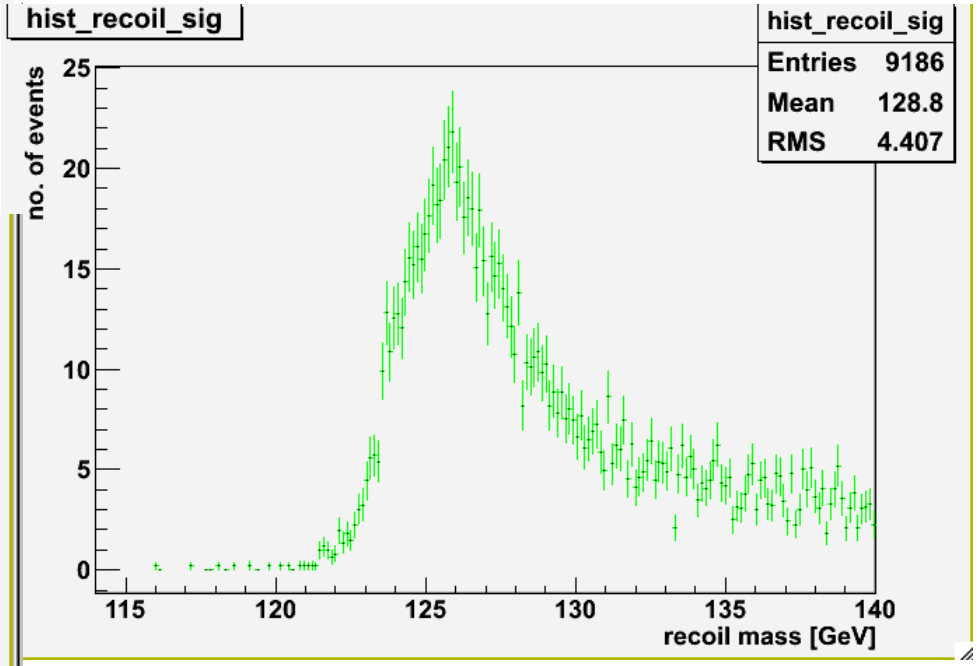
$$N\left[b\times\exp\left[-\frac{1}{2}\left(\frac{x-x_{mean}}{s}\right)^2\right]+(1-b)\exp\left[-k\left(\frac{x-x_{mean}}{s}\right)\right]\exp\left(k^2/2\right)\right] \quad \left(\frac{x-x_{mean}}{s}\right) > k$$



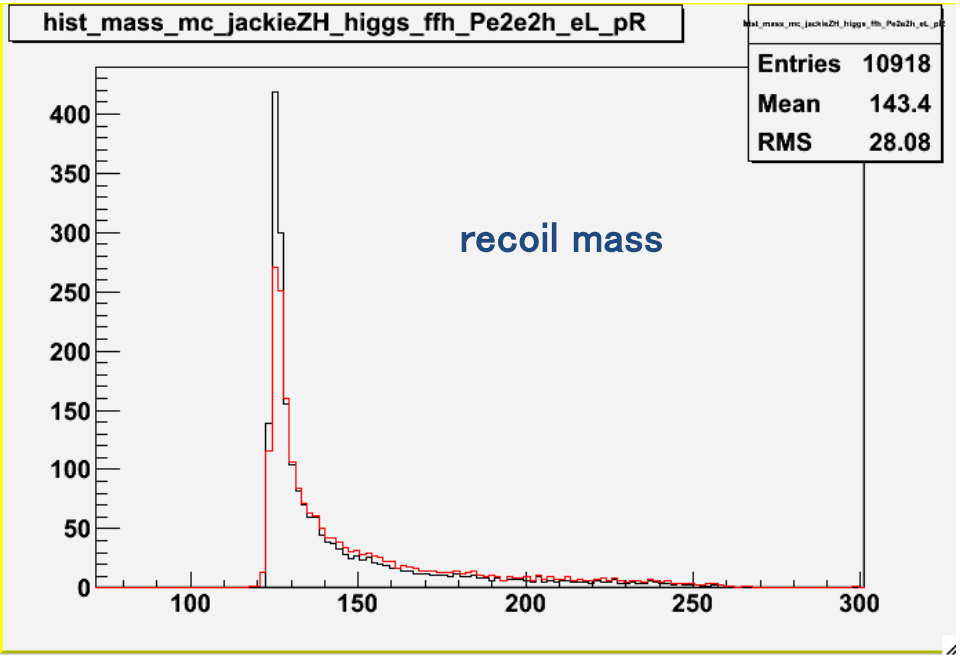
new fitting: using weighted bins

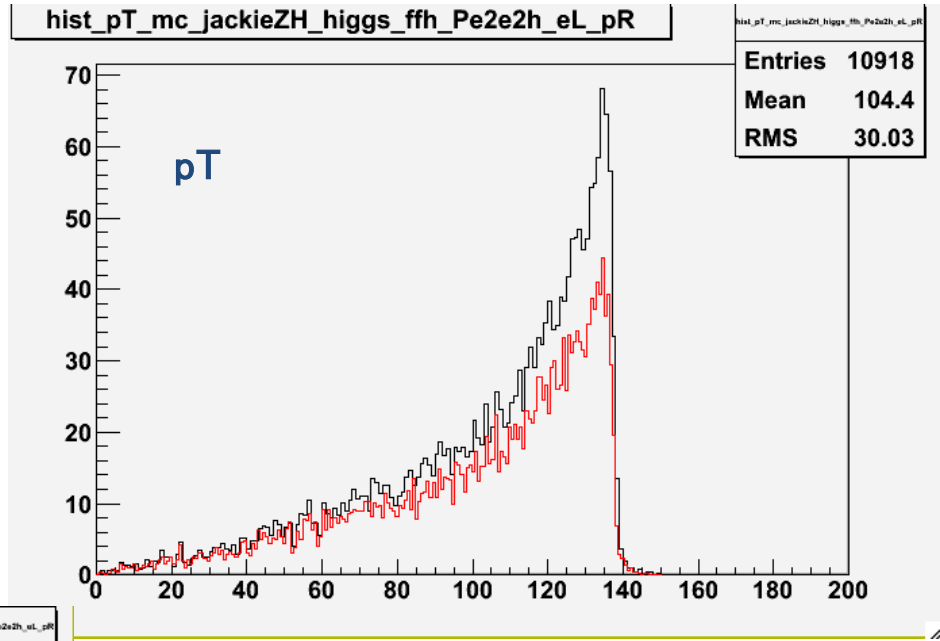
Only fit in region (120 – 140 GeV)

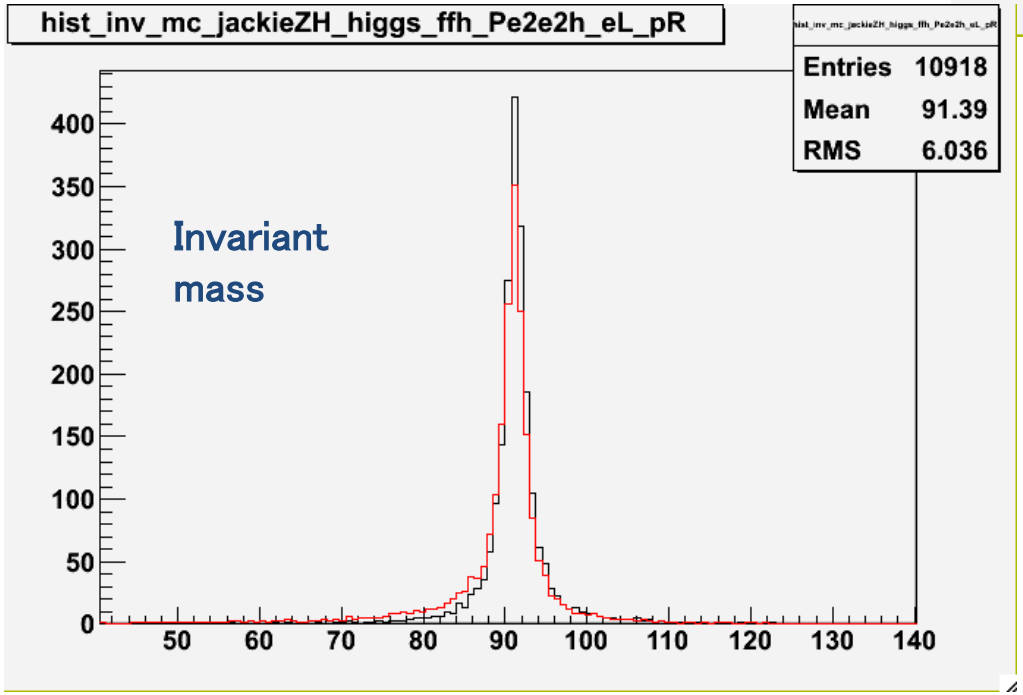




after implementing all cuts

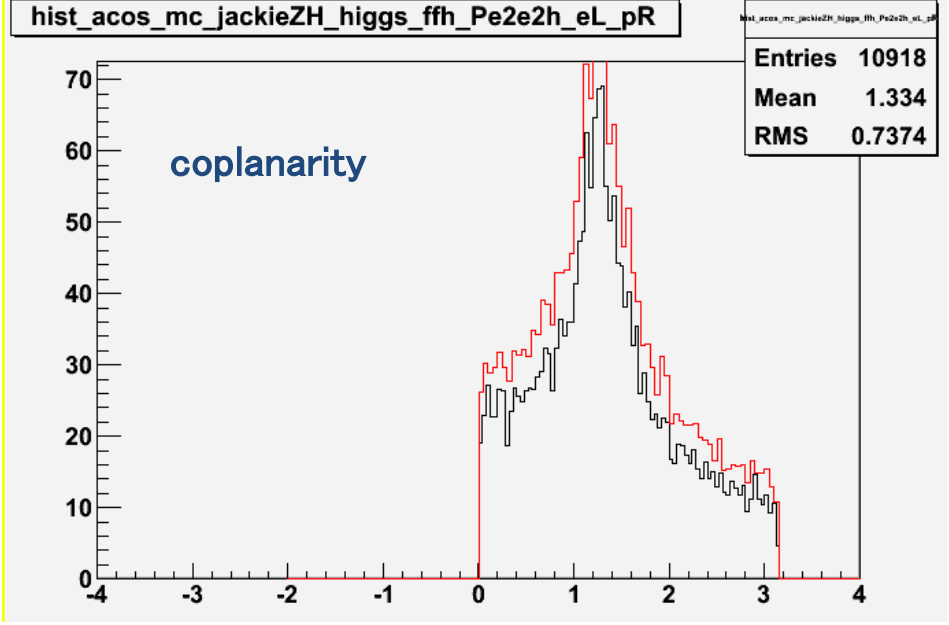


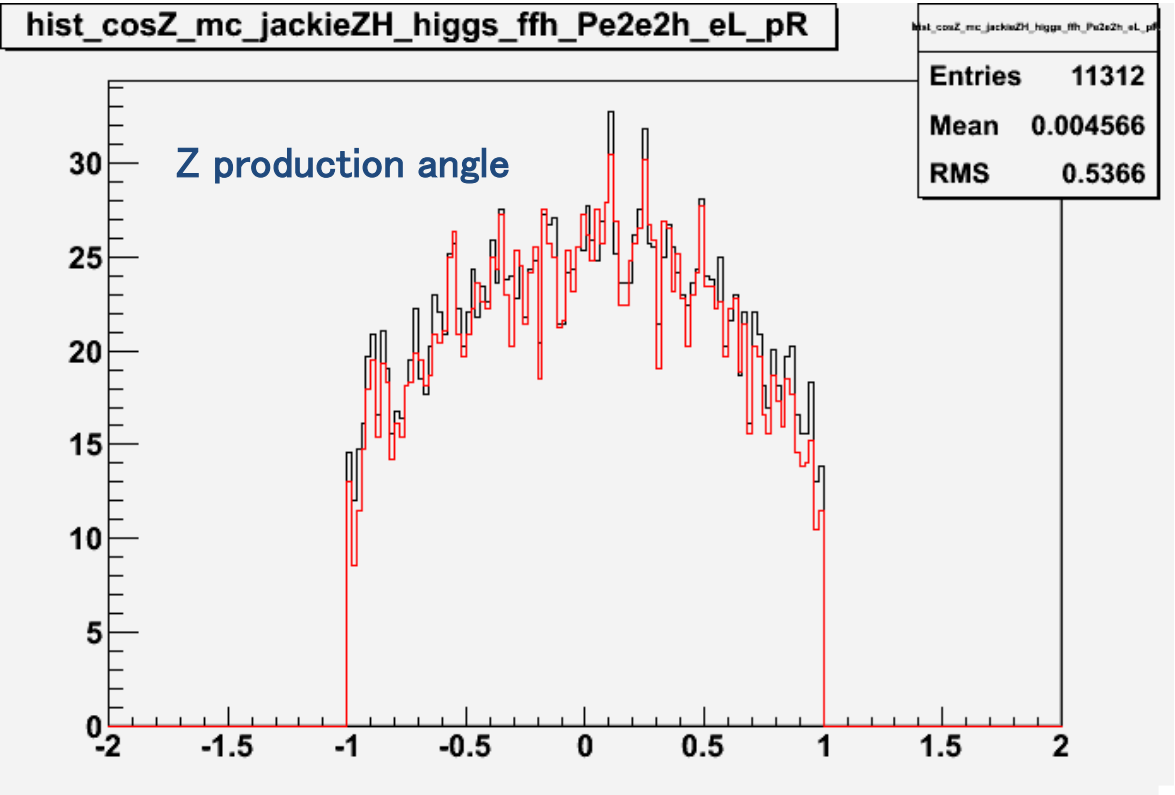




Black : MC

Red: reconstructed





Black : MC

Red: reconstructed

(-0.8, + 0.3)

<ε> = 40.4 +/- 0.5 %

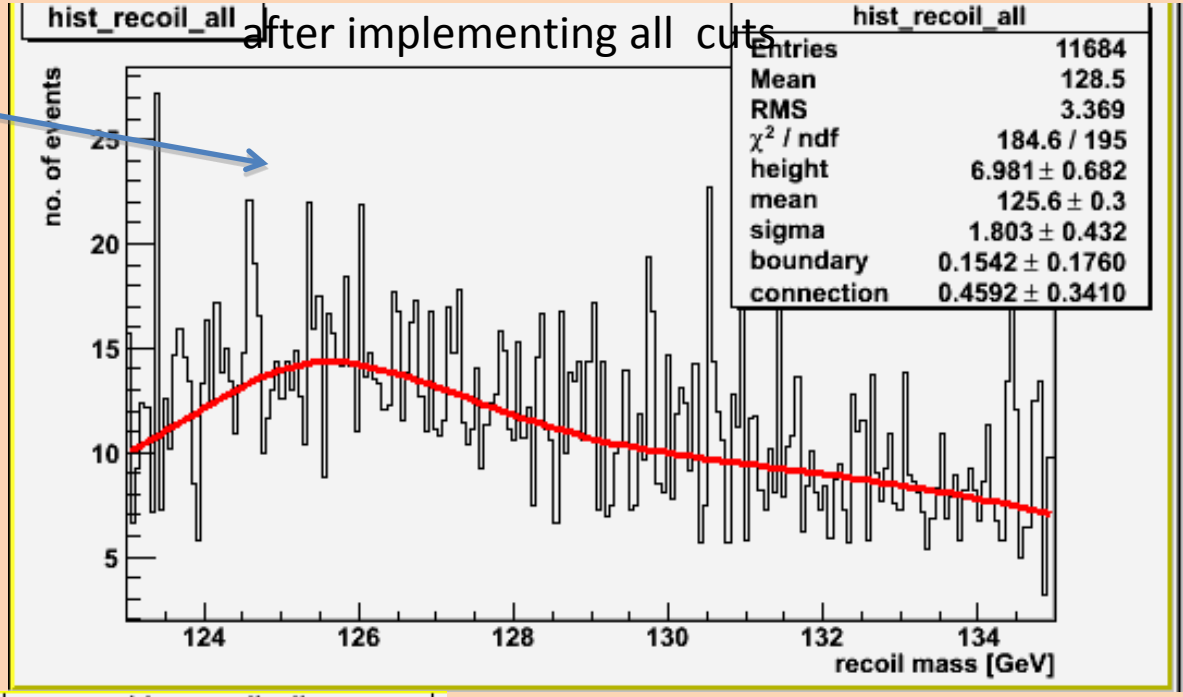
<n>/sqrt(<n>+<B>) = 16.6

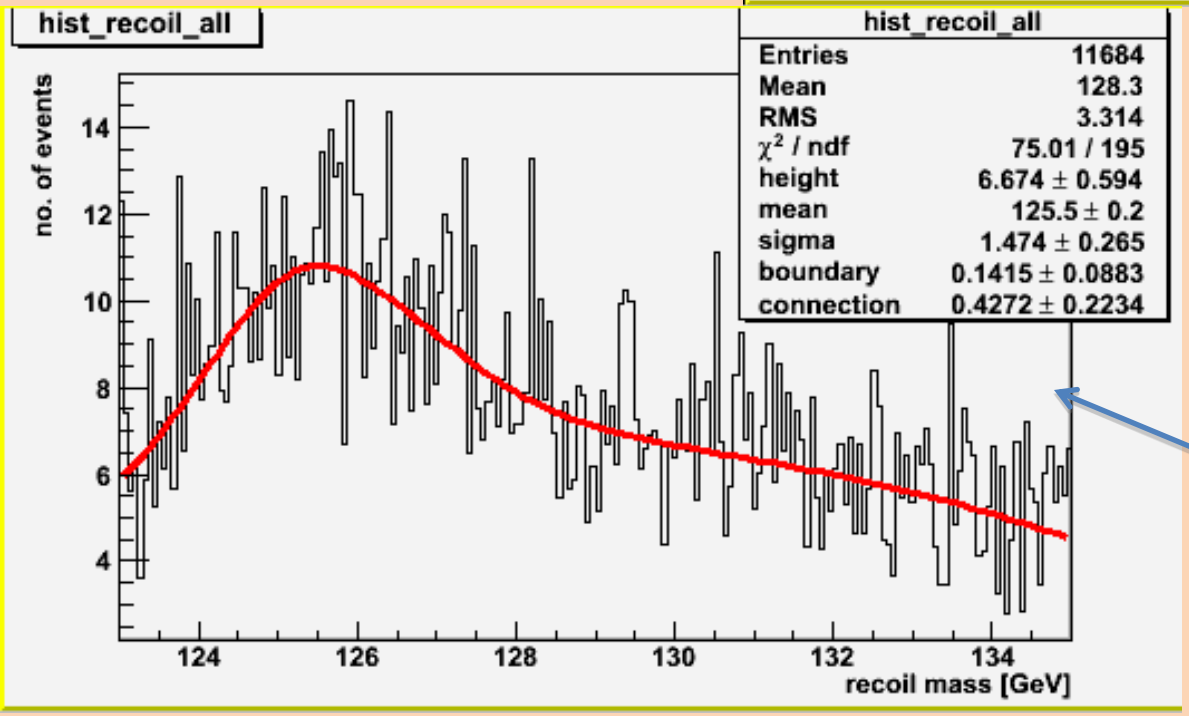
<n>/<B>=0.42

fitted recoil mass :

Mh =125.6 +/− 0.3 GeV

after implementing all cuts





(+0.8, - 0.3)

<ε> = 40.4 +/- 0.5 %

<n>/sqrt(<n>+<B>) = 15.8

<n>/<B>=0.68

fitted recoil mass :

Mh =125.6 +/− 0.2 GeV

Compare different polarization scenarios

sqrt(s) = 350 GeV L = 333 fb-1

For now, keep same cut parameters as (-0.8, +0.3)
(they could be optimized)

(-0.8, + 0.3)

Pol weight(eLpR) = 0.9*0.65
Pol weight(eRpL) = 0.1*0.35

<n> = 923 +/- 23
<ε> = 40.4 +/- 0.5 %
<n>/sqrt(<n>+<B>) = 16.6
<n>/<B>=0.42

Δσmeas> / <σmeas> = 6.0 %
8.8 % if consider BG uncertainty

(+0.8, -0.3)

Pol weight(eLpR) = 0.1*0.35
Pol weight(eRpL) = 0.9*0.65

<n> = 625 +/- 19
<ε> = 40.4 +/- 0.5 %
<n>/sqrt(<n>+<B>) = 15.9
<n>/<B>=0.68

Δσmeas> / <σmeas> = 6.4 %
7.6 % if consider BG uncertainty

(-0.8, 0)

Pol weight(eLpR) = 0.9*0.5
Pol weight(eRpL) = 0.1*0.5

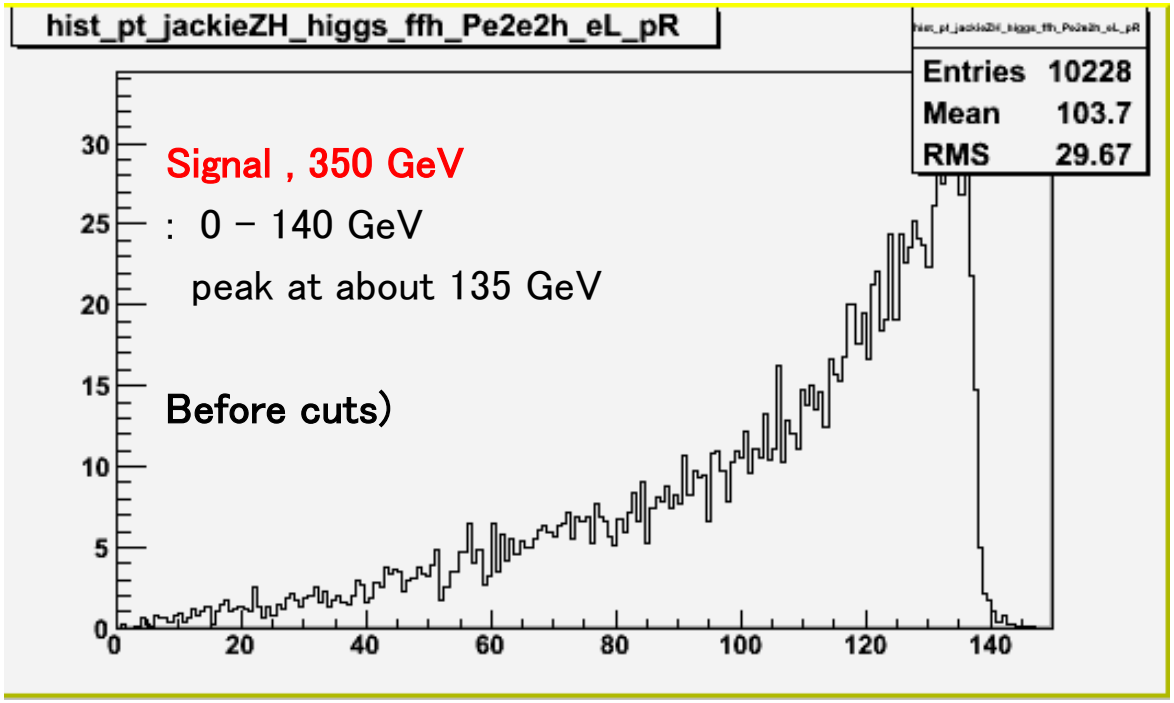
<n> = 733 +/- 21
<ε> = 40.4 +/- 0.5 %
<n>/sqrt(<n>+<B>) = 14.8
<n>/<B>=0.43

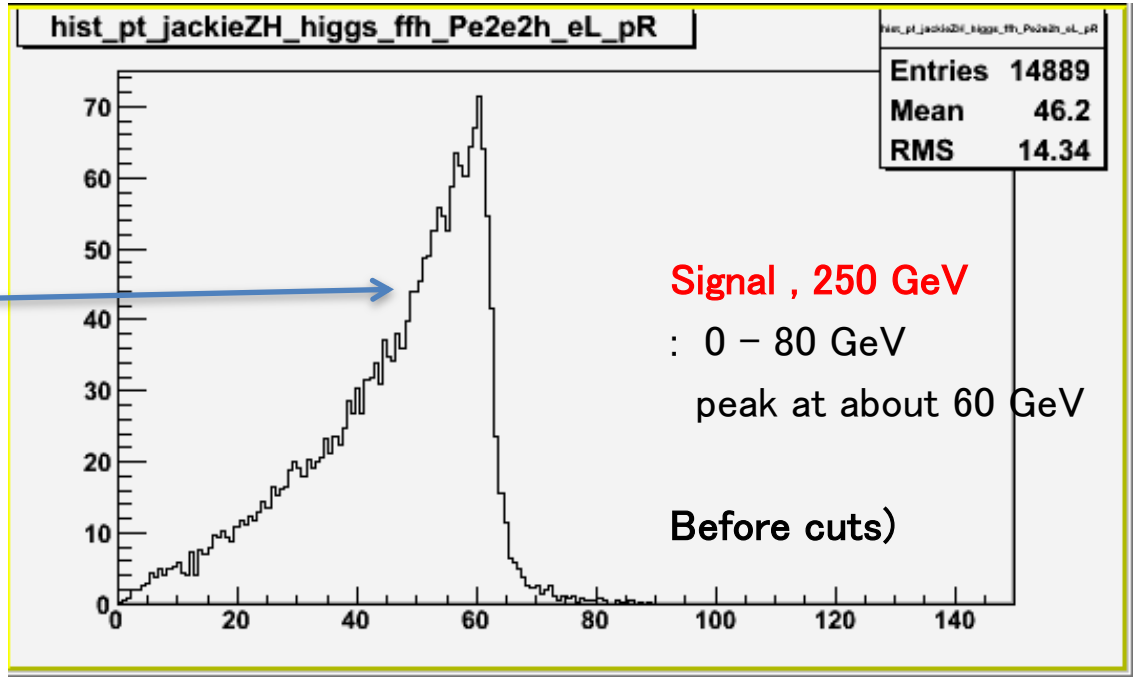
Δσmeas> / <σmeas> = 6.8 %
9.2% if consider BG uncertainty

dilepton PT, 350 GeV

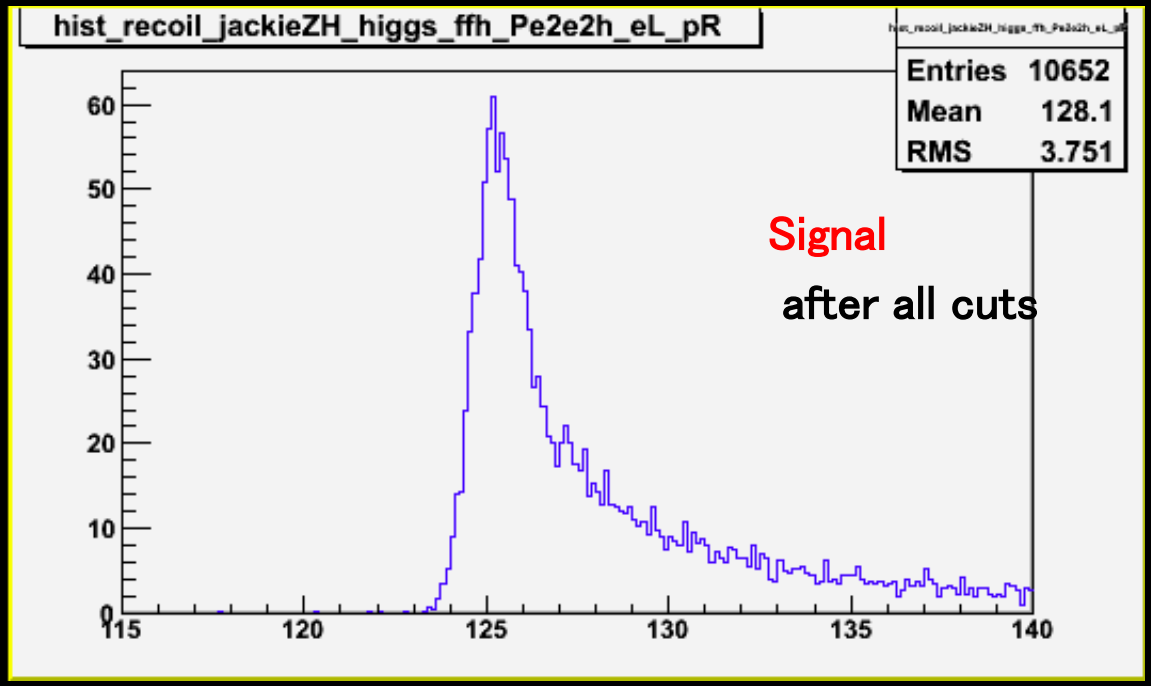
do cut :

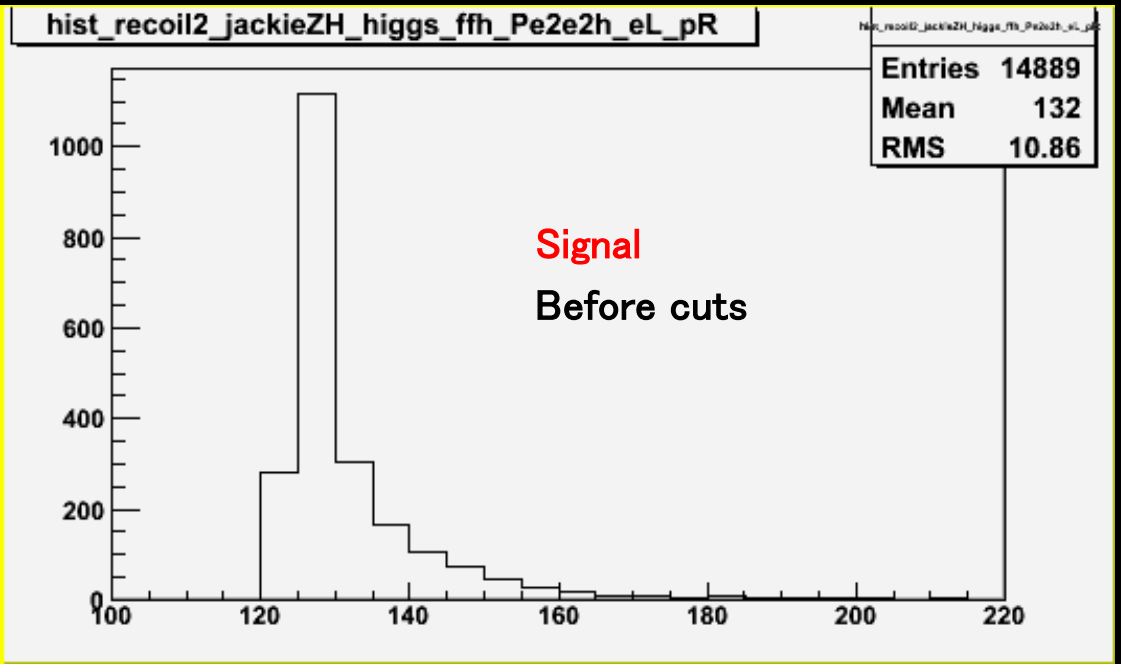
10 GeV< pT_dl < 140 GeV





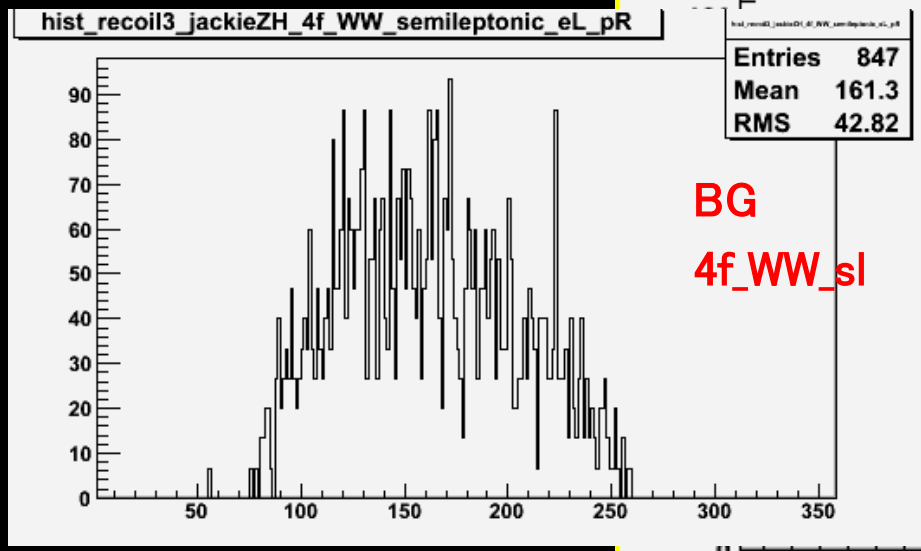
recoil mass of signal, 250 GeV

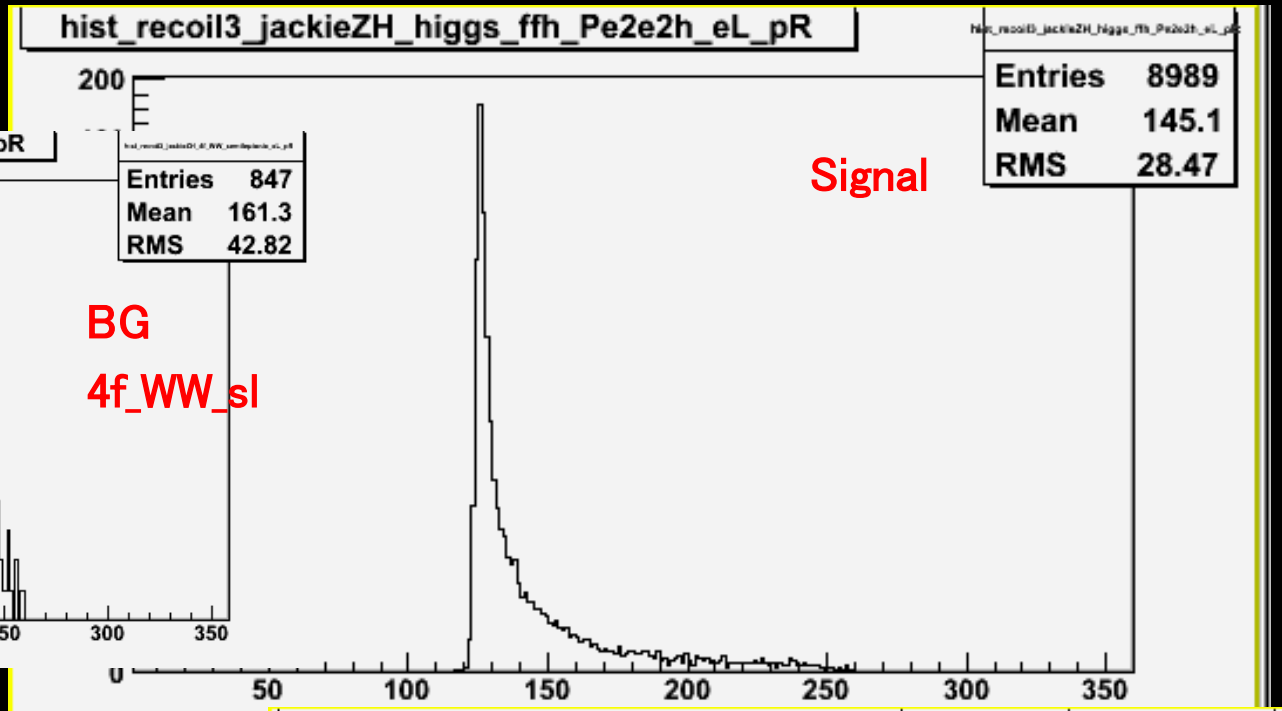


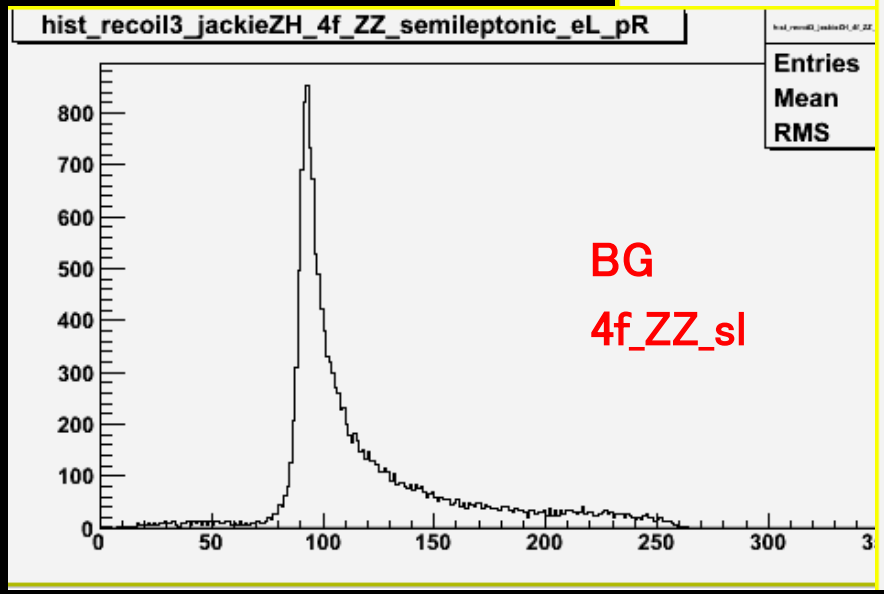


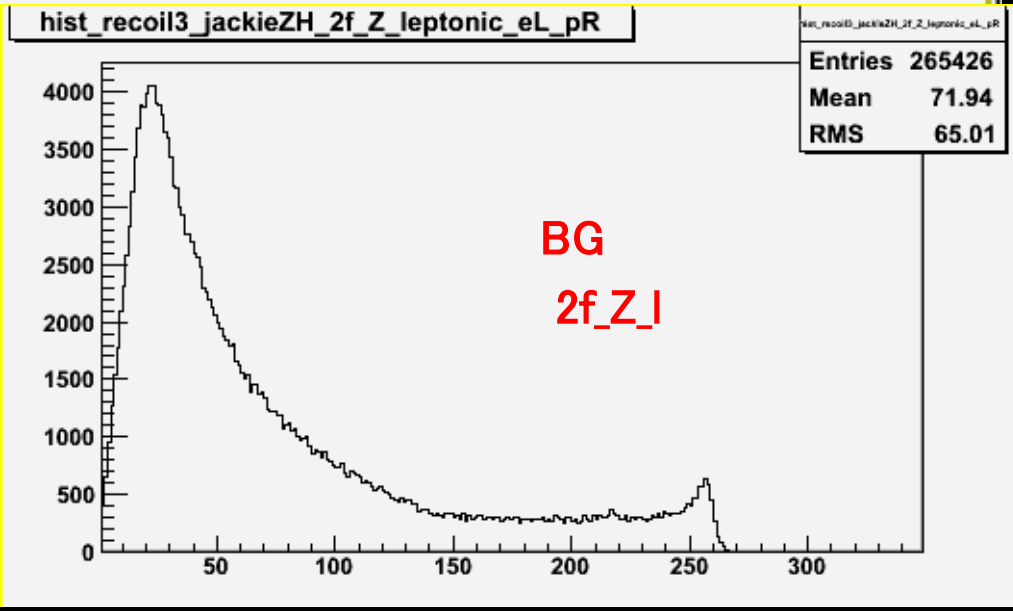
recoil mass 350 GeV

After inv mass cut



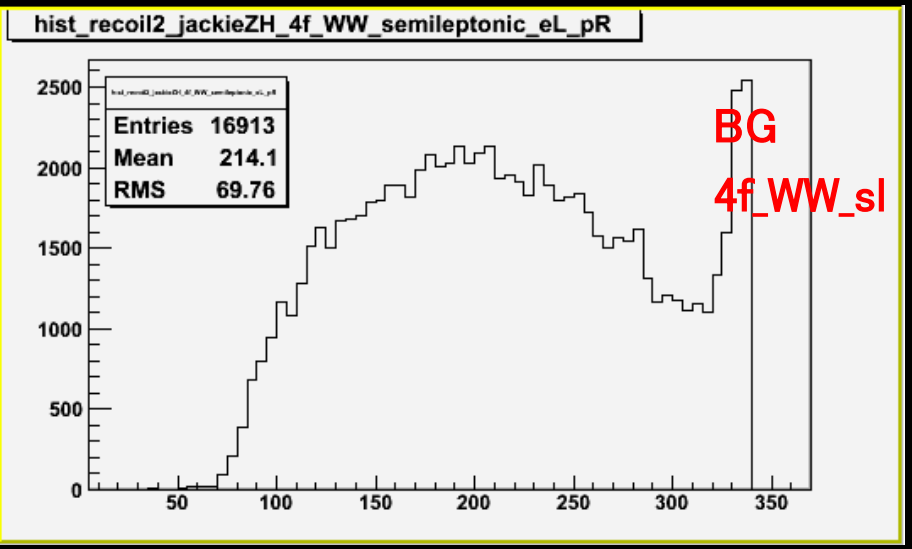


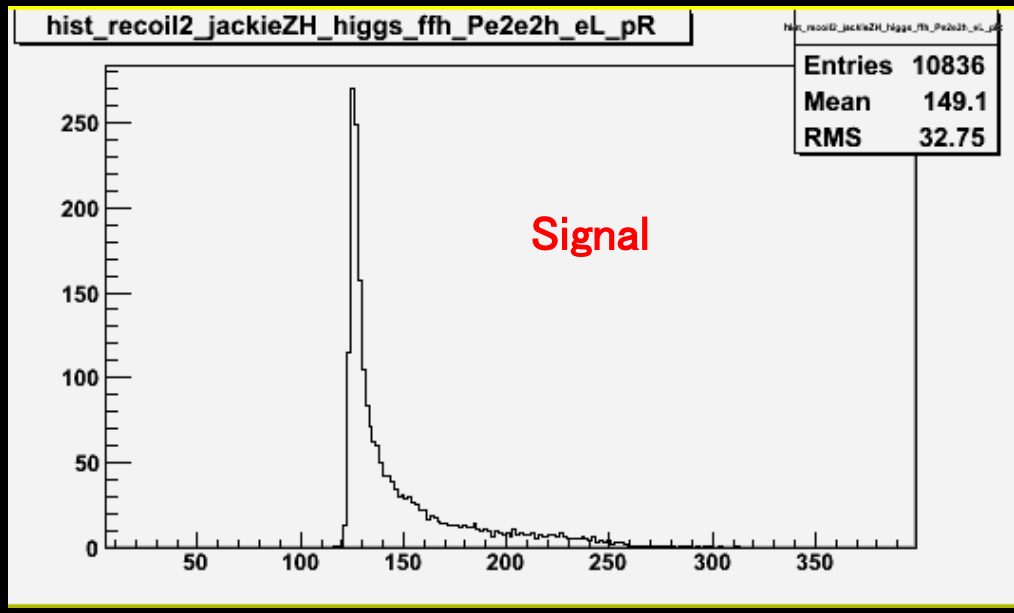


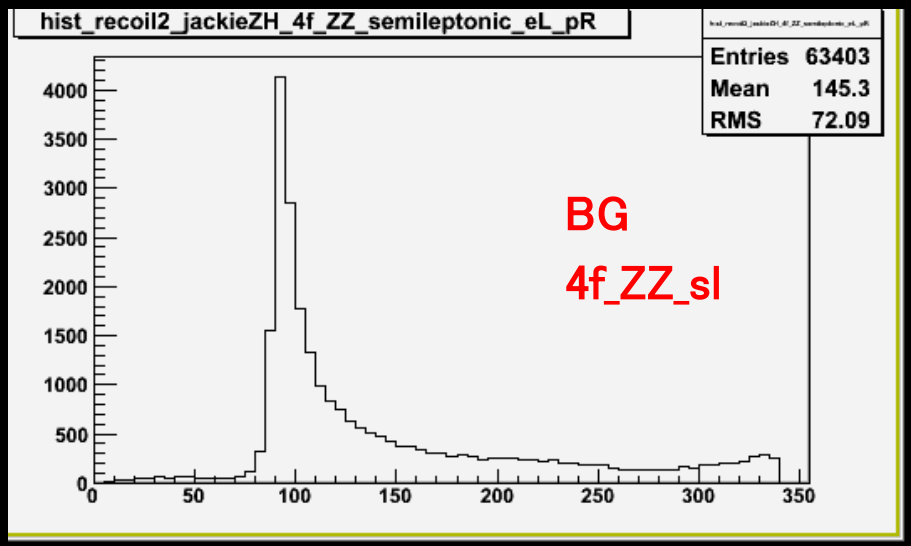


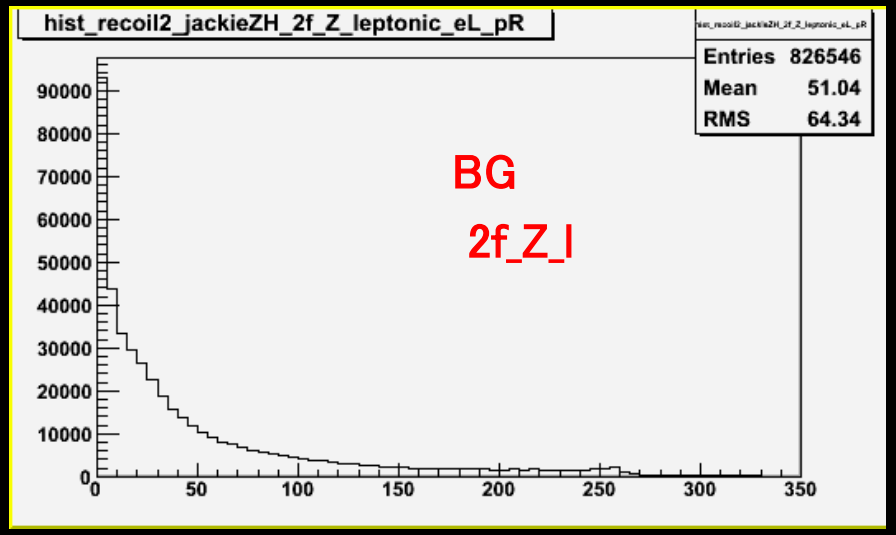
recoil mass 350 GeV

Before cut





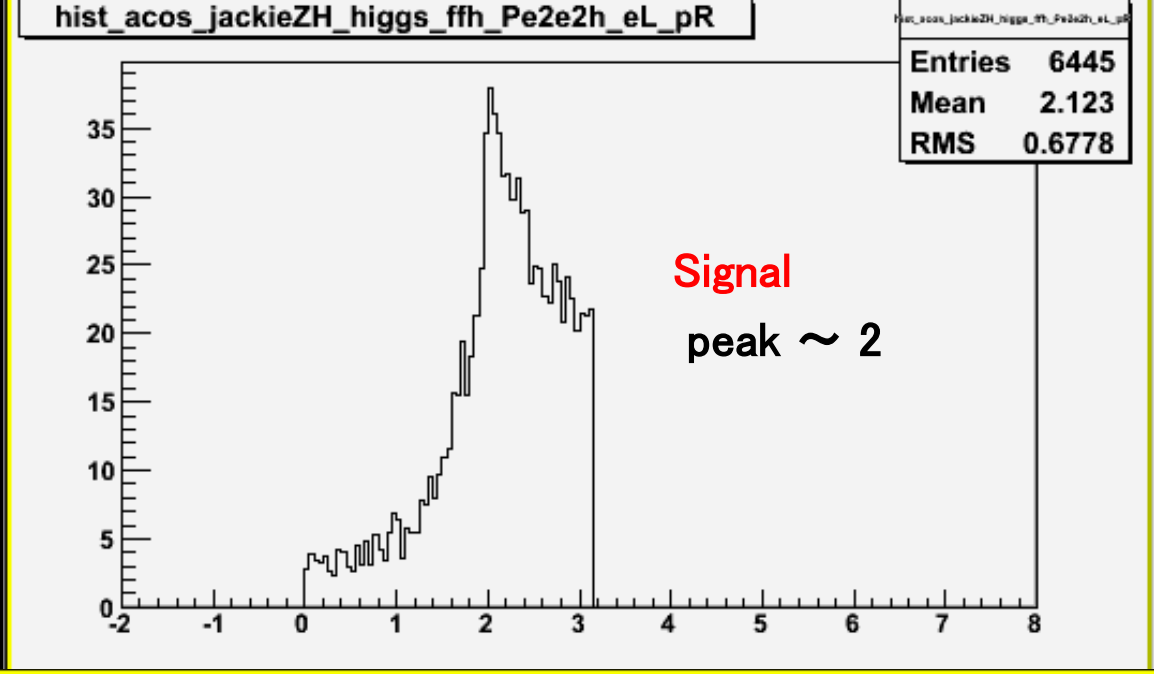


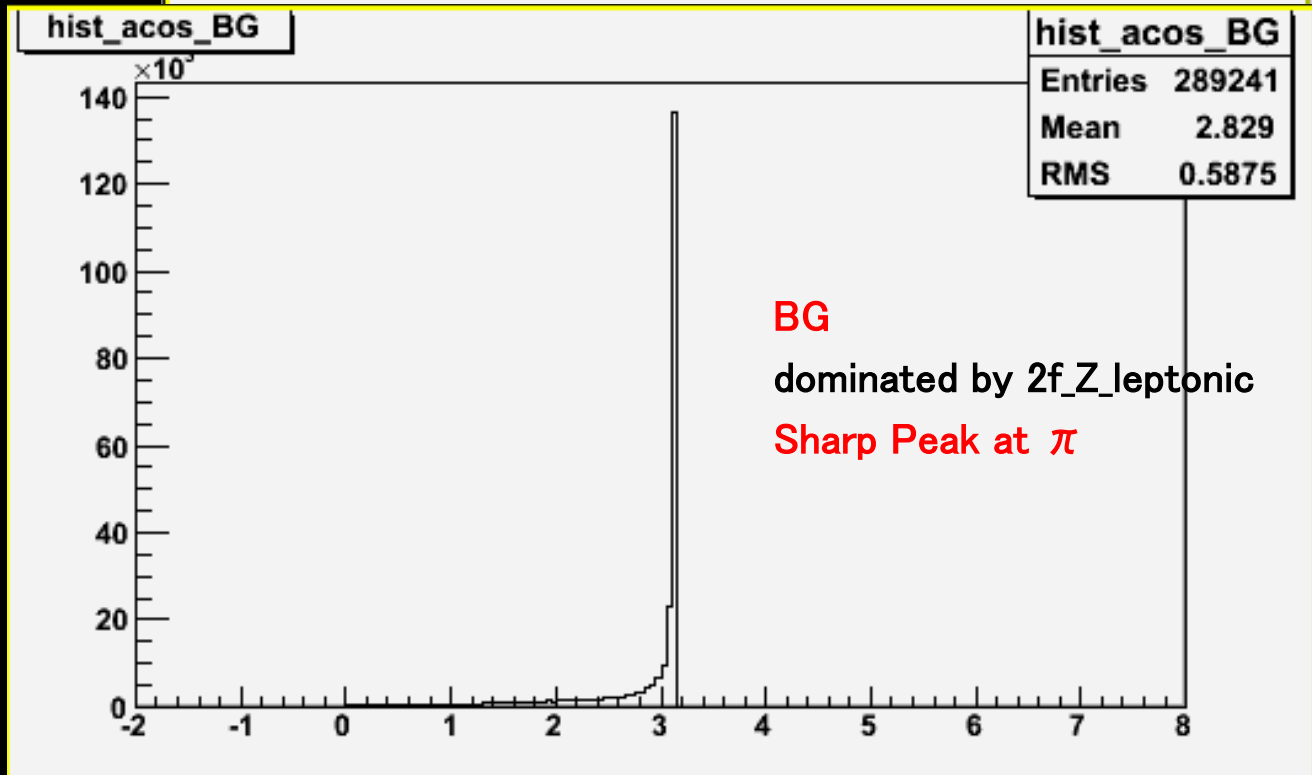


coplanarity, before cut ,
250 GeV

No coplanarity cut applied

wanted to maintain high signal eff.



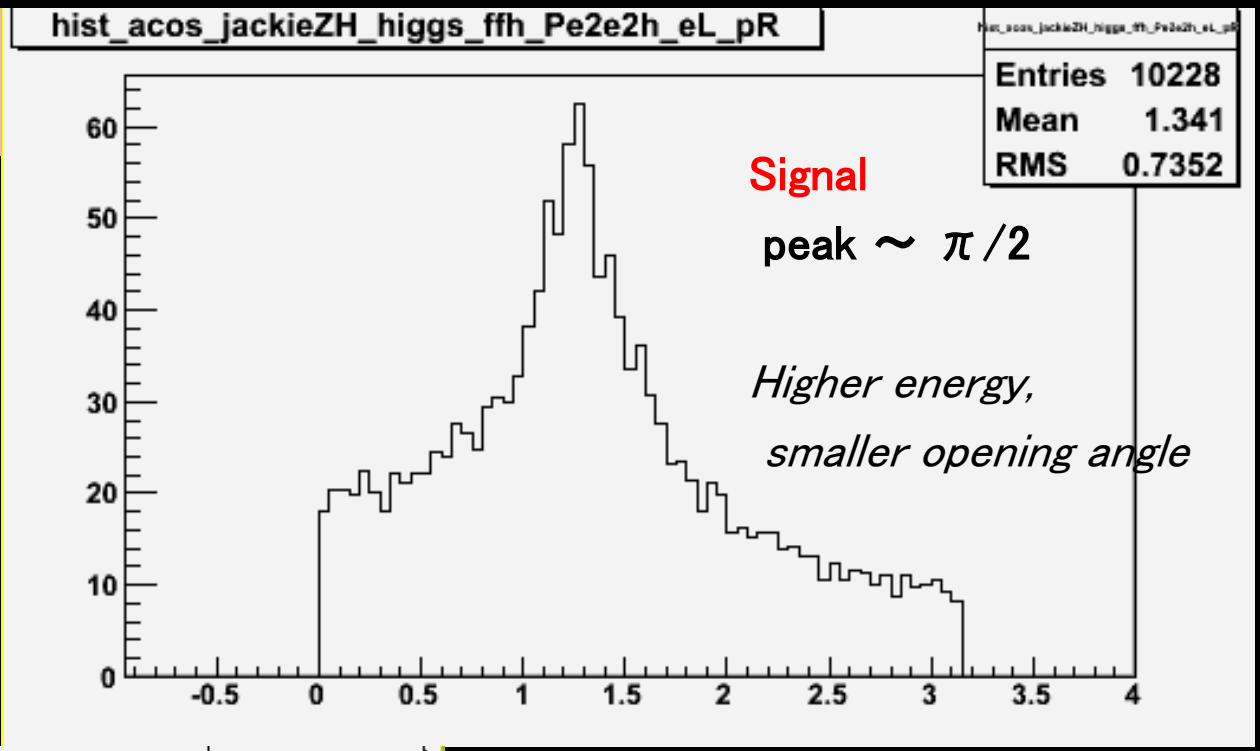


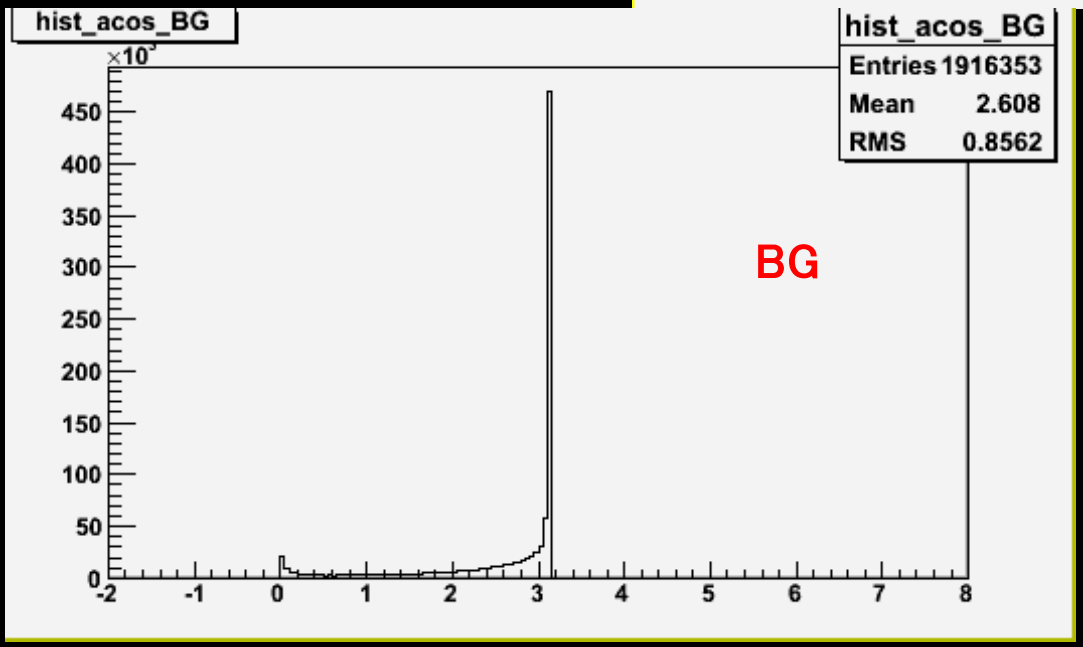
coplanarity, before cut 350 GeV

Cut:

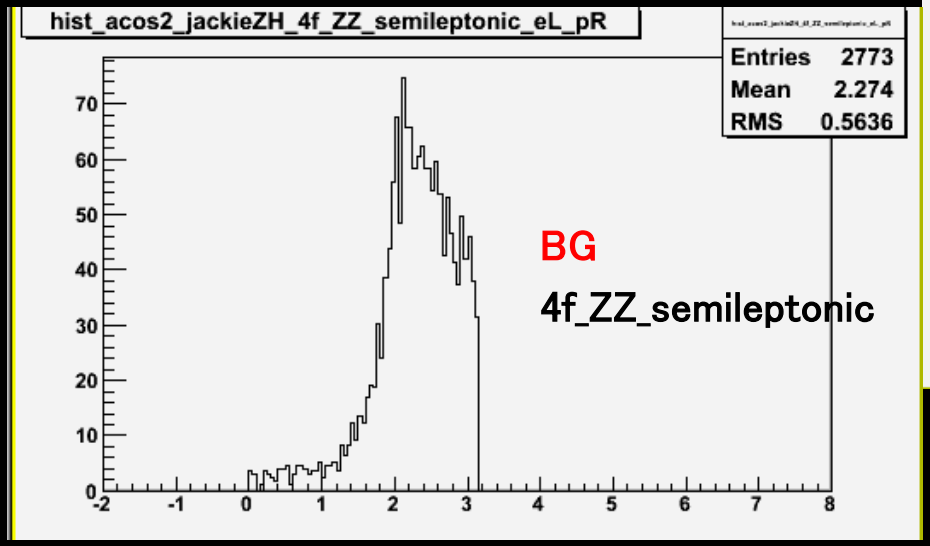
coplanarity ＜ 0.29

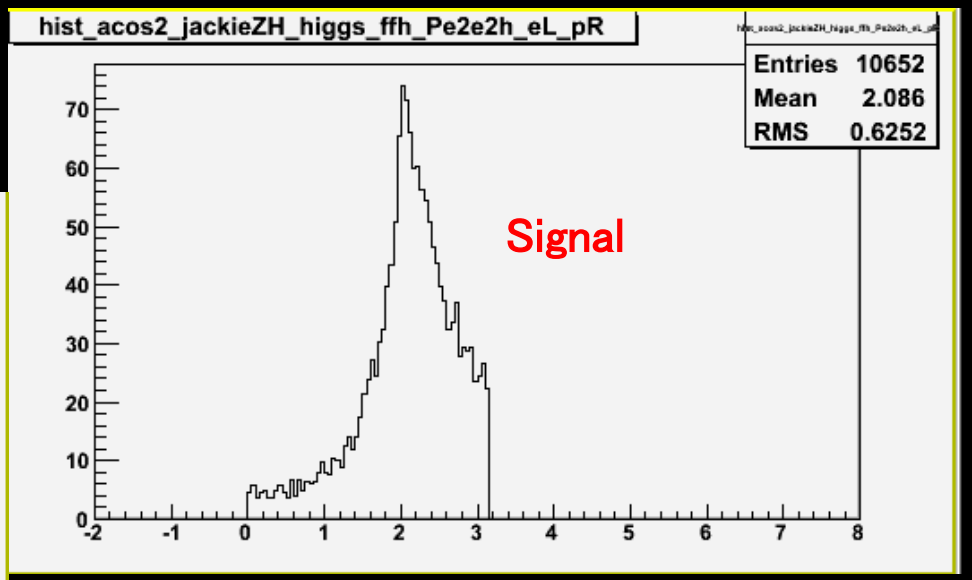
in order to remove more BG



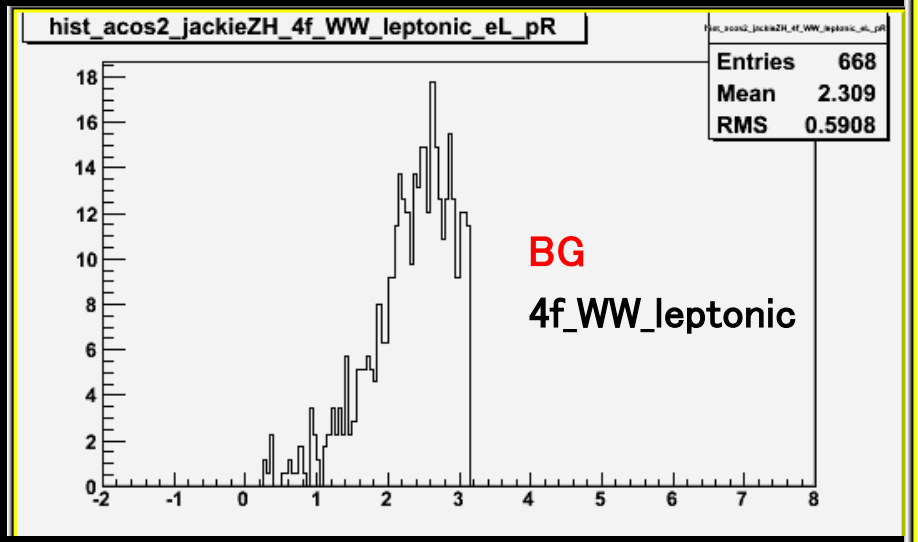


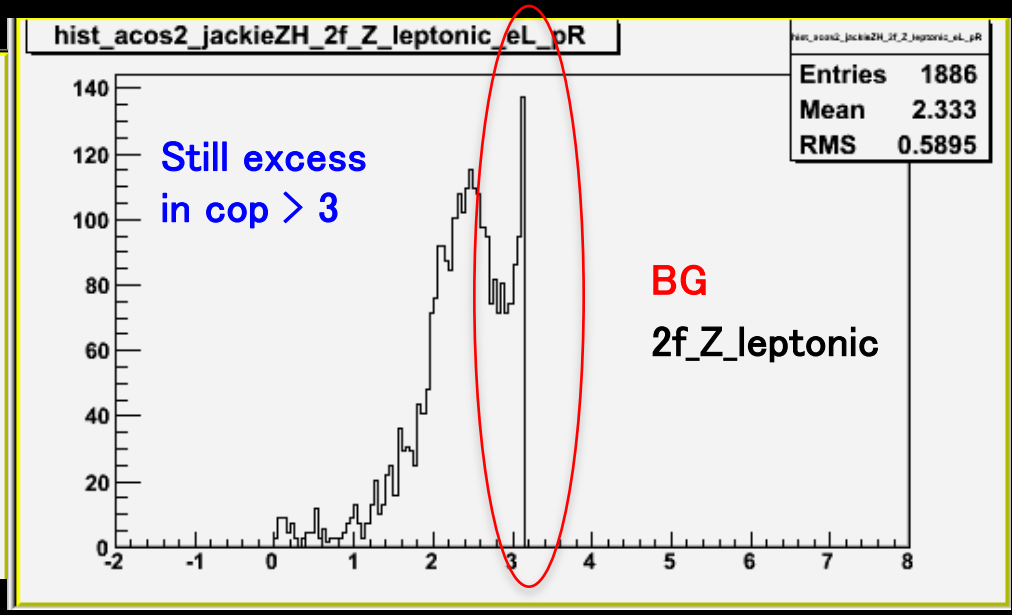
coplanarity, after all other cuts





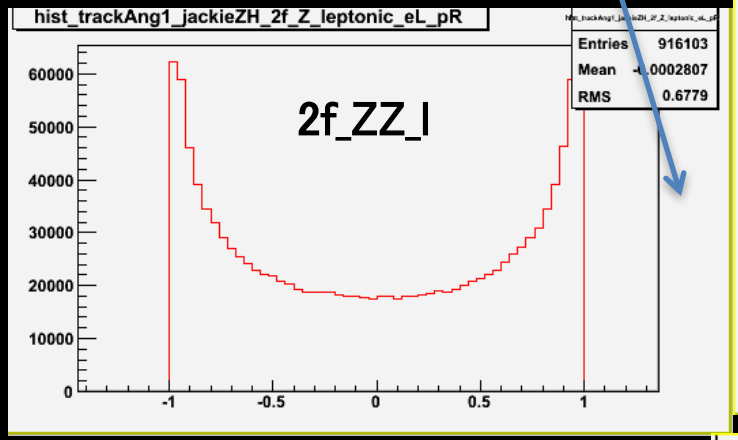
Trying to decide whether to use coplanarity cut

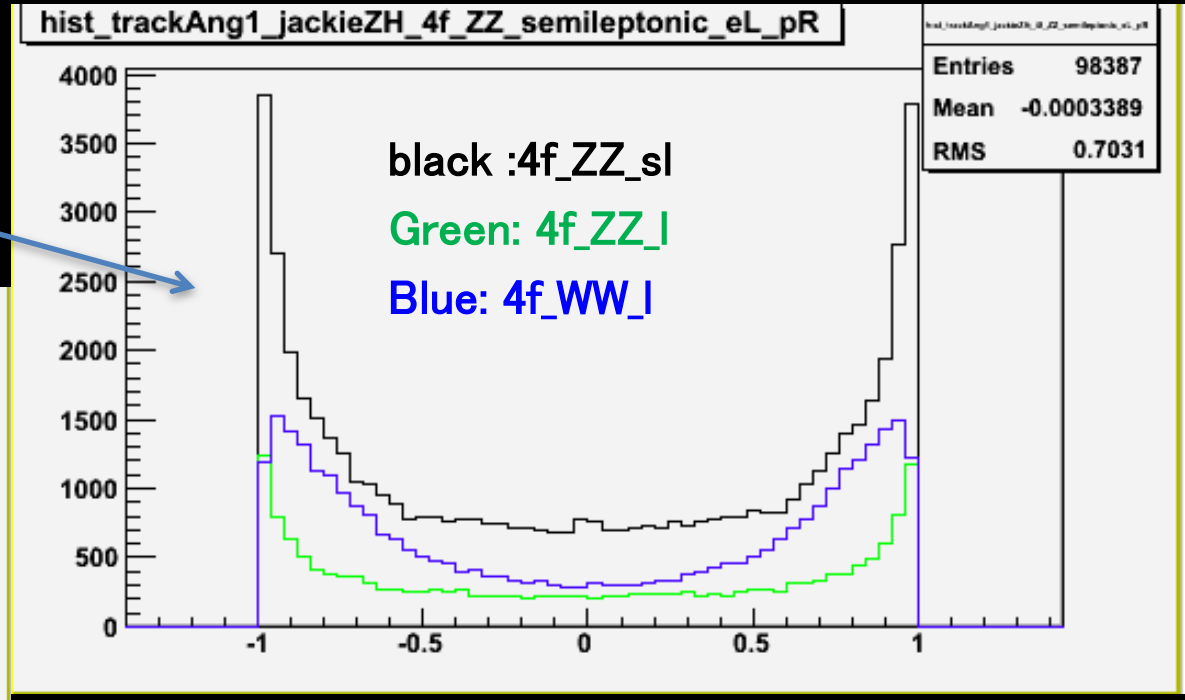




Cos(track angle) ,
250 GeV

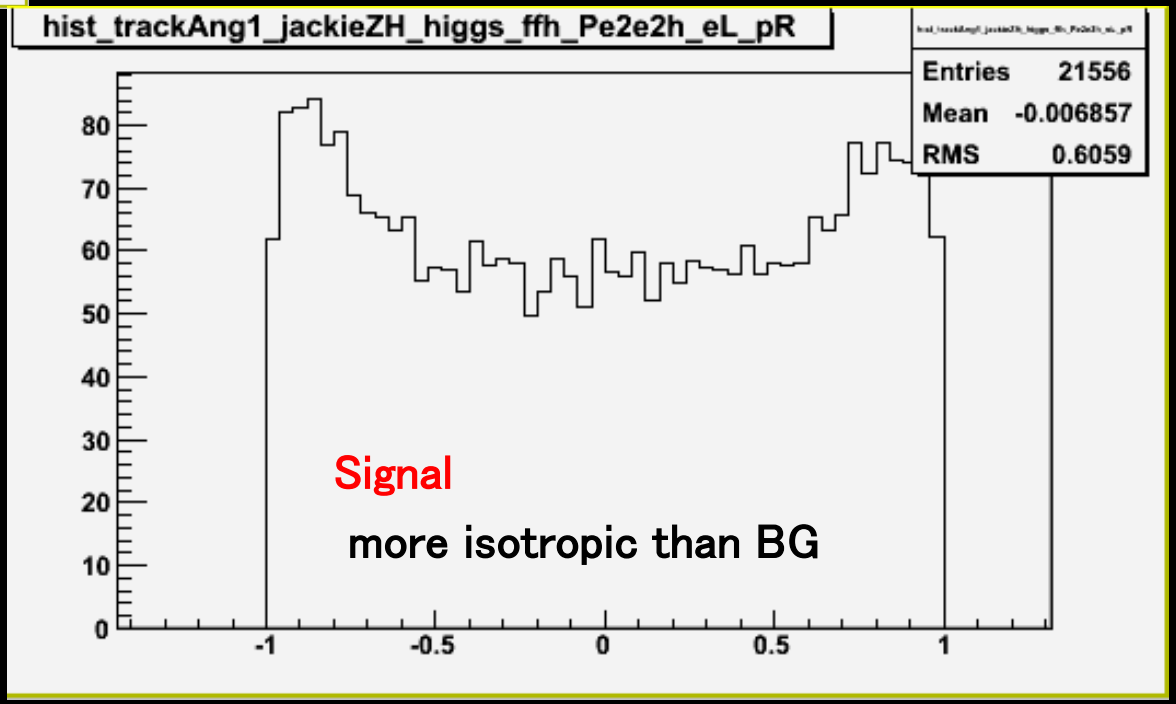
BG is More forward





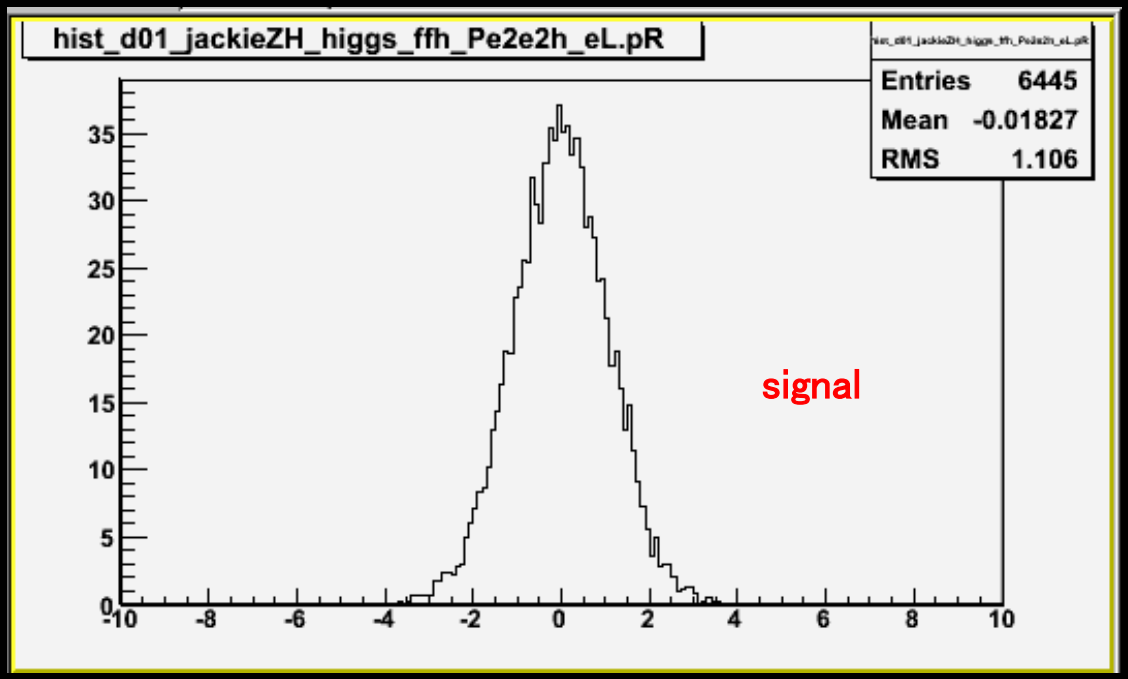
do cut :

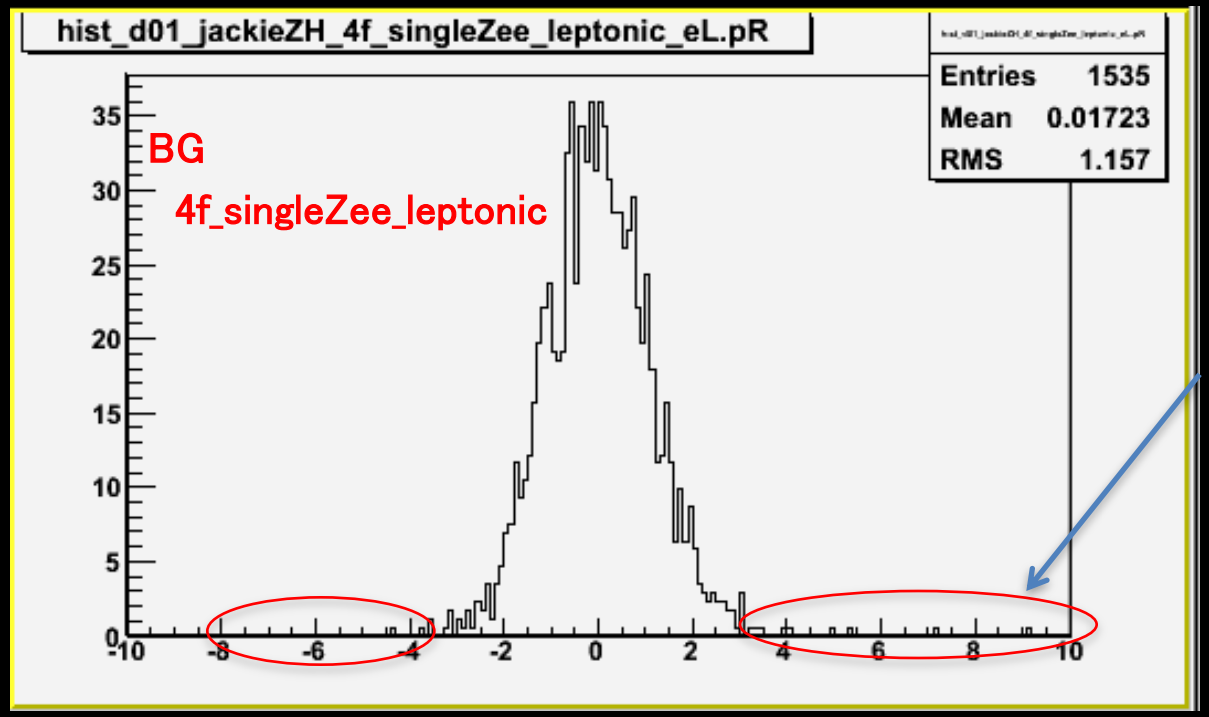
cos(trackAngle) < 0.95



Impact parameter

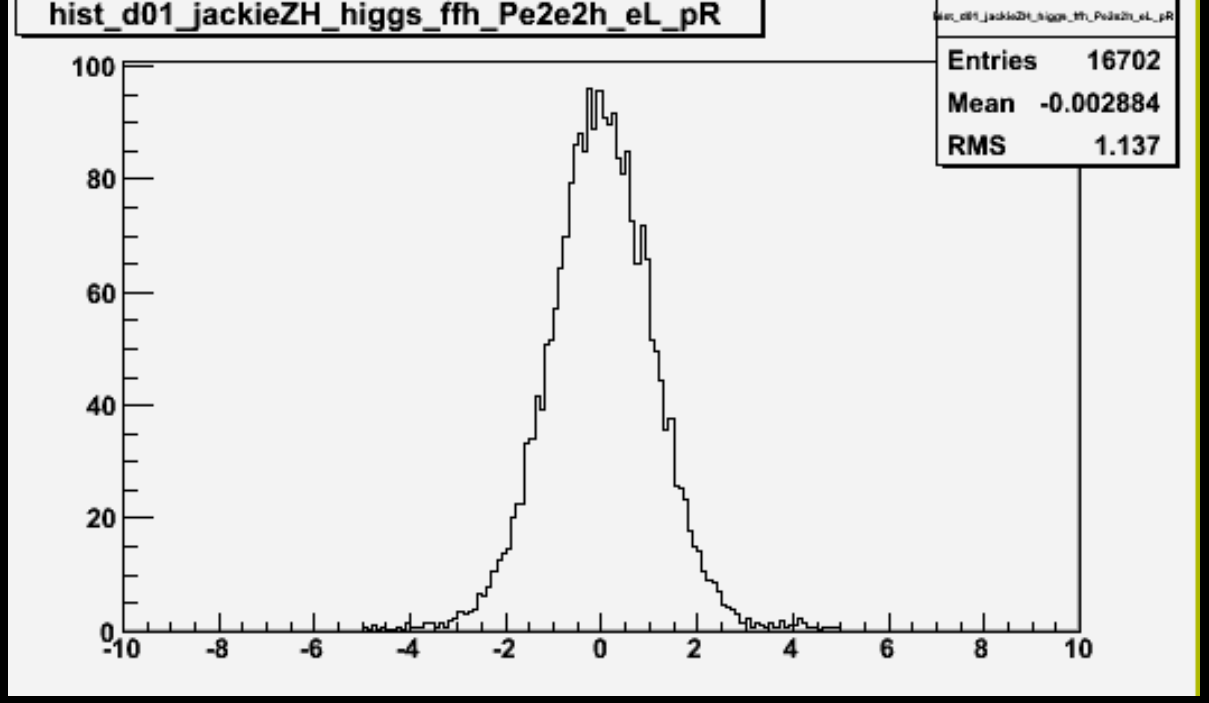
D0/ δ D0

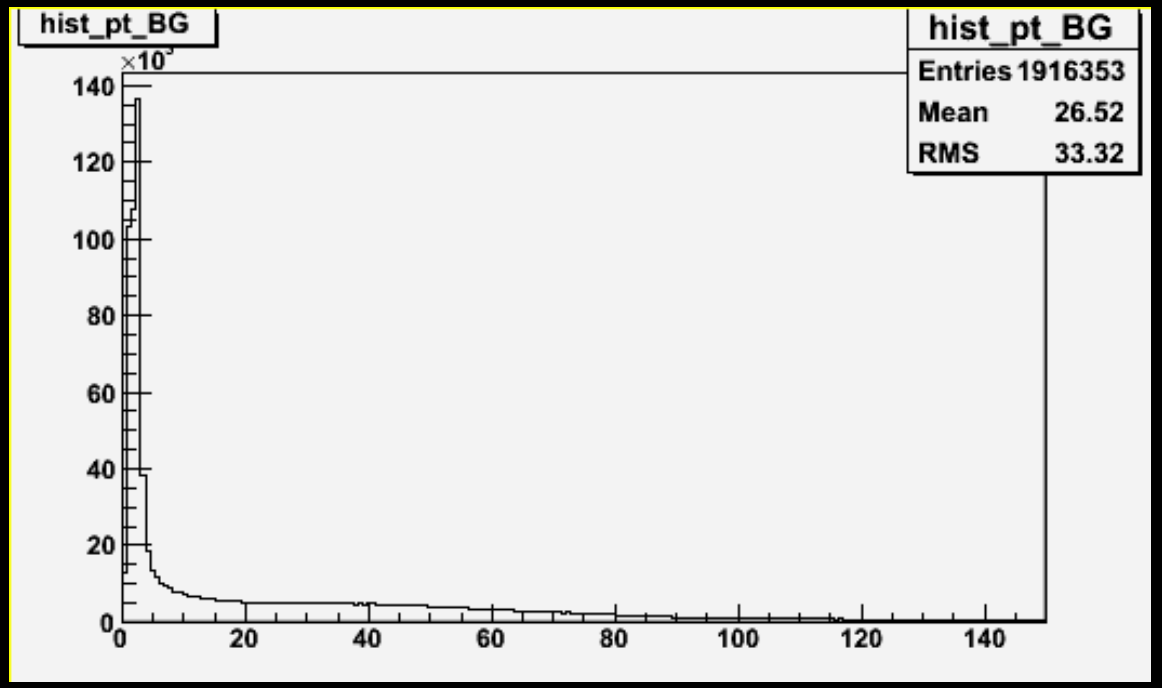




For some BG processes exceed +/− 4 slightly

do cut : $|D0/\delta D0| < 4$


hist_d01_jackieZH_higgs_ffh_Pe2e2h_eL_pR
Entries 16702
Mean -0.002884
RMS 1.137
100
80
60
40
20
0
-10
-8
-6
-4
-2
0
2
4
6
8
10


hist_pt_BG
hist_pt_BG
Entries 1916353
Mean 26.52
RMS 33.32
×10³
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140