Higgs Recoil Mass Study

Apr 4 , 2014

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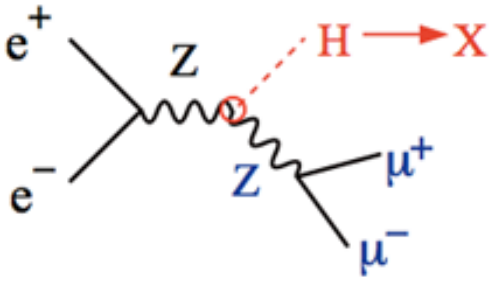
recoil mass study using e+e- → Zh → μ+μ-h

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)



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

Goal:

precise measurement of

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

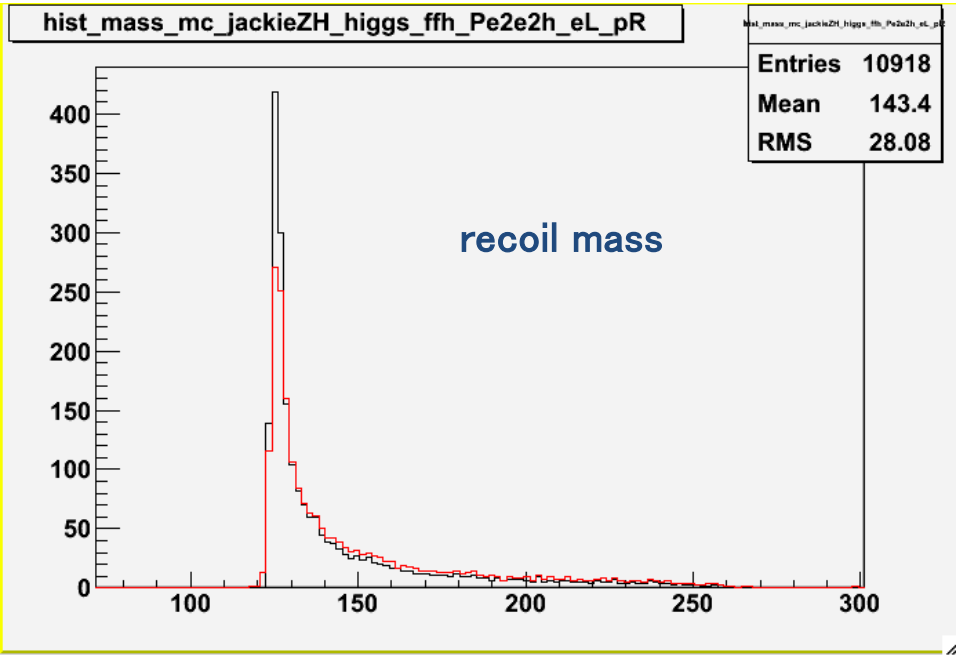
What's new this week

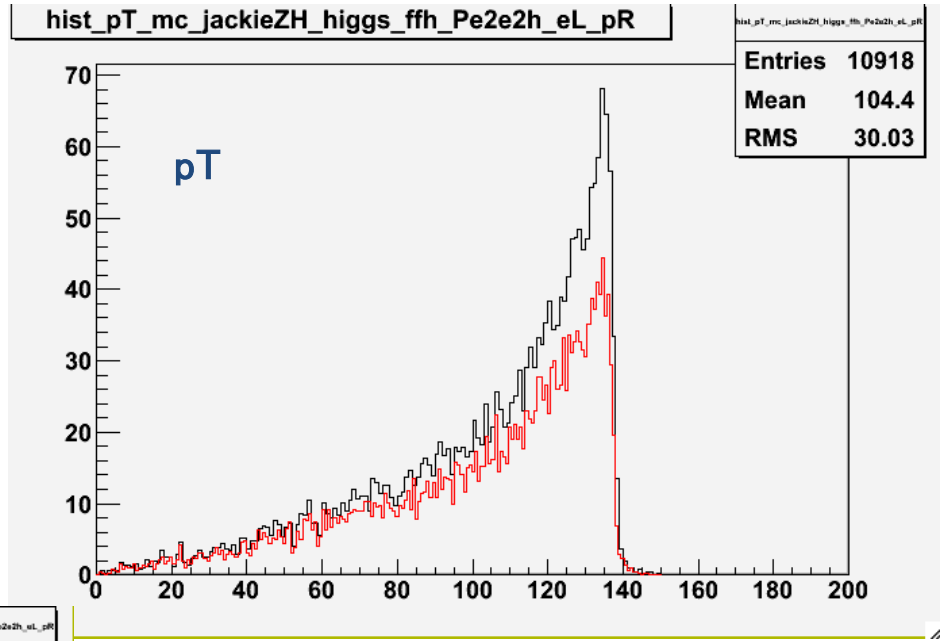
- resolved (again !!) problem of efficiency decrease after track selection for 250 GeV
- Tried widening recoil mass cut window
- began study using MC particle "truth"

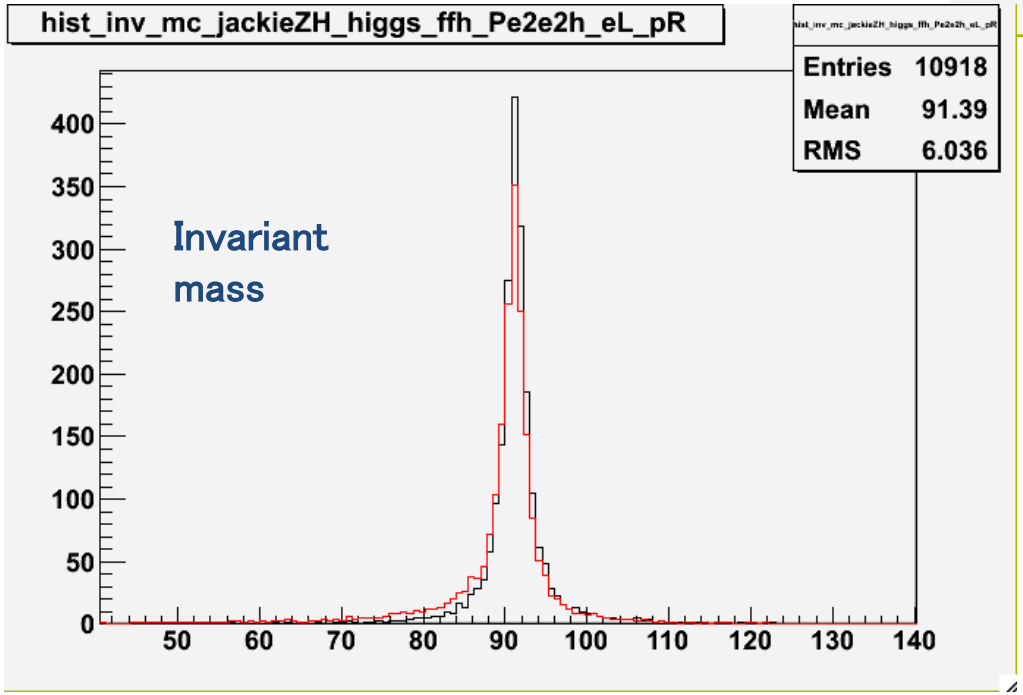
Study using MC particles

- only best muon selection
- No other cuts

after implementing all cuts

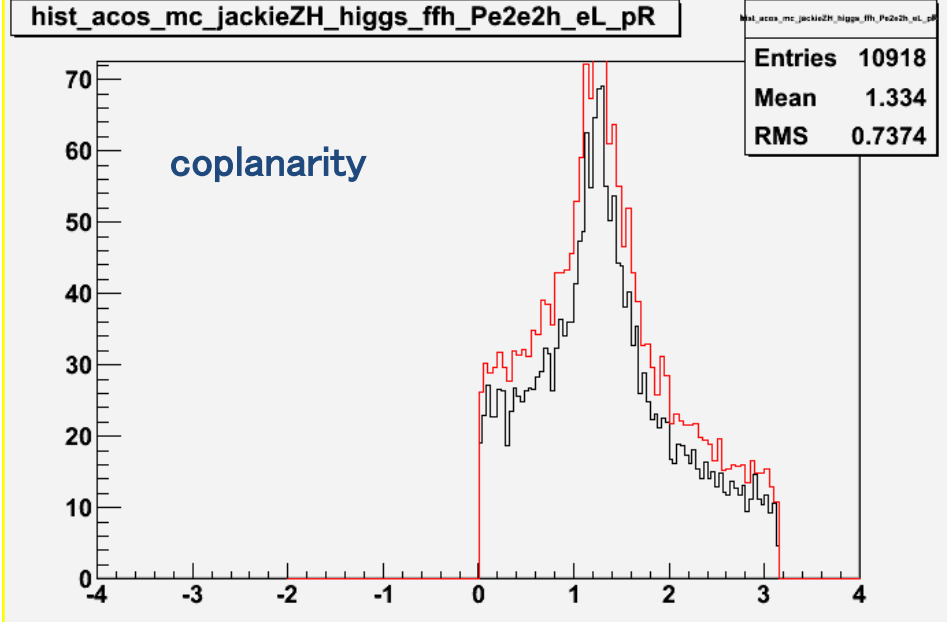


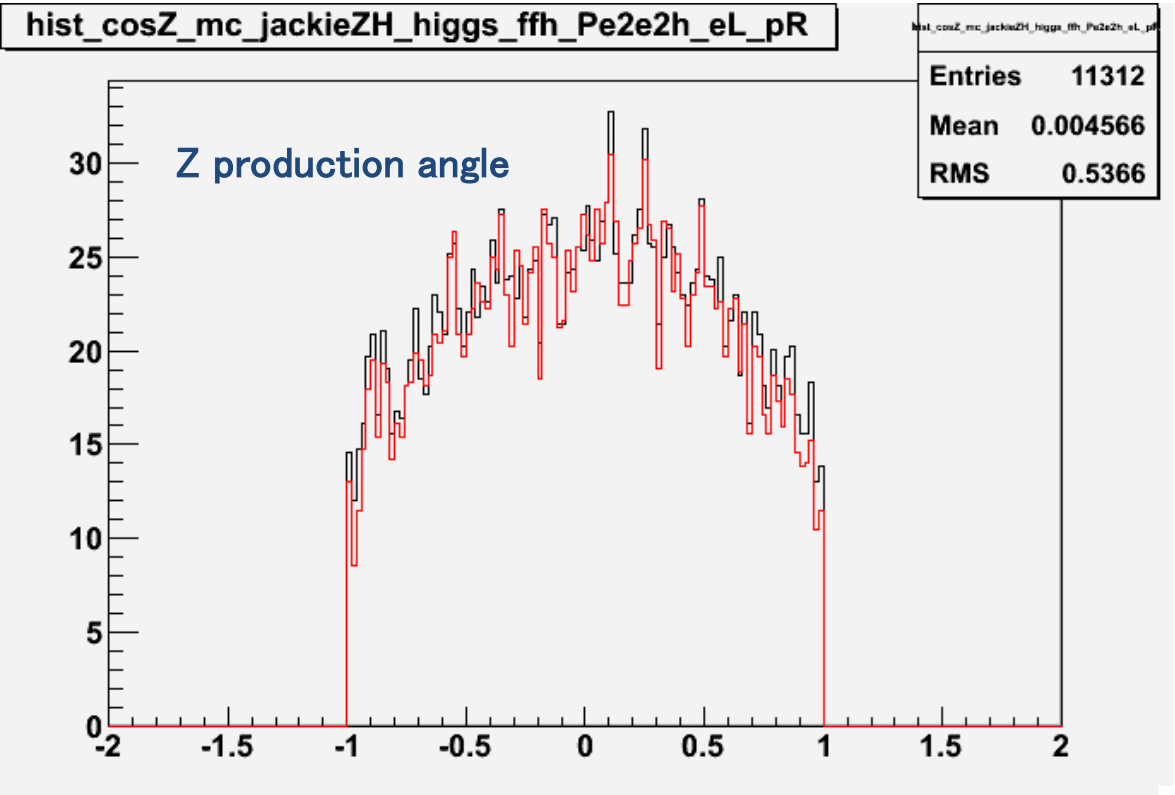




Black : MC

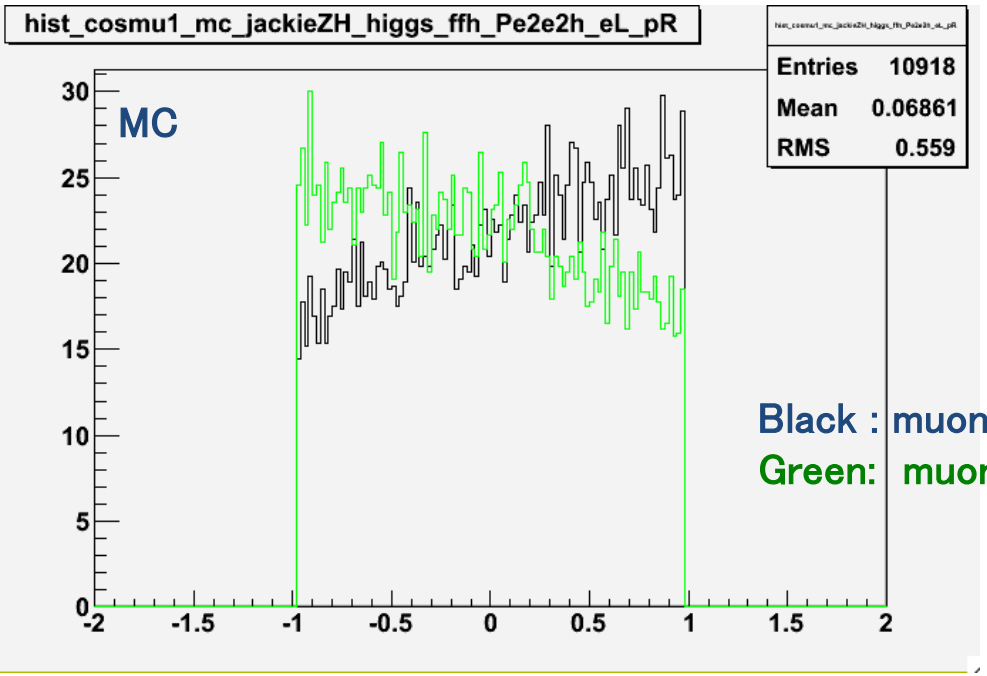
Red: reconstructed





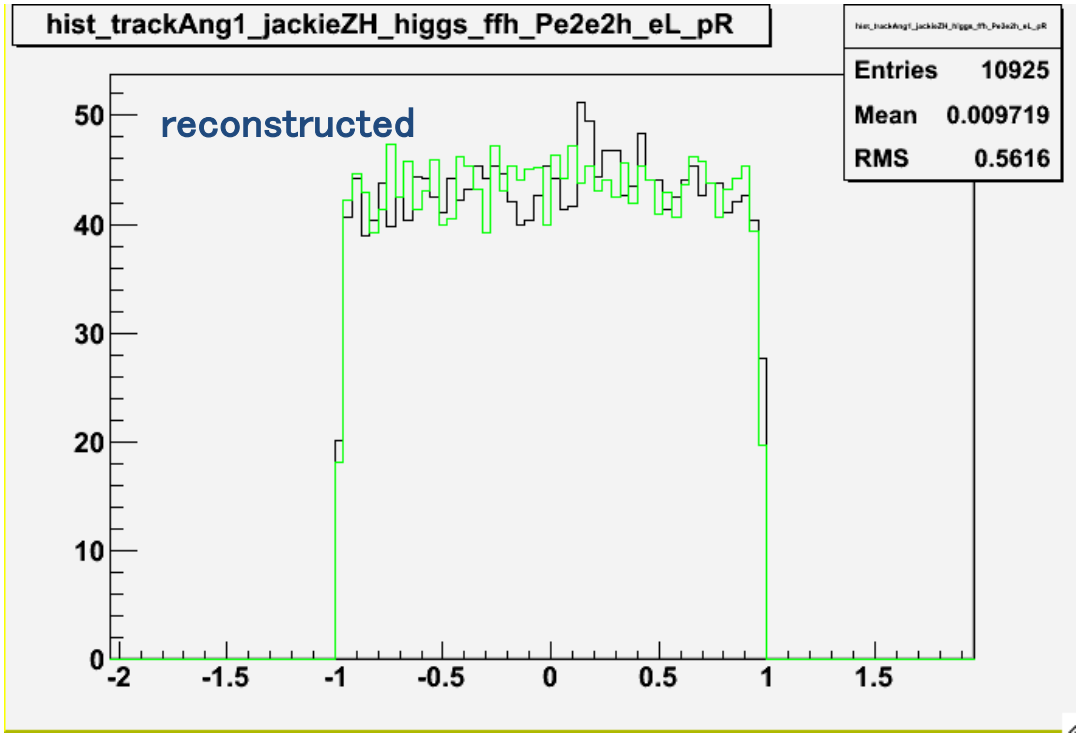
Black : MC

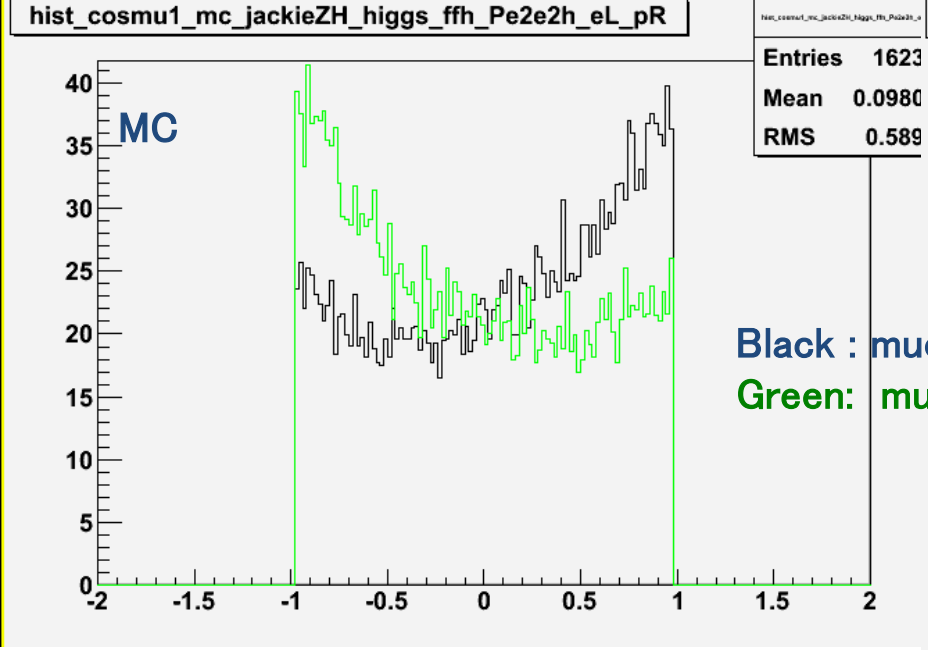
Red: reconstructed

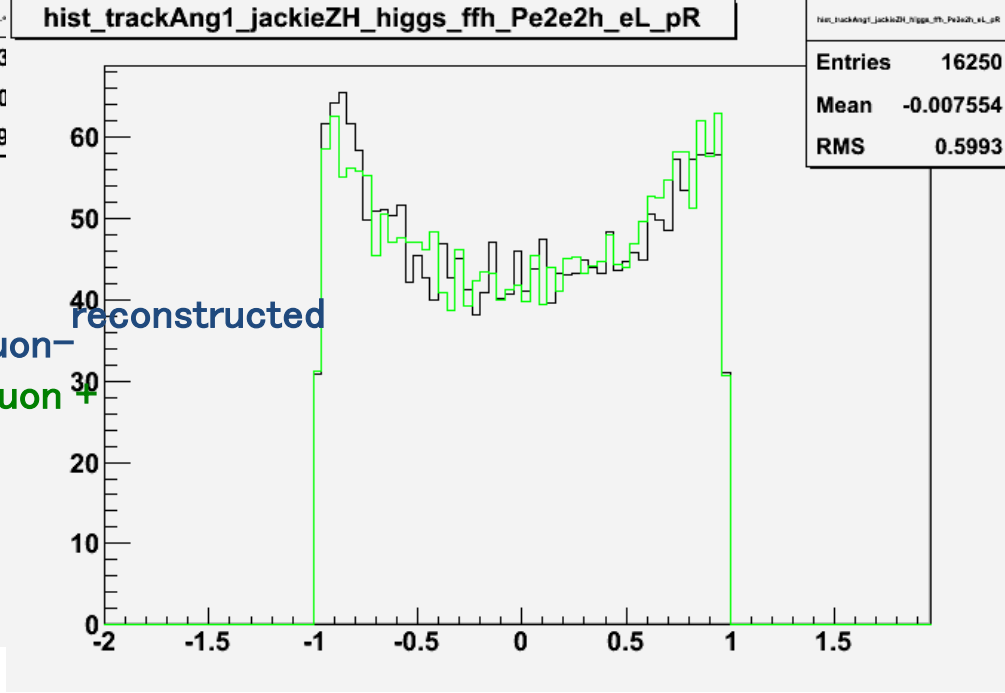


why MC is more forward ??

sqrt(s) = 350 GeV



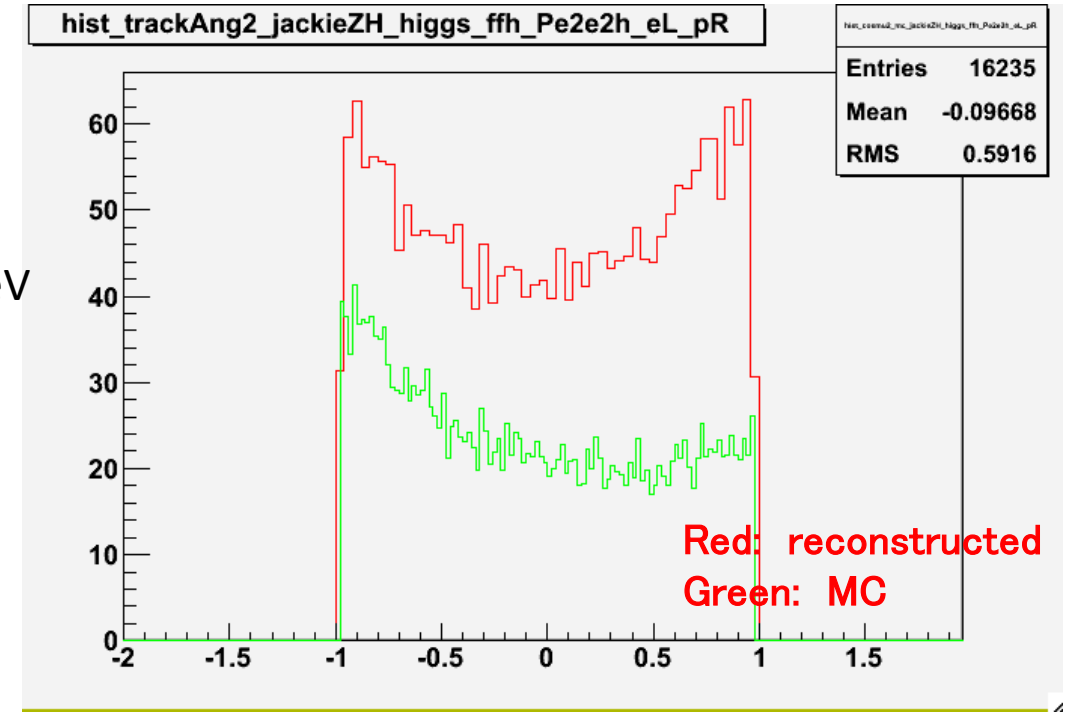




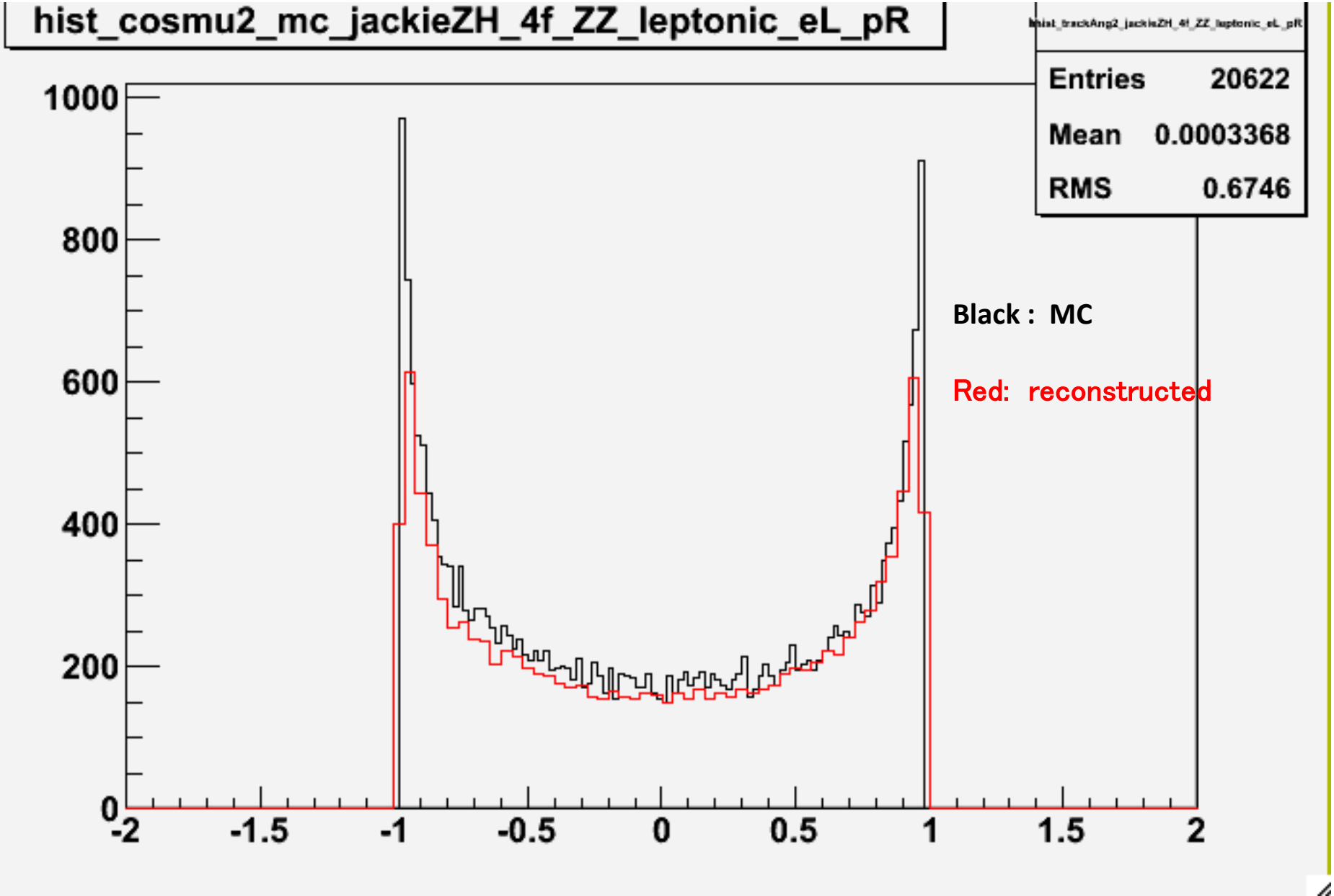
Black : muon−
Green: muon +

MC is more forward/ asymmetrical for 250 GeV as well ?

sqrt(s) = 250 GeV



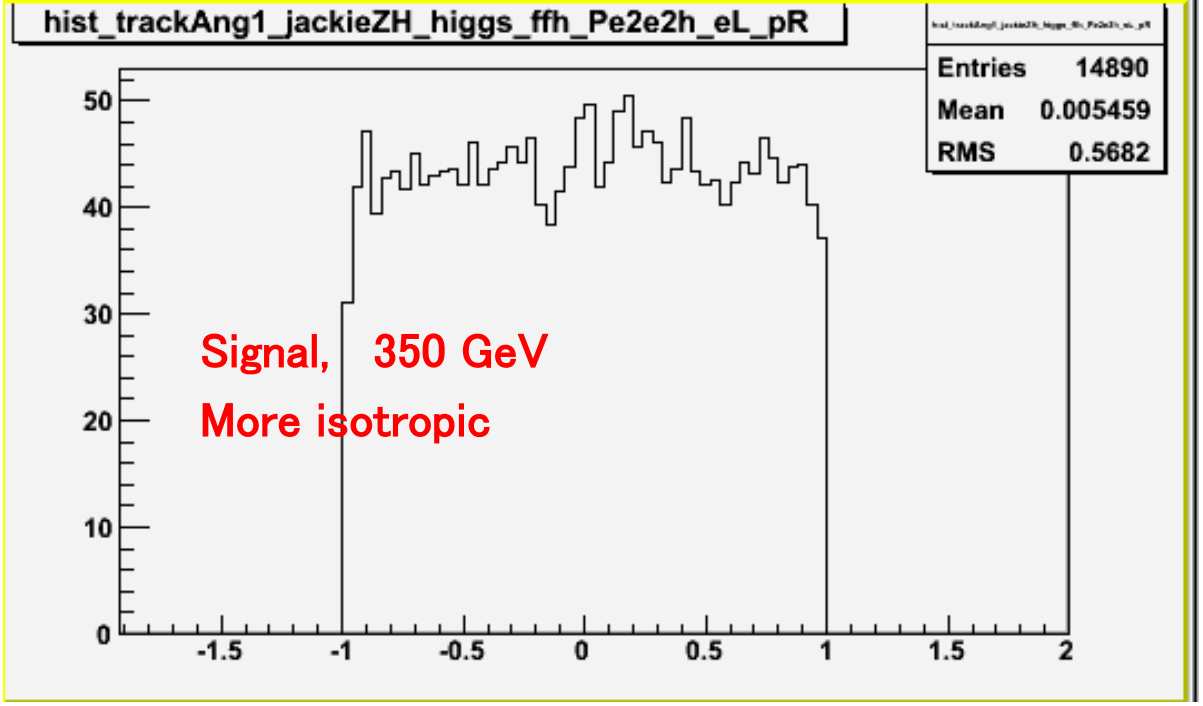
BG (4f_ZZ_leptonic) is much more forward



Cos(track angle), 350 GeV

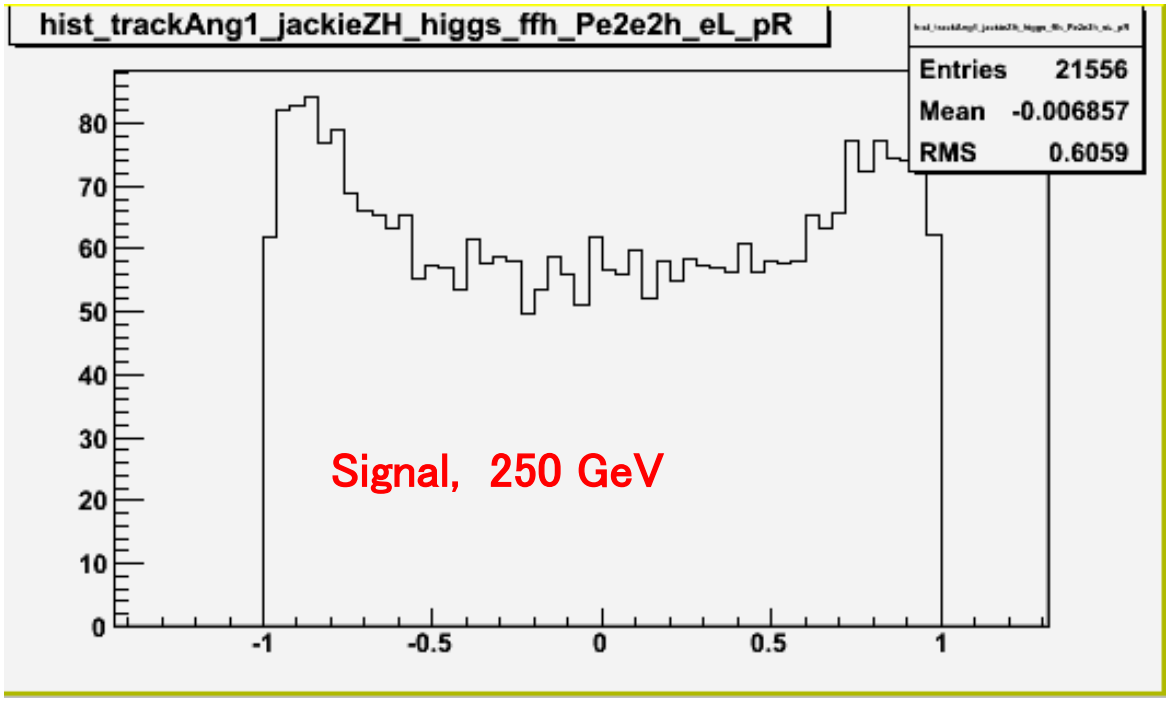
do cut

cos(trackAngle) < 0.98



do cut :

cos(trackAngle) < 0.98



- **cannot understand why track angle is much more forward for MC compared to reconstructed for 350 GeV**

- **for MC : large decrease in efficiency after track angle selection**

need to confirm no bugs , this is just a preliminary observation

	reconstructed signal		MC signal	
after cuts	1089	47.6%	1256	54.9%
no rec mass	1707	74.6%	1291	56.4%
no cosZ	1791	78.3%	1353	59.1%
no coplanarity	1818	79.5%	1368	59.8%
no Pt	1824	79.7%	1373	60.0%
no inv mass	2207	96.5%	1530	66.9%
no trackAng	2238	97.8%	1582	69.1%
raw	2288	100.0%	2288	100.0%

- **same problem with BG also**

- **for MC : large decrease in efficiency after track angle selection**

need to confirm no bugs , this is just a preliminary observation

	reconstructed 2f_ZZ_leptonic		MC	
after cuts	1106	0.0%	1053	0.0%
no rec mass	10816	0.3%	1177	0.0%
no cosZ	22771	0.7%	2255	0.1%
no coplanarity	26212	0.8%	2521	0.1%
no Pt	95041	2.9%	7632	0.2%
no inv mass	304764	9.2%	11721	0.4%
no trackAng	342407	10.4%	18904	0.6%
raw	3297412	100.0%	3297412	100.0%

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

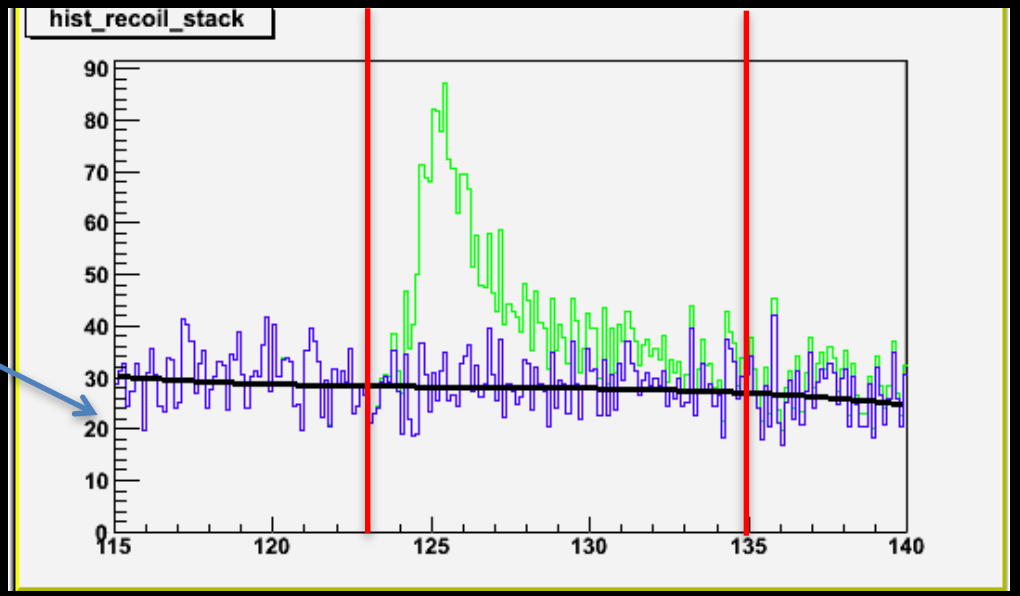
analysis after filling root files

- **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

Data selection : 123 – 135 GeV

old: Sqrt(s)= 250 GeV

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	1965	75%	41734	0.60%	0.0471	9.40
ΔD0/D0 < 5	1955	75%	35507	0.51%	0.0551	10.10
cos(trackAng)<0.98	1912	73%	32845	0.47%	0.0582	10.26
84 <M_inv <98	1734	67%	10750	0.16%	0.1613	15.52
10 <P_Tdl<70	1709	66%	5440	0.08%	0.3142	20.21
cos(θZ)<0.91	1603	62%	4104	0.06%	0.391	21.22
123 GeV <M_rec <135GeV	1598	61%	4056	0.06%	0.394	21.25

Problem of sudden sig. efficiency decrease

Signal efficiency 61 %

S/N → 0.39

Significance ~21.3

cut	4f_ZZ_l	4f_ZZ_sl	2f_Z_l	4f_WW_l	4f_WW_sl	4fSingleZee_l	4fSingleZn_l	4f_ZZWWMix_l
raw	23972	214232	3248465	228894	2771978	167469	28534	239742
only best mu pair	607	2538	16708	3542	11017	1407	497	5418
ΔD0/D0 < 5	576	2408	14948	1289	9132	1385	492	5277
cos(trackAng)<0.98	527	2265	13858	1177	8496	926	458	5138
84 <M_inv <98	248	902	7728	257	184	123	254	1054
10 <P_Tdl<70	220	877	2529	252	177	118	247	1020
cos(θZ)<0.91	179	757	1593	229	157	93	212	884
123 GeV <M_rec <135GeV	177	748	1574	227	157	92	209	872

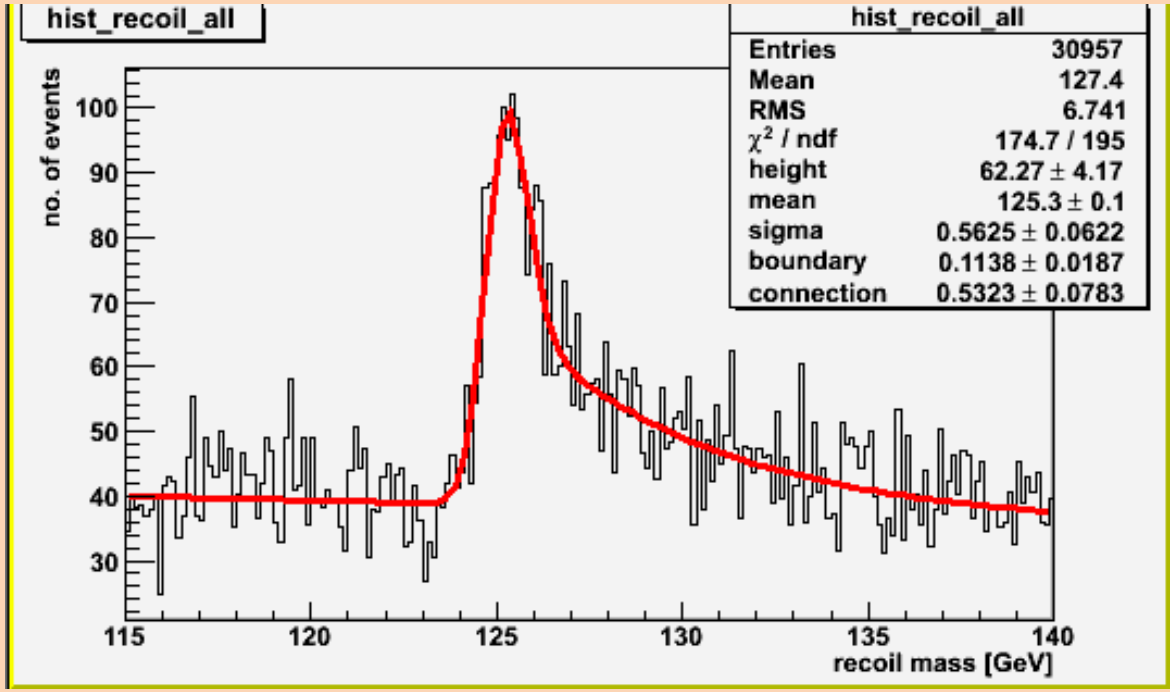
recoil mass

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)

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

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

Results for 350 GeV

Tried widening recoil mass window

123- 135 GeV

Changed to

120 - 140 GeV

Tried to widen recoil mass cut window

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

(-0.8, + 0.3)

Pol weight(eLpR) = 0.9*0.65

Pol weight(eRpL) = 0.1*0.35

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

signal eff is up, though not satisfactorily high

However S/N is worse → a problem since signal peak is already quite buried in BG

May have improvements after I use fitted results (instead of integrating histogram)

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

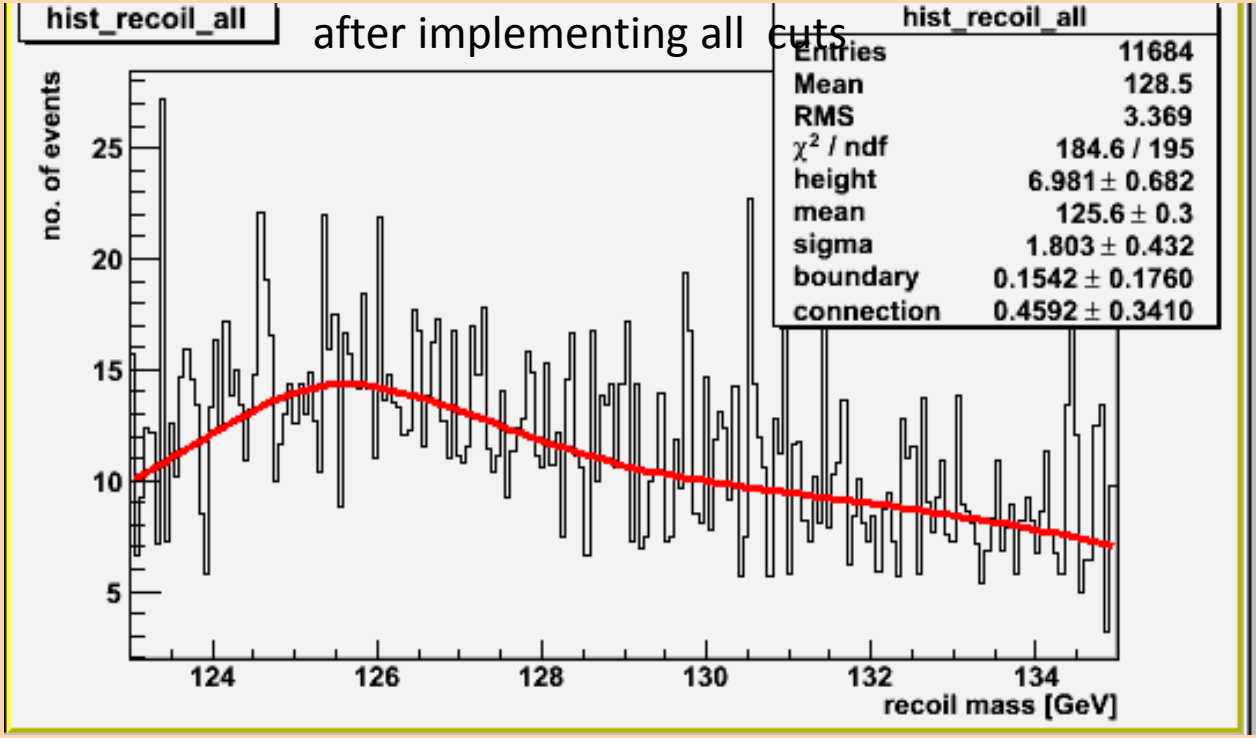
cut	4f_ZZ_l	4f_ZZ_sl	2f_Z_l	4f_WW_l	4f_WW_sl	4fSingleZe_l	4fSingleZnn_l	4f_ZZWWMix_l	6f
raw	19632	188087	2226358	226193	2715937	243879	43056	541352	37989
only best mu pair	4231	20482	349026	25340	145897	37121	8924	94303	3726
ΔD0/D0 < 5	3969	17431	330450	10706	112044	36560	8760	88832	1901
cos(trackAng)<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

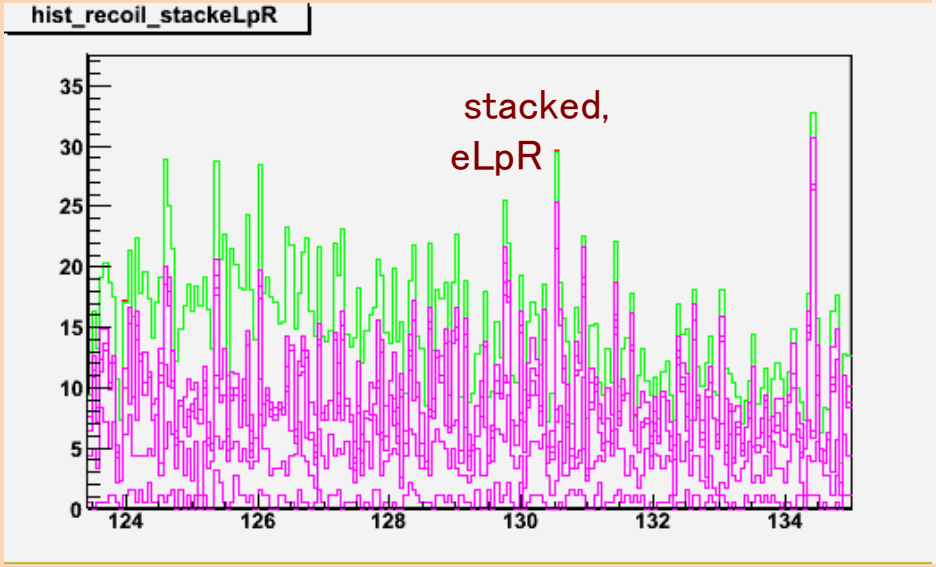
recoil mass

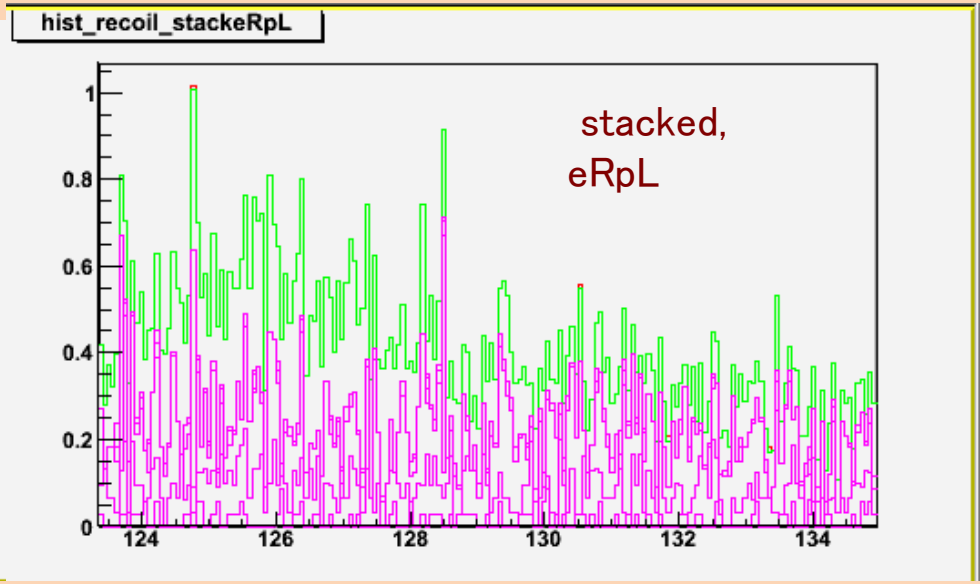
fitted **recoil mass** :

Mh =125.6 +/− 0.3 GeV

calculate recoil mass with correction for 14 mrad beam crossing angle







BACKUP

(-0.8, + 0.3)

<ε> = 40.4 +/- 0.5 %

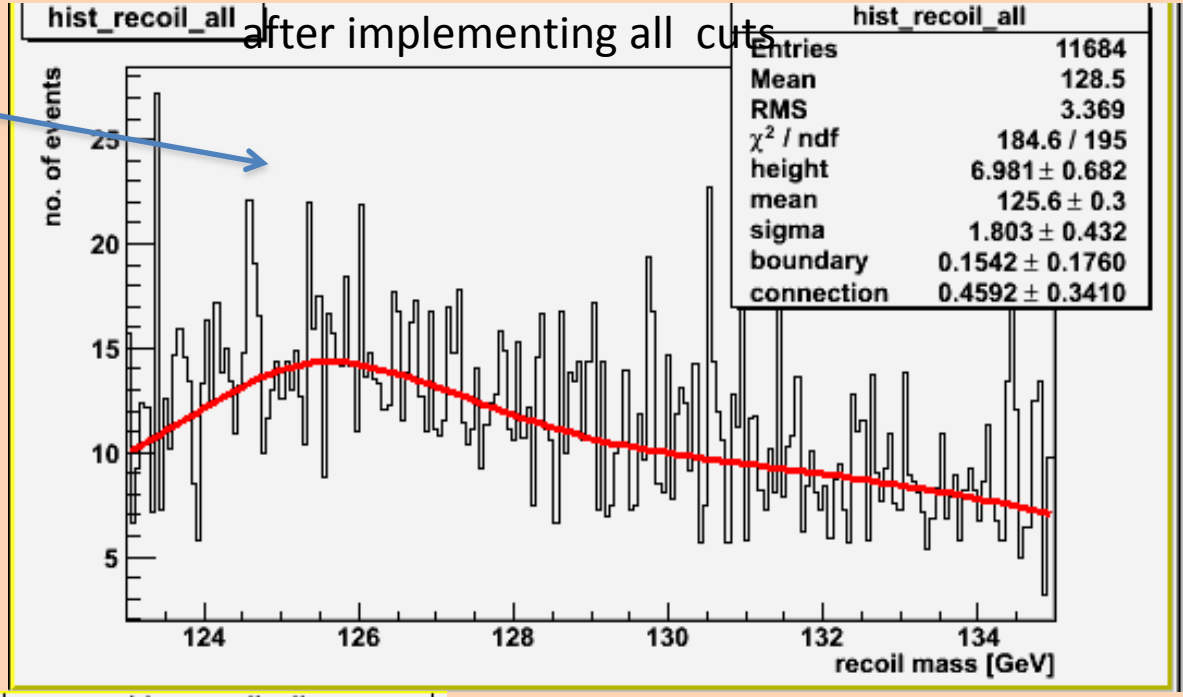
<n>/sqrt(<n>+<B>) = 16.6

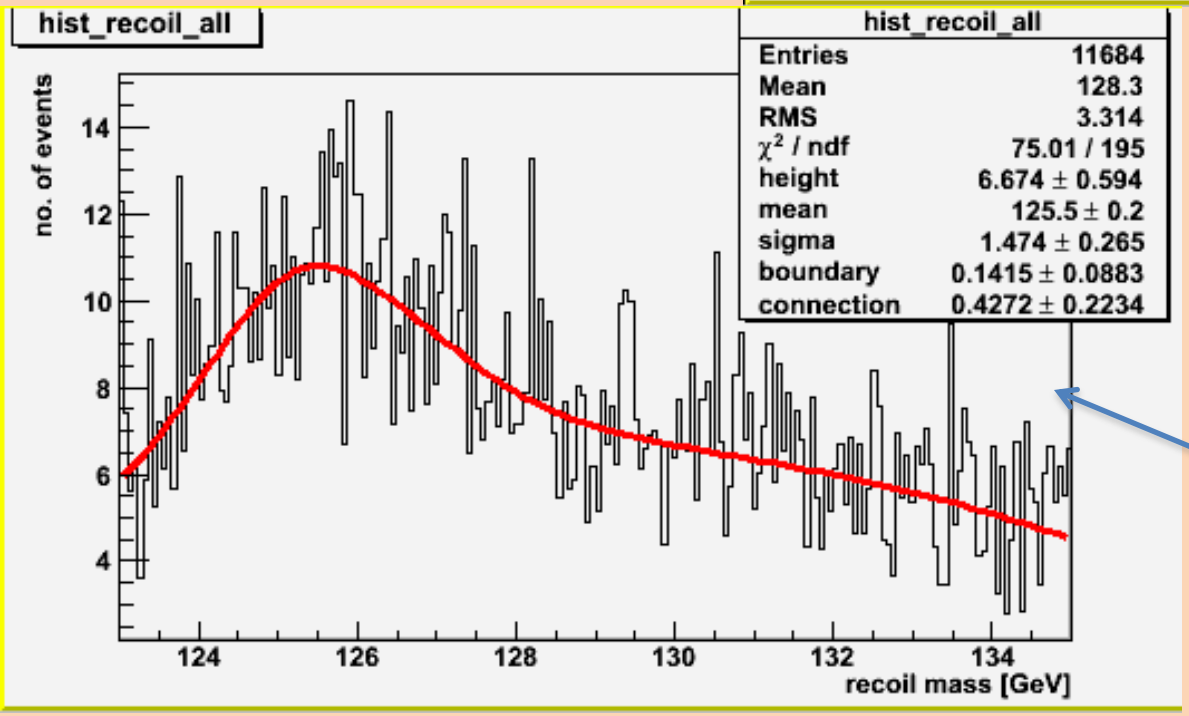
<n>/<B>=0.42

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

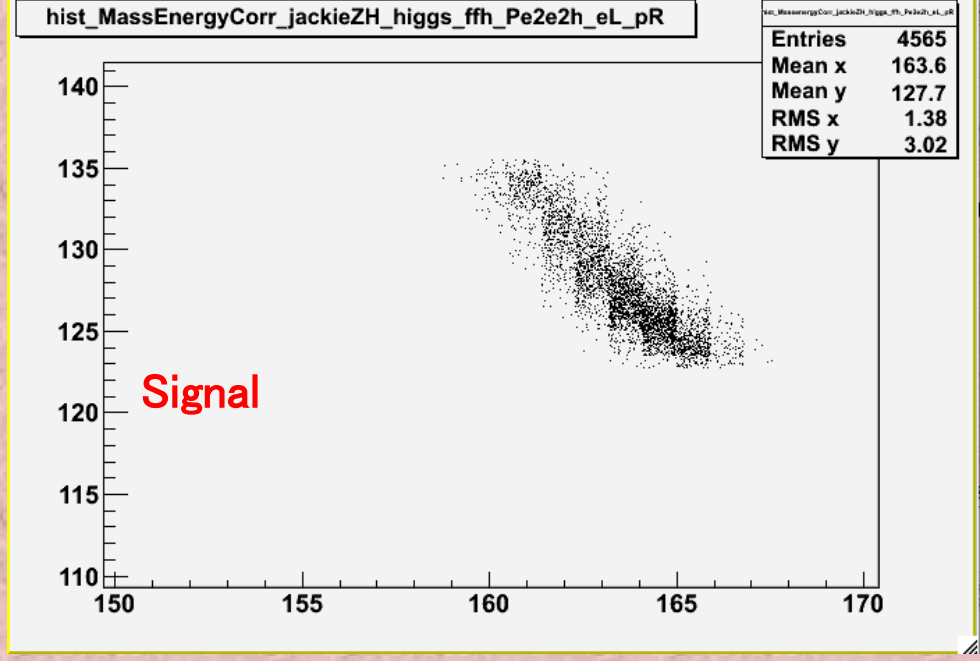
fitted recoil mass :

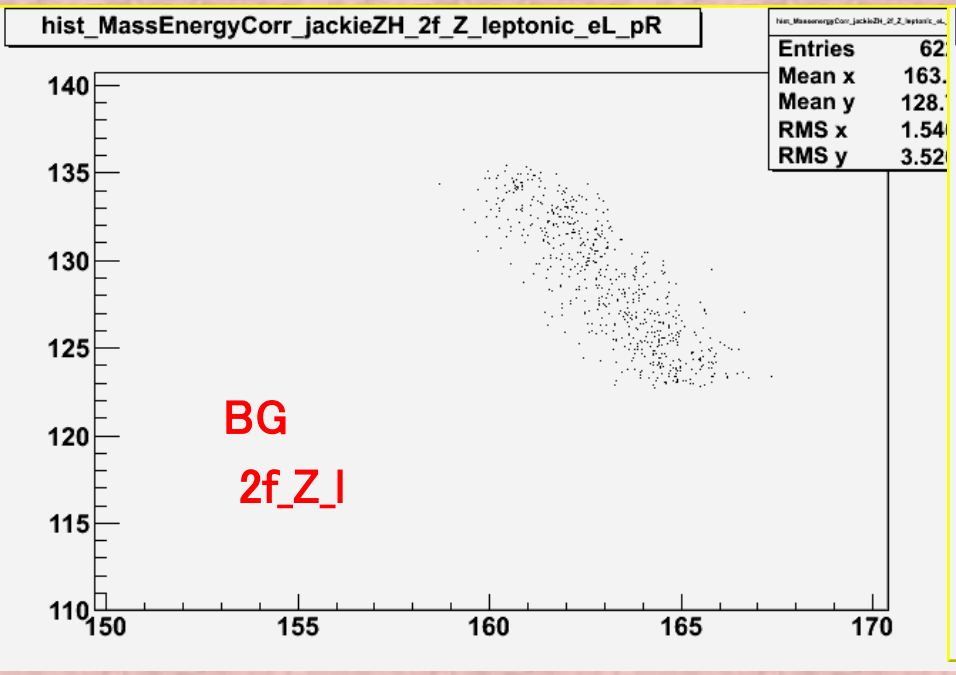
Mh =125.6 +/− 0.2 GeV

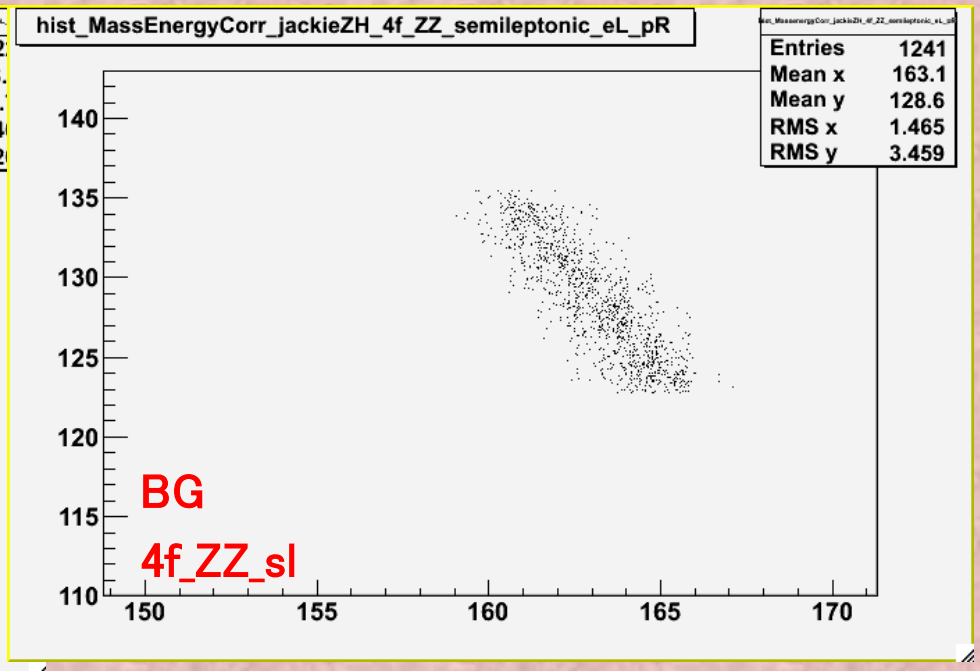
X axis : Z energy (reconstructed)

Y axis : recoil mass

After cut



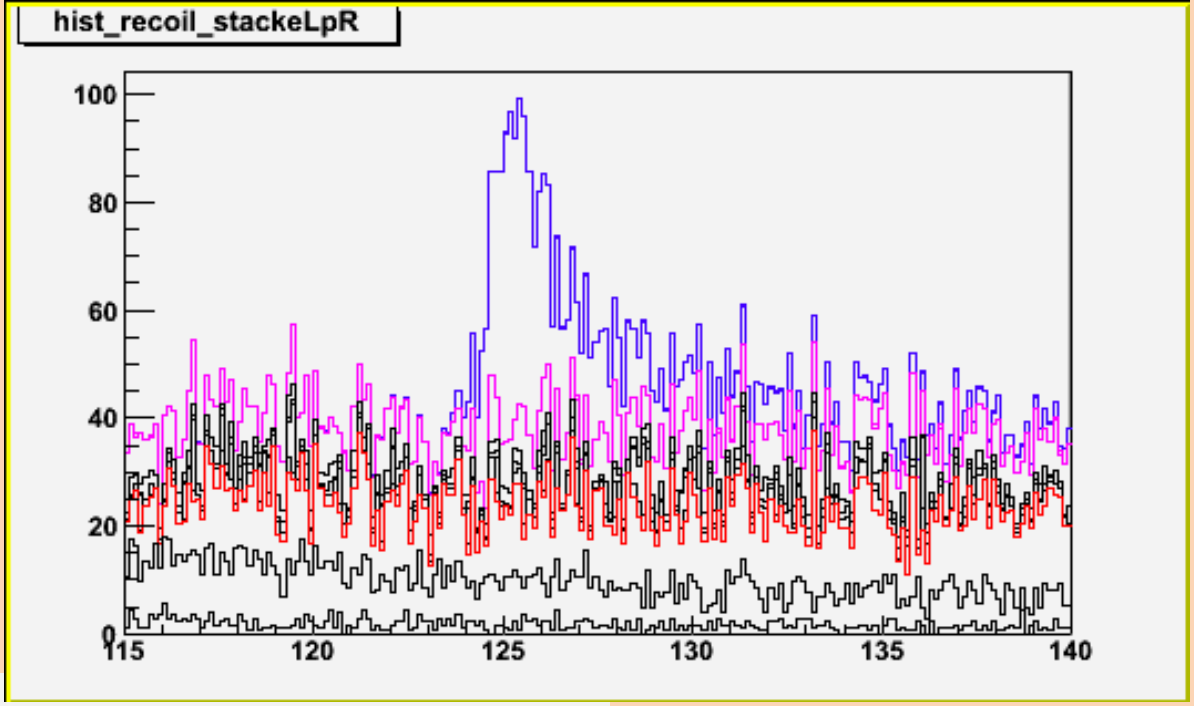


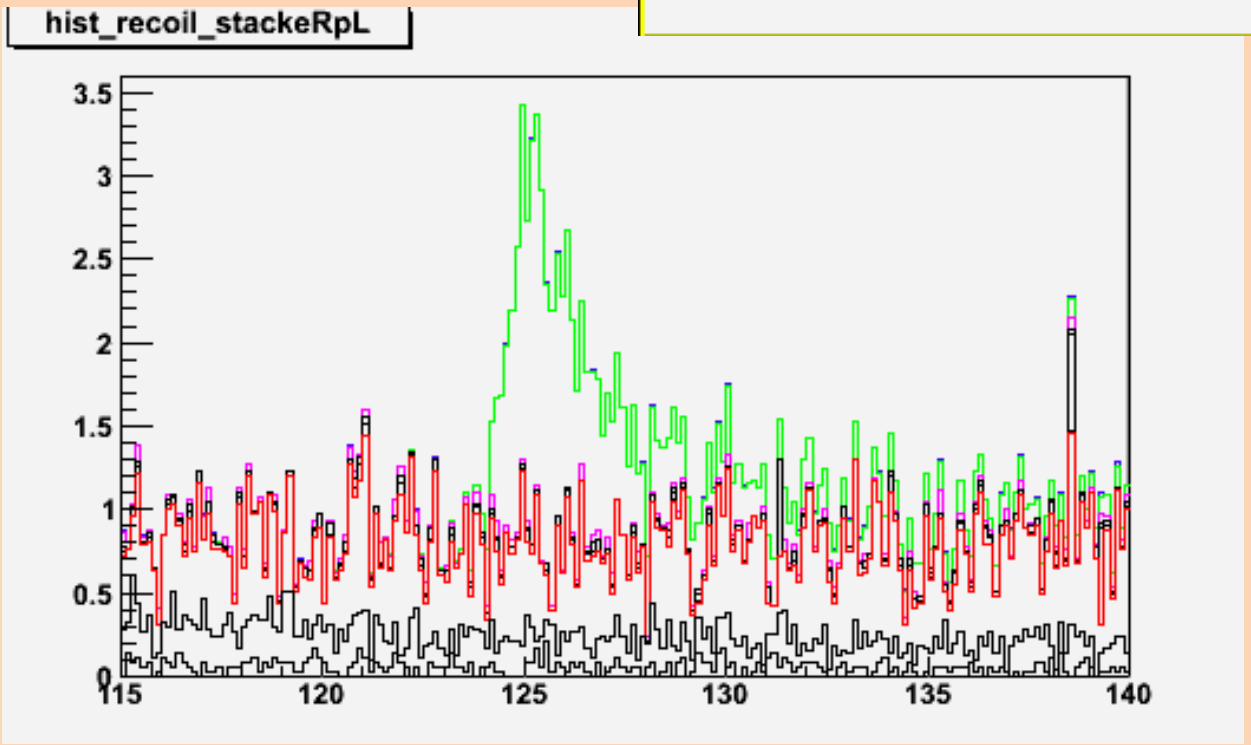


recoil mass (stacked)

Red: 2f_Z_l

Pink: 4f_ZZWWMix_l : small for eRpL





DBD Samples

Sample statistics 1000 fb-1

event weight = pol_weight * (process_cross_section * assumed_integrated_luminosity)
/ (number_of_reconstructed_events)

250 GeV

/grid/ilc/prod/ilc/mc-dbd/ild/dst-merged/250-TDR_ws/

20 x Higher statistics data : /hsm/ilc/grid/storm/user/a/amiyamot/myprod/ild/dst-merged /250-TDR_ws/
reference: meta files and diagrams in http://ilcsoft.desy.de/dbd/generated/other.html

350 GeV

/grid/ilc/prod/ilc/mc-dbd/ild/dst-merged/350-TDR_ws/
List of samples: http://www-jlc.kek.jp/~miyamoto/CDS/prod_status/REC_ILD_o1_v05_350GeV.html

Lumosity

TDR baseline
sqrt(s)=250 GeV, Lumi=0.75 x 10^34 cm^-2 s^-1 → assume L = 250 fb-1
sqrt(s)=350 GeV, Lumi=1.0 x 10^34 cm^-2 s^-1 → assume L = 333 fb-1

Polarization: **(-0.8, + 0.3)** → compare with (+0.8, -0.3)

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

250 GeV

eLpR	cross sec	weight
higgs	17.14	0.146
BG in order of large cross section		
2f_Z_l	21226.4	1.46
4f_ZZWWMix_l	1636.04	0.583
4f_WW_l	1564.21	0.573
4f_ZZ_sl	1422.14	0.583
4f_singleZee_l	1084.1	0.581
4f_singleZnn_l	192.75	0.47
4f_ZZ_l	157.96	0.578

after all cuts, dominant BG are:

sqrt(s) = 250 GeV : #1) 2f_Z_l #2) 4f_ZZ_sl #3) 4f_ZZWWMix_l

sqrt(s) = 350 GeV : #1) 4f_ZZ_sl #2) 2f_Z_l #3) 4f_WW_sl

no ttbar BG left after data selection

Summary

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

- **optimized data selection method**
- Compared cross section error with (without) considering BG MC statistics

- updated results:
  250 GeV:
- **ε_sig = 61.4 +/-0.4 %,** S/B ~ 0.4, **significance ~21.4**
  Δσmeas> / <σmeas> = 4.7 % (6.4%)
  fitted recoil mass : 125.2 GeV +/- 70 MeV

  350 GeV:
- **ε_sig = 40.4 +/-0.4 %,** S/B ~ 0.42, **significance ~16.6**
  Δσmeas> / <σmeas> = 6.0 % (8.8%)
- fitted recoil mass : 125.6 +/- 0.3 GeV

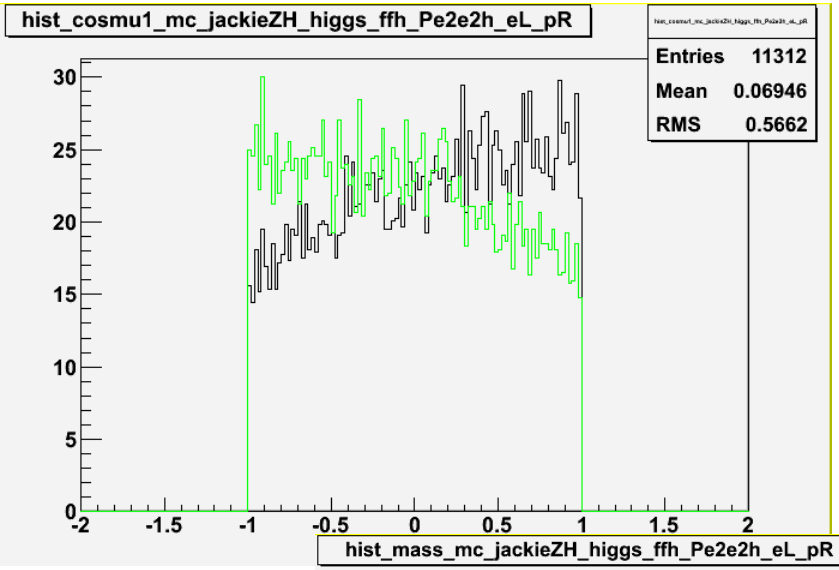
- Compared different **polarization** scenarios : **(-0.8, 0.3) vs (+ 0.8, -0.3) vs (-0.8 ,0)**

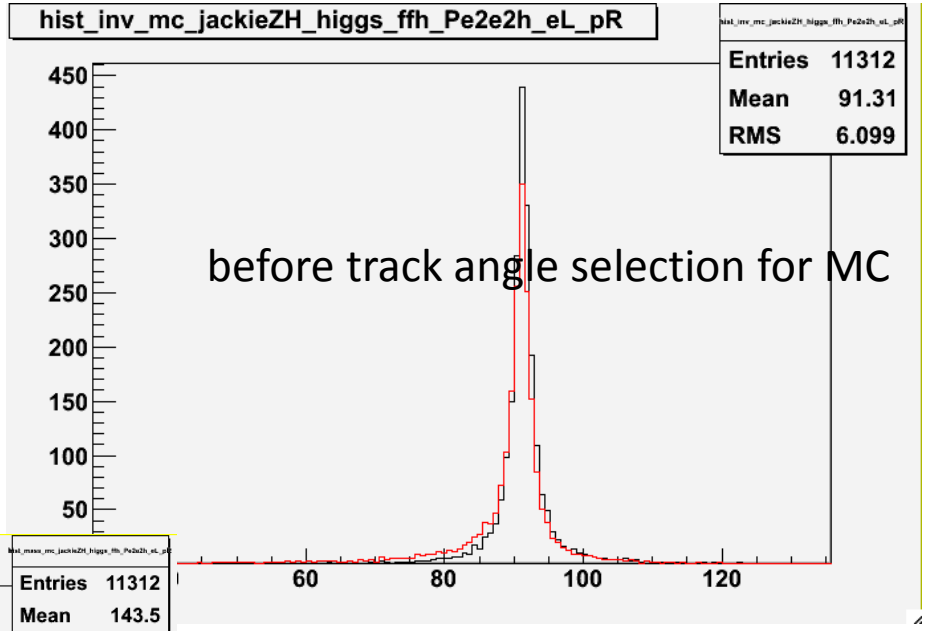
Further Plans

- **focus on analysis at Ec.m.s. = 350 GeV**

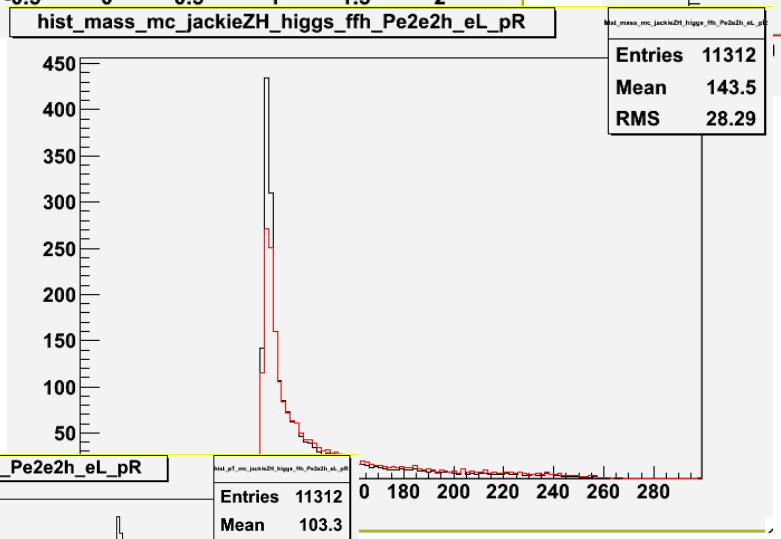
- **how to cut much more BG without losing too much signal ?**
  - further optimization of data cut values, add dPT,bal cut

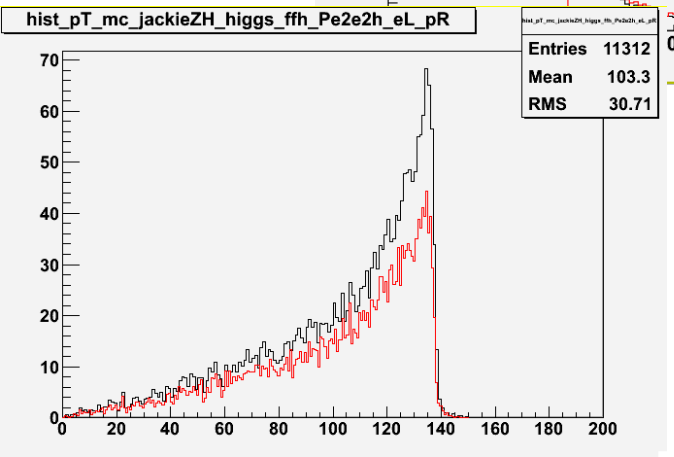
- **improve fitting method**
  - Multiple step fitting, fix values from previous fit
  - evaluate efficiency by integrating fitted curve (c.f. integrate histogram**)**

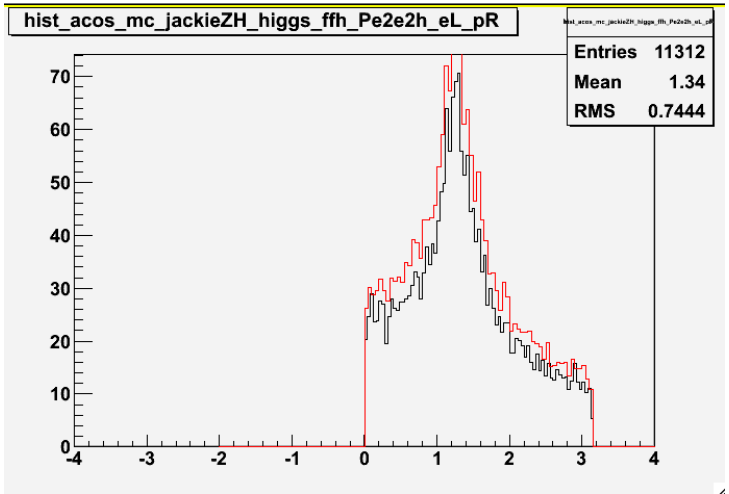




before track angle selection for MC







Muon Selection

- reject neutrals
- Ptot > 5 GeV
- small E_cluster / P_total < 0.5
- opposite charge
- ■ Best track selection
  cos(track angle) < 0.98
  |D0/δD0| < 5

Best Z Candidate Selection

2 mu candidates with **opposite charge**

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

Final Selection for 350 GeV

- 84 GeV < M_mumu < 98 GeV
- 10 GeV < pT_mumu < 140 GeV
- coplanarity < 3
- |cos(θ_Zpro)| < 0.91
  (Z production angle)
- 123 GeV < Mrecoil < 135 GeV

calculate recoil mass with correction for 14 mrad beam crossing angle

Evaluated within range of 123 – 135 GeV

L = 333 fb-1

<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

if only L = 250 fb-1

<n> = 694 +/- 20

<ε> = 40.4 +/- 0.4 %

<n>/sqrt(<n>+<B>) = 14.4

<n>/<B>=0.42

Δσmeas> / <σmeas> = 6.9 %

9.5% if consider BG uncertainty

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

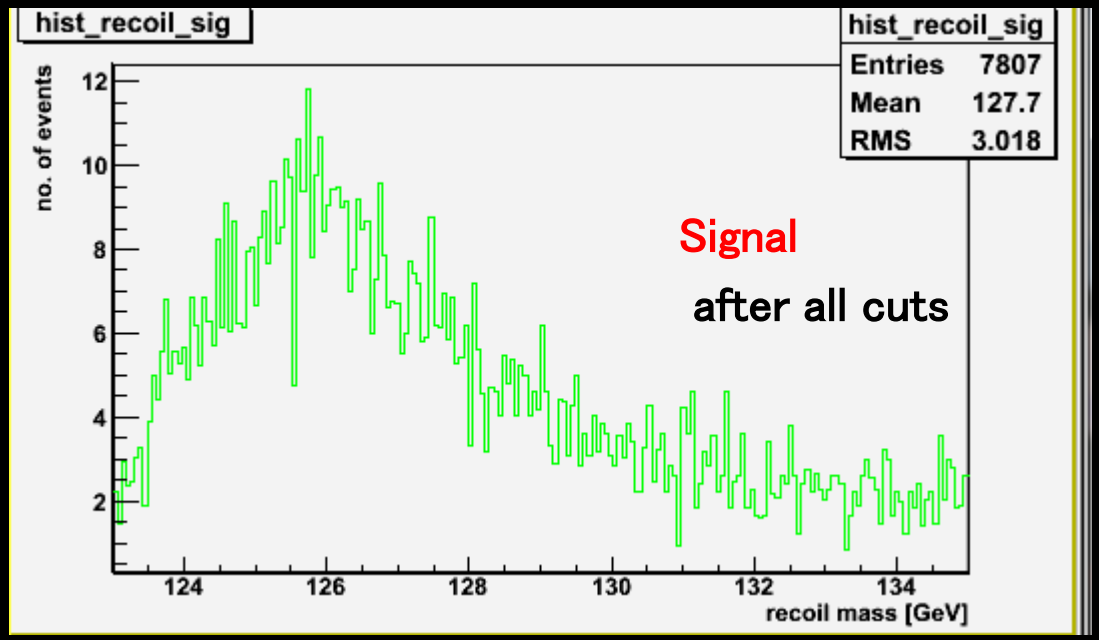
Δσmeas> / <σmeas> = 6.8 %
9.2% if consider BG uncertainty

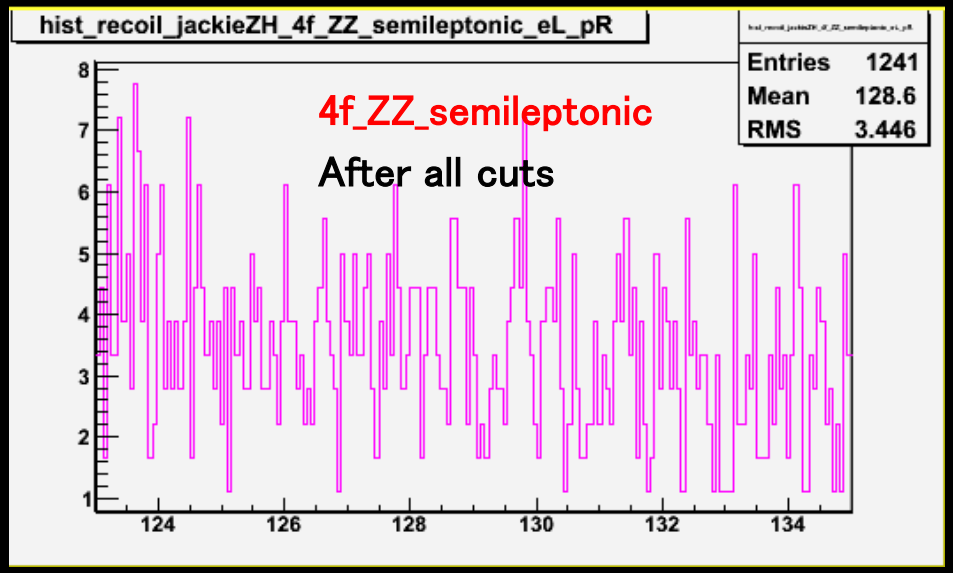
recoil mass 350 GeV

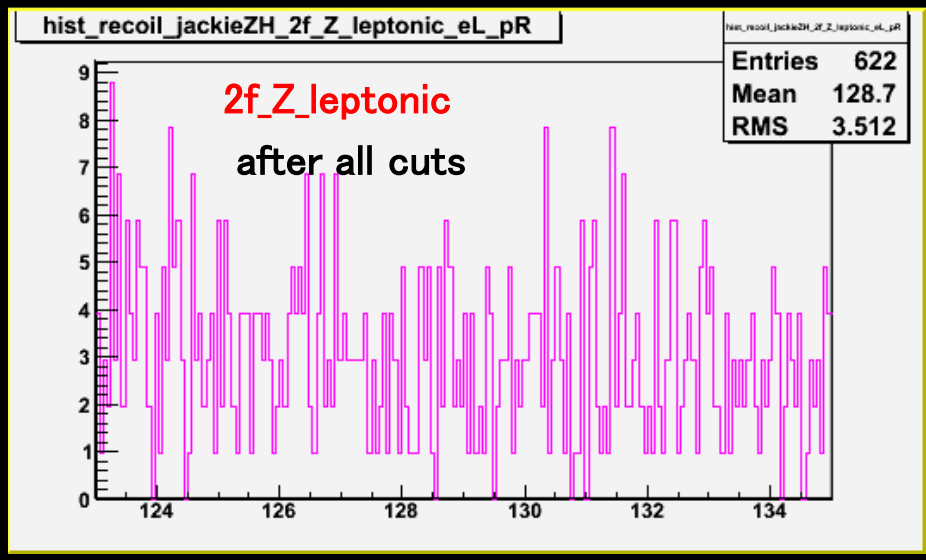
After cuts

There is still too much BG left

covers up signal peak !!



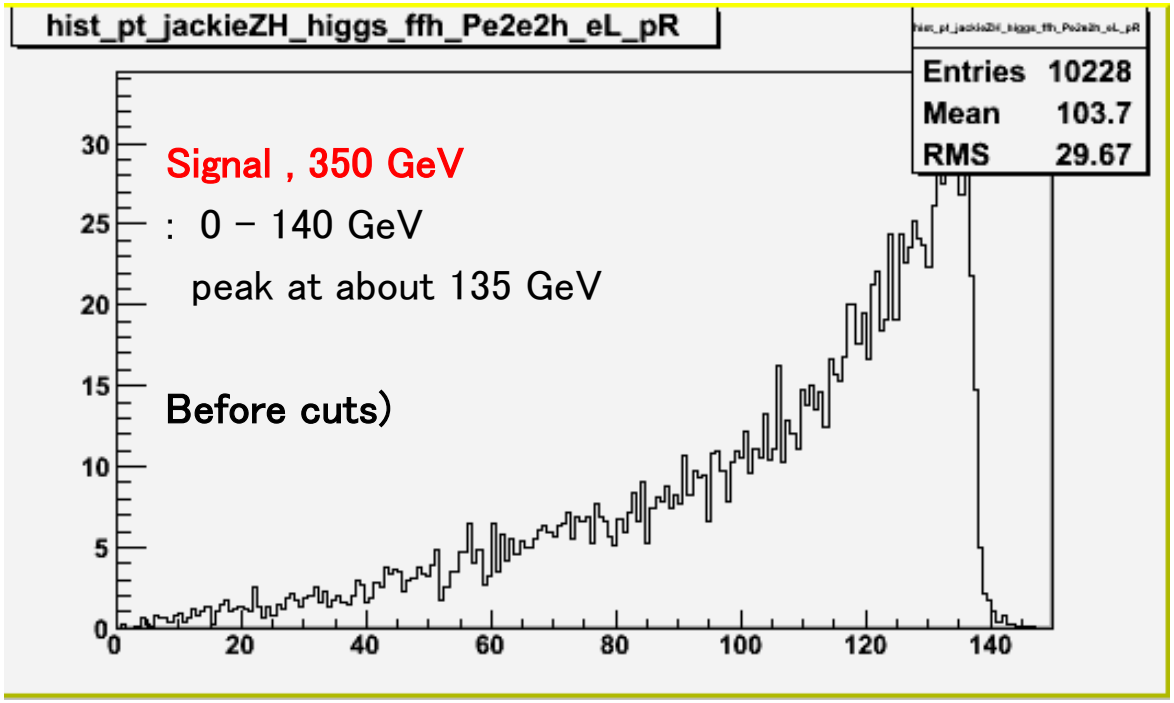


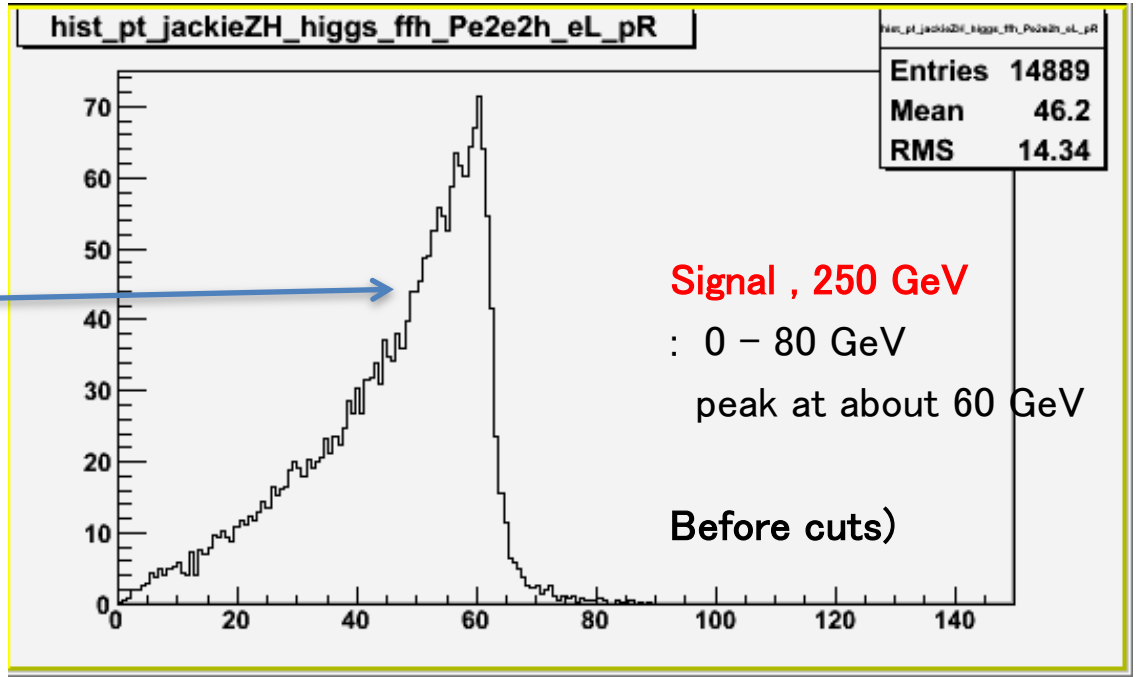


dilepton PT, 350 GeV

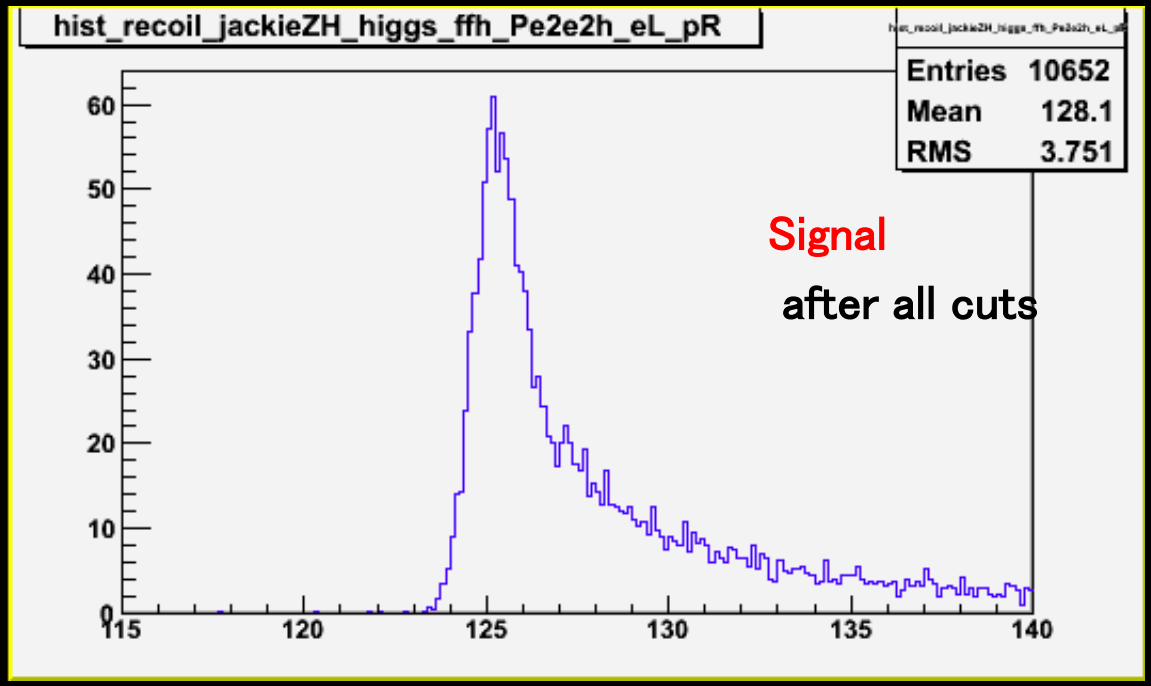
do cut :

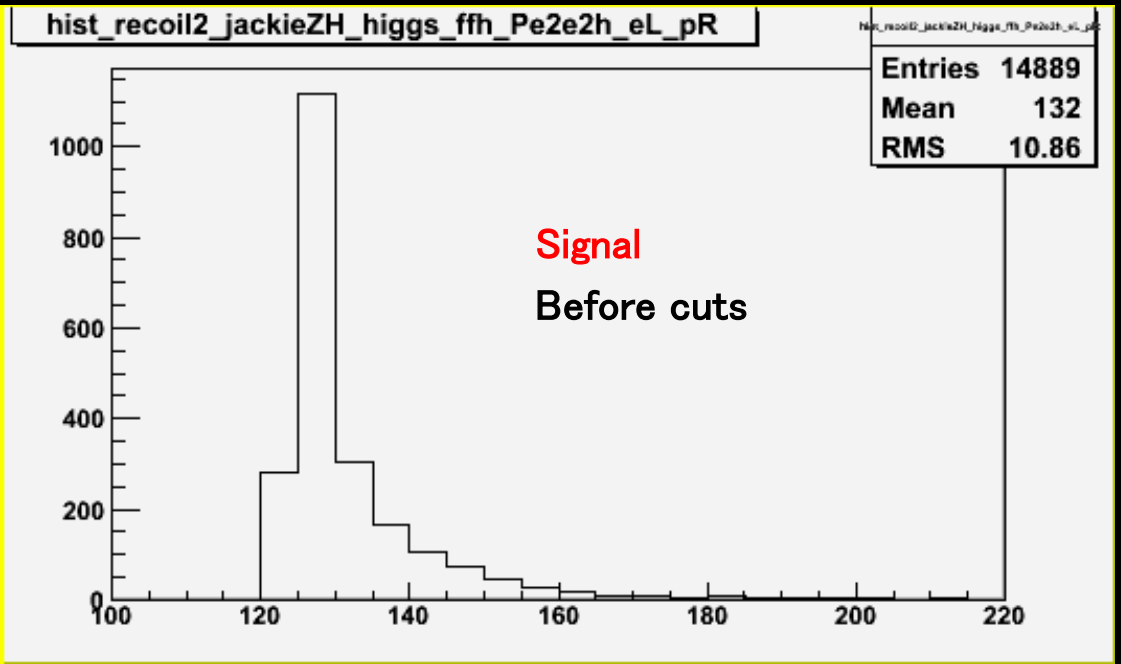
10 GeV< pT_dl < 140 GeV





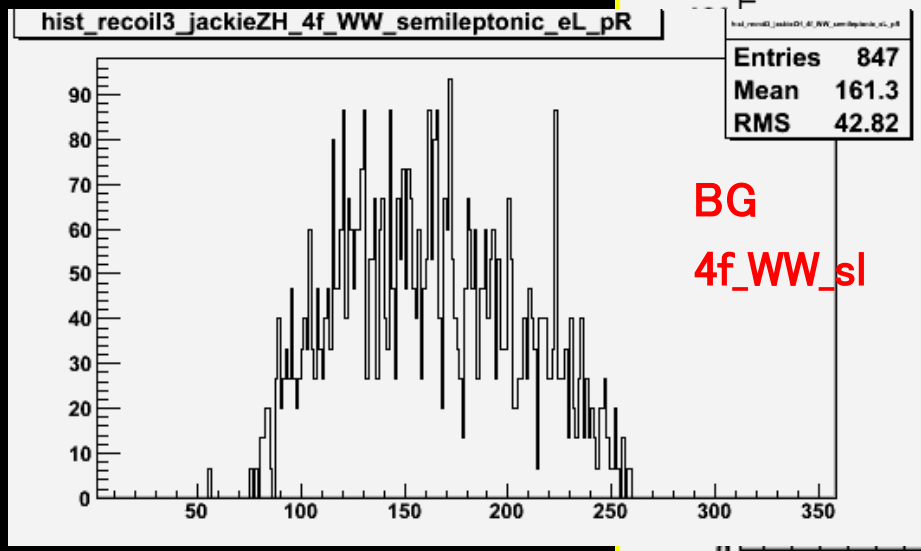
recoil mass of signal, 250 GeV

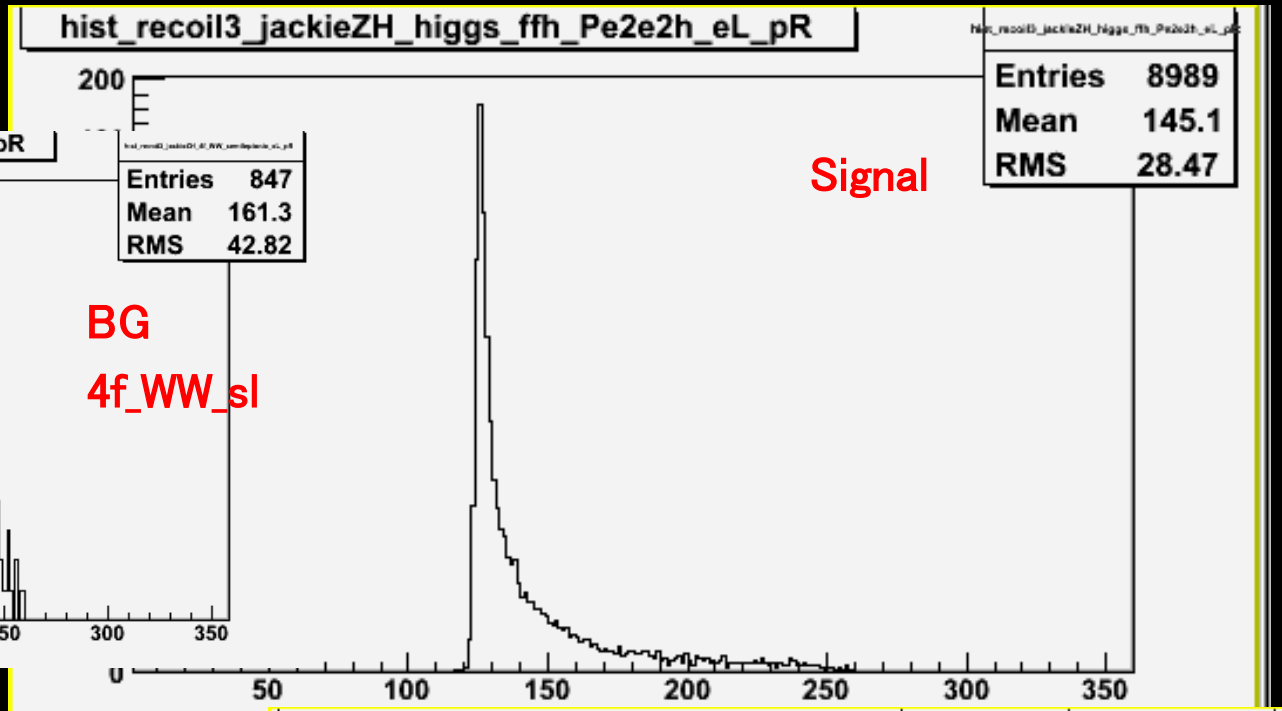


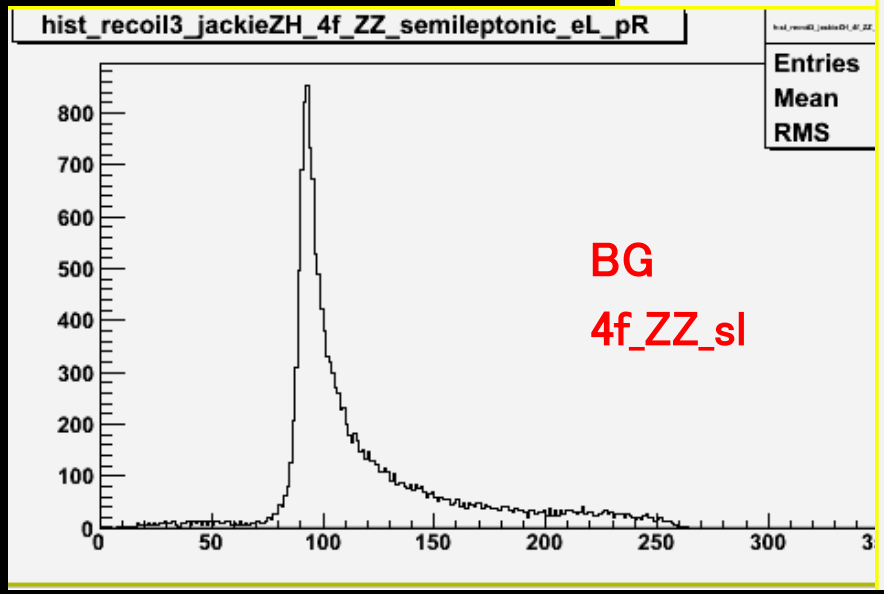


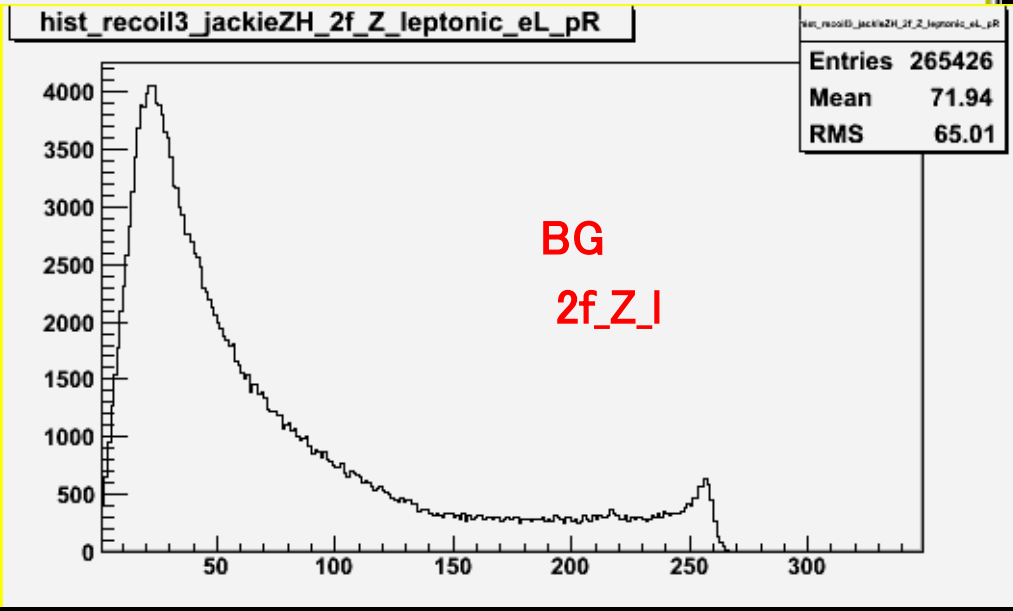
recoil mass 350 GeV

After inv mass cut



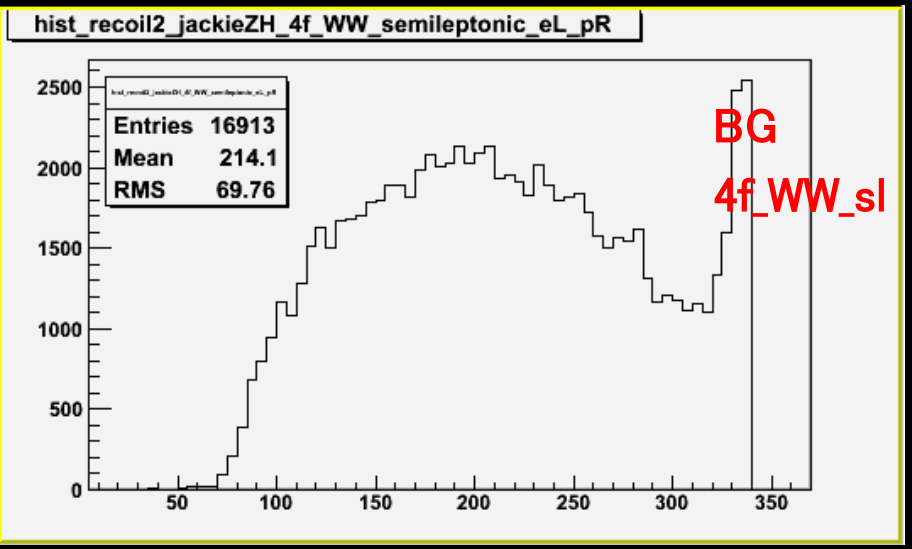


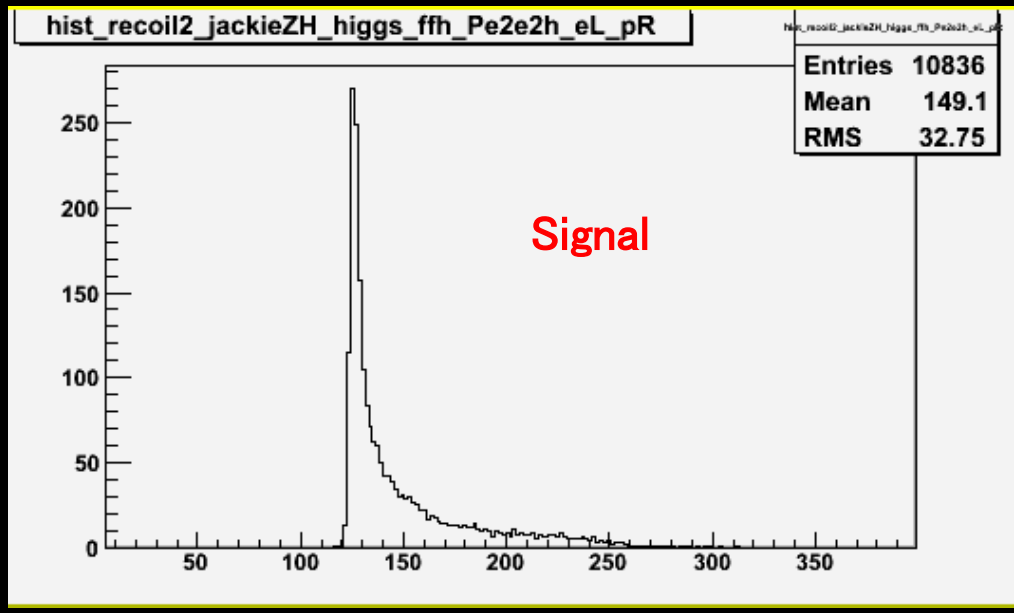


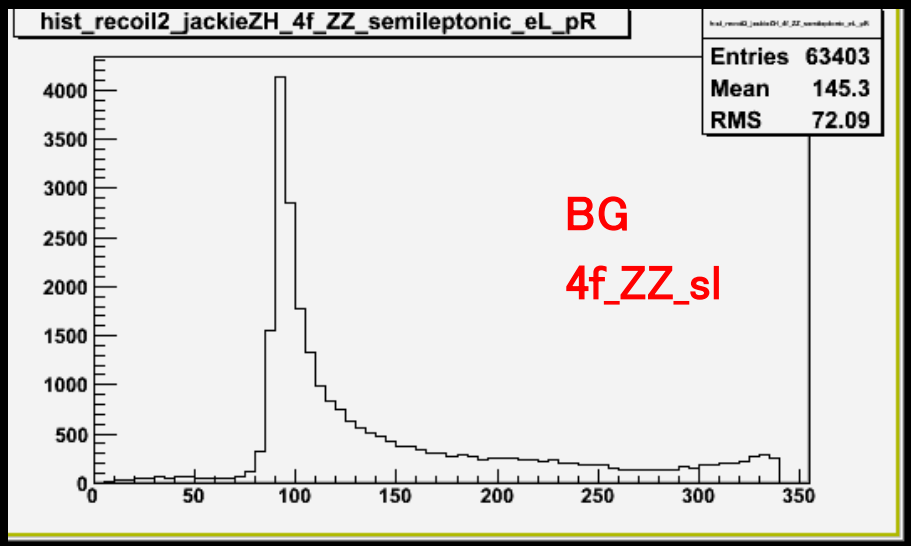


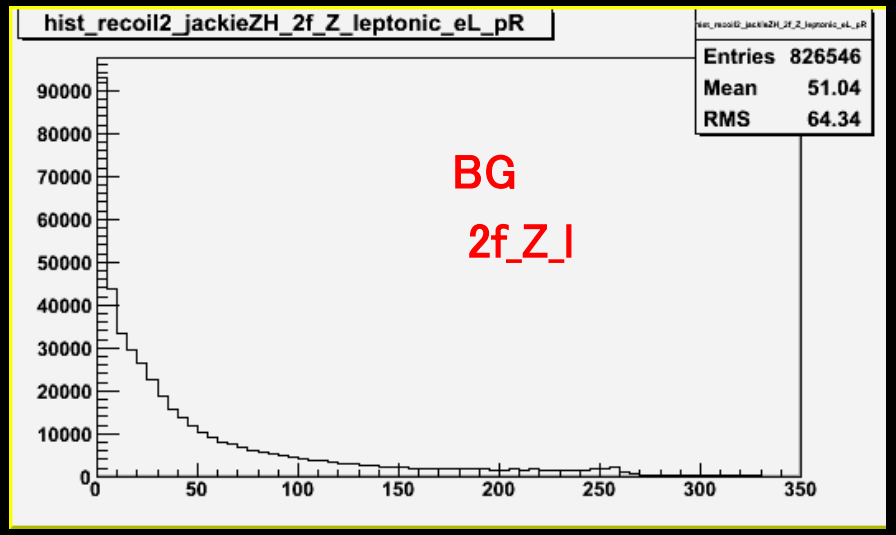
recoil mass 350 GeV

Before cut



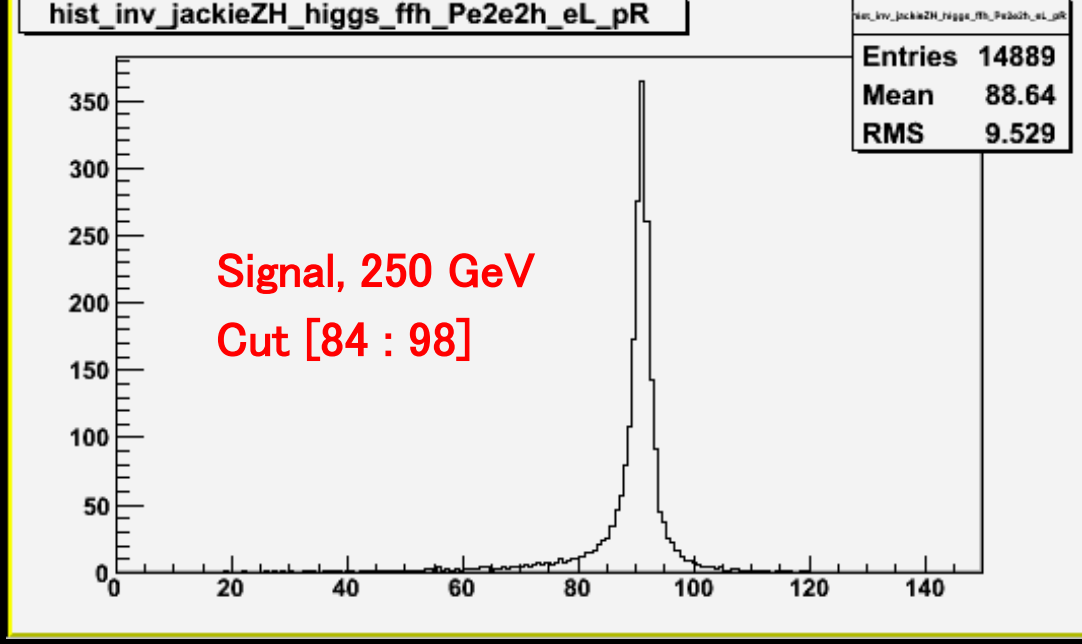


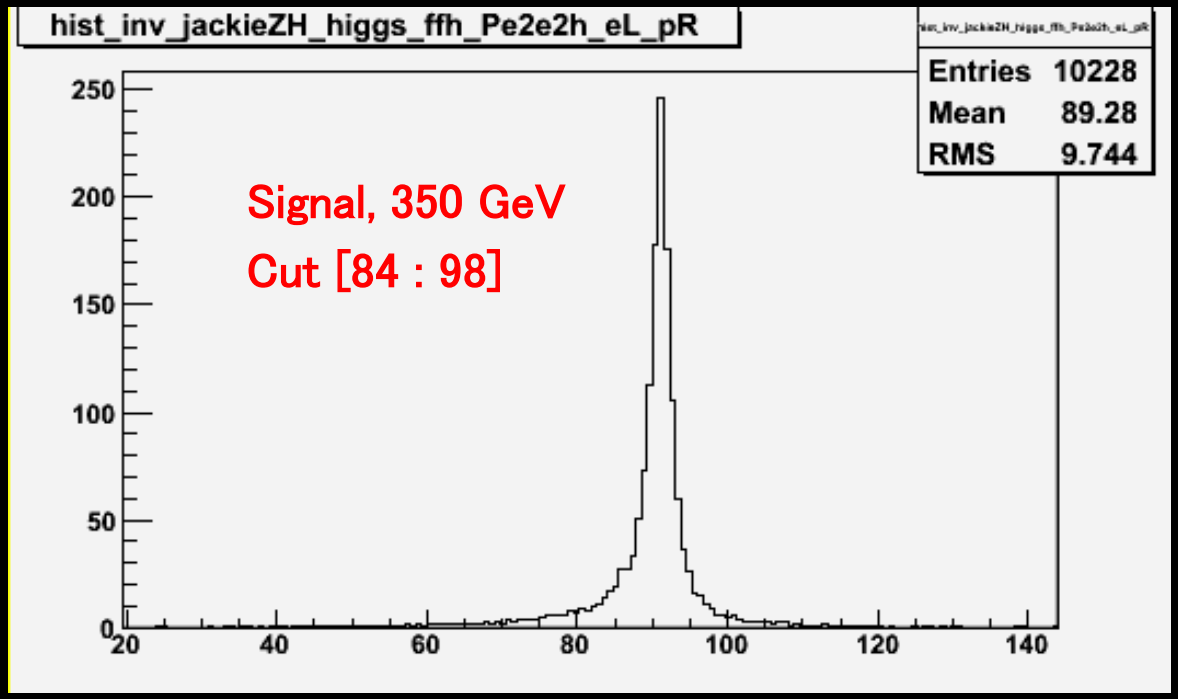




invariant mass

before cut

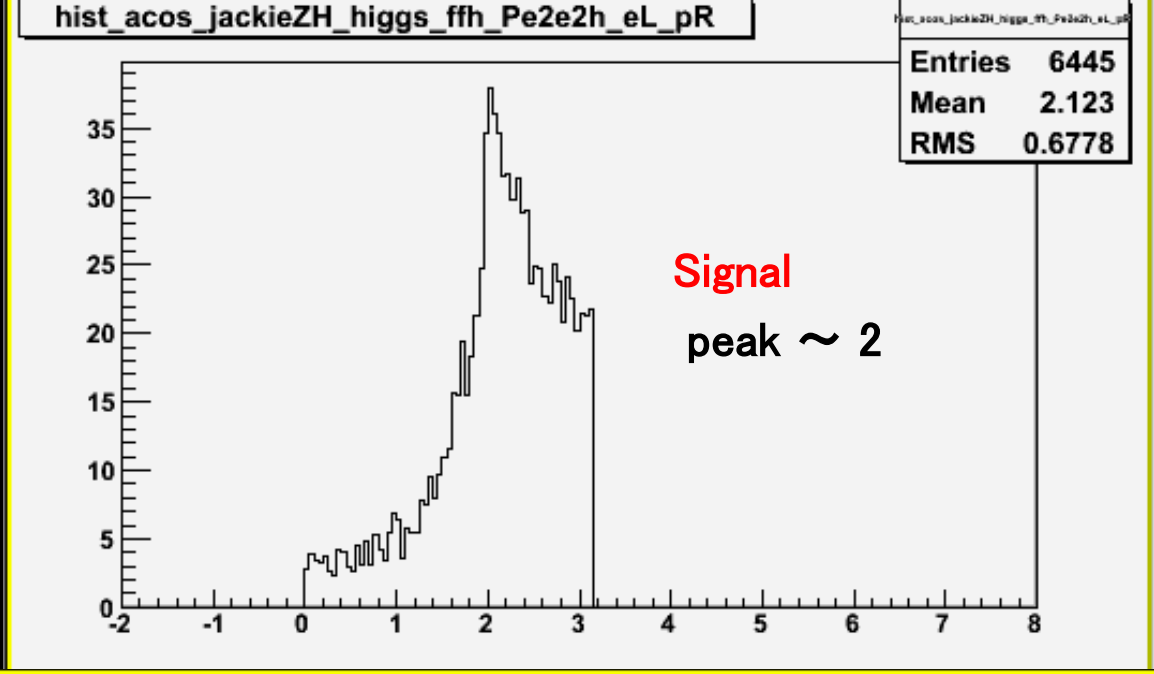


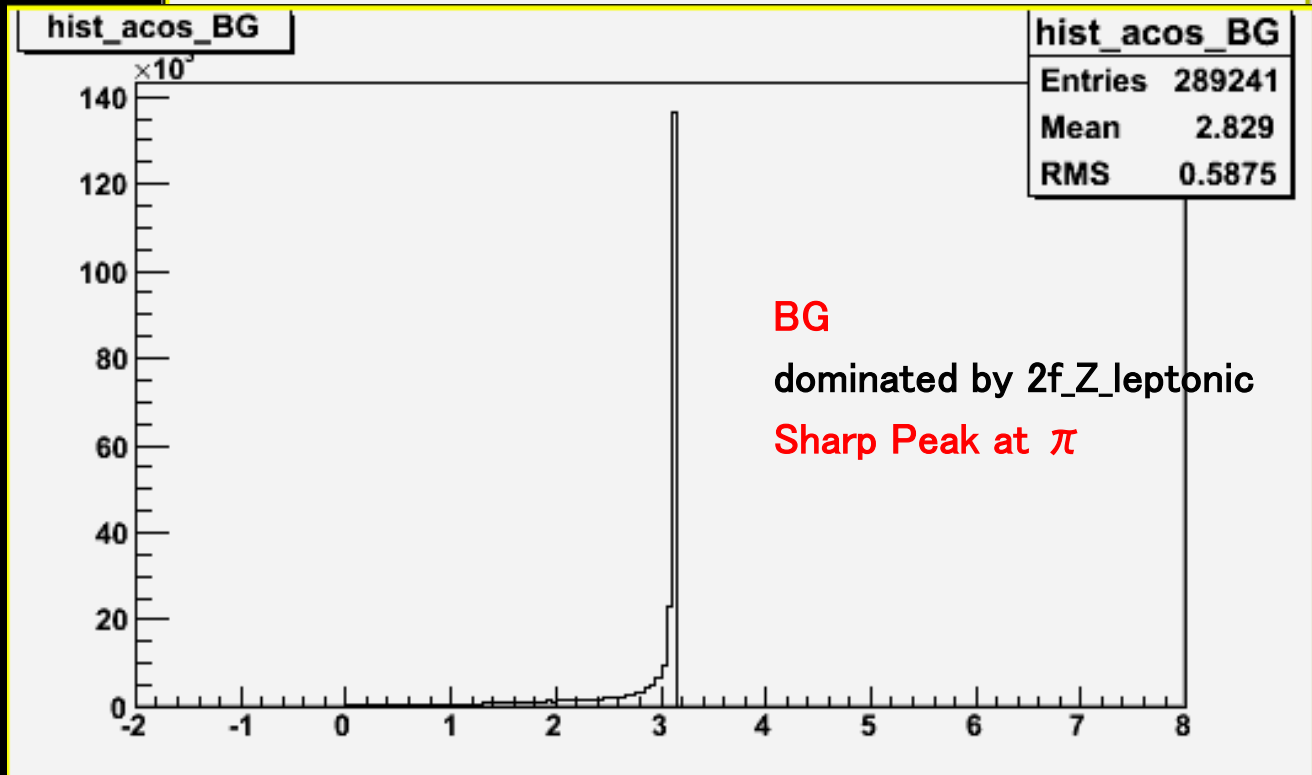


coplanarity, before cut ,
250 GeV

No coplanarity cut applied

wanted to maintain high signal eff.



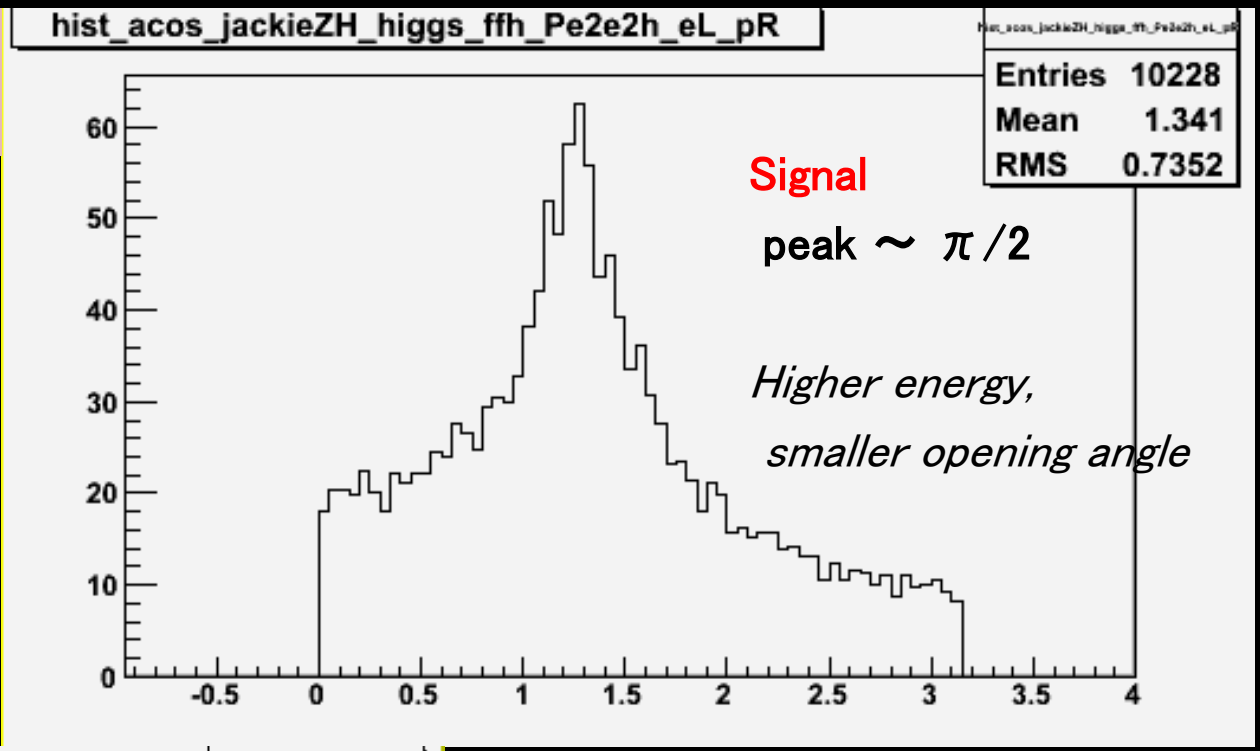


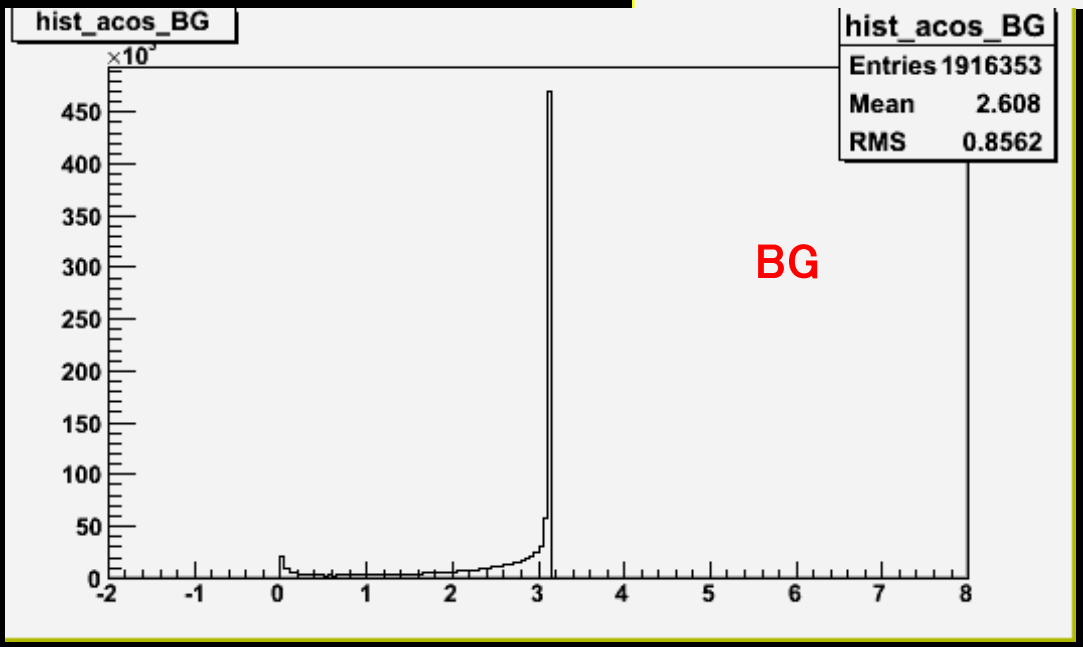
coplanarity, before cut 350 GeV

Cut:

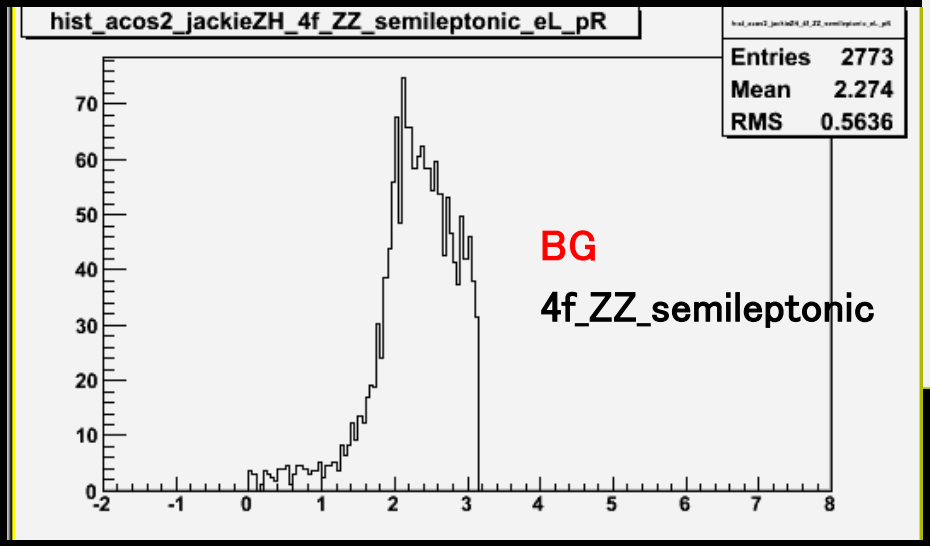
coplanarity ＜ 0.29

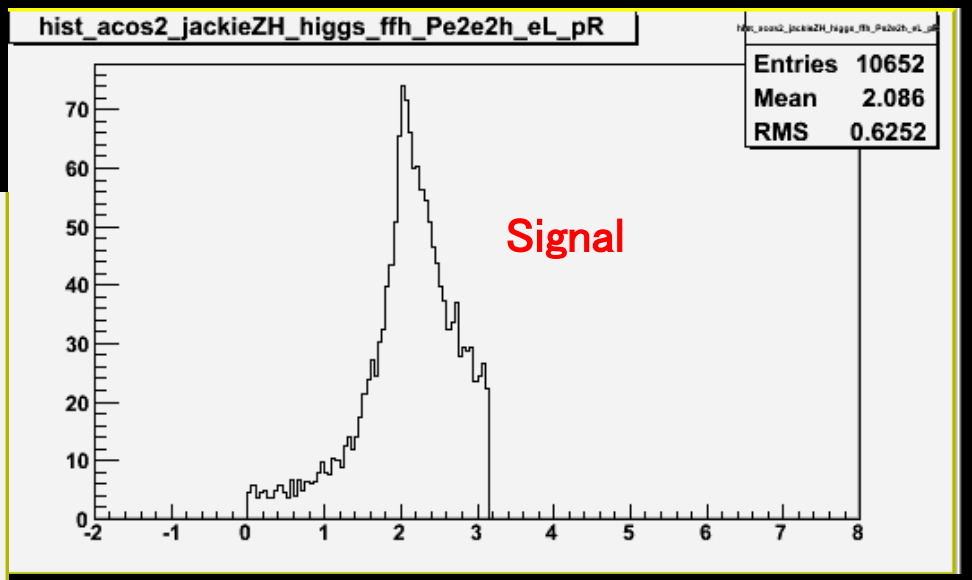
in order to remove more BG



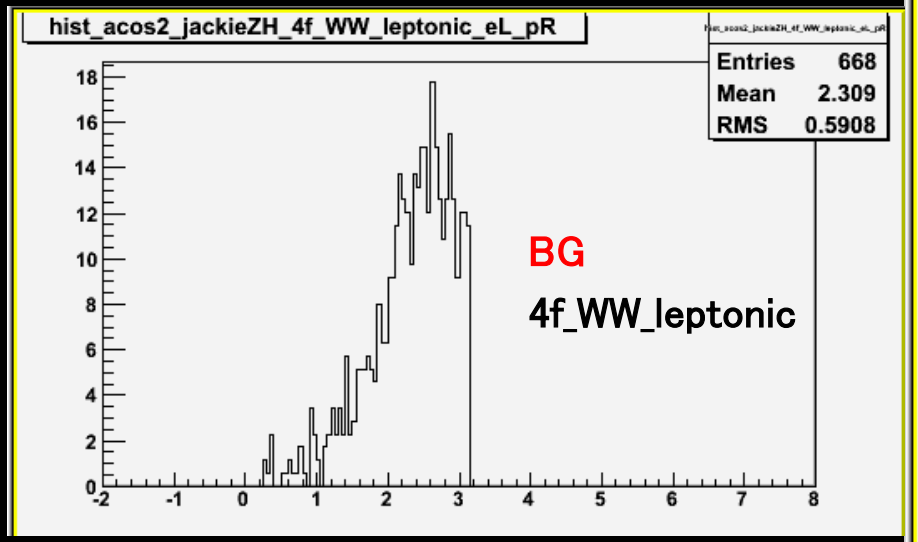


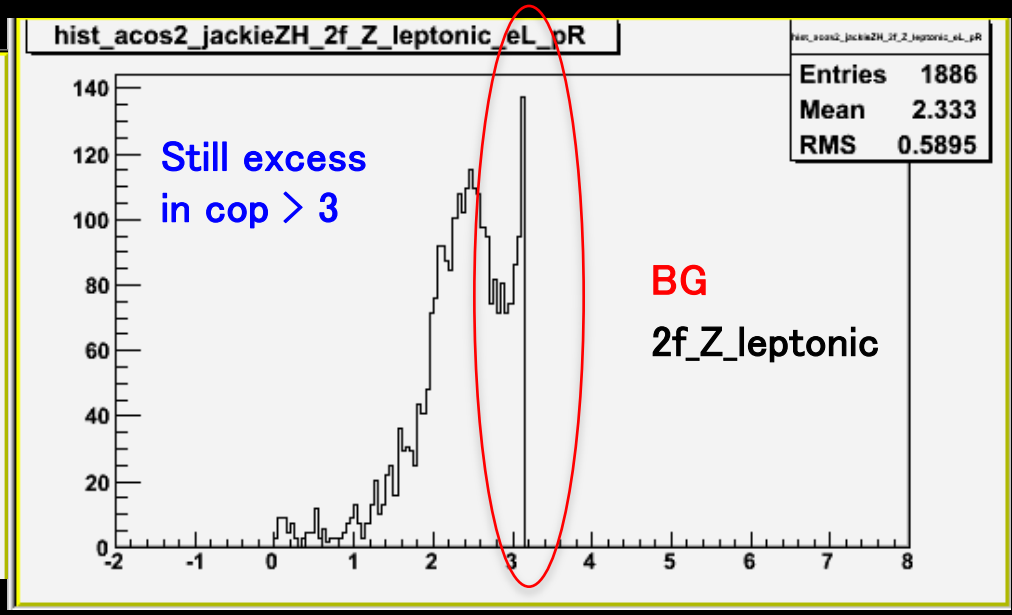
coplanarity, after all other cuts





Trying to decide whether to use coplanarity cut





Z production angle

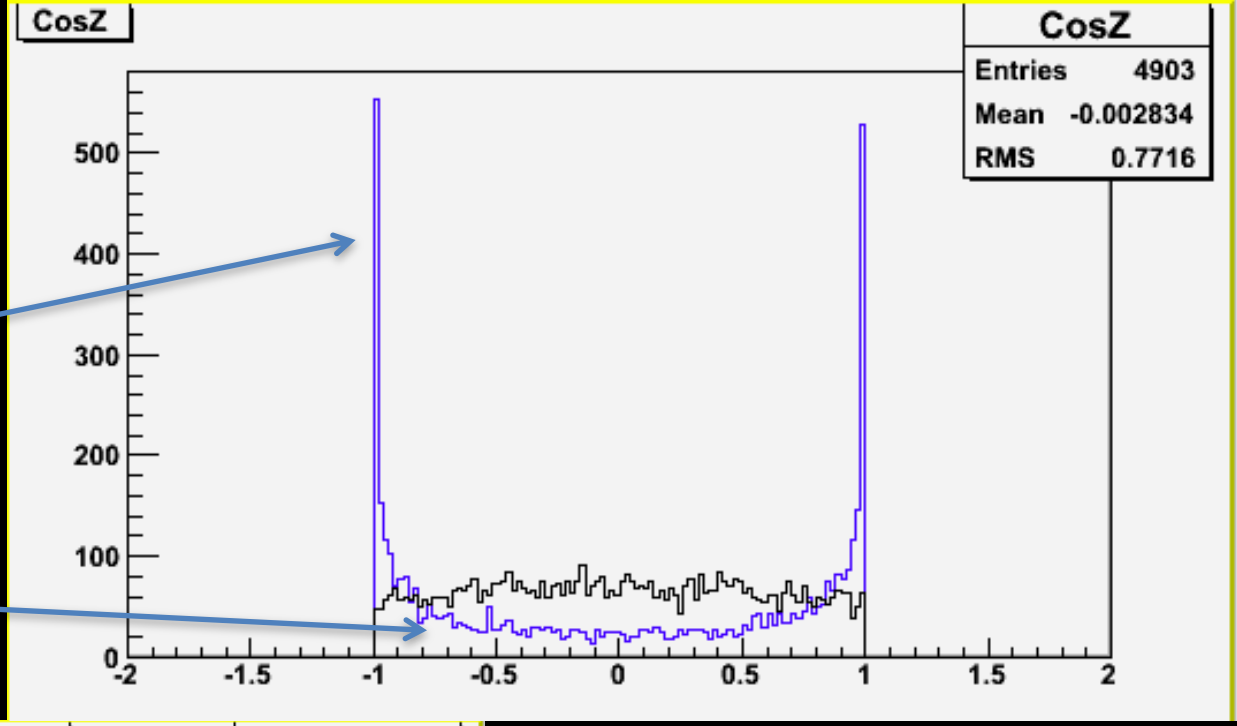
blue: BG (4f_ZZ_l

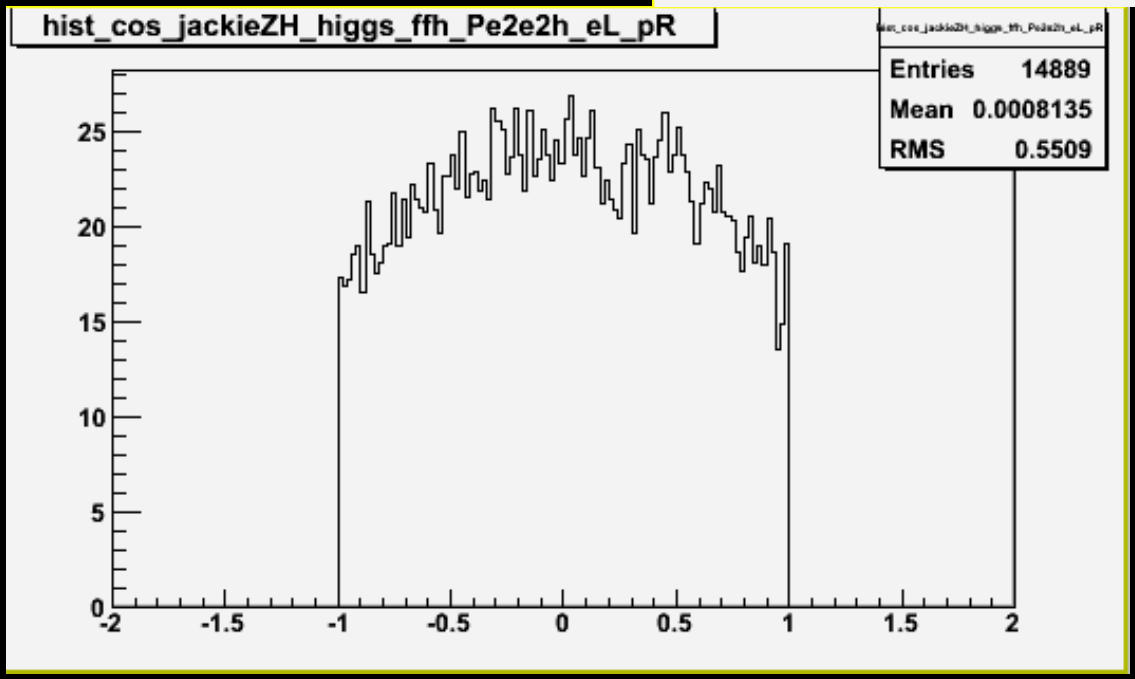
very forward

→ use for cut

Black: Signal

isotropic



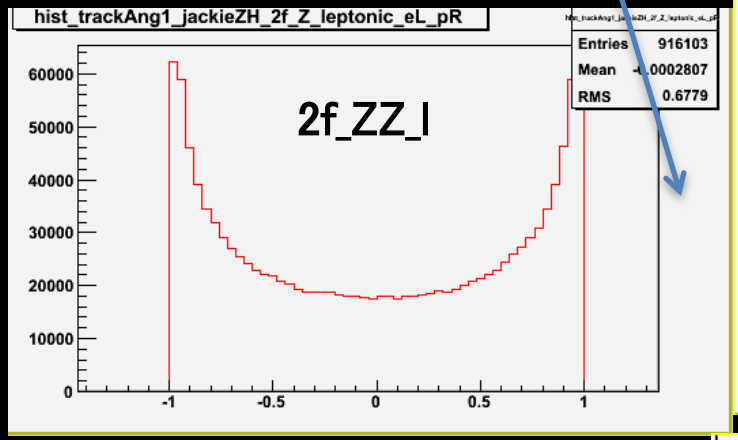


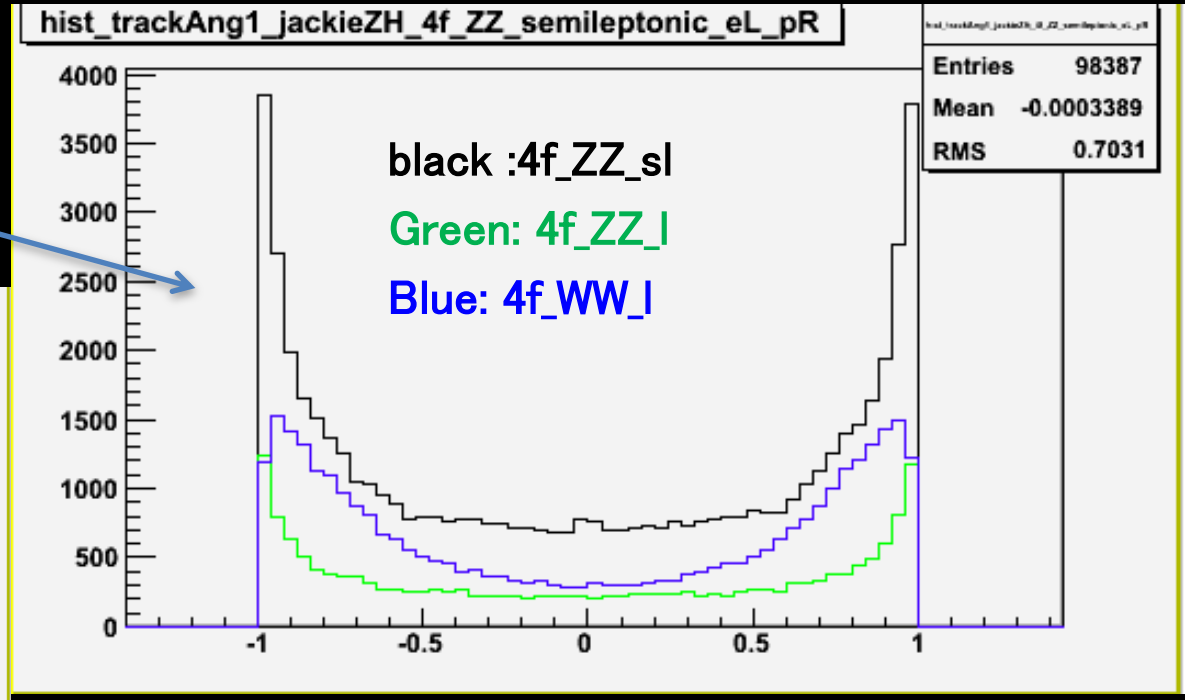
do cut :

$|\cos(\theta\_Zpro)| < 0.91$

Cos(track angle) ,
250 GeV

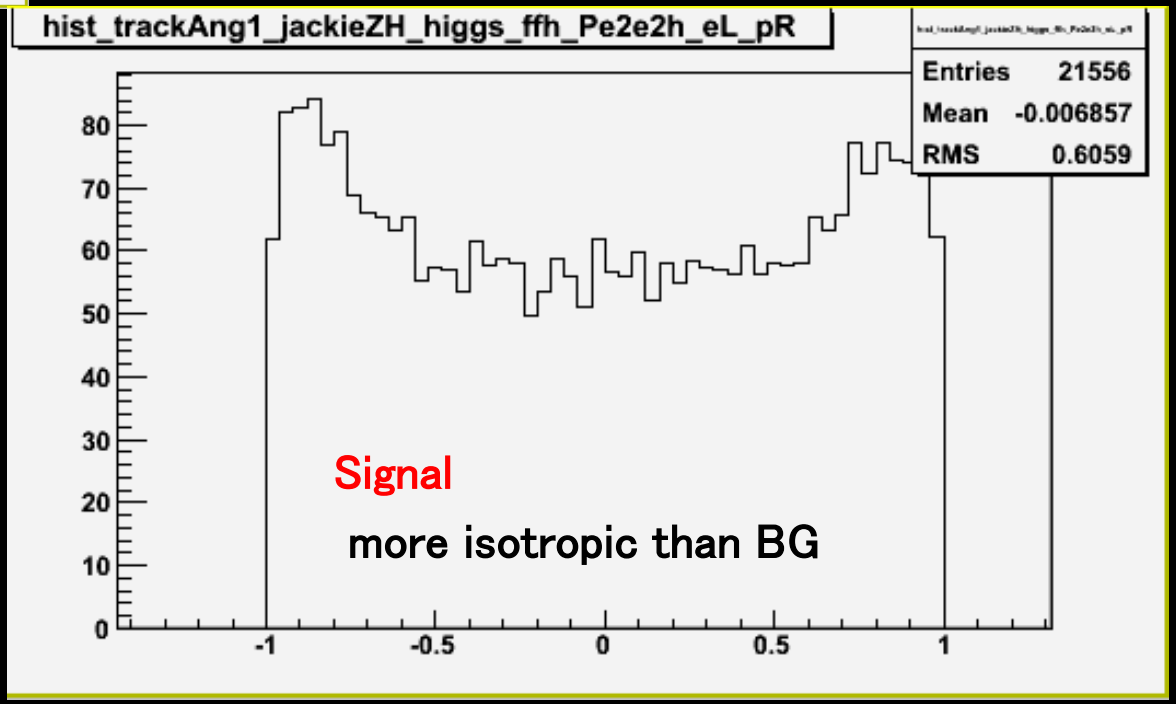
BG is More forward





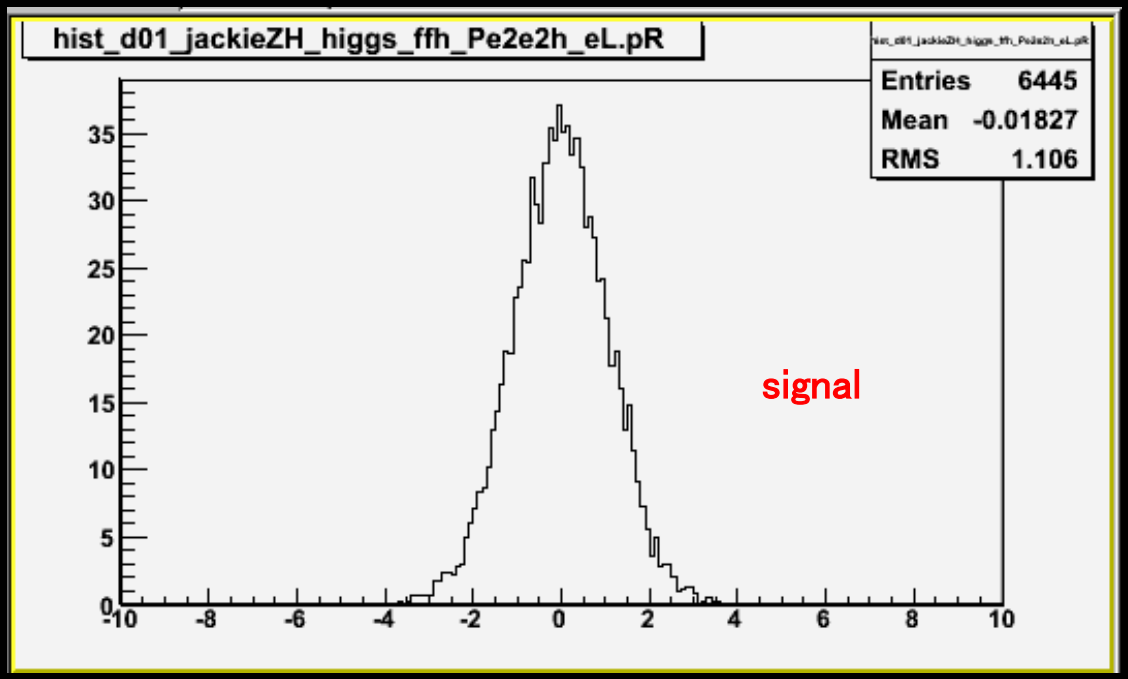
do cut :

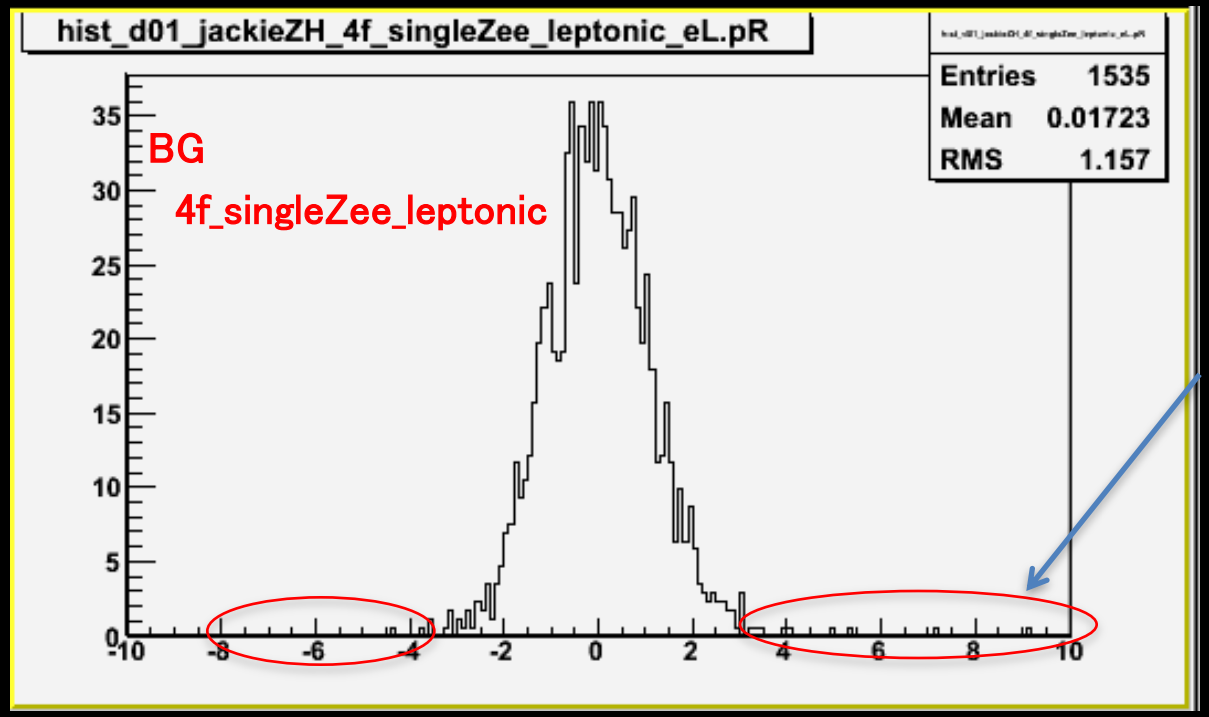
cos(trackAngle) < 0.95



Impact parameter

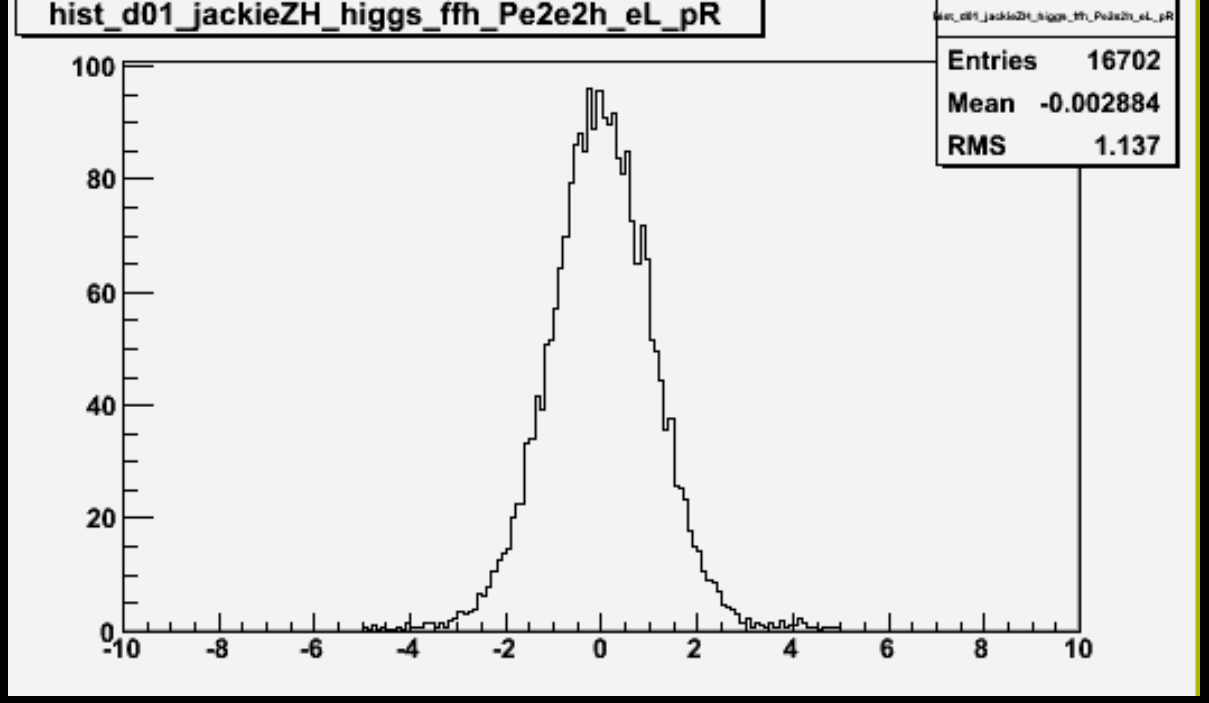
D0/ δ D0

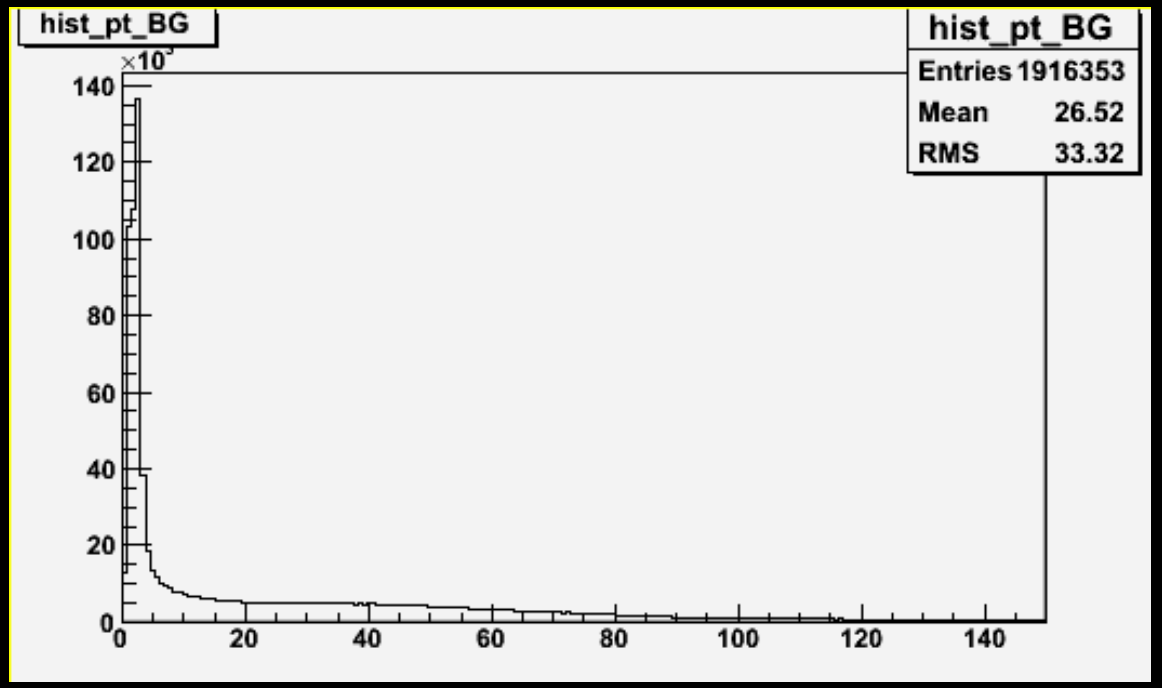




For some BG processes exceed +/− 4 slightly

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