

Higgs Recoil Mass Study

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**recoil mass study using $e^+e^- \rightarrow Zh \rightarrow \mu^+\mu^-h$
@ $E_{c.m.s.} = 250 \text{ GeV}$, $L = 250 \text{ fb}^{-1}$**

Goal:

precise measurement of Higgs mass

Dimuon recoil mass \rightarrow peak @ $m_h \sim 125 \text{ GeV}$

measure Higgs without having to look directly at Higgs !!

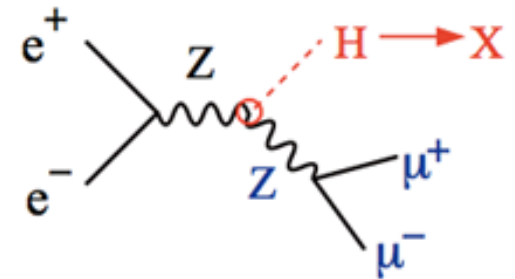
$e^+e^- \rightarrow Zh \rightarrow \mu^+\mu^-h$ process is important for

model independent measurement of absolute Zh coupling :

$$g_{hZZ}^2 \propto \Gamma(h \rightarrow ZZ^*) / \Gamma_{\text{tot}}$$

also useful for other couplings and branching ratios

polarization:
(e^-, e^+) = (0.8, 0.3)



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

$250 \text{ fb}^{-1} @ 250 \text{ GeV}$ $m_H = 125 \text{ GeV}$

$$\Delta\sigma_H / \sigma_H = 2.6\%$$

$$\Delta m_H = 30 \text{ MeV}$$

$BR(\text{invisible}) < 1\% @ 95\% \text{ C.L.}$

Samples

for now, only used eLpR and eRpL

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

Assign weight based on cross section, luminosity, polarization

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

Signal sample:

higgs_ffh/ILD_o1_v05/v01-16-p10_250

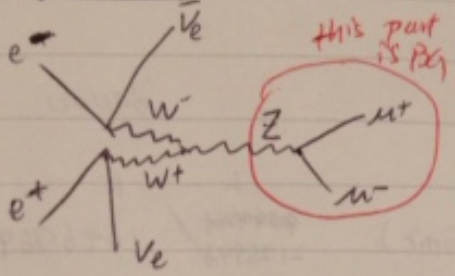
rv01-16-p10_250.sv01-14-01-p00.mILD_o1_v05.E250-TDR_ws.I106479.Pe2e2h.eL.pR-00001-DST.slcio

rv01-16-p10_250.sv01-14-01-p00.mILD_o1_v05.E250-TDR_ws.I106480.Pe2e2h.eR.pL-00001-DST.slcio

List of BG process for Zmumu

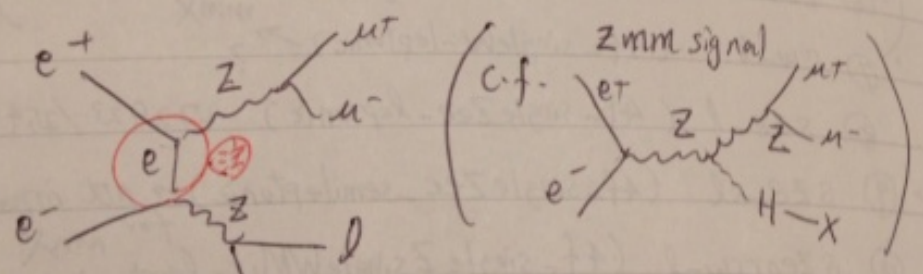
- 4f_ZZ_leptonic
- 4f_ZZ_semileptonic
- 2f_Z_leptonic
- 4f_WW_leptonic
- 4fSingleZee_leptonic
- 4fSingleZnu_nu_leptonic
- 4f_ZZWWMix_leptonic

single Zmumu



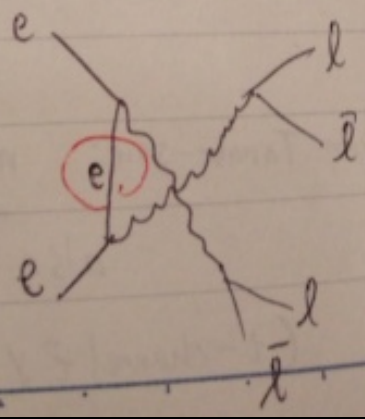
example diagrams for BG process for Zmumu

4f-ZZ-l

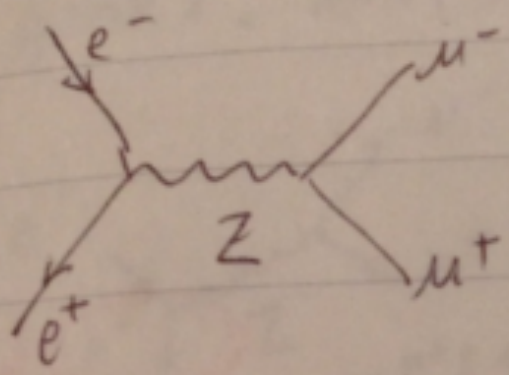


$e^+e^- \rightarrow$
 $\nu_e \bar{\nu}_e \mu^+ \mu^-$
 $e^+ e^- \mu^+ \mu^-$
 $\mu^+ \mu^- \mu^+ \mu^-$
 (or Z)?

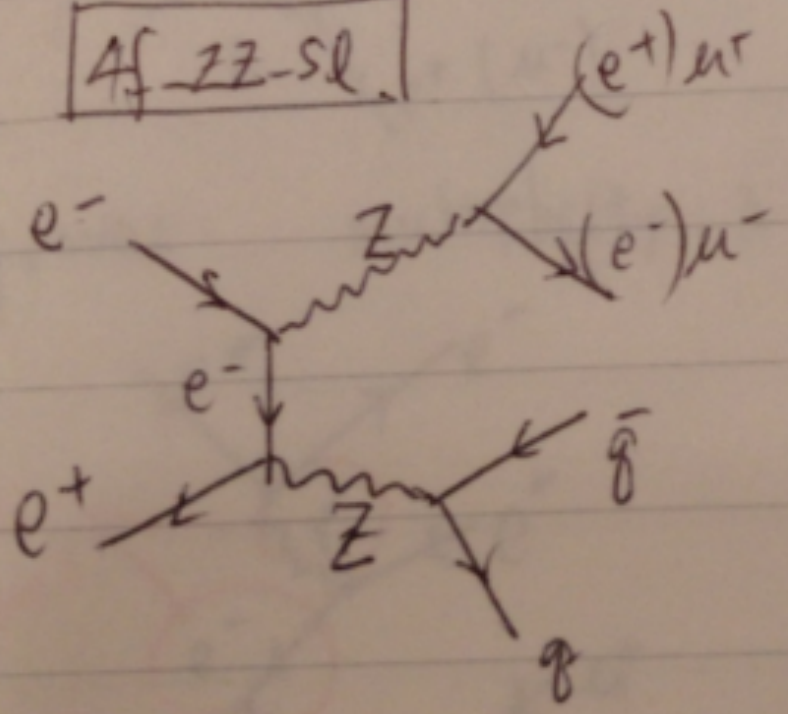
crossed



Z-l. (zf)



4f ZZ-sl



Primary Cut

(to select di-muons)

- reject neutrals
- $P_{tot} > 5 \text{ GeV}$
- $\text{small } E_{\text{cluster}} / P_{\text{total}} < 0.5$
- opposite charge



Final Selection criteria

analysis after filling root files

- $86 \text{ GeV} < M_{\text{inv}} < 95 \text{ GeV}$ (di-lepton invariant mass)
- $115 \text{ GeV} < M_{\text{recoil}} < 140 \text{ GeV}$
- $10 \text{ GeV} < p_{T_dilepton} < 70 \text{ GeV}$
- $|\cos(\theta_{Z\text{pro}})| < 0.91$ (Z production angle)
- $0.2 < \text{acoplanarity} < 3$
- $dP/P^2 < 5E-5$
- $|D0/\delta D0| < 4$

actually only effective for suppressing muons from tau decays

fitting for recoil mass

◆ **BG:** 3rd order polynomial

◆ **signal :** GPET:

5 parameters : Gaus (left-side) , Gaus + expo (right side)

$$N \exp \left\{ -\frac{1}{2} \left(\frac{x - x_{\text{mean}}}{\sigma} \right)^2 \right\} \quad (x < x_0 = 125.5 \text{ GeV})$$

$$N \left[b \cdot \exp \left\{ -\frac{1}{2} \left(\frac{x - x_{\text{mean}}}{\sigma} \right)^2 \right\} + (1 - b) \exp \left\{ -k \left(\frac{x - x_{\text{mean}}}{\sigma} \right) \right\} \exp(k^2 / 2) \right] \quad (x \geq x_0)$$

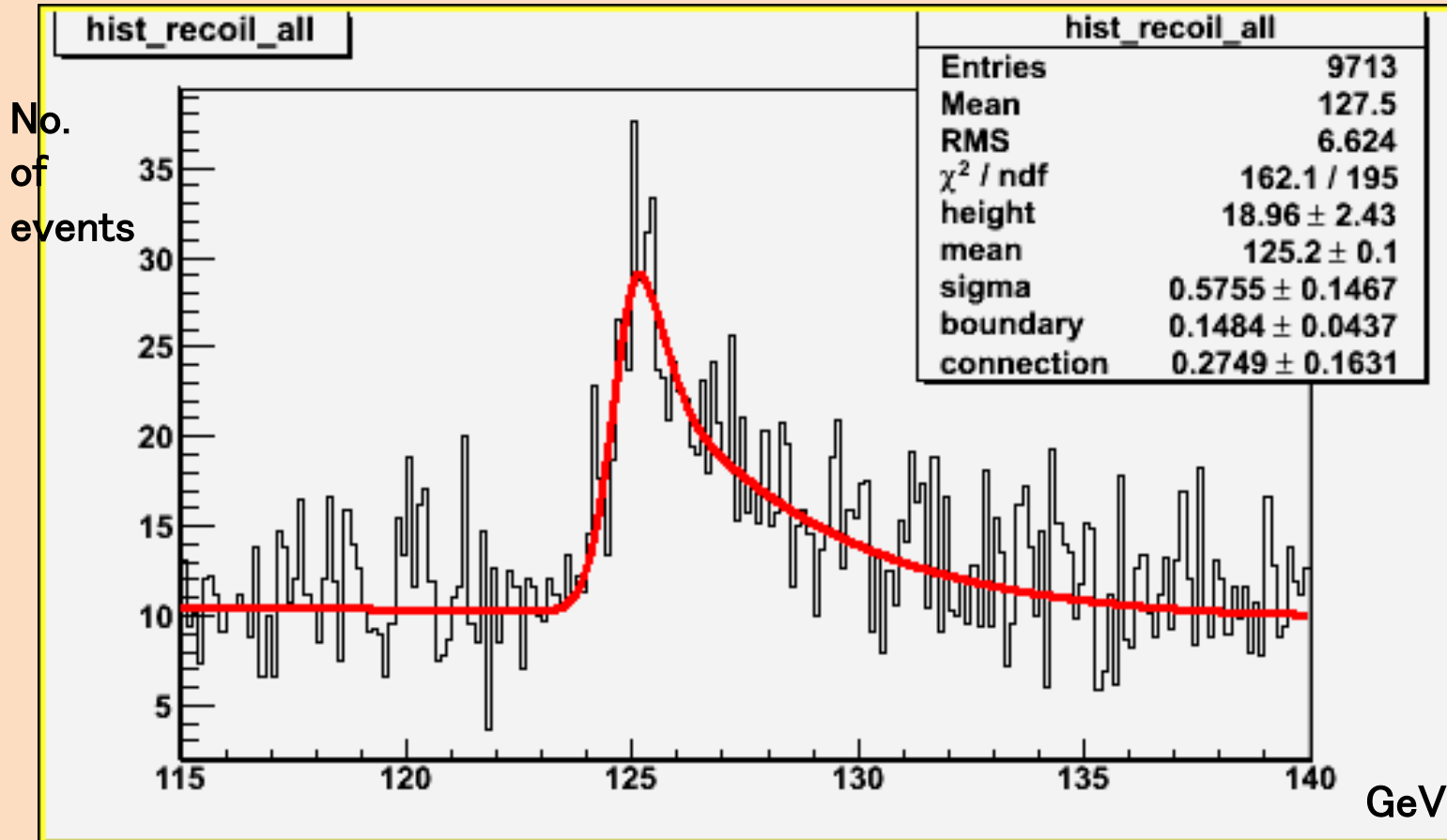
recoil mass

after implementing all cuts (see pg 5)

fitted recoil mass :

$$M_h = 125.2 \pm 0.1 \text{ GeV}$$

Corrected for 14 mrad beam crossing angle



BG Rejection Efficiency

cut	signal	eff	BG_all	eff	S/N
no cut	35795	100%	2196102	100%	0.02
M_inv	10574	29.54%	289241	13.17%	0.04
M_rec	9669	27.01%	14558	0.66%	0.66
P_Tdl	9532	26.63%	8792	0.40%	1.08
acop	8692	24.28%	7384	0.34%	1.18
θ_Z	8218	22.96%	6054	0.28%	1.36
dP/P ²	5820	16.26%	4195	0.19%	1.39
D0/ δ D0	5788	16.17%	3925	0.18%	1.47

Maybe cut too much signal

BG reduced to 0.2% !!

S/N improved to ~ 1.5

after M_rec cut


PT_dl, cos θ_Z , and acop cut seem quite effective for improving S/N

cut	4f_ZZ_l	4f_ZZ_sl	2f_Z_l	4f_WW_l	4fSingleZee_l	4fSingleZnn_l	4f_ZZWWMix_l
no cut	58330	145289	1606715	60118	97197	22282	206166
M_inv	7968	20901	246006	2360	2371	3535	6100
M_rec	827	2224	8169	930	295	626	1497
P_Tdl	750	2141	2676	910	277	598	1440
acop	629	1860	2001	780	240	530	1346
θ_Z	527	1634	1342	701	183	480	1193
dP/P ²	357	1224	895	356	123	373	867
D0/ δ D0	351	1208	891	126	121	372	856

Summary

- Higgs recoil mass study using $e^+e^- \rightarrow Zh \rightarrow \mu^+\mu^-h$ @ $E_{c.m.s.} = 250$ GeV, $L = 250$ fb⁻¹
- applied cuts using M_{inv} , M_{rec} , PT_{dl} , Z production angle, acoplanarity, dP/P^2 , $D0/\delta D0$
- after final selection: **signal \rightarrow 16%**, **BG \rightarrow 0.2 %** , **S/N \sim 1.4**
- **fitted recoil mass : 125.2 ± 0.1 GeV**
mass resolution is still not very good , need improvements in analysis method

Further Plans

- **optimize BG rejection efficiency**  *try not to cut so much signal ??*
- **what other types of cuts can I use ??**
- **include eLpL and eRpR, and other processes**
tau related , hadronic , ect..... (just to be sure)
- **estimate mass resolution using pseudo-experiments**
(generate Toy-MC events according to histogram / fitted function, *try both !!*)
- **try analysis at $E_{c.m.s.} = 350$ GeV (??)**

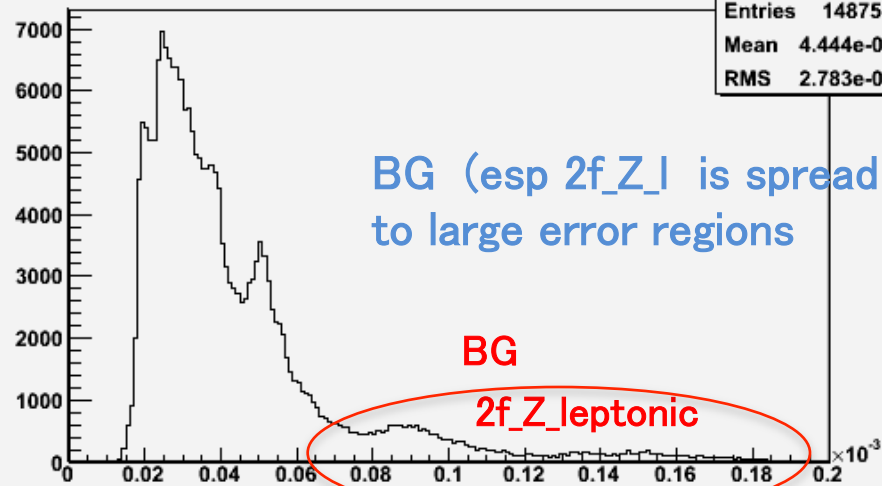
Comparison of Some Parameters between Signal and BG Processes

good track selection

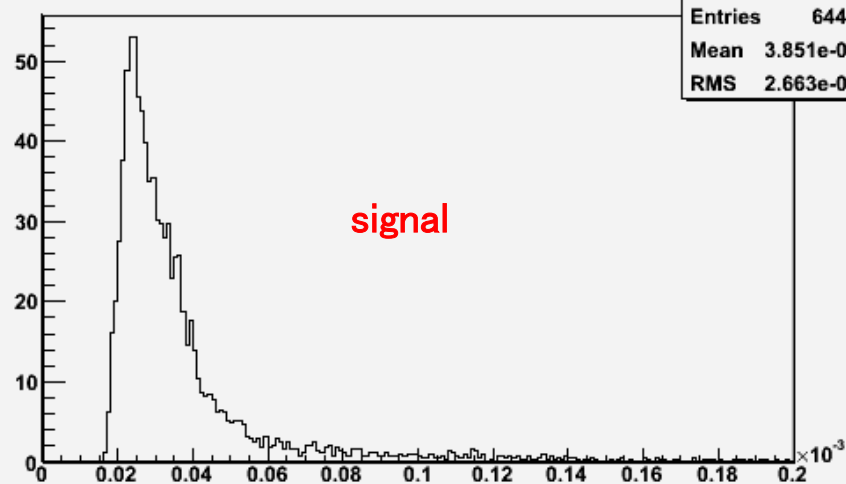
dP/P^2

do cut : $dp/p^2 < 5E-5$

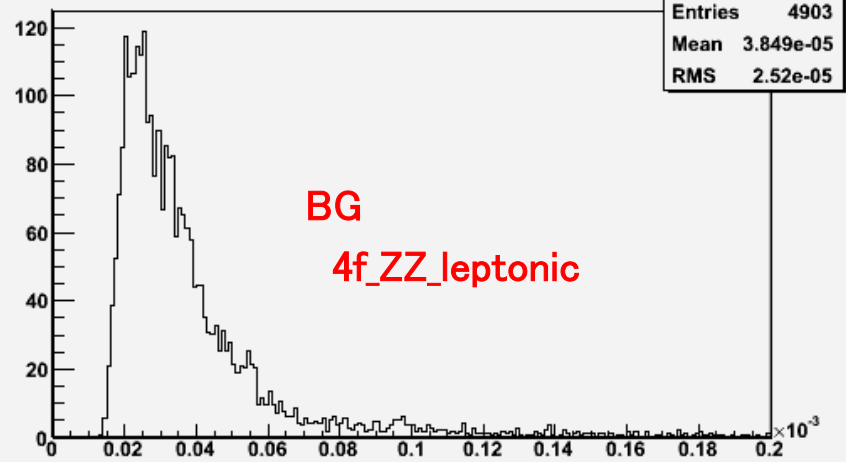
hist_track1_jackieZH_2f_Z_leptonic_eL.pR



hist_track1_jackieZH_higgs_ffh_Pe2e2h_eL.pR



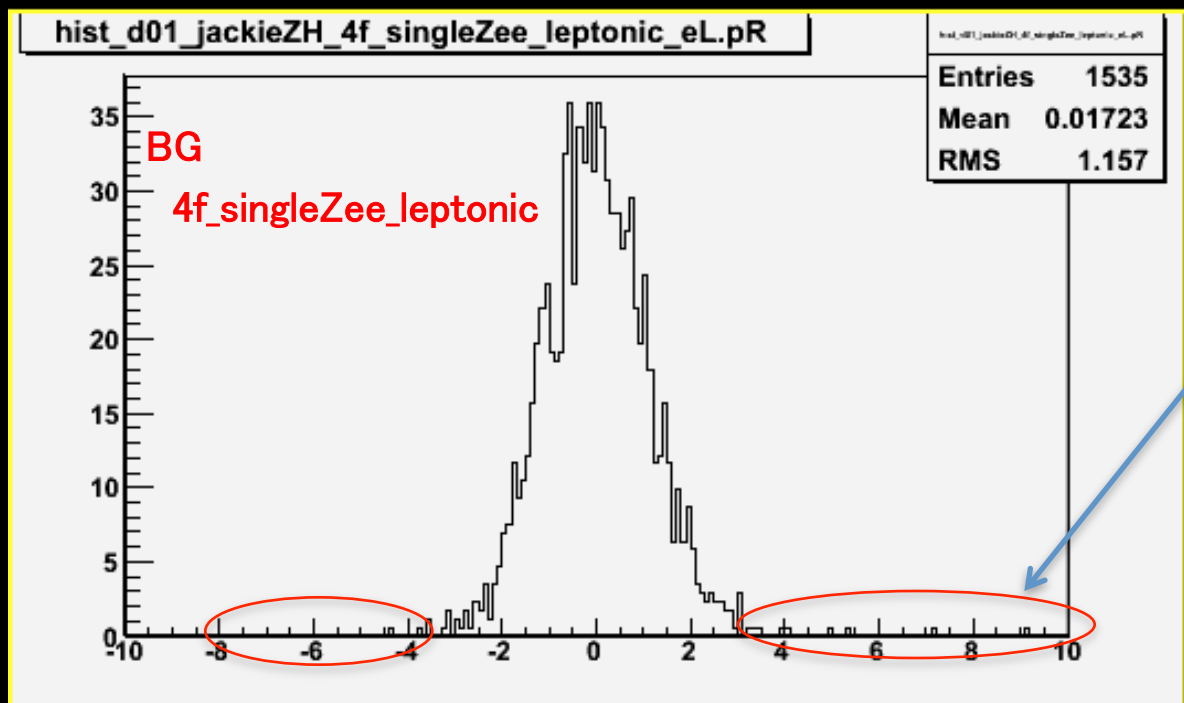
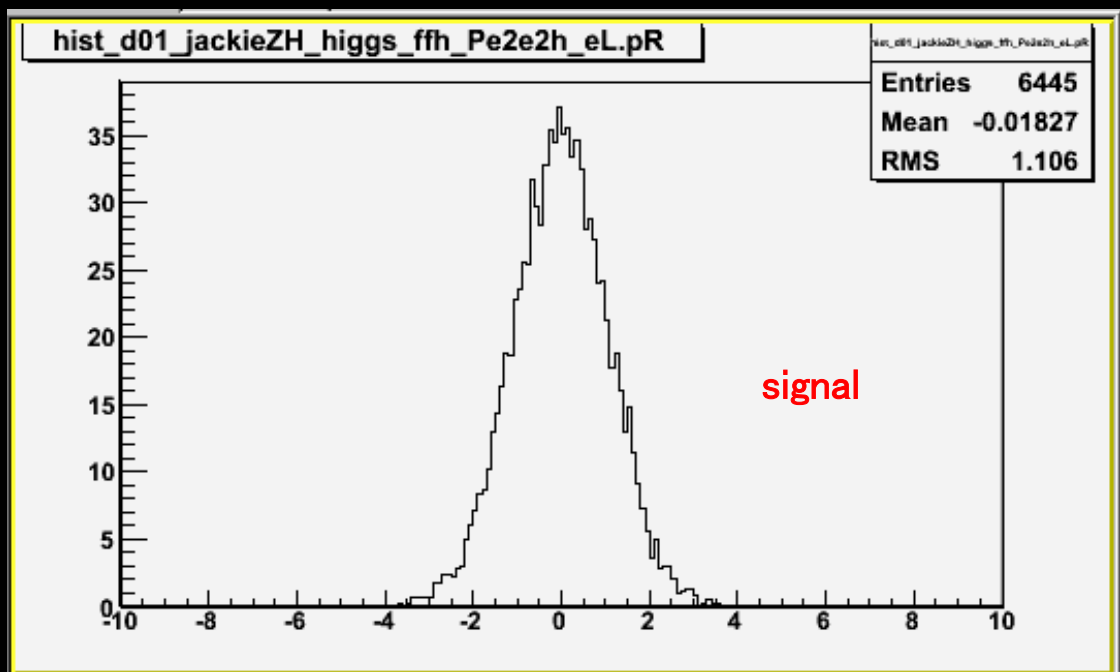
hist_track1_jackieZH_4f_ZZ_leptonic_eL.pR



Impact parameter

$$D0 / \delta D0$$

Maybe this cut is not really effective yet since tau-tau samples have not been included

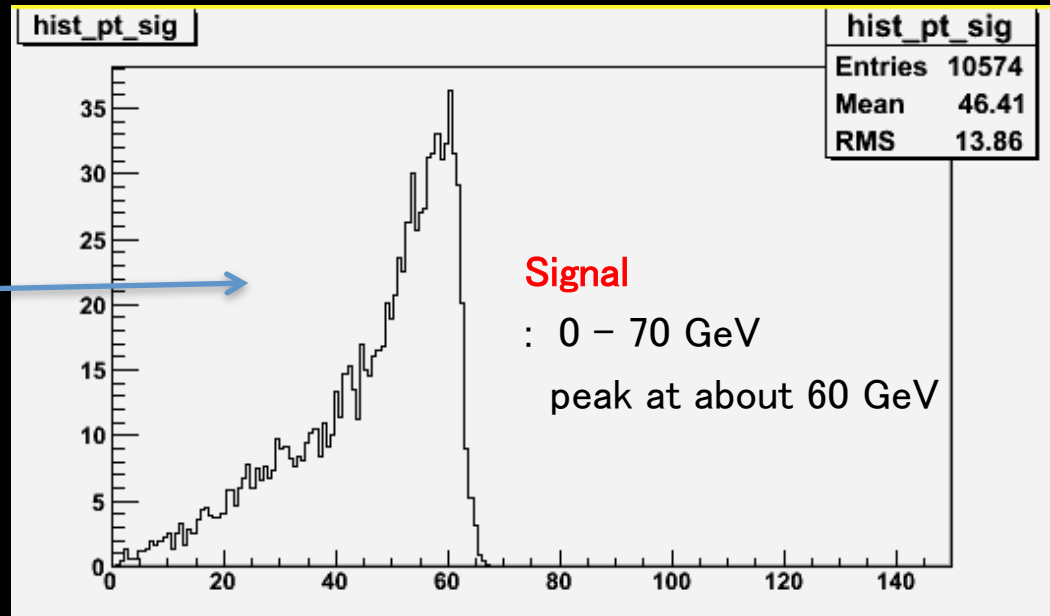


For some BG processes
exceed ± 4 slightly

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

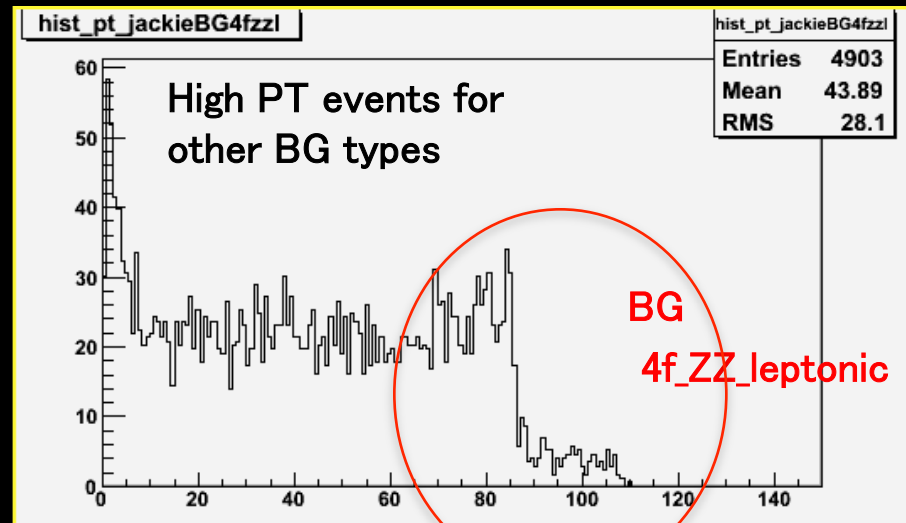
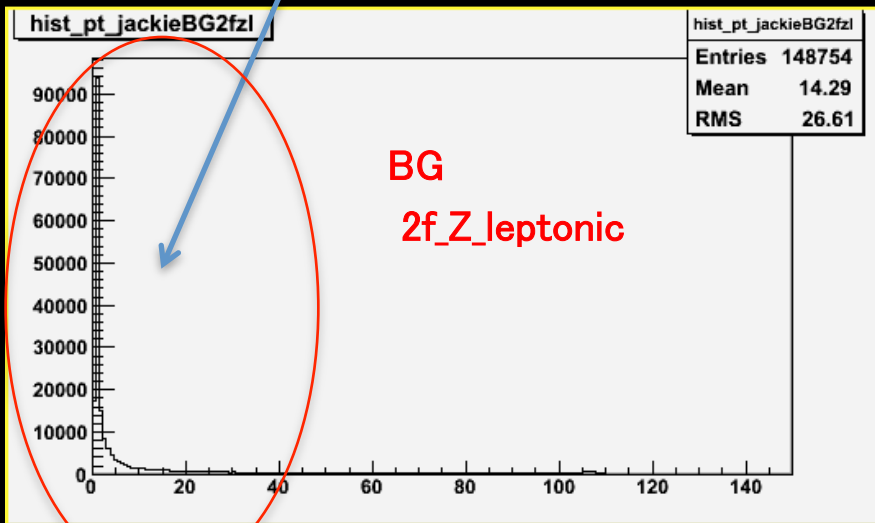
PT of dilepton system

do cut : $10 \text{ GeV} < p_{T_dl} < 70 \text{ GeV}$



BG

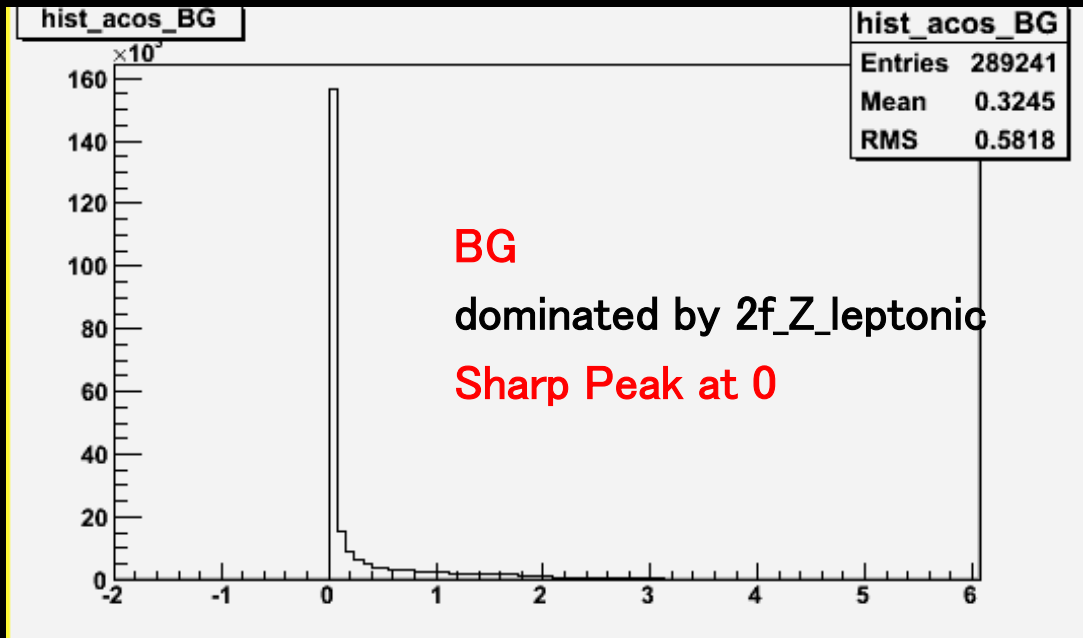
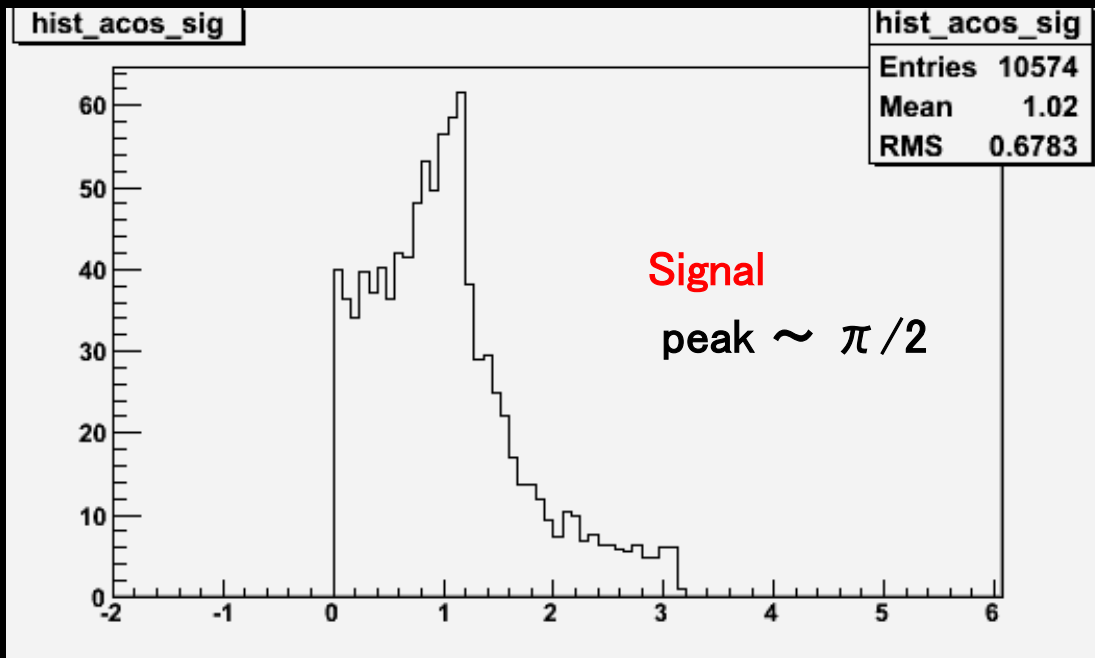
dominated by $2f_Z_leptonic$,
many low PT events



acoplanarity

do cut : $0.2 < \text{acop} < 3$

```
fabs (atan2(py1,px1) -  
atan2(py2,px2))  
if (acos>pi) {acos = 2*pi - acos;}  
acos = pi-acos;
```

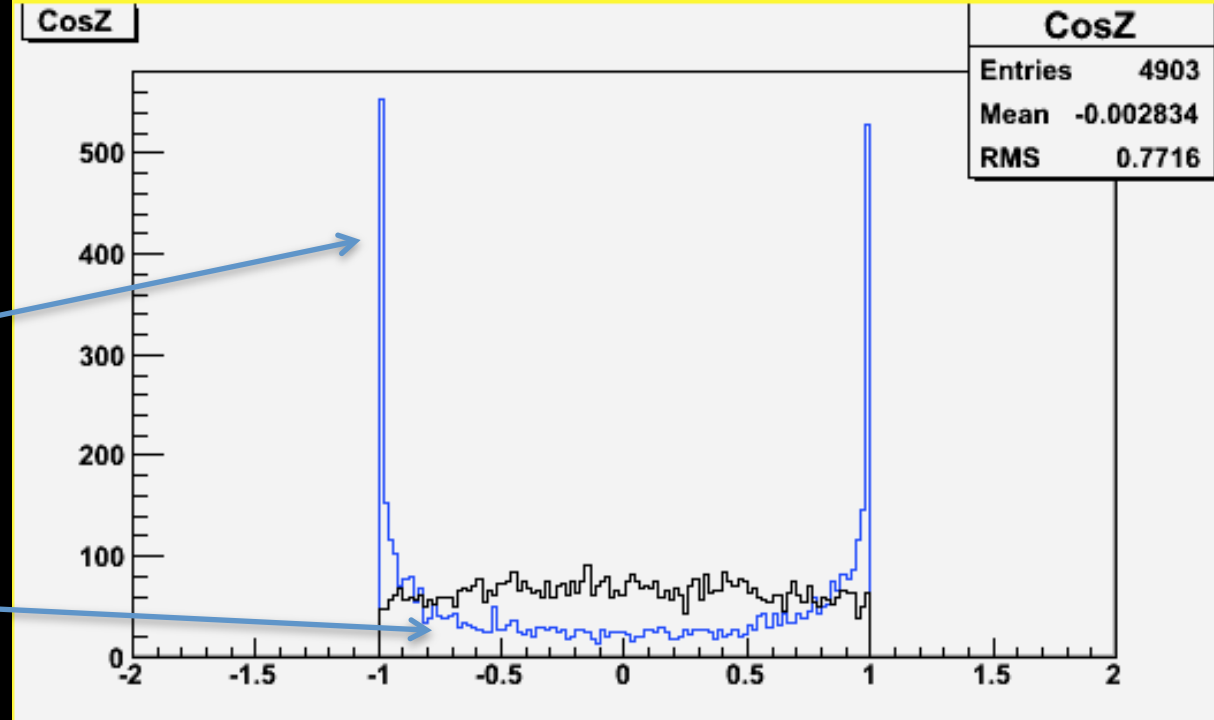


Z production angle

blue: BG (4f_ZZ_I)
very forward

→ use for cut

Black: Signal
isotropic



do cut : $|\cos(\theta_{Zpro})| < 0.91$

Thank You everyone for Listening

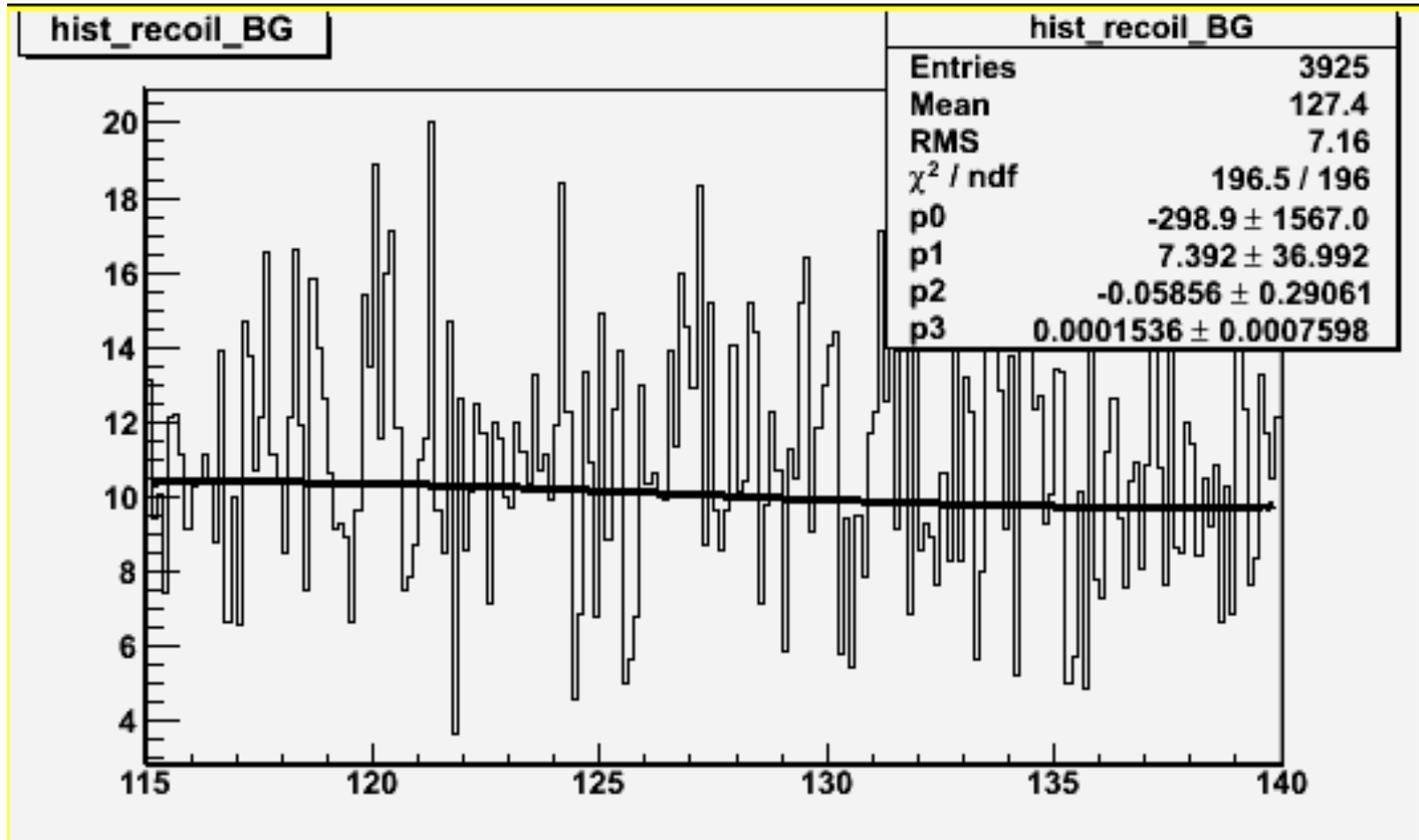
Thank you to

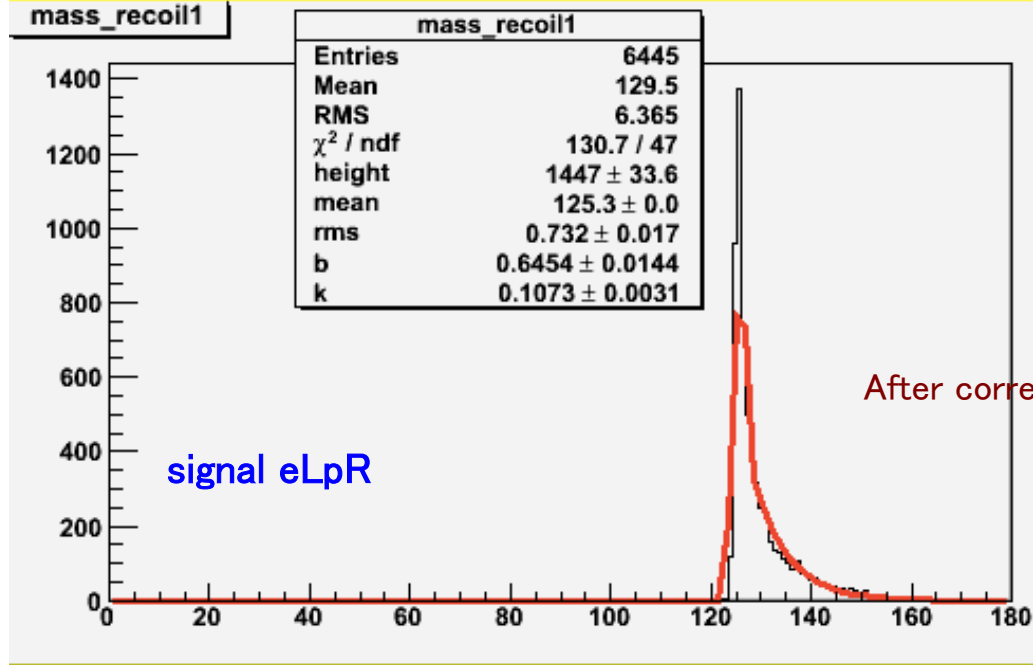
**Daniel-san, Fujii-san, Suehara-san, Tanabe-san, Watanuki-san, Miyamoto-san and others
for your help and advice**

BACKUP

recoil mass

total BG in region 115 – 140 GeV





recoil mass of signal events ONLY

After correcting for 14 mrad beam crossing angle

fitted recoil mass :
Mh = 125.3 GeV

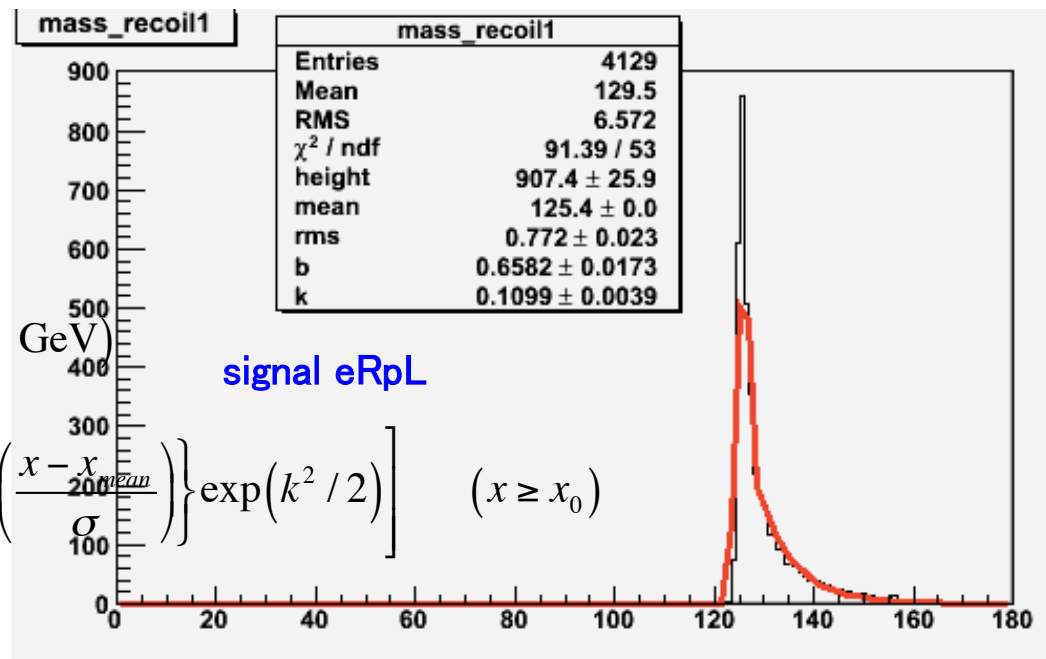
Fitting for signal :

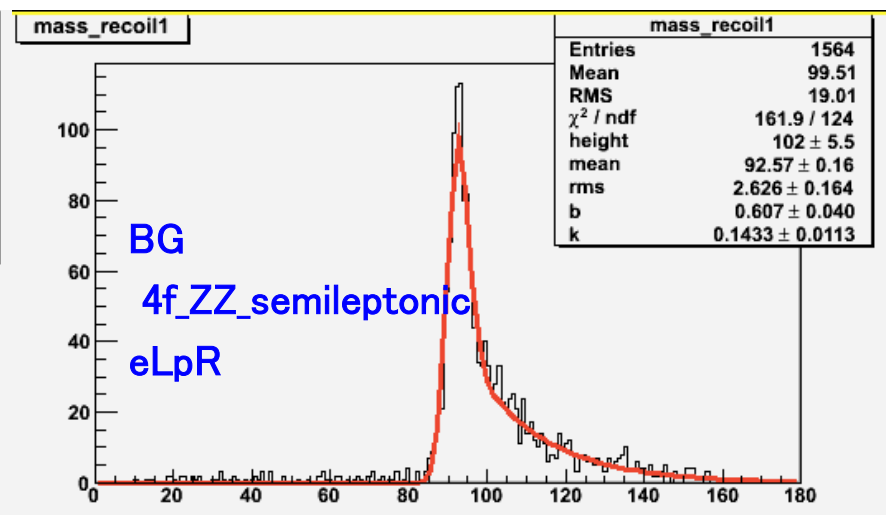
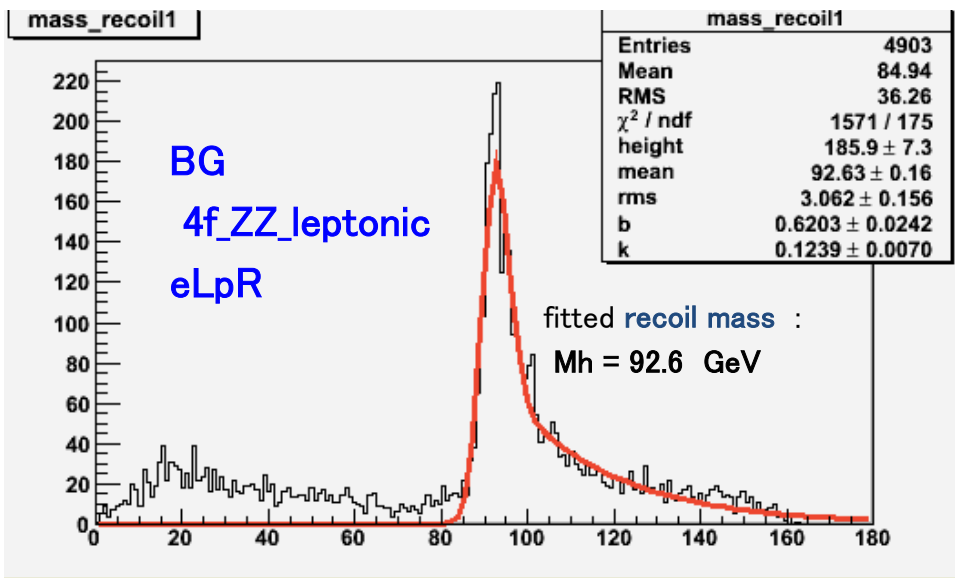
GPET: 5 parameters

Gaus (left-side) , Gaus + expo (right side)

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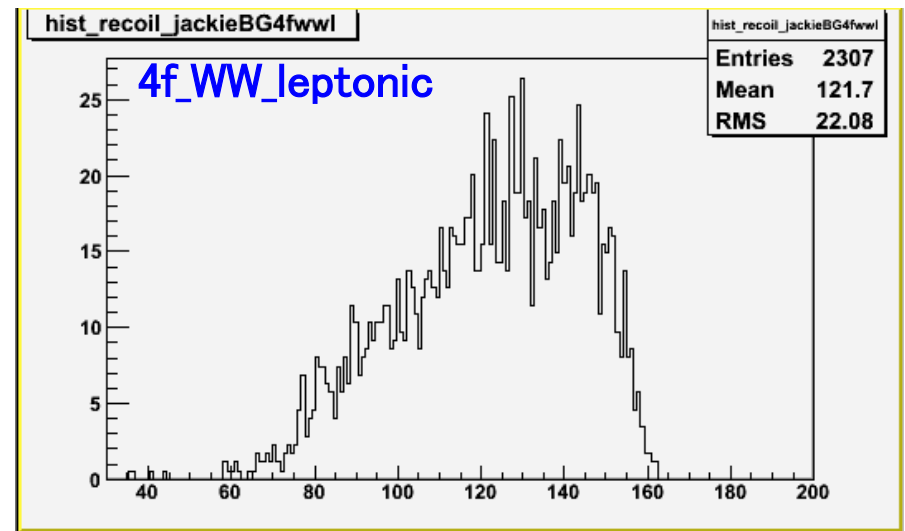
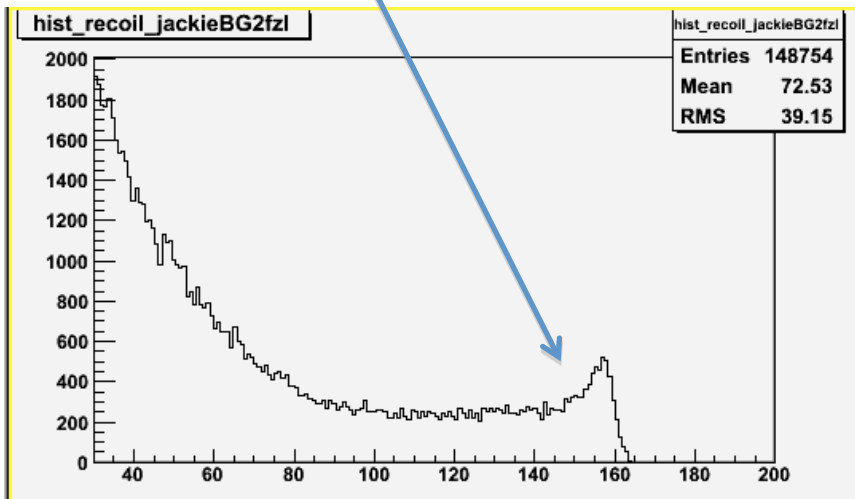




recoil mass distribution for some BG processes

2f_Z_leptonic

This may be causing high energy BG in combined histogram



Calculation of Event Weight

Assign weight based on cross section, luminosity, polarization

$$\text{event weight} = \text{pol_weight} * (\text{process_cross_section} * \text{assumed_integrated_luminosity}) / (\text{number_of_reconstructed_events})$$

Ec.m.s = 250 GeV

luminosity 250fb⁻¹

ILC polarization: ex) if eLpR : $(PL+PR)/(PL-PR)$: (e⁻, e⁺) = (0.8, 0.3) :

➤for electron: 90% is left-handed (10% is right handed)

➤for positron: 65% is left (35% is right)

