

# Higgs Recoil Mass Study at 350 GeV

Weekly Physics Meeting

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recoil mass study using  $e^+e^- \rightarrow ZH \rightarrow \mu^+\mu^-H$

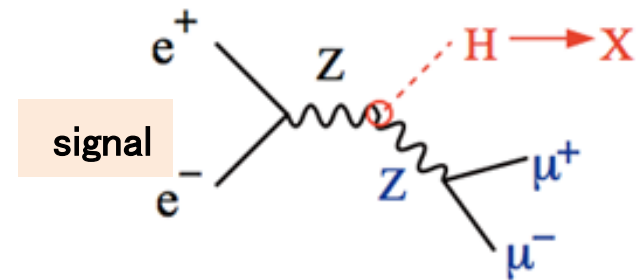
Ec.m.s. = 350 GeV,  $L = 333 \text{ fb}^{-1}$

And also Ec.m.s. = 250 GeV,  $L = 250 \text{ fb}^{-1}$

### Goal:

- precise measurement of Higgs cross section  $\sigma_H$
- contribute to the decision for ILC run scenario

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



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

Pe2e2h\_eL.pR & Pe2e2h\_eR.pL

BG :

included all 2f, 4f, 6f processes

Full ILD detector simulation

### What's new this week

- ◆ try wider fitting range for better estimation of BG function

before : 115 – 150 GeV → now: 100 – 200 GeV

- ◆ Comments from AWLC14

# **Data Selection Method and Fitting Method for Recoil Mass Plot**

**Before: fitting was done in 115–150 GeV**

**Now: wider range 100 – 200 GeV**

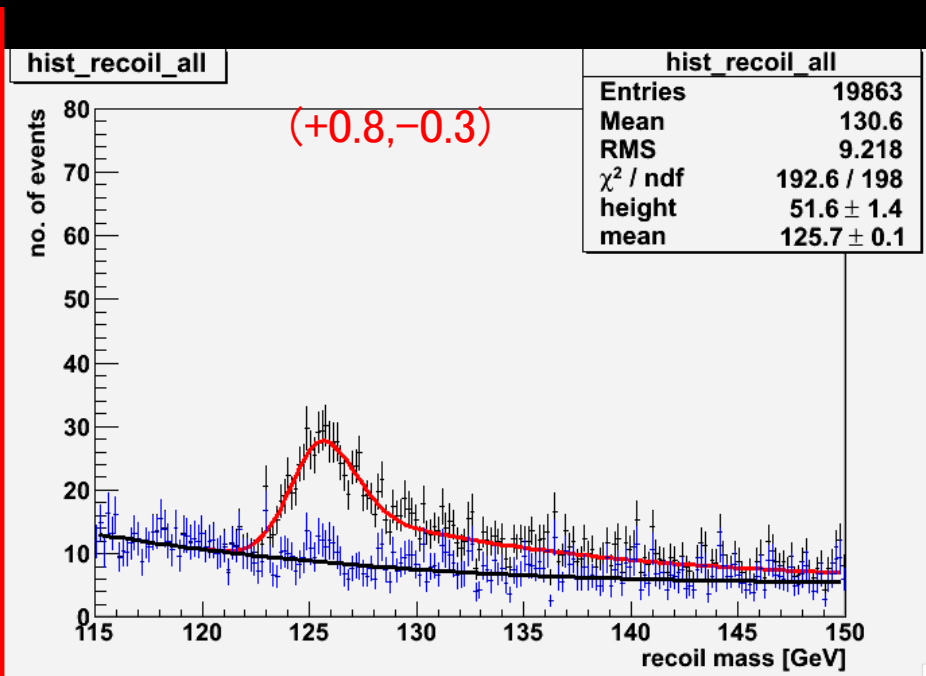
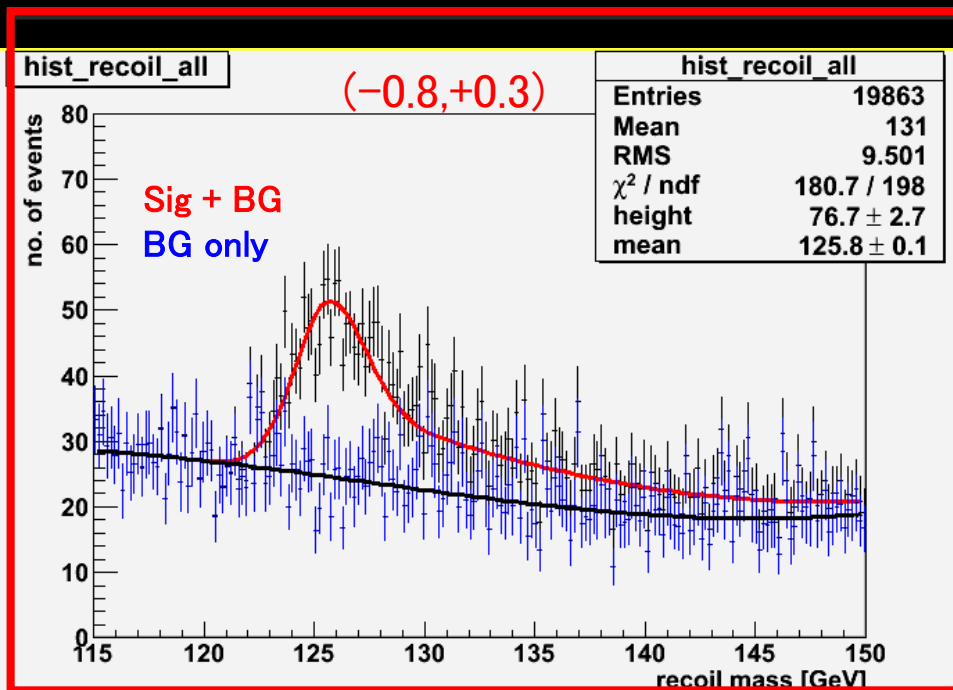
**Get better estimation of BG function**

results for sqrt(s) = 350 GeV , L = 333 fb<sup>-1</sup>

Fit in 115–150 GeV

evaluated using Toy MC generated from fitted function shapes

	$\epsilon$	$\Delta \sigma / \sigma$	xsec	Nsig	S/N	significance
350 GeV						
(-0.8,+0.3)	47.6+/-0.5%	4.9+/-0.2%	6.71+/-0.34	1092+/-55	0.4	17.7
(+0.8,-0.3)	47.8+/-0.5%	5.0+/-0.2%	4.53+/-0.26	720+/-41	0.75	17.8

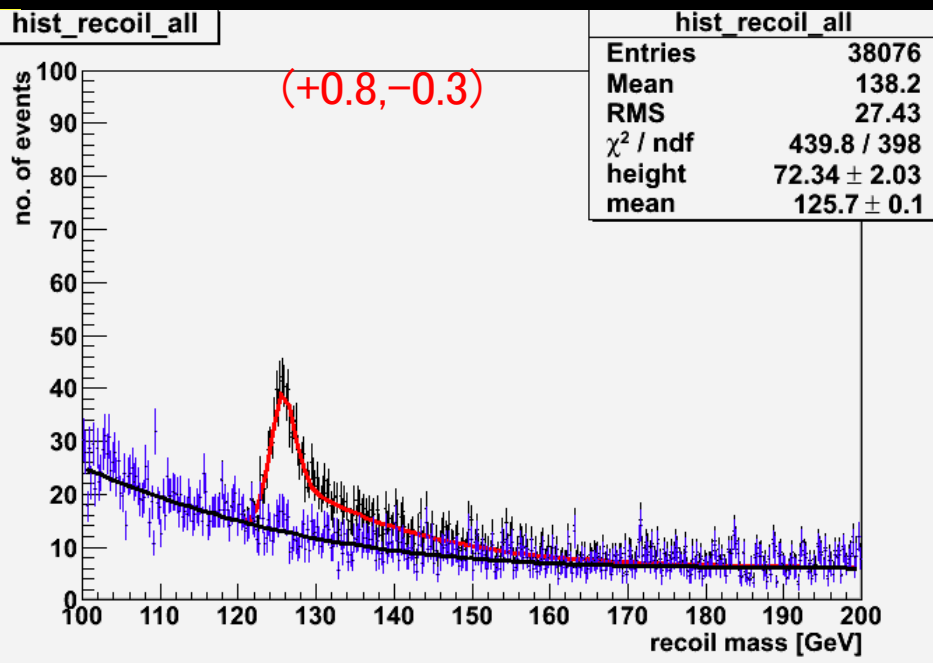
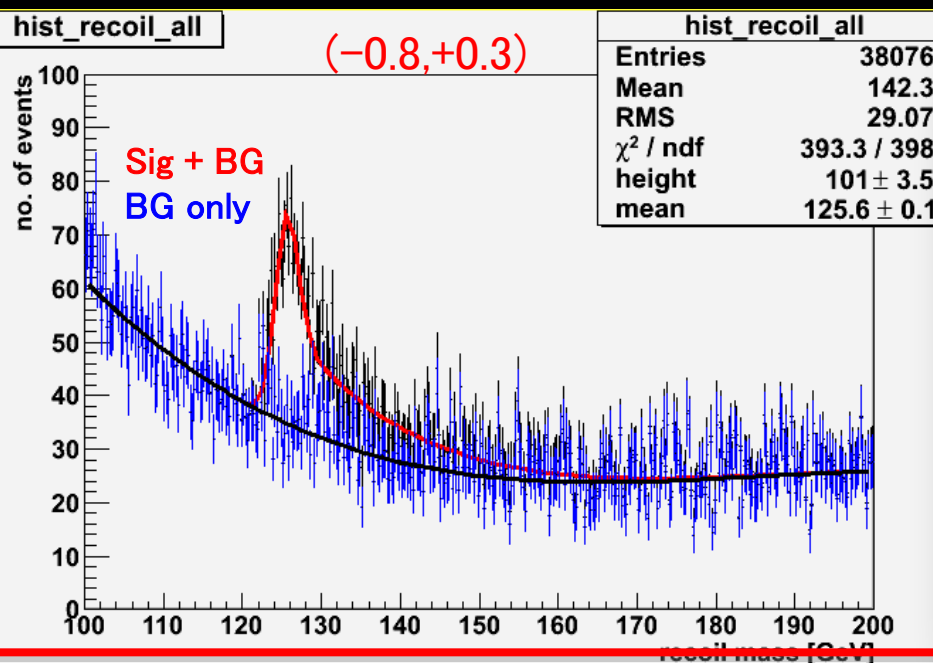


results for  $\sqrt{s} = 350$  GeV ,  $L = 333$  fb $^{-1}$

Fit in 100–200 GeV

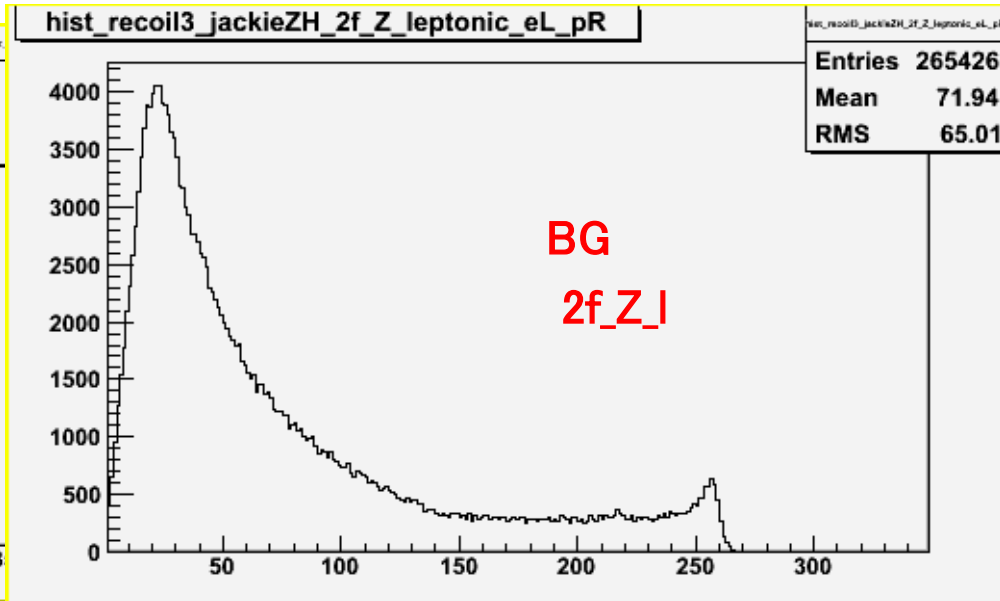
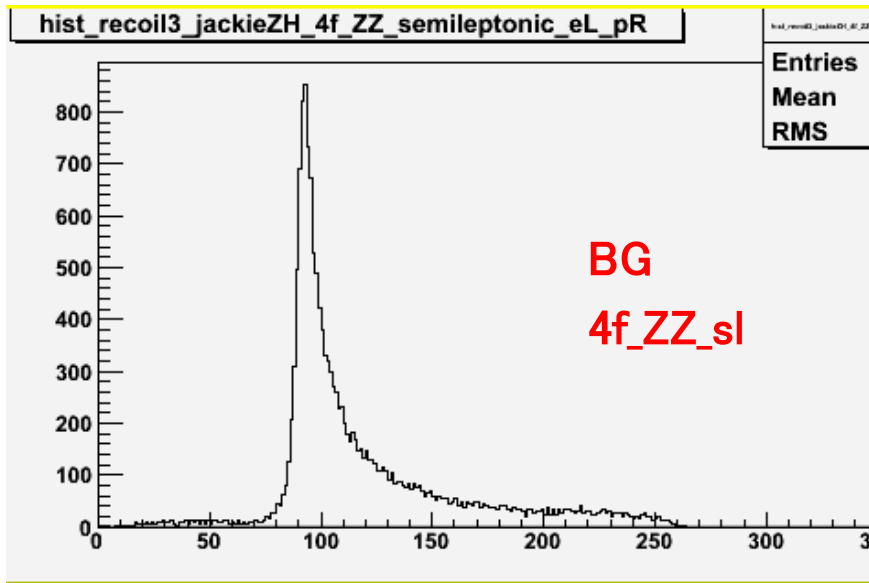
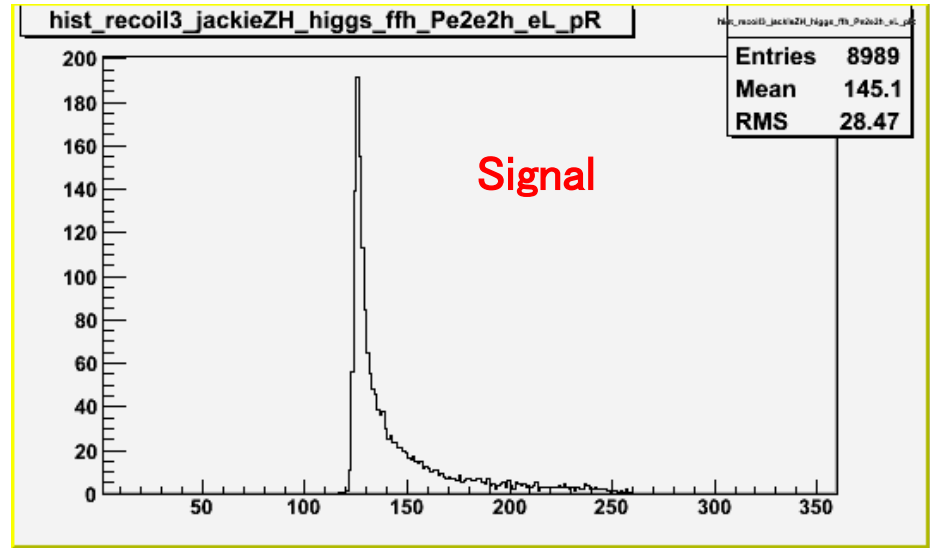
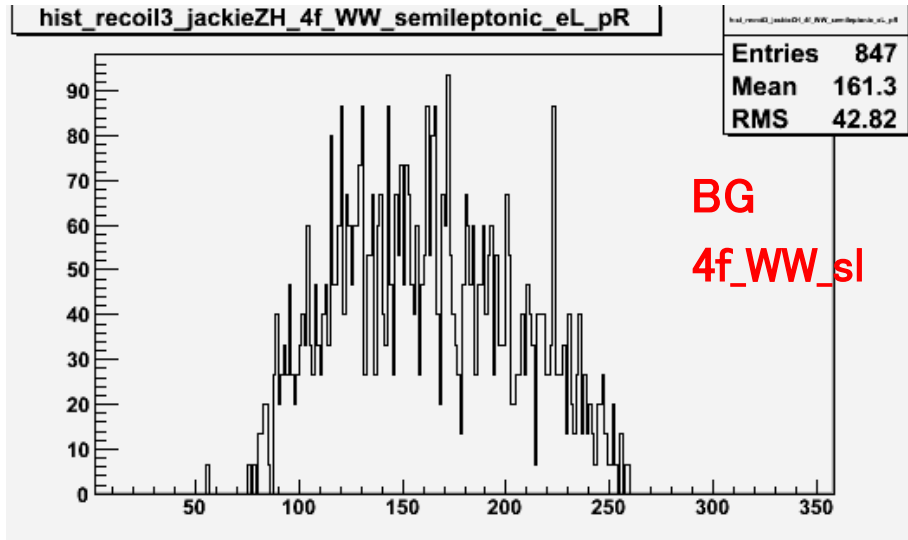
evaluated using Toy MC generated from fitted function shapes

	$\epsilon$	$\Delta \sigma / \sigma$	xsec	Nsig	S/N	significance
350 GeV						
(-0.8,+0.3)	47.6+/-0.5%	4.5+/-0.2%	6.71+/-0.34	1092+/-55	0.4	17.7
(+0.8,-0.3)	47.8+/-0.5%	4.8+/-0.2%	4.72+/-0.24	750+/-40	0.75	17.8



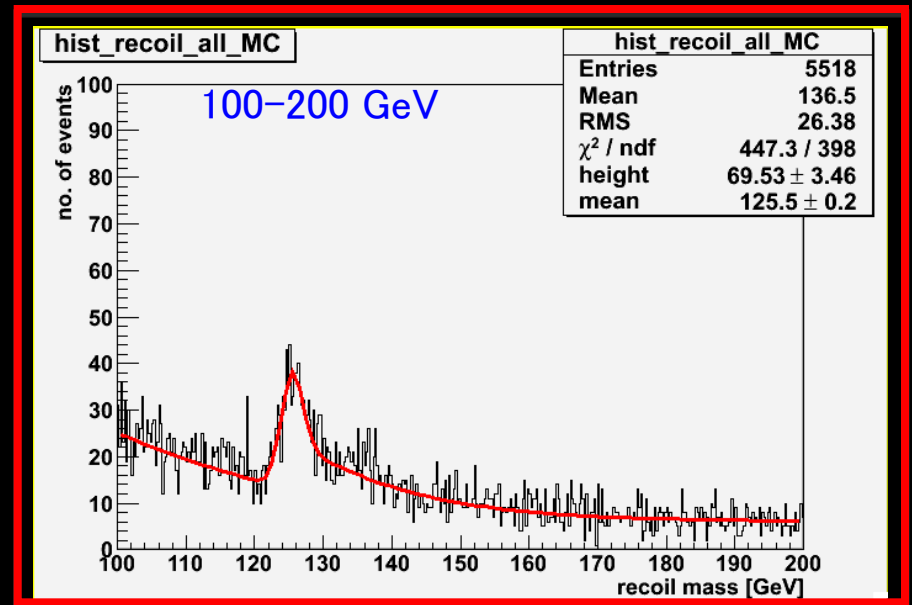
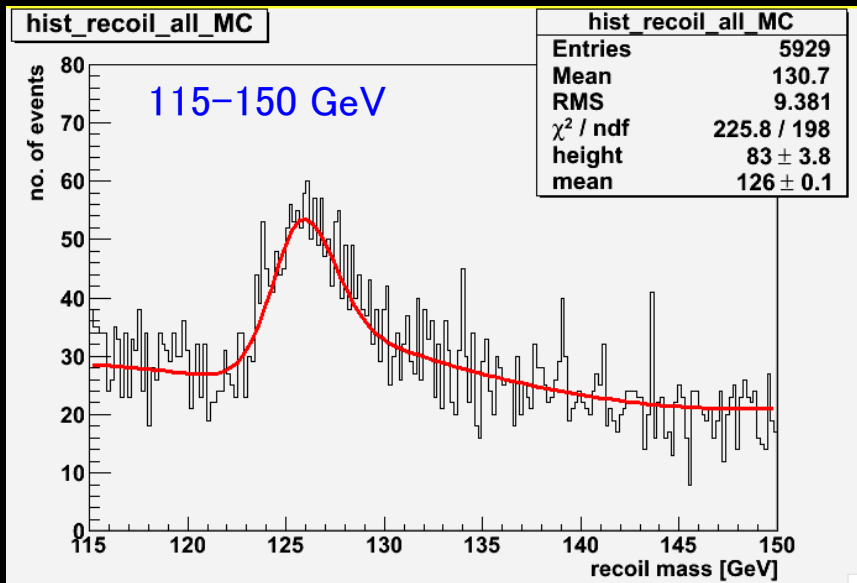
recoil mass 350 GeV

After inv mass cut



# Toy MC

10000 seeds



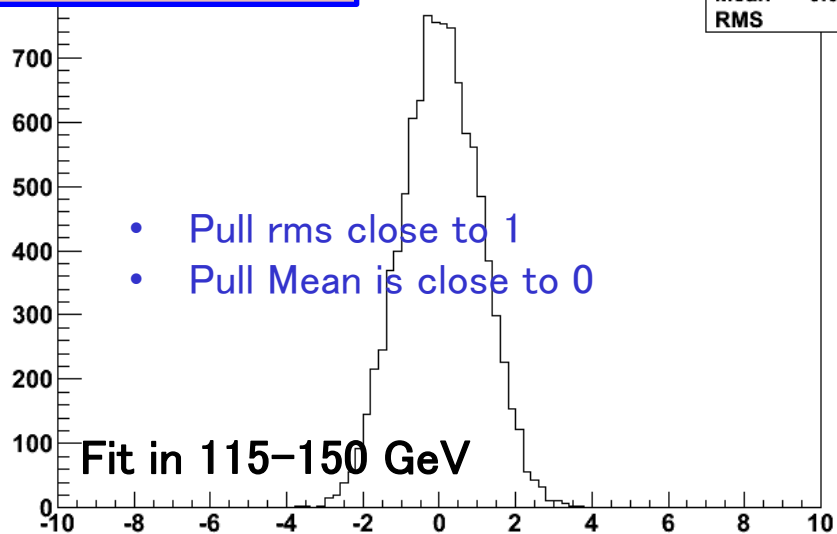
For wide range fitting:

- Pull plot bias is larger , RMS is about same
- Nsig and xsec slightly deviated from “real values from sample”

example of results on next page

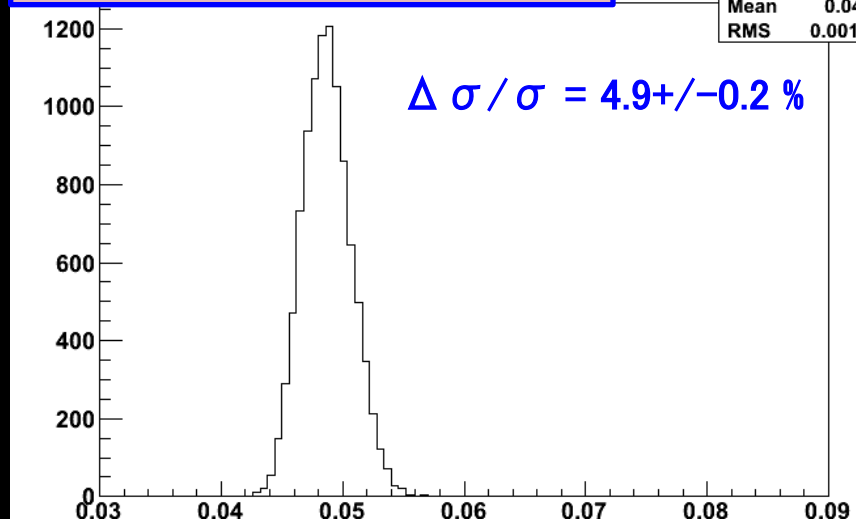
### Pull plot for xsec

pull	
Entries	10000
Mean	0.04213
RMS	1.04



### Relative xsec error

rel xsec error	
Entries	10000
Mean	0.04871
RMS	0.001998



Result of Toy MC 10000 seeds

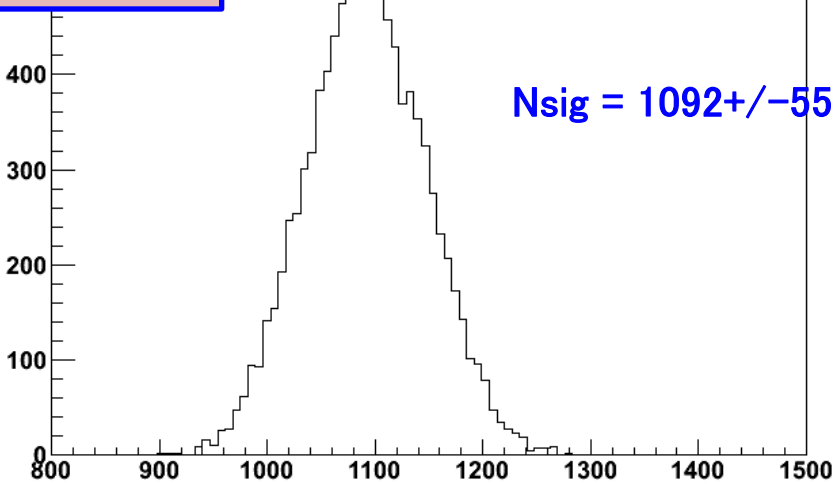
sqrt(s)=350 GeV

• “real xsec = 6.686” , “real Nsig = 1088”

Consistent within error ranges

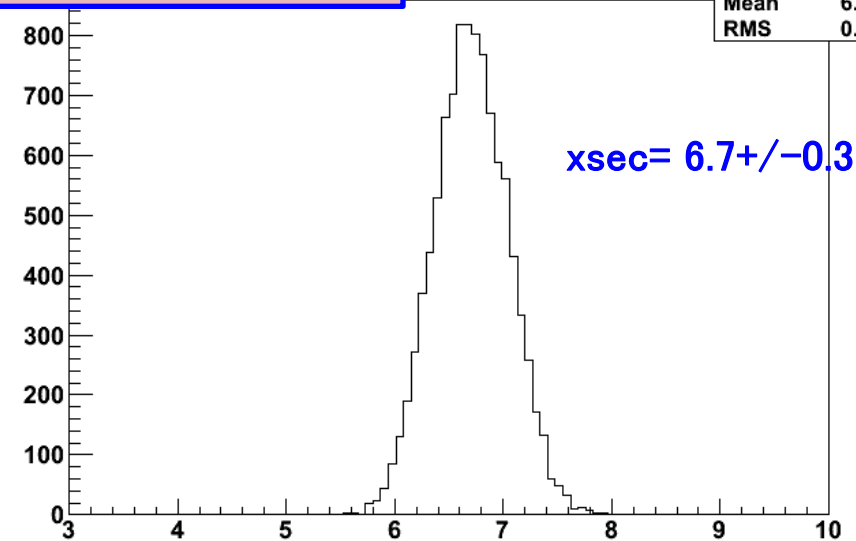
### # of signal (Nsig)

Nsig	
Entries	10000
Mean	1092
RMS	55.2



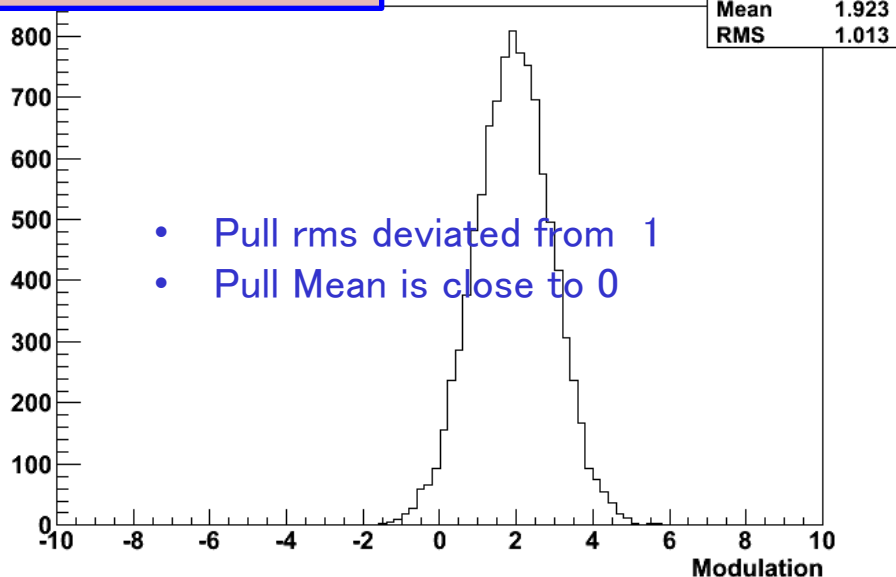
### Cross section (xsec)

xsec	
Entries	10000
Mean	6.705
RMS	0.339

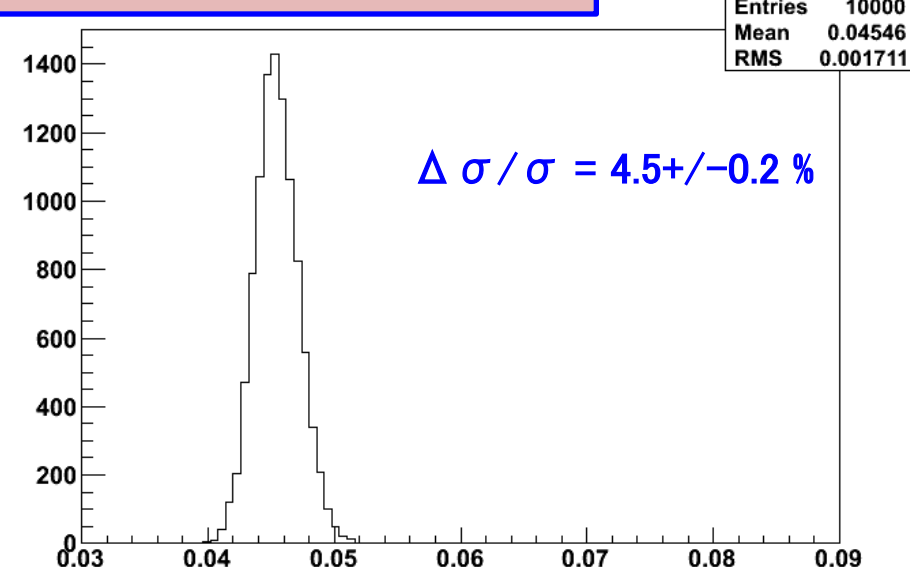




### Pull plot for xsec



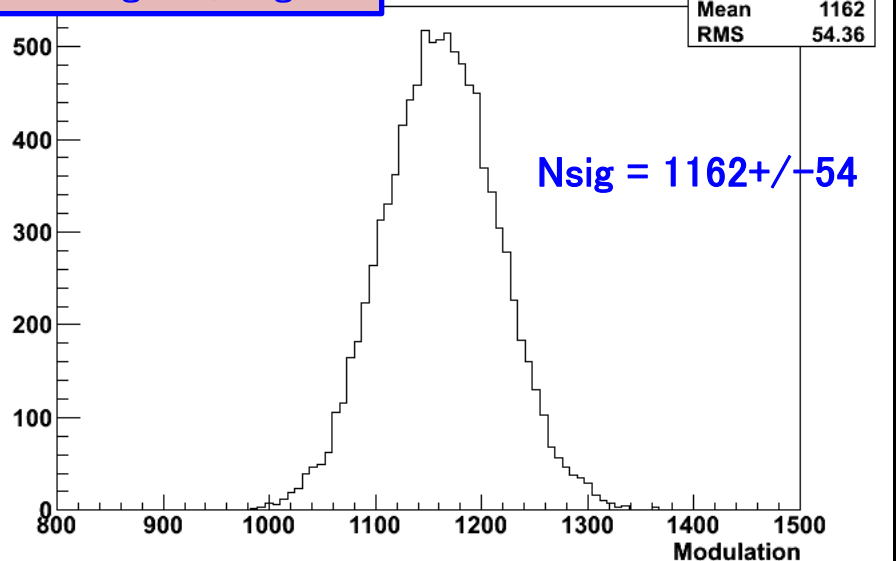
### Relative xsec error



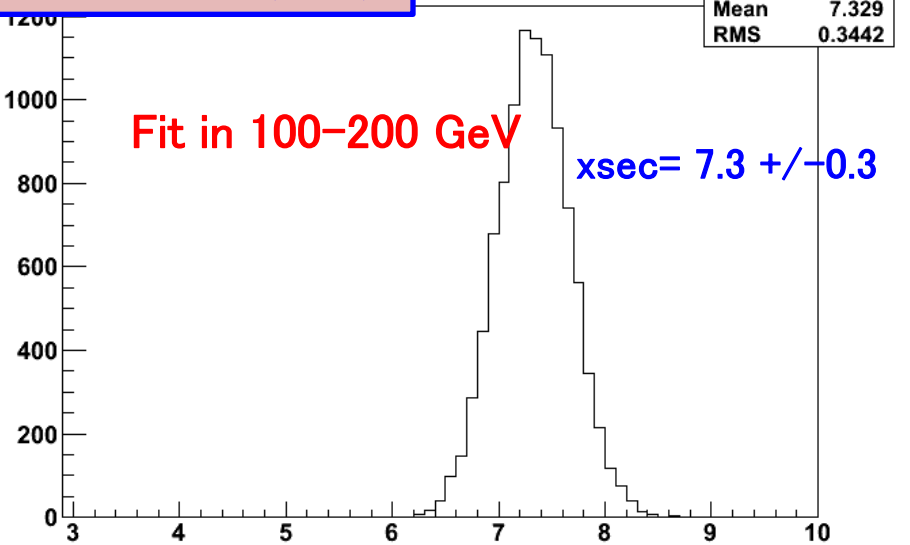
Result of Toy MC 10000 seeds  
sqrt(s)=350 GeV

• “real xsec = 6.686” , “real Nsig = 1088”

### # of signal (Nsig)



### Cross section (xsec)



## Summary

### try wider fitting range

- Before 115-150 GeV
- Now: 100-200 GeV : to get better estimate of BG function

**xsec error is improved by about 0.4% for (-0.8,+0.3) and 0.2% for (+0.8, -0.3)**

< Preliminary results >

**350 GeV: 100- 200 GeV fitting range**

(-0.8, +0.3)  $\Delta\sigma / \sigma = 4.5 \pm 0.2 \%$ ,  $\epsilon_{\text{sig}} = 47.6 \pm 0.5 \%$ , S/B  $\sim 0.40$

(+0.8, -0.3)  $\Delta\sigma / \sigma = 4.8 \pm 0.2 \%$ ,  $\epsilon_{\text{sig}} = 47.8 \pm 0.5 \%$ , S/B  $\sim 0.75$

**350 GeV: 115-150 GeV fitting range**

(-0.8, +0.3)  $\Delta\sigma / \sigma = 4.9 \pm 0.2 \%$

(+0.8, -0.3)  $\Delta\sigma / \sigma = 5.0 \pm 0.2 \%$

## Plans for next week

- study **precision of fitted recoil mass  $M_H$**
- study **alternative polarization scenarios** e.g. (-0.8, 0) (+0.8, 0) ...etc...

**BACKUP**

## Muon Selection

- reject neutrals
- $P_{\text{total}} > 5 \text{ GeV}$
- $\text{small } E_{\text{cluster}} / P_{\text{total}} < 0.5$
- $\cos(\text{track angle}) < 0.98$  &  $|D0/\delta D0| < 5$

## Data Selection Method

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

## Best Z Candidate Selection

2 muon candidates with **opposite charge**  
choose pair **with invariant mass closest to Z mass**

## Definitions

- $M_{\text{inv}}$  : invariant mass of 2 muons
- $pT_{\text{mumu}}$  :  $pT$  of reconstructed muons
- $pT_{\gamma_{\text{max}}}$  :  $pT$  of most energetic photon
- $\theta_{Z\text{pro}}$  = Z production angle

## Final Selection for $\sqrt{s}=350 \text{ GeV}$

- $84 \text{ GeV} < M_{\text{inv}} < 98 \text{ GeV}$
- $10 \text{ GeV} < pT_{\text{mumu}} < 140 \text{ GeV}$
- $dptbal = |pT_{\text{mumu}} - pT_{\gamma_{\text{max}}}| > 10 \text{ GeV}$
- $\text{coplanarity} < 3$
- $|\cos(\theta_{Z\text{pro}})| < 0.91$

$120 \text{ GeV} < M_{\text{recoil}} < 140 \text{ GeV}$

for  $\sqrt{s}=250 \text{ GeV}$ ,  
 $10 \text{ GeV} < pT_{\text{mumu}} < 70 \text{ GeV}$ , and no coplanarity cut

## Results after selection

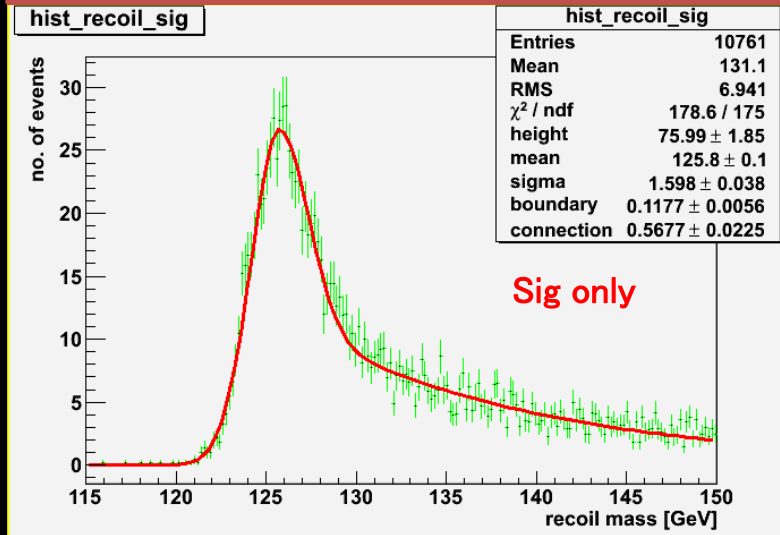
( $\sqrt{s}=350 \text{ GeV}$ )

- Sig efficiency =  $47.6 \pm 0.5\%$
- $S/B = 0.40$ , significance = 17.2
- # of signals =  $1092 \pm 55$

# fitting for recoil mass histogram

## 1<sup>st</sup> time fitting:

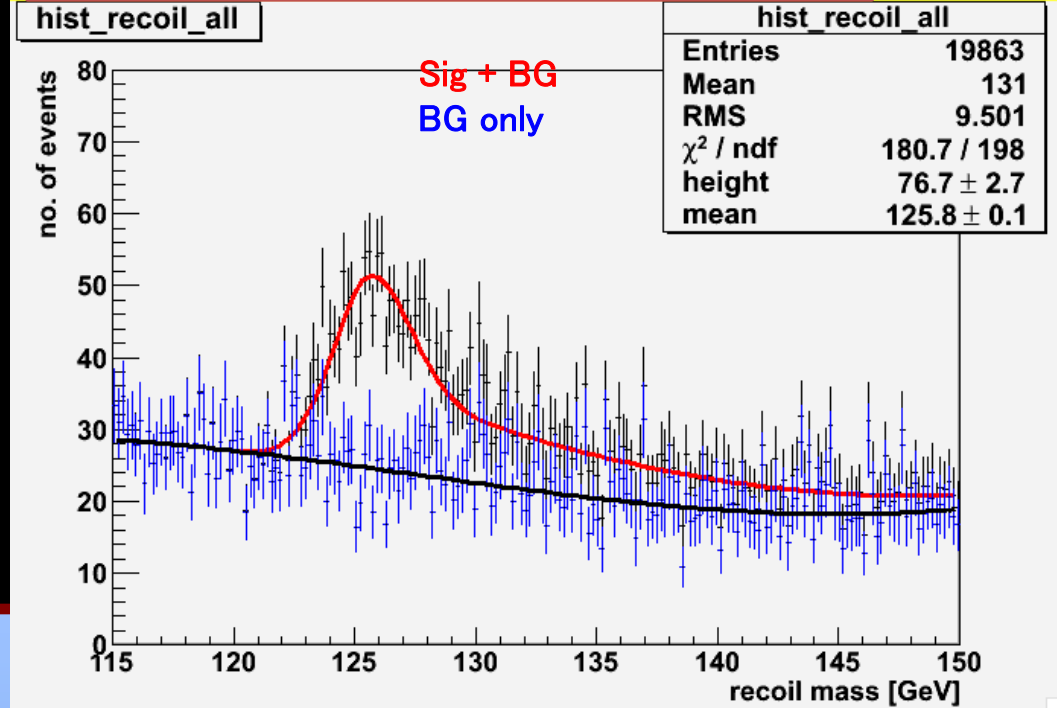
- fit only signal : float all 5 GPET pars
- fit BG only 3<sup>rd</sup> order polynomial



## Final fitting:

float only height and mean,

Fix BG function and remaining GPET pars from 1<sup>st</sup> time fitting

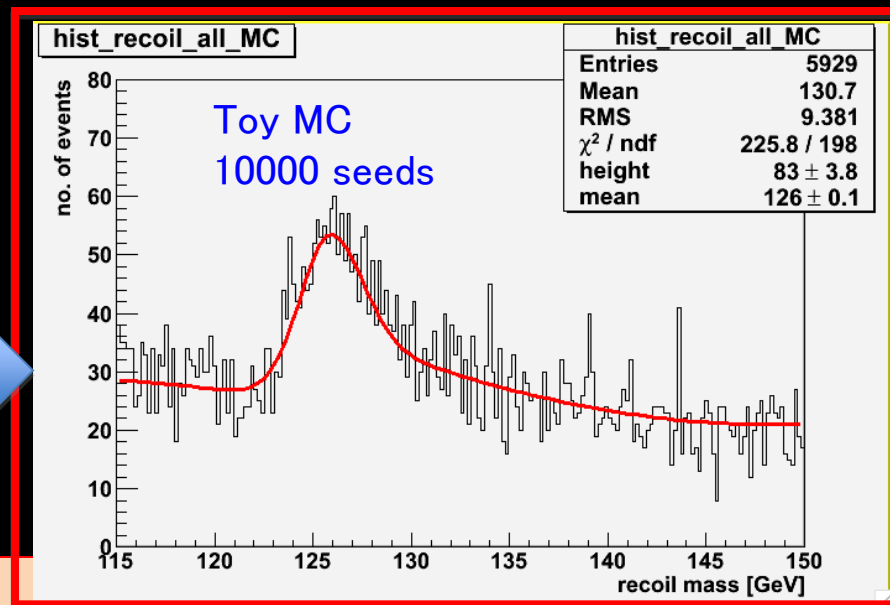
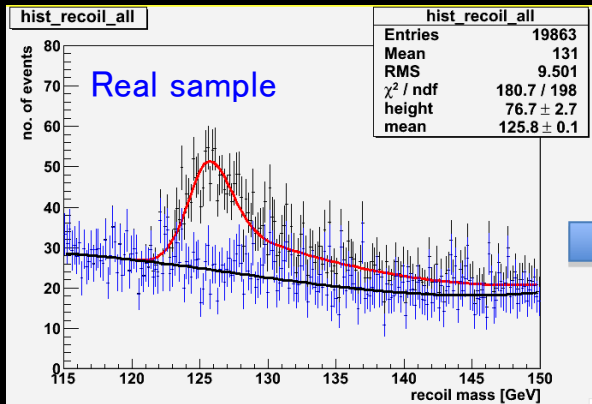


- ◆ **SIGNAL: GPET: 5 parameters :**  
Gaus (left-side) , Gaus + expo (right side)

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

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

# Toy MC Studies



## Goal:

- **test validity of fitting** : Pull plot for  $x_{\text{sec}} = [(\text{fitted } x_{\text{sec}}) - (\text{“real” } x_{\text{sec}})] / (x_{\text{sec}} \text{ fitting error})$
- **Evaluated precision of  $x_{\text{sec}}$  and number of signals ( $N_{\text{sig}}$ )**

## Method:

- Generate MC according to fitted function (GPET + BG) for real sample
- Input #of events according to Poisson distr (mean = real # of input)
- Fit MC histogram with same function
- Integrate under GPET to get  $N_{\text{sig}} \rightarrow$  calculate  $x_{\text{sec}}$

## Results:

- Pull plot seems reasonable
- $N_{\text{sig}}$  and  $x_{\text{sec}}$  consistent with “real values from sample” within rms error ranges

example of results on next page

Compare sqrt(s) =350 GeV and sqrt(s)= 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

	$\epsilon$	$\Delta \sigma / \sigma$	xsec	Nsig	S/N	significance
<b>350 GeV</b>						
(-0.8,+0.3)	47.6+/-0.5%	4.9+/-0.2%	6.71+/-0.34	1092+/-55	0.4	17.7
(+0.8,-0.3)	47.8+/-0.5%	5.0+/-0.2%	4.53+/-0.26	720+/-41	0.75	17.8
<b>250 GeV</b>						
(-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

$\Delta \sigma / \sigma$  : no big difference between 2 polarization scenarios

◆ for (+0.8, -0.3) : S/B much higher:

- WW BGs significantly suppressed (< 1/10 of (-0.8, +0.3)), other major BGs less also
- however statistics is lower

# Cut Efficiency

More detailed table in BACKUP

	2f_Z_l	eff	4f_WW_sl	eff	4f_ZZ_sl	eff	signal	eff	BG	eff
raw events	2226362	100.00%	2732834	100.00%	188087	100.00%	2288	100.00%	31657512	100.00%
best mu pair	946129	42.50%	236802	8.67%	42345	22.51%	2254	98.51%	2373876	7.50%
D0	925330	41.56%	152599	5.58%	39825	21.17%	2241	97.95%	1813049	5.73%
track angle	843738	37.90%	136568	5.00%	36073	19.18%	2205	96.37%	1618485	5.11%
84 <M_inv <98	269446	12.10%	5702	0.21%	16365	8.70%	1826	79.81%	313998	0.99%
10 <P_Td<140	71877	3.23%	5659	0.21%	14934	7.94%	1819	79.50%	111823	0.35%
dpTbal>10 GeV	10674	0.48%	5505	0.20%	14108	7.50%	1798	78.58%	48694	0.15%
copl < 3	9612	0.43%	4578	0.17%	13347	7.10%	1773	77.49%	44735	0.14%
cos(θ Z)<0.91	5709	0.26%	2940	0.11%	9147	4.86%	1698	74.21%	30428	0.10%
120 GeV <M_rec <140 GeV	276	0.01%	405	0.01%	1123	0.60%	1088	47.55%	2700	0.01%

after all cuts, dominant BG are:

sqrt(s) = 350 GeV : #1) 4f\_ZZ\_sl #2) 4f\_WW\_sl #3) 2f\_Z\_l no ttbar BG

left

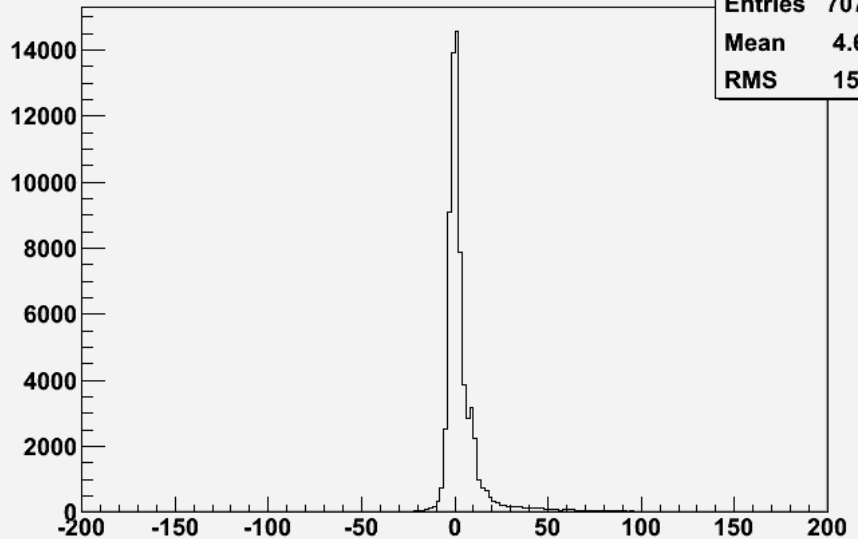
sqrt(s) = 250 GeV : #1) 4f\_ZZWWMix\_l #2) 4f\_ZZ\_sl #3) 2f\_Z\_l



		2f_Z_l	eff	4f_WW_sl	eff	4f_ZZ_sl	eff	signal	eff	BG	eff
raw events	eLpR	2128619		2714856		182762			2204		
	eRpL	97743		17978		5325			84		
	total	<b>2226362</b>	100.00%	<b>2732834</b>	100.00%	<b>188087</b>	100.00%	<b>2288</b>	100.00%	<b>31657512</b>	100.00%
best mu pair	eLpR	906955		235263		41072			2171		
	eRpL	39174		1539		1273			83		
	total	<b>946129</b>	42.50%	<b>236802</b>	8.67%	<b>42345</b>	22.51%	<b>2254</b>	98.51%	<b>2373876</b>	7.50%
D0	eLpR	886948		151718		38624			2158		
	eRpL	38382		881		1201			83		
	total	<b>925330</b>	41.56%	<b>152599</b>	5.58%	<b>39825</b>	21.17%	<b>2241</b>	97.95%	<b>1813049</b>	5.73%
track angle	eLpR	808861		135726		35002			2124		
	eRpL	34877		842		1071			81		
	total	<b>843738</b>	37.90%	<b>136568</b>	5.00%	<b>36073</b>	19.18%	<b>2205</b>	96.37%	<b>1618485</b>	5.11%
84 <M_inv <98	eLpR	259828		5673		15959			1758		
	eRpL	9618		29		406			68		
	total	<b>269446</b>	12.10%	<b>5702</b>	0.21%	<b>16365</b>	8.70%	<b>1826</b>	79.81%	<b>313998</b>	0.99%
10 <P_Tdl<140	eLpR	69251		5630		14566			1752		
	eRpL	2626		29		368			67		
	total	<b>71877</b>	3.23%	<b>5659</b>	0.21%	<b>14934</b>	7.94%	<b>1819</b>	79.50%	<b>111823</b>	0.35%
dpTbal>10 GeV	eLpR	10272		5478		13761			1731		
	eRpL	402		27		347			67		
	total	<b>10674</b>	0.48%	<b>5505</b>	0.20%	<b>14108</b>	7.50%	<b>1798</b>	78.58%	<b>48694</b>	0.15%
copl < 3	eLpR	9252		4557		13019			1707		
	eRpL	360		21		328			66		
	total	<b>9612</b>	0.43%	<b>4578</b>	0.17%	<b>13347</b>	7.10%	<b>1773</b>	77.49%	<b>44735</b>	0.14%
cos( $\theta_Z$ )<0.9	eLpR	5492		2921		8927			1635		
	eRpL	217		19		220			63		
	total	<b>5709</b>	0.26%	<b>2940</b>	0.11%	<b>9147</b>	4.86%	<b>1698</b>	74.21%	<b>30428</b>	0.10%
120 GeV <M_rec <140 GeV	eLpR	265		403		1098			1048		
	eRpL	11		2		25			40		
	total	<b>276</b>	0.01%	<b>405</b>	0.01%	<b>1123</b>	0.60%	<b>1088</b>	47.55%	<b>2700</b>	0.01%

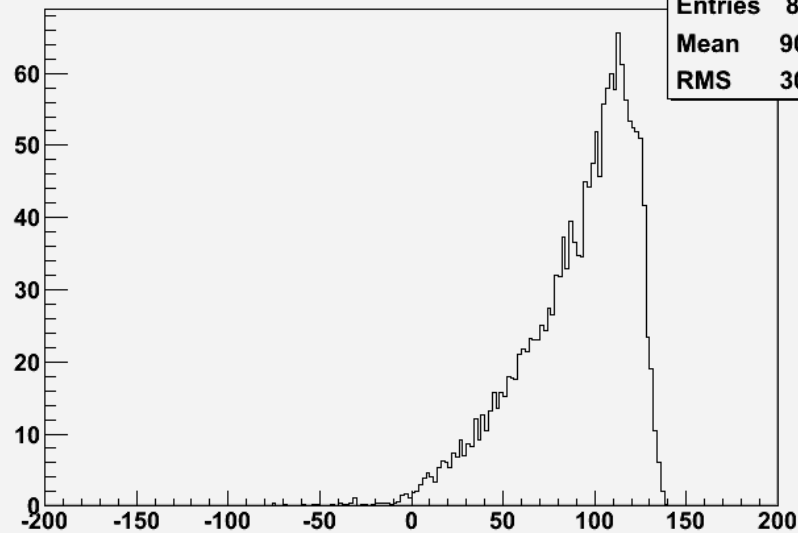
		(+0.8,-0.3)									
		2f_Z_l	eff	4f_WW_sl	eff	4f_ZZ_sl	eff	signal	eff	BG	eff
raw events	eLpR	127353		162427		10934			132		
	eRpL	1633703		1076		89009			1411		
	total	1761057	100.00%	163503	100.00%	99943	100.00%	1543	100.00%	16166900	100.00%
best mu pair	eLpR	54262		14076		2457			130		
	eRpL	654769		92		21274			1389		
	total	709031	40.26%	14168	8.67%	23731	23.74%	1519	98.44%	1146571	7.09%
D0	eLpR	53065		9077		2311			129		
	eRpL	639852		53		20077			1383		
	total	692917	39.35%	9130	5.58%	22388	22.40%	1512	97.99%	938198	5.80%
track angle	eLpR	48393		8120		2094			127		
	eRpL	582938		50		17901			1356		
	total	631331	35.85%	8170	5.00%	19995	20.01%	1483	96.11%	827736	5.12%
84 <M_inv <98	eLpR	15545		339		955			105		
	eRpL	160766		2		6790			1130		
	total	176311	10.01%	341	0.21%	7745	7.75%	1235	80.04%	191148	1.18%
10 <P_Tdl<140	eLpR	4143		337		871			105		
	eRpL	43892		2		6145			1123		
	total	48035	2.73%	339	0.21%	7016	7.02%	1228	79.59%	60616	0.37%
dpTbal>10 GeV	eLpR	615		328		823			104		
	eRpL	6715		2		5806			1113		
	total	7330	0.42%	330	0.20%	6629	6.63%	1217	78.87%	19128	0.12%
copl < 3	eLpR	554		273		779			102		
	eRpL	6015		1		5478			1097		
	total	6569	0.37%	274	0.17%	6257	6.26%	1199	77.71%	17591	0.11%
cos( $\theta_Z$ )<0.9 1	eLpR	329		175		534			98		
	eRpL	3624		1		3680			1052		
	total	3953	0.22%	176	0.11%	4214	4.22%	1150	74.53%	11306	0.07%
120 GeV <M_rec <140 GeV	eLpR	16		24		66			63		
	eRpL	191		0		419			675		
	total	207	0.01%	24	0.01%	485	0.49%	737	47.76%	977	0.01%

hist\_dptbal\_jackieZH\_2f\_Z\_leptonic\_eL\_pR



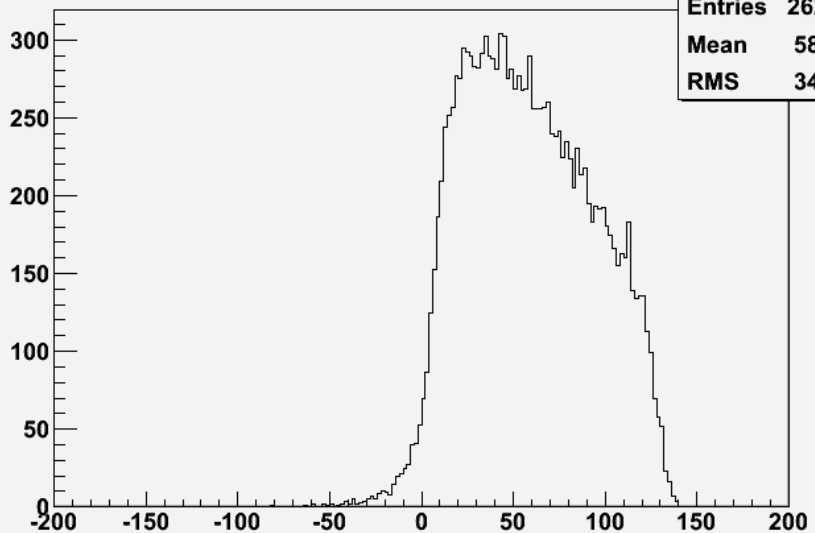
Entries 70743  
Mean 4.653  
RMS 15.07

hist\_dptbal\_jackieZH\_higgs\_ffh\_Pe2e2h\_eL\_pR



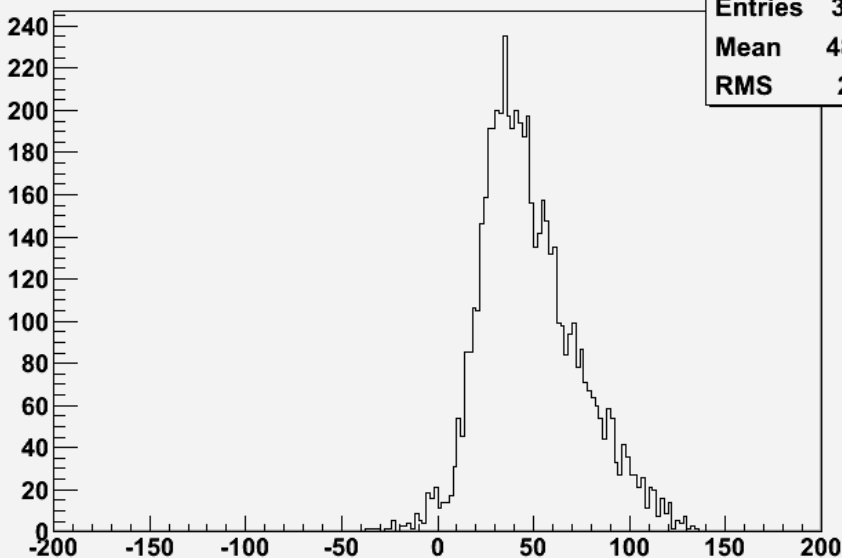
Entries 8994  
Mean 90.22  
RMS 30.52

hist\_dptbal\_jackieZH\_4f\_ZZ\_semileptonic\_eL\_pR



Entries 26232  
Mean 58.17  
RMS 34.94

hist\_dptbal\_jackieZH\_4f\_WW\_semileptonic\_eL\_pR



Entries 3969  
Mean 48.31  
RMS 25.5

## 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
- 4fSingleZnu\_nu\_leptonic
- 4f\_ZZWWMix\_leptonic
- 6f backgrounds ( $\sqrt{s}=350$  GeV)