

Higgs Recoil Mass Study at 350 GeV

Weekly Physics Meeting

May 30, 2014

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

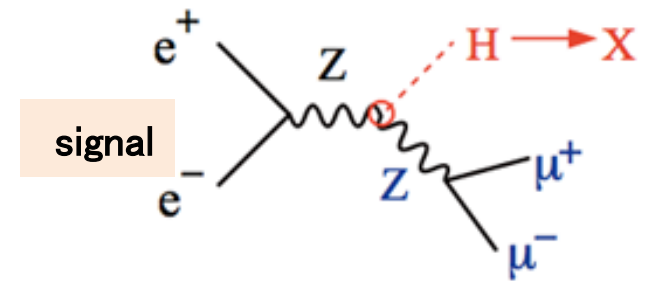
Ec.m.s. = 350 GeV, L = 333 fb⁻¹

And also Ec.m.s. = 250 GeV, L = 250 fb⁻¹

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



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

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~~ 160 GeV

- ◆ Resolve bias of Pull mean

Data Selection Method and Fitting Method for Recoil Mass Plot

Before: fitting was done in 115–150 GeV

Now: wider range: 100 – 160 GeV ~~100 – 200 GeV~~

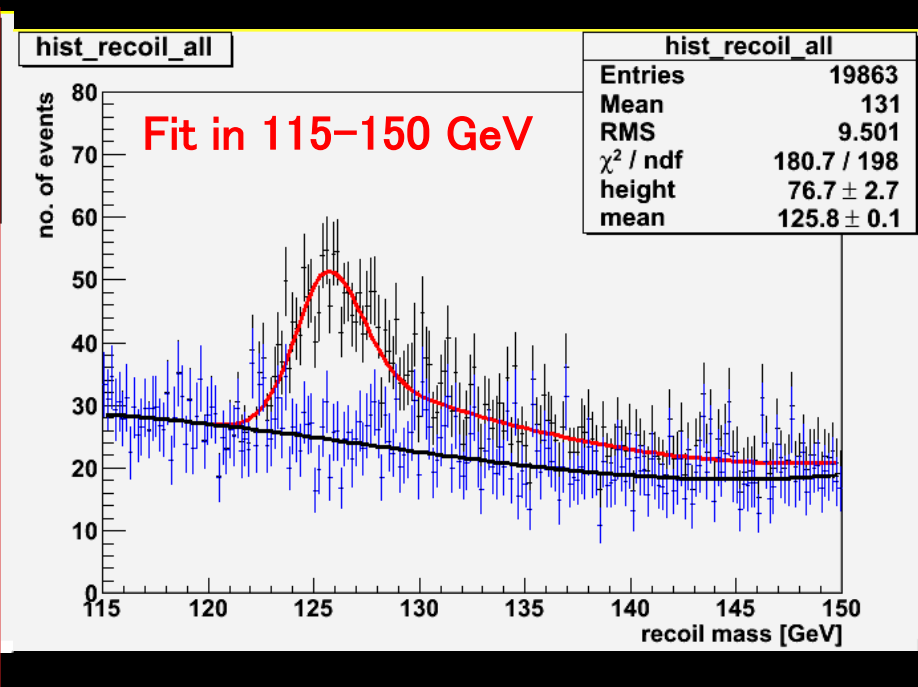
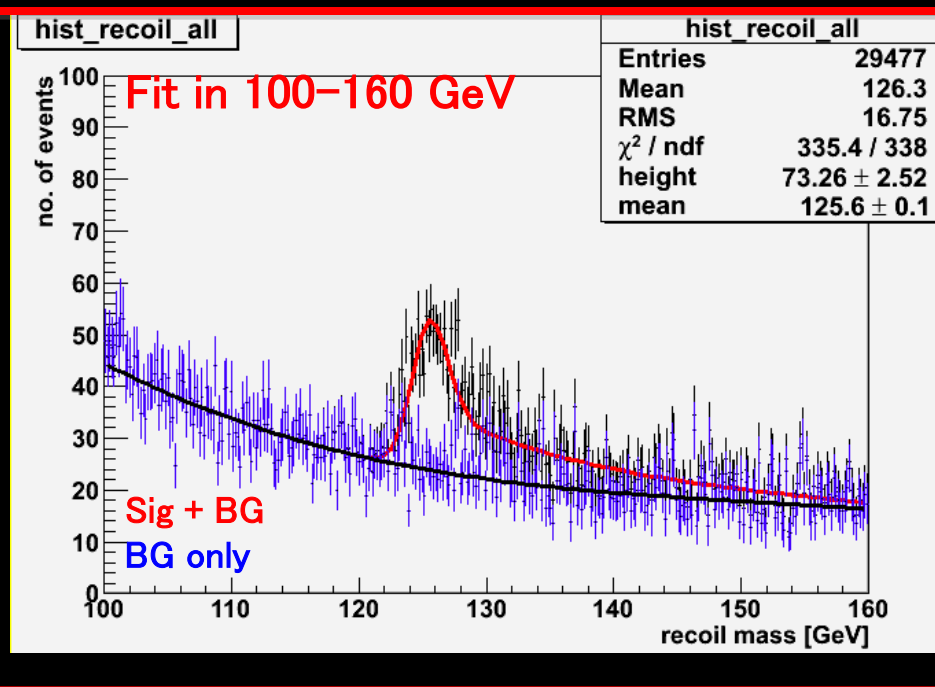
Get better estimation of BG function

results for sqrt(s) = 350 GeV , L = 333 fb⁻¹

Fit in 100–160 GeV

evaluated using Toy MC generated from fitted function shapes

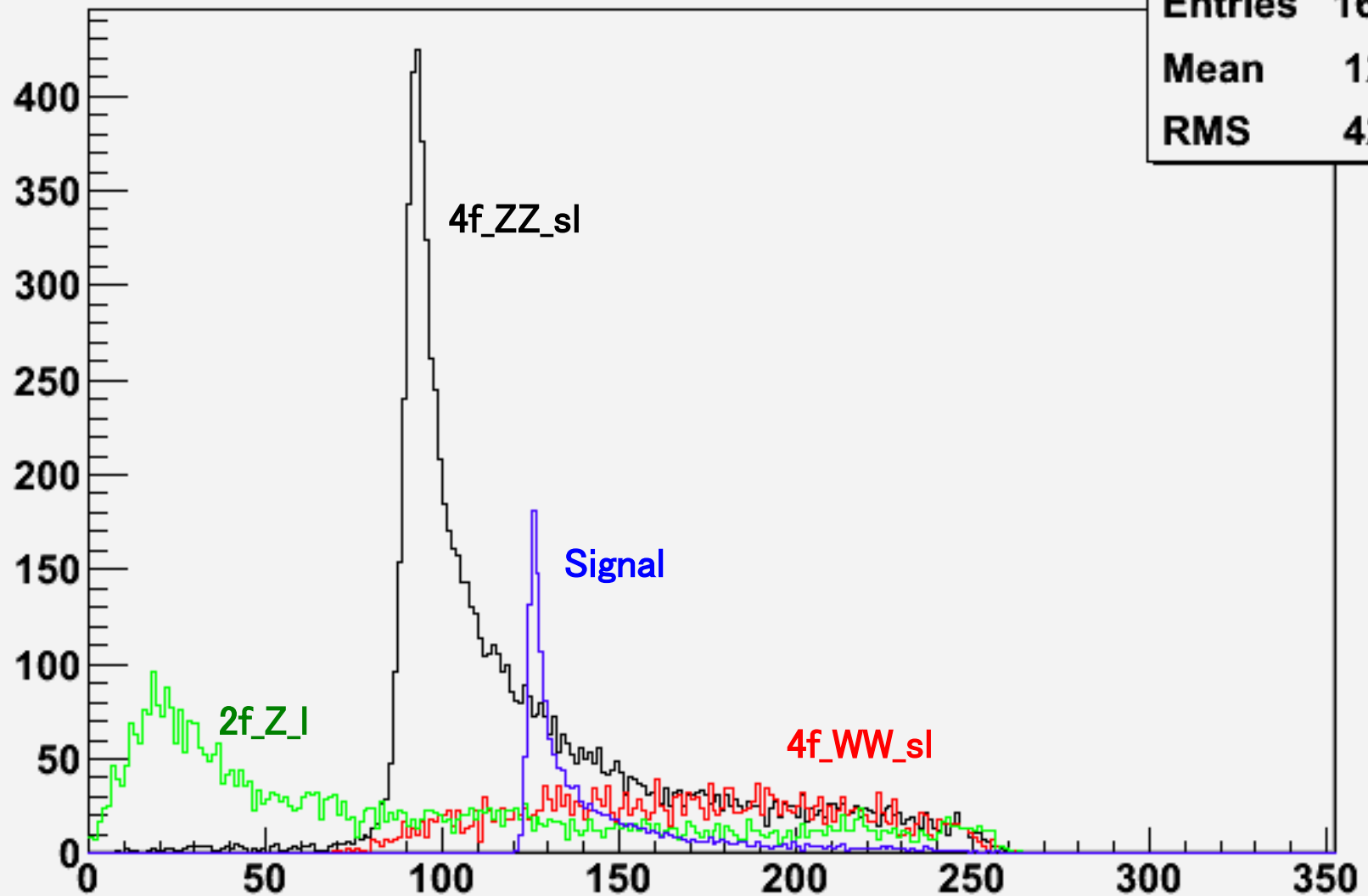
	ϵ	$\Delta \sigma / \sigma$	xsec	Nsig	S/N	significance
350 GeV						
(-0.8,+0.3)	47.6+/-0.5%	4.7+/-0.2%	6.9+/-0.3	1092+/-53	0.4	17.7
(-0.8,+0.3)	47.6+/-0.5%	4.9+/-0.2%	6.7+/-0.3	1092+/-55	0.4	17.7



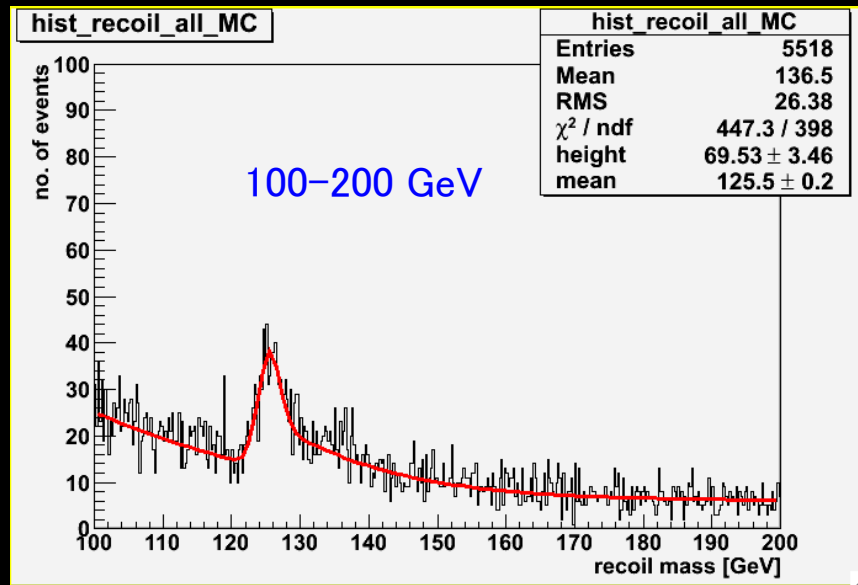
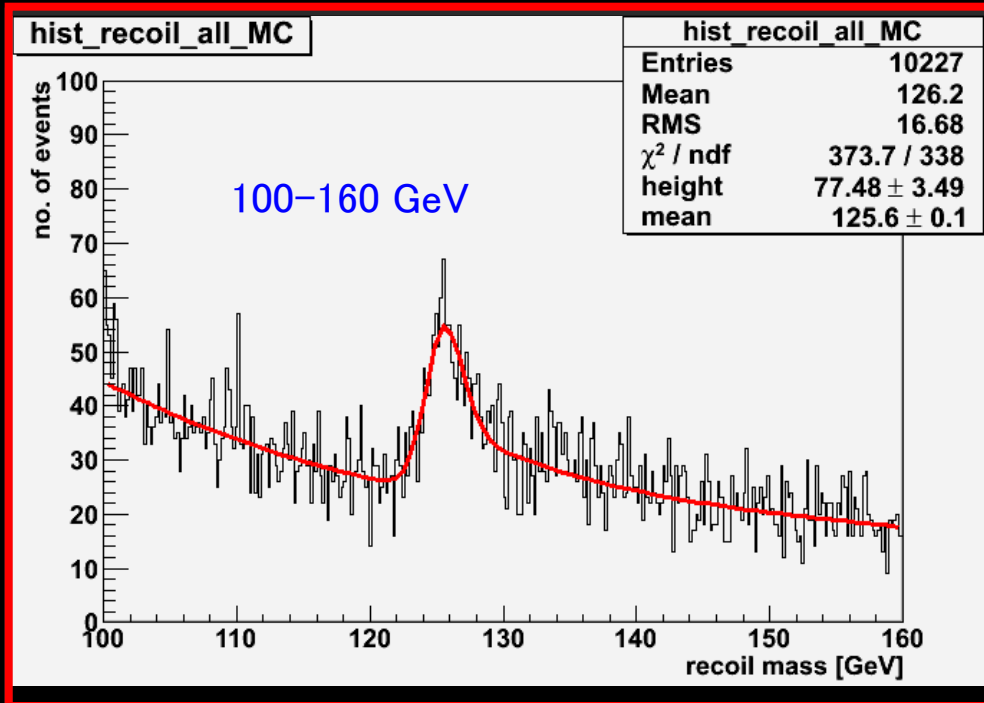
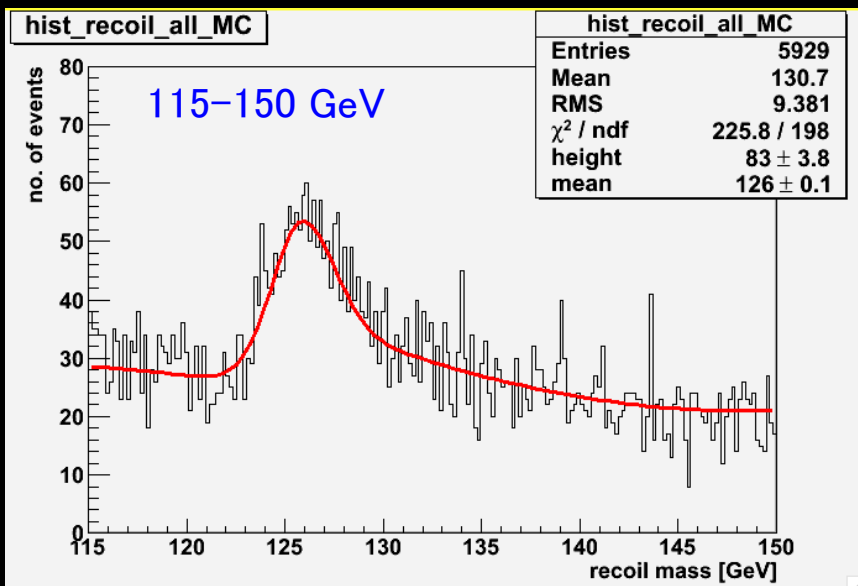
recoil mass 350 GeV : almost at end, just before recoil mass cut

hist_recoil3_jackieZH_4f_ZZ_semileptonic_eL_pR

hist_recoil3_jackieZH_4f_ZZ_semileptonic_eL_pR



Entries	16076
Mean	125.2
RMS	42.99



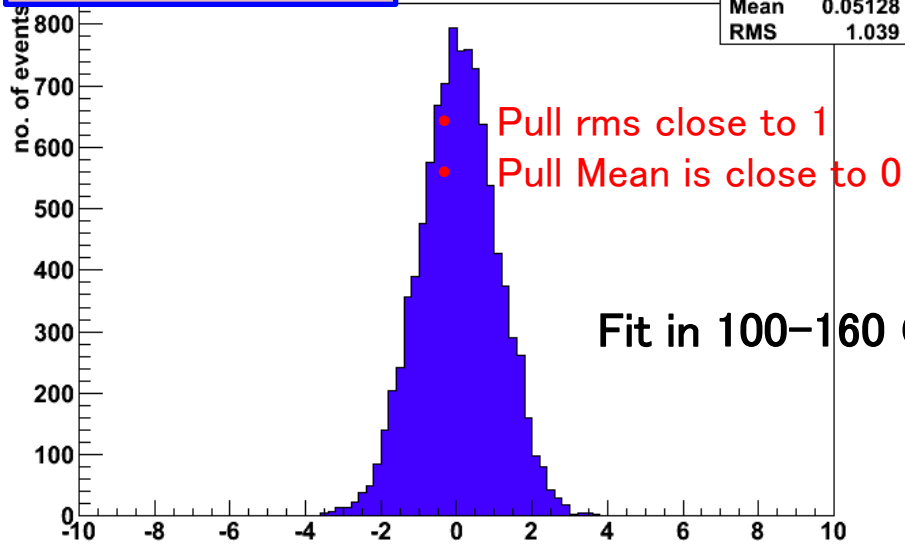
New findings for this week

Last week, actually I mistakenly inputted “real xsec” = 6.68 instead of 6.87, *sorry!!*

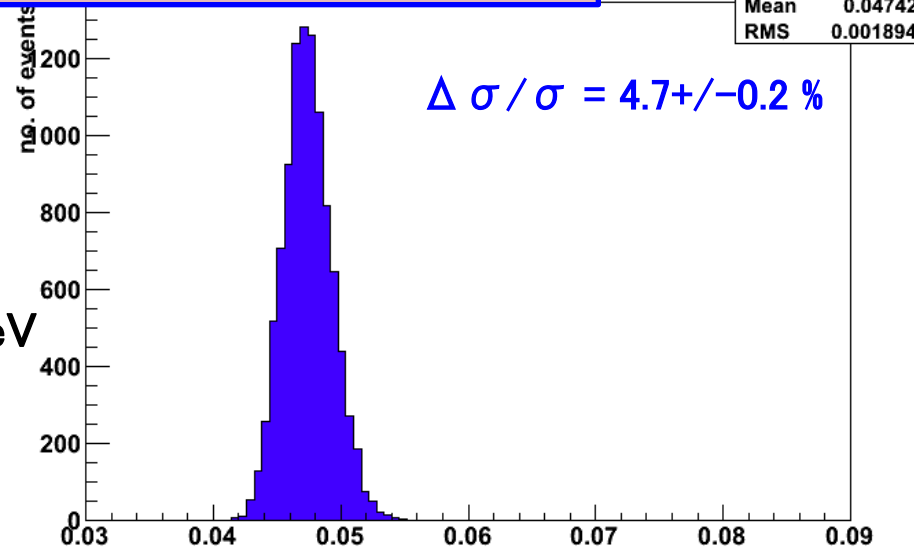
after fixing this, pull mean bias for (100–200) reduced (1.9→1.3) but not gone, and xsec and Nsig still biased, so must be something to do with too wide fitting range

for (100–160): no bias , consistent with “real”

Pull plot for xsec



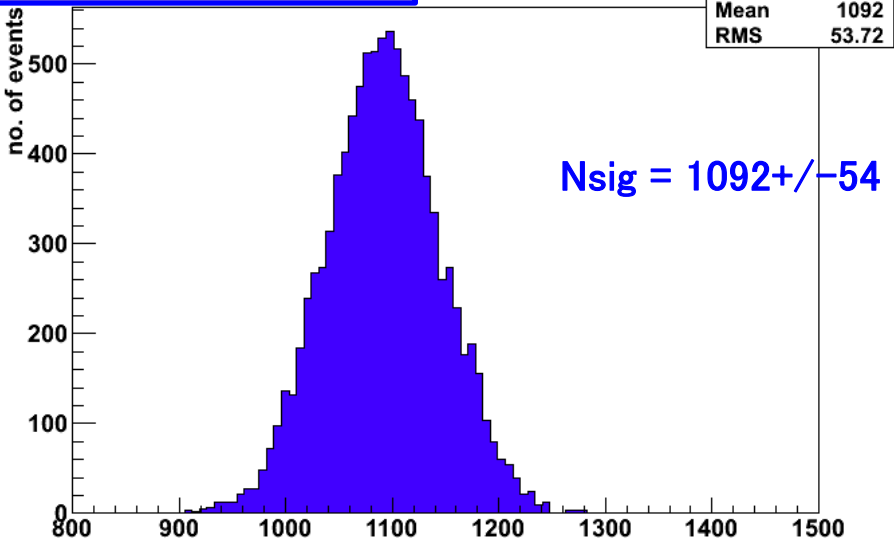
Relative xsec error



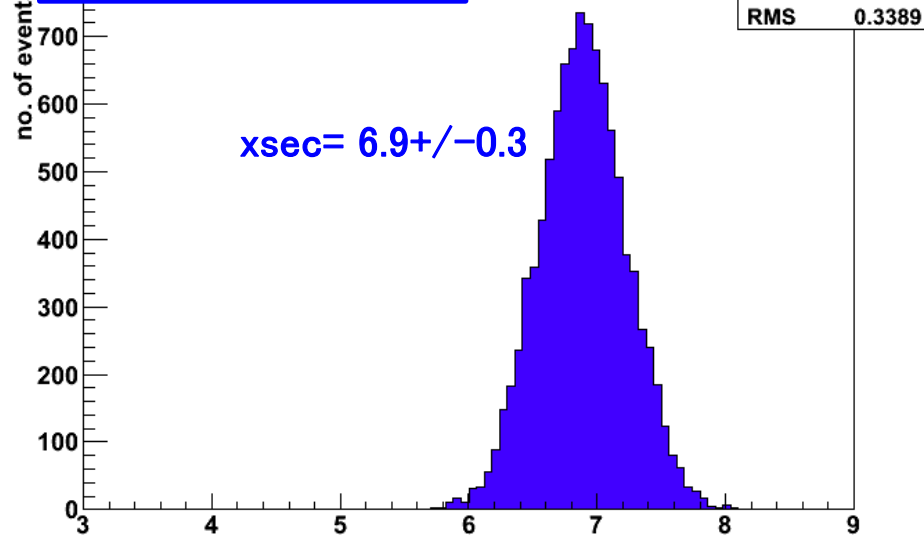
Result of Toy MC 10000 seeds
sqrt(s)=350 GeV

• “real xsec = 6.87” , “real Nsig = 1089”
Consistent within error ranges

of signal (Nsig)

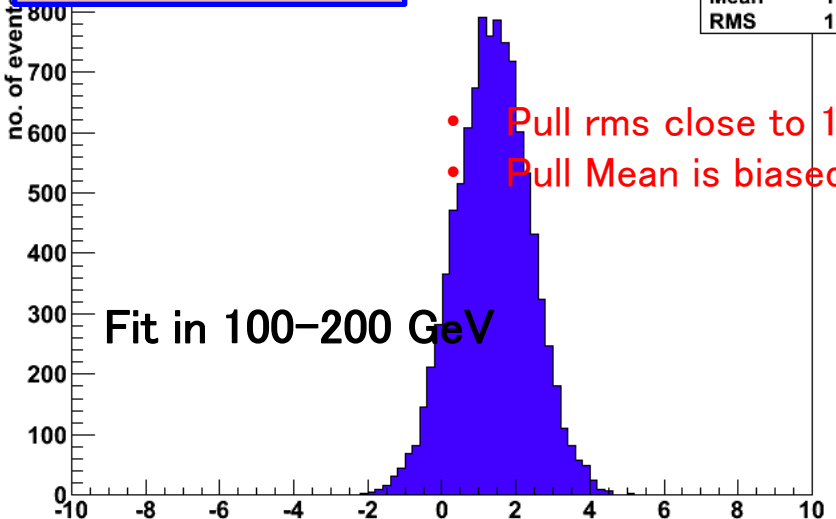


Cross section (xsec)



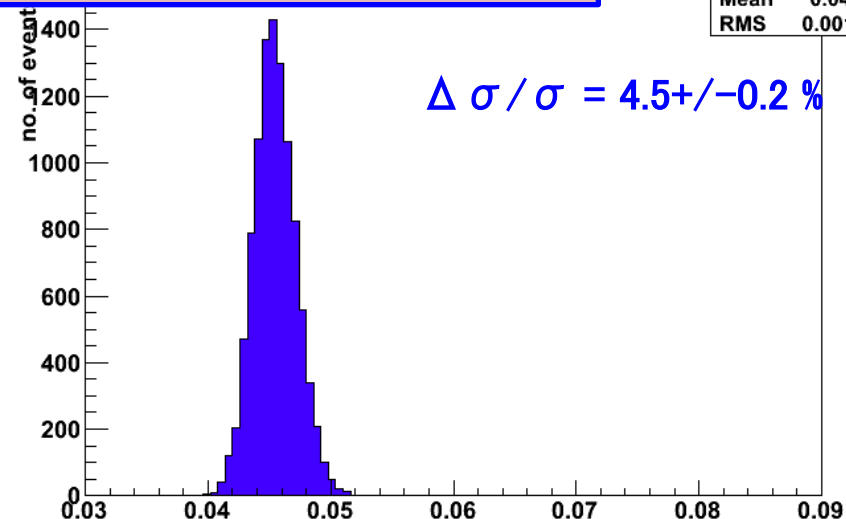
Pull plot for xsec

pull	
Entries	10000
Mean	1.369
RMS	1.018



Relative xsec error

xsec err	
Entries	10000
Mean	0.04546
RMS	0.001711



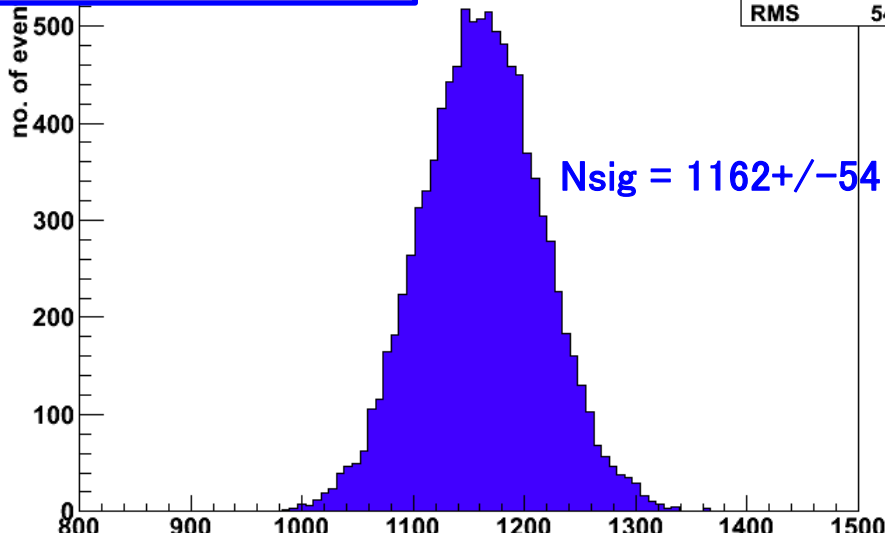
Result of Toy MC 10000 seeds

sqrt(s)=350 GeV

- “real xsec = 6.87” , “real Nsig = 1089”
- Slightly deviated from real (why ??)

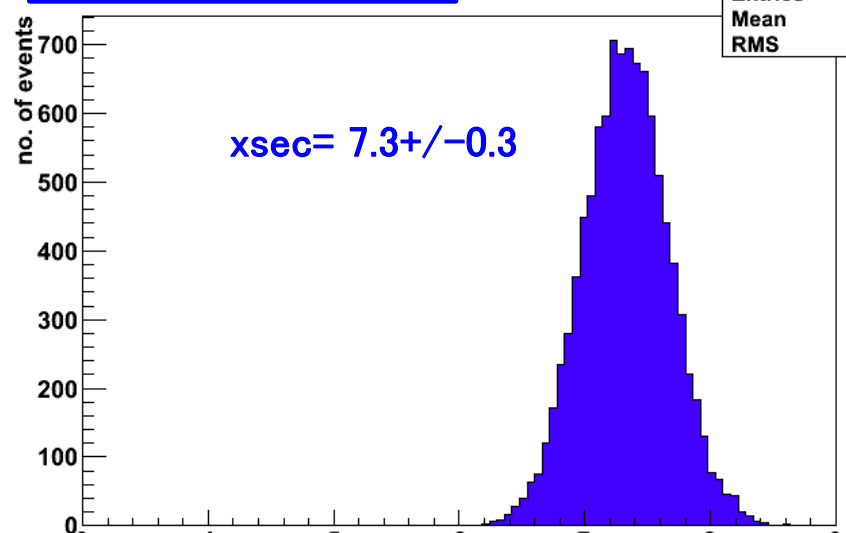
of signal (Nsig)

Nsig	
Entries	10000
Mean	1162
RMS	54.36



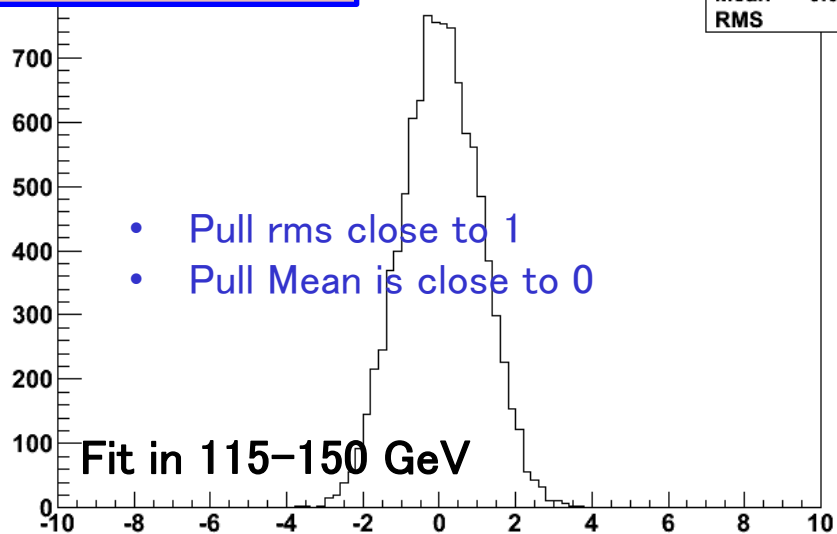
Cross section (xsec)

xsec	
Entries	10000
Mean	7.329
RMS	0.343



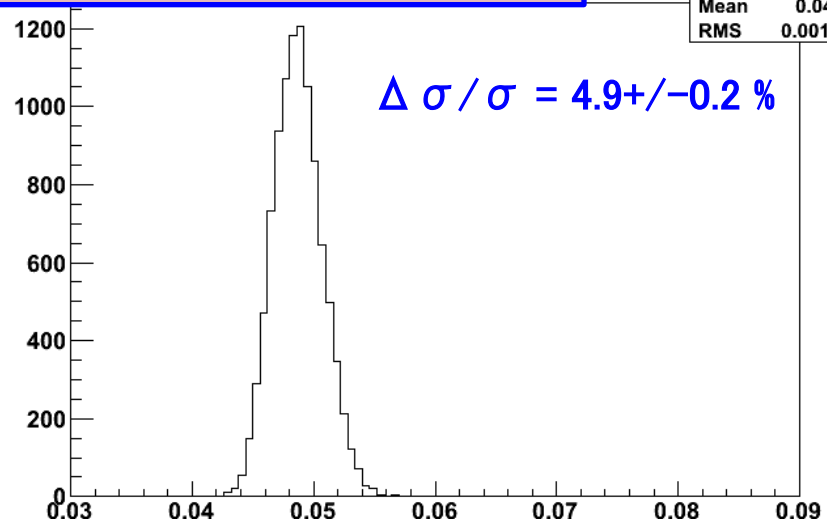
Pull plot for xsec

pull	
Entries	10000
Mean	0.04213
RMS	1.04



Relative xsec error

rel xsec error	
Entries	10000
Mean	0.04871
RMS	0.001998



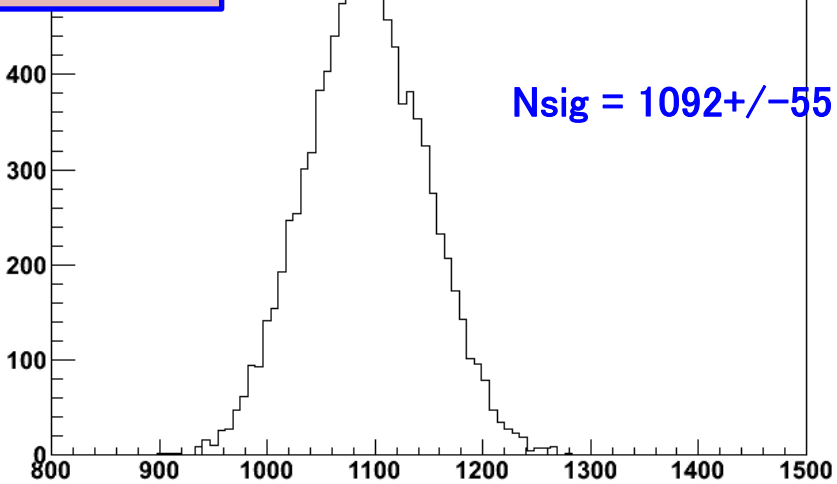
Result of Toy MC 10000 seeds

sqrt(s)=350 GeV

- “real xsec = 6.87” , “real Nsig = 1089”
Consistent within error ranges

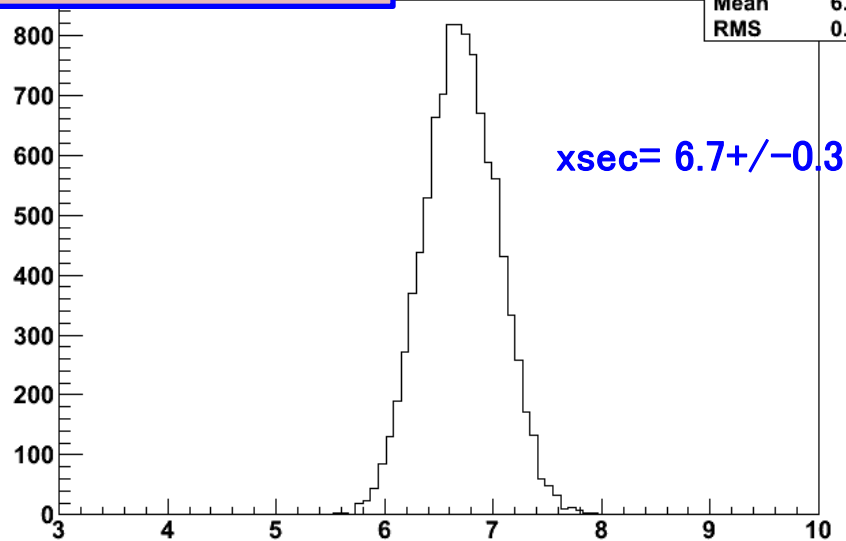
of signal (Nsig)

Nsig	
Entries	10000
Mean	1092
RMS	55.2



Cross section (xsec)

xsec	
Entries	10000
Mean	6.705
RMS	0.339



Summary

try wider fitting range

• Before 115-150 GeV

• Now: 100-160 GeV : to get better estimate of BG function

xsec error is improved by about 0.2% for (-0.8,+0.3) ~ 5% improvement

Pull plot, Nsig, xsec from Toy MC all seem fine

< Preliminary results >

350 GeV: 100- 160 GeV fitting range

(-0.8, +0.3) $\Delta\sigma / \sigma = 4.7 \pm 0.2 \%$, $\epsilon_{\text{sig}} = 47.6 \pm 0.5 \%$, S/B ~ 0.40

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 June

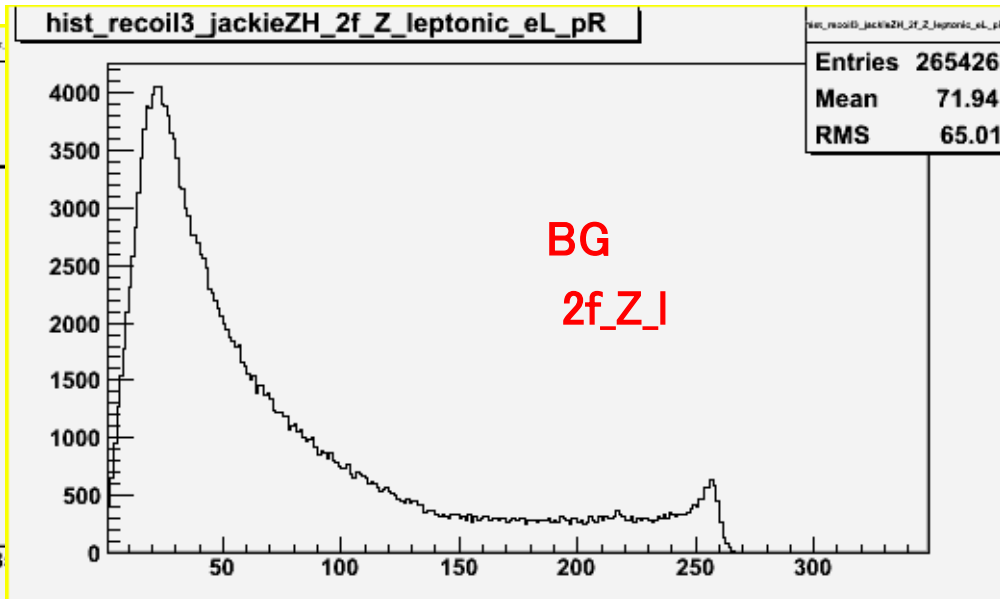
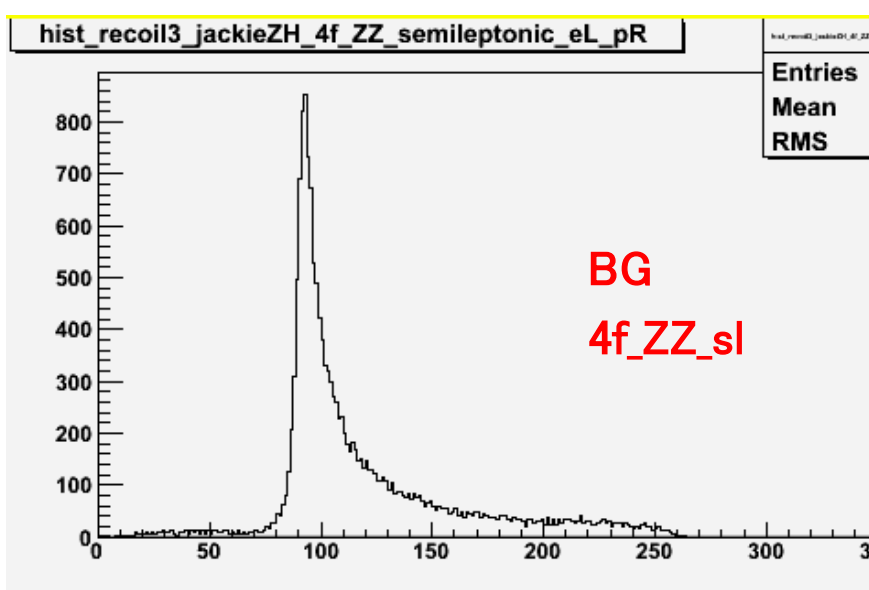
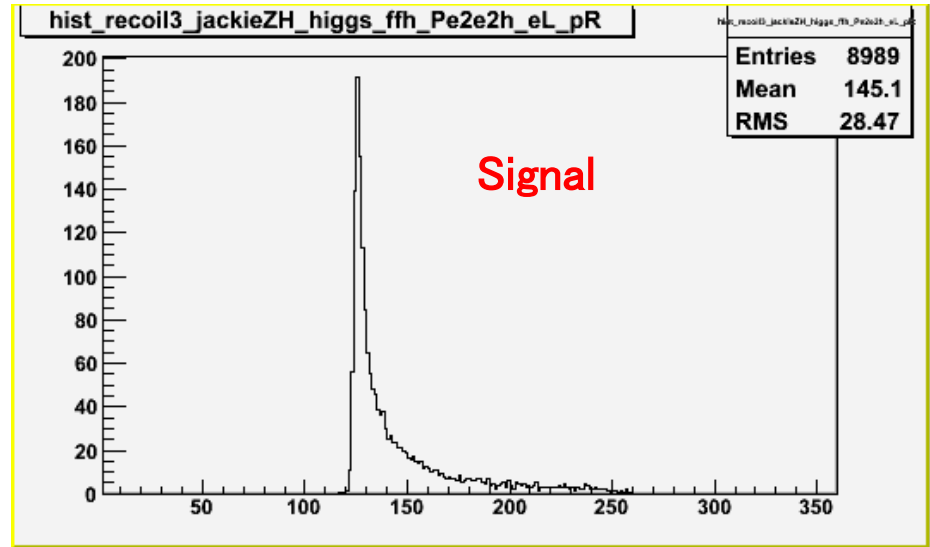
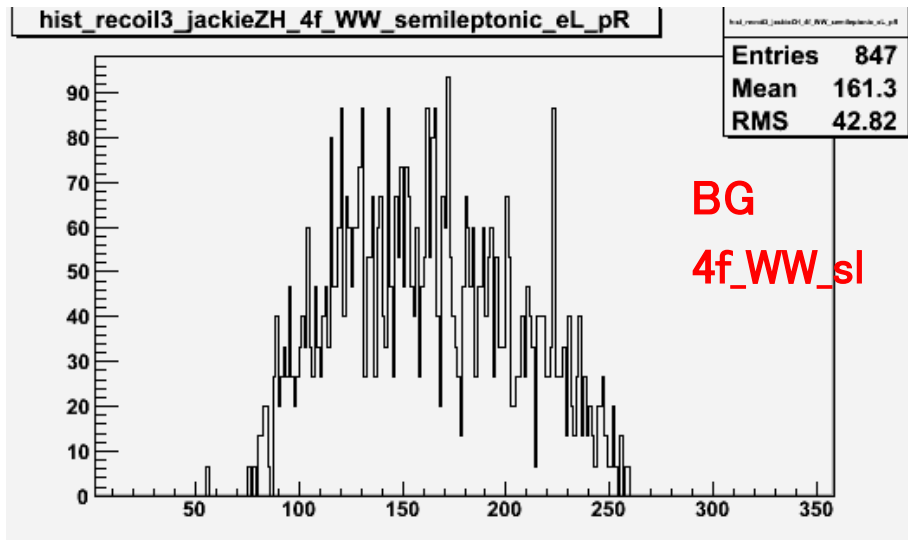
(1st week in June, absent for TIP2014)

- study **precision of fitted recoil mass M_H**
- study **alternative polarization scenarios** e.g. (-0.8, 0) (+0.8, 0) ...etc...
- muon isolation cut to reduce WW_sl BG

BACKUP

recoil mass 350 GeV

After inv mass cut

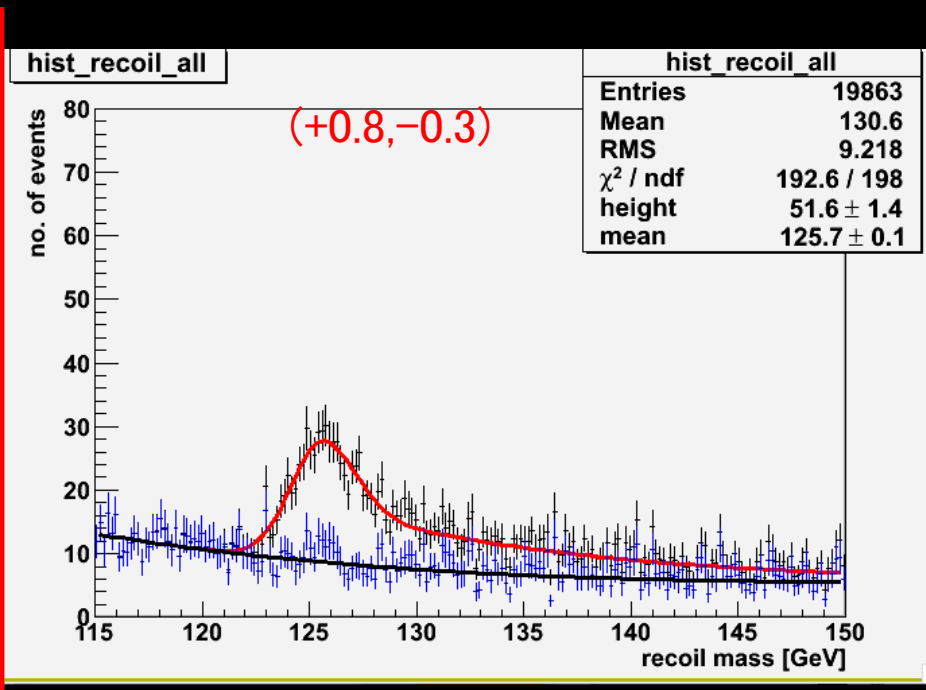
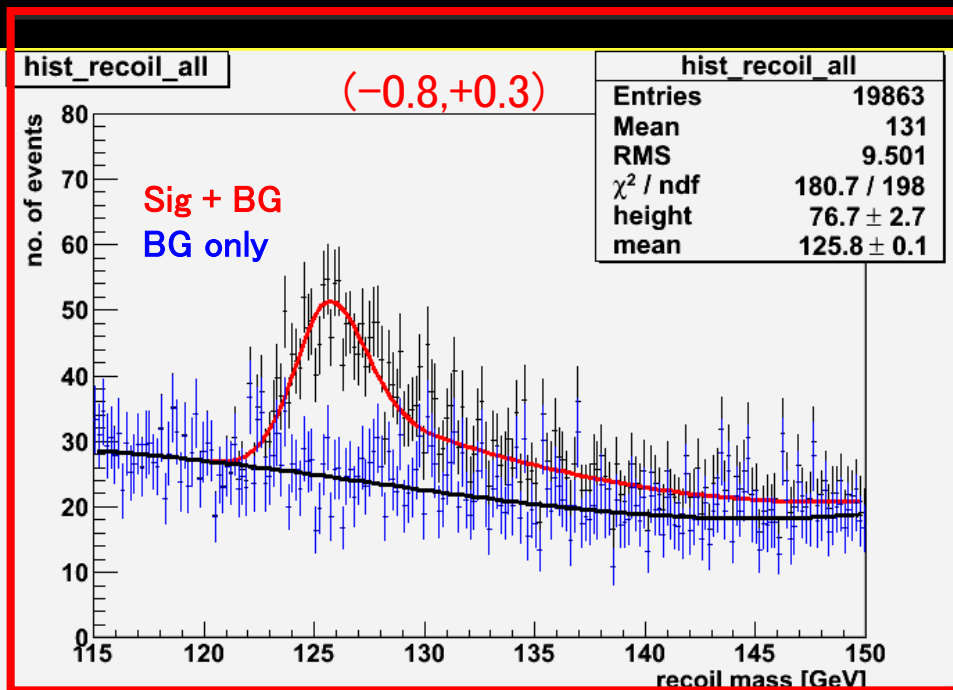


results for sqrt(s) = 350 GeV , L = 333 fb⁻¹

Fit in 115–150 GeV

evaluated using Toy MC generated from fitted function shapes

	ϵ	$\Delta \sigma / \sigma$	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



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_{inv} : invariant mass of 2 muons
- pT_{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

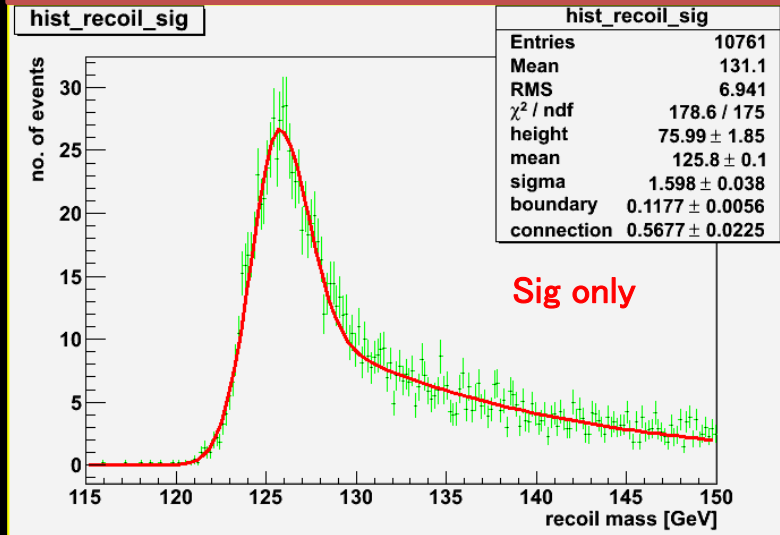
($\sqrt{s}=350 \text{ GeV}$)

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

fitting for recoil mass histogram

1st time fitting:

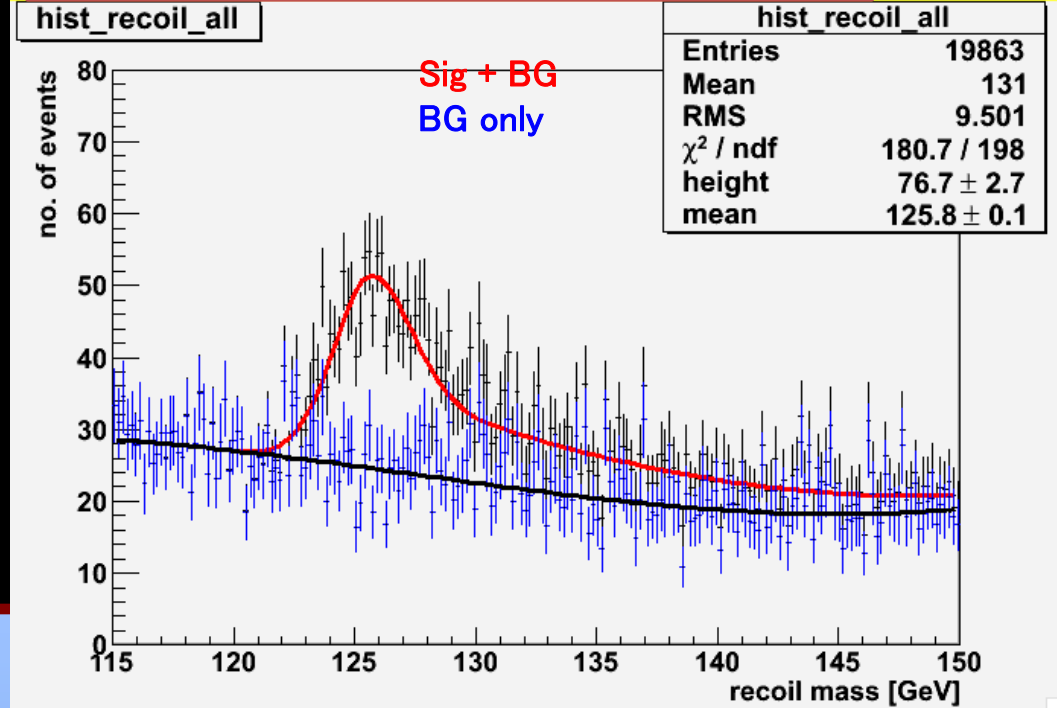
- fit only signal : float all 5 GPET pars
- fit BG only 3rd order polynomial



Final fitting:

float only height and mean,

Fix BG function and remaining GPET pars from 1st time fitting

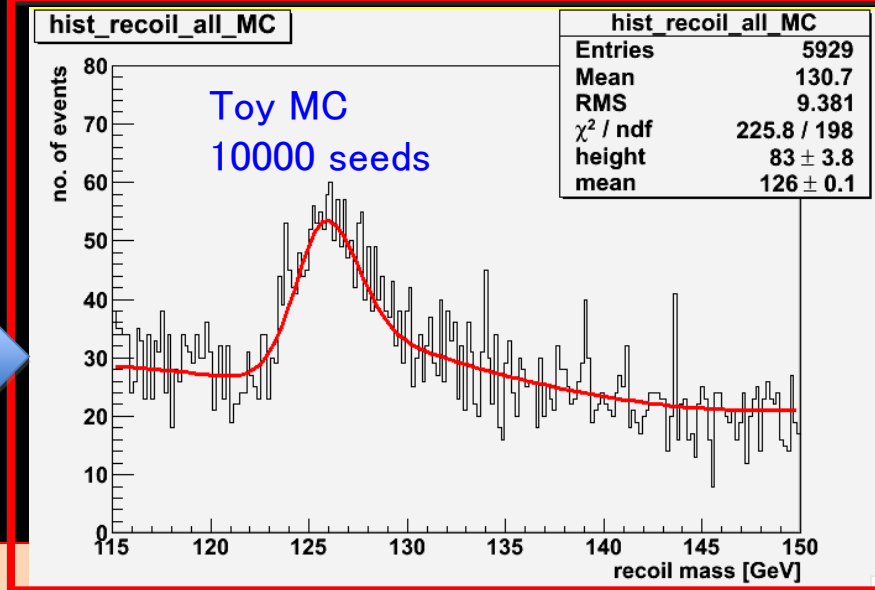
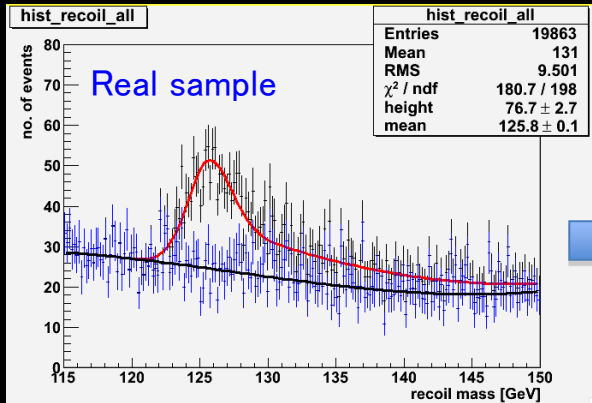


- ◆ **SIGNAL: GPET: 5 parameters :**
Gaus (left-side) , Gaus + expo (right side)

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

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

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_{sec} and number of signals (N_{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_{sec}

Results:

- Pull plot seems reasonable
- N_{sig} and x_{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

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

Signal sample:

Pe2e2h_eL.pR & Pe2e2h_eR.pL

relevant BG process for Zmumu

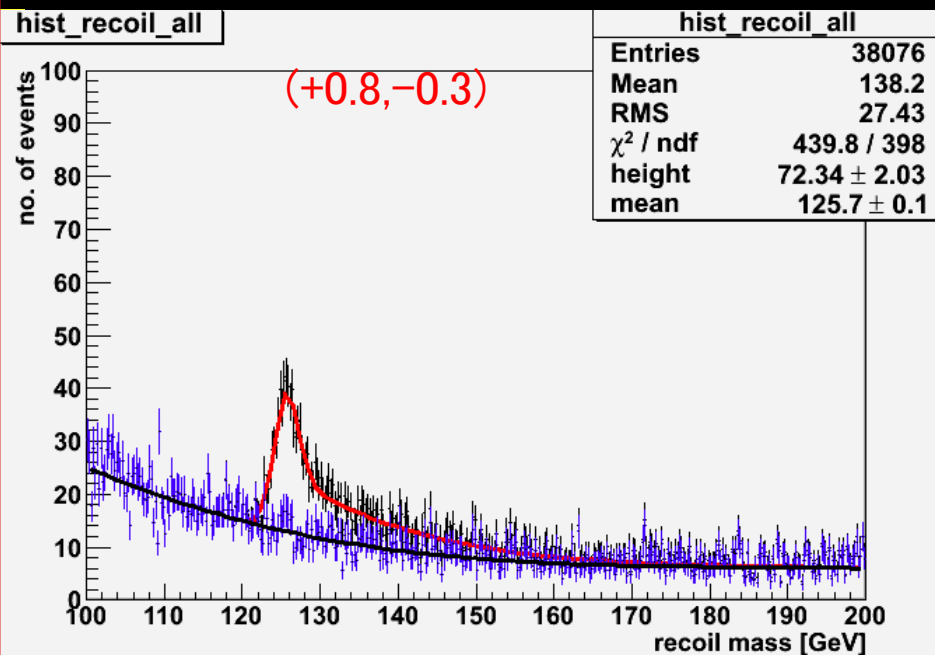
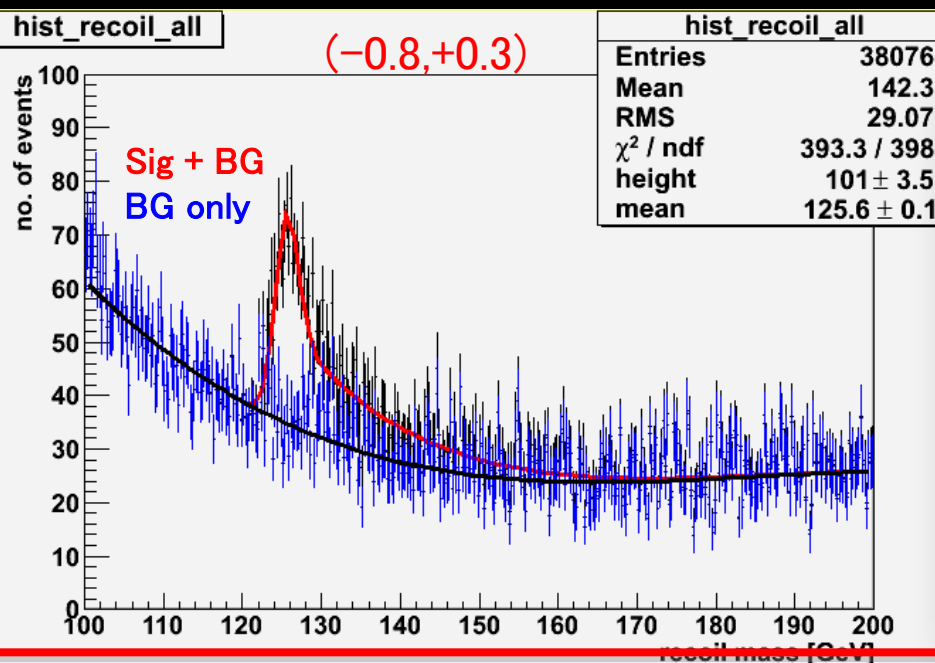
- 4f_ZZ_leptonic
- 4f_ZZ_semileptonic
- 2f_Z_leptonic
- 4f_WW_leptonic
- 4f_WW_semileptonic
- 4fSingleZee_leptonic
- 4fSingleZnu_nu_leptonic
- 4f_ZZWWMix_leptonic
- 6f backgrounds ($\sqrt{s}=350$ GeV)

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

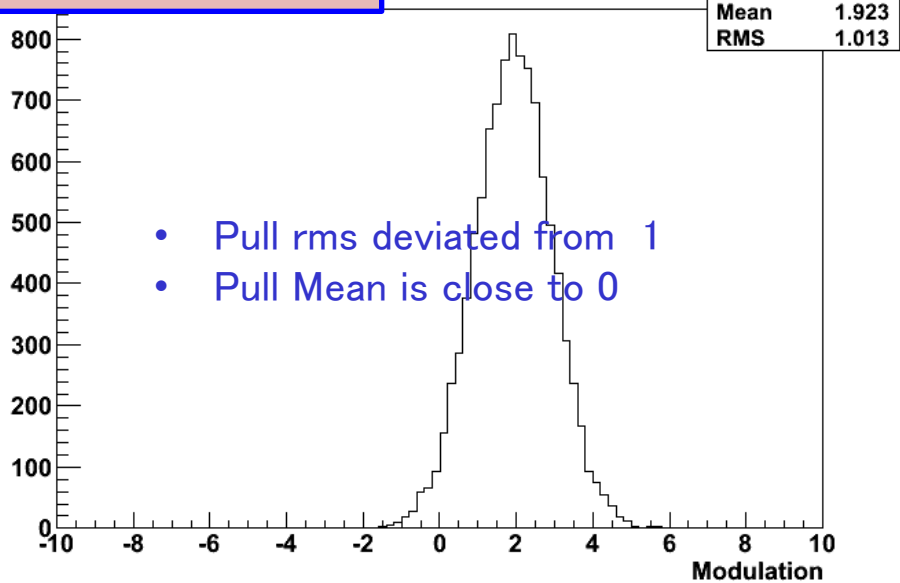
Fit in 100–200 GeV

evaluated using Toy MC generated from fitted function shapes

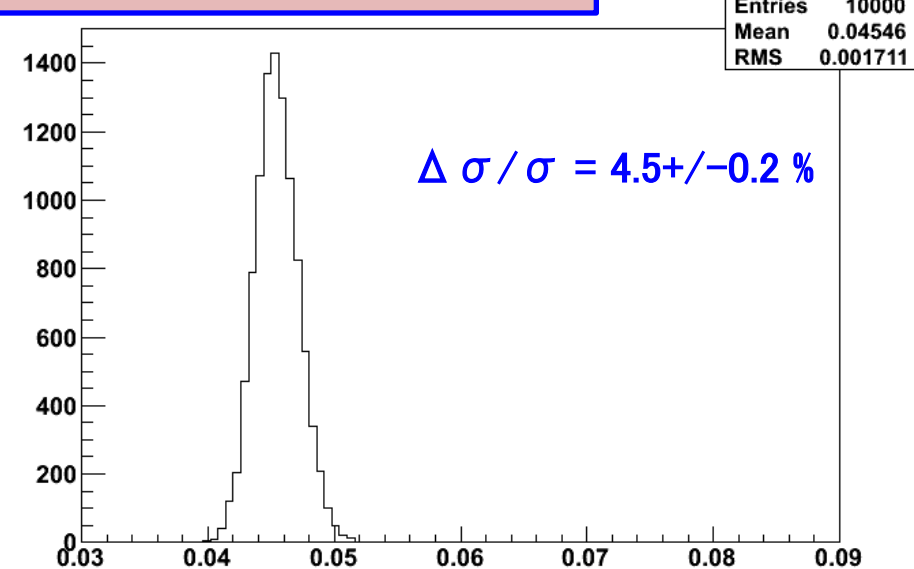
	ϵ	$\Delta \sigma / \sigma$	xsec	Nsig	S/N	significance
350 GeV						
(-0.8,+0.3)	47.6+/-0.5%	4.5+/-0.2%	6.71+/-0.34	1092+/-55	0.4	17.7
(+0.8,-0.3)	47.8+/-0.5%	4.8+/-0.2%	4.72+/-0.24	750+/-40	0.75	17.8



Pull plot for xsec



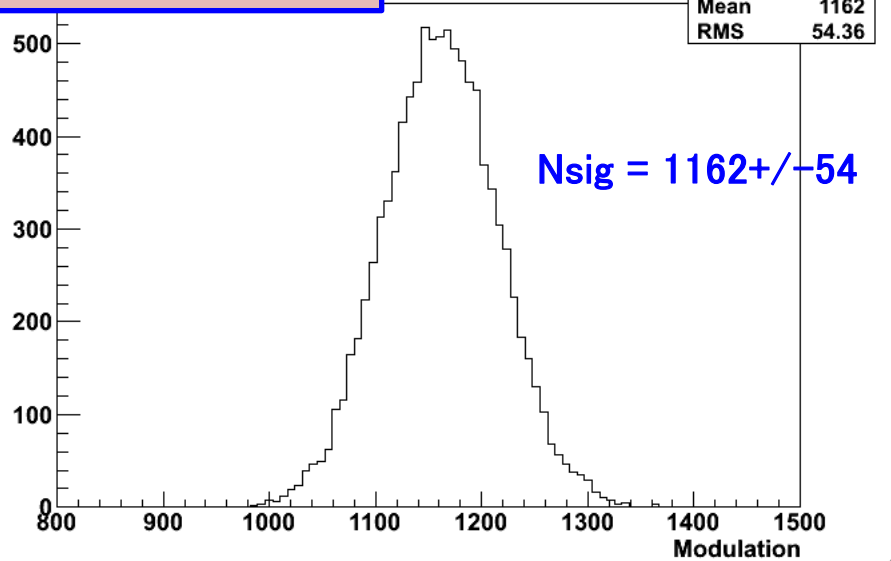
Relative xsec error



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

• “real xsec = 6.87” , “real Nsig = 1089”

of signal (Nsig)



Cross section (xsec)

