Higgs Recoil Mass Study at 350 GeV

Weekly Physics Meeting

June 27 , 2014

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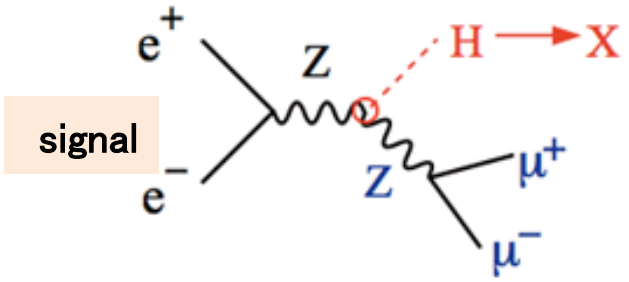
recoil mass study using e+e- → ZH → μ+μ-H
Ec.m.s. = 350 GeV, L = 333 fb-1
And also Ec.m.s. = 250 GeV, L = 250 fb-1



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

Pe2e2h_.eL.pR & Pe2e2h._eR.pL

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

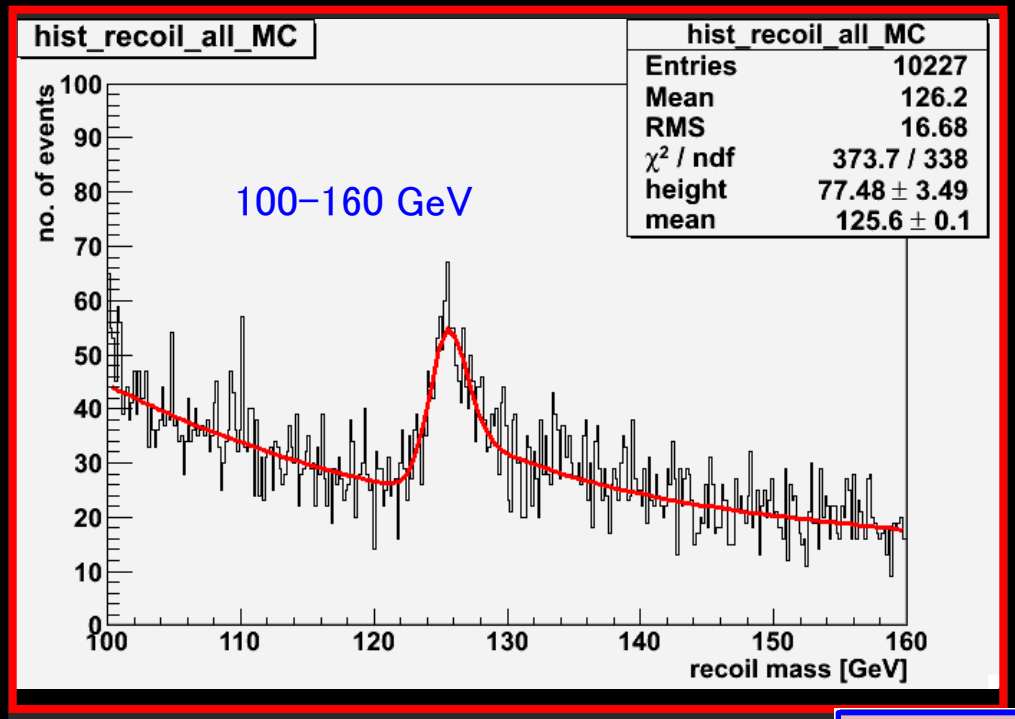
BG :
included all 2f, 4f, 6f processes

Full ILD detector simulation

What's new this week

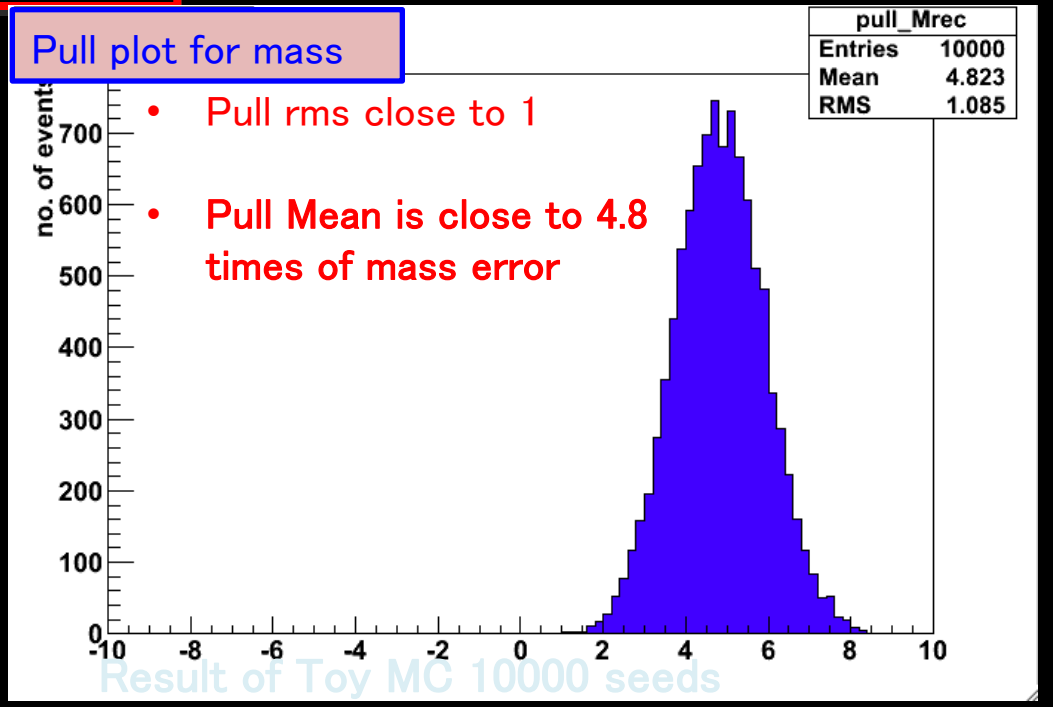
Observe bias of fitted recoil mass

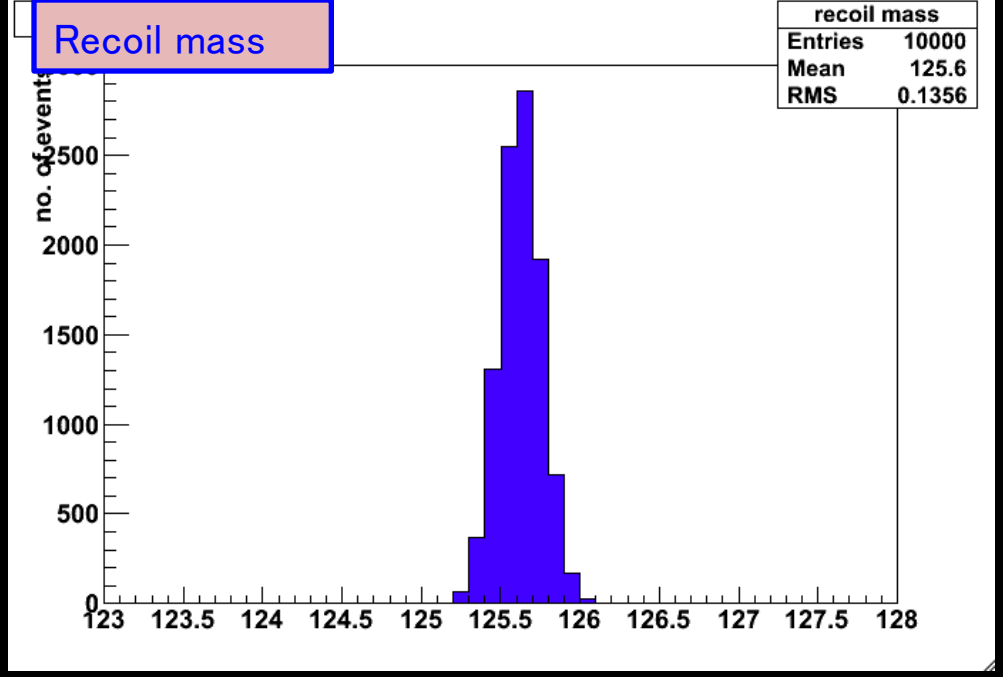
use wider fitting range now: 100 – 160 GeV



Toy MC 10000 seeds

Fit in 100-160 GeV

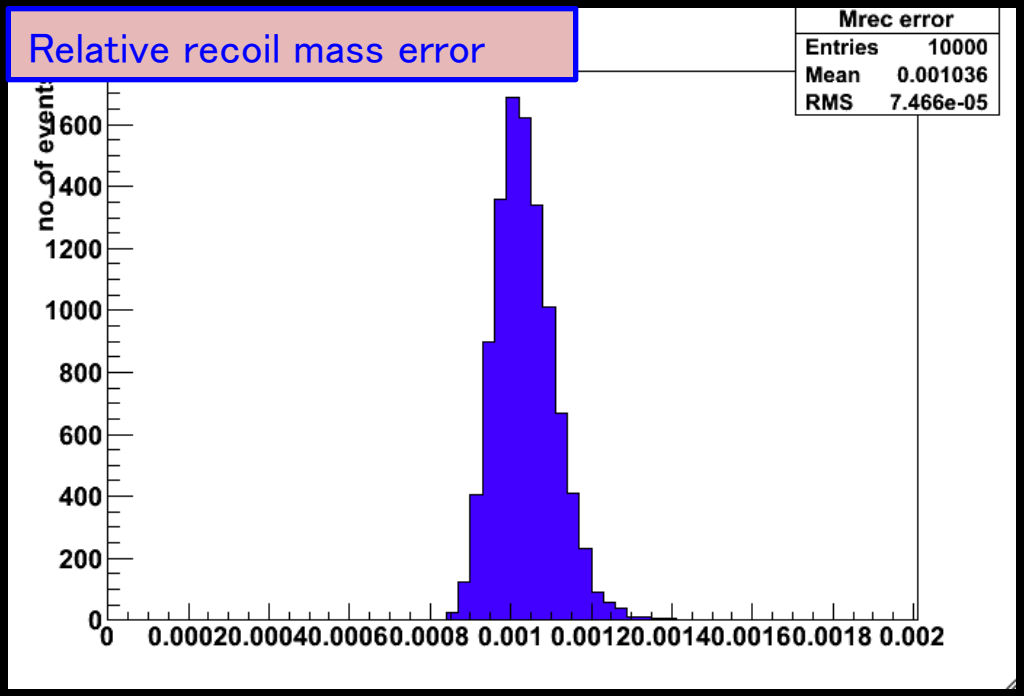




Mrec from Toy MC: 125.6 +/− 0.1 GeV

real Mrec = 125 GeV

0.1% relative error　(in fitting)

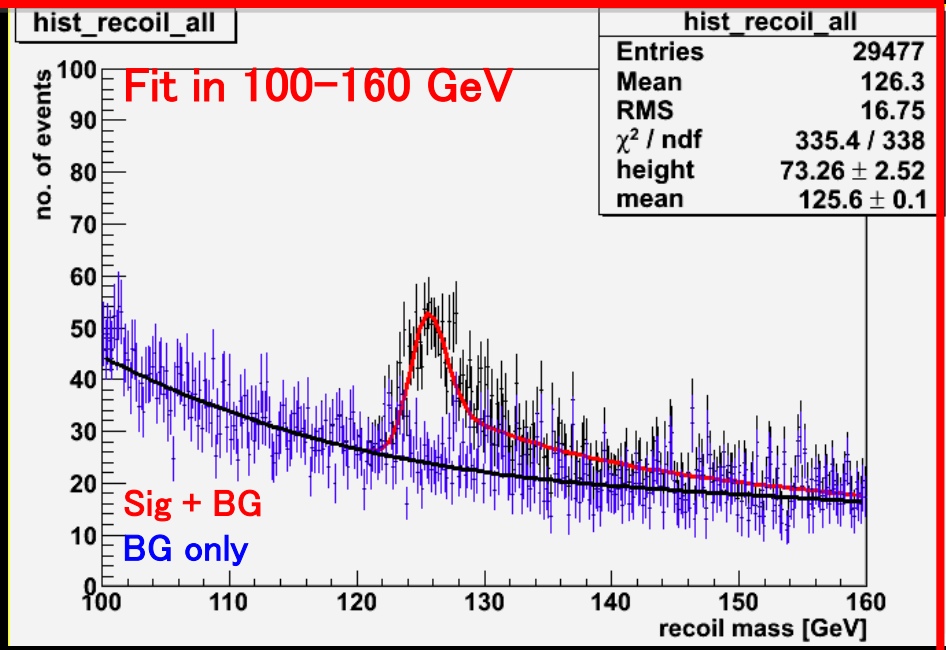


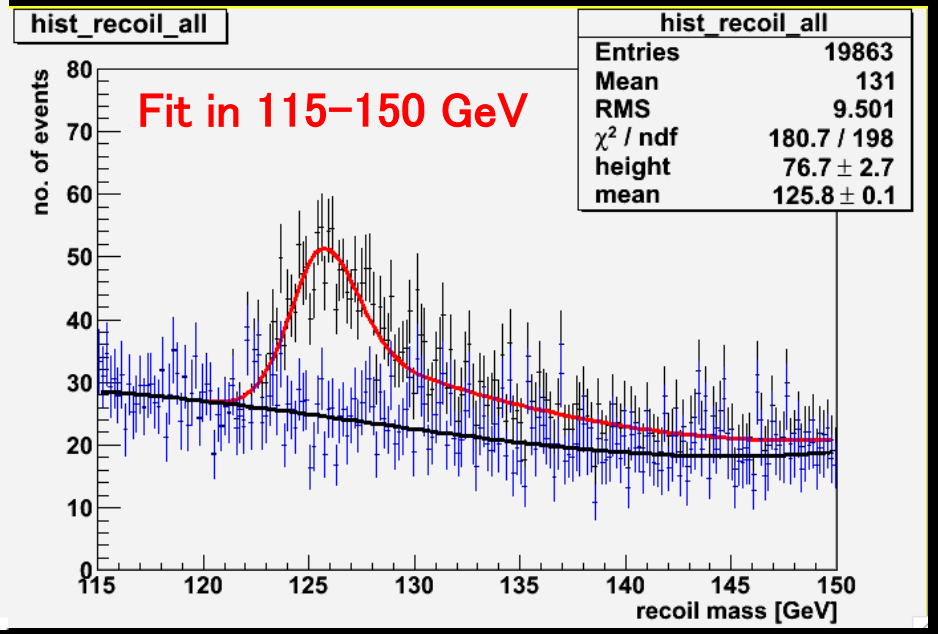
results for sqrt(s) =350 GeV , L = 333 fb−1

Fit in 100−160 GeV

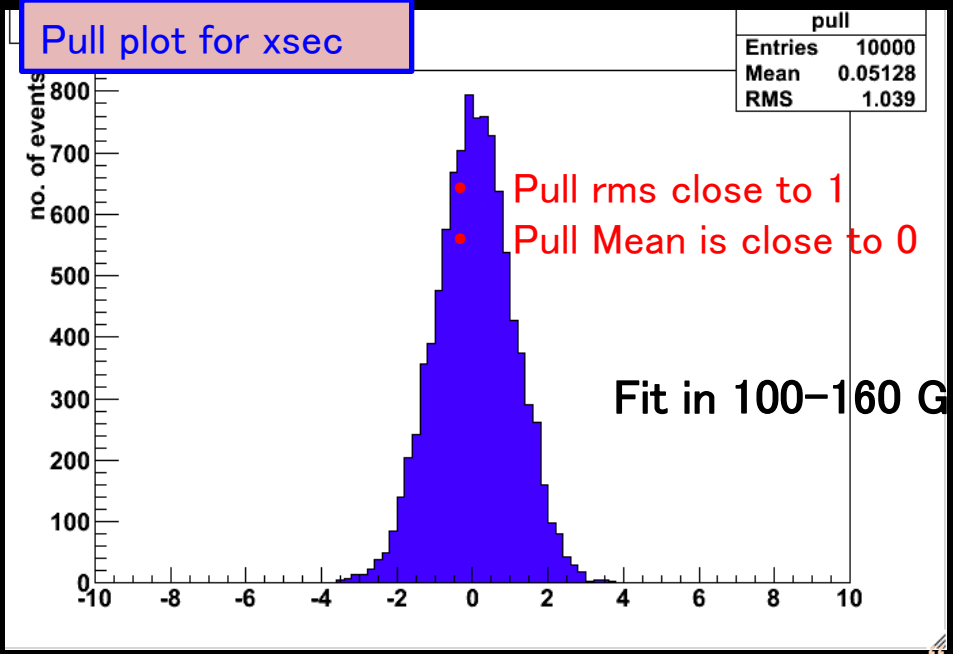
evaluated using Toy MC generated from fitted function shapes

350 GeV	ε	Δσ/σ	xsec	Nsig	S/N	significance
(−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

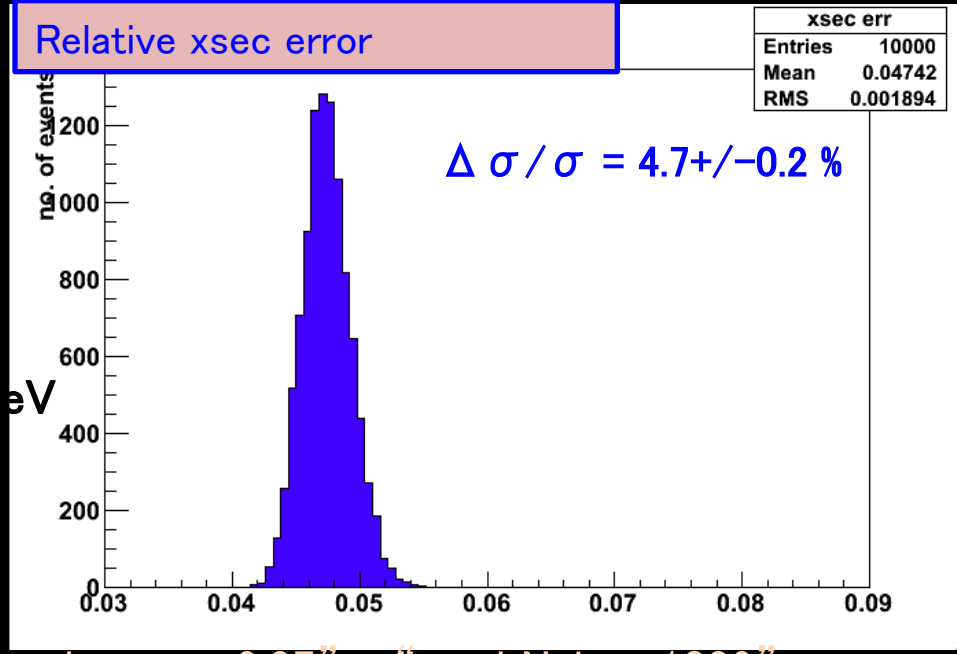




Pull plot for xsec



Relative xsec error



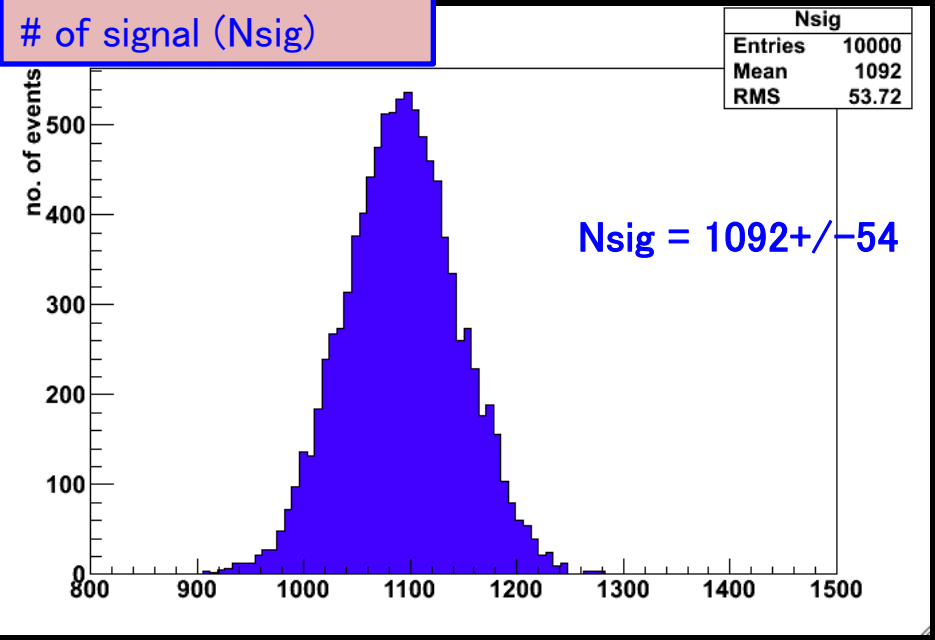
Result of Toy MC 10000 seeds

sqrt(s)=350 GeV

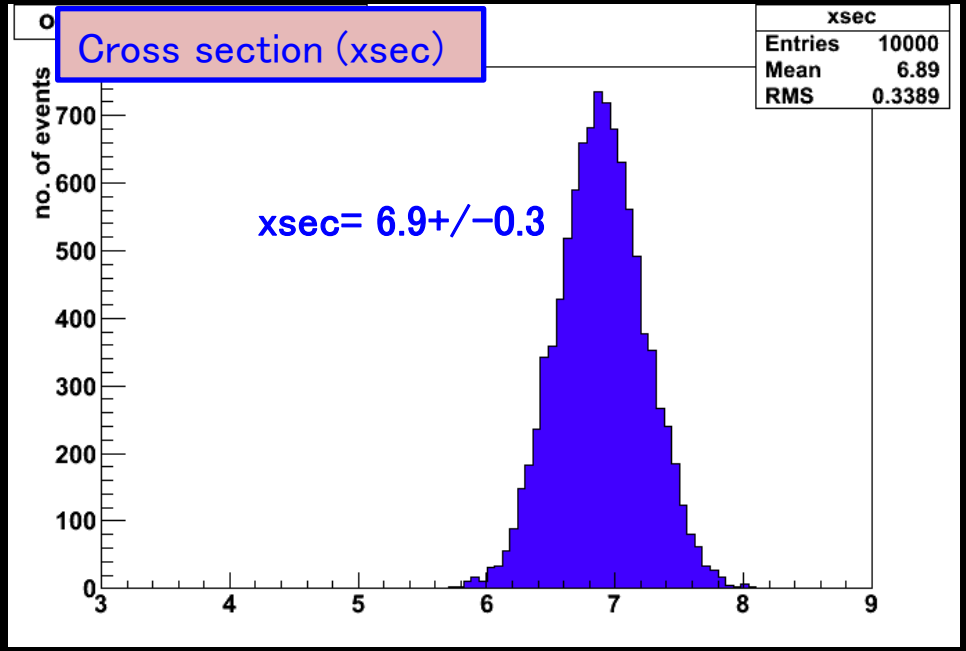
- "real xsec = 6.87" , " real Nsig = 1089"

Consistent within error ranges

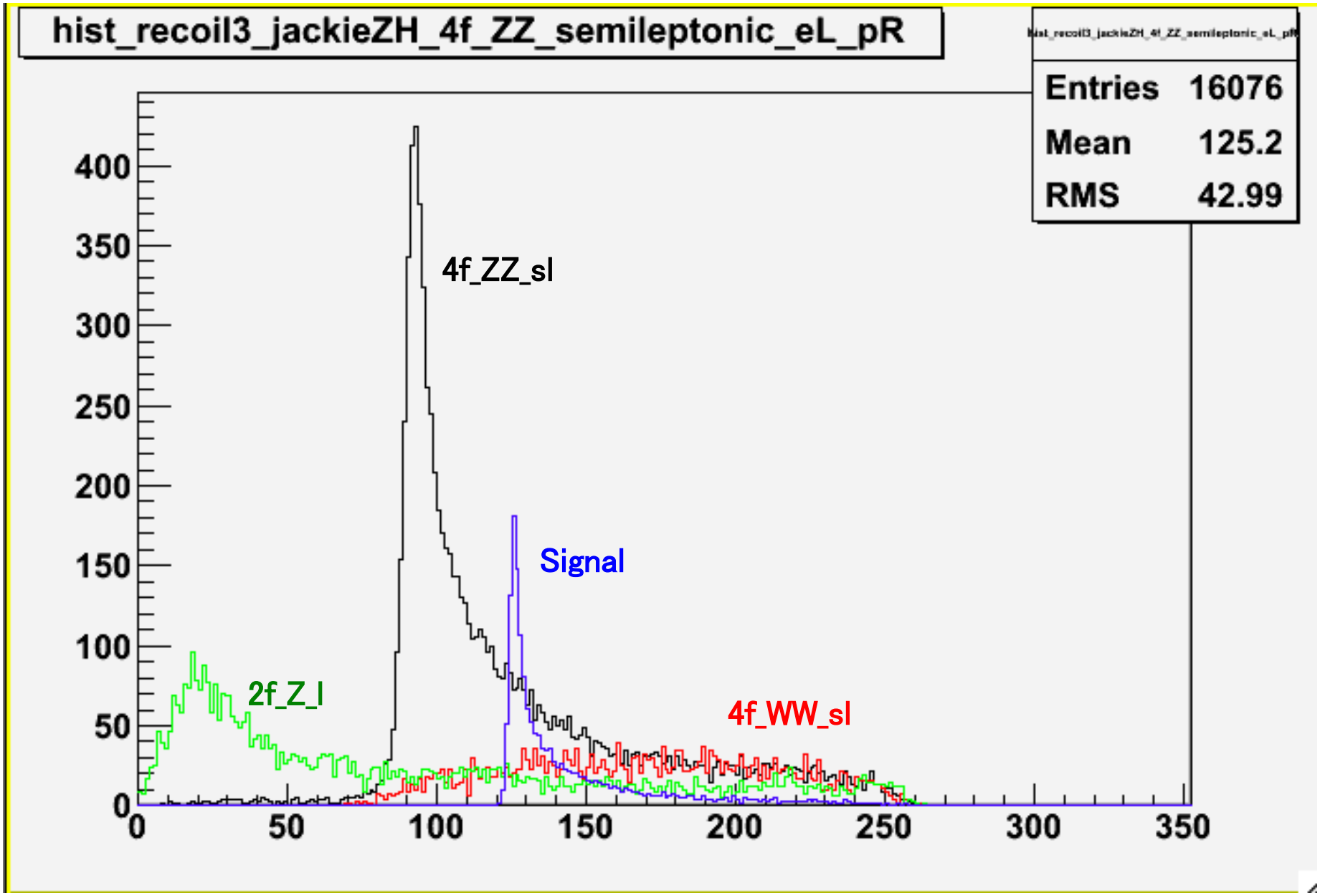
of signal (Nsig)



Cross section (xsec)



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



Summary

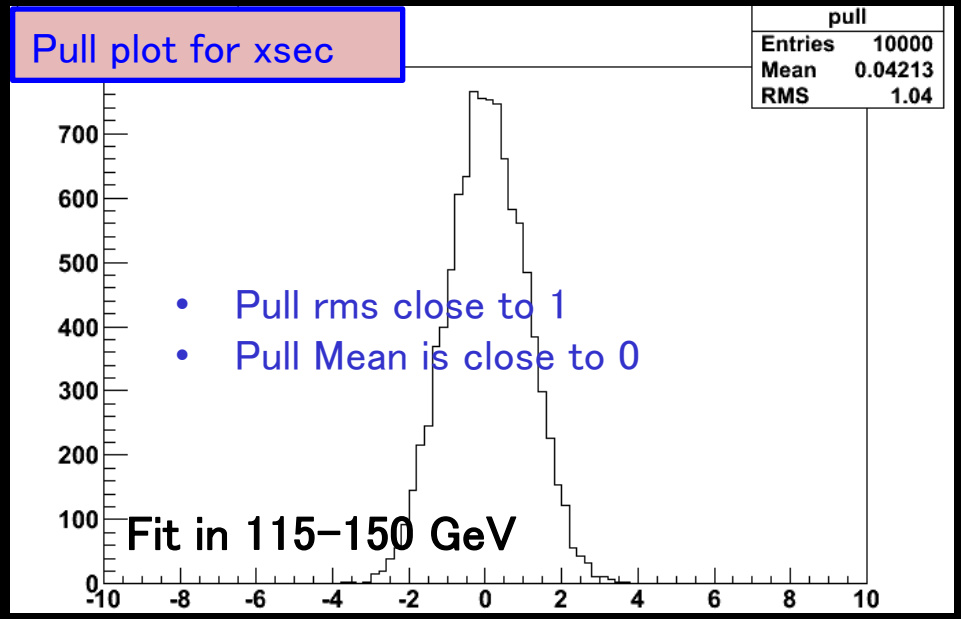
fitted recoil mass is 4.8 sigmas away from 125 GeV

- **Now fitting in range: 100-160 GeV : to get better estimate of BG function**

plan to study bias of recoil mass (before ILC summer camp ?)

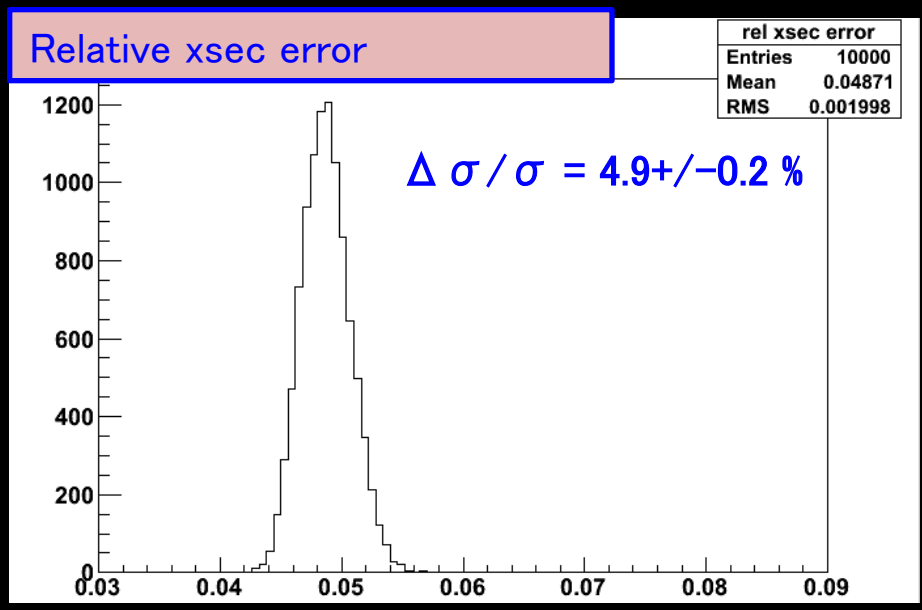
BACKUP

Pull plot for xsec



- Pull rms close to 1
- Pull Mean is close to 0

Relative xsec error



Result of Toy MC 10000 seeds

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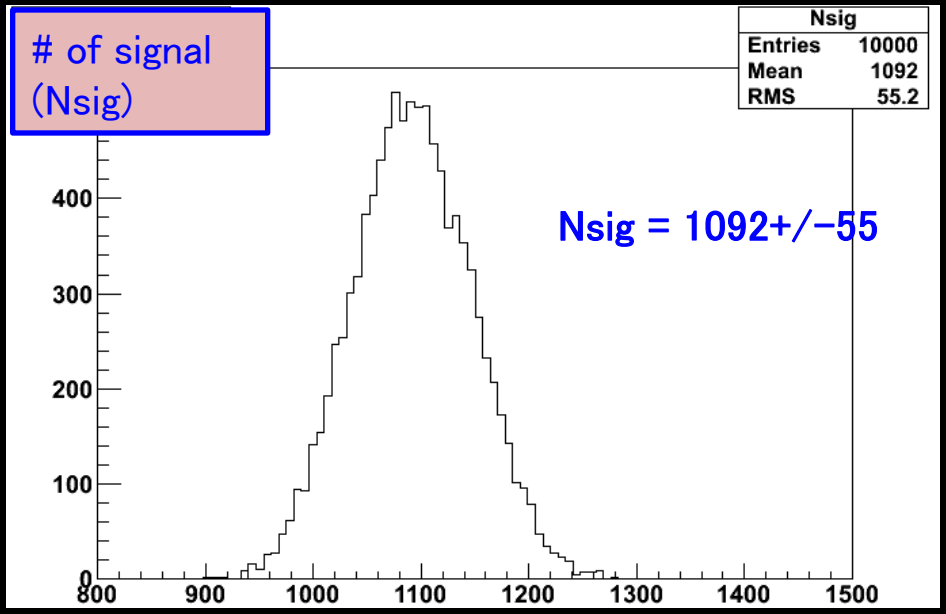
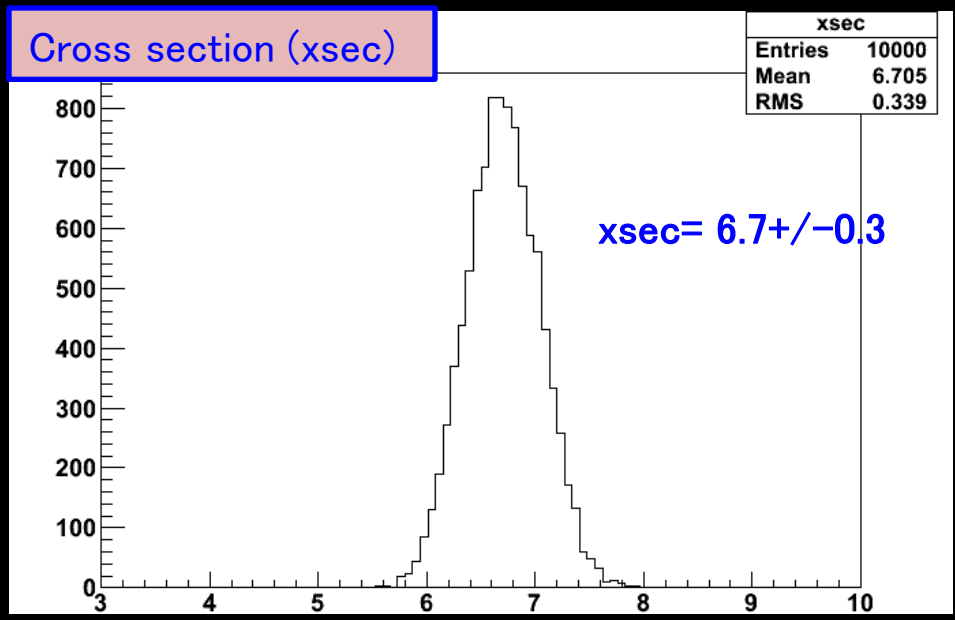
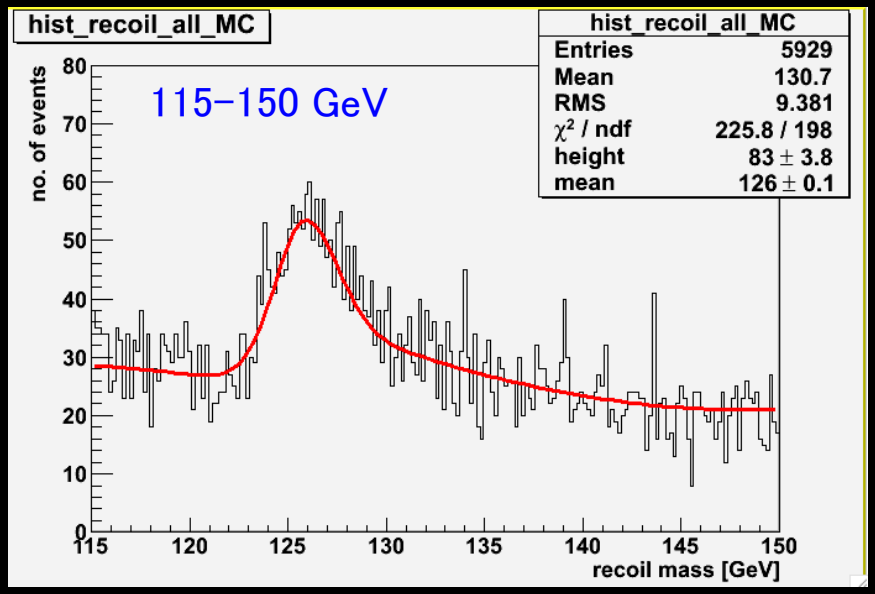
Consistent within error ranges

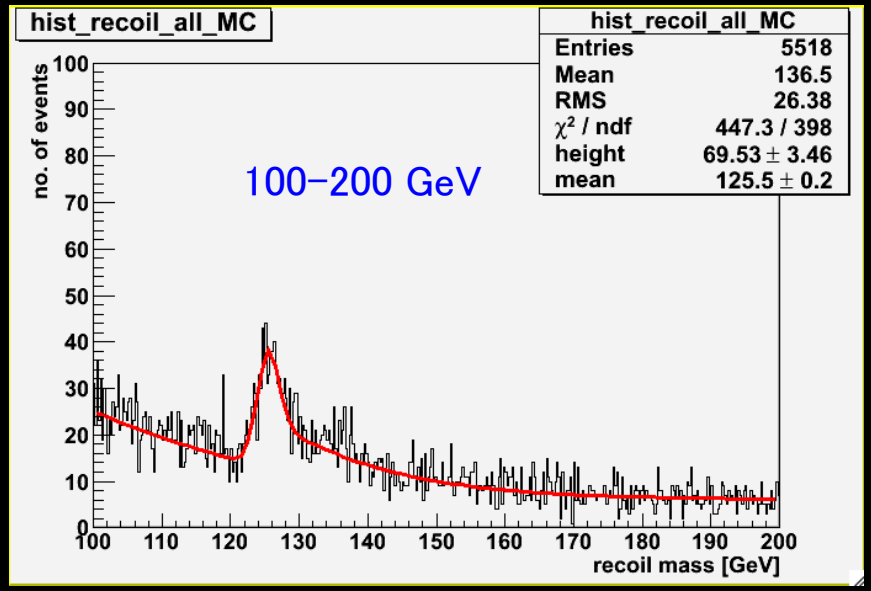
of signal (Nsig)

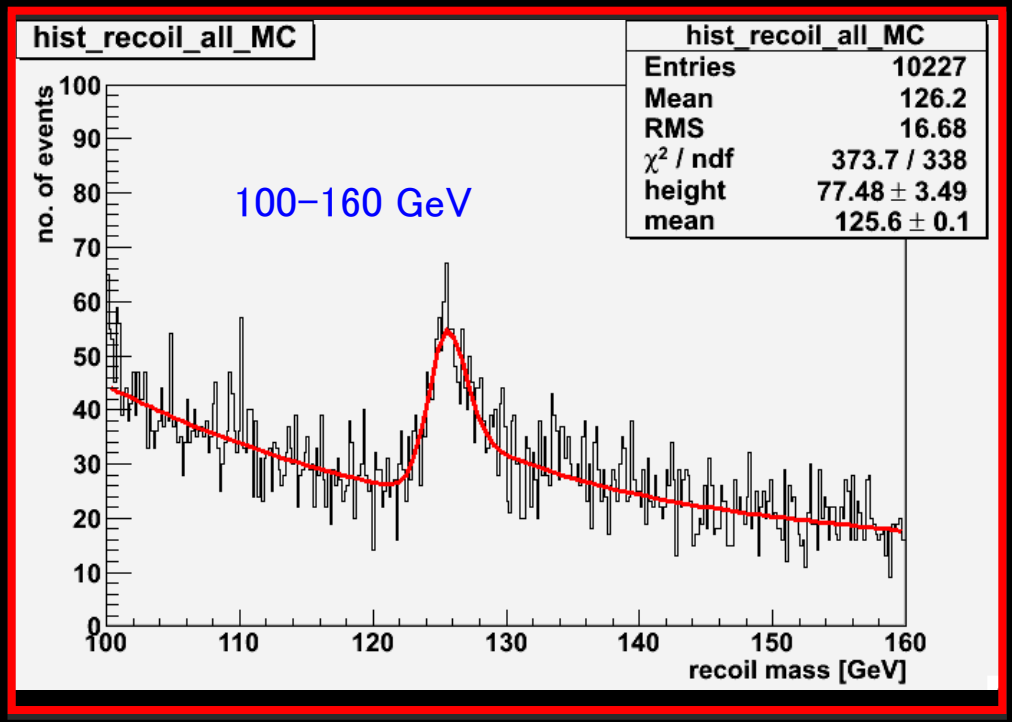


Cross section (xsec)









New findings for this week

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

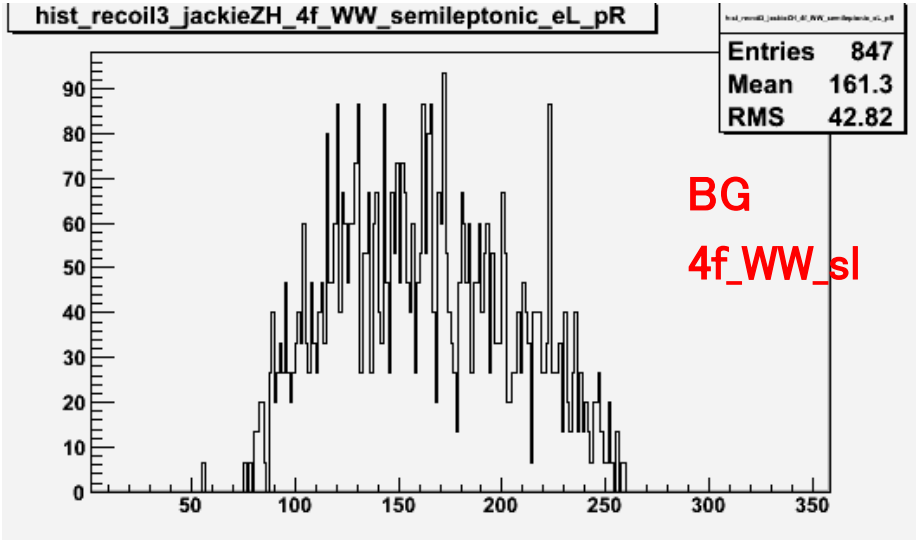
after fixing this, pull mean bias for (100–200) reduced (1.9→1.3) but not gone, and xsec and Nsig still biased, so must be something to do with too wide fitting range

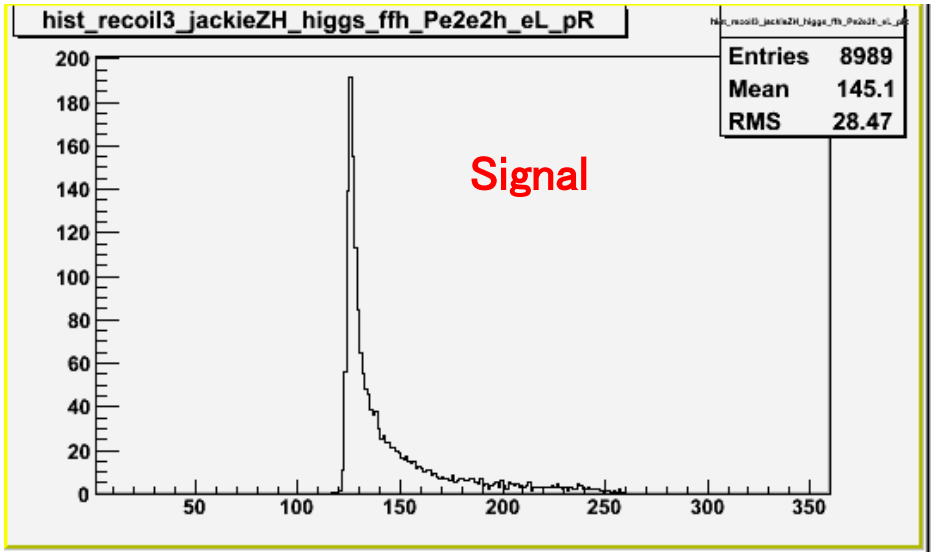
Toy MC 10000 seeds

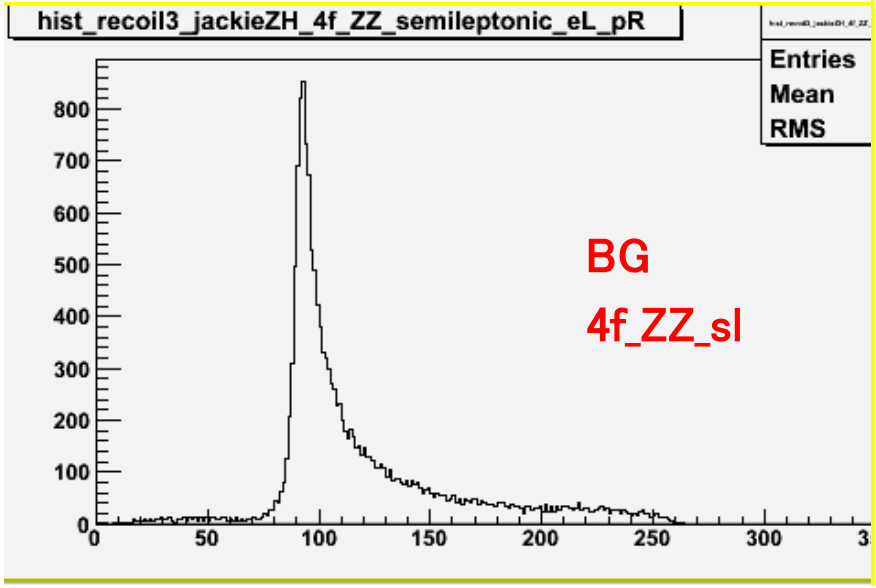
for (100–160): no bias , consistent with "real"

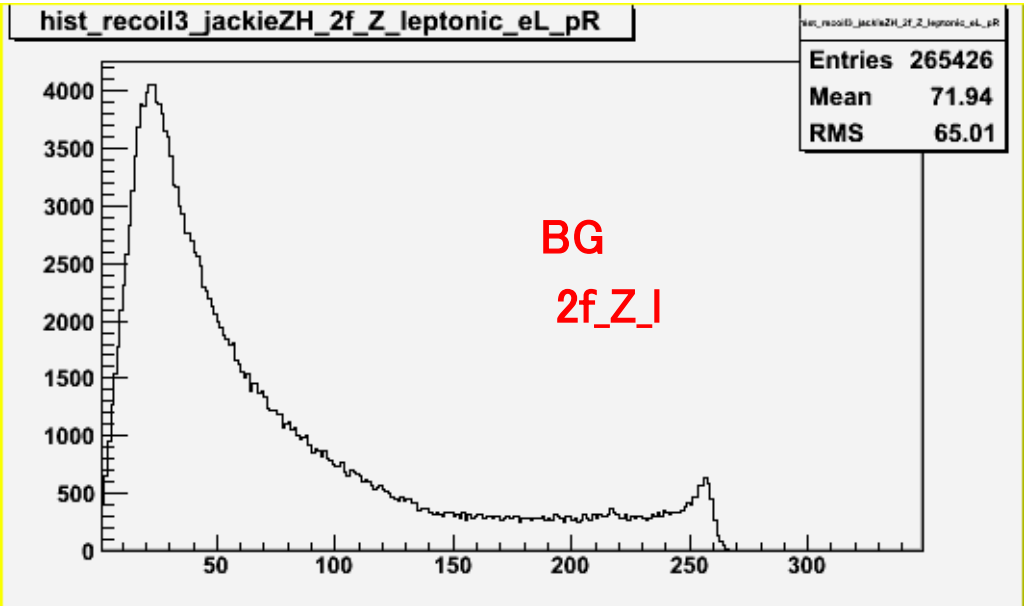
recoil mass 350 GeV

After inv mass cut









Muon Selection

- reject neutrals
- P_total > 5 GeV
- small E_cluster / P_total < 0.5
- cos(track angle) < 0.98 & |D0/δD0| < 5

Data Selection Method

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

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
- pTγ_max : pT of most energetic photon
- θ_Zpro = Z production angle

Final Selection for sqrt(s)= 350 GeV

- 84 GeV < M_inv < 98 GeV
- 10 GeV < pT_mumu < 140 GeV
- dptbal = |pT_mumu – pTγ_max| > 10 GeV
- coplanarity < 3
- |cos(θ_Zpro)| < 0.91

120 GeV < Mrecoil < 140 GeV

for sqrt(s)=250 GeV,
10 GeV < pT_mumu<70 GeV, and no coplanarity cut

Results after selection

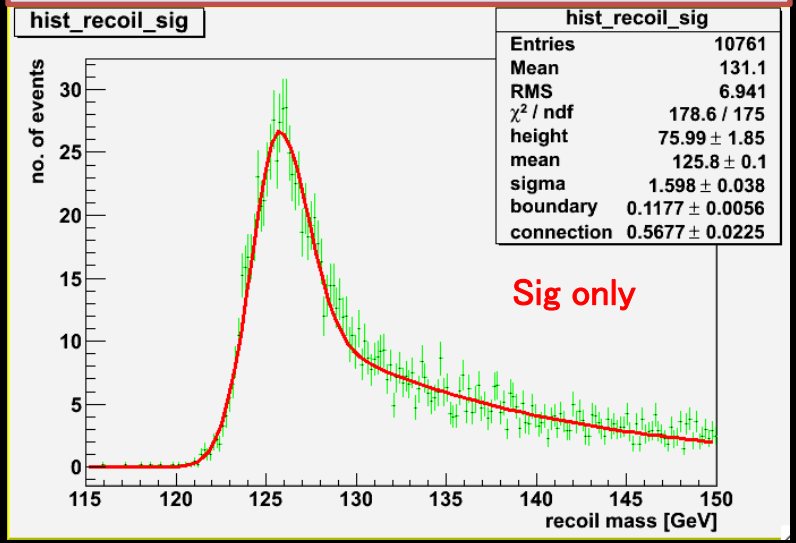
(sqrt(s)=350 GeV)

- Sig efficiency = 47.6 +/- 0.5%
- S/B = 0.40, significance = 17.2
- # of signals = 1092+/−55

fitting for recoil mass histogram

1st time fitting:

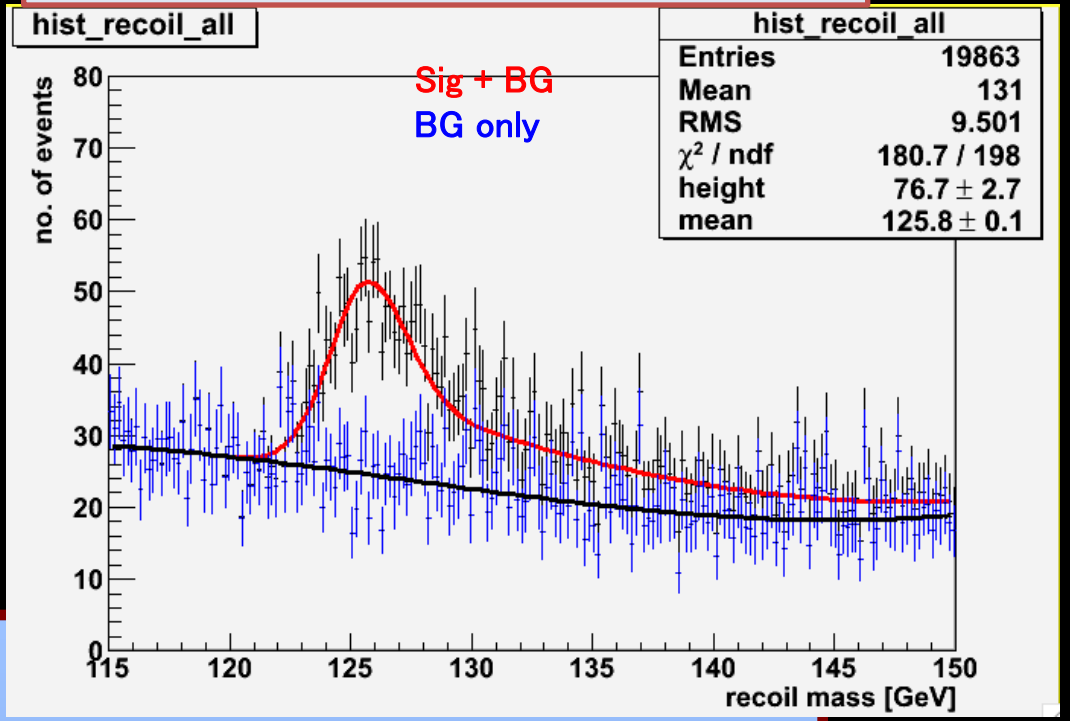
- fit only signal : float all 5 GPET pars
- fit BG only 3rd order polynomial



Final fitting:

float only height and mean,

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



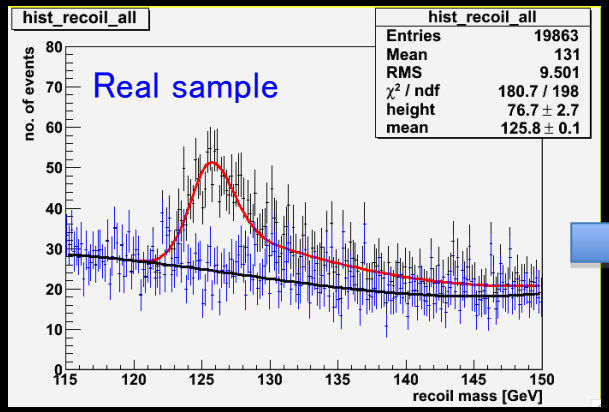
◆ **SIGNAL: GPET:** 5 parameters :

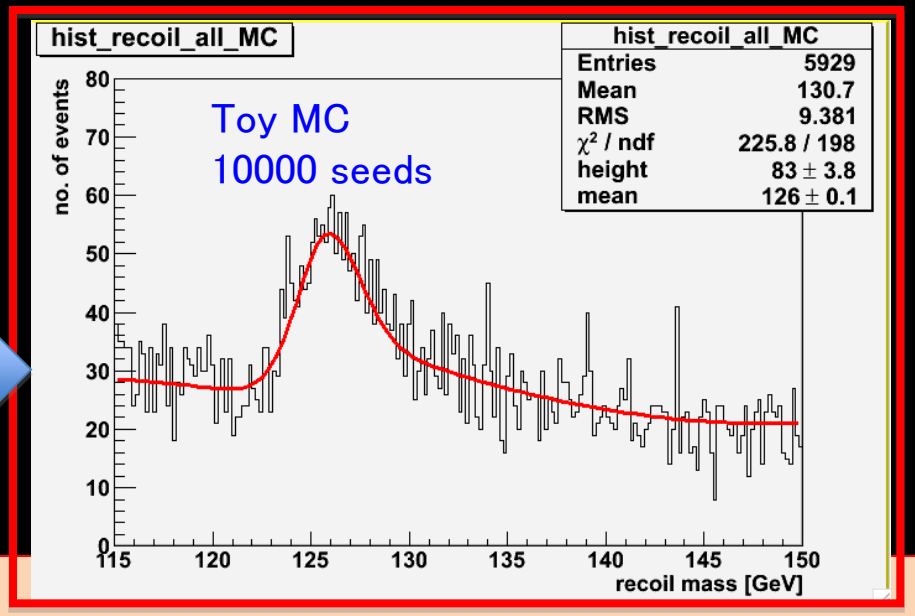
Gaus (left-side) , Gaus + expo (right side)

$$\frac{N}{\sqrt{2\pi}s}\exp\left(-\frac{1}{2}\left(\frac{x-x_{mean}}{s}\right)^2\right) \qquad \frac{x-x_{mean}}{s} \le k$$

$$\frac{N}{\sqrt{2\pi}s}\left(b\times\exp\left(-\frac{1}{2}\left(\frac{x-x_{mean}}{s}\right)^2\right)+(1-b)\exp\left(-k\frac{x-x_{mean}}{s}+\frac{k^2}{2}\right)\right) \qquad \frac{x-x_{mean}}{s} > k$$

Toy MC Studies





Goal:

- **test validity of fitting** : **Pull plot** for xsec = [(fitted xsec)−(“real” xsec)]/ (xsec fitting error)
- **Evaluated precision of xsec and number of signals (Nsig)**

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 Nsig → calculate xsec

Results:

- **Pull plot seems reasonable**
- **Nsig and xsec 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	Δσ/σ	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

Δσ/σ : 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_Tdl<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 1	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)<0.91	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
- 4fSingleZnunu_leptonic
- 4f_ZZWWMix_leptonic
- 6f backgrounds (sqrt(s)=350 GeV)