Higgs recoil mass study

ILC Physics Meeting
3/20/2015

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Last week

- improvement of xsec precision and BG rejection due to mainly….
- new techniques in removing 2f_Z_leptonic BG while preventing signal loss
- implemented isolation cut for muon and gamma

This week

- Further improvement of xsec precision and BG rejection due to

  most importantly

- an isolated lepton finder processor introduced by Junping-san
- rejects almost ALL 4f_WW_semileptonic BG (used to be dominant residual BG)

- now we have $\Delta\sigma/\sigma$ = 4.01 +/- 0.00 % with a much higher signal eff
- 89% (!) before Mrecoil cut (120-140 GeV) / 56% after Mrecoil and likelihood cut

- Last week's best: $\Delta\sigma/\sigma$ = 4.04 +/- 0.00 %
- 83.5 % before Mrecoil cut (120-140 GeV) / 46% after Mrecoil and likelihood cut

- isolated lepton finder processor introduced by Junping-san

- Uses “MLP” : neural-net algorithm based on root package TMVA

- Apply cut on calculate the MVA output (←→ likeness) to distinguish signal isolated lepton from other particles

- recovery of photon from FSR / beamstrahlung

<u>My current procedure for generating rootfiles with muon candidates</u>

1. run isolated lepton finder processor
2. Run my original processor → put relevant variables into “muon” tree
3. do final selection inside an analysis file

definition
- 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

• Econe_mu: cone energy (cosθ>0.9) around muon
• Econe_γ: cone energy (cosθ>0.9) around most energetic γ
•Pt_sum = |Pt_dl − Pt_γ| (in vectors)

Final Selection NEW

- ~~Econe_mu < 110 GeV~~
- **73 GeV < M_inv < 120 GeV**
- 10 GeV < pT_mumu < 140 GeV
- **Econe_γ > 40 GeV (*)**
- dptbal = pT_mumu – pTγ_max > 20 GeV
- |cos(θ_Zpro)| < 0.9
- 120 GeV < Mrecoil < 140 GeV

No more Econe cut needed

Keep same wide Minv cut

Simplified dptabl cuts

(*) used in coincidence with extra requirements to prevent signal loss

Now most dominant BG after all selection are

4f_ZZ_semileptonic : 990

4f_ZZWWMix_leptonic: 324

4f_Z_leptonic : 211

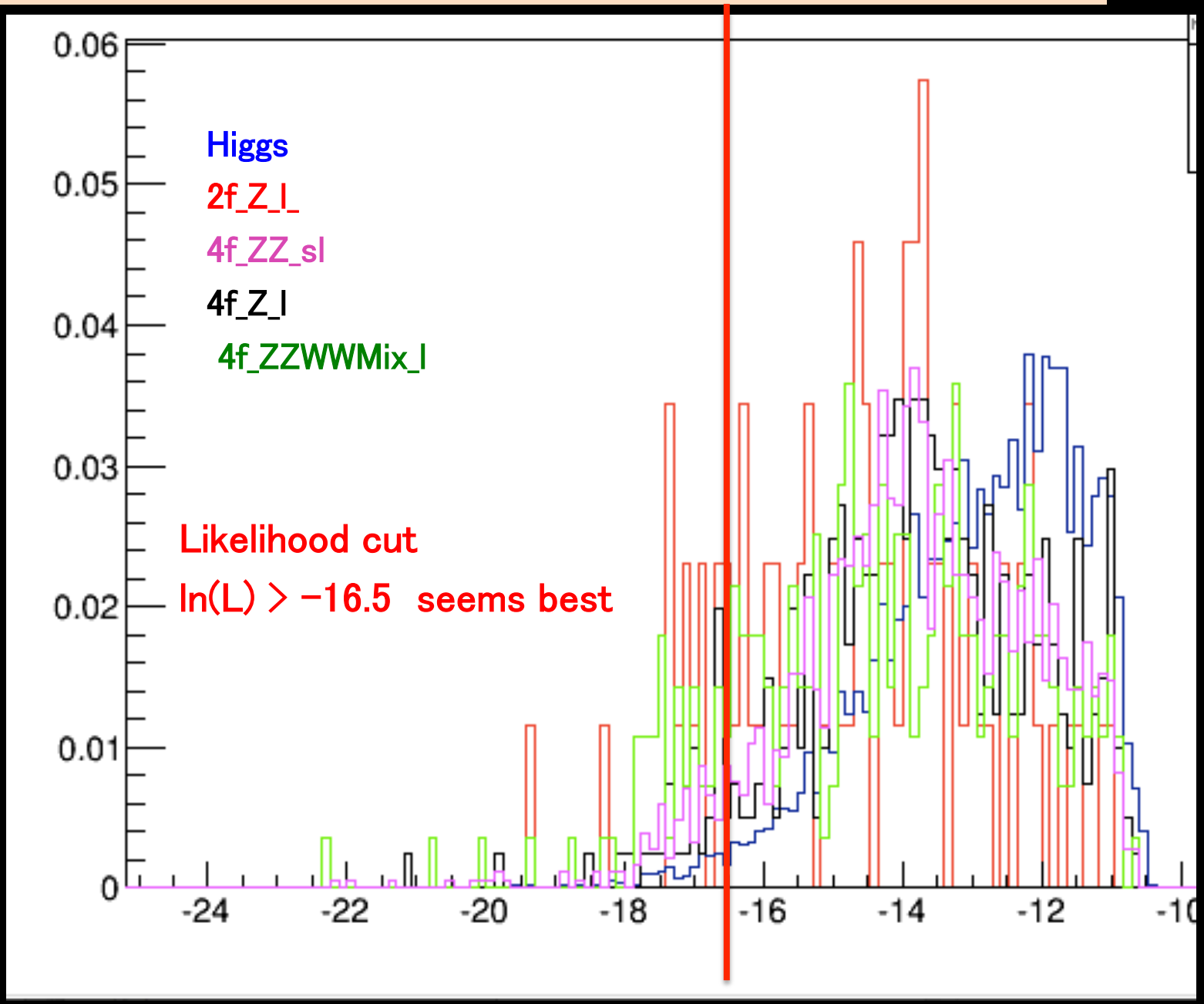
vs

Higgs: 1174

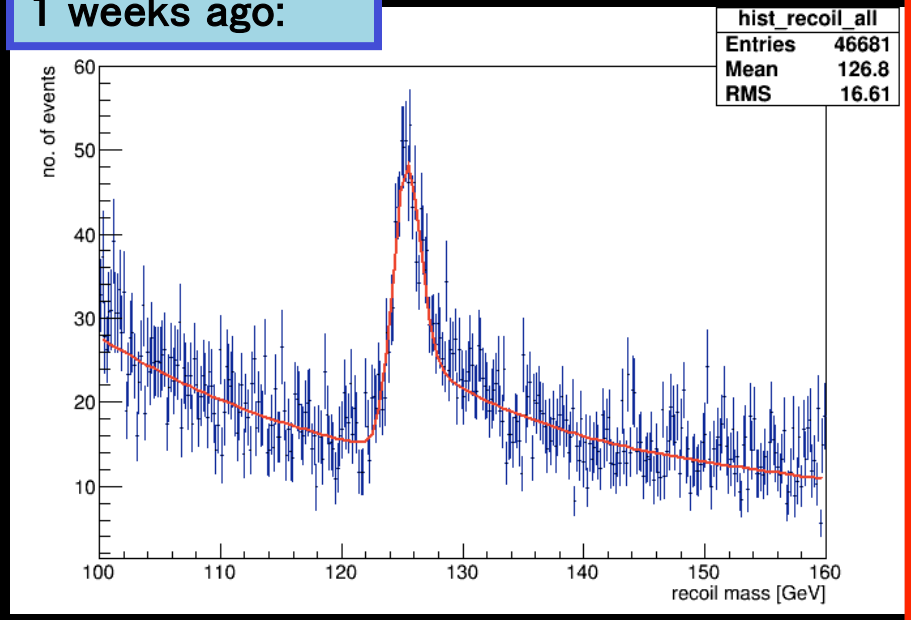
The number of events (correctly weighed) after each selection step is in

/ home/ ilc / jackie / jackieZHProcessornew / data / output_150320.dat

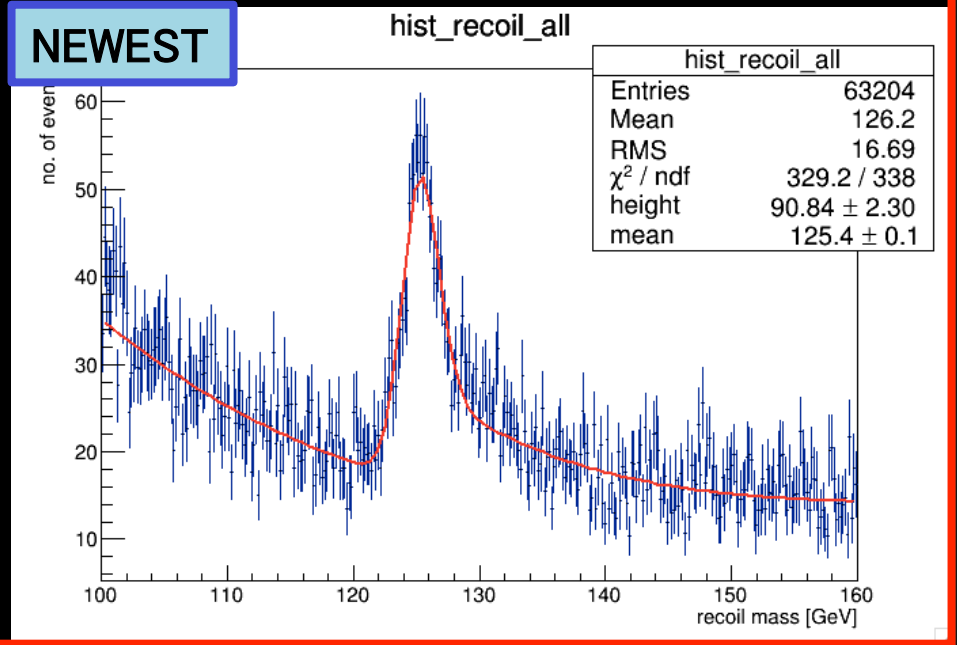
Likelihood function: L = P(M_inv) * P(Pt) * P(CosZ) * P(Pt_bal)

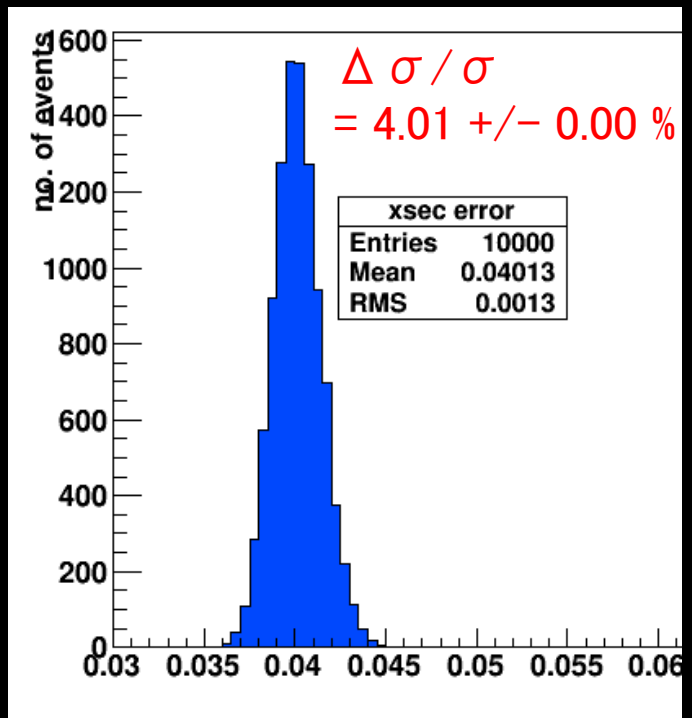


1 weeks ago:



NEWEST





Conclusion

Thanks to new lepton finder ,
I can obtain similar BG rejection and a slightly improved xsec precision while maintaining higher signal efficiency

now $\Delta\sigma/\sigma$ = 4.01 +/− 0.00 % sig_eff = 89% before Mrecoil cut

Next steps :

How can I make xsec error go below 4% ????

apply similar method to
other polarization scenarios and ECM= 250 GeV
and compare

In time for ALCW15 (physics session)

- I will also start Zee analysis

BACKUP

Final Selection

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

definition

- 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

- Econe_mu: cone energy (cosθ>0.9) around muon
- Econe_γ: cone energy (cosθ>0.9) around most energetic γ
- **Pt_sum = |Pt_dl – Pt_γ| (in vectors)**

Final Selection NEW

- **Econe_mu < 110 GeV**
- **73 GeV < M_inv < 120 GeV** widened
- 10 GeV < pT_mumu < 140 GeV
- **Econe_γ > 10 GeV (*)**
- **Pt_sum > 40 GeV**
- **dptbal = pT_mumu – pTγ_max > 60 GeV (*)**
- |cos(θ_Zpro)| < 0.91
- 120 GeV < Mrecoil < 140 GeV

Added isolation

Combine two types of pt_balance cuts

(*) used in coincidence with extra requirements to prevent signal loss

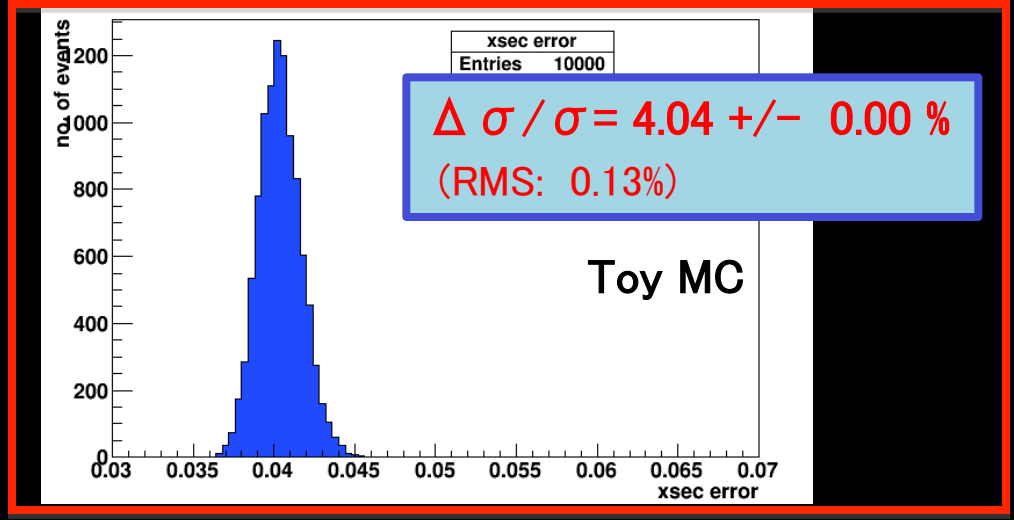
The improvement reported at last week's meeting

cuts		(both eLpR and eRpL) Nsig	Nbg	S/B ratio	sig eff	Δσ/σMC)		(only eLpR) 2f_Z_l	4f_WW_sl	4f_ZZ_sl
2 weeks ago		1056	2189	0.48	46.1 (74%)	4.39+/−0.00%	(RMS: 0.16%)	225 (0.011%)	241 (0.009%)	950 (0.52%)
1 week ago (best result)		1062	2010	0.53	46.4 (74%)	4.27+/−0.00%	(RMS: 0.15%)	95 (0.004%)	306 (0.010%)	967 (0.53%)
current (best result)	ln(L)>−20	1056	1740	0.61	46.2 (84%)	4.05+/−0.00%	(RMS: 0.13%)	34 (0.002%)	116 (0.004%)	840 (0.46%)
	ln(L)>−19.8	1041	1643	0.63	45.5 (84%)	4.04+/−0.00%	(RMS: 0.13%)	31 (0.001%)	111 (0.004%)	802 (0.44%)

- Significant reduction in each major BG (25% reduction !!)
- improvement in xsec precision
- Signal efficiency before M_recoil cut is about 10% higher

<u>What contributed ??</u>

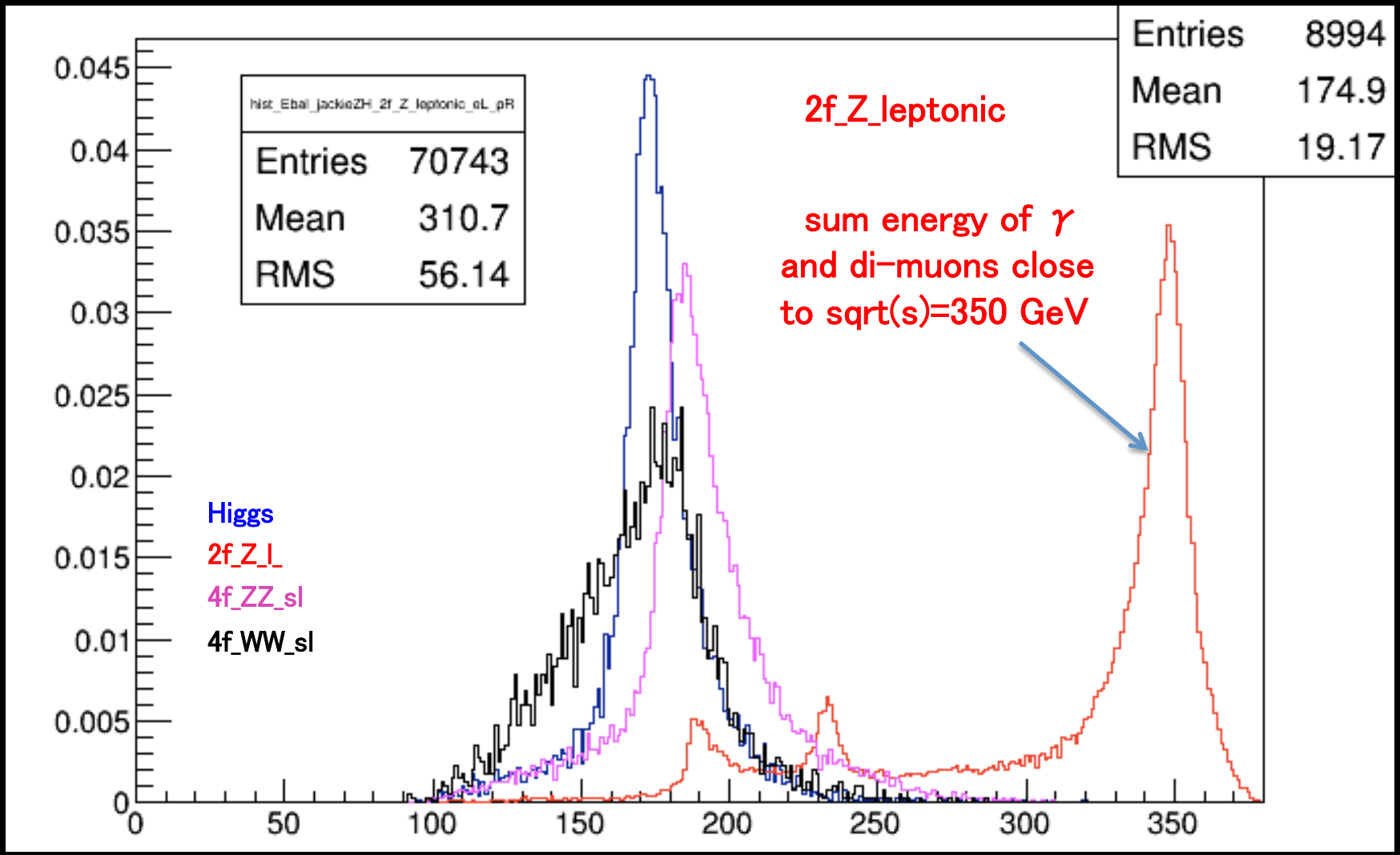
- More sophisticated methods to remove 2f_Z BG without losing much signal
- isolation cuts for muon and gamma
- usage of likelihood cut



I applied a condition to prevent signal bias

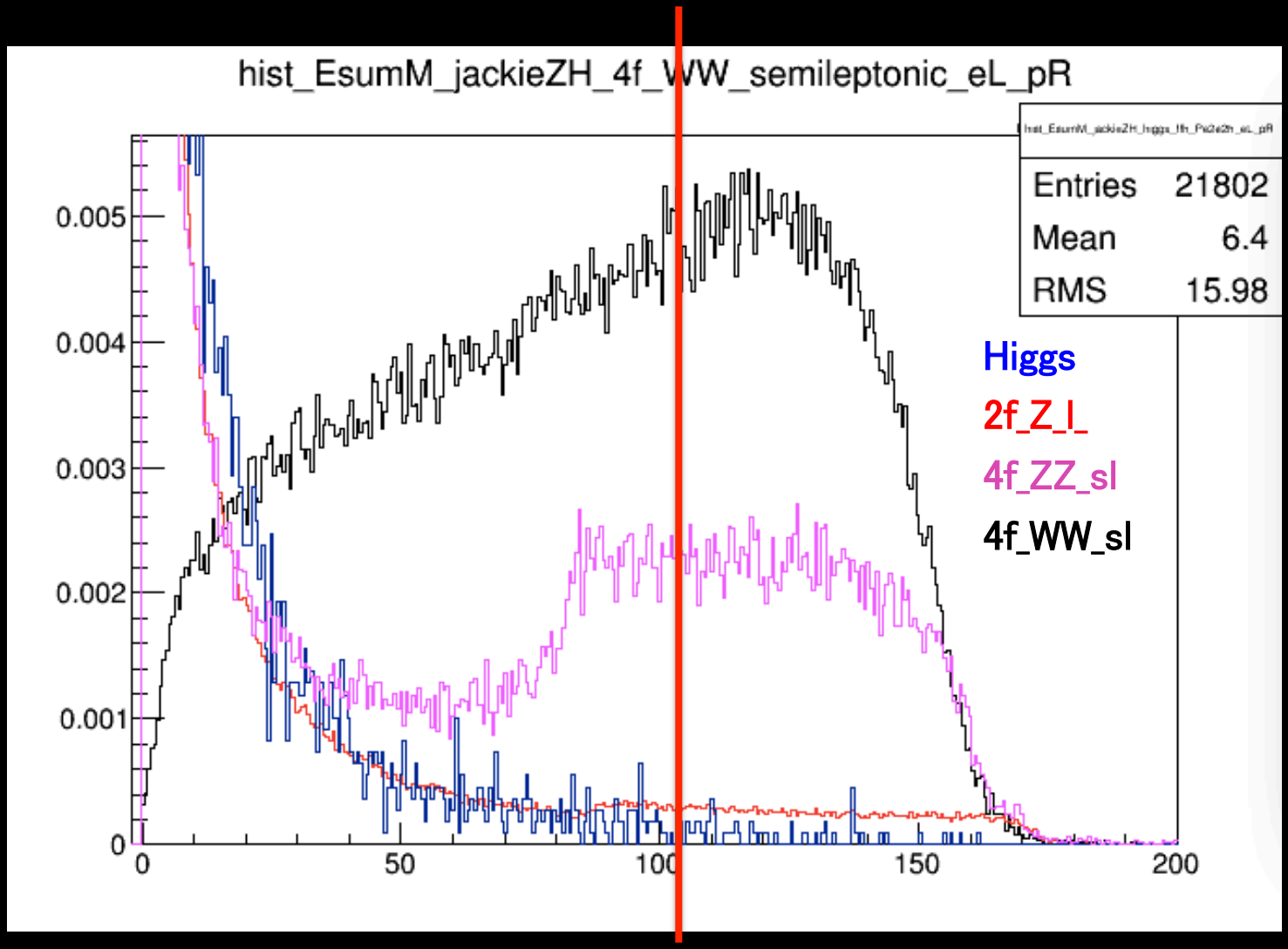
I required energy sum of γ and di-muon to be > 0.8 * sqrt(s)

signature of 2f_Z_leptonic BG



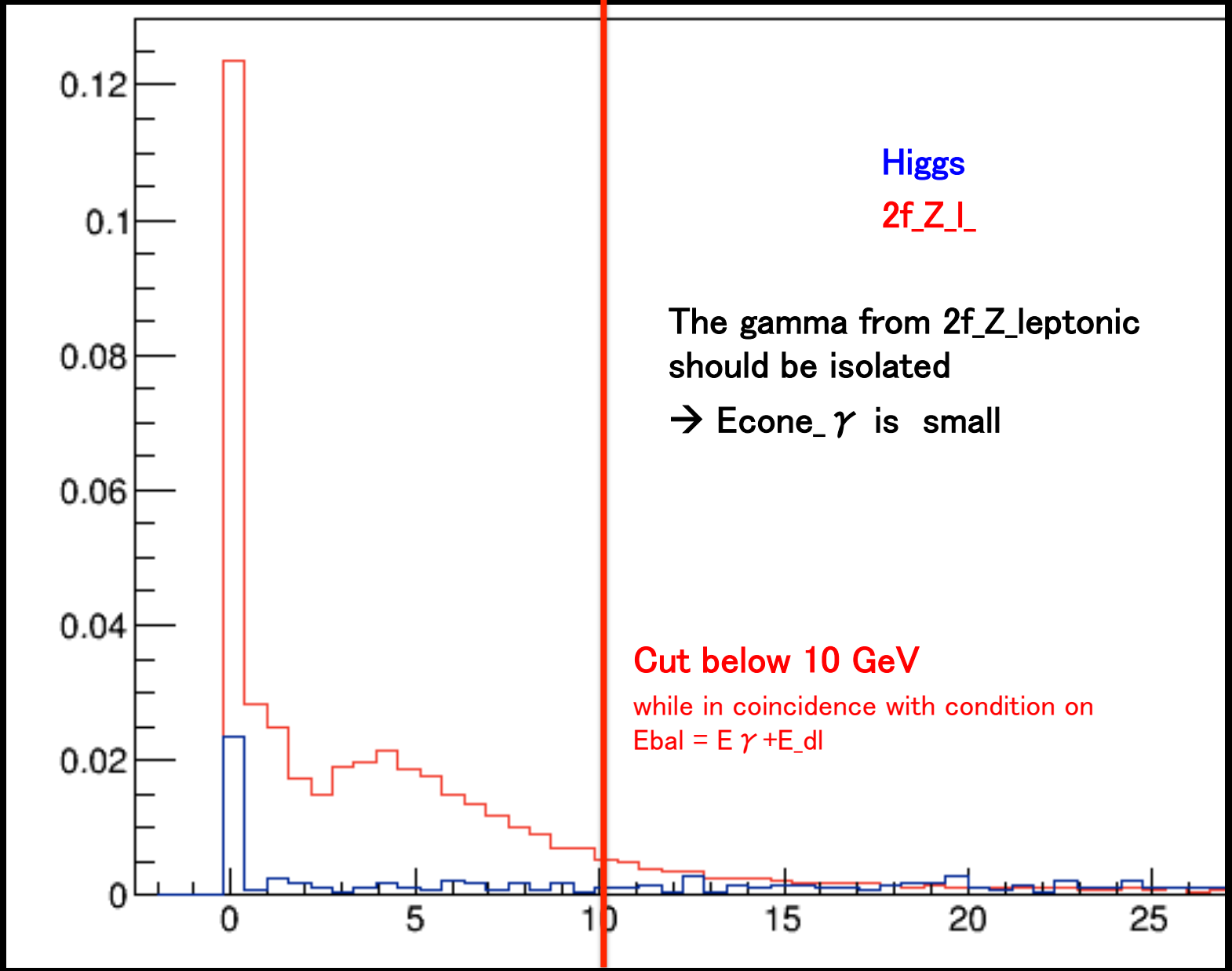
Cone energy around muon （～ 26 deg）

Effective for removing 4f_WW_sl BG



cut above 110 GeV

Cone energy around most energetic gamma
(～ 26 deg)



Higgs

2f_Z_l_

The gamma from 2f_Z_leptonic should be isolated

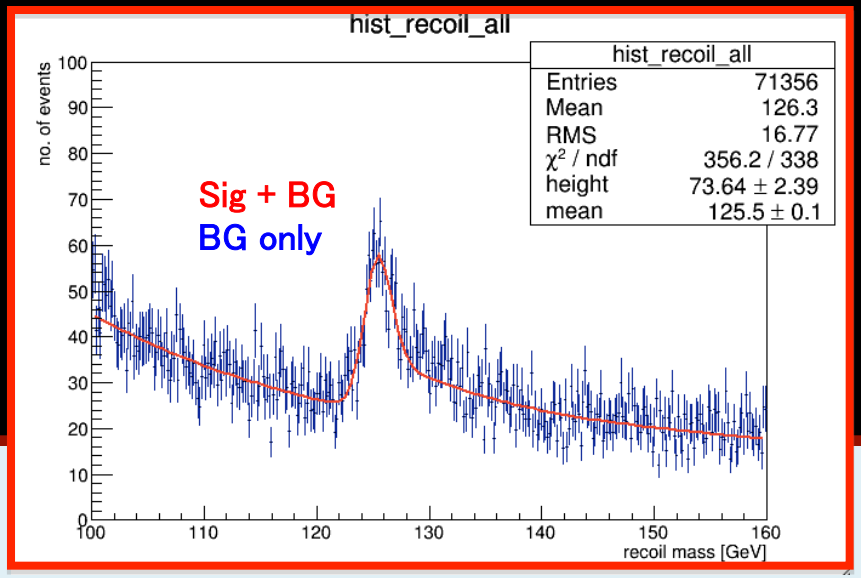
→ Econe_γ is small

Cut below 10 GeV

while in coincidence with condition on
Ebal = E γ +E_dl

recoil mass fitting method

Fit range: 100–160 GeV



1st step:

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

2nd step :

fit Sig + BG : only float height and mean

fix others from step 1

◆ **SIGNAL: GPET:** 5 parameters :

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

Gaus (left-side) ,

$$\frac{N}{\sqrt{\pi}\sigma}\left[b\cdot\exp\left\{-\frac{1}{2}\left(\frac{x-x_{mean}}{\sigma}\right)^2\right\}+(1-b)\exp\left\{-k\left(\frac{x-x_{mean}}{\sigma}\right)\right\}\exp\left(k^2/2\right)\right] \qquad \left(\frac{x-x_{mean}}{\sigma} \ge k\right)$$

Gaus + expo (right side)

Toy MC study

Toy MC 10000 seeds

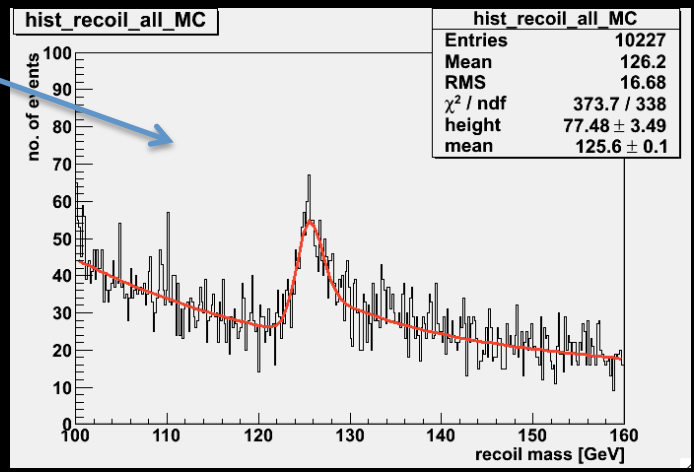
goal: test quality of fitting method

in terms of M_h、 xsec etc……

method:

generate MC events according to fittied "real" data (Poisson)

fit MC hist with same GPET function → get Nsig, xsec



断面積測定の精度の評価 ： 異なるECMとビーム偏極の比較 NEW

ECM	Pol	ε	Δσ/σ	xsec [fb]	Nsig	significance
350 GeV	(−0.8,+0.3)	47.7+/−0.5%	4.9+/−0.2%	6.71+/−0.34	1092+/−55	17.7
	(+0.8,−0.3)	47.8+/−0.5%	5.0+/−0.2%	4.53+/−0.26	720+/−41	17.8
250 GeV	(−0.8,+0.3)	66.4+/−0.5%	3.6+/−0.1%	10.52+/−0.38	1747+/−64	21.7
	(+0.8,−0.3)	64.4+/−0.5%	3.3+/−0.1%	8.68+/−0.30	1398+/−48	22.7

注） この表の fitting範囲は115-150 GeV （AWLC14 @ Fermilabより）
現在350 GeV のみ範囲を広げて、 Δσ/σが 4.7 +/− 0.2 % へ改善した

比較#1: ECM =350 GeV ←→ ECM = 250 GeV :
ECM= 250 GeVの方がΔσ/σ と Mh 精度 が良い *μの運動量測定の分解能は低いPTほど良い*

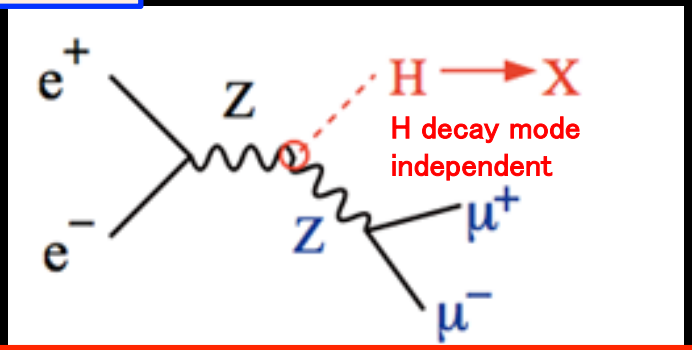
比較#2: Pol: (−0.8,+0.3) ←→ (+0.8, −0.3) :
- 異なる偏極の間でΔσ/σに大きな差がなさそう
- (+0.8, −0.3) : 統計が少ないが、S/B がずっと高い : WW BGが顕著に抑制

注意） 先行studyとの色んな違い :
- assumed L (350, 250 GeV) = (333 , 250 fb-1) vs RDR: (300 fb-1, 188 fb-1)
- このstudy : ALL 2f, 4f, 6f BGs (whizard generator) vs only WW, ZZ (pythia generator ?)

ILC sample used in analysis

chanel	mh	ECM	L	Spin polarization	Detector simulation
e+e→Zh->μμh	125 GeV	350 GeV	333 fb-1	P(e-,e+) = (-0.8,+0.3) (+0.8,-0.3)	Full ILD (ILD_01_v05 DBD ver.)

signal Pe2e2h_.eL.pR / Pe2e2h._eR.pL



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

Higgs recoil against di-lepton (μ μ) system

BG :

all 2f, 4f, 6f processes

major BG after event selection:

2f_Z_l (μ μ), 4f_WWsl , 4f_ZZ_sl (μ μ ff, μ μ ν ν)