Higgs Recoil Mass Study using Z→ll at ECM=250, 350 GeV and 500 GeV ILC

The 42nd General Meeting of the ILC Physics Working Group

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recoil mass study using leptonic channels
ECM = 250 GeV, 350 GeV, and 500 GeV

precise model–independent measurement of absolute Higgs cross section and recoil mass

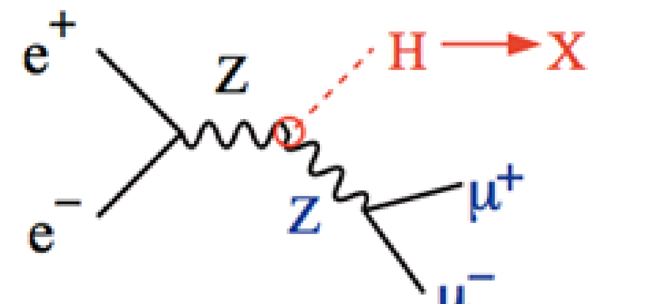
- σ_{ZH} is a "must–have"
  for measurement of total Higgs width & couplings
- **study impact of ECM and polarization**

- contribute to the decision for ILC run scenario

originally study was focused on the new field of 350 GeV since many physics become important → this time, extended to all ECM and both leptonic channels

signal

H decay mode independent



Higgs recoil against di–lepton system

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

ILC sample used in analysis

chanel	mH	ECM	L	Spin polarization	Detector simulation
e+e→Zh->μμh e+e→Zh->eeh	125 GeV	250 GeV 350 GeV 500 GeV	250 fb-1 333 fb-1 500 fb-1	P(e-,e+) = (-0.8,+0.3) (+0.8,-0.3)	Full ILD (ILD_01_v05 DBD ver.)

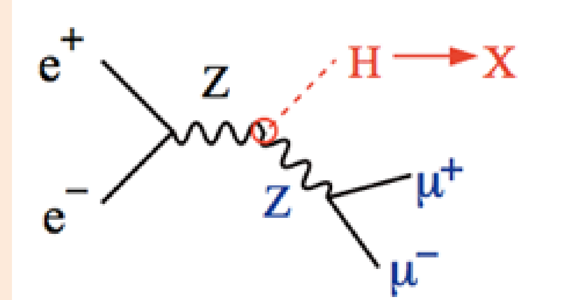
Layout of this Talk

- Evaluation of data analysis performance
- Comparison between different ECM and polarization
- Summary & Plans

Data Selection Method

Signal signature

a pair of isolated energetic leptons (μ / e) with invariant mass (M_{inv}) close to Z mass



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

Recoil mass

Dominant backgrounds	**Signatures**
• e+ e- → Z Z → l+ l- X :	forward Z production angle
• e+ e- → γ Z → γ l+ l- :	energetic ISR γ which balance dilepton pt
• e+ e- → W W → l+ l- ν ν :	broad M_{inv} distr.

- data selection is based on signal / BG characteristics
- a final recoil mass window (100 – 160 GeV) is effective for cutting BG

Progress since the last (41th) General Meeting (April 11)

Last Time

- **only Z→ μμ channel**
- **only ECM = 250 GeV and 350 GeV**
- **only study of xsec precision**
- **slight Higgs decay mode bias caused by BG rejection method**

Features of This Time

- **both Z→μμ and Z→ee channels**
- **all three ECM (250 , 350 , 500 GeV)**
- **study of both xsec and mass precision**
- **signal bias is minimized due to improved techniques (details later)**

+ *deeper study of the signal and BG statistics of each channel*

- Currently converging towards a **full set of statistical error study results**
- **optimized data selection method for each of the 12 scenarios** (3 ECM x 2 leptonic channels x 2 polarizations) in aim of best xsec and mass precision
- Removed systematic bias due to method of fitting or data selection

Lepton Pair Candidate Selection

opposite +/− 1 charge

- E_cluster / P_total : ＜0.5 (μ) / ＞0.9 (e)
- isolation (small cone energy)

  → removes nearly all 4f_WW_sl BG

- Minv closest to Z mass
- |D0/δD0| < 5

Data selections designed to guarantee Higgs decay mode independence

Optimized in terms of signal significance and xsec measurement precision

definition

- M_inv : invariant mass of 2 muons
- pt_dl : pt of reconstructed lepton pair
- pt,γ : pt of most energetic photon
- θ_missing = polar angle of undetected particles
- θ_Z = Z production angle

Final Selection

- **73 < GeV < M_inv < 120 GeV**
- **10 GeV < pt_dl < 140 GeV**
- $\left|\overrightarrow{P}_{t,sum}\right| \circ \left|\overrightarrow{P}_{t,g}+\overrightarrow{P}_{t,dl}\right|$ **> 10 GeV**
- **|cos(θ_missing)| < 0.98**
- **|cos(θ_Z)| < 0.9**
- **100 GeV < Mrecoil < 160 GeV**
- **Likelihood cut**

Example of ECM=350 GeV,

- Effective for cutting $\mu\mu$ / ee BG
- Use info of most energetic photon (pt_γ, cone energy)

meanwhile minimize bias on signal

red box:
key improvements w.r.t. previous studies

similar methods applied to all ECM and polarizations

Performance of data selection

in fitting range 100–160 GeV

(−0.8,+0.3)		significance	Nsig	Nbg
250GeV	Zmm	18.3	1879	8692
	Zee	14.4	1502	9394
350GeV	Zmm	17.7	1462	5332
	Zee	14.1	1156	5597
500GeV	Zmm	11.1	626	2572
	Zee	8.7	439	2087

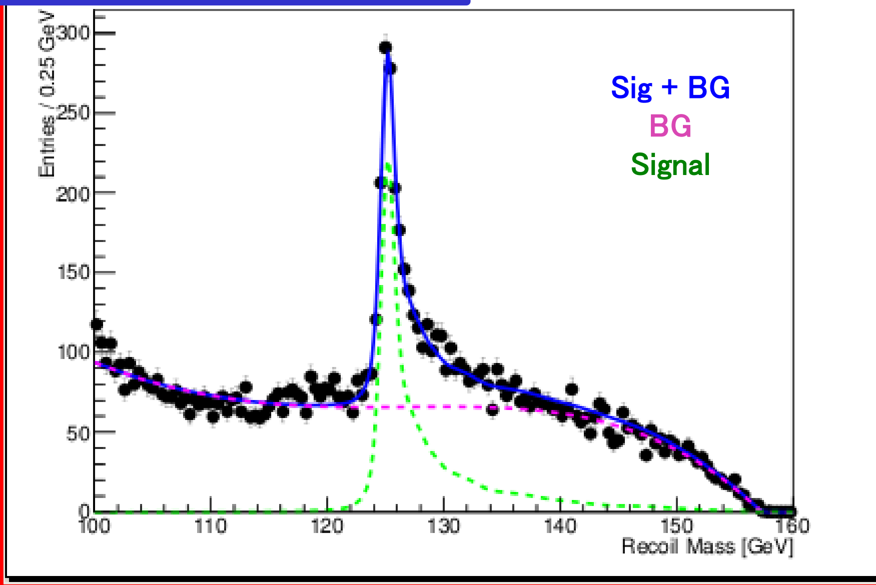
(+0.8,−0.3)		significance	Nsig	Nbg
250GeV	Zmm	19.7	1264	2834
	Zee	12.8	1096	6231
350GeV	Zmm	17	1002	2486
	Zee	12.7	602	1627
500GeV	Zmm	9.9	414	1339
	Zee	8.9	325	1003

- In general, significance is 250 > 350 > 500 GeV, Zmm > Zee
- right hand polarization: case by case:
  (lower BG, but also smaller signal statistics)

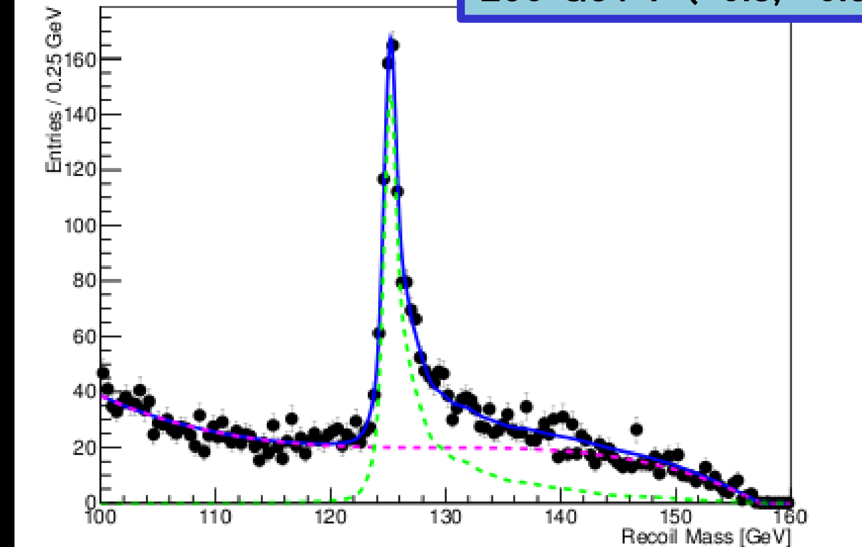
Z→μμ channel

Reconstructed data
recoil mass histogram

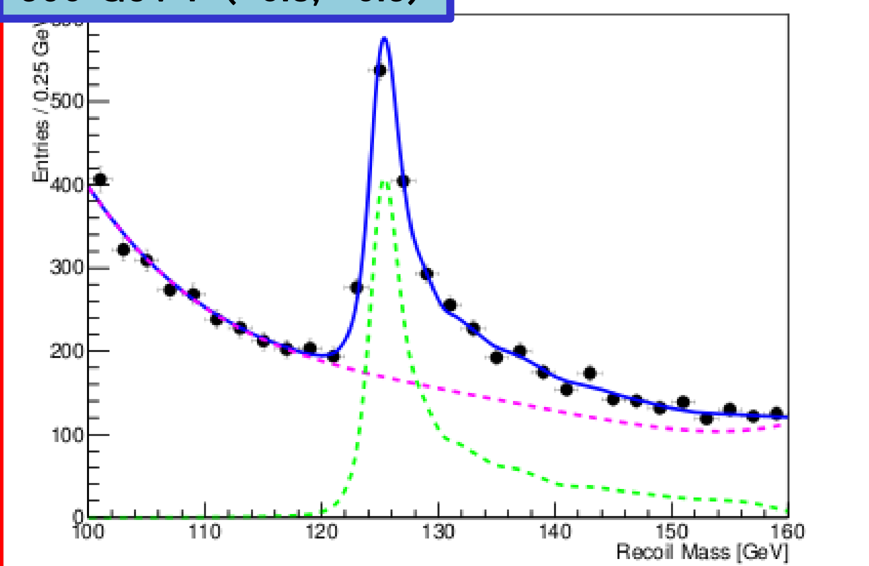
250 GeV : (− 0.8, + 0.3)



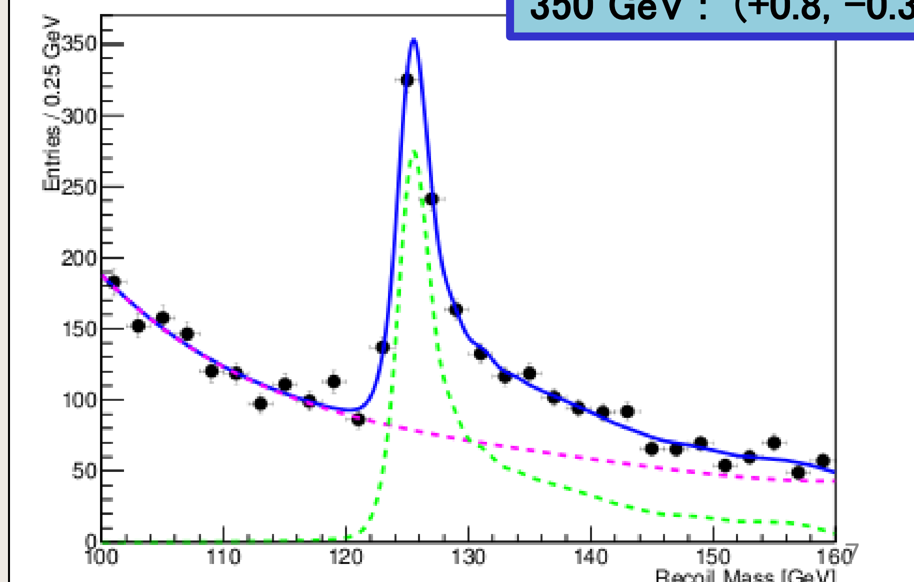
250 GeV : (+0.8, −0.3)



350 GeV : (−0.8, +0.3)



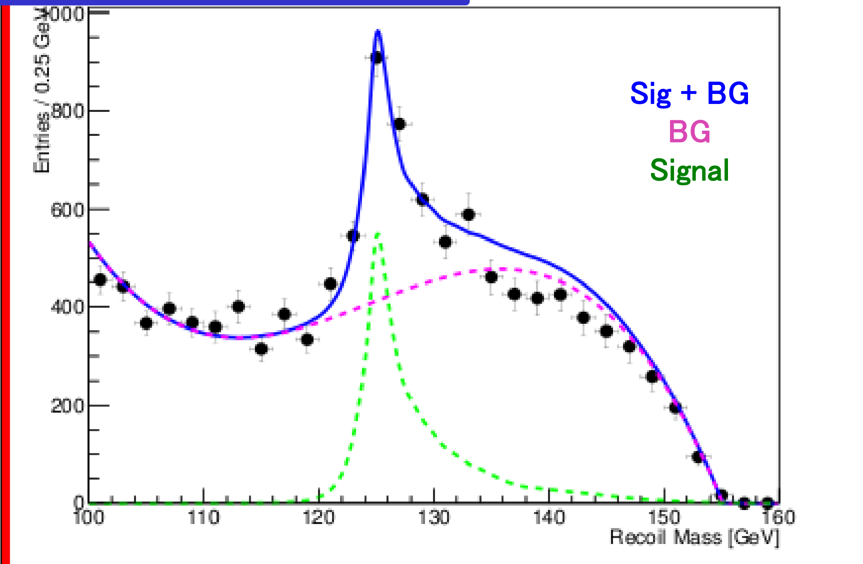
350 GeV : (+0.8, −0.3)



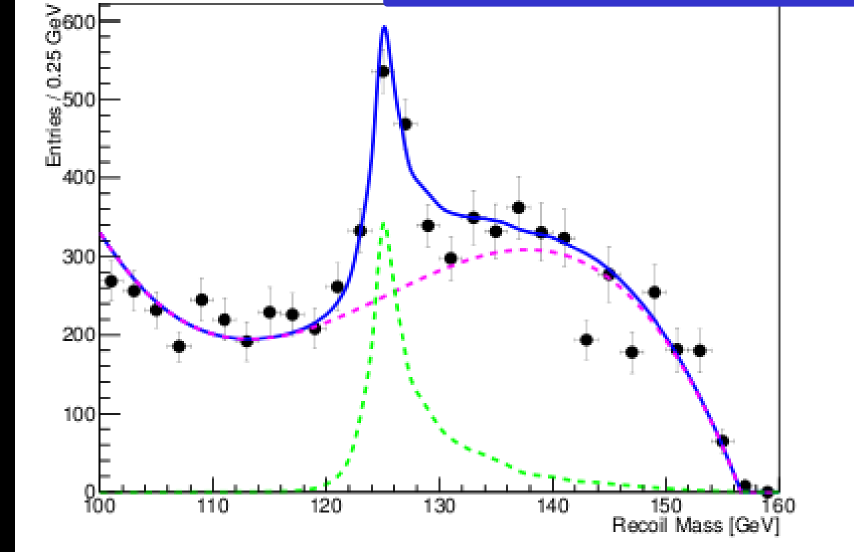
Reconstructed data
recoil mass histogram

Z→ee channel

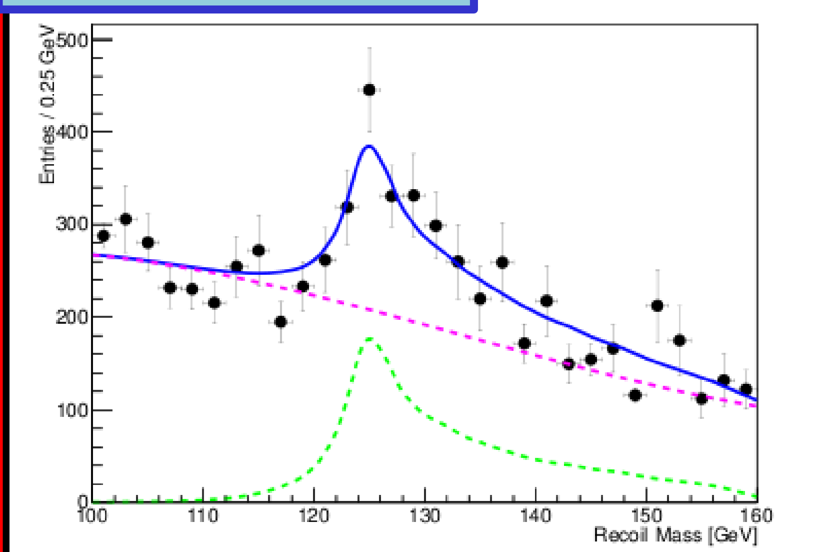
250 GeV : (− 0.8, + 0.3)



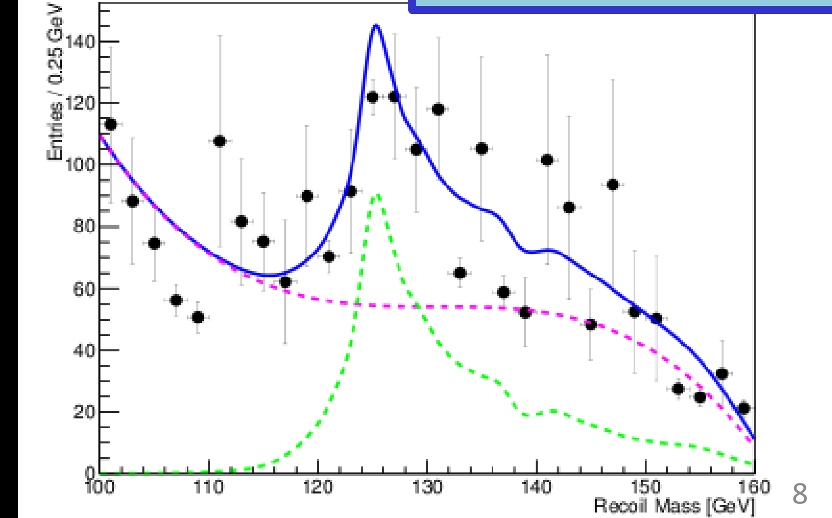
250 GeV : (+0.8, −0.3)



350 GeV : (−0.8, +0.3)

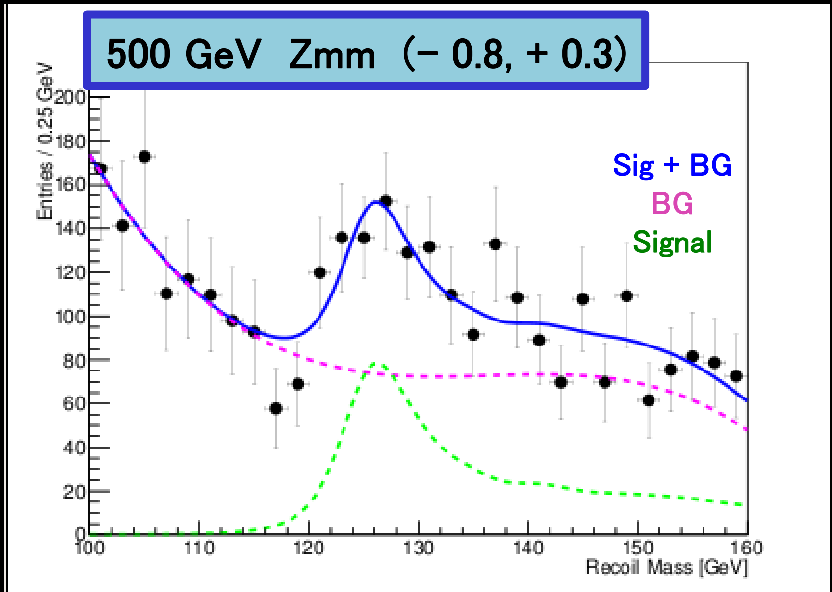


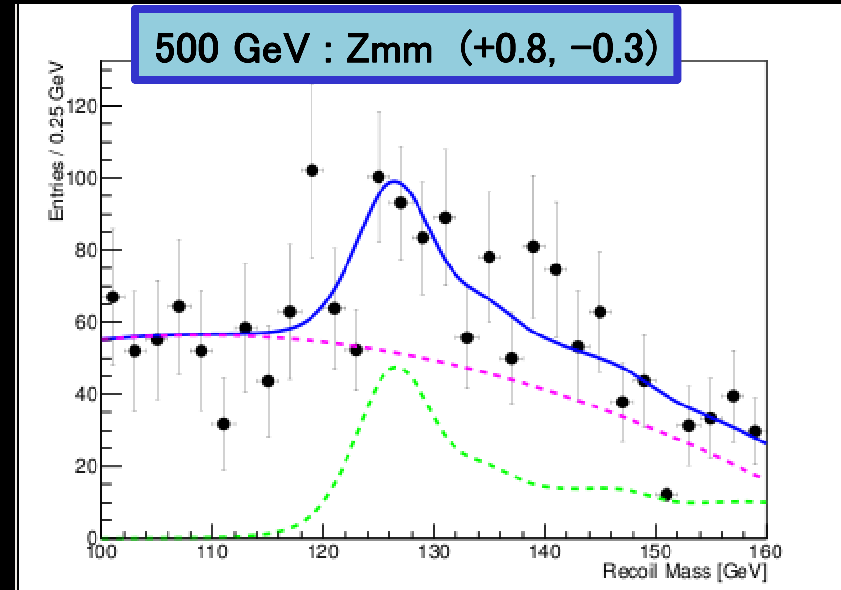
350 GeV : (+0.8, −0.3)

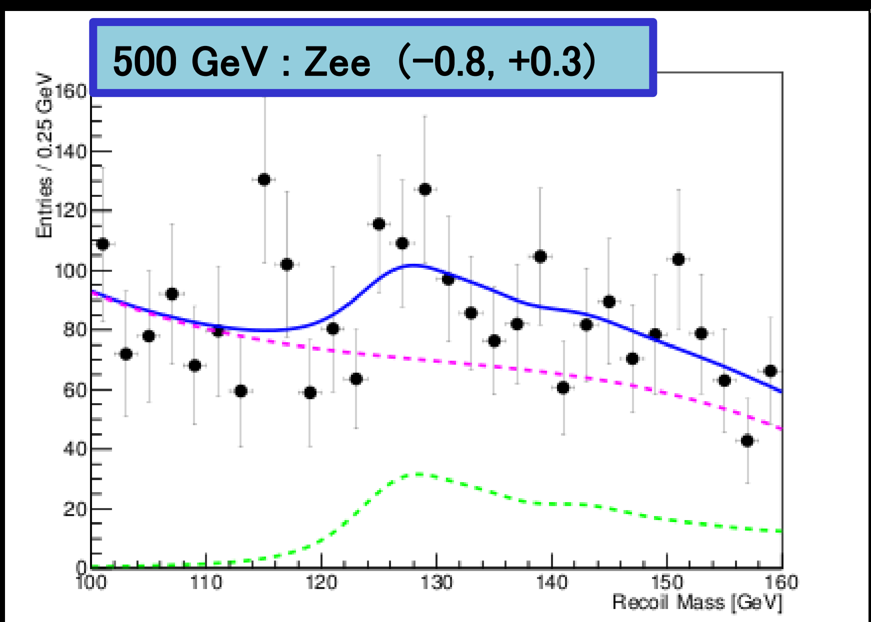


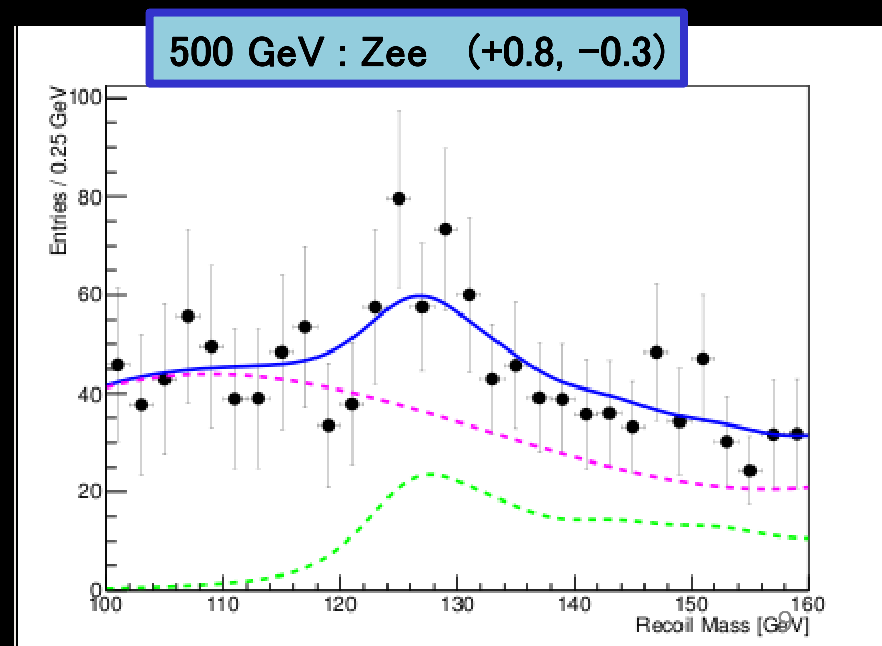
500 GeV

many challenges remaining : low statistics, low S/B ratio , ect…



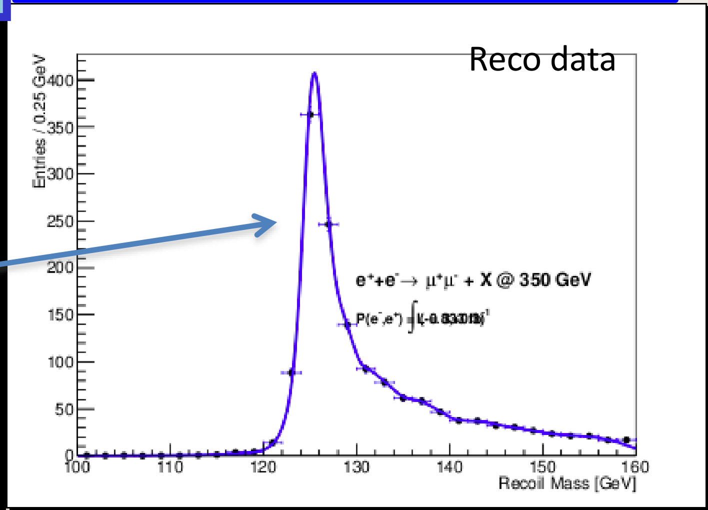




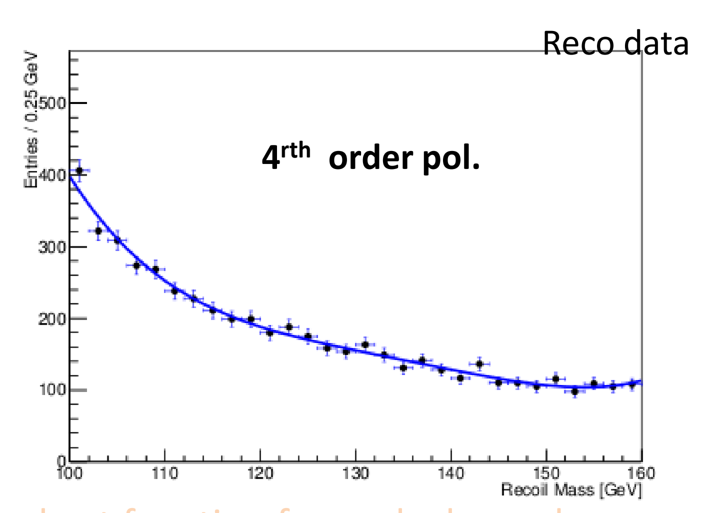


Fitting of recoil mass spectrum

Signal : Kernel function



BG : 3[rd] or 4[rth] order polynomial



Kernel function fitting does not cause significant systematic bias in recoil mass (c.f. GPET)

Observe distribution to determine best function for each channel

Toy MC study

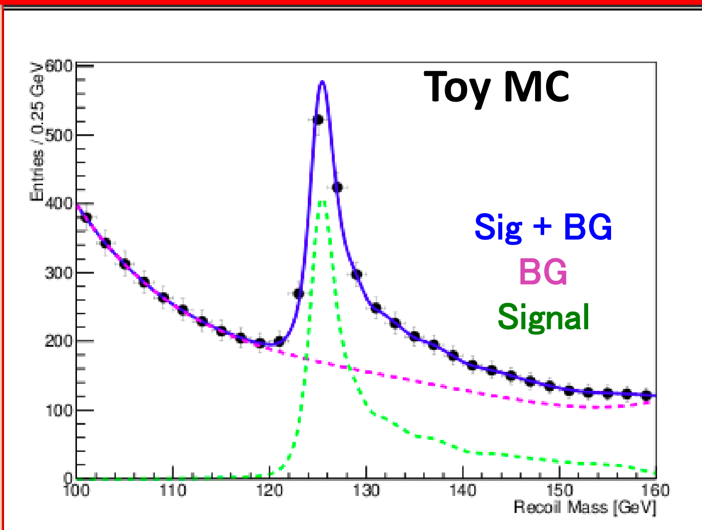
<u>goal:</u> test quality of fitting method

evaluate precision of xsec and recoil mass

<u>method</u>:

- generate MC events with 1000 x statistics according to fitted result of "real" data
- fit Toy events with same function : Kernel + polynomial

→ get **signal yield, mass shift, and errors**



Statistical error study results
Z→μμ and Z→ee combined

(−0.8,+0.3)		xsec err	mass err [MeV]
250GeV	Zmm	3.35%	40.4
	Zee	4.76%	109
	Total	**2.74%**	**37.9**
350GeV	Zmm	3.90%	101
	Zee	5.63%	327
	Total	**3.21%**	**96.5**
500GeV	Zmm	6.95%	474
	Zee	9.89%	1540
	Total	**5.69%**	**453**

xsec error

- 350 GeV is 17 % worse w.r.t. 250 GeV
- 500 GeV is much worse
- Zee is worse by > 40% w.r.t. Zmm
- right hand pol is worse by 5 – 10 % w.r.t. left hand

Mass error

- 350 GeV is worse by factor of slightly less than 3 w.r.t. 250 GeV
- Zee is worse by a factor of 2 – 3 w.r.t. Zmm
- Systematic error of fitted recoil mass is negligible (< few MeV for 250 , 350 GeV)

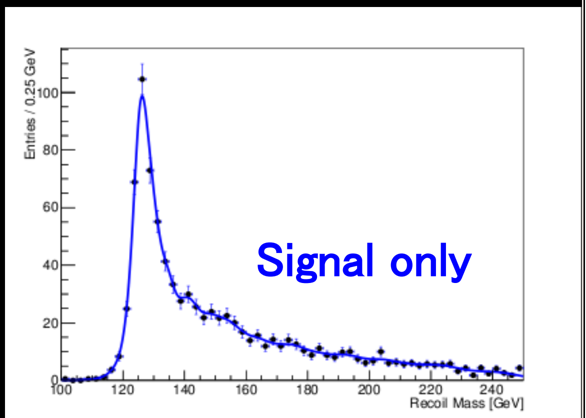
xsec error almost same as past results using GPET

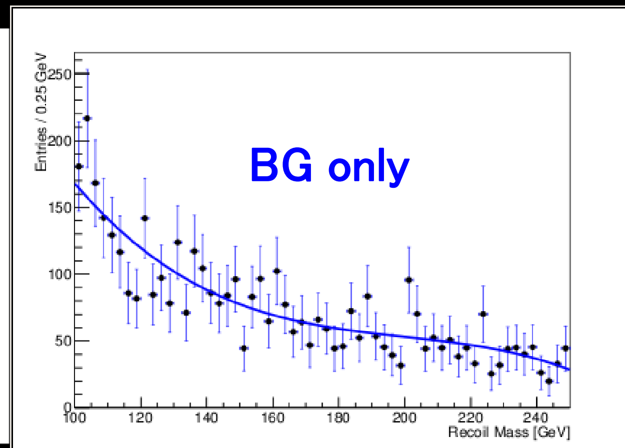
(+0.8,−0.3)		xsec err	mass err [MeV]
250GeV	Zmm	3.57%	40.5
	Zee	5.14%	121
	Total	**2.93%**	**38.4**
350GeV	Zmm	4.31%	112
	Zee	6.26%	296
	Total	**3.55%**	**105**
500GeV	Zmm	8.36%	613
	Zee	9.85%	1510
	Total	**6.37%**	**568**

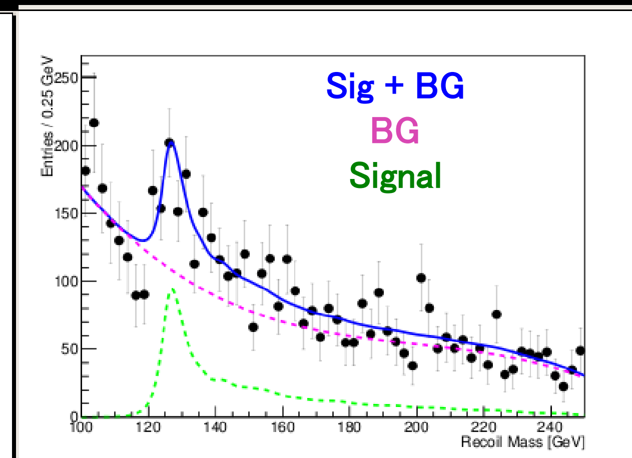
Can precision can be slightly improved if we fit over a wider range ?
assuming we can neglect the H*→WW bump beyond 160 GeV

500 GeV, Zee (-0.8,+0.3)

fit in 100 – 250 GeV (c.f. 100-160 GeV)





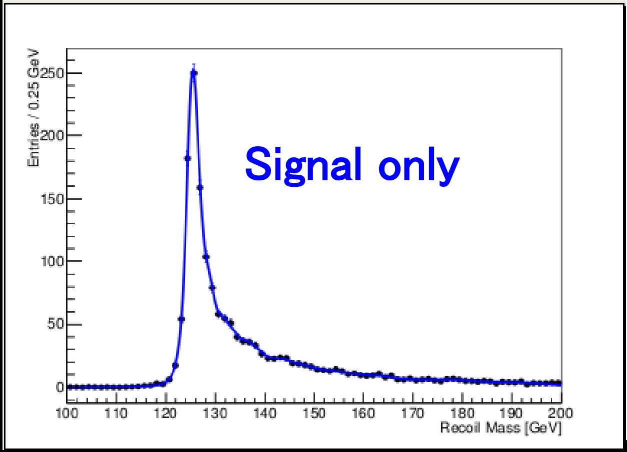


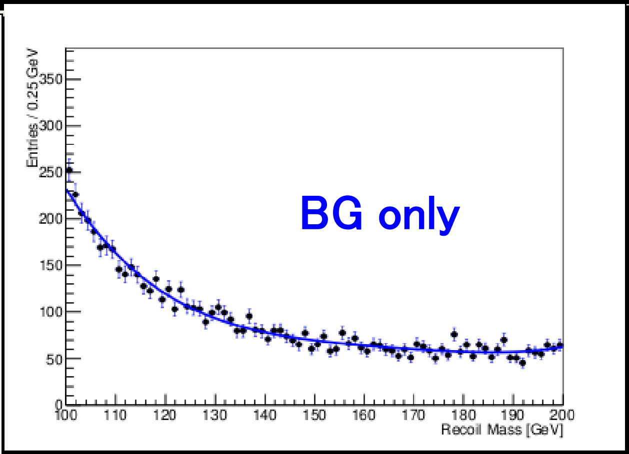
		xsec error (%)		mass error (MeV)	
(−0.8,+0.3)		narrow	wide	narrow	wide
500GeV	Zmm	6.95%	6.50%	474	468
	Zee	9.89%	7.86%	1540	1540
	Total	**5.69%**	**5.01%**	**453**	**448**
(+0.8,−0.3)					
500GeV	Zmm	8.36%	7.27%	613	572
	Zee	9.85%	7.86%	1510	1530
	Total	**6.37%**	**5.33%**	**568**	**536**

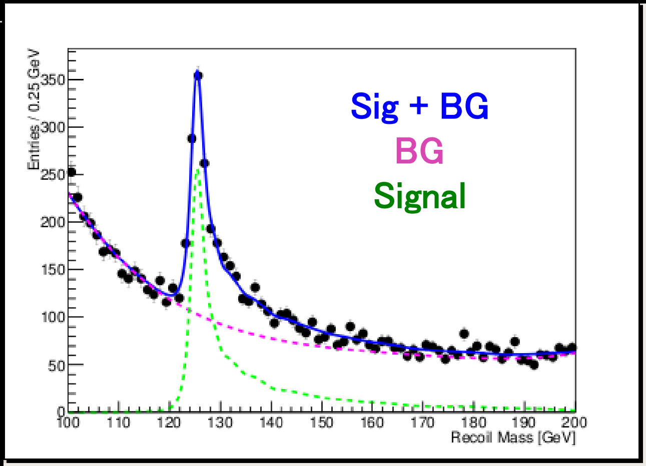
10-20 % improvement on xsec and a few % on mass precision

Can precision can be slightly improved if we fit over a wider range ??
assuming we can neglect the H*→WW bump beyond 160 GeV

350 GeV, Zee (-0.8,+0.3) **fit in 100 – 200 GeV** (c.f. 100-160 GeV)

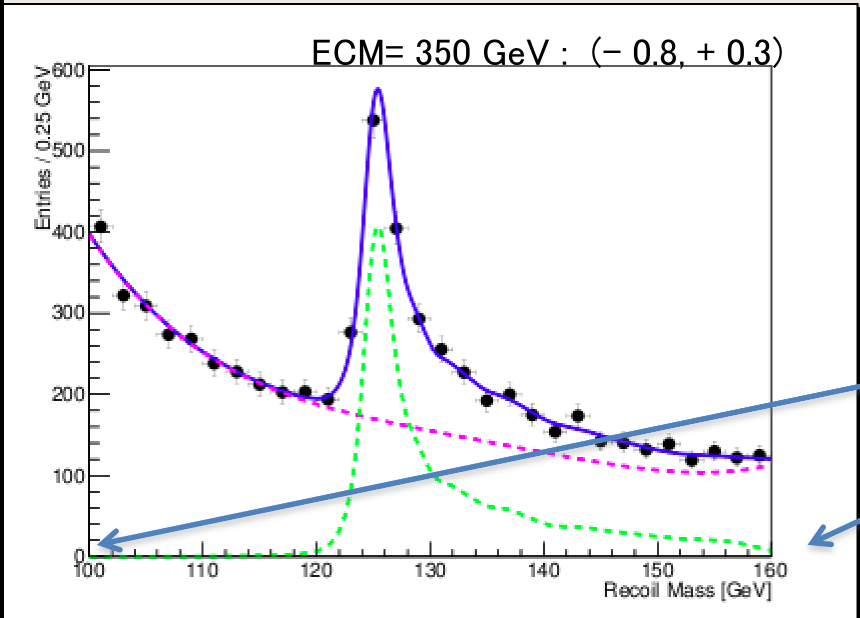






		xsec error (%)		mass error (MeV)	
(−0.8,+0.3)		narrow	wide	narrow	wide
350GeV	Zmm	3.90%	3.83%	101	103
	Zee	5.63%	5.48%	327	340
	Total	3.21%	3.14%	96.5	98.6
(+0.8,−0.3)					
350GeV	Zmm	4.31%	4.24%	112	113
	Zee	6.26%	6.15%	296	328
	Total	3.55%	3.49%	105	107

Not much room for improvement



BG level fluctuation is controlled by fitting recoil mass over a wide range (100 – 160 GeV)

an improvement from previous studies

- BG level is usually fixed for Toy MC (optimistic scenario)
- xsec error is about 10 % worse if we float BG (pessimistic scenario)

  not a big degradation since I fit recoil mass spectrum over a wide range *GOOD*

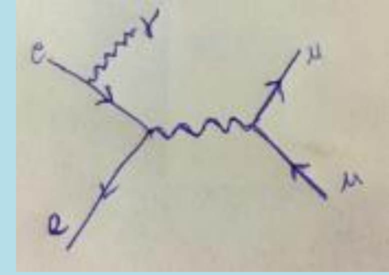
Example:

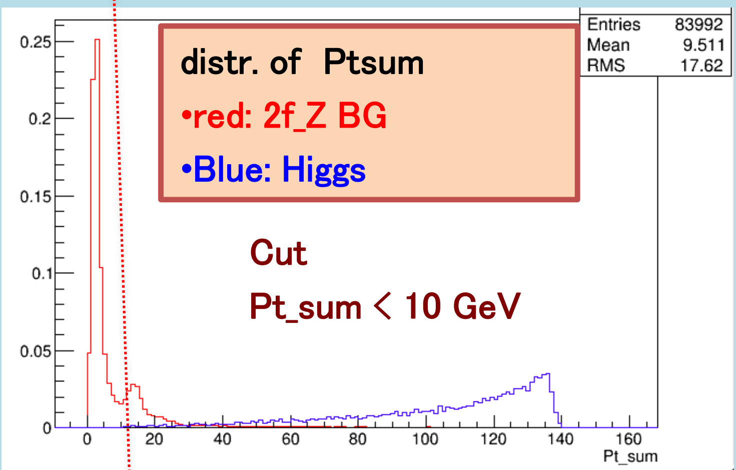
Zmm	xsec	Recoil mass	BG fluc
250GeV	3.35% → 3.62%	40 MeV, no change	1.23%
350GeV	3.90% → 4.39%	101 → 95 MeV	1.67%

Prevention of signal bias i.e. Higgs decay mode dependence

- the "traditional" dptbal (= |Pt,dl | − |Pt, γ|) cut for removing 2f BG

(γ back–to back w.r.t. di–lepton) caused signal bias (esp. H → $\tau\,\tau$, $\gamma\,\gamma$)



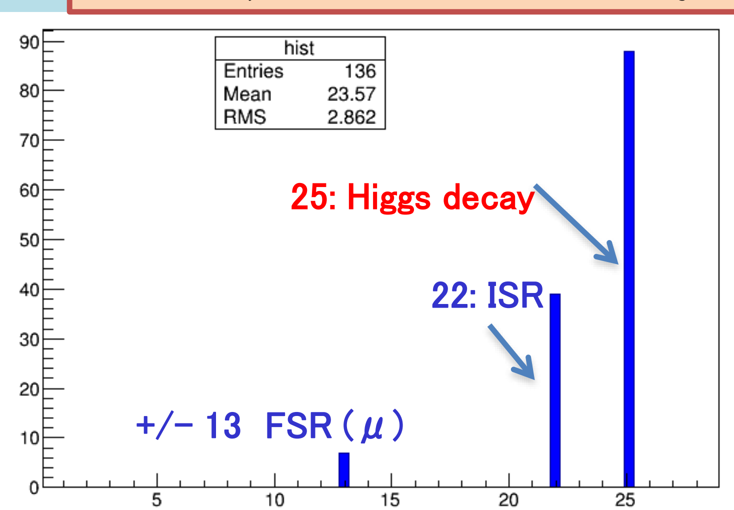


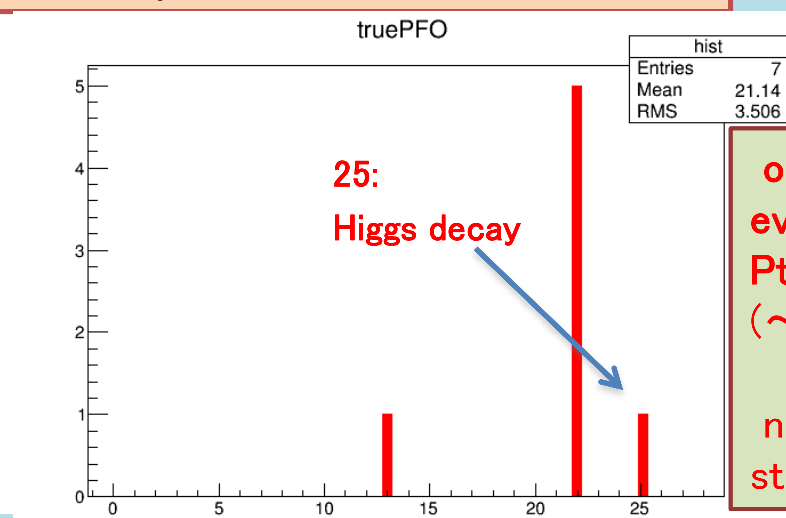
NEW #1 <u>isolated photon finder:</u> γ we look at have small cone energy) not from Higgs decay

NEW #2 Now use (instead of dptbal) $\left|\overrightarrow{P_{t,sum}}\right| \equiv \left|\overrightarrow{P_{t,g}} + \overrightarrow{P_{t,dl}}\right|$

vector direction info singles out back to back events

PDG of γ for events removed by Ptsum /dptbal cut (250 GeV Zmm)





only < few unweighed events removed by Ptsum cut
(~ 0 weighed events)

negligible compared to statistical uncertainties

~100 Higgs decay related γ events removed by dptbal cut !!

need more careful study of
Higgs decay mode bias using high stat sample

Higgs recoil study using **e+e- → ZH → l+l-**H (l = μ / e)
@ ECM = 250 , 350 , 500 GeV

Summary

studied impact of ECM and polarization on model – independent measurement of ZH xsec

- contributes to deciding ILC run scenario and detector design optimization

Study has made progress since previous general meeting
converging towards a full set of study results

< Preliminary results >
(both leptonic channels combined)

250 GeV: **(-0.8, +0.3)** **Δσ / σ = 2.7 %** **ΔM = 38 MeV** **(+0.8, -0.3)** **Δσ / σ = 2.9 %** **ΔM = 38 MeV**

350 GeV: **(-0.8, +0.3)** **Δσ / σ = 3.2 %** **ΔM = 97 MeV** **(+0.8, -0.3)** **Δσ / σ = 3.5 %** **ΔM = 105 MeV**

500 GeV: **(-0.8, +0.3)** **Δσ / σ = 5.7 %** **ΔM = 453 MeV** **(+0.8, -0.3)** **Δσ / σ = 6.4%** **ΔM = 568 MeV**

- **signal bias is minimized i.e. prevent Higgs decay mode dependence**
- **negligible systematic error due to fitting method**

xsec precision :

- **ECM= 350 GeV worse by 17% w.r.t. 250 GeV**
- **Zee worse by > 40% w.r.t. Zmm**
- **right pol worse by 5-10% w.r.t. left pol.**

Higgs mass precision:

- **ECM=350 GeV worse by factor of < 3 w.r.t. ECM = 250 GeV**
- **Zee worse by factor of 2 -3 w.r.t. Zmm**

Note : extrapolated results (TDR) for 250 GeV : xsec error 2.6%, ΔM = 32 MeV
methods are slightly different, hard to directly compare

Plans and Goals

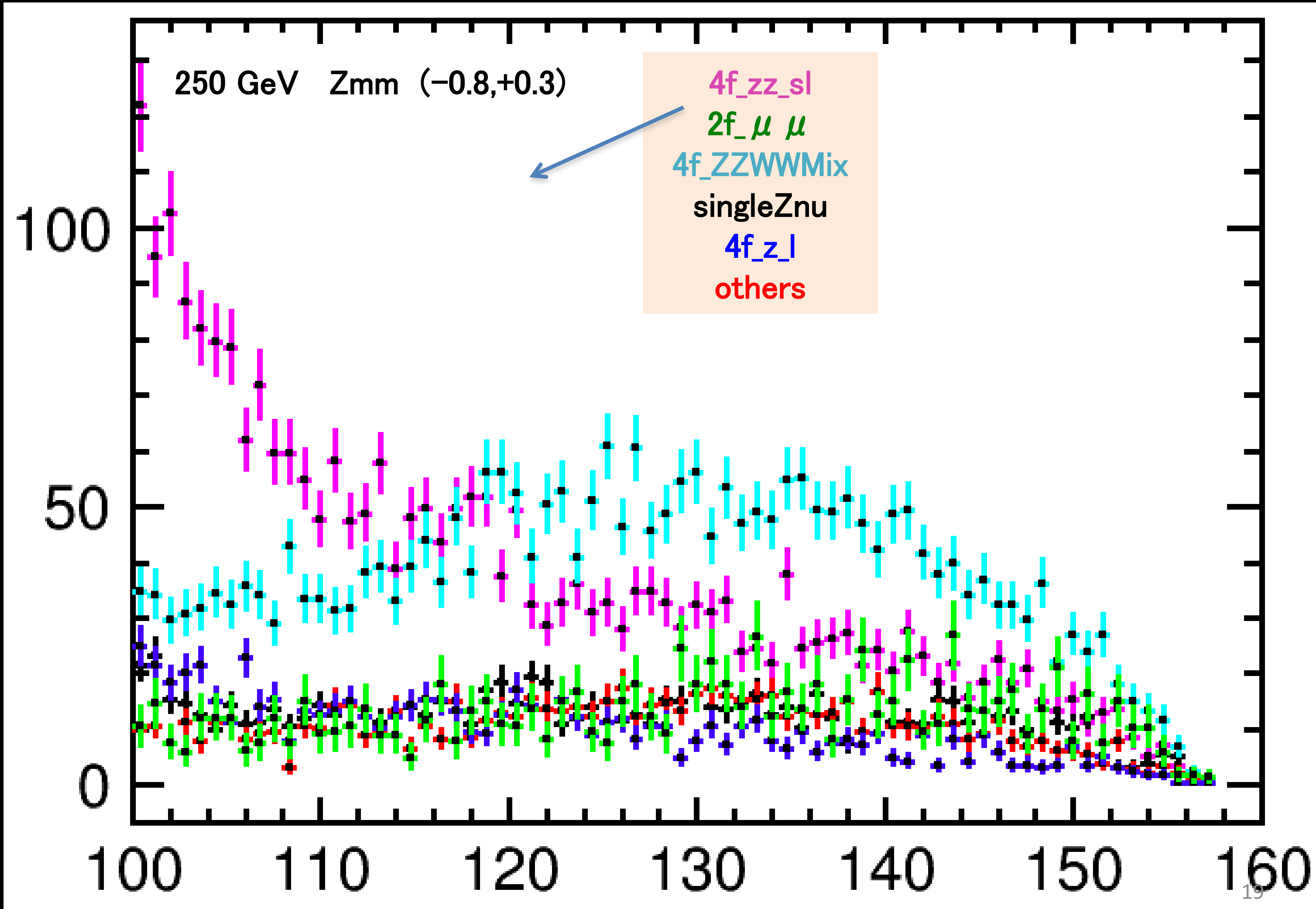
- analysis using higher MC statistics sample
  → deeper investigations of systematic errors

- ZZ fusion analysis (Zee mode)

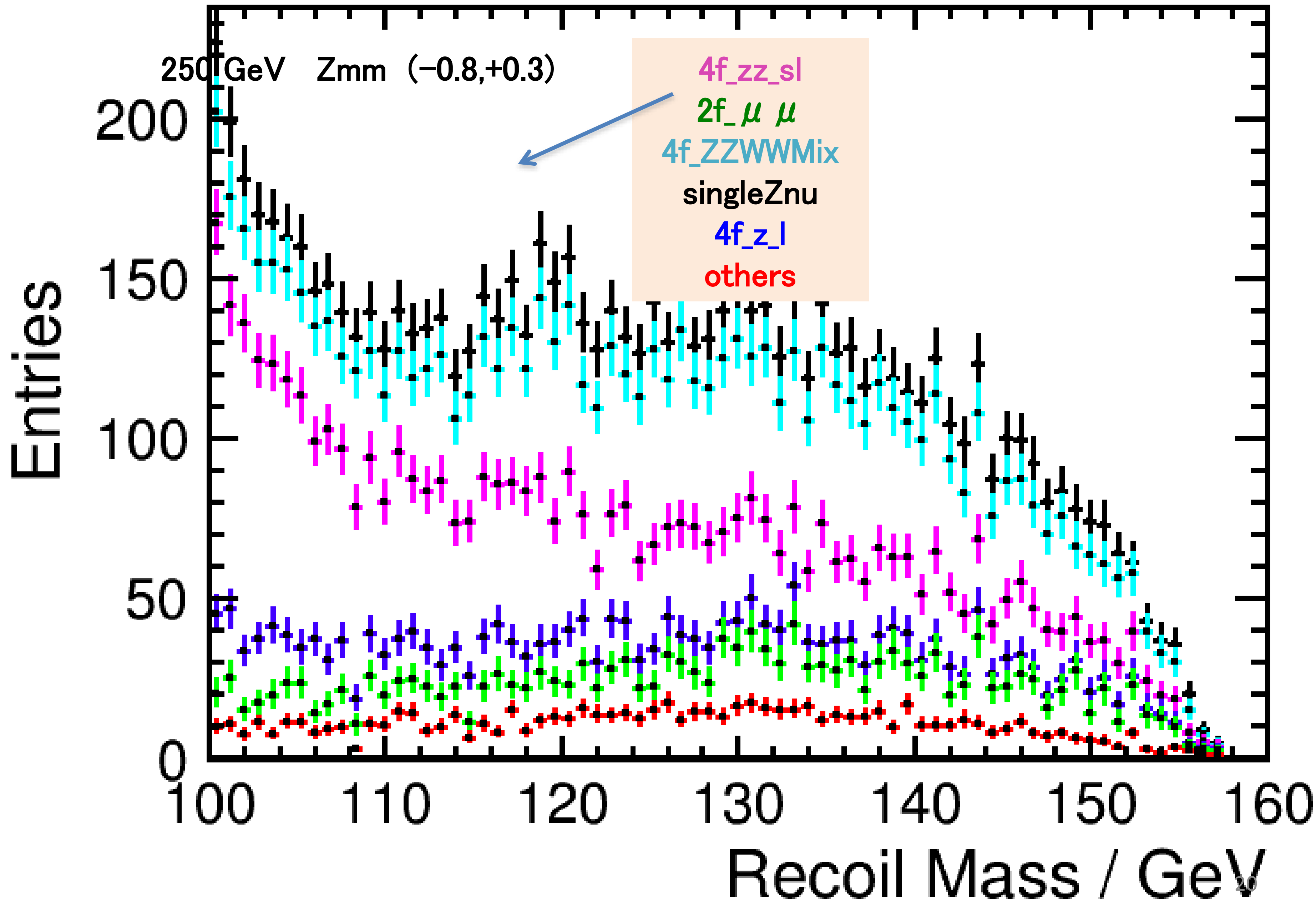
- semi-model independent analysis:
  separate Higgs visible and invisible decay modes.
  → this will suppress the major BG $ll\nu\nu$
  expect improvement in xsec precision

BACKUP

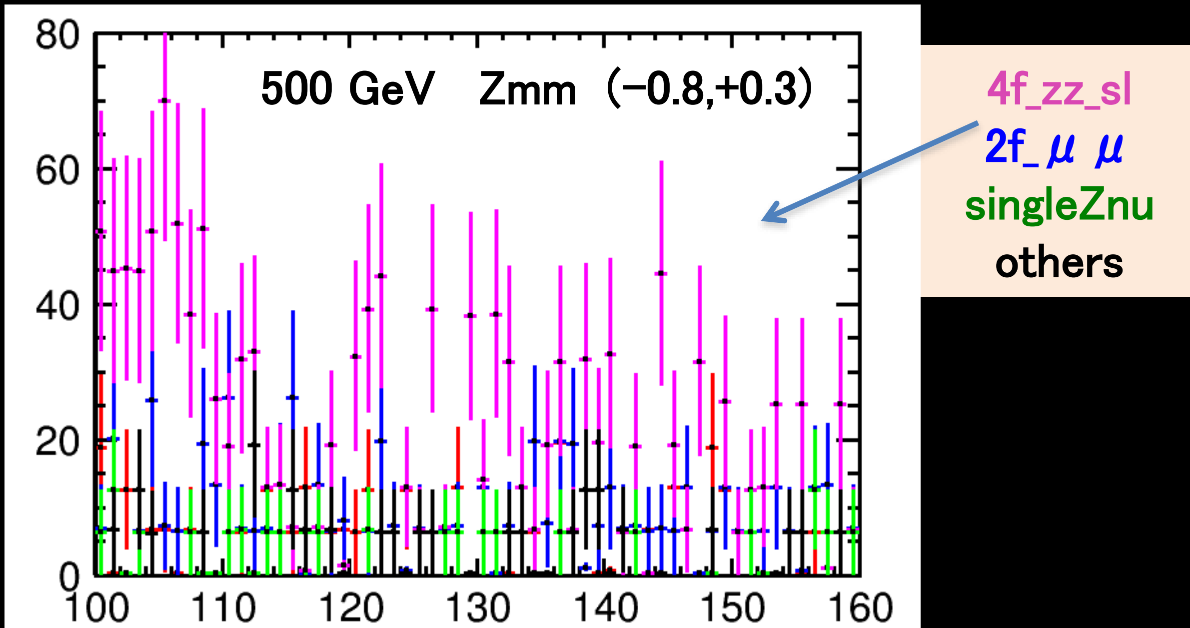
250 GeV Zmm left pol, major BG

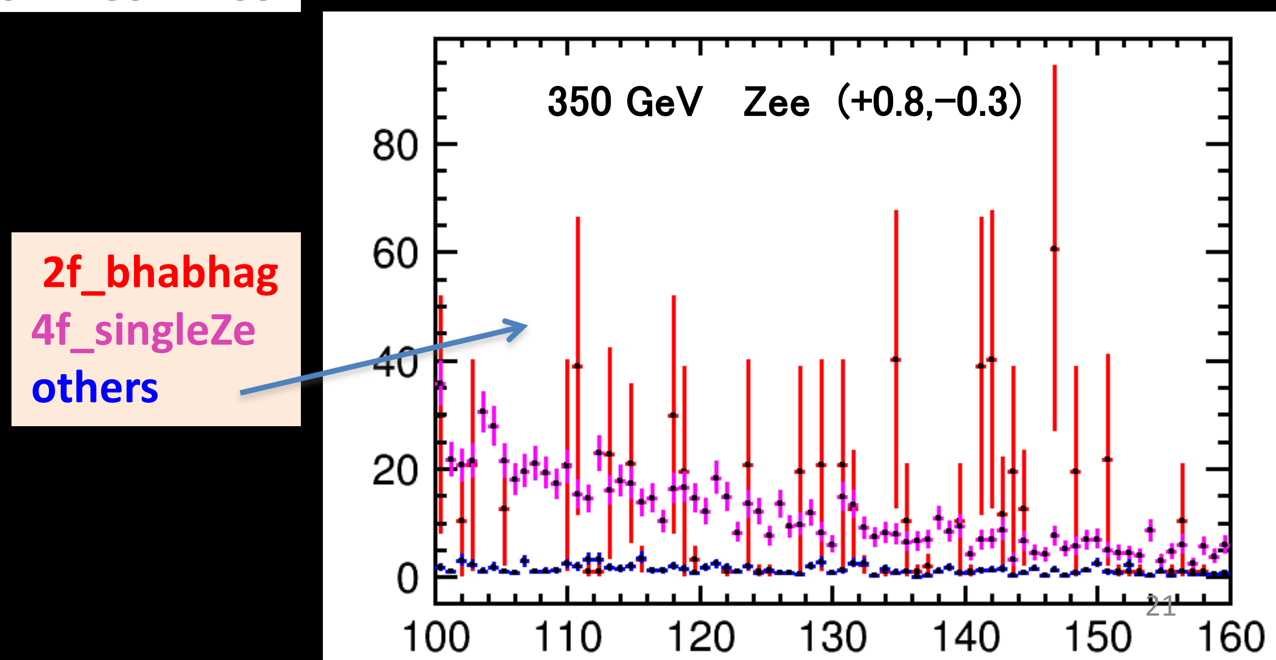


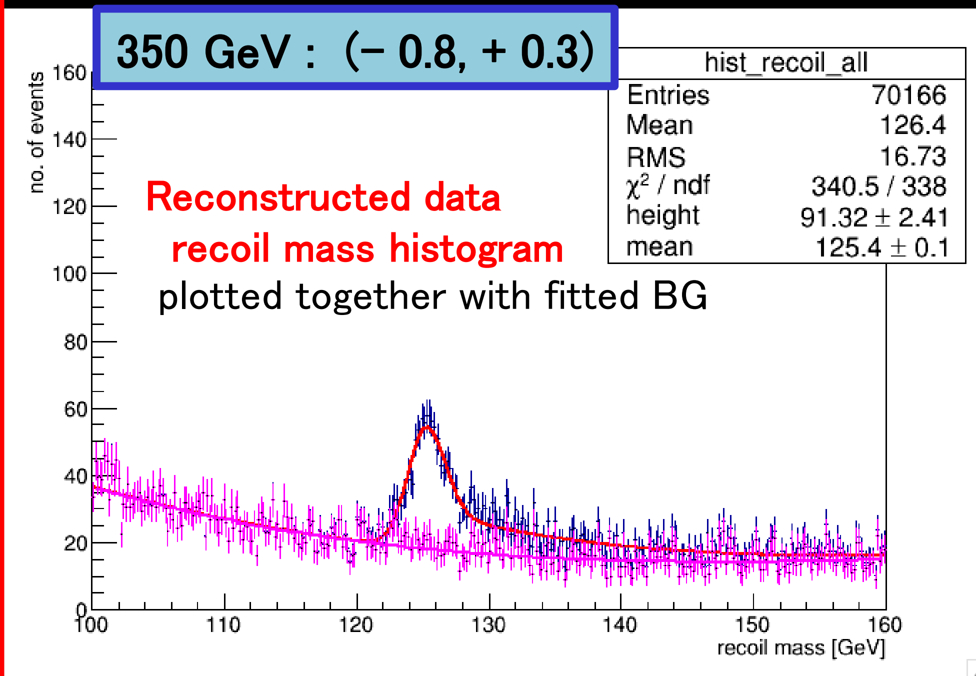
250 GeV Zmm left pol major BG, stacked

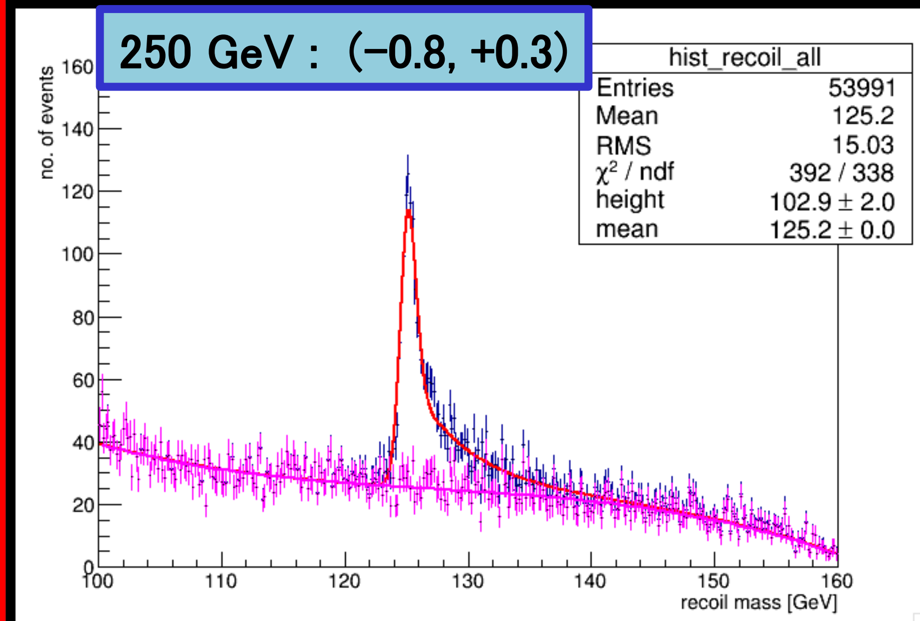


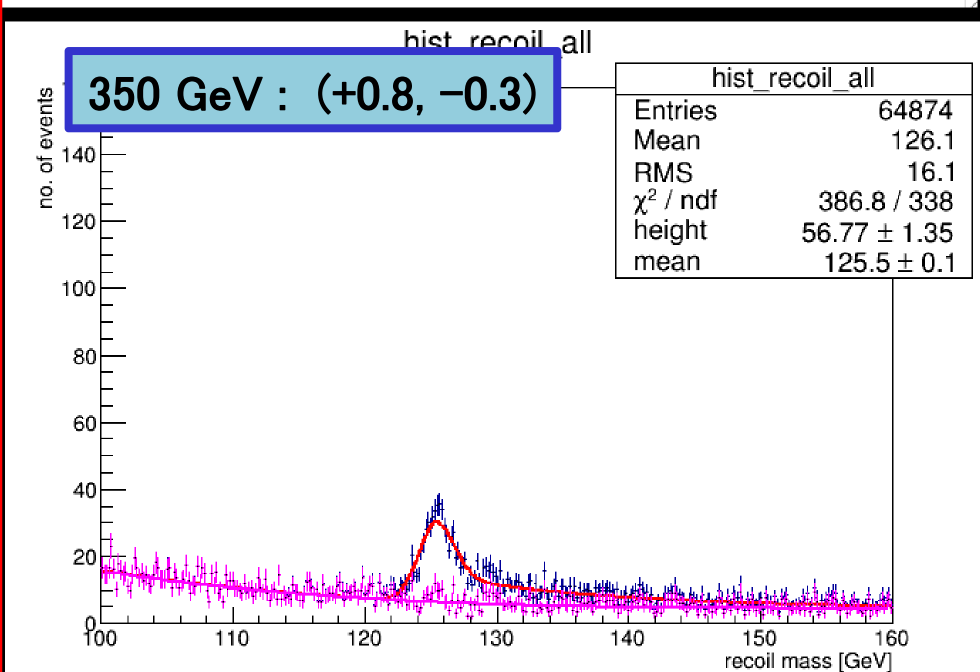
Dominant BG with low MC statistics cause large errorbars
(a technical problem planned to be solved by generating higher statistics samples)

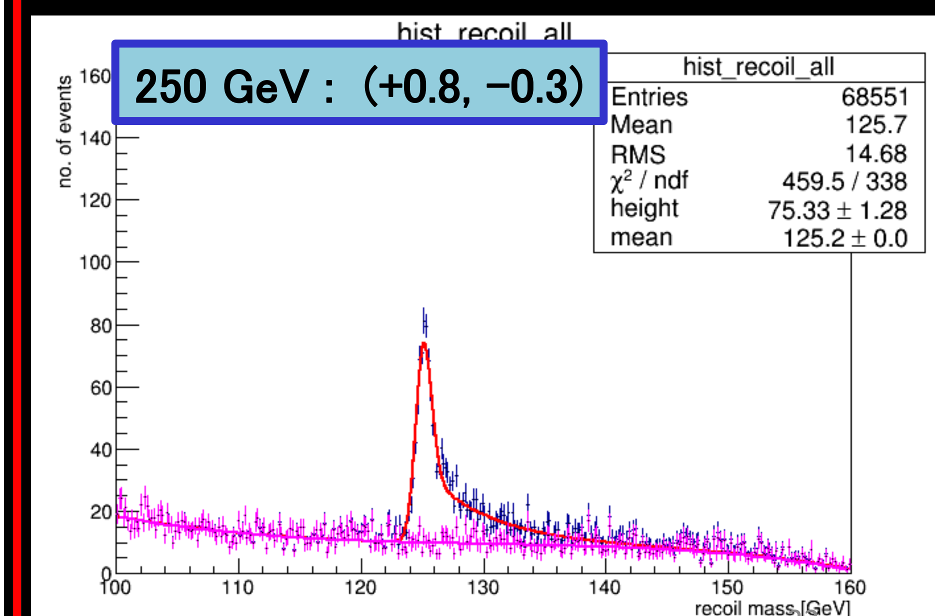





350 GeV : (– 0.8, + 0.3)
Reconstructed data
recoil mass histogram
plotted together with fitted BG
hist_recoil_all
Entries 70166
Mean 126.4
RMS 16.73
χ² / ndf 340.5 / 338
height 91.32 ± 2.41
mean 125.4 ± 0.1
no. of events
recoil mass [GeV]

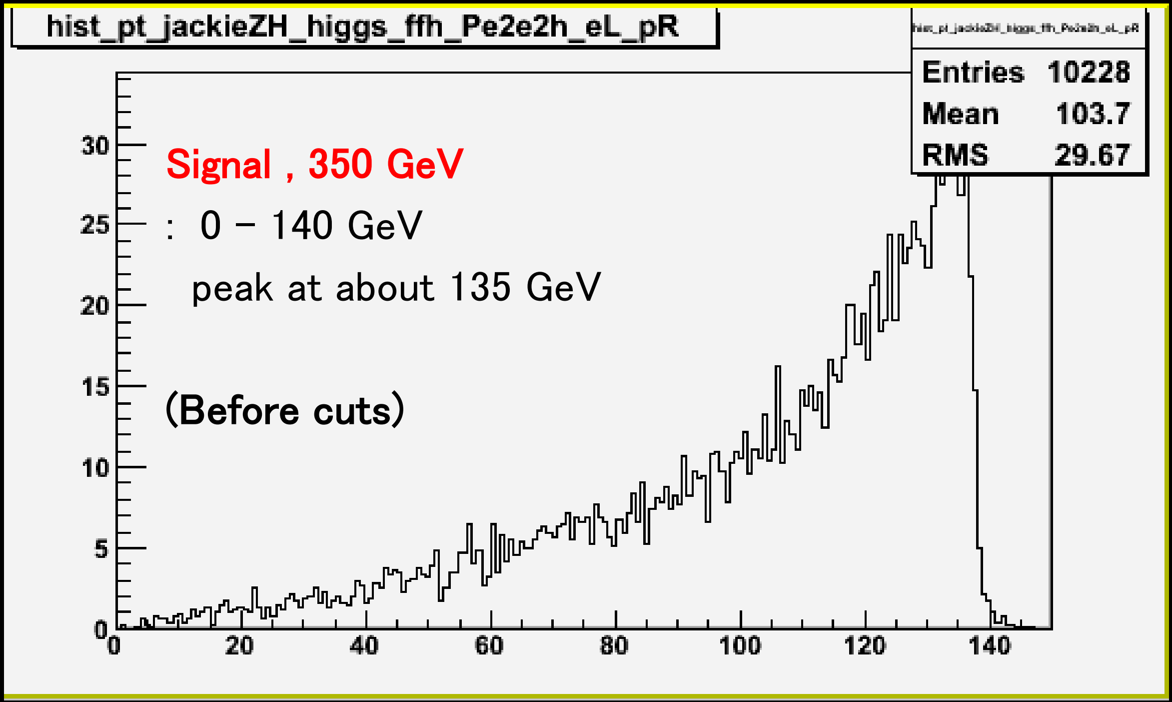

250 GeV : (–0.8, +0.3)
hist_recoil_all
Entries 53991
Mean 125.2
RMS 15.03
χ² / ndf 392 / 338
height 102.9 ± 2.0
mean 125.2 ± 0.0
no. of events
recoil mass [GeV]

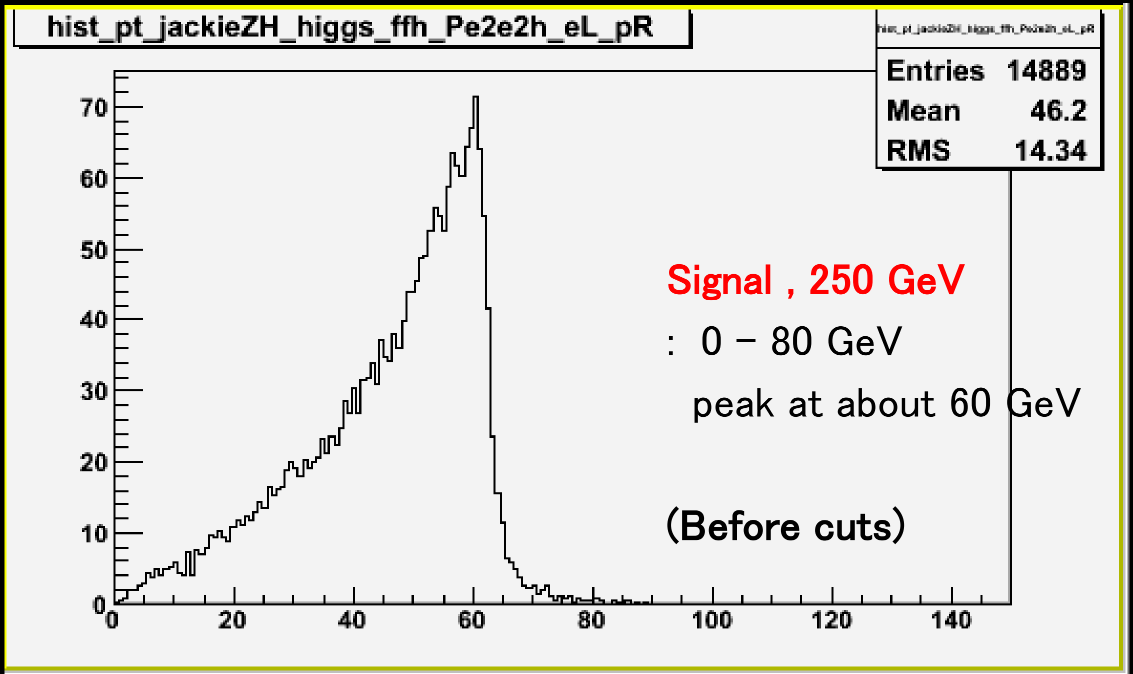

hist_recoil_all
350 GeV : (+0.8, –0.3)
hist_recoil_all
Entries 64874
Mean 126.1
RMS 16.1
χ² / ndf 386.8 / 338
height 56.77 ± 1.35
mean 125.5 ± 0.1
no. of events
recoil mass [GeV]


hist_recoil_all
250 GeV : (+0.8, –0.3)
hist_recoil_all
Entries 68551
Mean 125.7
RMS 14.68
χ² / ndf 459.5 / 338
height 75.33 ± 1.28
mean 125.2 ± 0.0
no. of events
recoil mass [GeV]

dilepton PT, 350 GeV

do cut :
10 GeV< pT_dl < 140 GeV





Pe2e2h_.eL.pR & Pe2e2h._eR.pL

- 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)

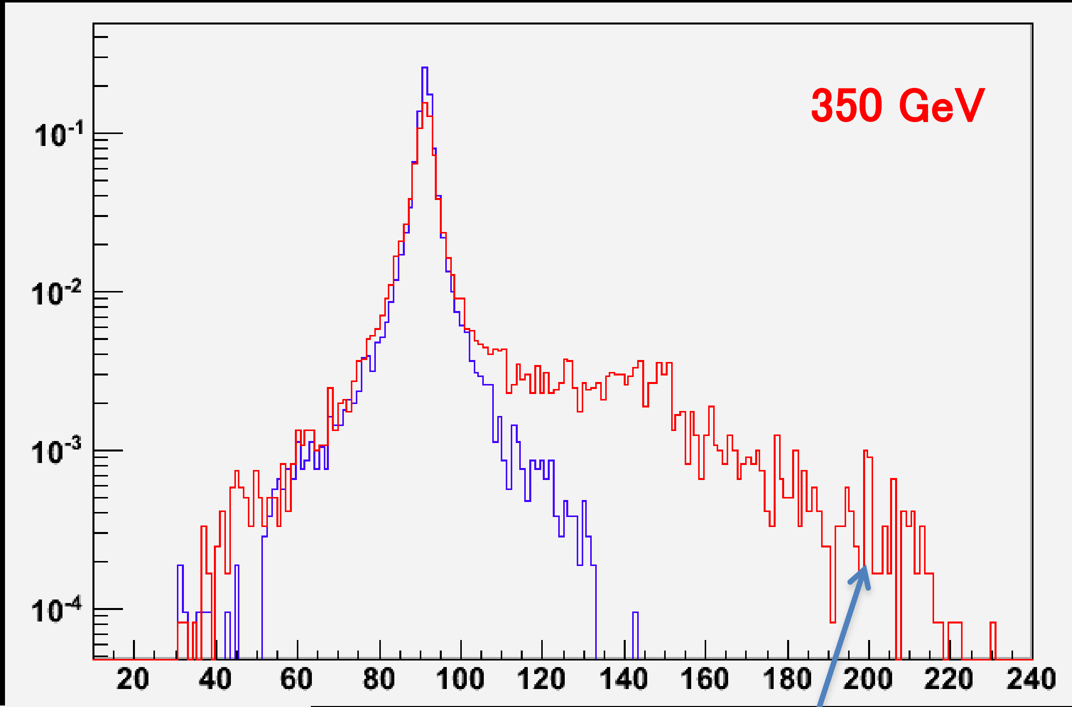
note that difference from past studies maybe sue to:

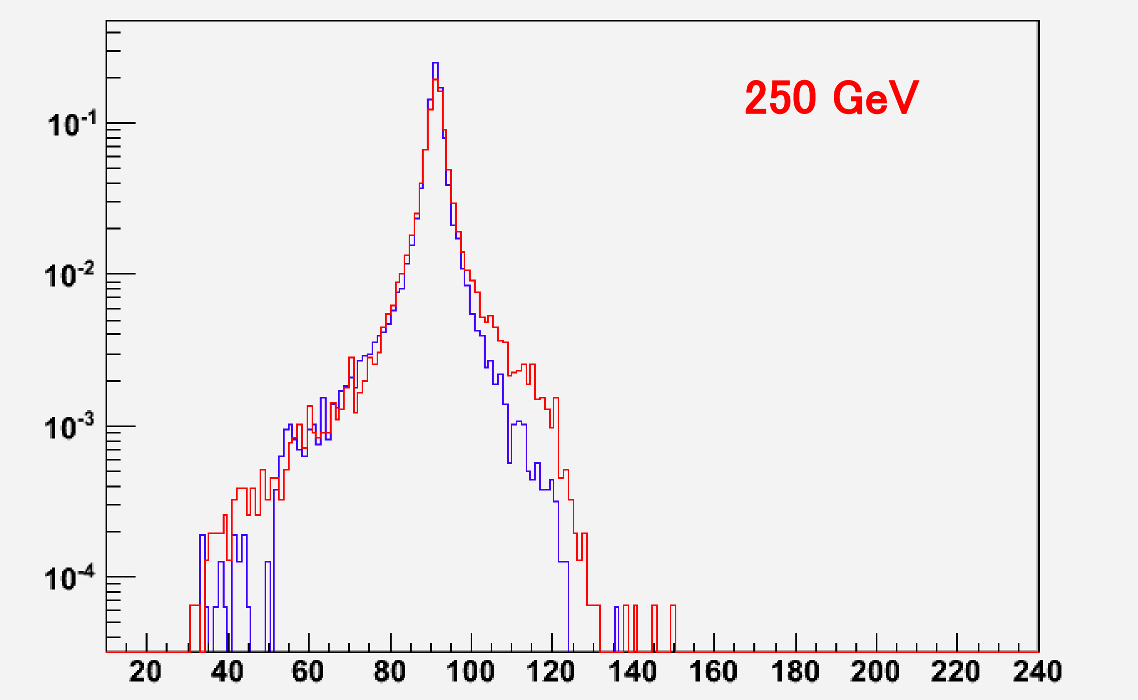
- assumed L (350, 250 GeV) = (333 , 250 fb-1) vs RDR: (300 fb-1, 188 fb-1)
- this analysis include all 2f, 4f, 6f BGs (whizard generator) vs only WW, ZZ (pythia generator ?)

compare dilepton invariant mass distribution

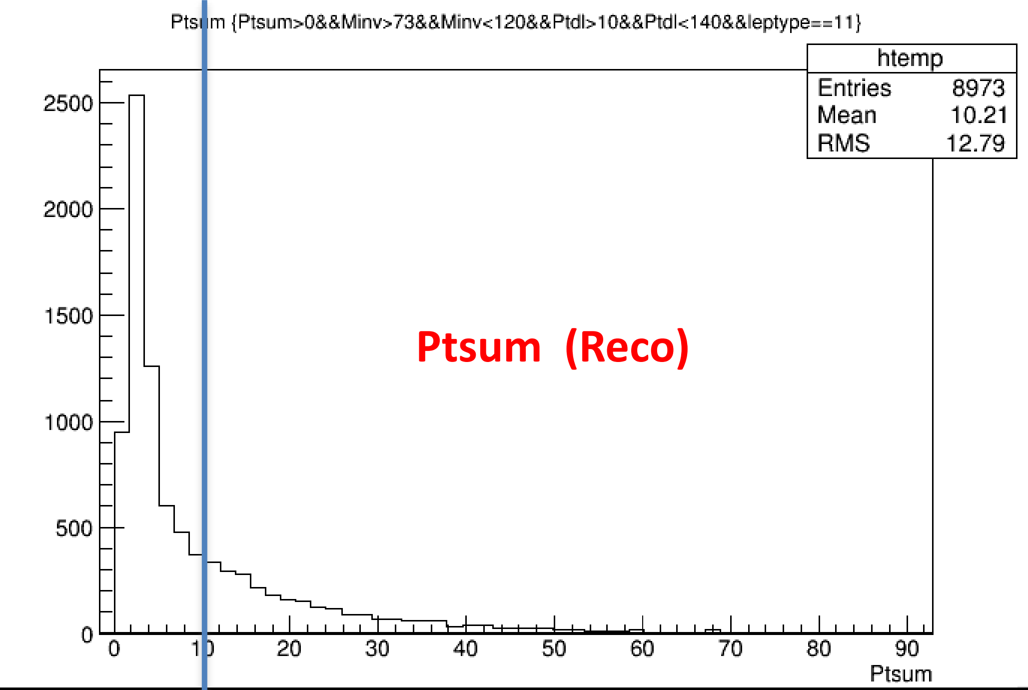
Zee (red)

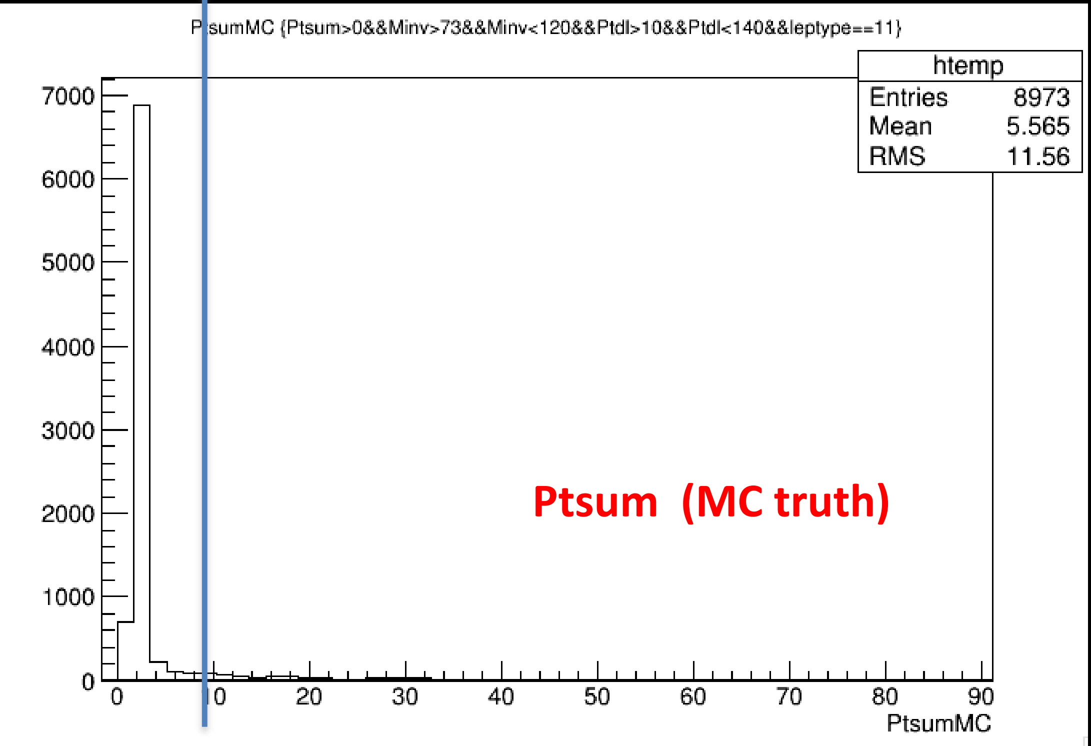
vs Zmumu (blue)





- Zmumu much sharper
- Zee has a long tail towards large inv. Mass (ZZ fusion)
- Broader width due to bremsstrahlung (partially recovered)





events before Ptsum cut

2f_bb

Realized a large difference in Ptsum between Reconstructed particles and MC Truth

Ptsum if formed from sum of vectors !!

Ptdl should be near zero if no brem

If one lepton emit brem and lose energy,

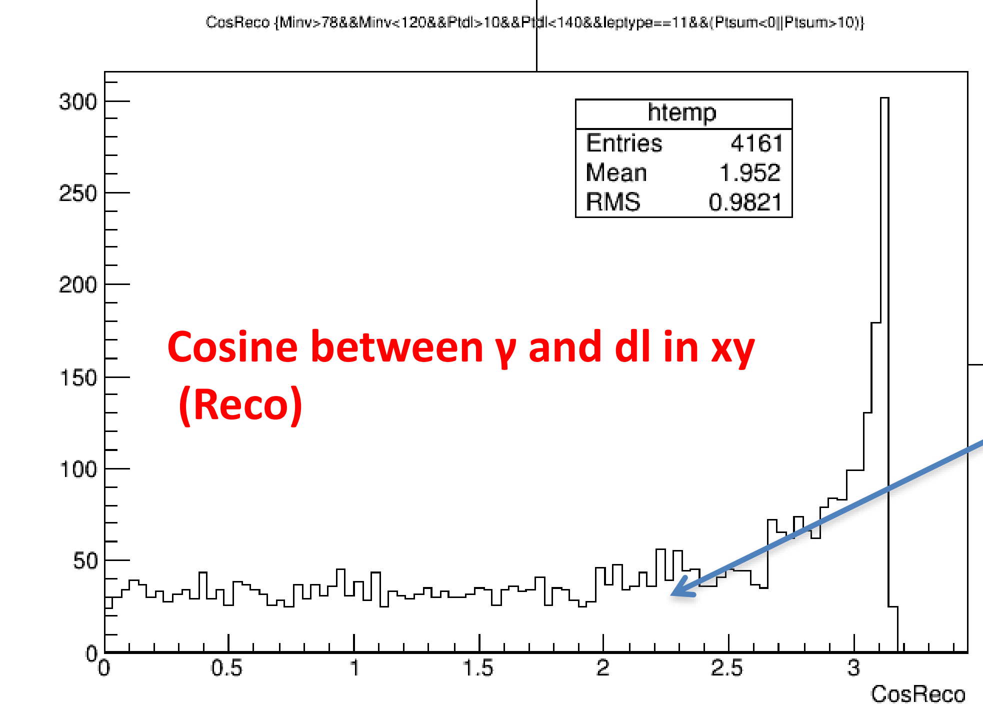
Pt_dl will incrrease

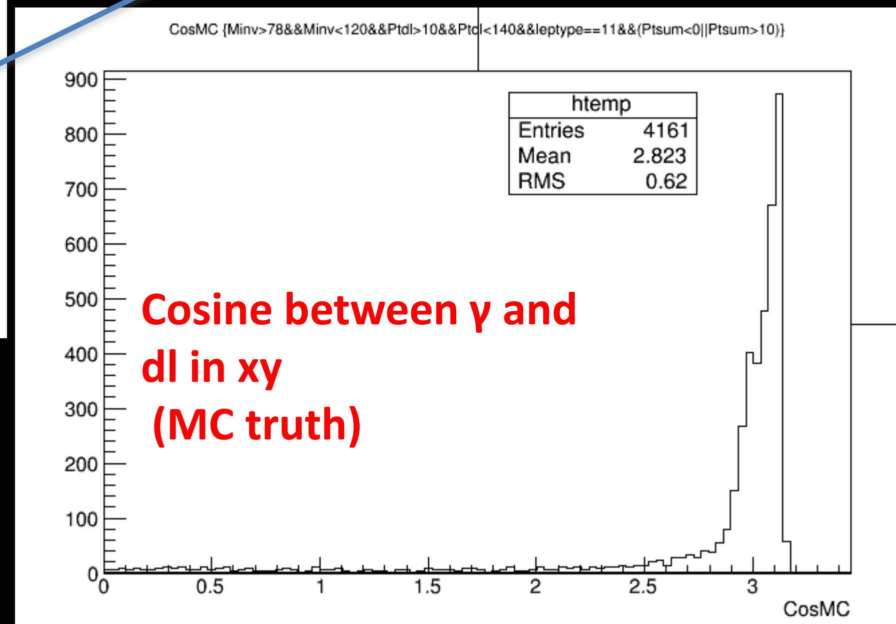
→ long Ptsum tail

→ Ptsum cut lose power

MC truth is much more back-to-back (as expected)

How to explain the long isotropic tail for Reco ?

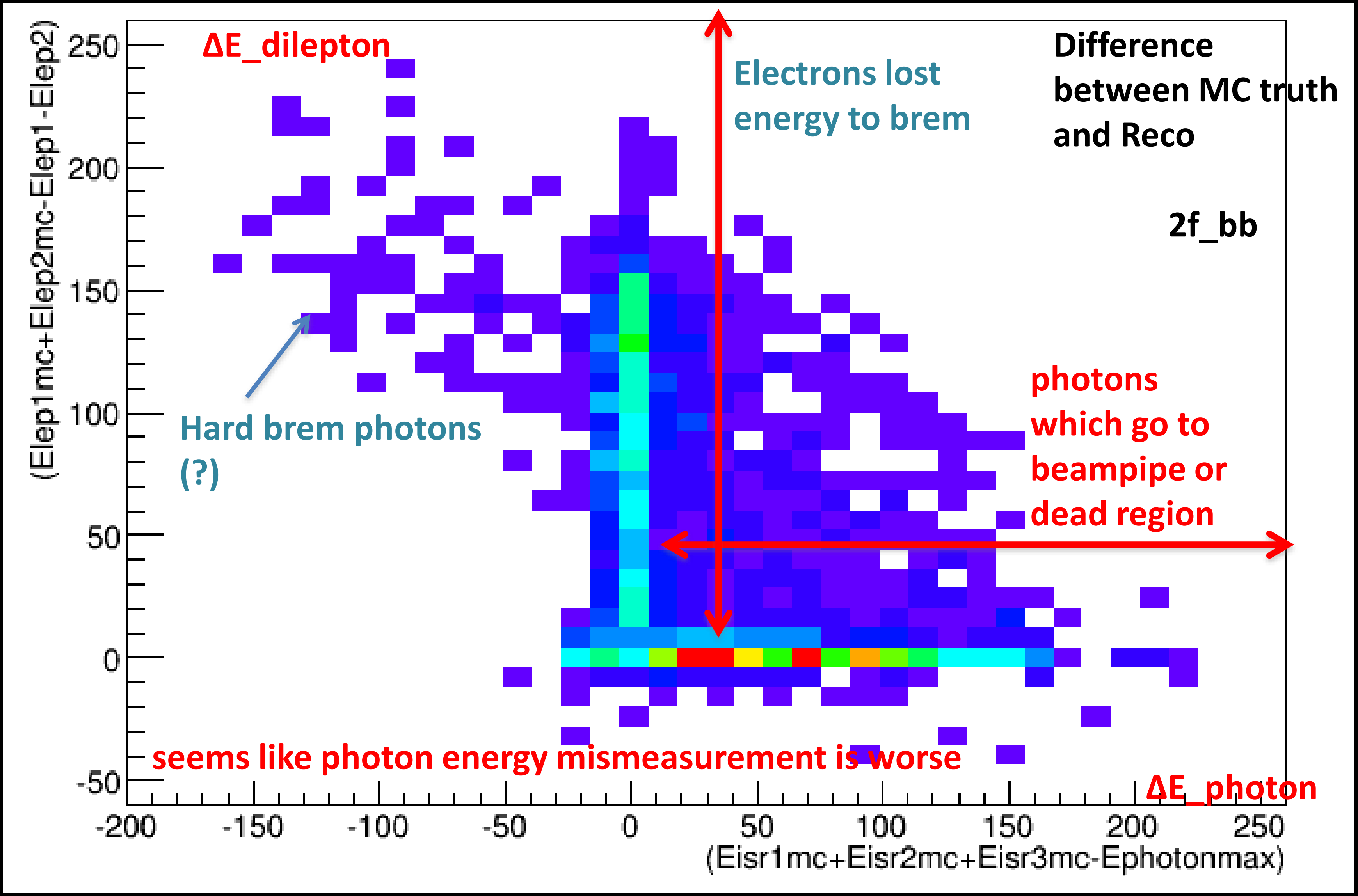




There are a few potential explanations

From here on we will investigate the reason for the non-back-to-back ness

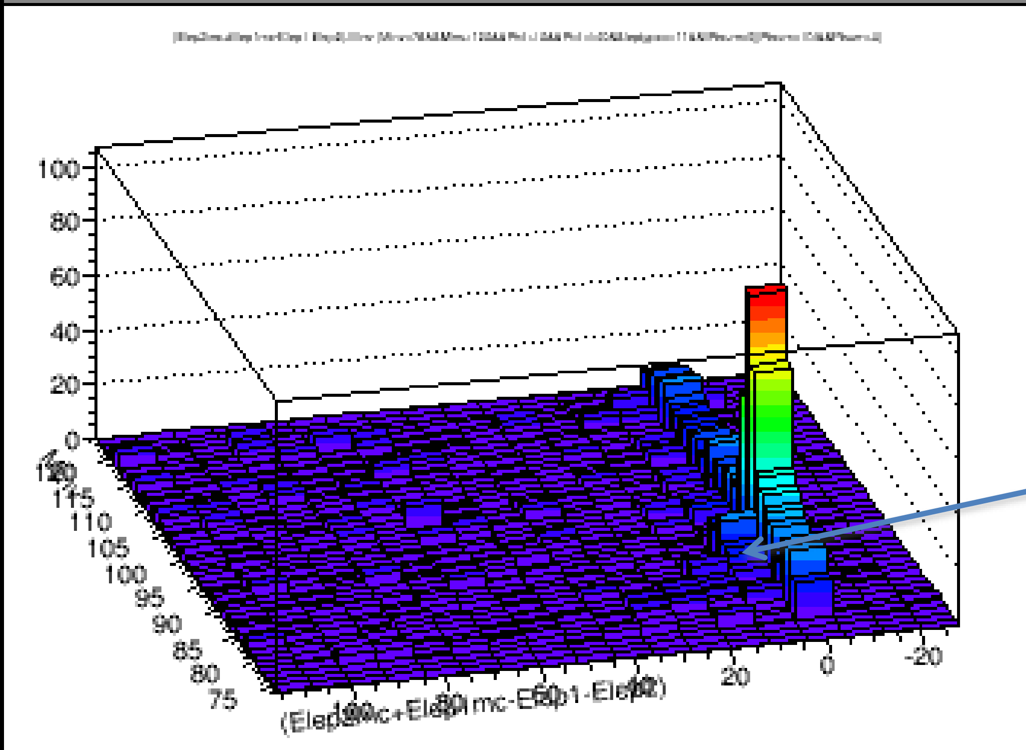
especially the long isotropic tail



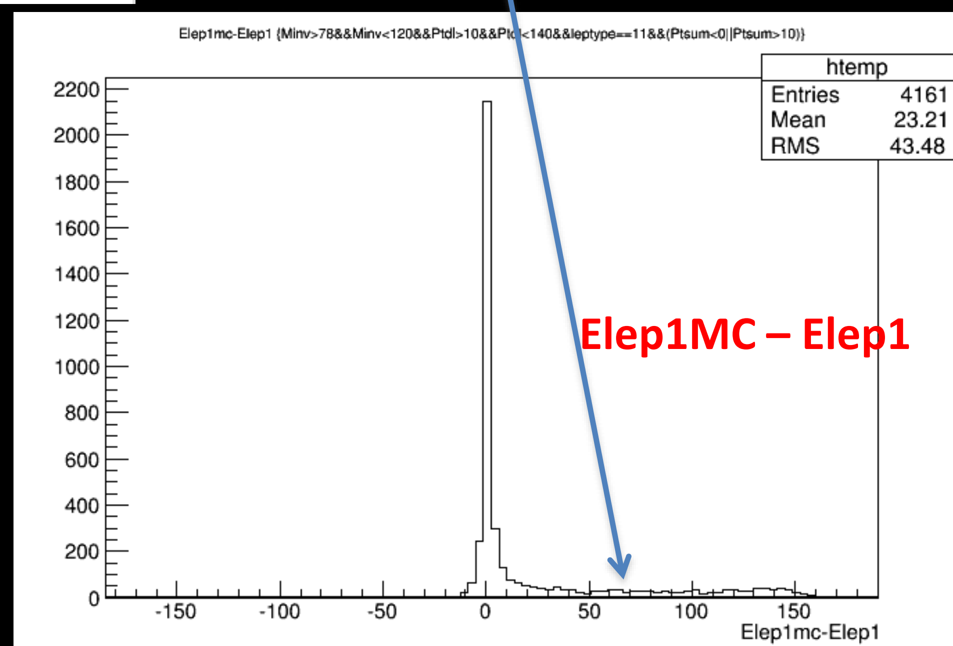
energy mis-measurements explain ONLY A PART of discrepancy in non - BTB ness

- leptons lose energy due to brem
- Photons go very forward to beampipe or dead regions of detector

Other parts : angle resolution (?), More than 1 hard ISR photon (still needs confirmation)

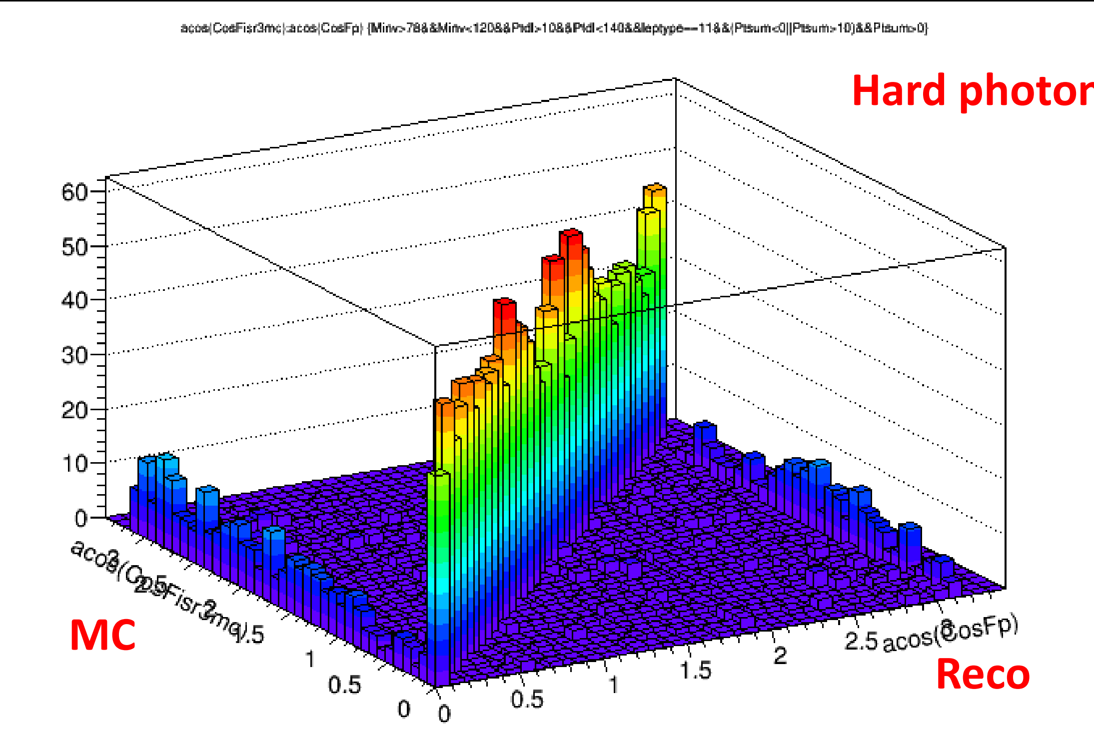


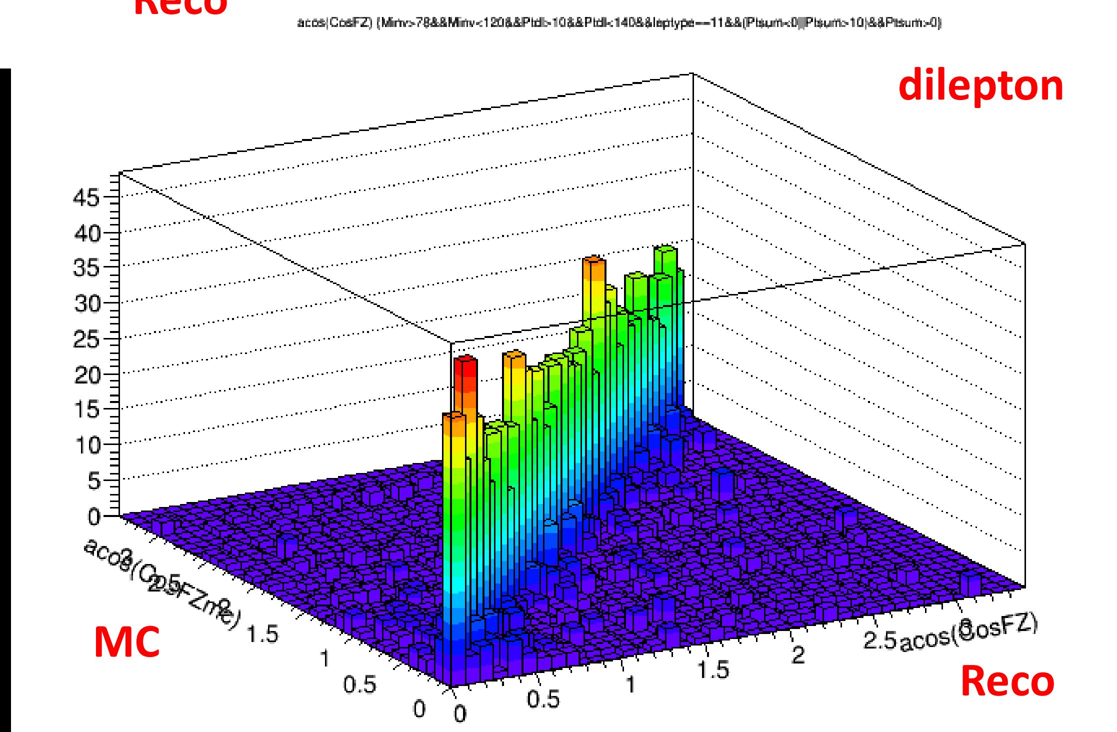
Events which emit brem contribute to lower Minv tail



Elep1MC – Elep1

Angle ϕ in x-y plane

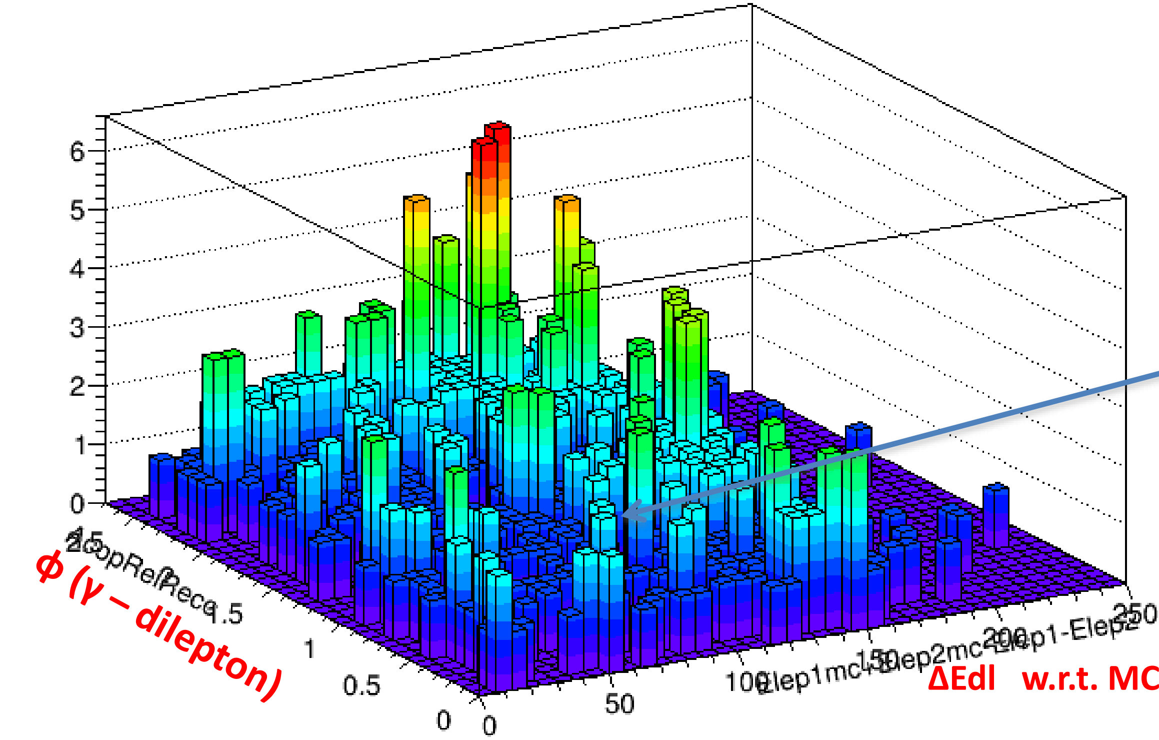




Angle precision seems not too bad for lepton and photon

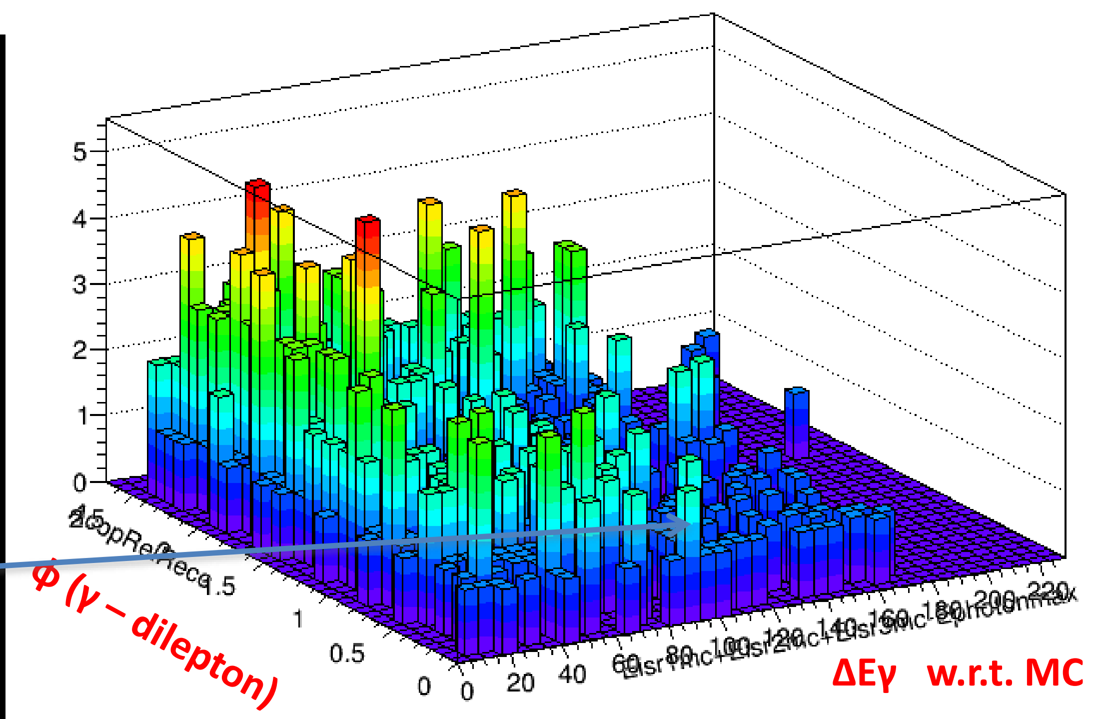
(photon slightly worse)

Only events with non-”back-to-back” ness (angle < 2.5 rad)



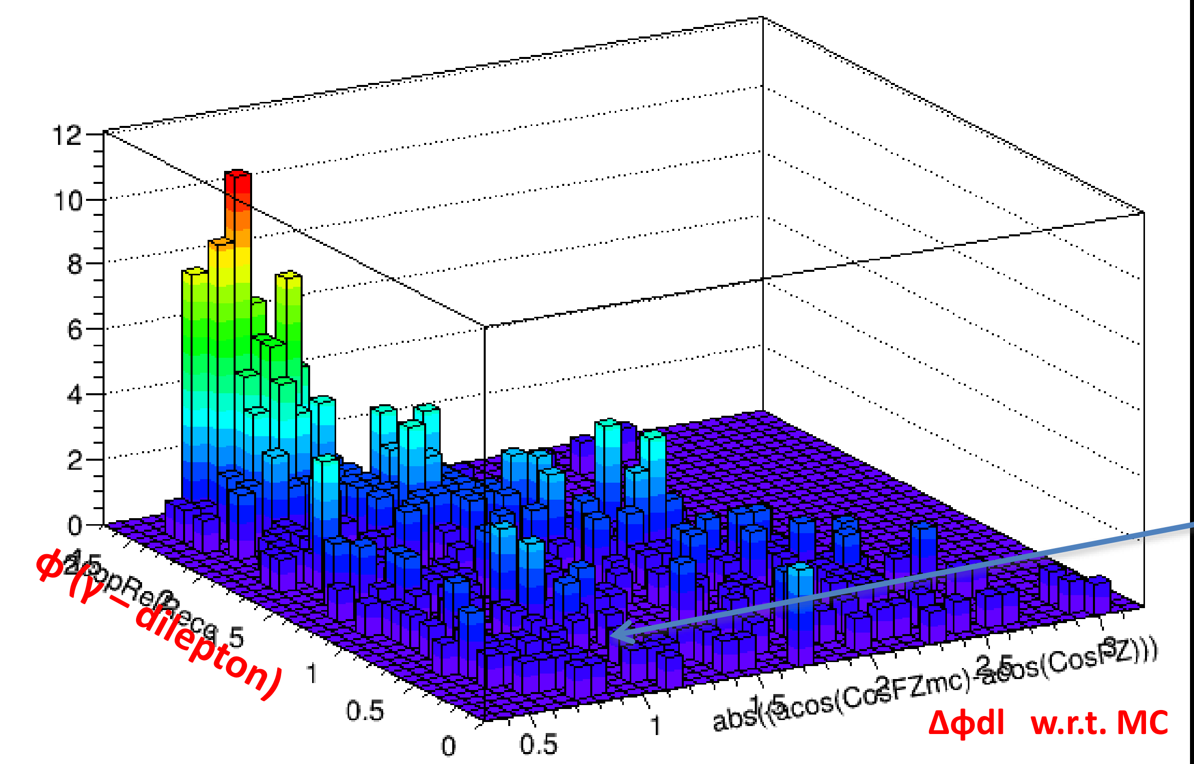
Not well measured dilepton energy: 60%

brem explains part of non-”BTB”

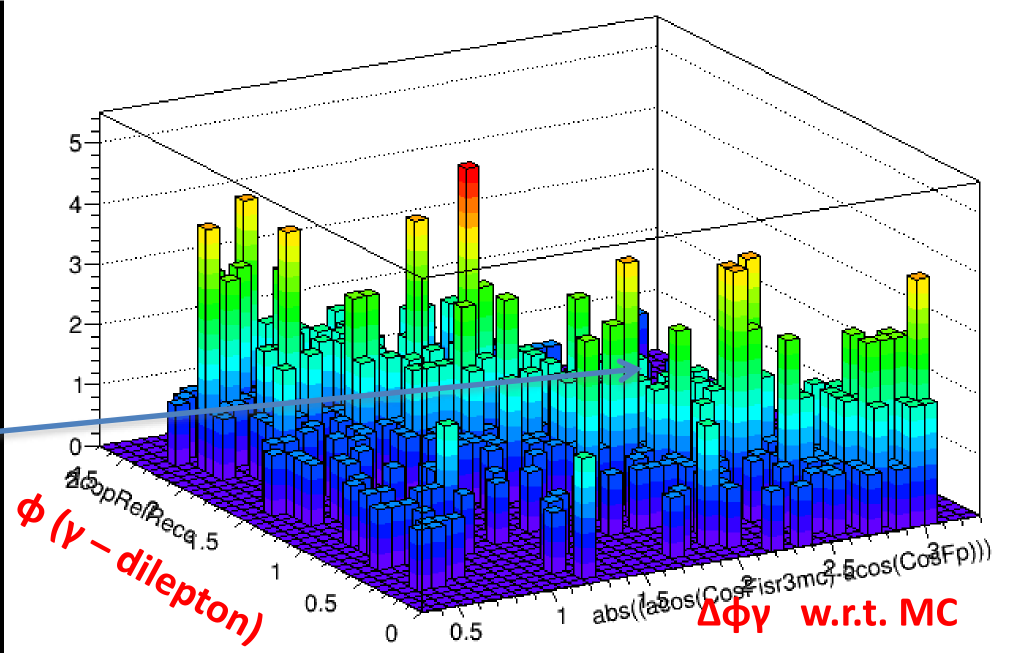


Not well measured γ energy: 55%

Only events with non-"back-to-back" ness (angle < 2.5 rad)

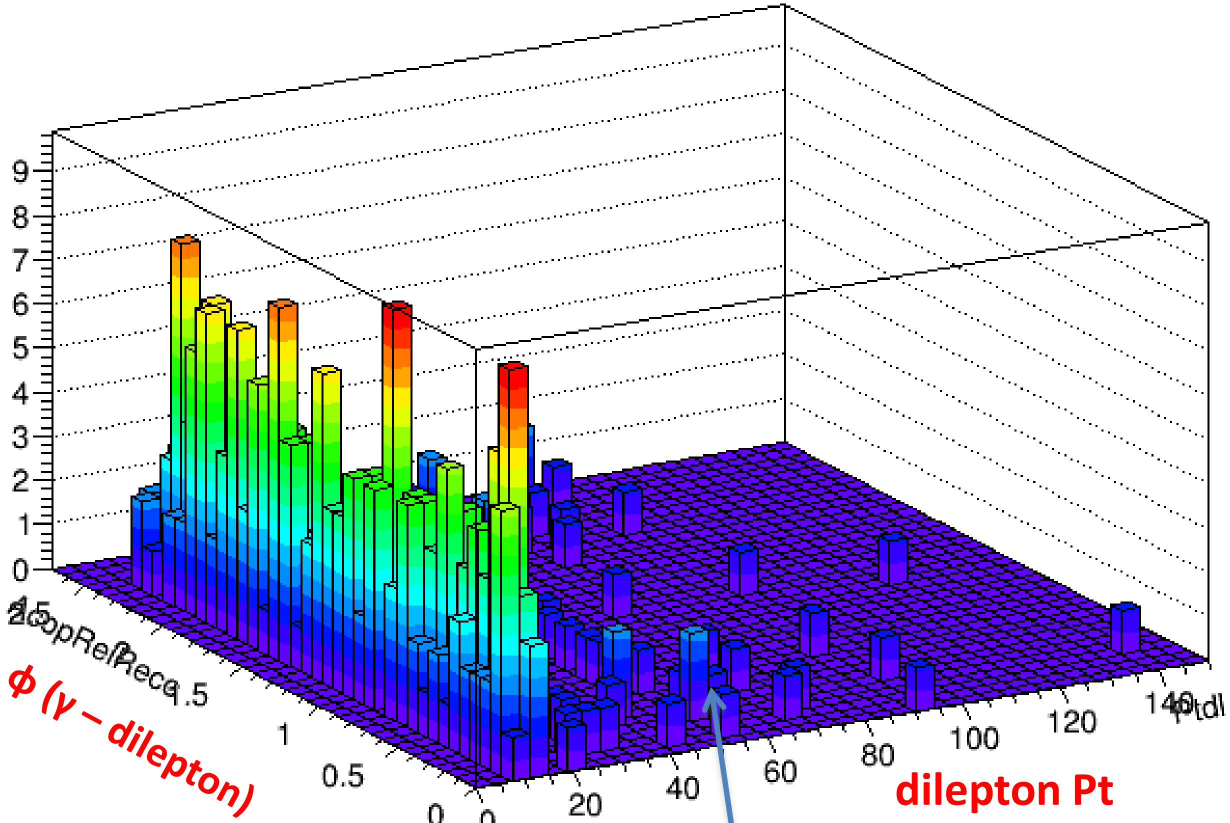


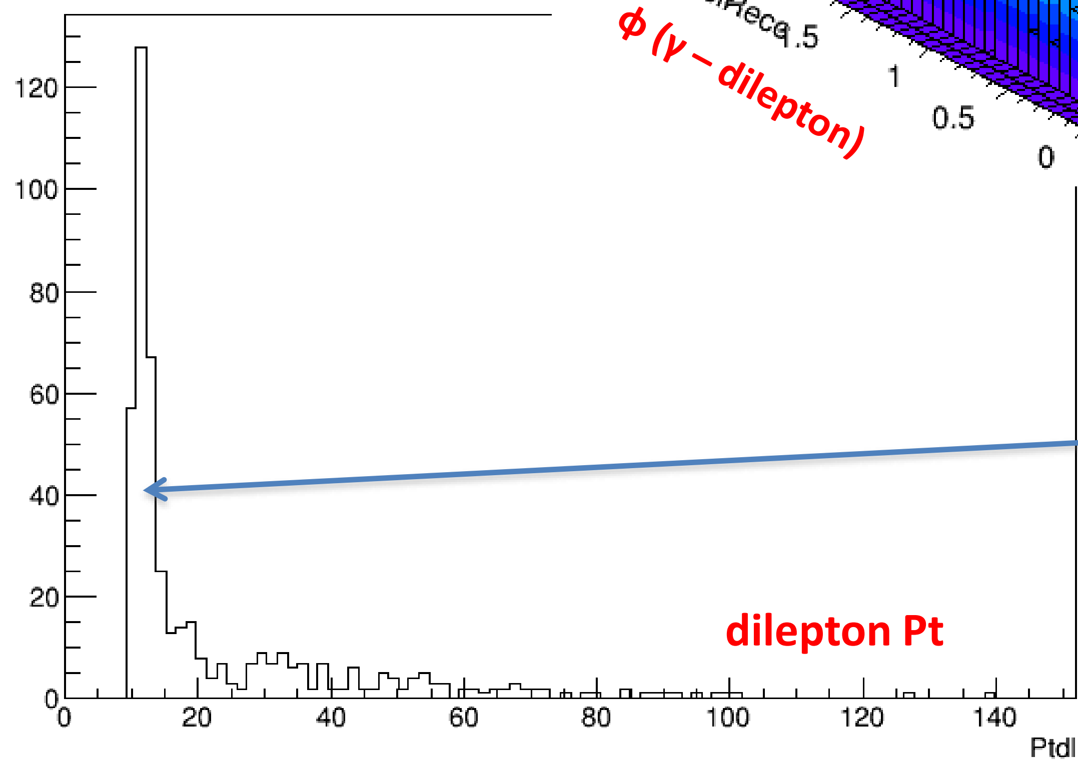
Not well measured dilepton angle : 40%



Not well measured γ angle : 45%

events with non-"back-to-back" ness (angle < 2.5rad)
and well measured dilepton energy and angles

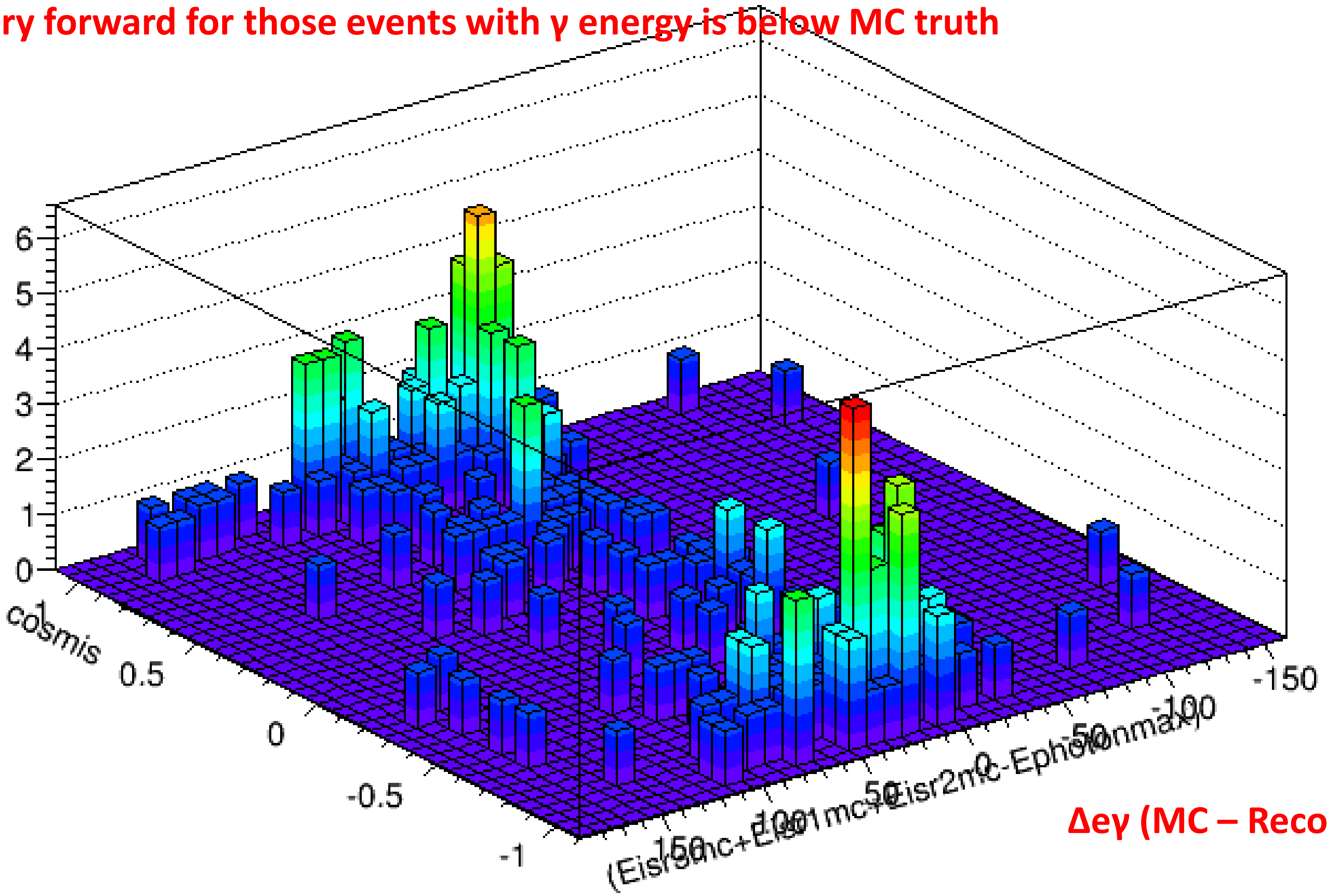




For these events, dilepton Pt is very small
(limit of Pt resolution ?)

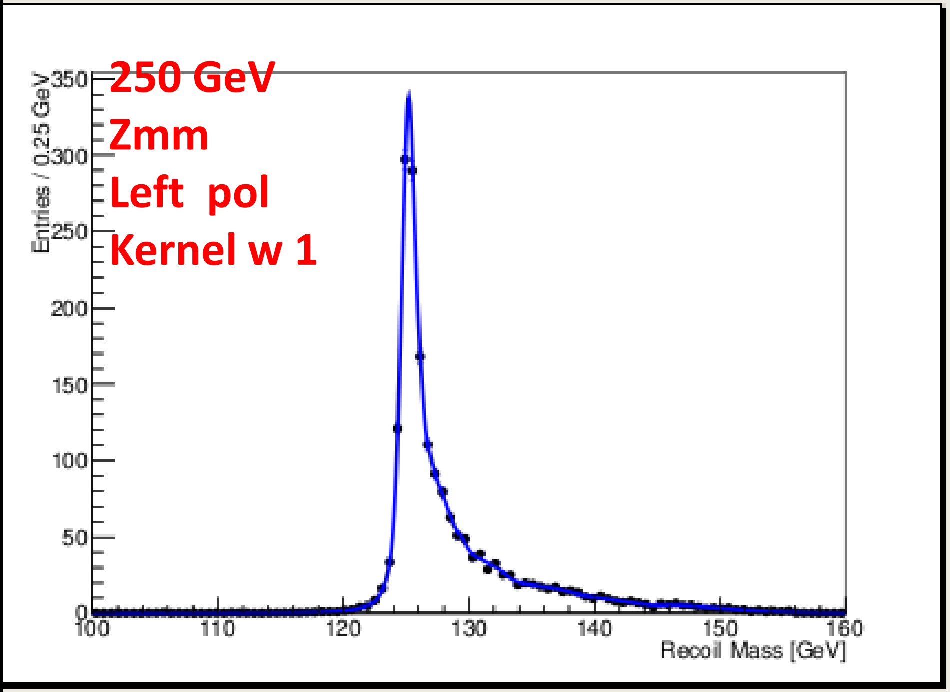
cos(miss) = cosθ of undetected particles

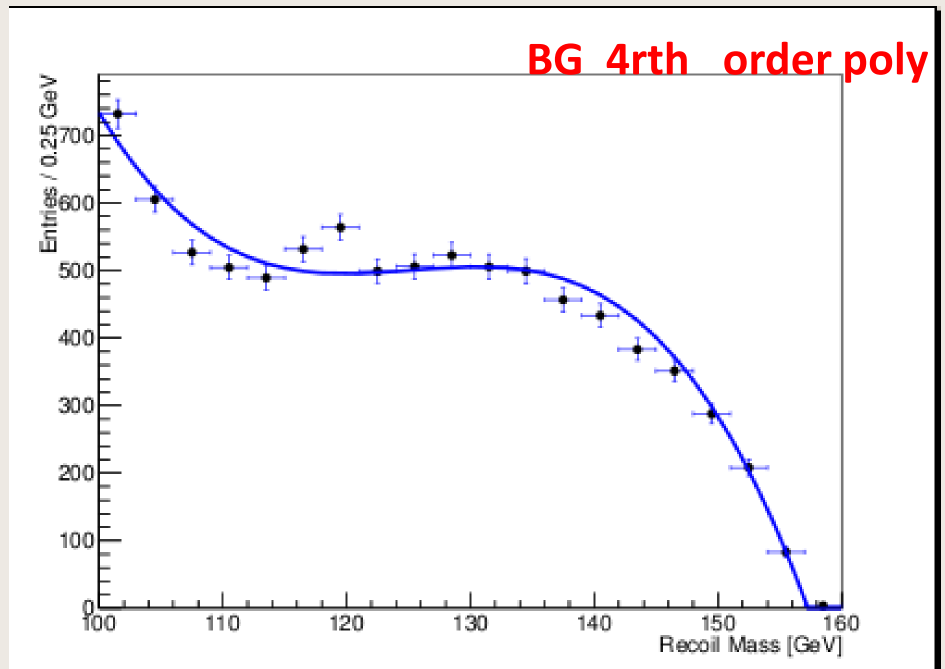
very forward for those events with γ energy is below MC truth

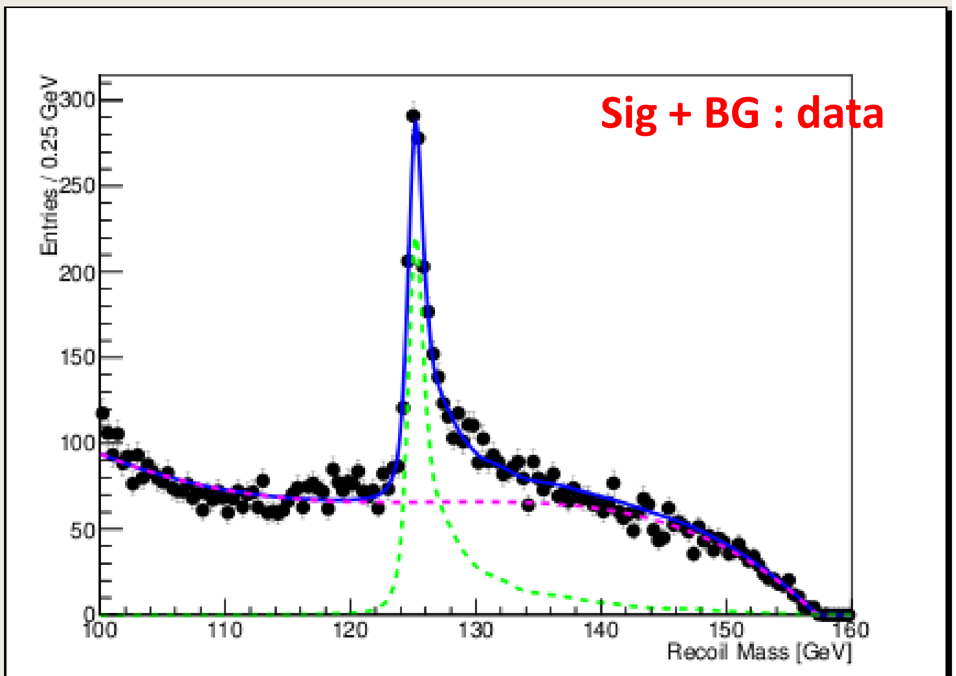


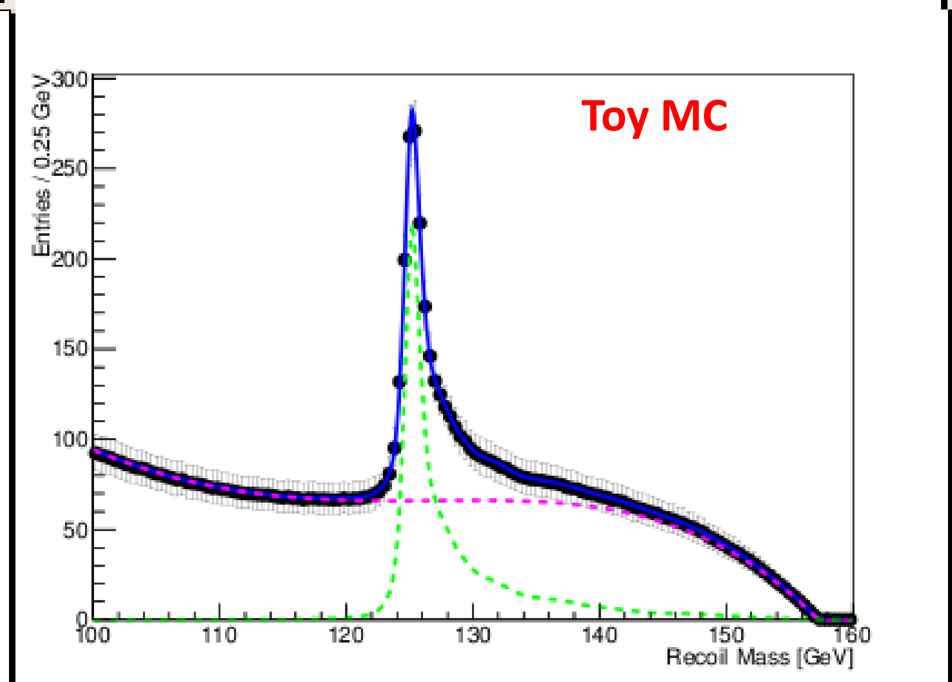
Δeγ (MC – Reco)

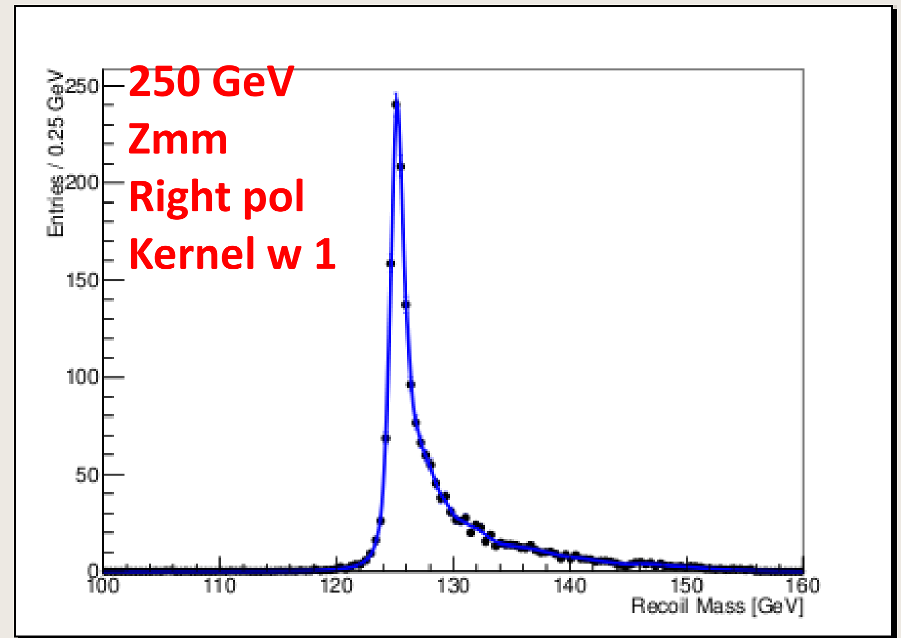
2f_bb

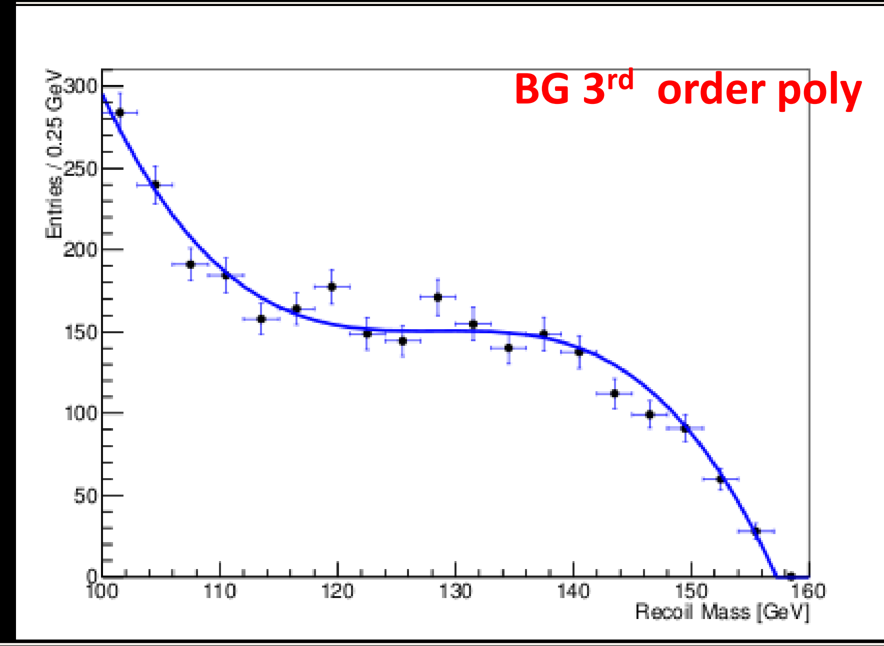

250 GeV
Zmm
Left pol
Kernel w 1
Entries / 0.25 GeV
Recoil Mass [GeV]

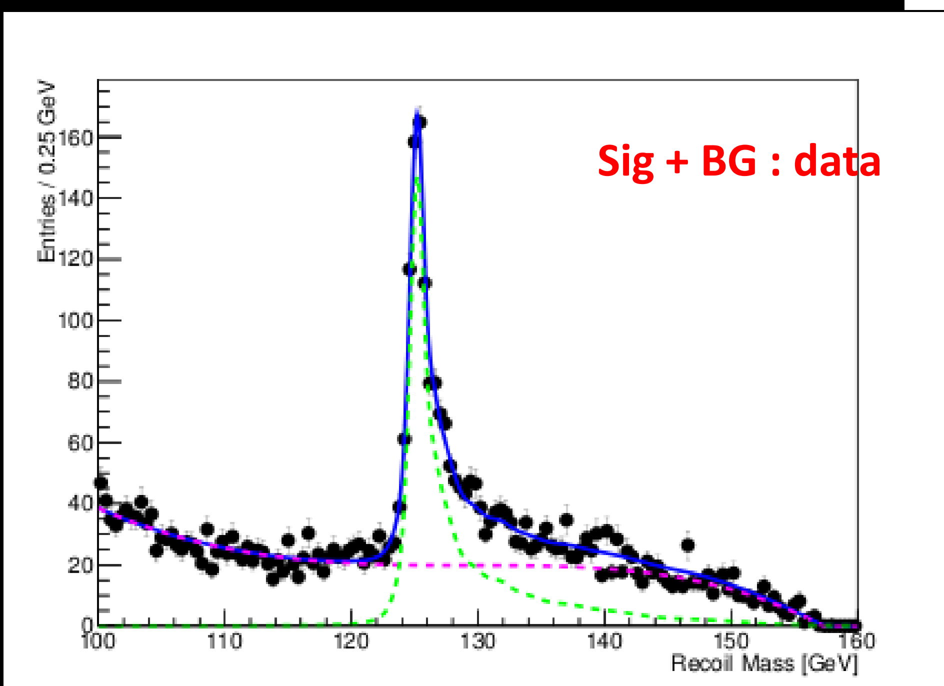

BG 4rth order poly
Entries / 0.25 GeV
Recoil Mass [GeV]

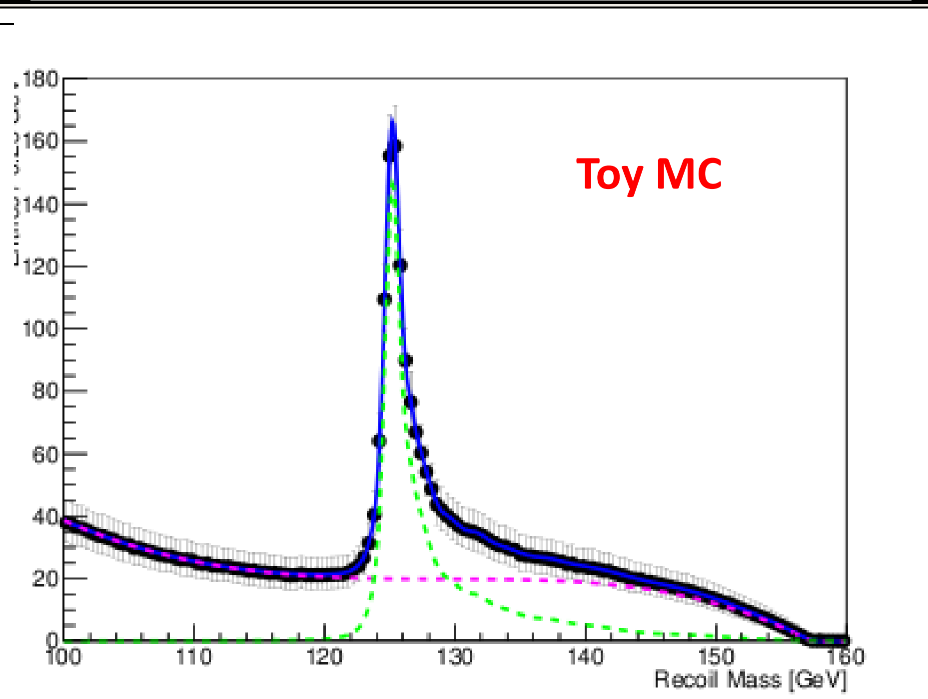

Sig + BG : data
Entries / 0.25 GeV
Recoil Mass [GeV]

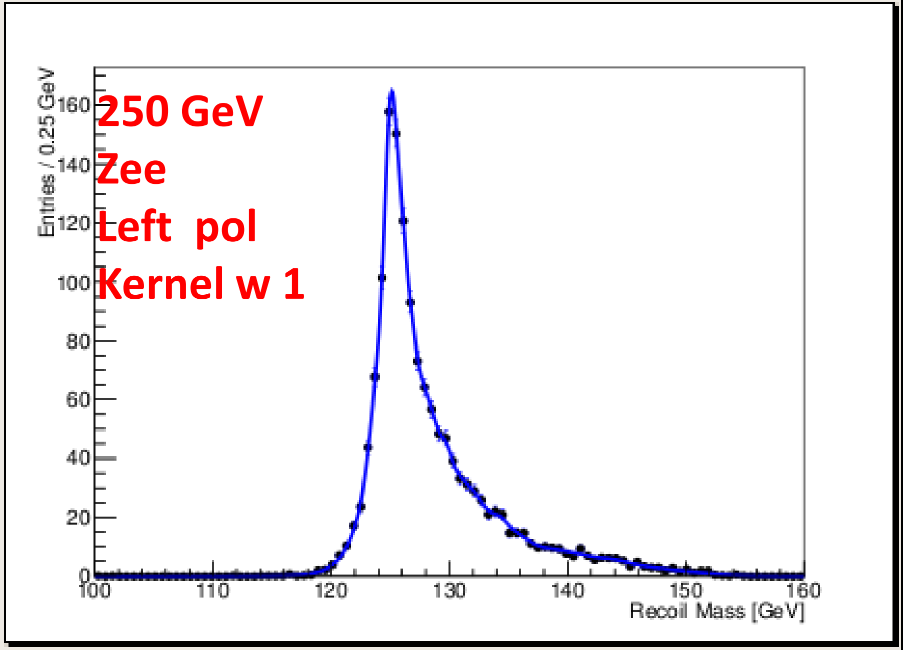

Toy MC
Entries / 0.25 GeV
Recoil Mass [GeV]

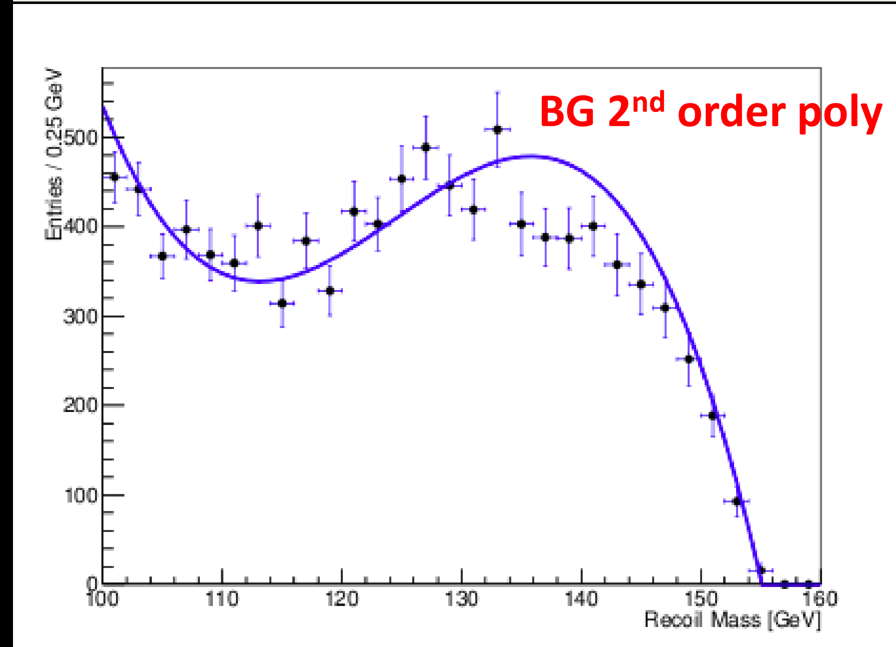

250 GeV
Zmm
Right pol
Kernel w 1
Entries / 0.25 GeV
Recoil Mass [GeV]

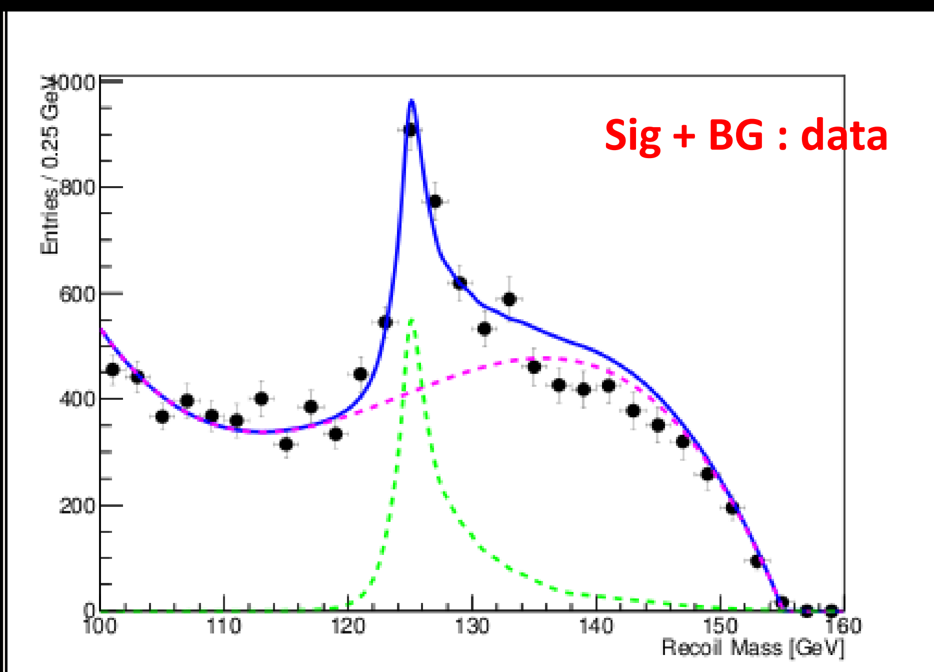

BG 3rd order poly
Entries / 0.25 GeV
Recoil Mass [GeV]

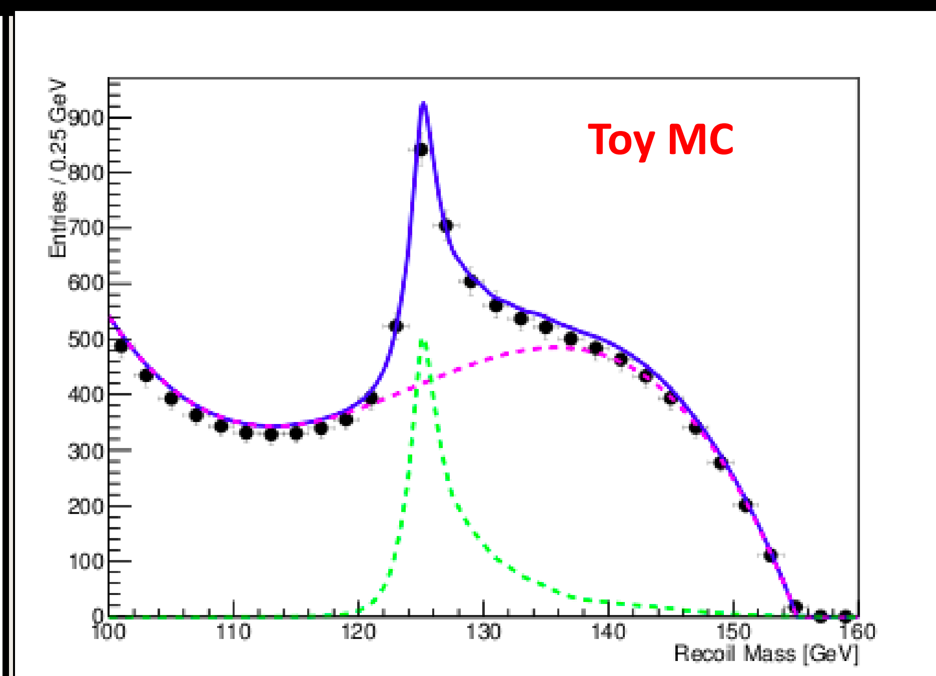

Sig + BG : data
Entries / 0.25 GeV
Recoil Mass [GeV]

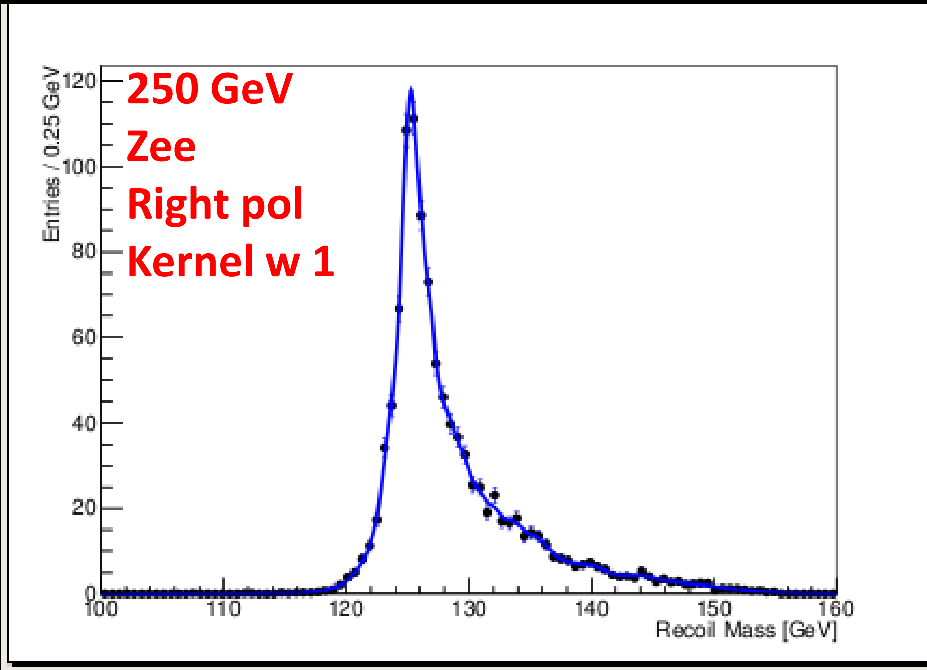

Toy MC
Recoil Mass [GeV]

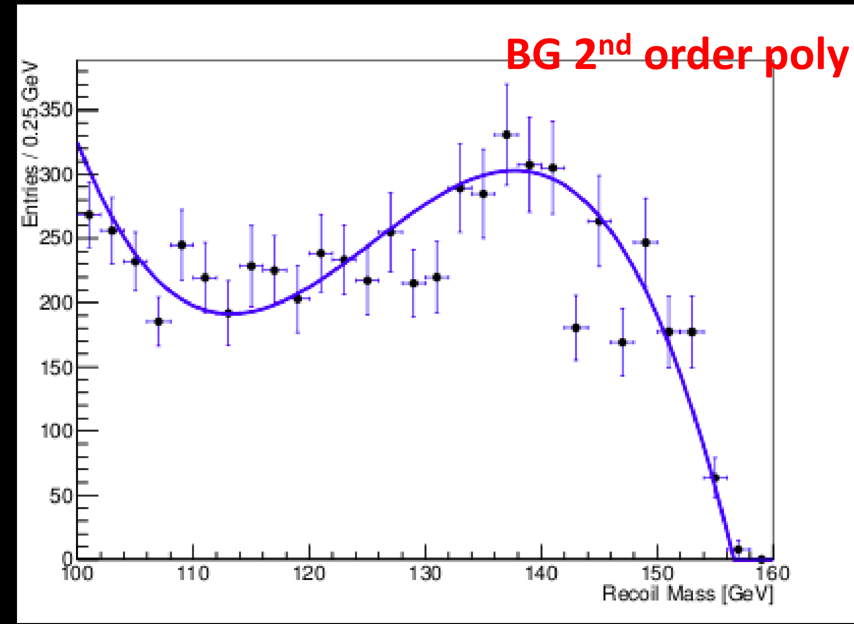

250 GeV
Zee
Left pol
Kernel w 1
Entries / 0.25 GeV
Recoil Mass [GeV]

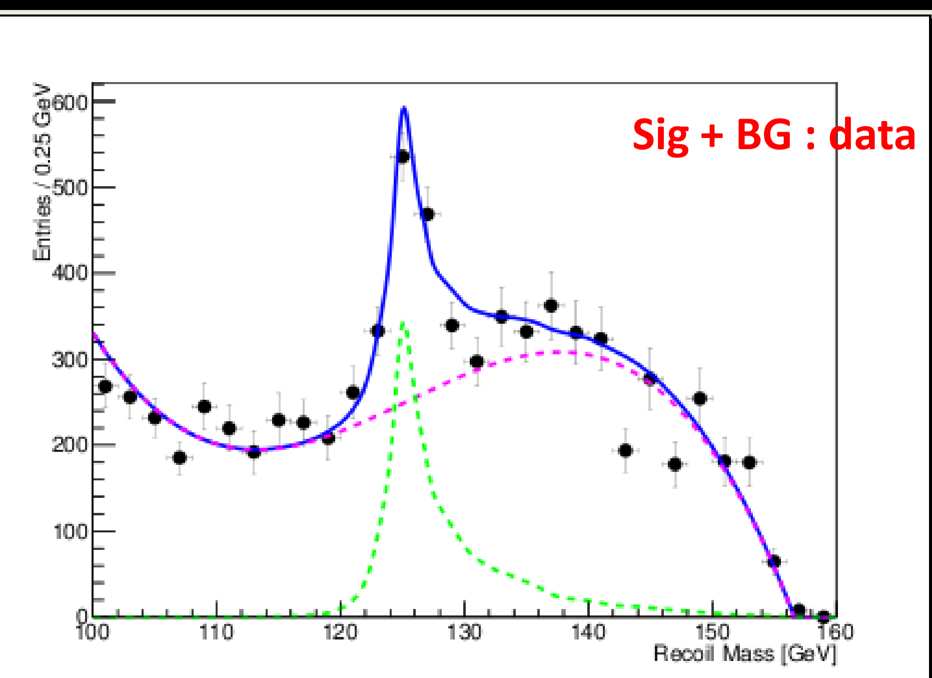

BG 2nd order poly
Entries / 0.25 GeV
Recoil Mass [GeV]

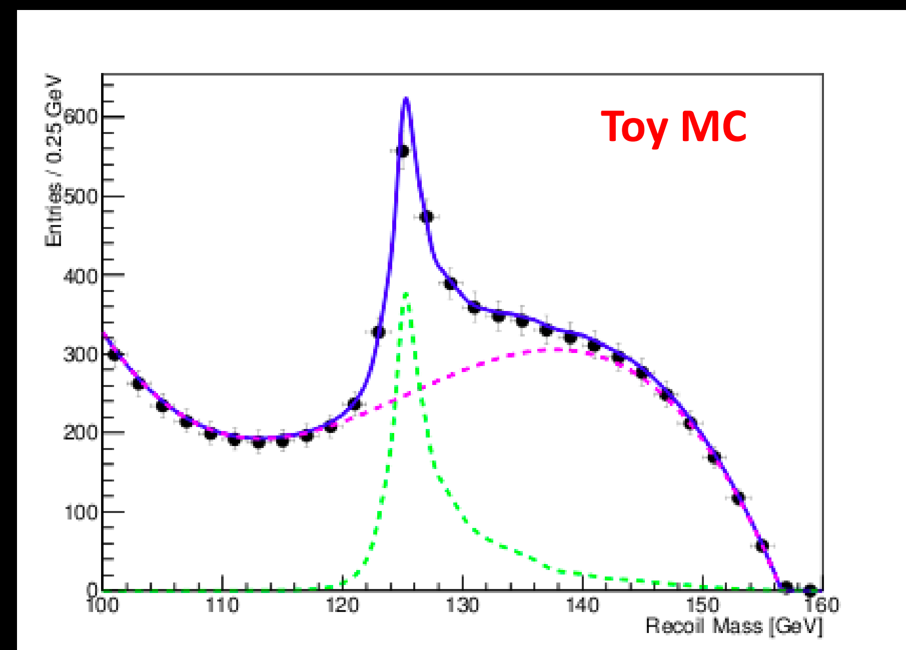

Sig + BG : data
Entries / 0.25 GeV
Recoil Mass [GeV]

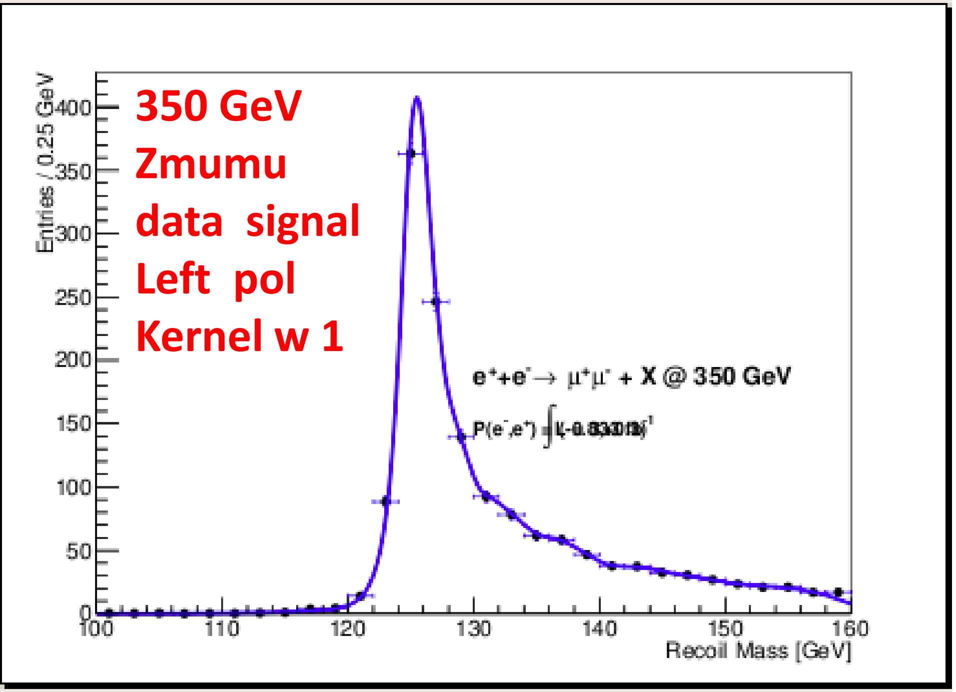

Toy MC
Entries / 0.25 GeV
Recoil Mass [GeV]

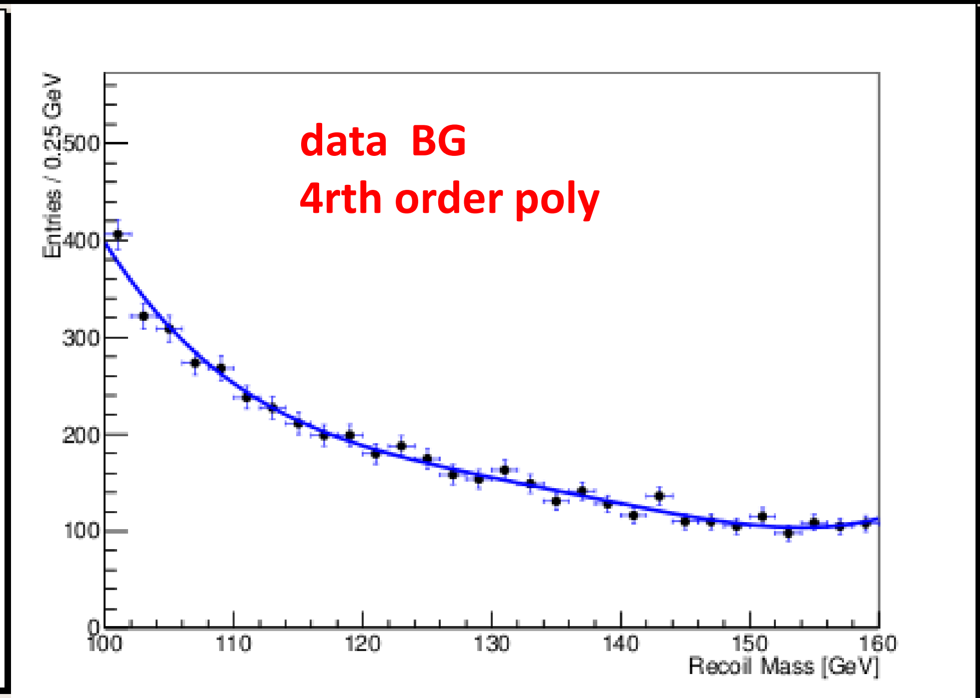

250 GeV
Zee
Right pol
Kernel w 1
Entries / 0.25 GeV
Recoil Mass [GeV]

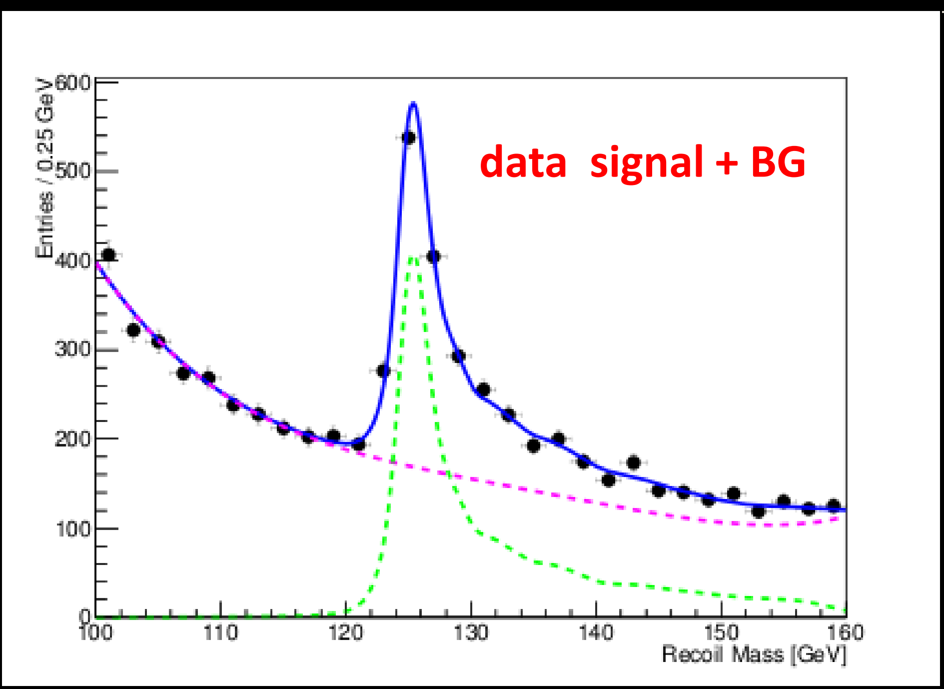

BG 2nd order poly
Entries / 0.25 GeV
Recoil Mass [GeV]

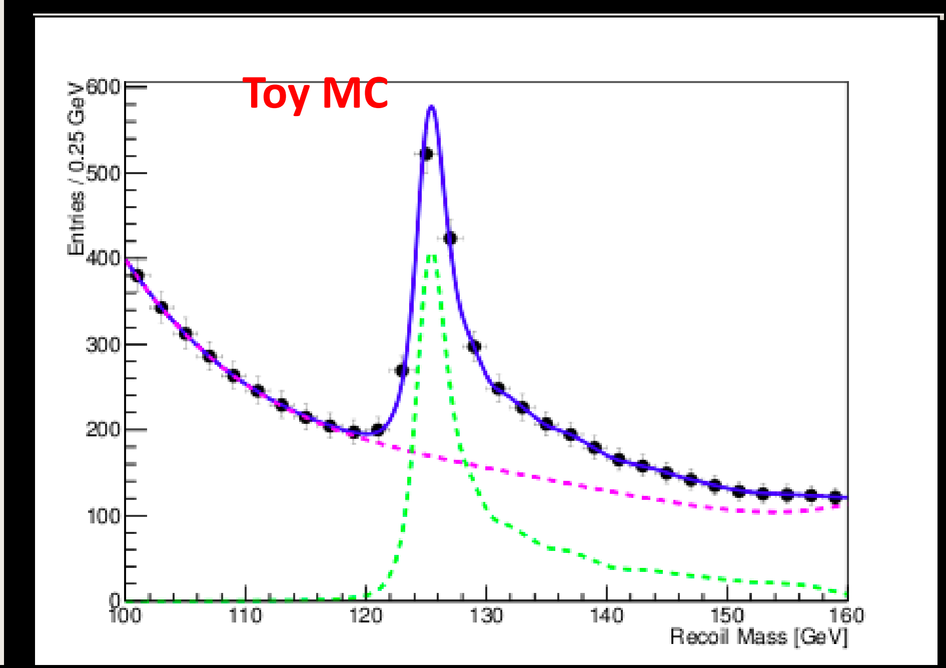

Sig + BG : data
Entries / 0.25 GeV
Recoil Mass [GeV]

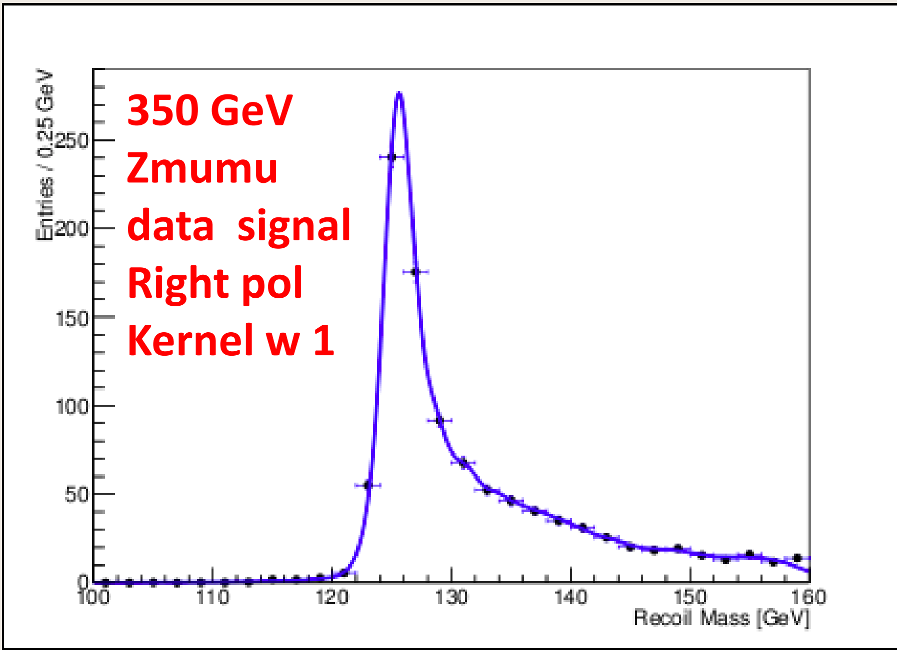

Toy MC
Entries / 0.25 GeV
Recoil Mass [GeV]

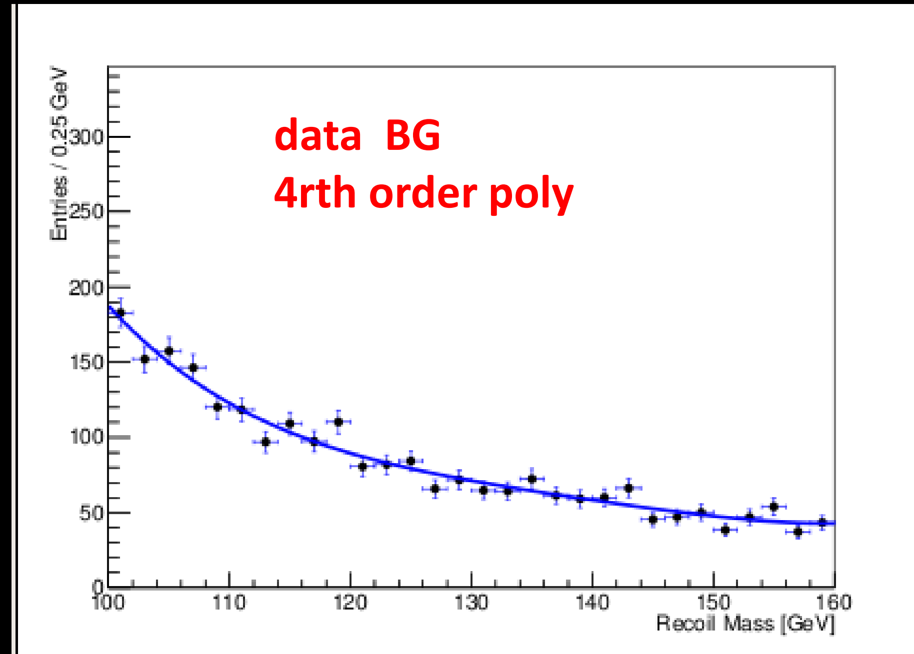

350 GeV
Zmumu
data signal
Left pol
Kernel w 1
e+e- → μ+μ- + X @ 350 GeV
Entries / 0.25 GeV
Recoil Mass [GeV]

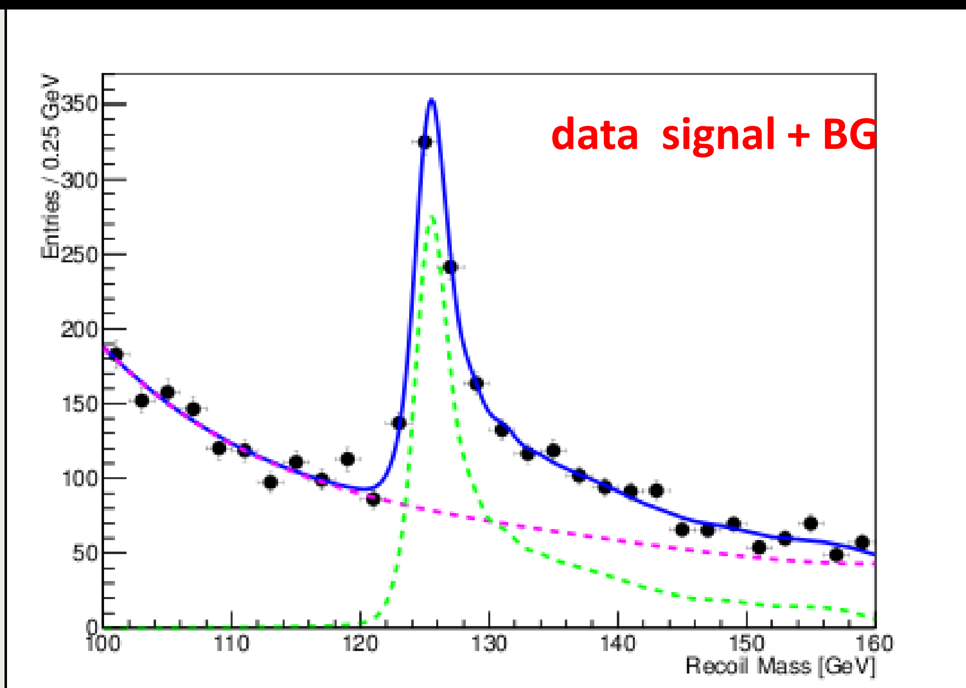

data BG
4rth order poly
Entries / 0.25 GeV
Recoil Mass [GeV]

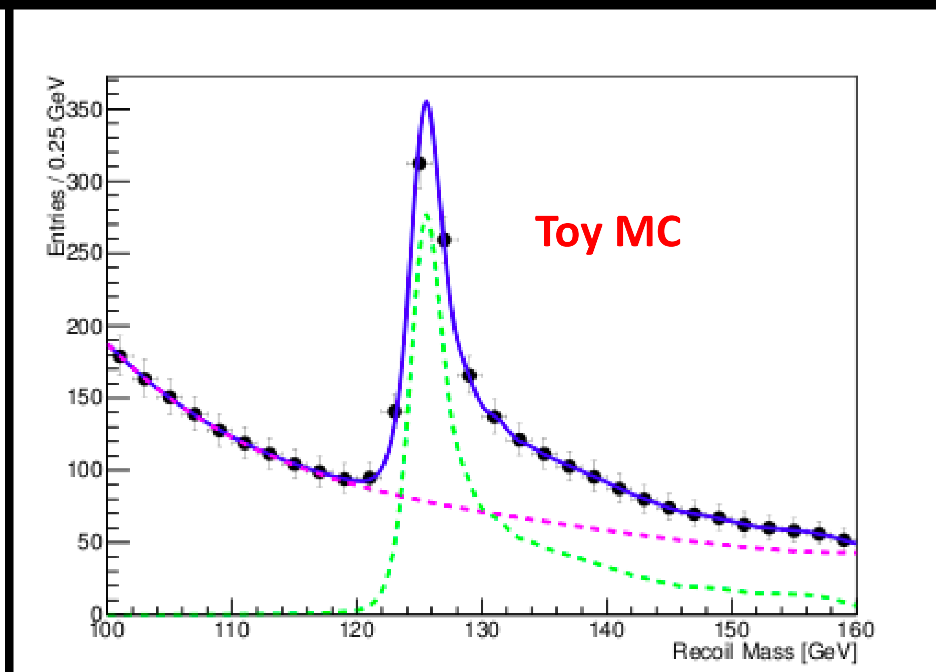

data signal + BG
Entries / 0.25 GeV
Recoil Mass [GeV]

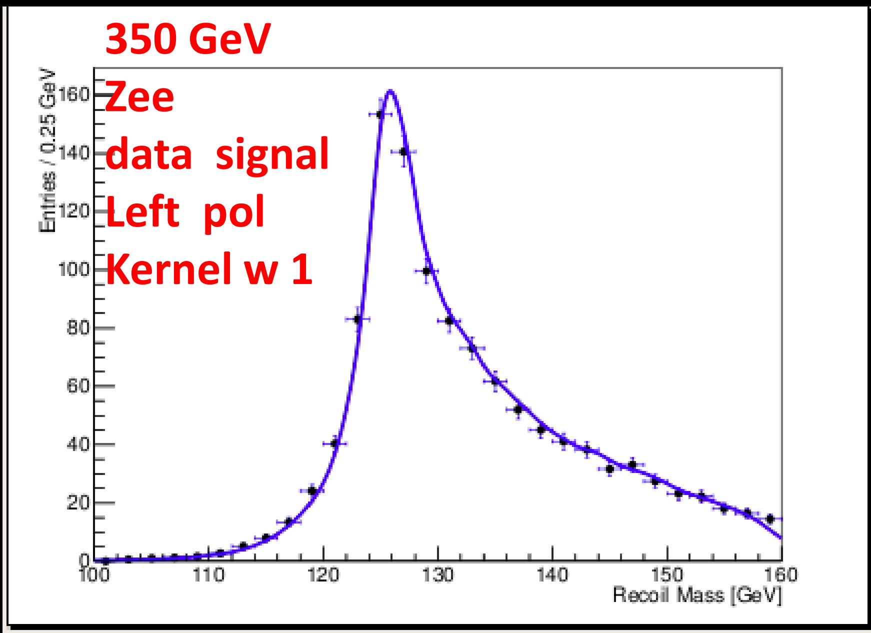

Toy MC
Entries / 0.25 GeV
Recoil Mass [GeV]

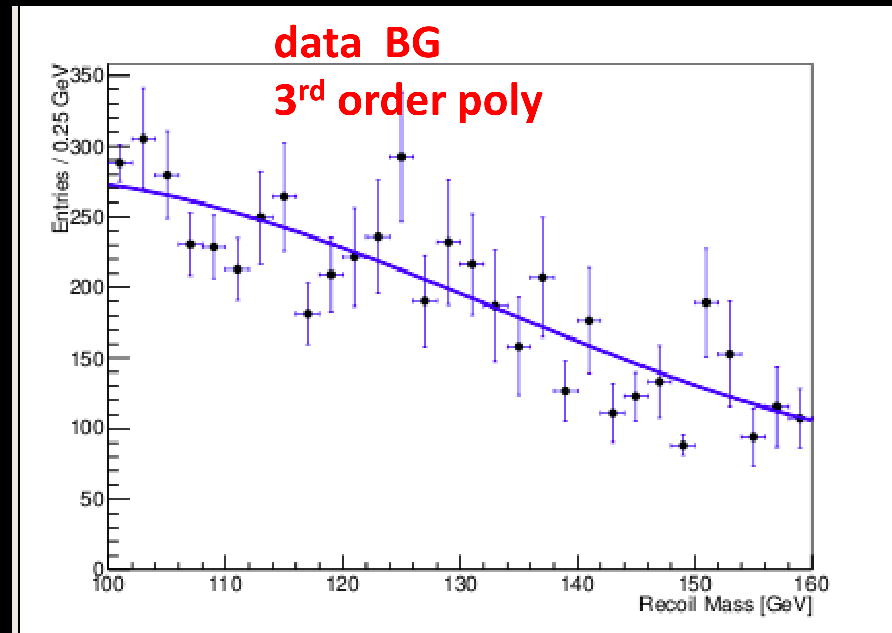

350 GeV
Zmumu
data signal
Right pol
Kernel w 1
Entries / 0.25 GeV
Recoil Mass [GeV]

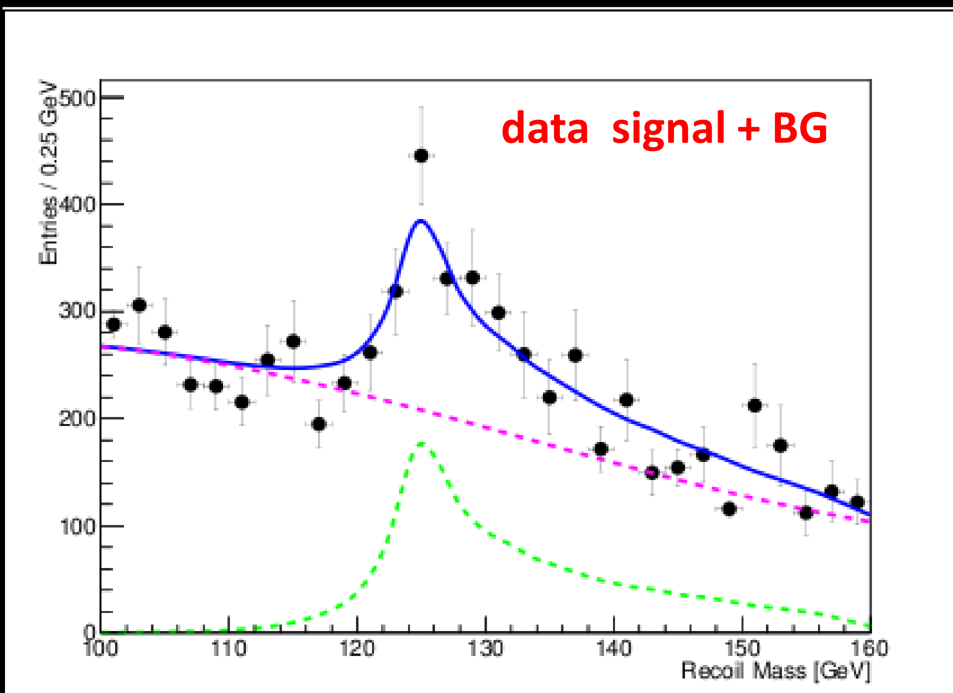

data BG
4rth order poly
Entries / 0.25 GeV
Recoil Mass [GeV]

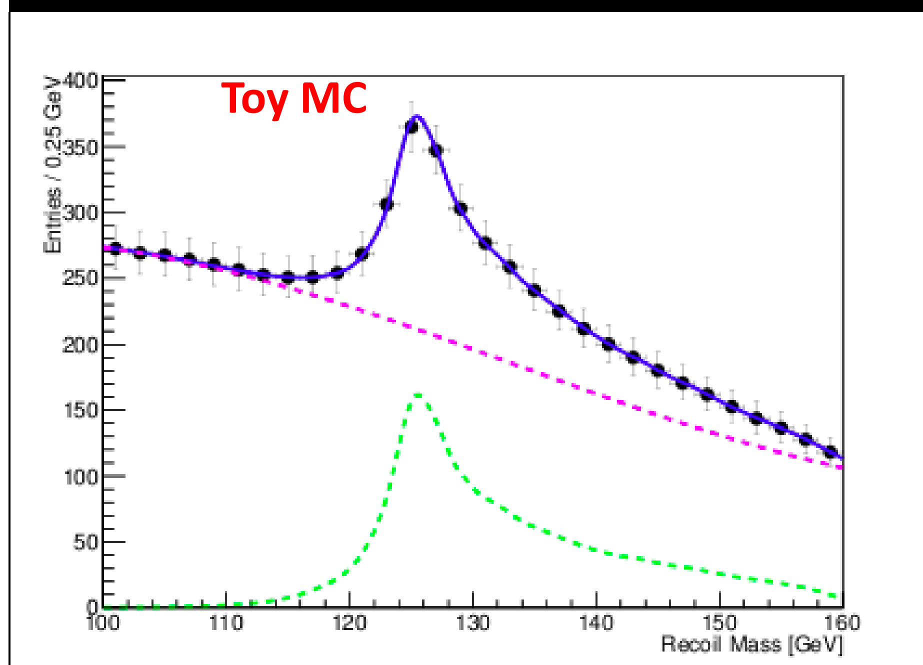

data signal + BG
Entries / 0.25 GeV
Recoil Mass [GeV]

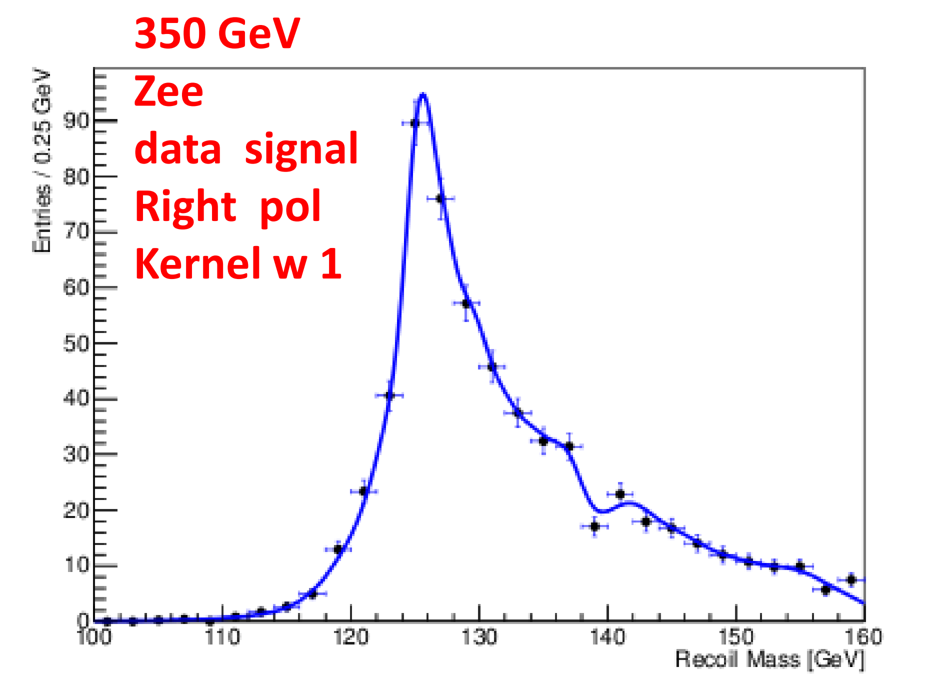

Toy MC
Entries / 0.25 GeV
Recoil Mass [GeV]

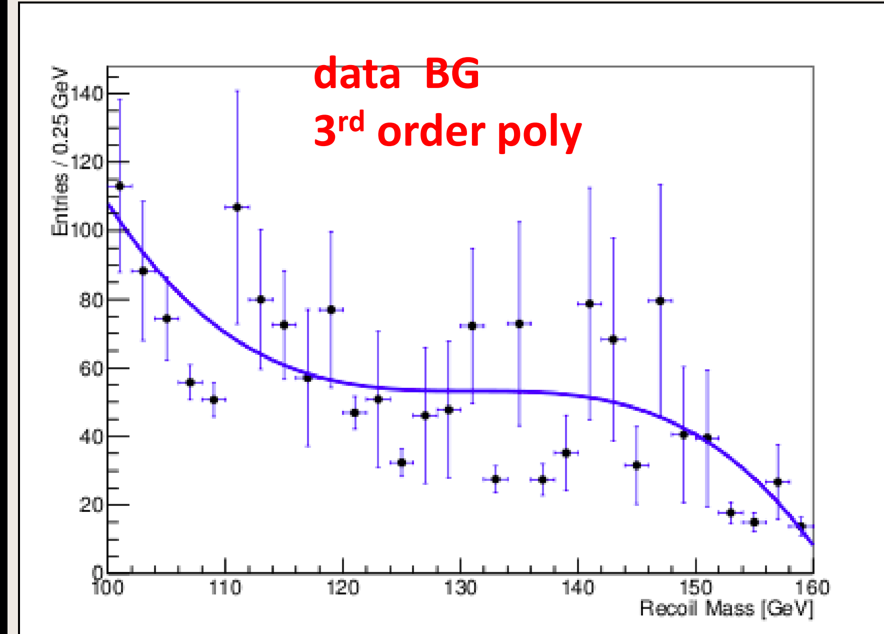

350 GeV
Zee
data signal
Left pol
Kernel w 1
Entries / 0.25 GeV
Recoil Mass [GeV]

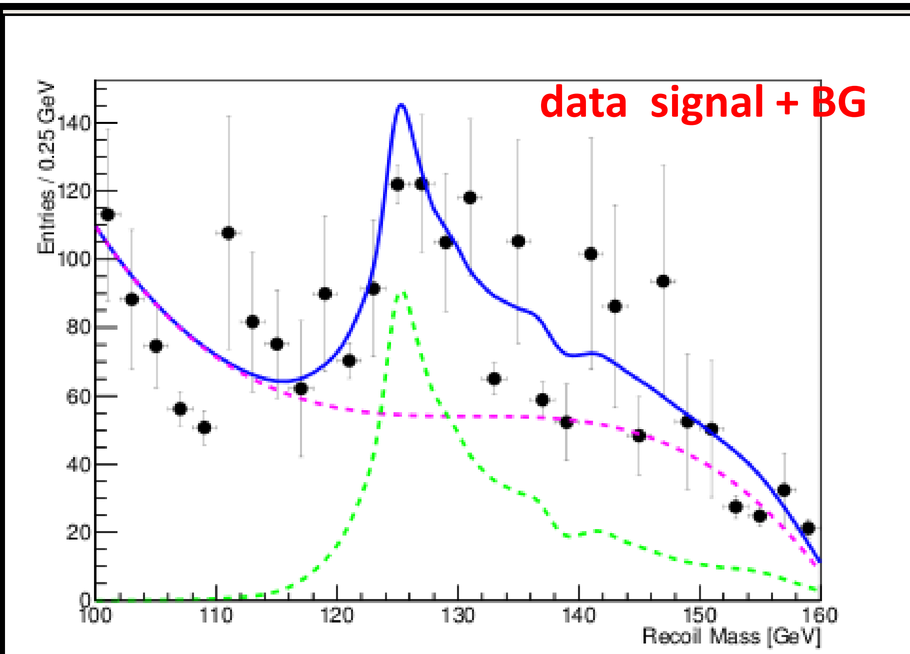

data BG
3rd order poly
Entries / 0.25 GeV
Recoil Mass [GeV]

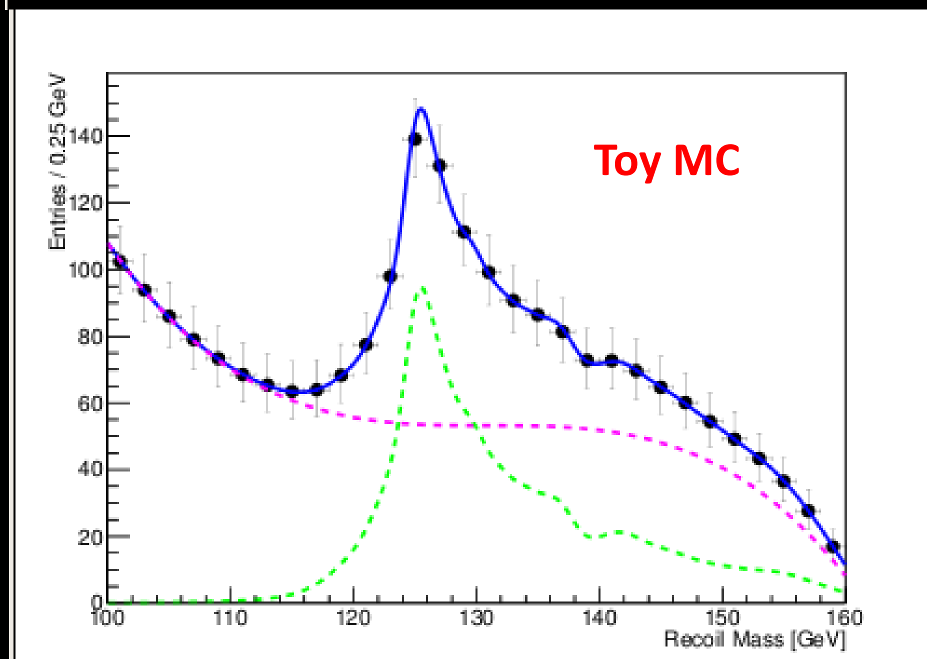

data signal + BG
Entries / 0.25 GeV
Recoil Mass [GeV]

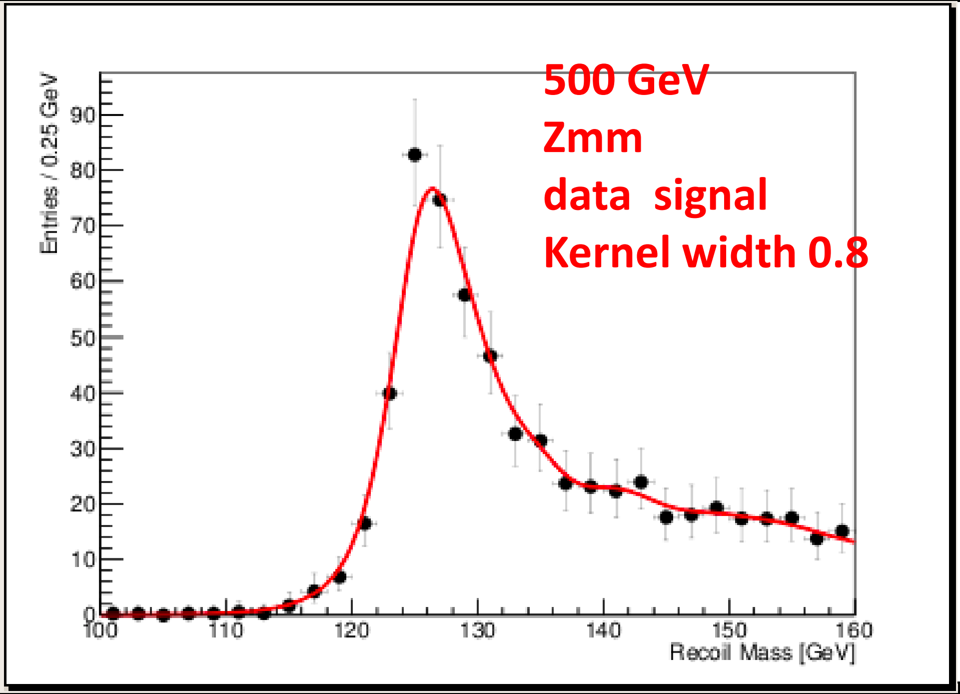

Toy MC
Entries / 0.25 GeV
Recoil Mass [GeV]

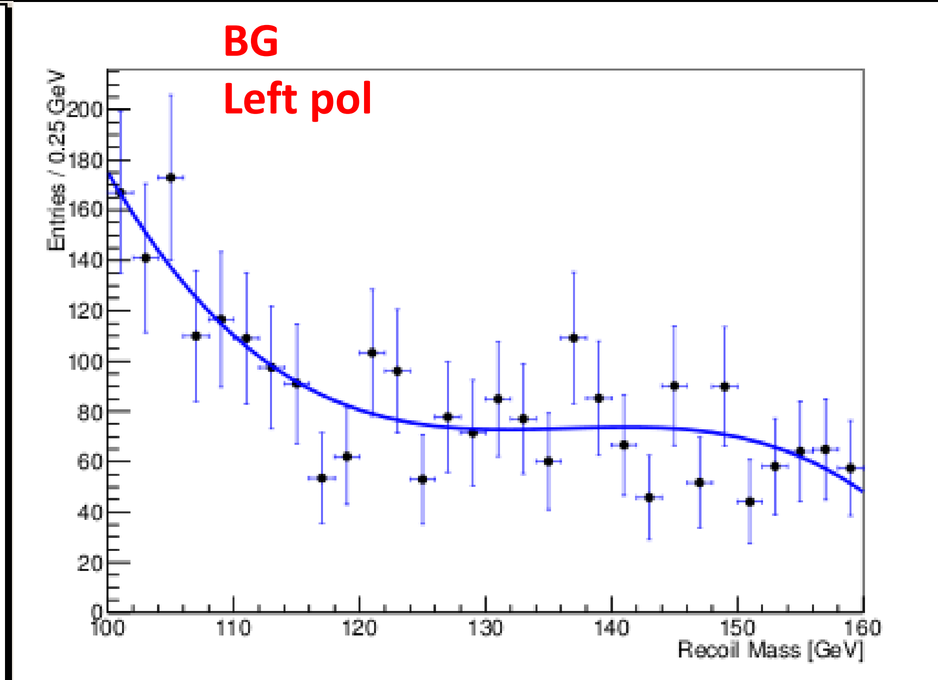

350 GeV
Zee
data signal
Right pol
Kernel w 1
Entries / 0.25 GeV
Recoil Mass [GeV]

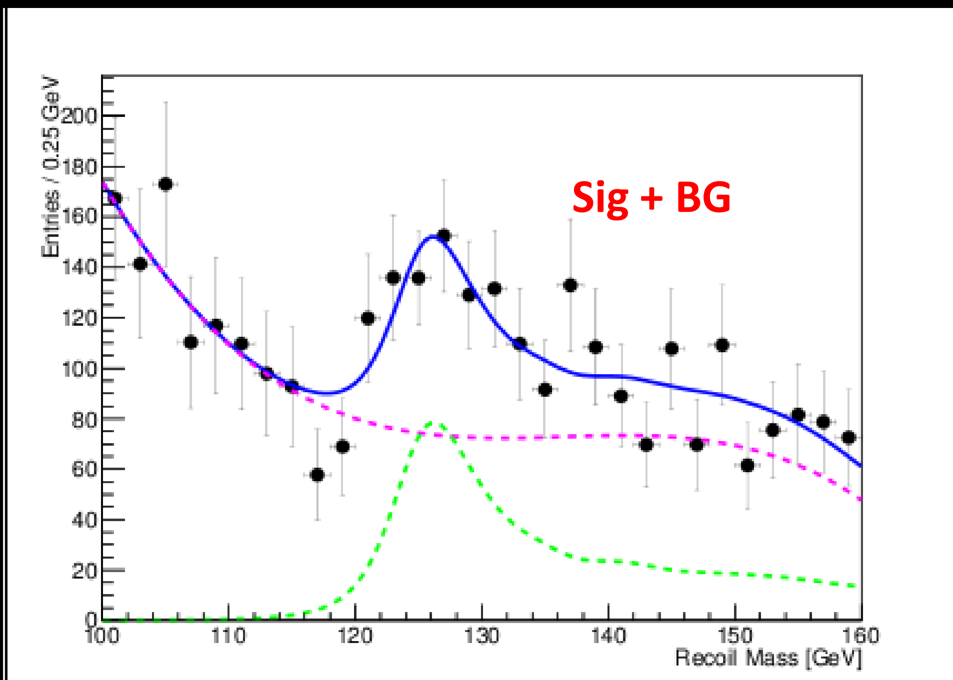

data BG
3rd order poly
Entries / 0.25 GeV
Recoil Mass [GeV]

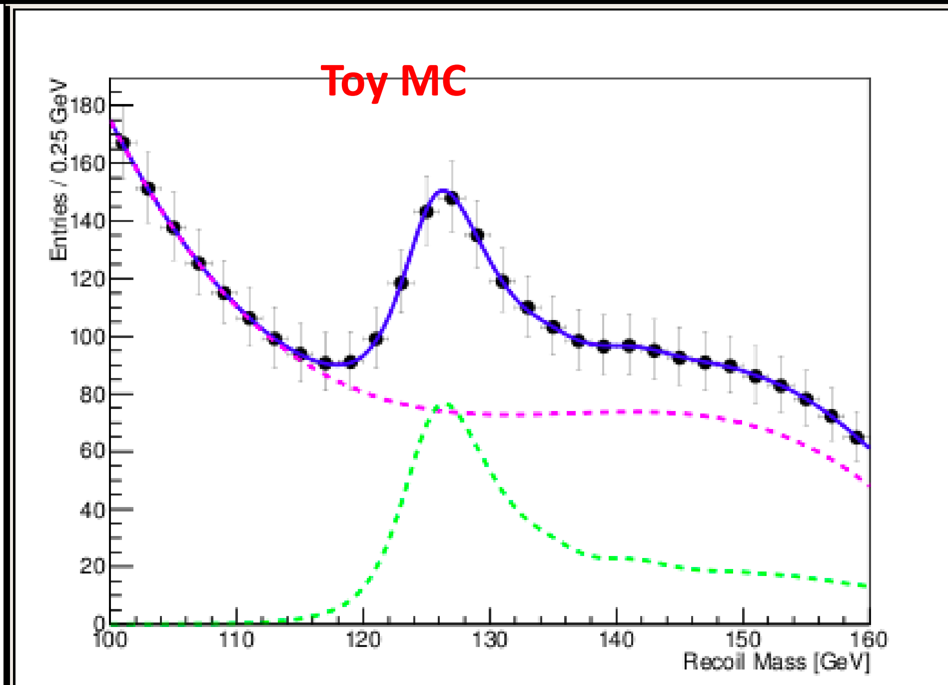

data signal + BG
Entries / 0.25 GeV
Recoil Mass [GeV]

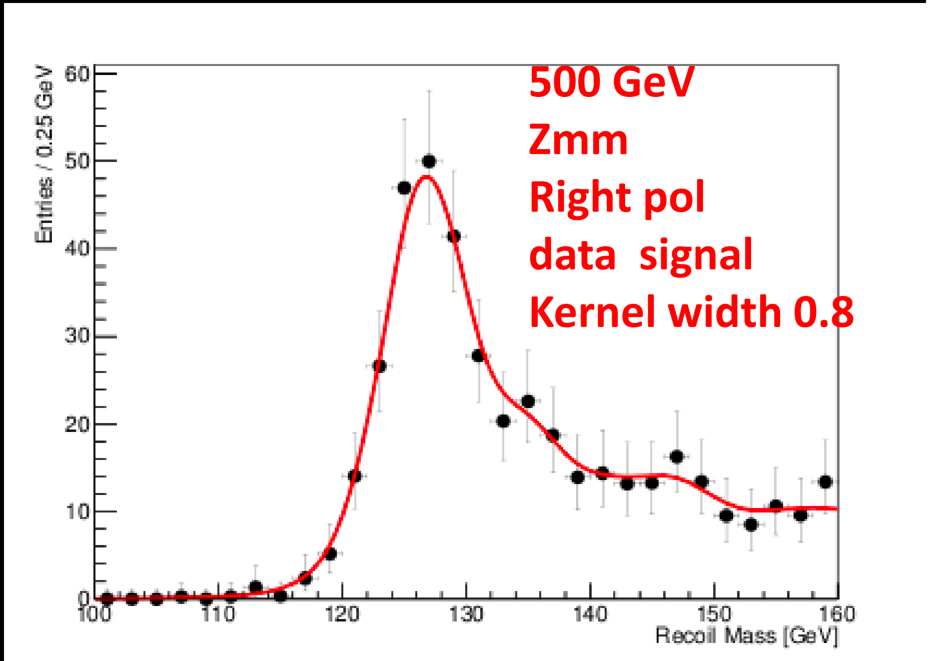

Toy MC
Entries / 0.25 GeV
Recoil Mass [GeV]

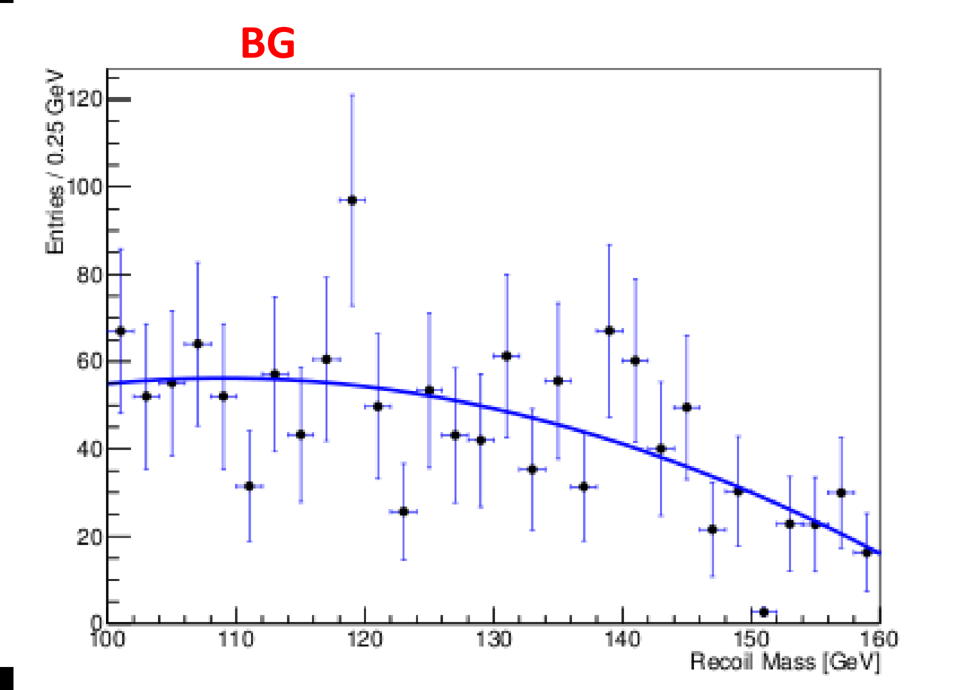

500 GeV
Zmm
data signal
Kernel width 0.8
Entries / 0.25 GeV
Recoil Mass [GeV]

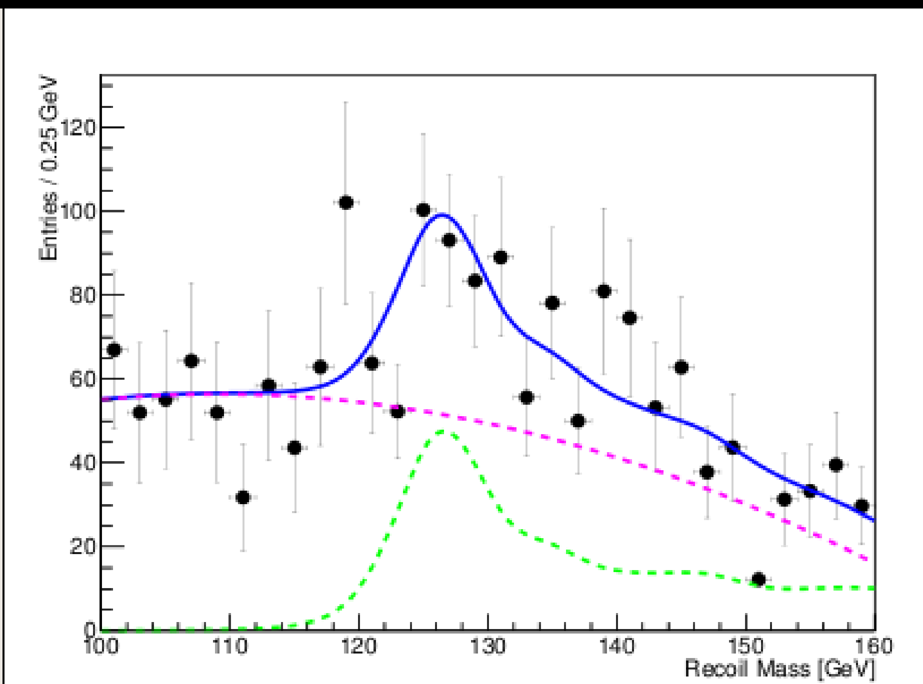

BG
Left pol
Entries / 0.25 GeV
Recoil Mass [GeV]

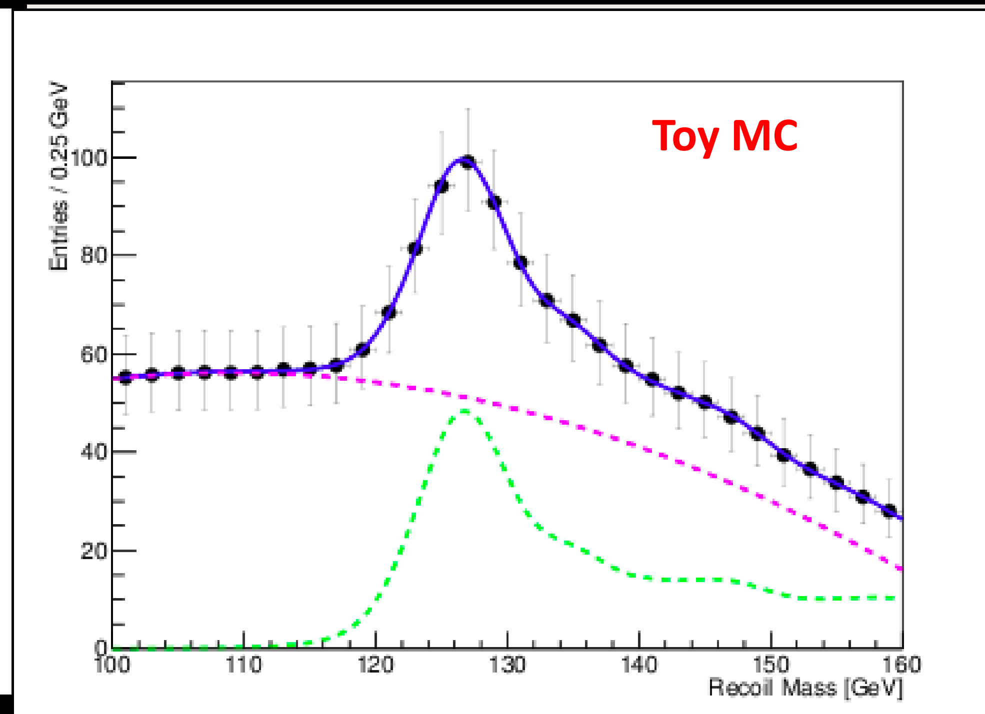

Sig + BG
Entries / 0.25 GeV
Recoil Mass [GeV]

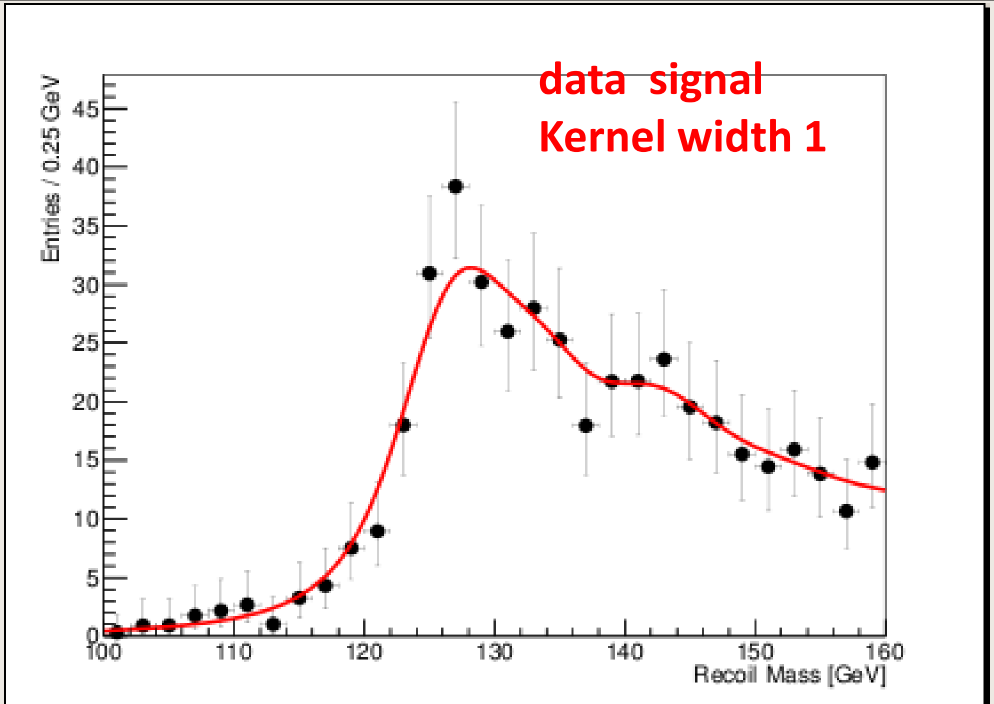

Toy MC
Entries / 0.25 GeV
Recoil Mass [GeV]

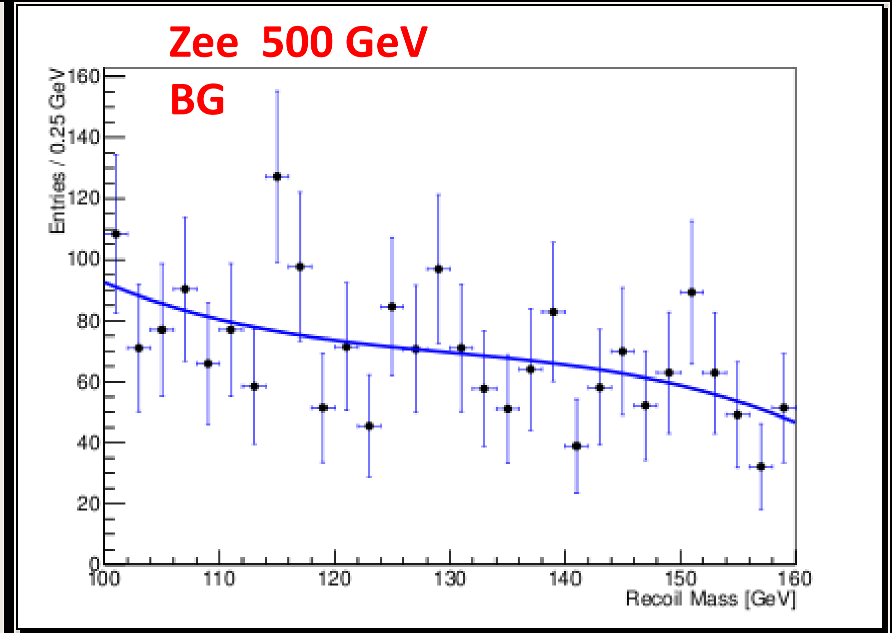

500 GeV
Zmm
Right pol
data signal
Kernel width 0.8
Entries / 0.25 GeV
Recoil Mass [GeV]
0
10
20
30
40
50
60
100
110
120
130
140
150
160

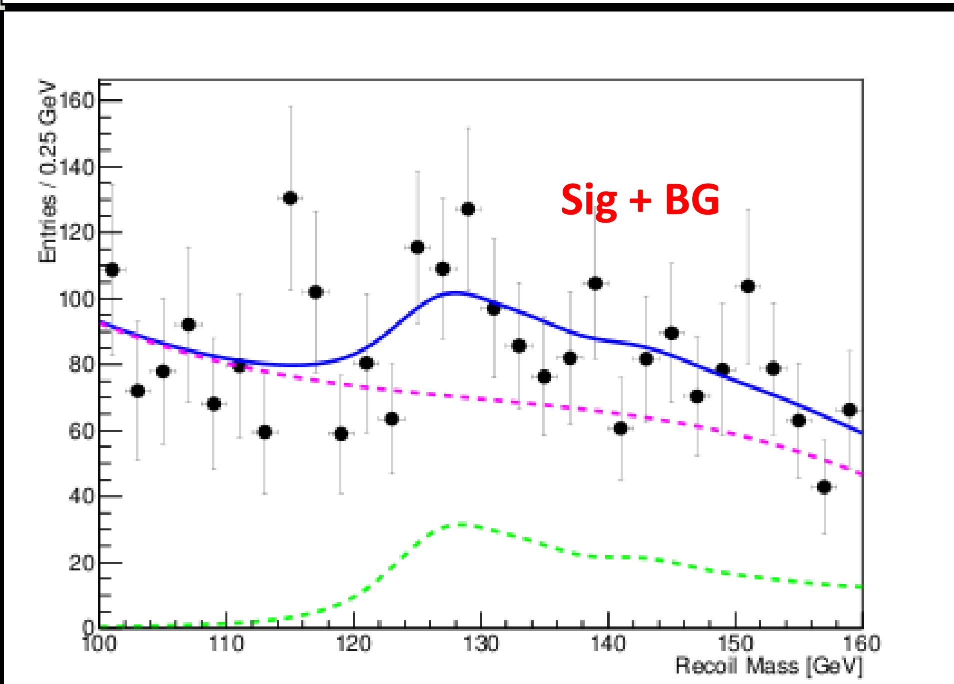

BG
Entries / 0.25 GeV
Recoil Mass [GeV]
0
20
40
60
80
100
120
100
110
120
130
140
150
160

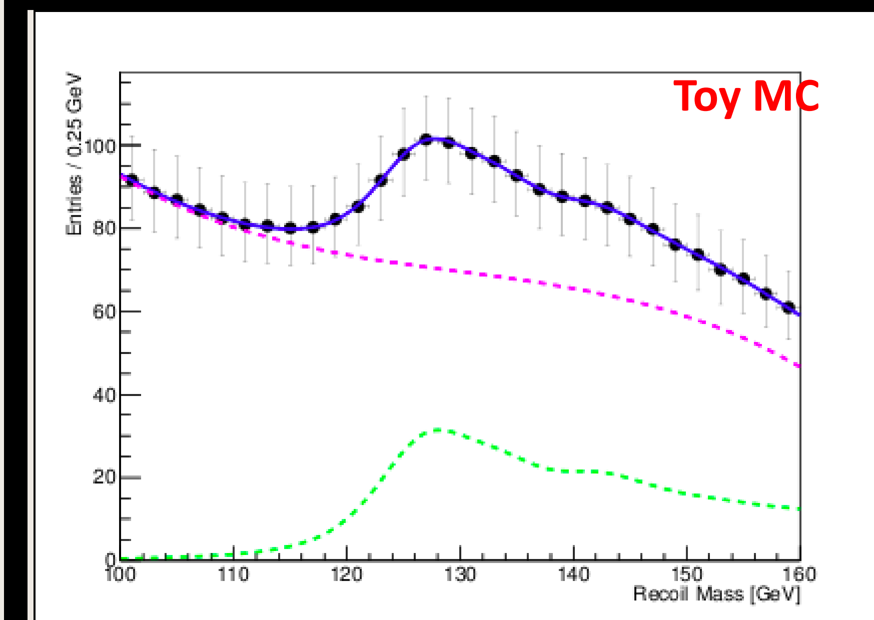

Entries / 0.25 GeV
Recoil Mass [GeV]
0
20
40
60
80
100
120
100
110
120
130
140
150
160

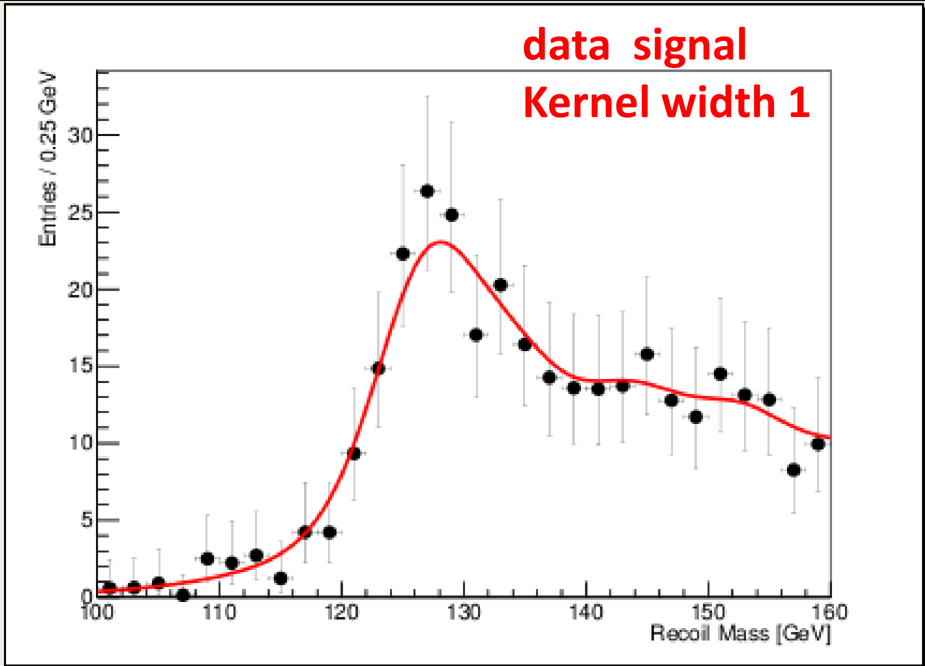

Toy MC
Entries / 0.25 GeV
Recoil Mass [GeV]
0
20
40
60
80
100
100
110
120
130
140
150
160

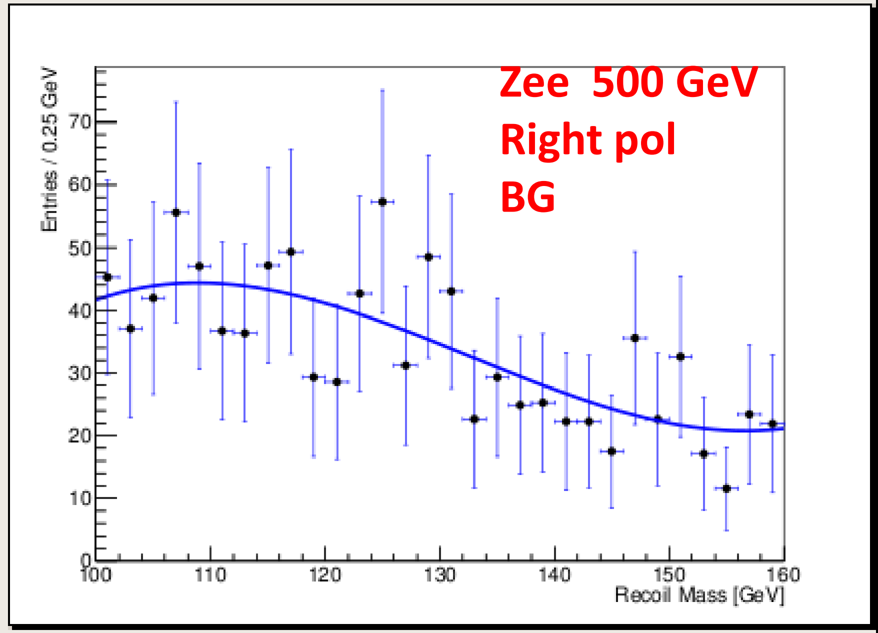

data signal
Kernel width 1
Entries / 0.25 GeV
Recoil Mass [GeV]
0
5
10
15
20
25
30
35
40
45
100
110
120
130
140
150
160

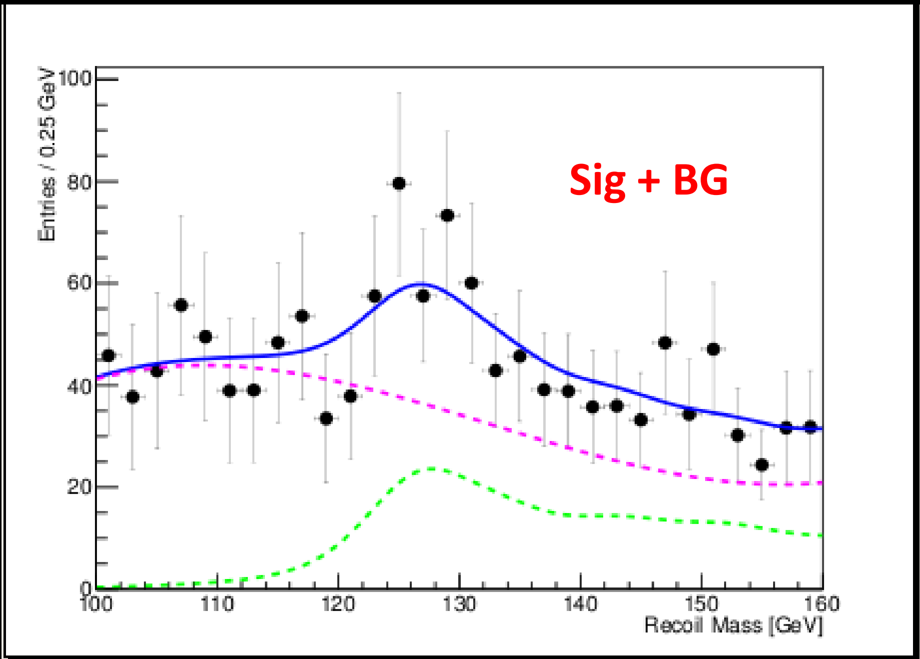

Zee 500 GeV
BG
Entries / 0.25 GeV
Recoil Mass [GeV]
0
20
40
60
80
100
120
140
160
100
110
120
130
140
150
160

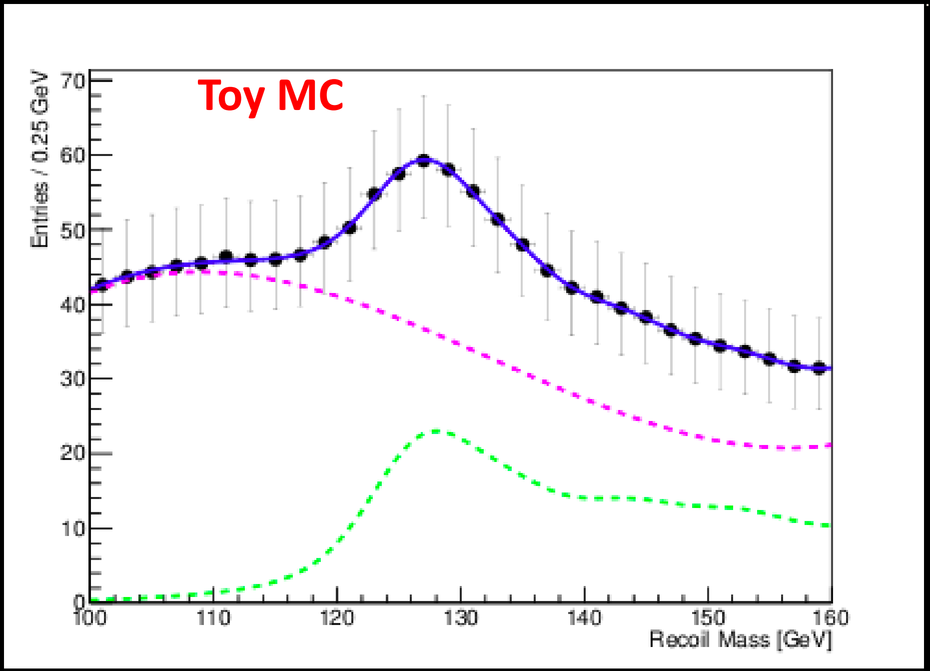

Sig + BG
Entries / 0.25 GeV
Recoil Mass [GeV]
0
20
40
60
80
100
120
140
160
100
110
120
130
140
150
160


Toy MC
Entries / 0.25 GeV
Recoil Mass [GeV]
0
20
40
60
80
100
100
110
120
130
140
150
160


data signal
Kernel width 1
Entries / 0.25 GeV
Recoil Mass [GeV]


Zee 500 GeV
Right pol
BG
Entries / 0.25 GeV
Recoil Mass [GeV]


Sig + BG
Entries / 0.25 GeV
Recoil Mass [GeV]


Toy MC
Entries / 0.25 GeV
Recoil Mass [GeV]