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

ILC Physics Meeting

Aug 28, 2015

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LAST MEETING

- Improvement due to implementing visible energy cut
- some efforts to suppress Higgs decay mode dependence

THIS WEEK

◆ replaced likelihood cut with TMVA cut (Boosted Decision Tree)

➔ more efficient BG reduction, improvement in precision of xsec and mass

◆ continue study of Higgs decay mode dependence

for all three ECM **250, 350, 500 GeV**

◆ first preliminary draft of Higgs recoil paper

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

Final Selection

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

Example of ECM=350 GeV,

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

- 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

A bug was discovered in the cosθmissing cut (cosθmiss < 0.98)

cosθmissing cut is targeted at removing 2f BG, not much more than leptons and γ

In order to prevent Higgs events (with neutrinos in jets) to be cut away
a safety protection was placed as
only cut if :: "Evis – Elep1-Elep2-Eγ < 10 GeV" && "cosθmiss > 0.98"

This should be "**Evis - Eγ < 10 GeV**"
because the calculated Evis already exclude energy of isolated leptons !!

We were cutting away a lot of Higgs events!! (mainly WW and γγ modes)

After correction, Higgs decay mode bias was greatly reduced !!

However BG (2f BG) rejection also less → precision slightly worse

From here on, will refer to (*) in "**Evis - Eγ < (*) GeV**" **as the "protection limit".**

After correcting **cosθmissing cut** , bias on Higgs decay mode was greatly reduced !!

Mode bias weighed by SM BR

Zmm 250 GeV

old

	eff(final)	dev*BR
bb	82.58%	0.170%
cc	82.59%	0.008%
gg	82.50%	0.018%
tt	82.02%	−0.017%
ww	81.98%	−0.066%
zz	82.02%	−0.007%
aa	68.38%	−0.032%
	Weighed avg	82.29%

new

	eff(final)	dev*BR
bb	82.99%	0.075%
cc	82.87%	0.000%
gg	82.63%	−0.020%
tt	82.68%	−0.011%
ww	82.96%	0.022%
zz	83.41%	0.015%
aa	80.71%	−0.005%
	Weighed avg	82.86 %

- efficiency of H→ γ γ rise by ～ 12% (68.4% →80.7%)
- efficiency of other modes rise by 0.5 – 1%
- Important ! : WW, ZZ no longer significantly biased (despite "mistaken lepton pairing)

	BR
bb	57.8%
cc	2.7%
gg	8.6%
tt	6.4%
ww	21.6%
zz	2.7%
aa	0.2%

Efficiency values weighed by SM BR

❖ IF assume full knowledge of decay modes and BR : syst error is (max) 0.075%

❖ IF assume "no exotic decay, but no knpwledge of BR", syst error is 3.2 % (0.94% excluding H-->γ γ)

$\sigma = N/L/\varepsilon$ :: $\Delta\sigma/\sigma = \Delta\varepsilon/\varepsilon$

What about the possibility of unknown exotic decay modes ?➔ see next page

What about the possibility of unknown exotic decay modes ?

- So far, we have explored a wide kinematic range (the 7 known modes)
- **any exotic decay modes should resemble one of these modes**
- **Strategy: assign 10% of "unknown mode" to one of the known SM modes**
- **for the remaining part, we can make use of SM BR information**

Signature	Syst err
$\gamma\gamma$-like	0.20%
gg-like	0.18%
bb-like	0.07%
WW-like	0.06%

- some residual bias on $\gamma\gamma$ mode from Ptsum cut
- gg mode suffers from lower lepton finder efficiency (jets are widely spread)
- "mistaken lepton pairing" may not be that serious ?

From LHC data, it is unrealistic to expect large $\gamma\gamma$ BR ?

Pushing all 10% (big ratio !) of an unknown decay mode to a certain signature is a very pessimistic (conservative) assumption

Now we are getting close to ensuring leptonic recoil is mode independent !

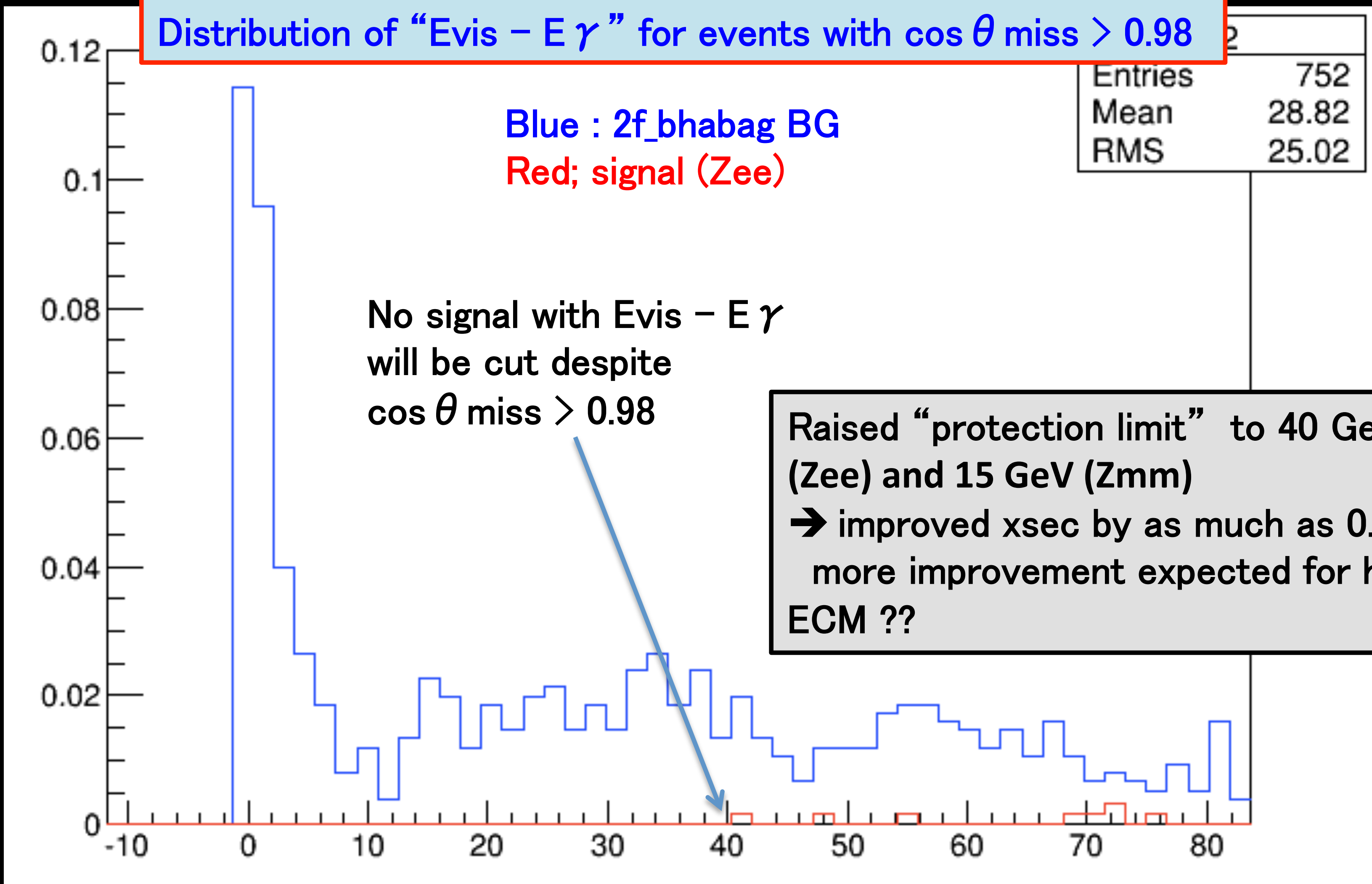
In addition, also checked efficiency consistency within two sigmas between L and R polarizations (only ZZ* mode slightly out of bounds, due to angular distr.)

try to improve efficiency of cos θ miss cut

Find "protection" which yields best signal–BG separation

observe distribution of Evis – E γ for 2f_BG and signal

Distribution of "Evis – E γ" for events with cos θ miss > 0.98



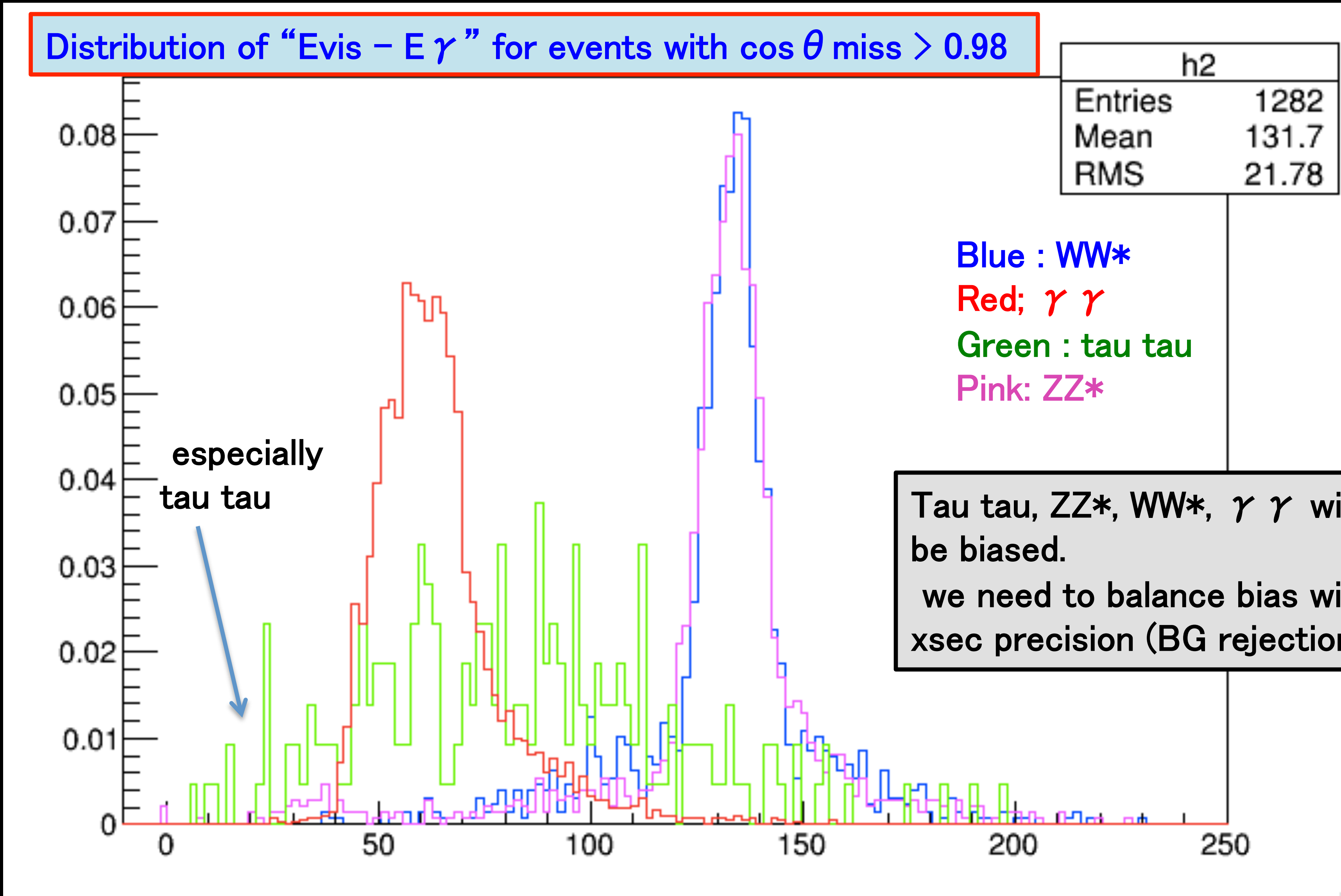
Raised "protection limit" to 40 GeV (Zee) and 15 GeV (Zmm)

➔ improved xsec by as much as 0.2%

more improvement expected for higher ECM ??

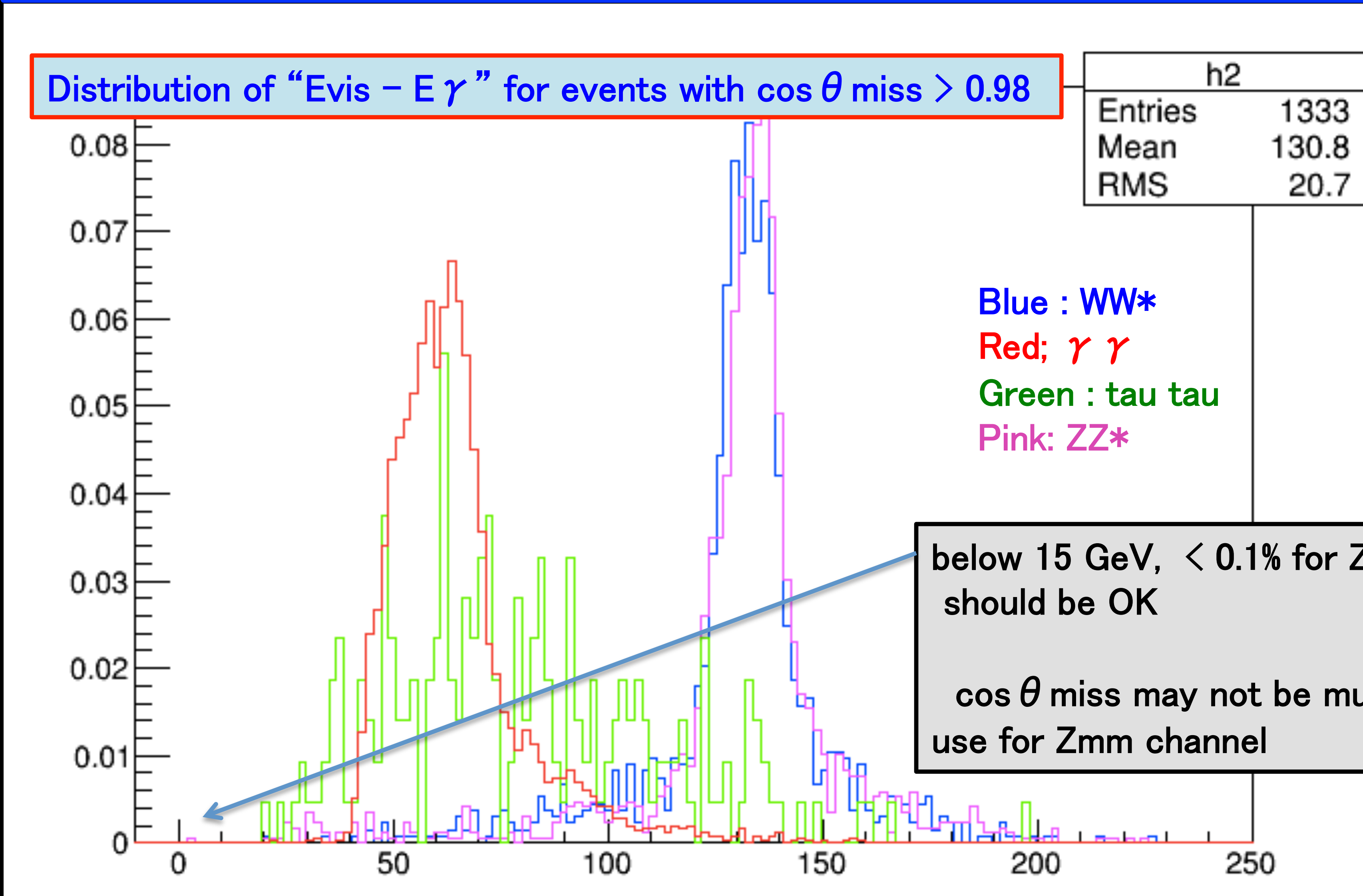
try to improve efficiency of cos θ miss cut

observe distribution of Evis − Eγ signal modes (Zee) using high statis sample



try to improve efficiency of cos θ miss cut

observe distribution of Evis − E γ signal modes (Zmm) using high statis sample



Even if we move protection limit upwards (20 GeV for Zmm, 40 GeV for Zee) mode decay bias is not affected much

- Any reduction in efficiency is below MC stat uncertainty for almost all modes
- final efficiency (after all cuts) not affected
- we can confidently move the limit up after checking mode bias

Cut6 is cosθmiss

Zmm

E	bb	cc	gg	tt	ww	zz	aa
Cut0 :	93.7 +/- 0.1	93.68 +/- 0.1	93.4 +/- 0.11	93.89 +/- 0.1	93.62 +/- 0.1	93.86 +/- 0.1	93.7 +/-0.077
Cut1 :	93.7 +/- 0.1	93.68 +/- 0.1	93.4 +/- 0.11	93.89 +/- 0.1	93.62 +/- 0.1	93.86 +/- 0.1	93.7 +/-0.077
Cut2 :	92.12 +/- 0.11	92.06 +/- 0.12	91.76 +/- 0.12	92.17 +/- 0.11	91.95 +/- 0.11	92.28 +/- 0.11	91.24 +/-0.089
Cut3 :	90.09 +/- 0.12	90.2 +/- 0.13	89.84 +/- 0.13	90.21 +/- 0.12	90.05 +/- 0.12	90.45 +/- 0.12	89.38 +/-0.095
Cut4 :	89.88 +/- 0.13	90.01 +/- 0.13	89.64 +/- 0.13	90.01 +/- 0.12	89.84 +/- 0.12	90.24 +/- 0.12	89.21 +/-0.096
Cut5 :	89.83 +/- 0.13	89.94 +/- 0.13	89.57 +/- 0.13	89.54 +/- 0.13	89.74 +/- 0.13	90.13 +/- 0.12	87.38 +/- 0.1
Cut6 :	89.83 +/- 0.13	89.94 +/- 0.13	89.57 +/- 0.13	89.54 +/- 0.13	89.74 +/- 0.13	90.12 +/- 0.12	87.37 +/- 0.1
Cut7 :	83.16 +/- 0.15	83.03 +/- 0.15	82.8 +/- 0.15	82.88 +/- 0.15	83.14 +/- 0.15	83.56 +/- 0.15	80.89 +/- 0.12
Cut8 :	82.99 +/- 0.15	82.87 +/- 0.15	82.63 +/- 0.15	82.67 +/- 0.15	82.96 +/- 0.15	83.41 +/- 0.15	80.7 +/- 0.12
Cut9 :	82.99 +/- 0.15	82.87 +/- 0.15	82.63 +/- 0.15	82.67 +/- 0.15	82.96 +/- 0.15	83.41 +/- 0.15	80.7 +/- 0.12
Cut10:	75.17 +/- 0.16	74.9 +/- 0.17	74.93 +/- 0.17	75.13 +/- 0.16	75.38 +/- 0.16	76.01 +/- 0.16	73.49 +/- 0.12

Zee

E	bb	cc	gg	tt	ww	zz	aa
C[illegible]	89.08 +/- 0.13	88.89 +/- 0.13	88.5 +/- 0.13	88.99 +/- 0.13	89 +/- 0.13	89.18 +/- 0.13	89.43 +/- 0.09
Cut1 :	89.08 +/- 0.13	88.89 +/- 0.13	88.5 +/- 0.13	88.99 +/- 0.13	89 +/- 0.13	89.18 +/- 0.13	89.43 +/- 0.09
Cut2 :	87.4 +/- 0.14	87.25 +/- 0.14	86.78 +/- 0.14	87.2 +/- 0.14	87.36 +/- 0.14	87.41 +/- 0.14	86.64 +/-0.098
Cut3 :	85.15 +/- 0.14	85.01 +/- 0.14	84.51 +/- 0.14	84.84 +/- 0.14	85.1 +/- 0.14	85.09 +/- 0.14	84.34 +/- 0.1
Cut4 :	85.04 +/- 0.14	84.92 +/- 0.15	84.43 +/- 0.15	84.75 +/- 0.14	84.99 +/- 0.14	84.99 +/- 0.14	84.26 +/- 0.1
Cut5 :	84.99 +/- 0.14	84.84 +/- 0.15	84.36 +/- 0.15	84.29 +/- 0.15	84.89 +/- 0.14	84.88 +/- 0.14	82.54 +/- 0.11
Cut6 :	84.99 +/- 0.14	84.84 +/- 0.15	84.36 +/- 0.15	84.2 +/- 0.15	84.88 +/- 0.14	84.74 +/- 0.14	82.46 +/- 0.11
Cut7 :	78.76 +/- 0.16	78.69 +/- 0.16	78.12 +/- 0.16	78.21 +/- 0.16	78.67 +/- 0.16	78.78 +/- 0.16	76.45 +/- 0.11
Cut8 :	78.56 +/- 0.16	78.44 +/- 0.16	77.84 +/- 0.16	77.97 +/- 0.16	78.43 +/- 0.16	78.52 +/- 0.16	76.19 +/- 0.11
Cut9 :	78.56 +/- 0.16	78.44 +/- 0.16	77.84 +/- 0.16	77.97 +/- 0.16	78.43 +/- 0.16	78.52 +/- 0.16	76.19 +/- 0.11
Cut10:	69.82 +/- 0.17	69.55 +/- 0.17	69.33 +/- 0.17	69.57 +/- 0.17	69.74 +/- 0.17	70.11 +/- 0.17	68.07 +/- 0.12

Replacing likelihood cut with TMVA based cut (Boosted decision tree)

- TMVA is more effective since it handles correlation between training variables
- BG is greatly reduced, especially in lower end
- Significance rise by 10 – 15%

Fitting range is narrowed to 110 – 155 GeV (before 100-160 GeV)
Xsec and mass precisions rise (mainly for Zee channel)

	likelihood	TMVA	improvement
xsecL	2.59	2.51	3.09%
xsecR	2.99	2.89	3.34%
massL	34.8	34.2	1.72%
massR	40.3	39.2	2.73%

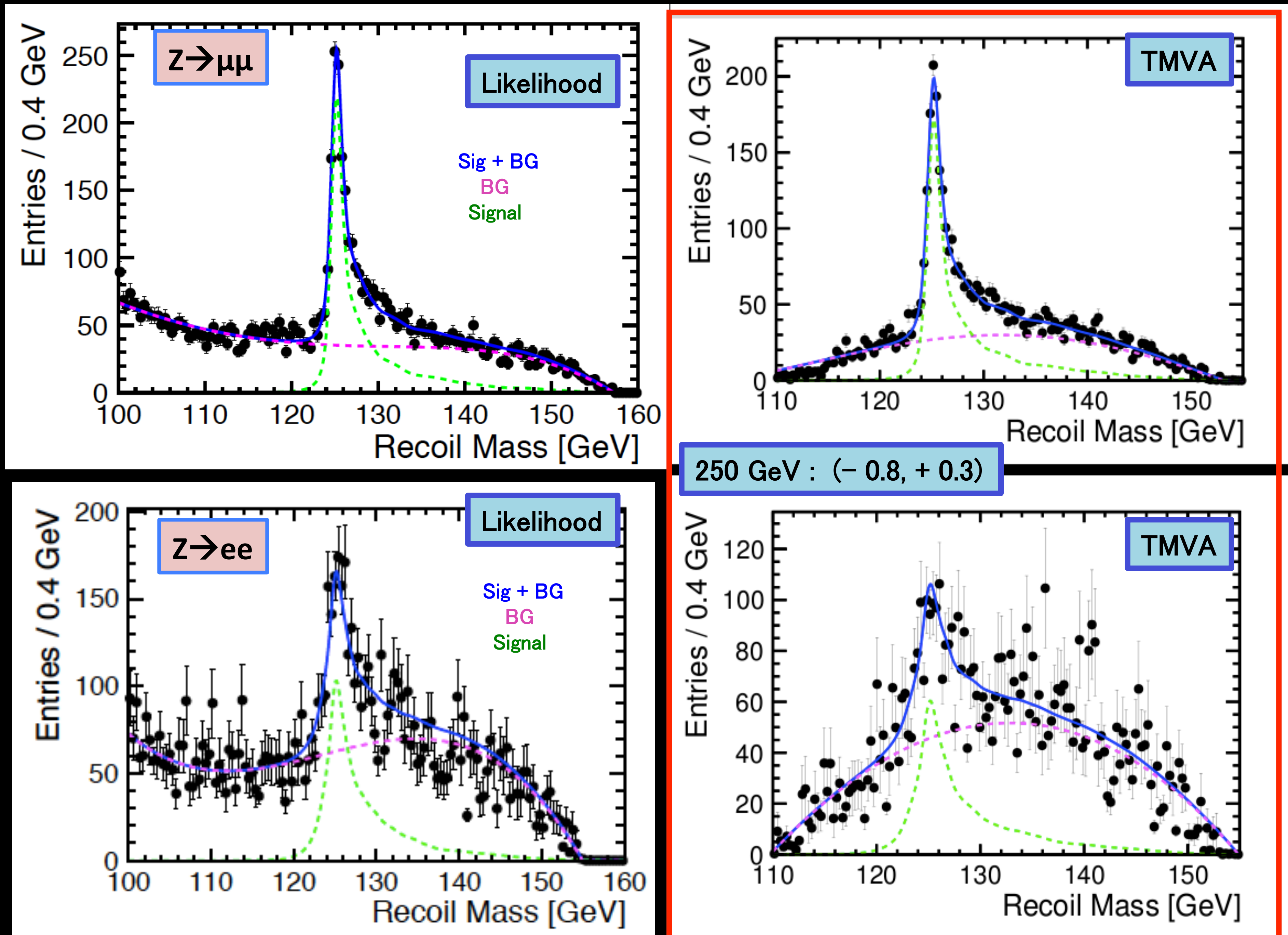
250 GeV

Combined results of Zmm and Zee

xsecZmmL	3.12%	3.09%	0.96%
xsecZmmR	3.58%	3.52%	1.68%
xsecZeeL	4.66%	4.29%	7.94%
xsecZeeR	5.41%	5.04%	6.84%
massZmmL	36.8	36.2	1.63%
massZmmR	42.5	41.5	2.35%
massZeeL	107	103	3.74%
massZeeR	128	120	6.25%

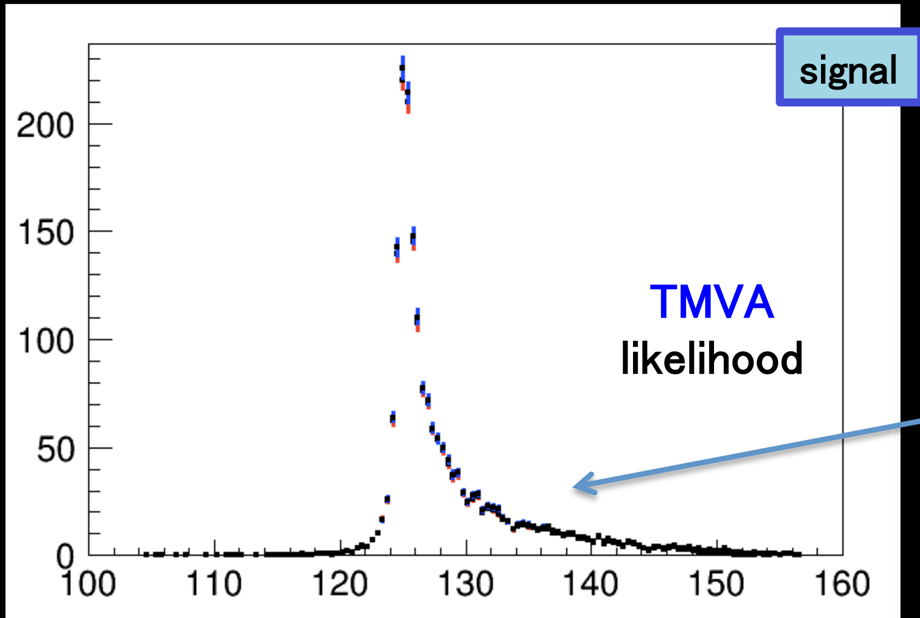
Expect similar or better effects of TMVA for higher ECM

Ongoing …….



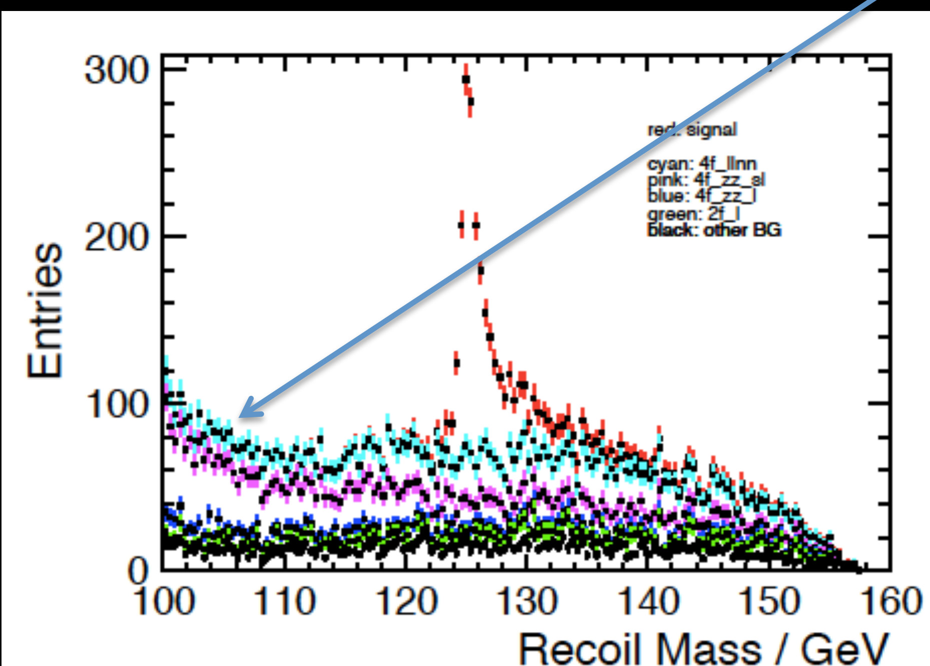
Z→μμ
Likelihood
Sig + BG
BG
Signal
Entries / 0.4 GeV
Recoil Mass [GeV]
TMVA
Entries / 0.4 GeV
Recoil Mass [GeV]
250 GeV : (− 0.8, + 0.3)
Z→ee
Likelihood
Sig + BG
BG
Signal
Entries / 0.4 GeV
Recoil Mass [GeV]
TMVA
Entries / 0.4 GeV
Recoil Mass [GeV]

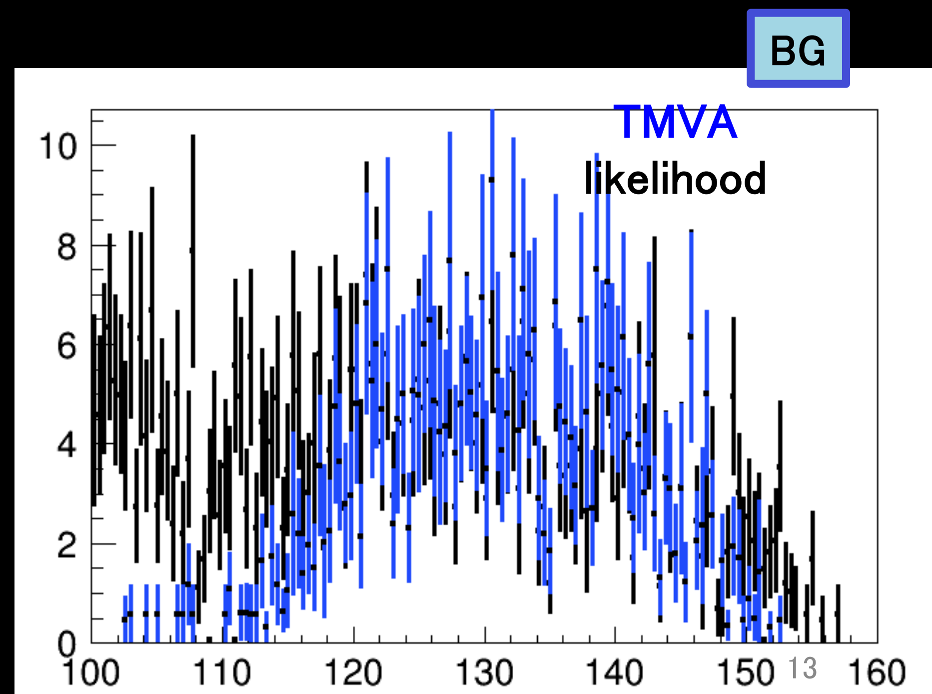
Z→μμ channel
250 GeV : (− 0.8, + 0.3)



When TMVA is used in place of likelihood:

- signal is not much affected
- BG is greatly reduced, especially in lower end mainly ll$\nu\nu$ (ZZWWMiix) and 4f_zz_sl BG





Summary

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

replacing likelihood cut with TMVA based cut improves xsec and mass precisions, esp for Zee channel, even more improvement expected for higher ECM (optimization ongoing)

< best-so-far Preliminary results >
(both leptonic channels combined)

	250 GeV
xsecL	**2.51%**
xsecR	**2.89%**
massL (MeV)	**34.2**
massR (MeV)	**39.2**

- **Investigation of Higgs decay mode dependence**
- **Bias seems to be resolved due to a bug discovered related to cosθmiss cut**

possibility of unknown decay modes have been investigated.

- **Now we can really say syst. error due to mode bias is far below best achievable xsec precision**

- **Currently balancing bias with xsec precision**

Higgs recoil paper in progress : first draft written, now updating with new improvements

Next Steps

◆ further optimization of TMVA cut

❖ add other variables , e.g. track angle of each lepton, angle between leptons (now only using Minv, cos θ _Z, Pt_dl)

❖ Converge to a set of TMVA based results for all ECM, channels by time of General Meeting (a total of 12 cases)

◆ improve efficiency of cos θ miss cut

❖ Find "protection" which yields best signal-BG separation for each scenario

◆ finalize study of Higgs decay mode dependence

- also need to include TMVA cut

◆ revise Higgs recoil paper draft + write an internal KEK report on Higgs mode independence which is essential as a reference

BACKUP

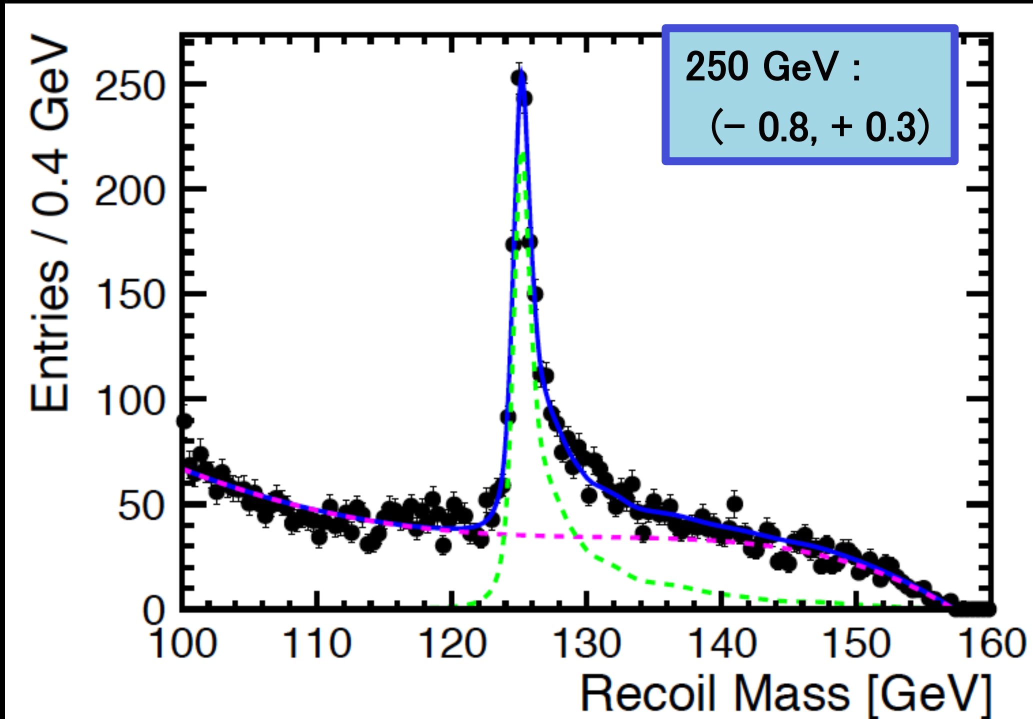
From Junping-san's talk at ALCW2015

BR(inv) upper limit	P(e-,e+) =(-0.8,+0.3)	P(e-,e+) =(+0.8,-0.3)
250 fb^{-1} @ 250 GeV	0.86%	0.61%
330 fb^{-1} @ 350 GeV	1.23%	1.10%
500 fb^{-1} @ 500 GeV	2.39%	1.73%

Combined Higgs visible and invisible decay results

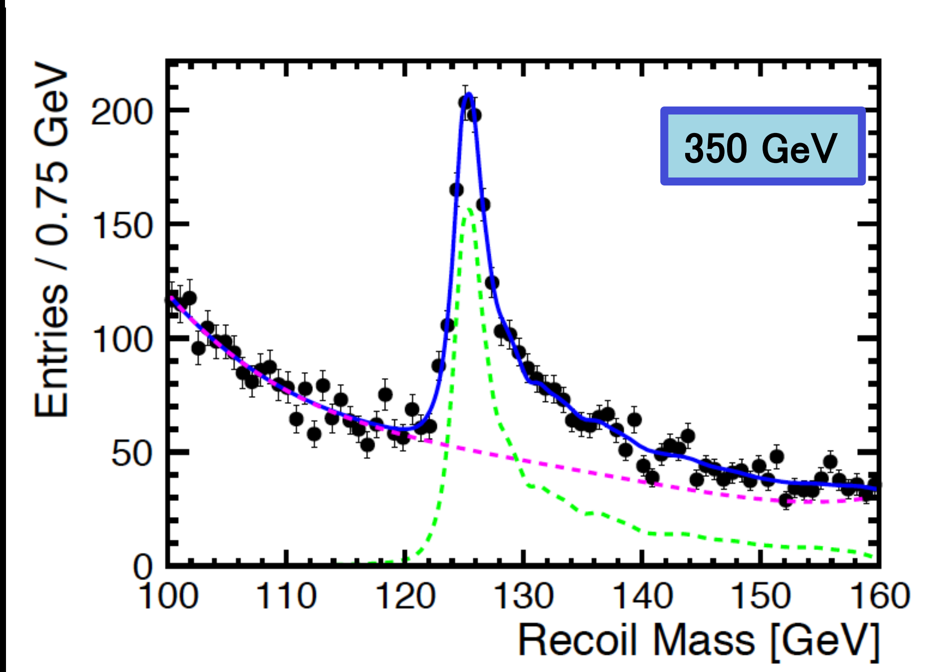
	250 GeV	350 GeV	500 GeV
xsecL	2.49%	3.08%	4.79%
xsecR	2.85%	3.47%	5.24%
massL [MeV]	33.8	86.5	456
massR [MeV]	38.2	97.5	540

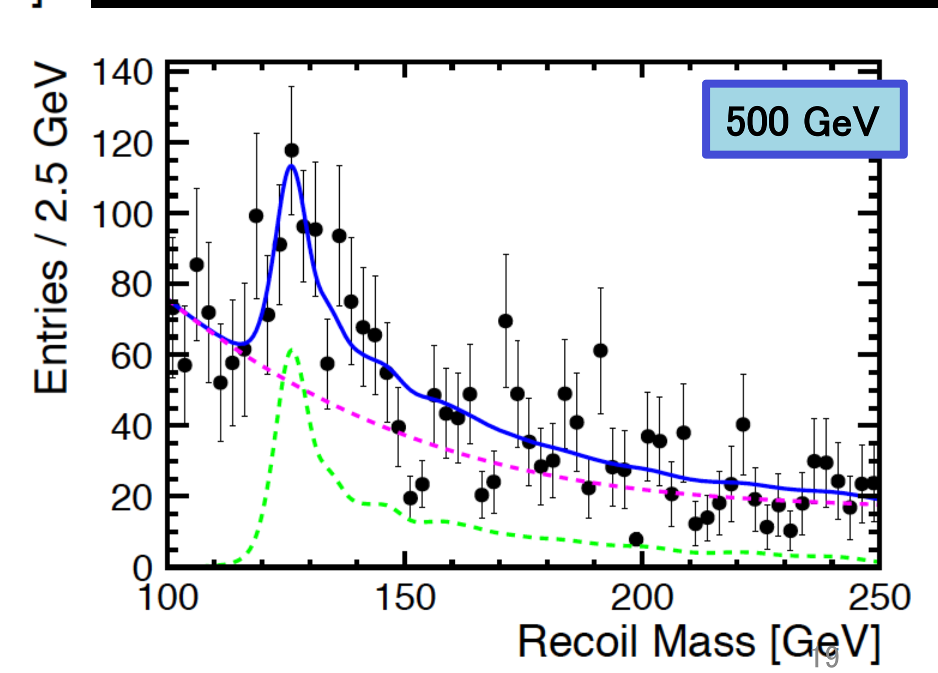
	250 GeV			350 GeV			500 GeV		
	new	old	improvement	new	old	improvement	new	old	improvement
xsecL	2.45%	2.74%	10.58%	3.02%	3.21%	5.92%	4.64%	5.01%	7.39%
xsecR	2.83%	2.93%	3.41%	3.43%	3.55%	3.38%	5.17%	5.33%	3.00%
massL	33.8	37.9	10.82%	86.5	96.5	10.36%	456	448	−1.79%
massR	38.2	38.4	0.52%	97.5	105	7.14%	540	536	−0.75%
xsecZmmL	2.98%	3.35%	11.04%	3.68%	3.90%	5.64%	6.09%	6.50%	6.31%
xsecZmmR	3.45%	3.57%	3.36%	4.17%	4.31%	3.25%	6.99%	7.27%	3.85%
xsecZeeL	4.30%	4.76%	9.66%	5.26%	5.63%	6.57%	7.25%	7.86%	7.76%
xsecZeeR	4.96%	5.14%	3.50%	6.04%	6.26%	3.51%	7.67%	7.86%	2.42%
massZmmL	36	40.4	10.89%	90.2	101	10.69%	479	468	−2.35%
massZmmR	40.5	40.5	0.00%	104	112	7.14%	580	572	−1.40%
massZeeL	97.4	109	10.64%	306	327	6.42%	1500	1540	2.60%
massZeeR	116	121	4.13%	281	296	5.07%	1480	1530	3.27%



Z→μμ channel

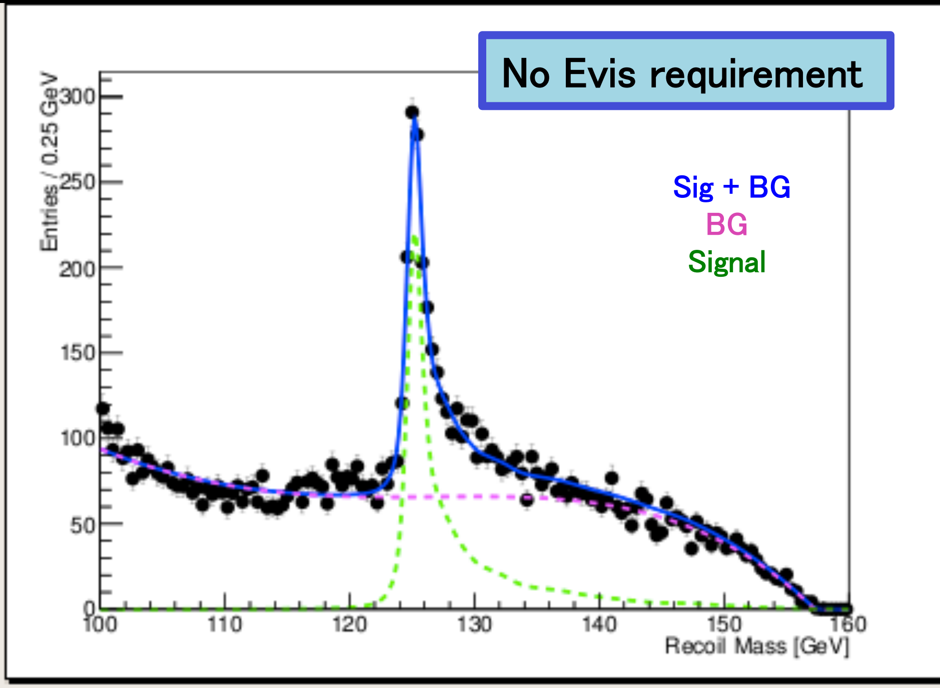
Sig + BG
BG
Signal

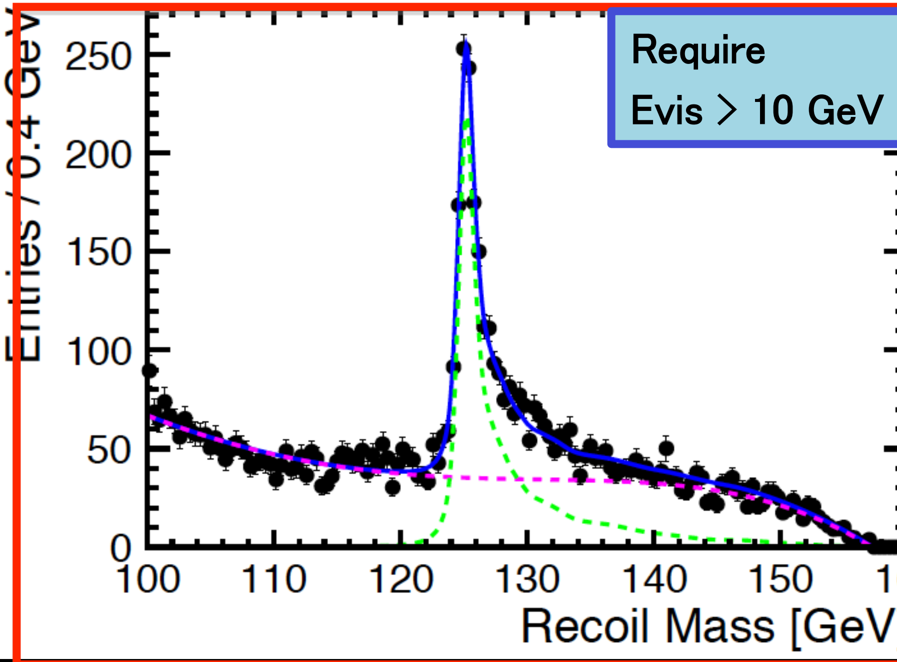




Z→μμ channel

250 GeV : (− 0.8, + 0.3)





after requiring Evis (visible energy) > 10 GeV i.e. only visible Higgs Decay

- signal peak is apparently sharper
- llνν (ZZWWMiix) BG reduced by a factor of 5

In order to maintain model independence, xsec errors need to be convoluted with results from invisible Higgs decay analysis (corresponding to BSM)

https://agenda.linearcollider.org/event/6557/session/12/contribution/129/material/slides/0.pdf

the contribution should be small

Higgs Decay Mode Bias

Problem#1

isolated lepton finder efficiency is lower for H→ gg, ww

due to more overlap of jets from Higgs decay

already resolved thanks to new weights trained by Junping-san

used **H→gg mode to train weight for TMVA** (before: qqqq

Now: gg mode suffers almost no bias, consistent efficiency with bb, cc

Problem#2

"wrong lepton pairing" for H→ zz, ww

- Even if leptons are from a non-prompt Z, they might satisfy Minv, but not Mrec

leads to low efficiency due to cuts on Invariant mass and recoil mass in analysis stage

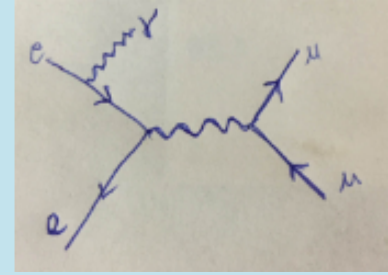
IMPROVEMENT: For Zmm channel : **select best pair by minimizing chi^2 based on Mrec and Minv**
(c.f. before: select pair with Minv closest to Z mass)

Problem#3

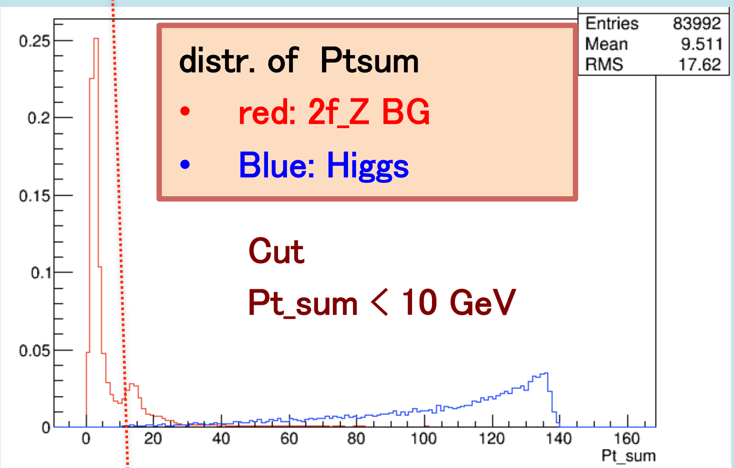
Cos(θmiss) cut and Ptsum cut bias H→ γγ 、 ττ (tolerable ?)

- These **cannot be sacrificed** due to xsec precision and negligible after weigh by BR

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 → τ τ , γ γ)



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

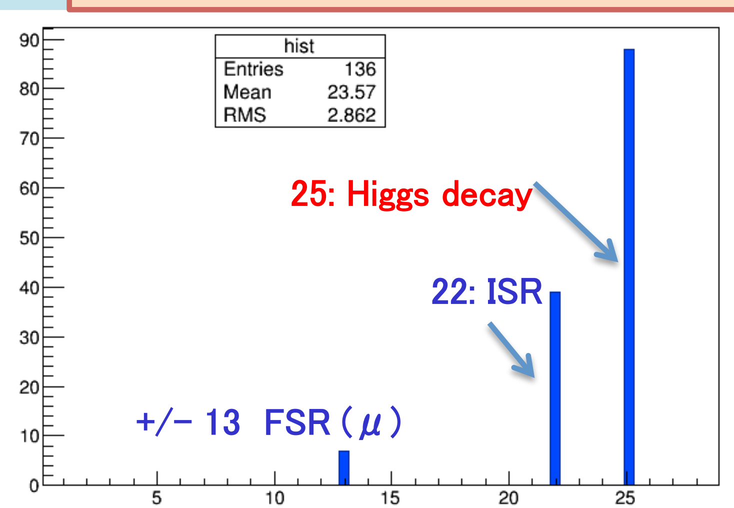
NEW #2 Now use

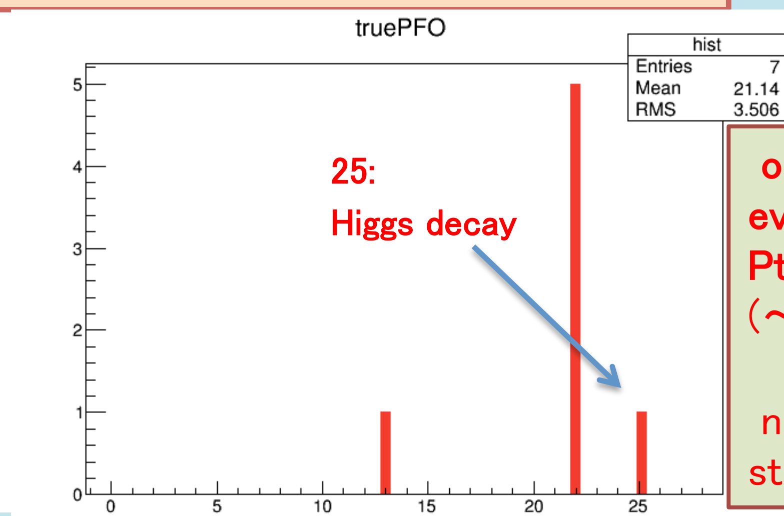
$$\left|\overrightarrow{P_{t,sum}}\right| \equiv \left|\overrightarrow{P_{t,\gamma}} + \overrightarrow{P_{t,dl}}\right|$$

(instead of dptbal)

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

lepton pairing mistake is reduced for ZZ, WW modes without additional bias on other modes

OLD

	250 GeV zz	250 GeV ww	350 GeV zz	350 GeV ww
Total	100.00%	100.00%	100.00%	100.00%
C1	94.66%	98.13%	94.40%	97.69%
C2	4.97%	1.46%	5.32%	2.00%
C3	4.63%	0.46%	4.77%	0.59%

NEW

	250 GeV		350 GeV	
Total	100.00%	100.00%	100.00%	100.00%
C1	95.47%	98.29%	95.64%	98.27%
C2	4.26%	1.37%	4.08%	1.42%
C3	3.85%	0.48%	3.68%	0.60%

Pairing mistake

C1: correct

C2: two real leptons exist, but at least one wrong lepton

C3: both leptons wrong

- efficiency of H→ $\gamma\gamma$ rise by ~ 12% (68.4% →80.7%)
- efficiency of other modes rise by 0.5 – 1% also
- especially important : WW, ZZ no longer significantly biased (despite some "mistaken lepton pairing)

is the remaining bias this a worry ?

H→ $\gamma\gamma$

corrected

Eff. (%)	bb	cc	gg	tt	ww	zz	aa
Cut0 :	93.7 +/- 0.1	93.68 +/- 0.1	93.4 +/- 0.11	93.89 +/- 0.1	93.62 +/- 0.1	93.86 +/- 0.1	93.7 +/-0.077
Cut1 :	93.7 +/- 0.1	93.68 +/- 0.1	93.4 +/- 0.11	93.89 +/- 0.1	93.62 +/- 0.1	93.86 +/- 0.1	93.7 +/-0.077
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Cut5 :	89.83 +/- 0.13	89.94 +/- 0.13	89.57 +/- 0.13	89.54 +/- 0.13	89.74 +/- 0.13	90.13 +/- 0.12	87.38 +/- 0.1
Cut6 :	89.83 +/- 0.13	89.94 +/- 0.13	89.57 +/- 0.13	89.54 +/- 0.13	89.74 +/- 0.13	90.13 +/- 0.12	87.38 +/- 0.1
Cut7 :	83.16 +/- 0.15	83.03 +/- 0.15	82.8 +/- 0.15	82.88 +/- 0.15	83.14 +/- 0.15	83.56 +/- 0.15	80.89 +/- 0.12
Cut8 :	82.99 +/- 0.15	82.87 +/- 0.15	82.63 +/- 0.15	82.68 +/- 0.15	82.96 +/- 0.15	83.41 +/- 0.15	80.71 +/- 0.12
Cut9 :	82.99 +/- 0.15	82.87 +/- 0.15	82.63 +/- 0.15	82.68 +/- 0.15	82.96 +/- 0.15	83.41 +/- 0.15	80.71 +/- 0.12
Cut10:	75.17 +/- 0.16	74.9 +/- 0.17	74.93 +/- 0.17	75.13 +/- 0.16	75.38 +/- 0.16	76.01 +/- 0.16	73.49 +/- 0.12

Cut6 is cosϑmiss

mistake

Eff. (%)	bb	cc	gg	tt	ww	zz	aa
Cut0 :	93.7 +/-0.079	93.69 +/- 0.08	93.4 +/-0.081	94.02 +/-0.077	94.04 +/-0.076	94.36 +/-0.074	93.71 +/-0.066
Cut1 :	93.7 +/-0.079	93.69 +/- 0.08	93.4 +/-0.081	93.99 +/-0.077	94.02 +/-0.076	94.15 +/-0.075	93.7 +/-0.066
Cut2 :	92.12 +/-0.087	92.06 +/-0.089	91.76 +/- 0.09	92.14 +/-0.087	91.96 +/-0.087	91.99 +/-0.087	91.21 +/-0.077
Cut3 :	90.09 +/-0.097	90.2 +/-0.098	89.84 +/-0.099	90.06 +/-0.097	89.77 +/-0.097	89.78 +/-0.097	89.35 +/-0.084
Cut4 :	89.88 +/-0.098	90.02 +/-0.098	89.64 +/-0.099	89.87 +/-0.097	89.53 +/-0.098	89.53 +/-0.098	89.17 +/-0.085
Cut5 :	89.83 +/-0.098	89.94 +/-0.099	89.57 +/- 0.1	89.39 +/-0.099	89.43 +/-0.098	89.42 +/-0.099	87.34 +/-0.091
Cut6 :	89.28 +/- 0.1	89.58 +/- 0.1	89.42 +/- 0.1	88.64 +/- 0.1	88.66 +/- 0.1	88.56 +/- 0.1	73.67 +/- 0.12
Cut7 :	82.75 +/- 0.12	82.75 +/- 0.12	82.67 +/- 0.12	82.23 +/- 0.12	82.16 +/- 0.12	82.28 +/- 0.12	68.48 +/- 0.13
Cut8 :	82.58 +/- 0.12	82.59 +/- 0.12	82.5 +/- 0.12	82.02 +/- 0.12	81.98 +/- 0.12	82.02 +/- 0.12	68.38 +/- 0.13
Cut9 :	82.58 +/- 0.12	82.59 +/- 0.12	82.5 +/- 0.12	82.02 +/- 0.12	81.98 +/- 0.12	82.02 +/- 0.12	68.38 +/- 0.13
Cut10:	74.8 +/- 0.14	74.65 +/- 0.14	74.8 +/- 0.14	74.55 +/- 0.14	74.47 +/- 0.14	73.83 +/- 0.14	64.9 +/- 0.13

Performance of data selection

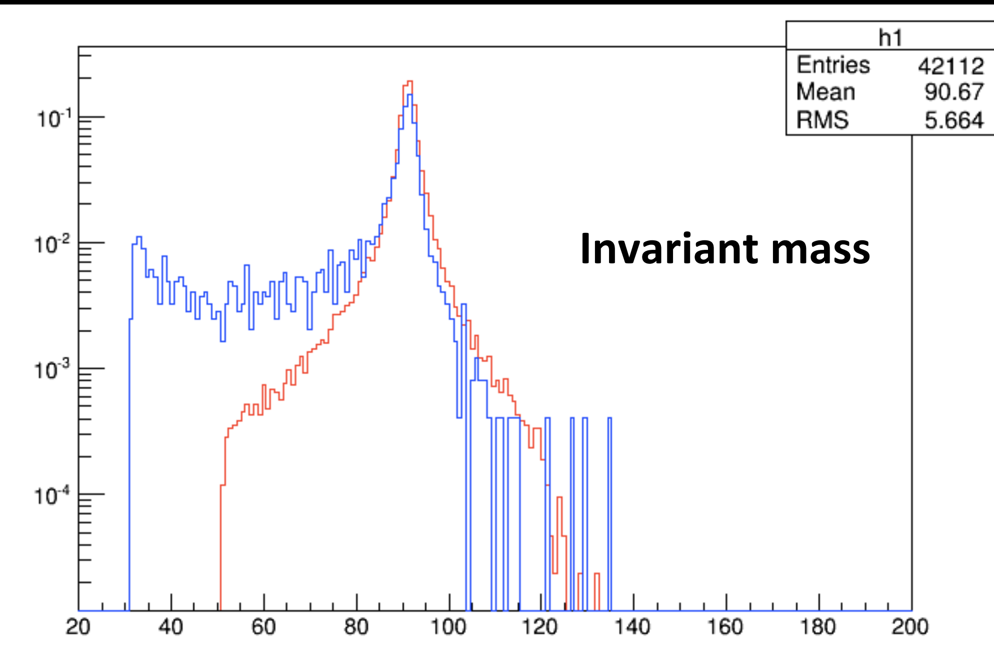
in fitting range 100–160 GeV

(−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

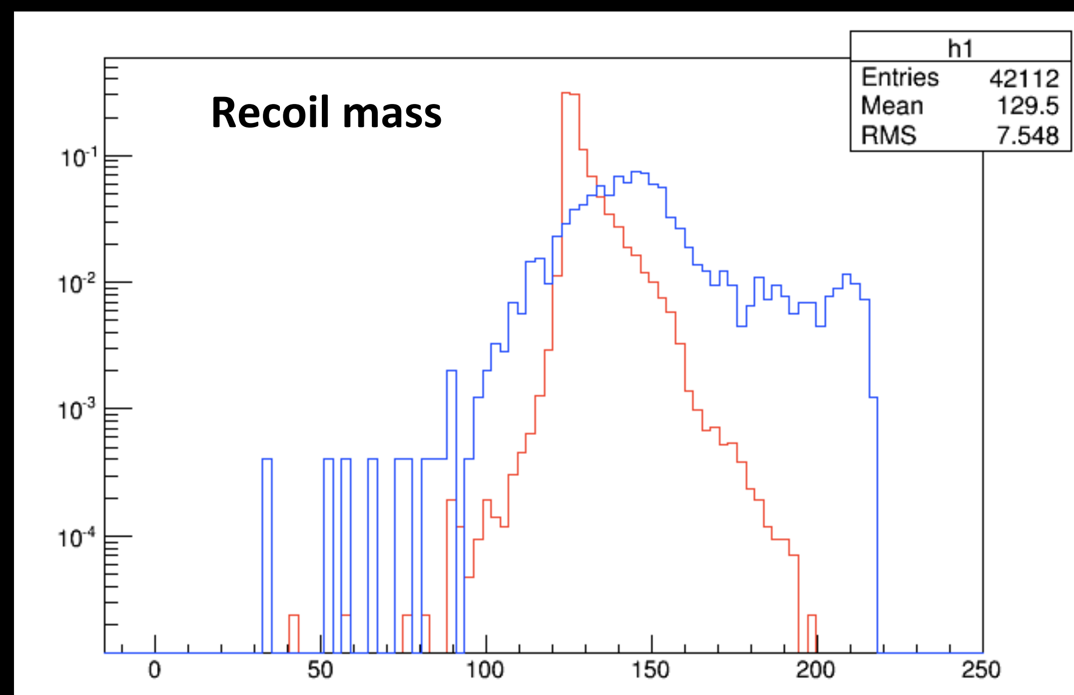
(+0.8,−0.3)		significance	Nsig	Nbg
250GeV	Zmm	19.7	1264	2834
	Zee	12.8	1096	6231
350GeV	Zmm	17	1002	2486
	Zee	12.7	602	1627
500GeV	Zmm	9.9	414	1339
	Zee	8.9	325	1003

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

H→zz mode
ECM = 250 GeV



Blue : wrong pair
Red: right pair



Check lepton pairing mistake is reduced : Zmm channel

OLD

250 GeV	bb	cc	zz	ww	tautau	gg	aa
Total	100.00%	100%	100.00%	100.00%	100.00%	100%	100.00%
C1	100.00%	100%	94.66%	98.13%	99.35%	100%	99.94%
C2	0.00%	0	4.97%	1.46%	0.51%	0.00%	0.06%
C3	0.00%	0	4.63%	0.46%	0.26%	0.00%	0.00%
C4	0.00%	0	0.36%	0.41%	0.14%	0.00%	0.00%
C5	0.00%	0	0.00%	0.00%	0.00%	0.00%	0.00%

NEW

250 GeV							
Total	100.00%	100%	100.00%	100.00%	100.00%	100%	100.00%
C1	100.00%	100%	95.47%	98.29%	99.41%	100%	99.91%
C2	0.00%	0	4.26%	1.37%	0.49%	0.00%	0.09%
C3	0.00%	0	3.85%	0.48%	0.28%	0.00%	0.00%
C4	0.00%	0	0.27%	0.33%	0.10%	0.00%	0.00%
C5	0.00%	0	0.00%	0.00%	0.00%	0.00%	0.00%

C1: correct

Pairing mistake

C2: two real leptons exist, but at least one wrong lepton

C3: both leptons wrong

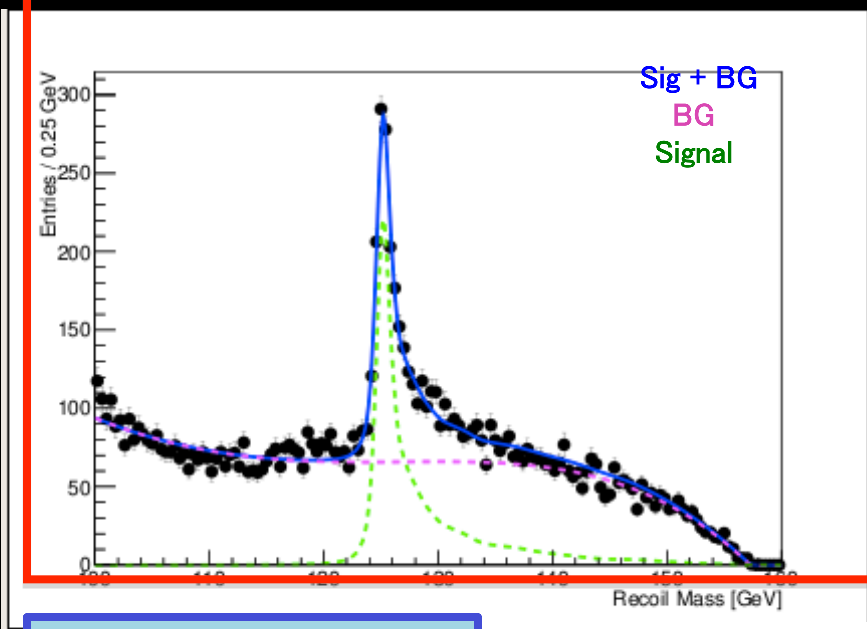
C4: only 1 real lepton

C5: no real lepton

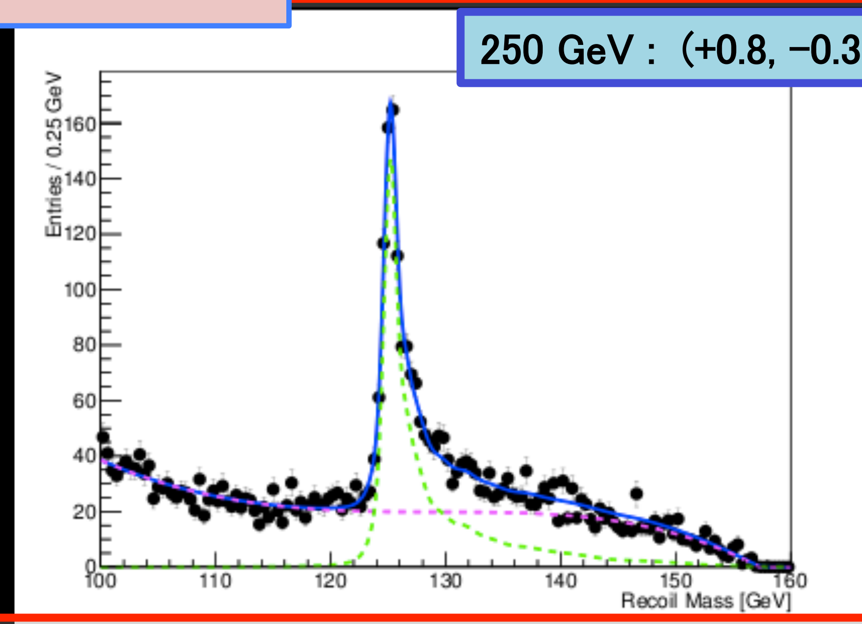
Z→μμ channel

Reconstructed data
recoil mass histogram

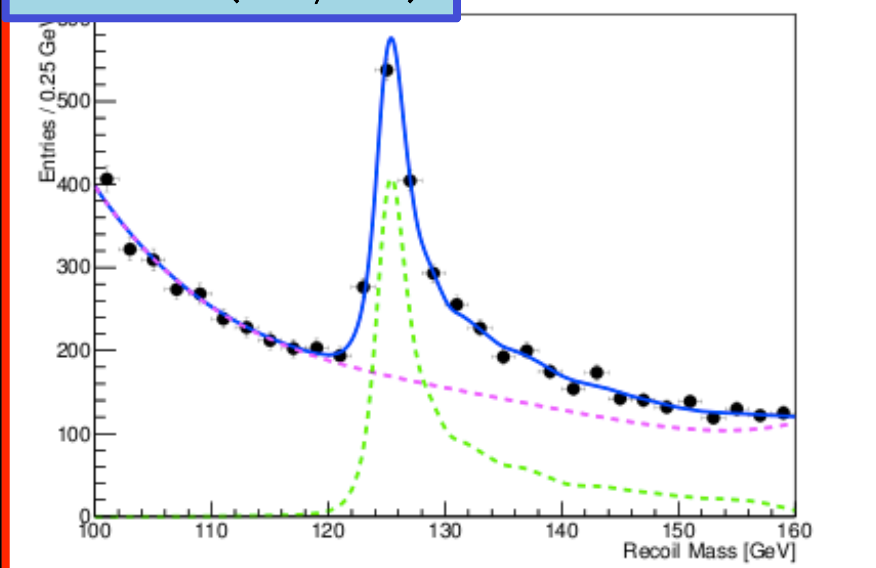
250 GeV : (− 0.8, + 0.3)



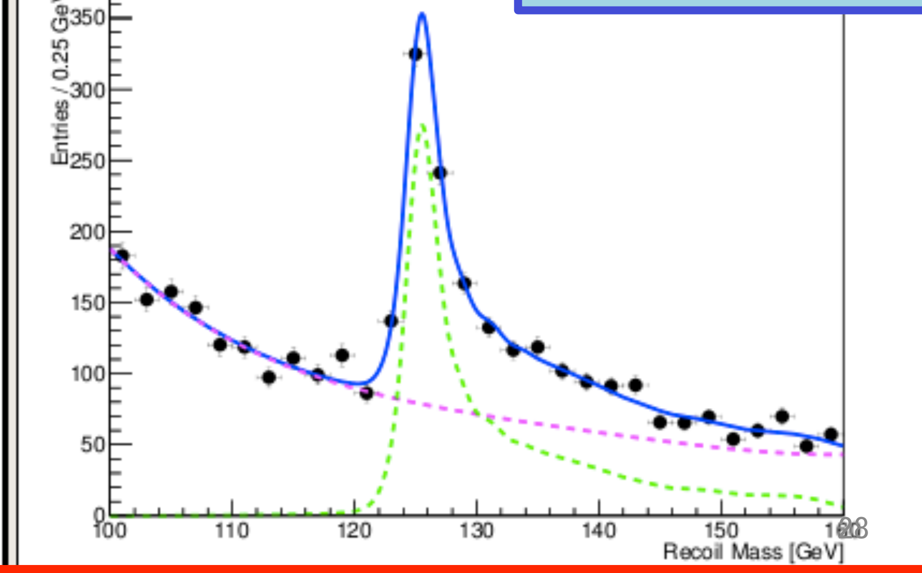
250 GeV : (+0.8, −0.3)



350 GeV : (−0.8, +0.3)



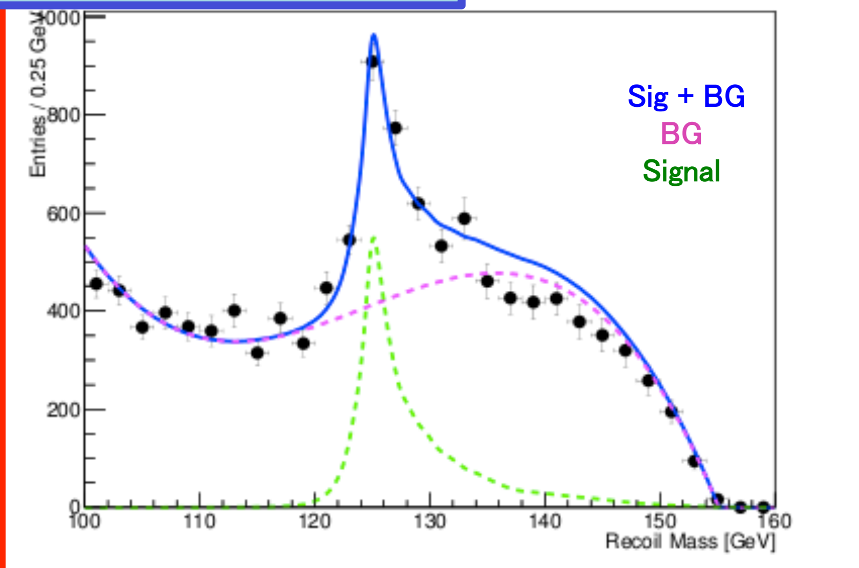
350 GeV : (+0.8, −0.3)



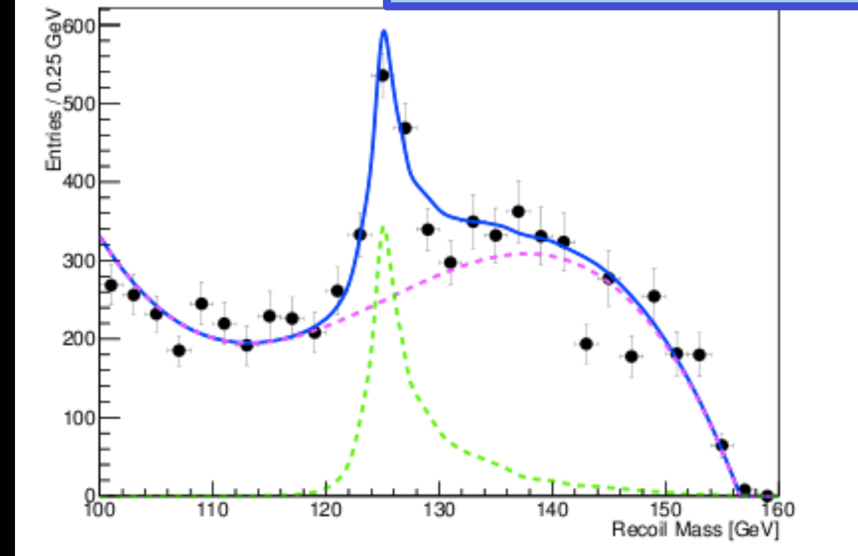
Reconstructed data
recoil mass histogram

Z→ee channel

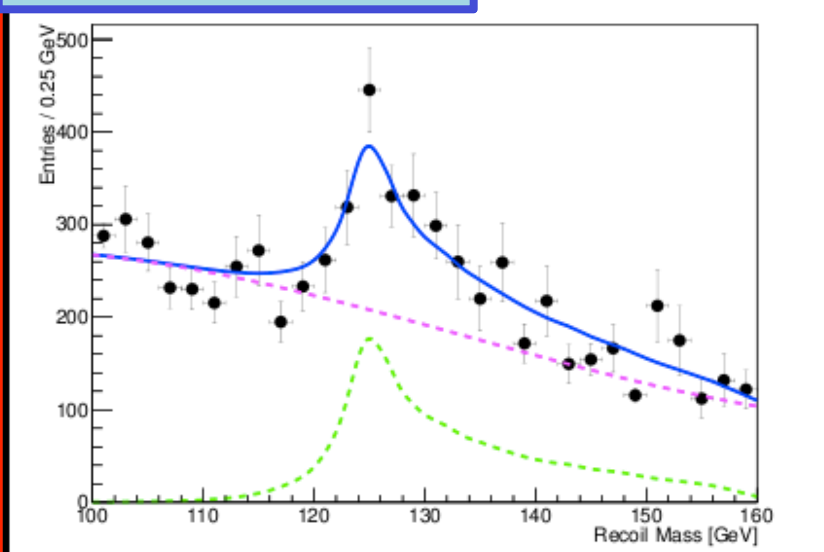
250 GeV : (− 0.8, + 0.3)



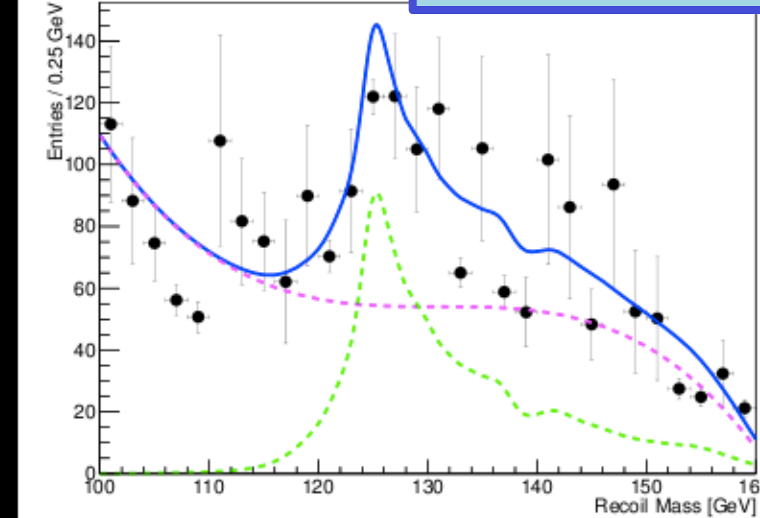
250 GeV : (+0.8, −0.3)



350 GeV : (−0.8, +0.3)

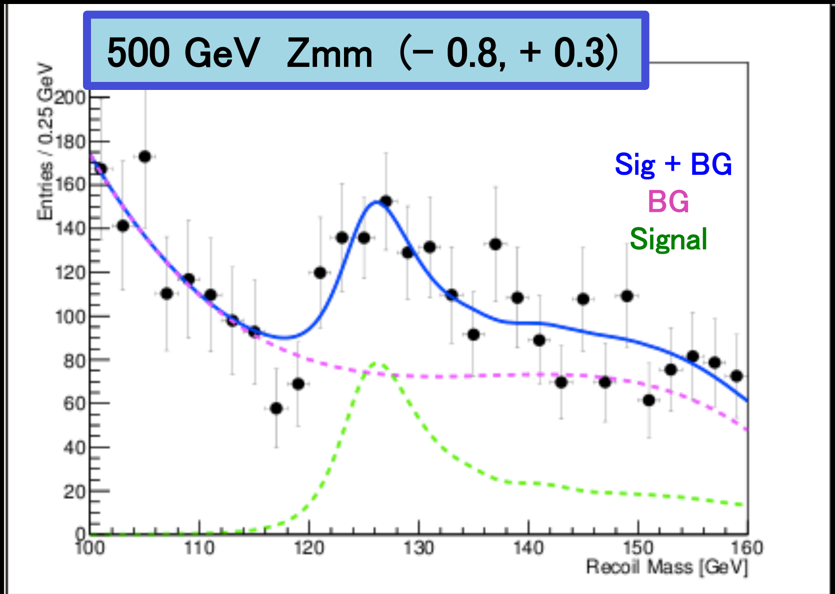


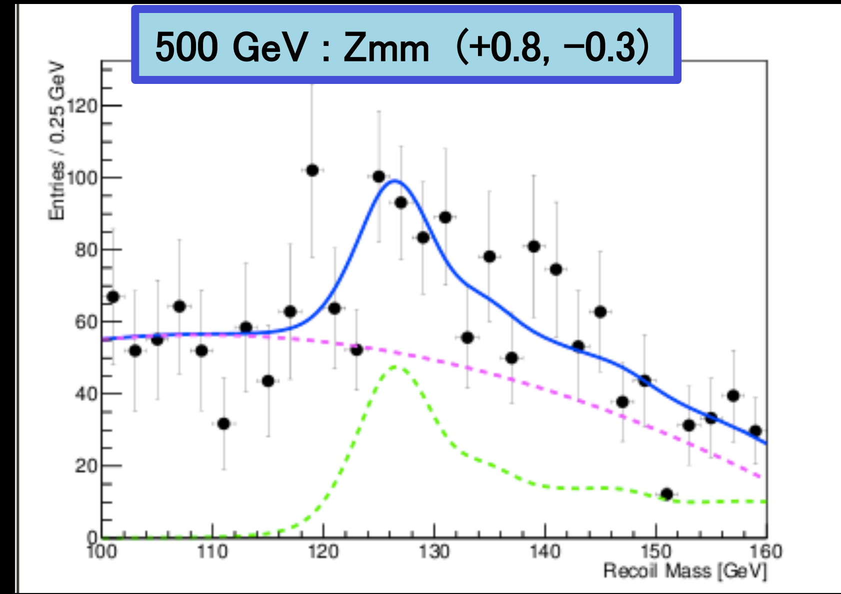
350 GeV : (+0.8, −0.3)

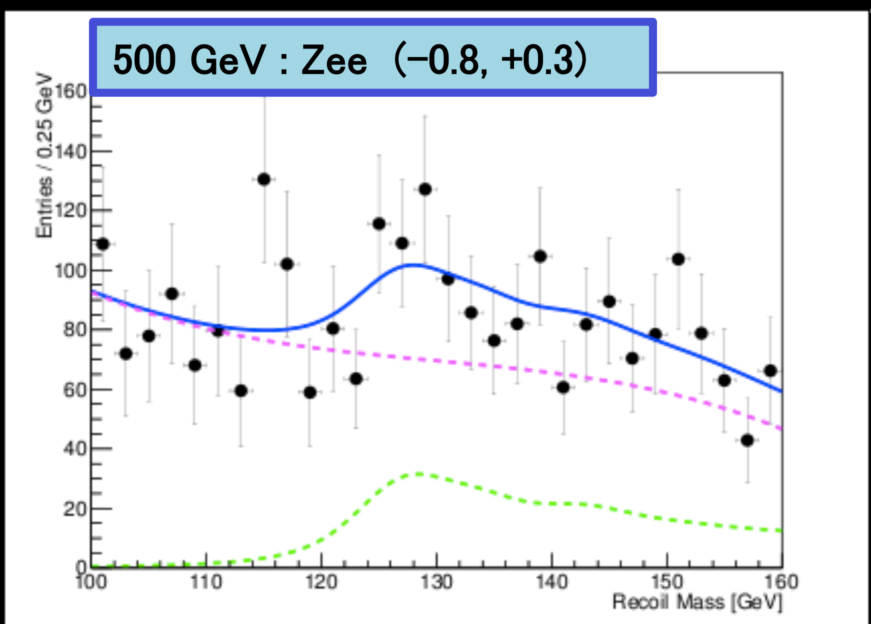


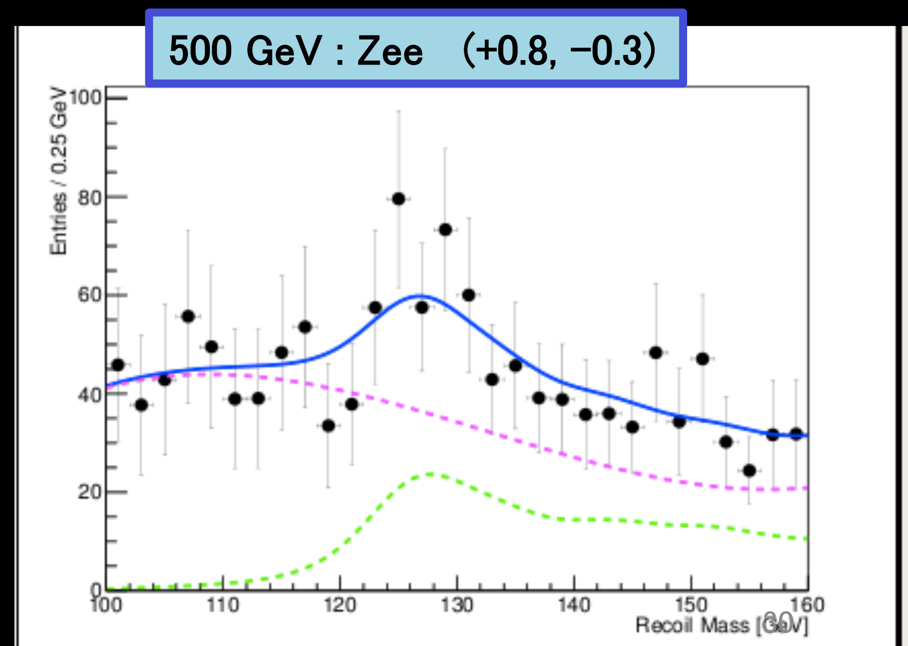
500 GeV

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





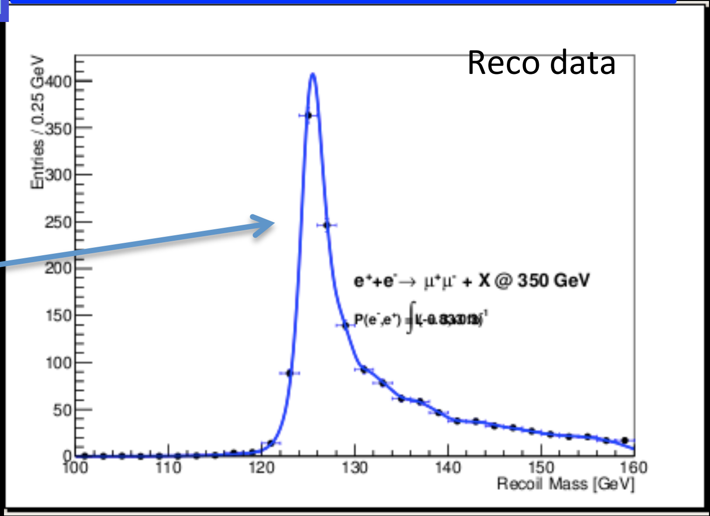


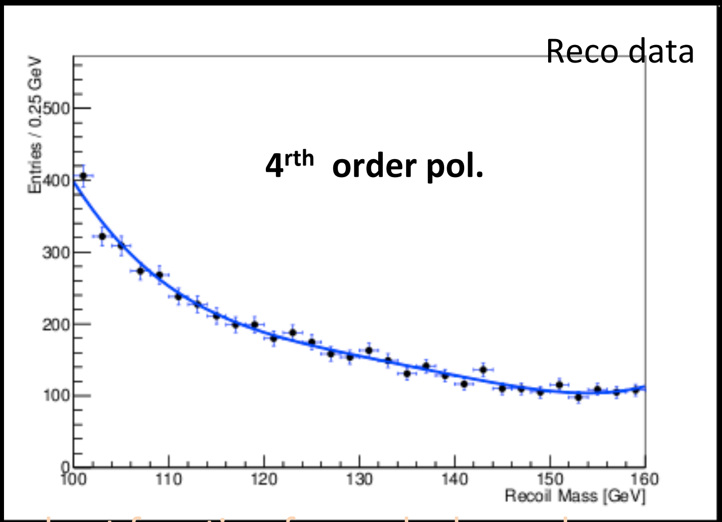


Fitting of recoil mass spectrum

Signal : Kernel function

BG : 3rd or 4rth 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

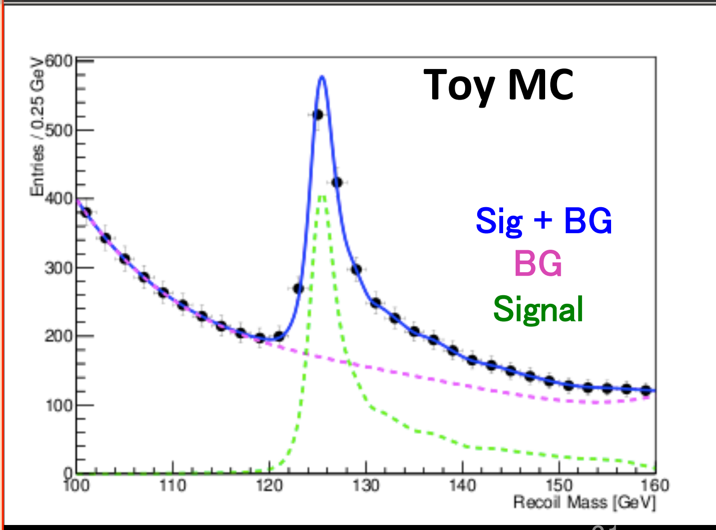
goal: test quality of fitting method

evaluate precision of xsec and recoil mass

method:

- 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



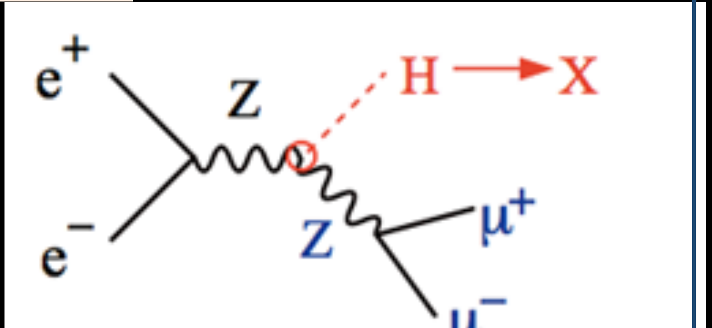
# recoil mass study using leptonic channes
ECM = 250 GeV, 350 GeV, and 500 GeV

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

signal

H decay mode independent



Higgs recoil against di-lepton system

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

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

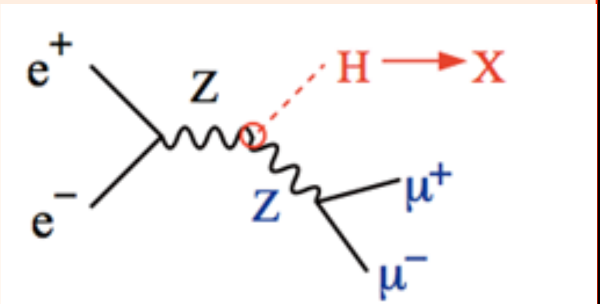
ILC sample used in analysis

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.)

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

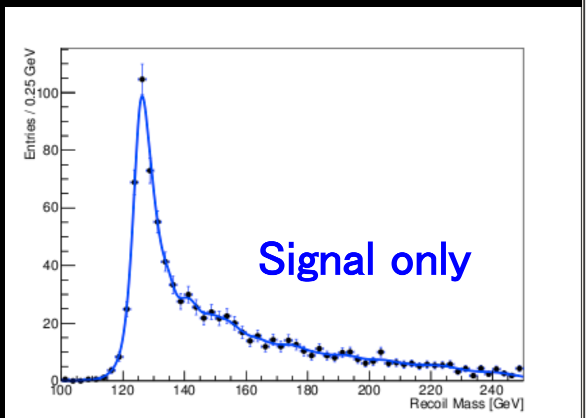
Dominant backgrounds	Signatures
e+ e- → Z Z → l+ l- X :	forward Z production angle
e+ e- → γ Z → γ l+ l- :	energetic ISR γ which balance dilepton pt
e+ e- → W W → l+ l- ν ν :	broad M_{inv} distr.

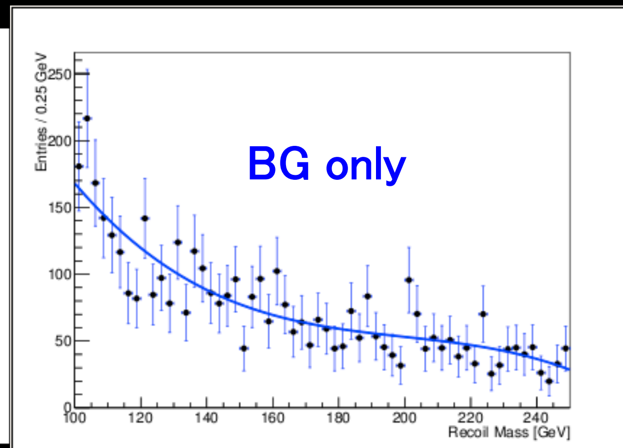
- data selection is based on signal / BG characteristics
- a final recoil mass window (100 – 160 GeV) is effective for cutting BG

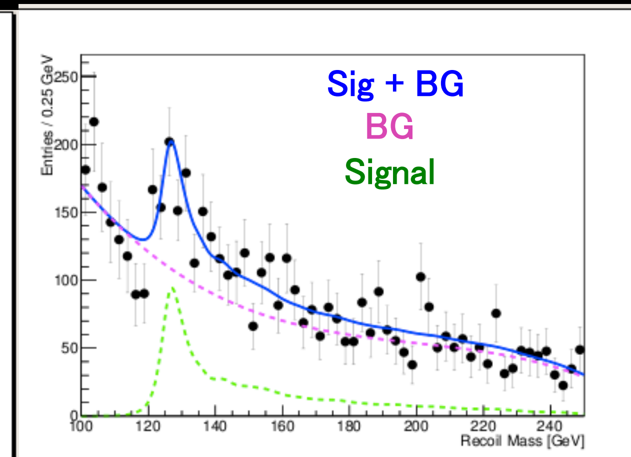
Can precision can be slightly improved if we fit over a wider range ?
assuming we can neglect the H*→WW bump beyond 160 GeV

500 GeV, Zee (-0.8,+0.3)

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

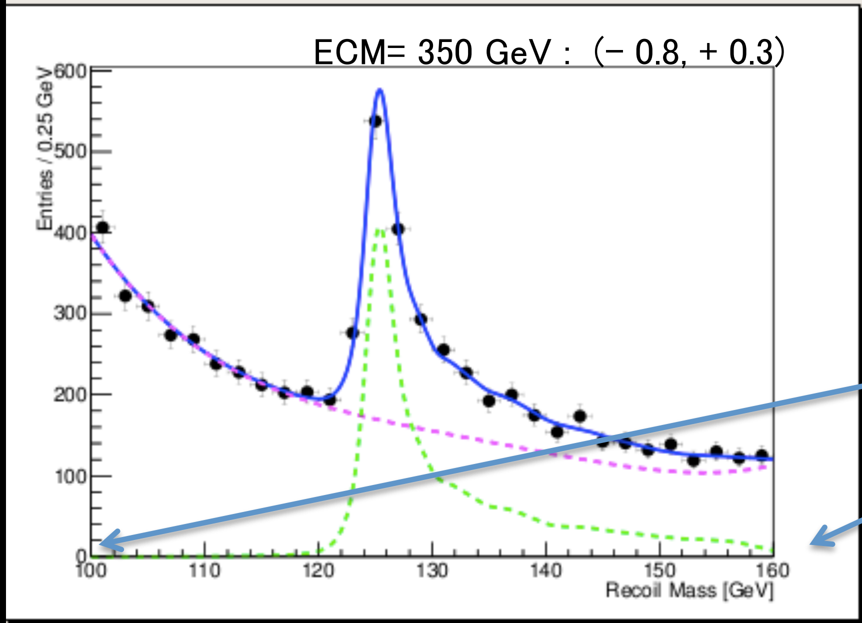






		xsec error (%)		mass error (MeV)	
(−0.8,+0.3)		narrow	wide	narrow	wide
500GeV	Zmm	6.95%	6.50%	474	468
	Zee	9.89%	7.86%	1540	1540
	Total	**5.69%**	**5.01%**	**453**	**448**
(+0.8,−0.3)					
500GeV	Zmm	8.36%	7.27%	613	572
	Zee	9.85%	7.86%	1510	1530
	Total	**6.37%**	**5.33%**	**568**	**536**

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



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%

Check lepton pairing mistake : Zee channel

250 GeV	bb	cc	zz	ww	tautau	gg	aa
Total elec	100.00%	100%	100.00%	100.00%	100.00%	100.00%	100.00%
C1	99.91%	100%	97.36%	96.89%	98.35%	99.92%	98.15%
C2	0.05%	0.03%	1.97%	2.16%	1.06%	0.01%	1.38%
C3	0.00%	0.00%	1.17%	0.01%	0.01%	0.00%	0.02%
C4	0.04%	0.02%	0.66%	0.89%	0.52%	0.01%	0.41%
C5	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%

C1: correct

Pairing mistake

C2: two real leptons exist, but at least one wrong lepton

C3: both leptons wrong

C4: only 1 real lepton

C5: no real lepton

250 GeV Zmm left pol