ILCの重心系エネルギー250、350、500 GeVにおけるHiggs反跳質量測定精度の評価

加速器・物理
合同ILC夏の合宿2015

群馬県伊香保温泉　ホテル天坊
2015年　7月　18ー21日

ジャクリン　ヤン（KEK 素核研）

Leptonic channel を用いたHiggs反跳測定
@ ECM = 250 GeV, 350 GeV, and 500 GeV

Z崩壊由来のdi-leptonのkinematicsからHiggsの質量を測定
Zの反跳質量＝ヒッグス粒子の質量

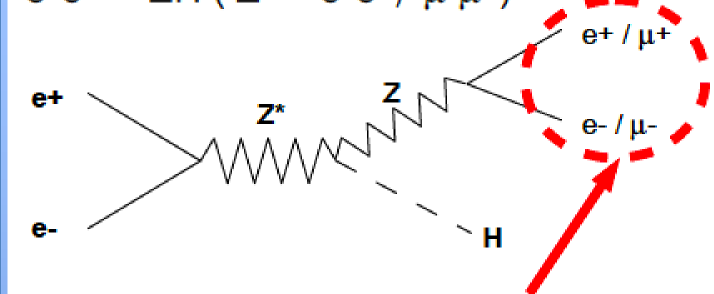
Higgsの崩壊過程に依らない
i.e. Model independent

主要目的:
•Higgs 断面積（σ_{ZH}）と 質量 (M_H) の精密測定
•重心系エネルギー(ECM) とビーム偏極の影響を評価する
➔ ILC 実験計画の検討、加速器と測定器の最適化 に貢献する

σZH は各Higgs崩壊モードの崩壊分岐比
coupling, total width の絶対値測定への鍵
c.f. LHC では全ての測定はσ×BR

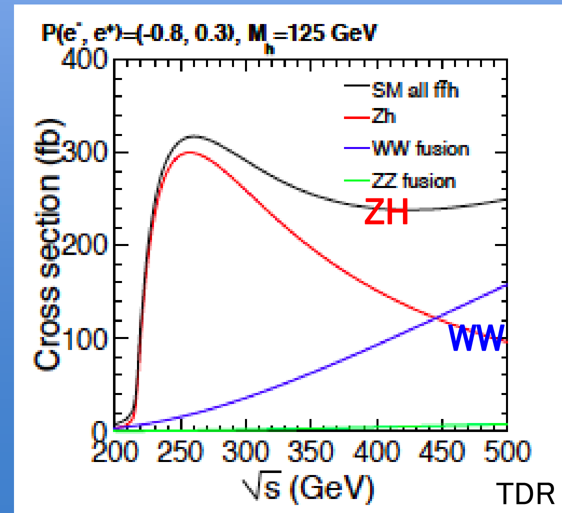
signal Higgs が di-lepton に対して反跳

$e^+e^- \rightarrow ZH\ (Z \rightarrow e^+e^- / \mu^+\mu^-)$



Higgsの4元運動量

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



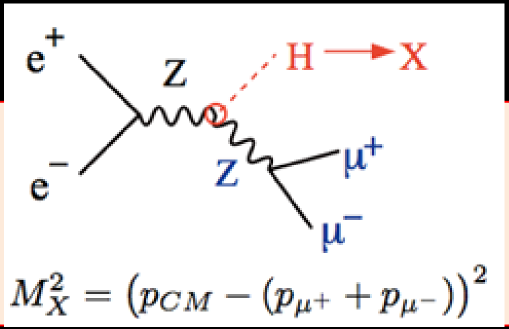
解析に用いたILC標準MCデータサンプル

chanel	mH	ECM	L (TDR)	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+) = 左巻き (-0.8,+0.3) 右巻き (+0.8,-0.3)	Full ILD (ILD_01_v05 DBD ver.)

本講演の　LAYOUT

- ◆ 解析に用いるデータ選別手法の最適化
- ◆ Higgs生成断面積と質量の測定性能の評価
  - ➔ 異なる重心系エネルギーとビーム偏極の間の比較
- ◆ Higgs崩壊モード依存性からくる系統誤差の評価
- ◆ Summary & Plans

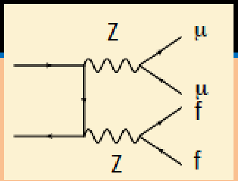
signal / BG の特徴に合わせて解析手法を最適化する

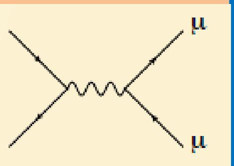


Signal の特徴

不変質量がZ質量に近い

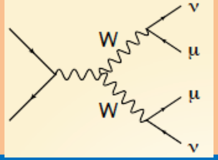
isolated energetic lepton (μ / e) のペア





支配的なBGの特徴

- 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.



Lepton Pair Candidate Selection

- 反対電荷 （ +/− 1 ）
- E_cluster / P_total : ＜0.5（μ）/ ＞0.9（e）
- isolation (small cone energy)
  → 4f_WW_sl BG を大幅に除去
- MinvがZ質量 (91.18 GeV) に近い
- impact parameter |D0/δD0| < 5

解析手法を最適化する基準

- signal significance
- 断面積の精度
- Higgs崩壊モード非依存を保つ

変数の定義

- 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

ECM=350 GeVの場合

- 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

Minv, Ptdl, CosZ
から構成するlikelihood

- 2f（μ μ / ee）BG の除去に有効
- 一番高エネのISR γの情報を使う
  signalにバイアスをかけないように注意を払う

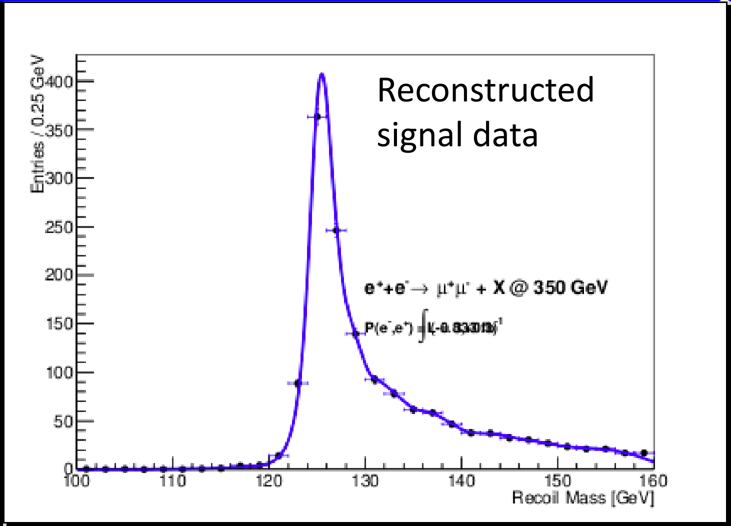
赤囲み： 先行studyに対する改善点

反跳質量分布のfitting

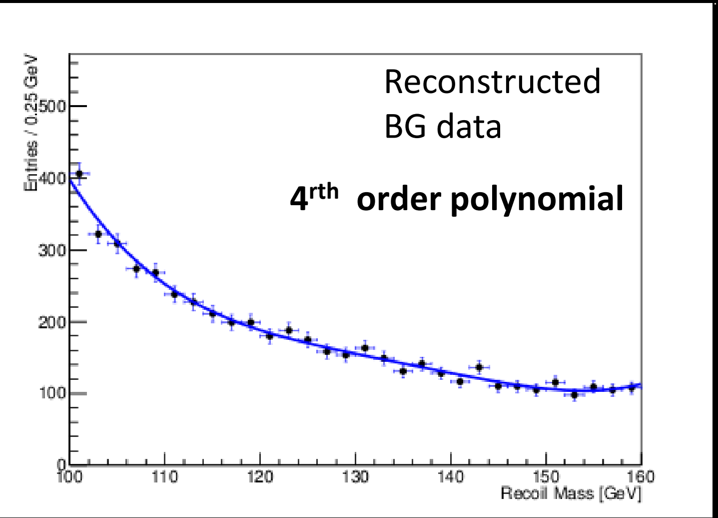
カーネル
密度推定法

各標本点の周りの
Gaussianの重ね合わせ

Signal : Kernel function



BG : 3rd or 4rth order polynomial



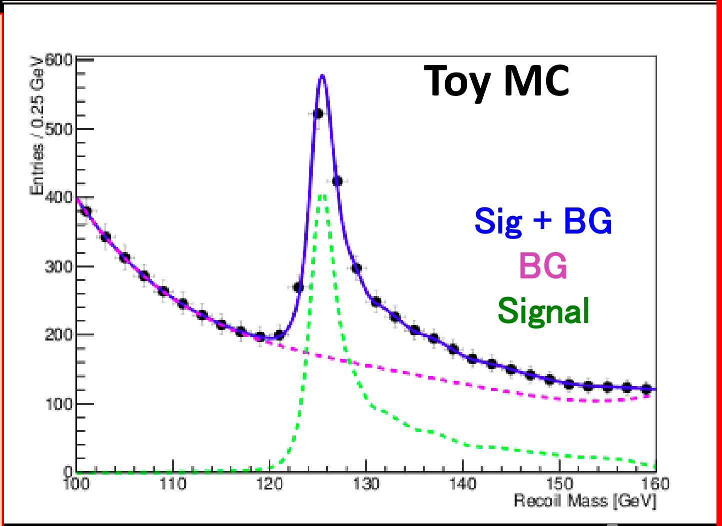
Toy MC study

目的： Fitting手法の妥当性を検討
M_h、 σZH などの精度を評価

手法：
実データのfit結果に従って1000 x 統計でToy MCデータを生成
➔MCの分布を同じ関数でfit : Kernel + polynomial
➔ signal yield、mass shift, と σZH、MHの統計誤差 を得る

断面積
σZH

非常に小さい（数MeV）ので
殆ど系統誤差にならない

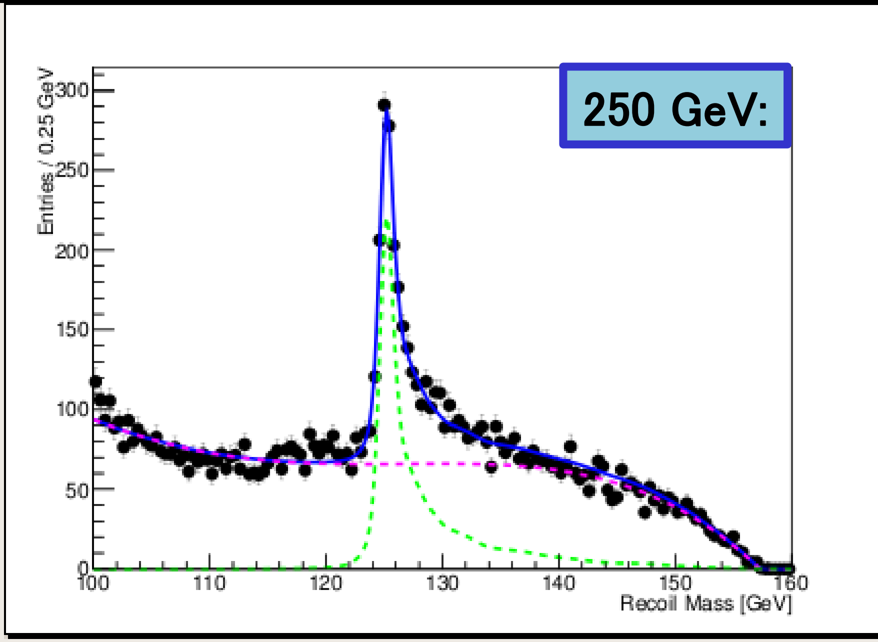


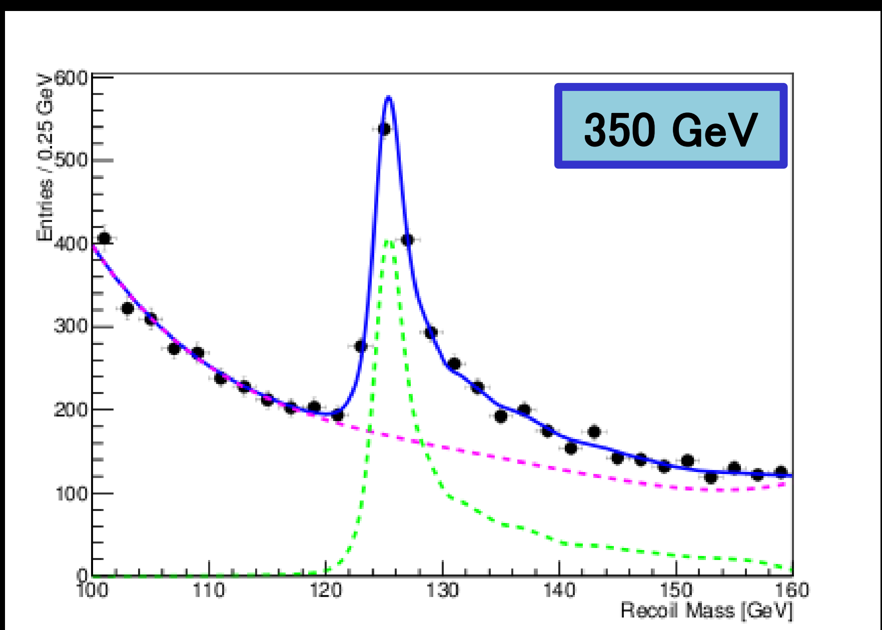
Fitted Recoil Mass Plot の例

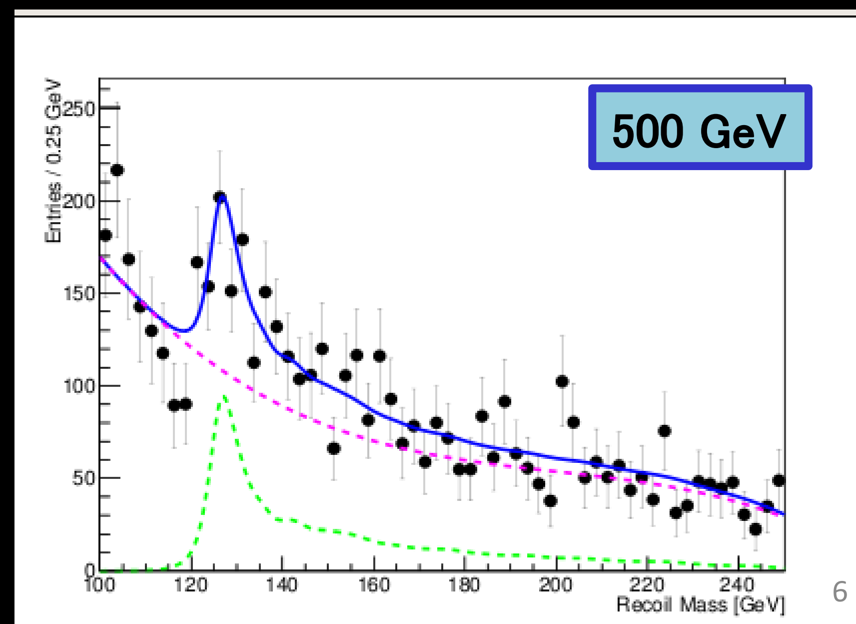
e+e- →ZH→μμH channel

● MCデータ点
Sig + BG
BG
Signal

Reconstructed data
ビーム偏極左巻き ((− 0.8, + 0.3)







注）500 GeVはfit範囲を広くとっている

データ選別の結果
Signal significance

反跳質量分布のfit
範囲 100−160 GeV

ECM		左巻き	右巻き
250GeV	Zmm	18.3	19.7
	Zee	14.4	12.8
350GeV	Zmm	17.7	17
	Zee	14.1	12.7
500GeV	Zmm	11.1	9.9
	Zee	8.7	8.9

Significance は
250 > 350 > 500 GeV　　Zmm > Zee

断面積と質量の測定精度 (TDR 設定)

Toy MC studyの結果

左巻き偏極: (Pe−,Pe+)=(−0.8,+0.3)

右巻き偏極: (Pe−,Pe+)=(−0.8,+0.3)

ECM		xsec err 左巻き	xsec err 右巻き	mass err [MeV] 左巻き	mass err [MeV] 右巻き
250GeV	Zmm	3.35%	3.57%	40.4	40.5
(250 fb−1)	Zee	4.76%	5.14%	109	121
	Total	2.74%	2.93%	37.9	38.4
350GeV	Zmm	3.90%	4.31%	101	112
(333 fb−1)	Zee	5.63%	6.26%	327	296
	Total	3.21%	3.55%	96.5	105
500GeV	Zmm	6.50%	7.27%	468	572
(500 fb−1)	Zee	7.86%	7.86%	1540	1530
	Total	5.01%	5.33%	448	536

生成断面積
- **350 GeV は250 GeVに 17 % 劣る**
  (leptonの運動量分解能の影響)
- **ZeeはZmmに > 40%劣る** (bremの影響)
- **右巻きは左巻きに 5 – 10 % 劣る** (統計量の影響)

反跳質量
- 350 GeV は250 GeVに < 3倍 劣る
- ZeeはZmmに 2-3倍劣る

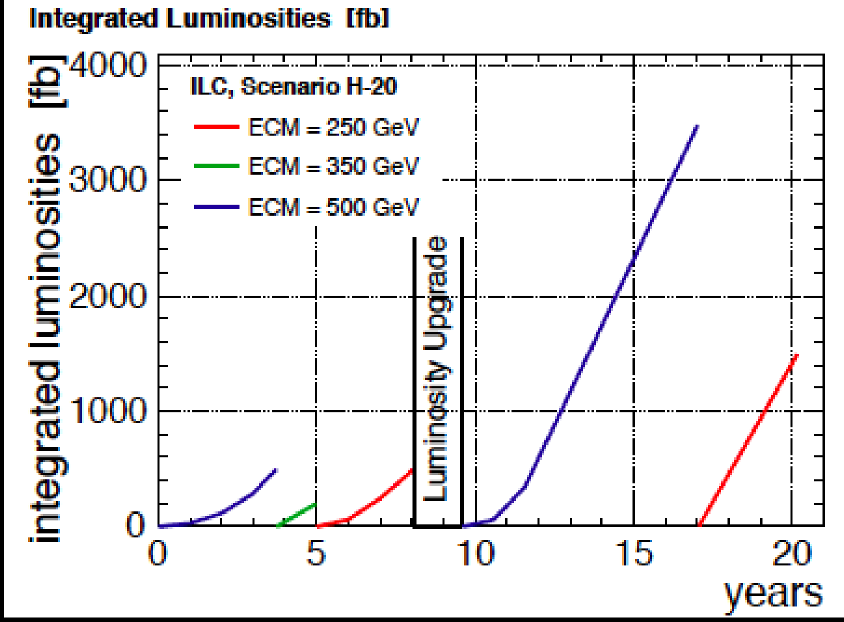
断面積と質量の測定精度： H20 シナリオにスケールした場合

ECM	xsec err 左巻き	xsec err 右巻き	xsec err combined	mass err [MeV] 左巻き	mass err [MeV] 右巻き	mass err [MeV] combined
250GeV (2 ab−1)	1.18%	2.18%	**1.04%**	16.3	28.6	**14.2**
350GeV (0.2 ab−1)	5.04%	9.66%	**4.47%**	152	286	**134**
500 GeV (4 ab-1)	2.80%	2.98%	**2.04%**	250	300	**192**

３つのECMの結果を全て合わせたときに、
H20 runから期待できる σZH誤差は0.9%, MH誤差は14 MeV

Lumi	$\sqrt{s}$ [GeV]	$\int \mathscr{L} dt$ [fb^{-1}]
Physics run	500	500
Physics run	350	200
Physics run	250	500
Shutdown		
Physics run	500	3500
Physics run	250	1500

- H20での350 GeVの運転期間が短いので精度がTDR設定に劣る
- 250, 500 GeVでたくさんデータを取る予定



polarization

$\sqrt{s}$	fraction with sgn$(P(e^-), P(e^+))$ = (-,+) [%]	(+,-) [%]	(-,-) [%]	(+,+) [%]
250 GeV	67.5	22.5	5	5
350 GeV	67.5	22.5	5	5
500 GeV	40	40	10	10

- Higgs反跳質量測定はmodel independent である事がセールスポイント

少しでもHiggs崩壊モードのバイアスがあると断面積への系統誤差となる

ここで、バイアスをstudyした

- 通常のMCサンプルは小さい分岐比(BR)モードがに統計が制限を受ける
  ➔ BRに関係なく各崩壊モードごとに生成された高統計のサンプルを使った

- 極力バイアスが生じないようにデータ選別（BG排除）の手法を改善してきた

以上を以て、

崩壊モード依存性由来の系統誤差は十分に無視可能

であることを提示できた

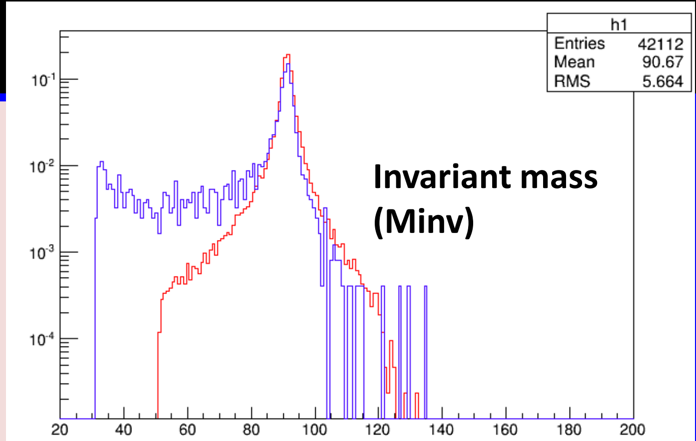
以降、 詳細を話して行きます。。。。。。

Higgs崩壊モード依存性： 問題提起と解決

[問題1] Lepton pair を組む際に、 Higgs崩壊由来のものを間違って取ってくることがある

•主にH→ZZ*, WW* に顕著

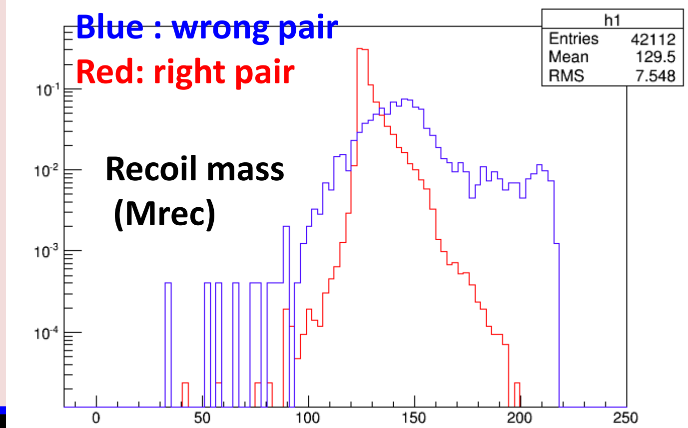
•後ほどかける厳しいMinv やMrec のカットをクリアできず、
最終的にefficiency が低くなる



対策： ”best lepton pair”の選別条件を工夫する

以前： MinvがZ質量に一番近い

間違った組み合わせでもたまたま満たす場合があるが、
MrecがM_Hから離れている可能性が大きい



現在： MinvとMrecで構成されたχ^2 を最小にする

[問題2] 2f BG を除去するために使用するカットが H→$\gamma\gamma$, $\tau\tau$ モードにバイアスを及ぼす

以前：

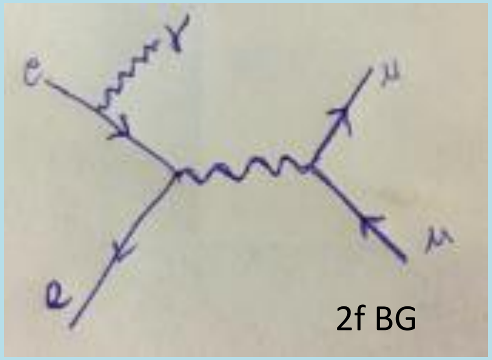
$$dP_{t,bal} \equiv \left|\overrightarrow{P_{t,dl}}\right| - \left|\overrightarrow{P_{t,g}}\right|$$

dptbal < 10 GeVをカット

現在： ISR γとdilepton の方向の情報も取入れた新しいカット

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

Ptsum < 10 GeVをカット



γ back-to back
w.r.t. di-lepton

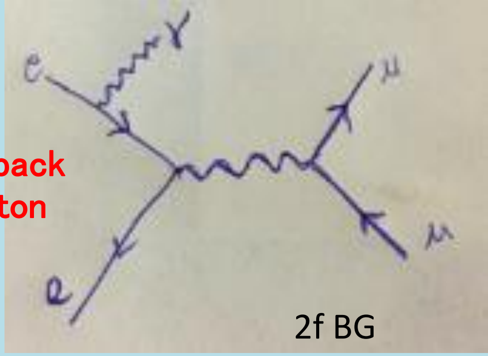
2f BGを安全に除去する試み

従来の2f BG排除手段が H

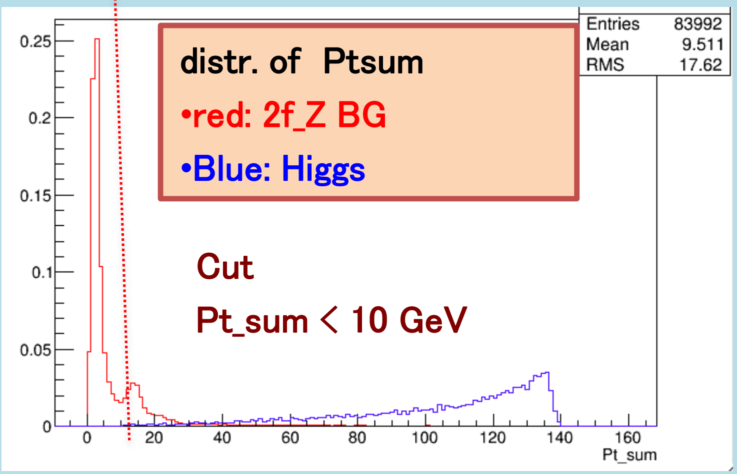
→ ττ，γγにバイアスを引き起こす

$$dP_{t,bal} \equiv \left|\overrightarrow{P_{t,dl}}\right| - \left|\overrightarrow{P_{t,g}}\right|$$

γ back-to back
w.r.t. di-lepton



2f BG



NEW #1 <u>isolated photon finder:</u>

tagしているγ がISRであってHiggs崩壊からではないことを保証 (small cone energy)

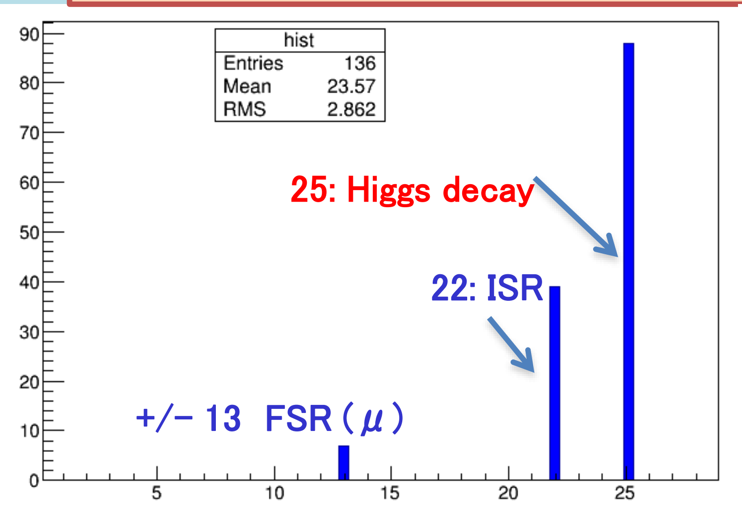
NEW #2 新しいカット変数

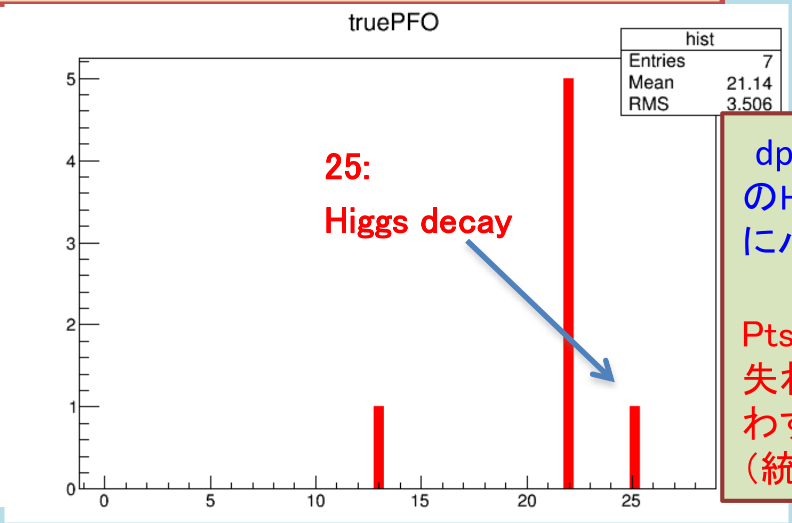
$$\left|\overrightarrow{P_{t,sum}}\right| \equiv \left|\overrightarrow{P_{t,g}} + \overrightarrow{P_{t,dl}}\right|$$

(dptbalの代わりに)

ベクトルの大きさと方向の両情報を併用

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





dptbal cut が～ 100 個のHiggs崩壊由来γのeventにバイアスをかける

Ptsumに切り替えれば失われるHiggs事象はわずか数個
（統計的に有意ではない）

"lepton pairing mistake" の行方

OLD: |Minv – M_Z| を最小化
➔ NEW: χ^2 (Mrec – MH, Minv – M_Z) を最小化

OLD

	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

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

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

C3: both leptons wrong

C4: only 1 real lepton

C5: no real lepton

結果： **組み間違いが減少した**
（H→ZZ*： 14% 減少　H→WW*：6%減少）

ところが、残留の間違いは許せるのか？

- BR(H→ZZ*)～2%と小さいので大丈夫そうだが、
  BR(H→WW*)～22%と大きいので問題的かもしれない
- **実際high statistics sample の結果をHiggs分岐比でスケールして考察した**

現実的なケース： 標準模型のHiggs分岐比を考慮した場合

Zmm real

	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%
	avg eff:	82.29%

Zee real

	eff(final)	dev*BR
bb	78.14%	0.237%
cc	78.14%	0.011%
gg	77.69%	−0.003%
tt	77.32%	−0.026%
ww	77.44%	−0.063%
zz	75.74%	−0.053%
aa	64.69%	−0.030%
	avg eff:	77.73%

Cheat: MC truth を利用して、Higgs崩壊由来のleptonを絶対に組まないようにしている

Zmm cheat

	eff(final)	dev*BR
bb	82.58%	0.110%
cc	82.59%	0.005%
gg	82.50%	0.009%
tt	82.17%	−0.014%
ww	82.30%	−0.019%
zz	82.87%	0.013%
aa	68.41%	−0.032%
	avg eff	82.39%

Zee cheat

	eff(final)	dev*BR
bb	78.14%	0.150%
cc	78.14%	0.007%
gg	77.69%	−0.016%
tt	77.53%	−0.022%
ww	77.76%	−0.026%
zz	78.00%	0.003%
aa	65.32%	−0.029%
	avg eff	77.88%

Efficiency values weighed by SM BR

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

Zee はZμμよりも間違いが起きやすい

- H→bb, cc, gg は本来バイアスがないので”real”と”cheat”が一致
- “cheat” の場合、efficiency はH→zz が1%, H→wwが 0.3%上昇（元々然程悪くない？）
- **σZHへの系統誤差は＜0.17% (Zμμ)、＜0.24% (Zee)**
  H20 run から得られる最善のσZHの統計精度をはるかに下回る（～0.9%)

Summary

e+e- → ZH → l+l-H (l = μ / e)過程を用いたHiggs反跳質量測定 @ ECM = 250 , 350 , 500 GeV

Higgs質量とZH生成断面積 (全てのHiggs couplingへの鍵！）のmodel independent 測定

•**ECM とビーム偏極が測定精度に与える影響**を評価した

•合計12通りの統計誤差を出した : ECM(3) x レプトンチャンネル(2) x ビーム偏極(2)

< **TDR設定**を仮定した解析結果> (Zμμ Zee channels combined)

ECM	(Pe-,Pe+)			(Pe-,Pe+)		
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 = 5.0 %	ΔM = 448 MeV	(+0.8, -0.3)	Δσ / σ = 5.3%	ΔM = 536 MeV

LuminosityがECMに比例するTDR設定では、

•**350 GeVは250 GeVに比べてσZH 精度は然程悪くないが、MHの精度は250 GeVが２倍以上優秀**

• **ZμμはZee比べて断面積も質量も2–3倍優秀**

•**左巻き偏極は右巻き偏極に比べて断面積が 5-10% 優秀**

•**H20 シナリオに焼き直すと3つのECM合わせて σZHの精度=0.9%, MH精度=14 MeV**

Higgs崩壊モードバイアスによるσZHへの系統誤差はH20で期待されるベスト統計精度に比べて有意ではないことを提示した ＜0.17% (Zμμ)、 ＜0.24% (Zee)

➔ ILCのセールスポイントの１つを確保！！

Higgs Recoil Study のプラン

（1） 500 GeVからILCの運転を開始するH20シナリオの視点から

500 GeVでのleptonic recoil の精度の改善

＋　500 GeVのhadronic recoil 解析の開始

の優先順位の高い（主観的に）

（2） 全てのECMで更なるσZH精度の改善

- H→visible とH→invisibleに分けた解析

  ➔ 支配的なμμννBGの影響を抑えられる

（3） beam spectrum からくる系統誤差のstudy

現在　Title（preliminary）: Leptonic Higgs Recoil Analysis at the ILC

の論文を書いています　　**（今年（度）中完成？）**

Abstract of Leptonic Higgs Recoil Paper

Leptonic Higgs Recoil Analysis at the ILC

This paper reports **on the expected precision for the model independent measurement of the absolute Higgs boson production cross section for the Higgsstrahlung process at the ILC.** Only possible at the ILC, this unique measurement is **indispensable for extraction of all Higgs branching ratios and couplings** from event rates. Also reported is the expected **precision for the Higgs recoil mass**, which provides a window into physics beyond the Standard Model. The study here is based on full simulation of the ILD detector as proposed in the Technical Design Report. In the clean Higgsstrahlung process, the Higgs Boson is produced together with a Z boson which decays into a well-measurable dilepton system (Z--> $\mu\mu$ or Z-->ee). In accordance with the most up to date plan of ILC accelerator operation, analysis has been carried out for three center of mass energies (Ecm) of 250, 350, and 500 GeV, and alternative beam polarization scenarios. **Methods of signal selection are optimized to achieve the best ZH cross section precision while maintaining Higgs decay mode independence.** At Ecm=250 GeV, where the best detector resolution is obtainable, the **ZH cross section can be determined with a precision of 2.7%, while the expected Higgs mass precision is 39 MeV.** (Reasonable precision a have also been demonstrated for the higher energies of 350 and 500 GeV which extend the physics reach).

BACKUP

カーネル密度推定（Kernel density estimation）

カーネル密度推定を用いて標本データの母集団のデータを外挿する

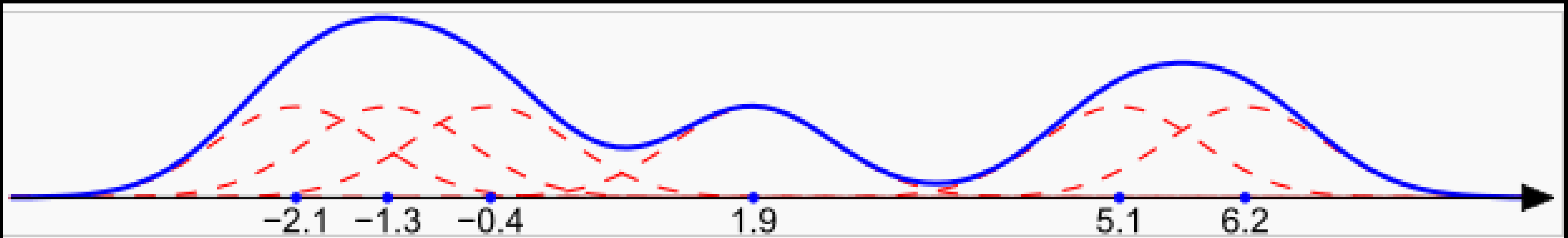
x1, x2, ..., xN　を確率変数の独立かつ同一な分布に従う標本とする
確率密度関数のカーネル密度推定は

$$\hat{f}_h(x) = \frac{1}{Nh}\sum_{i=1}^{N} K\left(\frac{x - x_i}{h}\right)$$

$$K(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}x^2}$$

K = カーネル関数 (通常 Gaus(0,1))　　h = バンド幅（平滑化パラメータ）

標本を一定幅の箱に入れて数えて漸近的に一致させているわけではない
カーネル関数から決定されたコブを各標本に与える
つまり、「コブの総和」によって推定が形成されるため、結果として非常に滑らかになる



6つのガウス曲線（赤）とそれらの総和（青）。パルツェン窓密度推定 f(x) は、この総和を6（元のガウス曲線の数）で割ることで得られる。ガウス関数の分散は 0.5 に設定されている。見ての通り、標本点が稠密にあるほど、密度推定値は大きくなる。

Efficiency of each Higgs decay mode (after each cut)

Resolved problem of poor isolation in lepton finder

Weights trained using H→qqqq

Eff. (%)	bb	cc	gg	tt	ww	zz	aa
Cut0 :	92.41 +/-0.086	92.43 +/-0.087	91.66 +/- 0.09	93.27 +/-0.081	92.67 +/-0.083	93.01 +/-0.082	92.84 +/- 0.07
Cut1 :	92.41 +/-0.086	92.43 +/-0.087	91.66 +/- 0.09	93.24 +/-0.081	92.64 +/-0.083	92.77 +/-0.083	92.83 +/- 0.07
Cut2 :	90.85 +/-0.094	90.84 +/-0.095	90.05 +/-0.098	91.37 +/-0.091	90.56 +/-0.093	90.6 +/-0.094	90.48 +/- 0.08
Cut3 :	88.92 +/- 0.1	89.07 +/- 0.1	88.23 +/- 0.11	89.39 +/-0.099	88.53 +/- 0.1	88.49 +/- 0.1	88.69 +/-0.086
Cut4 :	88.71 +/- 0.1	88.88 +/- 0.1	88.03 +/- 0.11	89.2 +/- 0.1	88.29 +/- 0.1	88.24 +/- 0.1	88.52 +/-0.087
Cut5 :	88.66 +/- 0.1	88.8 +/- 0.1	87.97 +/- 0.11	88.73 +/- 0.1	88.18 +/- 0.1	88.13 +/- 0.1	86.7 +/-0.092
Cut6 :	88.16 +/- 0.1	88.47 +/- 0.1	87.82 +/- 0.11	87.99 +/- 0.1	87.43 +/- 0.11	87.3 +/- 0.11	73.14 +/- 0.12
Cut7 :	81.72 +/- 0.13	81.74 +/- 0.13	81.23 +/- 0.13	81.62 +/- 0.13	81.04 +/- 0.13	81.14 +/- 0.13	67.98 +/- 0.13
Cut8 :	81.55 +/- 0.13	81.59 +/- 0.13	81.07 +/- 0.13	81.42 +/- 0.13	80.85 +/- 0.13	80.87 +/- 0.13	67.89 +/- 0.13

Weights trained using H→ gg

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

cut definition

```
Process: ZH --> mu+ mu- H
Polarization: (e-,e+) = (-0.8,+0.3)
----------Cuts----------
Cut  0 :
Cut  1 :   leptype==13
Cut  2 :   Ptdl>10&&abs(Minv-91.18)<40&&Mrec>100&&Mrec<300
Cut  3 :   Minv>73&&Minv<120
Cut  4 :   Ptdl>10&&Ptdl<70
Cut  5 :   (Ptsum<0||Ptsum>10)
Cut  6 :   !((Evis-Elep1-Elep2-Ephotonmax)<10&&Ephotonmax>0&&abs(cosmis)>0.98)
Cut  7 :   abs(cosz) < 0.9
Cut  8 :   Mrec>100&&Mrec<160
```

- Lepton finder efficiency rise by 2% for gg , also higher for ww
- Now gg eff consistent with bb, cc

Efficiency of each Higgs decay mode (after each cut)

Real data

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

Cheat pairing using MC truth

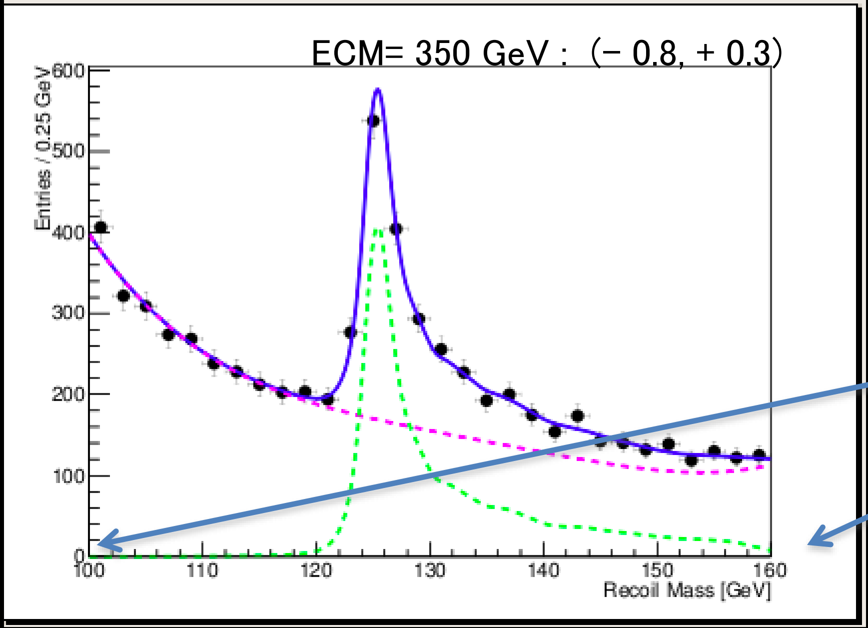
Eff. (%)	bb	cc	gg	tt	ww	zz	aa
Cut0 :	93.7 +/-0.079	93.68 +/- 0.08	93.4 +/-0.081	93.89 +/-0.077	93.62 +/-0.078	93.86 +/-0.077	93.7 +/-0.066
Cut1 :	93.7 +/-0.079	93.68 +/- 0.08	93.4 +/-0.081	93.89 +/-0.077	93.62 +/-0.078	93.86 +/-0.077	93.7 +/-0.066
Cut2 :	92.12 +/-0.087	92.06 +/-0.089	91.76 +/- 0.09	92.17 +/-0.087	91.95 +/-0.087	92.28 +/-0.086	91.24 +/-0.077
Cut3 :	90.09 +/-0.097	90.2 +/-0.098	89.84 +/-0.099	90.21 +/-0.096	90.05 +/-0.096	90.45 +/-0.094	89.38 +/-0.084
Cut4 :	89.88 +/-0.098	90.01 +/-0.098	89.64 +/-0.099	90.01 +/-0.097	89.84 +/-0.097	90.24 +/-0.095	89.21 +/-0.084
Cut5 :	89.83 +/-0.098	89.94 +/-0.099	89.57 +/- 0.1	89.54 +/-0.099	89.74 +/-0.097	90.13 +/-0.096	87.38 +/- 0.09
Cut6 :	89.28 +/- 0.1	89.58 +/- 0.1	89.42 +/- 0.1	88.79 +/- 0.1	88.97 +/- 0.1	89.31 +/-0.099	73.71 +/- 0.12
Cut7 :	82.75 +/- 0.12	82.75 +/- 0.12	82.67 +/- 0.12	82.36 +/- 0.12	82.49 +/- 0.12	82.97 +/- 0.12	68.51 +/- 0.13
Cut8 :	82.58 +/- 0.12	82.59 +/- 0.12	82.5 +/- 0.12	82.17 +/- 0.12	82.3 +/- 0.12	82.83 +/- 0.12	68.41 +/- 0.13
Cut9 :	82.58 +/- 0.12	82.59 +/- 0.12	82.5 +/- 0.12	82.17 +/- 0.12	82.3 +/- 0.12	82.83 +/- 0.12	68.41 +/- 0.13
Cut10:	74.8 +/- 0.14	74.65 +/- 0.14	74.8 +/- 0.14	74.72 +/- 0.14	74.79 +/- 0.14	75.52 +/- 0.14	64.95 +/- 0.13

eff for H→ZZ, ww is high now

	difference between real and cheat	MC stat error
bb	0.00%	0.12%
cc	0.00%	0.12%
gg	0.00%	0.12%
tt	−0.15%	0.12%
ww	−0.32%	0.12%
zz	−0.85%	0.12%
aa	−0.03%	0.13%

"cheat pairing" (MC truth) results indicate that indeed the problem is due to paring non-prompt Z decay leptons.

maybe the only problem left



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%

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	6.50%	468
	Zee	7.86%	1540
	Total	**5.01%**	**448**

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)

500 GeV : fitted over wide range

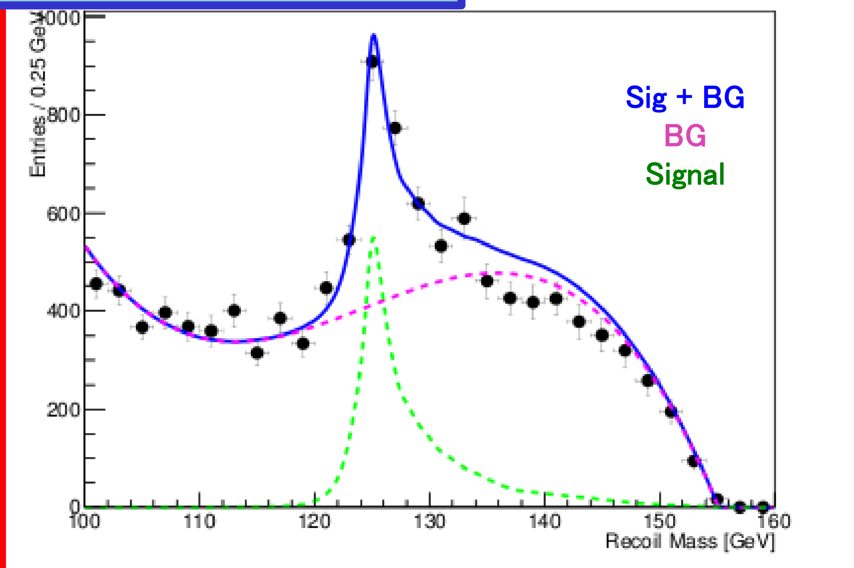
xsec error almost same as past results using GPET

(+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	7.27%	572
	Zee	7.86%	1530
	Total	**5.33%**	**536**

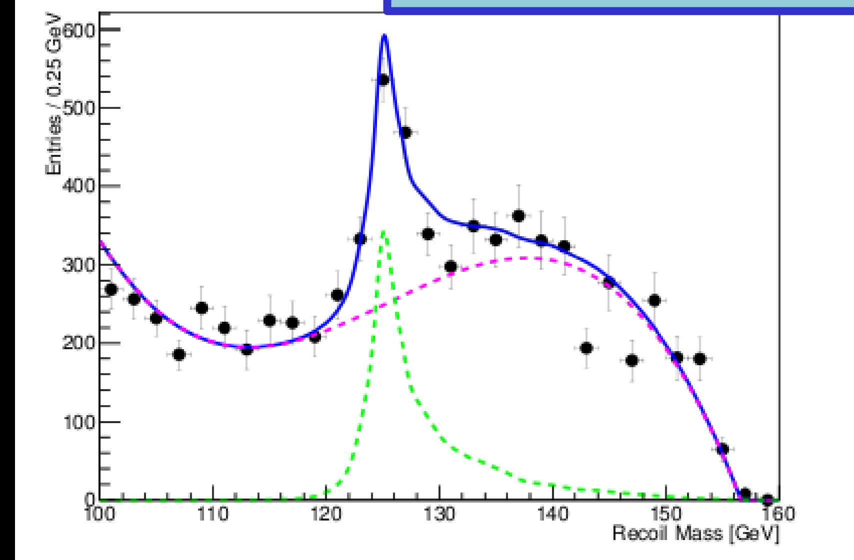
Reconstructed data
recoil mass histogram

Z→ee channel

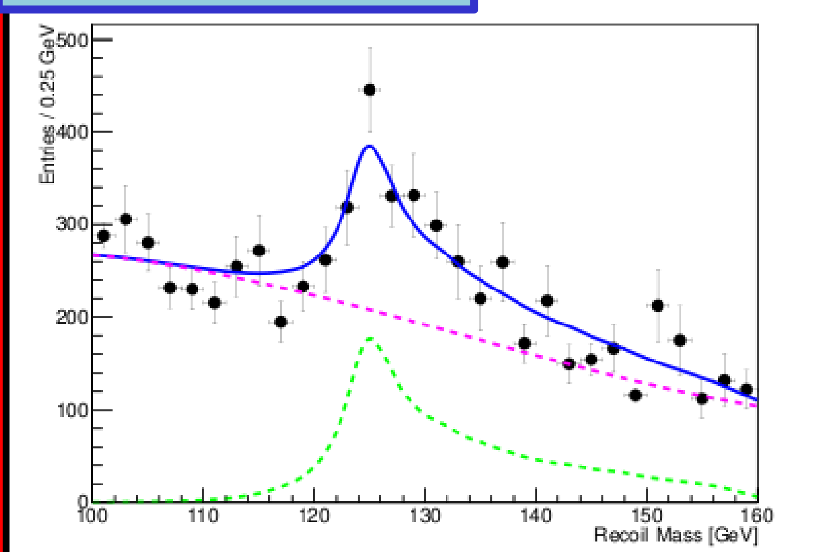
250 GeV : (− 0.8, + 0.3)



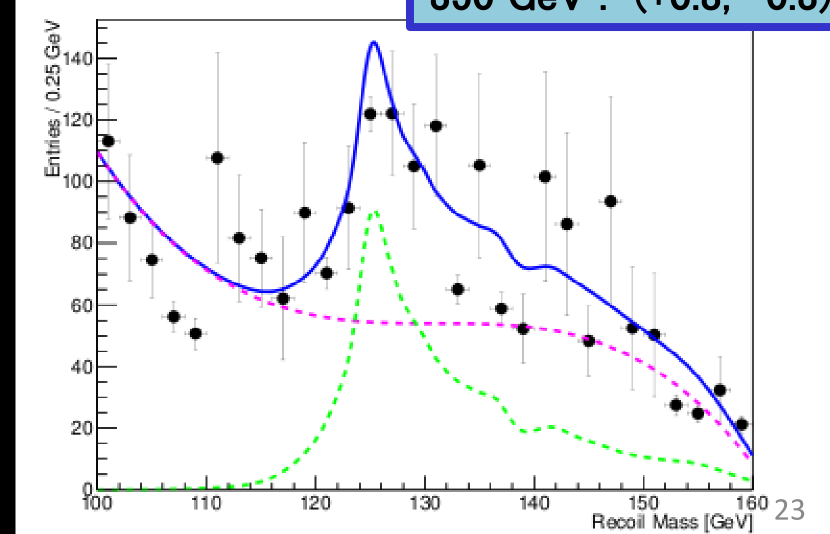
250 GeV : (+0.8, −0.3)



350 GeV : (−0.8, +0.3)



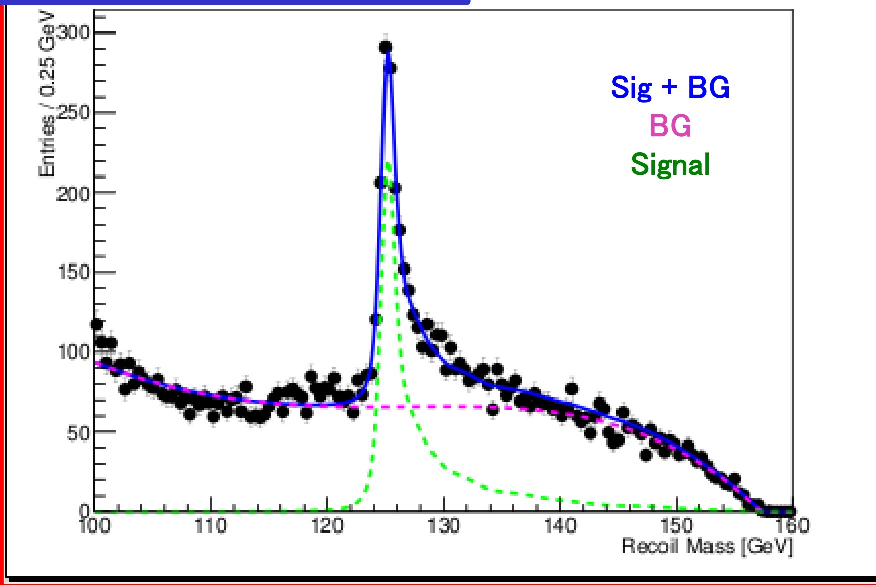
350 GeV : (+0.8, −0.3)



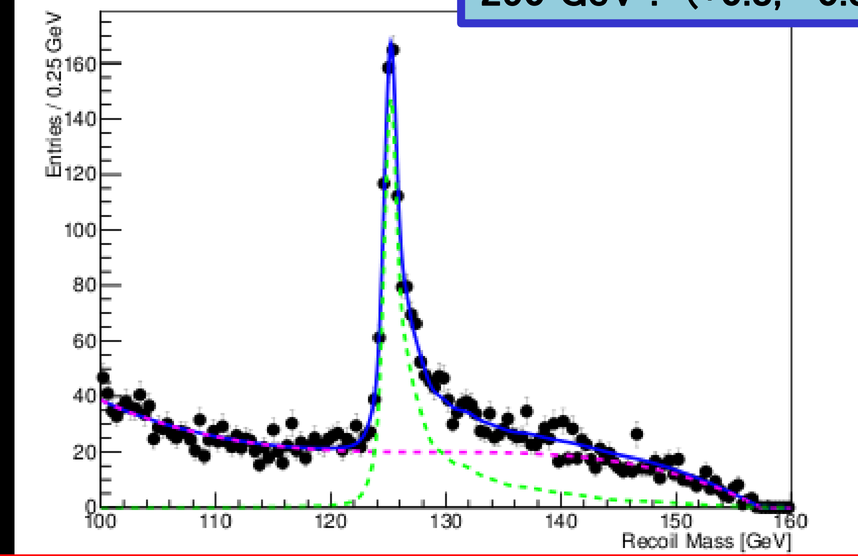
Z→μμ channel

Reconstructed data recoil mass histogram

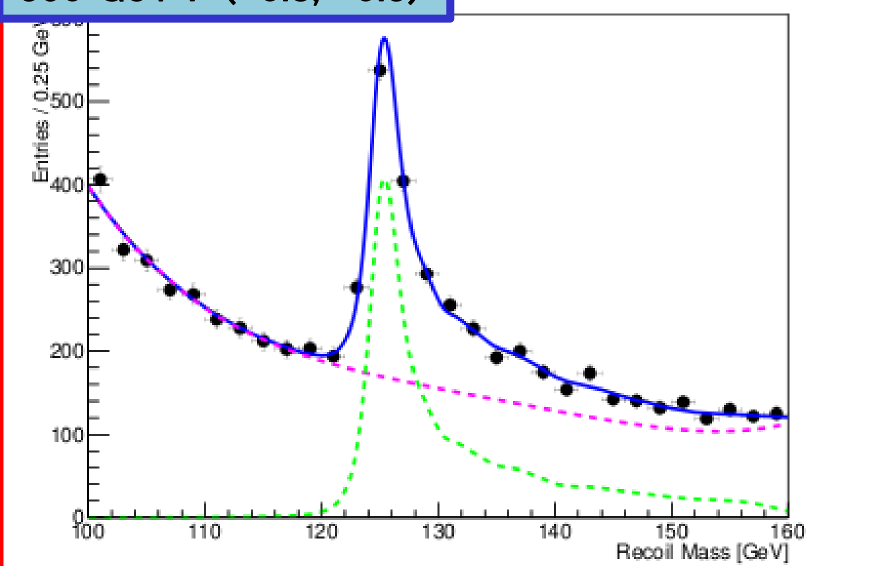
250 GeV : (− 0.8, + 0.3)



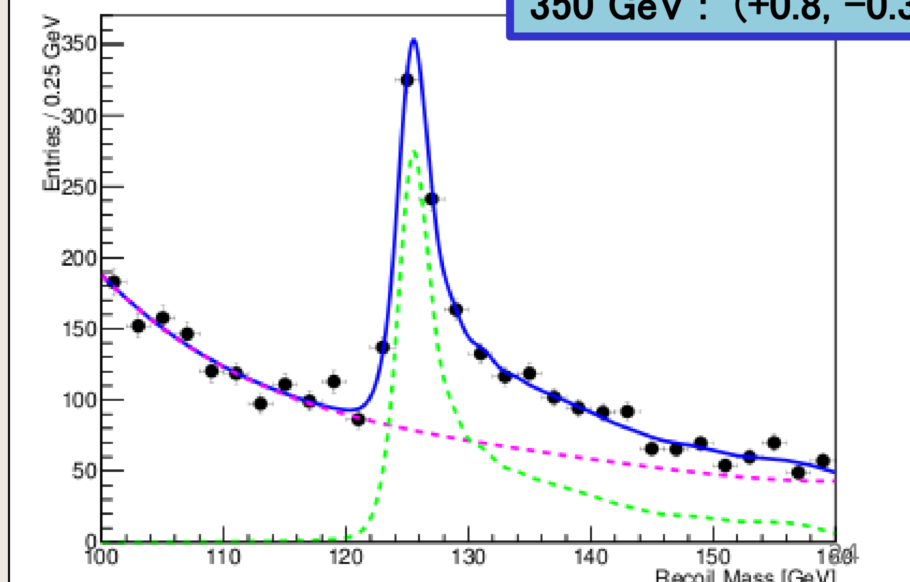
250 GeV : (+0.8, −0.3)



350 GeV : (−0.8, +0.3)

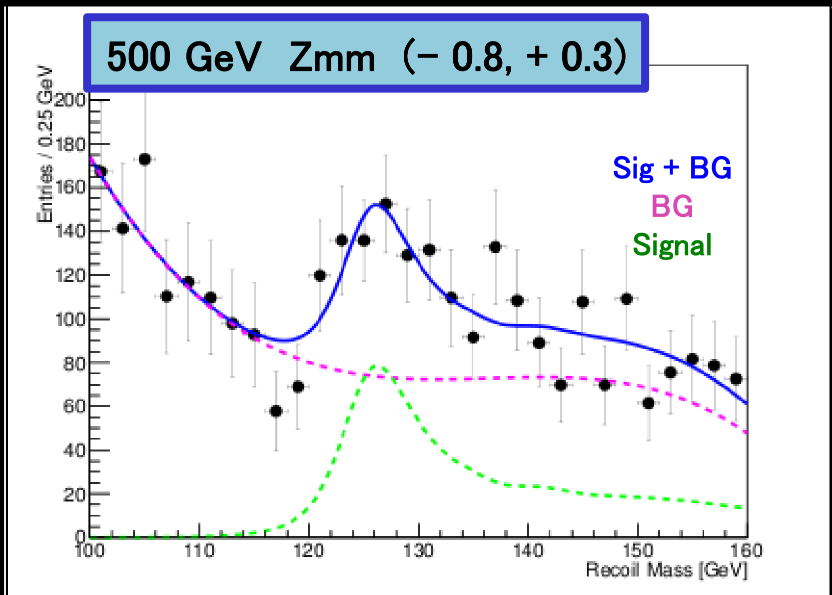


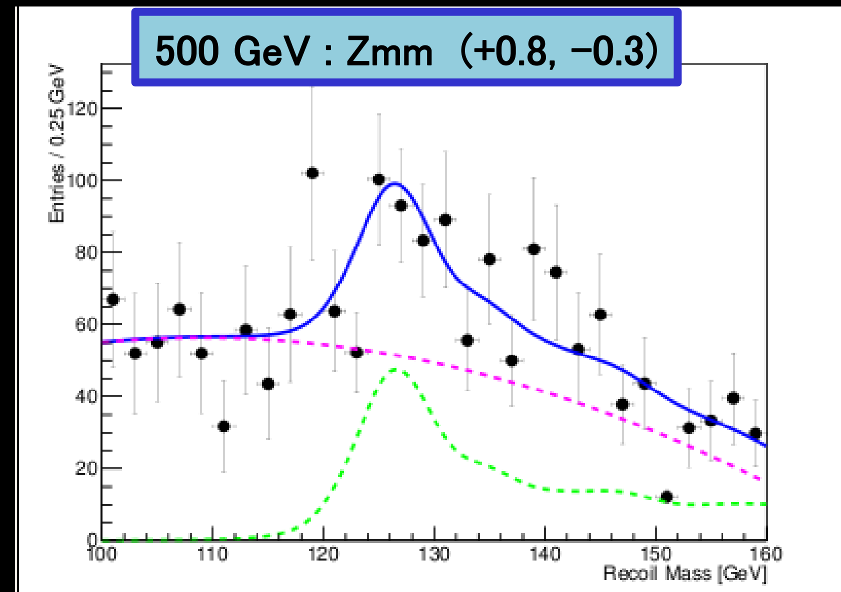
350 GeV : (+0.8, −0.3)

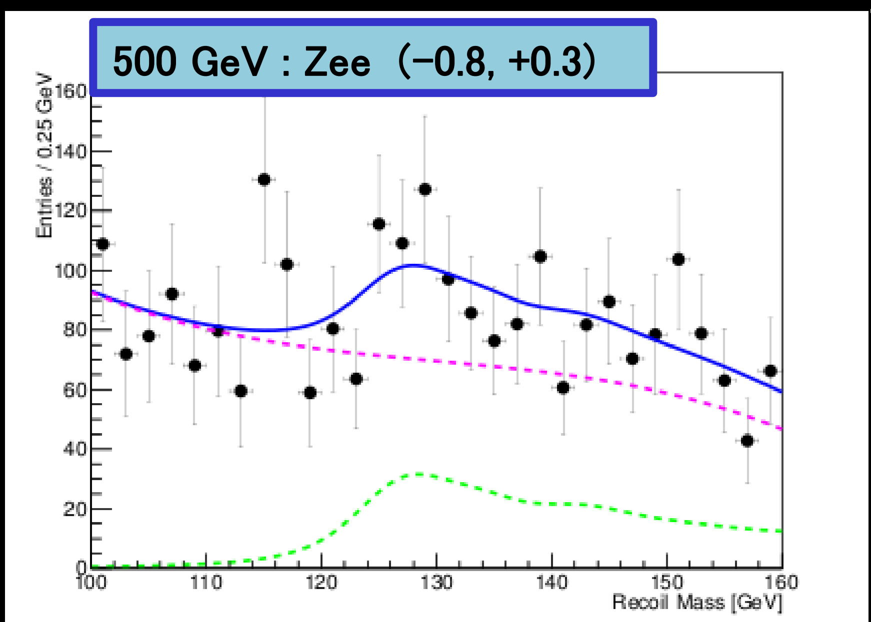


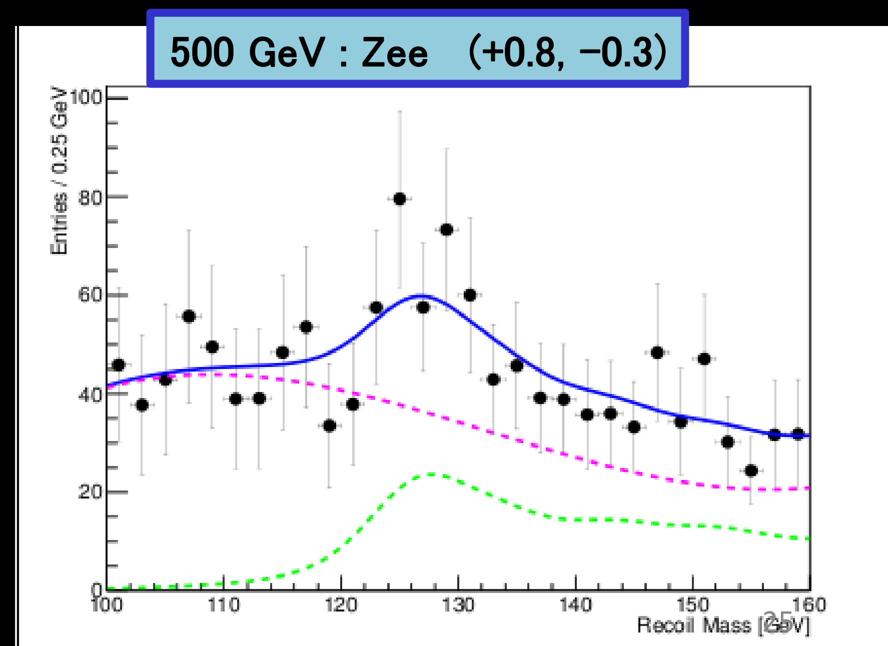
500 GeV

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





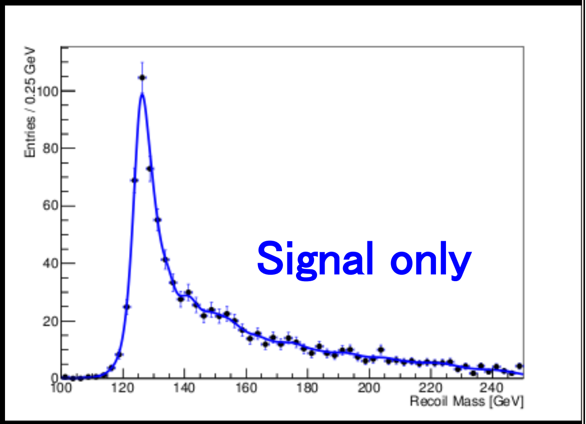


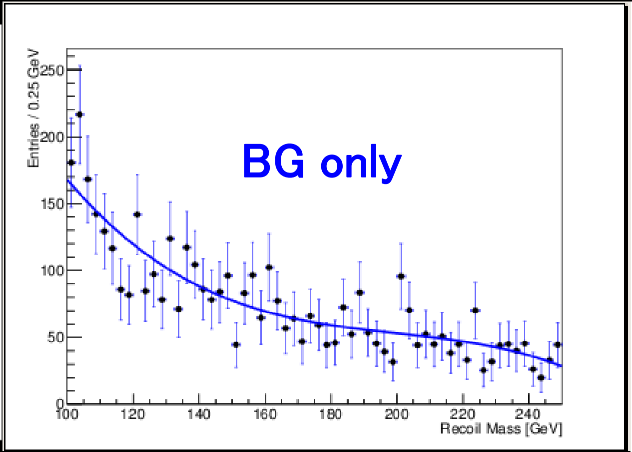


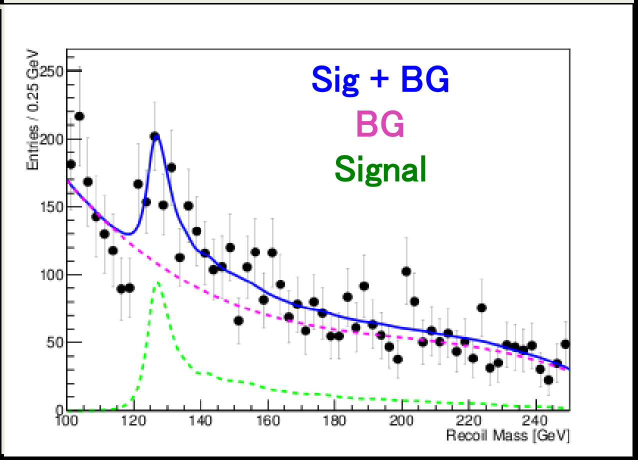
Can precision can be slightly improved if we fit over a wider range ?
assuming we can neglect the H*→WW bump beyond 160 GeV

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

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

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)

(+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**

xsec error almost same as past results using GPET

250 GeV	e2e2_Lpol				deviation	deviation
	N(100-160)	N_err	eff	eff_err	from avg	from ALL
bb	1885	5	72.40%	0.15%	0.42%	0.21%
cc	1882	5	72.29%	0.15%	0.31%	0.10%
tt	1883	5	72.33%	0.14%	0.35%	0.15%
gg	1872	5	71.91%	0.15%	-0.08%	-0.28%
ww	1866	5	71.67%	0.14%	-0.31%	-0.51%
zz	1856	5	71.29%	0.15%	-0.69%	-0.90%
all modes	1883	9	72.19%	0.27%		
		avg of 6	71.98%			

Efficiency of each Higgs decay mode (after all cuts)

- systematic bias is < **1.3% for Zmm. < 4.2% for Zee**
- **H→zz, H→ww most affected**

(lepton pair containing lepton not from prompt Z decay)

250 GeV	e1e1_Lpol				deviation	deviation
	N(100-160)	deltaN	eff	eff_err	from avg	from ALL
bb	1491	6	54.65%	0.17%	-1.15%	-0.39%
cc	1497	6	54.86%	0.16%	-0.94%	-0.18%
tt	1480	6	54.21%	0.16%	-1.58%	-0.83%
gg	1484	6	54.38%	0.16%	-1.42%	-0.66%
ww	1469	6	53.83%	0.16%	-1.96%	-1.21%
zz	1442	6	52.83%	0.16%	-2.96%	-2.21%
all modes	1502	10	55.04%	0.28%		
		avg of 6	54.13%			

Efficiency of each Higgs decay mode (after each cut)

MC truth , with costhetamiss

Eff. (%)	bb	cc	gg	tt	ww	zz	aa
Cut0 :	92.41 +/-0.086	92.43 +/-0.087	91.66 +/- 0.09	93.1 +/-0.082	92.19 +/-0.086	92.41 +/-0.085	92.83 +/- 0.07
Cut1 :	92.41 +/-0.086	92.43 +/-0.087	91.66 +/- 0.09	93.1 +/-0.082	92.19 +/-0.086	92.41 +/-0.085	92.83 +/- 0.07
Cut2 :	90.85 +/-0.094	90.84 +/-0.095	90.05 +/-0.098	91.41 +/- 0.09	90.56 +/-0.093	90.86 +/-0.093	90.51 +/- 0.08
Cut3 :	88.92 +/- 0.1	89.07 +/- 0.1	88.23 +/- 0.11	89.52 +/-0.099	88.74 +/- 0.1	89.11 +/- 0.1	88.72 +/-0.086
Cut4 :	88.71 +/- 0.1	88.88 +/- 0.1	88.03 +/- 0.11	89.33 +/- 0.1	88.54 +/- 0.1	88.91 +/- 0.1	88.55 +/-0.087
Cut5 :	88.66 +/- 0.1	88.8 +/- 0.1	87.97 +/- 0.11	88.87 +/- 0.1	88.44 +/- 0.1	88.8 +/- 0.1	86.73 +/-0.092
Cut6 :	88.16 +/- 0.1	88.47 +/- 0.1	87.82 +/- 0.11	88.12 +/- 0.1	87.69 +/- 0.11	88.01 +/- 0.1	73.17 +/- 0.12
Cut7 :	81.72 +/- 0.13	81.74 +/- 0.13	81.23 +/- 0.13	81.74 +/- 0.12	81.29 +/- 0.12	81.76 +/- 0.12	68.01 +/- 0.13
Cut8 :	81.55 +/- 0.13	81.59 +/- 0.13	81.07 +/- 0.13	81.54 +/- 0.13	81.12 +/- 0.13	81.61 +/- 0.12	67.92 +/- 0.13
Cut9 :	81.55 +/- 0.13	81.59 +/- 0.13	81.07 +/- 0.13	81.54 +/- 0.13	81.12 +/- 0.13	81.61 +/- 0.12	67.92 +/- 0.13
Cut10:	74 +/- 0.14	73.88 +/- 0.14	73.63 +/- 0.14	74.22 +/- 0.14	73.8 +/- 0.14	74.53 +/- 0.14	64.49 +/- 0.13

MC Truth, no costhetamis

Eff. (%)	bb	cc	gg	tt	ww	zz	aa
Cut0 :	92.41 +/-0.086	92.43 +/-0.087	91.66 +/- 0.09	93.1 +/-0.082	92.19 +/-0.086	92.41 +/-0.085	92.83 +/- 0.07
Cut1 :	92.41 +/-0.086	92.43 +/-0.087	91.66 +/- 0.09	93.1 +/-0.082	92.19 +/-0.086	92.41 +/-0.085	92.83 +/- 0.07
Cut2 :	90.85 +/-0.094	90.84 +/-0.095	90.05 +/-0.098	91.41 +/- 0.09	90.56 +/-0.093	90.86 +/-0.093	90.51 +/- 0.08
Cut3 :	88.92 +/- 0.1	89.07 +/- 0.1	88.23 +/- 0.11	89.52 +/-0.099	88.74 +/- 0.1	89.11 +/- 0.1	88.72 +/-0.086
Cut4 :	88.71 +/- 0.1	88.88 +/- 0.1	88.03 +/- 0.11	89.33 +/- 0.1	88.54 +/- 0.1	88.91 +/- 0.1	88.55 +/-0.087
Cut5 :	88.66 +/- 0.1	88.8 +/- 0.1	87.97 +/- 0.11	88.87 +/- 0.1	88.44 +/- 0.1	88.8 +/- 0.1	86.73 +/-0.092
Cut6 :	88.66 +/- 0.1	88.8 +/- 0.1	87.97 +/- 0.11	88.87 +/- 0.1	88.44 +/- 0.1	88.8 +/- 0.1	86.73 +/-0.092
Cut7 :	82.09 +/- 0.12	82.01 +/- 0.13	81.35 +/- 0.13	82.25 +/- 0.12	81.93 +/- 0.12	82.32 +/- 0.12	80.3 +/- 0.11
Cut8 :	81.92 +/- 0.12	81.86 +/- 0.13	81.19 +/- 0.13	82.06 +/- 0.12	81.76 +/- 0.12	82.18 +/- 0.12	80.12 +/- 0.11
Cut9 :	81.92 +/- 0.12	81.86 +/- 0.13	81.19 +/- 0.13	82.06 +/- 0.12	81.76 +/- 0.12	82.18 +/- 0.12	80.12 +/- 0.11
Cut10:	74.35 +/- 0.14	74.11 +/- 0.14	73.74 +/- 0.14	74.63 +/- 0.14	74.38 +/- 0.14	75.01 +/- 0.14	72.98 +/- 0.12

cut definition

```
Process: ZH --> mu+ mu- H
Polarization: (e-,e+) = (-0.8,+0.3)
----------Cuts----------
Cut  0 :
Cut  1 :    leptype==13
Cut  2 :    Ptdl>10&&abs(Minv-91.18)<40&&Mrec>100&&Mrec<300
Cut  3 :    Minv>73&&Minv<120
Cut  4 :    Ptdl>10&&Ptdl<70
Cut  5 :    (Ptsum<0||Ptsum>10)
Cut  6 :    !((Evis-Elep1-Elep2-Ephotonmax)<10&&Ephotonmax>0&&abs(cosmis)>0.98)
Cut  7 :    abs(cosz) < 0.9
Cut  8 :    Mrec>100&&Mrec<160
```

If omit costhetamiss cut

- Bias on aa mode is greatly reduced by a factor of 10
- Remaining bias from Minv and Ptsum cut

Efficiency of each Higgs decay mode (after each cut)

MC truth , with costhetamiss

Eff. (%)	bb	cc	gg	tt	ww	zz	aa
Cut0 :	87.86 +/- 0.11	87.72 +/- 0.11	87.02 +/- 0.11	88.21 +/- 0.1	87.91 +/- 0.11	87.98 +/- 0.1	88.84 +/-0.083
Cut1 :	87.86 +/- 0.11	87.72 +/- 0.11	87.02 +/- 0.11	88.21 +/- 0.1	87.91 +/- 0.11	87.98 +/- 0.1	88.84 +/-0.083
Cut2 :	86.23 +/- 0.12	86.12 +/- 0.11	85.33 +/- 0.11	86.45 +/- 0.11	86.3 +/- 0.11	86.24 +/- 0.11	86.06 +/-0.091
Cut3 :	84.15 +/- 0.12	84.05 +/- 0.12	83.28 +/- 0.12	84.23 +/- 0.12	84.17 +/- 0.12	84.09 +/- 0.12	83.89 +/-0.096
Cut4 :	84.05 +/- 0.12	83.96 +/- 0.12	83.2 +/- 0.12	84.13 +/- 0.12	84.06 +/- 0.12	83.99 +/- 0.12	83.8 +/-0.097
Cut5 :	84 +/- 0.13	83.88 +/- 0.12	83.13 +/- 0.12	83.68 +/- 0.12	83.97 +/- 0.12	83.88 +/- 0.12	82.09 +/- 0.1
Cut6 :	83.51 +/- 0.13	83.54 +/- 0.12	82.95 +/- 0.12	83 +/- 0.12	83.19 +/- 0.12	83.13 +/- 0.12	70.04 +/- 0.12
Cut7 :	77.41 +/- 0.14	77.53 +/- 0.14	76.82 +/- 0.14	77.22 +/- 0.13	77.15 +/- 0.14	77.36 +/- 0.13	65.13 +/- 0.13
Cut8 :	77.22 +/- 0.14	77.3 +/- 0.14	76.56 +/- 0.14	77 +/- 0.14	76.93 +/- 0.14	77.11 +/- 0.13	64.97 +/- 0.13
Cut9 :	77.22 +/- 0.14	77.3 +/- 0.14	76.56 +/- 0.14	77 +/- 0.14	76.93 +/- 0.14	77.11 +/- 0.13	64.97 +/- 0.13
Cut10:	68.76 +/- 0.16	68.64 +/- 0.15	68.35 +/- 0.15	68.83 +/- 0.15	68.48 +/- 0.15	69 +/- 0.15	60.27 +/- 0.13

MC Truth, no costhetamis

Eff. (%)	bb	cc	gg	tt	ww	zz	aa
Cut0 :	87.86 +/- 0.11	87.72 +/- 0.11	87.02 +/- 0.11	88.21 +/- 0.1	87.91 +/- 0.11	87.98 +/- 0.1	88.84 +/-0.083
Cut1 :	87.86 +/- 0.11	87.72 +/- 0.11	87.02 +/- 0.11	88.21 +/- 0.1	87.91 +/- 0.11	87.98 +/- 0.1	88.84 +/-0.083
Cut2 :	86.23 +/- 0.12	86.12 +/- 0.11	85.33 +/- 0.11	86.45 +/- 0.11	86.3 +/- 0.11	86.24 +/- 0.11	86.06 +/-0.091
Cut3 :	84.15 +/- 0.12	84.05 +/- 0.12	83.28 +/- 0.12	84.23 +/- 0.12	84.17 +/- 0.12	84.09 +/- 0.12	83.89 +/-0.096
Cut4 :	84.05 +/- 0.12	83.96 +/- 0.12	83.2 +/- 0.12	84.13 +/- 0.12	84.06 +/- 0.12	83.99 +/- 0.12	83.8 +/-0.097
Cut5 :	84 +/- 0.13	83.88 +/- 0.12	83.13 +/- 0.12	83.68 +/- 0.12	83.97 +/- 0.12	83.88 +/- 0.12	82.09 +/- 0.1
Cut6 :	84 +/- 0.13	83.88 +/- 0.12	83.13 +/- 0.12	83.68 +/- 0.12	83.97 +/- 0.12	83.88 +/- 0.12	82.09 +/- 0.1
Cut7 :	77.82 +/- 0.14	77.82 +/- 0.14	76.96 +/- 0.14	77.71 +/- 0.13	77.82 +/- 0.13	77.91 +/- 0.13	76.11 +/- 0.11
Cut8 :	77.62 +/- 0.14	77.59 +/- 0.14	76.71 +/- 0.14	77.49 +/- 0.13	77.6 +/- 0.14	77.67 +/- 0.13	75.87 +/- 0.11
Cut9 :	77.62 +/- 0.14	77.59 +/- 0.14	76.71 +/- 0.14	77.49 +/- 0.13	77.6 +/- 0.14	77.67 +/- 0.13	75.87 +/- 0.11
Cut10:	69.11 +/- 0.16	68.9 +/- 0.15	68.46 +/- 0.15	69.24 +/- 0.15	69.08 +/- 0.15	69.46 +/- 0.15	67.84 +/- 0.12

cut definition

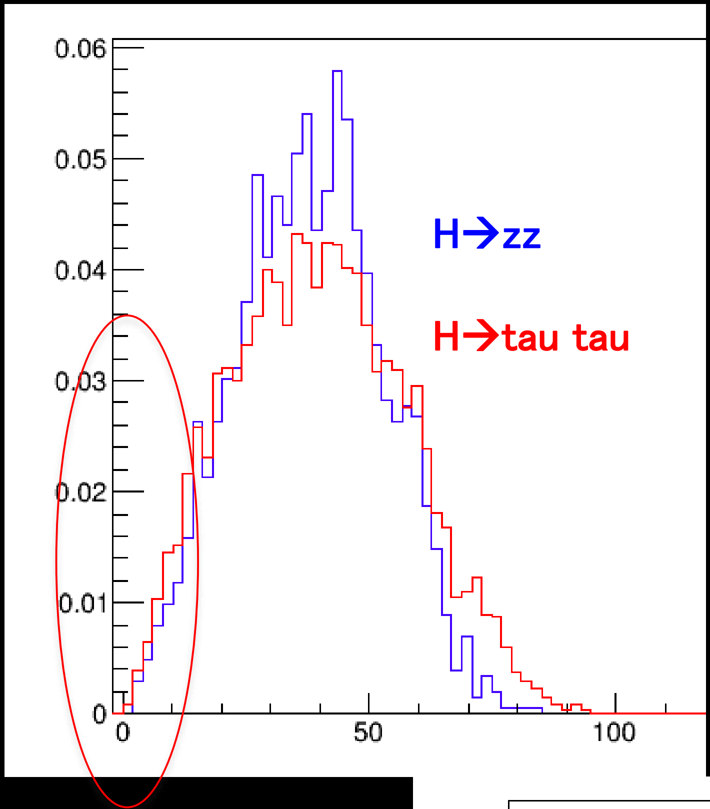
```
Process: ZH --> e+ e- H
Polarization: (e-,e+) = (-0.8,+0.3)
----------Cuts----------
Cut  0 :
Cut  1 :    leptype==11
Cut  2 :    Ptdl>10&&abs(Minv-91.18)<60&&Mrec>100&&Mrec<300
Cut  3 :    Minv>73&&Minv<120
Cut  4 :    Ptdl>10&&Ptdl<70
Cut  5 :    (Ptsum<0||Ptsum>10)
Cut  6 :    !((Evis-Elep1-Elep2-Ephotonmax)<10&&Ephotonmax>0&&abs(cosmis)>0.98)
Cut  7 :    abs(cosz) < 0.9
Cut  8 :    Mrec>100&&Mrec<160
```

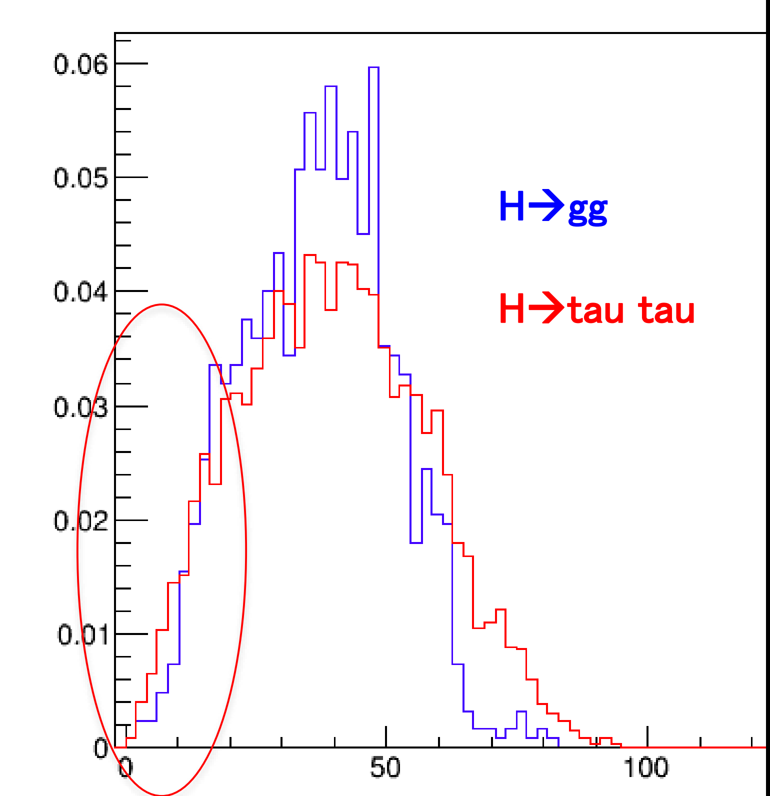
If omit costhetamiss cut

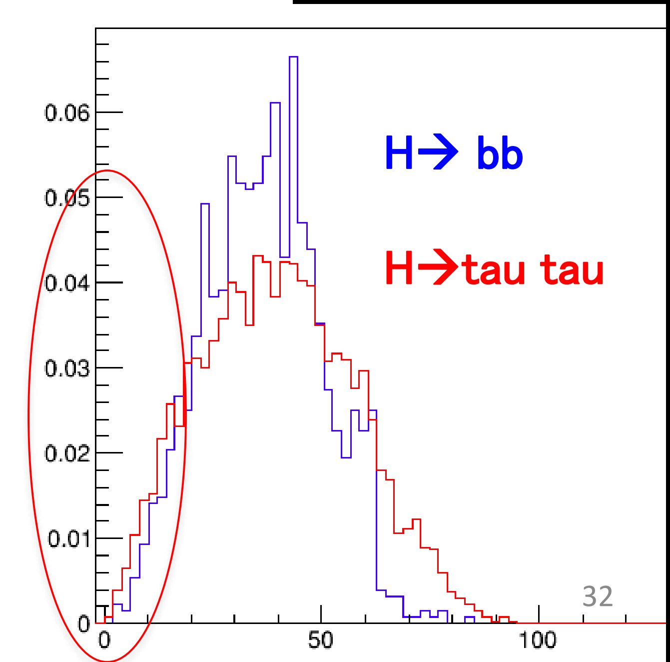
- Bias on aa mode is greatly reduced by a factor of 10
- Remaining bias from Minv and Ptsum cut

observation of Ptsum distr
(at stage just before Ptsum cut)
Zmm channel

Compare to other modes,
H→tau tau seem very slightly biased in region of Ptsum < 10

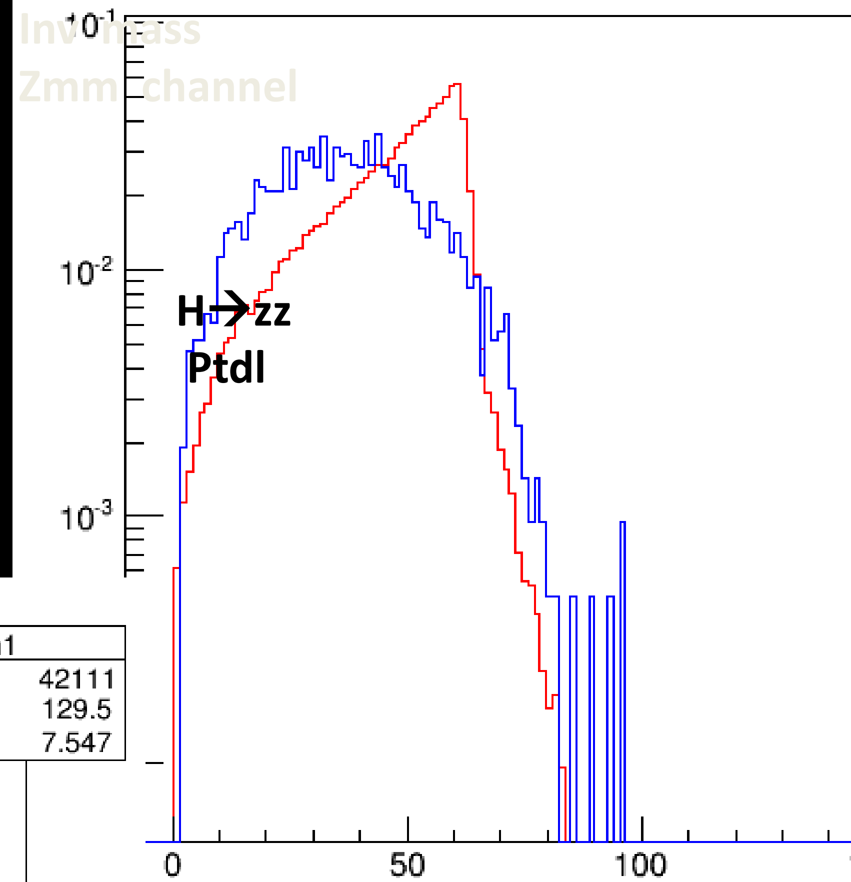






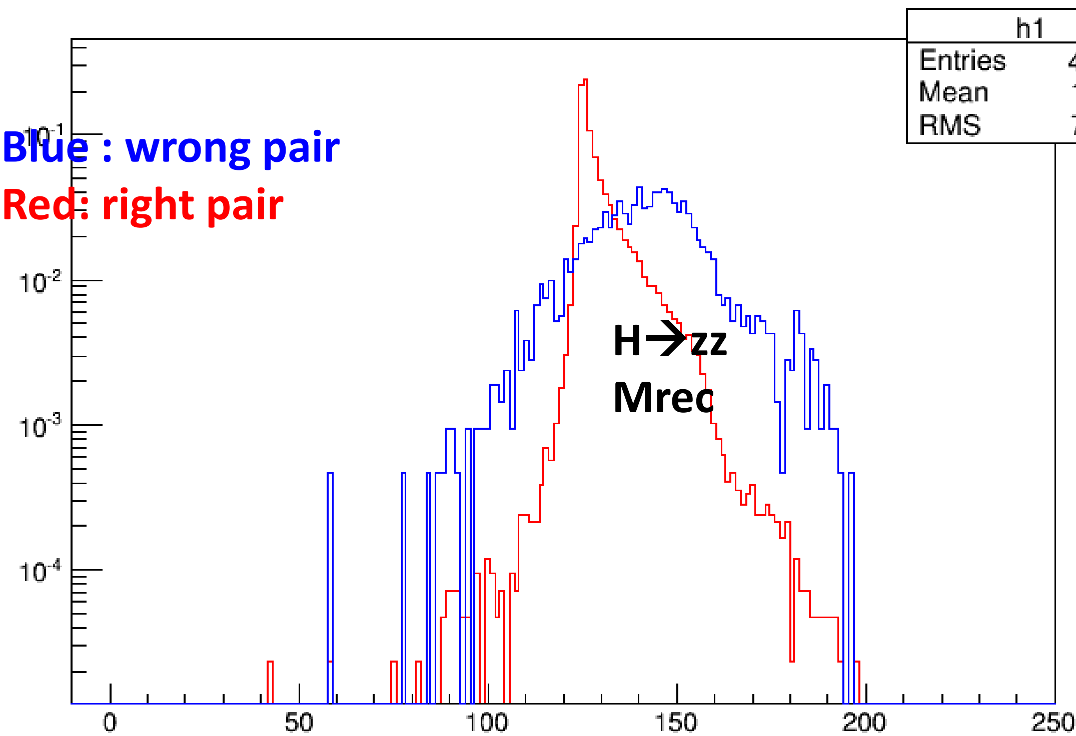
H→zz mode

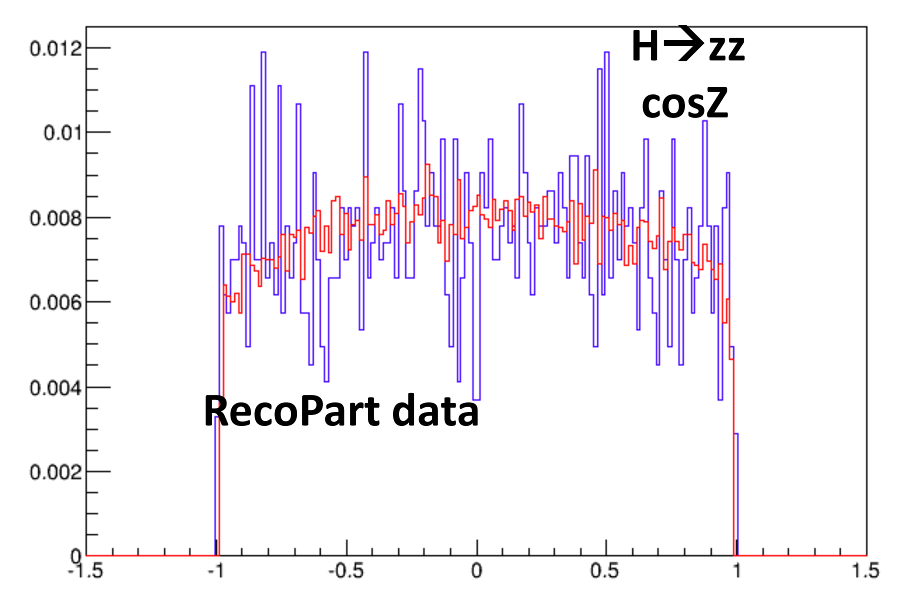
Events satisfy |Minv-MZ|<40 GeV

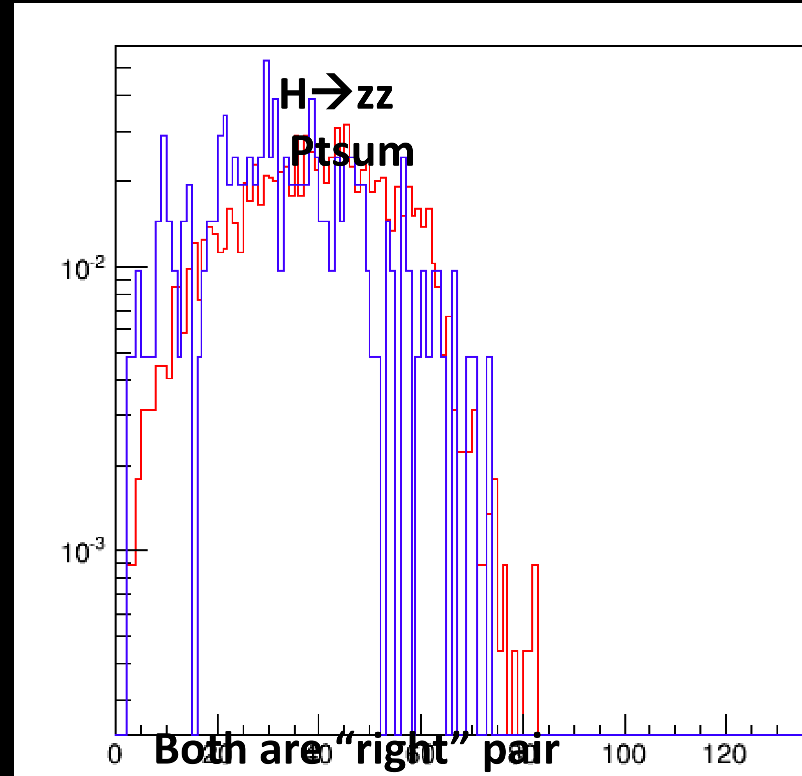


Blue : wrong pair

Red: right pair

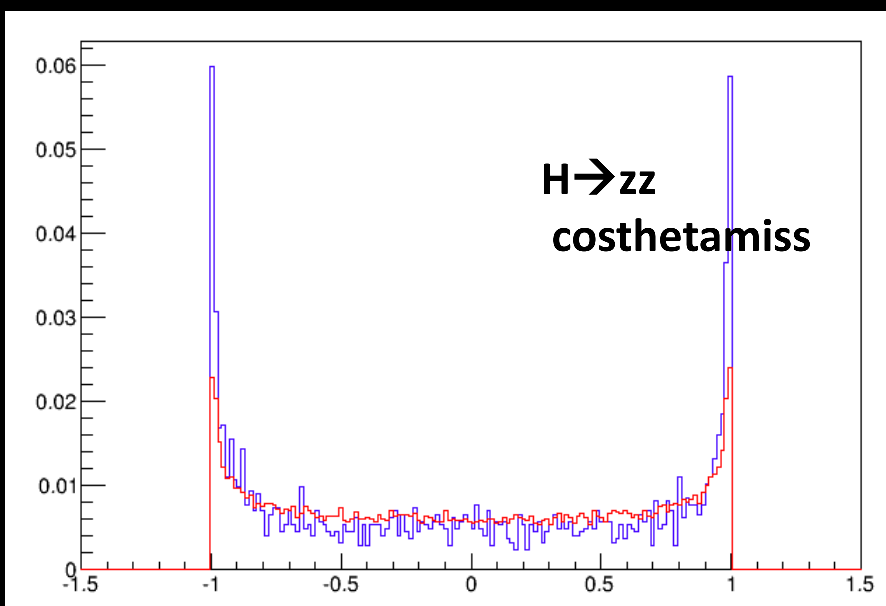


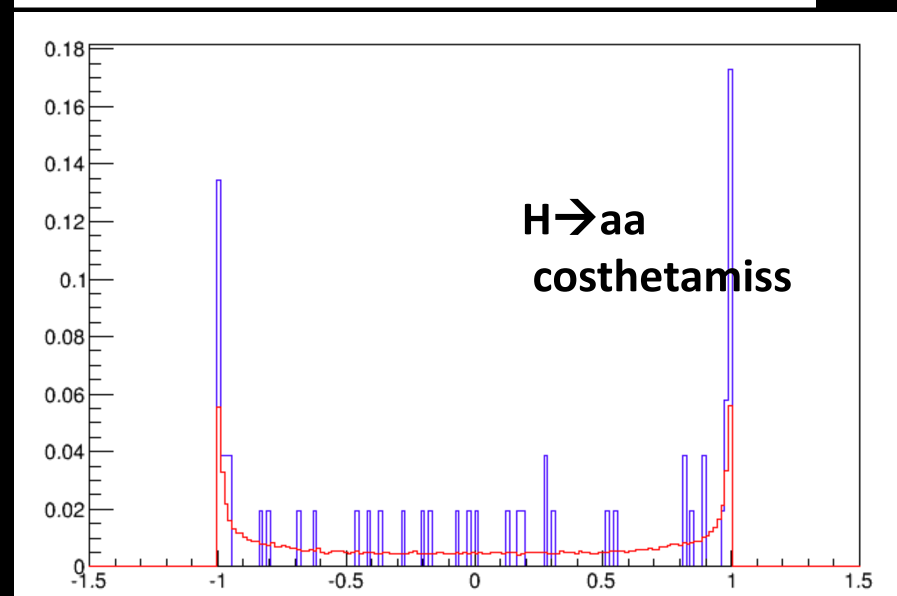




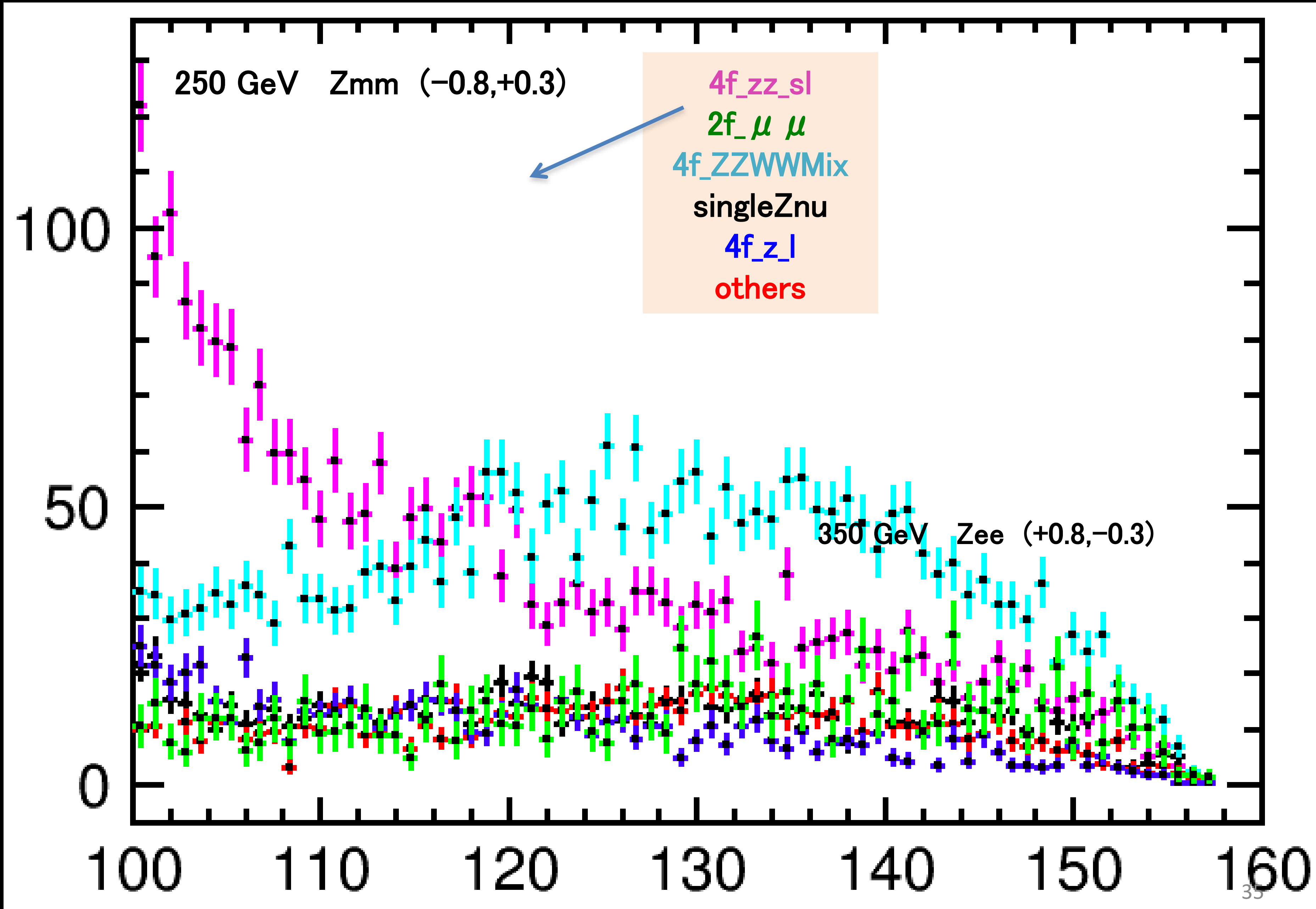
Blue : wrong pair

Red: right pair

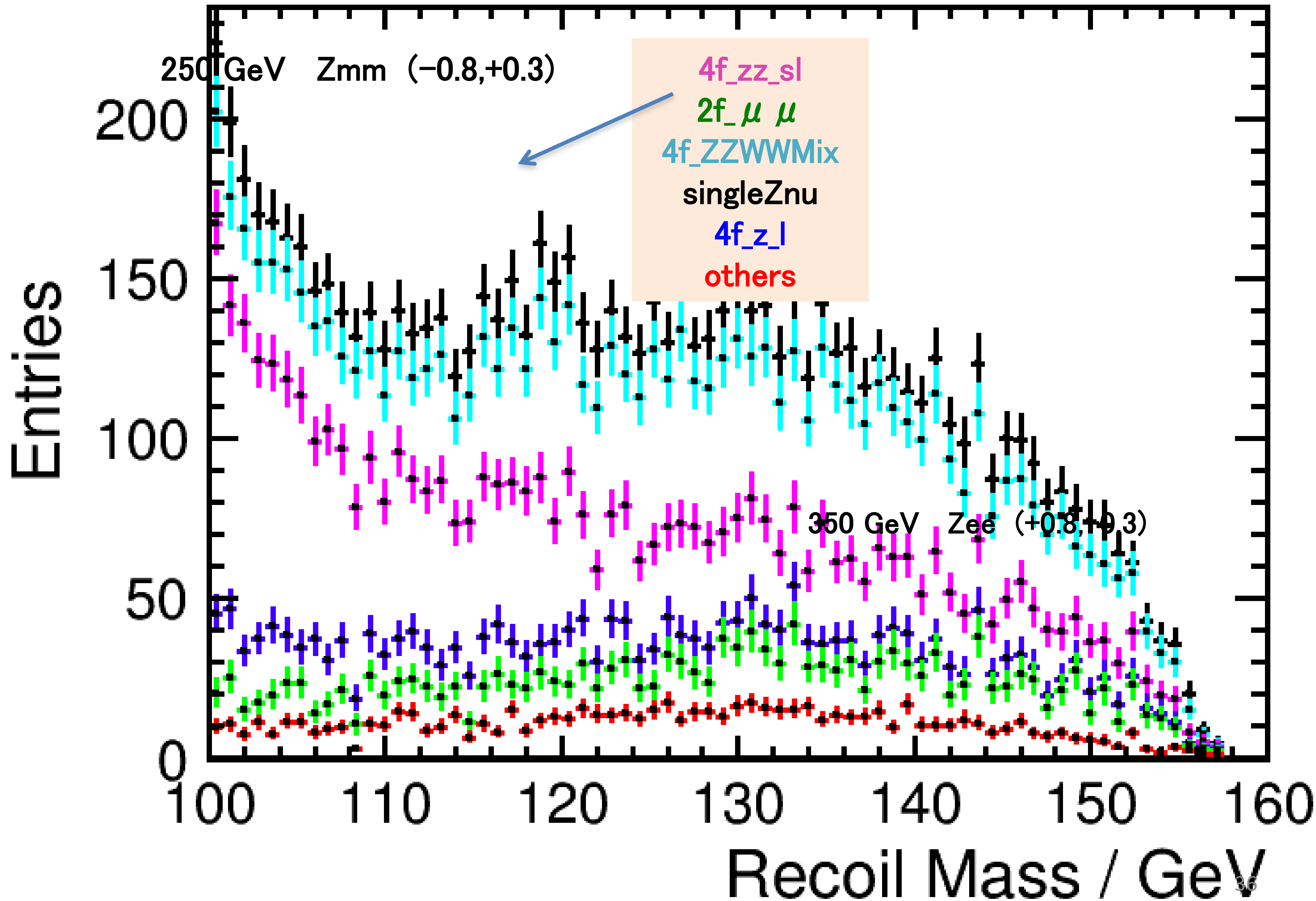




250 GeV Zmm left pol



250 GeV Zmm left pol



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 ?)