Higgs recoil mass study

ILC Physics Meeting
2/20/2015

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Z→ $\mu\ \mu$ at ECM = 350 GeV

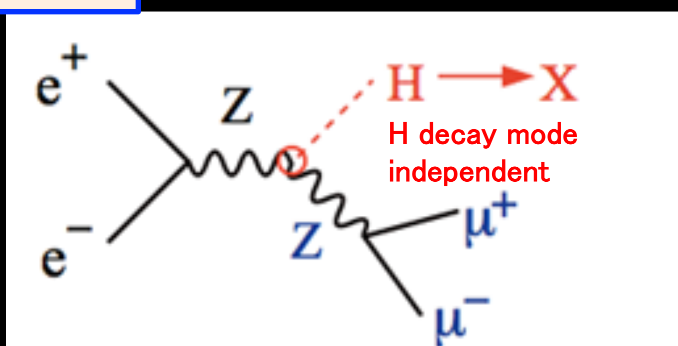
Rehabilitation of ZH recoil studies

- re−check and organize analysis results
- Investigating improved analysis methods
- reviewing the comparison of (e−, e+) = (−0.8,+0.3) , (+0.8, − 0.3) , (−0.8, 0), (0,0)
- beginning to implement likelihood cut at end of final selection

ILC sample used in analysis

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

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



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

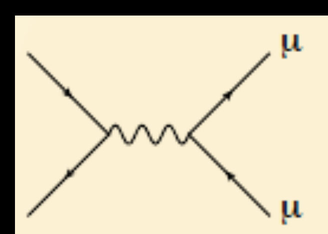
Higgs recoil against di−lepton ($\mu\ \mu$) system

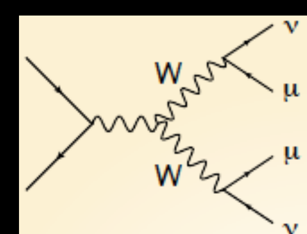
BG :

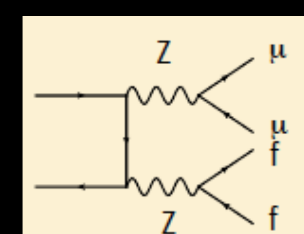
all 2f, 4f, 6f processes

major BG after event selection:

$\mu\ \mu$ 、 $\mu\ \mu\ \nu\ \nu$ 、 $\mu\ \mu$ ff







Study Plans in the Future : Evaluation of Luminosity Spectrum

Due to beam-beam effects, **collision occur below nominal ECM** i.e. ECM' < ECM

➔ **luminosity spectrum** (dL/dE_{CM}') (distr. of Nsig w.r.t. effective ECM')

- important for precision measurements requiring knowledge of σ

  e.g. Top mass , Higgs recoil mass , etc…….

accelerator and beam-beam factors affect ECM

difficult to simulate/ calculate

- ISR : relatively easy to calculate
- Beam energy spread : depend on RF phase and beam bunch length
- Beamstrahlung : depend on geometry of colliding bunches, energy correlation of 2 bunches

goal of study :

- precise evaluation of **Lumi spec and its effect on physics**
- apply experience in accelerator and beam physics to achieve more realistic simulations
- Study **systematic errors of reconstructed L spec from beam effects, detector simulation, physics BG**

Evaluate effective cross section

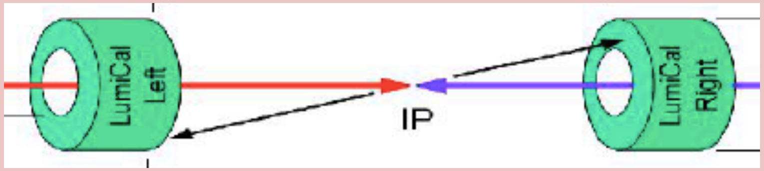
correct for beam beam effects

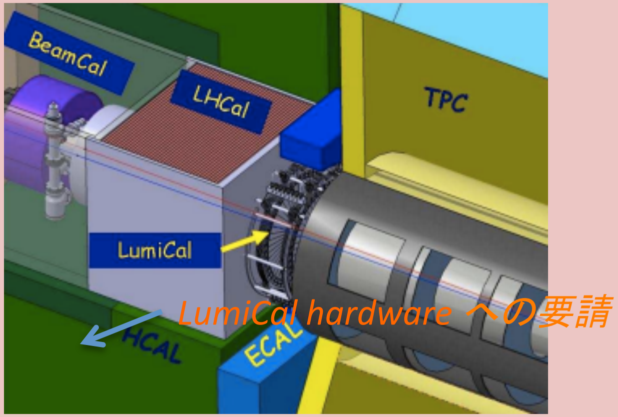
$$\sigma_{eff} = \int_0^{x_{max}} dx \cdot L(x)\sigma\left(x\sqrt{s}\right)$$

Study Plans in the (far) Future : Evaluation of Luminosity Spectrum

precision monitor to measure L : **LumiCal**

- 2.5 m from IP、30-80 mrad
- 2 calorimeters: W absorber, Si sensor pads sandwiched





Use **Bhabha scattering** to measure Luminosity

well known properties and sufficient statistics: $L = N_B/\sigma_B$

- Measures **angle (θ) and E of scattered e+e-**
- goal L precision : $O(10^{-3})$

(c.f. My past research in ILC accelerator was in aim of high “peak luminosity)

Strategy: (1) **reconstruct L spec as a function of x’ = ECM’ / ECM**

the simplest way: x’ is measured using **acollinearity of outgoing particles**

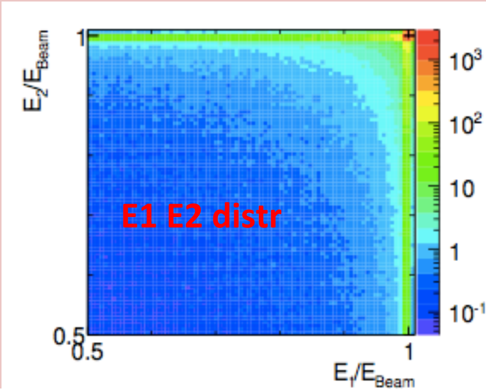
However, if we aim for higher precision, it is not so easy

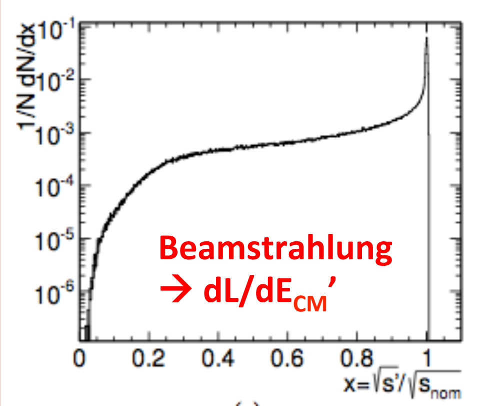
also need to take account of boost of initial system,

energy correlation between 2 particles

(2) **reconstruct L spec using a template fit using info of both E and θ**

Calculate distr of 4−vectors of Bhabha electrons





event selection

Cut values optimized in terms of signal efficiency and $\Delta\sigma/\sigma$

Muon Selection

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

Best muon pair candidate Selection

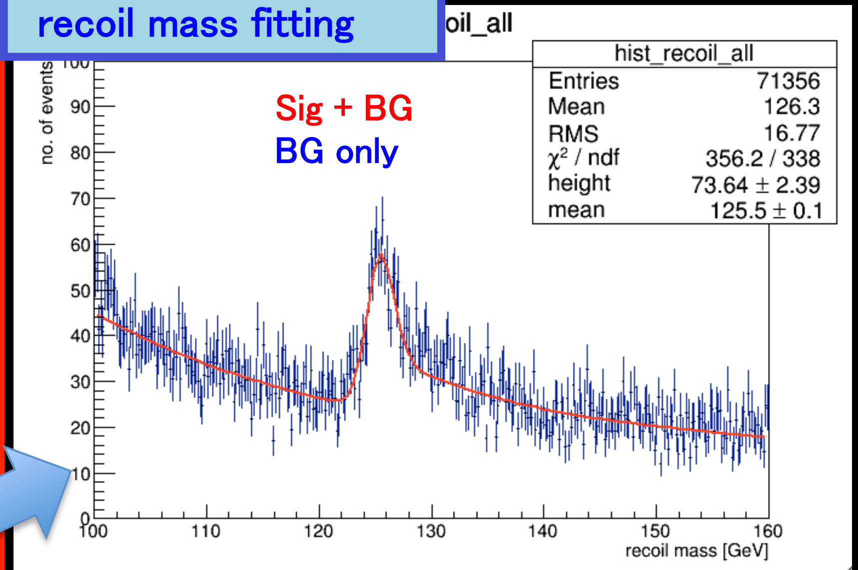
- **opposite charge**
- **invariant mass closest to Z mass**

Final Selection

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

120 GeV < Mrecoil < 140 GeV

recoil mass fitting



- **Signal : GPET**
- **BG: 3rd order polynomial**

definition

- M_inv : invariant mass of 2 muons
- pT_mumu : pT of reconstructed muons
- pTγ_max : pT of most energetic photon
- θ_Zpro = Z production angle

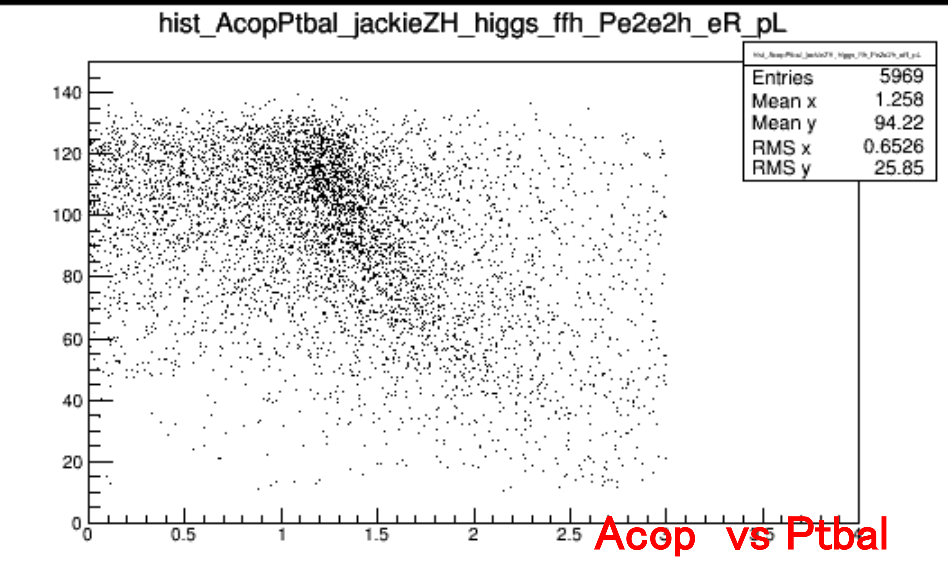
Final result: ECM =350 GeV

- **Eff_sig= 47.7 +/- 0.5%**
- S/B = 0.40, significance = 17.2

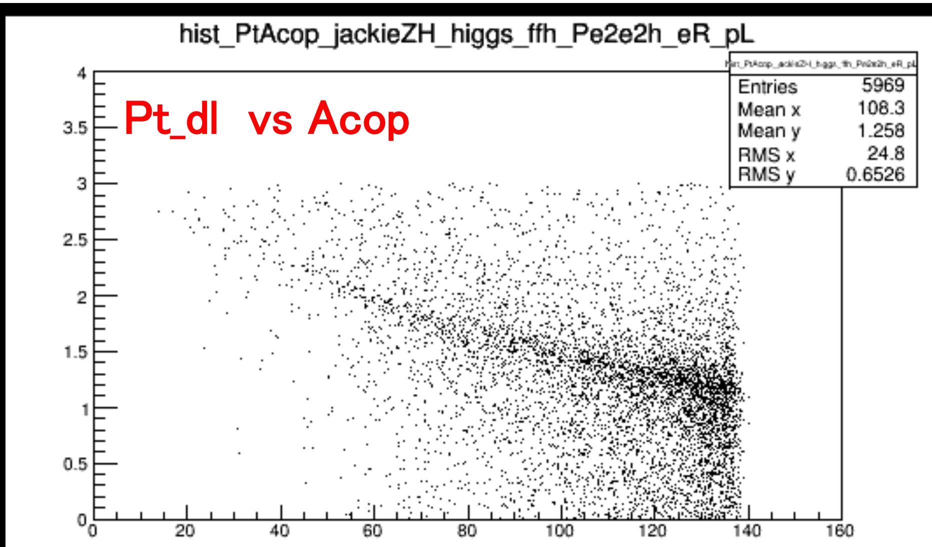
selection of parameters for use in Likelihood cut

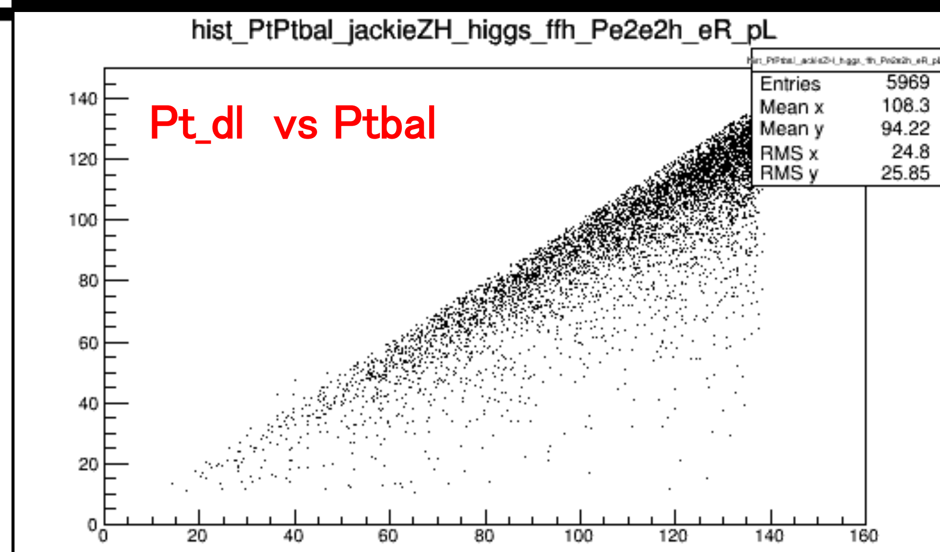
- 84 GeV < M_inv < 98 GeV
- 10 GeV < pT_mumu < 140 GeV
- dptbal = |pT_mumu – pTγ_max| > 10 GeV
- coplanarity < 3
- |cos(θ_Zpro)| < 0.91

120 GeV < Mrecoil < 140 GeV

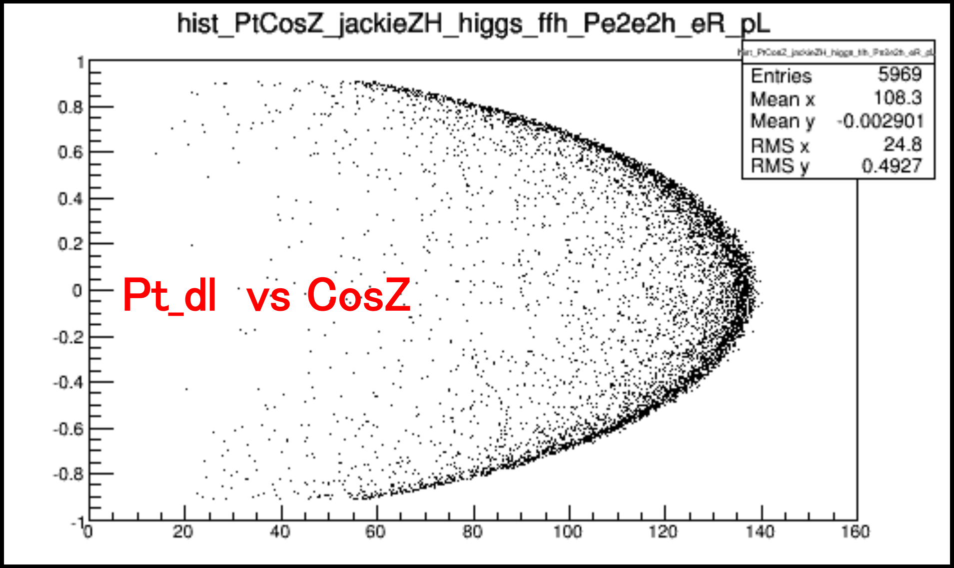


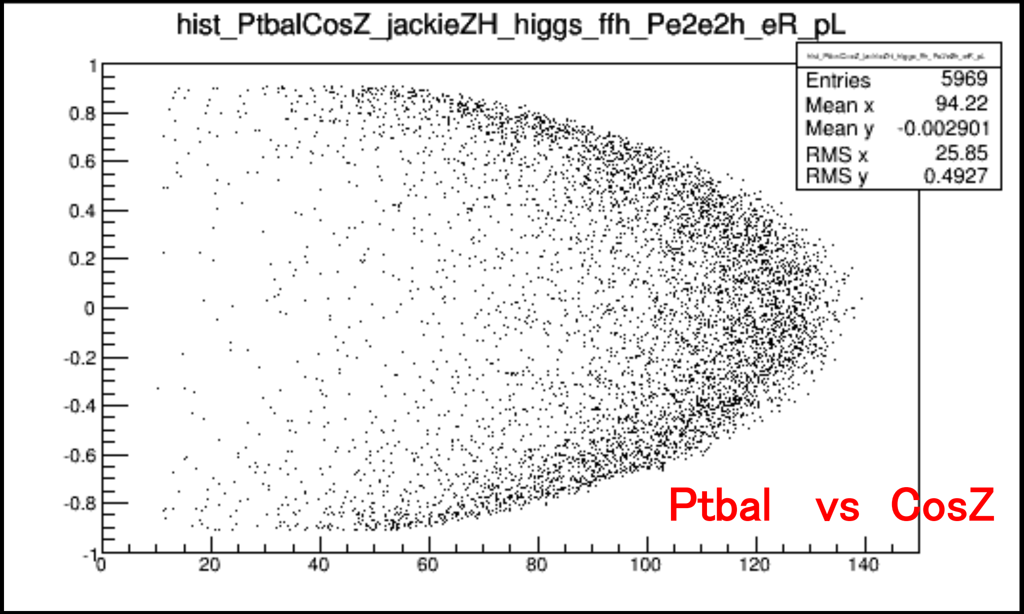
Parameters showing correlation: not good for likelihood cut (?)



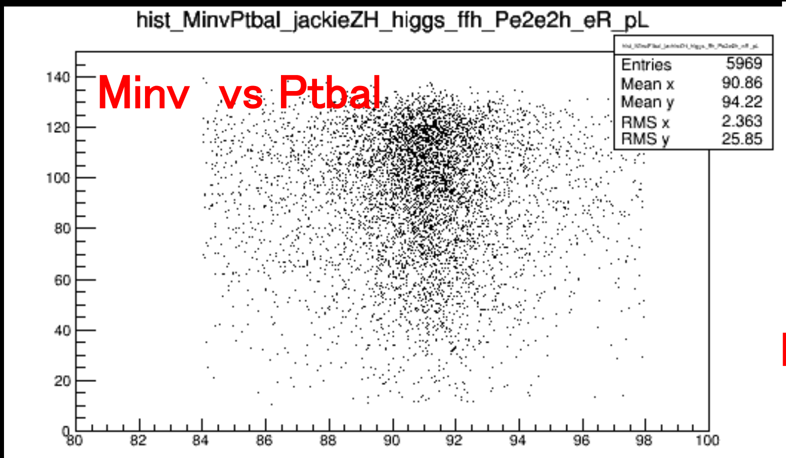


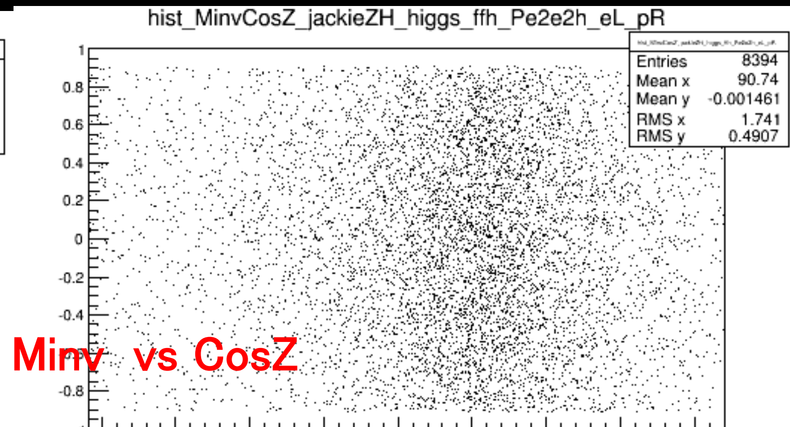
Parameters showing correlation: not good for likelihood cut (?)

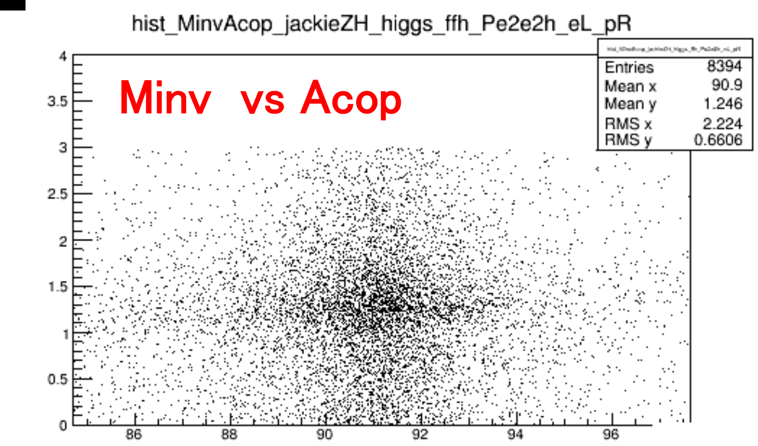


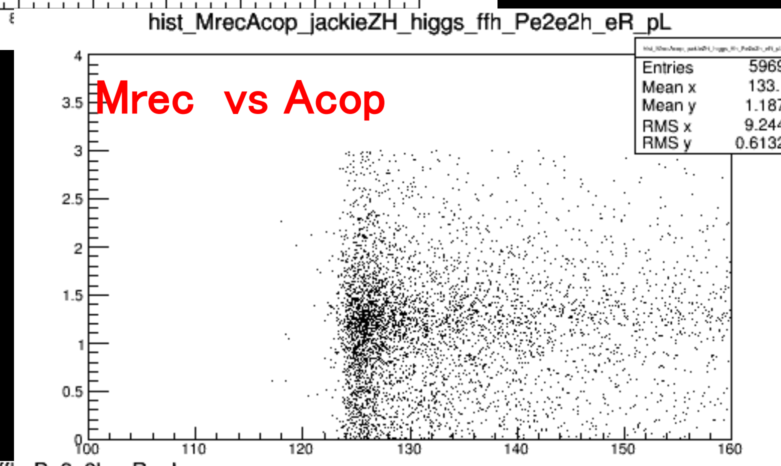


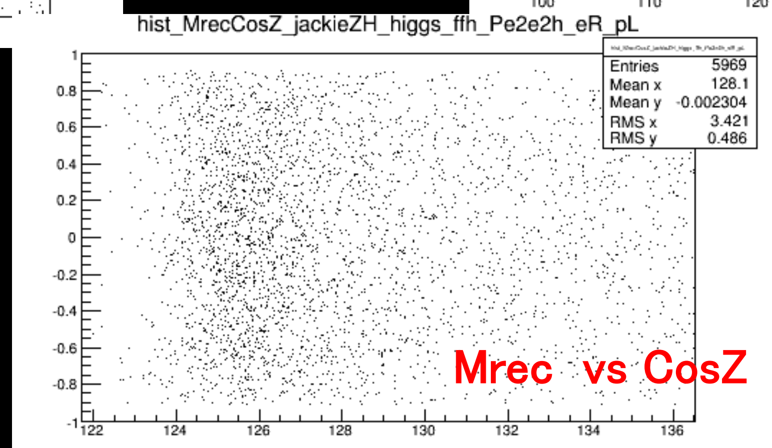
Parameters with no apparent correlation: good for likelihood cut (?)





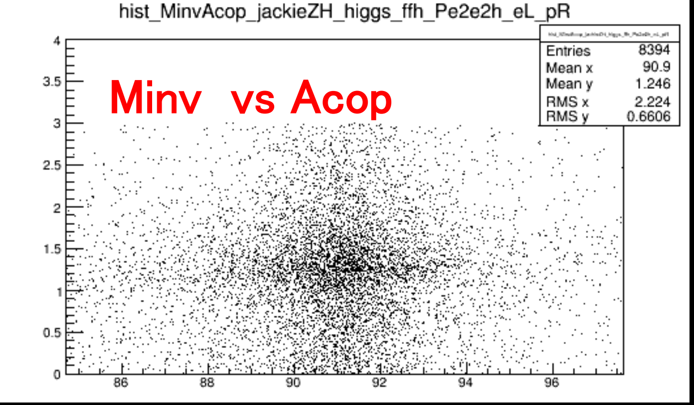


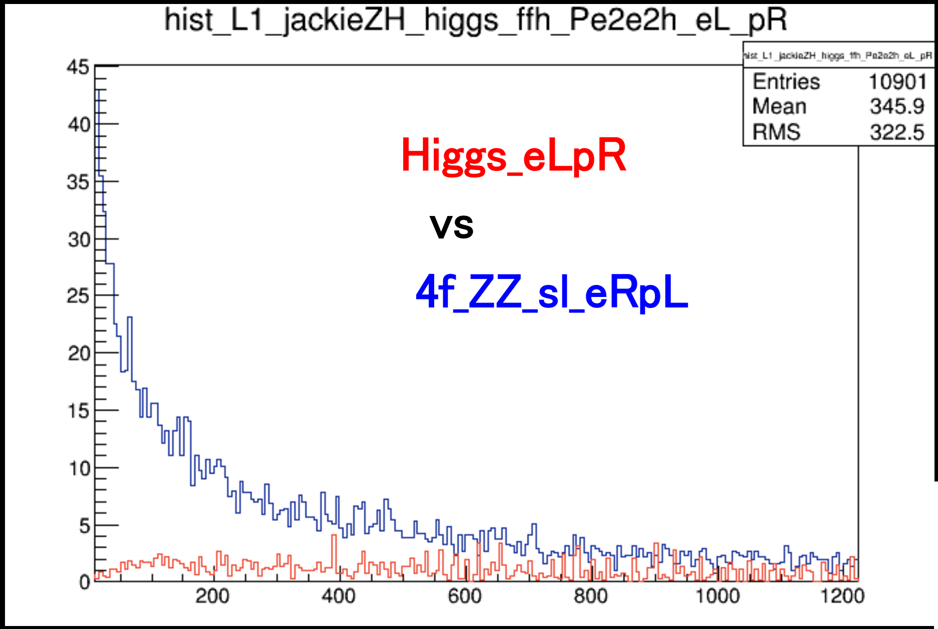


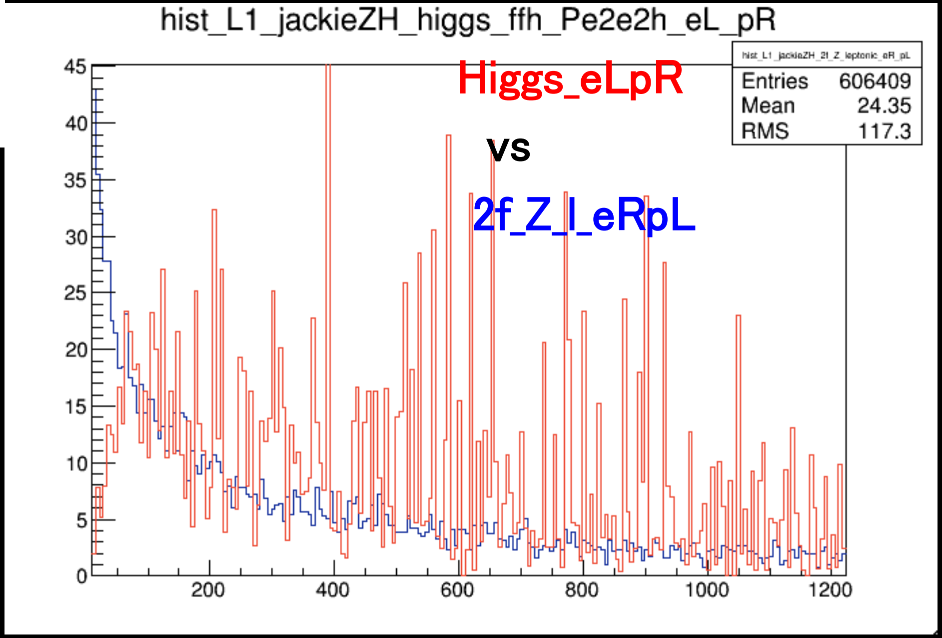


So far I have tried   L = P(M_inv) * P(Acop)

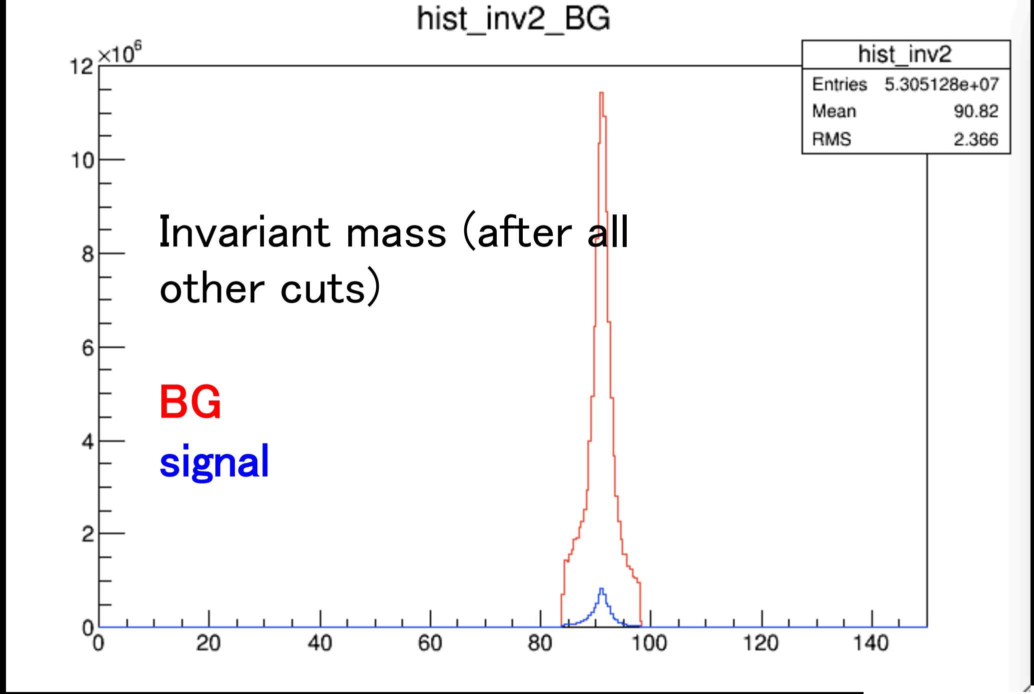
Other variations will follow up next week

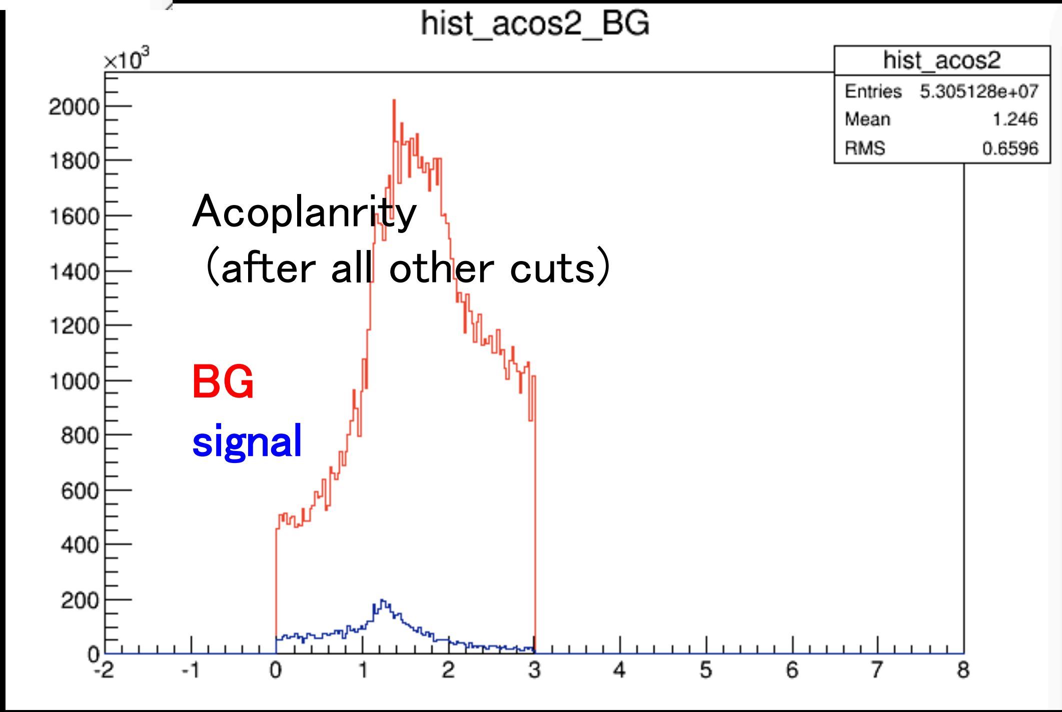






Cannot understand the difference between eL_pR and eR_pL for BG processes


hist_inv2_BG
hist_inv2
Entries 5.305128e+07
Mean 90.82
RMS 2.366
×10^6
Invariant mass (after all other cuts)
BG
signal
0 20 40 60 80 100 120 140


hist_acos2_BG
hist_acos2
Entries 5.305128e+07
Mean 1.246
RMS 0.6596
×10^3
Acoplanrity (after all other cuts)
BG
signal
-2 -1 0 1 2 3 4 5 6 7 8

recoil mass fitting method

1st step:

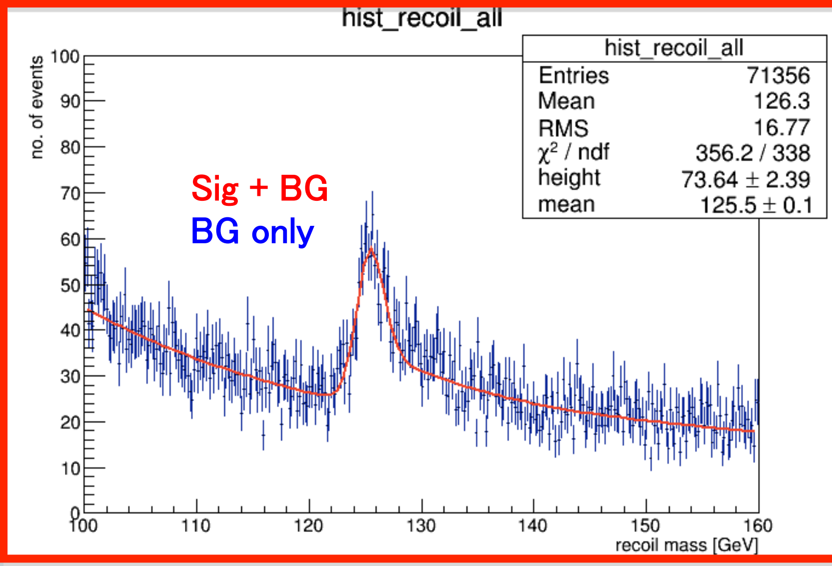
- Fit only signal with GPET   float all 5 pars
- Fit only BG: 3rd order polynomial

2nd step :

fit Sig + BG : only float height and mean

fix others from step 1

Fit range: 100–160 GeV



◆ **SIGNAL: GPET:** 5 parameters :

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

Gaus (left-side) ,

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

Gaus + expo (right side)

Toy MC study

Toy MC 10000 seeds

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

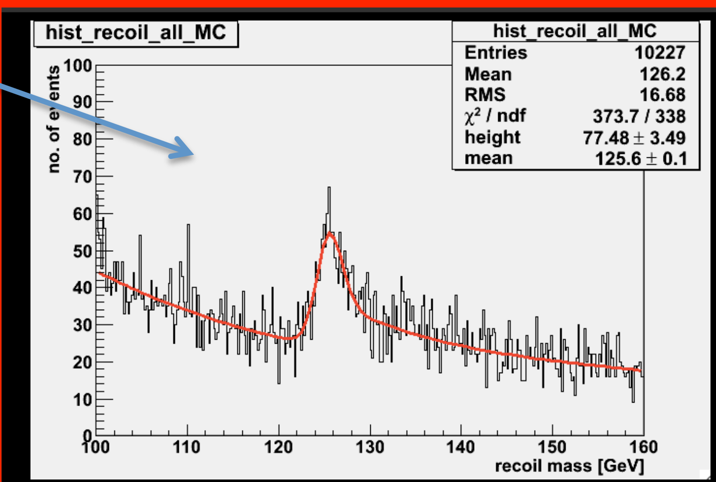
in terms of M_h、 xsec etc……

<u>method</u>:

generate MC events according to fittied “real” data

(Poisson)

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



Comparison of results between different beam polarizations : ECM=350 GeV

Pol	ε	xsec [fb]data	xsec [fb] MC	Δσ/σ MC	Xsec pull
(−0.8,+0.3)	47.7+/−0.5%	6.87+/−0.21	7.09+/−0.33	4.56+/−0.17%	0.67/1.03
(+0.8,−0.3)	47.7+/−0.5%	4.64+/−0.17	4.40+/−0.25	5.03+/−0.22%	−1.1 / 1.2
(−0.8, 0)	47.7+/−0.5%	5.45+/−0.19	5.46+/−0.30	5.23+/−0.23%	0.038/1.05
(0, 0)	47.7+/−0.5%	4.64+/−0.17	4.28+/−0.27	5.79+/−0.29	−1.48/1.09

except for (−0.8, 0) : some bias in signal event counting

What explains difference in Δσ/σ ?

Pol	Nsig data	Nsig (MC)	Mrec MC
(−0.8,+0.3)	1091+/−33	1126+/−53	125.5+/−0.1
(+0.8,−0.3)	739+/−27	699+/−40	125.5+/−0.1
(−0.8, 0)	865+/−29	868+/−48	125.5+/−0.1
(0,0)	737+/−27	679.+/−42	125.5+/−0.1

Ref) Location of full output data: for each polarization scenario

In directory /home/ilc/jackie/jackieZHPrecessornew/data/

Evt_350_ : Process name / number of events after each selection step

EvtRate_350_ : change ratio of # of events w.r.t. raw # after each selection step

Some issues: looking at Toy MC study result

Bias on fitted recoil mass

~ about 4 σ

w.r.t. 125 GeV (in meta-file)

long Mrecoil tail to the high energy side

possible causes: *still not well investigated yet*

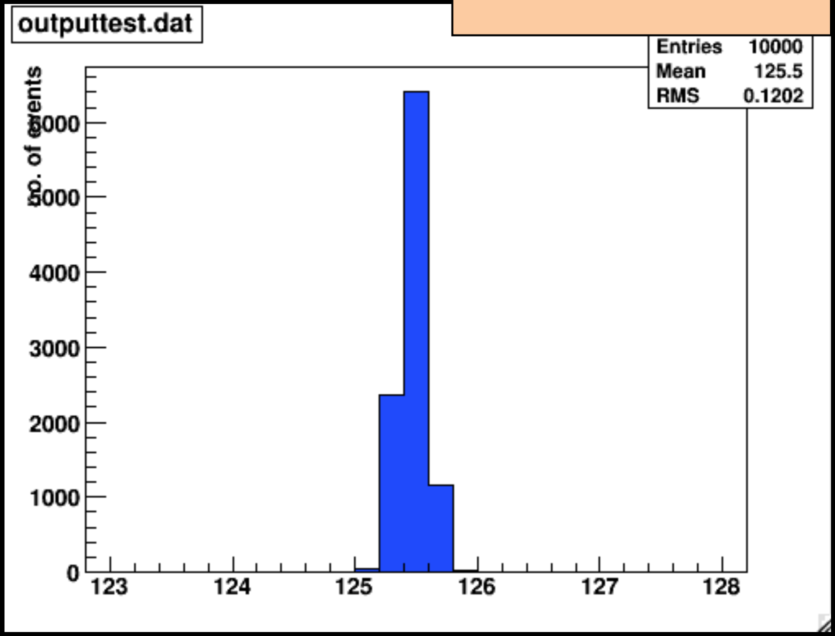
ISR, FSR, Beamstrahlung、fitting function

this is part of the motivation for Luminosity spectrum research ,

maybe the realistic case is worse (??!!)

how can we correct for this bias ?

m_H from Toy MC:
125.5 +/− 0.1 GeV

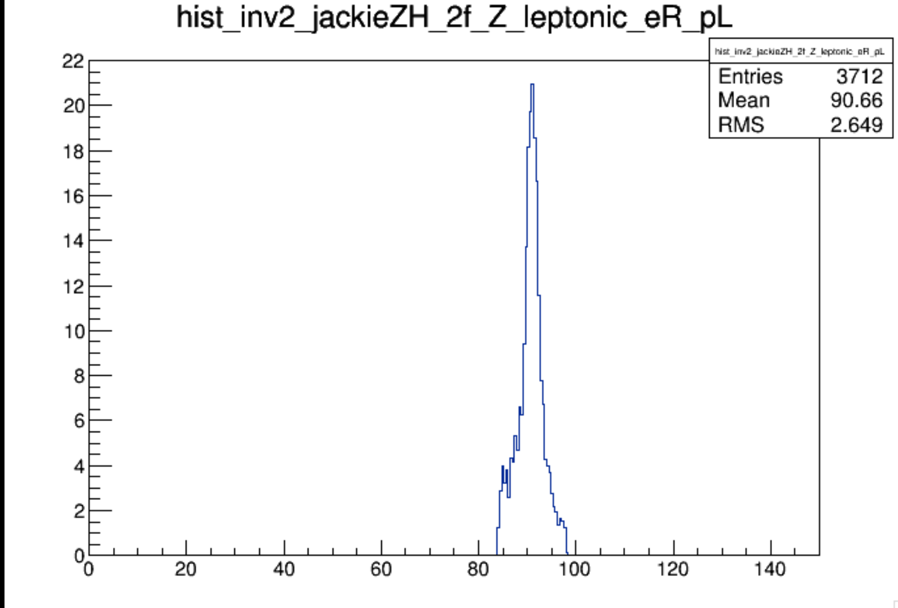


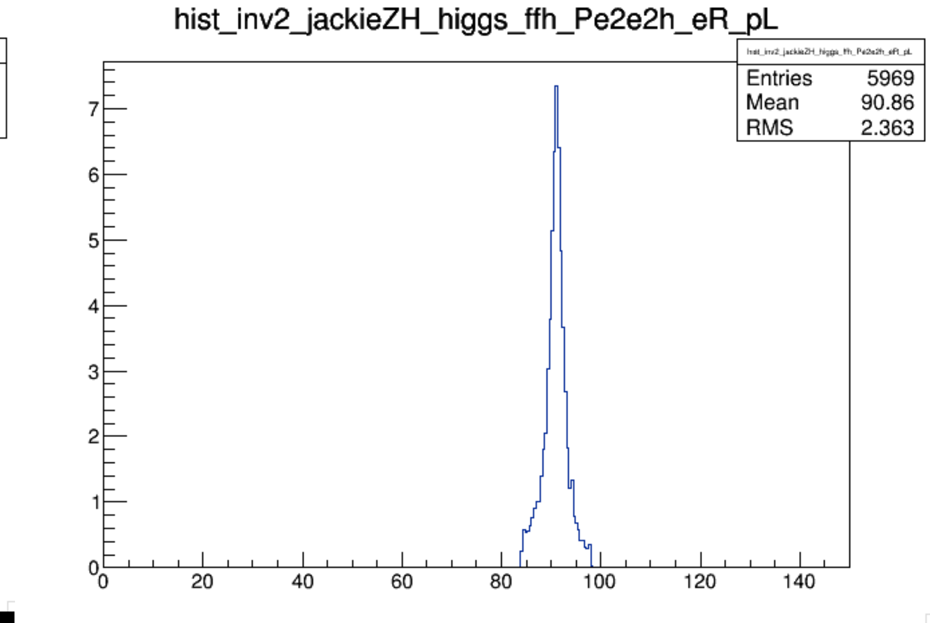
Discrepancies between Toy MC and reconstructed events

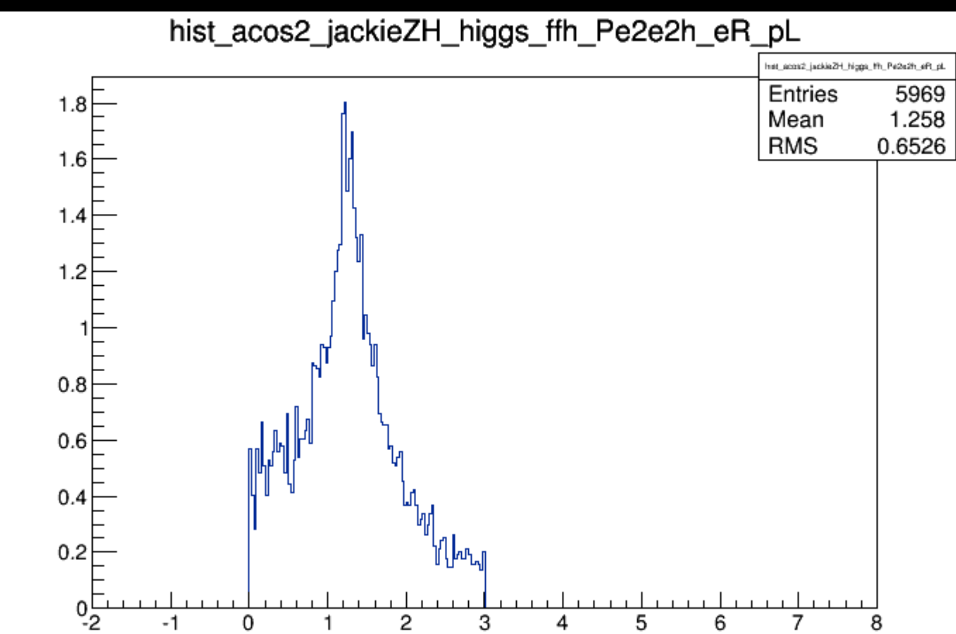
bias in pull plot <~ 1 σ For Xsec , Nsig

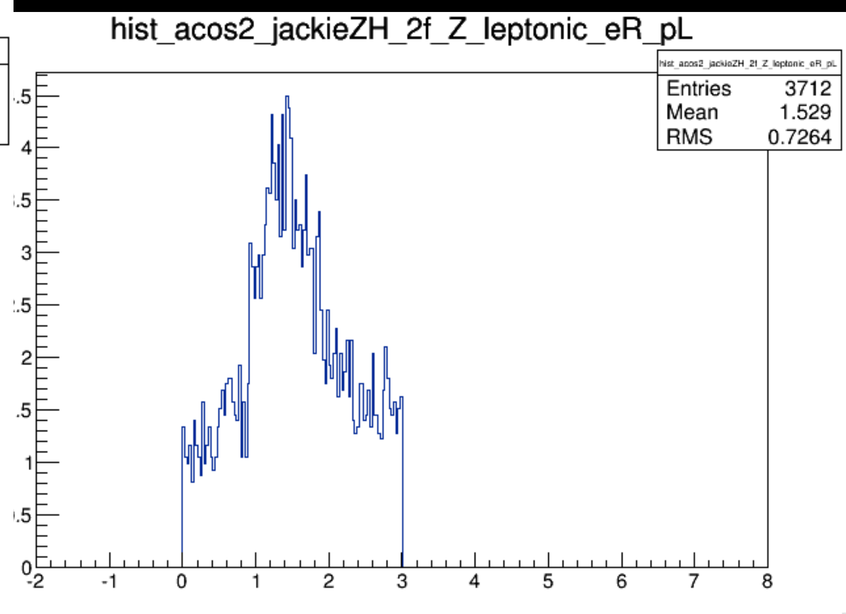
- **fitting function over− / under− estimates signal events**
- **shows dependency on beam polarization (?)**

BACKUP


hist_inv2_jackieZH_2f_Z_leptonic_eR_pL
Entries 3712
Mean 90.66
RMS 2.649

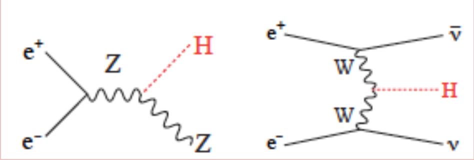

hist_inv2_jackieZH_higgs_ffh_Pe2e2h_eR_pL
Entries 5969
Mean 90.86
RMS 2.363


hist_acos2_jackieZH_higgs_ffh_Pe2e2h_eR_pL
Entries 5969
Mean 1.258
RMS 0.6526


hist_acos2_jackieZH_2f_Z_leptonic_eR_pL
Entries 3712
Mean 1.529
RMS 0.7264

- LHC でのHiggs 粒子の発見 ➔ Higgsを詳細を研究出来るILCの物理の意義が非常に強くなった
- ILC建設の機運が高まっている

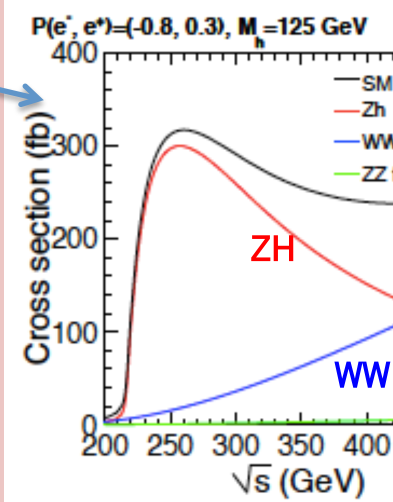
➔ 加速器増強・運転計画を考慮した現実的な性能評価の緊急性が増大



Higgs 結合定数の精度を評価する上。。。。

- ECM = 250 GeV : ZH随伴生成が最大
- ECM = 500 GeV : WW融合過程が十分強くなる

で評価が行われてきた



TDRより

- 中間の**ECM = 350 GeV** では多くの物理が重要となる(e.g. top物理)
- ILCでは、LINAC を拡張すれば、エネルギーを調整できる

今、350 GeVでのHiggs 測定の性能評価が重要視されている！

- 本研究ではその根幹となる、**ECM = 350 GeV** で

Higgs Recoil Measurement (反跳質量測定)を行う *TDR パラメータを基にした初のstudy*

- ILC の強みの1つを活かす: **Higgs Property のモデル非依存的な測定:**

具体的なGoal:

- **Higgs 断面積**（σ_H）と recoil mass (M_H) の精密測定
- 異なる ECM と偏極の間で期待性能を比較

➔ **ILC run scenarioの検討、加速器と測定器の最適化 に貢献する**

Luminosity の精密測定: Hardwareの視点

レーザーを使った高精度な測定系の経験をここで適用する

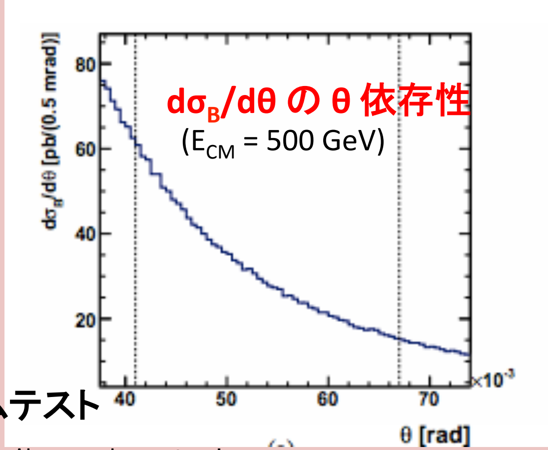
Bhabha 散乱断面積は極角度(θ)に鋭く依存: **dσ / dθ～θ-3**

- **θ の有効領域、特に下限θminの最適化** が重要: ΔL/L～2*Δθ/θ

要請: Δθmin < 10^{-3} mrad, 内径精度<数μm、θ分解能 2.2×10^{-2} mrad

重要な開発項目:

- **センサーパッドの径・方位角方向の細分割の最適化**
  θ測定と電磁シャワー位置再構成の精度のため
- カロリメータと内部センサー層の**Laser Alignment System (LAS)** の開発に参加
  先行開発を発展: **内部センサーの数μm精度を満たすプロトタイプの製作+ビームテスト**



H. Abramowicz et al,
"Forward Instrumentation for ILC Detectors"

Luminosity の精密測定:物理の視点

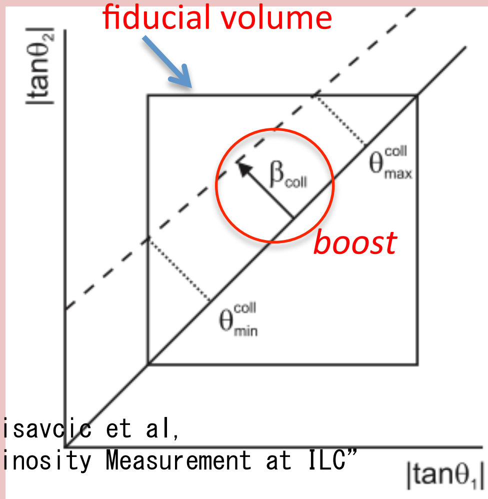
KEKで予定している研究は物理の部分がメイン
信号事象選別手法の開発、ビーム衝突効果の影響など

ビーム効果により、衝突毎に**衝突系がz方向にboost** (acollinearity)
→ **角度 acceptanceの損失** → **L の減少**
主要因:ランダムな非対称な **beamstrahlung / ISR**

ILCの高いE_{CM}と極細ビームでは深刻

❖ **θ acceptanceの減少によるLの系統誤差を補正する**
散乱角度を使って衝突系のboost速度を計算し、event毎にweightをかける

$$\beta_{coll} = \frac{\sin\left(\theta_1^{lab} + \theta_2^{lab}\right)}{\sin\left(\theta_1^{lab}\right) + \sin\left(\theta_2^{lab}\right)} \;\Rightarrow\; w\left(\beta_{coll}\right) = \frac{\int_{\theta_{min}}^{\theta_{max}} d\theta \left(d\sigma / d\theta\right)}{\int_{\theta_{min}^{coll}}^{\theta_{max}^{coll}} d\theta \left(d\sigma / d\theta\right)}$$



B. Jelisavcic et al,
"Luminosity Measurement at ILC"

Lの目標精密: **ΔL/L < 2 x 10^{-3} : ビーム、加速器、物理BGの全要因合わせて** (>80% * E_{CM}の領域内)
特に、ビーム効果の寄与 ΔL/L|beam を補正:10%→ < 1x 10^{-3} まで改善
先行研究の残留誤差を減らす

予定研究の重要部分は luminosity spectrum $dL/dE_{CM'}$ の精密測定

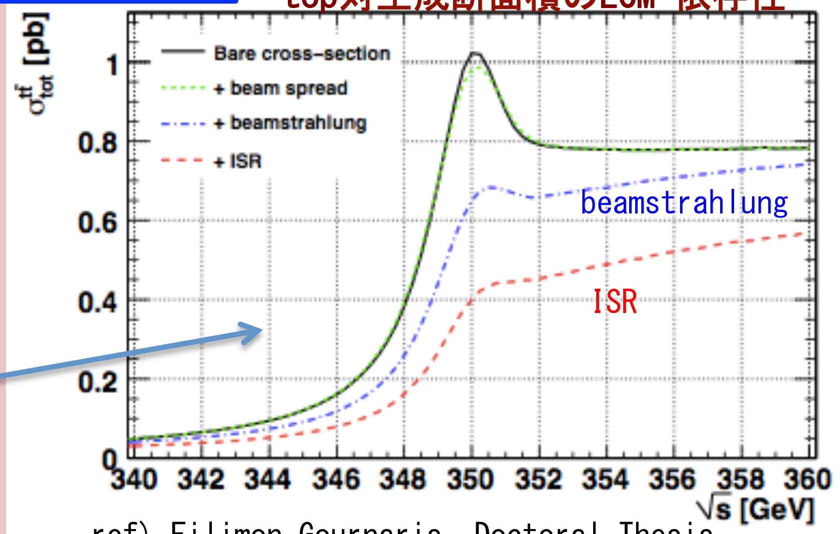
dL/dE_{CM}'の正確な情報が重要なILC物理解析に大インパクトを与える

代表例：
threshold scan によるtop quark 質量の精密測定
- E_{CM}=350 GeV周辺でtop対生成断面積の急上昇現象を利用
- Top-yukawa 結合定数、崩壊幅、SUSY質量の測定にも有用
- **実験由来の系統誤差が約80MeVと大きい！！**

（c.f. 理論誤差～100MeV、統計誤差～30 MeV）

ビーム効果は共鳴ピーク位置をsmear・シフトさせる

top対生成断面積のECM 依存性



ref) Filimon Gournaris, Doctoral Thesis

ビーム効果に起因する E_{CM}の変化が物理量決定に与える系統誤差を評価・補正することが重要

例）理論計算（ビーム効果無視）に**dL/dE_{CM}'で畳み込み積分**する

$$\sigma_{eff} = \int_0^{x_{max}} dx \cdot L(x)\sigma\left(x\sqrt{s}\right)$$

Luminosity Spectrum dL/dE_{CM}' 測定の流れ

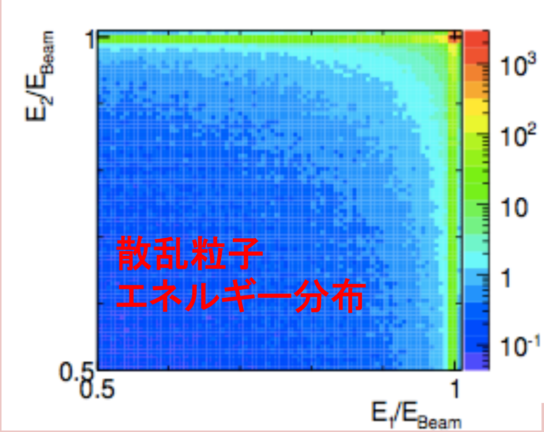
1. **dL/dE_{CM}' のモデルを特定の実験パラメータを基に構築 =「既知」のエネルギースペクトラム**
2. バンチ衝突シミュレーションで**「未知」のスペクトラムとBahbha事象を生成**
3. 1.と2. を比較 **(fitting) ➔** 生成データの **dL/dE_{CM}' を x = E_{CM}'/E_{CM}の関数として再構成**

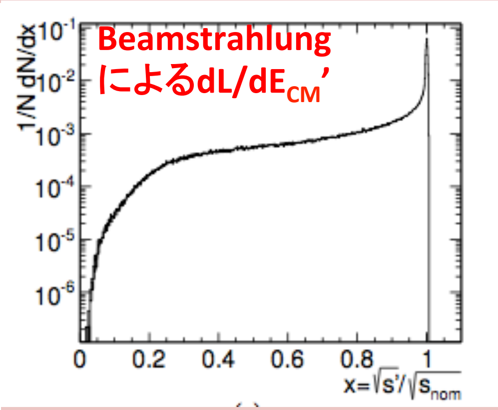
更に、 **dL/dE_{CM}' 再構成手法の性能試験を行う**
- モデルに使用される簡易化仮定からくる再構成の系統誤差
- 再構成精度のbeamstrahlungの酷さへの依存性

<u>従来のsimulation tool:</u>

- Beamstrahlungの生成： Guinea-Pig
- Bhabha 散乱、断面積の計算： BHWIDE (MC)

参照：Luminosity Spectrum Reconstruction at Linear Colliders, by Andre Sailer (CERN)





dL/dE$_{CM}$' 測定: 様々な課題

LumiCal hardware への要請

- 厳密なdL/dE$_{CM}$'再構成は 散乱後の θだけではなく、エネルギーも必要
  エネルギー分解能 (ΔE/E ～ 0.21 / sqrt(E[GeV])) と簡易化仮定をバランスさせた解析手法

先行研究を参考にしながら dL/dE$_{CM'}$ の測定手法を改善する

◆ 従来の簡易化仮定を発展させる:

- 粒子**間のエネルギー相関** 、非対称ビーム（交差角度）、OFF- axis ISR, 複数光子輻射

◆ ビーム情報をより忠実にシミュレーションに反映

- 加速器の中で **ビームパラメータが時間とともに変動** ←→ beamstrahlungとの相関
  バンチの形状、サイズ、電荷分布、位置オフセットはBeamCalやpair monitorのバンチ毎の測定を参照
- Beam energy spread、 ビーム偏極誤差、バンチ毎のエネルギーと位置のジッター、終状態 deflection

◆ 物理BG由来の系統誤差 を研究する （ΔL/L|BG ～ 2x10^{-3} 、4 fermion 過程が支配的）

- 色々な複雑な要素を考慮して**データ選別手法を最適化する**: （角度、エネルギーのcut など）

一方で、simulation と ビーム情報の正確さへの依存性を軽減させる手法を開発すべき

Cut Efficiency

OLD ONE : NOT UP TO DATE

	2f_Z_l	eff	4f_WW_sl	eff	4f_ZZ_sl	eff	signal	eff	BG	eff
raw events	2226362	100.00%	2732834	100.00%	188087	100.00%	2288	100.00%	31657512	100.00%
best mu pair	946129	42.50%	236802	8.67%	42345	22.51%	2254	98.51%	2373876	7.50%
D0	925330	41.56%	152599	5.58%	39825	21.17%	2241	97.95%	1813049	5.73%
track angle	843738	37.90%	136568	5.00%	36073	19.18%	2205	96.37%	1618485	5.11%
84 <M_inv <98	269446	12.10%	5702	0.21%	16365	8.70%	1826	79.81%	313998	0.99%
10 <P_Tdl<140	71877	3.23%	5659	0.21%	14934	7.94%	1819	79.50%	111823	0.35%
dpTbal>10 GeV	10674	0.48%	5505	0.20%	14108	7.50%	1798	78.58%	48694	0.15%
copl < 3	9612	0.43%	4578	0.17%	13347	7.10%	1773	77.49%	44735	0.14%
cos(θ Z)<0.91	5709	0.26%	2940	0.11%	9147	4.86%	1698	74.21%	30428	0.10%
120 GeV <M_rec <140 GeV	276	0.01%	405	0.01%	1123	0.60%	1088	47.55%	2700	0.01%

全カット後の支配的なBG :

sqrt(s) = 350 GeV : #1) 4f_ZZ_sl #2) 4f_WW_sl #3) 2f_Z_l *ttbar BG 残らず*

sqrt(s) = 250 GeV : #1) 4f_ZZWWMix_l #2) 4f_ZZ_sl #3) 2f_Z_l

断面積測定の精度の評価 ： 異なるECMとビーム偏極の比較 NEW

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

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

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

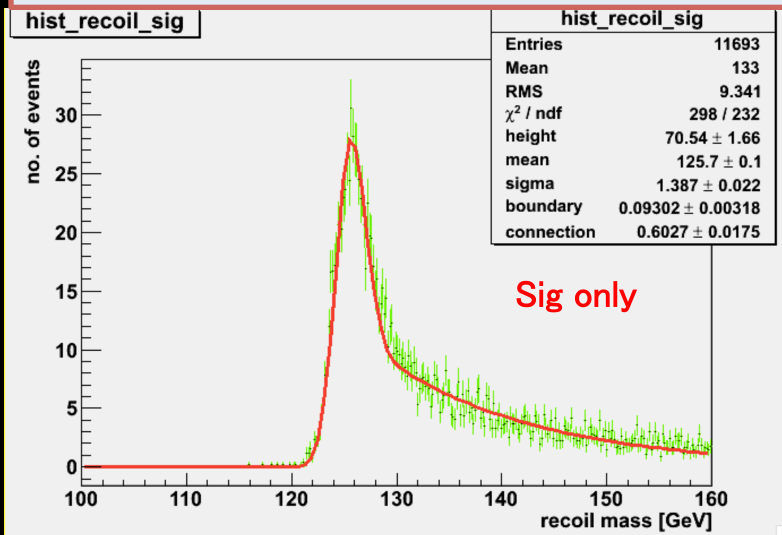
比較#2: Pol: （−0.8,+0.3） ←→ （+0.8, −0.3）:
- 異なる偏極の間で $\Delta\sigma/\sigma$ に大きな差がなさそう
- （+0.8, −0.3）: 統計が少ないが、S/B がずっと高い： WW BGが顕著に抑制

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

fitting for recoil mass histogram

1st time fitting:

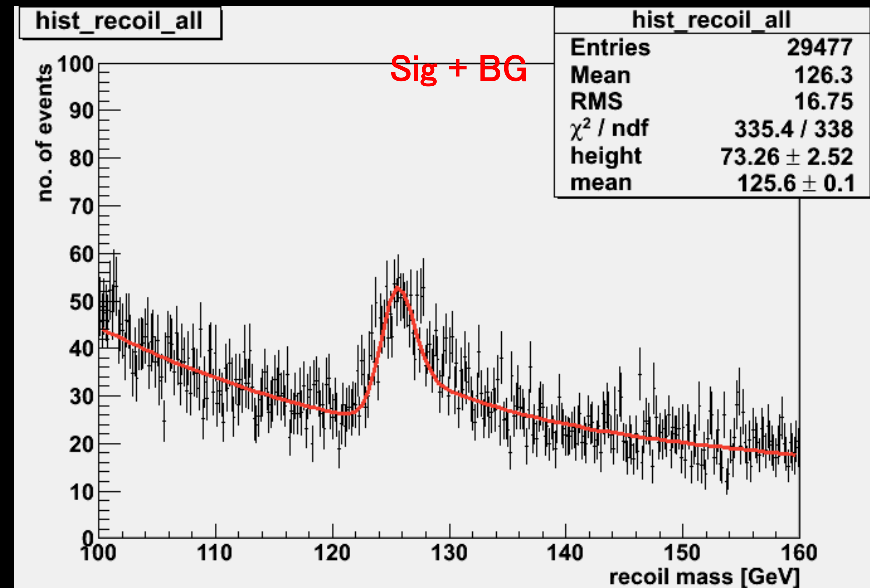
- fit only signal : float all 5 GPET pars
- fit BG only 3rd order polynomial



Final fitting:

float only height and mean,

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

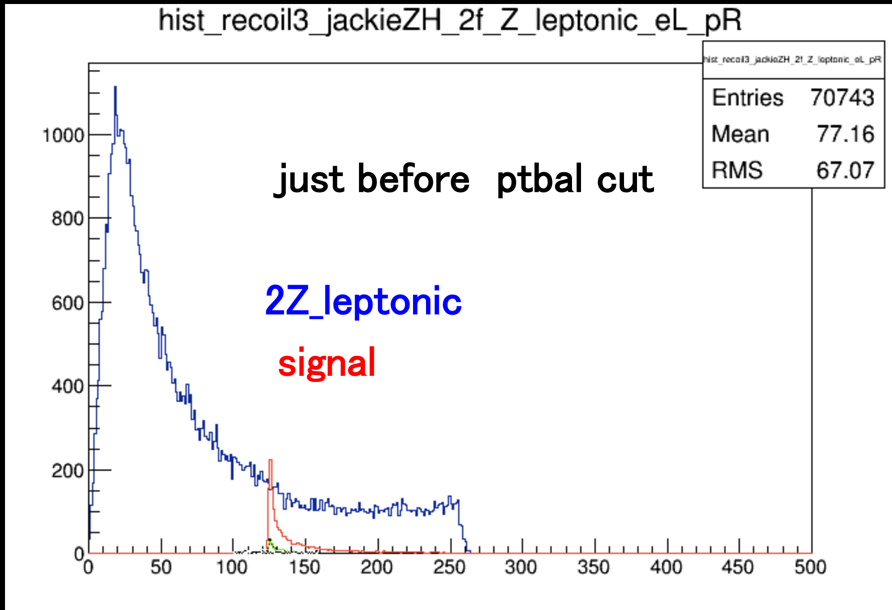


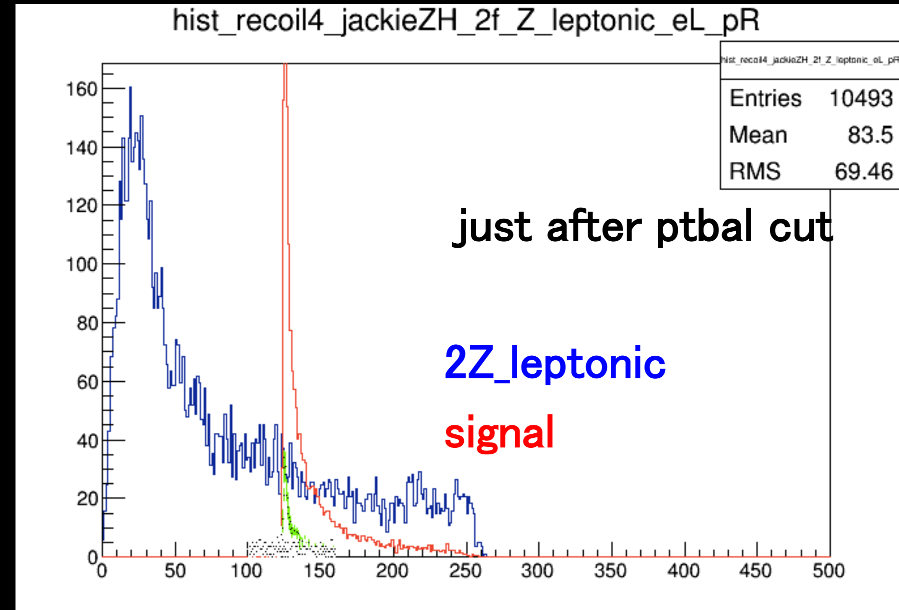
◆ **SIGNAL: GPET:** 5 parameters :

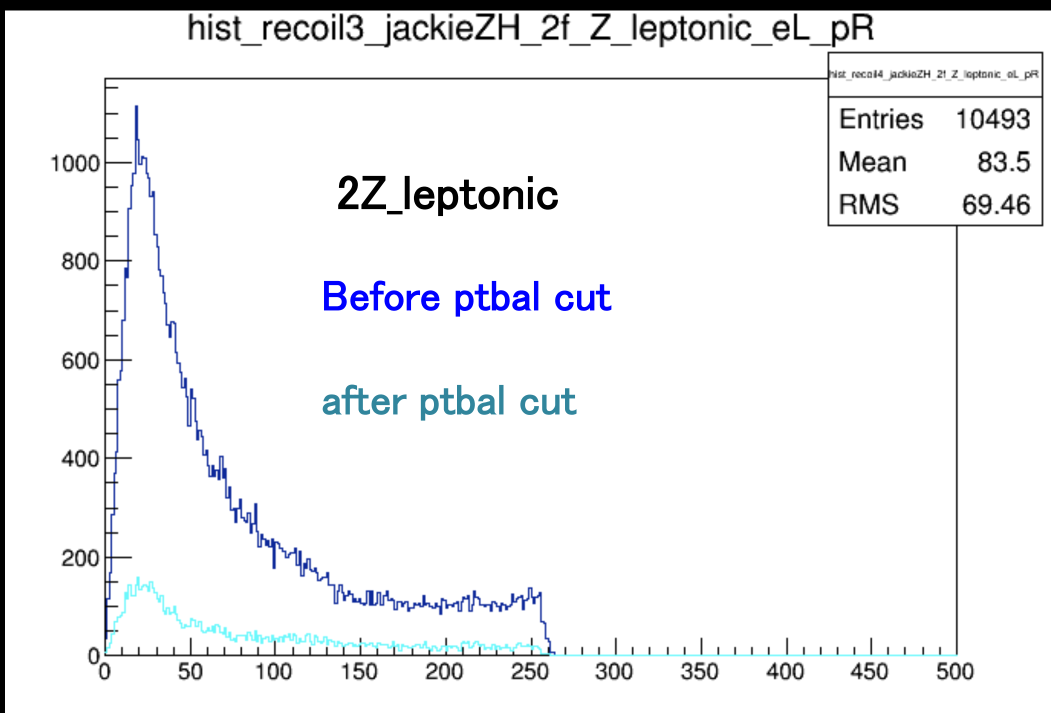
Gaus (left-side) , Gaus + expo (right side)

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

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


hist_recoil3_jackieZH_2f_Z_leptonic_eL_pR
hist_recoil3_jackieZH_2f_Z_leptonic_eL_pR
Entries 70743
Mean 77.16
RMS 67.07
just before ptbal cut
2Z_leptonic
signal
0
200
400
600
800
1000
0
50
100
150
200
250
300
350
400
450
500

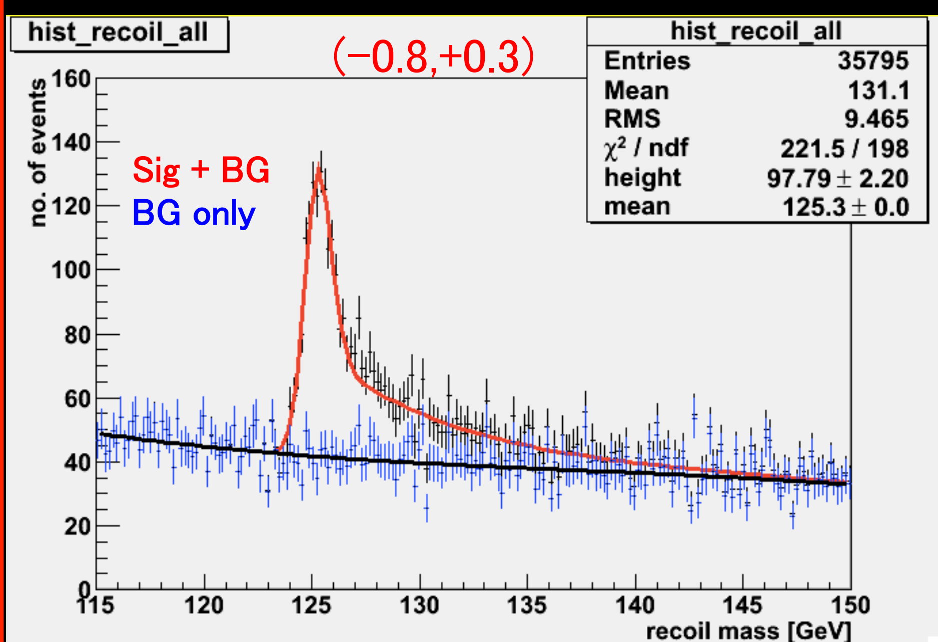

hist_recoil4_jackieZH_2f_Z_leptonic_eL_pR
hist_recoil4_jackieZH_2f_Z_leptonic_eL_pR
Entries 10493
Mean 83.5
RMS 69.46
just after ptbal cut
2Z_leptonic
signal
0
20
40
60
80
100
120
140
160
0
50
100
150
200
250
300
350
400
450
500

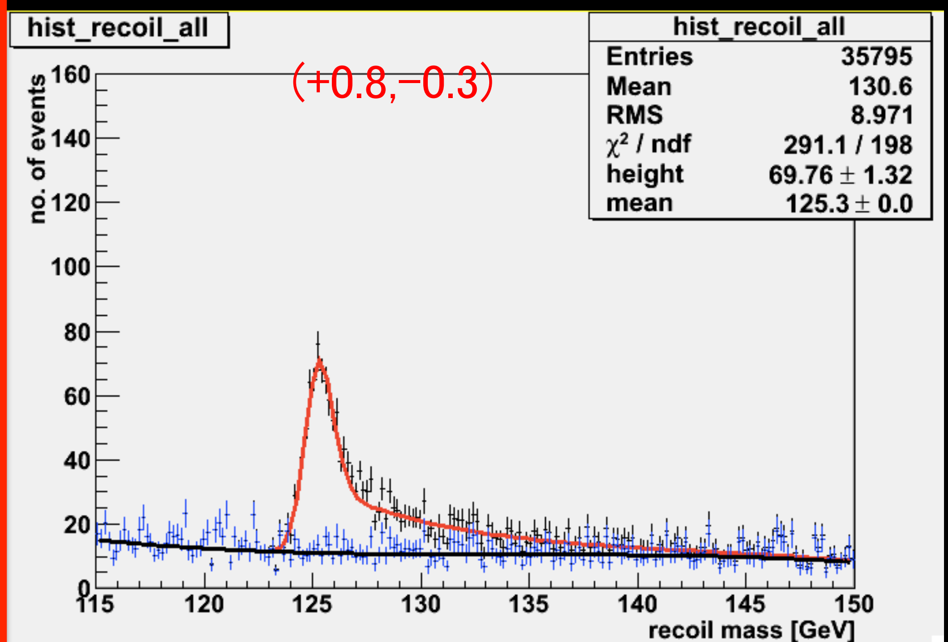

hist_recoil3_jackieZH_2f_Z_leptonic_eL_pR
hist_recoil4_jackieZH_2f_Z_leptonic_eL_pR
Entries 10493
Mean 83.5
RMS 69.46
2Z_leptonic
Before ptbal cut
after ptbal cut
0
200
400
600
800
1000
0
50
100
150
200
250
300
350
400
450
500

results for sqrt(s) =250 GeV , L = 250 fb-1

evaluated using Toy MC generated from fitted function shapes

250 GeV	ε	Δσ/σ	xsec	Nsig	S/N	significance
(−0.8,+0.3)	66.4+/−0.5%	3.6+/−0.1%	10.52+/−0.38	1747+/−64	0.37	21.7
(+0.8,−0.3)	64.4+/−0.5%	3.3+/−0.1%	8.68+/−0.30	1398+/−48	0.81	22.7





		2f_Z_l	eff	4f_WW_sl	eff	4f_ZZ_sl	eff	signal	eff	BG	eff
raw events	eLpR	2128619		2714856		182762		2204			
	eRpL	97743		17978		5325		84			
	total	2226362	100.00%	2732834	100.00%	188087	100.00%	2288	100.00%	31657512	100.00%
best mu pair	eLpR	906955		235263		41072		2171			
	eRpL	39174		1539		1273		83			
	total	946129	42.50%	236802	8.67%	42345	22.51%	2254	98.51%	2373876	7.50%
D0	eLpR	886948		151718		38624		2158			
	eRpL	38382		881		1201		83			
	total	925330	41.56%	152599	5.58%	39825	21.17%	2241	97.95%	1813049	5.73%
track angle	eLpR	808861		135726		35002		2124			
	eRpL	34877		842		1071		81			
	total	843738	37.90%	136568	5.00%	36073	19.18%	2205	96.37%	1618485	5.11%
84 <M_inv <98	eLpR	259828		5673		15959		1758			
	eRpL	9618		29		406		68			
	total	269446	12.10%	5702	0.21%	16365	8.70%	1826	79.81%	313998	0.99%
10 <P_Tdl<140	eLpR	69251		5630		14566		1752			
	eRpL	2626		29		368		67			
	total	71877	3.23%	5659	0.21%	14934	7.94%	1819	79.50%	111823	0.35%
dpTbal>10 GeV	eLpR	10272		5478		13761		1731			
	eRpL	402		27		347		67			
	total	10674	0.48%	5505	0.20%	14108	7.50%	1798	78.58%	48694	0.15%
copl < 3	eLpR	9252		4557		13019		1707			
	eRpL	360		21		328		66			
	total	9612	0.43%	4578	0.17%	13347	7.10%	1773	77.49%	44735	0.14%
cos(θZ)<0.91	eLpR	5492		2921		8927		1635			
	eRpL	217		19		220		63			
	total	5709	0.26%	2940	0.11%	9147	4.86%	1698	74.21%	30428	0.10%
120 GeV <M_rec <140 GeV	eLpR	265		403		1098		1048			
	eRpL	11		2		25		40			
	total	276	0.01%	405	0.01%	1123	0.60%	1088	47.55%	2700	0.01%

		(+0.8,−0.3) 2f_Z_l	eff	4f_WW_sl	eff	4f_ZZ_sl	eff	signal	eff	BG	eff
raw events	eLpR	127353		162427		10934		132			
	eRpL	1633703		1076		89009		1411			
	total	1761057	100.00%	163503	100.00%	99943	100.00%	1543	100.00%	16166900	100.00%
best mu pair	eLpR	54262		14076		2457		130			
	eRpL	654769		92		21274		1389			
	total	709031	40.26%	14168	8.67%	23731	23.74%	1519	98.44%	1146571	7.09%
D0	eLpR	53065		9077		2311		129			
	eRpL	639852		53		20077		1383			
	total	692917	39.35%	9130	5.58%	22388	22.40%	1512	97.99%	938198	5.80%
track angle	eLpR	48393		8120		2094		127			
	eRpL	582938		50		17901		1356			
	total	631331	35.85%	8170	5.00%	19995	20.01%	1483	96.11%	827736	5.12%
84 <M_inv <98	eLpR	15545		339		955		105			
	eRpL	160766		2		6790		1130			
	total	176311	10.01%	341	0.21%	7745	7.75%	1235	80.04%	191148	1.18%
10 <P_Tdl<140	eLpR	4143		337		871		105			
	eRpL	43892		2		6145		1123			
	total	48035	2.73%	339	0.21%	7016	7.02%	1228	79.59%	60616	0.37%
dpTbal>10 GeV	eLpR	615		328		823		104			
	eRpL	6715		2		5806		1113			
	total	7330	0.42%	330	0.20%	6629	6.63%	1217	78.87%	19128	0.12%
copl < 3	eLpR	554		273		779		102			
	eRpL	6015		1		5478		1097			
	total	6569	0.37%	274	0.17%	6257	6.26%	1199	77.71%	17591	0.11%
cos(θ Z)<0.91	eLpR	329		175		534		98			
	eRpL	3624		1		3680		1052			
	total	3953	0.22%	176	0.11%	4214	4.22%	1150	74.53%	11306	0.07%
120 GeV <M_rec <140 GeV	eLpR	16		24		66		63			
	eRpL	191		0		419		675			
	total	207	0.01%	24	0.01%	485	0.49%	737	47.76%	977	0.01%

Signal sample:

Pe2e2h_.eL.pR & Pe2e2h._eR.pL

relevant BG process for Zmumu

- 4f_ZZ_leptonic
- 4f_ZZ_semileptonic
- 2f_Z_leptonic
- 4f_WW_leptonic
- 4f_WW_semileptonic
- 4fSingleZee_leptonic
- 4fSingleZnunu_leptonic
- 4f_ZZWWMix_leptonic
- 6f backgrounds (sqrt(s)=350 GeV)