National University
The Graduate University
for Advanced Studies [SOKENDAI]

SHINSHU UNIVERSITY
Faculty of Science

Impact of two ECAL options

July, 22, 2014
T. Ogawa

Outline

1. Motivation
1. Z mass and Recoil mass
1. Recoil distribution with BG
1. ToyMC Estimation of Upper Limit
1. Summary

My Motivation - ILD ECAL

1. We have two ECAL candidates as ILD ECAL.

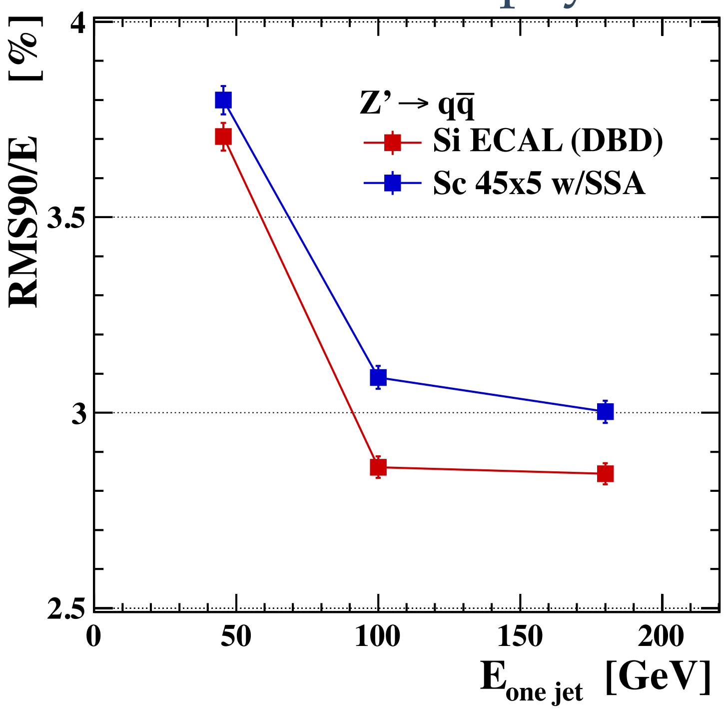
- Big difference is the cost.
- The cost of SiECAL is more than twice larger.

Table 5.3.2: Cost table of the electromagnetic calorimeter.

SiECAL		ScECAL	
Item	Cost [kILCU]	Item	Cost [kILCU]
Tungsten	16310	Tungsten + carbon parts	18500
Carbon fiber structure	2130	Module realisation	1700
Silicon sensors	75000	Scintillators	1030
Readout ASIC	16500	Photo Detectors	10200
Readout Board	21000	Readout ASIC	2500
Materials	1300	Readout Board	25000
Cables, connectors	2220	Readout System	6200
Tooling	9300	Cables, connectors	1000
Assembly	13500	Power supplies	4100
Integration	500	Tooling	3800
Sum SiECAL	157760	Sum ScECAL	74000

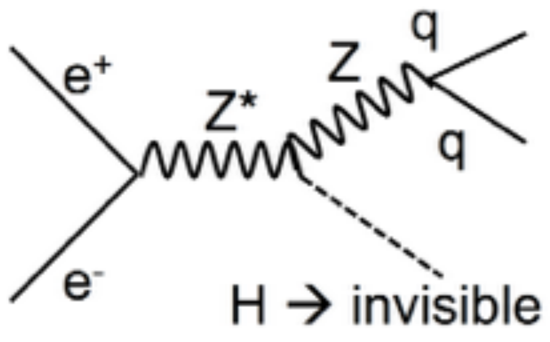
2. JER is also different.

- Most of people show us JER to compare performance.
- The difference of JER at 100 GeV jet is about 0.25% .
- We should know how large this difference effects on physics



2. It is clear signal for new physics if we can confirm sizable invisible Higgs decay.

- Final state has only two jets
- We can compare physics performance of ECAL simply.
  - For detectors. Jet Energy Resolution is essential.
  - For physics. It is clear signal for new physics.



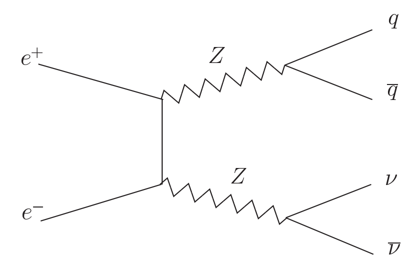
Simulation condition

1. Condition

E_{CM} = 250GeV and 350GeV.

Beam polarization P(e+,e-)= (-30%, +80%).

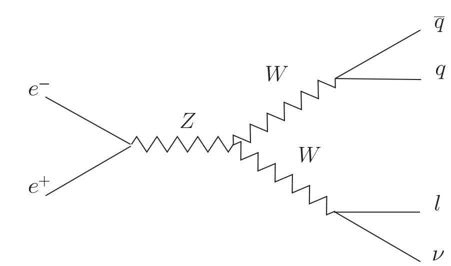
2. Process



(a) $e^+e^- \to ZZ$

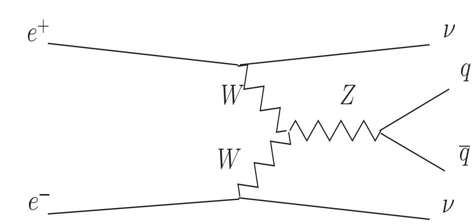
All process is full reconstructed by using each ECAL.

- Signal : $e^+e^- \to$ ZH, Z→qq, H→Invisible (→ZZ*→4ν ger).



(c) $e^+e^- \to WW$

- BackGround : ZZ semileptonic : one Z→qq, the other Z→ll,.
  WW semileptonic : one W→qq, the other W→lν
  $Z\nu_e\nu_e$, Z→qq $We\nu_e$, W→qq
  ZH→ννH   ZH → qqh



(b) $e^+e^- \to \nu\nu Z$

2. Cross section

$\sqrt{s}$=250GeV, L=250fb^{-1}, P(e^-, e^+)=P(−0.8, +0.3)

Process	σ(fb)	$\sigma \cdot$ L
ZH → qqH_{inv}	21.2	5300
ZH → qqH (SM)	212.2 - 21.2	53058 - 5300
ZH → vvH (SM)	78.3	1.9×10^4
ZZ → qqll	685.4	1.7×10^5
Zvv → qqvv	272.3	6.8×10^4
WW → qqll	10955	2.7×10^6
Wev → qqev	5910.1	1.5×10^6

$\sqrt{s}$=350GeV, L=350fb^{-1}, P(e^-, e^+)=P(−0.8, +0.3)

Process	σ(fb)	$\sigma \cdot$ L
ZH → qqH_{inv}	13.7	3425
ZH → qqH (SM)	137.7 - 13.7	34425 - 3425
ZH → vvH (SM)	99.6	2.5×10^4
ZZ → qqll	470.8	1.2×10^5
Zvv → qqvv	356.4	8.9×10^5
WW → qqll	8090.6	2.0×10^6
Wev → qqev	4963.8	1.2×10^6

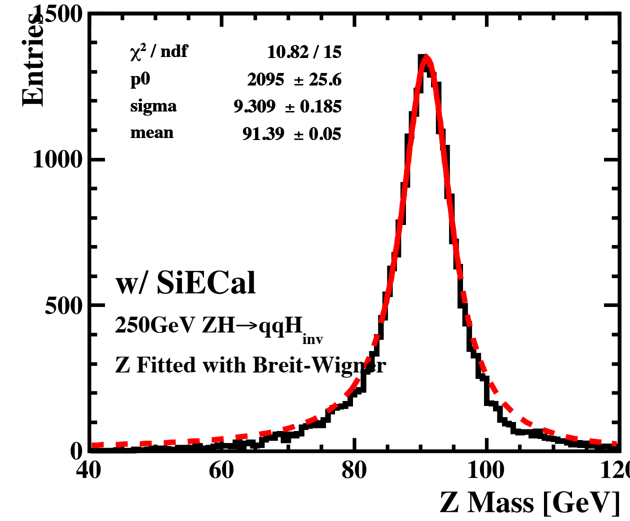
Signal: Z & H @$\sqrt{s}$=250GeV

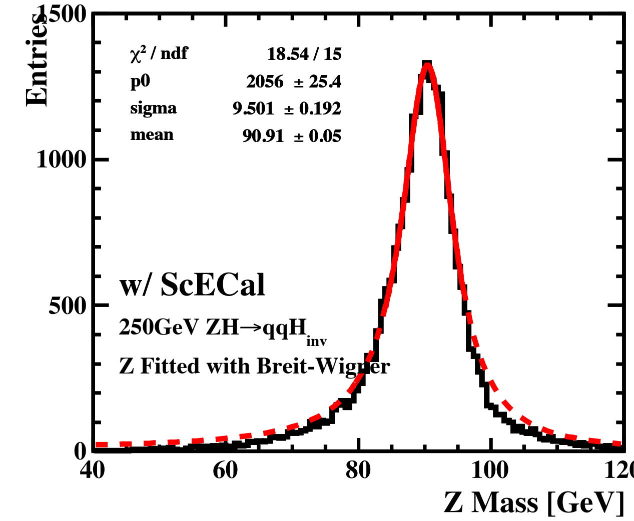
1. Comparison only signal

- Si: σ with B-W ~ 9.31 GeV.
  (Mean with B-W 91.4GeV)
  Mass resolution ~ 10.2%.

- Sc: σ with B-W ~ 9.50 GeV.
  (Mean with B-W 90.9GeV)
  Mass resolution ~ 10.4%.

Degradation of resolution is 2%

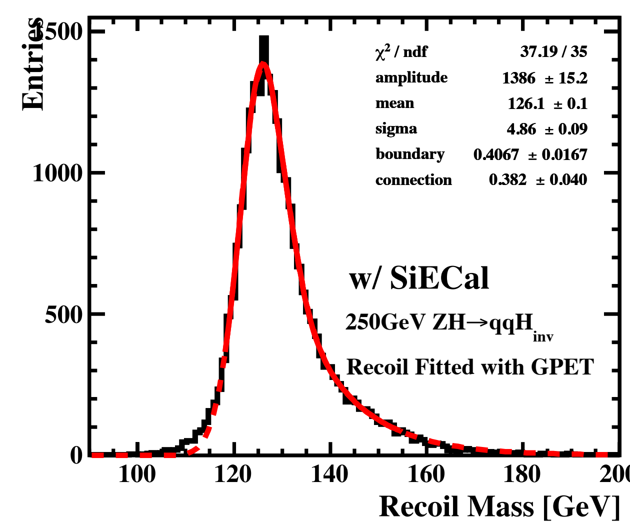


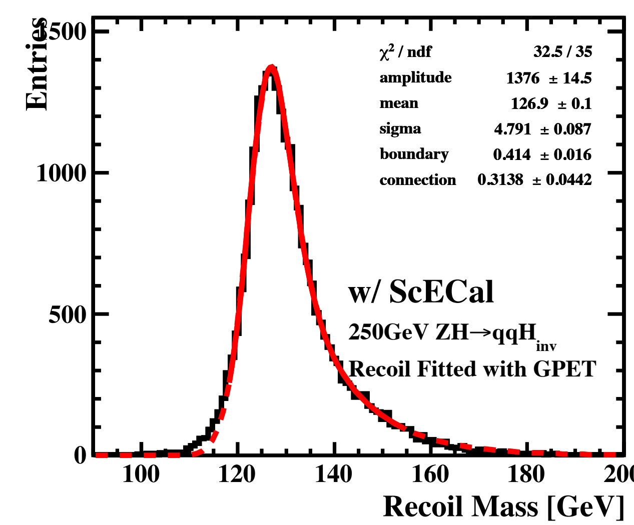


- Si: σ with GPET ~ 4.86 GeV.
  (Mean 126.1GeV)
  Mass resolution ~ 3.9%.

- Sc: σ with GPET ~ 4.79 GeV.
  (Mean 126.9GeV)
  Mass resolution ~ 3.8%.

Degradation of resolution is ?%





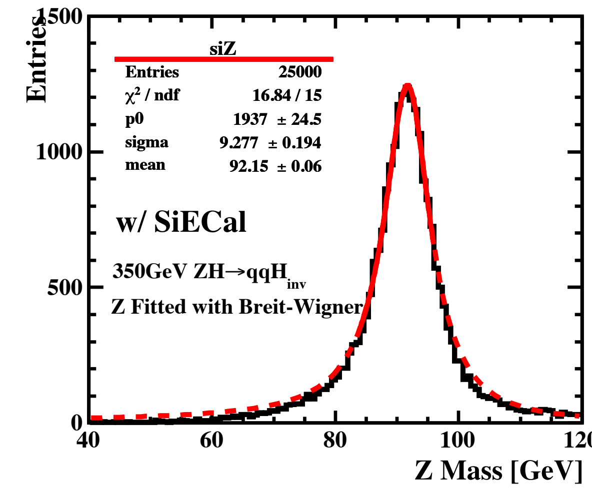
Signal: Z & H @$\sqrt{s}$=350GeV

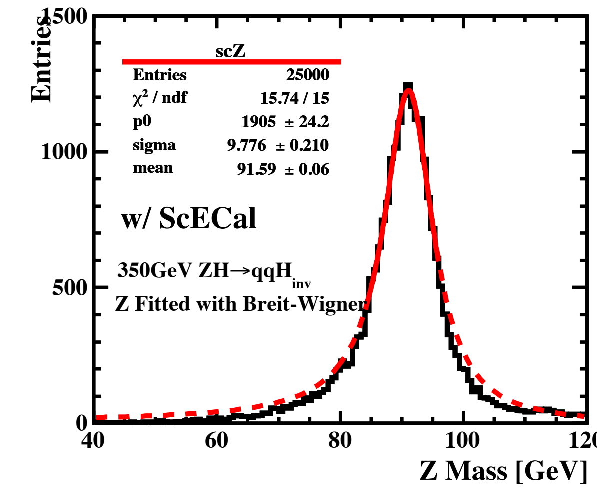
1. Comparison only signal

- Si: σ with B-W ~ 9.23 GeV.
  (Mean with B-W 92.1GeV)
  Mass resolution ~ 10.0%.

- Sc: σ with B-W ~ 9.78 GeV.
  (Mean with B-W 91.6GeV)
  Mass resolution ~ 10.7%.

Degradation of resolution is 7%

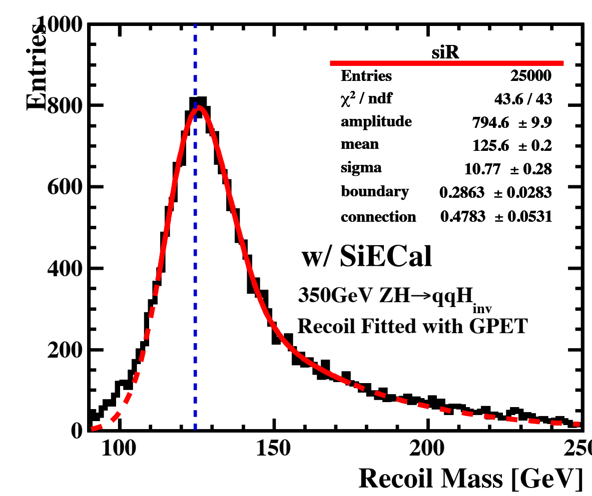


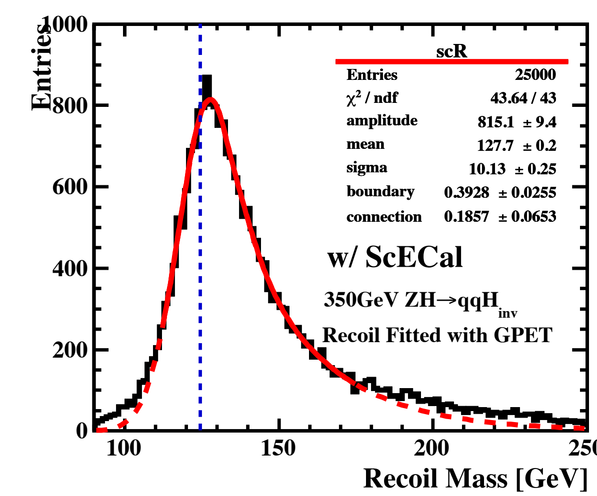


- Si: σ with GPET ~ 10.8 GeV.
  (Mean 125.6GeV)
  Mass resolution ~ 8.6%.

- Sc: σ with GPET ~ 10.1 GeV.
  (Mean 127.7GeV)
  Mass resolution ~ 7.9%.

Degradation of resolution is ?%



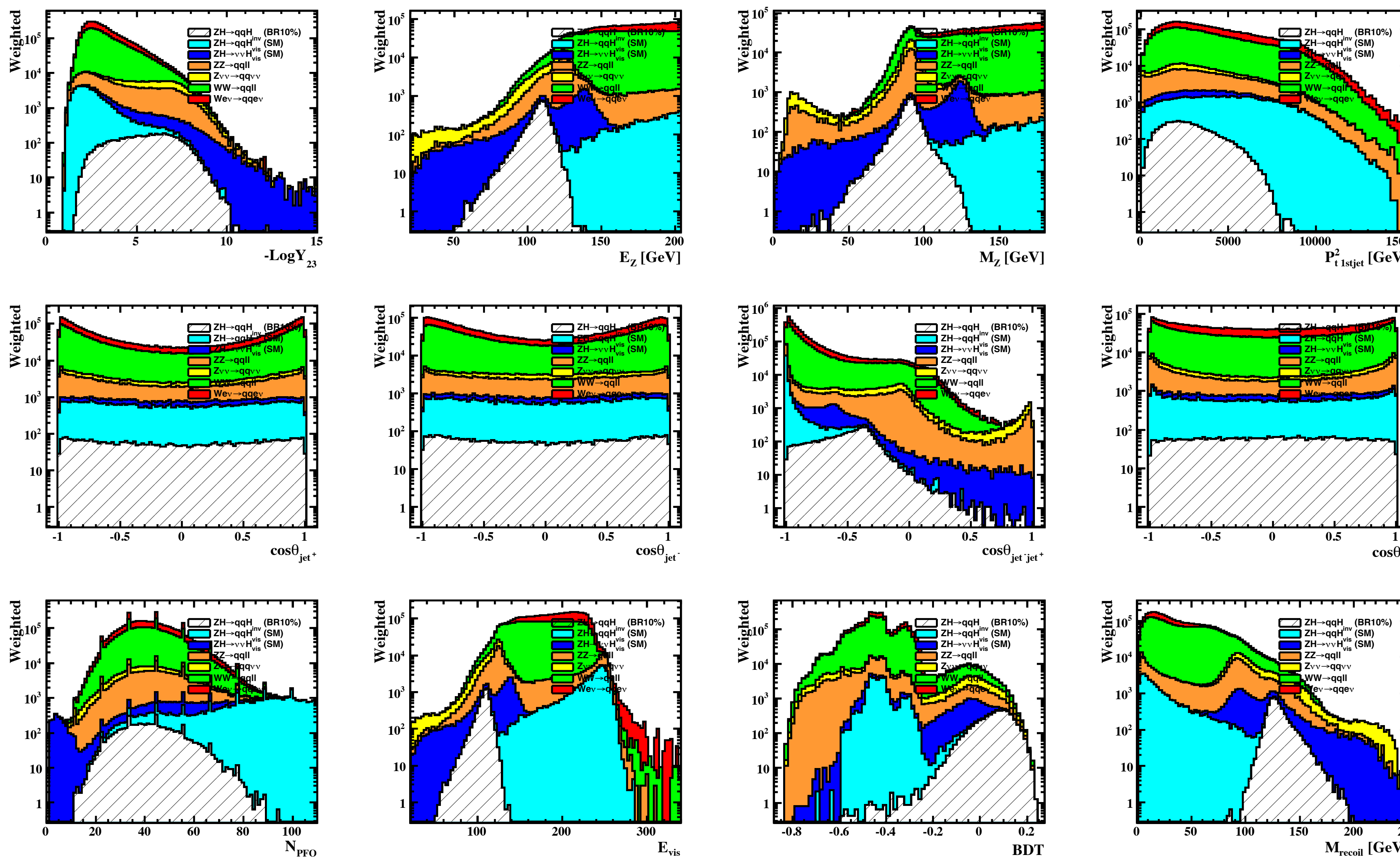


Cut variables

1. Cut variables to suppress BG

250GeV

get mu-pair or not == 1
100<zenergy<144
87<zmass<96
50<ptdilep<115
0.94<fabs(costhetamm)
0.94<fabs(costhetamp)
-0.95<costhetammp<-0.3
0.94<fabs(costhetaZ
3.0<acoplanarity
1.8<acollinearity<2.8
120<visenergy<280



Same cut applied for both ECALs

After applied above cut

Using remaining events + variable"recoil",

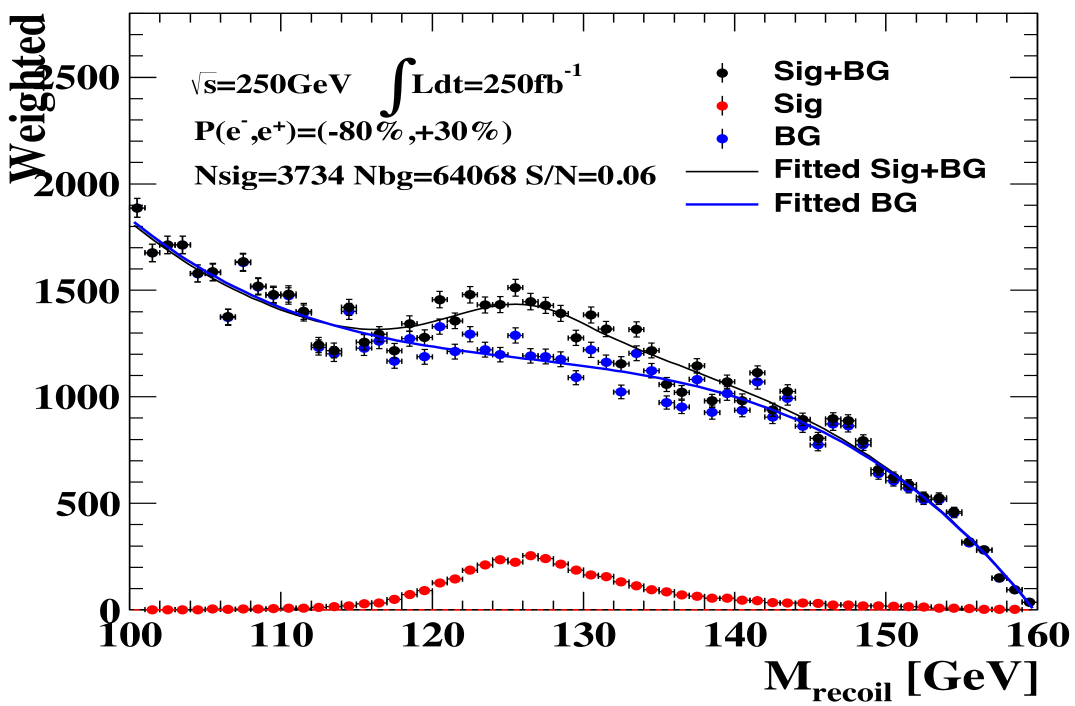
Do TMVA training

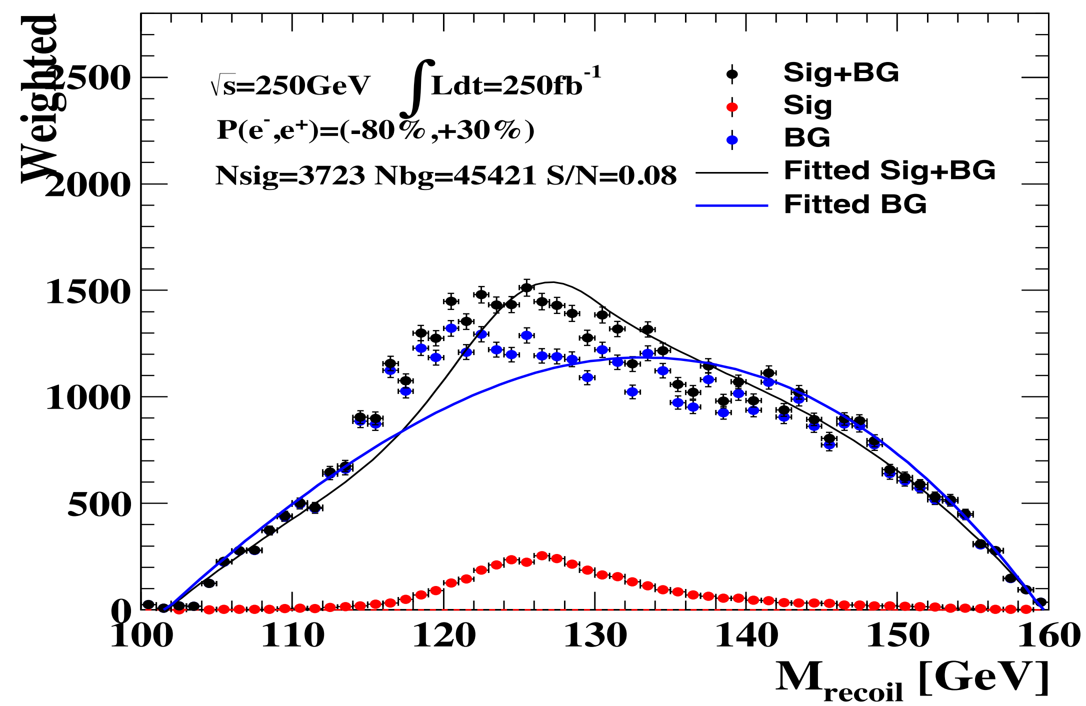
-0.07~-0.05<MVAoutput

Change this parameter to set same S/N ratio for each model.

Cut variables

- I f I apply more tight cut by using BDT parameter, it will be more difficult to fit BG with well known function.





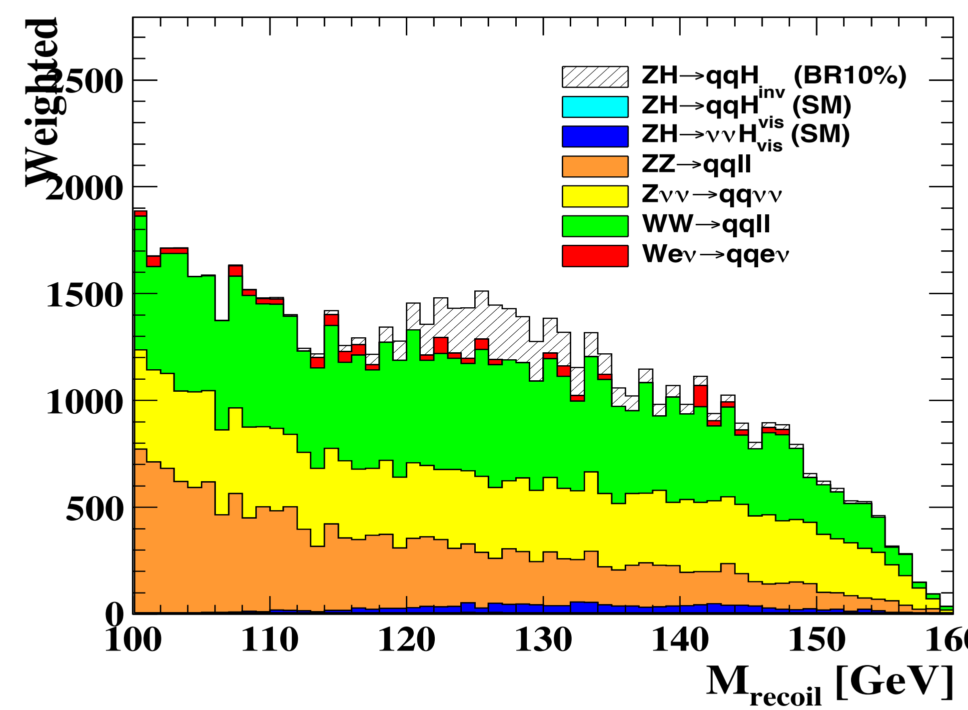
- For now I do not use BDT parameter.

Recoil Dist with BG @$\sqrt{s}$=250GeV

1. Recoil mass distribution.

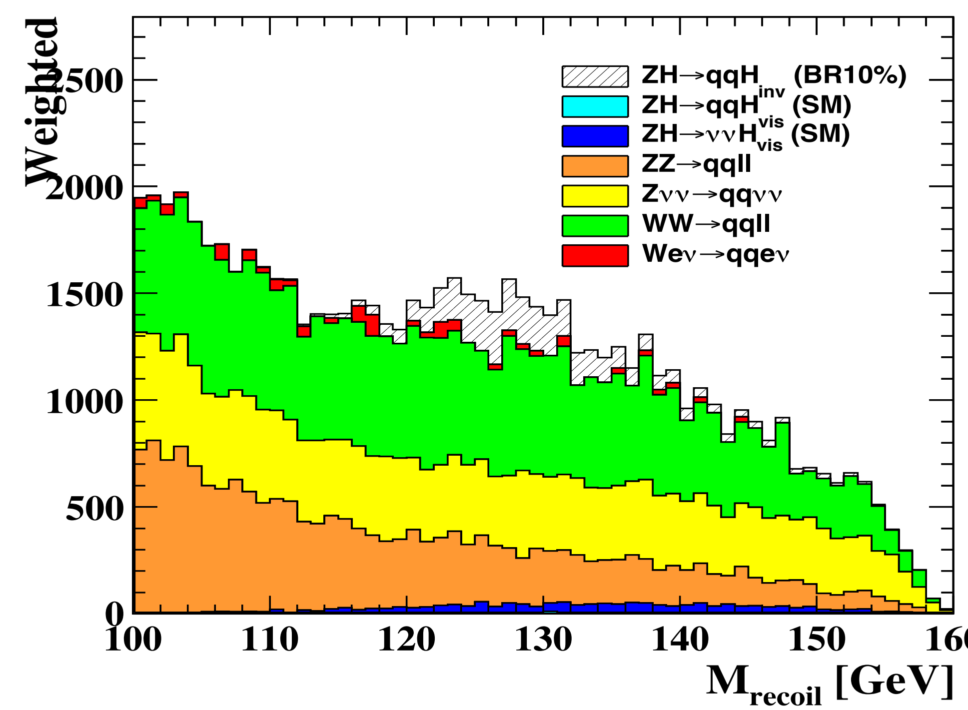
cut&process	qqh_inv	_zh_qqh	_zh_vvh	_zz_sl	_zvv_sl	_ww_sl	_wev_sl
# Raw MCdata	#25k	#25k	#25k	#60k	#60k	#600k	#60k
# xsection	21.2	212.2	78.3	685.4	272.3	10954.8	5910.1
lepveto	99.796	92.100	92.251	79.999	99.818	54.815	29.602
logy23	98.668	60.624	82.319	73.434	97.715	50.152	27.908
zenergy	94.540	0.364	17.990	31.943	64.043	3.293	0.237
zmass	89.148	0.236	9.616	28.023	57.921	2.749	0.162
ptdijet	87.240	0.224	9.107	25.335	53.809	2.475	0.147
costhetaj0	82.084	0.216	8.670	23.141	50.189	2.162	0.132
costhetaj1	75.692	0.196	8.169	21.899	47.691	2.039	0.122
costhetaj01	74.040	0.192	8.045	15.262	38.116	1.311	0.085
costhetaZ	70.524	0.180	7.600	13.366	33.984	1.132	0.077
visenergy	70.464	0.180	7.420	13.352	33.954	1.132	0.077
recoil 70.456	0.1807.3849.45028.340		0.9500.070				
#Remaining	#3734	#95	#1445	#16193	#19294	#26003	#1034

Nsig: 3734 Nbg: 64068 SN: 0.06



cut&process	qqh_inv	_zh_qqh	_zh_vvh	_zz_sl	_zvv_sl	_ww_sl	_wev_sl
# Raw MCdata	#25k	#25k	#25k	#60k	#60k	#600k	#60k
# xsection	21.2	212.2	78.3	685.4	272.3	10954.8	5910.1
lepveto	99.808	92.004	92.180	79.975	99.825	54.554	30.587
logy23	99.332	57.436	84.886	74.090	98.752	49.978	28.855
zenergy	94.928	0.380	19.849	34.610	68.209	3.735	0.233
zmass	89.480	0.228	10.299	30.525	61.728	3.130	0.162
ptdijet	87.588	0.220	9.762	27.707	57.239	2.813	0.152
costhetaj0	82.656	0.208	9.330	25.347	53.408	2.449	0.132
costhetaj1	76.164	0.188	8.697	23.987	50.829	2.305	0.122
costhetaj01	74.536	0.188	8.557	16.603	40.184	1.438	0.083
costhetaZ	71.136	0.172	8.072	14.543	35.782	1.238	0.075
visenergy	71.036	0.172	7.924	14.525	35.732	1.237	0.075
#Remaining	#3764	#91	#1544	#17661	#20447	#27892	#1083

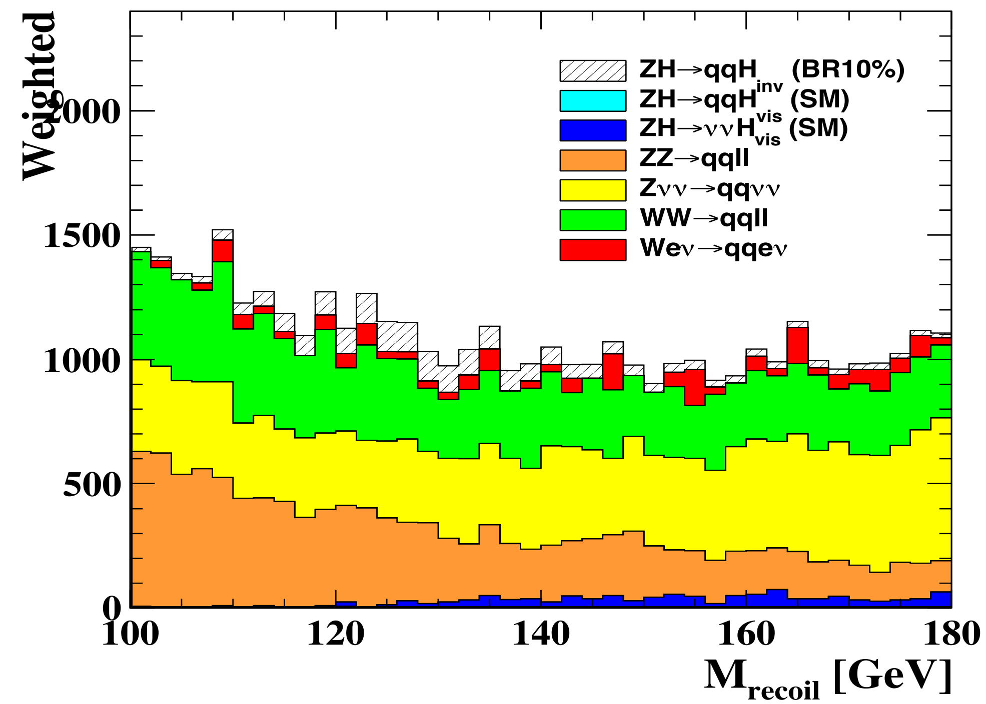
Nsig: 3764 Nbg: 68721 SN: 0.05



Recoil Dist with BG @√s=350GeV

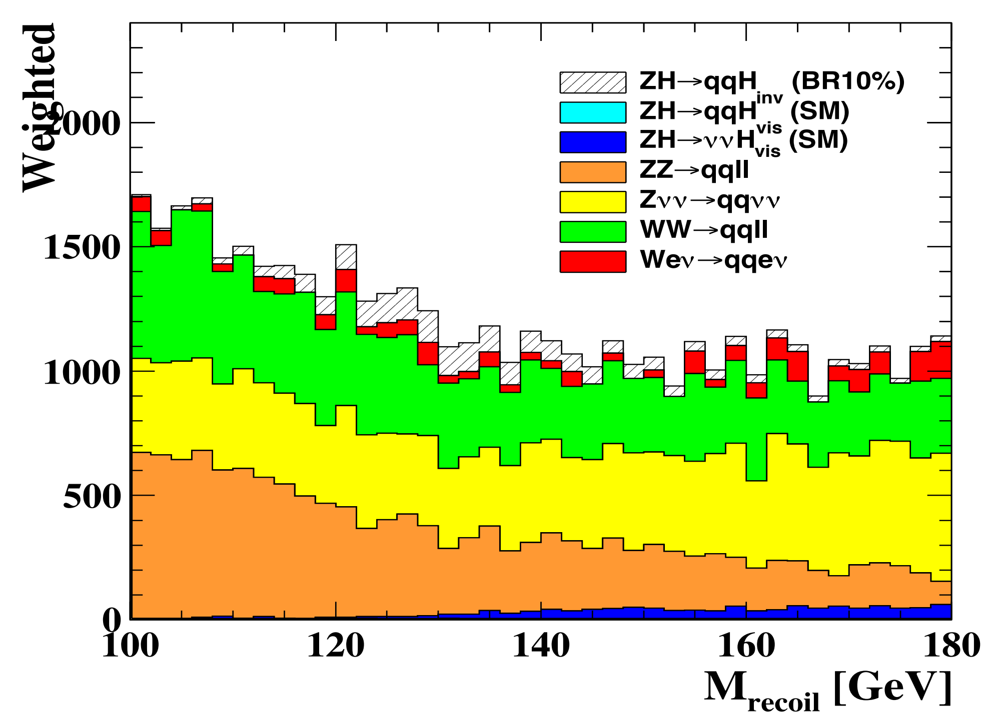
1. Recoil mass distribution.

cut&process	qqh_inv	_zh_qqh	_zh_vvh	_zz_sl	_zvv_sl	_ww_sl	_wev_sl
# Raw MCdata	#25k	#25k	#25k	#60k	#60k	#600k	#60k
# xsection	13.7	137.7	99.6	470.8	356.4	8090.6	4963.8
lepveto	99.872	91.948	92.629	80.532	99.828	59.113	38.680
logy23	98.824	72.864	85.337	77.529	98.693	58.477	38.273
zenergy	94.620	0.796	72.351	49.531	73.375	11.512	3.145
zmass	86.396	0.164	12.470	42.225	65.689	6.073	1.748
ptdijet	84.816	0.164	11.968	38.892	62.481	5.144	1.542
costhetaj0	80.788	0.160	11.281	32.630	55.653	3.813	1.070
costhetaj1	76.292	0.156	10.528	30.575	52.471	3.519	0.903
costhetaj01	54.480	0.112	8.811	17.946	39.118	1.558	0.428
costhetaZ	53.316	0.108	8.217	14.937	33.434	1.201	0.340
visenergy	53.204	0.108	7.807	14.904	33.354	1.199	0.338
#Remaining	#2193	#38	#1123	#11504	#15028	#12331	#1853



Nsig: 2193 Nbg: 41880 SN: 0.05

cut&process	qqh_inv	_zh_qqh	_zh_vvh	_zz_sl	_zvv_sl	_ww_sl	_wev_sl
# Raw MCdata	#25k	#25k	#25k	#60k	#60k	#600k	#60k
# xsection	13.7	137.7	99.6	470.8	356.4	8090.6	4963.8
lepveto	99.836	92.008	92.302	80.508	99.832	58.883	40.100
logy23	99.524	79.696	86.932	78.832	99.267	58.309	39.724
zenergy	95.324	0.884	74.915	50.503	73.580	12.299	3.537
zmass	86.856	0.176	13.659	42.685	65.706	6.273	1.939
ptdijet	85.444	0.176	13.053	39.355	62.449	5.289	1.701
costhetaj0	81.400	0.168	12.277	33.163	55.646	3.967	1.196
costhetaj1	76.920	0.160	11.351	31.060	52.503	3.652	1.019
costhetaj01	55.136	0.116	9.334	18.292	39.194	1.626	0.484
costhetaZ	53.964	0.112	8.709	15.247	33.492	1.250	0.390
visenergy	53.824	0.112	8.183	15.182	33.376	1.247	0.387
#Remaining	#2234	#40	#1158	#13344	#15709	#14114	#1969



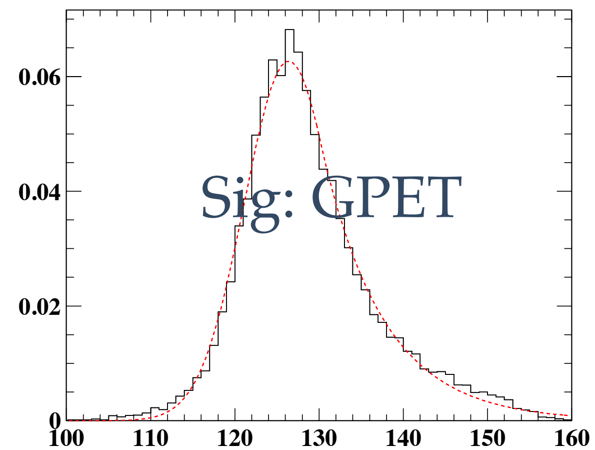
Nsig: 2234 Nbg: 46337 SN: 0.05

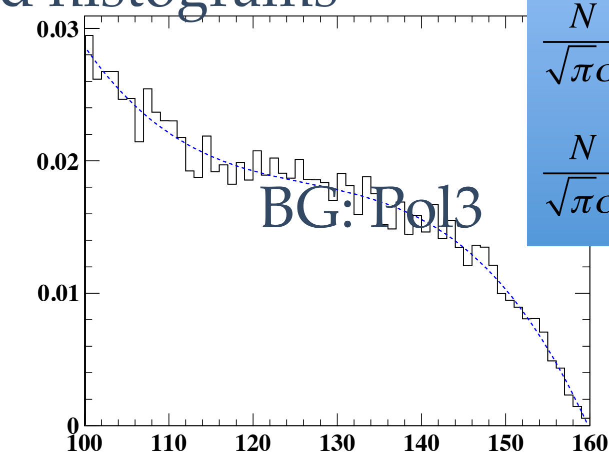
ToyMC

- Do Toy MC to estimate upper limit of BR(H➡invisible)

1. Fix function shape.

- After normalized histograms





◆ SIGNAL: GPET: 5 parameters :
Gaus (left-side) , Gaus + expo (right side)

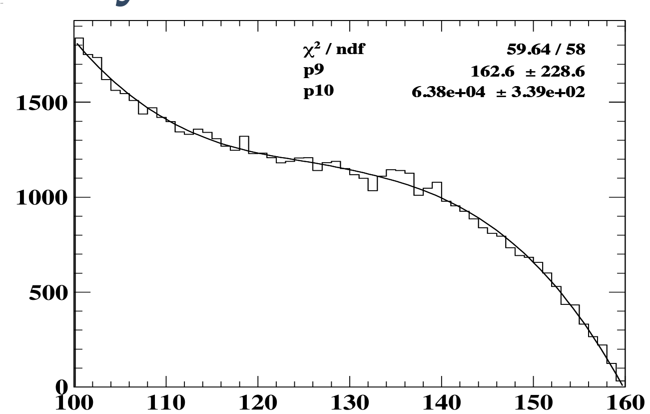
$$\frac{N}{\sqrt{\pi}\sigma}\exp\left\{-\frac{1}{2}\left(\frac{x-x_{mean}}{\sigma}\right)^2\right\} \qquad \left(\frac{x-x_{mean}}{\sigma}\leq k\right)$$

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

Define function :

Nsig * Fsig(Fix GPET) + Nbg * Fbg(Fix Pol3)

2. Toy MC



- Generated background sample based on fixed Pol3

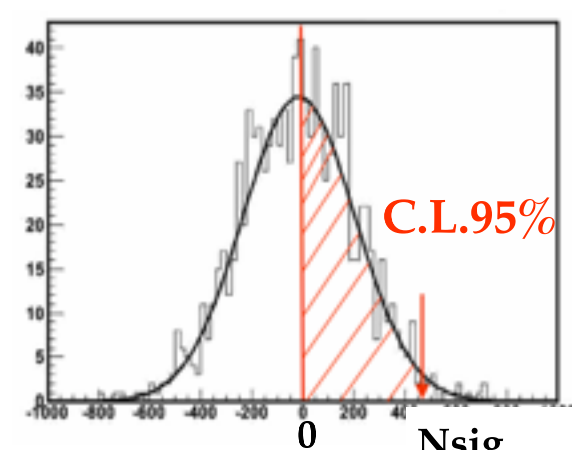
ToyMC : Xbg (Poisson)* Fbg(Fix Pol3)

- Fit with defined function and pull out parameter “Nsig"

3. Upper limit .

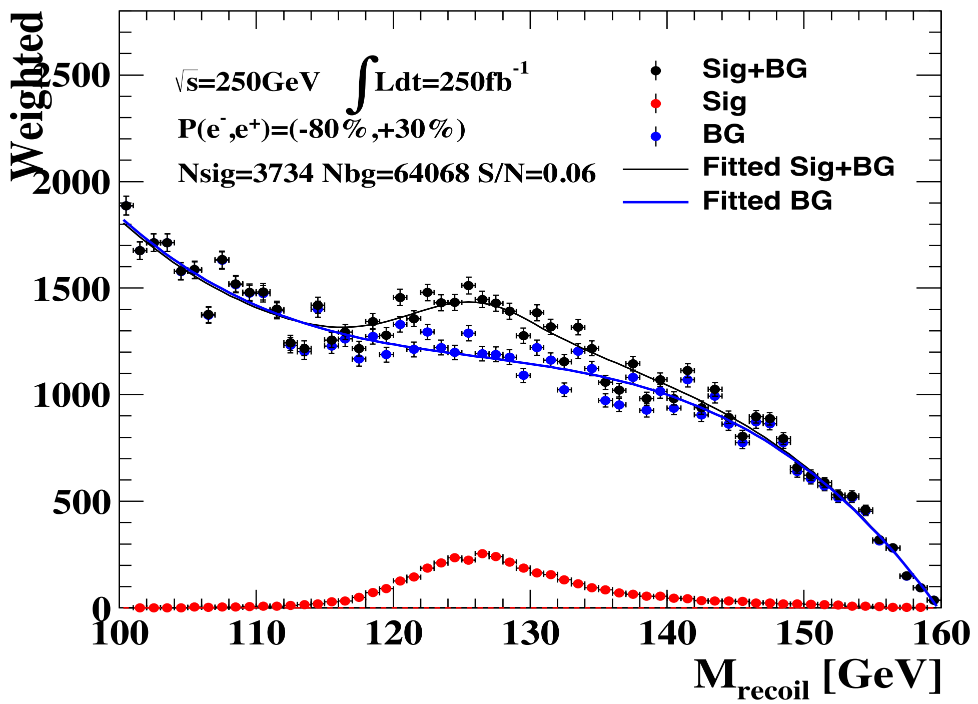
$$\sigma = \frac{N_{sig}^{upperlimit}}{fL}$$

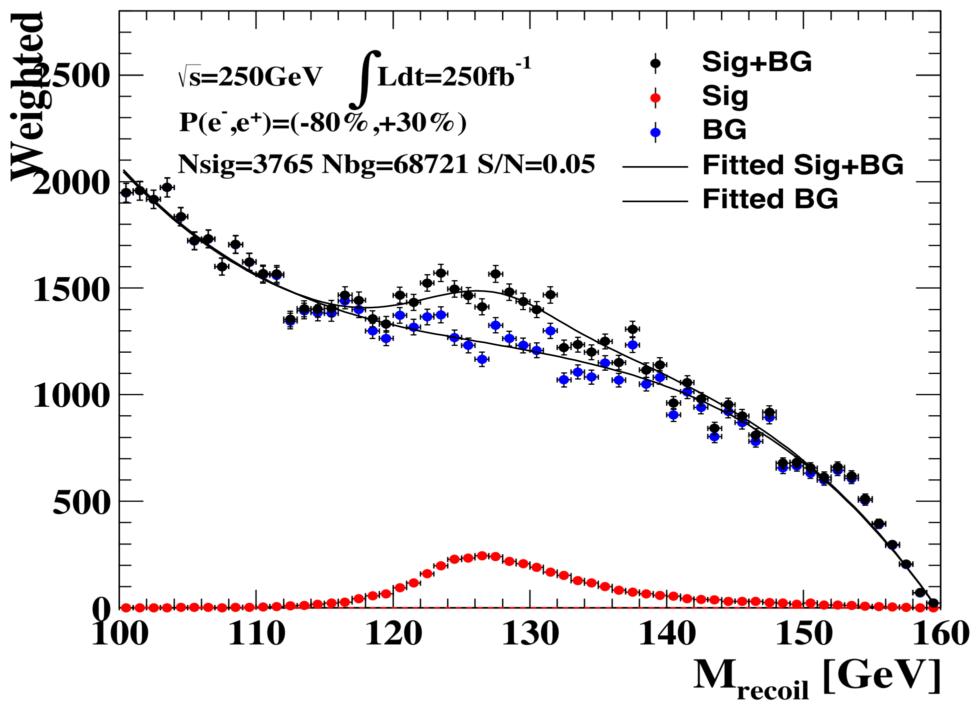
$$BR(H \rightarrow invisible) = \frac{\sigma_{invisible}^{C.L.95\,\%}}{\sigma(e^+e^- \rightarrow ZH)}$$



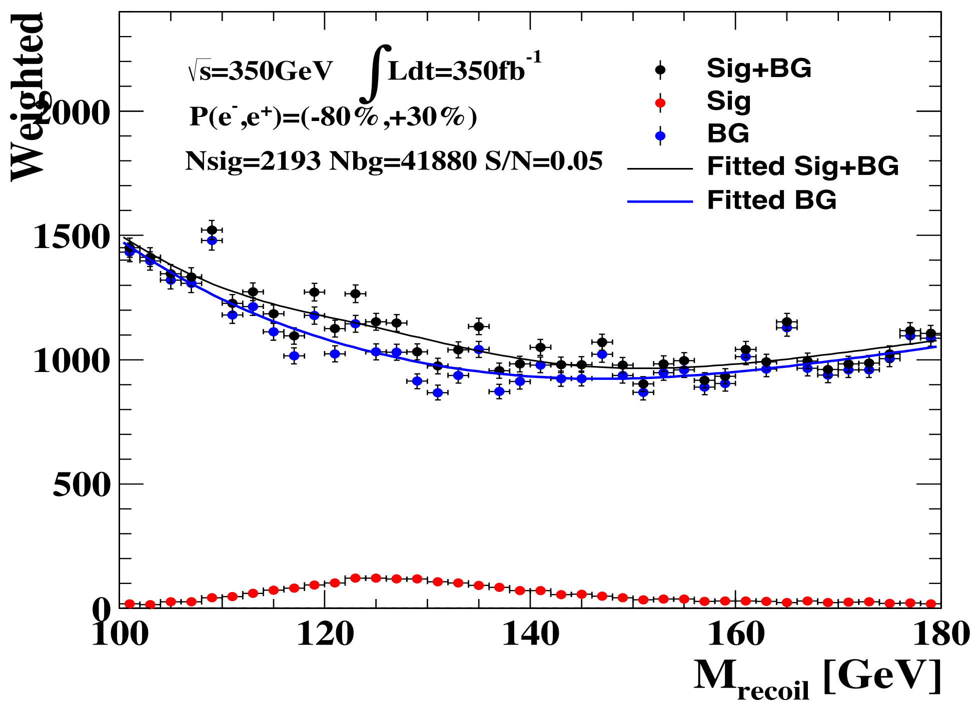
Shape of fitting function

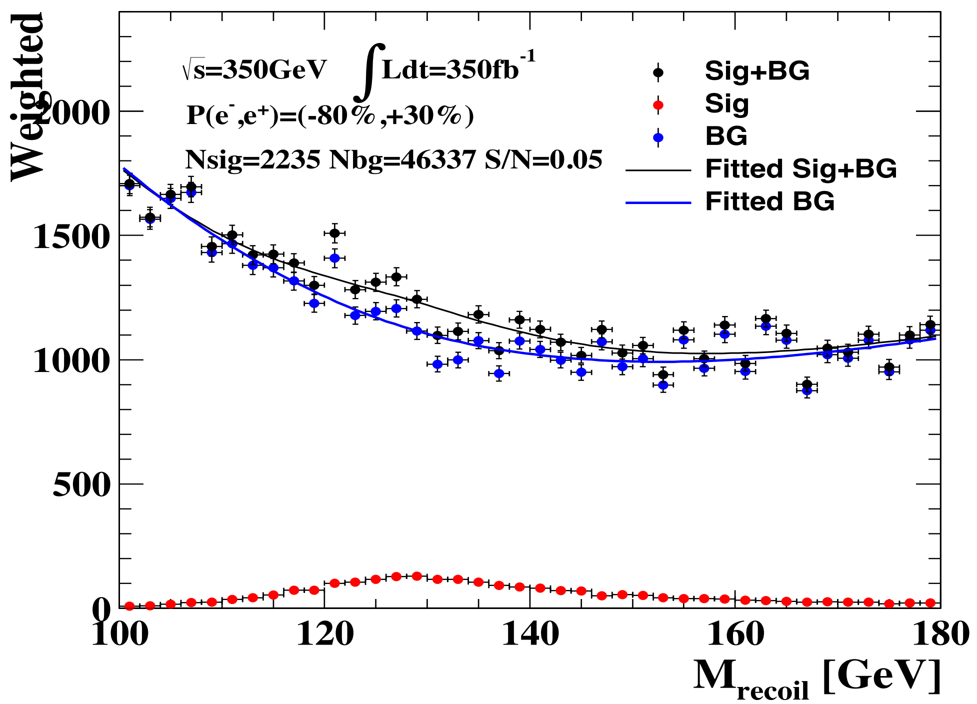
1. √s=250GeV (250fb^{-1}).





1. √s=350GeV (350fb^{-1}).



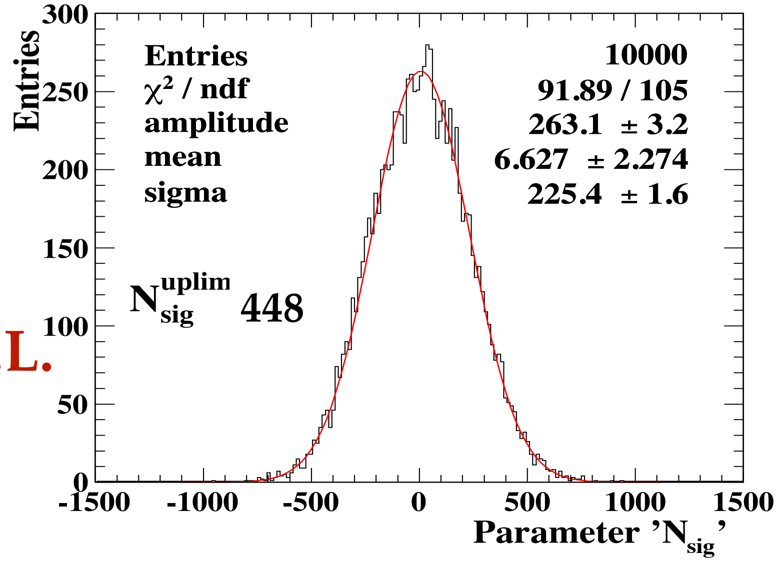


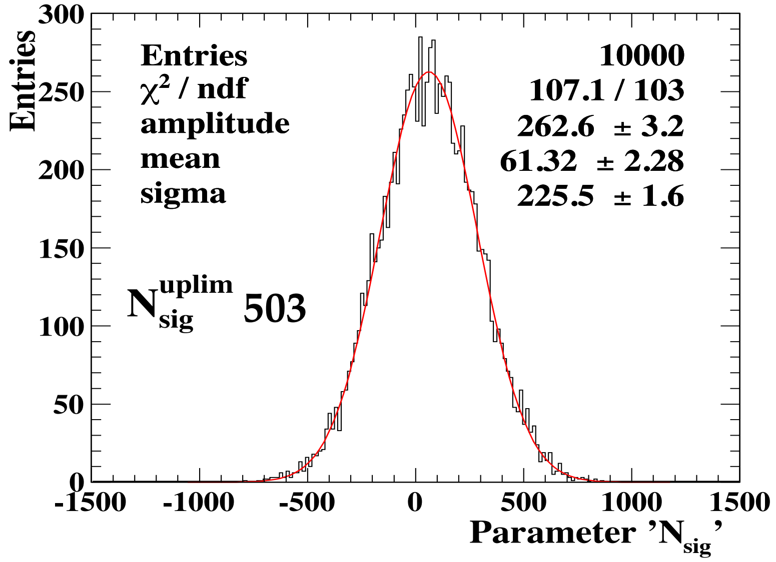
Upper Limit of BR(H➡invisible)

1. √s=250GeV (250fb⁻¹).

Si: ε_sig= 70.46[%], N_sig=448
➡ σ = 2.54[fb]
BR(H➡invisible) < 1.20% @95% C.L.

Sc: ε_sig= 71.03[%], N_sig=503
➡ σ = 2.83[fb]
BR(H➡invisible) < 1.33% @95% C.L.



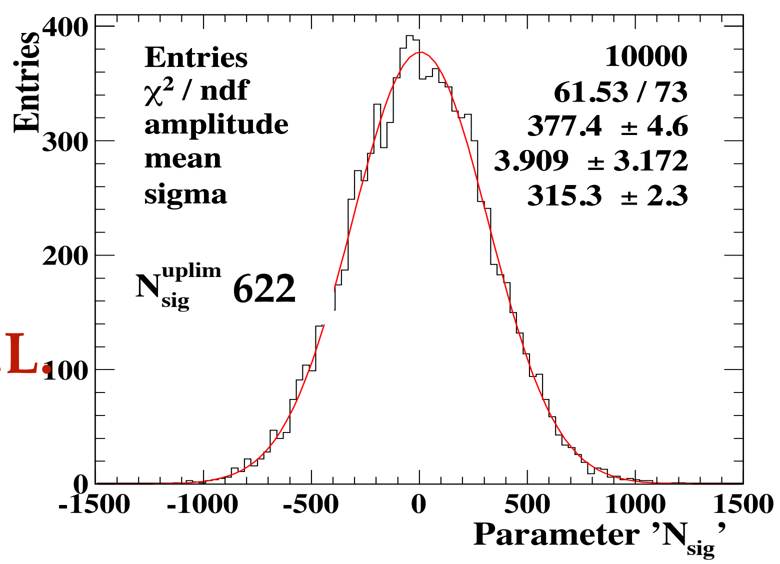


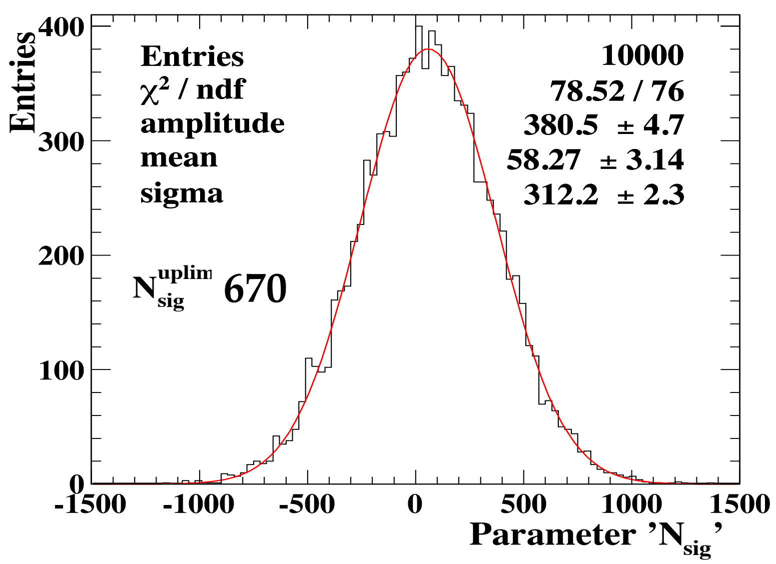
➡ Degradation of sensitivity is 11%

2. √s=350GeV (350fb⁻¹).

Si: ε_sig= 53.20[%], N_sig=622
➡ σ = 3.35[fb]
BR(H➡invisible) < 2.43% @95% C.L.

Sc: ε_sig= 53.82[%], N_sig=670
➡ σ = 3.56[fb]
BR(H➡invisible) < 2.58% @95% C.L.





➡ Degradation of sensitivity is 6.3%

Summary

1. I analyzed invisible Higgs decay to compare performance of ECALs

- The difference of JER at 100 GeV jet is about 0.25% .

2. By the current result is that

If we reduce the cost of ECAL more than 50% , (because our default is Si)
the sensitivity of invisible higgs decay will
get worse 7.5% at 250GeV (250fb^{-1}), 3.4% at 350GeV (350fb^{-1})

3. Need to investigate why shift occurs (higgs recoil mass in case of ScECAL).

3. Need to investigate bias of ToyMC (in case of ScECAL).

3. Need to optimize cut variables.

– (Ishikawa-san)"Left" polarization : BF (H→invisible) < 0.95% ? @ 95% CL ?