# Recoil mass analysis to prove performance not to be different between SiECAL and ScECAL

July, 18, 2014

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Today's report :

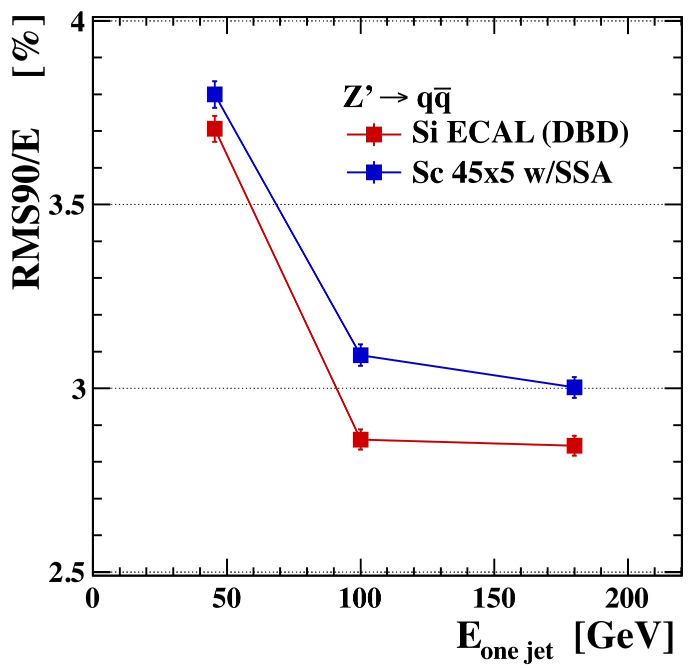
➡ Analysis of invisible higgs decay with two ECAL options.

# My Motivation

## 1. My motivation is to compare performance between SiECAL and ScECAL

- JER b/w Si and Sc is slightly difference, ~ 0.3%.

- Sc has problem due to fake hits.



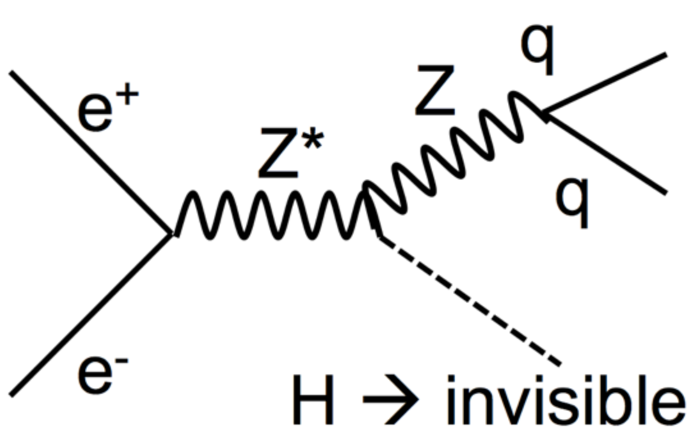

## 2. Invisible Higgs decays

- For detectors.

  - Jet Energy Resolution is essential.

- For physics.

  - It is clear signal for new physics.

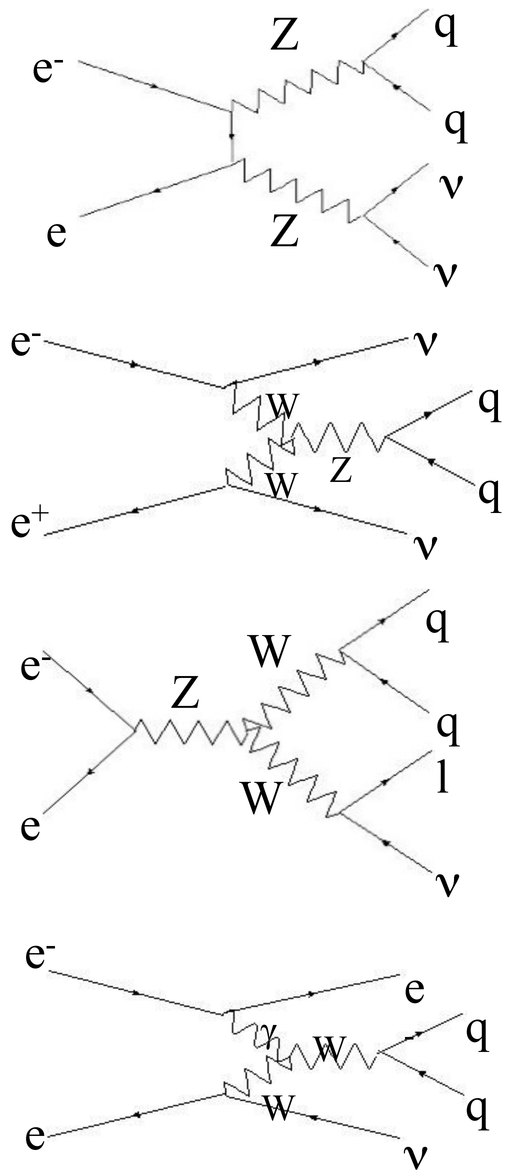


# My Simulation condition & Analysis flow

## 1. Simulation condition.

- Analysis process is ZH → qqH (H → inv).

- √s is 250GeV(L=250fb^-1), 350GeV(L=350fb^-1).
  Beam polarization is (-0.8, +0.3)




- All sample are full reconstructed by using SiECAL and ScECAL.

  Sig) ZH ➡ qqH : H ➡ invisible decay.  ( For now, H->ZZ->νννν. )
  I assumed Br is10%.

- Also I generated only most dominant BG by using each ECal.

  BG) ZZ→qqll, Zνν→qqνν, WW→qqll, Weν→qqeν,

## 2. Cross section.

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

| Process | $\sigma$(fb) | $\sigma \cdot$ L |
|---|---|---|
| ZH → qq$H_{inv}$ | 21.2 | 5300 |
| ZH → qqH (SM) | 212.2 - 21.2 | 53058 - 5300 |
| ZH → ννH (SM) | 78.3 | $1.9\times10^4$ |
| ZZ → qqll | 685.4 | $1.7\times10^5$ |
| Zνν → qqνν | 272.3 | $6.8\times10^4$ |
| WW → qqll | 10955 | $2.7\times10^6$ |
| Weν → qqeν | 5910.1 | $1.5\times10^6$ |

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

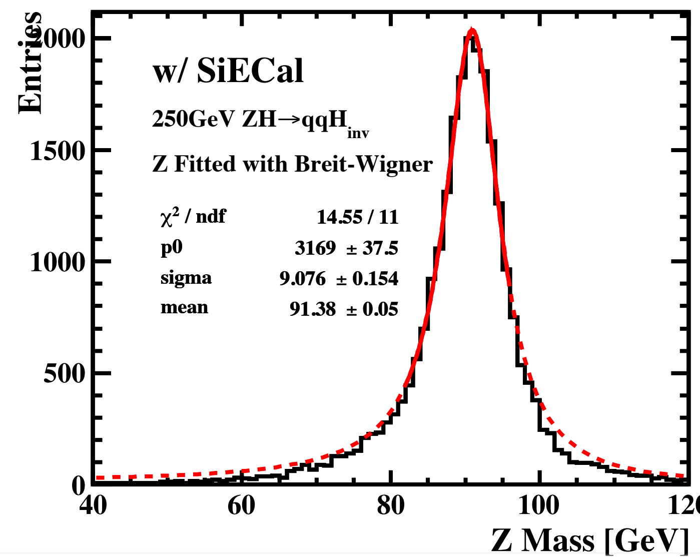
| Process | $\sigma$(fb) | $\sigma \cdot$ L |
|---|---|---|
| ZH → qq$H_{inv}$ | 13.7 | 3425 |
| ZH → qqH (SM) | 137.7 - 13.7 | 34425 - 3425 |
| ZH → ννH (SM) | 99.6 | $2.5\times10^4$ |
| ZZ → qqll | 470.8 | $1.2\times10^5$ |
| Zνν → qqνν | 356.4 | $8.9\times10^5$ |
| WW → qqll | 8090.6 | $2.0\times10^6$ |
| Weν → qqeν | 4963.8 | $1.2\times10^6$ |

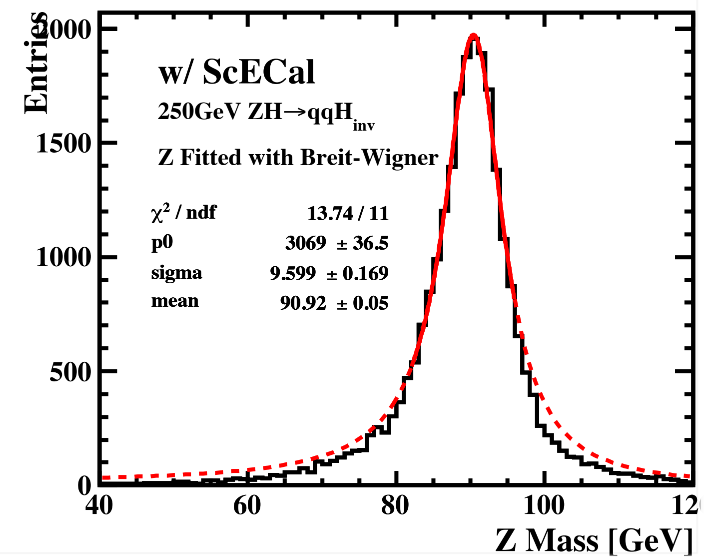
# Signal: Z mass and Recoil mass @ √s=250GeV

## 1. Comparison of Z mass.

- Si ECal: **Sigma with B-W ~ 9.08GeV.**
  (Mean with B-W 91.4GeV)
  **Resolution ~ 9.9%.**

- Sc ECal: **Sigma with B-W ~ 9.60GeV.**
  (Mean with B-W 90.9GeV)
  **Resolution ~ 10.5%.**

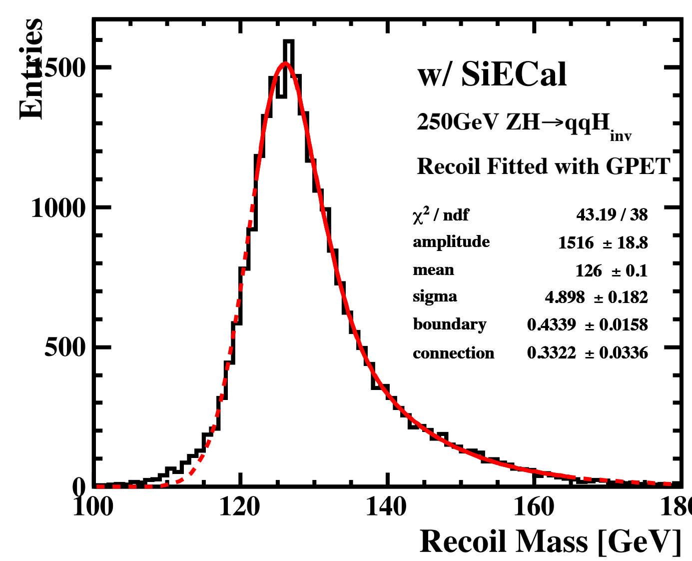


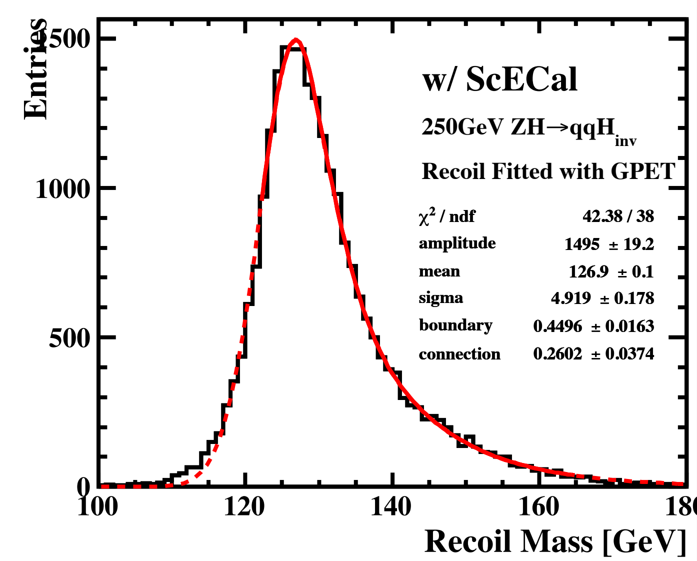




## 2. Comparison of Recoil mass.

- Si ECal: **Sigma with GPET ~ 4.90GeV.**
  (Mean with GPET 126.0GeV)

- Sc ECal: **Sigma with GPET ~ 4.91GeV.**
  (Mean with GPET 126.9GeV)

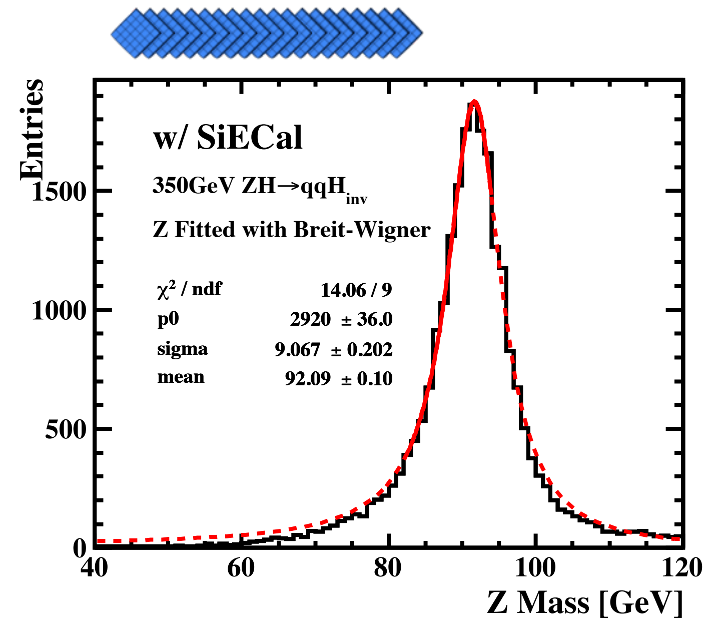


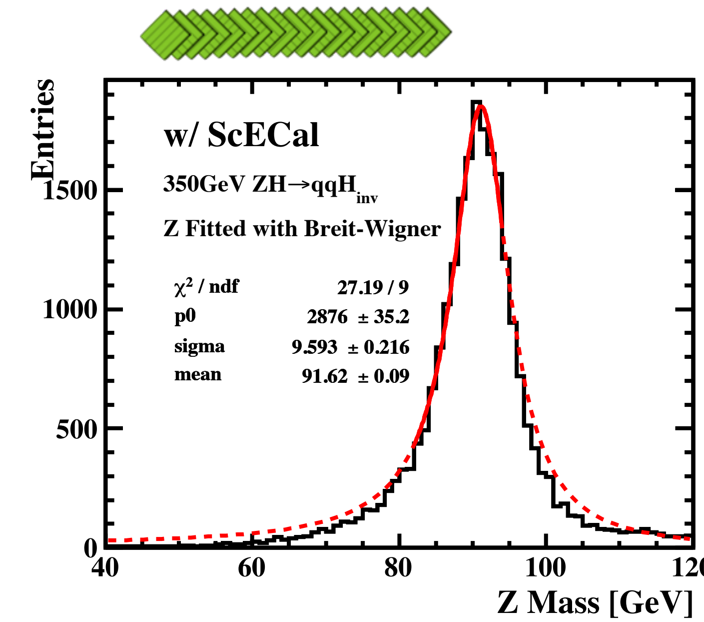



# Signal: Z mass and Recoil mass @ $\sqrt{s}$=350GeV

## 1. Comparison of Z mass.

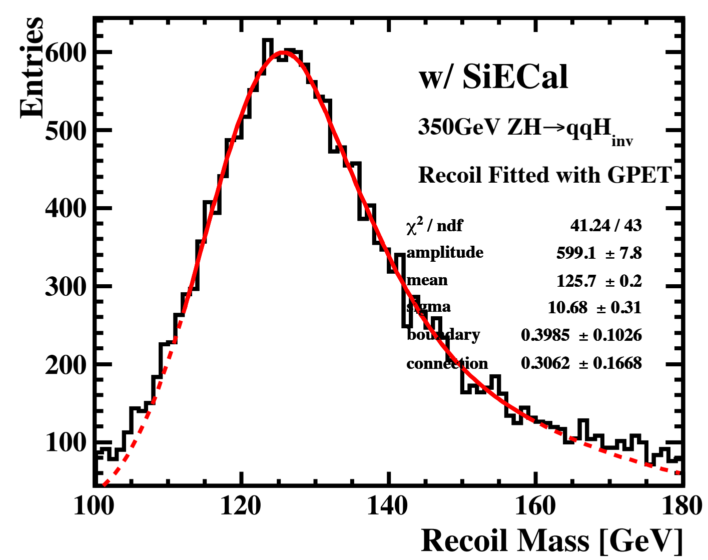
- Si ECal: **Sigma with B-W ~ 9.07GeV.**
  (Mean with B-W 92.0GeV)
  **Resolution ~ 9.48%.**
- Sc ECal: **Sigma with B-W ~ 9.59GeV.**
  (Mean with B-W 91.6GeV)
  **Resolution ~ 9.55%.**

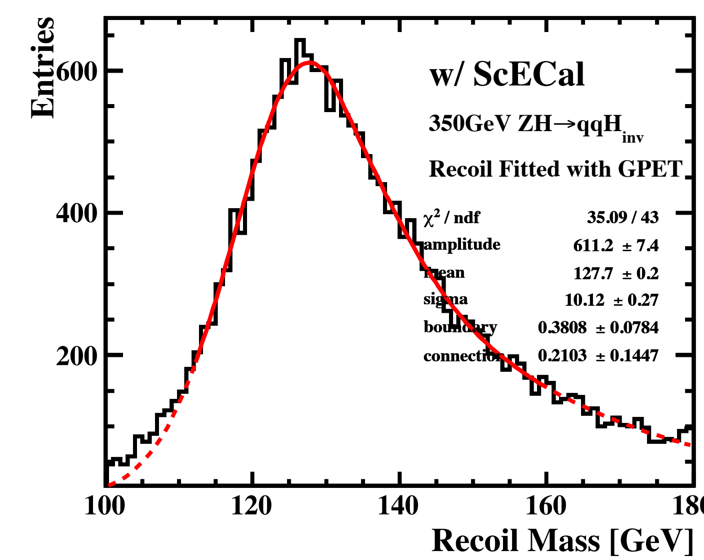



## 2. Comparison of Recoil mass.

- Si ECal: **Sigma with GPET ~ 10.7GeV.**
  (Mean with GPET 125.7GeV)
- Sc ECal: **Sigma with GPET~ 10.1GeV.**
  (Mean with GPET 127.7GeV)



# Recoil Distribution with BG @ √s=250GeV

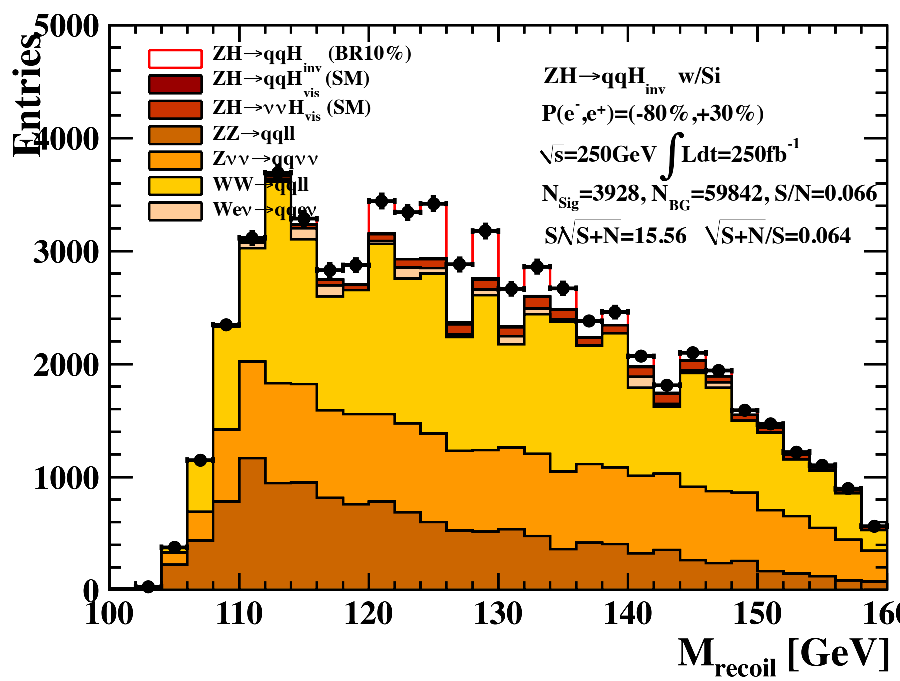
## 1. Recoil Distribution with BG.

Si ECAL @ 250 GeV

| Cuts(%) | ZH → qqH$_{inv}$ | ZH → qqH | ZH → ννH | ZZ → qqll | Zνν → qqνν | WW → qqll | Weν → qqeν |
|---|---|---|---|---|---|---|---|
| No cut | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| + Iso lepton veto=0 | 99.8 | 92.1 | 92.3 | 80.0 | 99.8 | 54.6 | 29.6 |
| + 1.5<−LogY$_{23}$<10.5 | 99.8 | 83.7 | 88.3 | 78.8 | 99.6 | 54.5 | 29.5 |
| + 20<#PFOs <75 | 98.0 | 16.7 | 74.6 | 76.0 | 95.0 | 53.8 | 29.2 |
| + $\|\cos\theta_{jet1}\|<0.95$ | 85.7 | 15.3 | 67.4 | 63.9 | 84.1 | 41.3 | 18.7 |
| + $\|\cos\theta_{jet12}\|<0.1$ | 84.7 | 15.3 | 66.8 | 60.7 | 78.4 | 39.0 | 18.0 |
| + $\|\cos\theta_Z\|<0.95$ | 81.4 | 14.2 | 63.6 | 52.9 | 70.7 | 34.7 | 17.0 |
| + 75<Mz<105 | 75.4 | 14.0 | 50.0 | 51.0 | 66.7 | 34.0 | 16.9 |
| + 75<Ez<105 | 75.1 | 4.24 | 15.5 | 34.3 | 59.4 | 9.10 | 4.00 |
| + $Pt^2_{jet1}<7000$ | 74.7 | 0.21 | 8.67 | 26.2 | 53.1 | 2.47 | 0.13 |
| + BDT<0.0 | 74.4 | 0.19 | 8.14 | 7.93 | 26.9 | 0.98 | 0.05 |
| + 110<Mrecoil<160 | 74.1 | 0.19 | 7.88 | 7.84 | 26.2 | 0.95 | 0.05 |

Sc ECAL @ 250 GeV

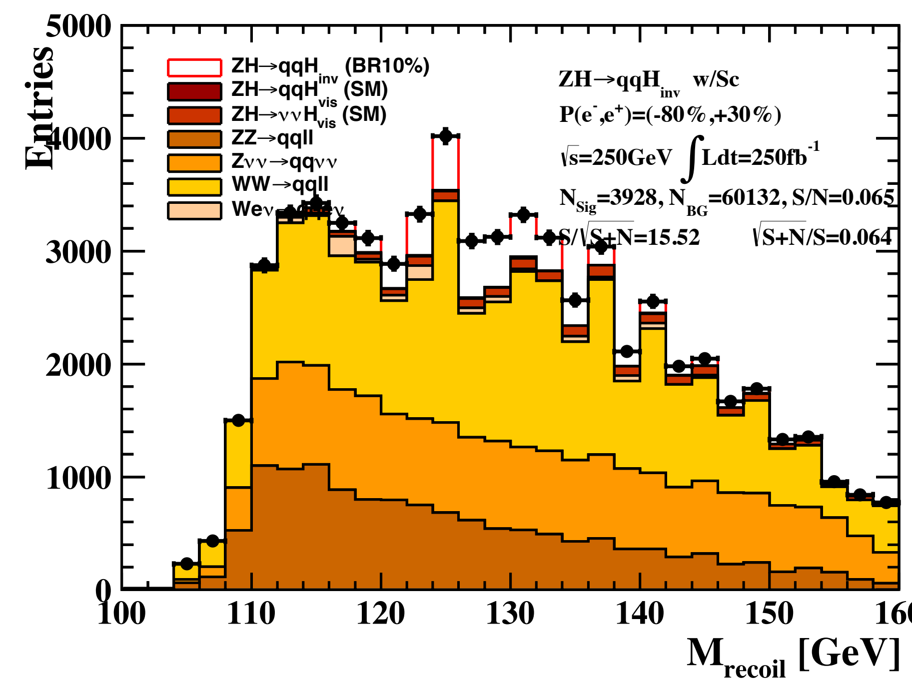
| Cuts(%) | ZH → qqH$_{inv}$ | ZH → qqH | ZH → ννH | ZZ → qqll | Zνν → qqνν | WW → qqll | Weν → qqeν |
|---|---|---|---|---|---|---|---|
| No cut | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| + Iso lepton veto=0 | 99.8 | 92.0 | 92.2 | 80.0 | 99.8 | 54.5 | 30.6 |
| + 1.5<−LogY$_{23}$<10.5 | 99.8 | 83.5 | 89.2 | 79.2 | 99.8 | 54.3 | 30.5 |
| + 20<#PFOs <75 | 97.8 | 14.9 | 72.4 | 76.0 | 95.0 | 53.4 | 30.1 |
| + $\|\cos\theta_{jet1}\|<0.95$ | 85.5 | 13.6 | 65.4 | 63.7 | 84.1 | 41.1 | 19.4 |
| + $\|\cos\theta_{jet12}\|<0.1$ | 84.6 | 13.6 | 64.8 | 60.4 | 78.3 | 38.9 | 18.7 |
| + $\|\cos\theta_Z\|<0.95$ | 81.3 | 12.7 | 61.7 | 52.8 | 70.5 | 34.5 | 17.7 |
| + 75<Mz<105 | 75.3 | 12.4 | 47.2 | 50.7 | 66.4 | 33.8 | 17.6 |
| + 75<Ez<105 | 75.0 | 3.54 | 15.3 | 34.8 | 60.3 | 9.03 | 4.50 |
| + $Pt^2_{jet1}<7000$ | 74.7 | 0.17 | 9.00 | 26.9 | 54.4 | 2.63 | 0.13 |
| + BDT<0.0 | 74.4 | 0.15 | 8.30 | 7.91 | 26.9 | 0.99 | 0.05 |
| + 110<Mrecoil<160 | 74.1 | 0.15 | 8.00 | 7.83 | 26.3 | 0.98 | 0.05 |




ε_sig = 74.1

N_sig = 3928, N_BG = 59842,

S/N = 6.6%, Significance = 15.5




ε_sig = 74.1

N_sig = 3928, N_BG = 60132,

S/N = 6.4%, Significance = 15.5

# Recoil Distribution with BG @ √s=350GeV

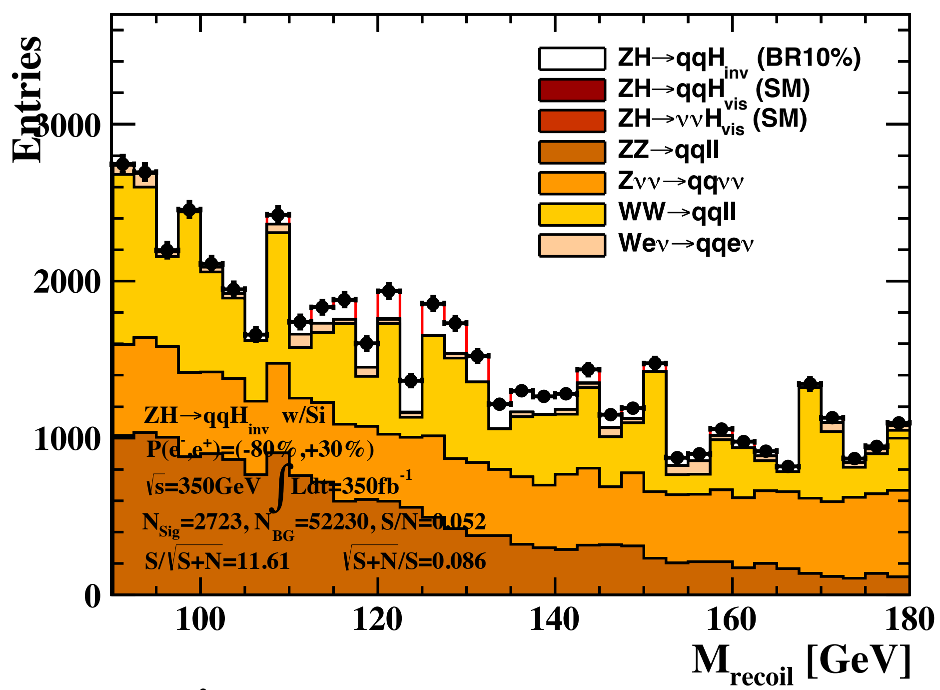
## 1. Recoil Distribution with BG.

Si ECAL @ 350 GeV

| Cuts(%) | $ZH \to qqH_{inv}$ | $ZH \to qqH$ | $ZH \to \nu\nu H$ | $ZZ \to qqll$ | $Z\nu\nu \to qq\nu\nu$ | $WW \to qqll$ | $We\nu \to qqe\nu$ |
|---|---|---|---|---|---|---|---|
| No cut | 100.0 | 100.0 | - | 100.0 | 100.0 | 100.0 | 100.0 |
| + Iso lepton veto=0 | 99.9 | 91.9 | - | 80.5 | 99.8 | 59.0 | 38.7 |
| + $2.0 < -\mathrm{Log}Y_{23} < 11.0$ | 99.5 | 72.9 | - | 77.9 | 99.2 | 58.3 | 38.3 |
| + 15<#PFOs <90 | 99.2 | 28.1 | - | 77.2 | 98.2 | 58.2 | 38.2 |
| + $\lvert\cos\theta_{jet1}\rvert < 0.92$ | 83.1 | 25.6 | - | 48.5 | 74.4 | 26.3 | 11.8 |
| + $\lvert\cos\theta_{jet12}\rvert < 0.92$ | 82.3 | 4.48 | - | 37.6 | 70.5 | 13.3 | 6.02 |
| + $\lvert\cos\theta_{Z}\rvert < 0.92$ | 80.1 | 3.13 | - | 29.5 | 59.0 | 10.4 | 4.86 |
| + 80<Mz<100 | 63.9 | 2.05 | - | 22.2 | 48.4 | 4.90 | 3.30 |
| + 90<Ez<210 | 63.7 | 0.36 | - | 20.4 | 46.3 | 1.77 | 1.01 |
| + $Pt^2_{jet2} < 6000$ | 63.6 | 0.36 | - | 20.3 | 44.7 | 1.76 | 1.01 |
| + BDT<-0.1 | 62.5 | 0.36 | - | 16.9 | 36.7 | 1.46 | 0.86 |
| + 90<Mrecoil<180 | 57.1 | 0.33 | - | 10.7 | 14.2 | 0.75 | 0.56 |

Sc ECAL @ 350 GeV

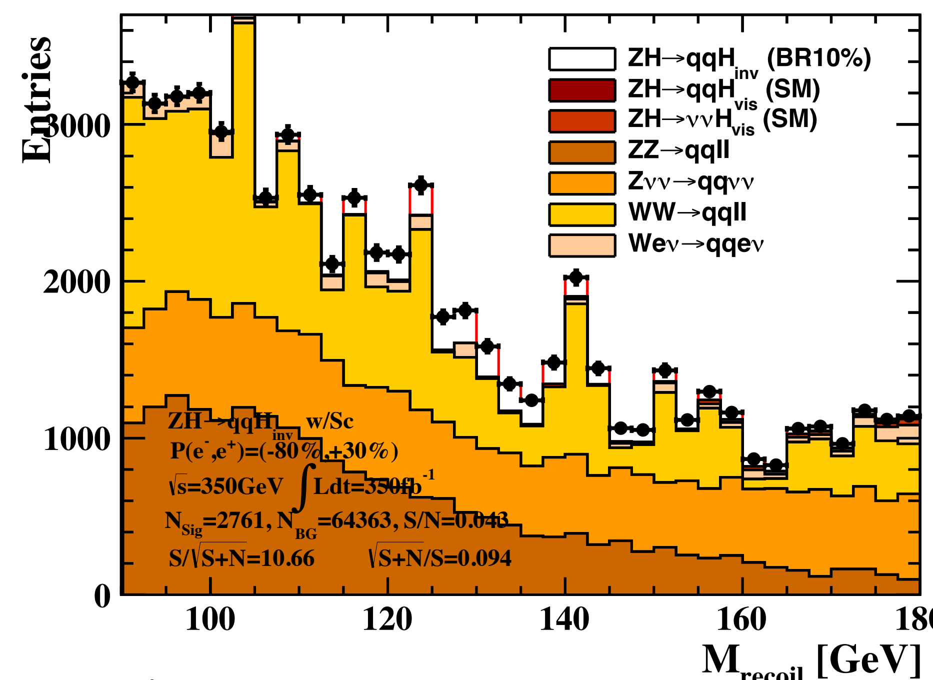
| Cuts(%) | $ZH \to qqH_{inv}$ | $ZH \to qqH$ | $ZH \to \nu\nu H$ | $ZZ \to qqll$ | $Z\nu\nu \to qq\nu\nu$ | $WW \to qqll$ | $We\nu \to qqe\nu$ |
|---|---|---|---|---|---|---|---|
| No cut | 100.0 | 100.0 | 100 | 100.0 | 100.0 | 100.0 | 100.0 |
| + Iso lepton veto=0 | 99.8 | 92.0 | 92.3 | 80.5 | 99.8 | 58.8 | 40.1 |
| + $2.0 < -\mathrm{Log}Y_{23} < 11.0$ | 99.6 | 79.7 | 88.5 | 79.0 | 99.4 | 58.2 | 39.7 |
| + 15<#PFOs <90 | 99.3 | 26.6 | 80.6 | 78.1 | 98.4 | 58.1 | 39.7 |
| + $\lvert\cos\theta_{jet1}\rvert < 0.92$ | 83.3 | 24.2 | 66.7 | 48.8 | 74.6 | 26.2 | 12.6 |
| + $\lvert\cos\theta_{jet12}\rvert < 0.92$ | 82.4 | 4.04 | 62.6 | 37.5 | 70.5 | 13.3 | 6.35 |
| + $\lvert\cos\theta_{Z}\rvert < 0.92$ | 80.3 | 2.95 | 57.0 | 29.3 | 59.2 | 10.4 | 5.16 |
| + 80<Mz<100 | 64.3 | 1.86 | 6.87 | 22.1 | 48.6 | 4.72 | 3.45 |
| + 90<Ez<210 | 64.1 | 0.37 | 5.94 | 20.5 | 46.4 | 1.81 | 1.10 |
| + $Pt^2_{jet2} < 6000$ | 64.0 | 0.37 | 5.23 | 20.4 | 44.8 | 1.80 | 1.09 |
| + BDT<-0.1 | 63.5 | 0.37 | 4.70 | 19.2 | 40.9 | 1.71 | 1.05 |
| + 90<Mrecoil<180 | 57.9 | 0.34 | 1.63 | 12.9 | 15.8 | 0.88 | 0.66 |




$\varepsilon$_sig = 57.1

N_sig = 2723, N_BG = 52230,

S/N = 5.2%, Significance = 11.6




$\varepsilon$_sig = 57.9

N_sig = 2761, N_BG = 64363,

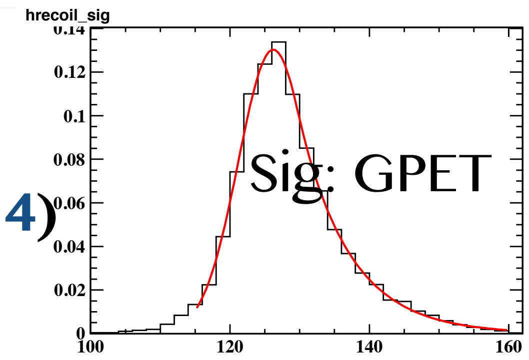
S/N = 4.3%, Significance = 10.7

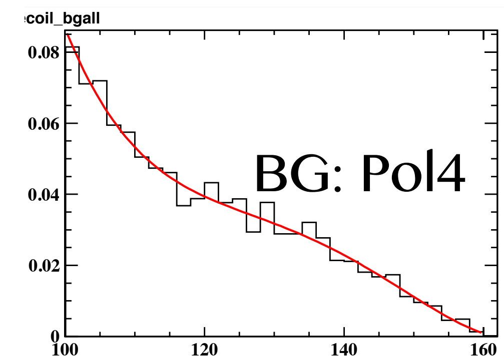
# ToyMC Estimation of Δσ/σ & Upper Limit

## 1. Decision of function shape.

Sig: GPET BG: Pol4

**FittingFunc: Nsig * Fsig(Fix GPET) + Nbg * Fbg(Fix Pol4)**

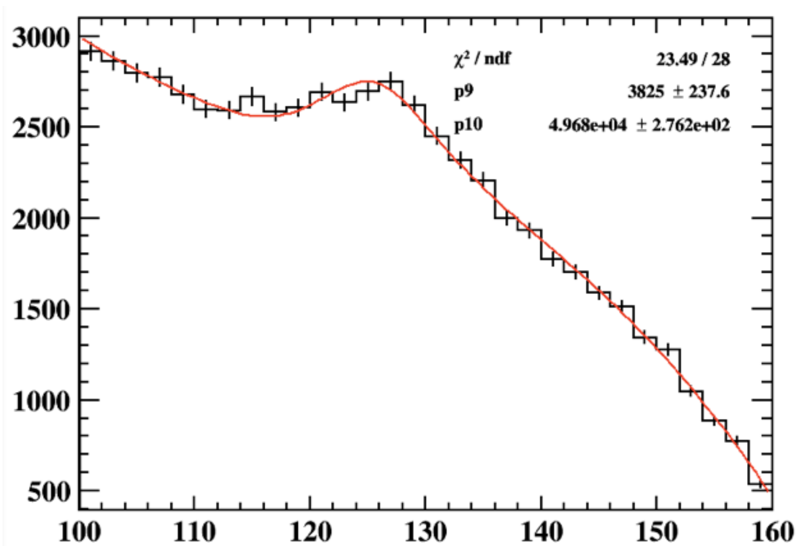



## 2. ToyMC.

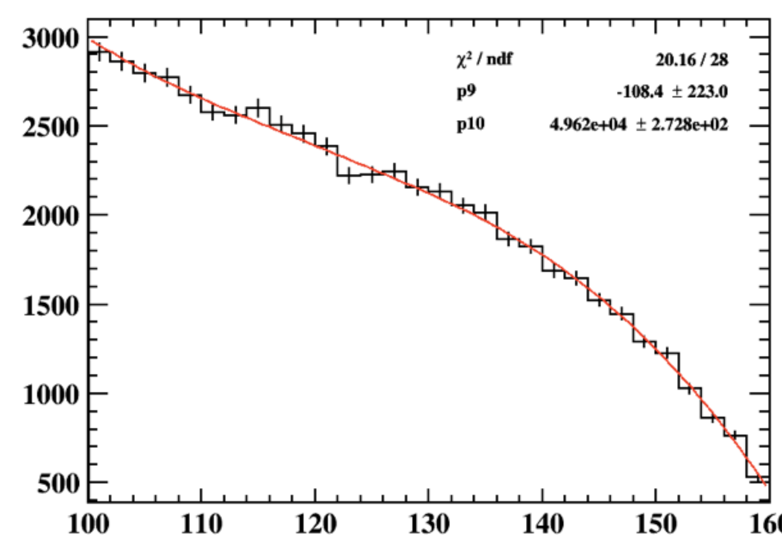
**Δσ/σ:** (This may be wrong?)

**ToyMC: Xsig (Poisson)* Fsig(Fix GPET)**
**+ Xbg (Poisson)* Fbg(Fix Pol4)**




**Upper Limit:**

**ToyMC: Xbg (Poisson)* Fbg(Fix Pol4)**



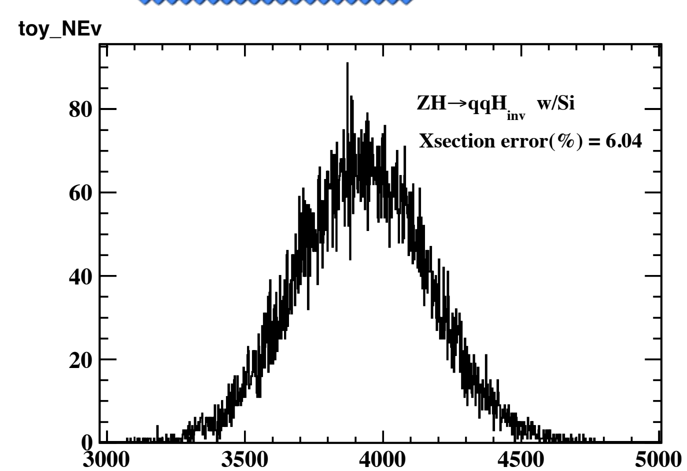

→Fit with fitting function and Pull out parameter "Nsig"

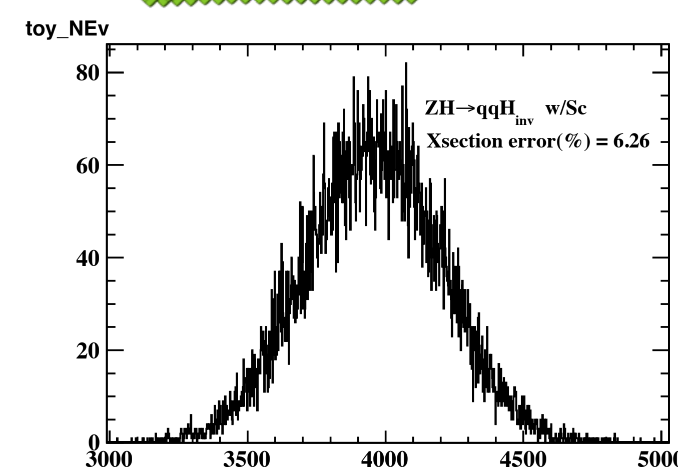
# Precision of Δσ/σ & Upper Limit of BR(H→invisible) @ √s=250GeV

## 1. Δσ/σ.

Si: Δσ/σ = 6.04%

Sc: Δσ/σ = 6.26%




## 2. Upper limit .

$$\sigma = \frac{N_{sig}^{upperlimit}}{fL} \qquad BR(H \to invisible) = \frac{\sigma_{invisible}^{C.L.95\ \%}}{\sigma(e^+e^- \to ZH)}$$

Si: ε_sig=74.1[%], N_sig=466

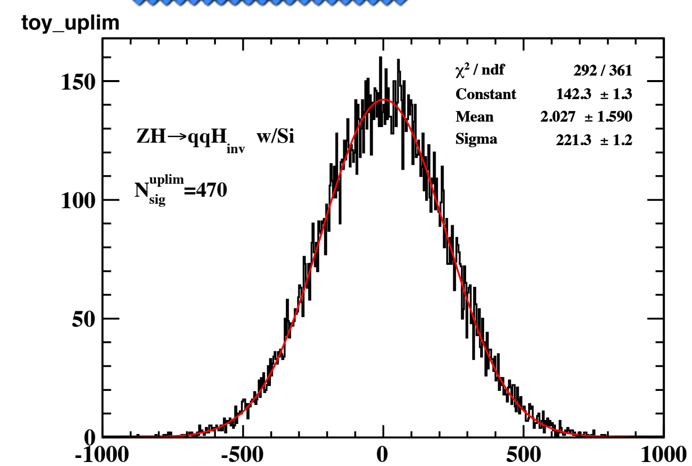
→ σ = 2.53[fb]

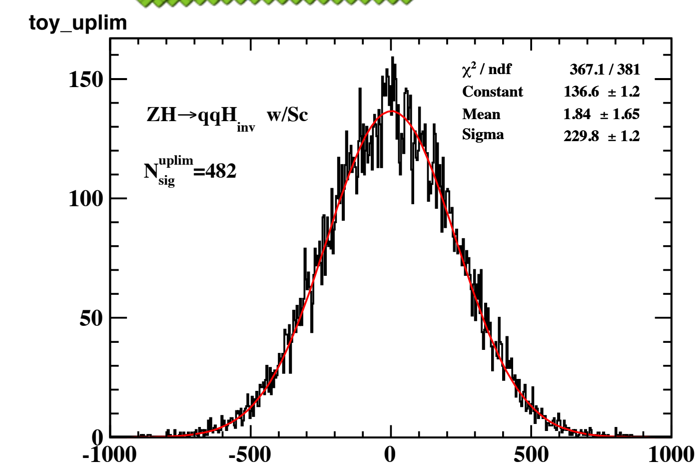
**BR(H→invisible) < 1.21% @ 95% C.L.**

Sc: ε_sig=74.1[%], N_sig=482

→ σ = 2.60[fb]

**BR(H→invisible) < 1.24% @ 95% C.L.**



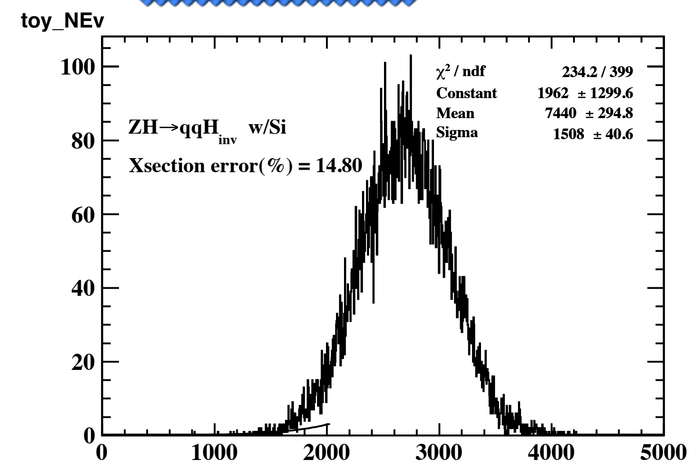
# Precision of Δσ/σ & Upper Limit of BR(H→invisible) @ √s=350GeV

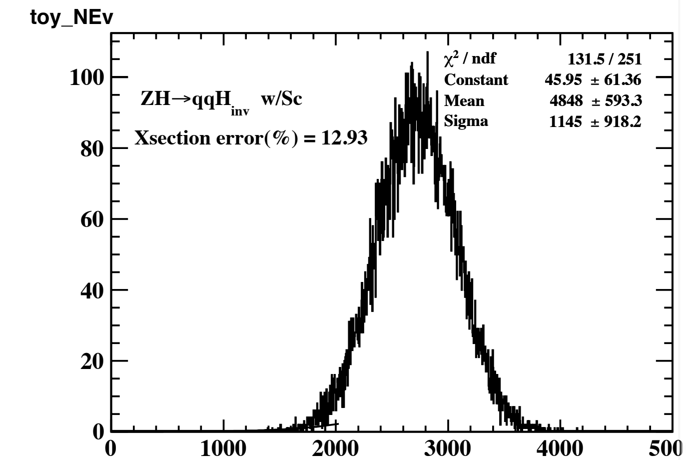
## 1. Δσ/σ.

For now, the result is strange

Si: Δσ/σ = 14.8%

Sc: Δσ/σ = 12.9%




## 2. Upper limit .

$$\sigma = \frac{N_{sig}^{upperlimit}}{fL} \qquad BR(H \to invisible) = \frac{\sigma_{invisible}^{C.L.95\ \%}}{\sigma(e^+e^- \to ZH)}$$

Si: ε_sig=57.1[%], N_sig=778

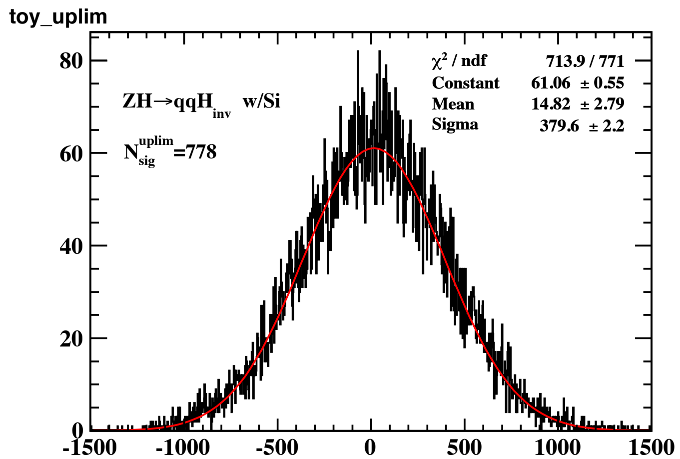
→ σ = 3.89[fb]

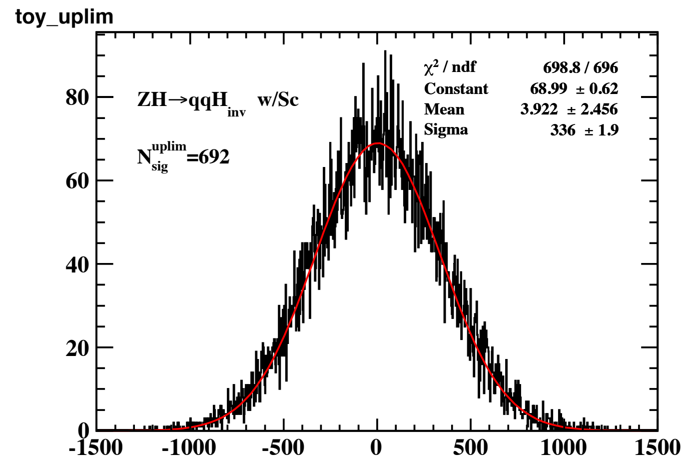
<u>BR(H→invisible) < 3.24% @ 95% C.L.</u>

Sc: ε_sig=57.9[%], N_sig=692

→ σ = 3.41[fb]

<u>BR(H→invisible) < 2.84% @ 95% C.L.</u>



# Summary

1. I analyzed invisible Higgs decay with two ECAL options.

1. For 250GeV case, performance of both ECALs seems to be almost same.

1. For 350GeV case, I need to check some parts and have to fix it.

1. Estimation method of upper limit should be fixed.

1. Summarize this higgs invisible analysis as possible as I can.