ATHENA ZERO DEGREE CALORIMETER UPDATE

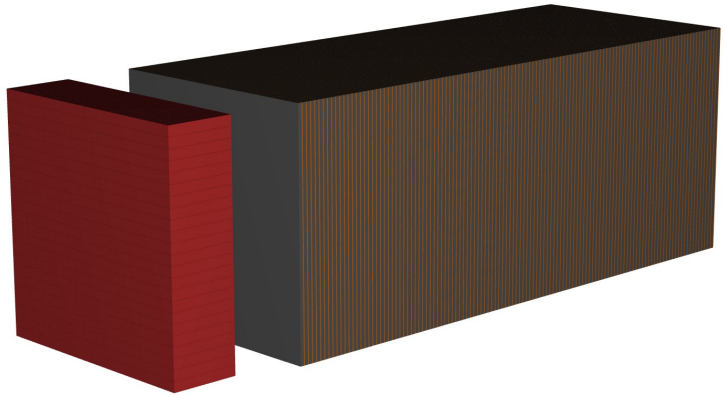
JIHEE KIM
Argonne National Laboratory

ZERO DEGREE CALORIMETER (ZDC)

Geometry

ECAL

- W/SciFi
- 2.5cm × 2.5cm × 17cm
- 23 X_0
- ~1 λ_I
- Same setup with pEcalEndcap



HCAL

- Pb/Sci
- 10cm × 10cm tower
- 1cm Pb absorber
- 2.5mm Plastic scintillator
- Total 120 layers
- ~7 λ_I

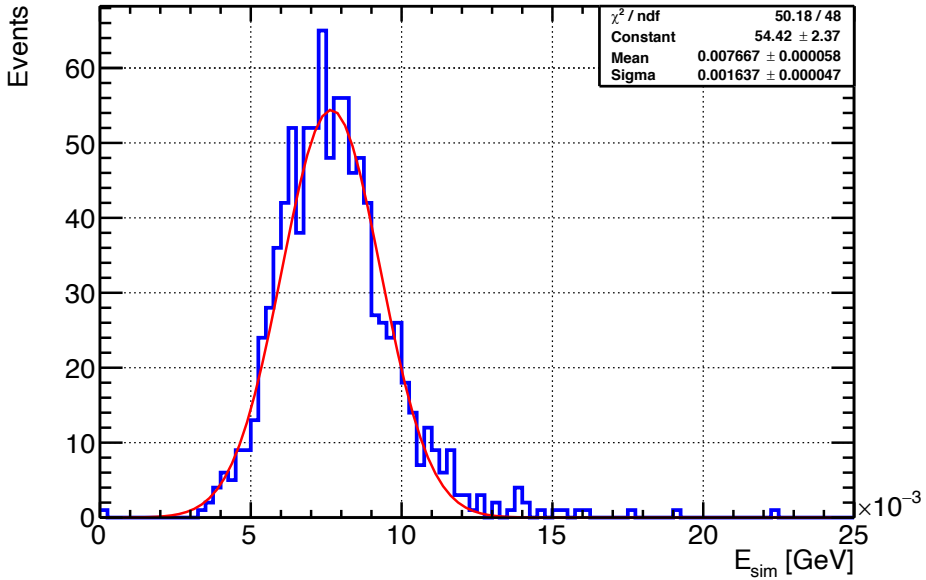
ZDC ECAL USING GAMMAS

With some gaps

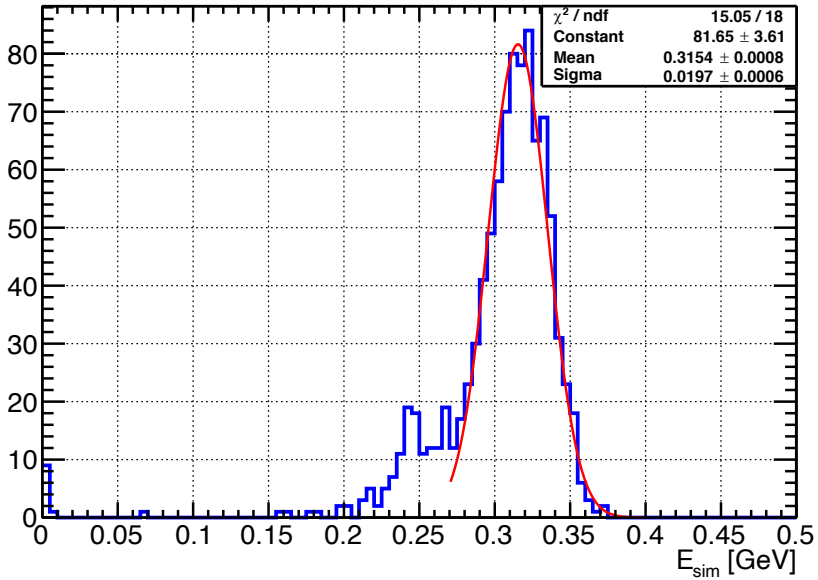
ZDC ECAL (1/2)

Energy Deposit

0.25 GeV Photons



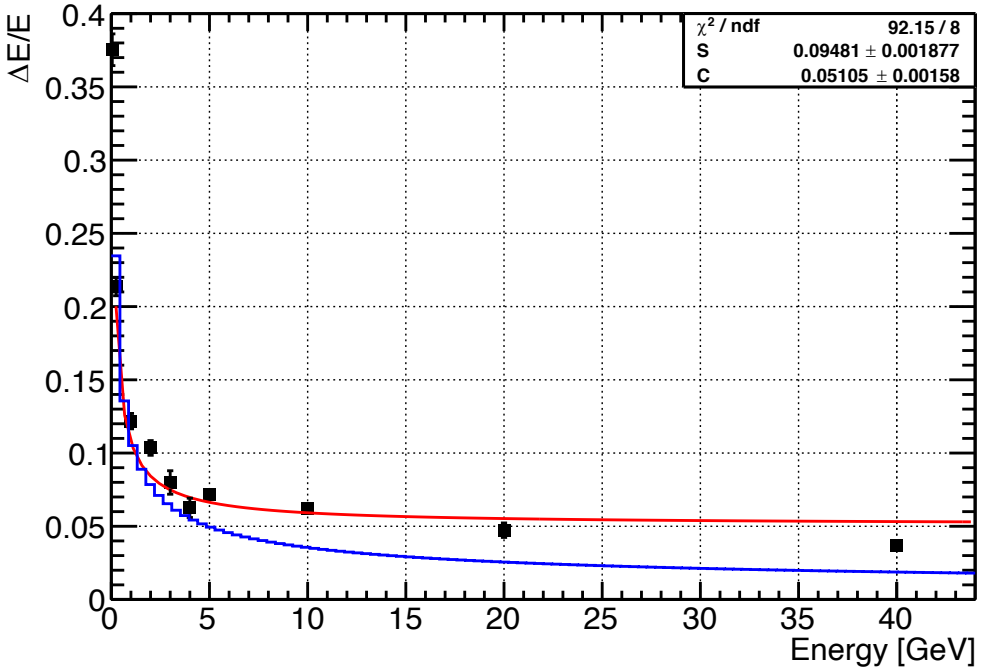
10 GeV Photons



With some gaps

ZDC ECAL (2/2)

Energy Resolution



ECAL: $\frac{9.5\%}{\sqrt{E}} \oplus 5.1\%$

As a reference,
ECAL (W/SciFi) in test beam (2014)

$$\frac{11\%}{\sqrt{E}} \oplus 0.7\%$$

~1 λ_I W/SciFi

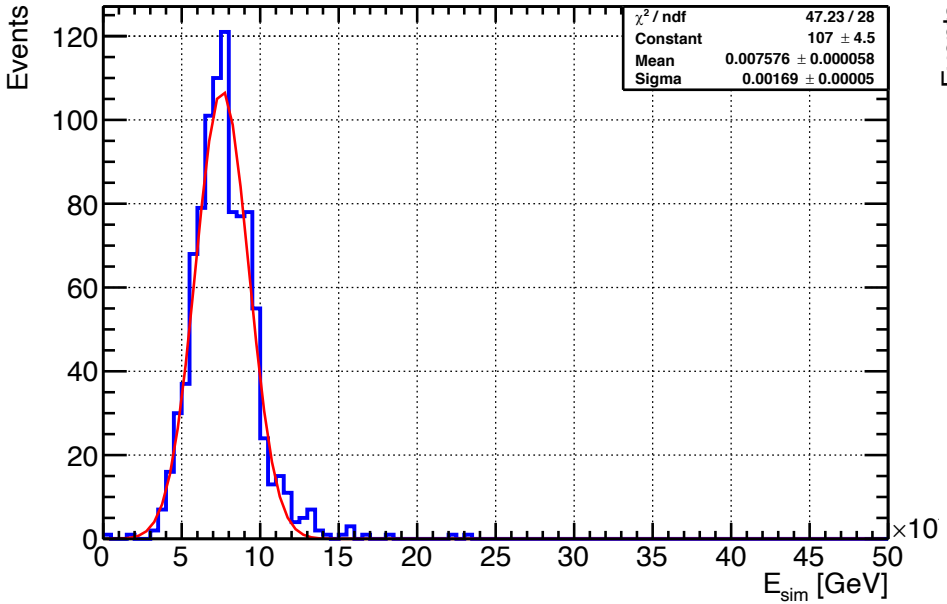
O D Tsai et al 2015 J.Phys.: Conf. Ser. 587 012053

With almost no gaps

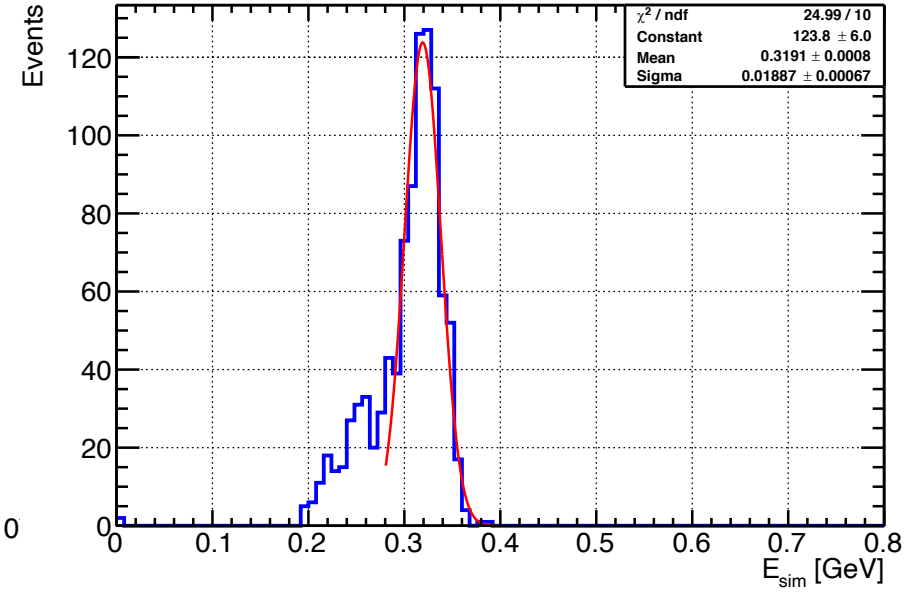
ZDC ECAL (1/2)

Energy Deposit

0.25 GeV Photons



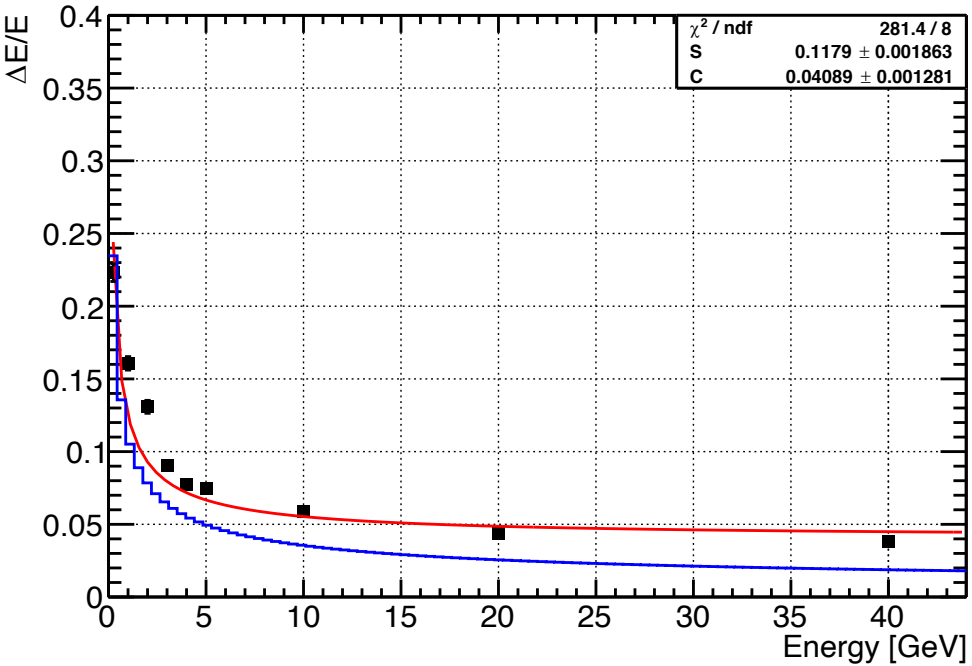
10 GeV Photons



With almost no gaps

ZDC ECAL (2/2)

Energy Resolution



ECAL: $\frac{11.8\%}{\sqrt{E}} \oplus 4.1\%$

As a reference,
ECAL (W/SciFi) in test beam (2014)

$$\frac{11\%}{\sqrt{E}} \oplus 0.7\%$$

~1 λ_I W/SciFi

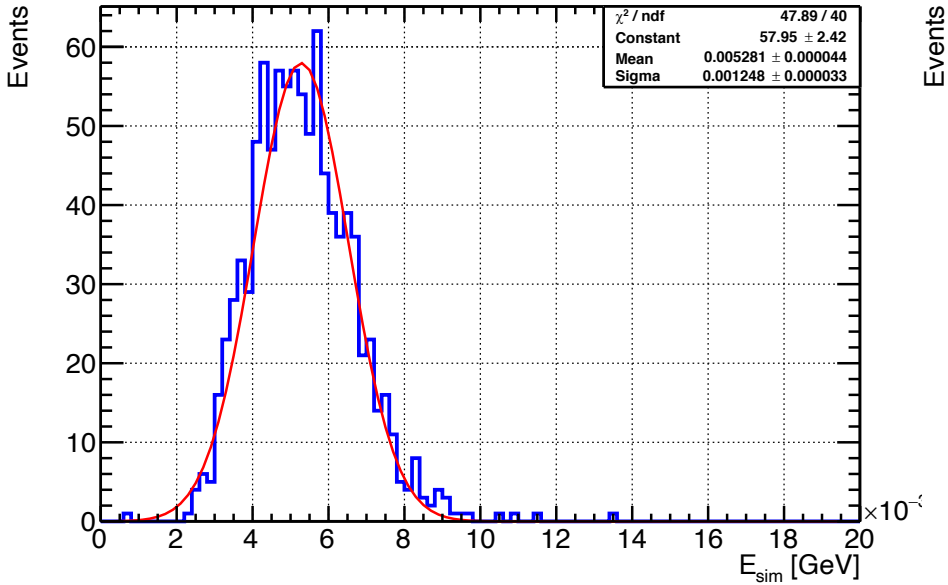
O D Tsai et al 2015 J.Phys.: Conf. Ser. 587 012053

With almost no gaps and θ_{thrown} = 0 deg

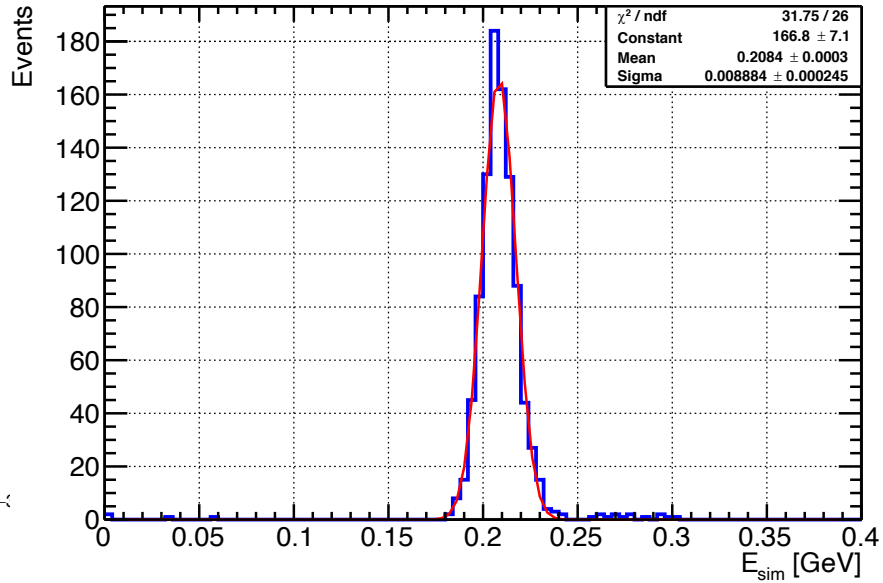
ZDC ECAL (1/2)

Energy Deposit

0.25 GeV Photons



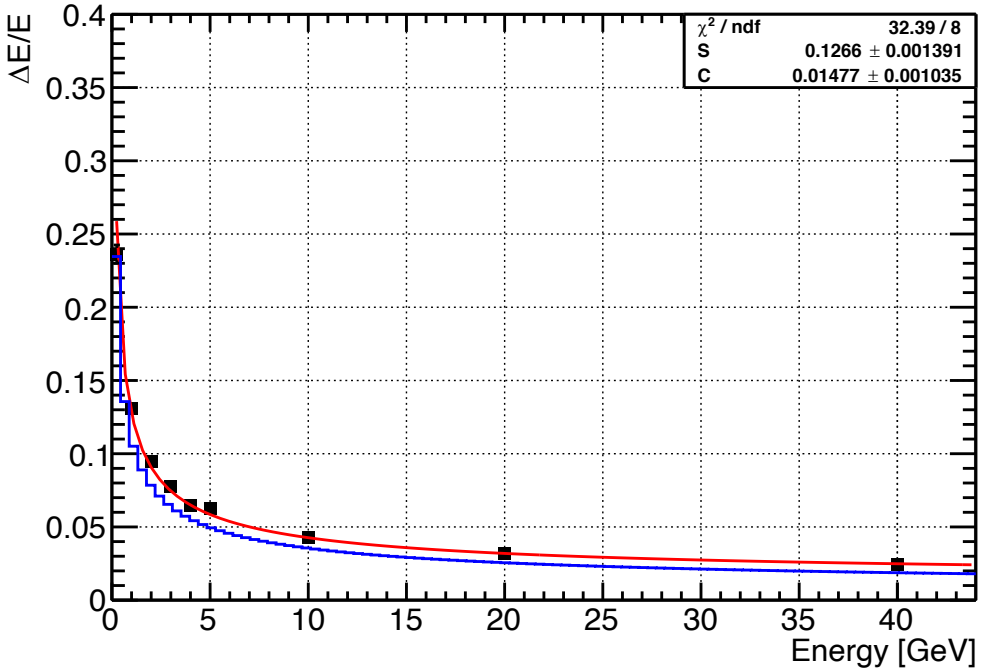
10 GeV Photons



With almost no gaps and θ_{thrown} = 0 deg

ZDC ECAL (2/2)

Energy Resolution



ECAL: $\frac{12.6\%}{\sqrt{E}} \oplus 1.5\%$

As a reference,
ECAL (W/SciFi) in test beam (2014)

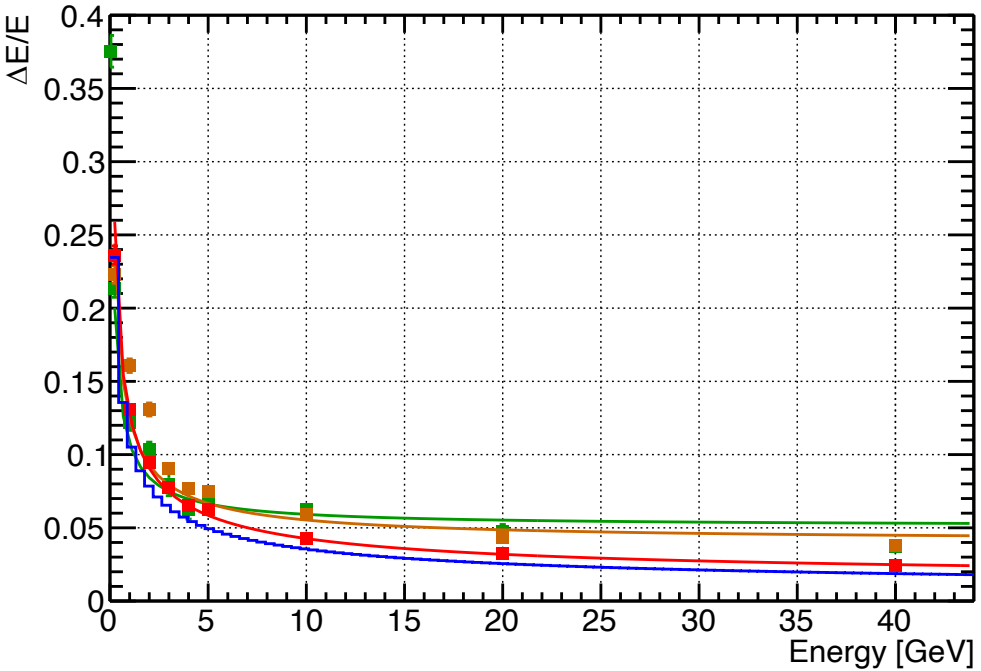
$$\frac{11\%}{\sqrt{E}} \oplus 0.7\%$$

~1 λ_I W/SciFi

O D Tsai et al 2015 J.Phys.: Conf. Ser. 587 012053

SUMMARY - ZDC ECAL

Energy Resolution



with some gaps

ECAL: $\frac{9.5\%}{\sqrt{E}} \oplus 5.1\%$

with almost no gaps

ECAL: $\frac{11.8\%}{\sqrt{E}} \oplus 4.1\%$

with almost no gaps and θ_{thrown} = 0 deg

ECAL: $\frac{12.6\%}{\sqrt{E}} \oplus 1.5\%$

As a reference,

ECAL (W/SciFi) in test beam (2014)

$$\frac{11\%}{\sqrt{E}} \oplus 0.7\%$$

~1 λ_I W/SciFi

O D Tsai et al 2015 J.Phys.: Conf. Ser. 587 012053

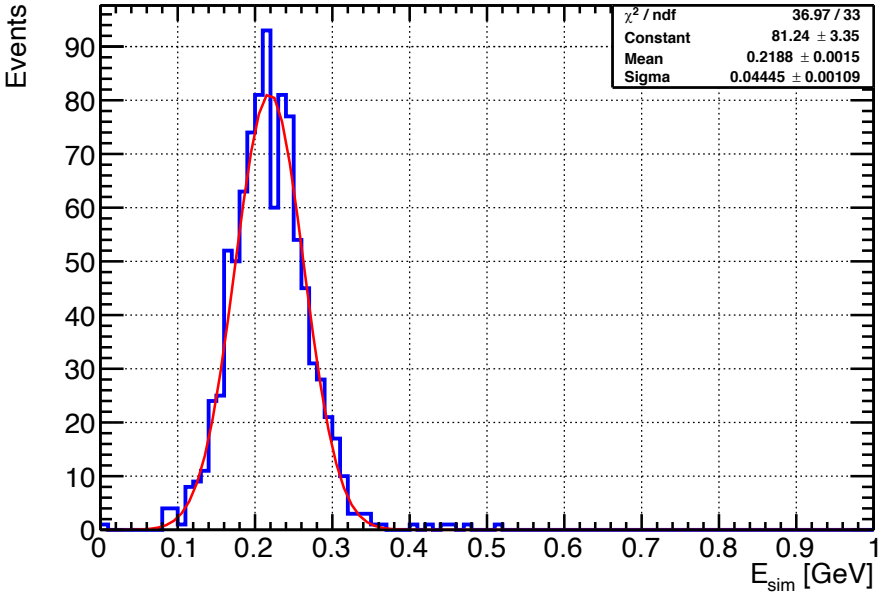
ZDC HCAL ALONE USING NEUTRONS

Using eRD27 Scintillator

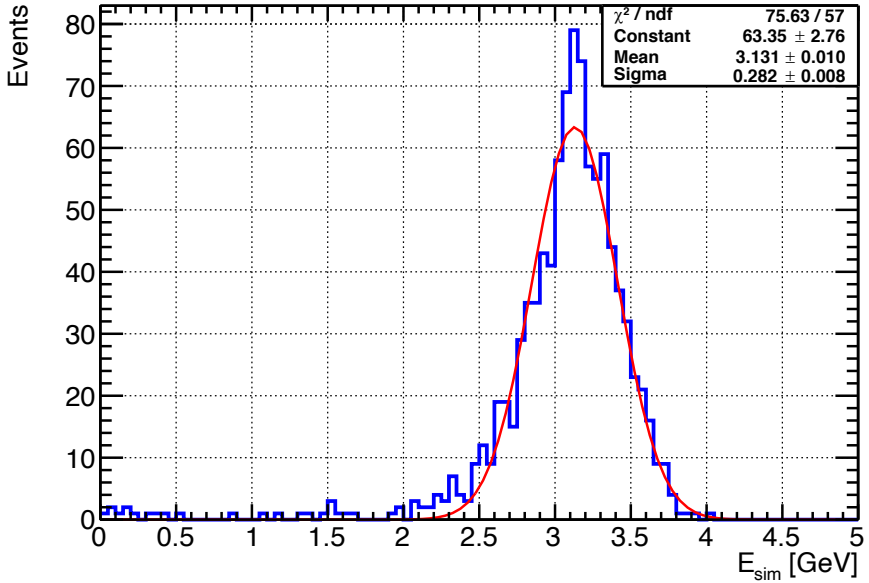
ZDC HCAL ALONE (1/2)

Energy Deposit

5 GeV Neutrons



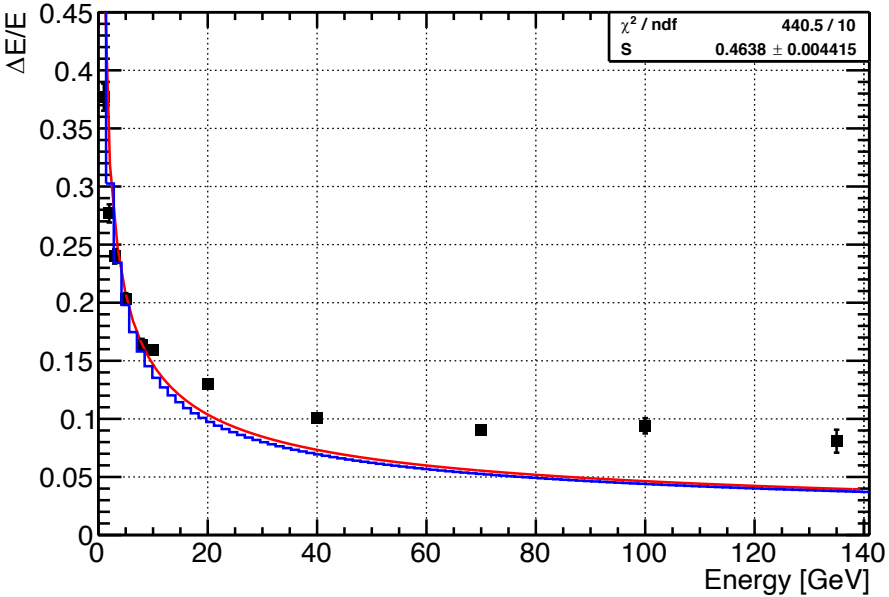
70 GeV Neutrons



Using eRD27 Scintillator

ZDC HCAL ALONE (2/2)

Energy Resolution



HCAL: $\frac{46.4\%}{\sqrt{E}}$

As a reference,
HCAL (Pb/Sci) in ZEUS 5 λ_I :

$\frac{44\%}{\sqrt{E}}$

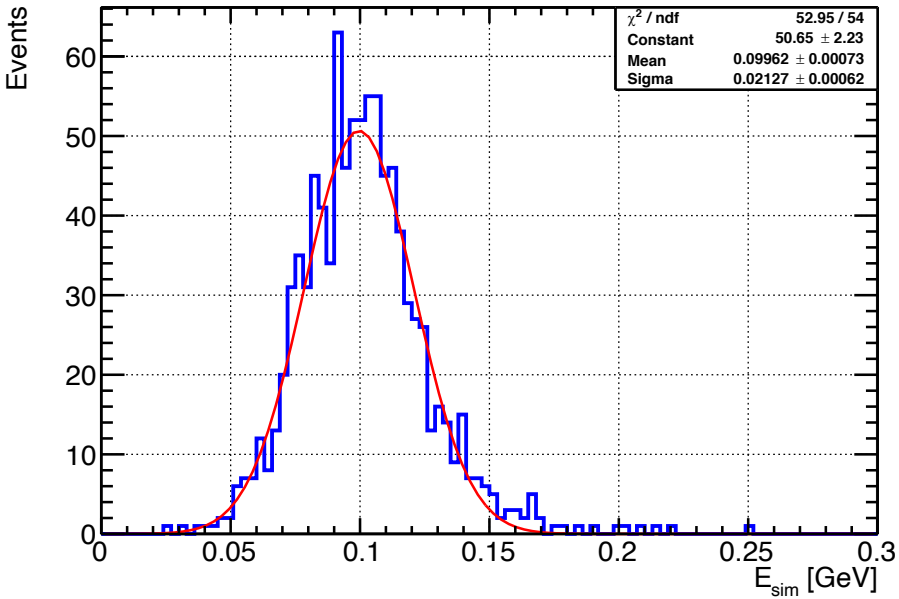
NIM A262 (1987) 229-242

Using typical Plastic Scintillator

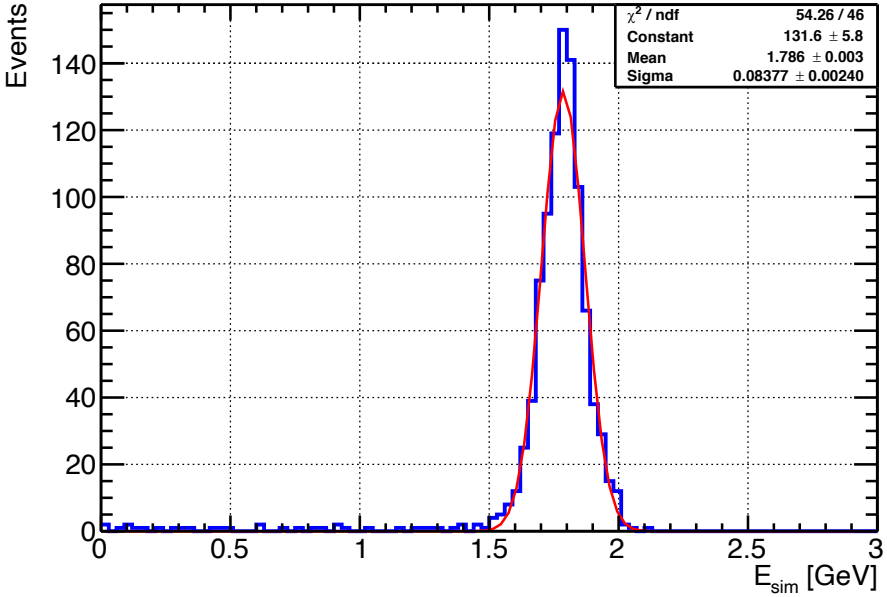
ZDC HCAL ALONE (1/2)

Energy Deposit

5 GeV Neutrons



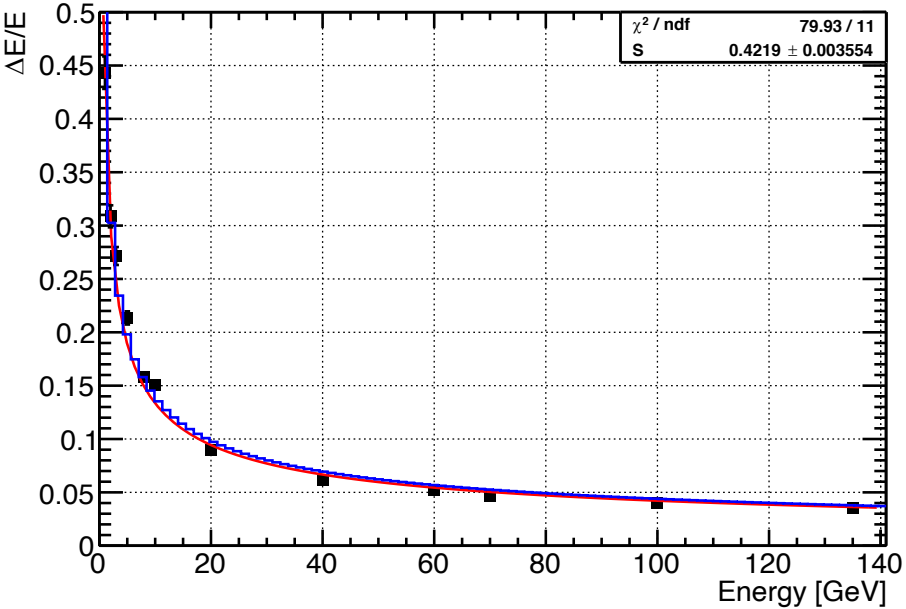
70 GeV Neutrons



Using typical Plastic Scintillator

ZDC HCAL ALONE (2/2)

Energy Resolution



HCAL: $\frac{42.2\%}{\sqrt{E}}$

As a reference,
HCAL (Pb/Sci) in ZEUS 5 λ_I :

$\frac{44\%}{\sqrt{E}}$

NIM A262 (1987) 229-242

ZDC ECAL+HCAL USING NEUTRONS

With some gaps and Using eRD27 Scintillator

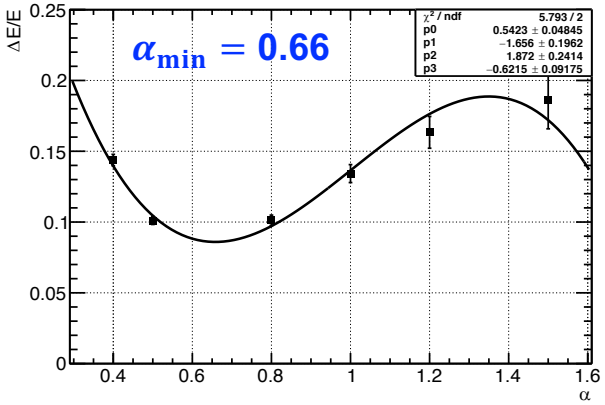
ZDC ECAL + HCAL (1/2)

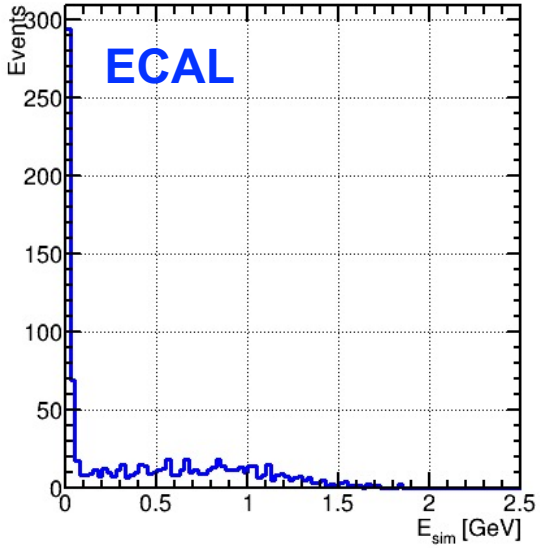
Energy Deposit

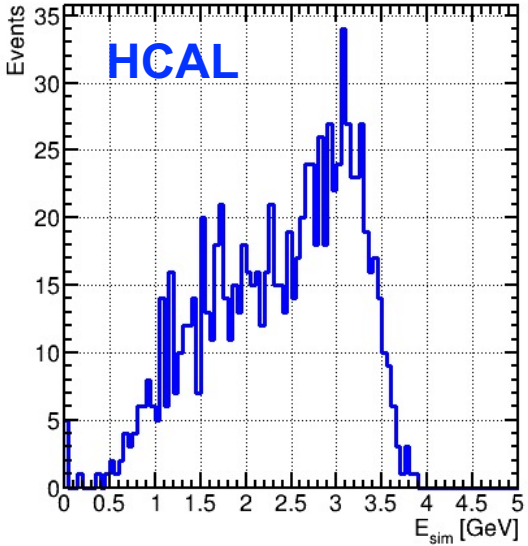
70 GeV Neutrons

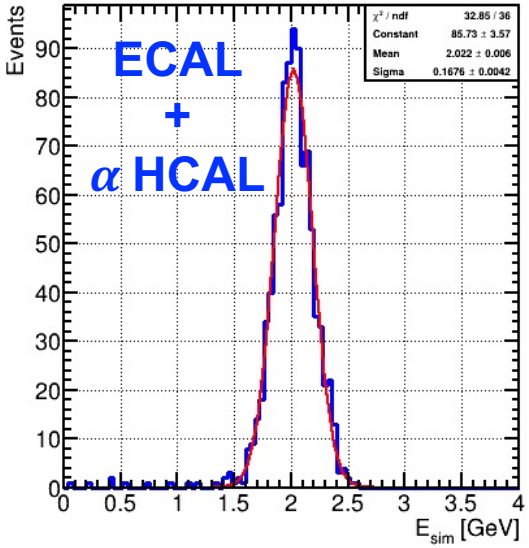
$$E = E_{\mathrm{ECAL}} + \alpha \times E_{\mathrm{HCAL}}$$

Find α to extract optimized resolution





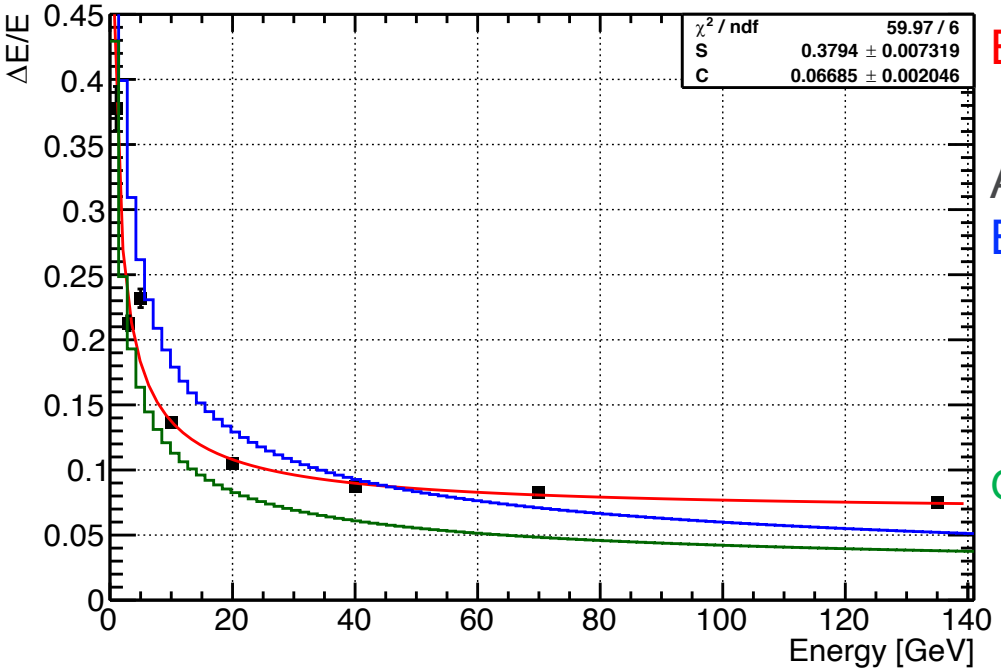




With some gaps and Using eRD27 Scintillator

ZDC ECAL + HCAL (2/2)

Energy Resolution



ECAL + HCAL: $\frac{37.9\%}{\sqrt{E}} \oplus 6.7\%$

As a reference,

ECAL + HCAL in test beam (2014)

$\frac{58\%}{\sqrt{E}} \oplus 1.5\%$

~1 λ_I W/SciFi + ~4 λ_I Pb/Sci

O D Tsai et al 2015 J.Phys.: Conf. Ser. 587 012053

GEANT4 stand-alone (W/SciFi + Pb/Sci):

$\frac{36\%}{\sqrt{E}} \oplus 2.2\%$

With some gaps and Using typical Plastic Scintillator

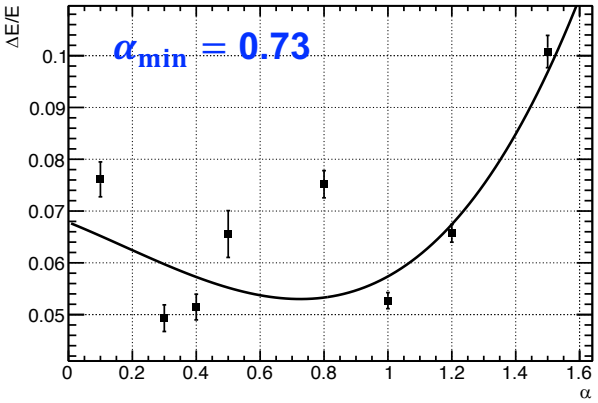
ZDC ECAL + HCAL (1/2)

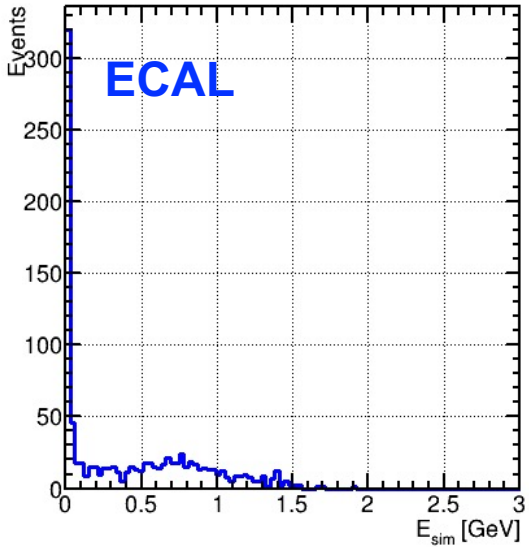
Energy Deposit

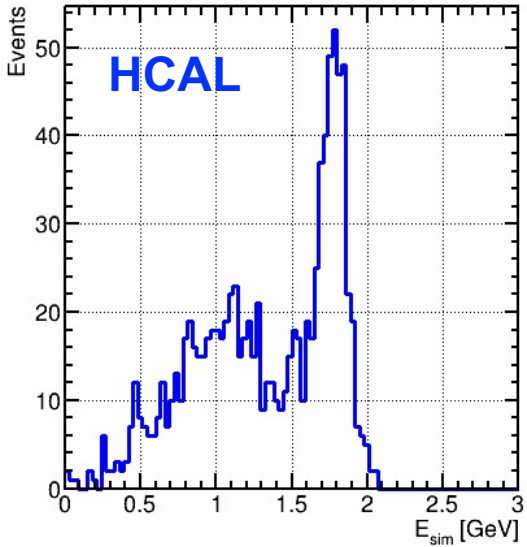
70 GeV Neutrons

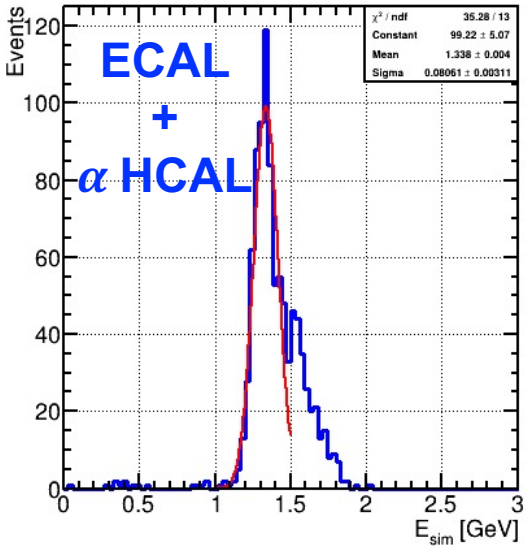
$$E = E_{\mathrm{ECAL}} + \alpha \times E_{\mathrm{HCAL}}$$

Find α to extract optimized resolution





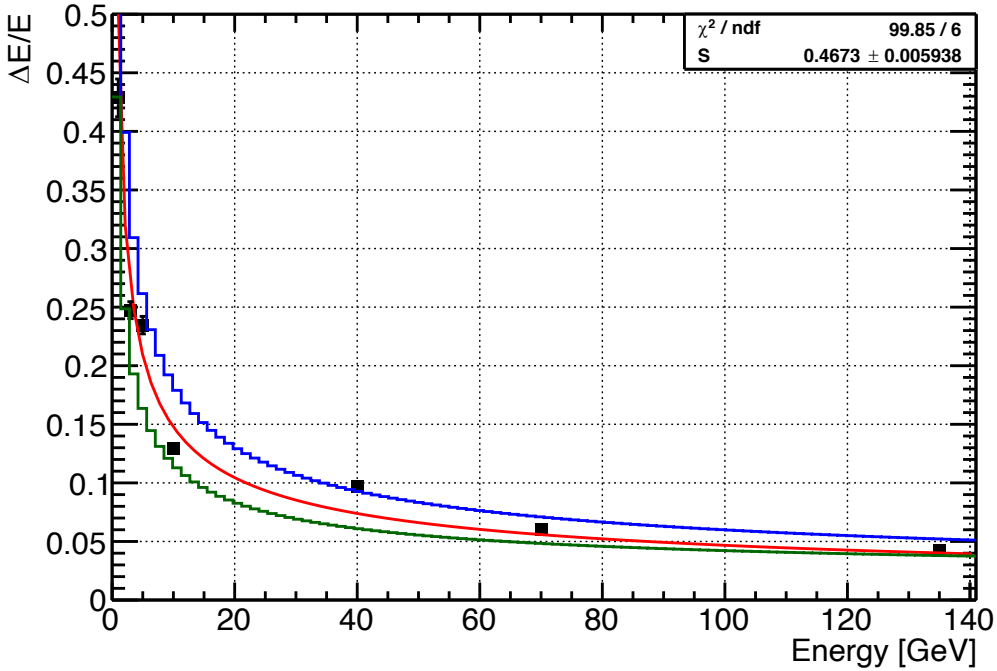




With some gaps and Using typical Plastic Scintillator

ZDC ECAL + HCAL (2/2)

Energy Resolution



ECAL + HCAL: $\frac{46.7\%}{\sqrt{E}}$

As a reference,

ECAL + HCAL in test beam (2014)

$$\frac{58\%}{\sqrt{E}} \oplus 1.5\%$$

~1 λ_I W/SciFi + ~4 λ_I Pb/Sci

O D Tsai et al 2015 J.Phys.: Conf. Ser. 587 012053

GEANT4 study (W/SciFi + Pb/Sci):

$$\frac{36\%}{\sqrt{E}} \oplus 2.2\%$$

With almost no gaps, Using typical Plastic Scintillator and θ_{thrown} = 0 deg

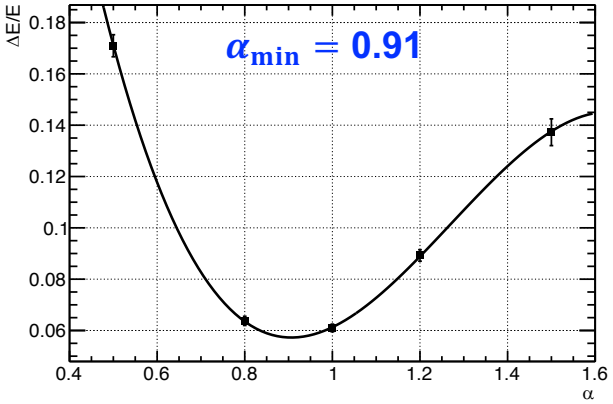
ZDC ECAL + HCAL (1/2)

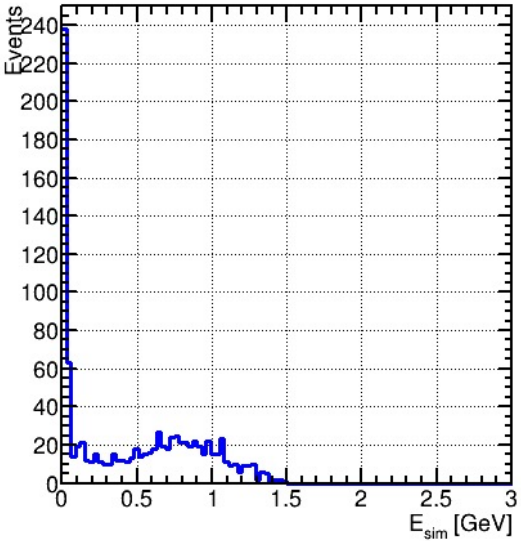
Energy Deposit

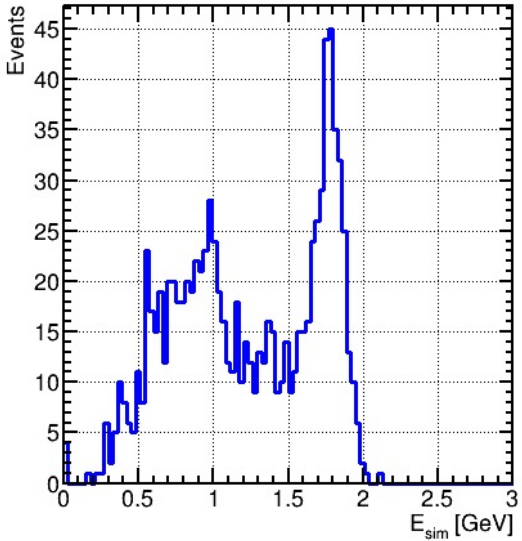
70 GeV Neutrons

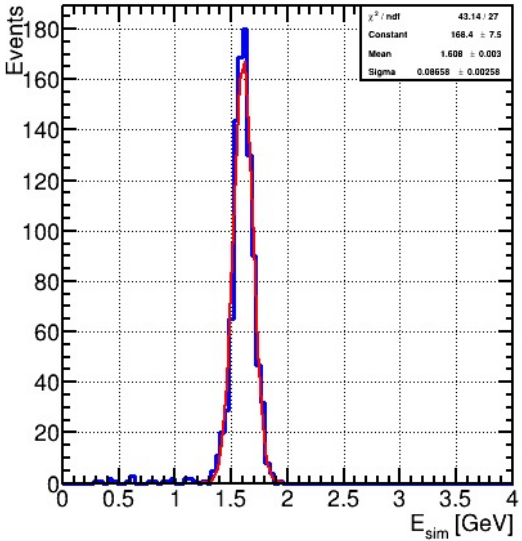
$$E = E_{\text{ECAL}} + \alpha \times E_{\text{HCAL}}$$

Find α to extract optimized resolution





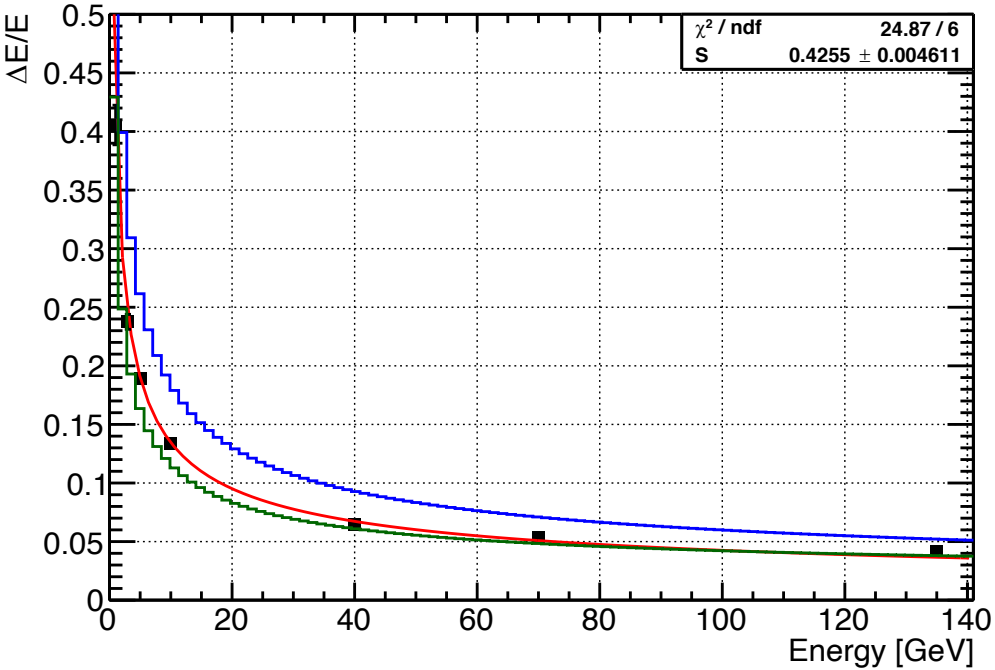




With almost no gaps, Using typical Plastic Scintillator and θ_{thrown} = 0 deg

ZDC ECAL + HCAL (2/2)

Energy Resolution



ECAL + HCAL: $\frac{42.6\%}{\sqrt{E}}$

As a reference,

ECAL + HCAL in test beam (2014)

$$\frac{58\%}{\sqrt{E}} \oplus 1.5\%$$

~1 λ_I W/SciFi + ~4 λ_I Pb/Sci

O D Tsai et al 2015 J.Phys.: Conf. Ser. 587 012053

GEANT4 stand-alone (W/SciFi + Pb/Sci):

$$\frac{36\%}{\sqrt{E}} \oplus 2.2\%$$

SUMMARY

- ZDC ECAL
  - Found strange response in terms of leakage and resulted in big constant term
  - With setting of incoming particle being perpendicular to detector, it affects on energy resolution a lot. A little worse, but not terribly off
  - Still need to look at carefully with/without gaps between em towers
- ZDC HCAL alone
  - Tested different materials; eRD27 scintillator and typical plastic scintillator
  - When used typical material, it is in a good agreement with GEANT4 stand-alone and eicroot
- ZDC ECAL + HCAL
  - Found compensation factor to weight on sum of HCAL to obtain optimized resolution. Compensation factor ~ 0.9
  - My results match the GEANT4 stand-alone
- Overall we have confirmed that the GEANT simulations in DD4hep and stand-alone are exactly the same

BACKUP

With some gaps and Using typical Plastic Scintillator

ZDC ECAL + HCAL (1/3)

Energy Deposit

3 GeV Neutrons

$$E = E_{\mathrm{ECAL}} + \alpha \times E_{\mathrm{HCAL}}$$

Find α to extract optimized resolution