

ATHENA ZERO DEGREE CALORIMETER UPDATE

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ATHENA Far-Forward WG meeting

02/14/2022

ZERO DEGREE CALORIMETER (ZDC) Geometry

ECAL

- W/SciFi
- 2.5cm $\times 2.5$ cm $\times 17$ cm
- 23 X₀
- ~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



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ZDC ECAL USING GAMMAS





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With some gaps **ZDC ECAL (1/2) Energy Deposit**



With some gaps **ZDC ECAL (2/2) Energy Resolution**



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

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

> 11% ⊕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**



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 $\theta_{thrown} = 0 \text{ deg}$ **ZDC ECAL (1/2) Energy Deposit**

Events Events γ^2 / ndf 47.89/40 γ^2 / ndf 31.75 / 26 57.95 ± 2.42 Constant 166.8 ± 7.1 Constant 180 60 0.005281 ± 0.000044 Mean 0.2084 ± 0.0003 Mean Siama 0.001248 ± 0.000033 Sigma 0.008884 ± 0.000245 160 50 140 120 40 100 30 80 60 20 40 10 20 ×10[∹] 0.35 0.4 E_{sim} [GeV] 0.25 18 20 0.05 0.1 0.15 0.2 0.3 0.4 S Λ 6 8 10 12 14 16 'n E_{sim} [GeV] U.S. DEPARTMENT OF ENERGY Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC. ATHENA Far-Forward WG meeting 02/14/2022 8 Jihee KIM Argonne

0.25 GeV Photons

10 GeV Photons

With almost no gaps and $\theta_{thrown} = 0 \text{ deg}$ **ZDC ECAL (2/2) Energy Resolution**





ZDC HCAL ALONE USING NEUTRONS



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Using eRD27 Scintillator **ZDC HCAL ALONE (1/2) Energy Deposit**

Events 36.97 / 33 Events γ^2 / ndf χ² / ndt 75.63/57 80 $\textbf{81.24} \pm \textbf{3.35}$ Constant Constant $\textbf{63.35} \pm \textbf{2.76}$ 90 0.2188 ± 0.0015 Mean 3.131 ± 0.010 Mean Sigma 0.04445 ± 0.00109 Sigma 0.282 ± 0.008 70 80 60 70 60 50 50 40 40 30 30 20 20 10 10E 0 4.5 5 E_{sim} [GeV] 0.5 1.5 2 2.5 3.5 0.9 1 E_{sim} [GeV] 3 4 5 'n 01 0.2 0.3 0.4 0.5 0.6 0.7 0.8 U.S. DEPARTMENT OF ENERGY Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC. ATHENA Far-Forward WG meeting 12 02/14/2022 Jihee KIM Argonne

5 GeV Neutrons

70 GeV Neutrons

Using eRD27 Scintillator **ZDC HCAL ALONE (2/2)** Energy Resolution



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



NIM A262 (1987) 229-242



Using typical Plastic Scintillator ZDC HCAL ALONE (1/2) Energy Deposit



Using typical Plastic Scintillator ZDC HCAL ALONE (2/2) **Energy Resolution**



HCAL:





ZDC ECAL+HCAL USING NEUTRONS





With some gaps and Using eRD27 ScintillatorZDC ECAL + HCAL (1/2)Energy Deposit $E = E_{ECAL} + \alpha \times E_{HCAL}$

70 GeV Neutrons



Find α to extract



With some gaps and Using eRD27 Scintillator

ZDC ECAL + HCAL (2/2) Energy Resolution



With some gaps and Using typical Plastic Scintillator **ZDC ECAL + HCAL (1/2) Energy Deposit** $E = E_{ECAL} + E_{ECA$

70 GeV Neutrons





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ΔE/E



With some gaps and Using typical Plastic Scintillator **ZDC ECAL + HCAL (2/2) Energy Resolution**



With almost no gaps, Using typical Plastic Scintillator and $\theta_{\rm thrown}$ = 0 deg

ZDC ECAL + HCAL (1/2) Energy Deposit $E = E_{\text{ECAL}}$

70 GeV Neutrons









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With almost no gaps, Using typical Plastic Scintillator and $\theta_{\rm thrown}$ = 0 deg

ZDC ECAL + HCAL (2/2) Energy Resolution



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 $E = E_{ECAL} + E_{ECAL}$

3 GeV Neutrons



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

0.25

E_{sim} [GeV]

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0.3

Find α to extract optimized resolution

