sPHENIX Calorimeter Calibrations

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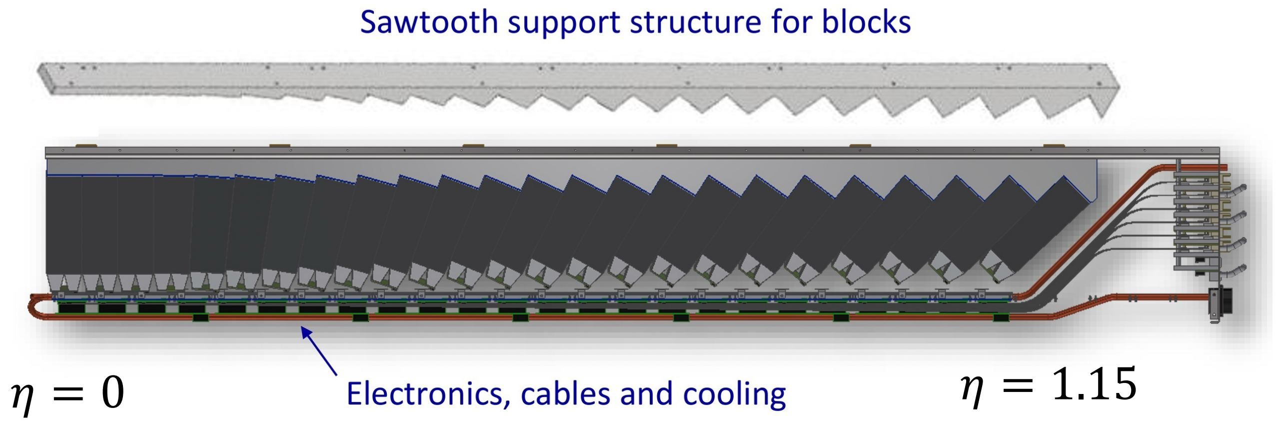
December 4th, 2023

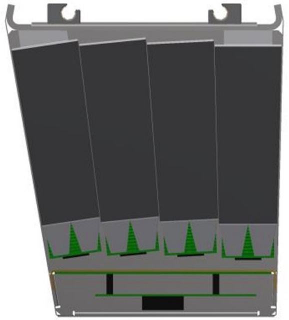
sPHENIX Collaboration Meeting

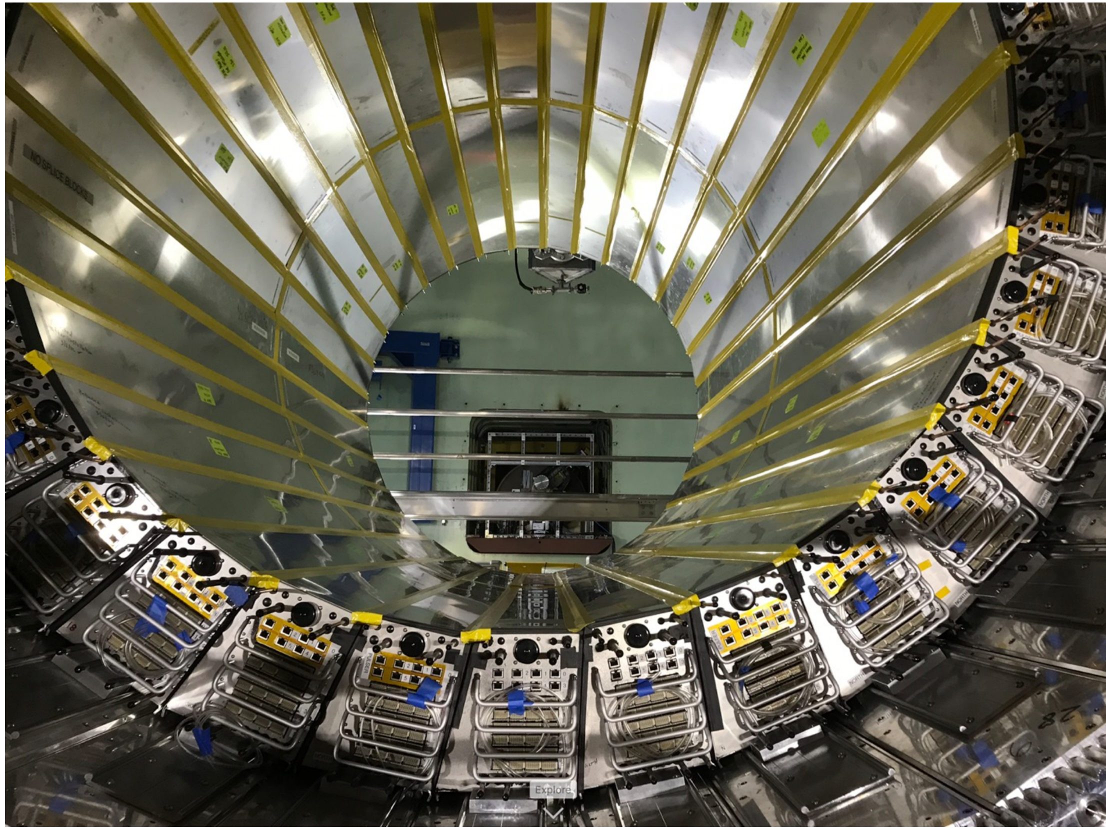
sPHENIX Calorimeters

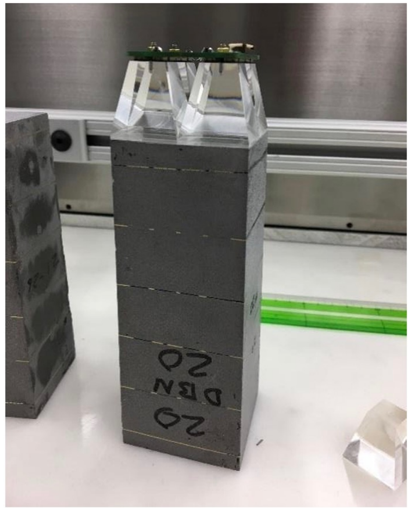
- Electromagnetic Calorimeter
- Energy reconstruction of photons and electrons



Blocks are tilted in η
Sectors are tilted in ϕ



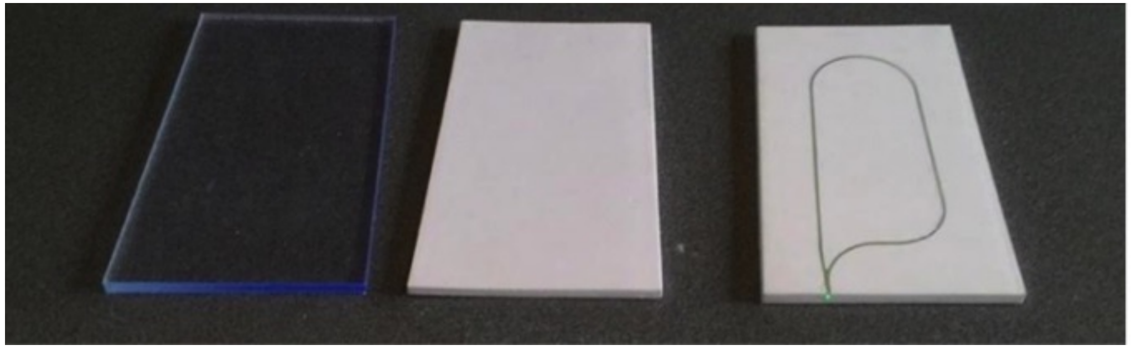


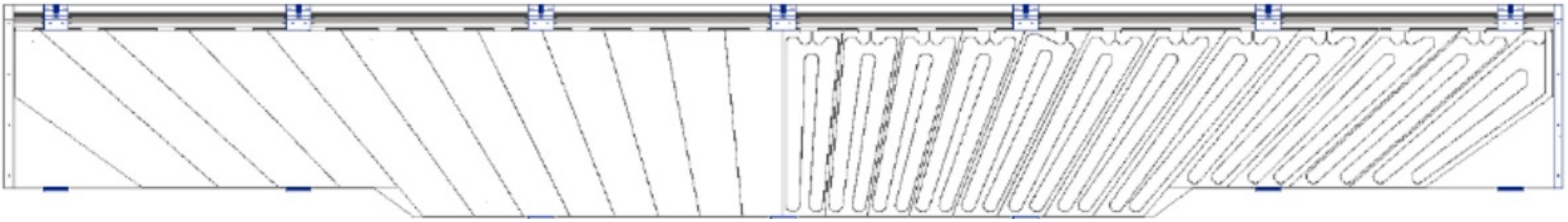


Slides by [Craig Woody]()

sPHENIX Calorimeters

- Inner and Outer hadronic calorimeters
- Charged and neutral hadronic energy measurement





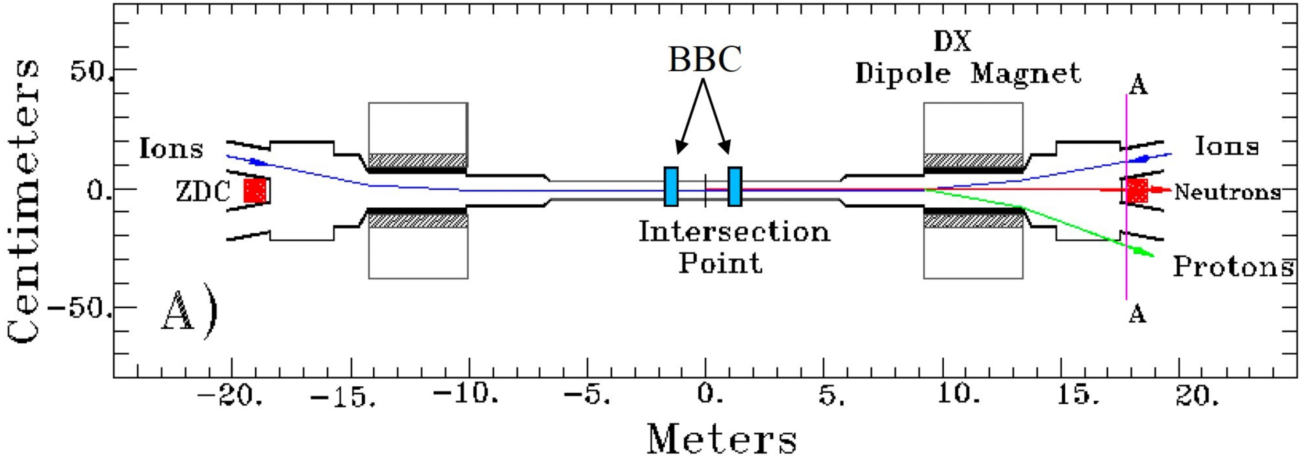
Outer Hadronic Calorimeter

Inner Hadronic Calorimeter

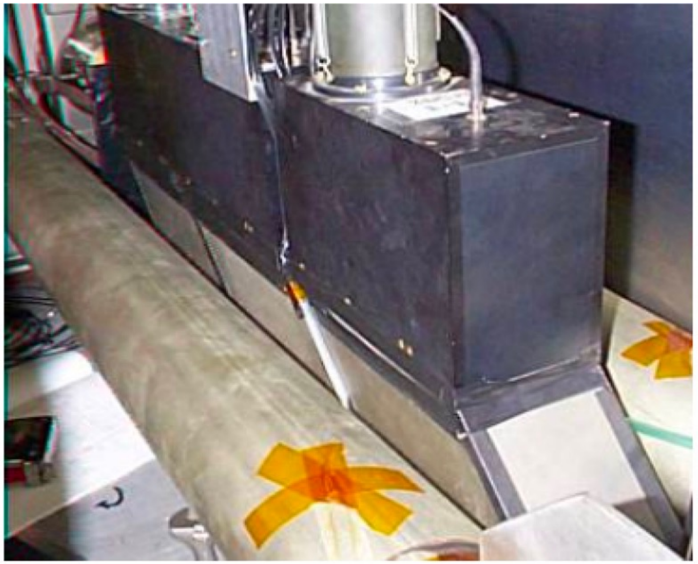
sPHENIX Calorimeters

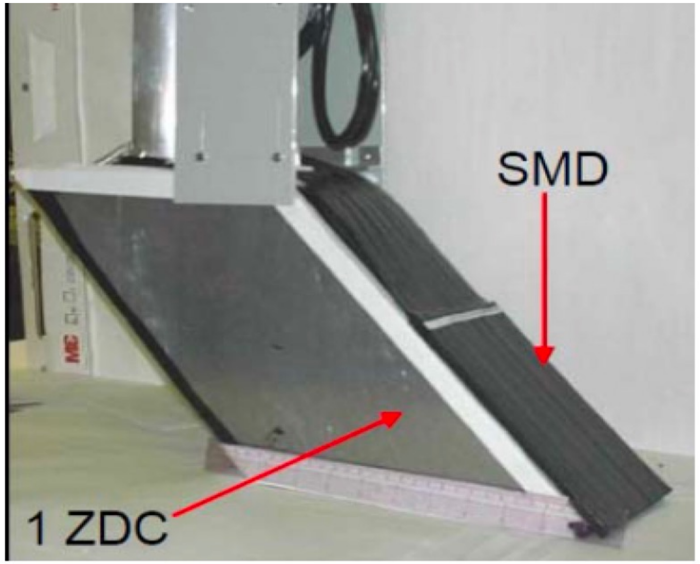
- Zero Degree Calorimeters
- Neutron energy measurement

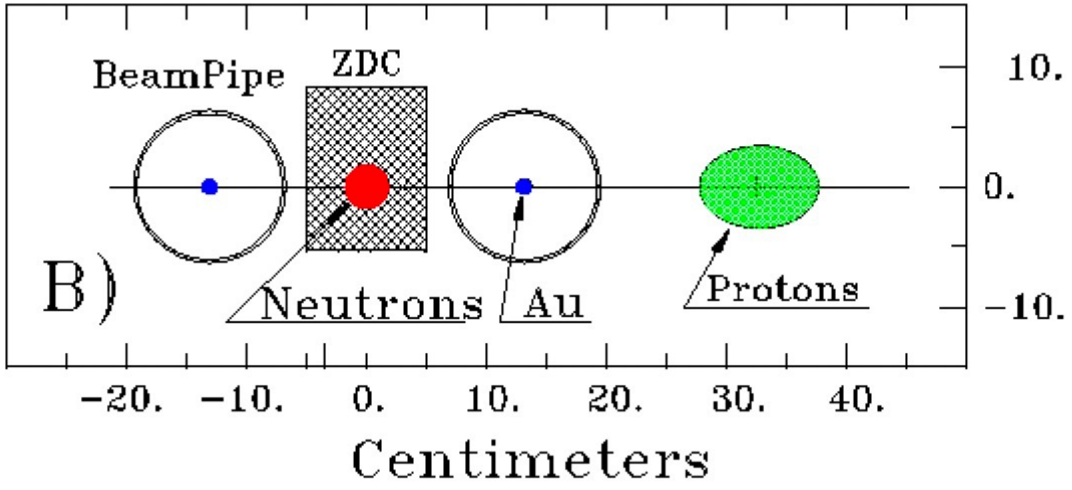
PHENIX Focus Slides by Mickey Chiu



PHENIX Documentation by Gabor David



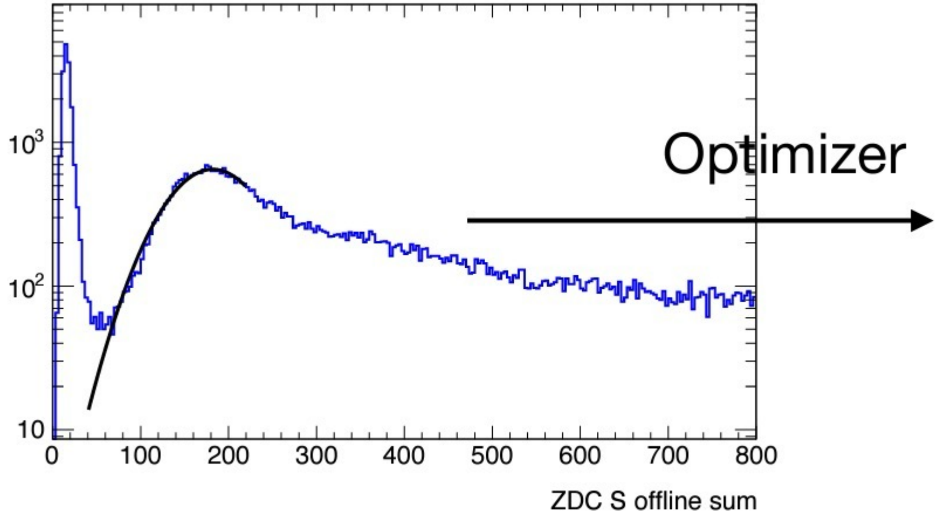




Energy Scale Calibration – ZDC

- ATLAS-style Lagrange multiplier method
- Uncalibrated energy distribution fit and width extracted
- Events with $\mu - \sigma < E_{ZDC} < \mu + \sigma$ are fed to an optimizer

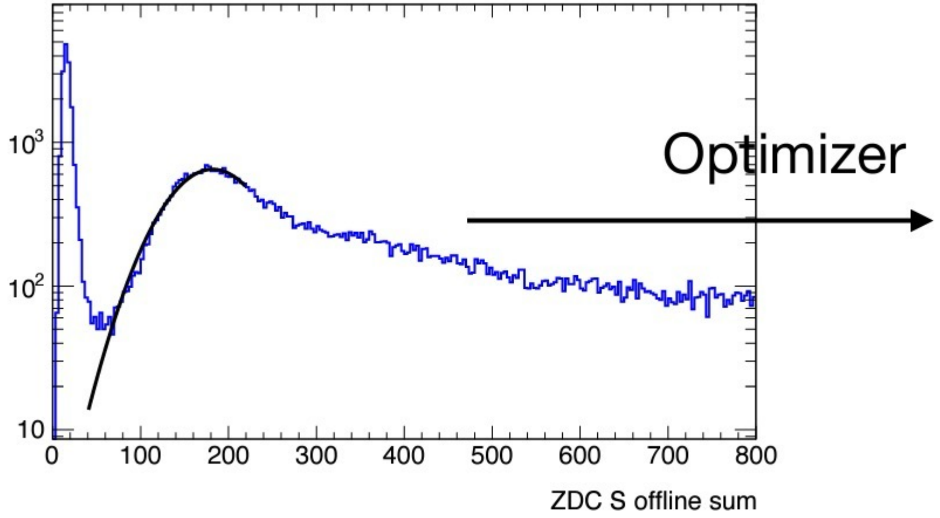
Slides by Ejiro Umaka

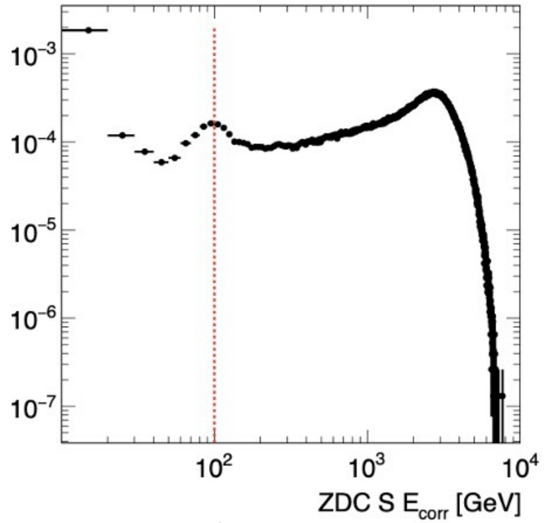


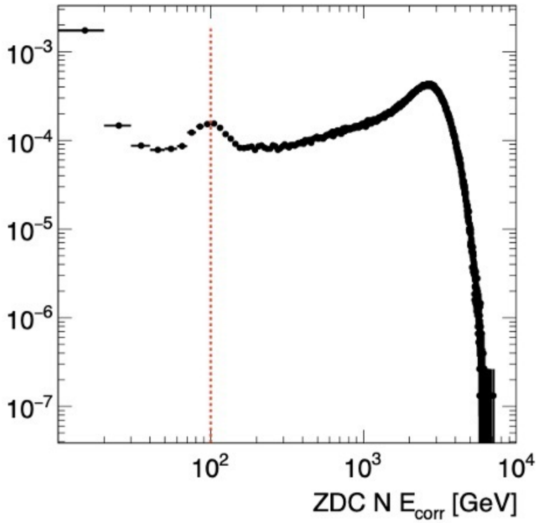
Energy Scale Calibration – ZDC

- ATLAS-style Lagrange multiplier method
- Uncalibrated energy distribution fit and width extracted
- Events with $\mu - \sigma < E_{ZDC} < \mu + \sigma$ are fed to an optimizer
- Optimizer then derives calibration constants based on minimizing variance of measured energy

Slides by Ejiro Umaka





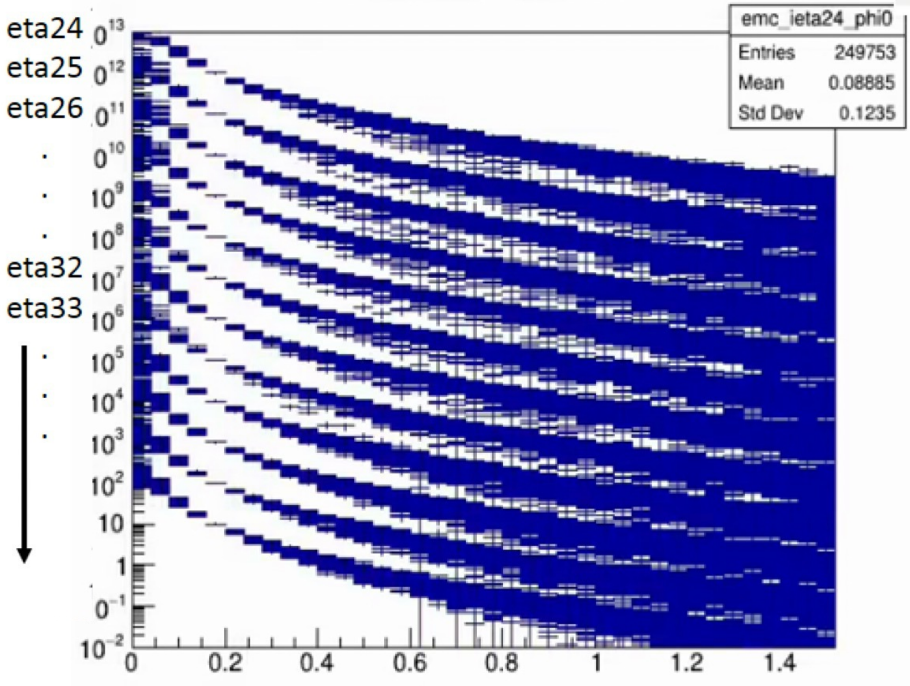


Relative Tower Calibrations

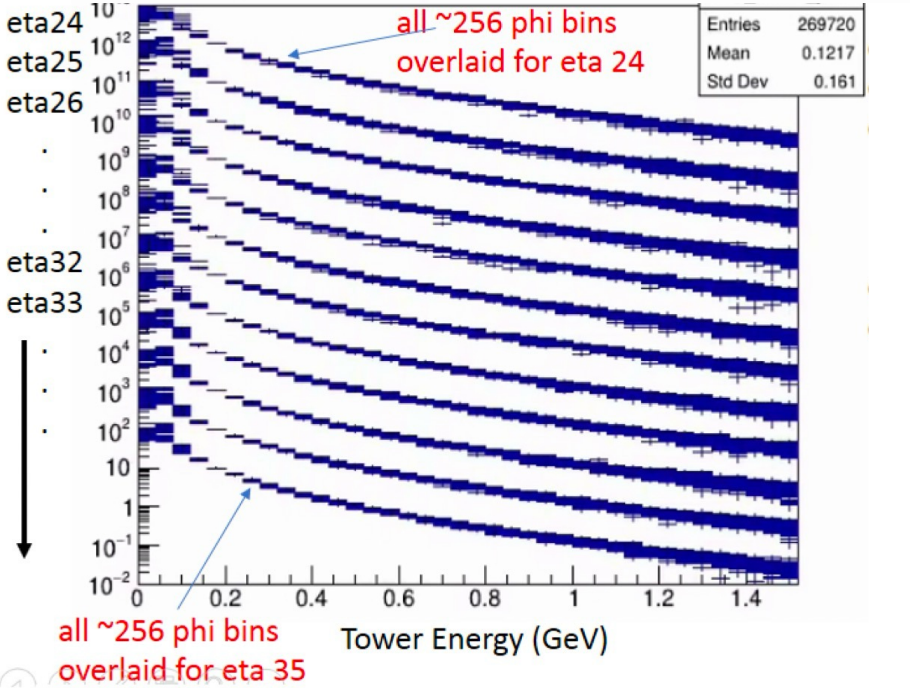
- Can be applied to EMCal and HCal
- Tower-slope method calibrates out gain differences between towers in same η bin/same ϕ ring
- Calibration extracted by fitting low energy portion of spectrum of each tower in η bin and calibrating to the average

Eta bins 24-47

Pre-tower slope calibration



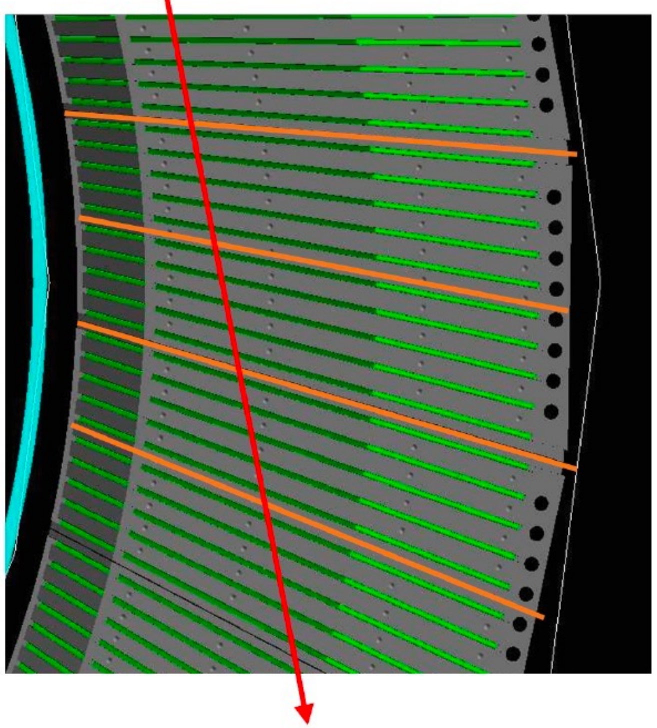
Post-tower slope calibration

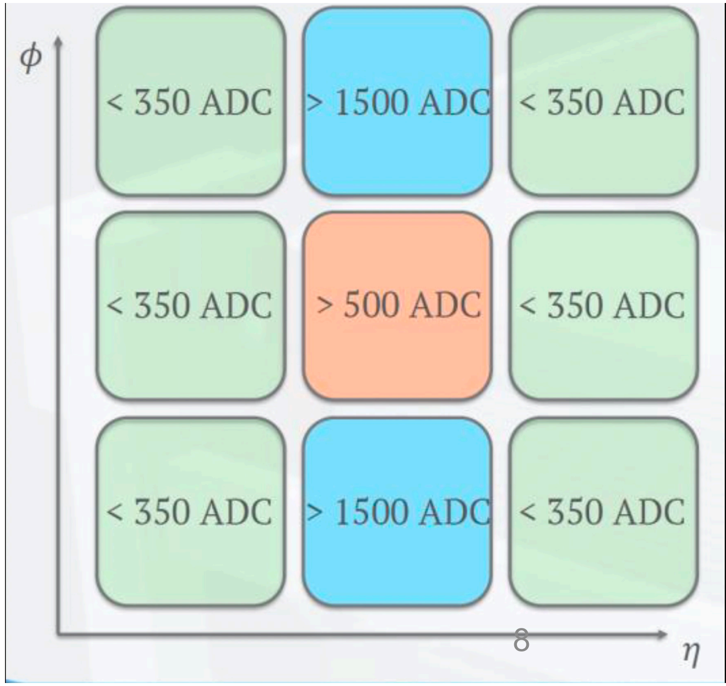


[EMCal Calibration note](#)
- Justin Bryan
- Justin Frantz
- Sijan Regmi

Energy Scale Calibration – HCals

- Calibrated the MIP scale via cosmic rays taken with cosmic ray trigger in 1008
- Additionally HCal response to muons is simulated via EcoMug simulator

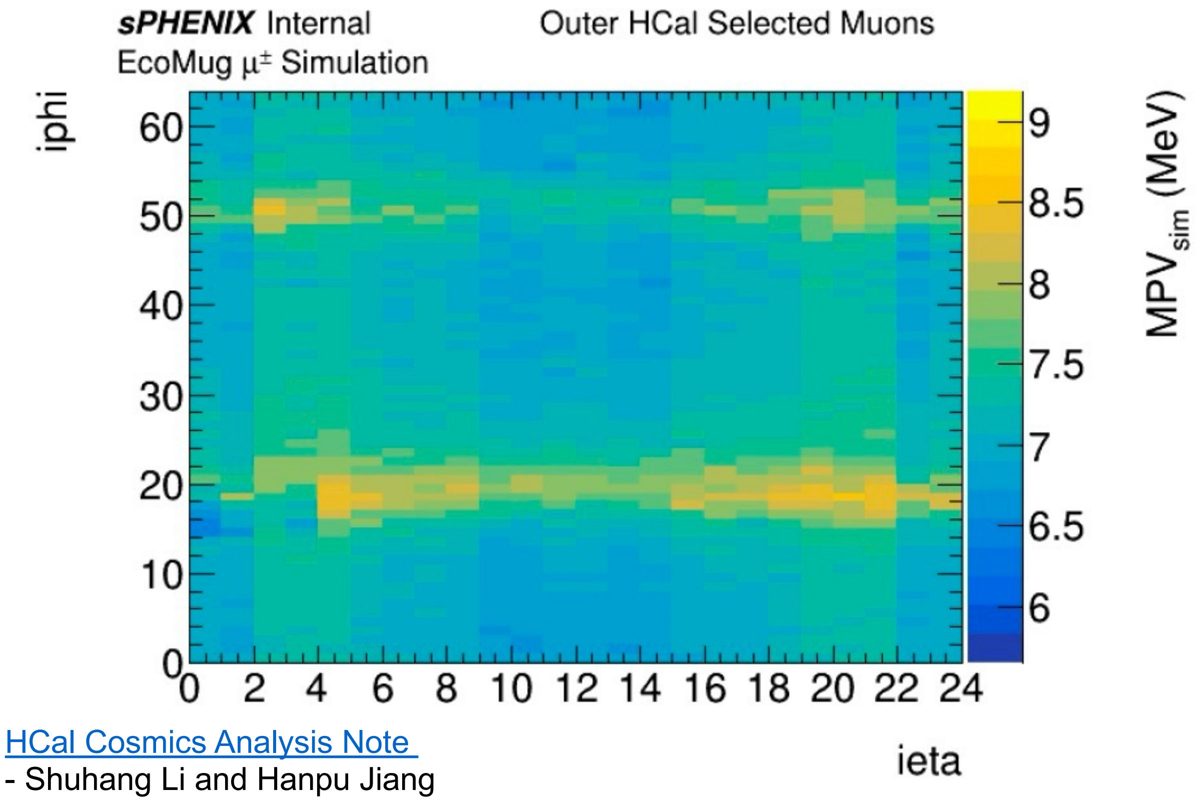


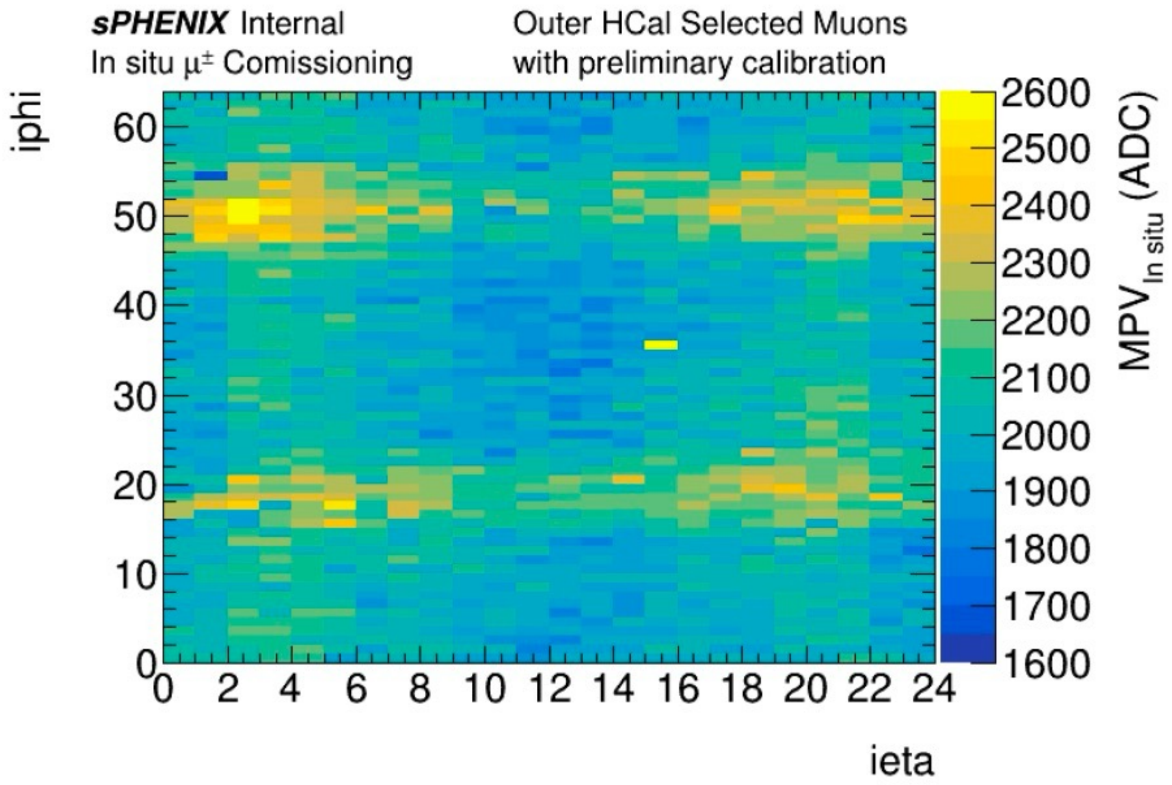


[HCal Cosmics Analysis Note](#)
- Shuhang Li and Hanpu Jiang

Energy Scale Calibration – HCals

- Comparison between simulated muon response (left) and data taken in 1008 experiment hall show excellent agreement





[HCal Cosmics Analysis Note](#)
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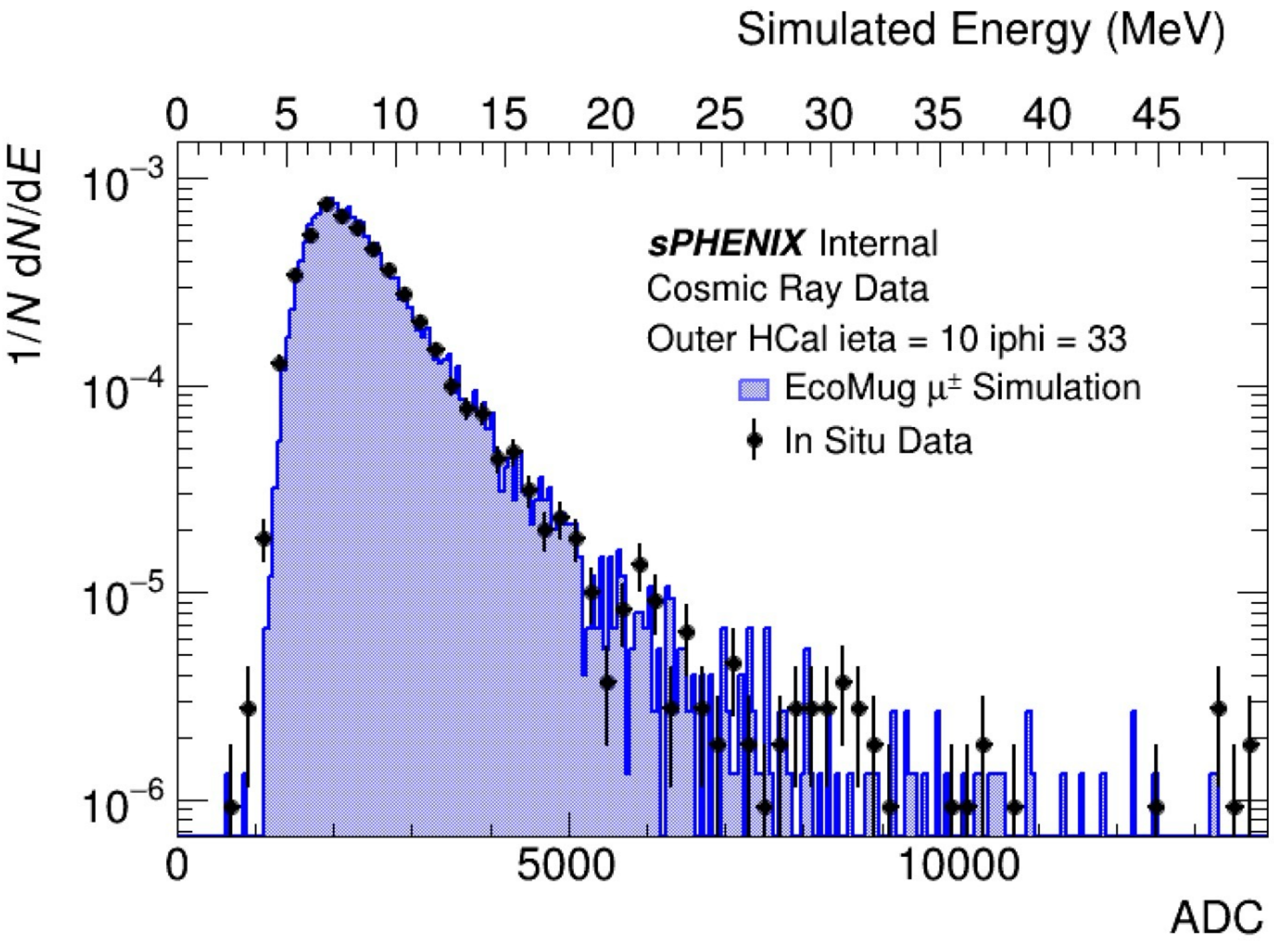
Energy Scale Calibration – HCals

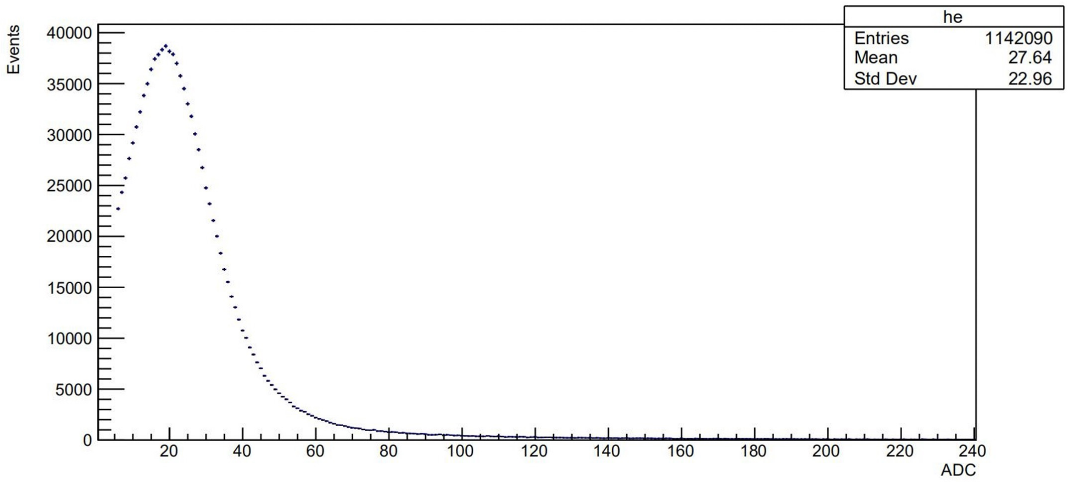
- Tower-by-tower comparison of MIP peaks (MPV) in data and simulation is used to extract calibration constant
- Calibration constants take into account high-gain running mode in data
- Also scaled by simulation derived sampling fraction



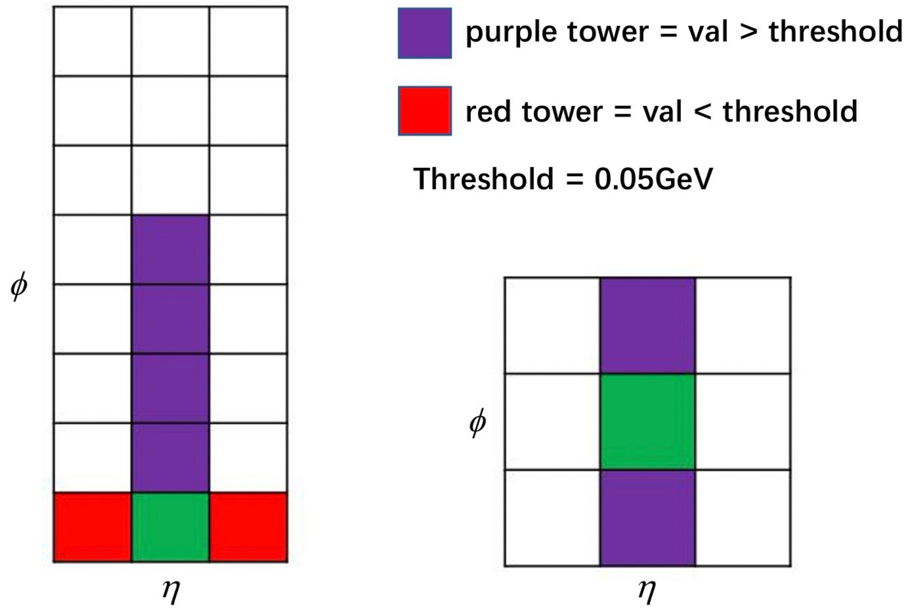
HCal Cosmics Analysis Note
- Shuhang Li and Hanpu Jiang

EMCal Cosmics Calibration

- Initial energy scale is set by cosmics
- Also contains tower-by-tower relative calibration to flatten response
- Primary benefit is that cluster energies are easier to handle and clusterizer χ^2 values are more sensical
- Simulation result shown at right



ADC distribution on all towers(768)



trigger on edge of phibin

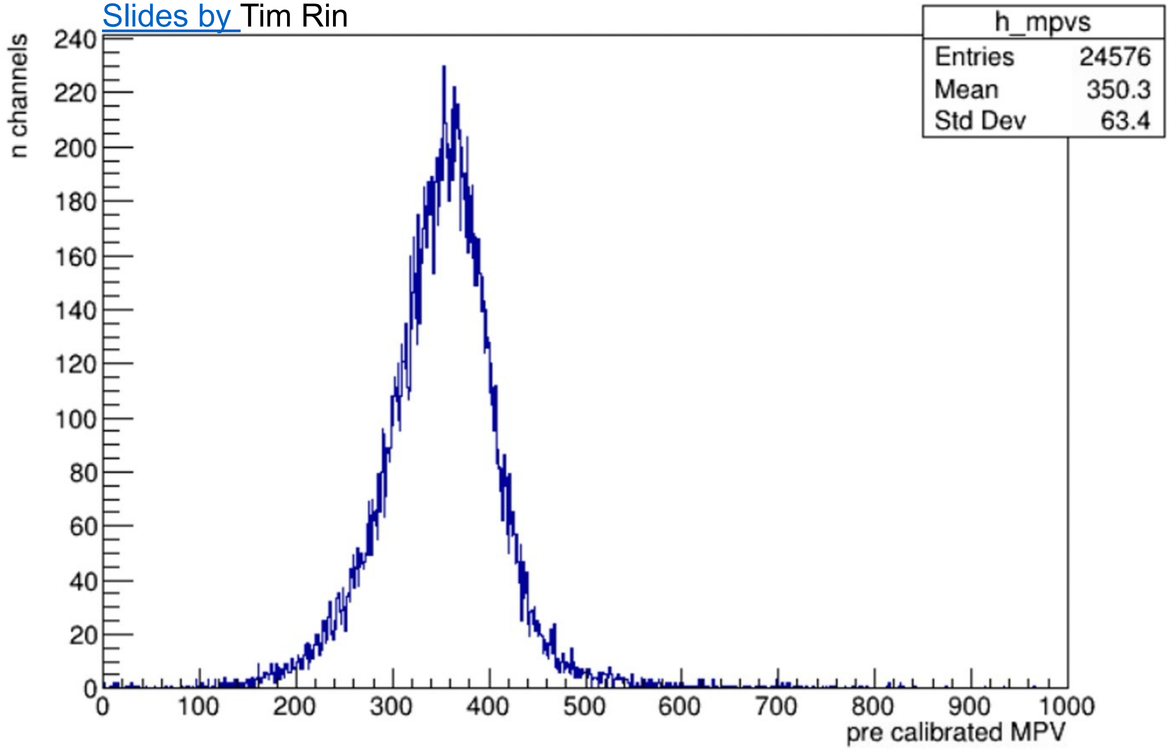
trigger on middle of phibin

Slides by Jingyu Zhang

EMCal Cosmics Calibration

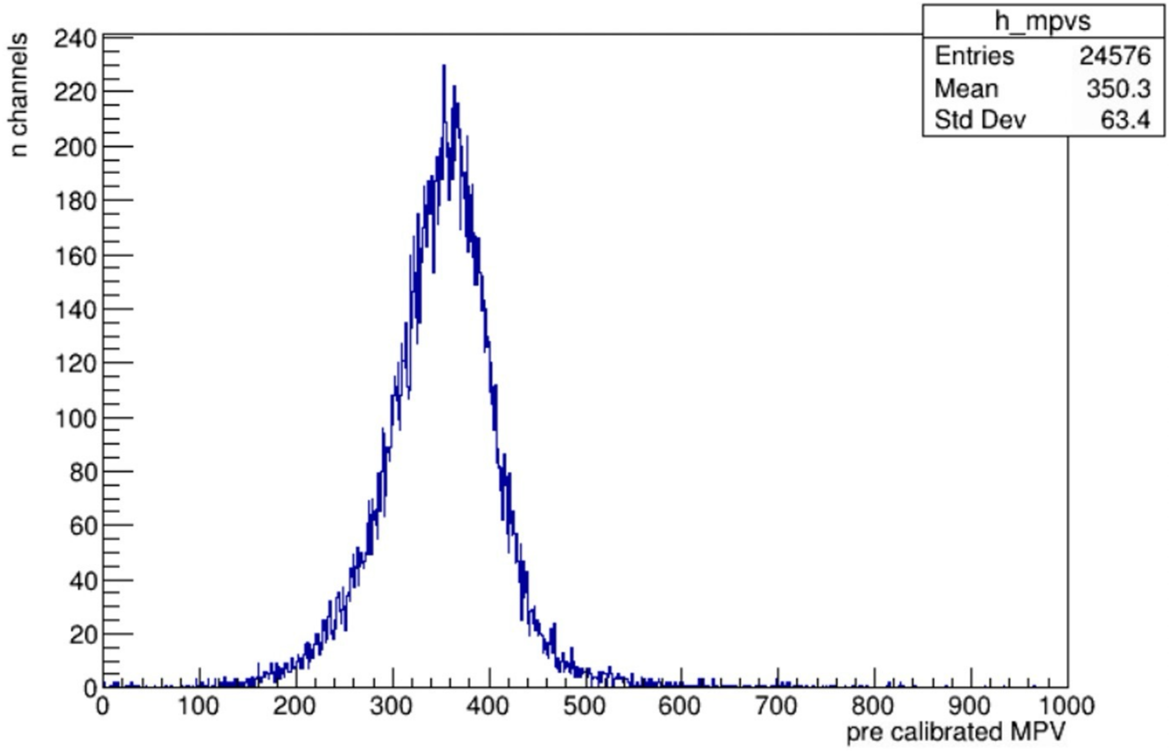
- Data result shown at right
- Cosmics from real data come from sectors in test stand with scintillator trigger

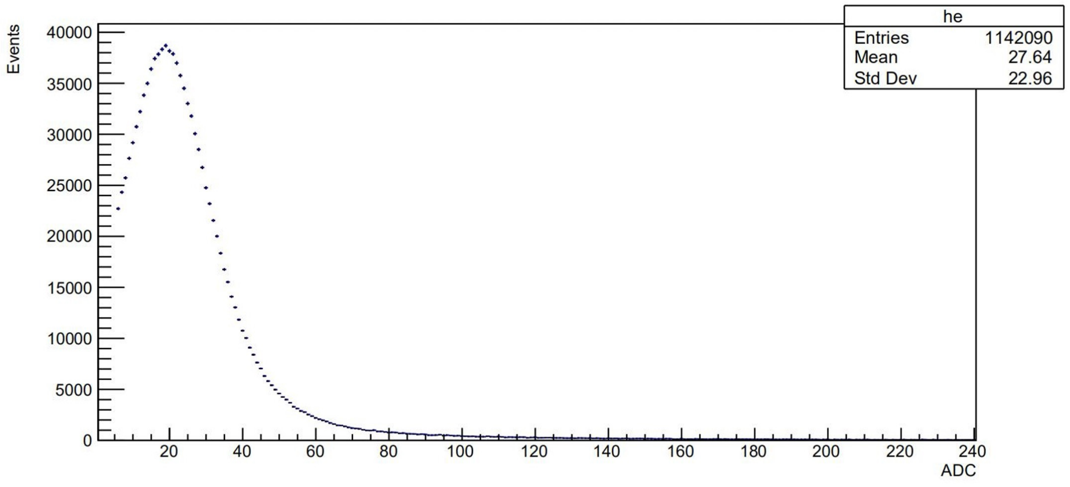
Slides by Tim Rin



EMCal Cosmics Calibratic

- Like HCal, EMCal cosmics calibration constants come from comparison of real data to simulation
- Used in early stages of EMCal data taking, replaced by run-independent, average π^0 energy scale calibration
- Cosmics still valuable, non-beam calibration source that can be tracked long-term

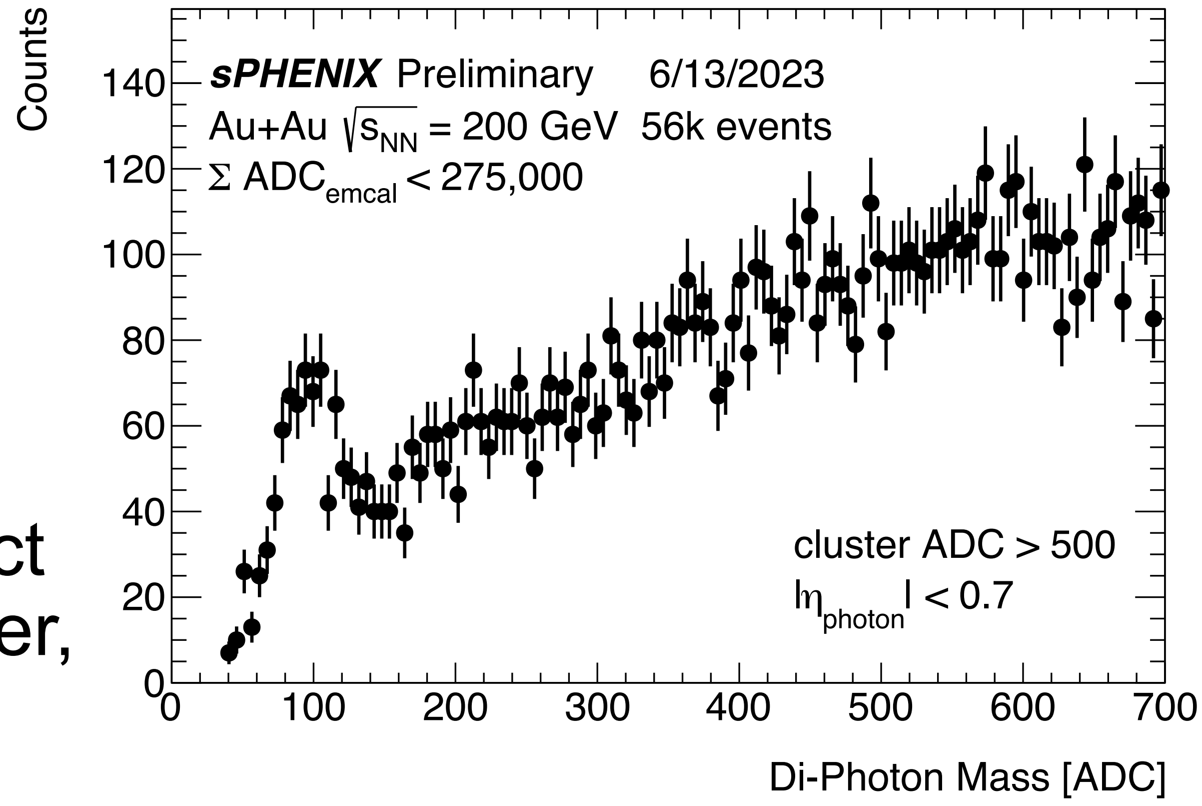




ADC distribution on all towers(768)

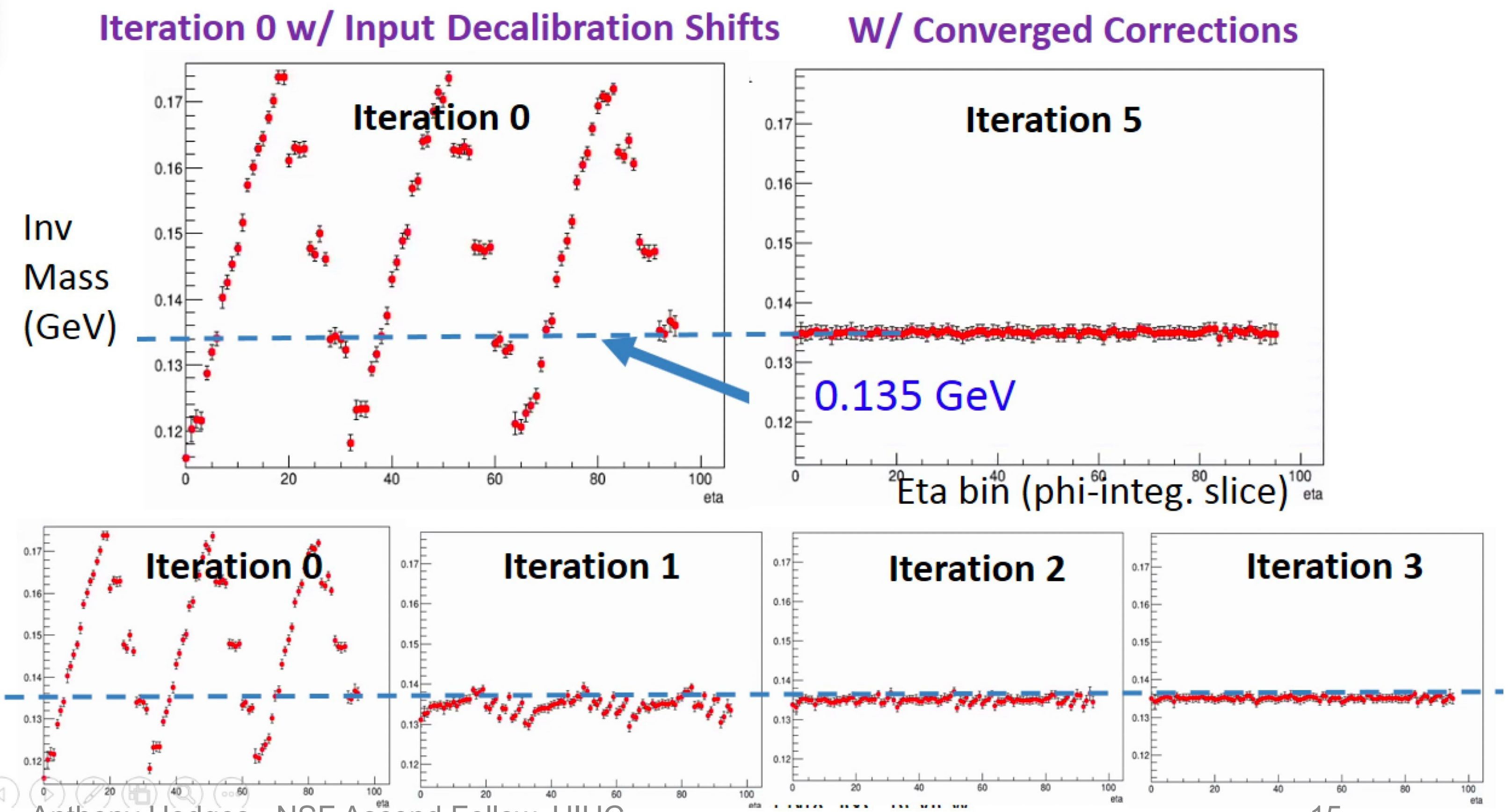
EMCal π^0 Calibration

- Utilize π^0 resonance to set energy scale
- Invariant mass calculated from pairs of clusters passing QA criteria
  - Leading cluster p_T
  - Sub-leading cluster
  - Cluster χ^2
  - Pair energy asymmetry
  - Cluster separation
- Reconstructed mass is attributed object relating to leading cluster (leading tower, η −bin, etc.)



EMCal π^0 Calibration

- Fully realized calibration is done *tower-by-tower*
- However, due to limited statistics, Run 23's is η-bin-by-η-bin
- Process is iterative
- Example shown here from simulation with known de-calibration to stress test method



[EMCal Calibration note](#)
- Justin Bryan
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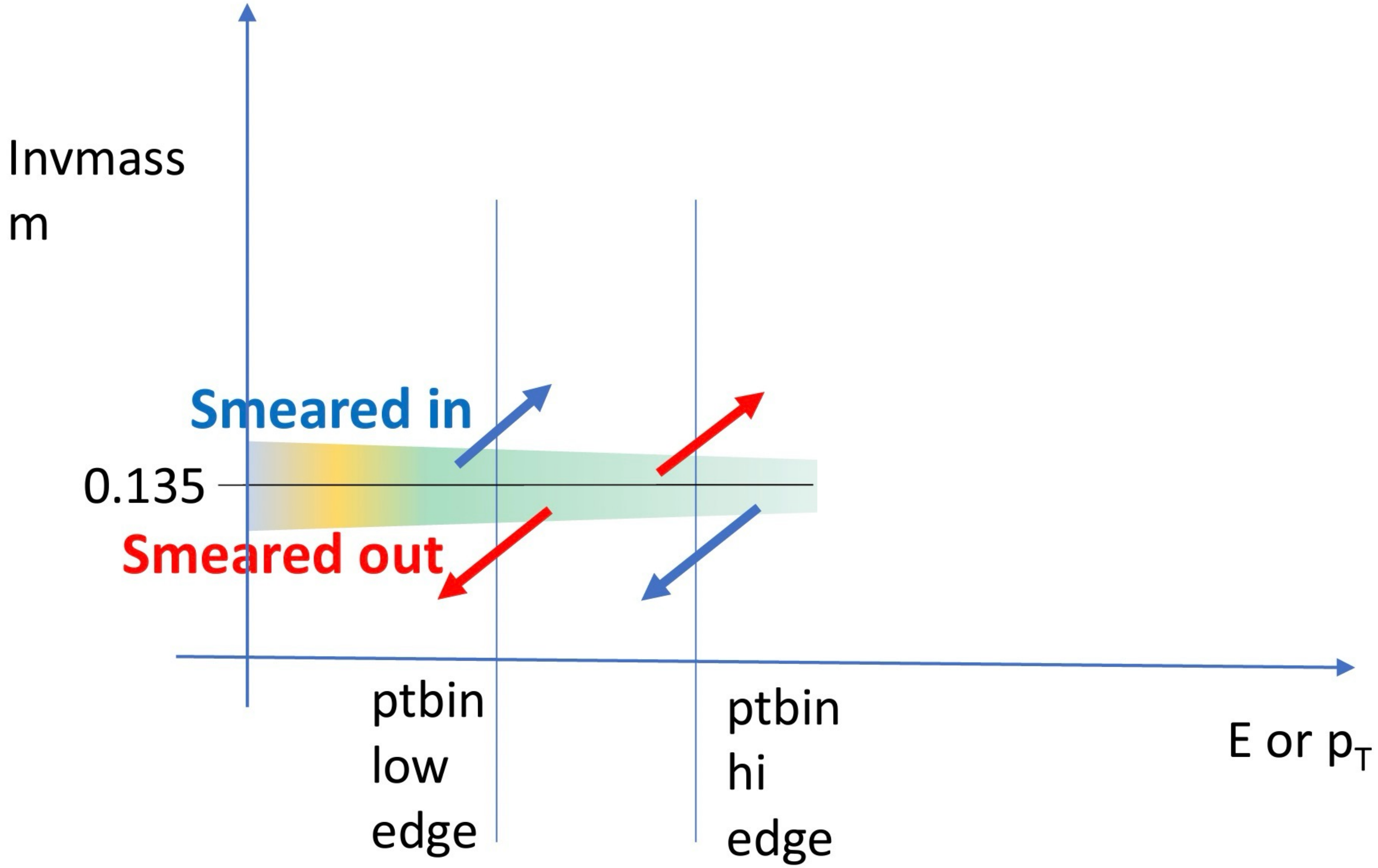
- Sijan Regmi

EMCal π^0 Calibration

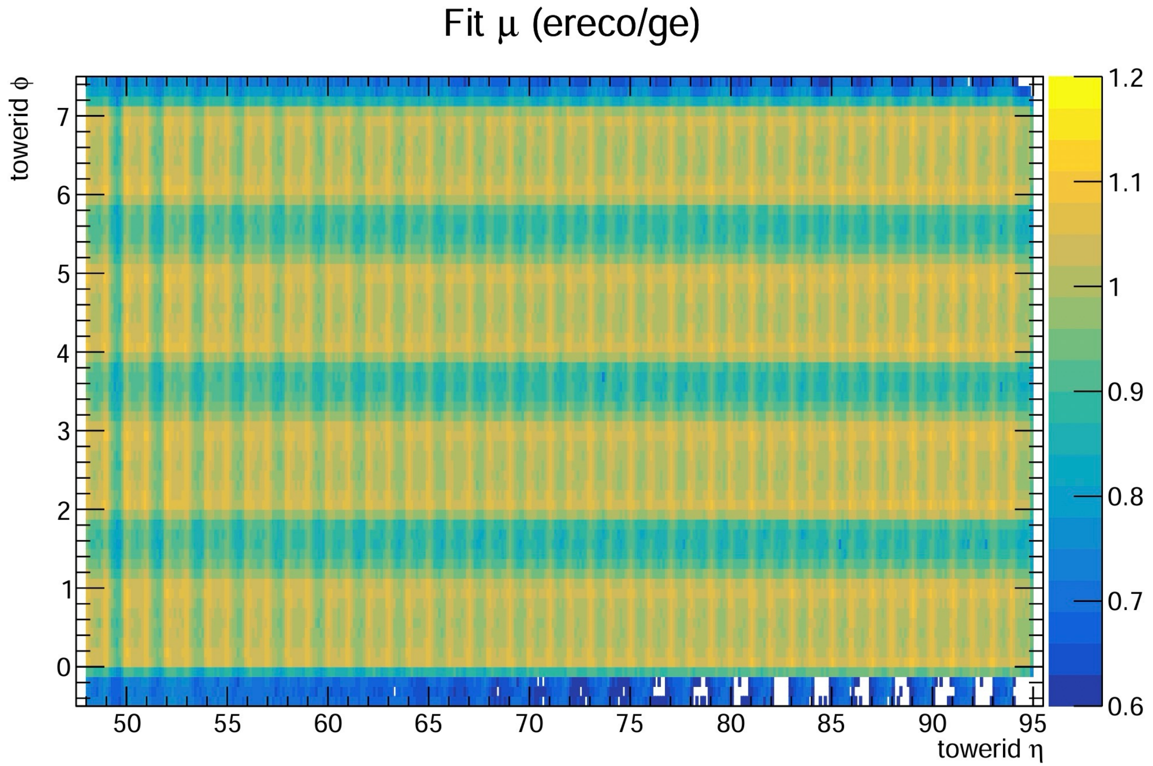
- Final calibration is *not* to PDG value of ~135$\mathrm{MeV/c^2}$
- Smearing of reconstructed π^0 mass and energy must be taken into account
- Because of steeply falling spectra, "true" π^0 mass is smeared upwards
- Final calibration value determined by Justin: 143.8$\mathrm{MeV/c^2}$

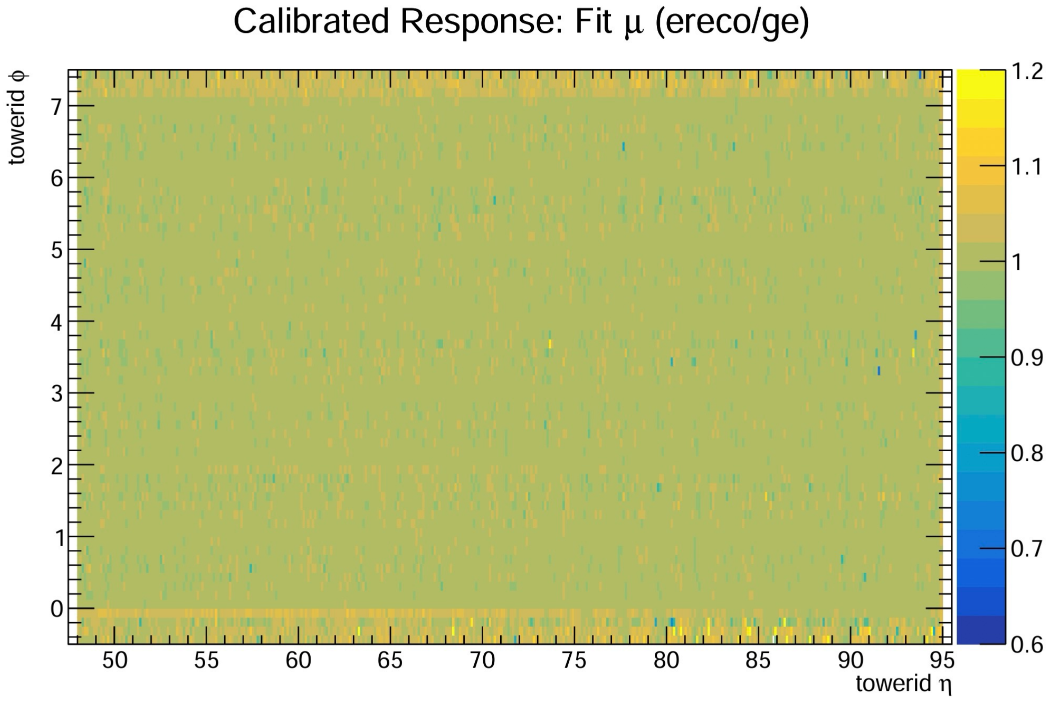
Slides by Justin Frantz



Cluster Position-Dependent Energy Correction

- Local inhomogeneity in towers can cause position-dependence in cluster energy response ($E_{Cluster}/E_{Truth}$)
- Sub-tower level corrections extracted from MC

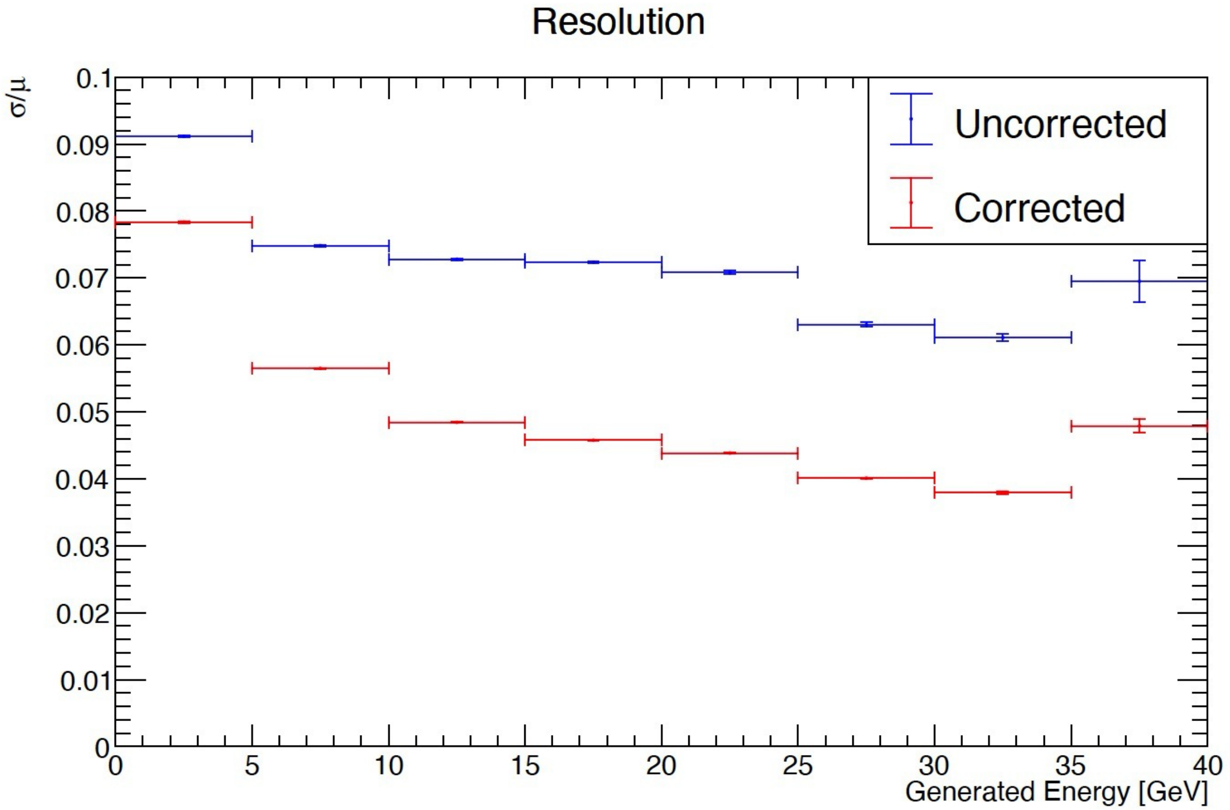


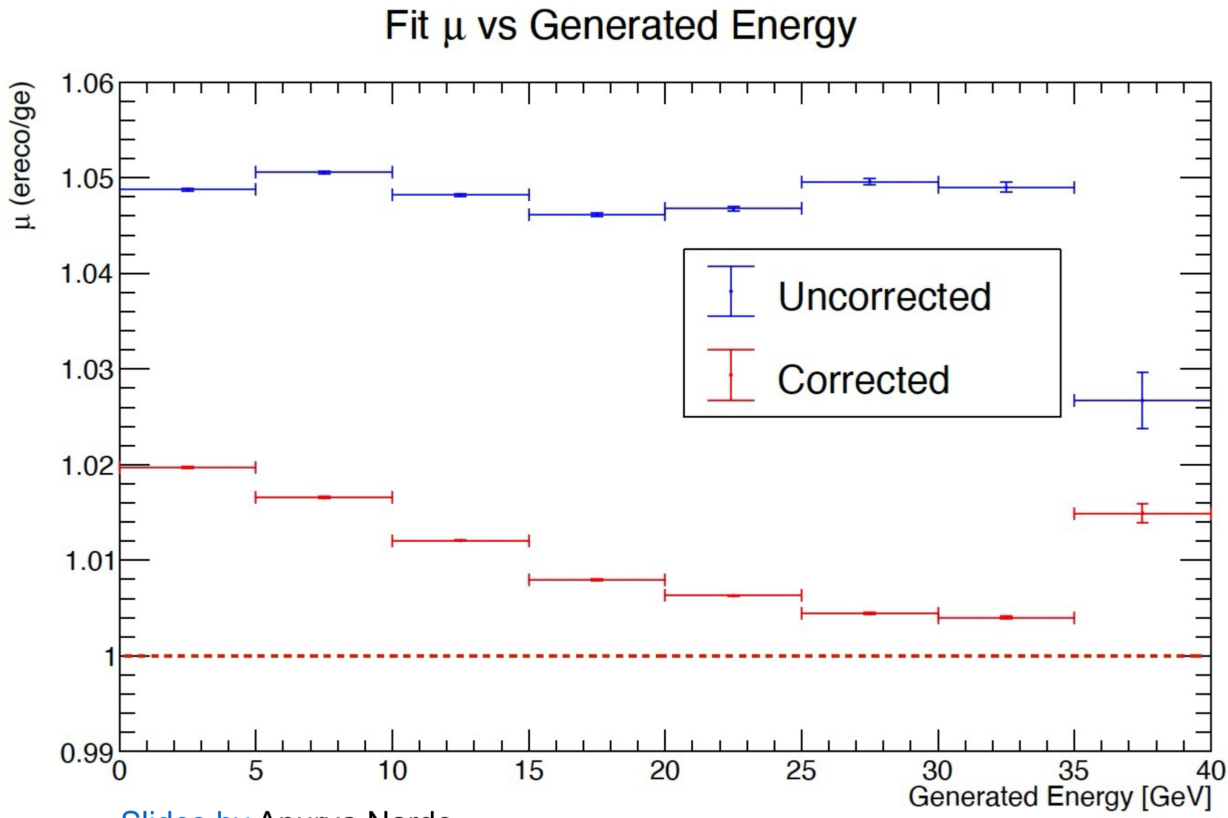


[Slides by]Apurva Narde

Cluster Position-Dependent Energy Correction

- Generally improves energy scale and resolution
- Currently improving closure at low p_T





[Slides by](#)Apurva Narde

Run 23 Initial Calibration Strategy

- ZDC: Energy scale calibration handled by calibrating single neutron peak
- HCals: Cosmic energy calibrations provide baseline, electromagnetic energy scale calibration
- EMCal: energy scale from simulation is characterized by π^0 peak in NC
  - π^0 peak in data is then calibrated to MC in each η bin
- Jet and cluster energy corrections, derived in MC at the “truth” level, can then be applied to data

Run 23 Future Calibration Strategy

- HCals: Cosmic data runs frequently taken and can update calibration when necessary
  - Possible to derive uncertainty/updated energy scale with E/p for electrons fired directly into calorimeter in MC
- EMCal: Energy scale in simulation to be studied further
  - Implementing realistic smearing, noise, and live areas derived from data
  - Determining correct value to calibration π^0 resonance to
- Jet and cluster energy corrections can then be quickly re-derived (hence push to gather all calibration software on Git) and reapplied

Questions, comments, how to get involved?

- Calorimeter Calibrations Co-Conveners:
  - Anthony Hodges (University of Illinois, Urbana-Champaign)
  - Blair Seidlitz (Columbia)
- Meeting time: Mondays, 11AM ET
  - Annoucements made to EMCal, HCal, and Calibrations mailing lists
- Current task list: https://docs.google.com/presentation/d/113vGaBIgGebYTPs1X_9iFZ4Yr13vIpCE9TyGYcz14mU/edit#slide=id.p