RHIC/AGS Annual Users Meeting
August 1st – 4th, 2023
Brookhaven National Lab

Derek Anderson
Iowa State University
for the ePIC Collaboration

PERFORMANCE AND CALIBRATION OF THE EPIC BHCAL

Abstract

Measurement of jets and their substructure will provide valuable information about the properties of the struck quarks and their radiative properties in Deep-Inelastic Scattering events. The ePIC Barrel Hadronic Calorimeter (BHCal) will be a critical tool for such measurements. By enabling the measurement of the neutral hadronic component of jets, the BHCal will complement the Barrel Electromagnetic Calorimeter and improve our knowledge of the jet energy scale. However, to obtain a physically meaningful measurement, the response of the BHCal must be properly calibrated. We provide a snapshot of ongoing studies exploring the use of Machine Learning to calibrate the response of the BHCal.

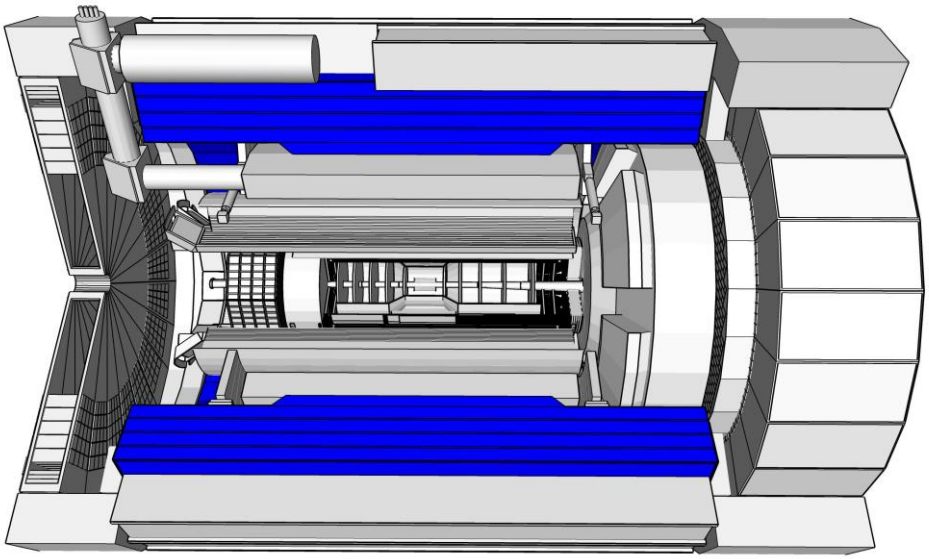
RHIC/AGS Annual Users Meeting
August 1st – 4th, 2023
Brookhaven National Lab

Derek Anderson
Iowa State University
for the ePIC Collaboration

PERFORMANCE AND CALIBRATION OF THE EPIC BHCAL

(1) Introduction

- **The BHCal will serve several roles at ePIC:**
  - Precise jet energy reconstruction (by incl. h^0)
  - Add. Handle on e^- kinematics
  - Solenoid flux return
  - Possible $\mu^{\pm}$ identification
- ePIC planning to reuse (outer) sPHENIX HCal
- **Below:** rendering of current design of the central ePIC detector
  - ☞ BHCal highlighted in blue



U.S. DEPARTMENT OF ENERGY | Office of Science

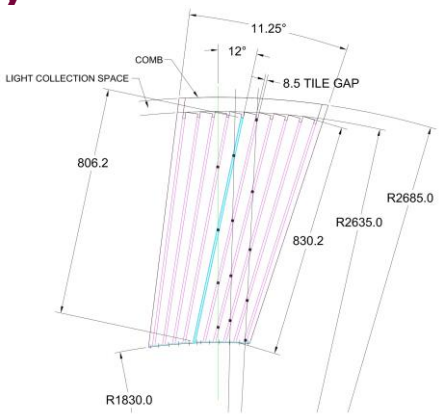
Derek Anderson
Iowa State University
for the ePIC Collaboration

PERFORMANCE AND CALIBRATION OF THE EPIC BHCAL

(2) BHCal Geometry

- Shashlik Geometry:
  - Alternating steel & scintillating tile (+ WLS fibers)
  - $|\eta| < 1.1$, 2π coverage
    - 48 towers/sector, 32 sectors
    - 5 tiles/tower
  - $\Delta\eta \times \Delta\varphi \sim 0.1 \times 0.1$
- sPHENIX reads out each tower with SiPMs

☞ **ePIC will read out each tile**



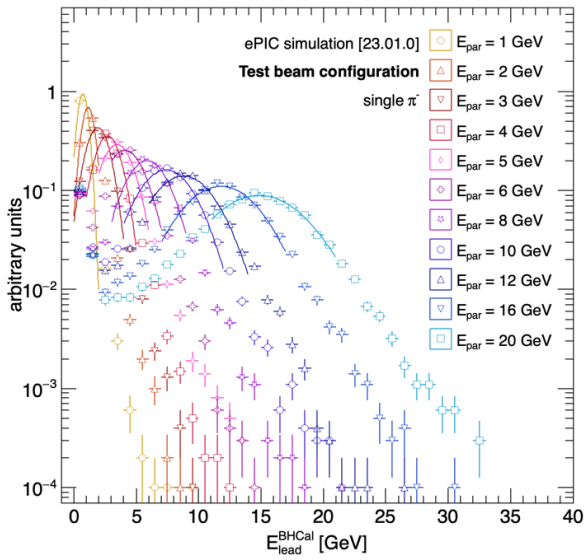
U.S. DEPARTMENT OF ENERGY | Office of Science

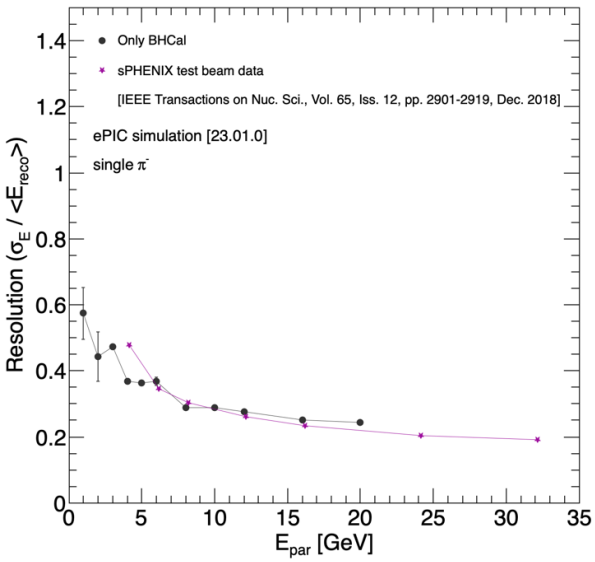
Derek Anderson
Iowa State University
for the ePIC Collaboration

PERFORMANCE AND CALIBRATION OF THE EPIC BHCAL

(3) Simulation Implementation

- BHCal implemented in DD4hep simulation of ePIC
  - **Left:** reconstructed energies in ePIC BHCal for single π^-
  - **Right:** resolutions from ePIC simulation vs. sPHENIX test beam data
    - **IEEE Transactions on Nuc. Sci., Vol. 65, Iss. 12, pp. 2901 – 2919, Dec. 2018**





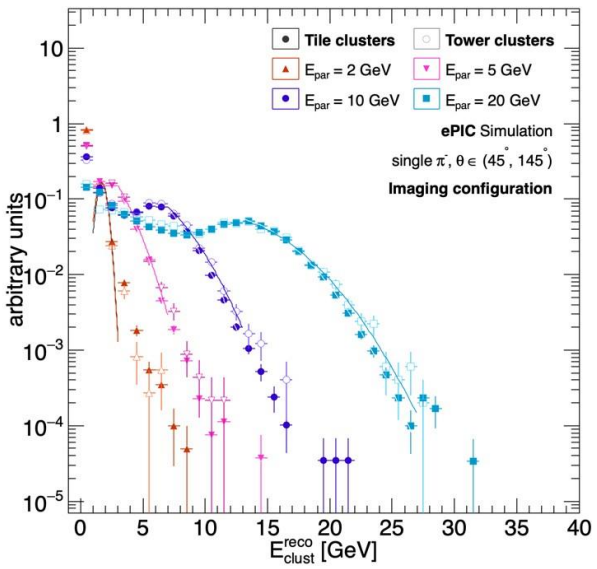
U.S. DEPARTMENT OF ENERGY | Office of Science

Derek Anderson
Iowa State University
for the ePIC Collaboration

PERFORMANCE AND CALIBRATION OF THE EPIC BHCAL

(4) Calibration Motivation

- Energy measured by BHCal degraded for several reasons:
  - Inefficiencies in clustering
  - Fluctuations in hadronic and EM parts of shower
  - Energy loss in inactive material
  - Loss due to nuclear-binding energies
  - Etc.
- **Right:** reconstructed energy of highest energy cluster in BHCal
  - ☞ **Measured energy has to be calibrated!**



U.S. DEPARTMENT OF ENERGY | Office of Science

Derek Anderson
Iowa State University
for the ePIC Collaboration

PERFORMANCE AND CALIBRATION OF THE EPIC BHCAL

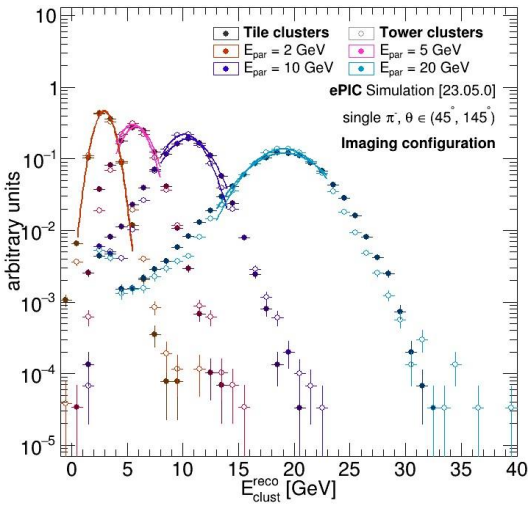
(5) Calibration Strategy

- EM part of shower corrected for
  - Nuclear binding energy etc. still need to be corrected

☞ **Used TMVA:**

- Trained on single particle events
- Regression analysis:
  - › Particle energy as target
  - › Using info of highest energy clusters from BECal/BHCal

- Calibrated energies **(right)** still show significant tails
  - Due to (unwanted) cluster splitting?



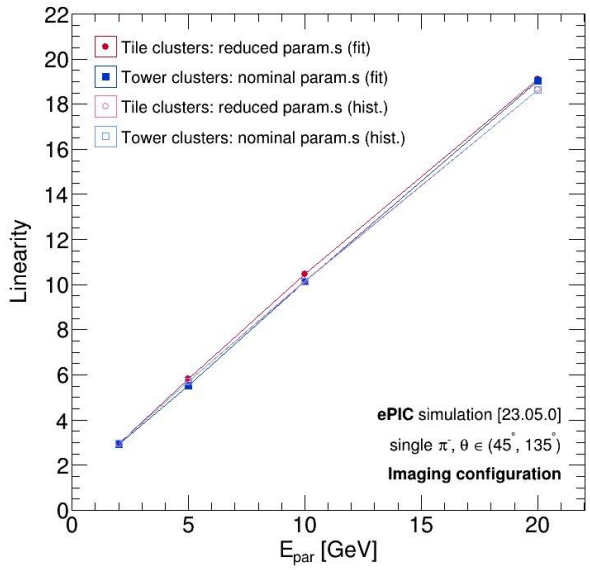
U.S. DEPARTMENT OF ENERGY | Office of Science

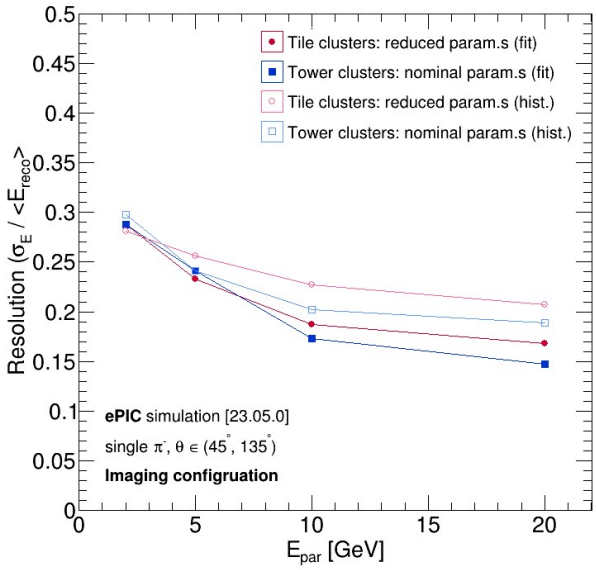
Derek Anderson
Iowa State University
for the ePIC Collaboration

PERFORMANCE AND CALIBRATION OF THE EPIC BHCAL

(6) Energy Resolution

- **Below:** linearity **(left)** and resolution **(right)** for tile- vs. tower-based clusters
  - Tower-based cluster resolution slightly better than tile-based
  - Clustering could use further tuning?





U.S. DEPARTMENT OF ENERGY | Office of Science

Derek Anderson
Iowa State University
for the ePIC Collaboration

PERFORMANCE AND CALIBRATION OF THE EPIC BHCAL

(7) Future Work

- **Near-term goals with calibration:**
  - Make use of full capability of imaging BECal
    - ☞ Segmentation gives additional information on shower
  - Improve ML model for calibration
    - › Hyperparameter scan
    - › Extend model to split clusters?
  - Integration into EIC software
- **Planned studies in near-term:**
  - Evaluate response to h^0 (e.g. neutrons)
  - Study response to $\mu^{\pm}$
  - Study impact on JES in realistic DIS events