Impact of BEMC Choice on BHCal Calibration

ePIC Calorimetry Meeting

March 15th, 2023

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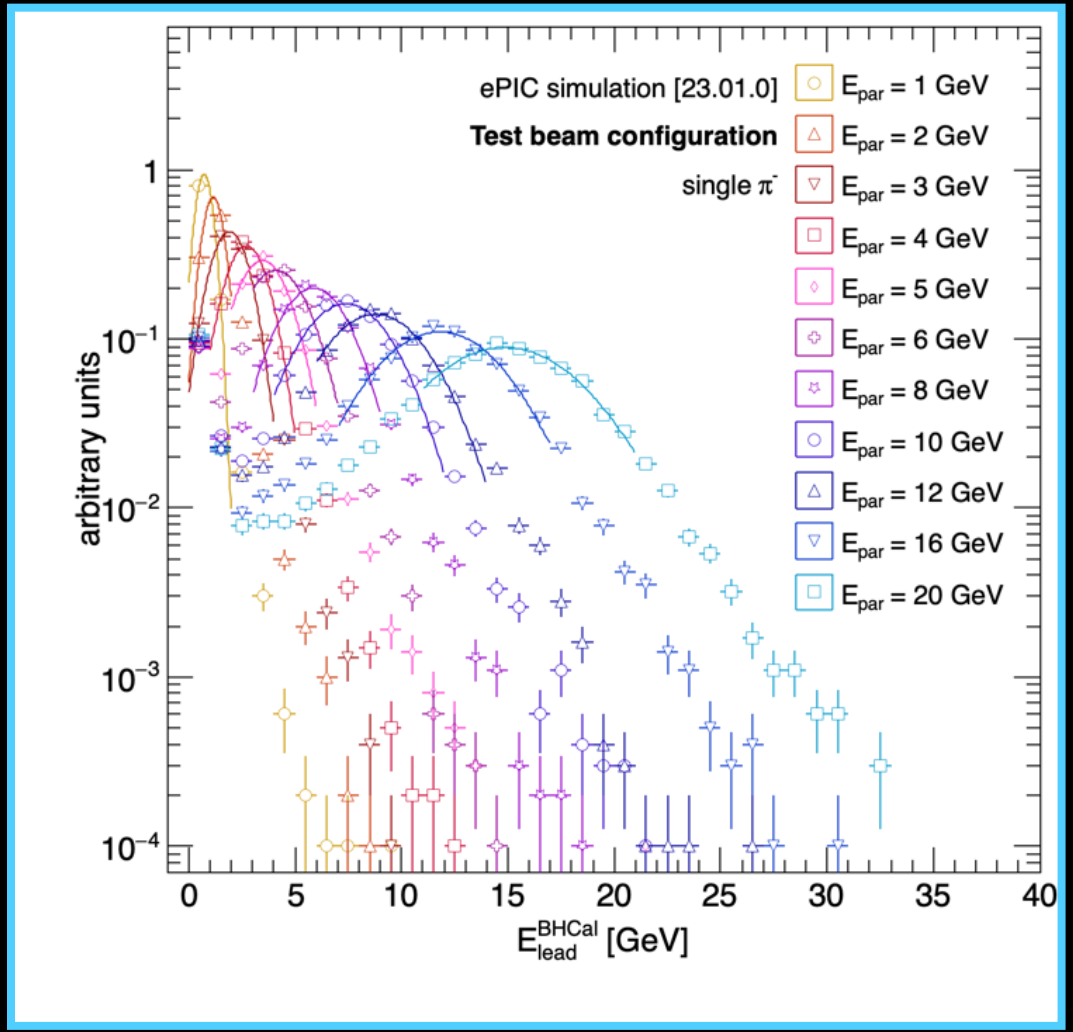
Only BHCal | Reconstructed Energies

- Energy of leading BHCal cluster for single π^- in ePIC simulation
  - ☞ Only BHCal in simulation
- Each distribution fit with gaussian

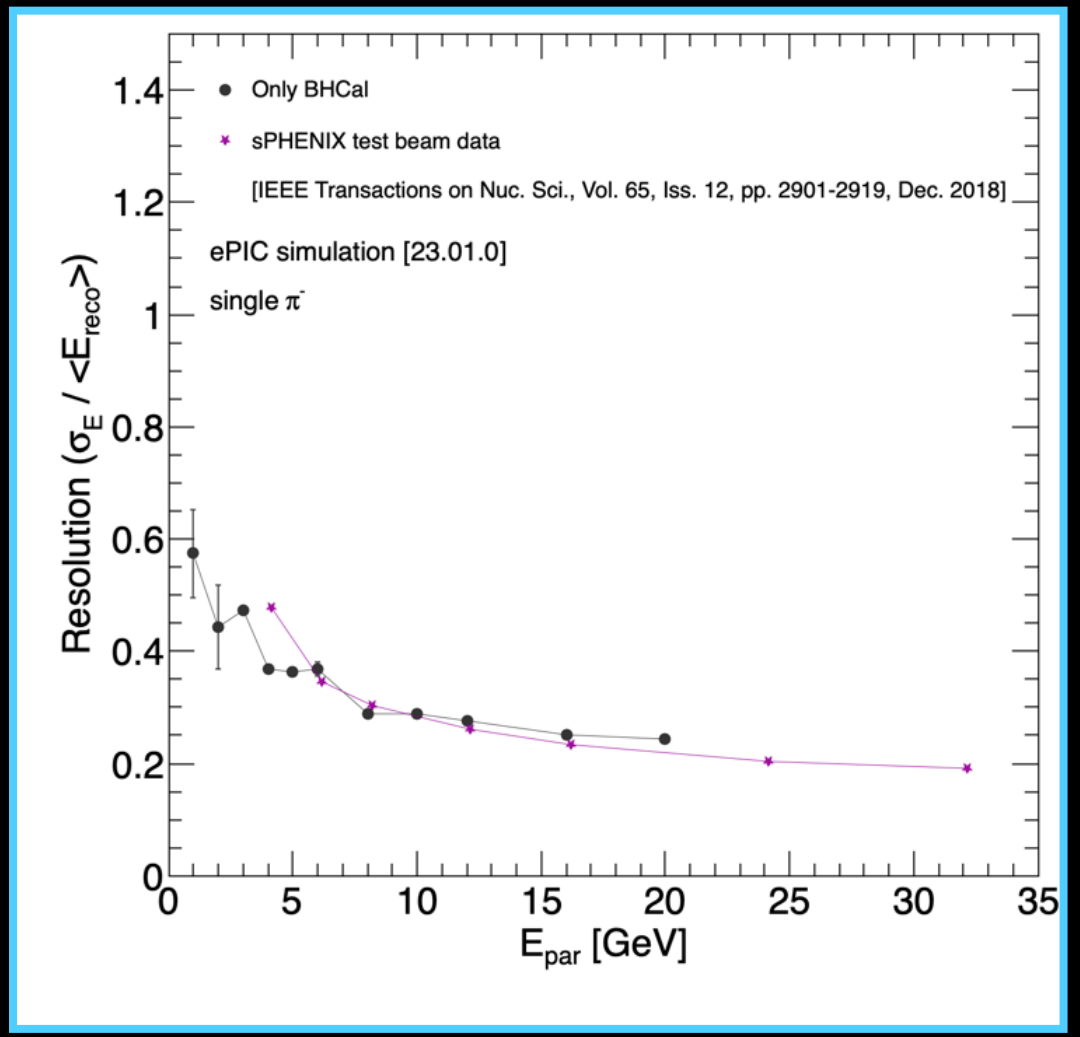


Only BHCal | Comparison to Test Beam Data

- Calculated energy resolution from ePIC simulation using fits

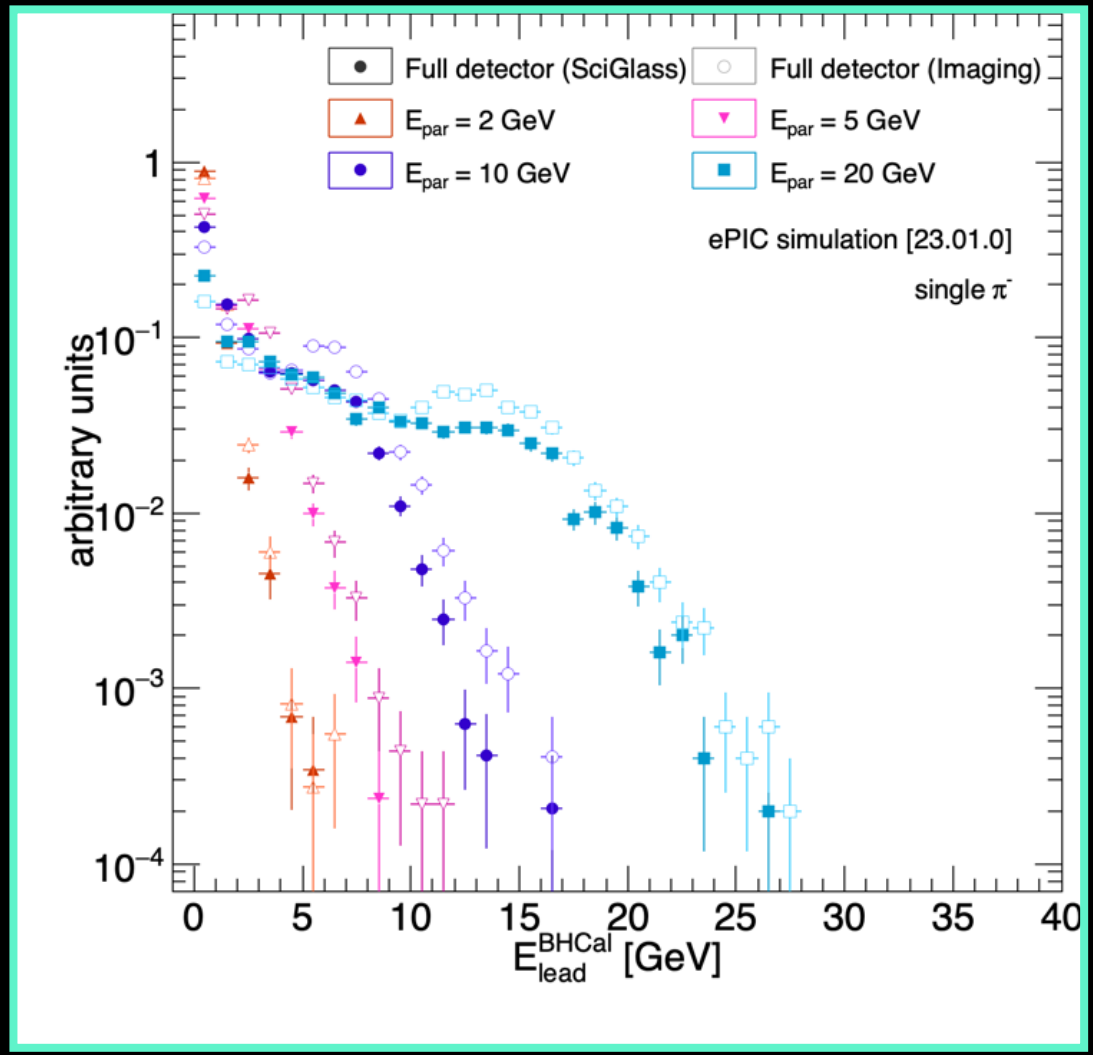
$$\mathbf{reso} = \sigma_{\mathbf{fit}}/\mu_{\mathbf{fit}}$$

- Compared resolution from ePIC simulation **(black circles)** against sPHENIX test beam results **(purple stars)**
  - 👉 **Agree well!**
  - Points from Fig. 28 of [IEEE Transactions on Nuc. Sci., Vol. 65, Issue 12, pp. 2901-2919, Dec. 018]



With BEMC | Uncalibrated Energies

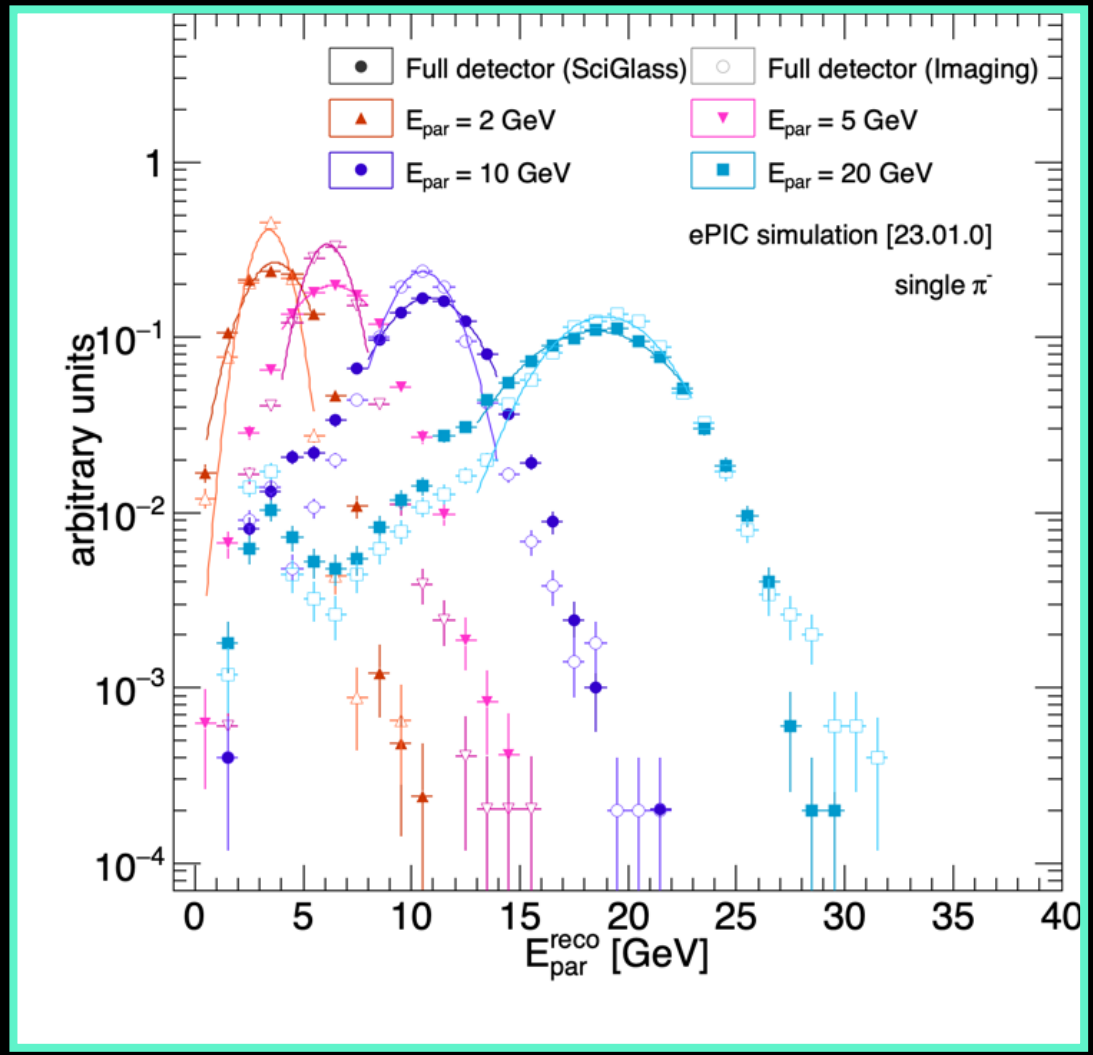
- **Shown:** energy of leading BHCal cluster for single π^- events with **full** ePIC simulation
  - With SciGlass BEMC **(closed markers)**
  - With Imaging BEMC **(open markers)**
- Energies need to be calibrated!



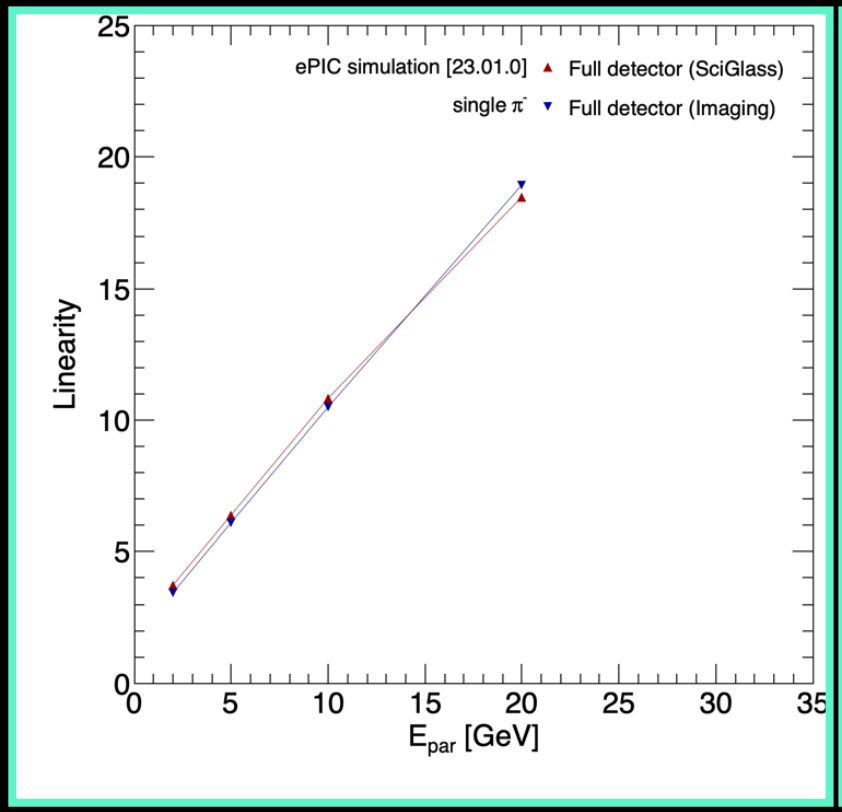
With BEMC | Calibrated Energies

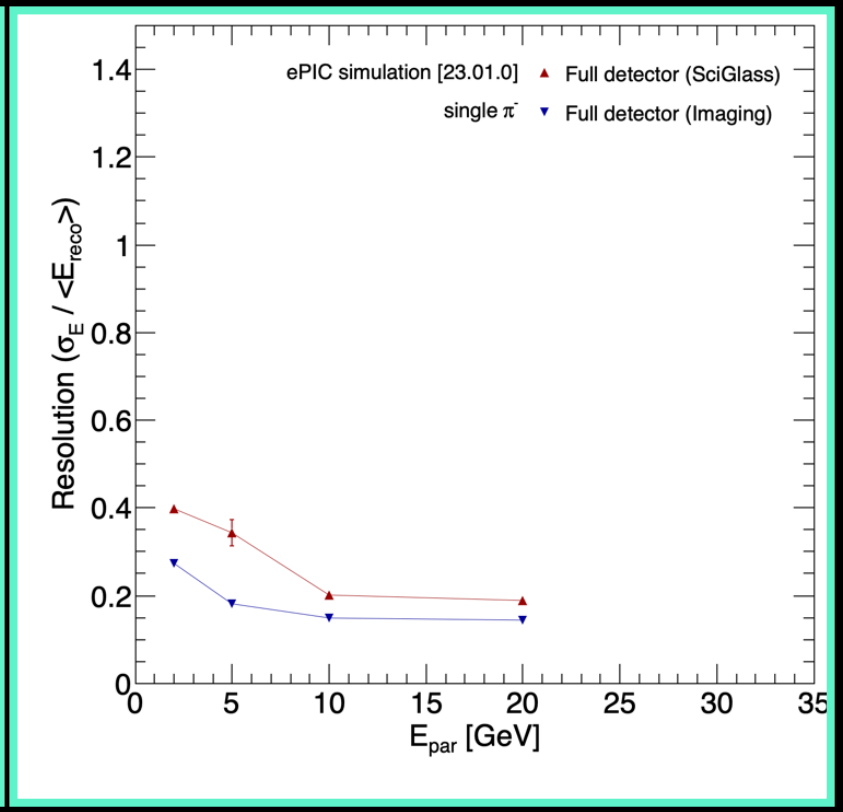
- Calibrated BEMC+BHCal response for both configurations via TMVA
  - Performed regression analysis on single particle events with particle energy as target
  - TMVA parameters in backup

- **Shown:** calibrated BEMC+BHCal for single π^- events with **full** ePIC simulation
  - With SciGlass BEMC **(closed markers)**
  - With Imaging BEMC **(open markers)**
  - ☞ Solid lines are gaussian fits



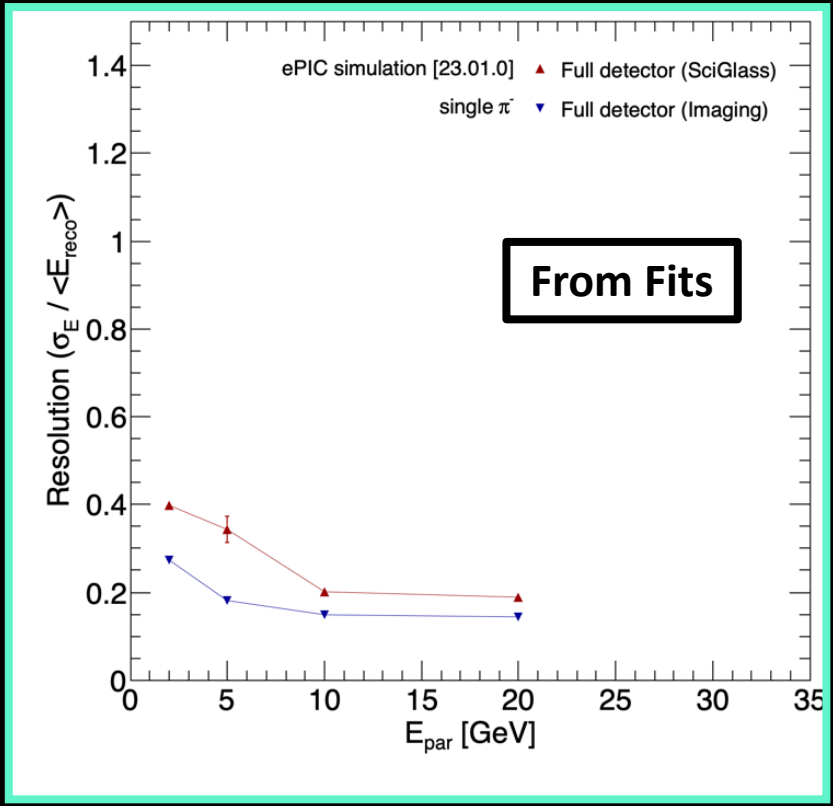
With BEMC | Linearity and Energy Resolutions

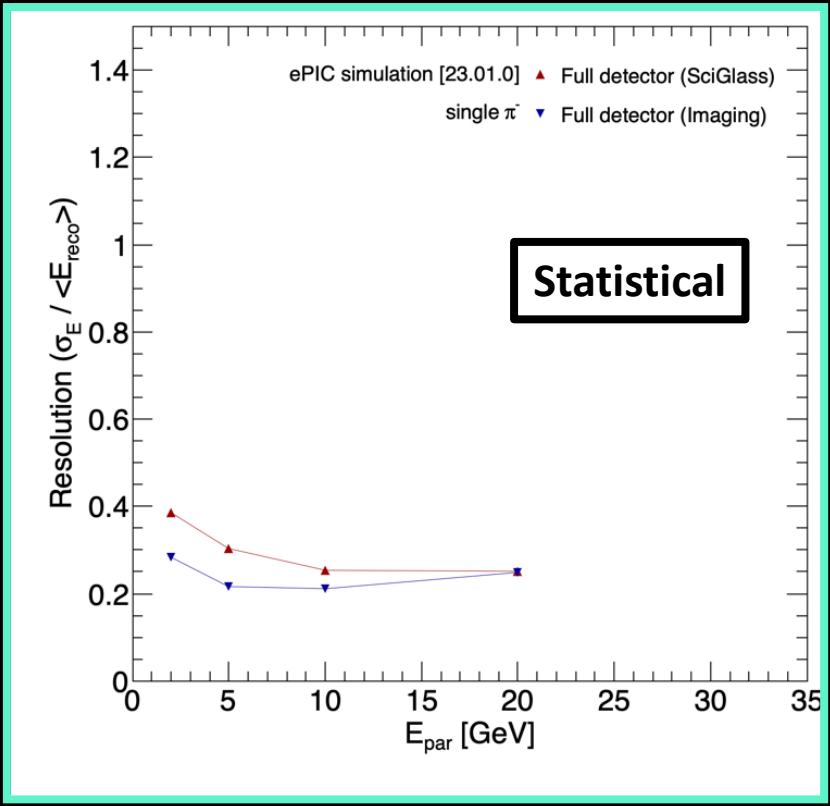




- Calculated linearity **(left)** and energy resolution **(right)** from fits
- **Legend:**
  - SciGlass config. **(red)**
  - Imaging config. **(blue)**

With BEMC | Resolution Cross-Check

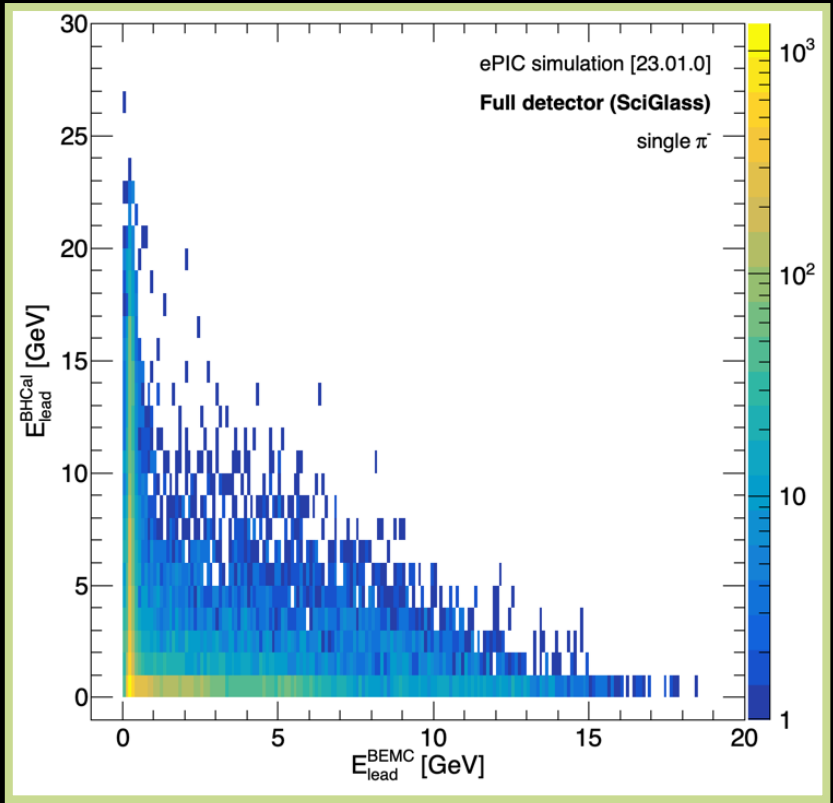


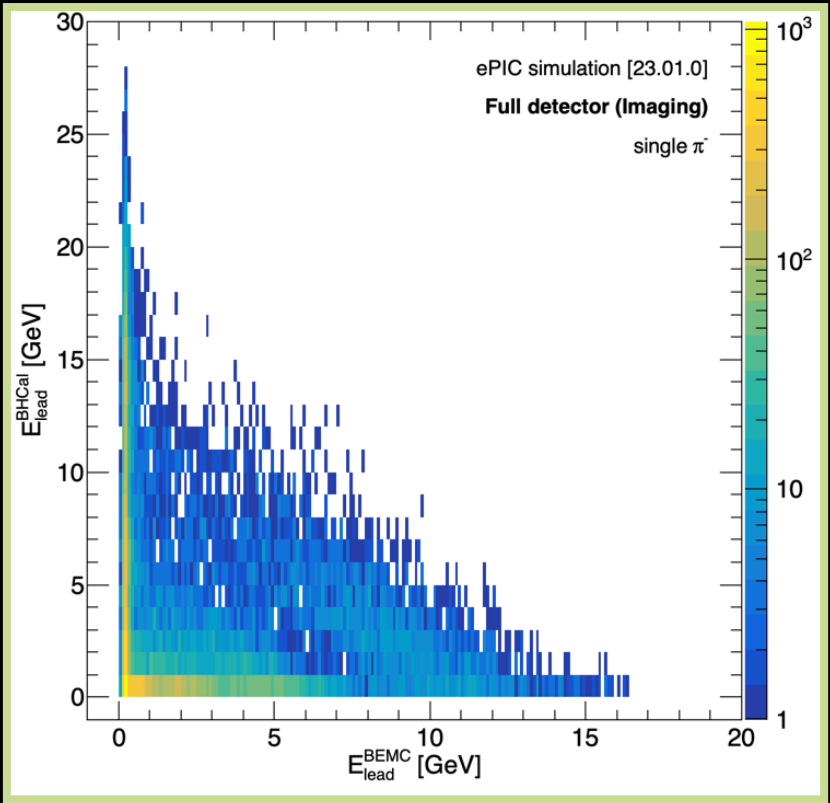


- Calculated resolution 2 ways
  a) From fits:
     $\mathbf{reso} = \sigma_{\mathbf{fit}}/\mu_{\mathbf{fit}}$
  b) Using statistical mean and RMS:
     $\mathbf{reso} = \mathbf{RMS}/< E_{\mathbf{par}}^{\mathbf{reco}} >$

- **Legend:**
  - SciGlass config. **(red)**
  - Imaging config. **(blue)**

Shower Depth | Lead BHCal vs. BEMC Energies

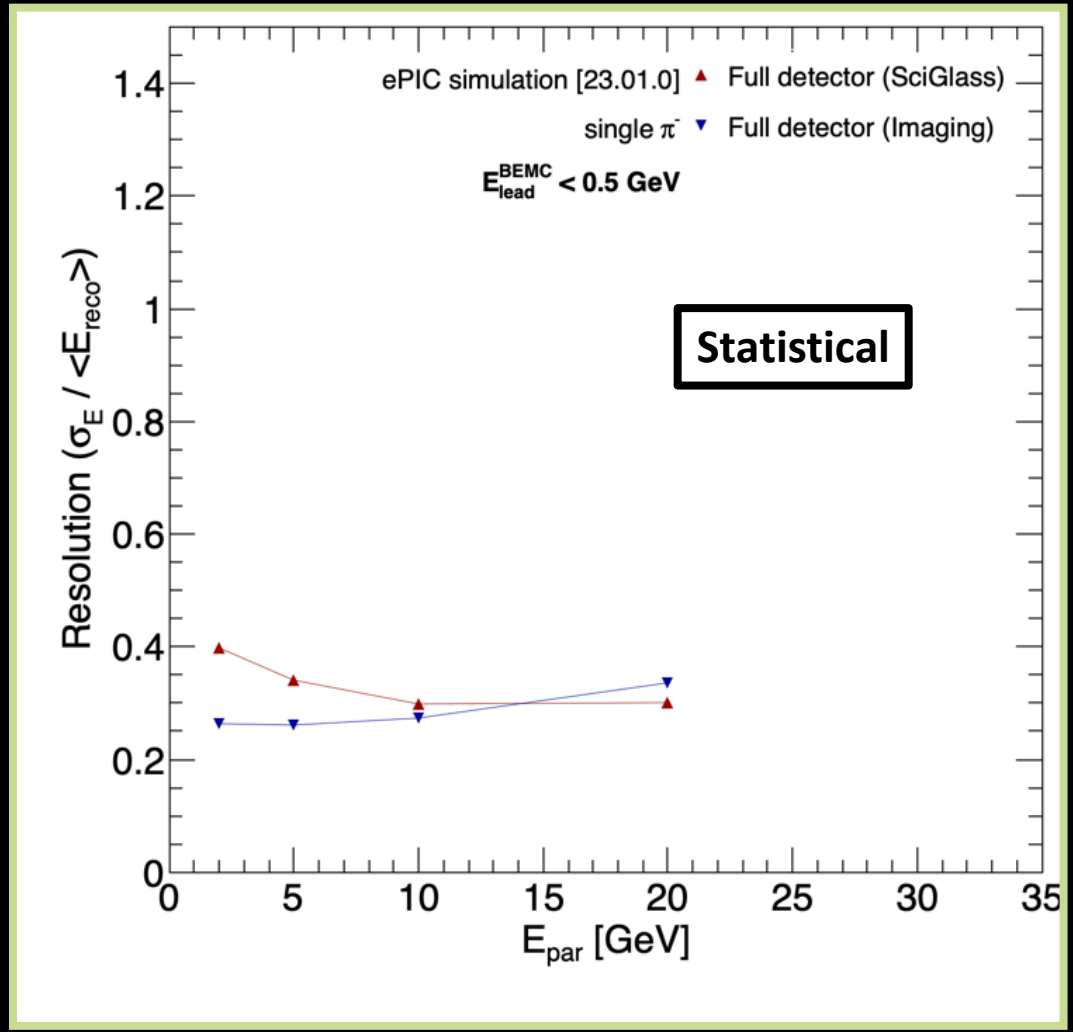




- Lead BHCal vs. BEMC cluster energies for SciGlass **(left)** and Imaging **(right)** BEMCs
  - Large peak at low BEMC energy due to π^- MIPing through BEMC
- **Note:** plots integrate over π^- energies from 2 – 20 GeV

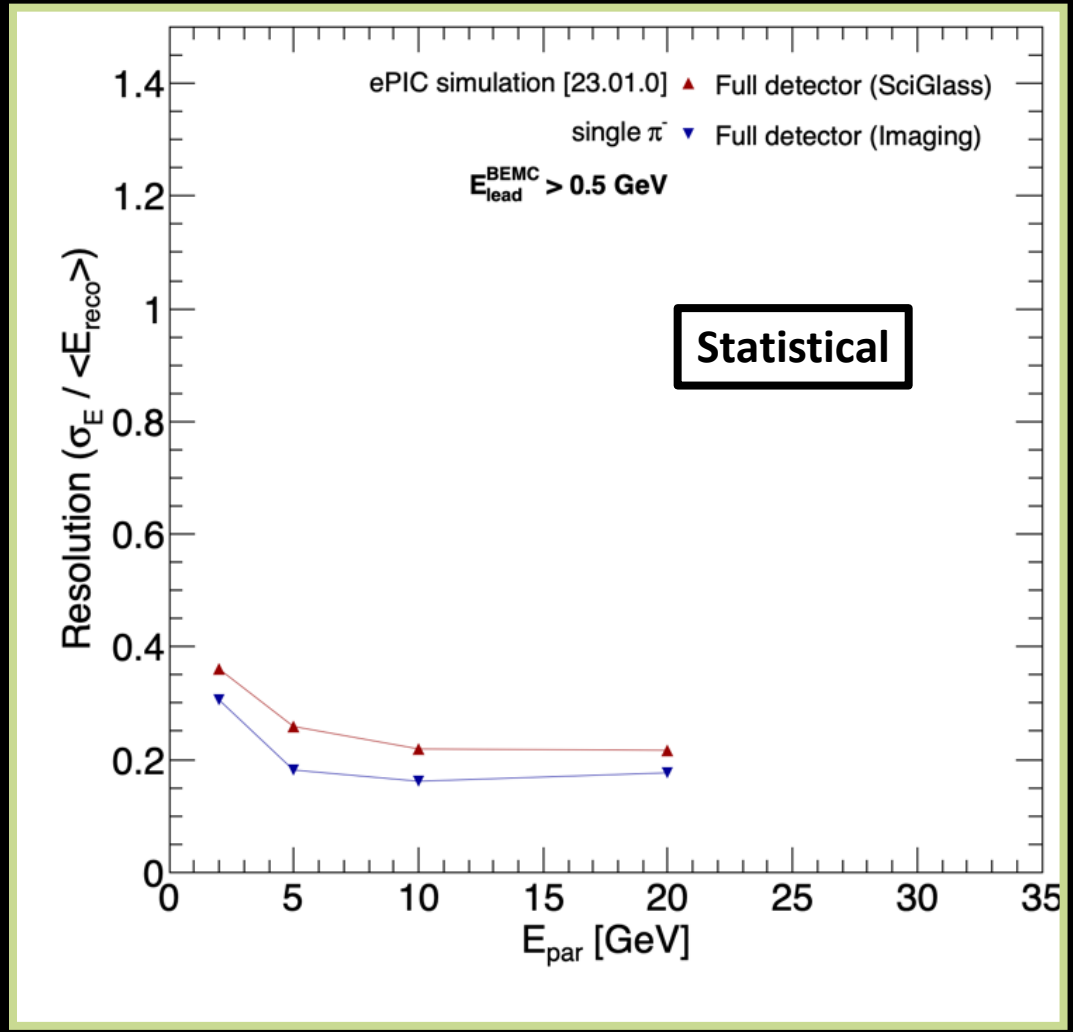
Shower Depth | MIP Resolution

- Selected MIPs by requiring lead BEMC cluster energy be **< 0.5 GeV**
- Calibrated BHCal+BEMC response for MIPs using TMVA trained on full sample
  - (Shown in backup)
- Then calculated resolution for MIPS in both configurations
  - Calculated using statistical values
  - (Resolution from fits in backup)



Shower Depth | Non-MIP Resolution

- Non-MIPs selected by requiring lead BEMC cluster energy be **> 0.5 GeV**
- Then BHCal+BEMC response were calibrated and resolution calculated as in last slide
  - Calibrated energies and resolution from fits in backup



Backup

Backup | simulation parameters

Detector Configuations

- Test Beam Configuration = only BHCal (fields also excluded)
- Full detector (SciGlass) = full epic simulation with SciGlass BEMC
- Full detector (Imaging) = full epic simulation with Imaging BEMC

Simulation Parameters

- gun.energy (test beam) = 1*GeV, 2*GeV, 3*GeV, 4*GeV, 5*GeV, 6*GeV, 8*GeV, 10*GeV, 12*GeV, 16*GeV, 20*GeV
- gun.energy (full detector) = 2*GeV, 5*GeV, 10*GeV, 20*GeV
- gun.particle = "pi+"
- gun.distribution = "cos(theta)"
- gun.thetaMin = 35*degree
- gun.thetaMax = 145*degree
- 23.01.0 Geometry [Arches]

Reconstruction

- EICRecon (+ changes described on next slide)

Backup | TMVA parameters

Parameters

- Regression analysis
- Trained on 1000 events
- 3 methods:
  a) Linear Discriminant (shown)
  b) MLP (neural network)
  c) Boosted Decision Tree

Training Variables

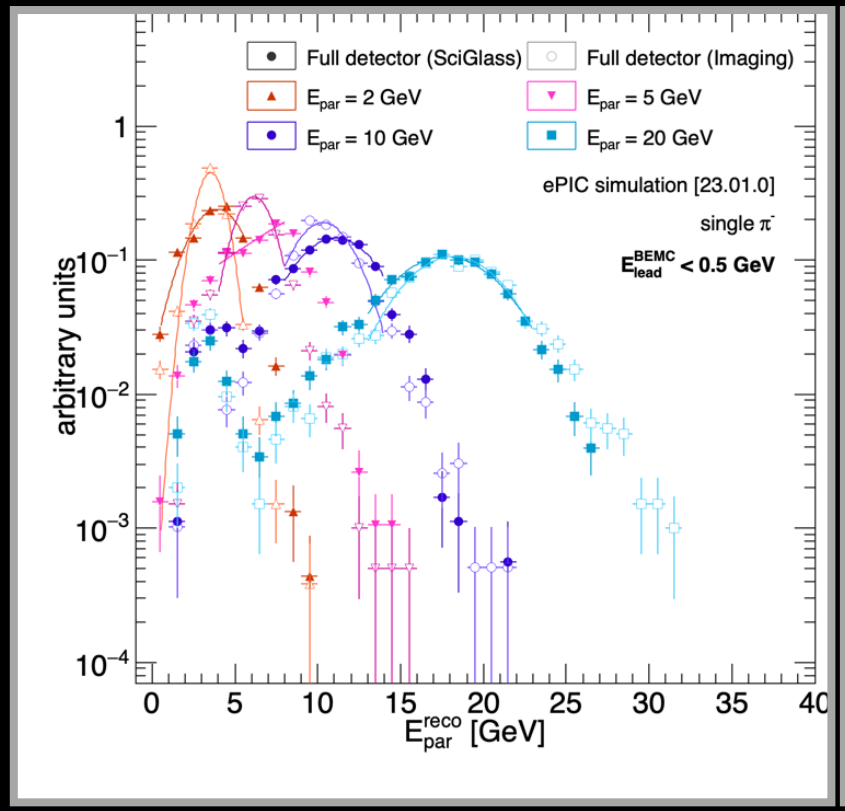
- Energy of leading BHCal and BEMC clusters
- Eta, phi of leading BHCal and BEMC clusters
- No. of hits in lead BHCal and BEMC clusters
- Sum of energy in imaging and SciFi layers
  - In imaging configuration only
- * No. of clusters in BHCal and BEMC
  - No. of merged clusters for imaging configuration

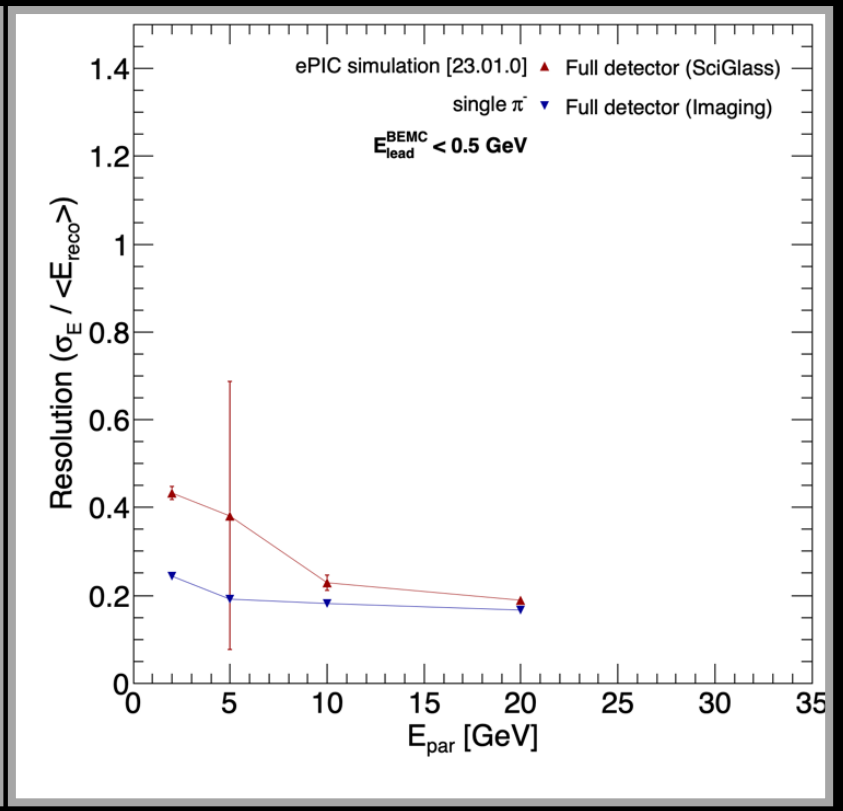
Target

- particle energy

* Used in testing, but not in shown results: calibrated energies and resolution in backup

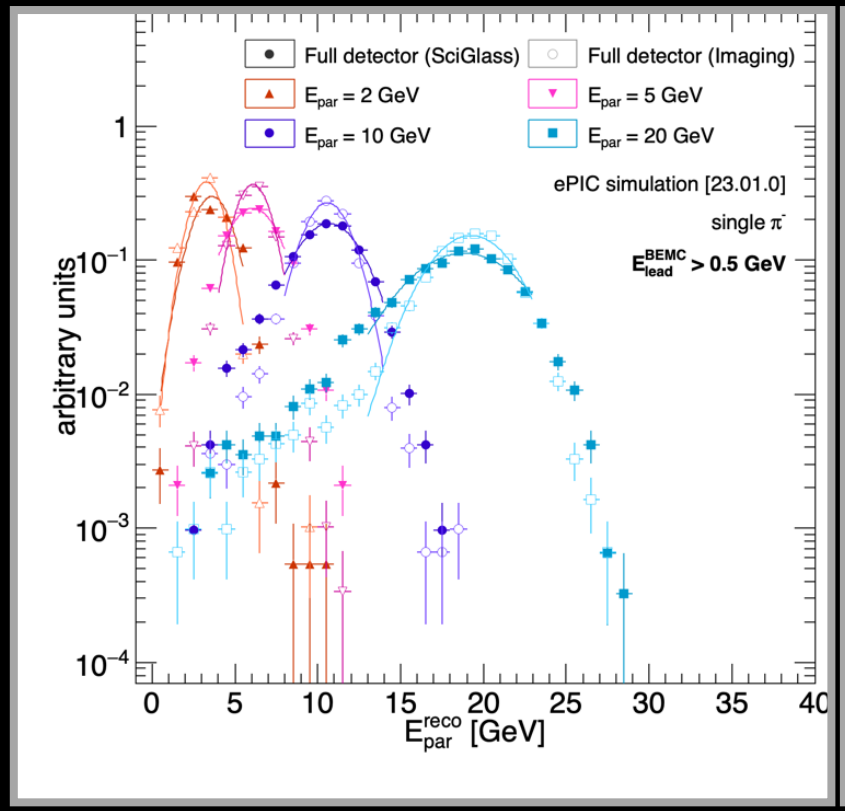
Backup | Calibrated MIP Energies & Fit Resolution

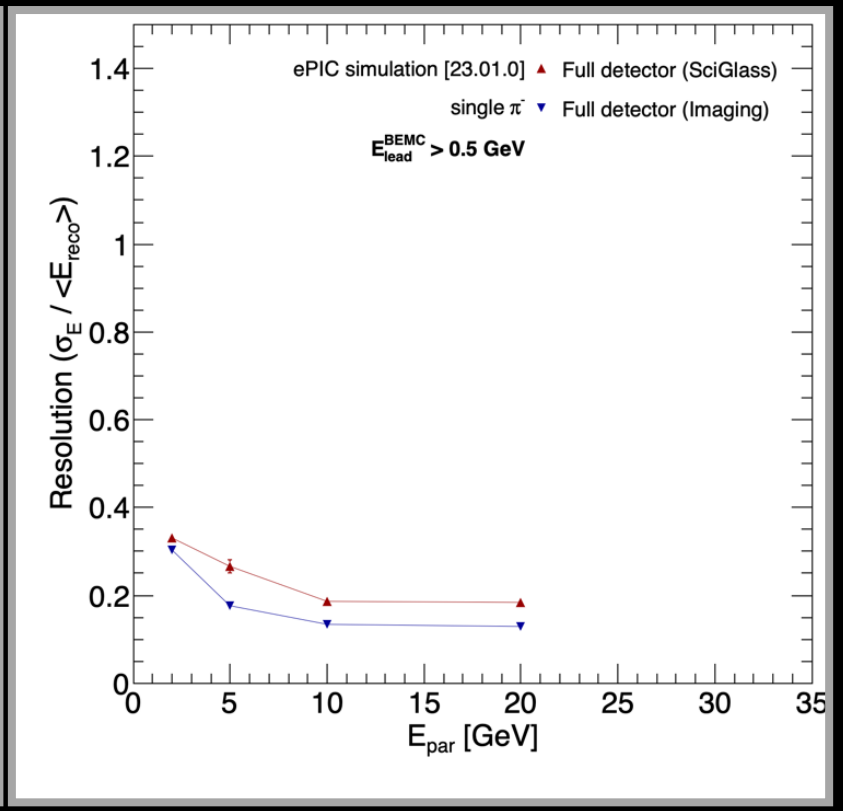




- **Left:** Calibrated lead BHCal energies
  Right: MIP energy resolution from fits

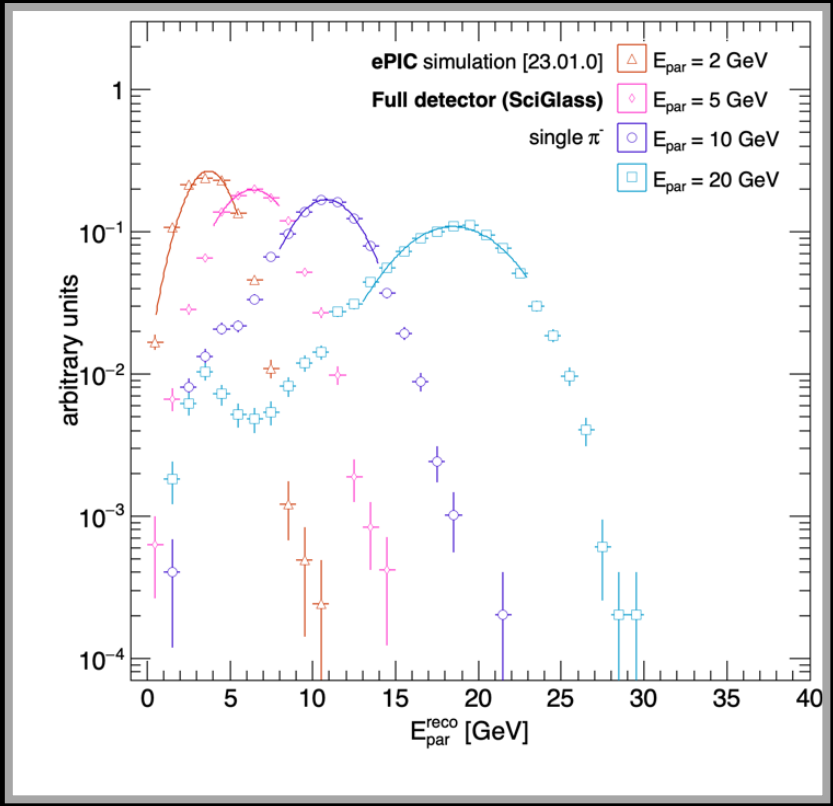
Backup | Calibrated Non-MIP Energies & Fit Resolution

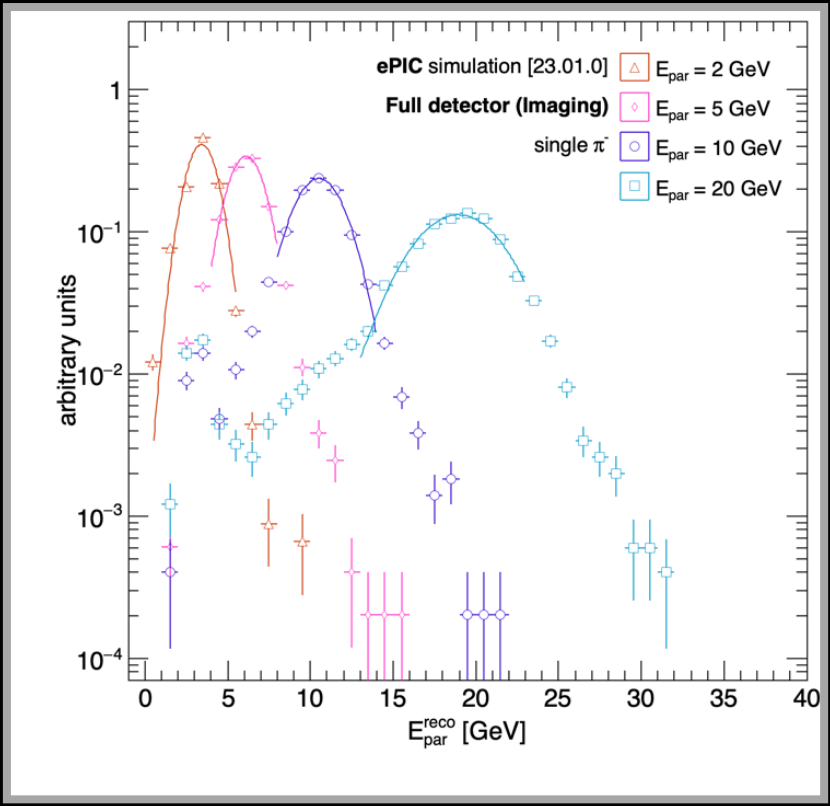




- **Left:** Calibrated lead BHCal energies
  Right: MIP energy resolution from fits

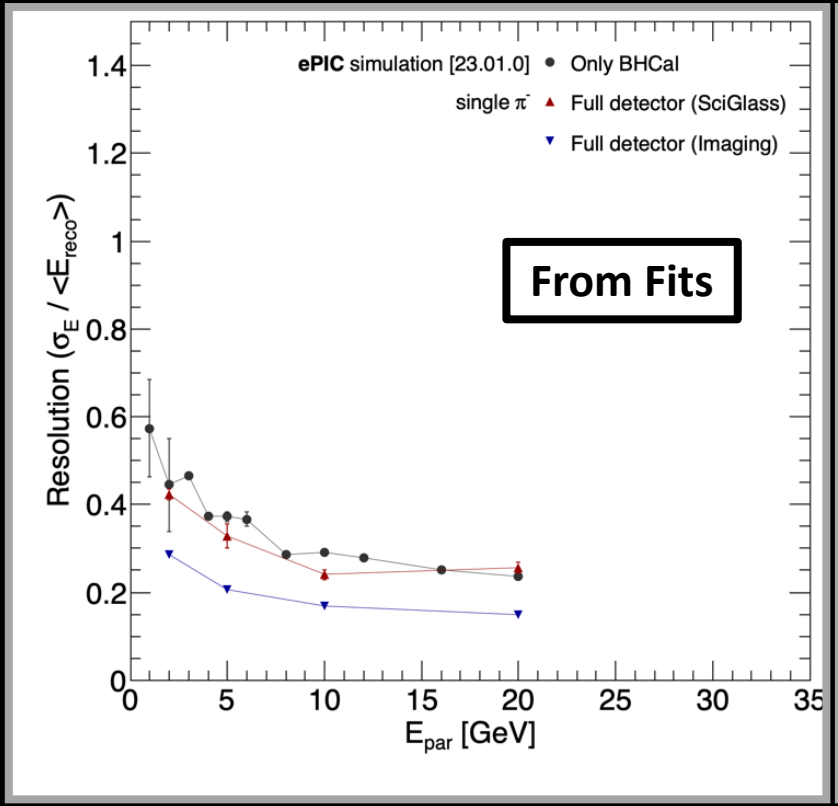
Backup | training with no. of clusters (calib. energies)

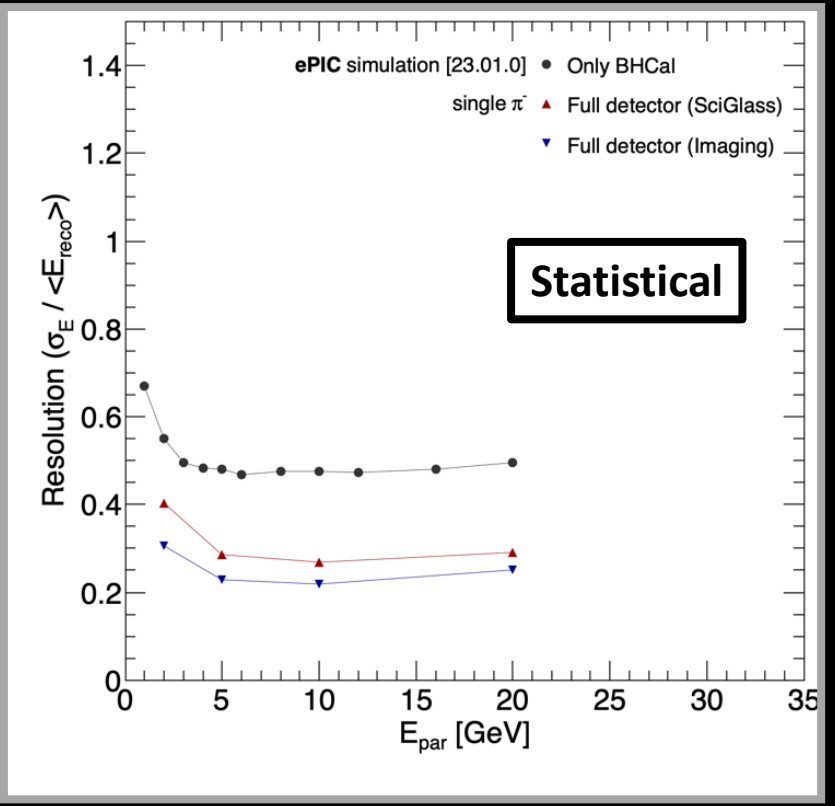




- Calibrated BHCal energies for both configurations via TMVA
  - No. of clusters in BHCal and BEMC included as training variable
  - No. of hits in lead clusters **not** used to train
- **Shown:** calibrated BHCal energies for SciGlass **(left)** and Imaging **(right)** configurations

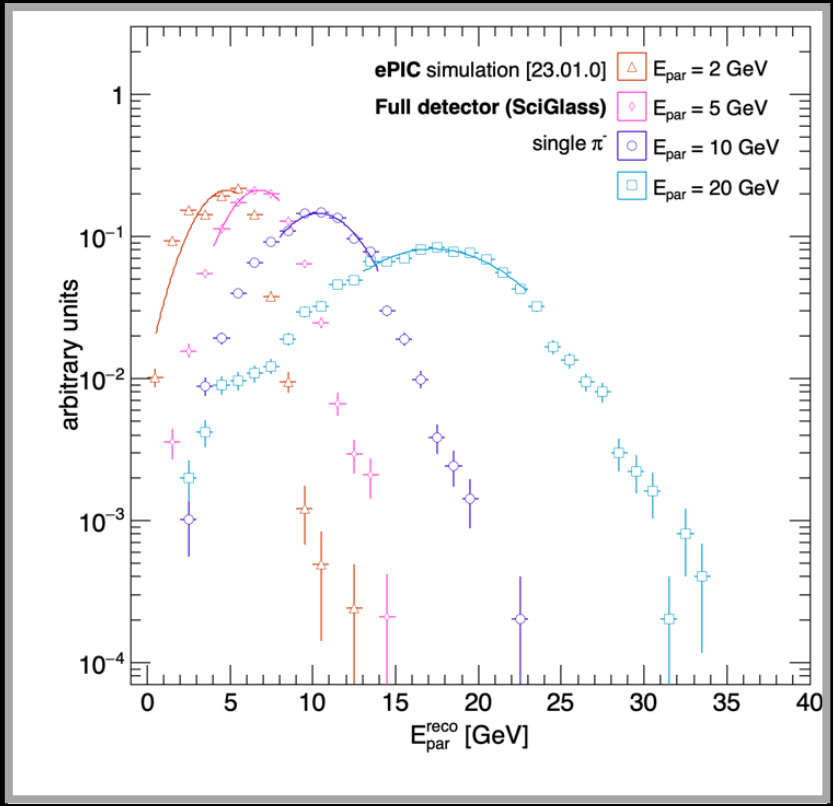
Backup | training with no. of clusters (resolutions)

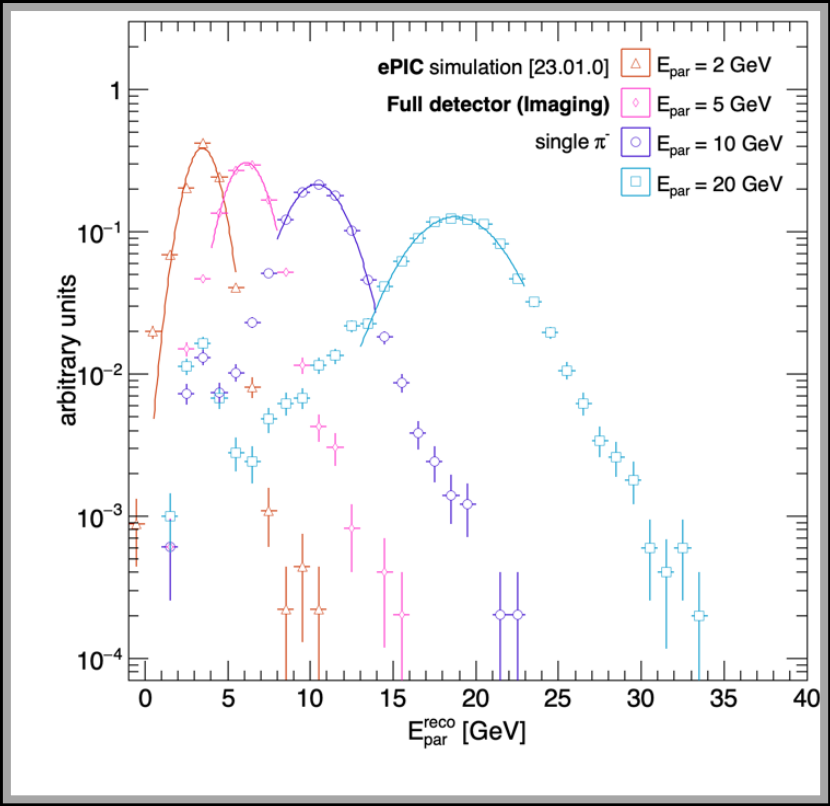




- Calibrated BHCal energies for both configurations via TMVA
  - No. of clusters in BHCal and BEMC included as training variable
  - No. of hits in lead clusters **not** used to train
- **Shown:** calculated resolutions with methods (a) (left) and (b) (right) for
  - Test beam config. **(black)**
  - SciGlass config. **(red)**
  - Imaging config. **(blue)**

Backup | training w/o no. of clusters (calib. energies)

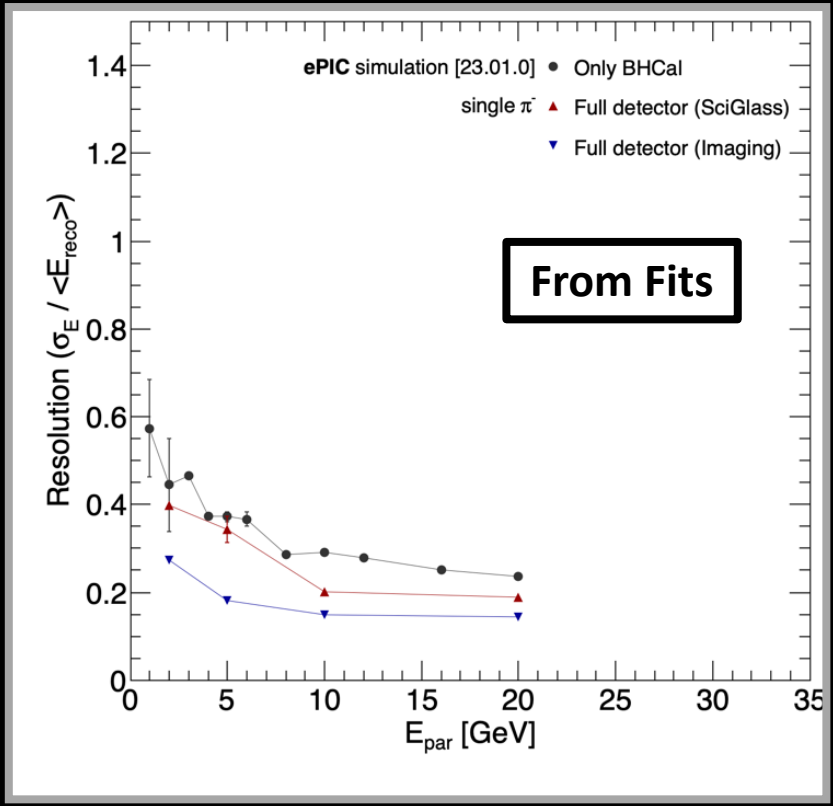


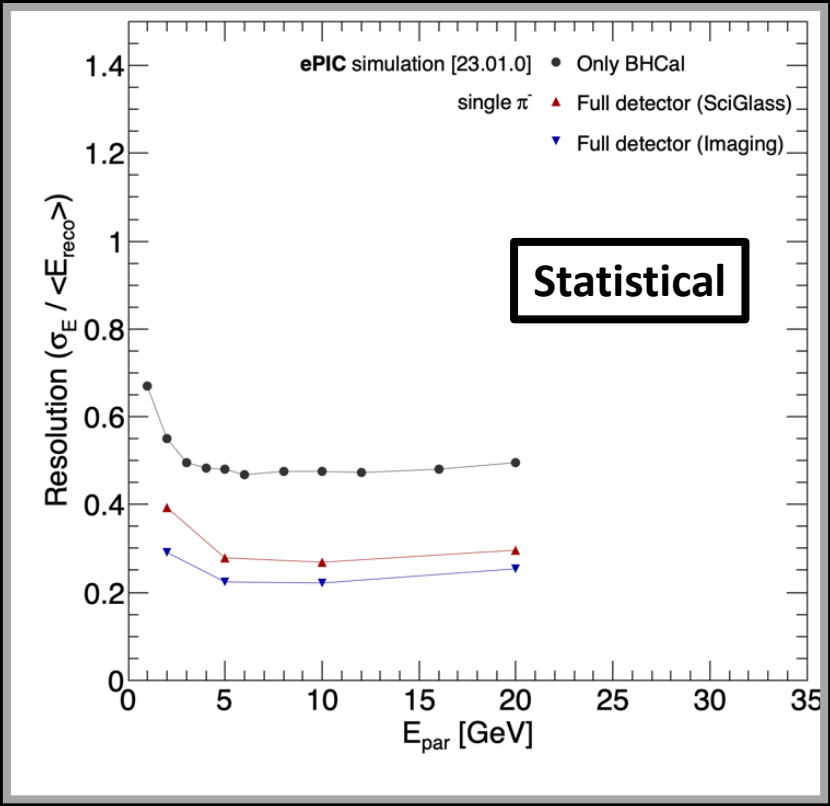


- Calibrated BHCal energies for both configurations via TMVA
  - No. of clusters in BHCal and BEMC **not** included as training variable
  - No. of hits in lead clusters **not** used to train

- **Shown:** calibrated BHCal energies for SciGlass **(left)** and Imaging **(right)** configurations

Backup | training w/o no. of clusters (resolutions)





- Calibrated BHCal energies for both configurations via TMVA
  - No. of clusters in BHCal and BEMC **not** included as training variable
  - No. of hits in lead clusters **not** used to train
- **Shown:** calculated resolutions with methods (a) (left) and (b) (right) for
  - Test beam config. **(black)**
  - SciGlass config. **(red)**
  - Imaging config. **(blue)**

Backup | changes to EICRecon

Changes to Digitization

- m_capADC = 256 → 65536
- m_dyRangeADC = 50 MeV → 1.0 GeV
- m_resolutionTDC = 1.0 ns → 1.0 ps
- u_fields = {} → {“tile”}
- u_refs = {} → {0}
- m_geoSvcName = “ActsGeometryProvider” → “geoServiceName”
- m_readout = “” → “HcalBarrelHits”
- (+ relevant changes to reco. hit parameters)

Changes to Clustering

- m_input_tag = “HcalBarrelmergedHits” → “HcalBarrelRecHits”

Changes to HCal.cc

- comment out adding merged hits factory (line 48)

Backup | adjacency matrix expression

```
(
  ((|s_1-s_2|==0) && (|t_1-t_2|==1)) == 1) +
  ((|s_1-s_2|==0) && (|(t_1%24)-(t_2%24)|==0)) == 1) +
  ((|s_1-s_2|==1) && (|(t_1%24)-(t_2%24)|==0)) == 1) +
  ((|(s_1%31)-(s_2%31)|==0) && (|(t_1%24)-(t_2%24)|==0)) == 1)
) == 1
```

- **Explanation**
  i. 1st term checks for adjacency in eta
  ii. 2nd term checks for adjacency in phi in a sector
  iii. 3rd term checks for adjacency in phi across neighboring sectors
  iv. 4th term checks for adjacency in phi across wraparound

- **Note:** using shorthand
  - `|*| = abs(*)`
  - `(x%y) = fmod(x, y)`
  - `s_i = sector_i`
  - `t_i = tower_i`