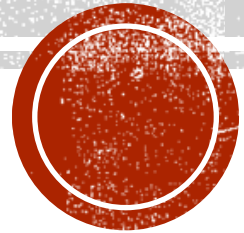
bHCAL Meeting – Neutron Calibration Update



Jan Vanek

University of New Hampshire

09/11/2026

OVERVIEW

- Manual neutron calibration status
  - Overview of status/action items/questions for calibrations (pre-)TDR plots

MANUAL CALIBRATION METHOD

- Single particle calibrations
  - Current calibration plots are using May campaign (26.05.0)
    - Can be easily updated for TDR
  - Have all particles from pre-TDR: π^+, π^-, and neutrons

- Using Method 2
  - Currently the only verified and fully implemented calibration method
  - $E_{calib} = A(E_{EMCAL} + BE_{bHCAL})$
  - Plot $(E_{EMCAL} + BE_{bHCAL})/E_{par,MC}$
    - First find B for which the distribution above has the smallest σ/μ
    - A is set as 1/mean of the distribution with optimal B

- **Method 2 should be sufficient for new TDR plots**

METHOD 2 CALIBRATION DETAILS

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  - Which energy do we use for the calibration?
    - **Original pre-TDR plots:** Reconstructed **leading clusters** in bHCAL

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    - **For new draft TDR plots:** Use **reconstructed clusters** in both bECAL (SciFi) and bHCAL
      - Do we use leading clusters, or sum of all clusters? (Some discussion later)
  - Requirements on energy deposition in bECAL and bHCAL?
    - Now strict requirement on non-zero energy deposition in bECAL and bHCAL
    - Scenarios where one calorimeter is empty causes calibration to be less reliable and thus is now avoided

bECAL ACTION ITEMS AND STATUS

- All major questions and action items for bECAL for neutron calibrations should be resolved

- **Solved issues/questions:**
  - Use only SciFi clusters for neutron (hadron) calibrations
    - Full clusters require matched cluster between Imaging and SciFi layers which is not suitable for hadrons
  - Clustering in SciFi layers looks reasonable for hadrons
    - Most energy reconstructed from individual hits recovered by a leading reconstructed cluster

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- **Possible questions/action items:**
  - Strictly requiring non-zero energy deposition in SciFi bECAL for calibrations
    - Method 2 works best when energy is deposited in both bECAL and bHCAL
  - Sampling fraction tuned on EM scale, rather than hadronic scale
    - Our calibration re-scales appropriately?

bHCAL ACTION ITEMS AND STATUS

- Several important action items/questions to be answered for the TDR calibration plots

- **Solved issues/questions:**
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    - Larger issue for low energy neutrons (hadrons) for which just small section of bHCAL is hit
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  - Energy deposition in solenoid
    - Currently not explicitly considered

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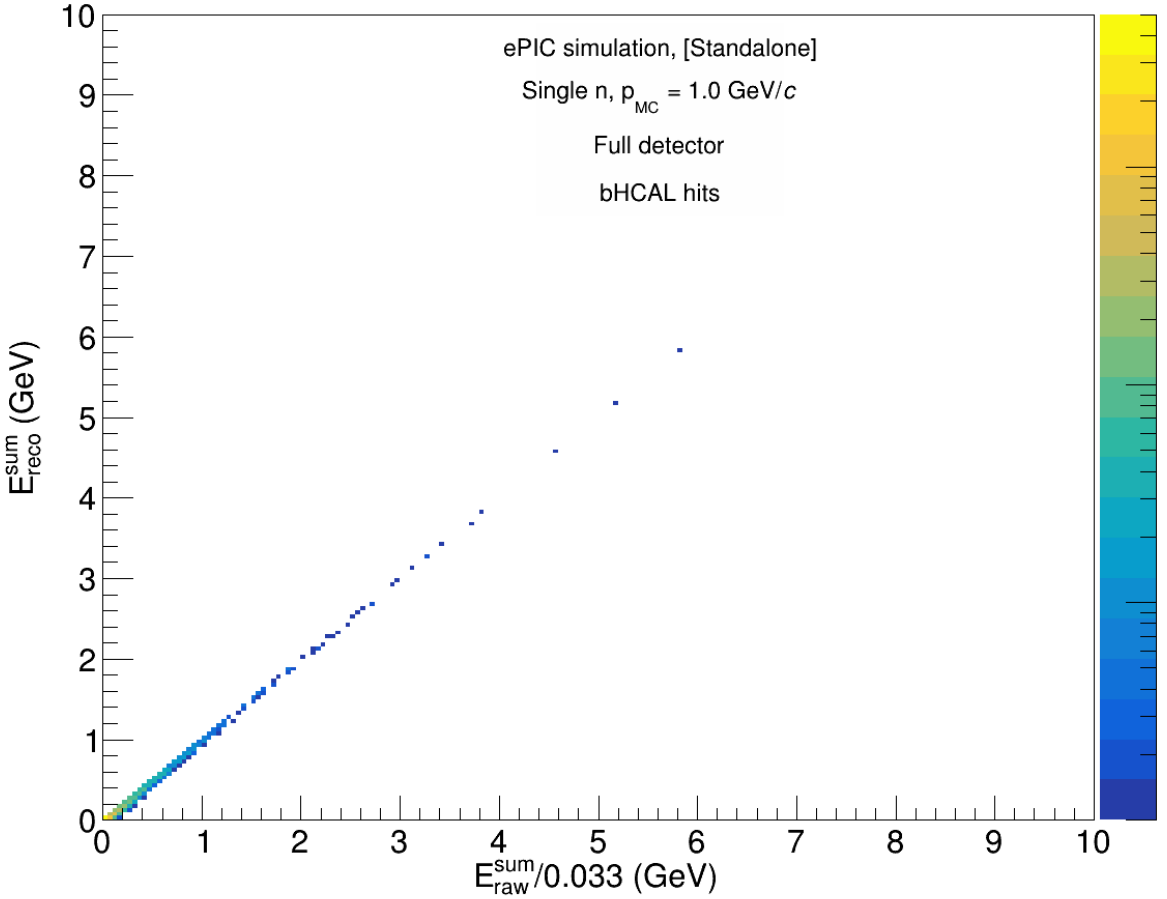
More details follow

bHCAL SAMPLING FRACTION

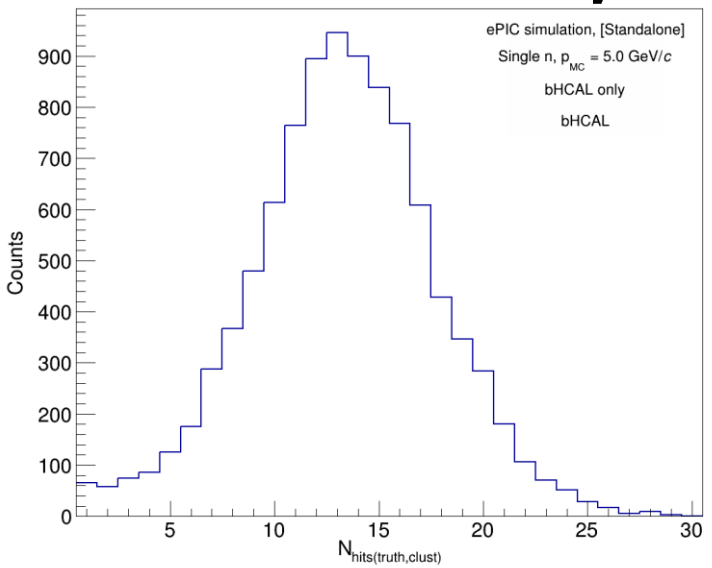
- Comparison of bHCAL deposited energy from sum of raw hits scaled by the sampling fraction and reconstructed hits from EICRecon
- Significant number of neutron have reconstructed energy deposition in bHCAL much larger than their true energy
- Could be caused by small clusters for low energy neutrons which may have a different sapling fraction
- **Q: Do we want/need to resolve this for the TDR calibrations?**
  - Will be partially corrected by our energy dependent calibration method



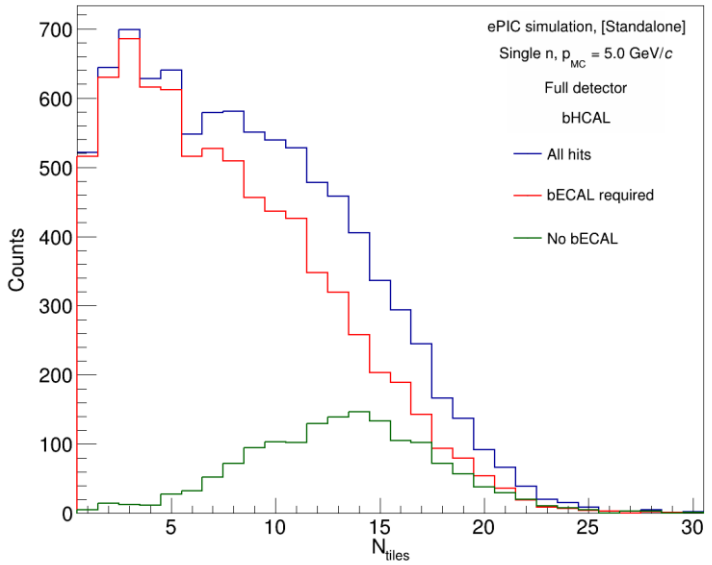
bHCAL CLUSTERING

- **(left)** Reconstructed leading cluster with bHCAL only (bottom) is able to recover good portion of truth cluster (top)
  - Can likely be improved, but appears to make sense
- **(right)** Reconstructed leading clusters with full ePIC appear overwhelmed by single tile clusters
  - Early showers leading to many separated hits in bHCAL?
  - Cut on single tile energy may not help as these are leading clusters
    - Cluster with max. energy in event
- **Work-aroud:** Use sum of all clusters.

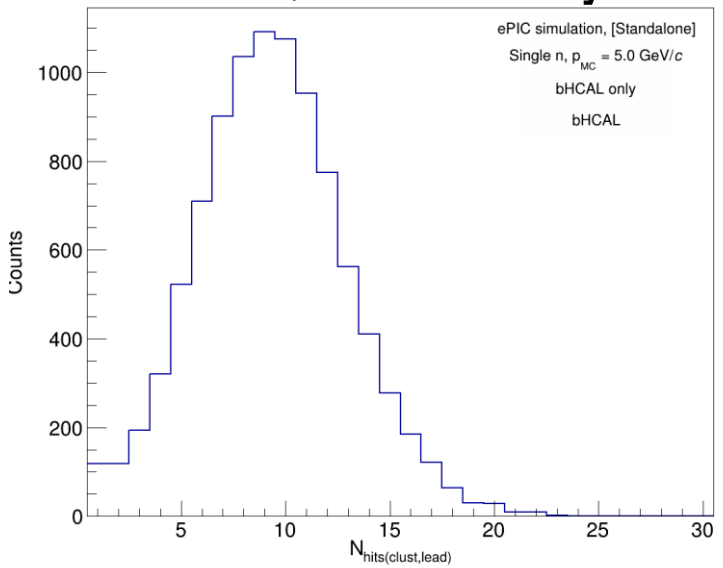
Truth, bHCAL only



Truth, full ePIC



Reco., bHCAL only



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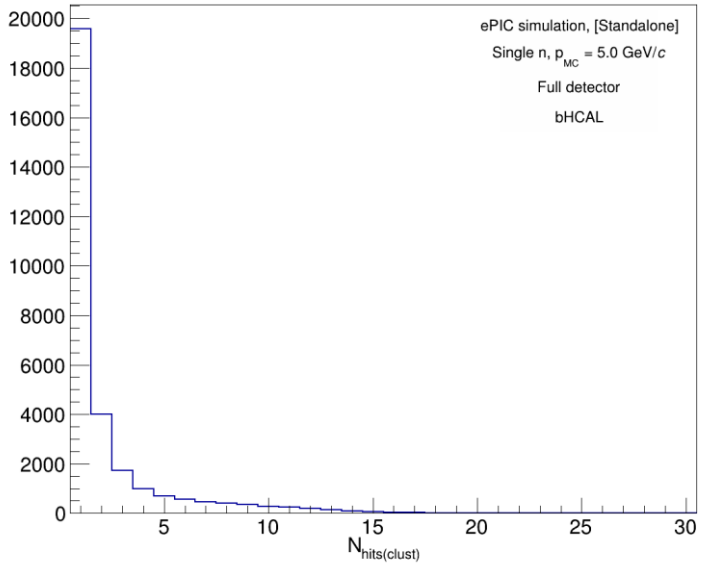
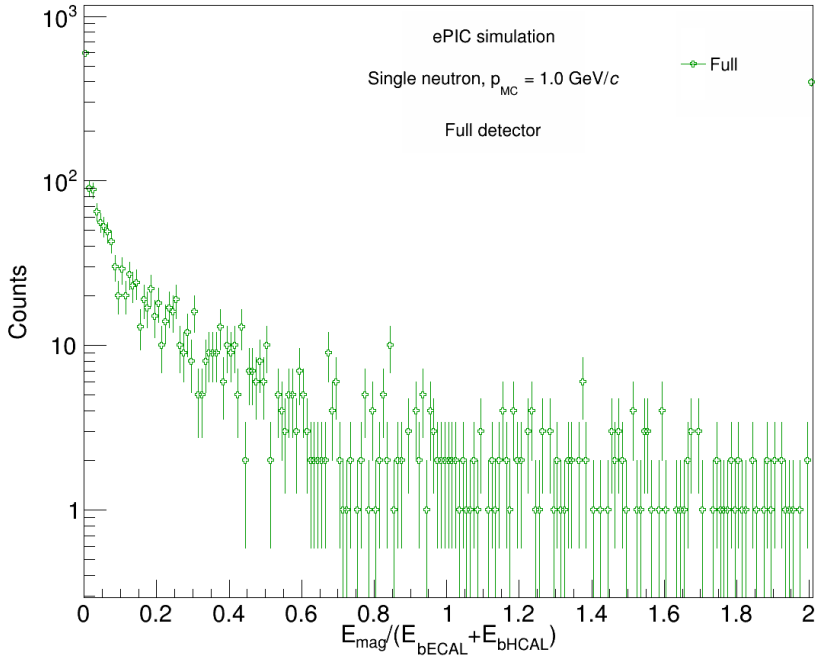
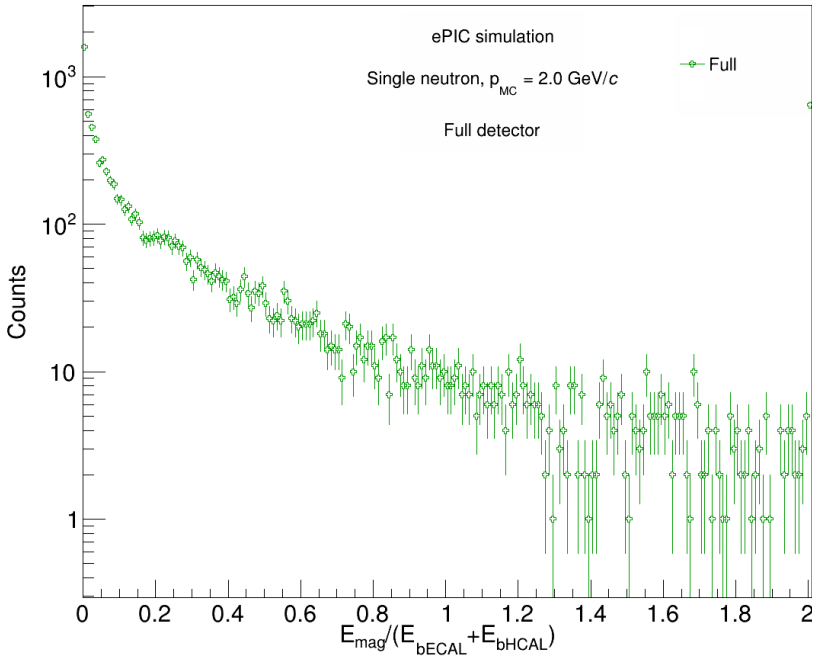
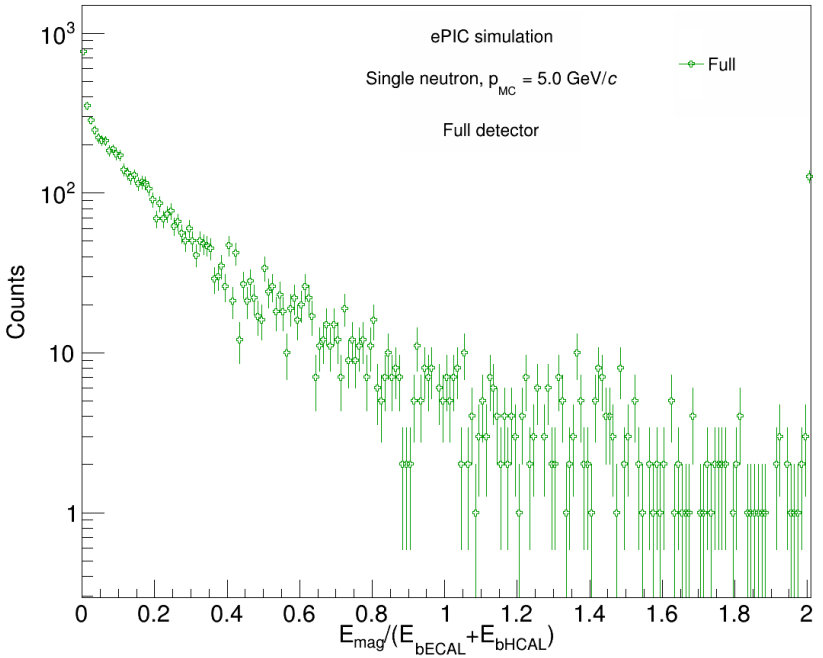


RELATIVE ENERGY DEPOSITION IN SOLENOID

- Relative energy deposition in the magnet with respect to bECAL+bHCAL energy deposition
  - $E_{mag}/(E_{bECAL} + E_{bHCAL})$
  - Three MC neutron momenta: (left) $1\ \mathrm{GeV}/c$, (middle) $2\ \mathrm{GeV}/c$, (right) $5\ \mathrm{GeV}/c$
  - Appears that for most events, only small fraction of energy is lost in the magnet
- **Not a major issue for simple Method 2 calibration?**







SUMMARY AND OUTLOOK

- **Resolved action items:**
  - Calibration method
    - Manual Method 2
  - bECAL information
    - Use SciFi only for hadrons
  - bHCAL sampling fraction known
    - Fixed at 3.3% from sPHENIX
  - bHCAL clustering updated to tile-by-tile, but with some sPHENIX based parameters

- **Remaining action items:**
  - Strict requirement on non-zero energy deposition in both bECAL and bHCAL
    - Makes most sense for Method 2 calibration
  - Fixed sampling fraction may not be optimal for tile-based readout at ePIC
    - **Possible solution:** Update to energy-dependent sampling fraction?
  - Reconstructed clustering not optimal for low energy neutrons (hadrons)
    - **Temporary work-around:** Use sum of all clusters?
  - Energy deposition in solenoid not considered
    - **Not a major issue?:** Average deposited energy small
  - **Anything else?**

- **Backup:**
  - Latest calibration plots
  - Now quite old, using May campaign and hits

THANK YOU FOR ATTENTION

BACKUP

FIG. 3.194 (OLD)

- Uncalibrated energy deposition in bHCAL for π^+ and π^-
  - **Uses bHCAL only simulation configuration:** Is this useful?
  - **Uses leading bHCAL clusters:** Do we trust current clustering?
- All calibrations and energy reconstruction will be done using bECAL+bHCAL system
- Additional smearing primarily from solenoid
  - Replace by bECAL+bHCAL without magnet and then compare to full detector simulation in Fig. 3.195?

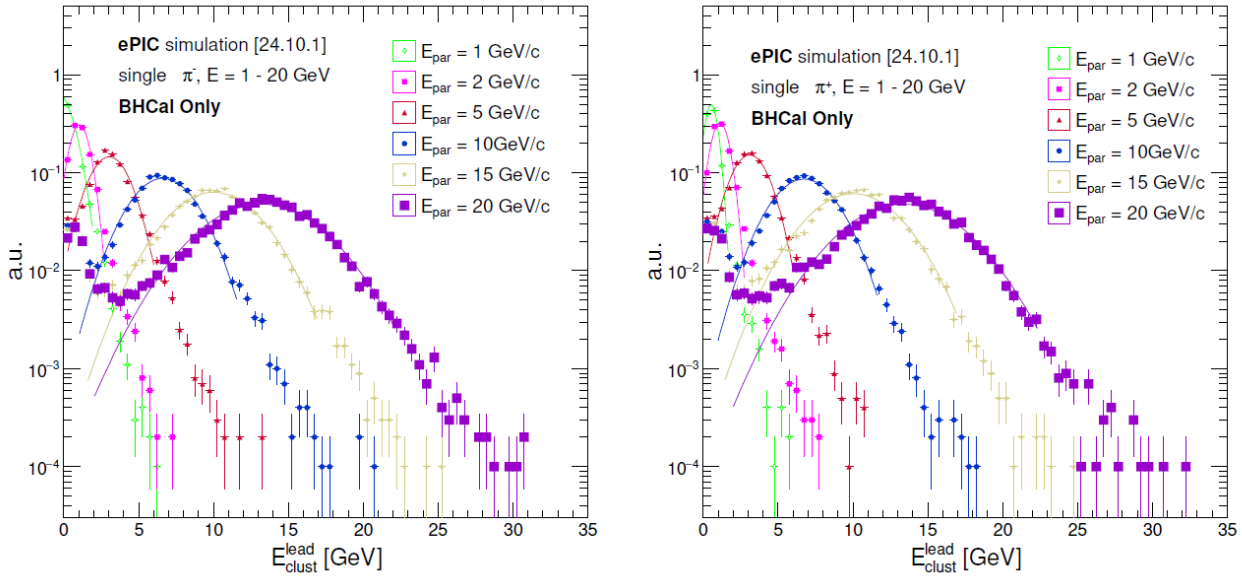


FIG. 3.195 (OLD)

- Uncalibrated energy deposition in bHCAL leading clusters for π^- (top left) and π^+ (top right)

- Calibrated energy in bHCAL leading clusters for π^- (left) and π^+ (right) using two ML methods from ROOT TMVA package
  - (middle) Linear-Discriminant (LD)
  - (bottom) Multi-Layer Perceptron (MLP)

- **Uses leading bHCAL clusters**

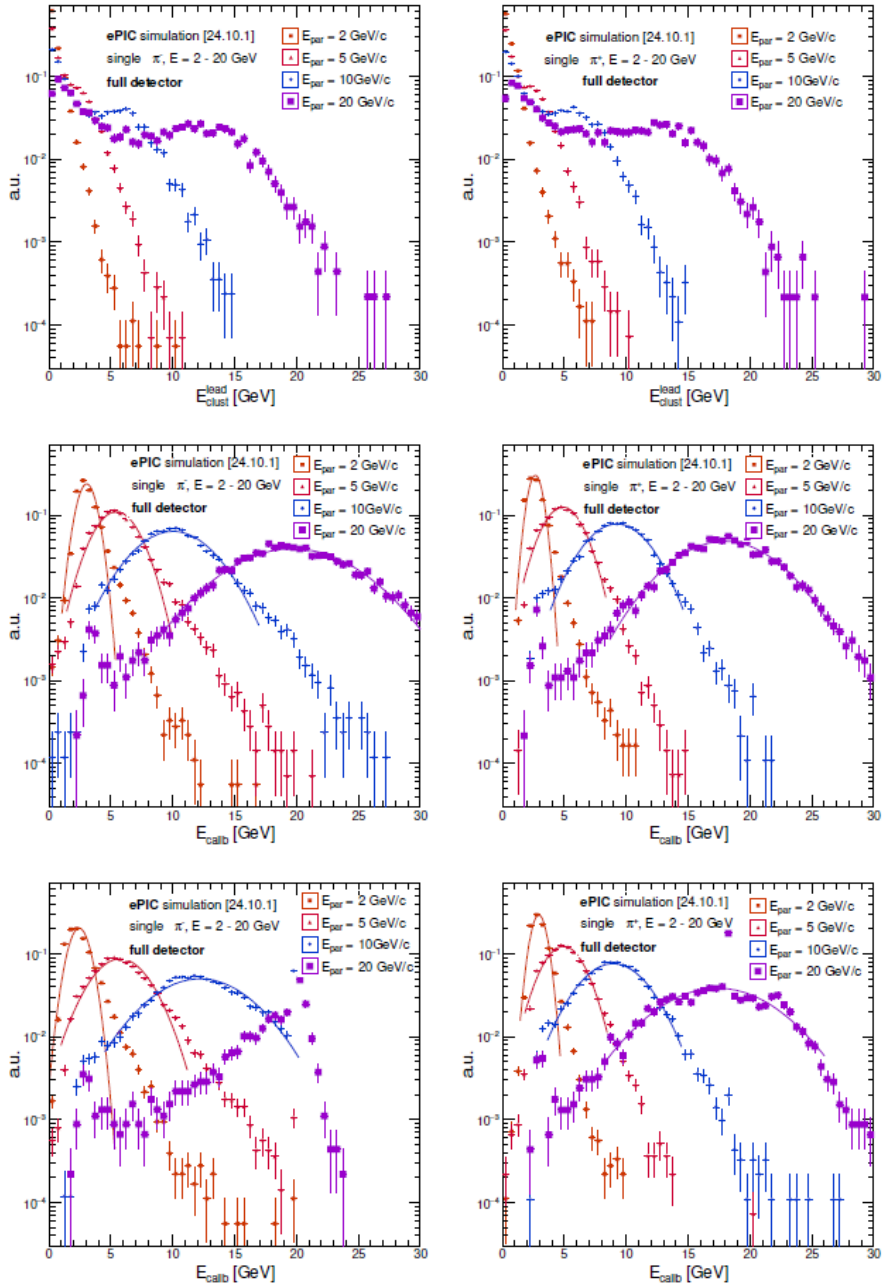
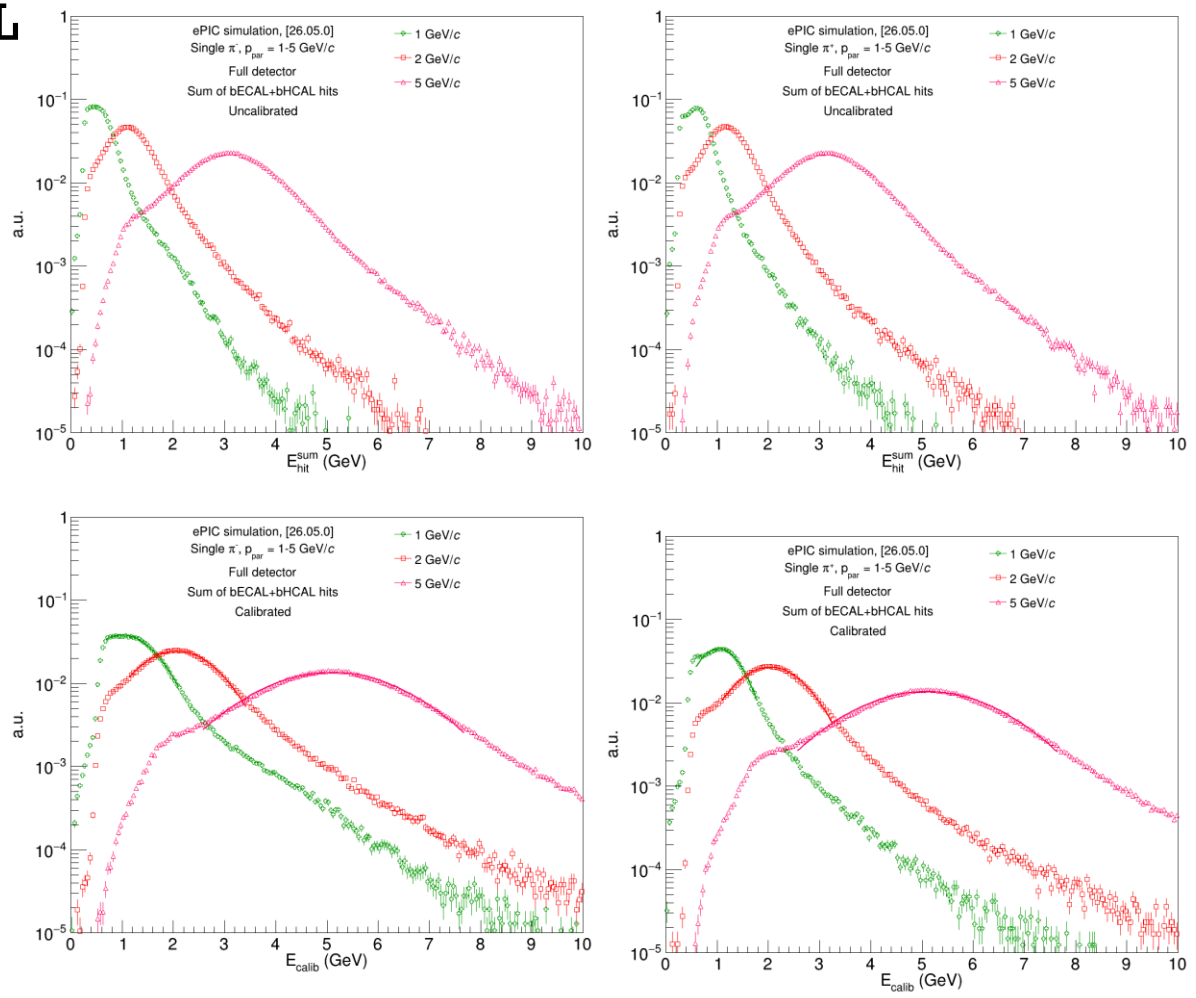


FIG. 3.195 (NEW)

- Uncalibrated energy deposition in bECAL+bHCAL hits for π^- (top left) and π^+ (top right)
- Calibrated energy for bECAL+bHCAL hits for π^- (left) and π^+ (right) using Method 2 manual calibration method
- **Key changes:**
  - Using bECAL (SciFi) and bHCAL hits rather than clusters to avoid clustering
  - Focus on lower energies
  - Manual calibration using information from tracking
- **Notes:**
  - Low energy shoulder shape (Slide 6)?



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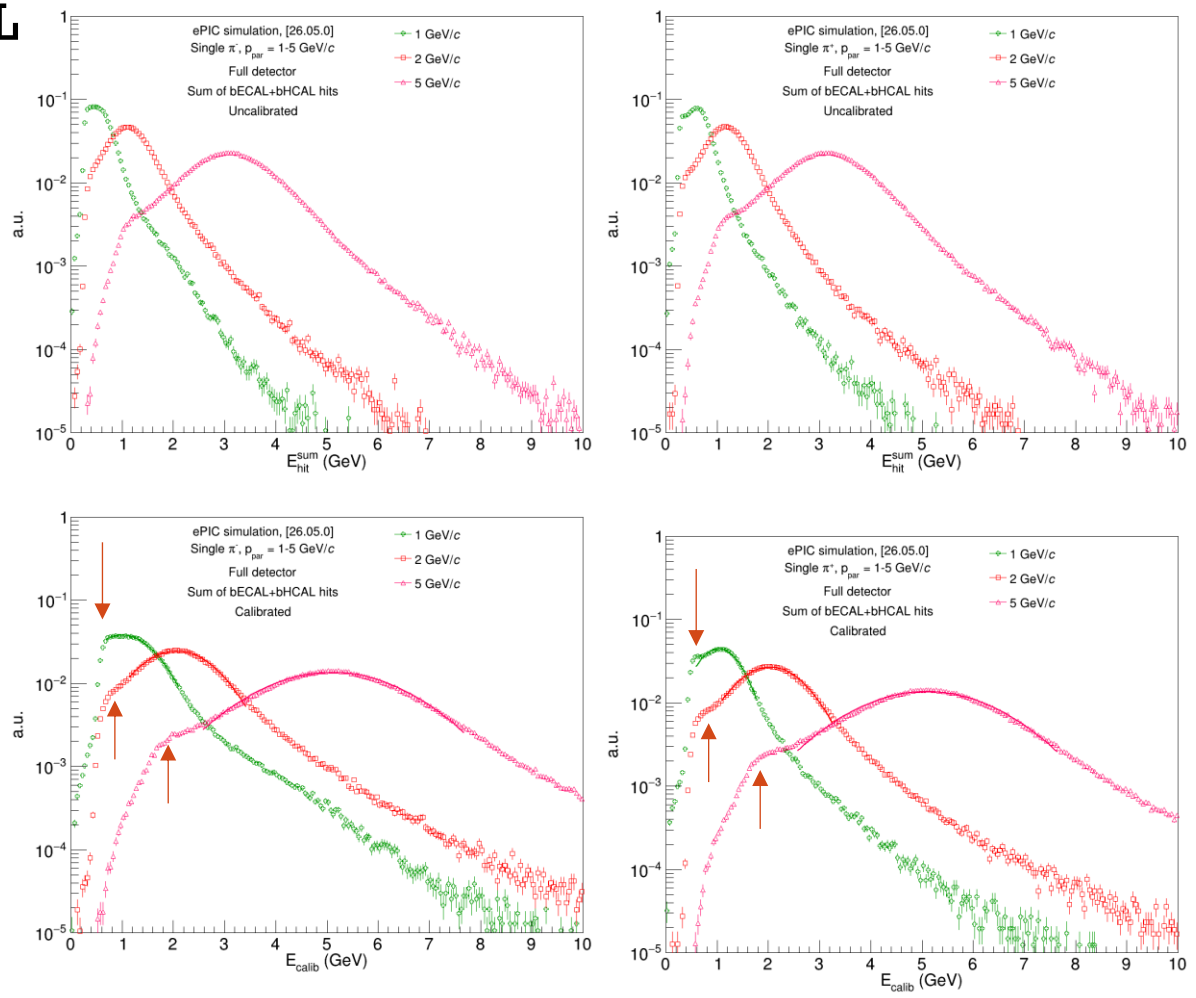
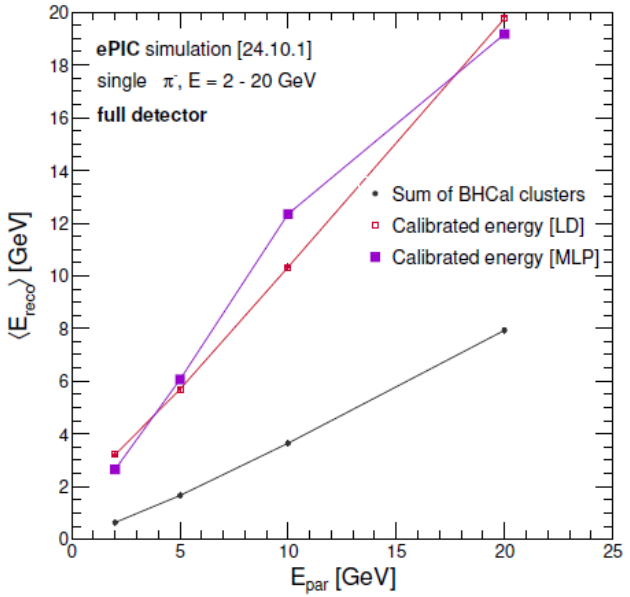
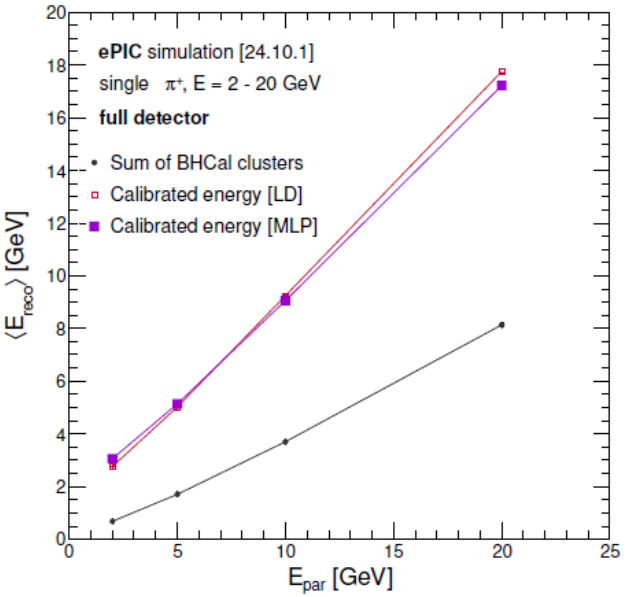


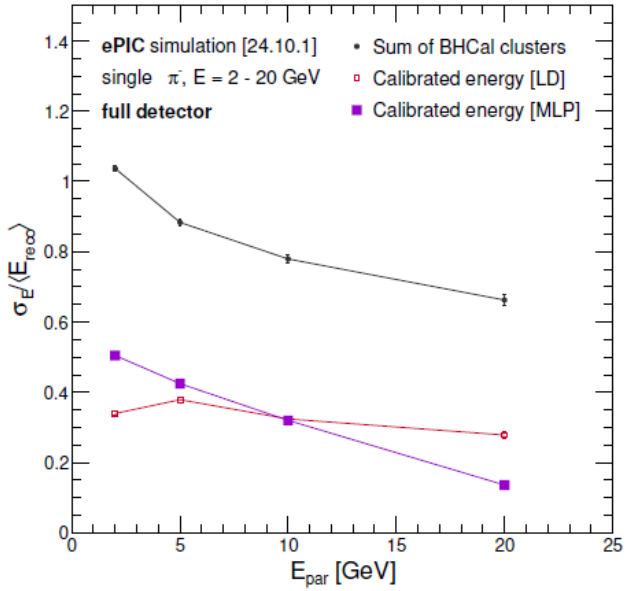
FIG. 3.196 (OLD)

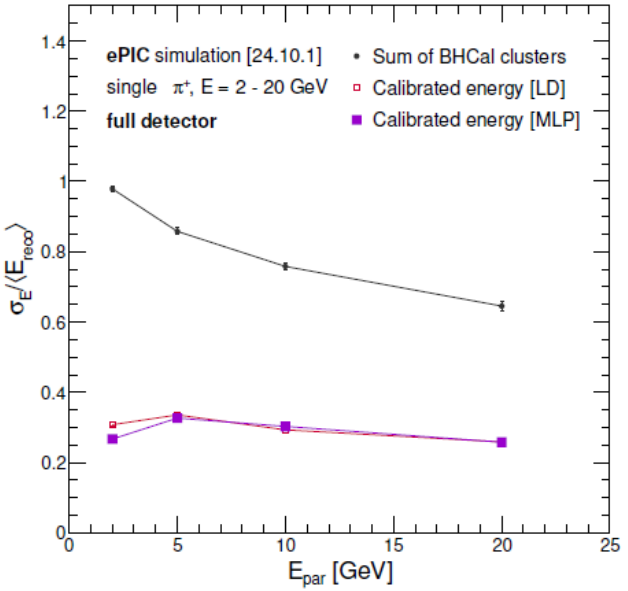
- Calibration results for π^- (left) and π^+ (right) using two ML methods from ROOT TMVA package
  - (top) Comparison of uncalibrated and calibrated energy
  - (bottom) Energy resolution

- **Uses leading bHCAL clusters**









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- **Key changes:**
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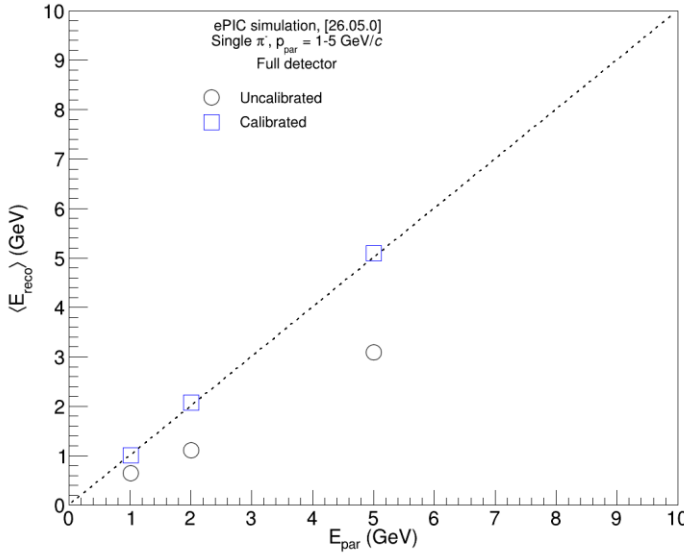
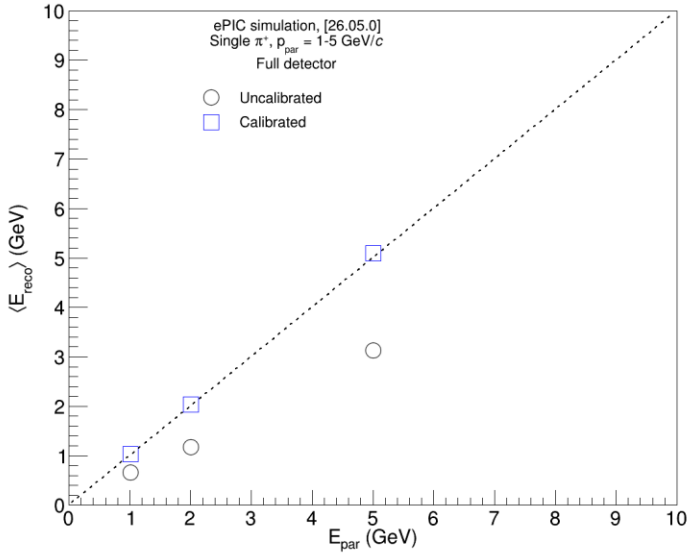
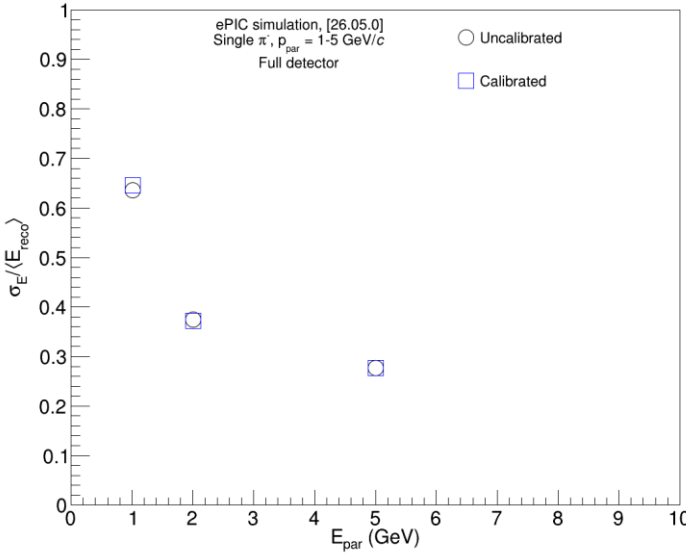
- **Notes:**
  - Worse performance for π^-







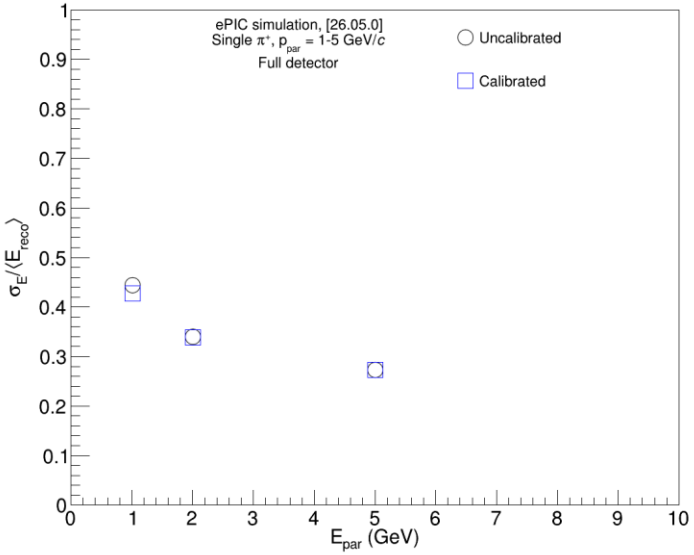


FIG. 3.197 (OLD)

- Uncalibrated energy deposition in bHCAL leading clusters for neutrons (top left)

- Calibrated energy in bHCAL leading clusters for neutrons using two ML methods from ROOT TMVA package
  - (top right) Linear-Discriminant (LD)
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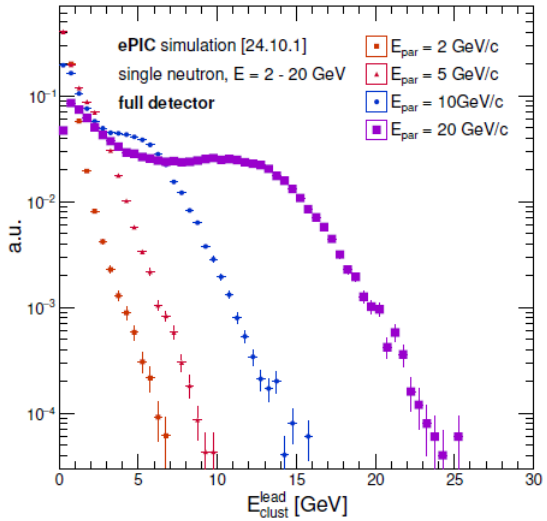
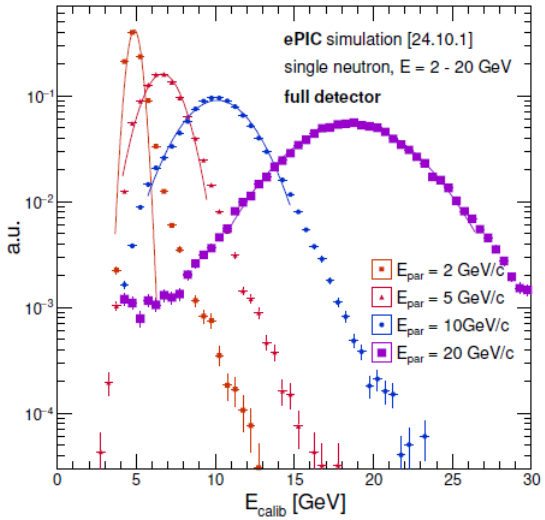
- **Uses leading bHCAL clusters**





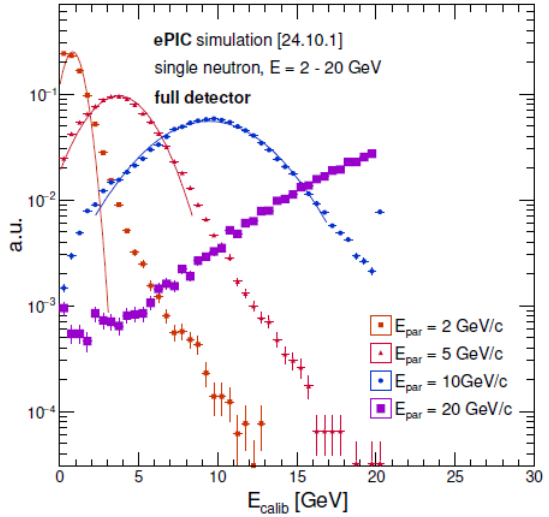
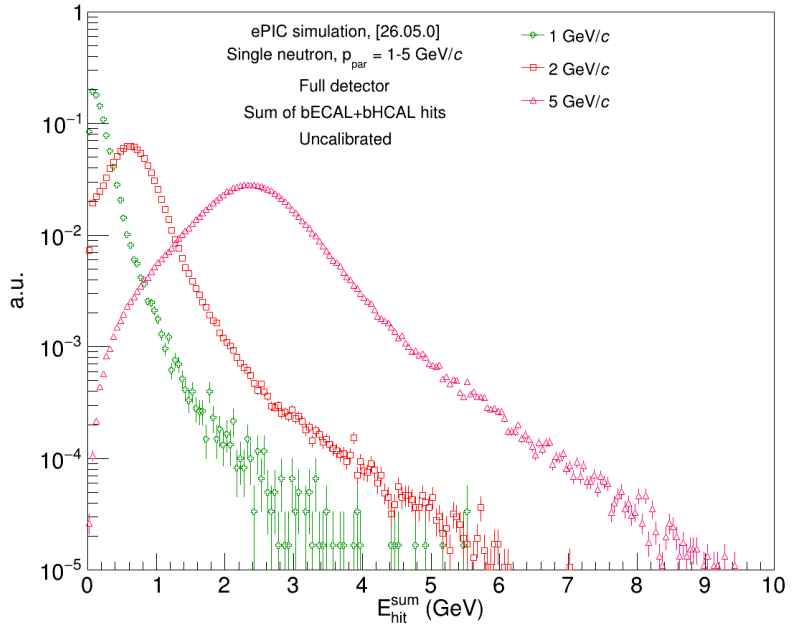


FIG. 3.197 (NEW)

- Uncalibrated energy deposition in bECAL+bHCAL hits for neutrons (top)
- Calibrated energy for bECAL+bHCAL hits for neutrons using Method 2 manual calibration method (bottom)
- **Key changes:**
  - Using bECAL (SciFi) and bHCAL hits rather than clusters to avoid clustering
  - Focus on lower energies
  - Manual calibration using information from MC



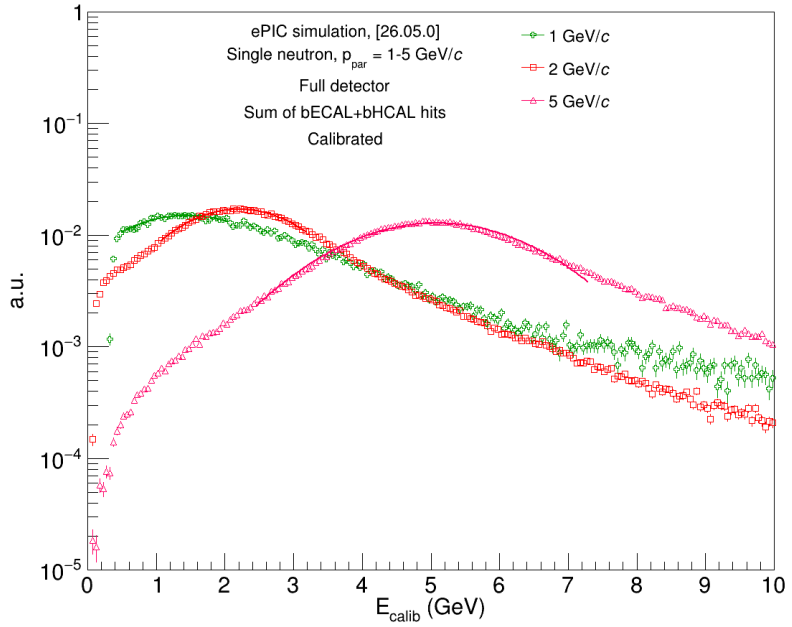


FIG. 3.198 (OLD)

- Calibration results for neutrons using two ML methods from ROOT TMVA package
  - (left) Comparison of uncalibrated and calibrated energy
  - (right) Energy resolution

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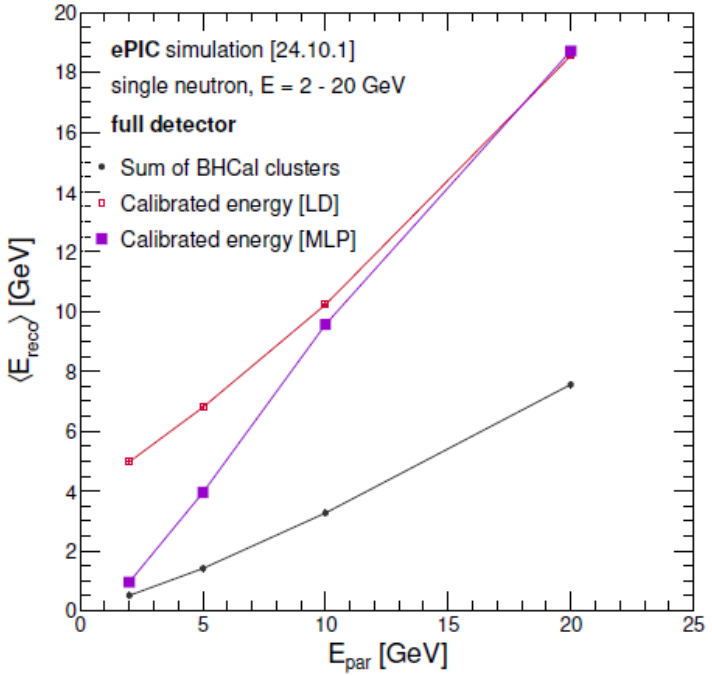

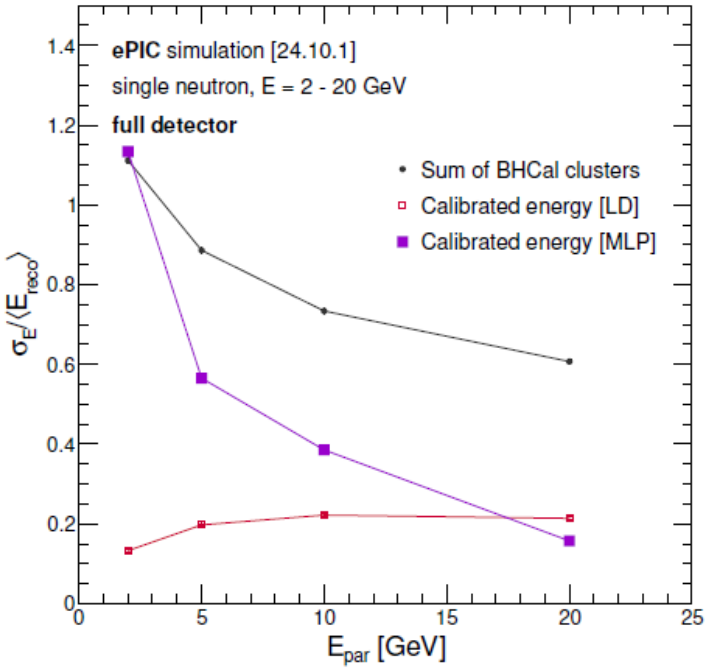

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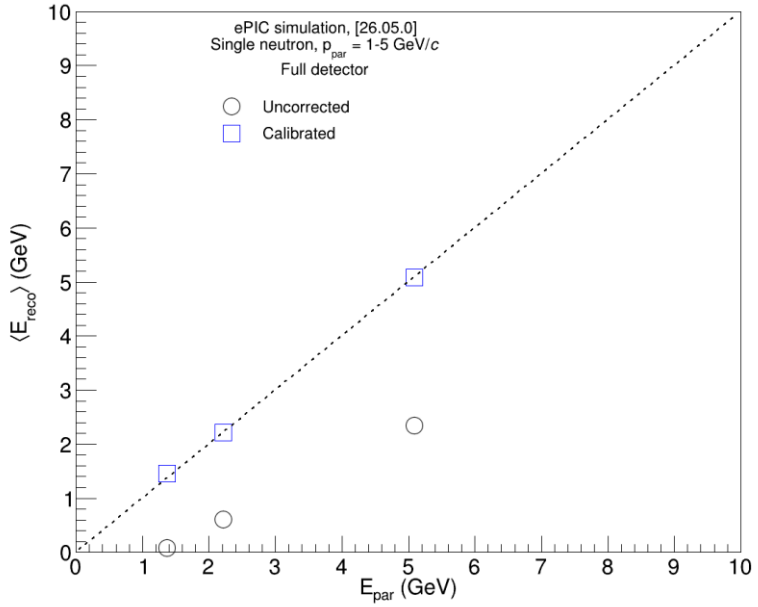
  - Focus on lower energies
  - Manual calibration using information from MC



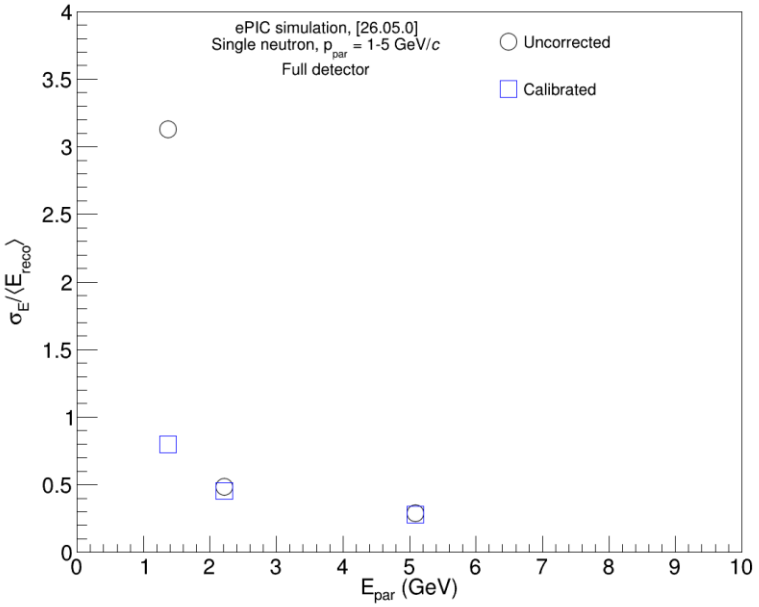


FIG. 3.199 (OLD)

- Comparison of energy deposition in leading bHCAL cluster and all bHCAL clusters for single neutrons

- Do we want this figure re-produced?
  - How much do we trust the current clustering implementation?