bHCAL Meeting – Neutron Calibration Update

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02/06/2025

OVERVIEW

- Summary of bHCAL neutron calibration efforts
- bHCAL parameters in EICRecon
- Overview of manual calibrations
  - Methods
  - Results
- Shower shape study
  - Cluster shape in bHCAL
  - Energy deposition vs. first layer in bECAL
- Sensitive magnet study

bHCAL PARAMETERS IN EICrecon

- Question raised during calibration discussions: What is the current packing fraction of bHCAL in the simulation?
- Other important parameters: ADC setup

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// Make sure digi and reco use the same value
decltype(CalorimeterHitDigiConfig::capADC) HcalBarrel_capADC        = 65536; //65536,  16bit ADC
decltype(CalorimeterHitDigiConfig::dyRangeADC) HcalBarrel_dyRangeADC = 1.0 * dd4hep::GeV;
decltype(CalorimeterHitDigiConfig::pedMeanADC) HcalBarrel_pedMeanADC = 300;
decltype(CalorimeterHitDigiConfig::pedSigmaADC) HcalBarrel_pedSigmaADC = 2;
decltype(CalorimeterHitDigiConfig::resolutionTDC) HcalBarrel_resolutionTDC =
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```

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app->Add(new JOmniFactoryGeneratorT<CalorimeterHitDigi_factory>(
    "HcalBarrelRawHits", {"EventHeader", "HcalBarrelHits"},
    {"HcalBarrelRawHits", "HcalBarrelRawHitAssociations"},
    {
        .eRes          = {},
        .tRes          = 0.0 * dd4hep::ns,
        .threshold     = 0.0, // Use ADC cut instead
        .capADC        = HcalBarrel_capADC,
        .capTime       = 100, // given in ns, 4 samples in HGCROC
        .dyRangeADC    = HcalBarrel_dyRangeADC,
        .pedMeanADC    = HcalBarrel_pedMeanADC,
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        .resolutionTDC = HcalBarrel_resolutionTDC,
        .corrMeanScale = "1.0",
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        .resolutionTDC   = HcalBarrel_resolutionTDC,
        .thresholdFactor = 0.0,      // not used; relying on flat ADC cut
        .thresholdValue  = 33,       // pedSigmaADC + thresholdValue = half-MIP (333 ADC)
        .sampFrac        = "0.033", // average, from sPHENIX simulations
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MANUAL CALIBRATION METHODS

- Simple neutron calibration for bHCAL

- Method 1
  - $E_{calib} = A(E_{EMCAL} + E_{bHCAL})$
  - Plot $(E_{EMCAL} + E_{bHCAL})/E_{par,MC}$
    - A is set as 1/mean of this distribution

- Method 2
  - $E_{calib} = A(E_{EMCAL} + BE_{bHCAL})$
  - 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 3:
  - χ^2 method
  - Simultaneously determine A and B parameters from method 2 by minimizing:
    - $\sum_{events} \left(E_{calib} - E_{par}\right)^2 / E_{par}^2$
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- Implemented
  - Method 2 can be improved:
    - With more granular manual scan of B values
    - Using minimizer (similar to Method 3)

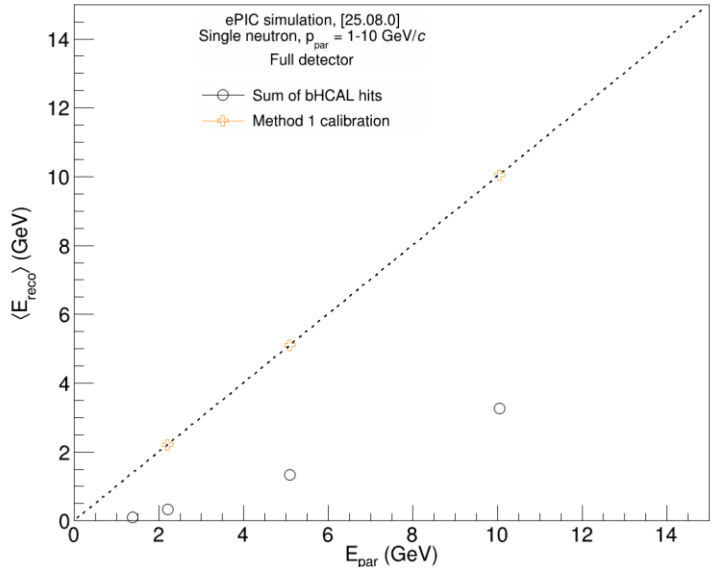
- Not implemented
  - Requires new framework – only if we decide that this method is preferred over 1 and 2

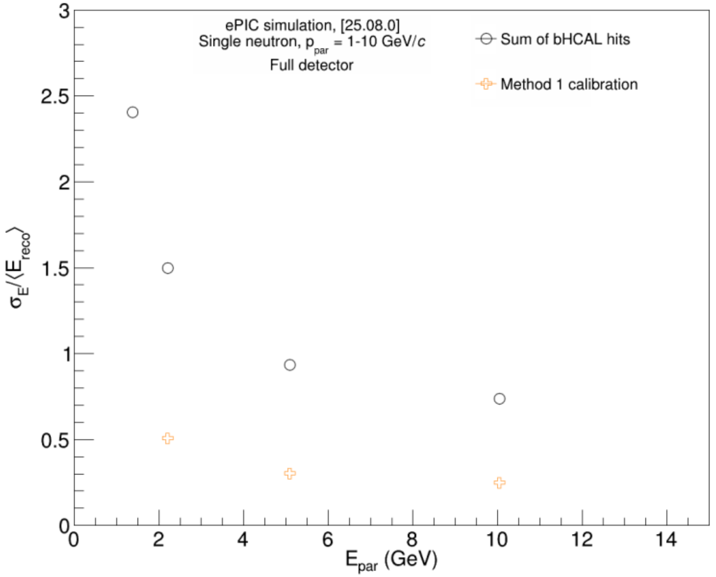
- How do we treat energy loss in magnet?

- Which method?

CALIBRATION RESULTS

- Currently have results only from early studies
  - Latest results for **Method 1** and manual Method 2
- Difficult/impossible to calibrate lowest energy
  - Missing peak structure in uncalibrated energy distribution
- Key questions:
  - How to calibrate low energies?
  - Which method are we going to use?
  - How do we treat the energy loss in the magnet in the calibration?
- Calibration slides:
  - bHCAL meeting on 10/24/2025
  - Via email on 10/25/2025
  - Via email on 10/26/2025





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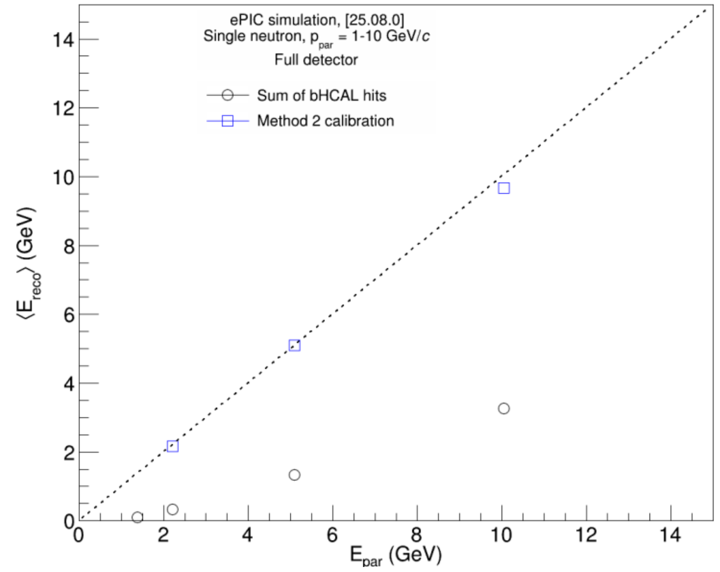
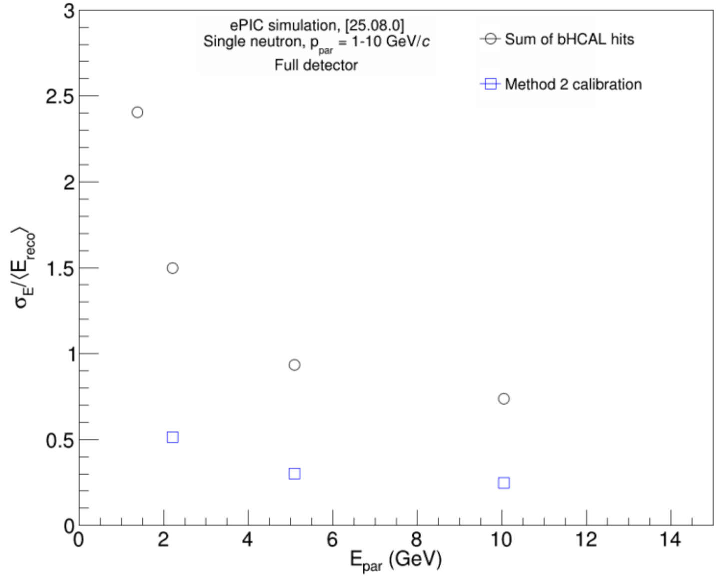
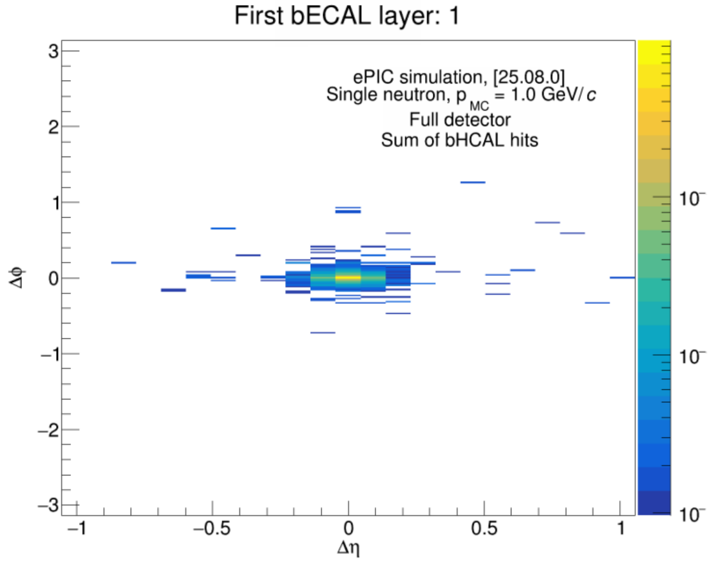
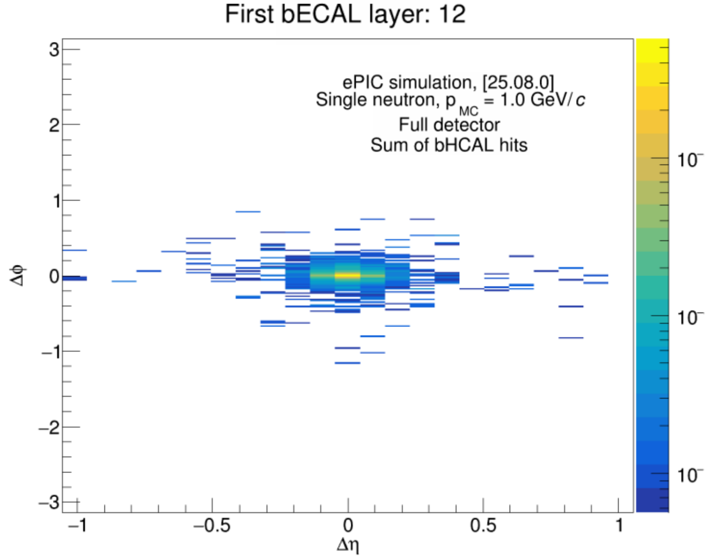




CLUSTER SHAPE IN bHCAL

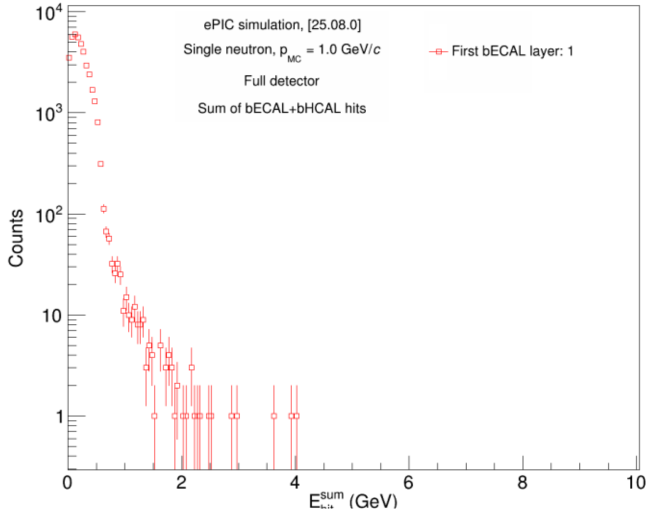
- $1\ \mathrm{GeV}/c$: No significant difference between different hit combinations observed
- $2\ \mathrm{GeV}/c$: Shower profile in bHCAL a bit wider when shower starts in early bECAL, but difference is small
- $5\ \mathrm{GeV}/c$: Shower profile in bHCAL substantially wider when shower starts early in bECAL (layer 1) compared to case where it starts late (layer 12)
- The widening of shower as it propagates through the bECAL+Magnet+bHCAL system seems to only be visible for high energy neutrons
- **Shower profile in bHCAL as a function of first layer in bHCAL does not seem to provide any useful information for manual calibrations of 1 GeV/c (for now)**
  - Might be useful for higher energies
- From bHCAL meeting slides on 12/05/2025

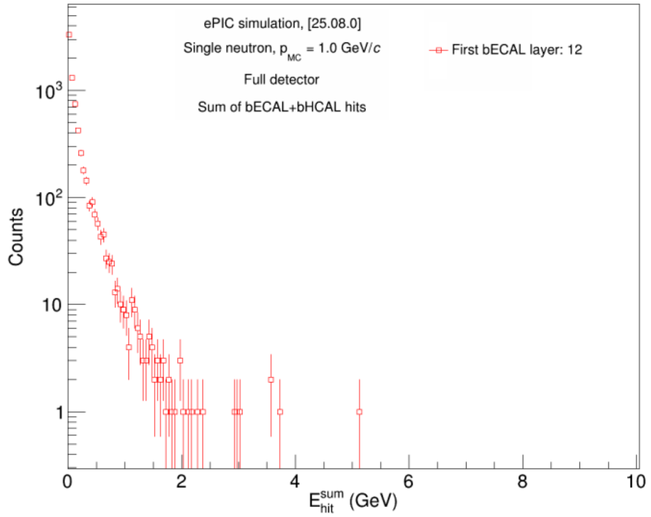




ENERGY DEPOSITION VS. FIRST bECAL LAYER

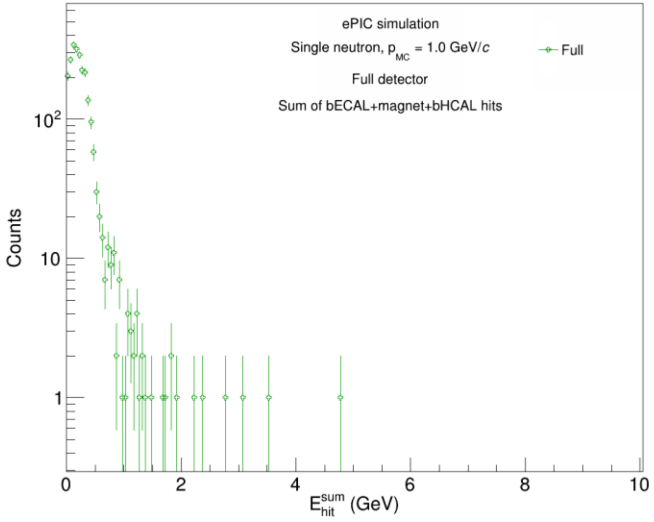
- The energy deposition in bECAL and bHCAL has clear and predictable structure depending on first layer in bECAL
- 1 GeV/c: Peak visible for total energy deposition in bECAL+bHCAL only somewhat visible when shower starts early in bECAL (layer 1)
- 2 GeV/c: Peak structure visible even for showers that start in the middle of bECAL (around layer 6)
- 5 GeV/c: Peak structure generally well visible for total energy deposition
- **Peak structure important as its mean can tell us about how far we are from the expected MC particle momentum**
- **This is problem for the lowest energy, as peak structure is generally not visible**
- From bHCAL meeting slides on 12/05/2025

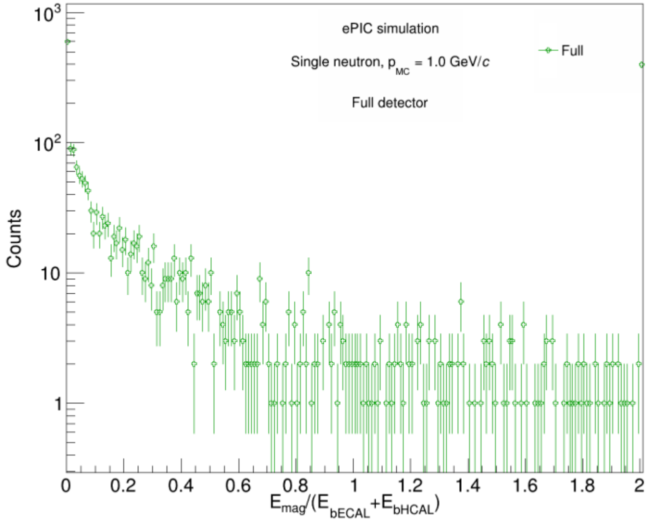




SENSITIVE MAGNET STUDY

- Successfully implemented sensitive solenoid to the ePIC simulation framework for bHCAL calibration studies
  - Seems to give reasonable results
  - Mean of total energy distributions with the energy from the solenoid seem to have stable mean, regardless of where the shower starts
  - Mean shifts when no magnet information is used
- Energy lost in the magnet relative to deposition in bECAL+bHCAL seems to be quite small
  - In most events, energy deposited in the magnet is less than 20% of total deposition in bECAL+bHCAL (before calibration)
- Energy lost in the magnet is not large, but is enough to complicate energy determination, especially at low neutron energies ($1\ \mathrm{GeV}/c$)
- From bHCAL meeting slides on 01/16/2026





SUMMARY

- Found location of relevant bHCAL parameters in EICRecon
  - We can check and adjust those if needed
  - Important information for interpretation of observed energy distributions
  - Useful for future studies (CALOROC)
- Have working calibration framework
  - Method 1 and 2 implemented
  - Method 2 can be improved, if needed
  - Can add Method 3, if desired
  - How do we treat energy loss in magnet in calibrations?
- Cluster shapes don't seem to provide useful information for manual calibration at low energy n
- First hit layer of bECAL provides useful information, but not enough to calibrate low energy n
- Only small fraction of neutron energy (on average) is lost in the magnet
- **What are our plans for the manual calibrations?**

THANK YOU FOR ATTENTION