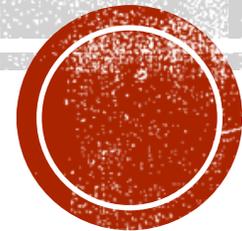# bHCAL Meeting – Neutron Calibration Update

Jan Vanek

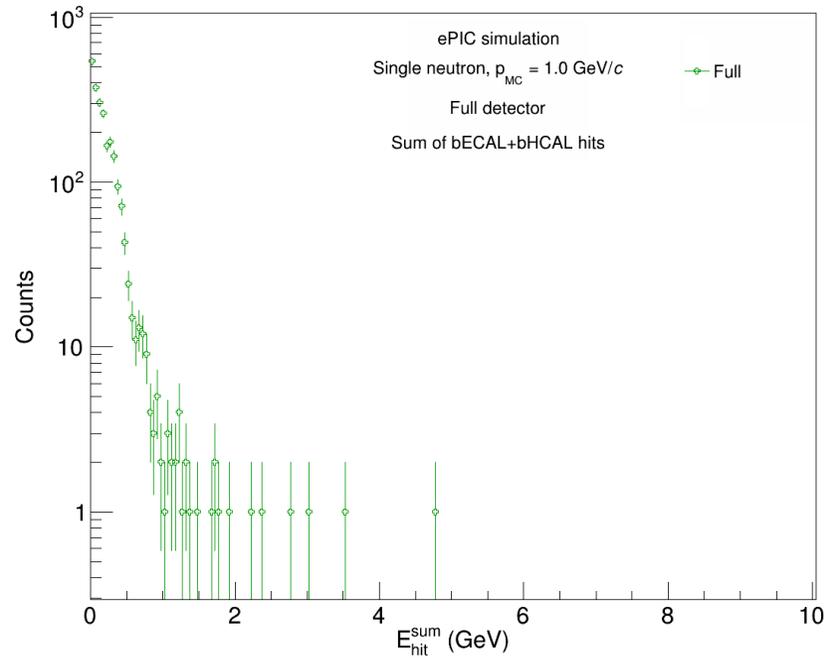University of New Hampshire

01/16/2025

OVERVIEW

- Study with sensitive solenoid magnet in ePIC simulation
  - Implemented in separate branch of the detector geometry and EICRecon
    - "bHCAL_sensitive_magnet" for both
  - Full solenoid geometry made sensitive
  - No segmentation (for now)
    - Adding segmentation would require more complex changes to the geometry
    - Should not be necessary for our needs, as we just need total deposited energy in the solenoid with single particle simulations

- Standalone simulation of single neutrons for testing
  - Three MC neutron momenta: $1\ \mathrm{GeV}/c$, $2\ \mathrm{GeV}/c$, and $5\ \mathrm{GeV}/c$
  - 10k simulated neutrons per energy
    - Uniform full coverage in ϕ
    - $\cos\theta$ distribution in polar angle in range: $(33.5, 146)$ deg
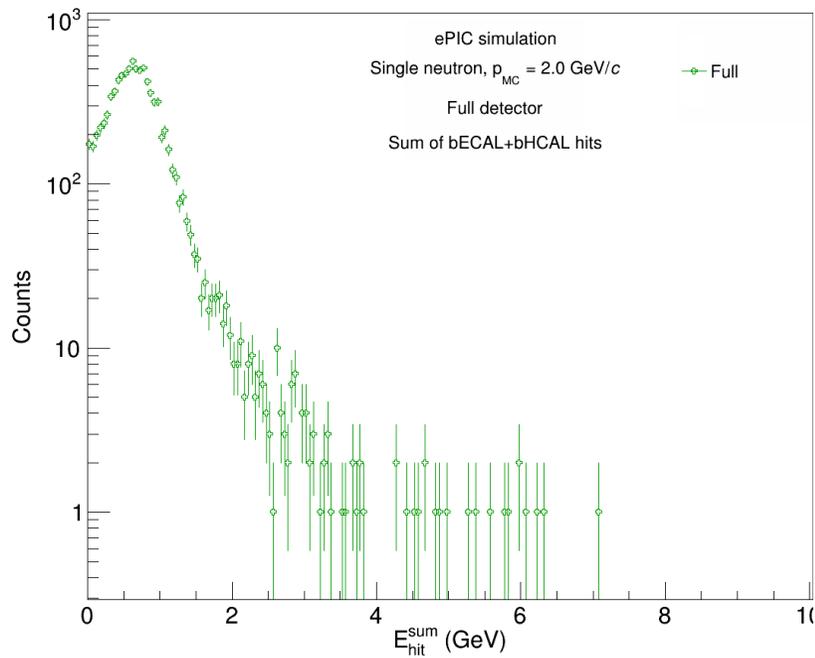
ENERGY IN bECAL+bHCAL

- Uncalibrated energy deposition in **bECAL+bHCAL** without information from sensitive magnet
  - Three MC neutron momenta
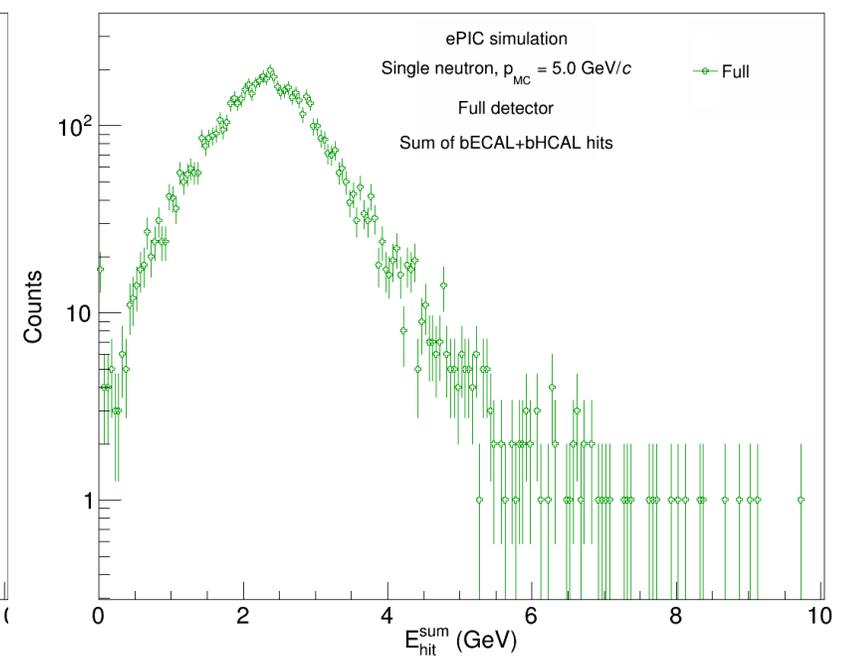   - (left) $1\ \mathrm{GeV}/c$, (middle) $2\ \mathrm{GeV}/c$, (right) $5\ \mathrm{GeV}/c$
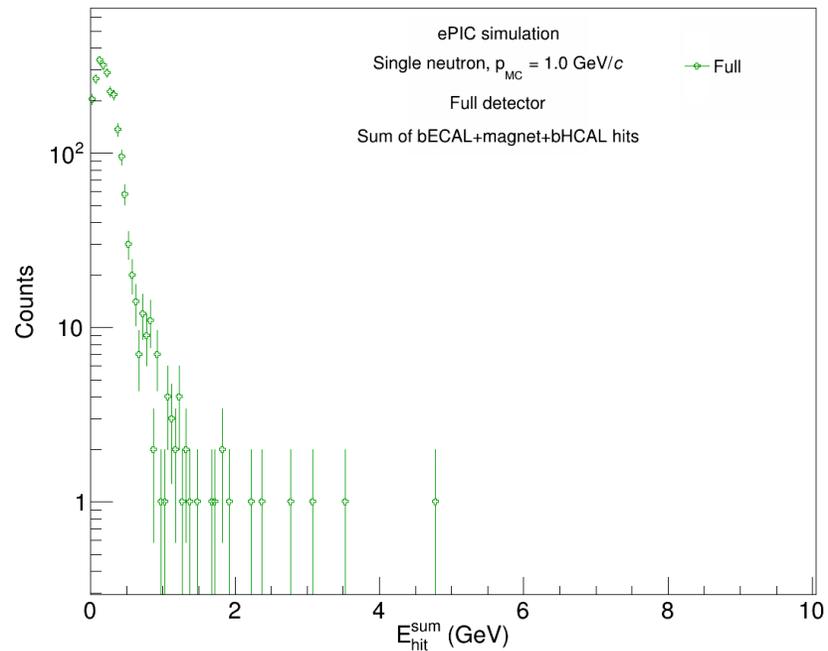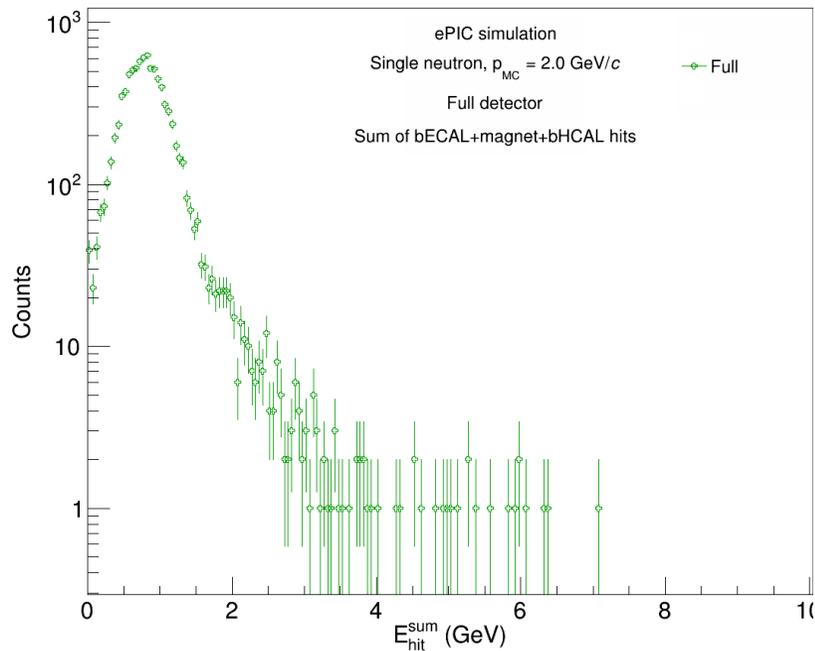
ENERGY IN bECAL+MAGNET+bHCAL

- Uncalibrated energy deposition in **bECAL+magnet+bHCAL**
  - Three MC neutron momenta
    - (left) $1\ \mathrm{GeV}/c$, (middle) $2\ \mathrm{GeV}/c$, (right) $5\ \mathrm{GeV}/c$
  - Mean shifted to higher energy, but not by much
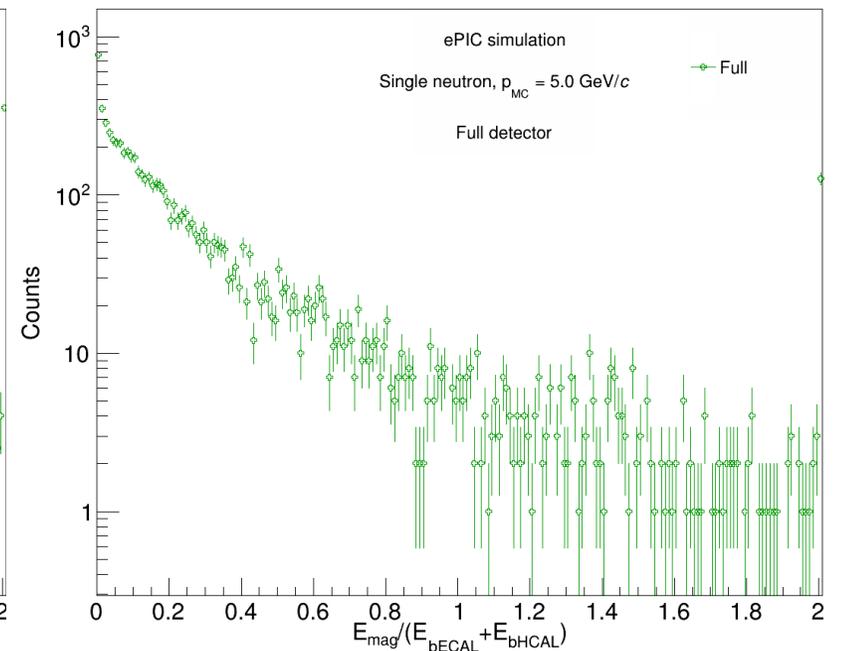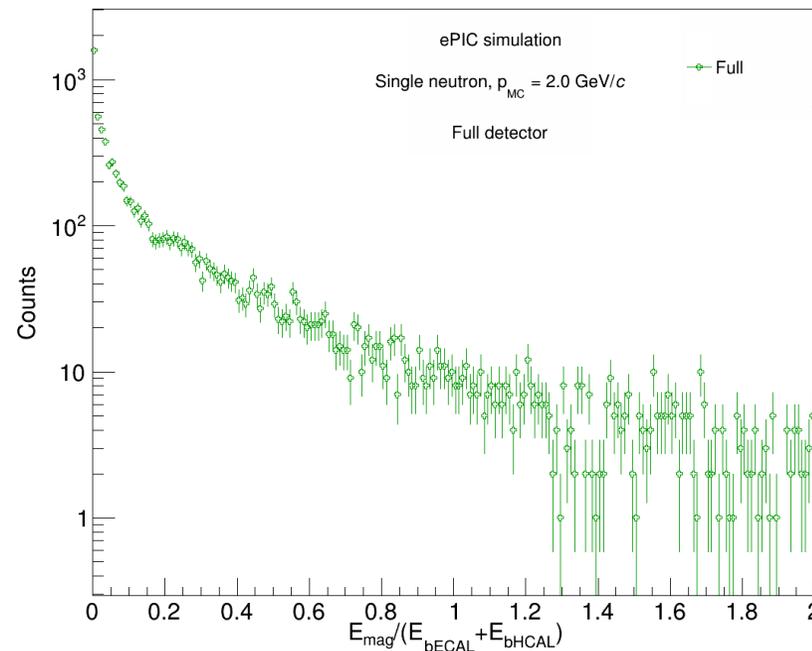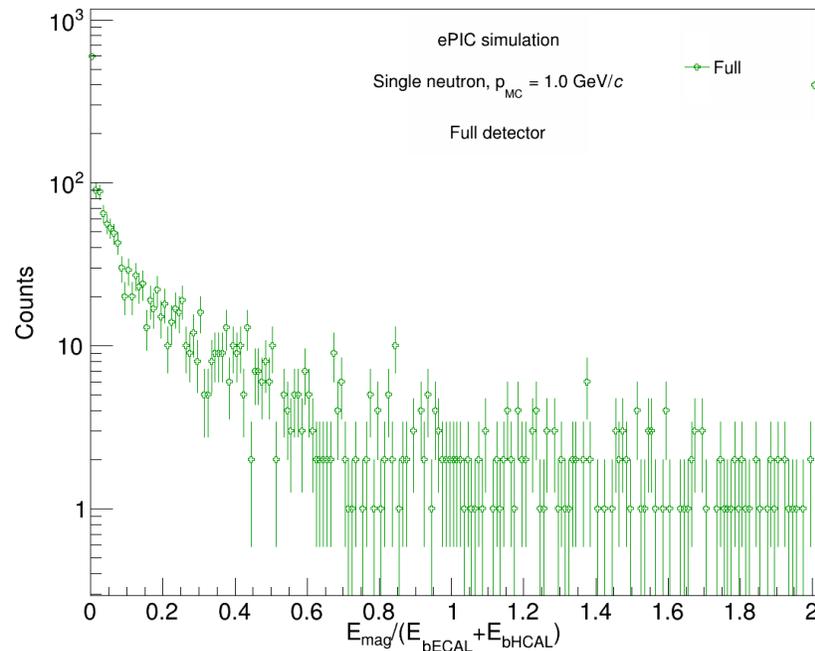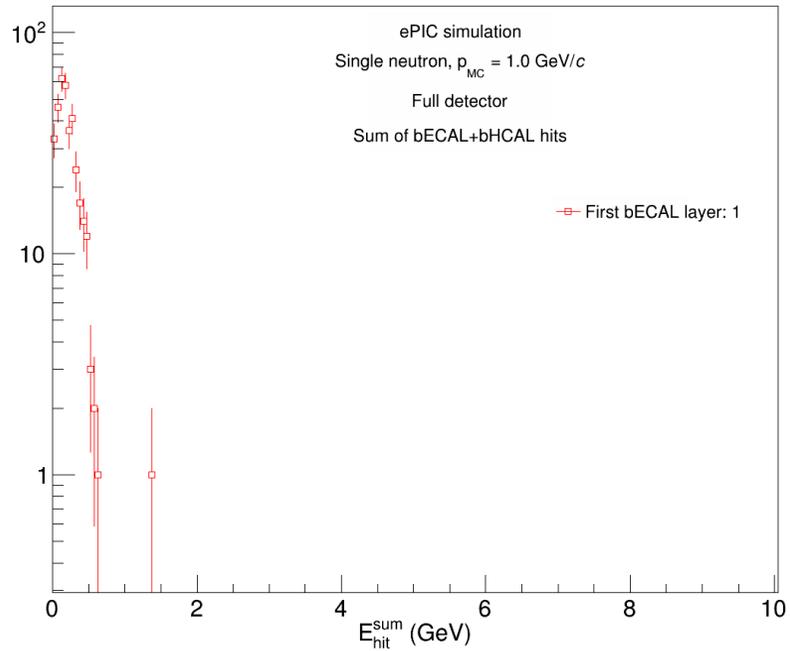
RELATIVE ENERGY DEPOSITION IN MAGNET

- 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)** $5\ \mathrm{GeV}/c$
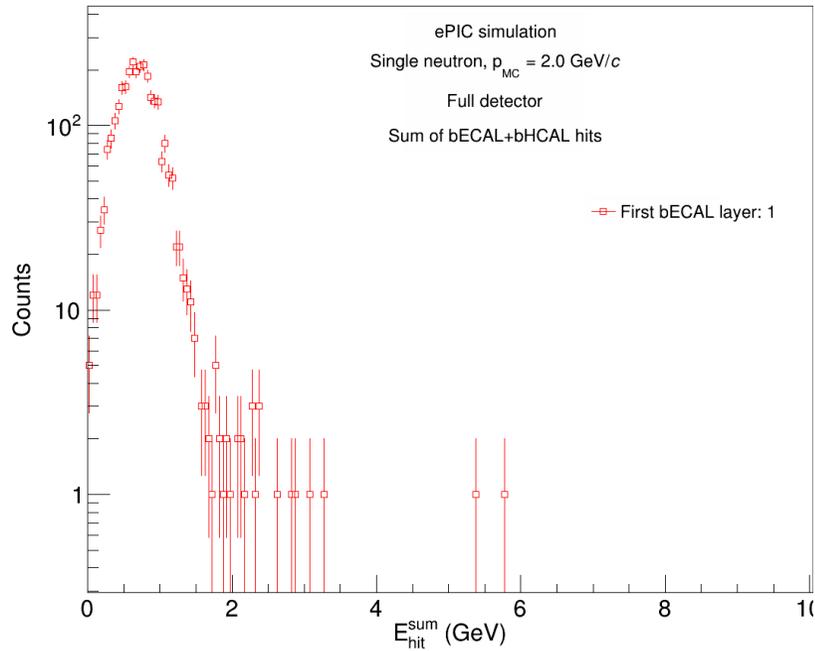   - Appears that for most events, only small fraction of energy is lost in the magnet

ENERGY IN bECAL+bHCAL — LAYER 1

- Uncalibrated energy deposition in **bECAL+bHCAL** without information from sensitive magnet
  - First bECAL layer with signal: Layer 1
  - Three MC neutron momenta
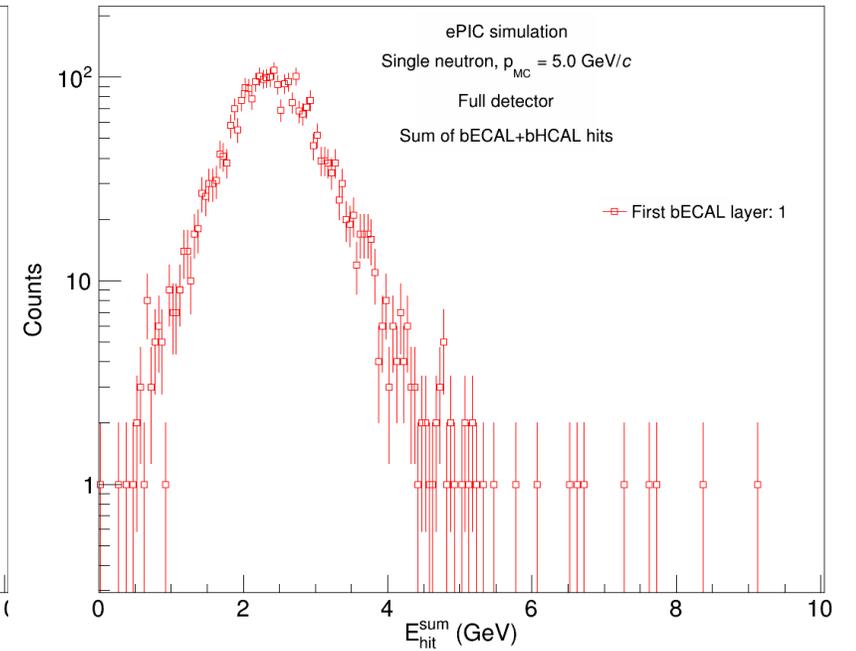   - (left) $1\ GeV/c$, (middle) $2\ GeV/c$, (right) $5\ GeV/c$

- Uncalibrated energy deposition in **bECAL+magnet+bHCAL**
  - First bECAL layer with signal: Layer 1
  - Three MC neutron momenta
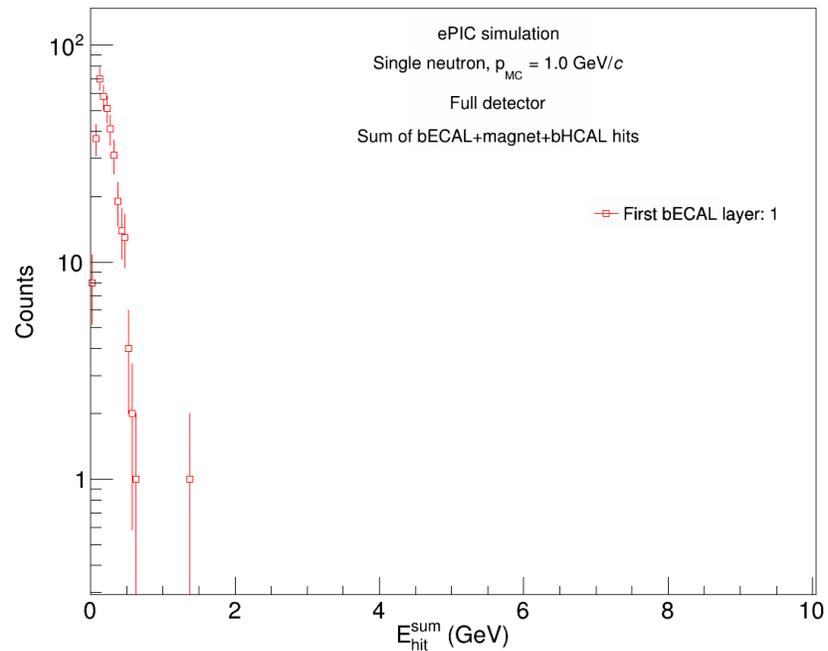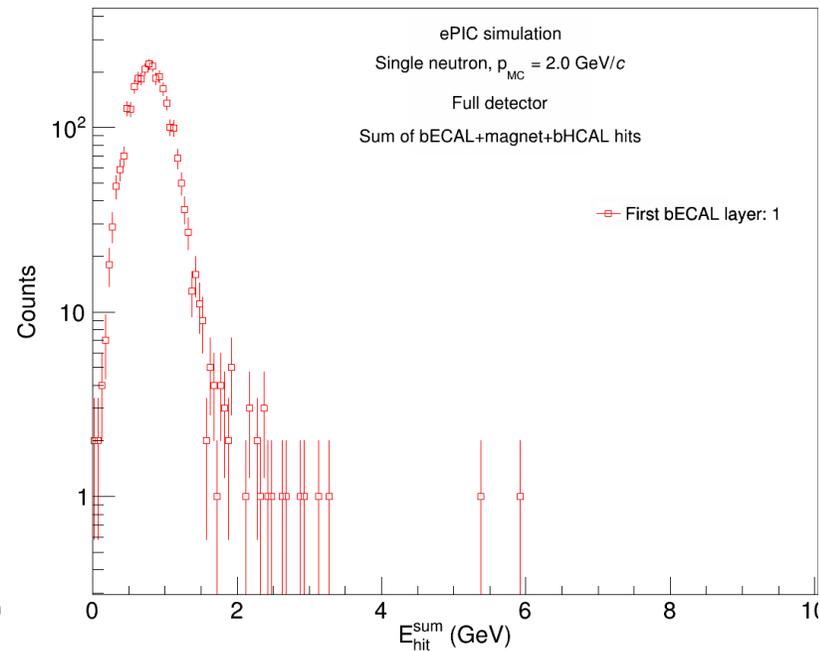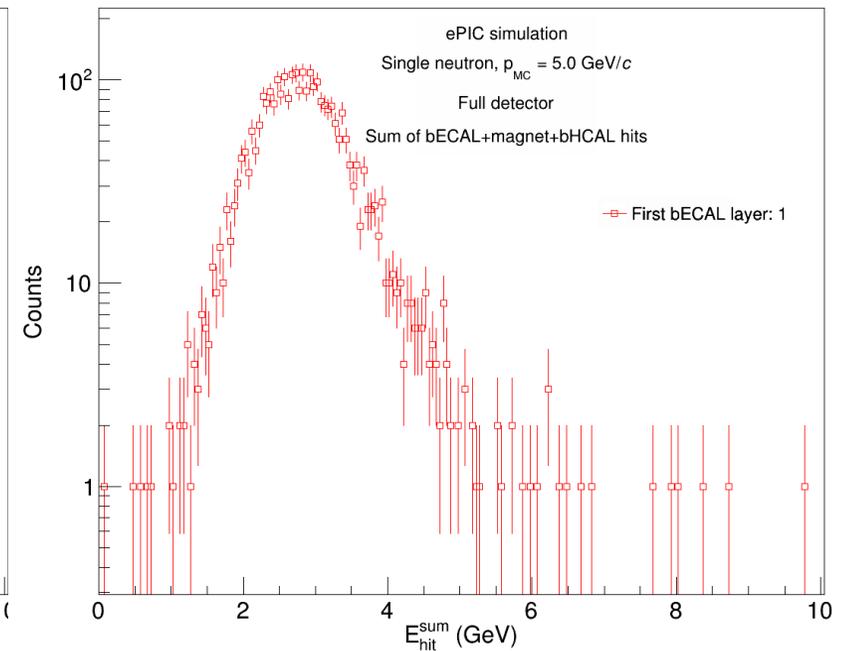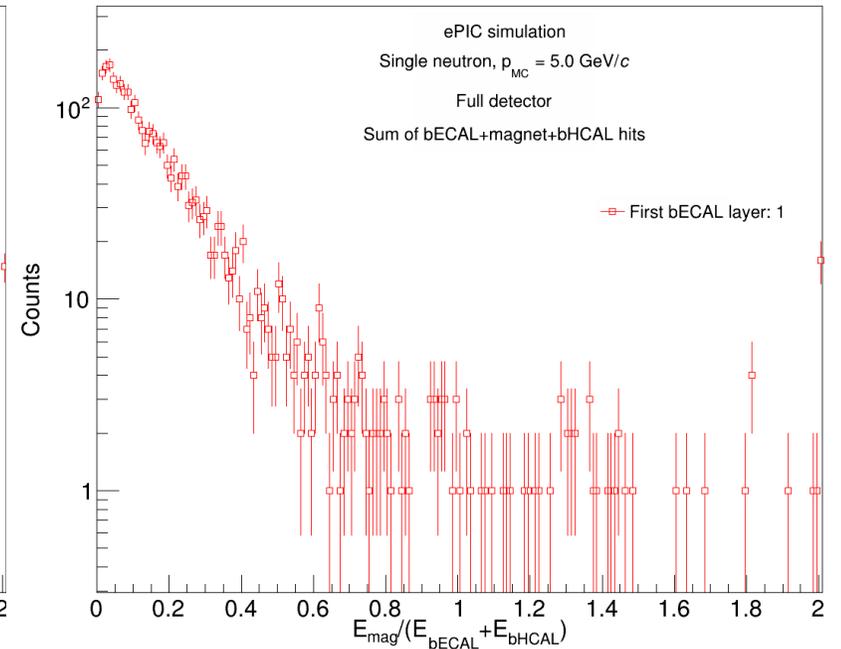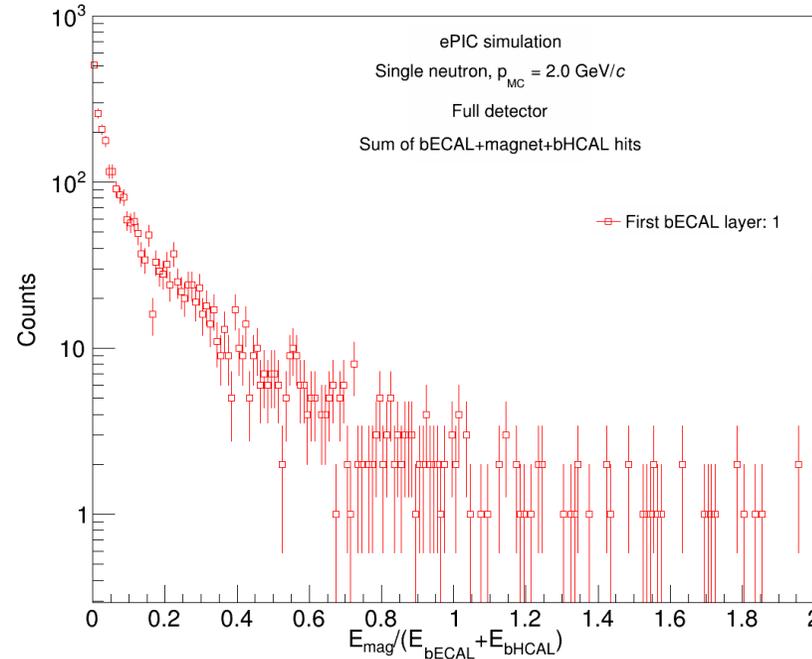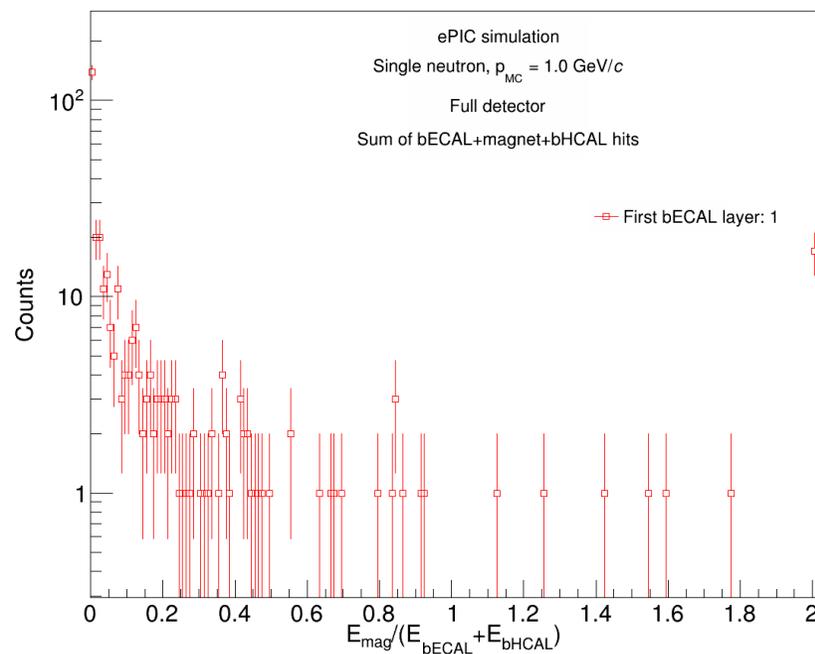   - (left) $1\,GeV/c$, (middle) $2\,GeV/c$, (right) $5\,GeV/c$

RELA. ENERGY DEPOSITION IN MAGNET – LAYER 1

- Relative energy deposition in the magnet with respect to bECAL+bHCAL energy deposition
  - $E_{mag}/(E_{bECAL} + E_{bHCAL})$
  - First bECAL layer with signal: Layer 1
  - Three MC neutron momenta
    - (left) $1\,\mathrm{GeV}/c$, (middle) $2\,\mathrm{GeV}/c$, (right) $5\,\mathrm{GeV}/c$
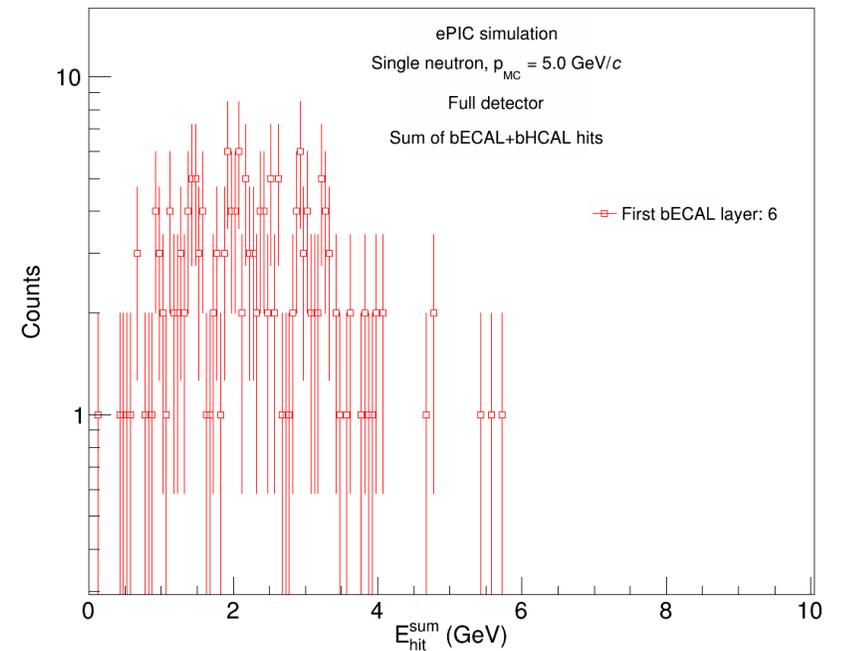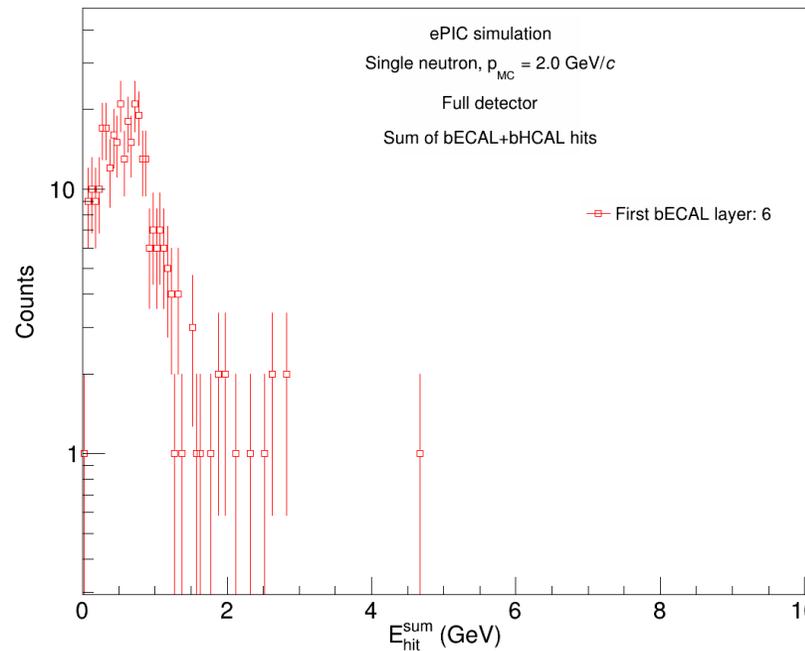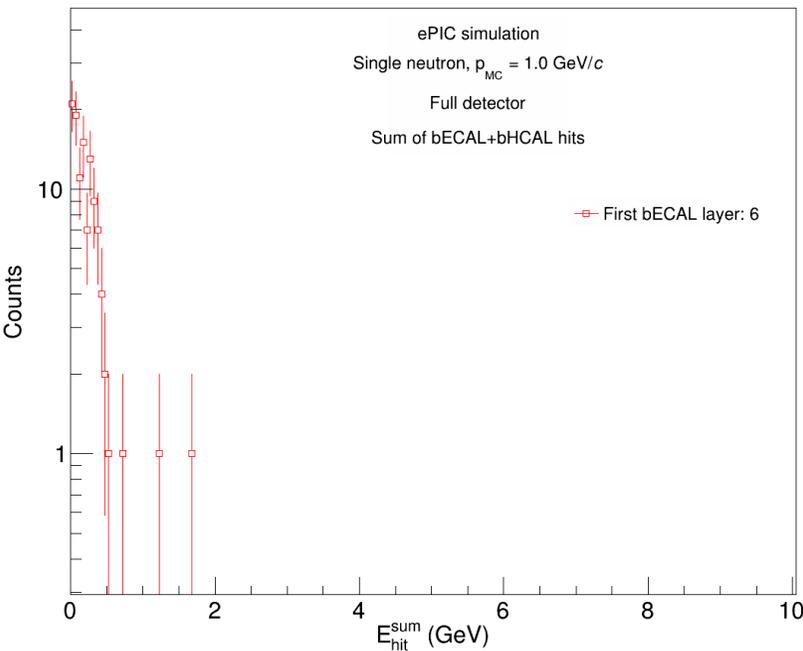
ENERGY IN bECAL+bHCAL — LAYER 6

- Uncalibrated energy deposition in **bECAL+bHCAL** without information from sensitive magnet
  - First bECAL layer with signal: Layer 6
  - Three MC neutron momenta
    - (left) $1\ GeV/c$, (middle) $2\ GeV/c$, (right) $5\ GeV/c$
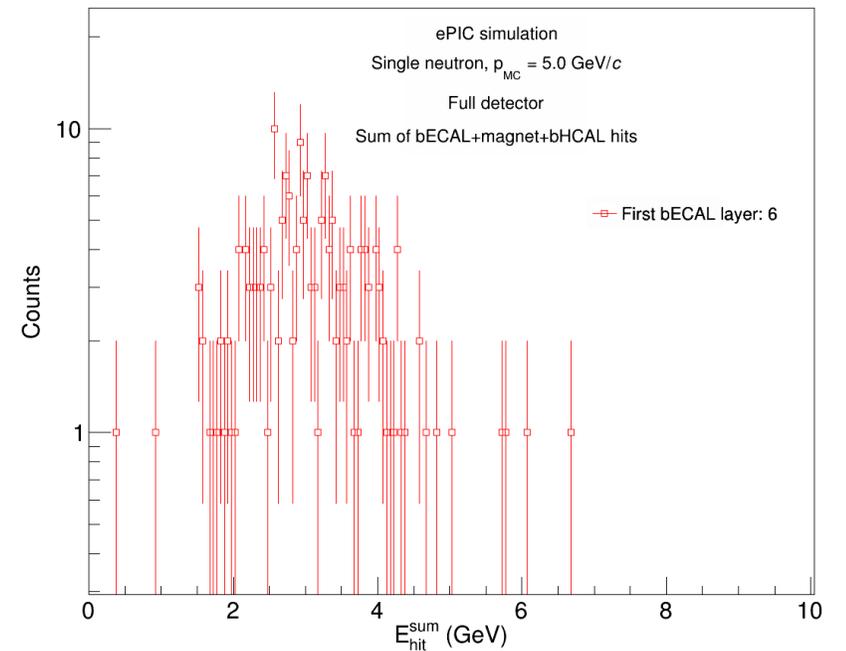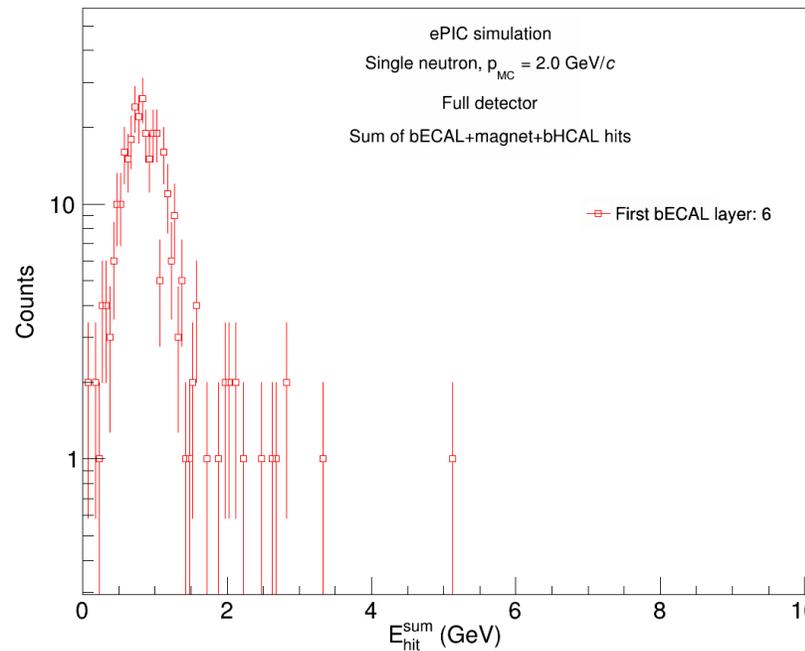
- Uncalibrated energy deposition in **bECAL+magnet+bHCAL**
  - First bECAL layer with signal: Layer 6
  - Three MC neutron momenta
    - (left) $1\,\mathrm{GeV}/c$, (middle) $2\,\mathrm{GeV}/c$, (right) $5\,\mathrm{GeV}/c$

No clear peak   Clear peak   Clear peak
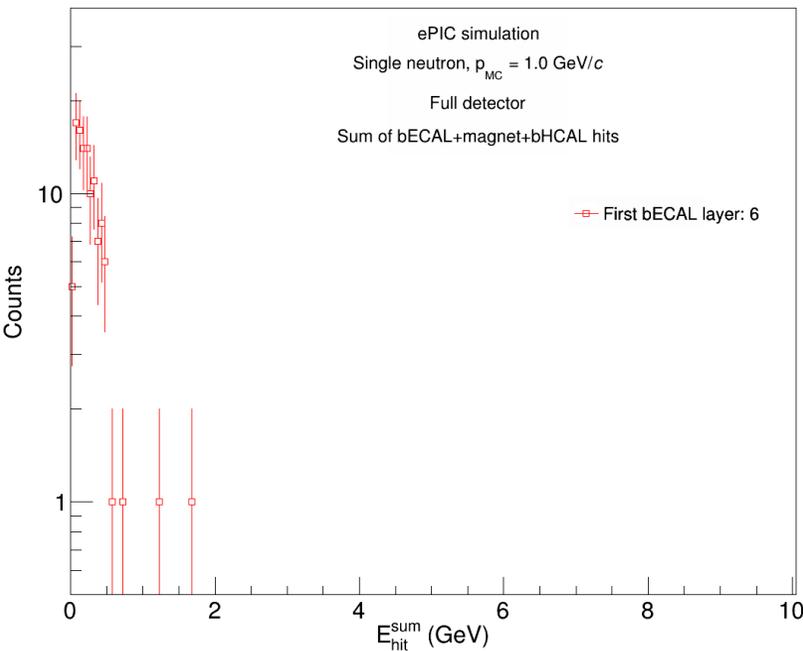
- Relative energy deposition in the magnet with respect to bECAL+bHCAL energy deposition
  - $E_{mag}/(E_{bECAL} + E_{bHCAL})$
  - First bECAL layer with signal: Layer 6
  - Three MC neutron momenta
    - (left) $1\ GeV/c$, (middle) $2\ GeV/c$, (right) $5\ GeV/c$

ENERGY IN bECAL+bHCAL — LAYER 12

- Uncalibrated energy deposition in **bECAL+bHCAL** without information from sensitive magnet
    - First bECAL layer with signal: Layer 12
    - Three MC neutron momenta
        - (left) $1\ \mathrm{GeV}/c$, (middle) $2\ \mathrm{GeV}/c$, (right) $5\ \mathrm{GeV}/c$

- Uncalibrated energy deposition in **bECAL+magnet+bHCAL**
  - First bECAL layer with signal: Layer 12
  - Three MC neutron momenta
    - (left) $1\ GeV/c$, (middle) $2\ GeV/c$, (right) $5\ GeV/c$
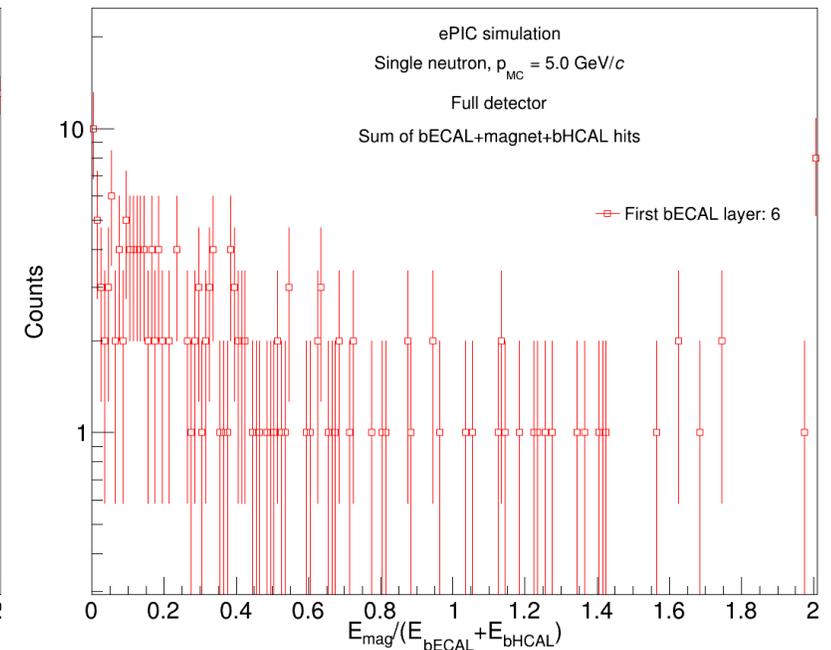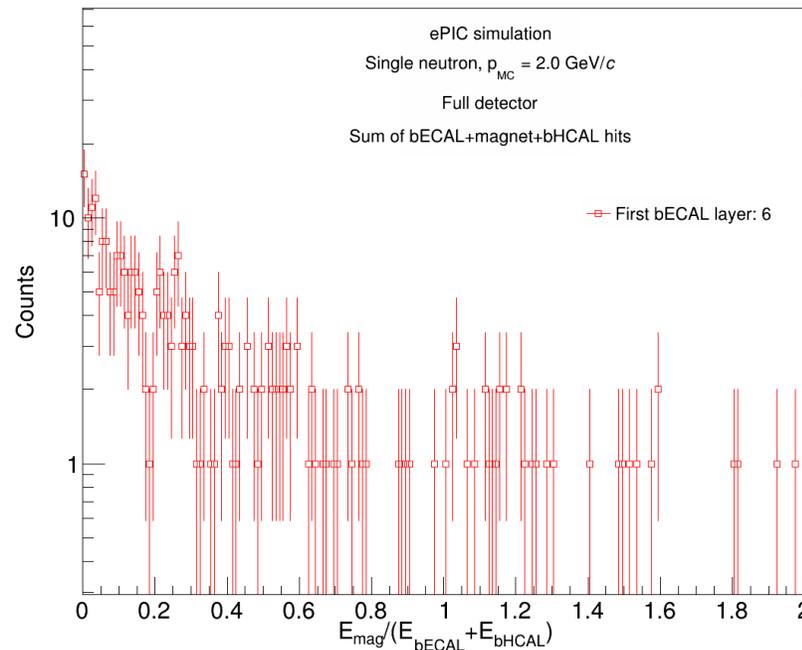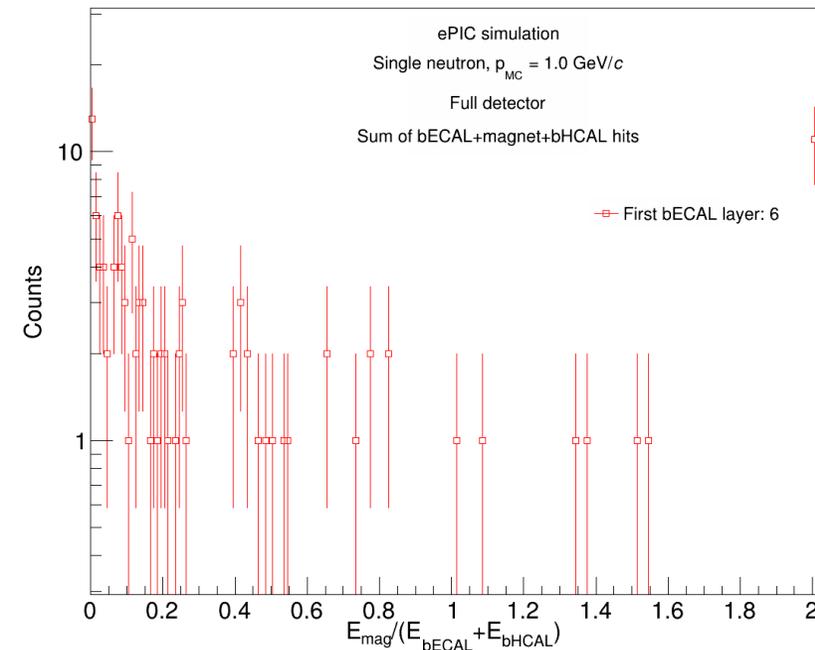
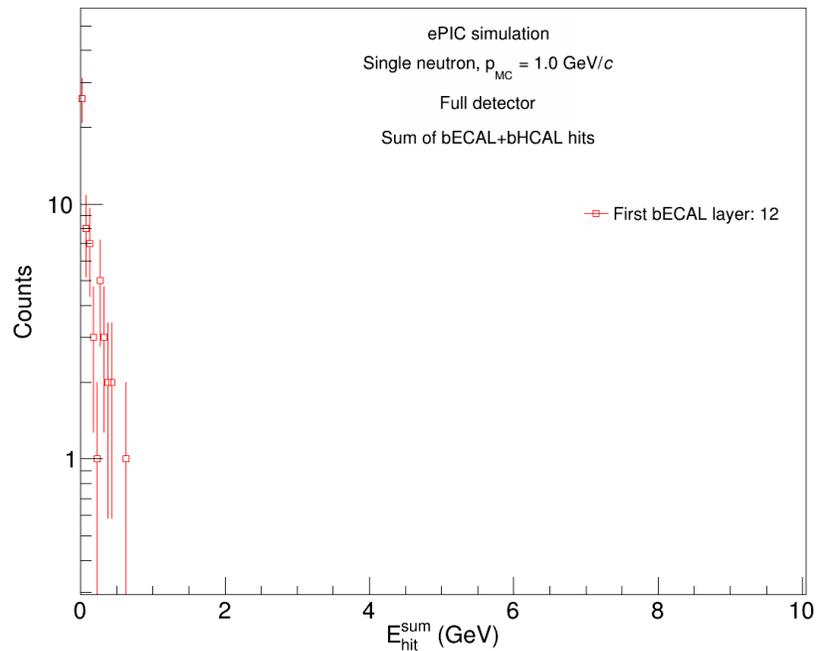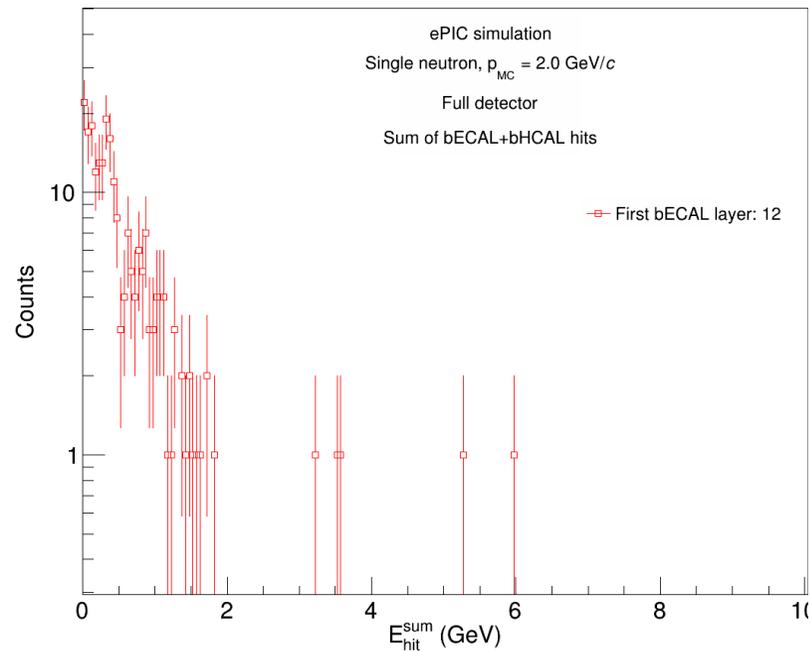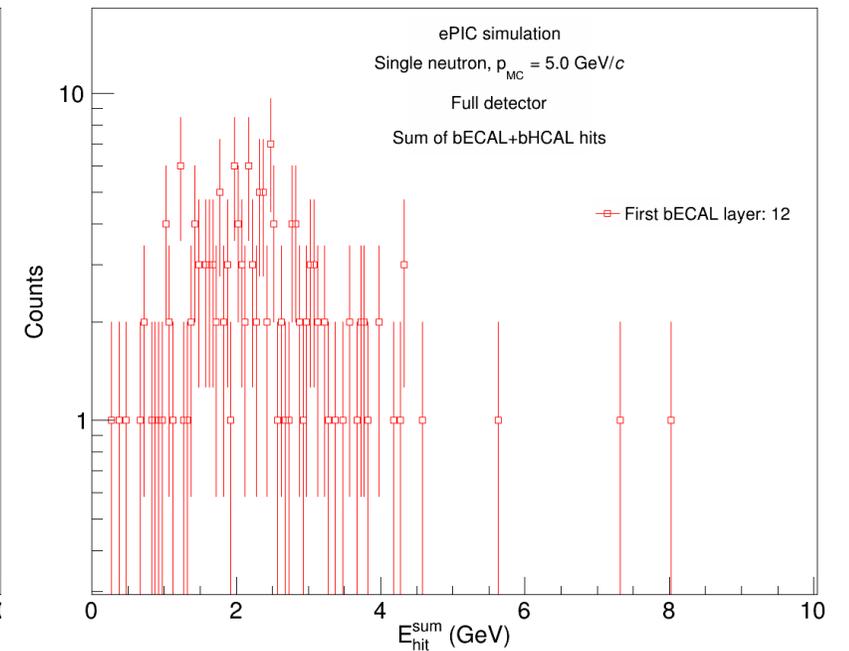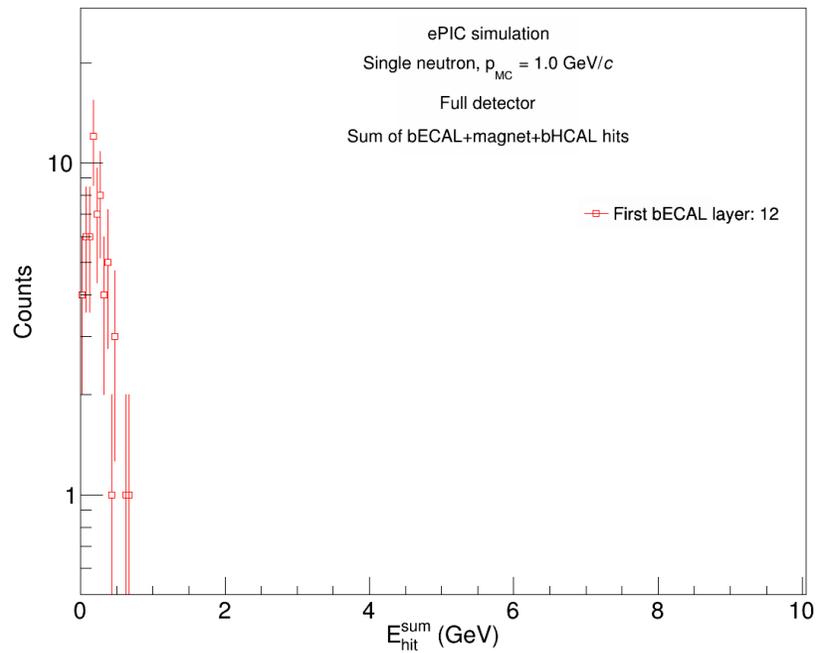# RELA. ENERGY DEPOSITION IN MAGNET — LAYER 12

- Relative energy deposition in the magnet with respect to bECAL+bHCAL energy deposition
  - $E_{mag}/(E_{bECAL} + E_{bHCAL})$
  - First bECAL layer with signal: Layer 12
  - Three MC neutron momenta
    - (left) $1\ \text{GeV}/c$, (middle) $2\ \text{GeV}/c$, (right) $5\ \text{GeV}/c$
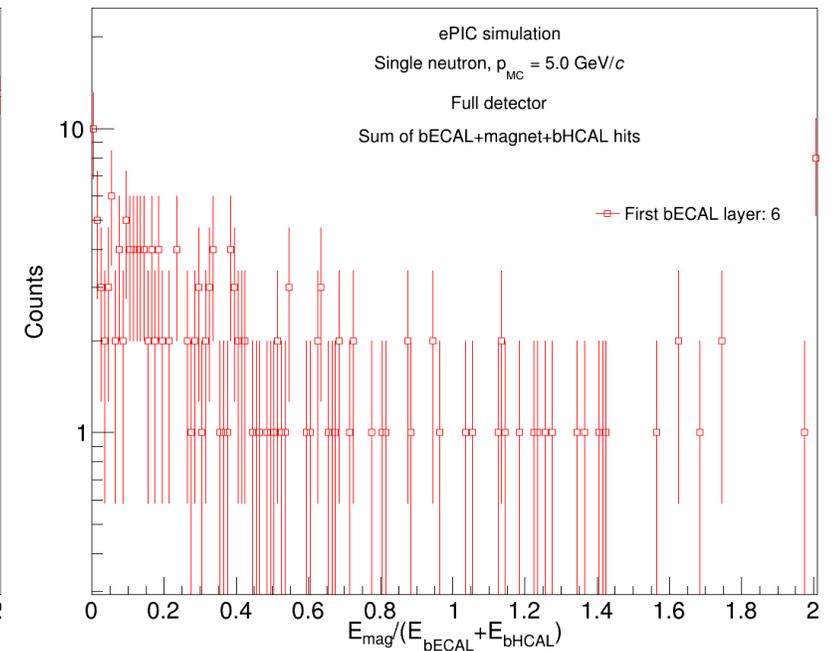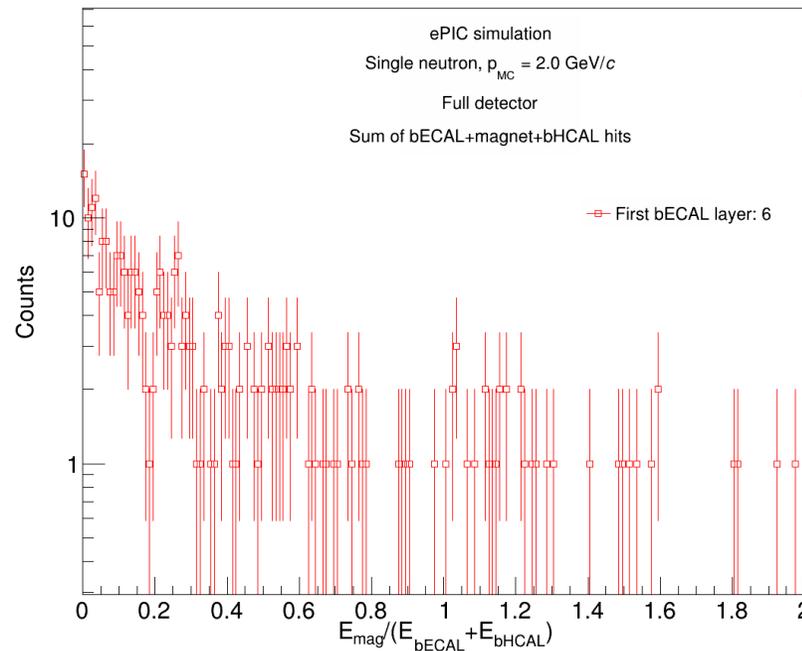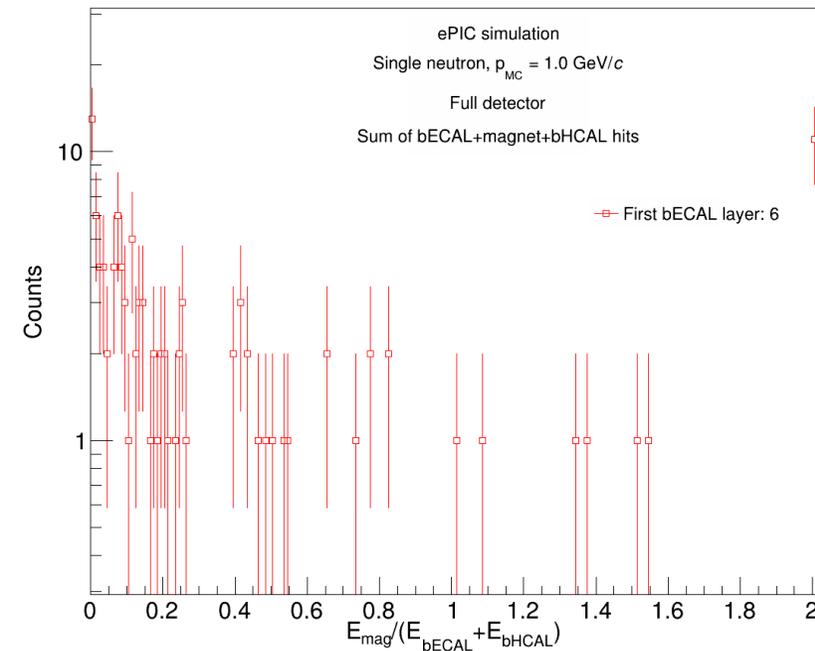
SUMMARY

- 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 $(1 \, \mathrm{GeV}/c)$

THANK YOU FOR ATTENTION

BACKUP

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