ePIC Calorimetry Meeting
Neutron Calibrations for bHCAL

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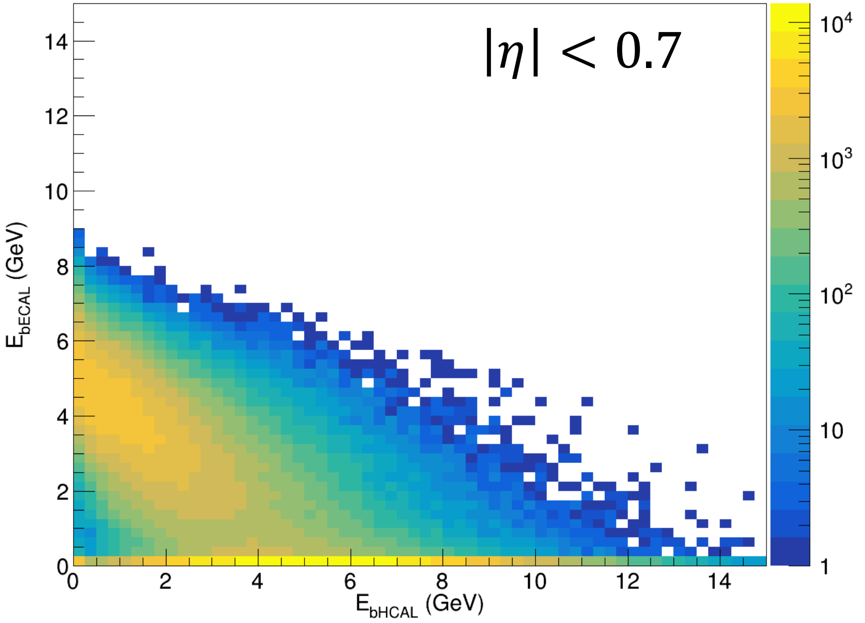
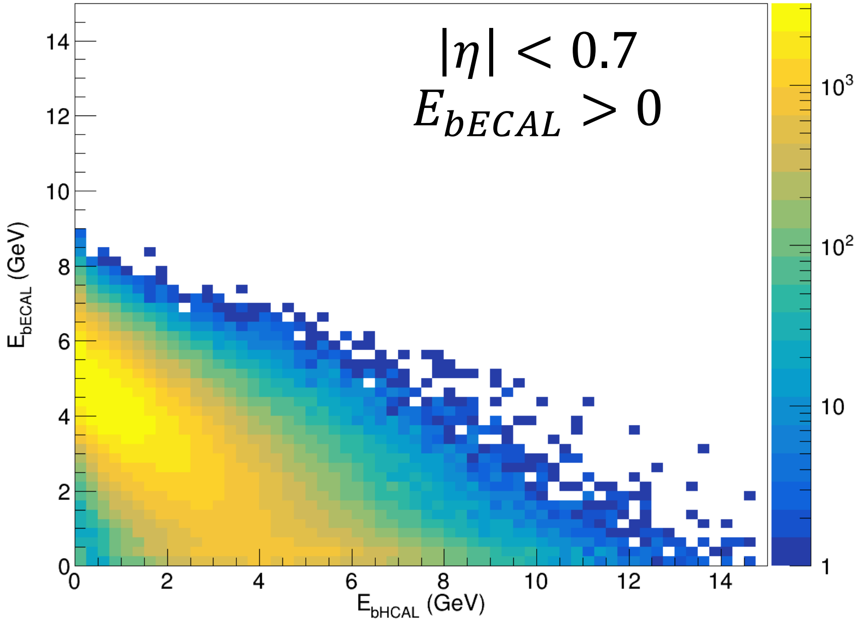
OVERVIEW

- Status of neutron calibrations in bHCAL

E_{bECAL} vs. E_{bHCAL} distributions

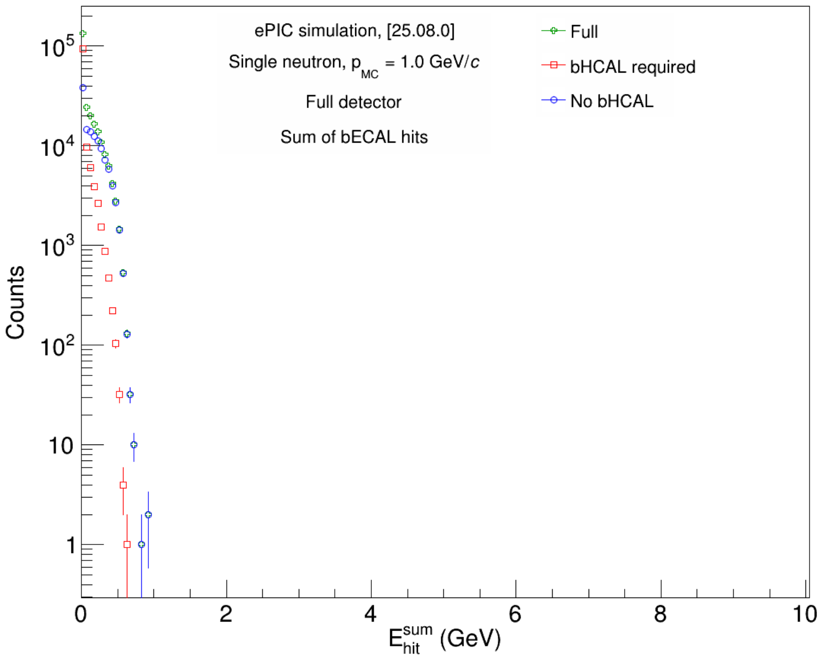
- E_{bECAL} vs. E_{bHCAL} distribution for all for 10 GeV/c neutrons
  - Example on 10 GeV/c neutrons for illustration
  - (left) All events
    - Fraction of events with no deposition in bECAL – shower starts in the magnet or bHCAL
  - (right) Accepting only events with $E_{bECAL} > 0$
- This is much more important for low energy neutrons as shower length is small
  - Can be contained only in bECAL/magnet/bHCAL, or combination of two

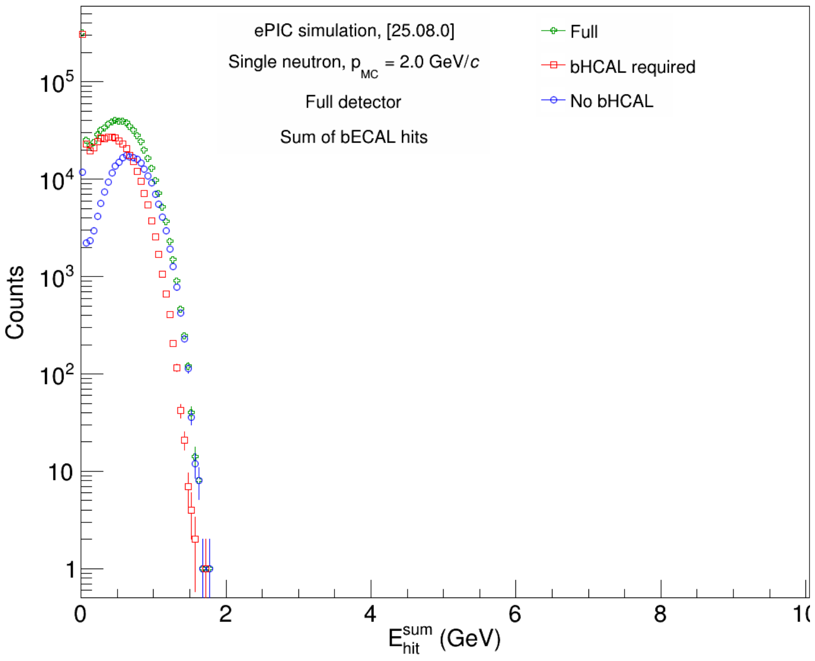


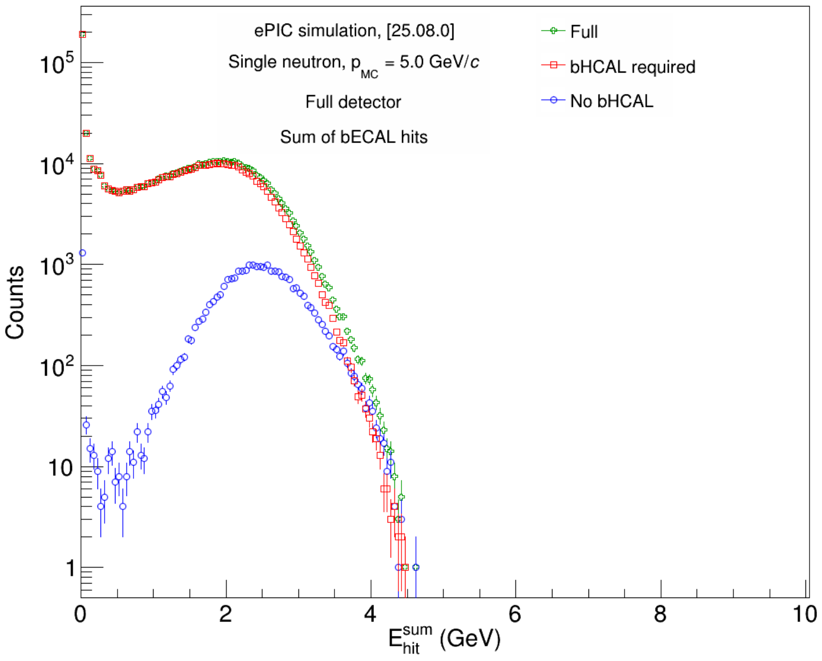


ENERGY DEPOSITION IN bECAL

- Uncorrected energy distribution for hits in bECAL for single neutrons at various MC momenta
  - Values in the legend are MC neutron momenta
  - Energy from **sum of individual hits**
  - Green – all hits, Red – require hits in bHCAL, Blue – require no hits in bHCAL

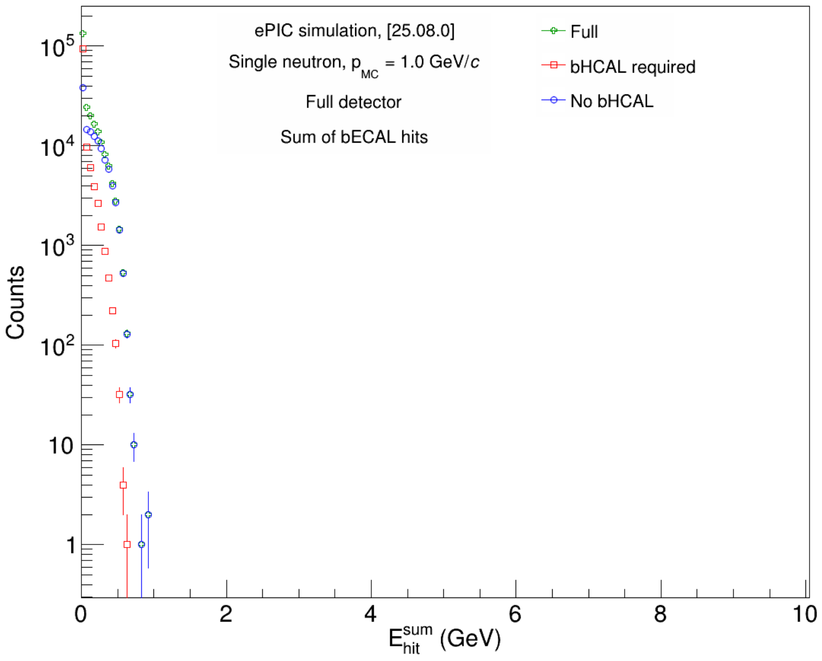


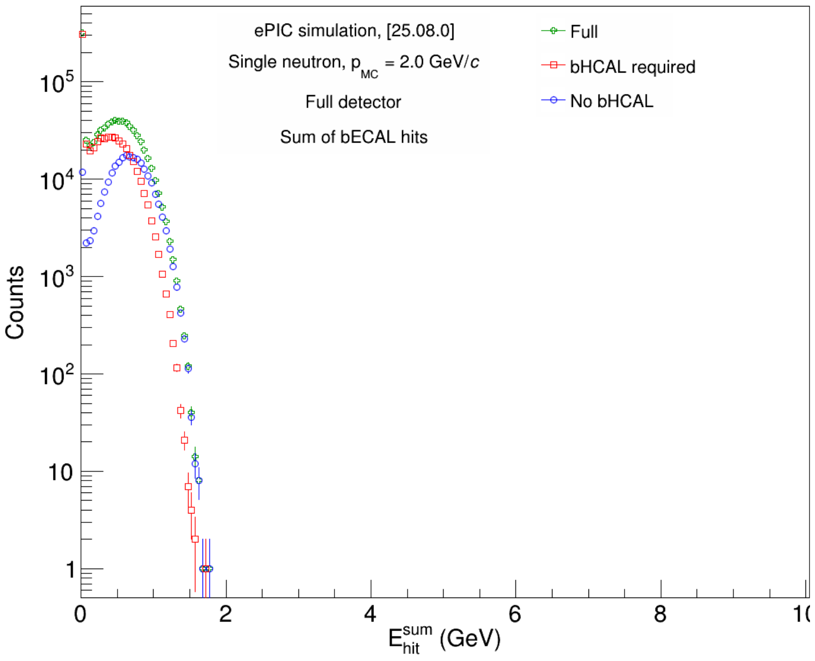


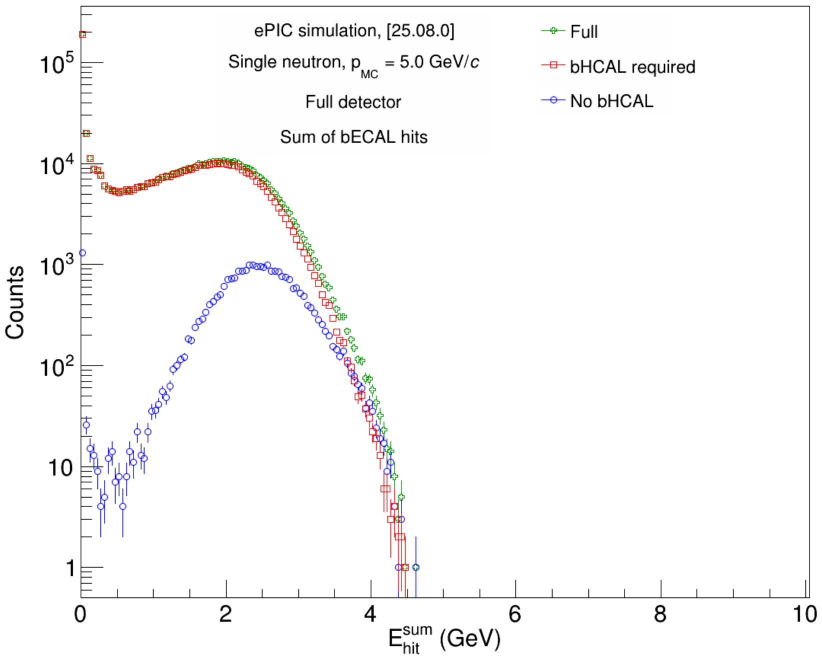


ENERGY DEPOSITION IN bECAL

- Key observations:
  - $1\ \mathrm{GeV}/c$: Majority of neutrons detected by bECAL don’t have signal in bHCAL
    - Expected – shower is short, so when it starts in bECAL, it’s likely that nothing reaches bHCAL
  - $2\ \mathrm{GeV}/c$: More substantial contribution of showers that reach both bECAL and bHCAL – longer shower
  - $5\ \mathrm{GeV}/c$: Majority of showers that start in bECAL also reach bHCAL – even longer shower







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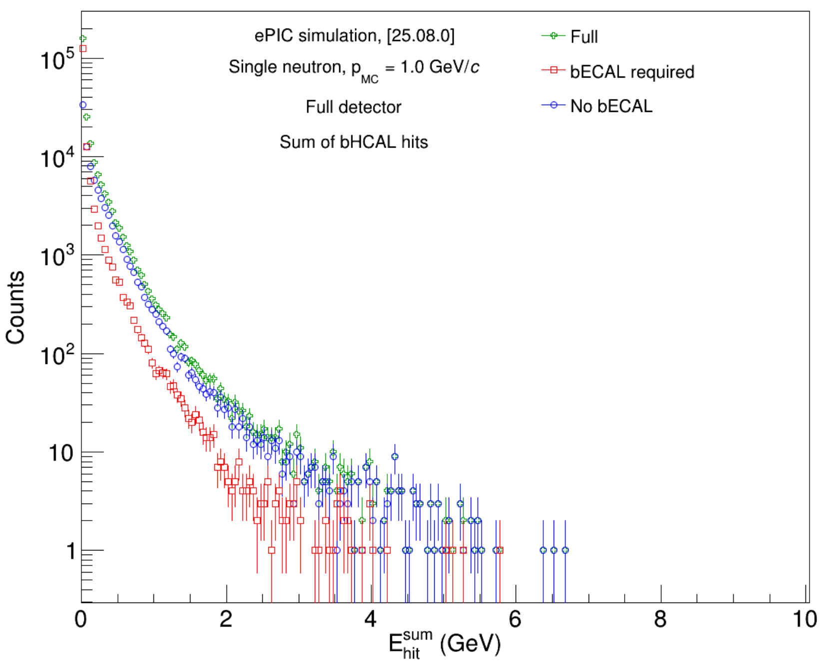
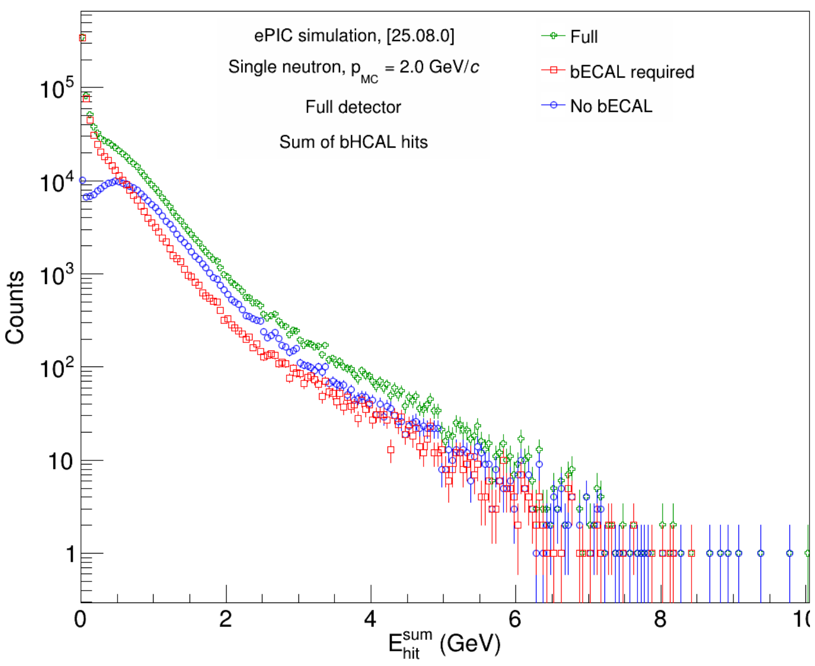
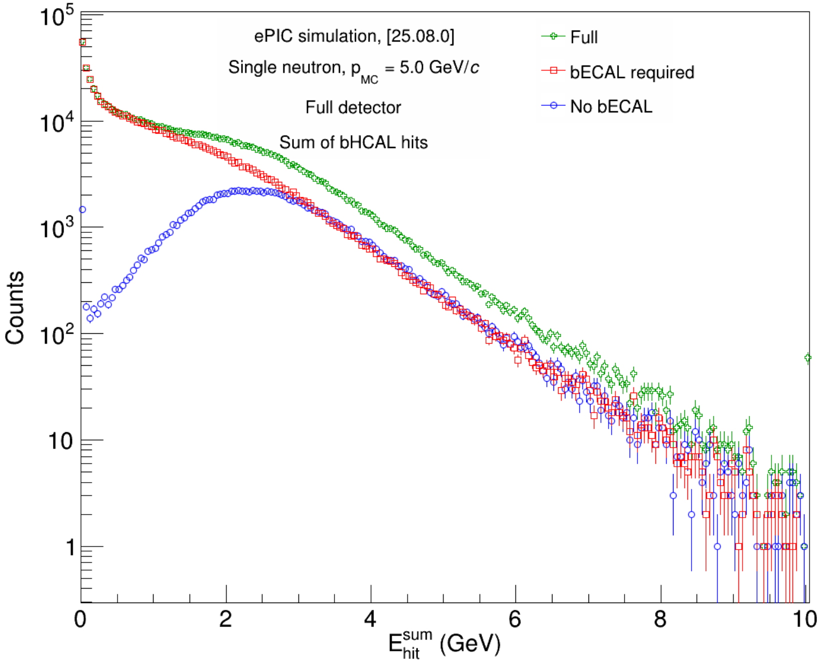
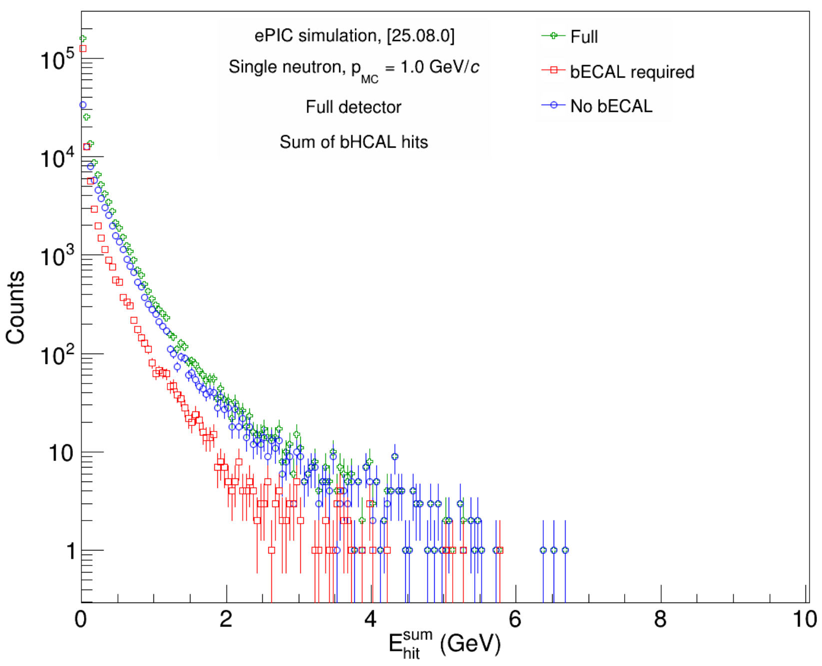


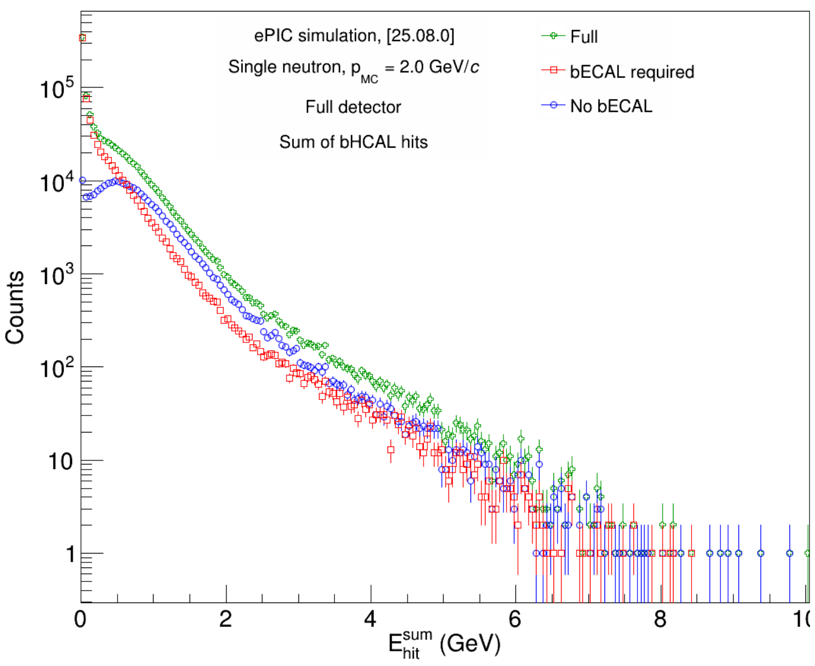


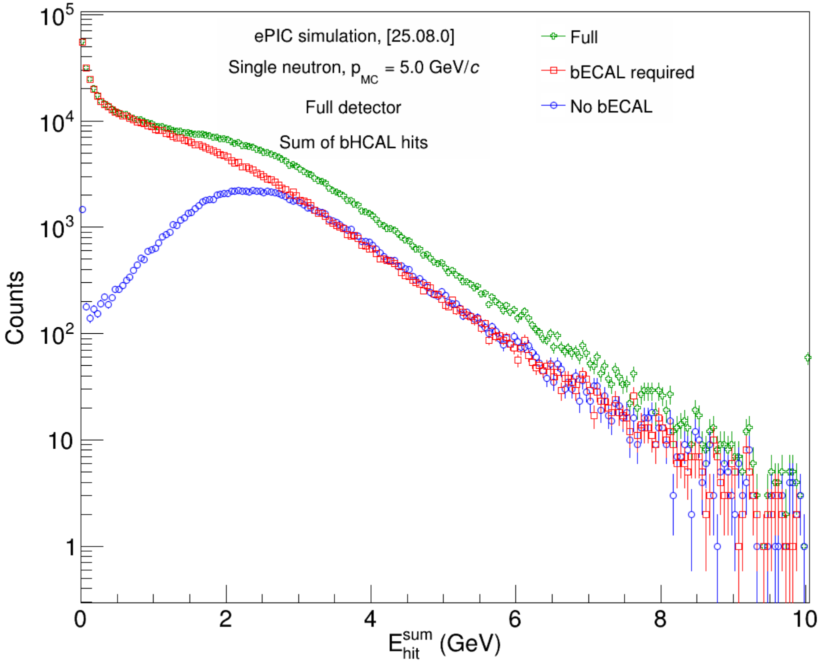


ENERGY DEPOSITION IN bHCAL

- Key observations:
  - 1 GeV/c: Majority of neutrons detected by bHCAL don't have signal in bECAL
    - Expected – shower is short, so it needs to start in the magnet or bHCAL itself to be detected
  - 2 GeV/c: More substantial contribution of showers that reach both bECAL and bHCAL – longer shower
  - 5 GeV/c: Many showers that reach bHCAL originate in bECAL – even longer shower

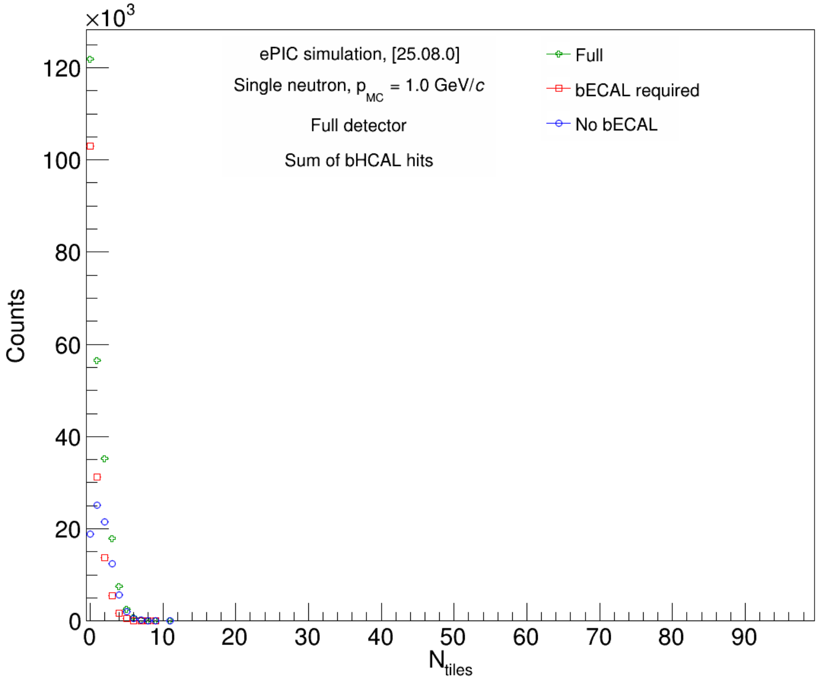


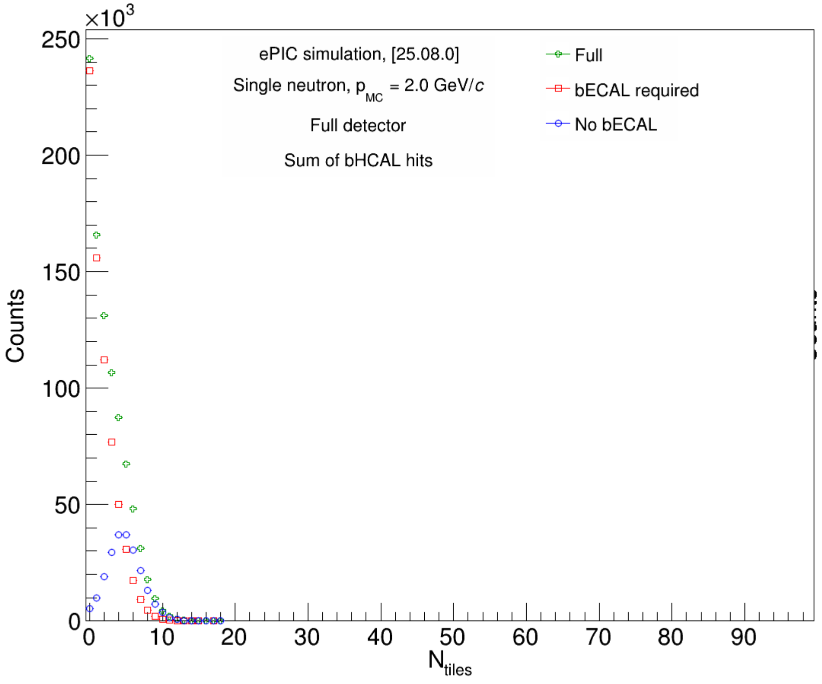


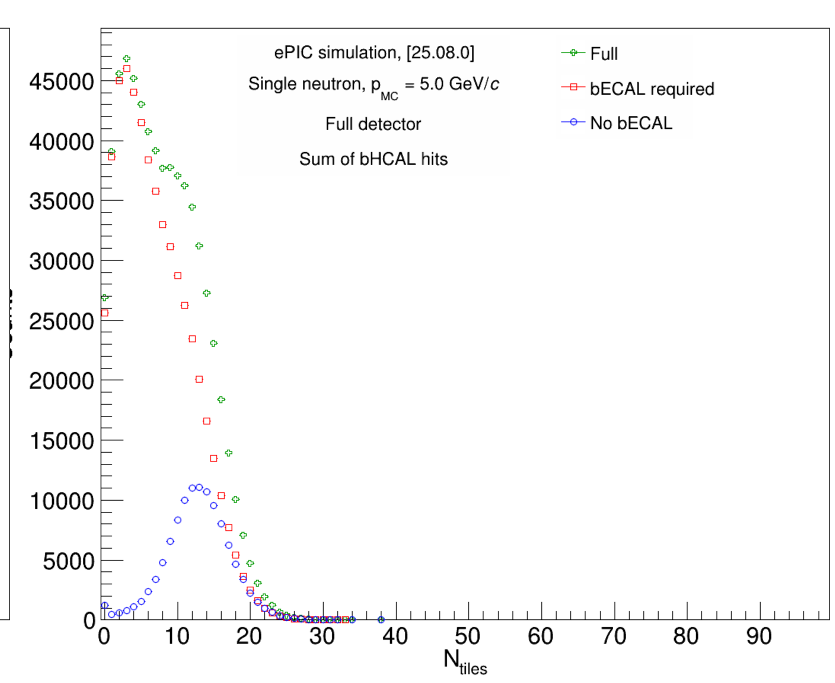


NUMBER OF TILES WITH SIGNAL IN bHCAL

- Number of tiles with non-zero energy deposition in bHCAL
  - Three MC neutron momenta
  - Linear scale
  - Green – all hits, Red – require hits in bECAL, Blue – require no hits in bECAL

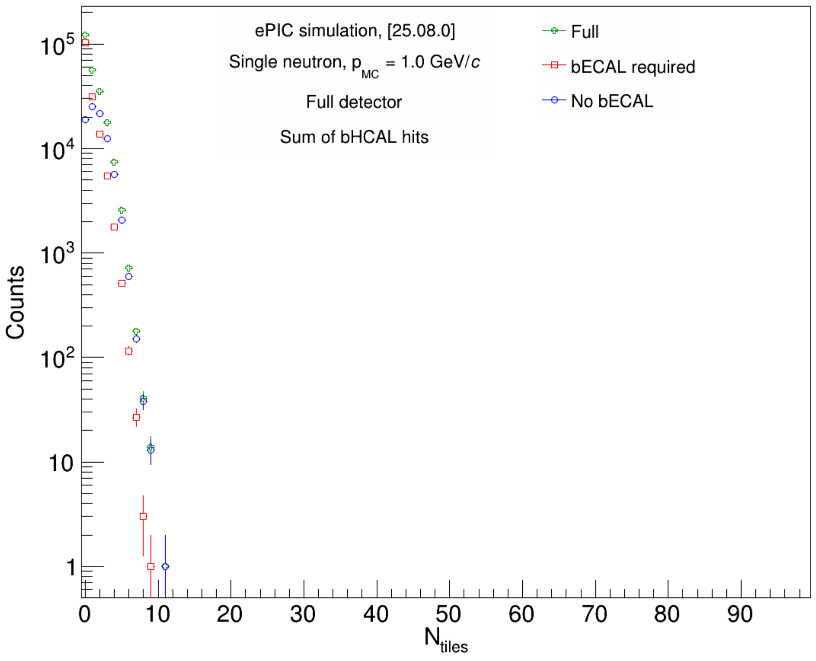


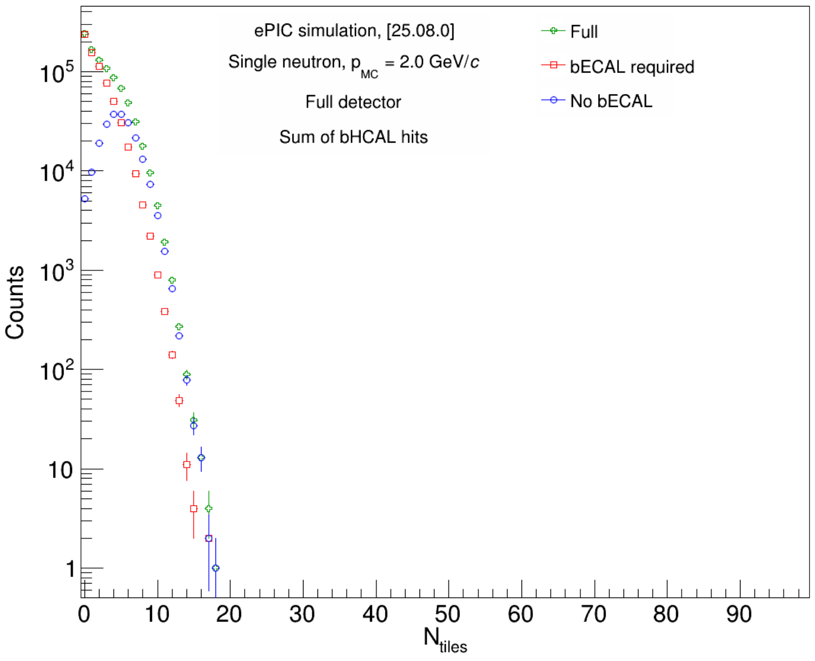


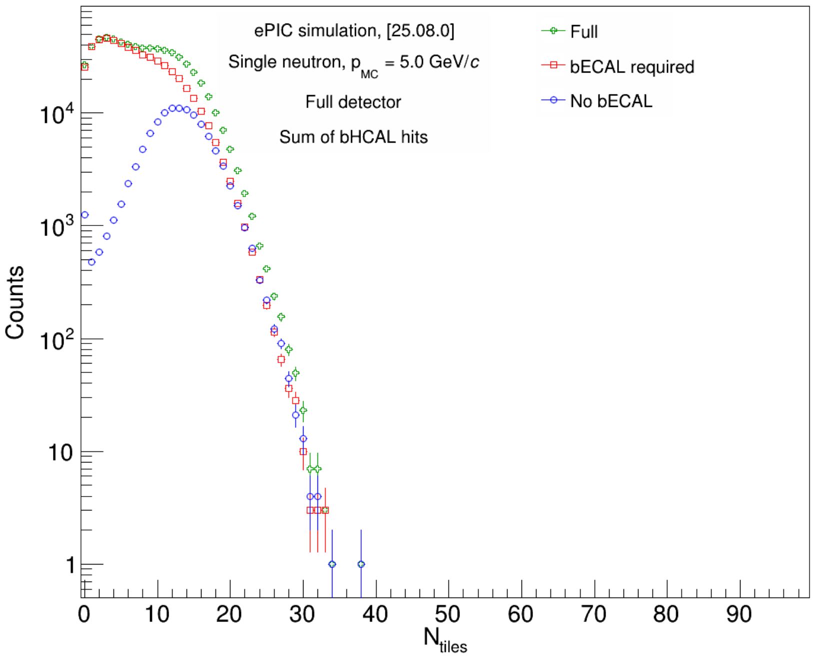


NUMBER OF HIT TILES IN bHCAL

- Number of tiles with signal in bHCAL
  - Three MC neutron momenta
  - Log-scale
  - Green – all hits, Red – require hits in bECAL, Blue – require no hits in bECAL

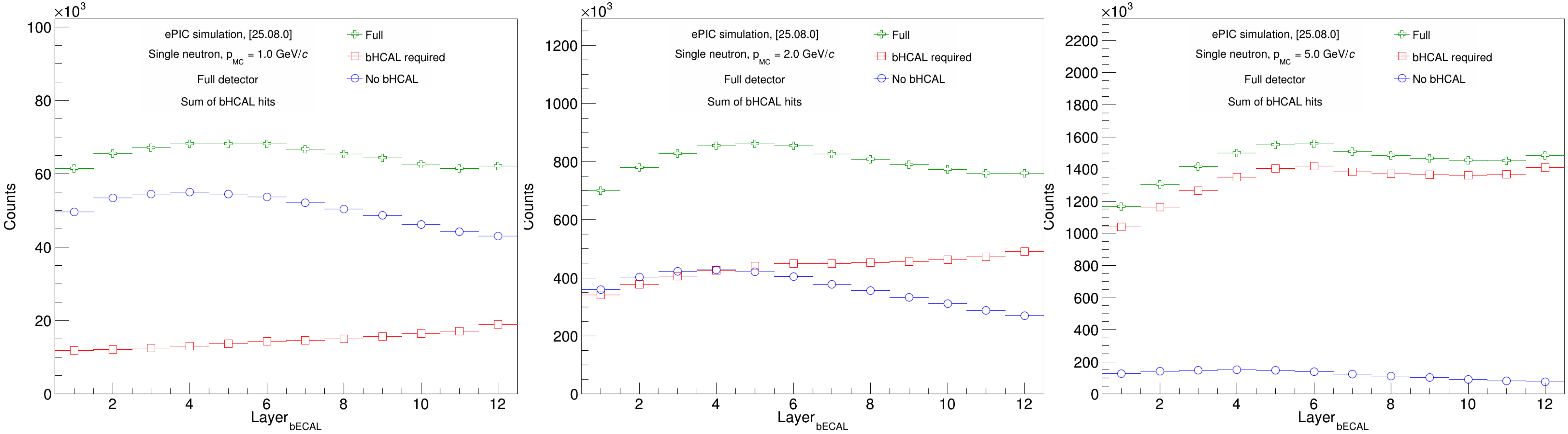






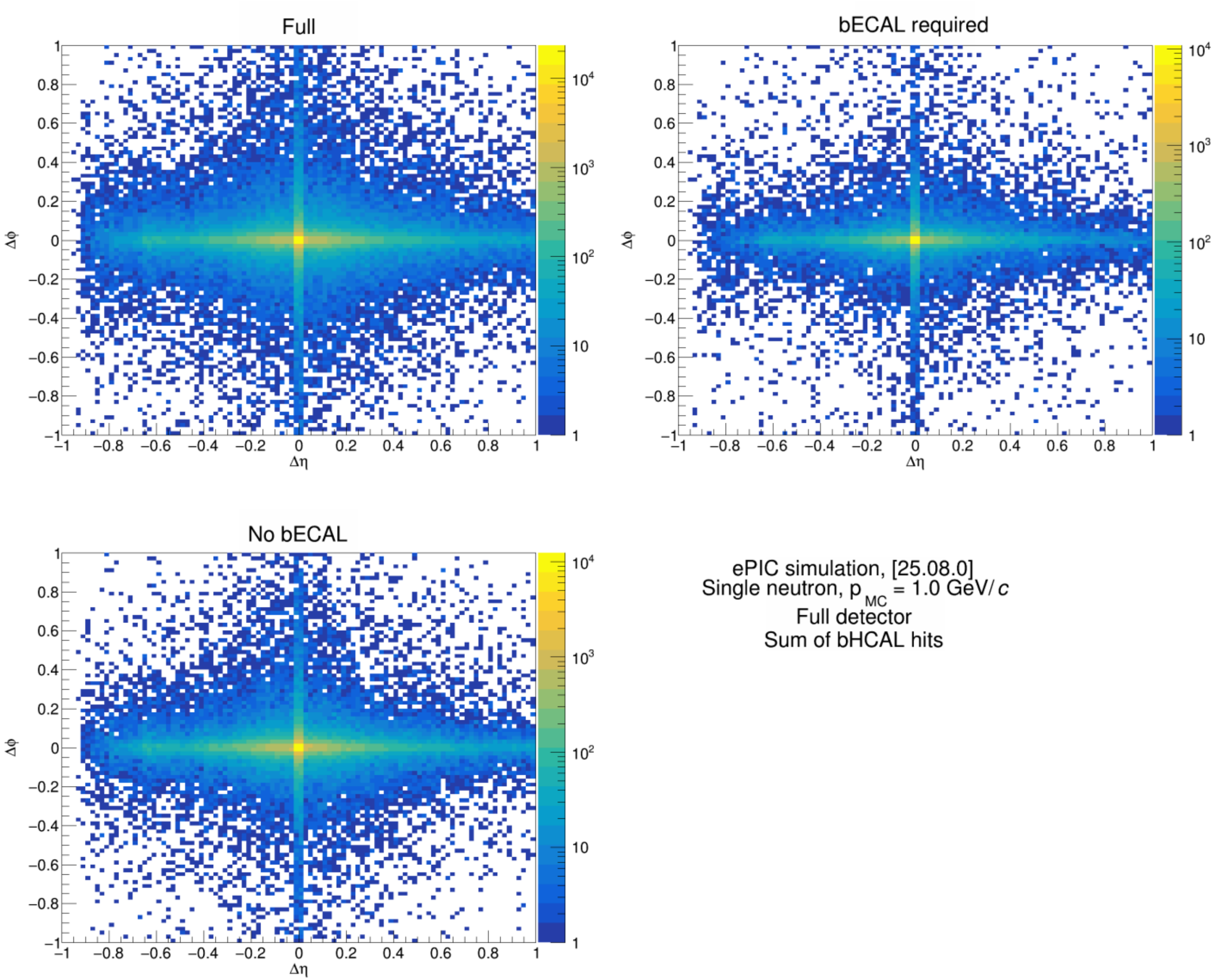
HITS IN LAYERS OF bECAL

- Hits recorded by individual SciFi layers of bECAL
  - All layers with signal
  - Three MC neutron momenta
  - Green – all hits, Red – require hits in bHCAL, Blue – require no hits in bHCAL



SHOWER TRANSVERSE SIZE IN bHCAL

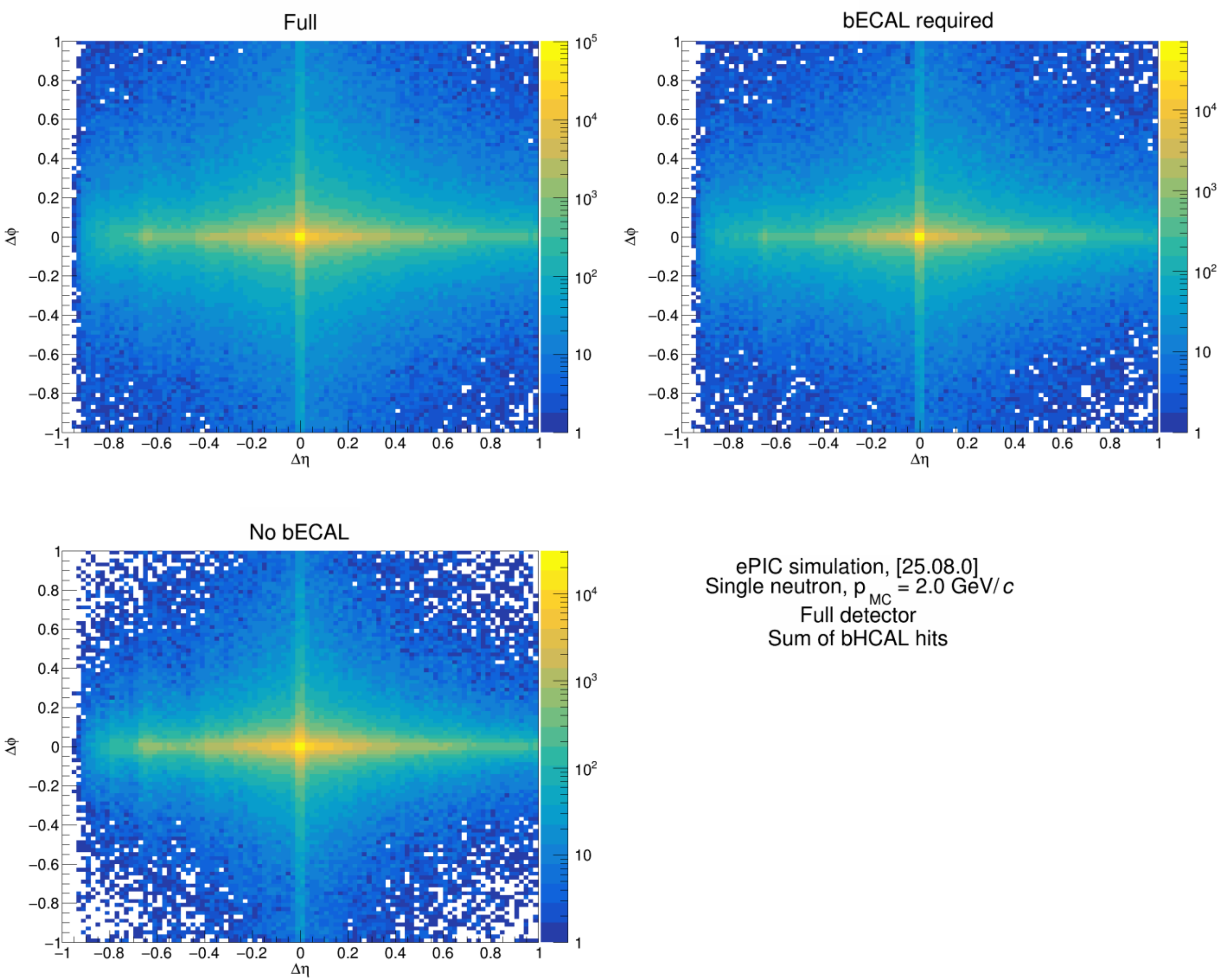
- Transverse size of shower in bHCAL
  - MC neutron momentum: $1\ \mathrm{GeV}/c$
  - (top left) All hits
  - (top right) Require hits in bECAL
  - (bottom left) Require no hits in bECAL
- $\Delta\eta = \frac{\eta_i - \bar{\eta}}{\bar{\eta}}, \bar{\eta} = \frac{\sum_i \eta_i E_i}{\sum_i E_i}$
  - Index i is for individual tiles with energy deposition E_i at η_i
  - Same method for $\Delta\phi$



SHOWER TRANSVERSE SIZE IN bHCAL

- Transverse size of shower in bHCAL
  - MC neutron momentum: $2\ \mathrm{GeV}/c$
  - (top left) All hits
  - (top right) Require hits in bECAL
  - (bottom left) Require no hits in bECAL

- $\Delta\eta = \frac{\eta_i - \bar{\eta}}{\bar{\eta}}, \bar{\eta} = \frac{\sum_i \eta_i E_i}{\sum_i E_i}$
  - Index i is for individual tiles with energy deposition E_i at η_i
  - Same method for $\Delta\phi$



SHOWER TRANSVERSE SIZE IN bHCAL

- Transverse size of shower in bHCAL
  - MC neutron momentum: $5\ \mathrm{GeV}/c$
  - (top left) All hits
  - (top right) Require hits in bECAL
  - (bottom left) Require no hits in bECAL

- $\Delta\eta = \frac{\eta_i - \bar{\eta}}{\bar{\eta}}, \bar{\eta} = \frac{\sum_i \eta_i E_i}{\sum_i E_i}$
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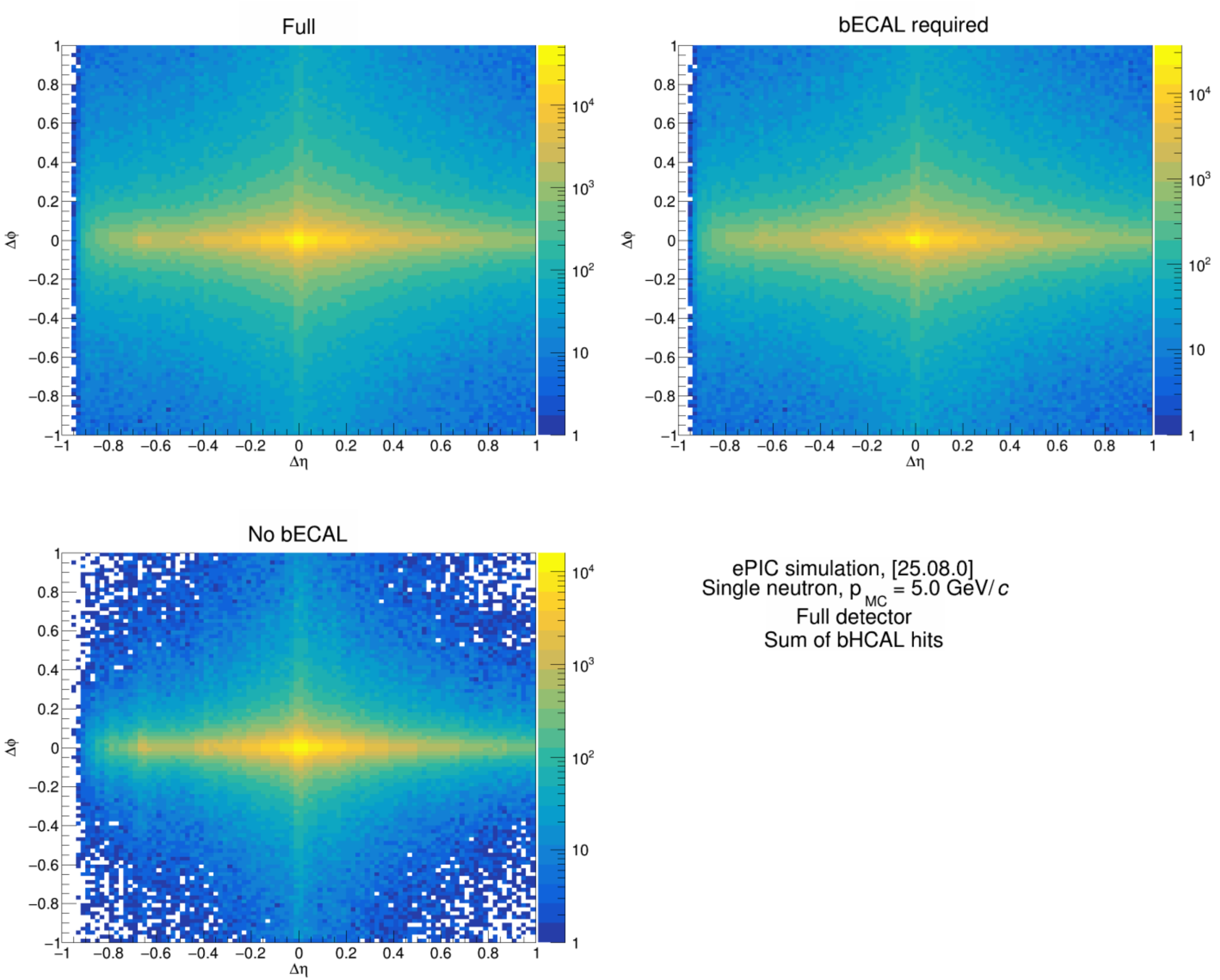
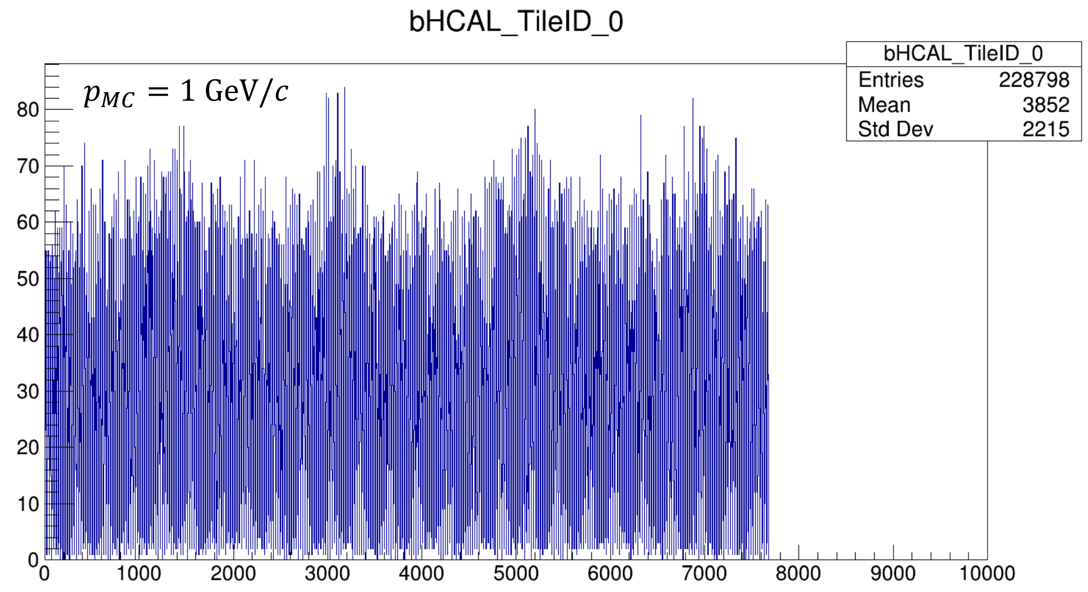
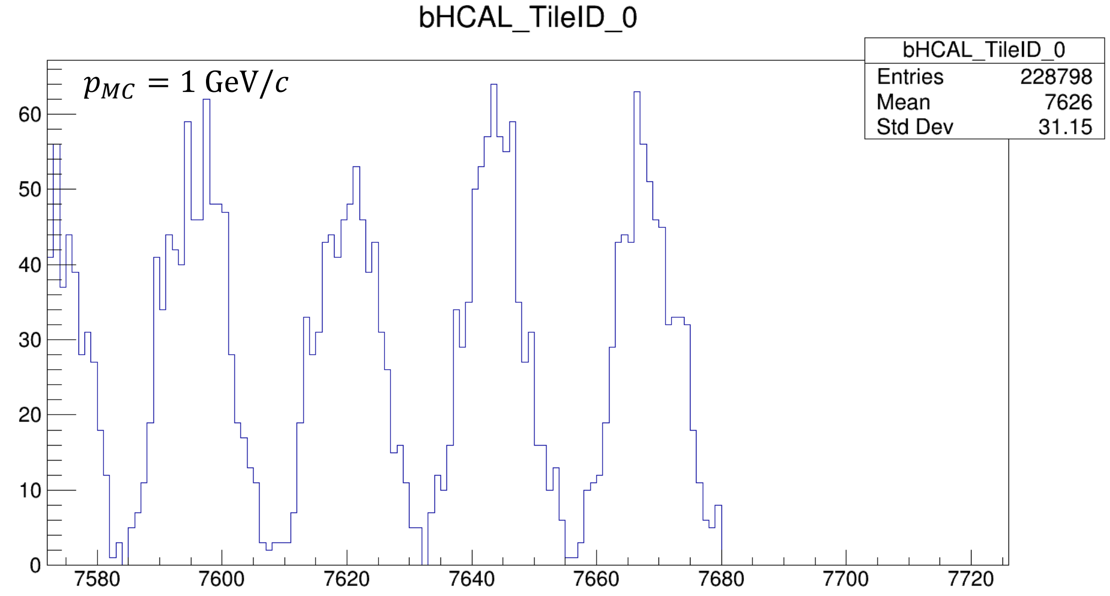


CELL ID MAPPING IN bHCAL

- One goal is to perform manual clustering
  - Need simple tile map
- Problem: Information in EICRecon output not easily usable
  - CellIDs have some form of encoding, so they are not simply tile indices starting at 0 or 1
  - Figured out manual translation of CellID from EICRecon to custom TileID
- (top) TileIDs for bHCAL calculated from CellID in full range
- (bottom) Same, but zoomed at large TileID values
  - Mapping seems to work – maximum TileID is 7680, which is the total number of bHCAL tiles
- Individual bumps should be profiles in z (η) for one row of tiles at given ϕ





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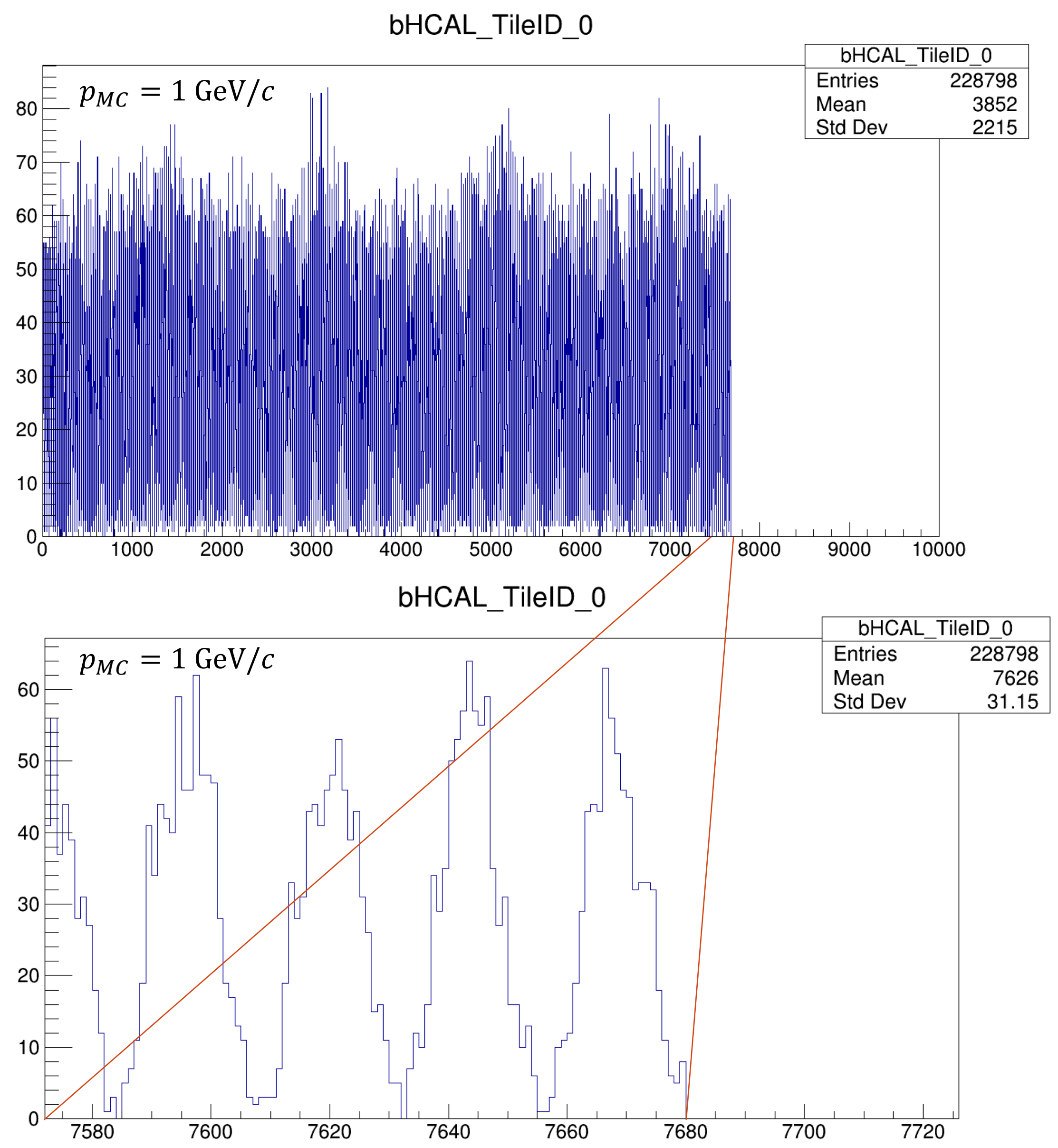

MANUAL CALIBRATION METHODS

- We have tried several 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
  - $E_{calib} = A(E_{EMCAL} + B \cdot E_{bHCAL})$
  - Plot $(E_{EMCAL} + B \cdot E_{bHCAL})/E_{par,MC}$
    - 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

- Both methods were determined to be too simple and not suitable for our purposes

SUMMARY

- Ongoing efforts to perform neutron calibrations for bHCAL

- Main challenge is energy loss in the magnet
  - Undetermined fraction of showers lost in the magnet
  - Showers can start at various places which leads to very different energy deposition in bECAL and bHCAL

- Ongoing efforts to understand how bECAL and bHCAL response depends on exact shower profile
  - Shower start
  - Shower longitudinal and transverse profile
  - Energy deposition per tile/layer
  - …

OUTLOOK

- More detailed study of shower evolution in bECAL and bHCAL
  - Ratio of energy deposition in bECAL and bHCAL
    - Similar to current simple calibration
  - Add information on size of shower
    - Number of hits, cluster size
  - Estimate energy loss in the magnet

- Make magnet sensitive volume in simulation
  - Directly retrieve the energy deposited in the magnet
  - Requires adding a new branch to EICRecon output

- Open questions about role of sampling fractions in current simulation

- More suggestions?

THANK YOU FOR ATTENTION