

# Muon Detection Study in the forward region at ePIC (for 2<sup>nd</sup> Detector)

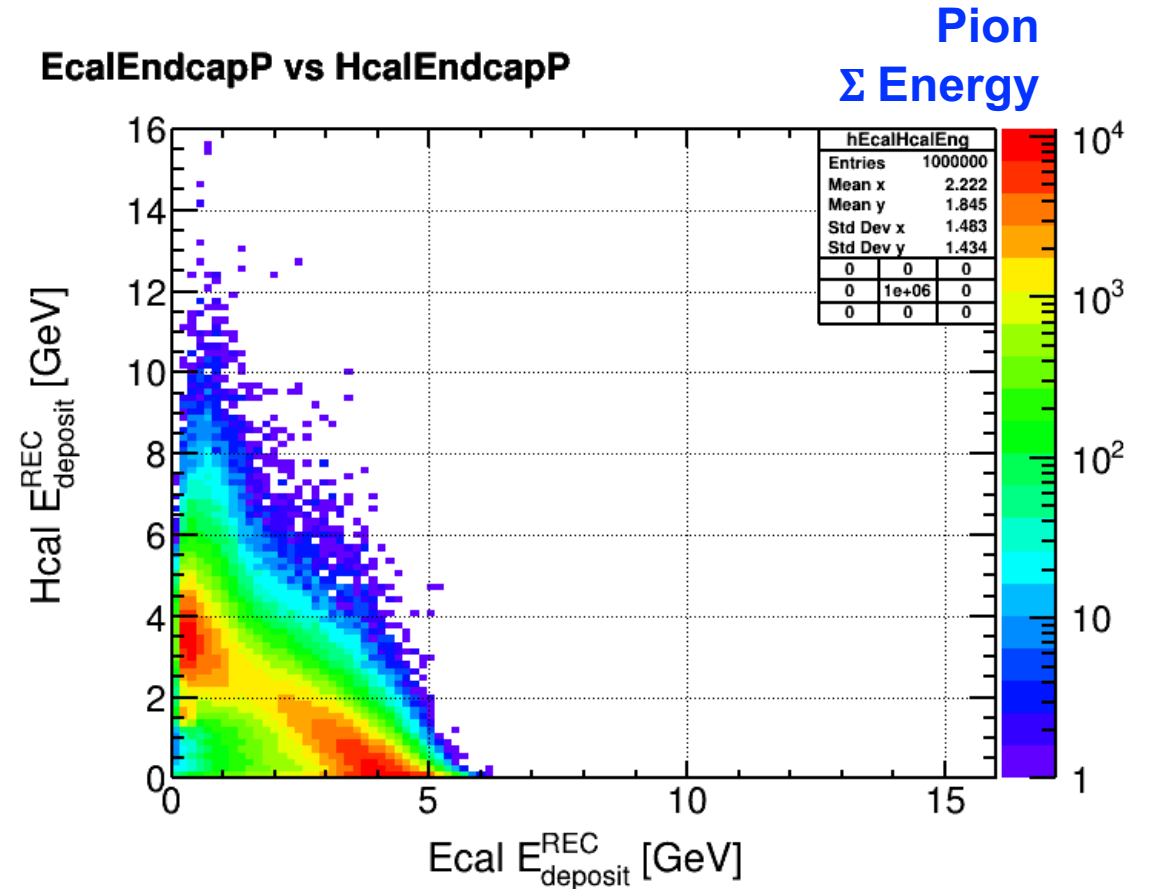
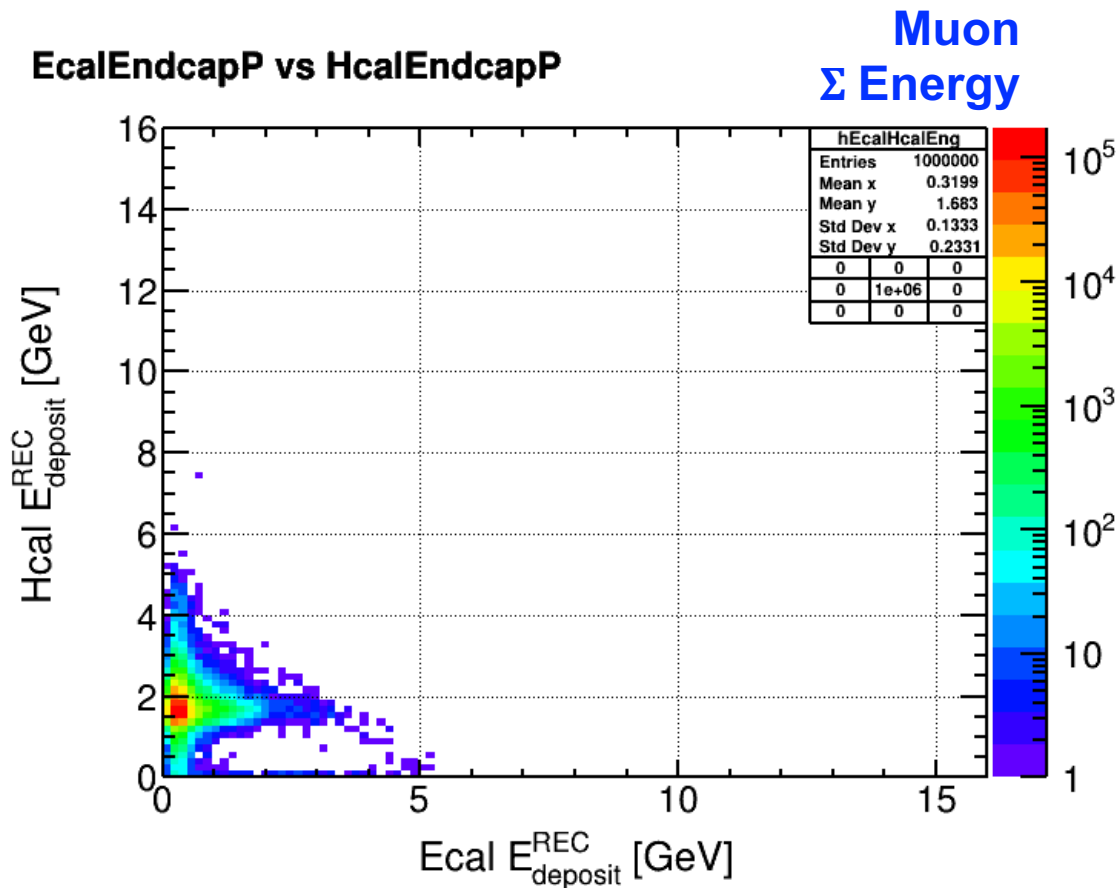
Jihee Kim ([jkim11@bnl.gov](mailto:jkim11@bnl.gov))

2024/11/04

# From Last Meeting

- Some questions were raised
  - Total energy reconstructed\* in forward ECAL (too much) and HCAL (less)  
\*Used reconstructed hits (calibrated and sampling fraction applied)
  - MIP-like event in pion sample in forward ECAL (less)  
Expected about 37 % of pions will be MIP-like event in ECAL ( $e^{-\lambda} = e^{-1} = 0.37$ )

# Reconstructed Energy in Forward

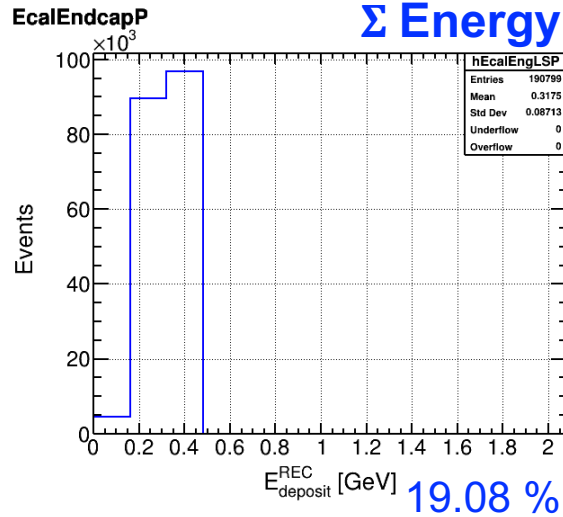


While muon sample has one hot spot, pion sample has three groups; pions showering from ECAL, pions showering from HCAL, and pions not showering at all (MIP-like)

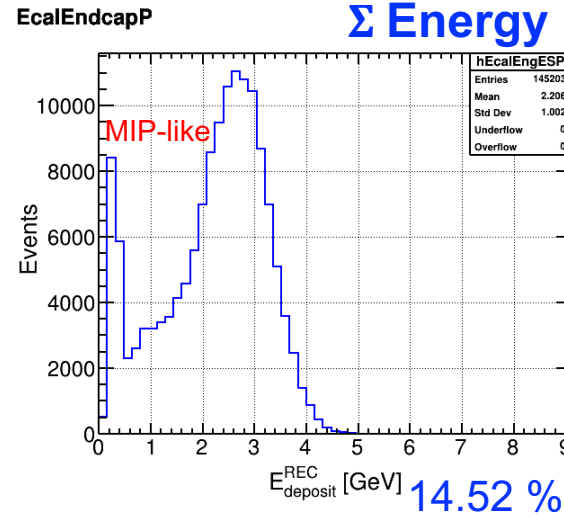
$p = 5 \text{ GeV}$  and  $\eta = 1.74$

# Pion Sample – $\Sigma$ Energy

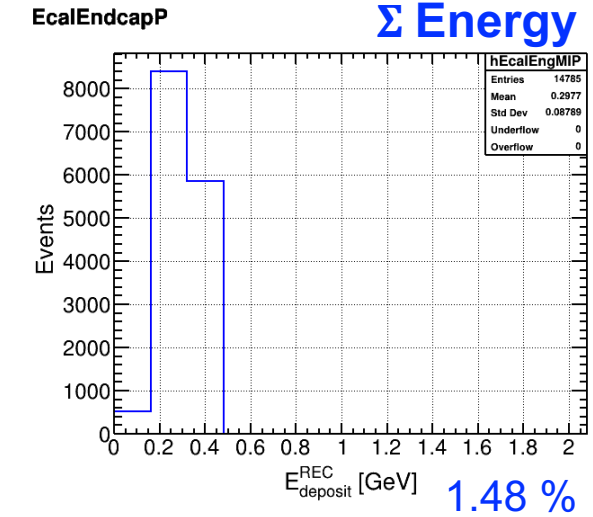
MIP-like in ECAL  
 $\Sigma$  Energy



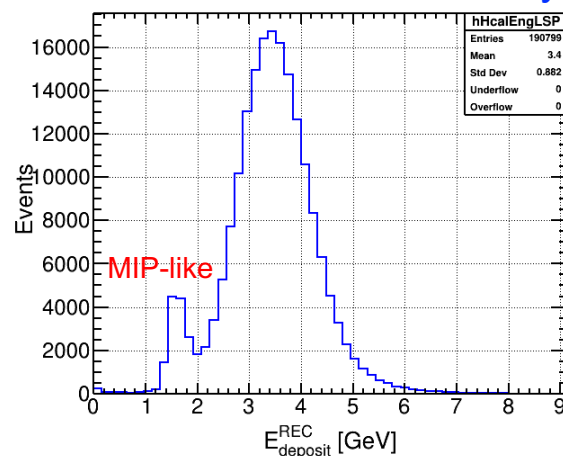
MIP-like in HCAL  
 $\Sigma$  Energy



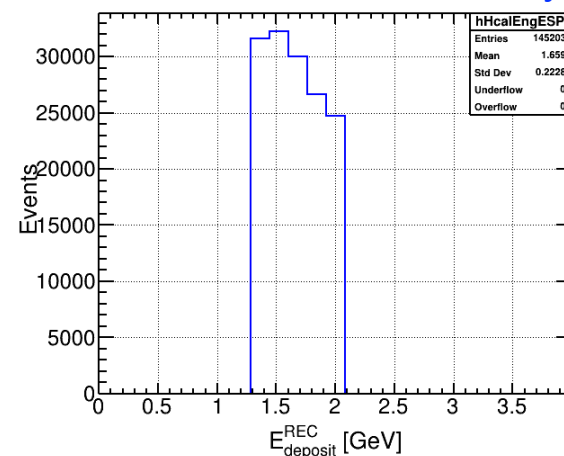
MIP-like in ECAL & HCAL  
 $\Sigma$  Energy



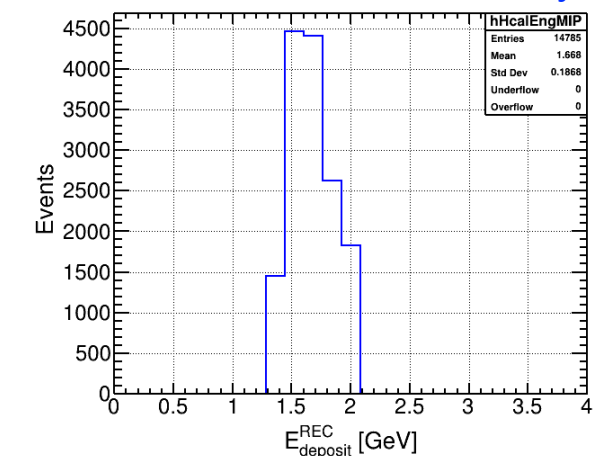
HcalEndcapP  
fake-ID efficiency



HcalEndcapP  
fake-ID efficiency



HcalEndcapP  
fake-ID efficiency



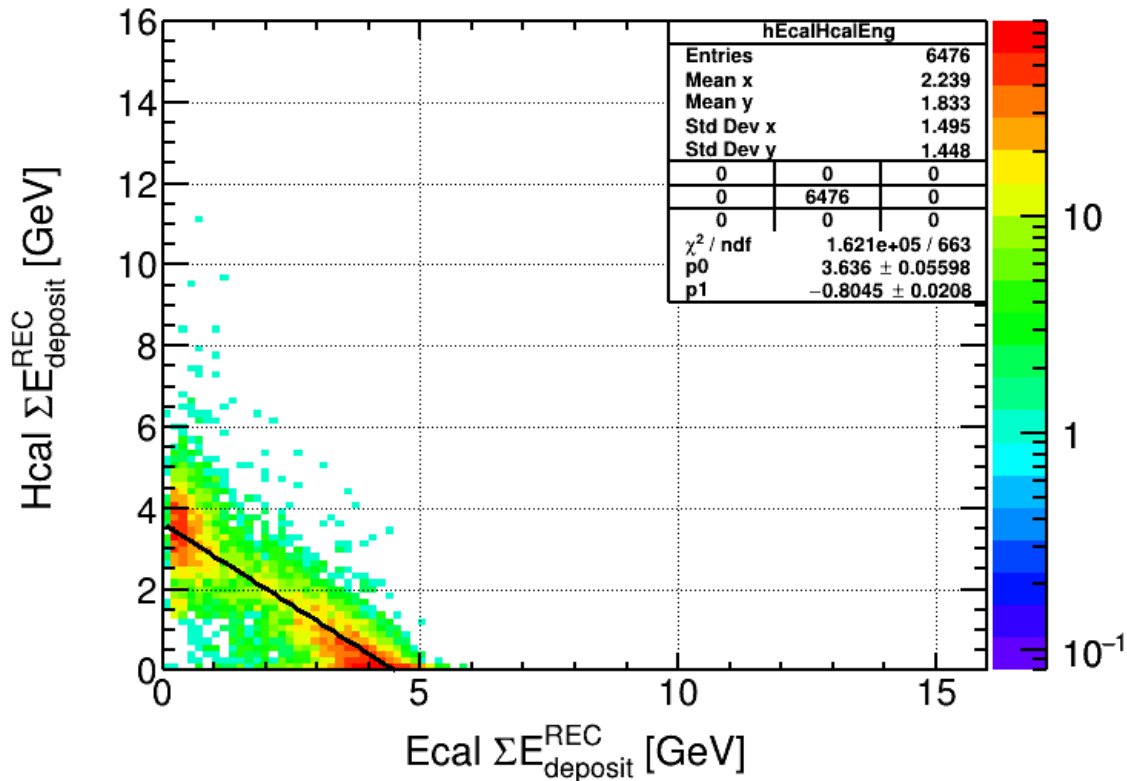
# To Understand Forward ECAL Better

- ☐ Compare with ePIC official simulation campaign single particle event
- ☐ Check material scan
- ☐ Check detector implementation

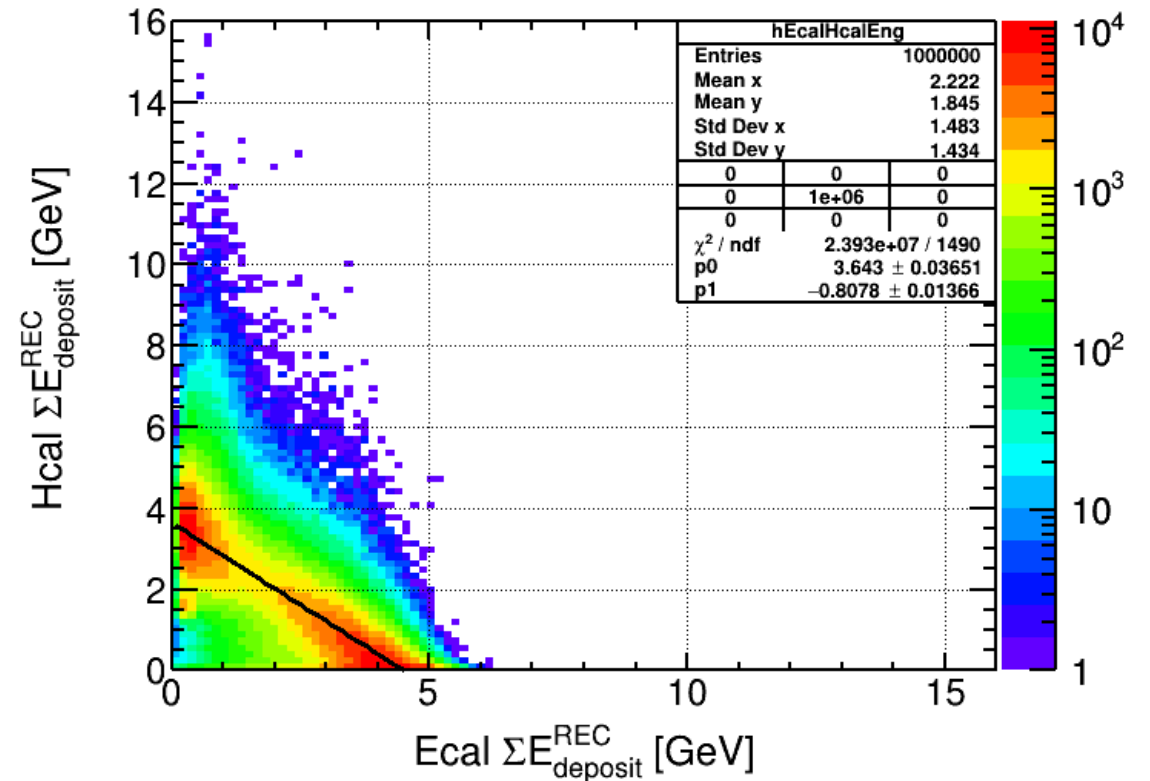
$p = 5 \text{ GeV}$  and  $\eta = 1.74$

# Reconstructed Energy in Forward

EcalEndcapP vs HcalEndcapP



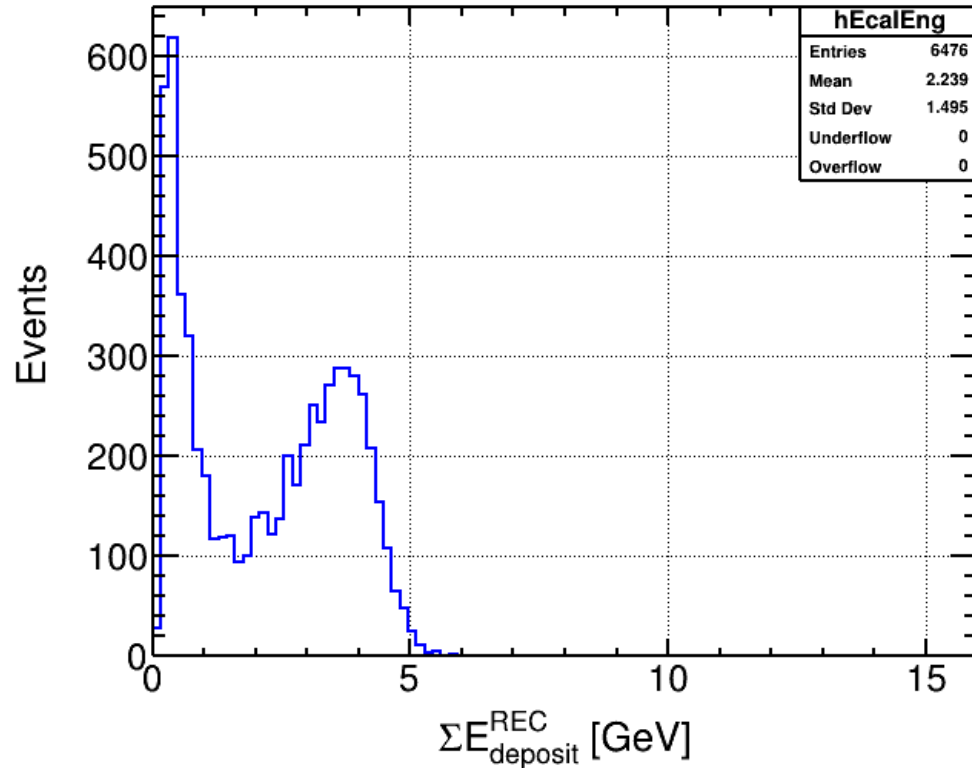
EcalEndcapP vs HcalEndcapP



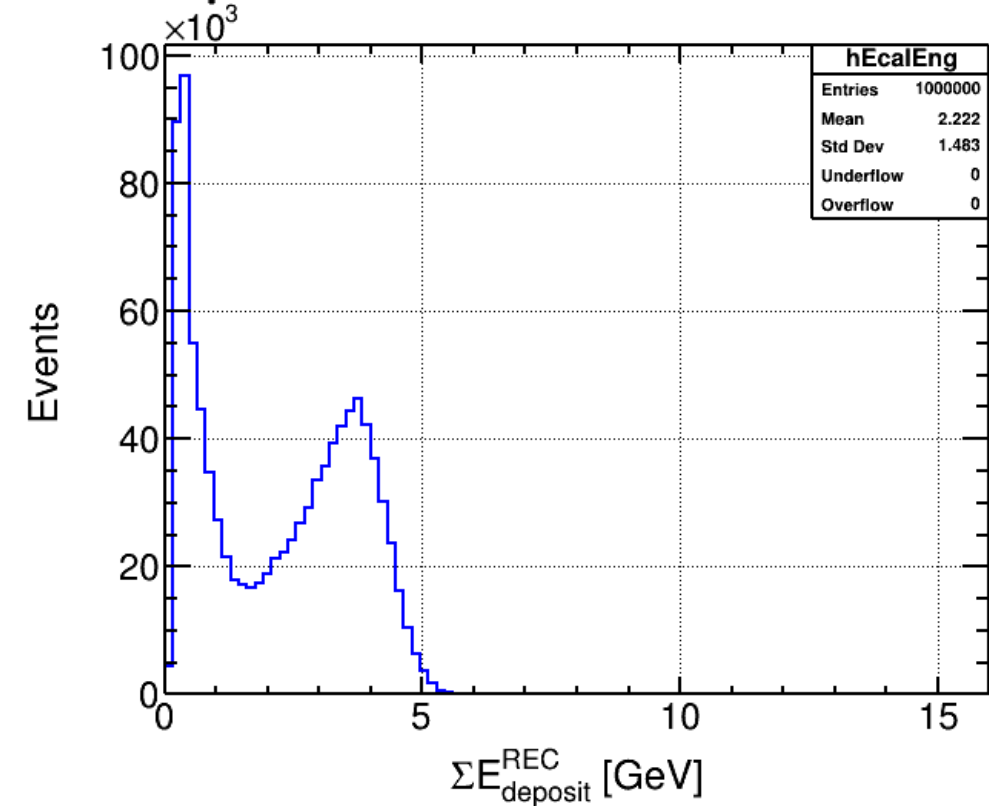
To fit a linear function to  $E_{\text{HCal}}$  vs.  $E_{\text{ECAL}}$  to extract energy sharing parameter

# Reconstructed Energy in Forward ECAL

EcalEndcapP

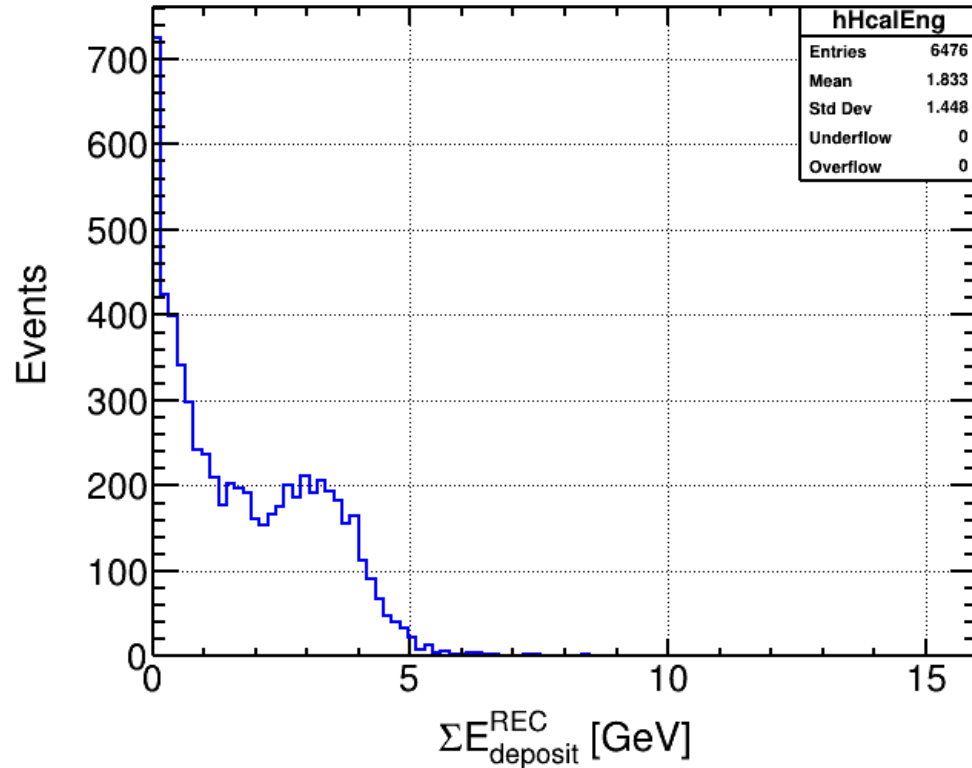


EcalEndcapP

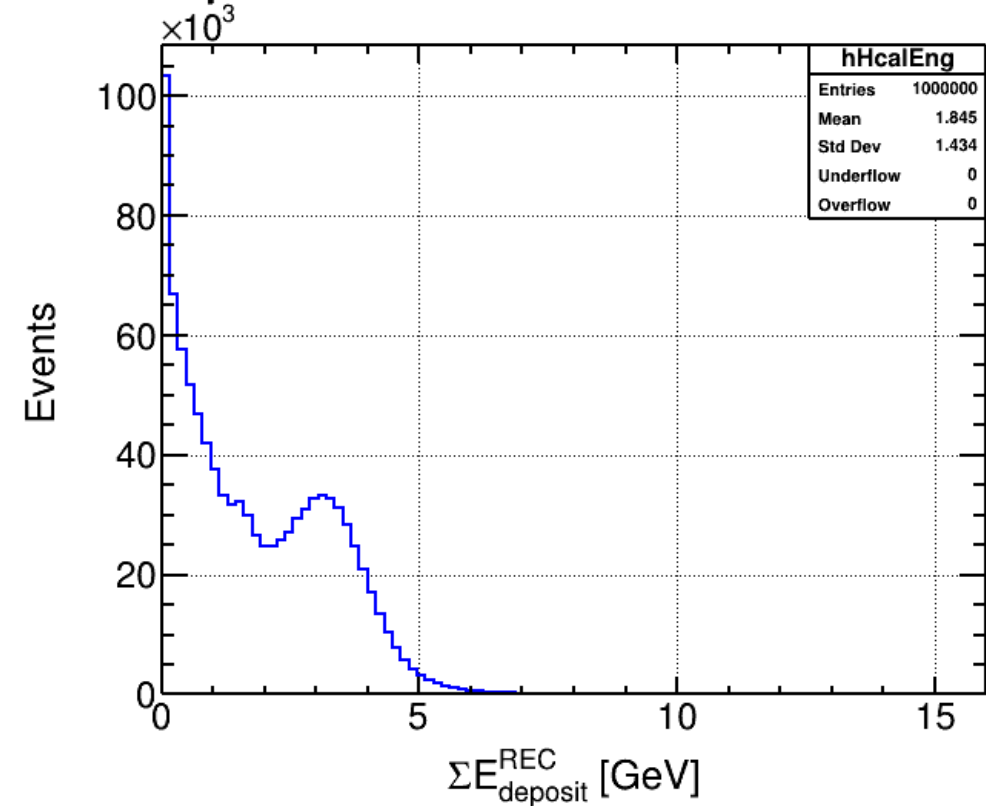


# Reconstructed Energy in Forward HCAL

HcalEndcapP



HcalEndcapP

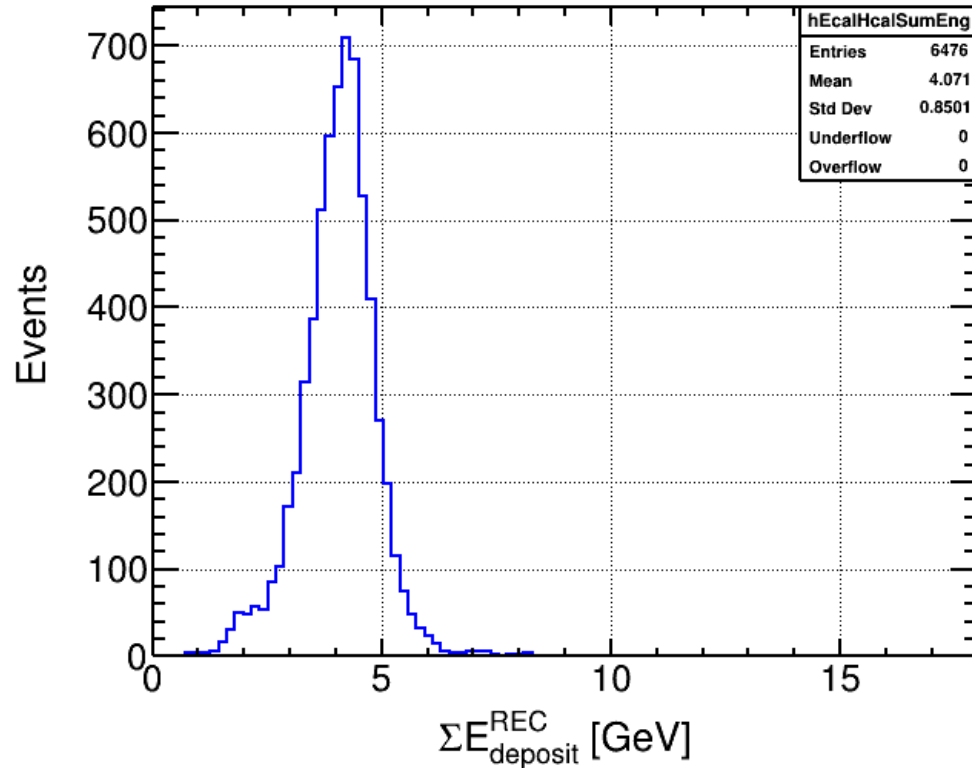




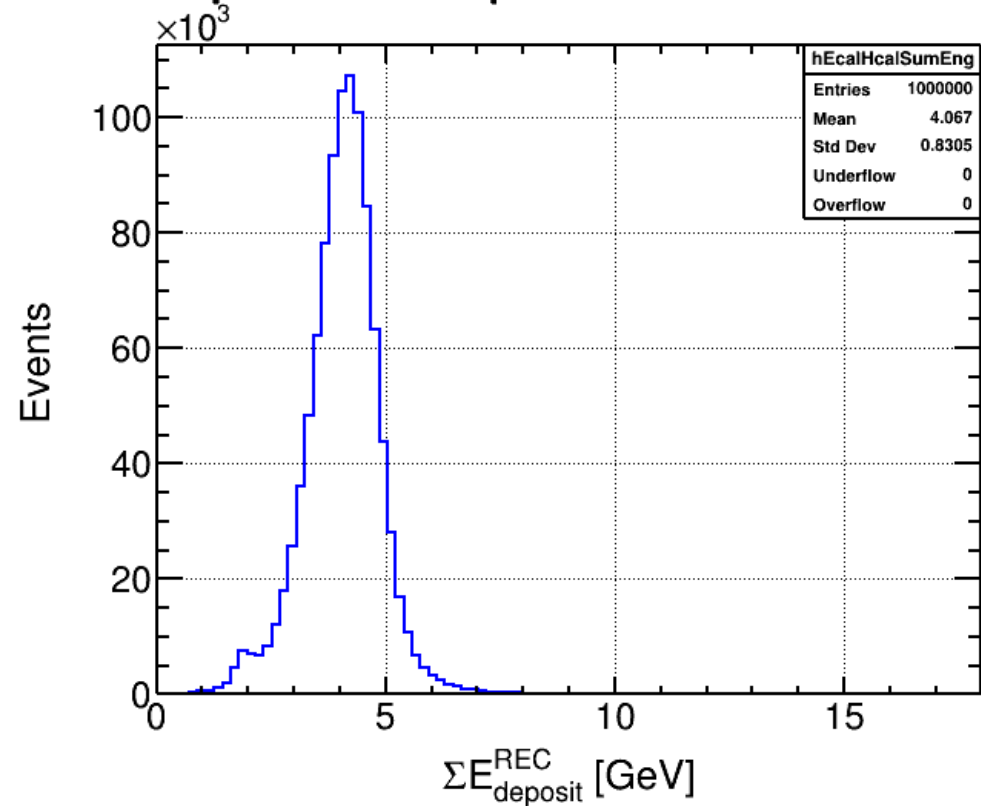
w/o energy sharing parameter

# Sum of Reconstructed Energy

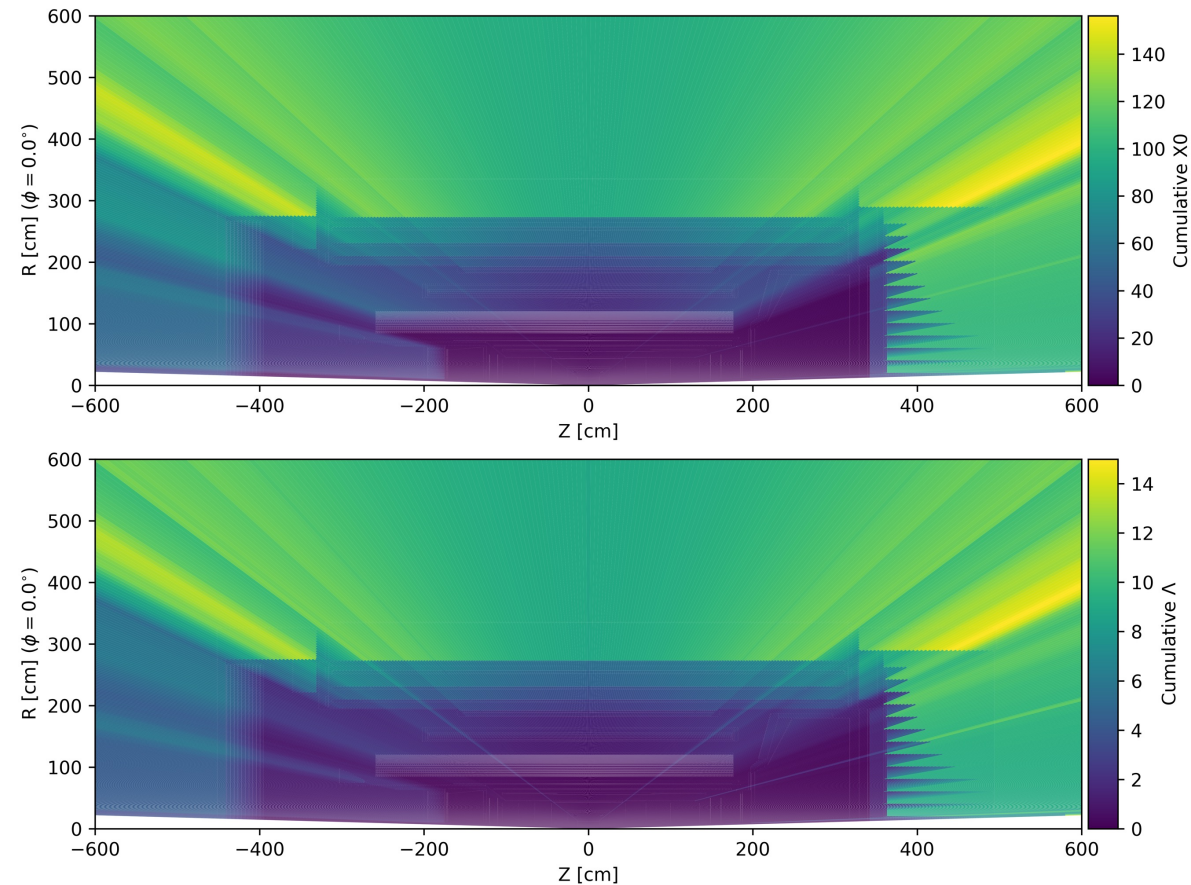
EcalEndcapP + HcalEndcapP



EcalEndcapP + HcalEndcapP

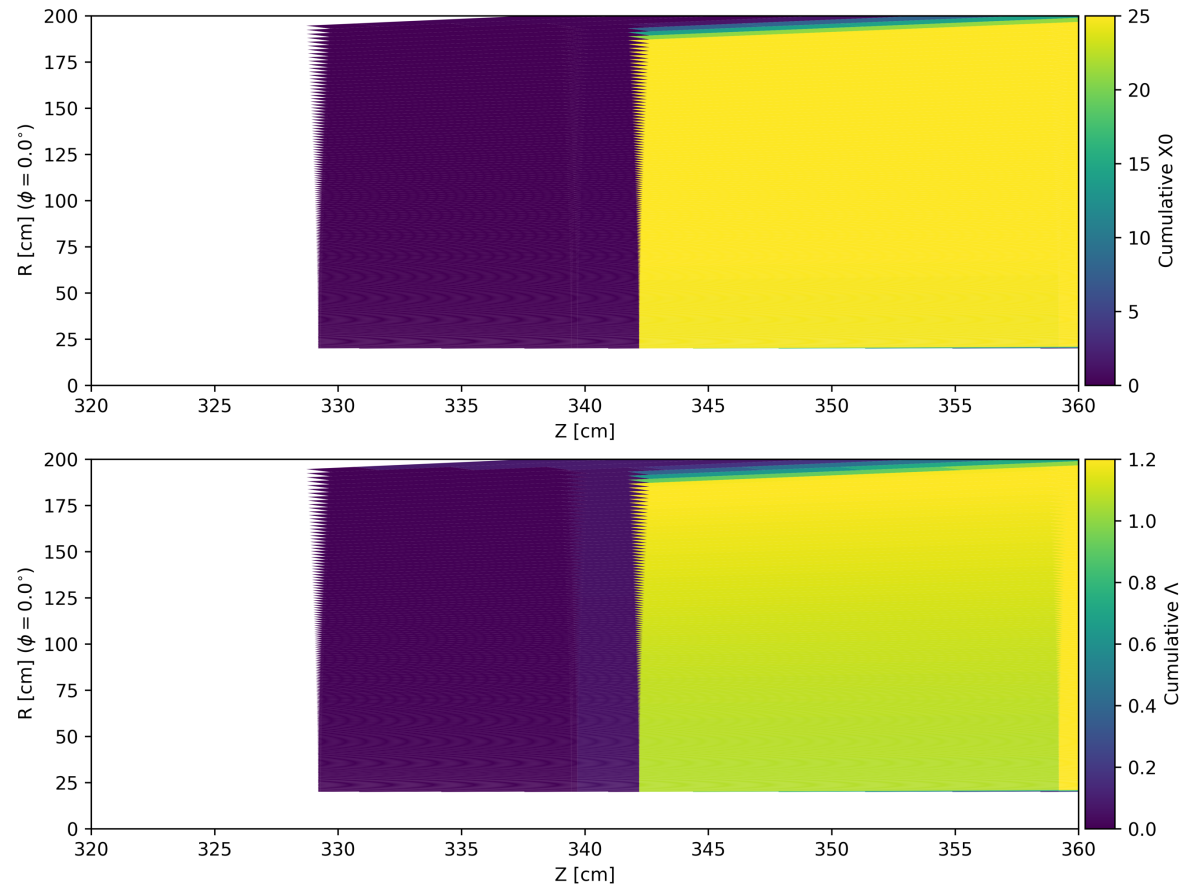


# Material Scan – ePIC craterlake



Thanks to Chao Peng <https://github.com/eic/epic/pull/780>

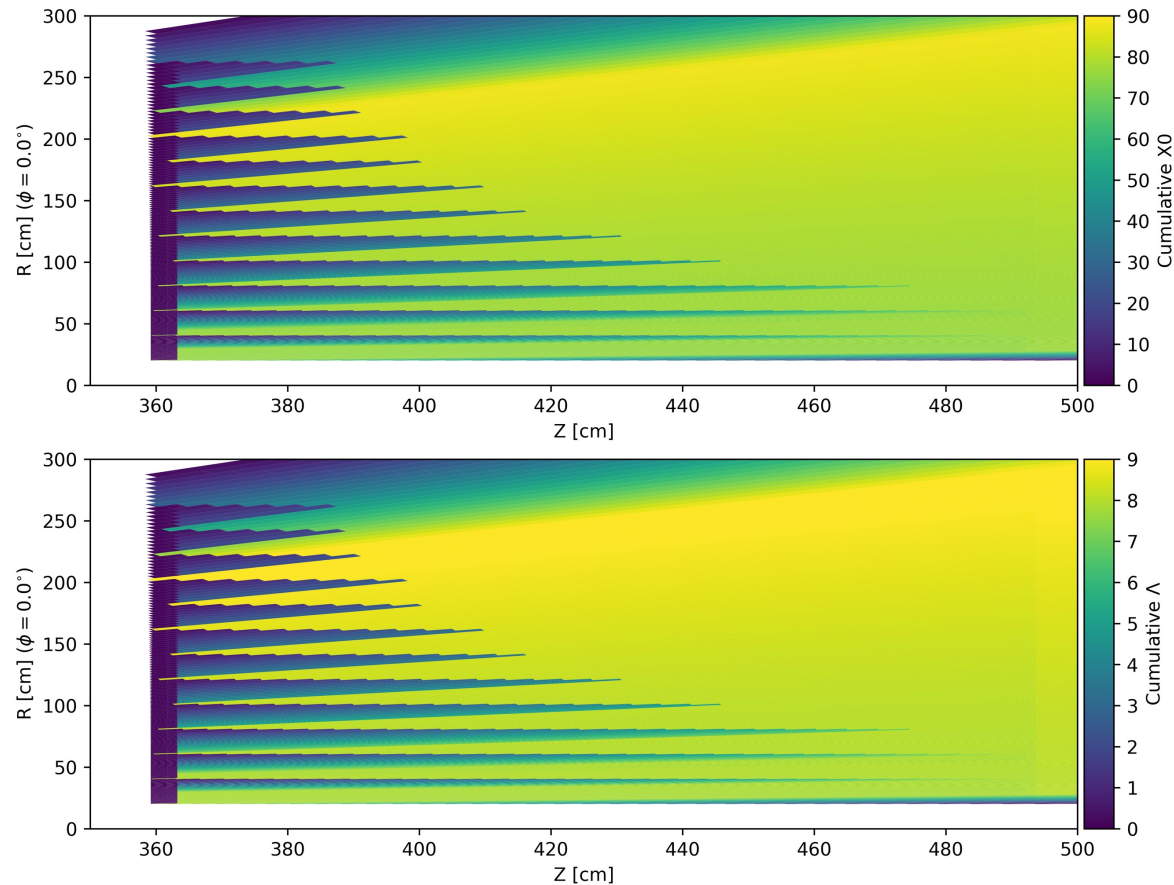
# Material Scan – Forward ECAL



Aluminum cover, air gap (10.15 cm), PCB, light guide (2.5 cm), and Scintillating material (17 cm)

- WScFi
- 30 cm length
- 1 layer
- $20 \text{ cm} < r < 195 \text{ cm}$
- $329.2 \text{ cm} < z < 359.2 \text{ cm}$
- $23 X_0$  (ref.  $X_0 = 7 \text{ mm}$ ) and  $2.5 \text{ cm} \times 2.5 \text{ cm}$  in transverse direction
- According to Zhongling Ji, in DD4hep/Geant4 it uses a homogeneous structure – energy sampling fraction is 100 %. Since real forward ECAL has a sampling fraction of 3 %, it rescaled energy in EICRecon

# Material Scan – Forward HCAL




- Steel-plastic scintillator sandwich
- 134.54 cm length
- $r_{\text{max}} = 289.56$  cm
- $359.2 \text{ cm} < z < 493.74 \text{ cm}$
- $6.5 \lambda/\lambda_0$  and  $5 \text{ cm} \times 5 \text{ cm}$  in transverse direction
- SiPM signals from tiles in 5-10 consecutive layers are summed up before digitization




# Next Steps

- Questions on forward ECAL simulation
  - Continue communicating with Zhongling Ji (postdoc, UCLA)
- Next move,
  - Discussed with Maria Zurek
  - Layer by Layer in HCAL (depth-dependent)
  - Shower or not? (wide distribution)
  - Energy/Position/# of hit titles per layer

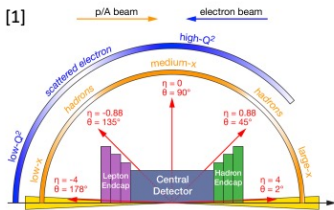


## Simulation Results of Proton-Endcap ECAL of the ePIC Experiment at Electron-Ion Collider

**Zhiwan Xu and Zhongling Ji, UCLA**  
for the ePIC pECAL Detector Consortium



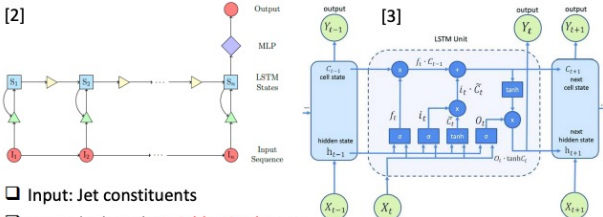
### ePIC Detector



- p/A beam: Forward/positive direction
- Electron beam: Backward/negative direction
- Hadron endcap (W/ScFi pECAL): Sampling ECAL, good energy resolution
- Lepton endcap (EEEMC): Homogeneous ECAL, excellent energy resolution

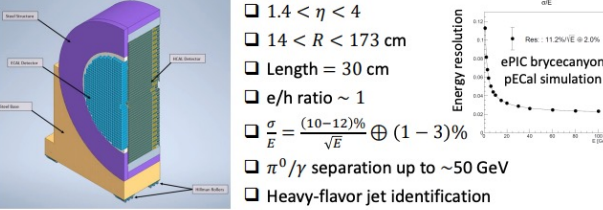
Focus on pECAL

### Long Short-Term Memory



- Input: Jet constituents
- LSTM deals with **variable-sized input**
- Cell states **memorize** previous input
- Previous hidden state ( $h_{t-1}$ ) and current input ( $X_t$ ) produce forget gate ( $f_t$ ), input gate ( $i_t$ ), cell candidate ( $\tilde{C}_t$ ), and output gate ( $O_t$ )
- Previous cell state ( $C_{t-1}$ ) and cell candidate ( $\tilde{C}_t$ ) produce current cell state:  $C_t = f_t \cdot C_{t-1} + i_t \cdot \tilde{C}_t$
- Cell state ( $C_t$ ) has memory and produces the next hidden state ( $h_{t+1}$ ) and the current output ( $Y_t$ ):  $Y_t = h_{t+1} = O_t \cdot \tanh C_t$

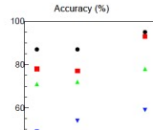
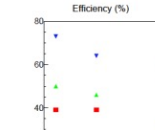
### pECAL Designs [1]



- $1.4 < \eta < 4$
- $14 < R < 173$  cm
- Length = 30 cm
- e/h ratio ~ 1
- $\sigma_E = \frac{(10-12)\%}{\sqrt{E}} \oplus (1-3)\%$
- $\pi^0/\gamma$  separation up to ~50 GeV
- Heavy-flavor jet identification

### Heavy-Flavor Jet Identifications

- Use LSTM to identify HF jets
- Input: Jet constituents
  - Four momentum
  - Track mom, E/HCAL energy
- Pythia DIS events:

# Backup Slides