Development of Future Electromagnetic Calorimeter Technologies and Applications for the Electron-Ion Collider with GEANT 4 Simulations

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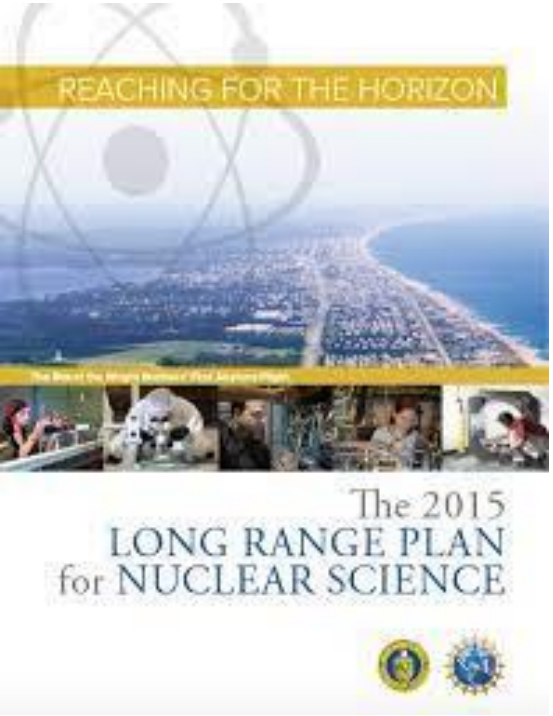
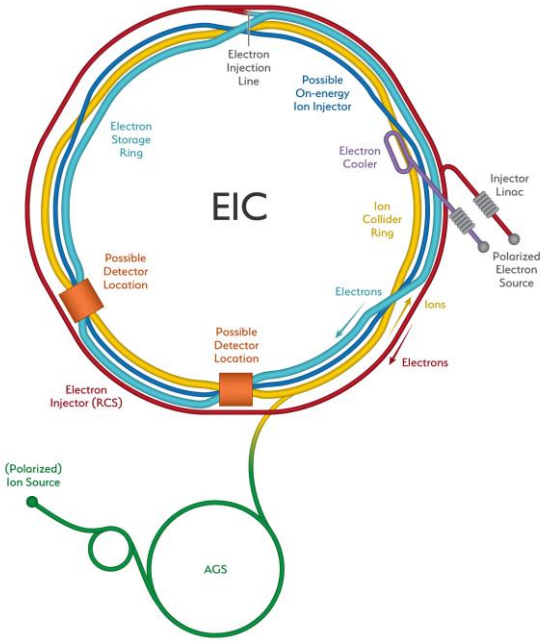
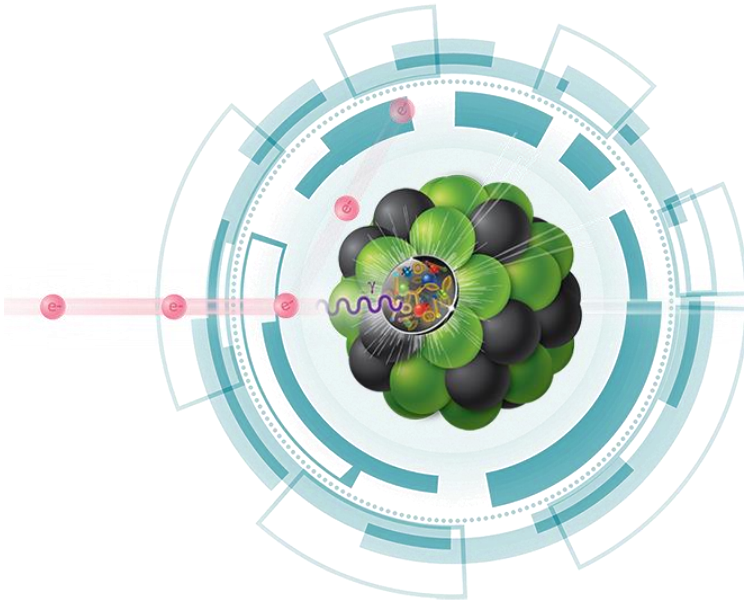
Introduction

DOE Long Range Plan for Nuclear Science – The Electron Ion Collider (EIC)







<u>Information about the EIC</u>

- Planned to be built at BNL in around 2030
- High luminosity and highly polarized beam
- Electron colliding with a variety of nuclei species at different energies
- Broad kinematic range coverage

Electromagnetic Calorimeters for EIC

EIC Physics Goals

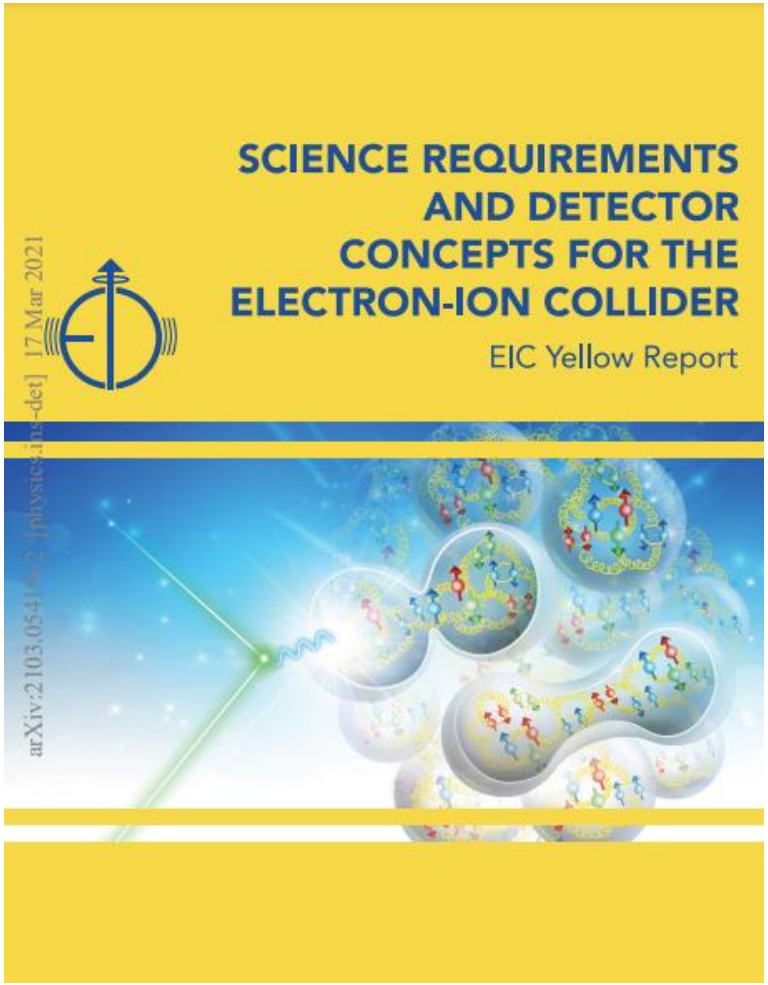
- Precision 3D imaging of nucleons and nuclei
- Proton spin structure
- Gluon saturation
- Color confinement

EIC EMCAL Requirements

- Excellent energy resolution
- Excellent electron identification capabilities
- High energy $\pi^0 \rightarrow \gamma\gamma$ reconstruction

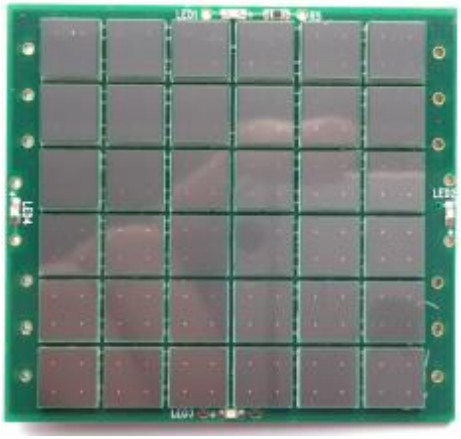
Technical Challenges

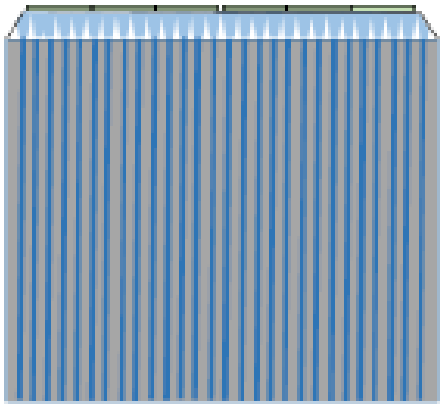
- Limited space → compact EMCAL design
- High granularity with high performance
- Radiation damage on SiPMs by neutrons



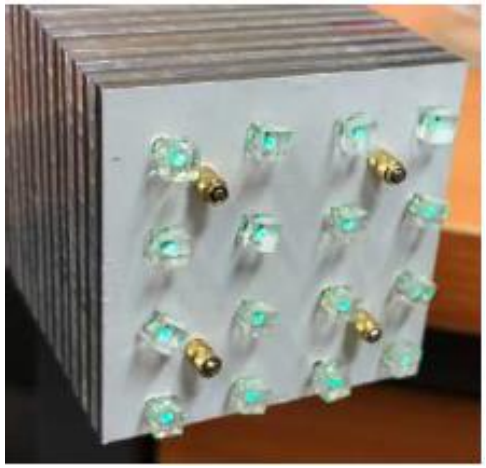
Proposed EIC EMCAL Design Options

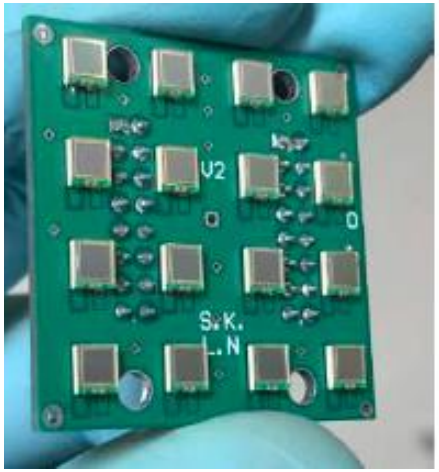
W/SciFi SPACAL design with more SiPMs and shorter light guides to have larger photocathode coverage





W/Shashlik tower design with high granularity and efficient readout



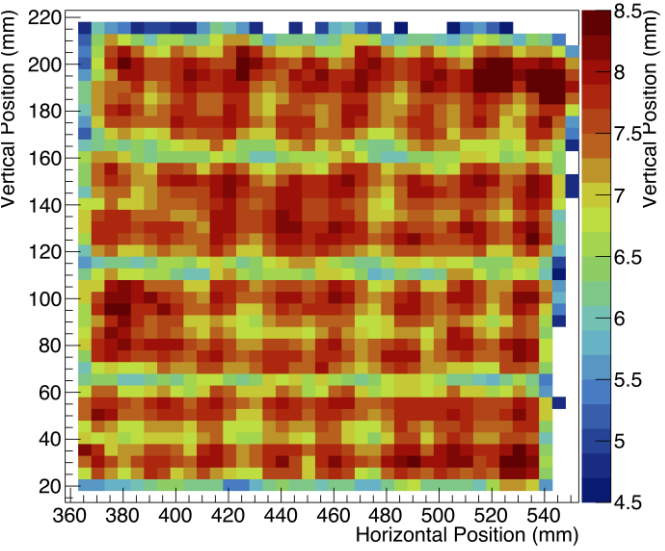


Proposed Novel Technologies

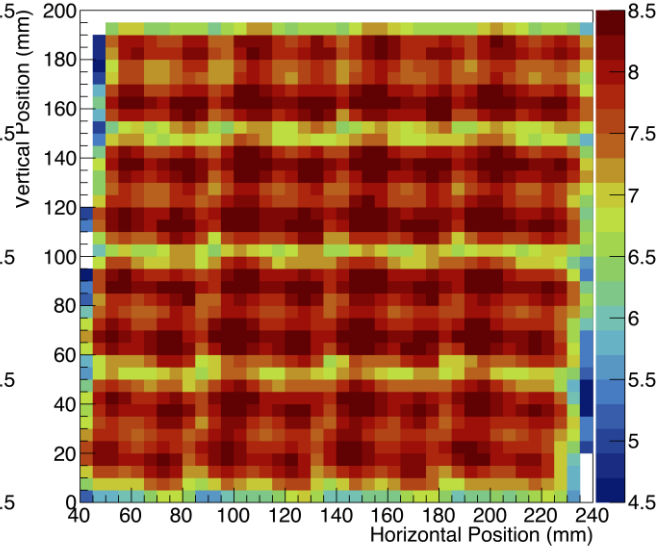
- W absorber for EMCAL to allow compact design to save space, crucial for EIC experiments
- Novel SiPMs with larger area and finer pixel size to improve light collection efficiency and uniformity
- High granularity shashlik calorimeter with SiPM readout on every fiber

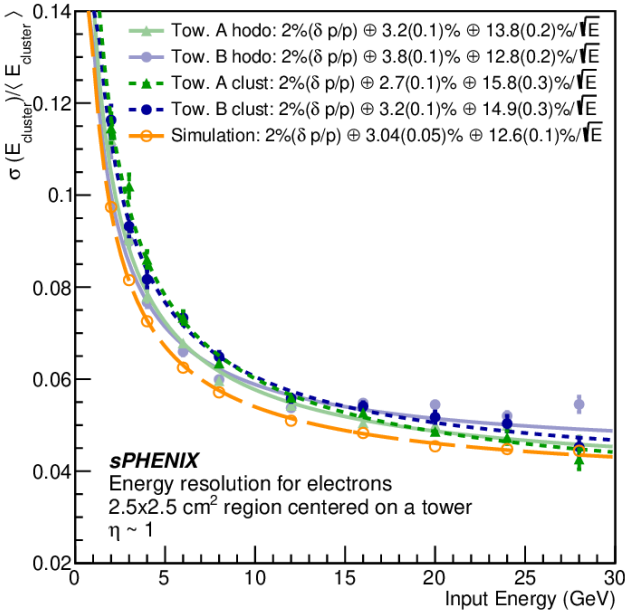
sPHENIX W/SciFi EMCAL Uniformity and Energy Resolution

Data



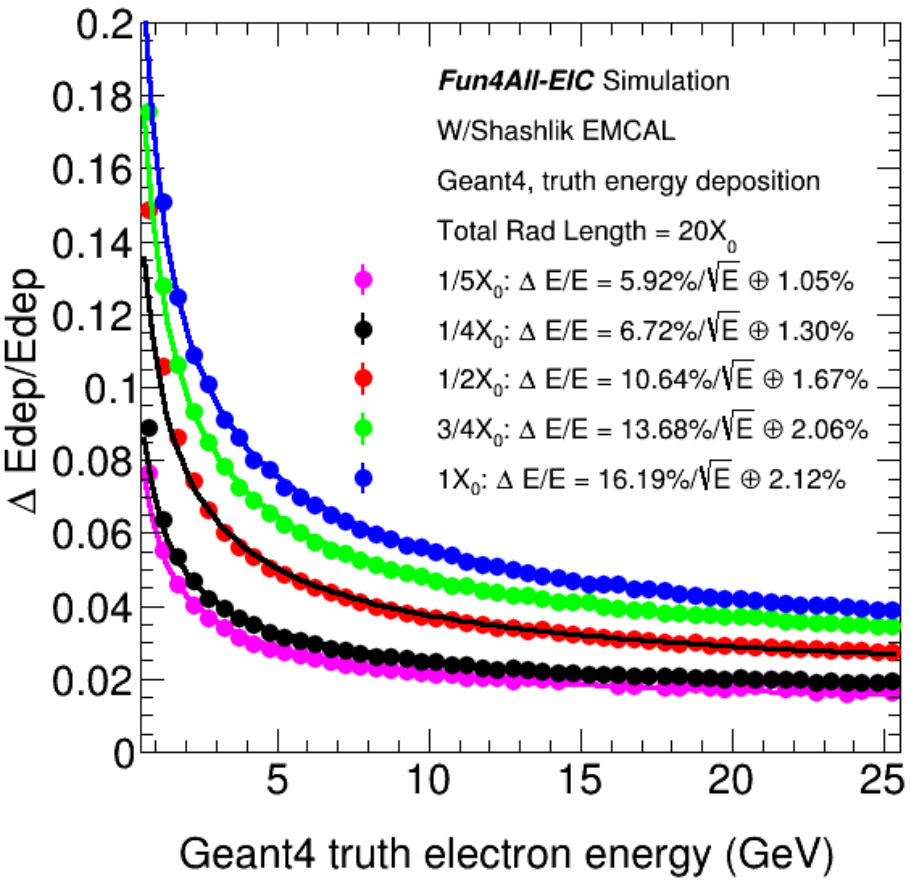
Simulation

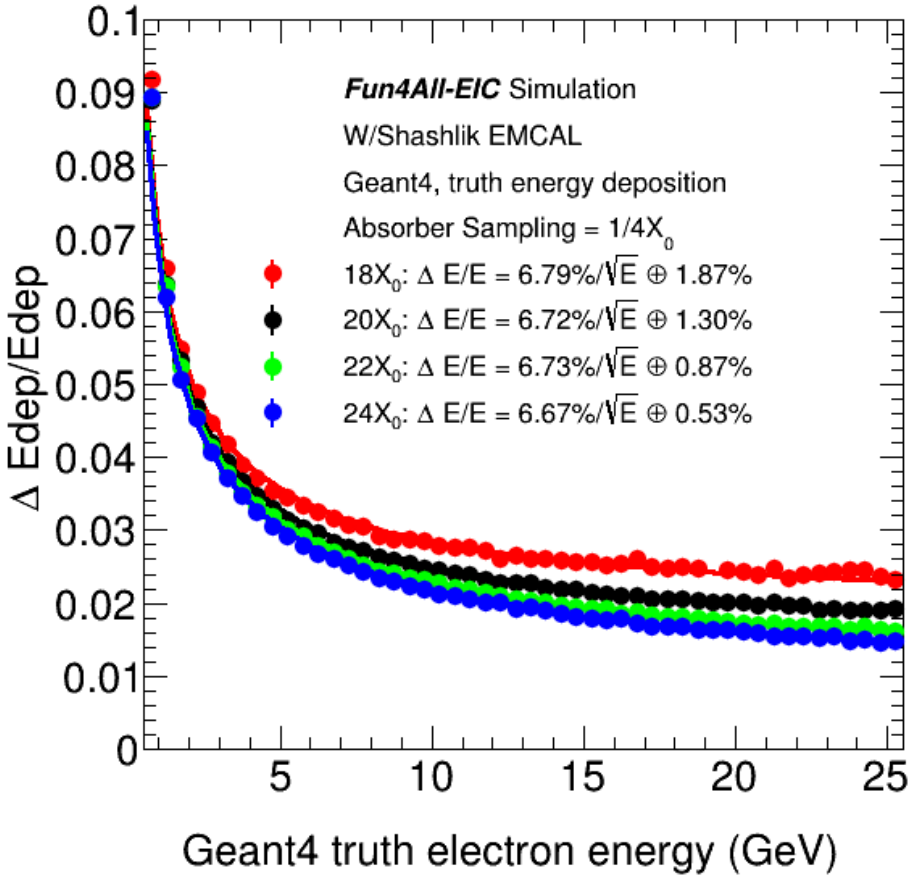




- Reasonably good agreement between the data and the simulation
- Significant non-uniformity, particularly between the block boundaries and the center of four blocks → position dependent correction with the simulations
- The uniformity and energy resolution both meet the requirements to achieve sPHENIX physics goals

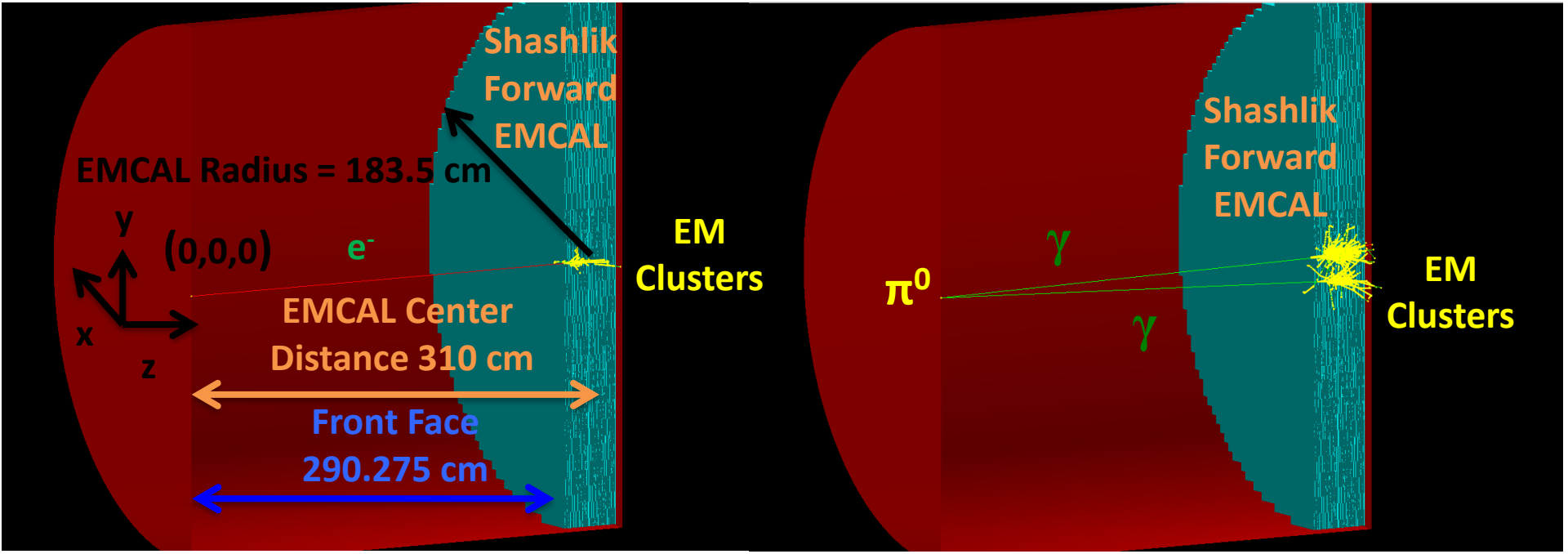
W/Shashlik EMCAL Energy Resolution





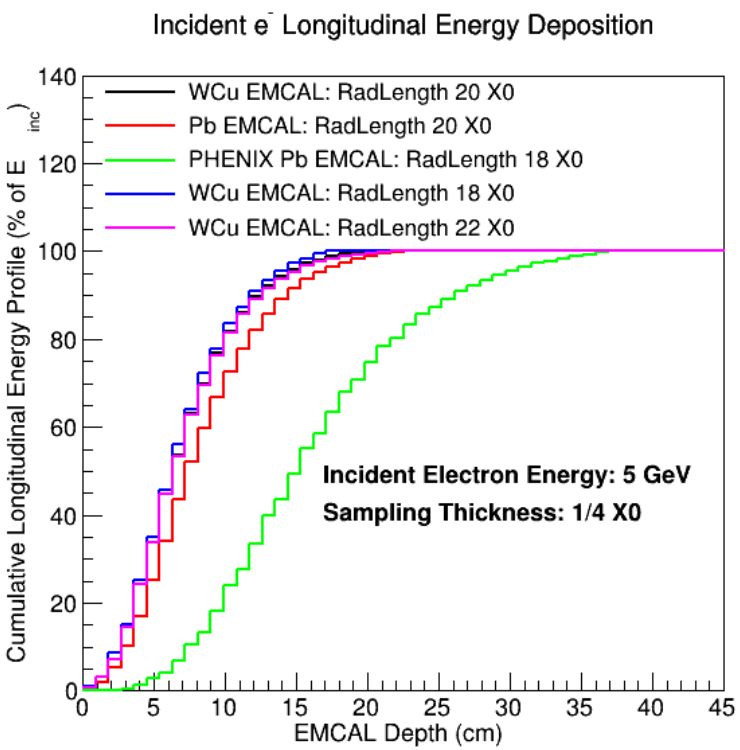
- The statistical term of the shashlik EMCAL improves as the sampling frequency increases
- The constant term of the shashlik EMCAL improves as the total radiation length increases
- This work is included in the EIC Yellow Report and ECCE and EIC Calorimetry workshops

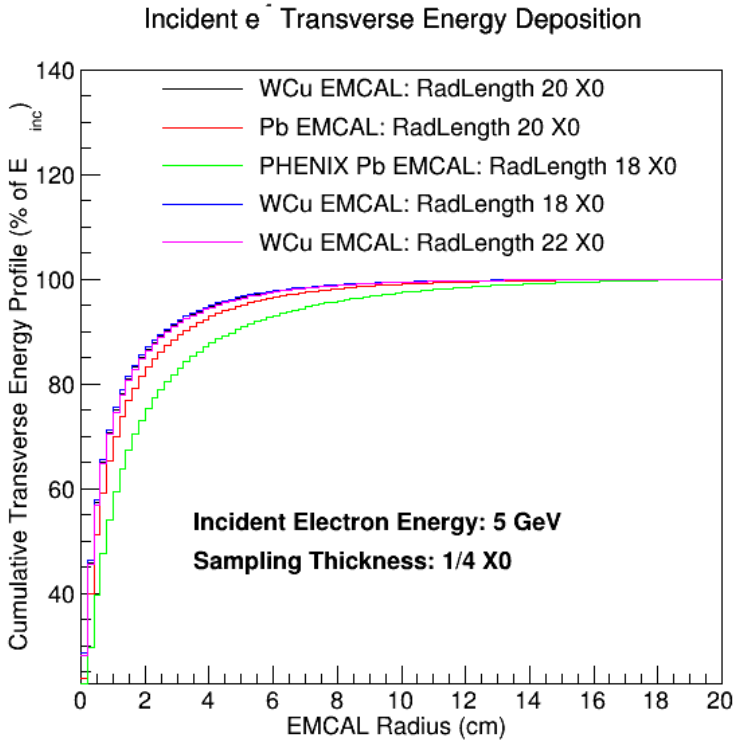
Event Displays of EIC Shashlik Forward EMCAL



- **Forward EMCAL:** hadron beam going direction
- **Left setup:** electron beam used to characterize the general performance of the shashlik forward EMCAL
- **Right setup:** π^0 beam at normal incidence used to reconstruct π^0 and study the merging probability of the two photon clusters into one

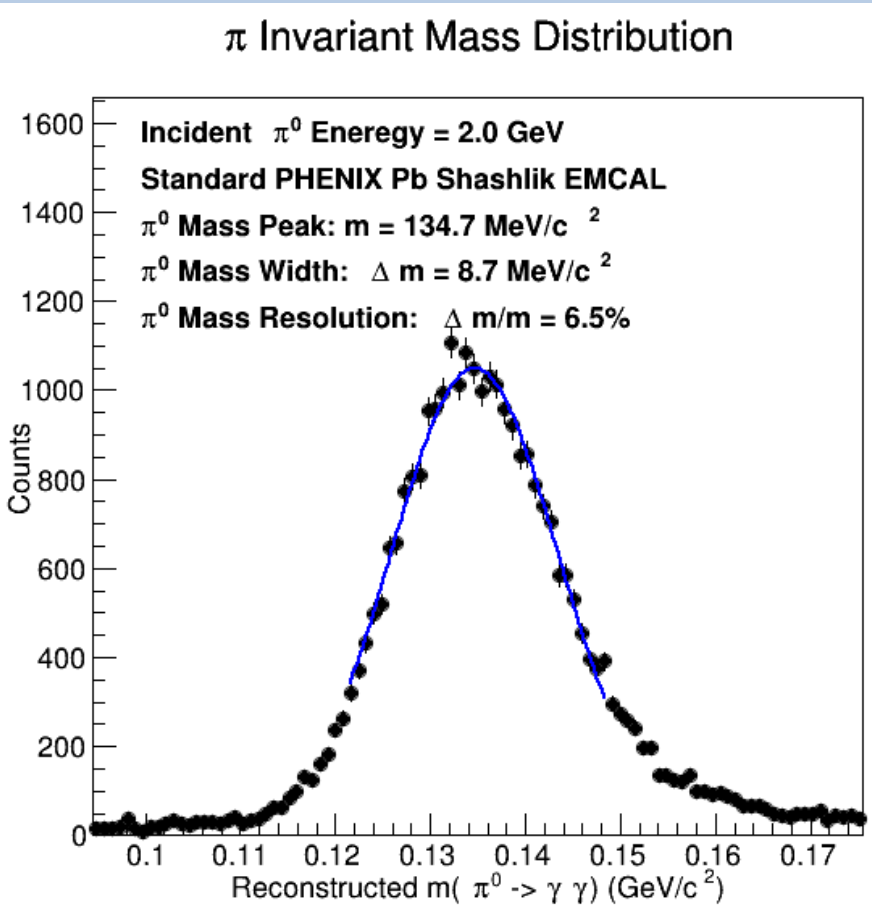
Forward Shashlik EMCAL Shower Profile

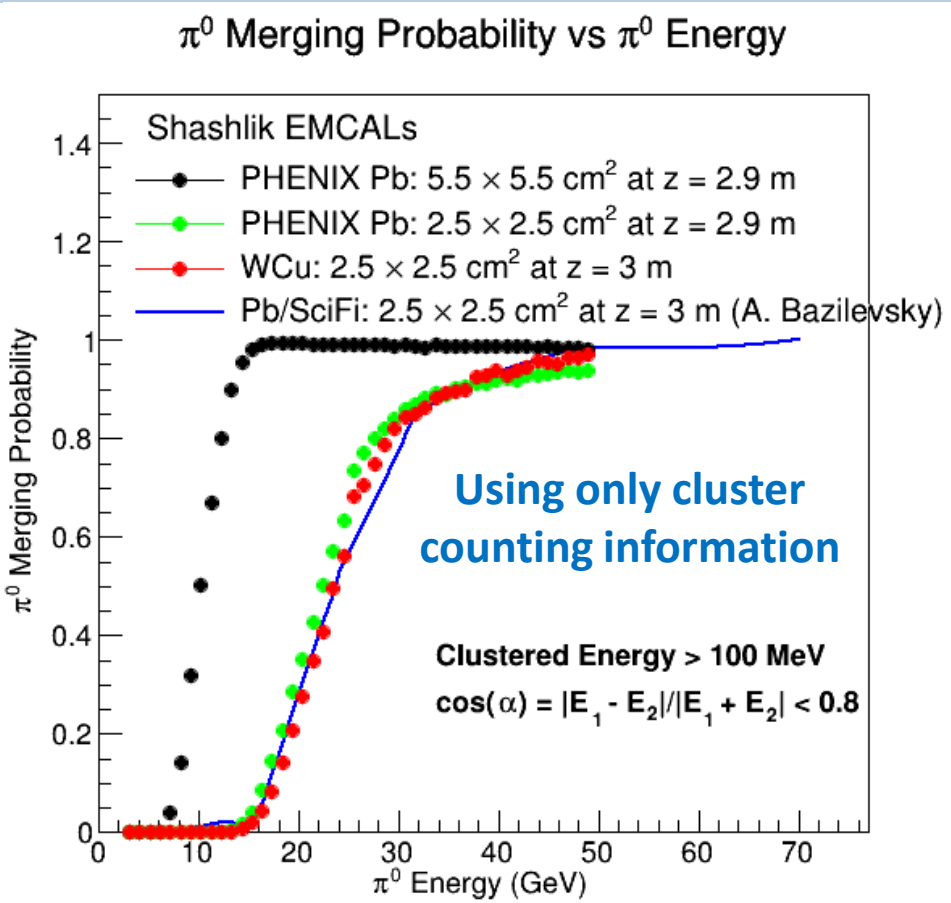




- **PHENIX EMCAL as reference:** Pb Shashlik EMCAL with total radiation length of 18 X0, scintillator thickness of 4.0 mm, and tower granularity about 5.5 × 5.5 cm^2
- **WCu**: an alloy of 80% W and 20% Cu absorber material for EIC shashlik EMCALs
- **WCu and Pb:** scintillator thickness of 1.5 mm
- **Longitudinal shower profile – effective radiation length:** PHENIX > Pb > WCu
- **Simulated Moliere radius:** WCu = 2.65 cm, Pb = 3.15 cm, PHENIX = 4.15 cm, reasonably consistent with the expected results WCu = 2.5 cm, Pb = 3.3 cm, and PHENIX = 4.5 cm

π^0 Reconstruction and Merging Probabilities

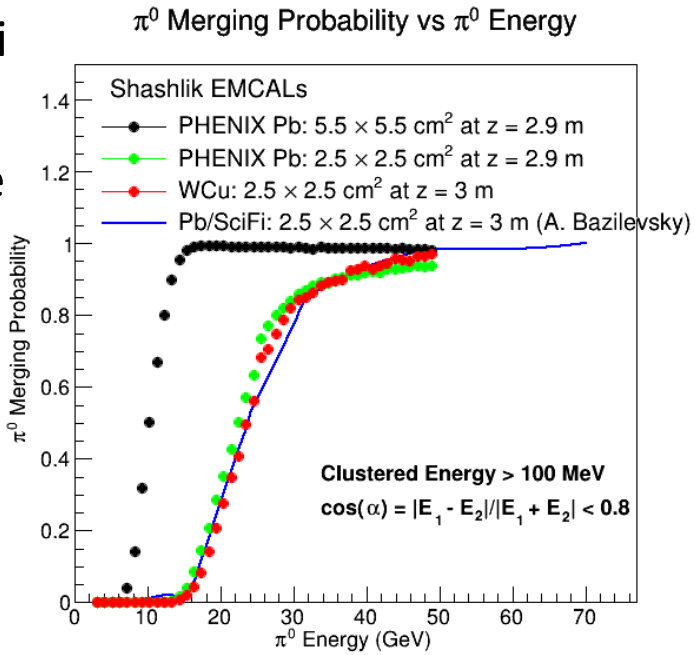




- π^0 merging probability decreases with finer granularity → reconstruct π^0 up to higher energy
- Strong dependence on granularity while weak dependence on Moliere radius
- Presented in EIC eRD1 Report and EIC Calorimetry workshops

Summary and Outlook

- Propose two designs options for EIC EMCAL: W/SciFi SPACAL and W/Shashlik with high granularity
- Simulations studies on shashlik EMCAL performance and π^0 decay photons separation capabilities
- Implementation of realistic light collection map to the shashlik towers
- Hardware and readout electronics studies at BNL
- Test beam studies on EIC EMCAL prototypes



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Thank you very much for your attention!

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