Laying the Framework for EMCAL R&D and Future Gamma Spectroscopy in Fixed Target Experiments

Mark Harvey
Texas Southern University

CFNS Workshop: Advancing Nuclear Physics: New Horizons with Fixed-Target Proton-Nucleus Experiments at Intermediate Energies
July 11, 2025

TSU

Introduction & Motivation

- Motivation: Develop an electromagnetic calorimeter (EMCAL) for gamma detection in fixed-target experiments
- Gamma spectroscopy is a powerful tool for studying nuclear structure and reaction dynamics
- Long-term interest: excited state dynamics in exotic nuclei (e.g., EIC)
- Current focus: detector development and student training

Project Overview

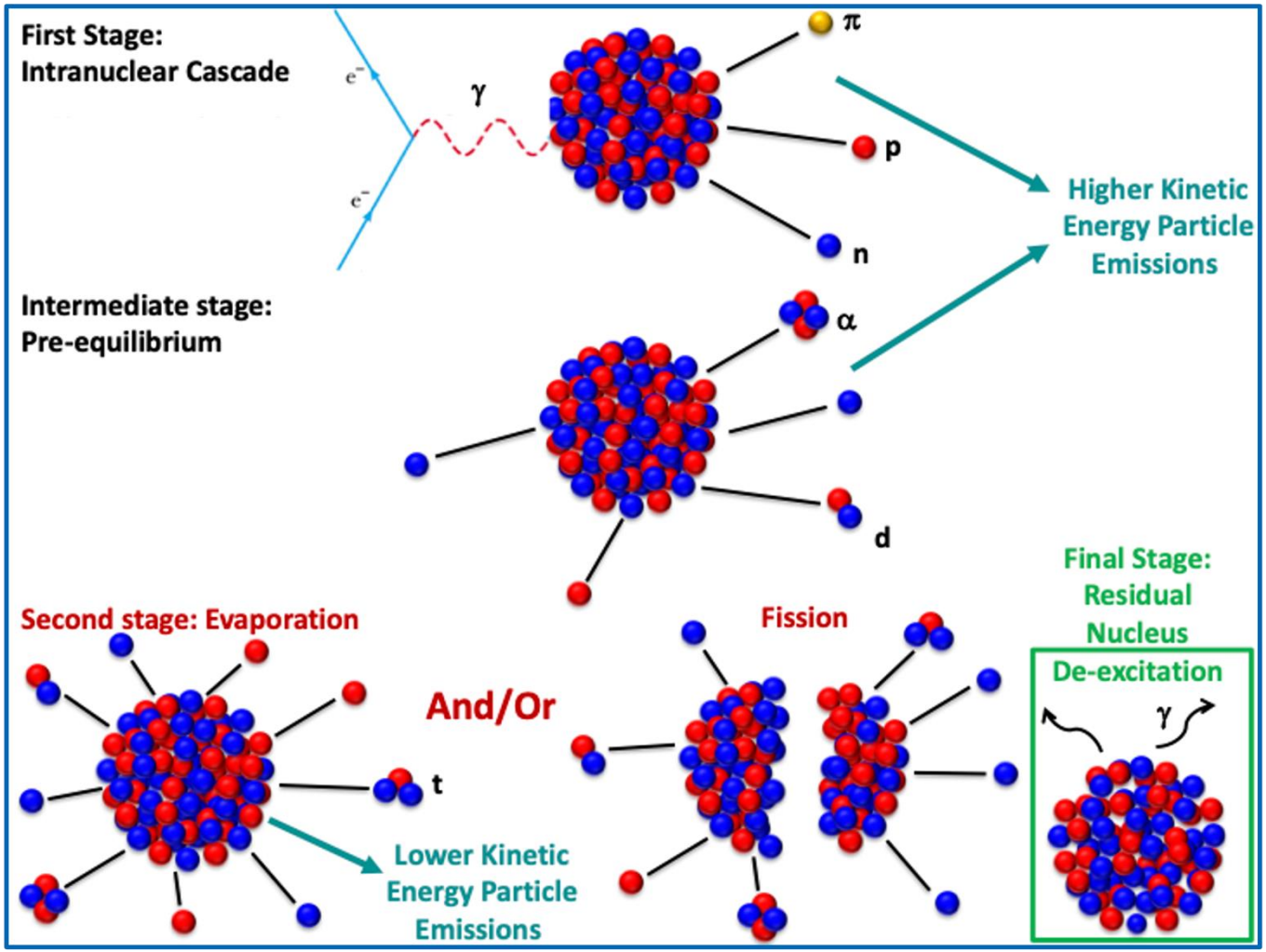
- Student-centered, early-stage R&D effort
- Not tied to a specific experiment yet
- Building capability and training students in simulation, construction, and testing

BeAGLE Simulations
Mark Ddamulira

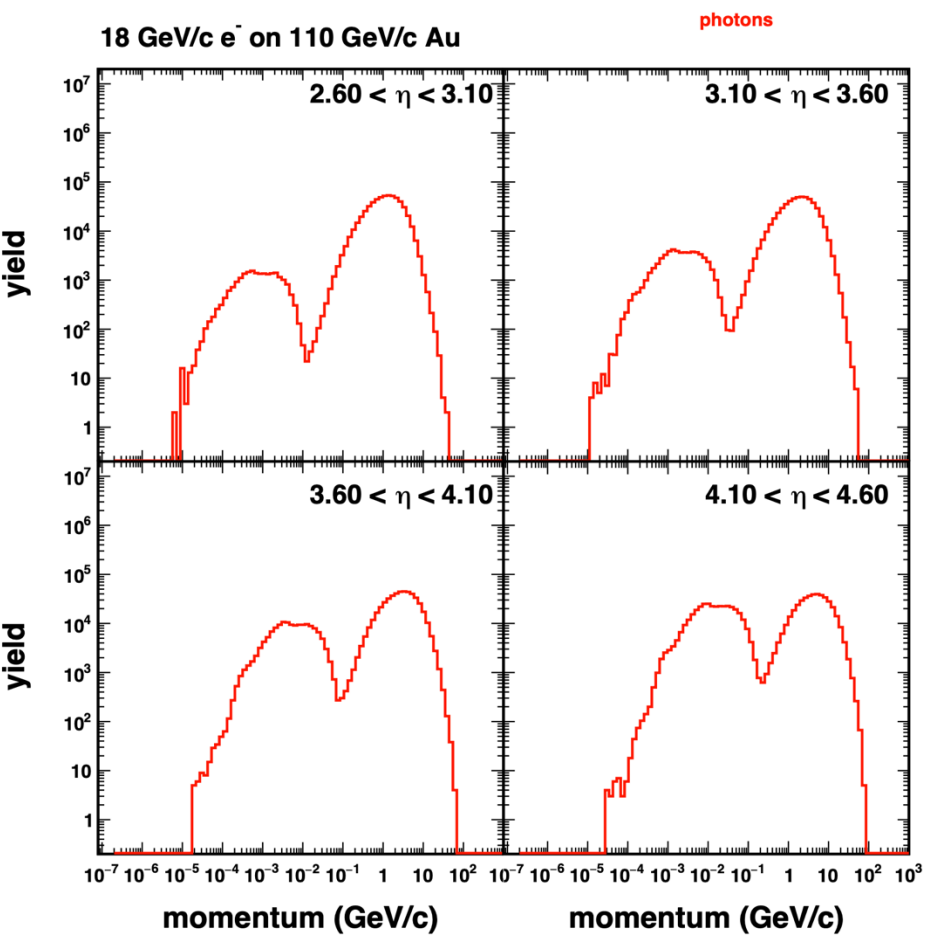
- **Simulating e-Au Collisions at EIC Energies Using BeAGLE**
- Simulated e-Au collisions with BeAGLE to study gamma production
- Investigated the potential for **rare isotope production** at the EIC
- **Identified forward-scattered gamma events** using pseudorapidity selection
- **Tagged photons by production stage**:
  - Hard scattering
  - Intranuclear cascade
  - Evaporation/Fission
- Enables **stage-specific analysis of gamma emission**
- Supports studies of **excited state dynamics** in exotic nuclei

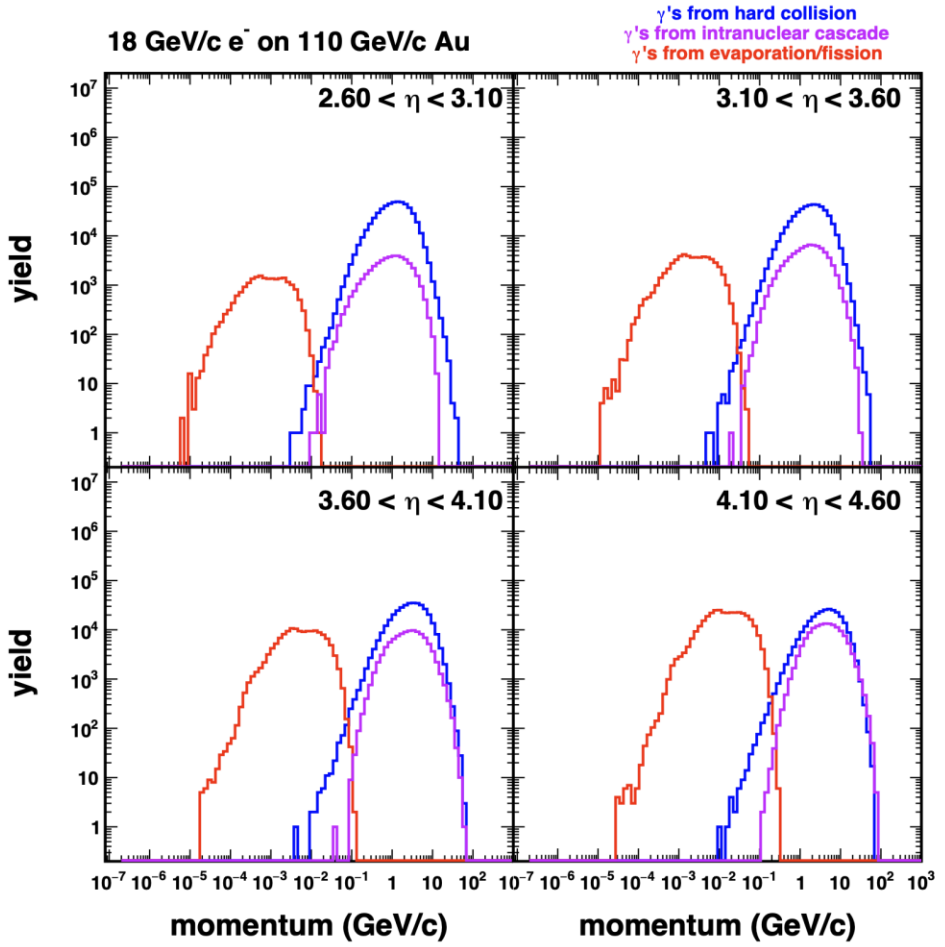
- Undergrad studies @ TSU
- NP graduate student at Michigan State University

Nuclear Reactions of Relevance



Results: Forward Scatters
M. Ddamulira





Dark Box Construction
Jerry Breda

- **Dimensions**: 1.3 m (L) × 0.60 m (W) × 0.7 m (H) –sizable enough to accommodate multiple detector components
- **Light Tightness**: Fully sealed with black sealant and rubber gaskets to block ambient light
- **Cable Connections**: Equipped with ten cable glands for secure BNC-type connections
- **Construction**: Built from durable particleboard with a matte black interior and finished exterior for durability and aesthetics

- Undergrad studies TSU
- NP graduate student at Howard University

Summer R&D at BNL
Giraude Griffin

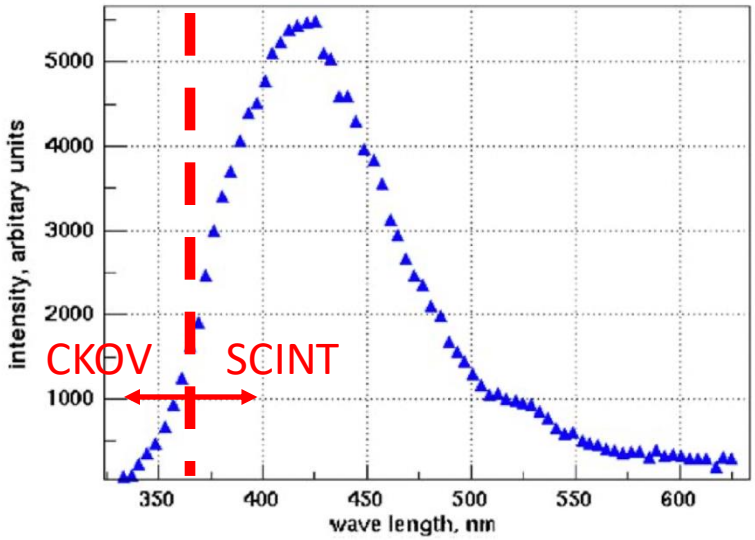
- **BNL – TSU Collaboration on SiPM Readout**
- Joint effort to develop software for test **readout platform for multi-tower CAL prototypes**
- Using **CAEN DT5702**: 32-channel SiPM readout, dynamic range of ~5000 p.e. at gain 1×10^6
- Initial tests by **M. Chiu (BNL)** and **G. Giraude (TSU)** show **promising results**
- Current setup uses **Hamamatsu S12572-015P** (same as in sPHENIX)
  → Coupled to **PHENIX $PbWO_4$ crystals** ($2.2\times2.2\times18$ cm^3)
- Serves as a testbed for evaluating the performance and integration of EMCAL components

- Undergrad studies @ TSU
- NP postbac student at TSU

Future R&D Plans
Giraude Griffin (w/ M. Chiu)

- **Goal: Develop Optimized EMCAL for HEET or Future EIC Upgrade**
- **SiPM R&D:**
  - **Currently testing:** HPK S12572-015P (3×3 mm², left in image)
  - **Large area option:** HPK S13360-6075CS (6×6 mm², center)
  - **UV-sensitive option:** HPK VUV4 (10×10 mm², right; sensitive <170 nm, developed for nEXO)
- **Calorimeter Material Studies:**
  - **$PbWO_4$:** Fast timing, but emission spectrum cuts off ~ 350 nm (see right plot)
  - **LYSO:** also under consideration…
  - Challenge: Need material (e.g., special glass?) transparent at low wavelengths
- **Toward "DREAM" Calorimeter (Dual Readout Concept):**
  - **CKOV Readout:** UV-sensitive SiPM, low-λ bandpass, fast timing → fast shaping needed (early waveform only)
  - **SCINT Readout:** Mid-high-λ bandpass, relaxed timing requirements

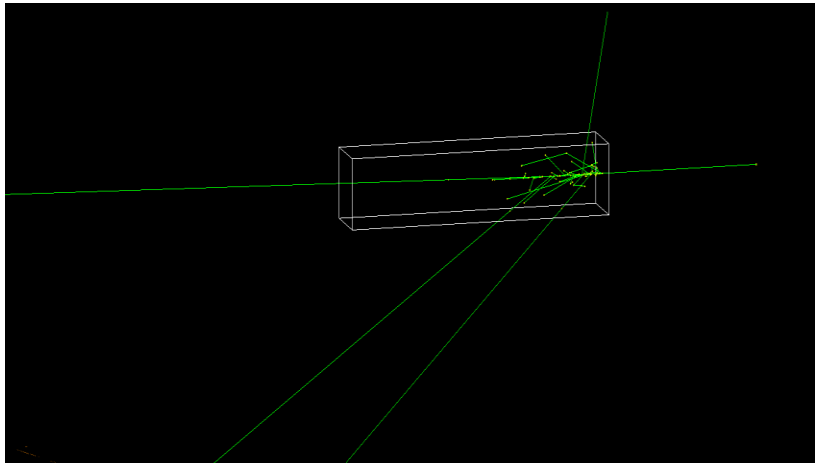
PHOS/MPC $PbWO_4$

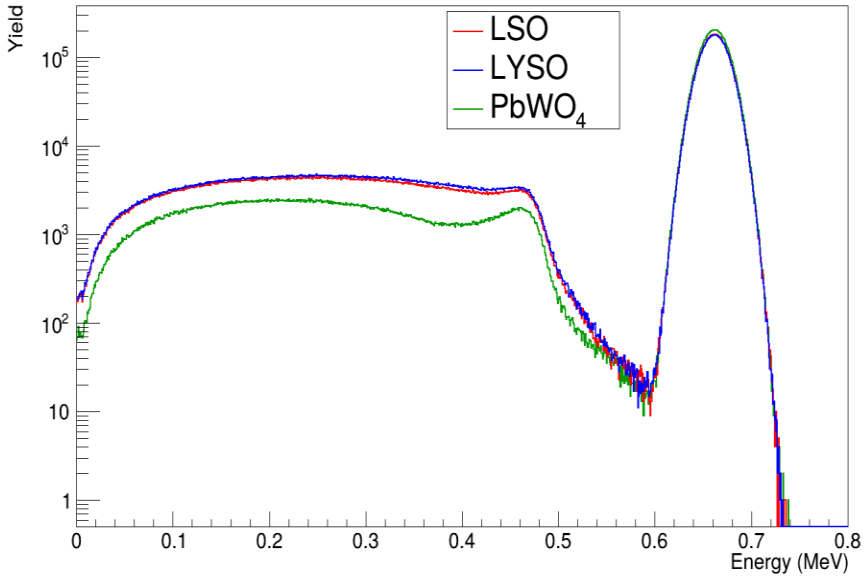


Radiat.Meas. 38 (2004) 813-816

Geant4 Simulations
J. Breda & G. Griffin

- **Students gaining hands-on experience** with Geant4 (v11.6) for detector simulation
- Successfully **modeled gamma interactions** in LSO(Ce), LYSO(Ce), and $PbWO_4$ (See image in upper right)
- Produced and analyzed **energy deposition spectra,** photopeak, and Compton edge
- Explore **material effects** on energy resolution and angular dependence
- Results inform **prototype design** for gamma detection in high-radiation environments
- **GPU-based photon tracing** using the Opticks package for faster, more detailed light propagation simulations (J. Breda/M. Chiu)





Next Steps

- Begin physical construction of EMCAL prototype
- Plan for test beam validation
- Continue simulation and material studies
- Engage students in all phases of development

Vision & Summary

- Foundational R&D effort with strong student involvement
- Focus on gamma detection in fixed-target experiments
- Flexible design for future nuclear physics applications
- Invitation for feedback and collaboration from the community

Acknowledgements

- Mickey Chiu (BNL & Texas Southern University), DOE Grant No. DE-SC0012704 (BNL), particularly the Nuclear Physics Traineeships program
- DOE Grant No. DE-SC0024606: HBCU Collider Consortium, Reaching a New Energy Sciences Workforce (RENEW); FAMU, TSU & Howard

Extra Slide

Exploratory Test Beam Possibilities at AGS/HEET – Motivated by Abhay's comments

- AGS/HEET offers a broad range of ion beams (e.g., p, He, Si, Au) and fixed-target infrastructure
- EMCAL prototypes can be tested in realistic photon-rich environments
- Use **enriched stable isotope targets** (e.g., Li-6, Be-9, C-13) for gamma production
  - **Enriched stable isotopes**: non-radioactive, available, and enable clean reactions for detector benchmarking
- Benchmark detector performance: resolution, timing, and efficiency
- Supports student training in beamline operations and detector commissioning
- Exploratory studies only – not a defined fixed-target physics program