

muCLAS12 workshop – March 9, 2026

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# The muCLAS12 simulation and reconstruction software

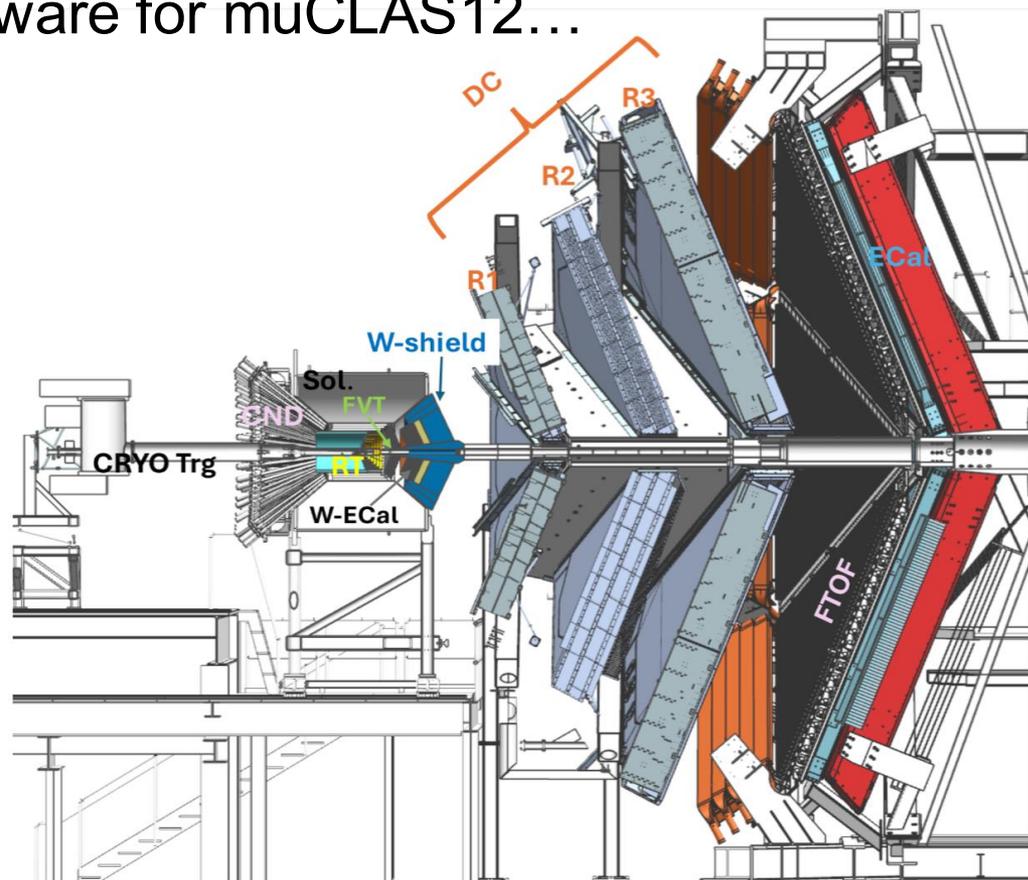
Raffaella De Vita (Jefferson Lab)  
and the CLAS Collaboration



# Outline

A walkthrough of offline software for muCLAS12...

- The simulation model
  - Background studies
  - Detectors' response
- Event reconstruction
  - Muons
  - Electron
  - Recoil
- Status and perspectives



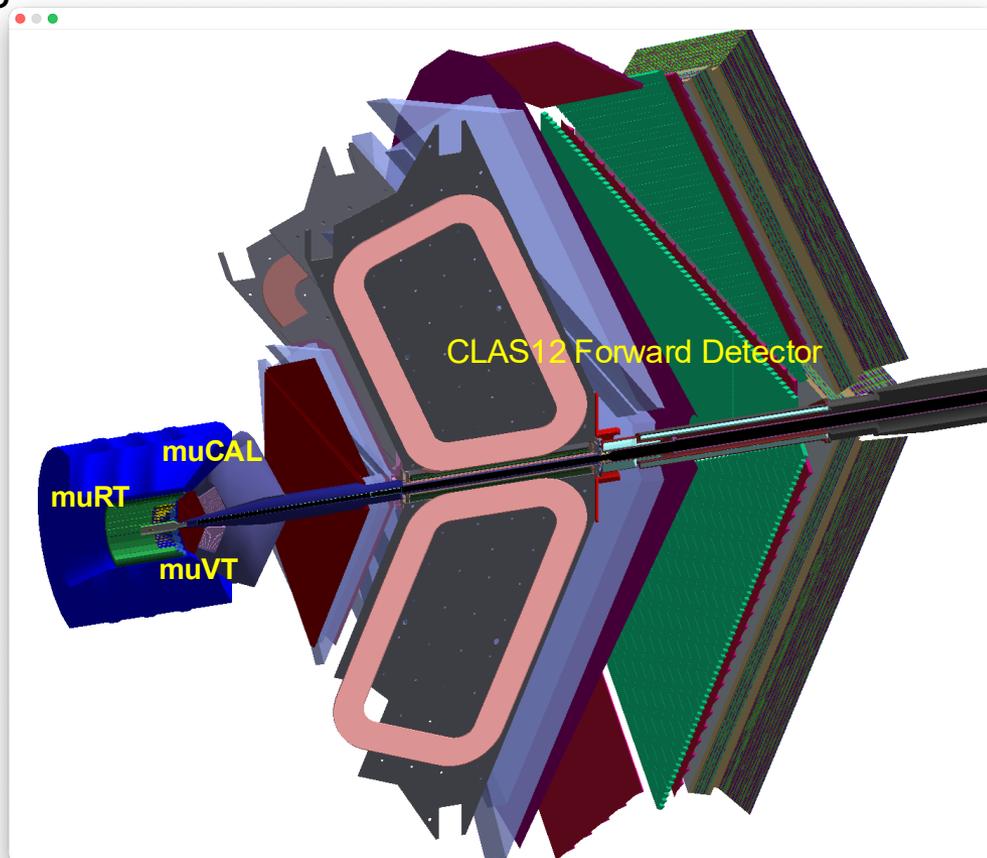
*Not my work but work of many (M. Bondi, T. Cao, R. Paremuzyan, M. Ungaro, N. Wuerfel, V. Ziegler, ...)*

# muCLAS12 in simulation

- Experiment setup implemented in CLAS12 GEANT4 simulation package

## GEMC

- New detectors
    - PbWO calorimeter
    - GEM vertex tracker
    - uRWell recoil tracker
  - Forward detector shield
  - Target and beamline
- 
- Used for
    - Setup optimization
      - Shield material and thickness
      - Beamline shielding
      - Detector configuration
    - Background studies
      - Radiation dose, particle fluxes, detector rates
    - Performance evaluation
      - Resolution and efficiency



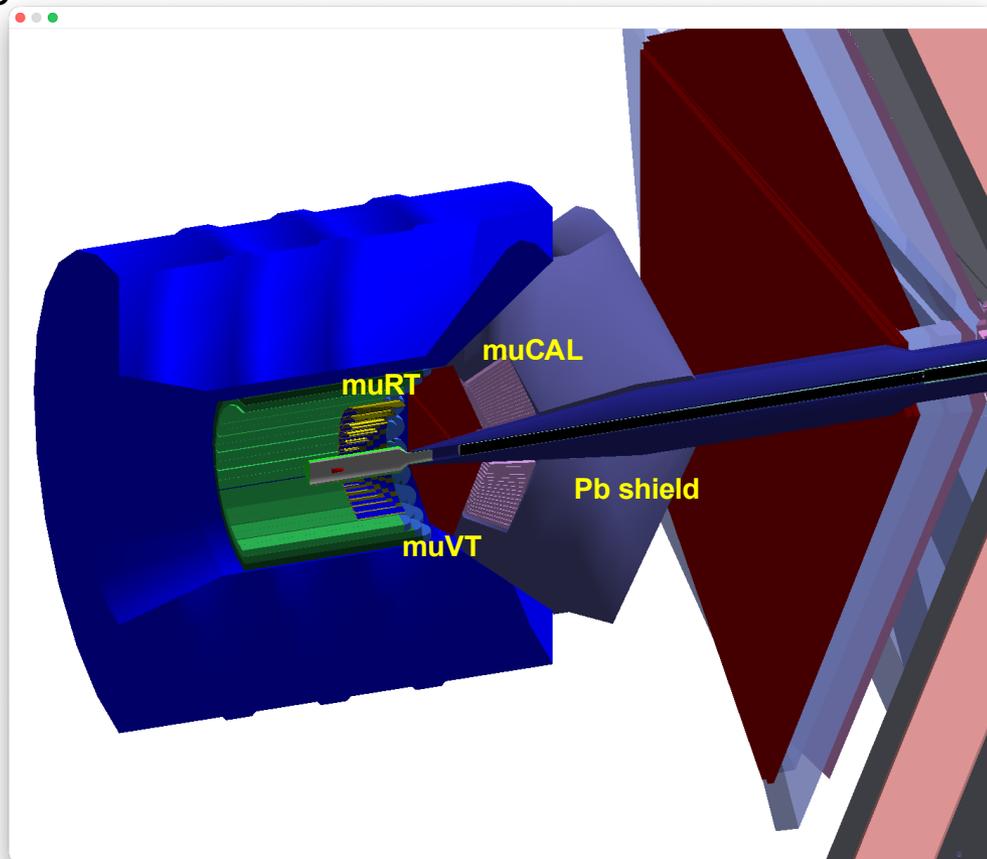
GEMC rendering of the muCLAS12 setup

# muCLAS12 in simulation

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## GEMC

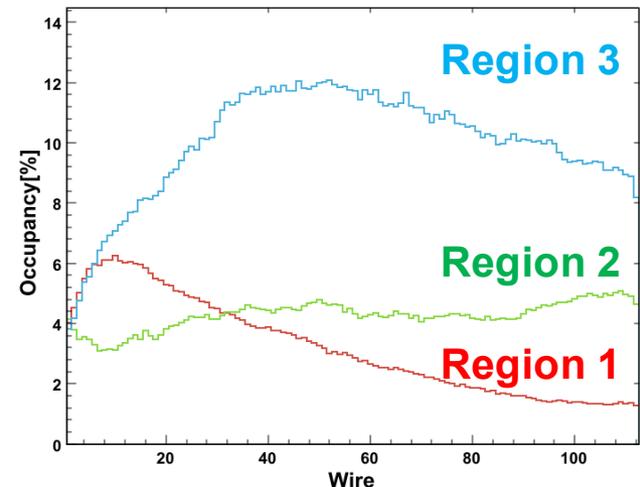
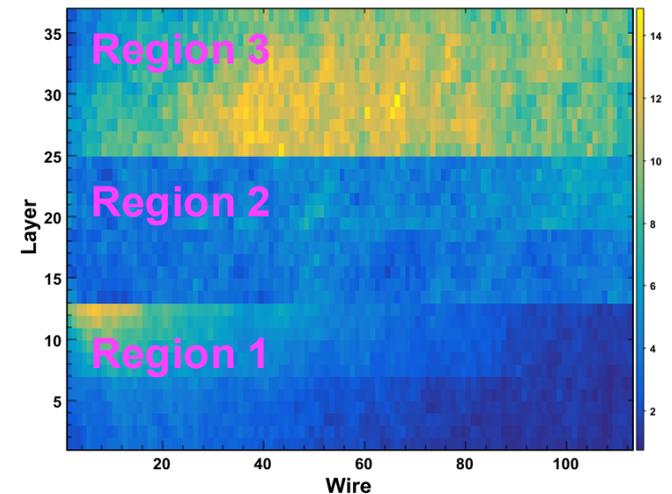
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# Background studies

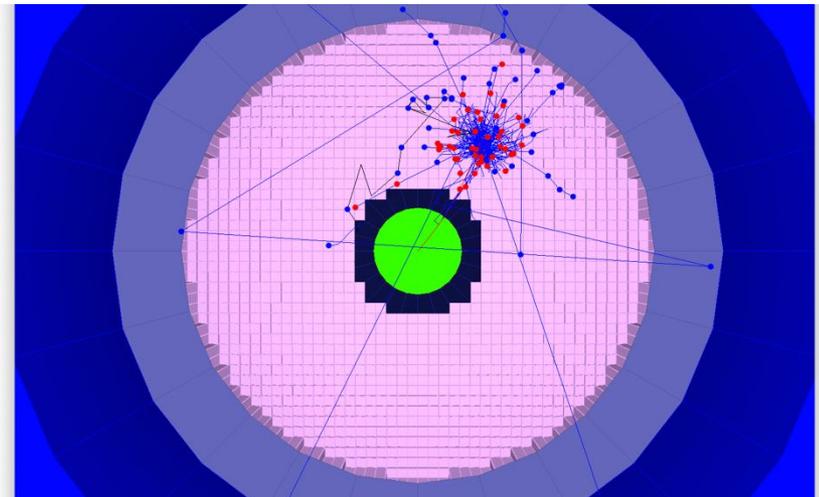
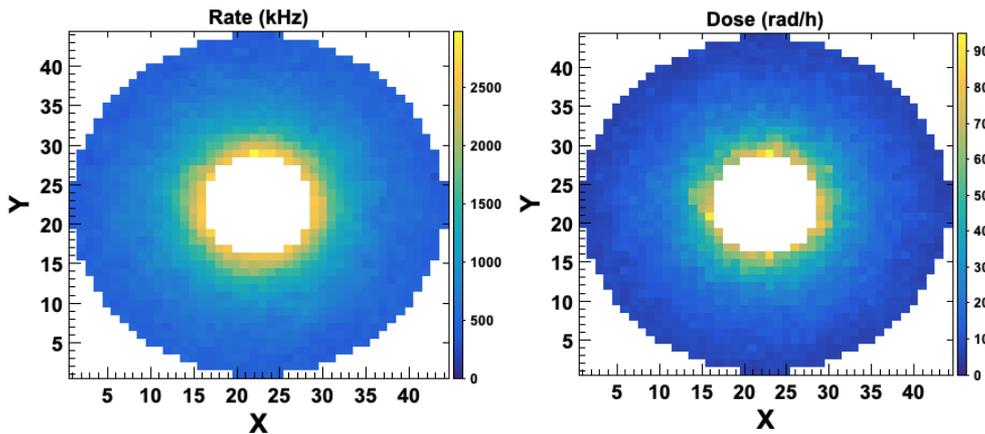
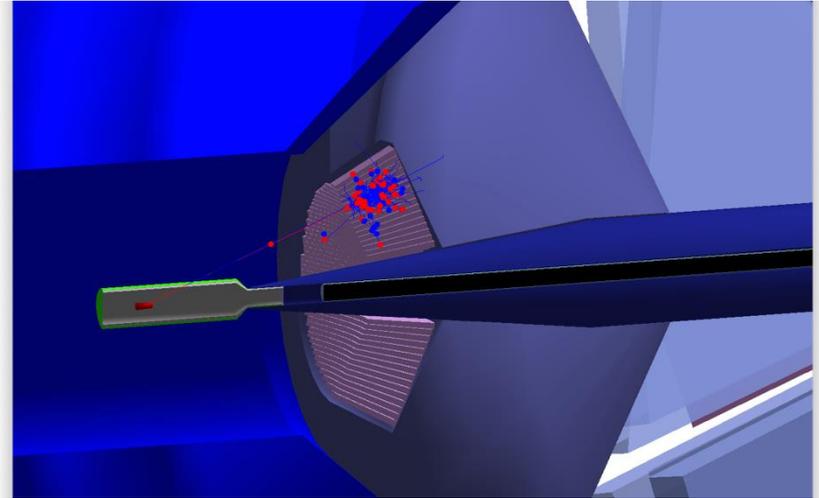
- Detector rates, particle fluxes, and radiation doses evaluated by simulating the electron beam going through the target
  - ~5 M electrons in a 100 ns time window for an event
  - $10^{37} \text{cm}^{-2}\text{s}^{-1}$  luminosity
  - Electromagnetic and hadronic processes according to GEANT4 physics models
  - Validated with existing CLAS12 data: agreement at 10-15%
  - Simulated background events can be “merged” with signal events for realistic performance evaluation

Drift Chambers Occupancy



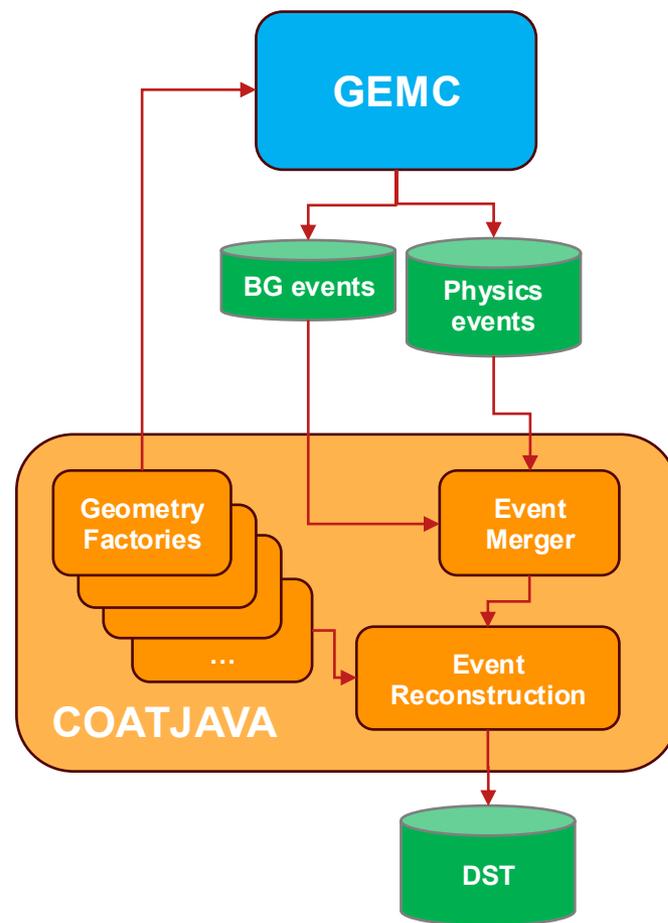
# Background studies: muCAL

- Fully implemented in the CLAS12 GEANT4 model
  - Trapezoidal crystals with APD readout
  - Digitized signal includes fluctuations in scintillation light, APD QE and noise, preamplifier noise
  - Estimated dose for 200 days  $< 5 \times 10^5$  rad = 5000 Gy



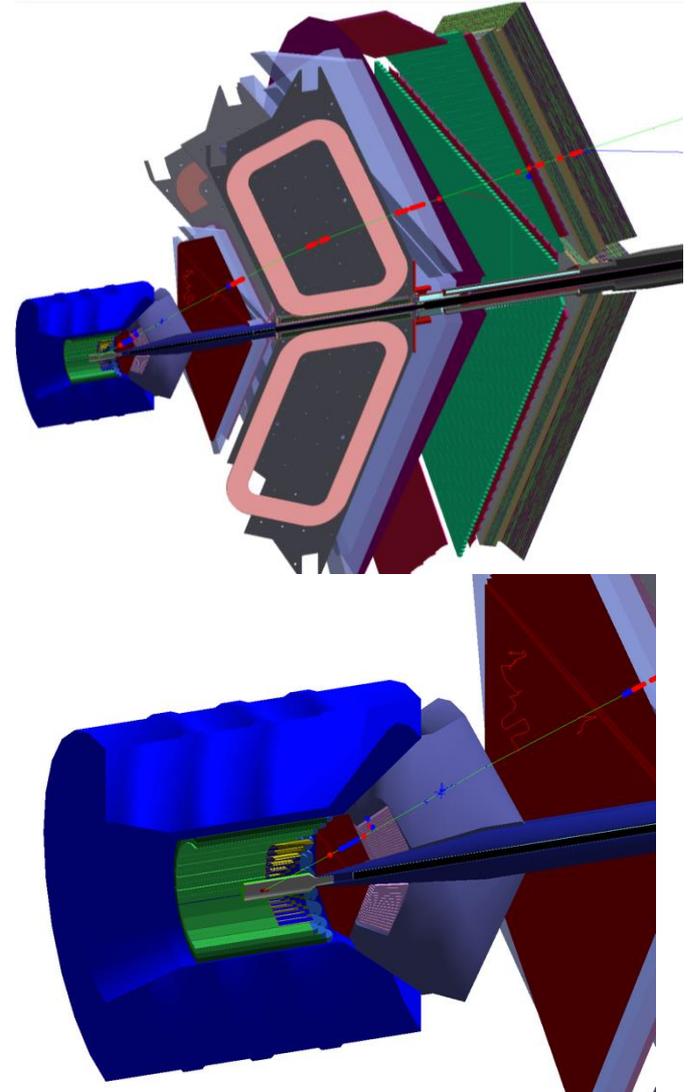
# muCLAS12 in reconstruction

- New detectors' reconstruction implemented in CLAS12 reconstruction framework, COATJAVA
  - Detector geometry
  - Low-level reconstruction, from "raw" data to hits and clusters
  - Track reconstruction
  - Event building
- Status
  - Tested on simulations of single particles and full physics events
  - First studies with simulated background
  - Still a lot to be done but software is operational!



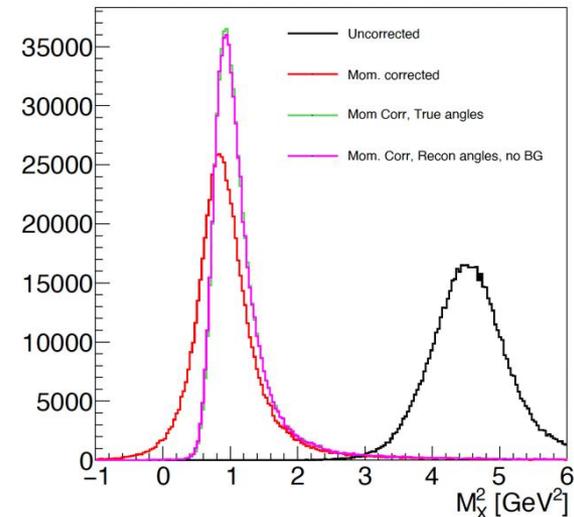
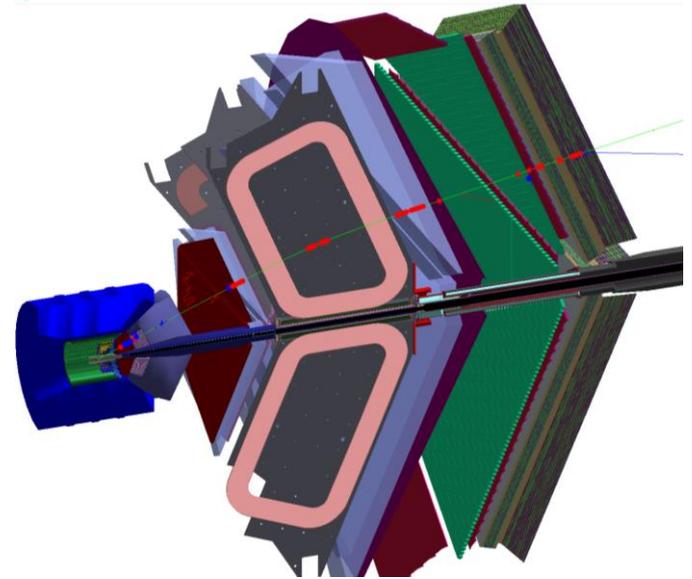
# Muon reconstruction

- Muons first reconstructed in the CLAS12 forward detector based on the standard algorithms
  - Tracks are matched to FTOF to determine event start time and ECAL to select MIPs
- Reconstructed muons are propagated back through the lead absorber and muCAL, accounting for energy loss and magnetic field
- Tracks are matched to clusters in the muVT and refitted to eliminate multiple scattering effects and improve angular resolution
- Finally, tracks are propagated back to the target and vertex is determined as point-of-closest-approach to the beamline



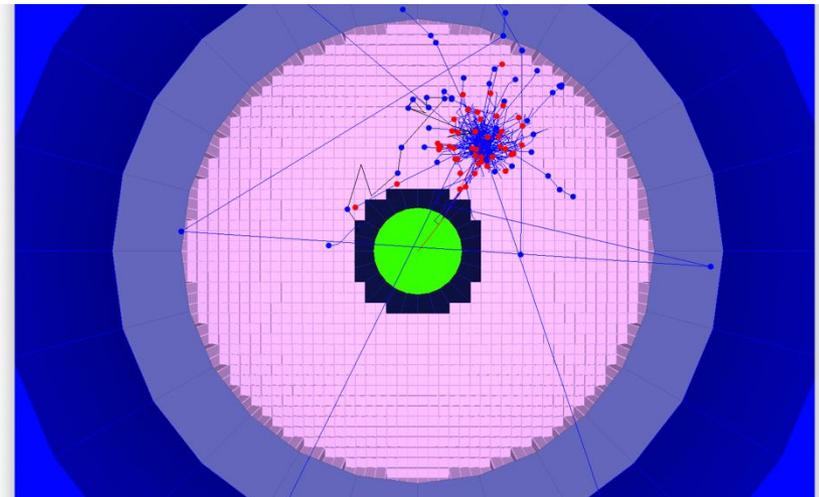
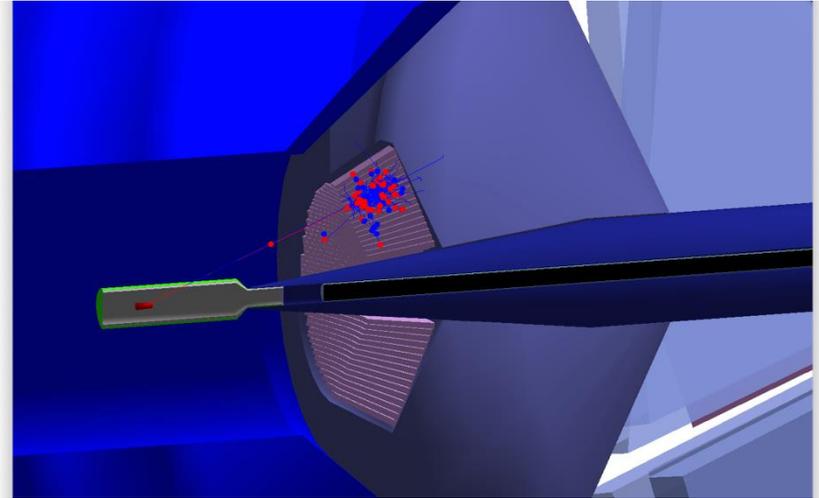
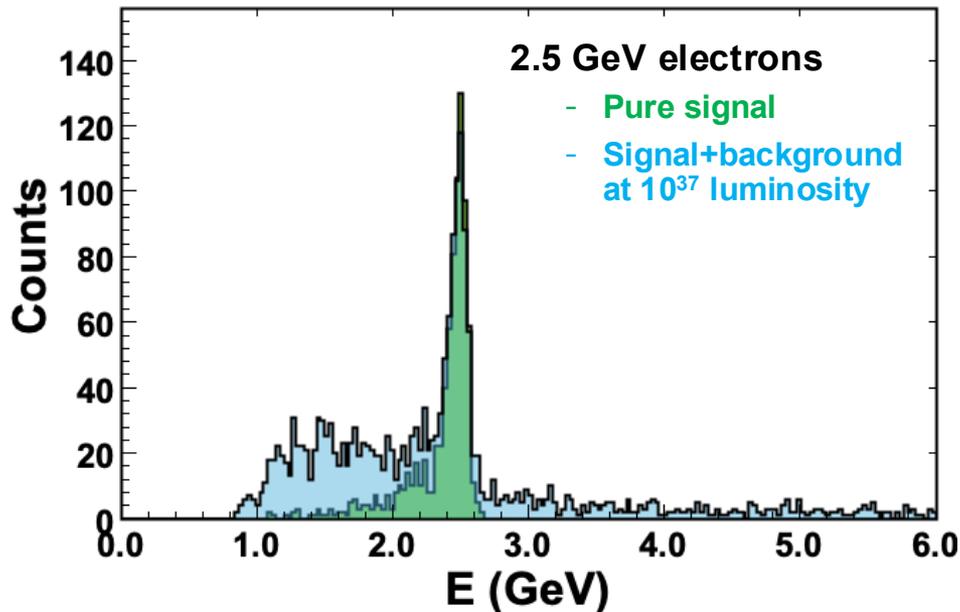
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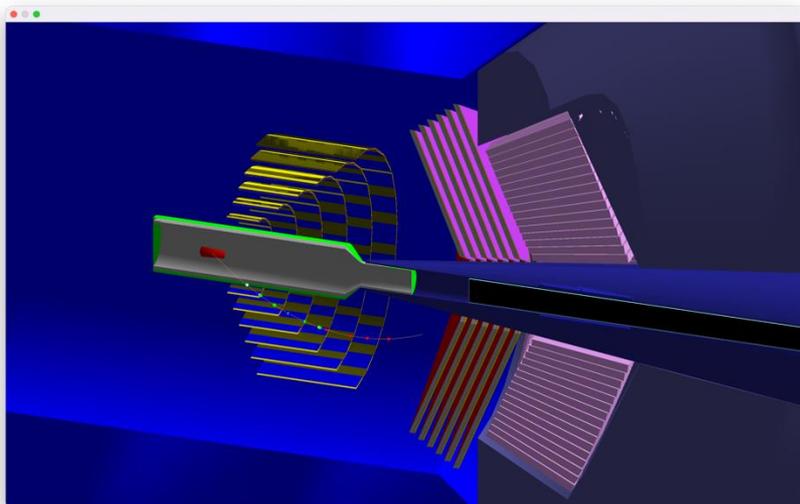
# Electron reconstruction

- Electron is detected in the muCLAS12 calorimeter
  - Cluster reconstruction
  - Energy-leakage correction to account for non-zero hit threshold and finite crystal length
  - In progress: propagation to the vertex

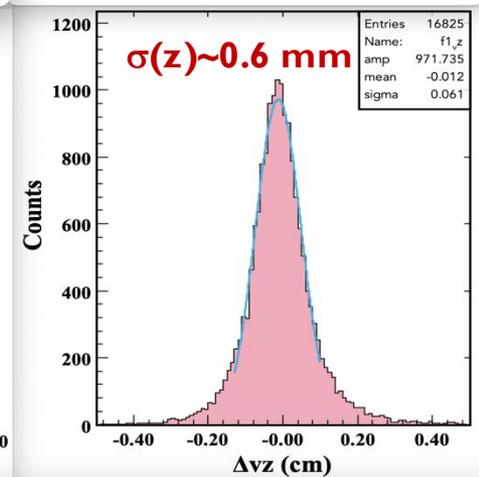
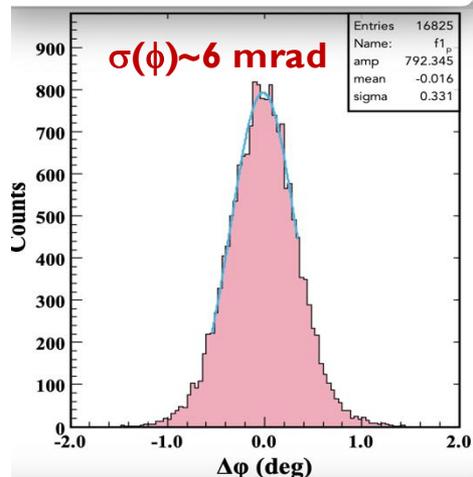
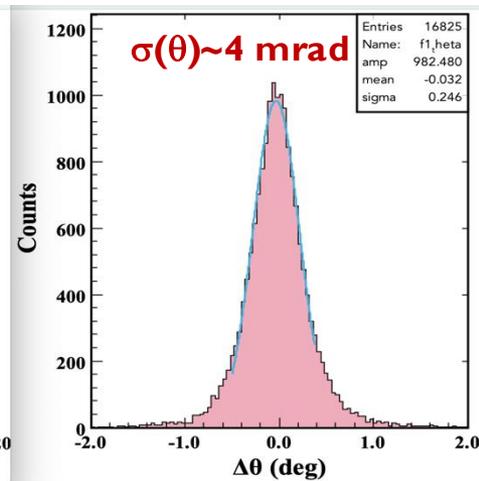
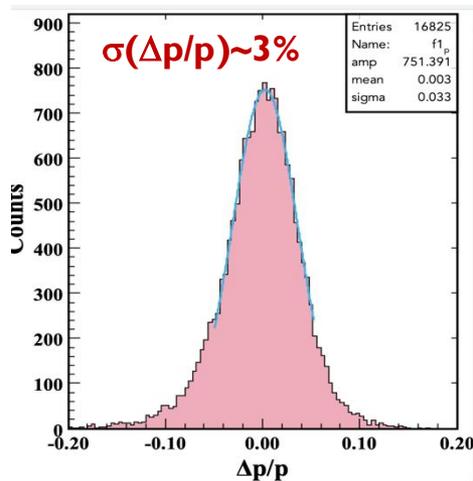


# The recoil tracker

- First implementation in simulation and reconstruction
  - 6 regions x 3 sectors of uRWell detectors
  - Readout with strips along and at fixed z (arcs), inspired by the layout of the existing CLAS12 central uMegas tracker
  - Proof-of-principle track finding and fitting



## Single proton tracks



# Status and perspectives

- Simulation and reconstruction software for the muCLAS12 experiment is being developed within the CLAS12 framework
- Still a lot to be done but “ready” to study backgrounds, detector responses, and physics
- To be included in next releases of GEMC and COATJAVA

