Counting Analysis

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Goals

- **Experiment Commissioning**
  - Align beam to collimator locations,
  - Demonstrate detector performance,
  - Calibrate the spectrometer optics model with sieve data at various beam energies;
- **Measure the event rate distribution** with the LH2 target measured at the thin quartz main detectors, to confirm simulation predictions and
  - test assumptions used in the deconvolution procedure to extract Moller asymmetry,
  - test assumptions used calculating the analyzing power for the accepted kinematics, which connects the measured asymmetry to the electron's weak charge;

Goals

- **Measure detector response** for thin quartz, showerMax, and pion detectors, in order to
  - calibrate the position sensitivity of each detector
  - characterize performance,
  - diagnose problems, and
  - monitor changes in light yield;
- **Measure e/π in Ring 5** of thin quartz, using tracking, showerMax and pion detectors;
- **Study backgrounds** due to rescattering from beam axis using blocker collimator

Spectrometer optics commissioning plan

Note: In all tracking configurations, data-taking rate is limited by DAQ throughput - signal-to-noise is expected to be high, so essentially every triggered event will be a “good” Moller or e-p event, so will pre-scale triggers to about 3 kHz event rate in all cases.

The full spectrometer optics commissioning is **not** required in initial MOLLER low current commissioning before transition to high current.

- First steps use thin ^{12}C targets with few nA beam.
- **GEM alignment**: Use tracks to mutually align the 4 GEMs in each sector (straight-line tracks).
  - Check alignment by projecting tracks to main detectors, upstream scanner
  - see outline of detector by requiring detector channel fired in coincidence with track.
  - Cross check by rotating GEMs to next open sector - same flux distribution seen by different sets of 4 GEMs

Spectrometer Optics Commissioning Plan, p2

- **Verify Optics Model:**
  - Insert sieve collimator, continue with thin ^{12}C targets, 10's of nA beam
  - Verify the sieve hole pattern of 12C-elastic events to verify optics model
  - Requires multiple beam energies (1,2 & 3 pass beam).
- **Event rate distribution**:
  - Remove sieve, use LH_2 target, 5-pass beam, and ultra-low beam current (200 pA)
  - Map event rate distribution over full azimuth and accepted radial range at 5-pass beam
  - This data is also used the develop a position-dependent response function for each thin quartz and showerMax detector
- **Background measurement:**
  - Use Blocker collimator, LH_2 target, 5-pass beam
  - measure rates in thin quartz and showerMax detectors, corresponding the backgrounds from rescattering of exhaust beam

Software repository and people

- https://github.com/JeffersonLab/moller-counting
  - This is part of the SBS software (code relevant for GEM and fADC data analysis).
  - Currently, this is used for the cosmic-ray test setup in W&M UMass cosmic setup (fADC data), and for the cosmic-ray JLab Test Lab setups(for GEM & fADC data)

- People
  - Chandan Ghosh (JLab)
  - Sayak Chatterjee - (UMass)
  - Asar Ahmed - (UVa)
  - Zuhal Seyma Demiroglu, James Shirk (SBU)
  - Lasitha Welianga, Buddhini Waidyawansa (LaTech)
  - David Armstrong, Tasneem Raza (W&M)

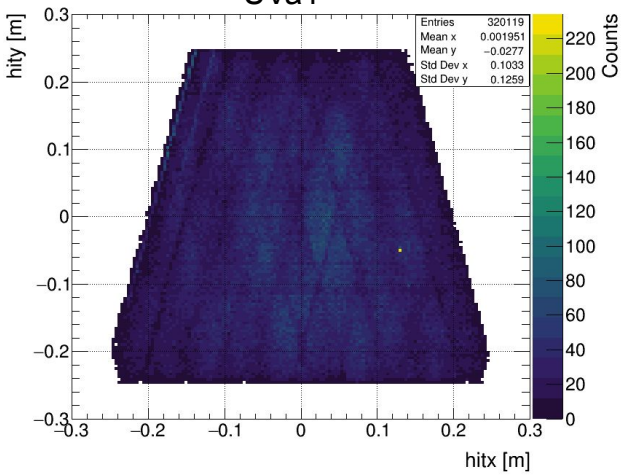
\+ additional student/postdoc effort from detector subsystem groups for detector-specific analysis scripts

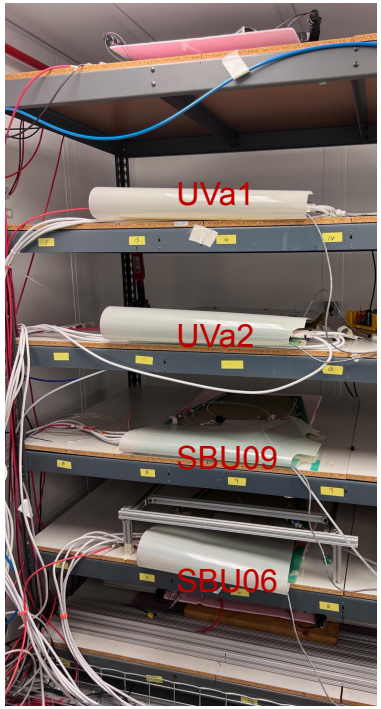
Cosmic data analysis - GEM detectors

- GEM code tested using cosmic-ray stand - 4 MOLLER tracking GEMs (two from UVa, two from SBU) in stack, essentially the same as 4 GEMs in a Rotator sector.
- Same readout chain as in the SBS experiment.
- Use SBS alignment code to mutually align the 4 GEMs
- Initial results show position resolution for exceeds our 1 mm requirement (see next slides).

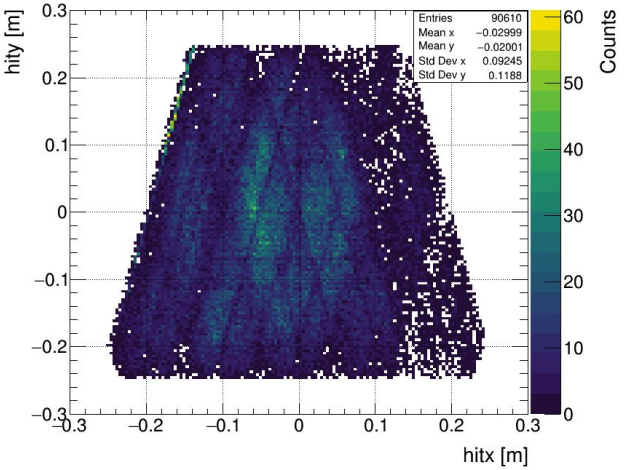
GEM analysis - 2D hits and Tracks

UVa1

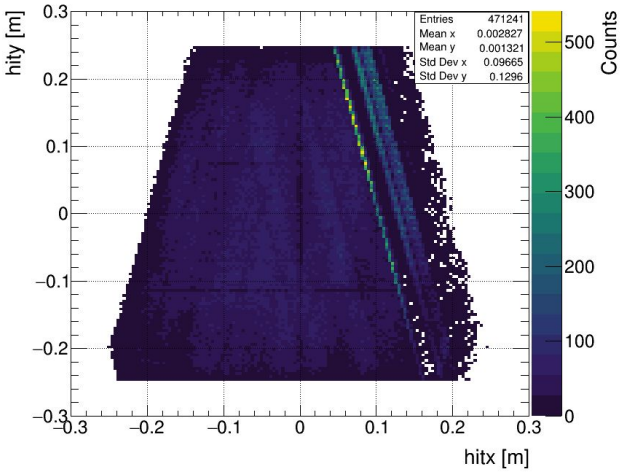


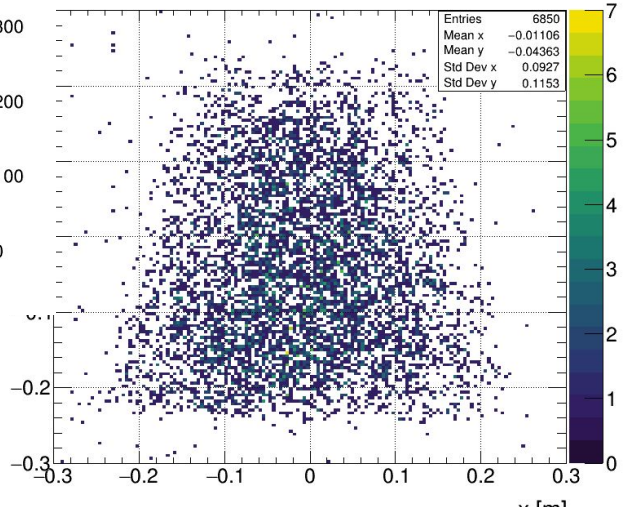


UVa2

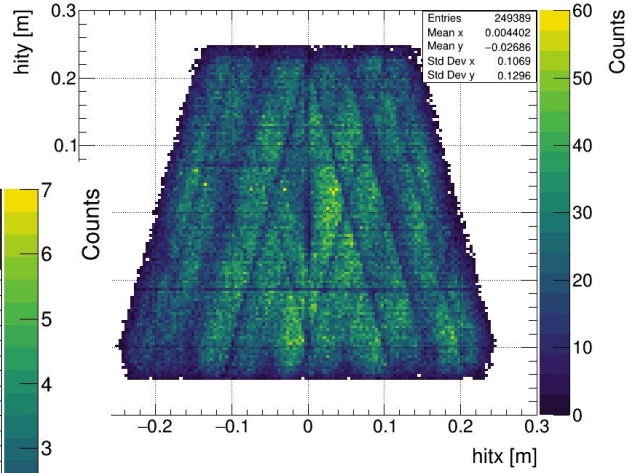


SBU09





SBU06



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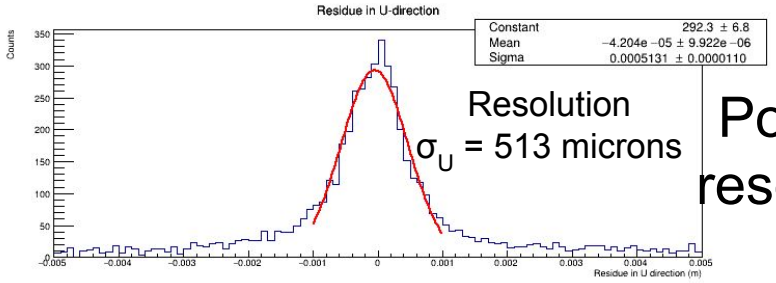
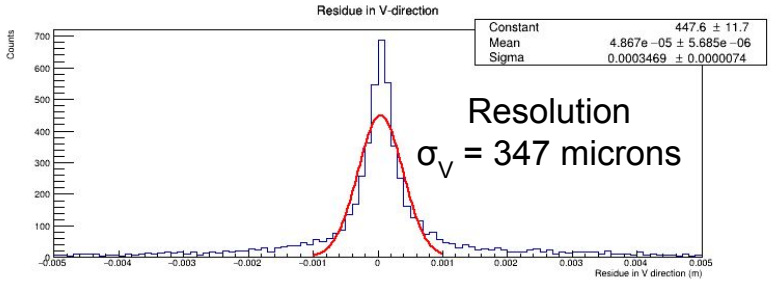
Analysis software based on SBS tools, is already in use with the W&M and JLab Cosmic Test Stand,

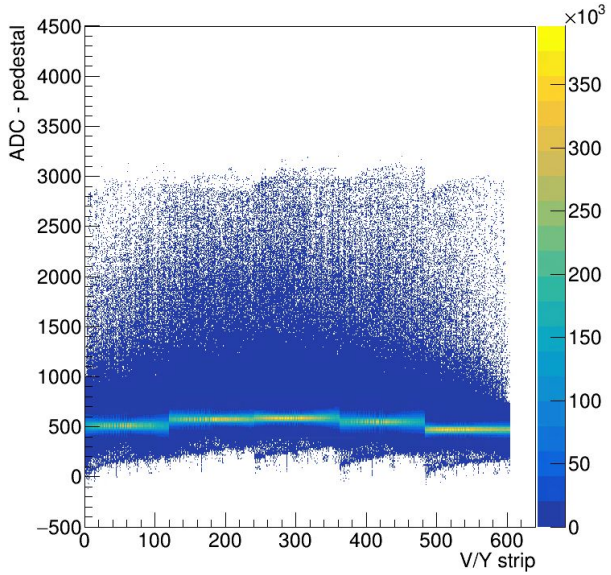


Resolution
σ_U = 513 microns

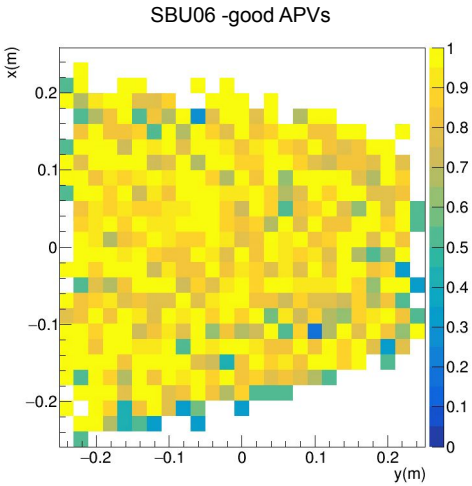
Position resolution

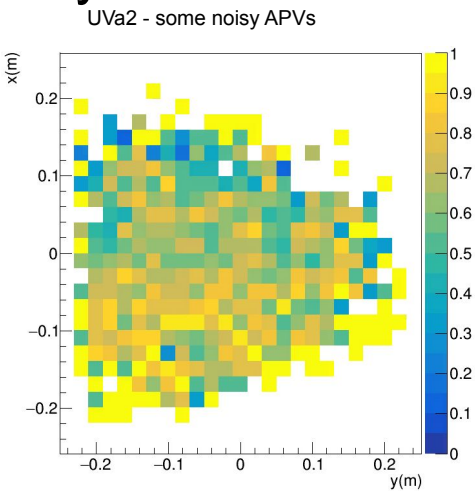


Resolution
σ_V = 347 microns



Efficiency





Can re-use the entire suite of low-level GEM diagnostic plots developed by SBS

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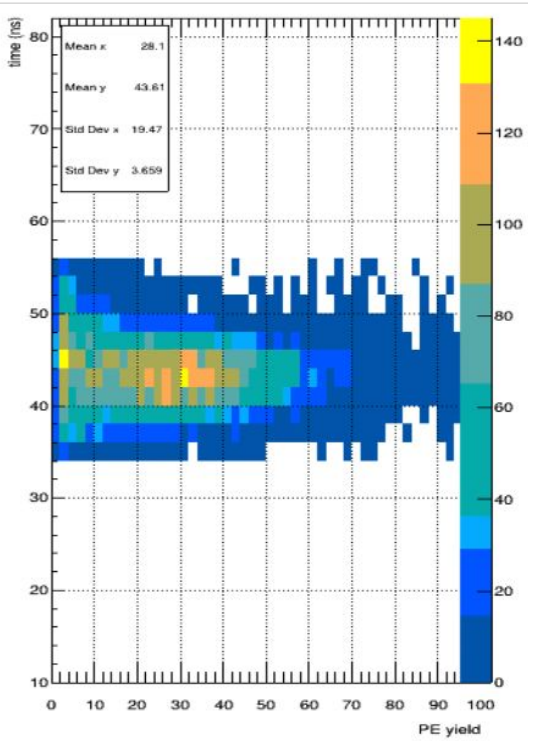
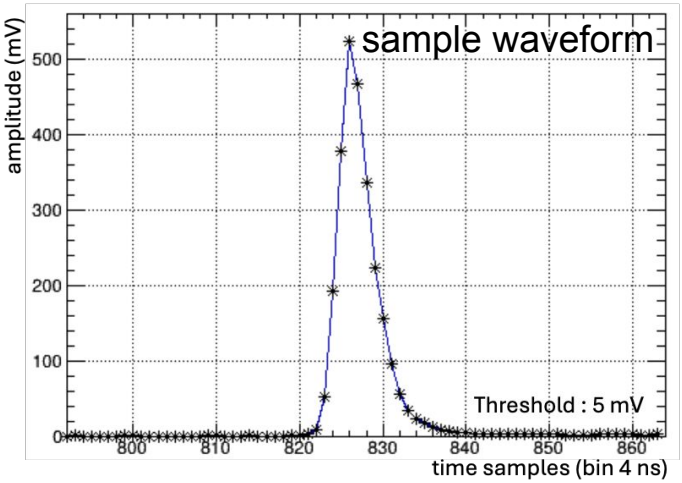
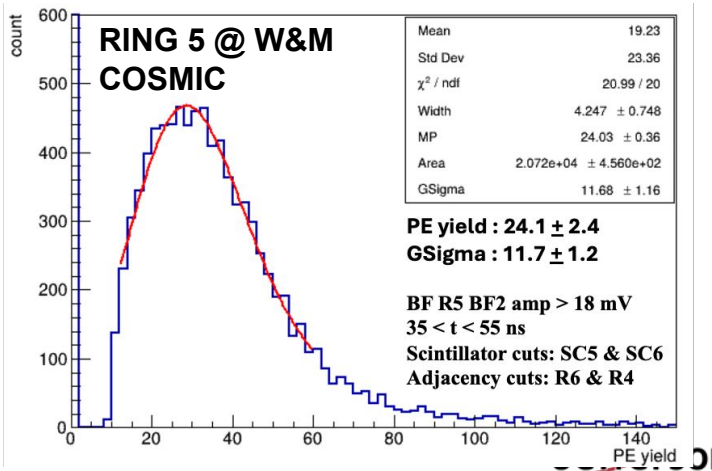
fADC250 based readout chain at W&M

- The main detectors are being tested with cosmic muons in the W&M setup.
- Data analysis is performed using the fADC decoding class from the MOLLER-counting repository.







Generating mock data for developing analysis code

- SBS uses detailed digitization procedure for simulated data
- MOLLER will use a similar approach, using digitized data from the *remoll* G4-based MOLLER simulation
- The digitized data will be sent through the analysis code to form tracks, ADC spectra
- Develop more analysis and debugging scripts for commissioning and running

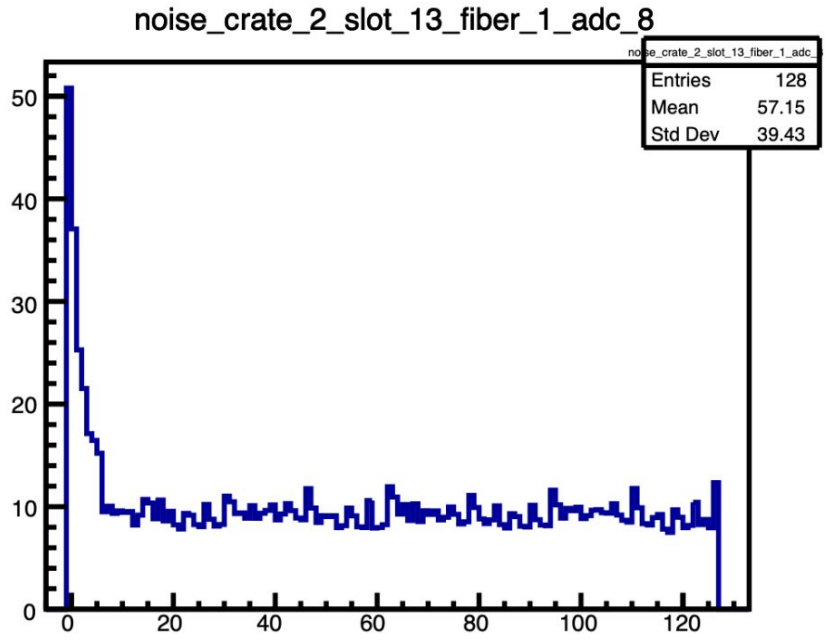
★ We are planning to form a dedicated counting analysis group
★ More resources will be focused on this as detector development work are completing.
★ Timeline: We are planning have a fully set of analysis, debugging chain ready by the summer next year.

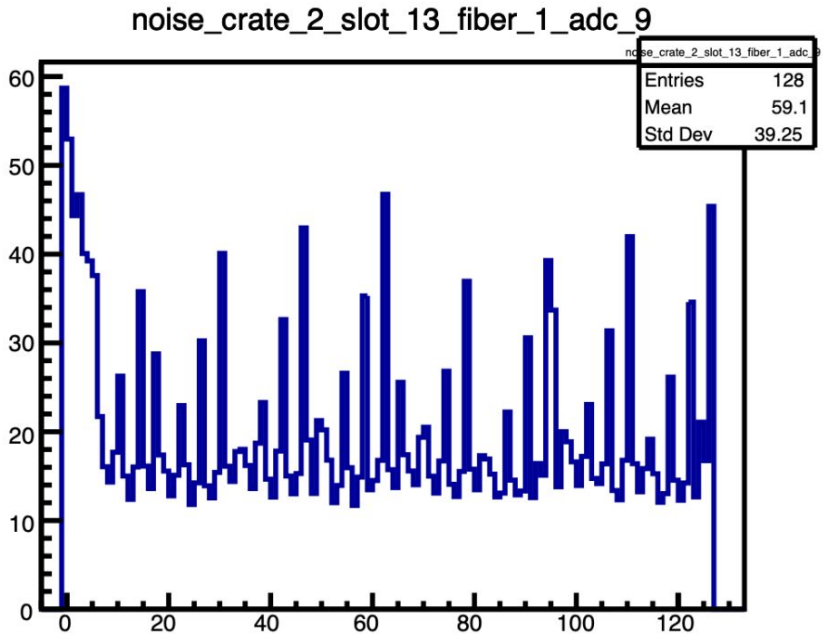
Summary

- Basic software for raw-data decoding exists for all the detectors (Cherenkov and GEMs).
  - Since the analysis scripts are based on the SBS, it is tested thoroughly during the SBS running.
  - The analysis chain is further tested for the MOLLER detector systems by many groups.
  - We have a clear path forward for developing advanced debugging and analysis scripts using simulated data
- Planning to bring more man power as we are planning to form a dedicated counting analysis group
- We are estimating by next summer we will have the complete analysis package ready using simulated data.

Back up

Comparison of noise occupancy for two APV cards in SBU09





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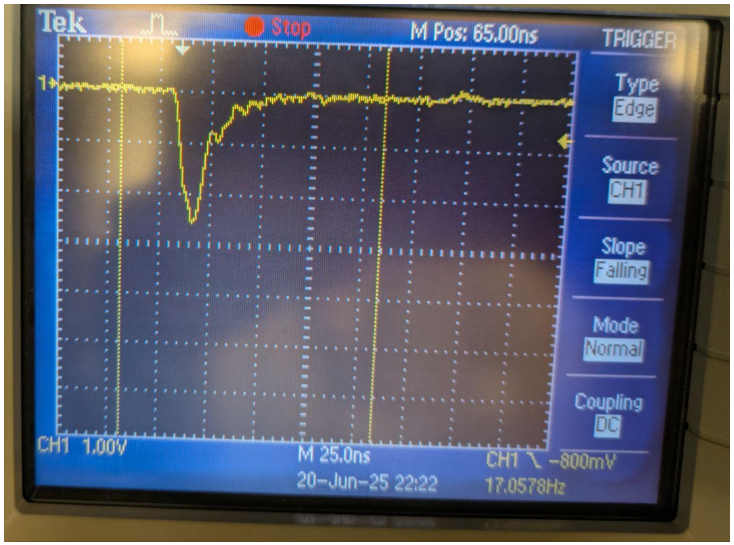
Plastic scintillator detector -used for GEM data taking



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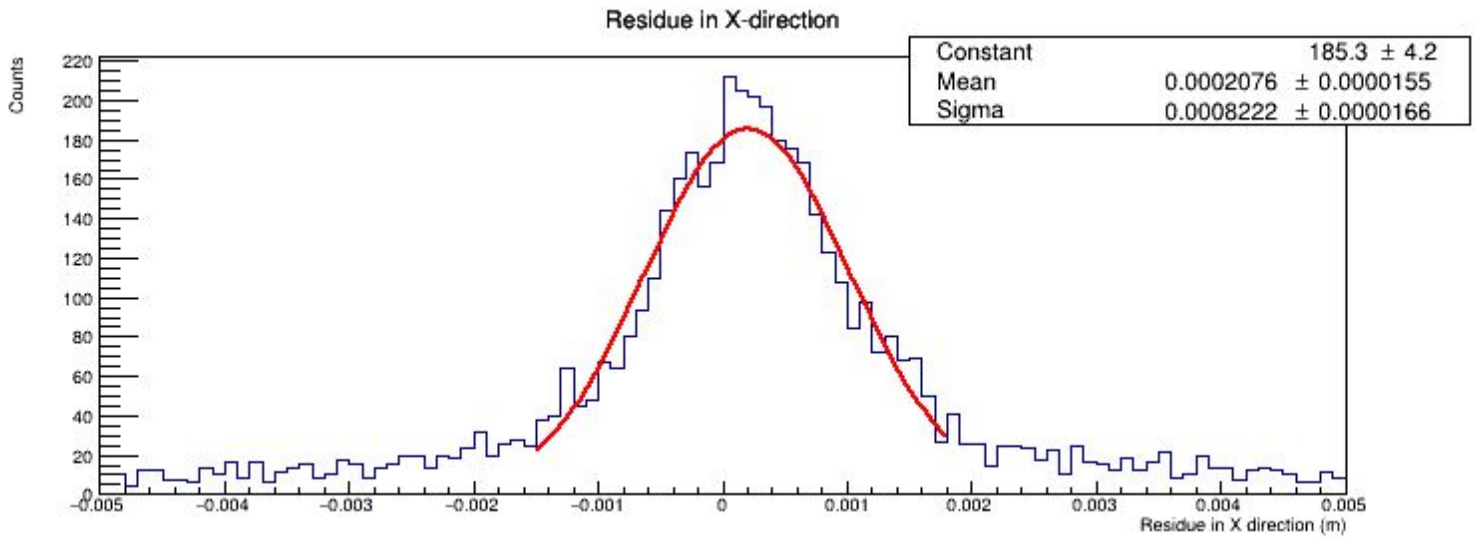
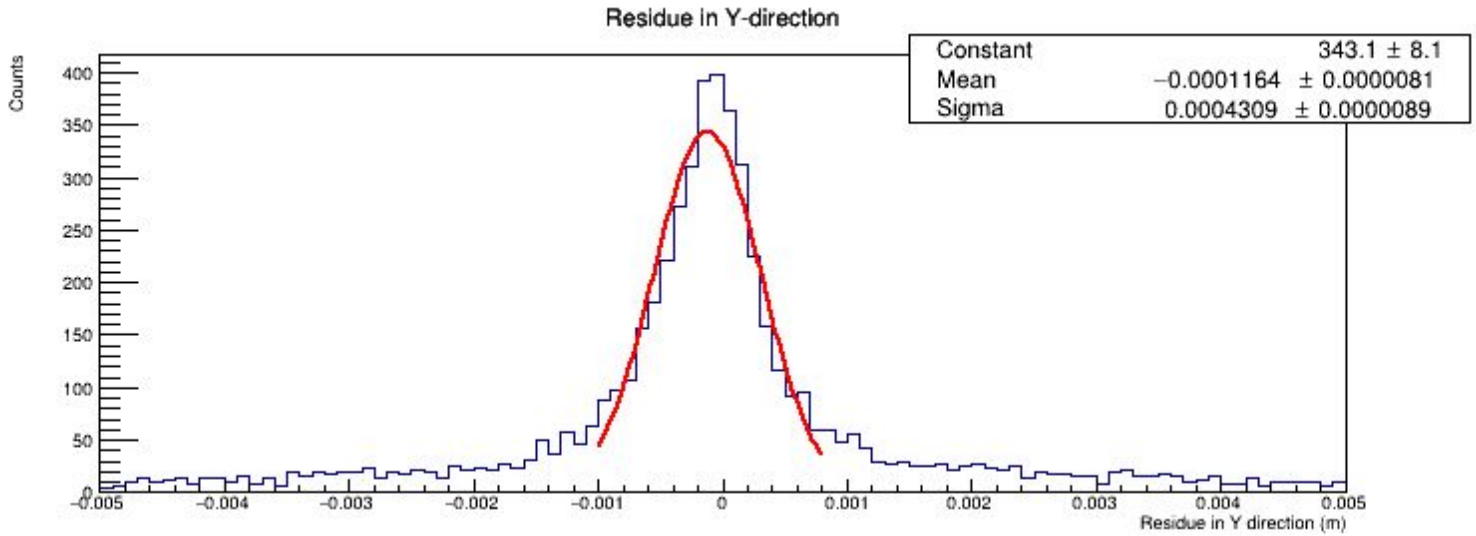
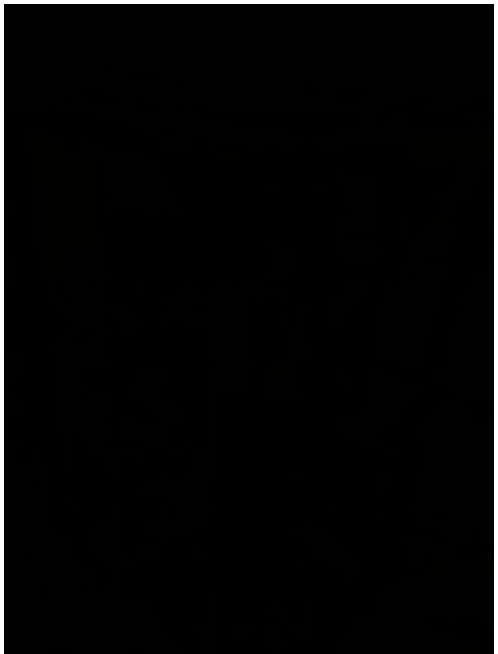
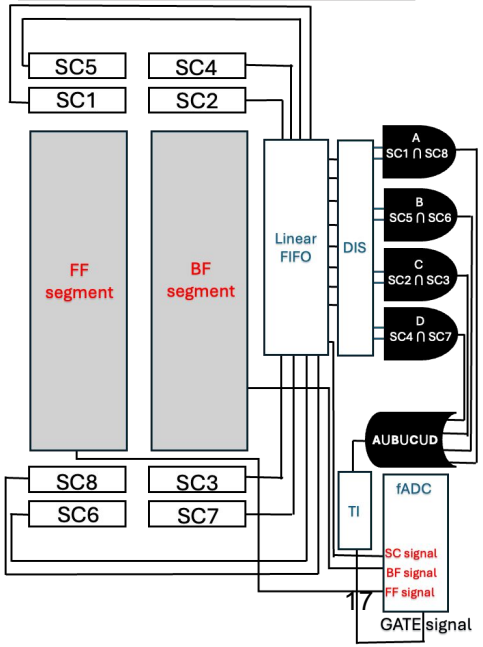
Position Resolutions in X/Y directions





fADC250 based readout chain at W&M





- Main detector production modules are being tested with cosmic muons at W&M
- fADC based readout (similar to MOLLER data taking configuration) is being used at W&M
- MOLLER-Counting framework is being used to analyse the data
- Data analysis includes the reconstruction of the waveforms to the output charge calculation
- The plan is to develop the existing framework and add additional classes for the other auxiliary detectors

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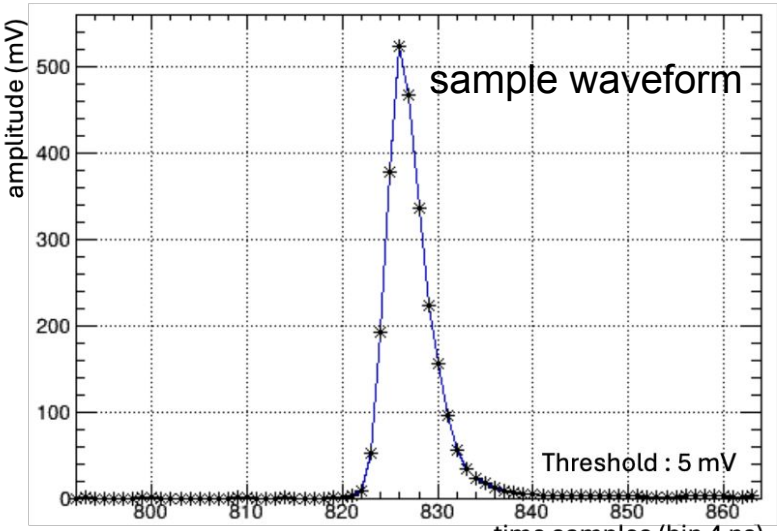
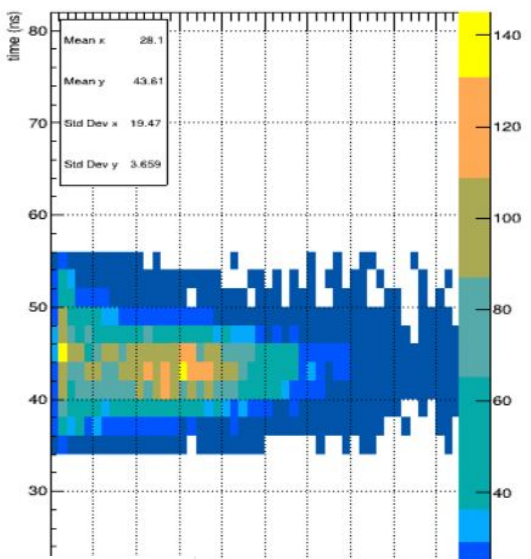
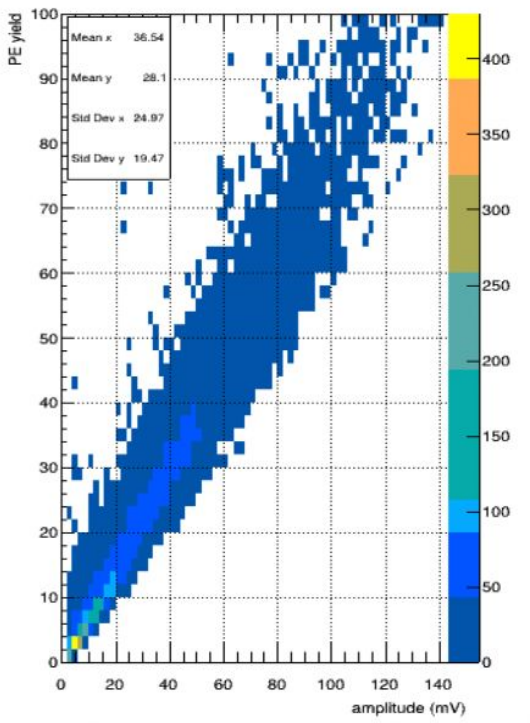
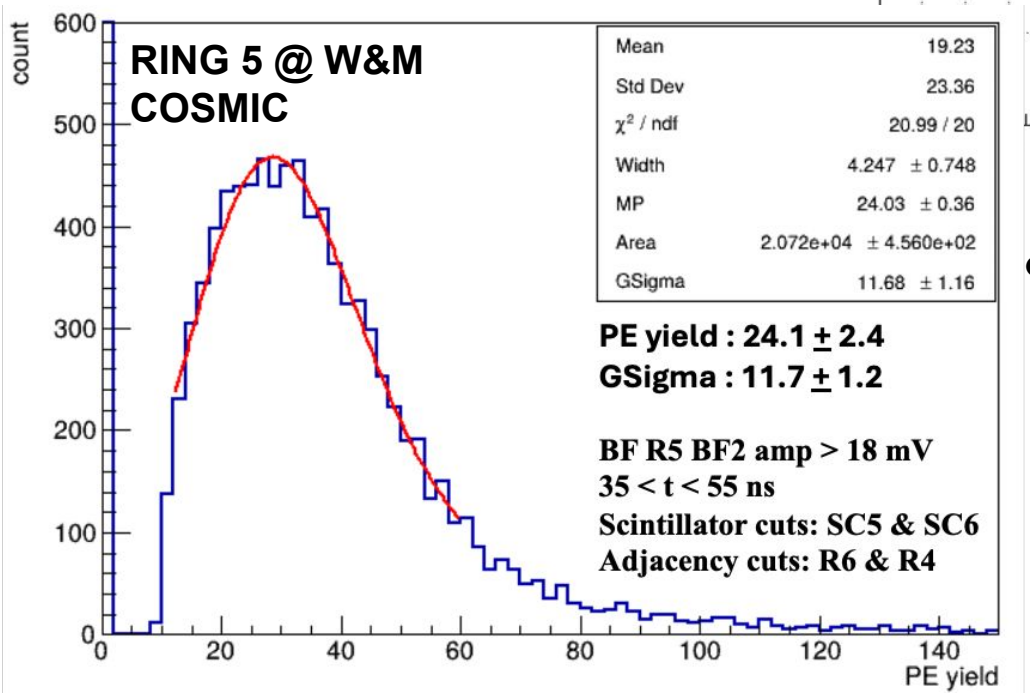
MOLLER-COUNTING: fADC250 data decoding and analysis









- MOLLER-COUNTING framework has been tested extensively in terms of decoding the data and calculating the PE yield using the production Main detector integrating modules in counting mode

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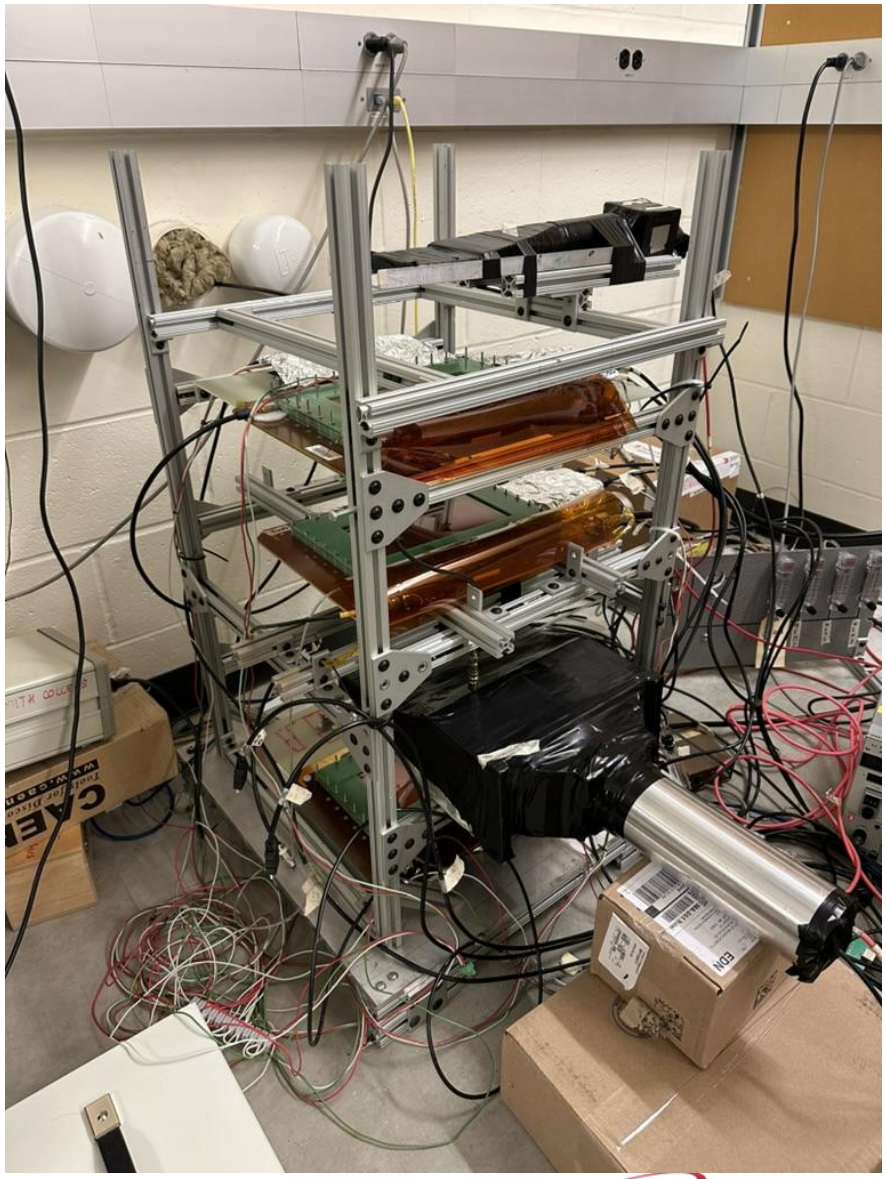
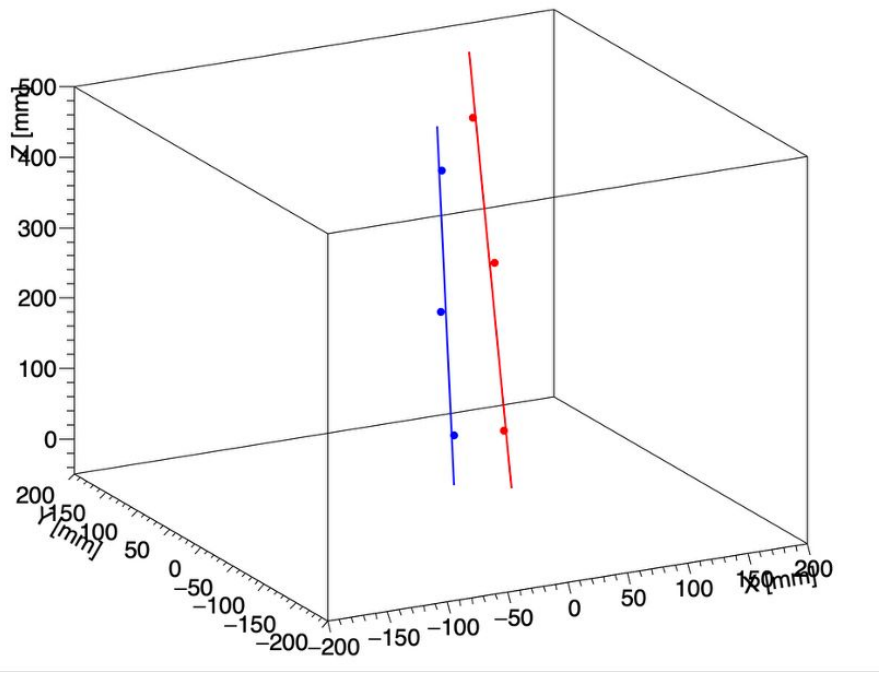
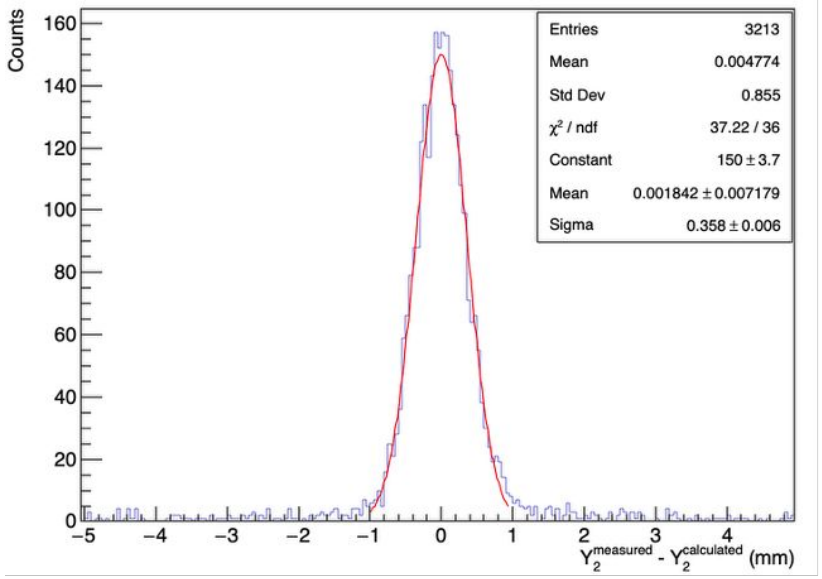
Testing of MPD+fADC based data decoding at UMass

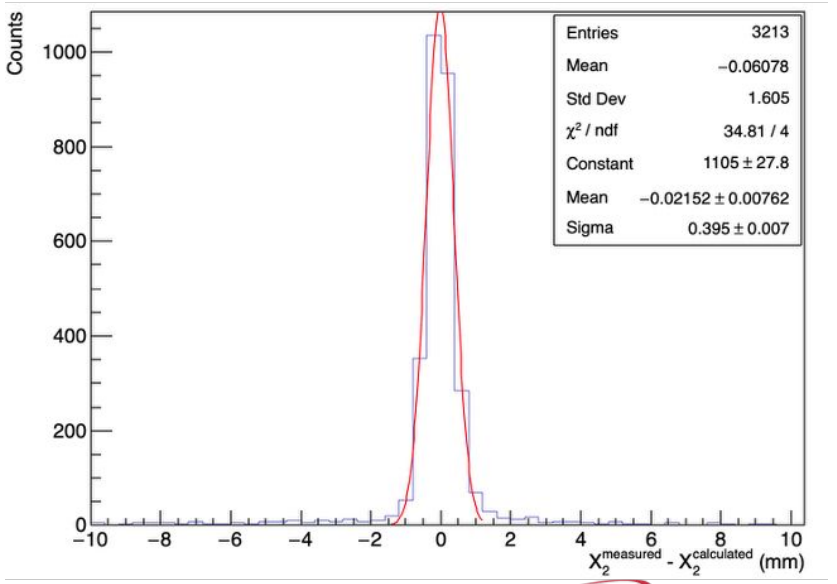
- A cosmic muon tracking system is setup at UMass using three triple GEM (10 cm × 20 cm) detectors
- Cherenkov detector prototype is placed in between the GEM chambers
- APV+MPD & fADC based DAQ system is used to readout the GEM & Cherenkov detector modules respectively
- Work is ongoing to use the MOLLER-COUNTING framework to decode the MPD and fADC data simultaneously and do the tracking



Tracking system performance at UMass (preliminary)







- Stand alone decoding of the GEM data
- Effort is ongoing to use the MOLLER-COUNTING framework and simultaneously decode the APV and fADC data
- Do the tracking to simulate the MOLLER commissioning phase

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