

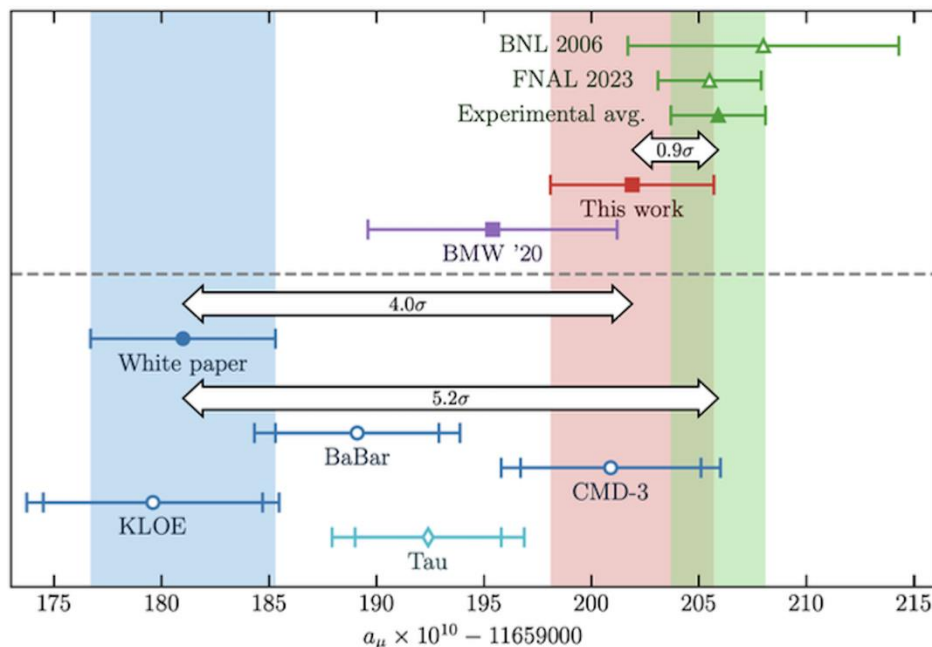
# News from the MUonE Experiment

Saskia Charity for the Liverpool MUonE Group

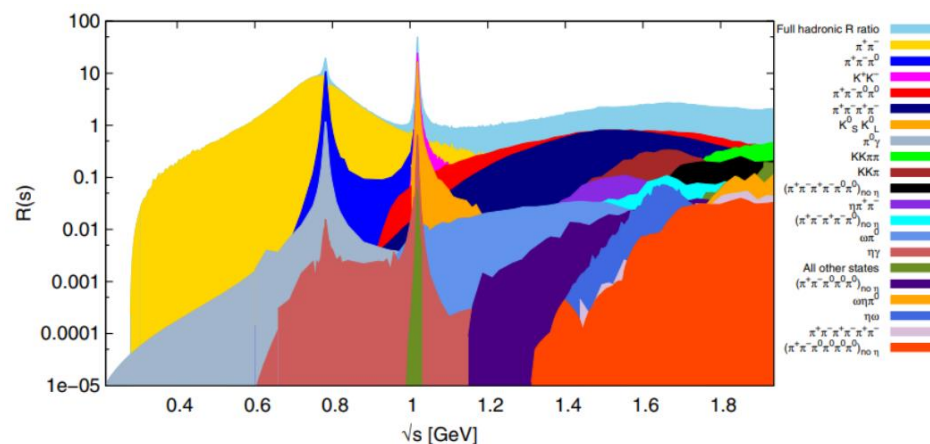
Liverpool HEP Annual Meeting

23<sup>rd</sup> May 2025

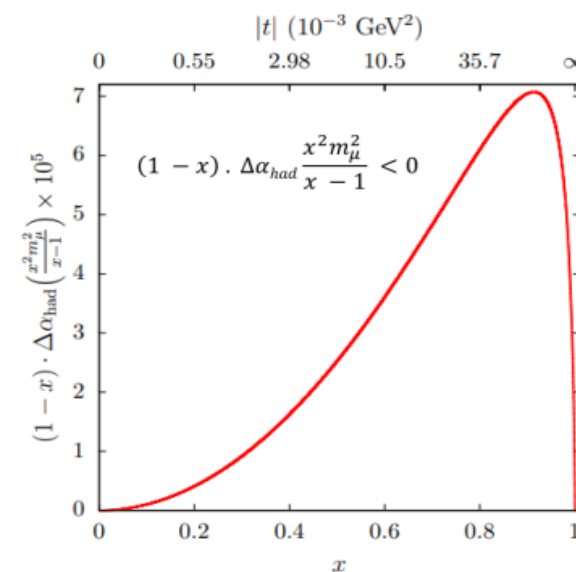
# Why MUonE?



- Tension between data-driven and lattice determinations of SM prediction of  $a_\mu$ 
  - Uncertainty dominated by non-perturbative hadronic vacuum polarisation (HVP) term



Dispersive approach:  
many different  
measurements,  
resonances

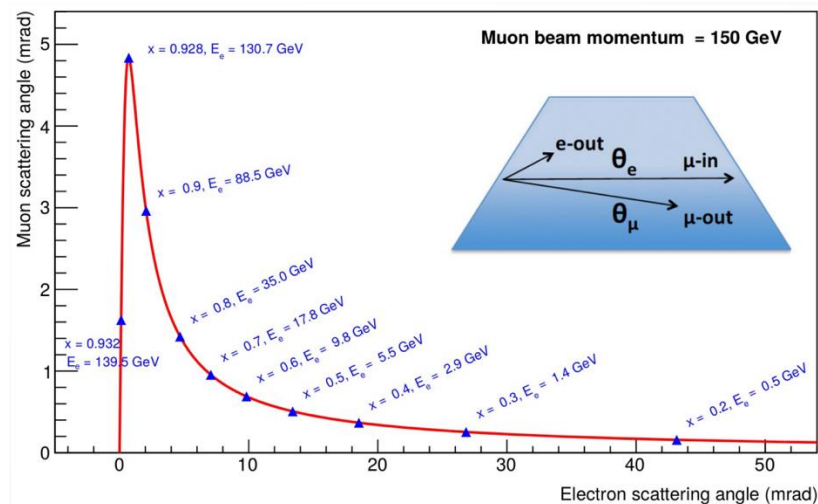


MUonE: single  
measurement in the  
spacelike domain →  
smooth function

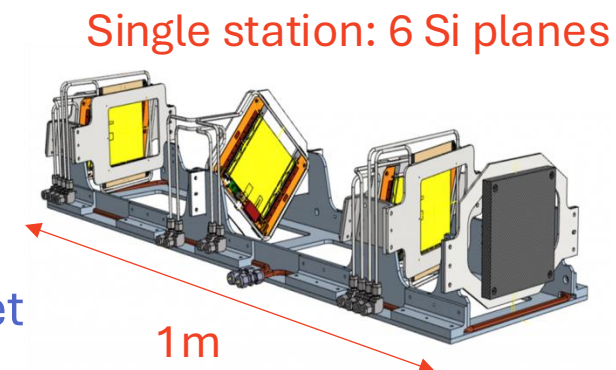
$$a_\mu^{HLO} = \frac{\alpha_0}{\pi} \frac{1}{2\pi} \int_0^1 dx (1-x) \Delta\alpha_{had}[t(x)]$$

# The MUonE Experiment at CERN

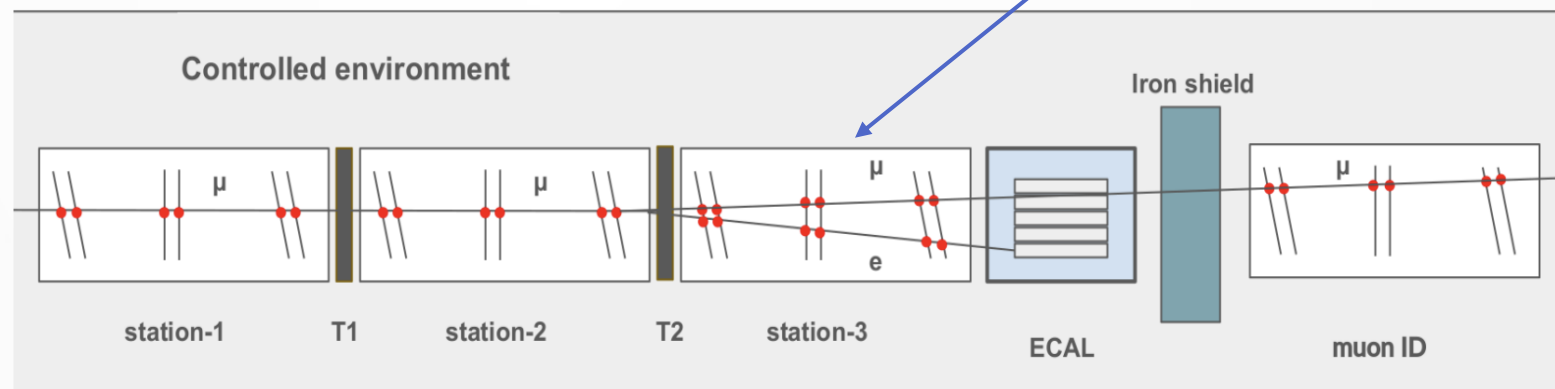
Elastic scattering: extract  $\Delta\alpha^{\text{had}}$  from correlation between outgoing muon and electron angles



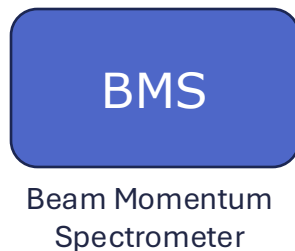
- 2025: 3 stations, 2 months
  - Measure  $\Delta\alpha^{\text{had}}$  to 20%
- Post-LS3: 40 stations, 3 years
  - Measure  $\Delta\alpha^{\text{had}}$  to 0.3%
- 10 ppm systematic uncertainty budget
  - 10  $\mu\text{m}$  longitudinal alignment
  - Multiple Scattering 1%
  - Uniform efficiency over full energy range
  - Beam energy measured to  $\sim$ few MeV



## June-July 2025 Phase-I: 3 stations



Liverpool contributing  
BMS  $\rightarrow$  upstream  
measurement of  
beam energy scale



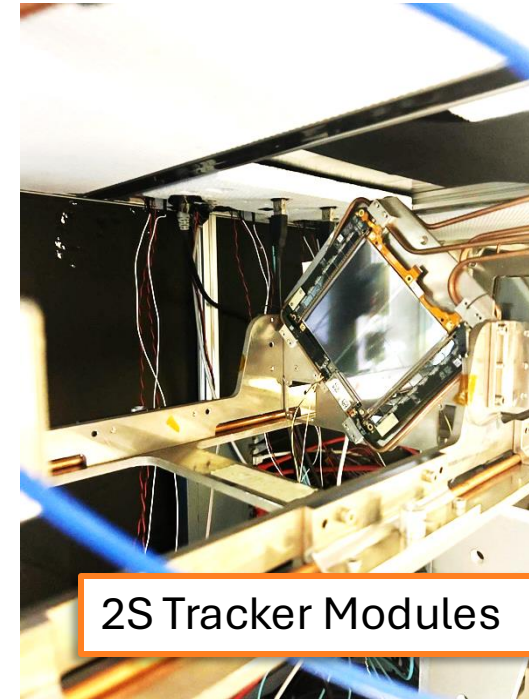
# MUonE at Liverpool

- Liverpool is one of the largest groups on MUonE
  - **HEP**: 6 Staff (GV, TB, FI, SC, TJ, JV), 4 Postdocs (EB, RP, AT, CZ), 4 Students (GC, CD, KF, NV)
  - **TP**: 2 Staff (TT, YU), 3 Postdocs (WTB, TD, JP), 2 students (PP, TT)
  - **Technical staff**: John Carroll, Ashley Greenall, Mark Whitley, Dave Sim, Tony Smith
- Major contributions to all areas of experiment
  - **Detector design and construction**: Beam Momentum Spectrometer (BMS)
  - **Track reconstruction** and **alignment software**
  - **Detector simulation** and test design of future setup
  - Development of **novel MC generators** for signal and background
  - **Data analysis** and extraction of  $\Delta\alpha^{\text{had}}$
  - **Data Quality Monitoring (DQM)** for 2025 run
  - **Leadership roles**: Institutional Board (GV), Technical Board (RP, SC), Software Manager (CD)

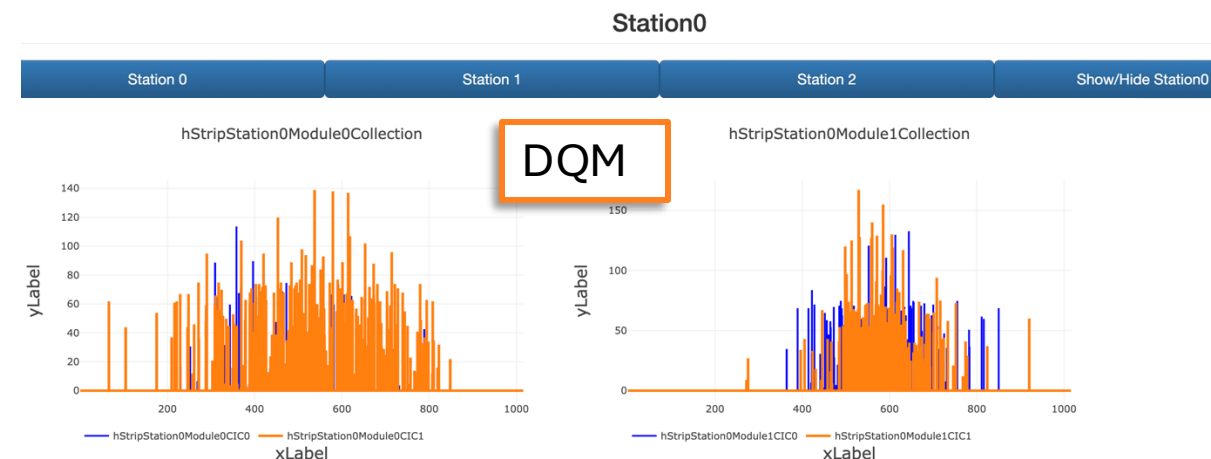


# 2025 Phase-I Run Activities

- Phase-I with 3 stations taking place this summer
- 2 months of running (June & July)
- Giorgia, Clement and Riccardo based out at CERN for the last few months
  - Mounting modules into frames
  - Testing 2S modules
  - Alignment development and shift coordination
- DQM Software

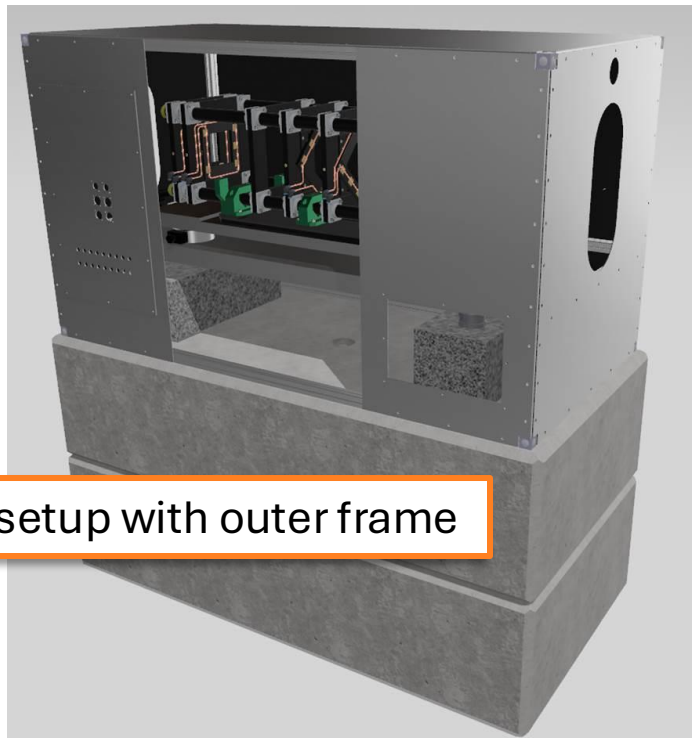


Setup in the M2 beamline enclosure

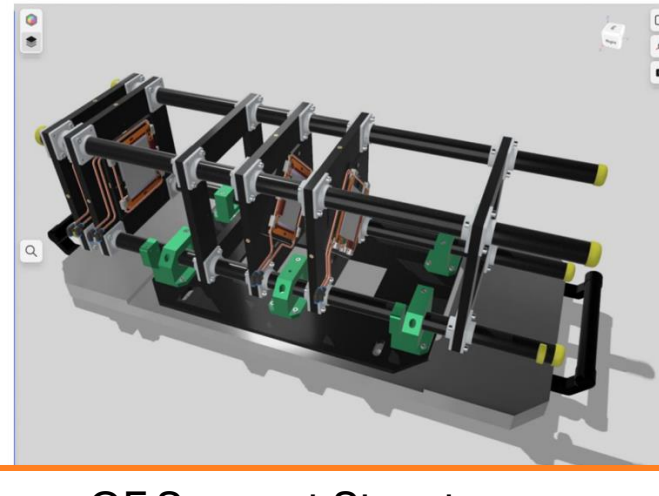


# BMS Detector – Purpose & Design

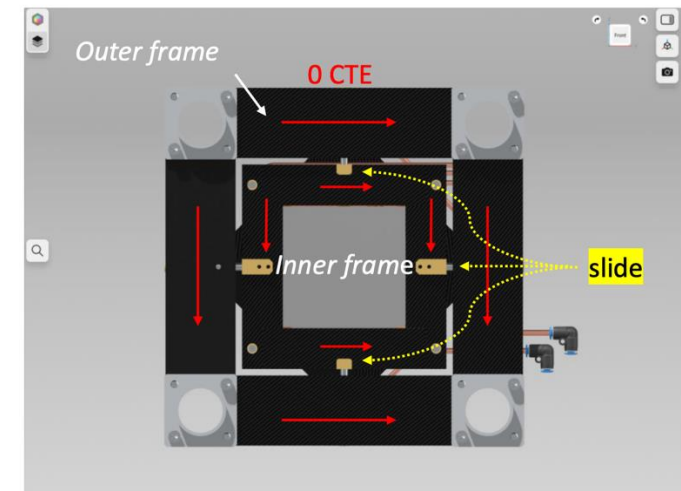
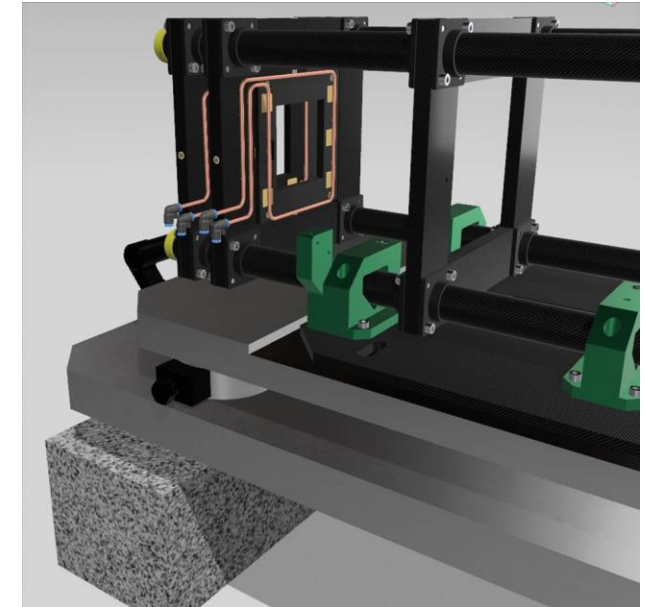
- Event-by-event measurement of incoming beam momentum
- Two locations (before/after M2 bending magnets)
- For 2025, same sensors & readout as main tracker (CMS 2S)
- Modular design – different number of layers, different orientations, ....
- Removable plate accurate to ~few  $\mu\text{m}$ , mount on fixed plate
- Sliding CF plate for fine-tuning yaw adjustment, CTE stability



Full setup with outer frame



CF Support Structure  
Sliding plates for fine-tuning





# BMS Detector – Assembly & Construction

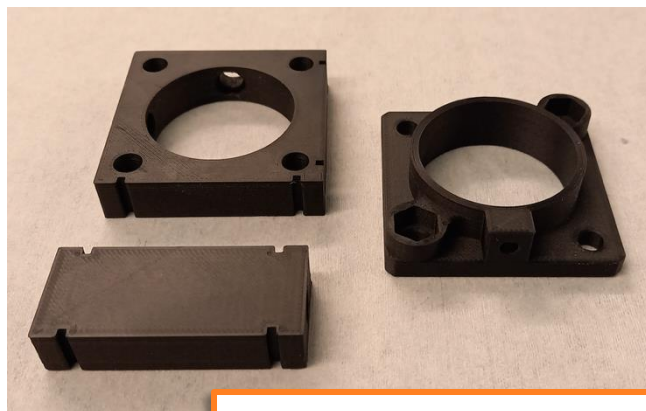


Aluminium fixed plate

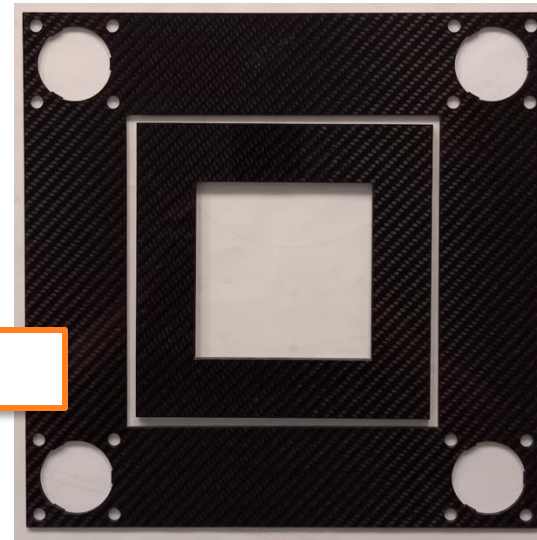


Clamps and rails

- Huge effort by workshop & LSDC to get the detector ready for 2025 run – thank you!
- Final assembly taking place now
- Ship to CERN for installation first week of June

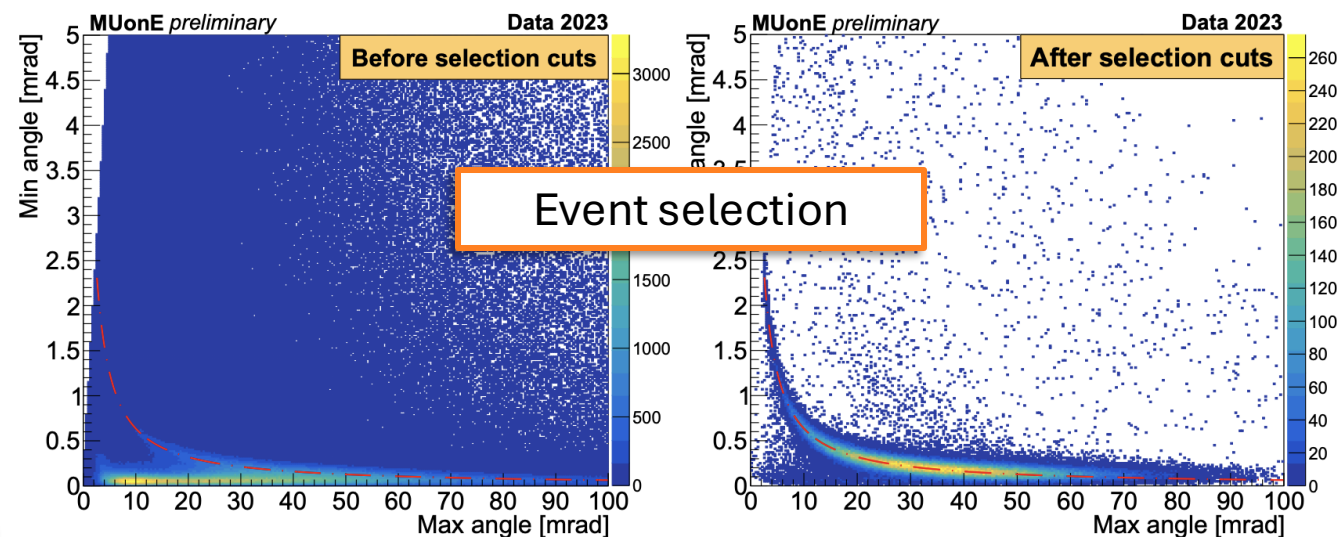
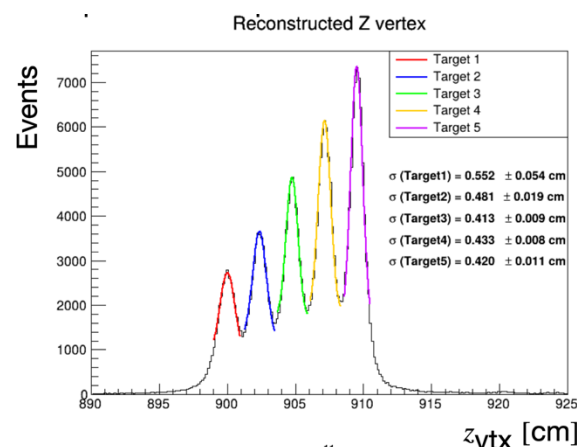
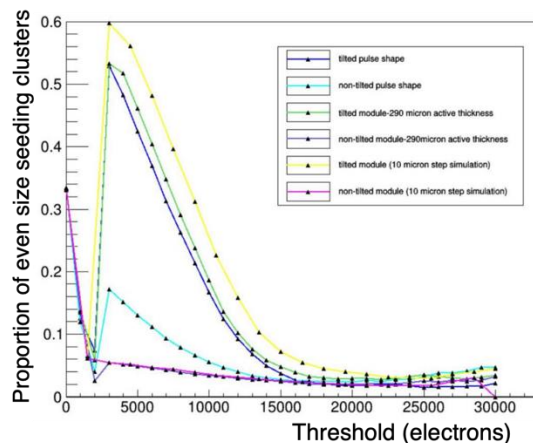
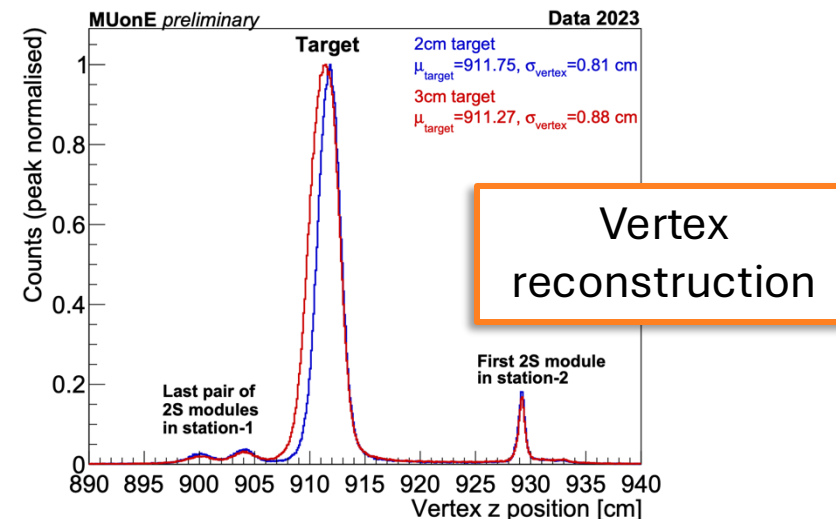


CF frames



# Analysis activities – past, present, future...

- **2023 Test Run analysis:** vertex resolution, track resolution, event selection, ... (Katie, Riccardo, Cedric)
- **2S modules simulation** (Giorgia, Elia)
- **Track and vertex reconstruction** algorithm, Kalman Filter (Clement, Riccardo)
- **Future detector & target studies** (Niels)
- **BMS Geant4 Simulation** (Fedor)
- & much more...





# Theory input

- Measurement of differential cross-section must be normalised by MC prediction
- **NNLO calculations** required
  - Some up to N<sup>3</sup>LO (!)
- Main challenges:
  - Radiative corrections
  - **Background processes** (nuclear pair production)
- Liverpool Theory Group has major contribution to theory effort
  - **RadioMonteCarLow** Workshop held in Liverpool (Nov 2024)  
→ many Liverpool contributions
- **Collaborative effort between TP and HEP**
  - Incorporate new generators into experimental MC
  - Data-MC comparisons using 2023 (and soon 2025) data

$$R_{had}(t) = \frac{\overset{\text{measurement}}{d\sigma_{\text{data}}(\Delta\alpha_{\text{had}} \neq 0)}}{\underset{\text{simulation}}{d\sigma_{\text{MC}}(\Delta\alpha_{\text{had}} = 0)}} \approx 1 + 2\Delta\alpha_{had}(t)$$

# Summary and Timeline

- Phase-I MUonE starting in 9 days(!)
  - Liverpool-built BMS detector being shipped to CERN
  - Major Liverpool input to commissioning and installation of experiment, shift coordination and preparation of analysis and reconstruction software
- MUonE abstract was accepted to the ESPPU ([link](#))
- Preliminary measurement of  $\Delta\alpha^{\text{had}}$  to 20% with Phase-I data (3 stations, ~2 months)
- Phase-II (40 stations) → 3 years running post-LS3
- Thanks to all for the hard work to prepare for Phase-II!



# Summary