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The MUonE experiment

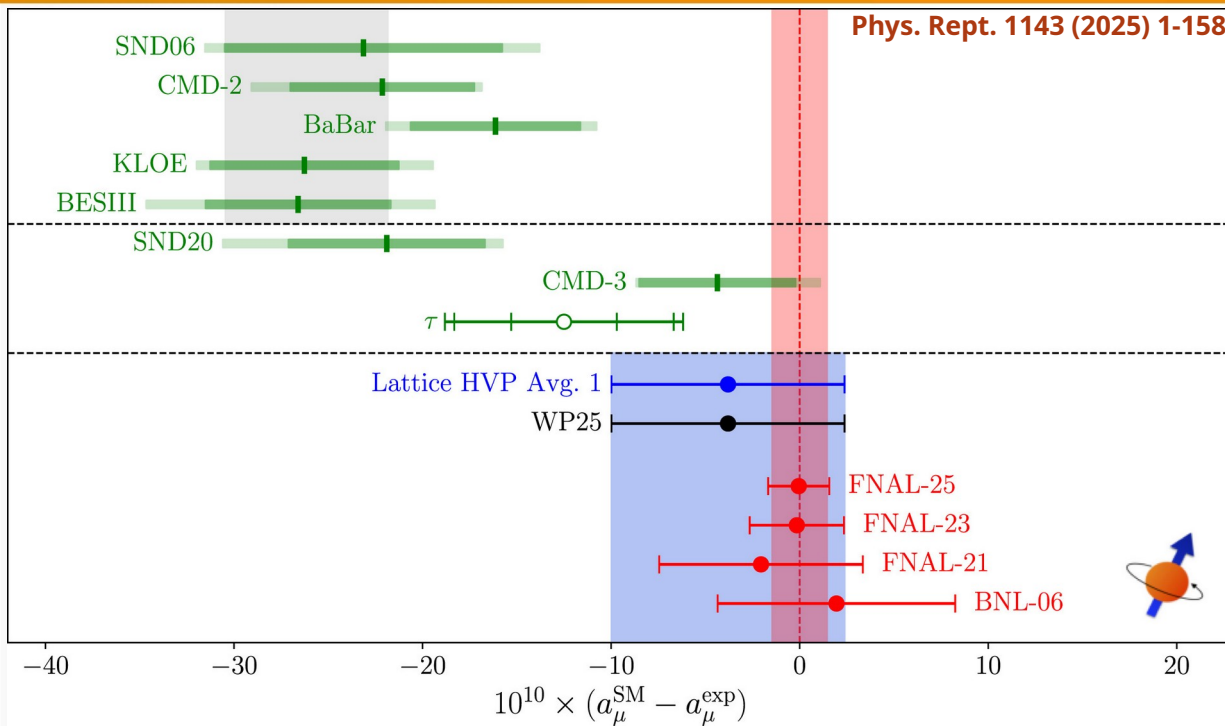
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International Workshop on Muon Physics at the Intensity and Precision Frontiers
(MIP2026)
Huizhou, 24-28 April 2026

Muon g-2: current status

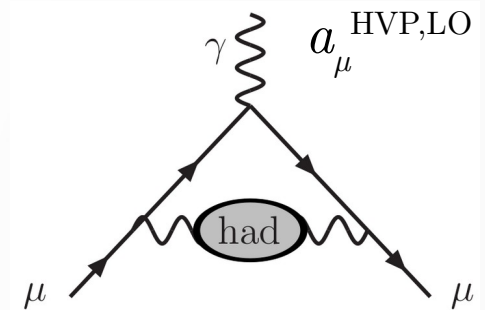
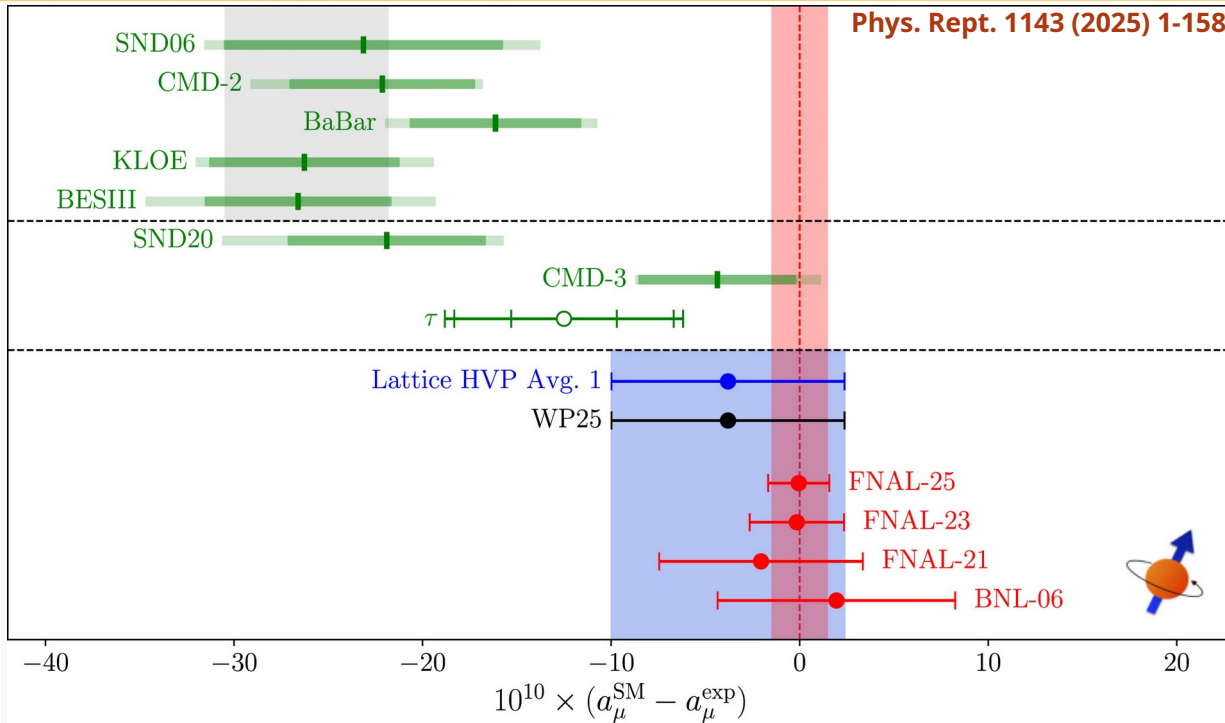


CERN/BNL/FNAL g-2 collaborations recently awarded with the Breakthrough Prize 2026!



At the Breakthrough Prize ceremony on April 18, 2026, left to right: Brookhaven National Laboratory Interim Director John Hill, Fermi National Accelerator Laboratory (Fermilab) physicist Chris Polly, Boston University physicist Lee Roberts, Fermilab Director Emeritus Young-Kee Kim, CERN Director General Mark Thomson, University of Washington physicist David Hertzog, and Brookhaven Lab physicist William Morse. (Courtesy of Kat Morse)

Muon g-2: current status



Main source of uncertainty of the theoretical prediction

Tensions in the evaluation of $a_\mu^{\text{HVP,LO}}$ using lattice QCD (WP2025) or e^+e^- hadronic cross sections

A clarification of the theoretical prediction is needed

The MUonE experiment



Phys. Lett. B 746 (2015), 325

Eur. Phys. J. C 77.3 (2017), 139

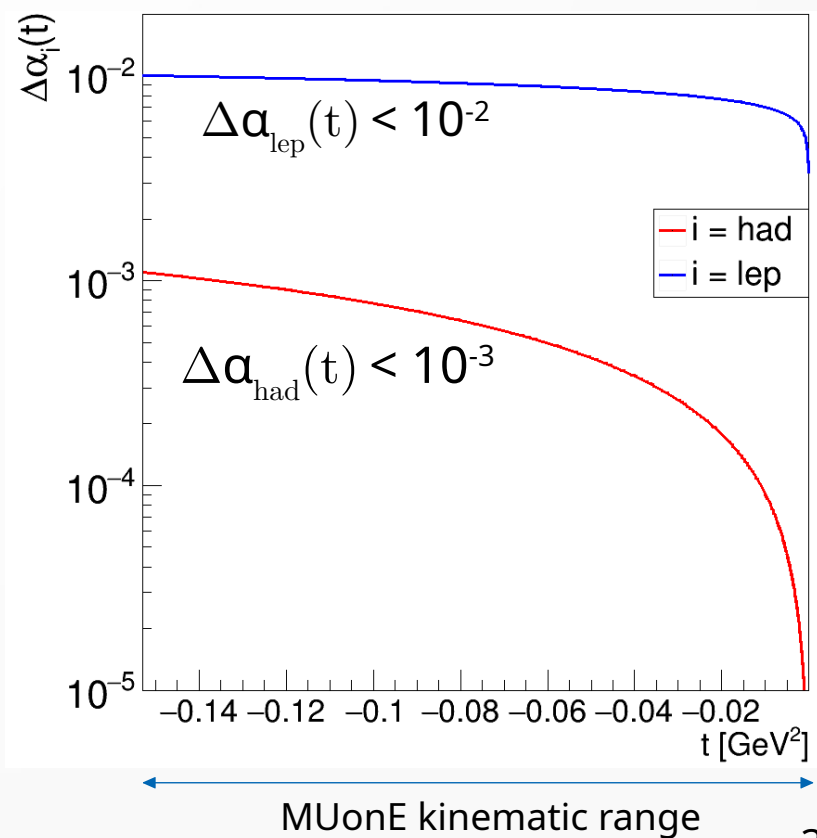
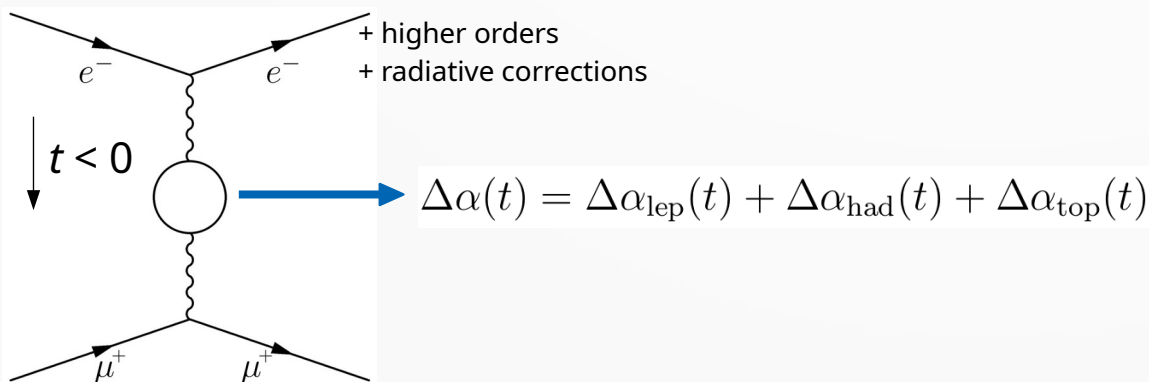
Letter of Intent CERN-SPSC-2019-026

Proposal for Phase 1 of the MUonE experiment

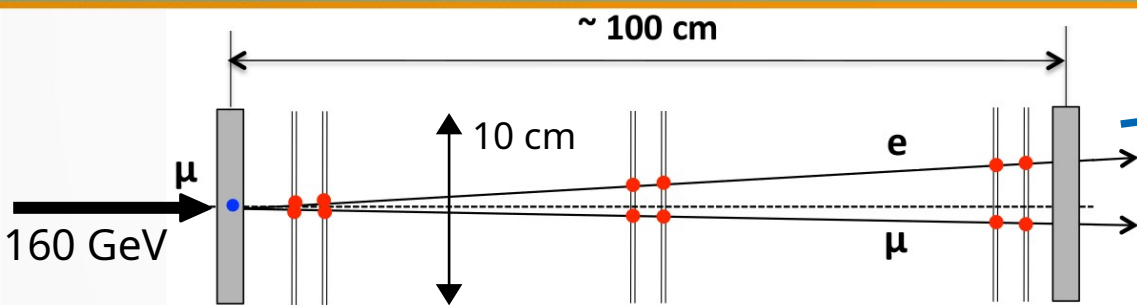
New independent evaluation of $\alpha_\mu^{\text{HVP,LO}}$, based on the measurement of $\Delta\alpha_{\text{had}}(t)$ in the space-like region

$$\alpha_\mu^{\text{HLO}} = \frac{\alpha_0}{\pi} \int_0^1 dx (1-x) \Delta\alpha_{\text{had}}[t(x)] \quad t(x) = \frac{x^2 m_\mu^2}{x-1} < 0$$

Extract $\Delta\alpha_{\text{had}}(t)$ from the *shape* of $\mu e \rightarrow \mu e$ differential cross section



The MUonE experiment

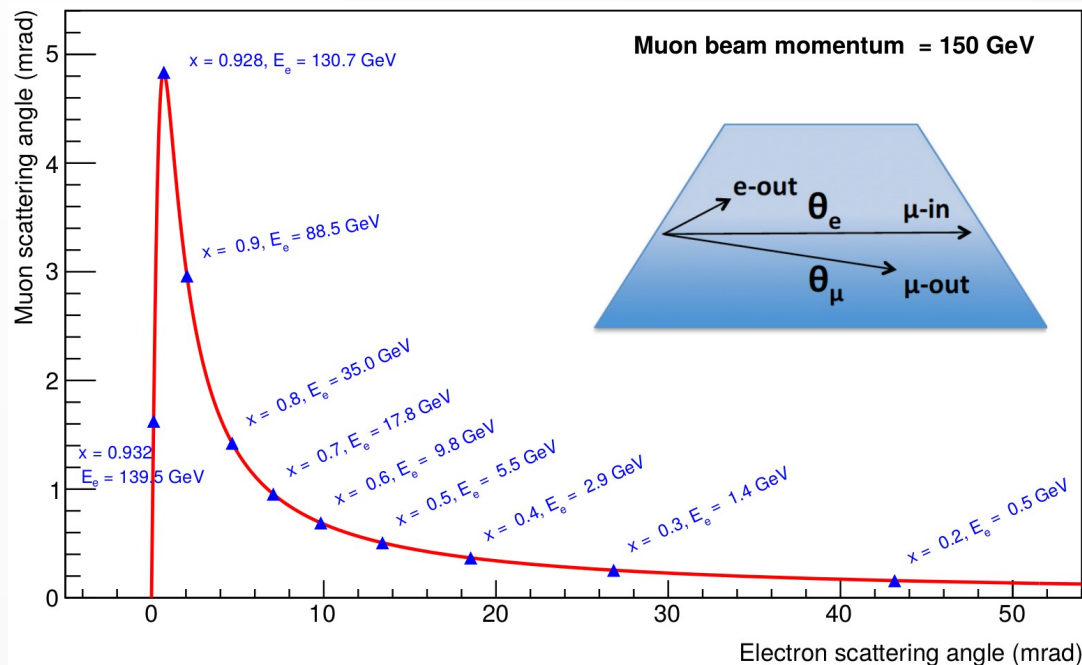


$$\frac{d\sigma_{\text{data}}(\Delta\alpha_{\text{had}})}{d\sigma_{\text{MC}}(\Delta\alpha_{\text{had}} = 0)} \sim 1 + 2\Delta\alpha_{\text{had}}(t)$$

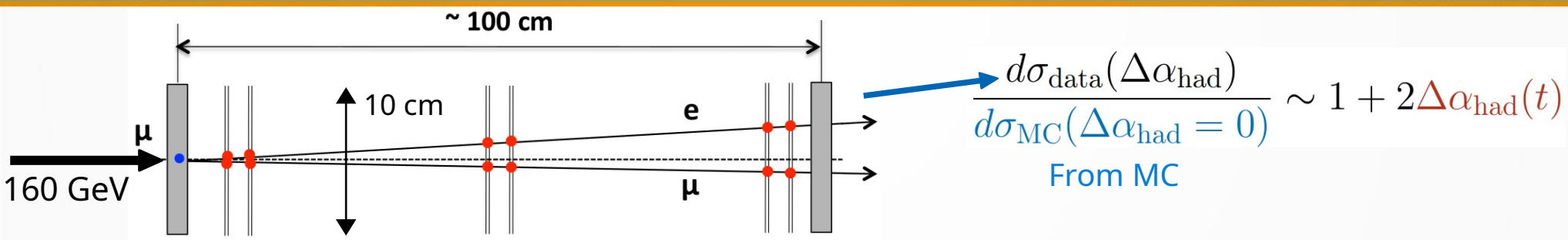
From MC

low-Z target ~1.5 cm
6 Si strip detectors (3 XY points)

- Observables: (θ_e, θ_μ)
- Exploit (θ_e, θ_μ) correlation to reject background (main source: $\mu N \rightarrow \mu N e^+e^-$)
- Boosted kinematics:
 $\theta_\mu < 5 \text{ mrad}$, $\theta_e < 32 \text{ mrad}$

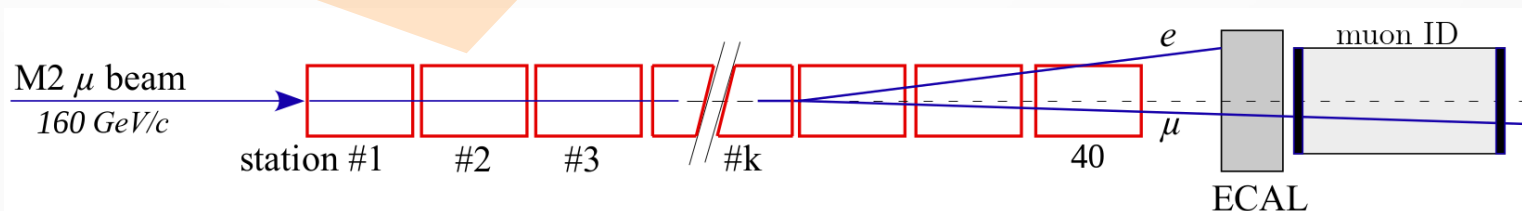


The MUonE experiment



BMS

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- Modular layout: each station measures the incident muon direction for the following one
- ECAL: PID + e^- energy
- Muon ID: PID
- BMS: beam momentum spectrometer

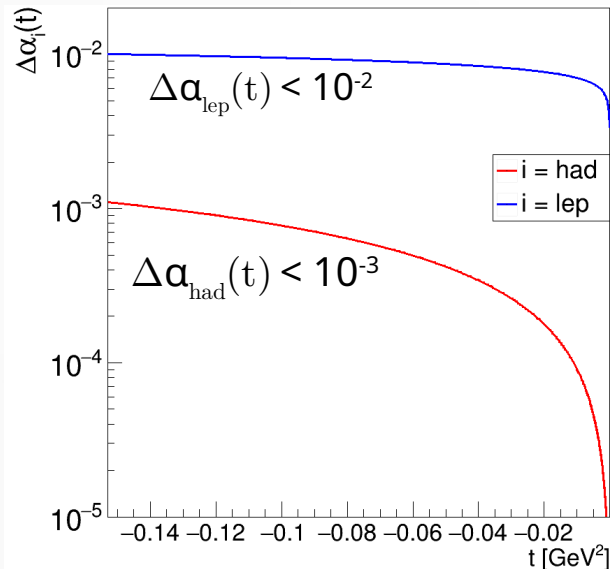
The MUonE experiment



MUonE final goal:

- ~3 years post LS3 (>2030)
- 40 stations
- 4×10^{12} elastic events
- $a_{\mu}^{\text{HVP,LO}} < 0.5\%$
- ~1% precision on $\Delta\alpha_{\text{had}}(t)$

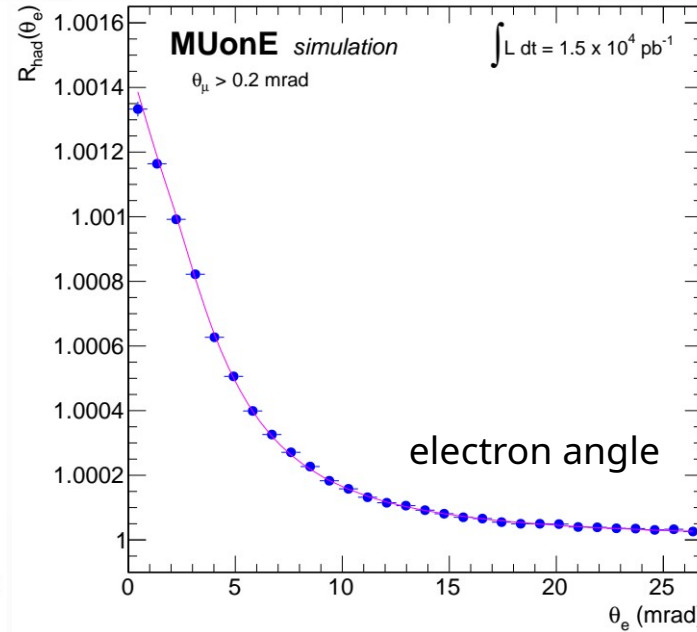
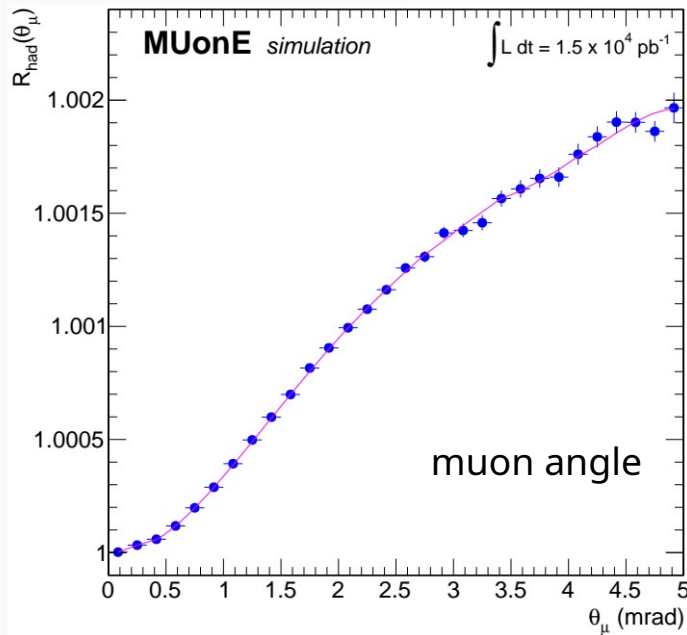
(error on $\Delta\alpha_{\text{had}}(t)$: 10^{-5} in the signal region)



Systematic error goal:
10 ppm on the shape of
the differential cross section

- 10 μm longitudinal alignment
- Measure beam energy at few MeV
- Multiple scattering ~1%
- Angular intrinsic resolution
- Uniform detector response over full angular range
- Need of dedicated MC generators: signal (>NNLO), main backgrounds

Sensitivity to $\Delta\alpha_{had}(t)$



Template fit to the distribution (θ_e, θ_μ) to extract $\Delta\alpha_{had}(t)$

$$R_{had} = \frac{d\sigma(\Delta\alpha_{had}(t) \neq 0)}{d\sigma(\Delta\alpha_{had}(t) = 0)}$$

$$R_{had} \sim 1 + 2\Delta\alpha_{had}(t)$$

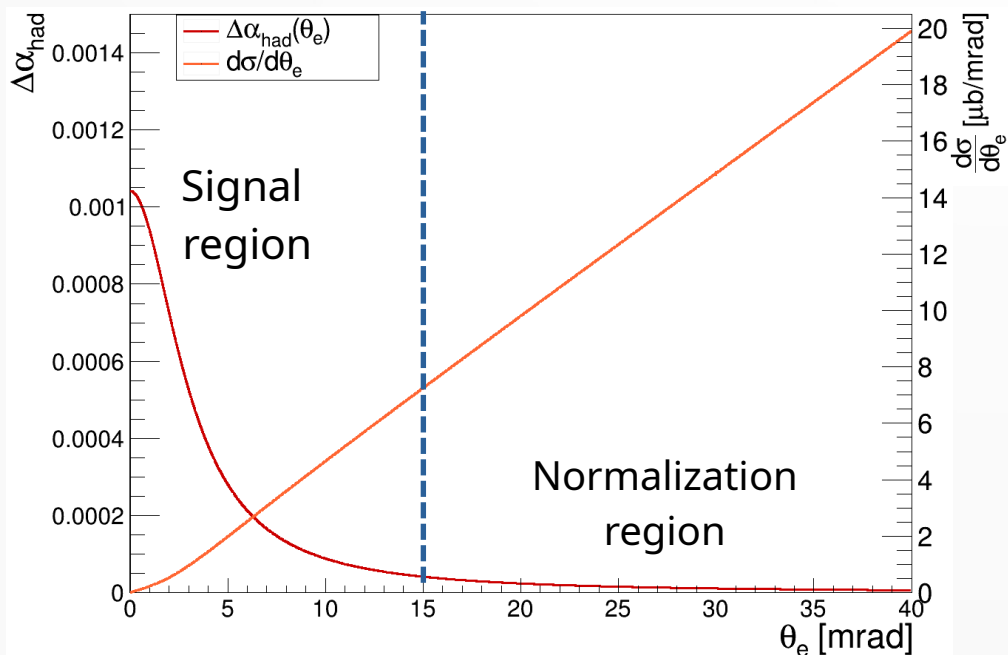
$\Delta\alpha_{had}(t)$ parameterization: inspired from the 1 loop QED contribution at $t < 0$:

$$\Delta\alpha_{had}(t) = KM \left\{ -\frac{5}{9} - \frac{4M}{3t} + \left(\frac{4M^2}{3t^2} + \frac{M}{3t} - \frac{1}{6} \right) \frac{2}{\sqrt{1 - \frac{4M}{t}}} \ln \left| \frac{1 - \sqrt{1 - \frac{4M}{t}}}{1 + \sqrt{1 - \frac{4M}{t}}} \right| \right\} \quad \text{2 parameters: } K, M$$

Strategy for the systematic effects

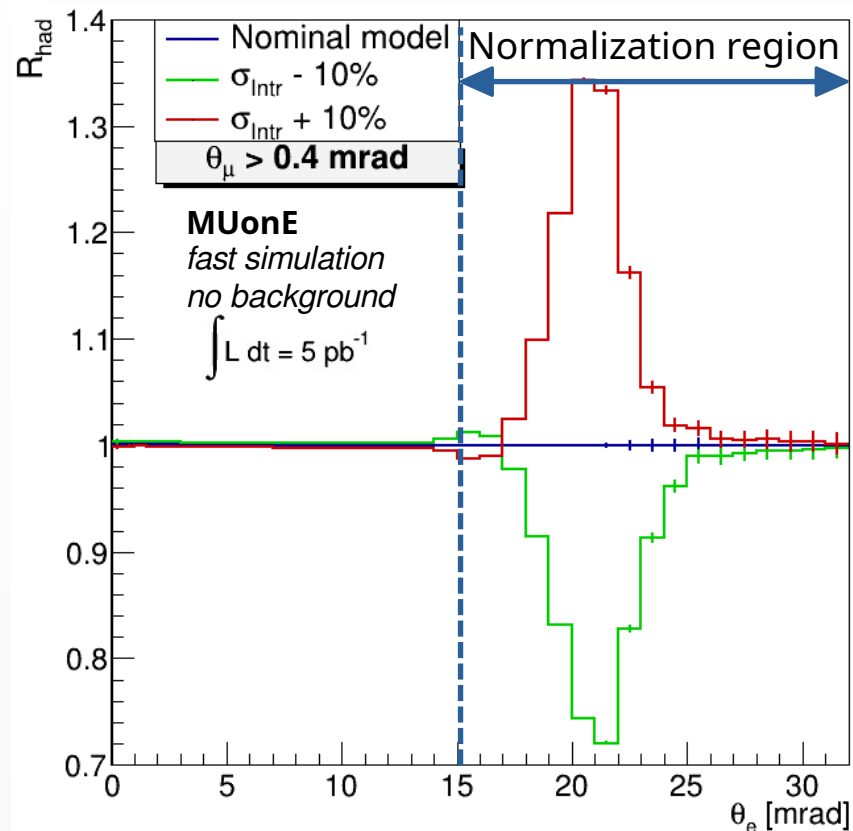
Promising strategy:

- Study the main systematics in the normalization region: large systematic effects but no sensitivity to $\Delta\alpha_{\text{had}}$
- Include residual systematics as nuisance parameters in a combined fit with signal



Example:

$\pm 10\%$ systematic error on the angular intrinsic resolution



Staged approach towards the full experiment



- 2017: test beam, multiple scattering studies JINST 15 (2020) P01017
- 2018: test beam, elastic scattering properties and event selection studies JINST 16 (2021) P06005
- 2021: first joint test CMS-MUonE
with 4 2S modules prototypes (parasitic)
- 2022:
 - test 1 tracking station
 - test the calorimeter
- 2023: test with 2 tracking stations + calorimeter
- 2024: 2 tracking stations (DAQ tests) + calorimeter (characterization)
- **2025**: run with a scaled version of the complete apparatus

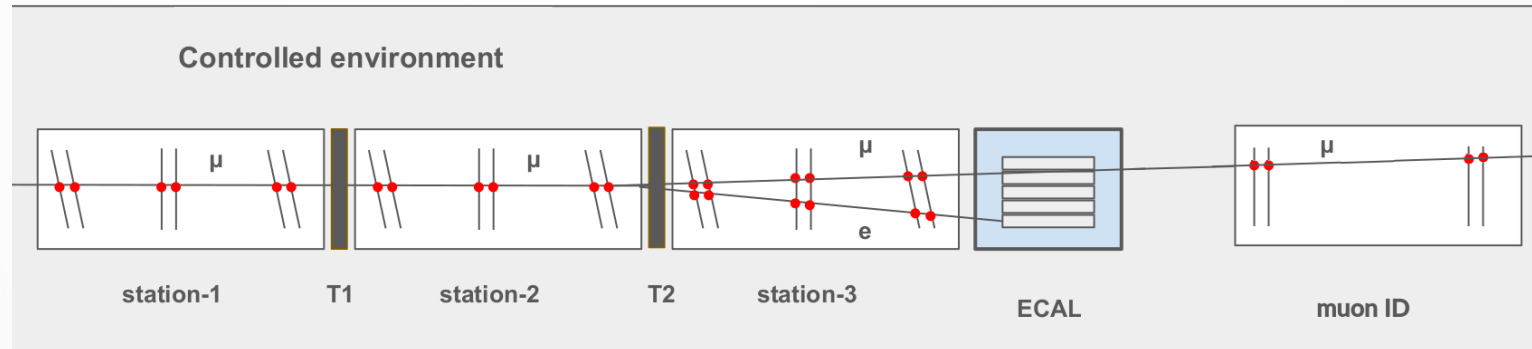
MUonE Phase-1: Test Run 2025



Proposal for Phase 1 of the MUonE experiment

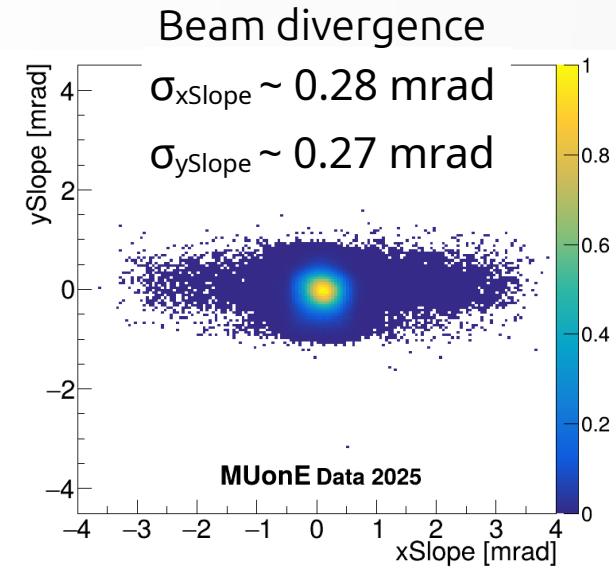
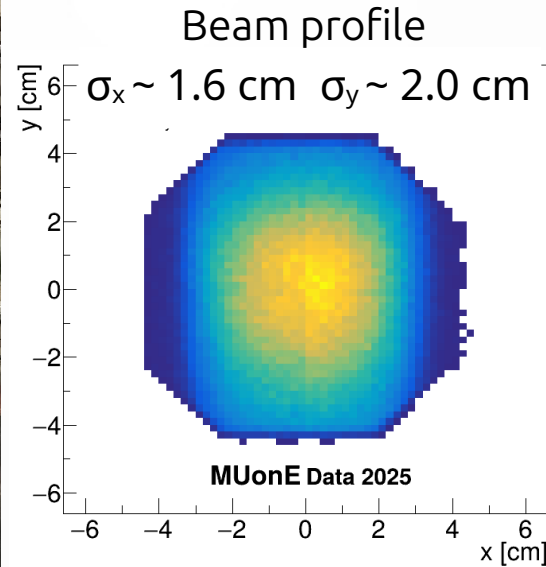
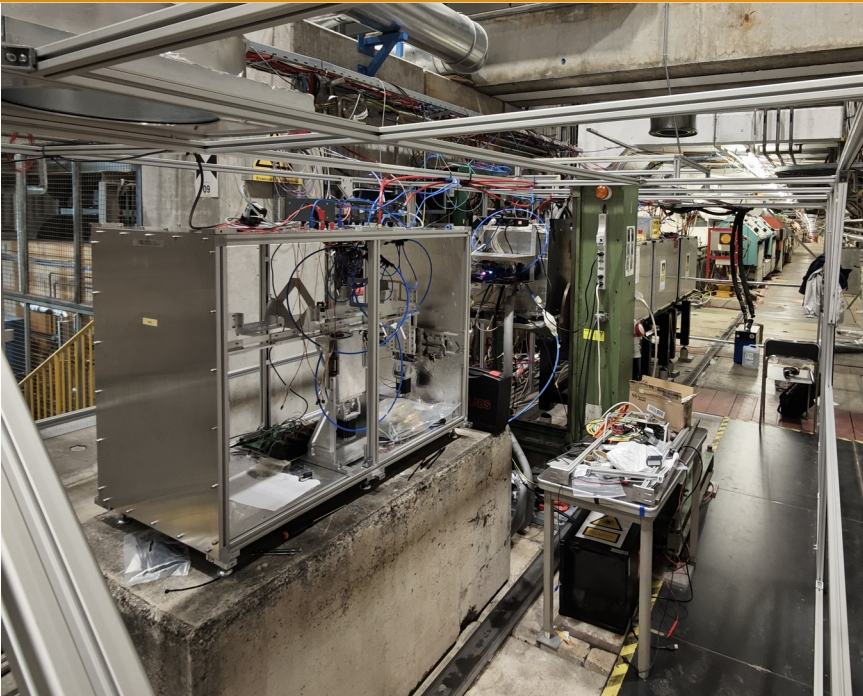
BMS

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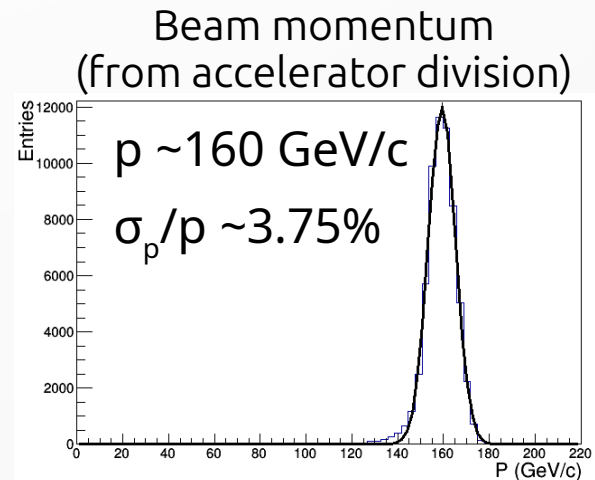


- 3 × tracking stations: muon beam direction and angles of the interaction products
- 2 × C targets (each 2 cm thick)
- ECAL: e^- PID + E_e measurement
- Timing detector: time of arrival of muons. 2 plastic scintillators before and after the tracking stations
- Muon ID: μ PID. Equipped with 4 prototype 2S modules
- BMS: measure p_μ event by event. 2 × tracking stations, each equipped with 4 prototype 2S modules

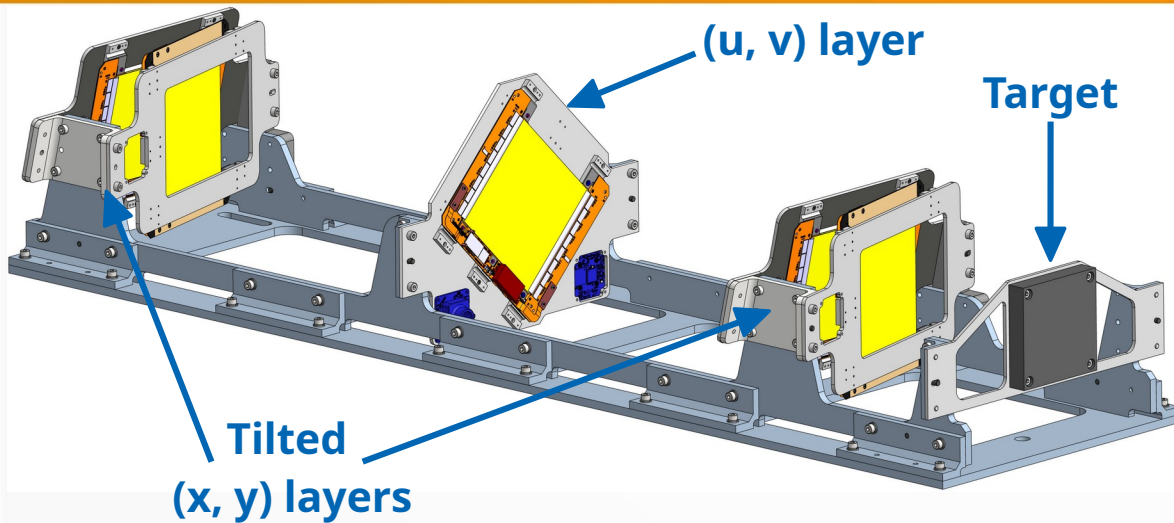
M2 beamline at CERN North Area



- MUonE location:
upstream of the AMBER detector
- Spill duration 4.8 s, $\sim 25\%$ duty cycle
- $\sim 2 \times 10^8 \mu^+/\text{spill} \rightarrow \sim 4 \times 10^7 \mu^+/\text{s}$
- Muons asynchronous to the DAQ clock



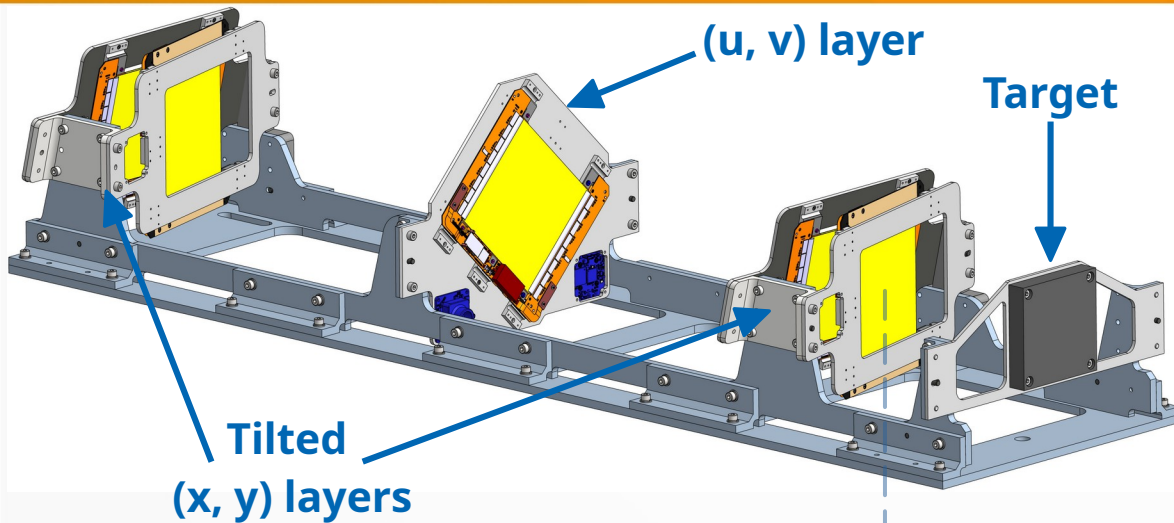
Tracking system



INVAR (Fe/Ni alloy)
CTE ~ 1.2 ppm/K
Laser holographic system
to monitor stability

- (x, y) layers:
tilted by 233 mrad \rightarrow $\sim 2\times$ hit
resolution improvement
- (u, v) layers:
solve reconstruction
ambiguities

Tracking system

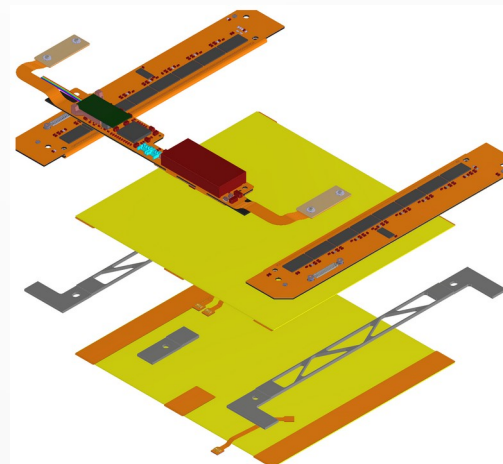


INVAR (Fe/Ni alloy)
CTE ~ 1.2 ppm/K
Laser holographic system
to monitor stability

2S modules (CMS Phase2 upgrade)

TDR CMS Tracker Phase2 Upgrade

- (x, y) layers:
tilted by 233 mrad \rightarrow $\sim 2\times$ hit
resolution improvement
- (u, v) layers:
solve reconstruction
ambiguities



- ~ 90 cm² active area
- 2×320 μ m thickness
- 40 MHz, binary readout
- 90 μ m pitch
(~ 26 μ m hit resolution)

Calorimeter & MuonID: E_e + PID



ECAL

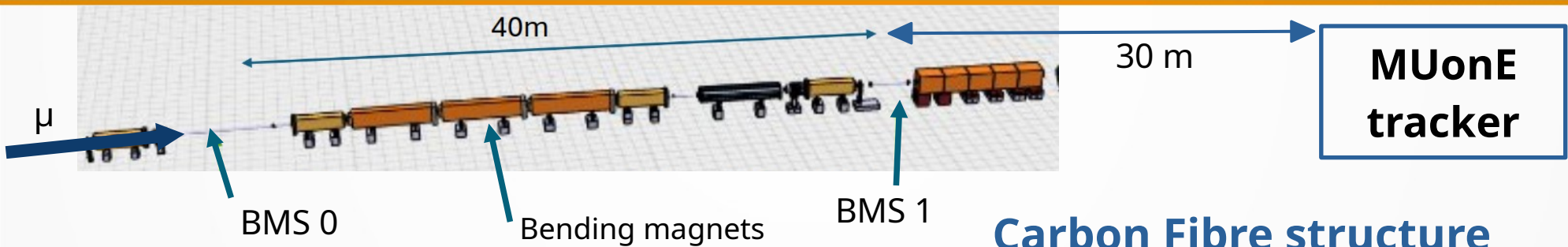


MuonID

- 5x5 PbWO₄ crystals (CMS ECAL)
 - area: $2.85 \times 2.85 \text{ cm}^2$
 - length: 23 cm ($\sim 25 X_0$)
- Total ECAL area: $\sim 14 \times 14 \text{ cm}^2$
- Readout: $10 \times 10 \text{ mm}^2$ APD

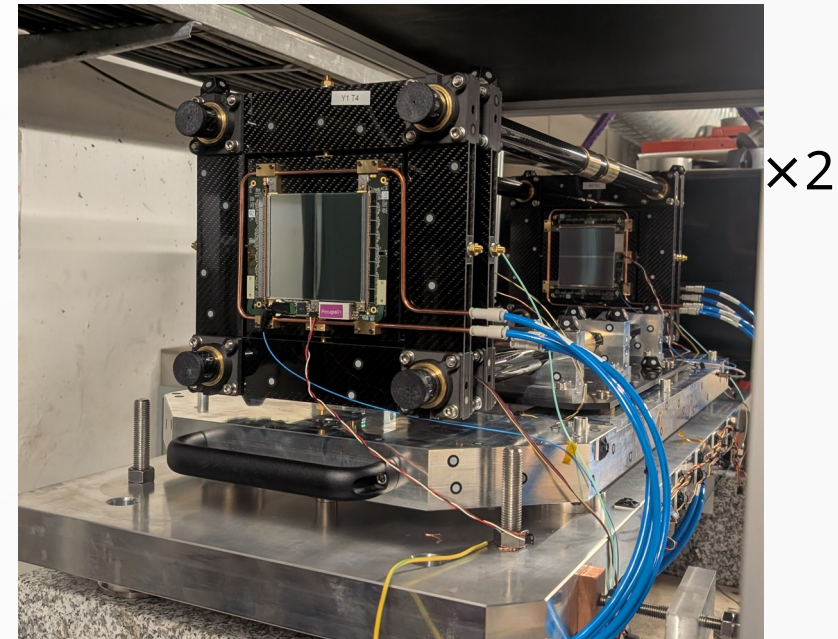
- Aluminum tracking station
- 4x2S modules (2 non-tilted XY pairs)
- Alternative solution R&D: scintillating fibres

BMS (Beam Momentum Spectrometer)



- Bending power: 16 T*m (30 mrad @160 GeV)
- Two tracking stations before/after bending magnets to measure deflection
- Proof of concept in 2025. First analysis ongoing. Challenges:
 - Alignment
 - B-field monitoring

Carbon Fibre structure



Each tracking station 1 m long
2 (x, y) non-tilted layers

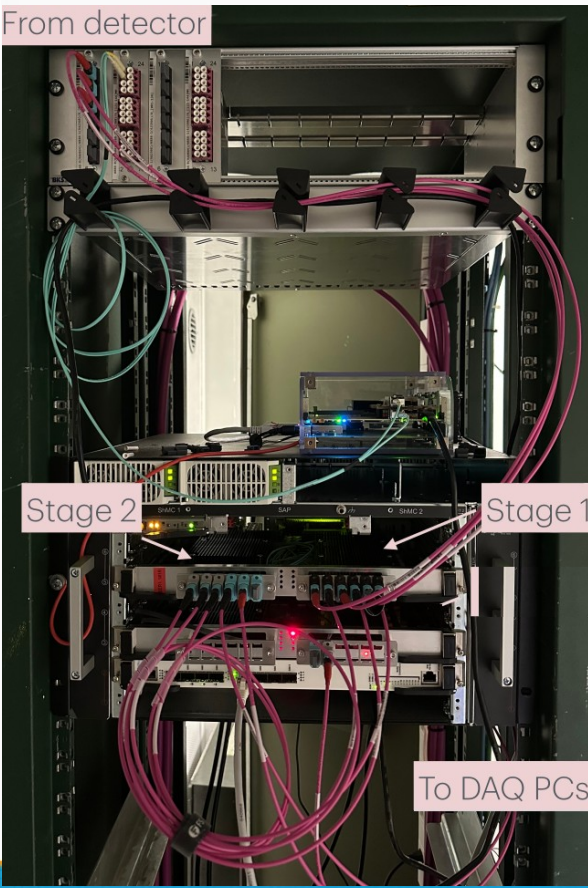
DAQ system



Based on the Serenity platform (developed for CMS Phase-2 Upgrade)

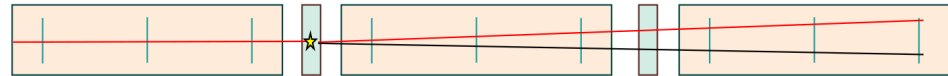
Two stage firmware design

- **Stage 1:** 36 communication links with sub-detectors
 - 30×2S modules
 - 2×Timing Detector
 - 4×ECAL
- Online selection based on tracker modules occupancy. Event rate is reduced from 40 MHz (no selection) to ~500 kHz

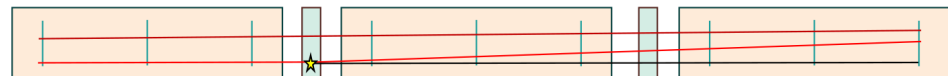


Event topologies

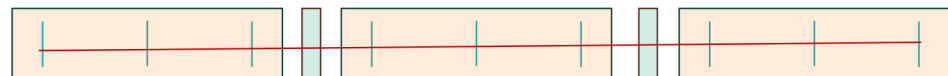
- Single muon interaction first (in the example) /second target



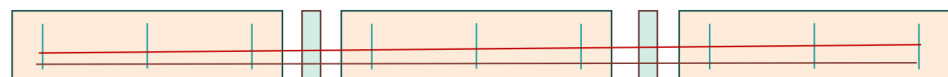
- Pileup muon interaction first (in the example) /second target



- Single passing muon station 1 && 2 / 2 &&3



- Pileup passing muon station 1 && 2 / 2 &&3



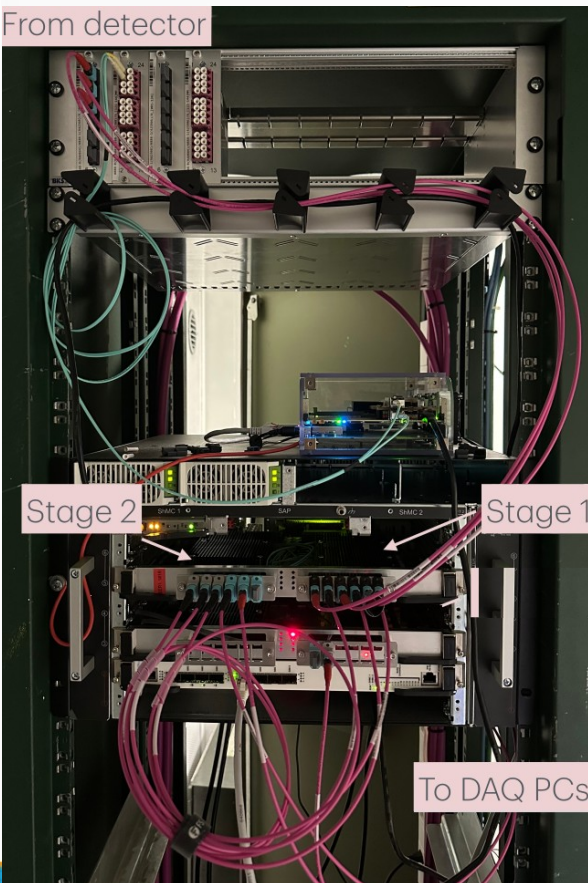
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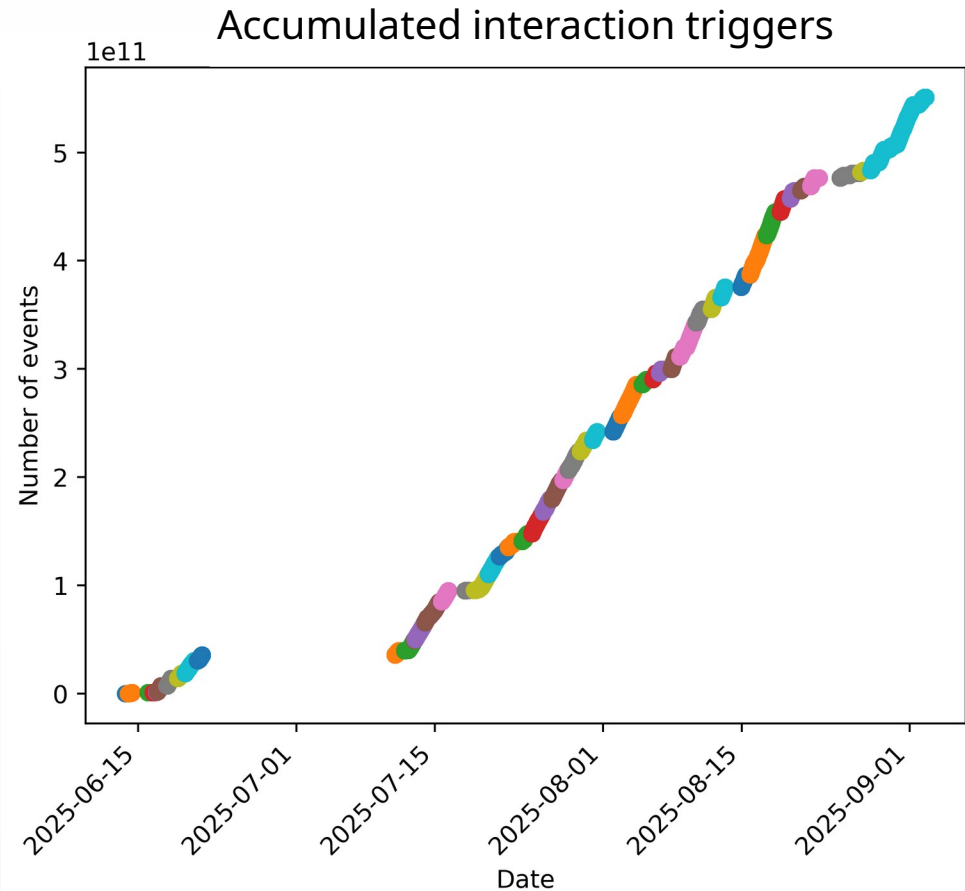
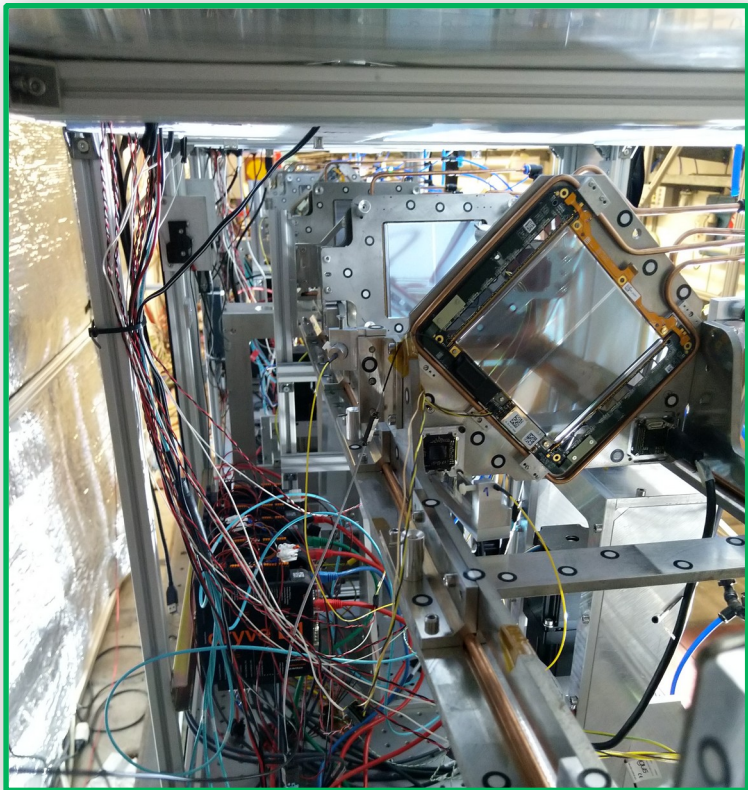
- **Stage 1:** 36 communication links with sub-detectors
 - 30×2S modules
 - 2×Timing Detector
 - 4×ECAL
- Online selection based on tracker modules occupancy. Event rate is reduced from 40 MHz (no selection) to ~500 kHz
- **Stage 2:** event building.
 - Group information from all sub-detectors in a time-coherent packet of data.
- Online decoding provides analysis-ready data in real time



Phase-1 final statistics



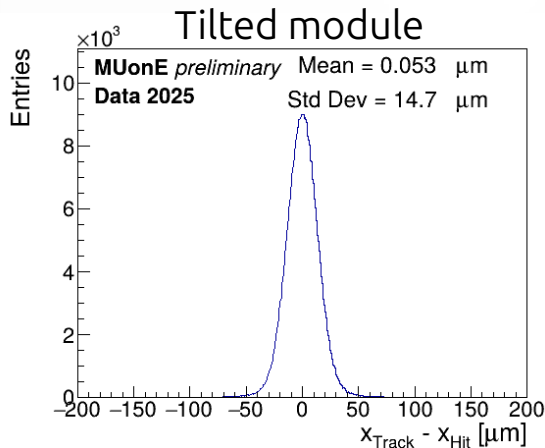
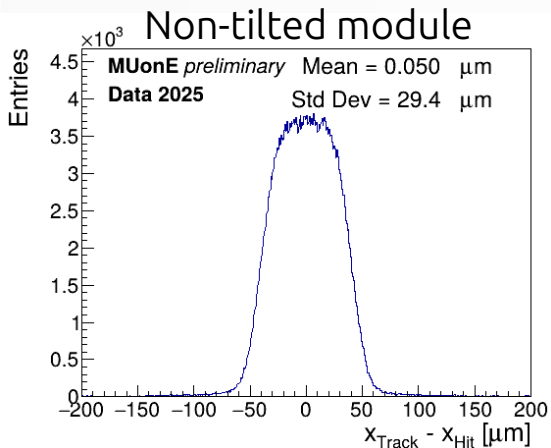
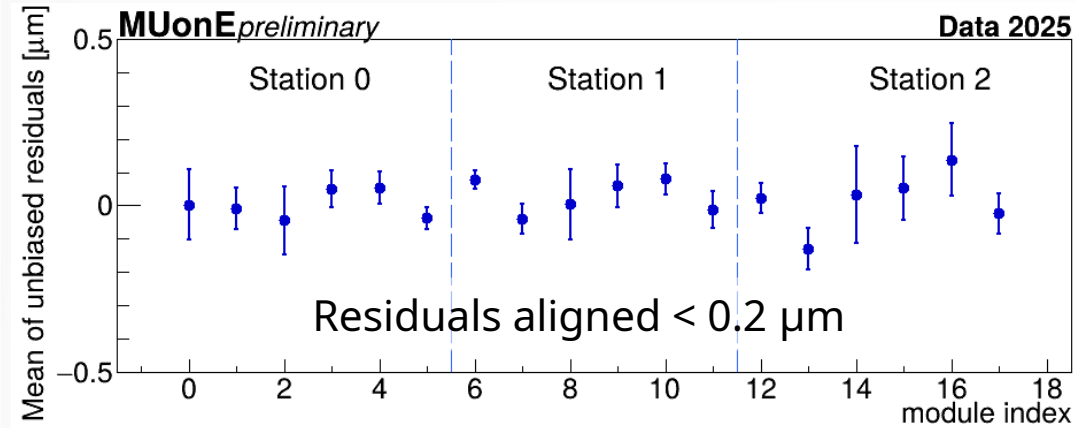
3-month data taking (June-August 2025):
more than 5×10^{11} interaction triggers recorded (~500 TB disk space)



Tracking performance



Unbiased residuals



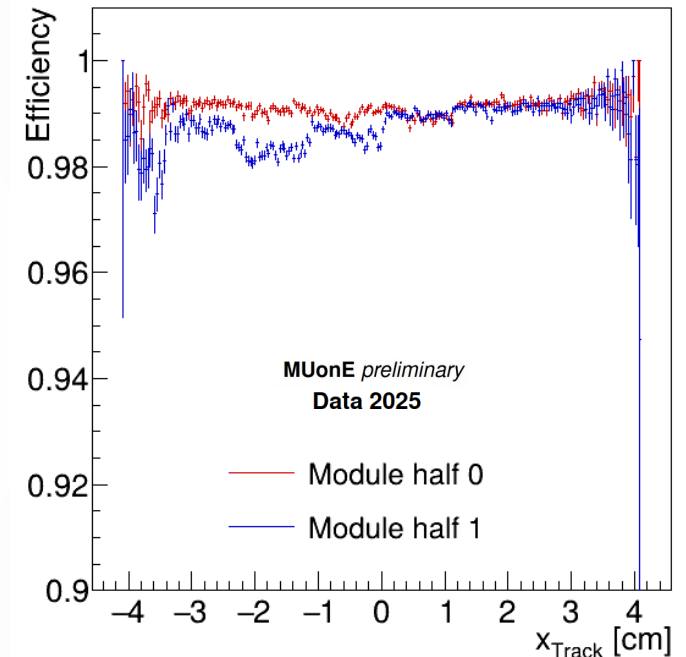
Hit resolution after track error subtraction:

$\sigma_{\text{hit}}(\text{non-tilted}) \sim 22 \mu\text{m}$

$\sigma_{\text{hit}}(\text{tilted}) \sim 12 \mu\text{m}$

2S-modules efficiency

Station 0 Module 4 (tilted)



- Typical efficiency: $\sim 98\%-99\%$
- Space uniformity: $\sim 0.3\%-0.6\%$ Steps due non-optimal threshold equalisation across different chips
- Spatial profiles included in MC

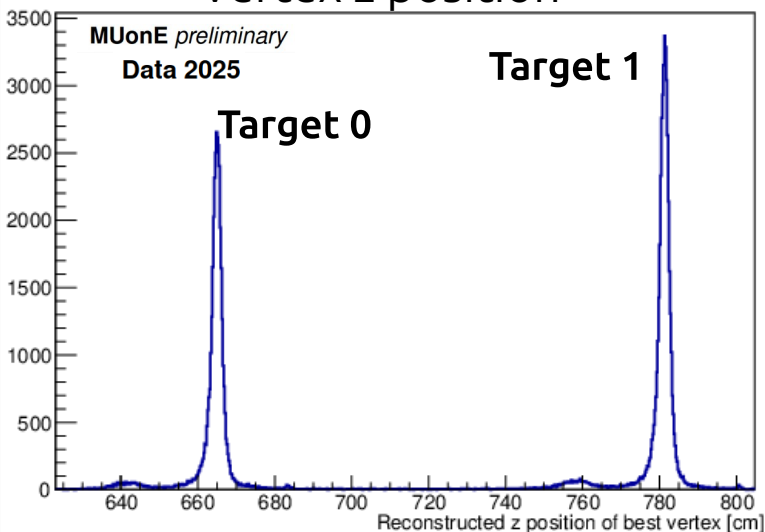
Elastic scattering events



Tracker event selection

- 1 incoming track, 2 outgoing tracks
- No shared hits between tracks
- No extra hits in the stations
- Reject non-planar events (background suppression)

Vertex z position



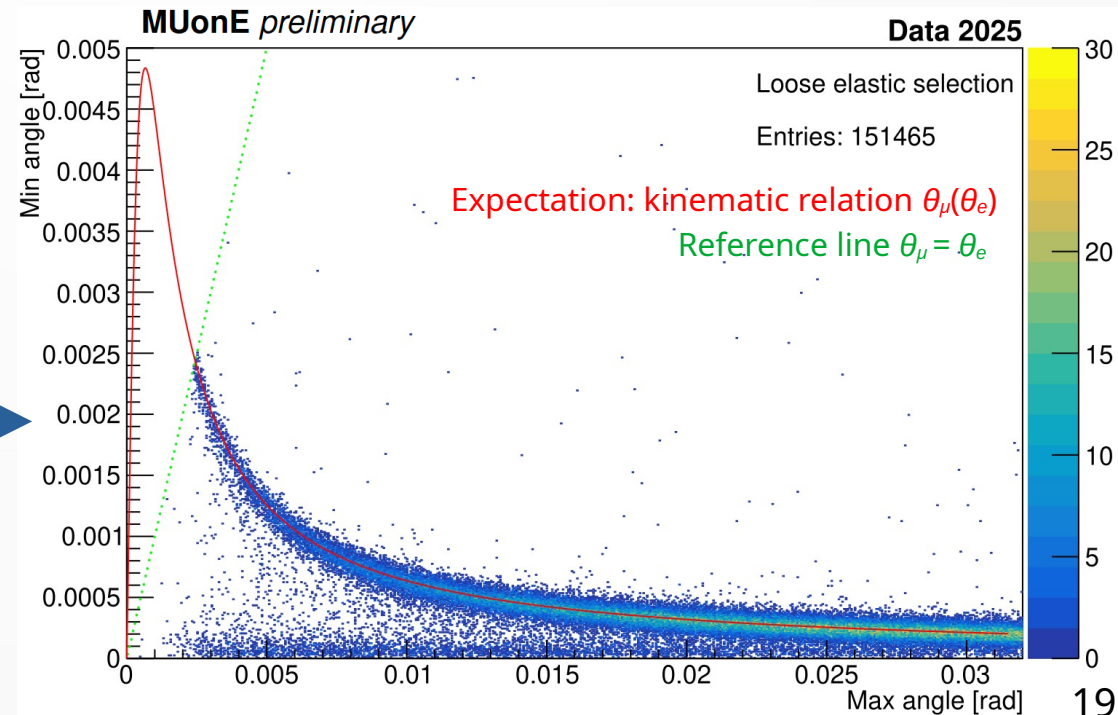
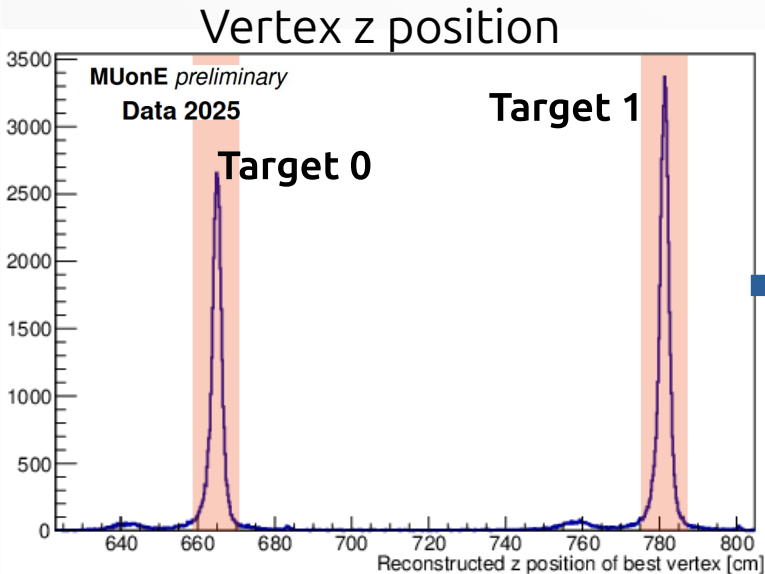
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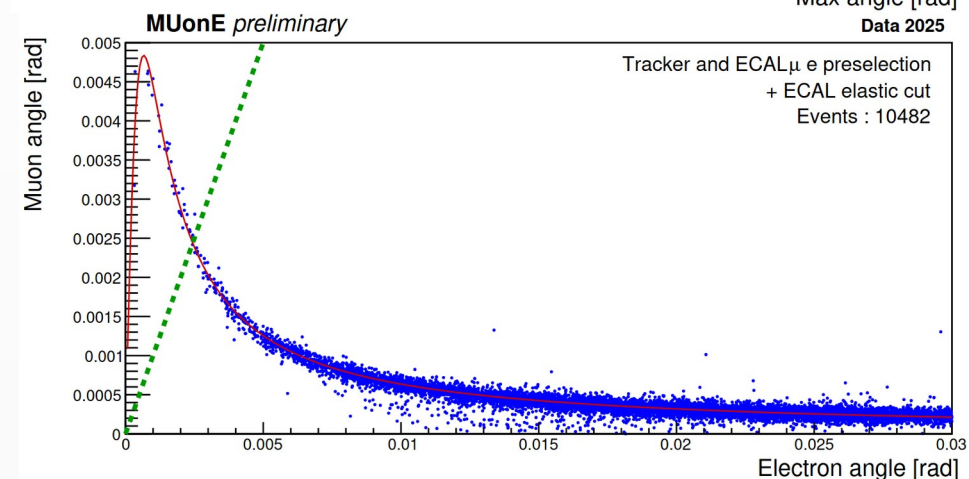
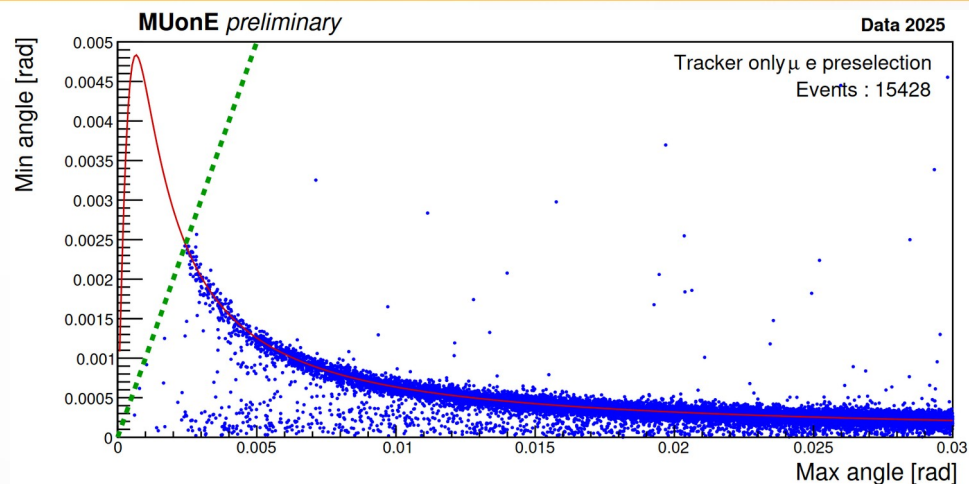
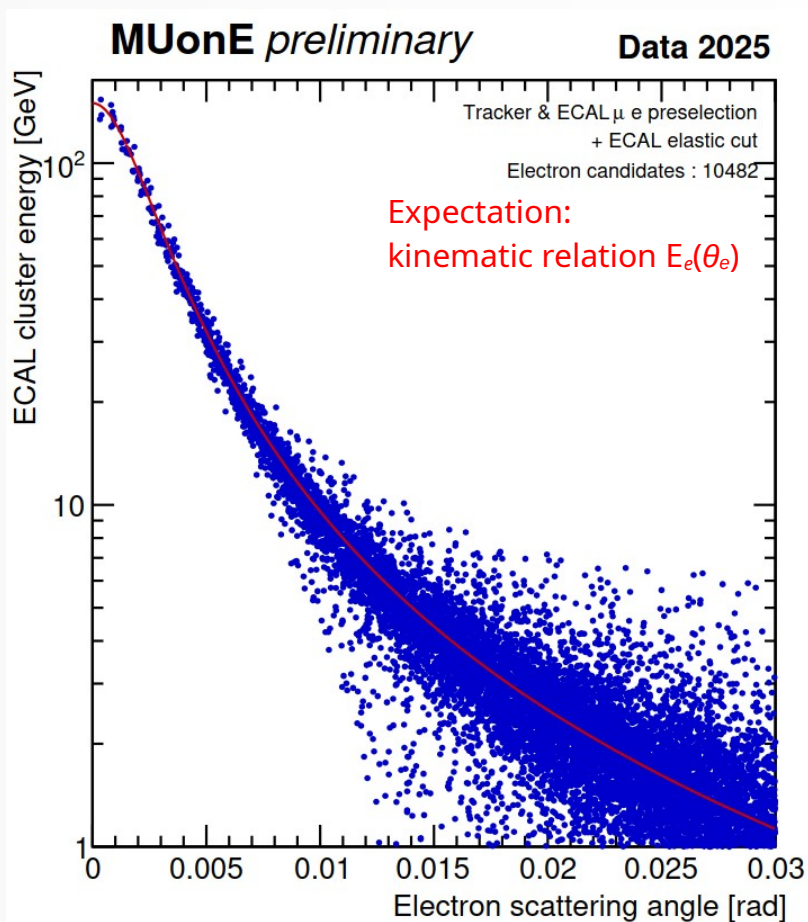
Not able to discriminate between μ and e^- :
plot θ_{\max} vs θ_{\min} to avoid misidentification
when $\theta_e < 5$ mrad



ECAL-based PID



Correlation between ECAL energy deposit and θ_e reconstructed in the tracker

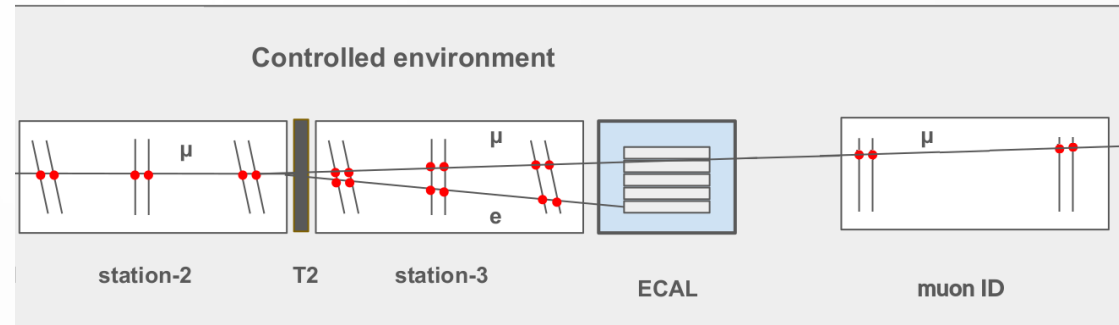


- ECAL energy > 1 GeV
- Loose elastic selection
- Matching between candidate e^- track and ECAL cluster centroid

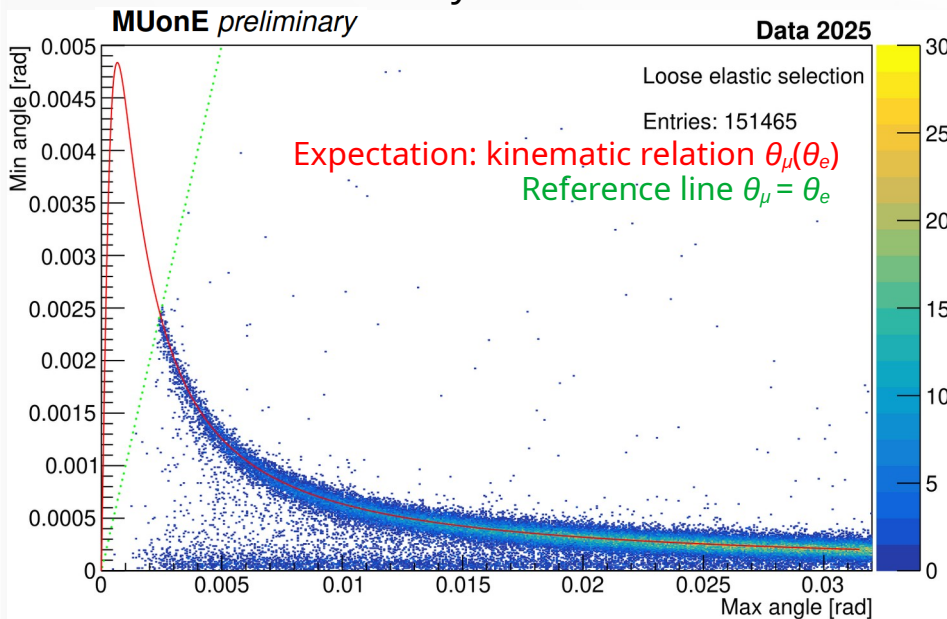
Muon ID-based PID



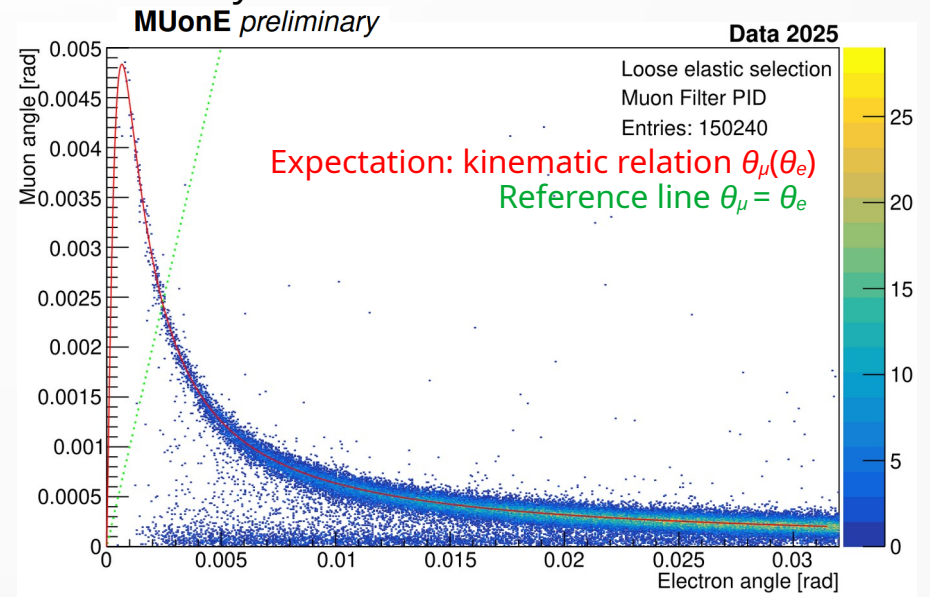
- Propagate tracks to the Muon ID
- Look for matching between a track and muon ID hits: select the muon track



Tracker-only event selection



Tracker-only event selection + muon ID-based PID

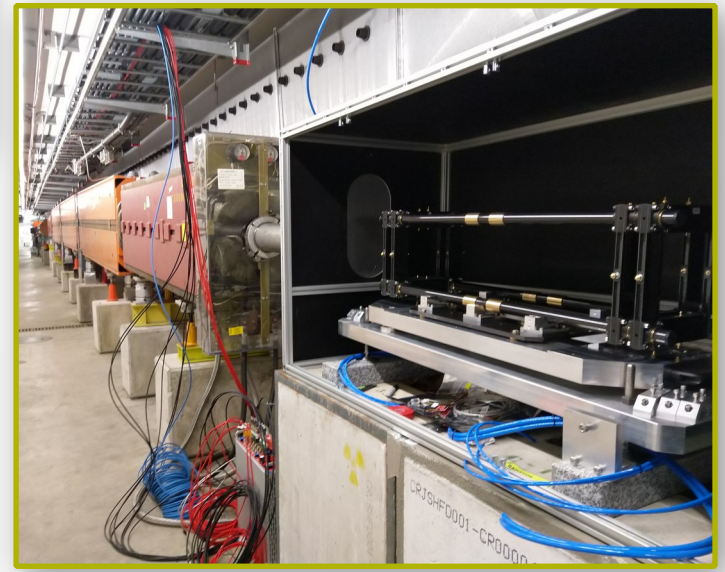
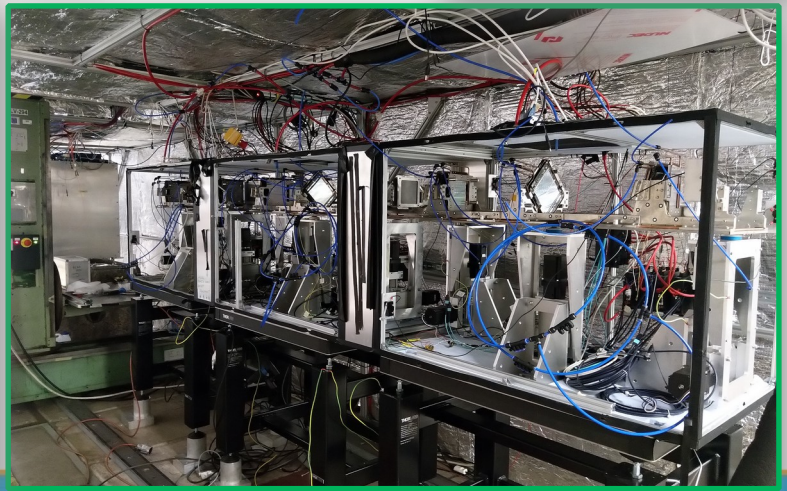
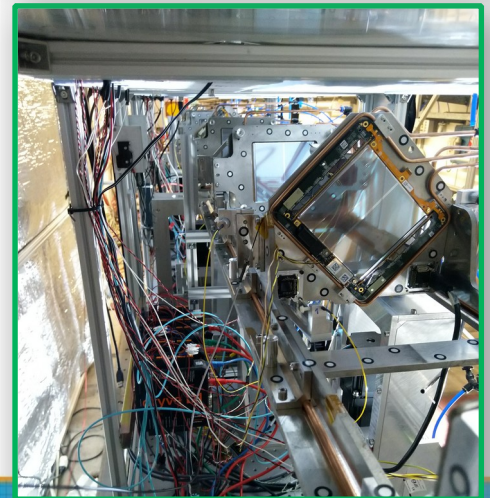
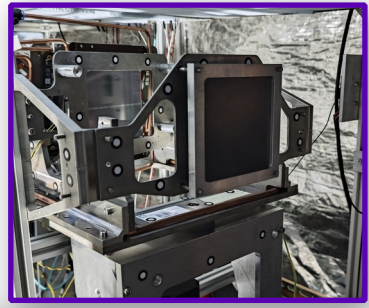
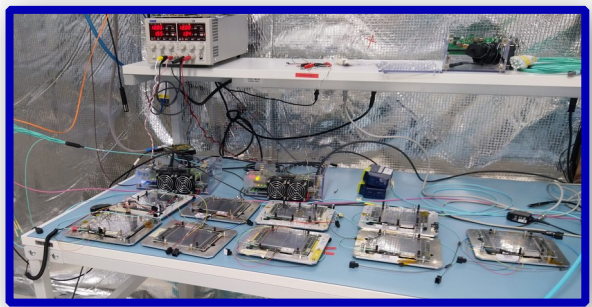
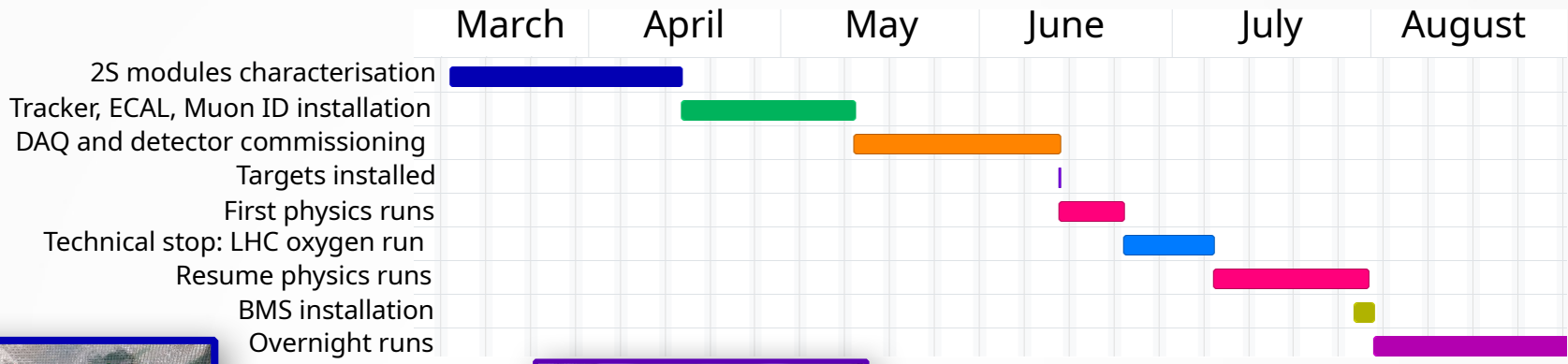


Conclusions

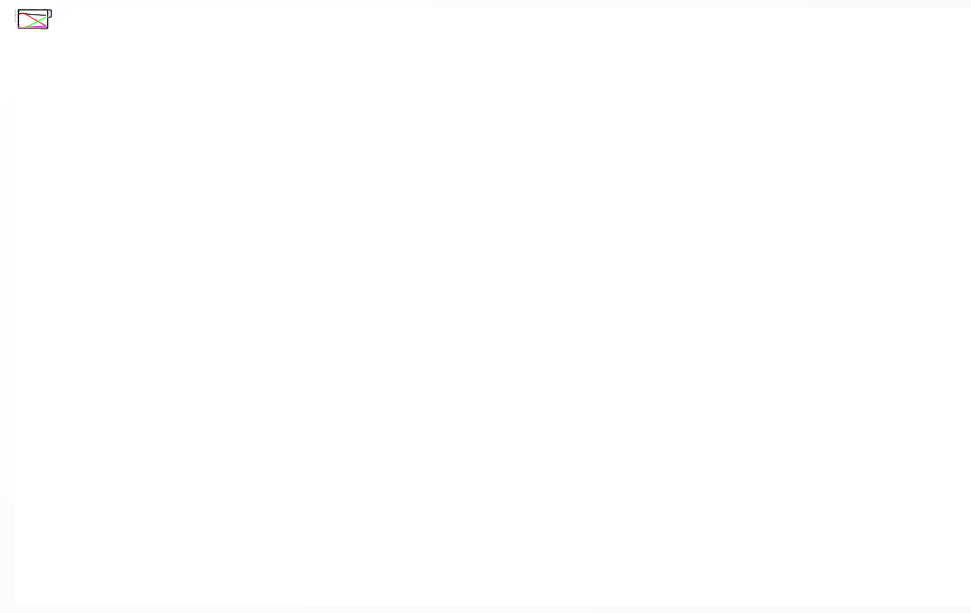
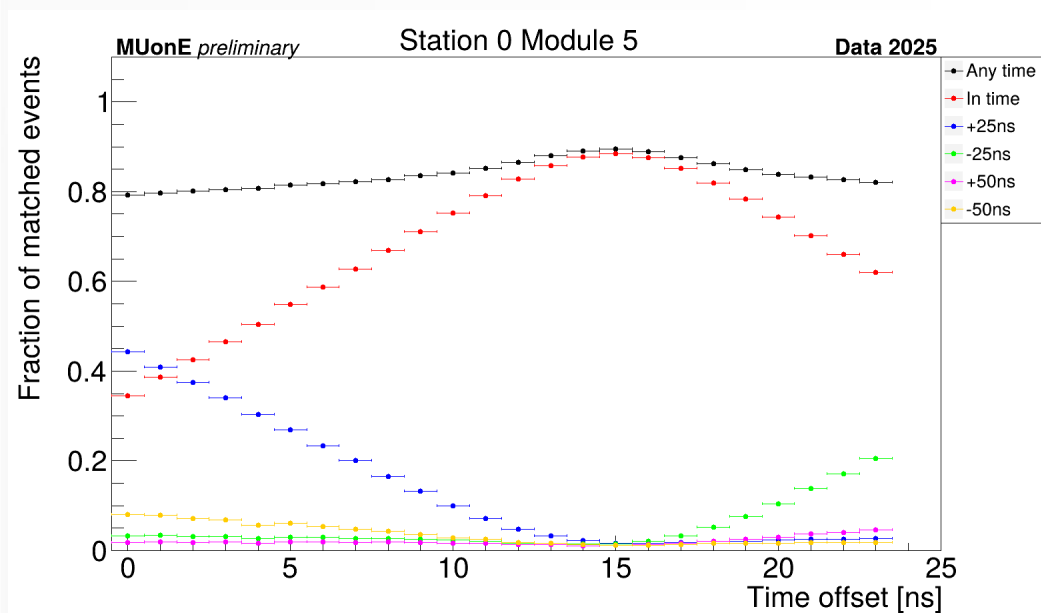
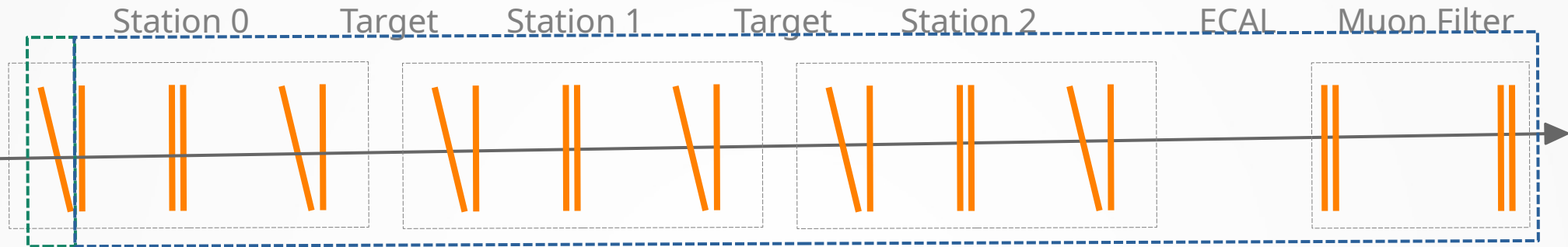
- MUonE aims to provide an independent evaluation of $a_{\mu}^{\text{HVP,LO}}$ competitive with the latest results.
- 2025 Test Run:
 - Successful ~3 months data taking with 3 stations (2 targets), ECAL and muon ID.
 - Integration of the BMS in the last few days of run.
- Analysis campaign underway. Goals:
 - Proof of principle measurement of $\Delta a_{\text{lep}}(t)$ (and comparison with 2023 data).
 - Preliminary measurement of $\Delta a_{\text{had}}(t)$ (~20% statistical error + similar systematic).
 - Study systematic effects.
- 2025 data will serve as a basis for the full-scale experiment proposal (40 tracking stations + ancillary detectors) to be prepared during the CERN Long Shutdown 3.

BACKUP

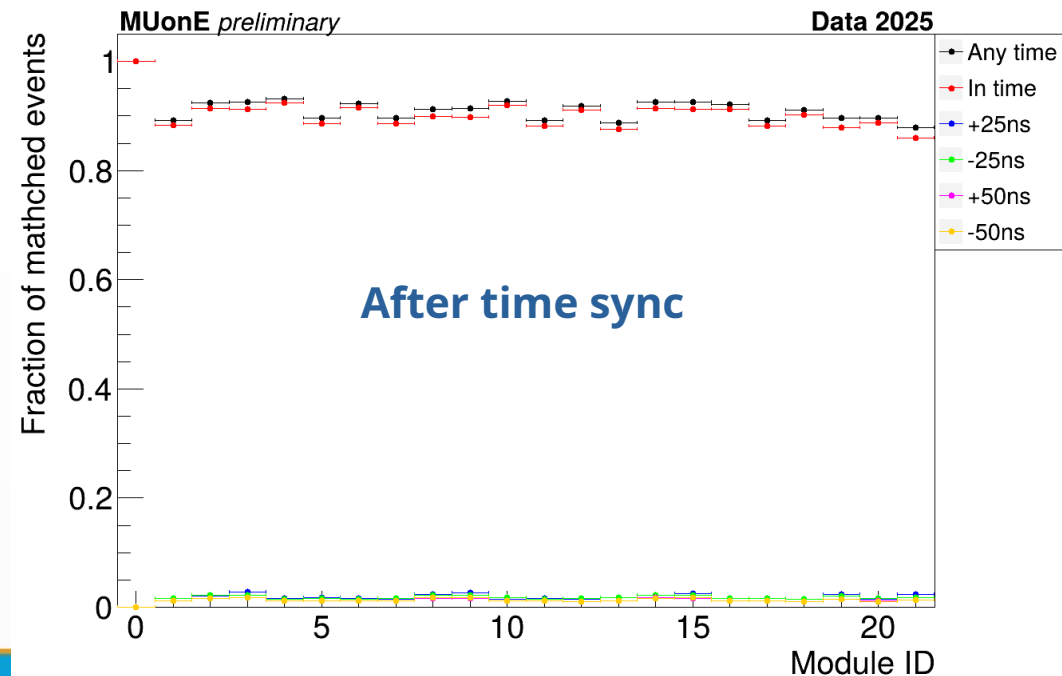
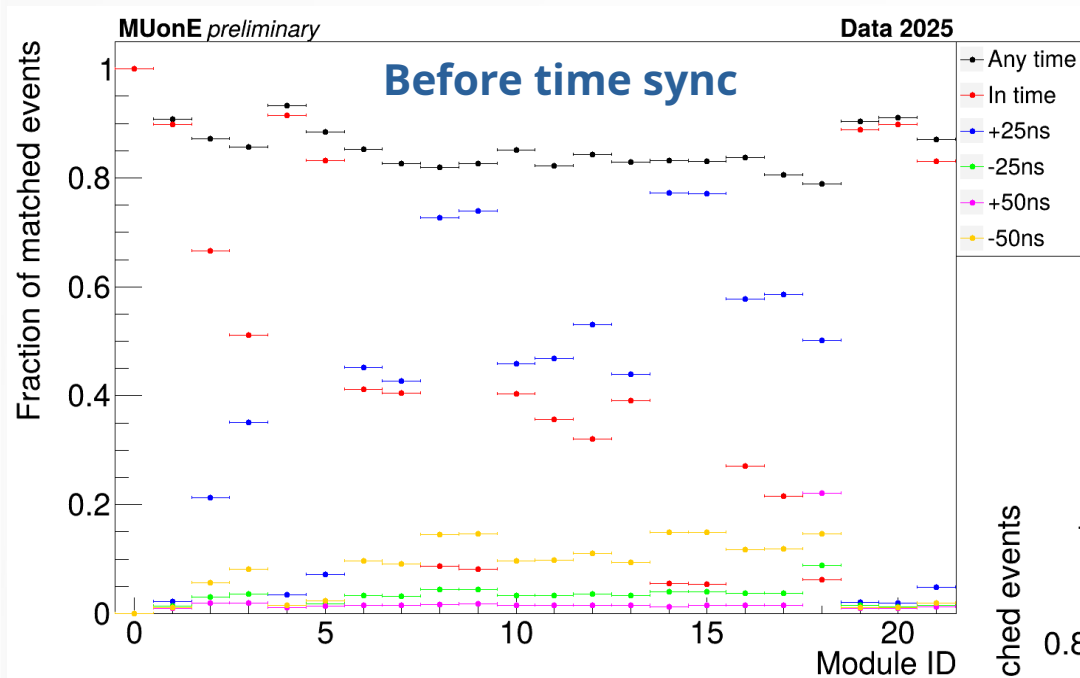
Test Run 2025 - timeline



TR 2025 – tracker time synchronisation



TR 2025 - tracker time synchronisation

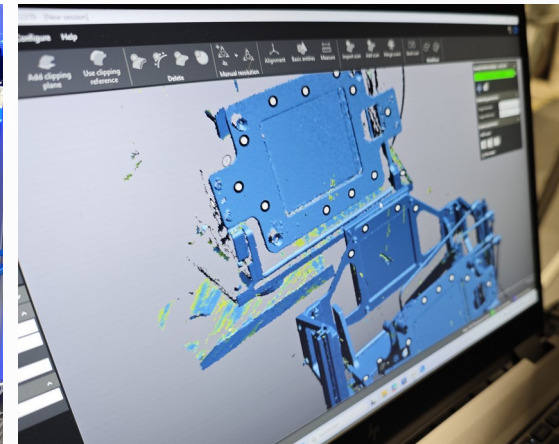


Alignment

- Hardware (stepper motors):
 - center the beam profile on each module ($< 500 \mu\text{m}$)
 - align the longitudinal axis of each station to the beam axis ($< 0.5\text{mrad}$)
 - align the 3 stations one relative to the other ($< 200 \mu\text{m}$)
- Software: local χ^2 minimization on a sample of single passing muons.

Metrology measurements of the detector ($< 100 \mu\text{m}$ precision)

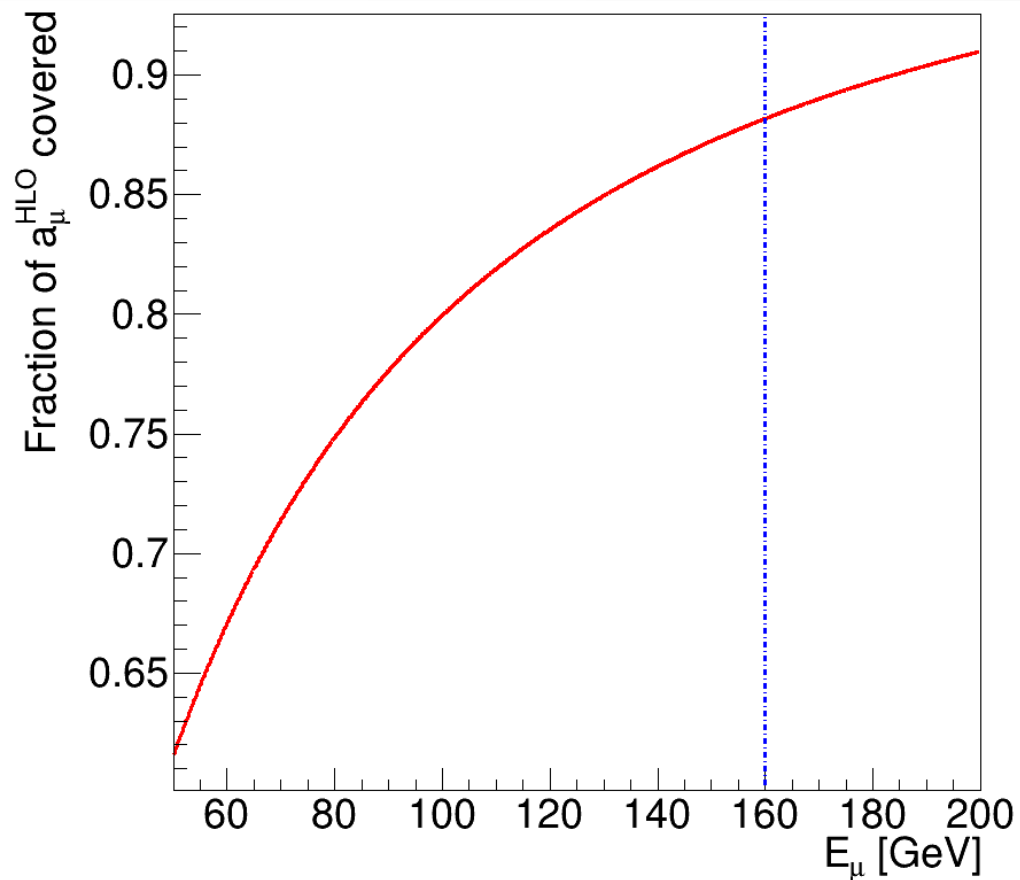
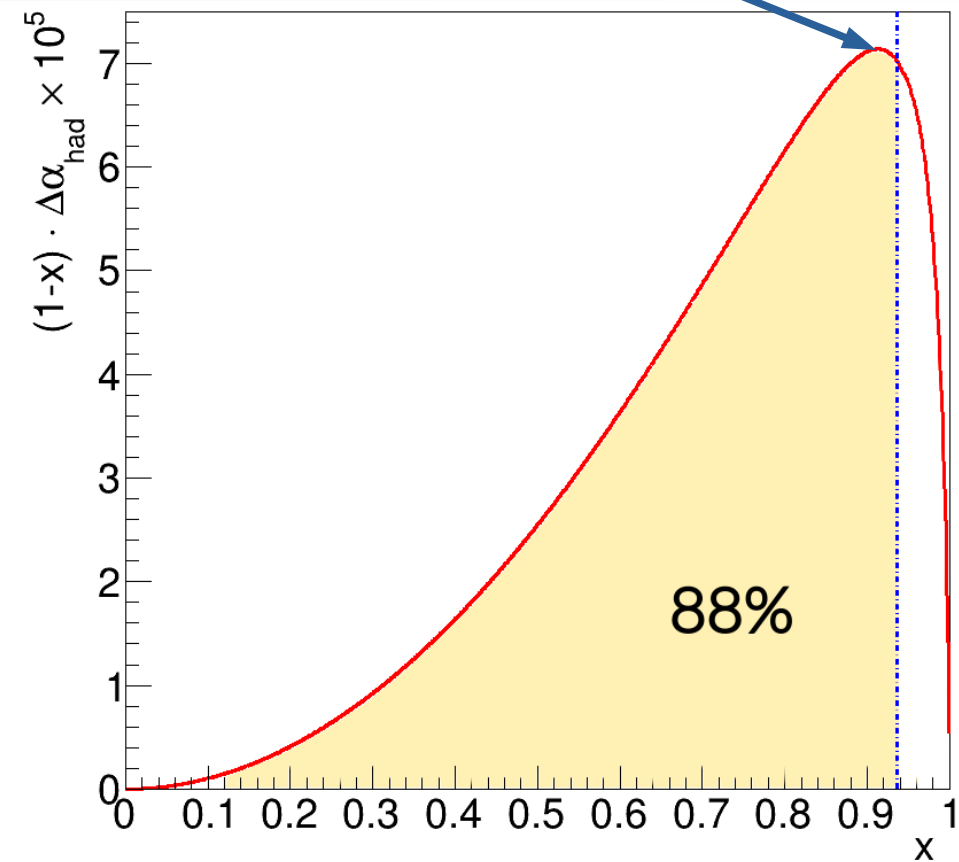
- 3D scanner photogrammetry:
 - position and orientation of each module within a station
- Laser survey:
 - relative position of the different subdetectors; absolute position with respect to beam elements
- To be used as starting point of software alignment



$$x < 0.936$$

$$t_{peak} \sim -0.108 \text{ GeV}^2$$

$$x_{peak} \sim 0.92$$

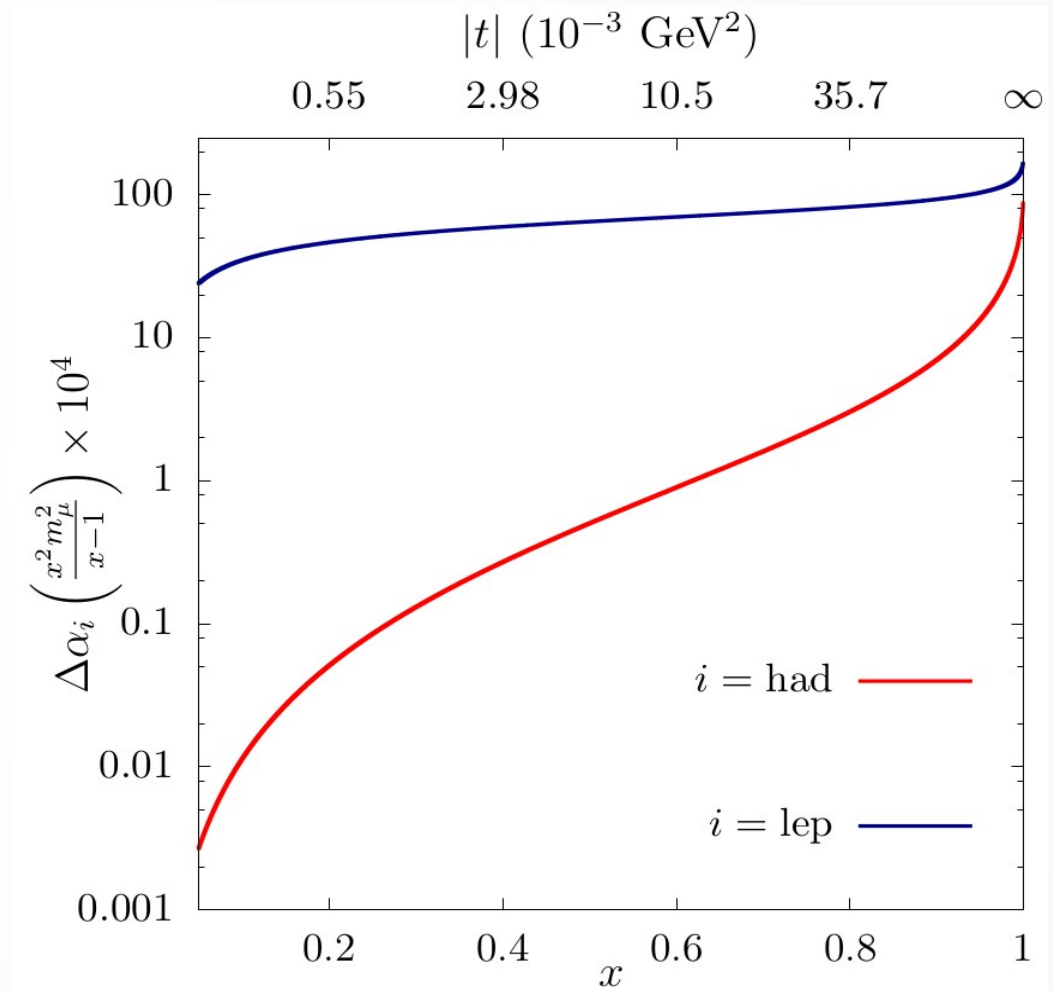


- 160 GeV muon beam on atomic electrons.

$$\sqrt{s} \sim 420 \text{ MeV}$$

$$-0.153 \text{ GeV}^2 < t < 0 \text{ GeV}^2$$

$$\Delta\alpha_{had}(t) \lesssim 10^{-3}$$



$\Delta\alpha_{had}$ parameterization



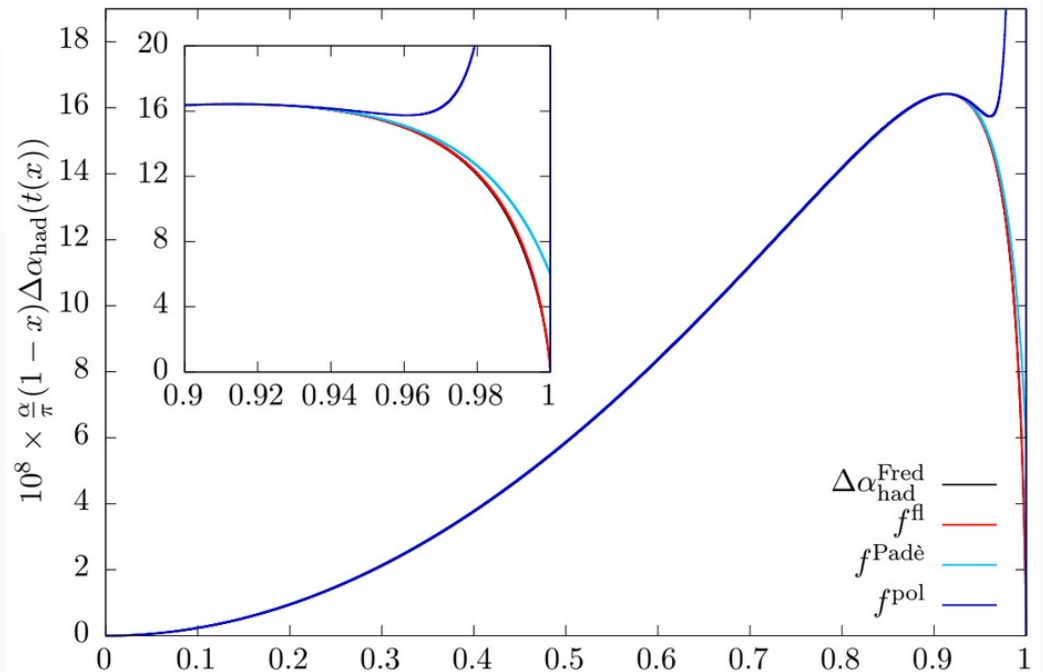
Inspired from the 1 loop QED contribution of lepton pairs and top quark at $t < 0$

$$\Delta\alpha_{had}(t) = KM \left\{ -\frac{5}{9} - \frac{4M}{3t} + \left(\frac{4M^2}{3t^2} + \frac{M}{3t} - \frac{1}{6} \right) \frac{2}{\sqrt{1 - \frac{4M}{t}}} \ln \left| \frac{1 - \sqrt{1 - \frac{4M}{t}}}{1 + \sqrt{1 - \frac{4M}{t}}} \right| \right\} \quad \text{2 parameters: } K, M$$

Allows to calculate
the full value of a_{μ}^{HLO}

Dominant behaviour in the
MUonE kinematic region:

$$\Delta\alpha_{had}(t) \simeq -\frac{1}{15} Kt$$



Alternative method to compute $a_\mu^{\text{HVP,LO}}$ from MUonE data



Based on [Phys. Rev. D 85 \(2012\)](#) [Phys. Rev. D 96 \(2017\)](#)

[Phys. Lett. B 848 \(2024\)](#)

Start from the dispersive integral

$$a_\mu^{\text{HLO}} = \frac{\alpha^2}{3\pi^2} \int_{s_{\text{th}}}^{\infty} \frac{ds}{s} K(s) R(s)$$

Approximated kernel + Cauchy theorem
to remove the problematic low energy part

$$a_\mu^{\text{HLO}} = a_\mu^{\text{HLO (I)}} + a_\mu^{\text{HLO (II)}} + a_\mu^{\text{HLO (III)}} + a_\mu^{\text{HLO (IV)}}$$

$$a_\mu^{\text{HLO (I)}} = -\frac{\alpha}{\pi} \sum_{n=1}^3 \frac{c_n}{n!} \frac{d^{(n)}}{dt^n} \Delta\alpha_{\text{had}}(t) \Big|_{t=0}$$

$$a_\mu^{\text{HLO (II)}} = \frac{\alpha}{\pi} \frac{1}{2\pi i} \oint_{|s|=s_0} \frac{ds}{s} c_0 s \Pi_{\text{had}}(s) \Big|_{\text{pQCD}}$$

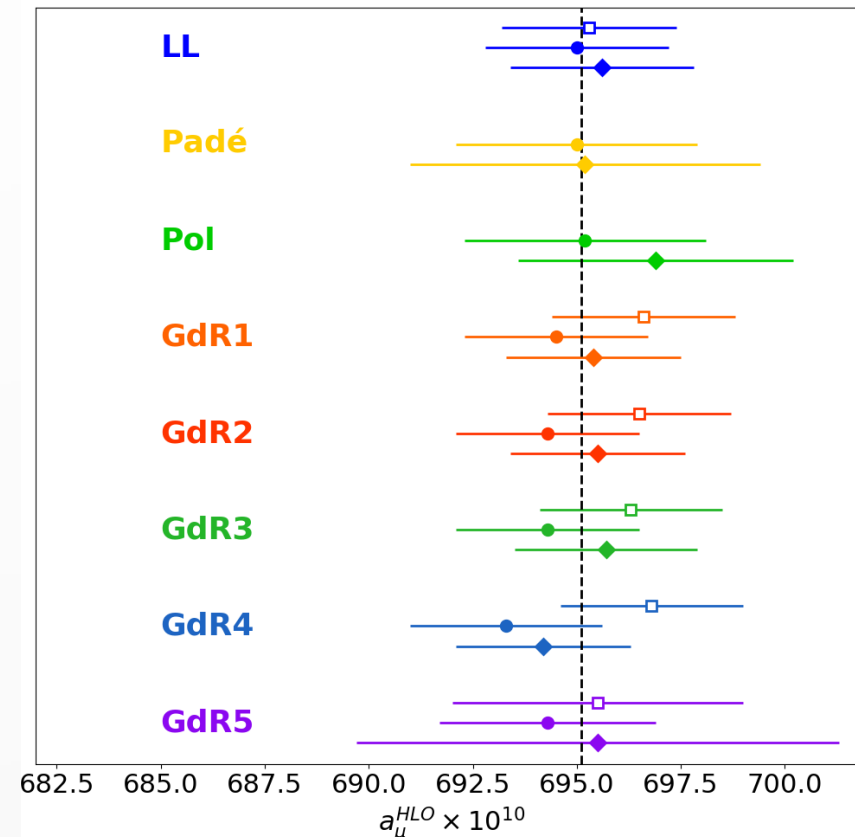
$$a_\mu^{\text{HLO (III)}} = \frac{\alpha^2}{3\pi^2} \int_{s_{\text{th}}}^{s_0} \frac{ds}{s} [K(s) - K_1(s)] R(s)$$

$$a_\mu^{\text{HLO (IV)}} = \frac{\alpha^2}{3\pi^2} \int_{s_0}^{\infty} \frac{ds}{s} [K(s) - \tilde{K}_1(s)] R(s)$$

MUonE
99%

Time-like
data
+
pQCD
1%

Competitive results independently
of the $\Delta\alpha_{\text{had}}(t)$ parameterization



Summary of the main sources of systematic errors and corresponding uncertainties for the 2025 run

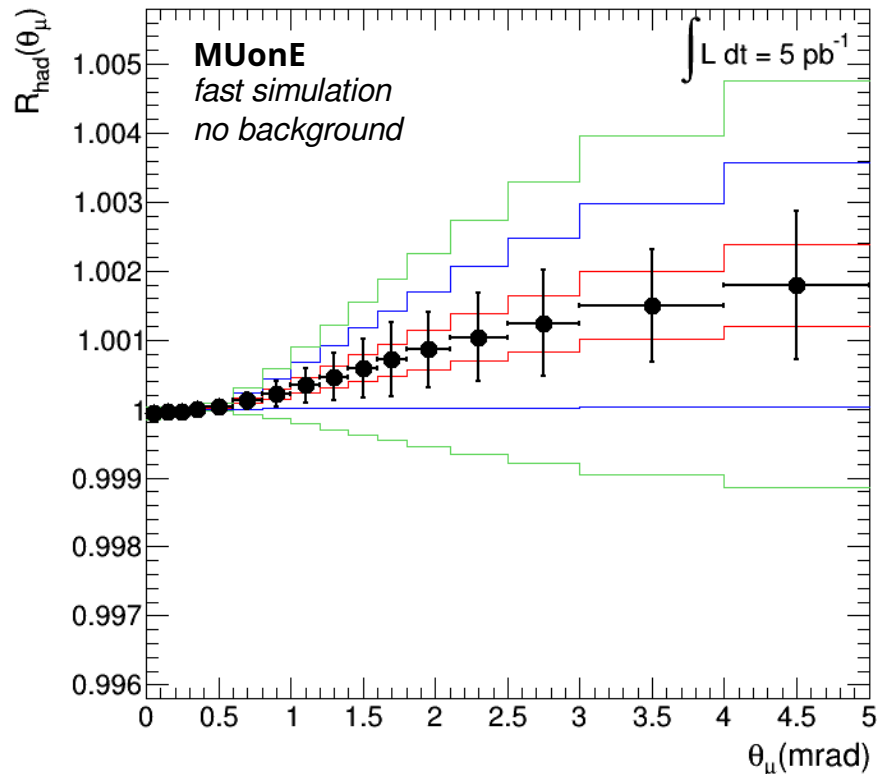


Source of systematic error	Uncertainty on the systematic source	Uncertainty on $\Delta\alpha_{had}$	Uncertainty on $d\sigma$
Intrinsic angular resolution	0.5%	10%	200 ppm
Multiple scattering	1%	10%	200 ppm
Beam energy scale	25 MeV	10%	200 ppm
z coordinate	100 μm	10%	200 ppm
Beam energy spread (3.75%)			
current BMS	4% ($\sigma_p/p \sim 1\%$)	1%	20 ppm
upgraded BMS	1% ($\sigma_p/p < 0.5\%$)	< 0.5%	5ppm
Other contributions (i.e. tracking efficiency and reconstruction uniformity, residual background)		15%	300 ppm
Total		25%	500 ppm

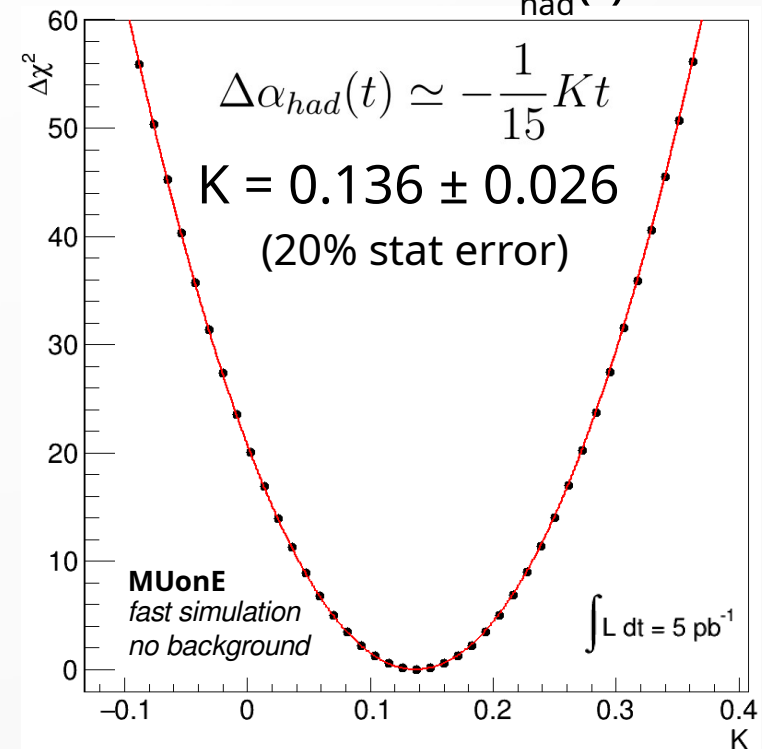
First measurement of $\Delta\alpha_{\text{had}}(t)$

Expected event yield: $\sim 10^9$ elastic events within acceptance
(one order of magnitude larger than 2023)

$$R_{\text{had}} = \frac{d\sigma_{\text{data}}(\Delta\alpha_{\text{had}})}{d\sigma_{\text{MC}}(\Delta\alpha_{\text{had}} = 0)} \sim 1 + 2\Delta\alpha_{\text{had}}(t)$$



Template fit procedure
to extract $\Delta\alpha_{\text{had}}(t)$

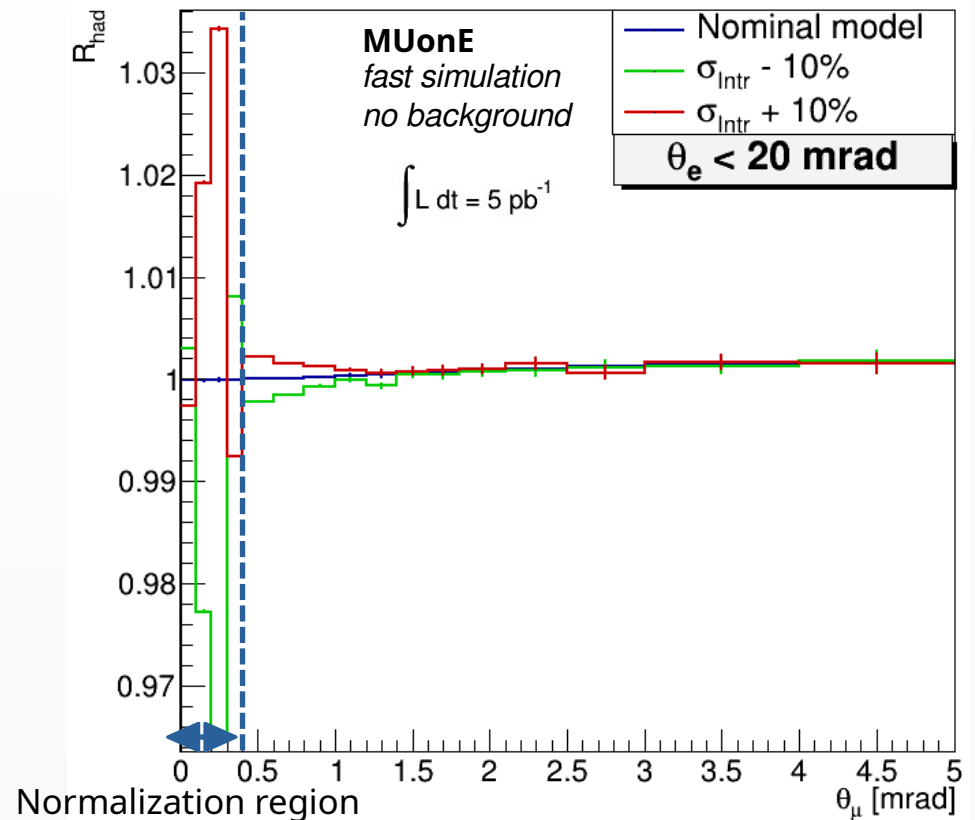
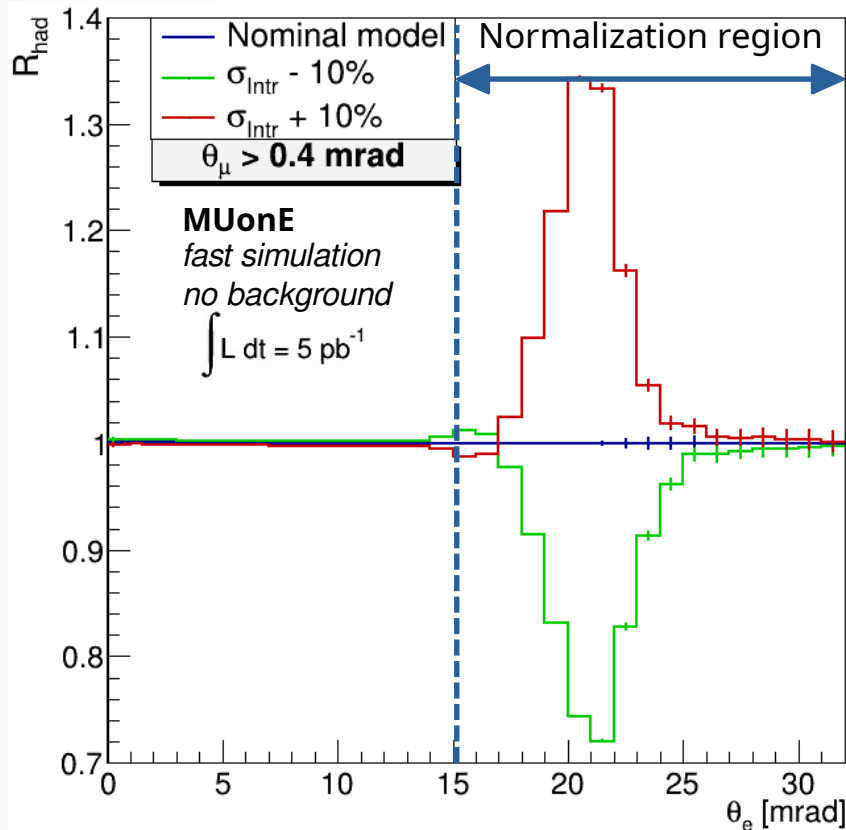


The need of including systematic effects in the analysis



Some systematic effects can produce huge distortions in the shape of the elastic scattering cross section

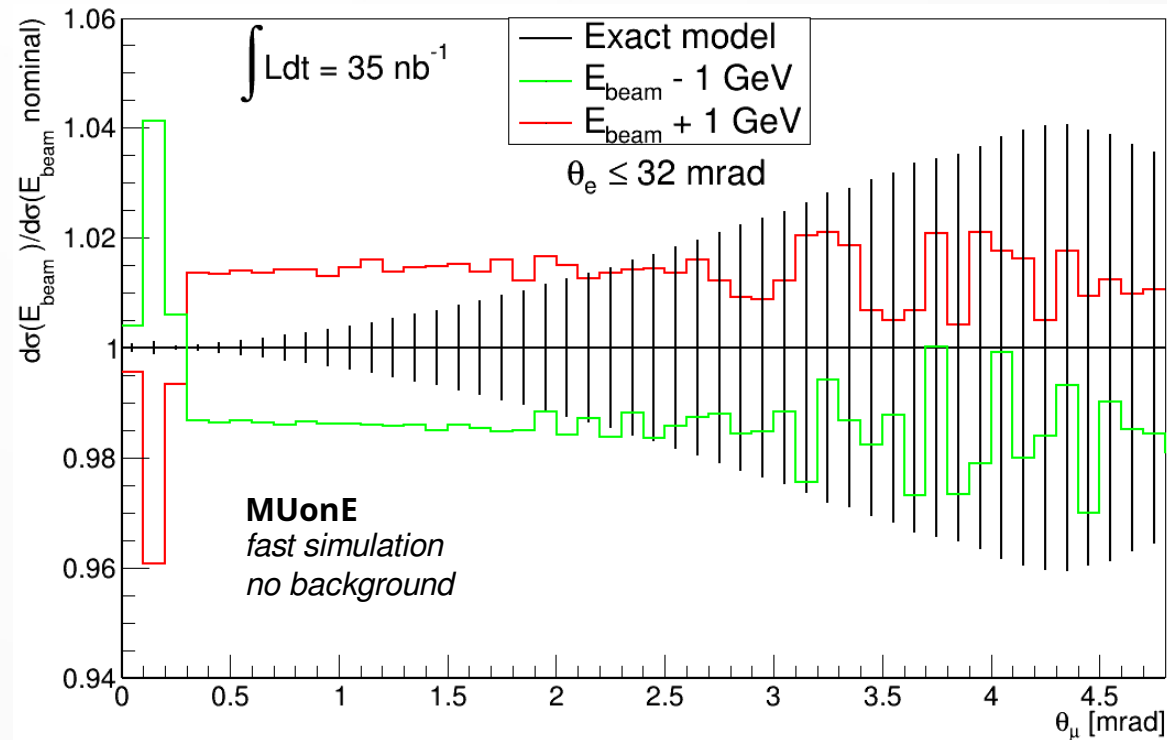
Example: $\pm 10\%$ error on the angular intrinsic resolution



Systematic error on the muon beam energy

Accelerator division
provides E_{beam}
with $O(1\%)$ precision
(~ 1 GeV)

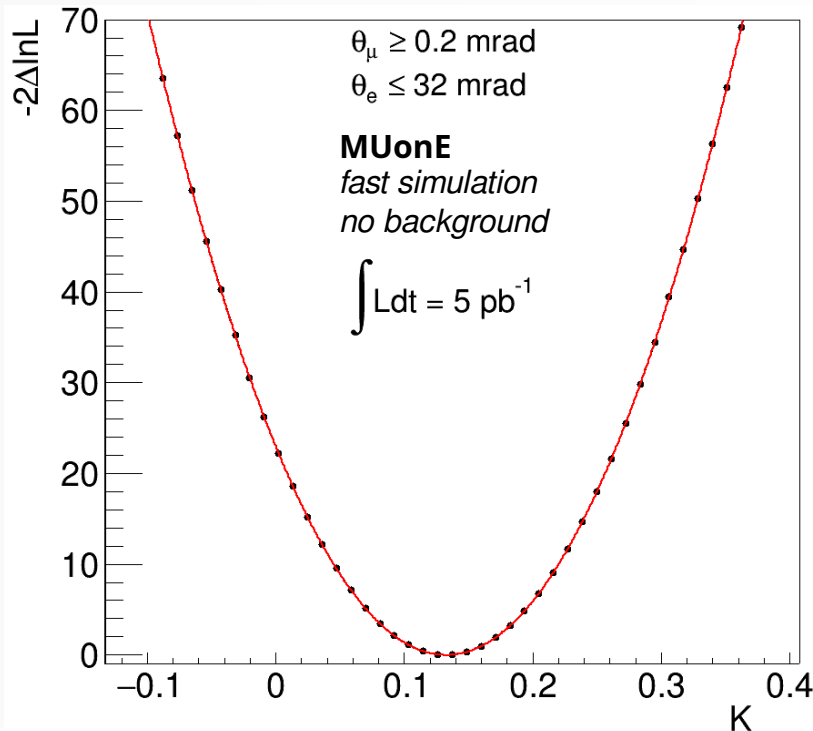
This effect can be seen
from our data in 1h
of data taking per station



Combined fit signal + systematics



- Include residual systematics as nuisance parameters in the fit.
- Simultaneous likelihood fit to K and systematics using the Combine tool.



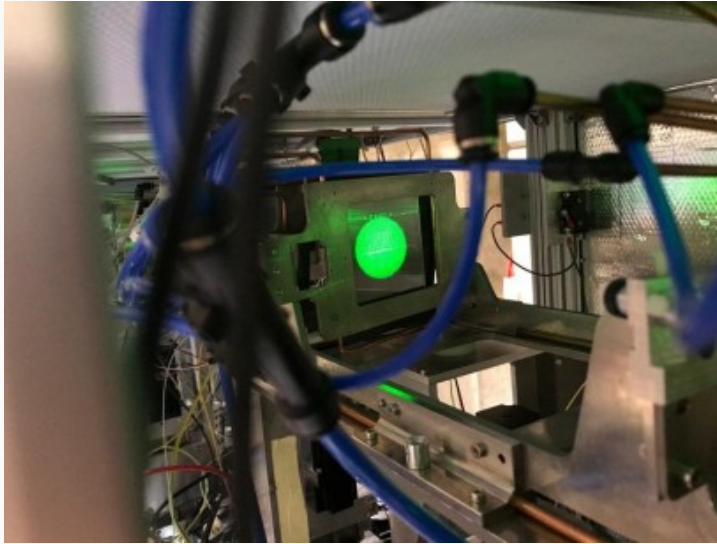
- $K_{\text{ref}} = 0.137$
- shift MS: +0.5%
- shift intr. res: +5%
- shift E_{beam} : +6 MeV

Selection cuts	Fit results
	$K = 0.133 \pm 0.028$
$\theta_e \leq 32$ mrad	$\mu_{\text{MS}} = (0.47 \pm 0.03)\%$
$\theta_\mu \geq 0.2$ mrad	$\mu_{\text{Intr}} = (5.02 \pm 0.02)\%$
	$\mu_{E_{\text{Beam}}} = (6.5 \pm 0.5) \text{ MeV}$
	$\nu = -0.001 \pm 0.003$

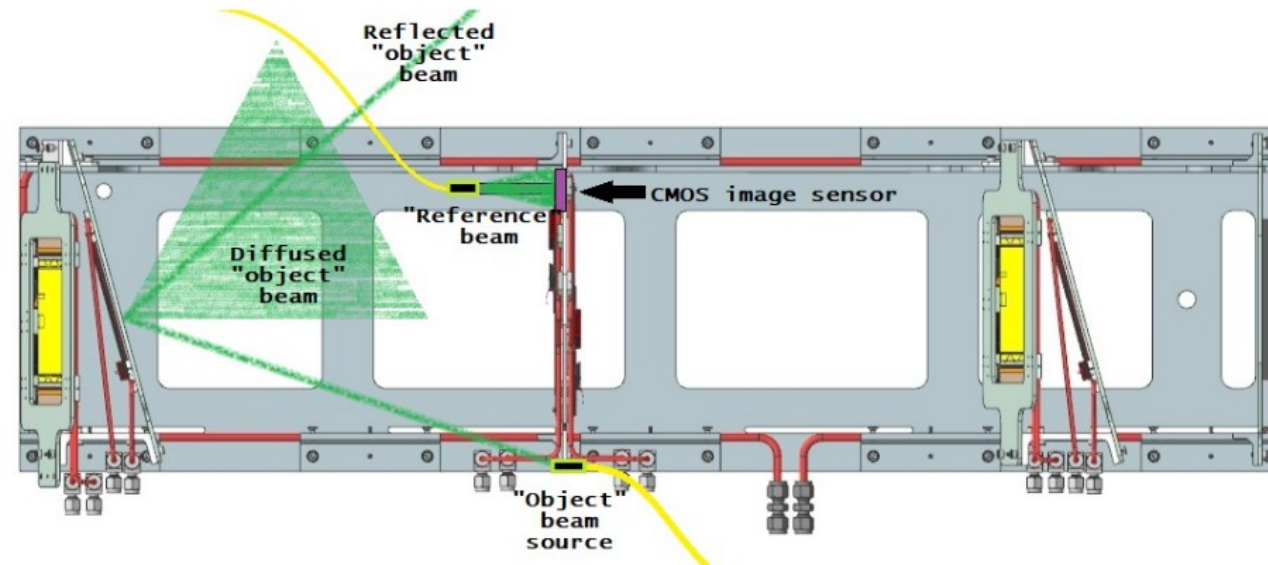
Similar results also for different selection cuts

Input shifts identified correctly.
No degradation on the signal parameter

Laser holographic system



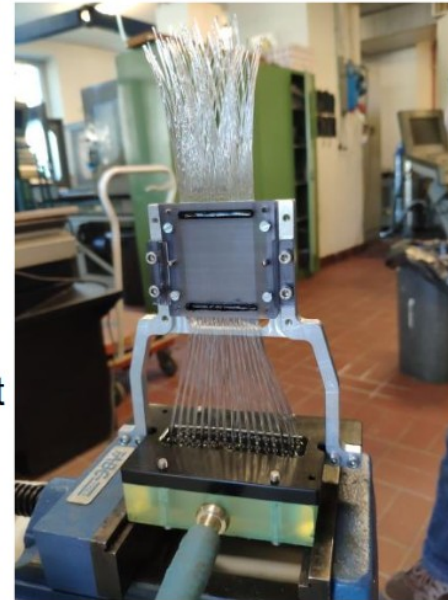
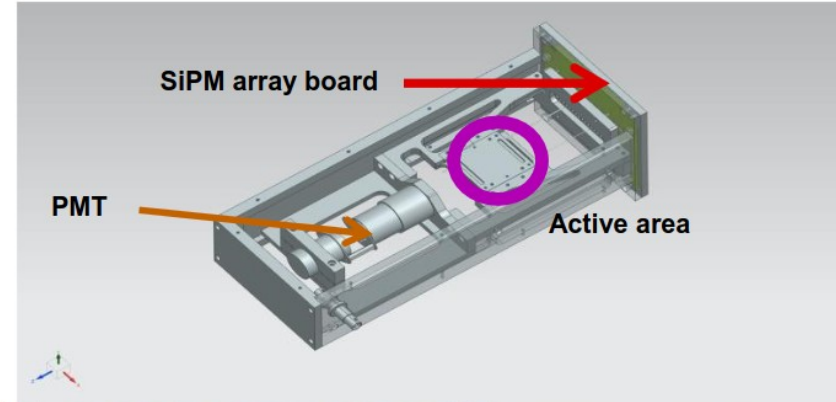
- Compare holographic images of the same object at different time
- Fringe pattern is related to deformations of the mechanical structure
- 532 nm fiber-coupled laser.
Resolution: $\sim 0.25 \mu\text{m}$ (half wavelength)
- Current limitation: Si sensors are sensitive to visible light \rightarrow continuous monitoring is not possible
- Improvement: use $>1500 \text{ nm}$ laser (IR)



SciFi Muon Filter (R&D)



- Prototype for the Muon Filter upgrade (final detector)
- 0.5 mm dia. plastic scintillating fibers (Kuraray SCSF-78MJ)
 - Polystyrene core, double cladding (6% of thickness)
- Double and shifted layer array: 4 fibers coupled to 1 SiPM
 - SiPMs $1.3 \times 1.3 \text{ mm}^2$ (Hamamatsu S13360-1350)
 - PMT (Hamamatsu R1924A) for triggering
- Pitch 1.25 mm – resolution $\sim 360 \mu\text{m}$
- Easy to cover large beam cross sections – easily scalable
- Custom front-end electronics (LIROC2 ASIC) in development

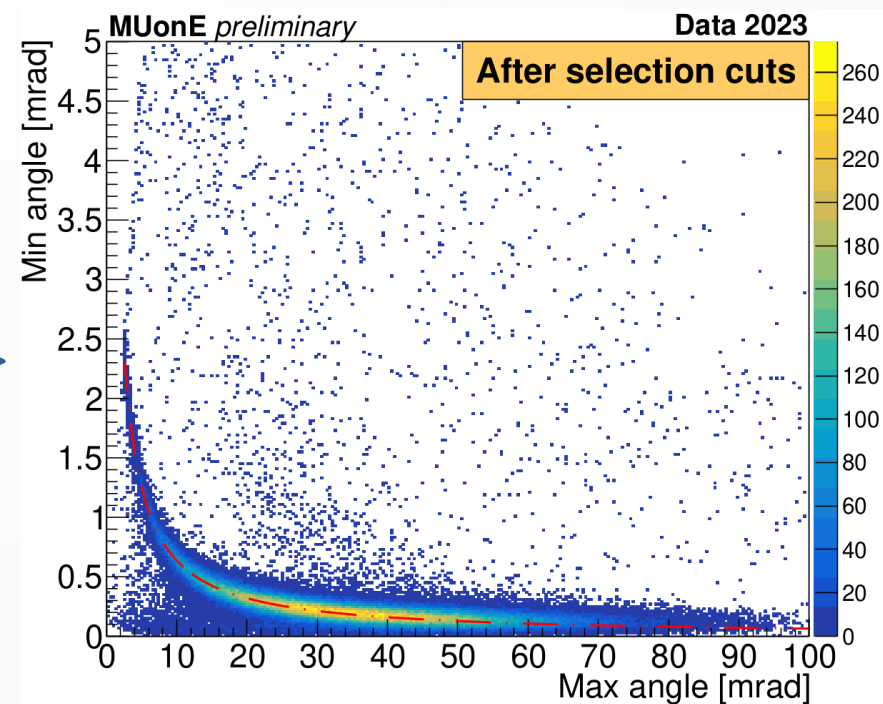
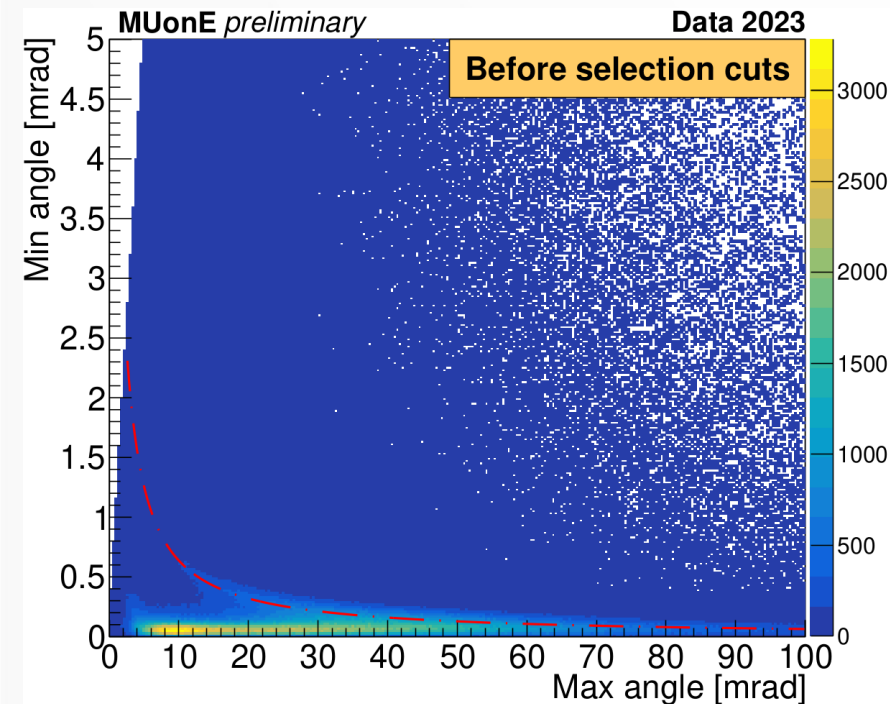


Pre-selection

- Single μ_{in} candidate
- μ_{out}, e_{out} pair candidate

Initial event selection

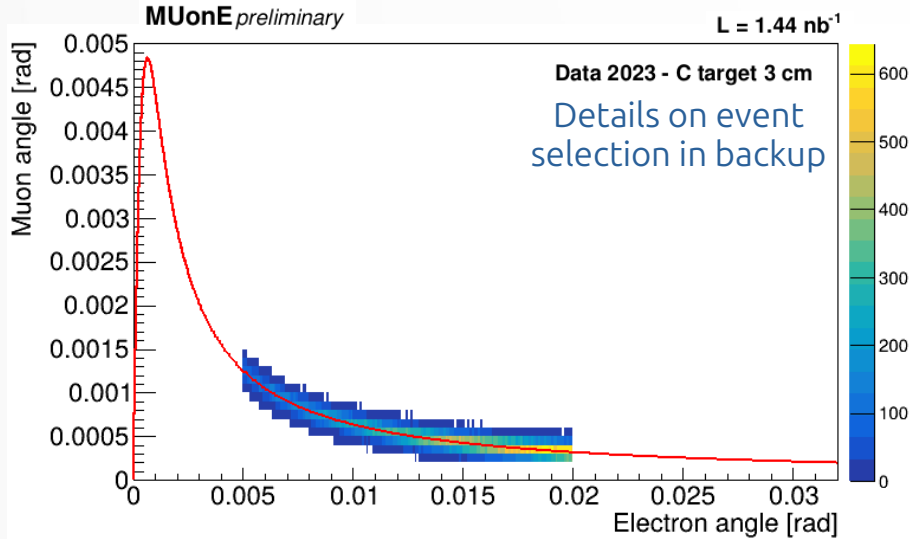
- ≥ 1 hit/module
- $|z_{\text{vtx}} - z_{\text{target}}| < 3$ cm
- Cut on N_{hits} (station2)
- Acoplanarity cut



Test Run 2023 - Data/MC comparison



Select elastic events in a clear region

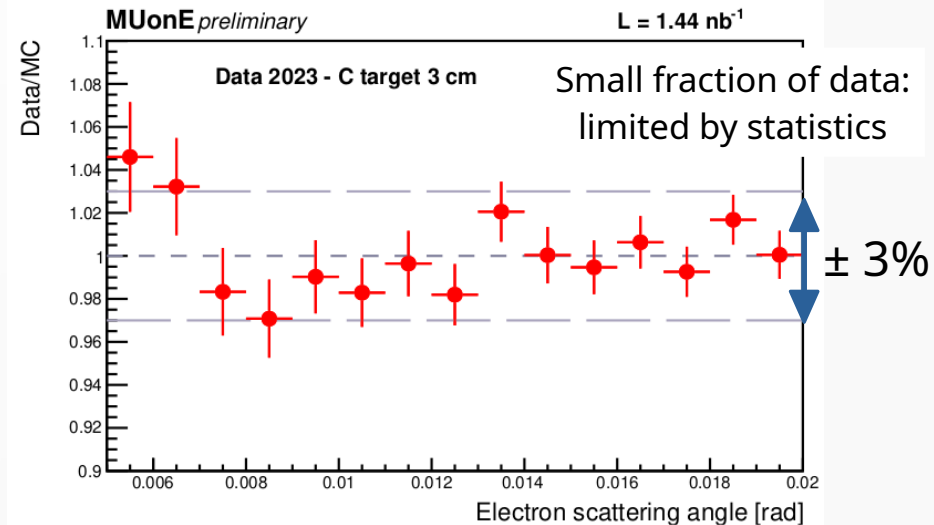
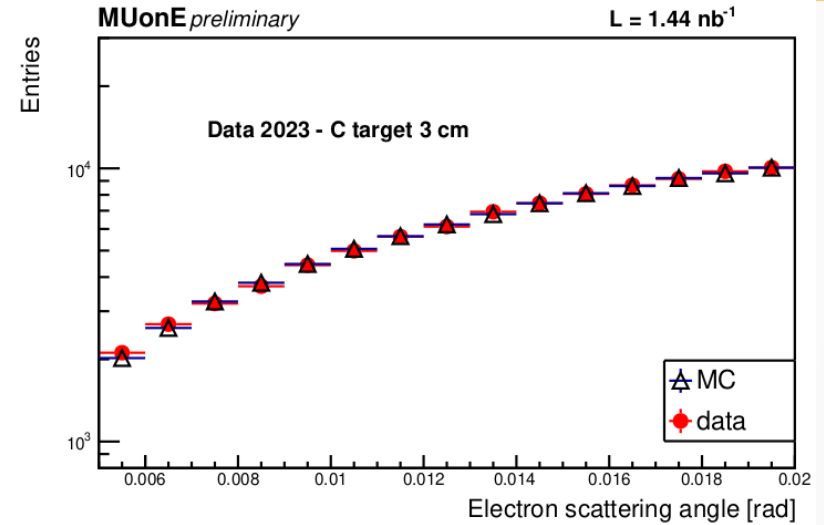


Count N_μ on target \rightarrow luminosity estimate

Data/MC comparison of the cross section within event selection:

$$\sigma_{\text{data}} = (75.1 \pm 3.1) \mu\text{b}$$

$$\sigma_{\text{MC}} = (77.75 \pm 0.14) \mu\text{b}$$



Data-MC comparison of elastic events

Data sample: run 6 $\rightarrow 97 \times 10^6$ events **after skimming** to be reconstructed

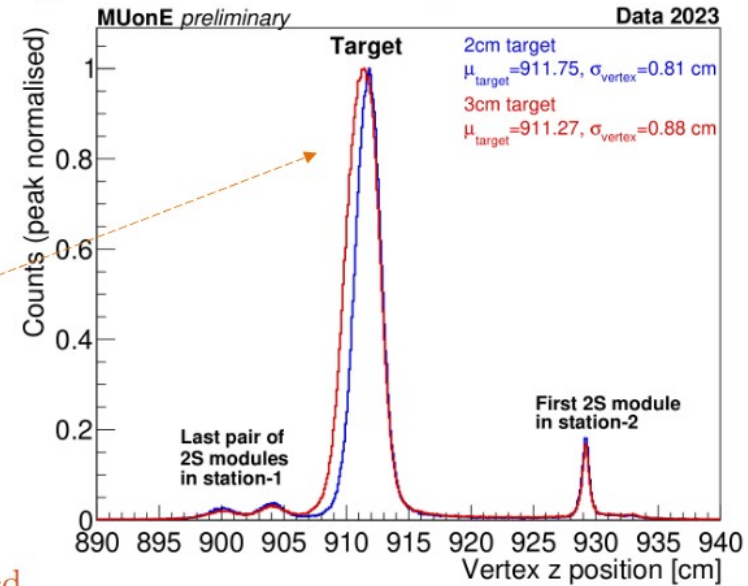
MC sample: MESMER generated signal elastic events $\rightarrow 16.5 \times 10^6$ to be reconstructed with **realistic misalignment scenario** (simulated geometry from real metrology followed by track-based alignment as with real data)

Fiducial selection:

- $N_{\text{hits}_{S0}} = 6 \rightarrow 1$ per module: golden muon (GM);
- GM impinges last 2 modules in S0 within ± 1.5 cm from centre in X and Y ;
- Reconstructed GM with $\theta < 4$ mrad.

Elastic selection:

- $N_{\text{hits}_{S1}} \leq 15$;
- Reconstructed Z vertex > 906 cm;
- $\theta_\mu > 0.2$ mrad, $5 < \theta_e < 20$ mrad;
 >0.2 mrad: main background removed
 >5 mrad: Avoid ambiguities in PID
 <20 mrad: region less affected by systematics
- Acoplanarity $|A_\phi| < 0.4$ rad;
- Elasticity condition: $|\theta_\mu - \theta_\mu^{exp}(\theta_e)| < 0.2$ mrad



$$\theta_\mu^{exp}(\theta_e) = \arcsin \left\{ \sin \theta_e \sqrt{\frac{E_e^2(\theta_e) - m_e^2}{[E_\mu + m_e - E_e(\theta_e)]^2 - m_\mu^2}} \right\}$$

Absolute luminosity normalization

From the **knowledge of the number of golden muons** (passing the fiducial selection) that can potentially interact in the target, we can estimate luminosity:

Fiducial selection:

$N_{\text{hits}_{S0}} = 6 \rightarrow 1$ per module: **golden muon** (GM);
 GM impinges last 2 modules in S0 within ± 1.5 cm from centre in X and Y ;
 Reconstructed GM with $\theta < 4$ mrad.

Luminosity **real data**:

$$\sigma = \frac{N_{\text{elastic}}}{\epsilon_{hw} L}$$

$$\epsilon_{hw} = 0.850 \pm 0.035 :$$

2 tracks reconstruction

efficiency which depends on
 modules efficiency

$$(\epsilon_{mod} = 0.980 \pm 0.005)$$

$$L = N_{\mu\text{T}} \cdot d_{\text{target}} \cdot \rho_{\text{target}}^e =$$

Golden muons on target

Target thickness

$$\text{Electron density target } \rho_{\text{target}}^e = \rho \cdot \frac{Z}{A} \cdot N_A$$

$$\text{Run 6} = (1443.0 \pm 8.0) \mu\text{b}^{-1}$$

Main error on:

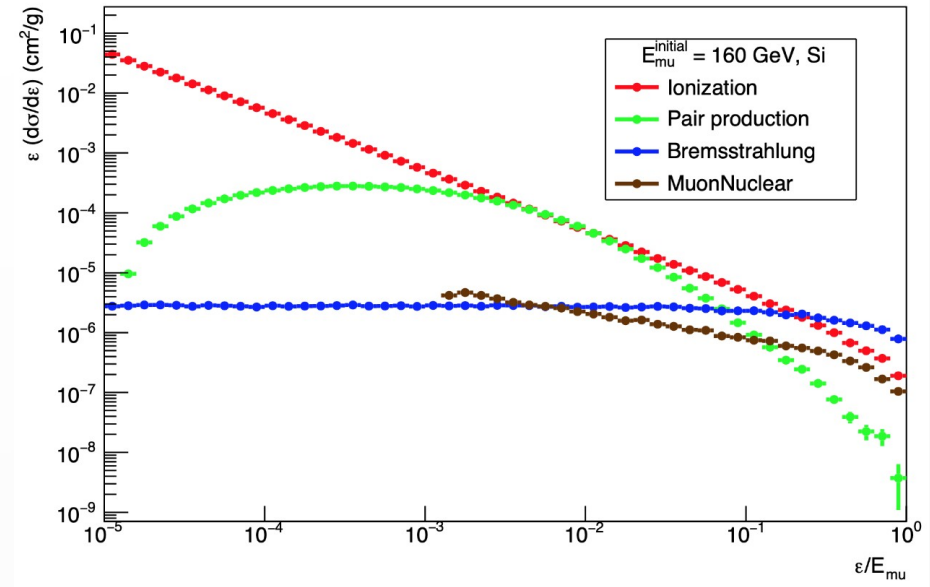
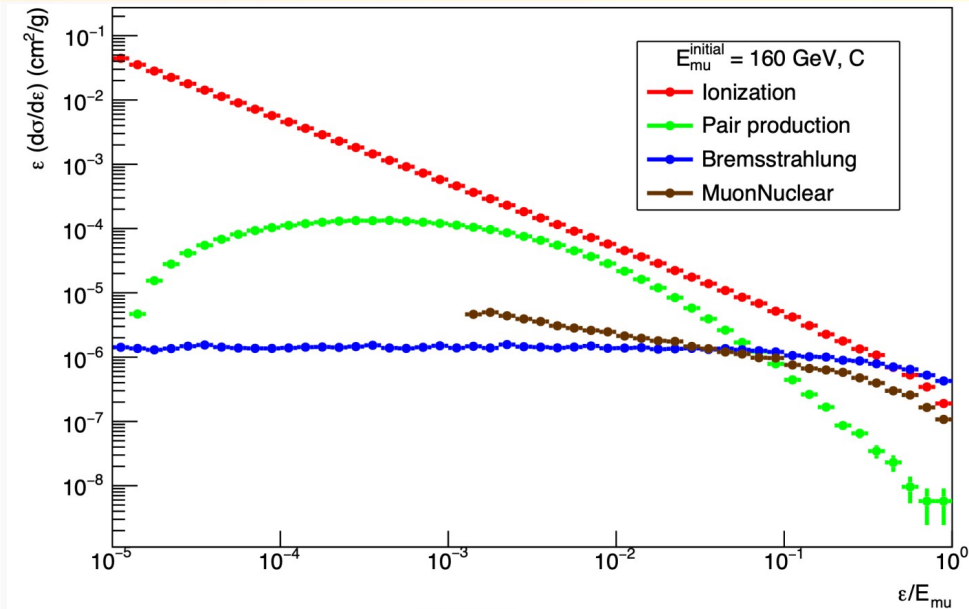
$$\rho = (1.83 \pm 0.01) \text{g/cm}^3$$

+

$$d_{\text{target}} = (3.000 \pm 0.001) \text{cm}$$

MC selection efficiency on σ_{MC} estimate: 76.5%

Backgrounds



← θ_e [mrad] 32 0

MESMER

- $\mu e^- \rightarrow \mu e^- \gamma$
- $\mu e^- \rightarrow \mu e^- l^+ l^-$
- $\mu N \rightarrow \mu N l^+ l^-$

$l = e, \mu$

GEANT4

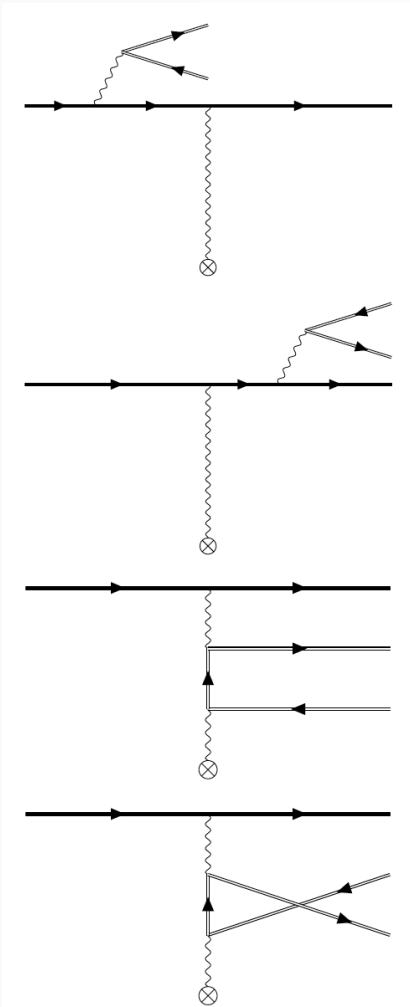
- $\mu N \rightarrow \mu N \gamma$
- $\mu N \rightarrow \mu X$

New Background MC generator

Main background: e^+e^- pair production

Implemented in MESMER

and interfaced with the MUonE detector simulation



Numerical results for $\mu^+ C \rightarrow \mu^+ C e^+ e^-$ (3)

