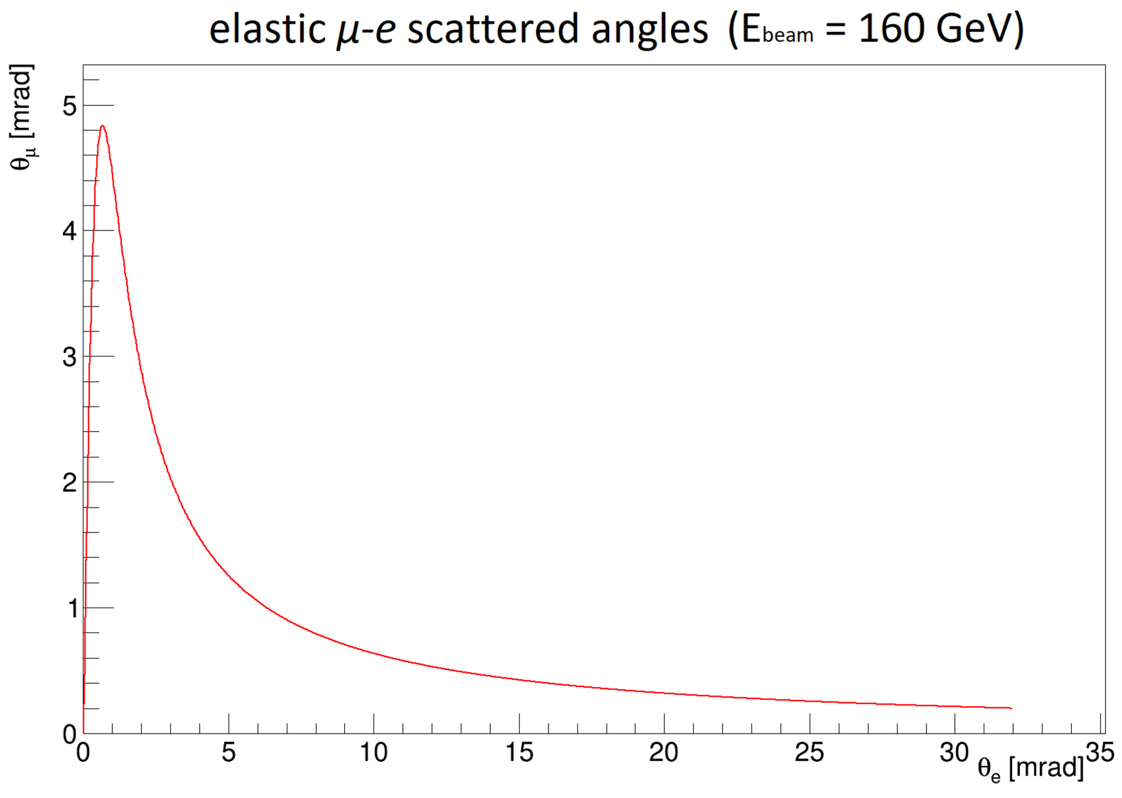
The 2023 MUonE Test Run

Clément Devanne, University of Liverpool

Introduction

The MUonE experiment [1, 2] aims to provide an independent measurement of a_μ^{HLO} by measuring the hadronic contribution to the running of the electromagnetic coupling constant $\Delta\alpha_{had}$ in the space-like region.

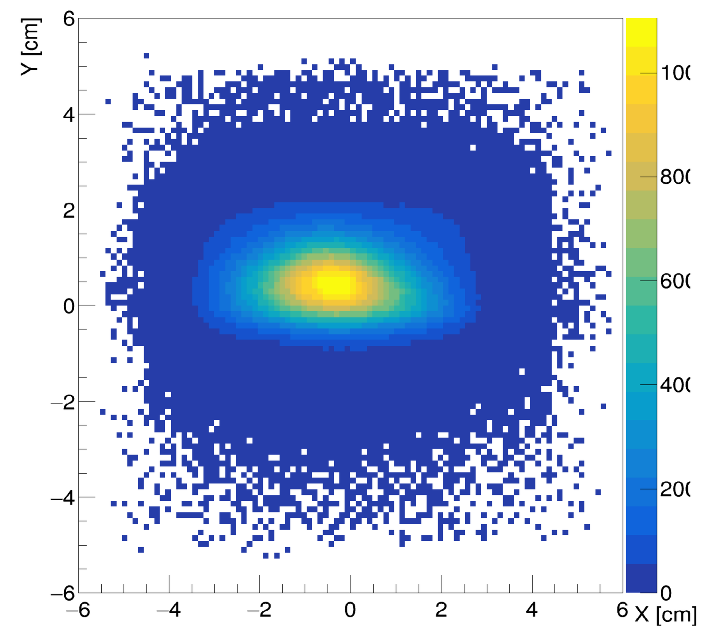
This is achieved through $\mu^+e^- \to \mu^+e^-$ elastic scattering. The shape of the differential cross section provides direct sensitivity to $\Delta\alpha_{had}$ and can be extracted directly from the measurement of the scattered angles of the muon and electron. To produce these elastic scattering events, the MUonE design utilizes a muon beam directed onto atomic electrons of a fixed target.



During the summer of 2023, a three week test run was conducted using the M2 beamline at CERN. The main purposes of this test run were to test the mechanics engineering, the DAQ and the track reconstruction algorithm. And at the physics level, we aim to proceed with the extraction of the leptonic running of the electromagnetic coupling constant $\Delta\alpha_{lep}$ to the level of precision $\sim 5\%$.

1. Beam profile

- The M2 beamline at CERN provides a 160 GeV muon beam ($\pm$3.75%)
- Two regimes of beam intensity have been used:
  - High-intensity: 40 MHz used for physics
  - Low-intensity: 2 MHz used for detector commissioning
- Here the beam profile for the high-intensity regime



beam spot:

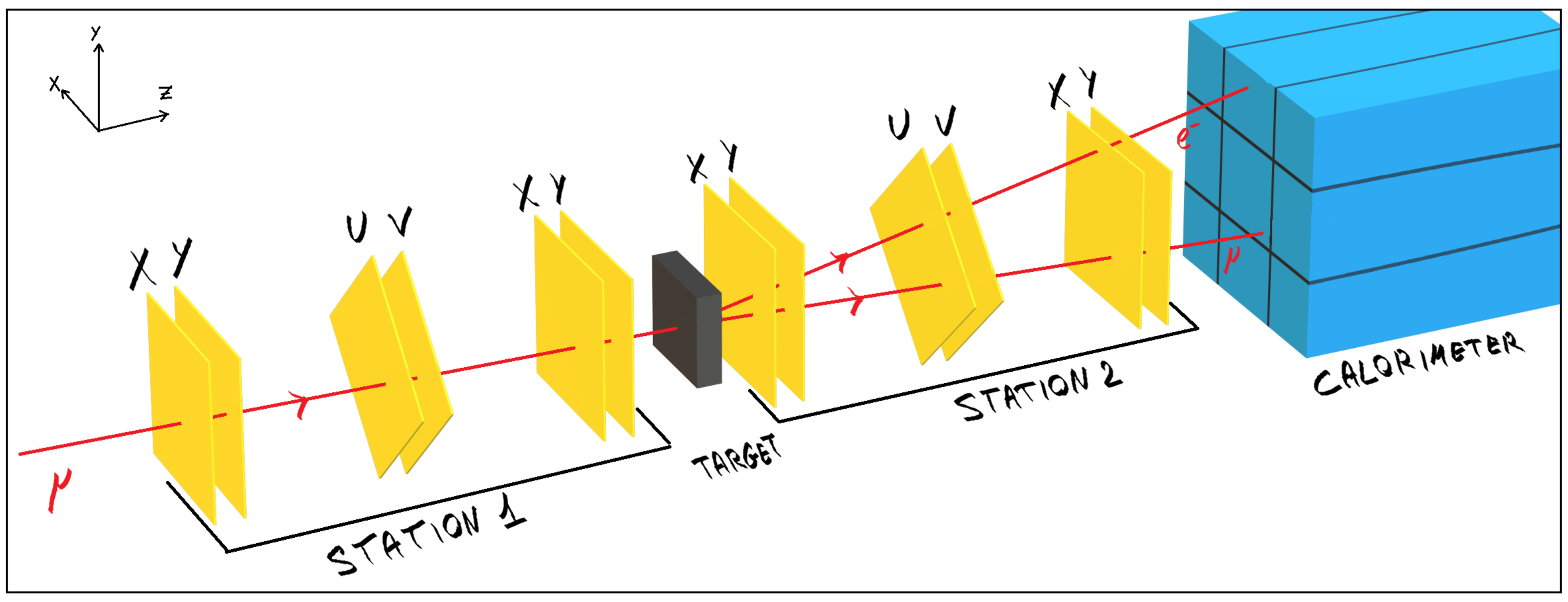
$\sigma_x = 13.5$ mm
$\sigma_y = 6.9$ mm

beam divergence:

$\sigma_{x'} = 0.57$ mrad
$\sigma_{y'} = 1.54$ mrad

2. The Setup

- A graphite target of 2cm or 3cm
- Two 1m long tracker stations, one upstream and one downstream of the target
- A station is made of six so-called 2S modules [3] which are 10cm x 10cm strip silicon sensors of pitch $90\mu m$
  - 2 modules measure hits along the X axis, tilted by 13° around the Y axis (improves the hit resolution)
  - 2 modules measure hits along the Y axis, tilted by 13° around the X axis
  - 2 modules for stereo hits U and V ($\pm$45 degree rotation)
- An electromagnetic calorimeter placed downstream of all the stations, to provide particle identification
  - 5x5 $PbWO_4$ crystals (2.85cm x 2.85cm x 25cm)
  - total area $\sim$ 14x14 cm^2



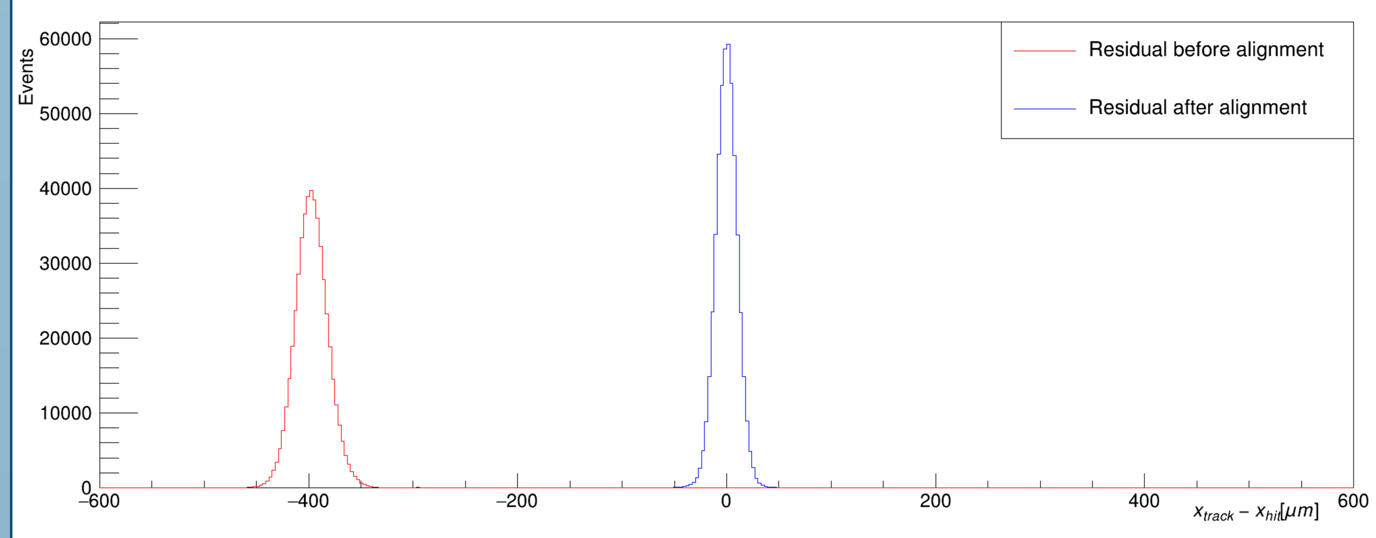
We took data with or without target and analyzed these data using *FairMUonE*, which is the official software of MUonE for the track reconstruction, event selection, and software alignment.

3. Alignment

The first challenge facing MUonE as a precision experiment is to achieve precise alignment of the modules and stations.

- Hardware alignment: Metrology measurements using laser survey
- Software alignment: With FairMUonE software

The software procedure used consists of aligning separately the 12 modules using tracks with one hit per module: each module is aligned by a correcting shift in the measured direction (X, Y, U or V) and a rotations around the Z-axis.



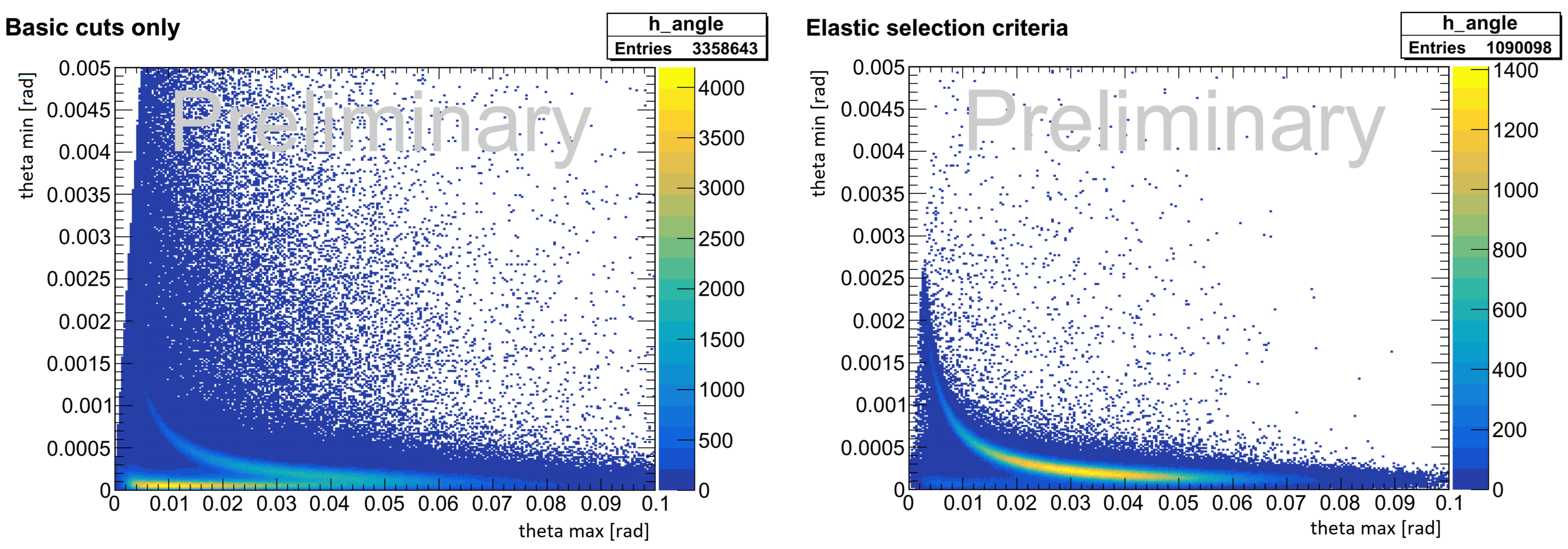
The figure shows the residuals before and after the alignment procedure for the first X module.

A global alignment algorithm is under development

4. $\mu - e$ elastic events

We conduct the initial analysis of elastic interactions by selecting events with single muons in the first station and at least two tracks in the second station.

We reject most of background by rejecting vertexes with outgoing tracks > 2. Then, we select elastic events by applying selection cuts on the vertex χ^2, acoplanarity of the event and position of Z-vertex. We also apply a cut by rejecting events with $\theta_\mu < 0.2$ mrad to get rid of radiative events, and the fiducial cut $\theta_e < 32$ mrad to take into accunt the geometrical acceptance of the tracking station.



The plot on the left represents the angle correlation of the muon and electron candidates for events with exactly 2 outgoing tracks before other selection cuts, and on the right after the selection cut.

5. Future Plans

The MUonE collaboration is working on the analysis of the different results provided by this test: hardware characterization, modules efficiency, Track reconstruction algorithm efficiency, data analysis, alignment procedure, and many other important aspects to study to prepare for the final experiement in the best condition. The final ambition for this test will be to extract $\Delta\alpha_{lep}$ with 5% precision.

We aim to submit an experiment proposal to the SPS Committee soon to request one month of data taking in 2025 with reduced detector of 3 tracker stations (pretracker + 2 targets), which will have for objective of refind measurement of $\Delta\alpha_{lep}$ and to extract preliminary results for $\Delta\alpha_{had}$ ($\sim 20\%$) , marking a significant milestone for MUonE.

Finally, we plan to run with the full setup with 40 stations in 2029 after the LHC long shutdown 3.

References

[1] G Abbiendi. *Letter of Intent: the MUonE project*. Tech. rep. Geneva: CERN, 2019.

[2] G. Abbiendi et al. "Measuring the leading hadronic contribution to the muon g-2 via μe scattering". In: *The European Physical Journal C* 77.3 (2017). DOI: 10.1140/epjc/s10052-017-4633-z.

[3] *The Phase-2 Upgrade of the CMS Tracker*. Tech. rep. Geneva: CERN, 2017. DOI: 10.17181/CERN.QZ28.FLHW.