3^{rd} Semester Report

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PhD Thesis Title: Analytical and Simulation Methods of Detector Physics in High Energy Experiments

Introduction

In my previous reports, I gave details on my work on the data analysis of test beam measurements done in 2024 as part of the ALICE 3 MuonID project. In the summer, an additional test beam measurement was carried out in order to complement the measurement data. This semester, I proceeded with the analysis of the newly acquired data.

Description of research work carried out in current semester

CERN ALICE MuonID 2025 test beam measurement:
Between July 30, 2025, and August 13, 2025, another test beam measurement was carried out, similarly to the previous year using 2, 3 and 6 GeV/c muon- and pion-enriched beams. The experimental configuration is shown in Figure 1.

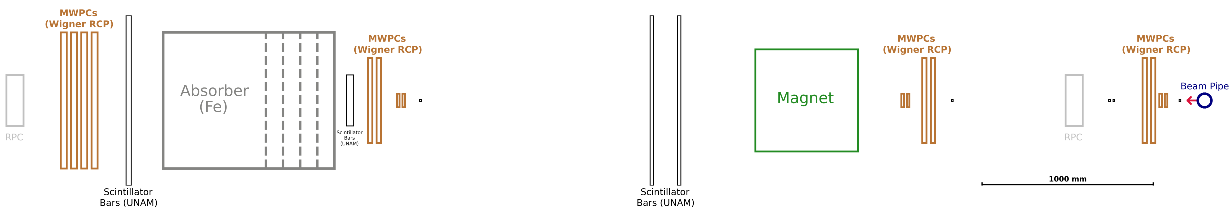


Figure 1: Depiction of the CERN MID 2025 beam test setup.

The main aspects of difference, compared to the 2024 beam test were the following:

- The MID chambers used were larger MWPCs (120 cm $\times$ 80 cm, 12 mm segmentation), characteristics more similar to the proposed final design of the ALICE 3.
- A magnet of bending power 0.4 Tm was installed and used in certain parts of the measurement, in order to make measurements on the beam momentum distribution.
- A high-pressure Cherenkov detector was used as a trigger/veto during the measurements, in order to get a high purity muon/pion beam. This was not done previously due to time constraints.
- Joint data taking with the UNAM team (scintillators) was systematically carried out, to provide us with the option of testing a hybrid (MWPC+scintillator) design for the muon system.

In the measurement, a five-fold scintillator trigger condition was used to localise the incoming beam, and 6 MWPC chambers were installed as a telescope for it. Additionally, 6 other MWPC detectors (smaller, but better segmentation) were also installed, and were used during the beam momentum distribution measurements. Unfortunately, the iron absorber used this year had service holes along the beam line, lowering the effective length of the absorber by approximately 14 cm. The total absorber lengths used were changed between 60 cm and a 100 cm, in 10 cm steps.

Geant4 simulations:

The experimental setup was modelled in Geant4. The triggers, MWPCs, magnet and absorber (including the aforementioned service holes) were included in the simulation. The scintillators of the UNAM group were also included in these simulations as sensitive volumes, to be used as a baseline for joint measurement analysis. To account for pion decay between the Cherenkov detector and our experiment, an additional 8 meters of empty path were included in the simulations ($\approx 4.7\%$ at 3 GeV/c).

Data filtering:

In order to enhance the performance of the χ^2-value-based muon tagger described in my previous report, the data (both from measurement and from simulation) were not only filtered for clean, single incoming tracks, but the position of the hits in the MID chambers were corrected for the incoming particle's measured trajectory. This resulted in the narrowing of the beam profiles. The filter also eliminated any significant dependence of our measurement on the beam intensity. For visualization, see Figure 2.

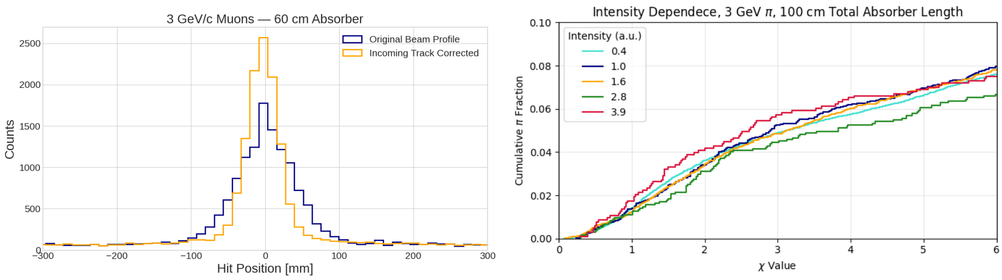


Figure 2: Left: example of the effect of the track correction on experimental muon data. Right: Intensity dependence of the pion χ-value distribution on the beam intensity after corrections.

The experimental data suffered from significant beam halo contribution that created a background. It is visualised along with the effect of the vetos in Figure 3.

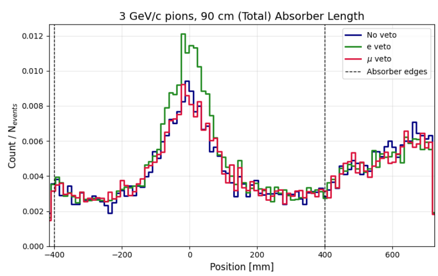
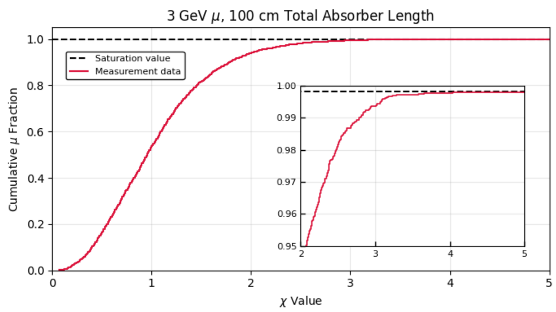


Figure 3: Effect of vetos: filtering out electrons decrease, while filtering out muons as well increases the area under the pion beam profile. The beam halo contribution causes a second peak in the beam profile, due to the detector being larger in area than the absorber used.

Results:
The result of the analysis of the 2025 beam test and corresponding simulations are shown in Figure 4. The muon χ distribution saturates around (99.7±0.1)% for all measurements (and simulations as well), meaning a very pure muon beam was produced using the Cherenkov muon trigger. The systematic shift between the simulation and the measurement in the hadron suppression results however implies a (1.5±0.5)% muon contamination in the pion beam.



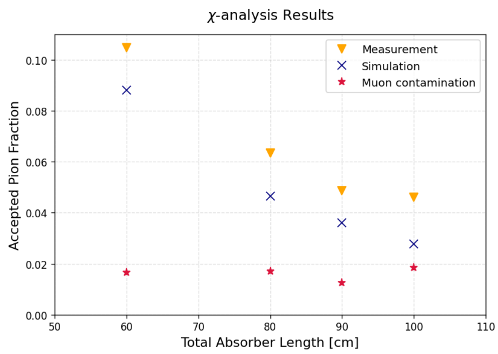


Figure 4: Left: Experimental cumulative distribution of χ values for muons. Right: hadron suppression results.

Preliminary results on joint data analysis suggest that a hybrid design could further decrease the hadron suppression value.

Publications

A publication on the 2024 test beam data analysis was published,[1] where I contributed via MWPC data analysis and Geant4 simulations. Another publication is expected to be submitted in the next semester. Also, the results of my research were shown as a poster on the 26th Zimányi School Winter Workshop on Heavy Ion Physics, as well as a presentation on the 6th ALICE Upgrade Week.

Studies in current semester

1. Experimental Methods in Particle Physics II. (FIZ/2/004E)
2. The Phase Diagram of Strongly Interacting Matter (FIZ/2/024E)

Teaching activity in current semester

1. Classical Physics Laboratory (fizlab2f19la)
2. Advanced Numerical Methods (halnumf19la)
3. Research Seminar in Physics 2. (EJC-MATFIZ-KUT/08)

Professional activities

Besides my teaching activities at ELTE, I gave lectures at "Eötvös József Tehetséggondozó Tábor", and also worked as one of the main organizers of this year's "Eötvös Természettudományos Tábor".

References

[1] J. E. Muñoz Méndez, A. Ortiz, A. Paz, P. Vargas Torres, R. Alfaro Molina, L. H. González Trueba, V. Grabski, A. Fernández Téllez, H. D. Regules Medel, M. Rodríguez Cahuantzi, G. Tejeda Muñoz, Y. A. Vásquez Beltran, J. C. Cabanillas Noris, S. Rojas Torres, G. G. Barnaföldi, D. Száraz, D. Varga, R. Vértesi, and E. García Solis. ML-based muon identification using a FNAL-NICADD scintillator chamber for the MID subsystem of ALICE 3. *Journal of Instrumentation*, 20(09):P09015, 2025. doi: 10.1088/1748-0221/20/09/P09015.