1^{st} Semester Report

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

Introduction

In 2022, the ALICE Collaboration presented to the LHCC a Letter of Intent detailing a substantial upgrade initiative for its detector, termed ALICE 3.[1] The main purpose of the upgrade is to reduce the size if the absorber to be able to identify low(er) energy muons ($p_T > 1.5$ GeV/c). In order to determine the optimal thickness of the new absorber, as well as in order to decide what detector technology to use for muon detection, test measurements must be carried out, as they were done as described below.

One possibility for the muon detector technology to be used are multi wire proportional chambers (MWPCs).[2] These gaseous particle detectors have been essential components of large-scale high-energy physics detector systems since the 1970s, and constitute a core aspect of my PhD research. A visualization of the working principle of MWPCs is shown in Figure 1.

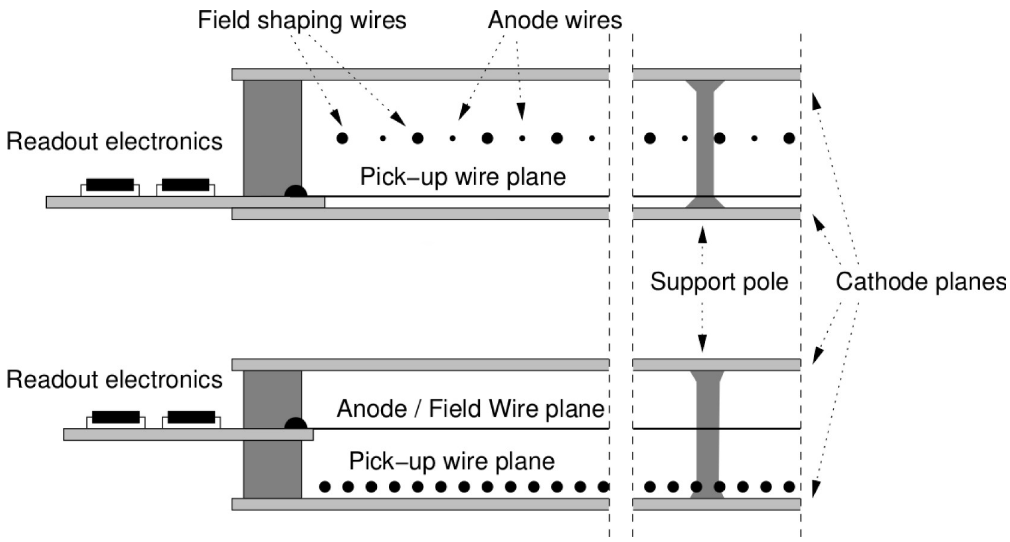

Figure 1: Schematic lateral sections of an MWPC. Field and pick-up wires are responsible for the determination of the position of the signal, while anode wires amplify and measure the amplitude of the signal.

Description of research work carried out in current semester

CERN ALICE MuonID 2024 test beam measurement:
Between October 9, 2024, and October 16, 2024, a measurement was carried out at CERN at the T10 secondary beam site as part of the ALICE MuonID experiment. The objective of the experiment was to measure the suppression of hadrons via π^- and μ^+ beams with an iron absorber. The reference beam energies were 2 GeV, 3 GeV and 6 GeV in both cases, while the absorber length was changed from 60 cm to 100 cm in 10 cm steps. The experimental setup can be seen in Figure 2. Four scintillator detectors were used as triggers for the beam, as it is also shown on the setup sketch. During the test beam, I was physically present, contributing to the measurement via setting up the MWPC detector system and performing on-site data analysis.

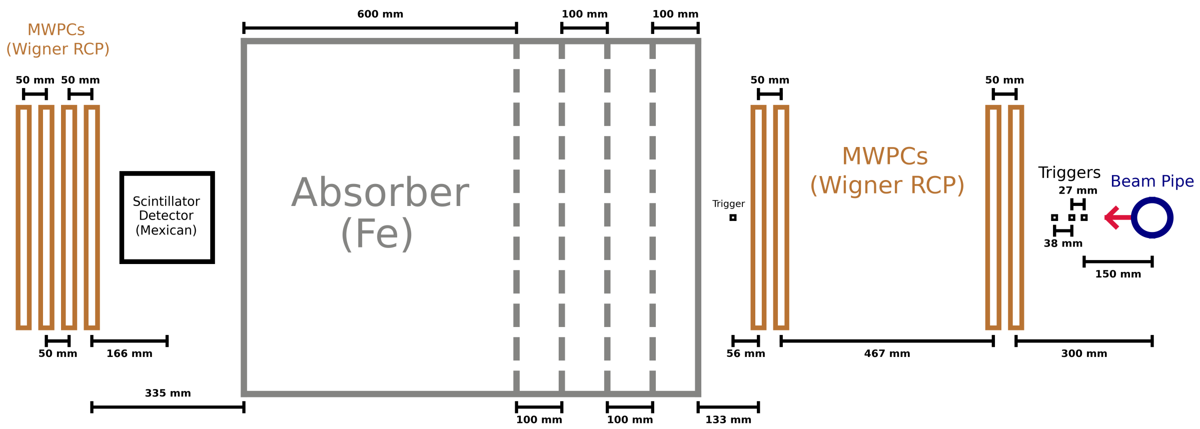

Figure 2: Depiction of the CERN MID beam test setup.

Geant4 simulations:
I created Geant4 simulations of the experimental setup in order to attempt to replicate the results of the measurement for a more detailed analysis and comparison. Each MWPC detector is represented by 2 adjacent layers — one horizontally and one vertically striped — of (512 mm $\times$ 8 mm $\times$ 8 mm) sensitive detector volumes made of $ArCO_2$ gas mixture, corresponding to the field and pick-up wires of the actual detectors. Each MWPC is covered on both sides by a 2 mm thick compound material made of epoxy and SiO2 (FR-4) and a 25 μm thick Cu layer. The iron absorber, of course, and the scintillator detector of the other measuring team was also included in the simulation — the latter modelled as 2 layers of 1 mm thick plastic scintillator material.

Software development:
For the mutual evaluation of simulation and measurement data, I have implemented a tracking algorithm capable of processing both data types to minimize errors from differences in handling simulation and measurement results. For the simulations, a 0.5 keV cutoff was used for minimum energy deposition, and a 1 μs cutoff for the maximum time-of-flight for detection, realizing the sensitivity of the detector, and the time window of triggers used during the measurement. Tracks were fitted separately for the four MWPCs before and the four MWPCs after the absorber. To account for the possibility of multiple incoming particles in the same time window, as it may be frequent due to the nature of bunches and the relatively long time-of-flight cutoff, only events with 1 incoming track were processed.

Preliminary results:
The evaluation of the measurement data is still ongoing. So far, we have managed to determine that the beams were significantly contaminated ($\approx$2% in case of the pion beams, and $\approx$(40-60)% in case of the muon beams, depending on energy), but preliminary absorption results were found to be independent of beam intensity, meaning no intensity dependent corrections should be applied. Fine-tuning the simulations to account for other known detector effects — for instance, signals from multiple adjacent channels caused by high energy deposition — is also still in progress.

Publications

A joint publication with the Mexican team, as well as a standalone publication on the results are planned once the evaluation of experimental data is done.

Studies in current semester

1. Selected Chapters from Experimental High Energy Physics (FIZ/2/117)
   Grade: 5 (Excellent)

2. Data Models and Databases in Science (FIZ/3/086)
   Grade: 5 (Excellent)

Teaching activity in current semester

1. Classical Physics Laboratory (fizlab2f19la)

2. Advanced Numerical Methods (halnumf19la)

3. Research Seminar in Physics 1. (EJC-MATFIZ-KUT/02)

References

[1] Letter of intent for ALICE 3: A next generation heavy-ion experiment at the LHC. Technical report, CERN, Geneva, 2022.

[2] Dezső Varga, Gábor Nyitrai, Gergő Hamar, and László Oláh. High efficiency gaseous tracking detector for cosmic muon radiography. *Advances in High Energy Physics*, 2016:1962317, 2016.