Hadron suppression measurements and simulation for the ALICE 3 MuonID upgrade

25th ZIMÁNYI SCHOOL WINTER WORKSHOP ON HEAVY ION PHYSICS

December 1-5, 2025
Budapest, Hungary

Dániel Száraz
szaraz.daniel@wigner.hun-ren.hu

Dezső Varga

DOI:10.1088/1748-0221/20/09/P09015

HADRON SUPPRESSION MEASUREMENTS AND SIMULATION FOR THE ALICE 3 MUONID UPGRADE

Dániel Száraz[1,2], Dezső Varga[1]

[1] HUN-REN Wigner Research Centre for Physics, 29-33 Konkoly-Thege Miklós út, 1121, Budapest
[2] Eötvös Loránd University, 1/A Pázmány Péter sétány, 1117, Budapest

25TH ZIMÁNYI SCHOOL WINTER WORKSHOP ON HEAVY ION PHYSICS

DECEMBER 1-5, 2025
BUDAPEST, HUNGARY

INTRODUCTION

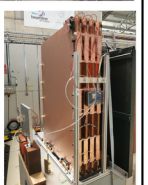
- In 2022, the ALICE Collaboration presented to the LHCC a Letter of Intent detailing a substantial upgrade initiative for its detector, termed ALICE 3
- One of the relevant goals of this upgrade is to optimize detection efficiency for muons below 1.5 GeV/c momentum (for the reconstruction of J/ψ meson decay events)
- Research is required to determine optimal absorber geometry, as well as appropriate detector technology to be used for the muonID system

MEASUREMENT DETAILS

- Between 30 July and 13 August 2025 at CERN T10, together with a team from UNAM
- Pion- and muon-enriched beams at 2, 3, and 6 GeV/c momenta
- Cast iron absorber used with lengths between 60 cm and 100 cm

- Inclusion of magnet with bending power 0.4 Tm for beam momentum distribution measurements
- Five scintillator triggers over more than 4 meters of distance for localized beam
- High pressure Cherenkov detector included in triggering for purer beam composition

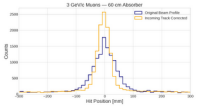
- (50 cm x 50 cm) MWPC detectors with 8 mm segmentation were used as a telescope for the incoming beam
- (20 cm x 5 cm) "borehole" MWPC detectors for momentum measurements (3 mm segmentation)
- (120 cm x 80 cm) MWPCs with 12 mm wire segmentation after the absorber for MuonID



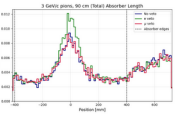
- Joint (coordinated) measurements with scintillators and MWPCs
- Note: the absorber used included service holes along the beam trajectory that reduced the total (nominal) absorber length by an effective thickness of ≈ 14 cm

EVALUATION METHODS

- Data filtering needed due to O(μs) readout time (causes intensity dependence):
  - Multiple incoming particles in a single event
  - Ignored triggers and off-trigger particles
- Filter for single tracks in the telescope chambers, restrict the number of clusters

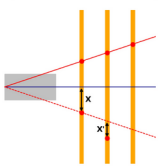


- Hit positions in MuonID MWPC detectors corrected by incoming track slope (tracking information)
- Expected hit uniformly centered for individual hits, beam profiles narrow



- Usage of Cherenkov veto for the measurements → effect of vetoed electrons and muons clearly visible
- Cherenkov coincidence for muon beams to achieve high purity

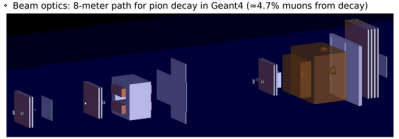
$$\chi^2 = \left(\frac{\text{Distance of hit from the beam center}}{\text{Width of all hit position peak}}\right)^2 + \left(\frac{\text{Relative distance of hit from expected position}}{\text{Width of expected hit position peak}}\right)^2 = \left(\frac{X}{\sigma}\right)^2 + \left(\frac{X}{\sigma}\right)^2$$



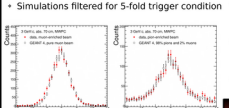
- χ-value analysis:
  - Determine threshold χ from muon data (95% algorithmic efficiency)
  - Apply the same χ threshold to pion data to obtain hadron suppression
  - Correct hadron suppression value by algorithmic efficiency

SIMULATION DETAILS

- Measurement setup implemented in Geant4 (triggers, scintillator bars and MWPCs as sensitive volumes, absorber, magnet and other detectors as material budget)
- MWPC wires modelled as two adjacent layers of sensitive cuboid blocks
- Realistic beam with position and angular spread, realistic absorber (with service holes)
- Beam optics: 8-meter path for pion decay in Geant4 (≈4.7% muons from decay)

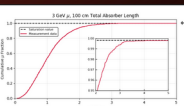


- Simulations filtered for 5-fold trigger condition

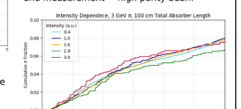


- Monte Carlo simulation → high compatibility with measurements (2024 beam test result)
- Possibility of parallel simulation for scintillator and MWPCs (for joint measurements)
- Beam momentum distribution to be set based on measurements

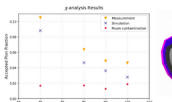
HADRON SUPPRESSION RESULTS



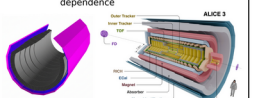
- χ-value analysis for muon data:
  - Saturation at (99.7±0.1)% in both simulations and measurement → high purity beam



- χ-value analysis for pion data:
  - Measurement and simulation are consistent
  - 95% algorithmic efficiency included
- Shift indicates muon contamination of (1.5±0.5)% in hadron beam



- Data filtering eliminates intensity dependence



- Additional hit and timing information from scintillators is expected to further reduce the measured hadron suppression

SUMMARY

- The MuonID 2025 test beam measurement has successfully been carried out, hadron suppression values have been determined
- Results indicate a pure muon beam and a hadron beam with less than 2% muonic contamination
- Data analysis is still in progress, with promising preliminary results for a hybrid scintillator-MWPC design for the ALICE 3 MuonID detector system

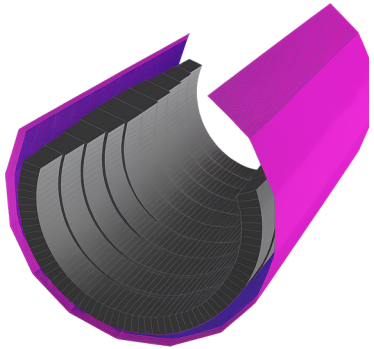
ACKNOWLEDGEMENTS

The presented work was supported by the Hungarian NRDI Fund project ID TKP2021-NKTA-10 and the VLAB Infrastructure.

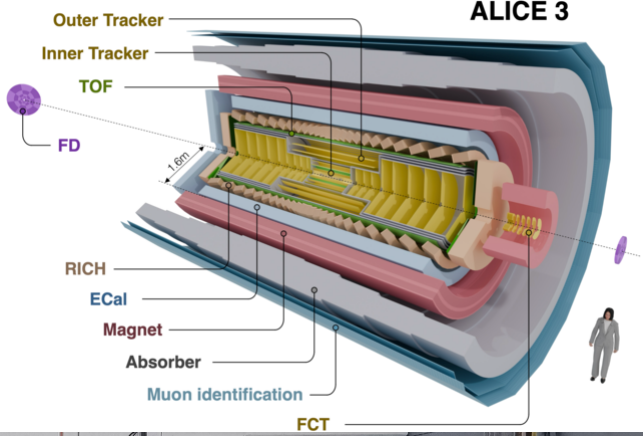
REFERENCES

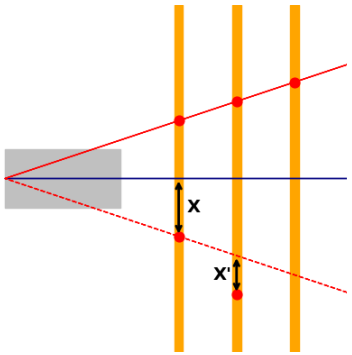
[1] Muñoz Méndez, J. E., et al. (2025). ML-based muon identification using a FNAL-MWPC prototype measurement for the ALICE 3. Journal of Instrumentation, 20(09), P09015. https://doi-org/10.1088/1748-0221/20/09/P09015
[2] ALICE Collaboration. (2022). Letter of Intent for ALICE 3: A next-generation heavy-ion experiment at the LHC. arXiv:2211.02491. https://arxiv.org/abs/2211.02491
[3] Alfaro, R., et al. (2024). Characterisation of plastic scintillator paddles and lightweight MWPCs for the MID subsystem of ALICE 3. Journal of Instrumentation, 19(04), T04006. https://doi.org/10.1088/1748-0221/19/04/T04006

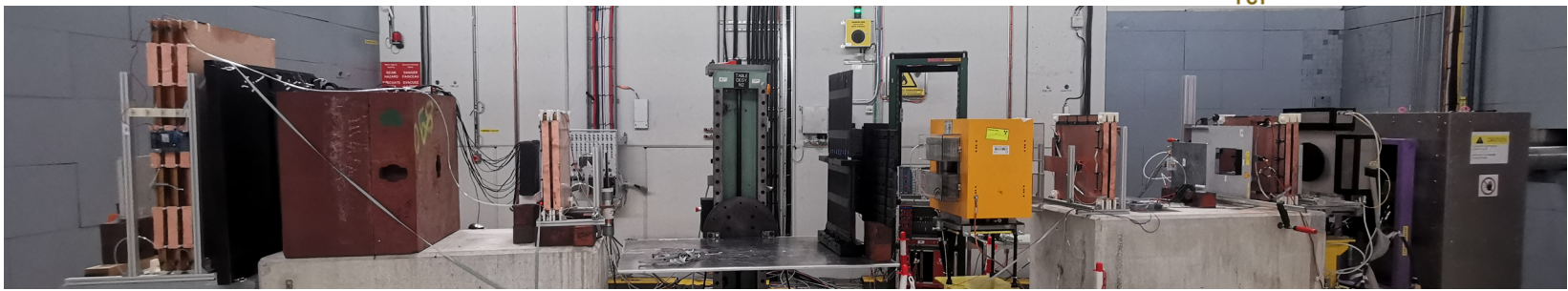
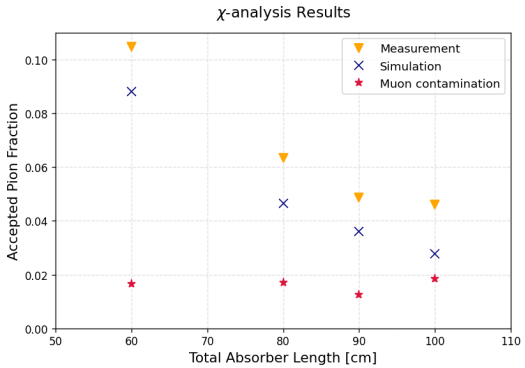
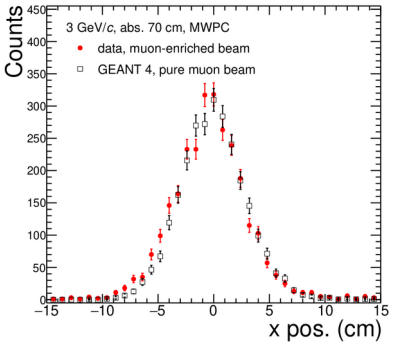
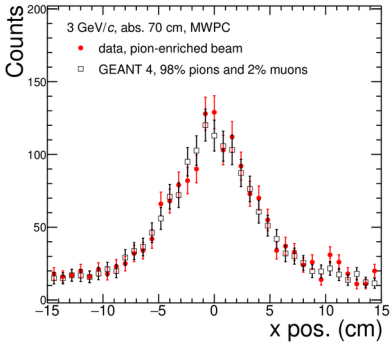
ALICE 3 MuonID



- CERN ALICE 3 upgrade → detection of muons below 1.5 GeV/c momentum (J/ψ meson decay)
- Problem: smaller absorber yield larger hadronic background
- Goal: determine optimal absorber geometry and MuonID detector technology







- Test beam measurements at CERN T10 → validate Geant4 simulations
- Methods of hadron suppression determination (accept muons while rejecting hadrons)
- Evaluate suppression and improve it through simulations