The Muon Identifier detector for the ALICE 3 experiment

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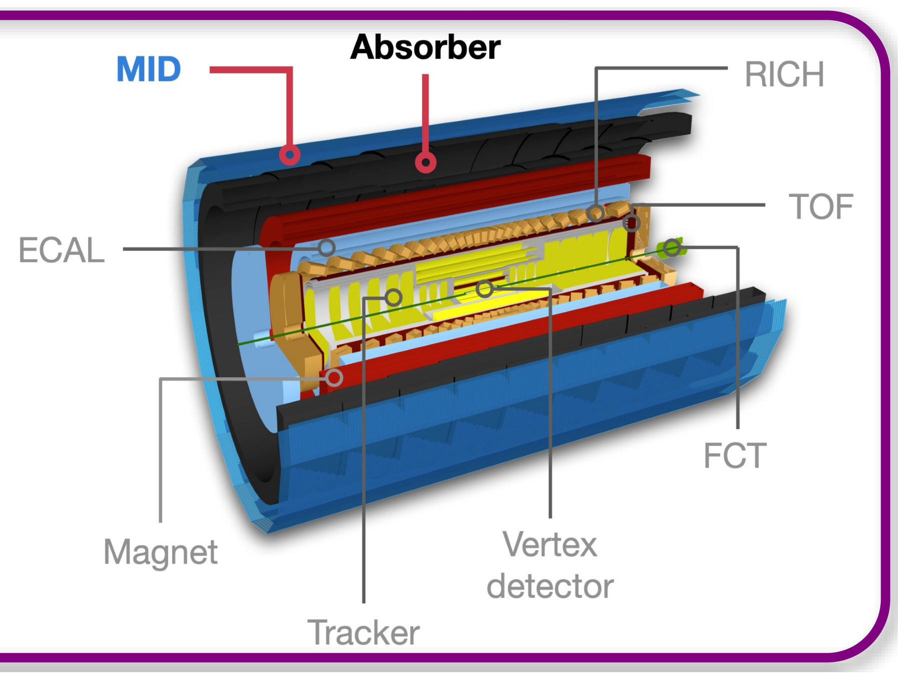
Introduction

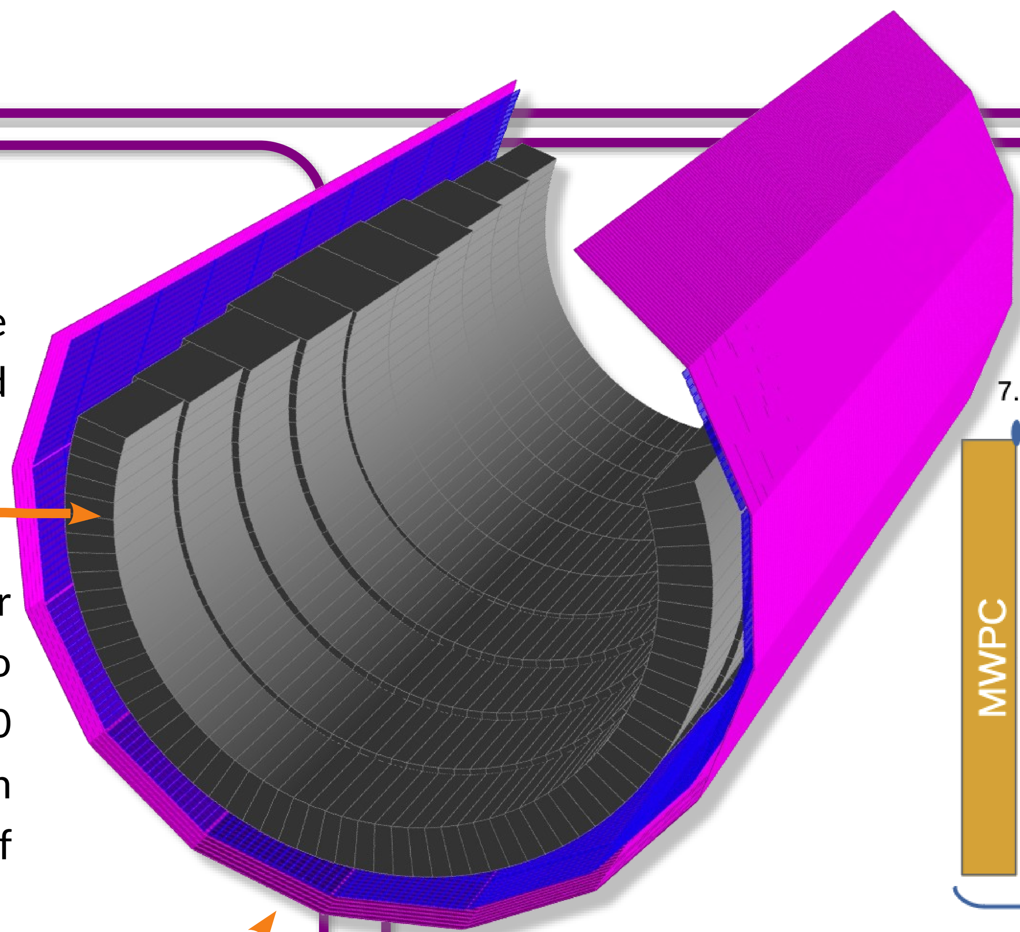
ALICE 3 is a new detector that is proposed to operate during LHC Runs 5 and 6. The Muon IDentifier (MID) detector is one of the ALICE 3 subsystems. It is optimized to detect muons down to momenta below 1.5 GeV/c for pseudorapidity $|\eta|<1.3$ allowing for the reconstruction of J/ψ vector mesons down to zero transverse momentum at midrapidity.

The ALICE 3 large-acceptance tracker will offer access to rare charmonium and exotic states that decay to J/ψ, pions, and photons. The MID detector will be installed outside the superconducting magnet and includes an absorber with variable thickness (70 cm to 38 cm). Plastic scintillator, multi-wire proportional chambers, and resistive plates chambers technologies are considered for the construction of MID.



Muon Identifier (MID) detector

The MID detector is designed to optimize the μ identification down to p_T=1.5 GeV/c, and pseudorapidity coverage $|\eta|<1.3$.



Muon absorber

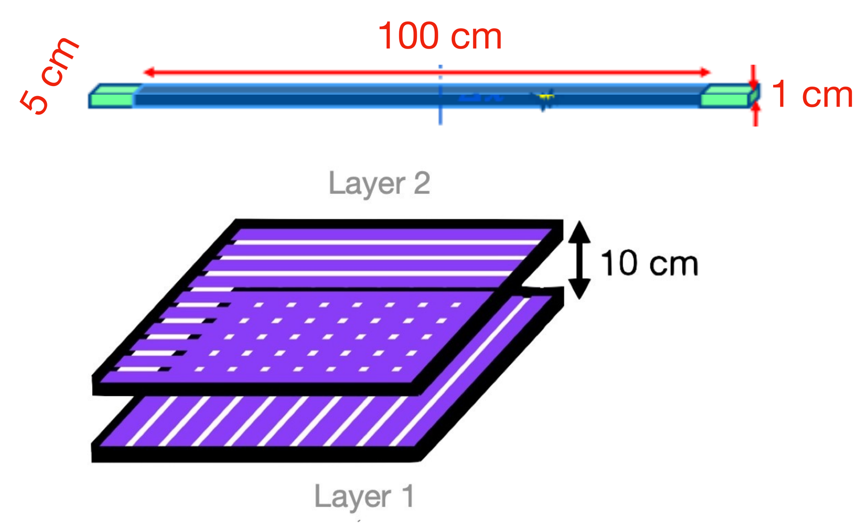
MID considers a magnetic iron absorber outside the magnet, with varying thickness to provide a ~4 nuclear lengths (thickness of ~70 cm at η=0) to provide 10^{-2} hadron rejection factor, and a low fluence rate (~4 Hz/cm²) of charged particles.

The expected scattering within the absorber of ~5 cm for p=1.5 GeV/c requires a granularity of 5x5 cm².

MID chambers

The base line option consist of 160 chambers of two 1x1 m² orthogonal layers made of 20 plastic scintillator bars (100x5x1 cm³) with WLS fibres; each bar is readout by SiPMs.

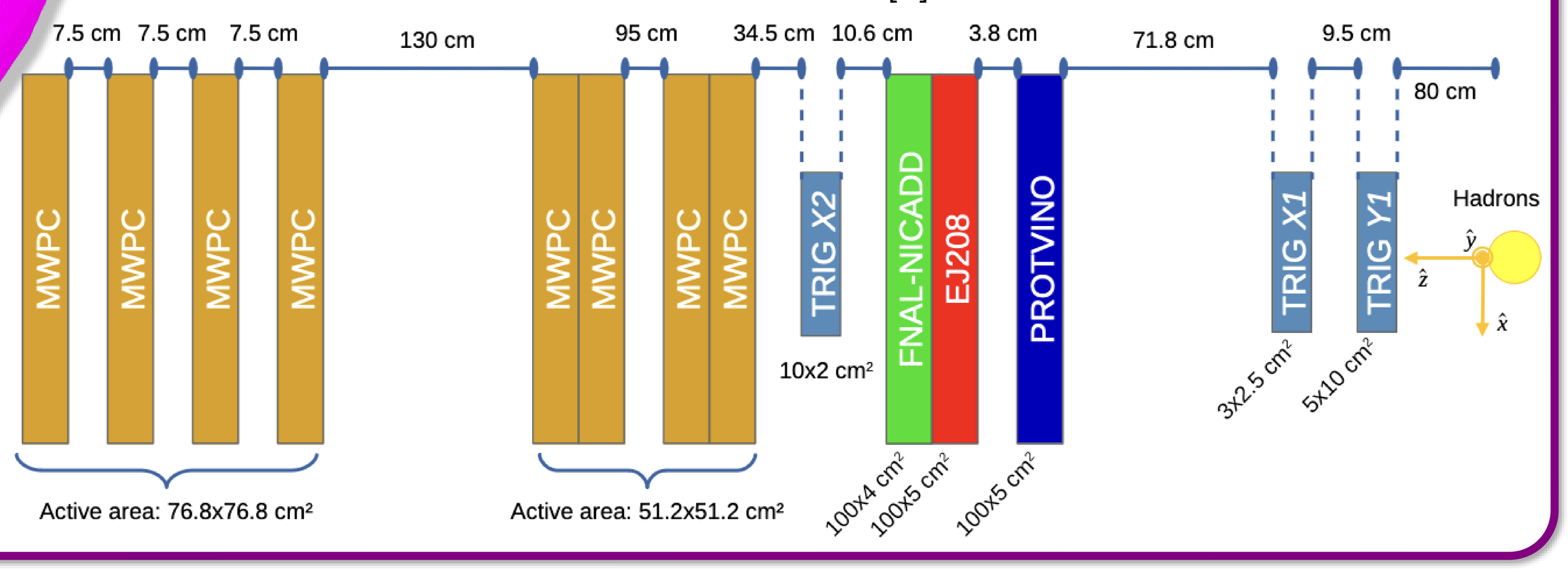
The $\Delta\eta$ x $\Delta\phi$ granularity will be 5x5 cm² cells.



Alternative options: 160 MWPCs modules and 320 RPCs modules

Beam test at CERN PS

The proposed technologies were tested at CERN in July 2023 at T10 beam area with hadron beam from 0.5 to 6 GeV/c momenta [1].

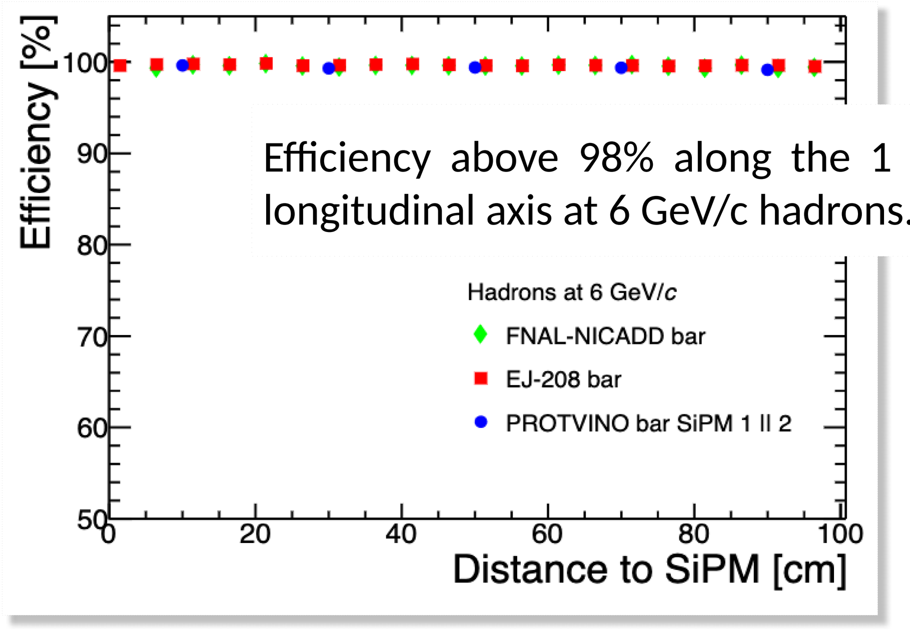


Scintillator bars

Three different scintillator prototypes were reported: FNAL-NICADD, EJ-208 and PROTVINO.

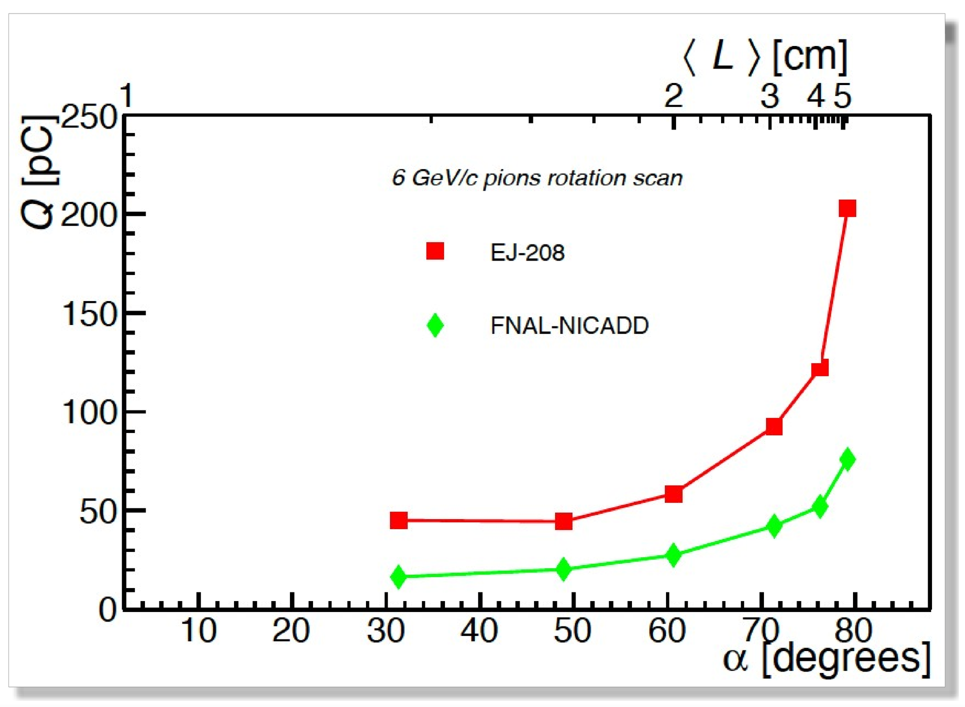
NuviaTech and custom made scintillators from Mexico are considered for further studies.

Studies of the efficiency in the longitudinal axis and the charge correlation with respect to the particle angular incidence (α).



Particles reaching MID at larger incidence angles (60° – 90°) from beam-induced background is expected.

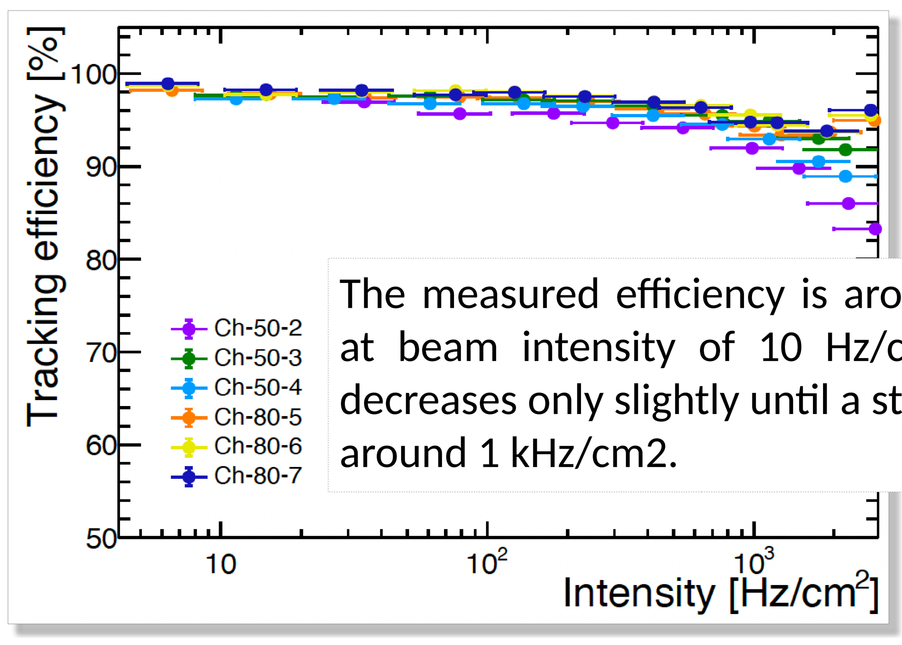
The charge shows a modest variation (~1.7) for incidence angles within 30°–60° and a steep increase with decreasing the incidence angle (four times at ~80°).



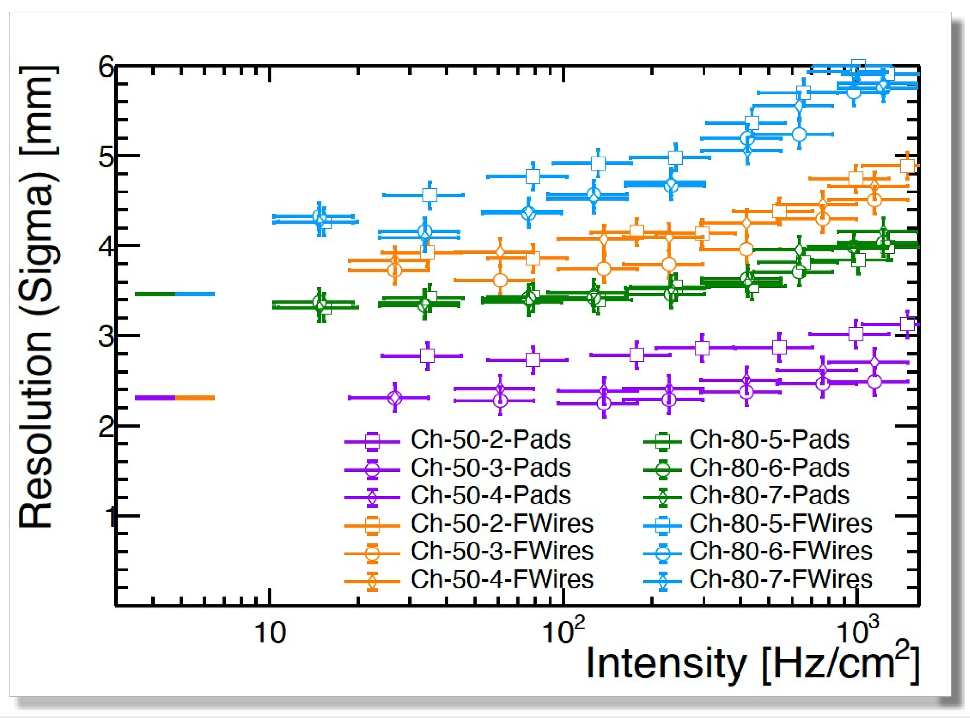
MWPCs

Eight chambers were tested: four of 50x50 cm² and four 80x80 cm², readout with a DAQ system designed for muon detection [2] with about 0.1 ms dead-time (10 kHz maximum rate for recording).

Tracking efficiency, and spatial resolution with respect to beam intensity were studied.



The resolution broadens to about 10–30% at higher intensities (around 1000 Hz/cm²), where the efficiency drops.



Upcoming beam test (October 2024)

Scintillator based chamber

- Build and test a chamber: FNAL-NICADD and custom made scintillator plastic
- Validate the muon tagging algorithms
- Test with commercial electronics readout
- Aiming to test a first version FEE prototype

MWPCs based chamber

- Test the dead zone reduction
- Test with optimized electronic design

Combined measurement

- Measure pion suppression with realistic absorber

Final comments

- The plastic scintillators bars showed a good efficiency and charge collection along the scintillator bars. The FNAL-NICADD equipped with WLS fibres showed a promising performance in addition to be an affordable option.
- The MWPCs showed high efficiency and excellent position resolution beyond the required particle fluence.
- In parallel to the construction of chambers with commercial plastic scintillator, R&D efforts are ongoing to develop custom scintillator production in Mexico and the front end electronics for the SiPM readout.
- The possibility of irradiation tests (both neutrons and gammas) at the Wigner research institute is being explored to measure the radiation hardness of the detectors.

References

[1] R. Alfaro et. al., JINST 19 (2024) 04, T04006. DOI:10.1088/1748-0221/19/04/T04006

[2] D. Varga et al., Detector developments for high performance Muography applications, Nucl. Instrum. Meth. A 958 (2020) 162236.