Simulation and testing of a MID prototype for ALICE 3

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for the ALICE Collaboration

5 nov 2024

SILAFAE 2024, México

ALICE overview

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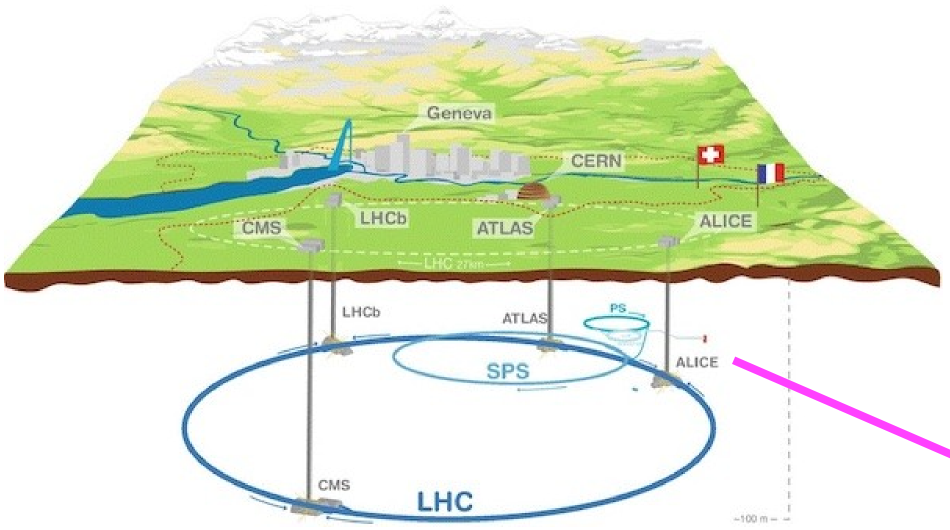
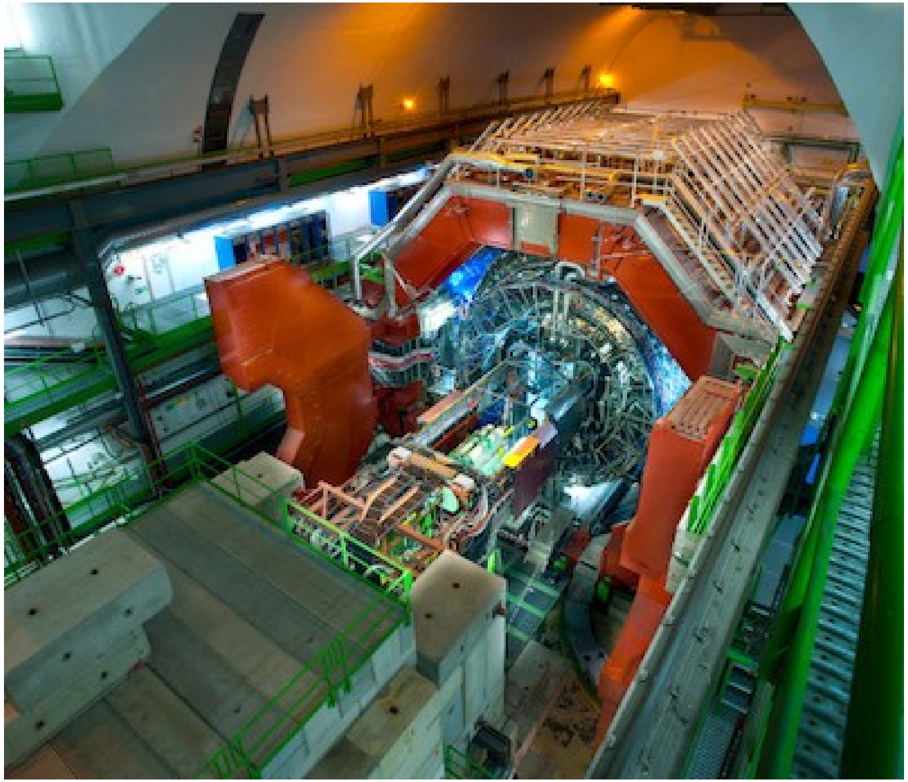
Instituto de Física UNAM

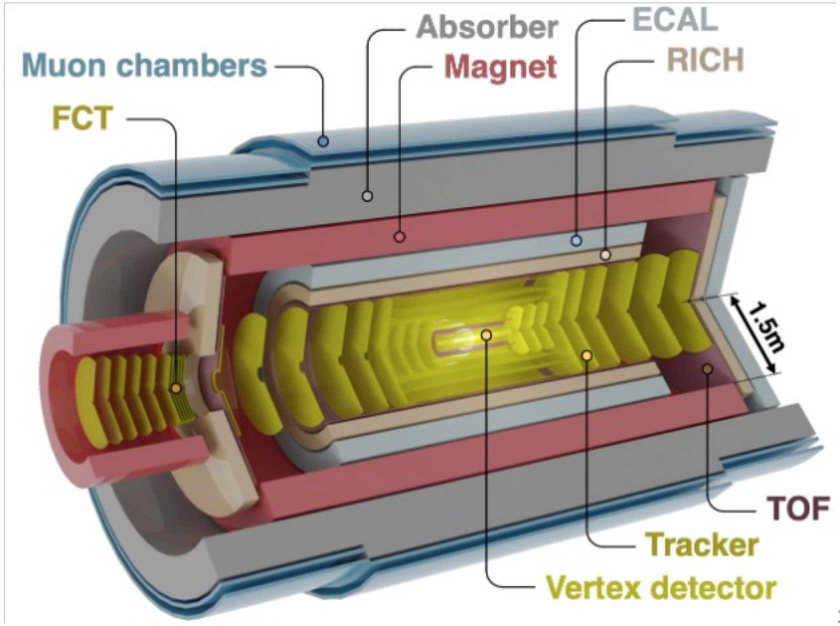




- ALICE
  The heavy ion collision experiment at CERN

See, Antonio Ortiz plenary talk: 4 nov 2024

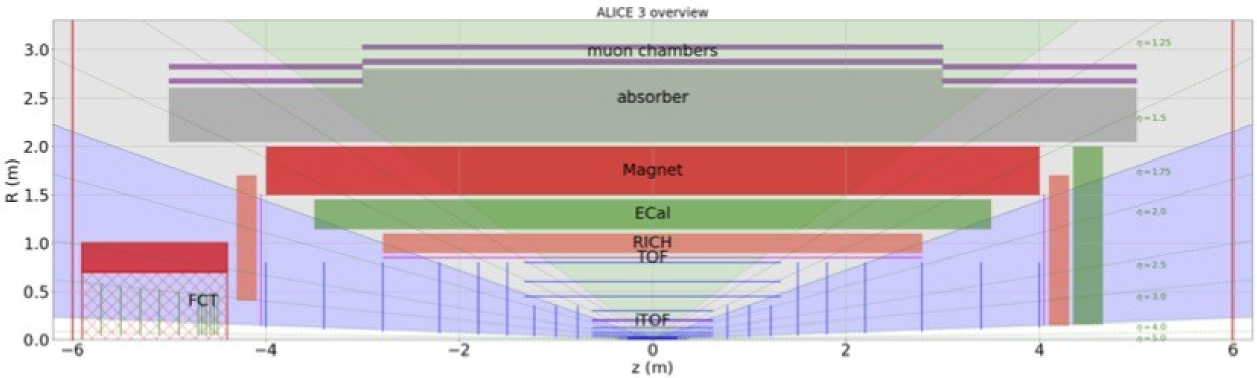
ALICE 3 overview



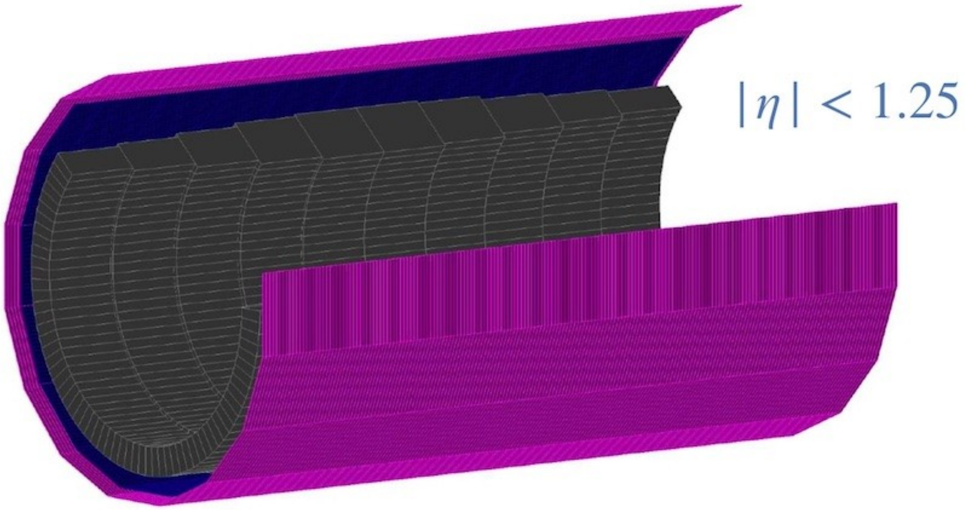
- Physics goal:
  Understand mechanisms affecting heavy-ion collisions: from early-stage medium formation to heavy-flavour diffusion, thermalization and hadronization in QGP

See, Jesus Muñoz talk: 4 nov 2024

- From 2035 onwards (runs 5 and 6)

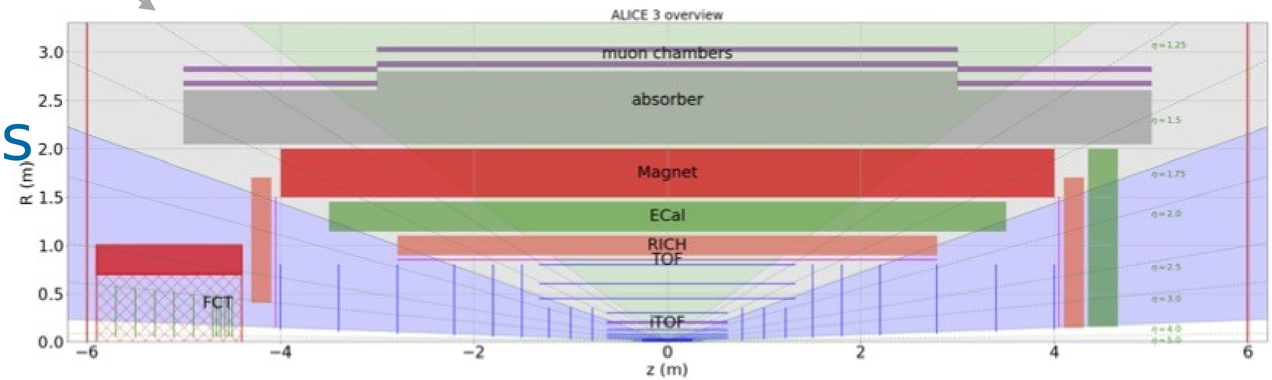


MID overview



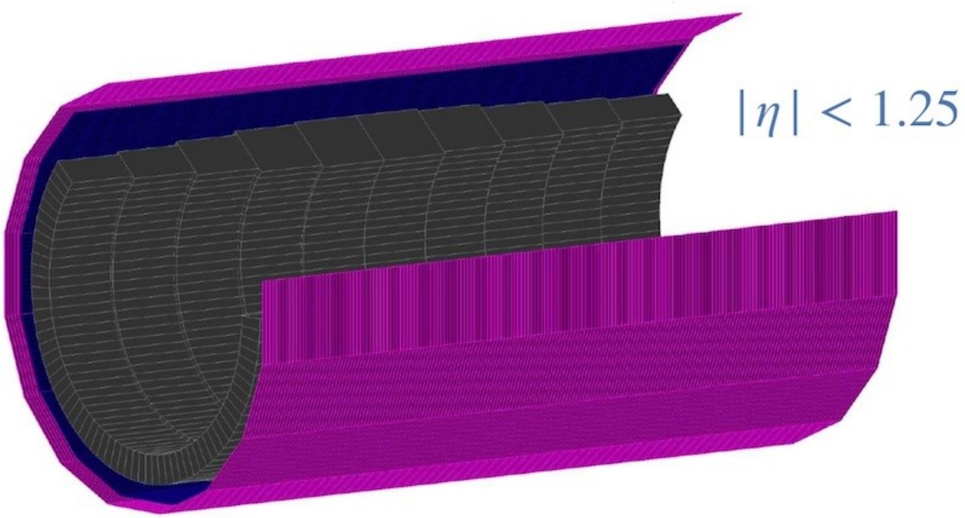
- Muon tagging: matching MID tracklets with tracks (tracker)
- Reconstruct J/ψ down to $p_T = 0$ ($|y| < 1.24$) in the dimuon decay channel
  - Muons down to $p \approx 1.5$ GeV/c at $\eta \approx 0$

$\eta = 1.25$



- ALICE has unique capabilities in LHC Runs 5 and 6 (ATLAS and CMS: J/ψ >6.5 GeV/c)

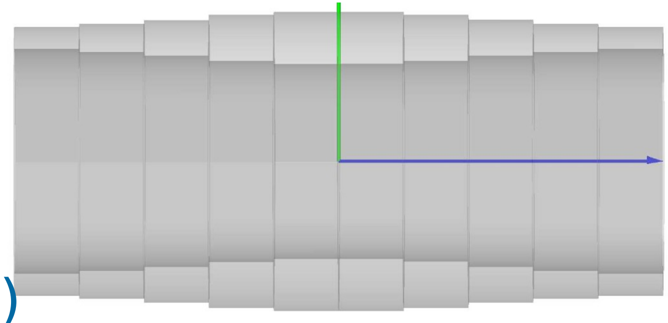
MID participating institutions



- Benemérita Universidad Autónoma de Puebla
- Universidad Autónoma de Sinaloa
- Universidad Nacional Autónoma de México
- Centro de Investigación y de Estudios Avanzados
- Czech Technical University in Prague
- Chicago State University
- HUN-REN Wigner Research Centre for Physics

Baseline option of MID

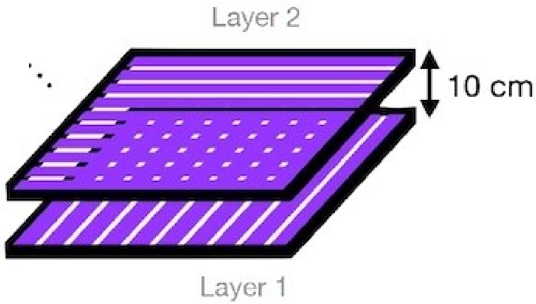
- Absorber (iron, variable thickness, 70 cm thick η=0):
  - ~10^{-2} hadron rejection factor
  - (Low) charged particle fluence: ≈ 4 Hz/cm^2
  - Scattering: ≈4-5 cm for p=1.5 GeV/c (granularity 5x5 cm^2 enough for 1.5-5 GeV/c)



Baseline option of MID

- Absorber (iron, variable thickness, 70 cm thick $\eta=0$):
  - $\sim 10^{-2}$ hadron rejection factor
  - (Low) charged particle fluence: $\approx$ 4 Hz/cm^2
  - Scattering: $\approx$4-5 cm for p=1.5 GeV/c (granularity 5x5 cm^2 enough for 1.5-5 GeV/c)

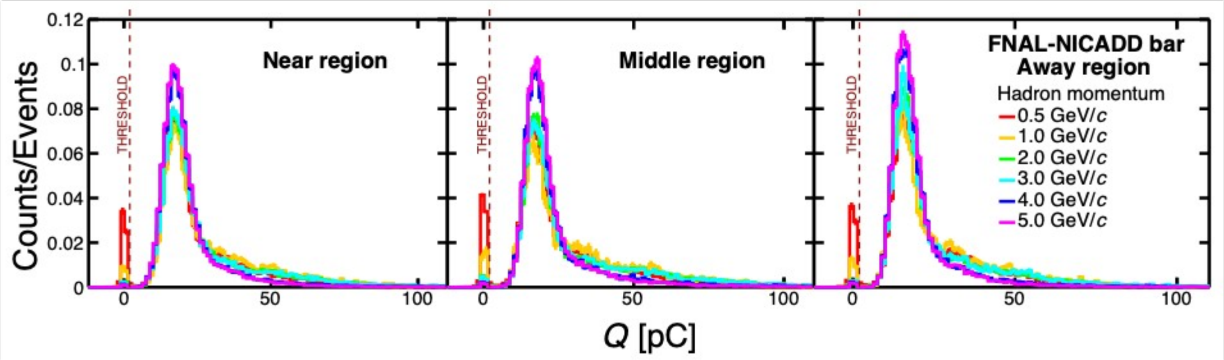
- Plastic scintillator bars with WLSF and SiPM:
  - Low cost
  - Time resolution in order of ns
  - Good performance under the expected radiation environment
  - No gas mixture, no high voltage needed



Prototype design

Prototype

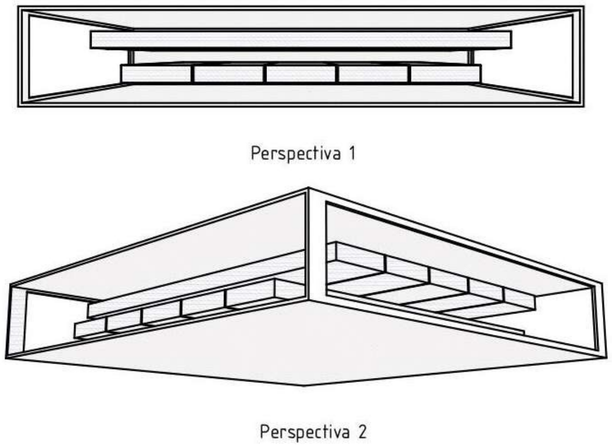
- Fermi bars selected
  (based on Test beam 2023 results)

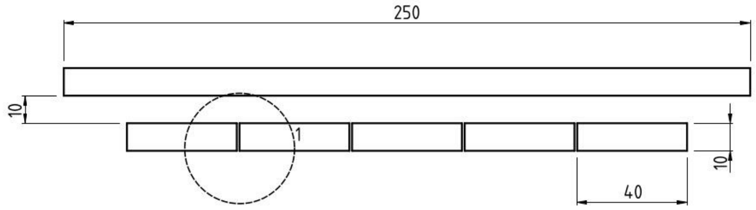


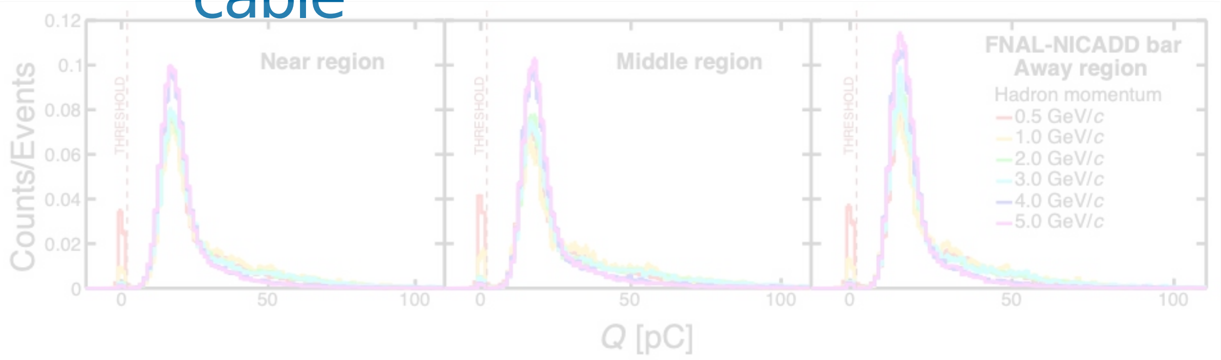
Journal of Instrumentation, Volume 19, April 2024, DOI 10.1088/1748-0221/19/04/T04006

Prototype

- Fermi bars selected
(based on Test beam 2023 results)
- Small chamber 20x20 cm² (10 bars)
  - Two layers configuration (10cm separation)
  - Signal and power through same cable





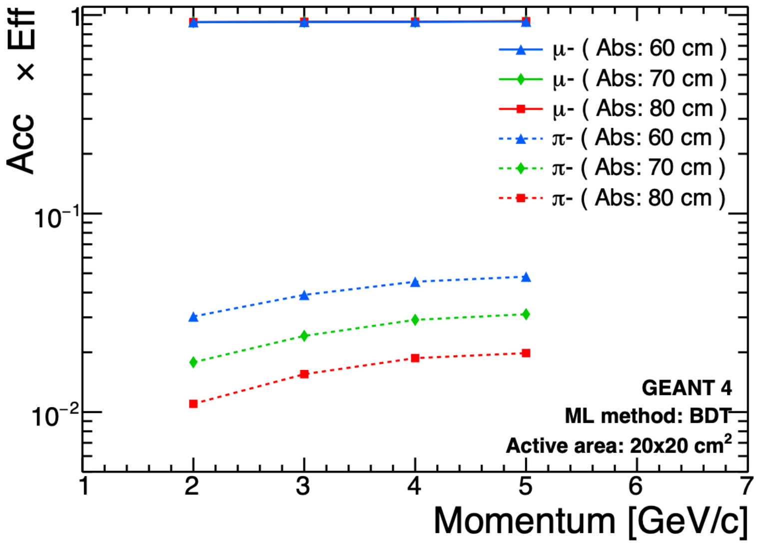


Journal of Instrumentation, Volume 19, April 2024, DOI 10.1088/1748-0221/19/04/T04006

Prototype

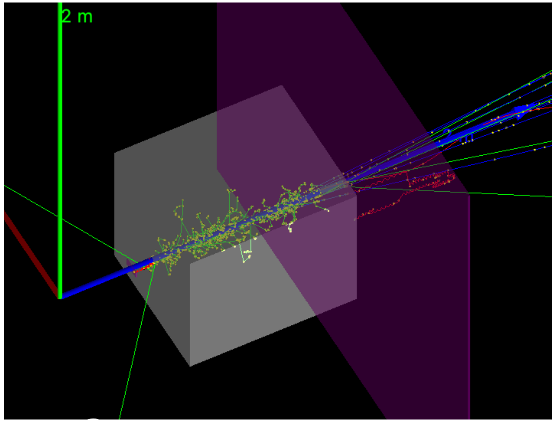
- Fermi bars selected (based on Test beam 2023 results)
- Small chamber 20x20 cm² (10 bars)
  - Configuration keeps 3% hadron rejection factor

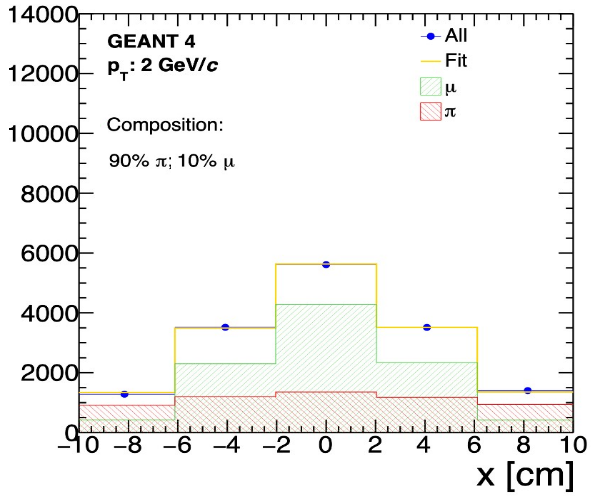
Journal of Instrumentation, Volume 19, April 2024, DOI 10.1088/1748-0221/19/04/T04006

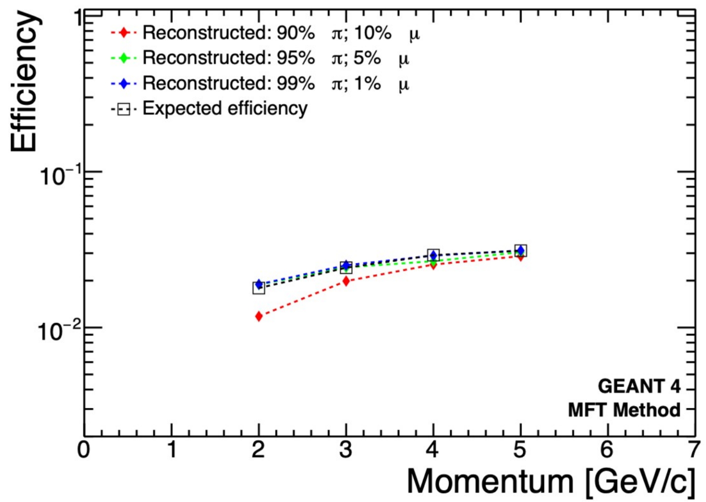


Absorber thickness can be increased up to 80 cm (different absorber thicknesses to be tested)

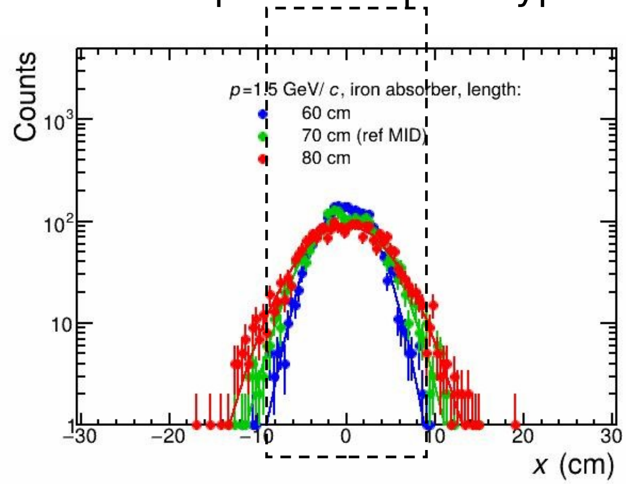
Simulations: reconstruction possible







Acceptance of prototype



prototype of 20x20 cm detects ⩾95% of particles for 60cm & 70cm

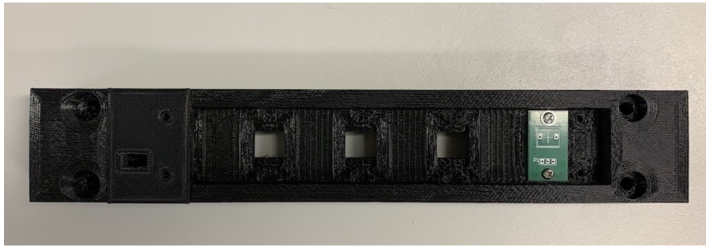
- Determine fractions of μ, π using a multi-template fit that matches the position distribution (samples with different compositions of muons and pions were tested)
- Reconstructed efficiency consistent with expectation (<25% for >1GeV/c)

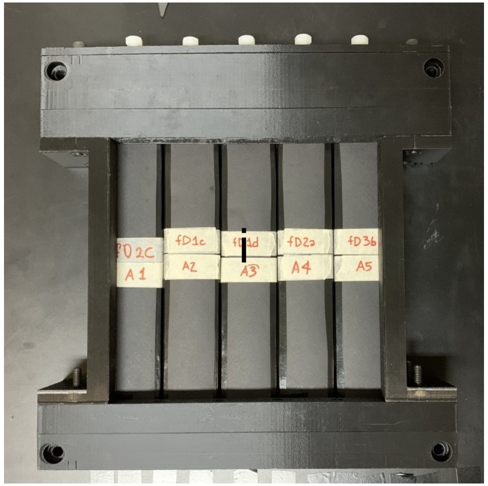
MC studies done by Paola Vargas and Antonio Ortiz

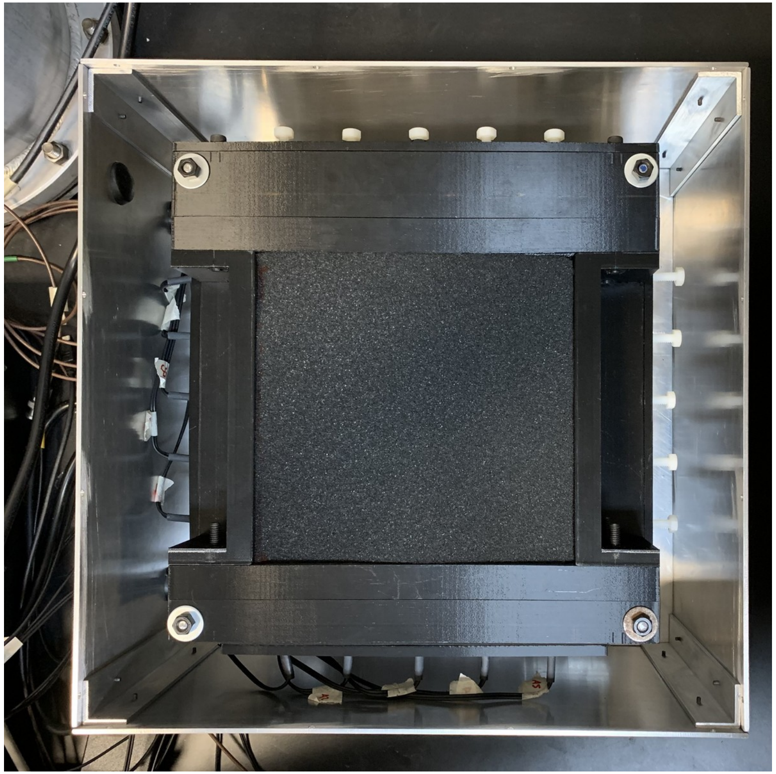
Prototype construction and first results using atmospheric muons

Chamber assembling

- Fiber-scintillator optical connection using optical grease
- 3D printed mechanics
- SiPM's PCB is exchangeable



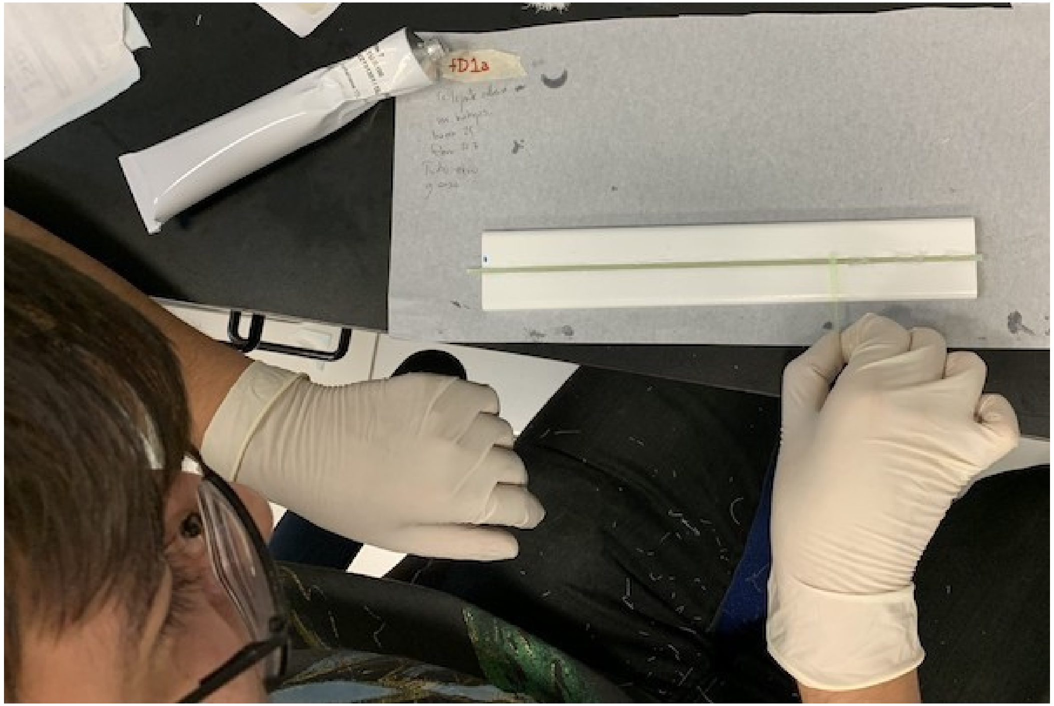




Mechanical design by Enrique Patiño, 2024aug

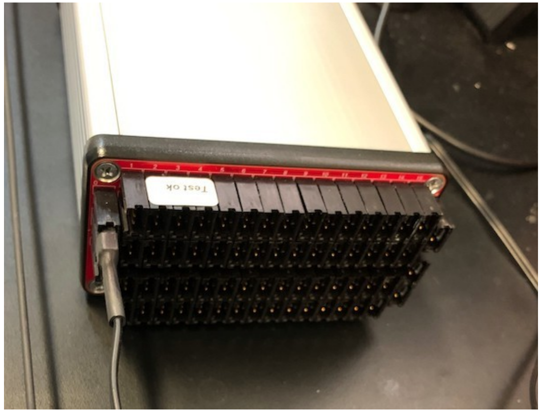
Setup and materials

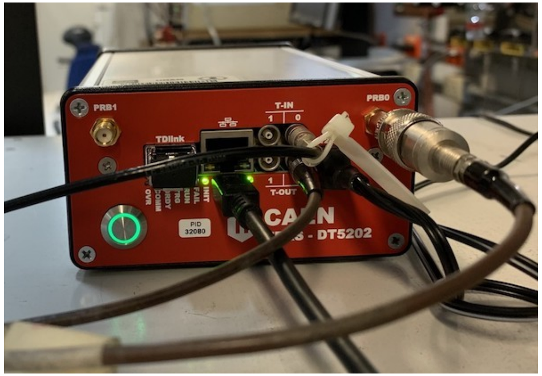
- Fermilab bars
- Fiber 1.5mm Kurarai
- Optical grease (bluesil Paste 7)
- SiPM Hamamatsu
  SiPM-13360-6050CS
  SiPM-13360-3050CS



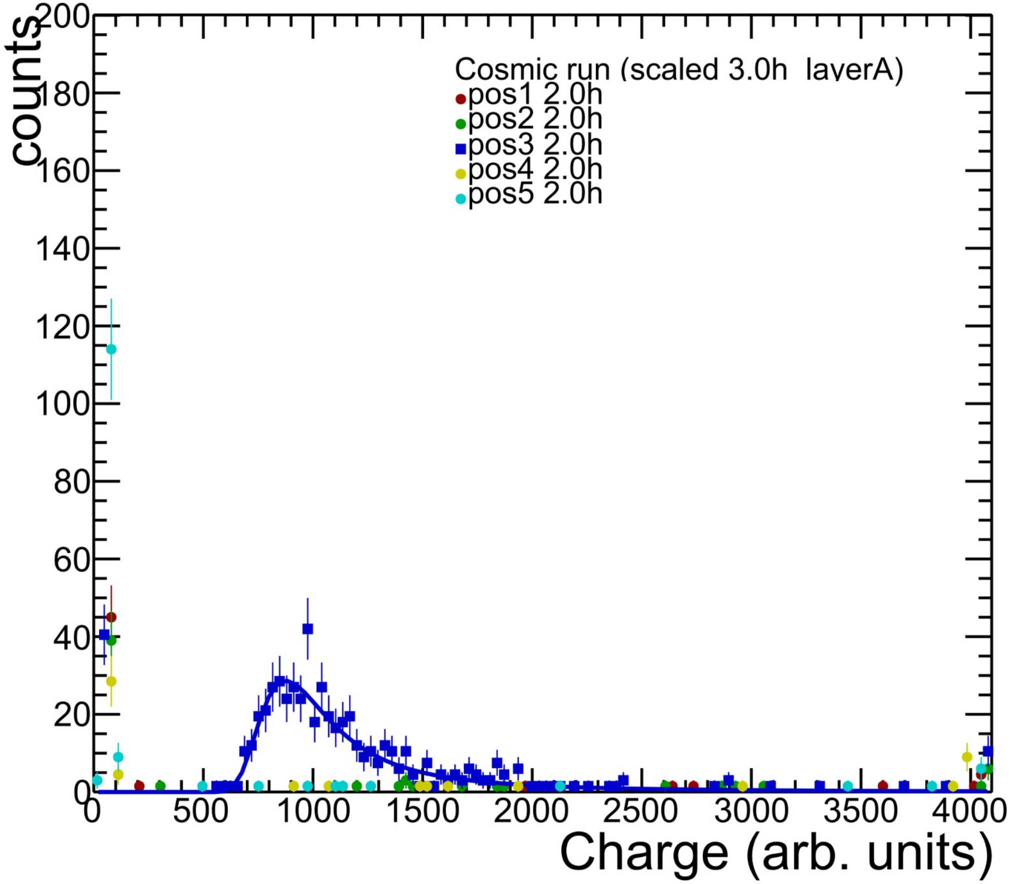
Readout DT5202

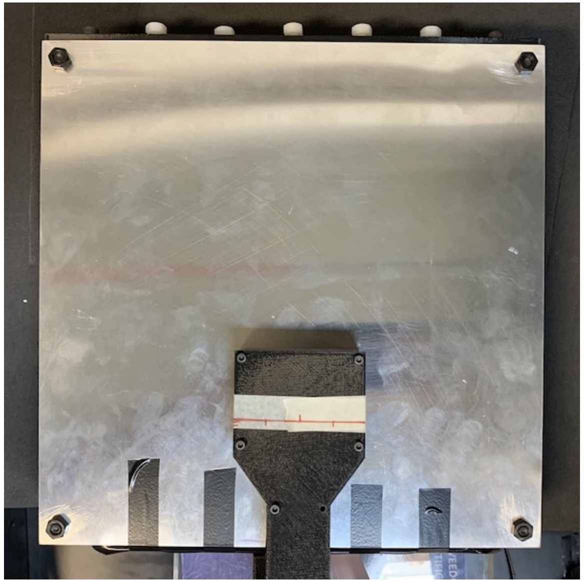
- 64 ports
- Voltage can be independently supplied to each ports
- Citiroc chip: for high radiation environments
- Connection through usb or ethernet

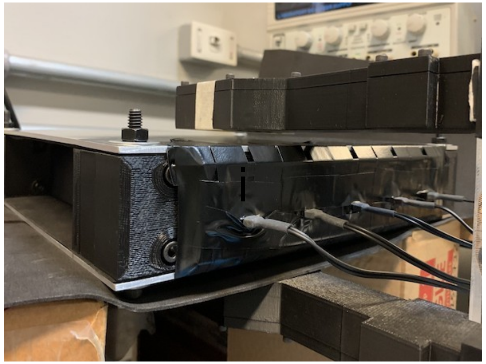




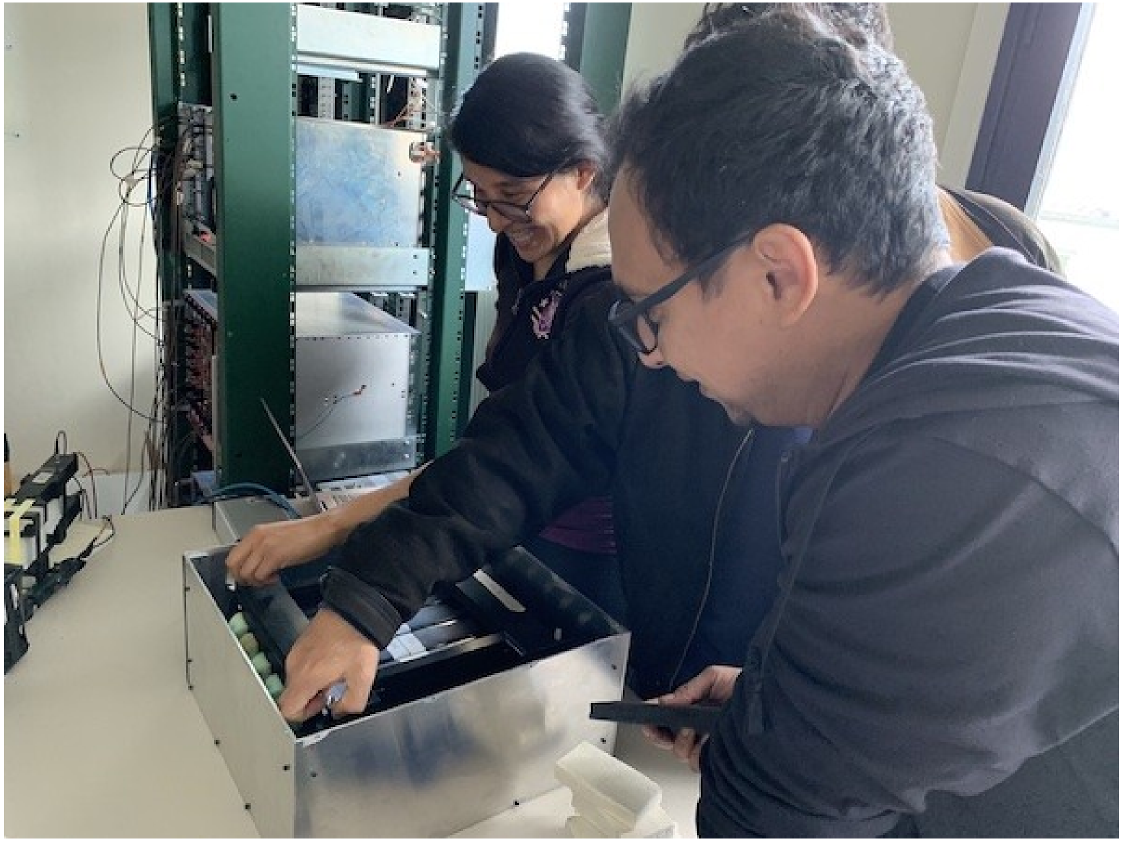
Layer by layer testing

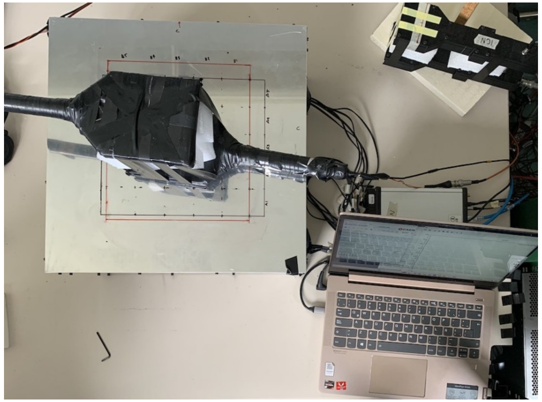




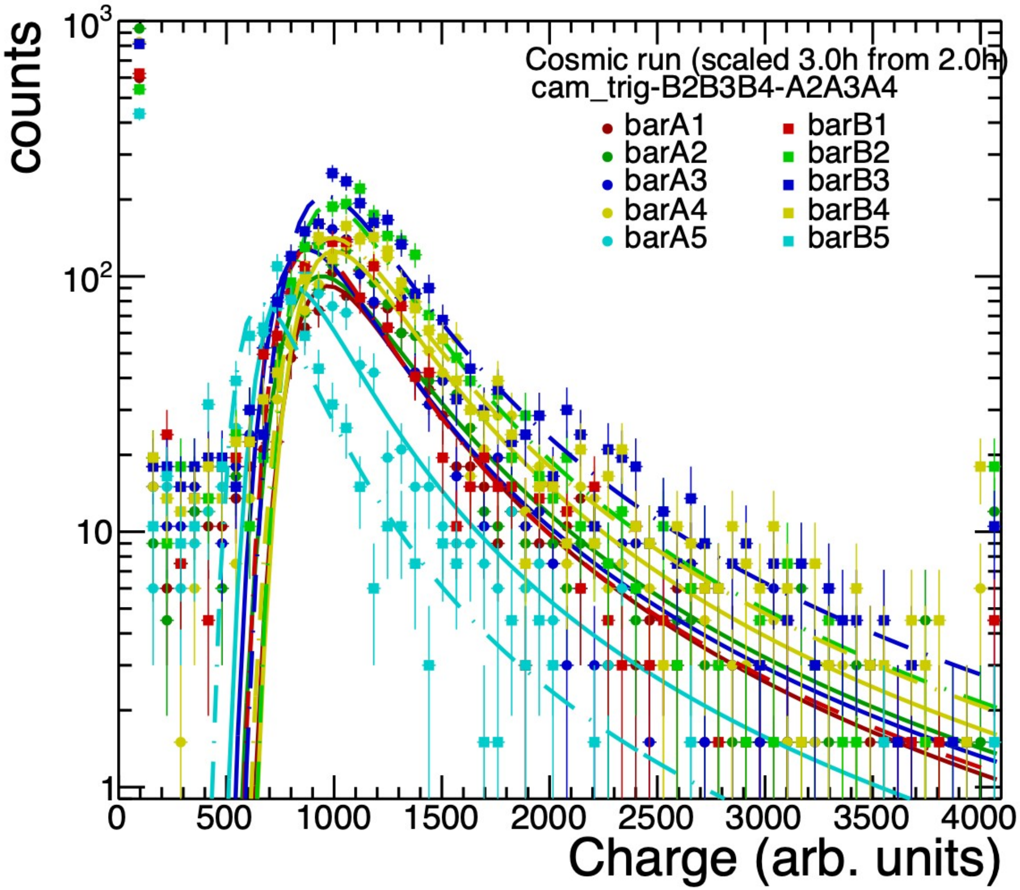


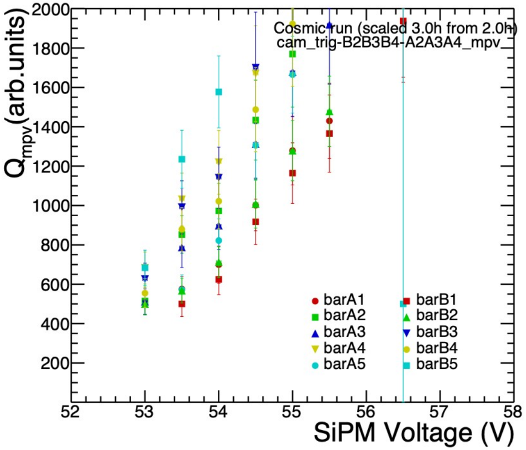
Reassembly at CERN

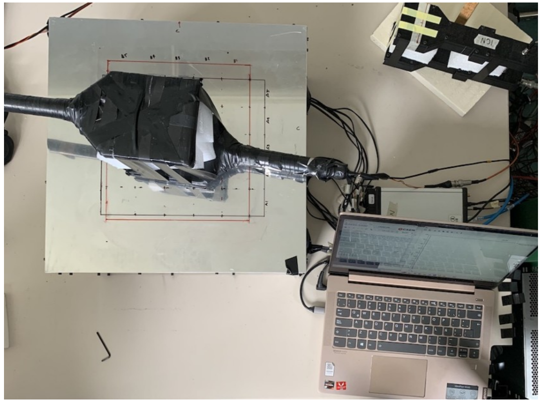




Scintillator-SiPM calibration (CR)

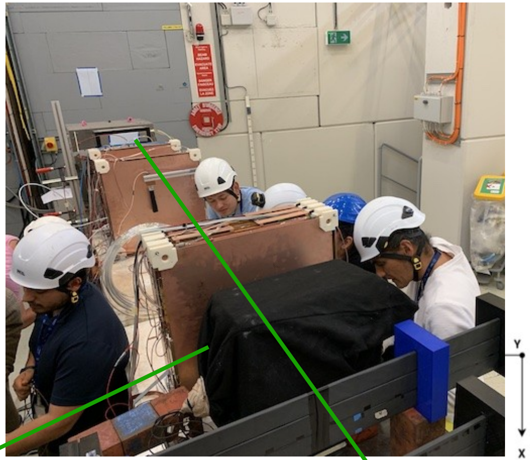


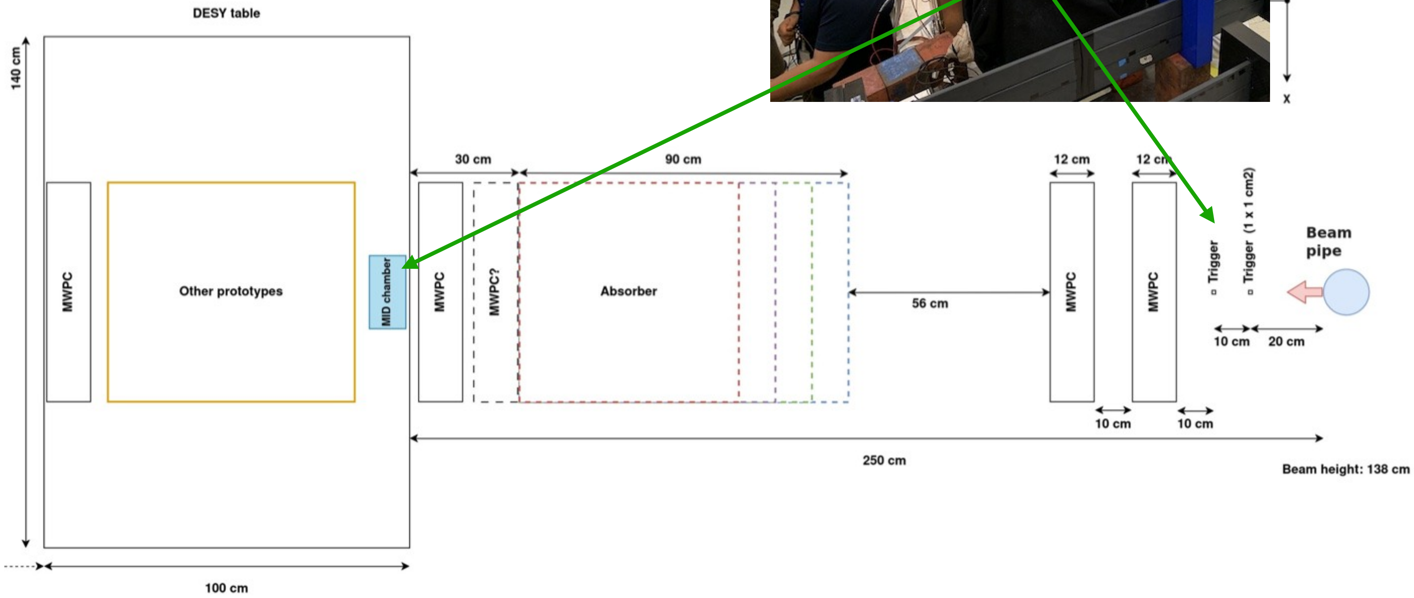




Test beam 2024
(October 9-16)
Muon- and pion-enriched beam performance plots

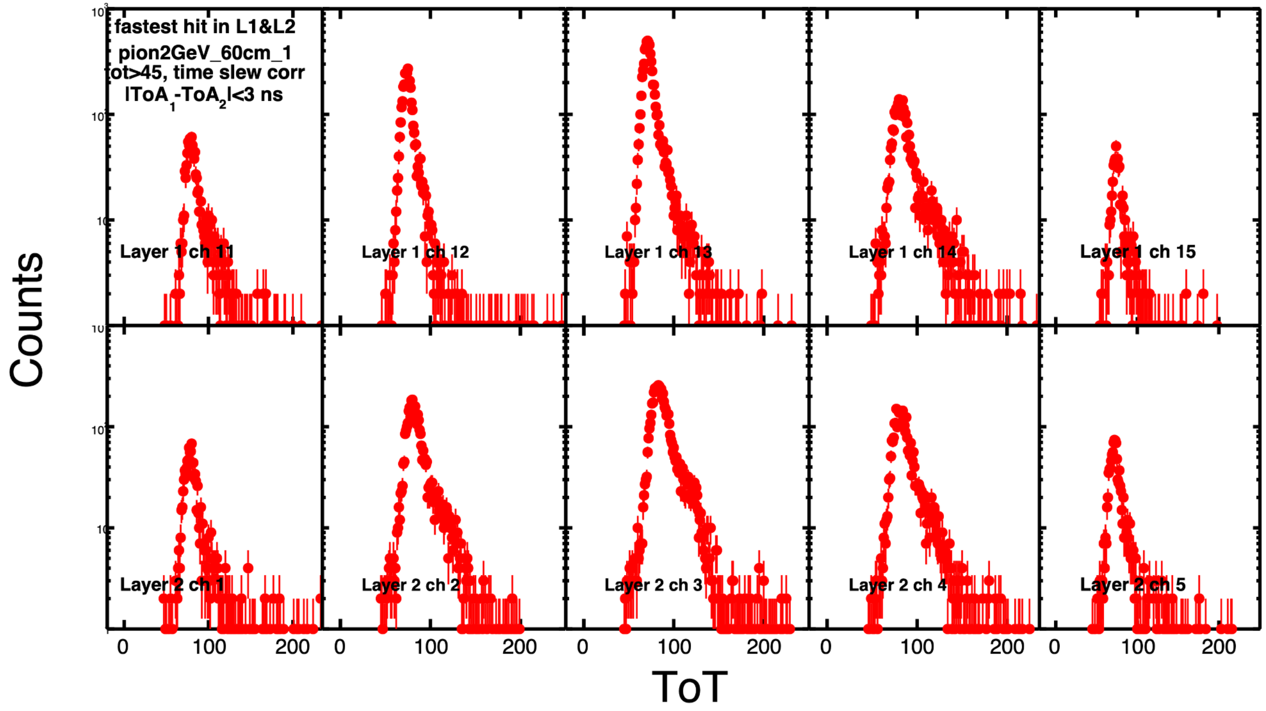
Setup





DESY table
140 cm
100 cm
MWPC
Other prototypes
MID chamber
MWPC
MWPC?
Absorber
30 cm
90 cm
56 cm
12 cm
12 cm
MWPC
MWPC
Trigger
Trigger (1 x 1 cm2)
Beam
pipe
10 cm
20 cm
10 cm
10 cm
250 cm
Beam height: 138 cm
Y
X

Charge on bars

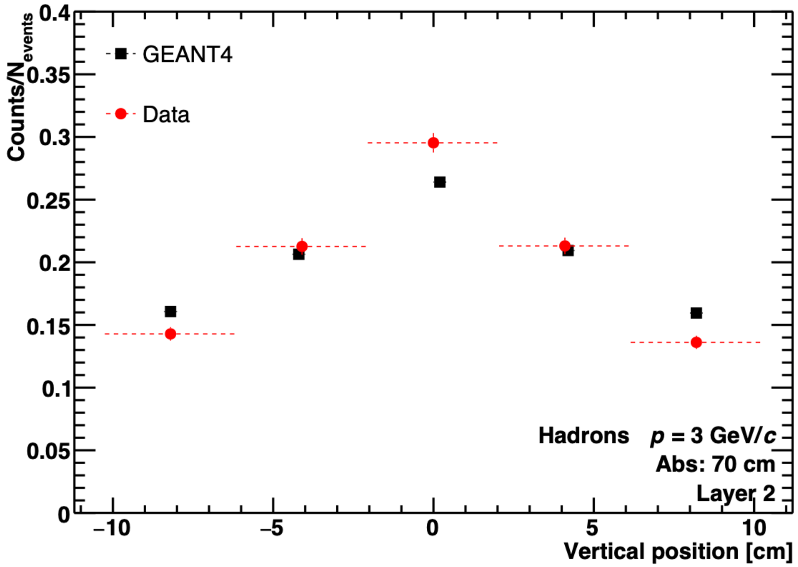


(each channel calibration ongoing)

Observed behavior

- Pion and muon-enriched beams were used (p =2, 3, 6 GeV/c)
- Expected behavior observed:
  - Muons: measurable scattering
  - Pions: strong suppression, increasing with absorber thickness
- Data analysis ongoing

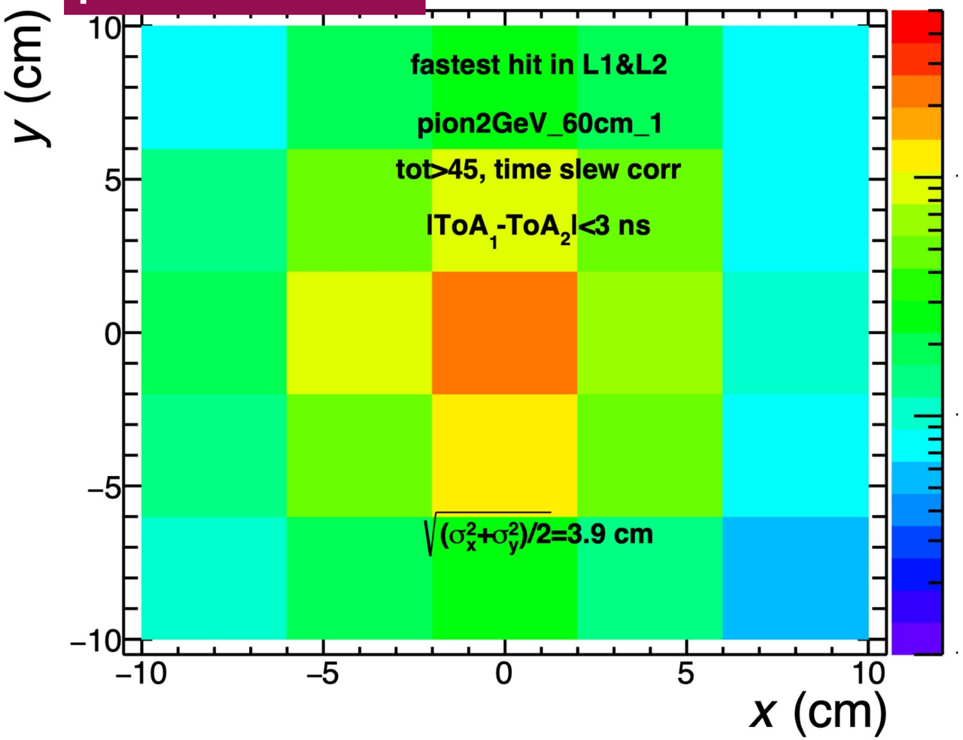
Detector performance



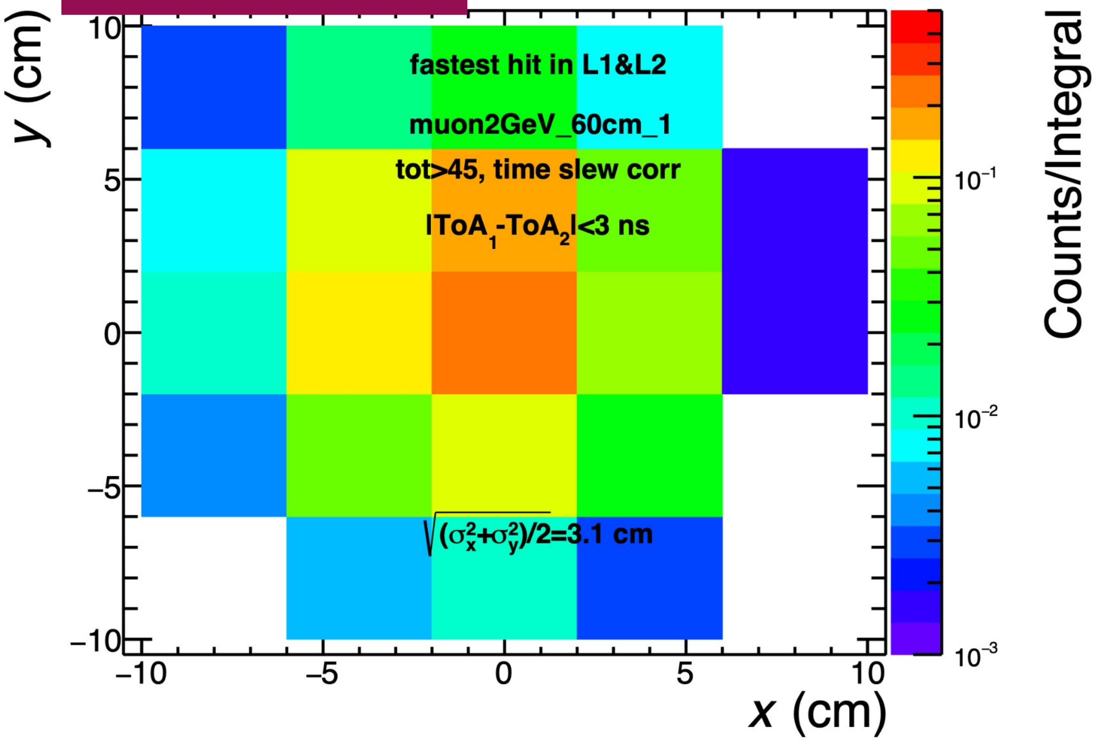
Position distribution of hits in the second layer of the camber (pion enriched beam)

p=2 GeV/c, abs 60 cm

pion beam



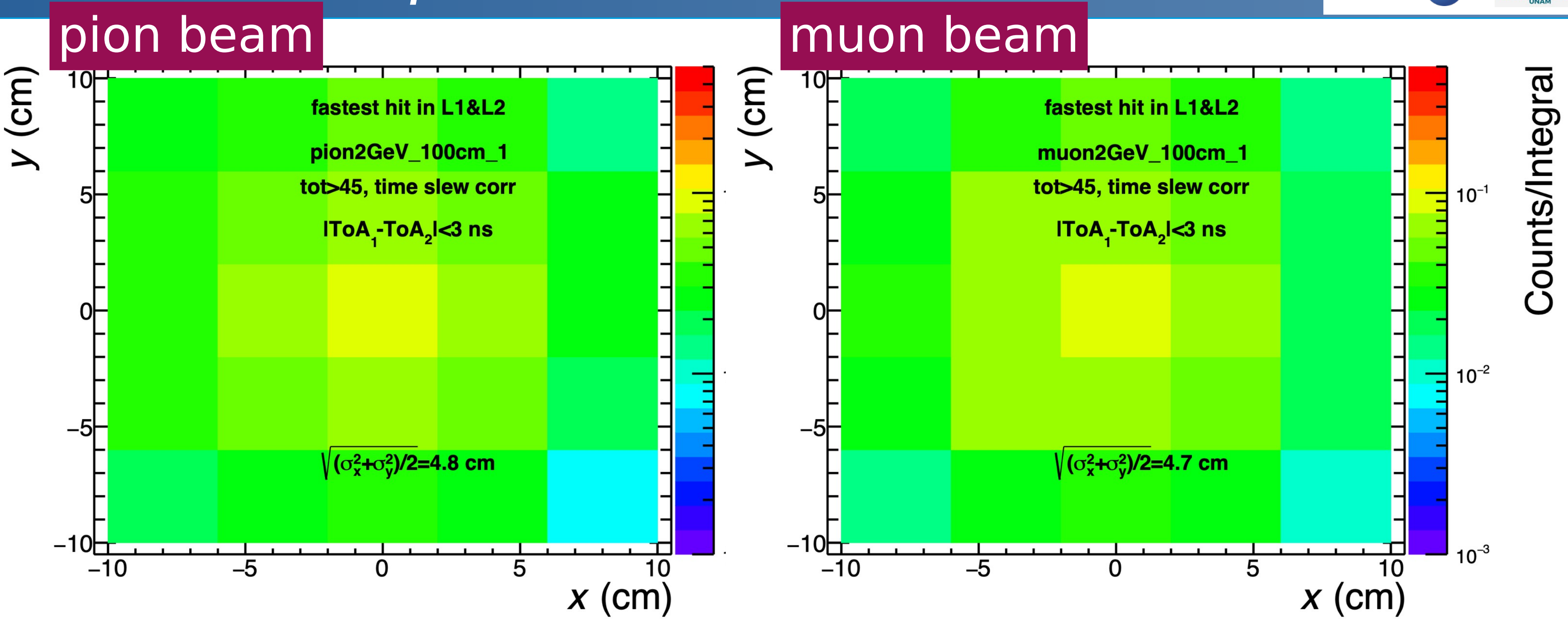
muon beam



Slightly wider spot probably because of secondary particles

From a scan we found that the chamber was not well aligned, the beam hits the detector at round x~0 cm, y~2 cm

p=2 GeV/c, abs 100 cm



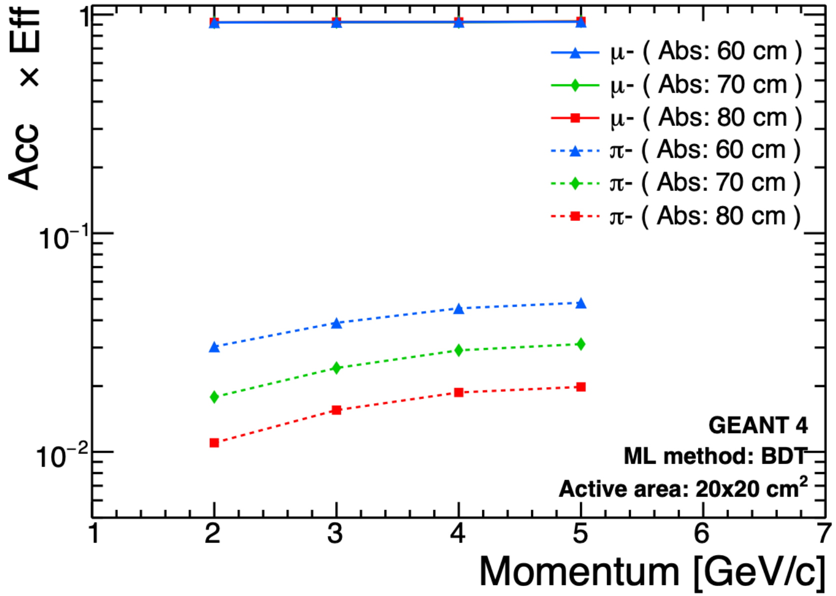
Wider spot (scattering)

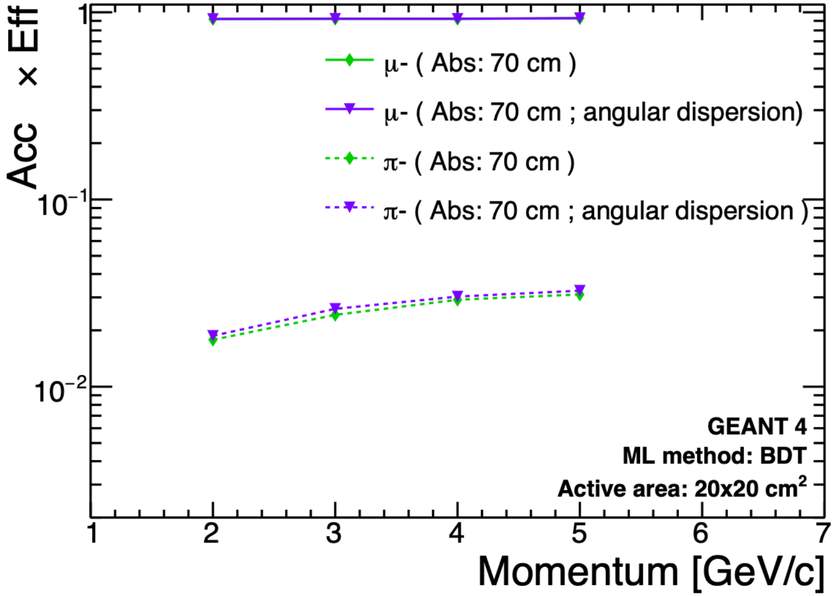
Summary

- Prototype of baseline MID built for Test Beam 2024
- Assembled and tested with atmospheric muons at CERN, to ensure SiPM-bars calibration
- Performed tests at CERN T10 using muon- and pion-enriched beams at p =2, 3, 6 GeV/c and with several absorber lengths (60-90cm)
- First results of data analysis show expected behavior for muons an pions

Backup

Expected hadron rejection (MC)



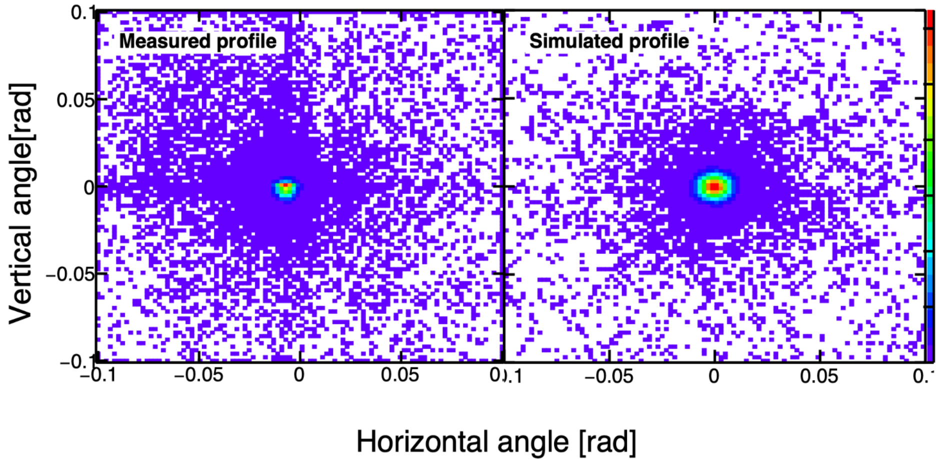


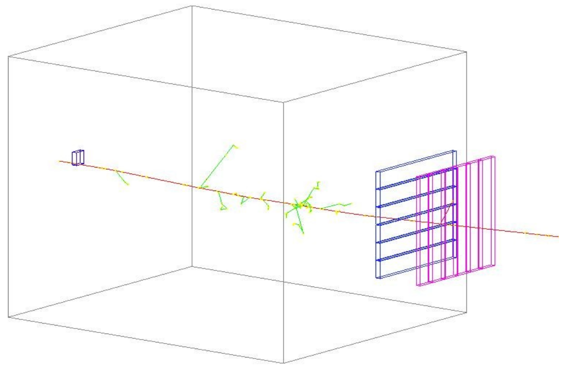
- Absorber thickness can be increased up to 80 (iron blocks will be used to test different absorber thicknesses)
- Finger triggers ensure minimal angular spread of the beam: expected effect is negligible

Construction process → previous work

- Some examples
  - Cleaning process
  - Fiber cutting and polishing
  - Fiber contact with SiPM
  - Cable contacts

Beam distribution





Distributions measured using MWPC

Physics performance - MC simulation

- Significance is above 10
  - 1000 for rejection factor 4%