ALICE 3 RICH R&D: 2024 beam test report

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5th ALICE Upgrade Week

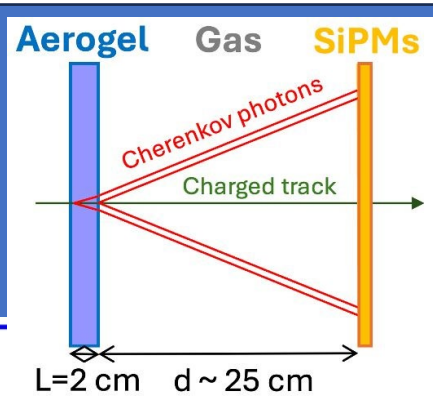
Kraków Oct 9, 2024

Outline

- ALICE 3 RICH layout recap
- 2024 beam test set-up
- Cherenkov angle resolution (preliminary results)
- Timing resolution (preliminary results)

ALICE 3 proximity-focusing RICH configuration

- SiPM sensors:
  - Pixel size of 2 mm
  - PDE > 40% at 400 nm
  - BOL DCR < 50 kHz/mm2 at RT
- Aerogel radiator tile
  - n=1.03
  - Thickness of 2 cm
  - Trasmission lenght > 6-7 cm at 400 nm
- Front-end SPTR < 100 ps
- R&D on going with on-the-shelf components
  - HPK SiPM S13361-2050/3050
    - A thin quartz window is also glued on the SiPM to produce local Cherenkov photons for charged particle timing
  - Areogel from Aerogel Factory & co.
  - Petiroc 2A and Radioroc 2 FE
  - picoTDC



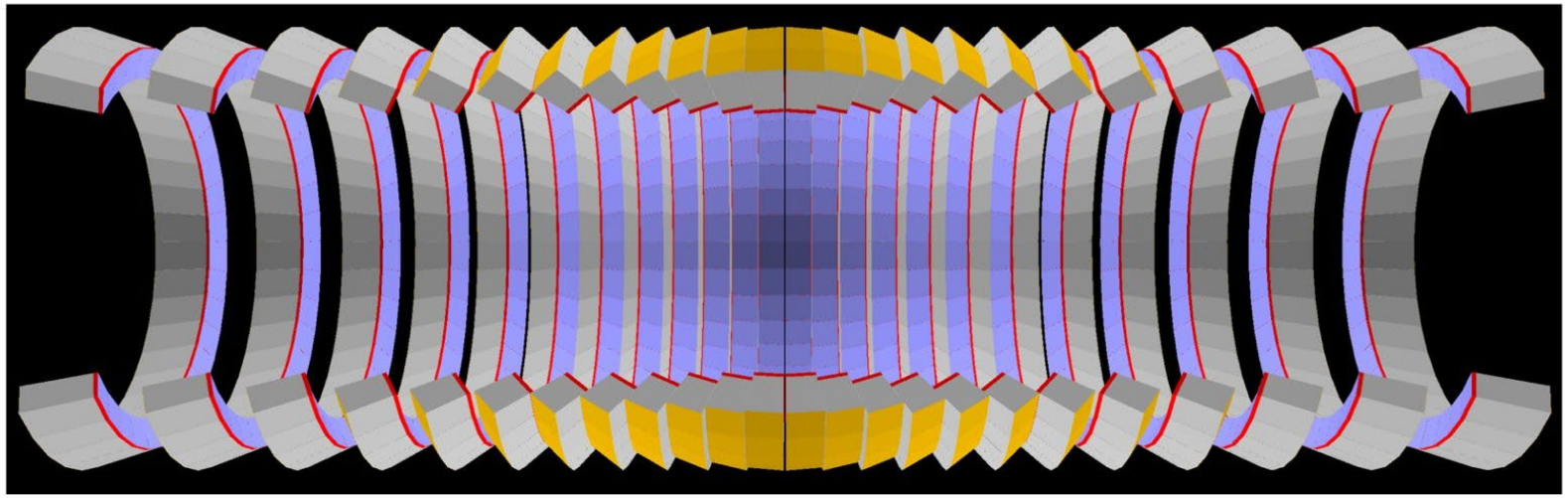
See Nicola Nicassio's talk on Oct 7, 2024

Geometry

- All tiles oriented toward nominal interaction point
- Full coverage to charged particles without overlaps
- Trapezoidal tile profile to maximize the acceptance

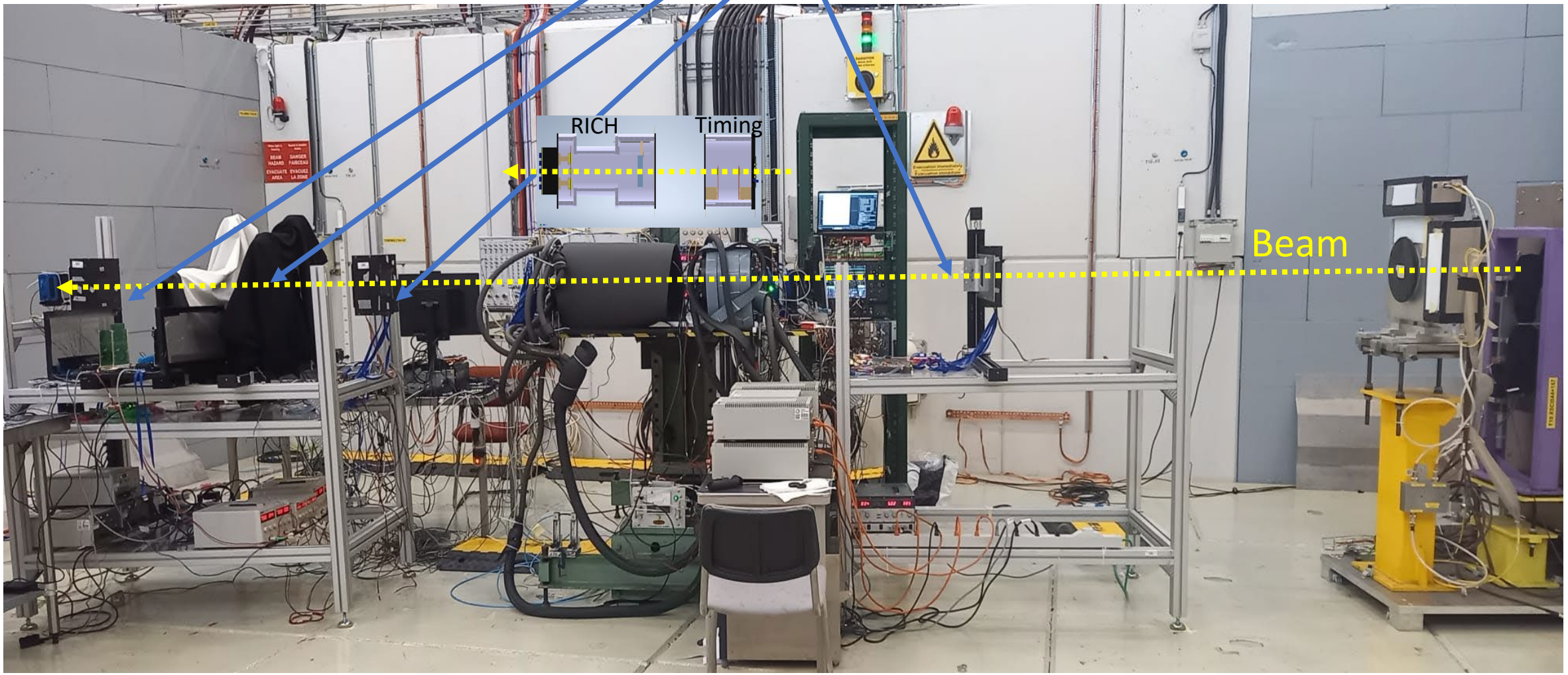
Segmentation

- 24 sectors x 36 modules
- Sensor area ≈ 30.7 m^2
- Total N channels ≈ 7M

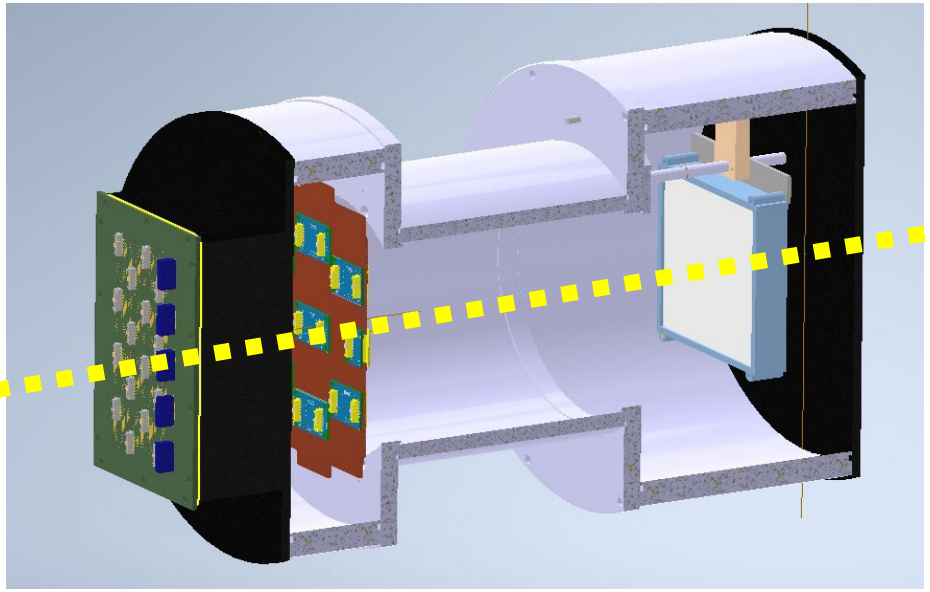


2024 beam test set-up@T10 (Sep, 25 – Oct, 9)

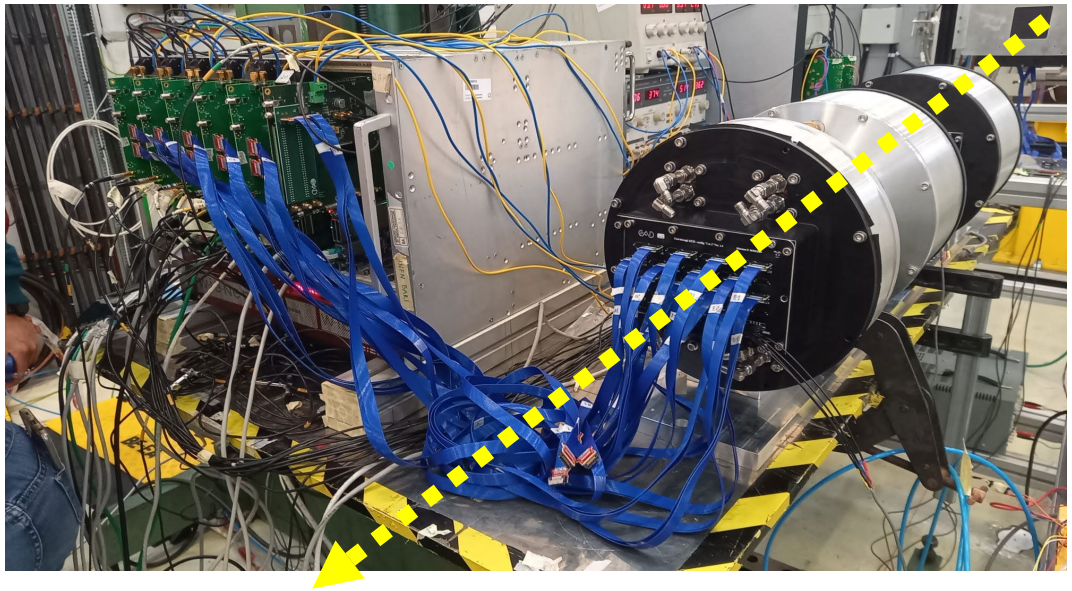
X-Y fiber tracker module: beam trigger and particle tracking

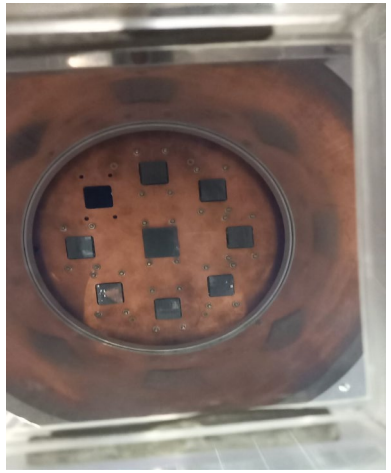


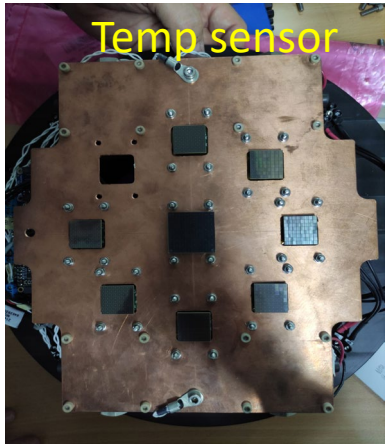
RICH set-up

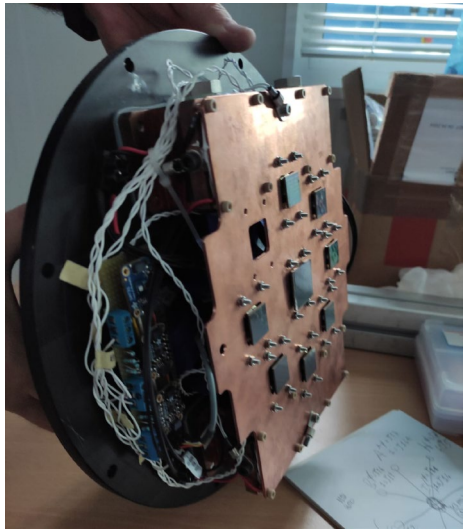


- SiPM RICH camera with a feedthrough board (SiPM signals, Peltier bias and environmental sensor signals)
  - Flushed with Argon or CO2
- Central marix: HPK SiPM S13361-3050AE-08 with 3 mm pitch and 1 mm thick quartz window
- Ring array: HPK SiPM S13361-2050AE-08 matrices
- Aerogel radiator:
  - Single tile 2 cm thick with n=1.03 (single layer)
  - Focusing aerogel tile with 1 cm n=1.030 (upstream) + 1 cm n=1.033 (downstream) (two layers aerogel)



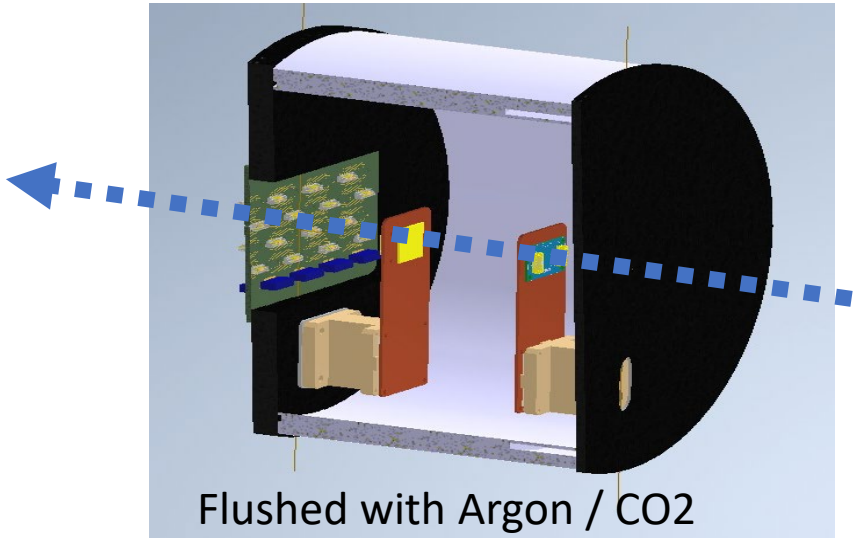


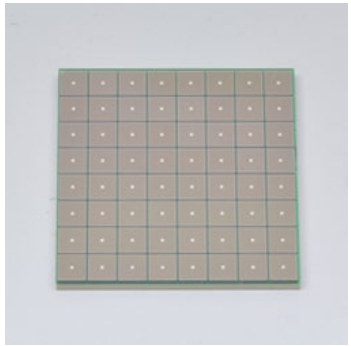


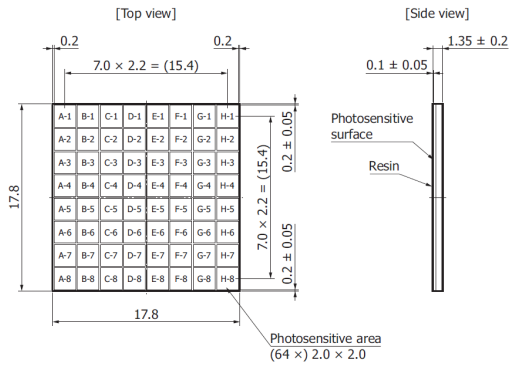


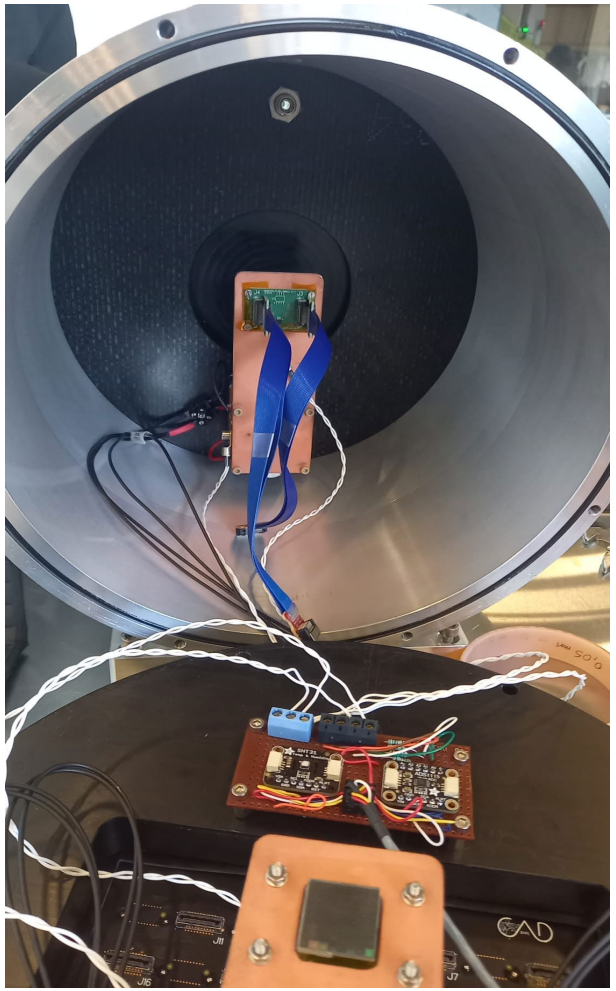
Timing set-up

- Two Hamamatsu SiPM S13361-2050AE-08 matrices with 2 mm pitch and 2 mm thick quartz window to produce local Cherenkov photons



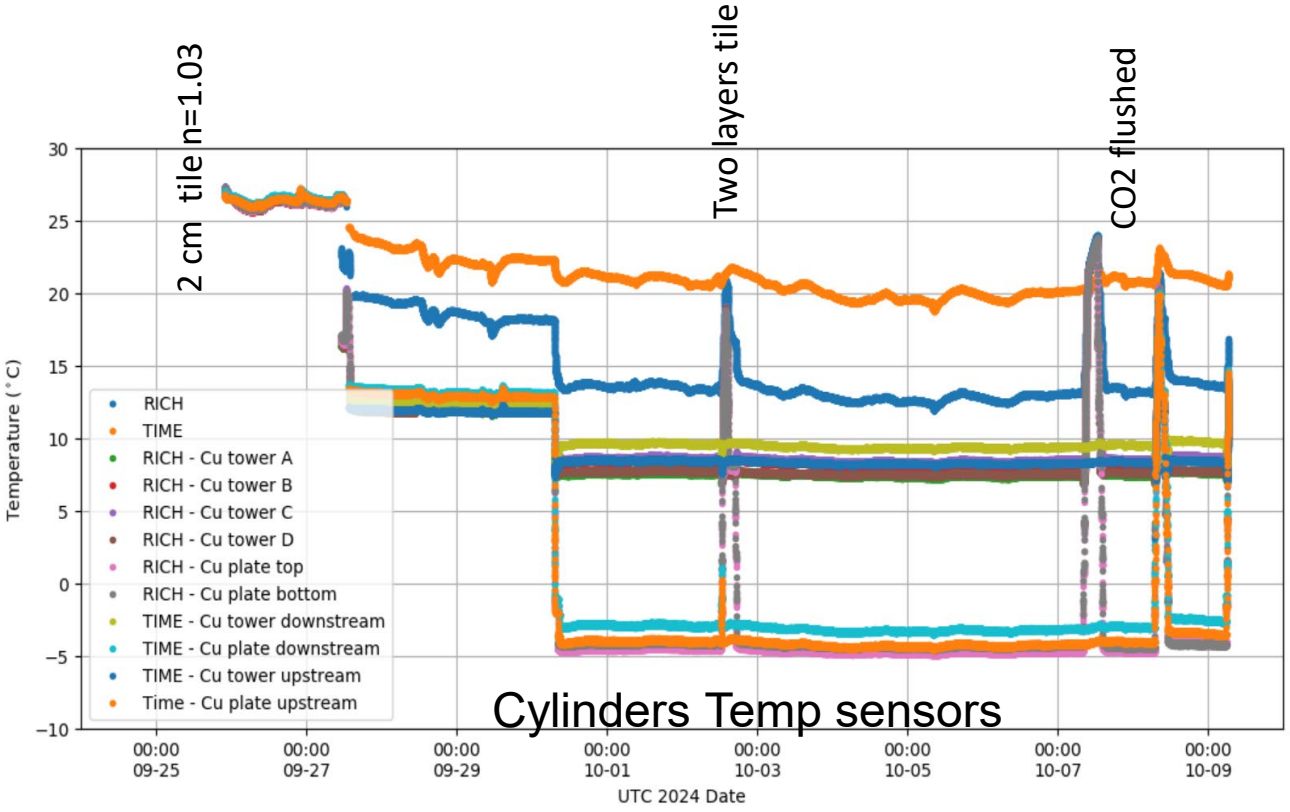


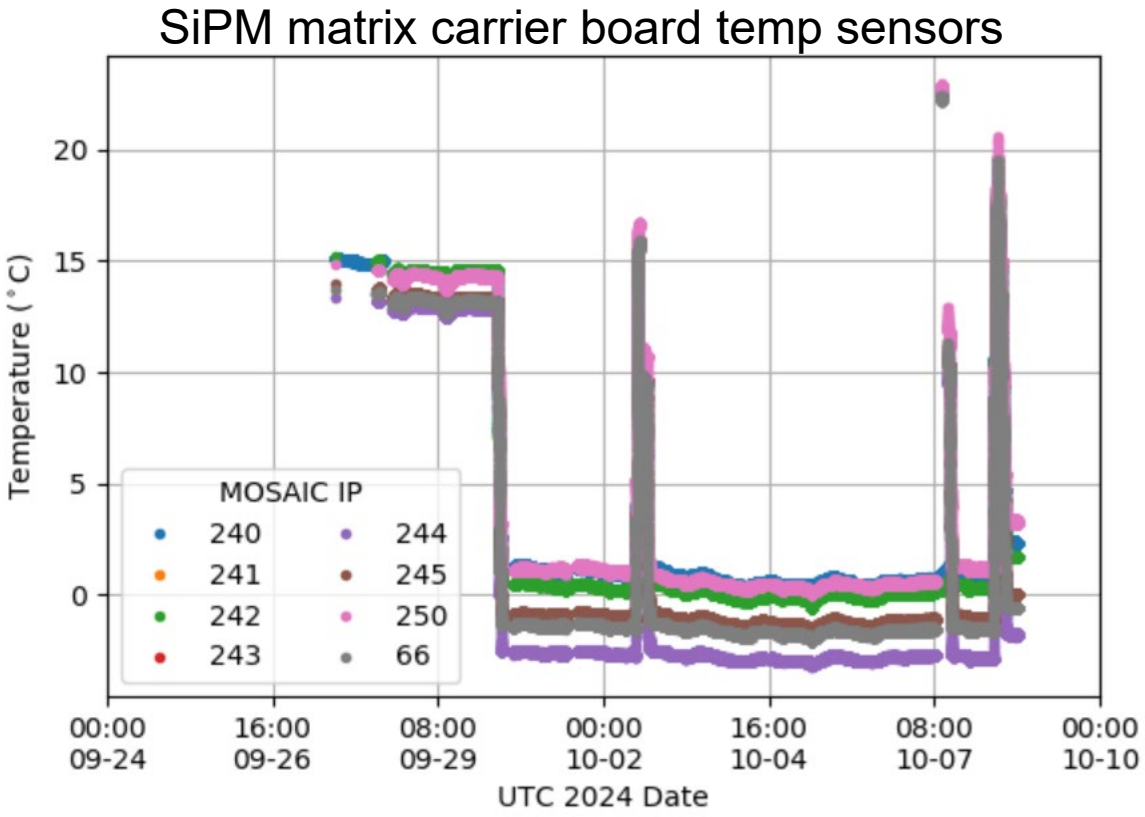




Run summary

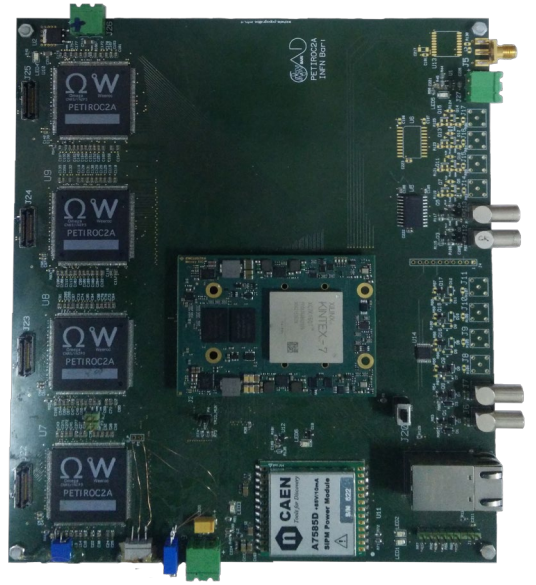
- Negative pions at 10 GeV/c
- Positive pions/protons at +8, +9 and +10 GeV/c

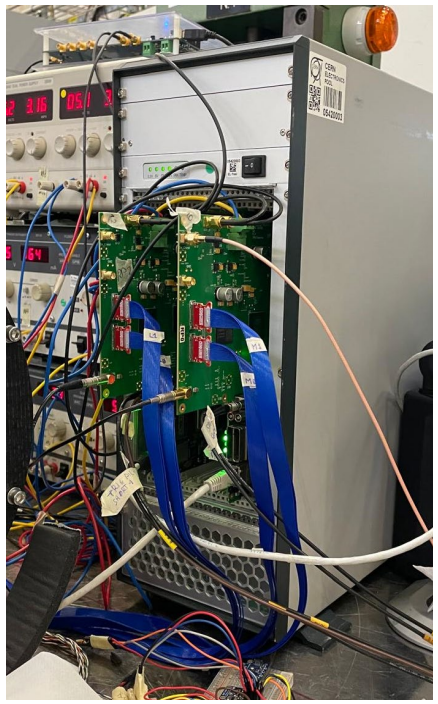


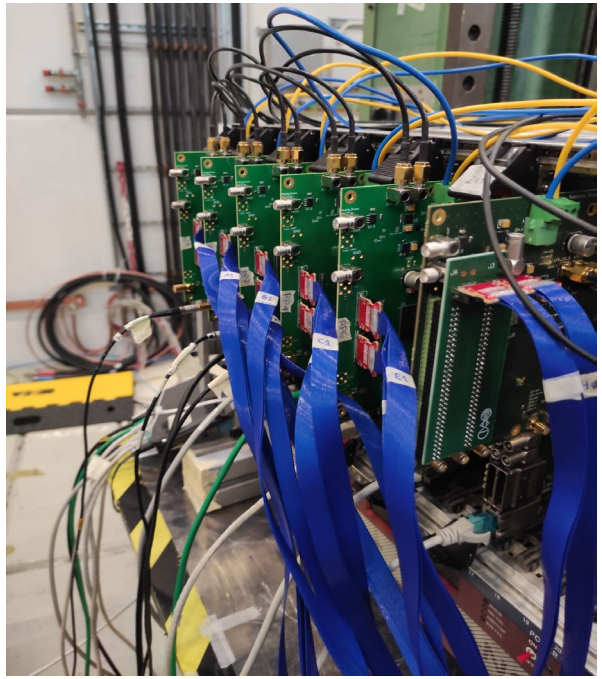


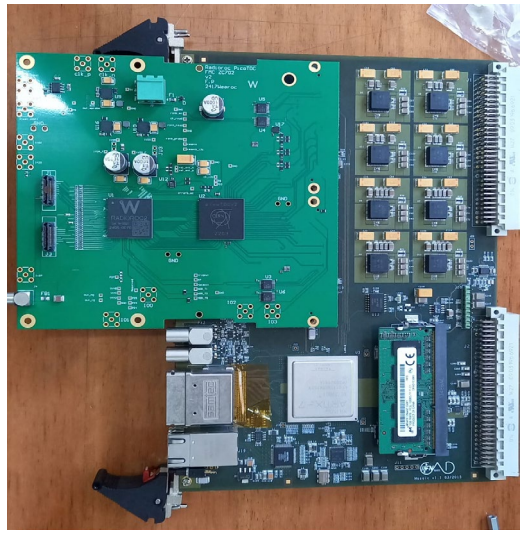
Front-end and DAQ boards

- Fiber tracker modules:
  - Custom boards based on the PETIROC2A FE ASICs with TDC (LSB ≈ 37 ps) and ADC and FPGA on board
    - As last beam test in 2023
- RICH and timing systems
  - Custom board based on the Radioroc 2 FE ASIC with picoTDC (LSB ≈ 3 ps) and read-out by MOSAIC boards
  - picoTDC in multihit configuration with ToA and ToT

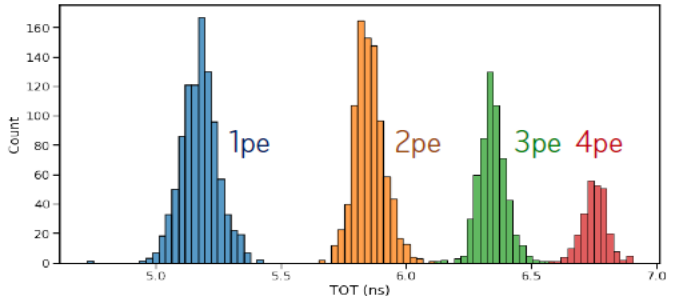


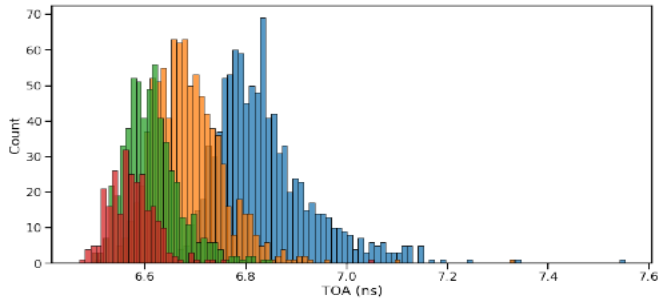




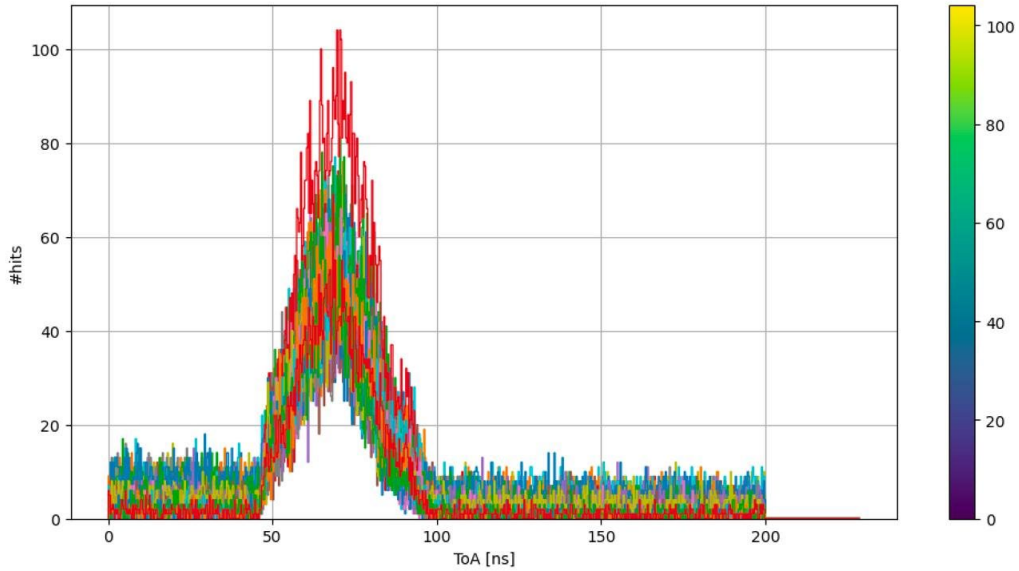


Radioroc 2 and picoTDC

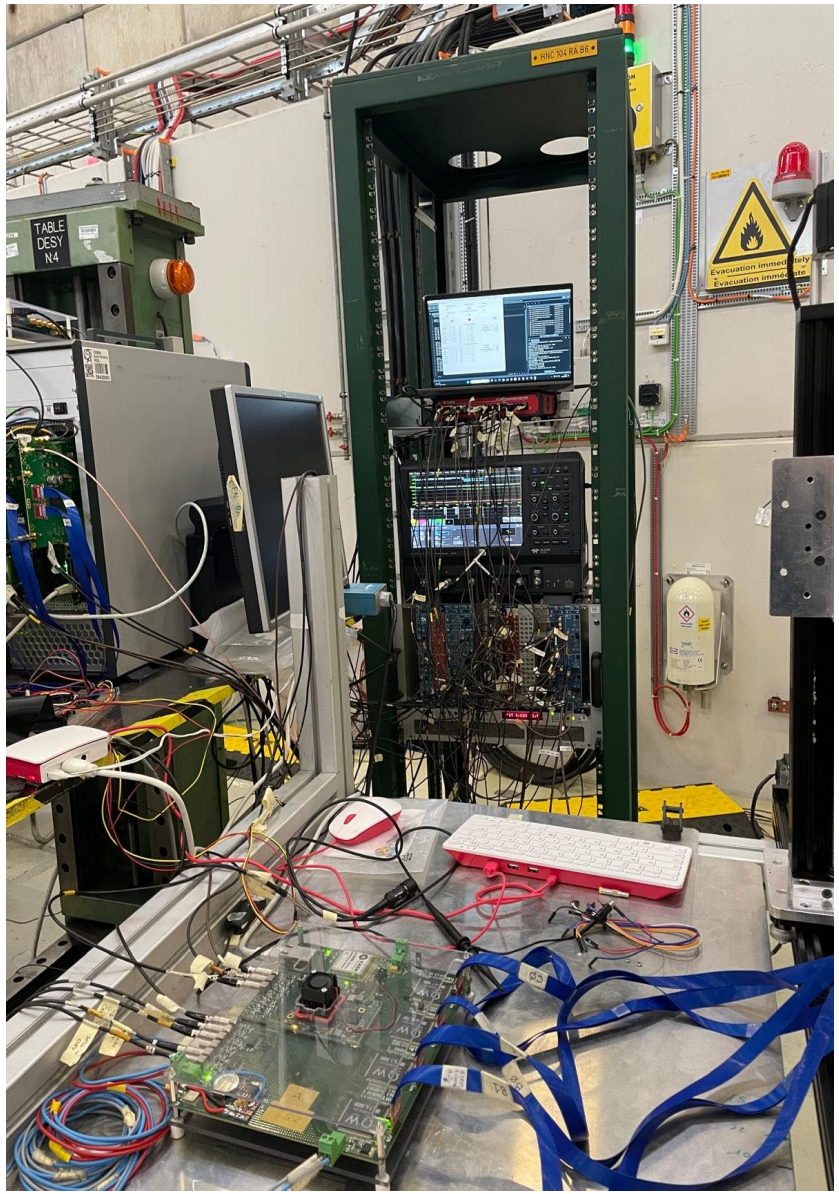




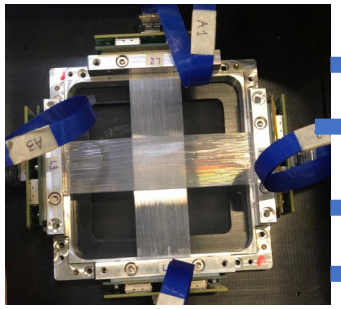
- Radioroc 2
  - ToT proportonial to the photo-electrons
  - Threshold at single P.E. level
- PicoTDC
  - ToA LSB ≈ 3.05 ps
  - ToT LSB ≈ 200 ps
  - Acquisition window of 200 ns



Trigger and DAQ system



Upstream fiber tracker module



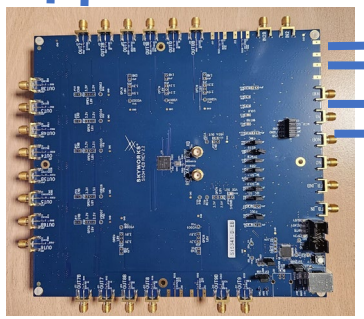
Beam
TRG

CAEN DT5495
Programmable
Logic Unit

TRG OUT
CLK
TAG

Max trigger rate 40 kHz

Single ended CLK

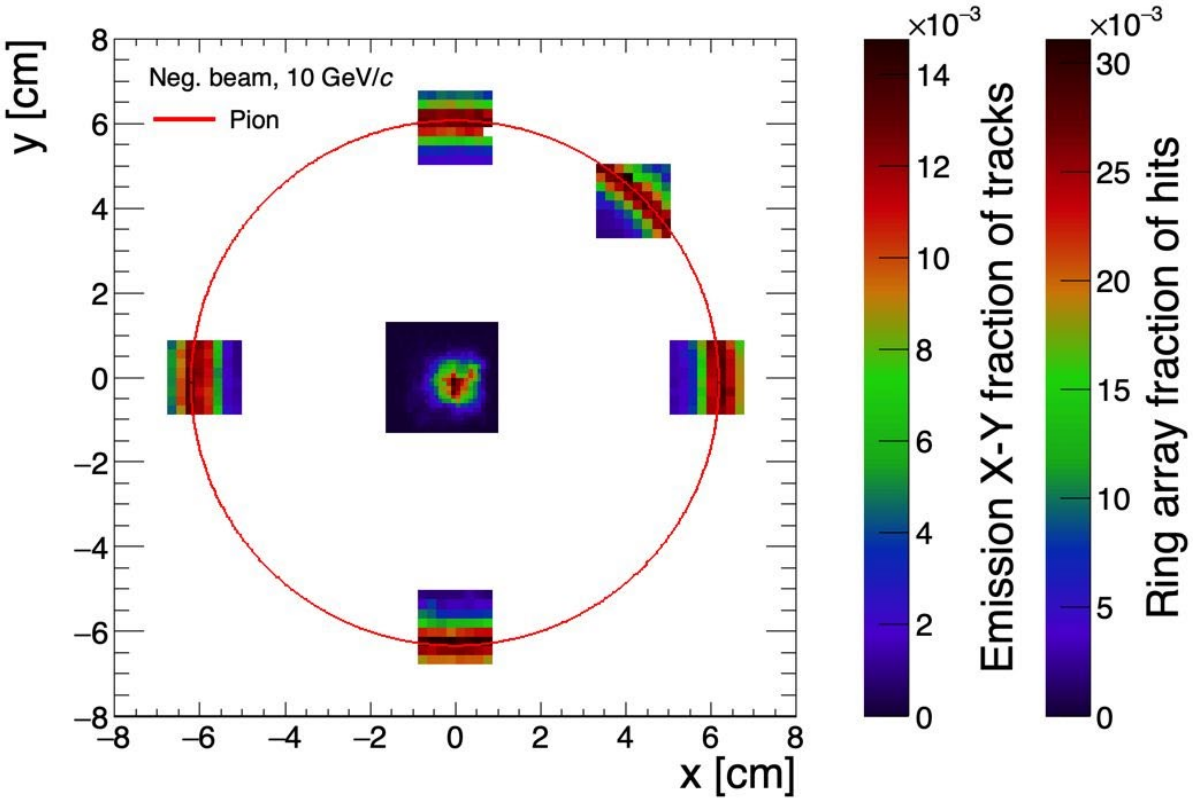


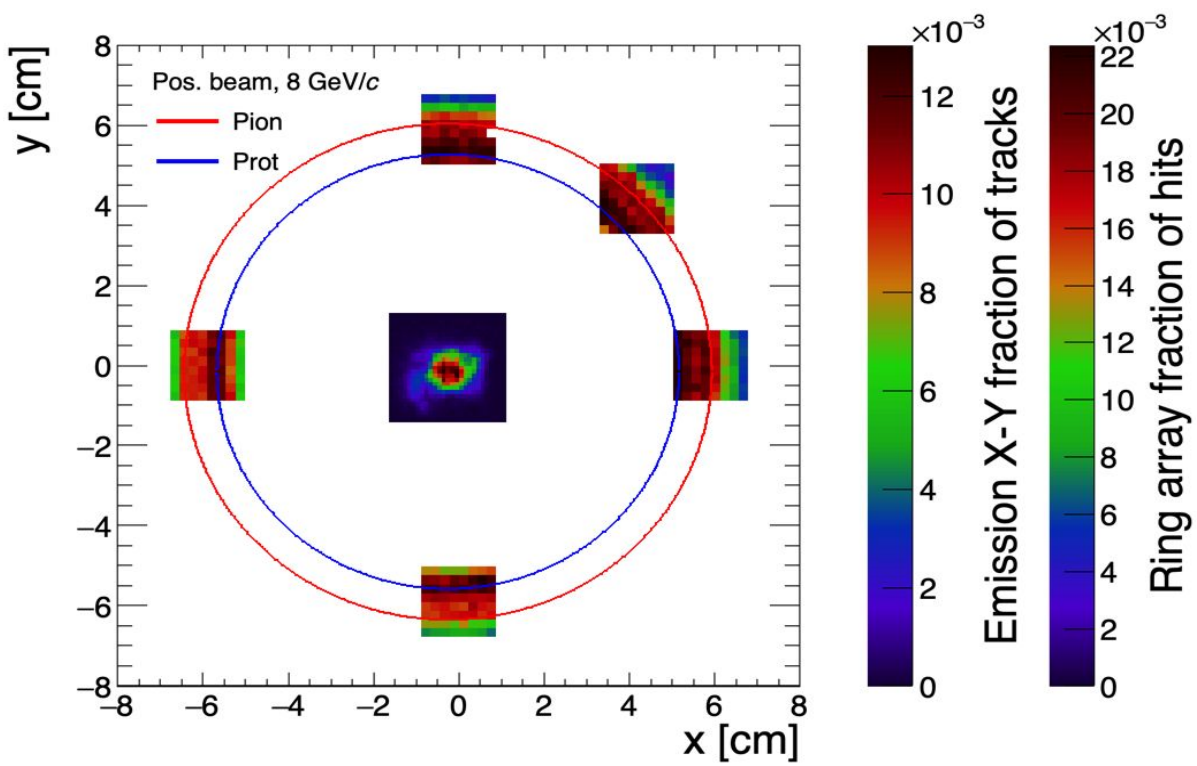
Differential
CLK board

Cherenkov angle reconstruction method

- All hit in the ring SiPM assumed as candidate Cherenkov photons
  - Emission position in the middle of the aerogel tile by means of particle track parameters
- Cherenkov angle reconstruction
  - Analytical backpropagation:
    - Pixel hit $\leftrightarrow$ Radiator by including Snell's law (at the areogel-argon surface)
- Angle resolution
  - Data fitted with Gaus(π) (+ Gaus(p)) + background template
    - Background due to random coincidences, dark count rate hits, optical cross-talk, wrong tracking, …
    - The background hits template looking ToA values outside the signal region

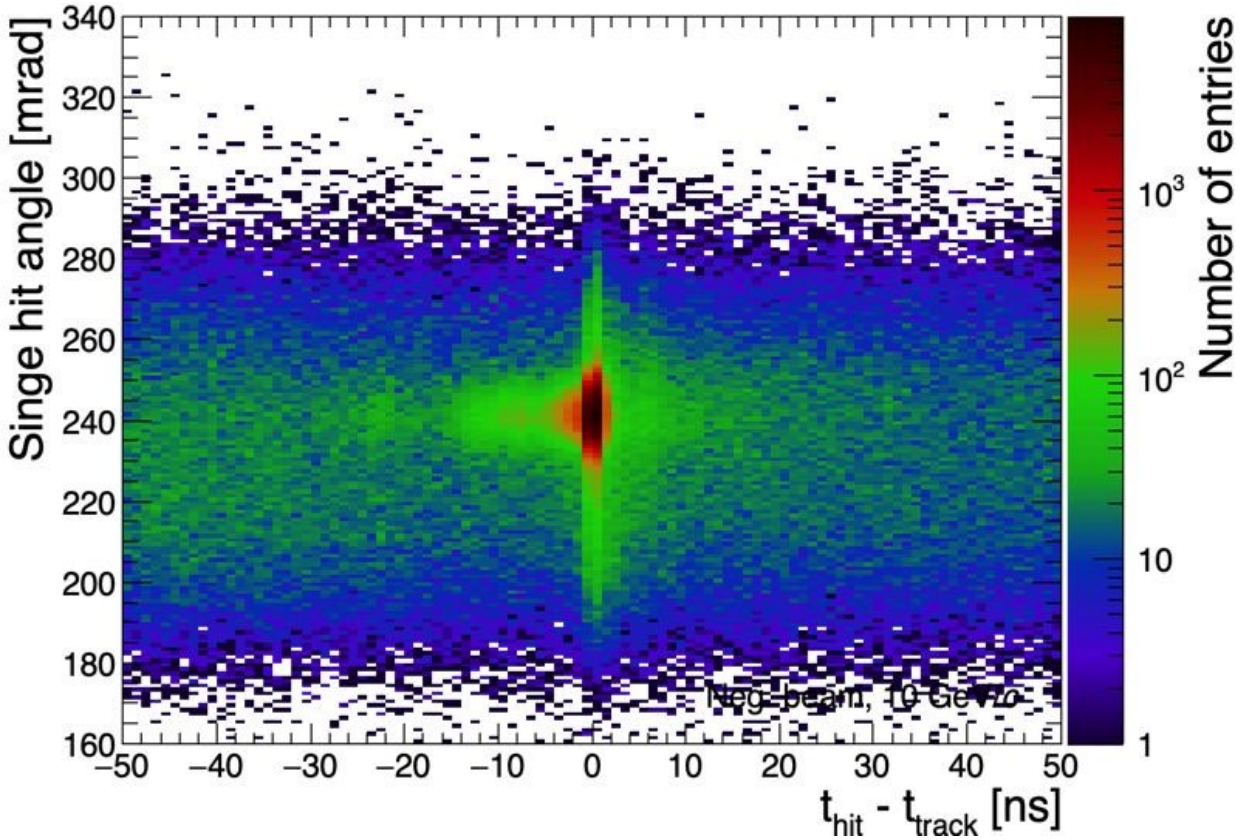
Hits map


Neg. beam, 10 GeV/c
Pion
y [cm]
x [cm]
×10⁻³
Emission X-Y fraction of tracks
Ring array fraction of hits

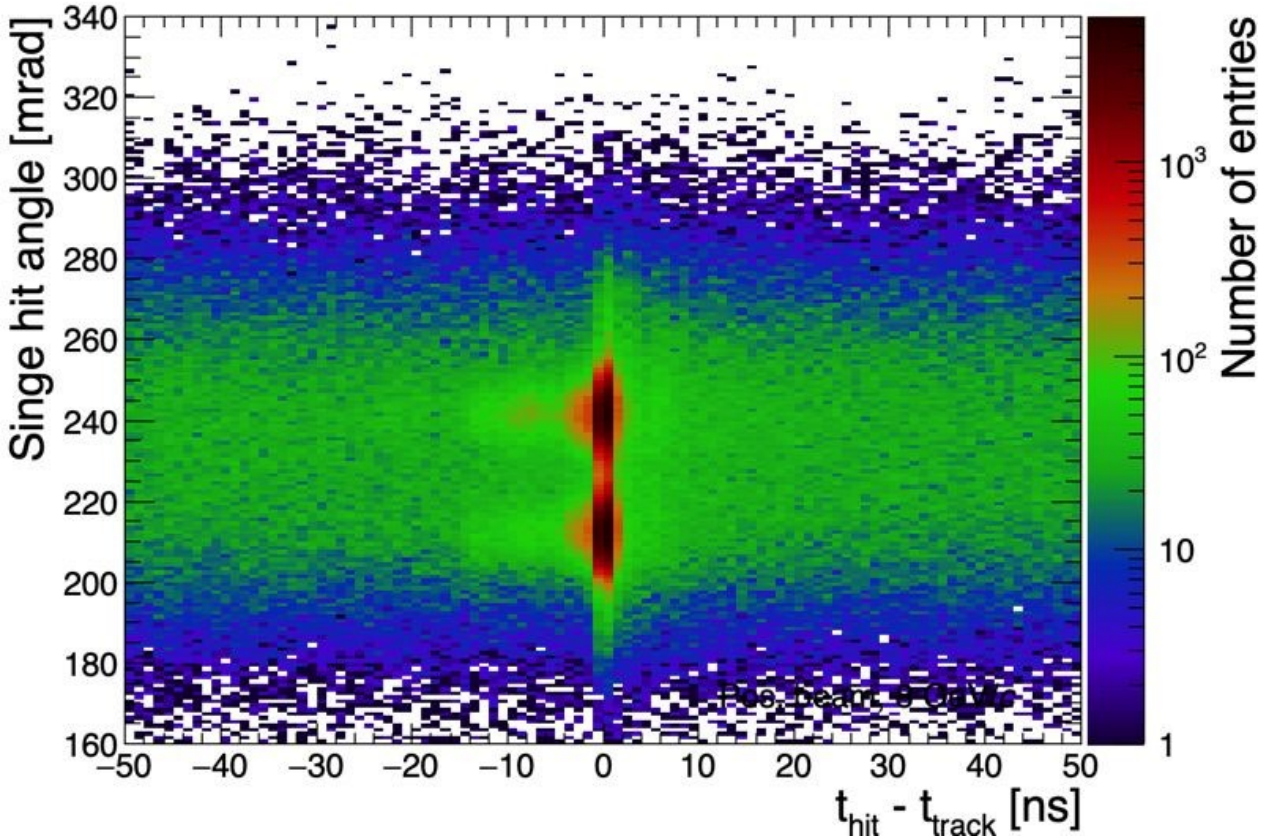

Pos. beam, 8 GeV/c
Pion
Prot
y [cm]
x [cm]
×10⁻³
Emission X-Y fraction of tracks
Ring array fraction of hits

Cherenkov Angle Vs hit time

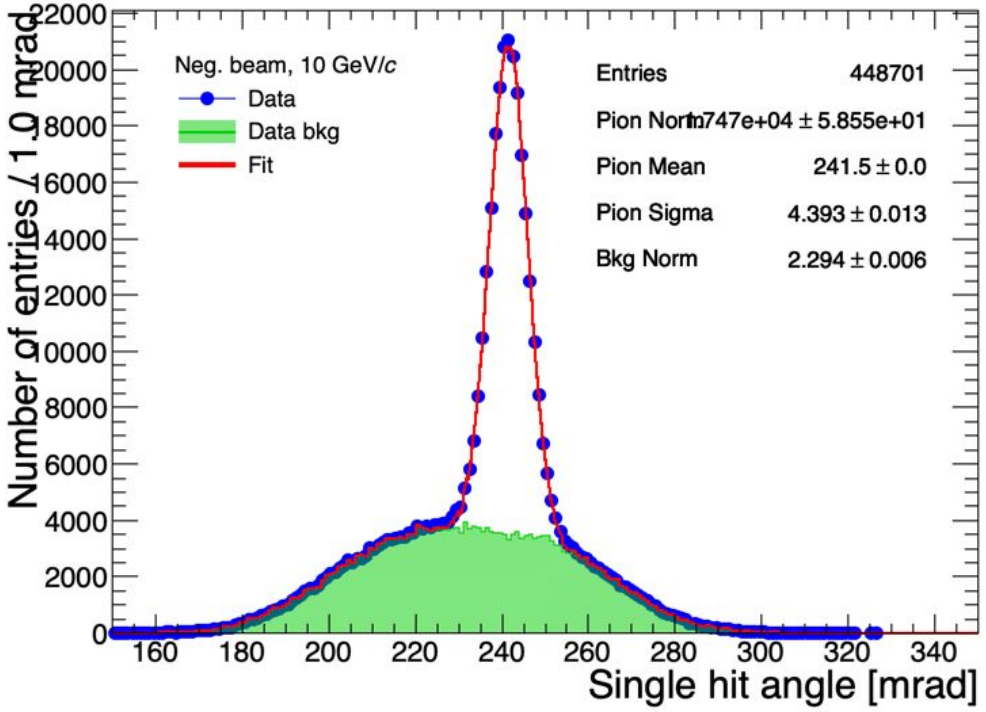
10 GeV π^-

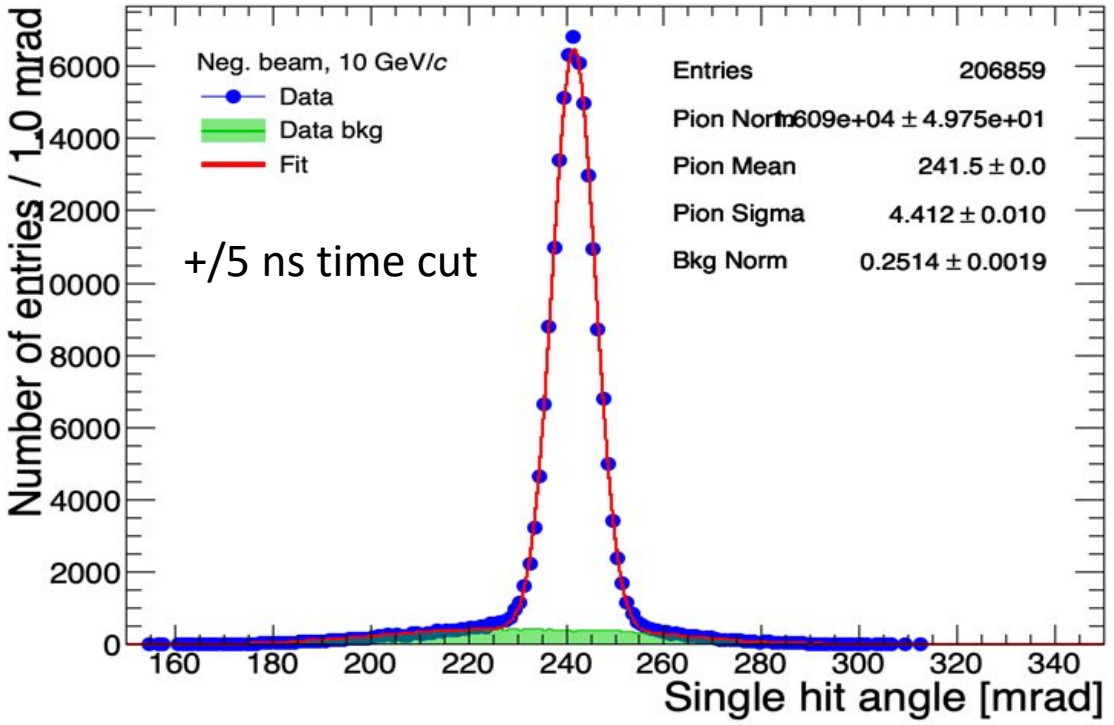


8 GeV π^+ *and protons*



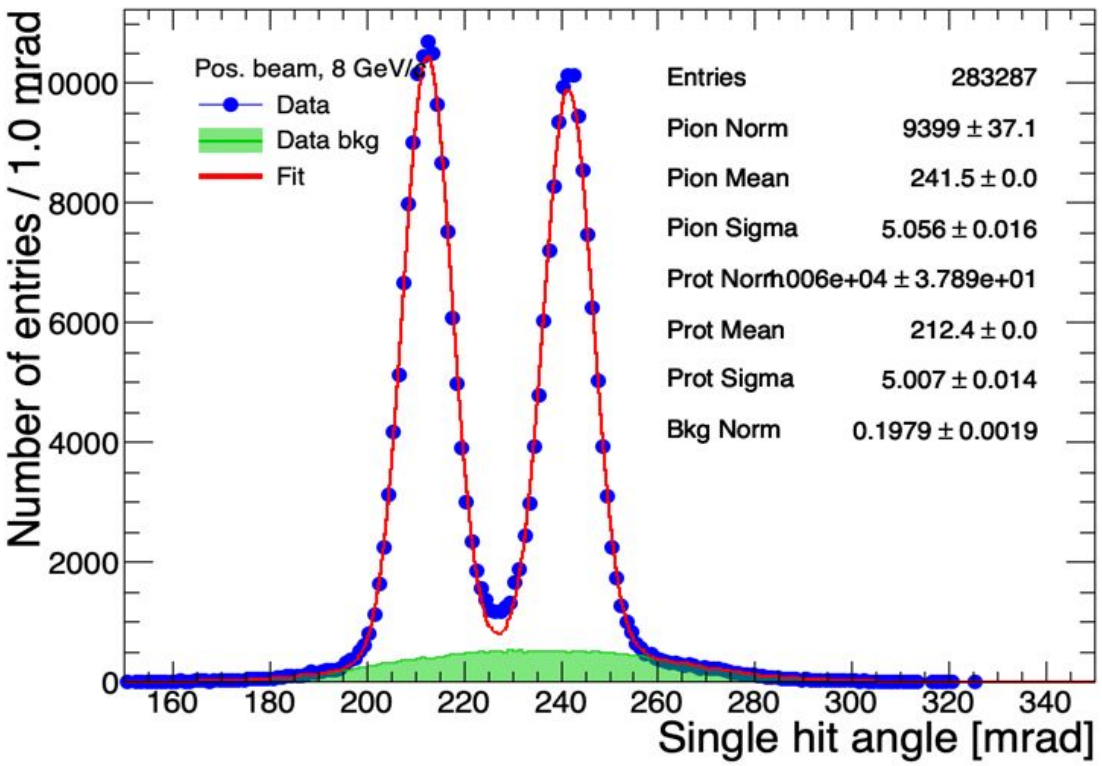
Angular resolution 10 GeV/c negative pions

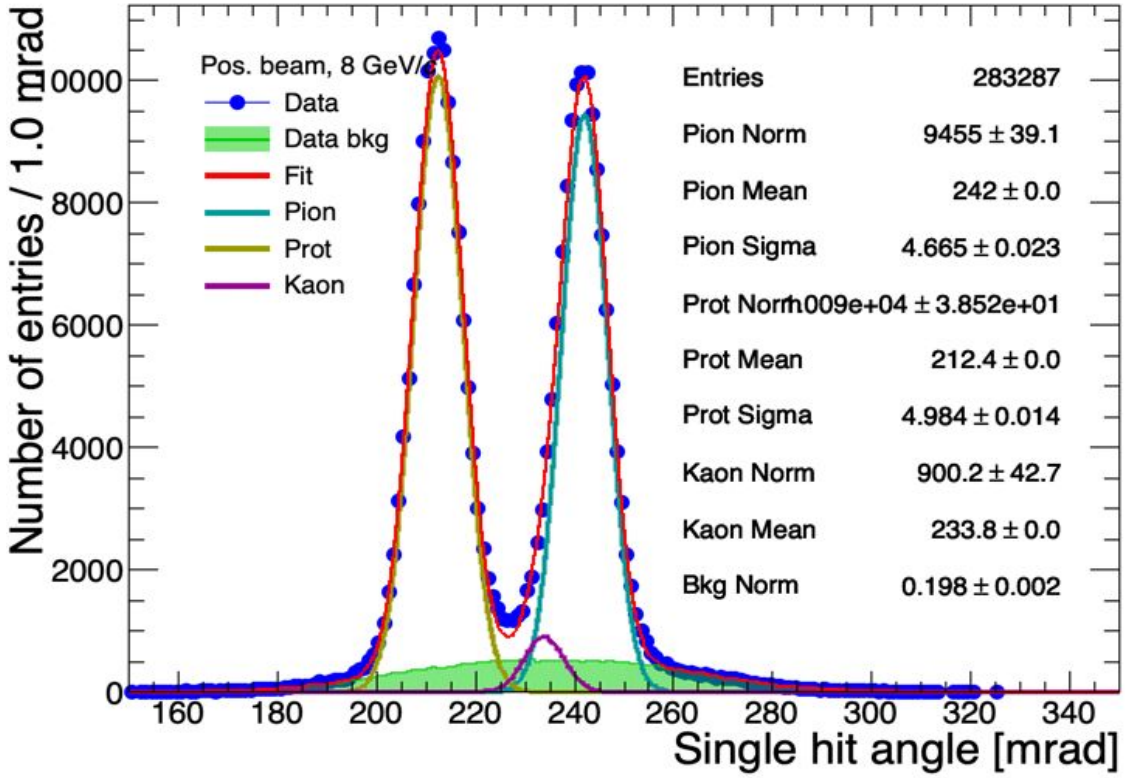




- Angular resolution as expected with 2 mm pixel size SiPM

Angular resolution 8 GeV/c positive pions+protons



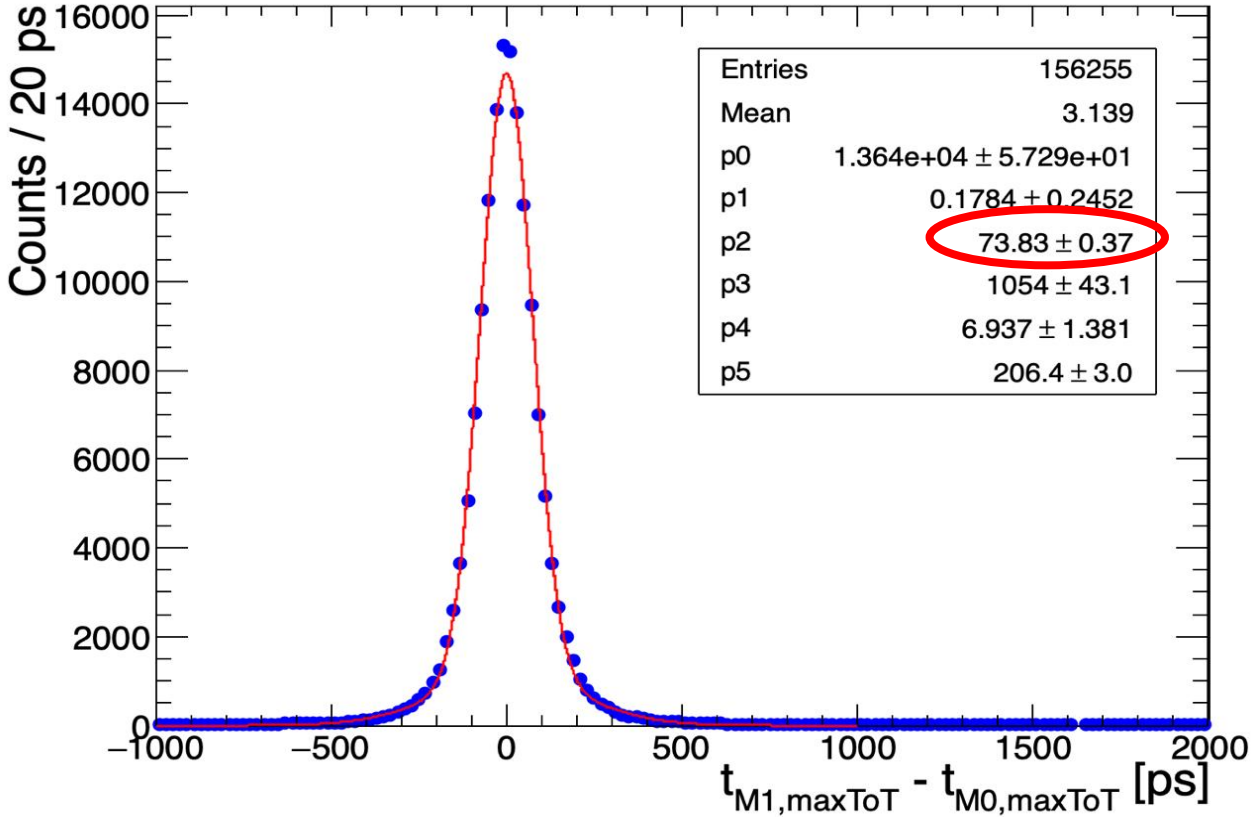


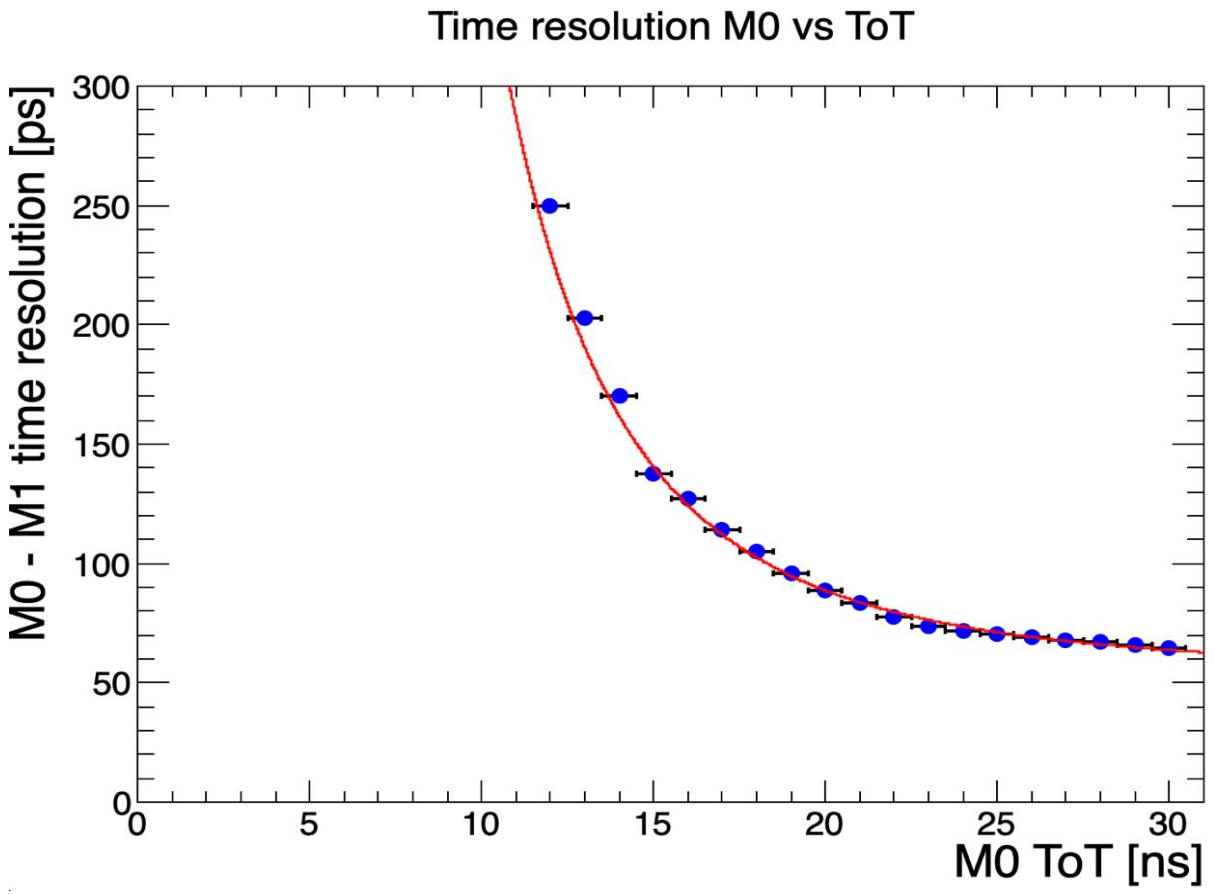
- Including kaons in the fit the pion resolution is recovered
  - The kaon fraction is compatible with the T10 particle beam composition at 8 GeV/c

Timing analysis

- In the set-up there are three SiPM arrays along the beamline with thin quartz window
  - M0 upstream TIME cylinder
  - M1 downstream TIM cylinder
  - M2 RICH cylinder
- All time offsets removed as well (included the time of flight)
- Timing resolution evaluated comparing the M0, M1 and M2 time responses
  - Currently we have selected the pixel with the maximum observed ToT value in each of those SiPM arrays

M0-M1 time resolution with maximum charge pixels





- Good time resolution without time walk correction
  - Single matrix resolution of about 73 ps/sqrt(2) = 50 ps

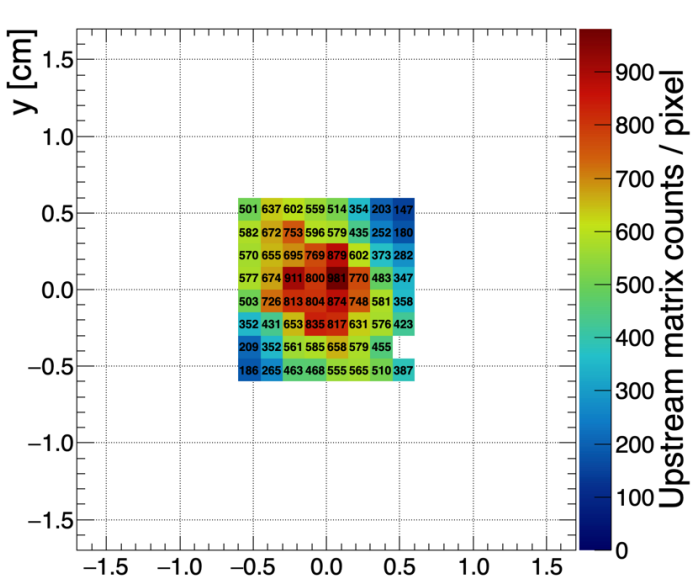
Conclusions

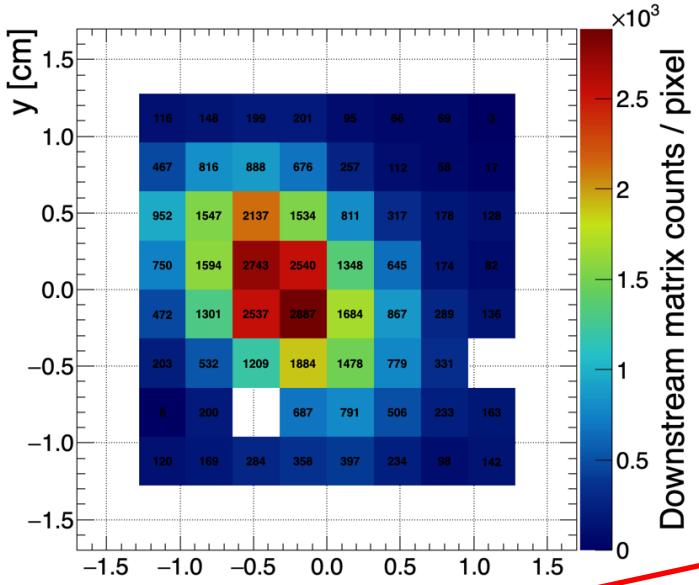
- Data analysis still in progress
  - We have collected many runs with several configurations, e.g.
    - Several bias voltages
    - Several temperature values
    - Focusing aerogel
    - Aerogel + CO2 Cherenkov emission with 3 GeV electrons
- Pion and proton Cherenkov single photon angle resolution of about 4-5 mrad in 8 - 10 GeV/c beam momenta
  - 2 cm aerogel with n=1.03 and a proximity gap of about 23 cm
  - SiPM pixel pitch of 2 mm
- The overall (electronic + SiPM) timing resolution of about 70 ps ($/\sqrt{2}$) or better
  - Possible improvement with time walk correction by means of the observed ToT values

BACKUP

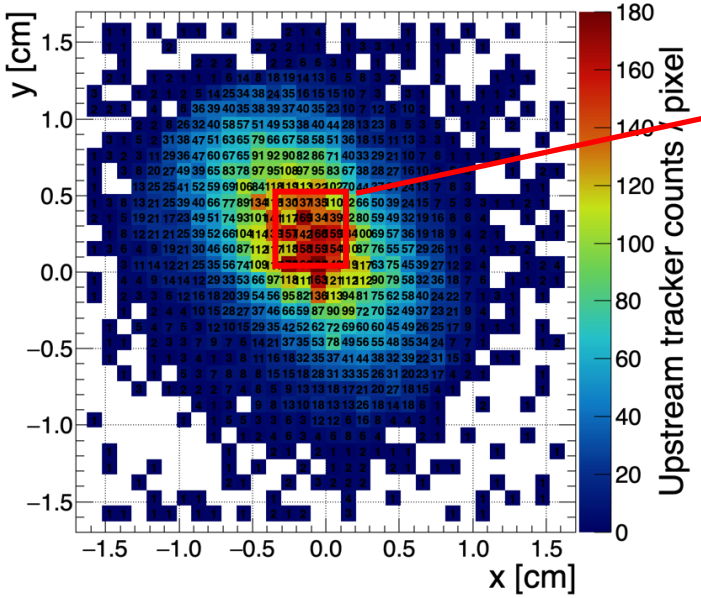
2023 - Beam spot on matrices and trackers

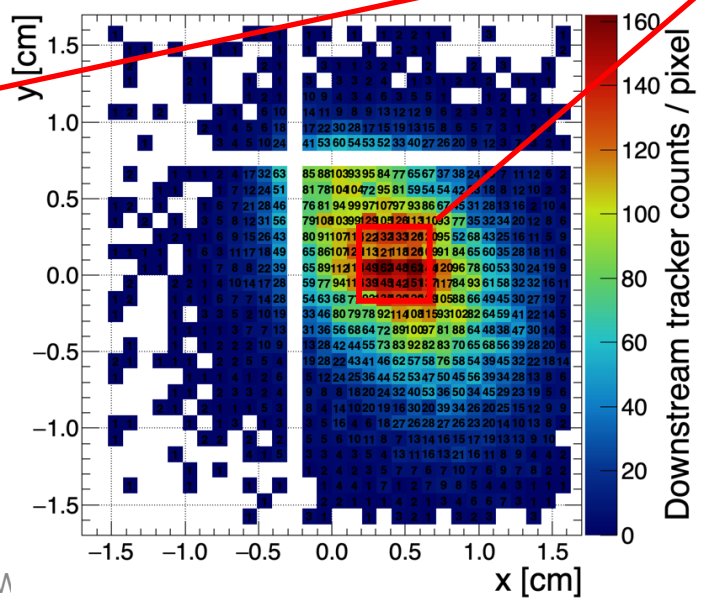
Upstream and downstream SiPM matrices





Upstream and downstream X-Y Fiber trackers

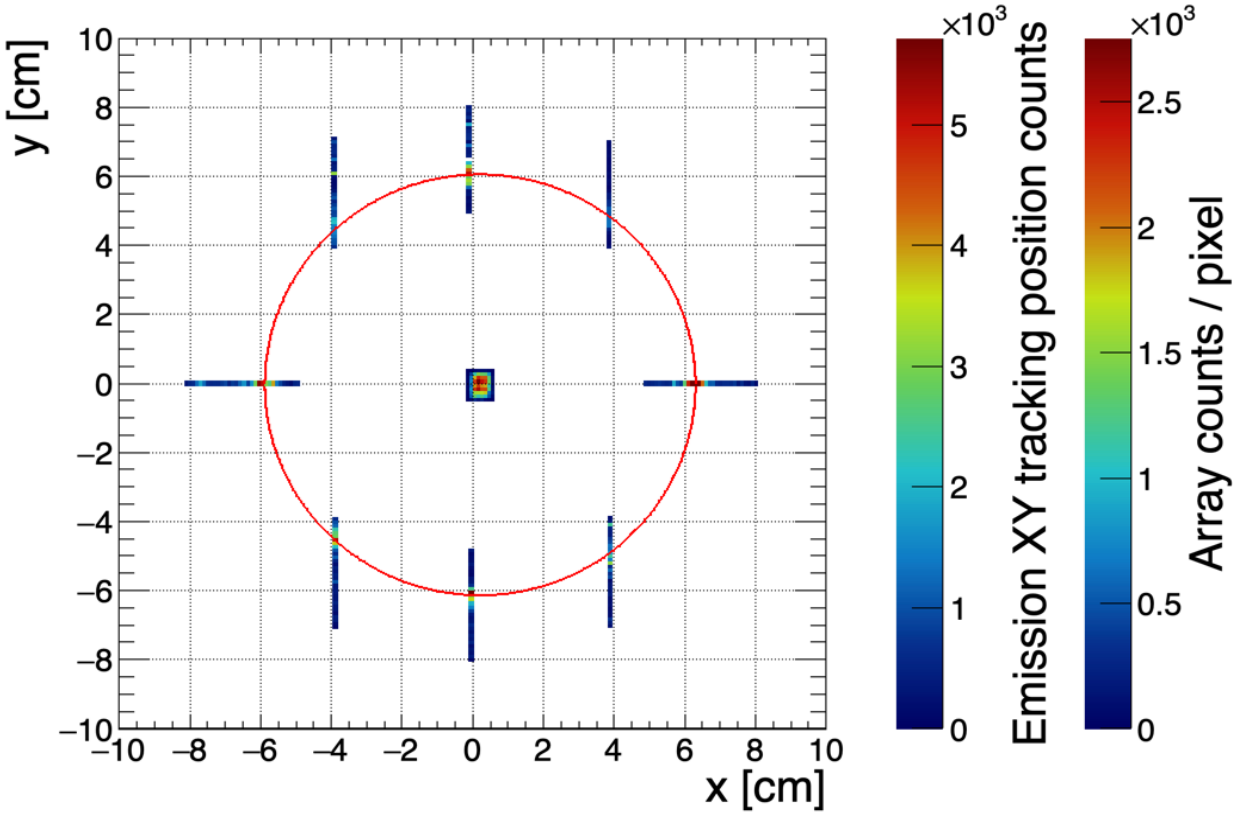




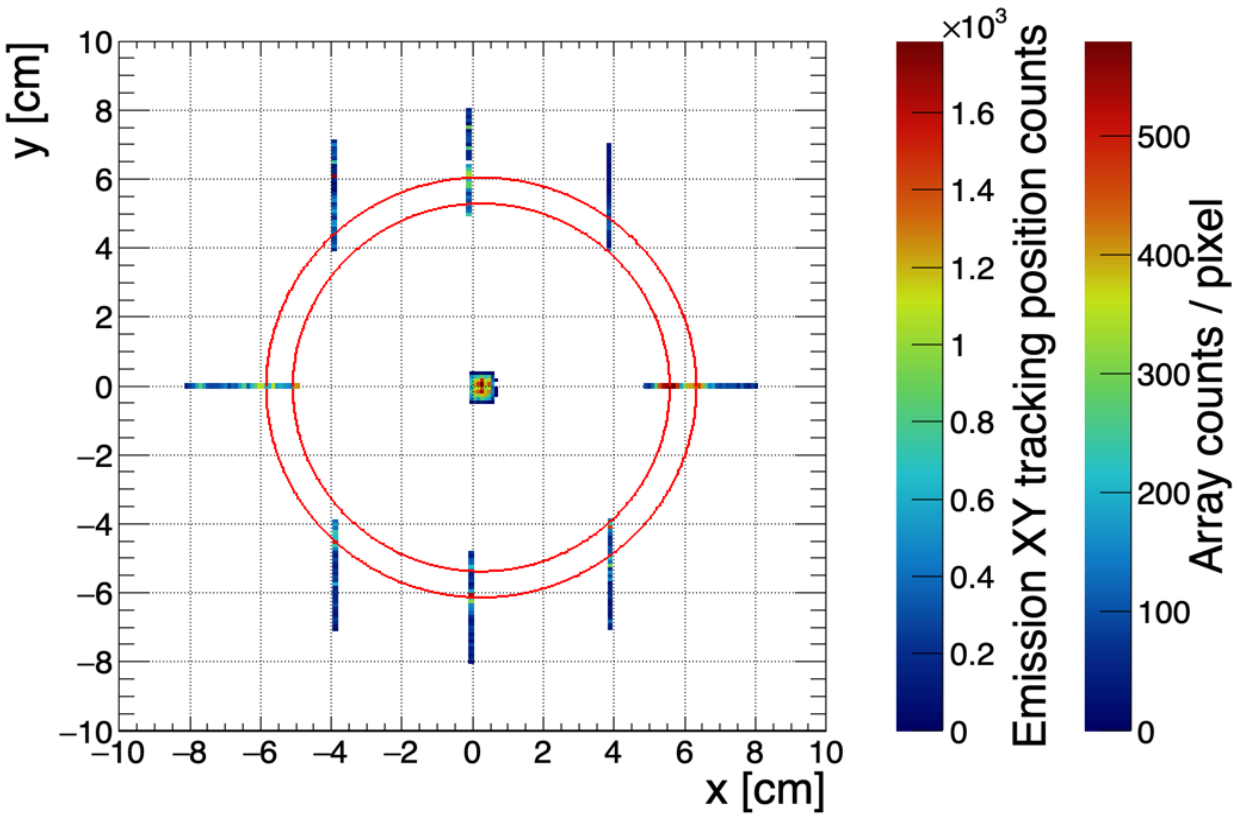
Tracker fiducial area for particle signal in both matrices

2023 Hit maps

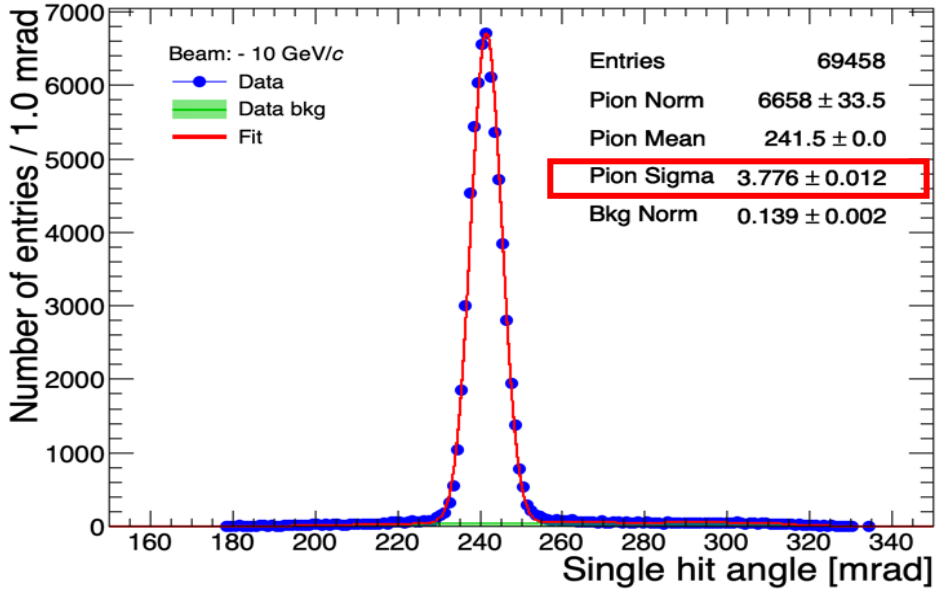
-10 GeV/c beam

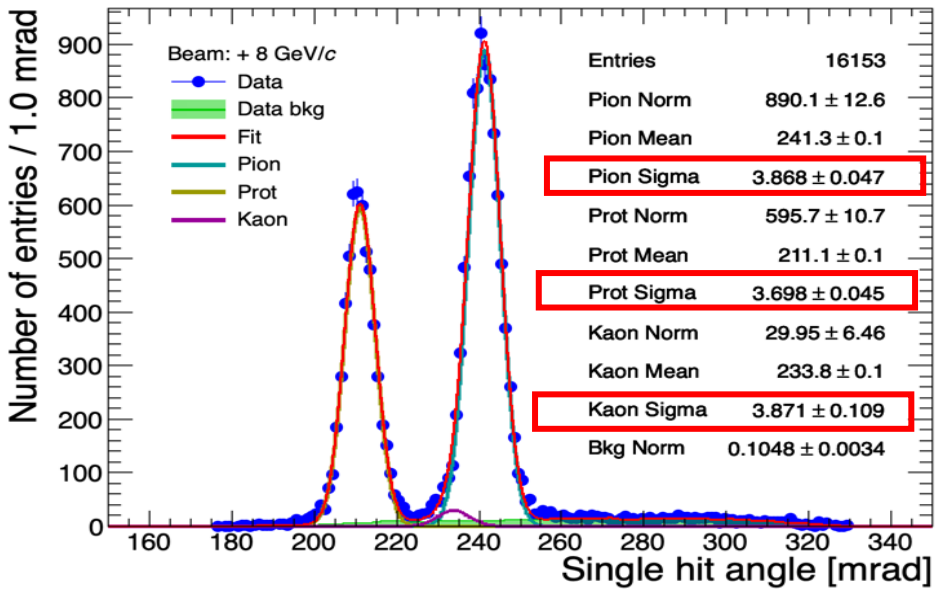


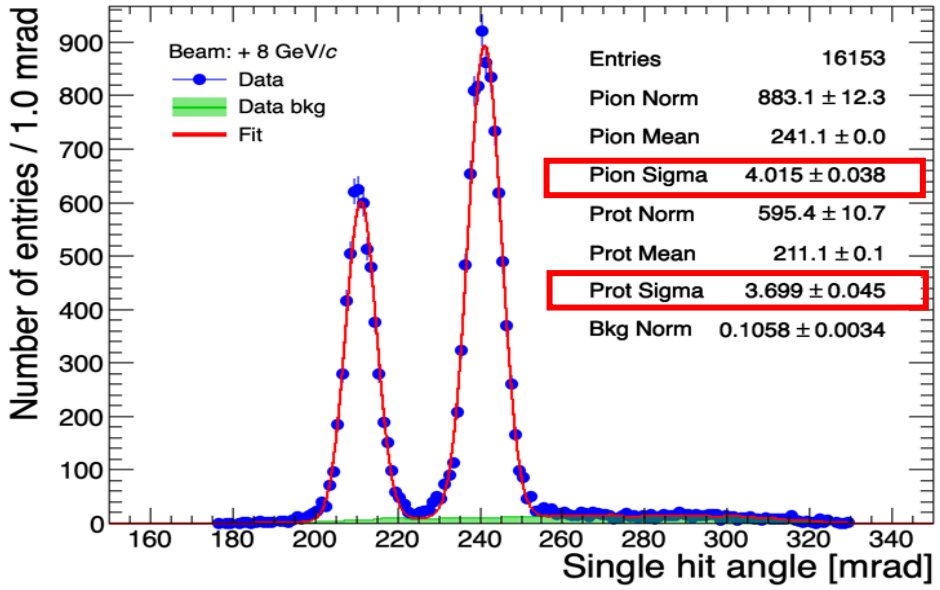
+8 GeV/c beam



2023 Angular resolution - signal hits within a ±5 ns

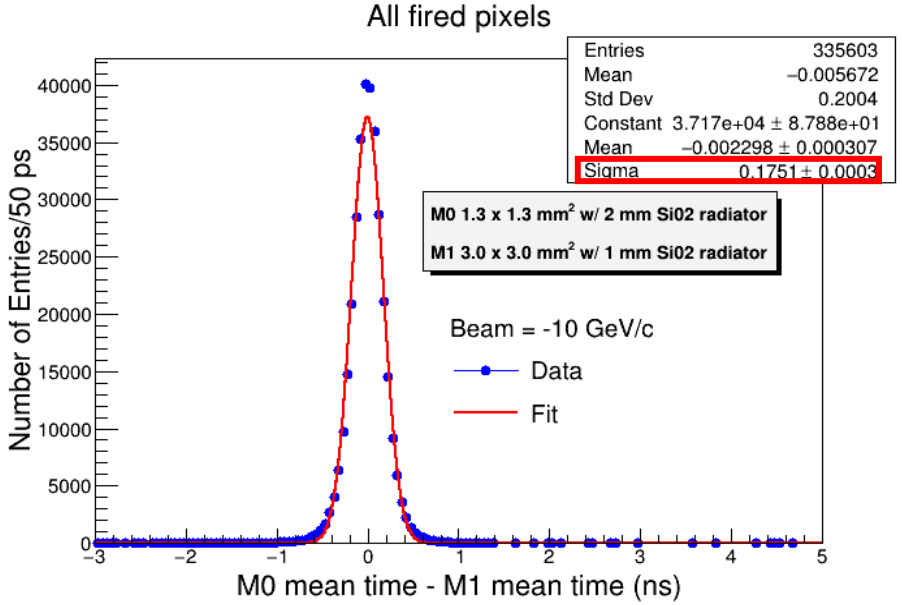


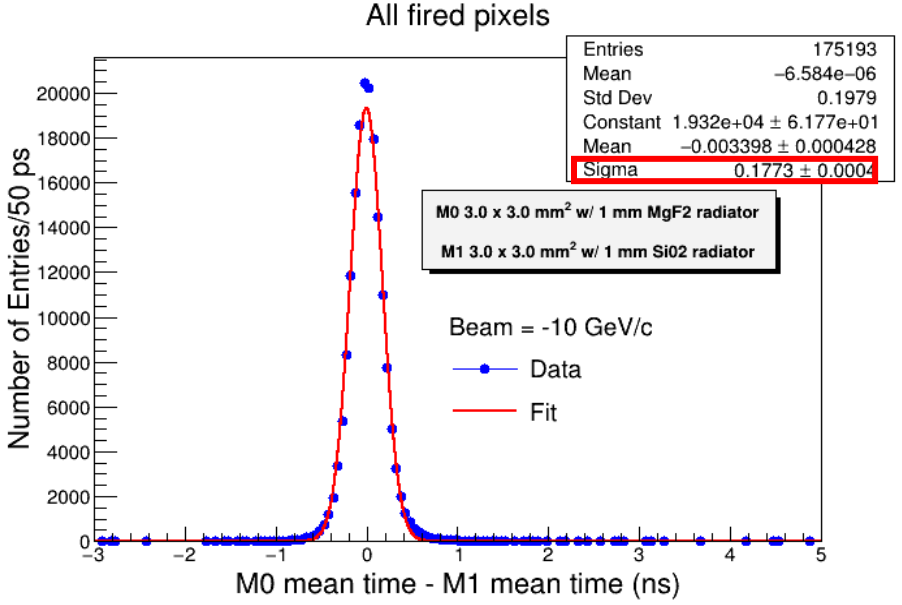


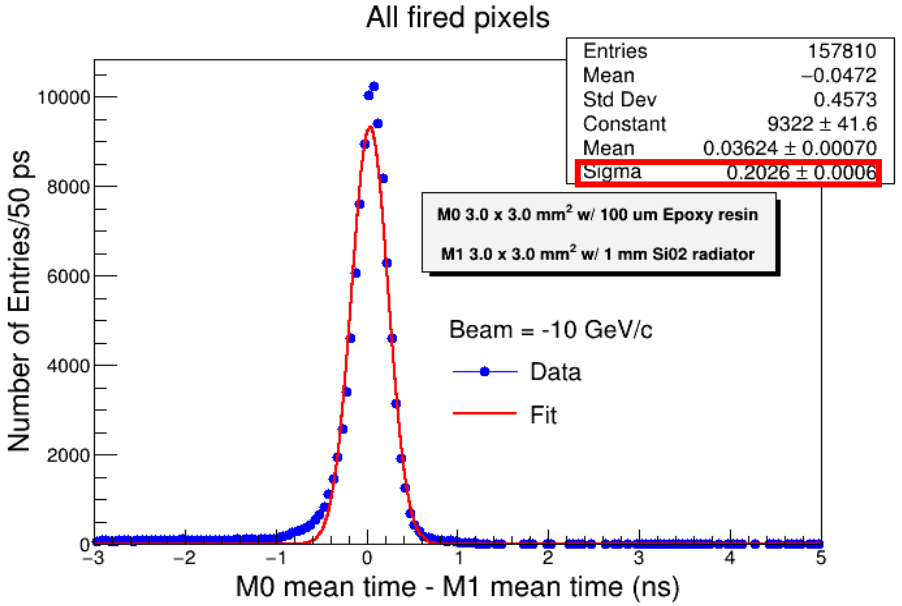


- Including kaons in the fit the pion resolution is recovered
  - The kaon fraction is compatible with the T10 particle beam composition at 8 GeV/c

2023 M0-M1 time resolution with all fired pixels

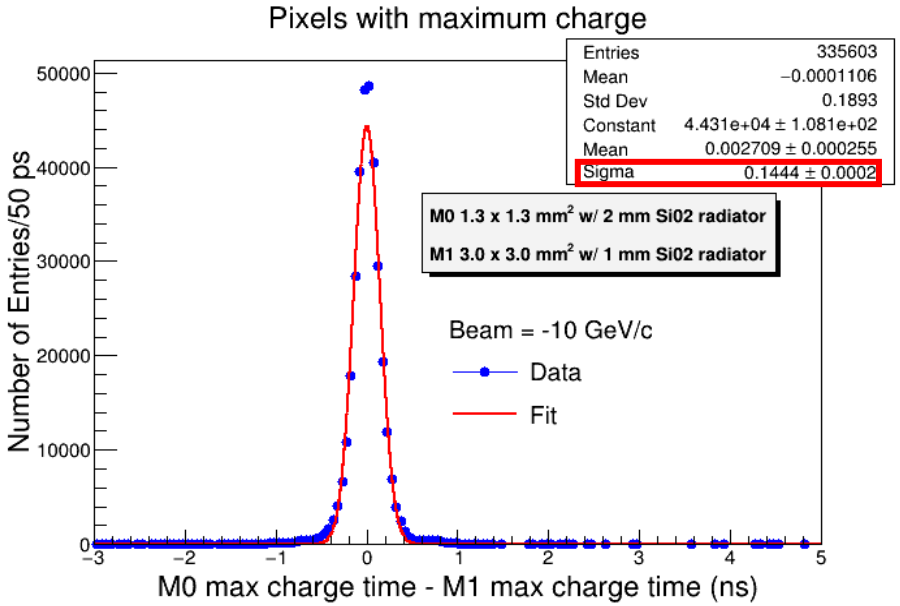


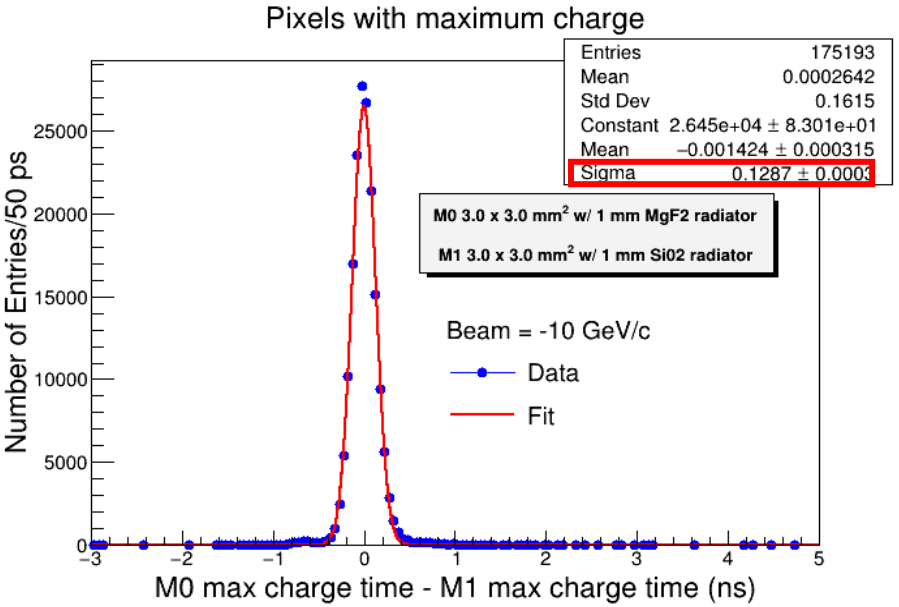


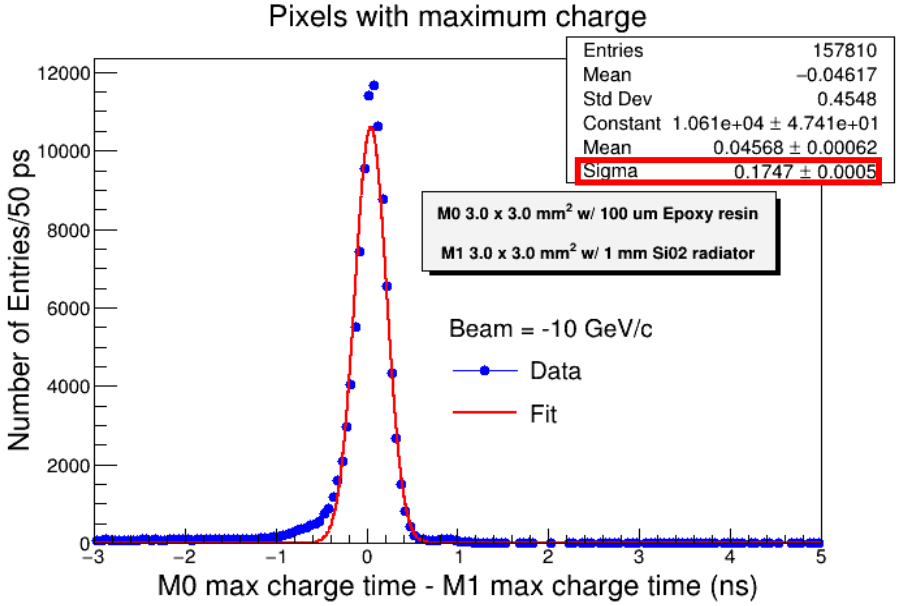


- Timing analysis:
  - Time walk correction, i.e. SiPM firing time vs Npe
  - Channel by channel offsets, i.e. routing, internal cabling, etc.

2023 M0-M1 time resolution with maximum charge pixels

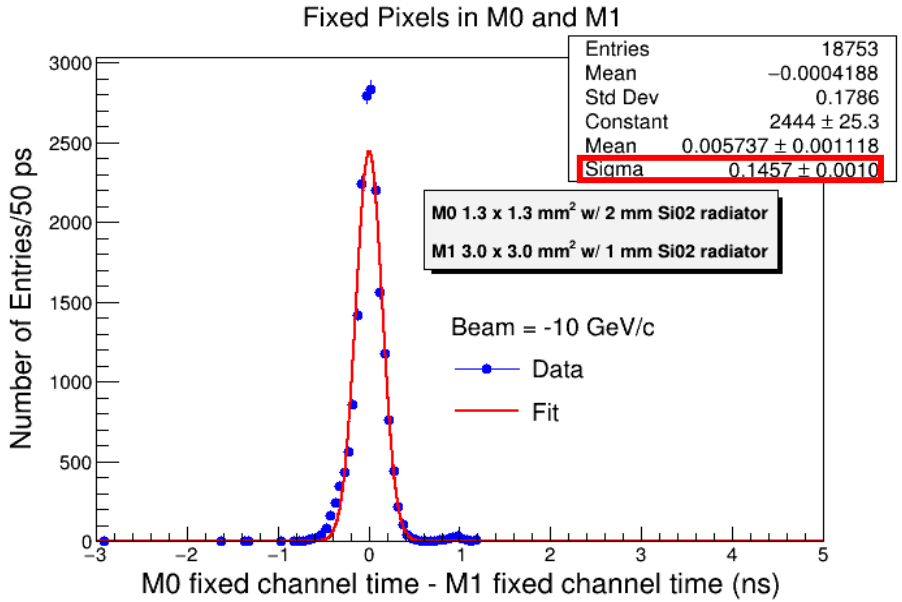


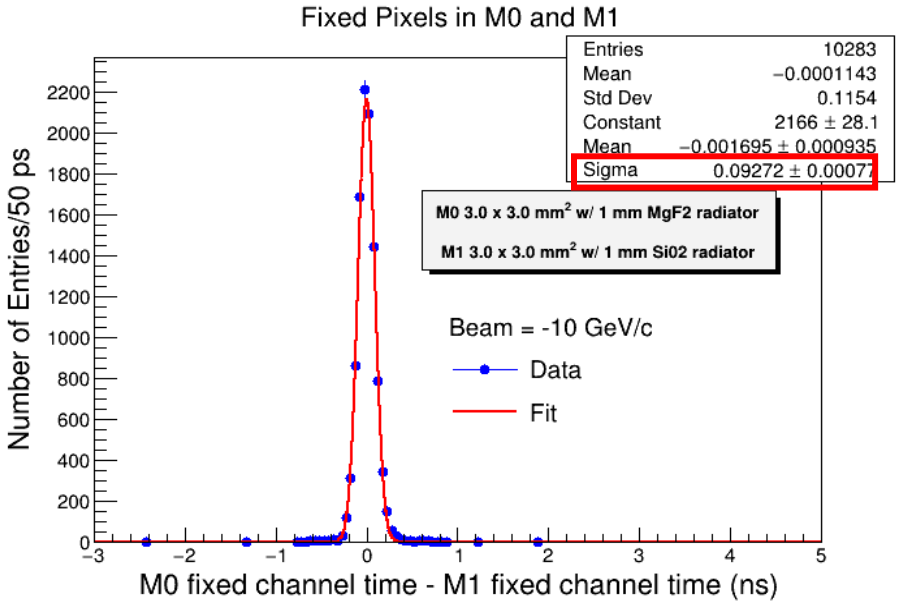


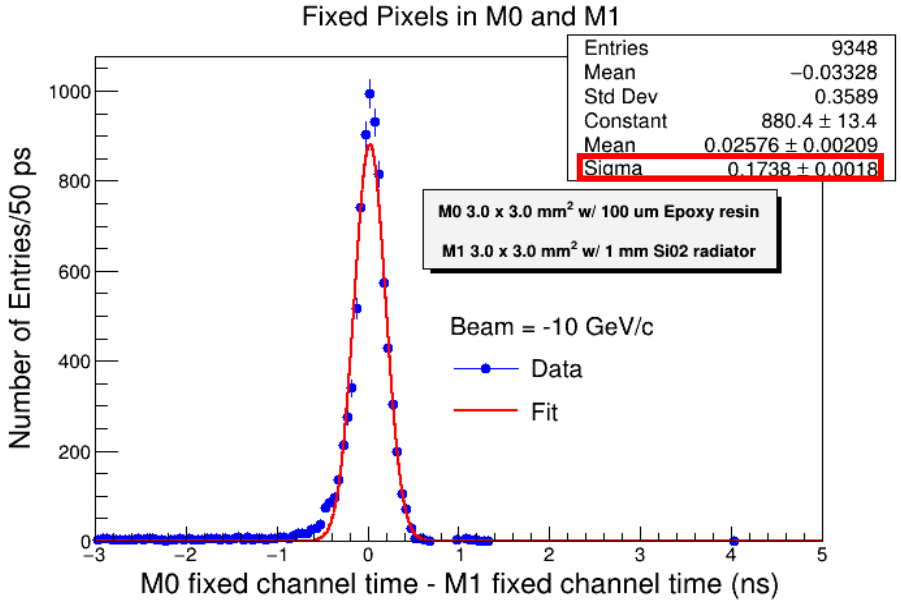


- Timing analysis:
  - Time walk correction, i.e. SiPM firing time vs Npe
  - Channel by channel offsets, i.e. routing, internal cabling, etc.

2023 M0-M1 time resolution fixing two pixels







- Timing analysis:
  - Time walk correction, i.e. SiPM firing time vs Npe
  - Channel by channel offsets, i.e. routing, internal cabling, etc.