The dual Ring Imaging Cherenkov detector for the Electron-Ion Collider

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EIC_NET

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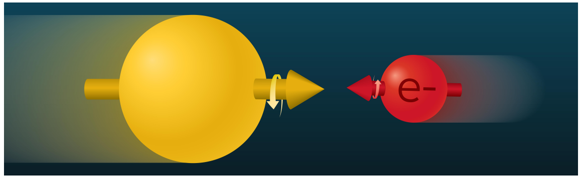
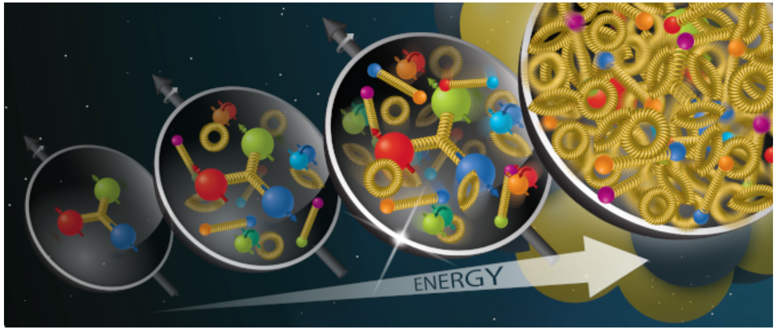
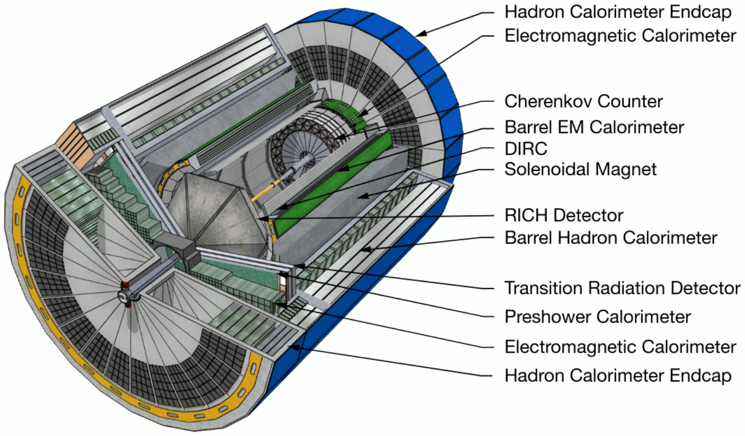
The Electron-Ion Collider

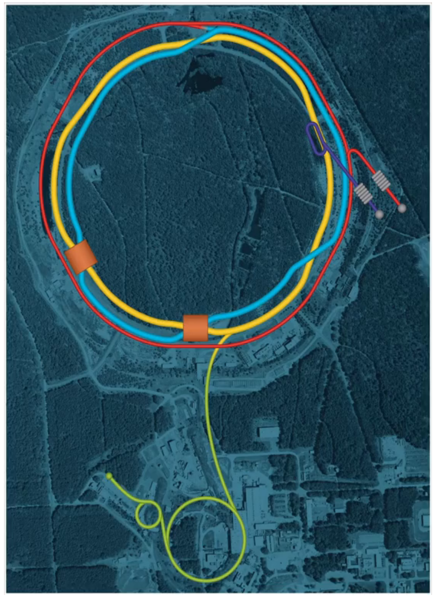
Brookhaven National Laboratory

- Highly polarized electron (~70%) and proton (~70%) beams
- Availability of ion beam from deuterons to heavy nuclei
- *e+p* center-of-mass energy up to 100 GeV
- High luminosity (up to 10^{34} $cm^{-2}s^{-1}$)



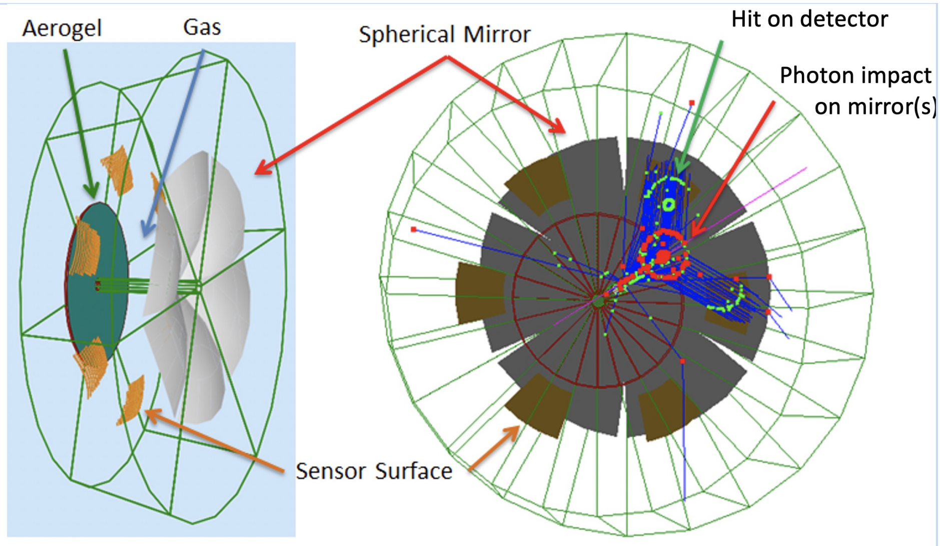






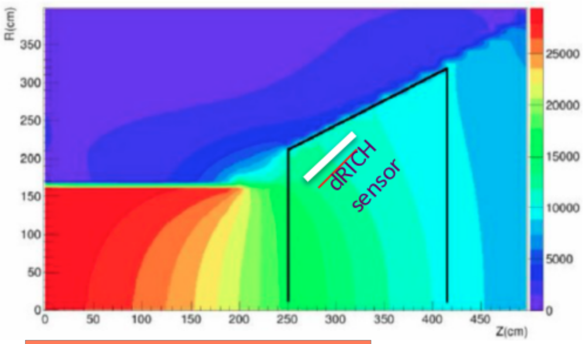
The dRICH at EIC

Challenges:
- **cover wide momentum range 3-60 GeV**
- **work in high (~1 T) magnetic field**

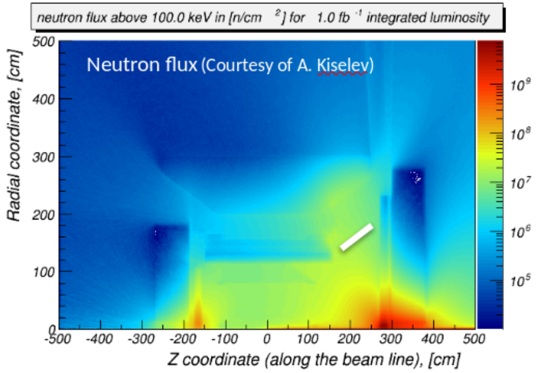


Effective solutions, part of EIC reference detector
Radiators: aerogel (n_{aero} ~1.02) + gas C2F6 (n_{gas} ~1.0008)
Detector: 0.5 m^2/sector, 3x3 mm^2 pixel, SiPM option

Magnetic field



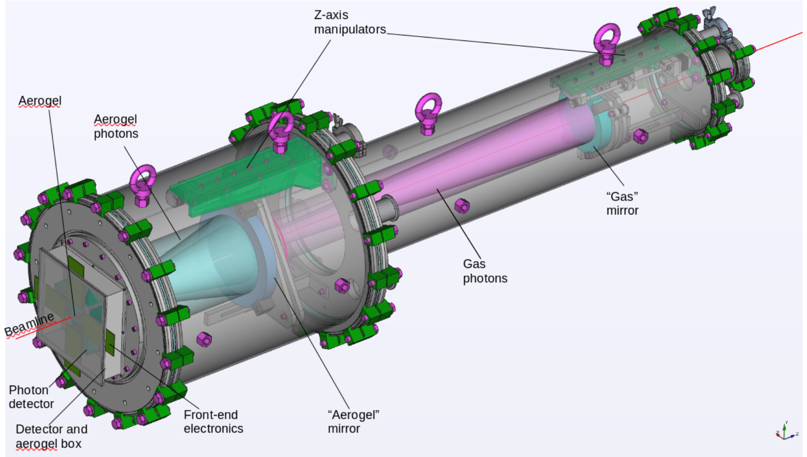
SiPM option



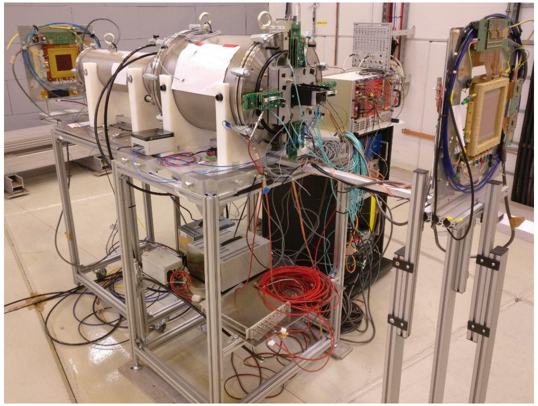
~$10^{11} n_{eq}/cm^2$

Study on radiation mitigation on SiPM

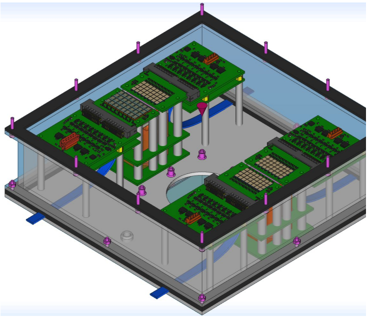
The dRICH prototype 2021 test beams



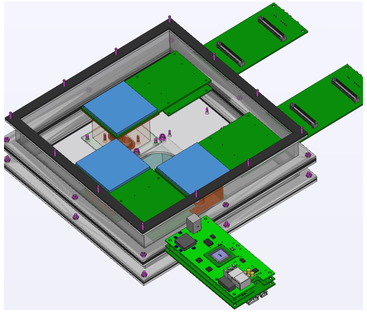
Test	Cherenkov medium	Energy [GeV]	Beam	Photon detector and DAQ
September at SPS	Aerogel	40÷120	π^+ π^-	SiPM and ALCOR
October parasitic runs at SPS	Aerogel	120	μ^- π^-	MPPC and MAROC
October at PS	Aerogel and Gas (C_2F_6)	4÷12	p and π^+ π^-	MAPMT and MAROC



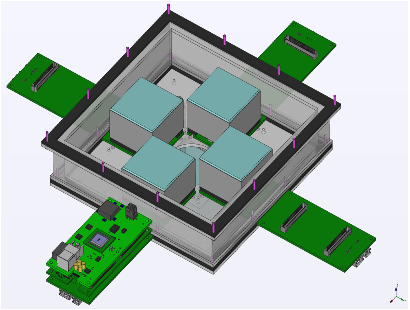
The dRICH setup at PS



SiPM



MPPC

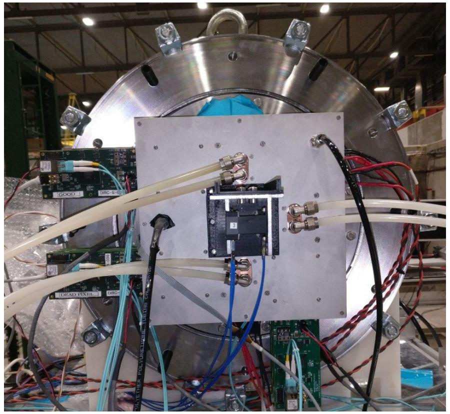


MAPMT

The dRICH prototype components

dRICH chamber

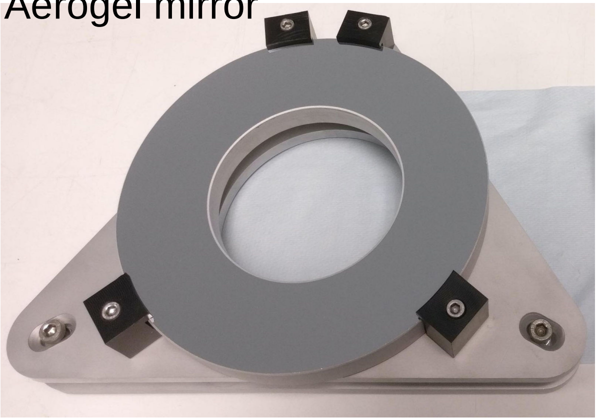
Gas mirror

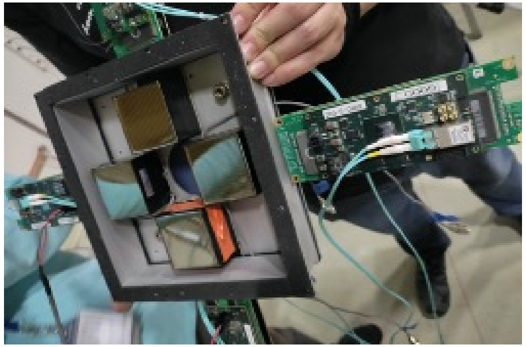


Frontal view

Support

Aerogel mirror





MAPMT detector box

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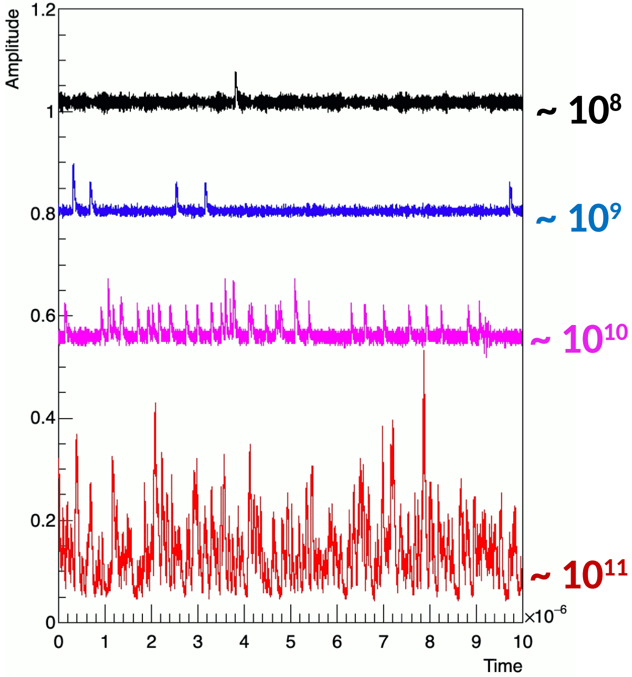
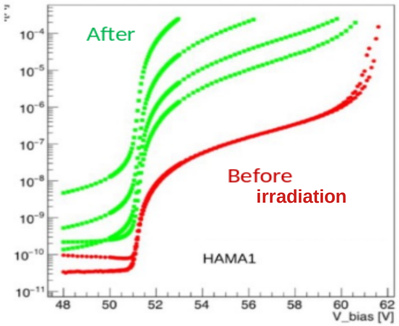
SiPM study

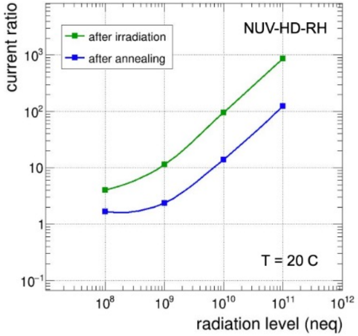
A study of radiation effects on SiPM and recover by annealing is ongoing.
We developed custom carriers for SiPMs of several producers, which can bear the high temperature (up to 170°C) of the annealing process.

Some carriers were irradiated in May at TIFPA (Trento) and in the following months underwent annealing at Bologna and Ferrara



IV characteristic





In just one week of annealing the SiPMs recovered one order of magnitude in dark current (or neutron dose).

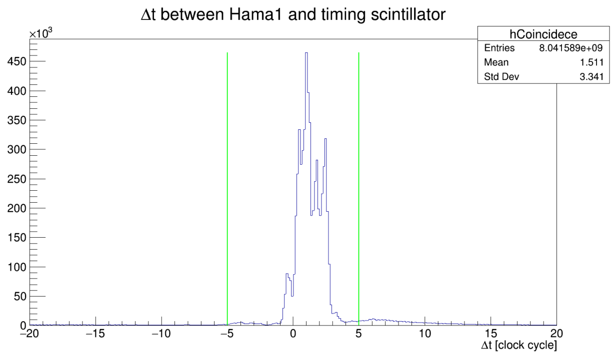
For more info, see P. Antonioli slides for eRD110 and N. Rubini poster and slides for the Fifth National Meeting of Nuclear Physics INFN 2022

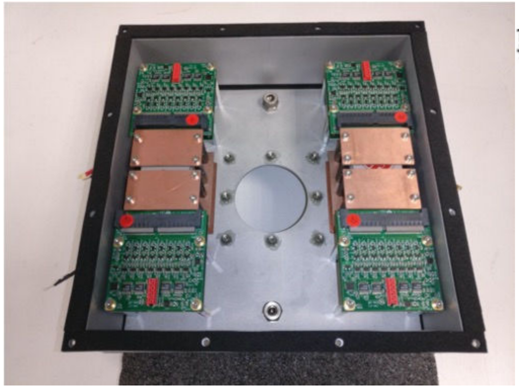
September tests at SPS

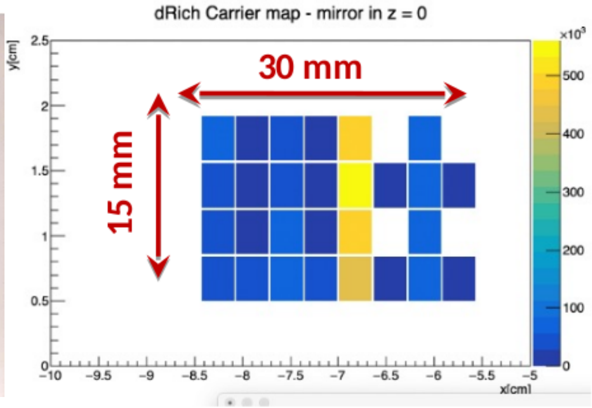
The september test main goal was to implement the readout chain based on ALCOR (with not irradiated SiPMs)

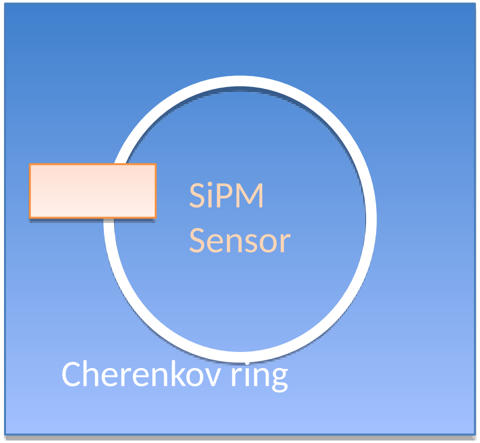
The ALCOR chip and ARCADIA DAQ are INFN developments designed to readout SiPM with precise time resolution (50 ps time binning) and at high rate (up to 500 kHz per channel).

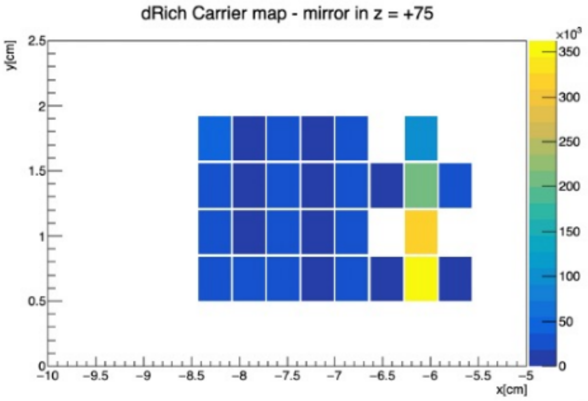
The plot shows the coincidence peak between the SiPM signal of dRICH and the timing and trigger scintillators.







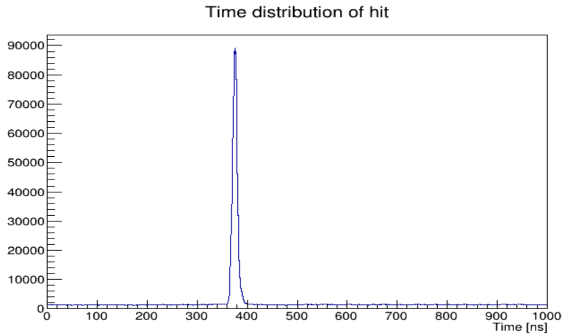




October test at PS

Goals:
- To operate the dual RICH by using both aerogel and gas;
- preliminary study the performance of the dRICH.

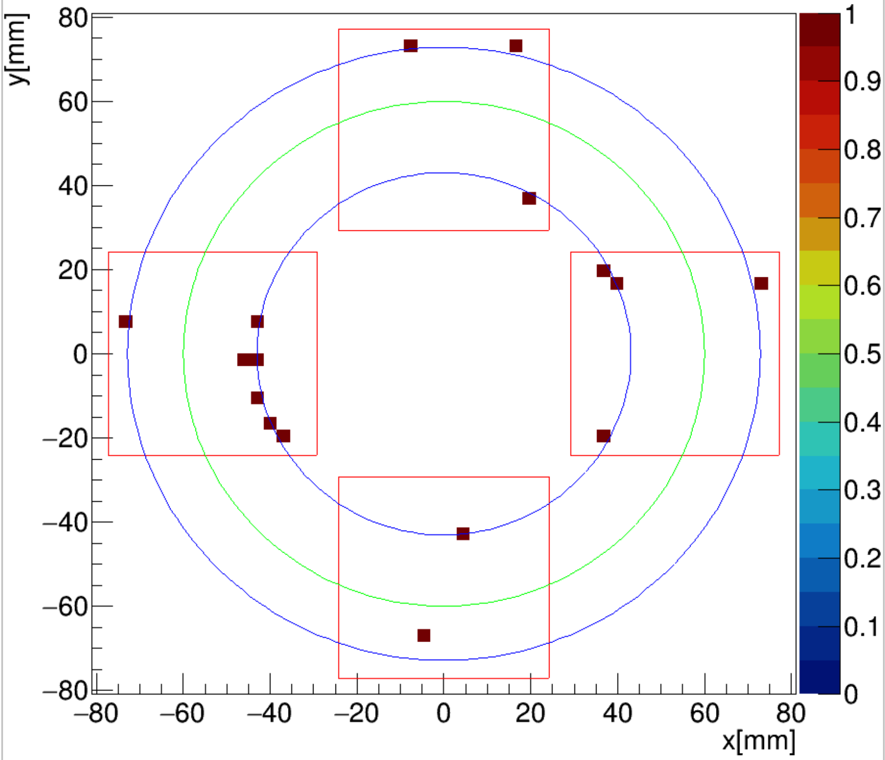
Difficulties:
- Sensors came late due to an overlap with another test beam;
- the renovated beam line was not completely commissioned;
- most of the time was parasitic.



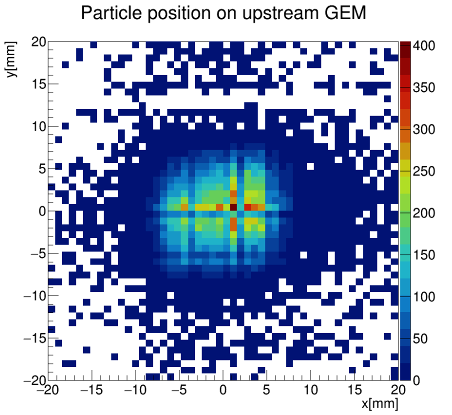
Distribution of hit time, the coincidence with the trigger time is clearly visible.

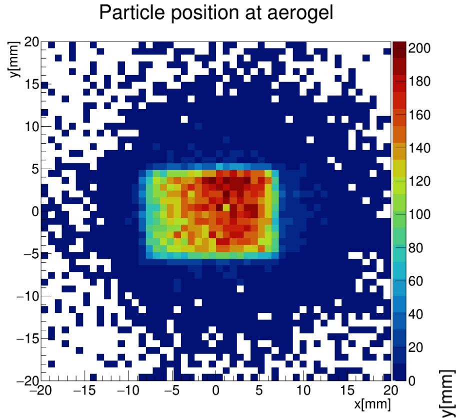
The right plot shows one event measured at PS.

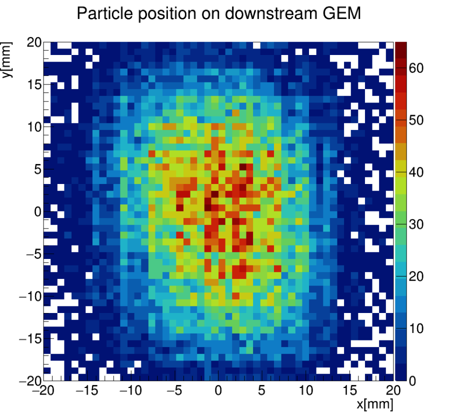
Legend:
- Little red square, a pixel of the MAPMTs turned on by a photon.
- Red line, edge of MAPMTs.
- Green, geometrical cut applied to distinguish gas (inner) and aerogel (outer) photon.
- Blue, gas and aerogel rings reconstructed.

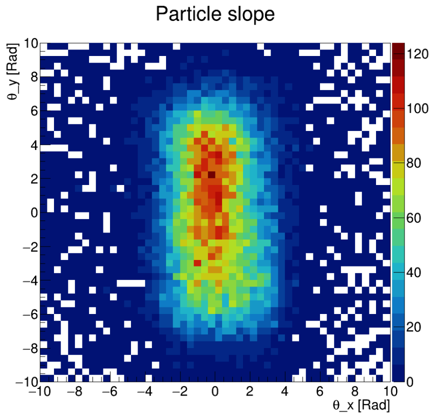


dRICH alignment & data corrections

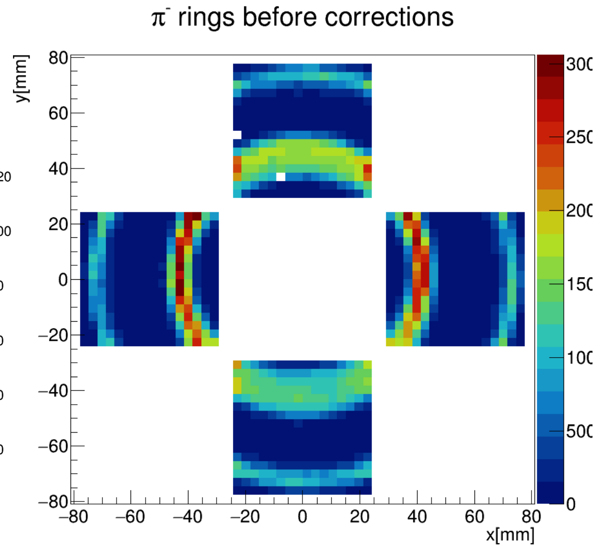


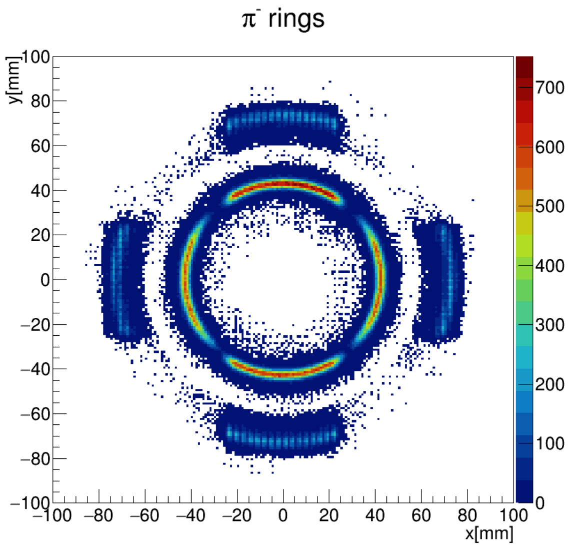




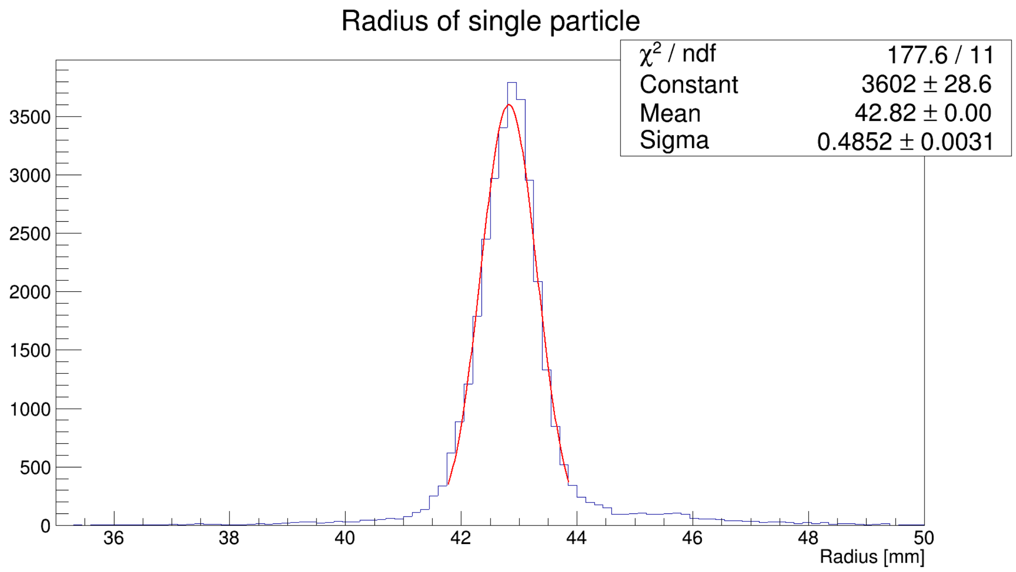


A tracking system based on two GEM detectors was used during the test beams to track the beam particles for misalignment and beam divergence,
The combination of the dRICH optical information and GEM track information allows to correct data on a event by event data.

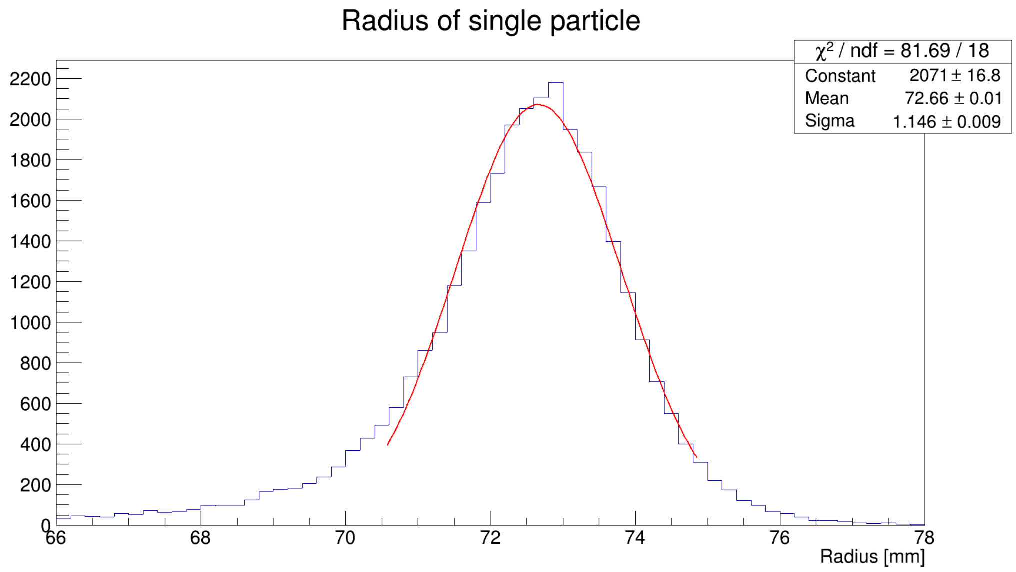




Preliminary results

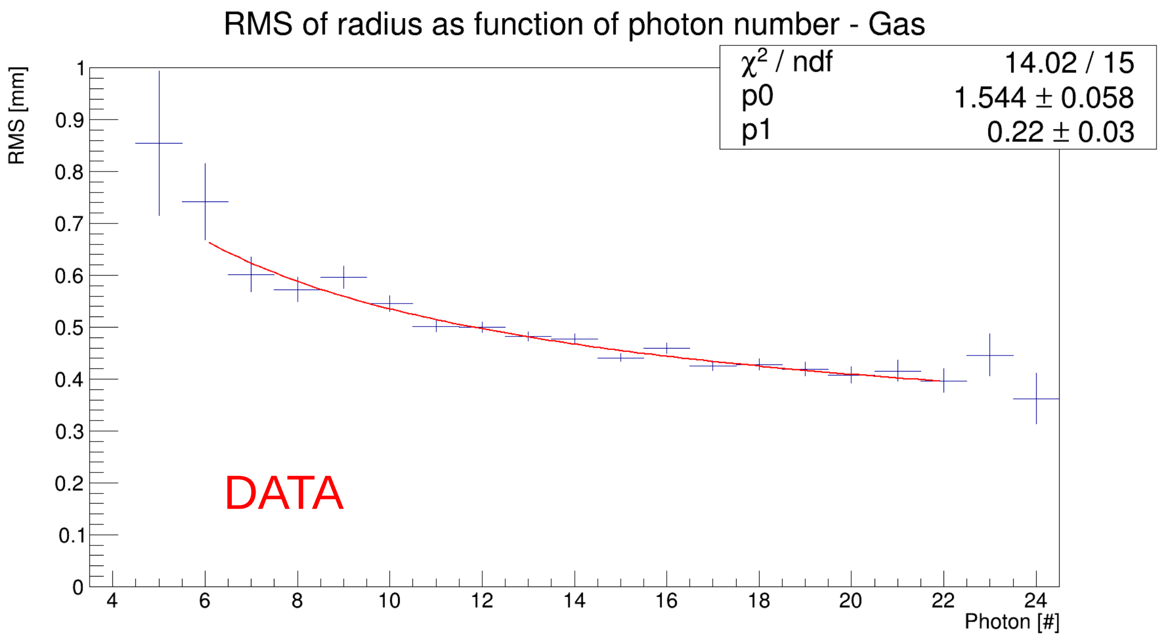


Radius of ring produced from 12 GeV π^- by crossing the gas



Radius of ring produced from 12 GeV π^- by crossing the aerogel

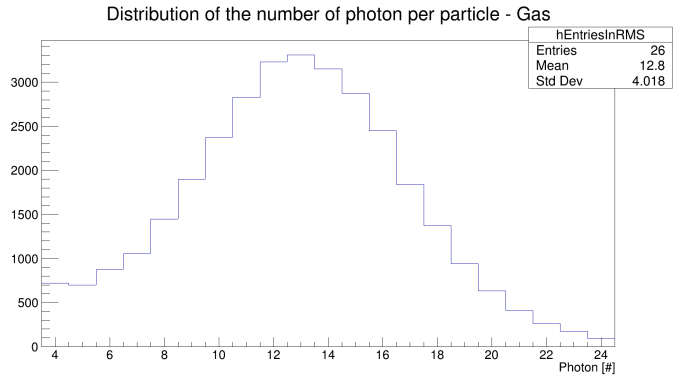
Result: Gas resolution



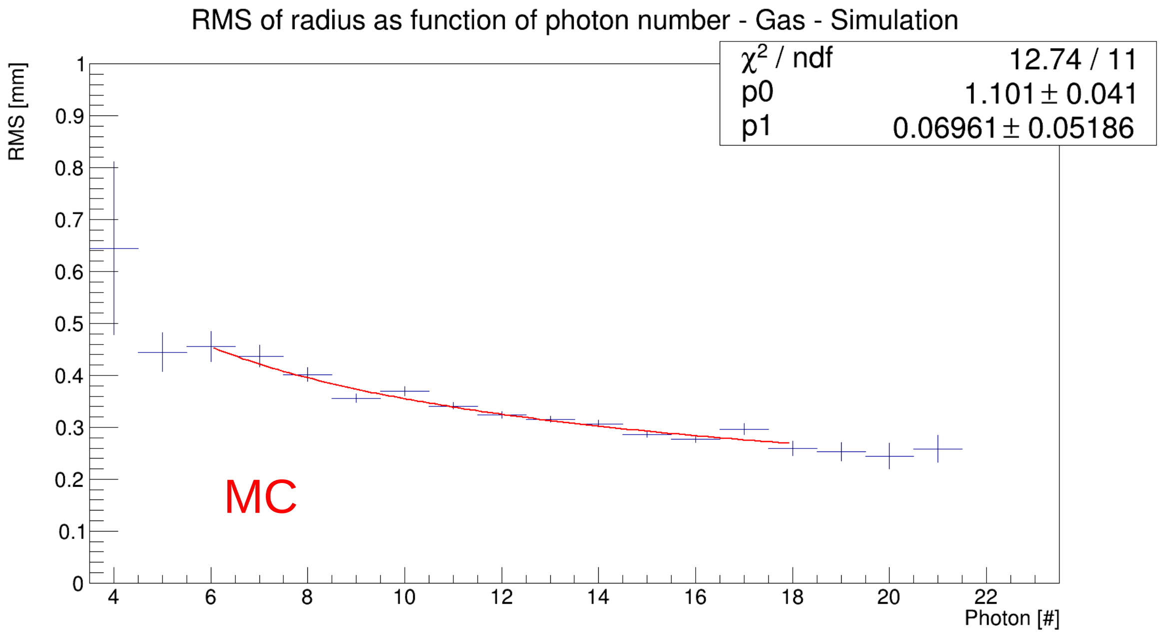
Fitting function: $$y = \sqrt{\frac{p_0^{\,2}}{x} + p_1^{\,2}}$$

p_0 = single photon resolution
p_1 = single particle resolution constant term

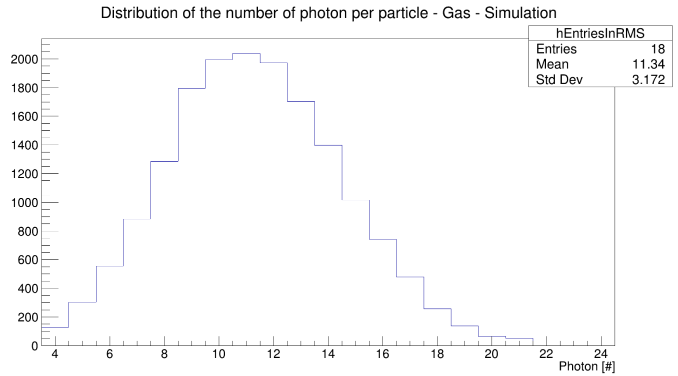
p_1 is not compatible with zero, so there is some residual systematic effect



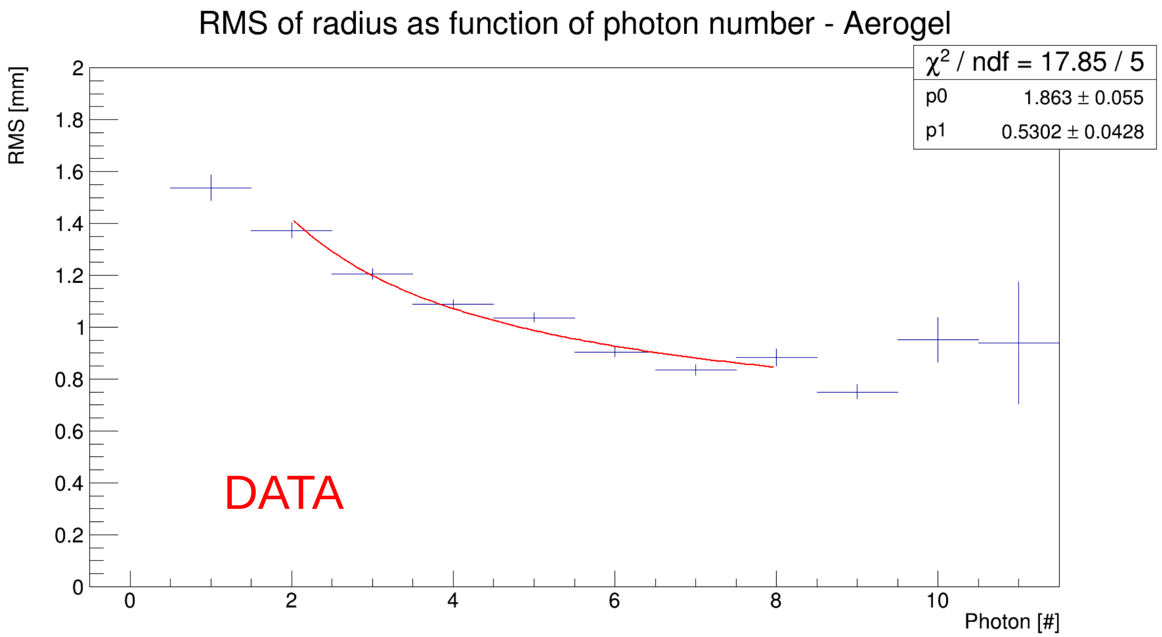
Simulation: Gas resolution



Gas	Data	Simulation
p_0 [mm]	1.5	1.1
p_1 [mm]	0.22	0.07
Avg photon	12.8	11.3



Result: Aerogel resolution



Fitting function: $$y = \sqrt{\frac{p_0^2}{x} + p_1^2}$$

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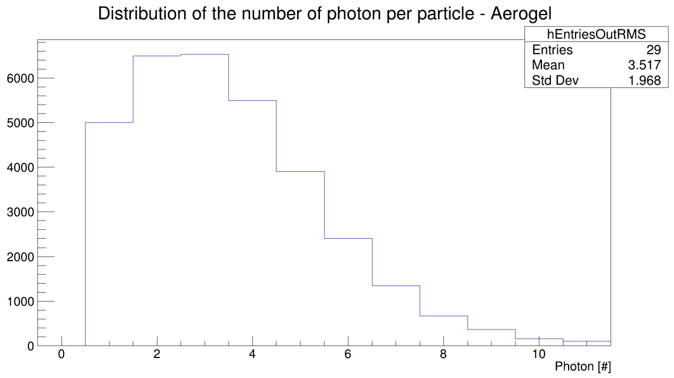
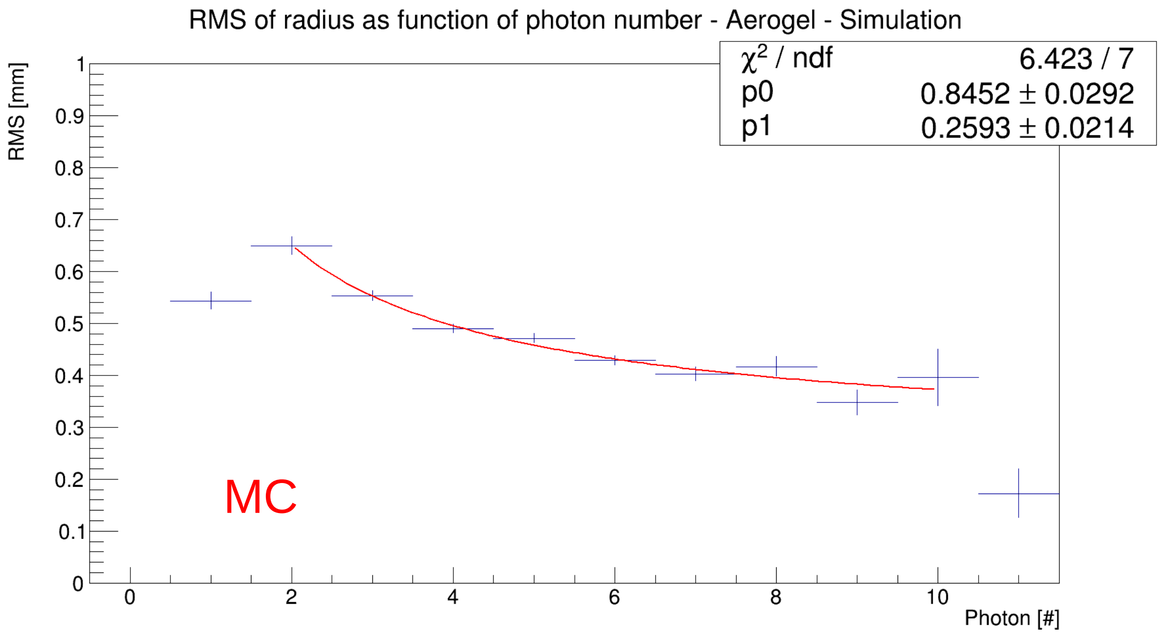
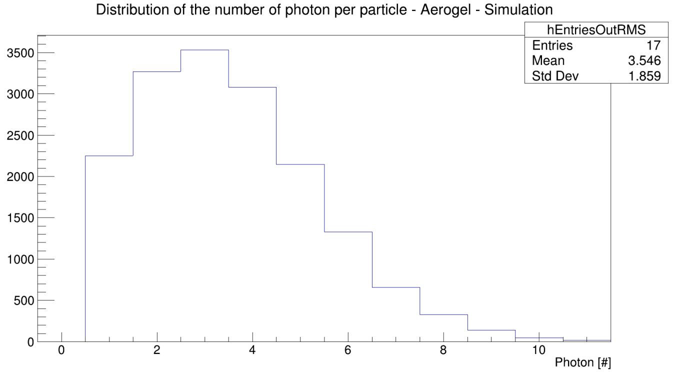
p_1 is not compatible with zero, so there is some residual systematic effect



Simulation: Aerogel resolution



Gas	Data	Simulation
p_0 [mm]	1.9	0.8
p_1 [mm]	0.53	0.26
Avg photon	3.5	3.5



Conclusions and future perspectives

- We develop a dRICH prototype and SiPM program to address the challenges of PID at the future EIC.
- We operated the dRICH prototype and all its subsystems, collecting a good set of data to compare with simulations.
- The obtained results are promising, but the expected resolution in not yet achieved.
- A larger amount of data will be acquired in the new test beams in fall 2022, making it possible to carry out systematic studies on the dRICH performance towards the design resolution.
- A new version of the reconstruction and analysis software is under development, which will allow an improved resolution and online monitoring.
- An improvement of the simulations is on going, based on the ongoing optical characterization of the dRICH components.

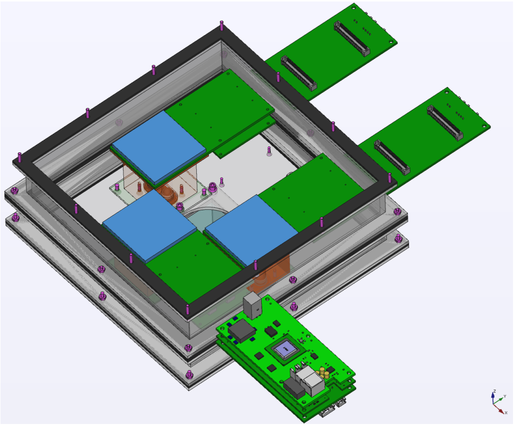
The end

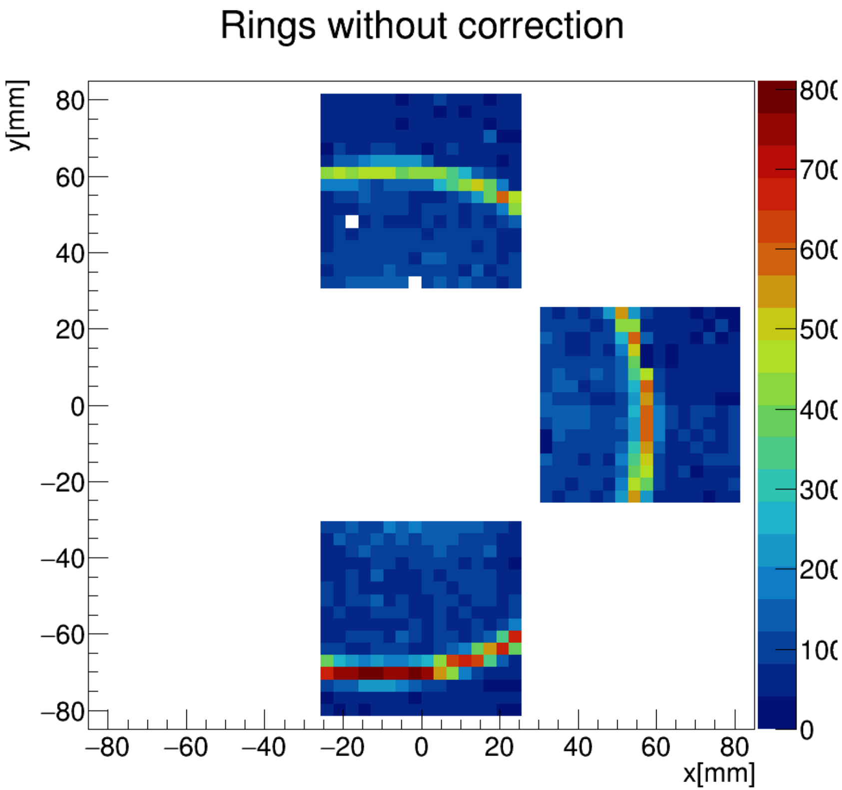
Thanks for your attention

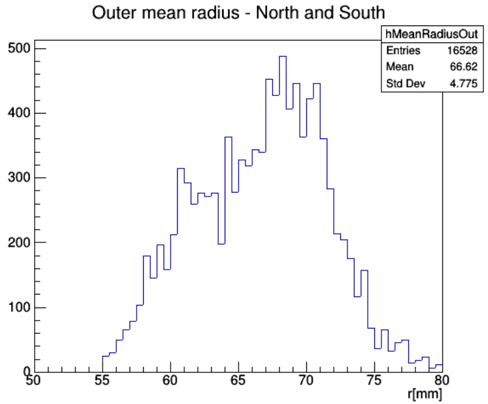
Backup slides

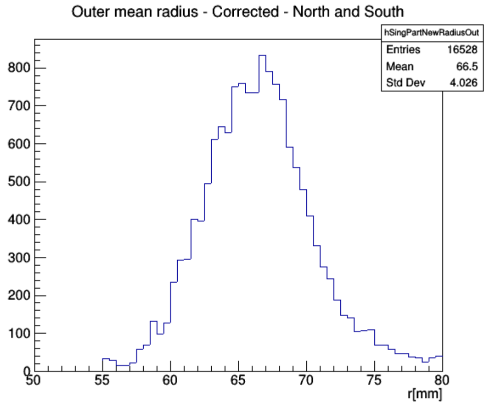
October parasitic runs at SPS

The MPPC detectors were used.
Data analysis is ongoing, but the different geometry requires a partially new data analysis which is under development.

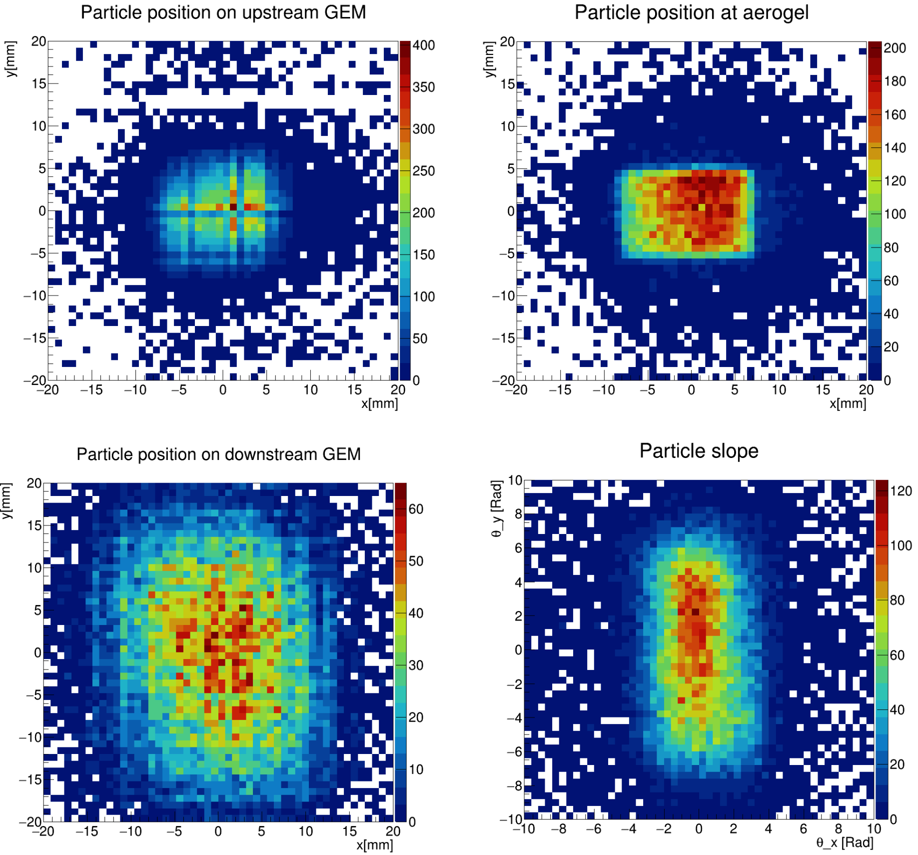








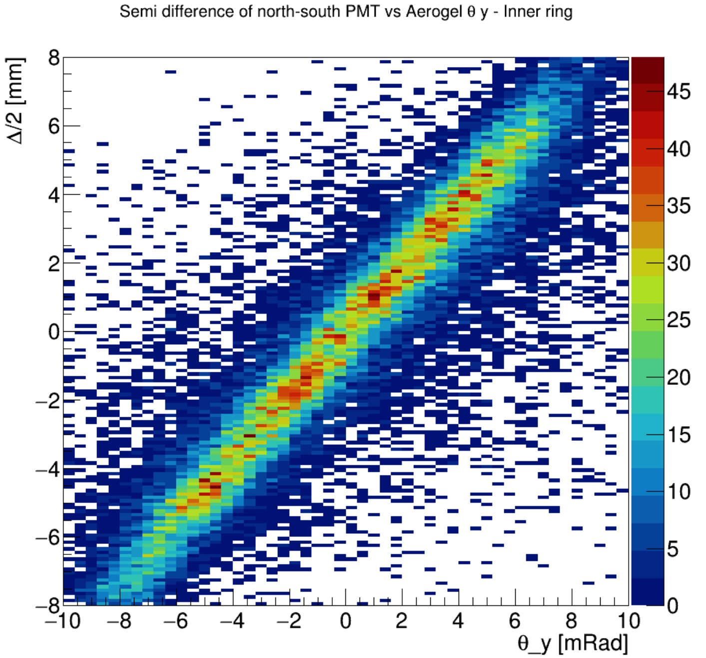
GEMs tracking



The GEMs provide the track of each event.

In this run, only the GEMs and the frontal scintillator were used as trigger.

We found a correlation between the semi-difference of the radius measured from two opposite MAPMTs and the particle slope provided by GEMs.



Computing the dRICH alignment

We define the coordinate of the dRICH-optical center as the mean value of the semi-difference between the radius measured in two opposite PMTs, evaluated by using only small angle events (slope < 1 mRad). This is a dRICH optical property, and the values are the same for each run (unless change on the mirrors orientation).
The coordinates of the single event center are provided by the sum of the optical center and the product of particle slope and length of path inside dRICH.