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

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EIC_NET

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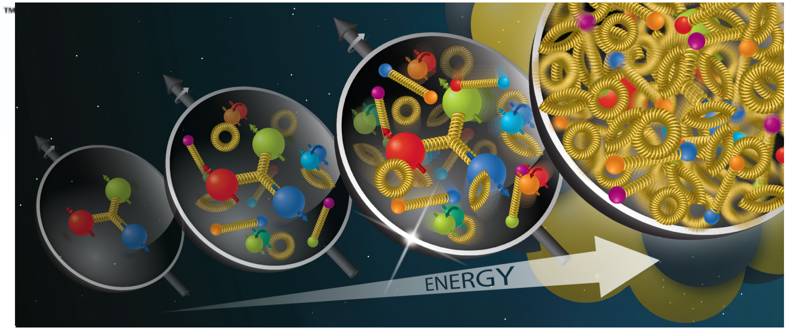
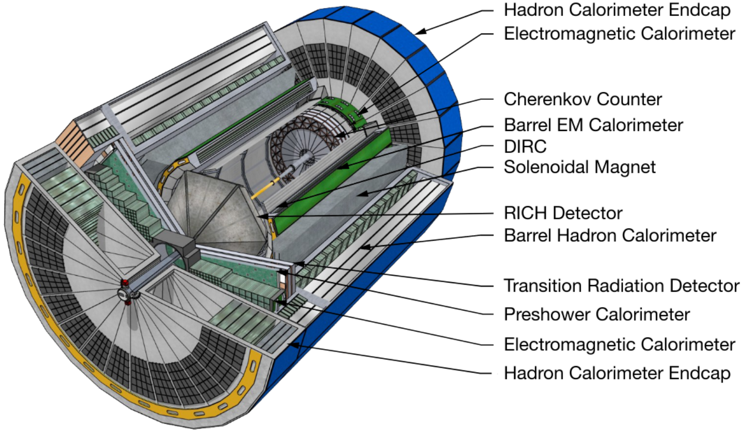
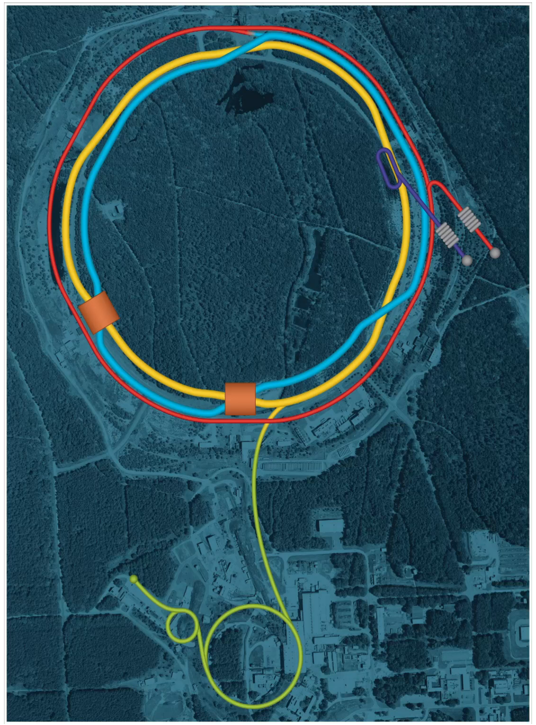
The Electron-Ion Collider

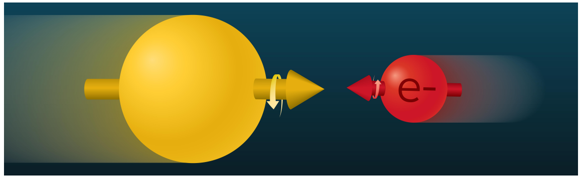
Brookhaven National Laboratory

- 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} $cm^{-2}s^{-1}$)





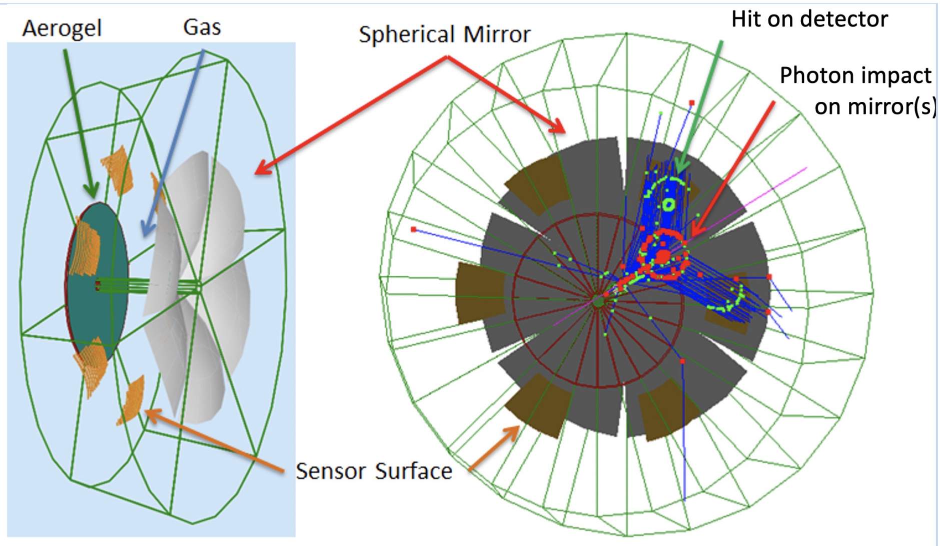




The dRICH at EIC

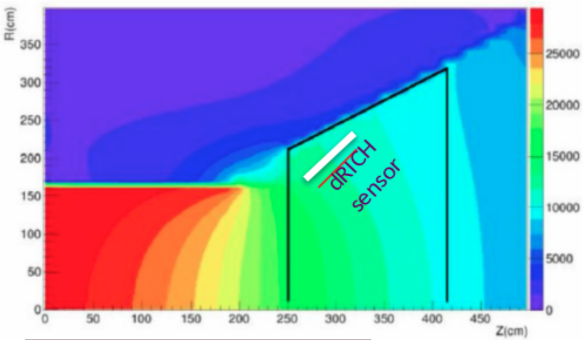
Challenges:

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

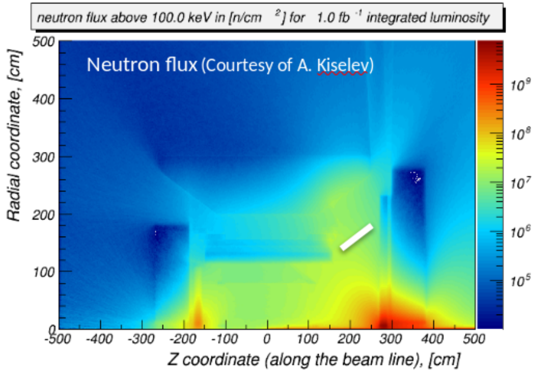


Effective solutions, part of EIC reference detector
Radiators: aerogel (n_{aero} ~1.02) + gas C2F6 (n_{gas} ~1.0008)
Detector: 0.5 m^2/sector, 3x3 mm^2 pixel, SiPM option

Magnetic field



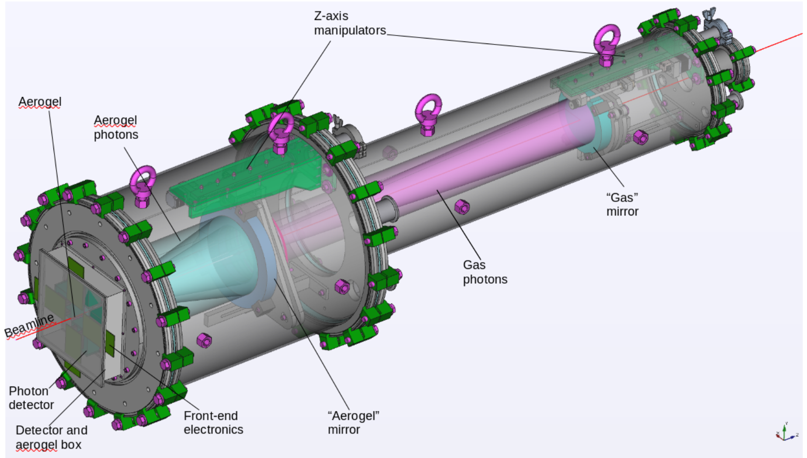
SiPM option



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

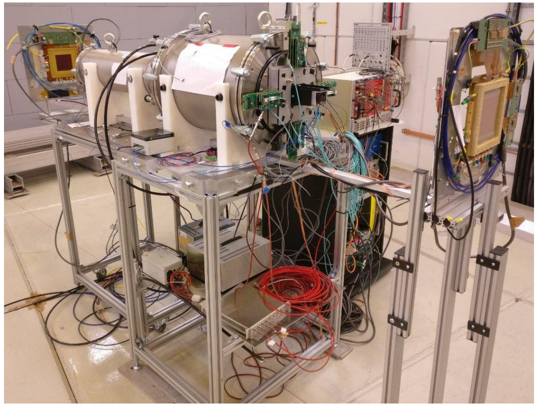
Study on radiation mitigation on SiPM

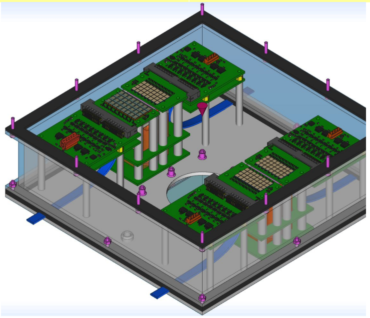
The dRICH prototype 2021 test beams



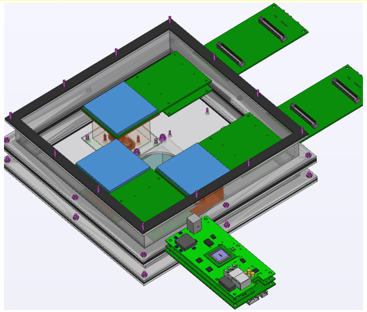
Test	Cherenkov medium	Energy [GeV]	Beam	Photon detector and DAQ
September at SPS	Aerogel	40÷120	π^+ π^-	SiPM and ALCOR
October parasitic runs at SPS	Aerogel	120	μ^- π^-	MPPC and MAROC
October at PS	Aerogel and Gas (C_2F_6)	4÷12	p and π^+ π^-	MAPMT and MAROC

The dRICH setup at PS

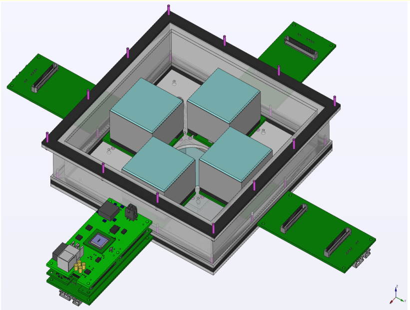




SiPM



MPPC

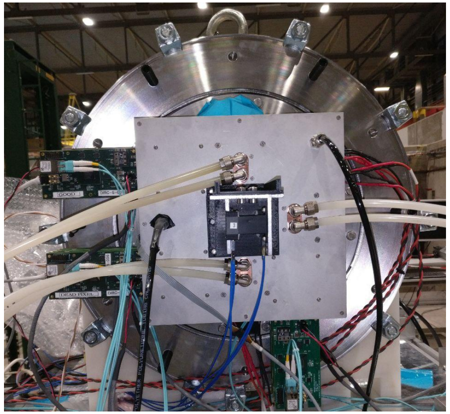


MAPMT

The dRICH prototype components

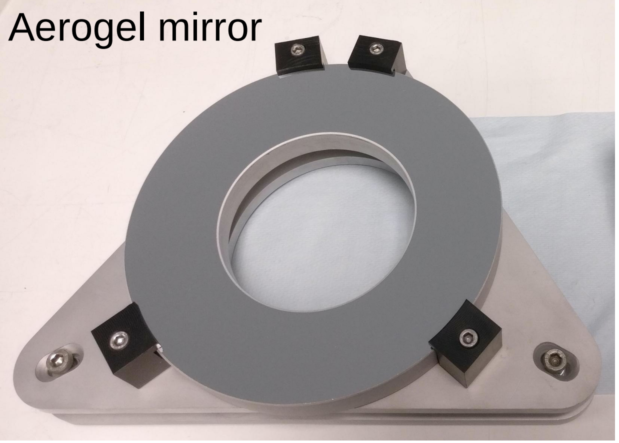
dRICH chamber

Gas mirror

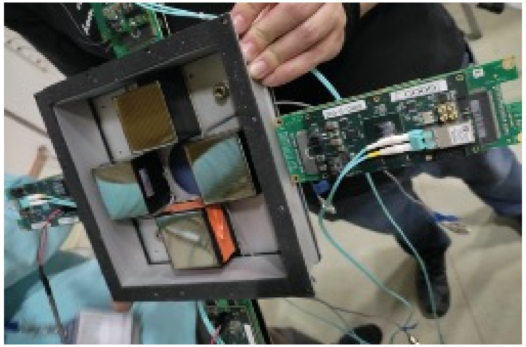


Frontal view

Support



Aerogel mirror

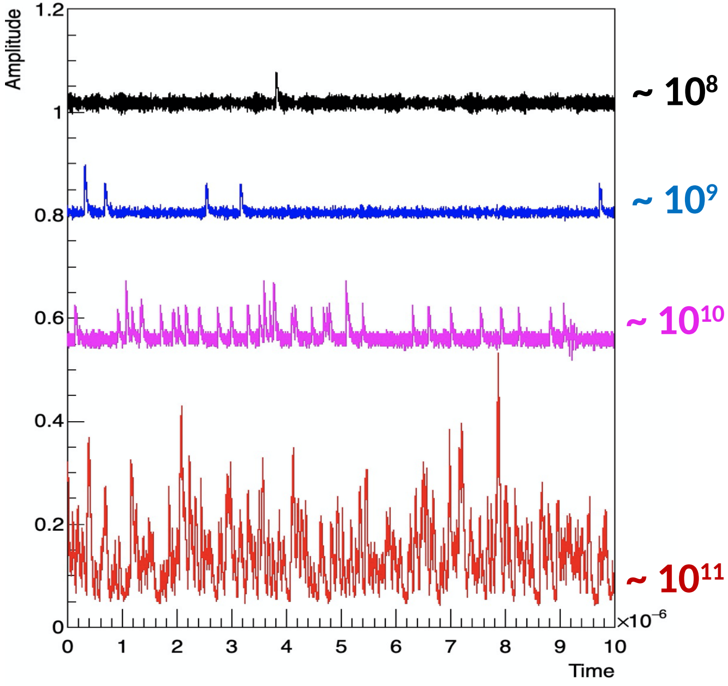


MAPMT
detector box

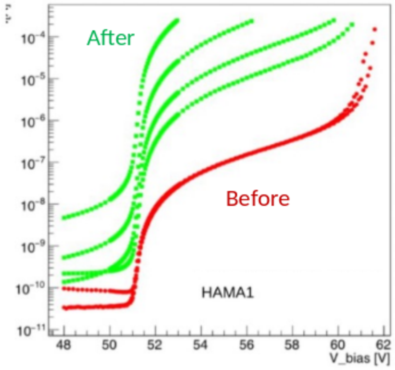
SiPM study

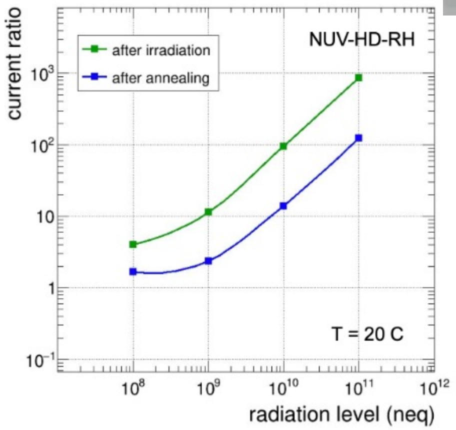
A study of radiation effects on SiPM and recover by annealing is ongoing by EIC_NET.
We developed custom carriers for SiPMs of several producers, which can bear the high temperature (up to 170°C) of the annealing process.

Some carriers were irradiated in may at TIFPA (Trento) and annealed in the following months at Bologna and Ferrara



IV characteristic





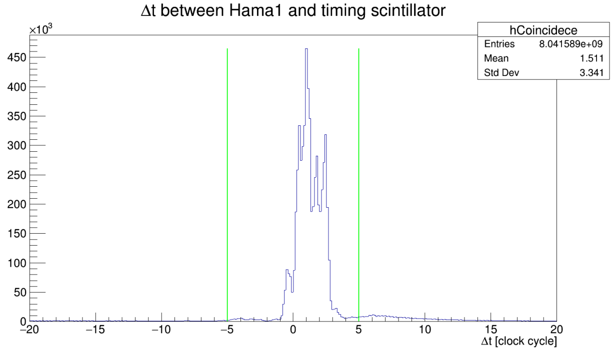
In just one week of annealing the SiPMs allows to recover the status associated to the 1 low-order irradiated detector.

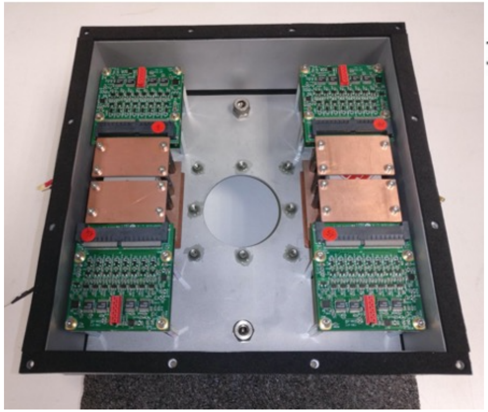
September tests at SPS

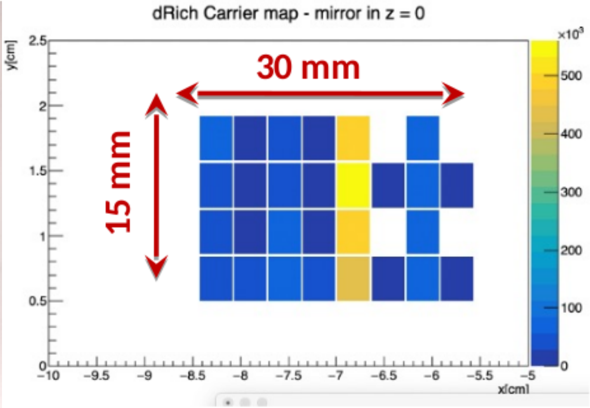
The september test main goal was to implement the readout chain based on not irradiated SiPMs and ALCOR

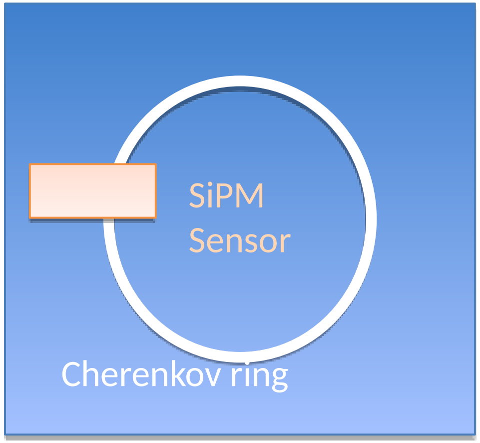
The ALCOR chip is designed to readout signals at high rates (500 kHz per channel) with low resolutions (50 ps time binning).

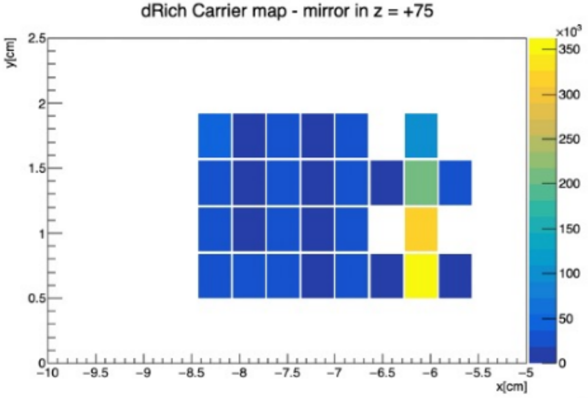
The plot shows the coincidence peak between the output of dRICH and the timing scintillators, which the trigger consisted of, proving the result achieved.







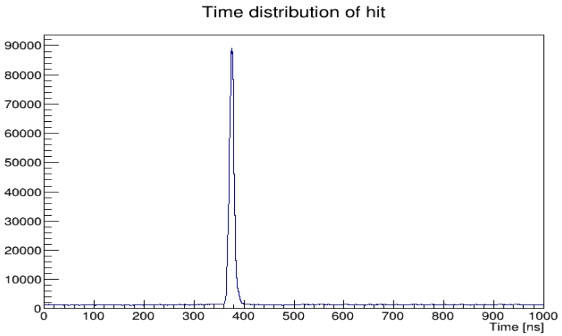




October test at PS

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

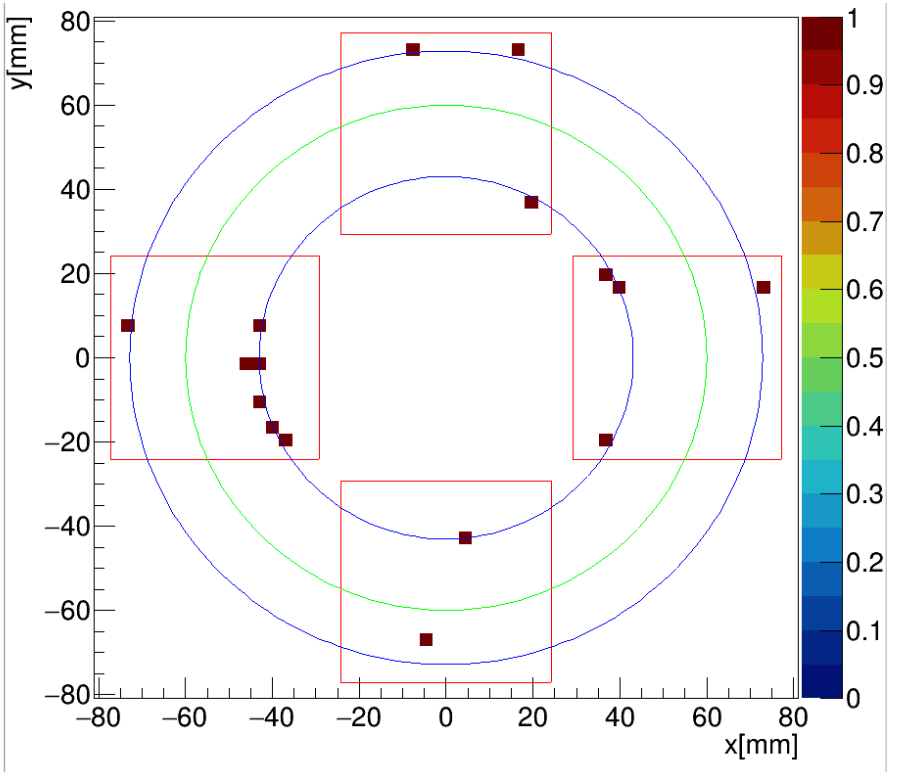
Difficulties:
- The MAPMTs came later for a overlap with another test beam
- The beam was not optimized.
- One component in the beamline was wrong → waste of time
- The beam Cherenkov detector didn't work



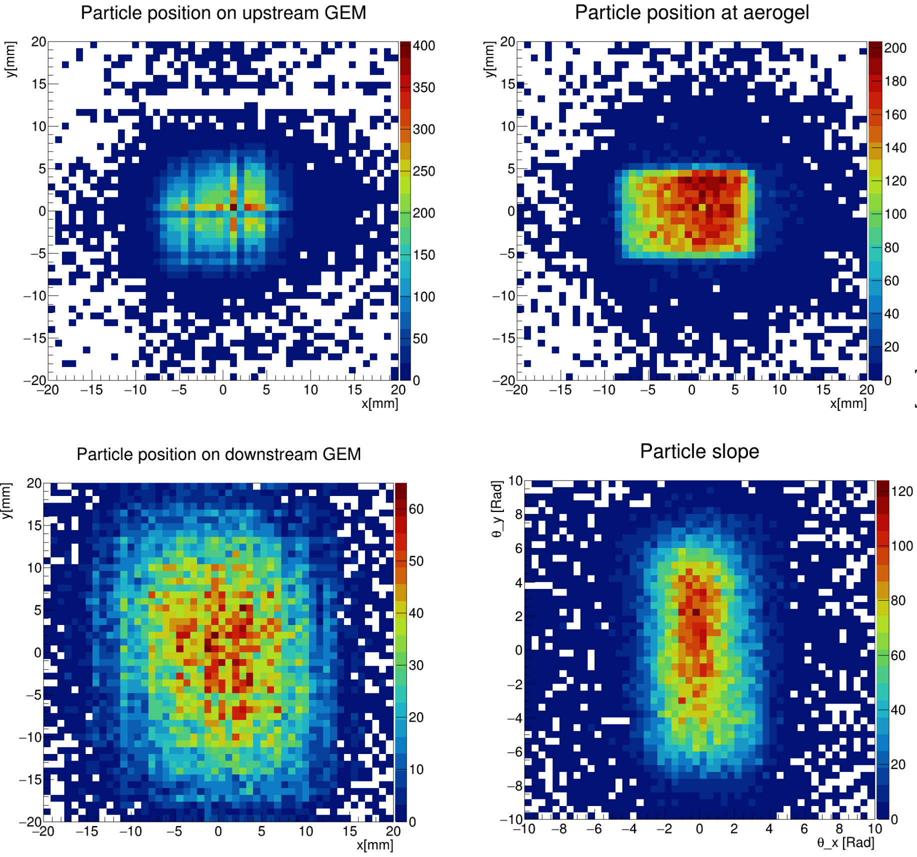
Distribution of time of hit, the coincidence peak is clearly visible. The time calibration is being developed, this will allows to narrow the time coincidence window

The right plot shows one event measured at PS.

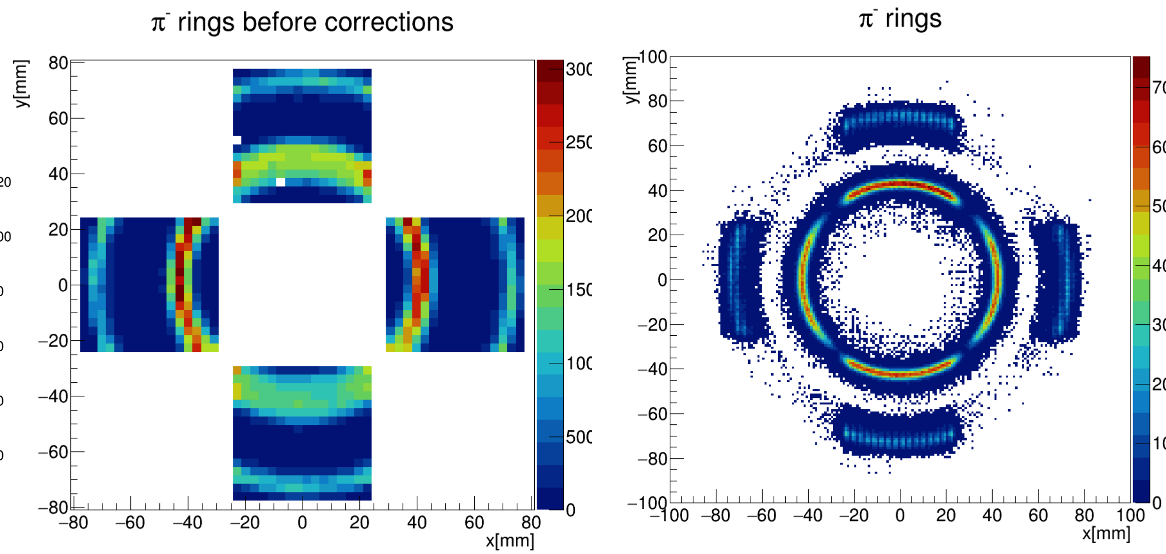
Legend:
- Little red square, a pixel of the MAPMTs turned on by a photon.
- Red line, edge of MAPMTs.
- Green, geometrical cut applied to distinguish gas (inner) and aerogel (outer) photon.
- Blue, gas and aerogel rings reconstructed.



dRICH alignment & data corrections



A tracking system based on two GEM detectors was used during the test beams and it allows to show the divergence of the beam.
The combination of the optical center of the measured rings and the track of particles provided by GEM detectors allows to develop the dRICH alignment and data correction algorithms.



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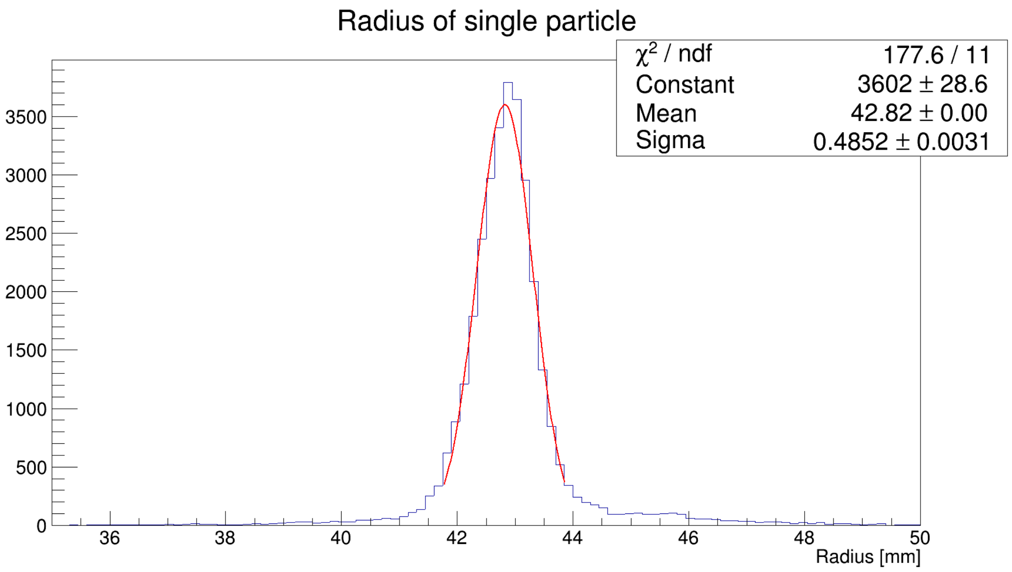
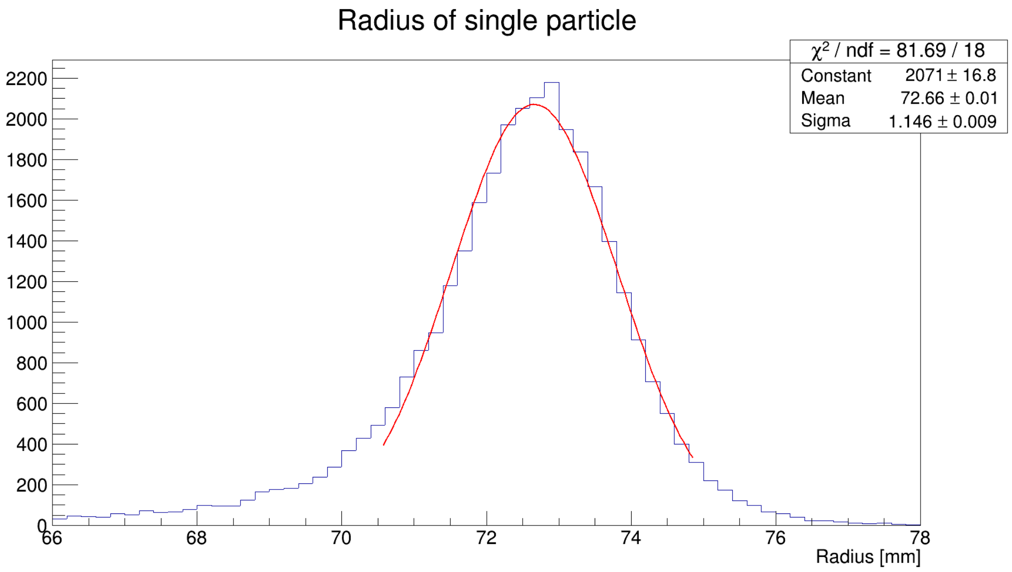
Preliminary results

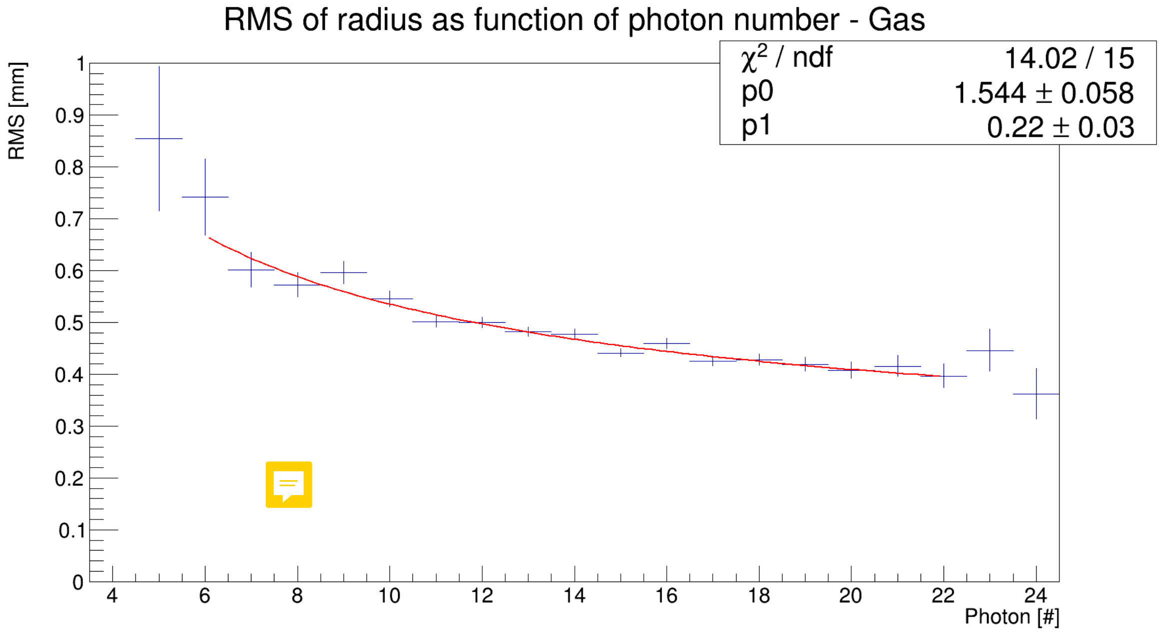




Radius of ring produced from 12 GeV π^- by crossing the gas

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

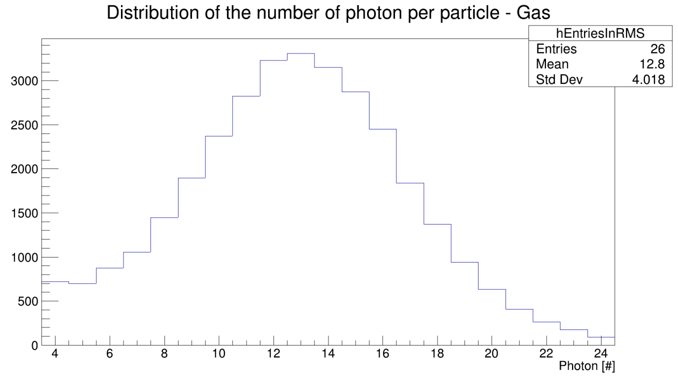
Result: Gas resolution



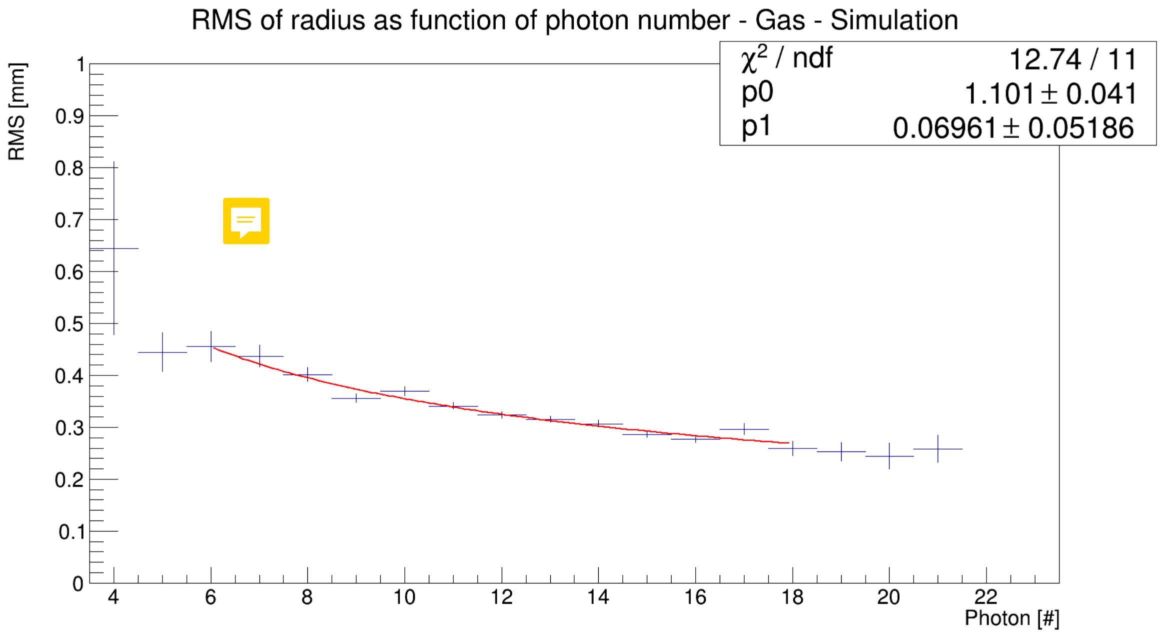
Fitting function: $y=\sqrt{\frac{p_0^2}{x}+p_1^2}$

p_0 = single photon resolution
p_1 = single particle resolution if photon number grows to the infinity

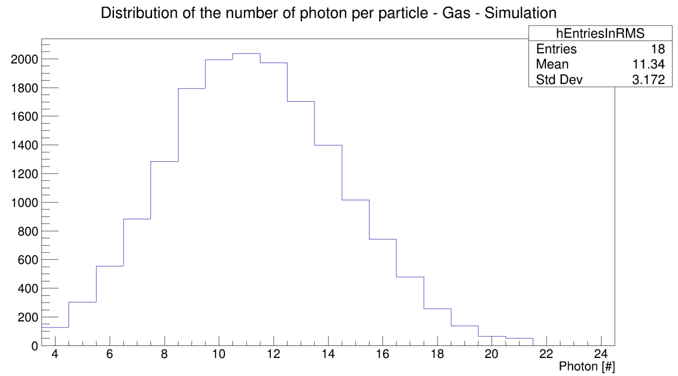
p_1 is not compatible with zero, so there are yet some systematic effect that are unclear.



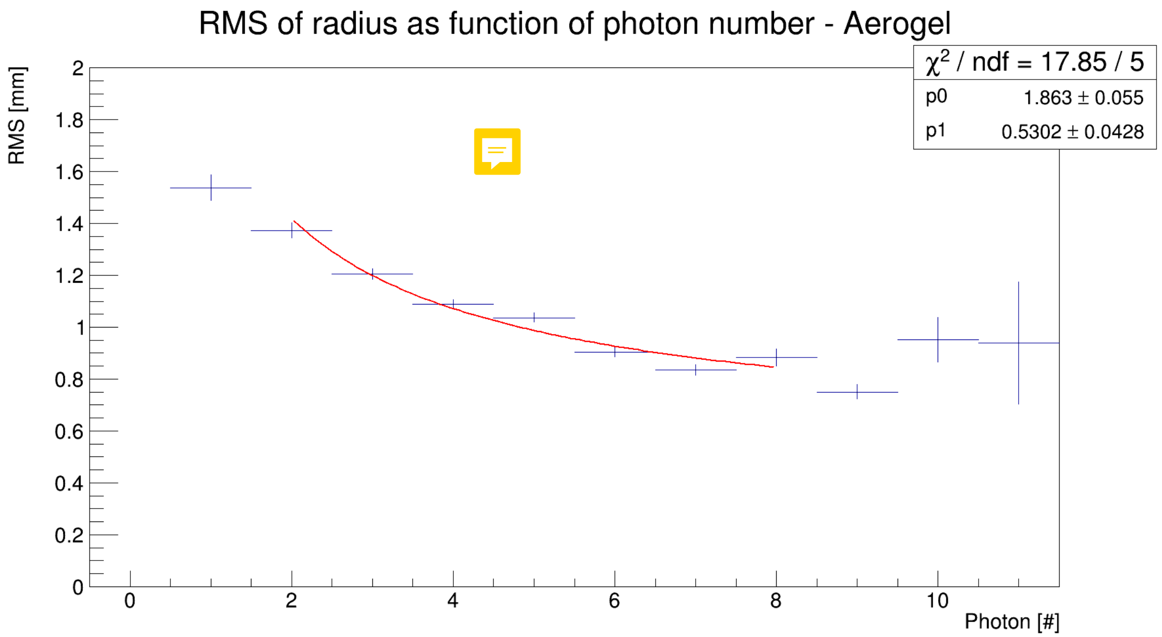
Simulation: Gas resolution



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

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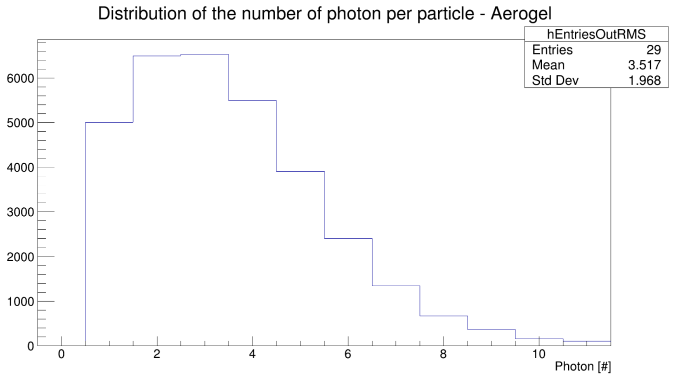
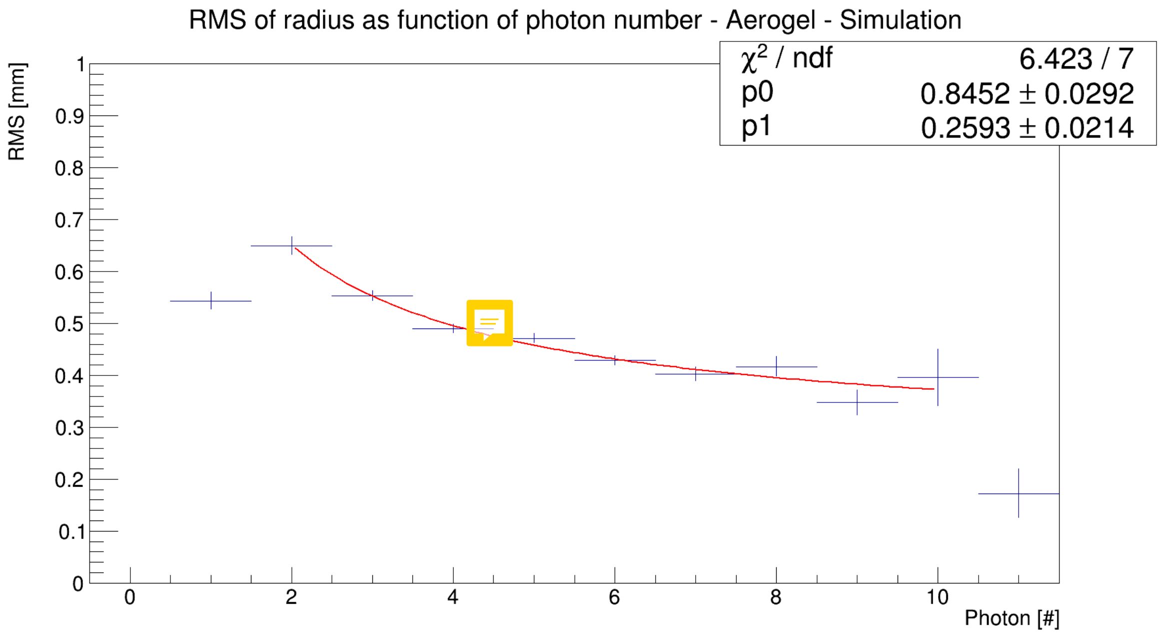
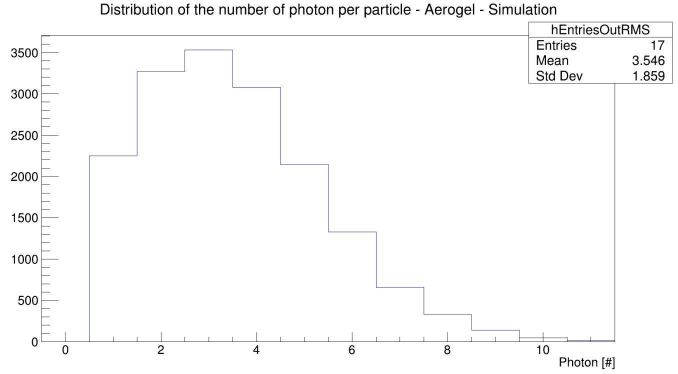
p_1 is not compatible with zero, so there are yet some systematic effect that are unclear.



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

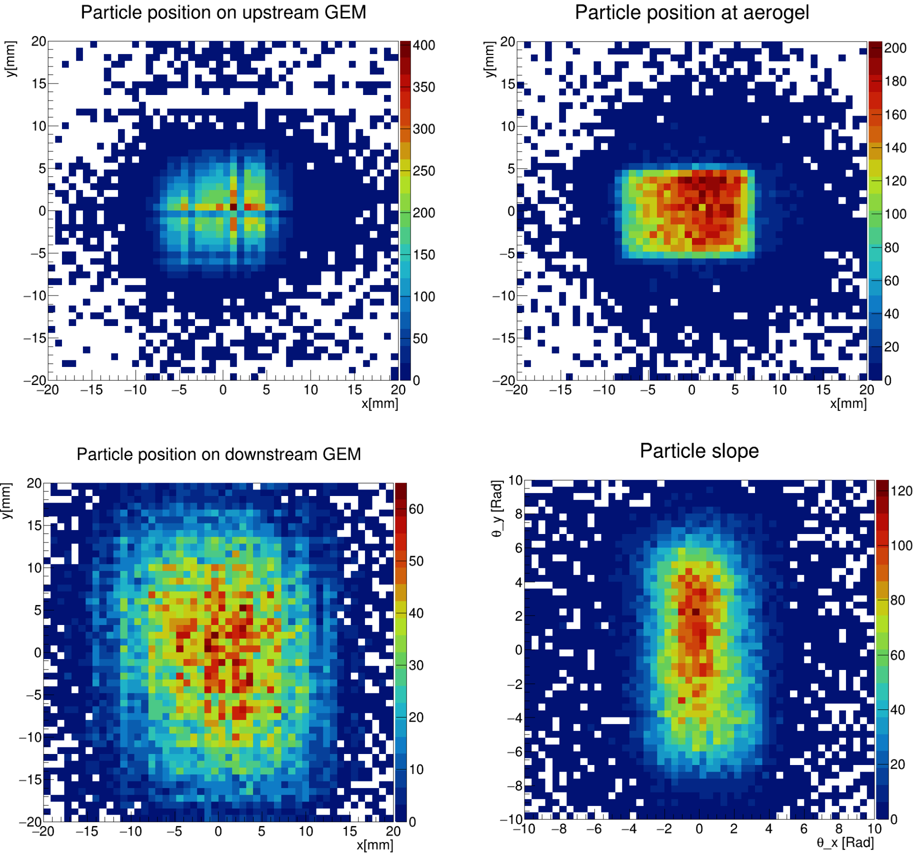
- We operated the dRICH and all its subsystems, collecting data to compare with simulations.
- The obtained results are partially in agreement with simulations, but the expected resolution in not yes achieved.
- A larger amount of data will be acquired in the new test beams in fall 2022, making it possible to carry out systematic studies on the dRICH performance.
- A new version of the reconstruction and analysis software is under development, which will allow to quickly obtain the results during the new tests.
- An improvement of the simulations is on going, using the measurement of the optical properties of some components.

The end

Thanks for your attention

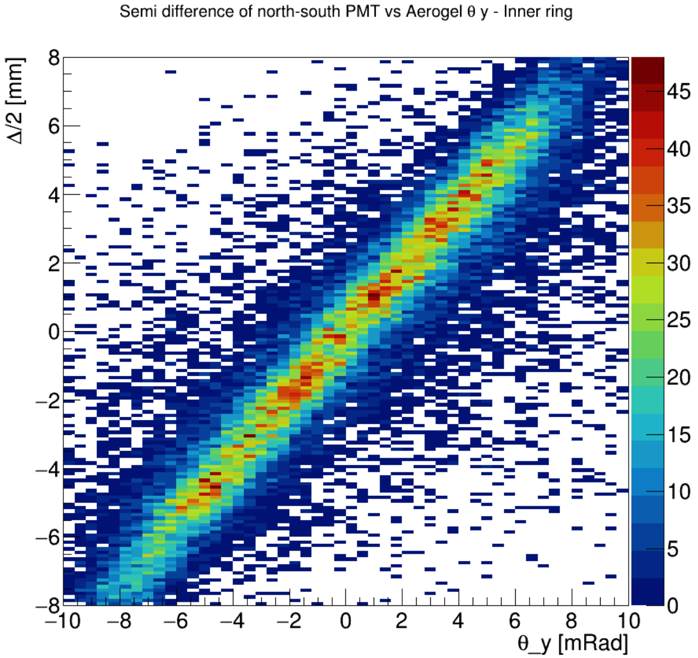
Backup slides

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.