dRICH beam test CERN-PS May 2024

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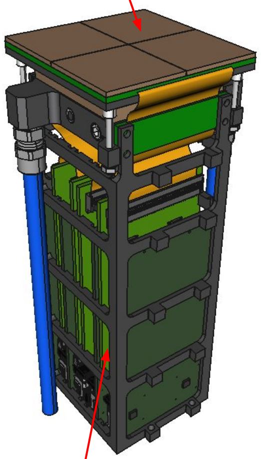
2023 test beam at CERN-PS

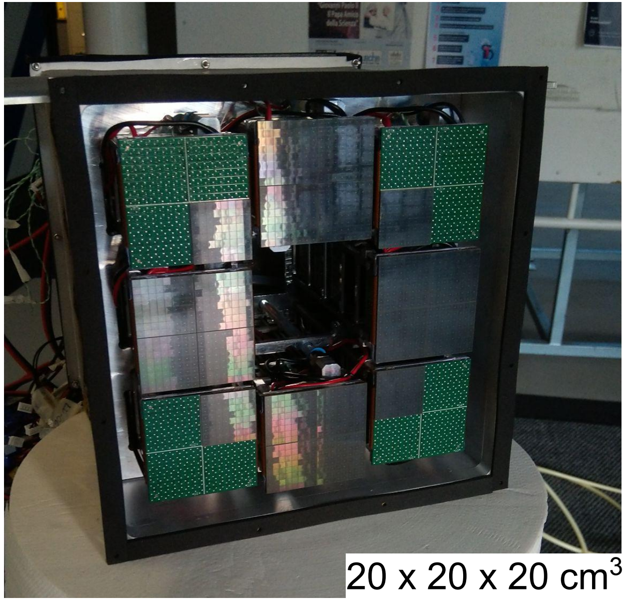
successful beam test with prototype SiPM photodetector units (CERN-PS, ended on 18th October)

PDU

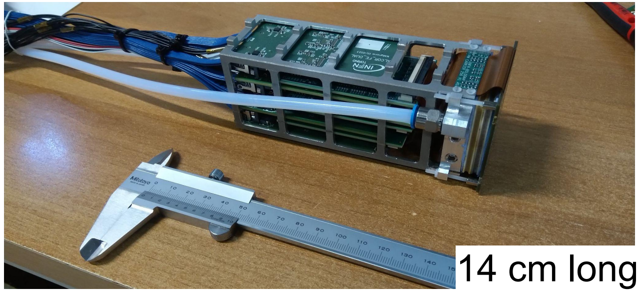
4x SiPM matrix arrays
(256 channels)



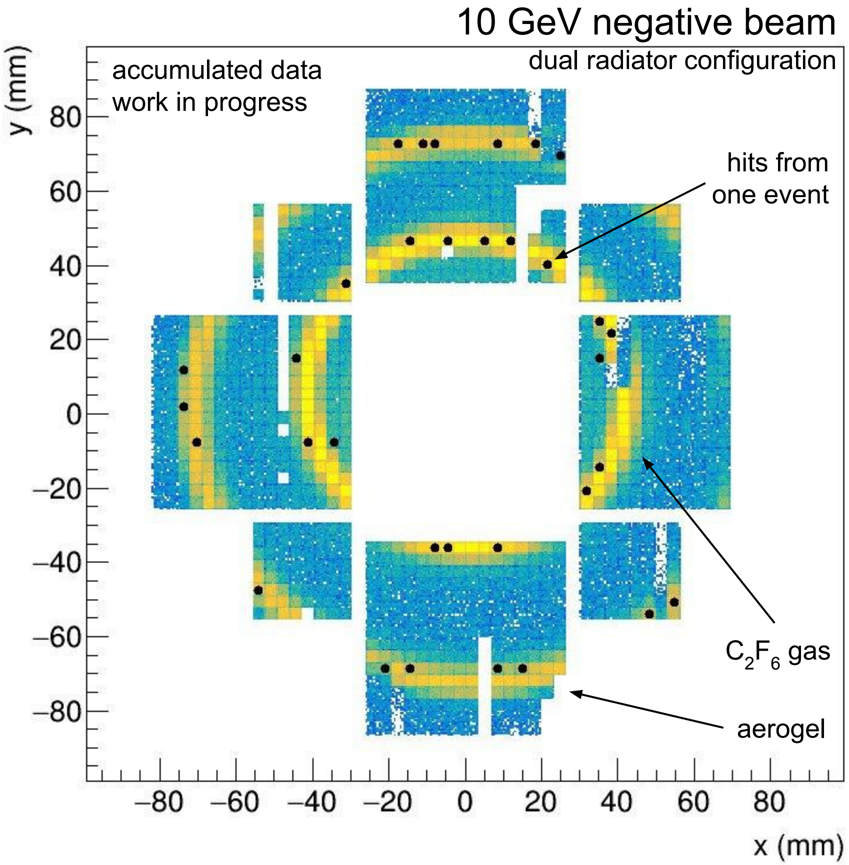
front-end electronics
(ALCOR ASIC inside)



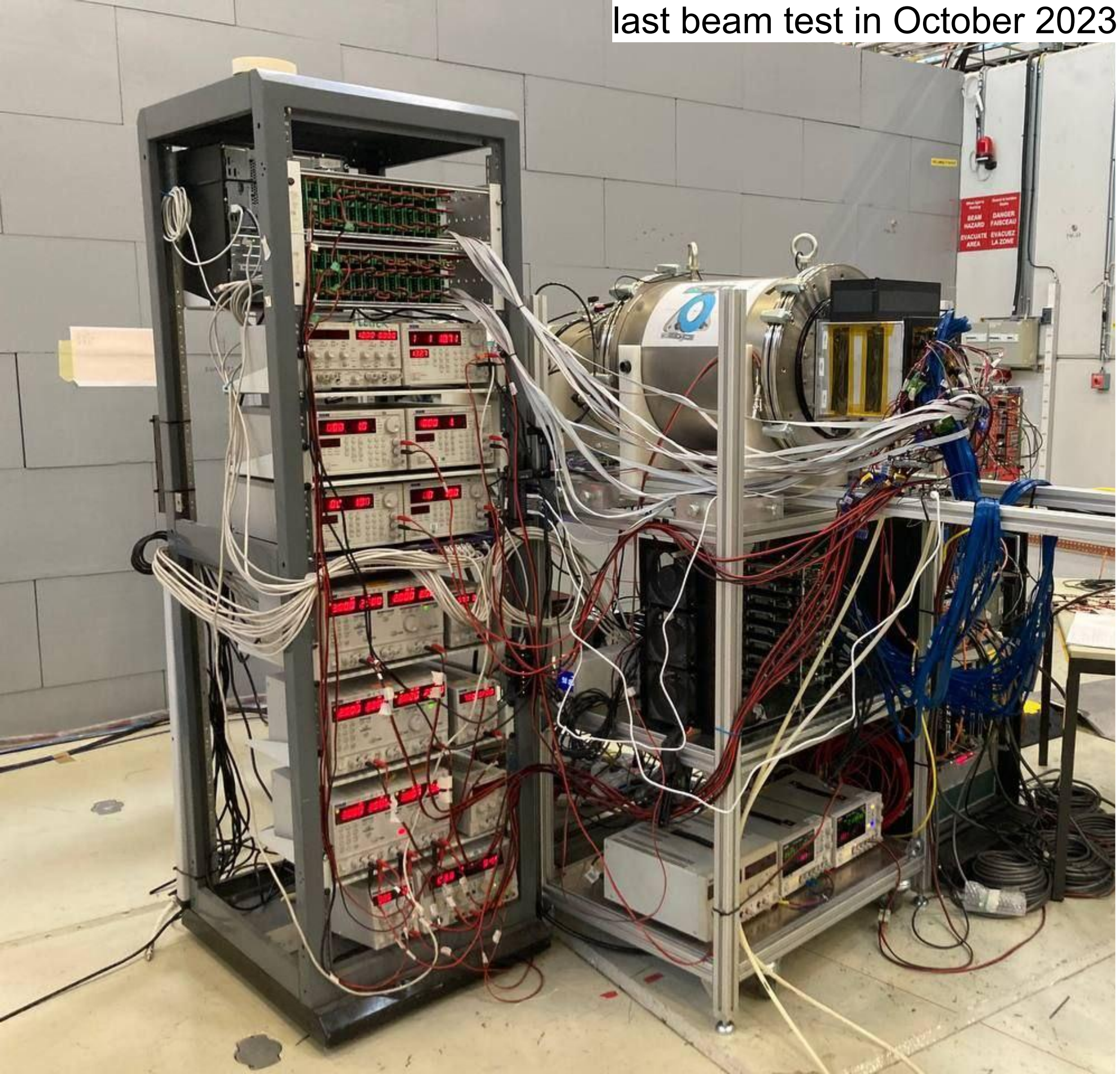
20 x 20 x 20 cm^3

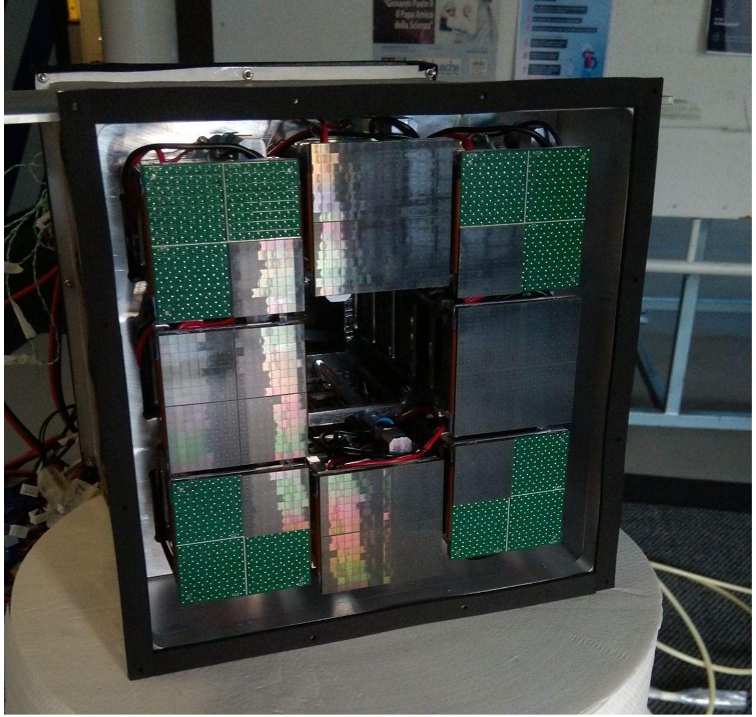


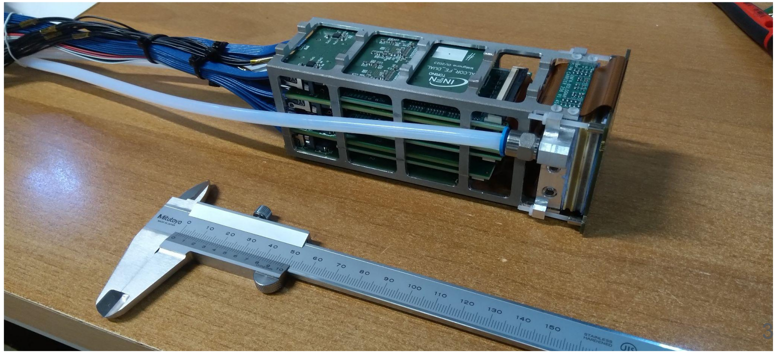
14 cm long



last beam test in October 2023







2024 hardware goals (important)

✅ **replace the partial PDUs at the corners**

- have 8x full 256-channels PDUs
- 2048 readout channels
- full ring imaging

✅ **test different Hamamatsu sensors**

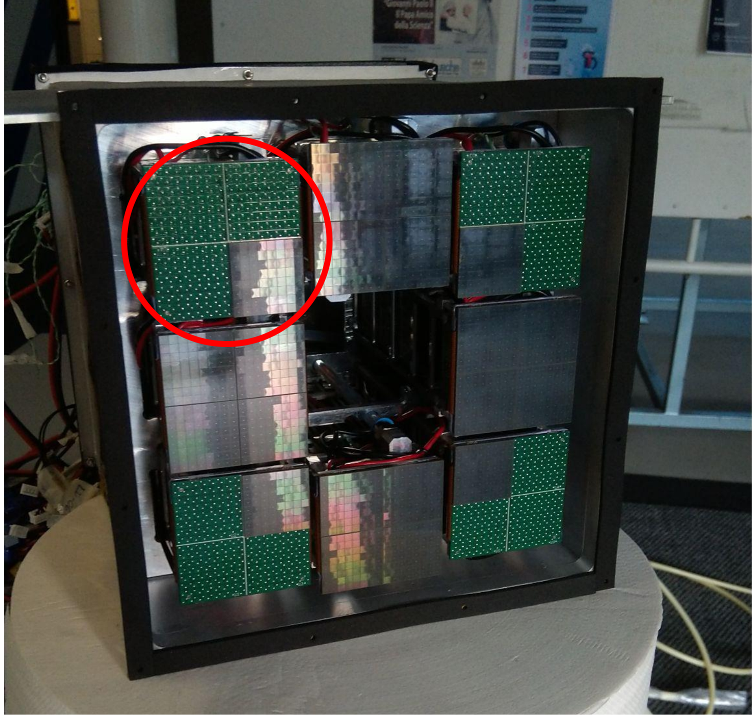
- we have matrices to build
  - 4x S13360-3050 PDU heads
  - 4x S13360-3075 PDU heads
  - 4x S14160-3050 PDU heads
- although not obviously simple to change configuration during beam test
- we eventually decided to equip the readout with
  - 4x S13360-3075 PDUs
  - 4x S13360-3050 PDUs

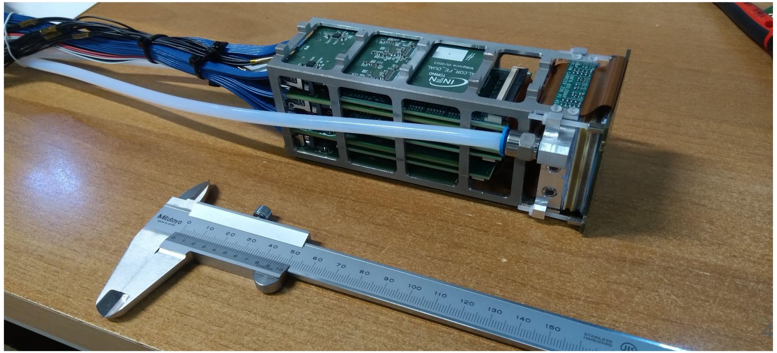
✅ **replace faulty electronics**

- use the new ALCOR v2.1 chips

✅ **include a tracker**

- GEMs or another tracking system
- add information on track direction





2024 hardware goals (less important)

❌ **sub-zero cooling with liquid fluid**

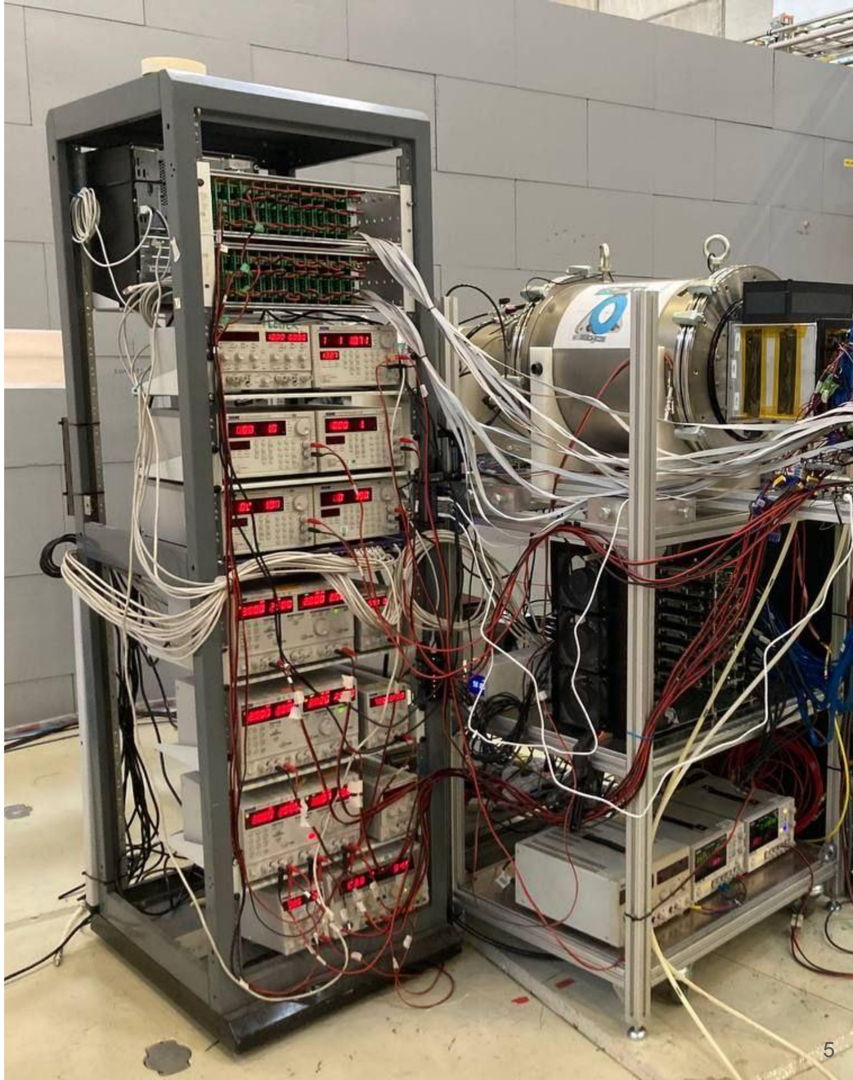
- this will be very unlikely
- presently still issues with tiny fluid leaks
  - even if we understand how to deal with soon, we will likely need a long rework of the PDU cooling system
  - unlikely to fit in the preparation schedule
- baseline is to keep Peltier cooling
  - need to improve humidity, on the right track

✅ **use compact power-supply system**

- LV distribution based on CEAN SY mainframe
  - might help reduce rack allocated space
  - will look closer to a real experiment detector

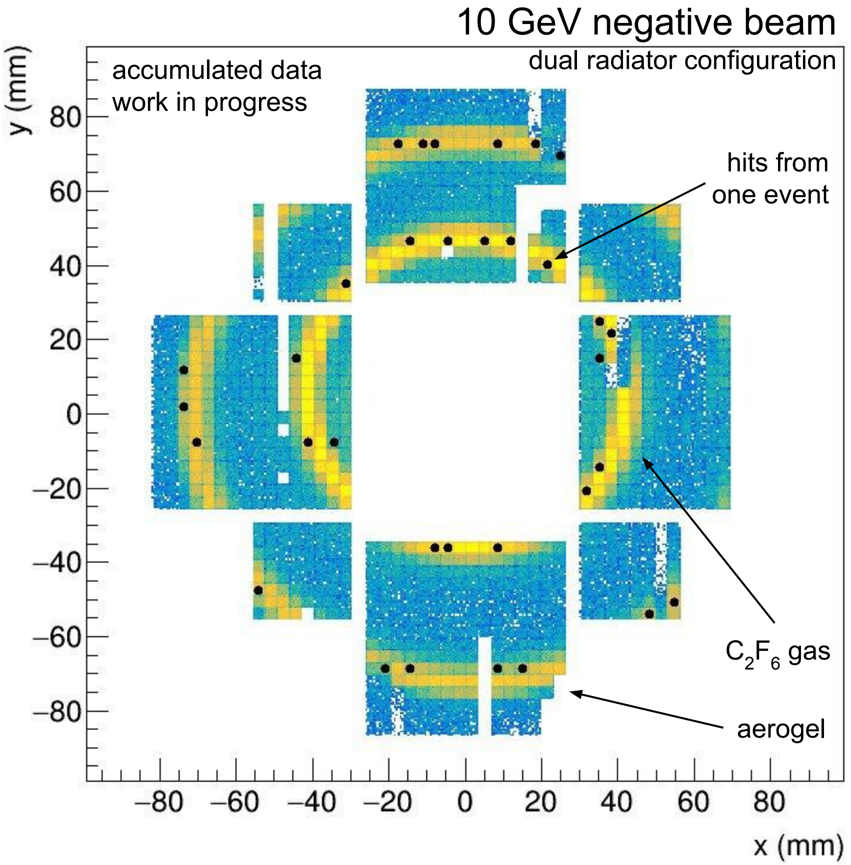
❌ **improve timing system**

- currently based on two scintillators
  - time resolution is not fantastic: 150-200 ps
- would be nice to go below 50 ps
  - system must be in sync with ALCOR readout
  - not impossible, but need extra work and thinking



2024 Physics goals (from the top of my head)

- **number of photoelectrons**
  - aerogel and gas
    - in 2023 we did not collect much gas data
  - compared to reference MAMPT readout
  - with different Hamamatsu SiPM sensors
  - with different aerogel
    - refractive index
    - thickness
  - with wavelength filters
    - number of SiPM detected photons vs. λ
    - effective SiPM chromaticity
- **single-photon angular resolution**
  - tune the position of mirrors for optimal focus
    - in 2023 we did it almost "by eye"
    - we need to have online performance analysis
  - make use of tracking system
- **particle identification**
  - as a function of beam momentum
  - with tracking and more photons might yield something unexpectedly nice 😉

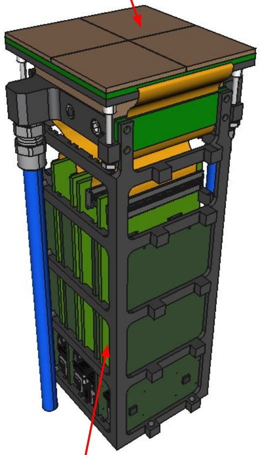


2024 test beam at CERN-PS

another successful beam test with prototype SiPM photodetector units (ended on 5th June)

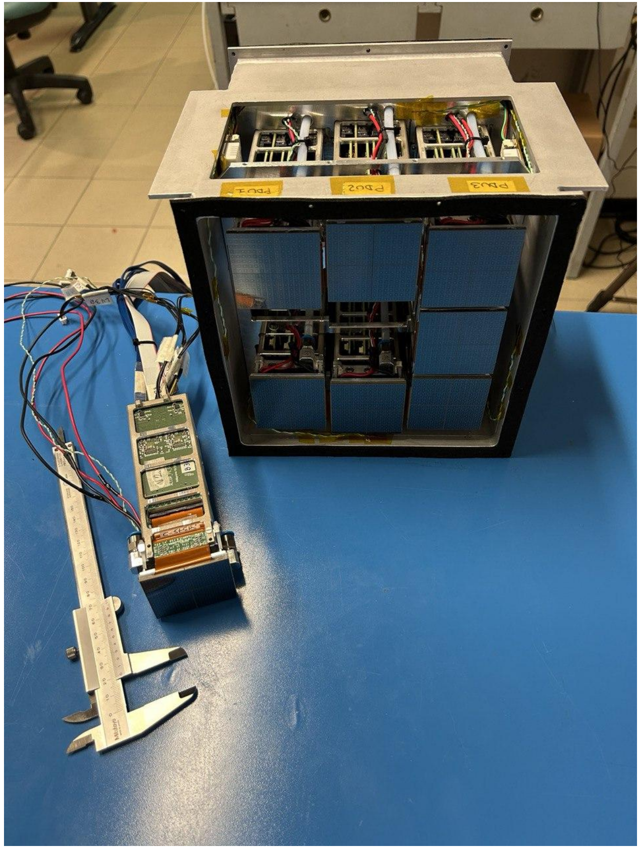
PDU

4x SiPM matrix arrays
(256 channels)



front-end electronics
(ALCOR ASIC inside)

SiPM readout box was dismounted
upgraded with full acceptance (2 k channels)
equipped with more temperature sensors



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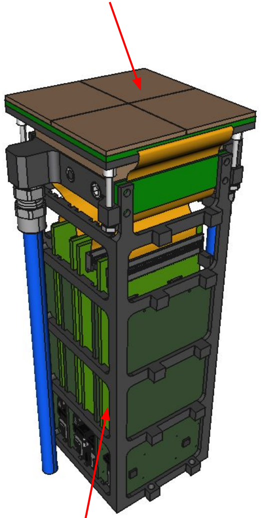

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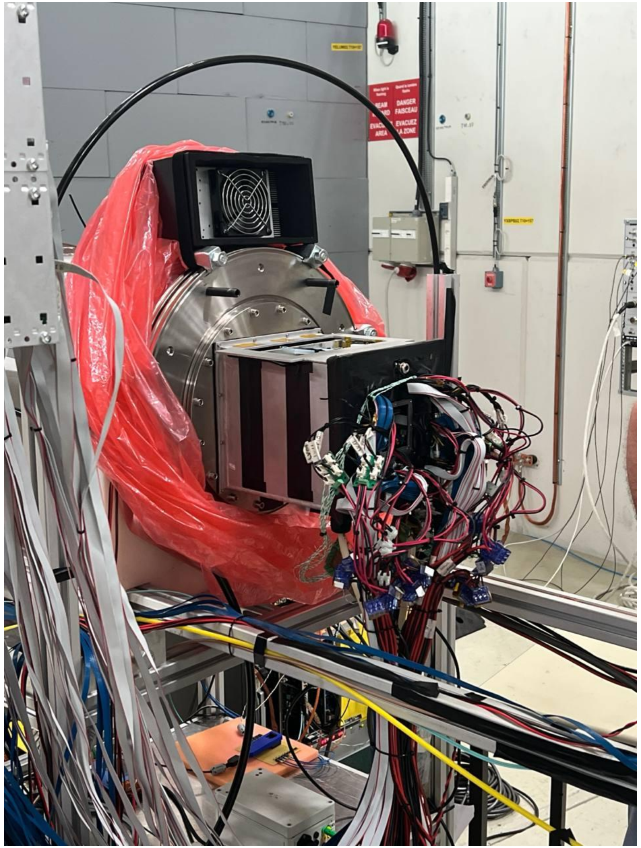
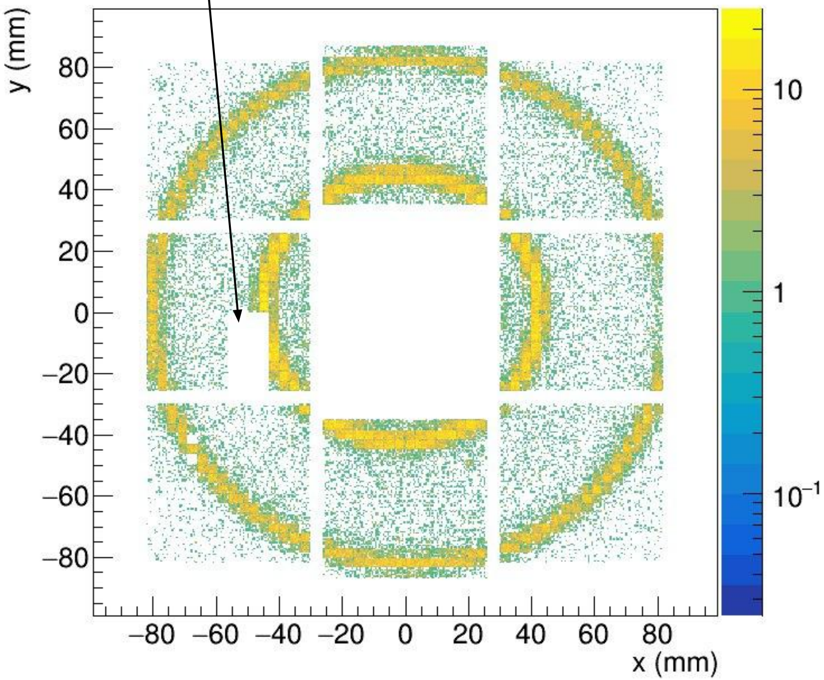
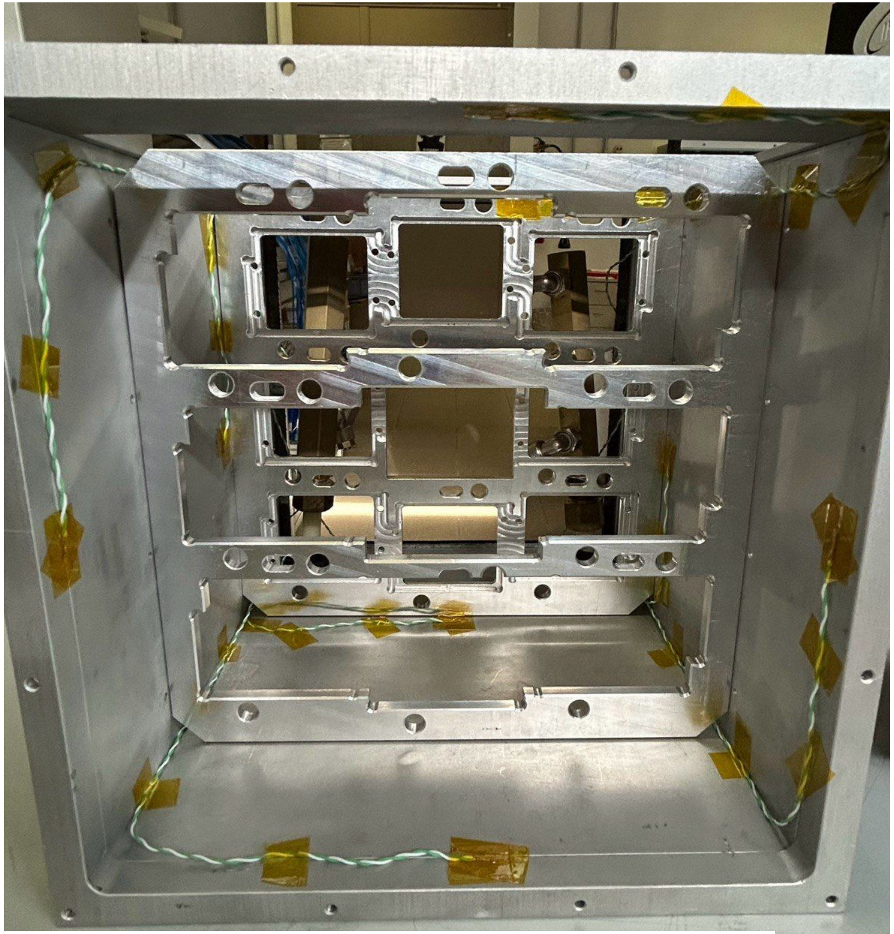


unfortunately one ASIC
chip (32 ch) had some
front-end problems

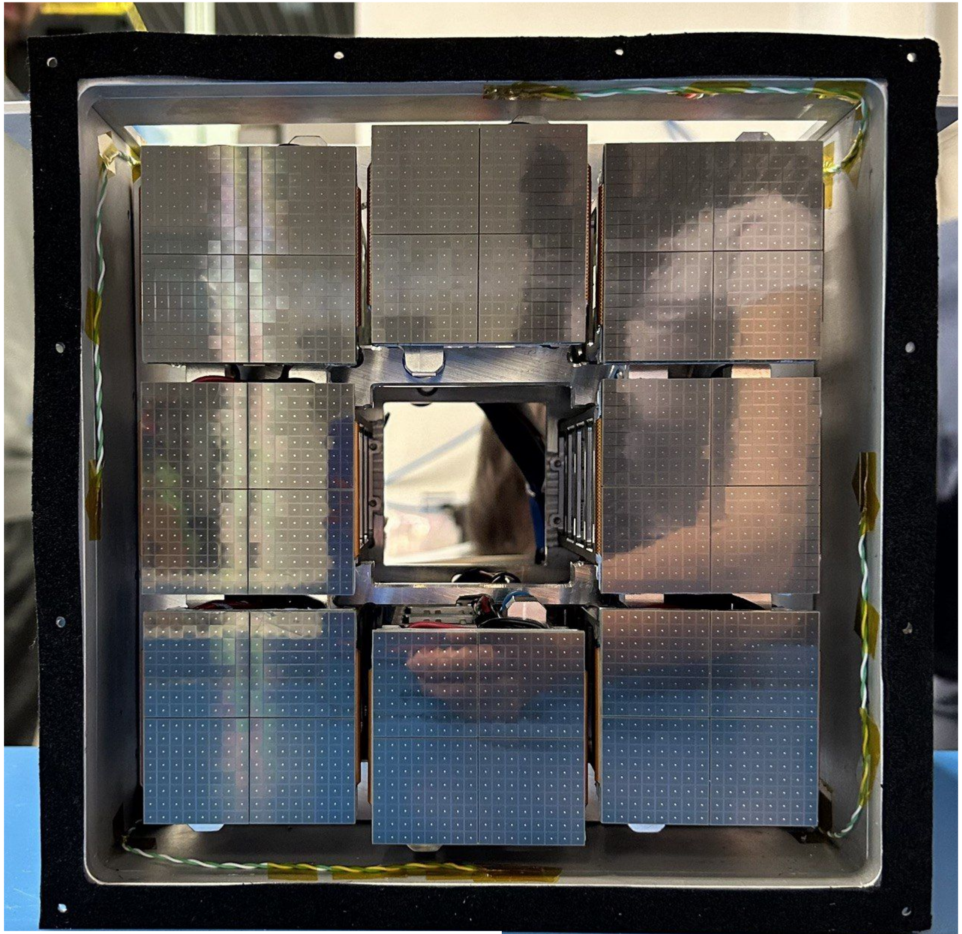


all the rest was rather full of photons:
> 2000 SiPMs with TDC readout at work

From an empty box to a full detector

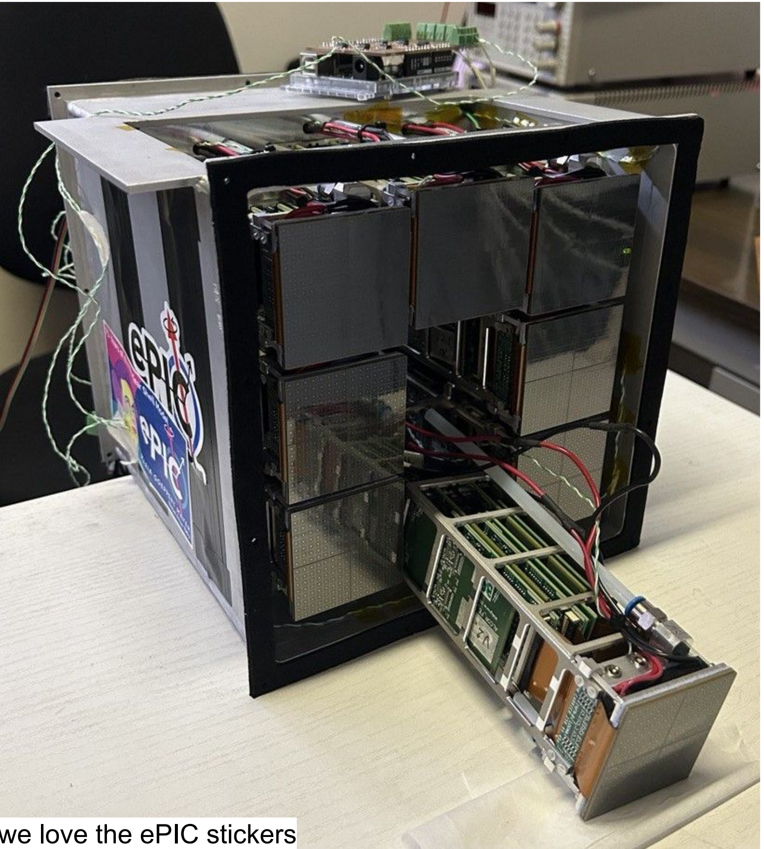


empty readout box with PDU housing and monitor thermocouples

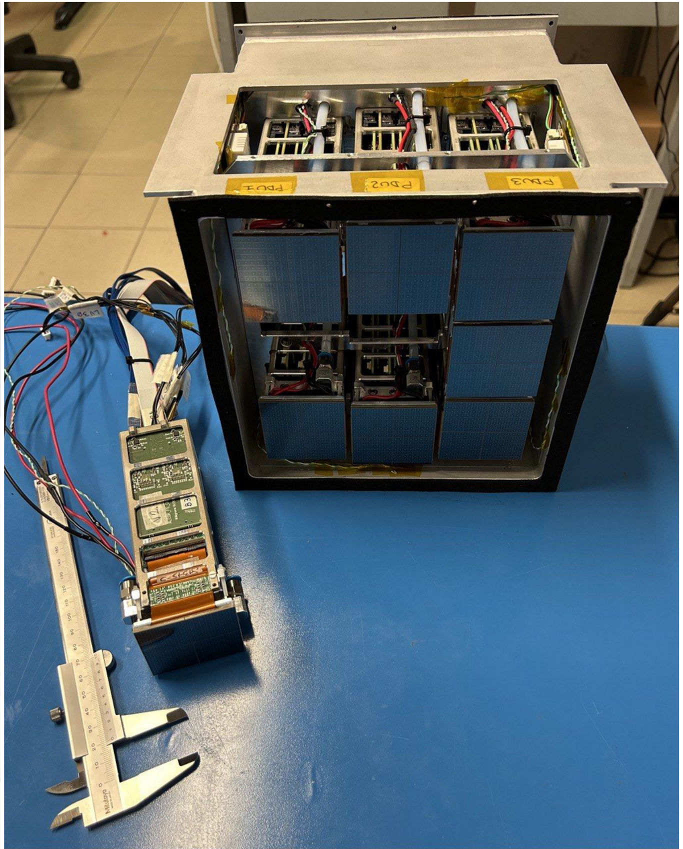


readout box filled with 8 PDUs ready to go

ePIC-dRICH SiPM readout box



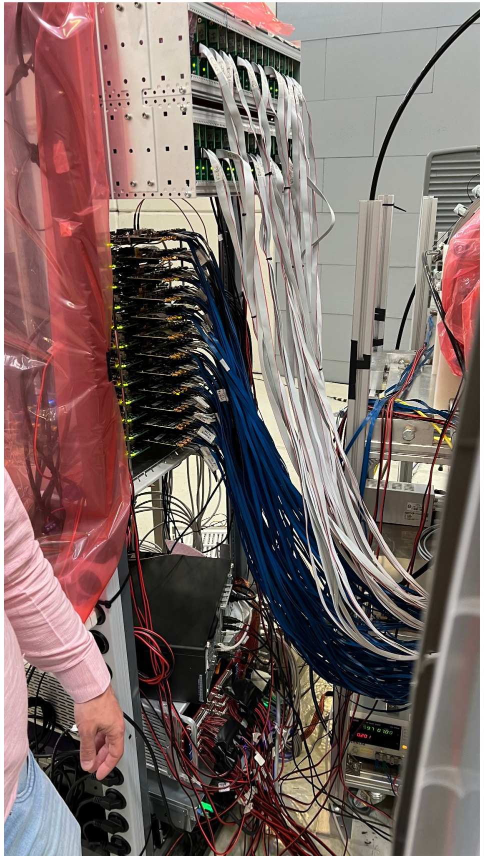
we love the ePIC stickers

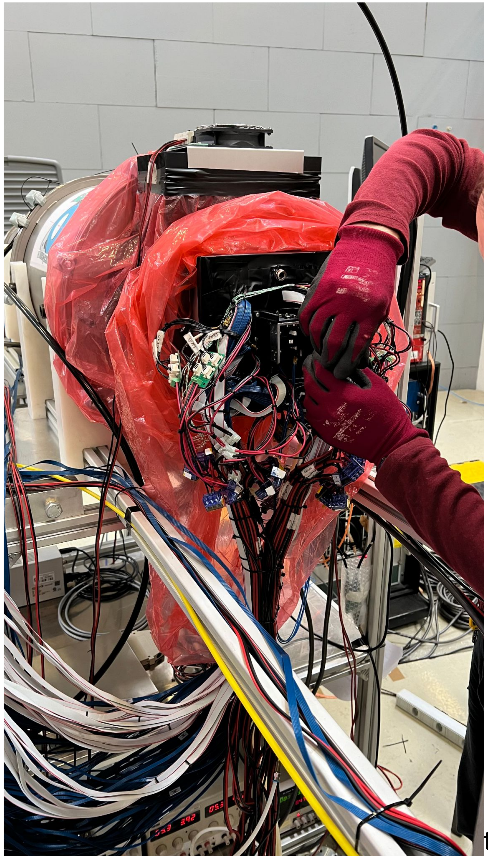


at INFN Bologna with big smiles

Beam test preparation at CERN PS

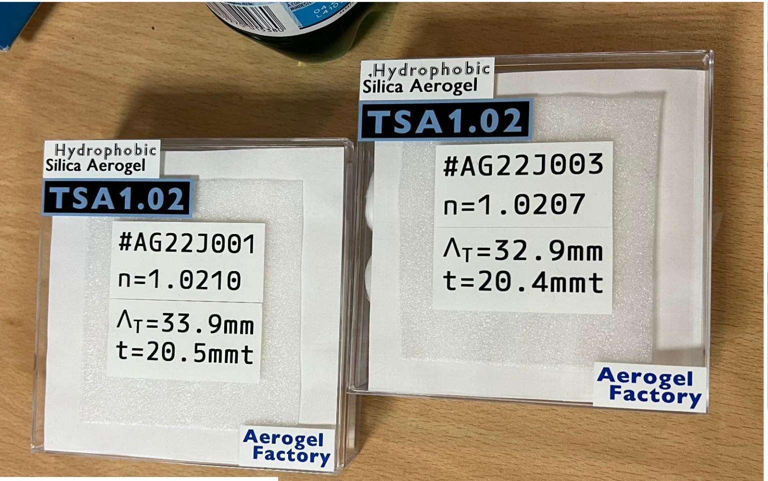
dRICH at T10 beam hall in May 2024



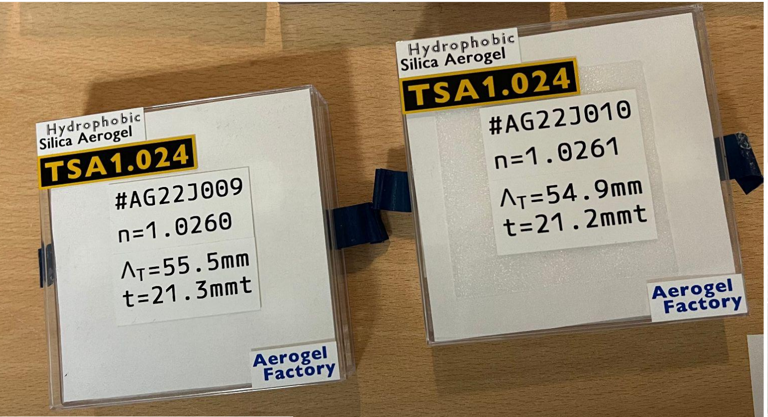



tracking and timing system

Aerogel operations



aerogel tiles at n = 1.02

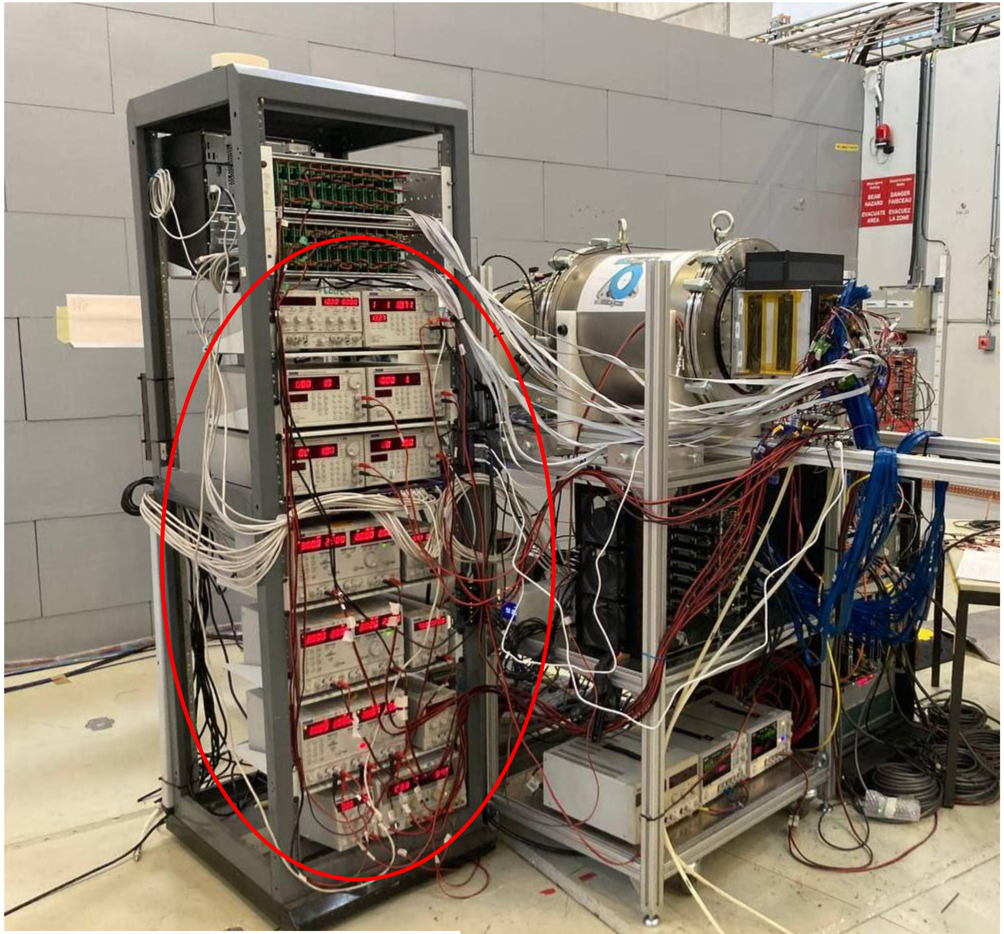


aerogel tiles at n = 1.026

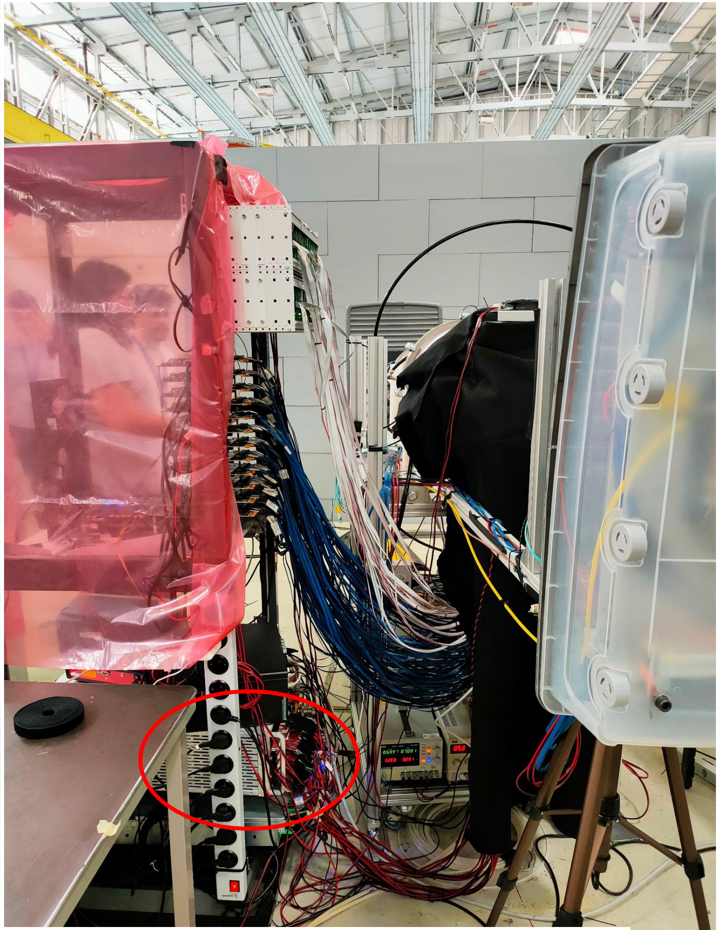
aerogel tiles and wavelength filter sandwich


operation insertion in the detector

Power supply



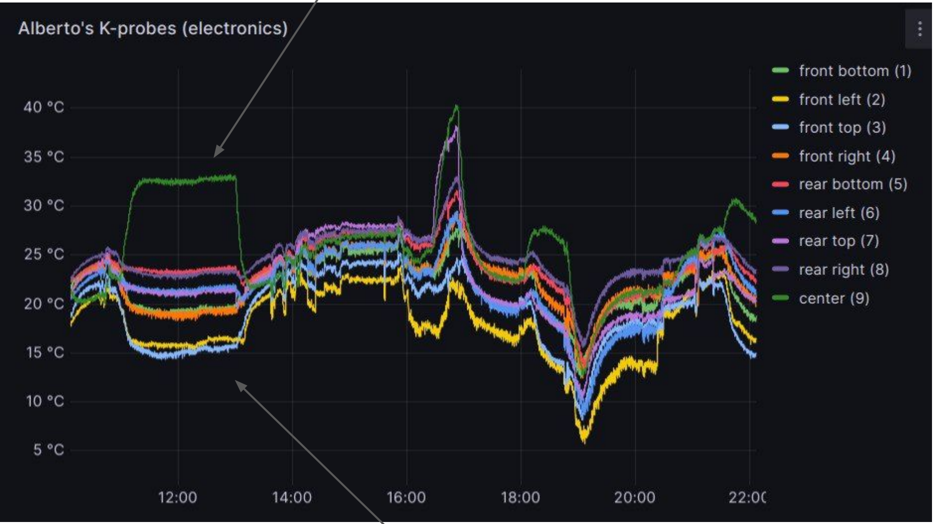
many table-top power supplies in 2023



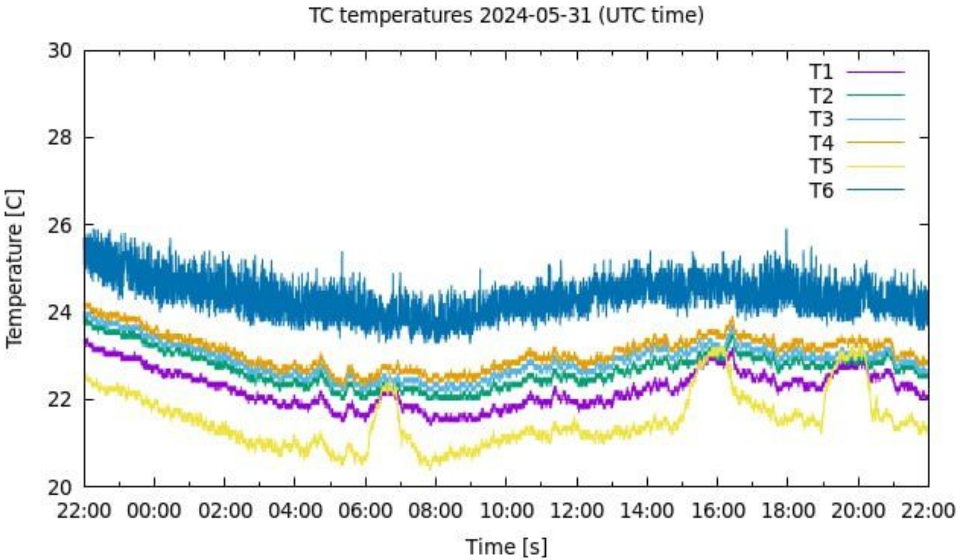
experiment-oriented CAEN power-supply unit in 2024

Temperature monitoring

centre of the box in
stable runs
(near electronics)



temperature probes in various places in the electronics box



temperature probes in various places in the gas radiator volume

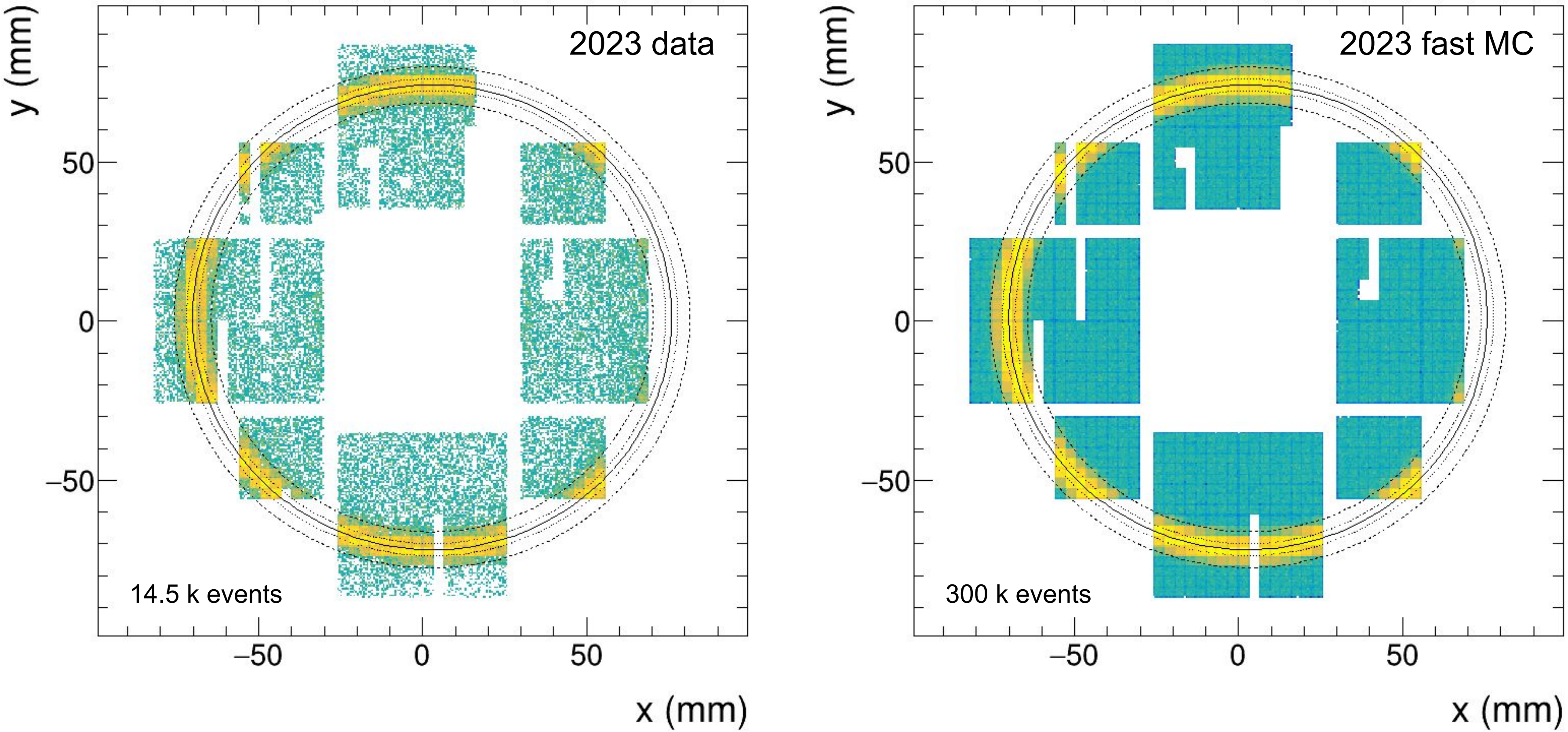
front of the box
in stable runs
(near SiPMs)

results

Number of photoelectrons

2D fit parameters match accurately fast MC input
notice redefinition of Nsig and Nbkg

Nsig	=	23.6048	+/-	0.0154101
X0	=	2.87125	+/-	0.00255149
Y0	=	1.18834	+/-	0.00193679
R	=	73.0013	+/-	0.00166626
sigmaR	=	1.88591	+/-	0.00123206
Nbkg	=	10.3538	+/-	0.0133316



large number of detected aerogel photons in 2023, on average **more than 9 photoelectrons over the active area**

Number of photoelectrons

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notice redefinition of Nsig and Nbkg

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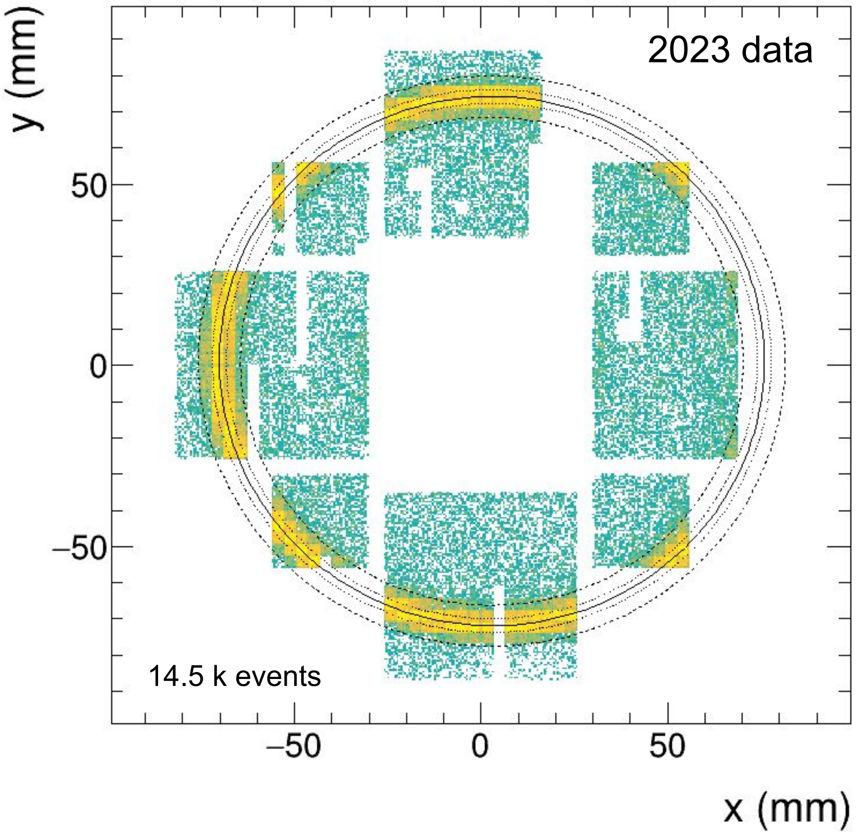
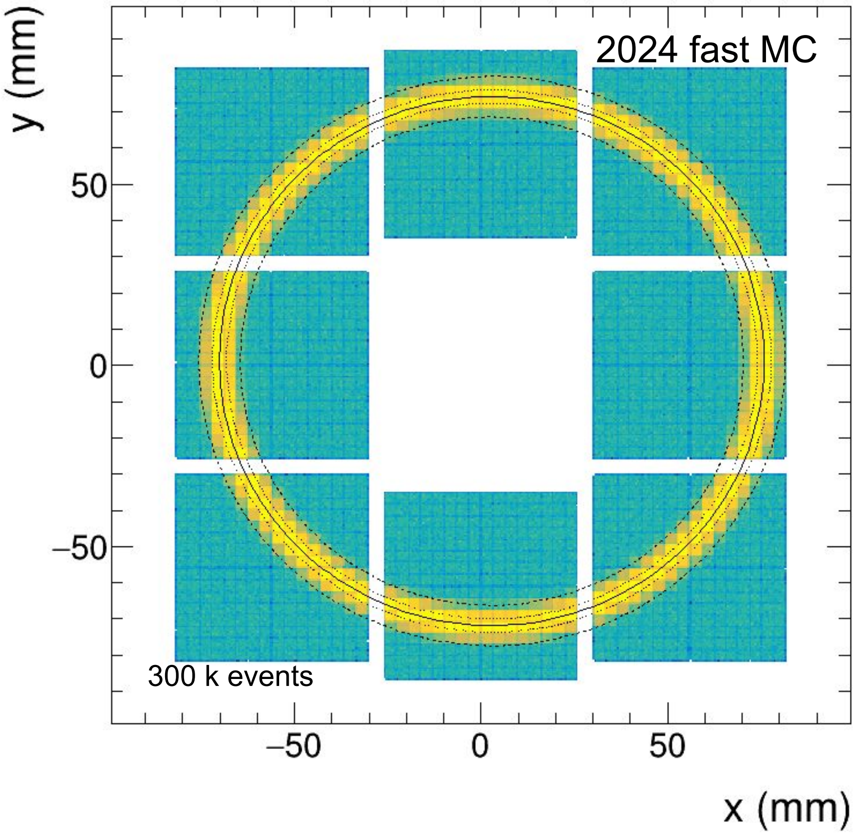


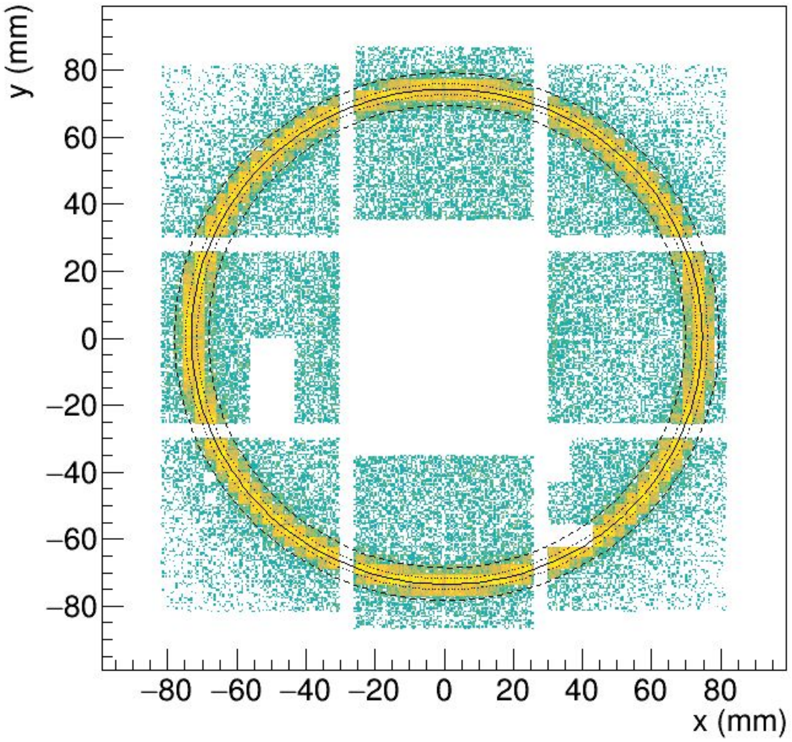


fast MC expectation for a 2024 beam test with 8x full PDUs is a **very large average number of photoelectrons for aerogel > 18**

Number of photoelectrons

is large as expected

11.5 GeV/c negative beam, n = 1.02 aerogel (accumulated events)



$X_0 = 0.75 \pm 0.01$ mm

$Y_0 = 0.45 \pm 0.01$ mm

$R = 73.87 \pm 0.00$ mm

$\sigma_R = 1.63 \pm 0.00$ mm

$N_{sig} = 29.13 \pm 0.07$

$N_{bkg} = 8.47 \pm 0.05$

average number of signal photons for 100% acceptance
includes SiPM efficiency

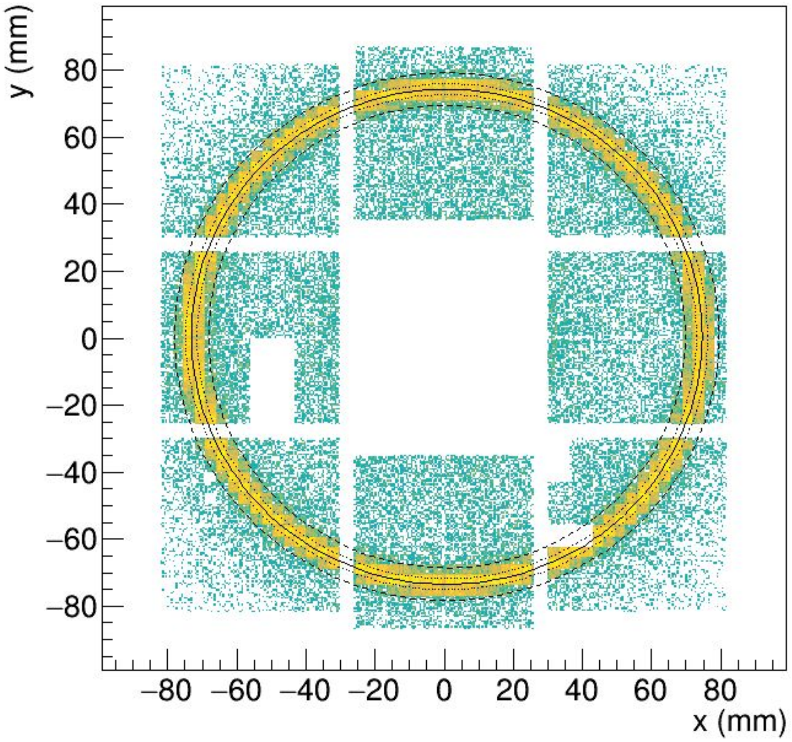
2D fit to accumulated data with realistic model (ring + background)

global ring parameters and performance, running also online

Number of photoelectrons

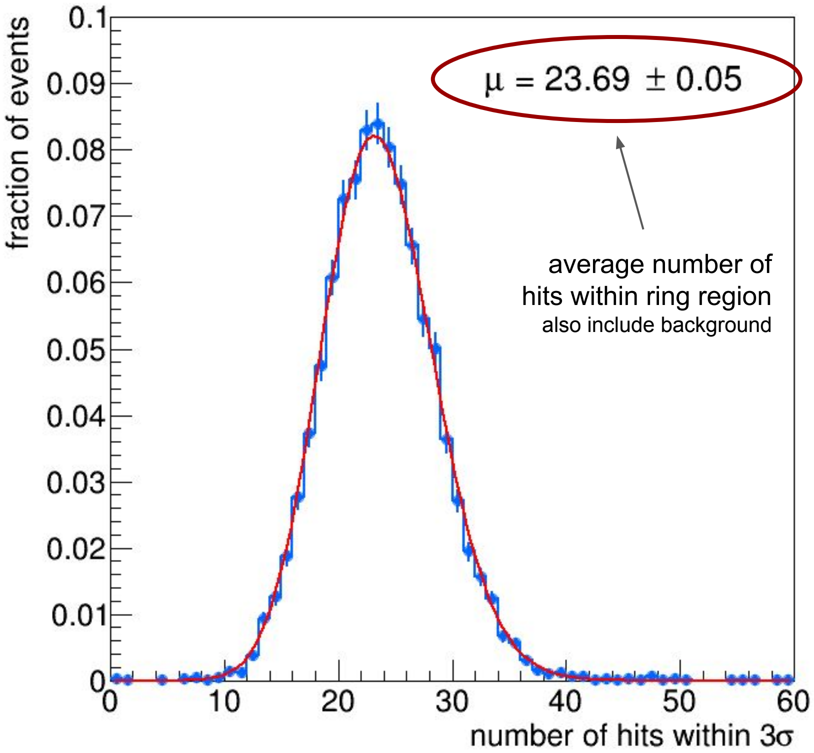
large as expected

11.5 GeV/c negative beam, n = 1.02 aerogel (accumulated events)



2D fit to accumulated data with realistic model (ring + background)

event-by-event distribution of hits in the ring



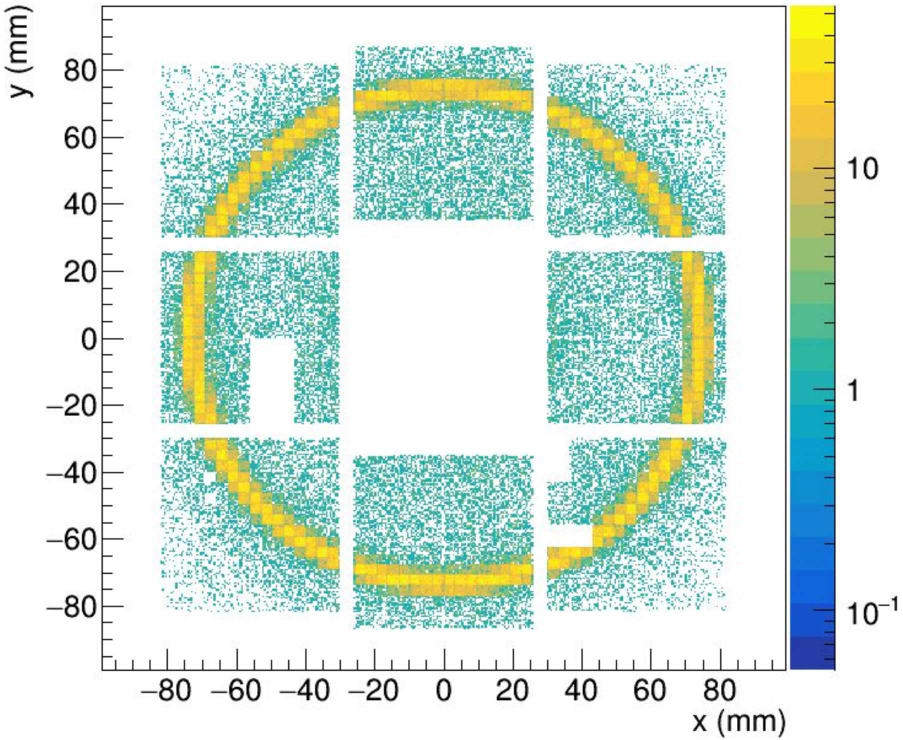
Poisson fit to data, average number of hits is large

Background studies

data taken without aerogel radiator

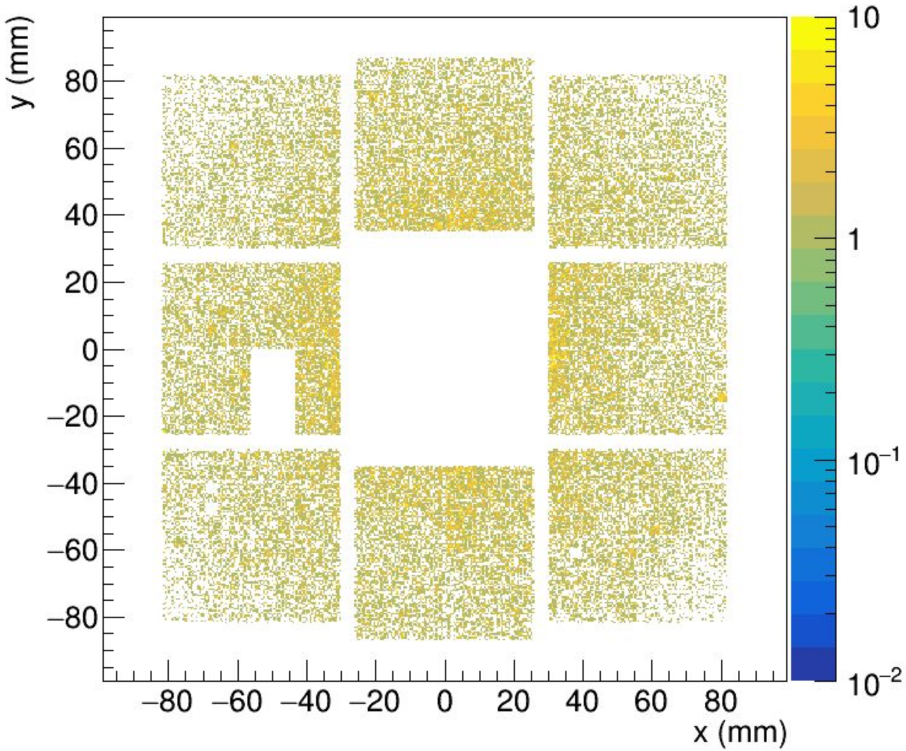
PRELIMINARY

with two n = 1.02 aerogel tiles (accumulated events)



with timing cuts applied, large background as seen in past years

without aerogel (accumulated events)

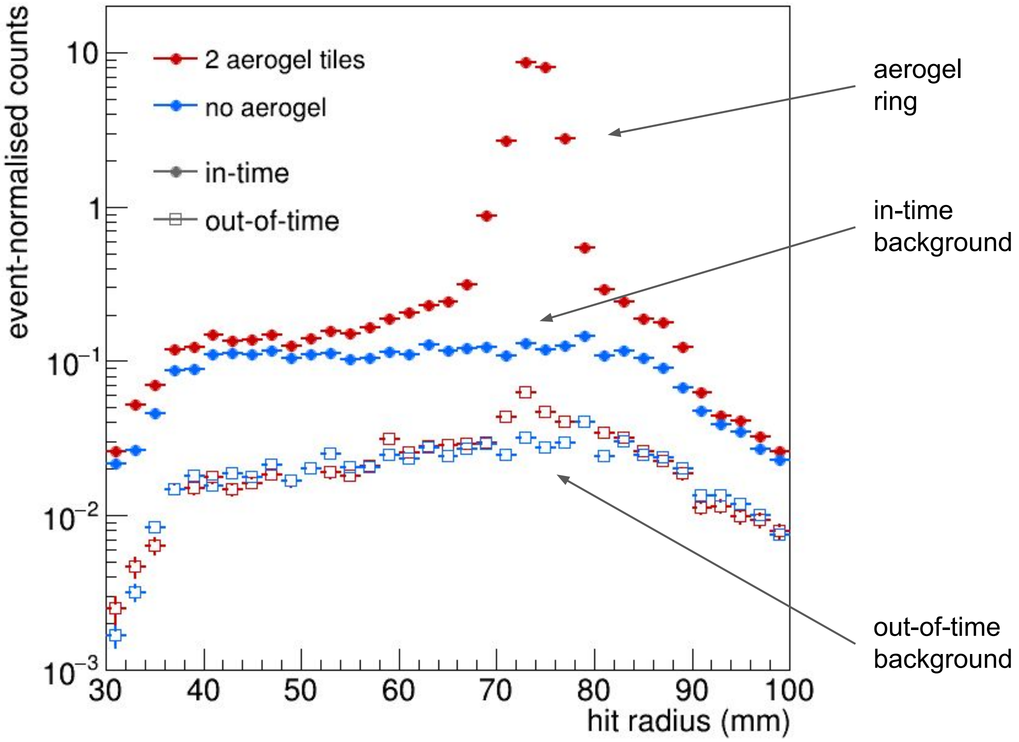


removed the aerogel tile, background remains

Background studies

basically all the background remains after removing aerogel, not from DCR

distribution hit radii with and without aerogel

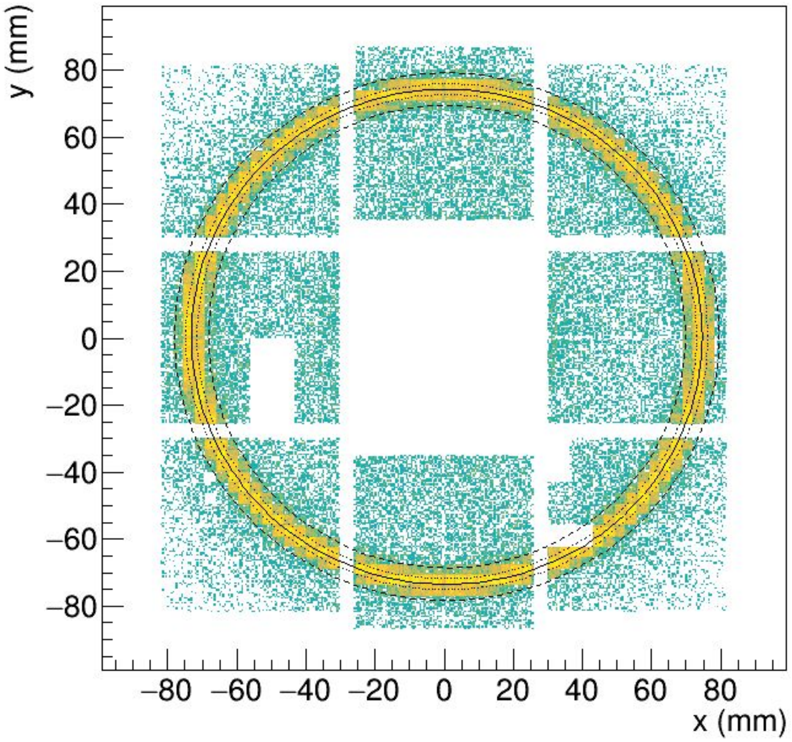


in-time (40 ns window) background is ~ 10x larger than out-of-time (40 ns window) background (mostly DCR) | origin still unclear | to be understood

Background studies

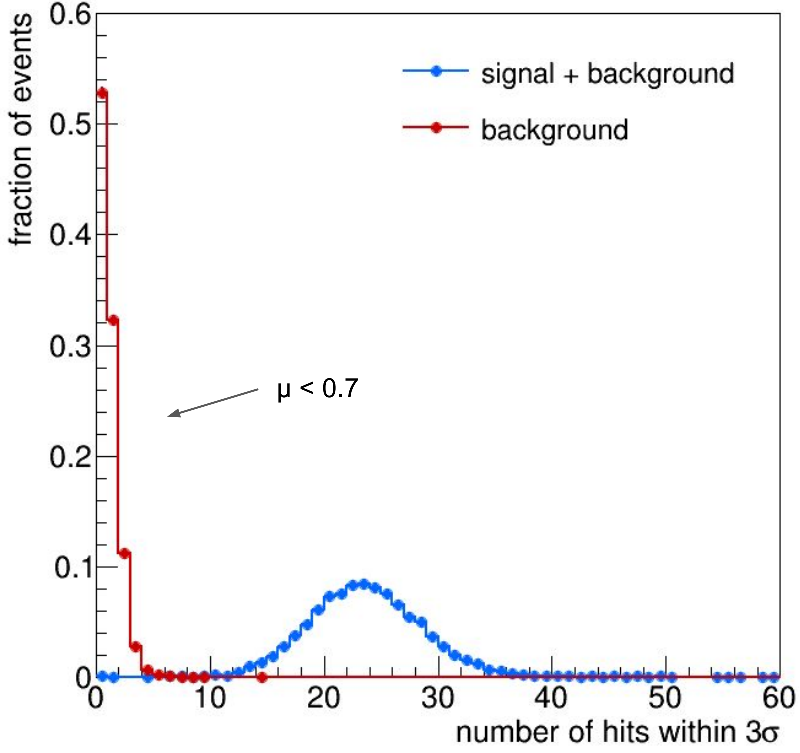
there is often one background hit in the ring, this will impact resolution

11.5 GeV/c negative beam, n = 1.02 aerogel (accumulated events)



2D fit to accumulated data with realistic model (ring + background)

event-by-event distribution of hits in the ring

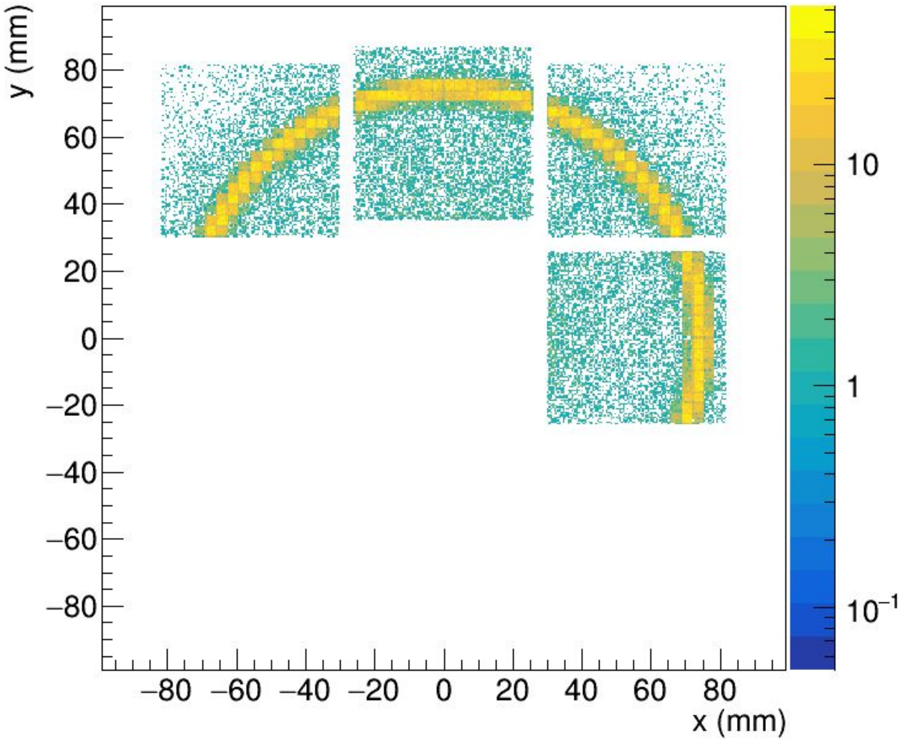


background in ring region estimated with data taken without aerogel

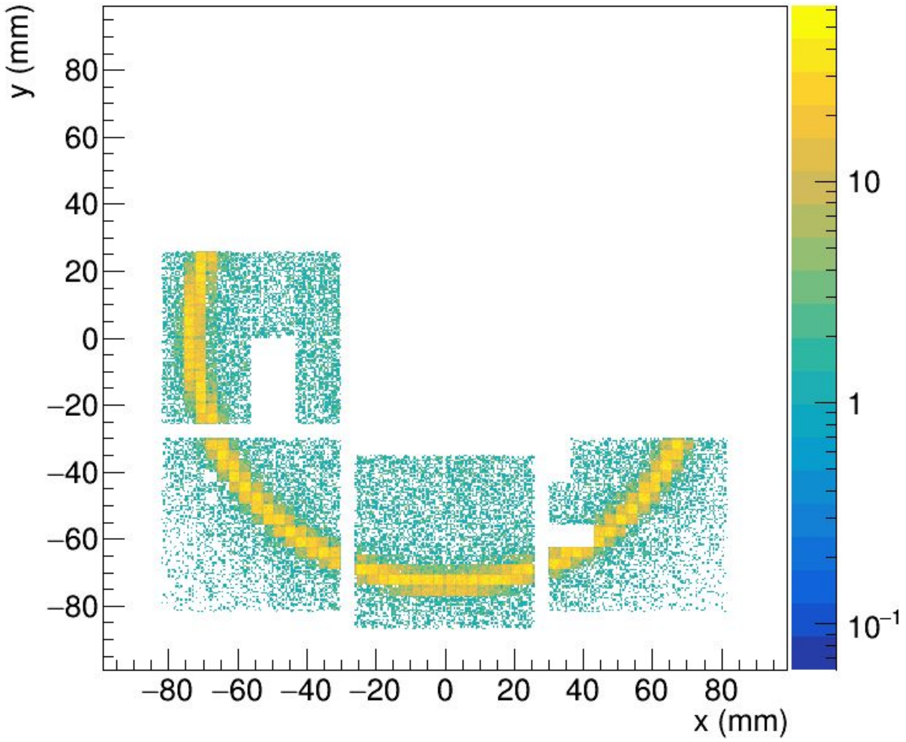
Comparison between different SiPM sensors

same Hamamatsu technology, different SPAD sizes

Hamamatsu S13360-3050 (50 µm)



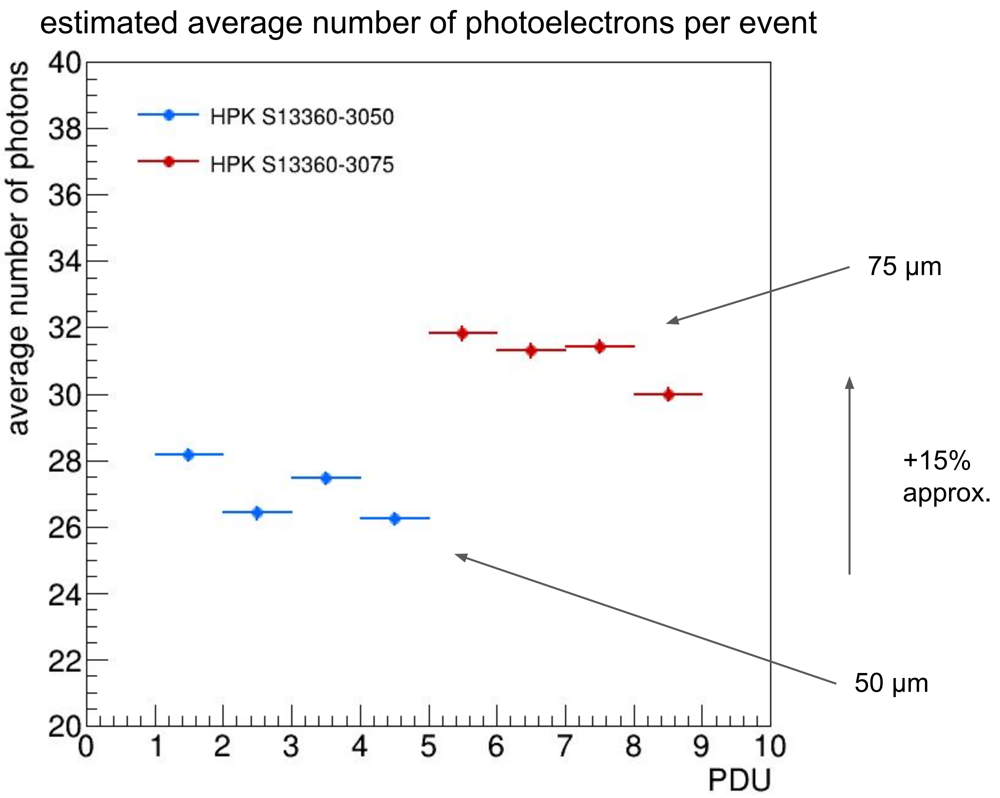
Hamamatsu S13360-3075 (75 µm)



4 PDUs were equipped with one type of sensors symmetrically, the other four with different sensors

Comparison between different SiPM sensors

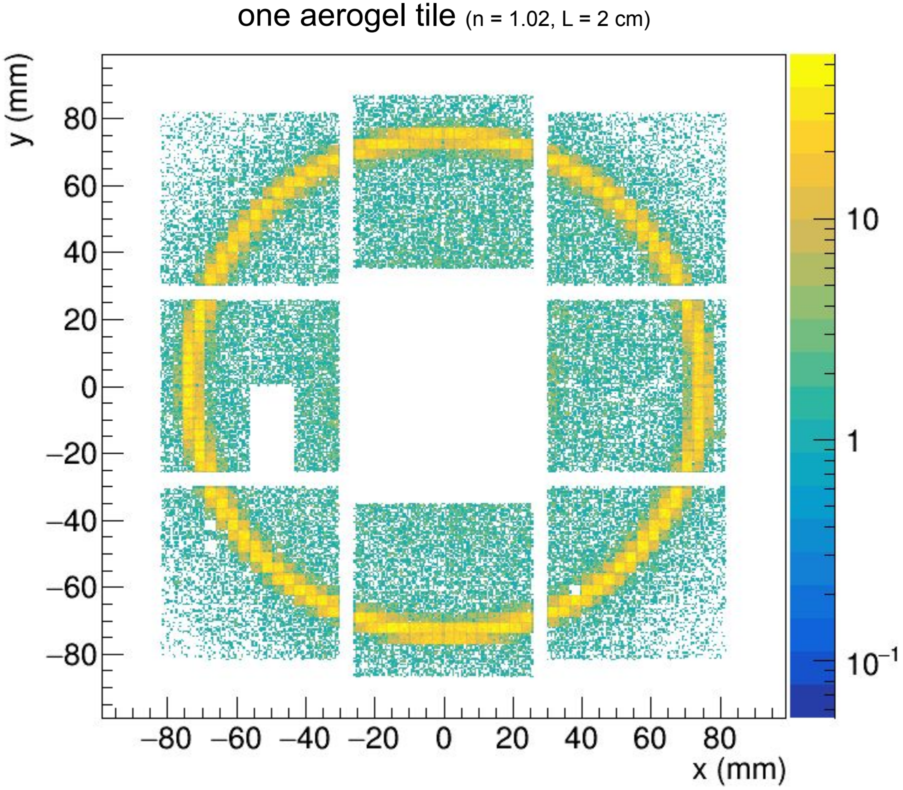
same Hamamatsu technology, different SPAD sizes

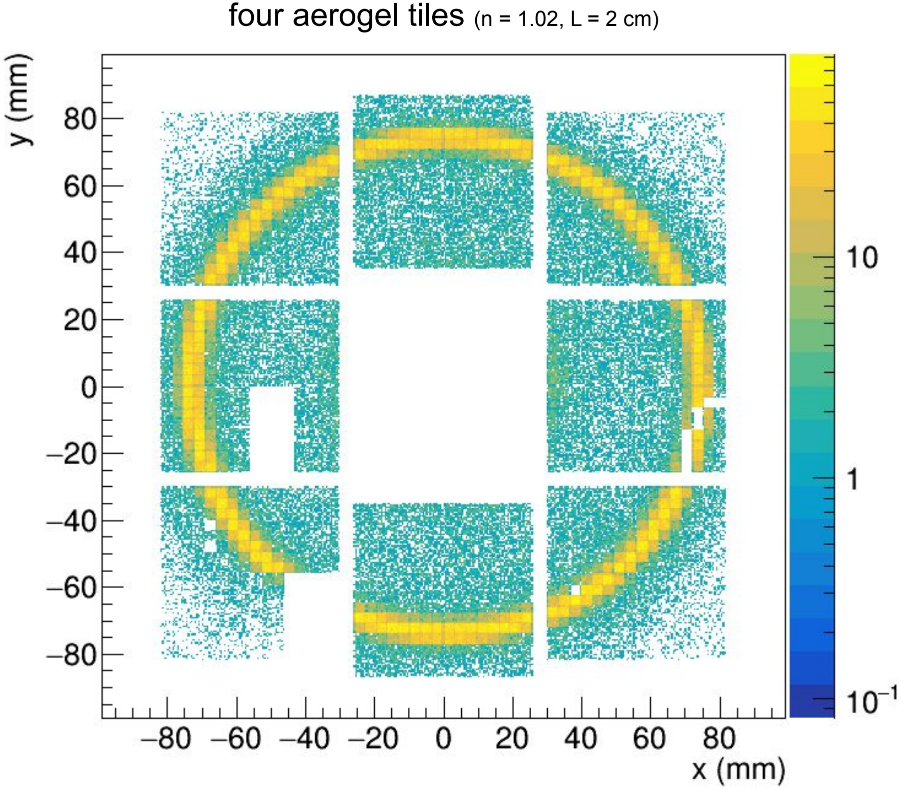


larger SPADs see more light (at the same overvoltage) than smaller SPADs | observed 15% more light | expected 25% higher PDE from datasheet

Increasing number of aerogel tiles

n = 1.02 aerogel tiles of L = 2 cm thickness





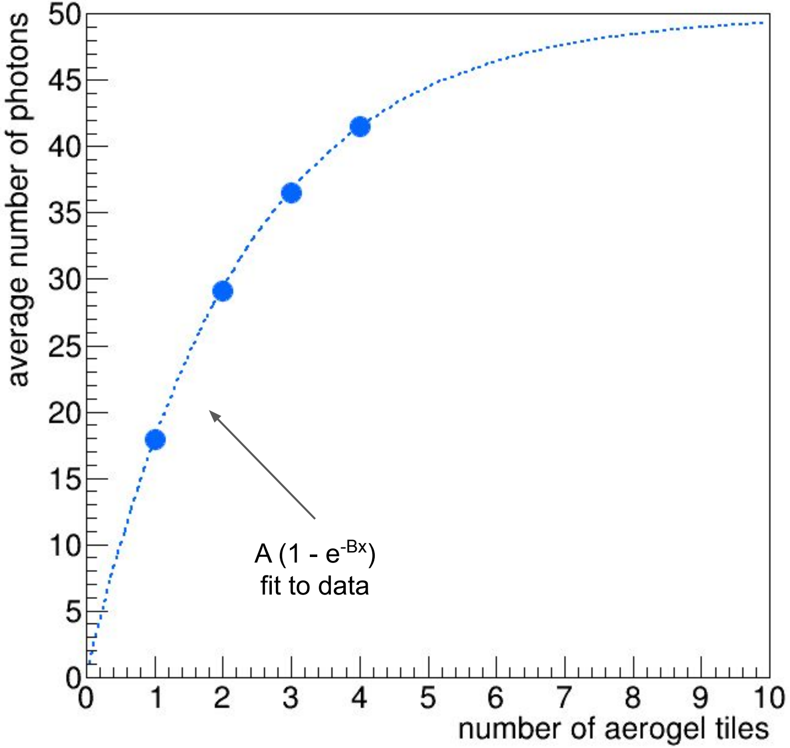
from 1 aerogel tile

up to four tiles

Increasing number of aerogel tiles

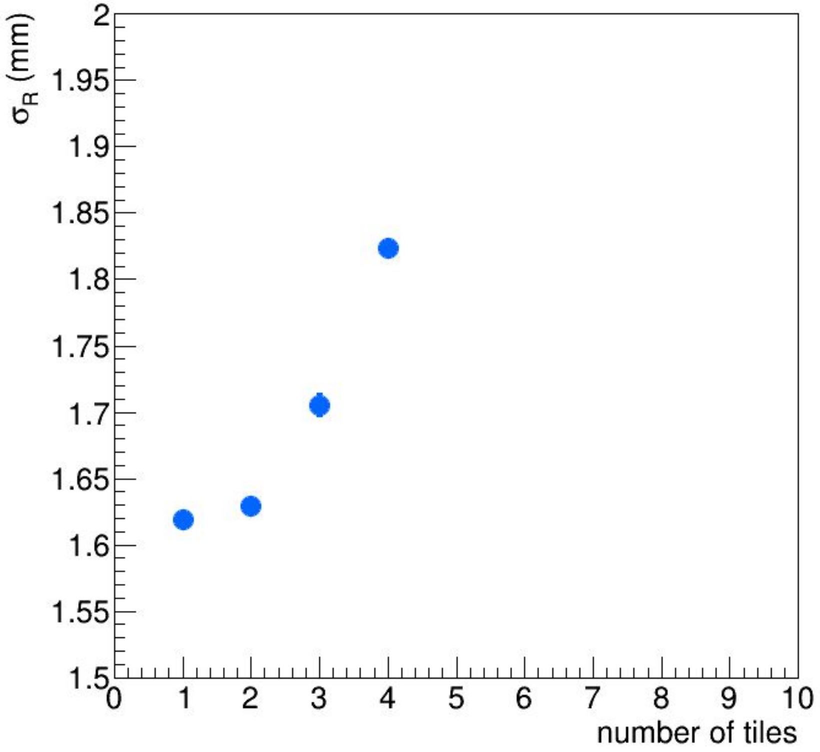
n = 1.02 aerogel tiles of L = 2 cm thickness

estimated average number of photoelectrons per event



adding tiles increases light, less and less effectively (absorption)

estimated single-photon radius resolution

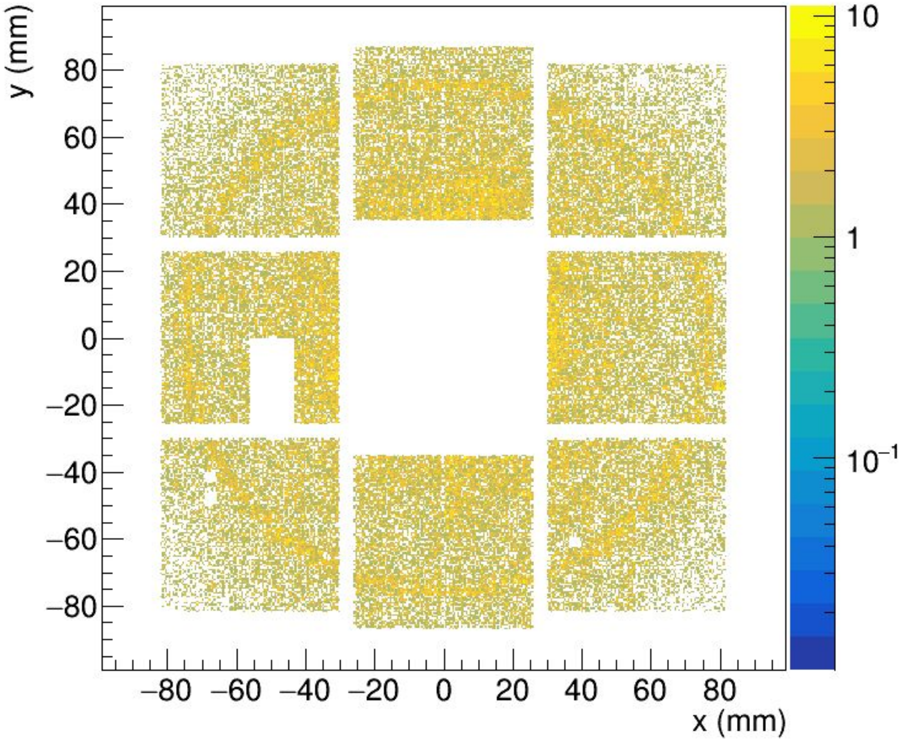


looks like single-photon resolution is degrading, not clear why

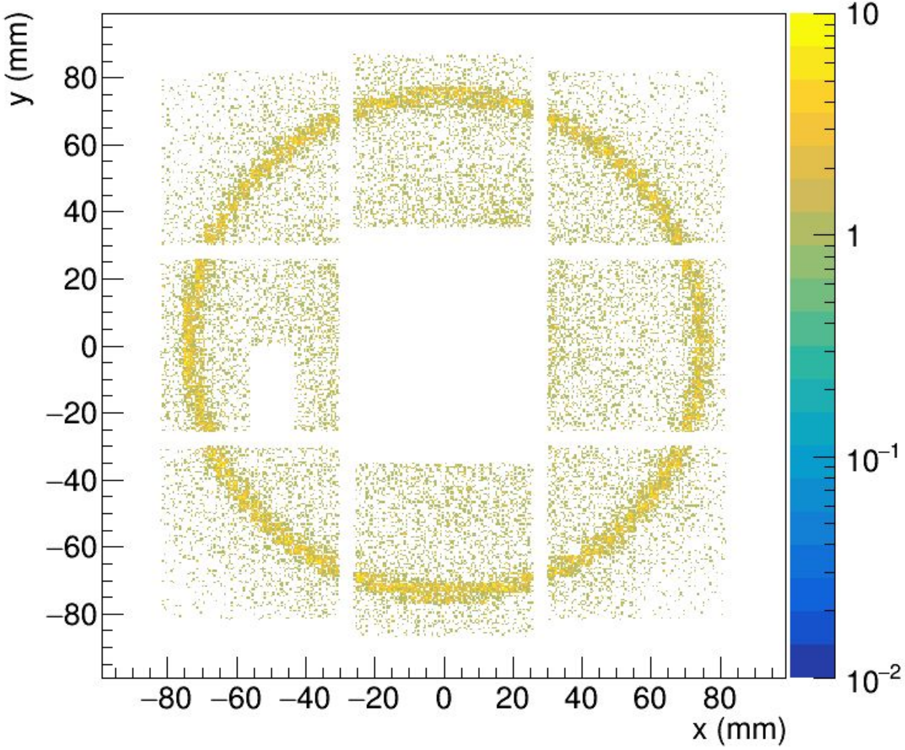
Wavelength filters

several filters used to select specific wavelength bands

near ultra-violet filter (λ ~ 350 nm)



blue filter (450 < λ < 500 nm)

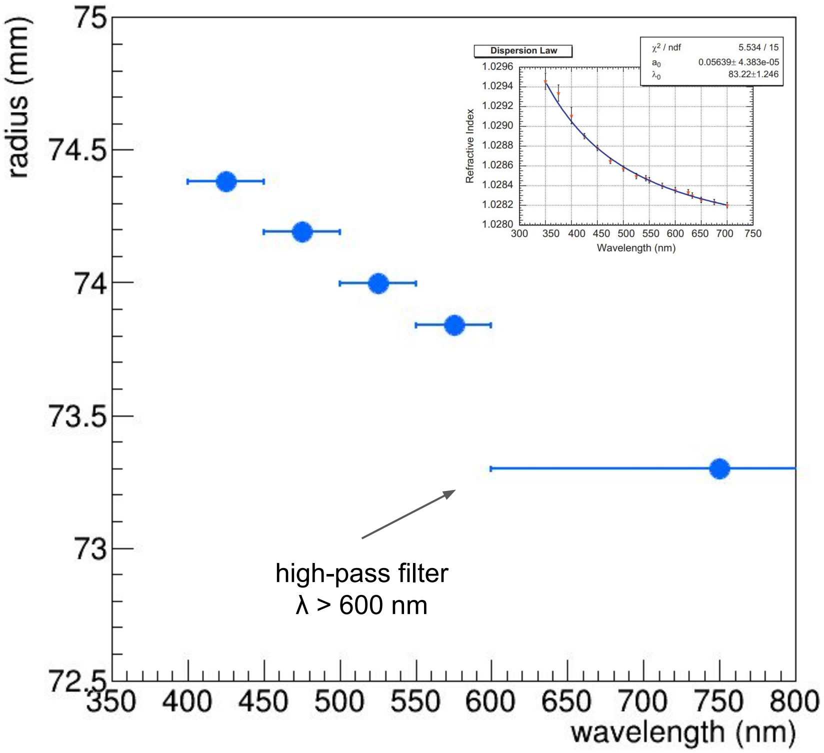


we still see the ring, but the "beam background" makes life difficult

Wavelength filters

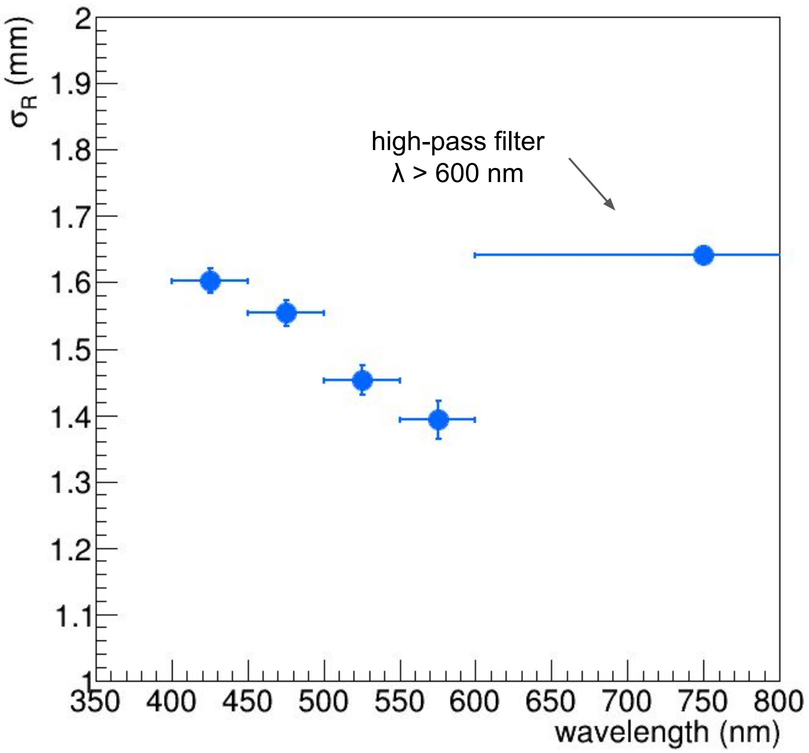
several filters used to select specific wavelength bands

estimated ring radius



ring radius decreases with increasing wavelength

estimated single-photon radius resolution

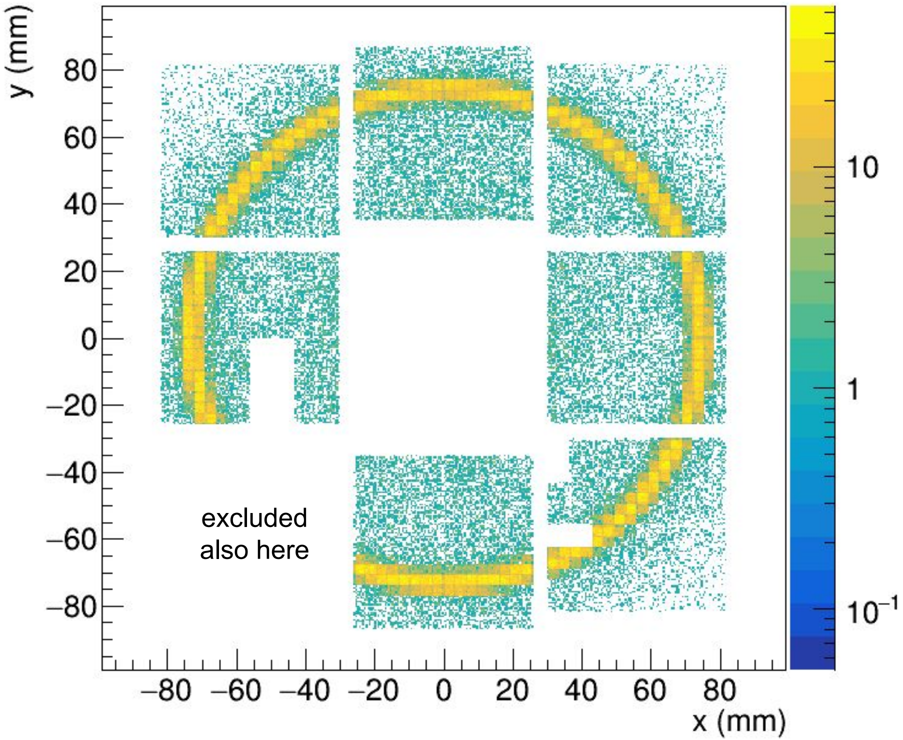


single-photon resolution improves, not clear why

n = 1.026 aerogel samples

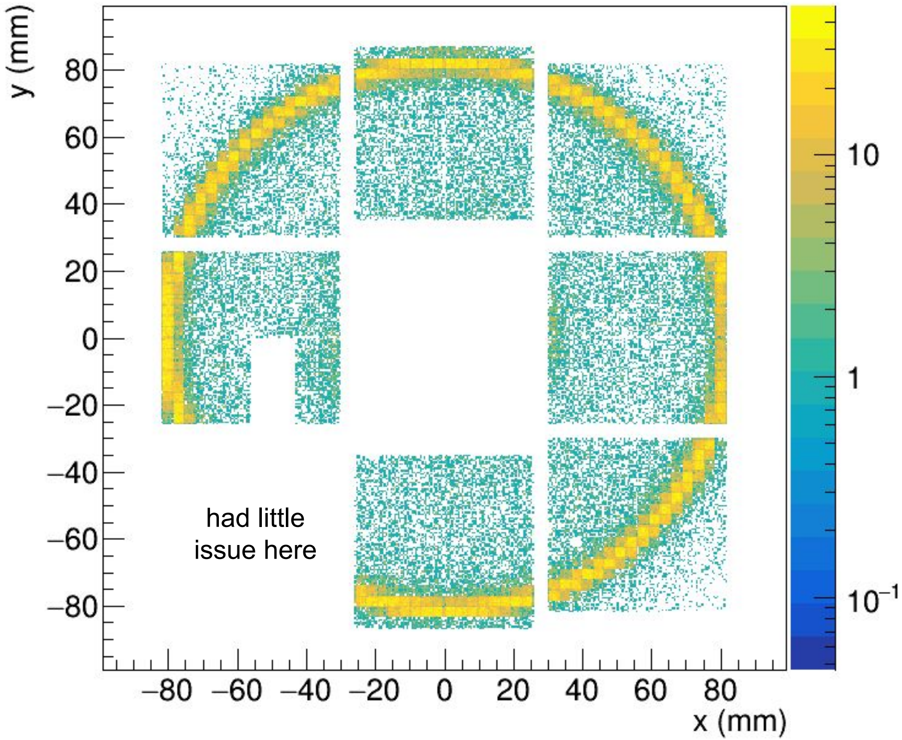
larger refractive index, expected larger rings and more light

two L = 2 cm tiles of n = 1.02 aerogel



excluded bottom-left corner in these runs because of little issue

two L = 2 cm tiles of n = 1.026 aerogel

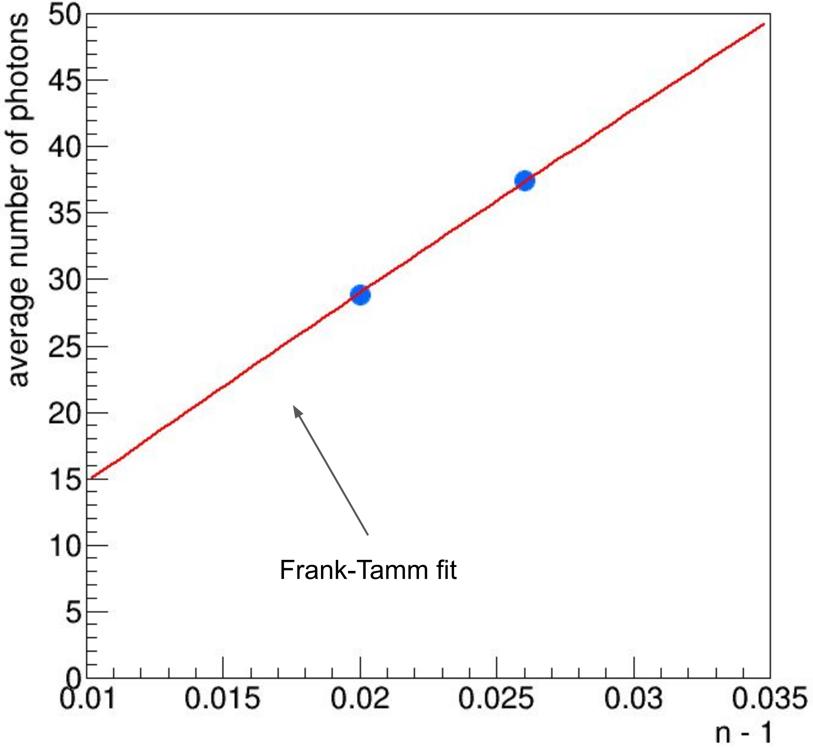


ring is larger, at the limit of the detector acceptance

n = 1.026 aerogel samples

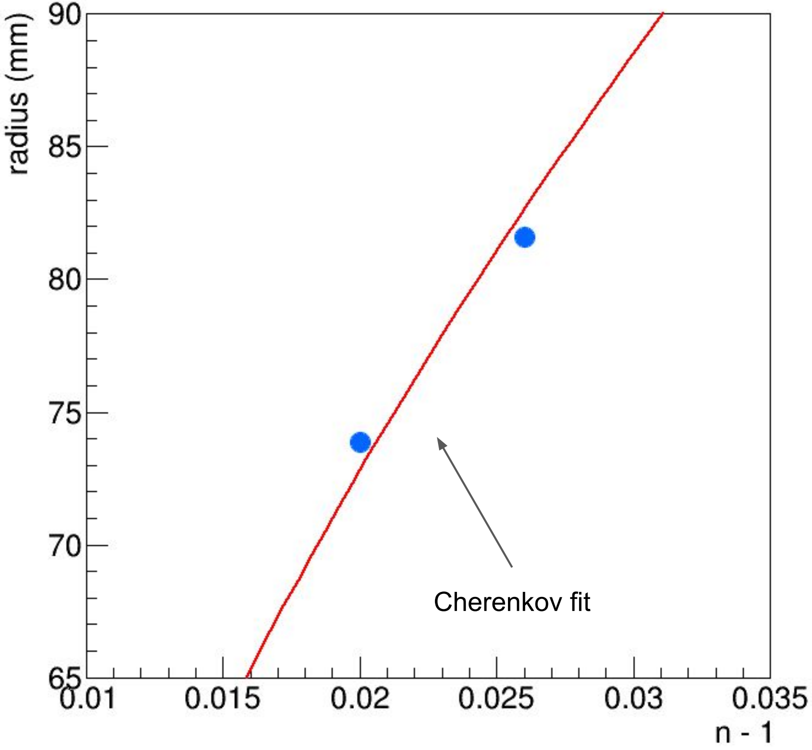
larger refractive index, expected larger rings and more light

estimated average number of photoelectrons per event



increases with refractive index (angle)

estimated ring radius

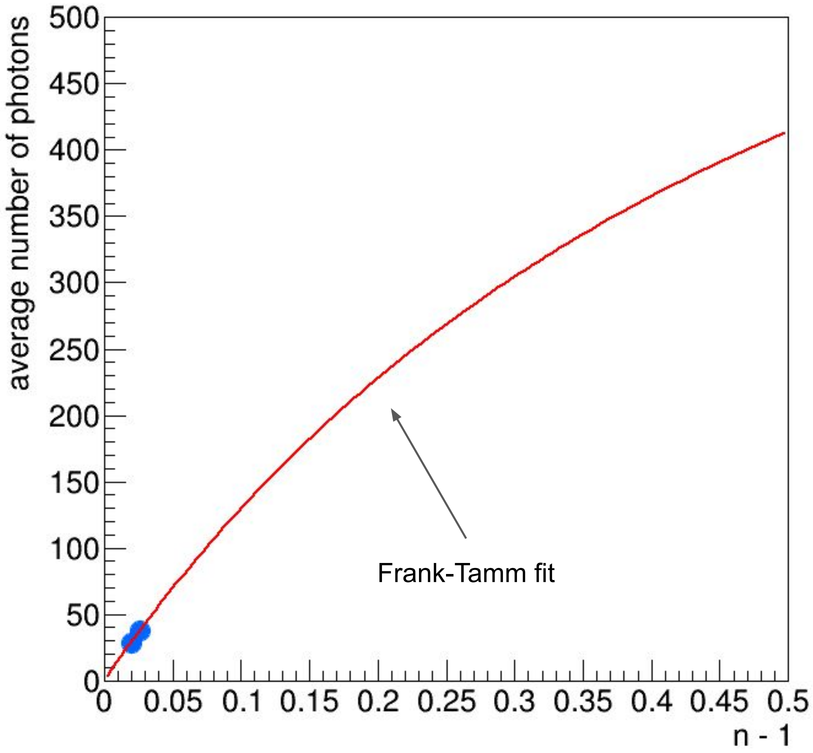


radius increases

n = 1.026 aerogel samples

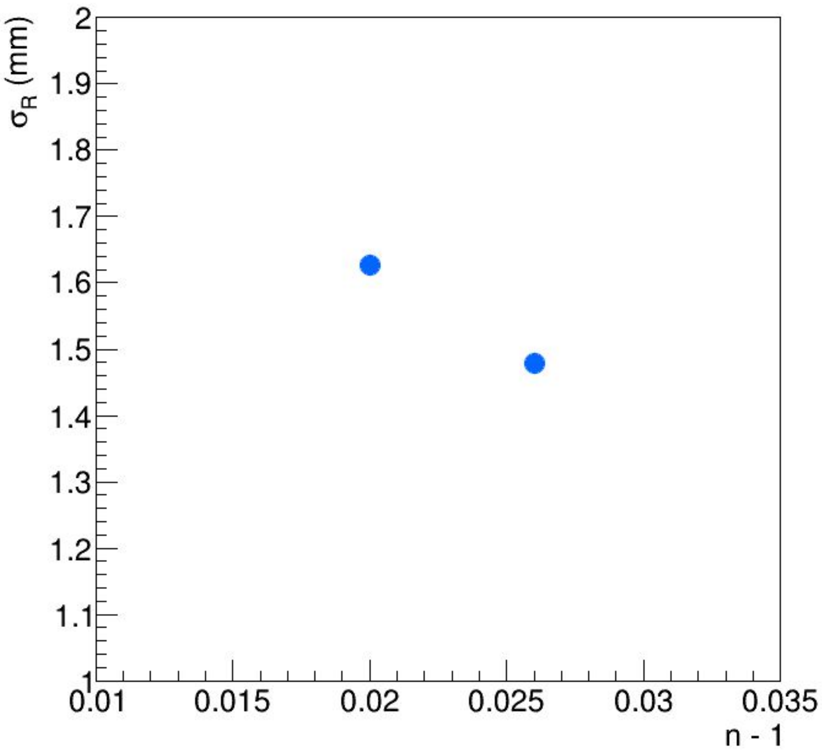
larger refractive index, expected larger rings and more light

estimated average number of photoelectrons per event



same view with extended range

estimated single-photon radius resolution



single-photon resolution improves

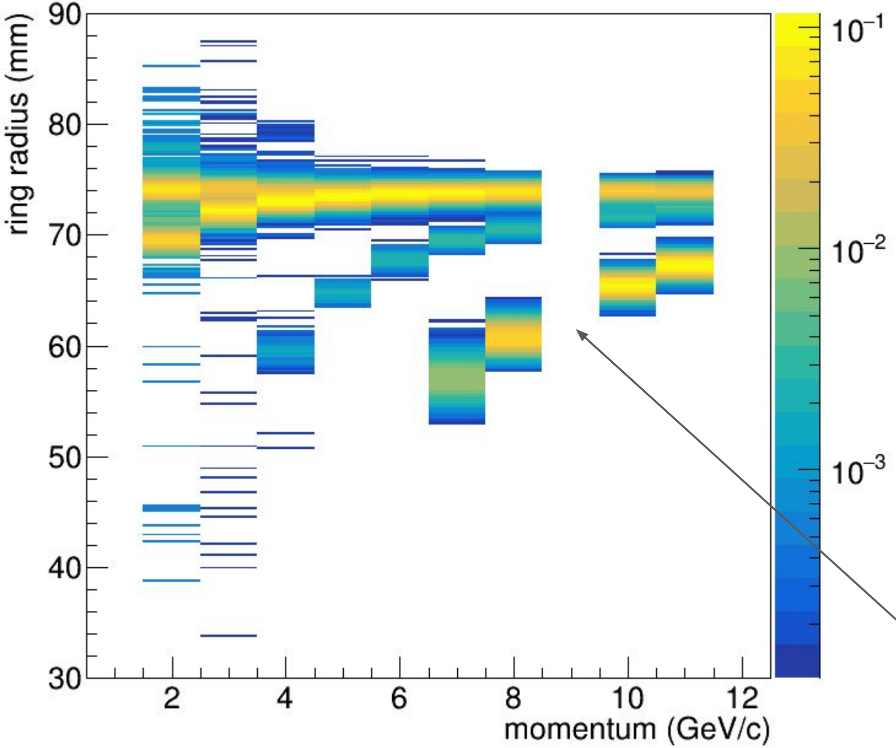
Beam momentum scan

positive particles, aerogel only

PRELIMINARY

INFN

reconstructed radii vs. beam momentum



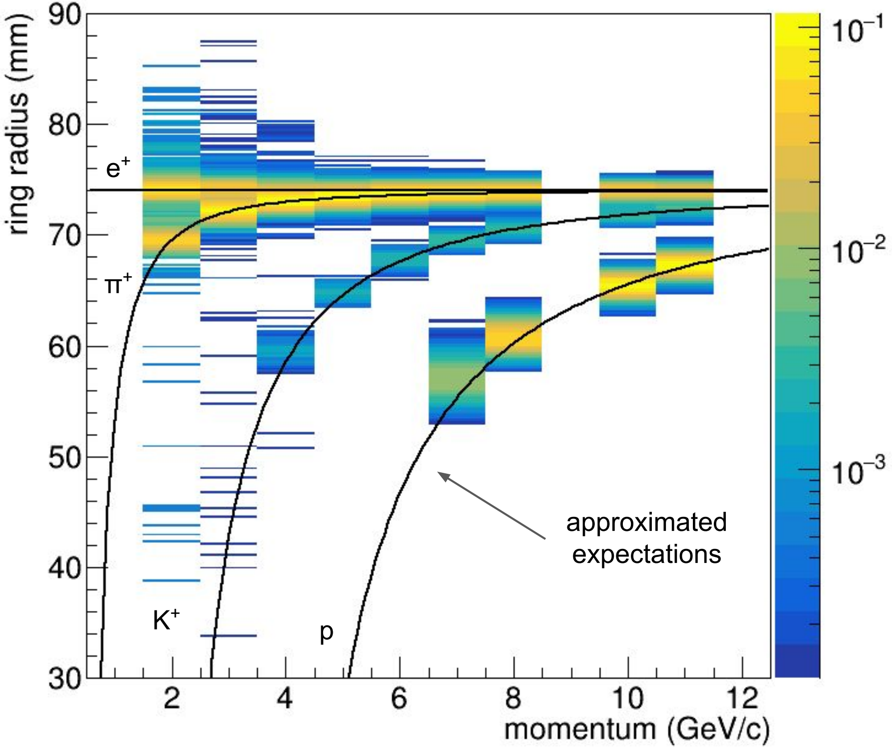
something has gone wrong with the beam configuration for 9 GeV (data not show)

nice!

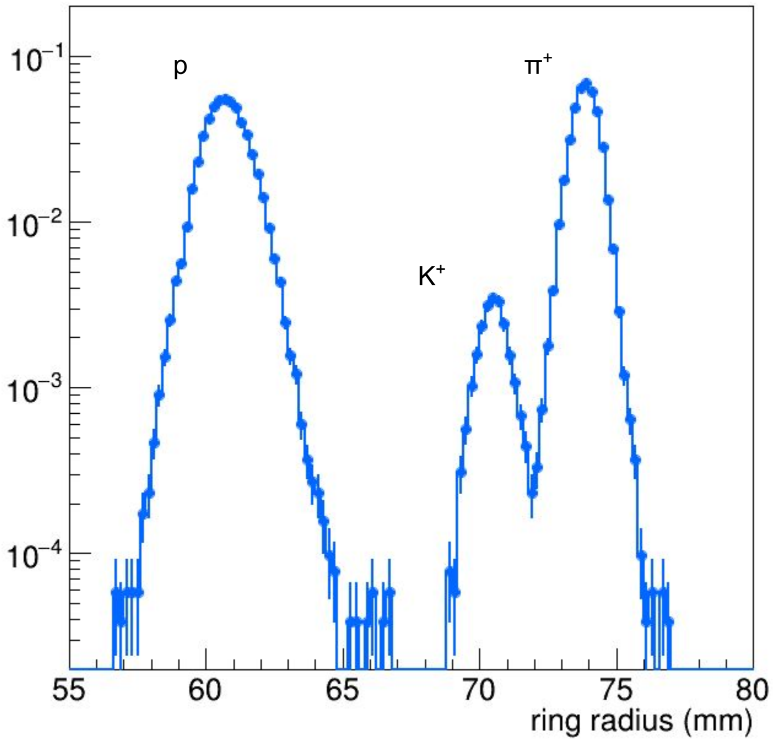
Beam momentum scan

positive particles, aerogel only

reconstructed radii vs. beam momentum



reconstructed radii at 8 GeV/c beam momentum



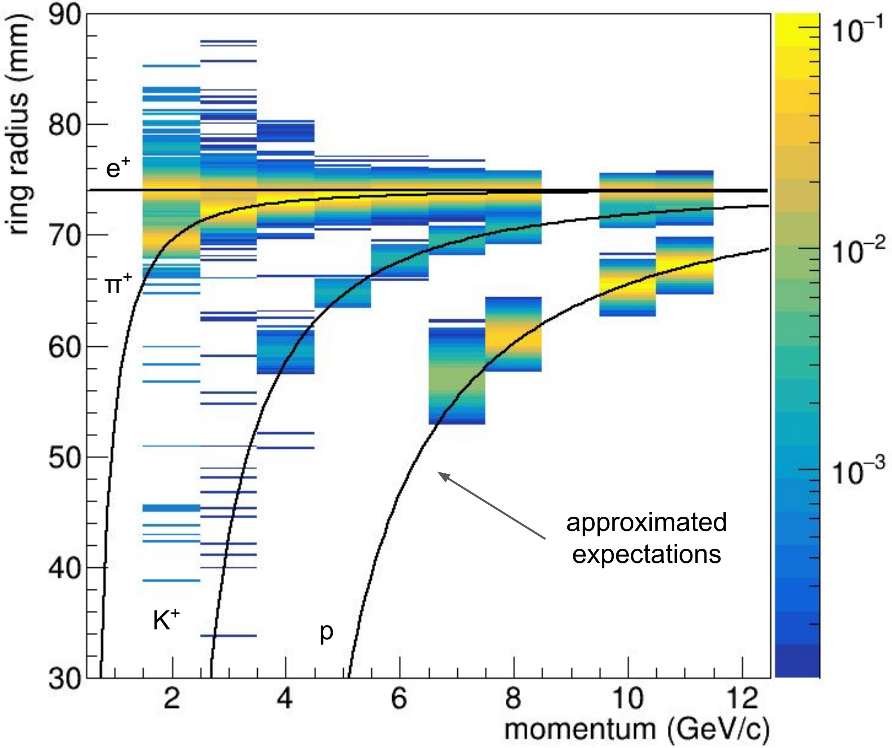
nice!

asdasdasd

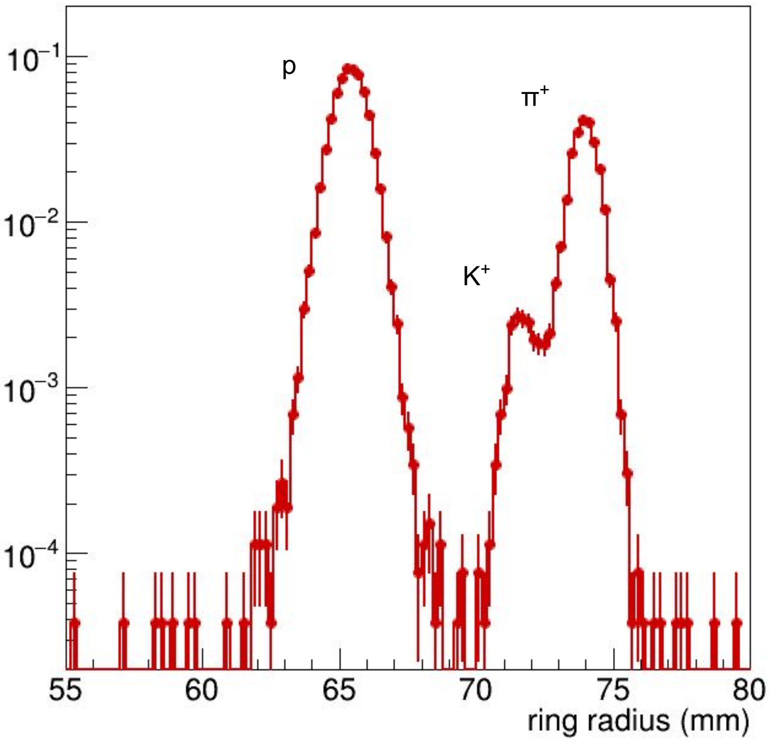
Beam momentum scan

positive particles, aerogel only

reconstructed radii vs. beam momentum



reconstructed radii at 10 GeV/c beam momentum



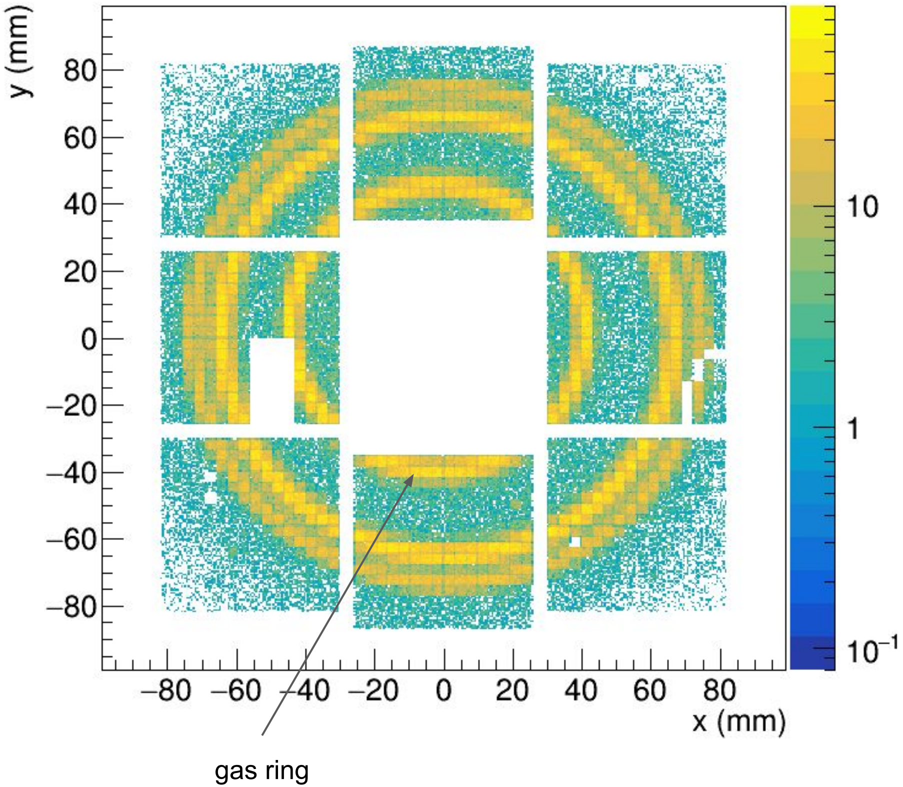
nice!

asdasdasd

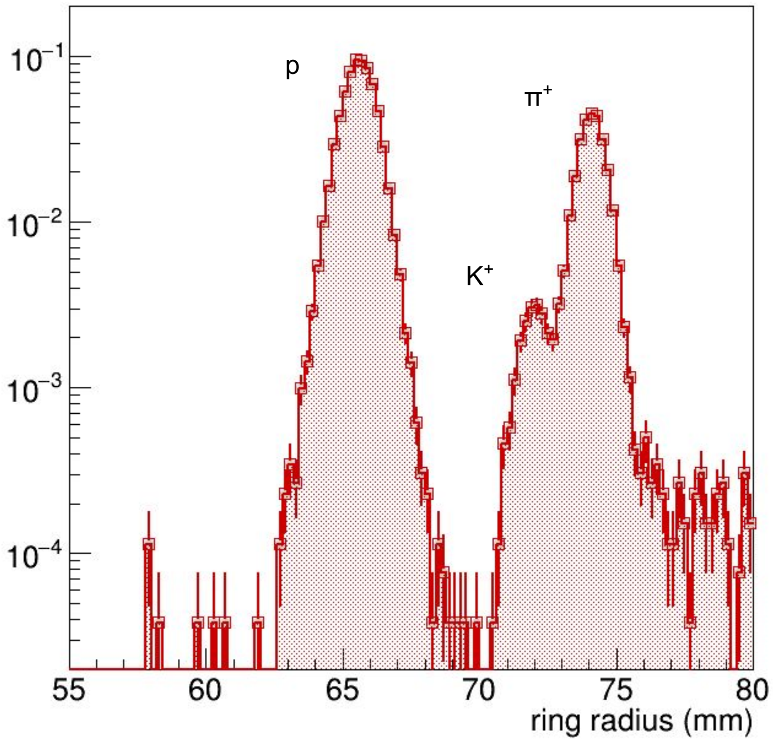
Interplay between radiators

gas ring tags pions, kaons and protons are below threshold

10 GeV/c positive beam with no selection applied



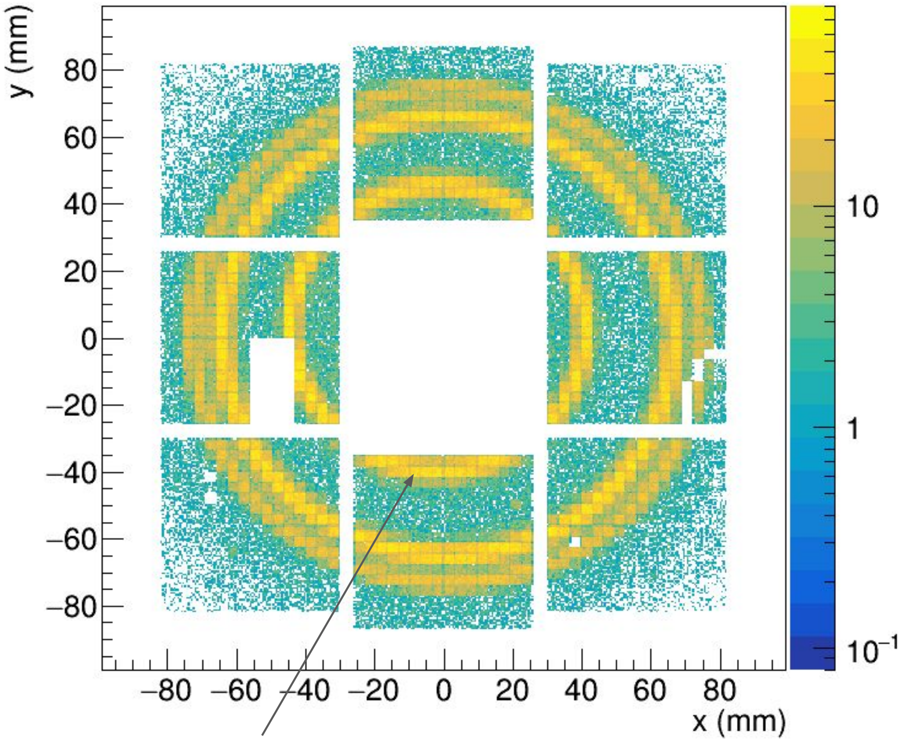
reconstructed radii at 10 GeV/c with no selection applied



Interplay between radiators

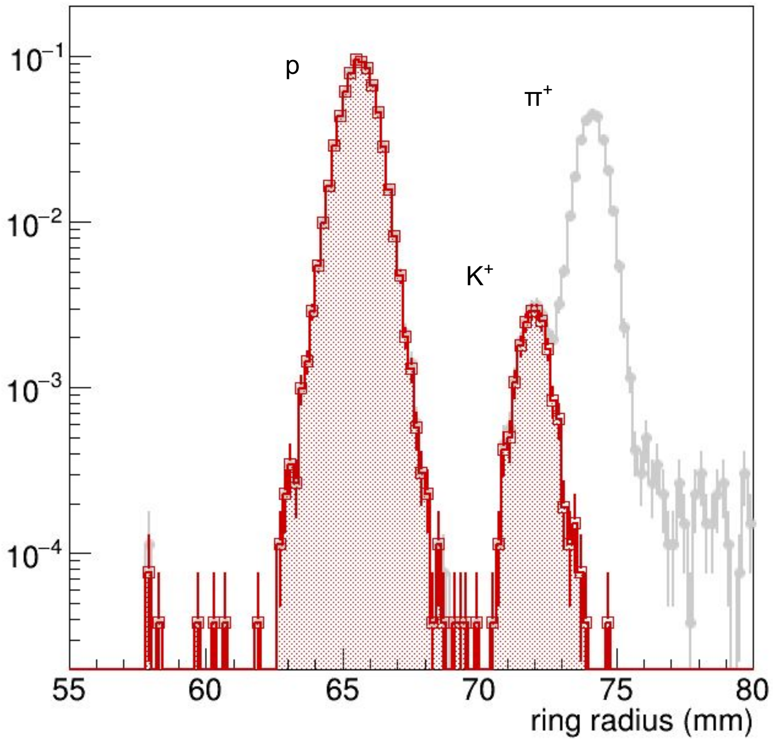
gas ring tags pions, kaons and protons are below threshold

10 GeV/c positive beam with no selection applied



gas ring

reconstructed radii at 10 GeV/c with gas veto

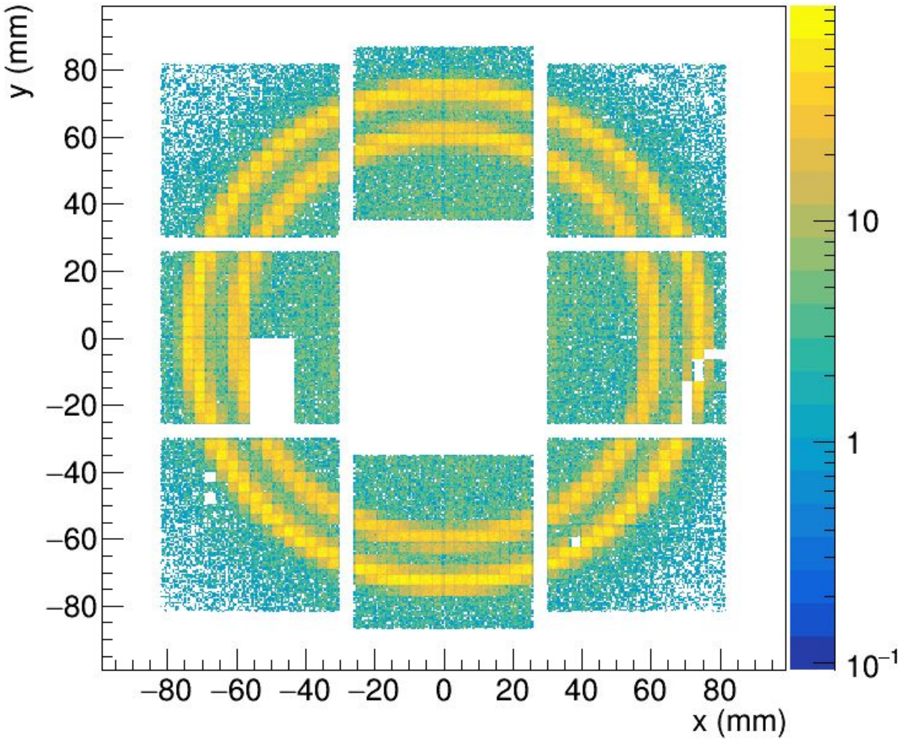


clean kaon identification at 10 GeV/c

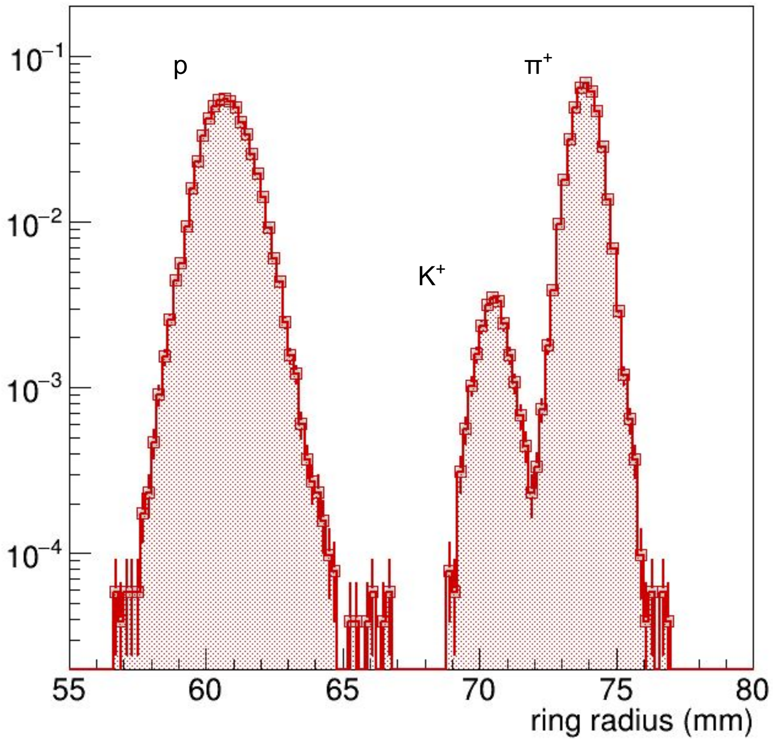
Threshold Cherenkov beam counters

TCh-1 set below kaon threshold, TCh-2 set below proton threshold

8 GeV/c positive beam with no selection applied



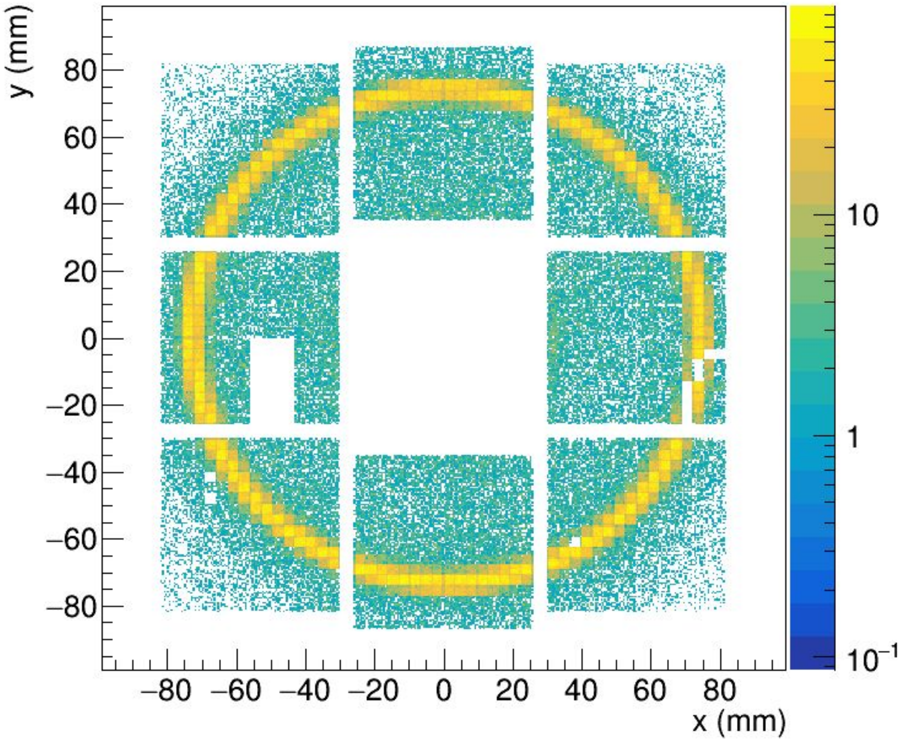
reconstructed radii at 8 GeV/c with no selection applied



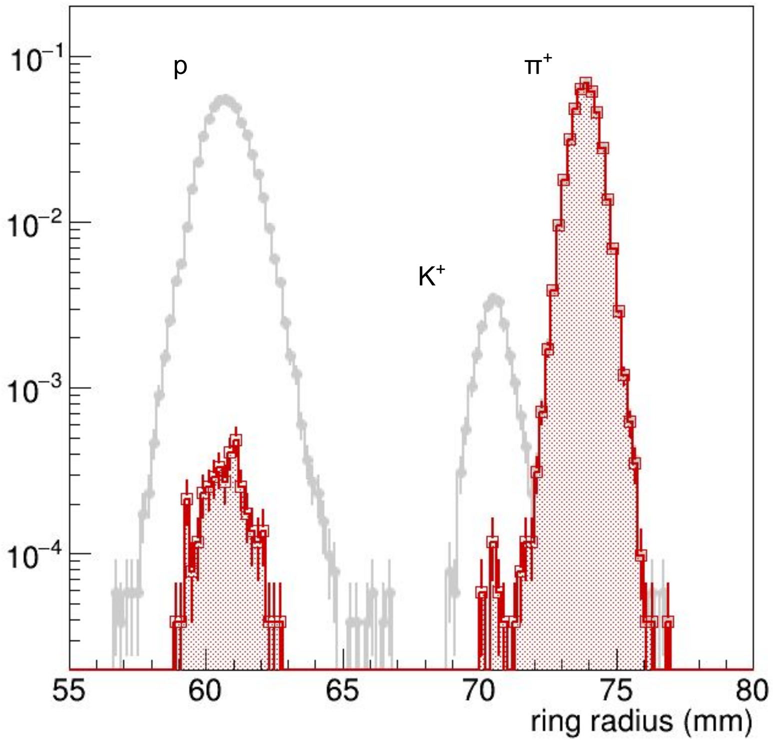
Threshold Cherenkov beam counters

TCh-1 set below kaon threshold, TCh-2 set below proton threshold

8 GeV/c positive beam with pion tag



reconstructed radii at 8 GeV/c with pion tag

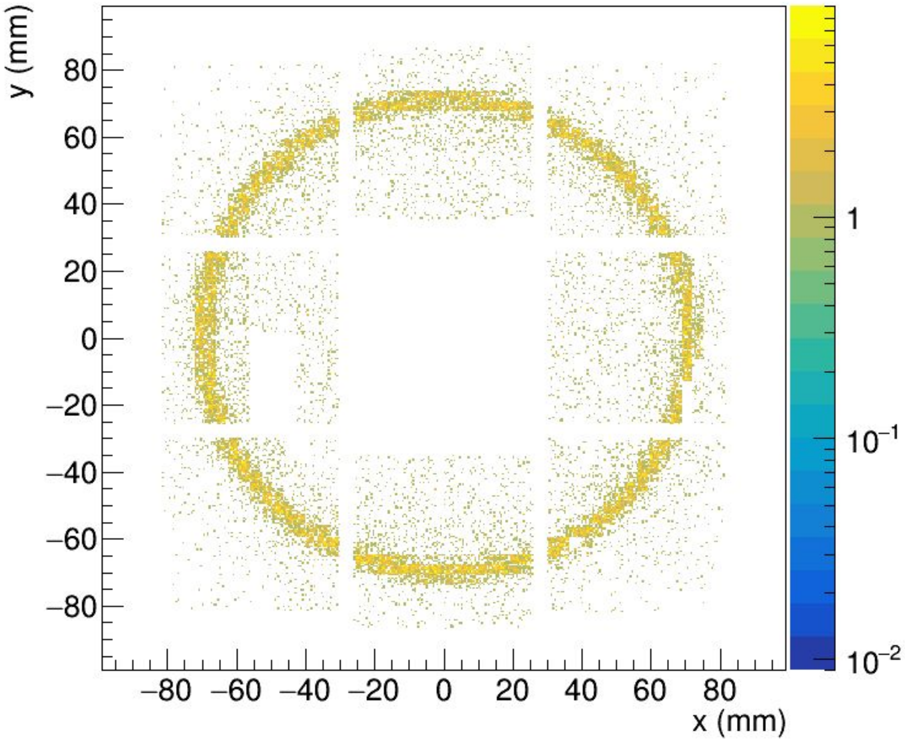


pion tag: TCh-1 required

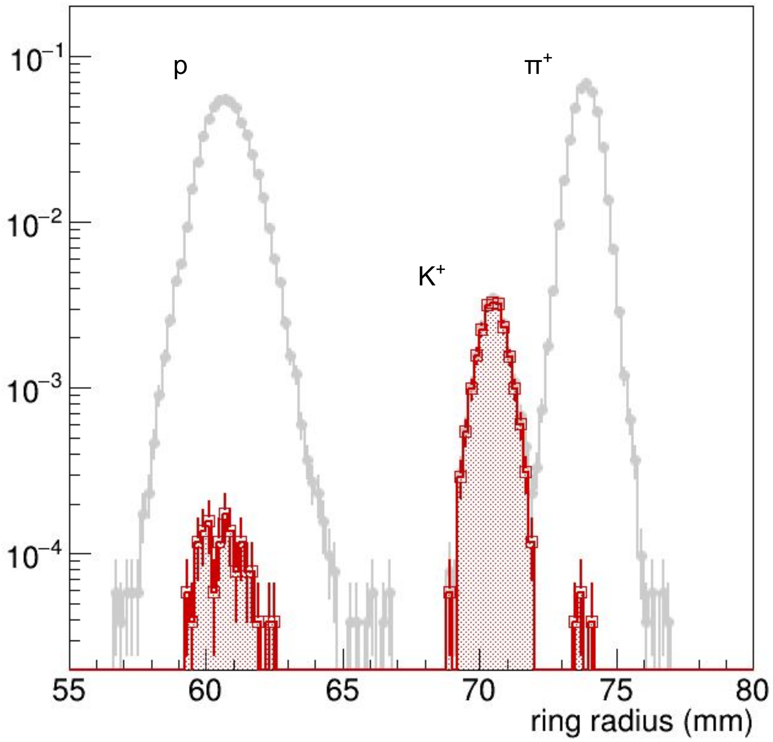
Threshold Cherenkov beam counters

TCh-1 set below kaon threshold, TCh-2 set below proton threshold

8 GeV/c positive beam with kaon tag



reconstructed radii at 8 GeV/c with kaon tag

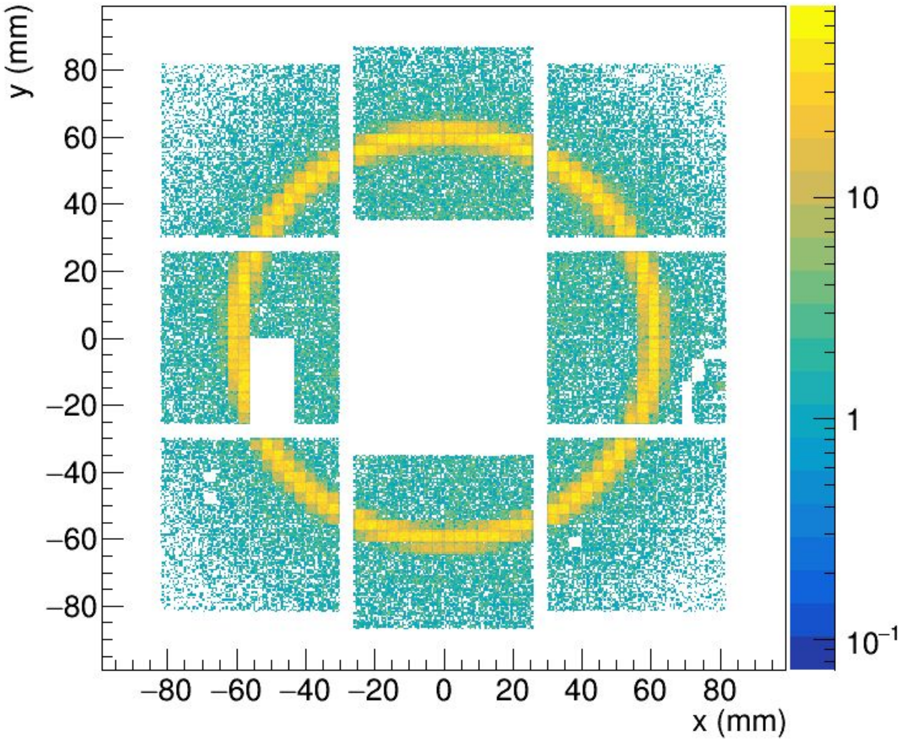


kaon tag: TCh-1 veto and TCh-2 required

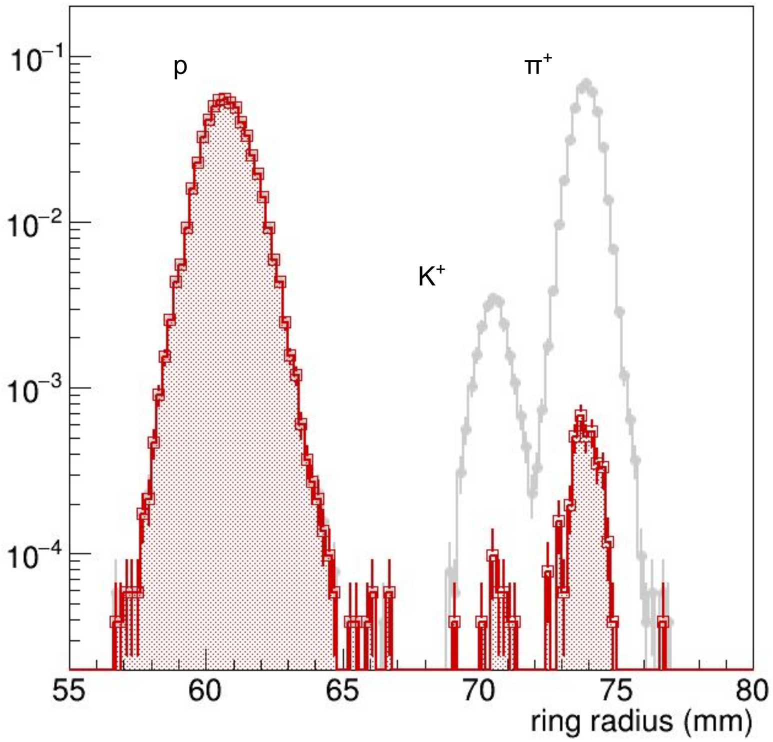
Threshold Cherenkov beam counters

TCh-1 set below kaon threshold, TCh-2 set below proton threshold

8 GeV/c positive beam with proton tag



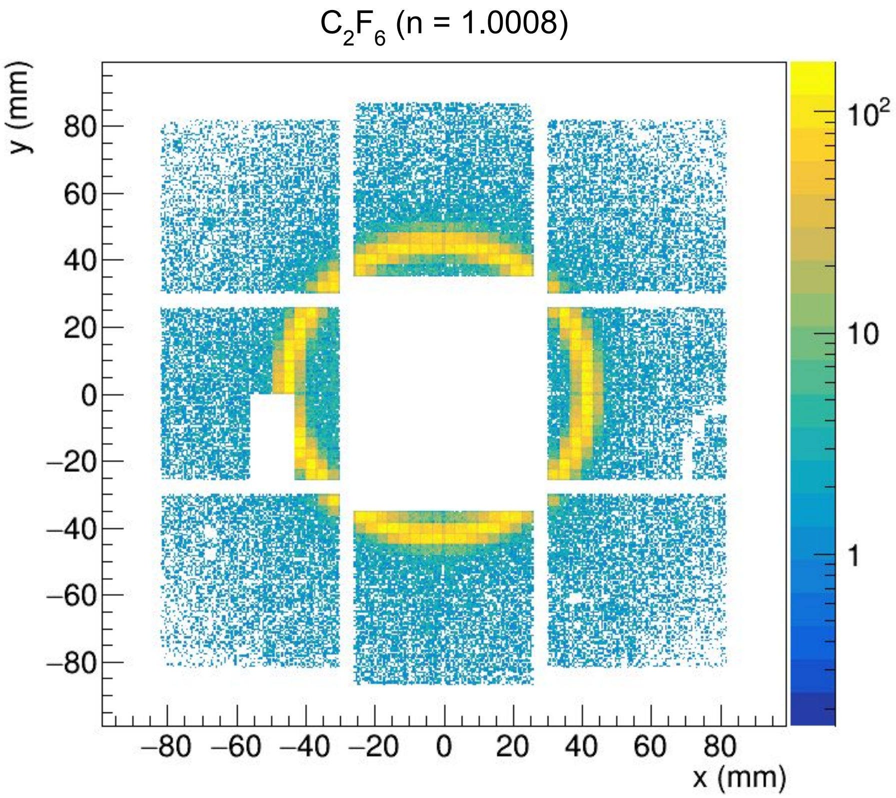
reconstructed radii at 8 GeV/c with proton tag

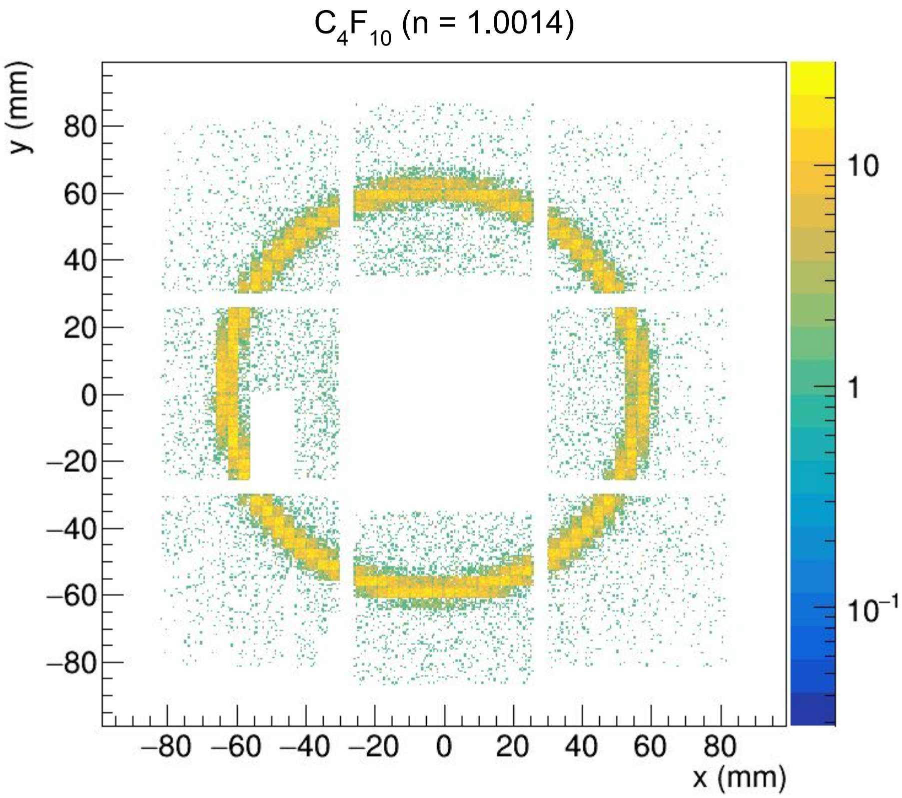


proton tag: TCh-1 veto and TCh-2 veto

Gas radiators

standard gas C_2F_6 (n = 1.0008) and heavier C_4F_{10} (n = 1.0014)



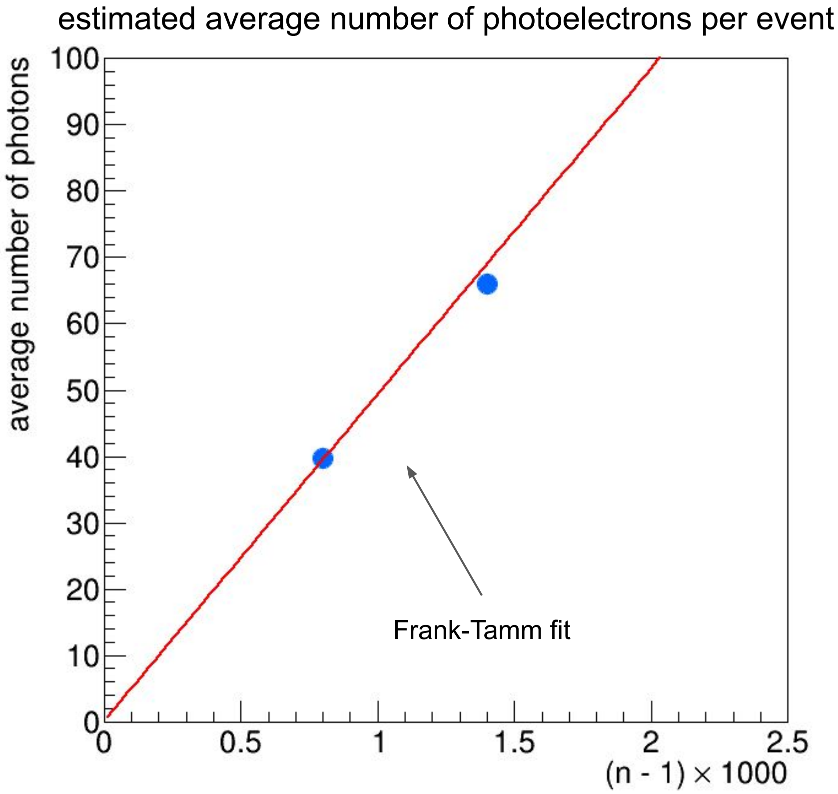


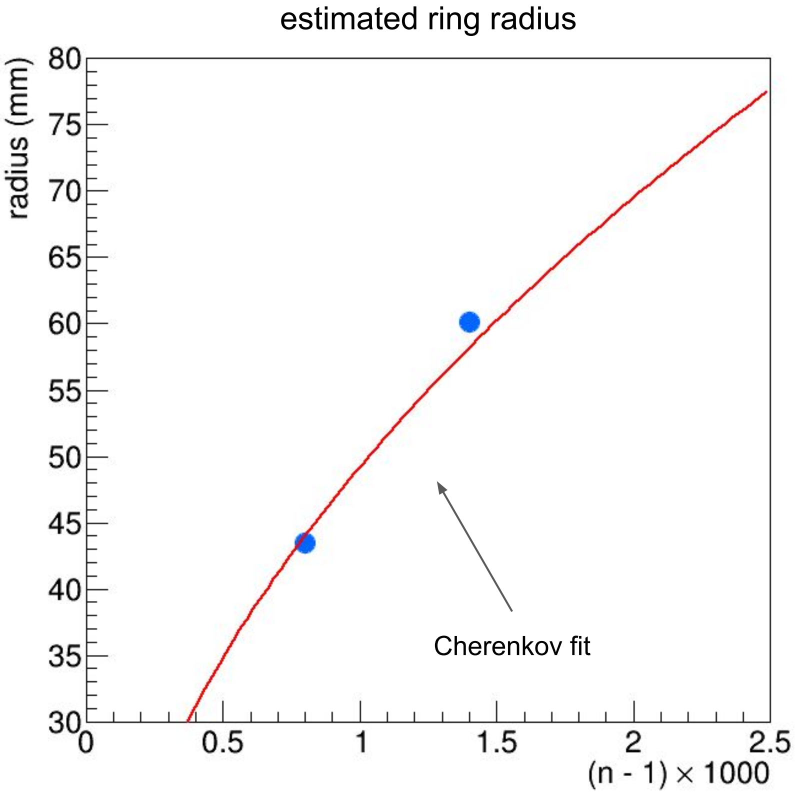
no aerogel in these data

heavier gas, larger refractive index, larger ring

Gas radiators

standard gas C_2F_6 (n = 1.0008) and heavier C_4F_{10} (n = 1.0014)





increases with refractive index (angle)

radius increases