EIC eRD102: Dual-Radiator RICH

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EIC DAC Meeting - 19th October 2022

The dRICH Project

Compact cost-effective solution for particle identification in the high-energy endcap at EIC

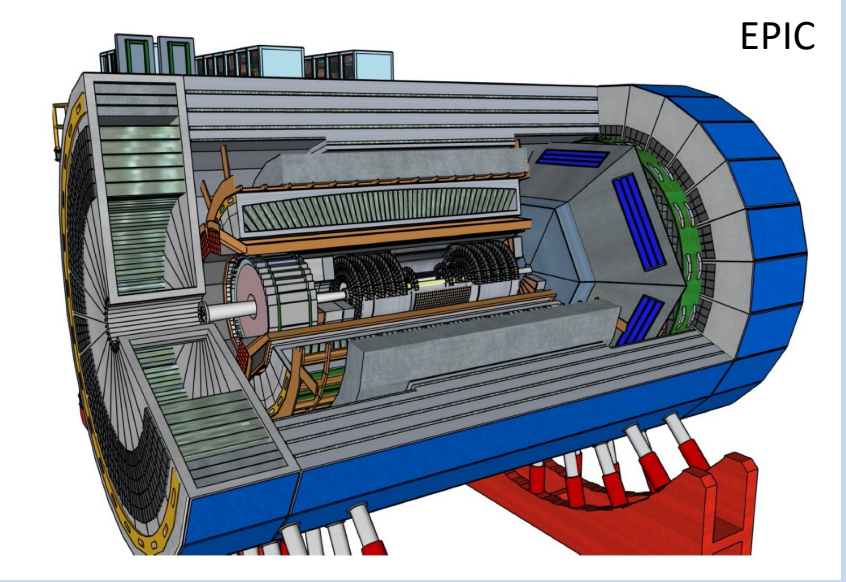
INFN

BA, BO, CS

CT, FE, GE,

LNF, LNS, RM1,

SA, TO, TS



Duke University

NISER

Georgia State University

Stony Brook University

p/A beam →

← e beam

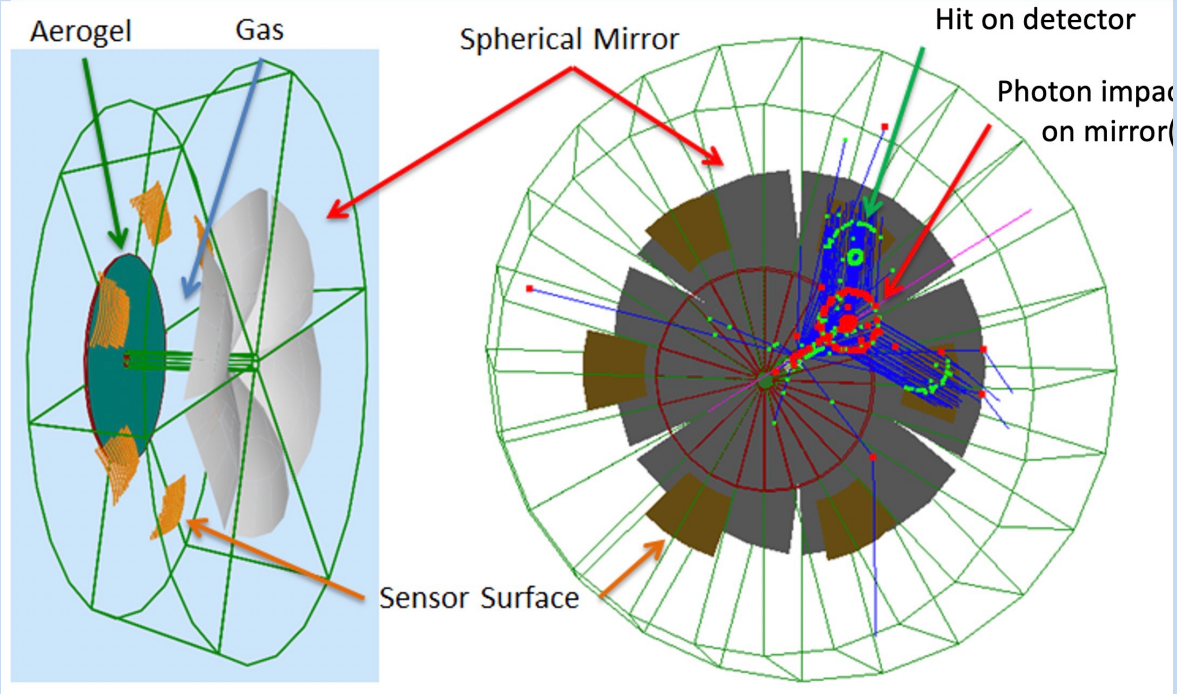
p: 41 GeV, 100 to 275 GeV

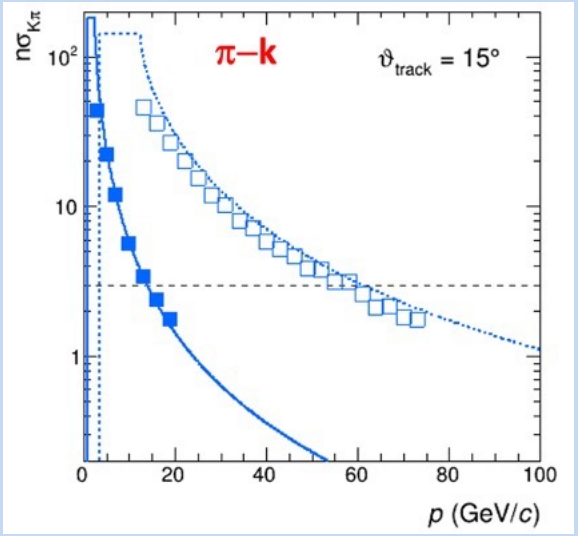
e: 5 GeV to 18 GeV

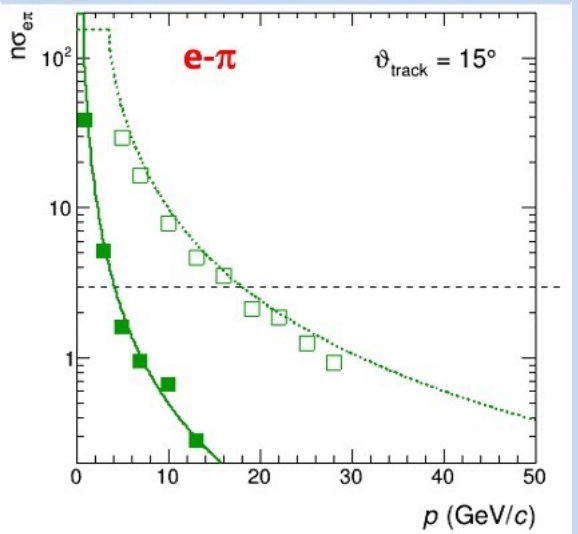
The dual-radiator RICH has been a common reference in the forward region since EIC Yellow Report
Important connections & synergies with other targeted EIC R&D (eRD102, eRD110, eRD109, ….)

Dual Radiator RICH @ EIC

Two main challenges : **cover wide momentum range 3 - 60 GeV/c**
work in high (~ 1T) magnetic field







dRICH: effective solution, part of EIC reference detector

Radiators: Aerogel (n_{AERO}~1.02) + Gas (n_{C2F6} ~ 1.0008)
extensive volume + focalization

Detector: 0.5 m^2/sector , 3x3 mm^2 pixel → SiPM option
detector box outside acceptance

Phase Space:
- Polar angle: 5-25 deg
- Momentum: 3-60 GeV/c

Risk Mitigation

Performance: Obtain an effective optics/resolution within EPIC constraints

- ✓ Benchmark propose solutions and radiatior's interplay with a prototype
- ✓ Simulate the non-trivial geometry (extended gas volume, field map)
- ✓ Study structure and services
- ✓ Interplay with other detectors (tracking, PID, material budget)

Photodetector: Realize a suitable (magnetic tolerant) photon detection plane

- ✓ Study dark rate and radiation damage mitigation for SiPM
- ✓ Implement a streaming readout chain (ALCOR ToT) ←→ eRD110
- ✓ Contribute to LAPPD development in parallel
- ✓ Prototype a suitable detector plane (SiPM + DAQ with integrated cooling) ←→ eRD109

Aerogel: Validate aerogel manufacturers alternative to Russia ←→ eRD101

- ✓ Characterization campaign for unprecedented aerogel with n=1.02
- ✓ Investigate ASPEN interest and capability in optical aerogel
- ✓ Work with Aerogel Factory for customized aerogel (transparency, dimensions,…)

Gas: Search alternatives to greenhouse gases

- ✓ Study mechanics of a pressurized vessel

Mirrors: Validate composite mirrors and structure materials

- ✓ Validate the new cost-effective manufacturing procedure with CMA
- ✓ Search for alternatives
- ✓ Study mirror support and alignment
- ✓ Study mechanics of the full-scale detector

✓ Well structured
✓ Ongoing
✓ Being started

eRD102 in FY22

Goal: Technical solution identification, specs definition, risk mitigation, cost assessement

FY22: Initial assessment on dRICH prototype based on the first test beams (12/22)

- ✓ Basic prototype commissioning with beam in Fall 2021
- ✓ Upgrade in alignment, timing, beam instrumentation reading, services
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Realistic implementation of dRICH into EIC detector (02/23)

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Suitable detector plane for the dRICH prototype (03/23)

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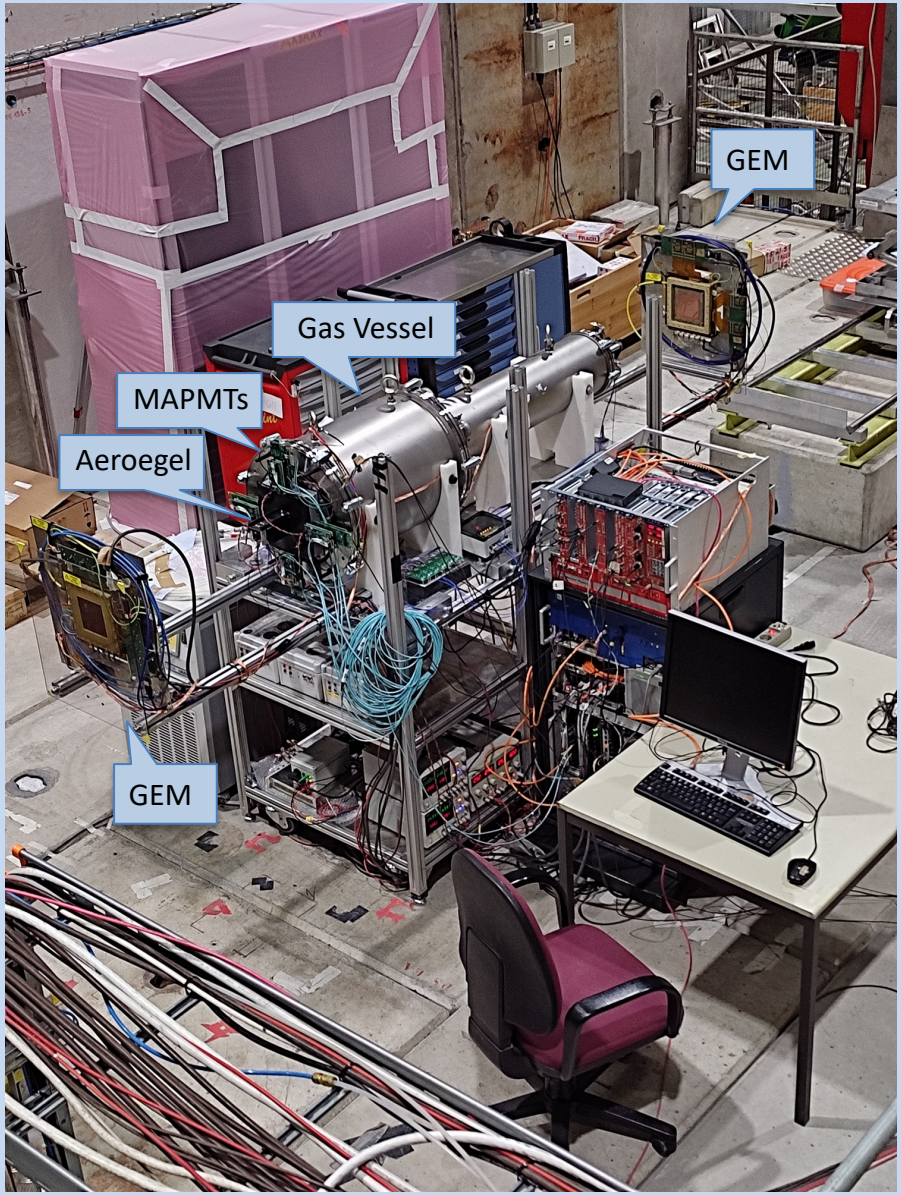
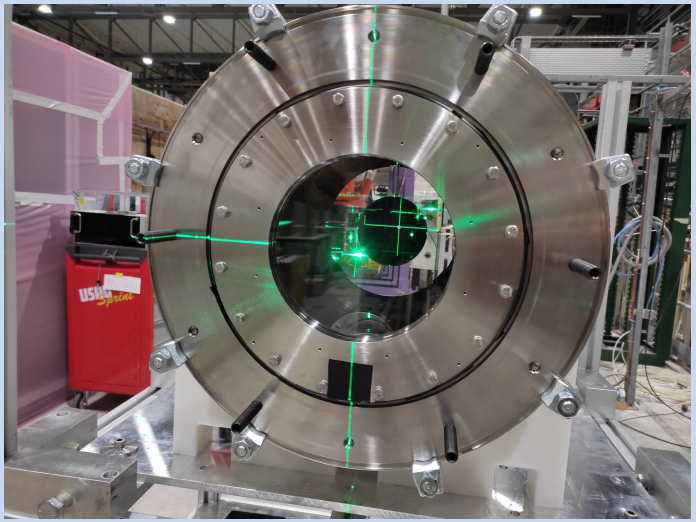
- ✓ ALCOR v2 submitted (better dynamical range and rate sustainability)
- ✓ Cooling scheme under study
- ✓ Electronic stack and mechanics design

dRICH Prototype

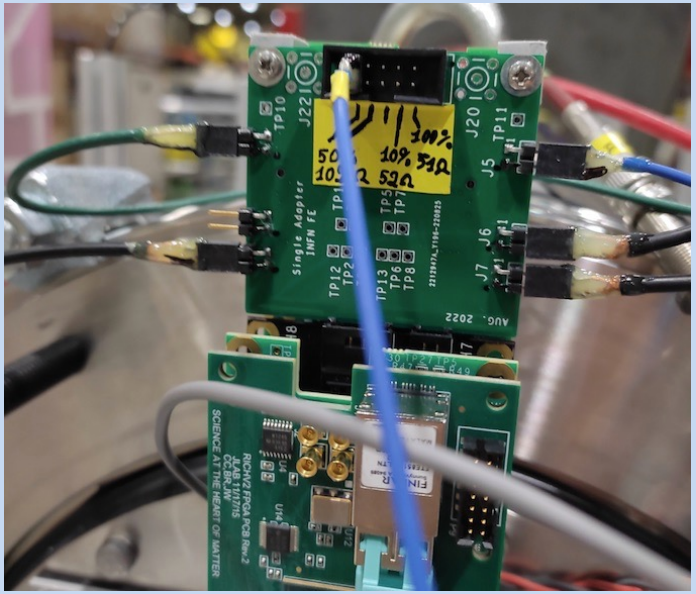
Test beam @ PPE158 - SPS September 2022



Refined alignment tools and procedure



Beam information: time and Cherenkov tagging

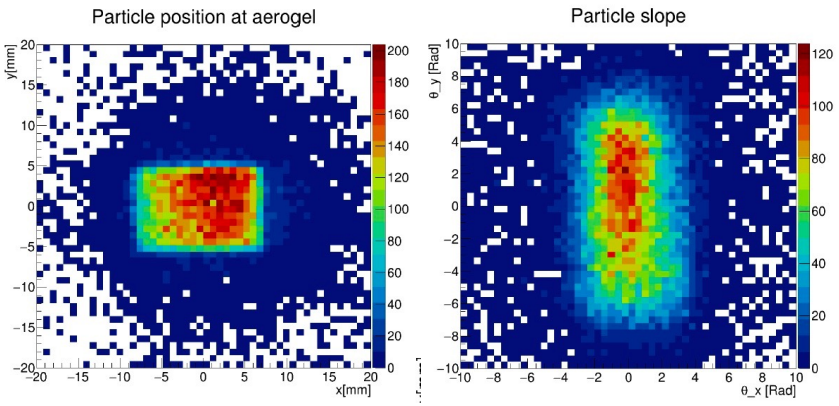


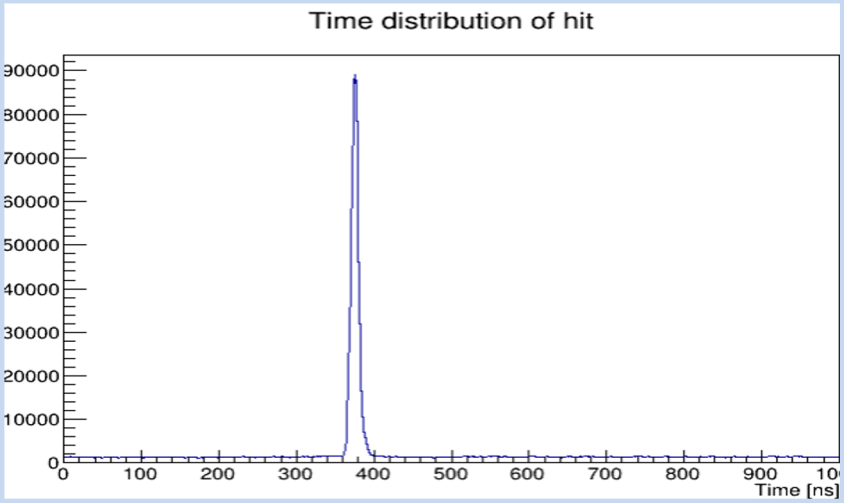
Prototype Commissioning

2021 beam time:

- Most of the time was parassitic
- Sensors + readout shared with eRD101
- Beam line still under commissioning

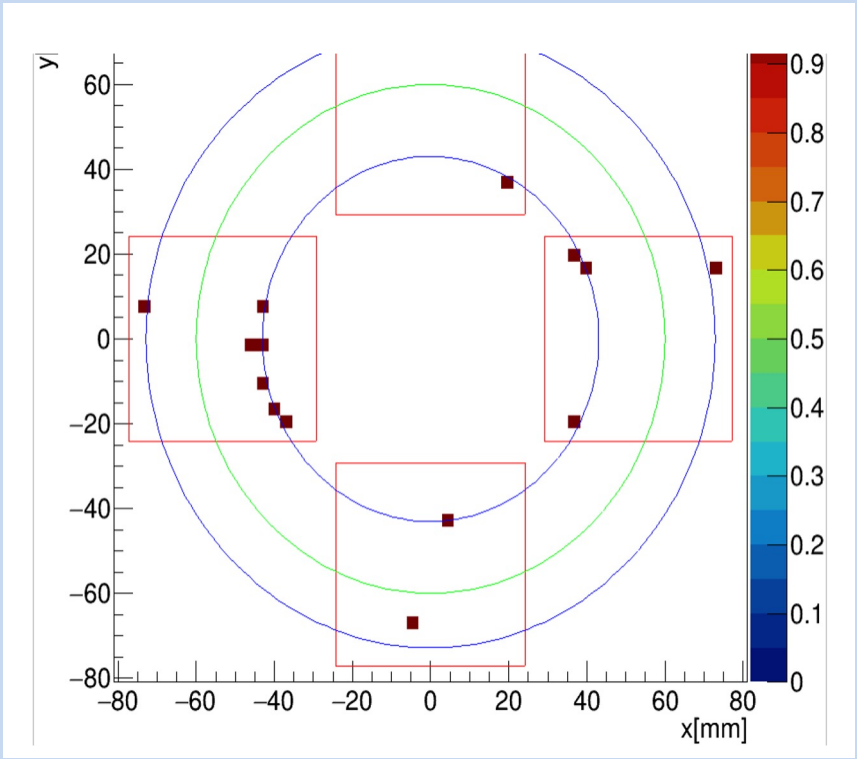
GEM tracking



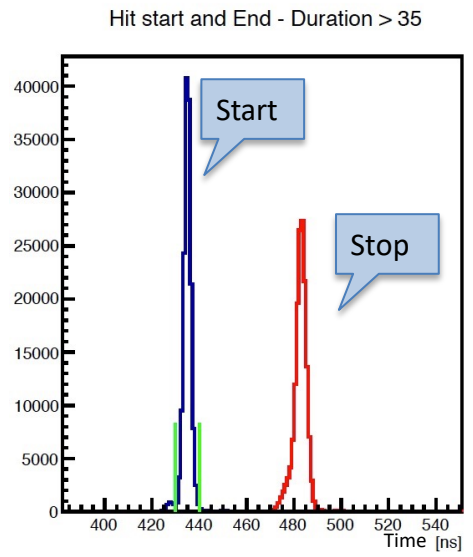


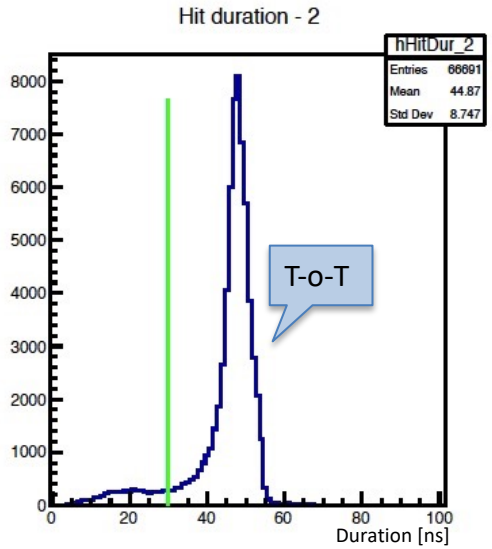
Example of event display

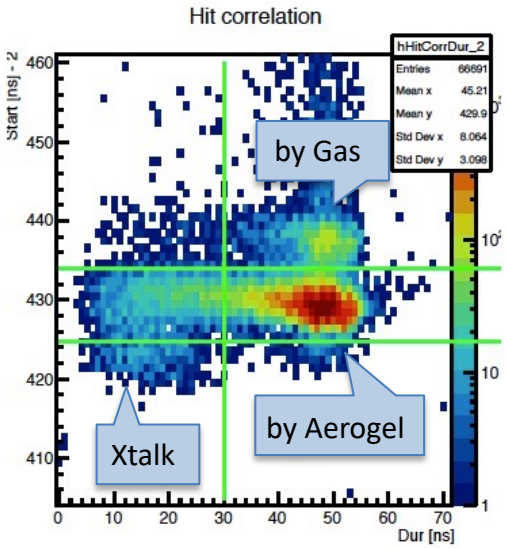
- Recorded hit
- Sensor
- Geometrical selection
- Gas and aerogel reconstructed rings

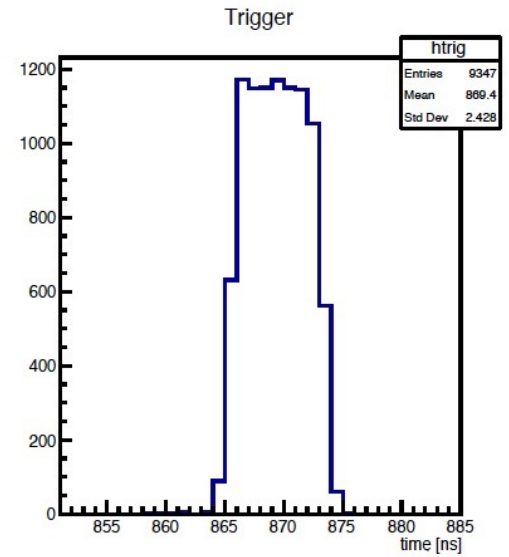


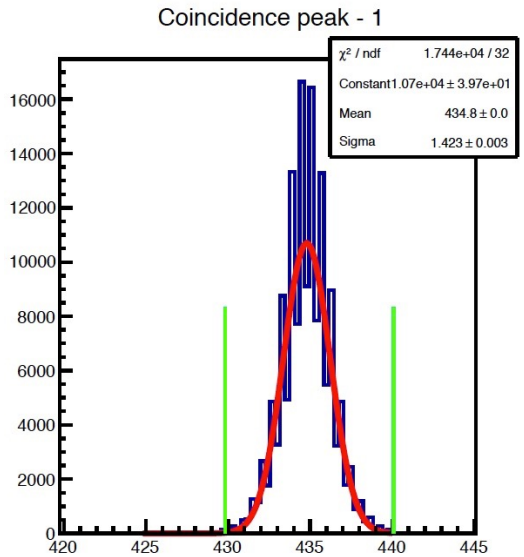
Online Time Analysis

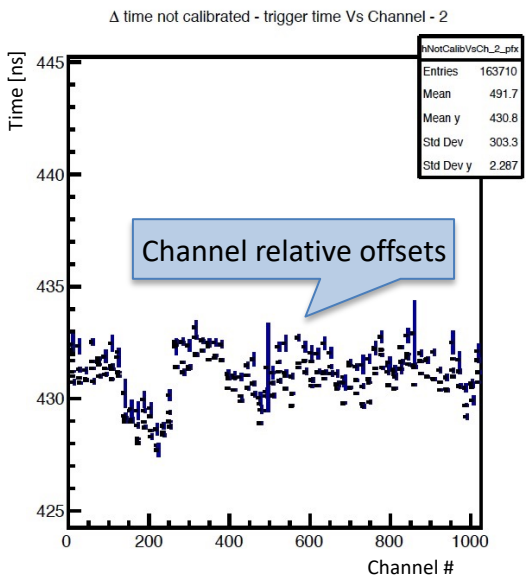






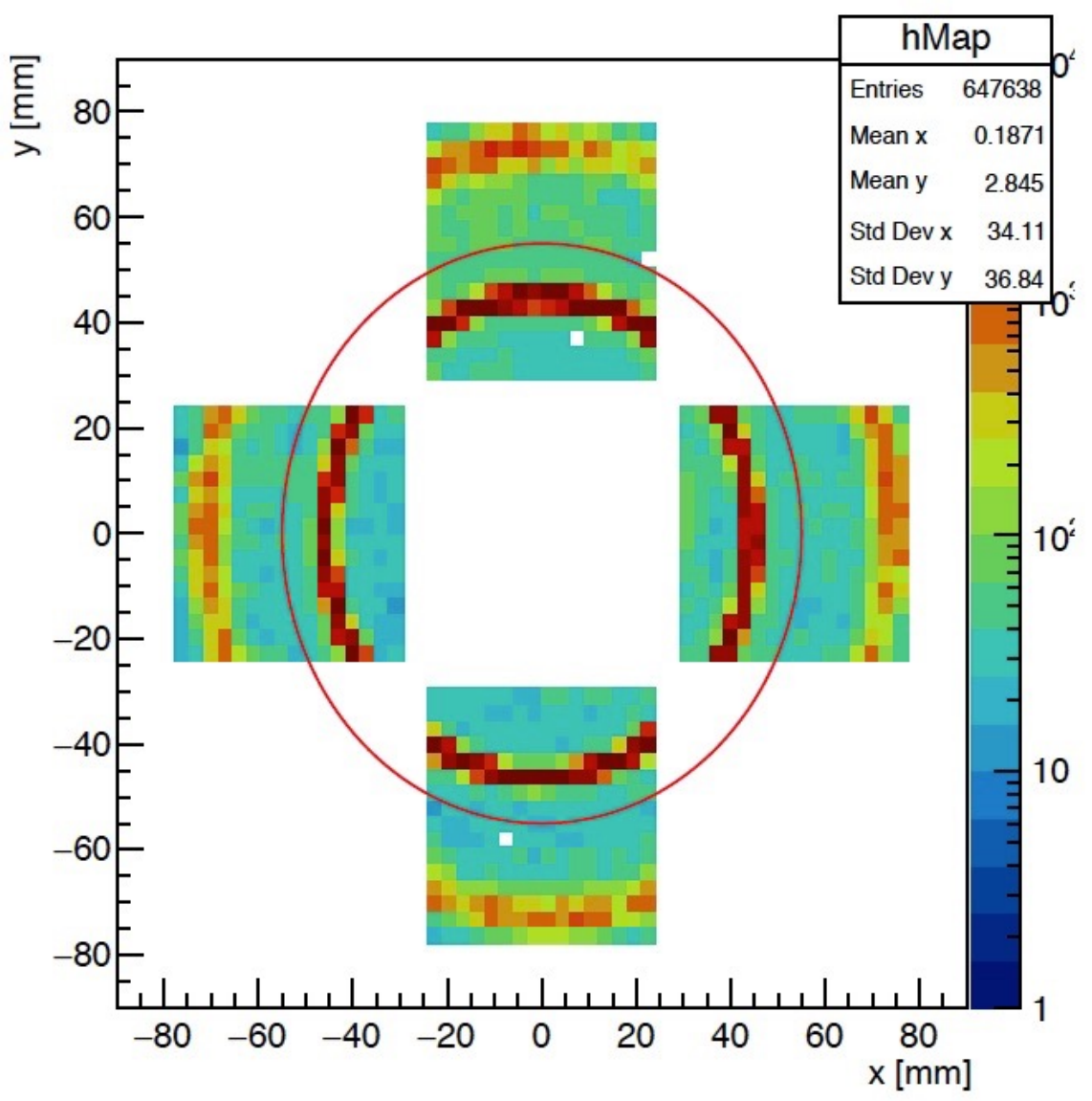


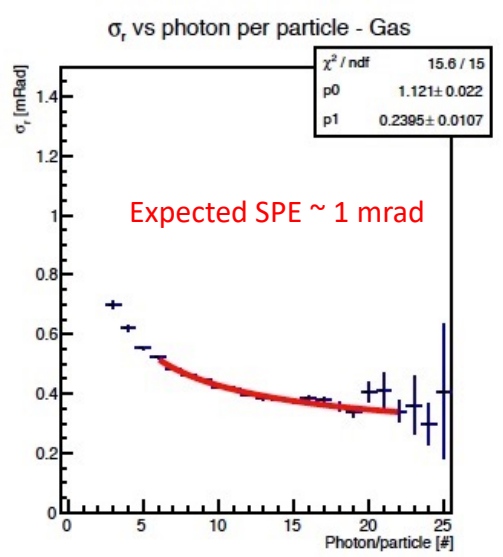


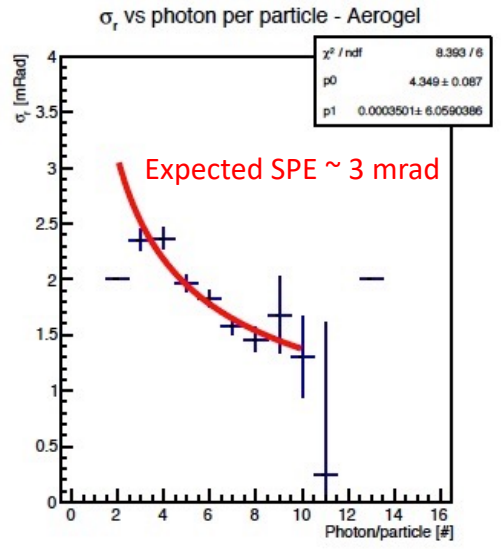


Online Cherenkov Analysis

2022 Preliminary results: Two radiators with 180 hadron beam with reference readout

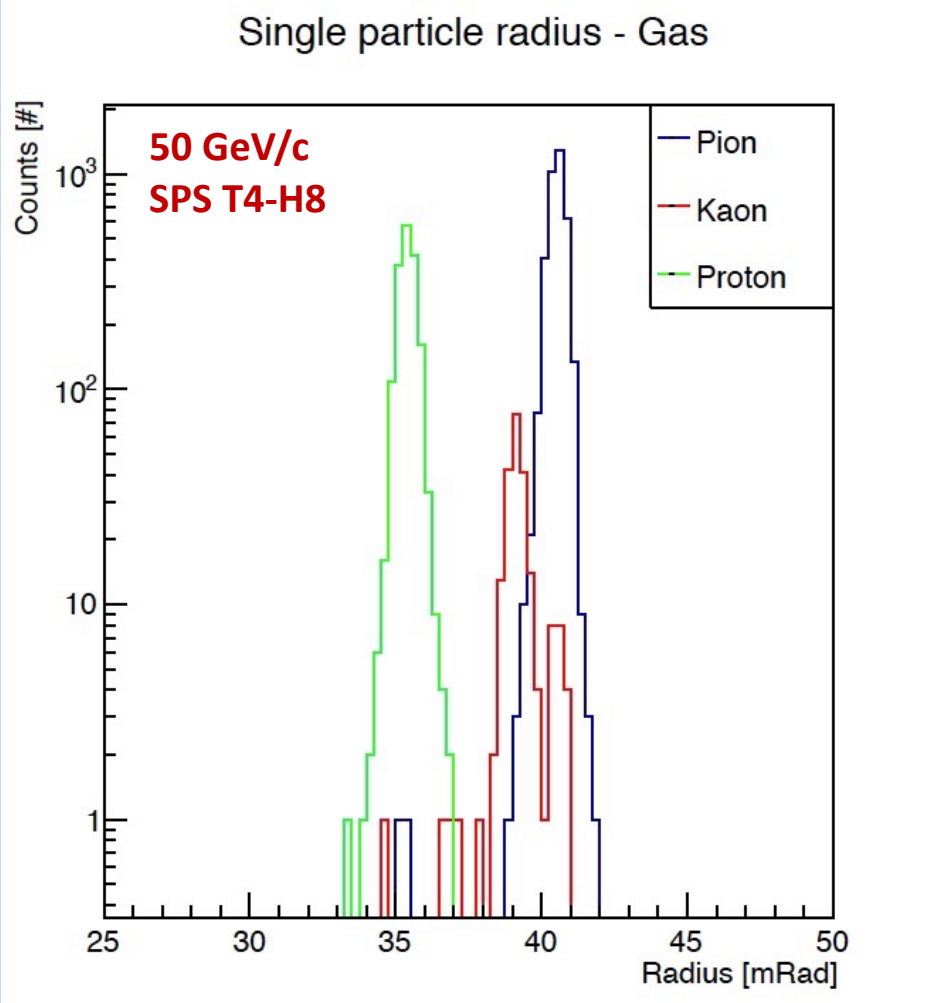


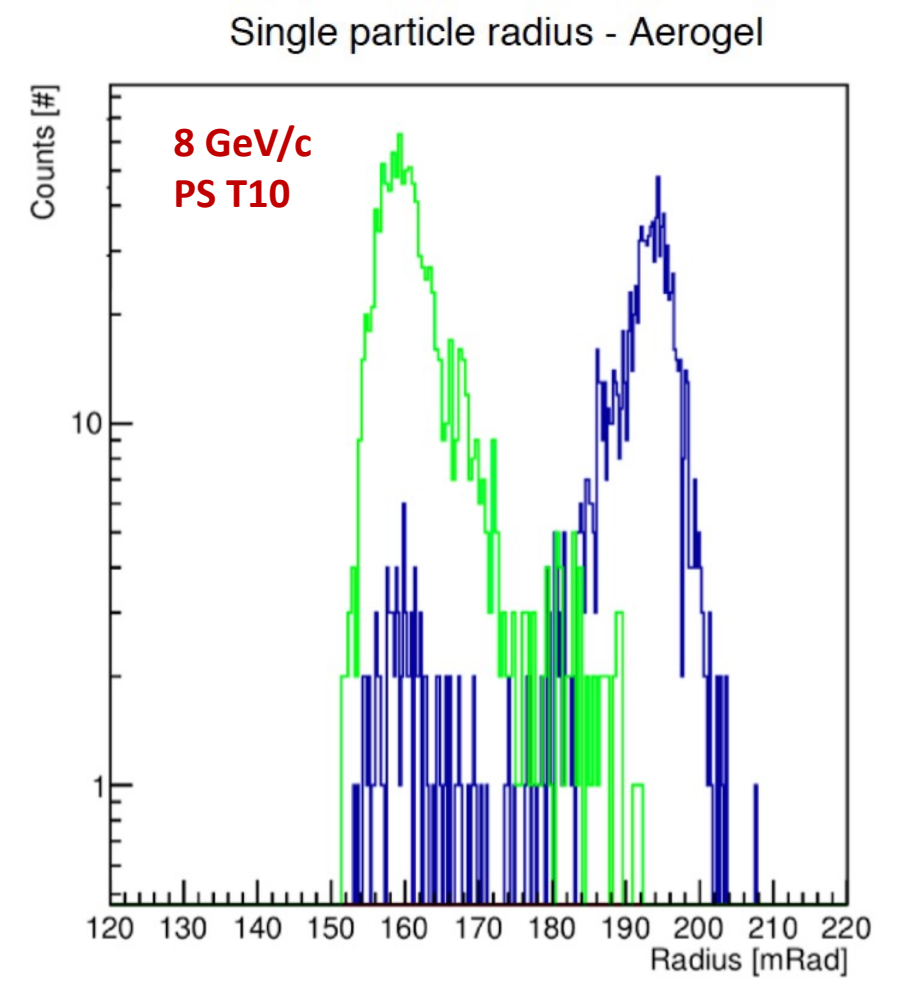




Prototype Radiator Interplay

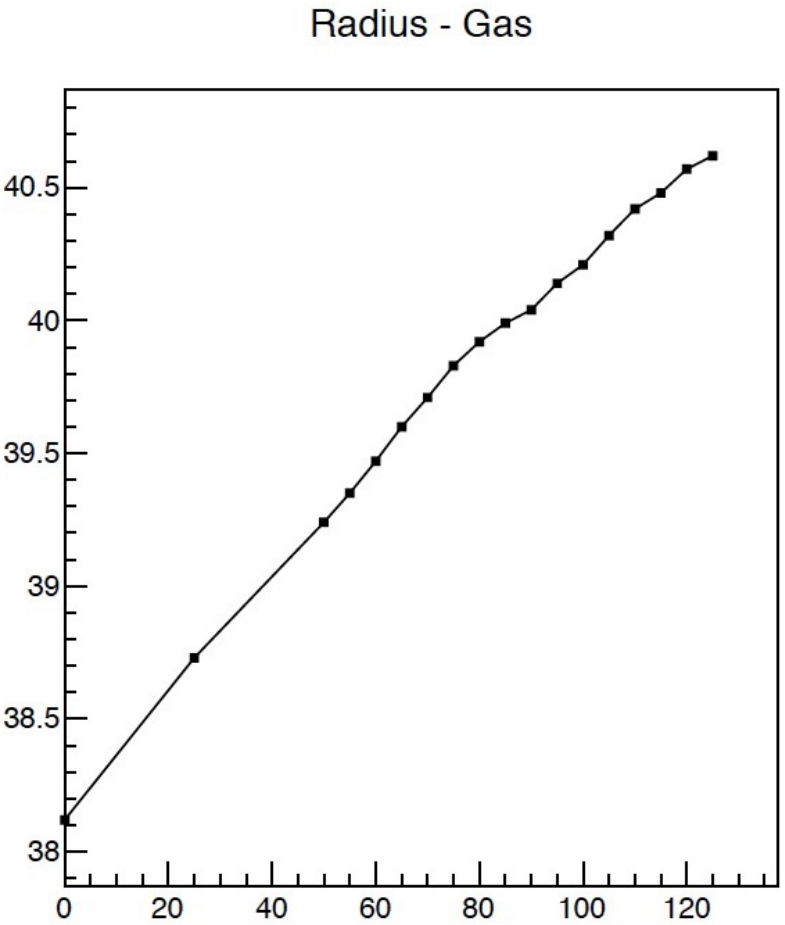
Test at 50 GeV mixed hadron beam with tagging by beam instrumentation (3x gas Cherenkov)

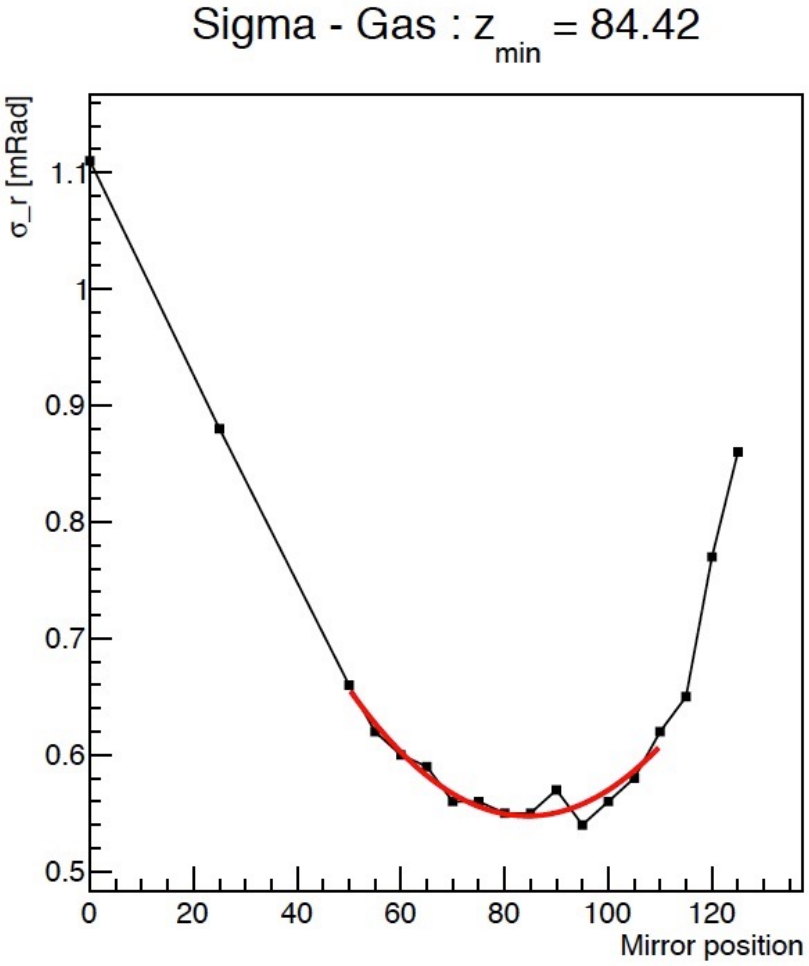




dRICH Gas

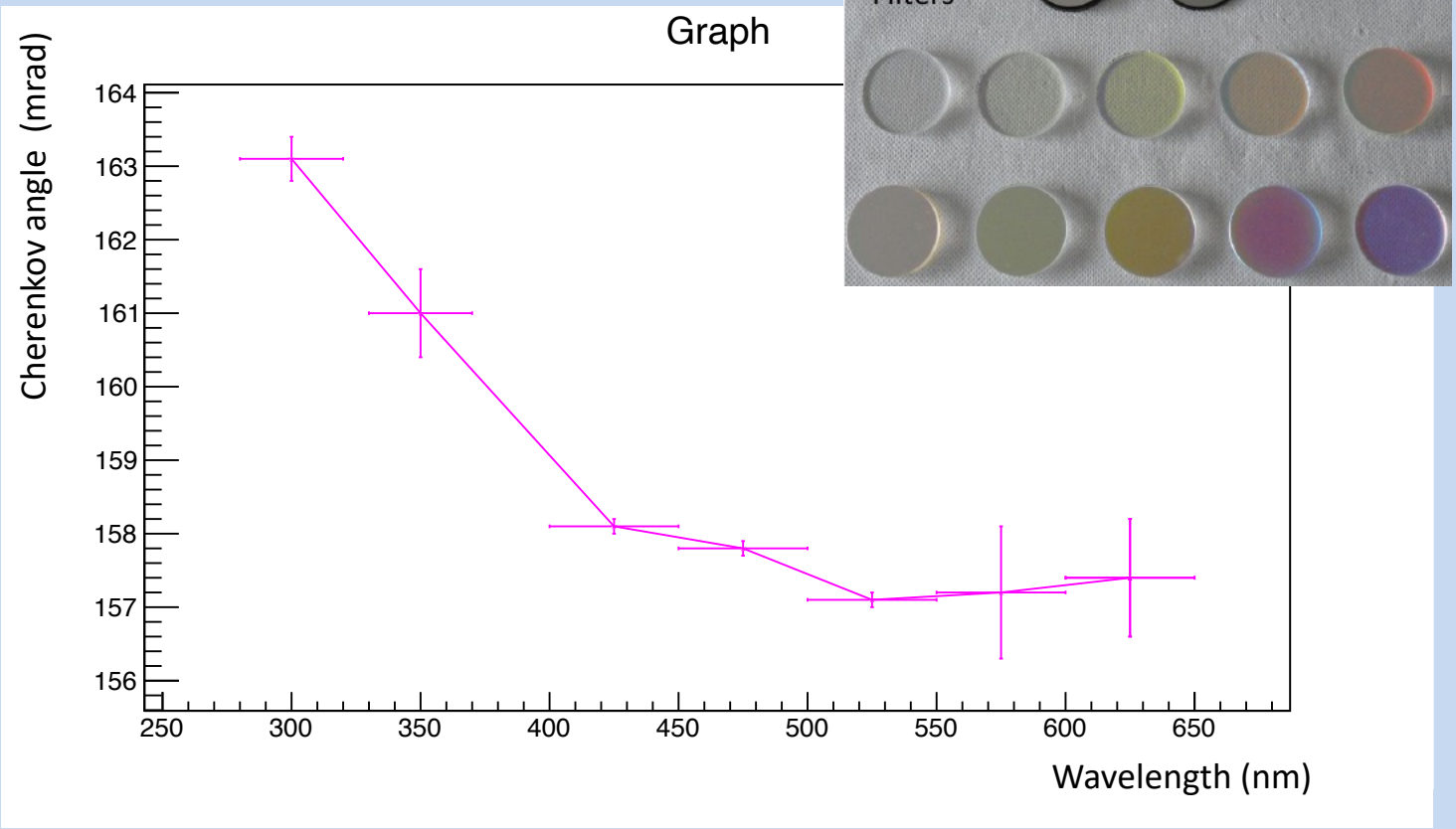
Scan the mirror position to align the focal plane on the sensor surface





dRICH Aerogel

Chromatic dispersion measured with the dRICH prototype and optical filters selecting the wavelength range



Quantify the largest expected contribution to the Cherenkov angle resolution
Can be used to derive a general relationship with aerogel density based on a quartz+air mix model

eRD102 in FY22

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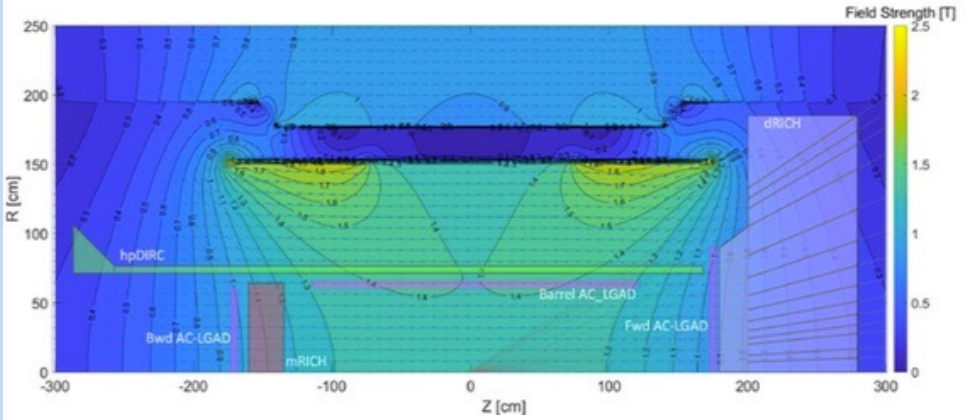
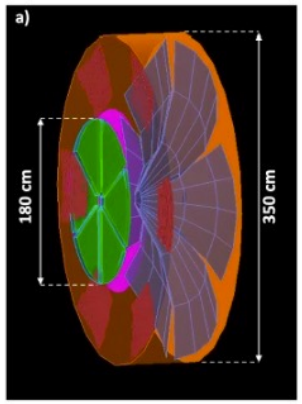
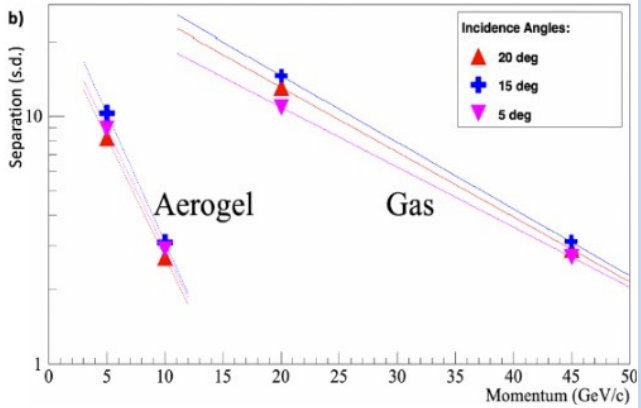
dRICH Simulations

C. Chatterjee @ RICH 2022

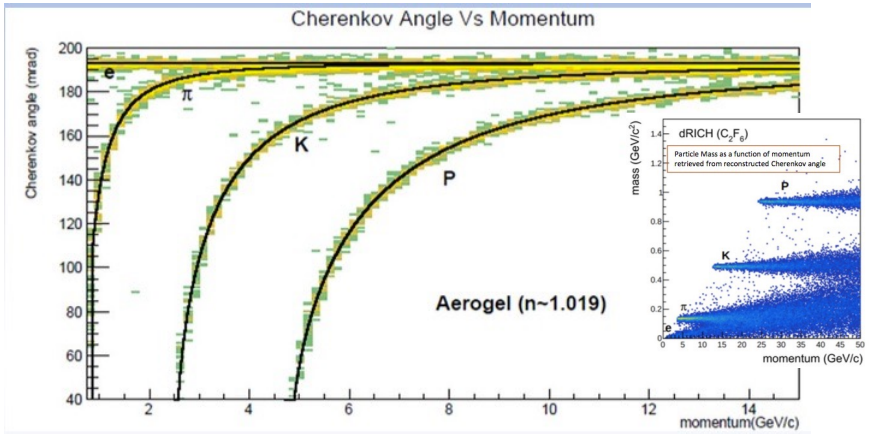
ECCE simulation

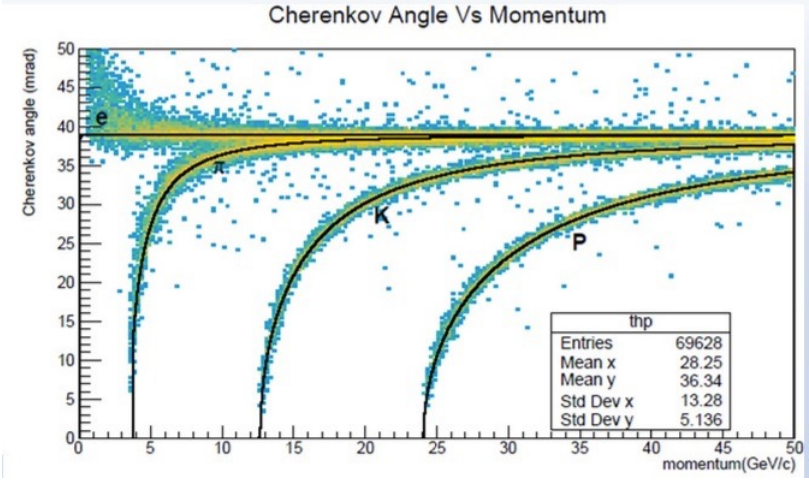




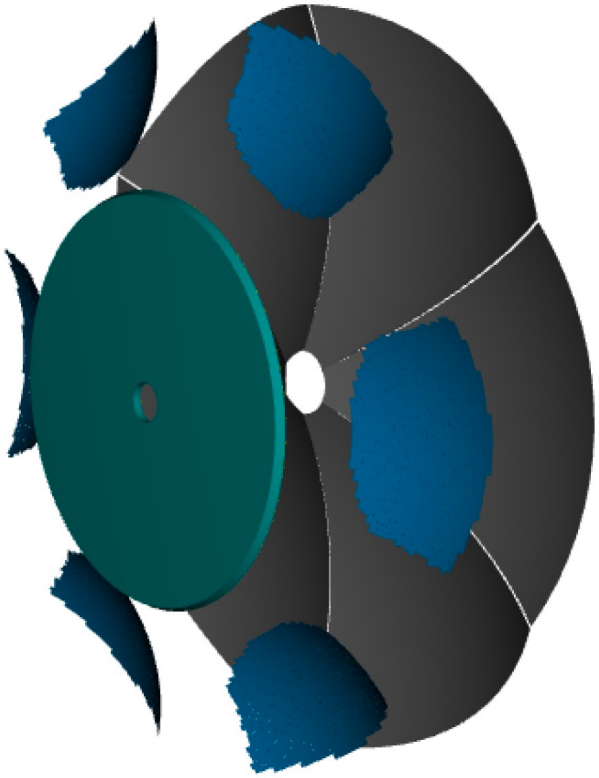


ATHENA simulation



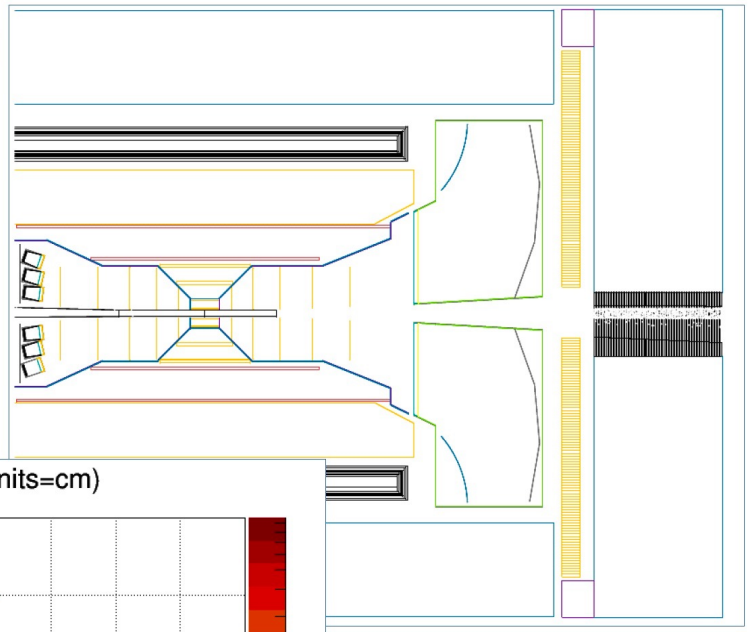


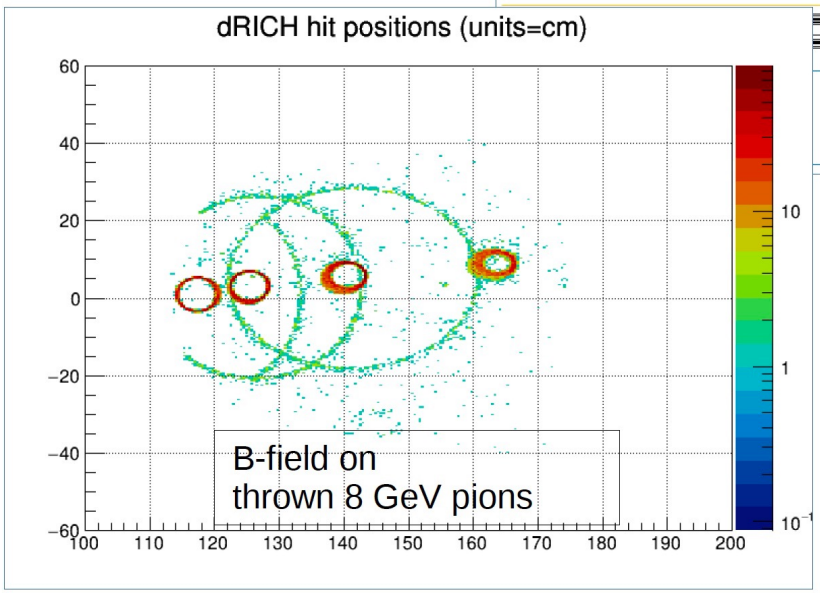
October Production Readiness: Simulation



Ready!

- Geometry consistent with menagerie
- Optics as good as ATHENA was





Two "modules" for reconstruction:

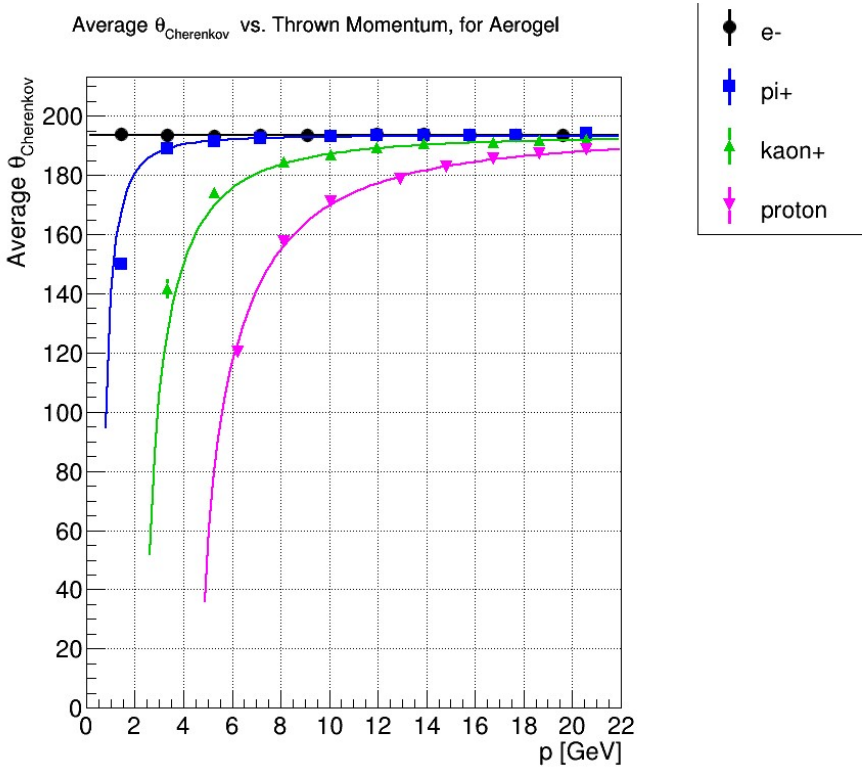
- Standalone Indirect Ray Tracing (IRT) library – **Ready!**
- Bindings of IRT to Reconstruction Framework
  - Working well, but with "**scaffolding**":

- For a full campaign, we need to take down the scaffolding, and bind to EICRecon (in progress...)

Reconstruction: Indirect Ray Tracing

Points: reconstructed Cherenkov Angle

Curves: expected Cherenkov angle



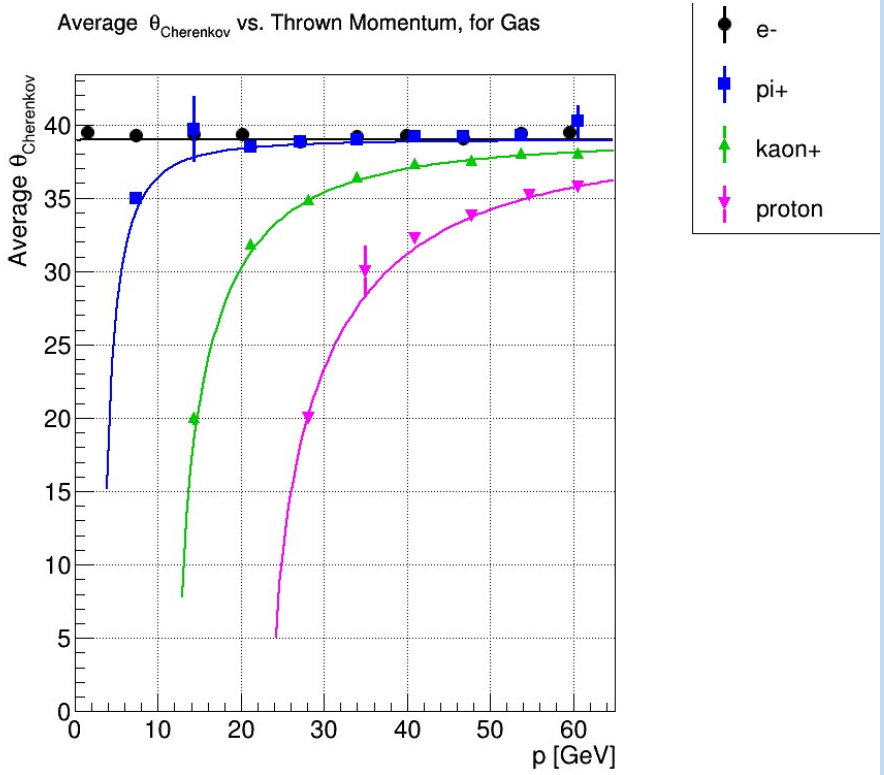


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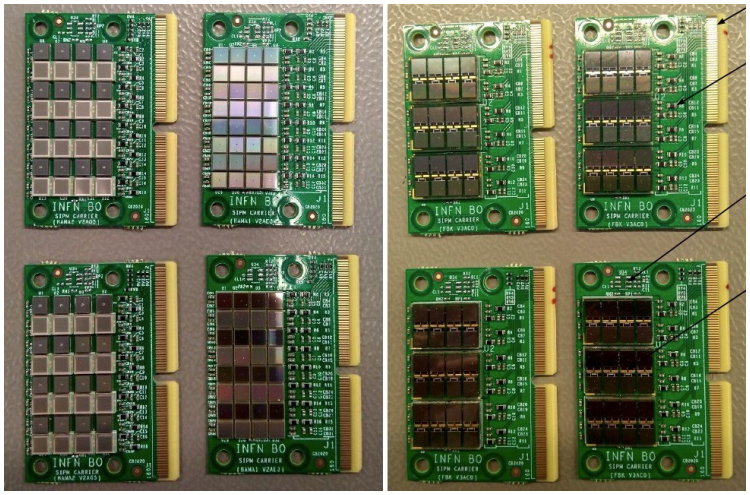
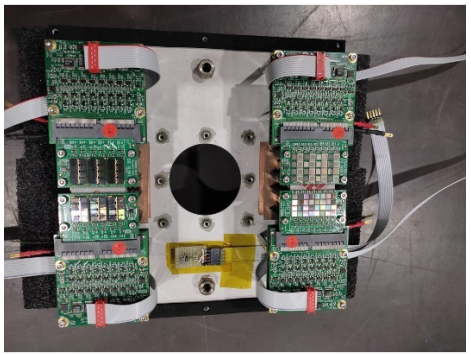
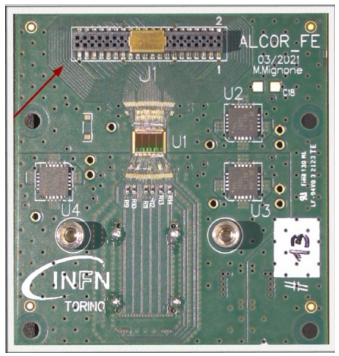
Photo-Sensor Program

Study solutions for single-photon detection within strong B-field (synergy with eRD110,eRD109)

SiPM program (reference)
Selection of candidates / R&D dark count mitigation







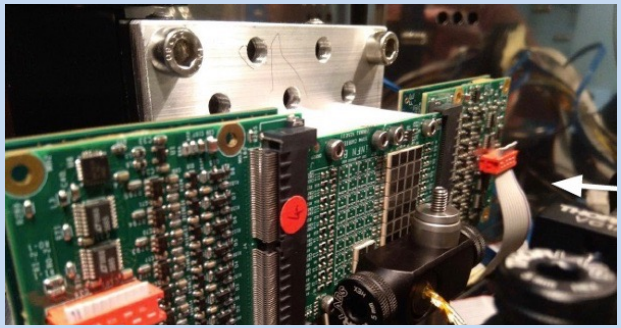
INFN: sensors, instrumentation, prototyping, test-beams

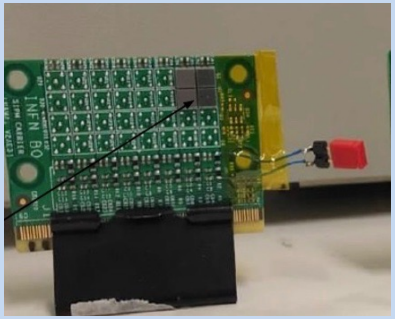
LAPPD program (backup)

Test & guide developments @ Incom

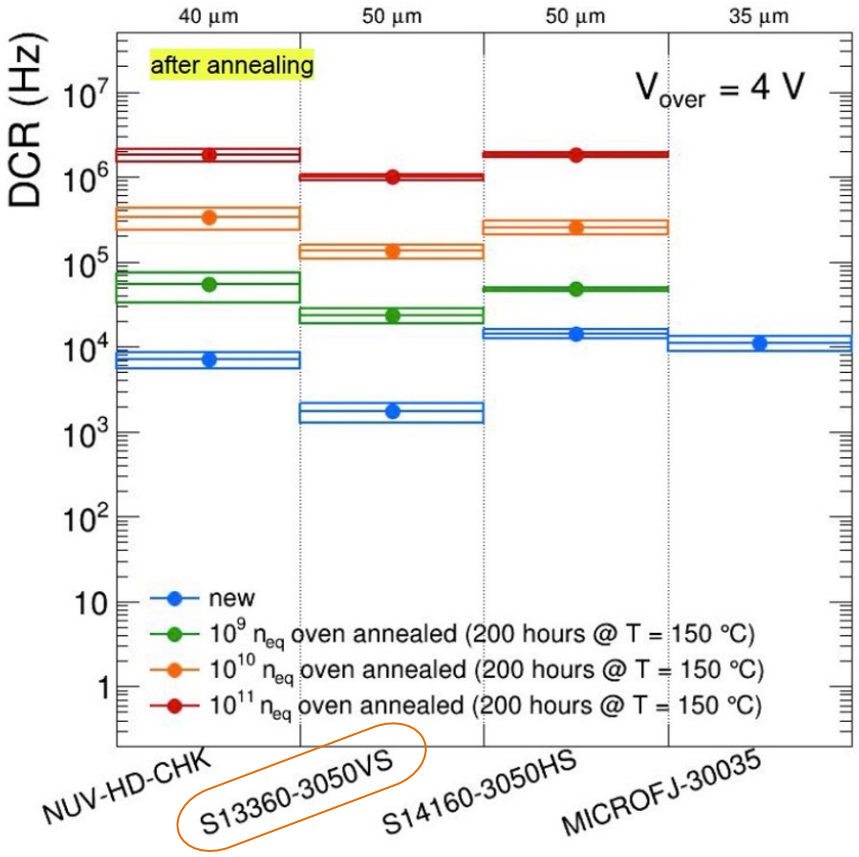
INFN: rent, instrumentation, test-beams

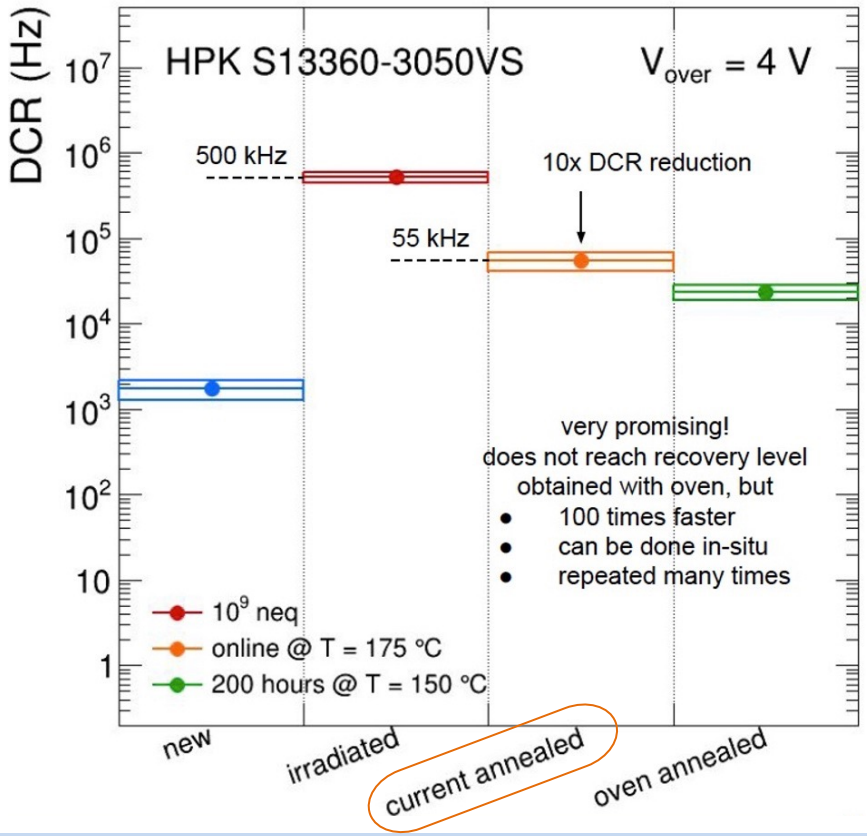
SiPMs





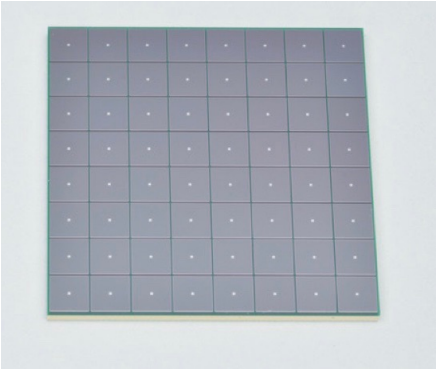
R. Preghenella @ RICH2022





SiPM Detector Plane

Hamamatsu S13361-3050



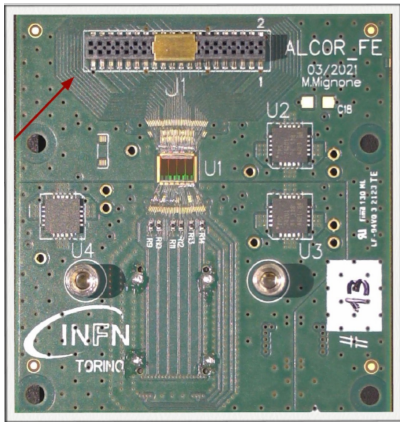
MPPC under procurement

ALCOR chip (high-rate ToT architecture) in streaming mode

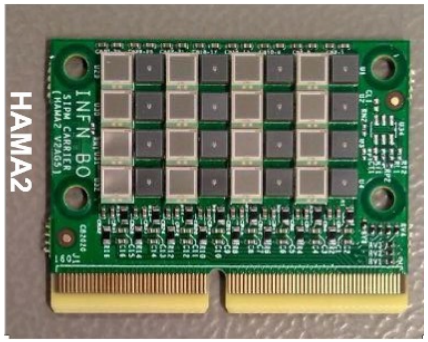
- 50 ps time bin
- 500 kHz rate per channel
- cryogenic compatible

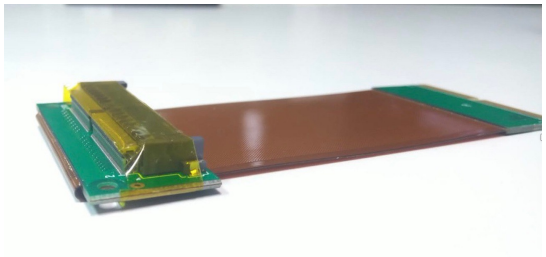
ALCOR v2 (bwetter dynamic range and rate) submitted for production (INFN in-kind)

ALCOR chip

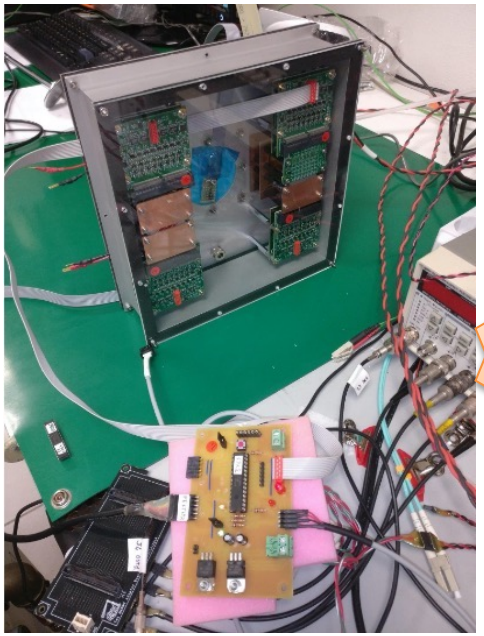


PCB with flex cable connection



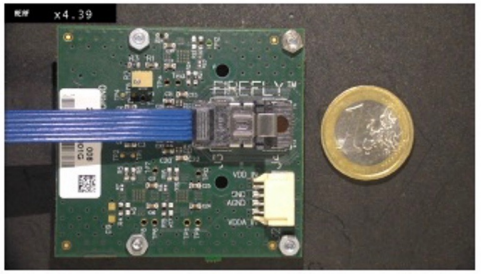


Integrated Cooling



FY23 funds

Streaming readout

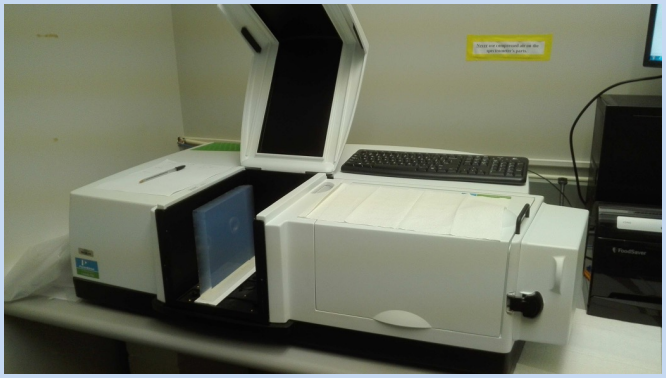


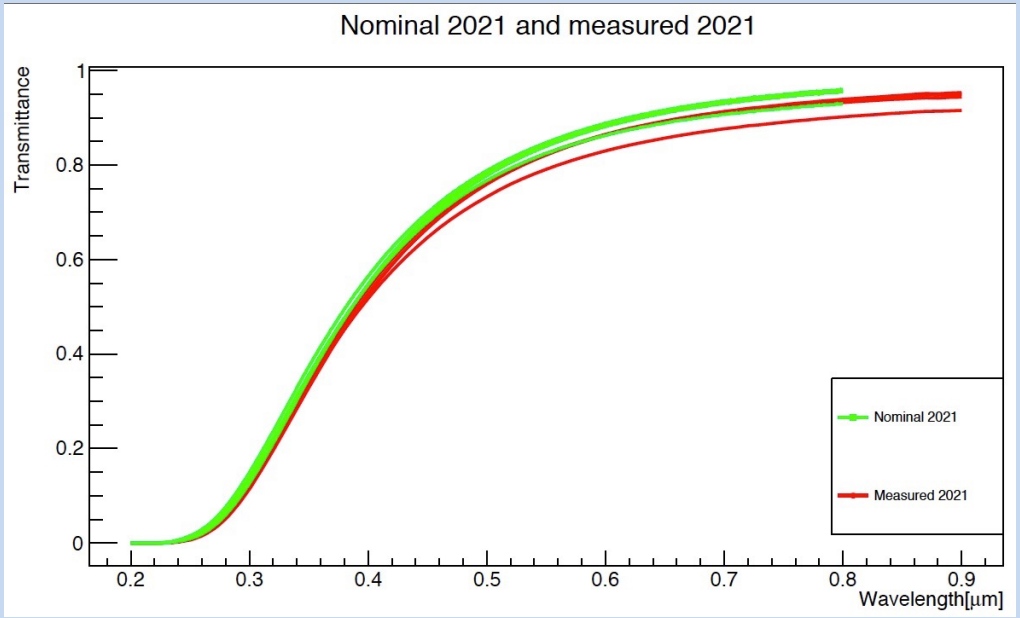
dRICH Aerogel

Existing facility (in-kind) to study detailed radiator optical properties and alternatives

Aerogel:
Safe handling and characterization (refractive index, surface planarity, forward scattering)

Interplay between radiators:
UV filters, refractive index optimization





INFN 2023: Funds for new samples

Aerogel Factory: negotiate production of large

goals: study reproducibility
1st batch: 1.0206, 1.0206, 1.0199, 1.0204
2nd batch: 1.0201, 1.0207, 1.0210, 1.0218

Goal: negotiate large (20x20 cm²) tiles with ALICE

ASPEN: initial contacts with CUA (Tanja Horn)

Goal: obtain few samples at 1.02

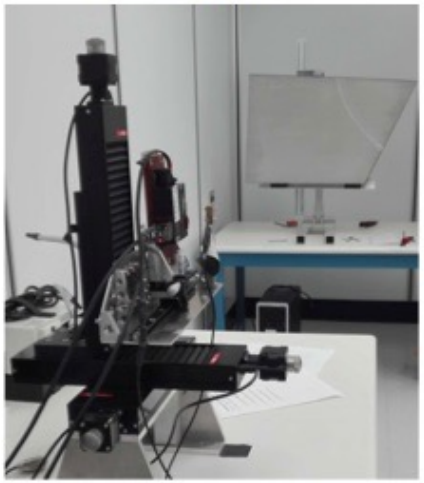
FY23 funds

Tsinghua and BINP: in collaboration with eRD101

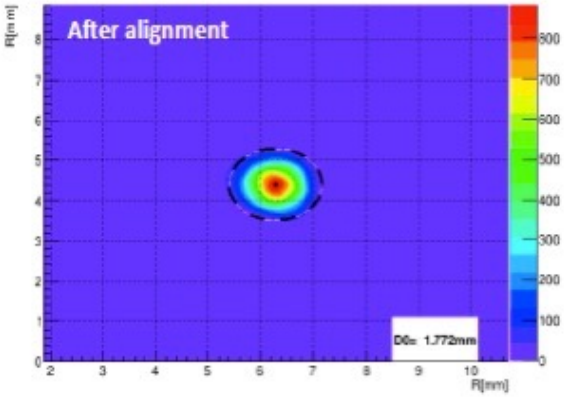
dRICH Mirrors

INFN: laboratory for mirror characterization

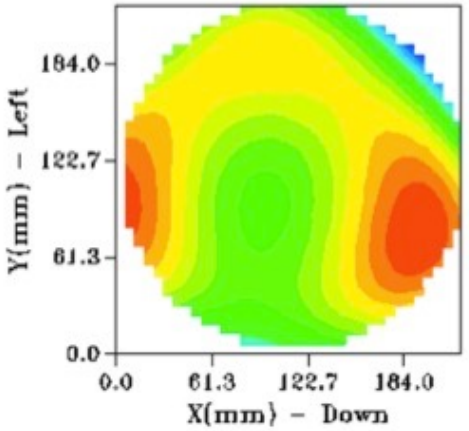
Surface Quality



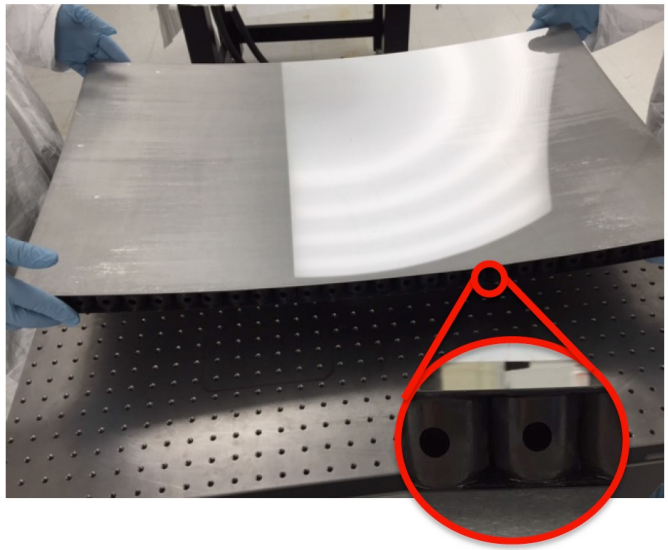
Pointlike source image



Shack-Hartmann sensor



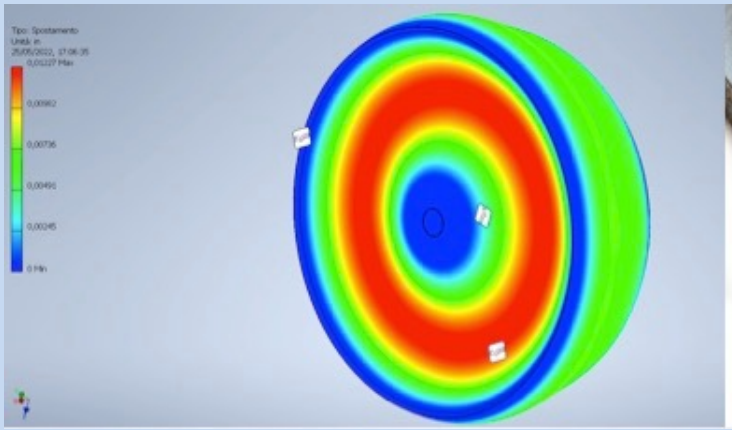
CMA: Carbon fiber mirror demonstrator (with cost-effective mold) and support

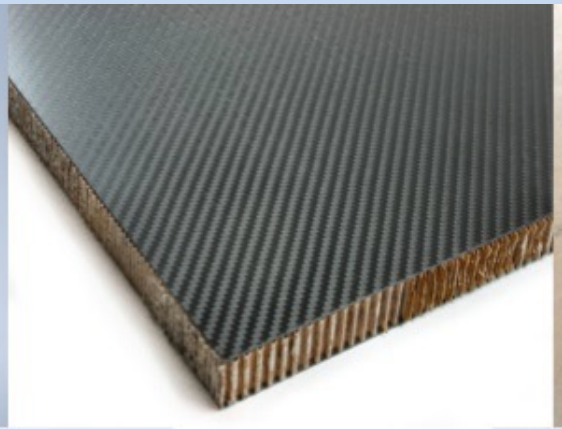


FY23 funds

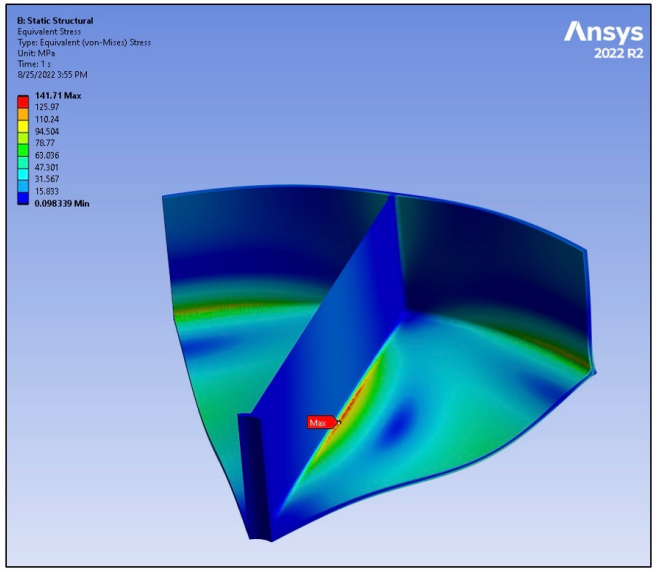
dRICH Mechanics

INFN 2032: funds for a composite material study (targeted to over-pressure case)

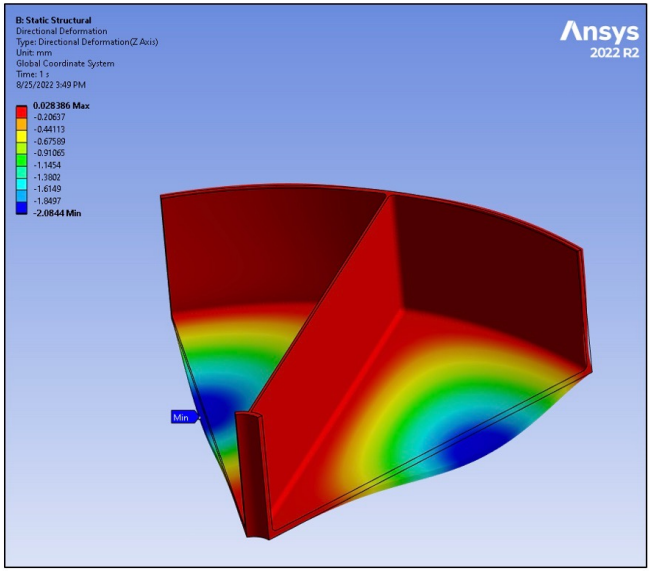




Contacts re-initiated with BNL and JLab for engineering support (for cooling, mechanics, high-pressure)



σ_{max} = 142 MPa



$\Delta_{Z\text{-}dir}$ = +0 / - 0.21 cm

Static structural Study @BNL

FY23 funds

dRICH Plans

FY23: Initial characterization of realistic mirror and aerogel components (02/23)

- ✓ Optical laboratory being refurnished (spectrophotometer, lasers, cameras)
- ✓ Alternative components procurement underway
- ✓ Targeted R&D being discussed with the manufacturers
- ✓ Extended measurement campaign being organized

Projected performance of the baseline detector as integrated into EPIC (06/23)

- ✓ Develop patter recognition
- ✓ Detail space allocation and services
- ✓ PID algorithm in conjunction with other detectors
- ✓ Validation with benchmark reactions
- ✓ Massive simulation campaign

Assessment of the dRICH prototype performance with the EIC-driven detection plane (10/23)

- ✓ Prototype adaptation to the new detection plane
- ✓ Upgrade of the services (~1k channels DAQ, cooling, power lines)
- ✓ Test temperature control and in situ-annealing
- ✓ New test-beam campaign

FY24/FY25: specs definition, targeted eRD109/110 developments integration, TDR preparation

Conclusions

Ongoing effort for the development of a forward RICH detector for particle identification at EIC

Cost-effective compact solution for hadron PID in EIC forward region in a wide kinematic range

Activity plan is organized following the EIC Critical-Decision timeline

R&D activity on innovative aspects with synergies with LHC (ALICE) and other EIC eRD & needs

Prototyping and test-beam campaigns: To address crucial PID aspects at EIC

Optimized and alternate radiators:
Aerogel of medium refractive index and high transparency, noble gas at high pressure

Novel cost-effective single-photon detector solution: to be operated in high magnetic field
SiPM post-irradiation and annealing imaging tests (LAPPD performance tests)

Readout: ToT architecture (ALCOR chip)

Cooling, support structure, pressurized vessel: US technical support is essential

FY23 program: Manpower can only be cofunded. Important in-kind contribution from INFN.

dRICH Timeline

Assumed funding profile k$.

	prototype	radiators	mirror	detector	personnel	technical	travel	total
FY23	10	20	20	20	100	10	10	190
FY24*	10	20	20	10	80	10	10	160
FY25*		20	20	10	60	10	10	130

*Projected cost. Dedicated manpower can only be cofunded. Important in-kind INFN.

Proposed funding per Institute k$.

	prototype	radiators	mirror	detector	personnel	technical	travel	total
INFN	10	20	30	10	60		5	135
DUKE					40		5	45
DOE						10		10

dRICH Timeline

Year	Detailed tasks
2021	• Development of basic prototype design, simulation and implementation • Optical components: First selection and tests • Basic prototype: Basic tracking, one choice per radiator, glass mirrors, reference readout • Beam Test 1: Proof of principle with reference detectors and readout , ideal beam • Import dRICH simulation into the supported EIC platforms
2022	• Analysis of the first test-beam • Refined prototype: refined components and readout, online reconstruction, precise tracking/alignment • Beam Test 2: Performance assessment with reference and custom detectors, hadron tagged beams
2023	• R&D on cooling • EIC configuration engineering and integrated PID • Optical components refinement and cost reduction study (e.g. glass-skin mirror
2024	• Component alternatives and optimization • Final prototype: various radiators, custom mirrors, gas system, optimized readout • Beam test 3: Performance assessment with optimized components
2025	• Engineering of cooling and services • Beam test 4: Contingency