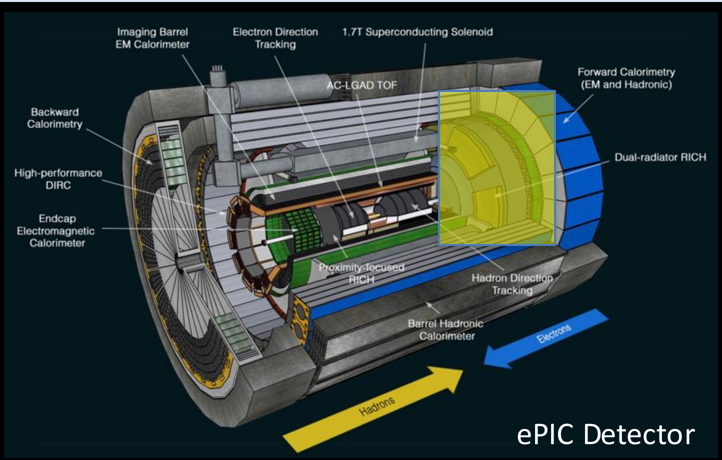
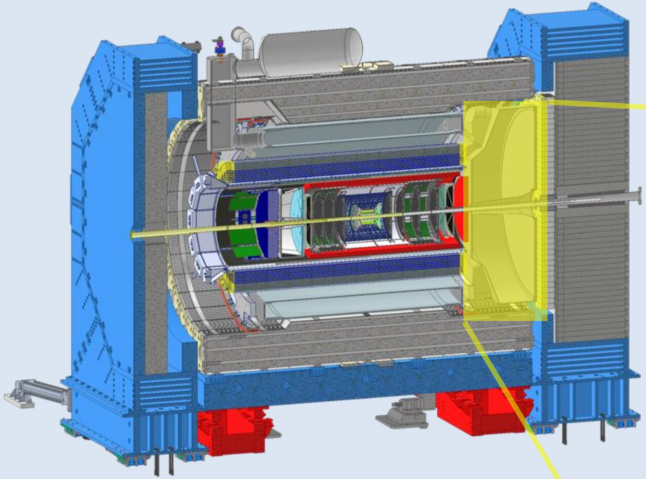
dRICH: Forward PID



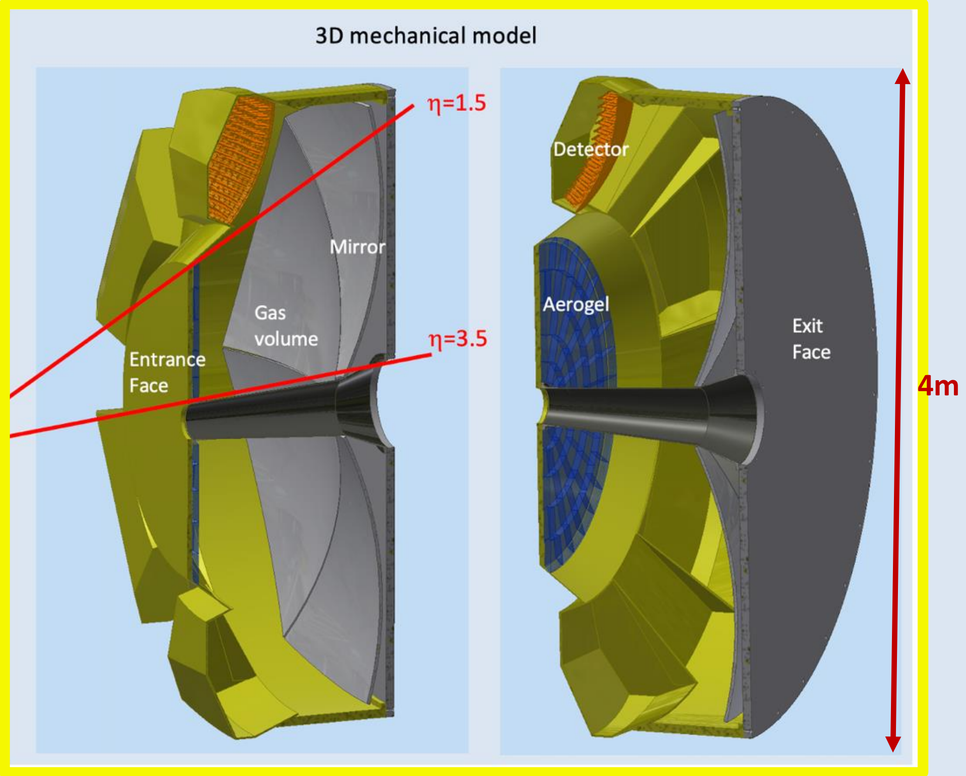
M. Contalbrigo – INFN Ferrara - DSCL

Incremental Preliminary Design and Safety Review of the pfRICH, dRICH and hpDIRC – April 1st and 2nd, 2025



Dual-radiator Ring-imaging Cherenkov Detector (dRICH)

Essential to access flavor information



Goals:

Hadron 3σ–separation between 3 - 50 GeV/c
Complement electron ID below 15 GeV/c
Cover forward pseudorapidity 1.5 (barrel) - 3.5 (b. pipe)

dRICH Features:

Extended 3-50 GeV/c momentum range --> Dual radiator
Single-photon detection in high Bfield --> SiPM
Limited space --> Compact optics with curved detector

Review Charges

Charge 1: Are the technical performance requirements appropriately defined and complete for this stage of the project?
Slides 4 - 5 - 8 - 9 -12 -13 - 16 - 18 - 21 - 26 - 27

Charge 2: Are the plans for achieving detector performance and construction sufficiently developed and documented for the present phase of the project?
Slides 6 - 10 -11 - 14 - 25 - 28 - 31 - 32 - 35 - 37

Charge 3: Are the current designs and plans for detector and electronics readout likely to achieve the performance requirements with a low risk of cost increases, schedule delays, and technical problems?
Slides 17 - 18 - 19 - 22 - 23 - 24

Charge 4: Are the fabrication and assembly plans for the various particle identification detector systems consistent with the overall project and detector schedule?
Slides 37

Charge 5: Are the plans for detector integration in the EIC detector appropriately developed for the present phase of the project?
Slides 29

Charge 6: Have ES&H and QA considerations been adequately incorporated into the designs at their present stage?
Slides 7 - 15 - 20 - 36 - 38

Charge 7: Have the recommendations from previous reviews been adequately addressed ?

Slides 30 - 33 - 34 - 36

Technical Performance Requirements

Charge 1

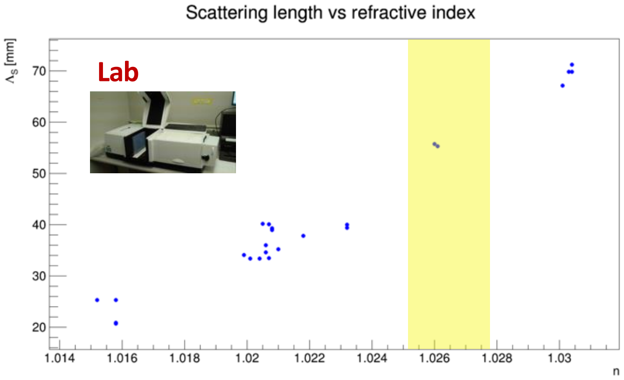
	Requirements		Solution
Aerogel:	Momentum reach above 15 GeV/c to overlap with gas More than 10 detected photons from 4 cm thickness Single photon resolution approaching 2 mrad		n = 1.026 $dn/d\lambda = 6\ 10^{-6}\ nm^{-1}$ scattering length > 50 mm
Gas:	Momentum reach above 50 GeV/c at pseudorapidity > 2.5 More than 20 detected photons from 1 m depth Single photon resolution better than 1 mrad	C_2F_6	with n = 1.00086 $dn/d\lambda = 0.2\ 10^{-6}\ nm^{-1}$ absorption length > 100 m
Mirror:	Focalization of Cherenkov light onto the detector surface Preservation of the Cherenkov information Material budget limited to O(2 %) of radiation length		Carbon fiber material Roughness of few nm Angular precision < 0.2 mrad Reflectivity $\gtrsim$ 90 %
Sensors:	Single photon detection capability in highly non-uniform magnetic field Excellent PDE in the visible range to cope with aerogel Marginal contribution to the angular resolution Preserve prompt Cherenkov information Tolerance to few 10^{10} 1-MeV neutron equivalent fluence	SiPM	Spatial resolution of 3 x 3 mm^2 Time resolution O(100 ps) Operation at < -30 degrees Annealing curing cycles
Readout:	Below 1 p.e. signal threshold capability Preserve sensor time resolution to cope with dark counts and accidentals More than 300 kHz/ch rate capability Streaming readout with suppression of no-particle frames	ALCOR	ALCOR chip (ToT architecture) Time resolution < 200 ps Rate > 300 kHz/ch Digital programmable shutter
Mechanics:	Acceptance maximized in 1.5 – 3.5 pseudorapidity range Material budget minimized in acceptance Compatibility with barrel maintenance at IP6		Composite materials Single open volume Detector in the barrel shadow

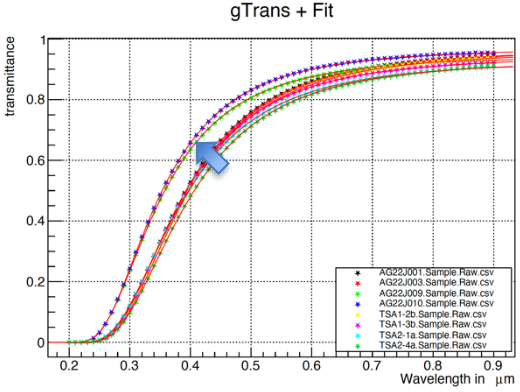
Aerogel Technical Performance

Charge 1

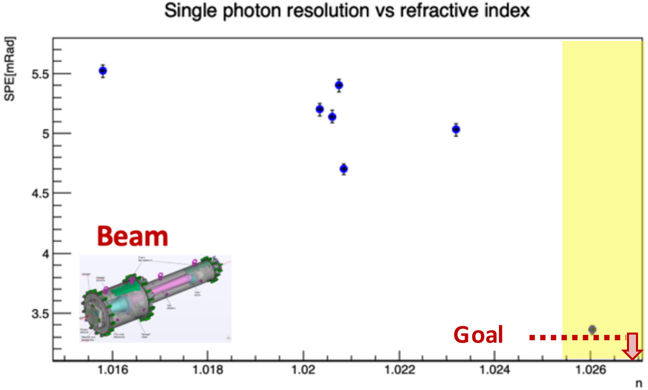
Defined with lab and prototype tests:

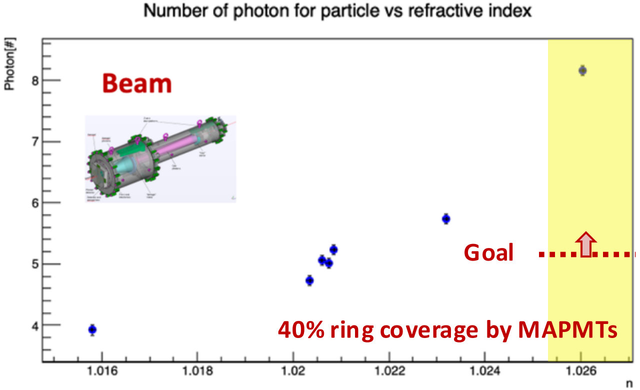
* meet SPE resolution expectations
* scattering length > 50 mm
* match with TOF end point (2.5 GeV/c)
* overlap with gas (> 12 GeV/c)
* photon yield > 10 per particle with MAPMTs





Various samples from Aerogel Factory





Charge 2

First large tile demonstrators delivered

based on dRICH baseline specifications

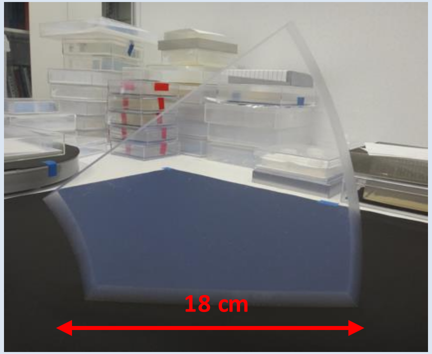
An effort should be pursued by the vendor to keep the aerogel quality parameters as close as possible or better than the following reference values.

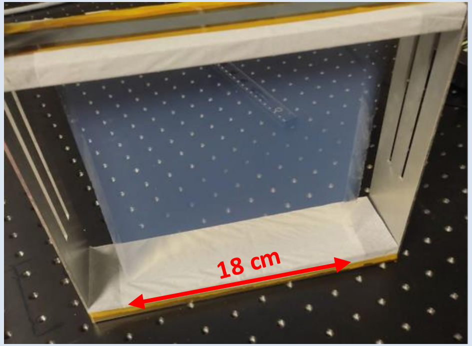
General specifications:

- No cracks or bubbles inside the block. Single spallings which decrease its area no more than 0.25 % are acceptable on the top surface;
- Lateral dimension tolerance within 0.25 mm;
- No evident disuniformity inside the tile volume.

Technical specifications:

- Refractive index, to be chosen by the customer, in the range from 1.025 to 1.030, with a maximum tile-to-tile variation of +/-0.002;
- Tolerance on thickness +/- 1 mm, being the error intended as the maximum tile-to-tile variation;
- Absorption coefficient, defined as the constant term of the Hunt parameterization of the aerogel transmission, bigger than 0.95;
- Scattering length wavelength bigger than 45 mm at 400 nm;
- Planarity of the transmission surface, defined as the maximum peak to valley variation, does not exceed 1.5 % of the lateral dimensions.





Engineering of the aerogel wall ongoing:

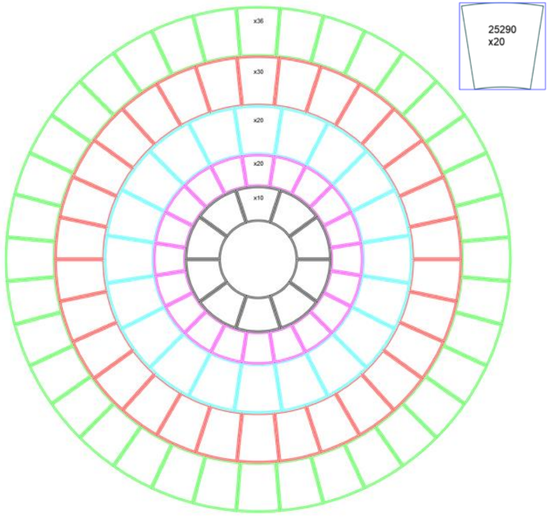
* optimize area vs number of tiles

* minimize the waste of material

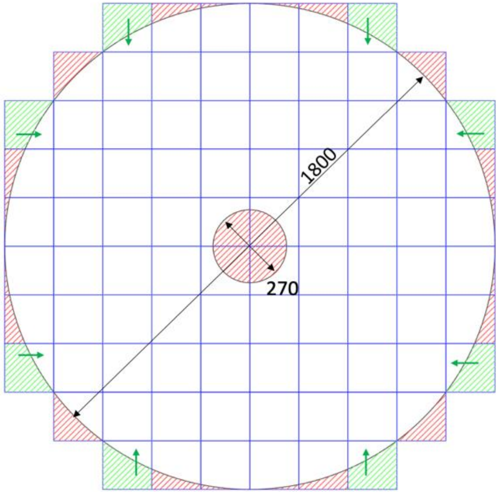
* minimize the dead/low-efficiency gaps

* optimize thickness:

  - photon yield vs resolution
  - planarity



Active Area = 21605 cm^2
Dead Ara = 3269 cm^2 (13%)
Wasted Area = 9112 cm^2 (27 %)



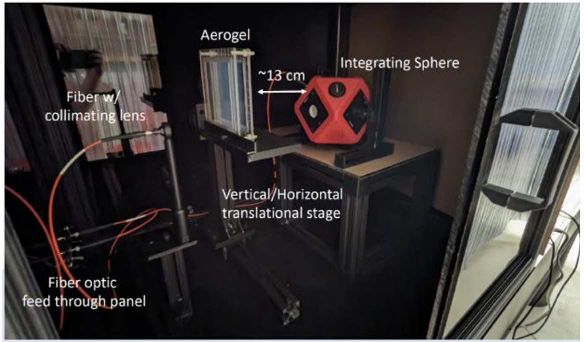
Active Area = 21368 cm^2
Dead Ara = 3506 cm^2 (14%)
Wasted Area = 1868 cm^2 (7 %)

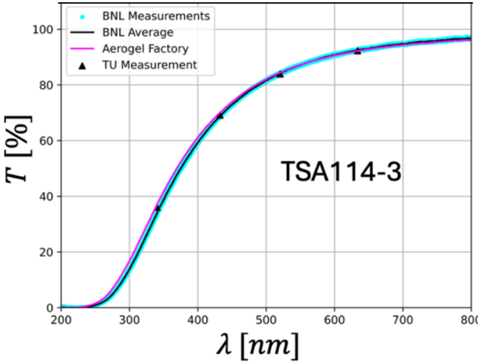
Aerogel Quality Assurance

Charge 6

Primary station at Temple University devloped as a common facility

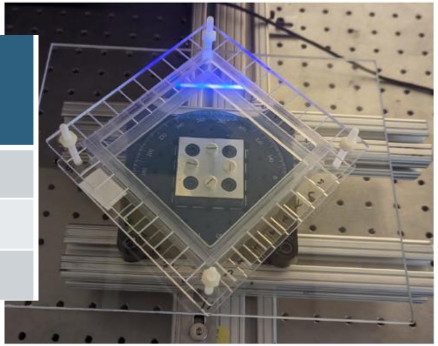
Transmission by LEDs + Integrating sphere – Temple U.





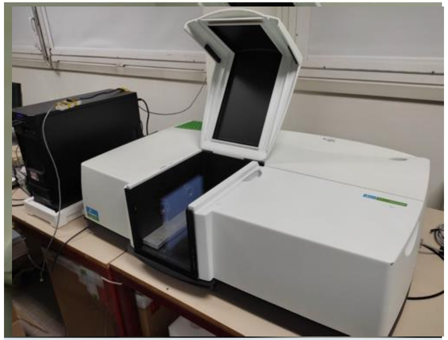
Refractive index by Prisma test – Temple U.

Tile	(TU-AF)/AF [%]
TSA120-1	0.087
TSA120-2	0.000
TSA114-3	0.062

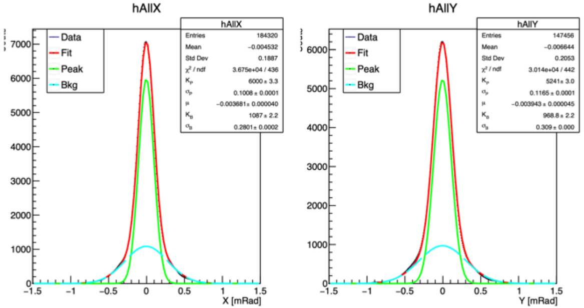


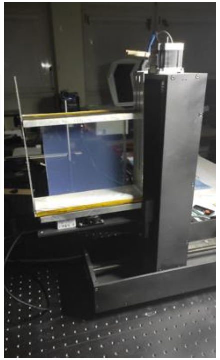
Secondary station at INFN (BA-FE) for sample tests or in-depth characterization

Perkin Elmer 650S (INFN FE) Transmission by Spectro-photometers Agilet Cary (INFN BA)



Forward Scattering by Laser + CMOS camera





Technical Performance Requirements

Charge 1

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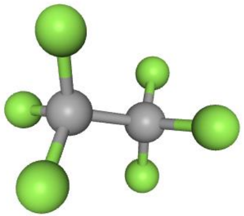
Mechanics:	Acceptance maximized in 1.5 – 3.5 pseudorapidity range Material budget minimized in acceptance Compatibility with barrel maintenance at IP6		Composite materials Single open volume Detector in the barrel shadow

Hexsafluoroethane



1 covalent + 6 hydrogen bonds

C_2F_6 molecular weight: 138.01 g/mol

boiling point: -78.1 °C

melting point: -100.6 °C

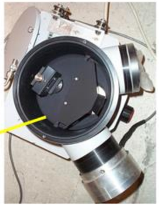
density: 5.734 kg/m³ at 24 °C

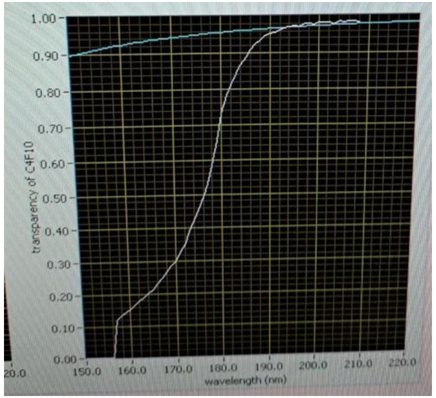
density: 16.08 kg/m³ at -78 °C

Gas	Npe(π/K)	θ_π	θ_K	σ_π	σ_K	N_σ	$\rho = \Delta\theta/\theta$ (λ = 300 nm)
C_2F_6	16.0/14.9	36.8	35.7	0.32	0.33	3.5	1.8 %
C_4F_{10}	24.8/23.8	48.6	47.8	0.29	0.30	2.8	2.4 %

Transmission in UV range > 98 %

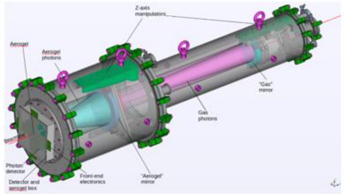
Deuterium UV lamp, Monochromator system, 1.6 m column for gas transparency measurement

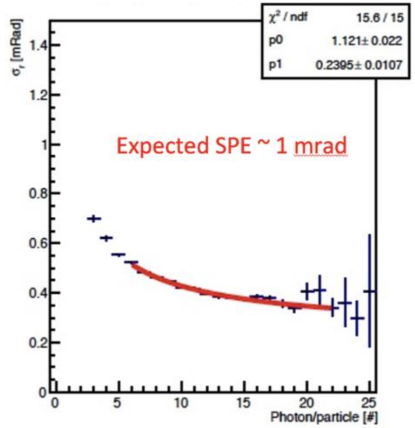




Measured 139.7 m/s speed of sound confirms negligible contaminants after few year in bottle

Expected performance obtained with dRICH prototype

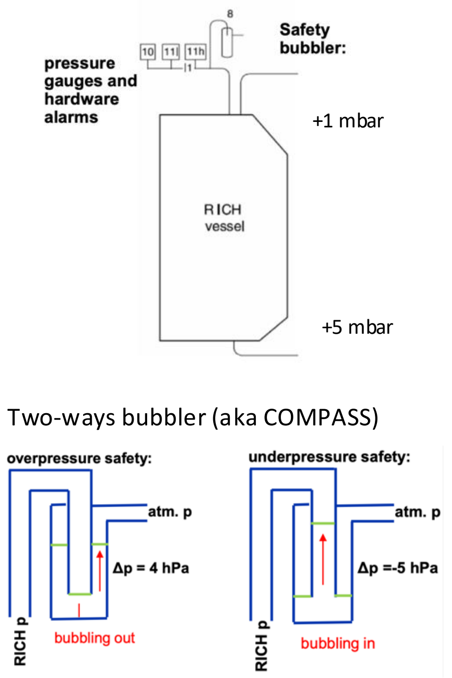




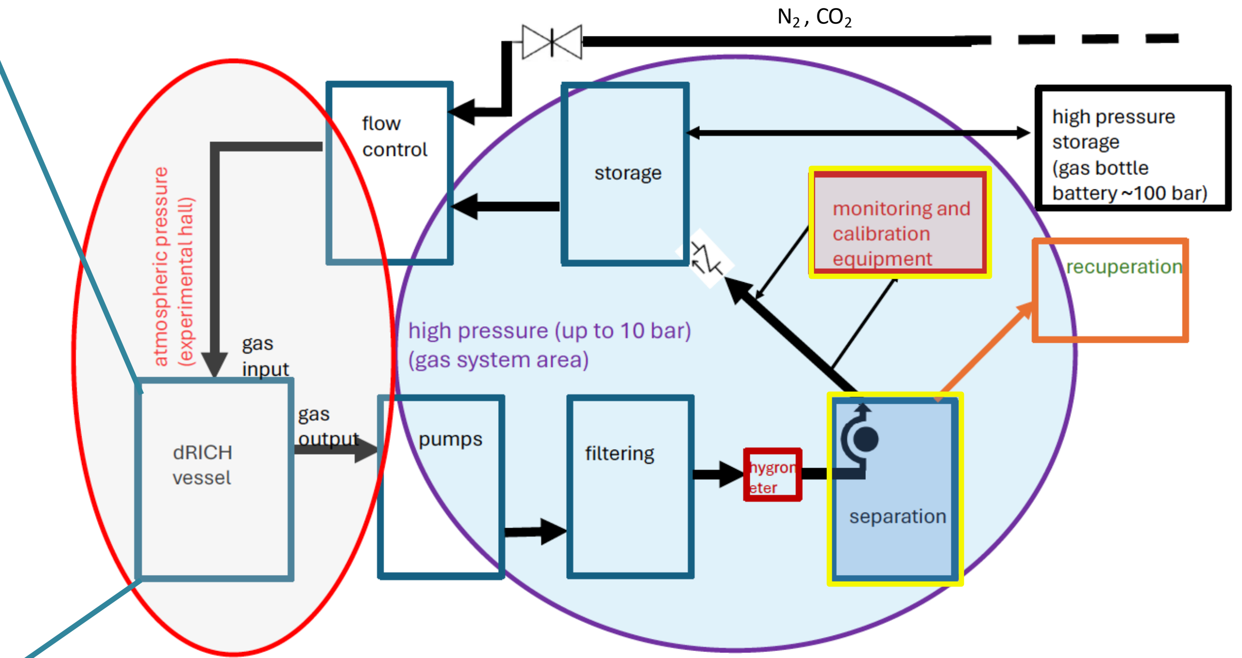
Charge 2

Being designed at INFN in collaboration with CERN, Realization at BNL with DOE standards

dRICH vessel



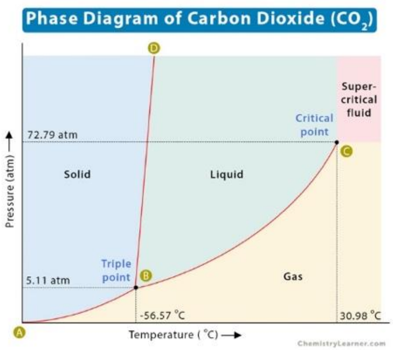
dRICH gas system

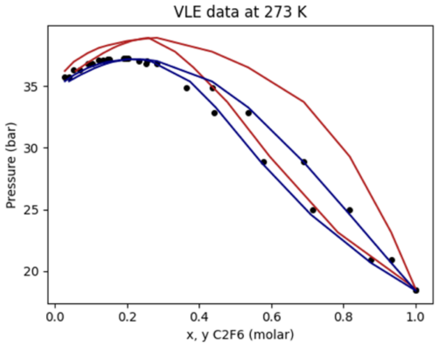


Charge 2

Purging via liquefaction of unwanted gas

Updated vapor-liquid equilibrium C_2F_6-CO_2 model, test in preparation at CERN

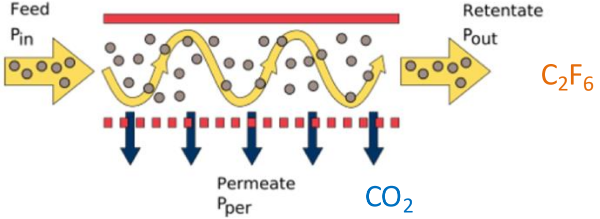


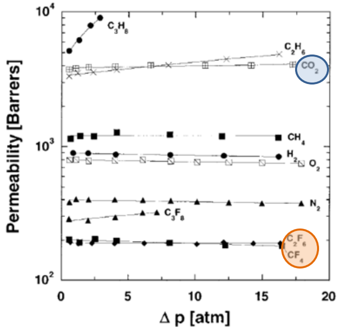


Purging via membranes

Effective separation of CF_4 and CO_2 has denostrated in LHCb
hpps://edms.cern.ch/document/2816490/1

R. Guida, B. Mandelli, M. Corbetta

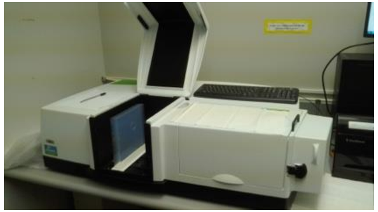


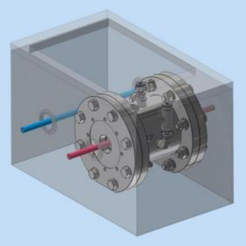


Developing online purity monitors

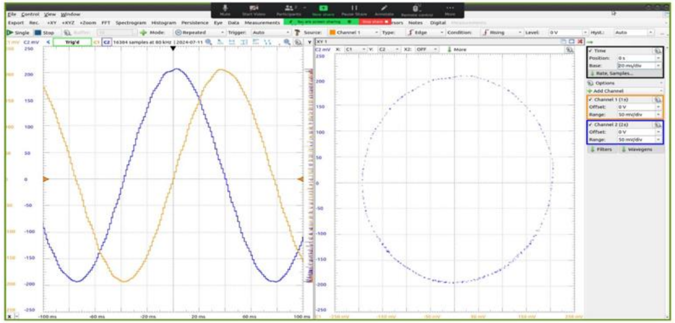
Sonar to measure speed of sound

10 bar chamber + specrophotometer to measure light transmission in the visible range





Jamin interferometer for precise n determination



Nominal sensitivity down to 10 ppm of refractive index

Technical Performance Requirements

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Aerogel:	Momentum reach above 15 GeV/c to overlap with gas More than 10 detected photons from 4 cm thickness Single photon resolution approaching 2 mrad		n = 1.026 $dn/d\lambda = 6\ 10^{-6}\ nm^{-1}$ scattering length > 50 mm
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Mechanics:	Acceptance maximized in 1.5 – 3.5 pseudorapidity range Material budget minimized in acceptance Compatibility with barrel maintenance at IP6		Composite materials Single open volume Detector in the barrel shadow

Characterizing the medium-size (~50 cm side) CMA demonstrator CFRP substrate before coating

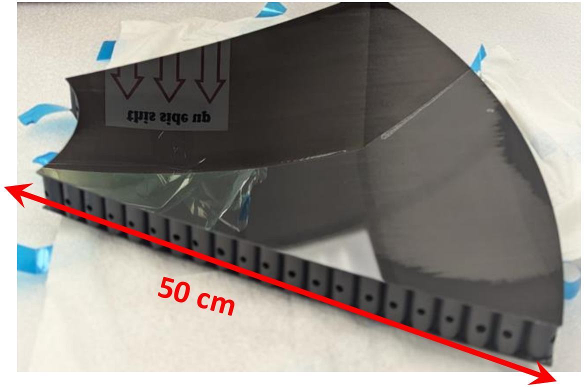
Annex C. Technical Requisite

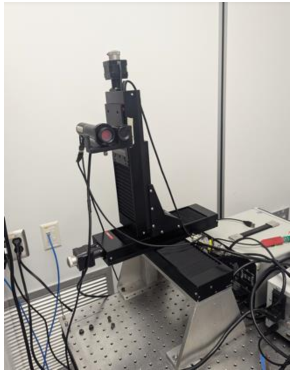
Each spherical mirror is supplied with

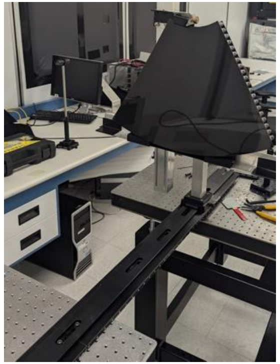
- a spot-size measurement,
- a report on dimensions,
- no reflective coating.

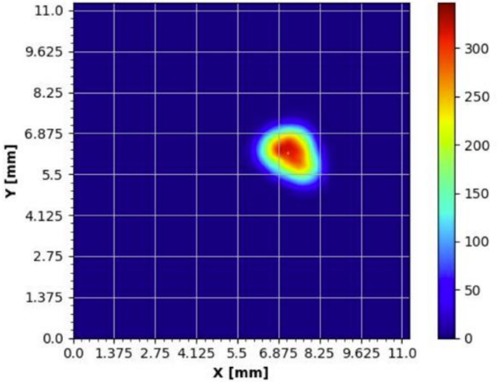
The spherical mirrors are replicated from the same mandrel. The latter is realized with the novel cost-effective technology that reduces the mandrel total mass and cost. Each mirror fulfills the following optical quality specification:

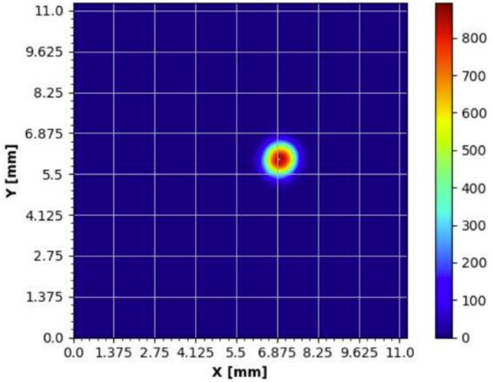
- Radius within 1% of nominal RoC value (the nominal RoC values is defined by the customer before production in the range 2000 mm +/- 10%),
- Roughness < 2 nm,
- Pointlike image spot size D0 < 2.5 mm,
- Compatibility with fluorocarbon gases (C_2F_6),
- Compatibility with SiO_2 reflecting coating.



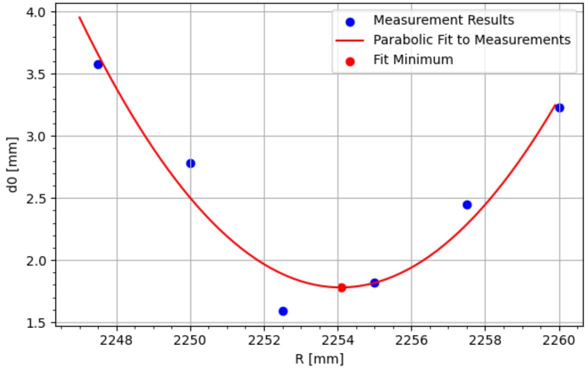








✓ D0 < 2.5 mm ✓ R = 2200 +/- 1%

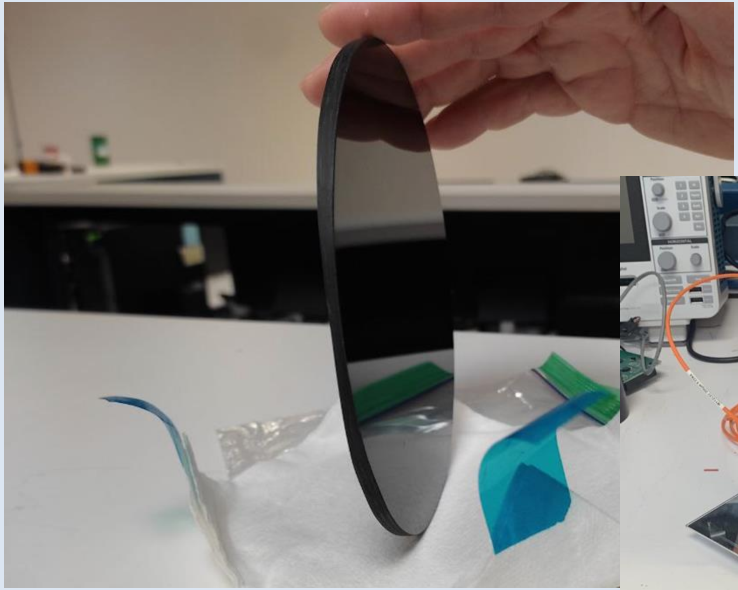


Mirror Substrate & Coating

Charge 2

Ongoing activities with possible synergies with pfRICH

Studying special material (ultra-low degassing)

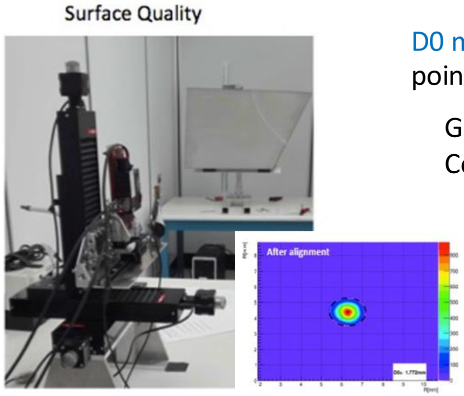


Developing portable reflectivity test beanch

Testing coating (SBU) on dRICH samples

Mirror Quality Assurance

INFN-DOE existing instrumentation at JLab



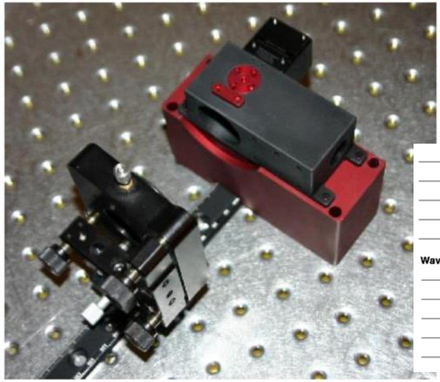
D0 measurement:
point-like image dimension

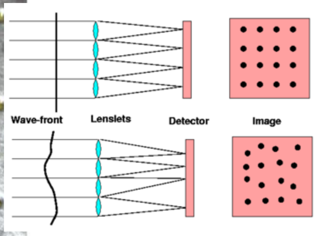
Global surface QA
Center of curvature

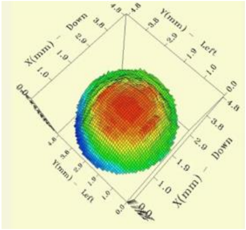
Stepper motor for alignment and center scan

LED source (1 mm dia.)

CMOS camera



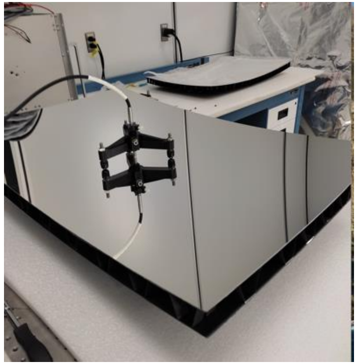




Shack-Hartmann sensor:
reflected waveform analysis

Surface mapping

Workforce training and instrumentation preparation at DUKE

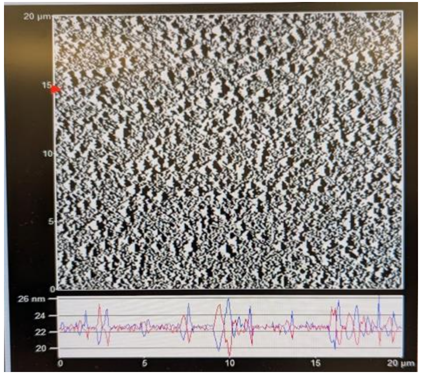


Reflectivity:
Portable instrument

Custom source + fiber distribution

Reference sensor

Compact spectrophotometer



SMiF | SHARED MATERIALS INSTRUMENTATION FACILITY

Access to a variety of instruments for precision characterization of materials

AFM images of coated surface (SBU) showing roughness of $< 100\ nm$

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Aerogel:	Momentum reach above 15 GeV/c to overlap with gas More than 10 detected photons from 4 cm thickness Single photon resolution approaching 2 mrad	⇨		n = 1.026 $dn/d\lambda = 6\ 10^{-6}\ nm^{-1}$ scattering length > 50 mm
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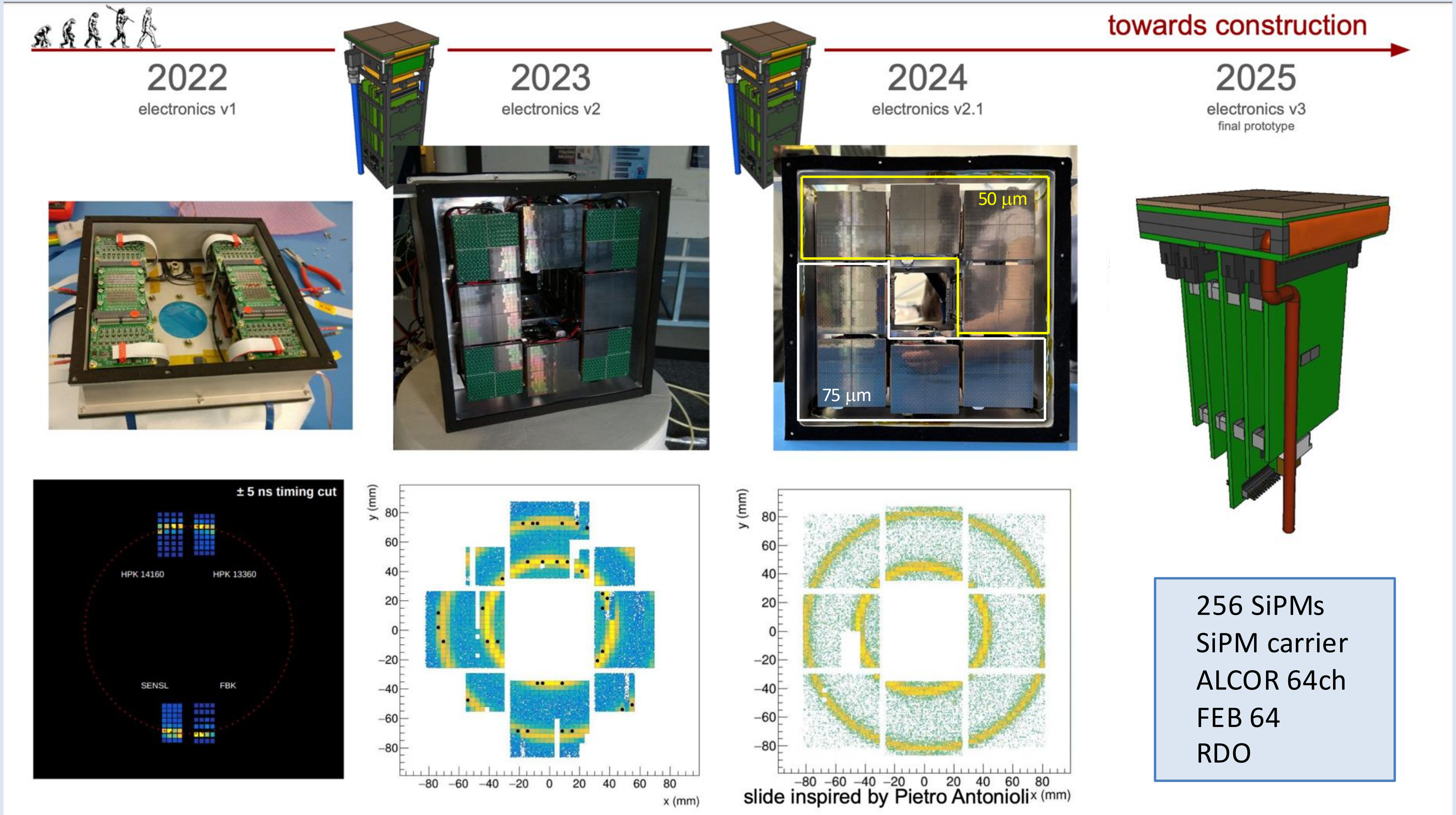
Mirror:	Focalization of Cherenkov light onto the detector surface Preservation of the Cherenkov information Material budget limited to O(2 %) of radiation length	⇨		Carbon fiber material Roughness of few nm Angular precision < 0.2 mrad Reflectivity $\gtrsim$ 90 %
Sensors:	Single photon detection capability in highly non-uniform magnetic field Excellent PDE in the visible range to cope with aerogel Marginal contribution to the angular resolution Preserve prompt Cherenkov information Tolerance to few 10^{10} 1-MeV neutron equivalent fluence	⇨	SiPM	Spatial resolution of 3 x 3 mm^2 Time resolution O(100 ps) Operation at < -30 degrees Annealing curing cycles
Readout:	Below 1 p.e. signal threshold capability Preserve sensor time resolution to cope with dark counts and accidentals More than 300 kHz/ch rate capability Streaming readout with suppression of no-particle frames	⇨	ALCOR	ALCOR chip (ToT architecture) Time resolution < 200 ps Rate > 300 kHz/ch Digital programmable shutter
Mechanics:	Acceptance maximized in 1.5 – 3.5 pseudorapidity range Material budget minimized in acceptance Compatibility with barrel maintenance at IP6	⇨		Composite materials Single open volume Detector in the barrel shadow

Photon Detector

Charge 3



256 SiPMs
SiPM carrier
ALCOR 64ch
FEB 64
RDO

Charge 3

SiPM technical specs

SiPM LLP Review September 2023

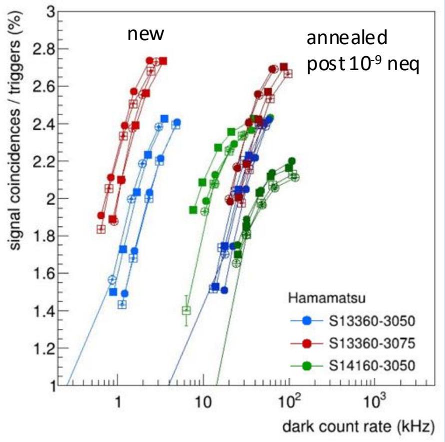
baseline sensor device
64 (8x8) channel SiPM array
3x3 mm^2 / channel

Parameters	Value	Notes (all parameters at the recommended operating voltage and T = 25 C, unless specified)
Device type	SiPM array	
Number of channels	64	8 x 8 matrix
Active Area	3 x 3 mm^2	active area of one channel, total active area is 64 x 3 x 3 mm^2
Device Area	< 28 x 28 mm^2	device area should be small such as to have > 75% fraction of active area over device total area
Pixel Size	40 - 80 um	pitch of the microcell SPAD
Package Type	surface mount	
Operating voltage	< 64 V	
Peak Sensitivity	400 - 450 nm	
PDE	> 35%	at peak sensitivity wavelength
Gain	> 1.5 10^6	
DCR	< 1.5 MHz	
Temperature coefficient of Vop	< 60 mV / C	
Direct crosstalk probability	< 10%	
Terminal capacity	< 600 pF	
Packing granularity		
Vop variation within a tray	< 300 mV	Vop variation between channels in one device
Recharge Time	< 100 ns	ctau recharge time constant
Fill Factor	> 70%	
Protective Layer	silicone resin (n = 1.5 - 1.6)	radiation resistant, heat resistant (up to T = 180 C)
DCR at low temperature	< 10 kHz	at T = -30 C
DCR increase with radiation damage	< 1 MHz / 10^9 neq	at T = -30 C, after a radiation damage corresponding to 10^9 1-MeV neutron equivalent / cm^2 (neq)
Residual DCR after annealing	< 25 kHz / 10^9 neq	at T = -30 C, after a radiation damage of 10^9 neq and a 150 hours annealing cycle at T = 150 C
Single photon time resolution	< 200 ps FWHM	corresponding to < 85 ps RMS

we will evaluate as part of QA, testing sensor samples in received batches

8

Based on PDE vs DCR studies over a variety of SiPM



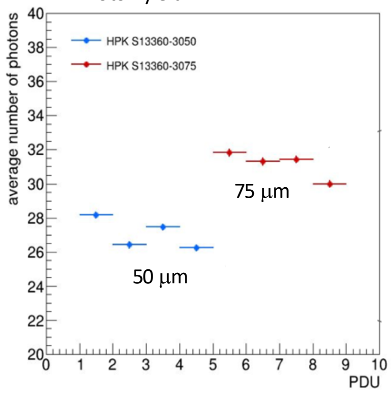
R. Preghenella talk

Charge 3

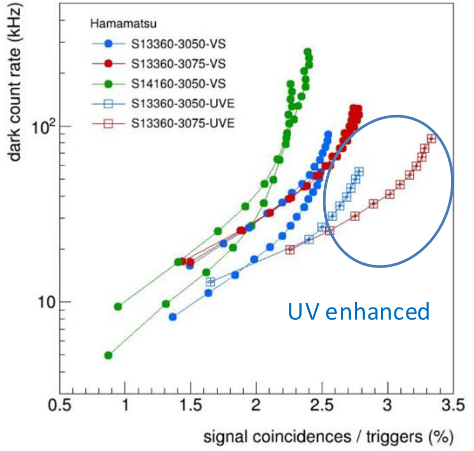
Detailed performance comparison between different sensor layouts

Comparing PAD size of Hamamatsu photo sensors

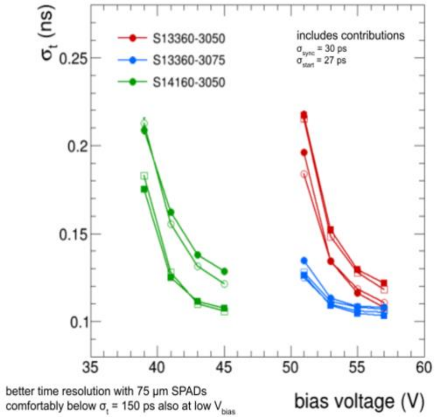
Photon yield



Testing new Hamamatsu sensors after
- 10^9 neq
- oven annealing

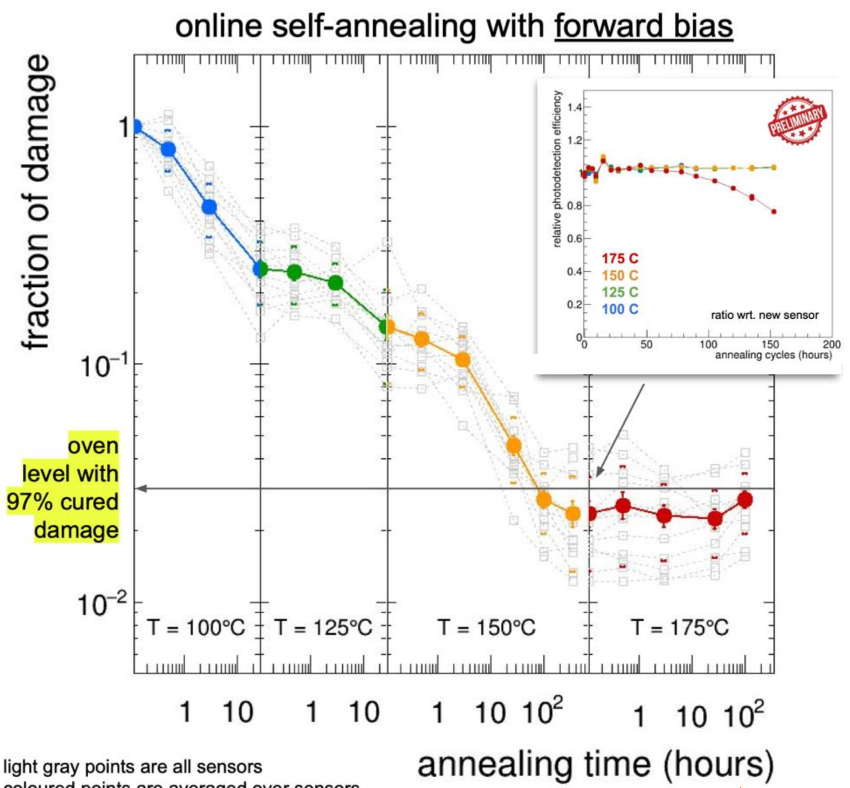


Time resolution with ALCOR redout



better time resolution with 75 μm SPADs comfortably below σ_t = 150 ps also at low V_{bias}

Details of in-situ annealing protocol based on Joule-effect



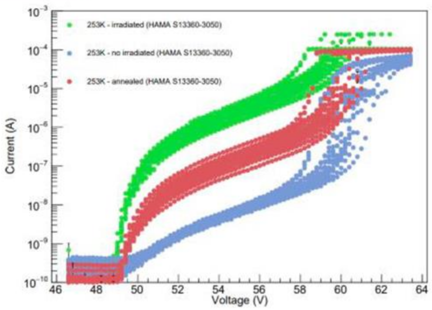
light gray points are all sensors
coloured points are averaged over sensors
coloured brackets is the RMS

R. Preghenella talk

Charge 6

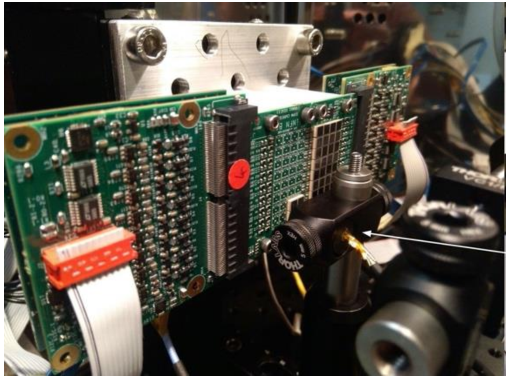
ALCOR based QA stations being developed at INFN CS-SA-CT and INFN TS in collaboration with local Universities

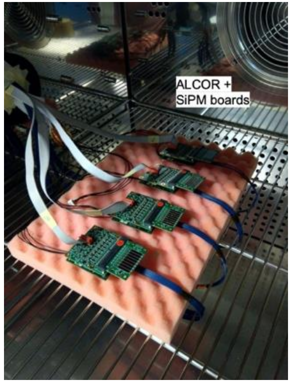
IV-curves



- 253K-no irradiated
- 253K-annealed
- 253K-irradiated

In-depth characterization station operative at INFN-BO: PDE - Timing





Technical Performance Requirements

Charge 1

	Requirements			Specifications
Aerogel:	Momentum reach above 15 GeV/c to overlap with gas More than 10 detected photons from 4 cm thickness Single photon resolution approaching 2 mrad	⇨		n = 1.026 $dn/d\lambda = 6\ 10^{-6}\ nm^{-1}$ scattering length > 50 mm
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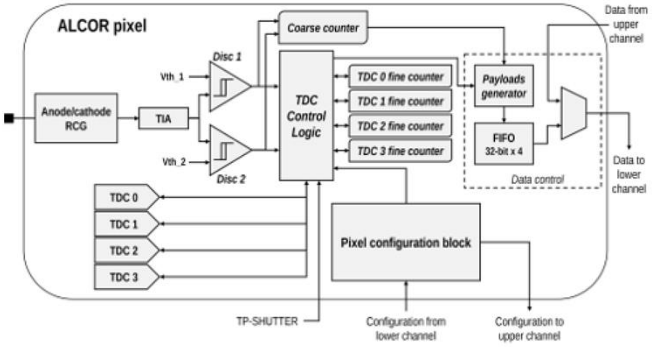
Mechanics:	Acceptance maximized in 1.5 – 3.5 pseudorapidity range Material budget minimized in acceptance Compatibility with barrel maintenance at IP6	⇨		Composite materials Single open volume Detector in the barrel shadow

Charge 3

Preparing ALCORv64 test production

MW run in March '25

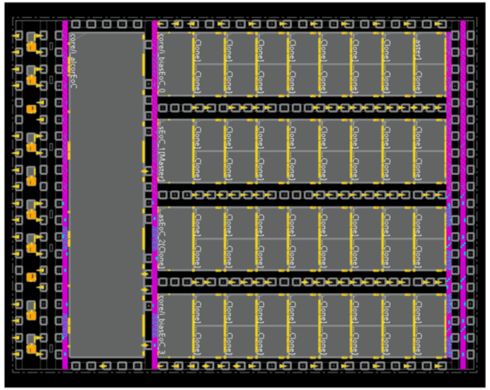
ALCOR block diagram



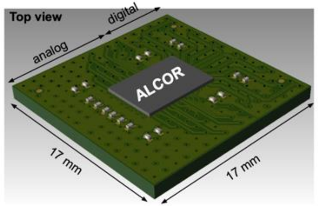
ALCOR key specifications

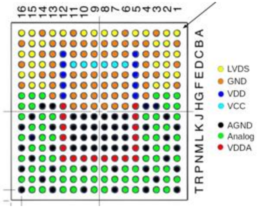
Function	Digitization from SiPMs with 1 p.e. sensitivity
Mode	Single-photon tagging or time and charge
Tech Node	110 nm CMOS
Channels	64 (8x8), dual polarity
Cdin	<1 nF
Digitization	20-40 ps TDCs, TOA + TOT; Timing <150 ps
Shutter	Width: 2–3 ns, programmable latency
Input Rate	<2.4 MHz (up to 5 MHz on single channel)
Clock	394.08 MHz operation from BX 98.5 MHz
Links	788 Mbps LVDS, SPI configuration
Power	12 mW/ch
Package	BGA
Rad Tolerance	Radiation hard

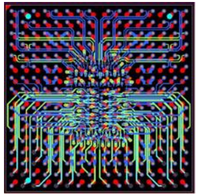
Silicon die layout



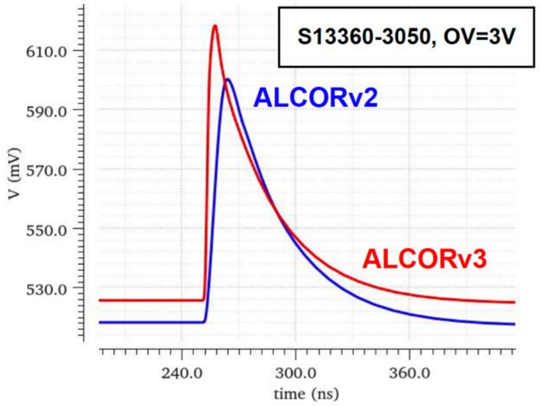
Compact BGA Package with interposer

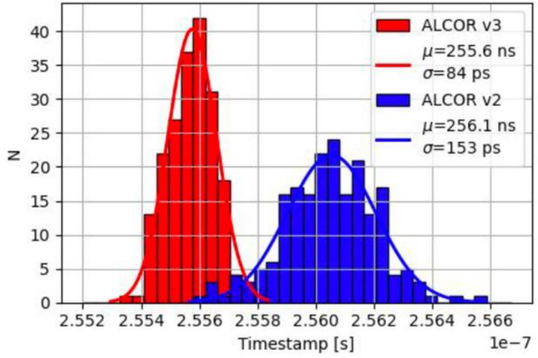






Improved timing and digital shutter

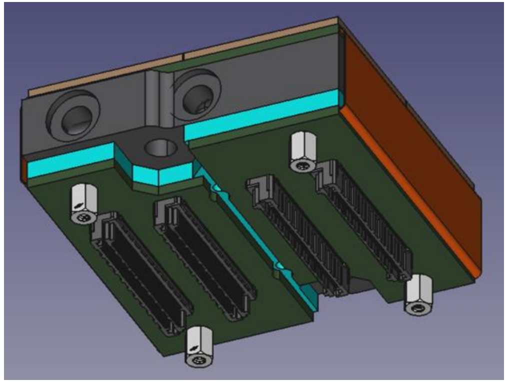


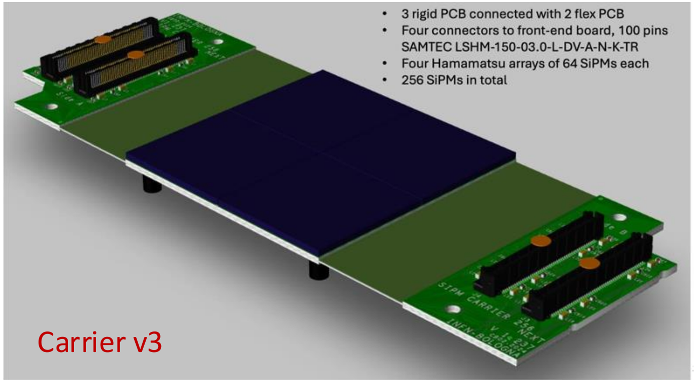


Charge 3

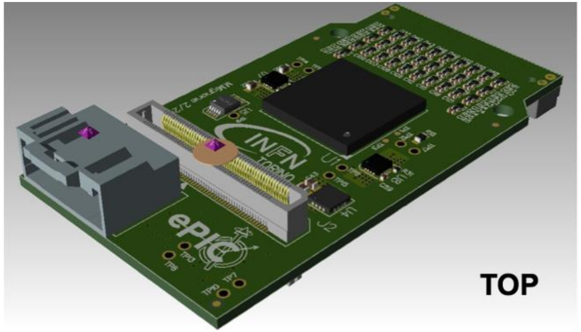
Preparing test production of readout electronics in its “final” ePIC layout

Pre-production started

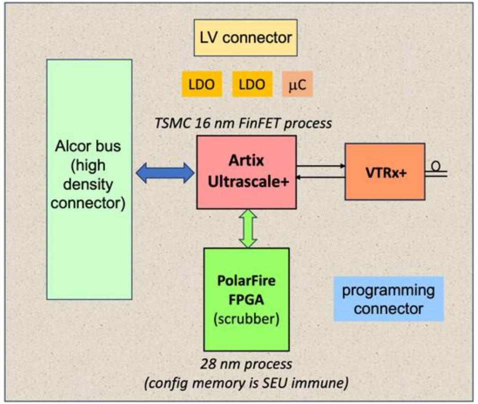




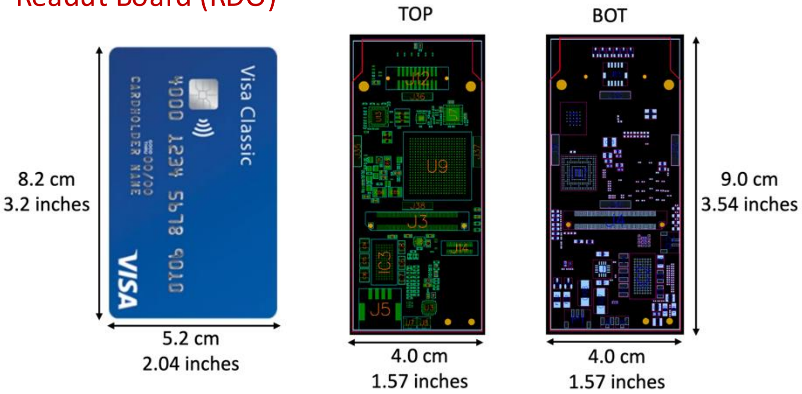
Carrier v3

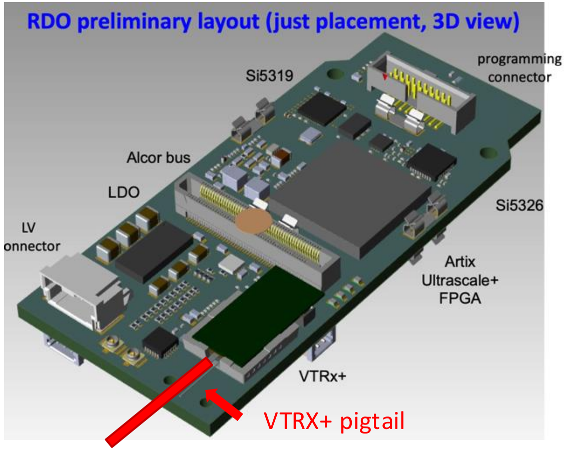


Front-End Board (FEB)



Readut Board (RDO)





Readout Irradiation Tests

Test indicate the SEU event rate of. dRICH electronics is manageable with standard firmware TMR, CRC, resets features

Regular irradiation campaign ongoing:

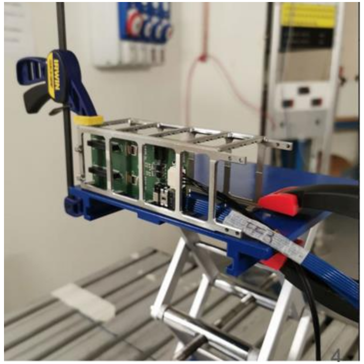
Neutron irradiation campaign at LNL-CN (9-11 October 24)

Gamma irradiation campaign at CERN-GIF (14-16 October 24)

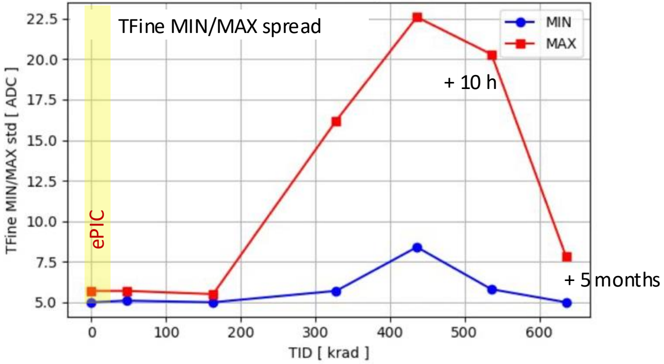
Proton irradiation campaign at TIFPA (12-14 December 24)

$TID_5 \cong 2.3$ krad
(for 1000 fb^{-1})

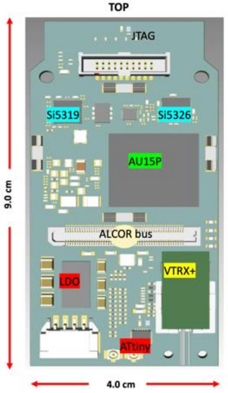
ALCOR radiation tolerance

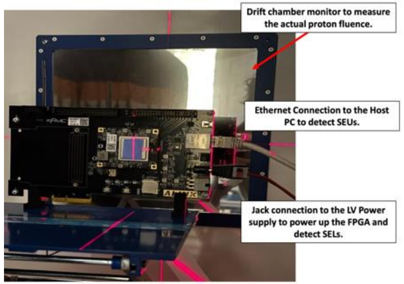


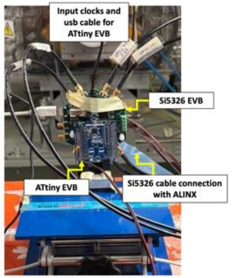
- ECCR σ = 9.8 · 10^{-14} cm^2/bit periphery register → no TMR in ALCOR v2.1
- BCR σ = 6.1 · 10^{-14} cm^2/bit periphery register → no TMR in ALCOR v2.1
- PCR **no SEU detected** re-written every 10 seconds to mimick TMR



RDO radiation tolerance





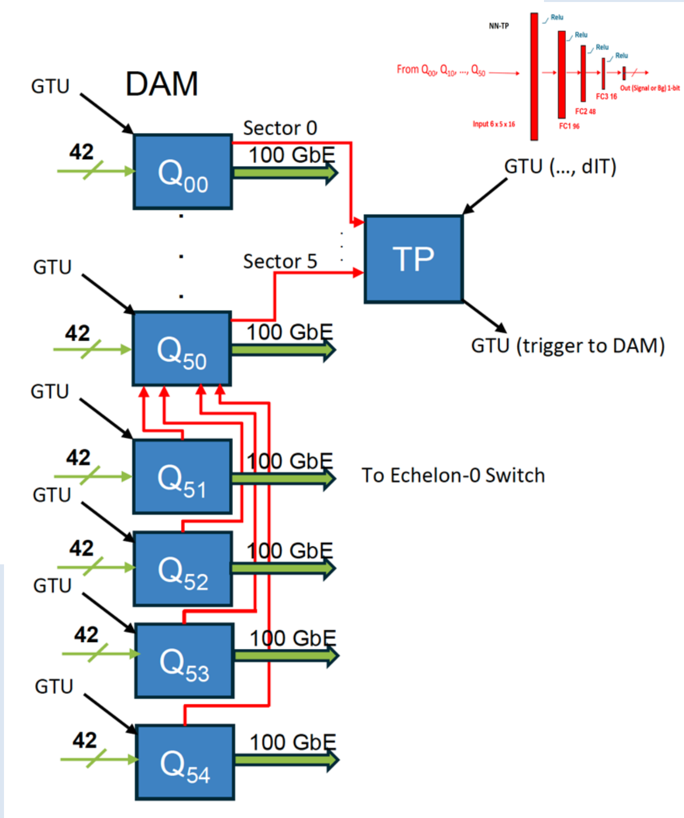


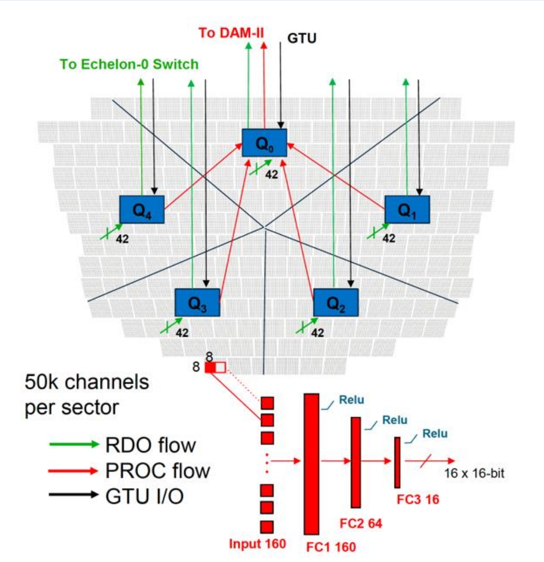
	Measured	Mean SEU time @ ePIC
Si5326 (clock)	$\sigma_{SEU} = (3.89 \pm 0.54) \cdot 10^{-14} \frac{cm^2}{bit}$	4 h
Attiny (power)	$\sigma_{SEU} = (2.11 \pm 0.50) \cdot 10^{-14} \frac{cm^2}{bit}$	3.8 h
AU15P (FPGA)		2 min

Our estimates	$\sigma_{SEU} \left(\frac{cm^2}{bit}\right)$
BRAM	$(1.78 \pm 0.23) \cdot 10^{-15}$
CRAM	$(2.30 \pm 0.28) \cdot 10^{-16}$

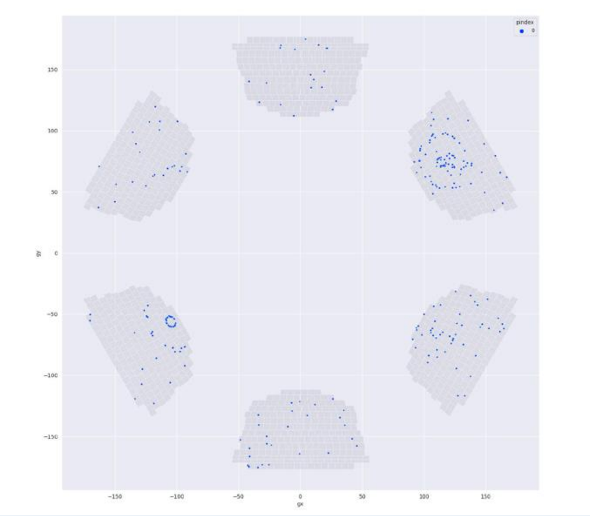
dRICH Online Filtering

Scheme based on ePIC DAM (Felix) &
APEIRON communication network (INFN)





Phys Signal+Phys Background+Noise

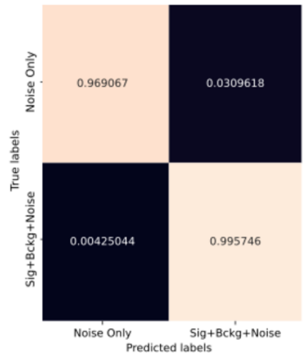


→Through **quantization**, we defined:
quantized fixed point<16,6> inputs
quantized fixed point<8,1> weights
quantized fixed point<8,1> biases

Obtaining a **~96,9% accurate noise classifie**
(wrt 16x16 grid input ~97,2% accurate one**)**

Preliminary tests

Recall



Precision

Technical Performance Requirements

Charge 1

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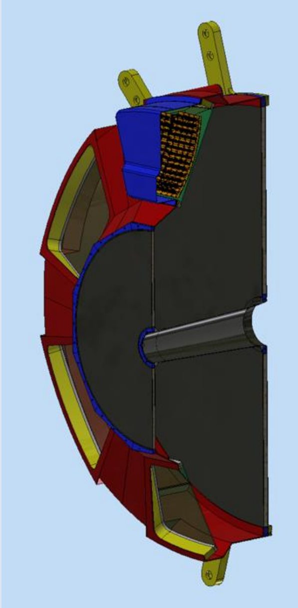
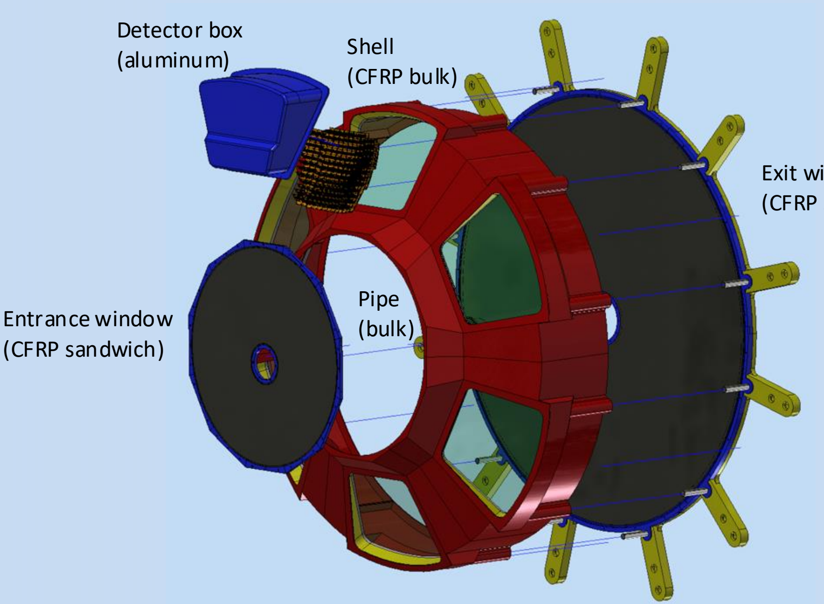
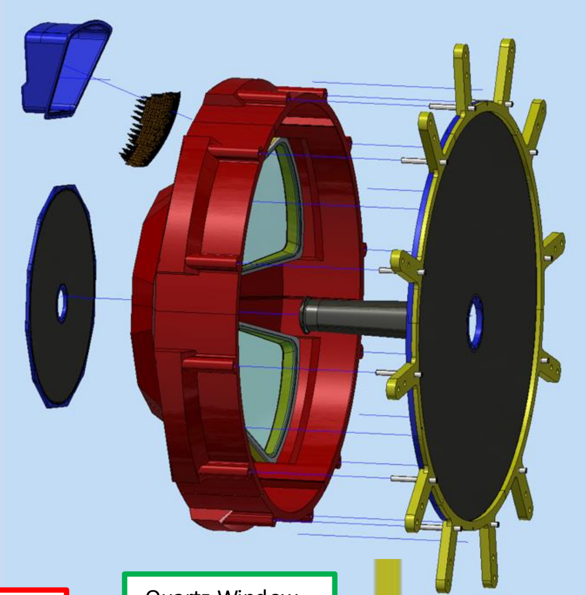
General Layout

Charge 1





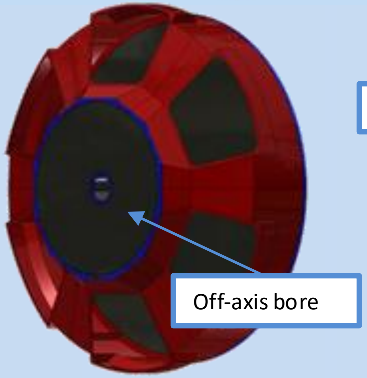


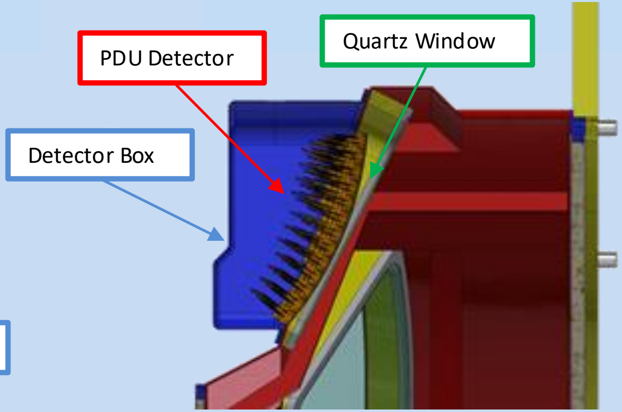
New assigned workforce

Cooling: **Carlo Mingioni (engineer, TO)**
Marco Nenni (engineer, TO)

Detector Box: **Michele Melchiorri (engineer, FE)**

Prototype: **Antonio Grmek (LNS)**
Giuseppe Laudani (PhD, LNS)



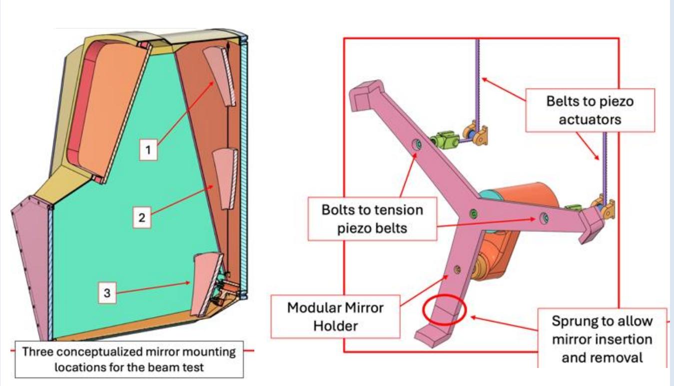


Charge 2

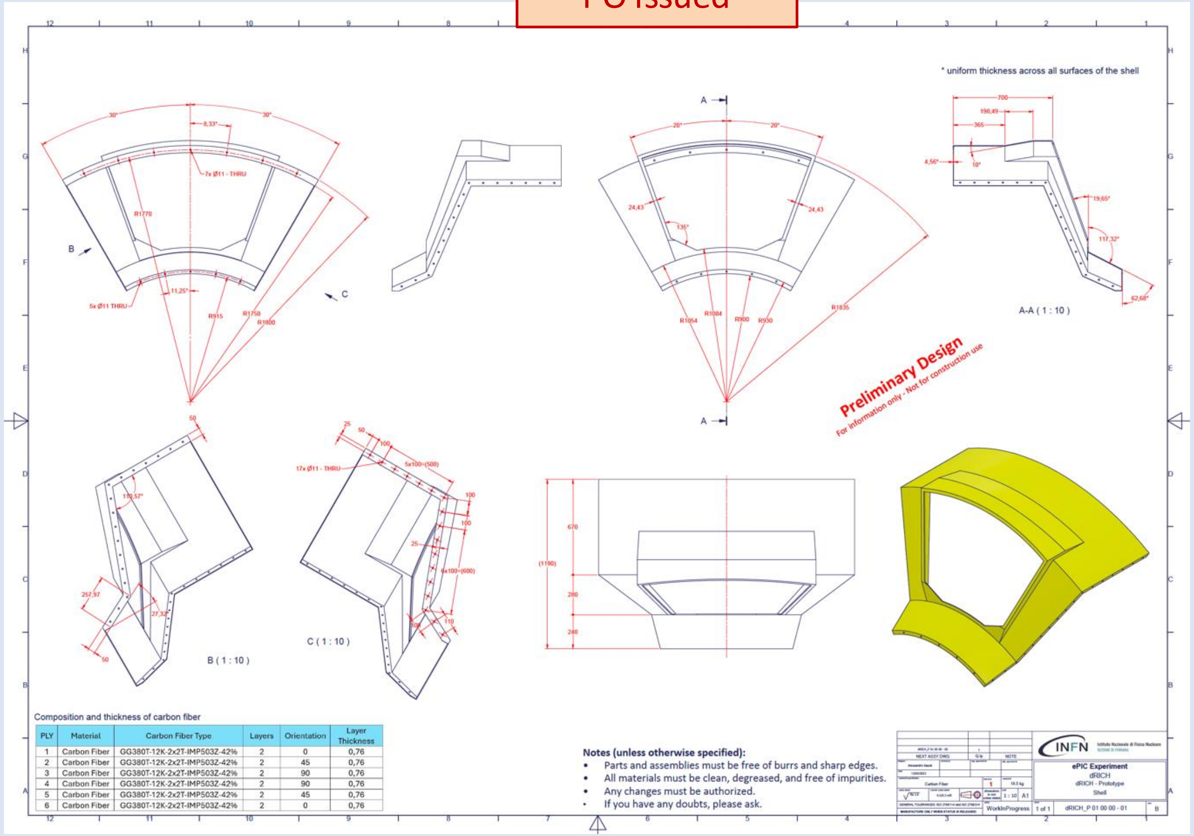
Entering the details of the mechanical model moving towards the executive design of the real-scale prototype

PO issued

Mirror mounting and alignment



CFRP Layer composition

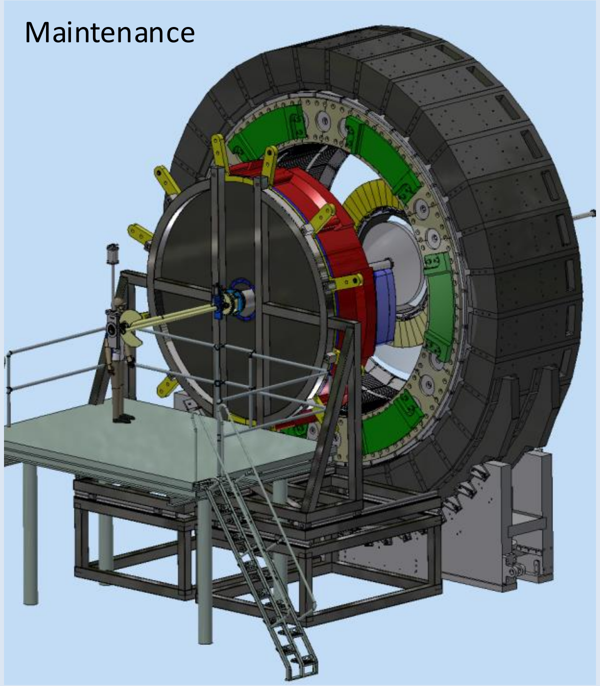


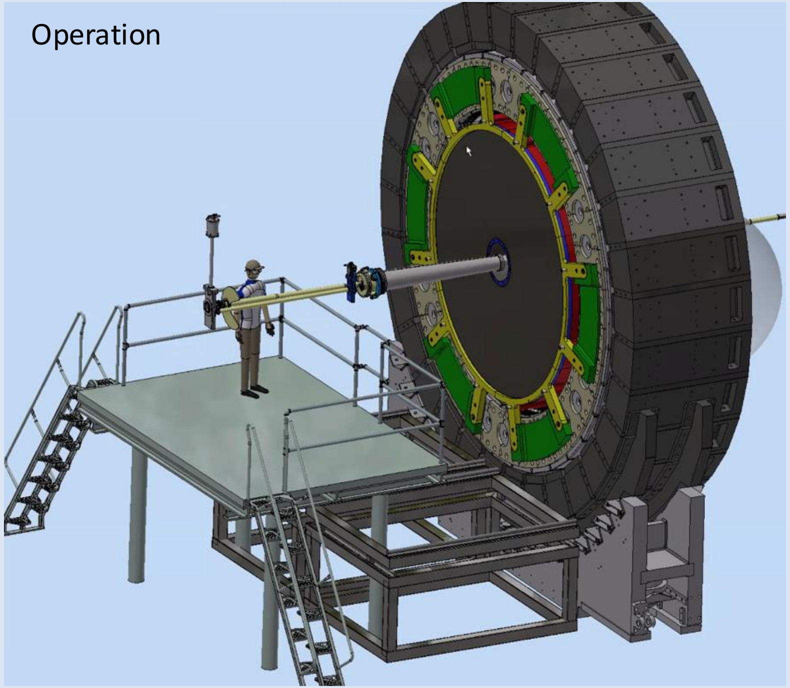
Composition and thickness of carbon fiber

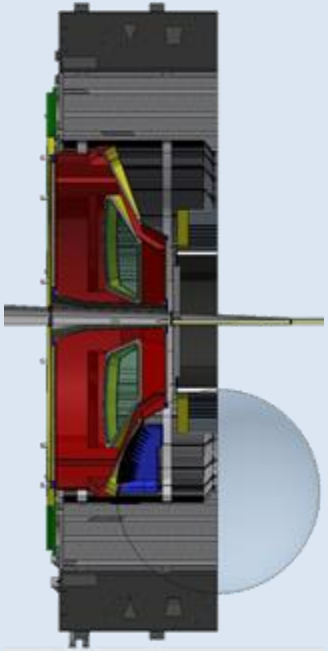
PLY	Material	Carbon Fiber Type	Layers	Orientation	Layer Thickness
1	Carbon Fiber	GG380T-12K-2x2T-IMP503Z-42%	2	0	0,76
2	Carbon Fiber	GG380T-12K-2x2T-IMP503Z-42%	2	45	0,76
3	Carbon Fiber	GG380T-12K-2x2T-IMP503Z-42%	2	90	0,76
4	Carbon Fiber	GG380T-12K-2x2T-IMP503Z-42%	2	90	0,76
5	Carbon Fiber	GG380T-12K-2x2T-IMP503Z-42%	2	45	0,76
6	Carbon Fiber	GG380T-12K-2x2T-IMP503Z-42%	2	0	0,76

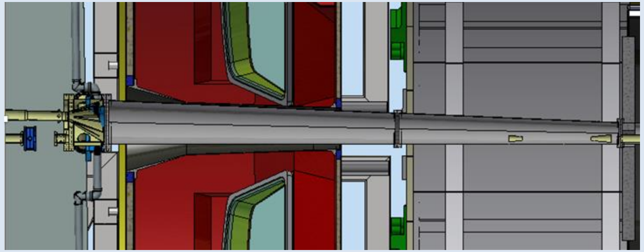
Integration

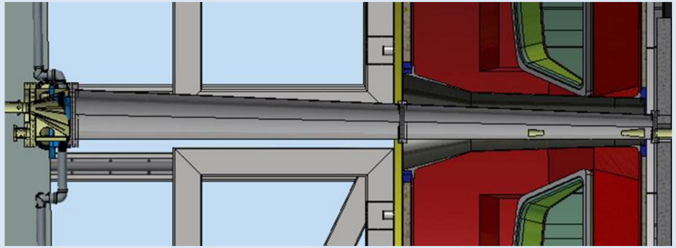
Charge 5











dRICH rolling in and out without vacuum break

A. Eslinger talk

Induced Gradients

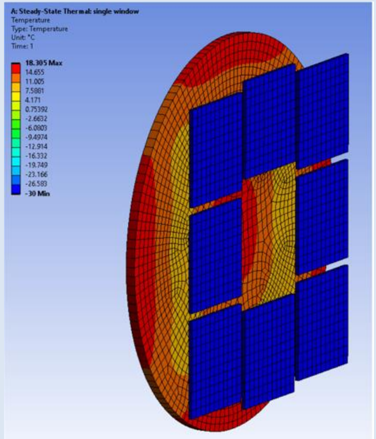
Ongoing study with ANSYS workbench simulations

Benchmarked by dRICH prototype

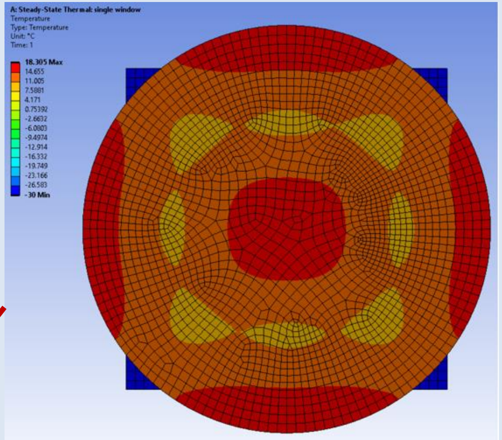
Gradients are largely mitigated by

- double lucite window (with air gap) x 0.5
- 8 mm thick quartz window
- inner gas recirculation x 0.1

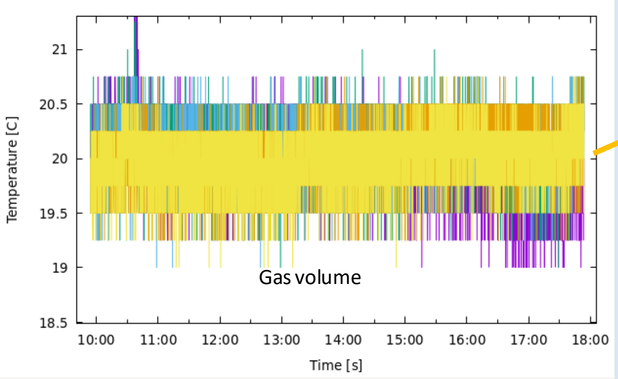
SiPM plane, cycled from 22º to -30º



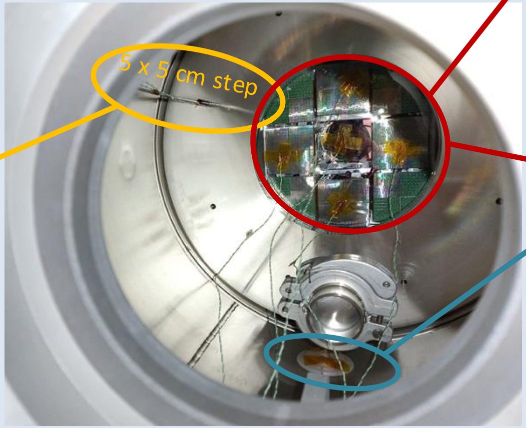
3 mm lucite window



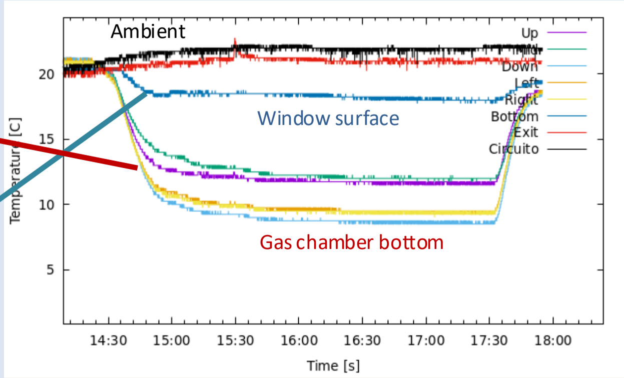
Temperature profile



Gas volume with thermocouples



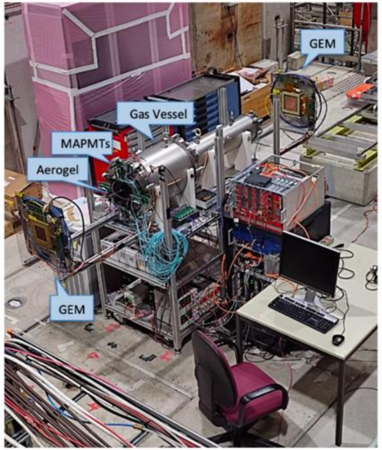
Temperature profile

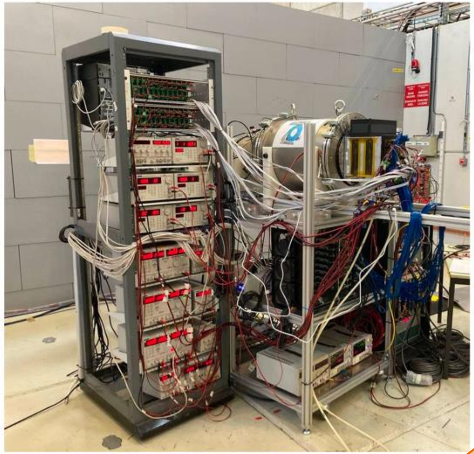


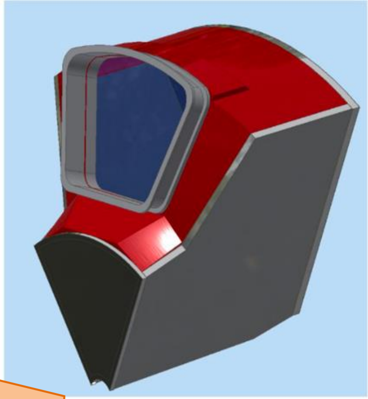
dRICH Prototypes

Previous validations:

- Dual-radiator concept
- C_2F_6 radiator gas performance
- Aerogel rafractive index
- SiPM-ALCOR readout chain
- EIC-drive readout plane
- Temperature gradients





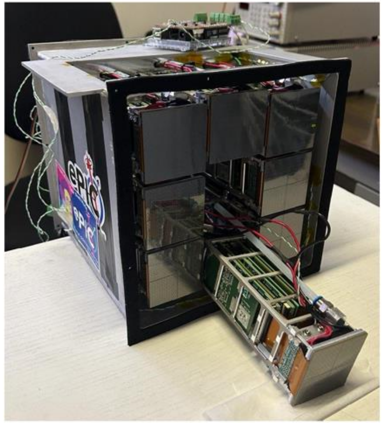


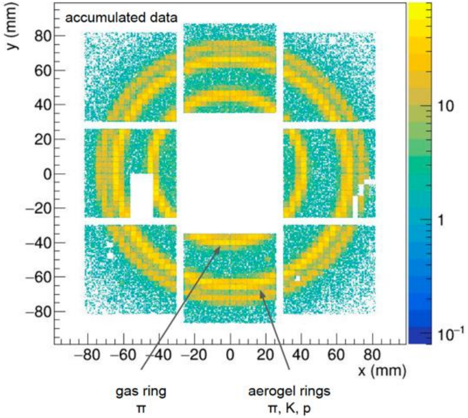
2025

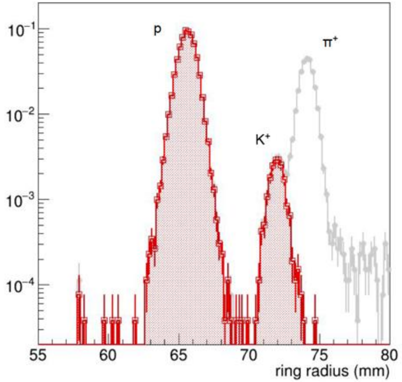
2025 main goals:

- Real scale 1-sector prototype with demo components
- ALCOR redout with RDO

Slot at SPS H8 in November







Essential to guide technological choices

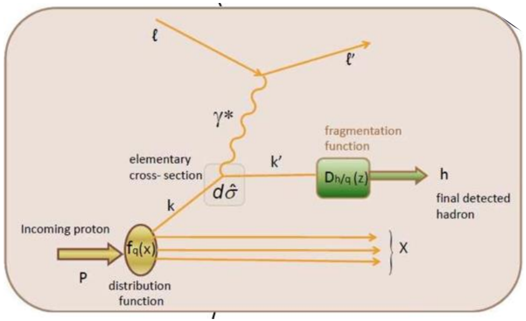
Effective entry-point for new collaborators

New performance study group being initiated

Focussed on SIDIS physics

Experience in Spin Physics and Nucelon Structure gained at HERMES (DESY), CLAS12 (JLab) and COMPASS (CERN)

INFN FE-BO-PV-TO-SA-LNS-TS (7 staff, 5 student/postdoc)

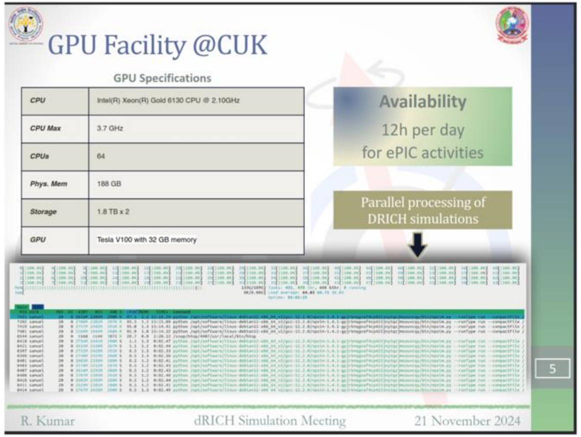


Close collaboration with Theory groups already active in inpact studies on (un-)polarized TMDs

INFN PV-TO (4 staff, 1 student/postdoc)

Significant reinforcement of the simulation group

- New group also provided resources to perform many new simulation - 12h/ day allocation for ePIC
  - Substantial use of GPUs
- Simulations and Reconstruction in EICrecon



CPU	Intel(R) Xeon(R) Gold 6130 CPU @ 2.10GHz
CPU Max	3.7 GHz
CPUs	64
Phys. Mem	188 GB
Storage	1.8 TB x 2
GPU	Tesla V100 with 32 GB memory

Central U. of Karnataka
Central U. of Haryana
Ramaiah U. of Applied Science
INFN TS-CS
U. of Salerno
Duke U.

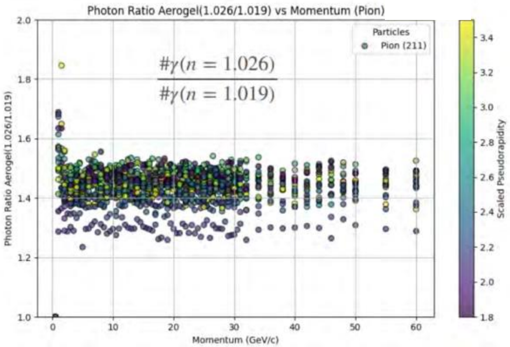
(5 staff, 11 student/postdoc)

Model based on laboratory characterization & test-beam data

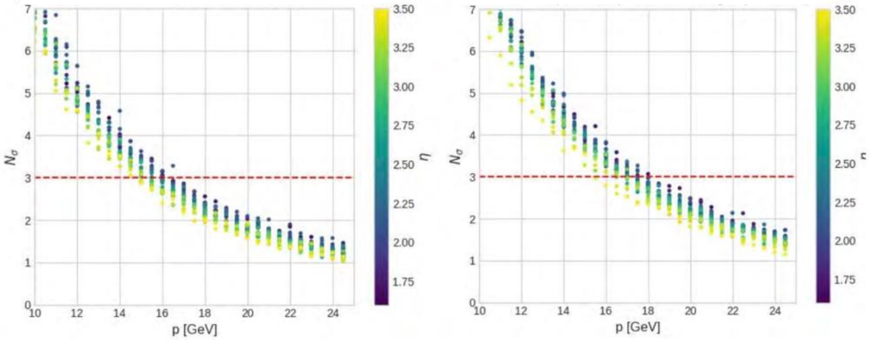
Simulation within ePIC dd4hep framework accounts for tracking

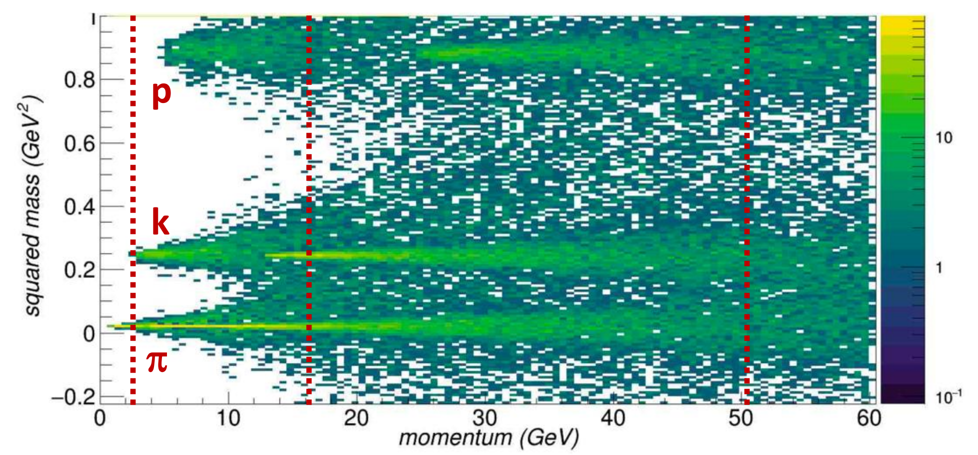
es. Impact of optimized refractive index

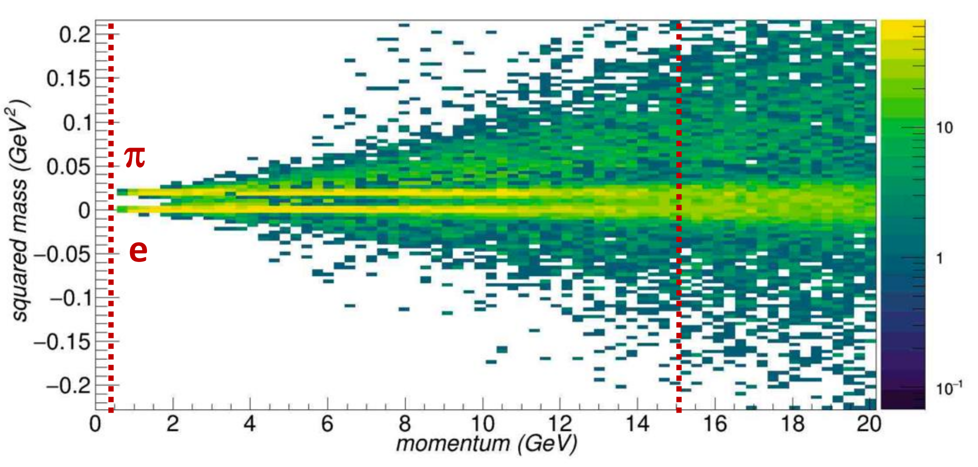
Photon yield



K^+ - π^+ Separation power







Layout Engineering

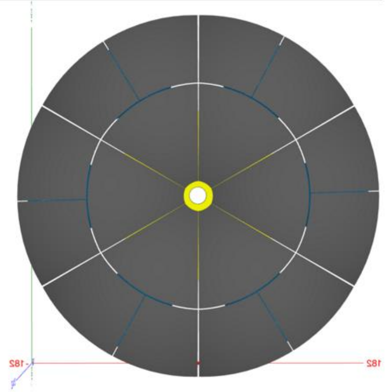
Charge 7

Ongoing optimization studies

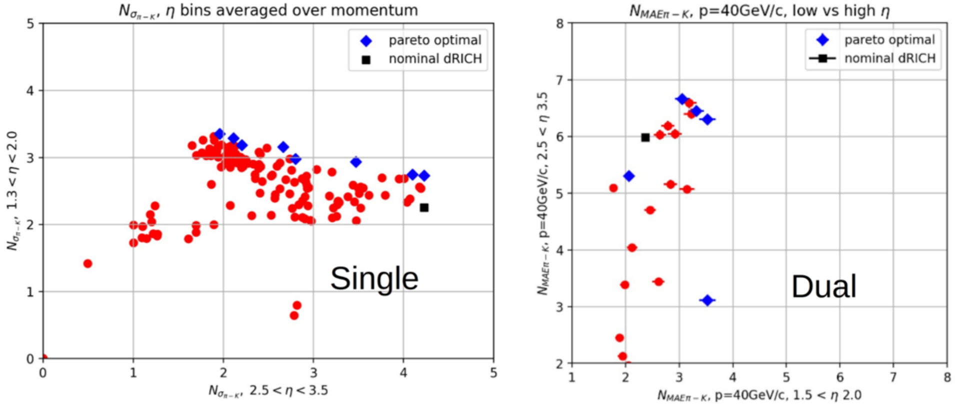
Optics parameters
es. mirror tessellation

Mechanical model
es. quartz window

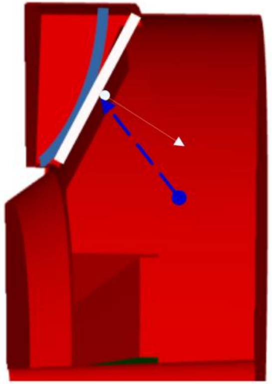
Mirror tessellation

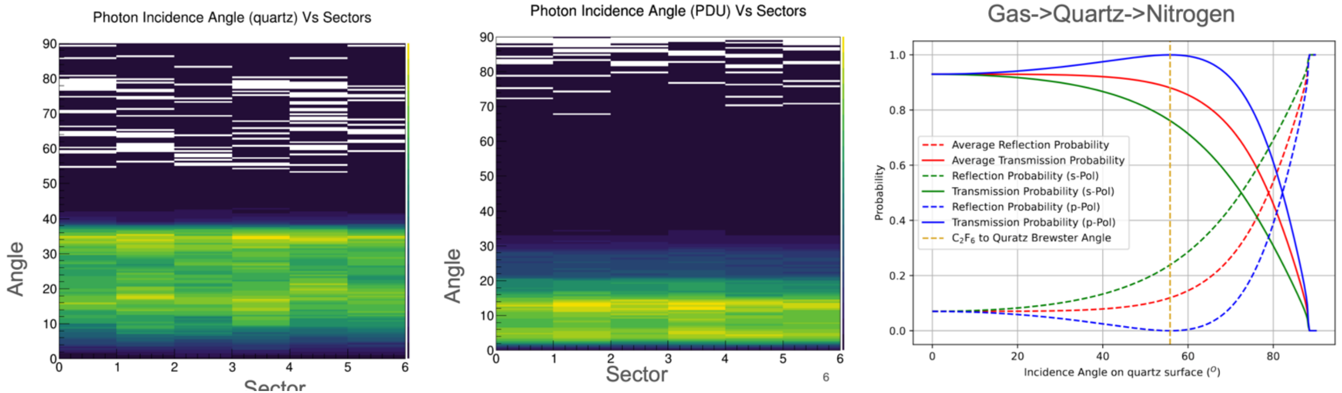


ML optimization of the mirror and detector radius of curvature



Photons impinging angles and transmission probability





dRICH Overview

Charge 2

Institution	Nation	Activity
INFN-FE	Italy	Mechanics, detecor box and control panels
INFN-BO	Italy	Photosensors, photodetection unit PDU and readout board RDO
INFN-TO	Italy	ALCOR and front-end board FEB
INFN-BA	Italy	Aerogel radiator
INFN-CS-SA-CT	Italy	SiPM quality assurance
INFN-GE	Italy	dRICH tagger
INFN-LNS	Italy	Mechanical design
INFN-RM1-RM-TV	Italy	Online data reduction
INFN-TS	Italy	Radiator gas, gas system and software, SiPM quality assurance
Duke-U.	USA	Mirror
JLab	USA	Mechanical design and mirror characterization
BNL	USA	Mechanical design, integration, infrasctructure
Temple U.	USA	Aeorgel quality assurance
M.S. Ramaiah U.	India	Simualtions and performance study
NISER	India	Performance study
Central U. of Haryana	India	Performance study
Central U. of Karnataka	India	Performance study

Italy: 24 staff, 18 postdocs/ students, 18 technicians/ engineers

USA: 8 staff, 2 postdocs/ students, 2 technicians/ engineers

India: 8 staff, 2 postdocs/ students

Many groups have committed to the construction phase of the above items
QA stations are of common interest: best performance with co-funded equipment & shared workforce
open to collaborators: opportunity for secondments and students traning

Quality Assurance

QA stations organized in order to

- Be close to the assembling site
- Ensure adequate personnel training
- Provide redundancy & investment synergy
- Support specific in-deep characterization studies

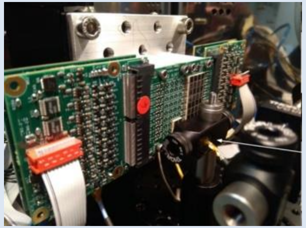
Aerogel: Integrity, defects, transmittance, refractive index, dimensions, planarity

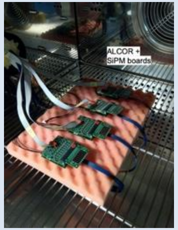
Mirror: Dimensions, shape accuracy, radius, reflectivity

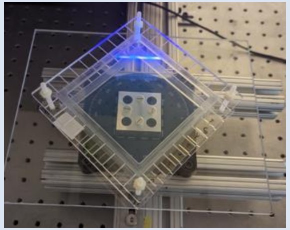
Sensors: Electrical connections, quench resistor, I-V characteristics, DCR, relative PDE

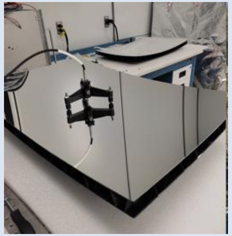
Readout: Electrical connections, bias levels, threshold and gain scans, time jitter, DAQ rate

Gas: Refractive index, transparency, sound speed, leakage rate





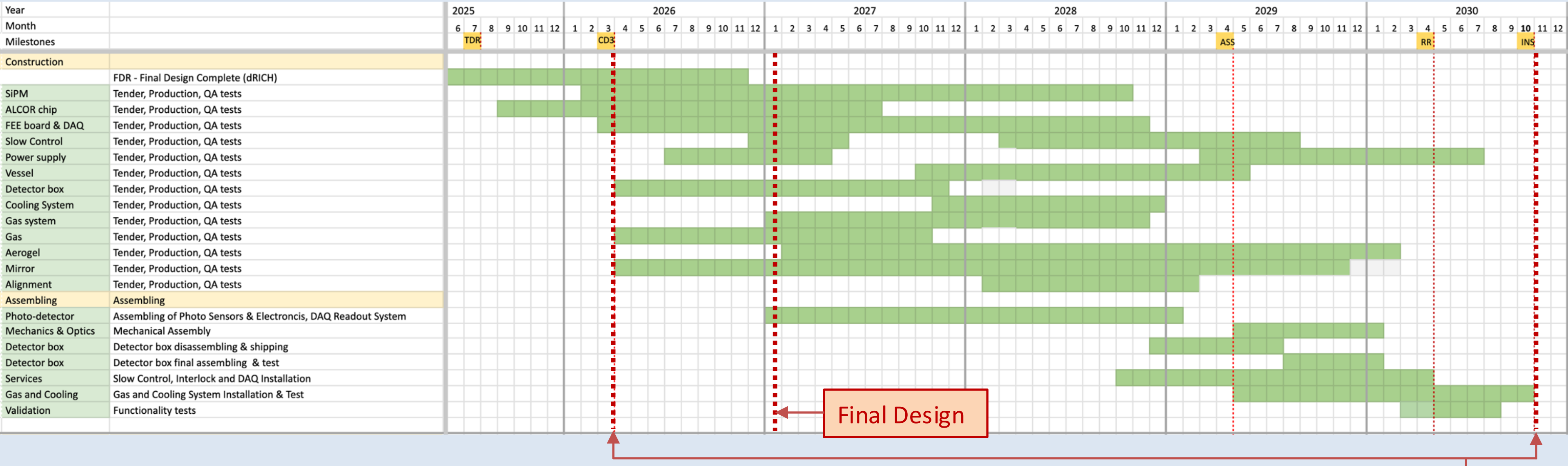




Component	QA station 1	QA station 2	QA detail and backup	QA Acceptance	In-depth
Aerogel	Temple U.	BNL	INFN-BA	100 %	5%
Gas	BNL		INFN-TS	2 %	2%
Mirror	JLab	Duke U.		100 %	10%
Sensor (SiPM)	INFN CS-SA-CT	INFN-TS	INFN-BO	100 %	1%
Readout	INFN-BO	INFN-FE	INFN-TO	100 %	1%

Construction Plan

Work out the time interval from CD3 to installation, with 6 months of contingency & functionality tests



Stage 1: Stage from beginning the procurement for the PDU components (asics, SiPM, carrier, FEB, RDO…)
Anticipate mirror and gas procurement to reduce risk

Stage 2 : Central 2-3 year for the detector box assembling before delivery to BNL
Aerogel production after engineering optimization
Gas system after BNL authority approval

Stage 3: Mechanical structures
Assembling and completion of services

Consistent with P6
To be shifted with CD3/CD4

Safety and Health

Charge 6

Safety: standard slow-control and interlock procedures to control power and cooling while monitoring gas flow, humidity and temperature.

Annealing: done during technical stops or annual stops of EIC

done for fractions of PDUs with total power comparable to operation

interlocked by internal and external temperature sensors and current monitor

Gas vessel: pressure regulators with UPS and 2-ways bubblers to ensure + 5 mbar overpressure (hydrostatic pressure)

standard ODH procedures in case of rupture

Gas system: leakage rate during operation minimized to be about 20 m^3 /year

Mechanics: *safety factor for quartz / structure stability;*

Commissioning & Calibration

Charge 6

Commissioning: 6 months functionality tests with cosmics prior of installation

Detector response: Dark count rate as healthy and damage monitor

Single-photon time over threshold as gain monitor

LED/laser system (sensor response and mirror alignment)

Time Calibration: Absolute time with respect bunch crossing and Forward TOF

Time intercalibration: photons hits from the same event

Particle ID: Control particle samples (identified by other systems)

Known meson decays (K_S, Λ, Φ)

Conclusions

Incremental dRICH Design Status is documented in pre-TDR:

Essential technical performance has been detailed for each dRICH component

Engineering is ongoing with pre-productions for performance vs cost optimization

Workforce is increasing, with focus in simulations and engineering

Ultimate achievements expected in 2025 (real-scale prototype, RDO, ALCOR64)

Clear commitments being defined

On track for Final Design completion in January 2027 as for P6

Work is ongoing to address past recommendations:

dRICH simulation within ePIC dd4hep model for an holistic approach with tracking and other PID detectors

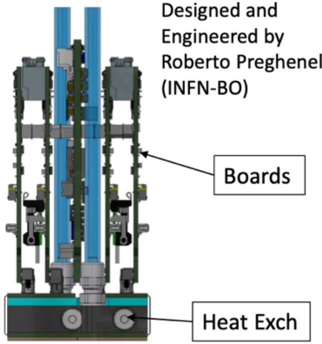
Thermal simulation initiated with benchmark from dRICH prototypes

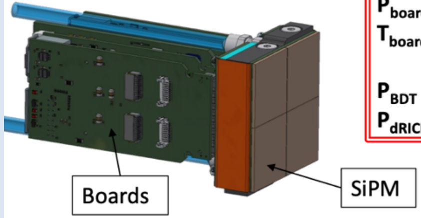
QA stations being organized with assigned workforce, required instrumentation and detailed acceptance-test plan

Backups

Cooling

Designed and Engineered by Roberto Preghenella (INFN-BO)





dRICH PDU = 1200
Detector Box PDU = 242
dRICH Detector Boxes = 6

SiPM

P_{PDU} **= 5 W** (cooling power to be supplied to each PDU unit)
T_{SiPM} **= -40°C** (SiPM temperature)

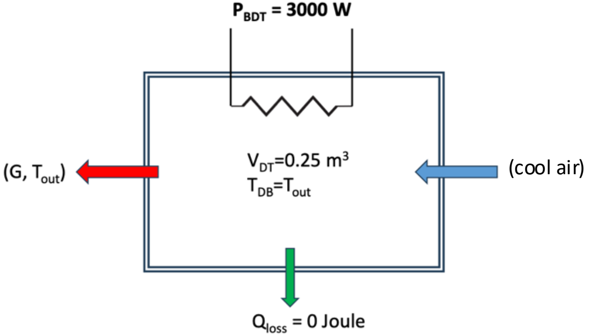
P_{DT} **= 242 × 5 W = 1210 W** (cooling power to be supplied to each detector box)
P_{dRICH} **= 6 x 1210 W = 7260 W** (cooling power to be supplied to dRICH)

Electronic Boards

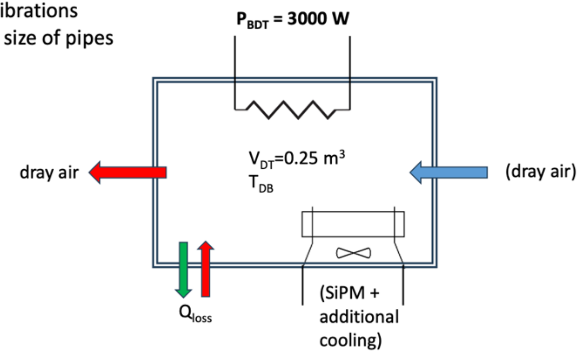
P_{boards} **= 11 W** (thermal power generated by each PDU unit)
T_{boards} = **30°C (maximum admissible boards temperature)**

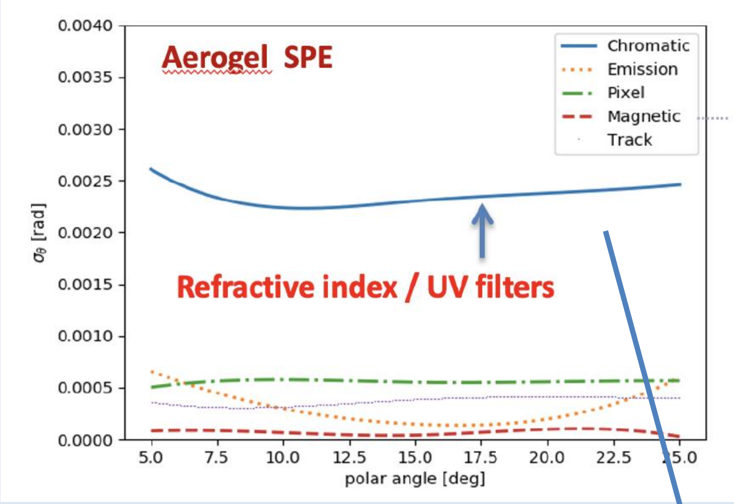
P_{BDT} **= 242 × 11 W = 2662 W** (thermal power generated by each detector box)
P_{dRICH} **= 6 x 2662 W = 15972 W** (thermal power generated by dRICH)

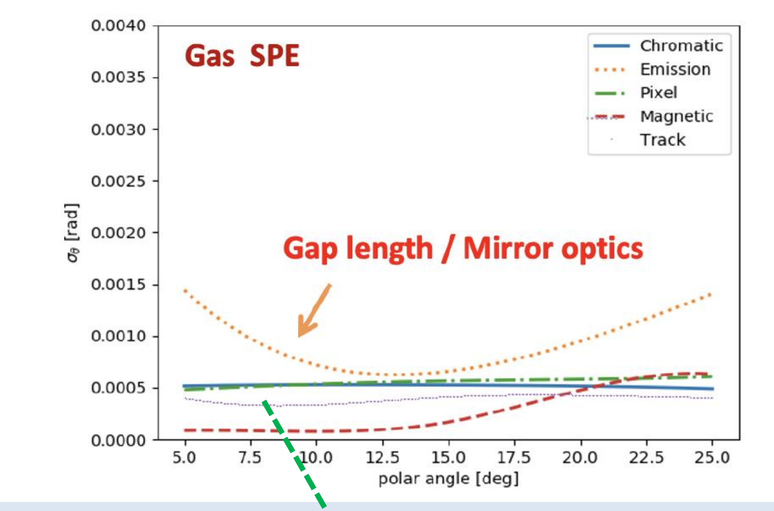
Disadvantages:
- Risk of condensation
- High noise
- High vibrations
- Big size of ducts



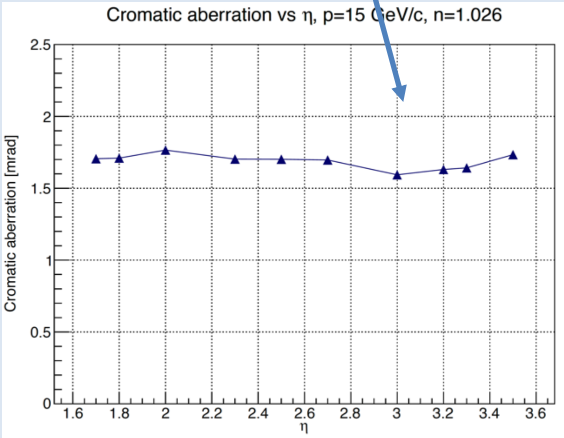
Advantages:
- Low risk of condensation
- No noise
- low vibrations
- small size of pipes

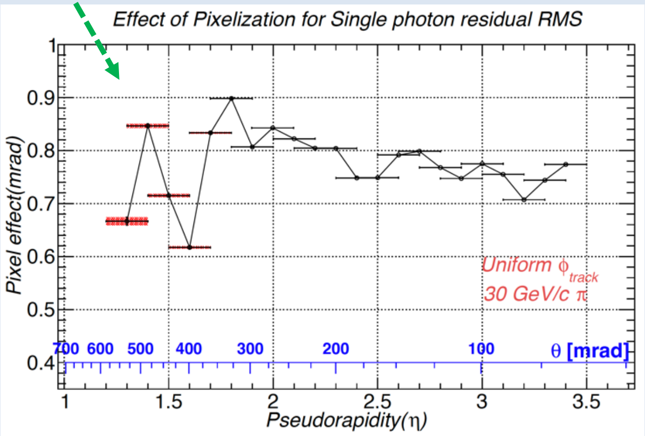






Enhanced capability allows for detailed studies





Single-photon Cherenkov angle resolution being (re)-studied within the ePIC framework

dRICH Sub-System Organization

6.10.04 Particle Identification Level-3 — CAM from Project

6.10.04.03 dRICH Level-4 — CAM from Project + DSTC from EPIC (**M. Contalbrigo**)

Work packages lead from EPIC

Photo-Detector	Level-5	**R. Preghenella**, INFN-BO, INFN-FE, INFN-CS, INFN-SA, INFN-LNF, INFN-CT, NISER
Front-end Asics	Level-5	**F. Cossio**, INFN-TO, INFN-BO
Data-acquisition	Level-5	**P. Antonioli**, INFN-BO, INFN-FE
Mechanics	Level-5	**A. Saputi**, INFN-FE, INFN-CT, INFN-GE, JLAB, BNL
Gas radiator	Level-5	**F. Tessarotto**, INFN-TS, BNL
Mirror	Level-5	**A. Vossen**, DUKE, INFN-FE
Aerogel Radiator	Level-5	**G. Volpe**, INFN-BA, INFN-FE, RICH Consortium
High-Pressure	Level-5	**S. Dalla Torre**, INFN-TS, INFN-FE, INFN-LNS
Simulation		**C. Chatterjee**, INFN-TS, DUKE, INFN-FE, RICH Consort.

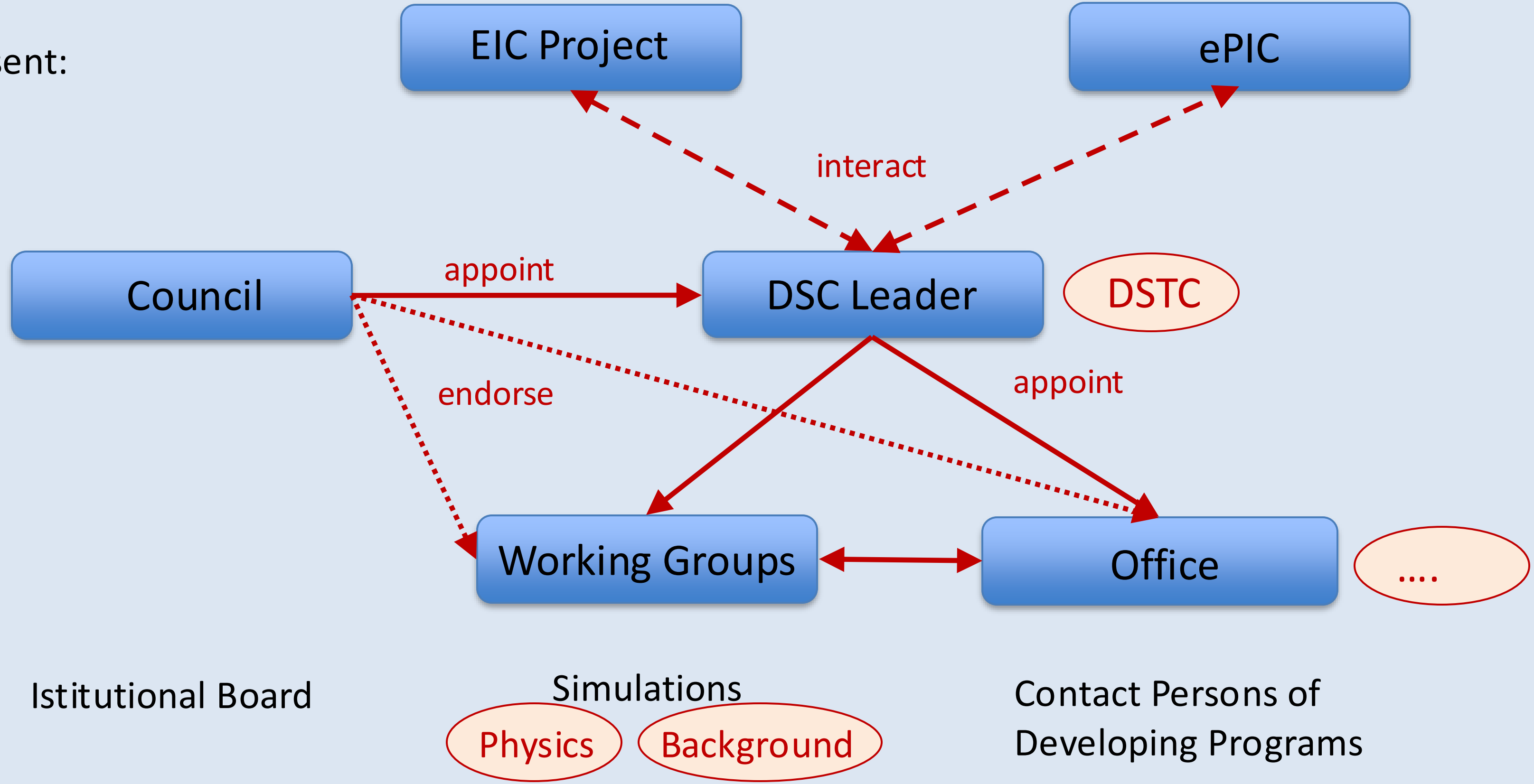
Work packages not yet active

- Interlock Level-5
- Slow Control Level-5
- Cooling Level-5
- Gas purging Level-5
- Detector box Level-5
- Alignment Level-5
- Power Supply Level-5
- …… Level-5

dRICH Sub-System Organization

Need to evolve towards CD3 with formal responsabilities & procedures

At Present:



Technical Performance Requirements

Charge 1

	Requirements			Specifications
Aerogel:	Momentum reach above 15 GeV/c to overlap with gas More than 10 detected photons from 4 cm thickness Single photon resolution approaching 2 mrad	⇨		n = 1.026 $dn/d\lambda = 6\ 10^{-6}\ nm^{-1}$ scattering length > 50 mm
Gas:	Momentum reach above 50 GeV/c at pseudorapidity > 2.5 More than 20 detected photons from 1 m depth Single photon resolution better than 1 mrad	⇨	C_2F_6	with n = 1.00086 $dn/d\lambda = 0.2\ 10^{-6}\ nm^{-1}$ absorption length > 100 m
Mirror:	Focalization of Cherenkov light onto the detector surface Preservation of the Cherenkov information Material budget limited to O(2 %) of radiation length	⇨		Carbon fiber material Roughness of few nm Angular precision < 0.2 mrad Reflectivity ≳ 90 %
Sensors:	Single photon detection capability in highly non-uniform magnetic field Excellent PDE in the visible range to cope with aerogel Marginal contribution to the angular resolution Preserve prompt Cherenkov information Tolerance to few 10^{10} 1-MeV neutron equivalent fluence	⇨	SiPM	Spatial resolution of 3 x 3 mm^2 Time resolution O(100 ps) Operation at < -30 degrees Annealing curing cycles
Readout:	Below 1 p.e. signal threshold capability Preserve sensor time resolution to cope with dark counts and accidentals More than 300 kHz/ch rate capability Streaming readout with suppression of no-particle frames	⇨	ALCOR	ALCOR chip (ToT architecture) Time resolution < 200 ps Rate > 300 kHz/ch Digital programmable shutter
Mechanics:	Acceptance maximized in 1.5 – 3.5 pseudorapidity range Material budget minimized in acceptance Compatibility with barrel maintenance at IP6	⇨		Composite materials Single open volume Detector in the barrel shadow