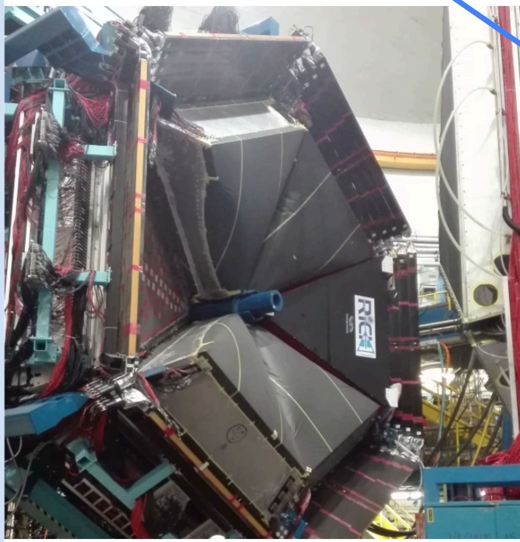
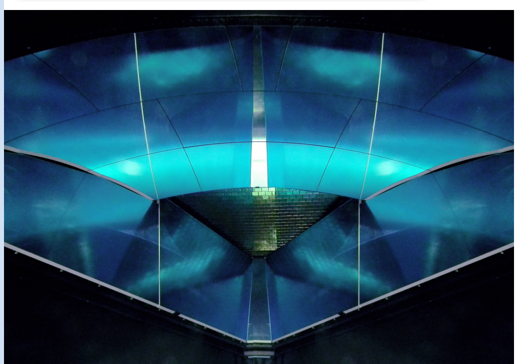
INFN Groups and eRD14

Several INFN groups interested to pursue dRICH and other activities within the eRD14 Consortium

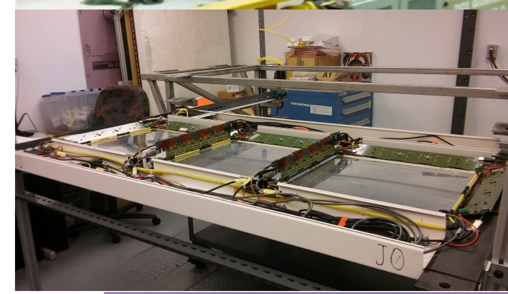
INFN-FE
CLAS12 RICH



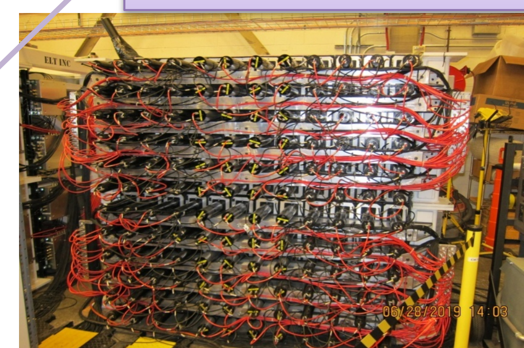
INFN-LNF
CLAS12 RICH



INFN-RM1
HERMES RICH
Hall-A Tracking



INFN-CT
Hall-A HCAL



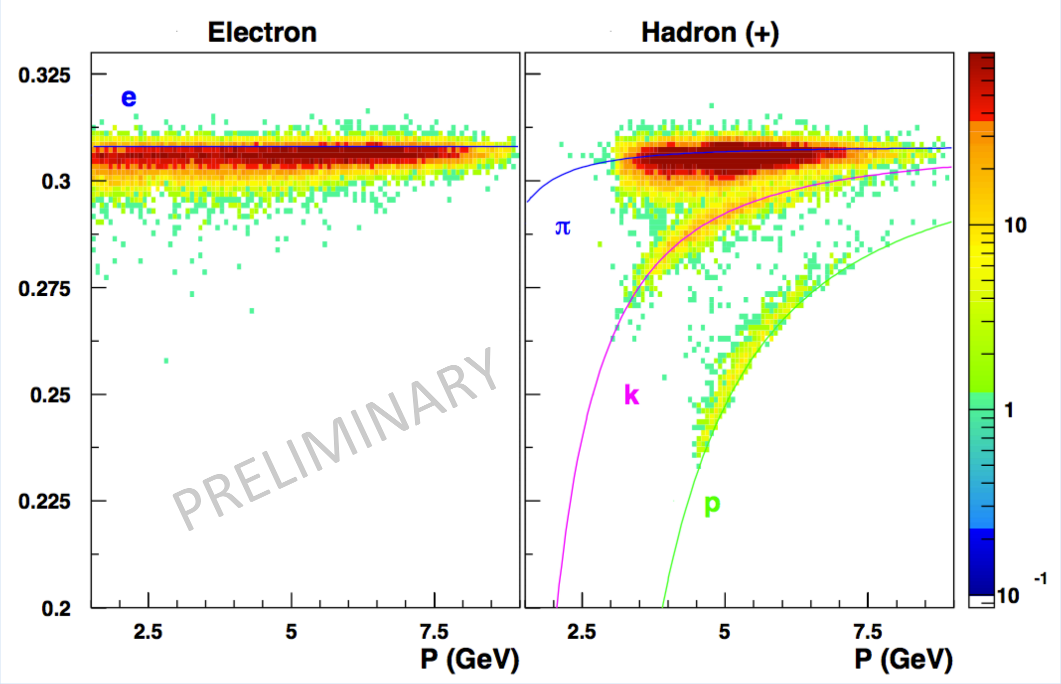
CLAS12 RICH

Contributors: **INFN-FE,LNF,RM1**,BA,GE, JLab, ANL, GWU, Duquesne U., UCONN, Glasgow U, UTFSM (Chile), KNU (Korea)

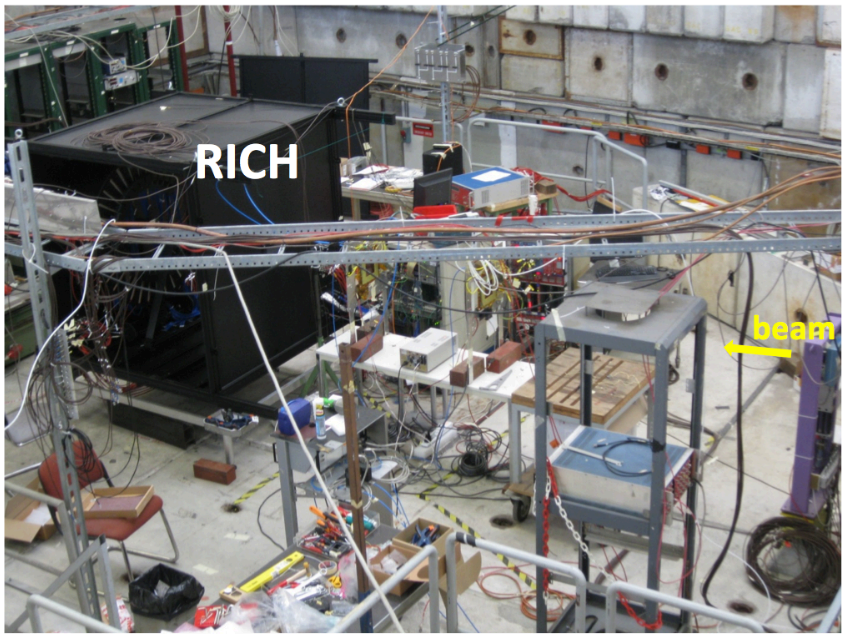
Dec 2012: Final T9 Test beam

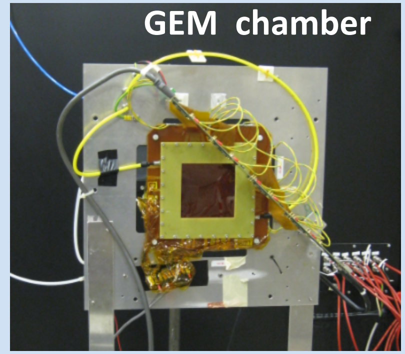
Sep 2013: TDR & DOE Review

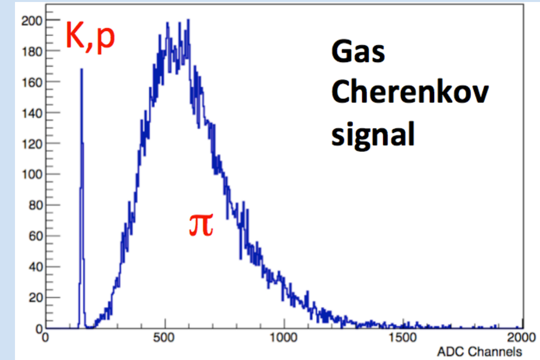
Jan 2018: **RICH 1st Module Installed**
Start 2nd module construction

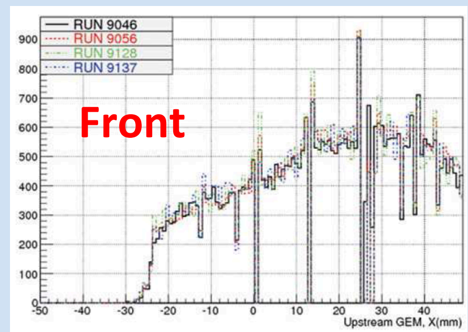


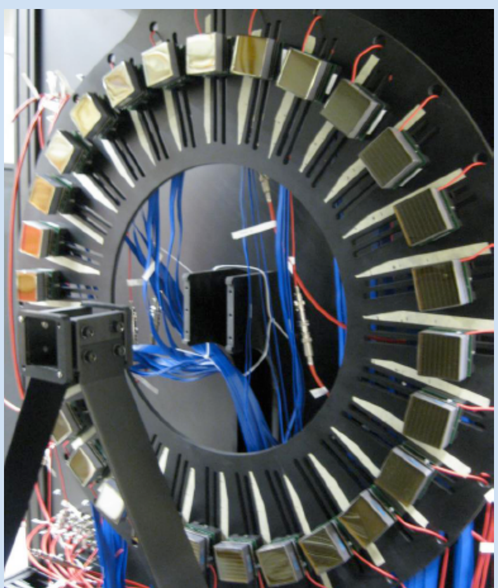
CLAS12 RICH Prototype @ CERN T9

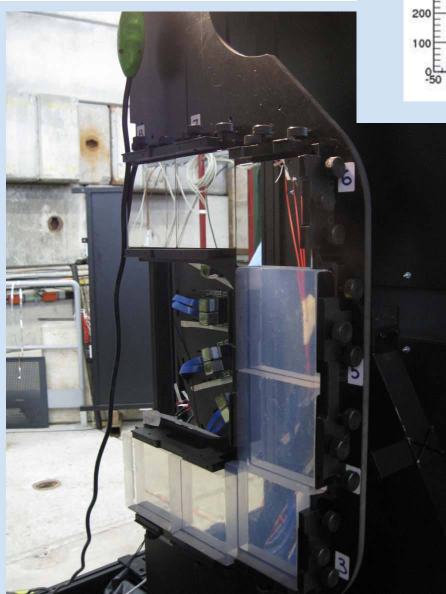




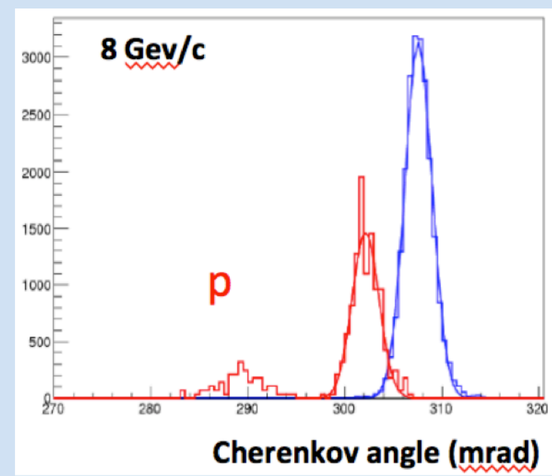






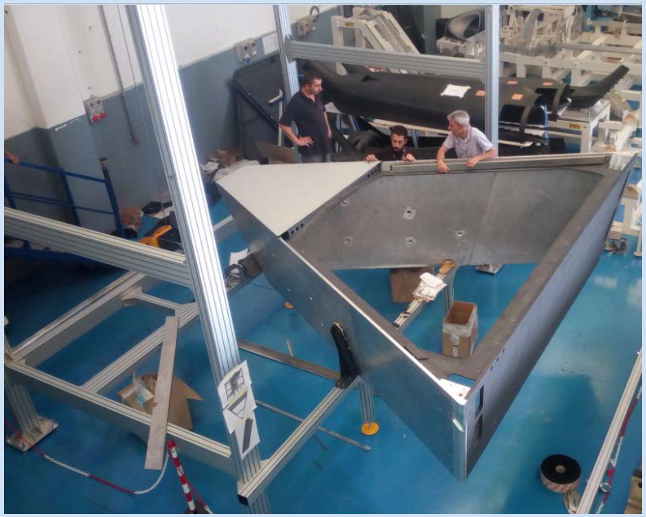


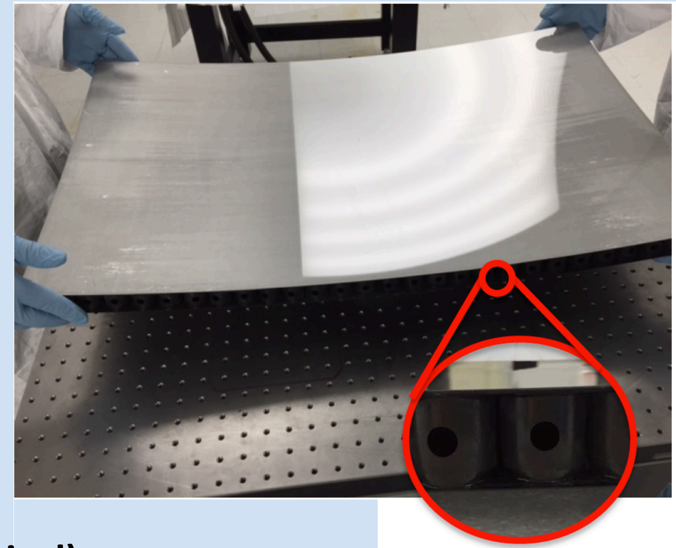
Goal:
Separation
up to 8 GeV/c



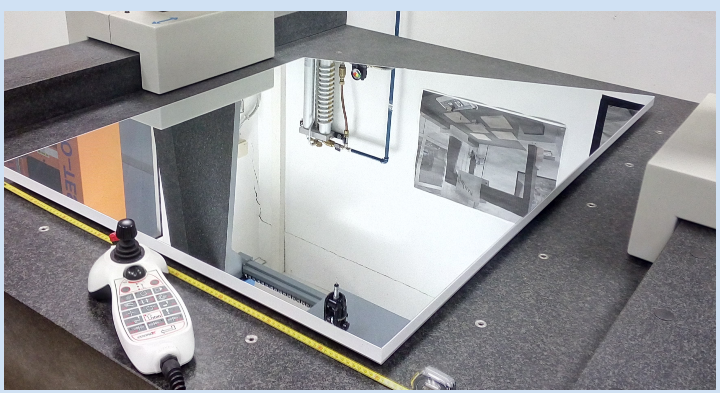
CLAS12 RICH Advances

Aeronautic technology for structure
to maximize lightness and stiffness. Trapezoid of composite materials: CFRP inside acceptance, Al outside

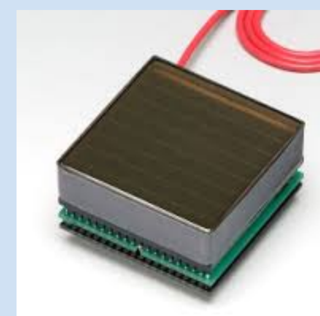




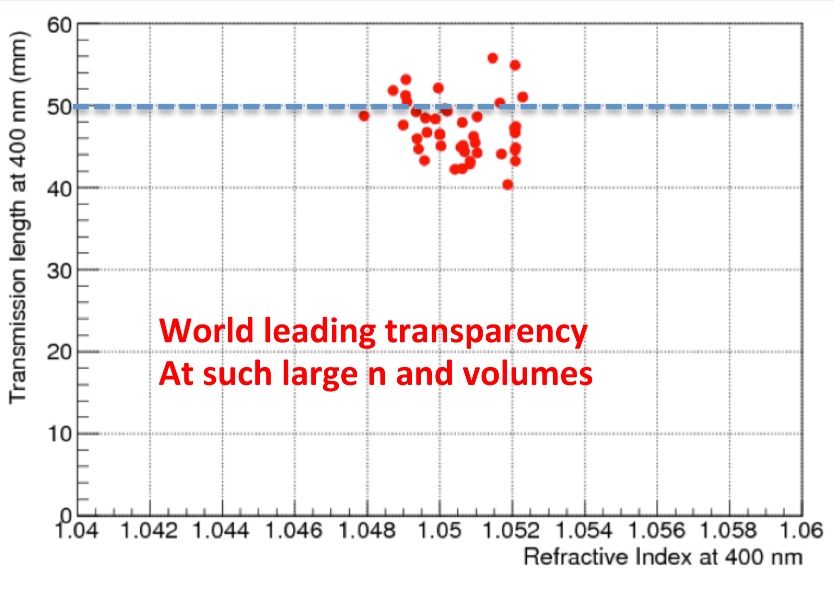
Carbon Fiber Mirrors (spherical)
to maximize lightness and stiffness. Consolidate technology (HERMES, AMS, LHCb) but ~ 30 % material budget reduction

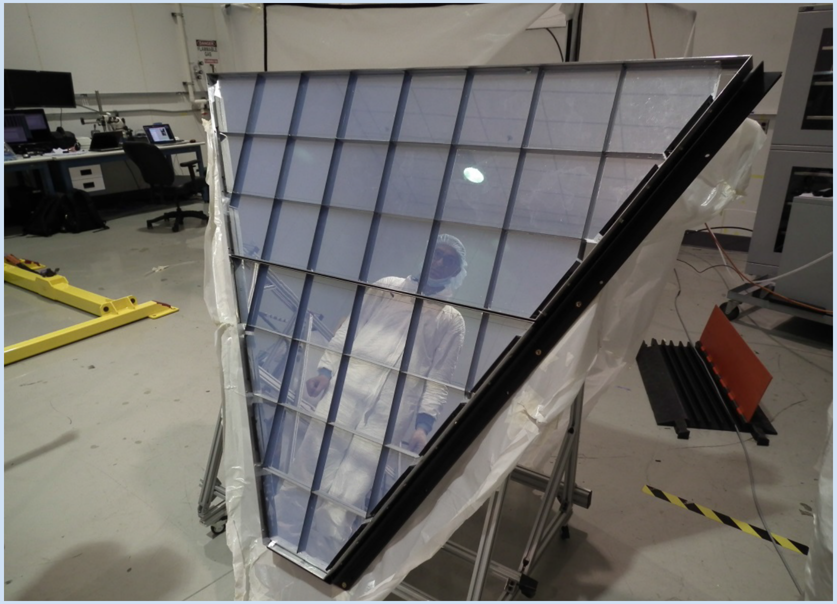


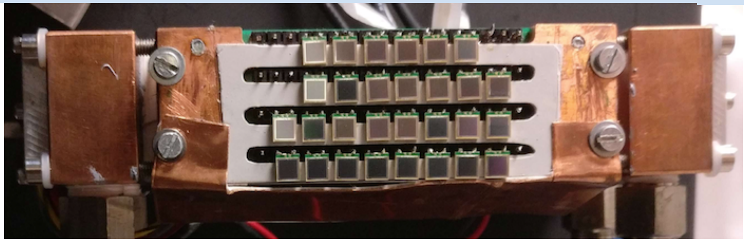
Photon Detector
First use of H8500/H12700 flat panel multi-anode PMTs
64 pixels on a 5x5 cm^2 area

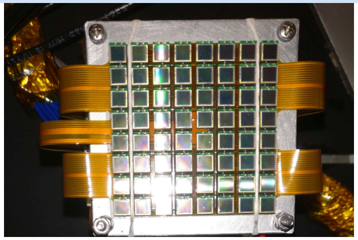


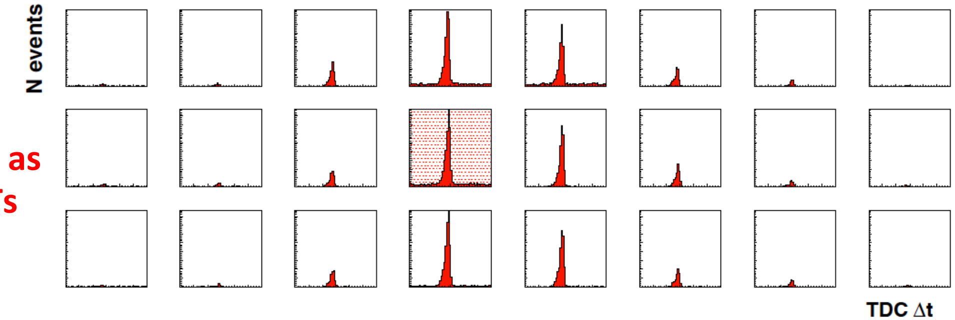
Glass-Skin Mirrors (planar)
Innovative technology never used in nuclear exps.
~ 1/5 cost for squared meter vs CFRP



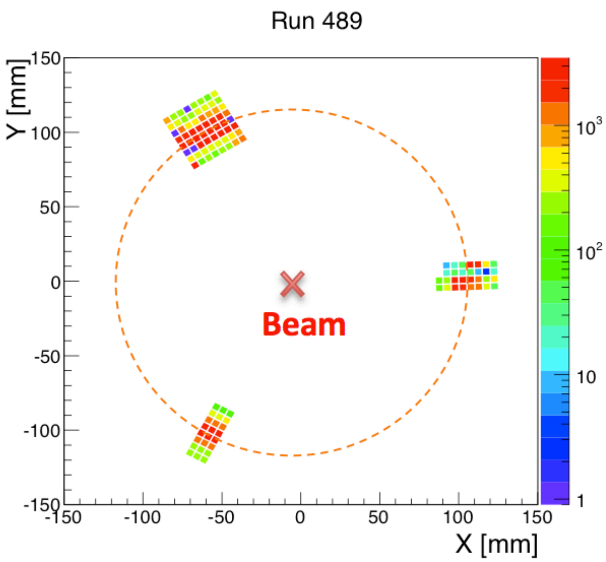








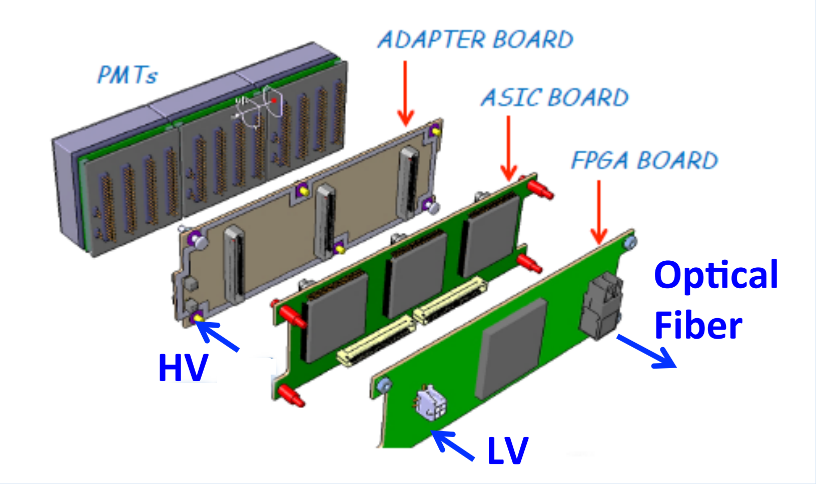
Cooled SiPM as good as PMTs

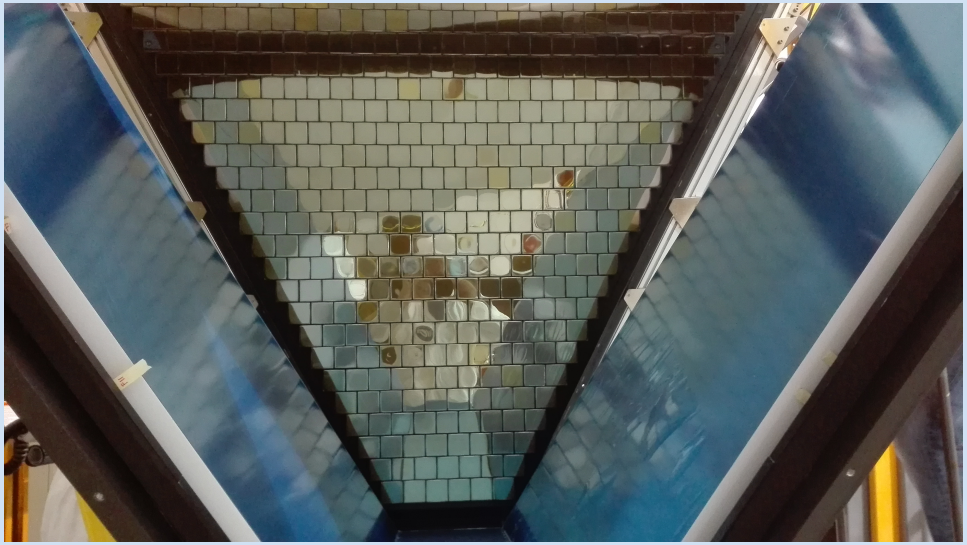


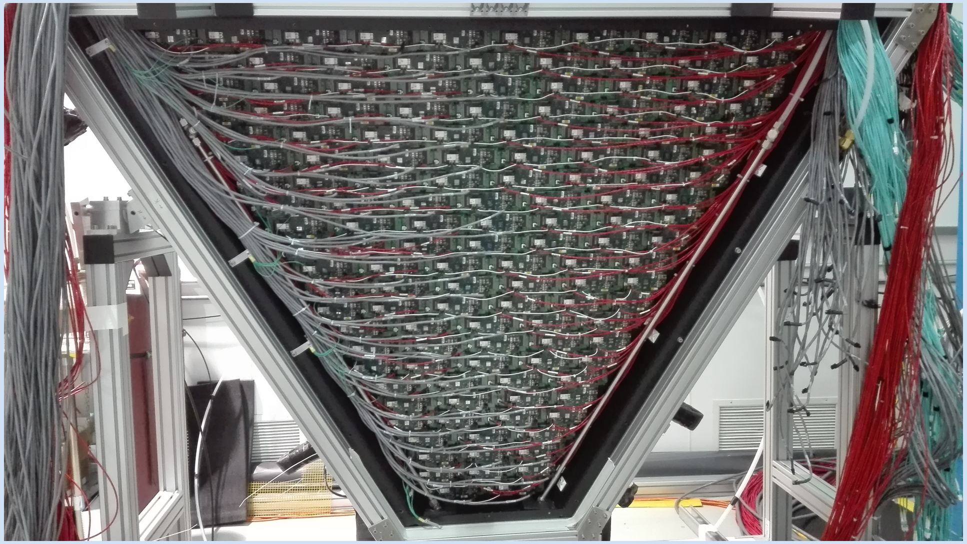
Front-end Electronics

Readout Electronics

Compact (matches sensor area)
Modular Front-End (Mechanical adapter, ASIC, FPGA)
Scalable fiber optic DAQ (TCP/IP or SSP)
Tessellated (common HV, LV and optical fiber)



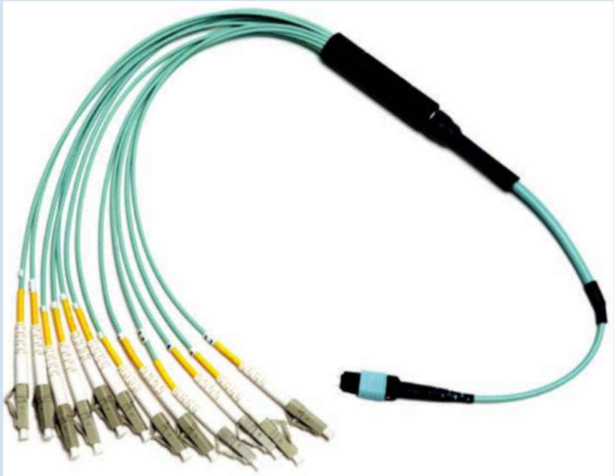




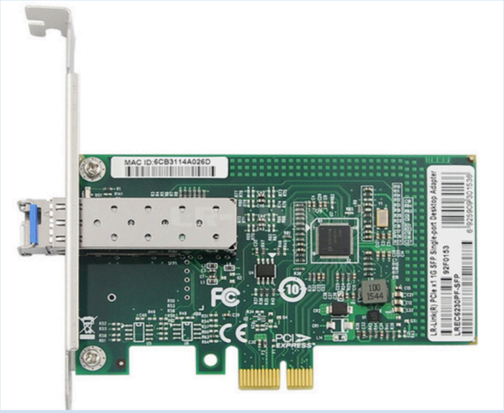
Applications:

- **EIC R&D**
- Gluex DIRC
- SOLID
- Medical Imaging
- Homeland Security

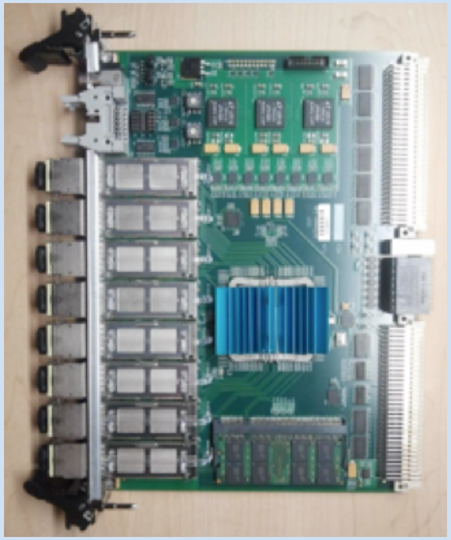
Back-end Electronics (JLab)



Optical bridge / PC Desktop
Few FPGA units ~ 500 channels



SSP board / VSX crate
2 RICH sectors ~ 50 k channels



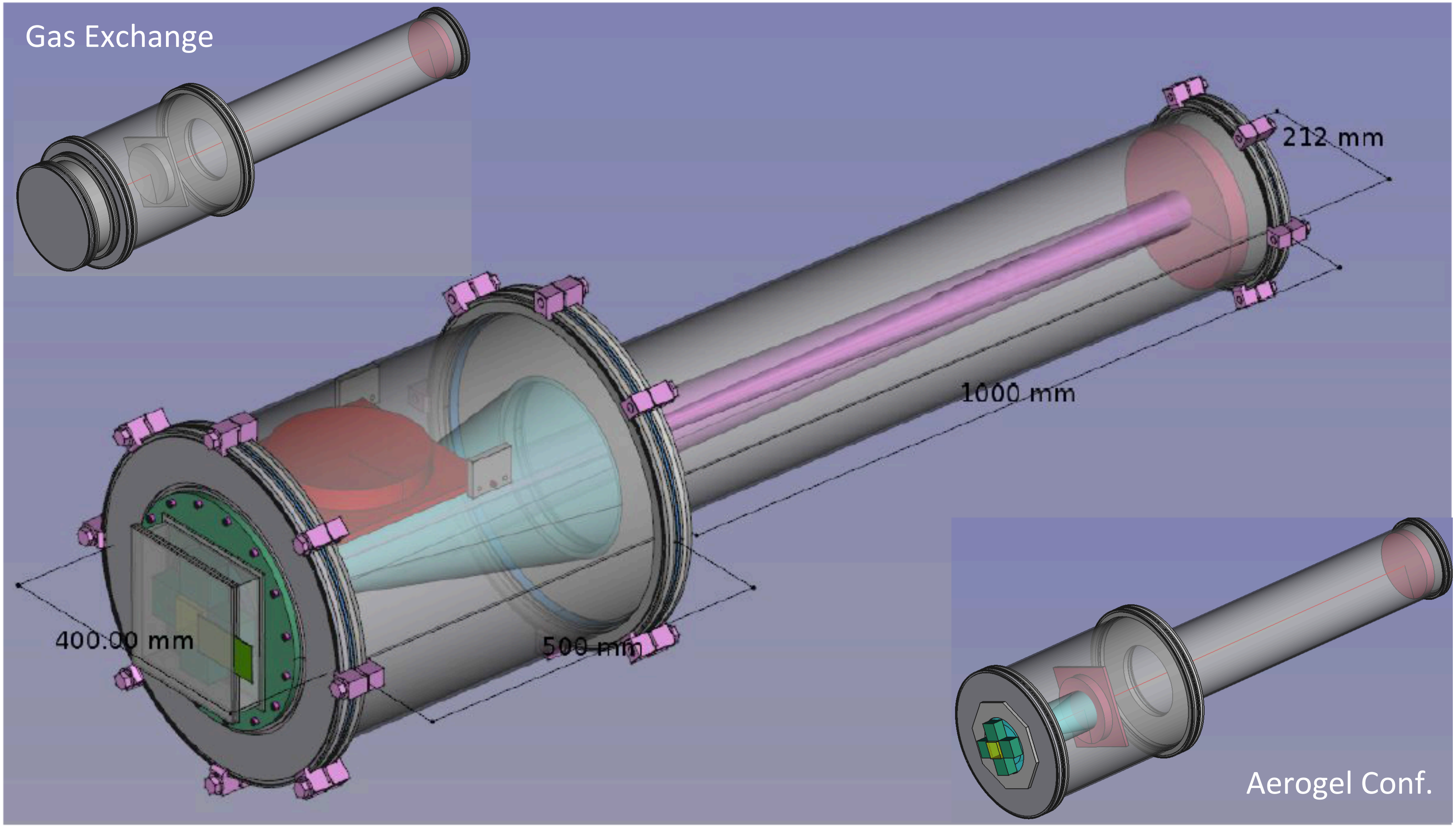
Optical ethernet (2.5 Gbps)

Small setups:
TCP/IP
Optical bridge / PC Desktop

Full experiment:
SSP protocol
SSP board / VSX crate

Next:
Ethernet Switches

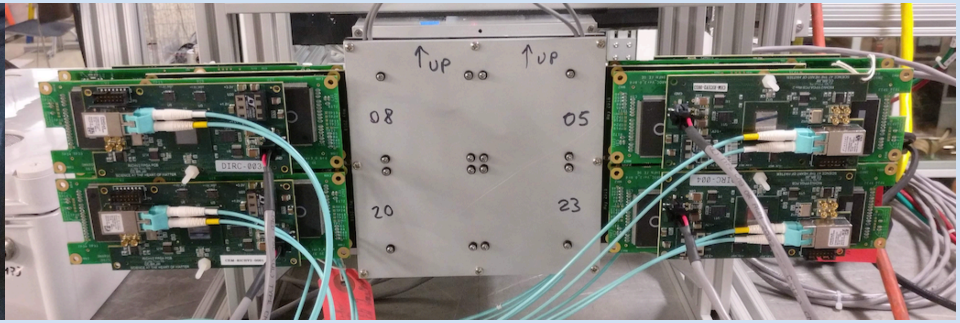
dRICH Prototype Design



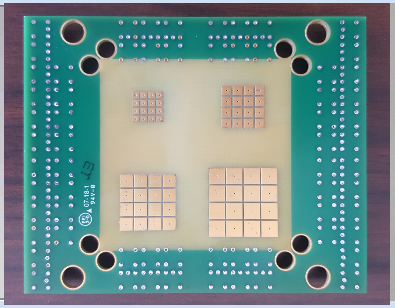
Commercial vacuum technology for safety and cost effectiveness

dRICH Prototype Test

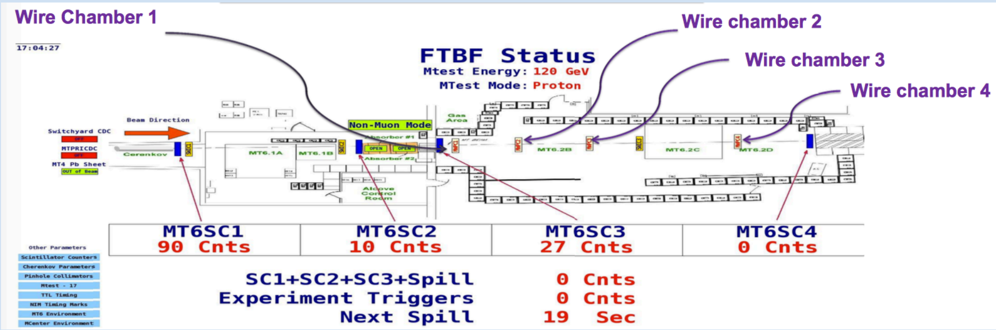
Readout box:
Independent element for flexibility: supports various detectors, cooling, UV filters….

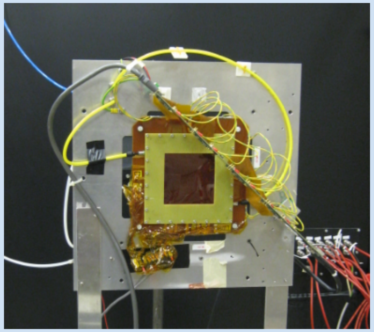



Sensors:
B-field tolerant
MCP-PMTs (LAPPs)
SiPMs
(MA-PMTs)

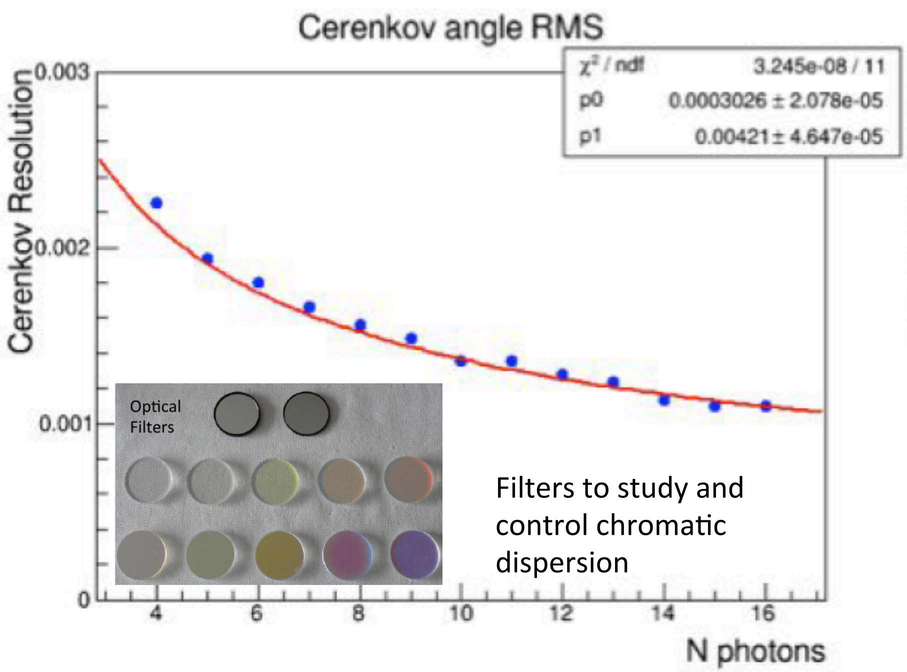

Ancillary Systems:



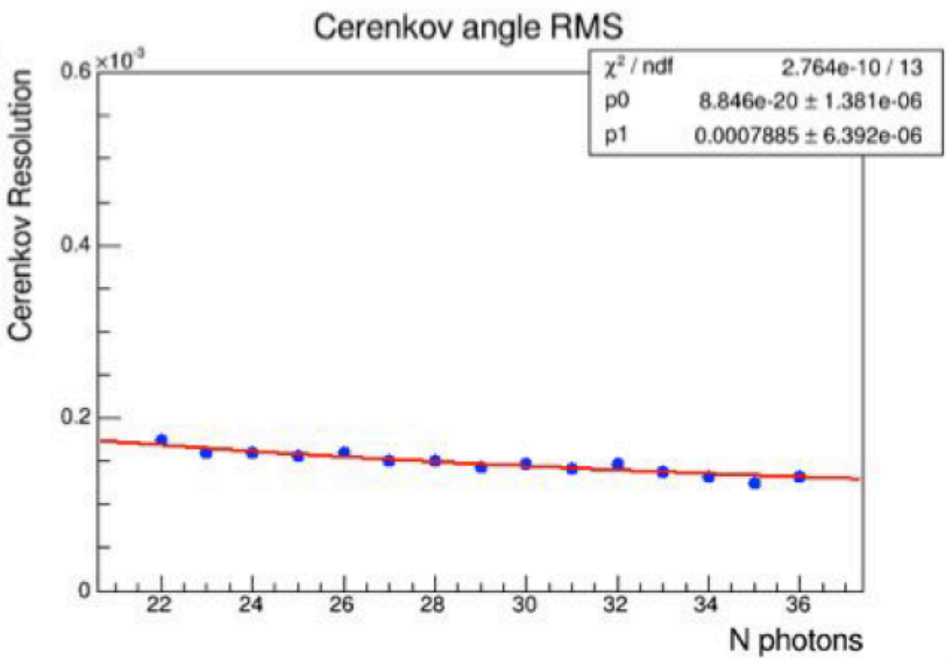


Gas Cherenkov for tagging	(FTBF beam line)
MWPC chambers for tracking	(FTBF beam line)
GEM chambers for tracking	(in house)
Gas recirculating circuit	(optional)

dRICH Prototype Performance



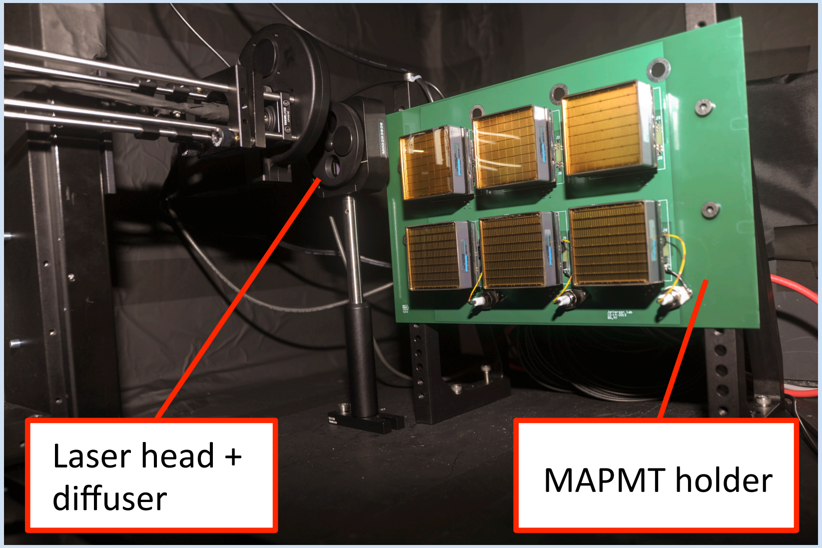
Filters to study and control chromatic dispersion



1 p.e. Error (mrad)	Aerogel	C_2F_6 Gas
Chromatic error	3.2 (3.2)	0.51
Emission	0.5	0.5
Pixel	2.5	0.42

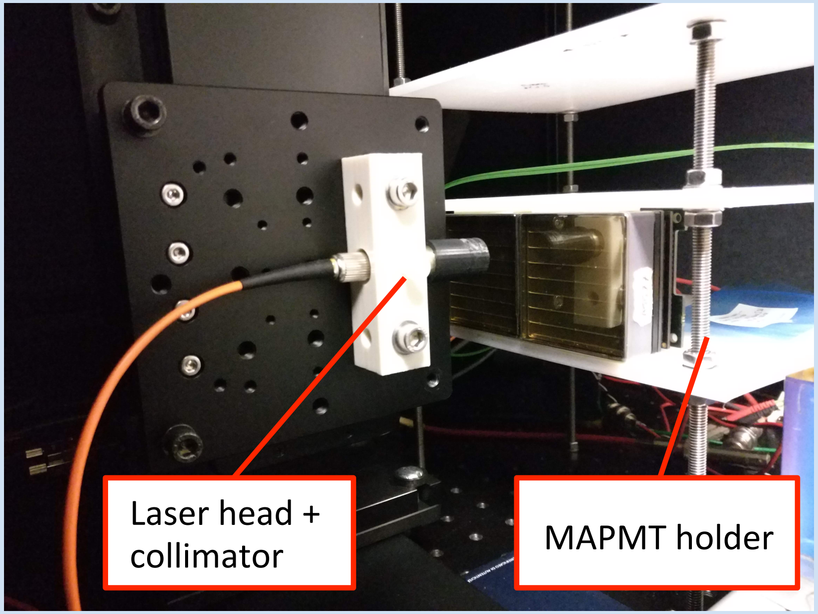
Pulsed Laser Test Benches

Detailed characterization
Sensors: gain, efficiency, cross-talk, radiation tolerance
Electronics: gain, cross-talk, thresholds, time resolution



JLab

632 nm picosecond pulsed laser light
Light diffuser to illuminate the whole MAPMT surface
Standardized system with CLAS12 electronics
H8500 6x6 mm^2 pixel sensor so far



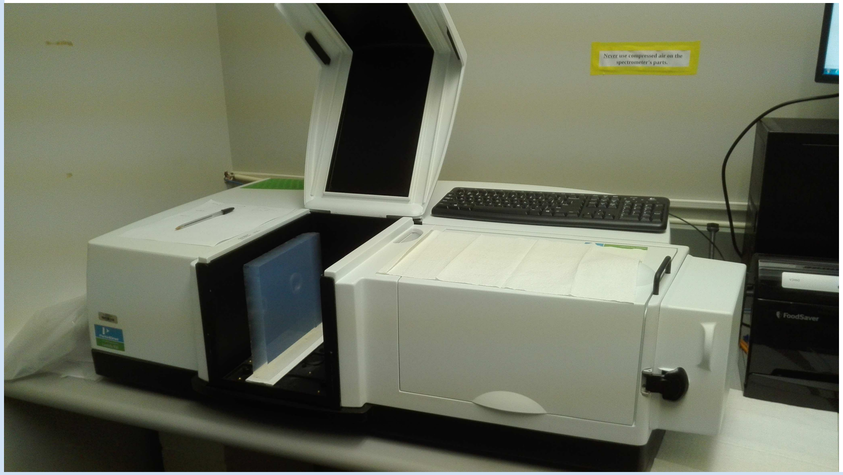
INFN

632 nm and 407 nm picosecond pulsed laser light
Light concentrator to scan the sensor surface
Flexible layout supporting various sensors and
Front-End electronics

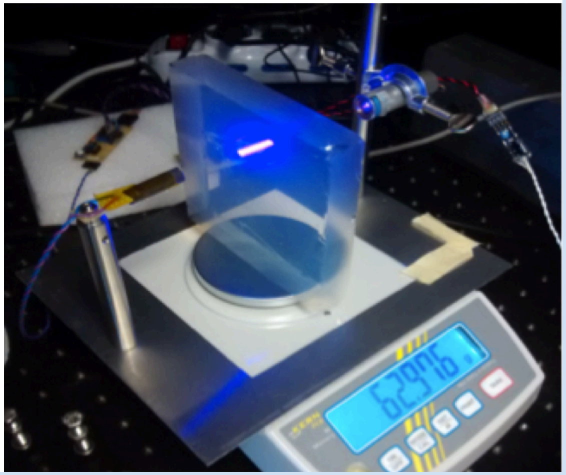
Aerogel Test Laboratory

Existing facility to study detailed aerogel optical properties
(refractive index, surface planarity, forward scattering)
safe handling and Interplay with gas radiator

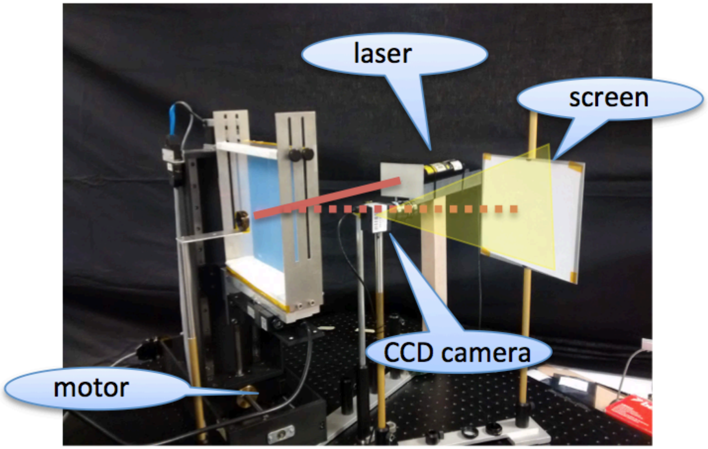
Spectrophotometer



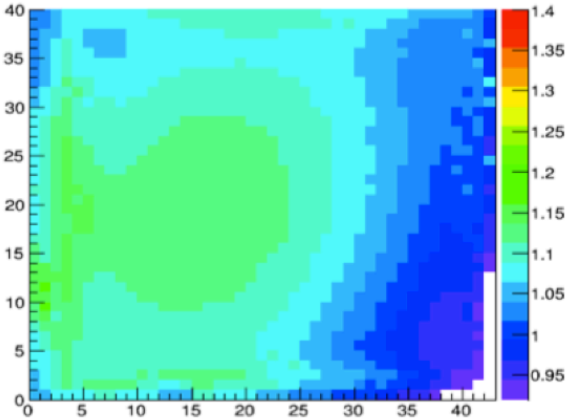
Characterization station

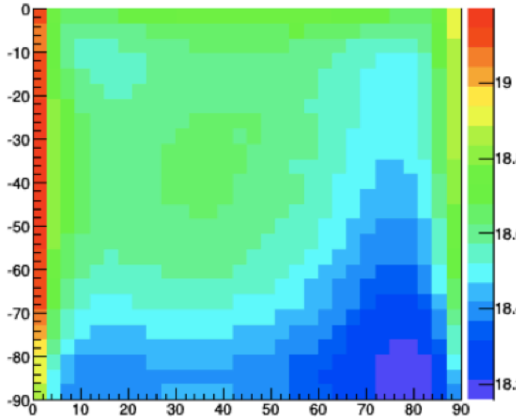


Controlled storage



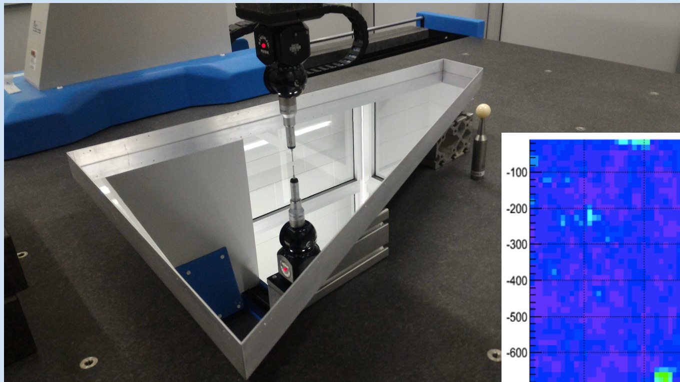
Surface map by laser setup vs touch machine



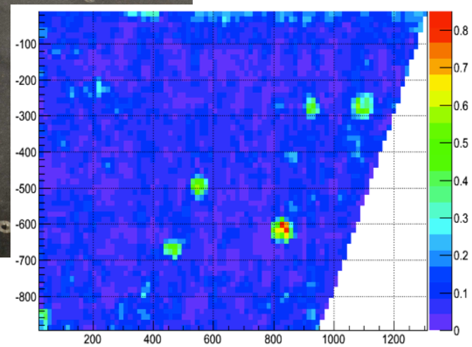


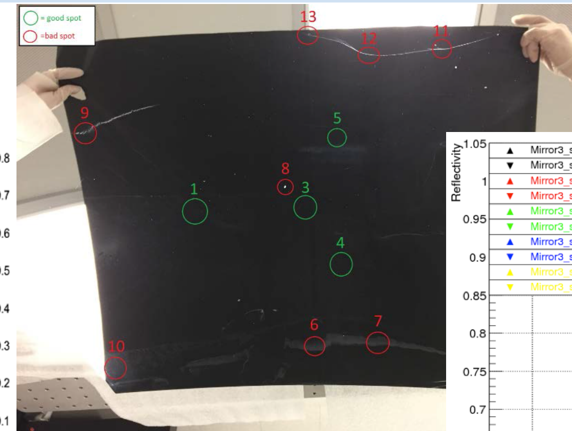
Mirror Test Laboratory

Existing facility to study detailed mirror optical properties (surface map, radius of curvature, reflectivity)

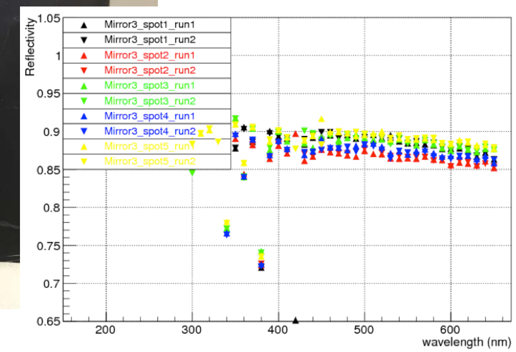


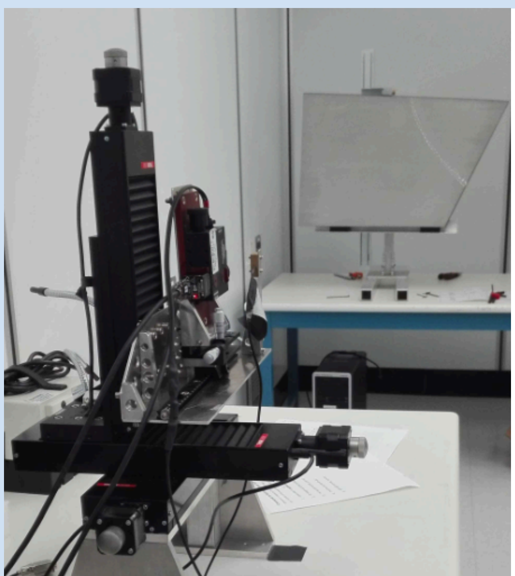
Planarity



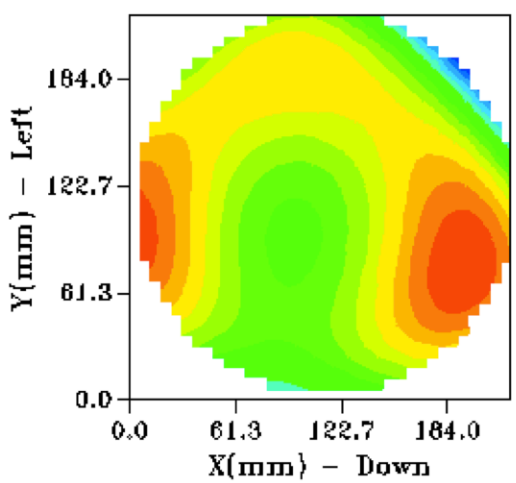


Reflectivity

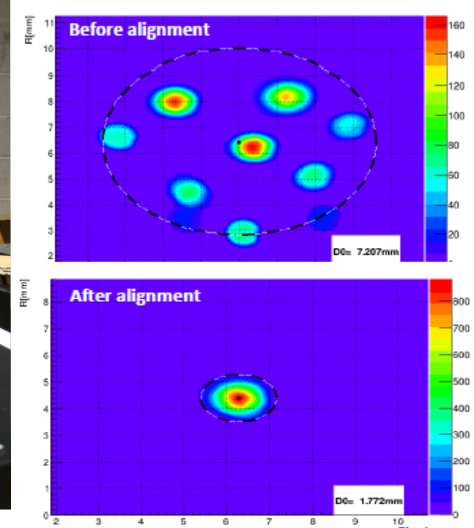




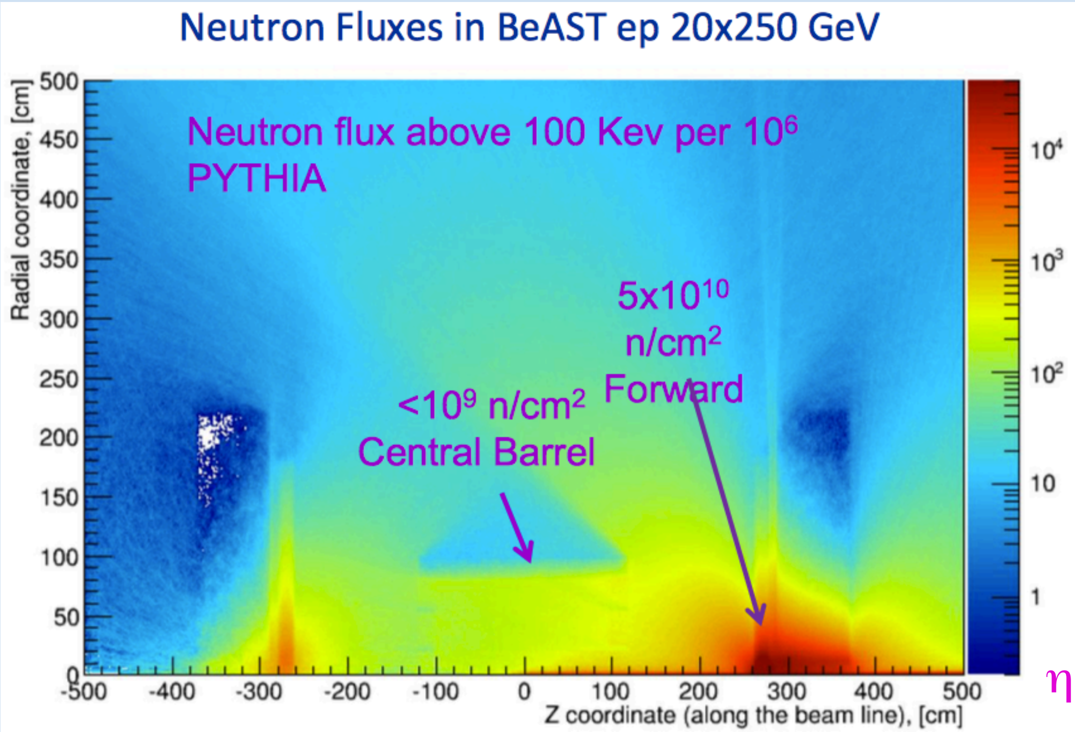
Shack-Hartmann: Aberrations



Point Image: Alignment

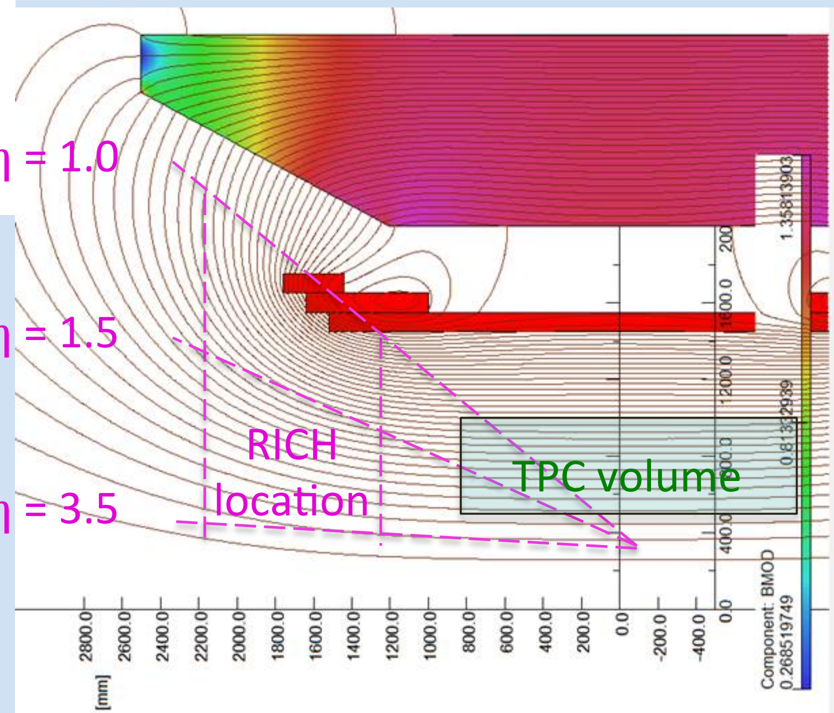


EIC Detector Environment



Neutron Fluence

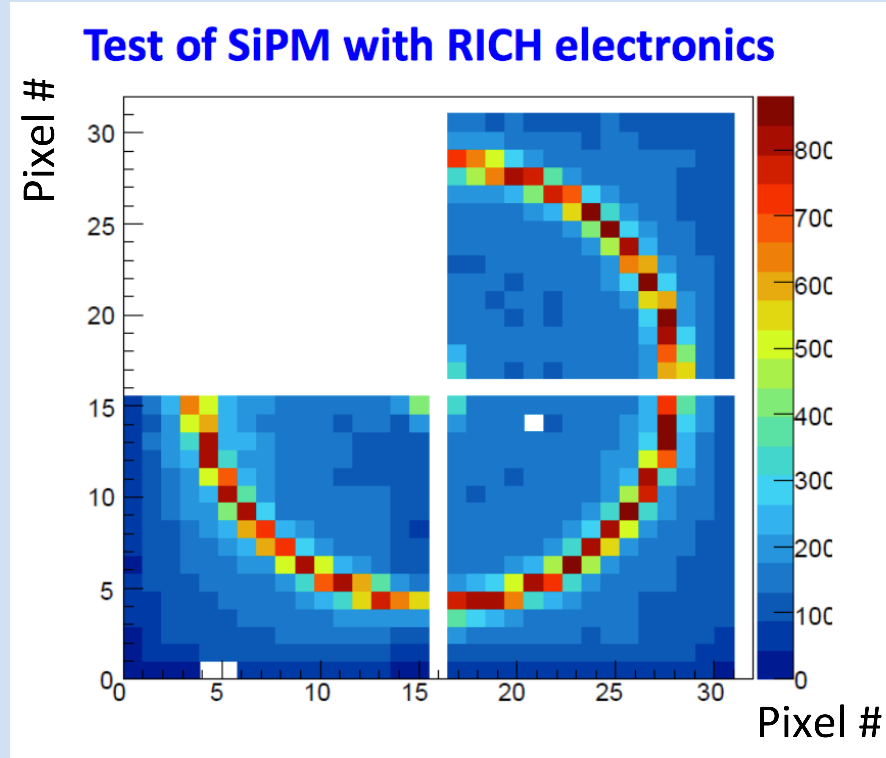
Under control outside the calo's

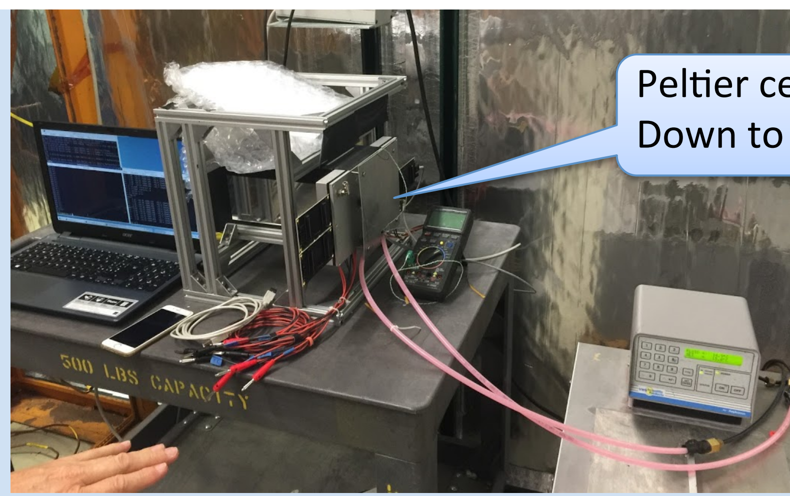


Magnetic Field

~ 1 T order of magnitude
Detector orientation to be tuned

SiPM Option

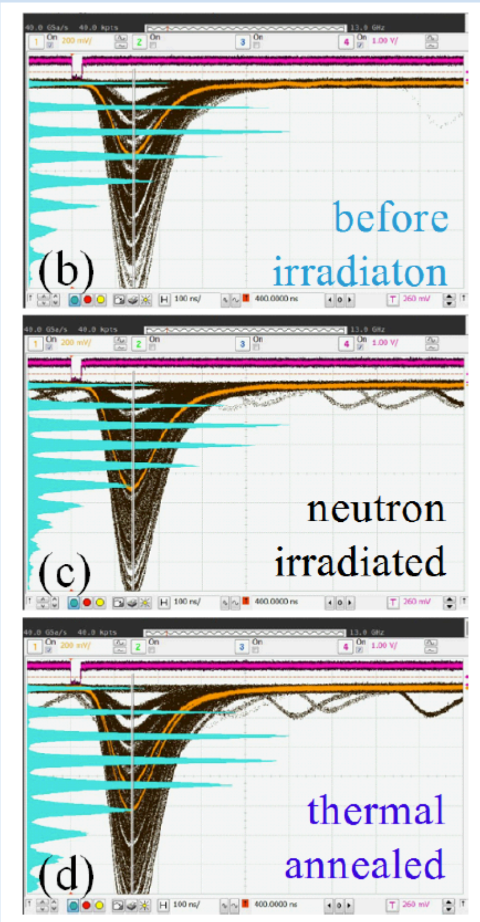




Peltier cell cooling
Down to -30° in N_2

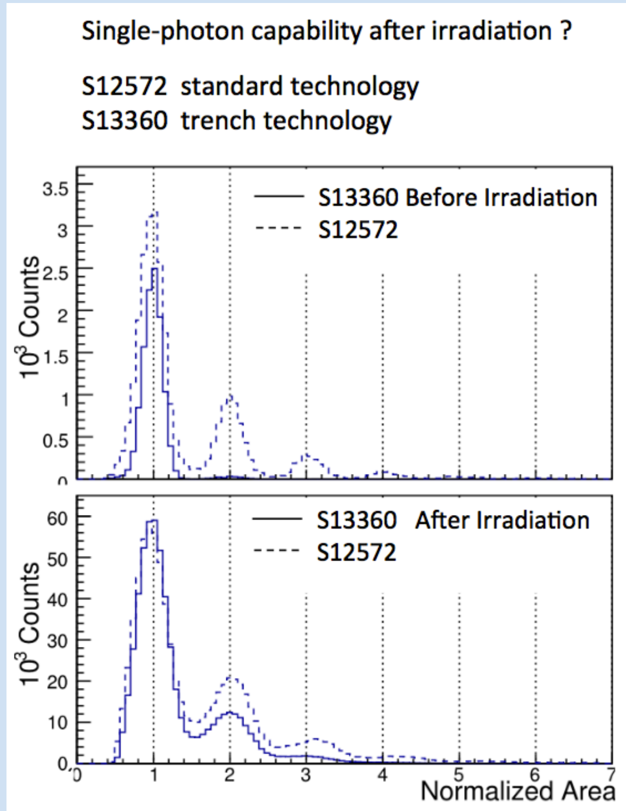
SiPM Radiation Tolerance

T. Tsang et al.
JINST 11 (2016) P12002



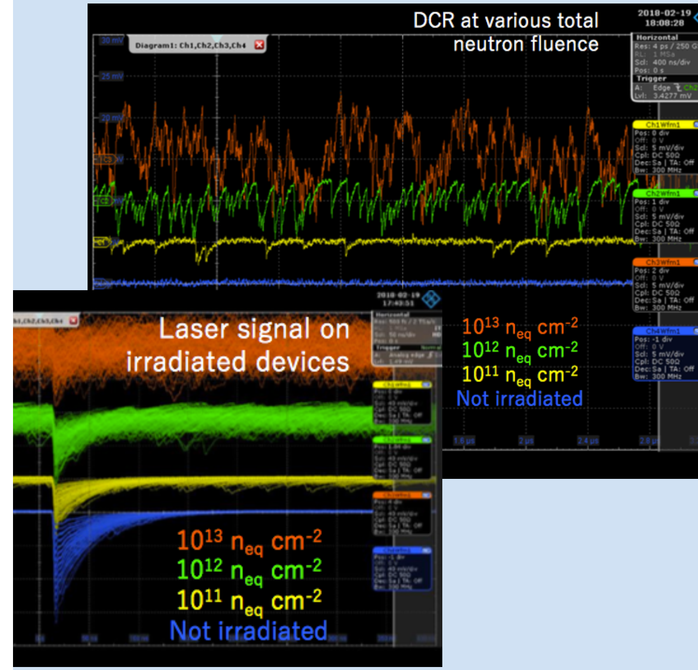
T= 84 K
10^9 n_{eq} cm^2
Annealing at 250 ^oC

I. Balossino et al.
NIMA 876 (2017) 89



T= 0 C
few 10^9 n_{eq} cm^2

Paolo Carniti
@ RICH 2018

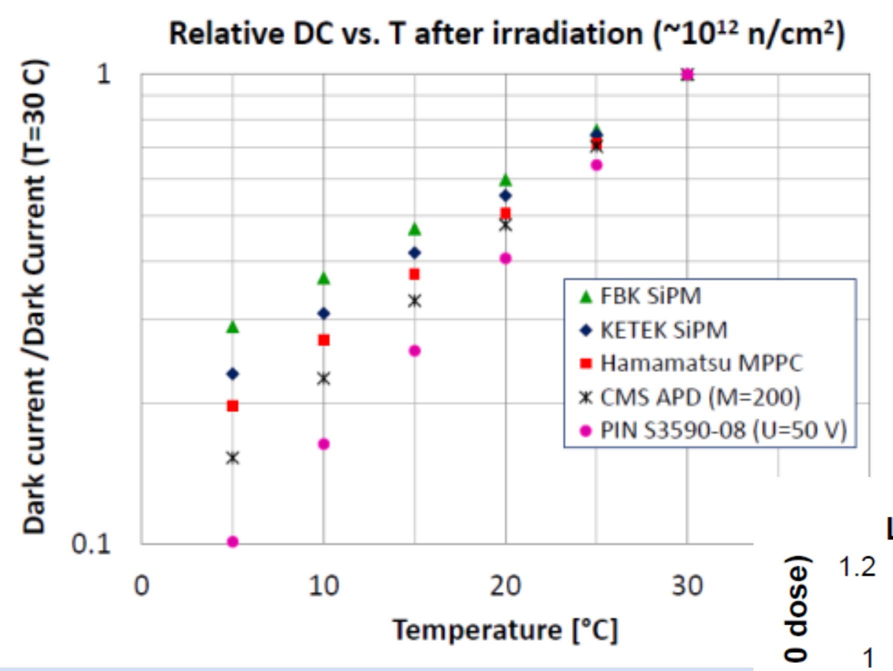


SiPM: Hamamatsu S13360-1350CS (50 μm cells)

Temperature: –30 °C

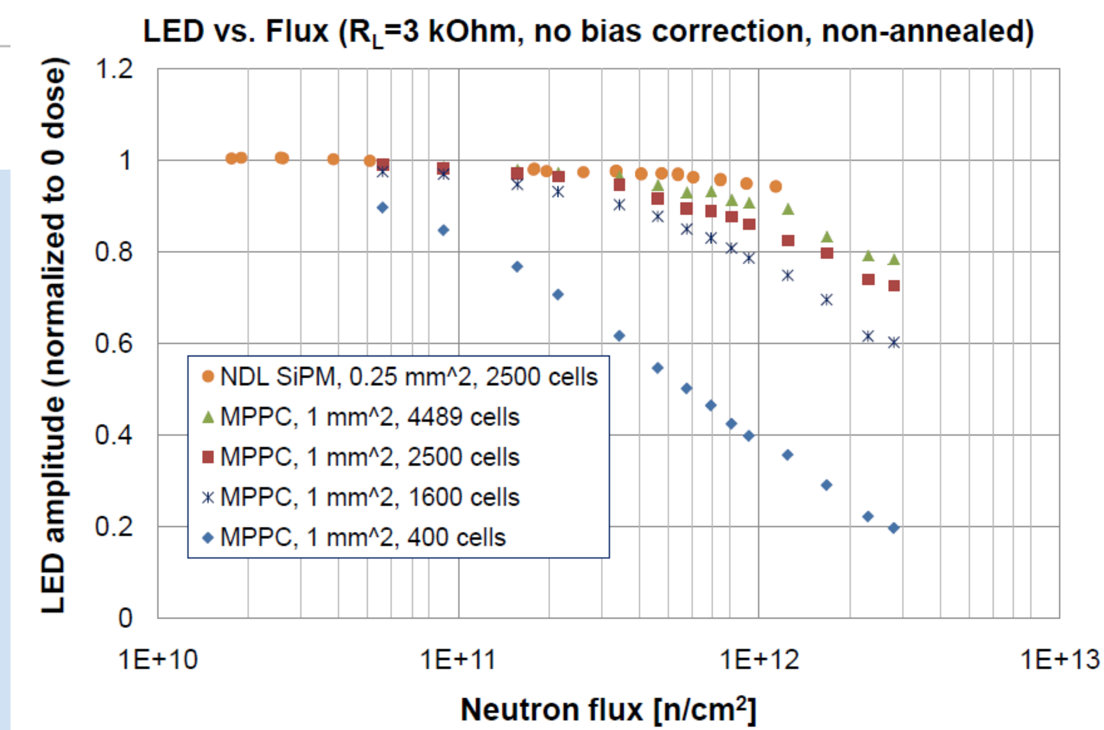
Bias: V_{BR} + 1.5 V

SiPM Radiation Tolerance



General trend is that SiPMs with high VB value have faster dark current reduction with the temperature

Yu. Musienko @ DIRC2019



SiPMs with high cell density and fast recovery time can operate up to $3*10^{12}$ neutrons/cm^2 (gain change is< 25%).

+ Low/uniform field
+ Entrance window
+ Packaging (Dt, cooling)
+ ……..

Activity

2020	Prototype Design and Simulation Basic Mechanics Components test
2021	Basic Prototype Ready (basic tracking, commercial mirrors, 1 radiator choice) Component tests Test-beam 1 MA-PMTs (SiPMs) Proton pencil beam
2022	Refined Prototype Ready (custom mirrors, various radiators, refined tracking, gas system) Component tests Test-beam 2 MCP-PMTs, SiPMs Hadron beam
2023	TDR

Activity

FY	20-1	20-2	20-3	20-4	21-1	21-2	21-3	21-4	22-1	22-2	22-3	22-4	23-1	23-2	23-3	23-4	Tot	INFN
Barion (Hardware)				40				40			20						100	
Post-doc (Simulations)				10				20				20				10	60	60
Travel (Test-beam)				4			8	10			10	8				10	56	40
Mechanics				5			5					5					15	15
Windows				8			8										16	
Gas system							5					10						
Electronics				2			2					2					6	6
Tracking							3					3					6	6
Mirrors							4					20					24	6
Aerogel							6					6					12	6
Gas							6					10					16	
MC-PMTs							40										40	
LAPPs												40					40	
SiPMs							10					10					20	20
Total personal				50				68				58				30	216	100
Total material				13				87				114				0	127	59

BACKUP

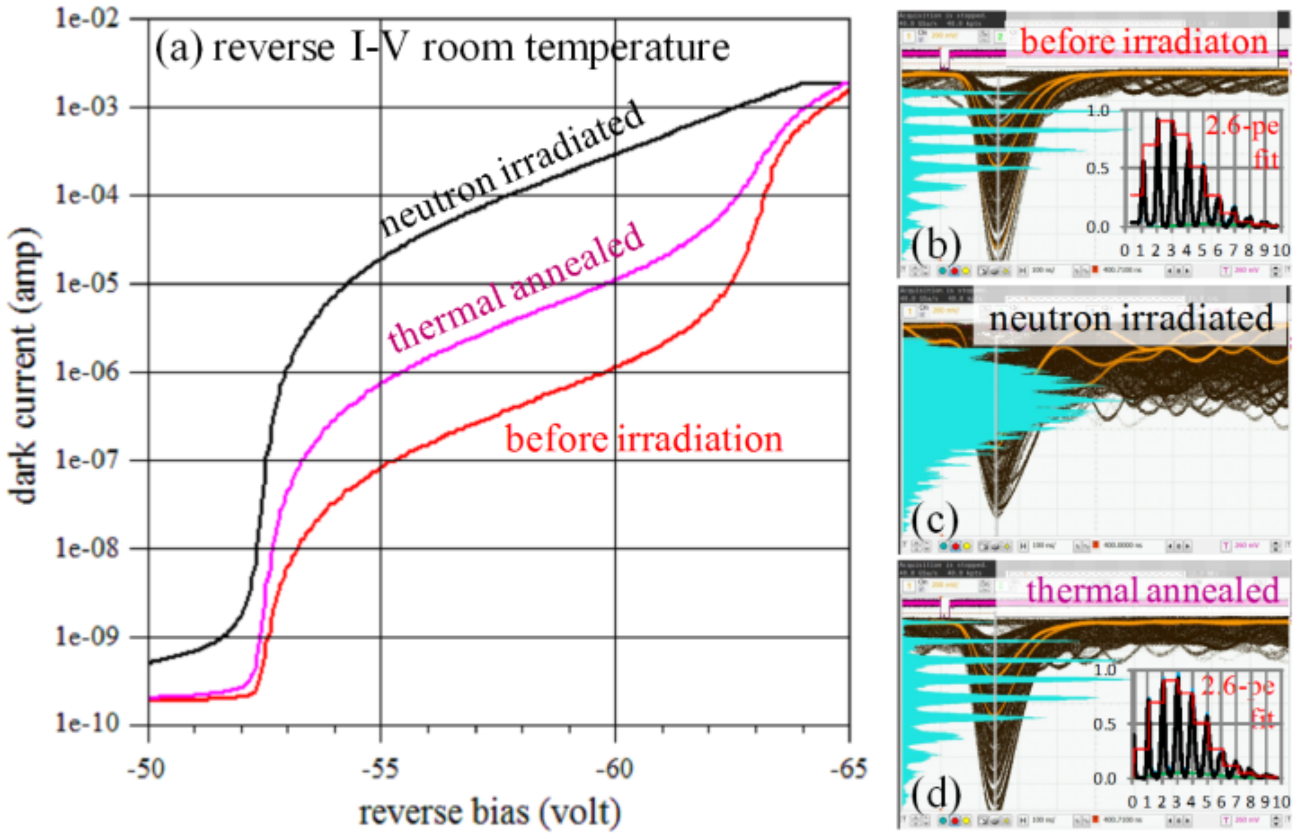
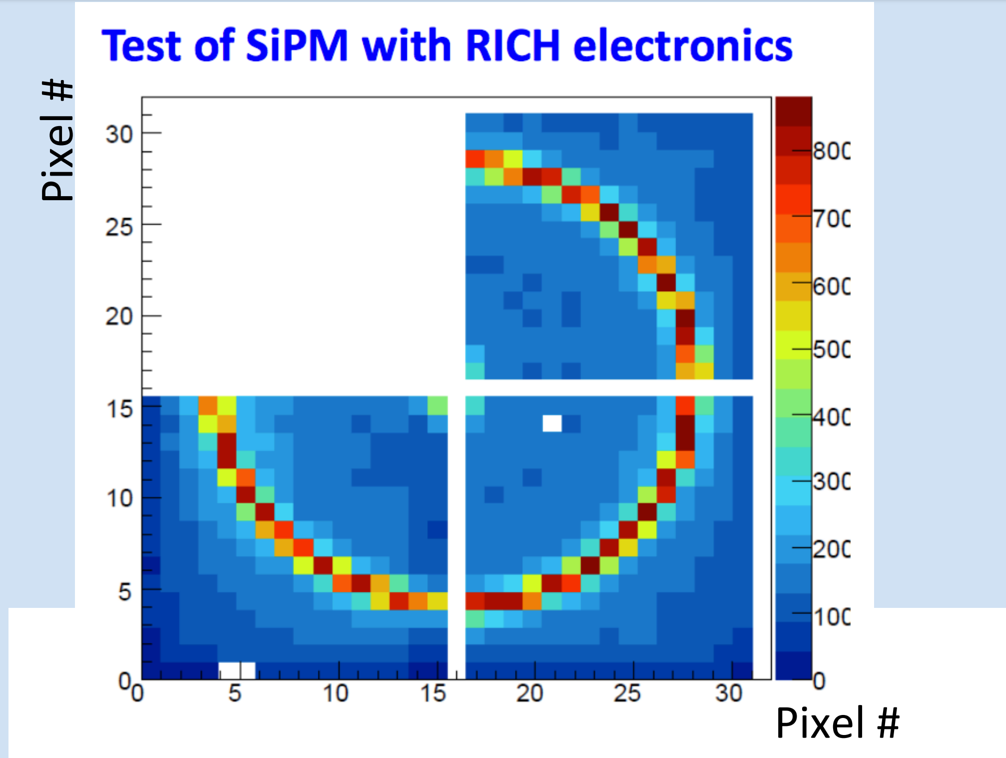
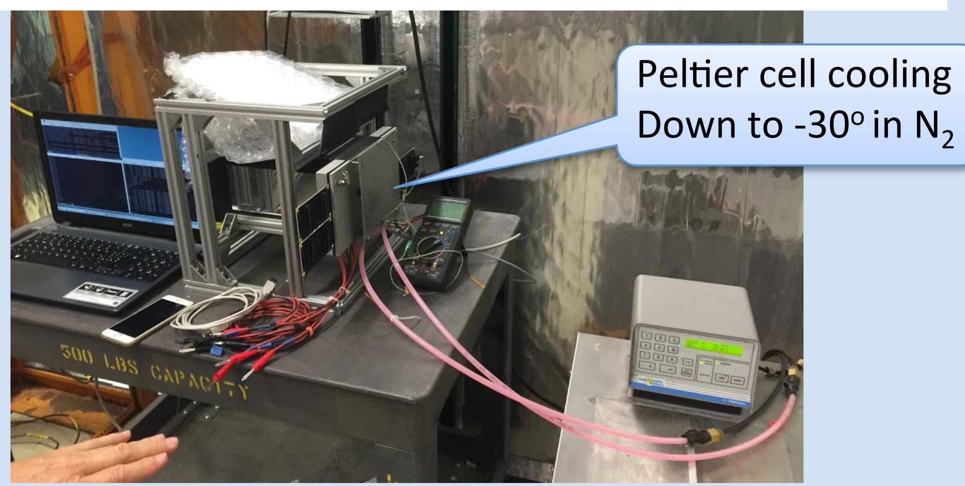


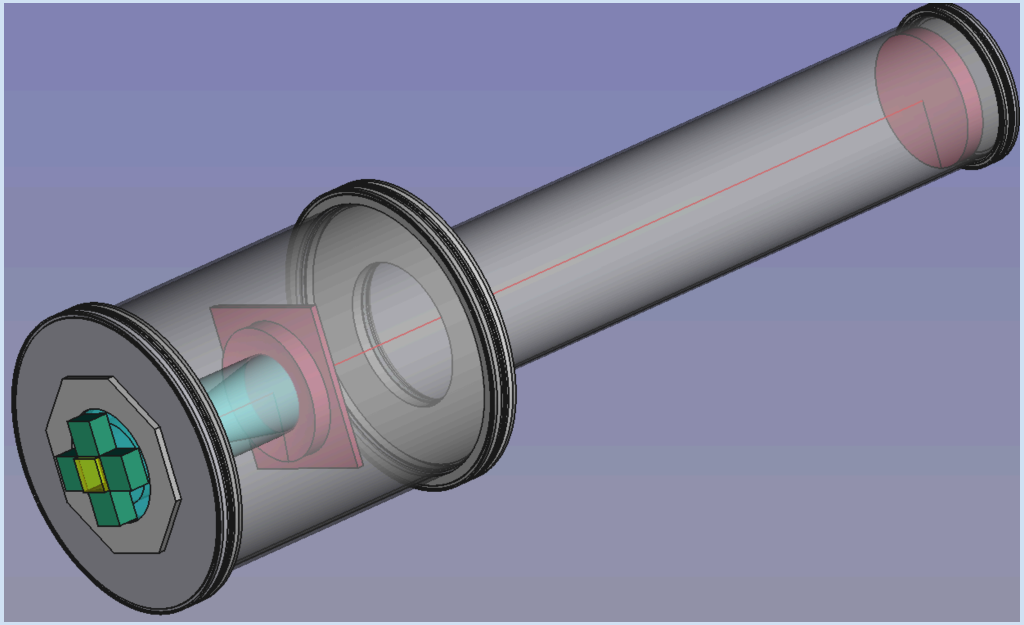
Figure 3. (a) Representative reverse I–V characteristic of SiPM at room temperature, and its cumulative collection of the photoelectron histogram sampled at the peak of the time-gated single photoelectron charge signal pulses at ~ 3 volt over-voltage (b) before irradiation, (c) after neutron irradiation to a dosage of 10^9 n/cm^2, and (d) followed by 250°C thermal annealing, respectively. Single photoelectron histograms are in cyan, insets in (b) & (d) are the corresponding Poisson fitted photon number resolving histograms to ~ 2.6 photoelectrons (red).

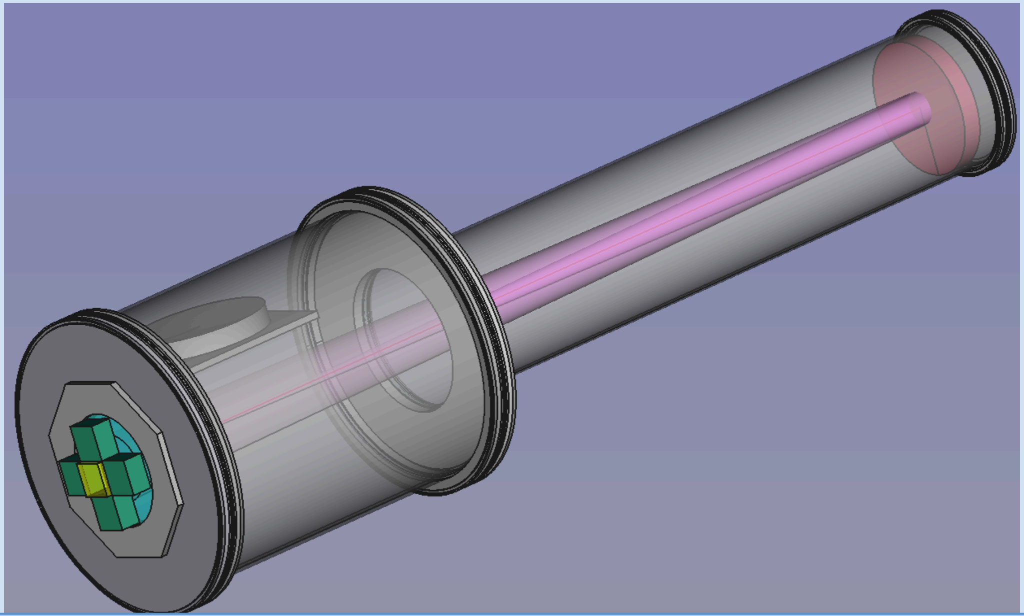
Application: SiPM Arrays





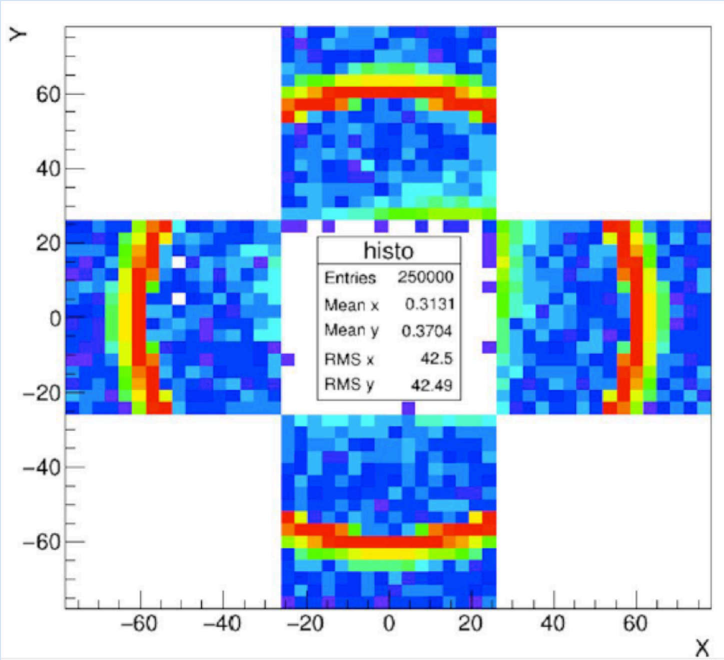
dRICH Prototype Design





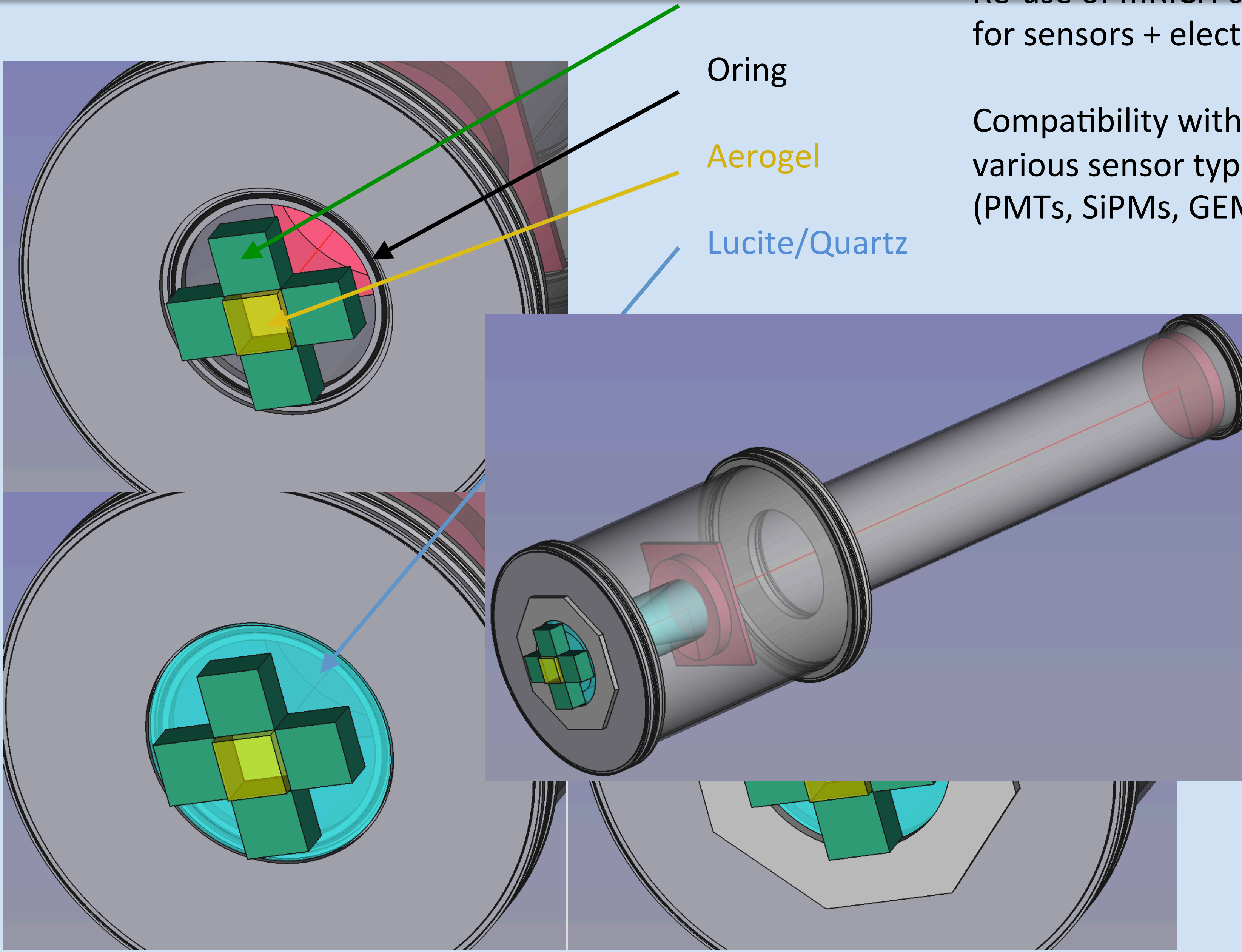
Two radiators with almost overlapping rings
(to optimize the active area)

Conf. 1: Aerogel ring



Conf. 2: Gas (freon) ring

dRICH Prototype Design



for sensors + electronics

Compatibility with various sensor types (PMTs, SiPMs, GEMs)

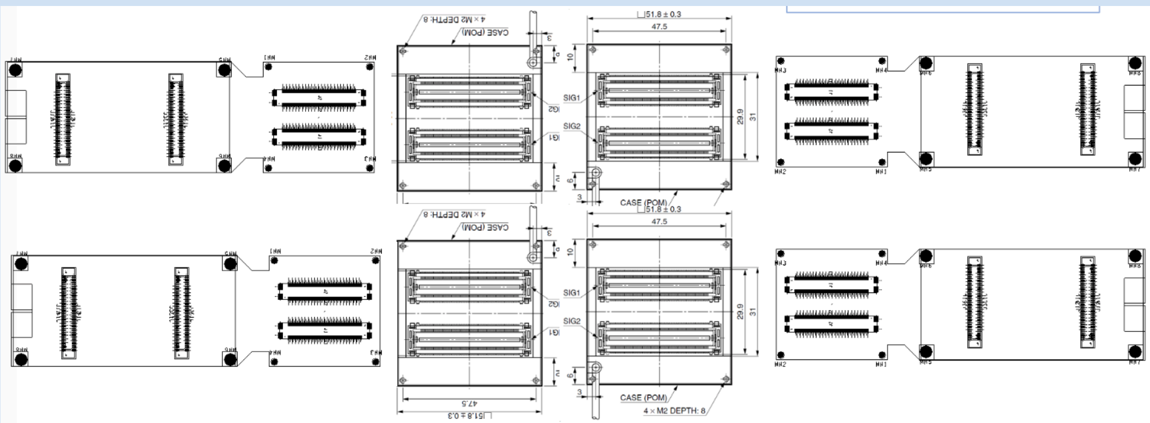
H13700 READOUT BOX

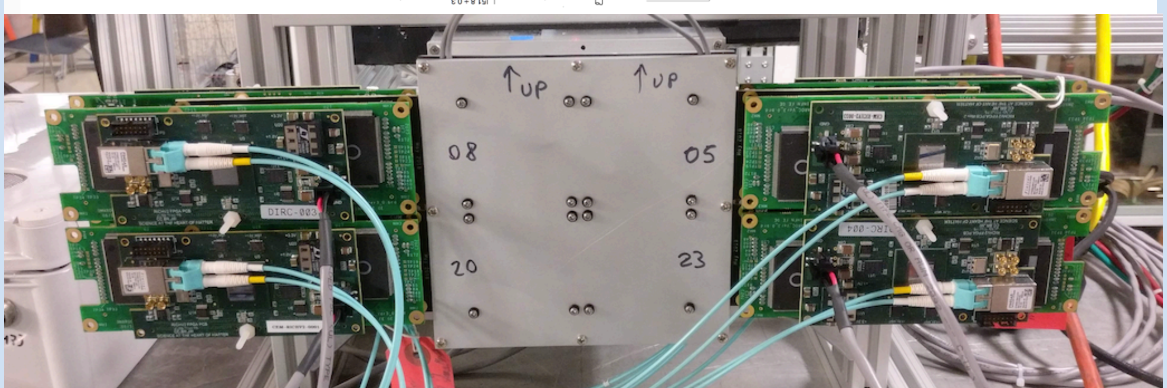
Derived from CLAS12 RICH readout:

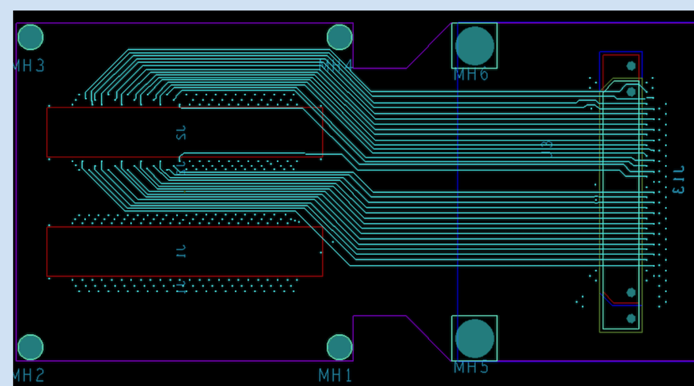
- 1024 channels
- MAROC 64 channel parallel digitalization
- FPGA generated 1 ns timestamp
- DAQ protocol based on VME/VSX SSP

Custom adapter boards

- Compact distribution
- Use of existing MAROC boards
- Light and gas tightness







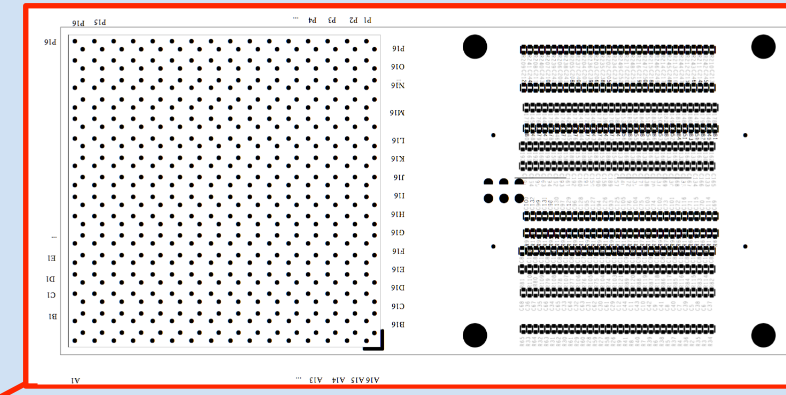
SIPM READOUT BOX

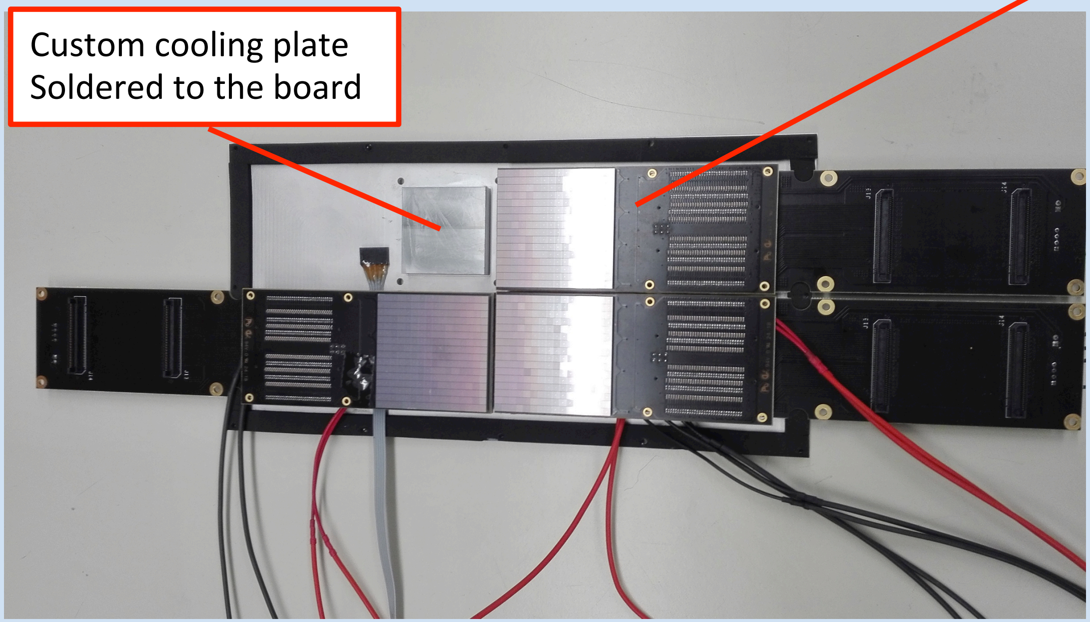
SiPM might offer a cheaper and more efficient solution, expecially in a longer time perspective for other sectors

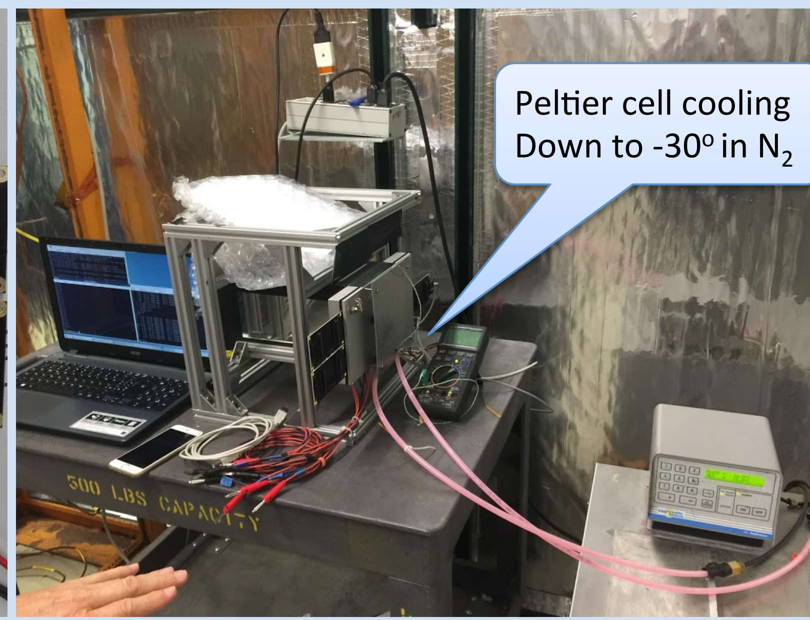
Robust device with low sensitivity to magnetic field
Fast improvement in dark rate and cost
but so far missing radiation hardness

Challenge: cooling integrated into the sensitive readout

Dedicated board for readout and cooling of a surface Mounting SiPM Matrix







26

Capitolo	Sezione	Anagrafica	Materiale	2019 (assegnato)	2020 (richiesto)
Consumo	CT	0.4 FTE (5)	Meccanica (flange / dark box)	3	4
	LNF	0.3 FTE (3)	Scheda lettura ottica	2	
			Mirrors and supports		4
	RM1	0.2 FTE (2)	Gas+aerogel	1.5	2
	FE	0.3 FTE (2)	SiPM + cooling	3	
			Adattamento elettronica		2

Goal: base prototype ready for a test-beam in 2020.

Notes:

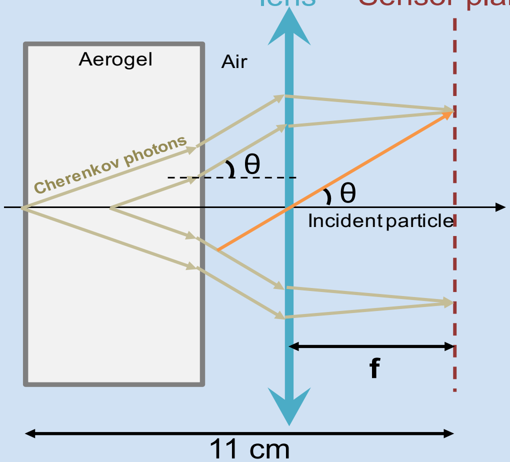
- bare mechanics elements costs quoted around 4 keu
  (does not account for mechanical adaptation for feed-throughs and windows)

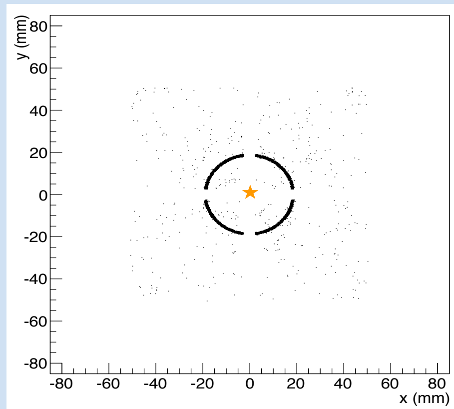
- Freon gas is expensive due to minimum delivery requirements

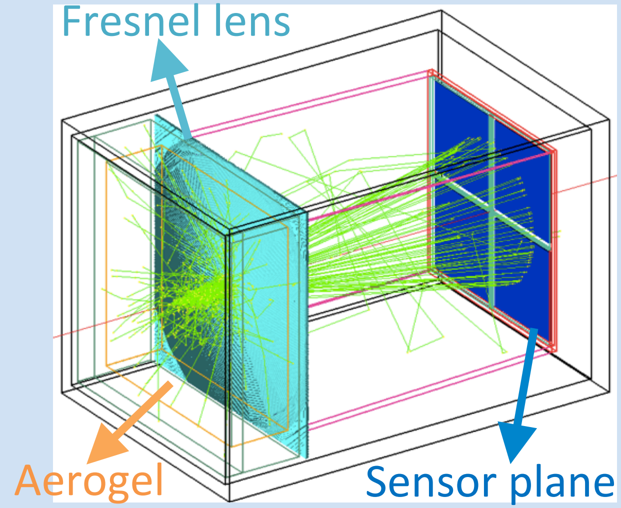
- Commercial mirrors are quoted around 1000 euro each
  The supports should allow alignment

Modular RICH @EIC

Compact and modular RICH indipendent elements



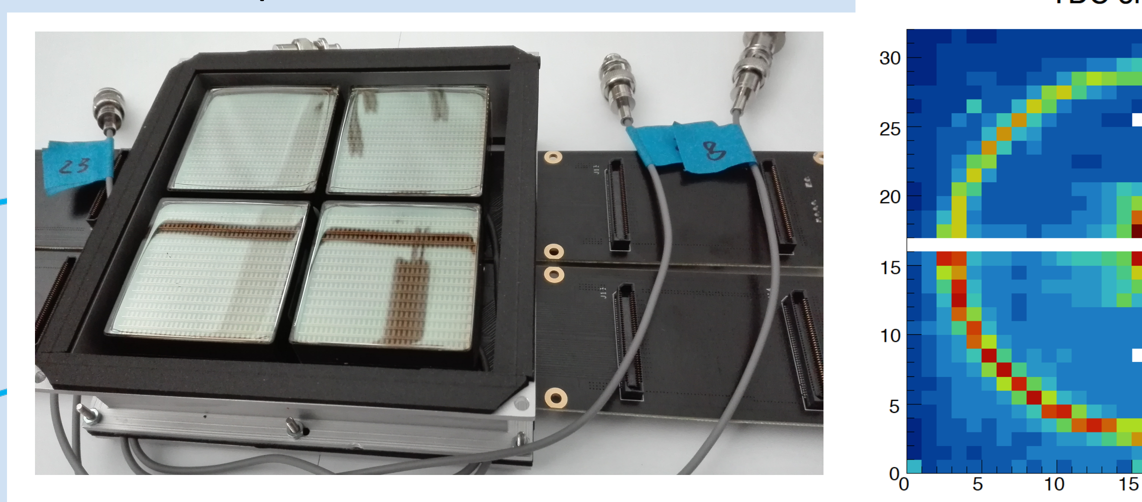


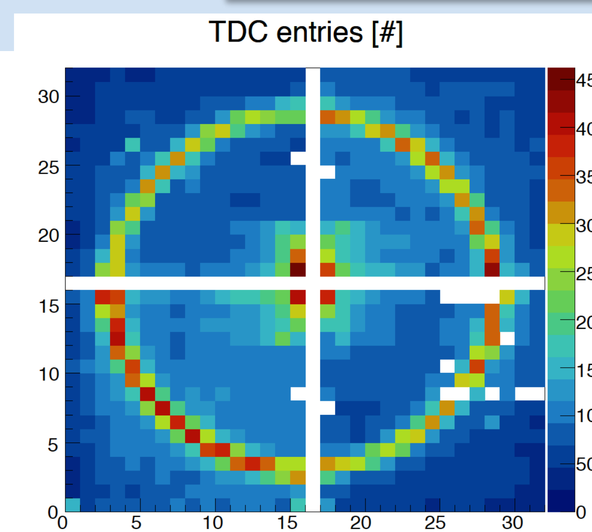


See Xiaochun He talk

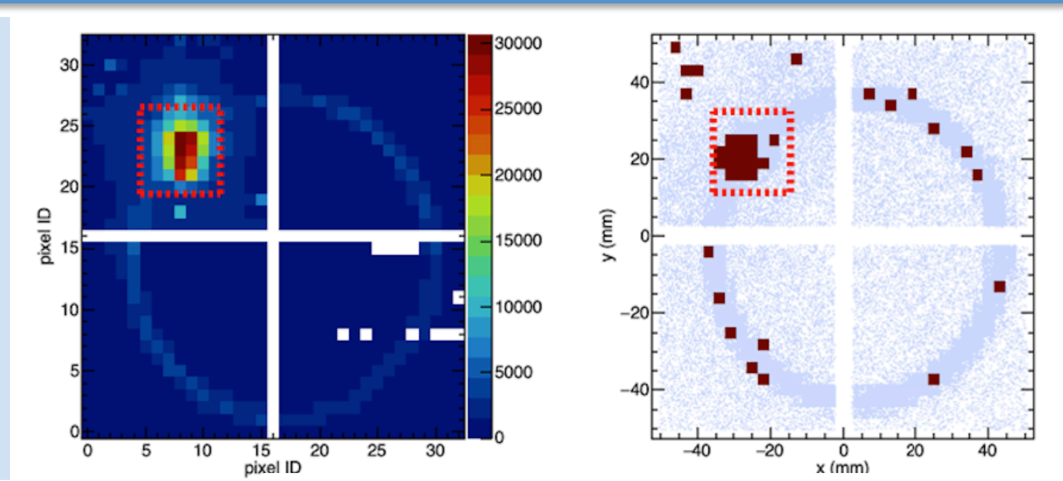
H13700 to reach the 3 mm spatial resolution

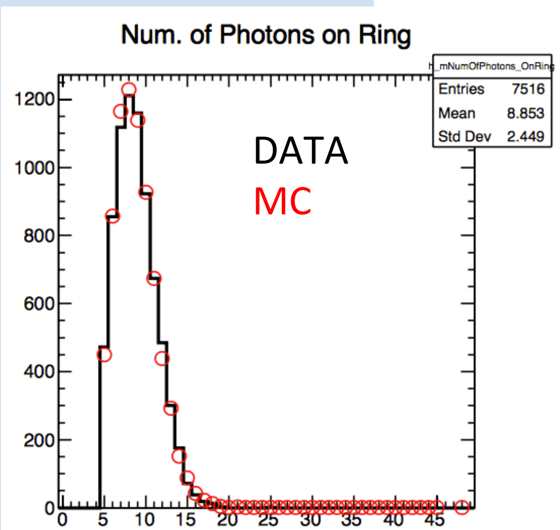
Two completed mRICH prototypes

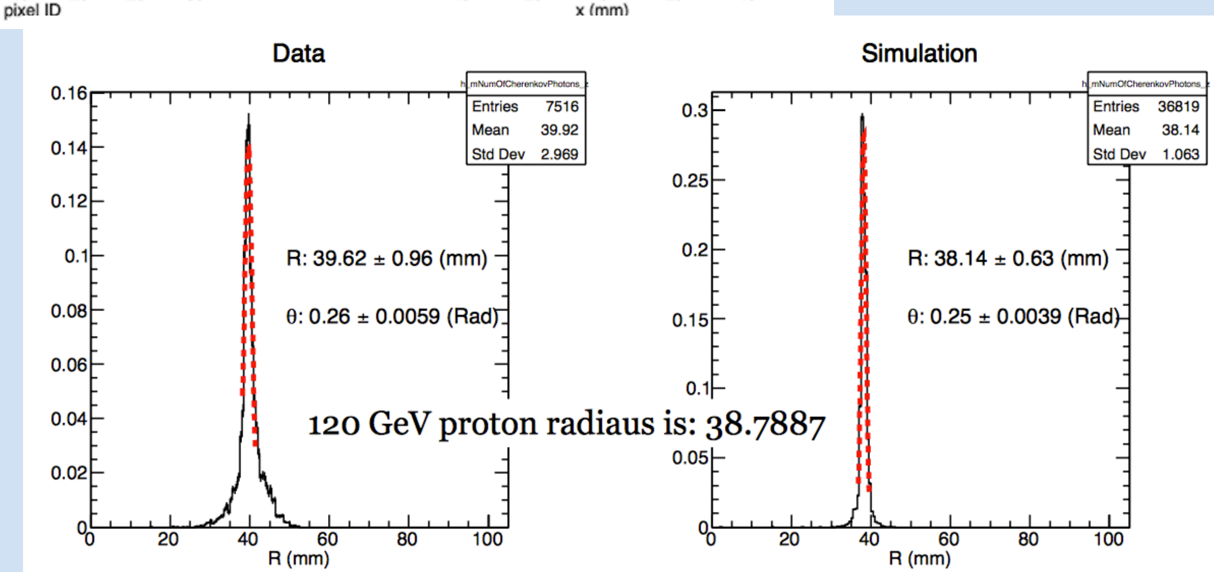




Modular RICH Analysis



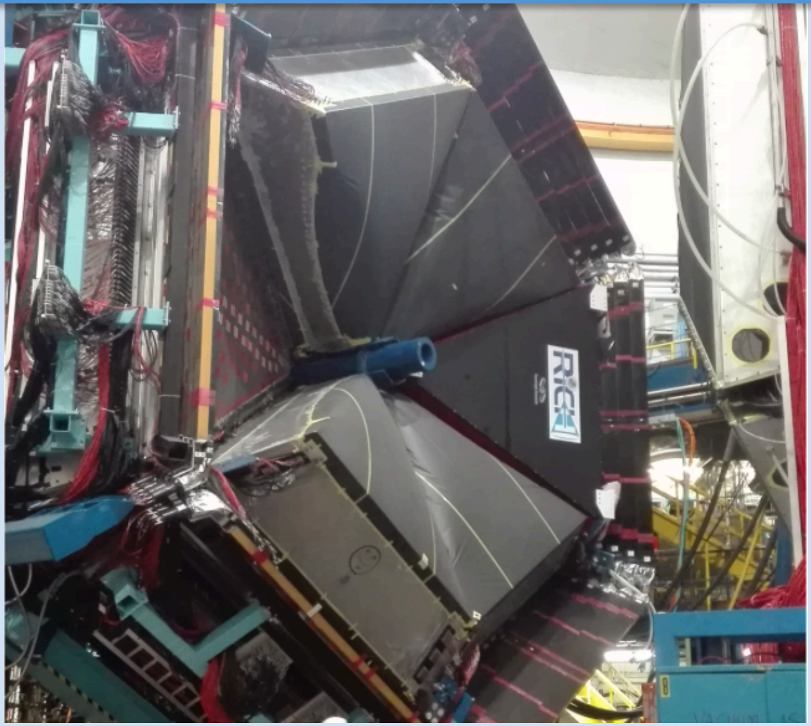




Milestone: Finalizzazione risultati test beam 2018 di modular RICH	30/06/19	90%

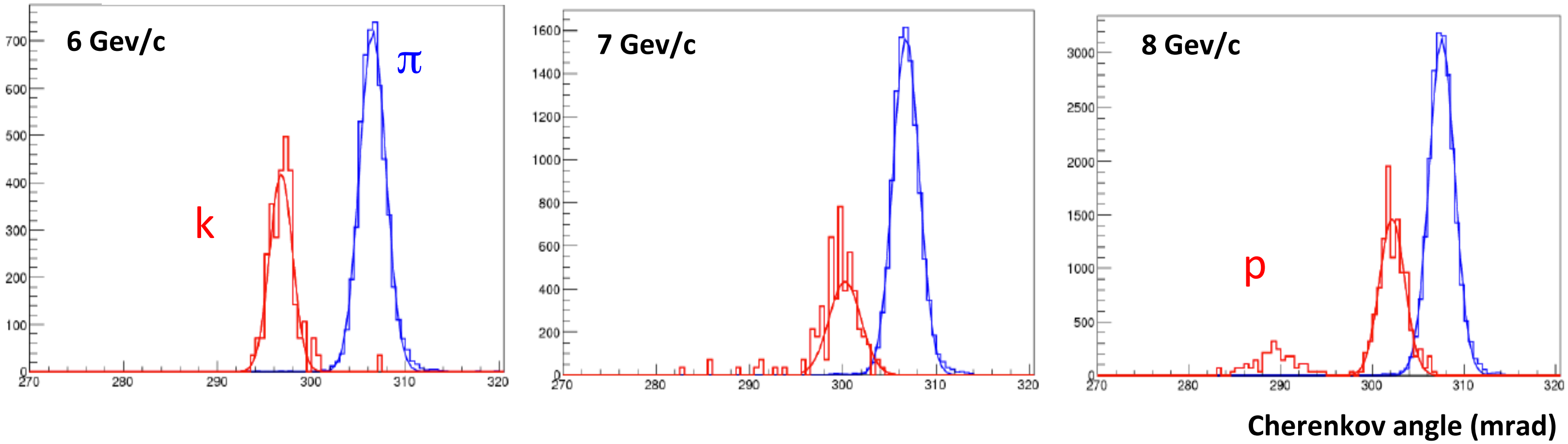
Mismatch between DATA and MC resolution due to: beam dispersion and/or refractive index uniformity in the aerogel stack

CLAS12 RICH

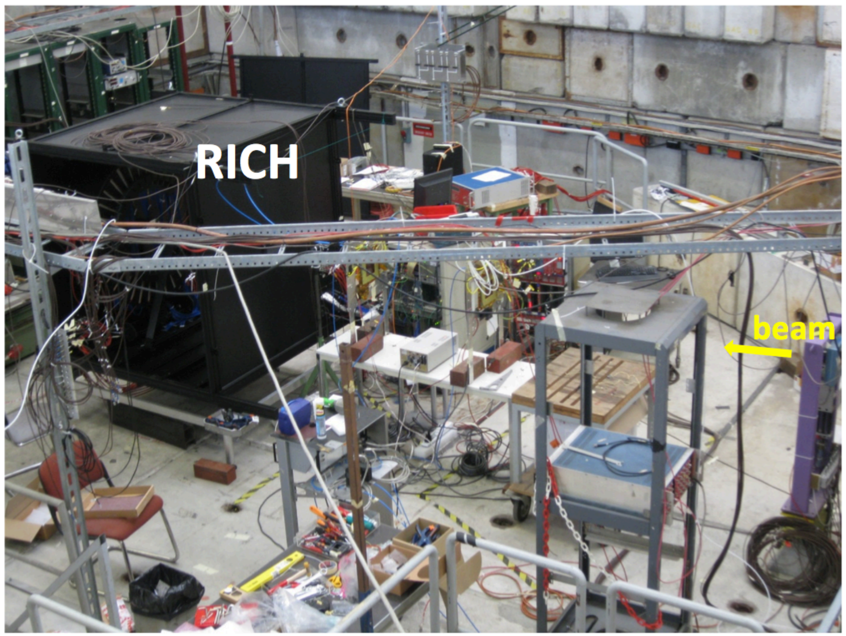


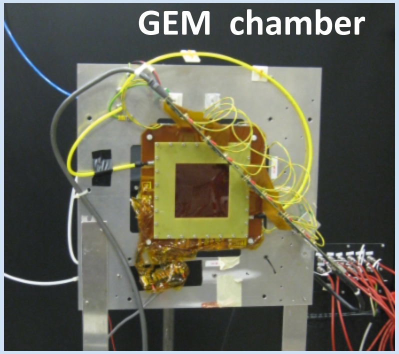
INSTITUTIONS
INFN (Italy) Bari, Ferrara, Genova, L.Frascati, Roma/ISS
Jefferson Lab (Newport News, USA)
Argonne National Lab (Argonne, USA)
Duquesne University (Pittsburgh, USA)
George Washington University (USA)
Glasgow University (Glasgow, UK)
Kyungpook National University, (Daegu, Korea)
University of Connecticut (Storrs, USA)
UTFSM (Valparaiso, Chile)

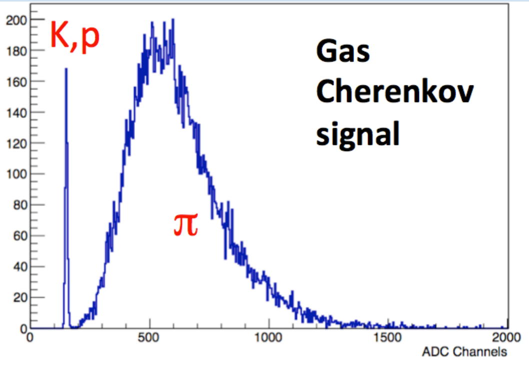
Goal kaon-pion separation up to 8 GeV/c (prototype results):

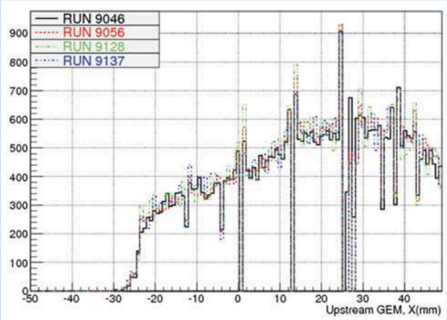


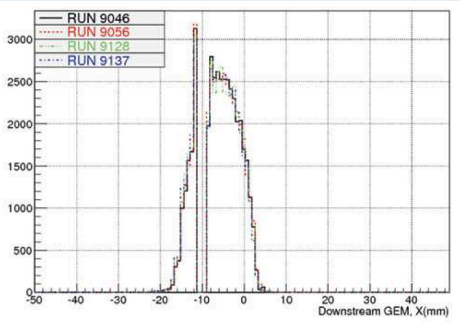
CALS12 RICH Prototype @ CERN-T9



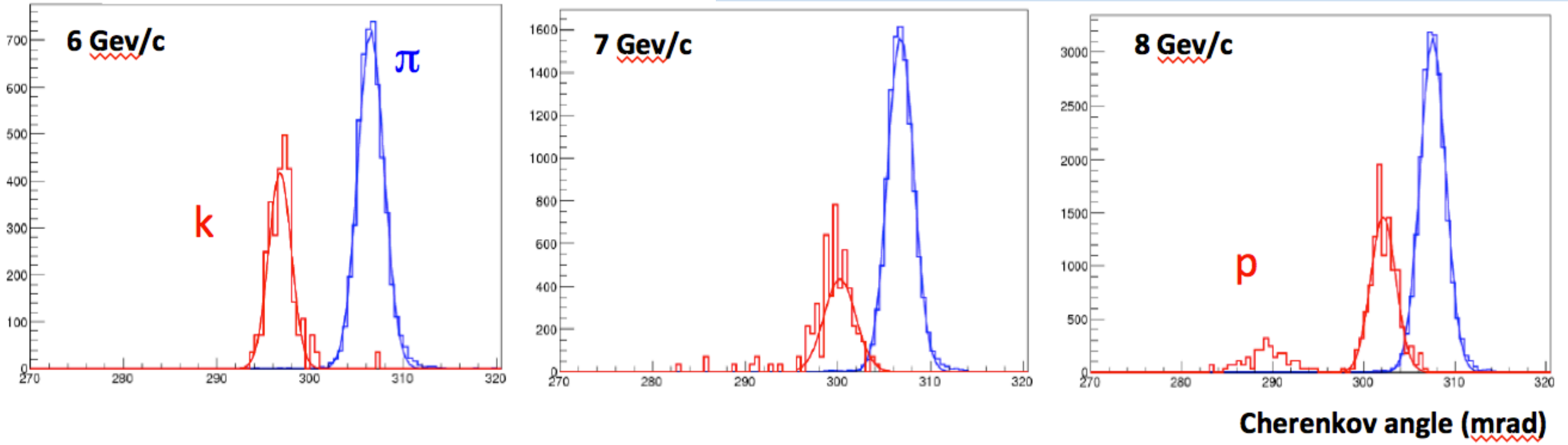








Goal kaon-pion separation up to 8 GeV/c



INFN Groups

INFN presence since the beginning (1991)
Increasing interest in 12 GeV era
Exp Users: ~40 FTEs, including ~15 students (PhD and post-doc)
Theo Support: ~ 30 scientists, including ~ 10 students

Spokespersonship: > 20% of approved 12 GeV experiments

Responsibility roles: Hardware, Analysis, Coordinating

P. Rossi	Deputy Associate Director
R. De Vita:	CLAS collaboration Chair (till 01/09) Hall-B Software Responsible
M. Battaglieri:	Hall-B Leader (since 16/09) Program Deputy for the Laboratory
M. Contalbrigo:	CLAS Coordinating Committee (till 01/09)
M. De Napoli:	HPS Executive Committee member
A. Celentano:	Chair of HPS Publications Committee

MoU: Renovated in September 2017

Management: Regular meetings
last: Ambasciata Italiana, December 4, 2019
A. Zoccoli, A. Masiero, E. Nappi, M. Taiuti

PAC members: INFN members since 1991
now: **A. Bacchetta** INFN-PV

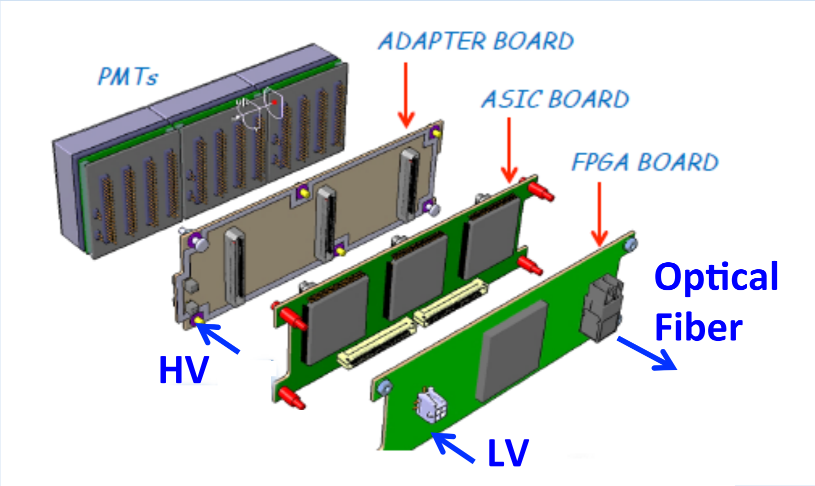
INFN Groups

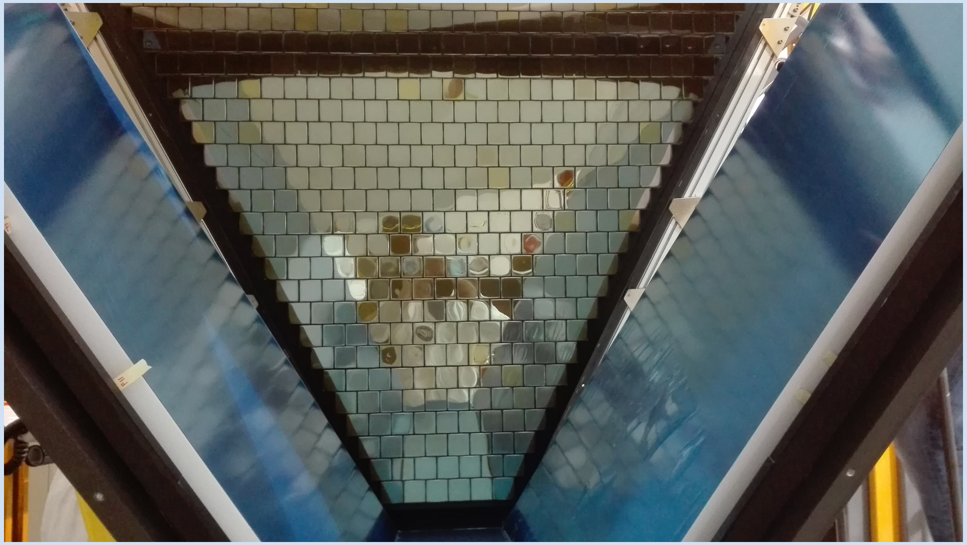
- Part of eRD14
- Joined

RICH Readout Electronics

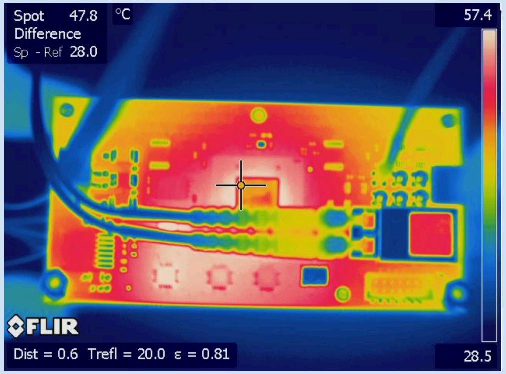
Readout Electronics

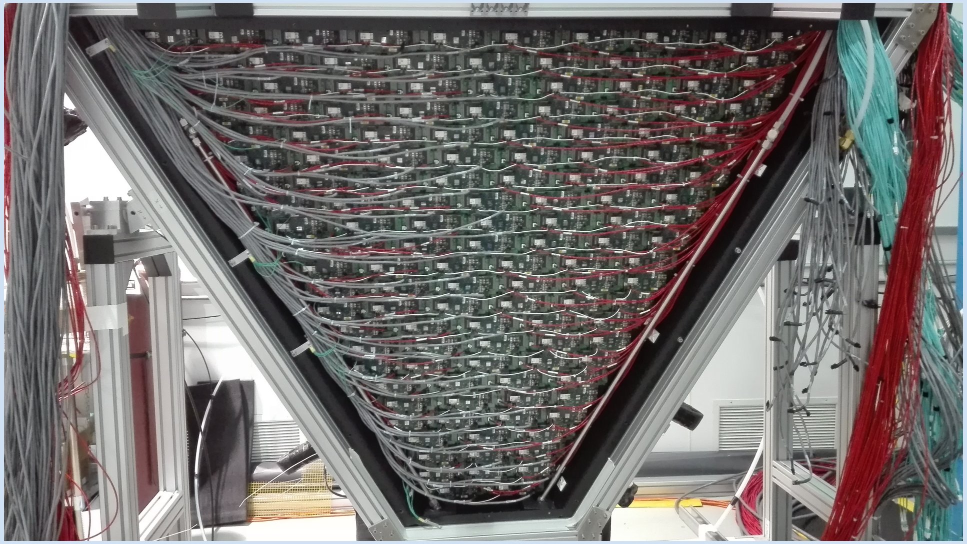
Compact (matches sensor area)
Modular Front-End (Mechanical adapter, ASIC, FPGA)
Scalable fiber optic DAQ (TCP/IP or SSP)
Tessellated (common HV, LV and optical fiber)





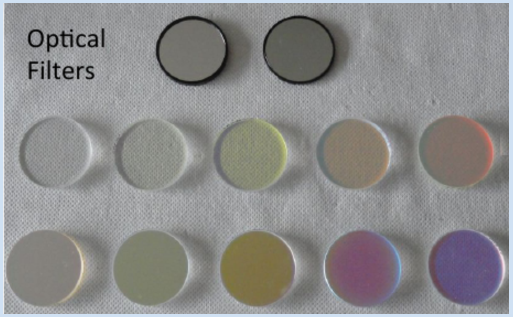
Tile power dissipation ~ 3.5 W

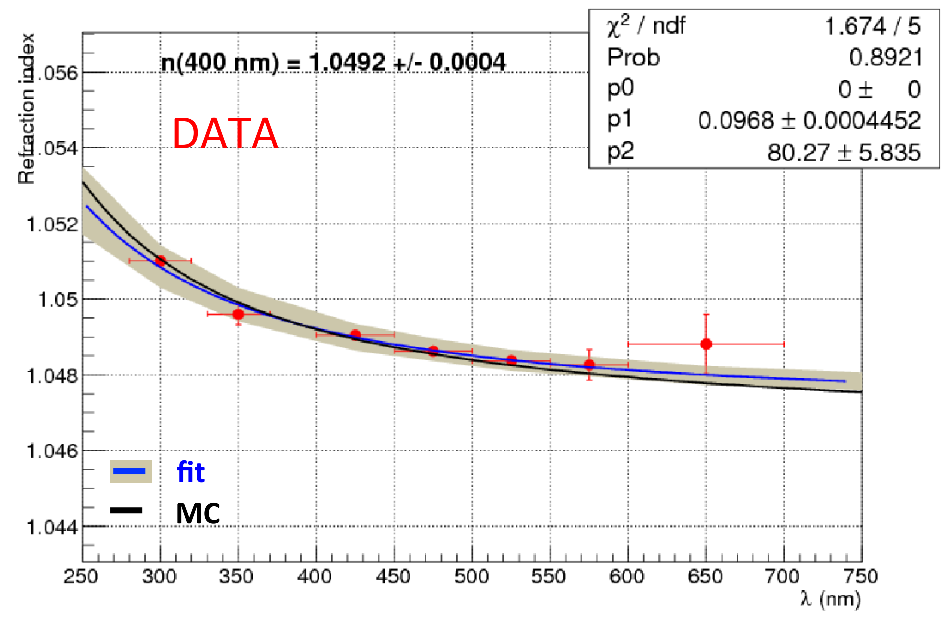




Aerogel Chromatic Dispersion by Filters

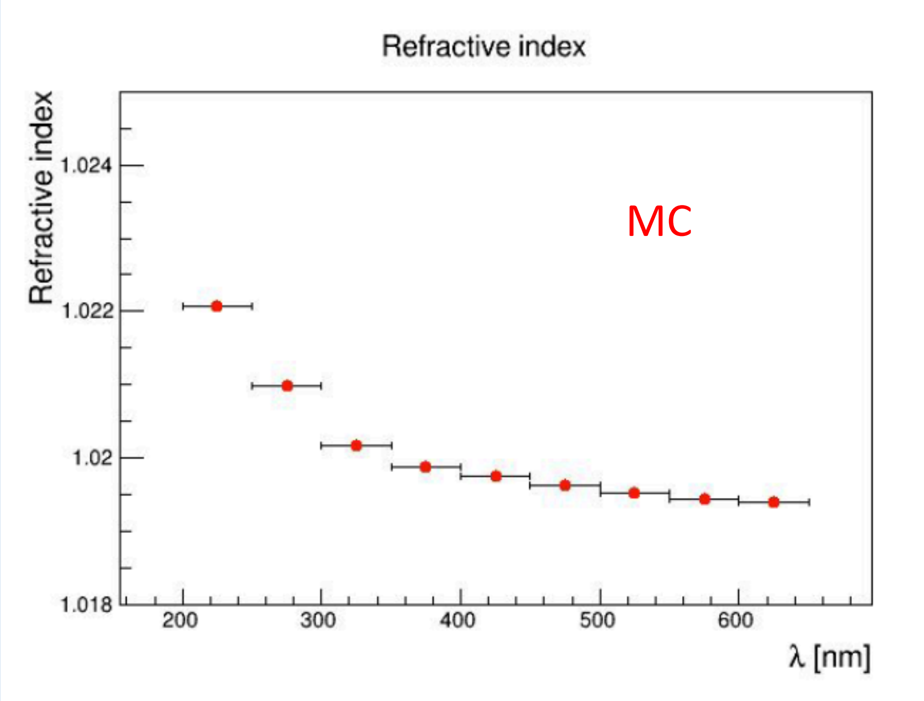
CLAS12 prototype





Expected value from density:
$n^2(400nm) = 1+0.438\rho$
$n(400nm) = 1.0492$

dRICH prototype

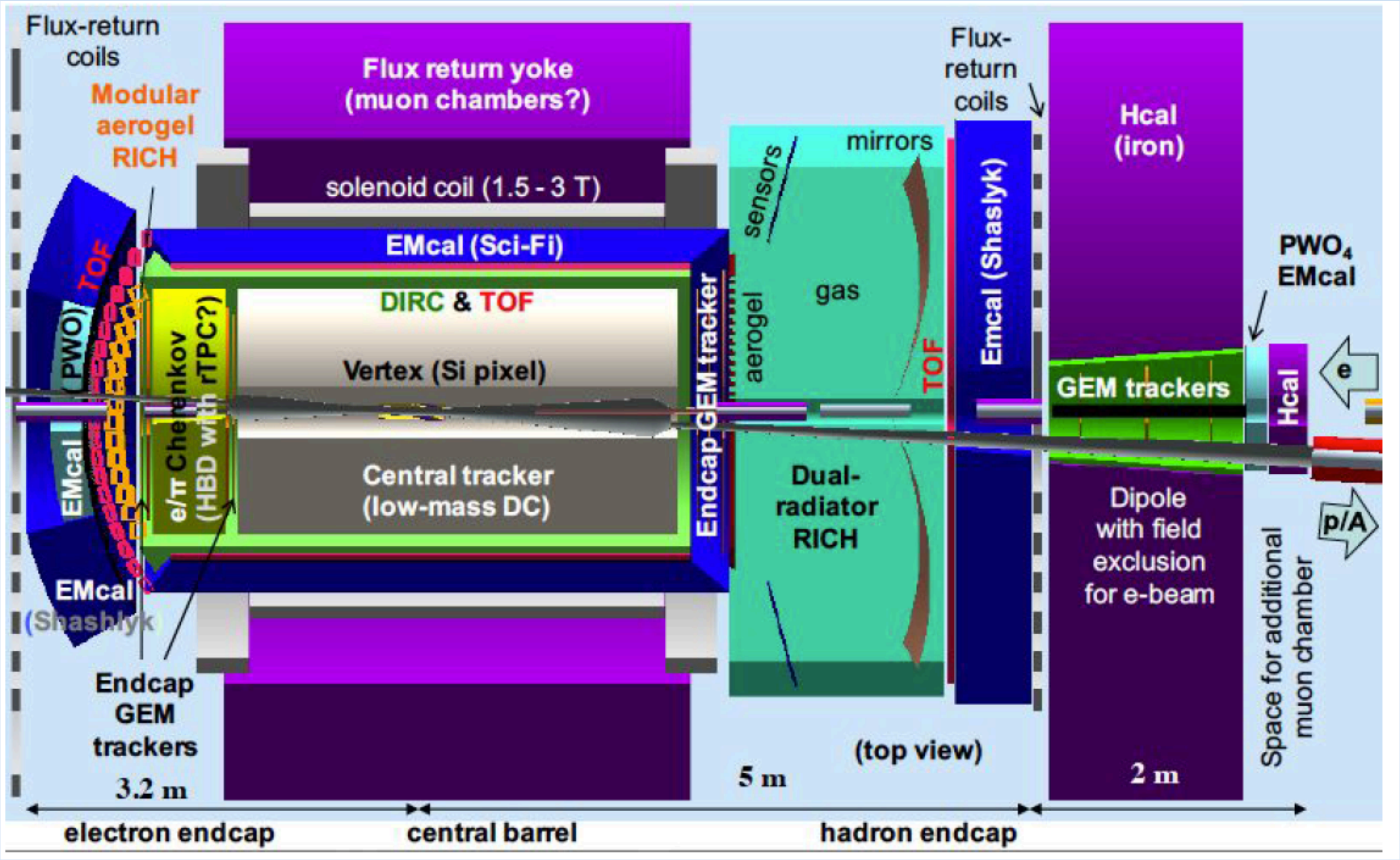


Direct measurement of the major expected contribution to the dRICH Cherenkov angle resolution.

EIC CHERENKOV DETECTORs (FE, LNF, CT, RM1)

mRICH as compact solution for Limited momentum range (up to ~ 10 GeV/c)

dRICH as dual radiator for Extended momentum range (up to ~ 50 GeV/c)



Collaboration with JLab, GSU, Hawaii U., DUKE