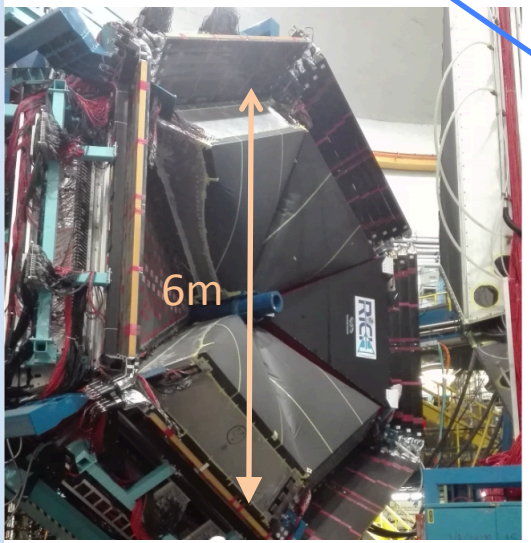
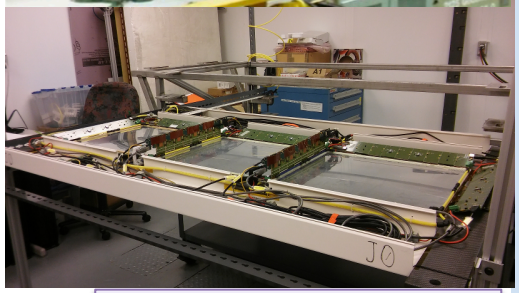
INFN Groups and eRD14

INFN-FE
CLAS12 RICH

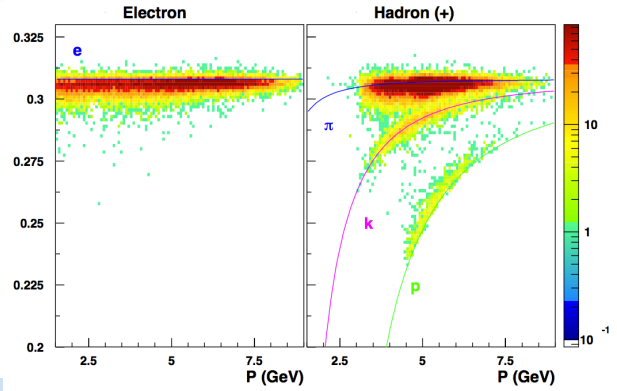
Several INFN groups interested to pursue dRICH and other activities within the eRD14 Consortium

INFN-RM1
HERMES RICH
Hall-A Tracking

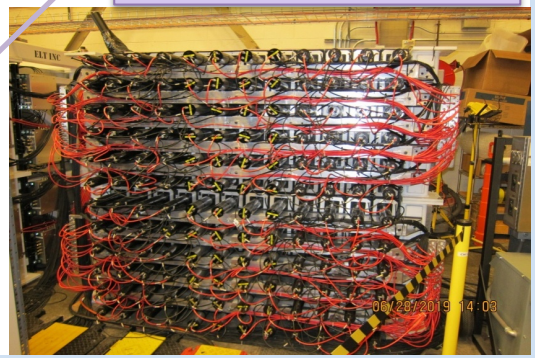




INFN-LNF
CLAS12 RICH

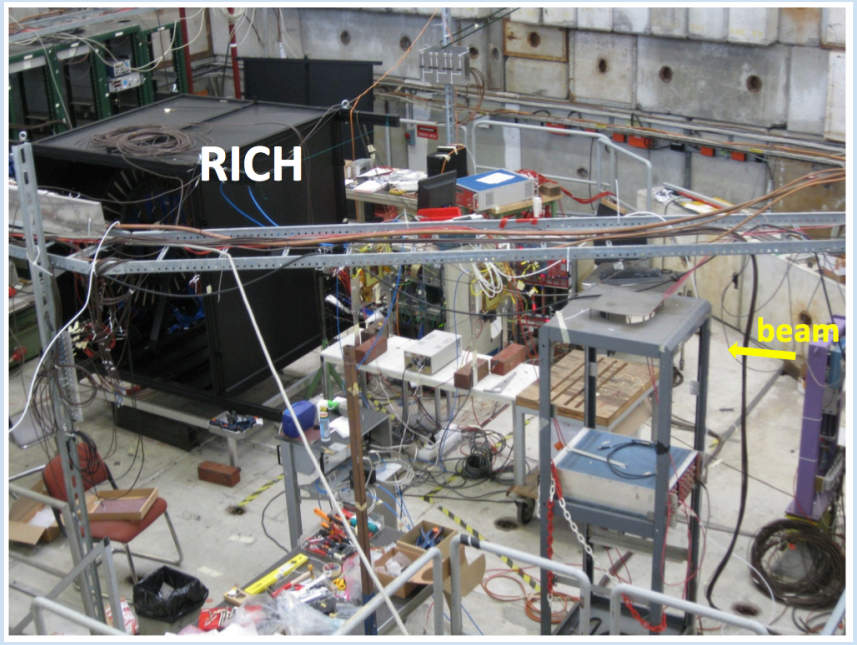


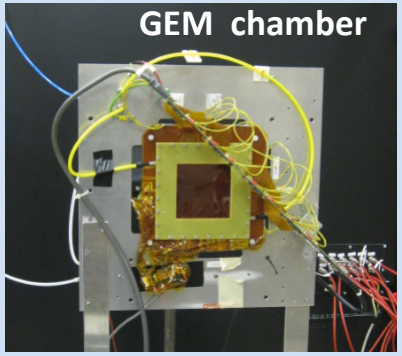
INFN-CT
Hall-A HCAL

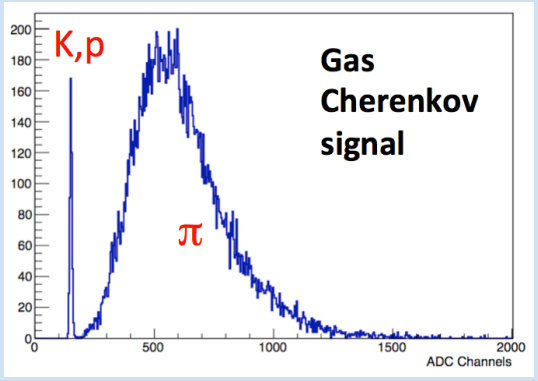


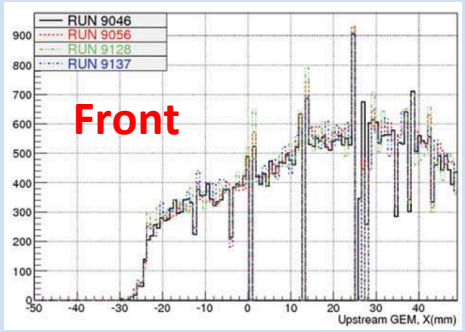
CLAS12 RICH Prototype @ CERN T9

S.A.Pereira et al, Eur. Phys. J. A (2016) 52: 23

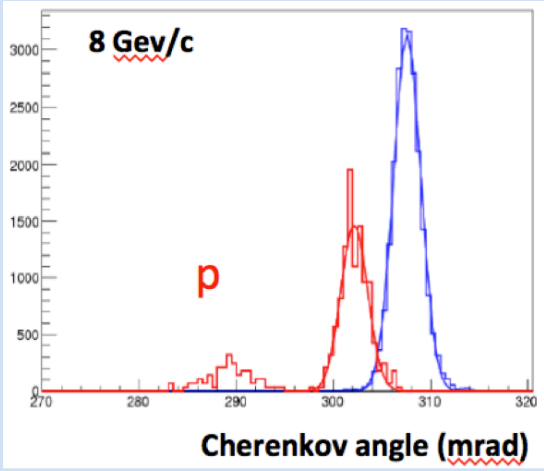








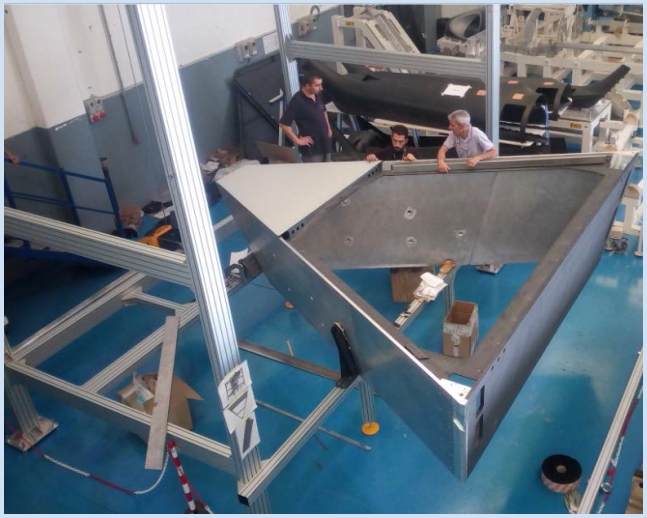
Goal:
Separation
up to 8 GeV/c

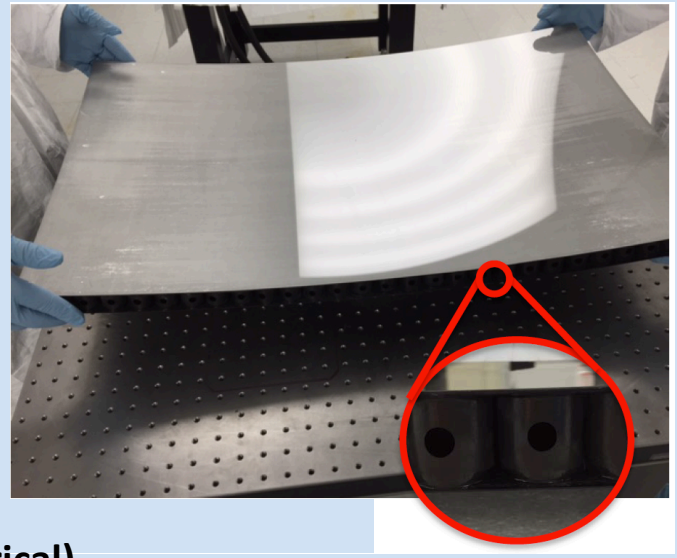


CLAS12 RICH Advances

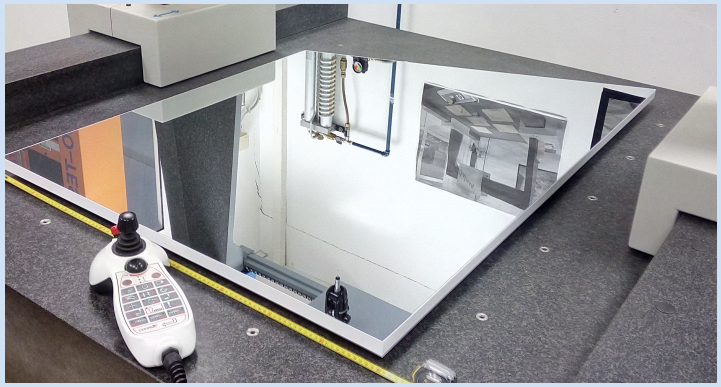
M.Mirazita et al., NIMA876 (2017) 54-58

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

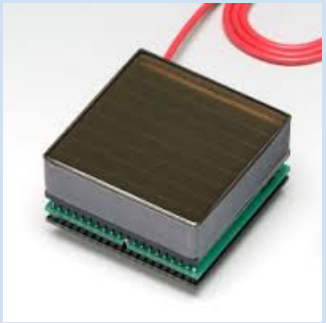




Carbon Fiber Mirrors (spherical)
to maximize lightness and stiffness. Consolidate technology (HERMES, AMS, LHCb) but ~ 30 % material budget reduction



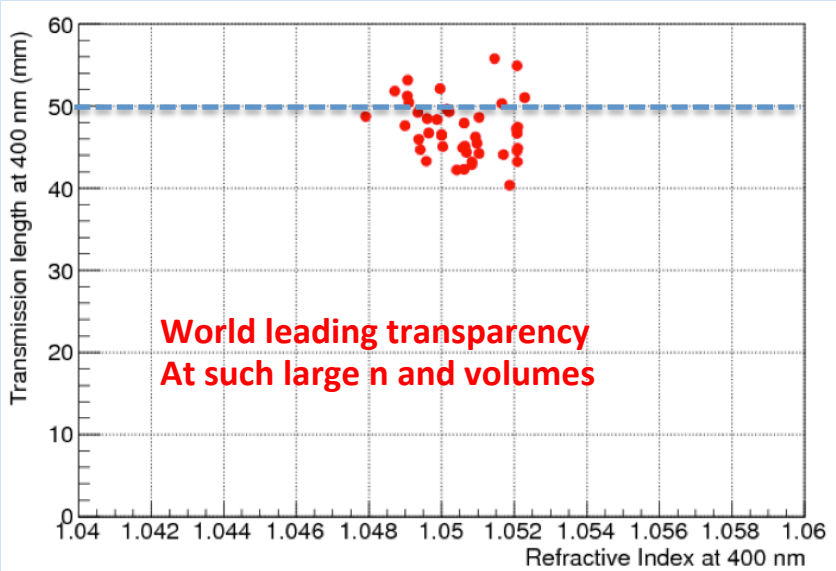
Photon Detector
First use of H8500/H12700
flat panel multi-anode PMTs
64 pixels on a 5x5 cm^2 area

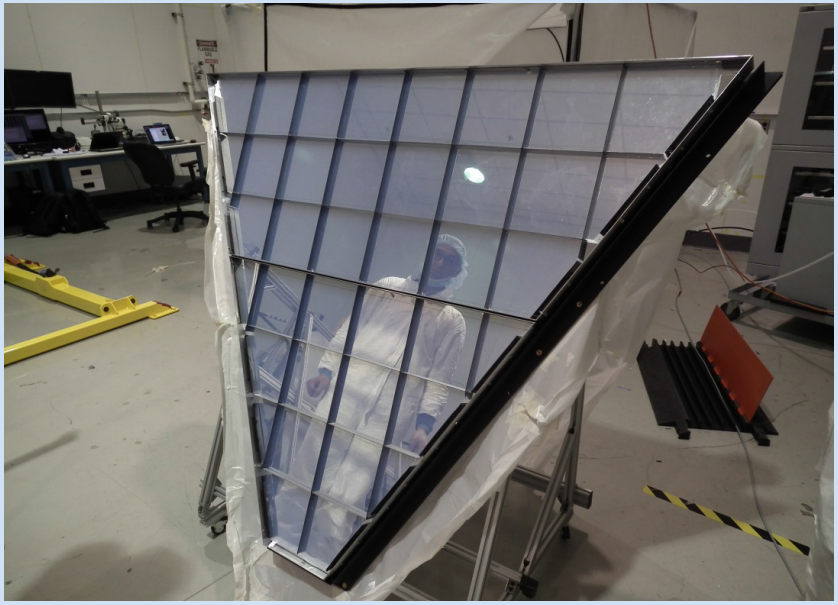


Glass-Skin Mirrors (planar)
Innovative technology never used in nuclear exps.
~ 1/5 cost for squared meter vs CFRP

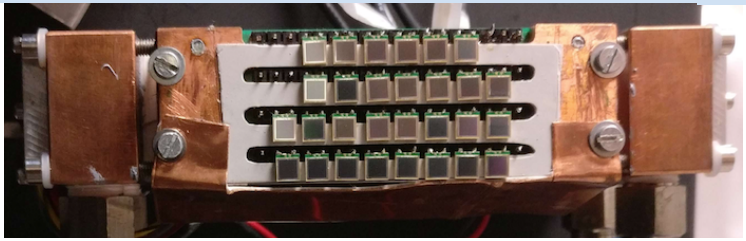
CLAS12 RICH Advances

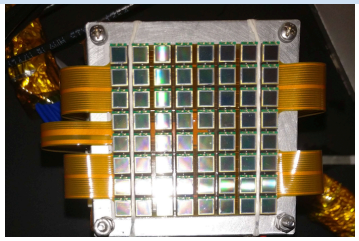
M. Contalbrigo et al., NIMA876 (2017) 168-172

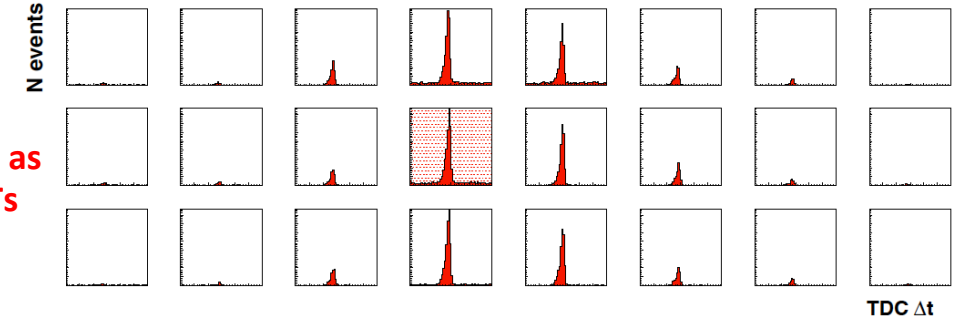




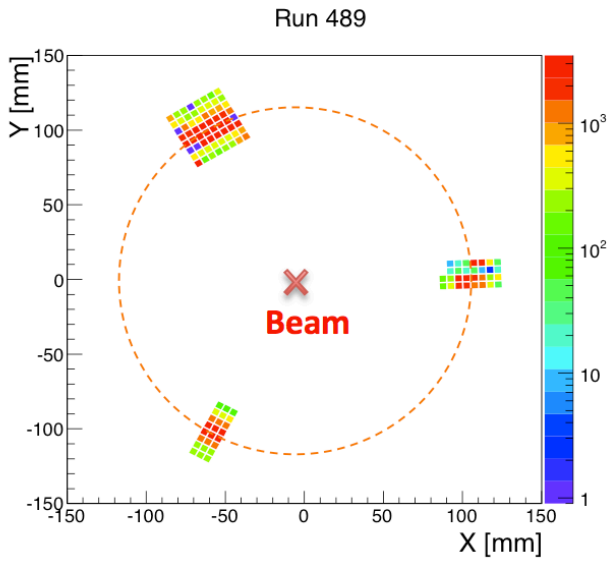
M. Contalbrigo et al., NIMA766 (2014) 22





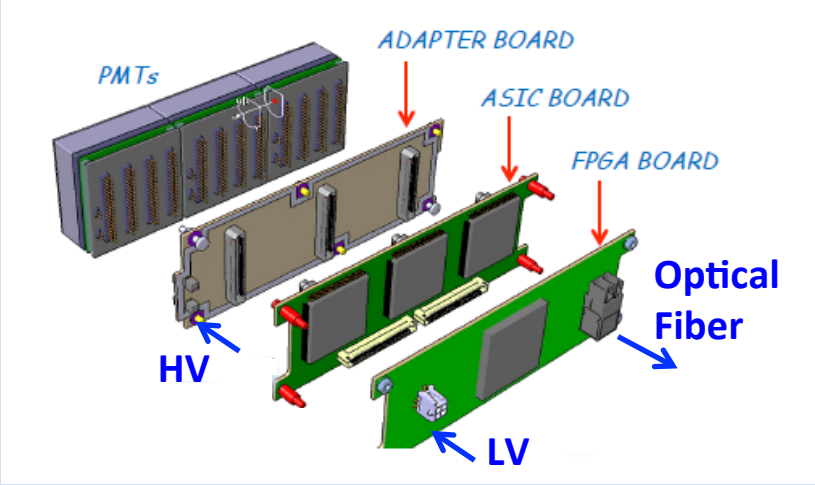


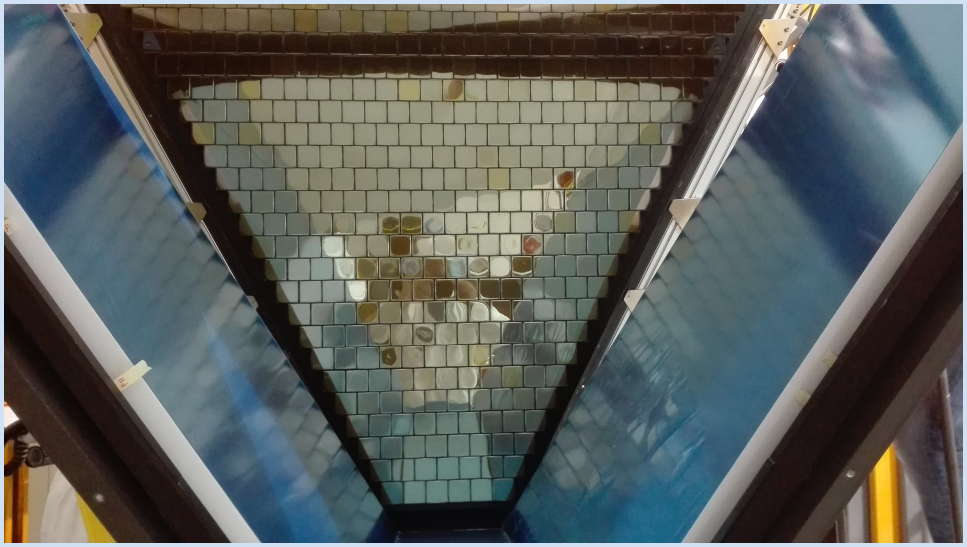
Cooled SiPM as good as PMTs

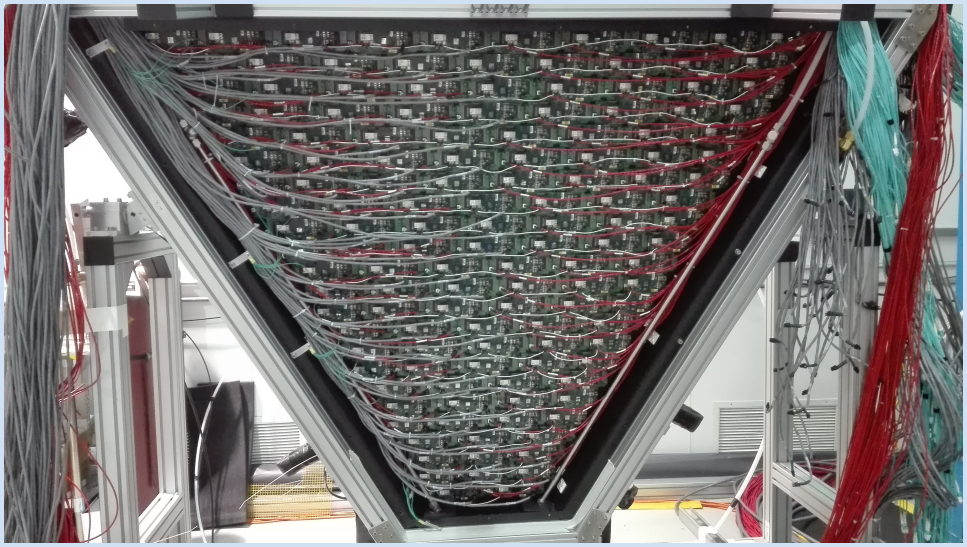


Readout Electronics

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)



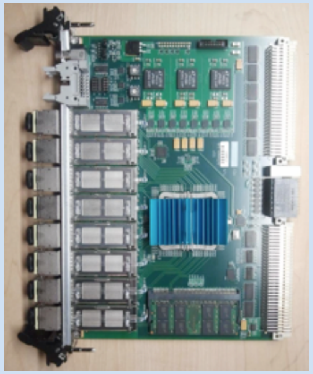




Constant threshold discrimination
1 ns FPGA timestamp (clock distribution driven)

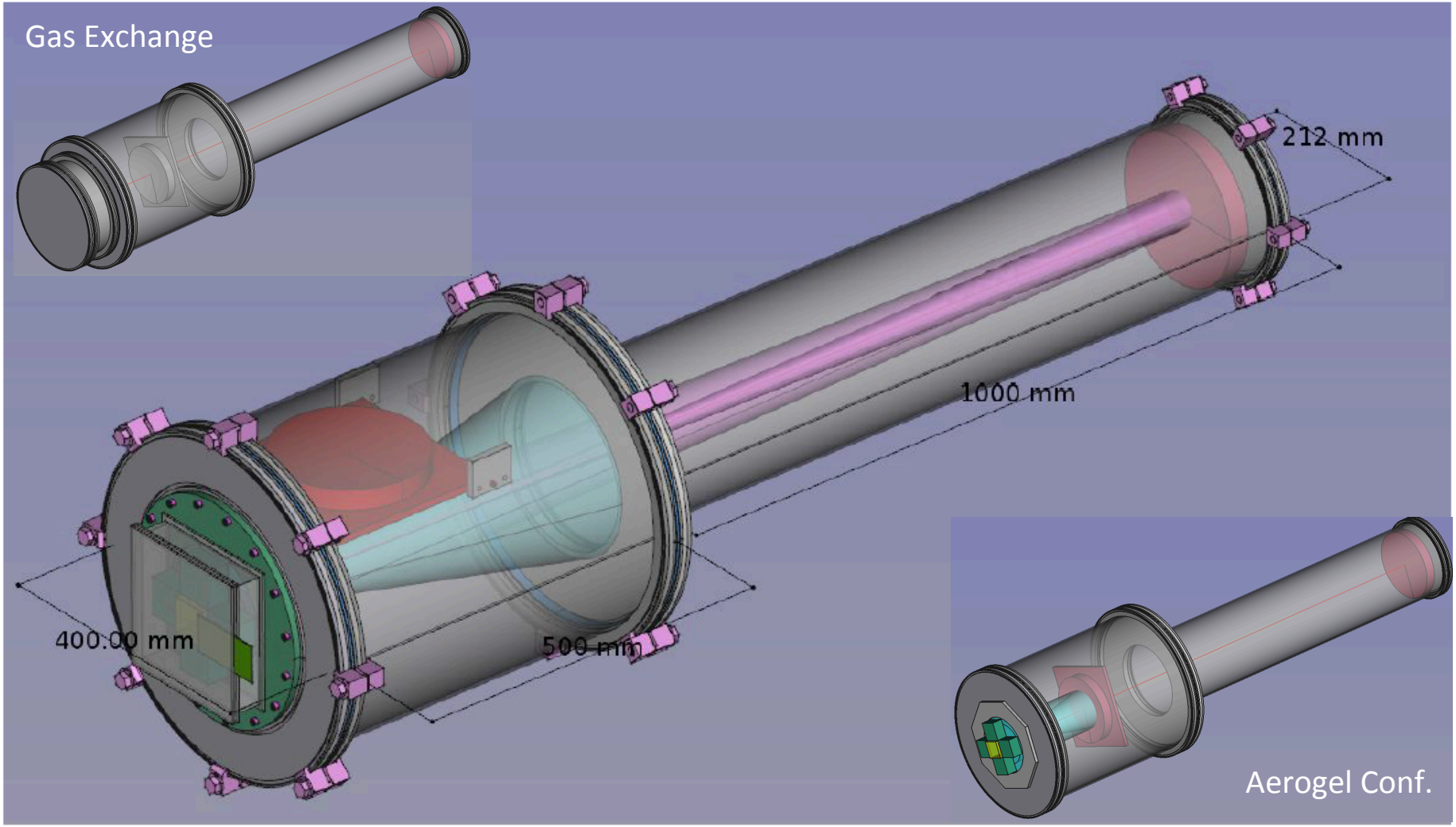
Applications:

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



SSP Back-end

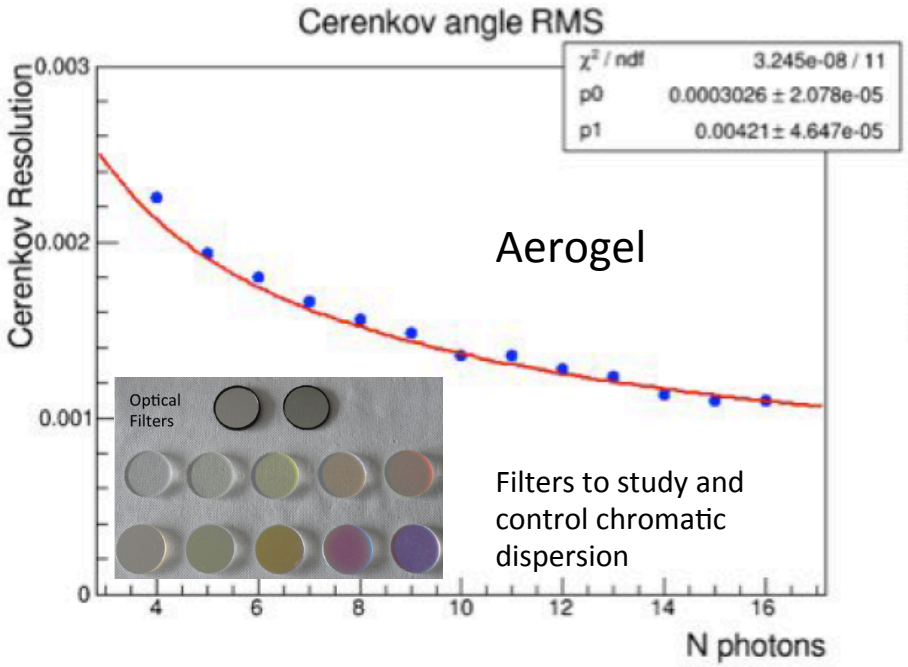
dRICH Prototype Design

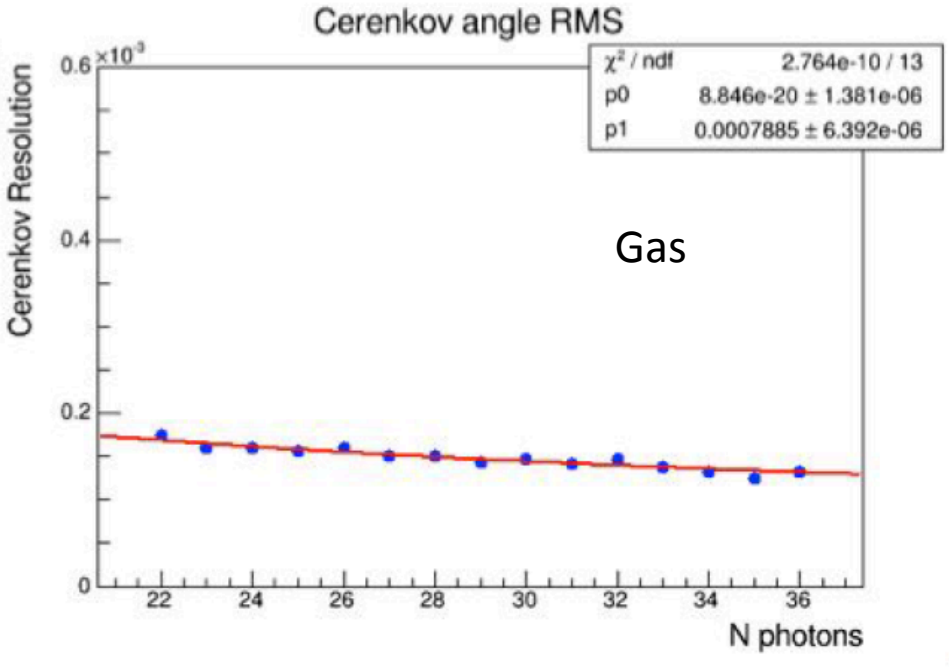


Commercial vacuum technology for safety and cost effectiveness
Overlapping rings for parallel beam particles

dRICH Prototype Performance

Montecarlo simulation

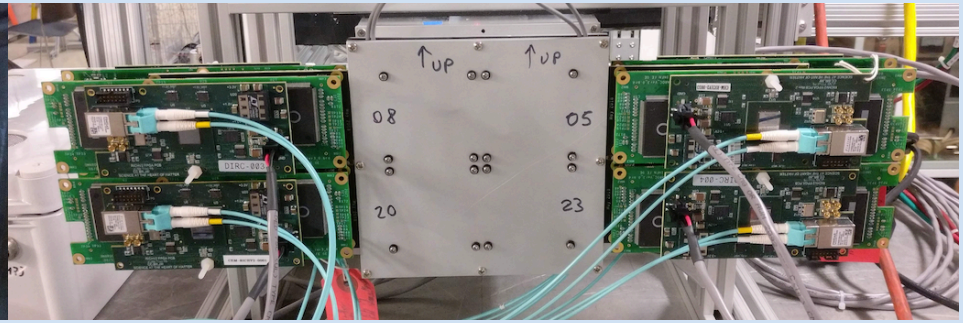




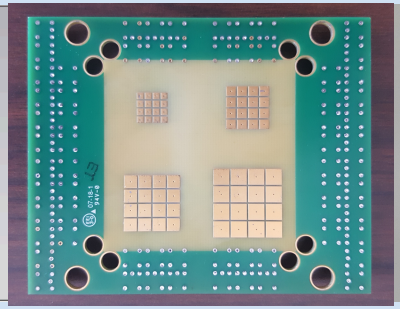
1 p.e. Error (mrad)	Aerogel		C_2F_6 Gas	
Chromatic error	3.2	(2.9)	0.51	(0.8)
Emission	0.5	(0.5)	0.5	(1.2)
Pixel	2.5	(0.5)	0.42	(0.5)

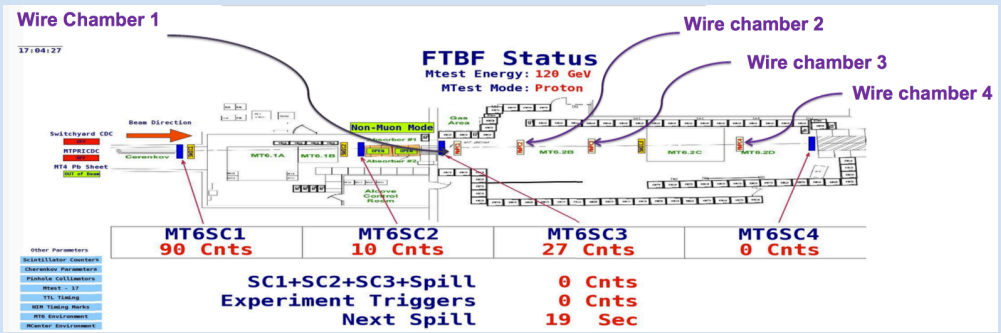
dRICH Prototype Test

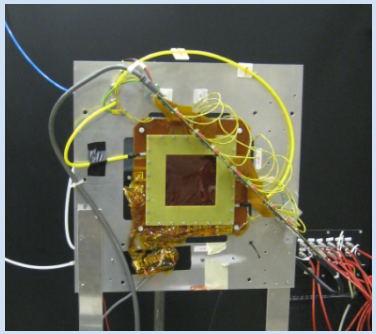
Readout box
Independent element for flexibility: supports various detectors, cooling, UV filters….
Reference:
MAROC + SSP/VSX
Dedicated:
SiREAD + SSP/ethernet

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



Ancillary Systems:

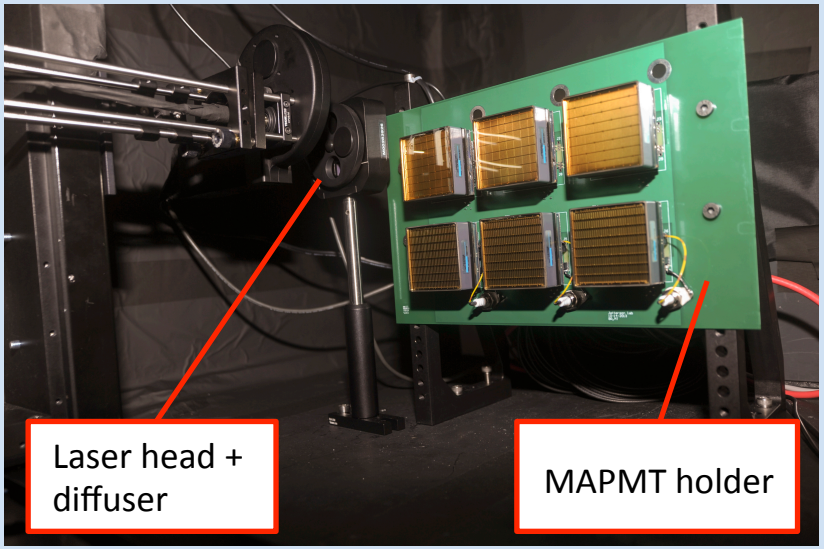
Gas Cherenkov for tagging	(FTBF beam line)
MWPC chambers for tracking	(FTBF beam line)
GEM chambers for tracking and alignment	(basic version in house)
Gas recirculating circuit	(optional)

Pulsed Laser Test Benches

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

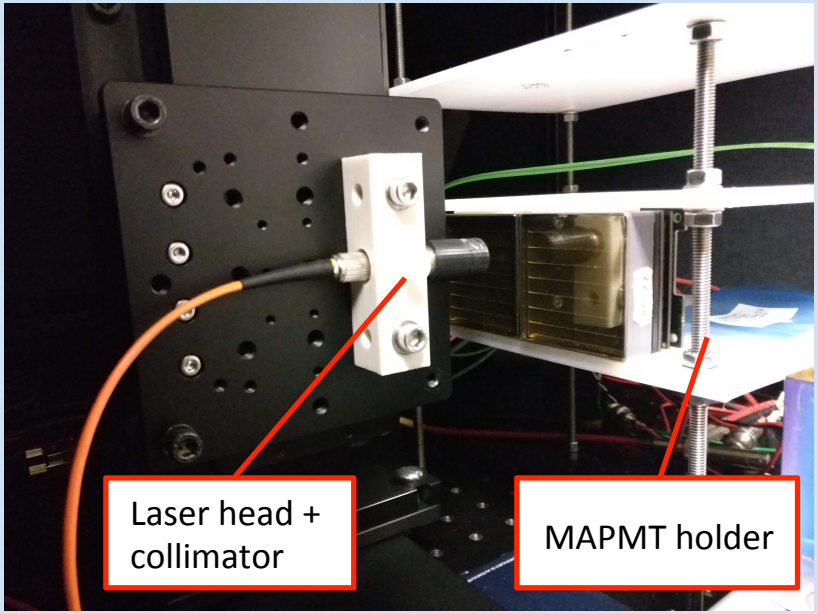
JLab

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

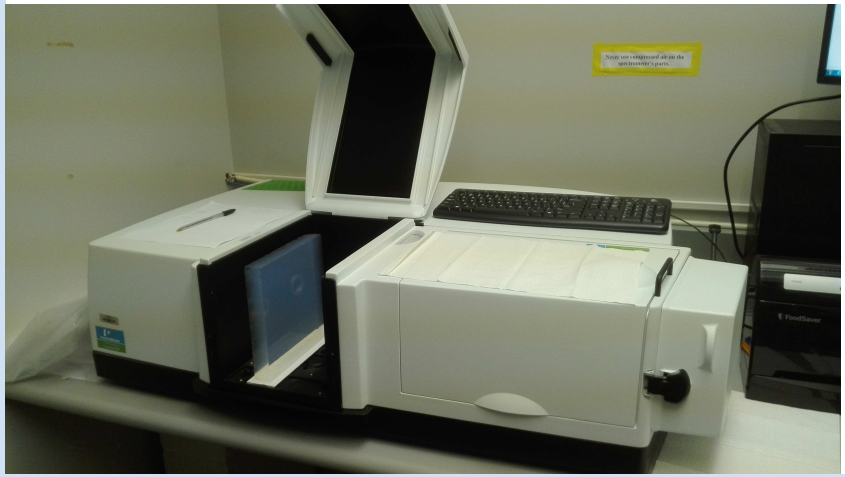


Aerogel Test Laboratory

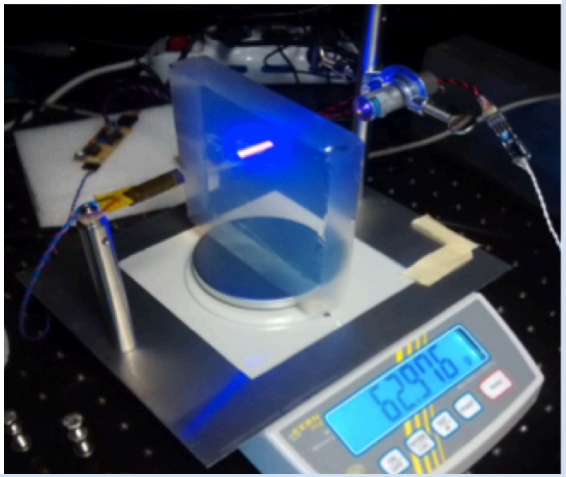
Existing facility to study detailed aerogel optical properties
(refractive index, surface planarity, forward scattering)
safe handling and Interplay with gas radiator

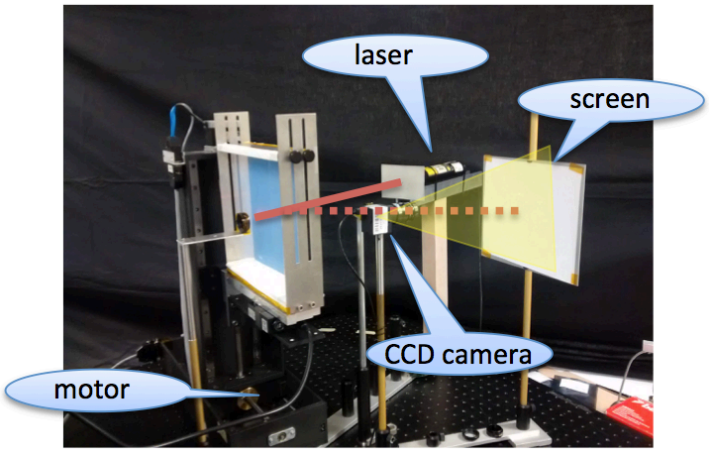
Controlled storage

Spectrophotometer

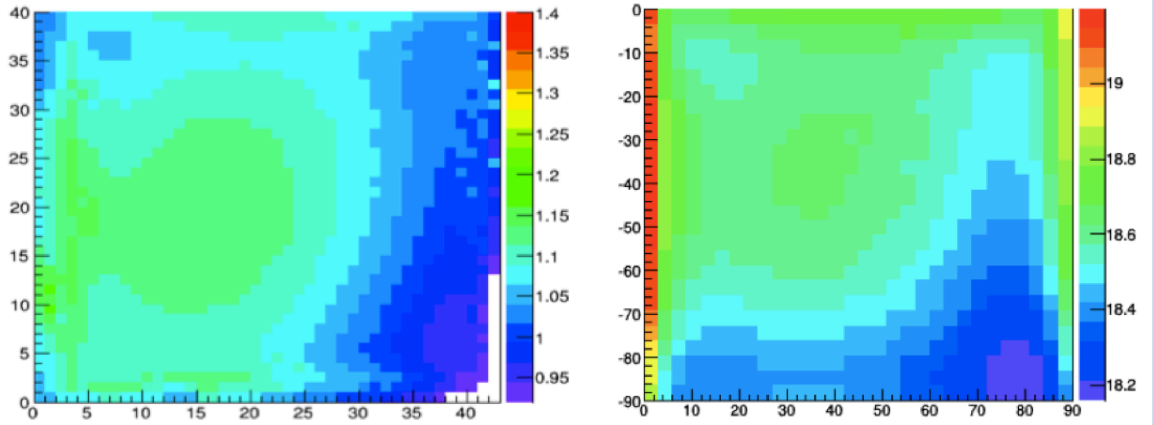


Characterization station



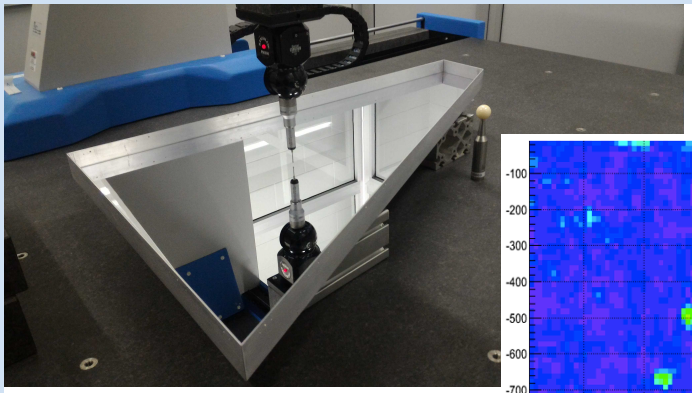


Surface map by laser setup vs touch machine

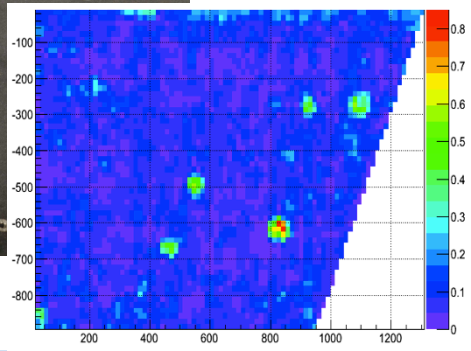


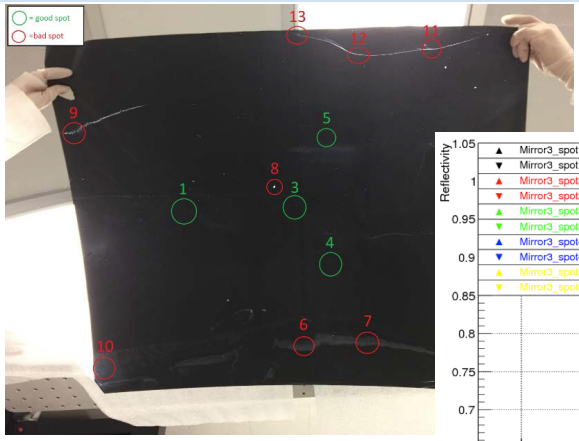
Mirror Test Laboratory

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

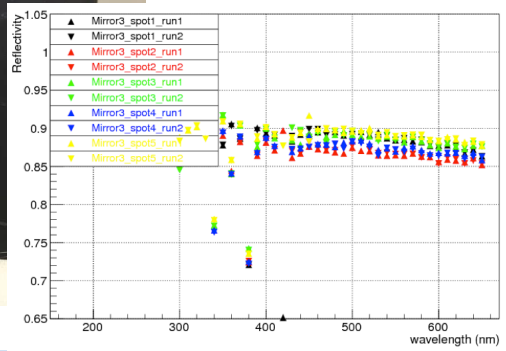


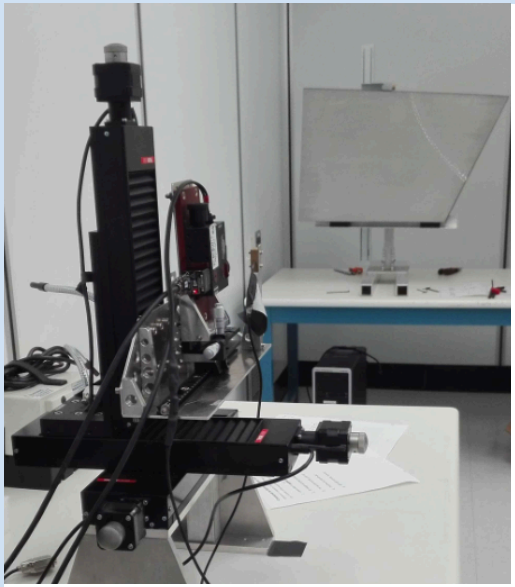
Planarity



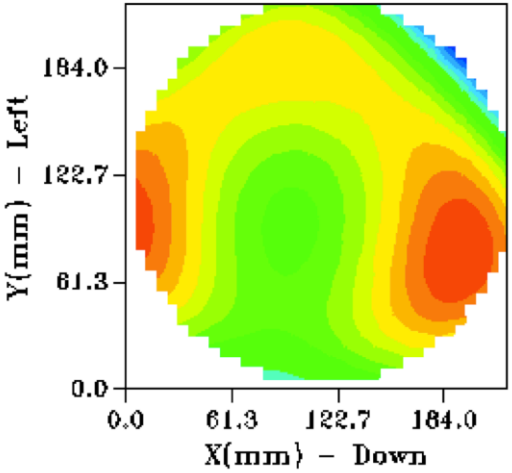


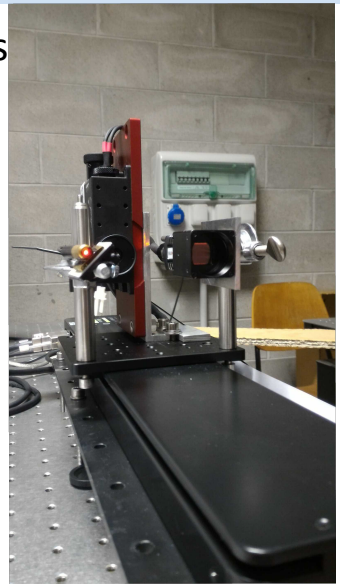
Reflectivity



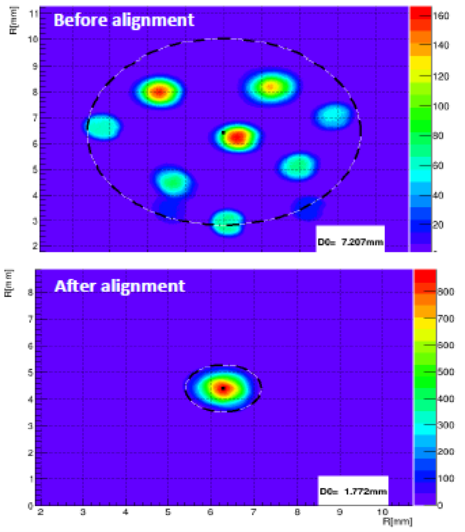


Shack-Hartmann: Aberrations

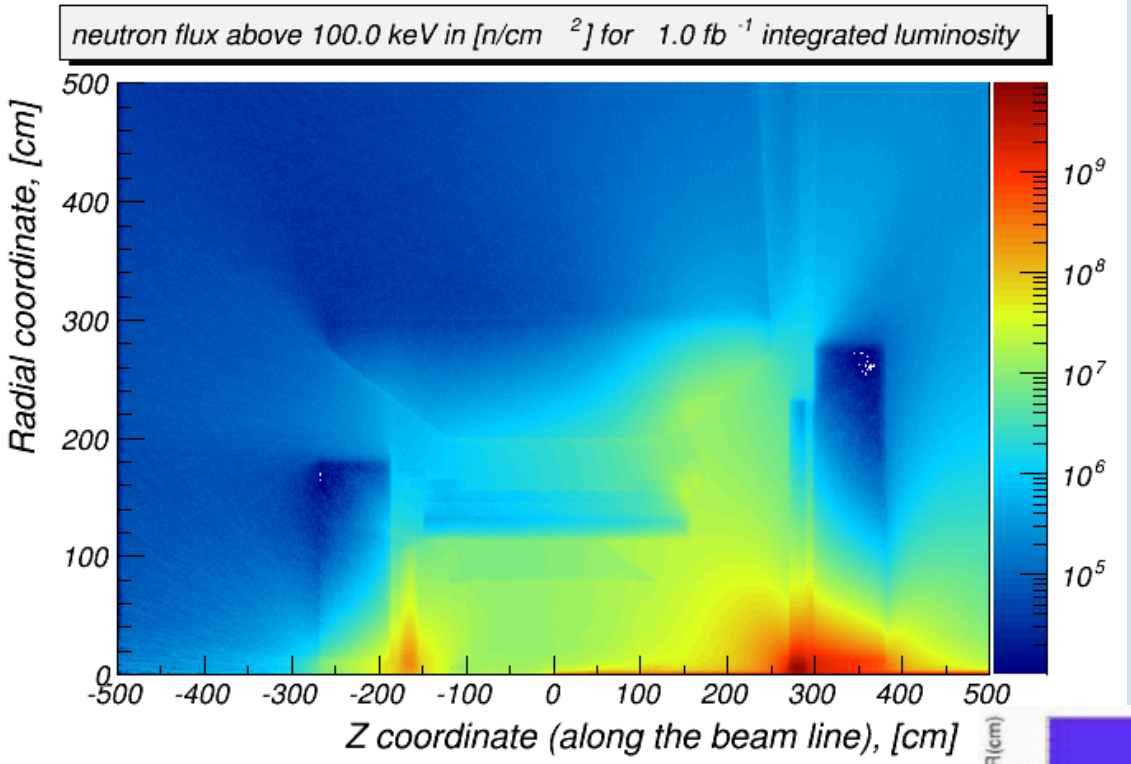




Point Image: Alignment



EIC Detector Environment



Neutron Fluence
(courtesy of A. Kiselev)

Moderate except for
very forward regions

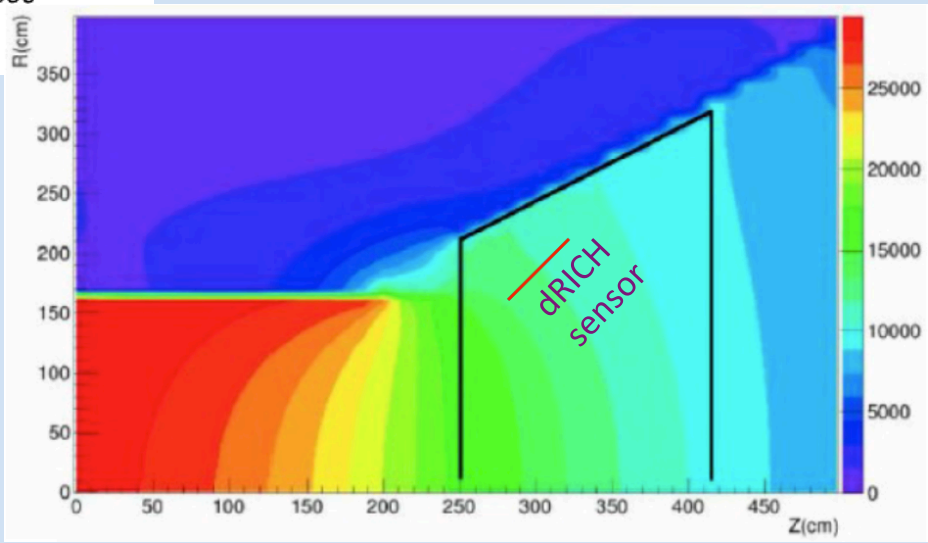
Reference value ~ 10^{11} n_{eq}/cm^2
for several years at max lumi (10^{34})

SiPM: single photon detection
study up to 10^{14} n_{eq}/cm^2
10.1016/j.nima.2019.01.013

Magnetic Field

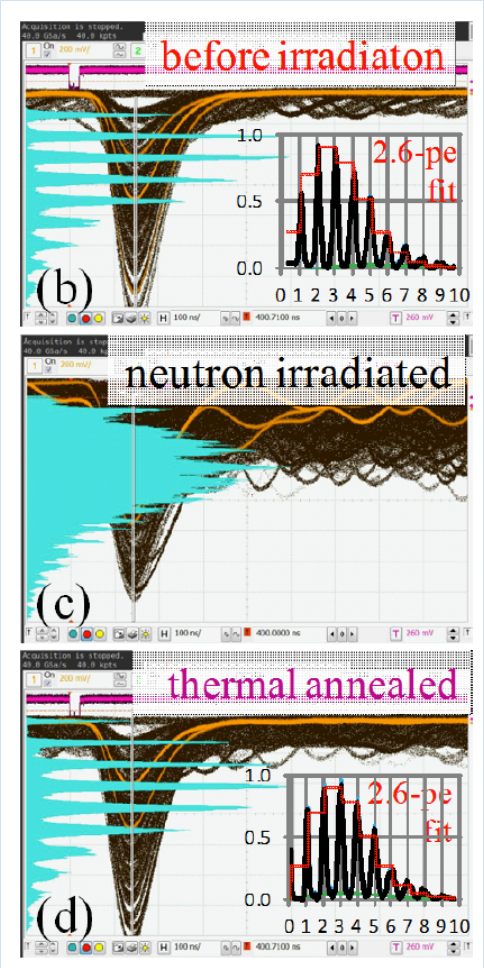
~ 1 T order of magnitude
Detector orientation to be tuned

SiPM: PET study up to 7 T
10.1109/NSSMIC.2008.4774097



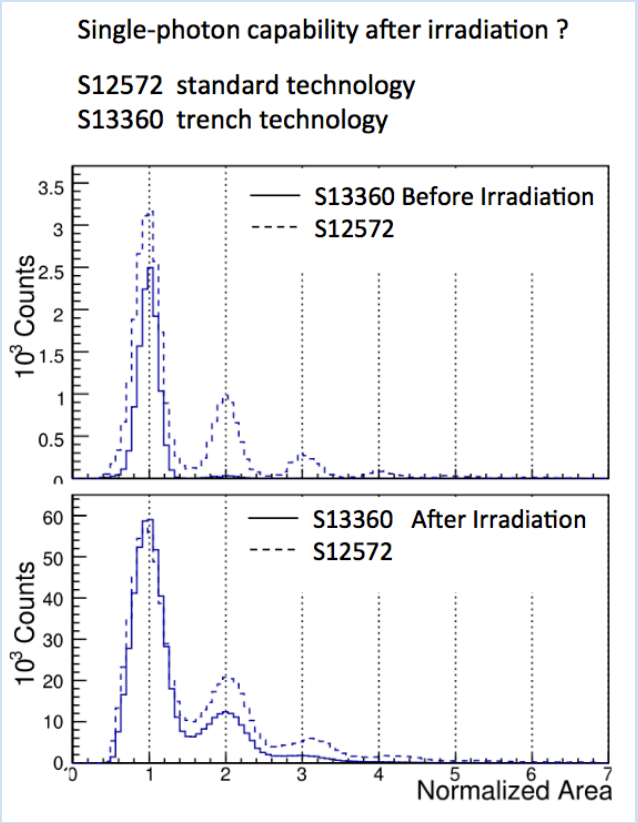
SiPM Radiation Tolerance

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



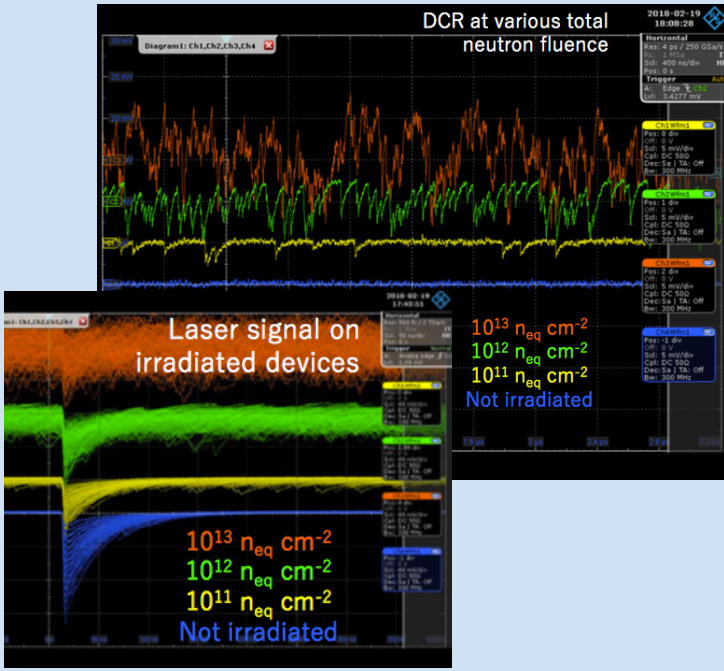
T= 25 C
10^9 n_{eq} cm^2
Annealing at 250 °C

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



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

M. Calvi et al.
NIMA 922 (2019) 243



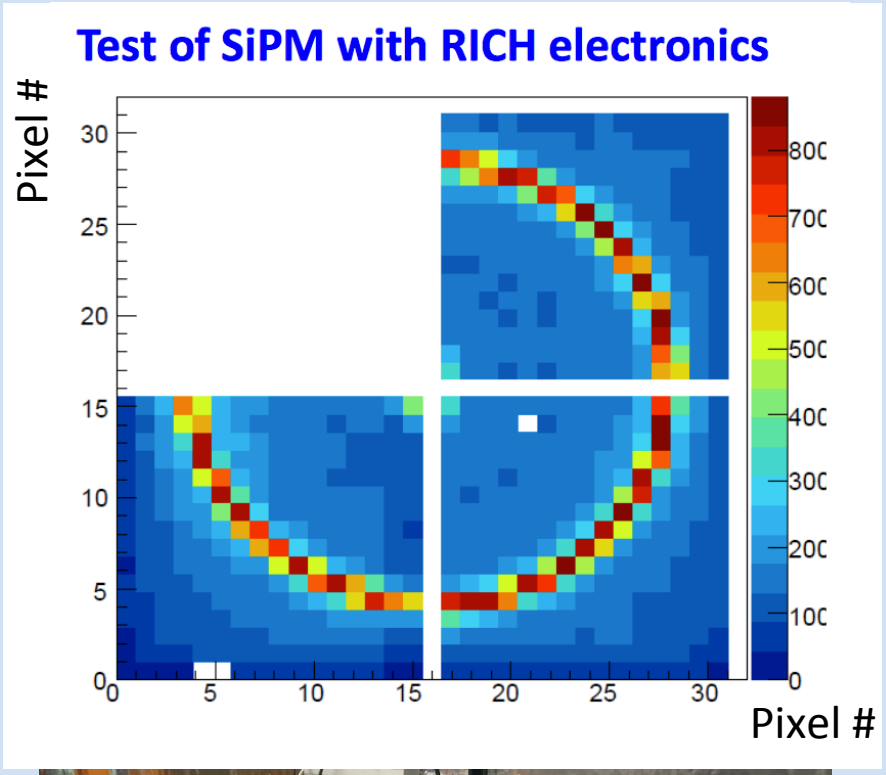
SiPM: Hamamatsu S13360-1350CS (50 µm cells)

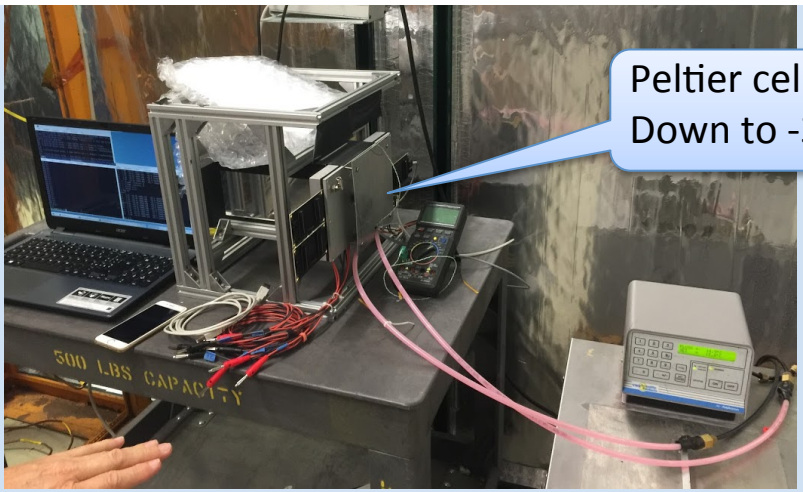
Temperature: –30 °C

≥ 10^{11} n_{eq} cm^2

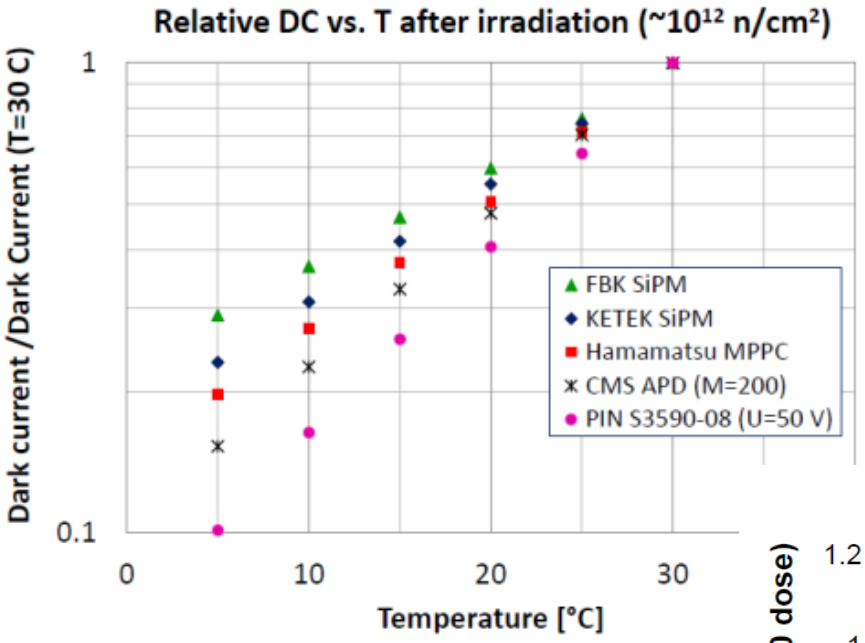
SiPM Option

Viable solution with cooling



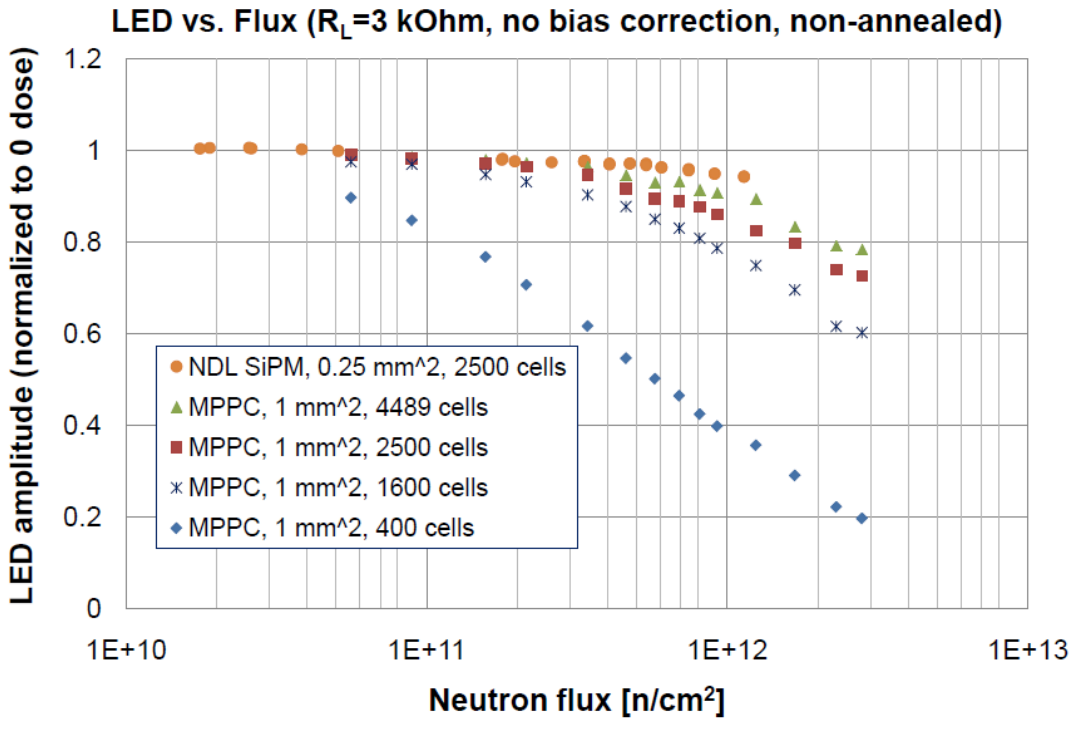


SiPM Radiation Tolerance Investigation



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 (annealing)
+ Packaging (ΔT, cooling)
+ ……

Activity 2020

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
Post-doc (Hardware)				20								50					120	
Post-doc (Design)				20								50		30			150	
Travel (Test-beam)				4							12	8				12	56	40
Mechanics				5								5					20	15
Windows				8													18	
Gas system												10					15	
Electronics				5								5					15	15
Tracking												5					10	10
Shipment, Incidentals												15				15	45	
Mirrors												20				40	65	5
Aerogel												10				10	30	10
Gas												10					15	5
MCP-PMTs (LAPPDs)																		
SiPMs												30				15	75	30
SiPM Coolling												10				10	30	20
Total personal				44				120				120				42	326	40
Total material				18				110				120				90	338	110

2020

Prototype design, simulation and implementation

Basic mechanics Electronics adaptation

Component test and selection

Start of INFN funds

Activity 2021

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
Post-doc (Hardware)				20				50									120	
Post-doc (Design)				20				50									150	
Travel (Test-beam)				4			8	12								12	56	40
Mechanics				5			10										20	15
Windows				8			10										18	
Gas system							5										15	
Electronics				5			5										15	15
Tracking							5										10	10
Shipment, Incidentals							15									15	45	
Mirrors							5									40	65	5
Aerogel							10									10	30	10
Gas							5										15	5
MCP-PMTs (LAPPDs)																		
SiPMs							30									15	75	30
SiPM Coolling							10									10	30	20
Total personal				44				120				120				42	326	40
Total material				18				110				120				90	338	110

2021

Basic prototype

- basic tracking
- 1 radiator choice
- commercial mirror
- reference readout

Beam Test 1

- MA-PMTs, SiPMs
- Proton beam
- Critical aspects

Optical components
test and selection

SiPM program
radiation tolerance
and cooling program

Activity 2022

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
Post-doc (Hardware)								50				50					120	
Post-doc (Design)								0				50		30			150	
Travel (Test-beam)								12			12	8				12	56	40
Mechanics												5					20	15
Windows							10										18	
Gas system							5					10					15	
Electronics							5					5					15	15
Tracking							5					5					10	10
Shipment, Incidentals							15					15				15	45	
Mirrors							5					20				40	65	5
Aerogel							10					10				10	30	10
Gas							5					10					15	5
MCP-PMTs (LAPPDs)																		
SiPMs							30					30				15	75	30
SiPM Coolling							10					10				10	30	20
Total personal				44				120				120				42	326	40
Total material				18				110				120				90	338	110

2022

Refined prototype

- precision tracking / alignment
- various radiators
- custom mirrors
- gas system
- optimized readout
- online reconstruction

Beam Test 2

- MCP-PMTs, SiPMs
- Hadron beam
- Performance optimization

Optical components
test and selection

SiPM program
radiation tolerance
and cooling program

Activity 2023

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
Post-doc (Hardware)				20								5					120	
Post-doc (Design)				20								50		30			150	
Travel (Test-beam)				4								8				12	56	40
Mechanics				5								5					20	15
Windows				8													18	
Gas system												10					15	
Electronics				5								5					15	15
Tracking												5					10	10
Shipment, Incidentals												15				15	45	
Mirrors												20				40	65	5
Aerogel												10				10	30	10
Gas												10					15	5
MCP-PMTs (LAPPDs)																		
SiPMs												30				15	75	30
SiPM Coolling												10				10	30	20
Total personal				44				120				120				42	326	40
Total material				18				110				120				90	338	110

2023

TDR readiness

EIC configuration
engineering, realistic PID

Contingency:
Beam test 3

- Performance assessment
- Component optimization

Optical components
refinement and
cost reduction study
(e.g. glass-skin mirror)

SiPM program
radiation tolerance
and cooling program

Activity 20-23

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
Post-doc (Hardware)				20				50				50					120	
Post-doc (Design)				20				50				50		30			150	
Travel (Test-beam)				4			8	12			12	8				12	56	40
Mechanics				5			10					5					20	15
Windows				8			10										18	
Gas system							5					10					15	
Electronics				5			5					5					15	15
Tracking							5					5					10	10
Shipment, Incidentals							15					15				15	45	
Mirrors							5					20				40	65	5
Aerogel							10					10				10	30	10
Gas							5					10					15	5
MCP-PMTs (LAPPDs)																		
SiPMs							30					30				15	75	30
SiPM Coolling							10					10				10	30	20
Total personal				44				120				120				42	326	40
Total material				18				110				120				90	338	110

dRICH Summary

In good position to achieve TDR readiness in 2023

Increasing interest within INFN groups with hardware expertise

Feasibility study completed for EIC generic requirements

Sophisticated software tools developed for further optimization

Technical risks:

- Radiator quality and interplay
- Availability of sensor solution in 3T magnetic field (shared within eRD14)
- Availability of an advanced (fast sampling) readout electronics (shared within eRD14)

Mitigations:

Only possible with:

- a prototype and a stable program of component development and tests
- a steady funding plan accounting for the necessary prototype validation and newly (cost-effective) technological solution assessment (SiPMs, mirrors)

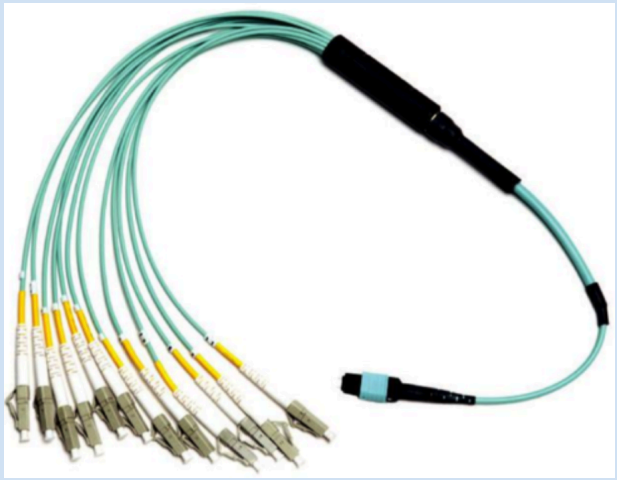
Backups

SiPM Facility

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
Post-doc (Back-end)				20				50				50		30			150	
Travel (Test-beam)				4			4	6			6	4				4	28	
Back-end				10				50				30				20	110	
Total personal				24				60				60				34	178	
Total material				10				50				30				20	110	

Back-end Electronics (INFN/JLab)



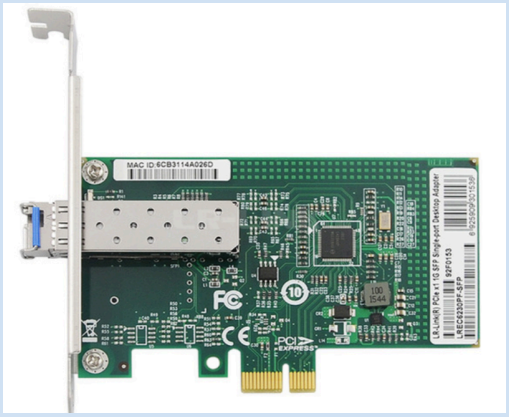
Optical ethernet (2.5 Gbps)

Small setups:
TCP/IP
Optical bridge / PC Desktop

Full experiment:
SSP protocol
SSP board / VSX crate

Next:
SSP + Ethernet Switches

Optical bridge / PC Desktop
Few FPGA units ~ 500 channels



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