

INFN Groups and eRD14

INFN-FE

CLAS12 RICH

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

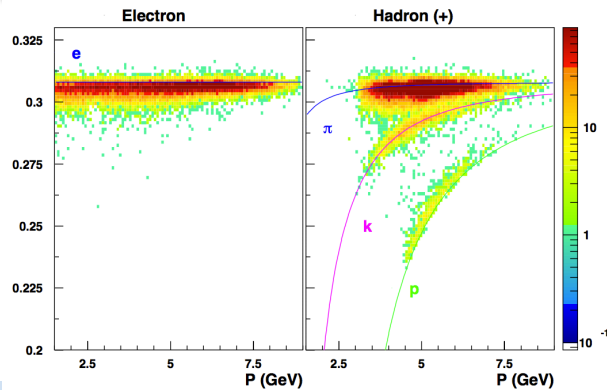
INFN-RM1

HERMES RICH
Hall-A Tracking



INFN-LNF

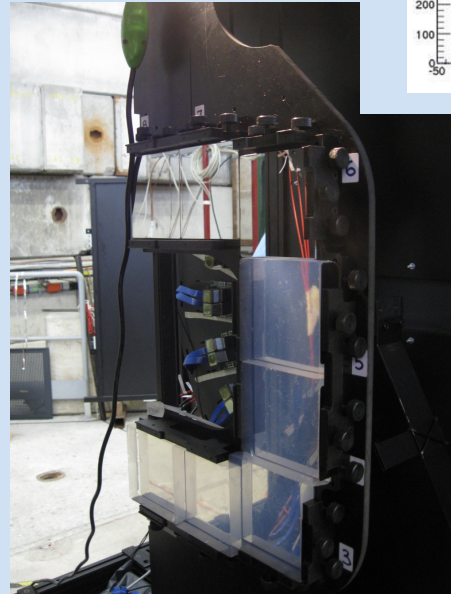
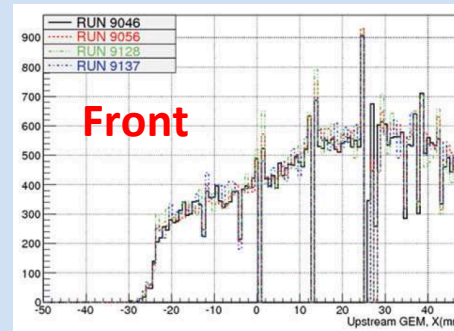
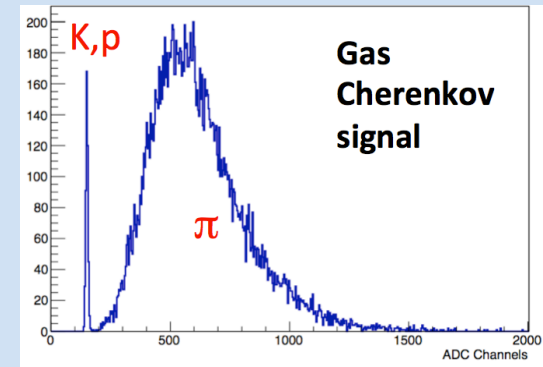
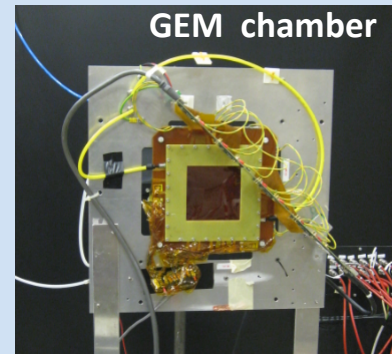
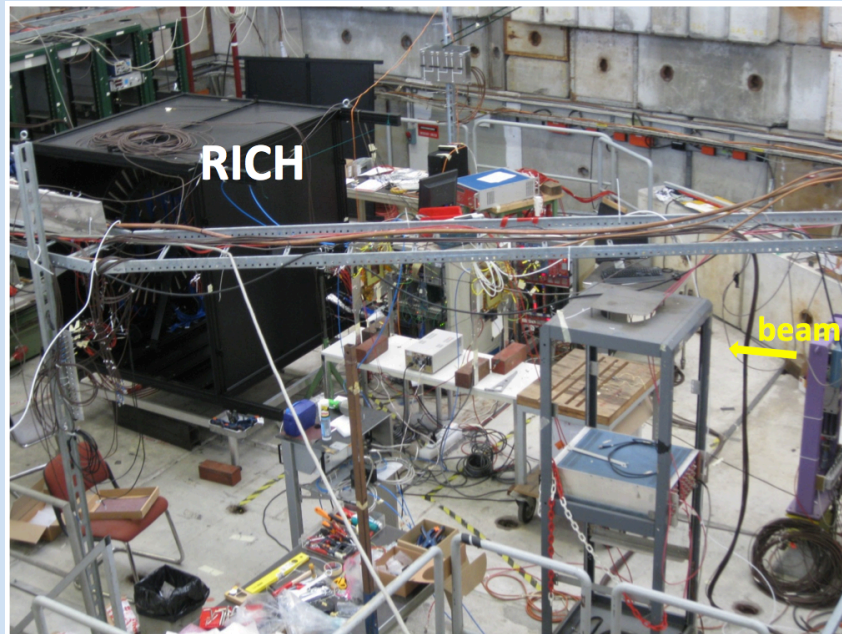
CLAS12 RICH



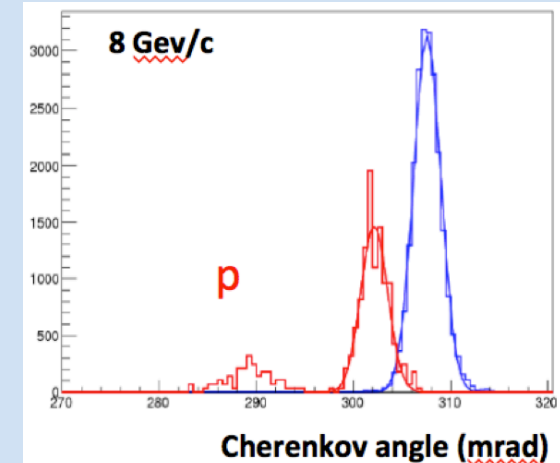
INFN-CT
Hall-A HCAL



CLAS12 RICH Prototype @ CERN T9

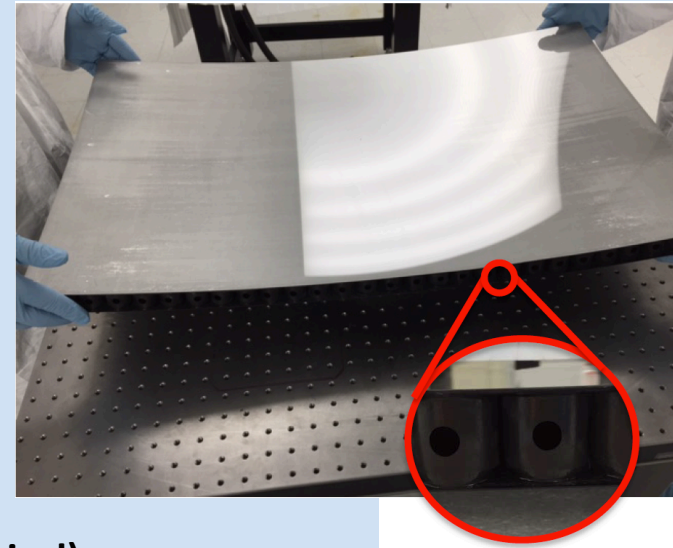
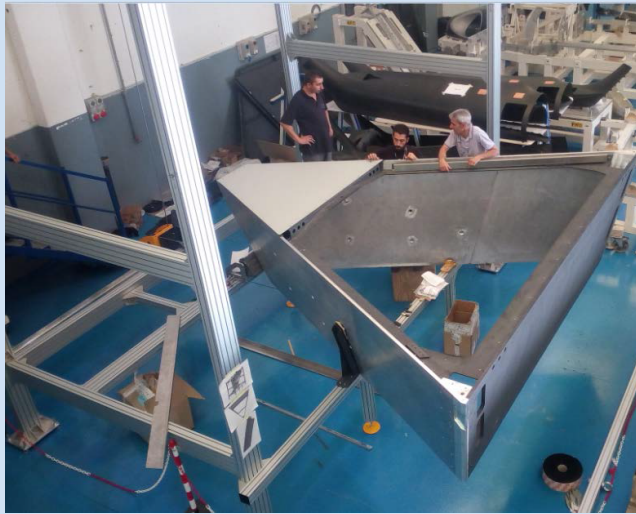


Goal:
Separation
up to 8 GeV/c



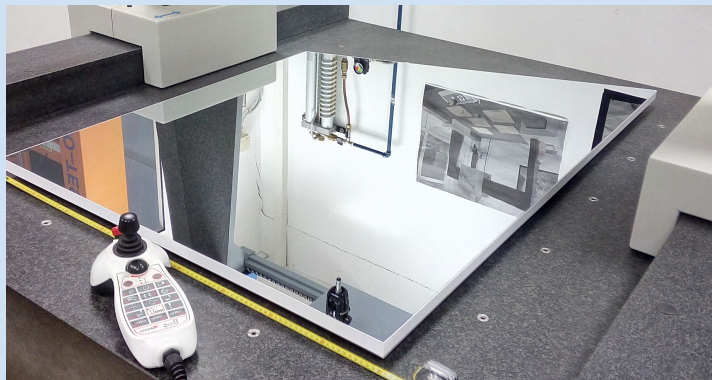
Aeronautic technology for structure

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



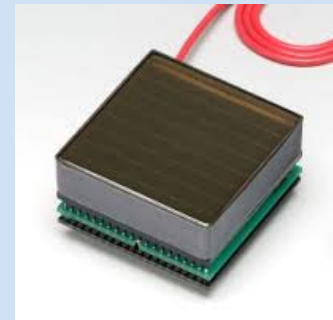
Carbon Fiber Mirrors (spherical)

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



Photon Detector

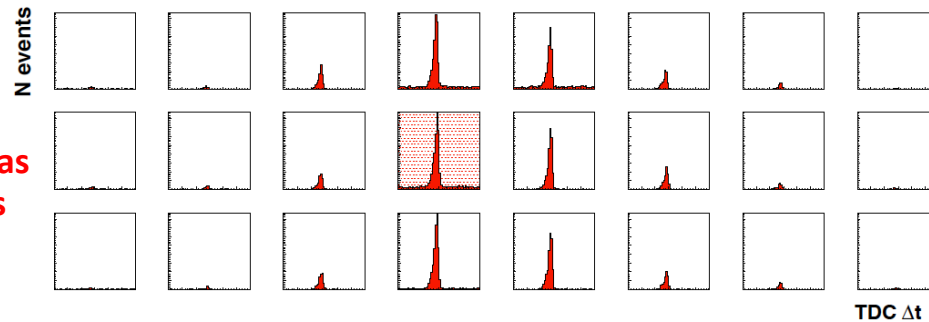
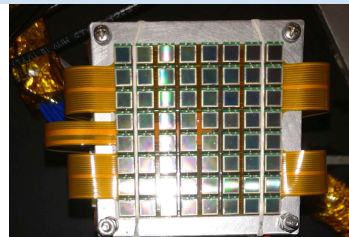
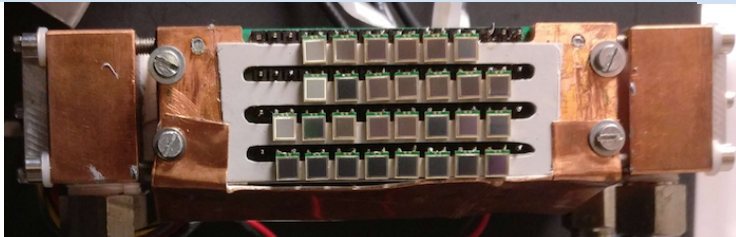
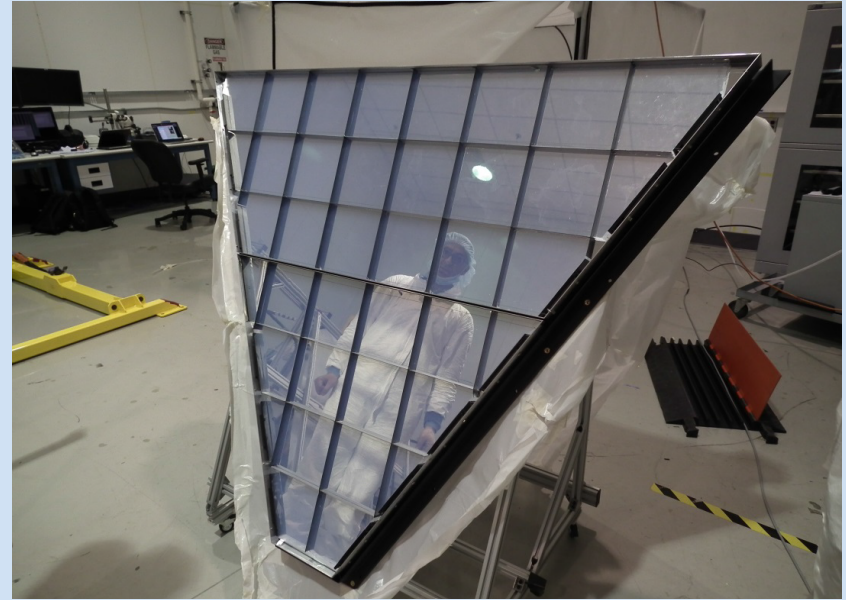
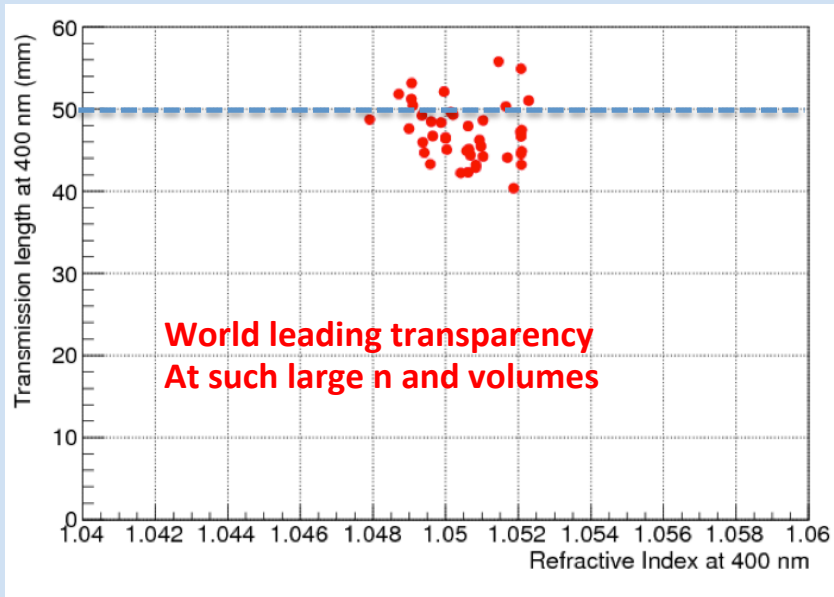
First use of H8500/H12700 flat panel multi-anode PMTs
64 pixels on a 5x5 cm² area



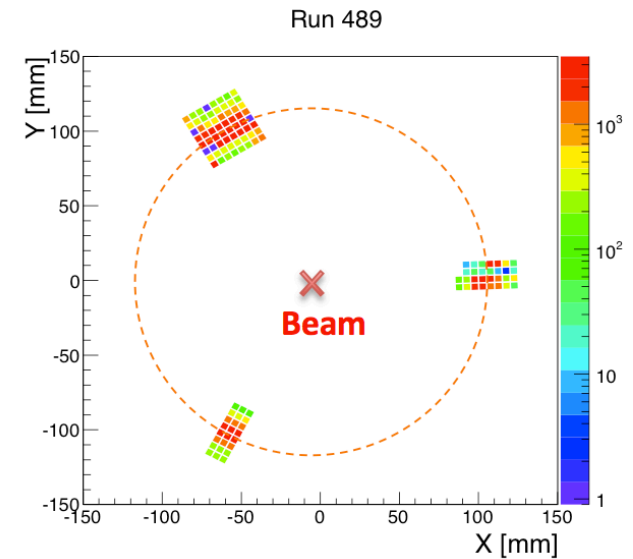
Glass-Skin Mirrors (planar)

Innovative technology never used in nuclear exps.
~ 1/5 cost for squared meter vs CFRP

CLAS12 RICH Advances



Cooled SiPM as
good as PMTs



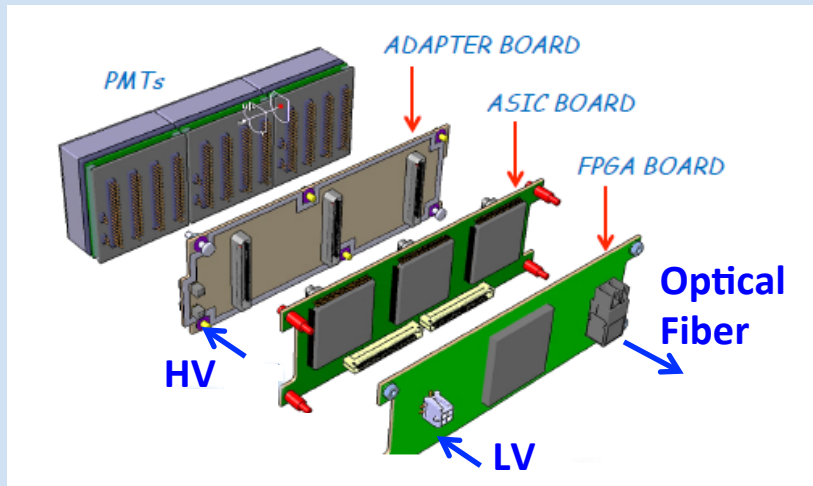
Readout Electronics

Compact (matches sensor area)

Modular Front-End (Mechanical adapter, ASIC, FPGA)

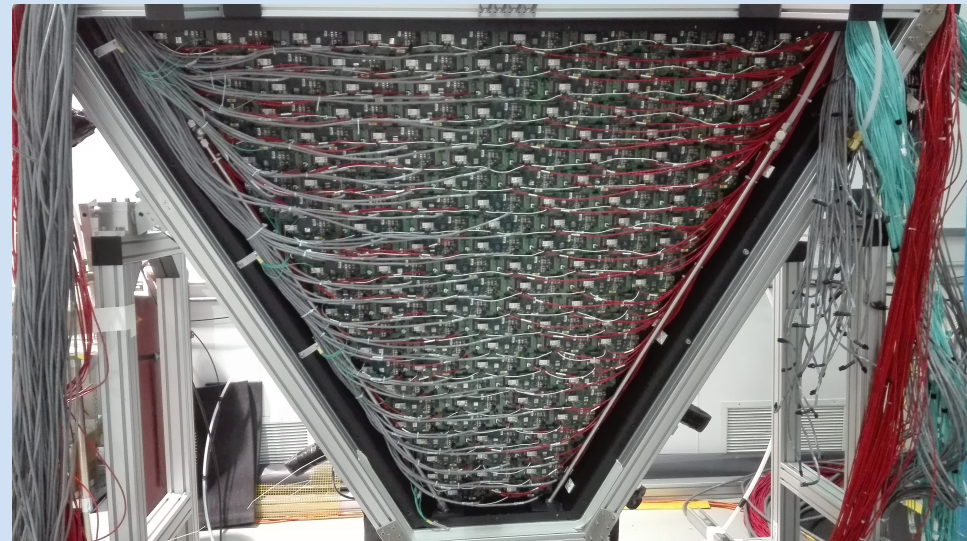
Scalable fiber optic DAQ (TCP/IP or SSP)

Tessellated (common HV, LV and optical fiber)

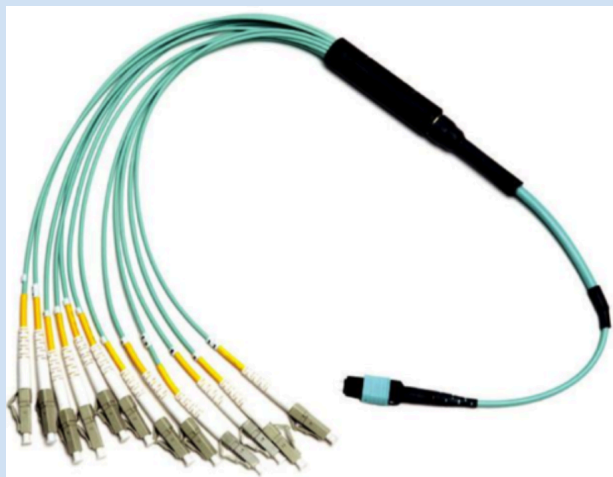


Applications:

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



Back-end Electronics (JLab)



Optical ethernet (2.5 Gbps)

Small setups:

TCP/IP

Optical bridge / PC Desktop

Full experiment:

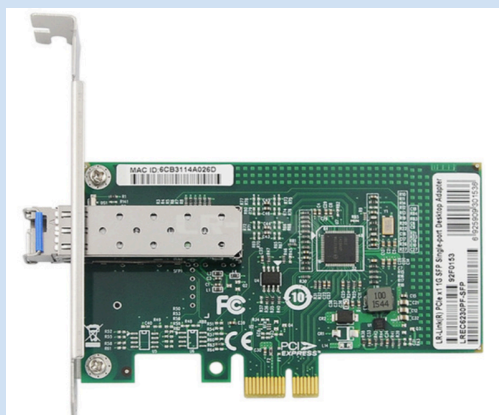
SSP protocol

SSP board / VSX crate

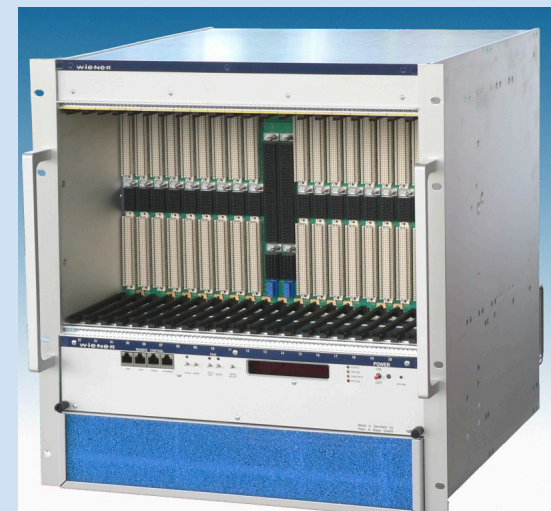
Next:

Ethernet Switches

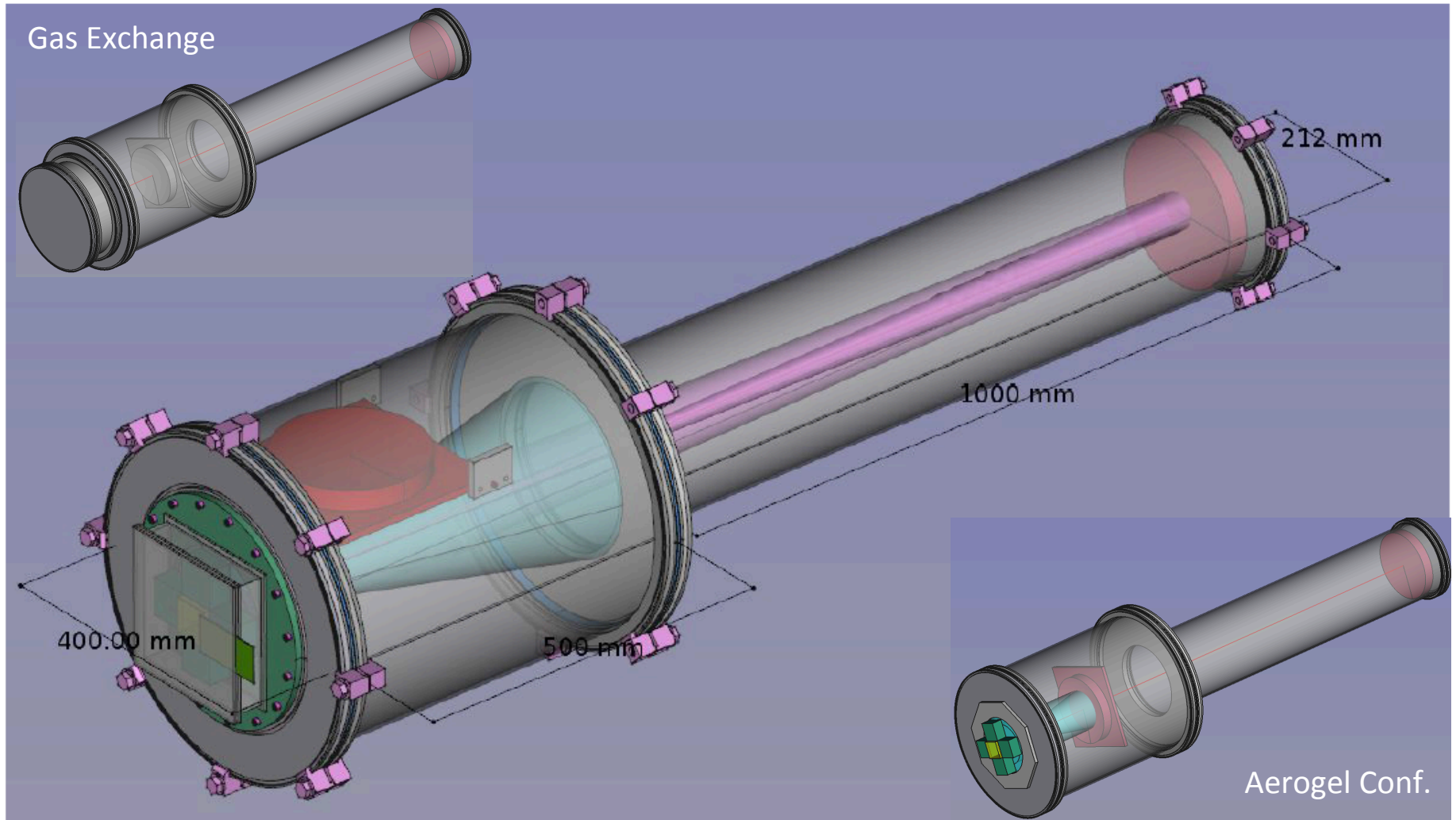
Optical bridge / PC Desktop
Few FPGA units ~ 500 channels



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



dRICH Prototype Design

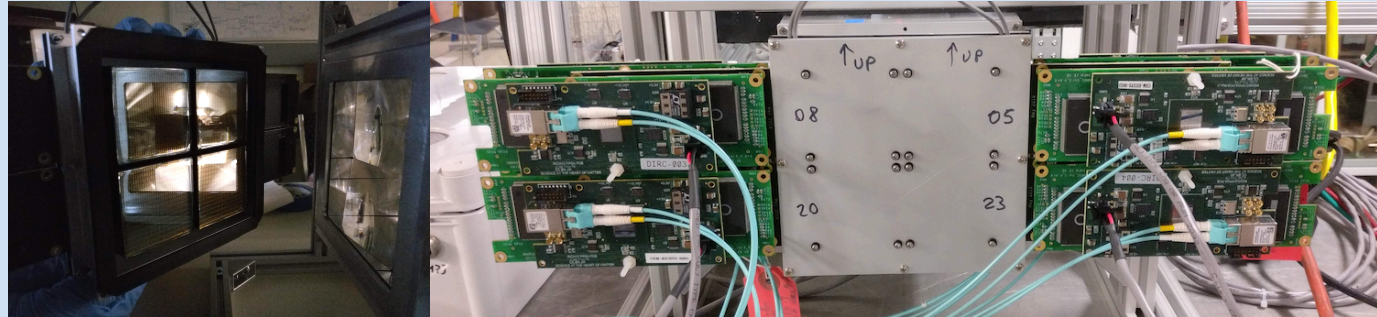


Commercial vacuum technology for safety and cost effectiveness
Overlapping rings for parallel beam particles

dRICH Prototype Test

Readout box

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



Sensors

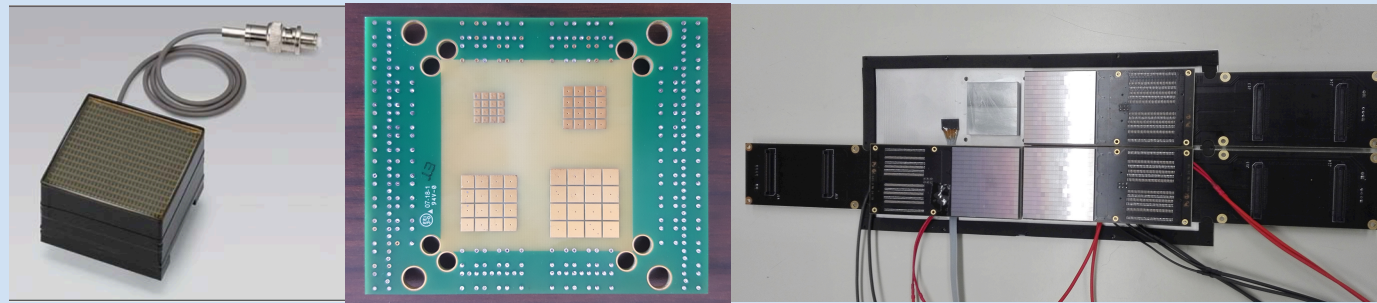
Reference:

MA-PMTs

B-field tolerant:

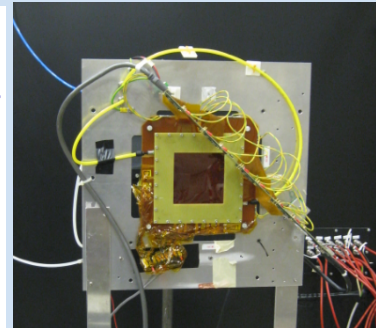
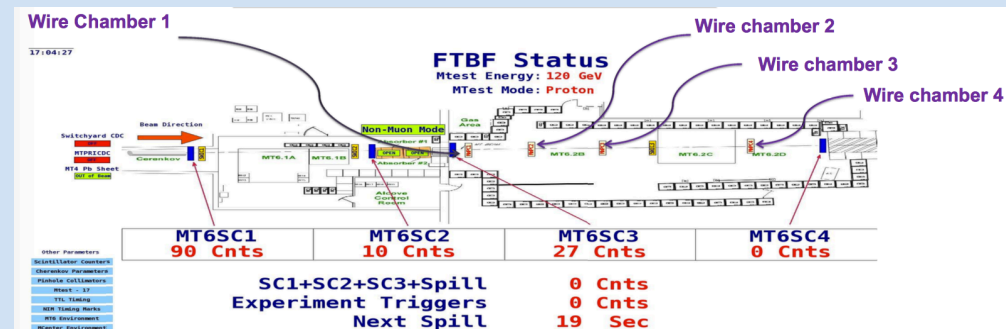
MCP-PMTs (LAPPDs)

SiPMs



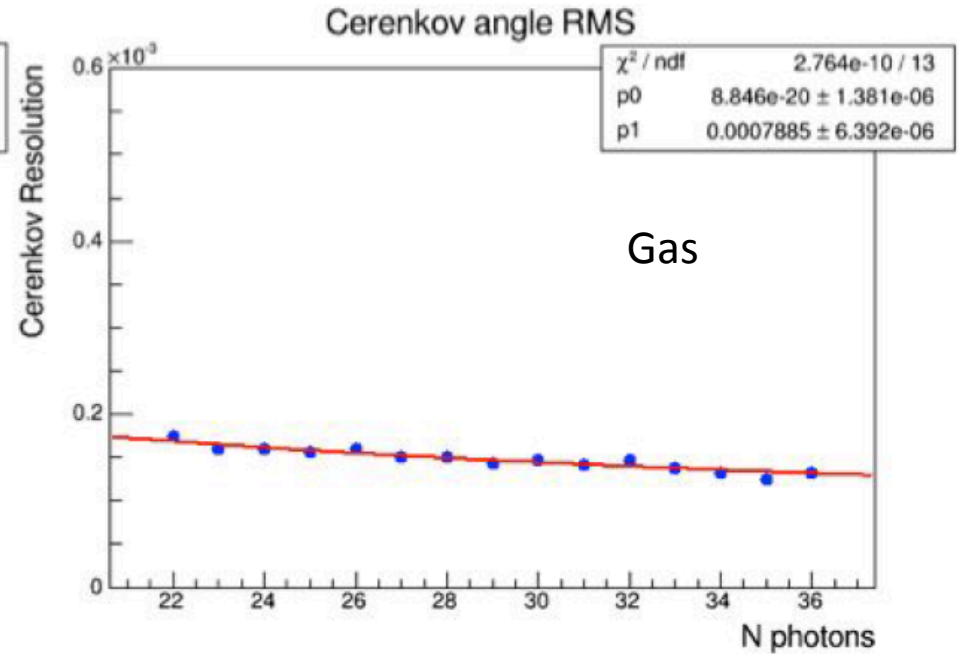
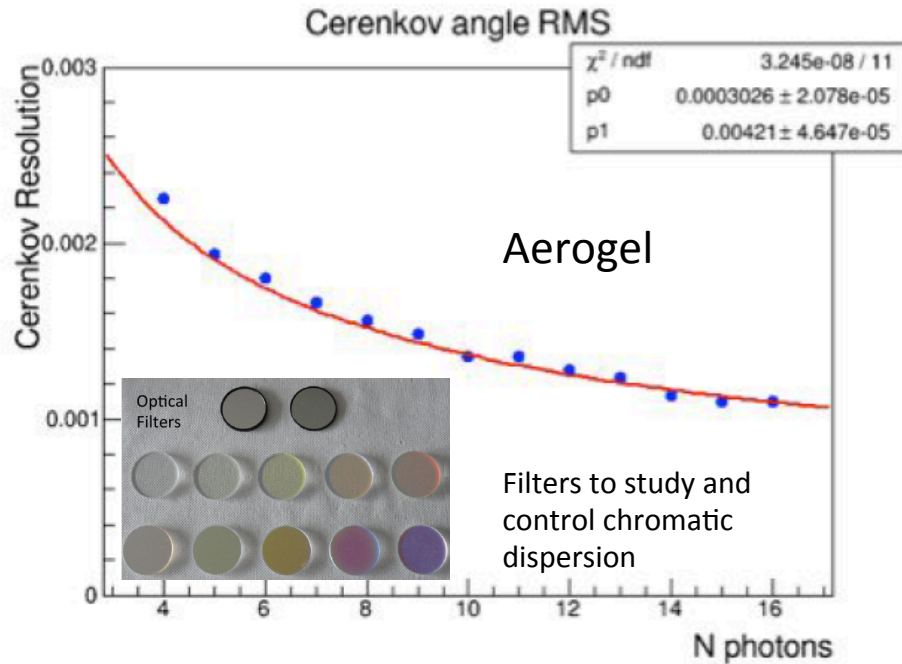
Ancillary Systems:

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



dRICH Prototype Performance

Montecarlo simulation



1 p.e. Error (mrad)	Aerogel		C ₂ F 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)

Pulsed Laser Test Benches

Detailed characterization

Sensors: gain, efficiency, cross-talk, radiation tolerance

Electronics: gain, cross-talk, thresholds, time resolution

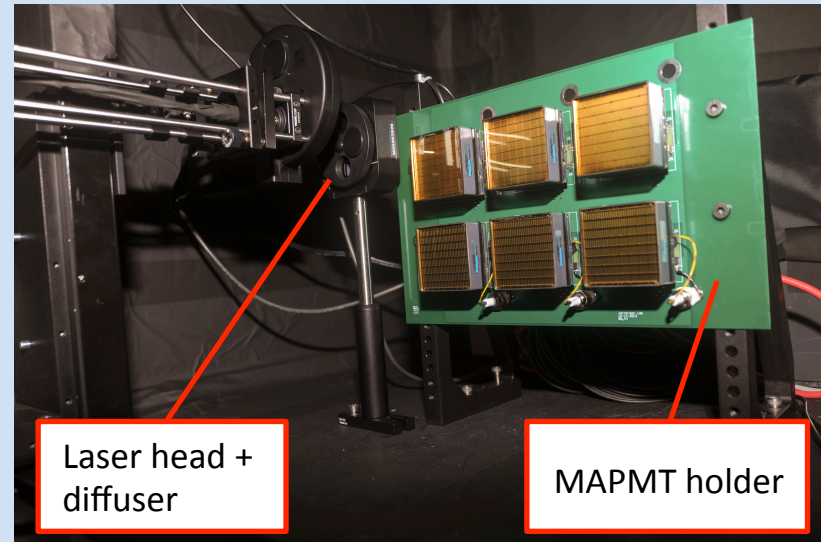
JLab

632 nm picosecond pulsed laser light

Light diffuser to illuminate the whole MAPMT surface

Standardized system with CLAS12 electronics

H8500 6x6 mm² pixel sensor so far



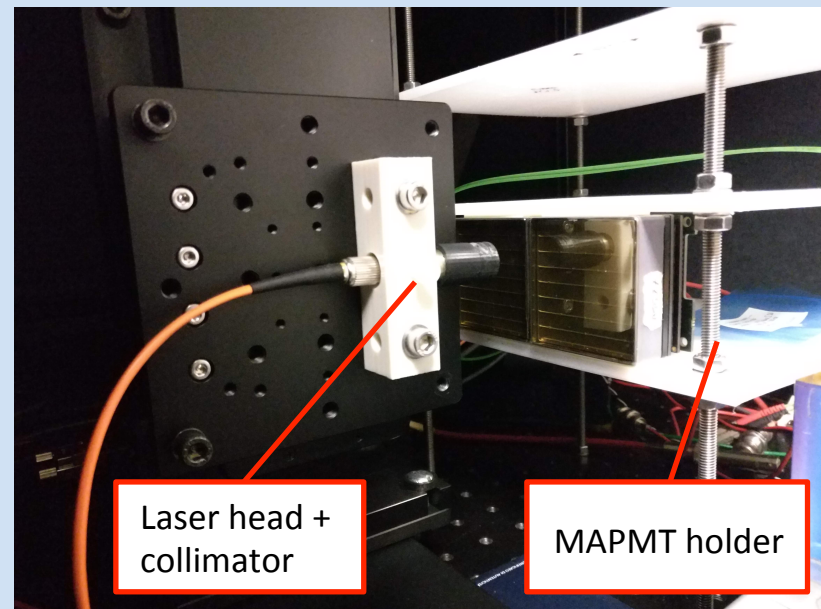
INFN

632 nm and 407 nm picosecond pulsed laser light

Light concentrator to scan the sensor surface

Flexible layout supporting various sensors and

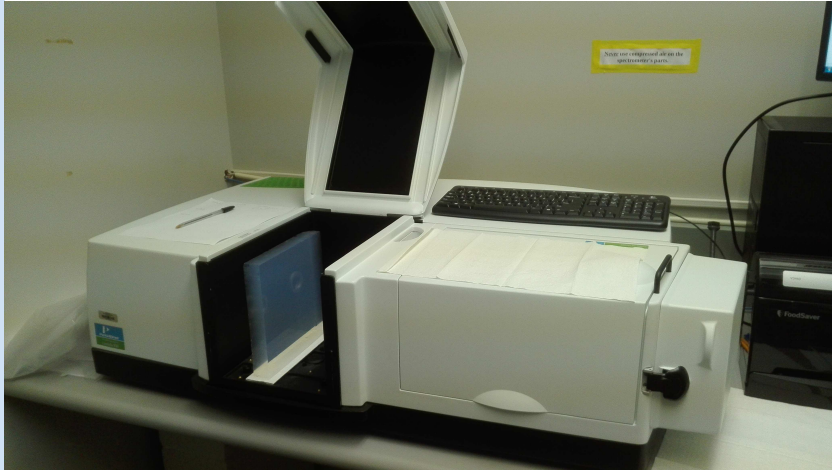
Front-End electronics



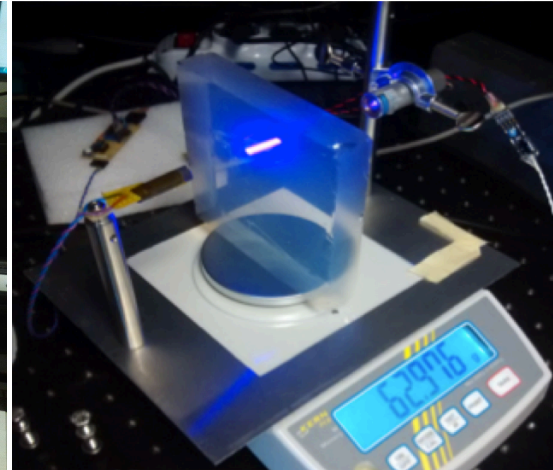
Aerogel Test Laboratory

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

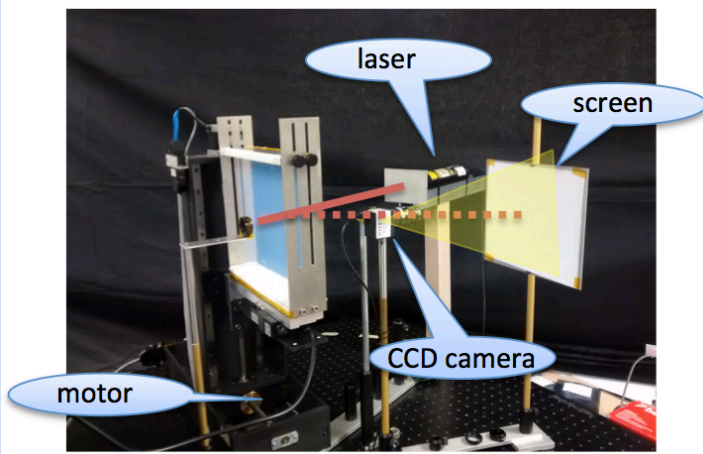
Spectrophotometer



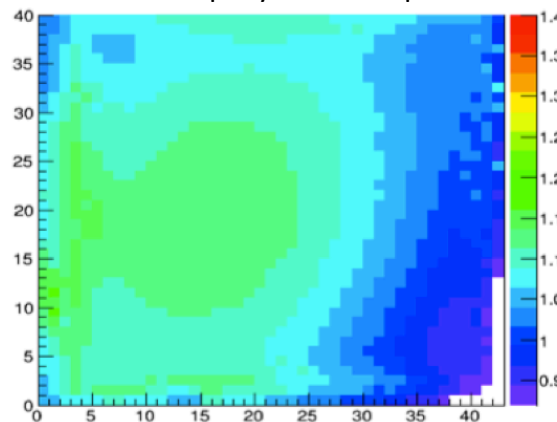
Characterization station



Controlled storage

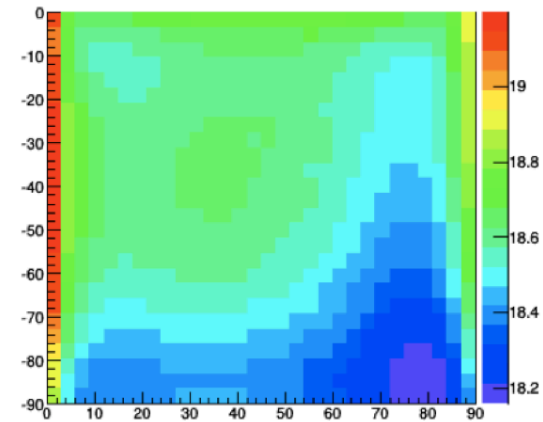


Surface map by laser setup



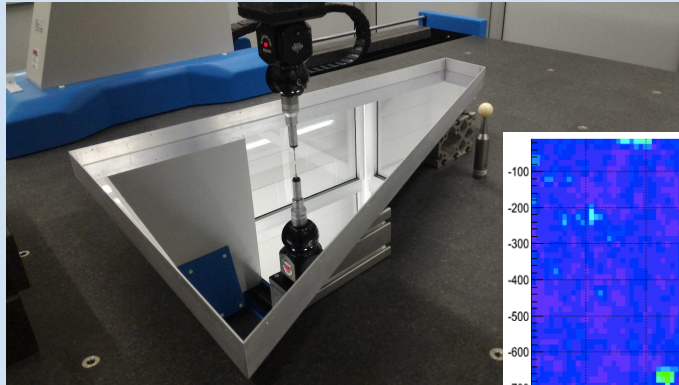
vs

touch machine

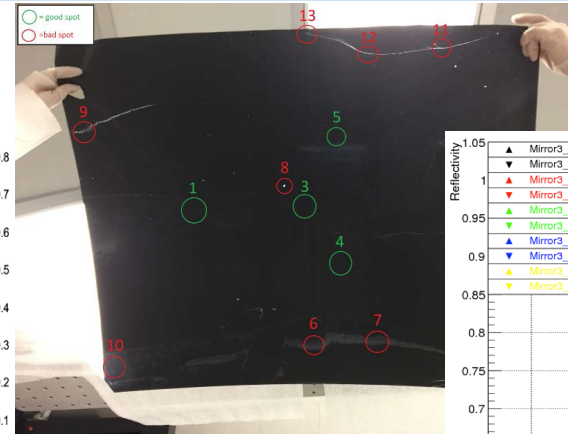
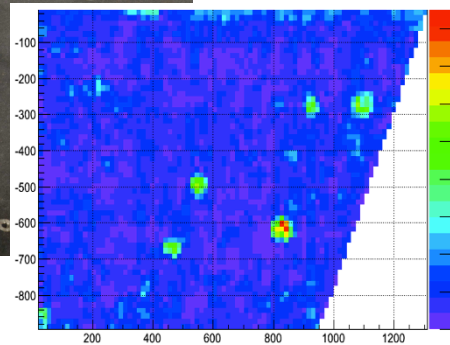


Mirror Test Laboratory

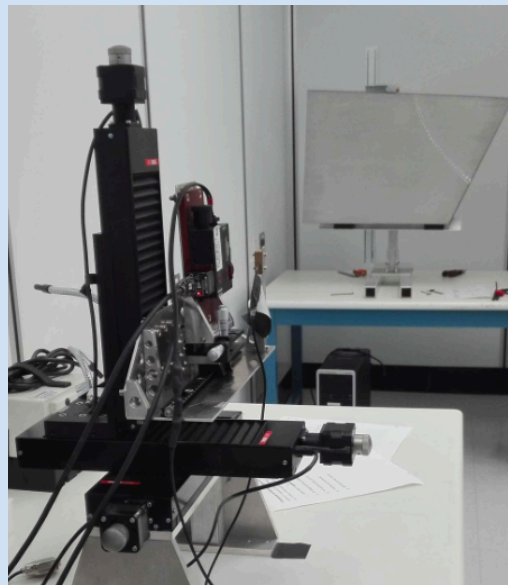
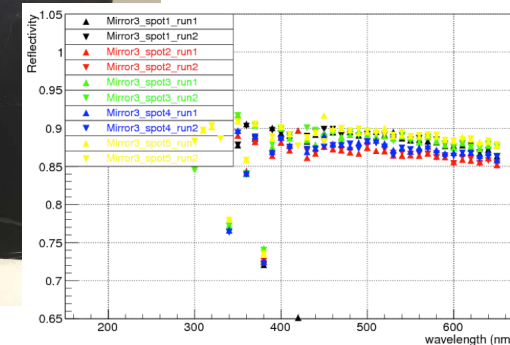
Existing facility to study detailed mirror optical properties
(surface map, radius of curvature, reflectivity)



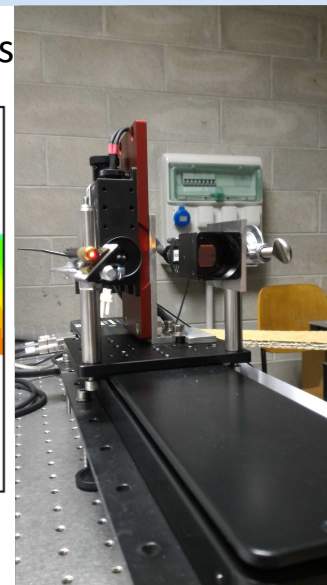
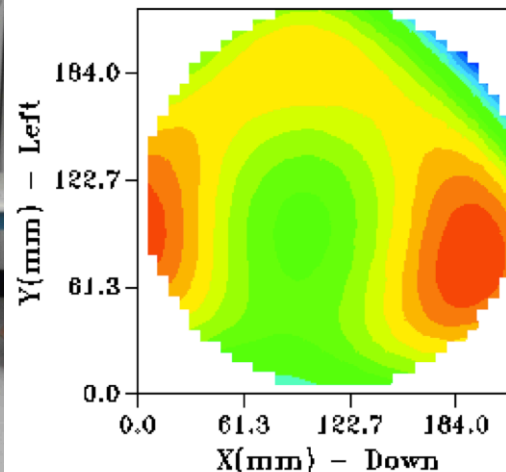
Planarity



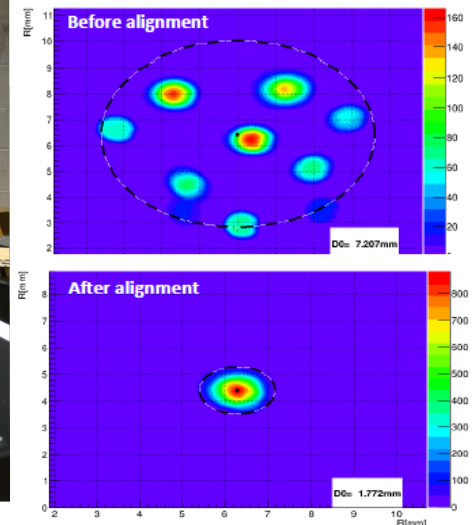
Reflectivity



Shack-Hartmann: Aberrations

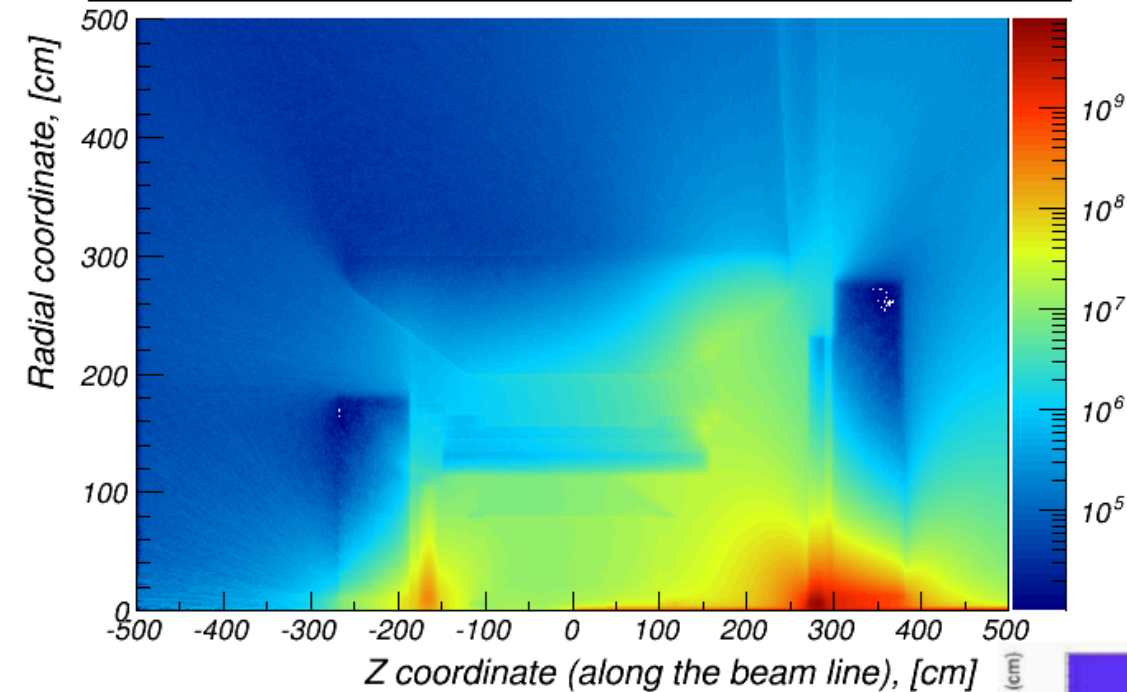


Point Image: Alignment



EIC Detector Environment

neutron flux above 100.0 keV in $[n/cm^2]$ for 1.0 fb^{-1} integrated luminosity



Neutron Fluence

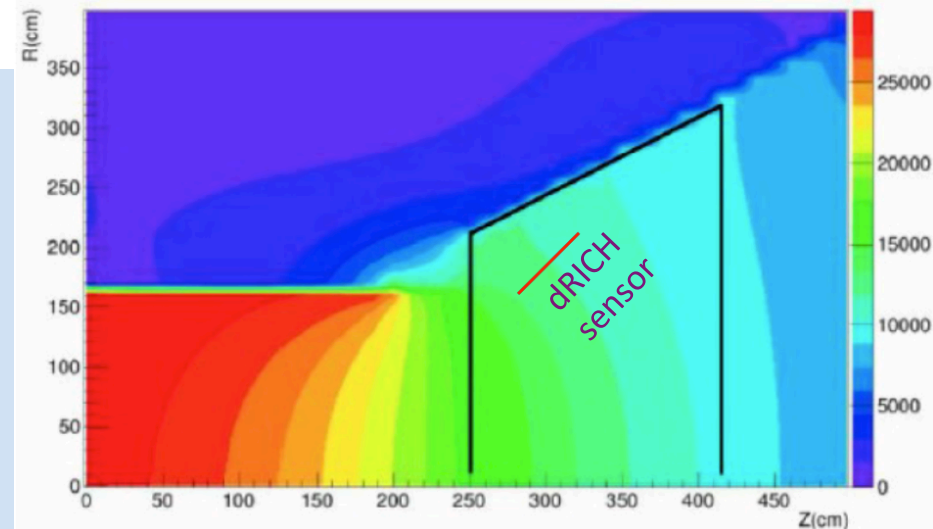
Under control outside the calo's

Reference value $\sim 10^{11} n_{eq}/cm^2$

Magnetic Field

$\sim 1 \text{ T}$ order of magnitude

Detector orientation to be tuned

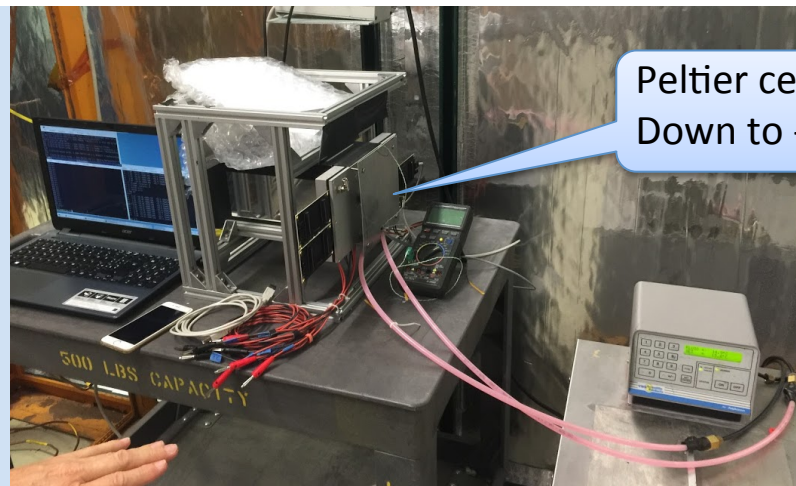
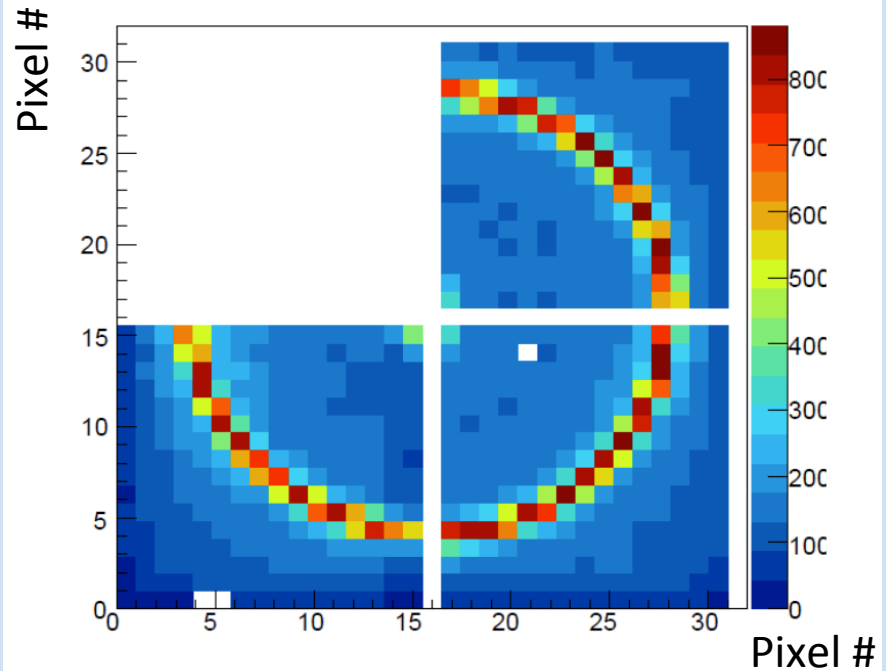


SiPM Option

Viable solution with cooling



Test of SiPM with RICH electronics

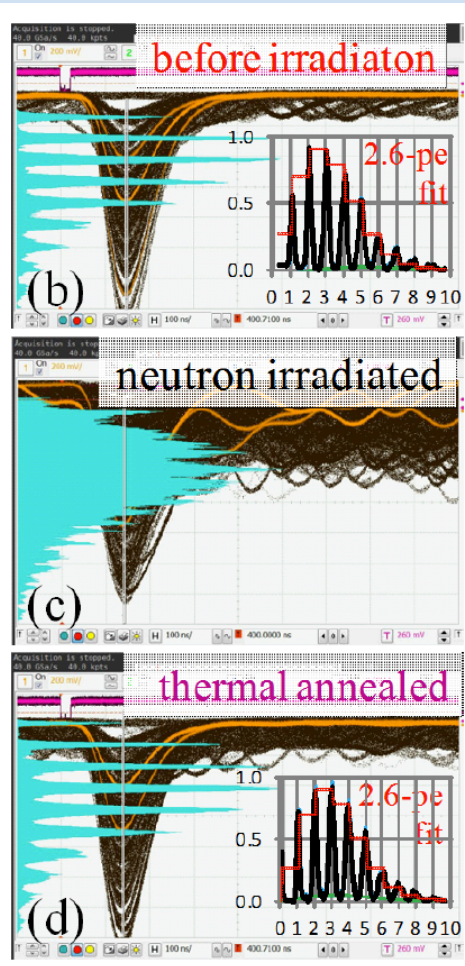


SiPM Radiation Tolerance

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

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

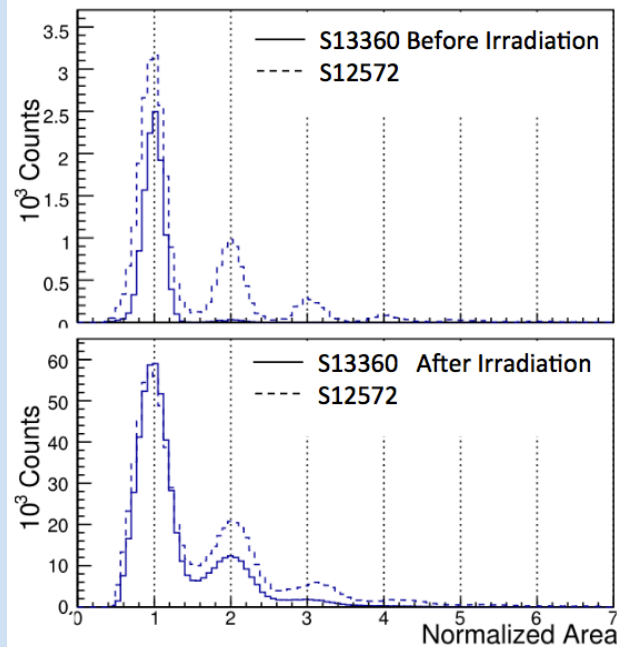
Paolo Carniti
@ RICH 2018



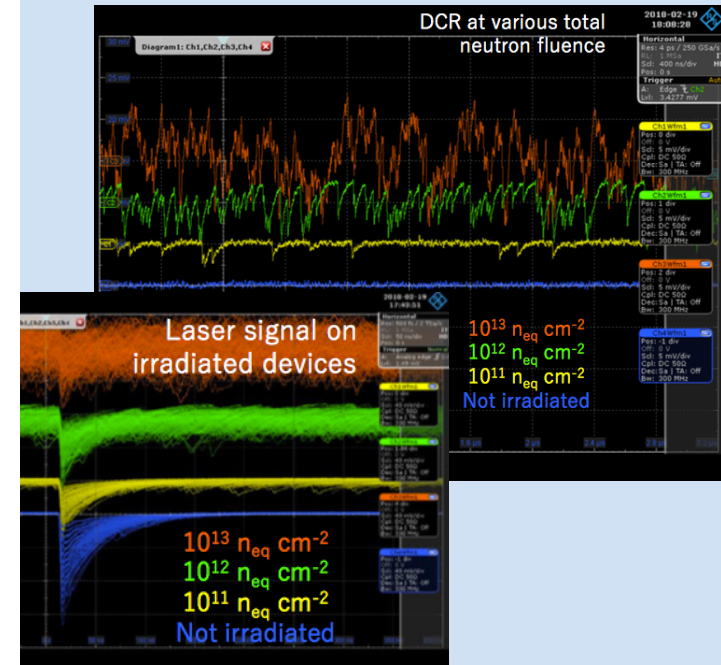
$T = 25\text{ C}$
 $10^9\text{ n}_{\text{eq}}\text{ cm}^2$
 Annealing at 250 C

Single-photon capability after irradiation ?

S12572 standard technology
 S13360 trench technology



$T = 0\text{ C}$
 few $10^9\text{ n}_{\text{eq}}\text{ cm}^2$

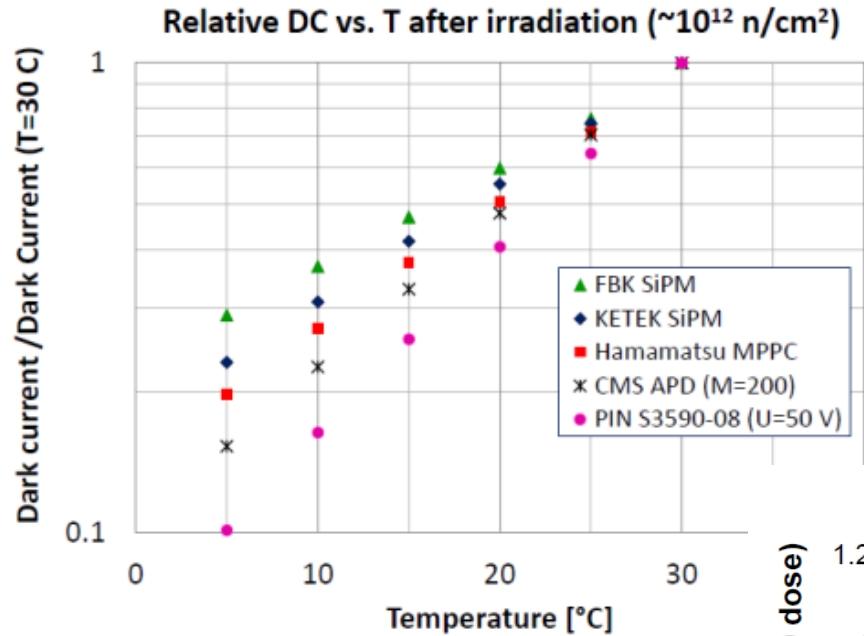


SiPM: Hamamatsu S13360-1350CS (50 μm cells)

Temperature: -30 C

Bias: $V_{\text{BR}} + 1.5\text{ V}$

SiPM Radiation Tolerance

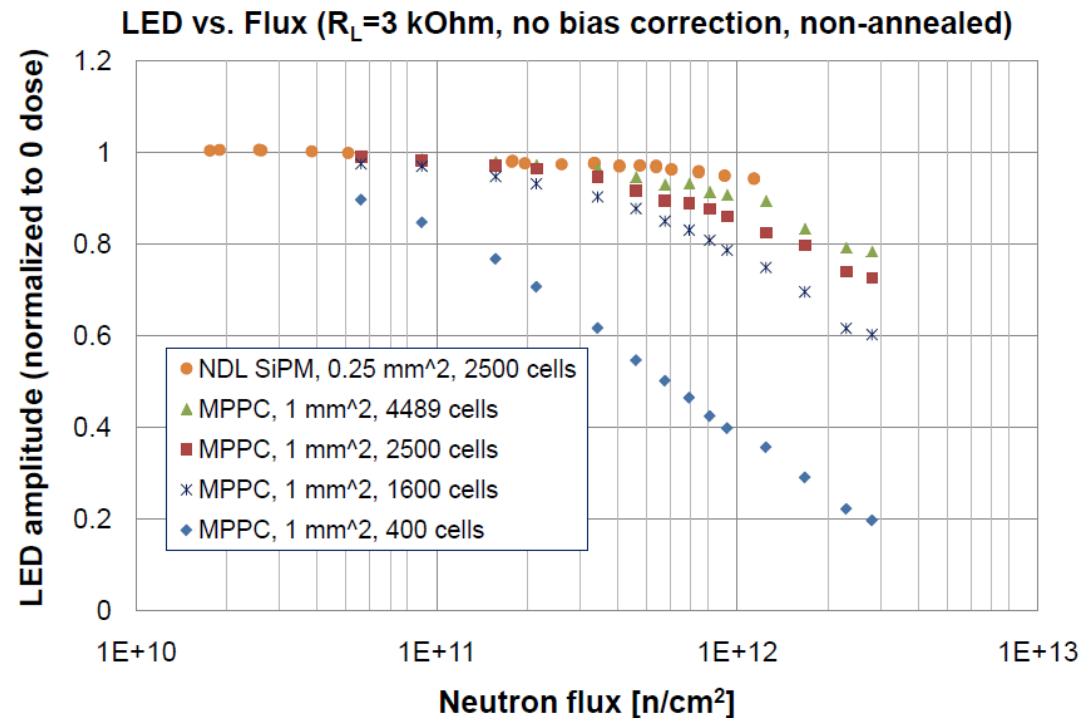


General trend is that SiPMs with high VB value have faster dark current reduction with the temperature

Yu. Musienko @ DIRC2019

SiPMs with high cell density and fast recovery time can operate up to $3 \cdot 10^{12}$ neutrons/cm² (gain change is < 25%).

- + Low/uniform field
- + Entrance window
- + Packaging (Dt, 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 Cooling							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)												50		30			150	
Travel (Test-beam)								12			12	8				12	56	40
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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 Cooling							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
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Post-doc (Design)				20								50		30			150	
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SiPM Cooling												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

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
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SiPM Cooling							10					10				10	30	20
Total personal				44				120				120				42	326	40
Total material				18				110				120				90	338	110

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 assessments (SiPMs, mirrors)

BACKUP

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	