Sviluppi per identificazione di adroni con tecniche Cherenkov ad immagine

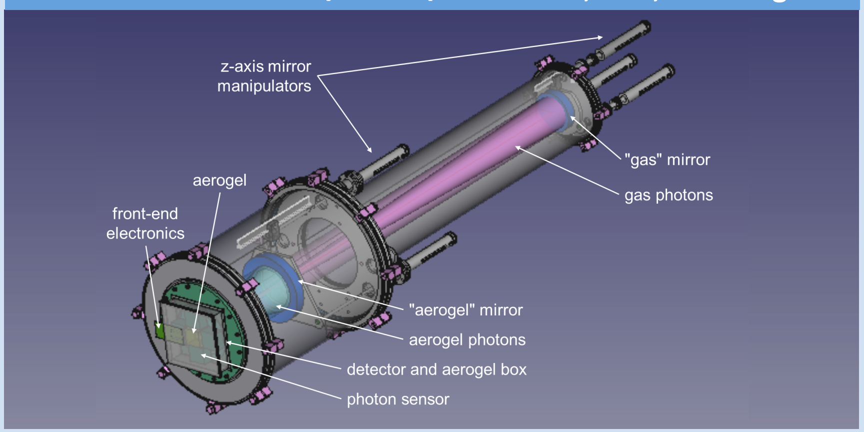
INFN R&D activity part of

eRD14 - EIC PID Consortium: An integrated program for PID at a future EIC

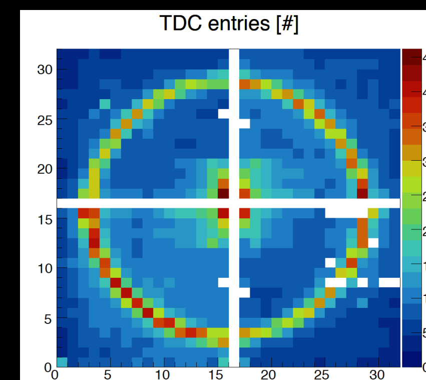
Sharing of sensors (e.g. LAPPD), electronics, infrastructures and expertise

Access to various readout architectures (sampling vs discriminating) and novel DAQ (ethernet, streaming)

Dual radiator RICH (dRICH) — DUKE, SBU, Edinburgh U.

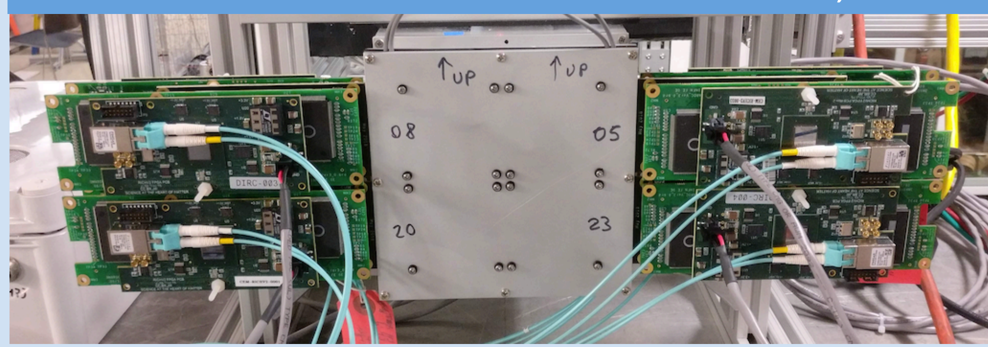


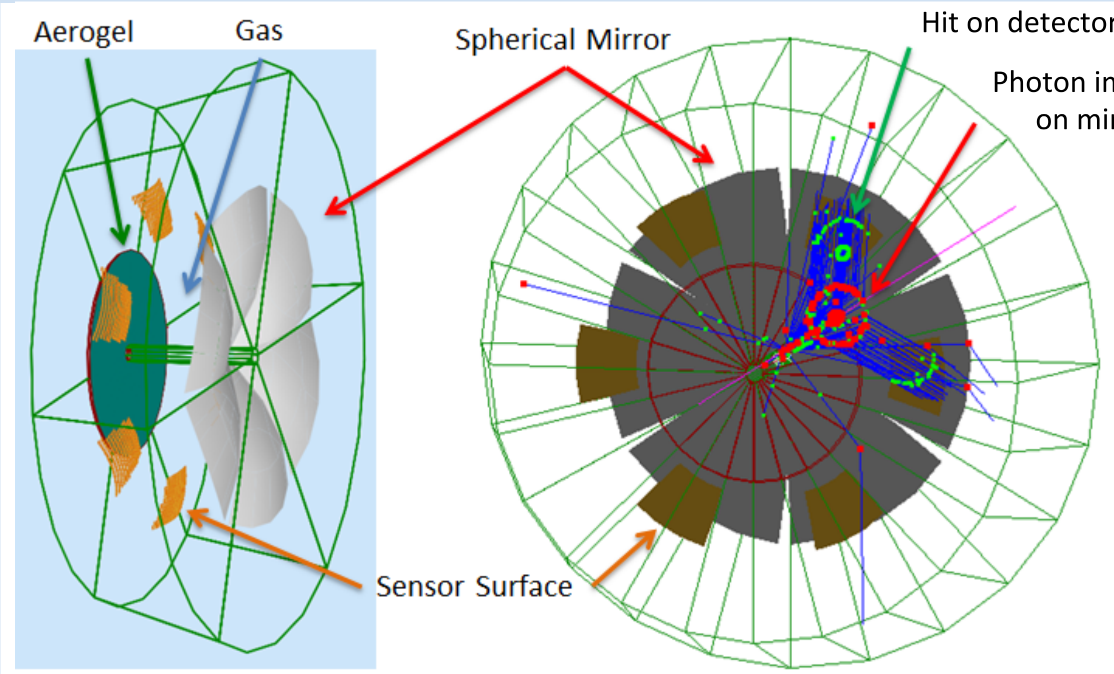
Modular RICH (mRICH) — GSU

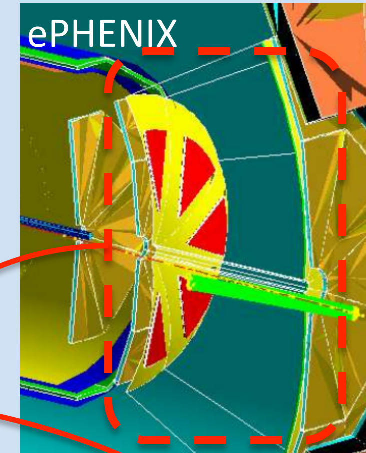


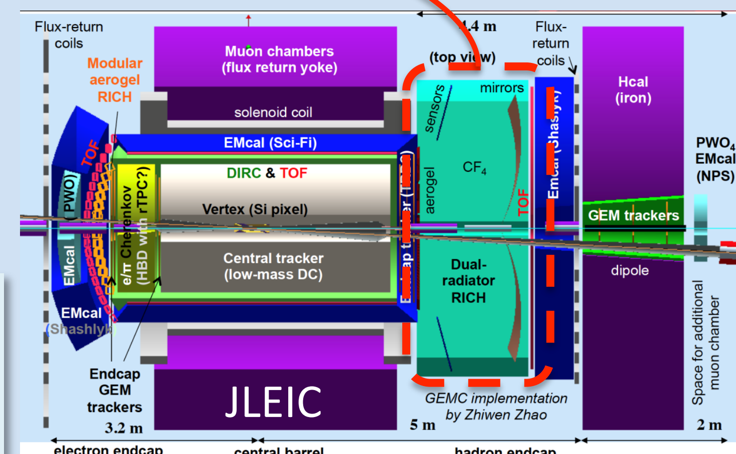
SiPM

Electronics — JLab, U. Hawaii









dRICH: flexible configuration (JLEIC, ePHENIX)

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

Detector: 0.5 m^2/sector , 3x3 mm^2 pixel

Single-photon detection in ~1T magnetic field

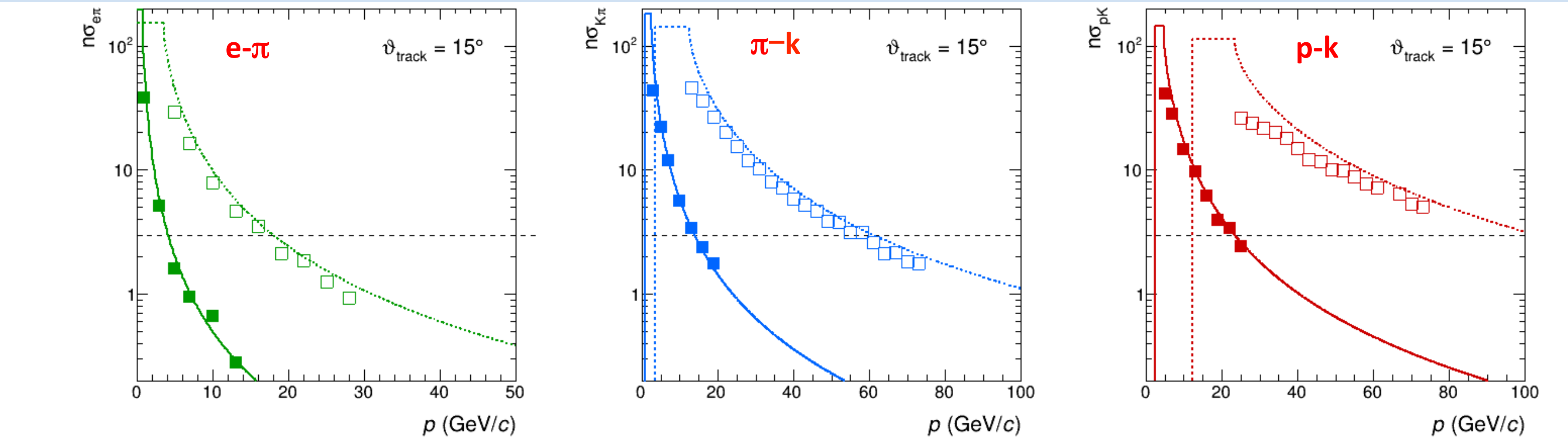
Outside acceptance, reduced constraints

→ best candidate for SiPM option

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

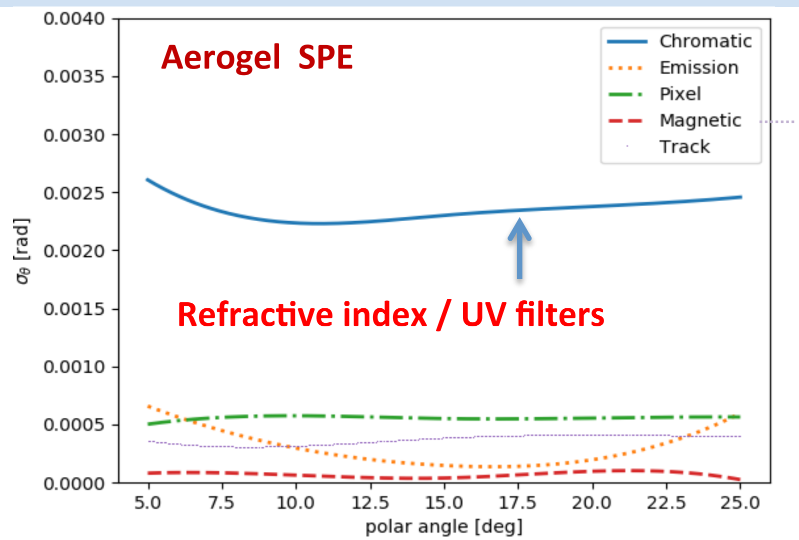
dRICH Feasibility Study

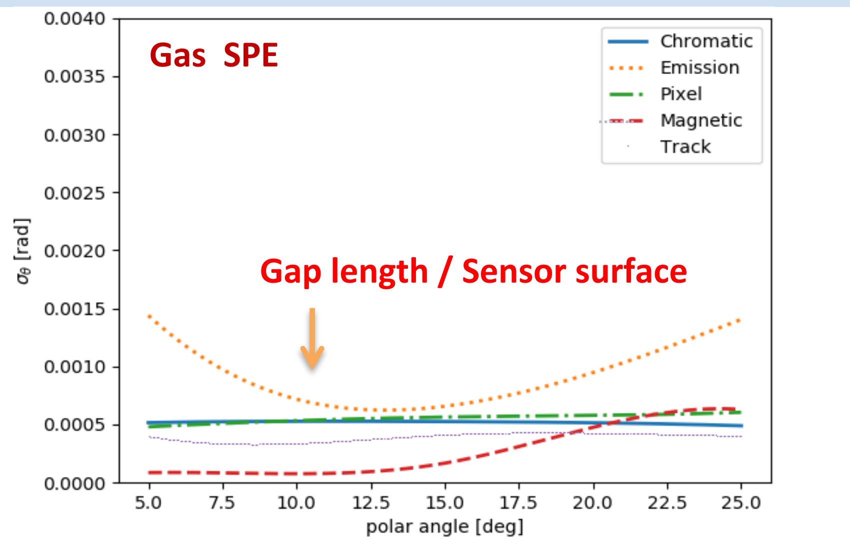
Compact and cost-effective solution for continuous momentum coverage (3-60 GeV/c)
Strong interest in the dRICH electron-pion separation capability



Studied with full Geant4 simulation, with Bayesian optimization and analytic parameterizations

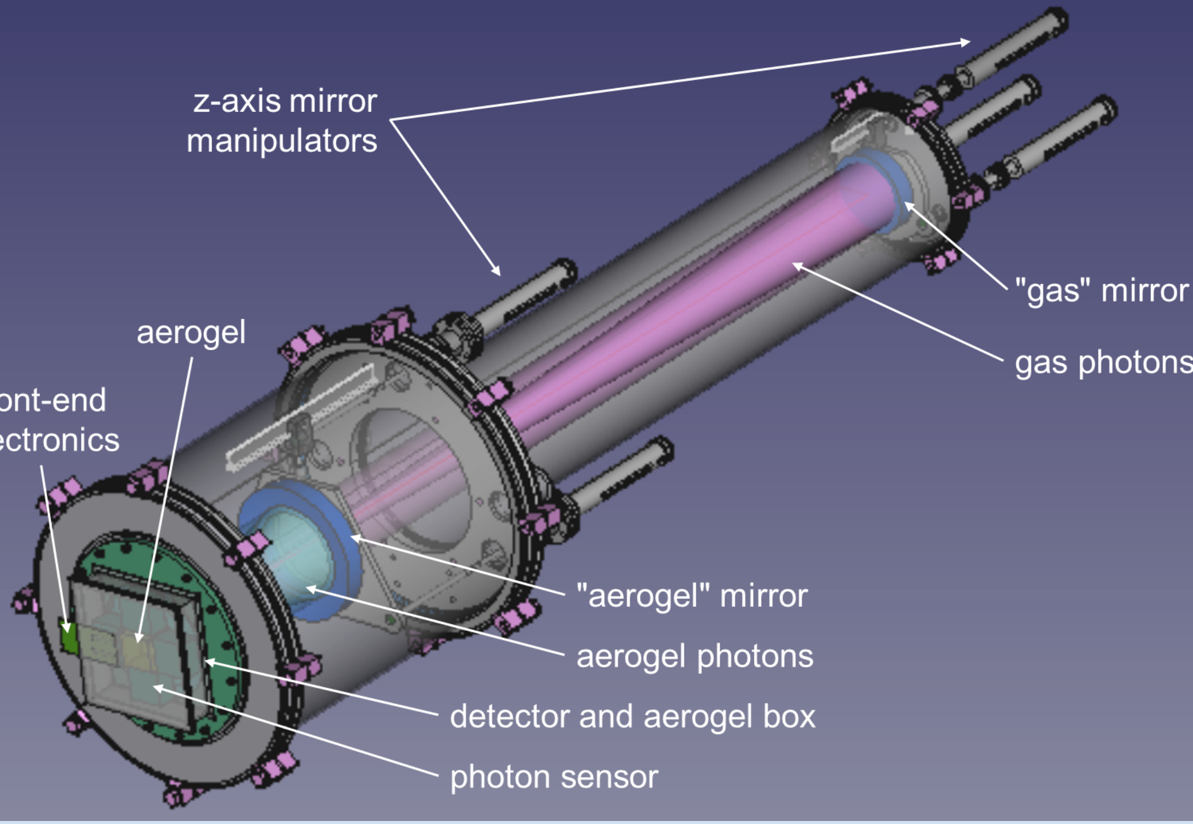
L. Barion et al., JINST 15 (2020) 02, C02040
E. Cisbani et al., JINST 15 (2020) 05, P05009





dRICH Prototype

Dual radiator imaging
Pressure vessel for gas & n tune
Sensor & readout friendly



Test-beams FY21 options (post COVID-19):

- Fermilab with SBU
- JLab
- CERN / DESY

Baseline design ready:

being refined following
* Yellow-report discussions
* EIC R&D advices
* SiPM program requirements

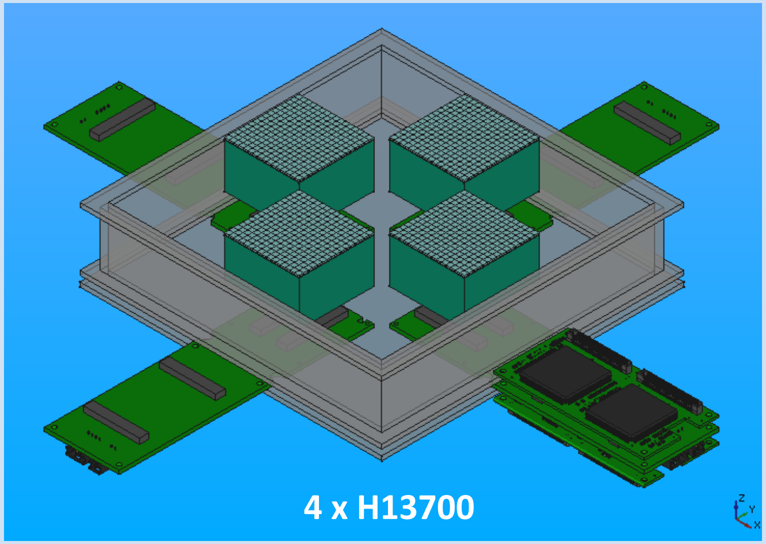
Procurement initiated (INFN in-kind):

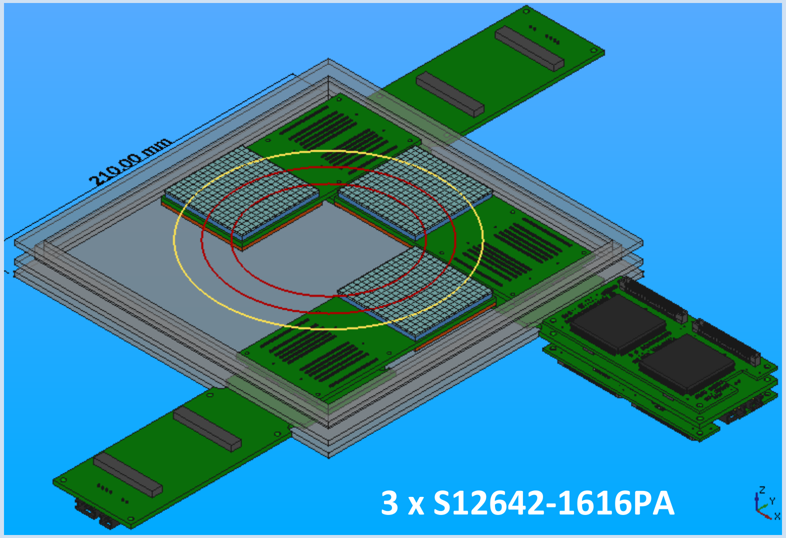
- Aerogel (n=1.02, n=1.03)
- Standard vacuum components (pipes, clamps, o-rings)
- Custom flanges

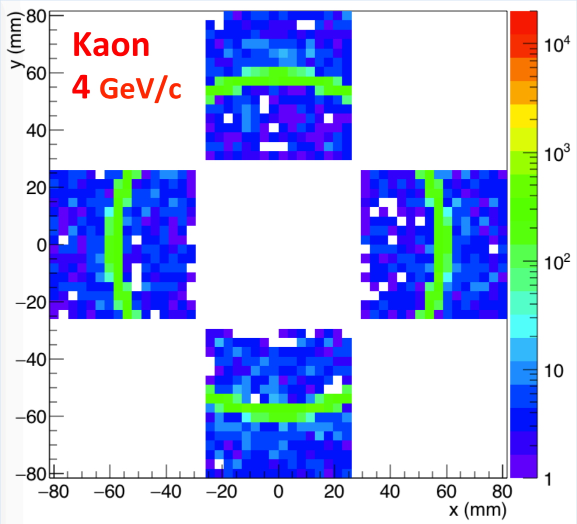
Survey ongoing:

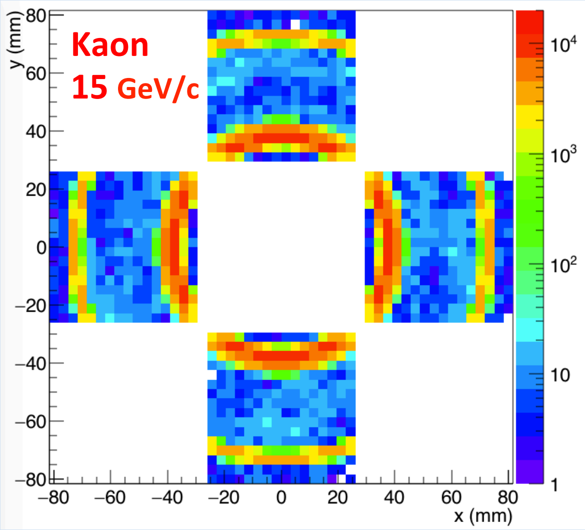
- Gas / mirrors / mechanics

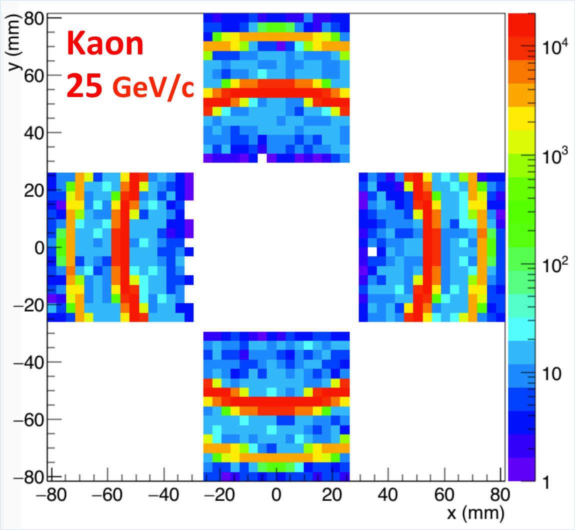
House the same principles and readout units used for mRICH test-beams
Compatible with H13700/S12642 + MAROC front-end
Allows to study the working principles and optical performance of the components







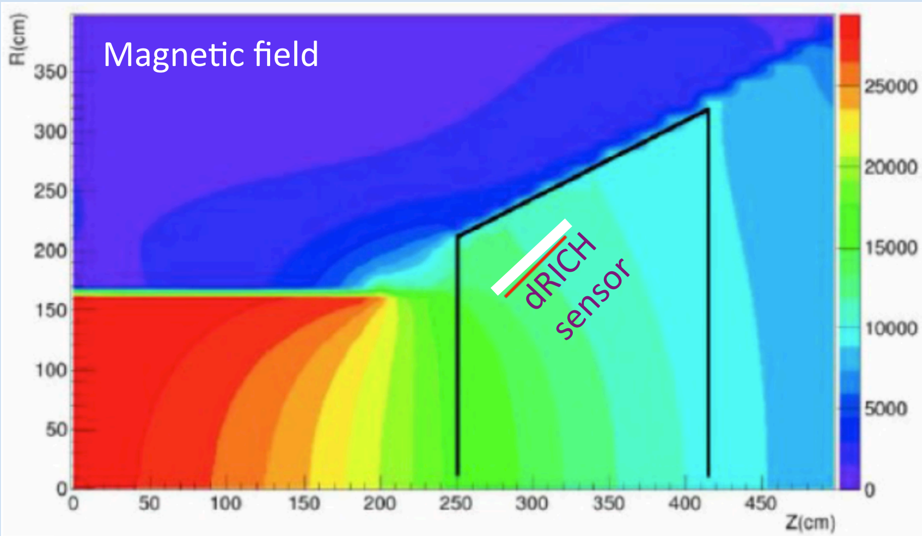


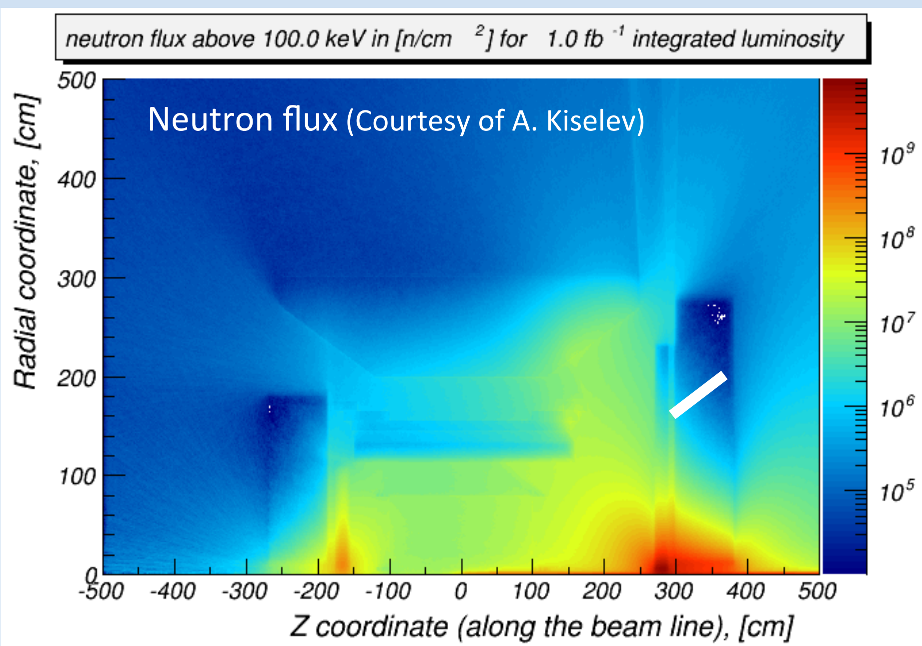


dRICH Key Hardware Components

Component	Function	Specs/Requirements	Critical Issues / Comments
Mechanics	Support all other components and services Keep in position and aligned	Large volume gas and light tightness; alignment of components	Technically demanding but feasible; no major challenges expected
Optics (Mirrors)	Focus (expecially for gas) and deflect photons out of particle acceptance and reduce sensor surface	sub-mrad precision reflectivity ≥ 90% low material budget	Spherical mirrors technology of CLAS12 suitable (optical fiber and/or glass skin); similar geometry; **Development for cost reduction**
Aerogel Radiator	Cover Low Mom. Range between TOF and Gas	$\geq 3\sigma$ π-K separation up to Gas region (~13 GeV)	Procurement: currently 1 active provider (2 main producers + 1 potential) **Long term stability assessment in conjunction with gas**
Gas Radiator	Cover High Mom. Range above Aerogel	$\geq 3\sigma$ π-K separation up to ~50 GeV and overlap to aerogel	Greenhouse gas: potential procurement issue **Search for alternatives**
Photon Detector	Single photon spatial detection	Magnetic field tolerant and radiation hardness; ~ few mm spatial resolution	MCP-PMT is likely doable, but expensive. LAPPD may represent an alternative. **R&D on SiPM:** a promising, quicky improving, wordwide pursued, and cheap technology.
Electronics	Amplify and shape single photon analog signal, convert to digital, transfer to DAQ nodes	Low noise Time res. ~ 0.5 ns μs signal latency	MAROC3 based readout available for prototyping; final choice will depend on sensor. **ASIC development for optimised streaming readout (discrimination vs sampling)**

dRICH Detector Environment





dRICH sensor location relaxes requirements on neutron dose tolerance and material budget

Magnetic Field

~ 1 T order of magnitude, varying orientation

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

Neutron Fluence

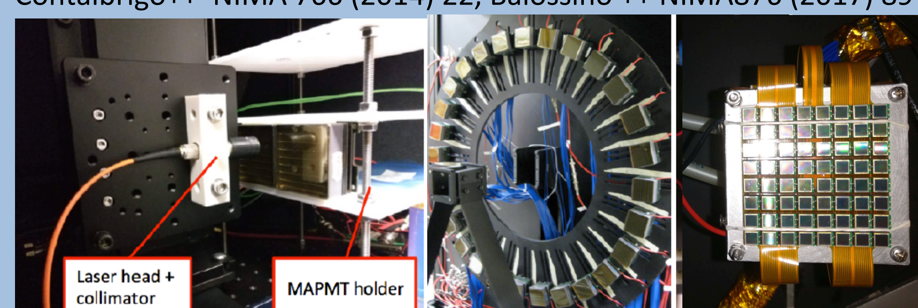
~ 10^{11} n_{eq}/cm^2

reference value for several years at max lumi (10^{34})

SiPM: radiation mitigation for SPE actively studied till 10^{11} n_{eq}/cm^2 and above 10.1016/j.nima.2019.01.013 10.1016/j.nima.2018.10.191

SiPM SPE capability under study since 2012 @ INFN

Contalbrigo++ NIMA 766 (2014) 22, Balossino ++ NIMA876 (2017) 89



SiPM & Electronics

SiPM board*: 4 SiPM samples for each vendor, type and dose mounted as 8 x 4 matrices for tests & imaging; compatible with irradiations, annealing cycles and laboratory characterization

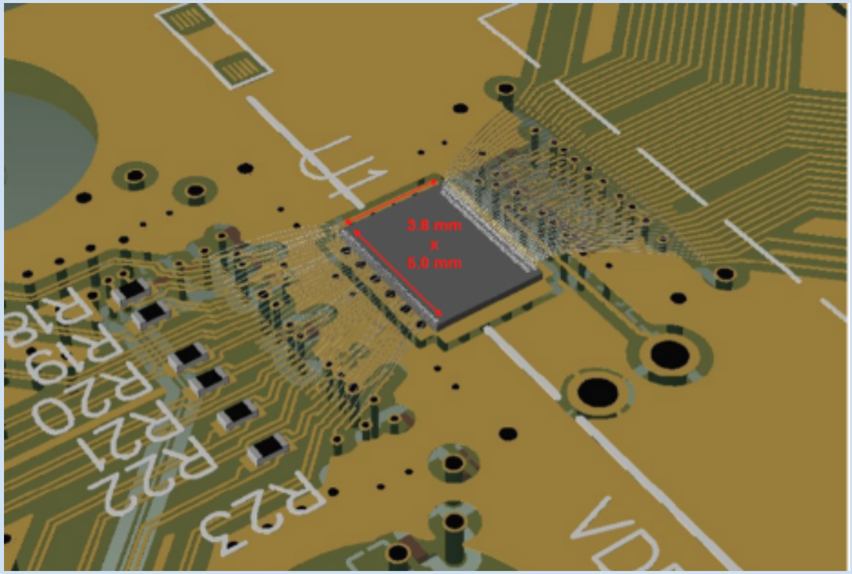
(**Adapter board*:** bias distributors and signal pre-conditioning)

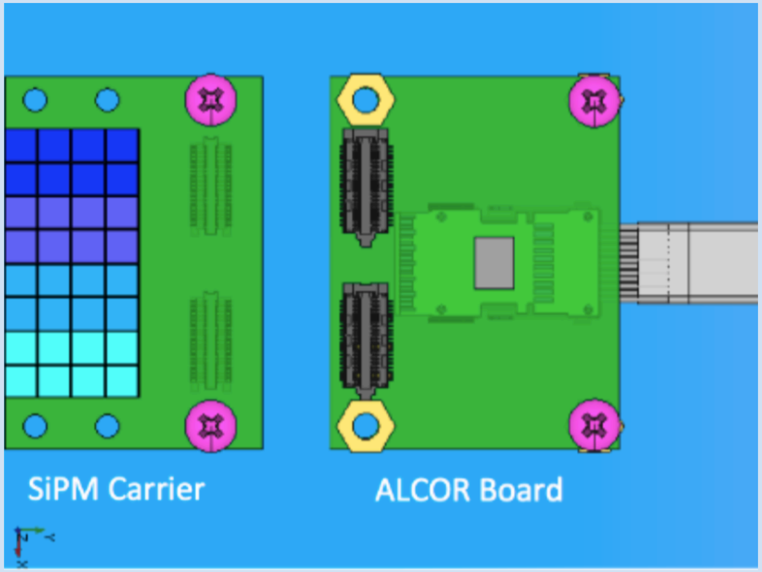
ALCOR board*: ALCOR chip + firefly DAQ

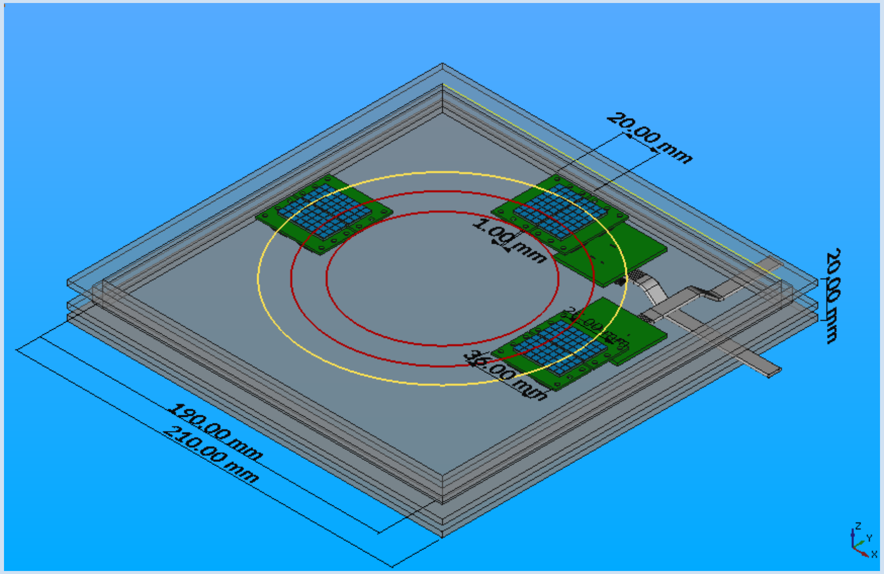
* Customized

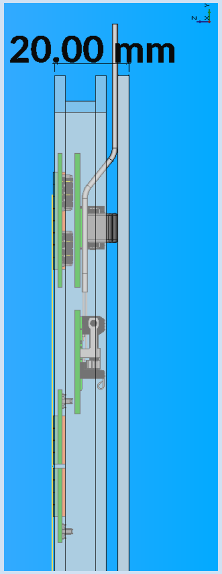
ALCOR chip: under development at INFN (DARKSIDE)
ToT architecture for cryogenic application
32 channels, 50 ps TDC, >500 kHz/channel

Firefly DAQ: derived from ARCADIA INFN GR5 project









Conclusions

Activity plan in line with the EIC R&D Committee recommendations for TDR readiness in 2023

To address crucial PID aspects at EIC synergic with other R&D programs (gaseous RICH, electronics, sensors):

cost-effective compact solution for hadron PID in the forward region in a wide kinematic range
in 1 year: baseline prototype completion and first test-beam

investigation of novel single-photon detector solution to be operated in high magnetic field
in 1 year: post-irradiation characterization and imaging of a status-of-the-art SiPM selection

Fund request:

EIC R&D (personnel)	~ 80 k$
INFN (Prototype baseline configuration completion)	11 keuro (FE)
INFN (SiPM sensors/electronics/tests)	29 keuro (BO+FE)

Proposal to INFN: anticipate a substantial fraction this year (new program, more groups)
'20 & '21 shared investment for 7 already active groups (Bo/Ct/Fe/LNF/Rm1/To/Ts) with a clear goal

Goal: have in ~1 year a full-chain assessment of the most innovative aspects/technology in preparation of the "Call for Detectors" expected in FY2021
(thanks to the past experience, the broad interest and the increased manpower/expertise)

Plan for TDR Readiness

Reviewed by the EIC R&D Committee in September 2019

2020

Prototype design, simulation and implementation

Basic mechanics
Electronics adaptation

Component test and selection

Start of INFN in-kind funds

SiPM program start

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

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
ALCOR v2

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
Custom SiPM selection

2021 Funding Plan

CON	Assegnazioni	Radiatore a gas (RM1)	3.0	0.0
	Assegnazioni	Sensori per sistema di slow control (FE)	2.0	0.0
	Assegnazioni	Sistema di allineamento specchi (CT)	4.0	0.0
	Assegnazioni	Sensori SiPM per irraggiamento	2.0	0.0
	Assegnazioni	Elettronica di front-end dedicata ai sensori	4.0	0.0
	Assegnazioni	Servizi e finestre accesso (LNF)	2.0	0.0
	Totale CON		17.0	0.0
TRA	Assegnazioni	Trasporti per test-beam	0.0	2.0
	Totale TRA		0.0	2.0

dRICH prototype

SiPM (Hamamatsu)