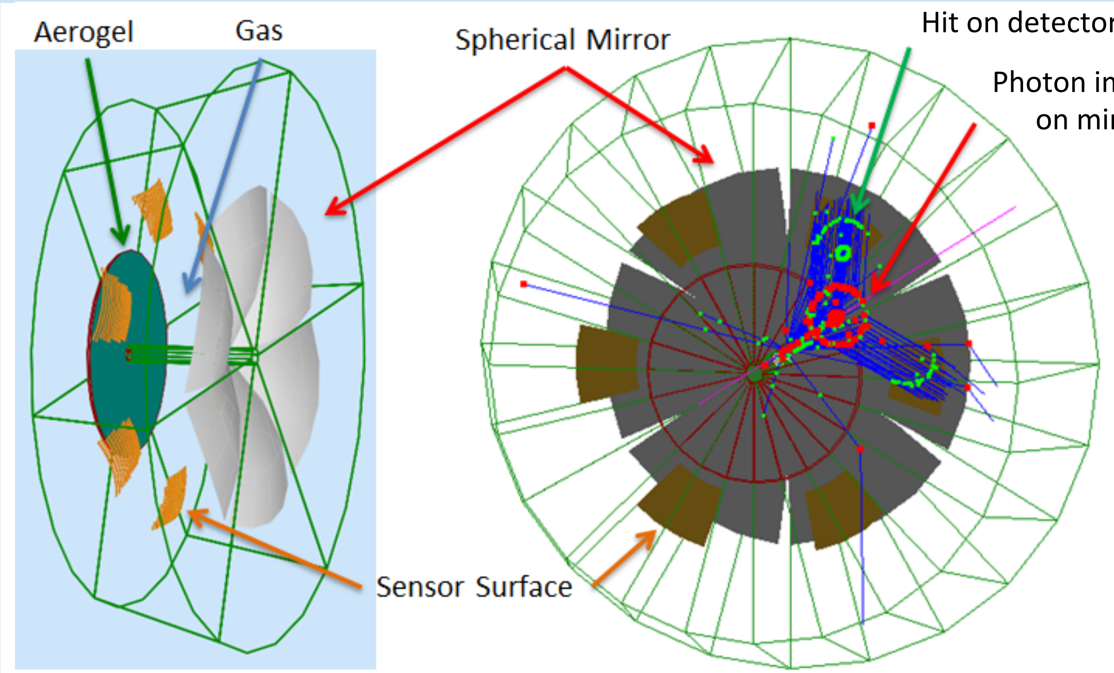
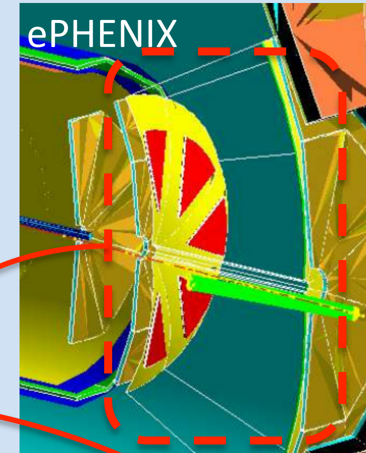
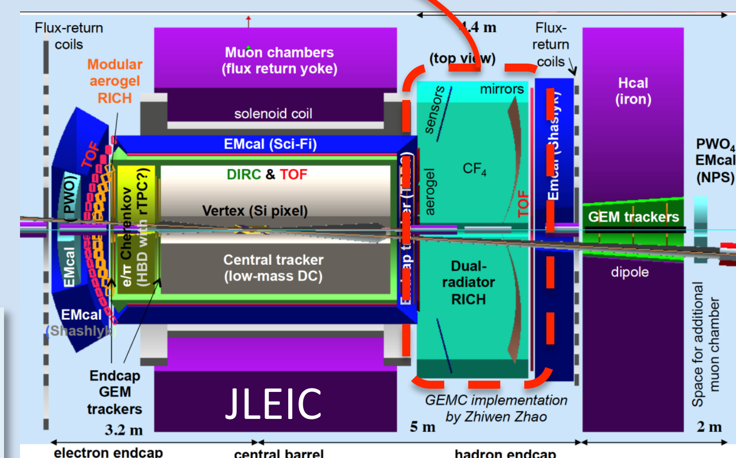
Dual Radiator RICH in EIC Hadron-endcap







INFN & DUKE

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

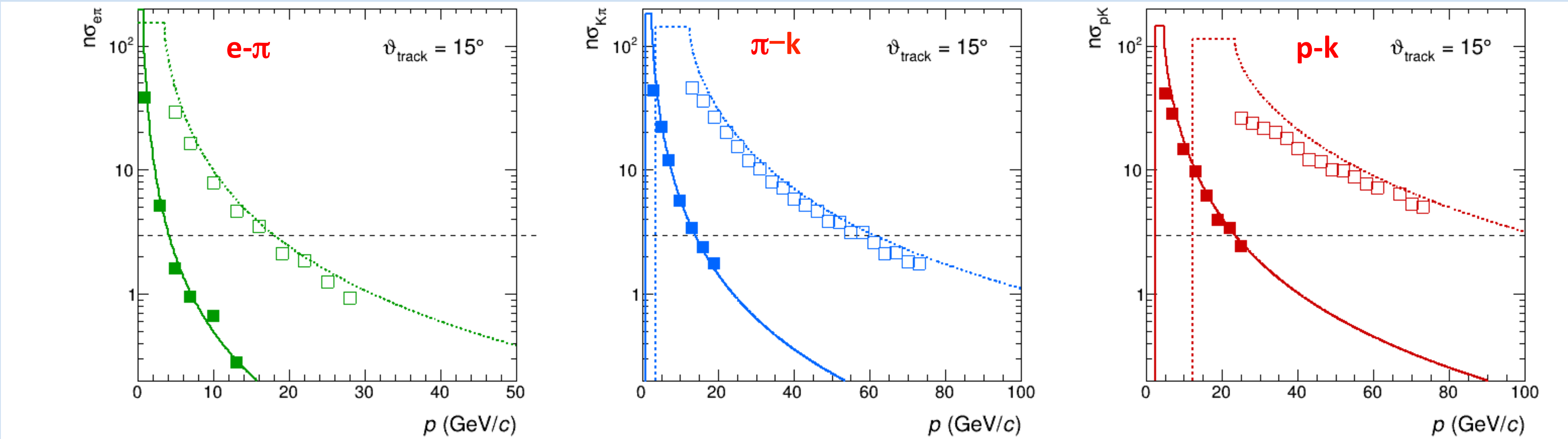
Outside acceptance, reduced constraints

→ best candidate for SiPM option

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

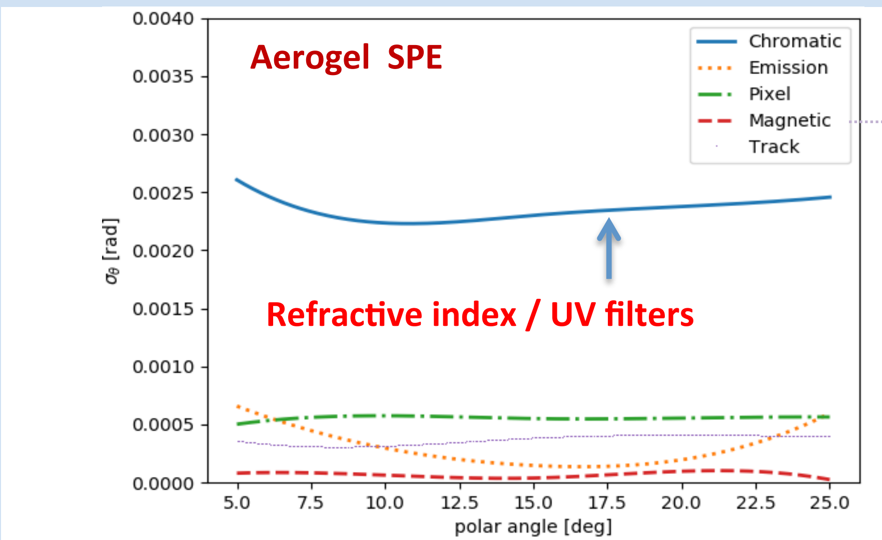
dRICH Feasibility Study

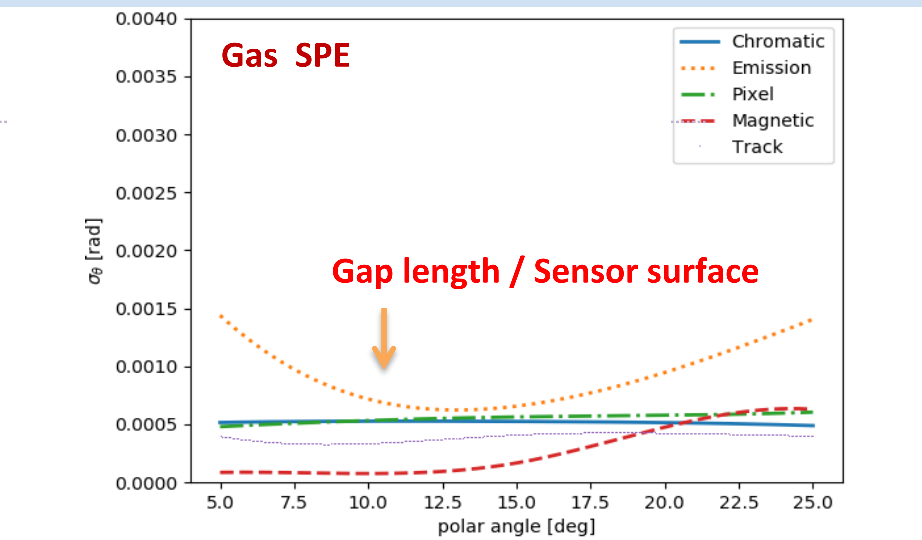
Compact and cost-effective solution for continuous momentum coverage (3-60 GeV/c)
Strong interest in the dRICH electron-pion separation capability



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

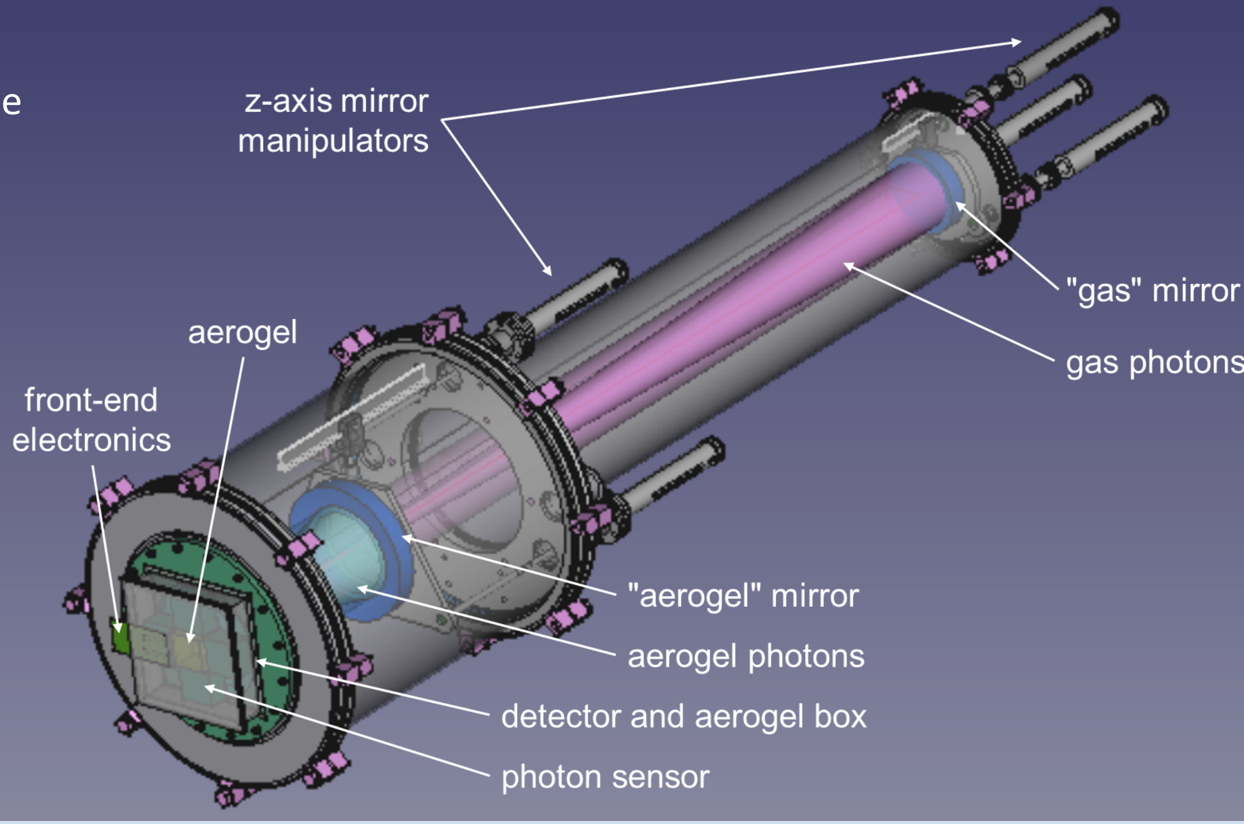
L. Barion et al., JINST 15 (2020) 02, C02040
E. Cisbani et al., JINST 15 (2020) 05, P05009





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

Procurement initiated (INFN in-kind):

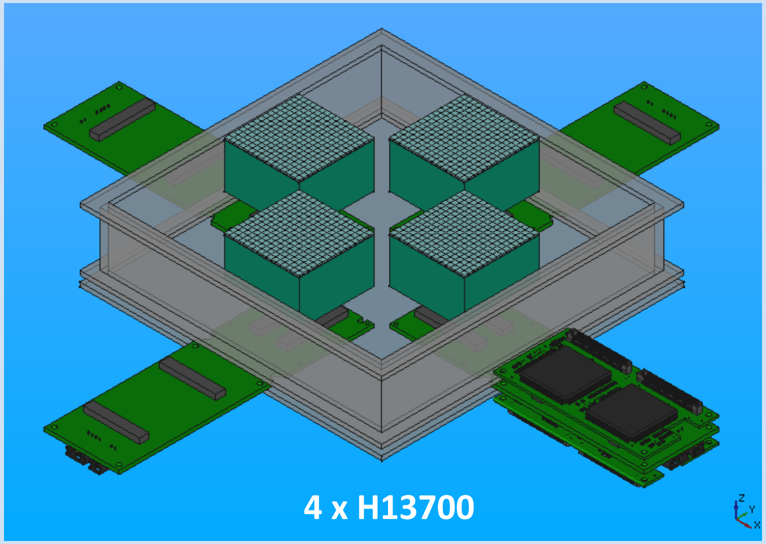
* Aerogel (n=1.02, n=1.03) with dimensions compatible with mRICH
- Standard vacuum components (pipes, clamps, o-rings)
- Custom flanges

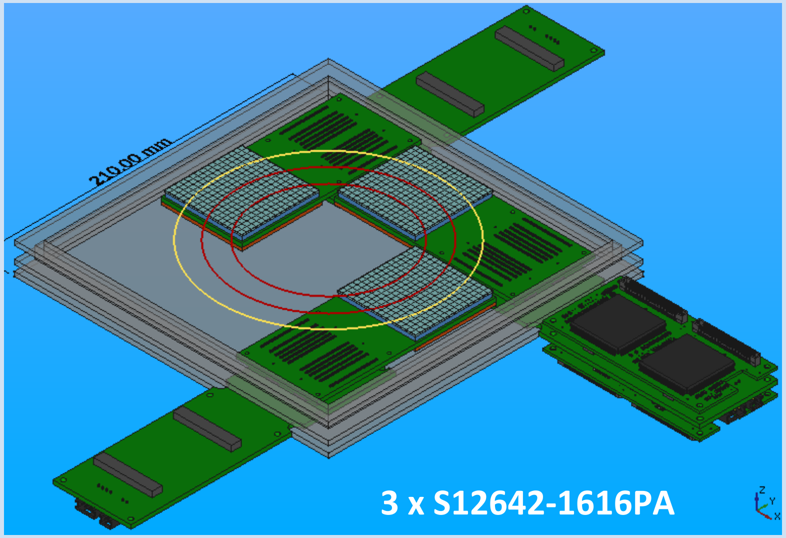
Survey ongoing:

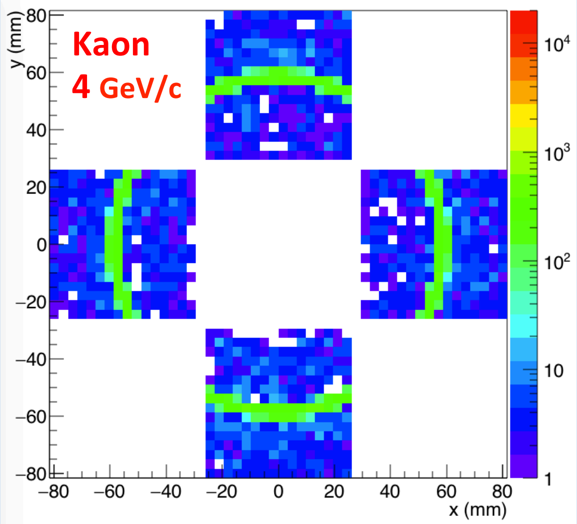
- Gas / mirrors / mechanics

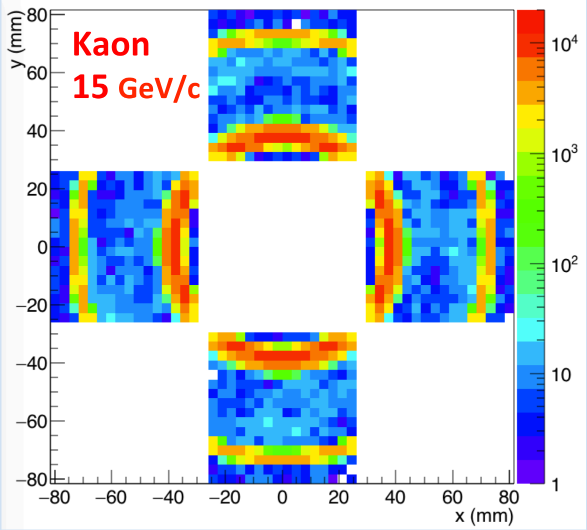
dRICH Imaging

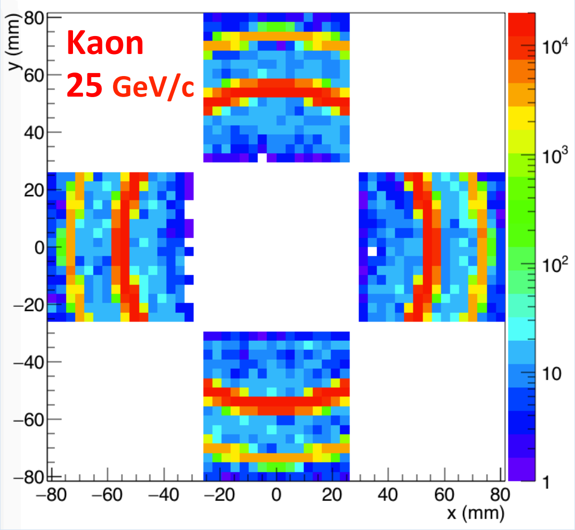
House the same principles and readout units used for mRICH test-beams
Compatible with H13700/S12642 + MAROC front-end
Allows to study the working principles and optical performance of the components







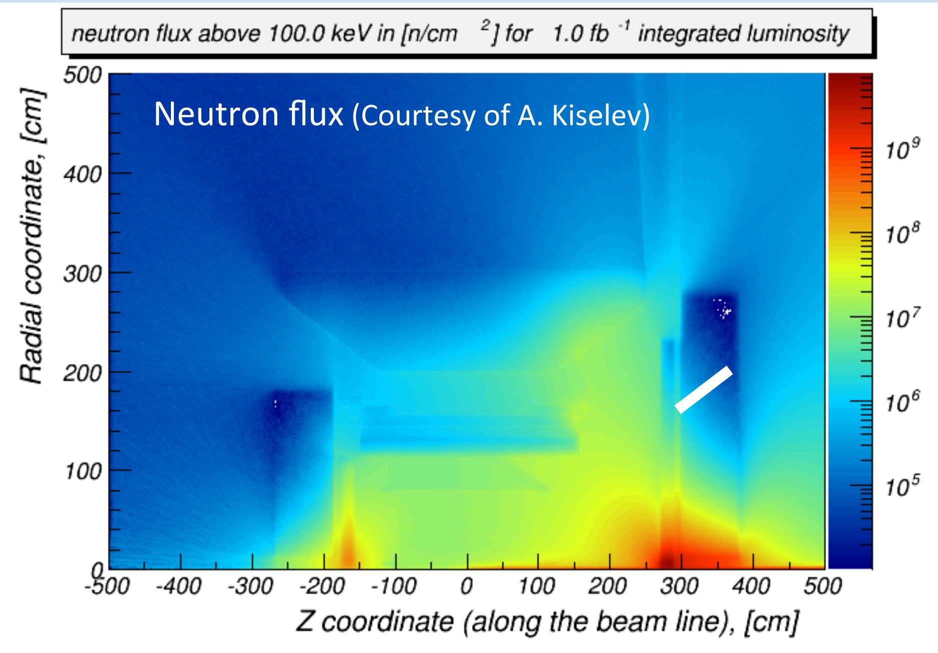


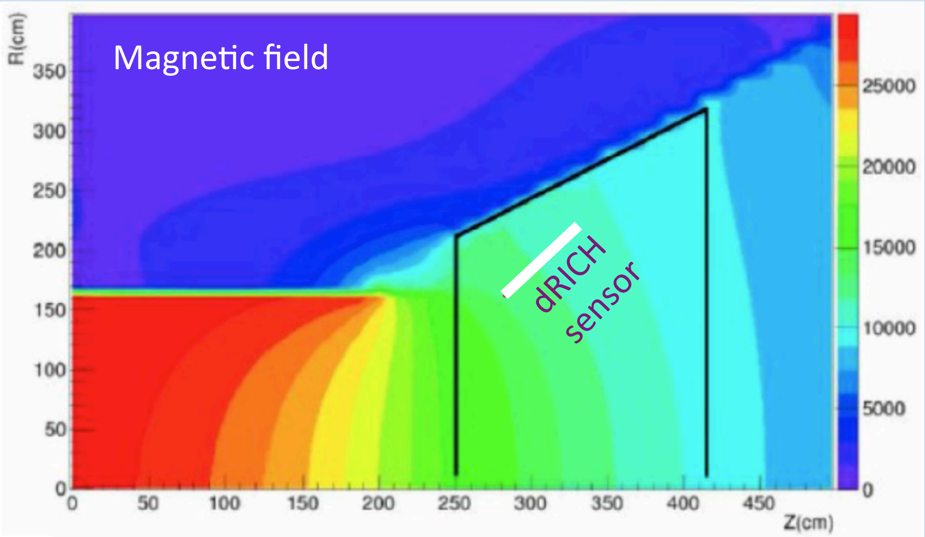


dRICH Key Hardware Components

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	≥3σ 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	≥3σ 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 and material budget

Neutron Fluence

Moderate except for very forward regions

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

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

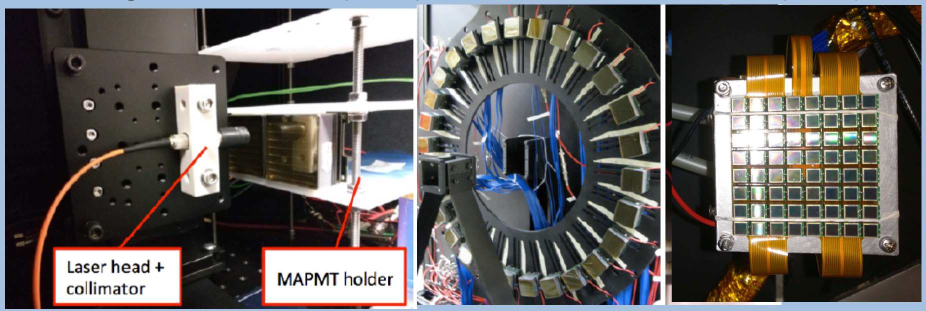
Magnetic Field

~ 1 T order of magnitude, varying orientation

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

SiPM SPE capability under study since 2012 @ INFN

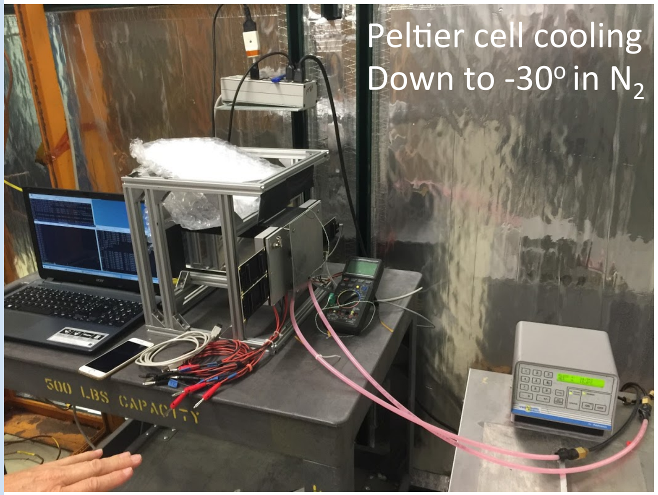
Contalbrigo++ NIMA 766 (2014) 22, Balossino ++ NIMA876 (2017) 89

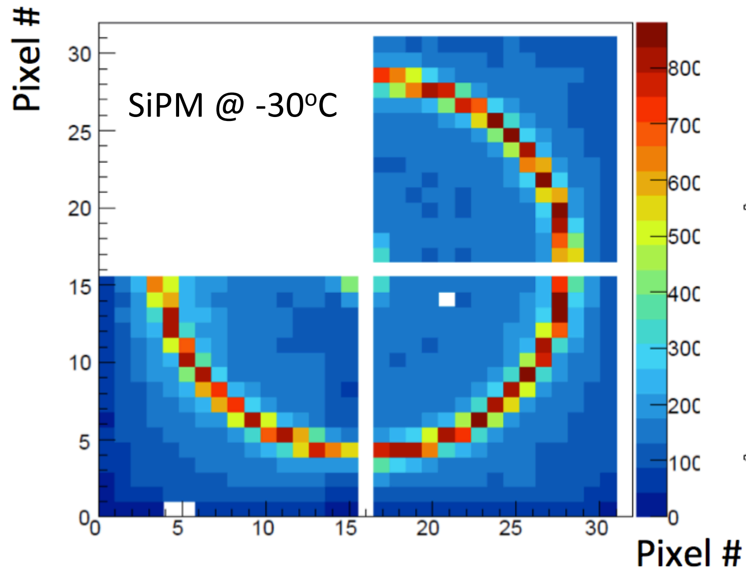


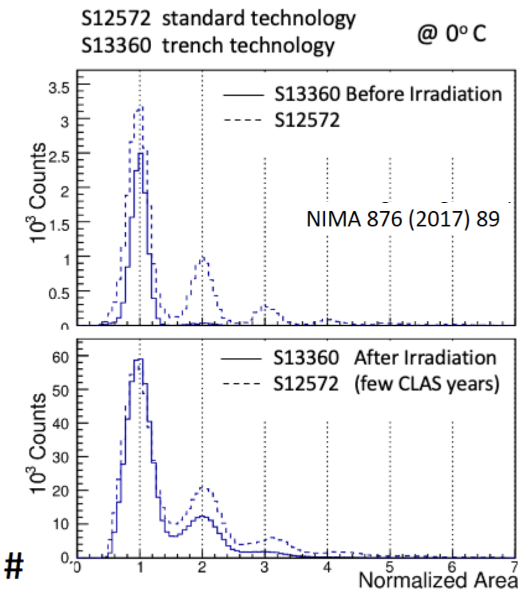
SiPM and Electronics

mRICH test-beam @ Fermilab 2018

SiPM irradiation 2016
NIMA 876(2017) 89







EIC Detector Advisory Committee, Report on dRICH 11/25/2019

"An important remaining issue is the SiPM noise rate after irradiation which should be clarified. We expect that it will take 2-3 years to fully understand if SiPMs can be used in RICH detectors at EIC"

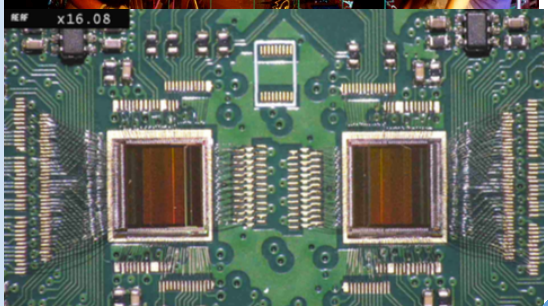
EIC Detector Advisory Committee, Report on Electronics 01/30/2020

"The committee again recommends the group to re-examine options that do not rely on waveform sampling, *e.g., a TOT-based design like the TOPFET2 ASIC, which is radiation hard, has low power consumption and has achieved a very good resolution per single photon with SiPMs."*

INFN Groups and eRD14

Enriched INFN expertise and manpower
to support dRICH, SiPM (and eRD14) program

INFN-TO
COMPASS RICH F-E
DARKSIDE F-E



INFN-BO
ALICE TOF
DARKSIDE SiPM

INFN-FE
CLAS12 RICH

INFN-RM1
HERMES RICH
Hall-A Tracking

INFN-LNF
CLAS12 RICH

INFN-CT
Hall-A HCAL

SiPM Program

Enriched INFN manpower and expertise towards a comprehensive program of post-irradiation SiPM + electronics single photon detection assessment.

Done so far, use few SiPM samples for the study of

- Cherenkov application prior of irradiation
- Single photon counting vs dose and temperature

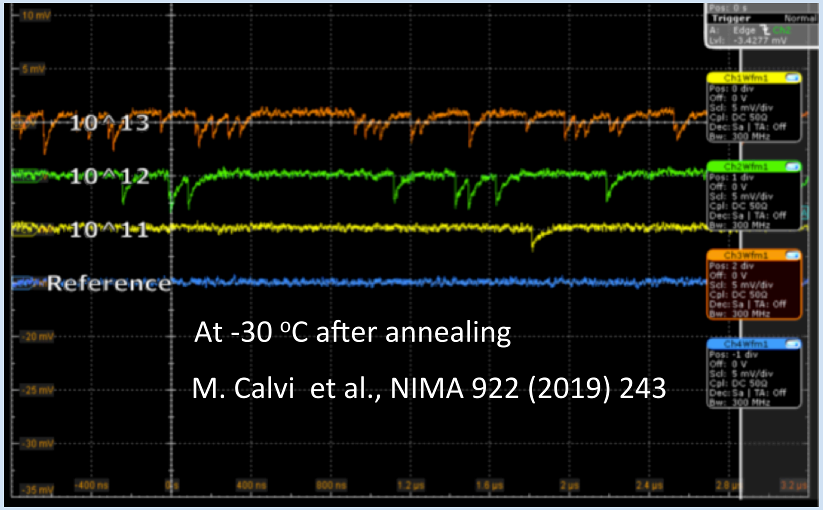
Short term goal (~ 1 year):

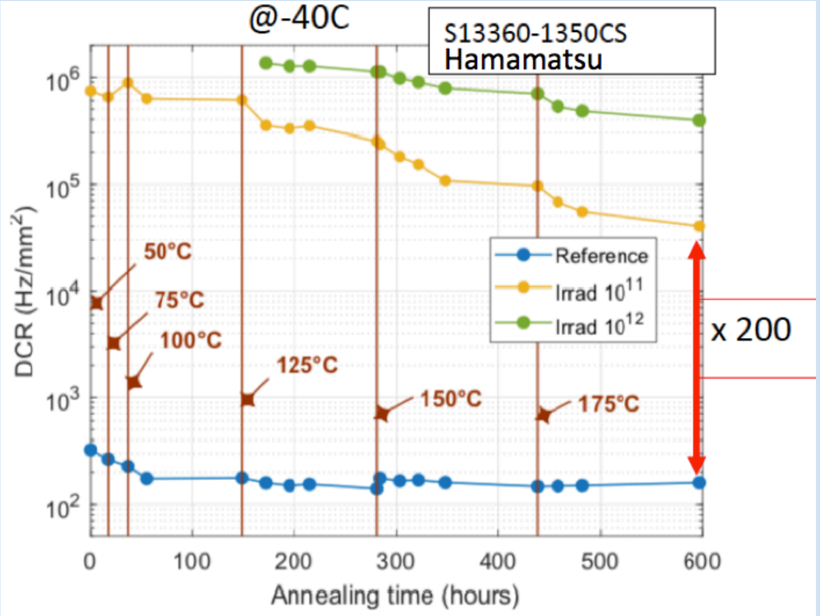
- Characterize irradiated status-of-the-art SiPM candidates
- Exploit in-house dedicated electronics
  (ToT based, for cooled SiPM + annealing)
- Cherenkov imaging after EIC-like irradiation
  (proof-of-principle)

Long term plan (~2-3 years):

- Systematic study towards performance optimization
- SiPM engineering with producers
- Temperature treatment protocols vs radiation
- Assess discriminating vs sampling readout performance
- Development of an optimized streaming readout

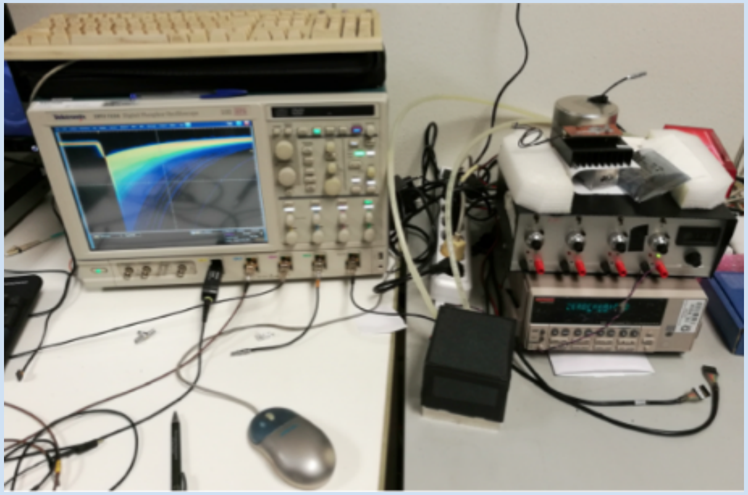
Key: Temperature treatment & dedicated readout





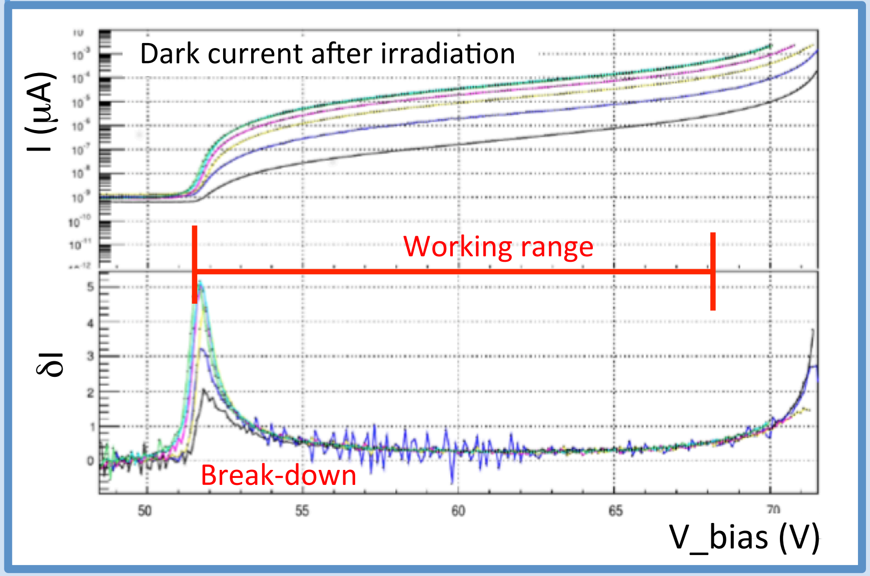
SiPM Characterization

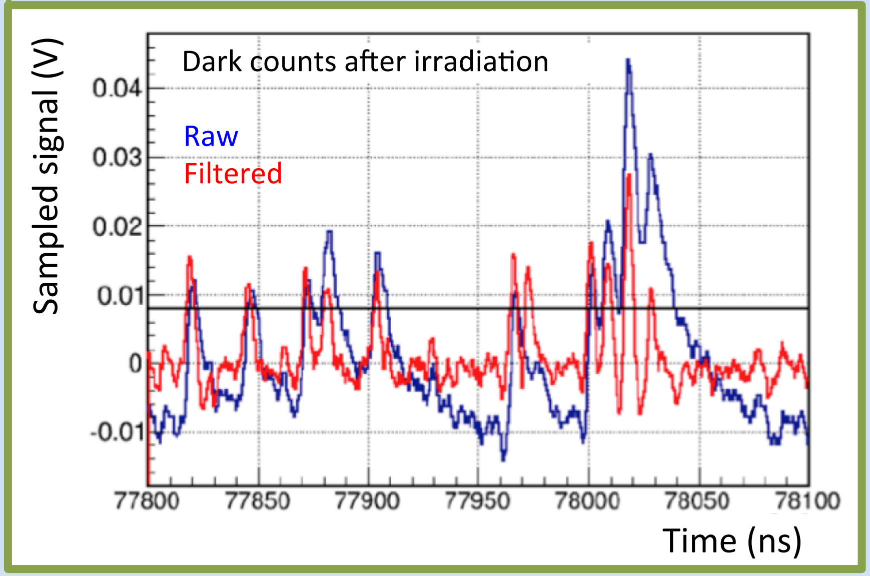
SiPM characterization and proton irradiation @ Proton Therapy Center of Trento, IT



I-V characteristics & Signal sampling

Temperature control and treatments





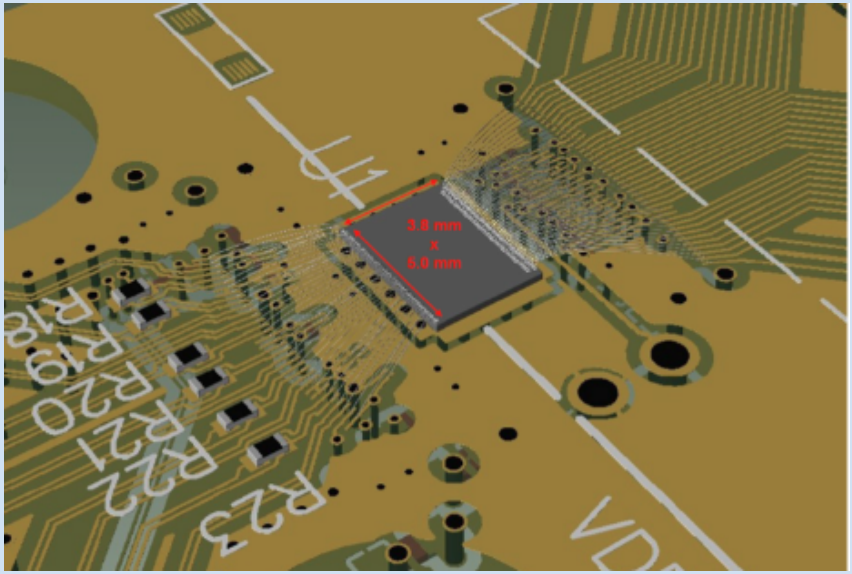
SiPM Readout

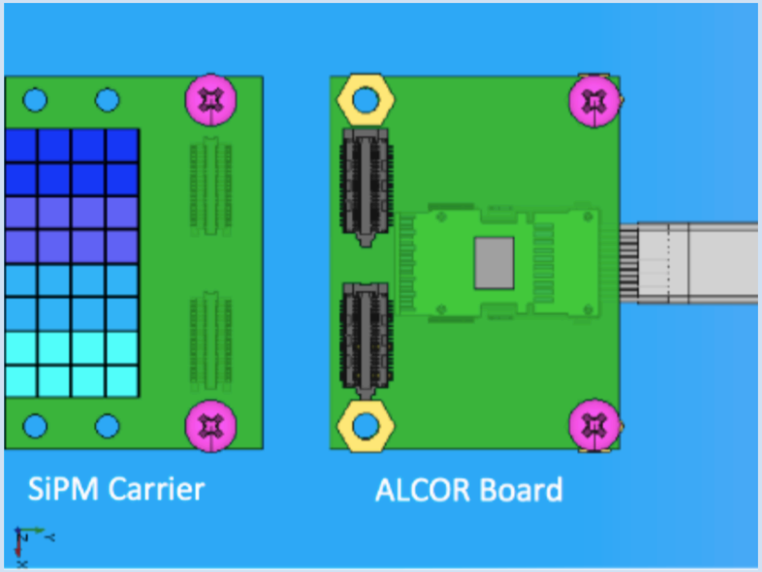
SiPM: sampled for vendor, type and dose (at groups of 4)
organized in 8 x 4 matrices for imaging

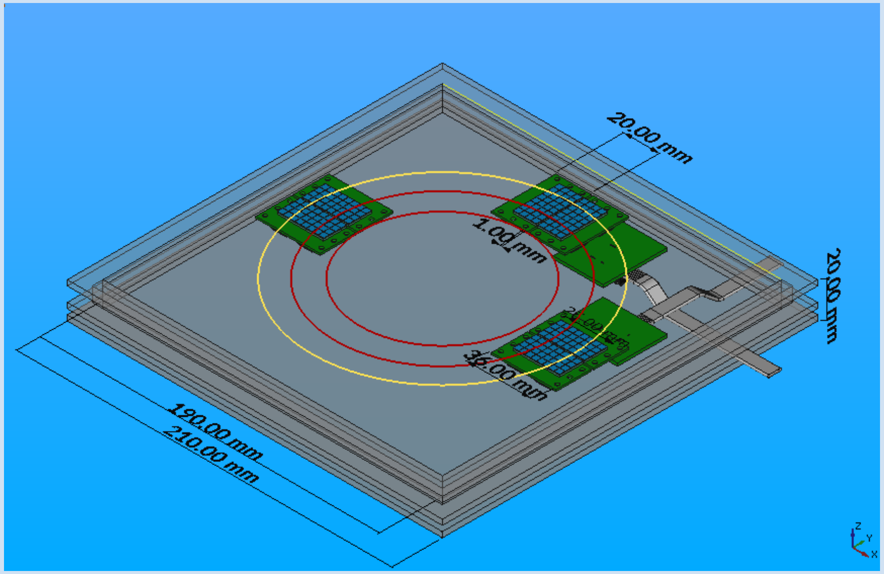
SiPM board: bias distributors and signal pre-conditioning
compatible with temperature treatments and
laboratory characterization

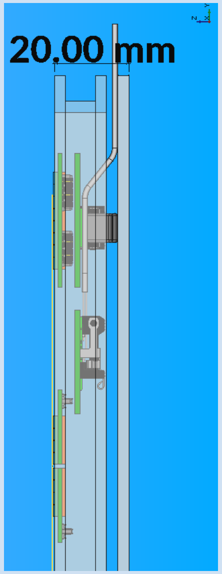
ALCOR chip: under development at INFN:
ToT architecture for cryogenic application
32 channels, 50 ps TDC, >500 kHz/channel

ALCOR board: connecting to a Xilinx FPGA via firefly lines









Activity Plan & Deliverables

As discussed with the EIC R&D Committee in September 2019 for TDR readiness in 2023

- ✔ Ongoing
- ✔ In preparation

2020

- ✔ Prototype design, simulation and implementation
- ✔ Basic mechanics Electronics adaptation
- ✔ Component test and selection
- ✔ Start of INFN funds

Prototype components
SiPM + electronics

2021

- ✔ **Basic prototype**
  - tracking
  - 1 choice per radiator
  - 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

Conclusions

INFN has developed a plan to address the EIC R&D Committee recommendations

To address crucial PID aspects at EIC:

cost-effective compact solution for hadron PID in the forward region in a wide kinematic range
in 1 year: prototype complete 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

	100%	80%	60%
Postdoc, INFN/JLAB, 2 months (Luca Barion)	$6k	$6k	$6k
Postdoc, INFN/JLAB, 6 months (Aram Movsisyan)	$20k	$20k	$12k
Technical personnel, 6 months	$20k	$20k	$20k
Prototype Components	$22k	$10k	$5k
Travel	$6k	$2k	$2k
Total	$74k	$58k	$45k

Goal: have in one year a full-chain assessment (proof-of-principle) of the proposed approach and investigated technologies

A mandatory step for INFN and eRD14 given the YR, EoI and announced Call for Detectors in FY2021