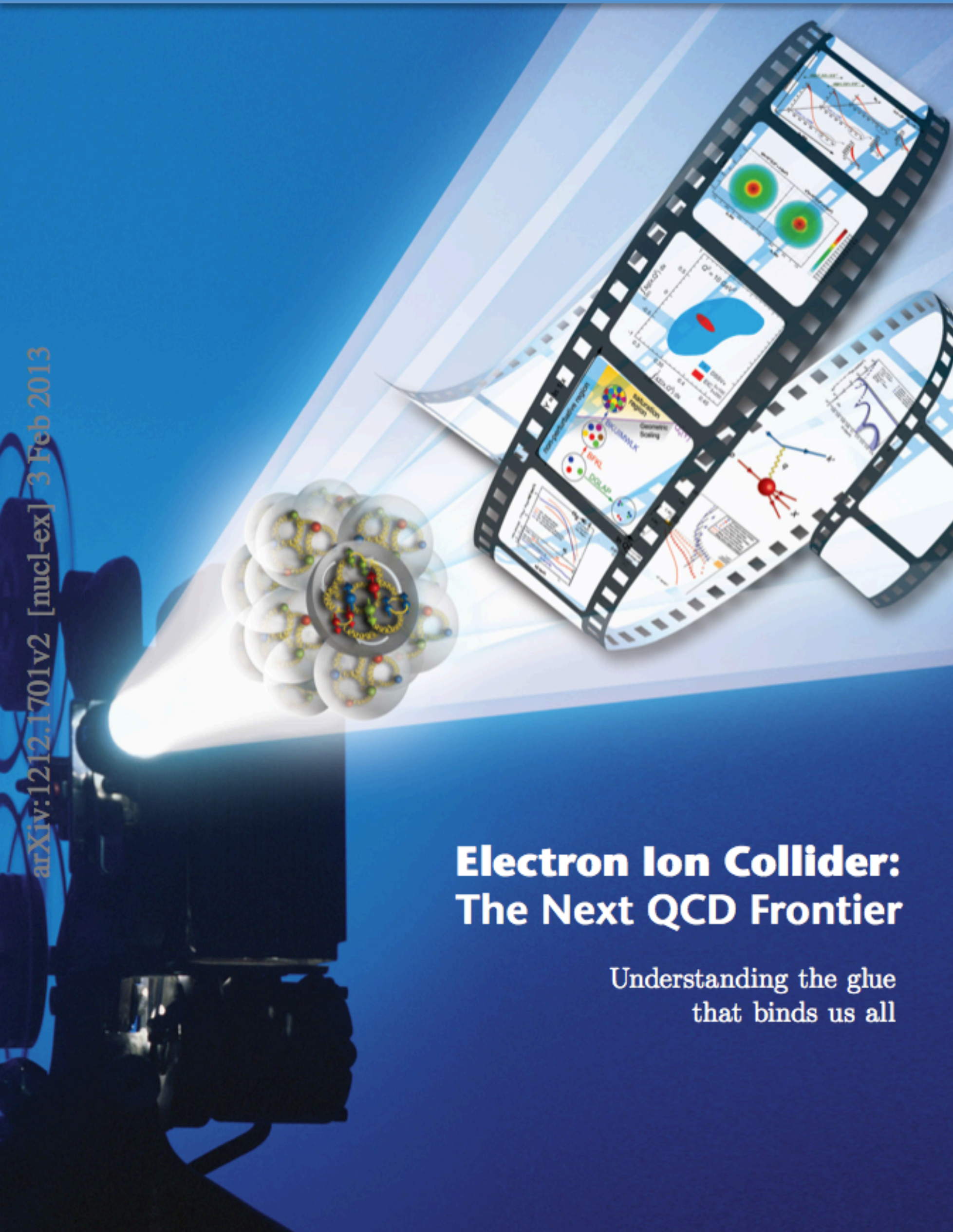
INFN ONGOING ACTIVITIES AND INITIAL INTENTS

Contalbrigo Marco
INFN Ferrara

INFN Meeting on EIC
March 1, 2018 - Presidenza INFN, Roma

EXECUTIVE SUMMARY



The Next QCD Frontier

EIC is a unique opportunity
for a comprehensive QCD study
and possible breakthroughs

This projects deserve the strongest
support as we may all benefit !!

In Italy: wide interest and a motivated community already supporting the project

EIC offers immediate opportunities
for supported R&D activities
on science and technology

At this early stage can still be
synergic with INFN current programs
(here detector R&D only)

EIC Detector Challenges

Specific requirements to move beyond the longitudinal description

- Resolve partons in nucleons

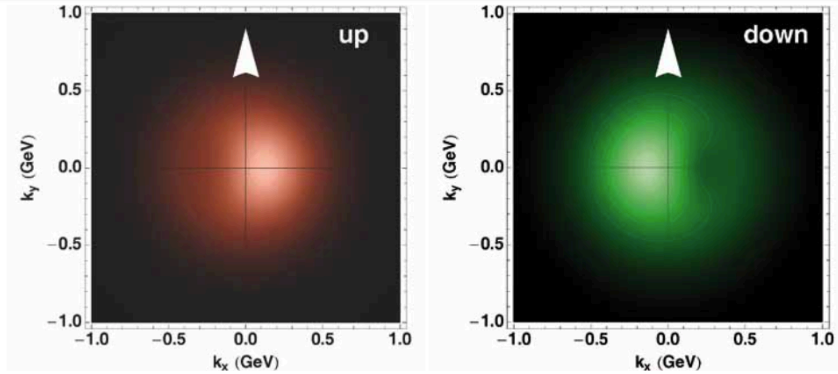
➔ high beam energies and luminosities Q^2 up to **~1000 GeV²**

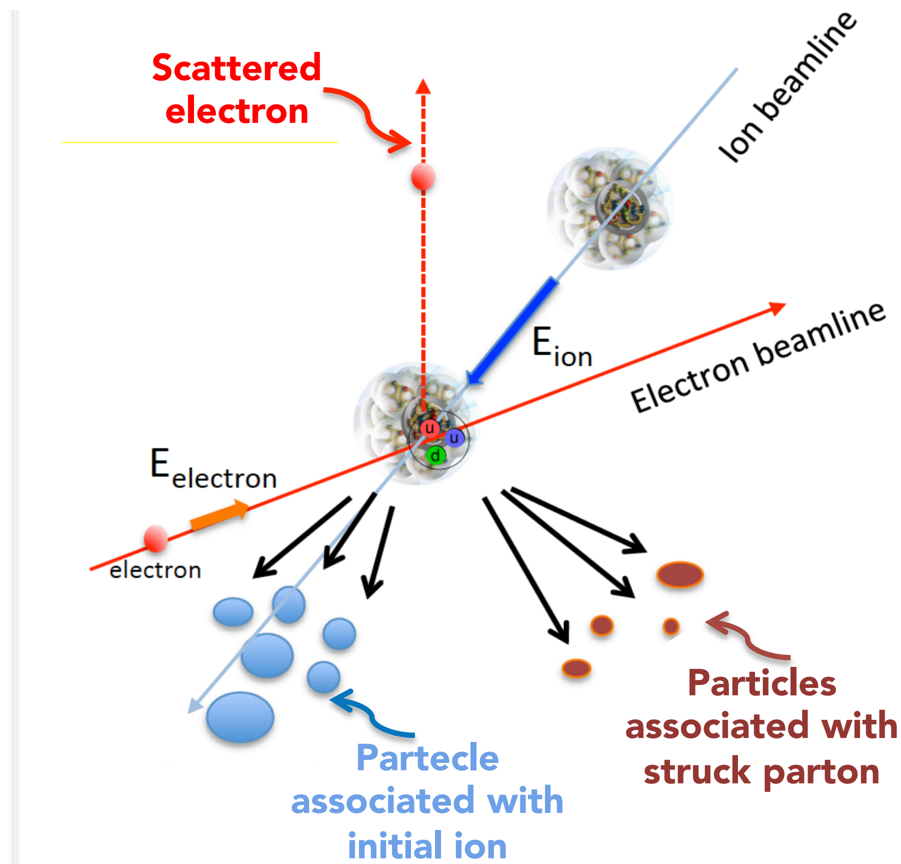
- Need to resolve quantities (k_t, b_t) of the order **a few hundred MeV** in the proton
Correlated quantitites, multi-D analyses

➔ High Granularity, wide dynamic range

- Need to detect **all types of remnants** to seek for correlations:
  - scattered electron
  - particles associated with initial ion
  - particles associated with struck parton

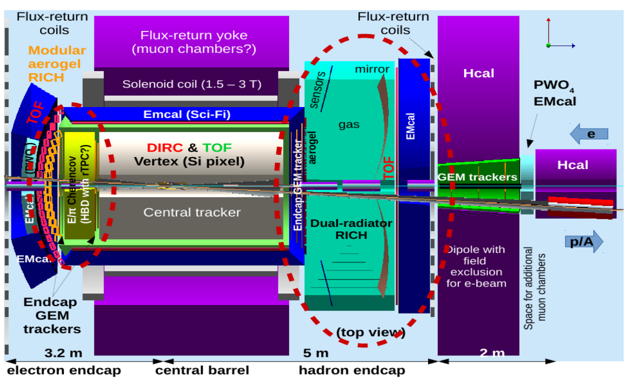
➔ Large acceptance, Forward particle detection, Excellent PID



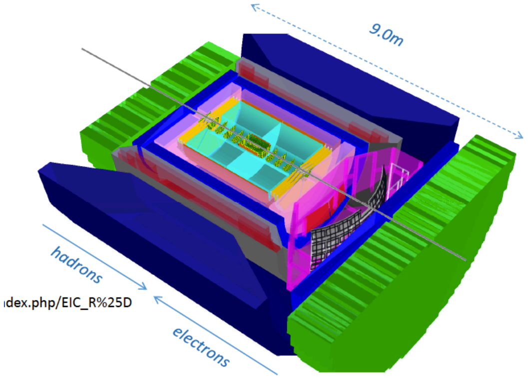


The Detector R&D Program

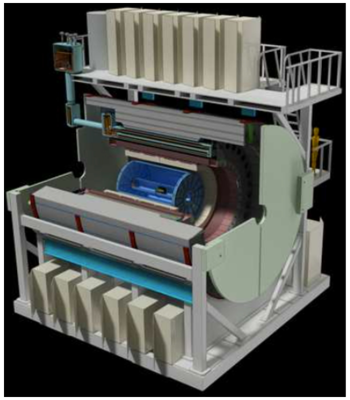
- Still focus on generic technology advance
  Not yet targeted on specific solutions
- Open to foreign Institutions
- Flexible support: Funds for hardware and personnel
  Post-doc positions (3 years maximum) to promote career progresses
- Summer meeting: review reports and call for new proposals
  Last Meeting held in July 12-13, JLAB
- Winter meeting: progress report
  FY18 Mid-term review on January 18-19, BNL



JLEIC



eRHIC



sPHENIX

EIC Software Consortium (ESC)

ESC in front of MIRA at ANL

ANL, BNL, FNAL, INFN Trieste, JLab, SLAC, William & Mary

ESC initiative from 16 scientists from 7 institutions

Global Objectives

Interfaces and integration
- connect existing frameworks / toolkits
- identify the key pieces for a future EIC toolkit
- collaborate with other R&D consortia

Planning for the future with future compatibility
- workshop to discuss new scientific computing developments and trends
- incorporating new standards
- validating our tools on new computing infrastructure

Organizational efforts with an emphasis on communication
- build an active working group and foster collaboration
- documentation about available software
- maintaining a software repository
- workshop organization

- **Current focus**
  - MCEG and self-descriptive MC file format (EicMC, HDF5)
  - Geant4 validation
  - Interoperability: unified tracking with universal geometry and detector interface
  - start HPC and (D)NN initiatives

User Requirements & Strategy

EIC MCEG initiative

- strong interplay experiment–theory
- connect MCEG efforts NP-HEP

Modern, flexible and comprehensive

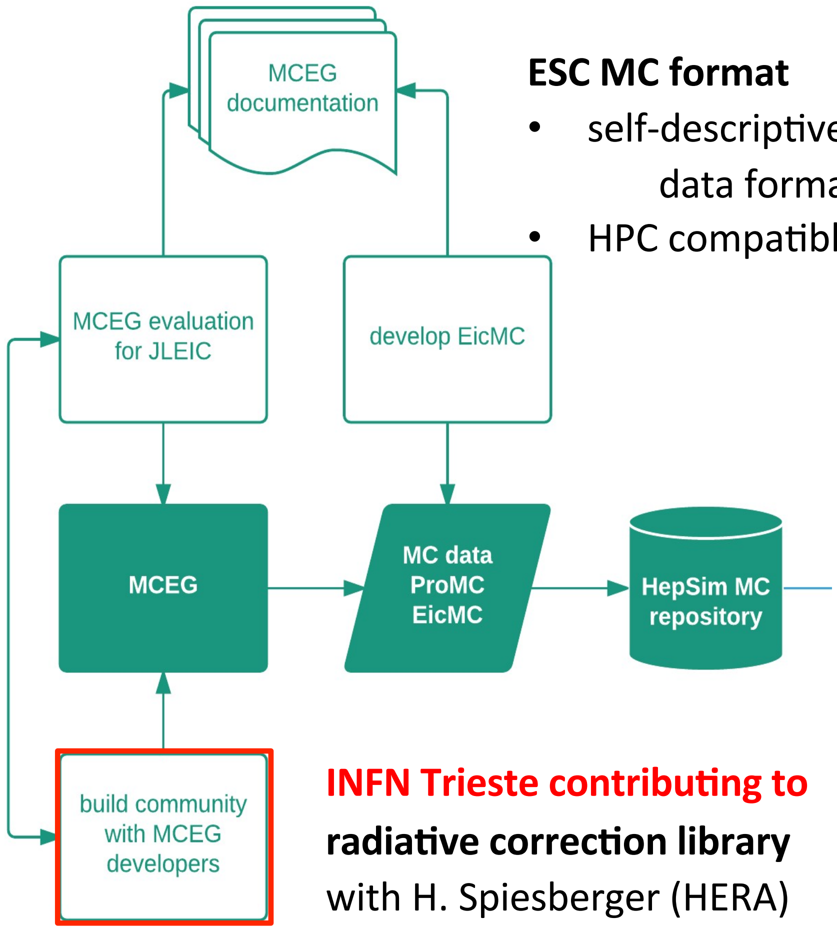
Use case 1 Physics studies

Use case 2 Detector studies

Requirements

- open access to physics simulations or interface to MCEG
- open access to accelerator specifications
- open access to detector information and simulation
- documentation

eRHIC – JLEIC
interplay and comparison

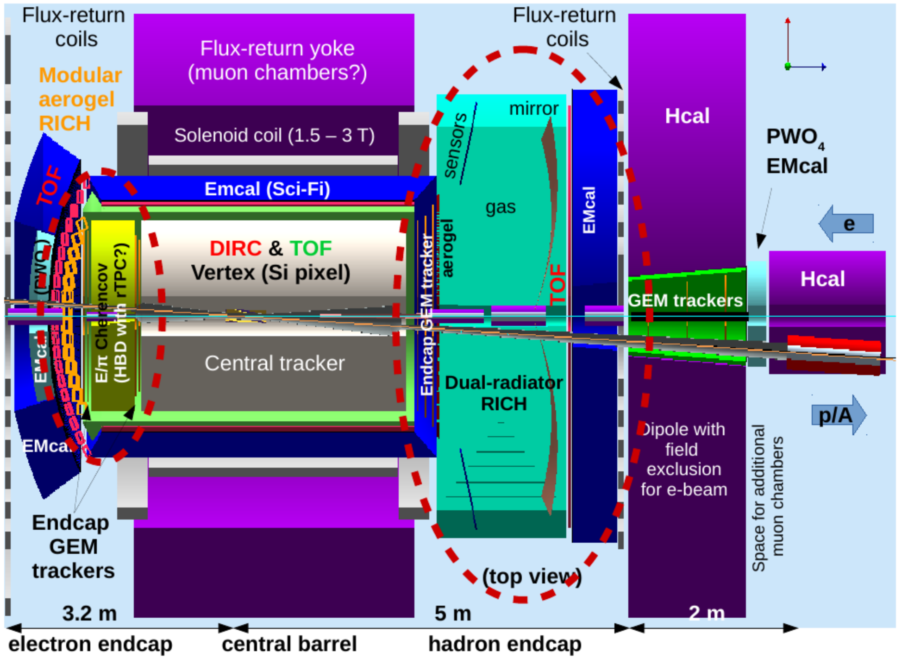


ESC MC format

- self-descriptive data format
- HPC compatible

INFN Trieste contributing to
radiative correction library
with H. Spiesberger (HERA)

Particle Identification @ EIC



Asymmetric detector

Compact solutions to contain the cost

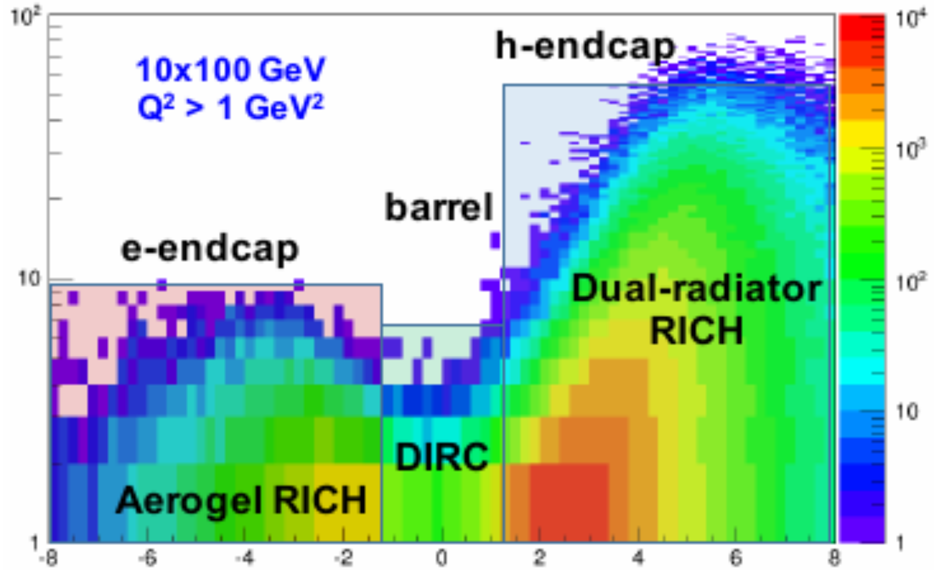
- new high-tech materials
- new technologies with emerging markets in medical imaging and homeland security

e-endcap:

medium momentum (< 10 GeV/c)
aerogel modular Cherenkov

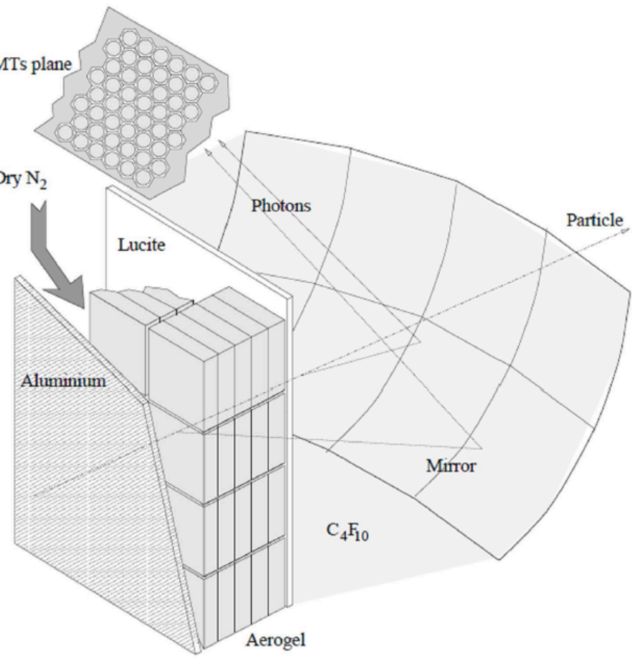
h-endcap:

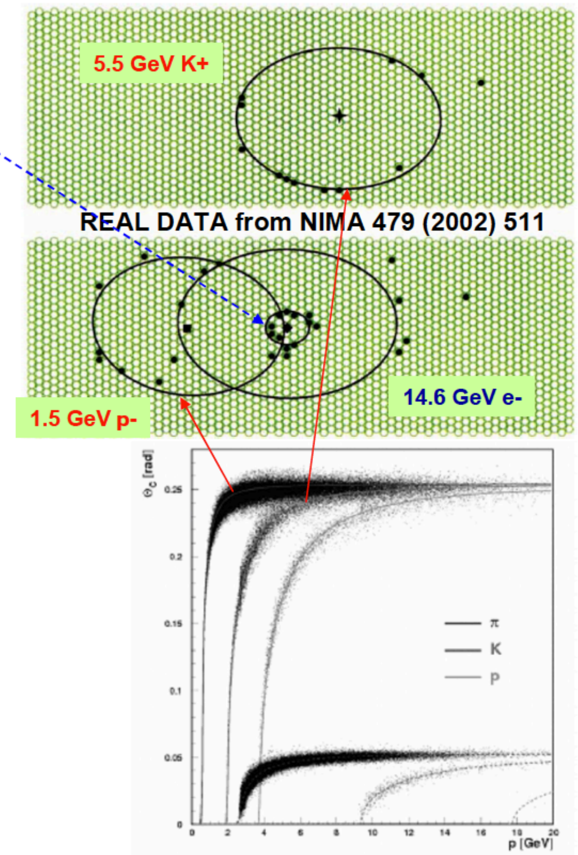
medium and high momentum (3-50 GeV/c)
gaseous and dual radiator Cherenkov



Construction, operation of the dual radiator HERMES RICH

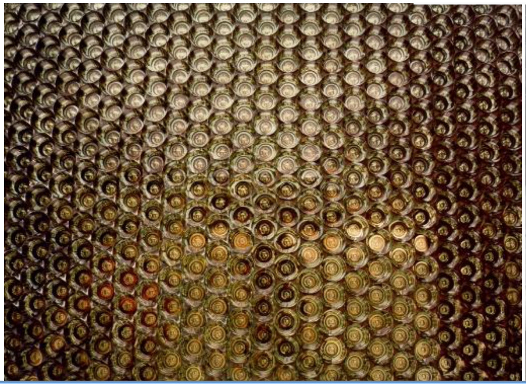
Reused in Hall-A at JLab

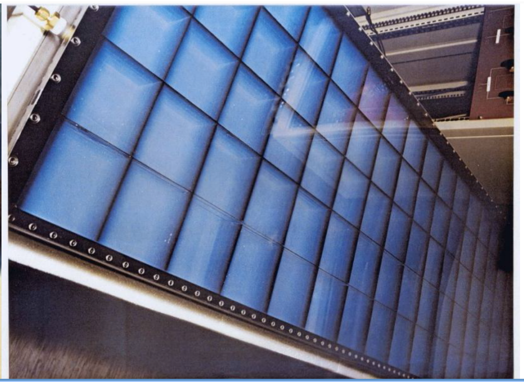




Two radiators: aerogel and gas
PMTs as photon detector
Focusing Optics

Reference: NIMA 479 (2002) 511-530

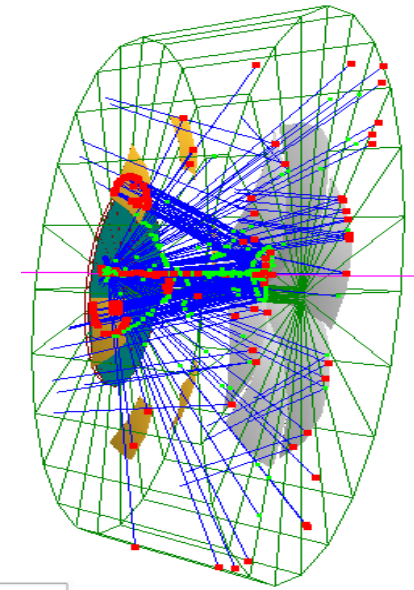




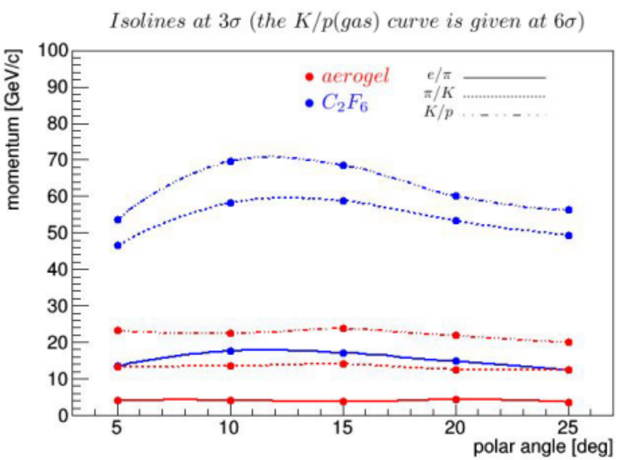
INFN Roma R&D for experiments @ EIC

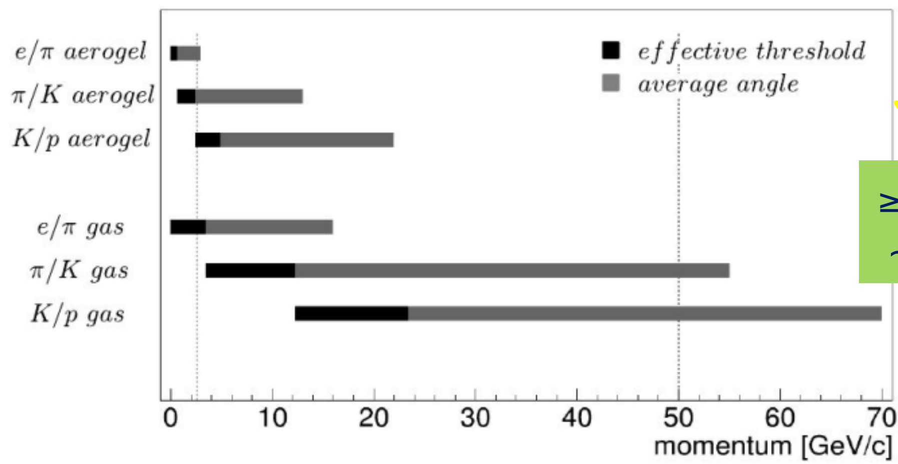
Dual-Radiator RICH within eRD14 - PID

- GOAL: Discriminate Hadrons in 3 to 50 GeV/c
  – need to operate in magnetic field



- Proposed configuration fitting the spectrometer constraints (evaluated by detailed GEANT4 simulations)
  -- dual radiator RICH: aerogel and C_xF_y gas
  -- focusing mirror
  -- 6 open sectors
  -- curved detector surface





≥3σ π/k separation
~ 2 ÷ 50 GeV/c

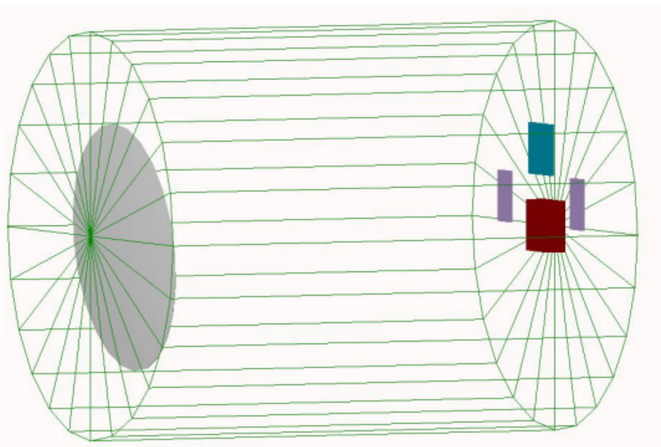
- Work in progress (as in FY18 eRD14 submitted proposal)
  – dRICH PID performances in exteded physics context of EIC
  – Adapt dRICH devel. framework to BNL (ePhenix) concept detectors

Past Funding, Future Activities

Feasibility study funded by DOE in 2015-2018: 3 year Post-DOC

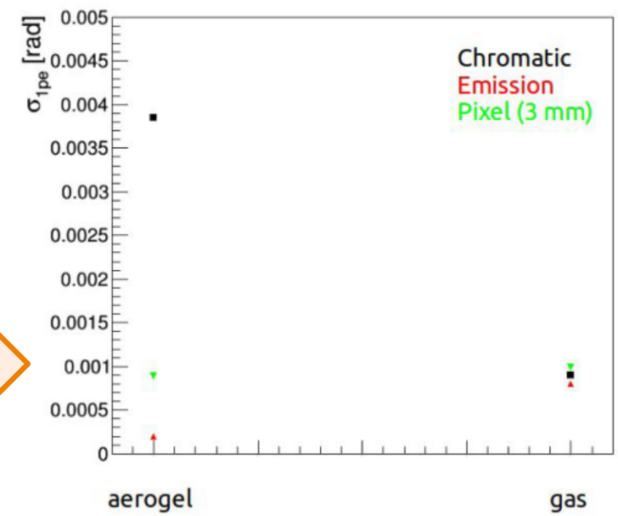
Potential ≥2019 activities (synergies with mRICH, CLAS12 and ePhenix), part of funding may come from EIC/USA.

1. Prototyping (draft system simulated – see below)
    - Investigate aerogel performances and aging (which are fundamental!)
    - SiPM feasibility
    - Operation in magnetic field of the gas
    - Non planar focal plane optimization



Proposed small scale «essential» prototype

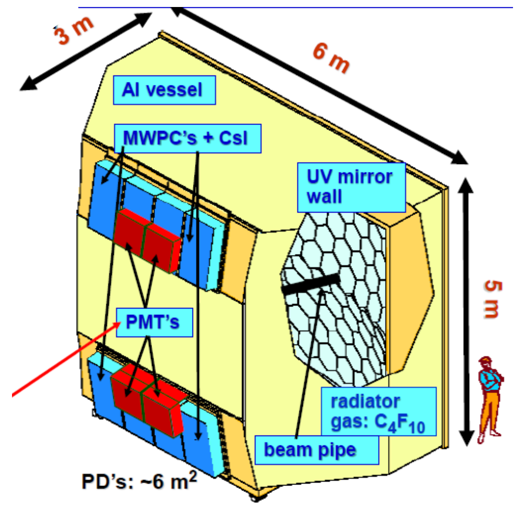
1 p.e. resolution for 30 GeV/c electrons in prototype



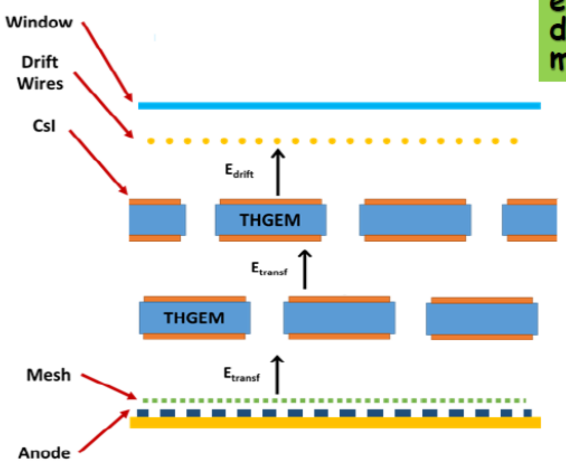
2. Evaluate performances of a «dRICH like detector» as ePhenix RICH
3. Develop rubust and global (event based) PID reconstruction algorithm(s)

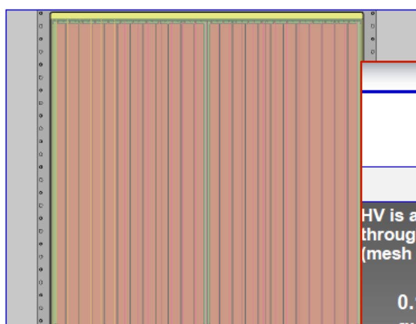
INFN Trieste

- Expertise in high momentum RICHes and MPGDs
  - design, project coordination, construction, operation of COMPASS RICH-1
  - most recently the construction of novel photon detectors by MPGD technologies for an upgrade of the RICH:

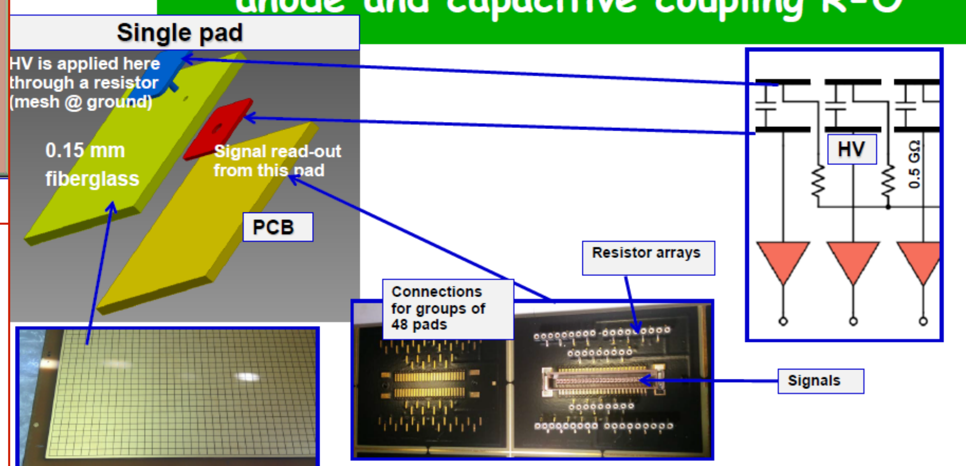


each 600 x 600 mm^2 detector consists of two modules having 600 x 300 mm^2





The bulk MICROMEGAS with resistive anode and capacitive coupling R-O



Thick GEM Multiplication
MicroMegas Detection

INFN Trieste R&D for Experiments @ EIC

GEM detectors within eRD6 – Tracking and PID

Goal hadron discrimination in the range $6 < p < 60$ GeV/c

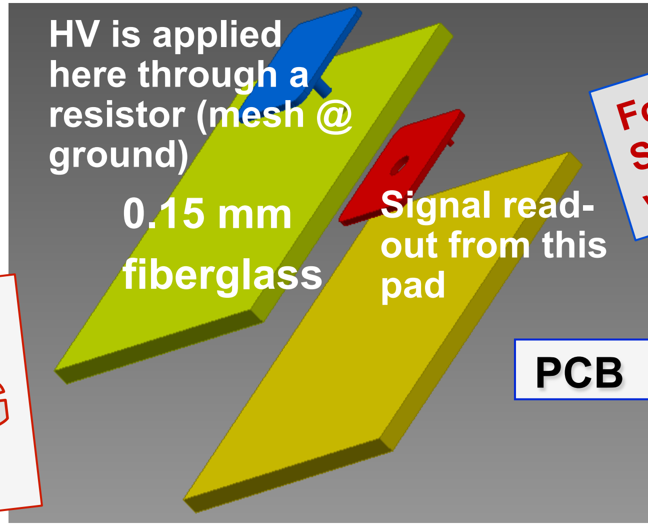
- Hadron endcap:
  - Radiator: gas is mandatory
  - Collider implementation: short (~ 1 m) radiator length
  - In literature, so far, only two attempts, both requiring deeper exploration
    - High pressure, studied for ALICE upgrade VHMPID
    - Towards the very far UV with window-less approach (prototype tested at Fermilab)
    - In both approaches gaseous photon detectors are mandatory:

→ further development of up-to-date gaseous photon detector

A strategic sector for experimental set-ups at EIC matching our expertise and with open issues

A Summary of the R&D Program

resistive MM with small pad size O(10 mm²)



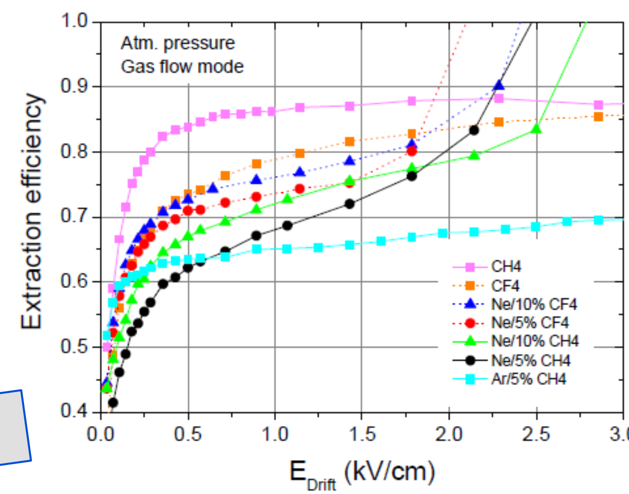
ALREADY ON GOING
next slide

For RICH, also SYNERGIC with TPC

Further reduction of the Ion BackFlow (IBF) rate:
presently ~ 5%

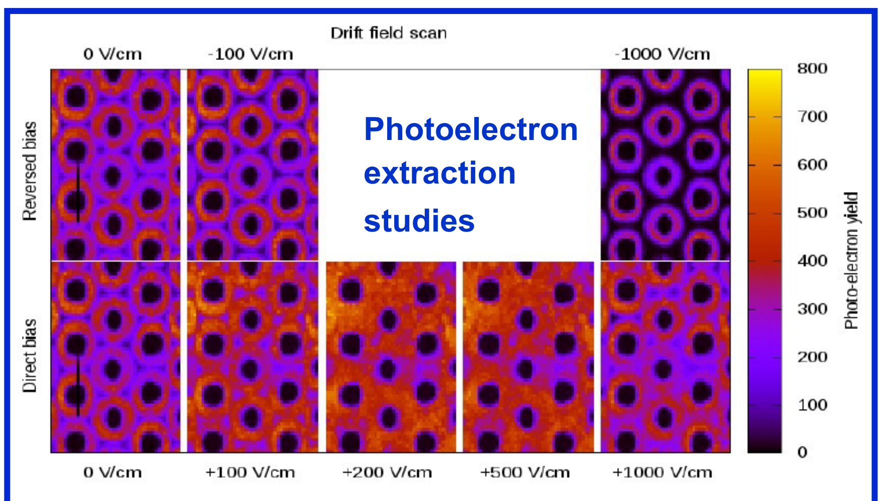
Issues related to hybrid MPGD-based PDs operated in C-F atmosphere:

- photoelectron extraction
- Detector gain
- ageing



C. D. R. Azevedo et al., 2010 *JINST* 5 P01002

GEM vs THGEM as photocathodes



RICH specific

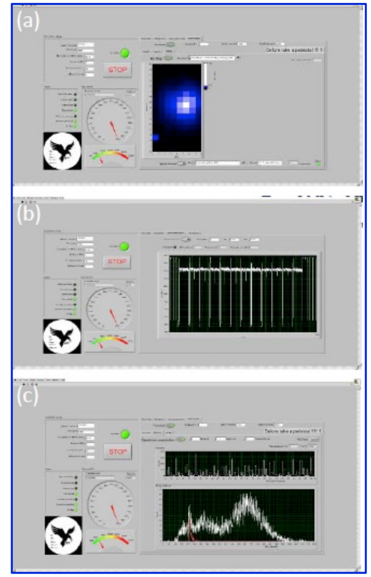
Prototype: Small PAD-Size Micromegas

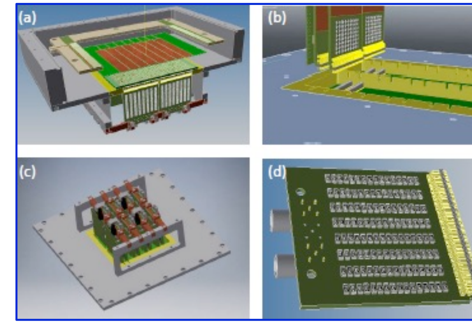
The development of the resistive MICROMEGAS prototype with miniaturized pad-size

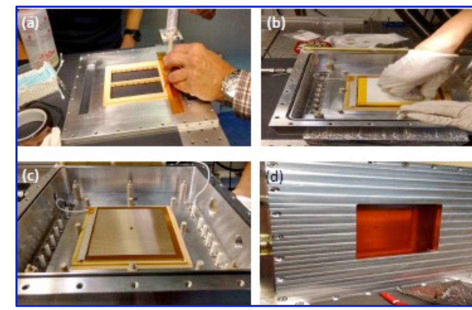
- Design & construction completed
- Pad size: 3 x 3 mm^2, pitch 3.5 mm
- Modularity for extendibility: for each group of 128 pads, read-out and services make use of an area as large as the pad group itself

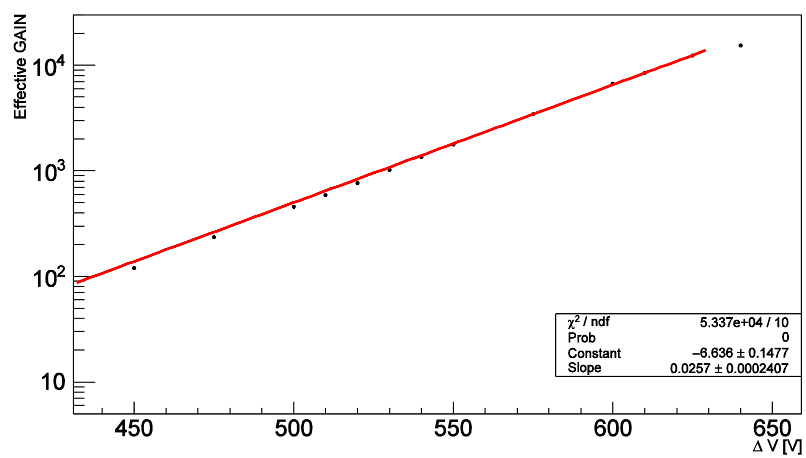
- Read-out via SRS by the <u>original DAQ system Raven</u>
    - LabView based, developed for larger band width (up to the saturation rate of the Gigabit Ethernet when the UPD protocol with Jumbo Frame format)
    - it takes care of APV25 setting (FE chips), data collection and visualization, including pedestal subtraction and zero suppression
    - user friendly graphical interface
- Preliminary test of the prototype

(MICROMEGAS stable up to large gain!)









A Very Recent New Option for the R&D

CsI, the only standard photoconverter compatible with gaseous atmospheres, has problematic issues, main ones:

- *It does **not** tolerate **exposure to air** (water vapour, oxygen)*
- ***Ageing** by ion bombardment*

From Antonio Valentini – Sezione INFN di Bari (2016)

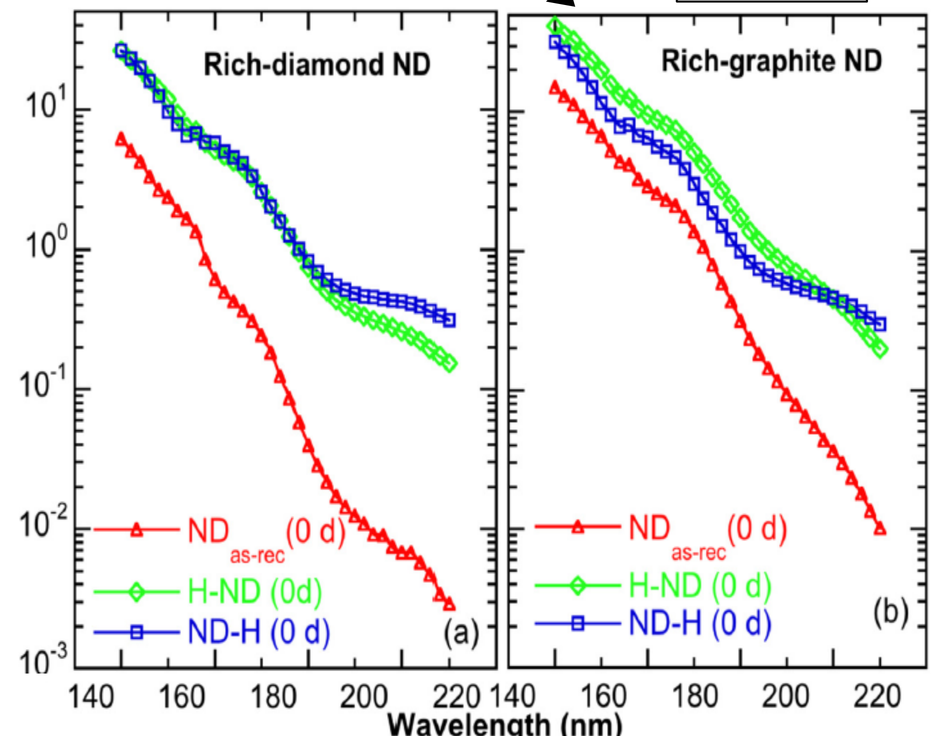
- *Italian patent application n. 102015000053374*
- *Photocatodes: hydrogenized diamon film obtained with Spray* Technique making use *of NC powder*
  - *Spray technique: **T ~ 120°** (instead of ~800° as in standard techniques)*

Coupling of ND photoconverter and MPGDs?

an exiting perspective with several open questions

- *Radiation hardness ?*
- *Ageing ?*
- *Compatibility and performance with gas atmospheres ?*

47 % (!)



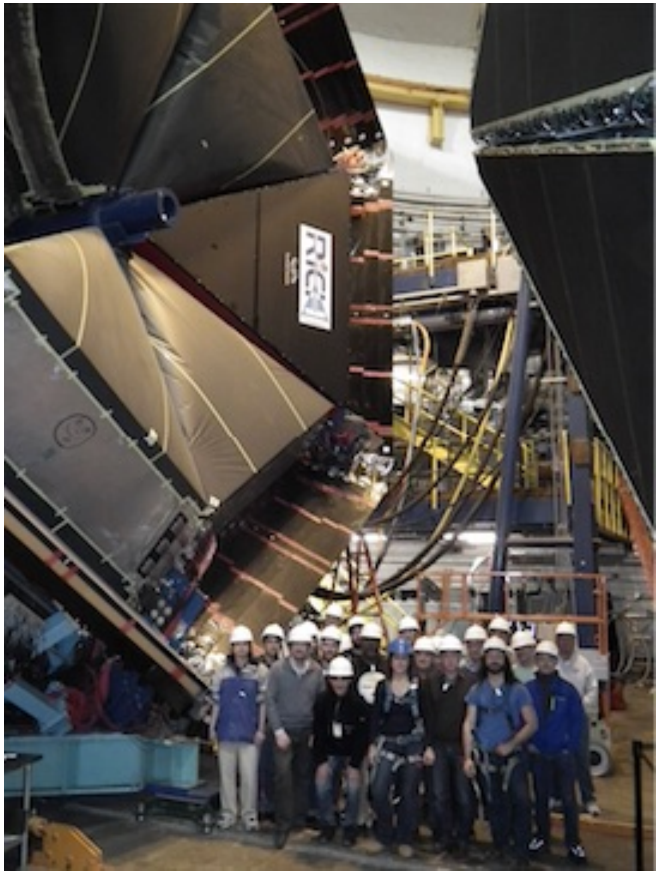
L.Velardi, A.Valentini, G.Cicala al., Diamond & Related Materials 76 (2017) 1

PRELIMINARY EVALUATION OF A POSSIBLE R&D,

starting in these weeks: first THGEMs with ND film produced

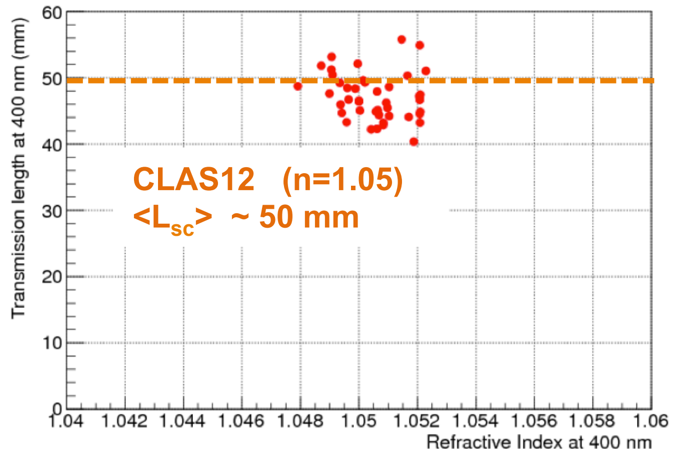
INFN Ferrara

Design, project coordination, construction, operation of the large-area hybrid-optic design CLAS12 RICH



High-transmittance Aerogel

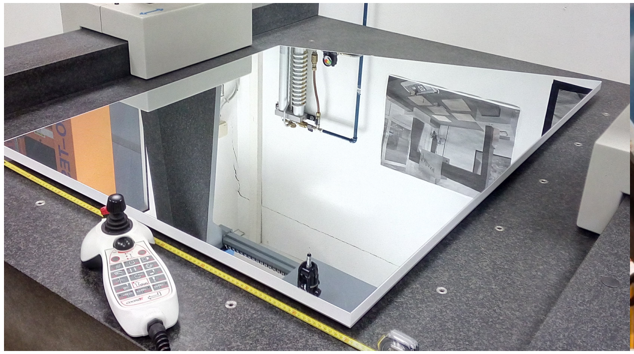
Unprecedented optical quality



Glass-skin planar mirrors

Derived from terrestrial telescopes

~ 1 % X_0 (comparable to carbon fiber)

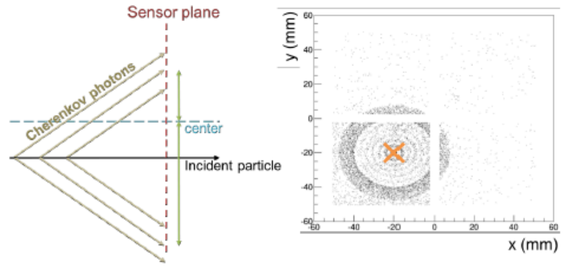


1st with Large-area MAPMTs

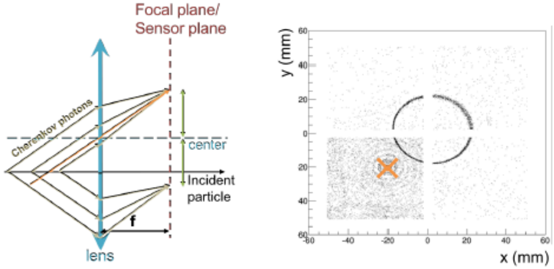
SPE detection even with not-optimized devices

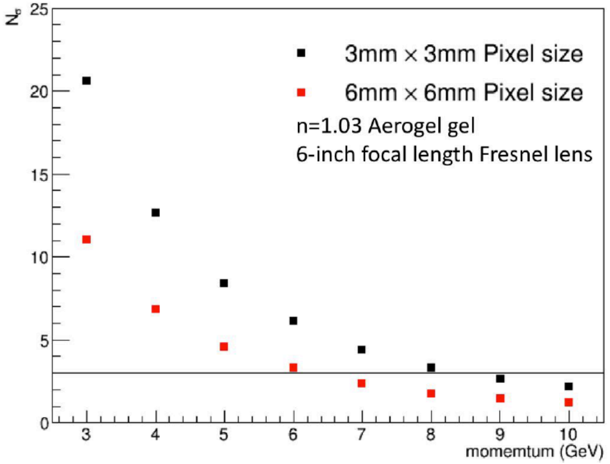
Modular RICH within eRD14 - PID

- GOAL: Discriminate Hadrons in 3 to 10 GeV/c

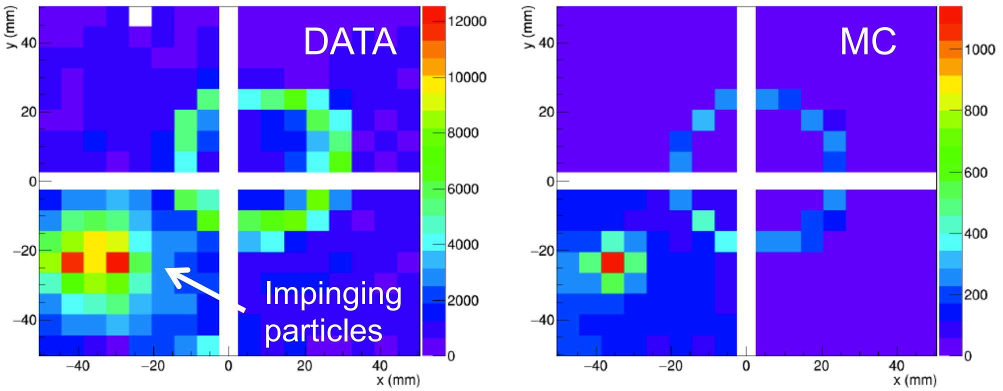


Fresnel lens focalization for a compact device

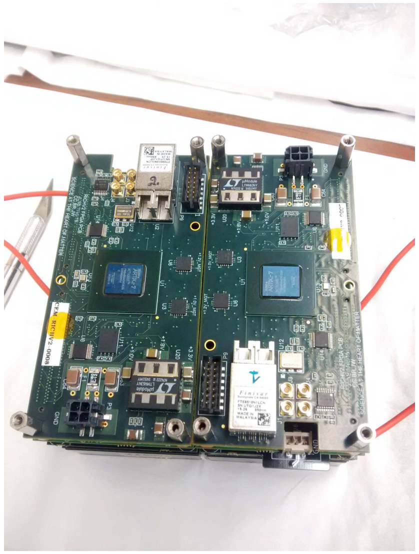


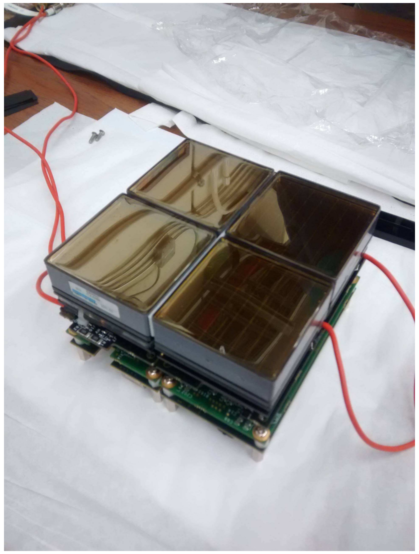


Test beam of small EIC mRICH prototype
Fermilab – April 2016

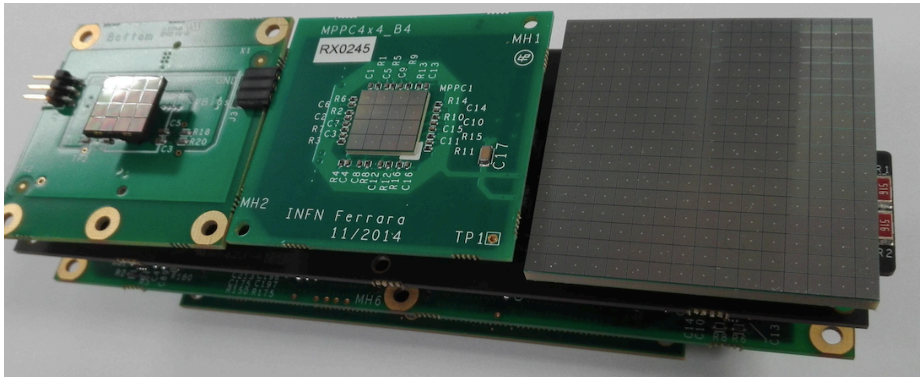


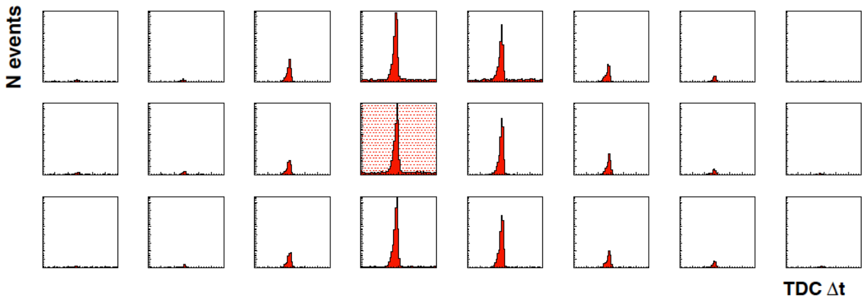
Cherenkov detector expertise from CLAS12 for aerogel radiator and readout electronics

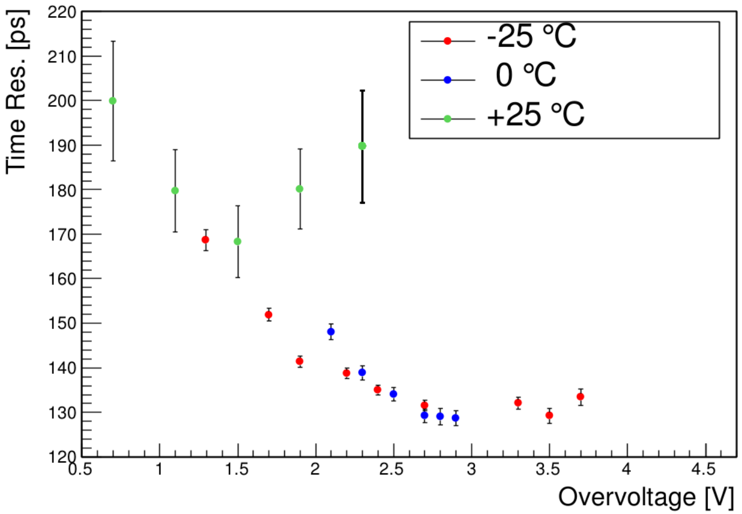




Next Steps

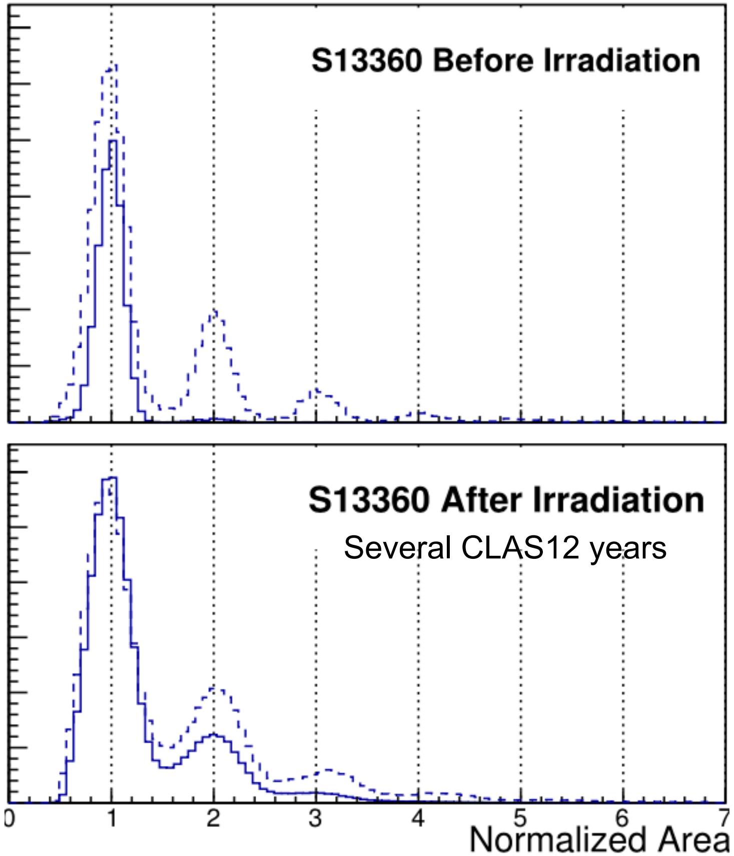




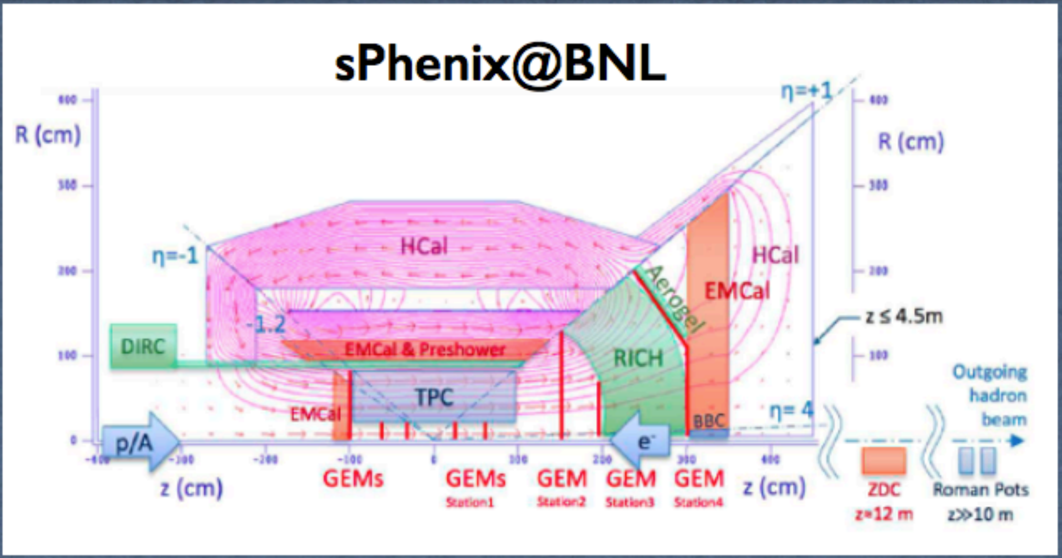


- Readout electronics for 3 mm pixel
- DAQ electronics
- New sensors (SiPM, LAPP)

SiPM SPE capability after irradiation ?



Calorimeters @ EIC

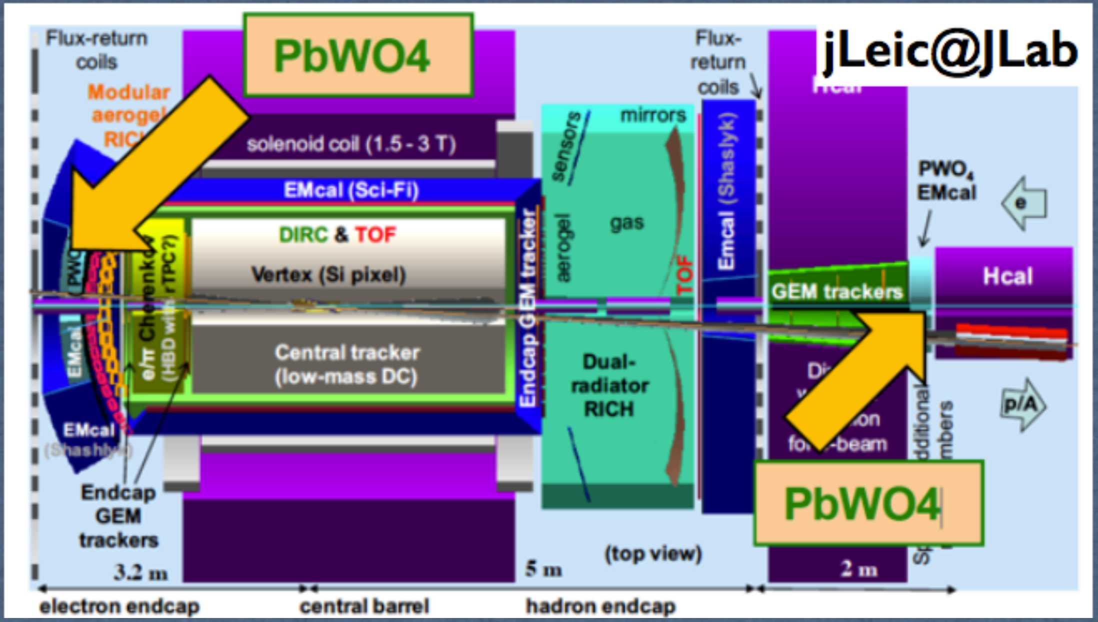


- *Particle IDentification*: important for discriminating single photons from, e.g., p0 decay and e/p
- *Particle Reconstruction*: driven by need to accurately reconstruct the four-momentum of scattered electrons at small angles, where the momentum (or energy) resolution from the tracker is poor.

Tracker momentum resolution rapidly degrades at η< -2 because of the vanishing B*dl integral of the solenoid field; this definitely affects {x,Q2} reconstruction quality

EM Inner Calorimeter Requirements

- Good resolution in angle to at least 1° to distinguish between clusters
- Energy resolution to a few %/sqrtE for measurements of cluster energy
- Ability to withstand radiation down to at least 1° wrt beam line



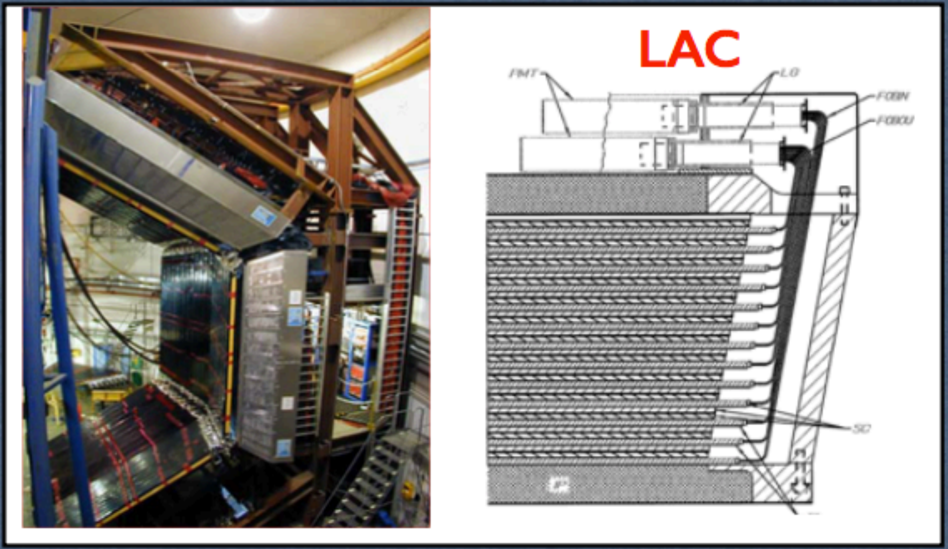
INFN Genova

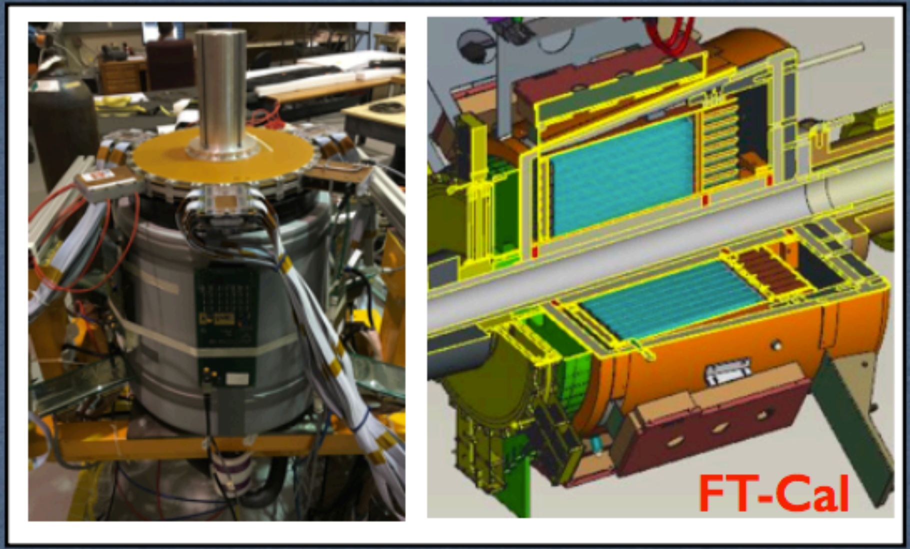
INFN-GE group: 5 staff + postdocs, students

Hadron spectroscopy + exotic matter search (light Dark Matter)

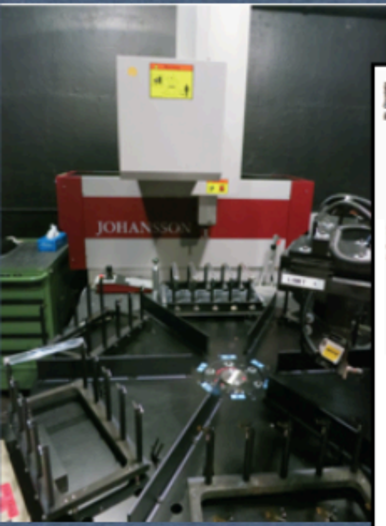
INFN-GE group has expertise in EM calorimeters

- BGO Ball (GRAAL - ESRF Grenoble FR): BGO, PMTs, CAMAC
- CLAS Large Angle Calorimeter (Jefferson Lab): sampling, plastic +Pb, PMT, FastBus
- HPS ECal (Jefferson Lab): PbWO, APD, fADC
- CLAS12 Forward Tagger FT-Cal (Jefferson Lab): PbWO, APD, fADC
- BDX calorimeter: CsI(Tl) (BaBar crystals), SiPM, fADC triggerless

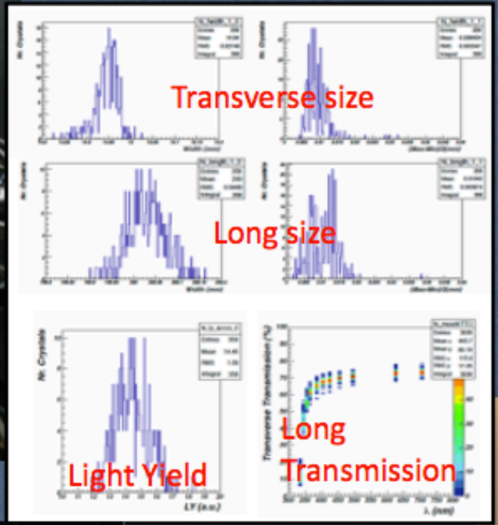




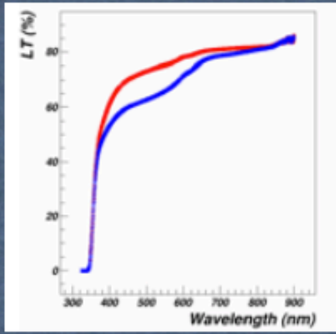
INFN Genova R&D for Experiments @ EIC



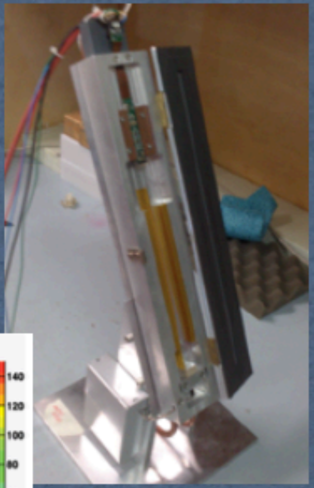
ACCOS@CERN



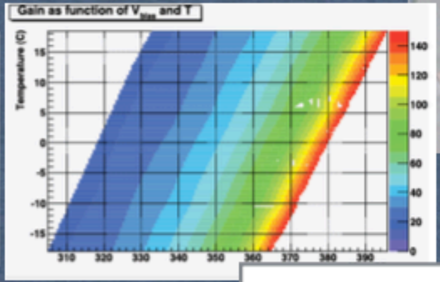
Sthralumcenter@GIESSEN



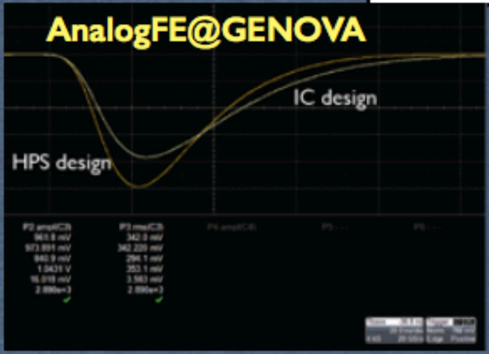
CrystalTest@GENOVA



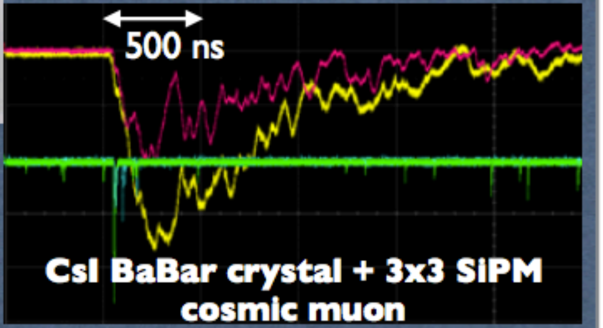
APDTest@GENOVA



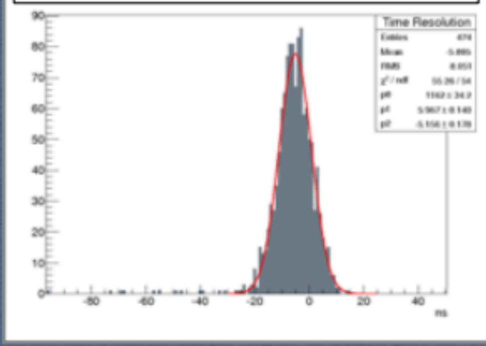
AnalogFE@GENOVA



Crystals (BSO, BaF, CsI(Tl)PbWO)
+sipm@GENOVA



CsI BaBar crystal + 3x3 SiPM
Time resolution: σ = 6ns



Triggerless DAQ

A triggerless data acquisition system for calorimetry: an R&D activity for the Electron Ion Collider (EIC)

M. Battaglieri, A. Celentano, R. De Vita, L. Marsicano, P. Musico, M. Osipenko, M. Ripani, M. Taiuti
Istituto Nazionale di Fisica Nucleare, Sezione di Genova e Dipartimento di Fisica dell'Università, 16146 Genova, Italy

EIC EMCal R&D proposal

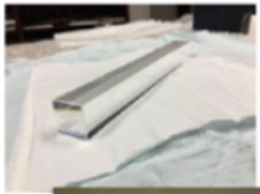
- Presented by A.Celentano at EIC Detector R&D meeting in July 2017
- *"The committee attributes much value to the study of triggerless data acquisition systems. However,given the tight budget constraints of the R&D program and the very early stage of the research program for the EIC, this project is currently not recommended for funding"*
- We are working with EIC-ECAL consortium to adapt the proposal to the different calorimeter technologies ready to resubmit the proposal this year

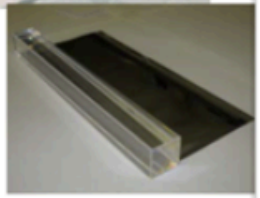
Triggerless DAQ implementation in EIC-ECal: case-study

A realistic implementation of the triggerless DAQ system in a test-case setup is necessary to validate the technology in the EIC-ECal context, understand issues, and demonstrate the expected performances.

A $PbWO_4$ matrix with SiPM readout

- A $PbWO_4$-based calorimeter is the leading choice for e^--side EIC-ECal, being extensively studied within ECAL consortium
- SiPM are a rapidly-growing technology, being investigated for EIC-ECal readout
- Results obtained from R&D activity can be exported to others technologies





Proposed activity outline:

- Implementation of a DAQ system based on a commercial FADC that allows for triggerless readout (e.g. CAEN v1725)
- **Development and test of trigger-less algorithms on a on-line CPU farm**
- Performance comparison with results obtained from a tradional, FPGA-based, triggered DAQ

Proposed R&D activity

Task 1: triggerless readout study

Goal: verify feasibility of triggerless system for EIC-ECal
Activity: setup and characterize a full prototype of front-end / readout / software-trigger chain. Study and implement algorithms to define trigger conditions corresponding to different event topologies (EM showers, cosmic rays, . . .)
Prototype response to cosmic rays and light sources will be measured to validate trigger algorithms

CAEN v1725

Task 2: comparison to triggered readout

Goal: test the same setup instrumented with a traditional, FPGA-based trigger and compare results
Activity: setup a triggered setup using JLab state-of-the-art trigger boards, implementing trigger algorithms on FPGAs

JLab fADC250

Task 3: optimized FE board for EIC-Ecal

Goal: design a FE board (block-diagram) that integrates the discrete components tested during the previous activity

Of Potential Interest

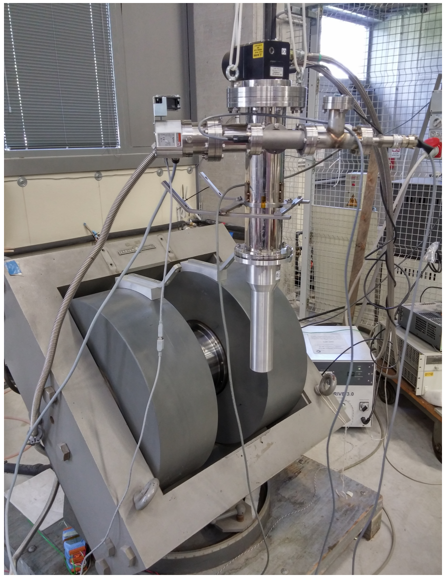
Torino: large area trackers and FE electronics
(derived from COMPASS)

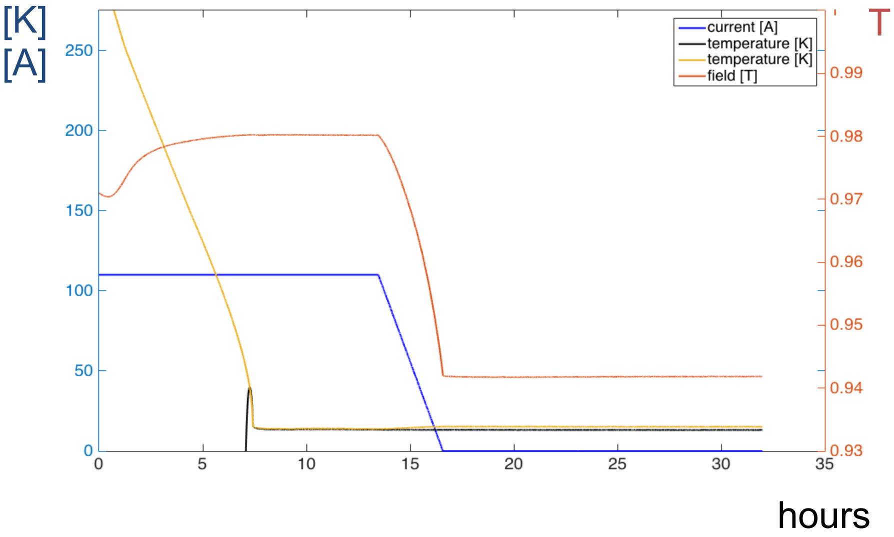
Roma Tor Vergata: calorimetry in collaboration with Genova

Bologna: Monte Carlo and TOF for PID

Bari: vertex detector and PID

Ferrara: bulk superconducting magnets and screens
(complementary to eRD2 − Magnetic Field Cloaking Device)





Financial Support

So-far growing external DOE fund support valuable for

* Promoting INFN expertise for future facilities
* Pursuing advances synergic with the ongoing activities (JLab, ALICE,⋯)

	Roma	Trieste	Ferrara	…
FY2015 DOE	16 k$ (post-doc)+			
FY2016 DOE	48 k$ (post-doc)+			
FY2017 INFN**		17 keuro		
DOE	48 k$ (post-doc)+	80 k$*		
FY2018 INFN**		12 keuro (10 s.j.)		
DOE	32 k$ (post-doc)+	44 k$* (post doc)	27 k$ (post-doc)+	
FY2019 INFN**	…	…	…	…
DOE	…	…	…	…

* No overhead INFN

** RD_FA CSNI

+ via USA Institutions