‘The strong interaction at the frontier of knowledge: fundamental research and applications’

JRA6 - Challenges for next generation DIS facilities

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STRONG-2020 Kick-off meeting

October 23-25, 2019

JRA6 - Challenges for next generation DIS facilities

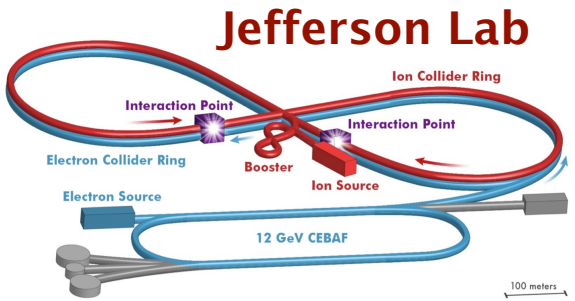
Electron-Ion Collider: World's first polarised electron-proton/light ion and electron-nucleus collider — high luminosity and large CM energies for unprecedented access to the quark-gluon sea.

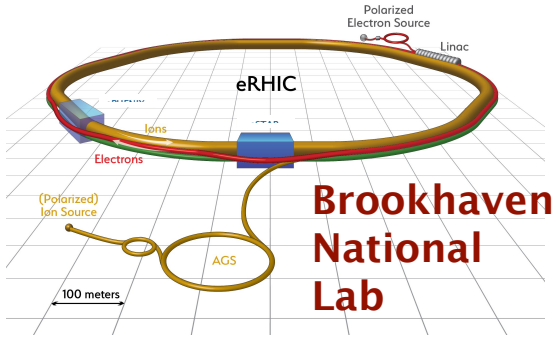
Some of the driving questions:

- Where does the saturation of gluon densities set in?
- What is the quark-gluon origin of the nuclear force and mass?
- What is the composition of nucleon spin across all scales? How do gluons contribute?
- What are the momentum and spatial distributions of quarks and gluons in nucleons and nuclei?
- How does a fast moving colour charge propagate in nuclear matter? Is the hadronisation process different for lights and heavy quarks?

Two sites under consideration:
decision expected 2020

- CoM energy: 20 - 140 GeV
- L ~ 10^{34} $cm^{-2}s^{-1}$



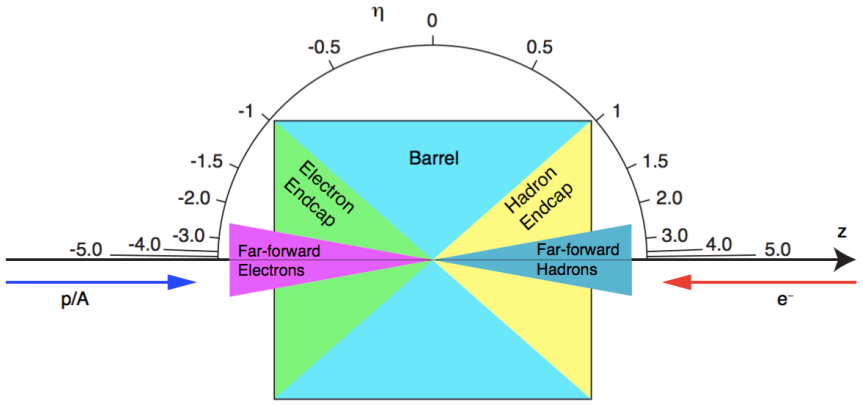


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

JRA6 - Challenges for next generation DIS facilities

Detector concepts - many requirements are site-independent:

- Hermetic detector
- Excellent vertex resolution
- Very good PID (e/π, π/K, p/K) in a wide momentum and angular range
- Excellent tracking



Objectives of JRA:

- Monte-Carlo simulations
- Very low ion-back-flow detectors for tracking with TPC
- Depleted MAPS for vertex detector and tracking
- PID with RICH

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JRA6 : Update on progress
Monte Carlo simulations

(Glasgow)

Experimental success depends on understanding and controlling systematic effects to a degree comparable to — or better than — statistical uncertainty.

→ Development of realistic Monte Carlo simulations:

- Basis for the design of an analysis network
- Informs detector design and refines detector parameters

STRONG-2020 funds for postdoc to focus, initially, on simulations of exclusive processes. Studies of the interaction region and full detector requirements, with specific focus on the optimisation of tracking and PID detectors.

- Reliable simulations of interaction region: radiation dose analysis, backgrounds, optimal detector configurations and resolution.

Final-year project student 2019-20, postdoc due to start early 2020 — recruitment starting.

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JRA6 : Update on progress
Very low IBF detectors for TPC

(Saclay, CEA)

- Time-projection chambers (TPCs) are among the best candidates for particle tracking in the central part of an EIC detector
- At high collision rate, the main limitation for a TPC solution is the back-flow of positive ions (IBF) in the drift volume.
- The IBF causes distortions to the electric field
- The top priority it to **minimize the IBF**
- CEA/Irfu aims to:
  - Develop Micromegas based solutions for TPC readout
  - Build and characterize multi-mesh prototypes

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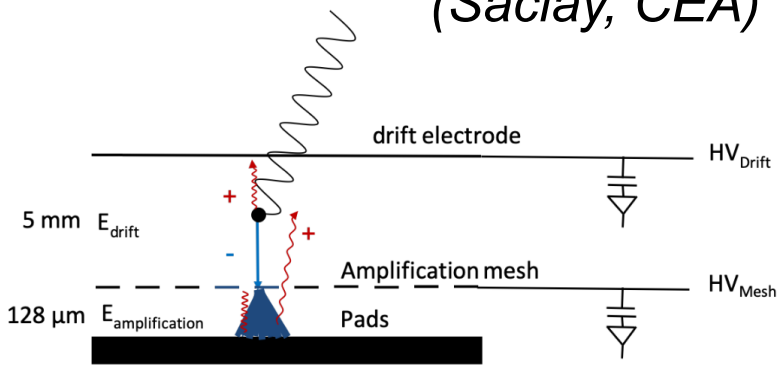
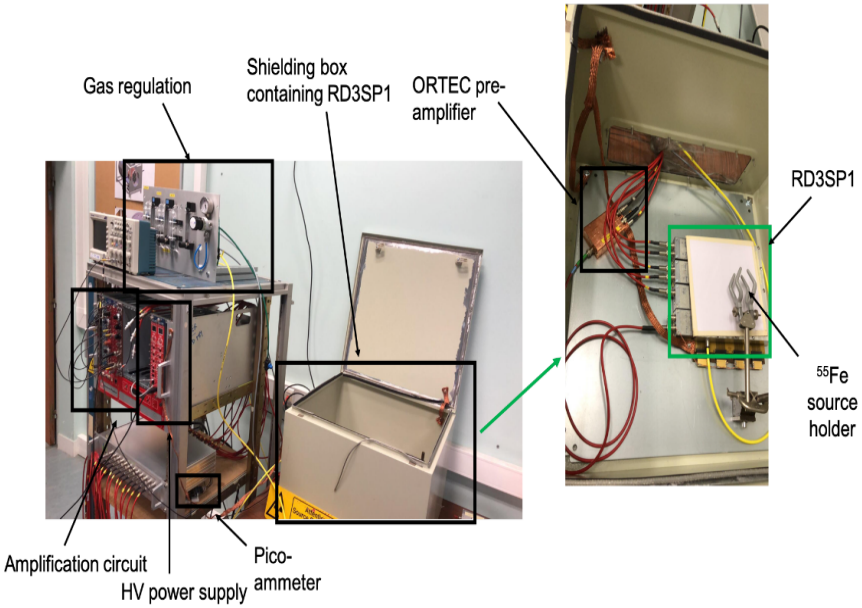
JRA6 : Update on progress
Very low IBF detectors for TPC

(Saclay, CEA)

- Work started already with an internship student during summer (A.Glaenzer). She will continue to work on this project for her PhD thesis.
- Setup of the test bench (photo) with picoammeter for very tiny current measurements
- A standard Micromegas and a 2GEMs + MM prototype tested as baseline
- Ongoing design of 2-mesh Micromegas prototype
- Garfield++ simulations of several geometries & mesh designs will be carried out to define the best configuration that minimizes the IBF





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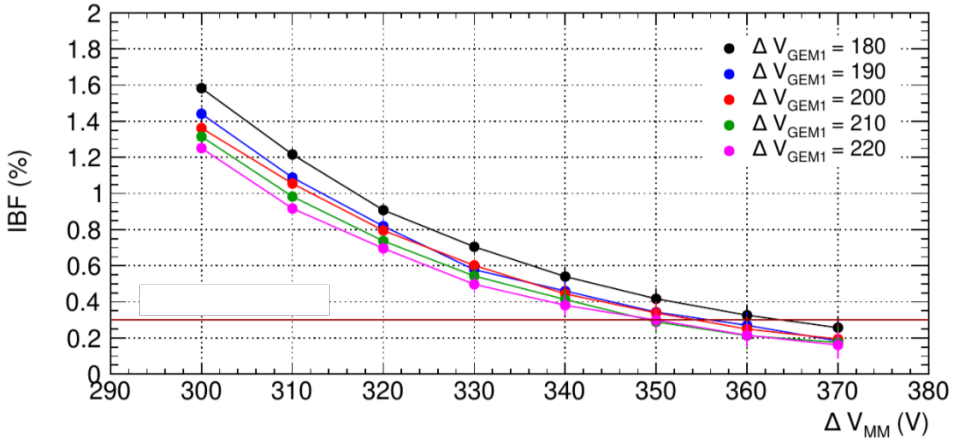
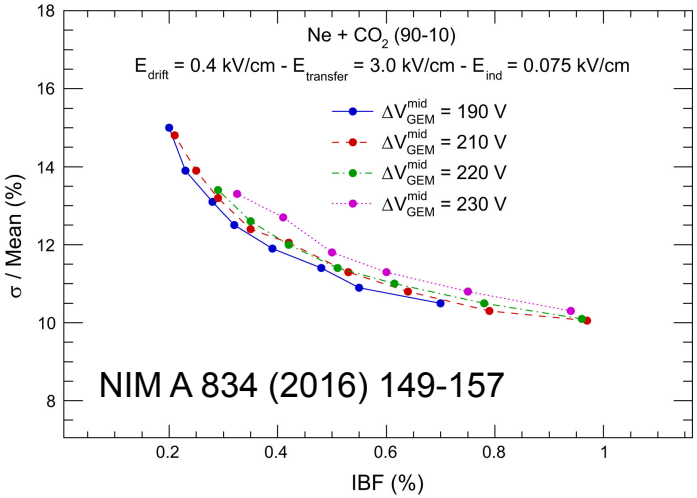
JRA6 : Update on progress
Very low IBF detectors for TPC

(Saclay, CEA)

Characterization of a MM + 2GEM hybrid prototype is ongoing:
- Possible alternative for sPhenix TPC readout
- aiming at improving the IBF with respect to literature
- IBF anti-correlates with energy resolution



This hybrid solution will be the baseline for comparing multi-mesh solutions.
- aiming also at improving the energy resolution



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JRA6 : Update on progress
Very low IBF detectors for TPC

(Saclay, CEA)

Milestone:

- To have working prototypes up and running (autumn 2020)

Deliverable:

- Irfu plans to publish the results on the IBF studies.

Note:

- The STRONG-2020 money will be used for:
  - ~1 year post-doc (the candidate has been selected and he will start in December)
  - Multi-mesh prototypes production
  - Possible test-beams

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JRA6 : Update on progress
Silicon vertex detector and tracker

(Birmingham)

- UoB is working on the development of a detailed concept for a central silicon vertex detector, exploring the potential advantages of **depleted MAPS (DMAPS) technologies**

- This project has been running since 2016 with continuous support from the **EIC Detector R&D Programme**
  - R&D funds provided to BNL by the DOE Office of Nuclear Physics

- The project focuses on the development of an EIC specific DMAPS sensor and conceptual design of the silicon vertex and tracking detector
  - **Sensor Development**
    - Exploit on-going R&D in Birmingham into DMAPS to investigate potential solutions for the EIC → **STRONG2020 funds enable further development of this part of the project**
  - **Silicon Detector Layout Investigations**
    - Study performance requirements in terms of numbers of layers, layout and spatial resolution of the pixel hits

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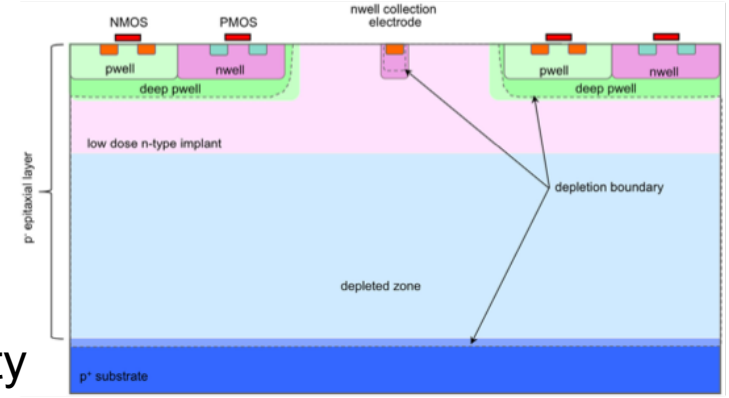
JRA6 : Update on progress
Silicon vertex detector and tracker

(Birmingham)

- Towards an EIC-specific DMAPS sensor
  - Aim for improved spatial resolution with respect to ALPIDE (ALICE ITS sensor)
    - Smaller pixels (20 x 20 mm^2)
    - Low mass detector layers (< 0.3% X/X_0)
  - Consider readout requirements for the EIC
    - Integration time and time-stamping capability

TJ 180 nm CMOS imaging process with modified cross section



W. Snoeys et al, http://dx.doi.org/10.1016/j.nima.2017.07.046

- Current status
  - **Technology** identified: TowerJazz modified process
  - Defined preliminary **specifications** for EIC-specific DMAPS sensor
  - Ongoing EIC specific DMAPS **design study** in collaboration with RAL CMOS sensor design group
- Next step: design and production of a prototype EIC DMAPS sensor

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JRA6 : Update on progress
Silicon vertex detector and tracker

(Birmingham)

- M1 – M12
  - Complete feasibility study
- M13 – M21
  - Design DMAPS prototype, DAQ preparation
- M22 – M24
  - DMAPS prototype submission & production, DAQ preparation
- M25 – M30
  - DMAPS prototype lab characterisation
- M31 – M48
  - DMAPS prototype characterisation in test beams
- Note
  - The funding received via STRONG2020 will be used to contribute to costs of the submission and production of the DMAPS prototype
  - Funding from other sources will be used to acquire the resources for the design and testing of the DMAPS prototype

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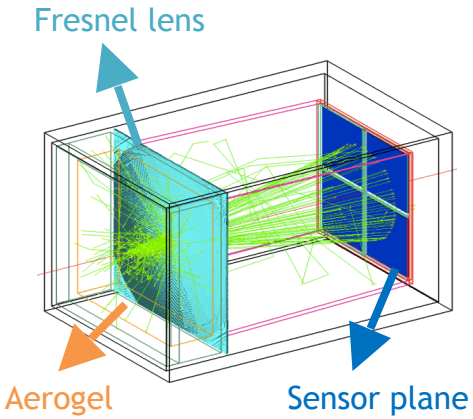
JRA6 : Update on progress
PID with RICH

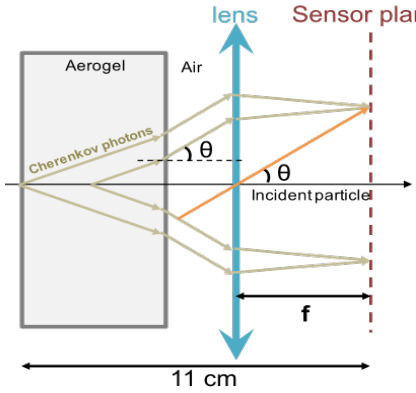
(INFN)

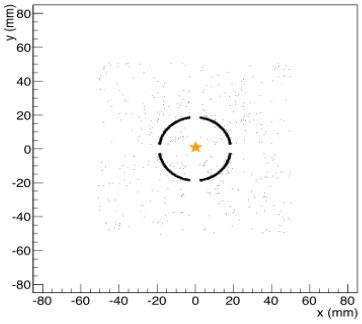
Compact modular solution for few-GeV range

mRICH: An aerogel RICH with Fresnel lens focalization for compact and projective imaging (electron endcap)

π/K sepration up to ~ 10 GeV/c

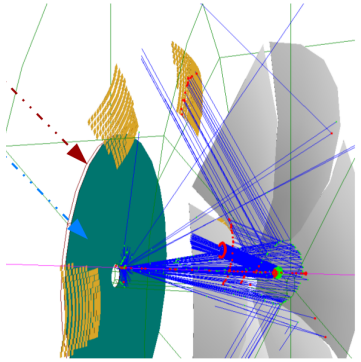






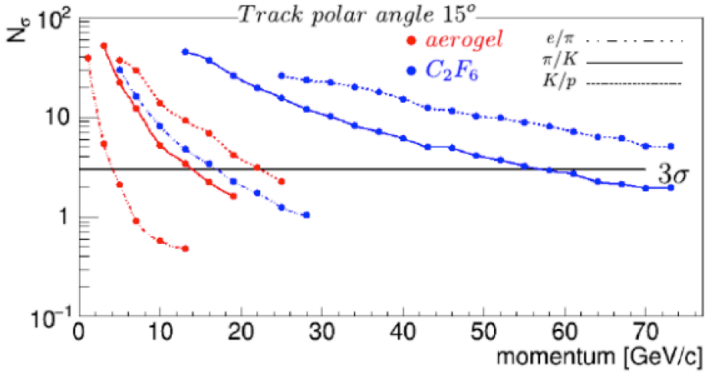
Dual-radiator for extended momentum range

dRICH: A RICH with two radiators (gas + aerogel) for wide momentum coverage (hadron endcap)



Separation

π/K up to ~ 50 GeV/c
e/π up to ~ 15 GeV/c



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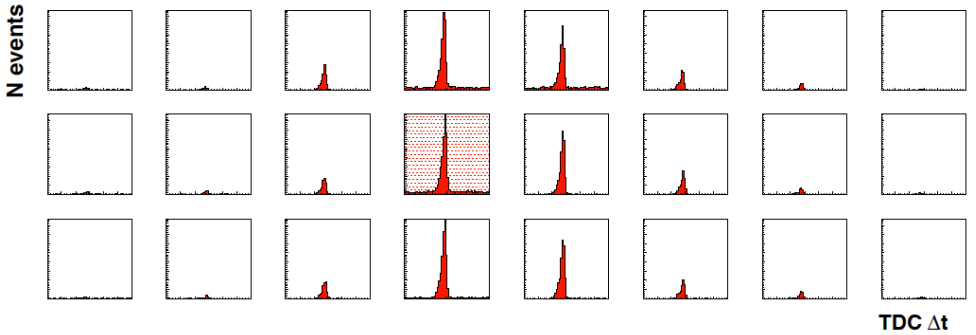
JRA6 : Update on progress PID with RICH

(INFN)

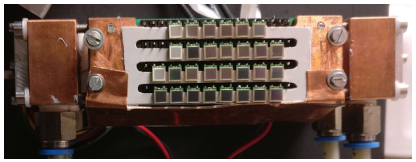
Photon-detectors:

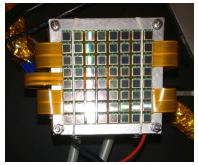
Studies of SiPMs and LAPPDs to identify best choice for EIC RICH

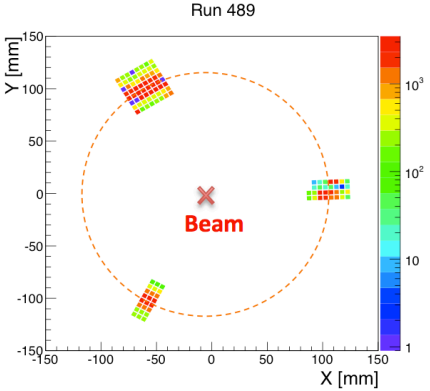


Resolution ~ 150 ps **Cooled SiPM as good as PMTs!**

SiPM tests in-beam:

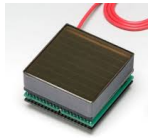






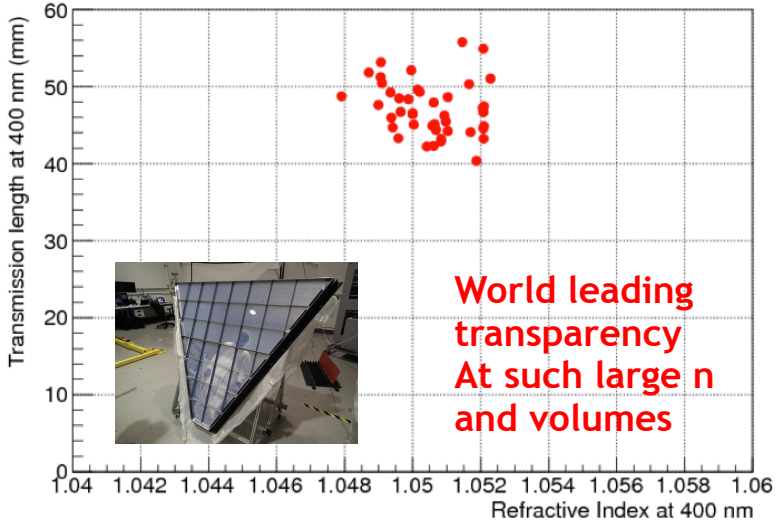
Reference detector:
H8500/H12700
flat panel multi-anode PMTs
64 pixels on a 5x5 cm² area

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



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

Modular RICH: aerogel transparencies



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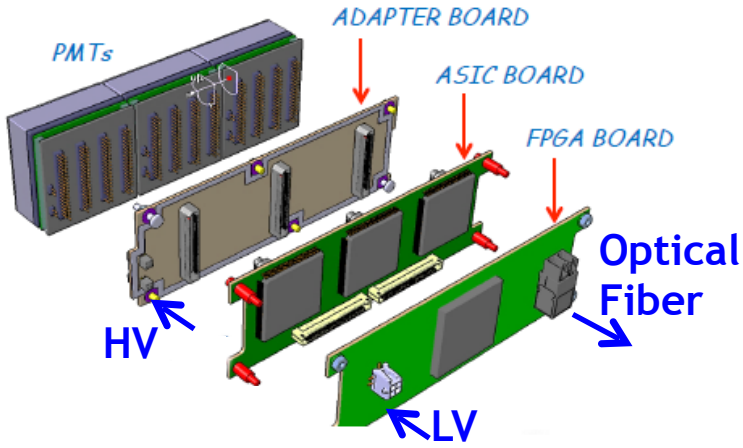
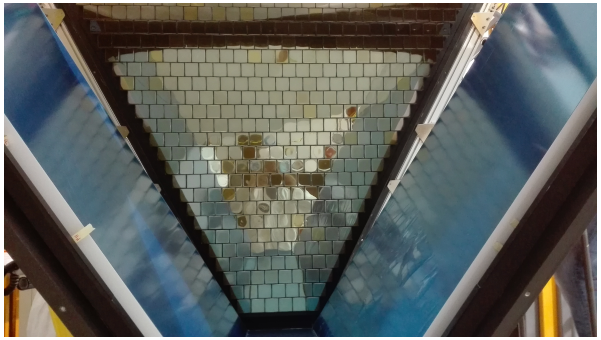
JRA6 : Update on progress PID with RICH

(INFN)

Modular Readout Electronics

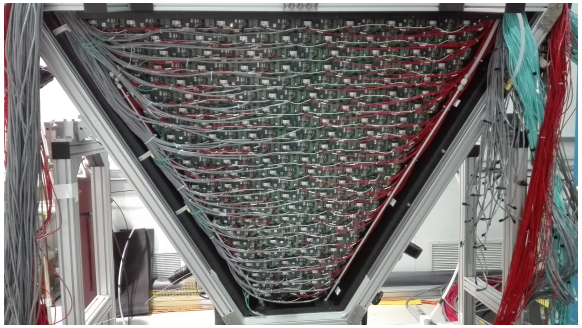
Compact (matches sensor area)
Modular Front-End (Mechanical adapter, ASIC, FPGA)
Scalable fiber optic DAQ (TCP/IP or SSP)
Tessellated (common HV, LV and optical fiber)





Applications:

- CLAS12 RICH
- **EIC R&D**
- Gluex DIRC
- SOLID
- Medical Imaging
- Homeland Security



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

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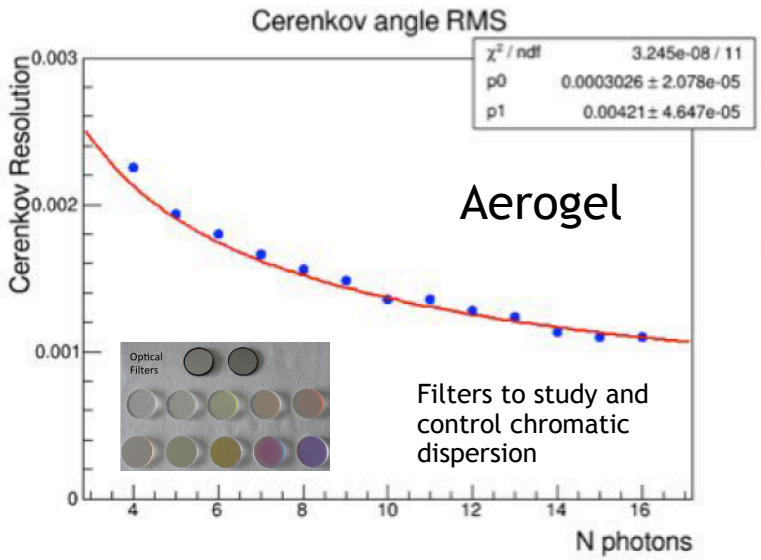
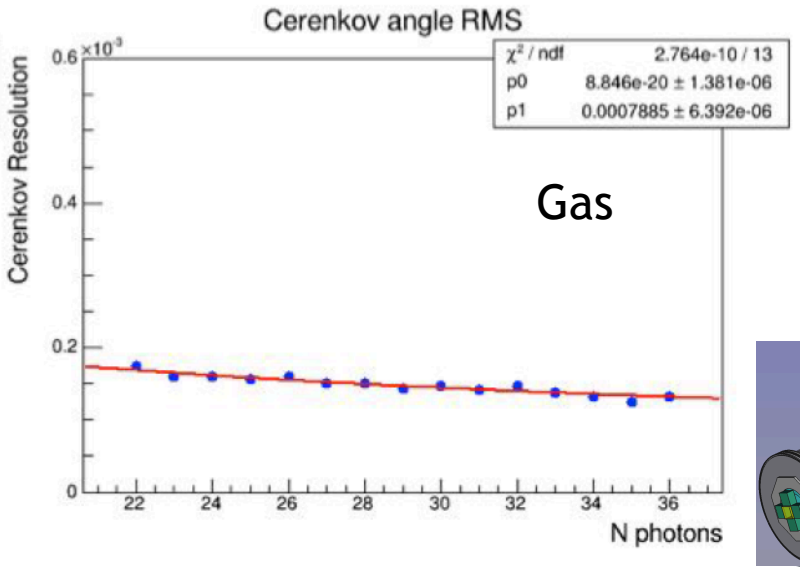
JRA6 : Update on progress PID with RICH

(INFN)

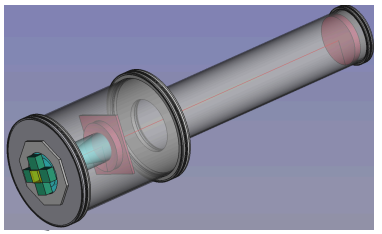
Montecarlo simulation: resolutions



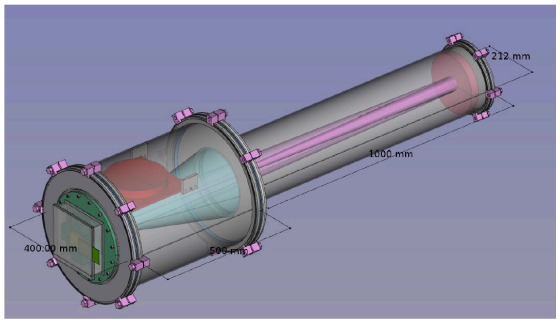
Filters to study and control chromatic dispersion



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



1 p.e. Error (mrad)	Aerogel	@EIC	C_2F_6 Gas	@EIC
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)



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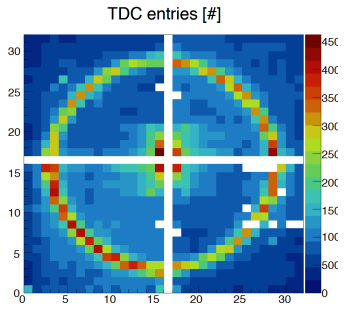
JRA6 : Update on progress
PID with RICH



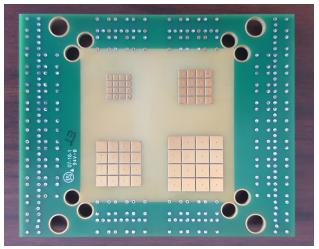
Readout Independent element for flexibility: supports various detectors with integrated cooling

Reference:
MAROC + SSP/VSX

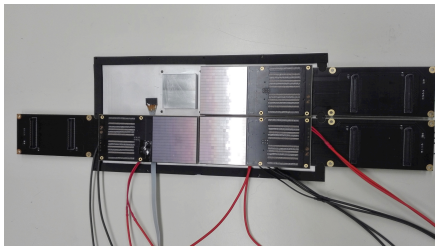
Dedicated:
SiREAD + SSP/ethernet

Reference:
MA-PMTs

B-field tolerant:
MCP-PMTs (LAPPDs)



SiPMs



Activity extends and integrates ongoing developments in synergy with the EIC R&D program (eRD14 PID Consortium).

Timeline:

- Construction of dRICH prototype
- Tests of photon sensors using a fast laser
- Lab characterisation of electronics with the new sensors
- Combine sensors, electronics and RICH prototypes for in-beam tests ~2021

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JRA6 : Deliverables & Milestones

- Deliverables due for Reporting Period 1: D24.1 in M18 (November 2020)

Deliverable Number[14]	Deliverable Title	Date	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D24.1	Optimisation of EIC tracking, PID and interaction region design	November 2020	Report	Public	18

- D24.1 'Optimisation of EIC tracking, PID and interaction region design'. Monte Carlo simulations using up-to-date and realistic generators for a range of physics reactions. These will be used to optimise the interaction region, tracking and PID designs and result in a technical publication.

Milestone number[18]	Milestone title	Date	Due Date (in months)	Means of verification
MS48	EIC PID and tracking design	November 2020	18	Report available
MS49	IBF-stopping device prototypes constructed	August 2020	15	Up and running

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JRA6 : Summary

- Simulations started with project student, main effort awaiting postdoc recruitment in early 2020 in Glasgow.
- Low-IBF detector development well underway in CEA-Saclay, on track for a prototype in 2020.
- Depleted MAPS sensor prototype design under development at Birmingham, together with RAL. Production expected in 2021.
- Photon sensors and electronics for RICH advancing in INFN — aim for beam-test of prototype dual-RICH in 2021.
- Workshop planned for spring 2020.

Detectors adaptable for either of the EIC designs: site decision expected ~2020.

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JRA6 : Participants

Brookhaven National Lab (BNL)
Centre National de la Recherche Scientifique (CNRS) *Institut de Physique Nucleaire d'Orsay*
Istituto Nazionale di Fisica Nucleare (INFN) *INFN Laboratori Nazionali di Frascati*
Istituto Nazionale di Fisica Nucleare (INFN) *INFN Sezione di Pavia*
Istituto Nazionale di Fisica Nucleare (INFN) *INFN Sezione di Roma 1*
Jefferson Lab (JLab)
University of Antwerpen (UAntwerp)
University of Edinburgh (UEdinburgh)
Universié Libre de Bruxelles (ULBrussels)
University of the Basque Country (UPV-EHU Bilbao)
University of Santiago de Compostela (USC)

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