STRONG-2020

HORIZON 2020

Annual Meeting 2024

JRA6 – Challenges for next generation DIS facilities (NextDIS)

F. Bossù (CEA)

Plan of presentation

01 Progress achieved by the WP during the last year

02 Important highlights of the performed work (last year + full project duration)

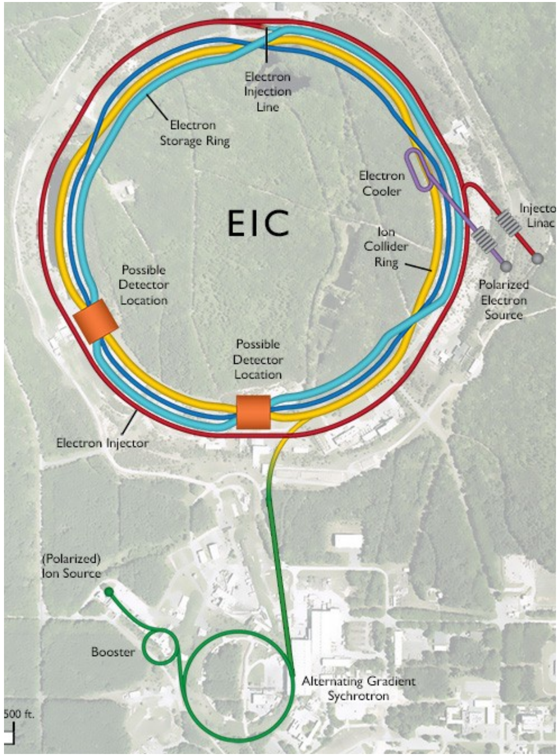
03 Tasks and achievements beyond the initial Work Program

The Next Generation DIS facility → EIC

The Electron-Ion Collider (EIC) is the next generation hadron physics facility on our immediate horizon focused on a range of critical questions in QCD that remain unanswered.

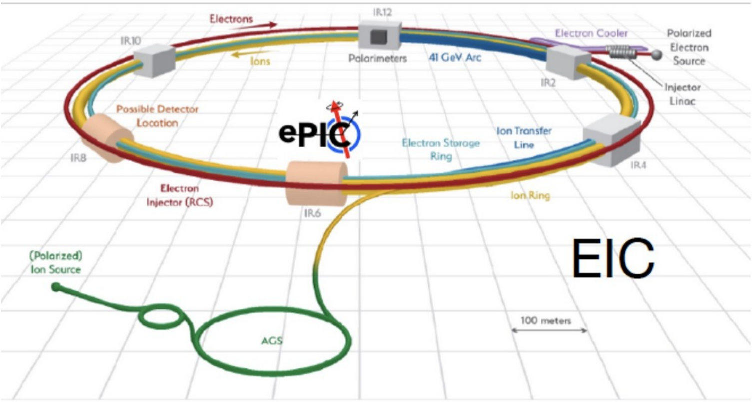
Electron-Ion Collider:

- 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

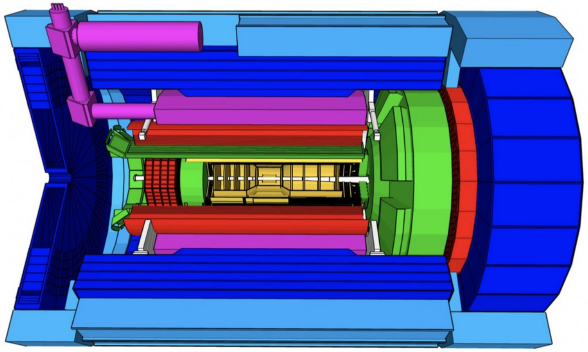


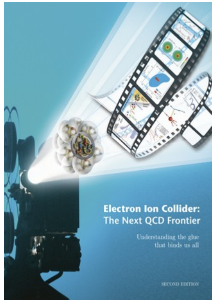
EIC milestones:
2020: **CD-0,** BNL is selected as host lab
EIC Yellow Report
2021: **CD-1**, the EIC project execution starts

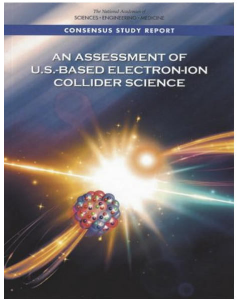
The Next Generation DIS facility → EIC

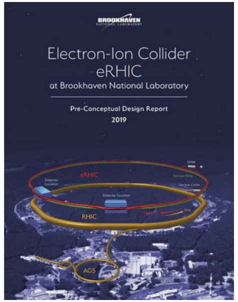


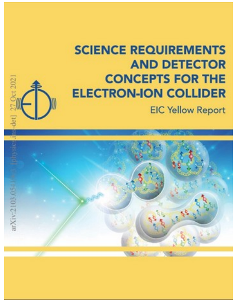
ePIC











2012 → now

A long journey

2022: **ePIC collaboration forms**

CD-3, expected 2025-26, will mark the start of the construction phase
Start of operations ~ mid 2030s

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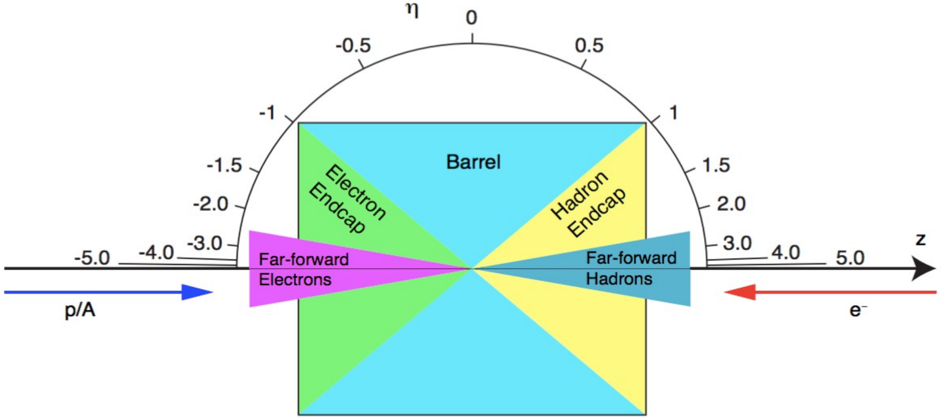
Electron-Ion Collider & JRA6 Objectives

Detector requirements:

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



Objectives of JRA:

1 Monte-Carlo simulations for detector requirement definition

2 Very low ion-back-flow detectors for tracking with TPC

3 Particle identification with RICH

4 Depleted MAPS for vertex detector and tracking

CAVEAT:
Many changes in the EIC detector choices steered our activities

Task 1: Monte Carlo simulations

- **Deliverable achieved in 2021**, coinciding with the EIC Yellow Report.
- Particular focus on exclusive reactions (DVCS, DVMP, TCS)
- **Use of EpIC generator (from the PARTONS framework, VA2)** in ePIC
- Since summer 2023, monthly simulation campaigns in ePIC
- Workflow example: TCS

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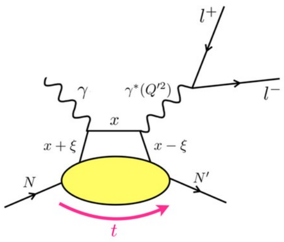
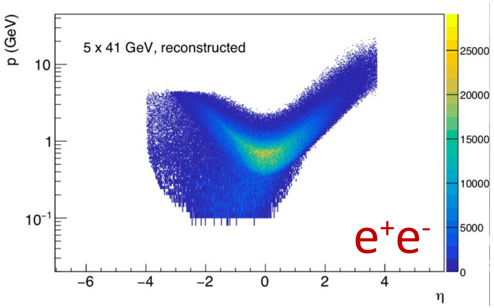
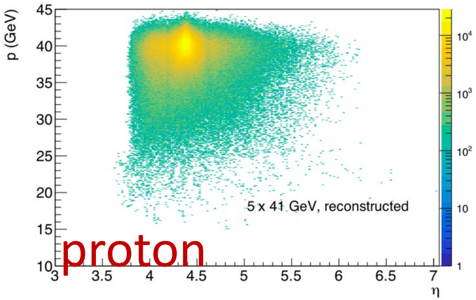
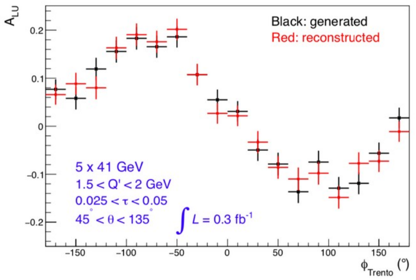
Generator → G4 → Reconstruction of final state particles → Physics analysis









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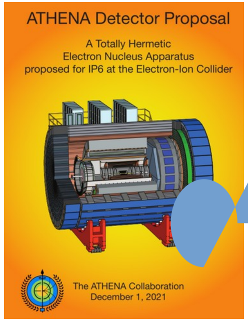
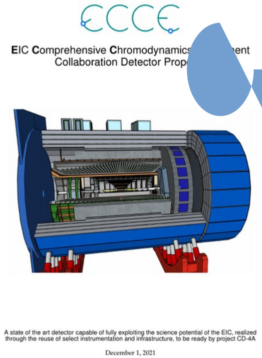
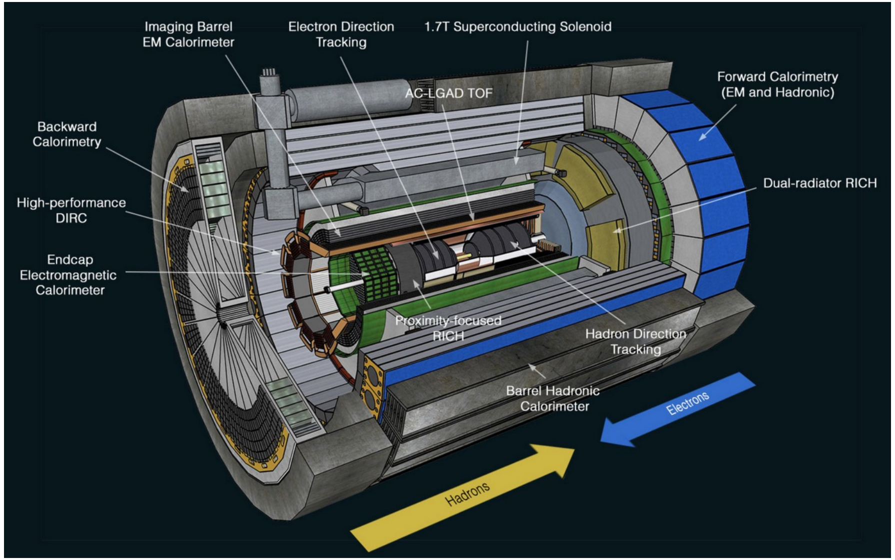
Simulations for EIC – ePIC

- JRA6-tasks members are involved in detector simulations for ECCE/ATHENA ⟶ ePIC
- From the 2022 detector baseline (the ECCE proposal), the ePIC detector evolved substantially
- Current focus: realistic implementation of detectors in Geant4:
  - Silicon Vertex Tracker (SVT)
  - MicroPattern Gaseous Detectors (MPGD)
  - Dual radiator RICH
- Performance studies



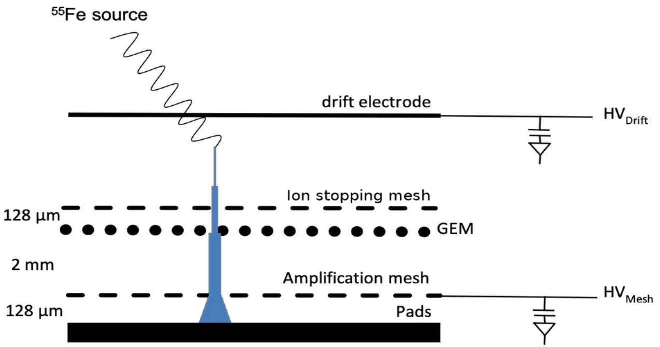


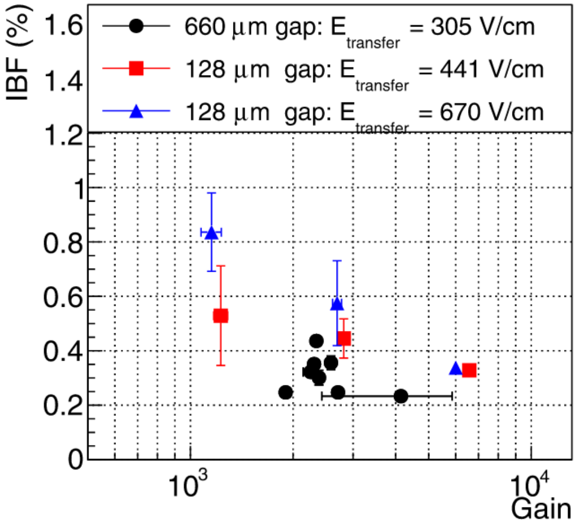


Task 2: Low IBF for TPC read out

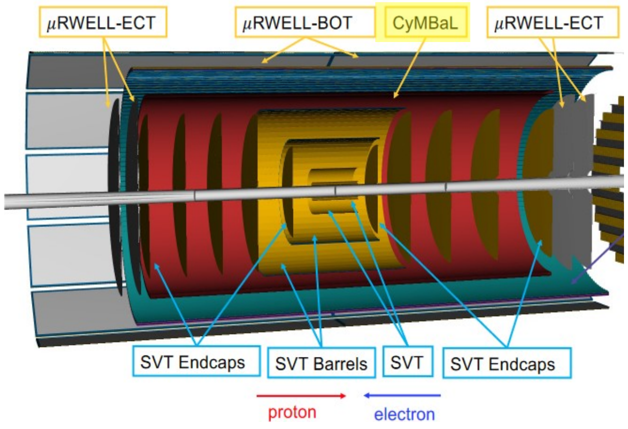
- A novel structure for ion backflow reduction was studied: a Micromegas detector was couple with a GEM+micromesh pre-amplification
- IBF values lower than 0.3% have been reached
- **Results have been published in 2022.**

doi:10.1016/j.nima.2022.167752

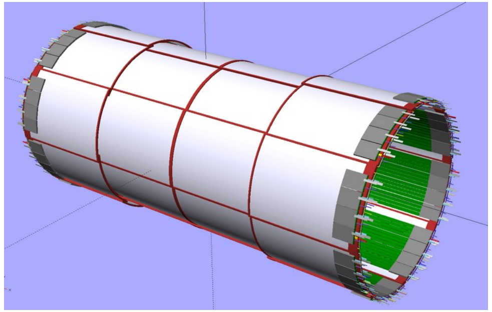




Task 2: MPGD for tracking in ePIC

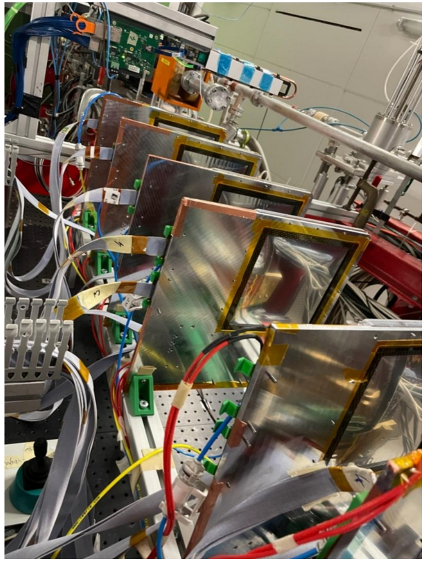


- **CyMBaL**: a tracking layer close to the inner silicon vertex tracker
- It provides **additional hit points for track finding**
- Requirements:
  - ~150µm spatial resolution,
  - ~10ns time resolution
  - Full acceptance
  - Low material budget
- Dimensions :
  - Inner radius 55 cm
  - Length 2.4 m
- **32 modules**
- **Readout based on a new ASIC: SALSA**



Technology

- Cylindrical resistive Micromegas technology developed for the CLAS12 experiment. At work since 2017 in high radiation and B=5 T
- Compact and modular
- **Ongoing R&D**
  - 2D readout with 1 mm pitch orthogonal strips

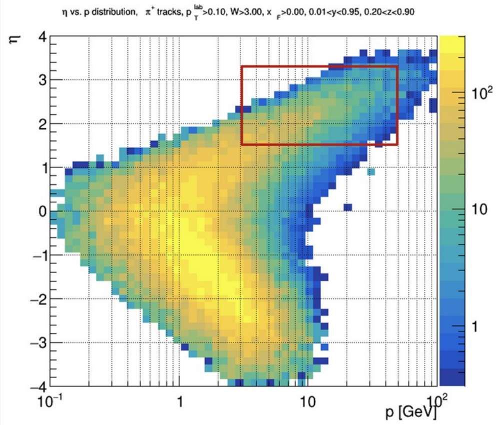


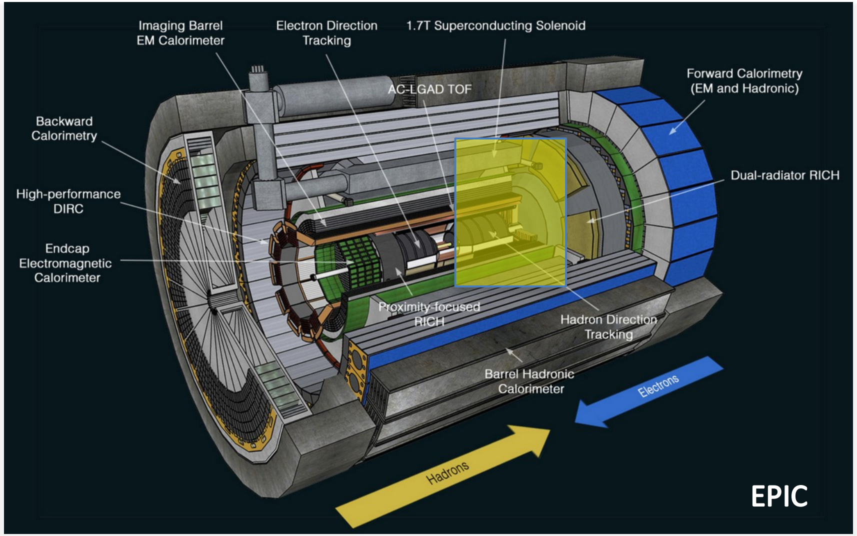
Test beam in MAMI in 2023

Task 3 – ePIC dRICH

Compact cost-effective solution for particle identification in the high-energy endcap at EIC

Essential for semi-inclusive physics due to
absence
of kinematics constraints at event-level





Forward particle detection

Hadron ID in the extended 3-50 GeV/c interval

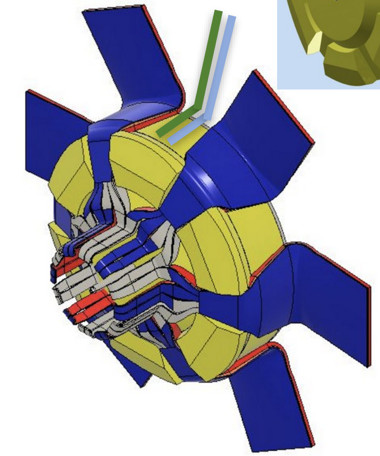
Support electron ID up to 15 GeV/c

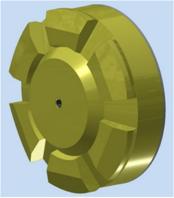
Main challenges:

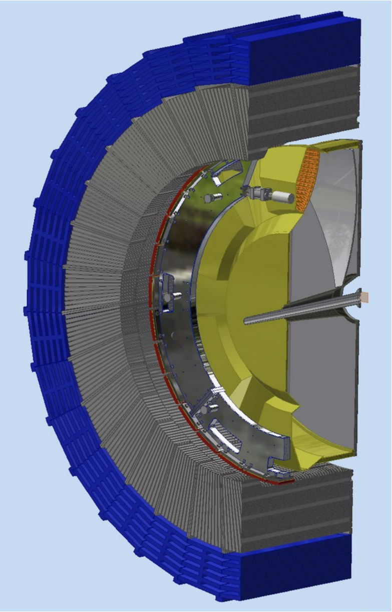
Cover wide momentum range 3 - 50 GeV/c -> dual radiator
Work in high (~ 1T) magnetic field -> SiPM
Fit in a quite limited (for a gas RICH) space -> curved detector

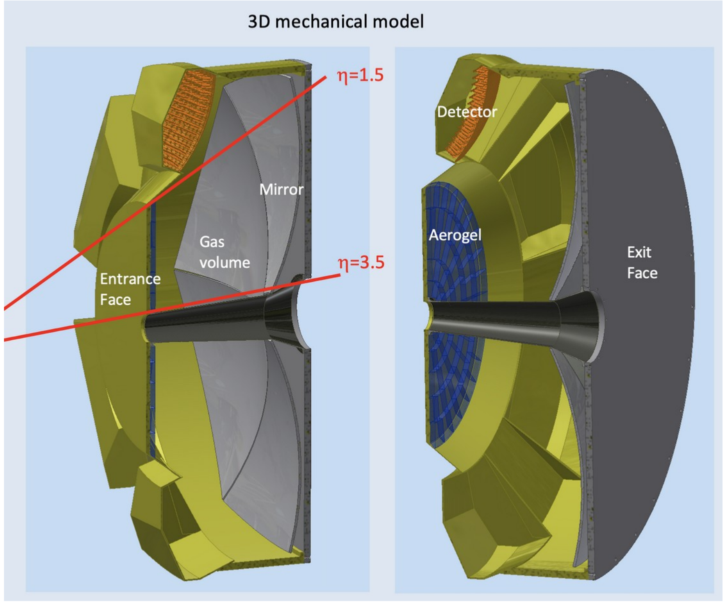
Task 3 – ePIC dRICH

- Φ3600 mm x L1200 mm
- Operating pressure up to 200 Pa
- Operating temperature of 22 °C





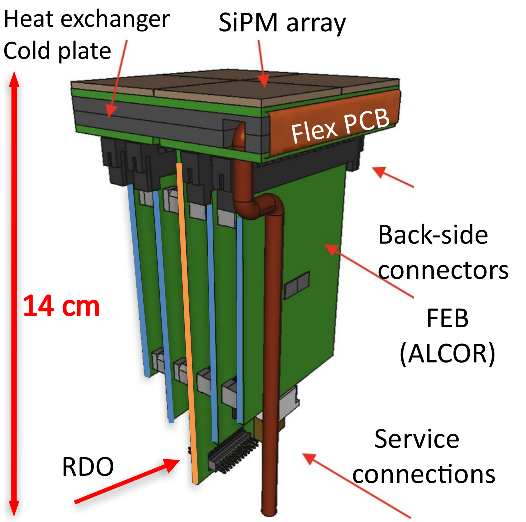


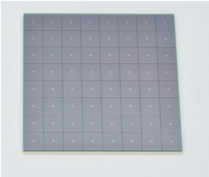


Acceptance: defined by pipe and barrel ECALl
minimize material budget with the use of composite materials

Interferences: material budget concentrated beheind the barrel ecal and its support ring
readout electronics design in order to minimize the detector box volume

Task 3 – dRICH Photo-Detector





SiPM array

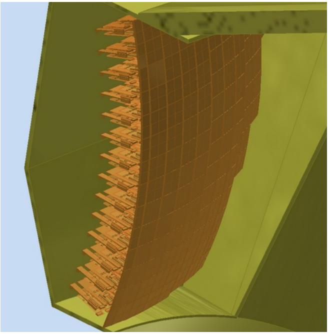
ALCOR chip

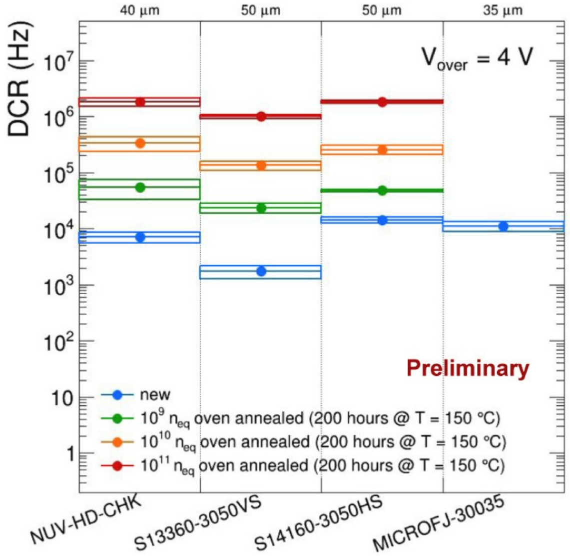
Photon Detector Unit (PDU):

Compact to minimize space

- 4x Hamamatsu S13361-3050HS SiPM arrays
- 4x Front-End Boards (FEB)
- 4x ALCOR chip (ToT discrimination)
- 4 x Annealing Circuitry
- 1x Read-Out Board (RDO)
- 1x Cooling plate (< -30 C)

Active area is shaped to resemble the focal surface and best exploits the focalization



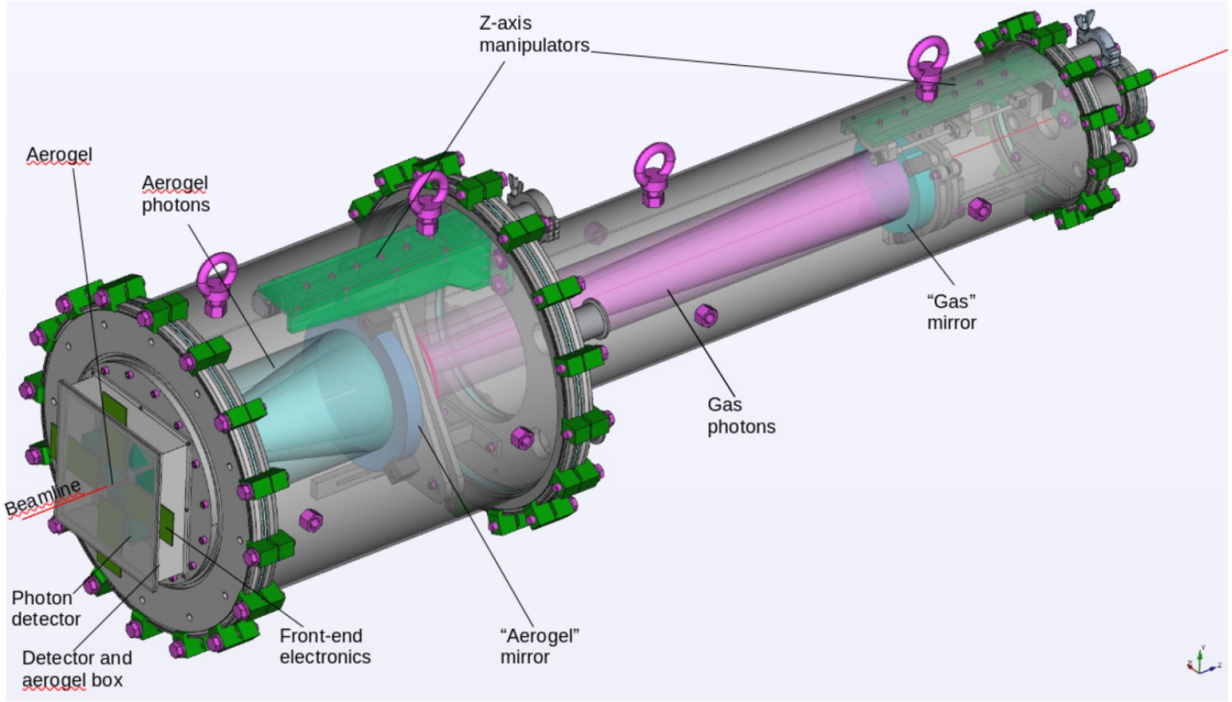


Radiation Tolerance Studies

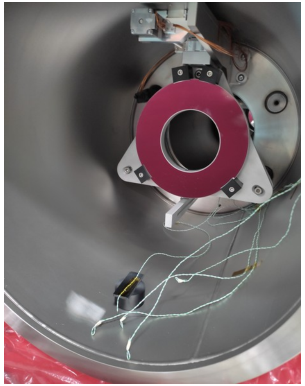
Task 3 – dRICH Prototype

On axis optics to minimize the active area, single or double radiator imaging

Vacuum technology & recovery system for efficient gas exchange



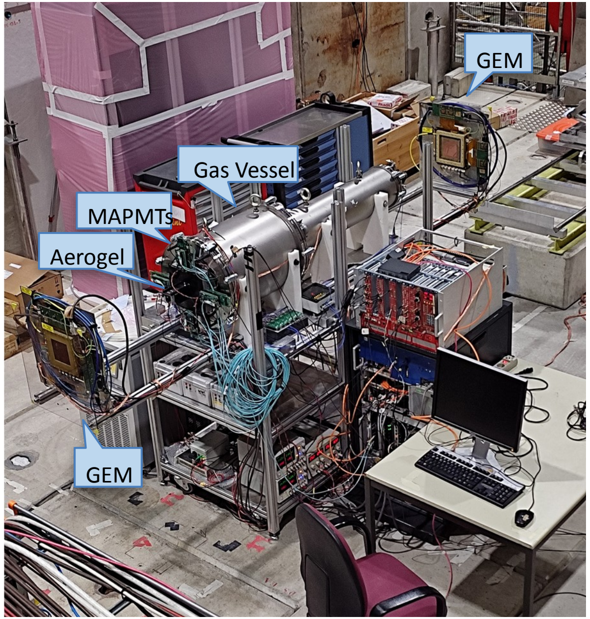
1st chamber



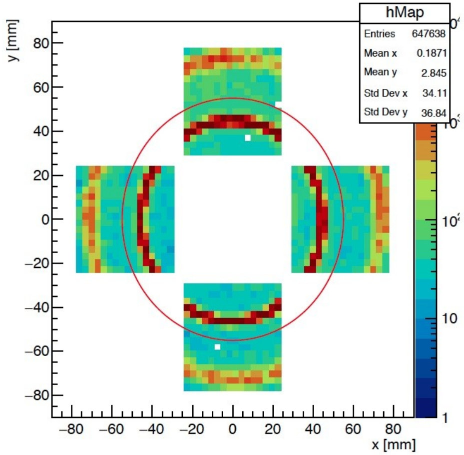
Gas recovery system

Task 3 – 2023 Test-beam

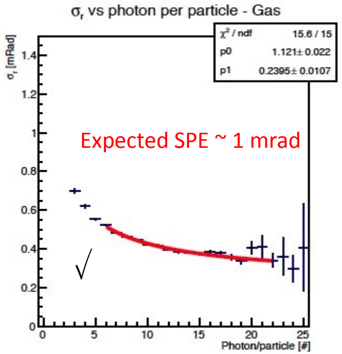
Operative prototype commissioned. Double ring imaging achieved. Performance in line with expectations except for aerogel single-photon angular resolution (worse by a factor ~ 1.5)

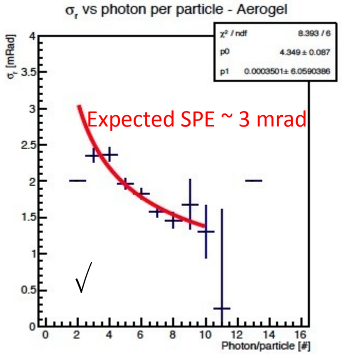


Reference readout from CLAS12 RICH:
H13700 MA-PMTs + ALCOR3 ToT chip



Gas ring coverage: 60%
Aerogel ring coverage: 40 %

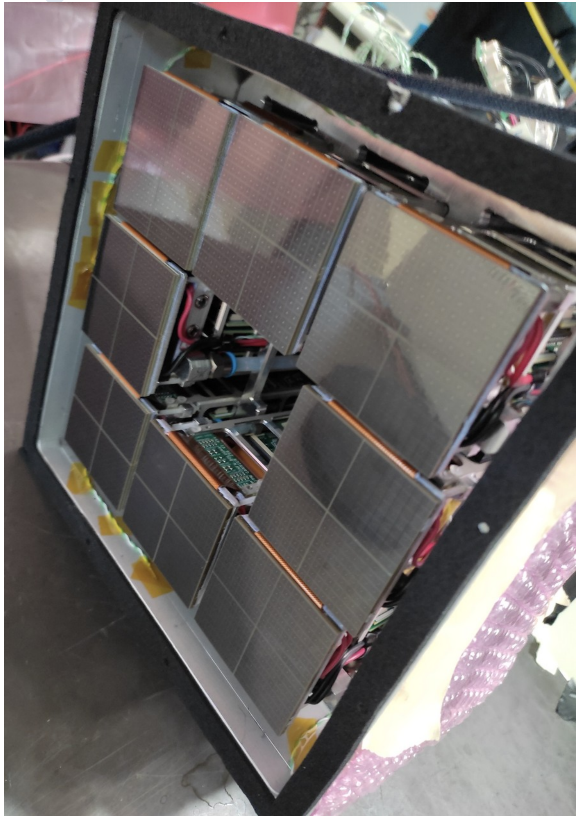




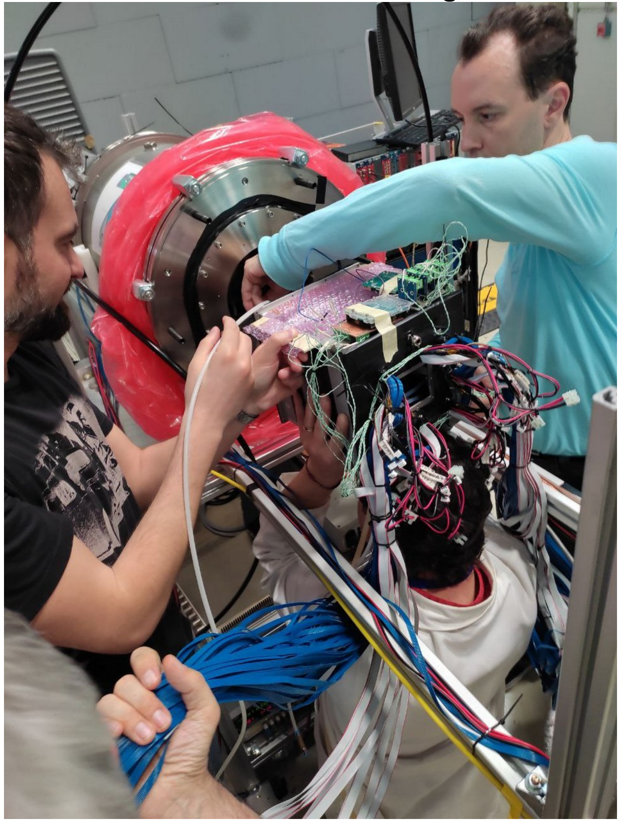
Optics at variance with respect EIC

Task 3 – 2024 Test-beam

SiPM Detector



Detector Mounting



Tracking GEM+SciFi

Task 3 – 2024 Test-beam

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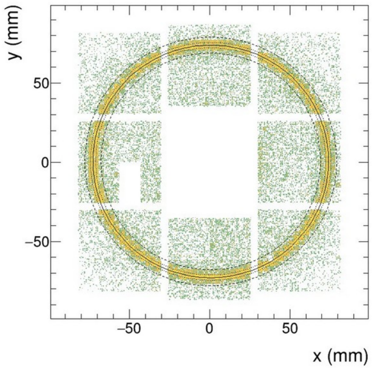
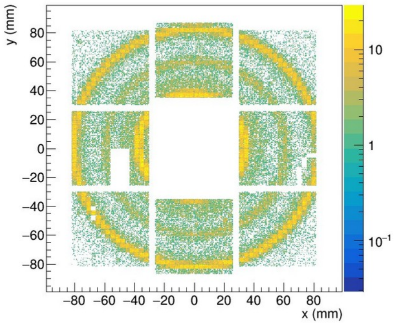
Aerogel (n=1.020),
negative beam, 10 GeV/c

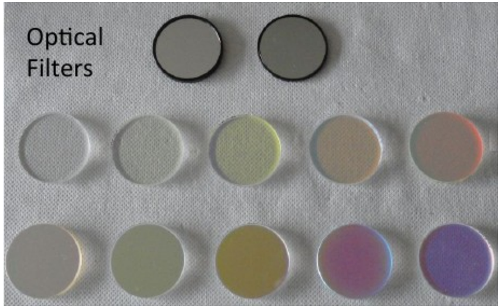


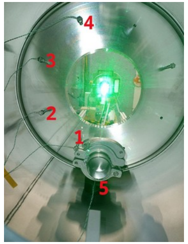
Aerogel (n=1.026) + C_2F_6 radiators,
positve beam, 8 GeV/c

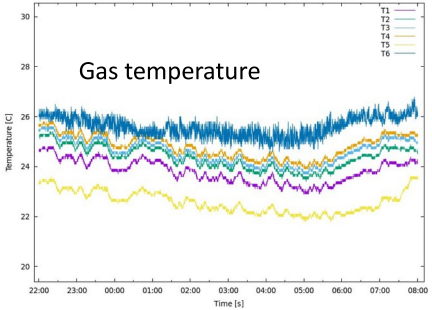


Successful campaign:

- Mixed hadron beam 2-11 GeV/c
- Various aerogel samples (1.020-1.026)
- Two gas radiators (C_2F_6, C_4F_{10})
- Two SiPM working points (-40 C and -20 C)
- Two tracking systems (GEM & SciFi)
- Many optical fiters
- Beam line Cherenkov tagging
- Temperature monitor

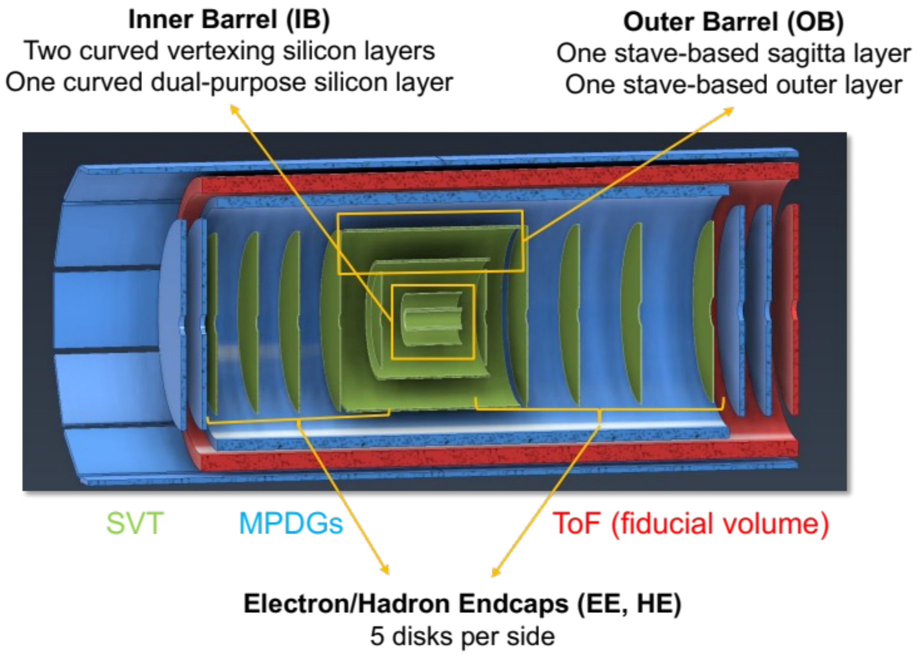






Task 4 – Silicon vertex and tracking for EIC

- The ePIC SVT is a **high precision silicon detector** based on **65 nm CMOS pixels**.



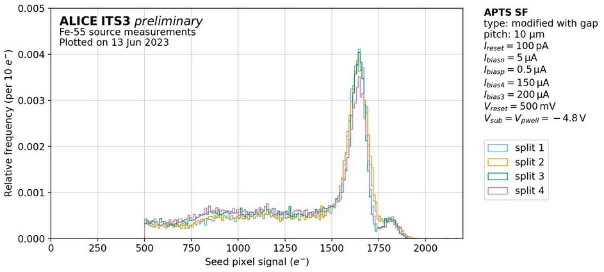
SVT Total (active) area ~ **8.5 m²**

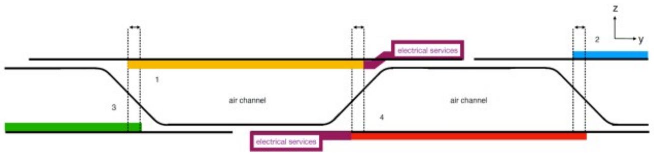
ePIC SVT target specifications	
Spatial resolution	~ 5 um
Power	< 40 mW/cm²
Frame rate	≤ 2 μs
Material budget (per layer)	IB: **0.05%** X/X_0 OB: **0.25, 0.55%** X/X_0 EE/HE: **0.25%** X/X_0

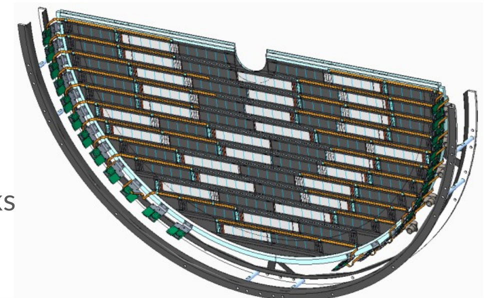
Task 4 – Silicon vertex and tracking for EIC

- The **ePIC SVT collaboration works with the ALICE ITS3 collaboration** to develop a new generation MAPS sensor in a commercial 65 nm CMOS imaging technology
    - **Technology validation** and stitching proof of concept completed on prototype structures (MLR1 and ER1 submissions)
        - STRONG-2020 milestones and deliverables completed

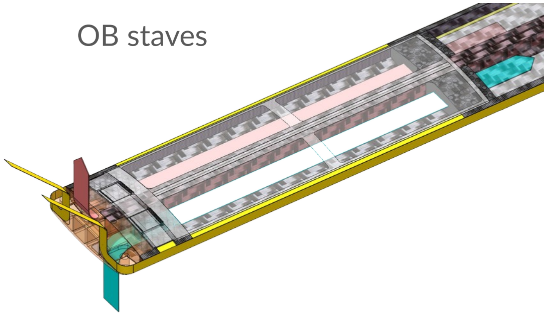
- Development of **low mass Outer Barrel and disks** structures with integrated air cooling
    - Open curved structure for staves; corrugated support for disks
    - Design embeds channels for air cooling and support for service flexible printed circuit
    - Readout boards with opto-electric data interface at end of staves/disks







EE/HE disks



OB staves

Task 4 – Silicon vertex and tracking for EIC

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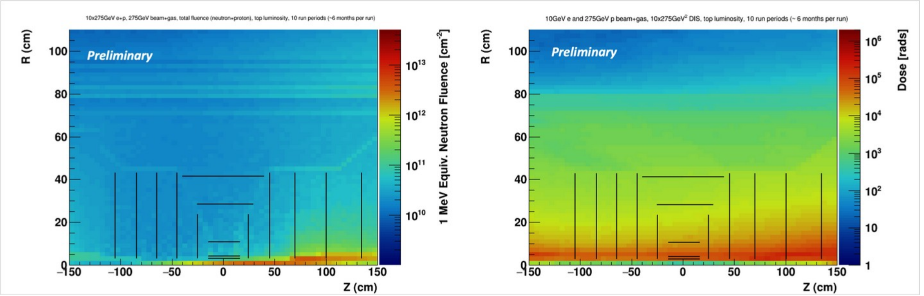
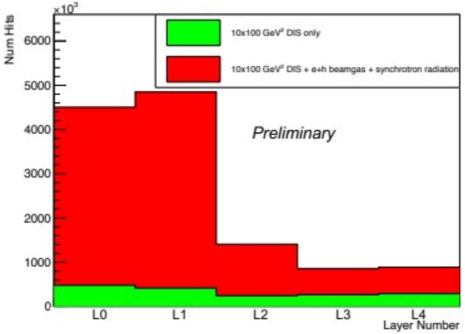
- Preliminary estimation of SVT **radiation levels and hit occupancy** to provide input for sensor design and specifications

- Low to moderate radiation levels
  - Fluence levels well below 10^{11} n_{eq} cm^{-2}. Only a few regions reaching 10^{12} n_{eq} cm^{-2}
  - Dose below 10 krad for most of the SVT, only areas close to the beam pipe will experience TID between ten and a few hundred krad

- Hit rate dominated by background events. Hit occupancy at most ~ 10^{-7} per pixel per frame

10 GeV x 275 GeV DIS ep events + beam gas backgrounds
Upper bound estimate: Top luminosity; 10x 6 months run periods at 100% run time





10 GeV x 100 GeV DIS ep events
10 GeV electron beam gas and SR, 100 GeV hadron beam gas
20.8 x 22.8 μm2 pixel, 2 μs frame rate

	Hits/pixel/frame		Hits/pixel/frame		Hits/pixel/frame
L0	7.00E-08	ED0	1.96E-08	HD0	2.11E-08
L1	5.65E-08	ED1	7.07E-09	HD1	7.87E-09
L2	6.56E-09	ED2	6.81E-09	HD2	7.68E-09
L3	8.85E-10	ED3	6.40E-09	HD3	6.59E-09
L4	3.80E-10	ED4	5.76E-09	HD4	5.62E-09

Summary

- The Next DIS facility will be EIC with the ePIC detector
- Major contributions to EIC and ePIC within JRA6
- All deliverables have been achieved
- Some activities adapted and extended their scopes accordingly to the needs of the EIC detector

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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)