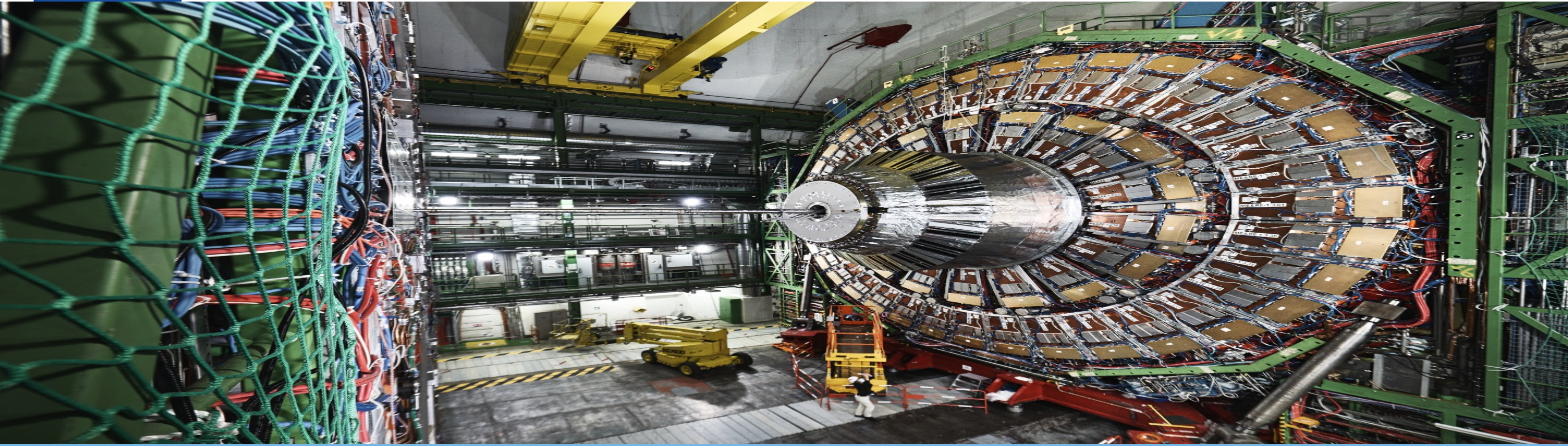


JRA6 – Challenges for Next Generation DIS facilities

Daria Sokhan

CEA Saclay, France *(on leave from U. of Glasgow)*

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

The Electron-Ion Collider

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.

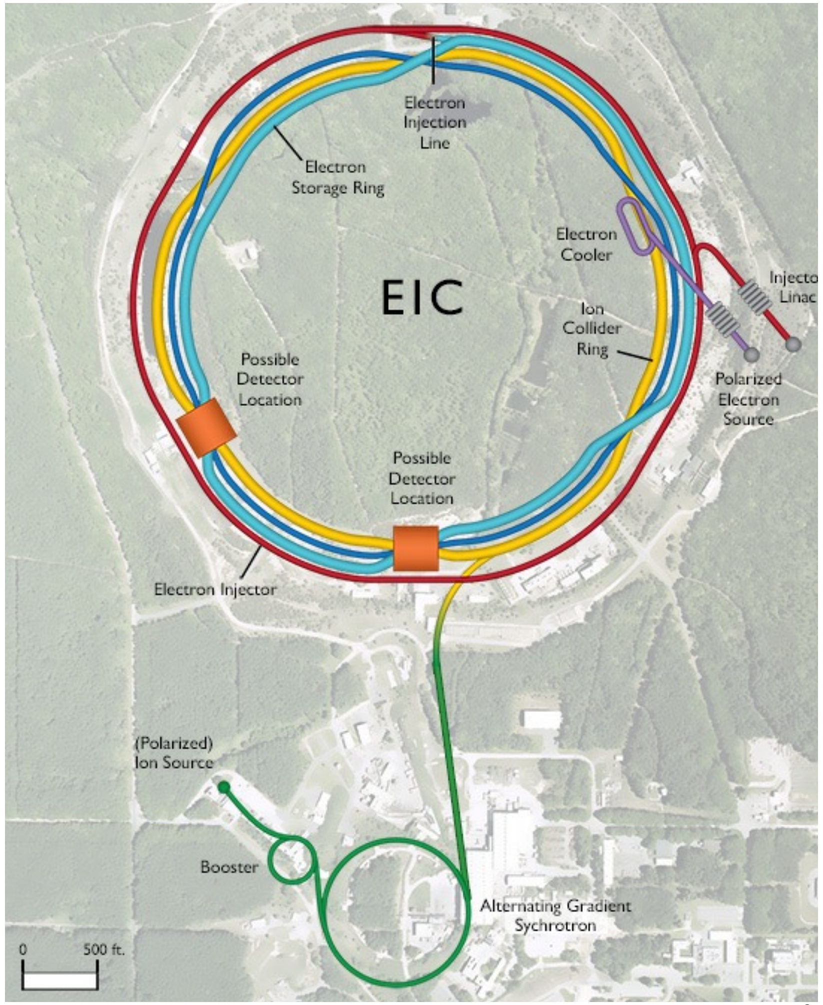
Electron-Ion Collider: World's first polarised electron-proton/light ion and electron-nucleus collider → high luminosity and large CM energies for unprecedented access to the quark-gluon sea.

2020: the EIC project awarded **CD-0** status**, Brookhaven National Lab** selected as the site.

The **EIC Yellow Report:** promoted and organised by the EICUG, defined detector requirements to meet the physics objectives. Published in March 2021.

2021: Call for **detector proposals** (deadline 1st Dec 2021), formation of proto-collaborations and consortia: ATHENA, ECCE, CORE.

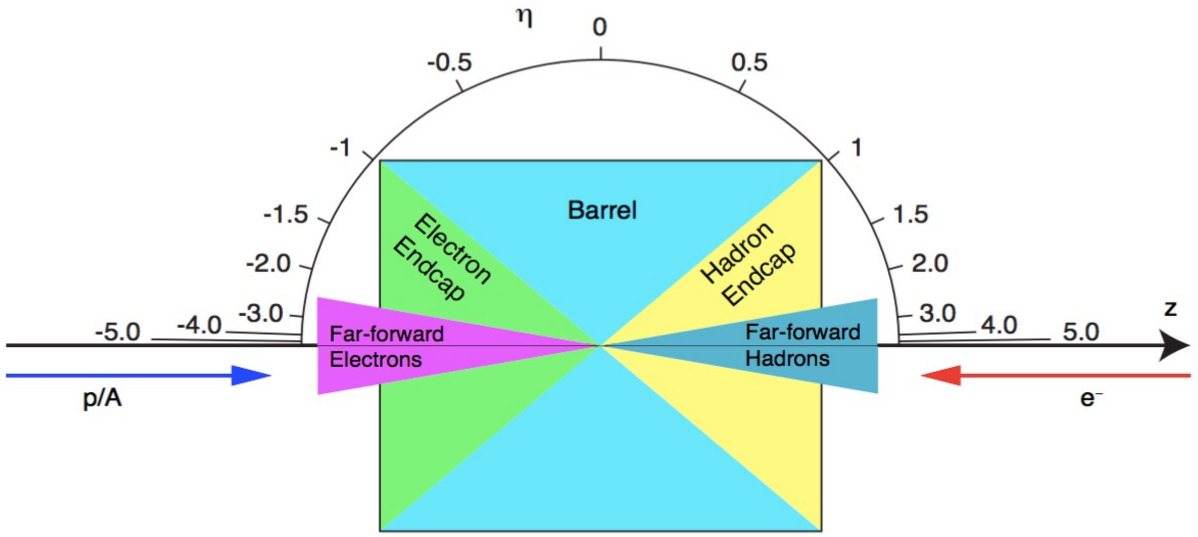
CD-1 status granted in July 2021: authorization to begin project execution.



Electron-Ion Collider & JRA6 Objectives

Detector concepts:

- 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:

1 Monte-Carlo simulations for detector requirement definition

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

3 PID with RICH

4 Depleted MAPS for vertex detector and tracking

Task 1: Monte Carlo Simulations

Carried out within the framework of the **Electron-Ion Collider Yellow Report (YR) activity** in 2020 and **detector proposals** in 2021 (ECCE and ATHENA).

YR: an intensive study of physics processes and detector constraints
https://arxiv.org/abs/2103.05419

Exclusive Reactions WG activities in YR and ATHENA proto-collaboration co-ordinated by D. Sokhan (CEA Saclay/U. of Glasgow) as co-convener.

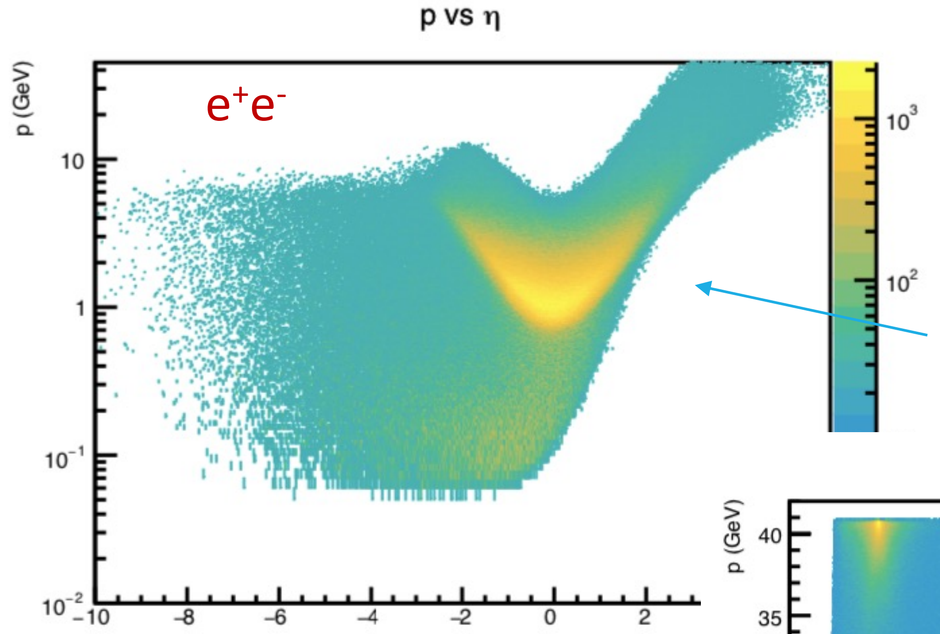
Processes under study:

- Deeply virtual Compton scattering
- Hard exclusive meson production
- Timelike Compton scattering
- Diffractive di-jet production
- Near-threshold Upsilon production
- Φ-production in *eA*
- Backward (u-channel) meson production

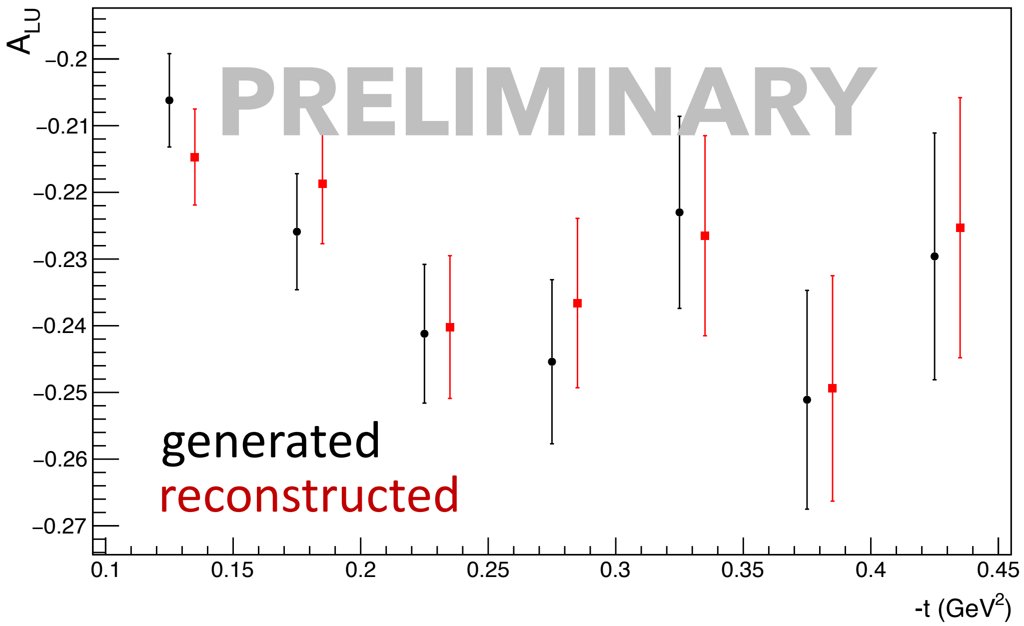
Yellow Report published, ATHENA proposal in preparation.

Postdoc hire @ Glasgow delayed due to pandemic, but now imminent: interviews next week.

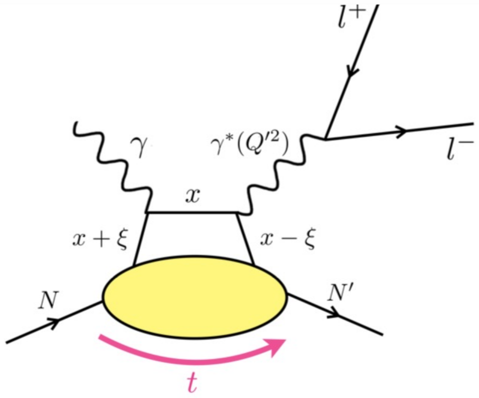
MC – Timelike Compton Scattering

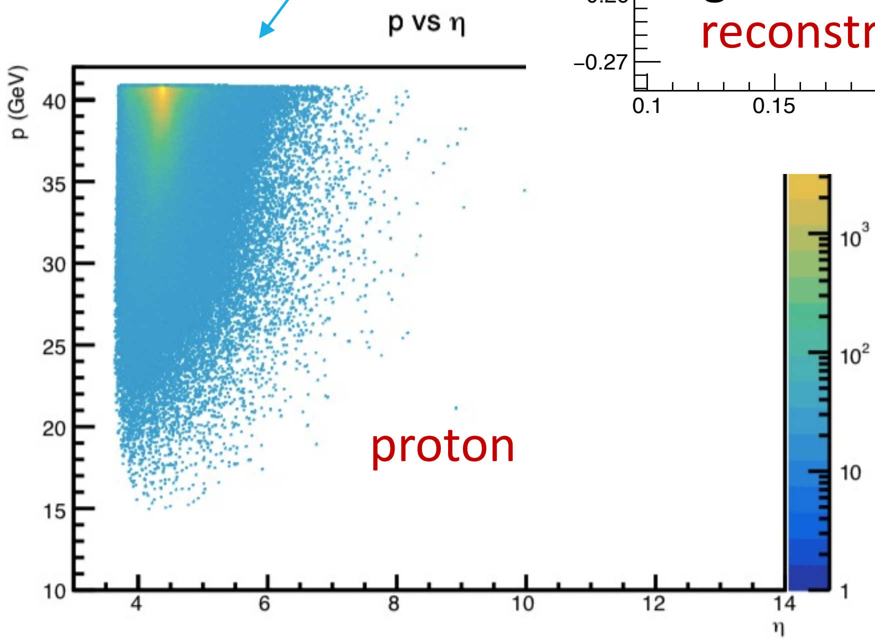


Beam Spin Asymmetry



Generated particle kinematics





Simulations for ATHENA proposal.
Collision energies: 5 x 41 GeV.
Generator: EpIC and the PARTONS framework *(see VA2).*

Complement to Task 1: Timepix-based detector for far-forward/backward regions

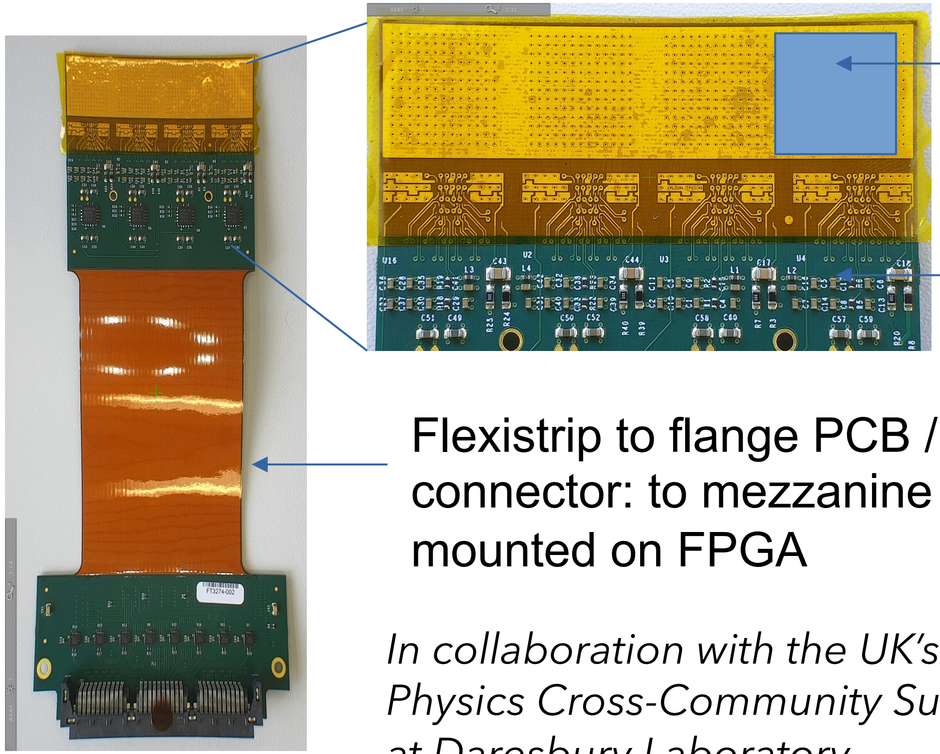
Stringent detector requirements for the detection of far-forward recoil and far-backward scattered electron (in quasi-real photoproduction): refocused part of U. of Glasgow effort on R&D into Timepix read-out chips for possible integration with the detectors.

Timepix:

- Compact
- Radiation-hard
- Excellent spatial resolution < 50μm

Study was within the Yellow Report Far-Forward Detector WG, the ATHENA / ECCE far-backward WG and in synergy with the Glasgow group's R&D on Timepix-based polarimeter for linearly-polarised photons and development of an RF-PMT for picosecond timing.

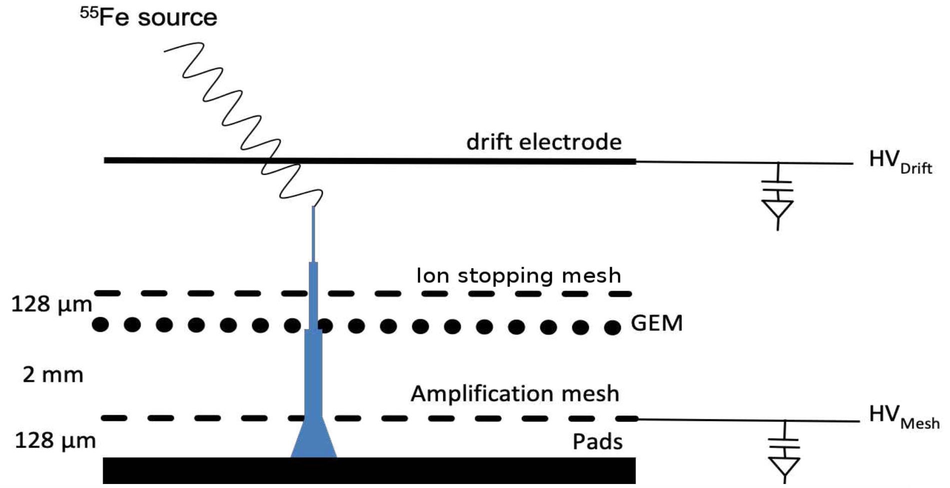
Current R&D on Timepix3 chip (in anticipation of release of Timepix4):

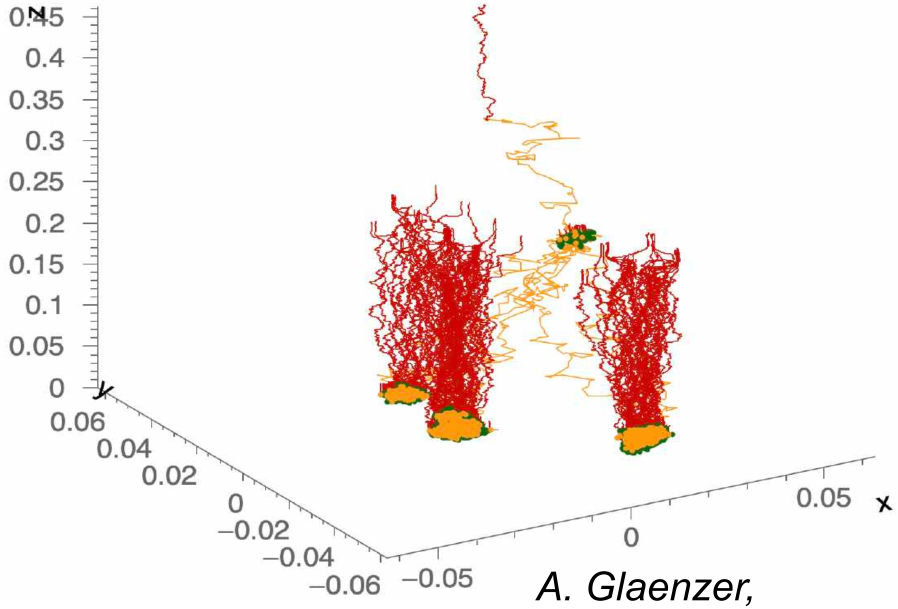


In collaboration with the UK's Nuclear Physics Cross-Community Support Group at Daresbury Laboratory.

Task 2: Low IBF for TPC read out

- Requirements for a Time Projection Chamber (TPC) at EIC
  - Gain: 2000 – 5000
  - Good energy resolution: dE/dx < 20%
  - Lowest possible Ion Back Flow (IBF)
- During Covid-19 lock-down, focus on exploring several hybrid combinations using GARFIELD++ (varying number of meshes and GEMs, their relative positions and E field configurations)
- Micromegas + (GEM + Micromesh), promising configuration
- Two prototypes have been prepared:
  - First prototype: 660 µm gap between GEM and top mesh
  - Second prototype: 128 µm gap between GEM and top mesh

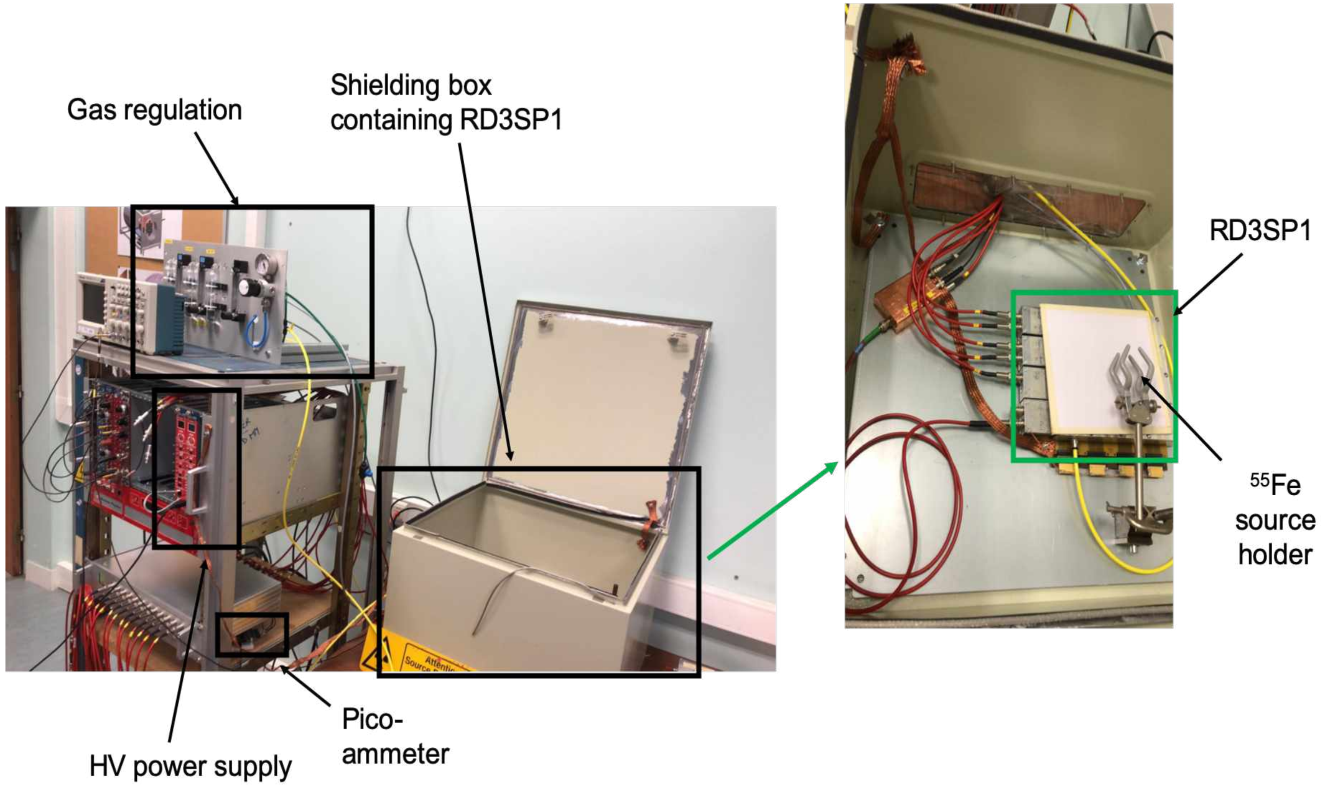


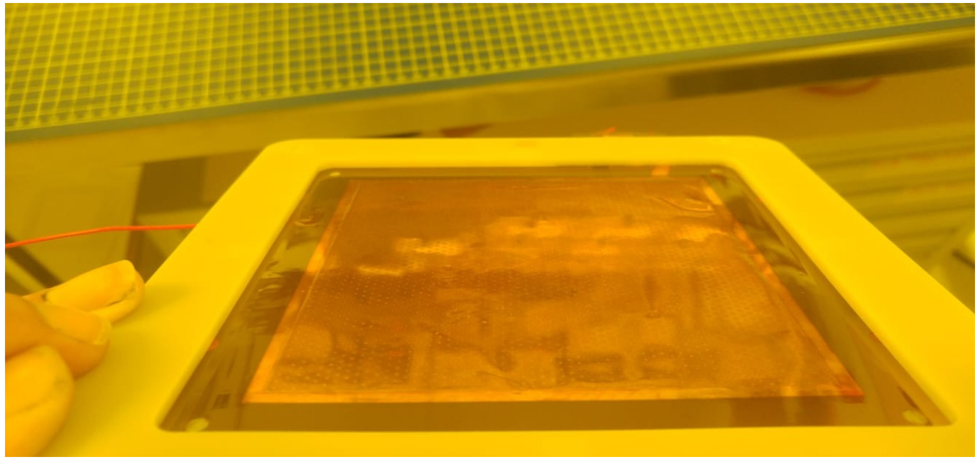


A. Glaenzer, PhD candidate

Low IBF prototype

- Testing setup at CEA Saclay. A Picoammeter used to measure the tiny currents on the electrodes
- Measurement campaigns at CEA-Saclay with ^{55}Fe sources done





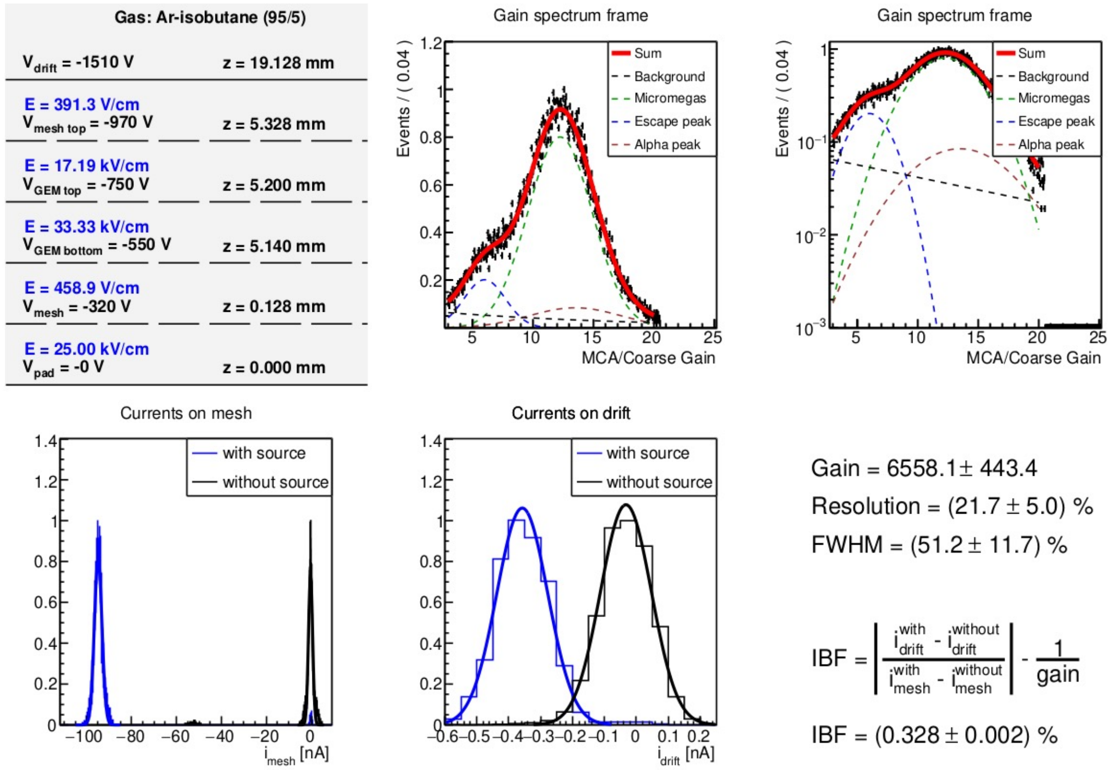
A. Glaenzer, PhD candidate

Low IBF prototype

- The two prototypes are fully characterized
- Data analysis under finalization

- Preliminary results show a good IBF reduction
- Paper draft in preparation
- Submission in Spring *(for deliverable D24.2)*

Example of a measurement



$$\mathrm{IBF} = \left| \frac{i_{drift}^{with} - i_{drift}^{without}}{i_{mesh}^{with} - i_{mesh}^{without}} \right| - \frac{1}{\mathrm{gain}}$$

IBF = (0.328 ± 0.002) %

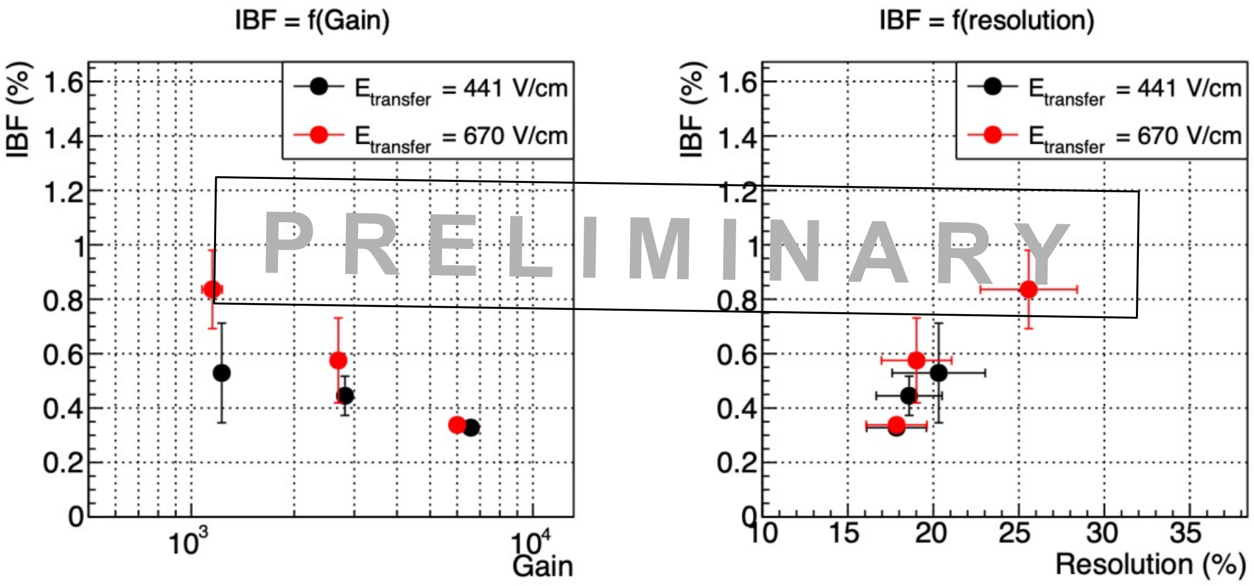
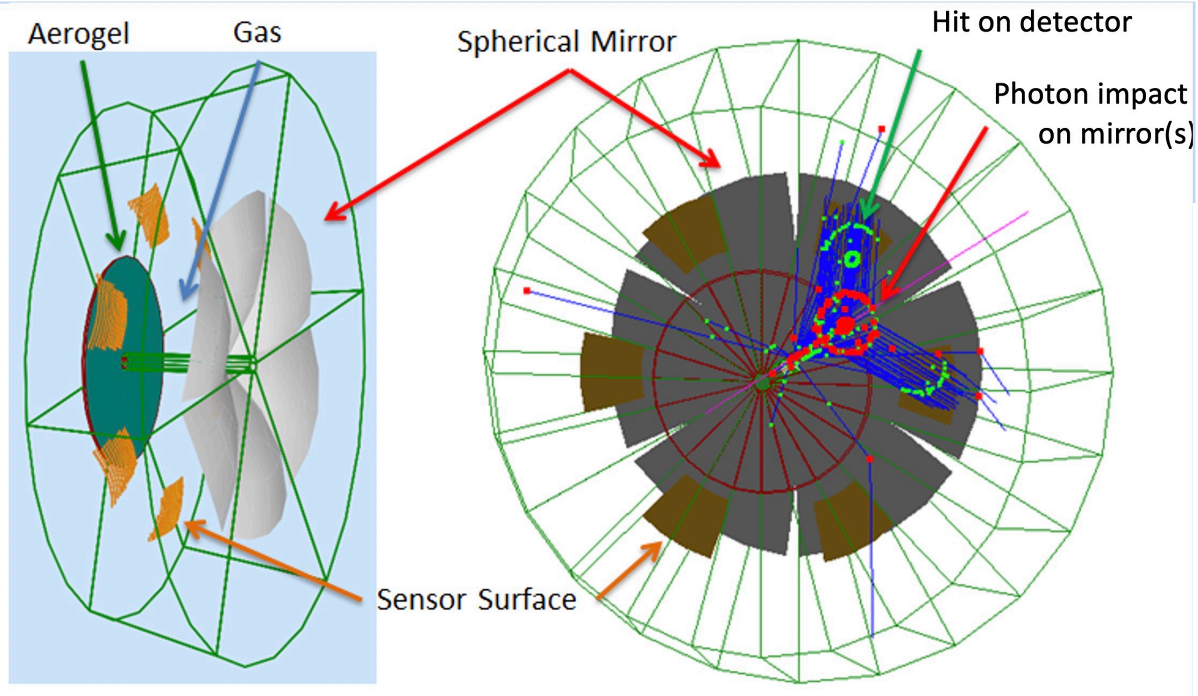


Figure 43: Ion backflow as a function of the gain (left) and the energy resolution (right).

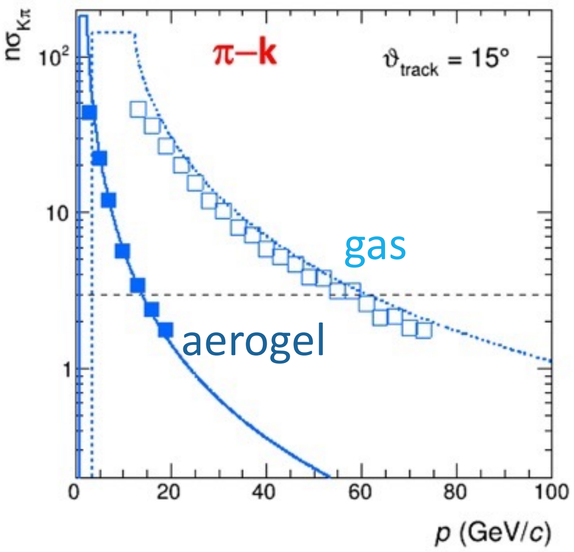
A. Glaenzer, PhD candidate

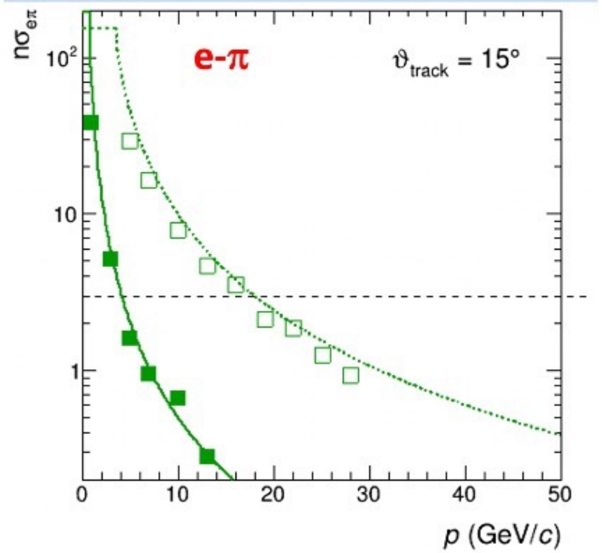
Task 3: Dual Radiator RICH @ EIC



Two challenges:

- cover wide momentum range 3 - 60 GeV/c
- work in high (~ 1T) magnetic field





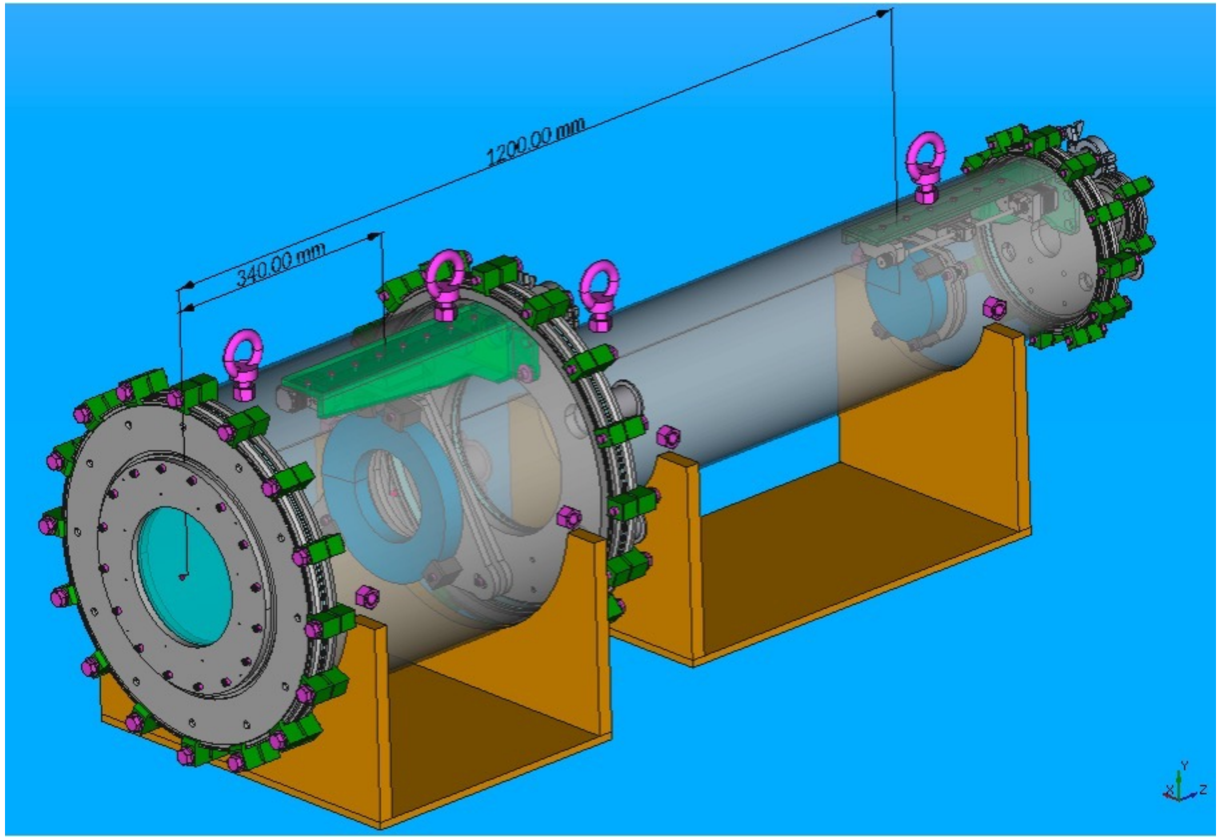
dRICH: effective solution, part of EIC reference detector

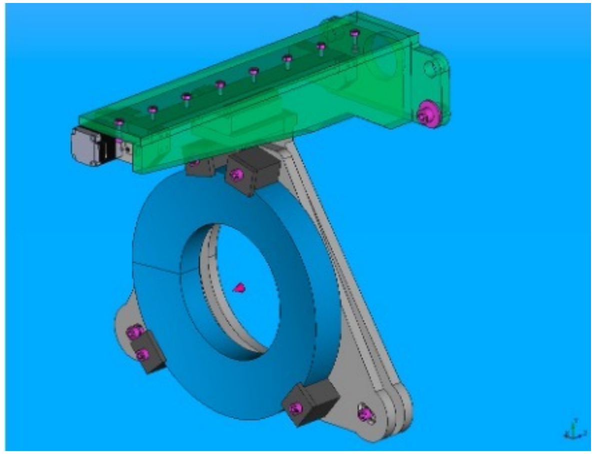
Radiators: Aerogel (n_{AERO}~1.02) + Gas (n_{C2F6} ~ 1.0008)

Detector: 0.5 m^2/sector , 3x3 mm^2 pixel. → SiPM option

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

dRICH Prototype





Dual radiator imaging

Pressure vessel for gas & n tune

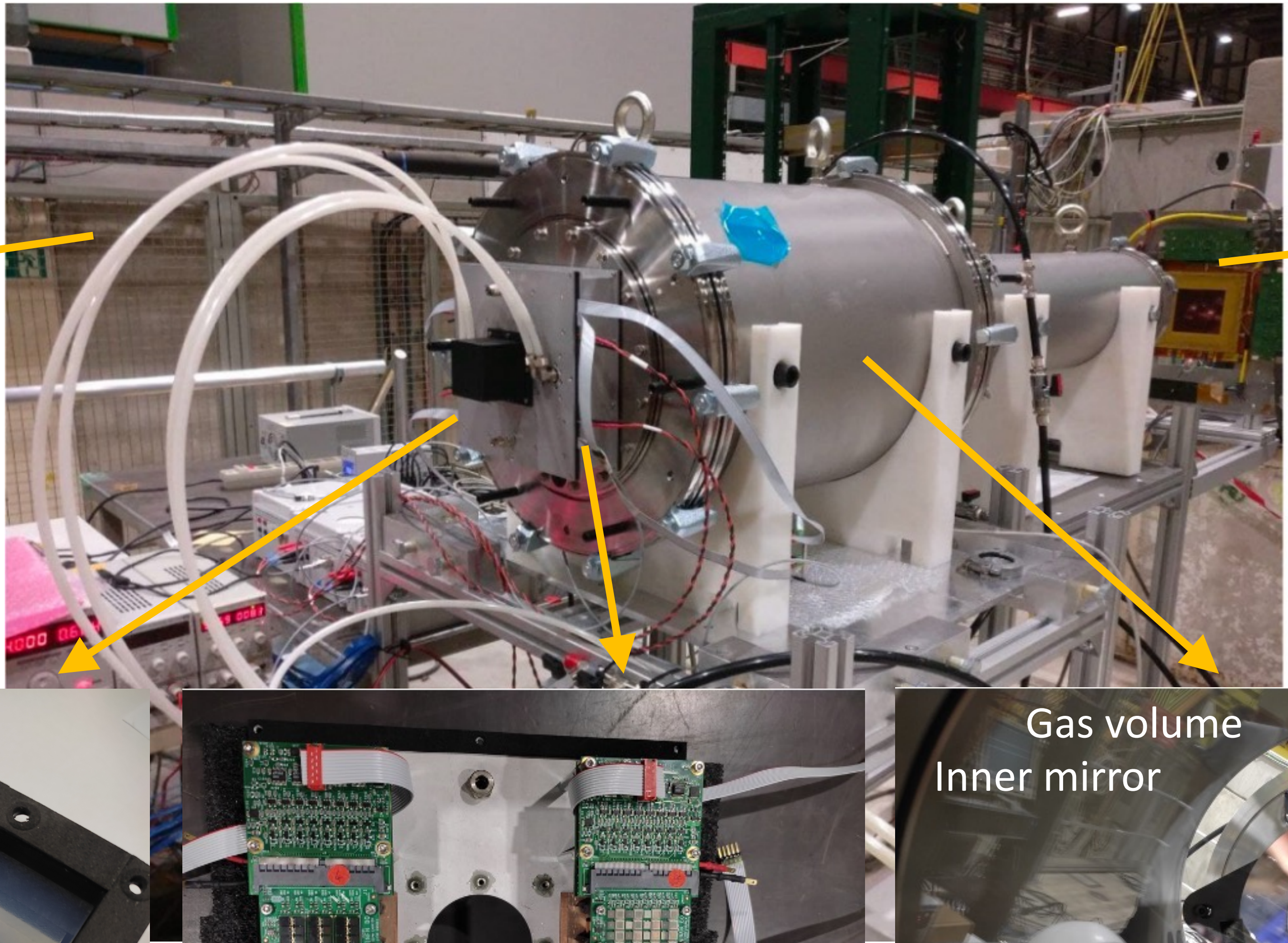
Sensor & readout friendly

Goals:

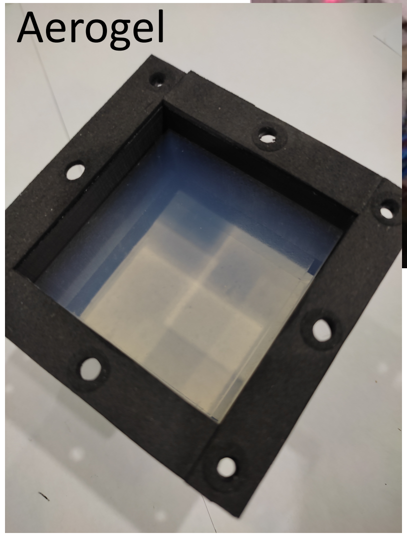
- Study dual radiator performance and interplay
- Study specifications and alternatives for optical components
- Test alternate single-photon detection systems
- First test-beams in September and October 2021 at CERN (in synergy with ALICE at PS T10)

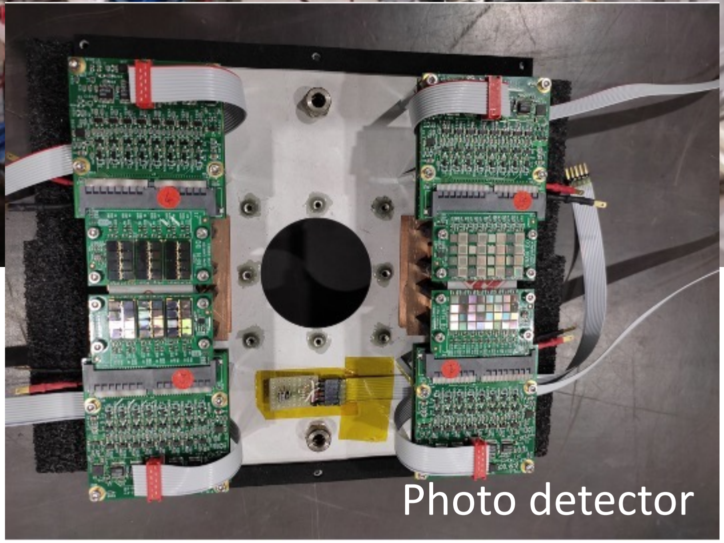
dRICH Setup

Cooling



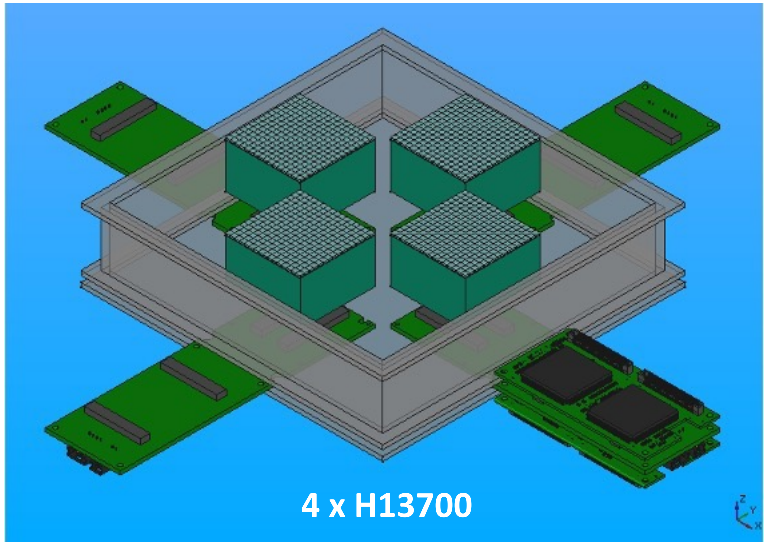
Trackign GEM

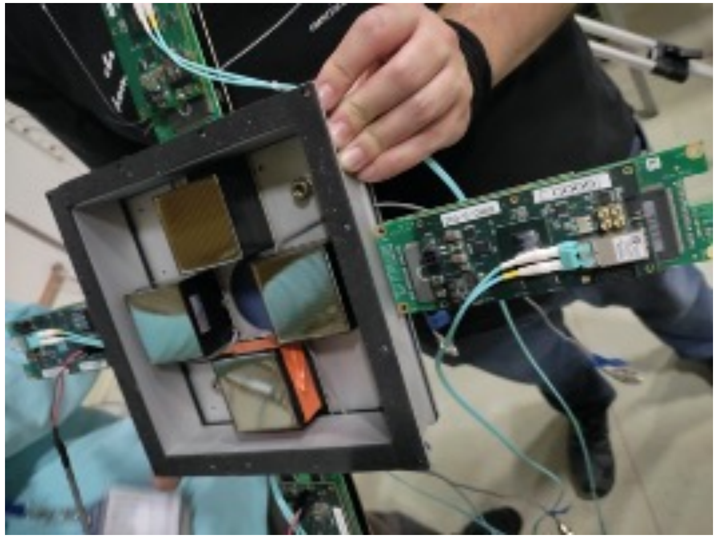


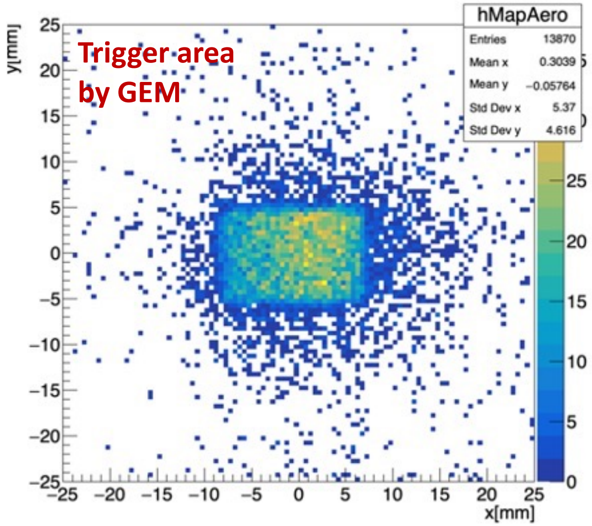


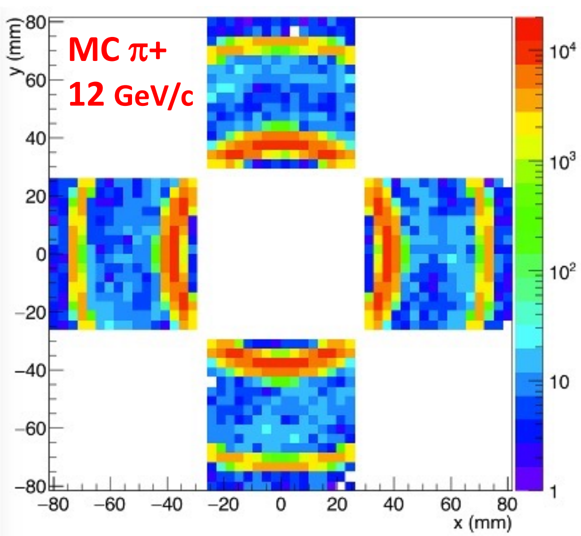
dRICH Online: imaging

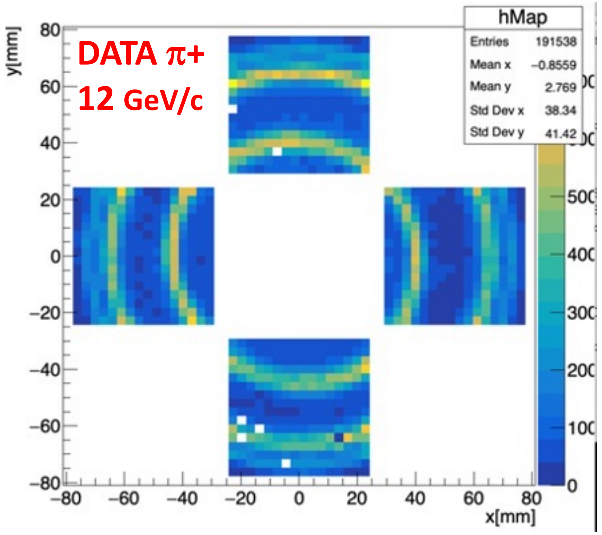
Use large area H13700 coupled to CLAS12 RICH MAROC front-end.
Allows to study the working principles and optical performance of the components.





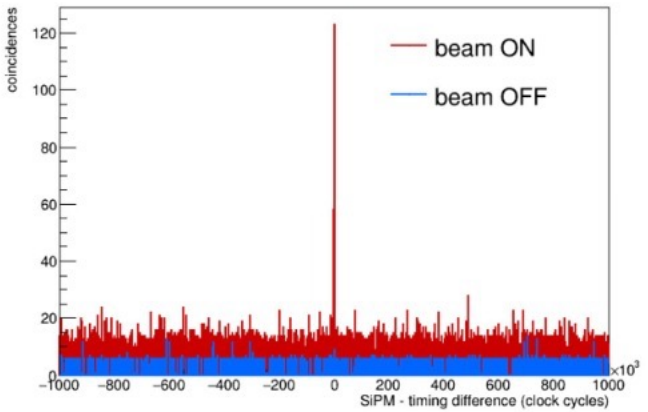


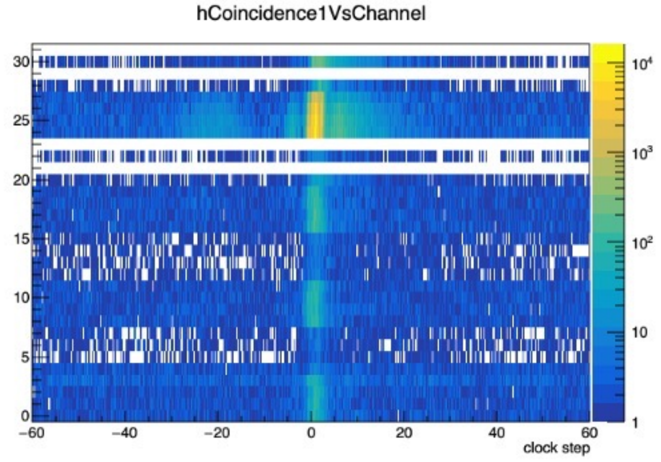




dRICH Online: SiPM Readout

Time coincidence with beam particle

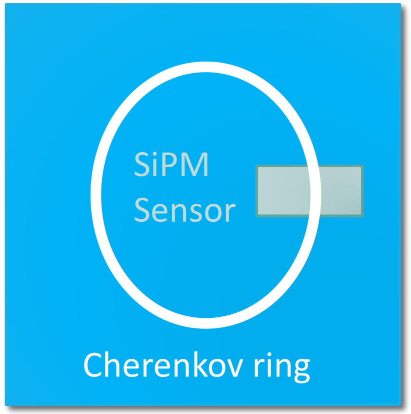




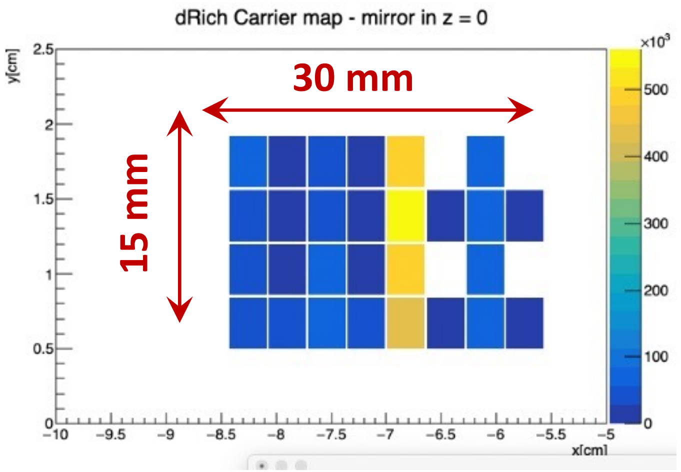
Test Cherenkov application for magnetic field insensitive sensor (SiPM)

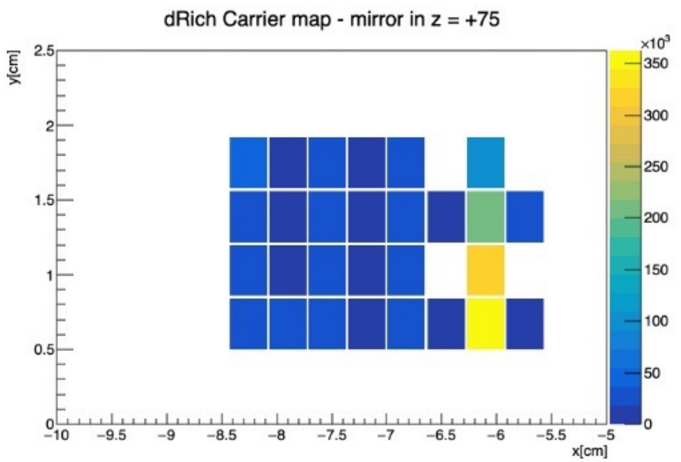
Control SiPM high dark count to isolate single photon signal (same amplitude!)

Use a new ALCOR chip (high-rate ToT architecture) in streaming mode



Reflected signal moves with mirror

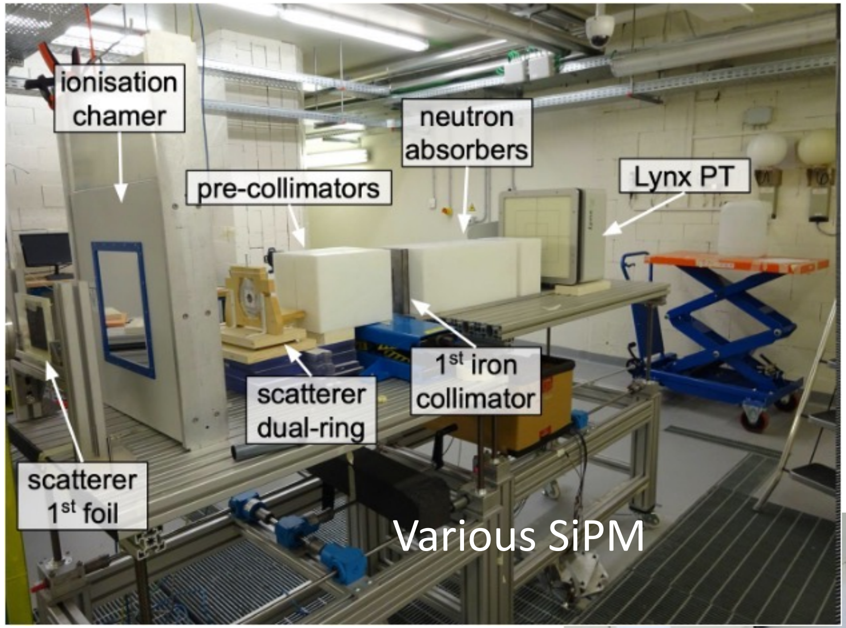


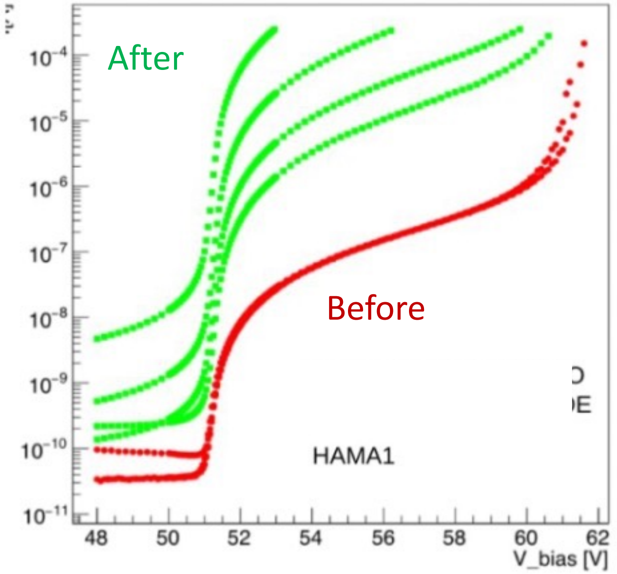


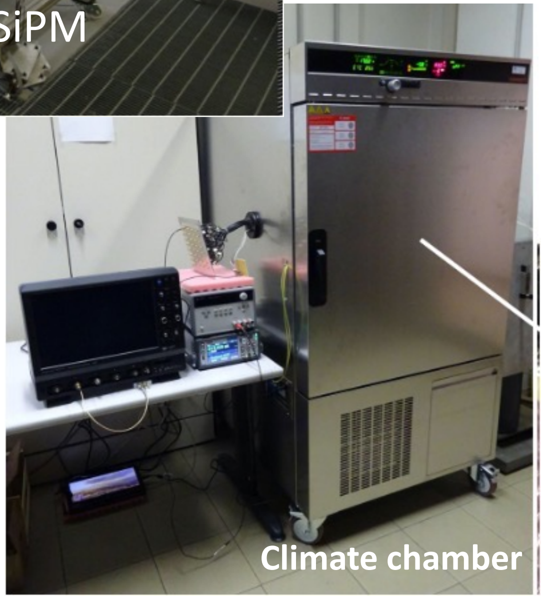
SiPM Irradiation Campaign

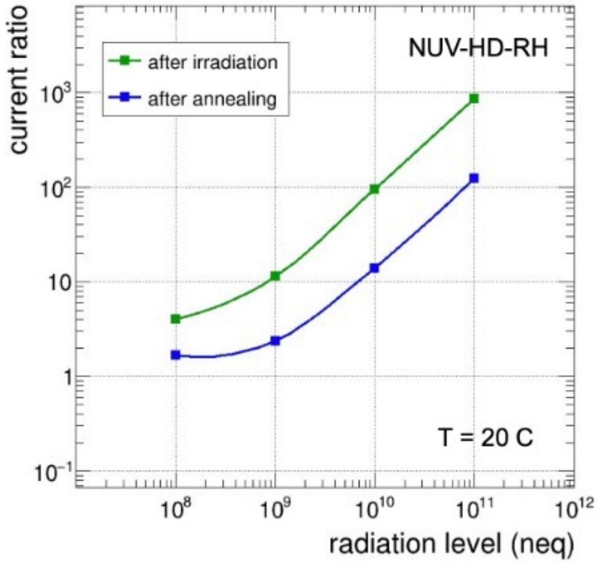
TIFPA Proton Beam Facility

Collimated Beam
10^9-10^{11} n_{eq}









Task 3: status and plans

2021: MC simulations

First SiPM irradiation + annealing campaign

Basic dRICH prototype

First dRICH test-beam with hadron beams (commissioning)

2022: Extended SiPM irradiation + annealing campaign

Improved prototype

Second test-beam campaign (realistic performance)

Data analysis and technical note (D24.3)

2023: Refined data analysis and simulation

Third test-beam campaign (component optimization)

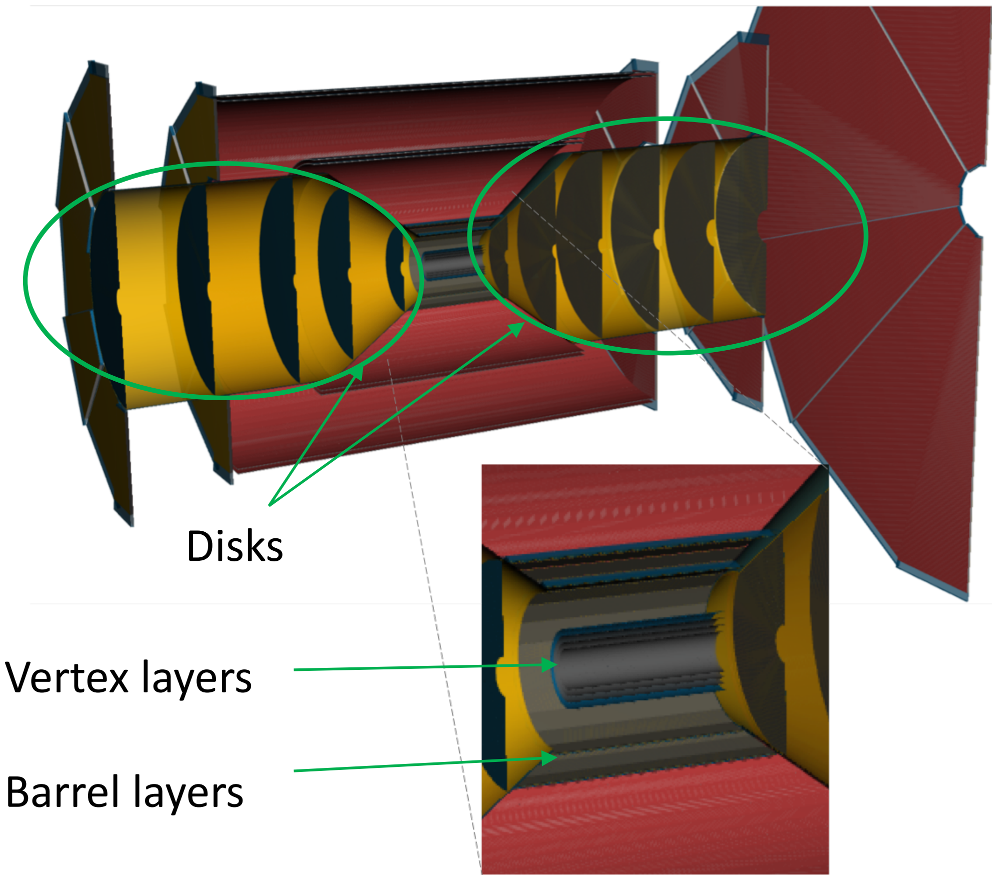
Final assessment

Task 4: EIC Silicon Vertex and Tracking (SVT) detector

- A **well integrated, large acceptance** silicon vertex and tracking (SVT) detector with **high granularity and low material budget** is needed to enable high precision measurements that are key to the EIC science programme.

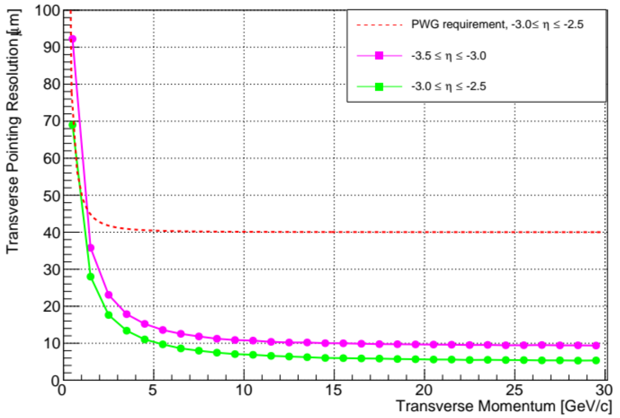
- Following on from the result presented last year, Birmingham continues the development of silicon tracking detector for EIC based on 65 nm MAPS.
  - Member of the ATHENA proto-collaboration working on the performance simulations of the ATHENA tracking hybrid detector.
  - Leading member of the EIC Silicon Consortium working on the development of the sensor technology.

Example: ATHENA tracking detector (~6m^2)

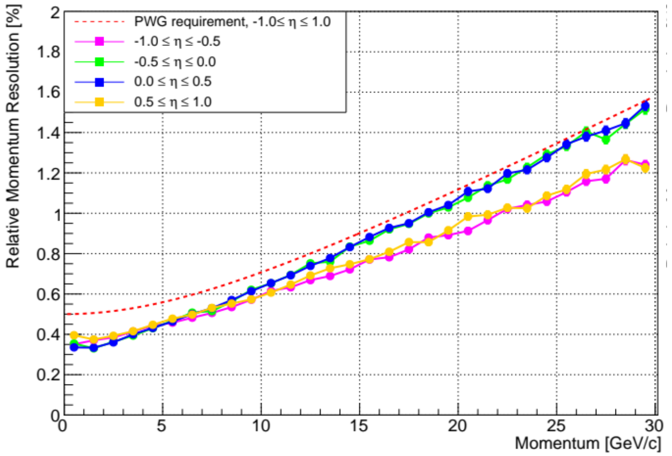


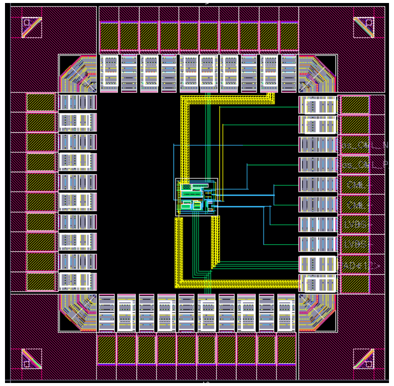
Task 4: EIC Silicon Vertex and Tracking (SVT) detector

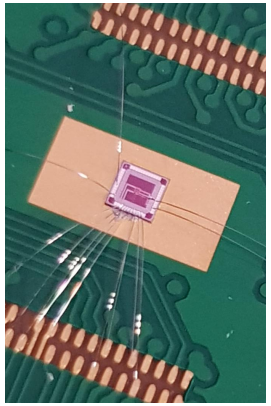
- Vertex and momentum resolution studies for the ATHENA hybrid tracker in support of the detector proposal (due December 1st).
  - Demonstrated good agreement with physics requirements over the covered pseudorapidity range.
- Work on sensor design is done in partnership with Rutherford Appleton Laboratory (RAL) colleagues.
  - Transmitter/receiver test structure (see picture) contributed to the first 65 nm submission within the CERN EP R&D programme/ ALICE ITS3 project.
  - Silicon returned from foundry and testing about to start.



Example plots from simulations







No milestone associated with this task in the reporting period.

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)

Milestones

Task 1: MS48 EIC PID and tracking design – month 18.

Delivered with some delay, as part of the Yellow Report study.

https://arxiv.org/abs/2103.05419

Task 2: MS49 IBF-stopping device prototypes constructed -- month 15

Achieved with some delay, up and running.

Deliverable D24.2: publication on IBF-stopping device – month 24

Related work delayed due to lockdowns, expected in Spring.

Summary

All tasks of JR6 well advanced:

- Simulations of physics processes for the EIC YR have defined tight constraints on the EIC detector, current simulations as part of ATHENA and ECCE are validating and the detector designs.

- Two prototypes of low IBF devices using GEMs and an additional mesh have been constructed and are undergoing testing and characterization.

- Optimization of dRICH design in simulation, ongoing beam-tests of photon sensors.

- A new 65 nm CMOS technology has been chosen for the EIC SVT design and validated in simulations. Test structure submission: undergoing tests and optimization.

Major participation of JRA6 members to the EIC Yellow Report and main detector proto-collaborations: significant impact on the EIC detector design and technologies.