JRA6 – Challenges for Next Generation DIS facilities

F.Bossù (CEA)

STRONG-2020 ANNUAL MEETING (2022)

JRA6

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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.

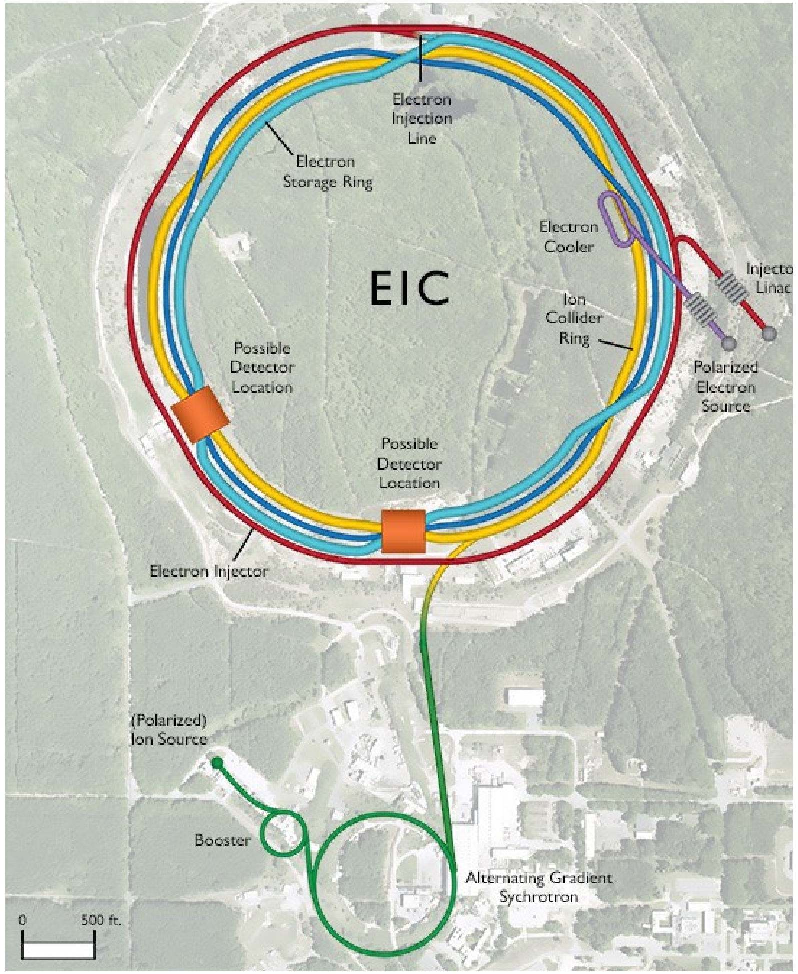
2020: the EIC project awarded **CD-0** status**, Brookhaven National Lab** selected as the site.

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**, formation of proto-collaborations and consortia: ATHENA, ECCE, CORE.

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

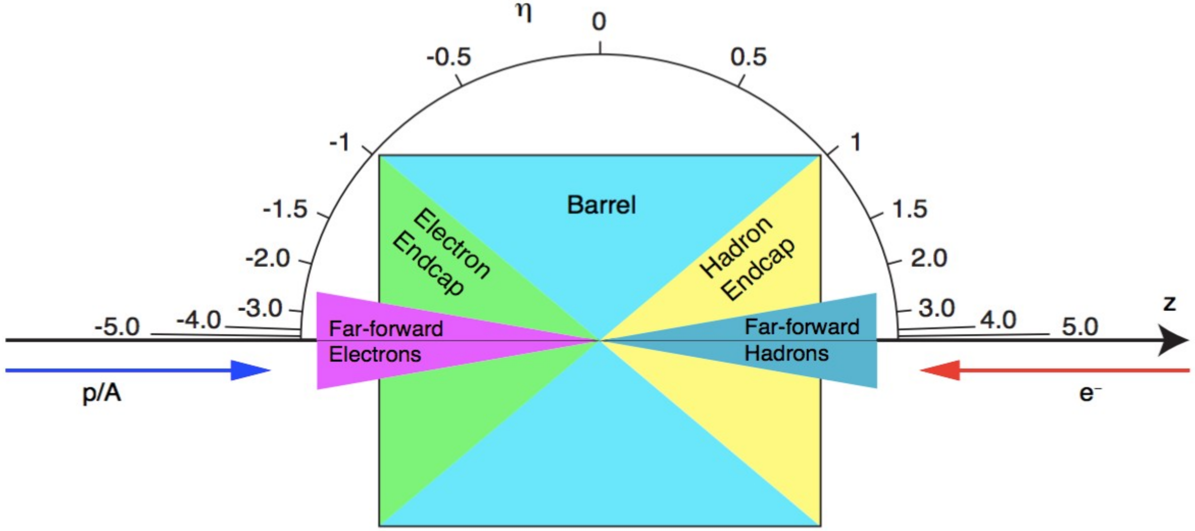
2022: ePIC collaboration forming from the merging of detector proposals, using ECCE as baseline



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

CAVEAT:
Many changes in the EIC detector choices have happened that steered our activities slightly out of the foreseen program

TASK 1 – MONTE CARLO SIMULATIONS

UNIVERSITY of GLASGOW

Carried out within the framework of the **Electron-Ion Collider Yellow Report (YR) activity** in 2020, **detector proposals** in 2021 (ECCE and ATHENA) and the **ePIC collaboration** in 2022.

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

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

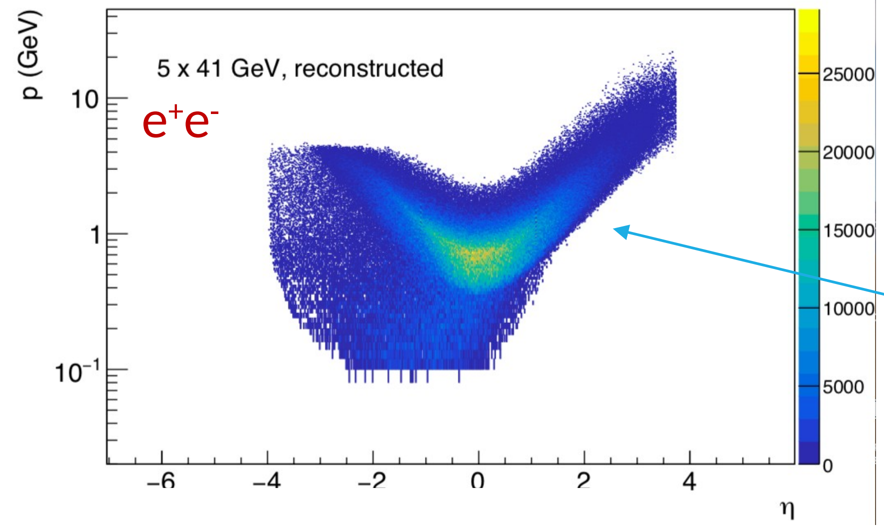
Some of the processes under study:

- Deeply virtual Compton scattering
- Hard exclusive meson production (J/Ψ, ρ, ω, …)
- Timelike Compton scattering
- Near-threshold Upsilon production
- *Φ*-production in *eA*
- Backward (u-channel) meson production

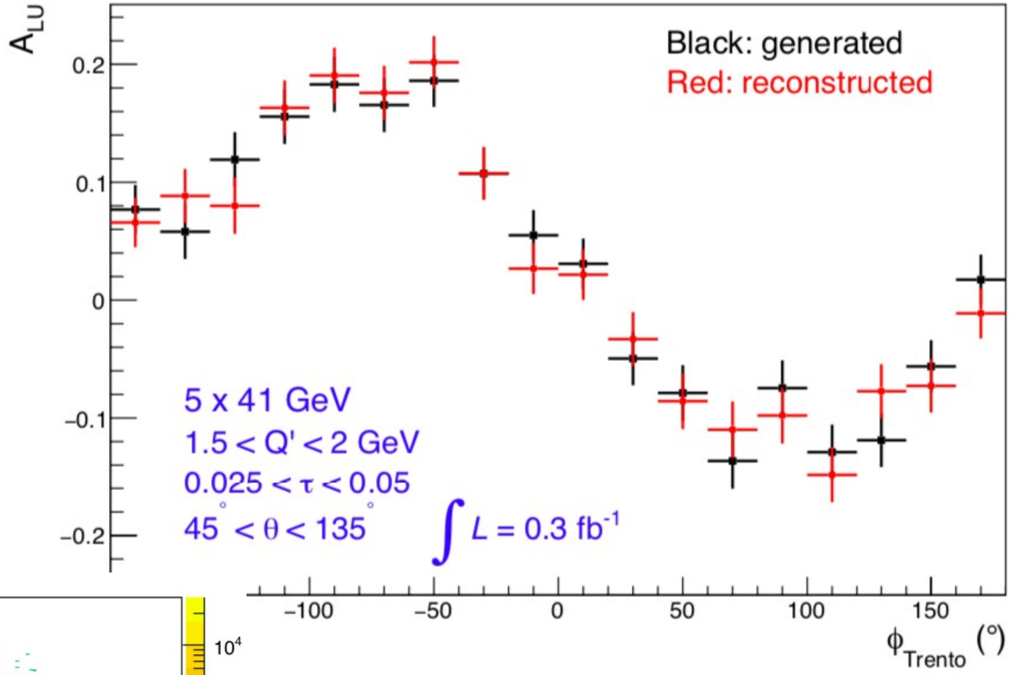
Yellow Report published, ATHENA proposal submitted, studies for the ePIC detector ongoing.

Postdoc started @ Glasgow in May 2022.

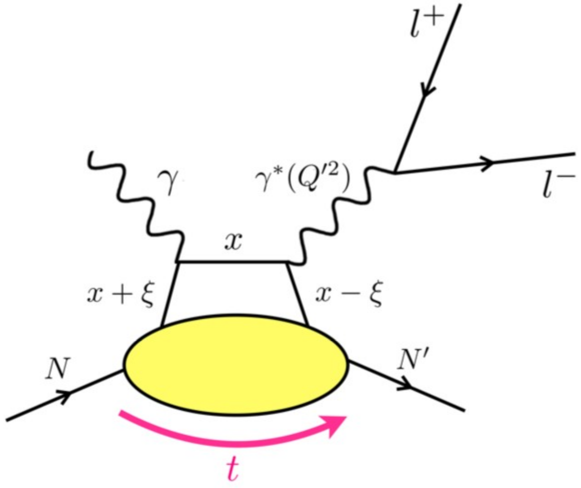
TASK 1 – MC – TIMELIKE COMPTON SCATTERING

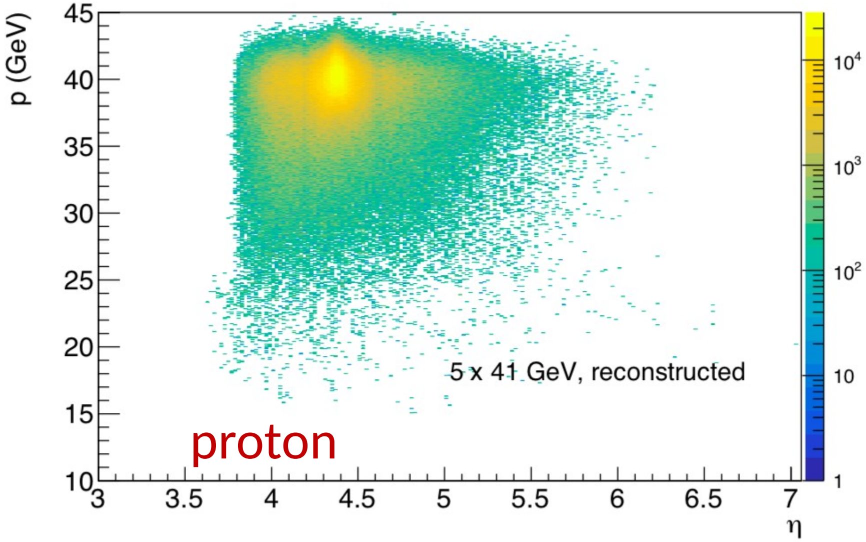


Beam Spin Asymmetry



Reconstructed particle kinematics



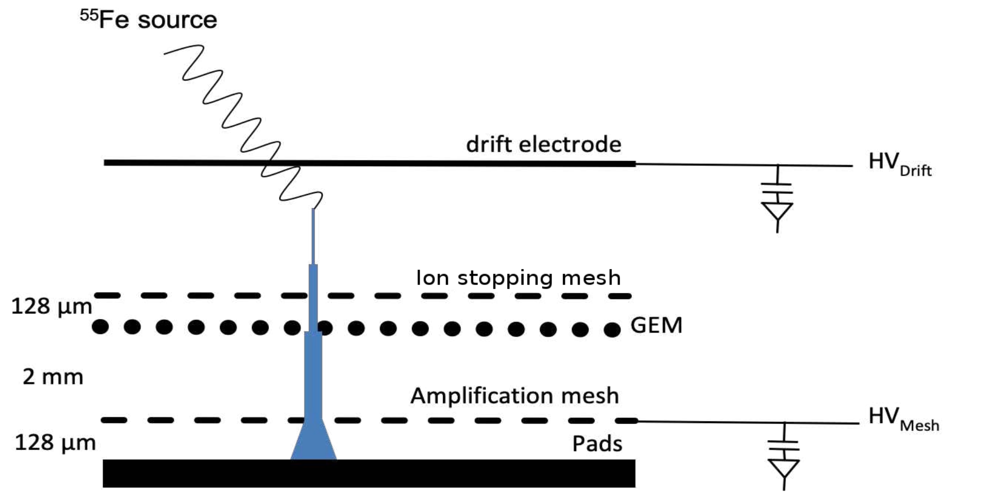


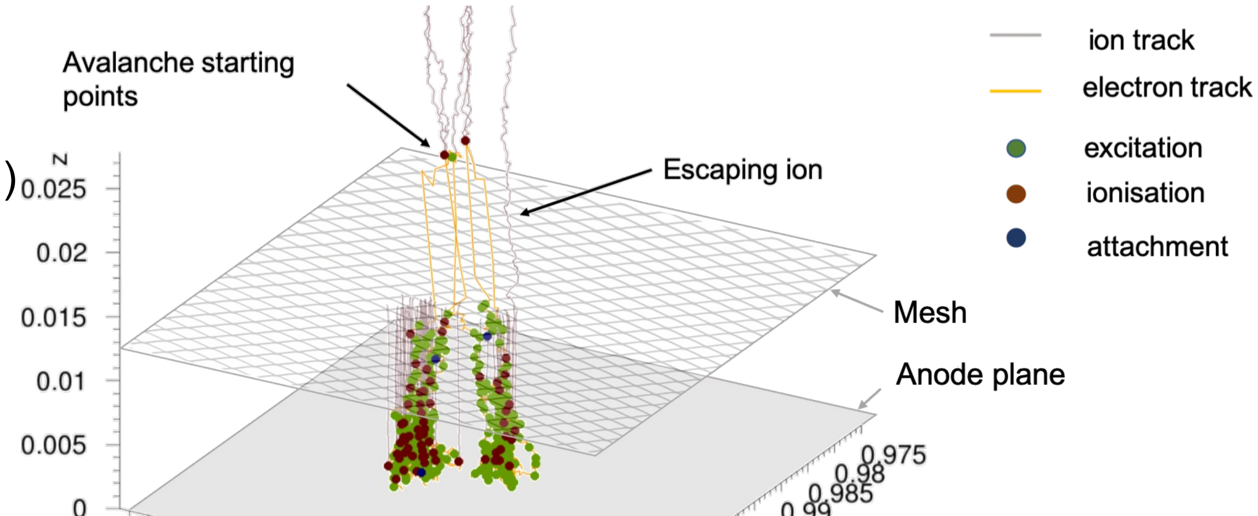
Simulations for ATHENA proposal.
Collision energies: 5 x 41 GeV.
Generator: EpIC and the PARTONS framework *(see VA2).*

Simulation campaign for the esPIC detector taking place this month.

TASK 2 – LOW IBF FOR TPC READ OUT

- Although not in the current design for the EIC detector 1, Time Projection Chambers (TPCs) are a viable alternative for tracking and PID
- Requirements for a
  - Gain: 2000 – 5000
  - Good energy resolution: dE/dx < 20%
  - Lowest possible Ion Back Flow (IBF)
- Novel amplification structure Micromegas + (GEM + Micromesh)
- 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

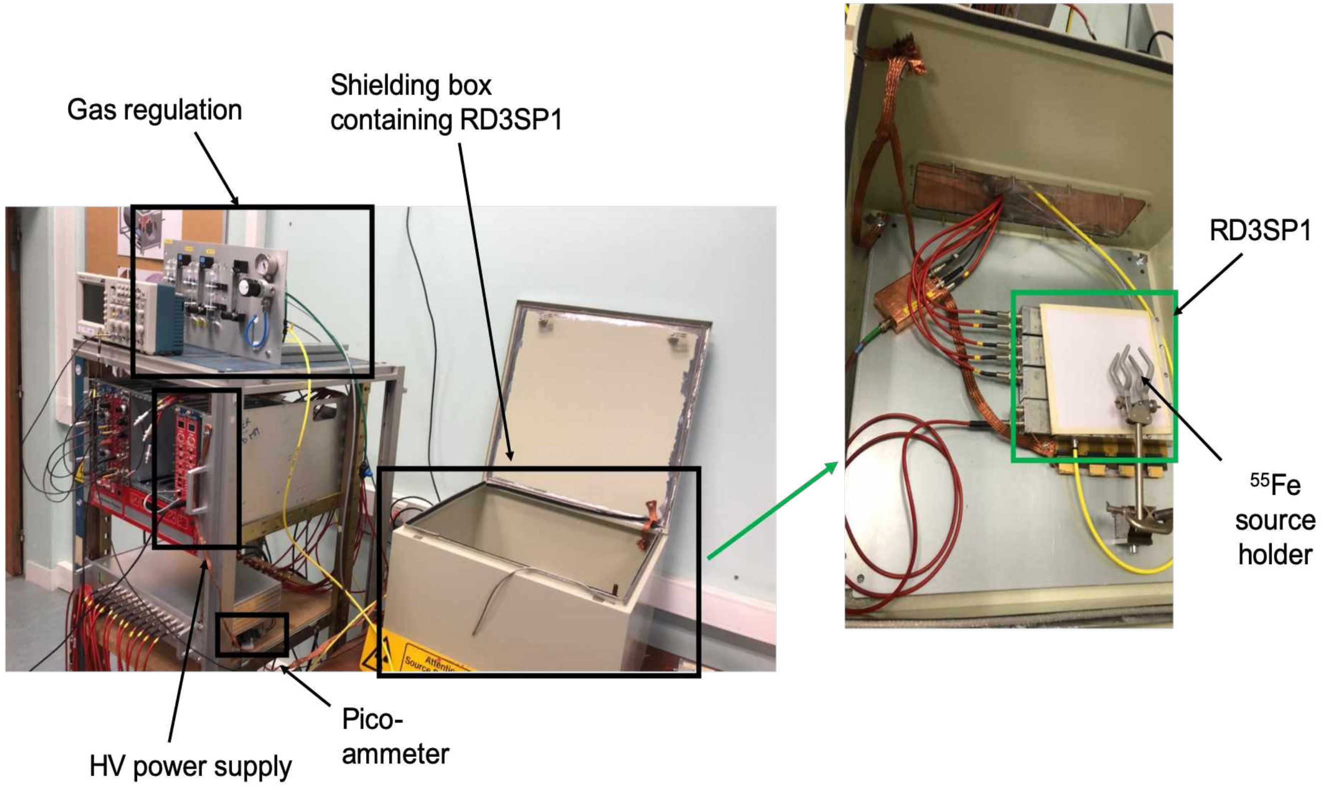


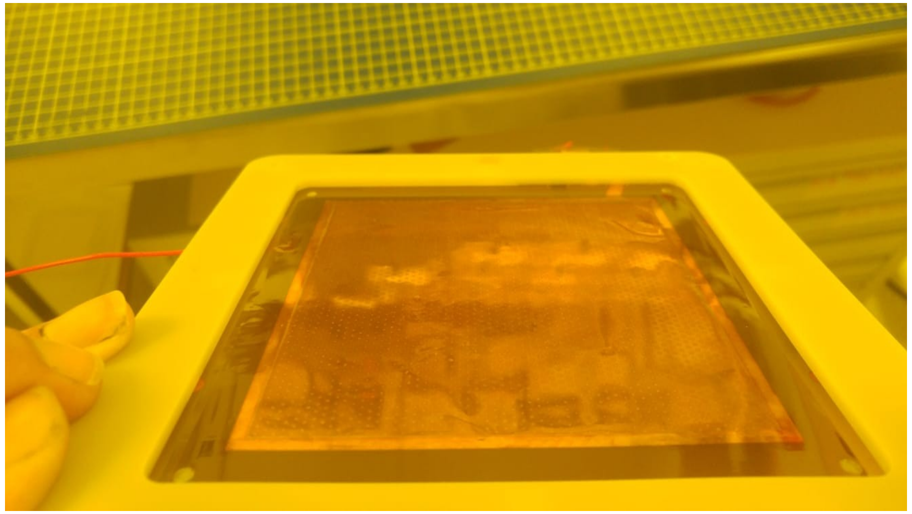


A. Glaenzer,et al. – submitted to NIM A

TASK 2 – PROTOTYPE

- Test 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





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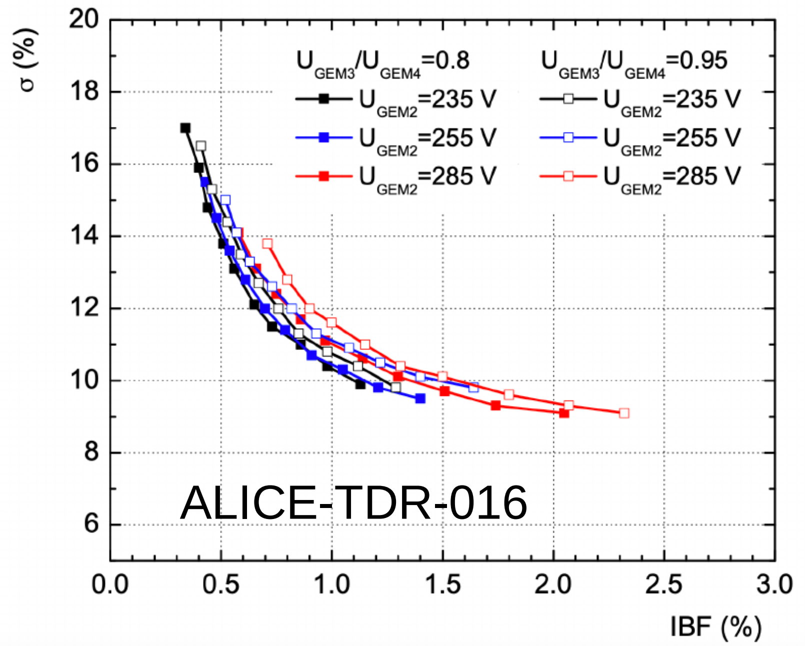
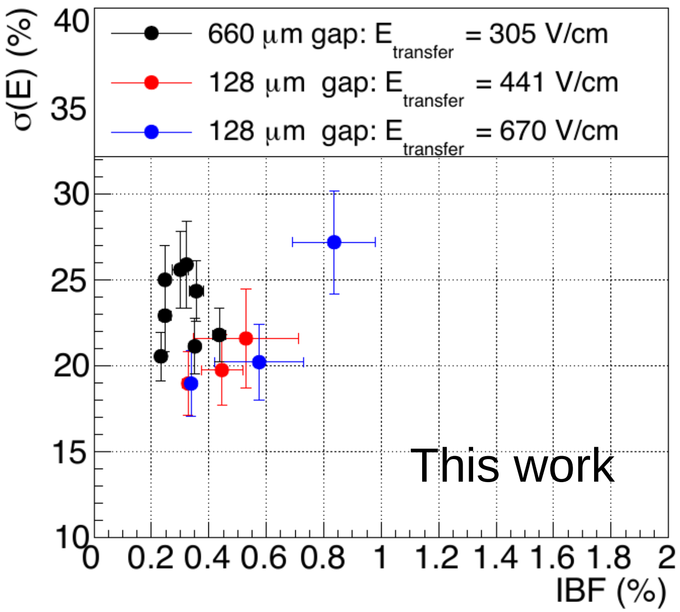
submitted to NIM A

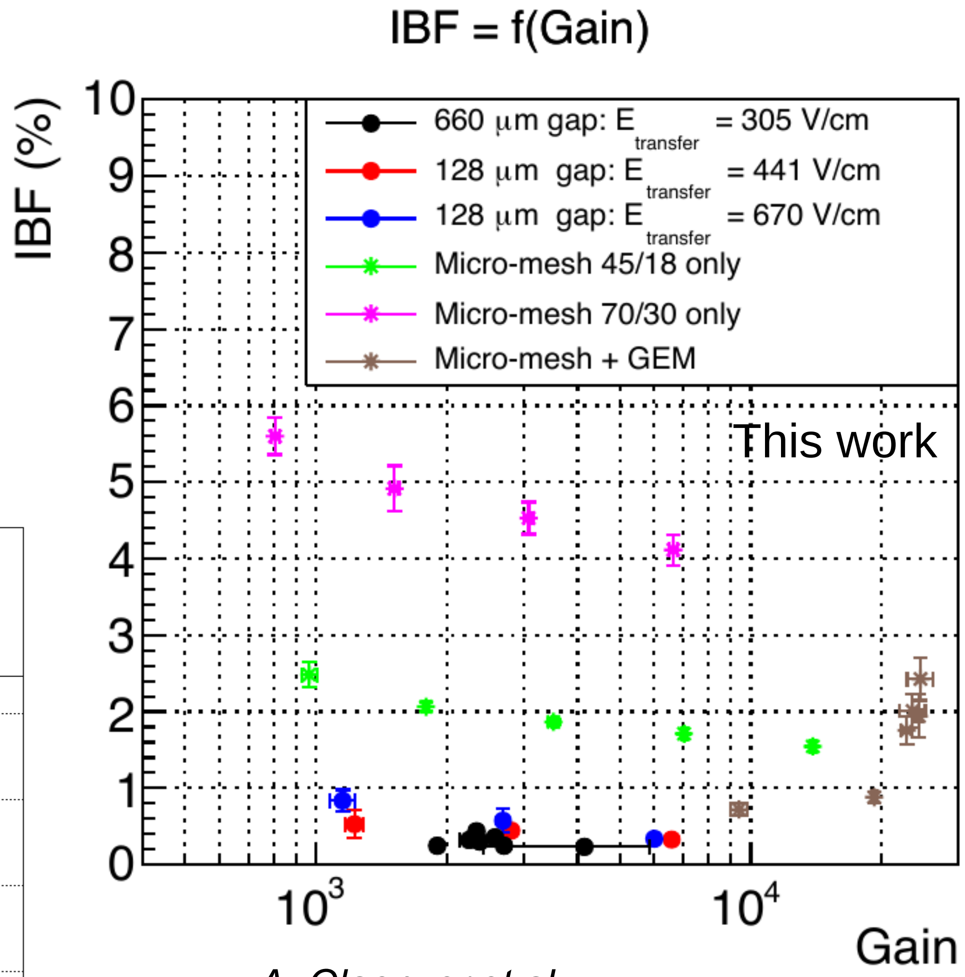
TASK 2 – LOW IBF RESULTS

- The novel structure mesh+GEM+mesh performs better than other hybrid (MMs + GEMs) amplification structures
- **IBF values lower than 0.3% reached**
- Worse energy resolution (at the same IBF) with respect to ALICE 4-GEMs solution
- But simpler mechanical structure

- Results have been finalized and the **paper has been submitted** to NIM A and presented at several conferences





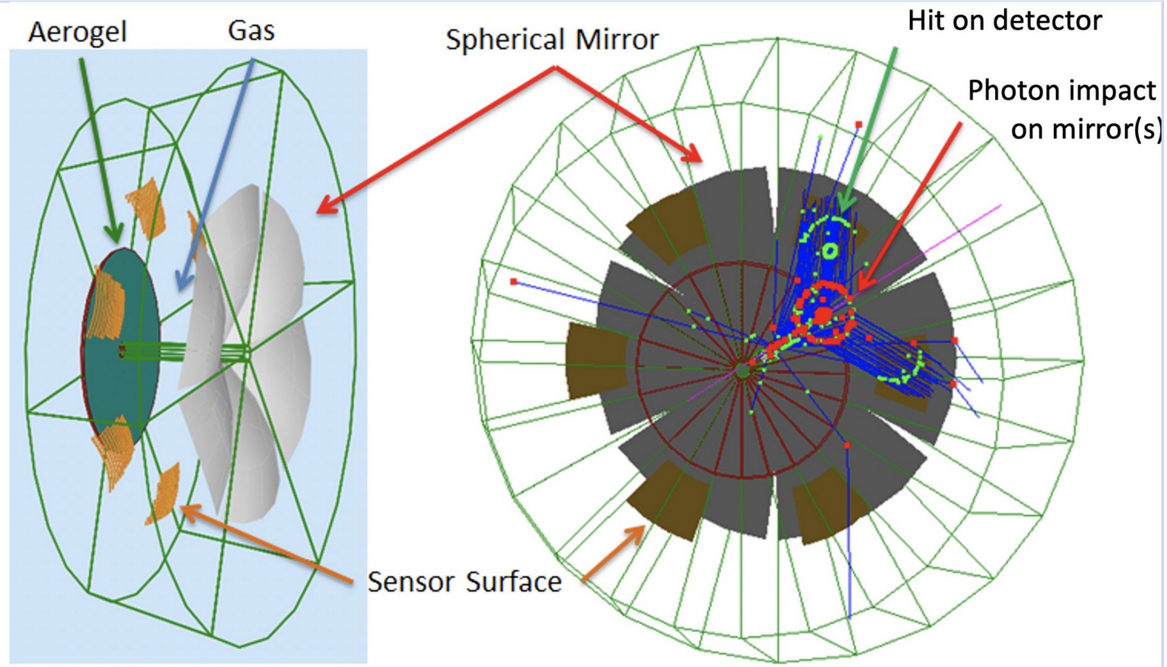


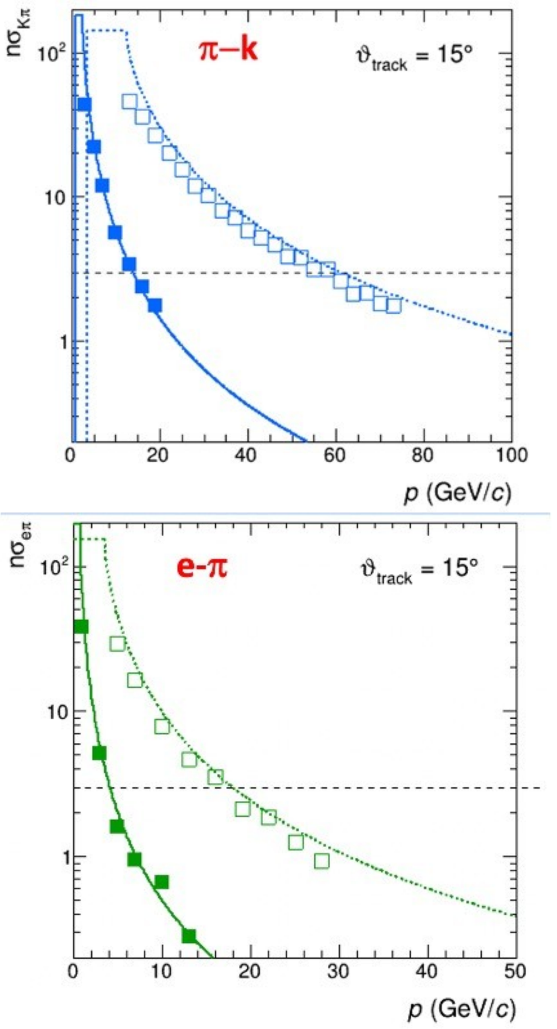
A. Glaenzer,et al. – submitted to NIM A

TASK 3 : DUAL RADIATOR RICH @ EIC

Two main 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)

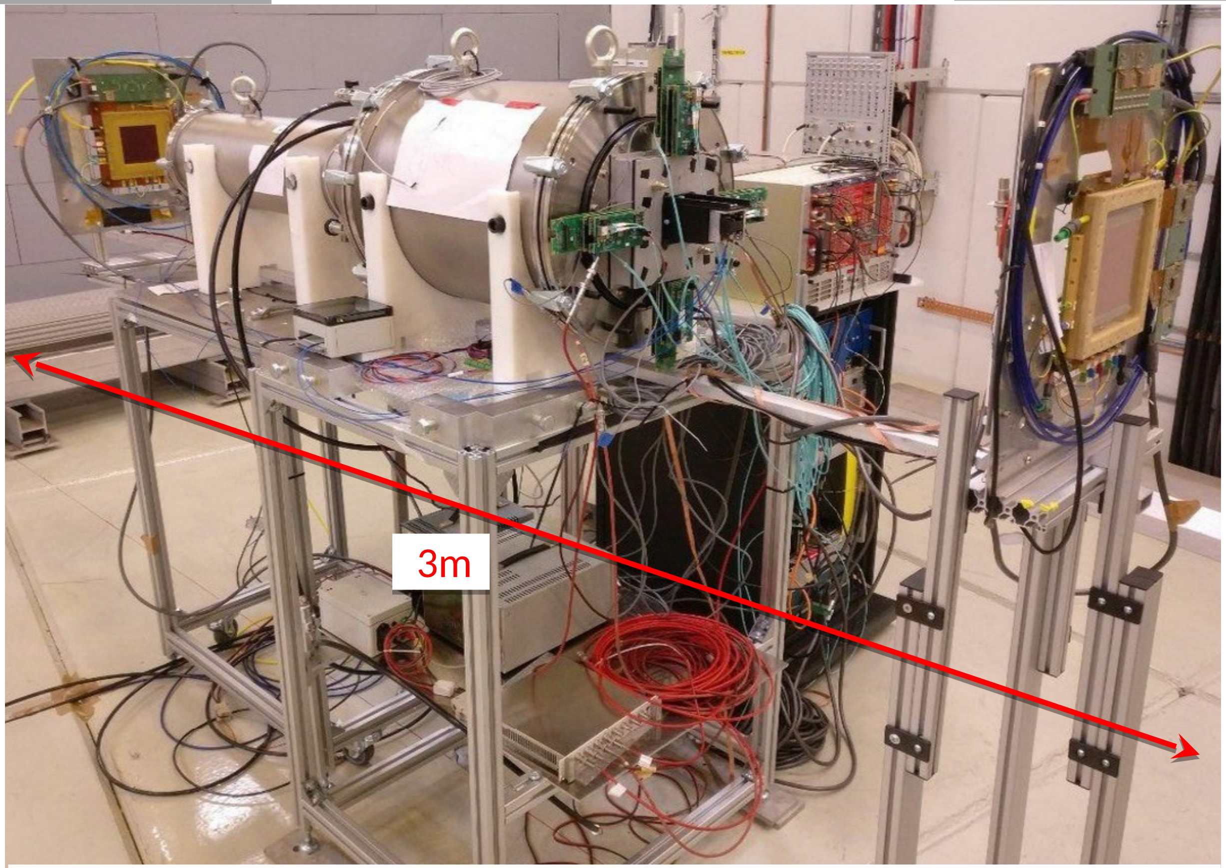
Detector: 0.5 m^2/sector , 3x3 mm^2 pixel. → SiPM option

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

TASK 3 : DRICH PROTOTYPE

D24.3 month 36
Prototype of photon
Detector for EIC RICH

MS50 month 36
EIC RICH photon detector
prototype assembled

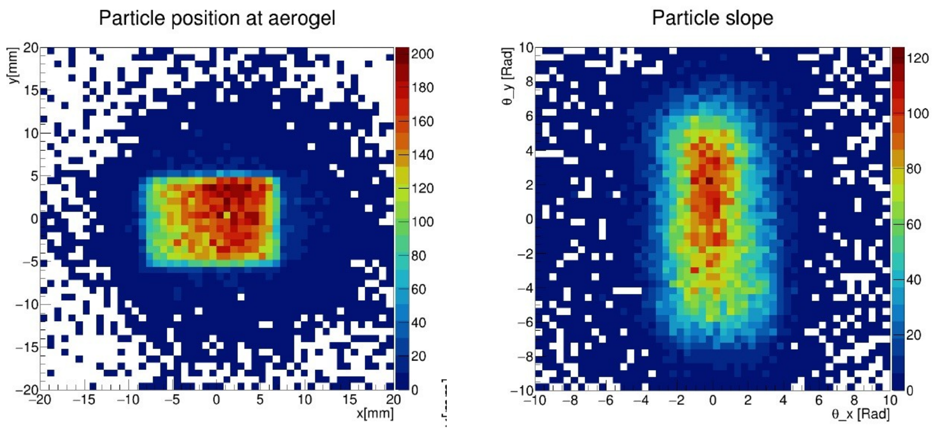


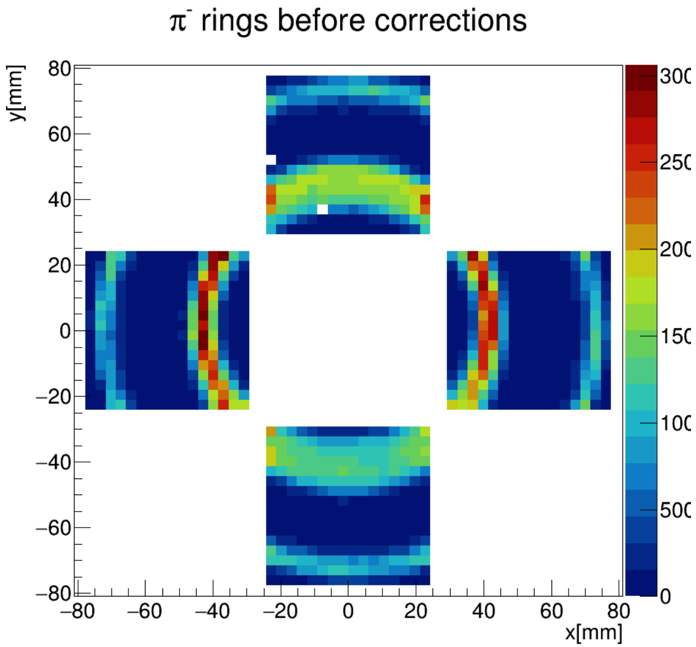
Prototype commissioning at CERN on fall 2021

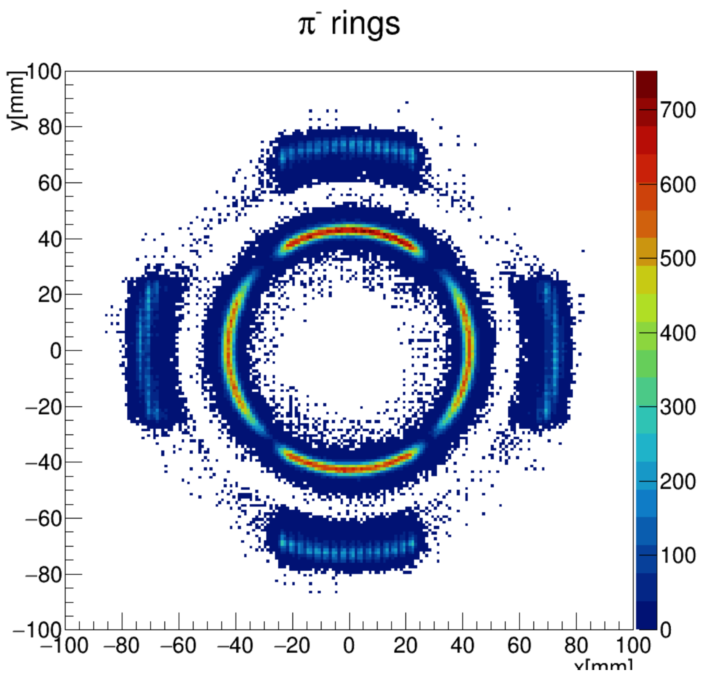
TASK 3 : CHERENKOV RINGS

A tracking system based on two GEM detectors was used during the test beam to correct for alignment and beam divergence.

The combination of the dRICH optical information and GEM track information allows one to correct data on an event by event analysis and study the detector performance for Cherenkov applications at EIC.



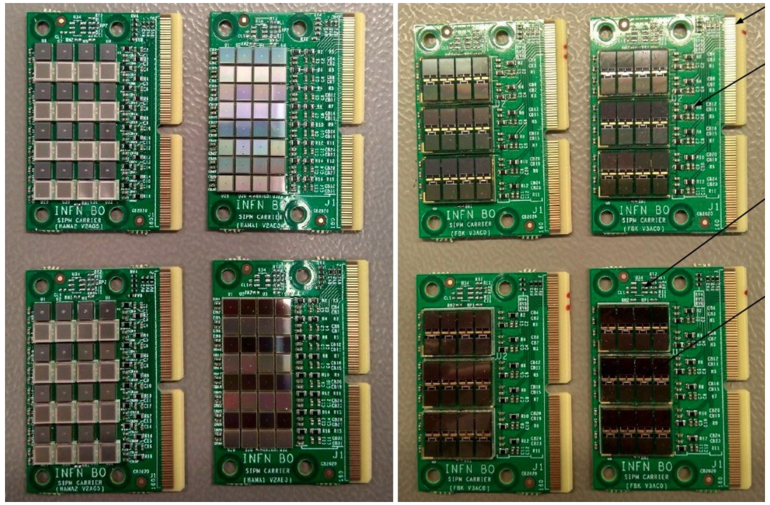




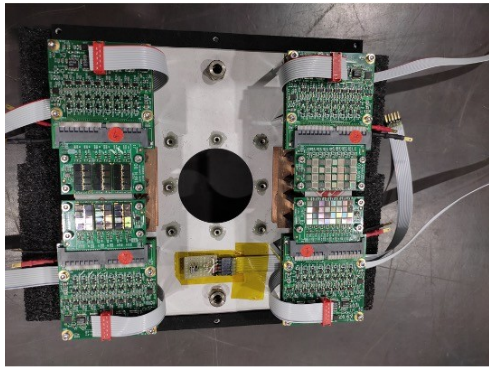
Simone Vallarino presentations at INFN2022 – LNGS and RICH2022 – Edinburgh University

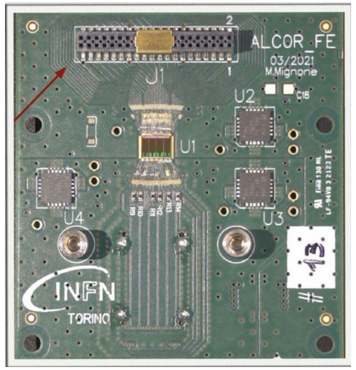
TASK 3 – PHOTO SENSORS

SiPM program: selection among various candidates R&D on dark count and radiation damage mitigation

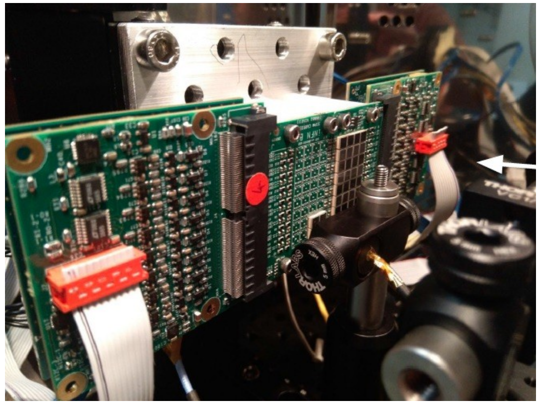


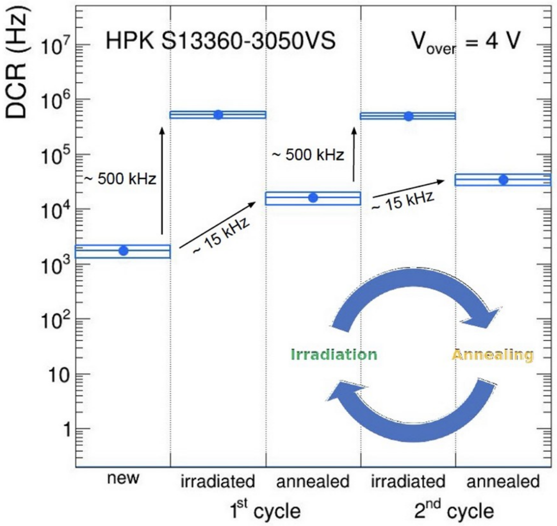
Combine laboratory characterization of sensors and beam tests with streaming readout and dRICH prototype





Study single photon detection after realistic cycles of irradiation and high-T annealing





Roberto Preghenella presentations at NDIP2022 – Troyes and RICH2022 – Edinburgh University

TASK 3 – STATUS AND PLANS

2022: Extended SiPM irradiation + annealing campaign

Improved prototype

Second test-beam campaign (realistic performance)

Data analysis

2023: Upgraded version of photon-detector plane (sensors, readout and cooling)

Third test-beam campaign (component optimization)

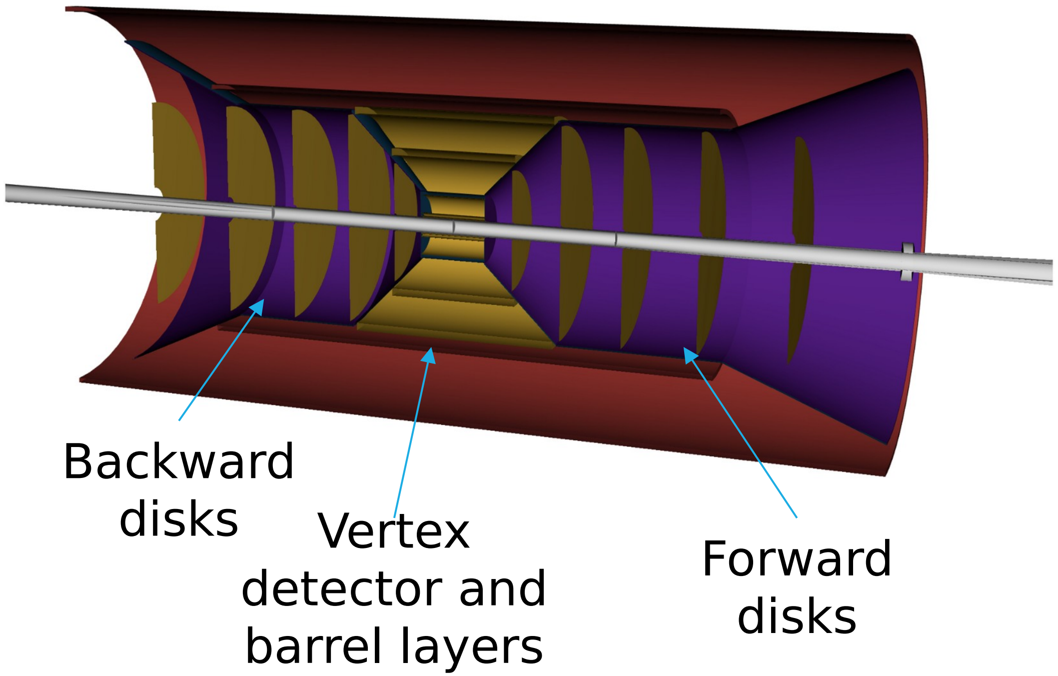
Refined data analysis and simulation

Final assessment

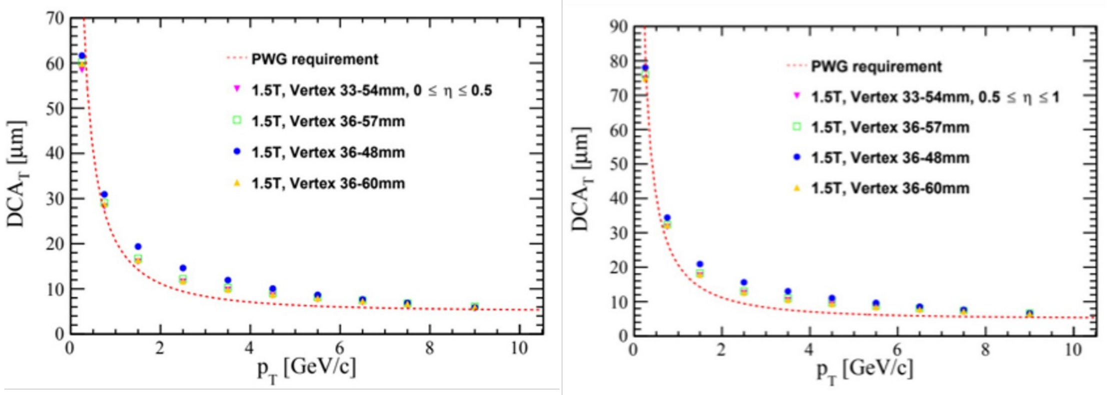
TASK 4: EIC SILICON VERTEX AND TRACKING (SVT) DETECTOR

- 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 a silicon vertex and tracking detector for the EIC based on 65 nm MAPS.
  - Performance simulations of the EPIC SVT.
  - Working on the development of the sensor technology → STRONG2020 funds enable further development of this part of the project (monetary contribution to sensor submission).

Current implementation of the EPIC SVT

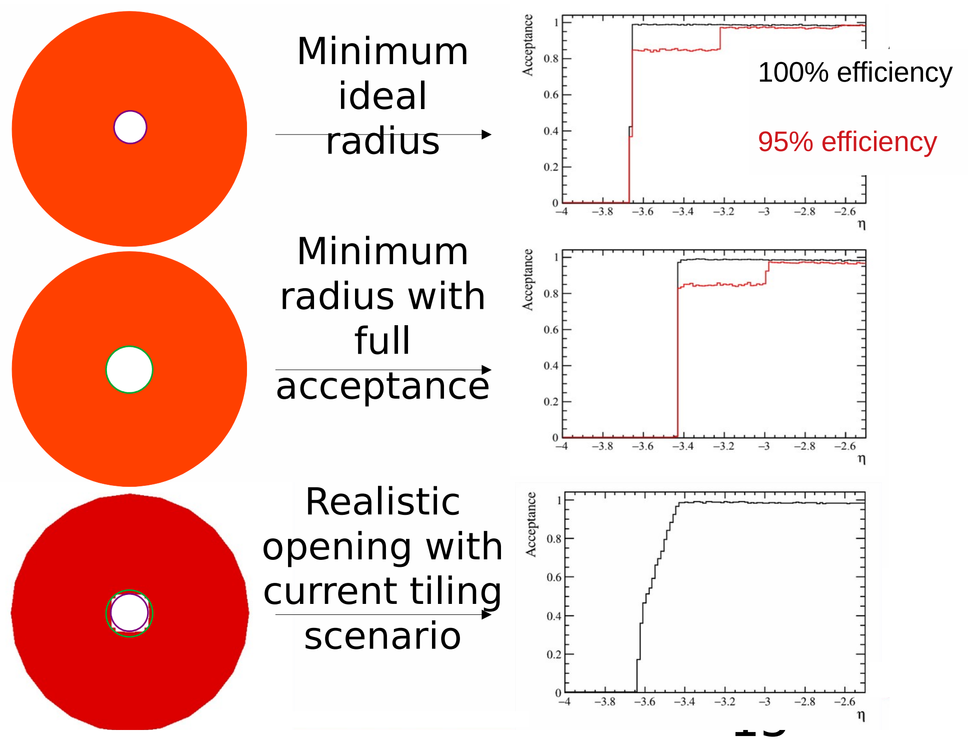


TASK 4: EIC SILICON VERTEX AND TRACKING (SVT) DETECTOR

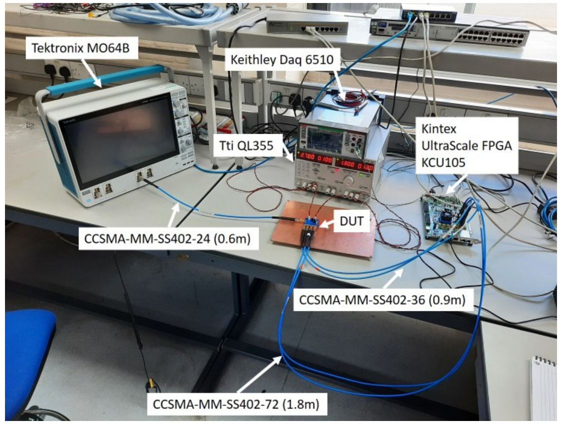


PERFORMANCE SIMULATIONS AND OPTIMISATIONS OF THE EPIC SVT

- A number of simulation studies are ongoing at Birmingham to optimise the performance of the EPIC SVT.
- Vertex layer radii definition taking into account the need for beam pipe bake out and constraints from the sensor size.
- Study of disks acceptance as a function of disks inner opening.
  - Tiling of disks with rectangular sensors results in disks inner opening that do not provide full acceptance close to the beam pipe. Estimate of acceptance degradation needed to inform further optimisation of sensor size and disk tiling.

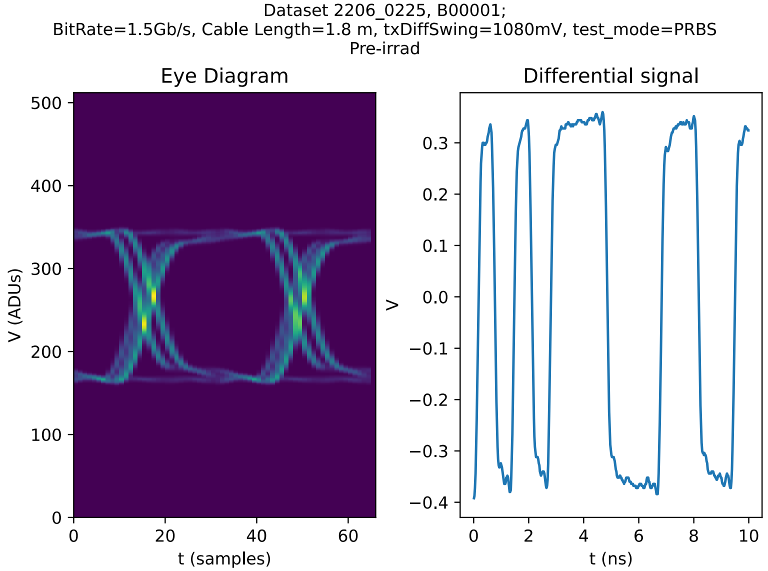


TASK 4: EIC SILICON VERTEX AND TRACKING (SVT) DETECTOR



65 nm MAPS SENSOR DEVELOPMENT

- The EIC Silicon Consortium collaborates with the ALICE ITS3 project to develop a new generation 65 nm MAPS sensor with minimal material budget.
- MLR (multiple-layer per reticule) submission in Q1-21: test structures to study technology performance.
  - EIC development (by STFC-RAL): LVDS-CML data transmission loop.
    - Test setup developed and testing ongoing at Birmingham and Daresbury.
    - Performance demonstrated to 1.5 Gbps.
  - Birmingham contributes to the ongoing programme of characterisation of the ITS3 APTS (Analogue Pixel Test Structure) chip; setup received over summer, commissioning almost completed.
- ER1(engineering run) submission planned for Q4-22: stitched wafer-scale sensor prototype.



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)

SUMMARY

- Simulations of physics processes for the EIC YR have defined tight constraints on the EIC detector. Currently, simulations are used for the optimization of the ePIC dector. Strong collaboration with VA2 (PARTONS)
- Two prototypes of a novel MPGD structure for low IBF detectors using GEMs micro-meshes have been constructed and tested. A publication has been submitted.
- A prototype of the dRICH has been built and tested in beam. Data are being analyzed. Campaigns on SiPM sensor radiation hardness have been conducted.
- A new 65 nm CMOS technology has been chosen for the EIC SVT design and validated in simulations. Strong collaboration with the ALICE ITS3 R&D. Prototype submissions in 2023.

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