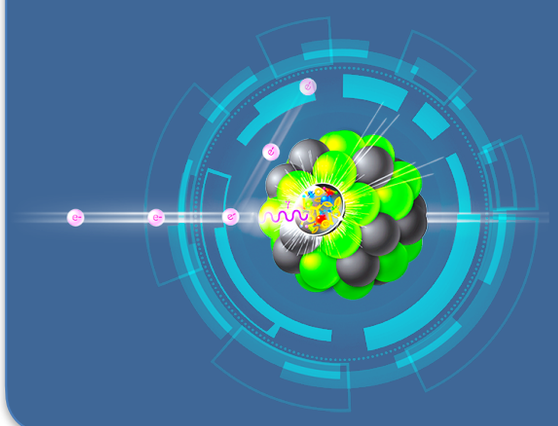
High Rate Picosecond Photon Detector



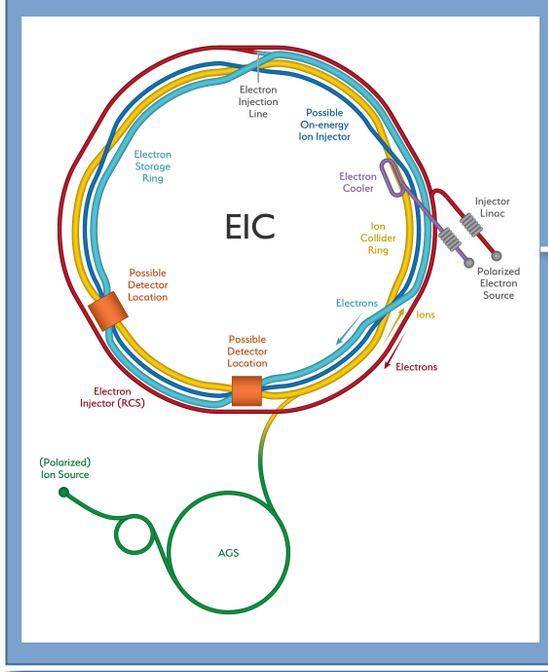
For the EIC/ePIC

First European School on the Physics of the Electron-Ion Collider, 18-22 June 2023, Corigliano-Rossano, Italy

HRPPD at the ePIC

Electron Ion Collider

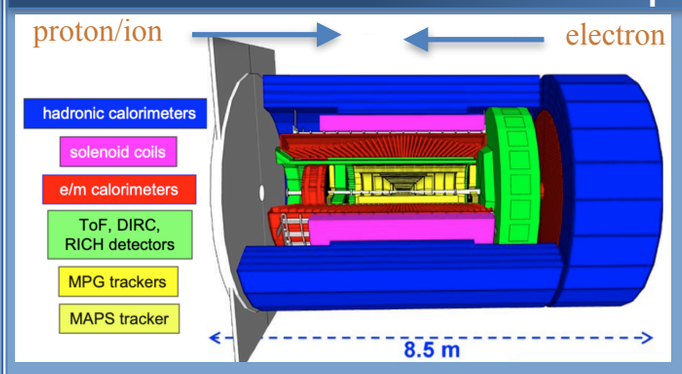
The questions EIC will address and the features it will have :



1. How the mass of the quarks (parton interaction) accounts for the mass of a nucleon
2. How the spins of the quarks and the gluons are combined to account for the spin of a proton
3. Properties of a dense quark-gluon system (hints to the early universe)
4. A truly 3D scanning machine for the proton and nuclei

1. Variable electron-proton center-of-mass energies from 20 to 140 GeV
2. Highly polarized electron (~ 70%), proton and light nuclear (~ 70%) beams.
3. Ion beams from deuterons to heavy nuclei such as gold, lead, or uranium
4. High collision electron-nucleon luminosity of 10^{33} - 10^{34}cm^{-2}s^{-1}
5. Possibility to have two interaction regions.

ePIC [IP6]

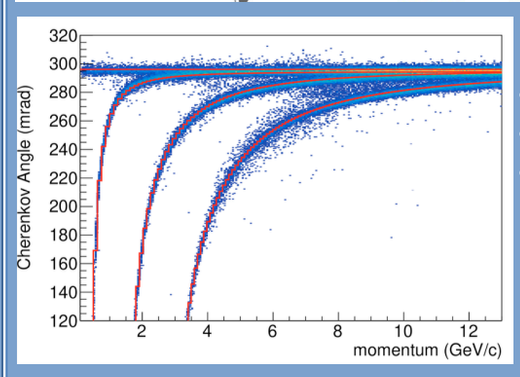


Tracker and the Magnet

- 1.7 T magnet solenoid
- Micromegas and µRWell
- Si-MAPS

Calorimeter

- Barel Imaging Calorimeter
- Backward: PbWO4 EMCal
- Forward: Finely segmented EMCal, hCal



PID

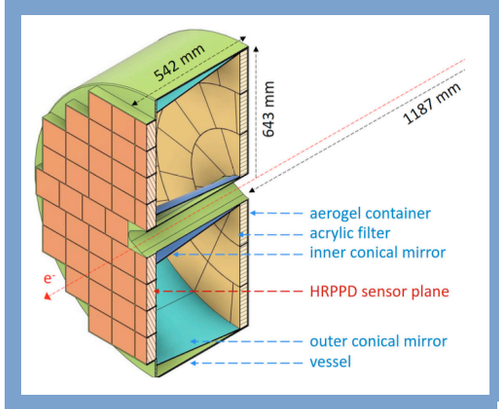
- Backward: pfRICH (HRPPD)
- Central: TOF (AC LGAD), DIRC (MCP-PMT/HRPPD)
- Forward: TOF (AC LGAD), dRICH (SiPM)

π/K separation requirement

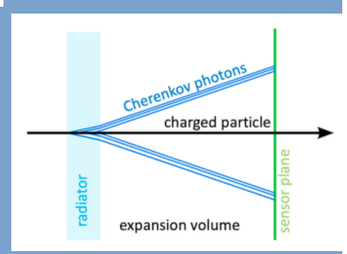
- Backward: up to 9 GeV/c
- Central: up to 6 GeV/c
- Forward: up to 50 GeV/c

pfRICH

electron EndCap RICH for the ePIC detector



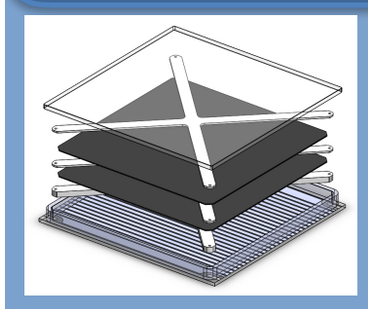
- Radiator : Aerogel 2.5 cm (contribution to angular resolution is below 5 mrad, N_{ep} ~12 near saturation angle of 295 mrad.)
- Peripheral Conical Mirrors
- Photon sensor: HRPPD

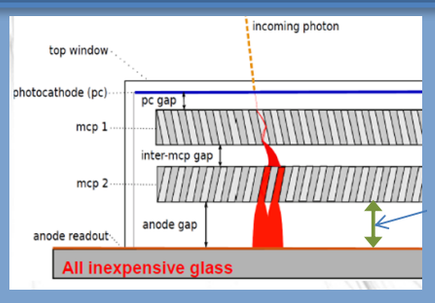


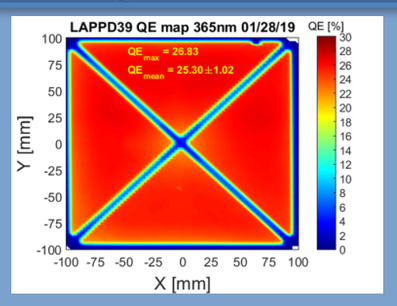
The pfRICH for ePIC

- A classical proximity focusing RICH
- pseudo-rapidity coverage : -3.5 < η <-1.5
- Uniform performance in whole $\eta\varphi$ range
- π/K separation above 3σ is up to 9 GeV/c
- t0 reference ~10-20 ps with 100% geometric efficiency

LAPPD/HRPPD: Setup in general [Trieste]



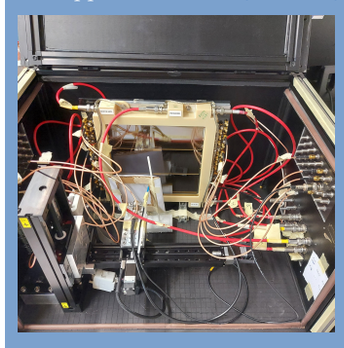


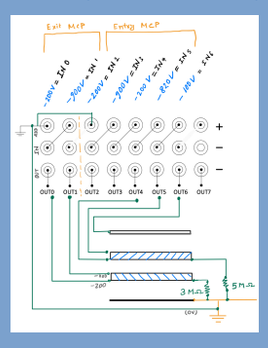


PhotoCathode (PC)

- Bi-alkali: Na_2KSb
- QE measured at 365 nm
- Highest avg. is 26.8%
- Observed stability > 2 years
- Blue sensitive PC for Cherenkov light
- On trial: Rb-K-Cs-Sb

- LAPPD, a vacuum sealed device, can be as large as 20 cm X 20 cm. [produced by INCOM]
- Observed position resolution ~400 µm, time resolution ~50 ps.
- Consists of a Photocathode (PC), two Micro Channels Plates (MCP), and an Anode.
- Application of novel ALD in the MCP pores reduces ion emission unprecedentedly, extending the life of the PC.
- Anode could be made directly coupled to the readout for faster charge evacuation, for high rate capability.
- Application: ePIC, DUNE, ANNIE, WATCHMAN, and applications beyond physics.

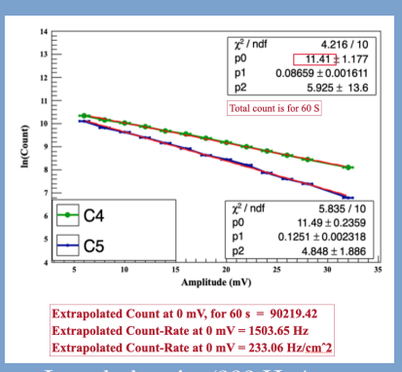




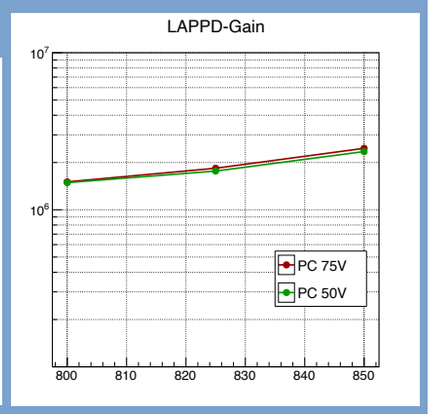
We are studying:

- Gain, HV stability,
- Dark count rate
- Rate capability,
- Time resolution
- CrossTalk
- Position resolution

- A dark box, LASER (404 nm, ~40 ps), XYZ table (10 µm precision), novel PCB
- Digitizer: V1742 (DRS4 chip, 5 GS/s),
- Proper High voltage scheme with CAEN DT1515ET; Custom made Amplifiers

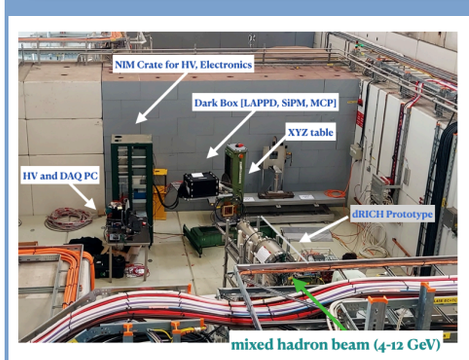


- Low dark-noise (233 Hz/cm^2) at room temperature

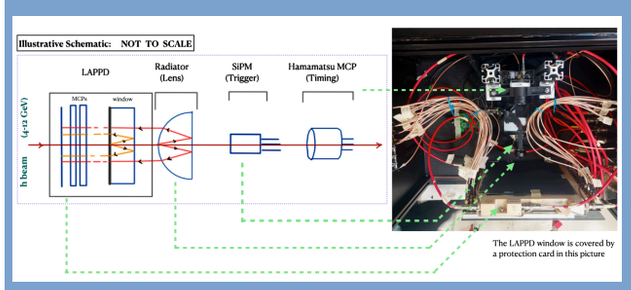


- Gain can reach as high as 10^7

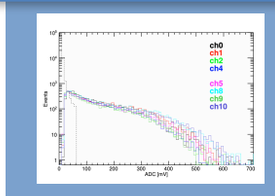
Beam Test at CERN PS

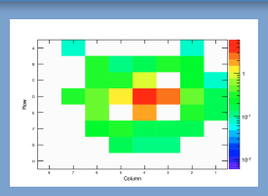


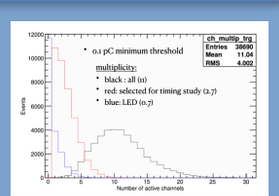
- We had a beam test at CERN PS during 5-19 Oct2022. We shared the beam line.
- A joint effort by Trieste, Genova, BNL.
- We aimed to measure single photoelectron time resolution with hadron beam.



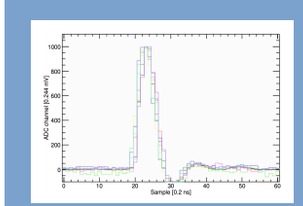
- Mixed hadron = 4-12 GeV
- Photosensor = LAPPD
- Radiator = Aspheric lens
- Trigger = SiPM (Kuraray 3HF(1500)MJ
- Reference Timing = Hamamatsu MCP-PMT (R3809U-50)

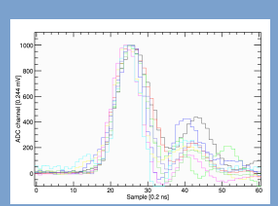


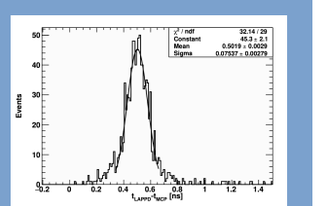




1. Amplitude calibration is done with LED and LASER in single photoelectron mode to get the number of photon in real time experiment.
2. Central pad is flooded for the beam, the average charge on the ring is around SPE.
3. 24% hits are selected for timing. Pad-multiplicity (Red) was ~2.7







1. Signal from the MCP-PMT, used for reference timing.
2. Signal from the LAPPD, 'good' channels from the Ring.
3. The time difference is fitted by a Gaussian within 2σ.
4. The best resolution found (in Channel 2) is 75 +-3 ps.

Conclusion

- With polarised electron, proton and light nuclei, EIC will be a precision and discovery machine.
- Different PID technologies are required for ePIC
- There will be a pfRICH for the PID at the e-cap.
- The proposed photosensors for pfRICH is HRPPD, with high rate capabilities, ~50 ns time resolution at SPE, working under magnetic field.

References

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[2] Electron Ion Collider Conceptual Design Report 2021 https://doi.org/10.2172/1765663

[3] ATHENA detector proposal — a totally hermetic electron nucleus apparatus proposed for IP6 at the Electron-Ion Collider https://doi.org/10.1088/1748-0221/17/10/P10019

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INFN Trieste[1], INFN Genova[2], BNL[3]