MEIC Central Detector

Zhiwen Zhao

for JLab MEIC Study Group

MEIC Collaboration Meeting

2015/10/07

MEIC Design Goals

Energy

Full coverage of √**s** from **15** to **65** GeV

Electrons **3-10** GeV, protons **20-100** GeV, ions **12-40** GeV/u

Ion species

Polarized light ions: **p**, **d**, **^{3}He**, and possibly **Li**

Un-polarized light to heavy ions up to A above 200 (Au, Pb)

Space for at least 2 detectors

Full acceptance is critical for the primary detector

High luminosity for the second detector

Luminosity

10^{33} to 10^{34}cm^{-2}s^{-1} per IP in a *broad* CM energy range

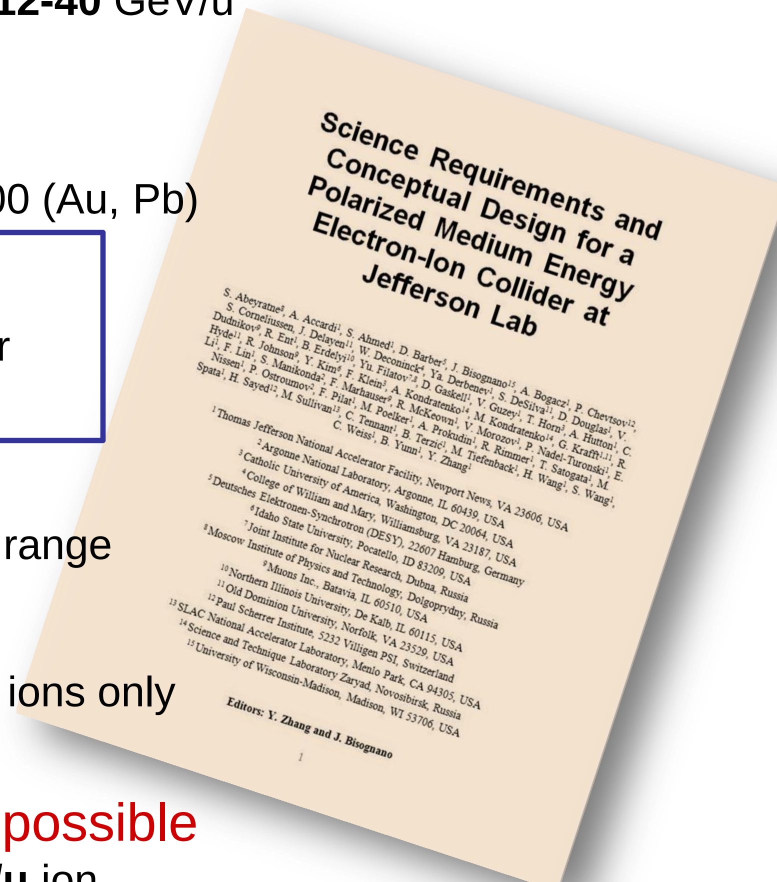
Polarization

At IP: longitudinal for both beams, transverse for ions only

All polarizations >70%

Upgrade to higher energies and luminosity possible

20 GeV electron, **250 GeV** proton, and **100 GeV/u** ion



Science Requirements and Conceptual Design for a Polarized Medium Energy Electron-Ion Collider at Jefferson Lab

S. Abeyratne[8], A. Accardi[1], S. Ahmed[1], D. Barber[5], J. Bisognano[15], A. Bogacz[1], P. Chevtsov[12], S. Cornelussen, J. Delayen[11], W. Deconinck[4], Ya. Derbenev[1], S. DeSilva[11], D. Douglas[1], V. Dudnikov[9], R. Ent[1], B. Erdelyi[10], Yu. Filatov[7,8], D. Gaskell[1], V. Guzey[1], T. Horn[3], A. Hutton[1], C. Hyde[11], R. Johnson[9], Y. Kim[6], F. Klein[3], A. Kondratenko[14], M. Kondratenko[14], G. Krafft[1,11], R. Li[1], F. Lin[1], S. Manikonda[2], F. Marhauser[9], R. McKeown[1], V. Morozov[1], P. Nadel-Turonski[1], E. Nissen[1], P. Ostroumov[2], F. Pilat[1], M. Poelker[1], A. Prokudin[1], R. Rimmer[1], T. Satogata[1], M. Spata[1], H. Sayed[12], M. Sullivan[13], C. Tennant[1], B. Terzic[1], M. Tiefenback[1], H. Wang[1], S. Wang[1], C. Weiss[1], B. Yunn[1], Y. Zhang[1]

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[14]Science and Technique Laboratory Zaryad, Novosibirsk, Russia
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Editors: Y. Zhang and J. Bisognano

1

Design goals consistent with the White Paper requirements

EIC Physics Highlights

- 3D structure of nucleons

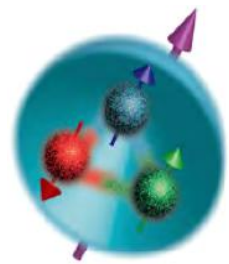
  How do gluons and quarks bind into 3D hadrons?

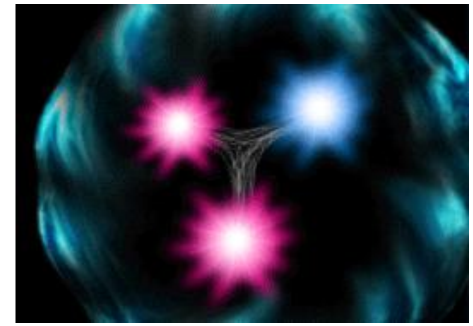
- Role of orbital motion and gluon dynamics in the proton spin

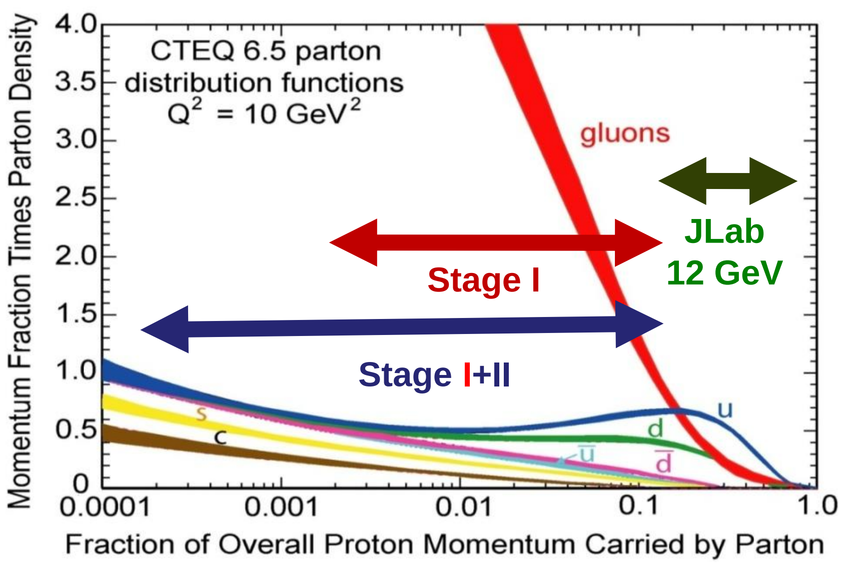
  Why do quarks contribute only ~30%?

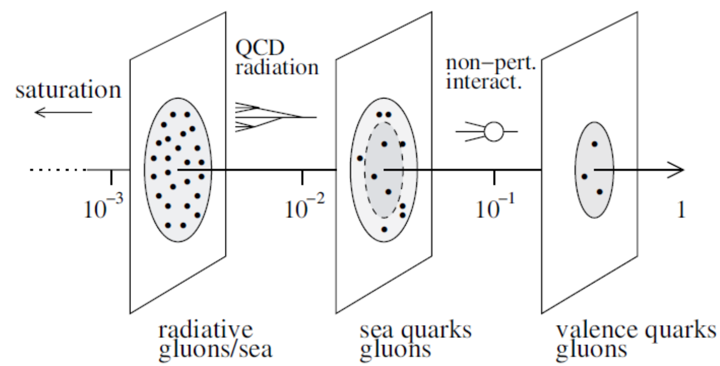
- Gluons in nucleon and nuclei (light and heavy)

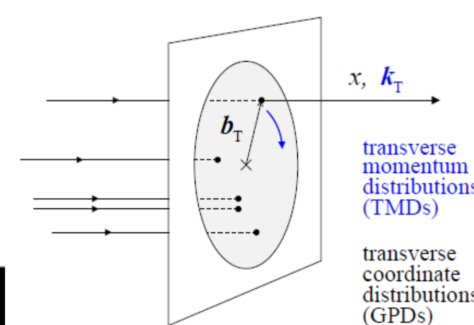
  Does the gluon density saturate at small x?





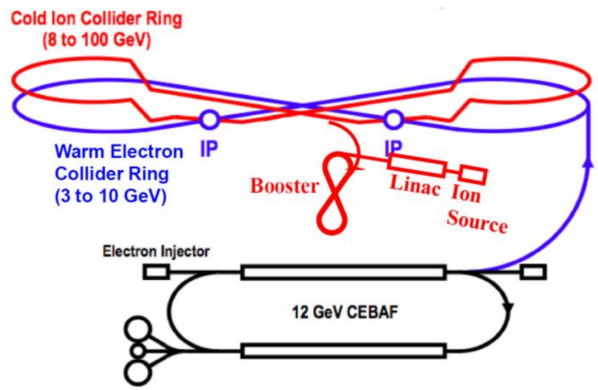




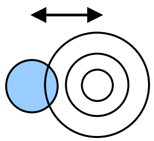


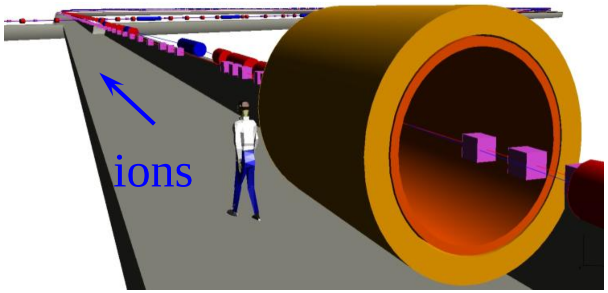
A stage I EIC (Jlab MEIC) covers the x and Q^2 range between JLab 12 GeV and HERA (or a future LHeC)

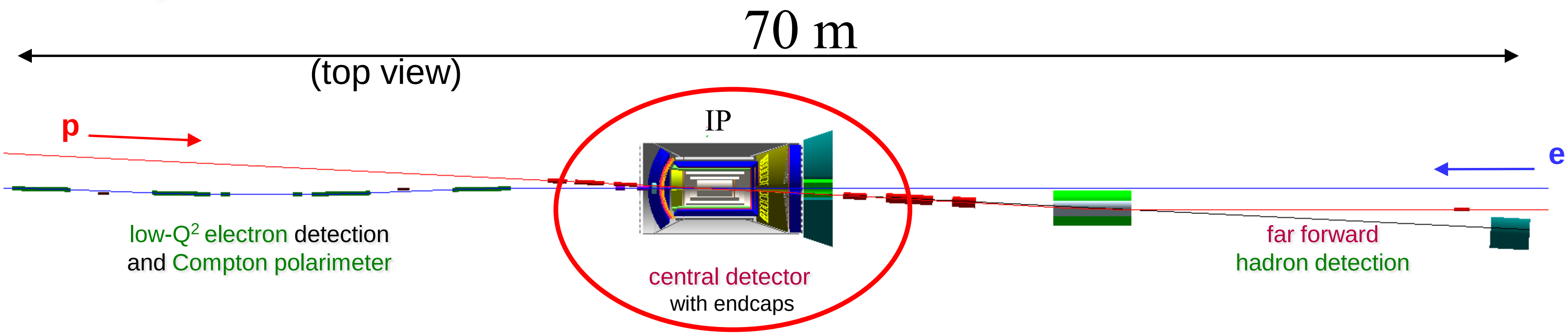
Interaction Region



50mrad Crossing Angle

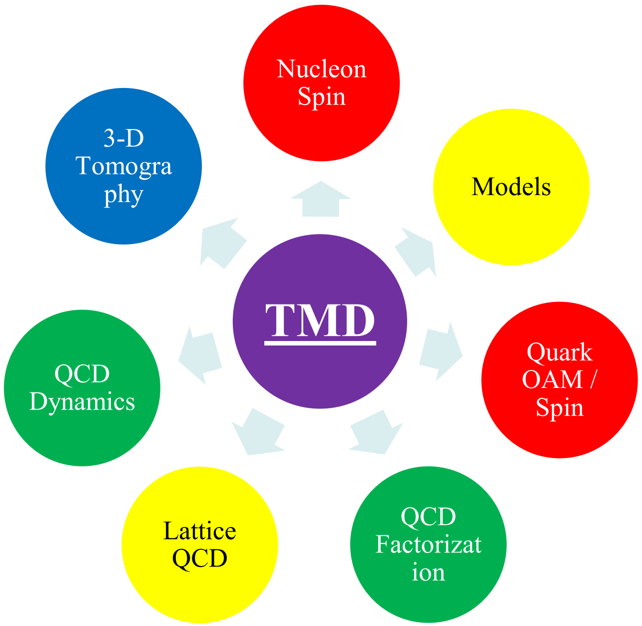




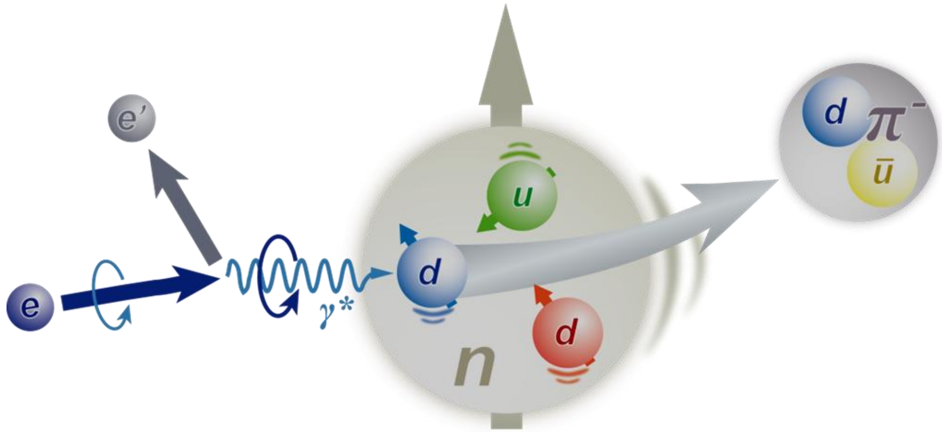


- Fully-integrated detector and interaction region satisfying
  - Detector requirements: full acceptance and high resolution
  - Beam dynamics requirements: consistent with non-linear dynamics requirements
  - Geometric constraints: matched collider ring footprints

Semi-Inclusive DIS (SIDIS) (one physics example)



Precision mapping of transverse momentum dependent parton distributions (TMD)

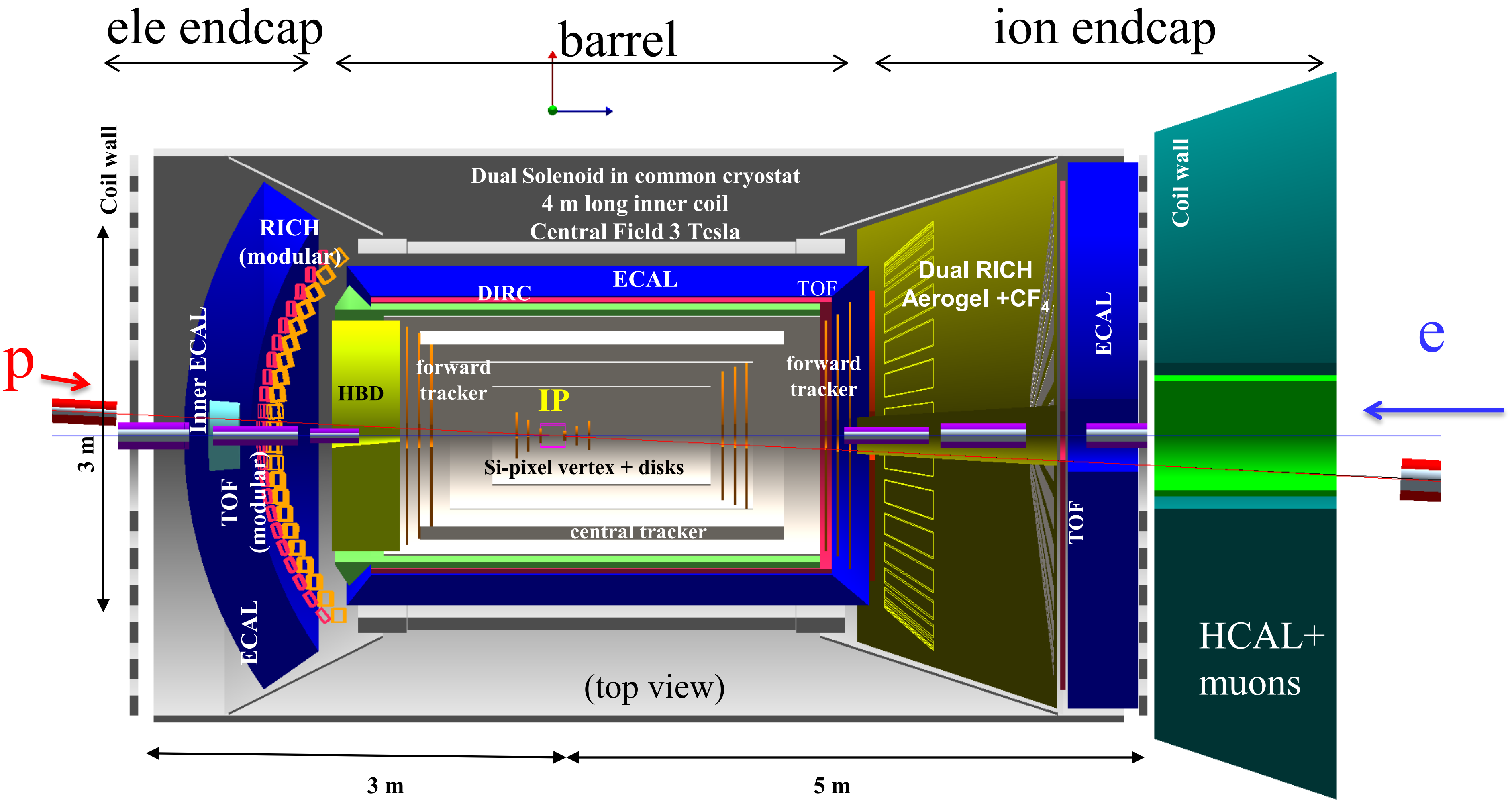


Iluustration of E06-010 Double Spin Asymmetry
Jin Huang <jinhuang@jlab.org>

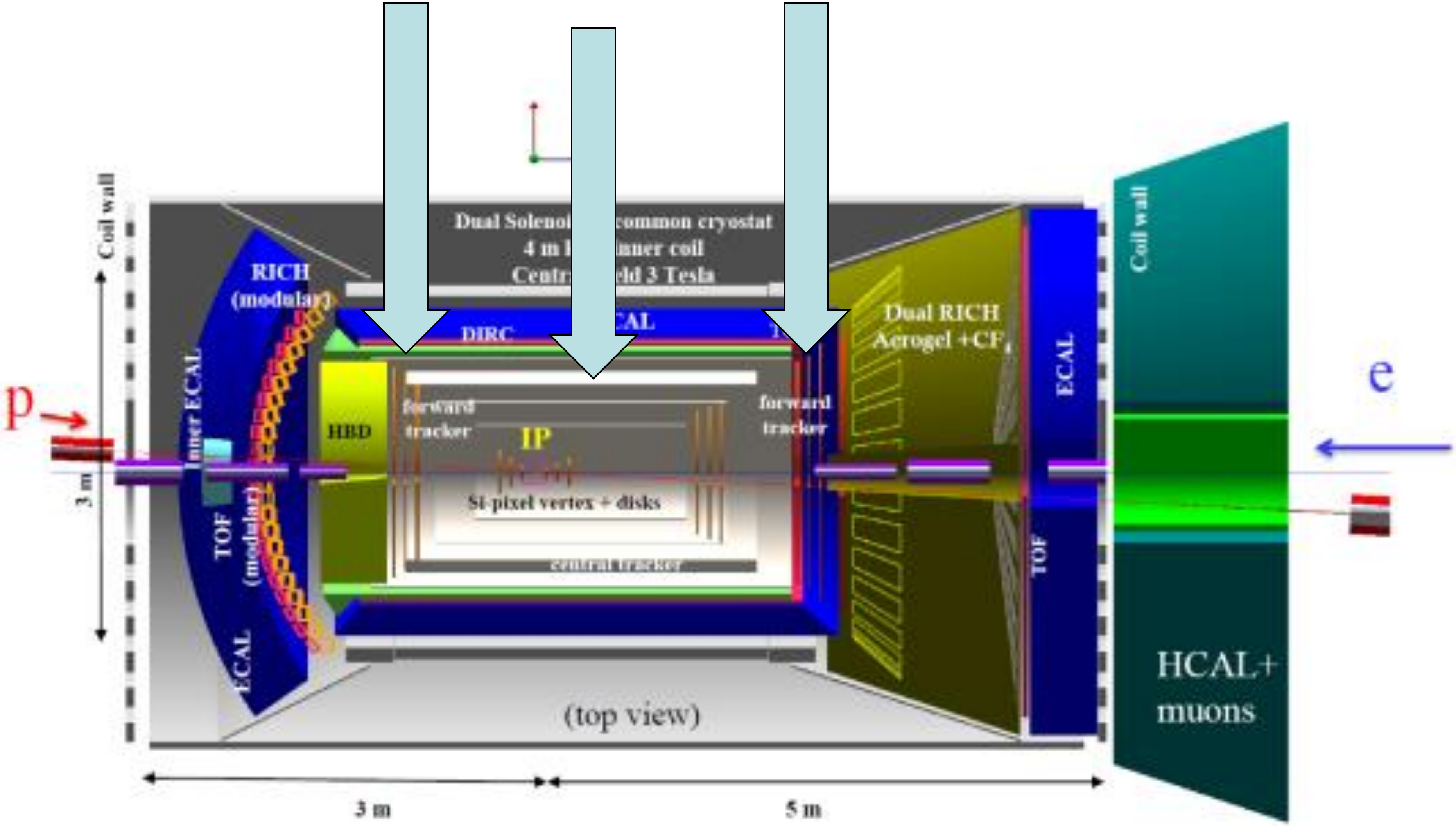
- Highly polarized electron collide with highly polarized nuclei (proton, deuteron, ^{3}He ,etc)
- Detect scattered electron and pion at full angle and full momentum range

MEIC IP1 Central Detector

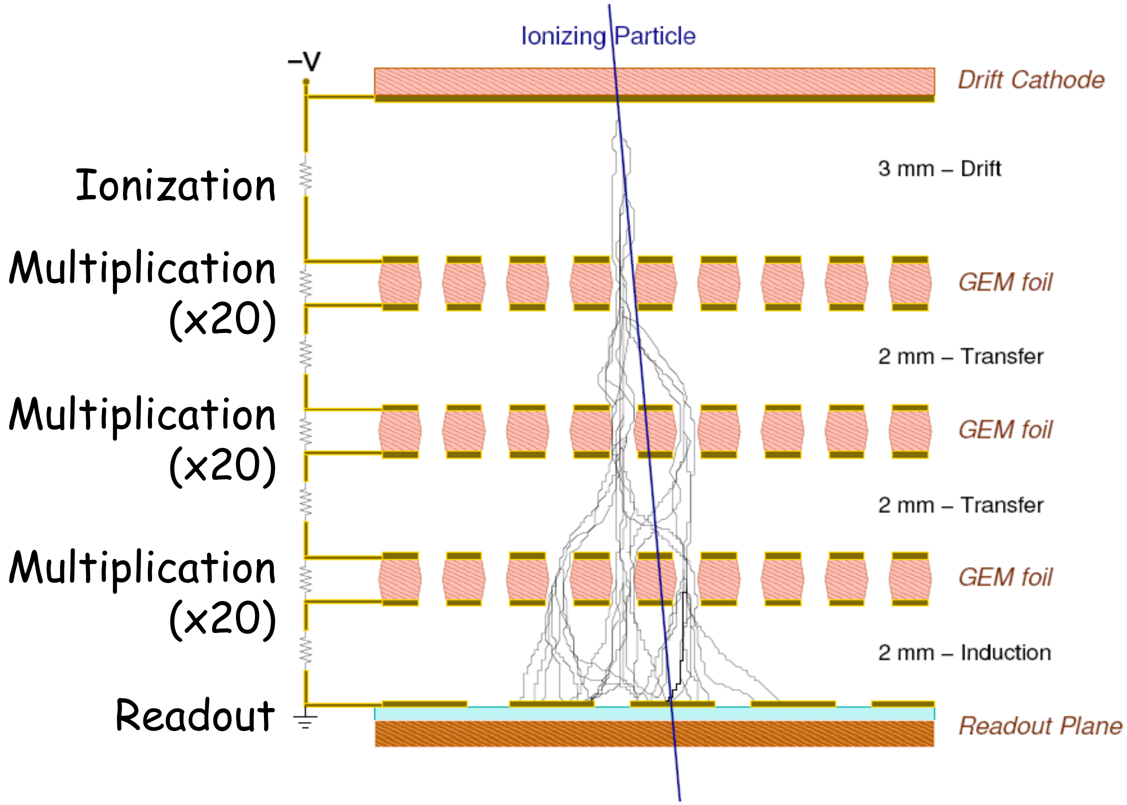
- Dual Solenoid Magnet, inner size similar to CLEO/BaBar magnet



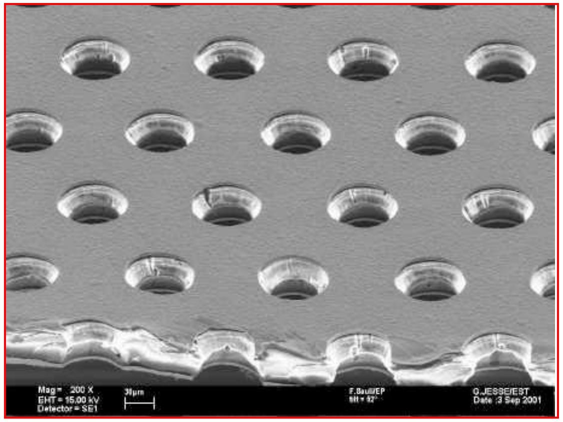
Tracking (Gas Electron Multiplier)

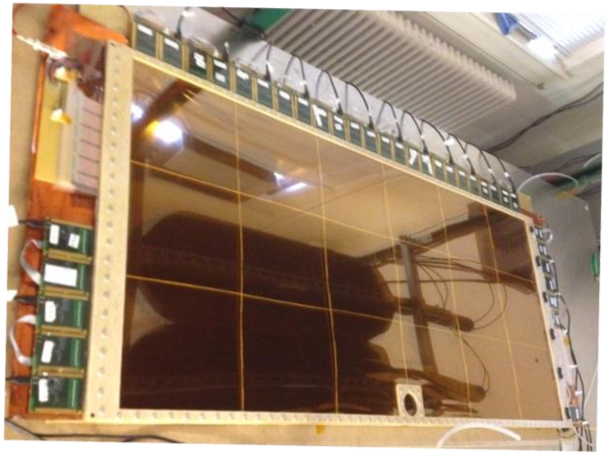


Tracking (Gas Electron Multiplier)



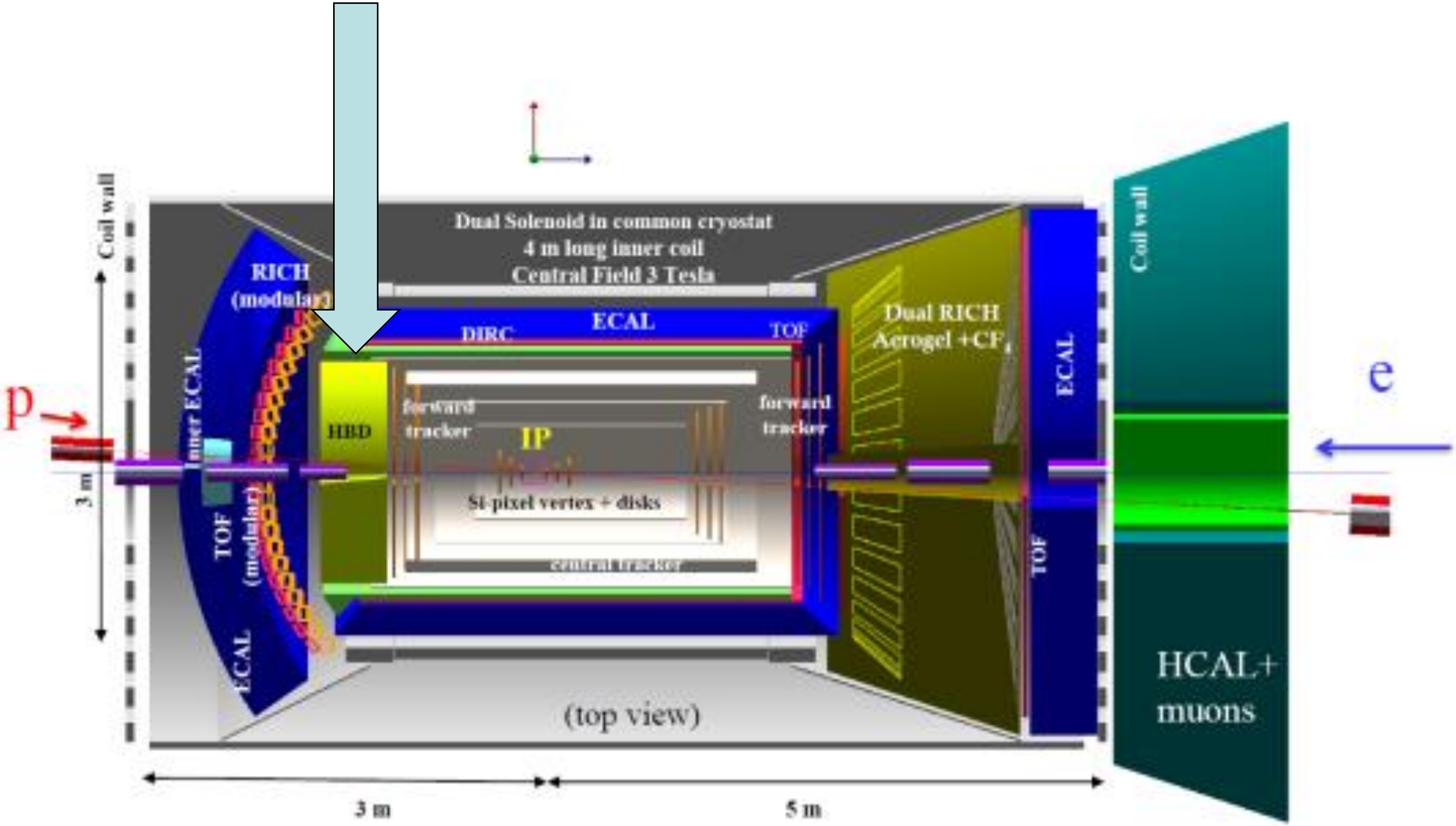
GEM foil: 50 μm Kapton + few μm copper on both sides with 70 μm holes, 140 μm pitch





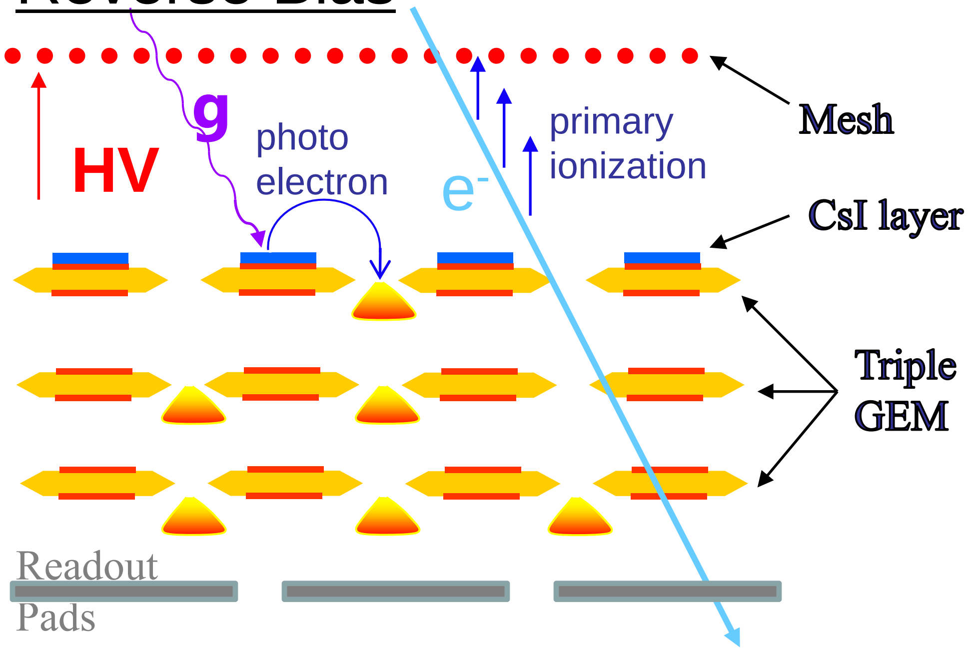
- Find particle tracks and measure momentum
- Work in high rate environment

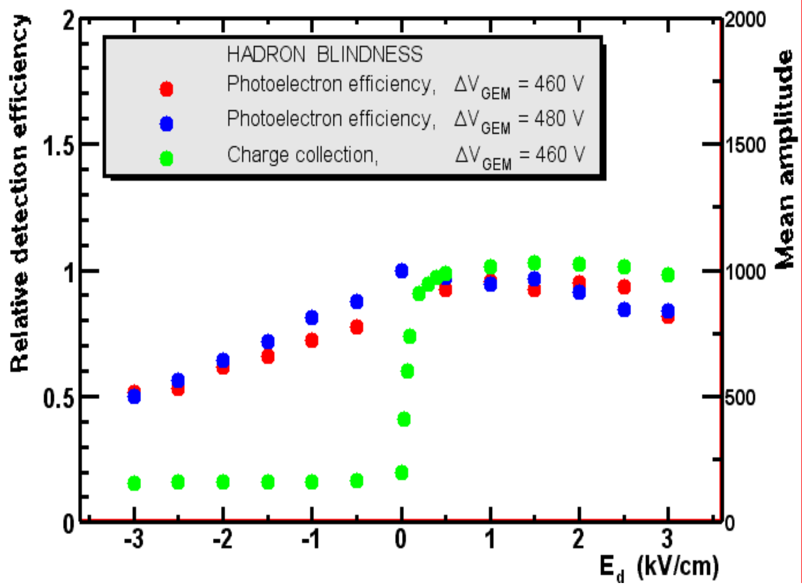
Particle Identification Detector (Hadron Blind Detector)



Particle Identification Detector (Hadron Blind Detector)

Reverse Bias

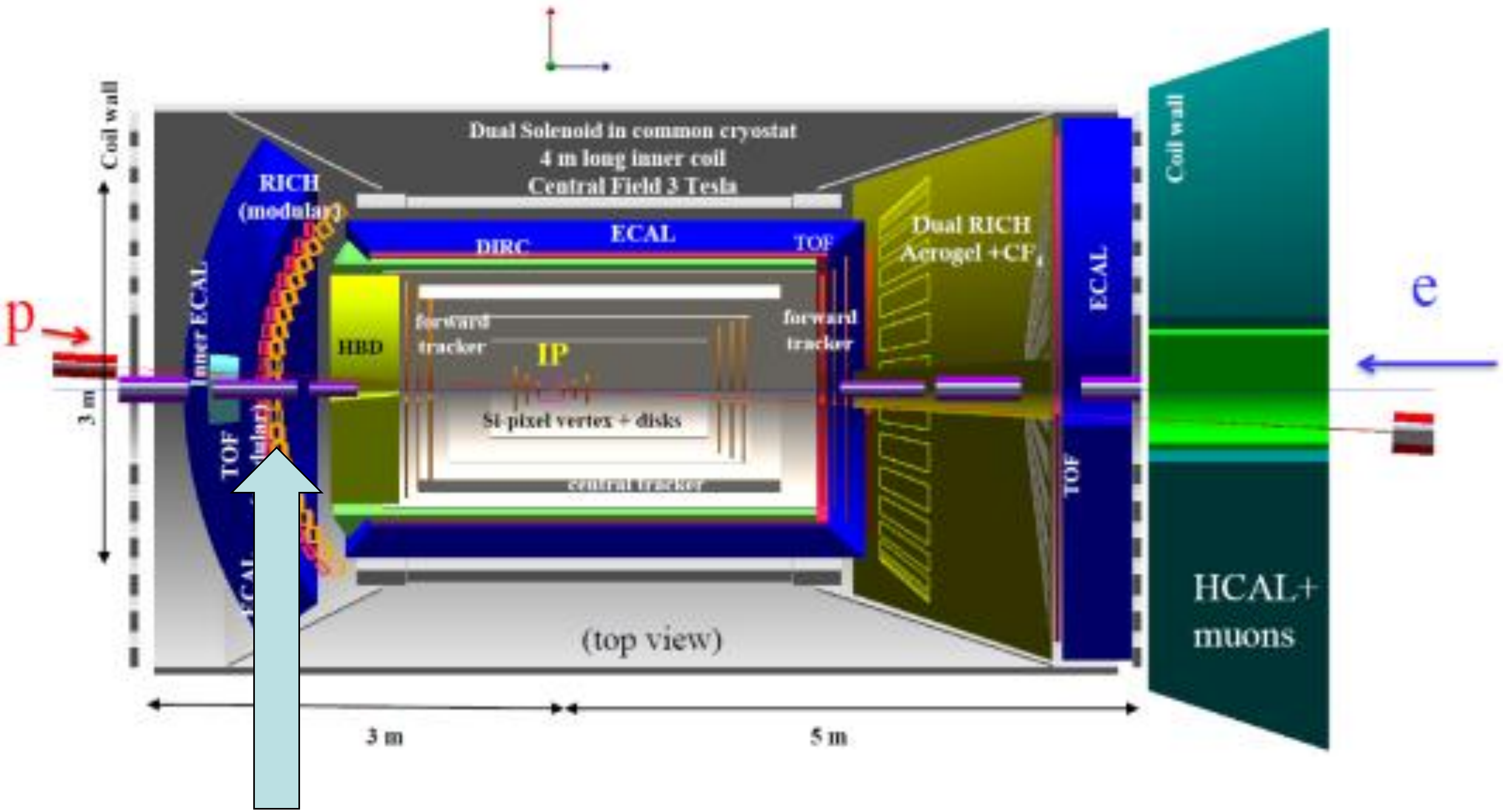




- Compact e/π PID detector
- Blind to hadron < 4GeV with CF_4 gas at PHENIX

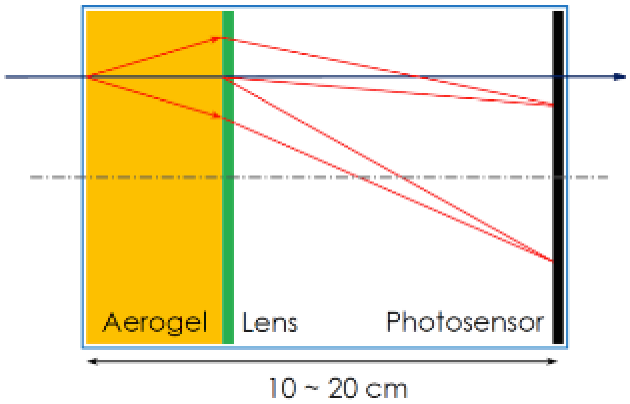
Tom Hemmick @ StonyBrook

Particle Identification Detector (Modular RICH)

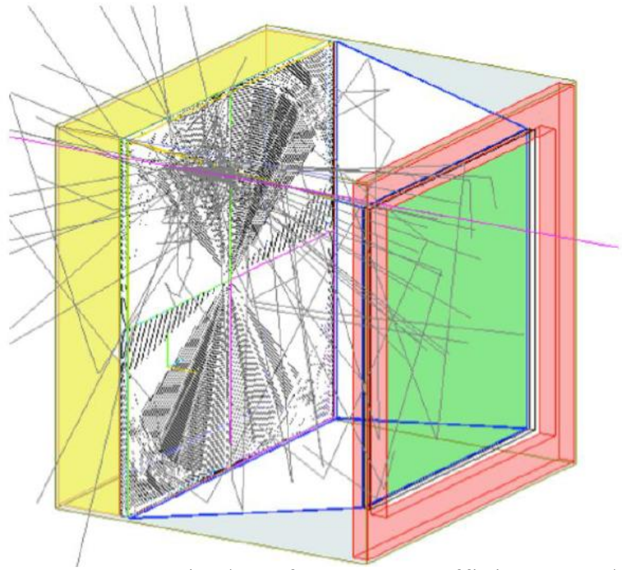


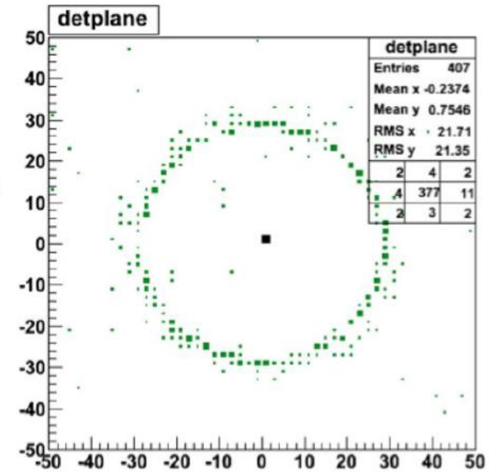
Particle Identification Detector (Modular RICH)

Concept



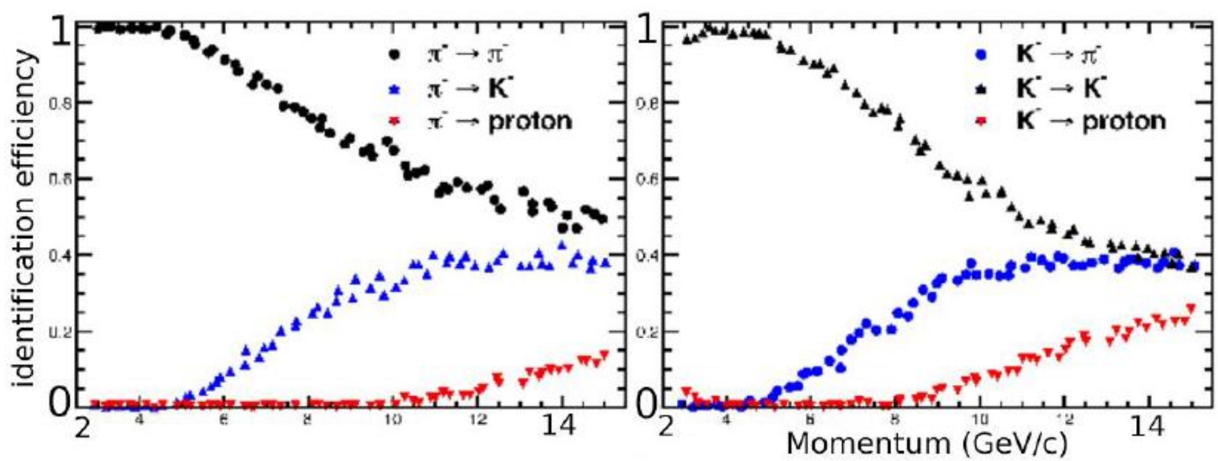
Simulation in **GEMC**





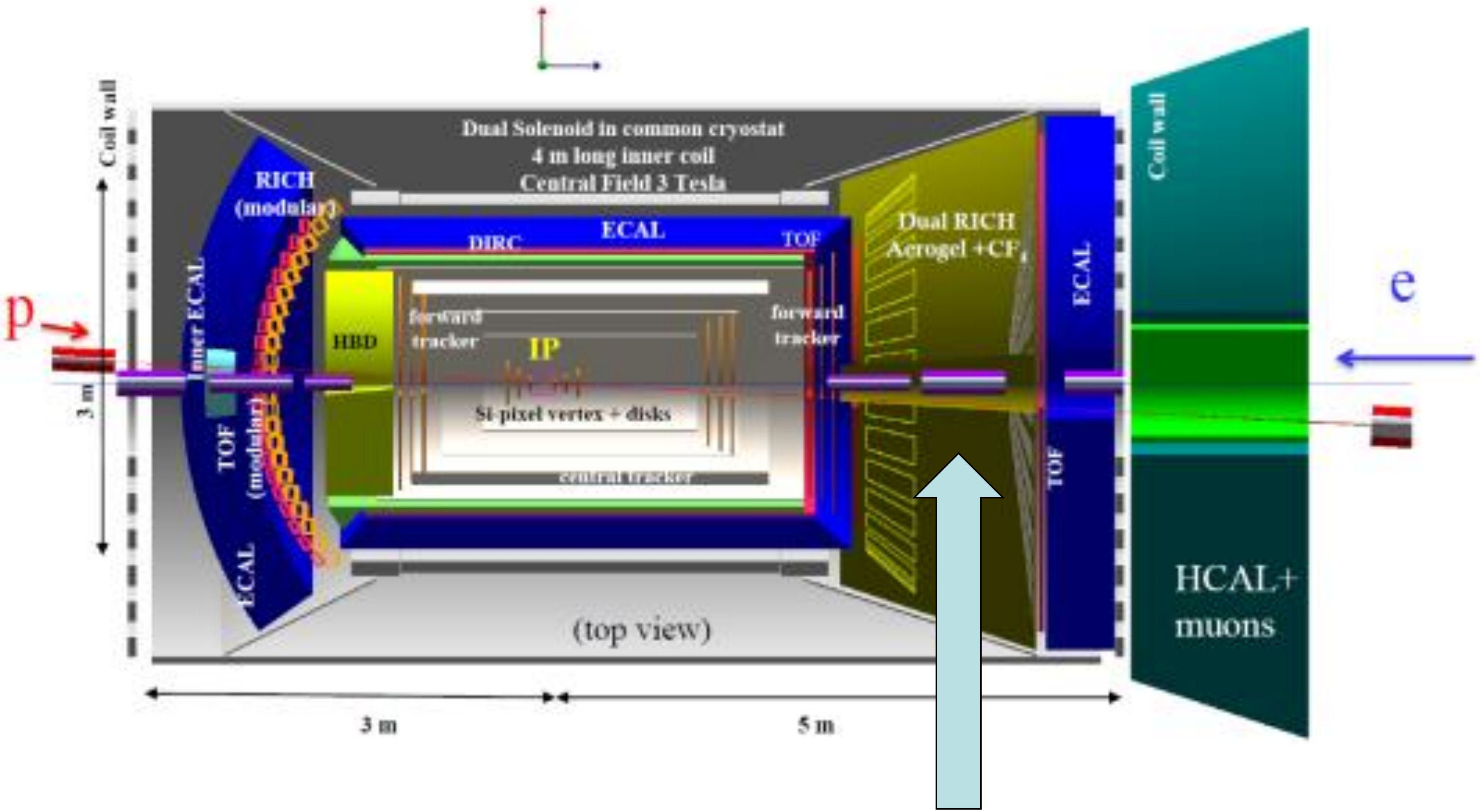
- Compact π/K PID detector at ele endcap
- Flexible arrangement, can be projective to IP at ele endcap

Final performance : Efficiency and mis-ID VS momentum



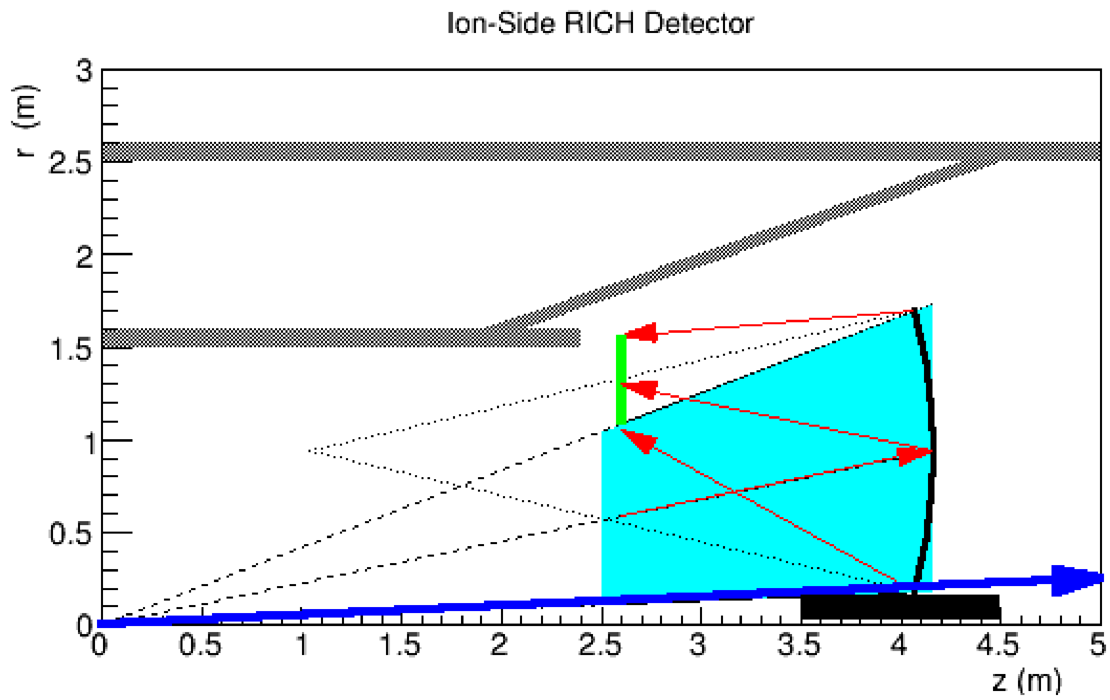
EIC R&D PID (RICH)

Particle Identification Detector (Dual Radiator RICH)



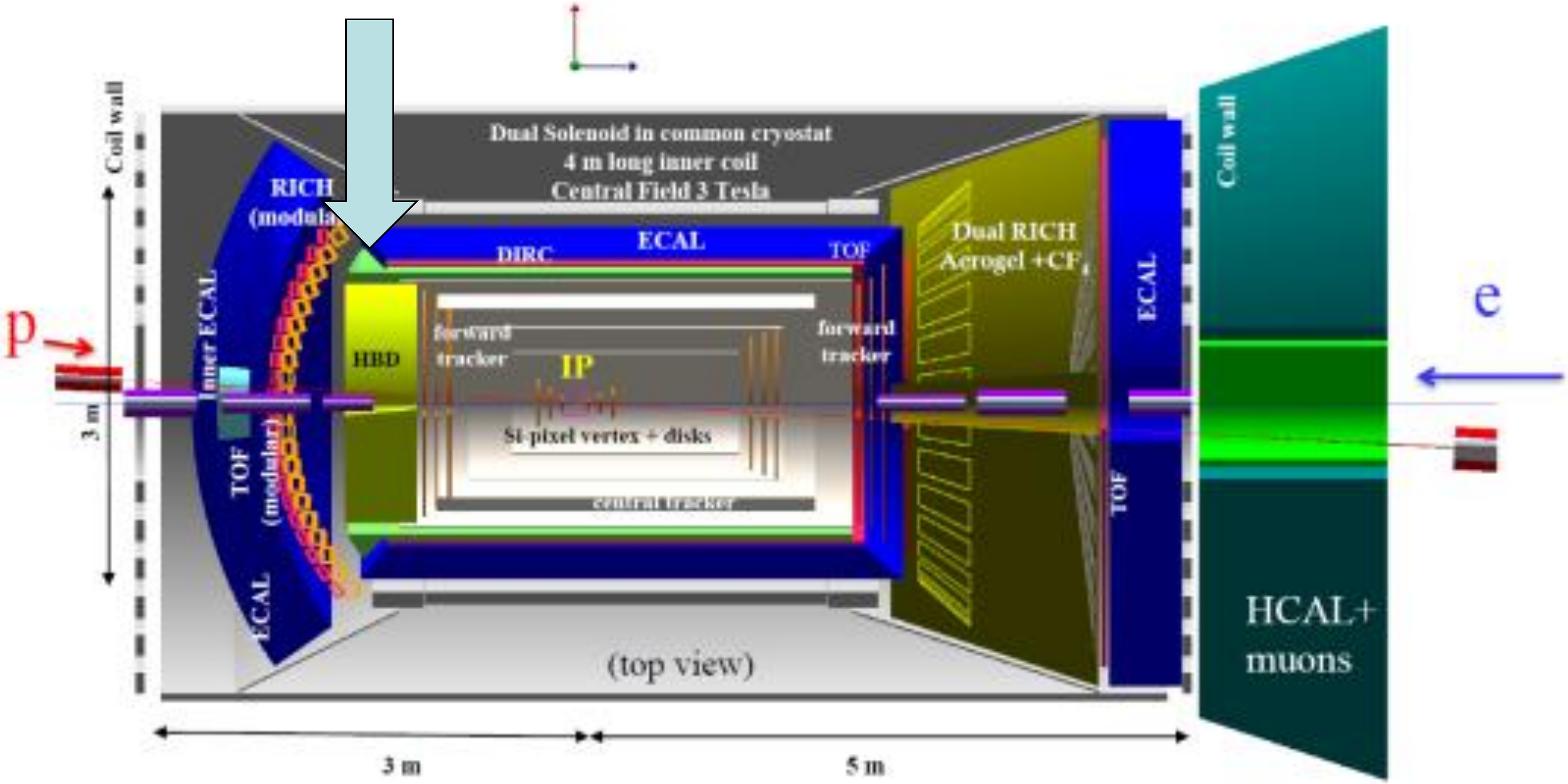
Particle Identification Detector (Dual Radiator RICH)

- π/K PID detector at ion endcap
- Aerogel with Fresnel lens ~75 cm focal length: image at focal point of mirror (also filter UV)
- CF_4 gas (visible + UV)
- 2nd mirror to place photo sensors in weaker field?



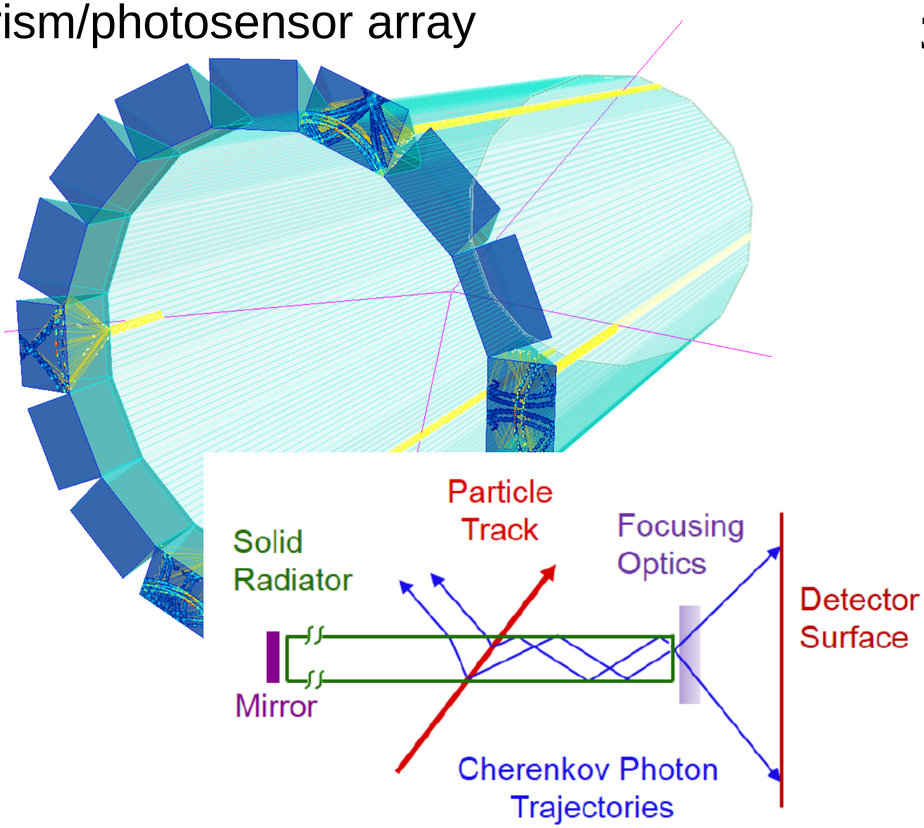
EIC R&D PID (RICH)

Particle Identification Detector (DIRC)

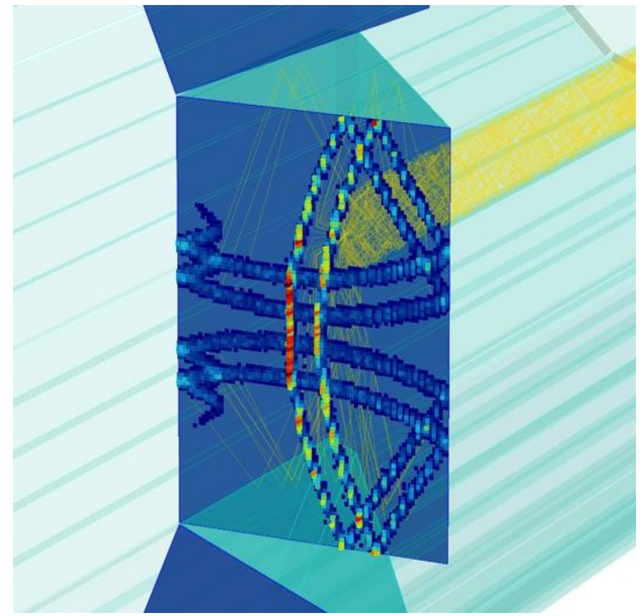


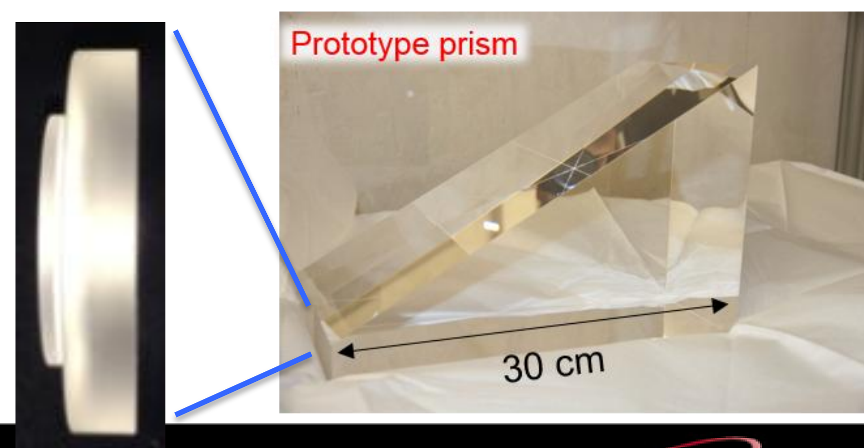
Particle Identification Detector (DIRC)

Narrow radiator bars grouped to common prism/photosensor array



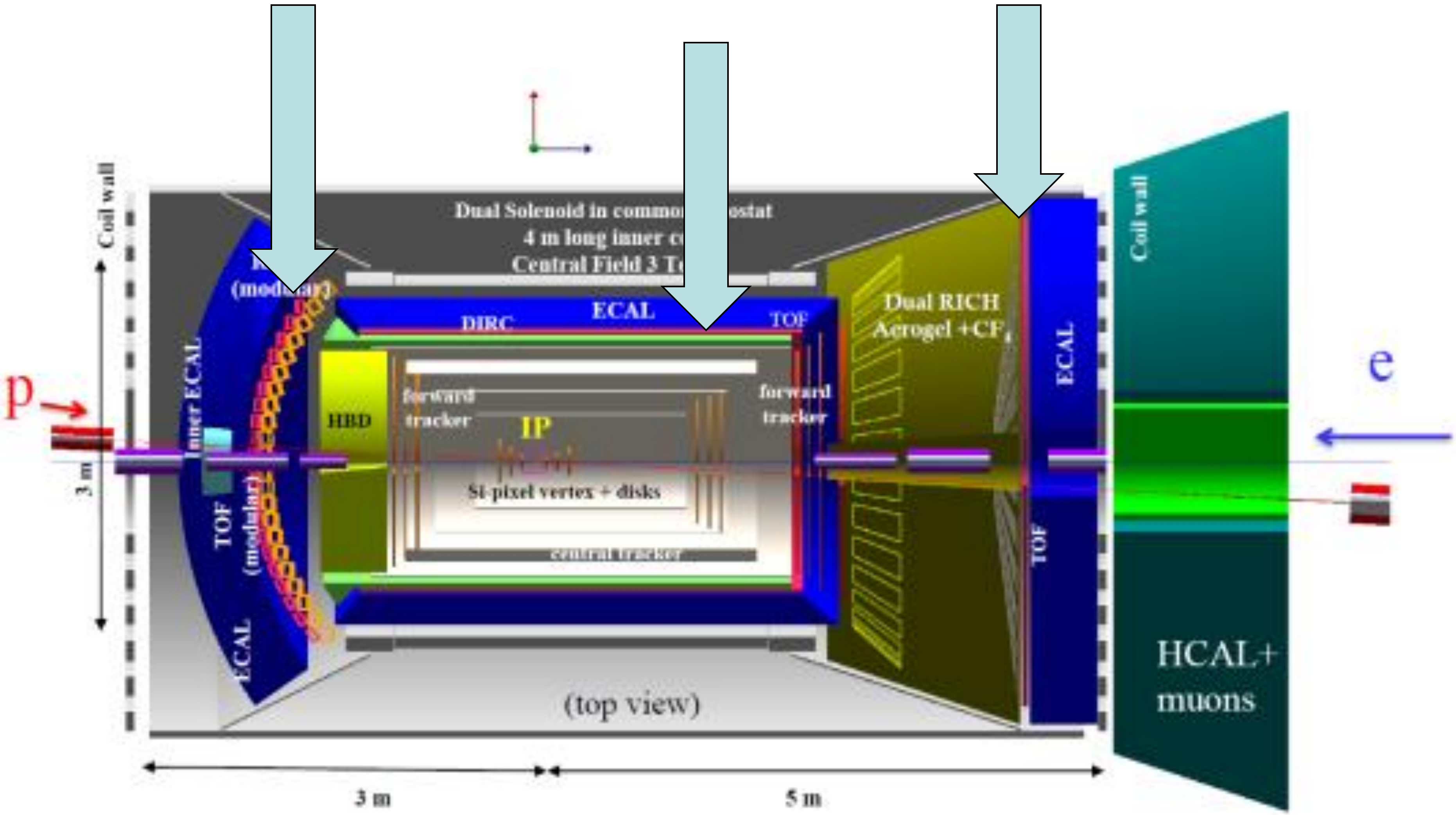
Close-up view of focal image with spherical 3-layer lens with no air gap



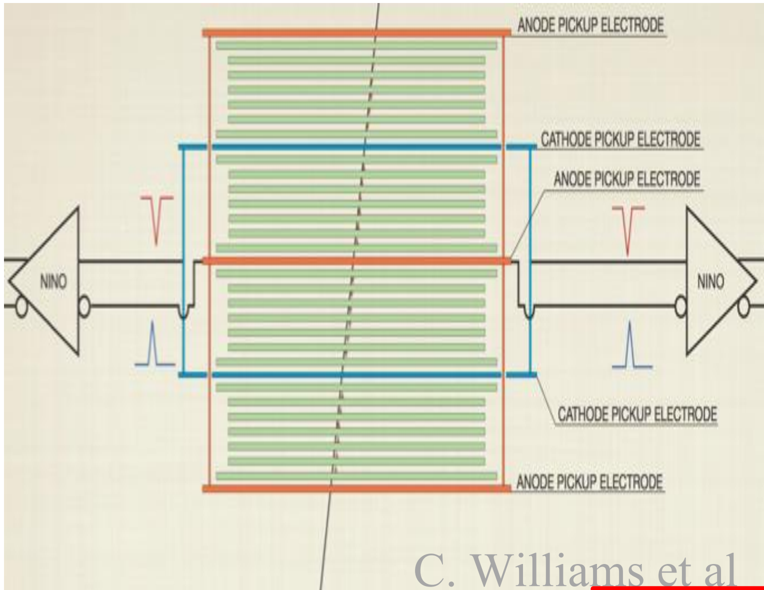


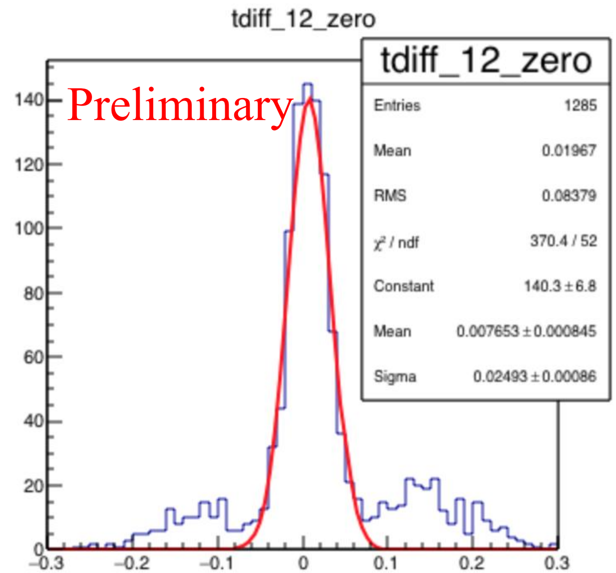
- Detection of internally reflected Cherenkov light (DIRC)
- Compact PID detector at barrel

Particle Identification Detector (Time of Flight)



Particle Identification Detector (Time of Flight)



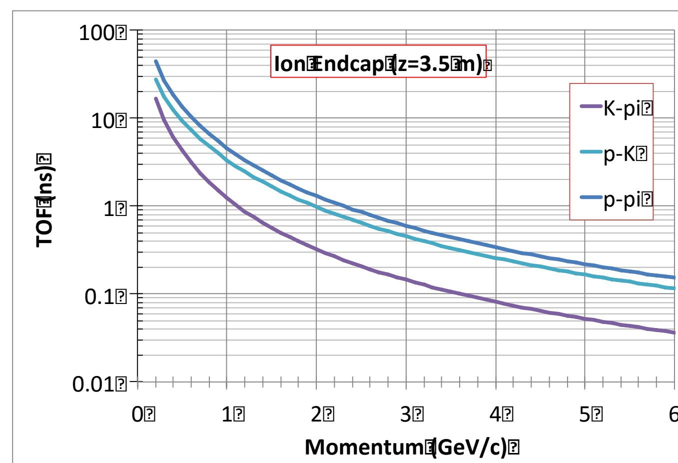


$\Delta t = t_2 - t_1$
$= 25$ ps

$\sigma_t = \Delta t/\sqrt{2}$
$= 18$ ps

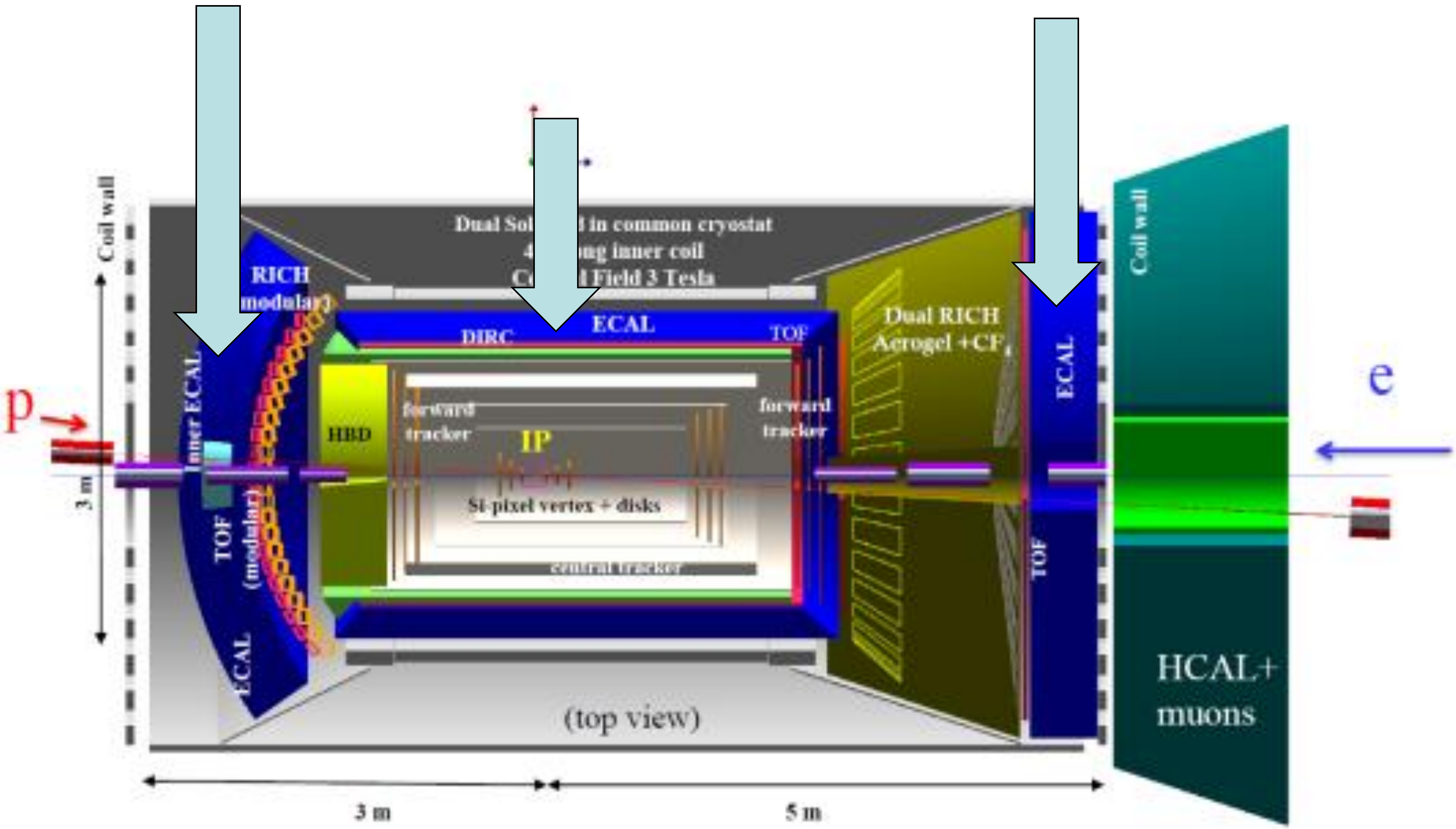
- Compact PID detector
- Flexible arrangement, can be modular, can be at both endcaps and barrel

EIC R&D PID (TOF)

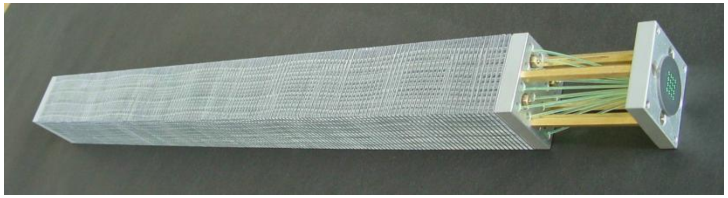


Jefferson Lab

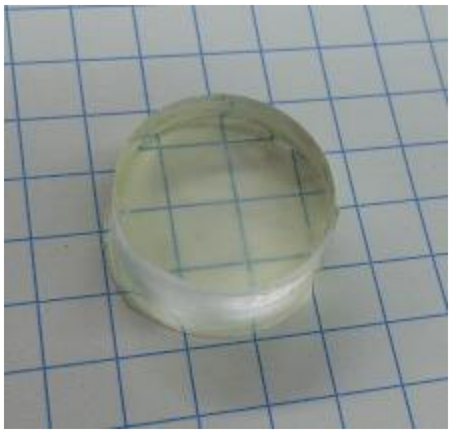
Particle Identification Detector (EMCal)



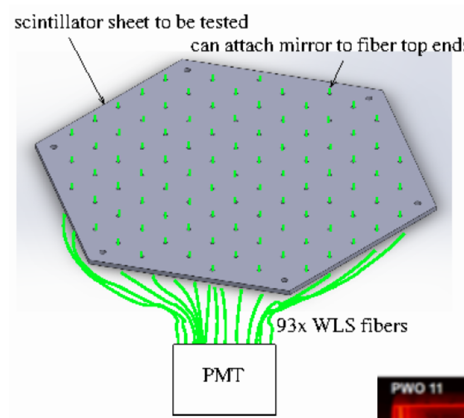
Particle Identification Detector (EMCal)



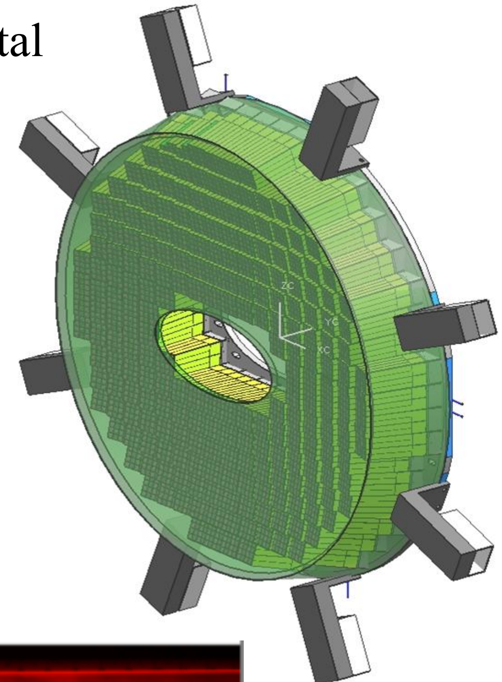
IHEP, COMPASS Shashlik, 2010

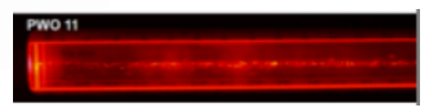


3D-printed scintillator at W&M

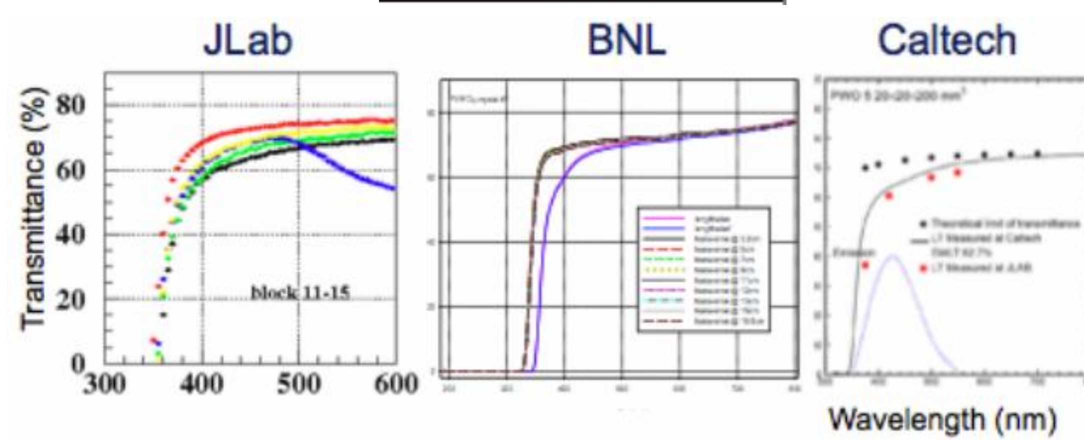


Panda Crystal endcap





- Shashlik type at large angle with balanced performance and cost
- Crystal type at small angle compensate for tracking resolution
- Pb/SciFi type at barrel

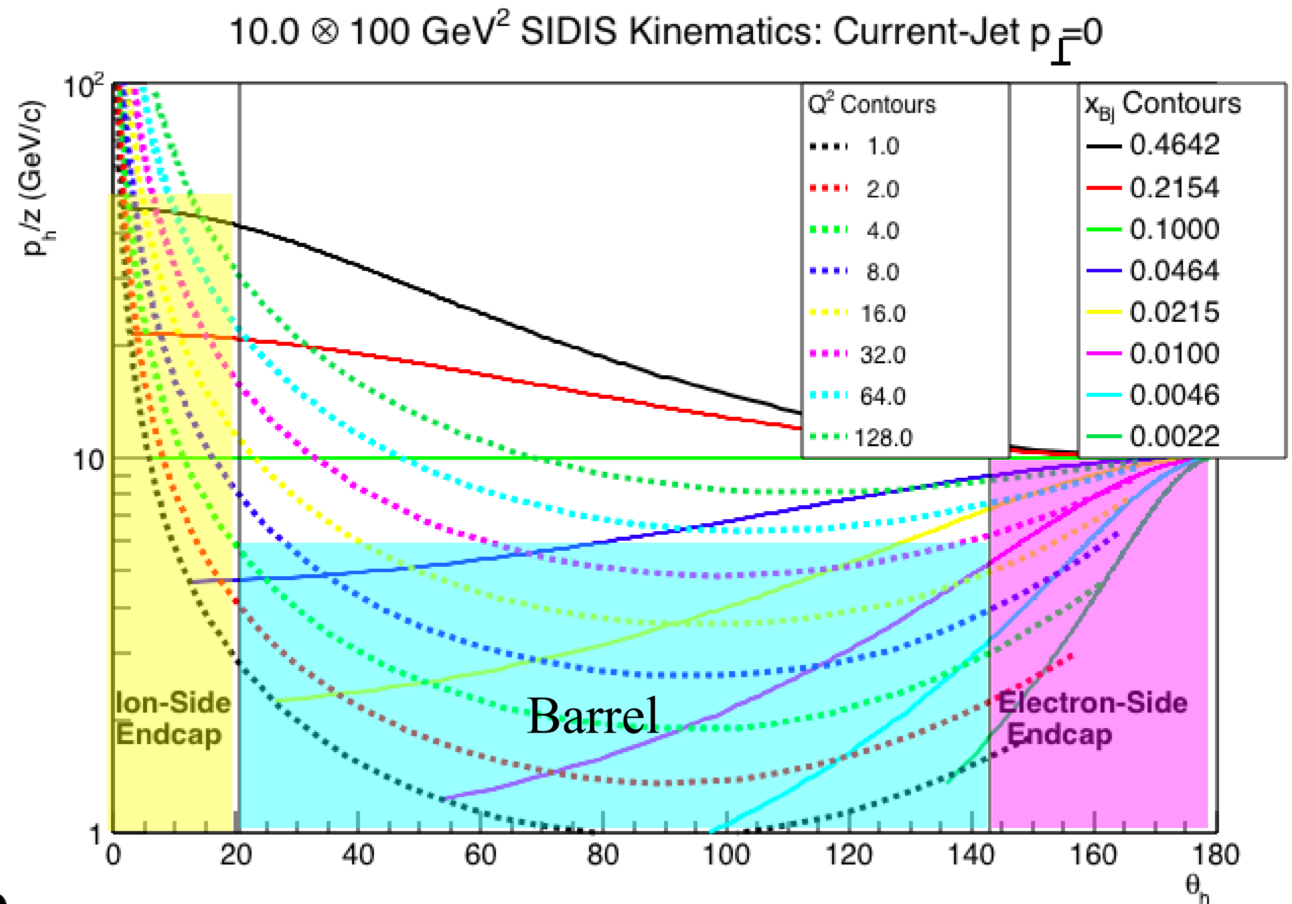


EIC R&D Calorimeter

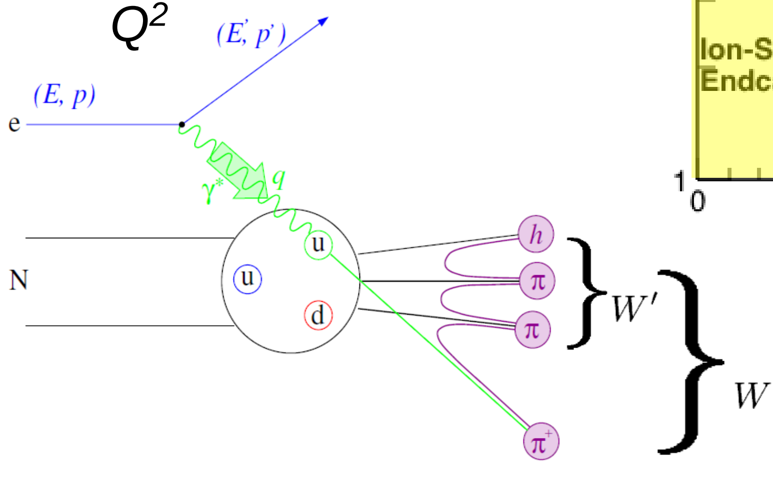
Jefferson Lab

SIDIS Kinematics

- Maximum hadron momentum *vs* hadron angle in contours of constant Q^2 or x_{Bj}
- Hadron momentum scales with *z*
- Projected π/K PID
- 2 decades exploration in x_B *and* Q^2



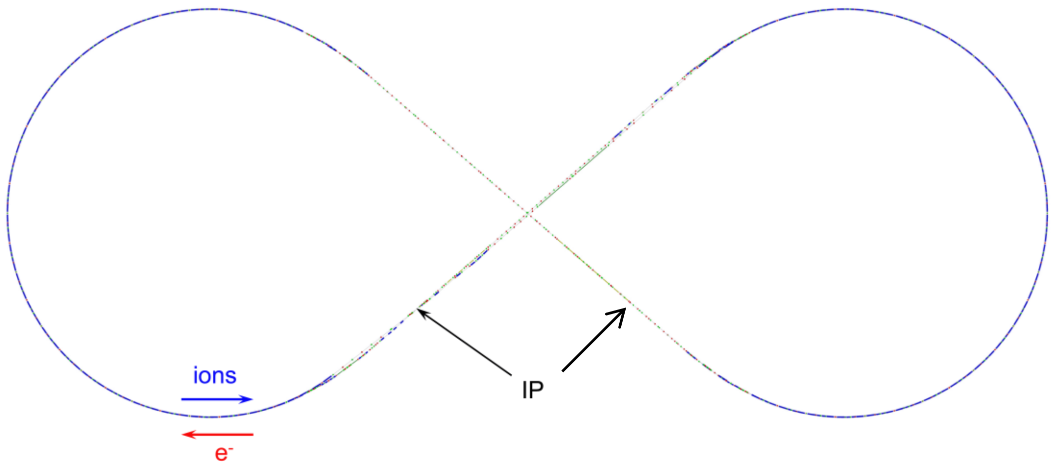
Charles Hyde @ ODU

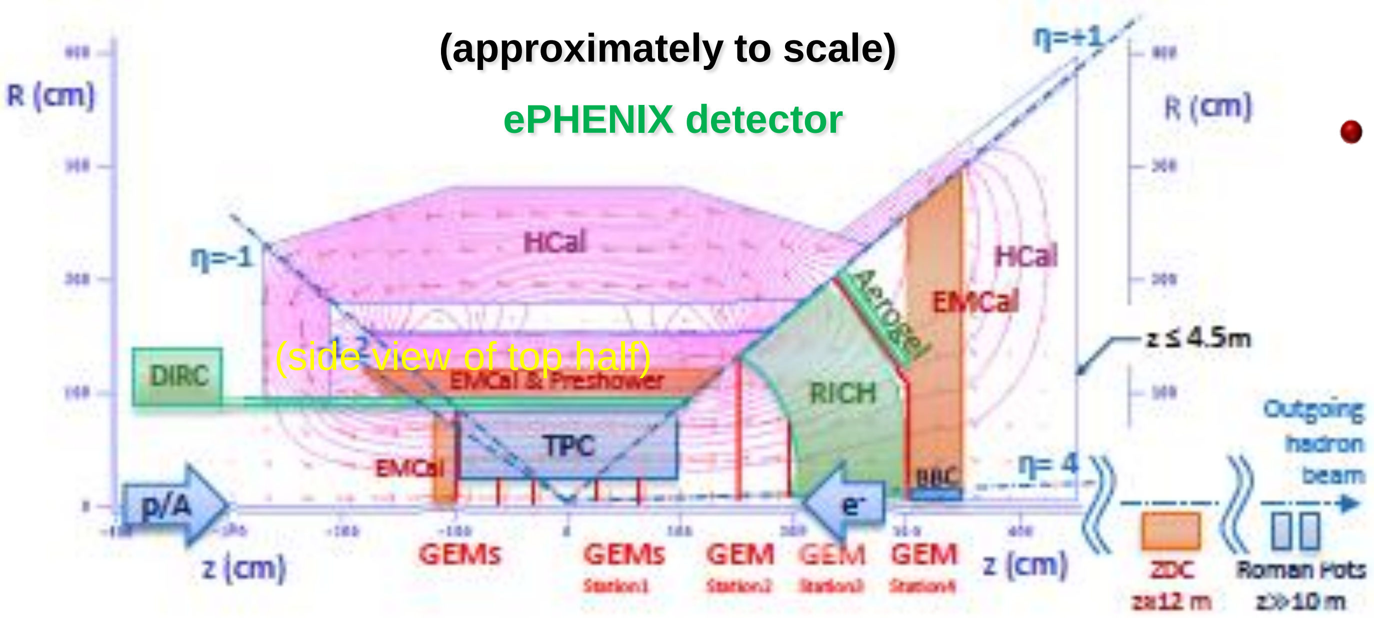


$z = E_\pi/\nu$

High Luminosity Central Detector

- MEIC IP1 (full-acceptance central detector)
  - Focus on exclusive processes and semi-inclusive DIS
  - Several solenoid options available





- MEIC IP2 (high luminosity central detector)
  - Focus on jet-physics
  - Possible to move ePHENIX to MEIC IP2?

Summary

- MEIC has fully-integrated detector and interaction region design
- IP1 central detector has full acceptance and high resolution
- IP2 will feature high luminosity central detector
- Detector technology has strong support from EIC R&D effort

Backup

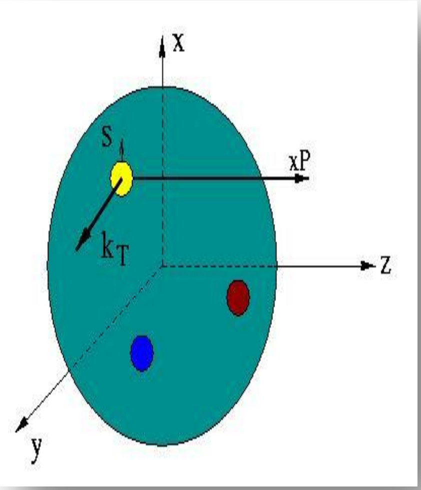
Unified View of Nucleon Structure

6D Dist.

$W_p^u(x,k_T,\boldsymbol{r})$ Wigner distributions

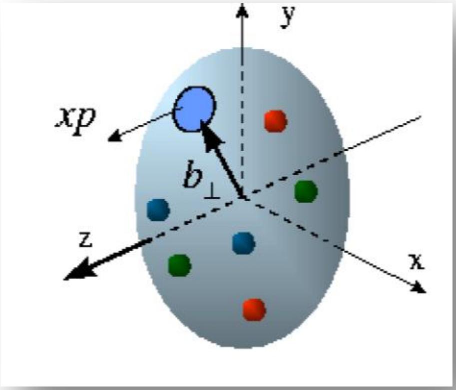
$d^3\boldsymbol{r}$

$d^2k_T\, dr_z$



TMD PDFs $f_1^u(x,k_T)$, .. $h_1^u(x,k_T)$

GPDs/IPDs

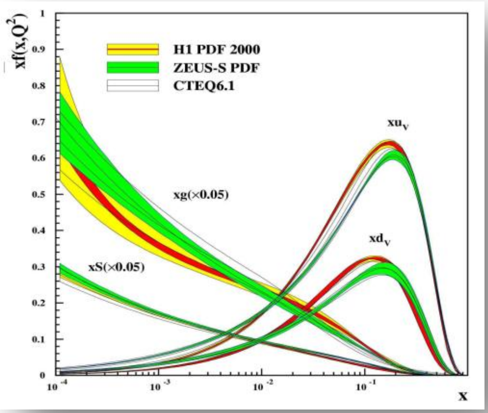


3D imaging

d^2k_T

d^2r_T

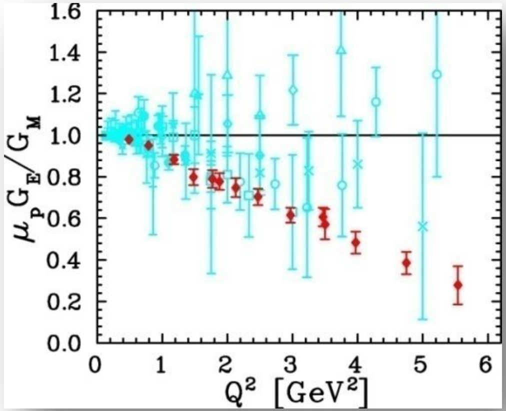
dx &
Fourier Transformation



PDFs
$f_1^u(x)$, .. $h_1^u(x)$

1D

Form Factors
$G_E(Q^2)$,
$G_M(Q^2)$



Leading-Twist TMD PDFs

		Quark polarization		
		Unpolarized (U)	Longitudinally Polarized (L)	Transversely Polarized (T)
Nucleon Polarization	U	$f_1 =$		$h_1^{\perp} =$ − Boer-Mulders
	L		$g_1 =$ − Helicity	$h_{1L}^{\perp} =$ − Worm Gear
	T	$f_{1T}^{\perp} =$ − Sivers	$g_{1T} =$ − Worm Gear	$h_1 =$ − Collins/Transversity $h_{1T}^{\perp} =$ − Pretzelosity

Nucleon Spin *Quark Spin*