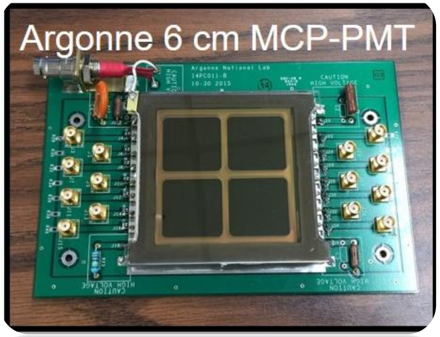
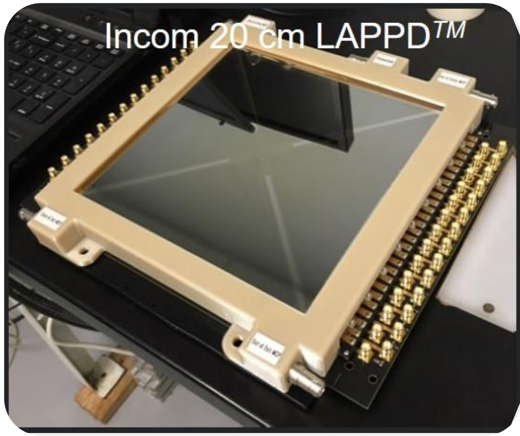
APPLICATION OF MCP-PMT/LAPPD FOR EIC PARTICLE IDENTIFICATION





Large Area Picosecond PhotoDetector (LAPPD^{TM})

JUNQI XIE

Medium Energy Physics
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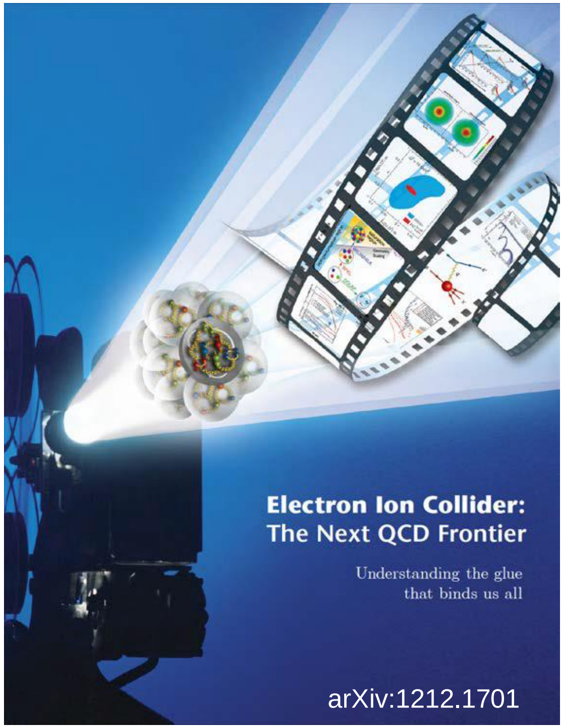
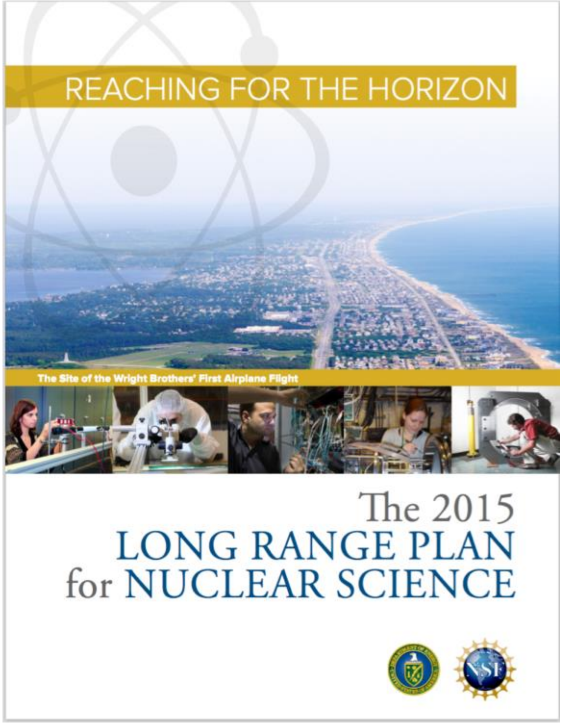
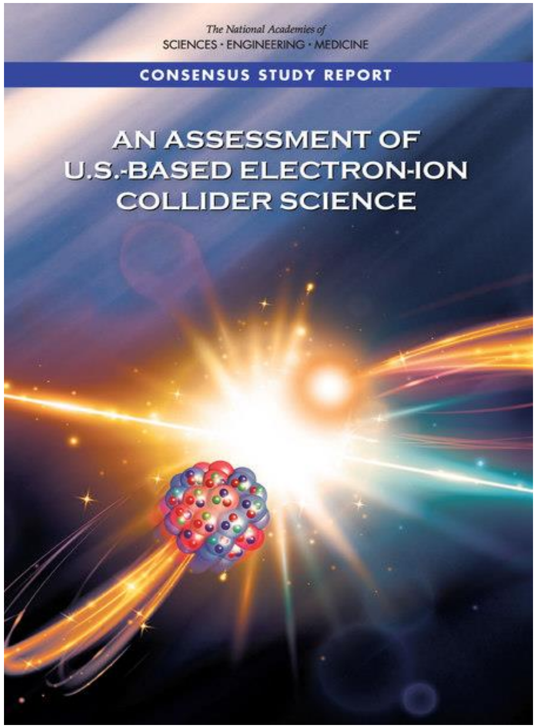
THE ELECTRON ION COLLIDER







EIC white paper, ***Developed by US QCD community over two decades.***

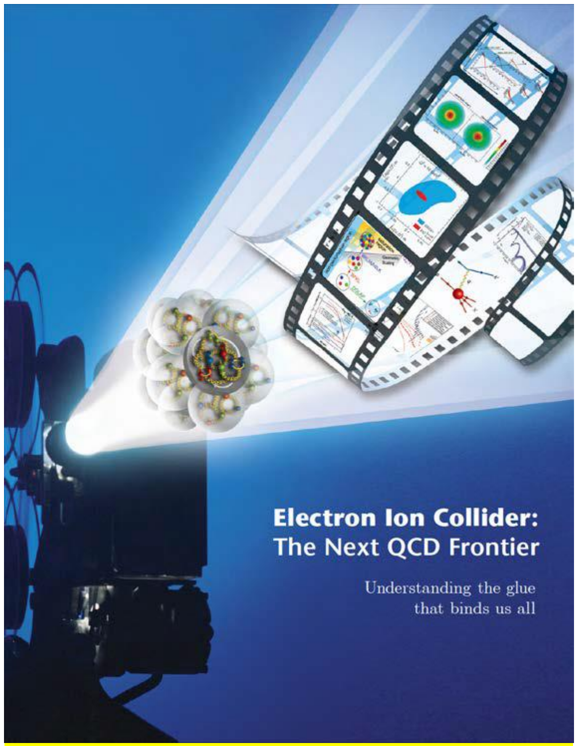
Recommendation III

We recommend a high-energy, high-luminosity polarized Electron Ion Collider as the highest priority for new facility construction following the completion of FRIB.

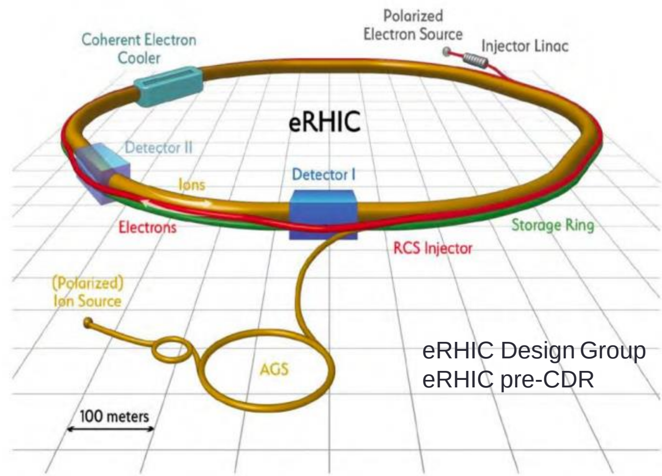
The committee ***unanimously*** finds that the science that can be addressed by an EIC is ***compelling, fundamental, and timely.***

THE ELECTRON ION COLLIDER

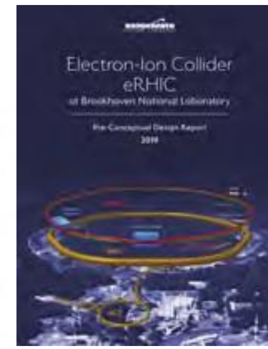
World's first Polarized electron-proton/light ion and electron-Nucleus collider

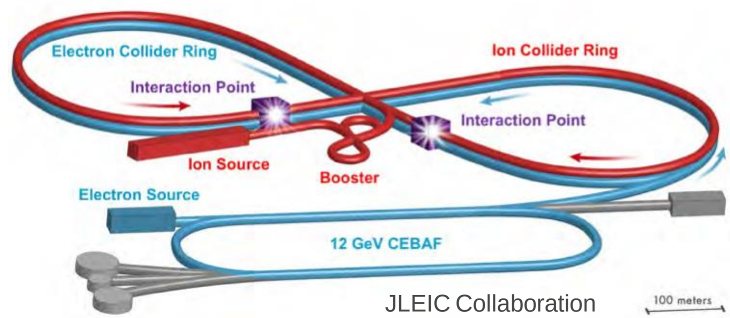


1212.1701.v3
A. Accardi et al
Eur. Phy. J. A, 52 9(2016)



eRHIC Design Group
eRHIC pre-CDR





JLEIC Collaboration
JLEIC Pre-CDR

Both designs use DOE's significant investments in infrastructure, with potentially two interaction points.

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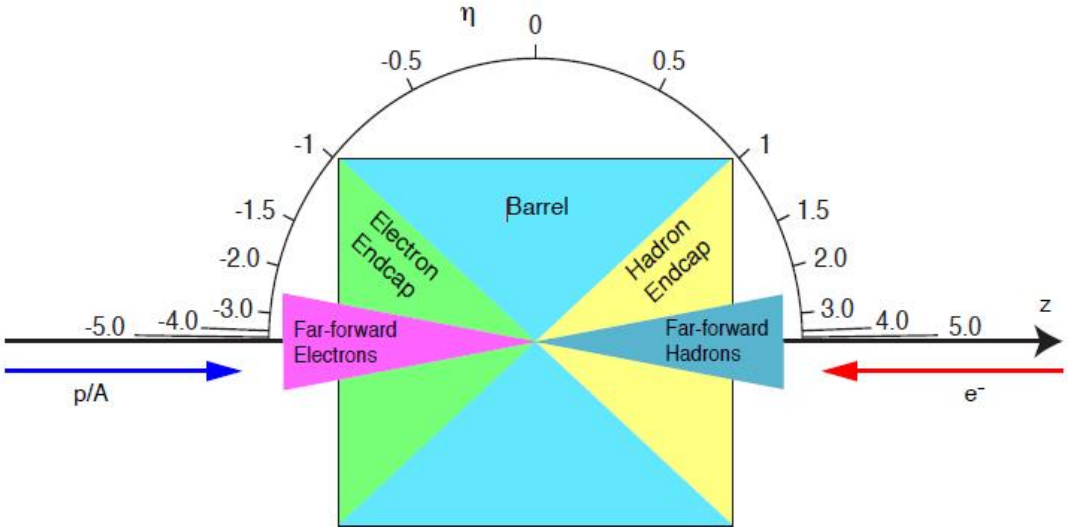
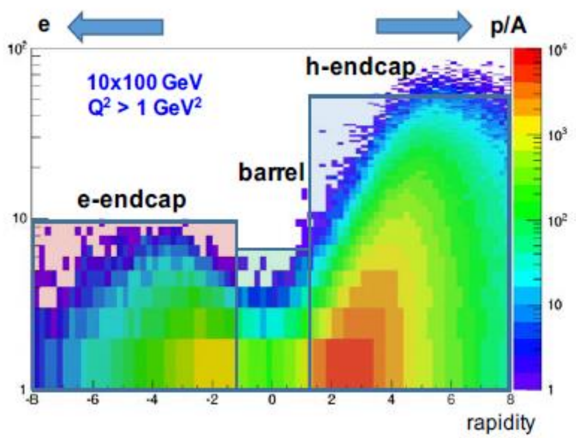
EIC DETECTOR REQUIREMENT

Requirement are mostly site-independent with some slight differences in the forward region (IR integration)

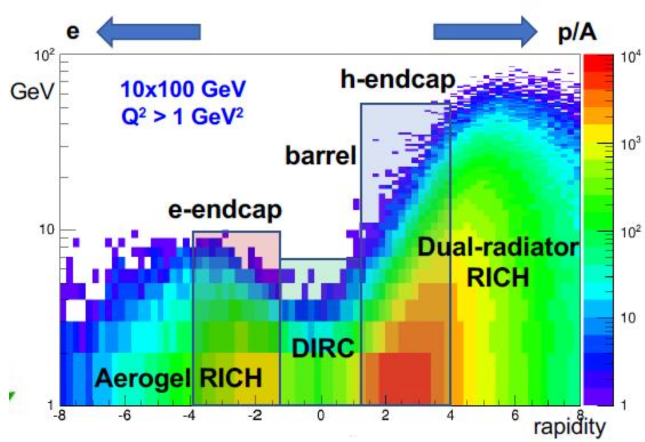
In Short:

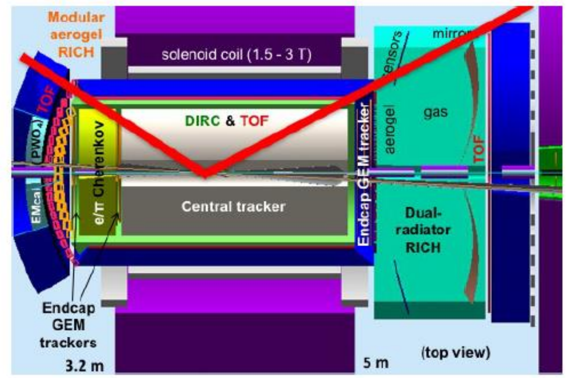
- Hermetic detector, low mass inner tracking, **good PID** (e and π/K/p separation) in wide range, calorimetry
- Moderate radiation hardness requirements, low pile-up, low multiplicity





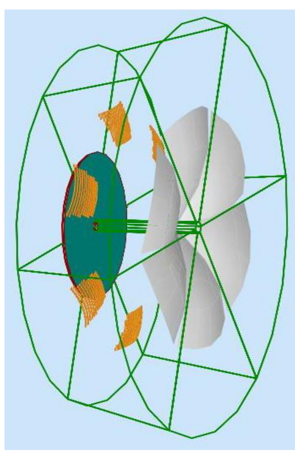
EIC-PID BASED ON CHERENKOV DETECTION



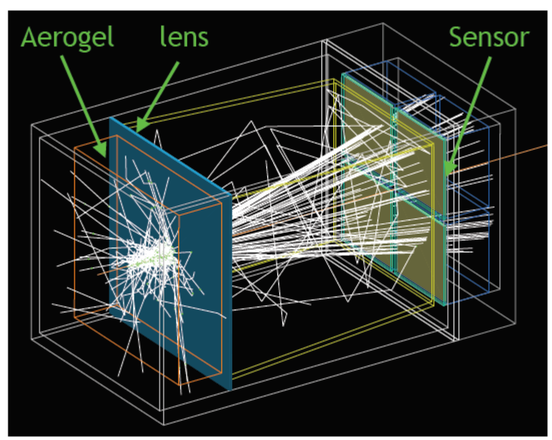


EIC-PID: Imaging Cherenkov detectors are the primary technology

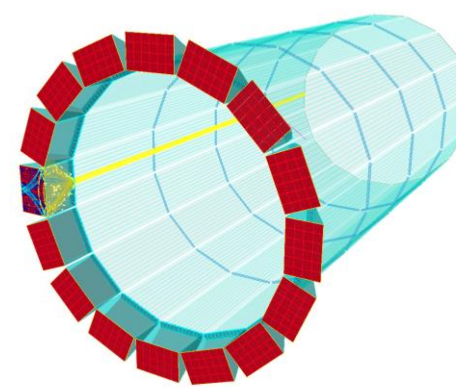
- **h-endcap**: A RICH with two radiators (gas + aerogel): π/K *separation up to ~50 GeV/c*
- **e-endcap**: A compact aerogel RICH: π/K *separation up to ~10 GeV/c*
- **barrel**: A high-performance DIRC: π/K *separation up to ~6-7 GeV/c*



dRICH



mRICH



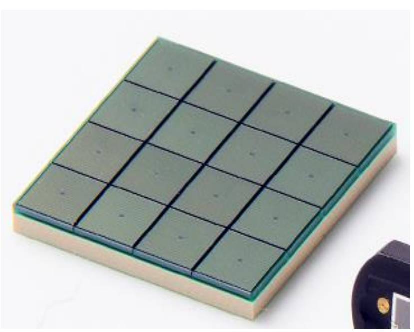
HP-DIRC

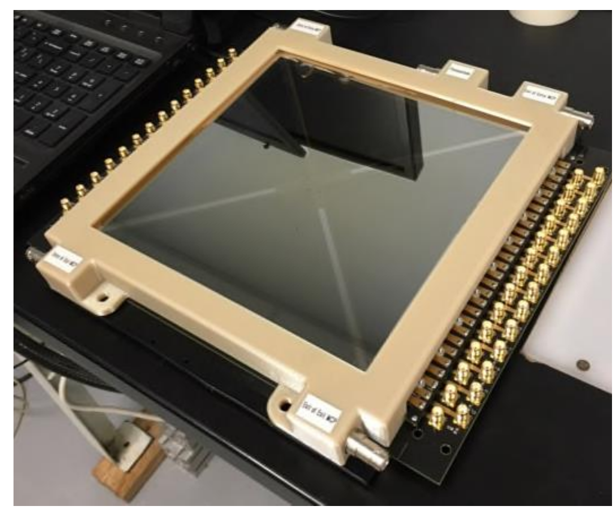
EIC-PID PHOTOSENSORS

Low-cost, reliable highly-pixelated (3x3 mm^2, minimal cross talk) photodetector with **high magnetic field tolerance** (>1.5 Tesla), **long lifetime, high rate capability** (≥200 kHz/cm^2), and **radiation hardness** (10 Mrad with 10^{15} n/cm^2) is needed for **Cherenkov detectors** for **EIC Particle Identification**.

SiPM: radiation harness is the major concern, also system cooling design and cost.
Photonis pixelated **Planacon** meets all requirements and available. Cons: Very expensive.

Low-cost **LAPPD** with performance reaching the requirement could be an alternative of Planacon.

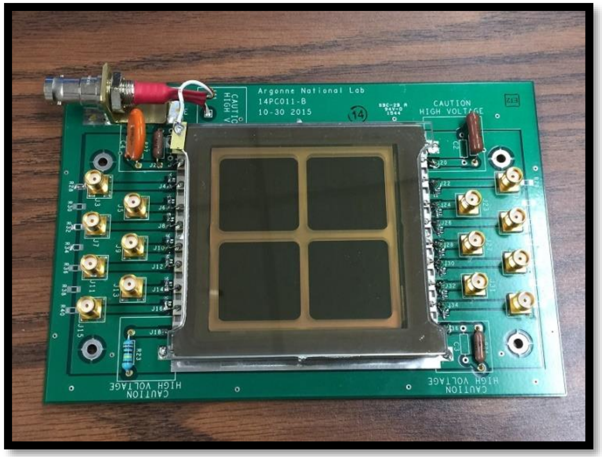




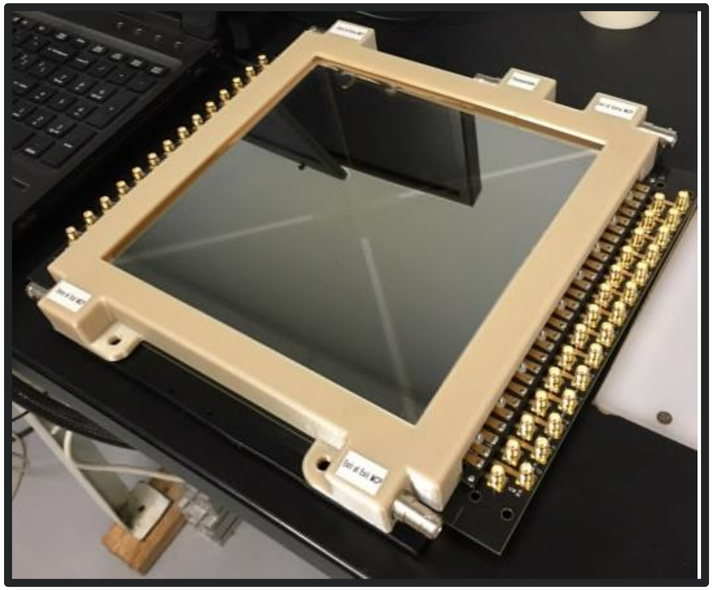
ARGONNE 6 CM MCP-PMT & LAPPD^{TM}

Small form factor LAPPD (6 cm MCP-PMT) was produced at Argonne for R&D. Knowledges, Design and Experiences were transferred to Incom to support commercialization of 20 cm LAPPD^{TM}

R&D test bed: 6x6 cm^2



Commercialization: 20x20 cm^2

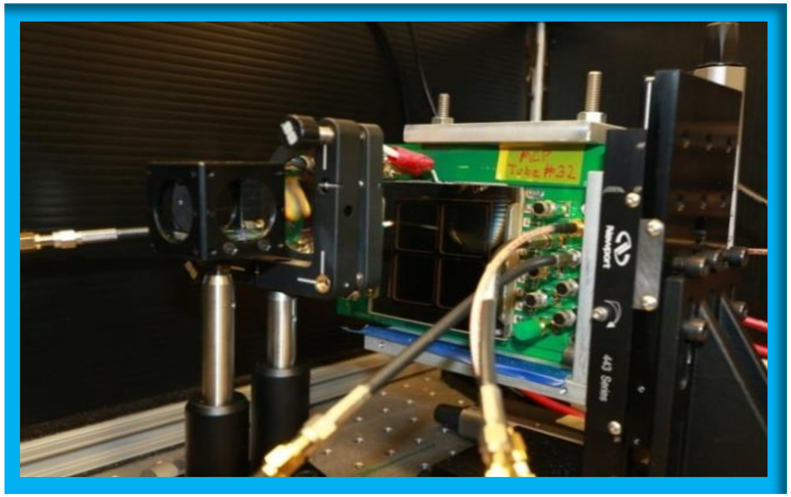


- The Argonne 6 cm MCP-PMT and Incom 20 cm LAPPD^{TM} share the same MCPs and similar internal configuration and signal readout.
- The Argonne 6 cm MCP-PMT serves as R&D test bed for performance characterization and design optimization; Incom 20 cm LAPPD^{TM} is the final commercialized product.
- Close collaboration and communication (bi-weekly meeting, joint SBIR program), optimized configurations are directly transferred to Incom production line for mass production.

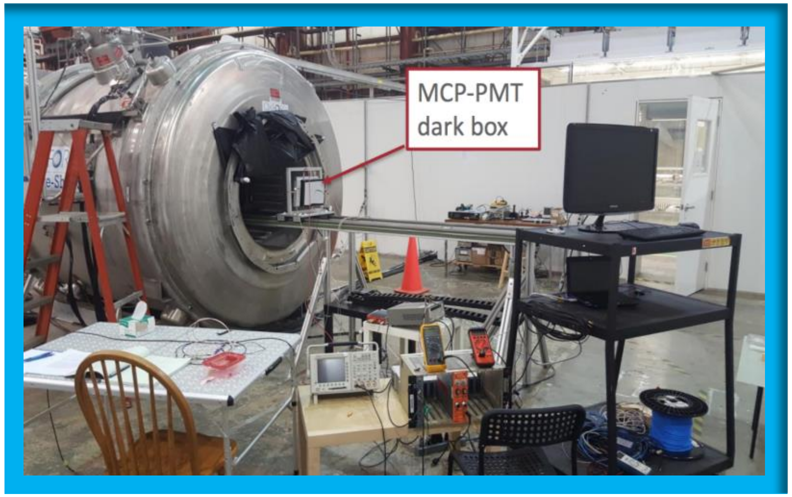
ARGONNE TEST CAPABILITIES

Optical Table for photocathode test

ps-Laser Facility for timing characterization



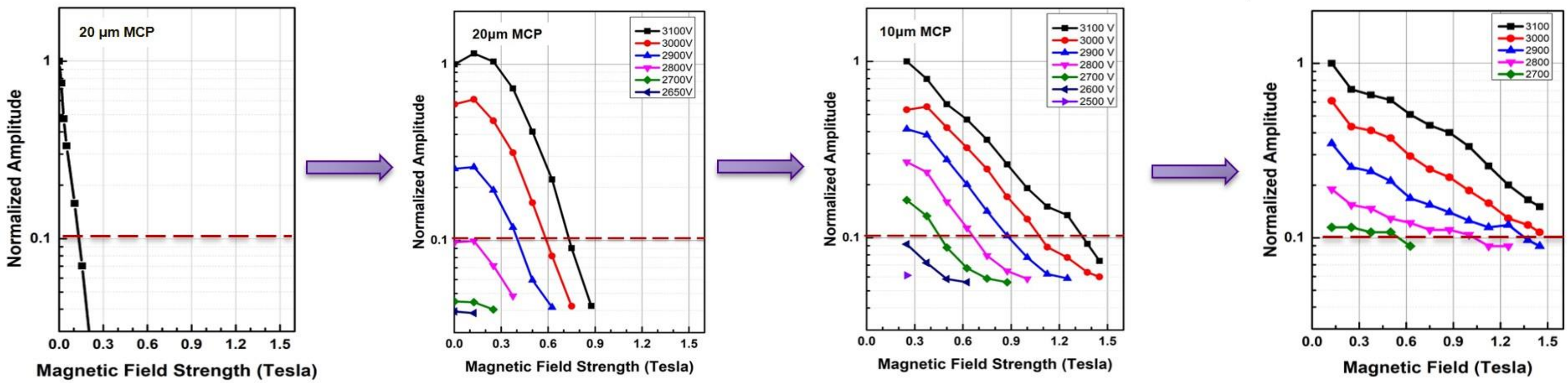
ANL g-2 Magnetic Field Test Facility



JLab/Fermilab Test Beam Facilities

IMPROVEMENT OF ARGONNE MCP-PMT PERFORMANCE IN MAGNETIC FIELD

ANL version 1 Internal resistor chain	ANL version 2 IBD design 20 µm MCP	ANL version 3 IBD design 10 µm MCP	ANL version 4 IBD design 10 µm MCP reduced spacing



0 < B < 0.15 T	0 < B < 0.7 T	0 < B < 1.3 T	0 < B < at least 1.5 T

Babar or CLEO Magnet: 1.5T

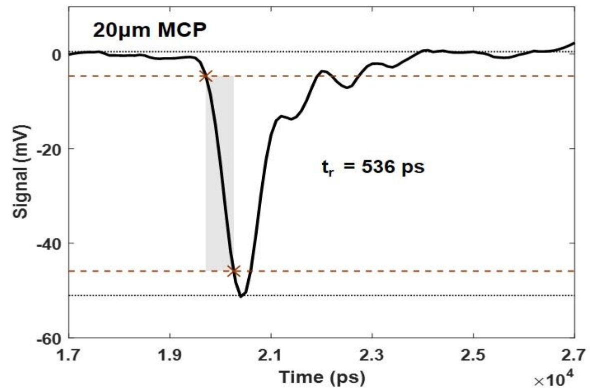
- Optimization of biased voltages for both MCPs: **version 1 -> 2**
- Smaller pore size MCPs: **version 2 -> 3**
- Reduced spacing: **version 3 -> 4**
- Further improvement if needed:

Smaller pore size is planned: 6 µm, version 4 -> 5 (future)

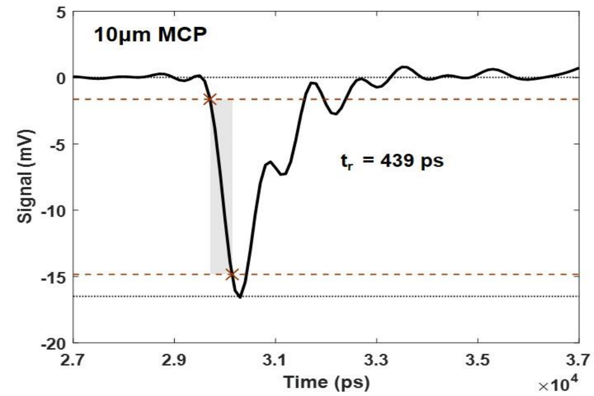
MCP-PMT TIMING RESOLUTION IMPROVEMENT

Rise time

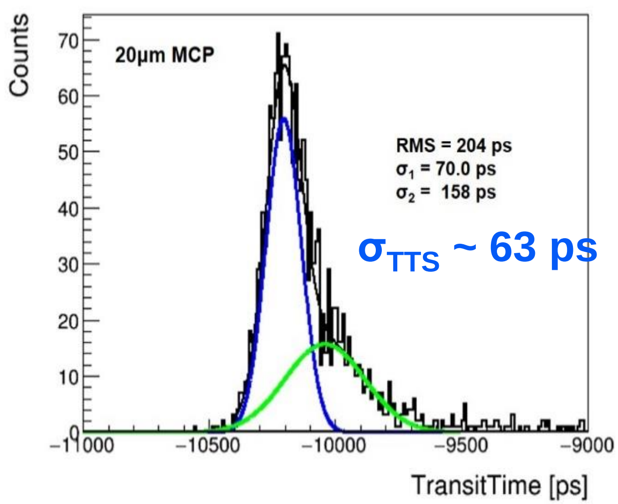
ANL version 2

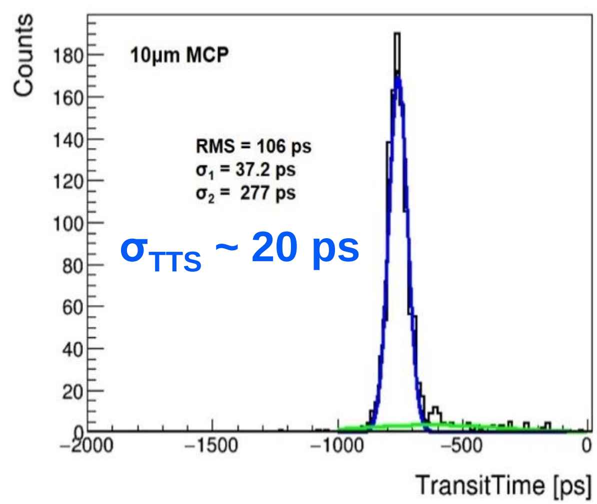


ANL version 3



Timing resolution (SPE)





$$\sigma_{MCP-PMT} = \sqrt{\sigma_1^2 - \sigma_{Laser}^2 - \sigma_{Ele.}^2}$$

System: σ_1 = 37.2 ps
Laser jitter: σ_{Laser} = 30 ps
Electronics: $\sigma_{Ele.}$ = 7 ps
10 µm MCP-PMT: ***σ ~ 20 ps***

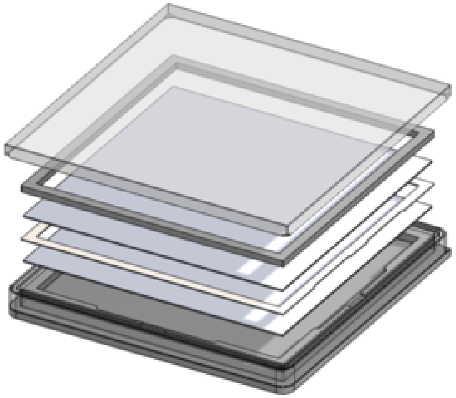
Suppressed back scattering signal

The ~100 ps RMS timing precision is practically important to enable 3σ π/K separation for the full phase space with designed EIC HPDIRC.

INTEGRATION OF THE PERFORMANCE IMPROVEMENT INTO INCOM DEVICE

Development of New 10 cm × 10 cm High Rate Picosecond Photodetector (HRPPD)

Feature	Large Area Picosecond Photodetector (LAPPD™)	High Rate Picosecond Photodetector (HRPPD)
Application	Picosecond Time of Flight	PET, TOF, UV Imaging
Detector Size	20 cm × 20 cm	10 cm × 10 cm
UHV Package Design	X-Spacers window support -> creates dead zones	X-Spacer free -> large effective area
Window	Fused Silica, B33 Glass	UV Fused Silica, MgF_2
λ Sensitivity	200 (300 for B33) - 600 nm	115 - 400 nm
Photocathode	Bialkali	UV optimized Bialkali
MCP Pore Size	20 µm & 10 µm	10 µm
MCP Stack	B-Field Optimized	B-Field Optimized
Anode	Direct readout of thick film strips or capacitive readout with application specific patterned anode	High density pixelated anode with direct or capacitive readout
Lower Tile Assembly	Side walls hermetically sealed to anode	Side walls hermetically sealed to anode
Connections	Through Frit Seal -> 2 side abuttable	Through anode -> 4 side abuttable with minimum dead space



Work with Incom on timely delivery of HRPPD applicable for EIC-PID.

Incom Inc. LAPPD, CPAD19, December 8 - 10, 2019, Madison, WI

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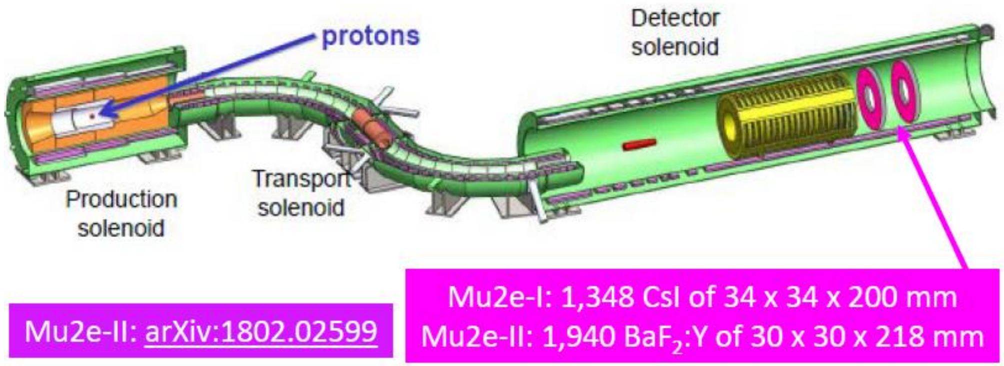
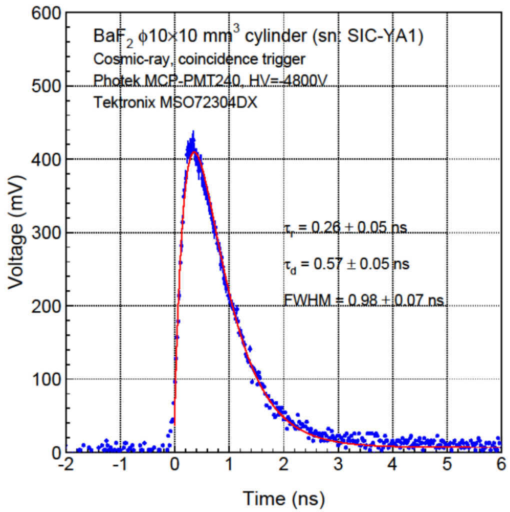
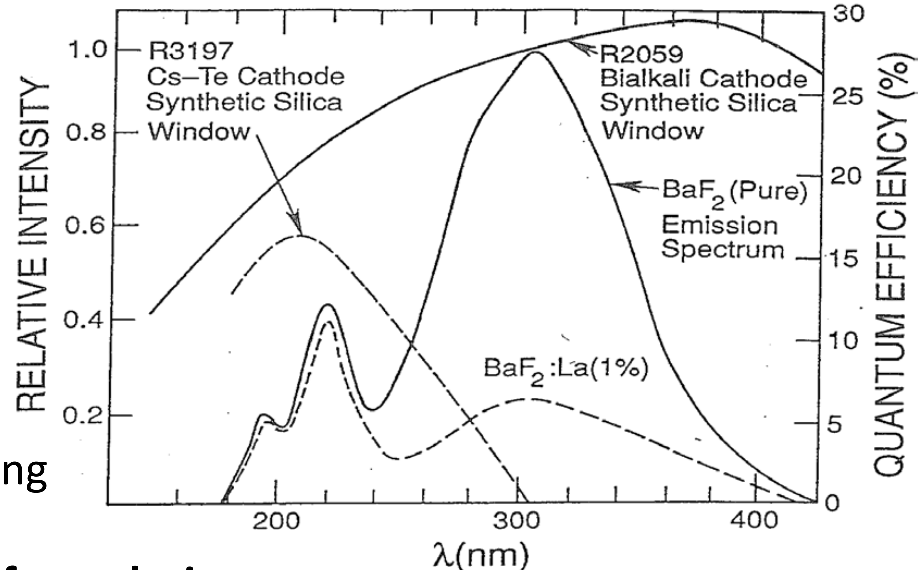
SOLAR BLIND MCP-PMT/LAPPD FOR FAST CALORIMETER







- BaF_2:Y fast component shows 260 ps rise time, 600 ps decay time, MCP-PMT is the only PMT for such fast light detection.
- Slow component of BaF_2 scintillation light was significantly suppressed by BaF_2:Y doping
- **Solar blind photocathode (Cs-Te) further suppresses the slow component, enabling fast calorimeter.**

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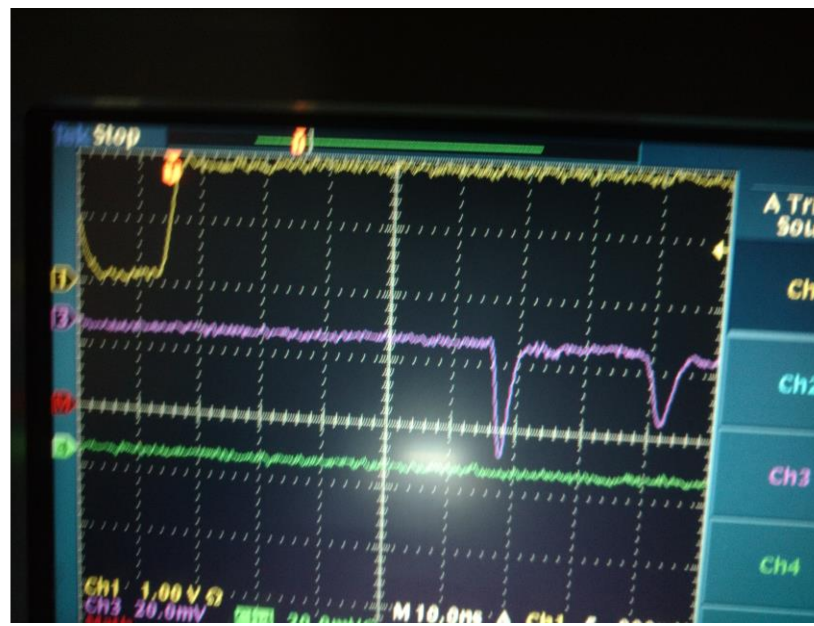
CRYOGENIC WORKABLE MCP-PMT/LAPPD



- **An MCP-PMT with low resistances ~300 kOhms, not functional at room temperature.**
- **Clear signal was observed at liquid N2 condition with increase of the resistance.**

- **MCP-PMT is workable at cryogenic temperature.**

SUMMARY

The U.S. based high-energy high luminosity polarized Electron Ion Collider (EIC) is quickly moving towards DOE "Mission Need" statement.

The EIC physics program demands excellent tracking resolution and particle identification (PID) coverage over a wide range of momenta to achieve the highest precision.

Imaging Cherenkov techniques (dRICH, mRICH and HPDIRC) were considered for proposed EIC detector concepts for momentum coverage up to 50 GeV/c.

An important challenge for EIC-PID is to provide a reliable highly pixelated photosensor working in high radiation and high magnetic field environment.

Magnetic field immunity, timing resolution approached EIC-PID requirement and integrated into Incom process for device fabrication.

Solar blind and cryogenic workable MCP-PMTs are possible with R&Ds.

ACKNOWLEDGMENTS

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And many others …

The LAPPD collaboration, The EIC PID consortium

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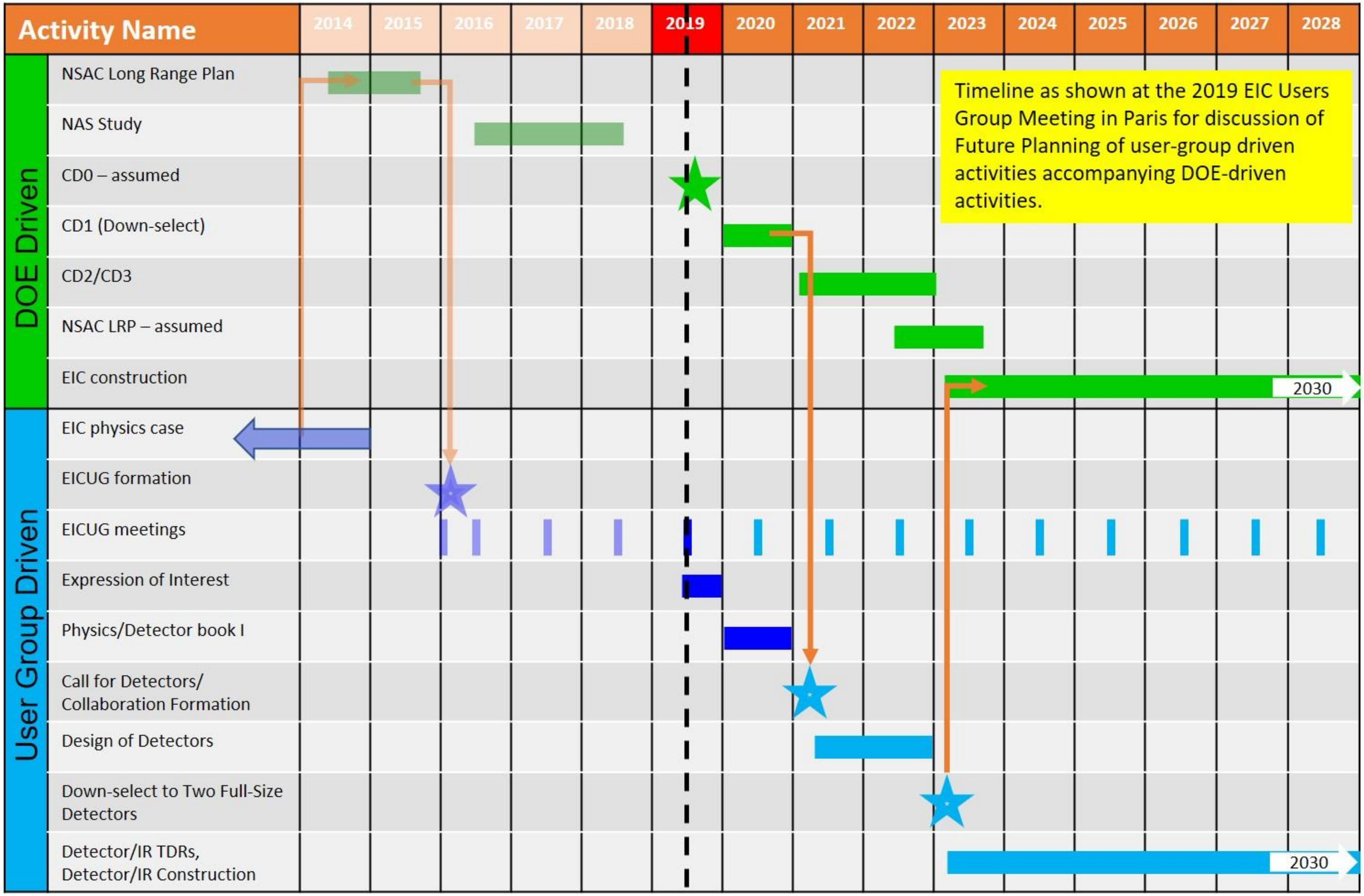
Thank you for your attention!

Questions?

THE ELECTRON ION COLLIDER TIMELINE



CD0 = DOE “Mission Need” statement; **CD1** = design choice and site selection
CD2/CD3 = establish project baseline cost and schedule