eRD14 – EIC PID consortium

- An integrated program for particle identification (PID) for a future Electron-Ion Collider (EIC) detector.

M. Alfred, L. Allison, M. Awadi, B. Azmoun, F. Barbosa, M. Boer, W. Brooks, T. Cao, M. Chiu, E. Cisbani, M.Contalbrigo, S. Danagoulian, A. Datta, A. Del Dotto, M. Demarteau, A. Denisov, J.M. Durham, A. Durum, R. Dzhygadlo, D. Fields, Y. Furletova, C. Gleason, M. Grosse-Perdekamp, J. Harris, X. He, H. van Hecke, T. Horn, J. Huang, C. Hyde, Y. Ilieva, G. Kalicy, A. Kebede, B. Kim, E. Kistenev, Y. Kulinich, M. Liu, R. Majka, J. McKisson, R. Mendez, I. Mostafanezhad, P. Nadel-Turonski, K. Park, K. Peters, R. Pisani, T. Rao, W. Roh, P. Rossi, M. Sarsour, C. Schwarz, J. Schwiening, C.L. da Silva, N. Smirnov, J. Stevens, A. Sukhanov, X. Sun, S. Syed, J. Toh, R. Towell, T. Tsang, G. Varner, R. Wagner, C. Woody, C.P. Wong, W. Xi, J. Xie, Z.W. Zhao, B. Zihlmann, C. Zorn.

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Generic Detector R&D for an Electron Ion Collider

Advisory Committee Meeting, BNL, January 18-19, 2018

Participating institutions

- Abilene Christian University (ACU)
- Argonne National Lab (ANL)
- Brookhaven National Lab (BNL)
- Catholic University of America (CUA)
- City College of New York CCNY)
- College of William & Mary (W&M)
- Duke University (Duke)
- Georgia State University (GSU)
- GSI Helmholtzzentrum für Schwerionenforschung, Germany (GSI)
- Howard University (HU)
- Institute for High Energy Physics, Protvino, Russia
- Istituto Nazionale di Fisica Nucleare, Sezione di Ferrara, Italy (INFN-Ferrara)
- Istituto Nazionale di Fisica Nucleare, Sezione di Roma, Italy (INFN-Rome)
- Istituto Superiore di Sanità, Italy (ISS)
- Jefferson Lab (JLab)
- Los Alamos National Lab (LANL)
- North Carolina A&T State University (NCAT)
- Old Dominion University (ODU)
- Stony Brook University (SBU)
- Universidad Técnica Federico Santa María, Chile (UTFSM)
- University of Hawaii (UH)
- University of Illinois Urbana-Champaign (UIUC)
- University of New Mexico (UNM)
- University of South Carolina (USC)
- Yale University (Yale)

PID – an essential part of the EIC physics program

- The physics program for a generic EIC is outlined in the 2015 NSAC LRP, the 2012 White Paper, the 2010 INT report, etc.
- Excellent PID is crucial for achieving these physics goals!

eRD14: an integrated program for PID at an EIC

1. A suite of detector systems covering the full angular- and momentum range required for an EIC detector

- Different technologies in different parts of the detector
- Focus on hadron ID with a supplementary electron ID capability

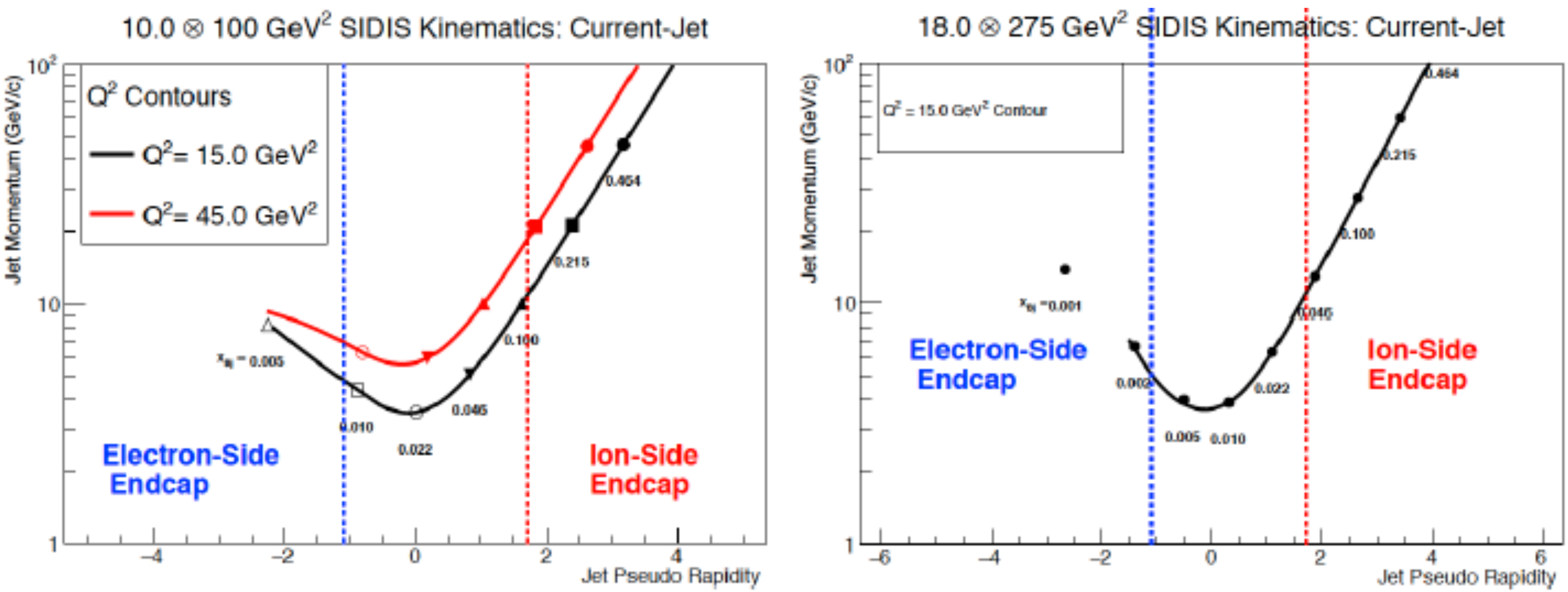
2. A cost-effective sensor and electronics solution

- Requirements and development of photosensors
- Development of readout electronics needed for prototyping

3. Maximized synergies and minimized cost of R&D

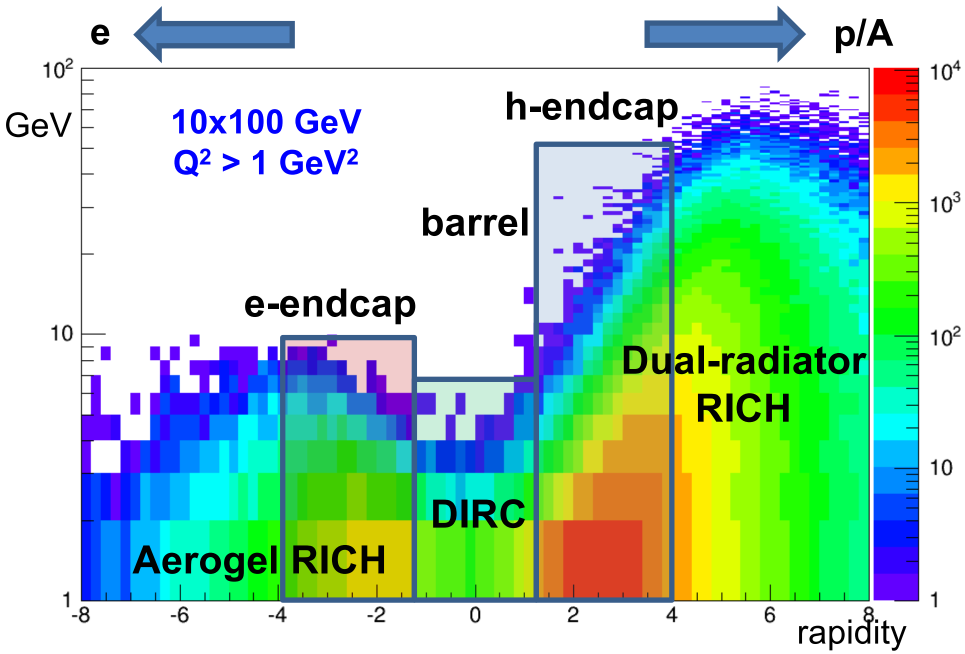
- Active collaboration within the consortium, sharing experience in weekly meetings, and drawing up common consortium goals and priorities.
- Strong synergies with non-EIC experiments and R&D programs (PANDA, CLAS12, GlueX, PHENIX, LAPPDs) resulting in large savings on hardware.

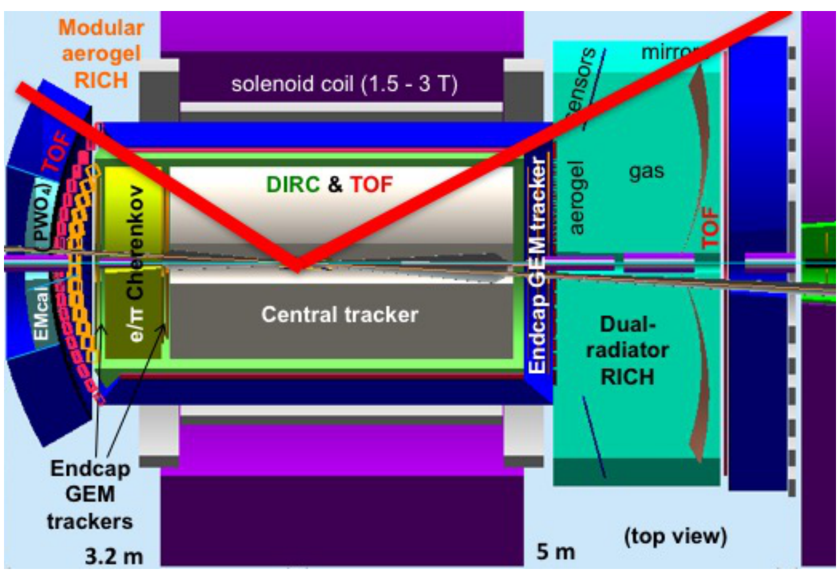
Hadron kinematics at an EIC



- The maximum hadron momentum in the two *endcaps* is close to that of the electron and ion beam energies, respectively.
- The momentum coverage needed in the *central barrel* depends on the desired kinematic reach (in particular in Q^2, which is important for QCD evolution, etc).
  - Weak dependence on the beam energies

A PID solution for the EIC - implementation

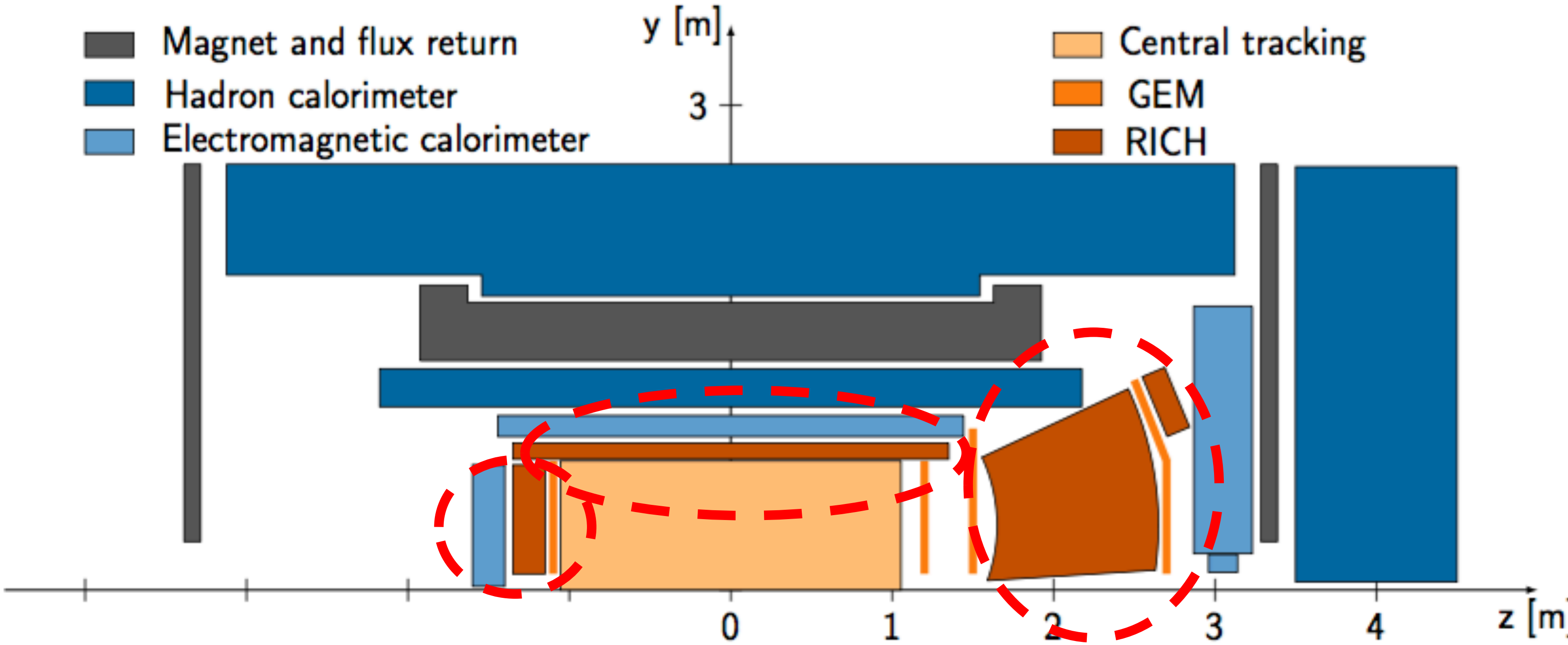




- **h-endcap**: A RICH with two radiators (gas + aerogel) is needed for
  π/K/p separation up to ~50 GeV/c
- **e-endcap**: A compact aerogel RICH which can be projective
  π/K/p separation up to ~10 GeV/c
- **barrel**: A high-performance DIRC provides a compact and cost-effective way to cover the area.
  π/K/p separation up to ~6-7 GeV/c
- **TOF (and/or dE/dx in TPC)**: can cover lower momenta.
- **Photosensors and electronics**: need to match the requirements of the new generation devices being developed – both for the final system and during the R&D phase

PID in the EIC concept detectors and integration of eRD14 systems

BNL ePHENIX EIC detector



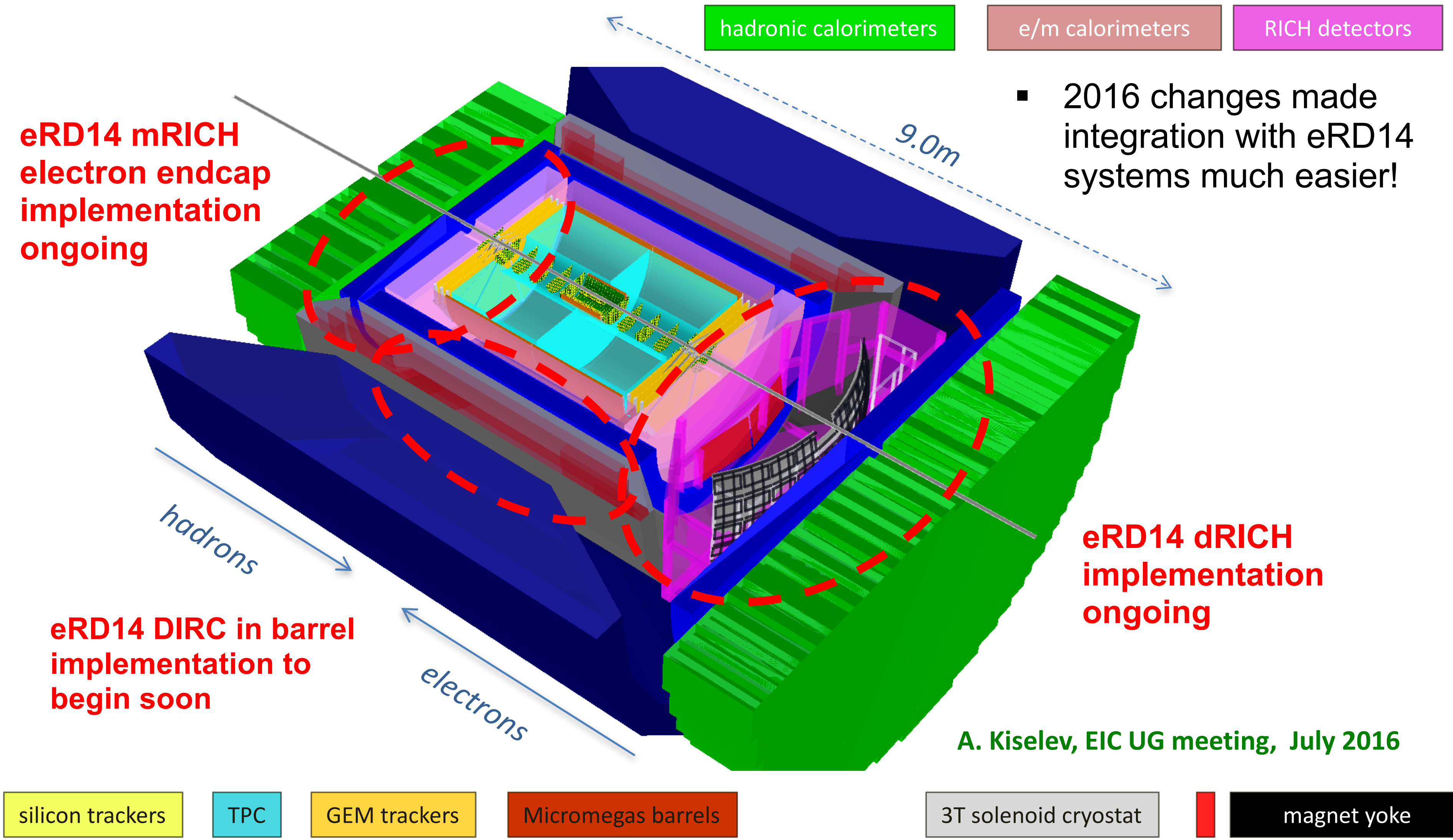
- The DIRC, mRICH, and TOF systems already part of the current concept. An implementation in Geant4 (Fun4All) is ongoing.
- In addition, either the eRD14 dRICH and eRD6 gas RICH could be used. The two options have been compared in a collaborative effort.

BNL BeAST EIC detector

-3.5 < η < 3.5: Tracking & e/m Calorimetry (hermetic coverage)

- 2016 changes made integration with eRD14 systems much easier!

eRD14 mRICH electron endcap implementation ongoing

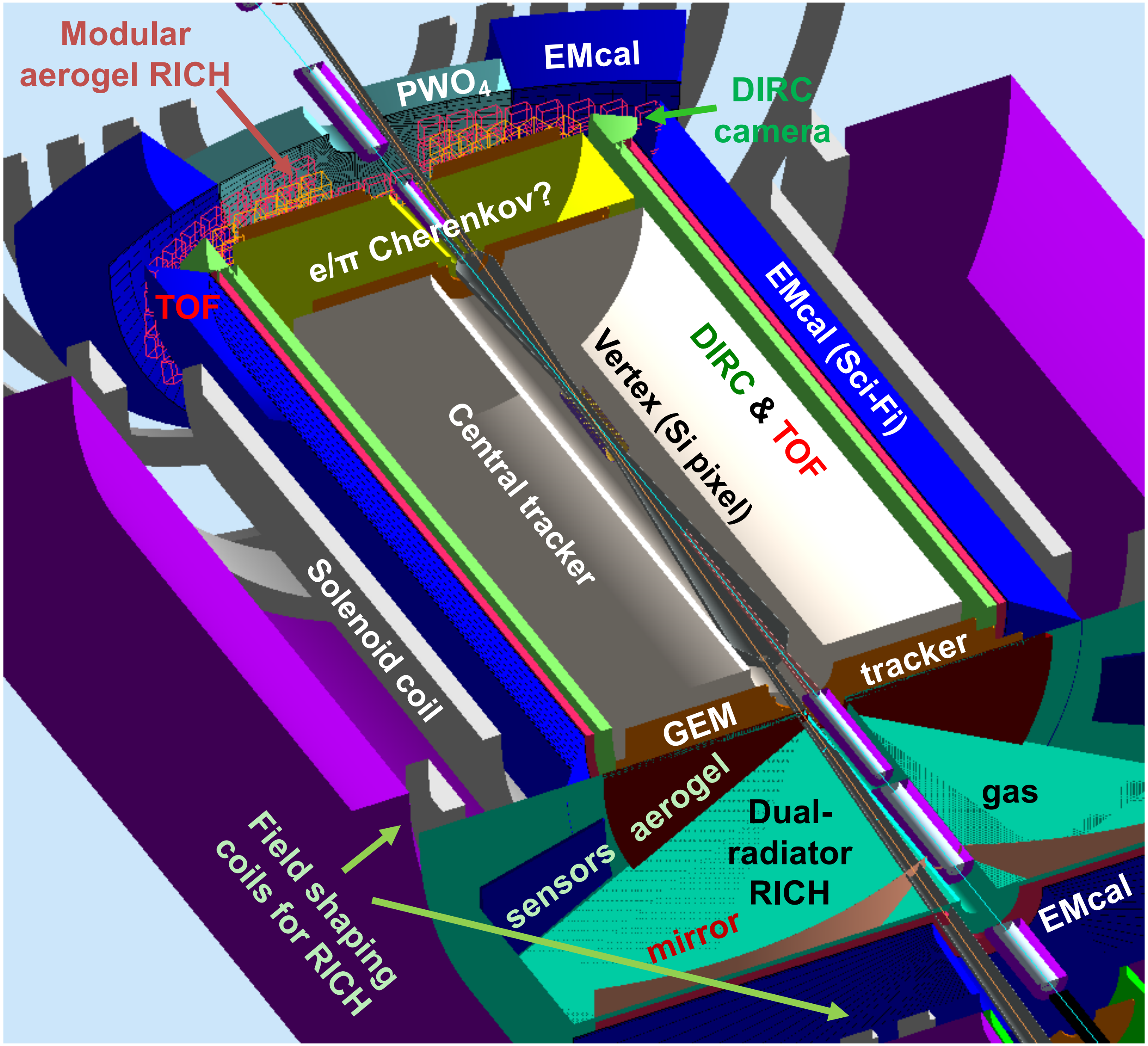


eRD14 dRICH implementation ongoing

eRD14 DIRC in barrel implementation to begin soon

A. Kiselev, EIC UG meeting, July 2016

JLab EIC detector showing PID integration



- All eRD14 systems (DIRC, mRICH, dRICH, and TOF) are part of the baseline JLab detector concept.

Dual-radiator RICH (dRICH)

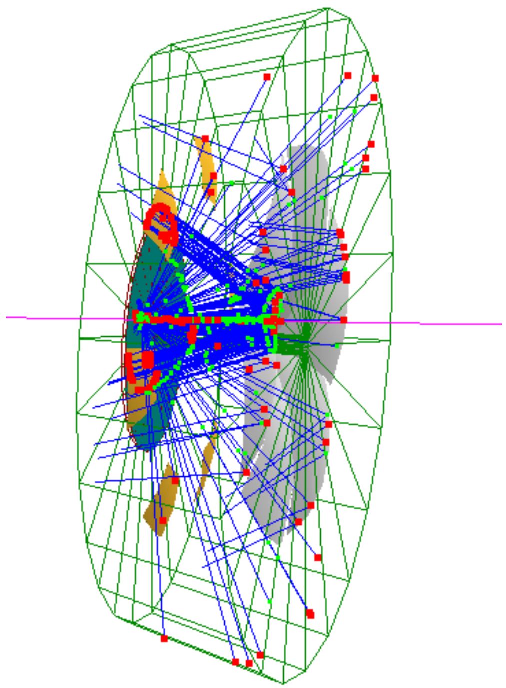
Goal:

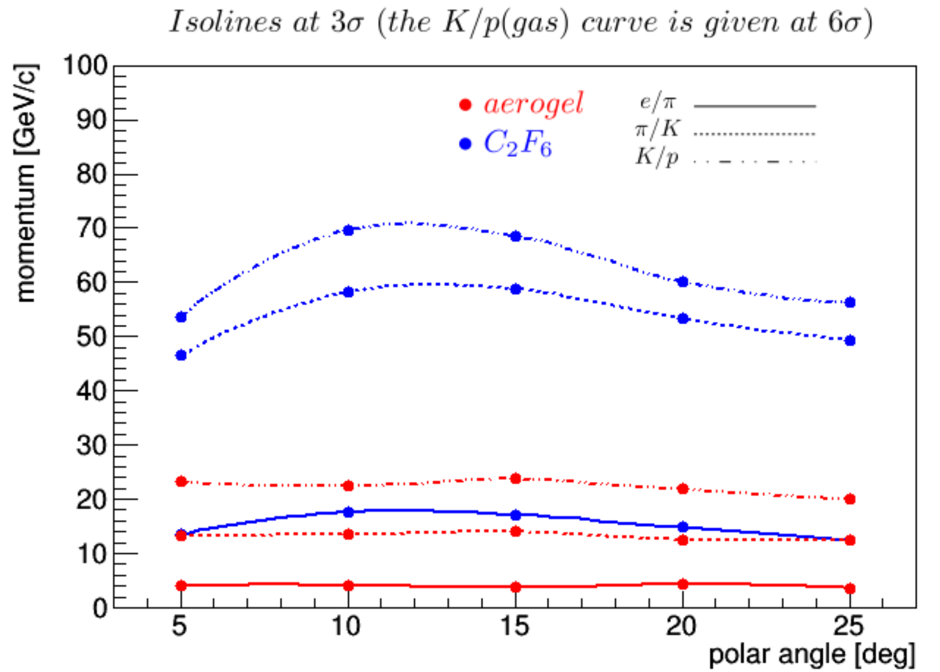
- Continuous coverage up to ~50 GeV/c for π/K and ~15 GeV for e/π
- First such device developed for the endcap of a solenoidal detector

FY 18:

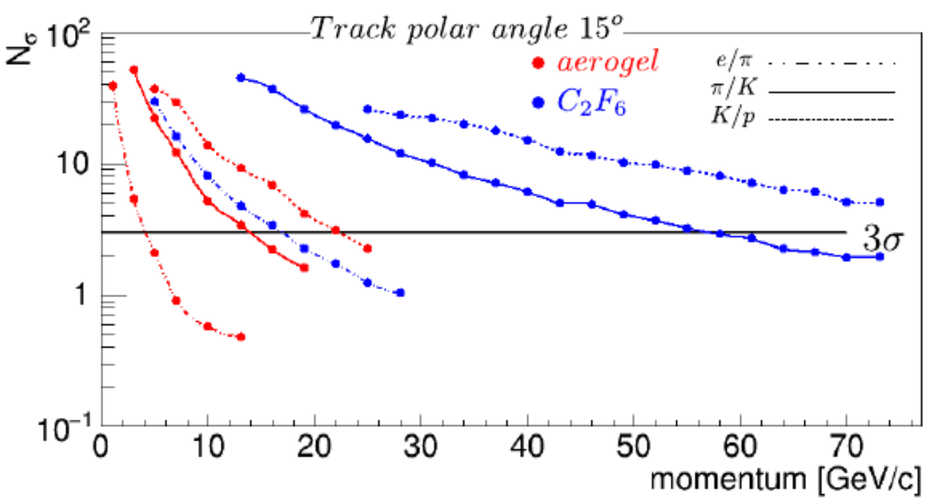
- Adaptation of dRICH geometry and comparison with eRD6 gas RICH
- Work on sensors (synergies with mRICH)

dRICH - JLab geometry





Geant4 simulation includes magnetic field

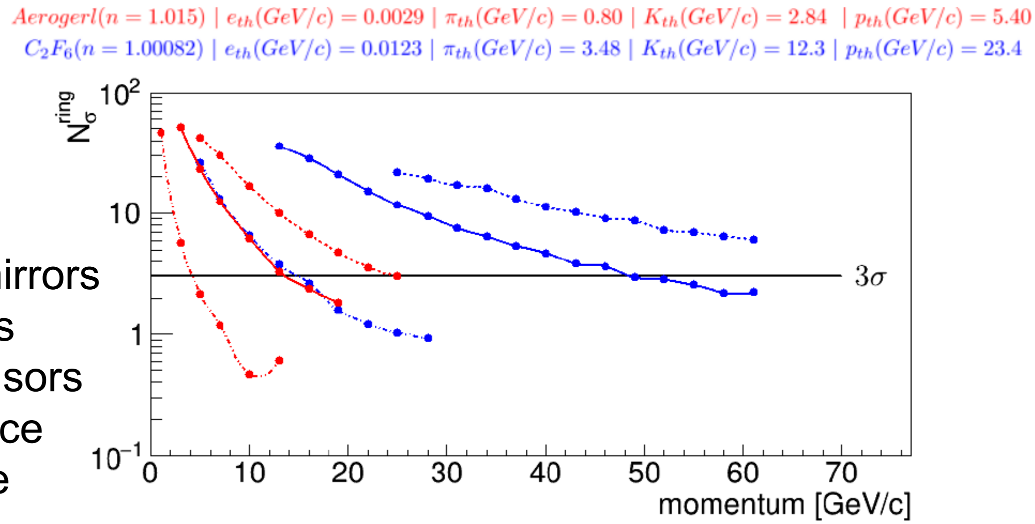


- Aerogel (n=1.02) & C_2F_6 gas
  - Continuous coverage
- Outward reflecting mirrors
  - Sensors away from the beam
  - No scattering in aerogel
- Sector-based 3D focusing
  - Reduced photosensor area
  - LAPPDs or SiPMs

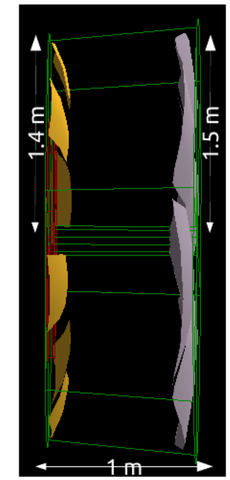
dRICH and eRD6 gas RICH – BNL geometry

dRICH
GEMC simulation:

- aerogel + C_2F_6
- outward reflecting mirrors
- six azimuthal sectors
- SiPM or LAPPD sensors
- Excellent performance despite reduced size



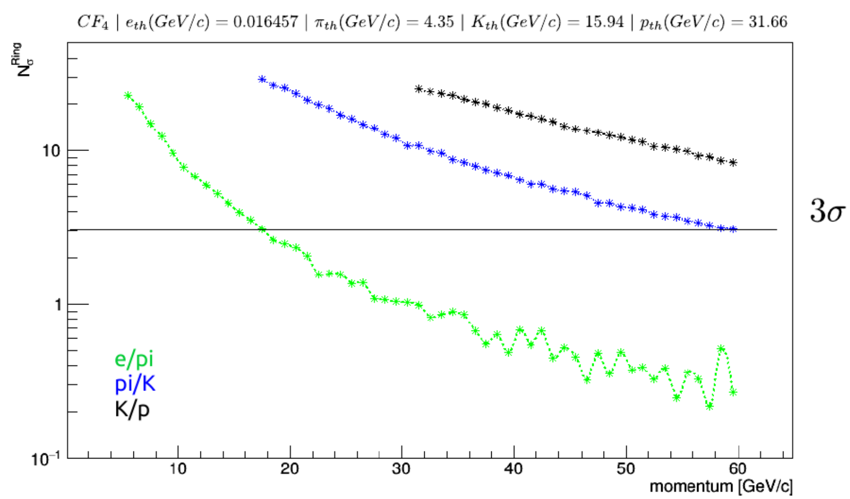
dRICH (ePHENIX)



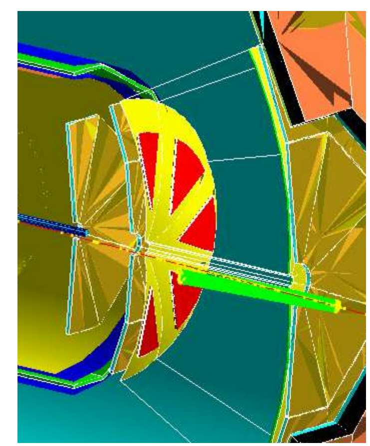
Spherical detector plane

eRD6 RICH
Fun4All simulation:

- CF_4 gas only
- inward reflecting mirrors
- eight azimuthal sectors
- GEM photosensors (sensitive in the UV)

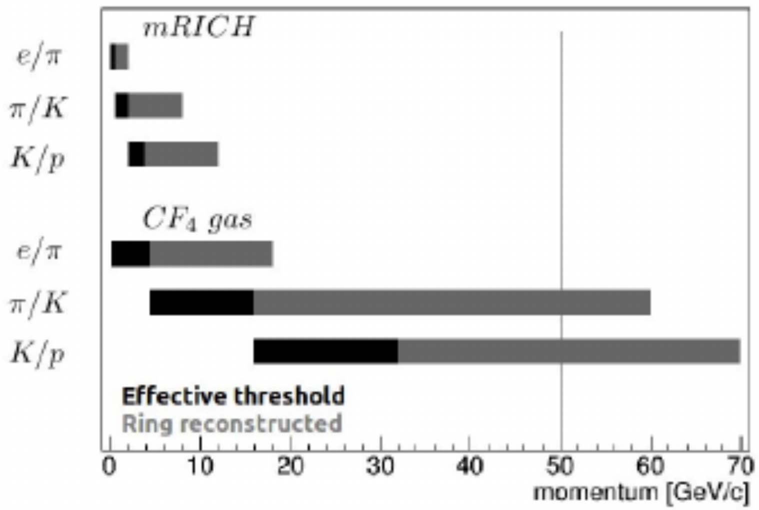


CF_4 gas RICH (ePHENIX)

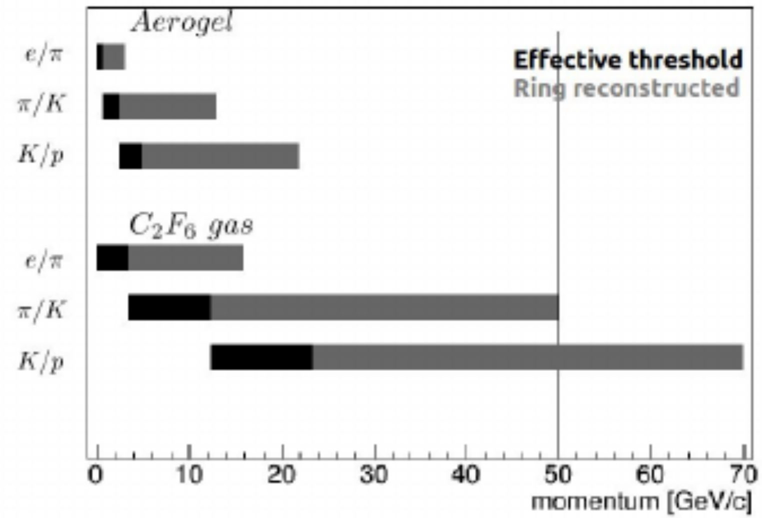


dRICH and eRD6 gas RICH – performance comparison

mRICH + CF_4 gas RICH (PHENIX)



dRICH (PHENIX)



- UV GEMs: chromatic dispersion in CF_4 gas dominates the resolution.
- mRICH + CF_4 gas do not provide continuous coverage in RICH mode for pi/K and not at all for K/p.
- Heavier gases, transparent in the UV region, shuld be explored.

- Outward reflection: emission error dominates the resolution at small angles, but it can be managed with careful design of the sensor plane.
- The dRICH provides continuous momentum coverage in RICH mode.

Planned FY18 activities

In FY18, two focus areas will be pursued:

1) Pursuing synergic activities with eRD6 on RICH development
2) Studying the dRICH performance in the presence of physics backgrounds

Work on the first point is already quite advanced, but needs to be documented upon completion.

The first point will, to the extent possible, include a study of a specific physics channel. It will also involve a PYTHIA study using the JLab dRICH simulation and a likelihood extension of the IRT algorithm.

The funding for the planned FY18 activities ends in May 2018.

Modular aerogel RICH (mRICH)

Goal:

- Compact device with coverage up to 10 GeV/c for π/K
- First aerogel RICH with lens-based focusing (for performance and cost)

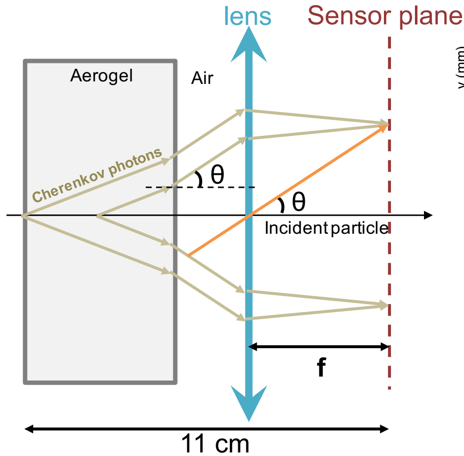
FY 18:

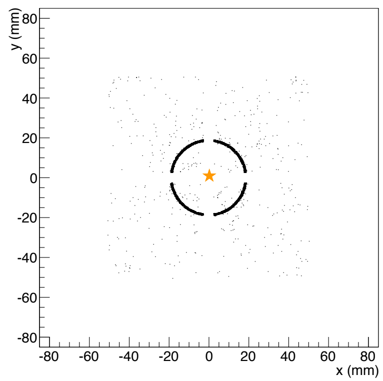
- Prepare and carry out 2nd test beam at Fermilab in the spring of 2018
- Implement the mRICH in full EIC detector simulations
- Use the mRICH to develop an integrated readout electronics solution
- Search for radiation-hard materials for Fresnel lens.

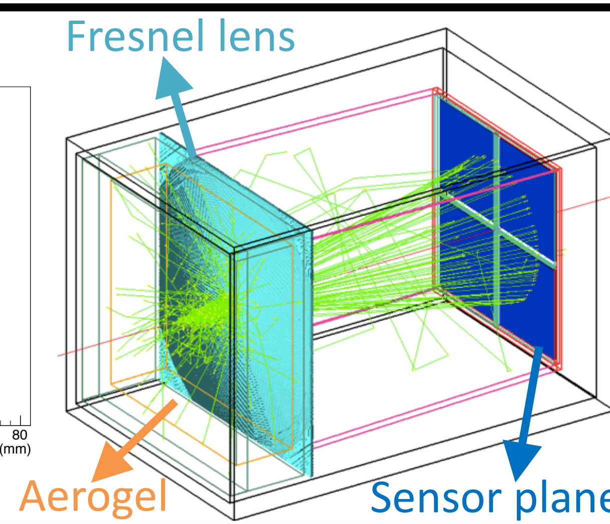
mRICH – lens-based focusing aerogel detector design

Smaller, but thinner ring improves PID performance and reduces length

Lens-Based mRICH Design

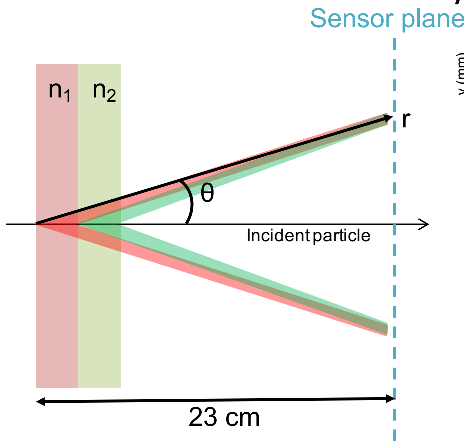


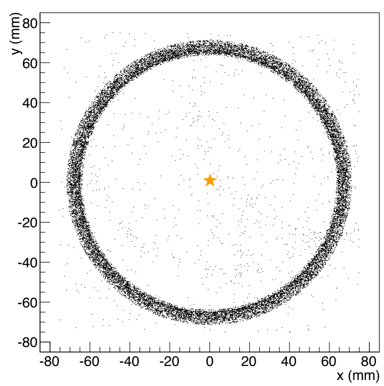




9 GeV/c pion beam launched at the center of xy plane in simulation

Two-Layer Proximity Focusing Design (BELLE-2 ARICH)



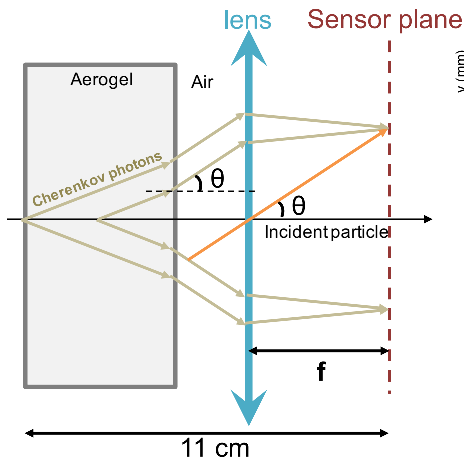


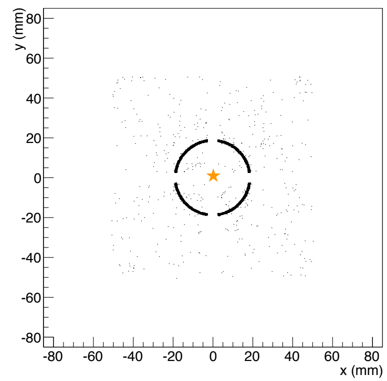
- EIC mRICH designed for K/π ID up to 10 GeV/c
- BELLE-2 ARICH aims to separate pion and kaon up to 4 GeV/c

mRICH – lens-based focusing aerogel detector design

Smaller, but thinner ring improves PID performance and reduces length

Lens-Based mRICH Design

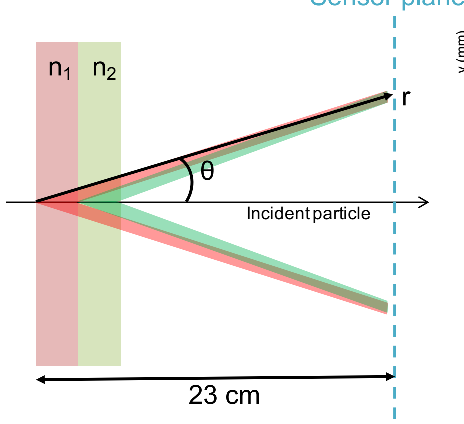


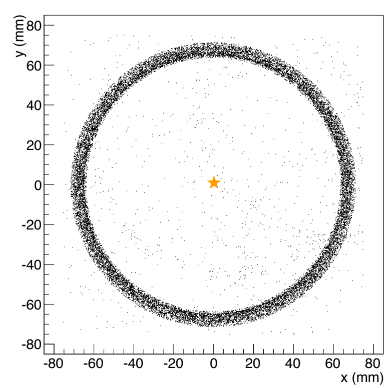


- 9 GeV/c pion beam launched at the center of xy plane in simulation
- **Smaller and thinner** ring image

9 GeV/c pion beam launched at the center of xy plane in simulation

Two-Layer Proximity Focusing Design (BELLE-2 ARICH)



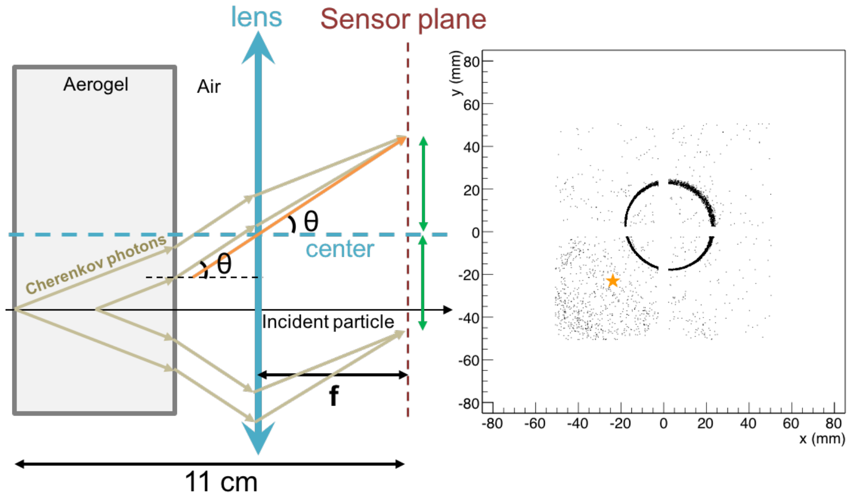


- EIC mRICH designed for K/π ID up to 10 GeV/c
- BELLE-2 ARICH aims to separate pion and kaon up to 4 GeV/c

mRICH – lens-based focusing shifts image to center

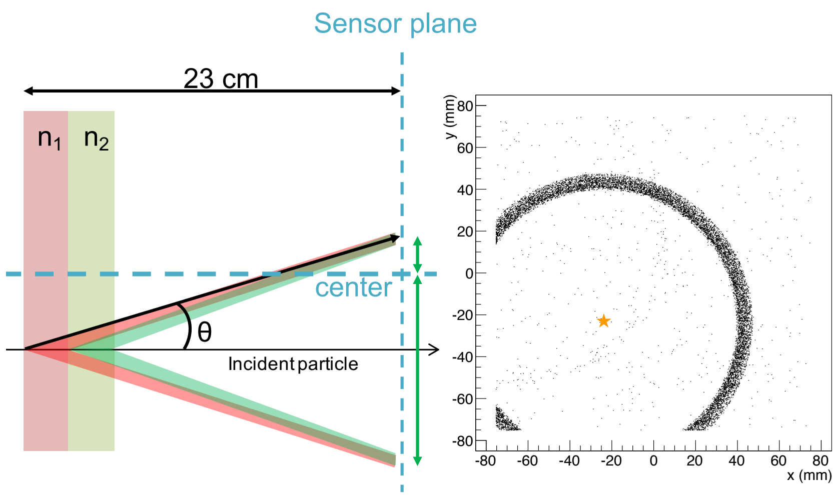
Ring centering of lens-based optics reduces sensor area (main cost driver)

Lens-Based mRICH Design



- 9 GeV/c pion beam incident at third quadrant (star) in simulation
- Ring image is center on the middle of the sensor plane

Two-Layer Proximity Focusing Design (BELLE-2 ARICH)



- 9 GeV/c pion beam incident at third quadrant (star) in simulation
- Ring is centered at point of incidence

mRICH – 2017 progress

1st mRICH prototype results have been published in NIM A871, 13-19 (2017)

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

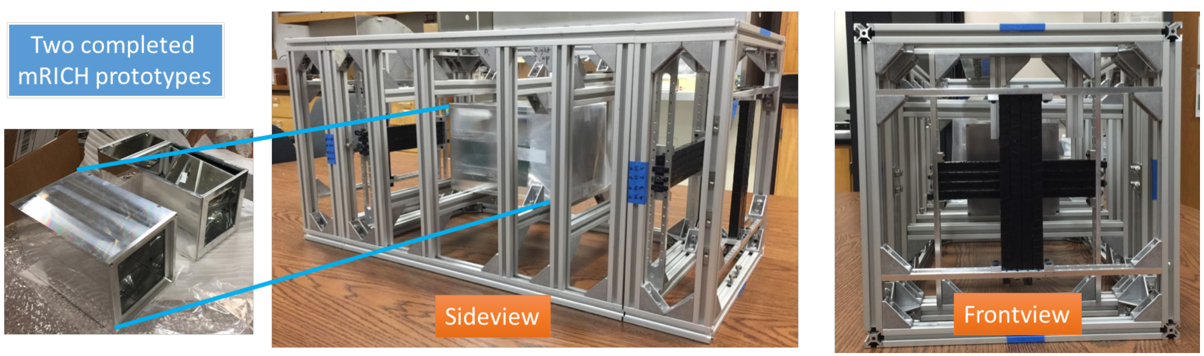
journal homepage: www.elsevier.com/locate/nima

ELSEVIER

Modular focusing ring imaging Cherenkov detector for electron–ion collider experiments[☆]

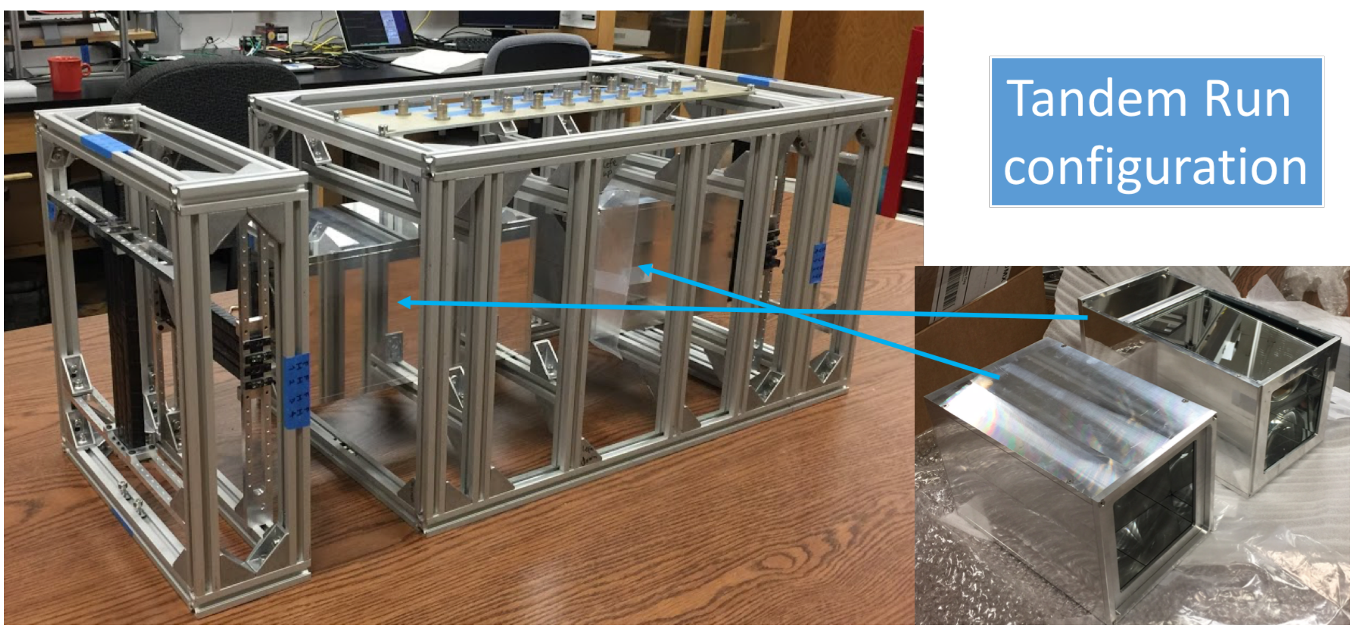
C.P. Wong[g,*], M. Alfred[i], L. Allison[o], M. Awadi[i], B. Azmoun[c], F. Barbosa[m], L. Barion[j,r],

2nd mRICH prototype beam test is under preparation (PID validation test)



mRICH – FY18 activity (I)

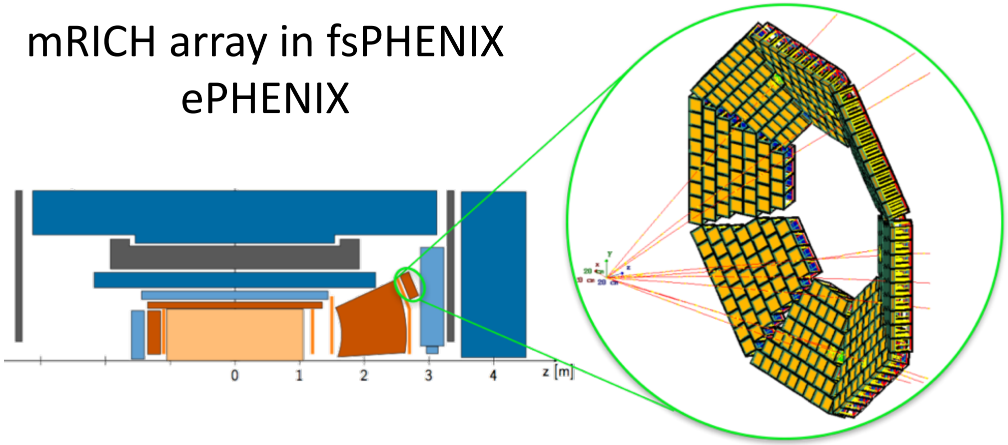
- 2nd mRICH prototype beam test in late spring of 2018 at Fermilab
  - Two prototype configurations will be tested (one with a Fresnel lens and one with a spherical lens)
  - Readout systems will be providedby INFN and Hawaii University
  - Goal: validation of mRICH PID capability up to 8 GeV/c



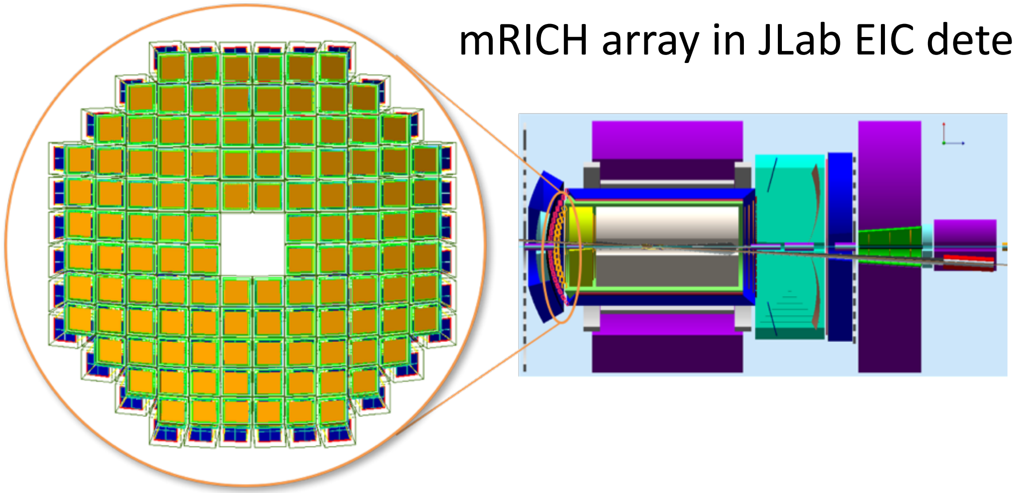
mRICH – FY18 activity (II)

Performance study of mRICH array in Forward ePHENIX and JLab EIC detector concept through simulation

mRICH array in fsPHENIX ePHENIX

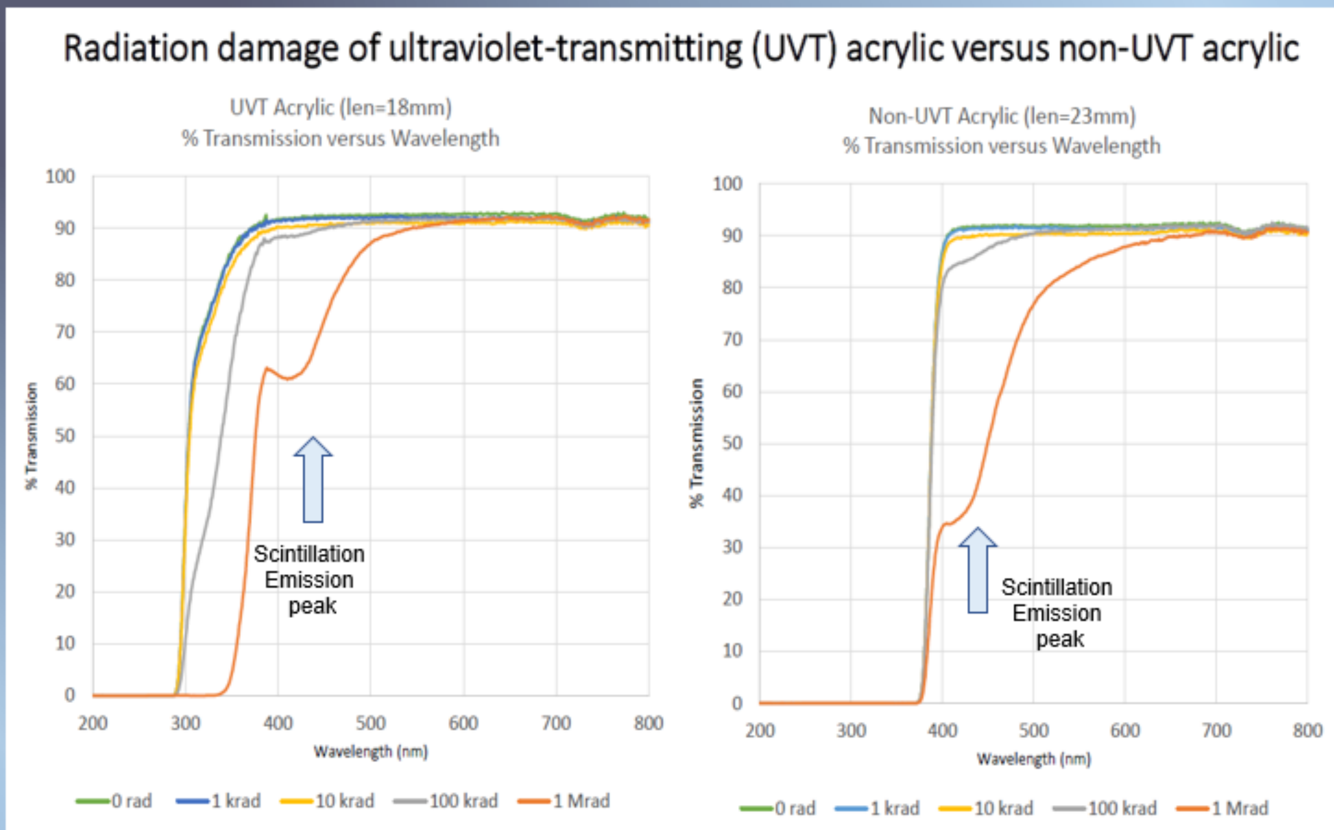


mRICH array in JLab EIC detector



mRICH – FY18 activity (III)

Radiation hardness study of Fresnel lens - address the committee concern!



Acrylic samples irradiated with ^{60}Co gamma rays at BNL SSGRIF facility.

Based on measurements and simulations of the experimental hall, the sPHENIX EMCal is expected to receive ~ 10 krad per run year.

So cumulative effects of radiation should be minimal - 2-3% over detector lifetime

Presented by Sean Stoll at IEEE NSS 2017

High-performance DIRC

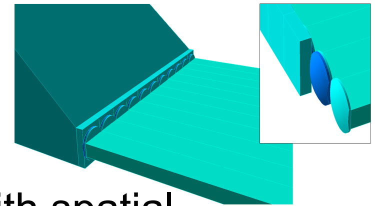
Goal:

- Very compact device with coverage up to 10 GeV/c for p/K, 6 GeV/c for π/K, and 1.8 GeV/c for e/π, pushing performance well beyond state-of-the-art
- First DIRC aiming to utilize high-resolution 3D (x,y,t) reconstruction (performance and cost)

FY 17 progress:

- Tested new cylindrical 3-Layer lens implemented in PANDA DIRC prototype in particle beam.
- Progress on analysis of 2017 CERN data, aimed at validating performance of new cylindrical lens and refining time-based reconstruction for wide radiator plates.
- Restarted simulation studies, aimed at optimizing design and implementing DIRC in a full EIC detector simulation (PHENIX).

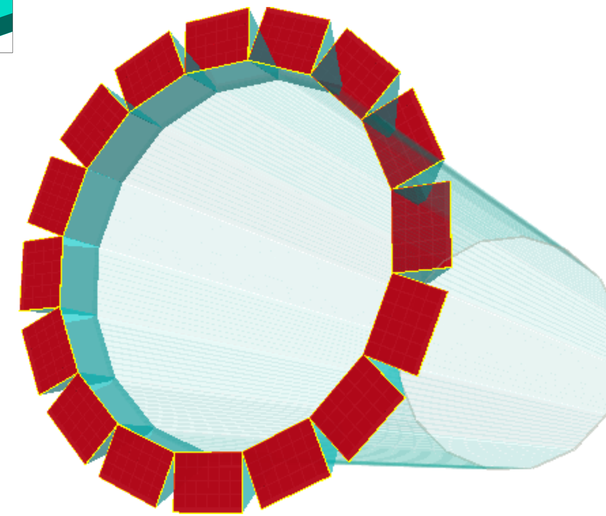
DIRC – overview



High-Performance DIRC simulations

- Time-based reconstruction in combination with spatial imaging can significantly improve performance and/or allow cost-optimized wide plate geometry.
- Better timing (~50 ps) and short bars would further improve the electron ID capabilities.
- DIRC is being implemented in a full EIC detector simulation (ePHENIX).
- Two papers on high-resolution DIRC in progress.

High-performance DIRC in Geant4



New cylindrical 3-layer lens prototype

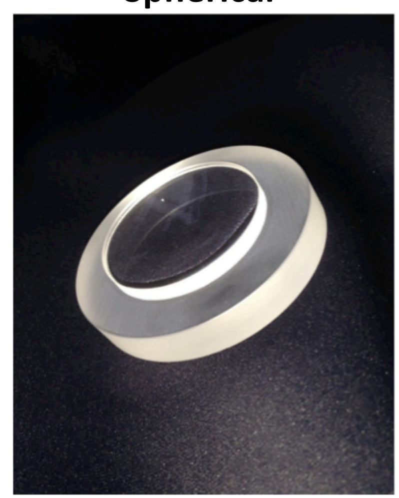
- Improved focusing for tests of wide radiator plate.
- Tested in prototype placed in particle beam (synergy with PANDA Barrel DIRC group)

Radiation hardness of NLaK33

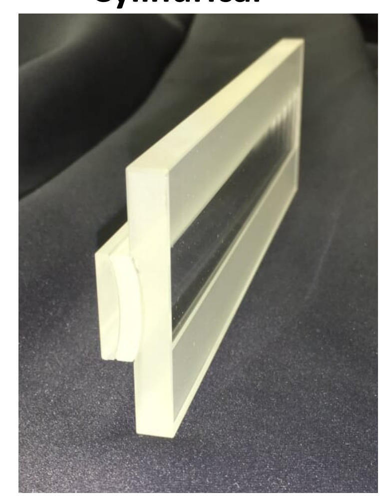
- Results suggest that NLaK33 may remain a candidate for use in the EIC DIRC.

3-layer lens prototypes

Spherical



Cylindrical

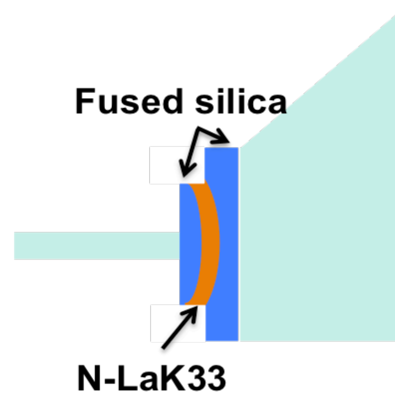


3-Layer Lens – Radiation Hardness

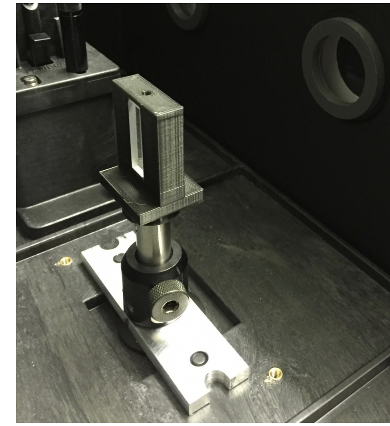
Radiation hardness tests of NLaK33 material at CUA

- Measurements using X-Ray source show the transmission at 420 nm drops by over 1% per 100 rad.
- Annealing process of the transmission observed, is being further investigated.
- Further studies of NLaK33 planned using Co^{60}, and neutron sources.
- A candidate for radiation-hard alternative to NLaK33 will be tested.

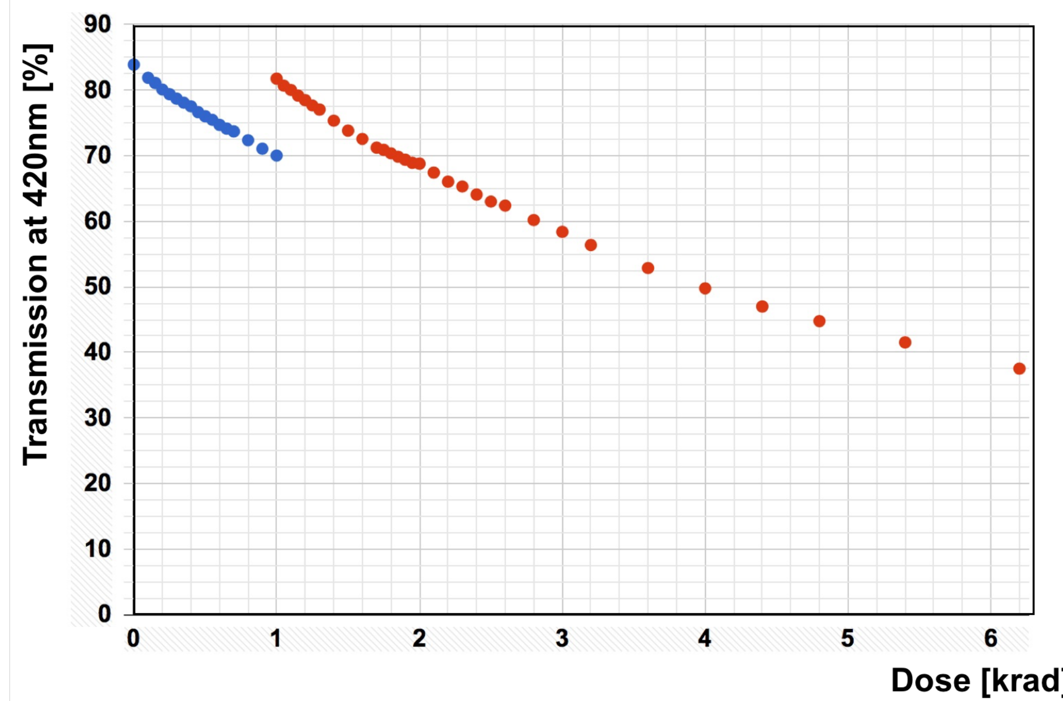
Spherical 3-layer lens



NLaK33 sample in CUA setup



Measured transmission (not Fresnel corrected) through the NLaK33 irradiation dose for 420 nm.

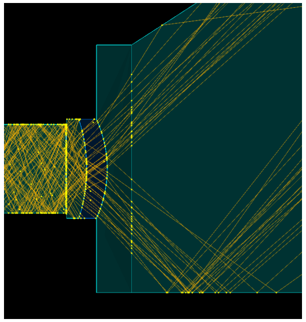


Cylindrical 3-Layer Lens – 2017 Beam Test

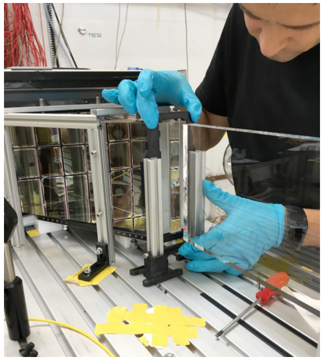
Evaluation of the performance of the new cylindrical 3-layer using the PANDA Barrel DIRC prototype at CERN PS

- Larger sensor pixels, slower electronics than EIC DIRC:
  → prototype goal: 3σ π/K separation @ 3.5GeV/c
- Optics similar to EIC DIRC design:
  narrow bar, fused silica prism, 3-layer spherical lens.
- Preliminary result of the Prototype with 3-layer cylindrical lens from the 2017 CERN test beam: a) Distribution of the hits per MCP-PMT pixel from 50k events for tagged pions at a polar angle of 20° and a momentum of 7 GeV/*c*; b) photon yield for tagged pions and protons at a polar angle of 25° and a momentum of 7 GeV/*c*.

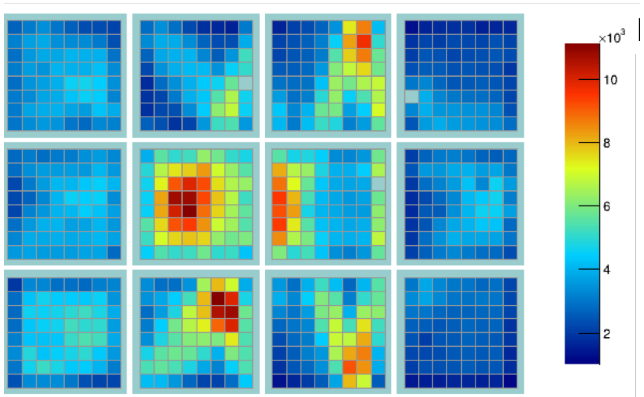
Cylindrical 3-Layer lens In Geant4 simulation



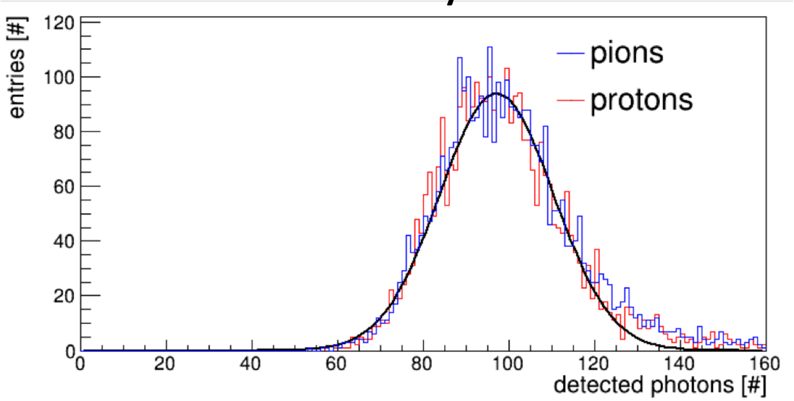
Wide plate coupled to cylindrical 3-Layer lens



Hit Pattern



Photon yield



Photosensors and Electronics

Goals:

- To evaluate commercial photosensors for EIC PID detectors and to develop alternative, cost-effective photosensors (LAPPDs).
- To develop readout electronics for PID detector prototypes.

Activities:

- Evaluation of photosensors in high-B fields at JLab.
- Adaptation of LAPPDs to EIC requirements at ANL.
- New FY18 effort on readout electronics (U. Hawaii and INFN-Ferrara)

Sensors in High-B Fields (at JLab)

Goals

- Identify the limitations of current MCP-PMTs and provide guidance for development of new photosensors
- Find the optimal location and orientation of sensors in the EIC detector
  - Example: tilt angle with respect to the local B-field different sensor options
- Investigate suitable parameters for operations in high magnetic fields

FY17 progress

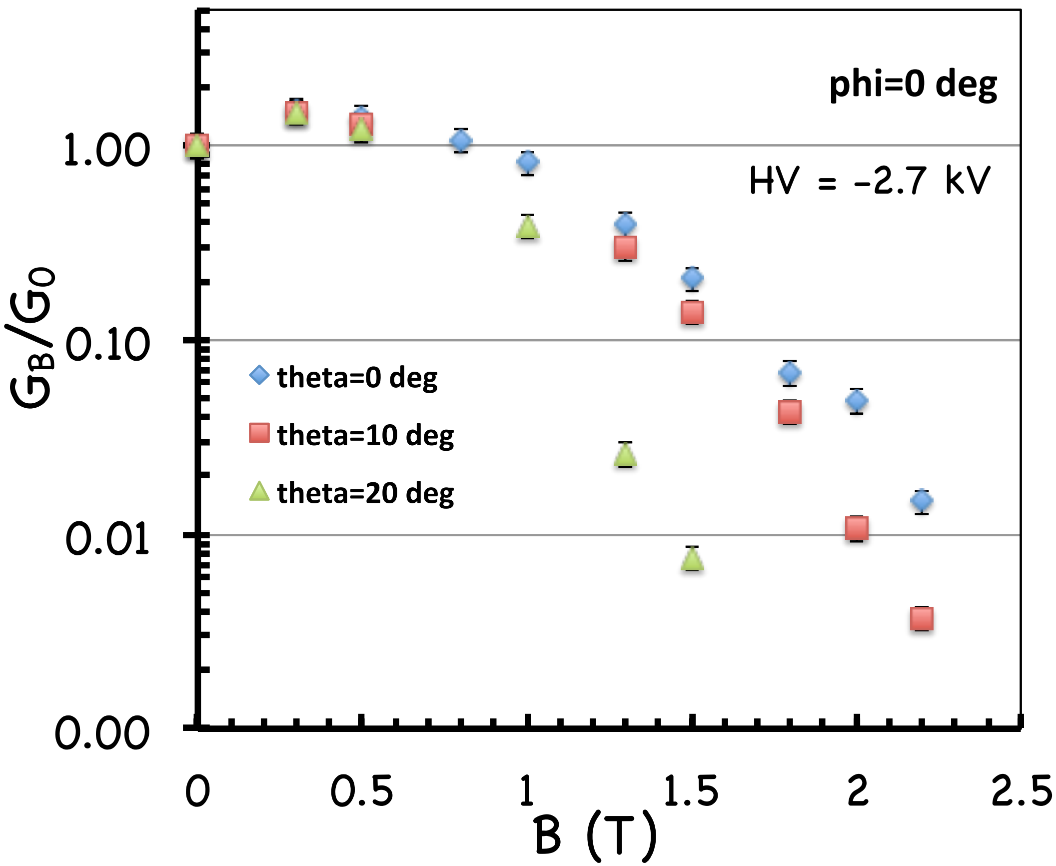
- Measurement of gain performance of 10-µm Planacon MCP-PMTs as a function of field and orientation

FY18 activities

- Gain and efficiency optimization of 10-µm Planacon using our universal voltage divider.
- Upgrade of JLab facility with a laser setup for timing studies
- Continue the development of a simulation for optimization of MCP–PMT design parameters

Results from Summer 2017 Gain Studies

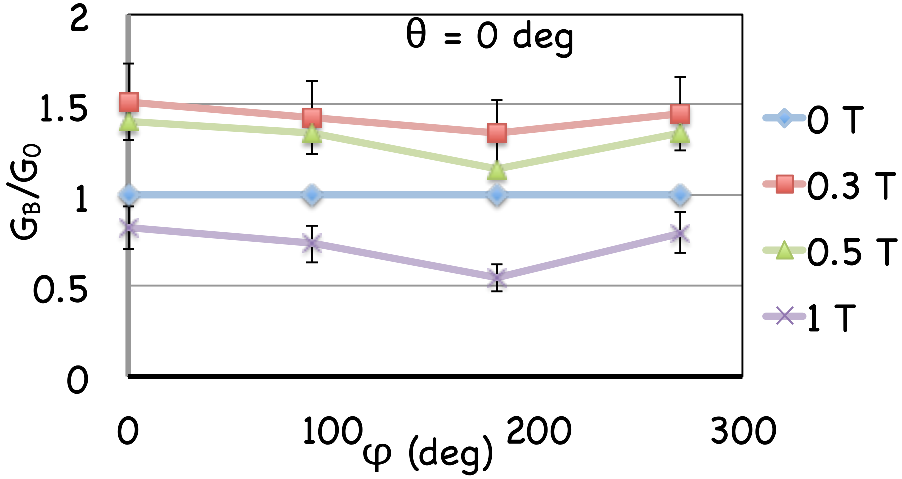
10-μm Planacon: Gain

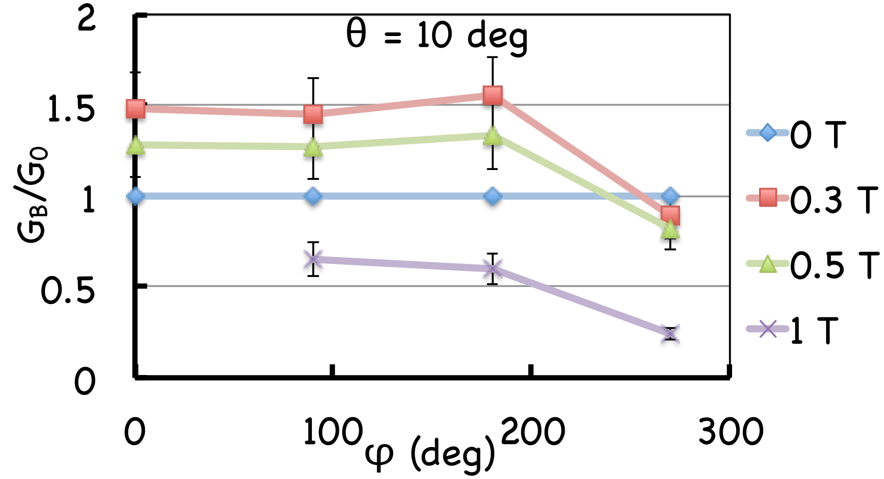


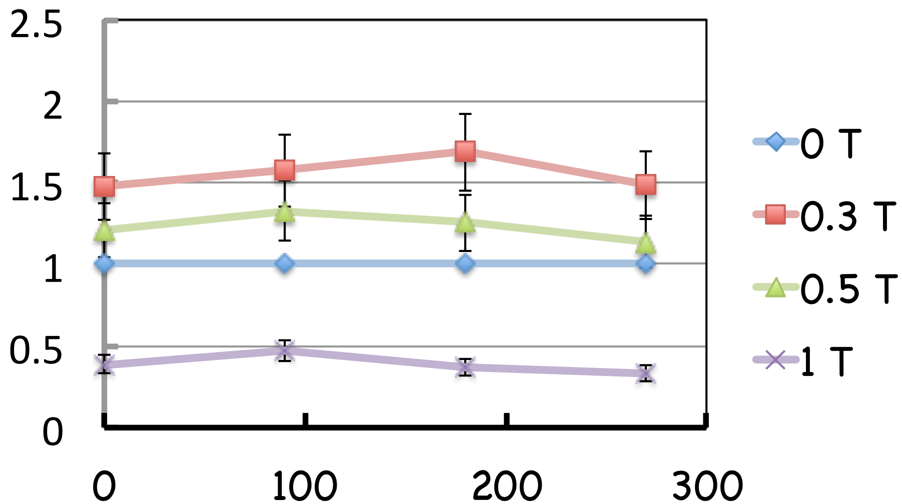
- HV at 96% of max. value
- Standard HV distribution
- Maximum gain at ~ 0.3 T
- Gain decreases fast above 1 T
- The rate of decrease depends on the orientation and is larger at larger polar angles.
- The φ dependence of the gain is much weaker than the theta dependence.

Results from Summer 2017 Gain Studies

10-μm Planacon: Gain







The azimuthal-angle dependence is weakly correlated with the polar angle:

- θ = 0° : minimum at φ = 180°
- θ = 10° : minimum at φ = 270°
- θ = 20° - no characteristic features

LAPPDs

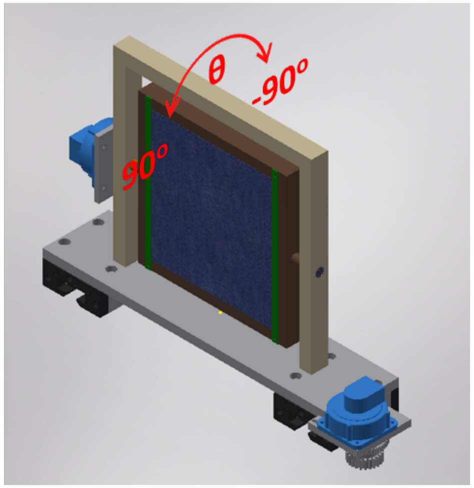
Goal:

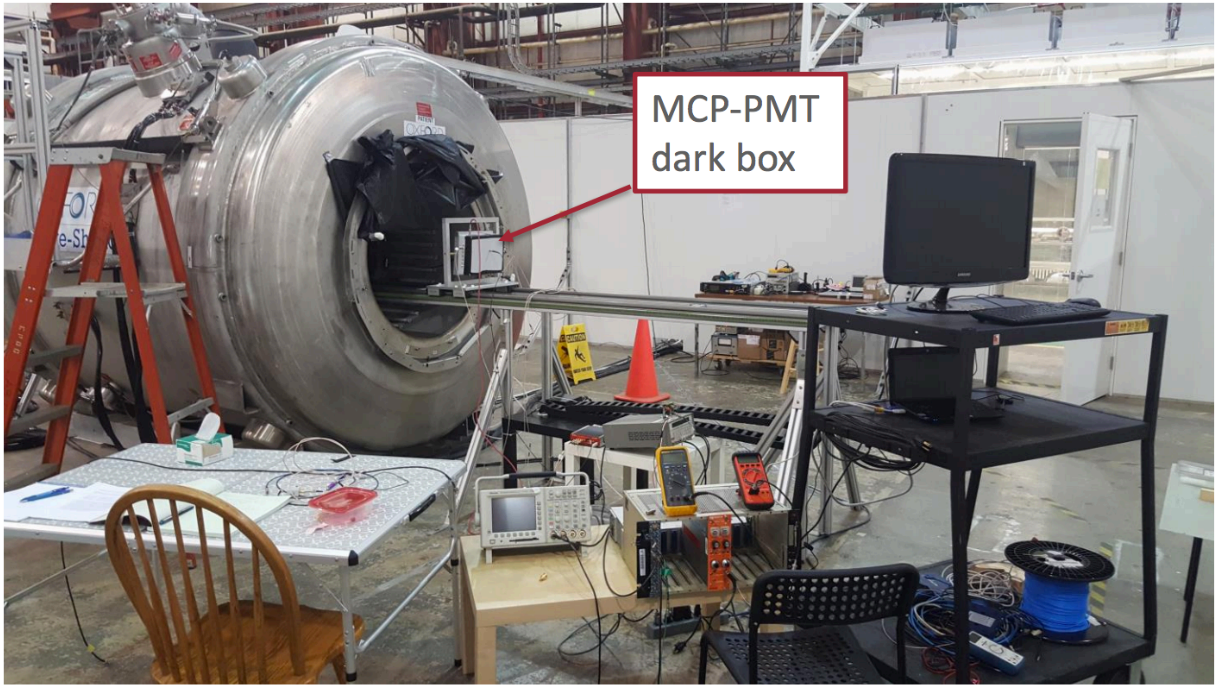
- Adapt LAPPDs to EIC requirements (pixelated readout, magnetic fields)

FY 18:

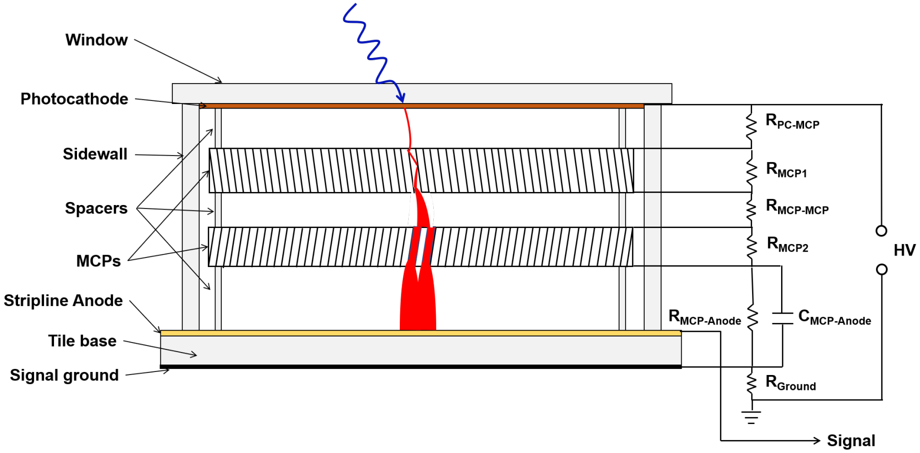
- Test the MCP-PMT with capacitive-coupling pixelated readout
- Produce pixelated readout board with 2.5 x 2.5 mm^2 pad size
- Produce and test an MCP-PMT with a 10-µm pore size MCP and reduced spacing to improve high-B performance and timing (<10 ps?)
- Evaluate the 20 x 20 cm^2 LAPPD for EIC applications (in modified ANL characterization facility)

LAPPDs – high-B test facility at ANL

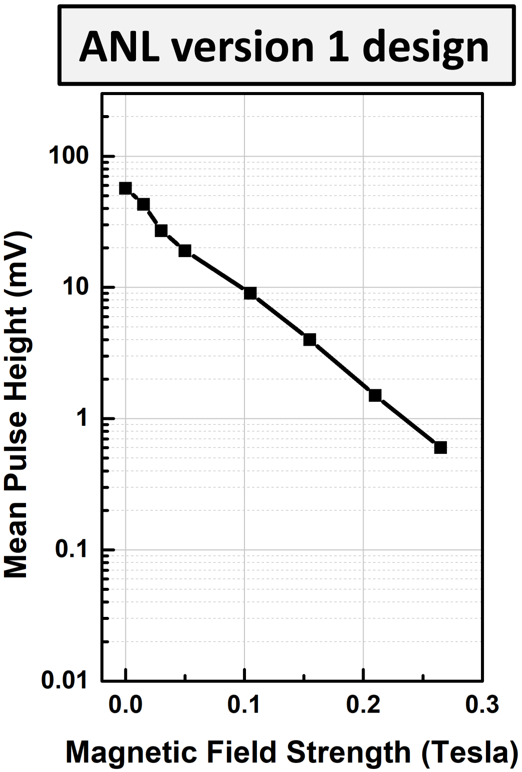


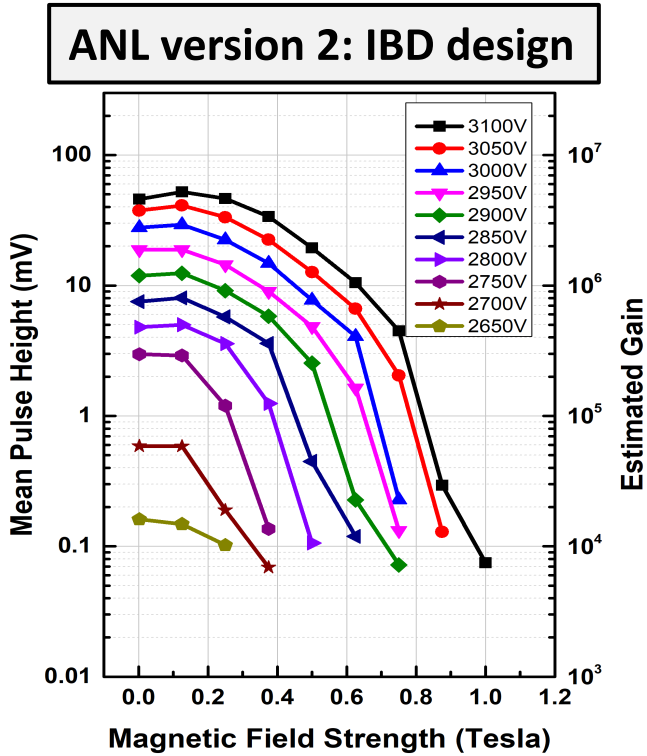


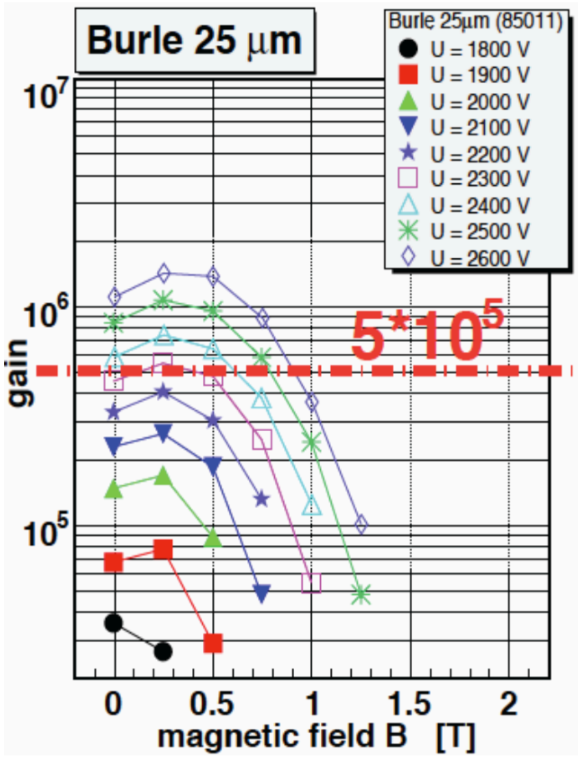
High voltage, magnetic field strength and angle dependences were all tested



High-B performance of 6x6 cm^2 LAPPD MCP-PMT







A. Lehmann NIMA 595 (2008) 173–176

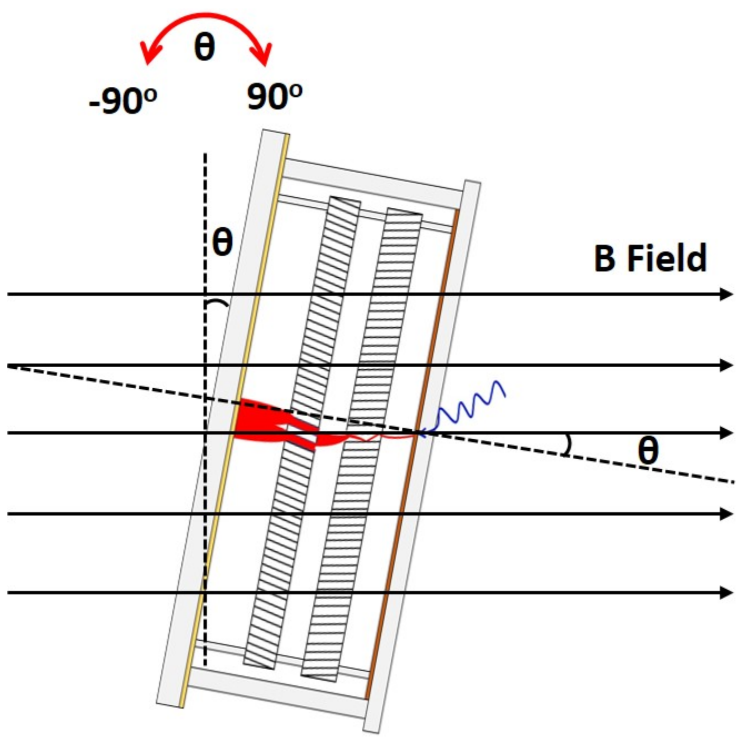
Internal resistor chain design
Gain drops quickly
0 < B < 0.15 T

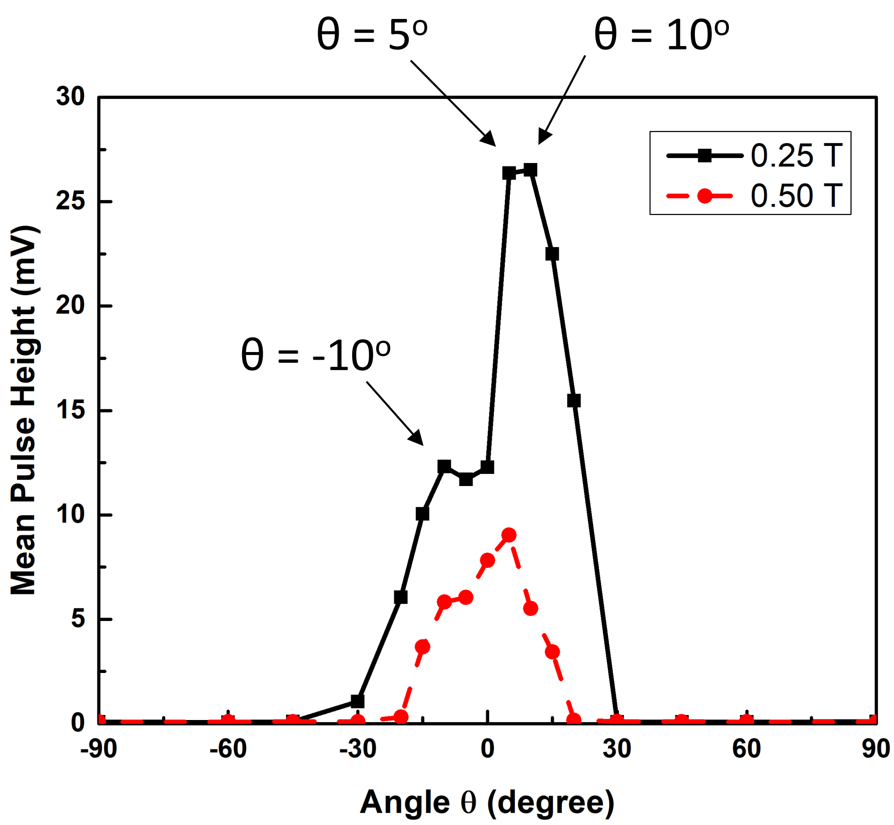
Individual biased design
B field tolerance
0 < B < 0.8 T

Burl 25um pore size MCP-PMT
B field tolerance
0 < B < 1.0 T

- Clear improvement from internal resistor chain design to individual biased design, optimization of biased voltages for both MCP is important
- Comparable performance of LAPPD (Not optimized yet) to Burl tube in B field

Measurement of the angular dependence of the gain





The standard LAPPD MCP-PMT design exhibit magnetic field tolerance up to 0.8 T at 0º.

The MCP-PMT performance in magnetic field is angle-dependent. Due to the 8º MCP bias angle, the highest gain is obtained around 8º. Notice the two peaks around -8º and 8º, indicating that the effect of upper and lower MCP angles are different.

Readout Electronics

New effort led by U. Hawaii (front end) and INFN-Ferrara (back end and integration)

Goal:

- Develop an integrated suite of readout electronics for the different photosensors used for the Cherenkov detector prototypes.

FY 18:

- Adaptation of CLAS12 electronics for 256 channel sensors and SiPMs
- Development of new front end based on TARGETX chip (Belle II)
- Integration of both front ends with a new back end based on CLAS12

Electronics – overview

Requirements

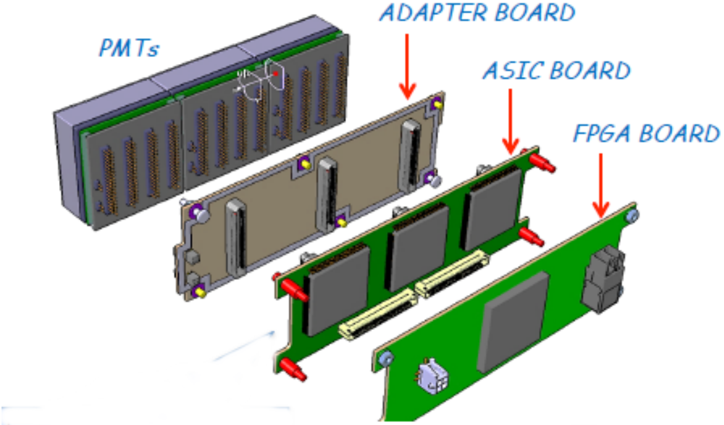
- Need to read out a range of different photosensors (MaPMTs, MCP-PMTs, and SiPMs) with similar sensor and pixel size (16x16 array of 3 mm pixels)
  - DIRC also requires good timing (<100 ps)
- Ultimate goal is to have common front end electronics with good timing that can be used for all sensors
- To reduce cost and risk, a staged approach is adopted for the front end.
  - The back end / DAQ will be compatible with all front ends

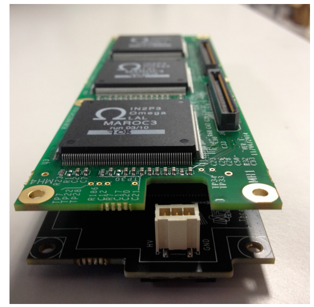
Implementation

- The Maroc-based CLAS12 front end which was used for the first mRICH beam test and will be adapted for smaller pixels and SiPMs
  - Maroc is not a long-term solution due to its poor timing
- A new front end based on TARGETX, which is used in Belle II, is being developed by U. Hawaii for the second mRICH prototype
  - Initial focus on MaPMTs; can support SiPMs and MCP-PMTs (< 100 ps timing)
- Ultimately, a front end based on the new SiREAD chip from Hawaii will be used for all EIC PID detectors and sensors.
  - SiREAD development is currently transitioning form SBIR Phase I to Phase II

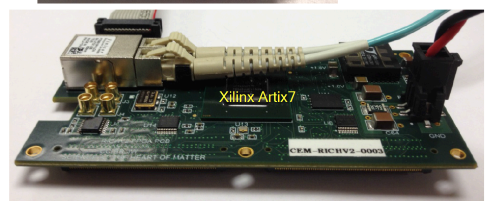
Electronics – Maroc

CLAS12 RICH electronics



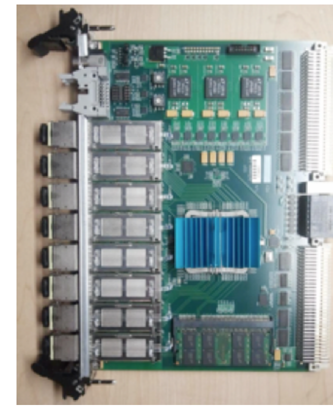


Adapter & Asics Boards



FPGA Board

SSP Fiber-Optic DAQ

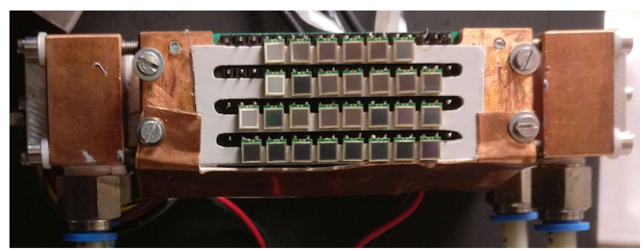


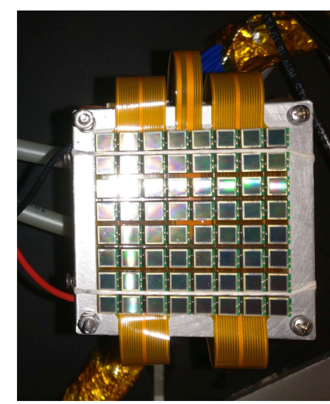
SiPMs

- ✓ Mass production technology
- ✓ Photon counting
- ✓ Excellent time resolution
- ✓ Compatible with magnetic field

- ✗ High dark rate
- ✗ Low radiation tolerance

} Work at low temperature





Electronics – TARGETX

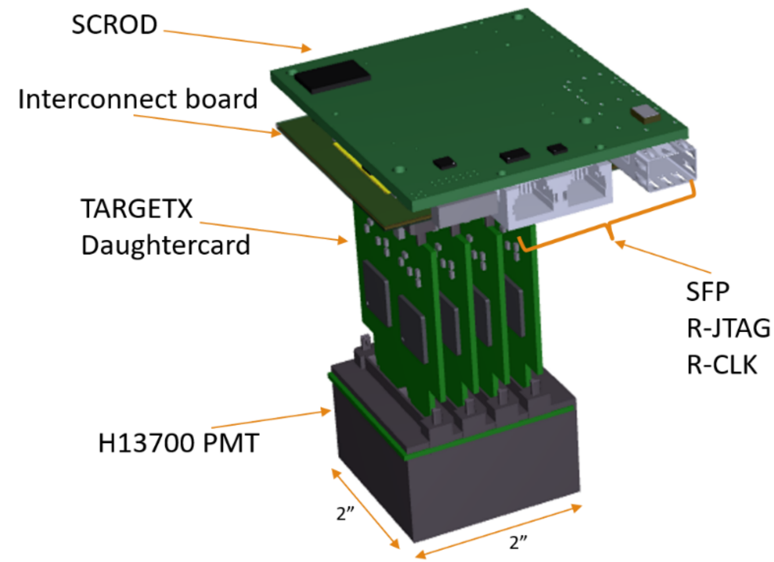
- 1st generation 1024 channel compact readout for the mRICH prototype based on existing TARGETX chip:
  - Initial sensor: 4 x H13700 MaPMTs, each with 256 channels
  - 1 GSa/s full waveform sampling
  - 16 us trigger buffer
  - 16 channels
  - Built-in comparator generates trigger primitives
  - Low cost 250nm CMOS
  - Readout close to PMT avoids costly cabling and amplification

- Technology already used in 3 projects – developed FW/SW base:
  - Belle II KLM upgrade, ~20k SiPM channels
  - Borehole Muon Detector (BMD) prototype: ~100 SiPM channels
  - Hawaii Muon Beamline (HMB): ~60 SiPM channels
  - Cherenkov Telescope Array (CTA) ~2k SiPM or PMT /telescope

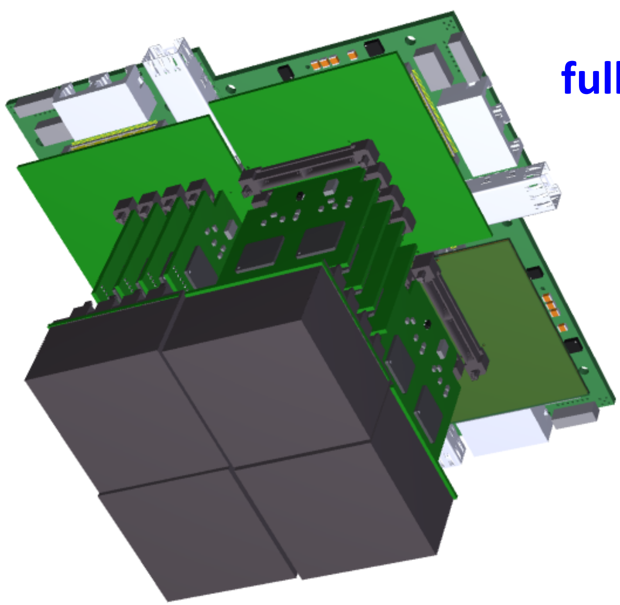
Electronics – TARGETX for mRICH, Rev 1.0 design

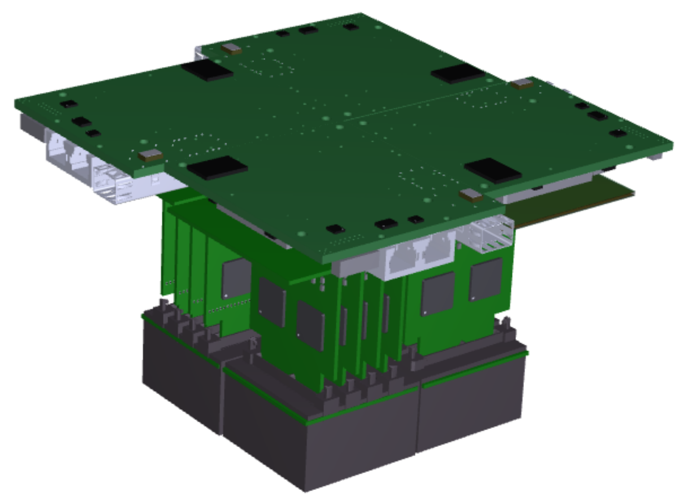
- Mechanical fitting and PCB routing
- 4 TARGETX chips on one daughtercard
- SCROD (s6 FPGA) boards already fabricated and tested
- Interconnect card purely passive routing
- Reuse KLM detector readout FW and SW
- Can readout all 256 PMT channels
- Compatible with mRICH layout (2x2 PMTs)

4x64 channel building block



full 4x256 channel readout block





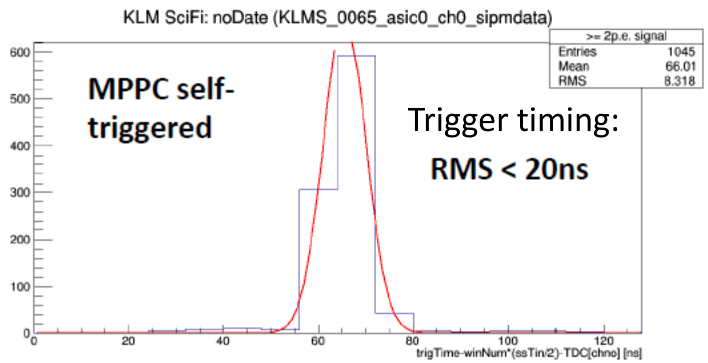
TARGETX / SiREAD – next steps

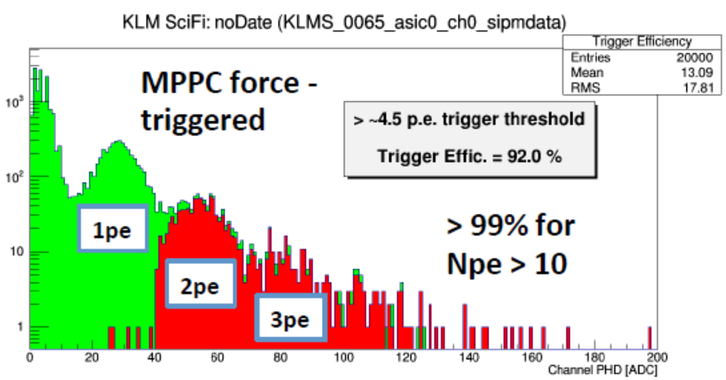
- Implement schematic/layout/mechanical
  - Almost done with design
  - Fabricate, power up and test Rev 1.0 by end of Feb 2018
  - Debug and submit revision if needed by mid March 2018
  - Prep for beam-test by mid April 2018

- 2^{nd} generation: SiREAD
  - Compact full waveform sampling SiPM readout System-on-Chip
  - Completed Phase I SBIR with DOE NP
  - Applying for DOE Phase II funding
  - SiREAD Rev 1.0 prototype has been submitted for fabrication

TARGETX – timing tests at Belle-II

KLM: Acceptance Tests Exceed Thresholds

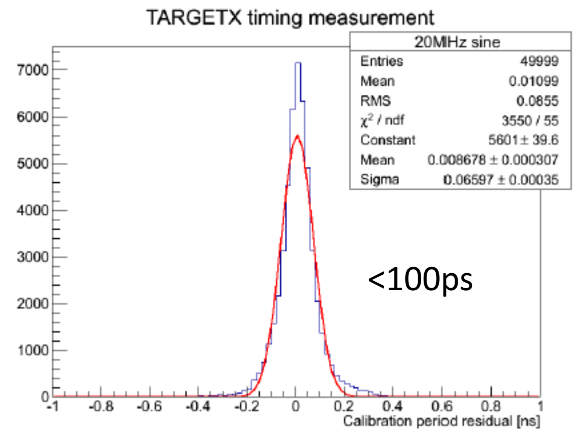




May 3, 2016

US Belle II Project CD-4 Directors Review

Expected SiREAD performance based on TARGETX predecessor



Sine scan data (zero crossing)

KLM Readout System Performance

Tolerance	Threshold	Objective
Good Channels	90%	98%
Deadtimeless Occupancy	0.5%	1%
99% minimum ionizing particle efficiency	10p.e.	7p.e.
Event Timing	10ns	5ns
Event Trigger timing	20ns	10ns

eRD14 FY18 budget (including overhead)

5.10 Budget by institution

	Requested	Final
ANL	$75k	$40k
BNL	$38k	
CCNY	$5K	$5K
CUA (and GSI)	$94k	$62k
GSU	$66.3k	$38.5k
U. Hawaii	$30k	$25k
INFN-Ferrara	$52.5k	$27.5k
JLab	$10.5k	$10.5k
USC (and INFN)	$48.7k	$43.5k
Total	$420k	$252k

5.9 Budget by project

	Requested	Final
dRICH	$36.5k	$31.5k
mRICH	$99.8k	$62k
DIRC	$94k	$62k
TOF	$43k	$5k
high-B	$27.7k	$22.5k
LAPPD	$75k	$40k
Electronics	$44k	$29k
Total	$420k	$252k

Recent publications

6. Publications

6.1 In Preparation

X. He, *Ring Imaging Cherenkov Detector Technologies for Particle Identification in the Electron-Ion Collider Experiments,* The Proceedings of the 21st Particles and Nuclei International Conference, to be published in International Journal of Modern Physics: Conference Series.

Y. Ilieva, *Particle Identification for a Future EIC Detector,* Proceedings of DIRC2017: Workshop on Fast Cherenkov Detectors, to be published in Journal of Instrumentation.

G. Kalicy, *The High-Performance DIRC for a Future EIC Detector*, Proceedings of DIRC2017: Workshop on Fast Cherenkov Detectors, to be published in Journal of Instrumentation.

6.2 Recently Published or Submitted

A. Del Dotto et al., *Design and R&D of RICH detectors for EIC experiments*, poster at RICH2016 (9th International Workshop on Ring Imaging Cherenkov Detectors), September 5–9, 2016, Bled, Slovenia, published in Nucl. Instrum. Meth. A 876, 237 (2017).

C.P. Wong, et. al., *Modular focusing ring imaging Cherenkov detector for electron-ion collider experiment*, Nucl. Instrum. Meth. A 871, 13 (2017).

J. Xie et al., *Rate capability and magnetic field tolerance measurements of fast timing microchannel plate photodetectors*, Nucl. Instrum. Meth. A (in press). https://doi.org/10.1016/j.nima.2017.10.059

7. Presentations

C.P. Wong, *A Novel Modular Ring Imaging Cherenkov (mRICH) Detector for the Experiments in the Electron-Ion Collider*, IEEE Nuclear Science Symposium, 21–28 October, Atlanta, GA, 2017.

X. He, *Ring Imaging Cherenkov Detector Technologies for Particle Identification in the Electron-Ion Collider Experiments,* The 21th Particles and Nuclei International Conference, September 1–5, IHEP, Beijing, China, 2017.

Y. Ilieva, *Particle Identification for a Future EIC Detector,* DIRC2017: Workshop on Fast Cherenkov Detectors, 7–9 August, Castle Rauischholzhausen, Germany, 2017.

G. Kalicy, *The High-Performance DIRC for a Future EIC Detector*, DIRC2017: Workshop on Fast Cherenkov Detectors, 7–9 August, Castle Rauischholzhausen, Germany, 2017.

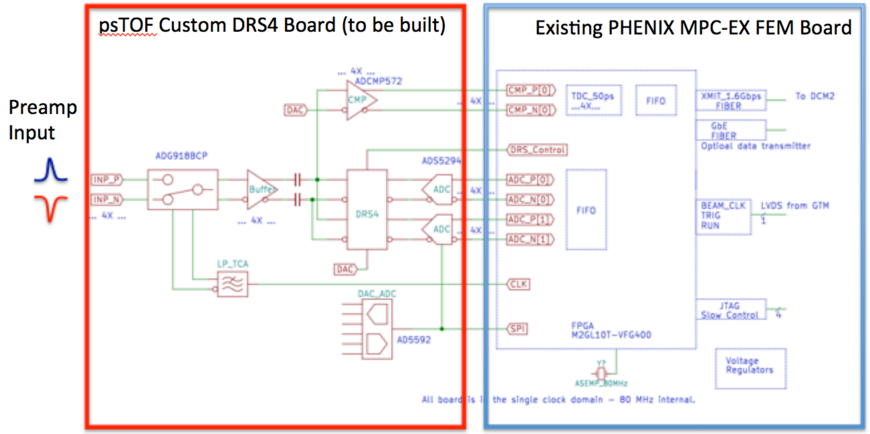
Thank you!

Also, please visit the eRD14 wiki

http://phynp6.phy-astr.gsu.edu/eRD14/index.php/Main_Page

Backup

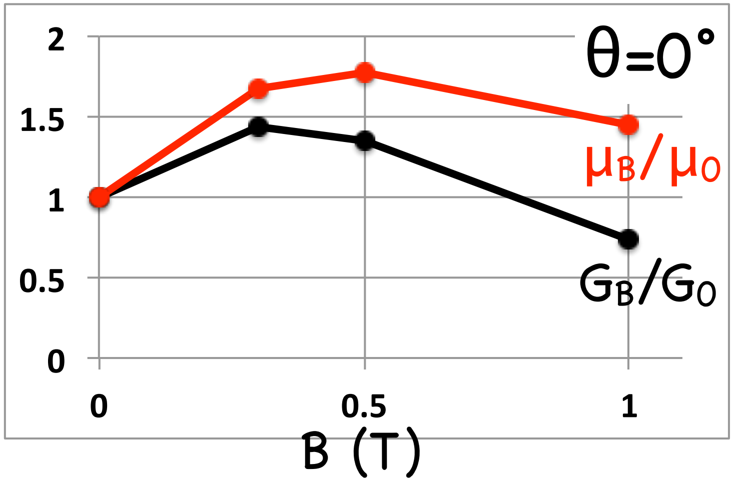
TOF – FY18 activities

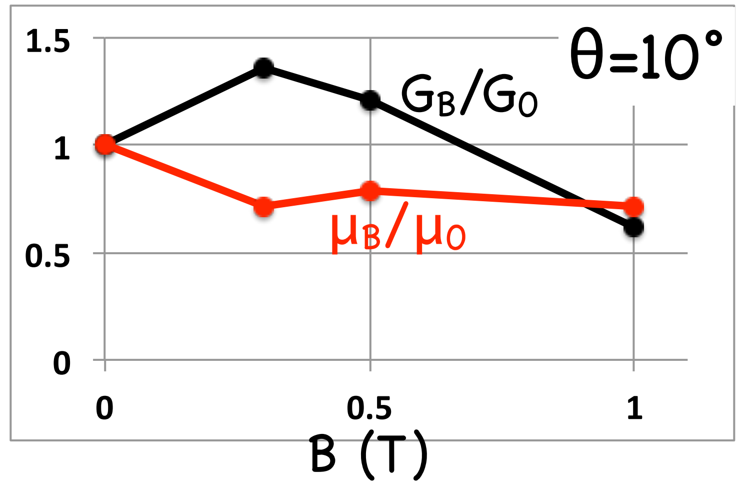


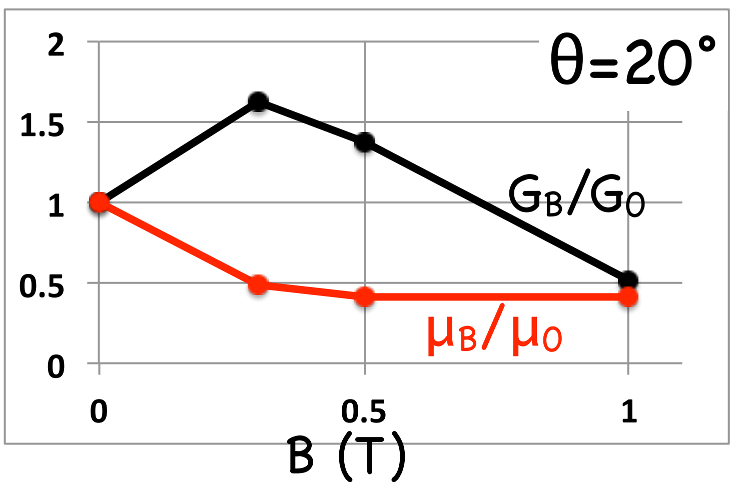
1. Rev2 of UFAMP (~0.8 GHz bandwidth and x10 gain) will be built and tested by CCNY/BNL
2. Ultra-thin glass (0.1 mm) mRPC with ~48 gas gaps (most ever), correcting impedance matches and bandwidth limits in Cu strip transmission bandwidth.
   - Test in cosmic rays using straw trackers, then in test beam at FNAL.
3. DRS4 prototype analog DRS4 board (1st prototype) will be built and tested.
   - Layout current being done by A. Denisov (IHEP), and FPGA control will be done by A. Sukhanov (BNL). Expect will need at least 3 iterations to perfect this board.
4. The QE and the TTS of single photoelectrons of the ANL UV sensitive MCP-PMT will be measured as a function of wavelength down to the cutoff of fused silica at ~170 nm

Results from Summer 2017 Gain Studies

10-μm Planacon: Efficiency





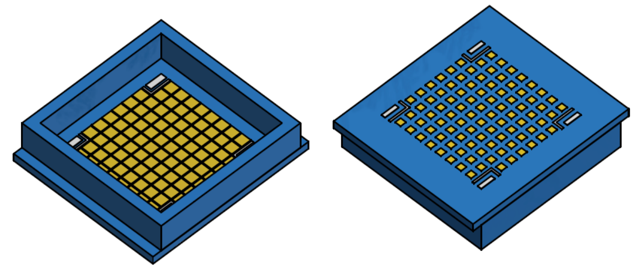


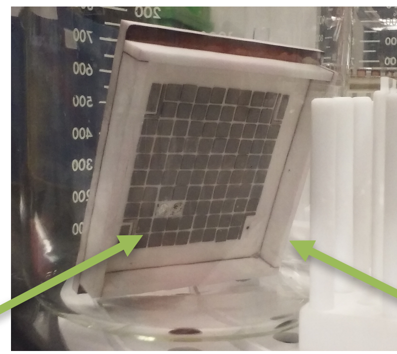
- HV at 96% of max. value.
- Standard HV distribution.
- μ: average number of photoelectrons. normalized to number of pedestals, aka *efficiency*
- Sensor orientation affects efficiency significantly.
- Loss at higher θ could be due to phe loss between photocathode and first MCP.
- Should be improved by increasing $Hv_{cathode-MCP1}$.

LAPPDs – pixelated readout

Baseline design is based on strip line readout, but EIC Cherenkov detectors (such as the DIRC) will see high rates and require pixelated pad readout

A new Cu pad and ceramic housing and thru-ceramic vias was designed w/ Innosys





Unfortunately, the pixelated design with VIAs failed due to technical difficulties

Current effort and FY 18 plan on pixelated readout:

Innoysys Inc. is making a second attempt to provide a new pad tile.

Meanwhile, we shifted our effort to pixelated readout detector through capacitive coupling design:

- The lower glass is coated with resistive ALD layer, 10kΩ
- Pad sizes are directly designed on the electronic board
- *Needs validation for Cherenkov applications*