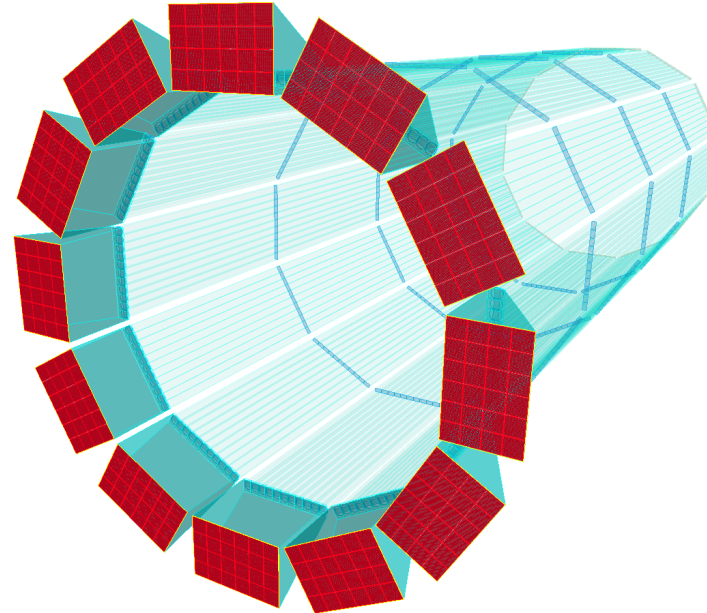


eRD103: THE HIGH-PERFORMANCE DIRC

Directed R&D Program to Mitigate Key Risks for the ePIC DIRC Detector

- hpDIRC overview
- FY24 progress
- hpDIRC Prototype in CRT
- BaBar DIRC bars reuse



Greg Kalicy  CUA

March 25th, 2024

eRD103 hpDIRC Group

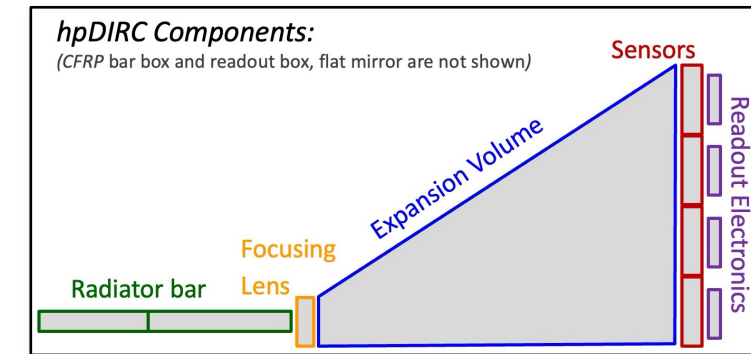
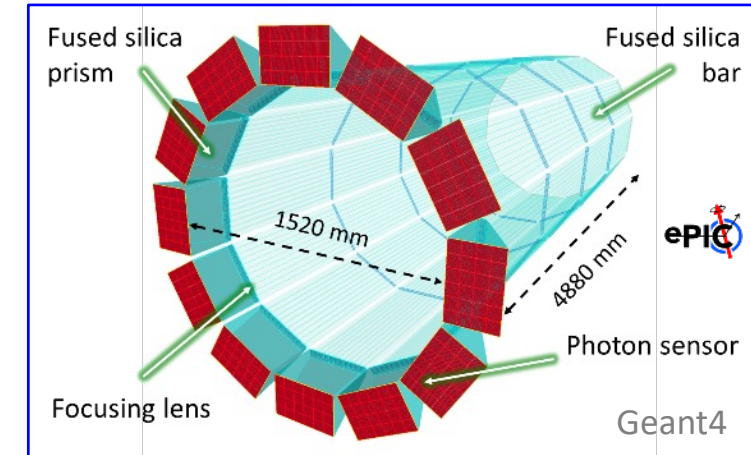
C. Ayerbe Gayoso, J. Datta, K. Dehmelt, A. Deshpande, R. Dzhygadlo, A. Garrett,
Y. Ilieva, C. Hyde, G. Kalicy, A. Lehmann, P. Nadel-Turonski, K. Peters,
C. Schwarz, J. Schwiening, N. Shankman, N. Wickramaarachchi



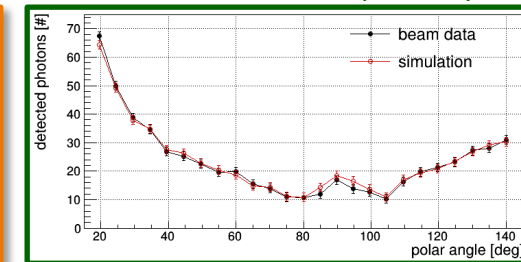
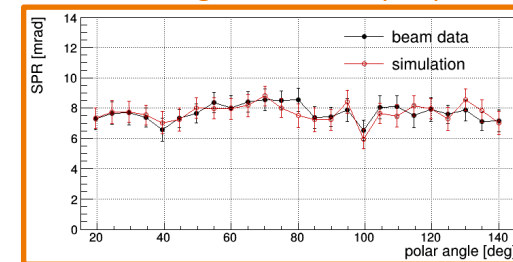
HPDIRC OVERVIEW

Compact fused silica prisms, narrow bars, 3-layer spherical lenses

- Barrel radius: 762 mm, 12 sectors, 10 long bars per sector
- Reuse bars from decommissioned BABAR DIRC, supplemented by new bars/plates
- Focusing optics: innovative radiation-hard 3-layer spherical lens
- Compact expansion volume: 30 cm-deep solid fused silica prism
- Readout system:
 - Small-pixel MCP-PMT sensors (~3 mm pixel pitch, e.g. Photek or Incom)
 - Fast ASIC-based readout (e.g. EICROC or FCFD)
- Full Geant4 simulation based on validated PANDA Barrel DIRC code is base for all hpDIRC simulation studies
(joint EIC/PANDA CERN beam tests 2015-2018)
- Preparation towards TDR readiness
 - Several key decisions to be made this summer/fall



Beam data/simulation comparison for 2018 CERN beam test
Cherenkov angle resolution per photon photon yield



HPDIRC R&D HIGHLIGHTS

hpDIRC prototype in Cosmic Ray Telescope (CRT):

- CRT to become test bench for incremental upgrades of new components (bars, sensors, readout electronics, eventually full hpDIRC modules)
- Setting up of CRT at SBU is progressing with initial DIRC prototype to be commissioned in the summer of 2024

hpDIRC prototype at SBU



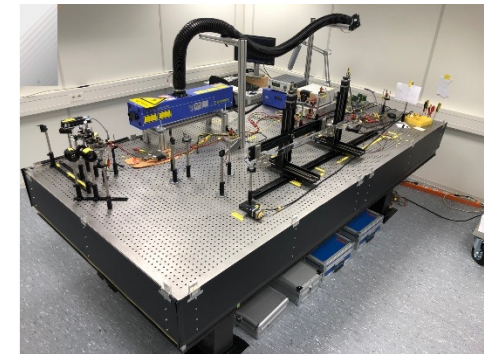
Validation of the BaBar DIRC bar reuse:

- Bar boxes transfer from SLAC to JLab starts next week
- Disassembly and QA at JLab (Q3/Q4 2024)
- Decision on reuse of bars expected by Q4/2024

BaBar DIRC bars



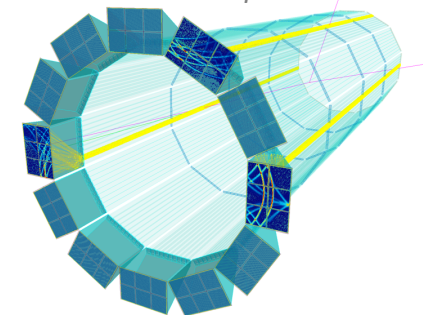
Laser lab at GSI



hpDIRC studies in simulation:

- Study of the hpDIRC performance with physical events and magnetic field
- CRT optimization and preparation for running done with hpDIRC simulation package
- Impact of measured BaBar bars optical quality on hpDIRC performance after disassembly

hpDIRC



eRD103 R&D FY24 MILESTONES

Milestones: (proposal schedule)

- Evaluated initial hpDIRC prototype with cosmic rays (CUA/GSI/SBU, Q1/2024)
- Cherenkov Tagger finished and integrated in CRT (CUA/ODU, Q1-Q2/2024)
- Commissioning of full CRT setup completed (CUA/ODU/SBU, Q1-Q2/2024)
- Functional hpDIRC prototype with single bar (CUA/SBU Q3/2024)
- Upgraded hpDIRC setup with two bars and radiation hard 3-layer lenses (Q4/2024)

DIRC lab and Cosmic Ray setup at SBU



eRD103 R&D FY24 MILESTONES

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Cherenkov Tagger

Tracking Station 1

Tracking Station 2

PicoSec



Tracking Station 3

FY24 activities towards CRT commissioning:

- Modular hpDIRC prototype ready for installation
- Cherenkov Tagger being finished at ODU with updated photosensor
- DAQ for tracking stations and hpDIRC prototype being integrated at SBU
- Preparation for PicoSec operation in April at CERN

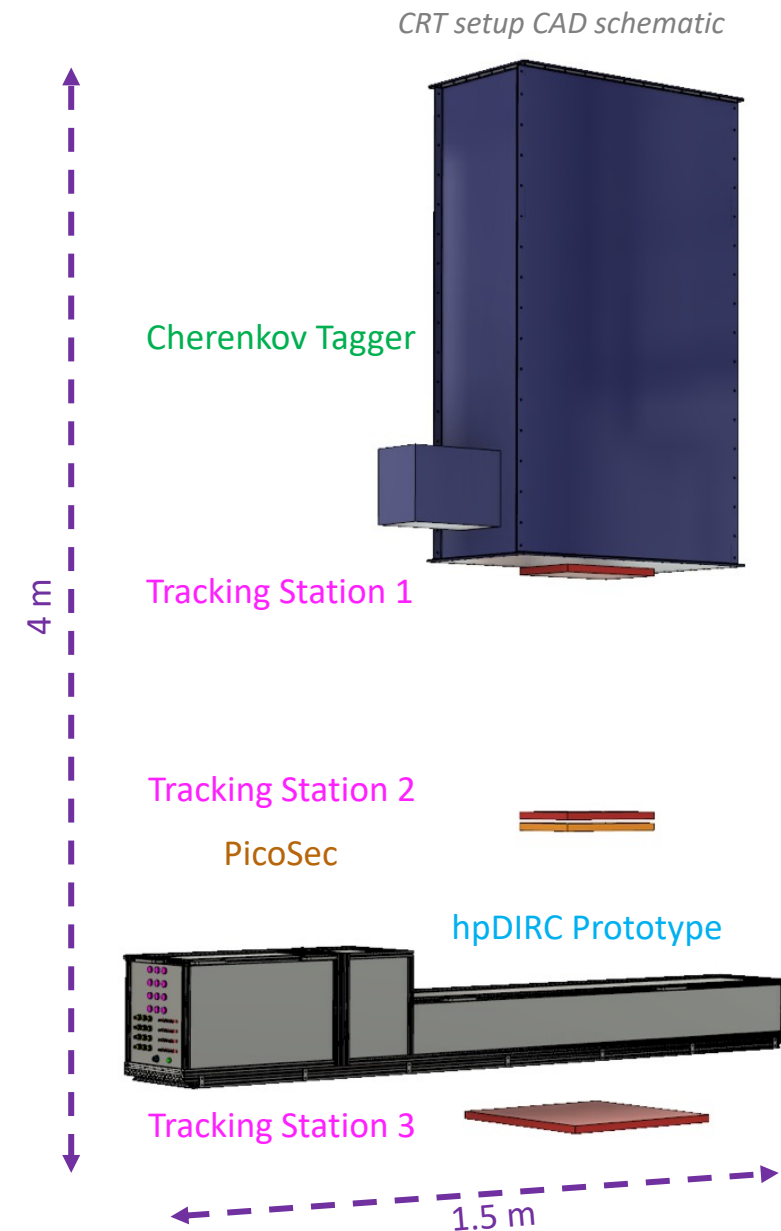


HPDIRC PROTOTYPE IN CRT

Cosmic Ray Telescope (CRT) at SBU

Facility to test incremental upgrades of prototype components, performance evaluation

- Initial **PANDA Barrel DIRC-based prototype** to commission setup
- Modular design will allow to add new ePIC hpDIRC components once they become available
- **Cherenkov Tagger** to select muons above 3.5 GeV/c
- Three **tracking stations** for high-precision 3D-track reconstruction (location optimized with simulations)
- **PicoSec detector** for event timing
- Geant4 simulation used to optimise setup arrangement



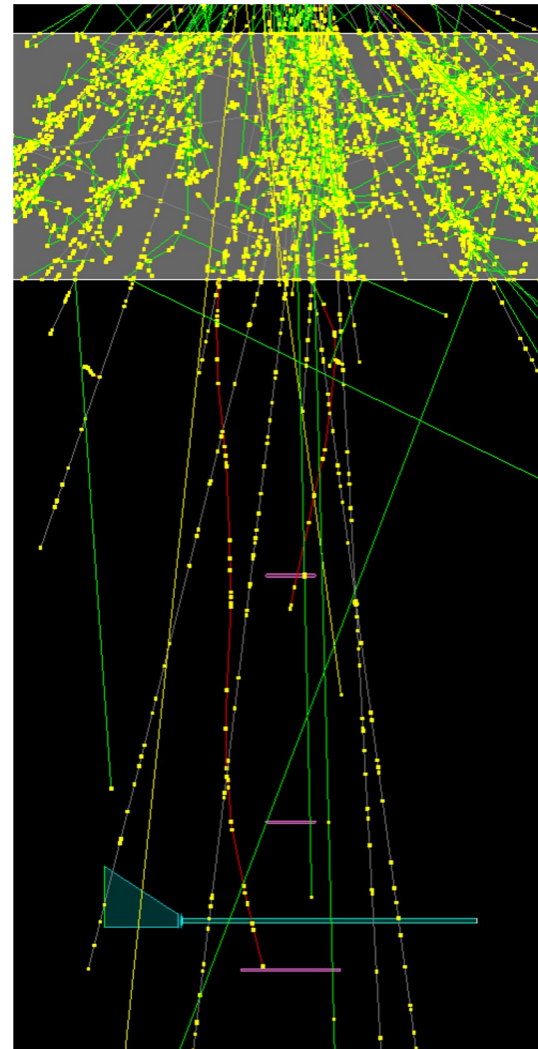
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Geant4 simulation of CRT setup



CRT setup CAD schematic



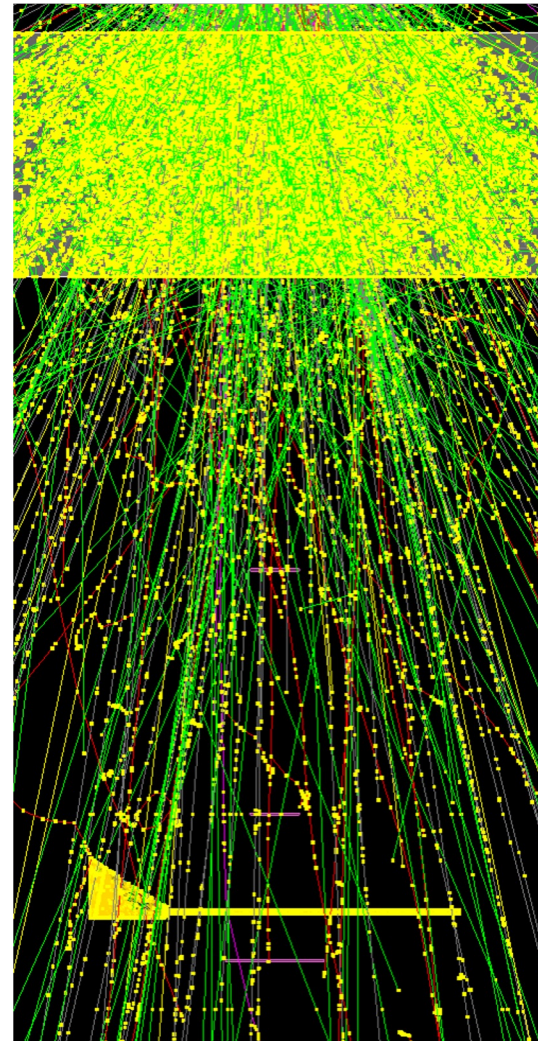
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Geant4 simulation of CRT setup



CRT setup CAD schematic



CRT DEVELOPMENT: MECHANICAL STRUCTURE

- **Support structure finished** and ready for installation of all CRT components
- Design optimized to allow usage of crane in the area to instal Cherenkov Tagger
- **Stewart platform** adapted to control position of hpDIRC prototype

Stewart platform for 3D motion of Prototype



DIRC lab/CRT support structure at SBU



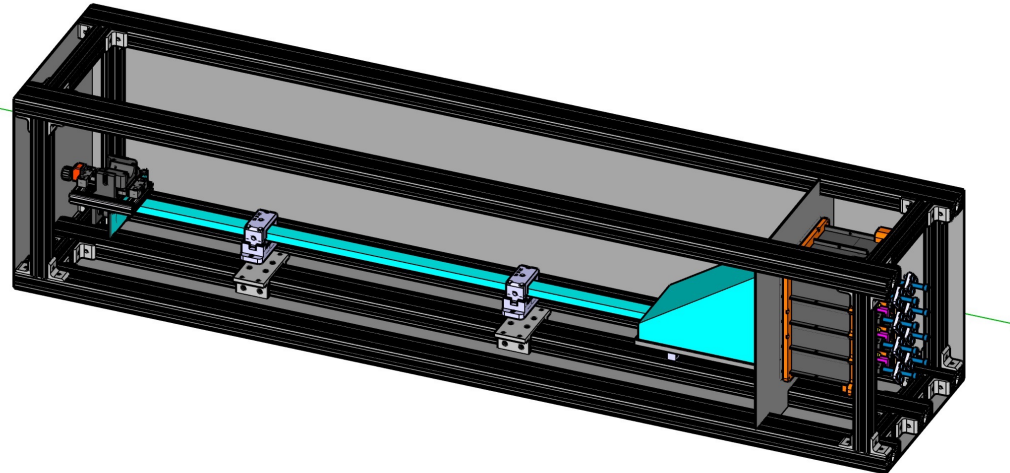
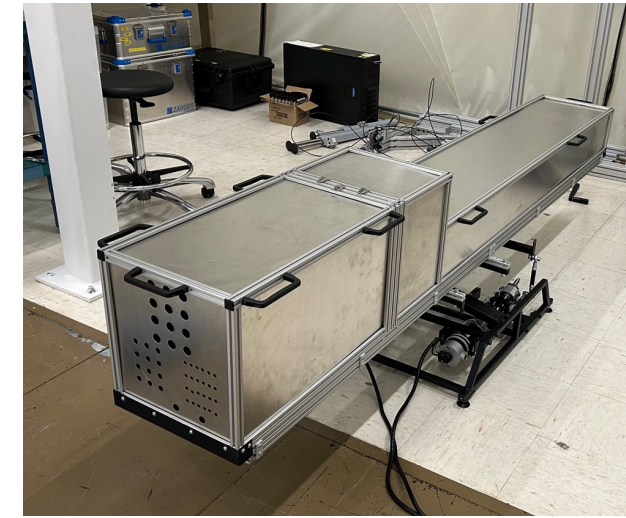
CRT setup CAD schematic



CRT DEVELOPMENT: HPDIRC PROTOTYPE

- Light-tight structure of prototype designed and built at SBU
- Bar installed on linear stage with micrometre adjustment
- Separate access to readout section with MCP-PMTs and readout electronics
- Remote motion-controlled platform adapted to select prototype position in 3D, scan hpDIRC phase space
- DAQ computer from GSI had to be replaced due to damage to multiple disks during transport to SBU

hpDIRC prototype on motion control stage



CRT DEVELOPMENT: TRACKING AND TIMING

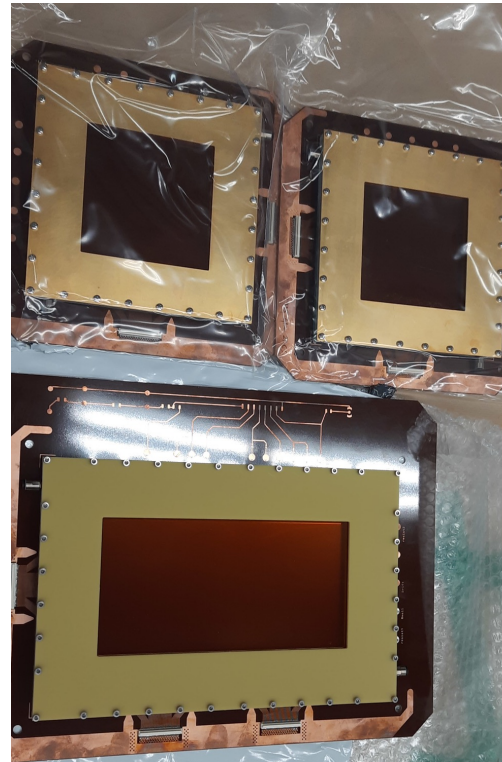
➤ Tracking

- Two μ RWELL stations (10 cm x 20 cm)
- One GEM tracker (50 cm x 50 cm)
- Each layer will measure the position of a cosmic particle with a spatial precision of about 60–70 μ m
- Tested in recent test beam in CERN
- DAQ tests and integration with DIRC prototype DAQ are in progress

➤ Event Timing

- PicoSec prototype will be obtained from CERN
- Readout ordered
- SBU expert will join CERN test beam in April to get familiar with operating procedure

Two μ RWELL and GEM tracking stations



DAQ test setup at SBU



CRT DEVELOPMENT: CHERENKOV TAGGER

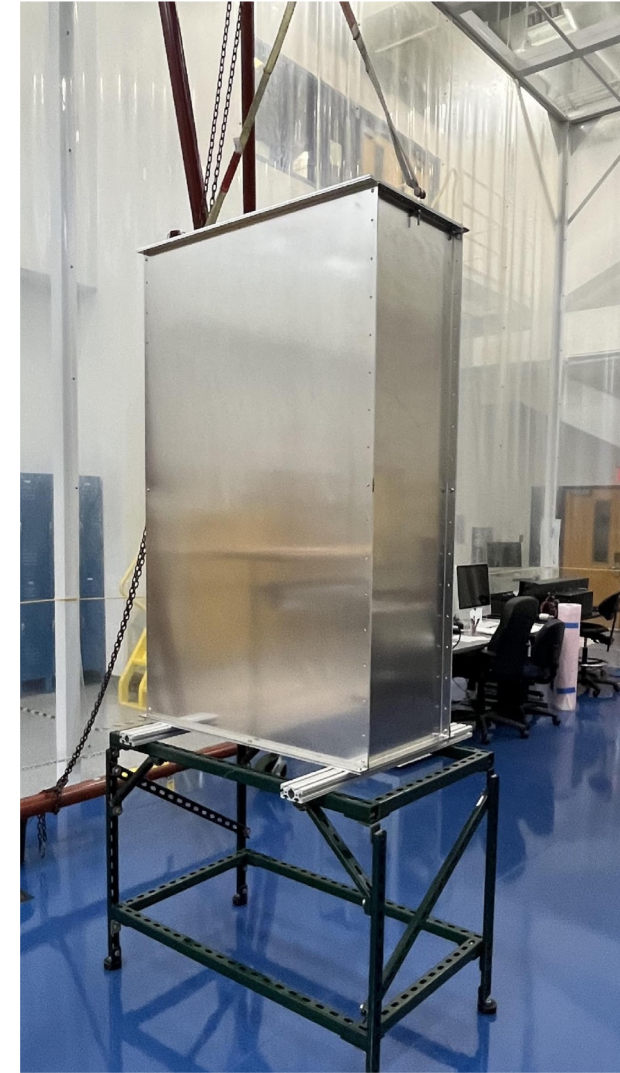
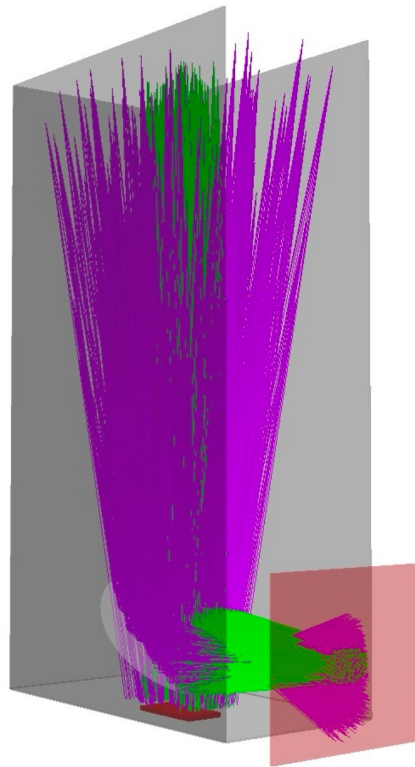
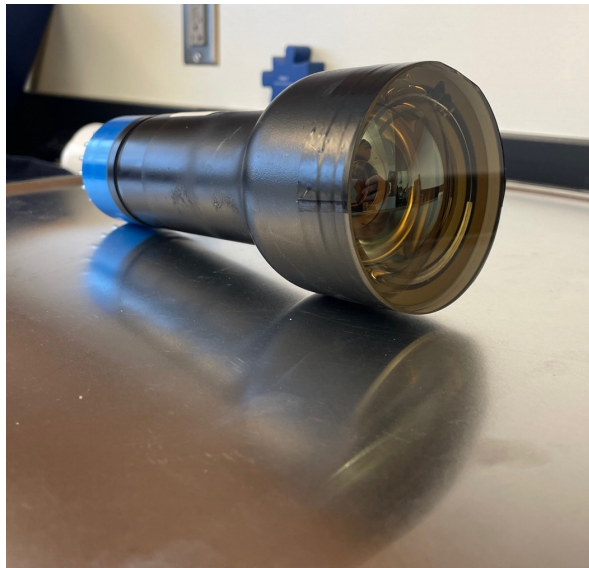
- Cherenkov tagger is being developed and constructed at ODU
(C. Hyde, C. Ayerbe Gayoso, A. Garrett)
- Readout section and mirror are being finished and installed
- 3-inch phototube is being tested

Cherenkov tagger in construction at ODU

Cherenkov tagger in simulation

CAD drawing of Cherenkov tagger

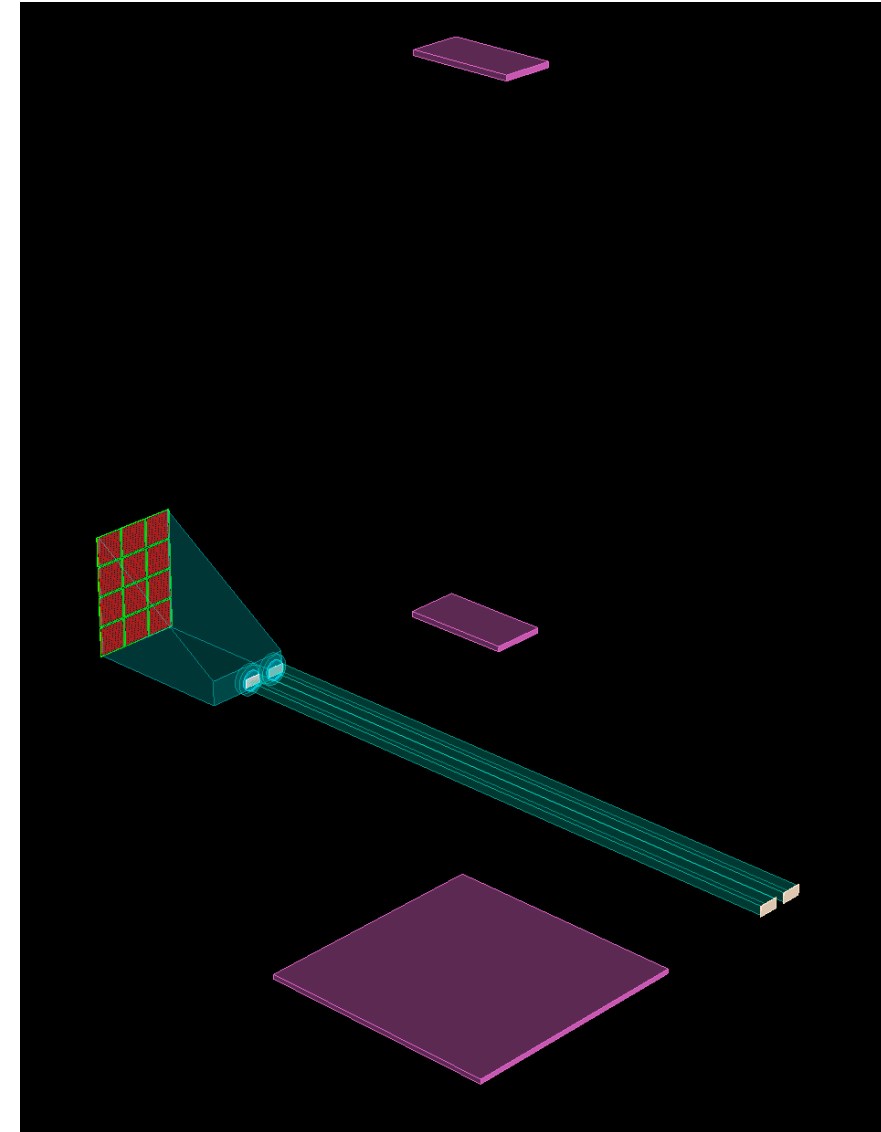
PMT



HPDIRC PROTOTYPE: PLANS FOR REMAINING FY24 AND BEYOND

- **Commissioning of full setup planned for summer 2024**
 - Initial prototype with bar from PANDA Barrel DIRC
 - Two **radiation-hard 3-layer lenses are in hand** and will be tested for the first time in prototype
- **Disassembled BaBar DIRC bars will be used once available**
- **Prototype with two bars arranged side-by-side** will enable studies of additional aspects of performance, increase statistics
- Readout box designed to allow easy addition of **small-pixel sensors** once they become available
- **Ultimate CRT goal: test of fully assembled ePIC hpDIRC modules**

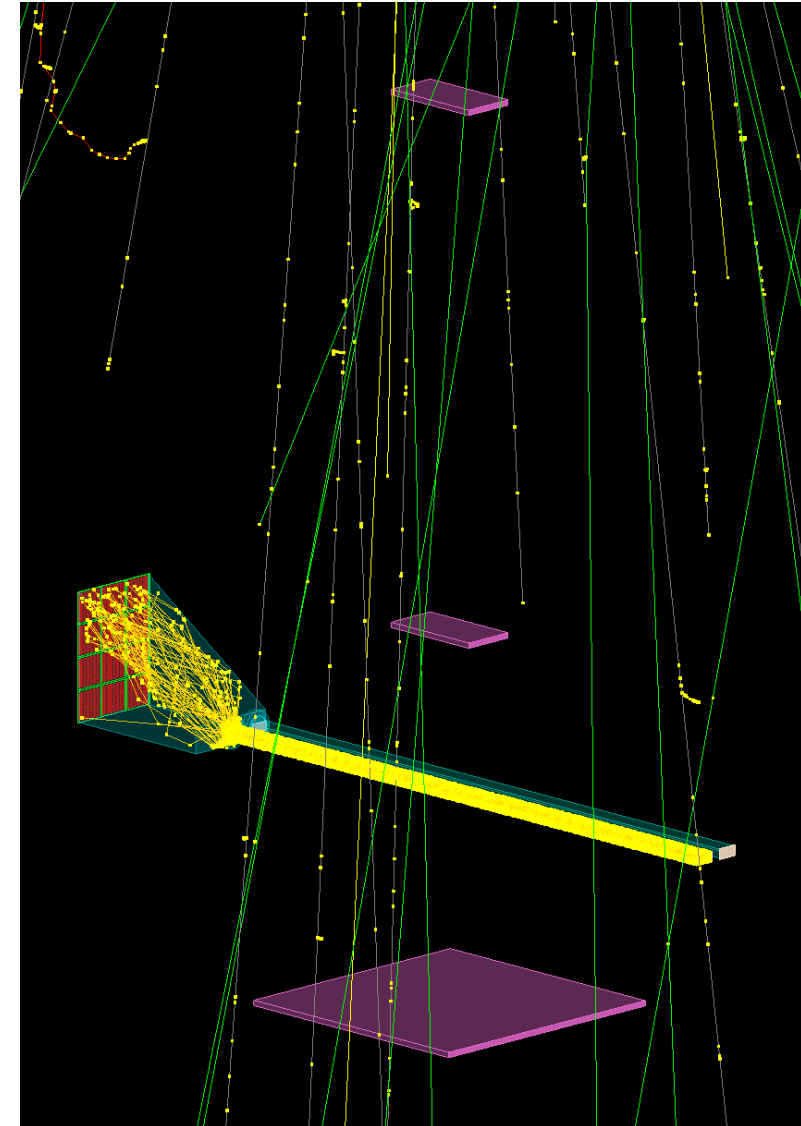
Simulation of hpDIRC Prototype with 2 bars in CRT



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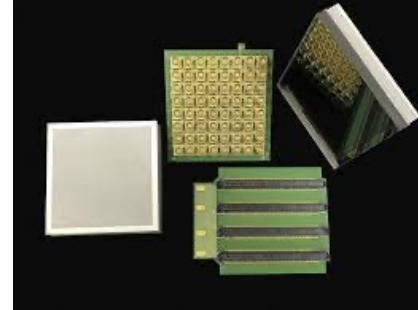
Simulation of hpDIRC Prototype with 2 bars in CRT



COMPLIMENTARY HPDIRC HARDWARE EFFORTS

- **MCP-PMT sensors:** commercial **Photek MAPMT253** (baseline) or **Incom HRPPD** (potential option)
 - Performance needs to be verified with single photons at high rates and occupancies
 - **eRD110** is coordinating test bench studies of both types of sensors
 - **HRPPDs** will be evaluated at BNL (pFRICH)
 - Preparations for **study of commercial MCP-PMT and HRPPDs in Glasgow** underway (Glasgow group, R. Montgomery et al)
- **Readout electronics:**
eRD109 is testing two options, **FCFD ASIC** with 128 channels and the **EICROC** with 1024 channels
- **Radiator bars:**
Disassembled BaBar DIRC bars will be validated on test bench in Jlab.

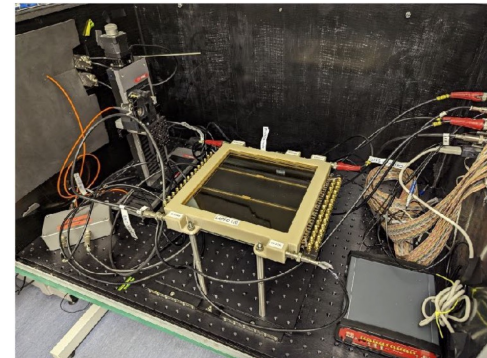
Photek MAPMT 253



INCOM Gen III HRPPD

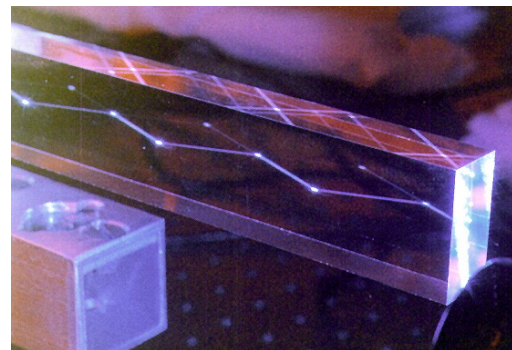
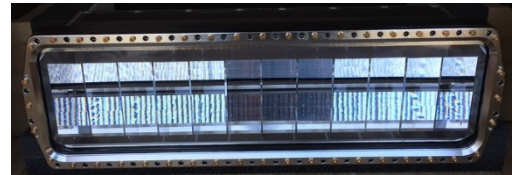


Setup at Glasgow



REUSE OF BABAR DIRC BARS

- BaBar DIRC decommissioned in 2010 SLAC/DOE made DIRC bars available for reuse
- 4 bar boxes awarded to JLab and installed as GlueX DIRC in 2018
- Remaining 8 boxes awarded to JLab for potential use in EIC DIRC
- Potentially saves up to \$10-15M in cost, reduces technical and schedule risk
- Full-size bar boxes are too long, do not fit into EIC central detector, wedges deteriorate resolution: need to disassemble bar boxes for reuse
- hpDIRC barrel requires total of 480 short bars (1-1.2 m length)
- Eight bar boxes currently located at SLAC could yield up to 384 short bars, sufficient to cover rapidity range $-1.65 \leq \eta \leq +1.65$ (360 bars needed)
- Quality of bar surfaces, 25 years after initial production and disassembly, to be verified
- Additional 120 ~80cm bars required for the light guide section, $\eta \leq -1.65$, to guide photons from BaBar DIRC bars to the lenses
- In spite of significant delays due to bureaucratic challenges, goal of decision about usability of BaBar DIRC bars for ePIC expected in time for the (pre-)TDR



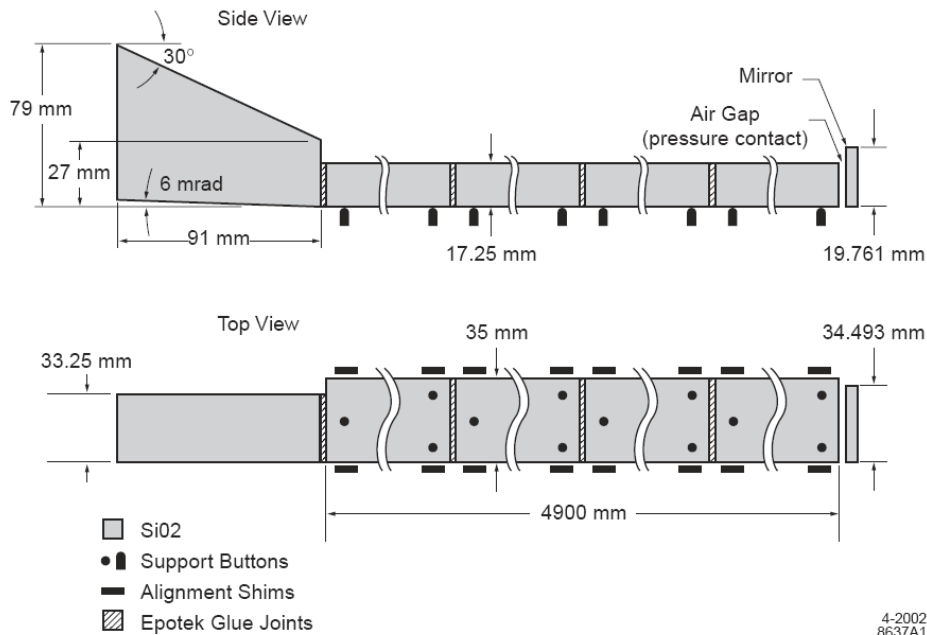
BABAR DIRC BARS

Bars were polished to $\sim 5\text{\AA}$ with non-squareness $< 0.25\text{-}0.4$ mrad

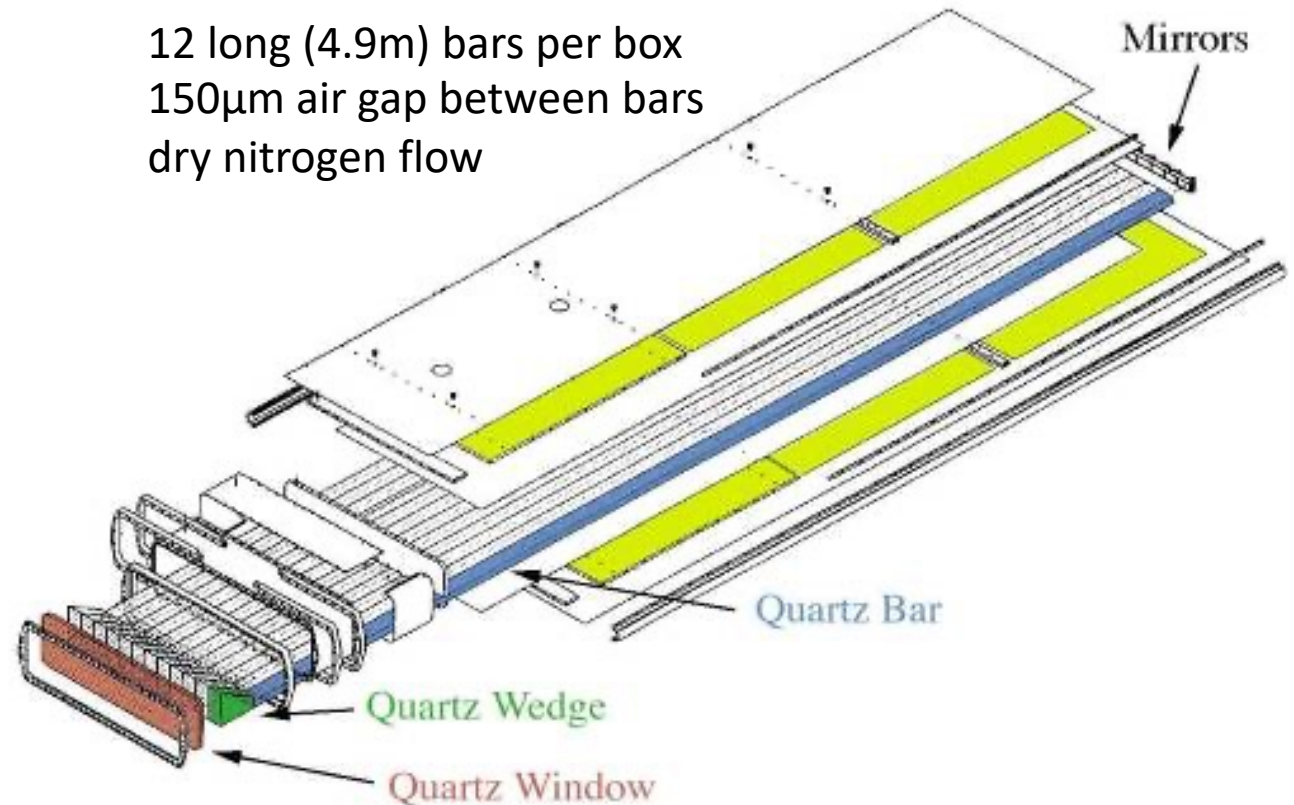
- $1\text{\AA} = 10^{-10}$ m (0.5\AA is radius of hydrogen atom)
- 1 mrad $\approx 0.06^\circ$



Long bar: 4 short (1.225m) bars
 Mirror on forward end
 Wedge on readout end

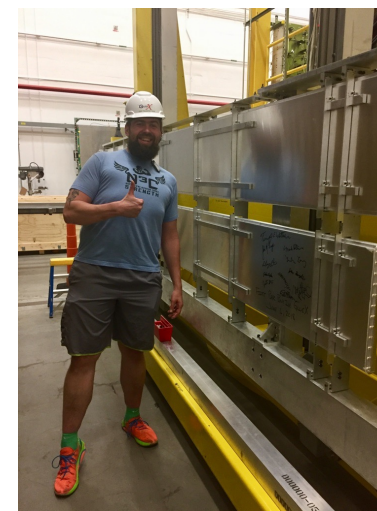
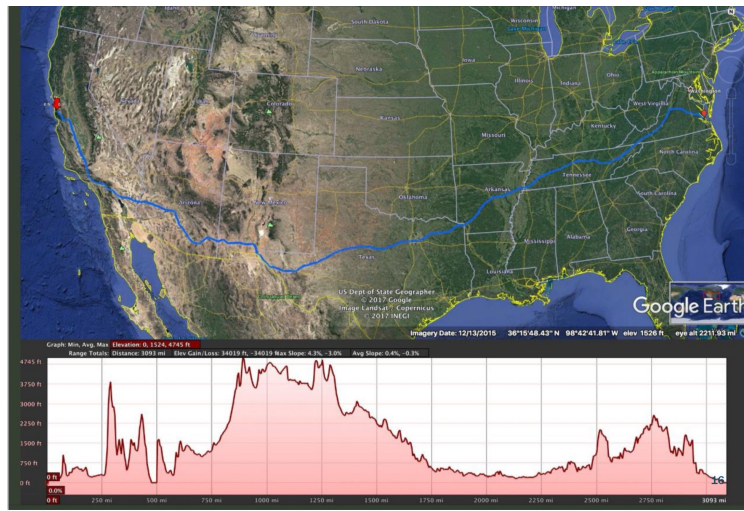
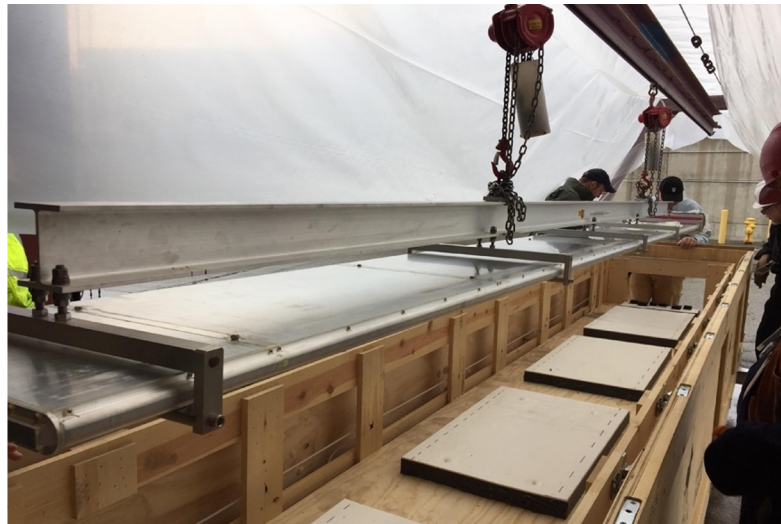


Bar box: 12 bar boxes in BABAR
 12 long (4.9m) bars per box
 150 μ m air gap between bars
 dry nitrogen flow



REUSE OF BABAR DIRC BARS

- We will use similar method as for the [successful GlueX bar box transport](#) in 2017/2018: wooden crates and shock absorption trays, air-ride and temperature-controlled trailers



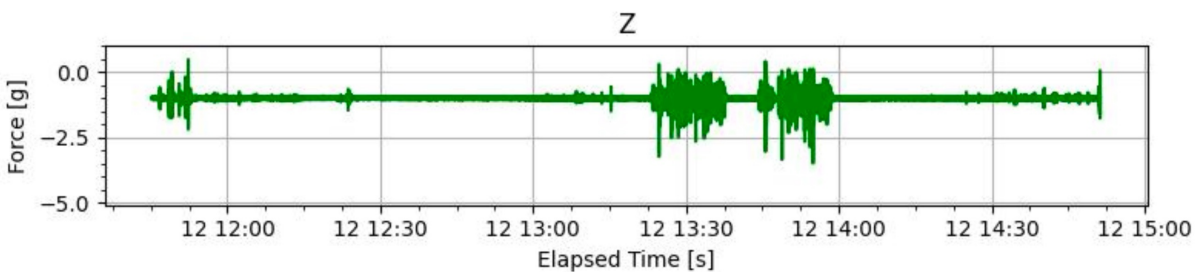
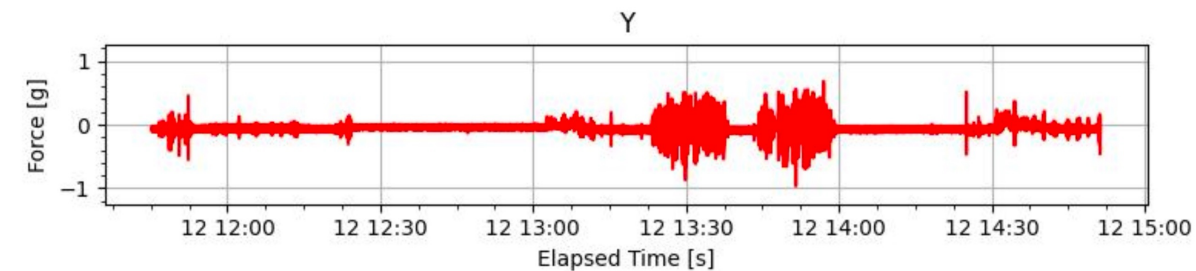
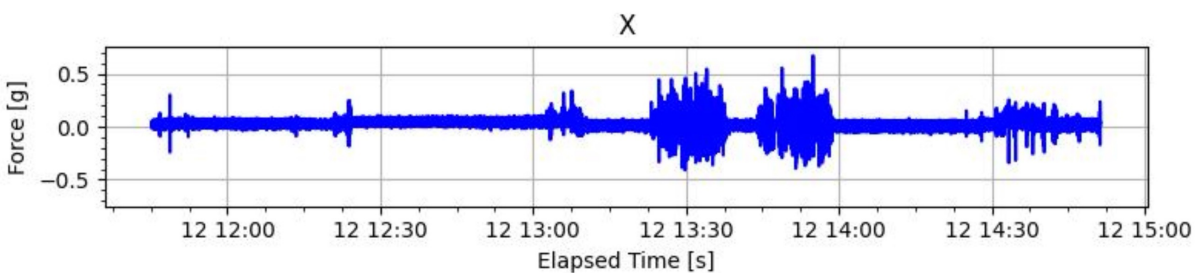
REUSE OF BABAR DIRC BARS

BaBar DIRC bar box transportation crates

- Transport of eight bar boxes from SLAC to JLab will start on April 2nd
- 2 older crates built for GlueX will be reused
- 6 new wooden crates are being tested with mock-up bar box (built for GlueX) and accelerometers



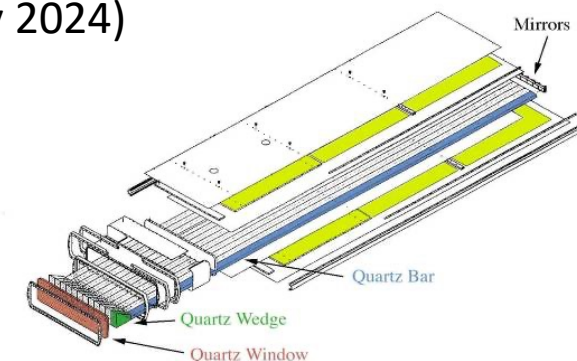
Test of completed new transportation crate with mock-up box



REUSE OF BABAR DIRC BARS

- Long bar in bar boxes will be disassembled into individual short bars at JLab (starting in May 2024)
 - Operation destructive for the bar box container
 - Never done before, working on detailed plan
 - Aluminum covers will need to be "opened", glue joints between bars dissolved
- Optical quality of bars after disassembly will be evaluated in QA DIRC lab, located next to disassembly tent
- QA DIRC lab almost ready to start test measurements
- Reference DIRC bars (never used in BaBar) from SLAC available for commissioning
- QA Lab will consist of three parts:
 - Cleaning/inspection station
 - Darkroom with laser setup to measure quality of DIRC bars
 - Storage (long and short-term)
- Reflection coefficient measurement to evaluate surface quality

Schematic of BaBar bar box



DIRC labs under construction at JLab



Bar cleaning station to the right (not visible on photo)

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Laser Lab at JLab (ready for operation soon)



PANDA DIRC bar in GSI laser lab

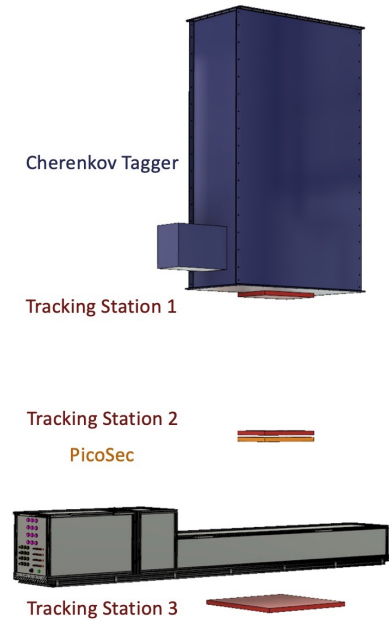


eRD103 R&D FY24 MILESTONES

Milestones:

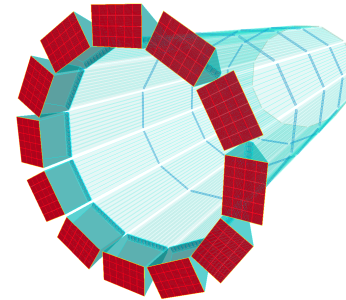
- Evaluated **initial hpDIRC prototype with cosmic rays** (CUA/GSI/SBU, Q3/2024)
 - **hpDIRC prototype ready for installation**
- **Cherenkov Tagger** finished and integrated in CRT (CUA/ODU, Q2-Q3/2024)
 - **Testing of replacement PMT and finishing of mechanical details in progress**
- **Commissioning of full CRT setup** completed (CUA/ODU/SBU, Q3-Q4/2024)
 - **CRT mechanical support structure ready**
 - **Integration of DAQs and commissioning of tracking on test bench in progress**
 - **Acquiring of PicoSec and training of operation arranged**
- **Functional hpDIRC prototype with single bar** (CUA/SBU, Q3-Q4 2024)
- **Upgraded hpDIRC setup with two bars and radiation hard 3-layer lenses** (Q4/2024-FY25)

DIRC lab and Cosmic Ray setup at SBU



SUMMARY/OUTLOOK

- Important eRD103 progress in 2024, on track to meet declared milestones with slight delay
- hpDIRC Prototype at Cosmic ray telescope (CRT):
 - Tracking, event timing, Cherenkov tagger and DAQ are being completed and tested with the goal of installation and commissioning in the summer of 2024
 - Preparing the way for future incremental upgrade of the hpDIRC prototype when bars, sensors, and readout electronics become available
 - The ultimate goal for CRT to test the full hpDIRC module is well-aligned with ePIC schedule
- Validation of BaBar bars reuse option, and completion of cost-optimized hpDIRC design expected by the fall of 2024 (new bars backup solution fits into ePIC schedule)
- eRD103 program fits roadmap towards readiness for the TDR and, ultimately, hpDIRC construction



hpDIRC Prototype at SBU



Transportation crates

