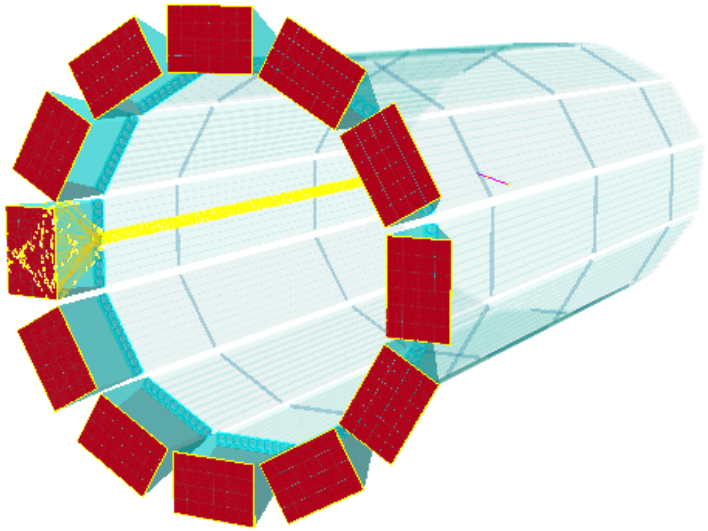
STATUS OF THE HIGH-PERFORMANCE DIRC



Nilanga Wickramaarachchi
on behalf of the EIC DIRC group

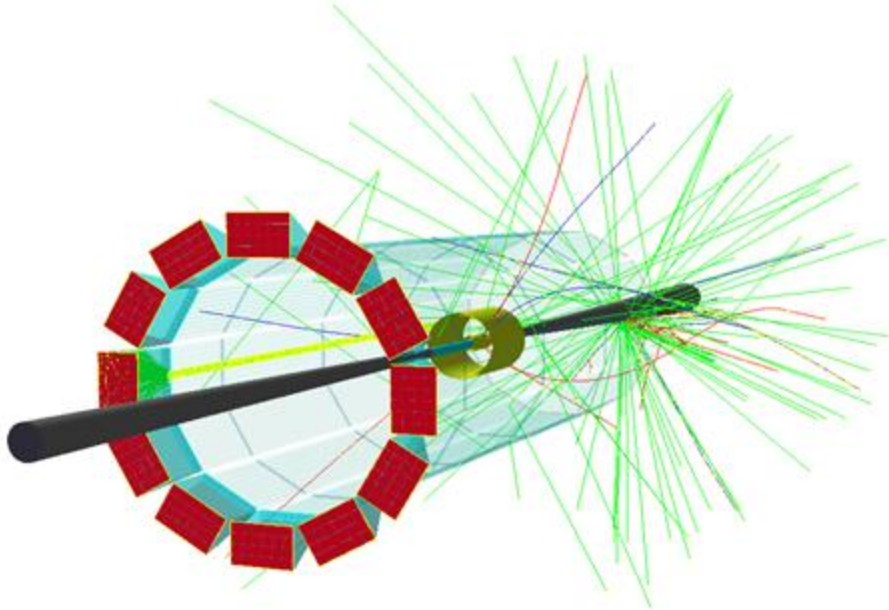
ePIC Collaboration Meeting

01/10/2023

THE CATHOLIC UNIVERSITY OF AMERICA

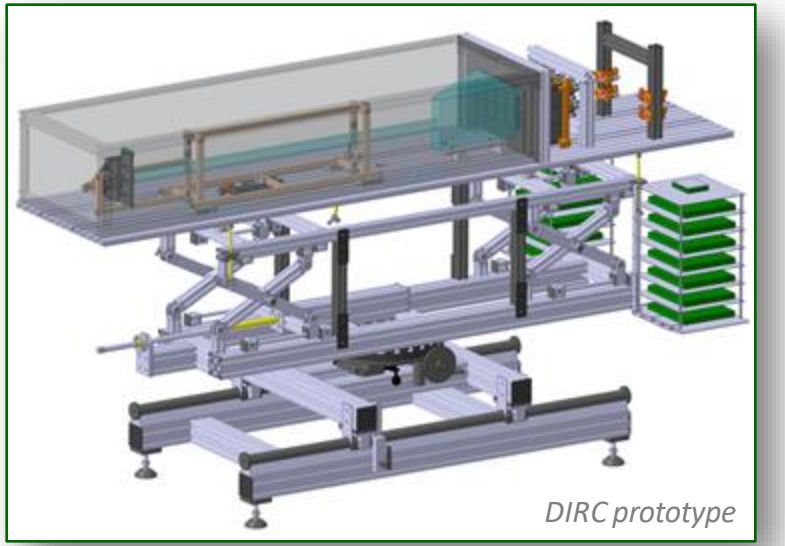
OUTLINE

- hpDIRC overview
- Roadmap towards TDR readiness
- Recent highlights
- Future plans



hpDIRC in Fun4All simulation

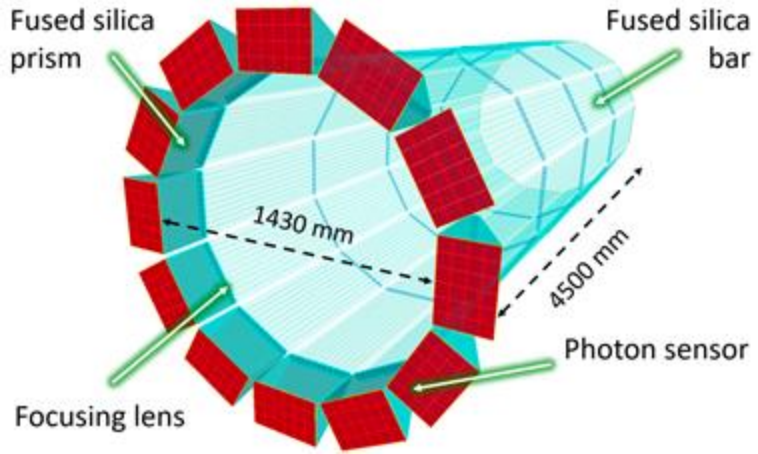
BaBar DIRC radiator bars in SLAC

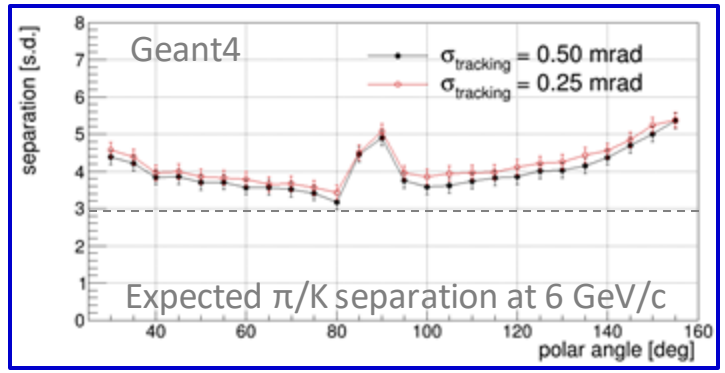


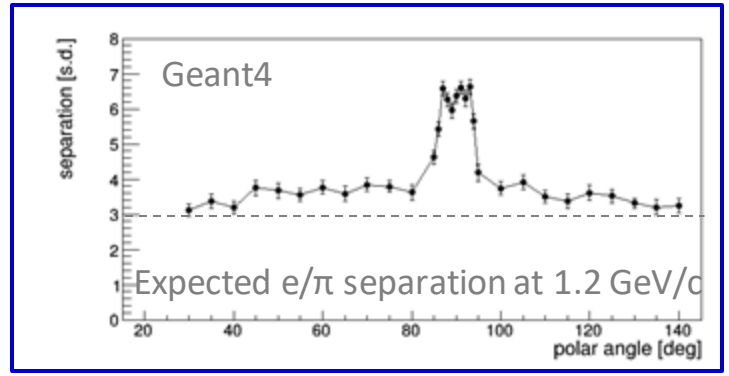
DIRC prototype

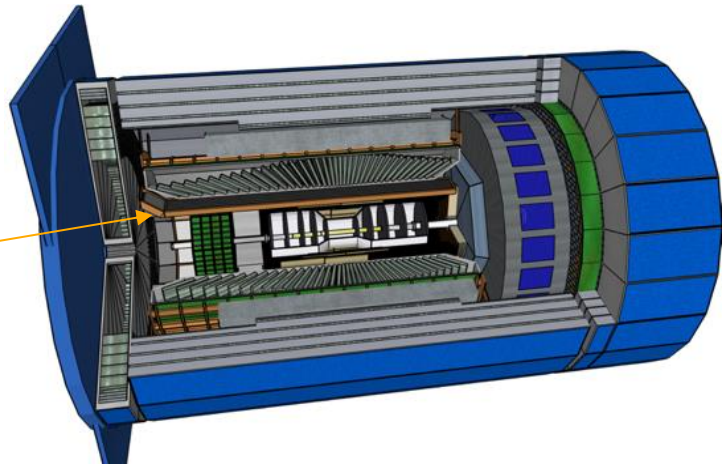
HPDIRC CONCEPT

- Fast focusing DIRC, utilizing high-resolution 3D (x,y,t) reconstruction
- Design based on BaBar DIRC, R&D for SuperB FDIRC, PANDA Barrel DIRC
- Radiator/light guide: narrow fused silica bars
- Innovative 3-layer spherical lenses
- Compact fused silica prisms as expansion volumes
- Fast photon detection using small-pixel MCP-PMTs and high-density readout electronics
- Detailed Geant4 simulation: ≥ 3 s.d. π/K separation at 6 GeV/c





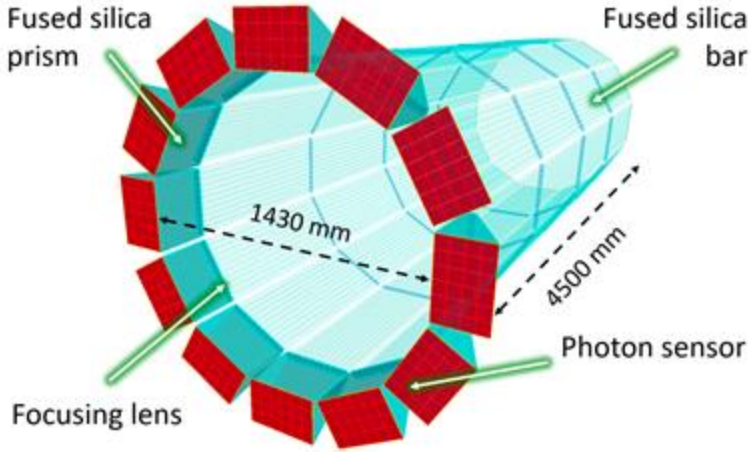




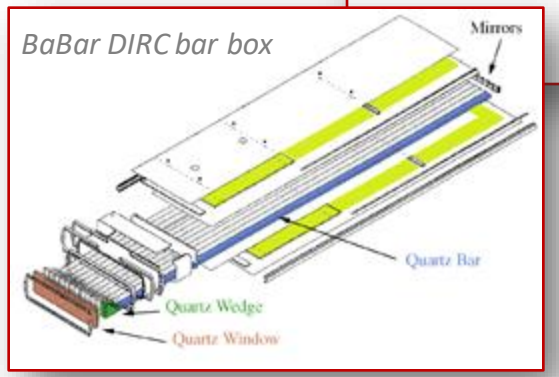
R&D PRIORITIES

hpDIRC is the baseline hadronic barrel PID system for ePIC

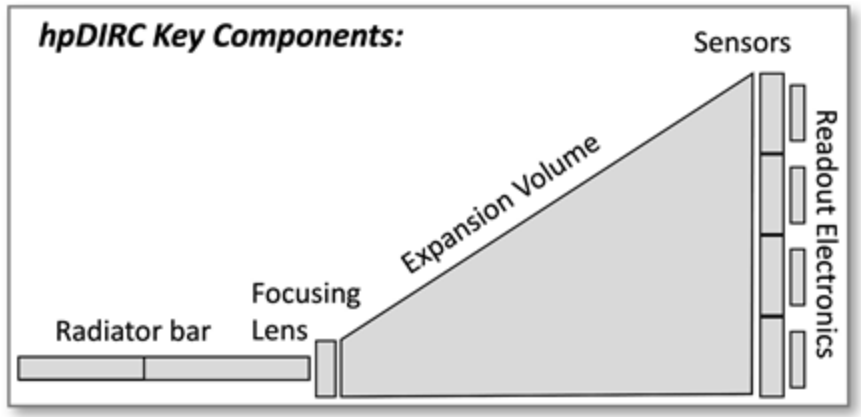
- Design advanced, key elements validated with particle beams
- Important R&D remains
  - Reuse of BaBar DIRC bars (transport, disassembly and validation)
  - Simulation studies
    - hpDIRC PID baseline design validation
    - Cost/performance optimization
  - Prototype program (integration and validation of components)
- Demanding project schedule: CD-3A (1/2024), CD-2 (1/2025), CD-3 (4/2025)
- Synergies with PANDA barrel DIRC and EIC R&D programs

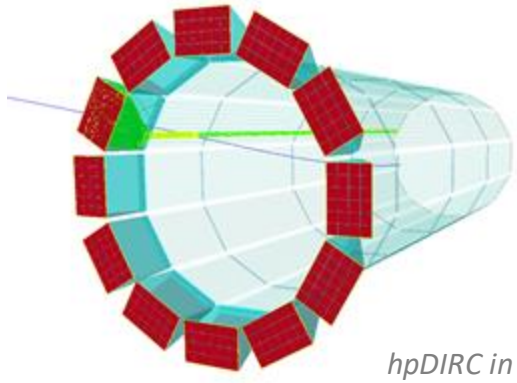


PANDA Barrel DIRC prototype



HPDIRC ROADMAP TOWARDS TDR READINESS





hpDIRC in Fun4All

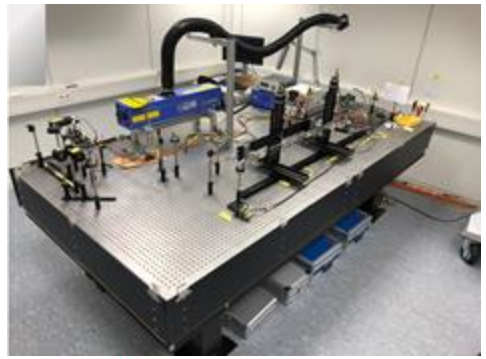
Category	Subject	Comments	Program
Design in simulation	Lightguide section	Narrow bar vs. wide plate	Generic R&D program
	Cost/performance optimization	Sensor coverage	eRD103
	Expansion volume	Geometry details	eRD103
Optics	Radiator bars	Reuse of BaBar bars	JLab DSG and CUA
	Focusing optics	Radiation-hard 3-layer lens	eRD14, eRD103
Readout	Sensors	Baseline identified, alternatives being studied	eRD14, eRD110, Incom SBIR, eRD103
	Readout electronics	UH/Nalu solution based on Belle II TOP	Nalu and Incom SBIRs, eRD109, eRD103
Construction	Mechanical design	Materials and integration	Synergy with PANDA Barrel DIRC

Recent Highlights

- Validation of the BaBar DIRC bar reuse (JLab support):
  - Build and commission QA laser setup to measure mechanical and optical quality of the bars

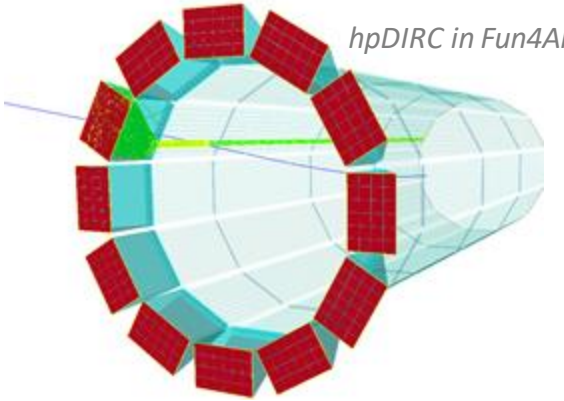
BaBar DIRC bars

Laser lab in GSI



- hpDIRC studies in simulation:
  - Implementation and validation of the hpDIRC in the full ePIC simulation
  - Initial study of the hpDIRC performance with background and magnetic field
  - Set up study of post hpDIRC tracking layer impact on performance

hpDIRC in Fun4All



- hpDIRC prototype:
  - Start of simulation studies of hpDIRC prototype with cosmic rays

CRT space at SBU

REUSE OF BABAR DIRC BARS

- BaBar DIRC decommissioned in 2010, SLAC/DOE made DIRC bars available for reuse, 4 bar boxes awarded to JLab GlueX DIRC, remaining 8 boxes awarded for potential use in EIC

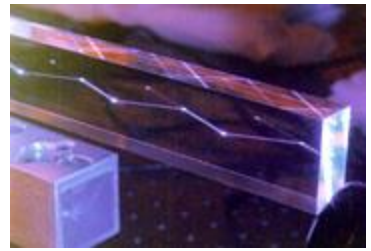
- Potentially saves up to $5M-10M in cost, reduces technical and schedule risk

- Full-size bar boxes are too long, do not fit into EIC central detector, wedges deteriorate resolution: need to disassemble bar boxes for reuse

- Eight bar boxes located at SLAC

  Four additional unmodified bar boxes already at JLab for GlueX DIRC since 2018, potentially available

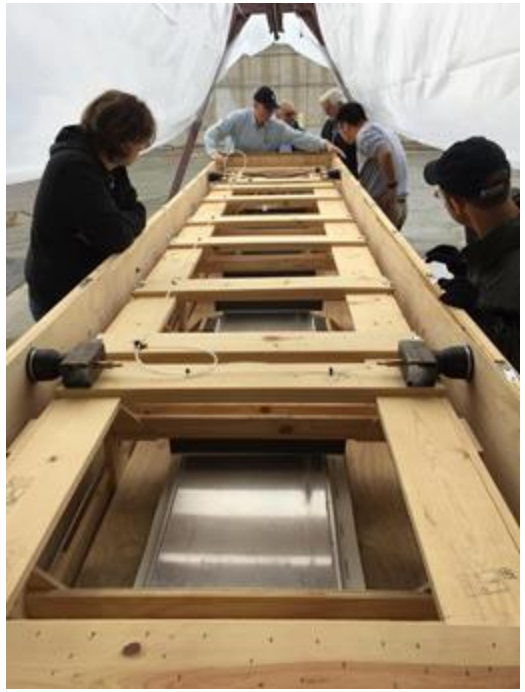
BaBar DIRC bar boxes in SLAC



BaBar DIRC Bar Box Transport

- Preparing transport of eight intact bar boxes from SLAC to JLab for disassembly at JLab, will likely use a similar method (wooden crates and shock absorption trays) as for the successful GlueX bar box transport (support from M. Shepherd)
- Once transported to JLab, the bar boxes will be disassembled into individual bars

BaBar DIRC bar box transportation for GlueX

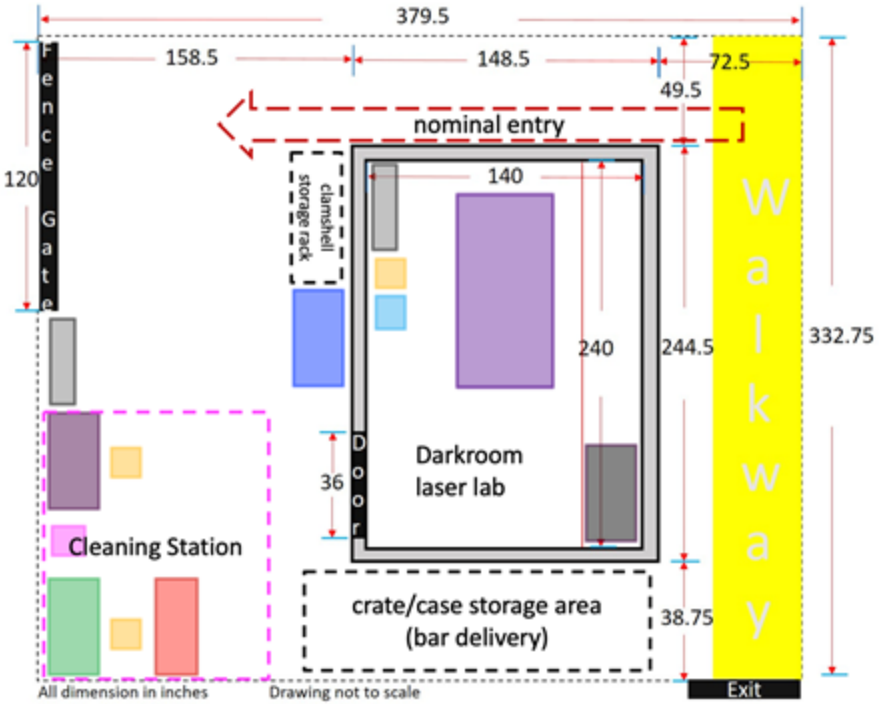


QA DIRC Lab: BaBar DIRC Bars

- Optical quality of bars will be evaluated in QA DIRC lab at JLab
- Construction of the QA Lab in advanced stage
- Sponsored by JLab and active help from Detector Support Group
- Most components already purchased and received
- Reference bars (never used in BaBar) from SLAC received for lab commissioning
- QA Lab will consist of three parts:
  - Storage (long and short-term)
  - Cleaning/inspection station
  - Darkroom with laser setup
- Reflection coefficient measurement to evaluate surface quality

DIRC QA Lab in construction at JLab

Plan of DIRC QA Lab at JLab



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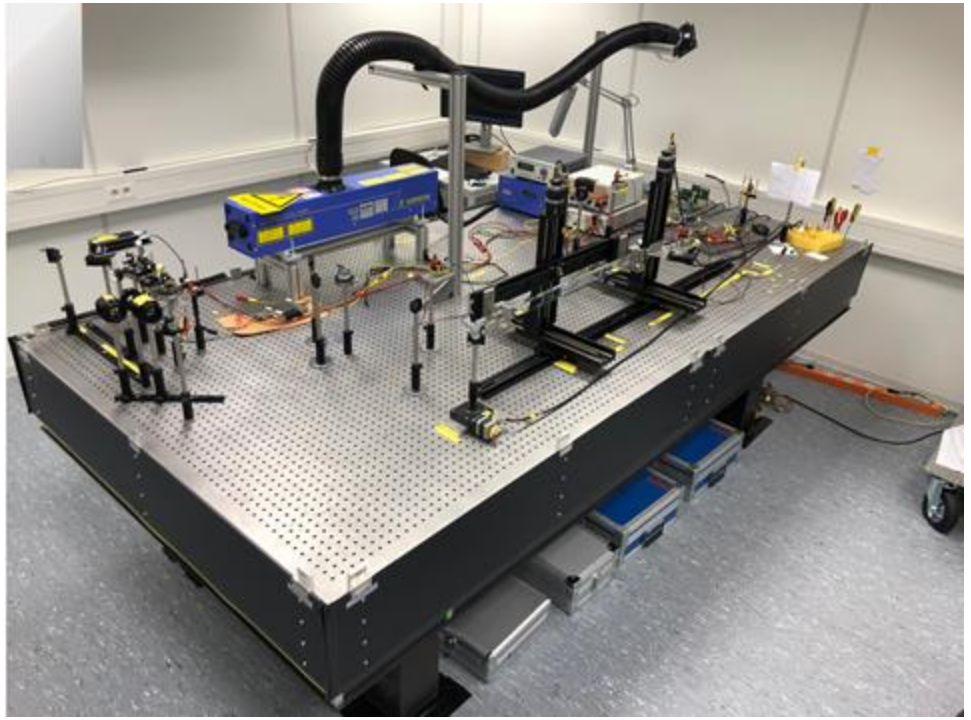
Laser lab in GSI



DIRC bar in laser lab

HPDIRC SIMULATION

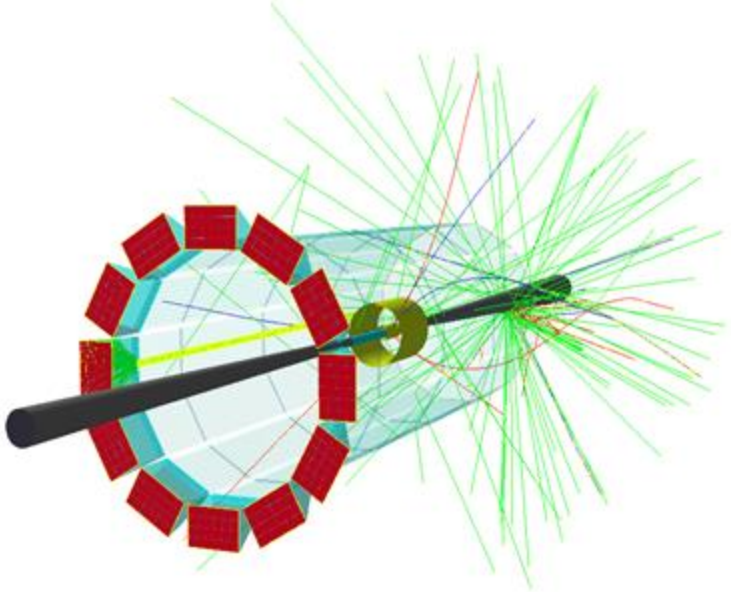
- Integration of well-established standalone G4 hpDIRC implementation into full ePIC simulation in Fun4All to enable studies of the impact of the magnetic field, multiple particles hitting one bar box or bar, and of beam background

- Realistic geometry and material properties based on prototypes, with wavelength-dependent material properties and processes with all relevant resolution terms

- Started studies with Pythia events to tackle more realistic performance

- Geometry implemented in ePIC DD4hep simulation framework (by Dmitry and Wouter), need additional workforce to help with further development (reconstruction etc.)

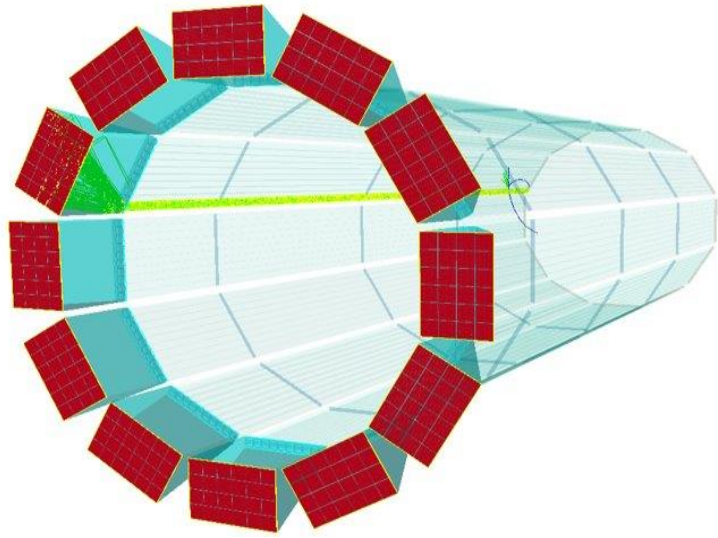
hpDIRC with Pythia event in Fun4All

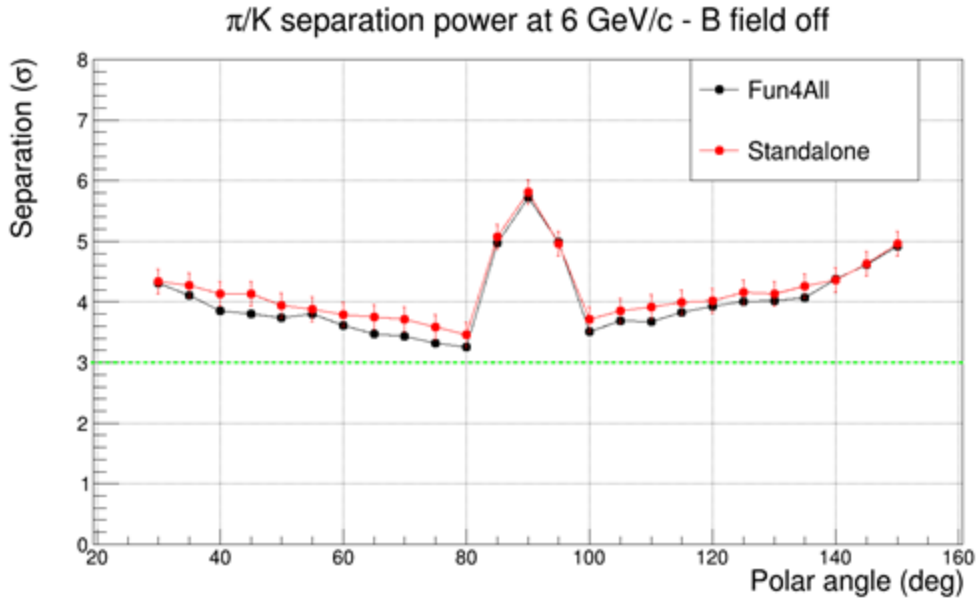


HPDIRC SIMULATION

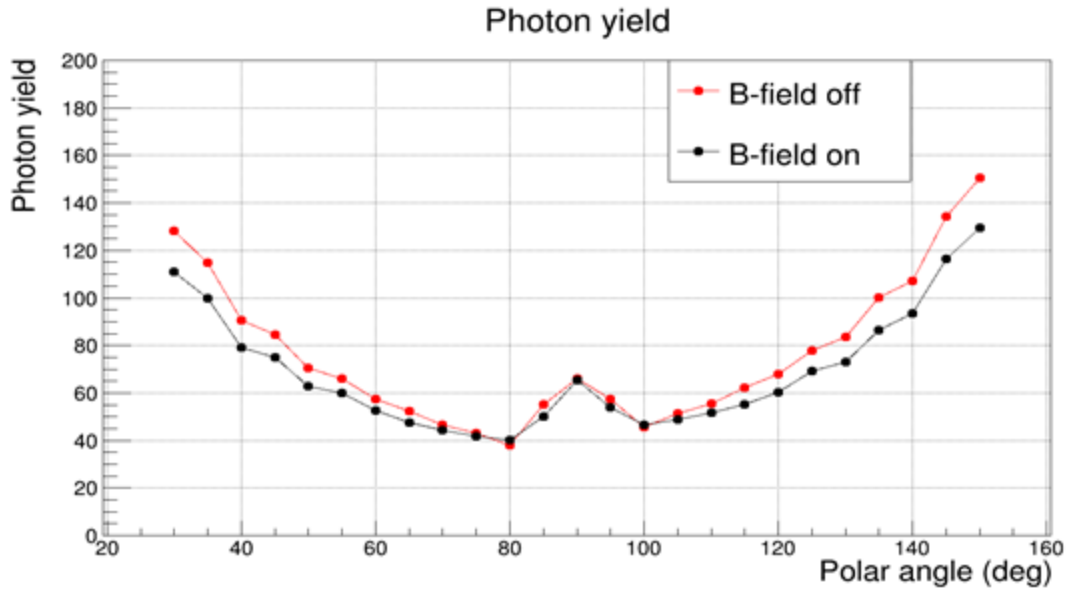
- Standalone simulation validated with test beam data results
  (joint PANDA/EIC beam test at CERN PS in 2018)
- Performance in Fun4All ePIC detector simulation matches standalone simulation results
  (small differences are due to hadronic processes in Fun4All)
- Preliminary studies on impact of magnetic field on performance

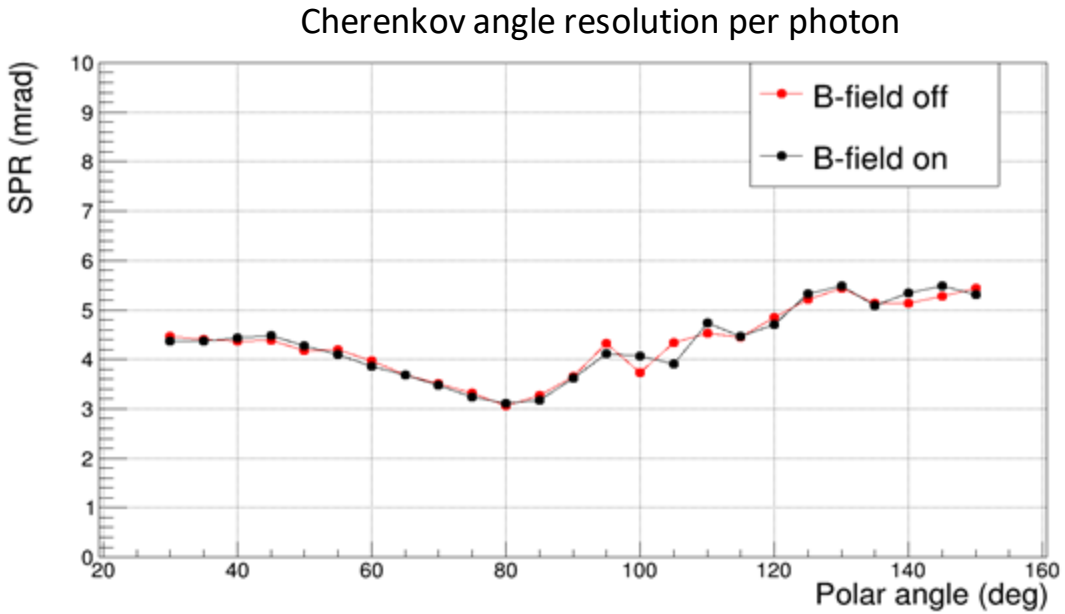
hpDIRC single track simulation in Fun4All

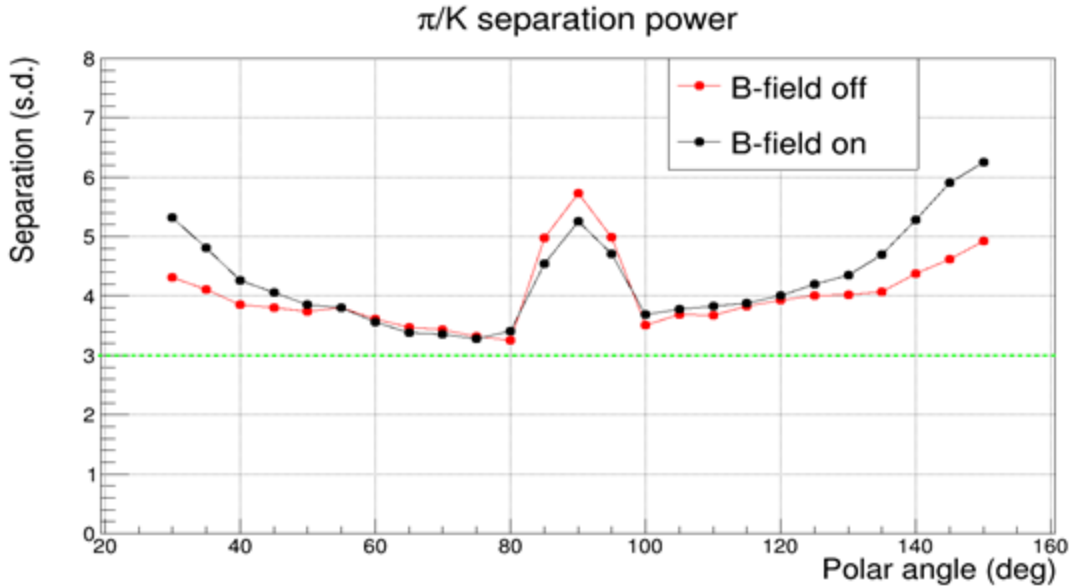




HPDIRC SIMULATION







- π^+/K^+ at 6.0 GeV/c
- 0.5 mrad track smearing
- B-field in Fun4All scaled by 1.7/1.5

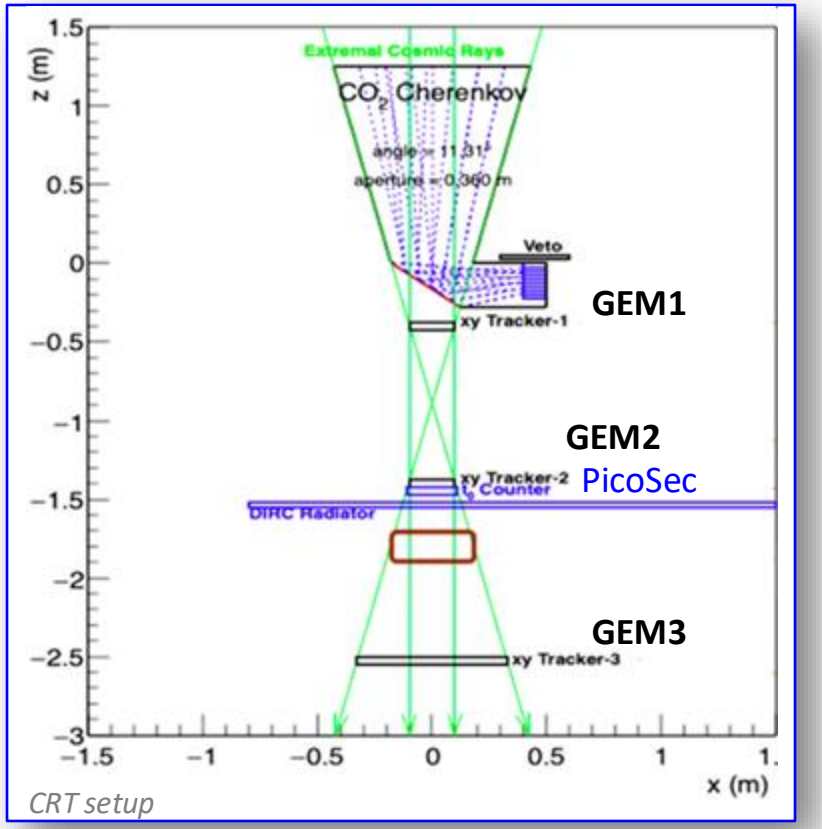
HPDIRC PROTOTYPE: DEVELOPMENT AND VALIDATION

Opportunity: Preparation of Tests of DIRC Prototype with Cosmic Rays

- Crowded beam test schedules – validate hpDIRC with cosmic muons
- Collaboration of CUA – GSI – ODU – SBU to develop cosmic ray telescope (CRT) design and measurement plan
- Work on mechanical and readout aspects of hpDIRC

Current design:

- Initial optics, sensors, electronics reused from PANDA barrel DIRC prototype (component transfer from GSI to SBU scheduled for Jan/Feb 2023)
- Momentum selection: new CO_2 Cherenkov threshold tagger ($p \geq 3.5$ GeV/c)
- 3D tracking: 3 GEM tracker stations (from sPHENIX) above and below DIRC bar
- Shower rejection: scintillator plates as veto counters
- T_0 start counter: PicoSec-Micromegas counter
- Mechanical design progressing, includes polar angle rotation and X/Y movement of bar
- Geant simulation package developed

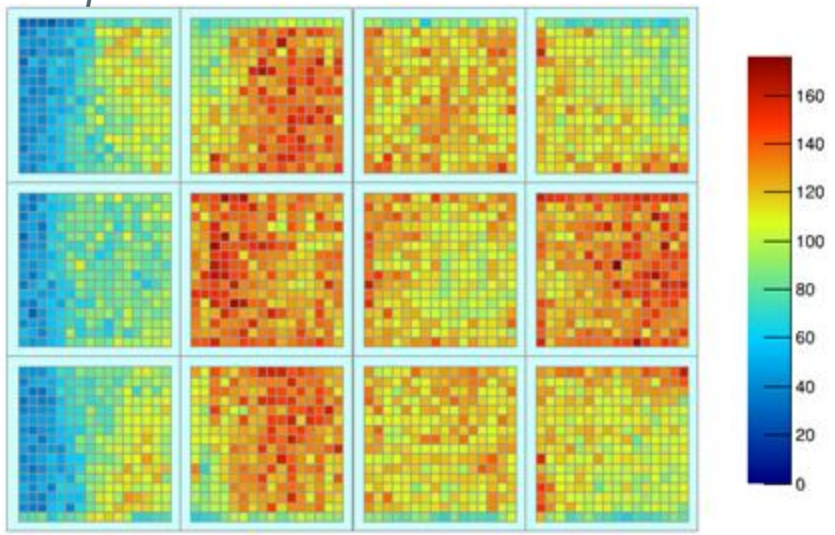


CRT setup

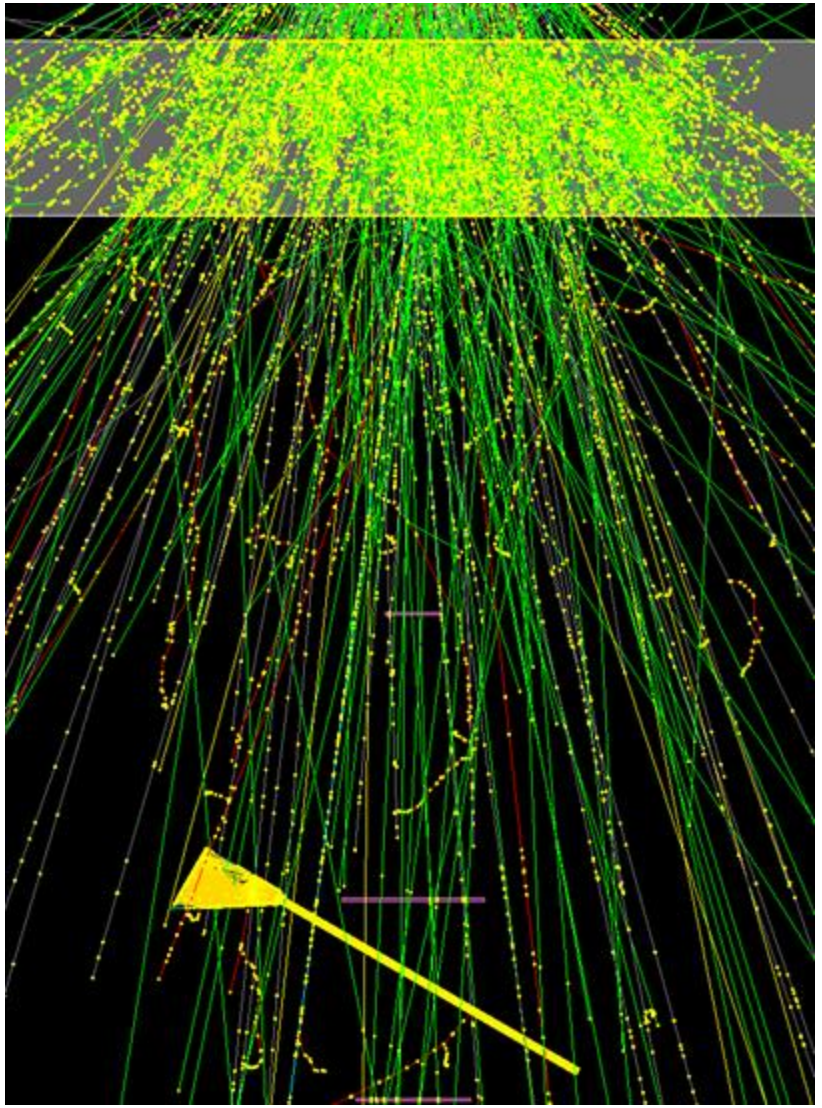
HPDIRC PROTOTYPE: SIMULATION STUDIES

- hpDIRC prototype implemented in Geant4 (CRT generator)
- Implemented tracking detectors and material budget above CRT
- The prototype is in 60° position relative to vertical axis.
- Only tracks with momenta above 3.5 GeV/c selected.
- Desired performance reached after 150 hours of collecting data.

Hit pattern accumulated over 240h



10s of hpDIRC in CRT simulation



From R. Dzhygadlo

HPDIRC PROTOTYPE: DIRC LAB AT SBU

- Space for hpDIRC Lab at SBU was recently used for construction of sPHENIX TPC detector
- Now empty and ready for CRT and hpDIRC components
- Cleanroom environment well-suited for DIRC prototype and future bar box assembly
- SBU group (K. Dehmelt et al.) committed to take the lead on future bar gluing

Space for CRT at SBU

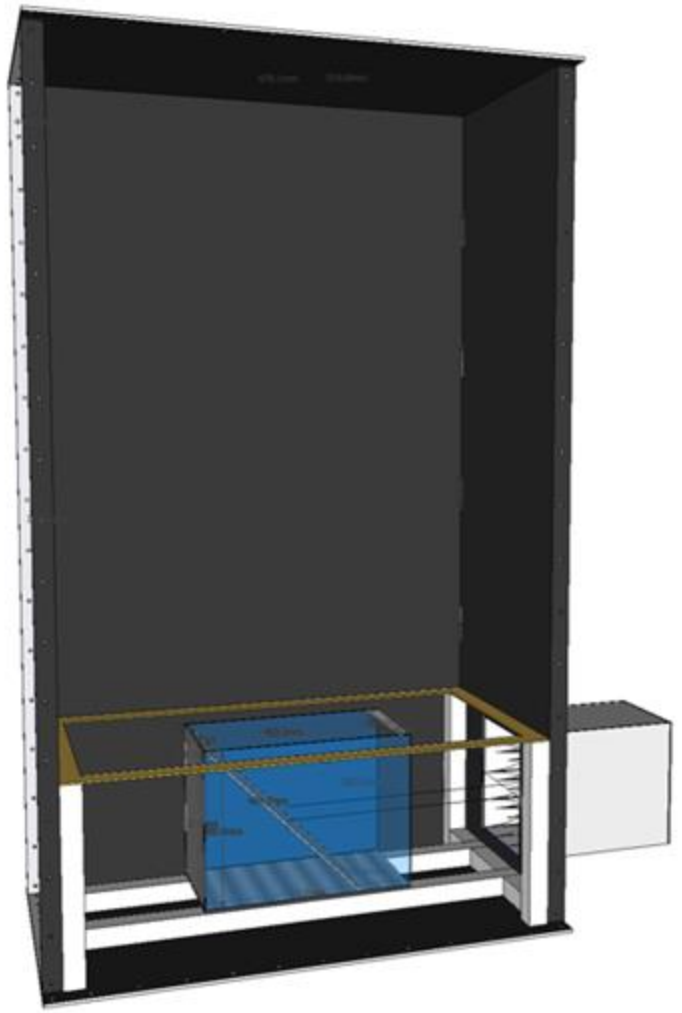
CRT Development: Cherenkov Tagger

- Cherenkov tagger is being developed and constructed at ODU (C. Hyde et al.)
- Mirror and light catcher will be coated at SBU to improve reflectivity
- Transport to SBU and installation in CRT planned soon

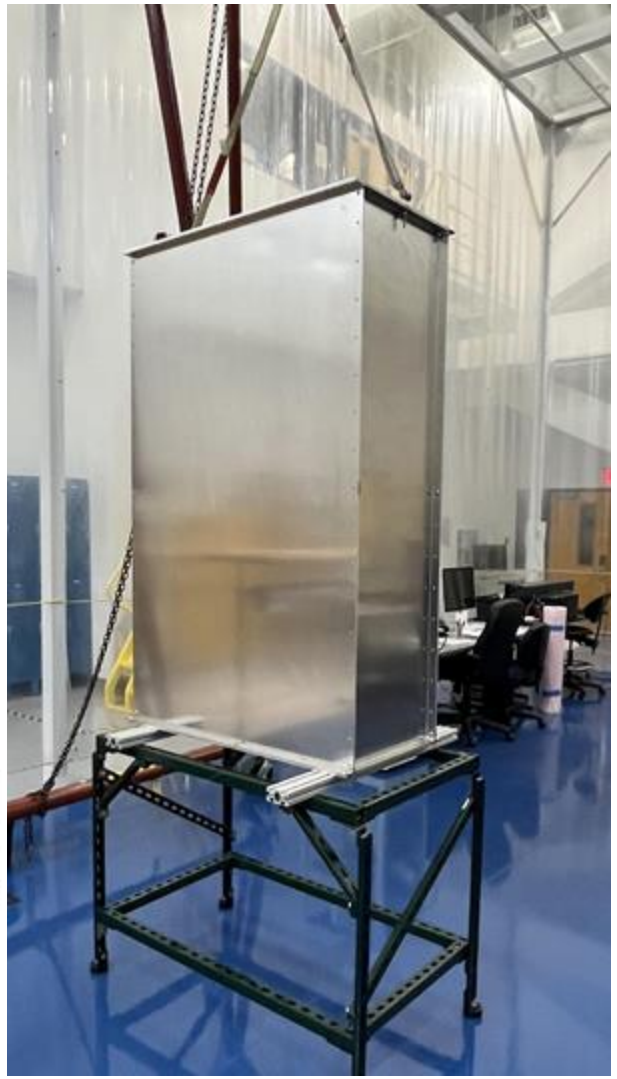
PMT

Light catcher

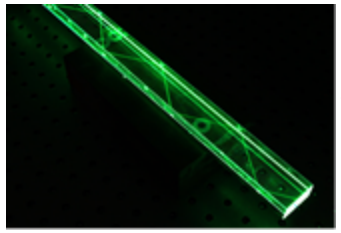
CAD drawing of Cherenkov tagger



Cherenkov tagger in construction at ODU



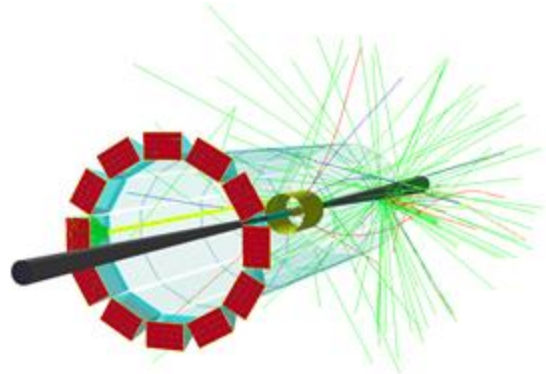
OUTLOOK



DIRC bar in laser lab

- Complete the DIRC lab at JLab and commission with reference bars
- Transport, disassembly and QA of BaBar DIRC bars, decision about reusability and further disassembly strategy
- Complete evaluation of cost/performance optimized EIC DIRC design options in simulation
- Complete integration of hpDIRC prototype into Cosmic Ray Telescope
- Prepare initial DAQ and CRT track reconstruction software
- Commission CRT setup

hpDIRC in Fun4All simulation



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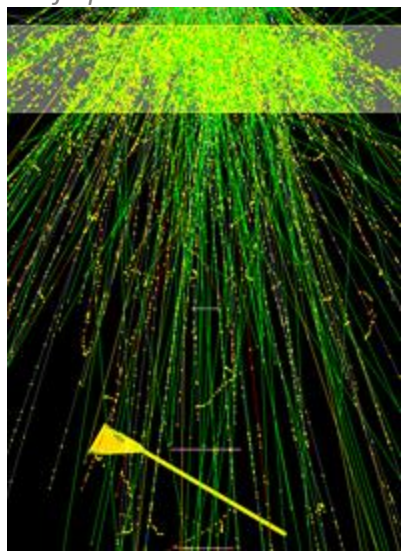


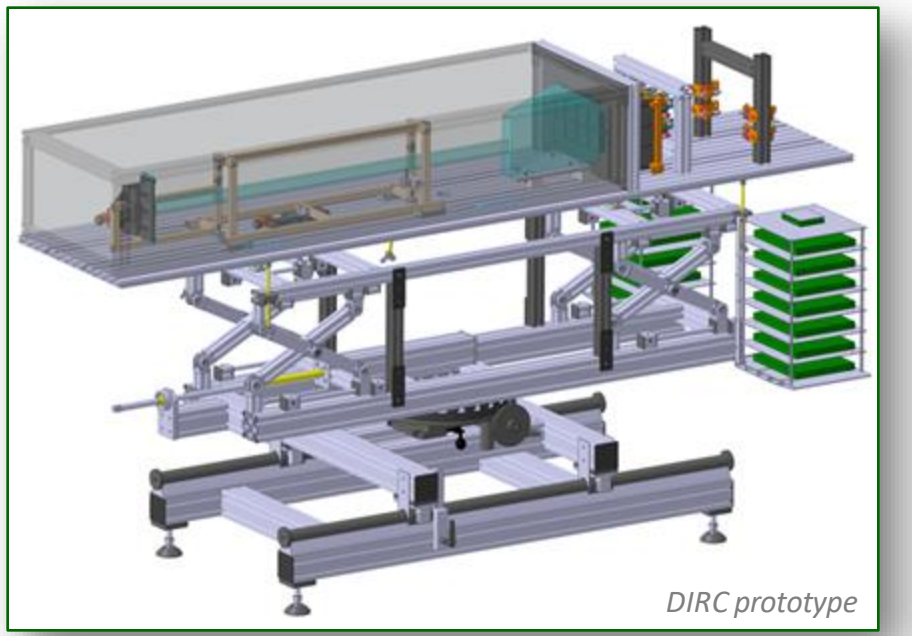
CRT space at SBU

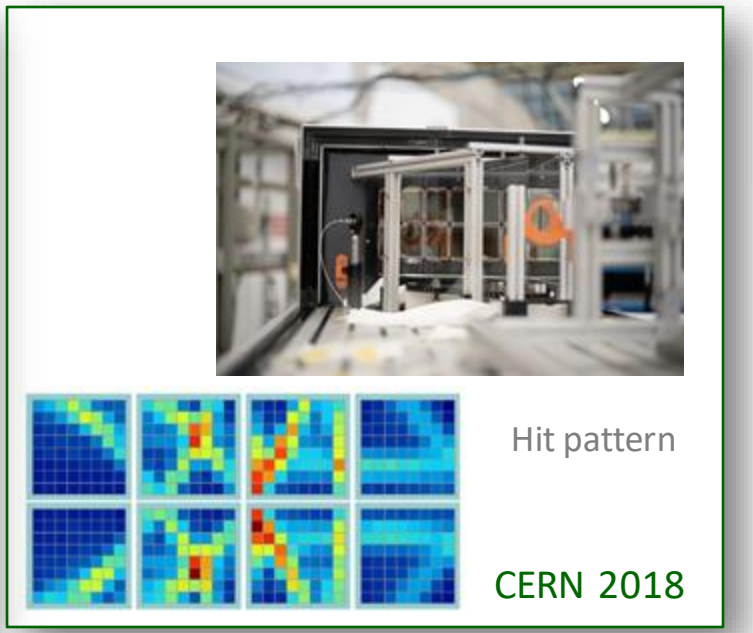
Backup slides

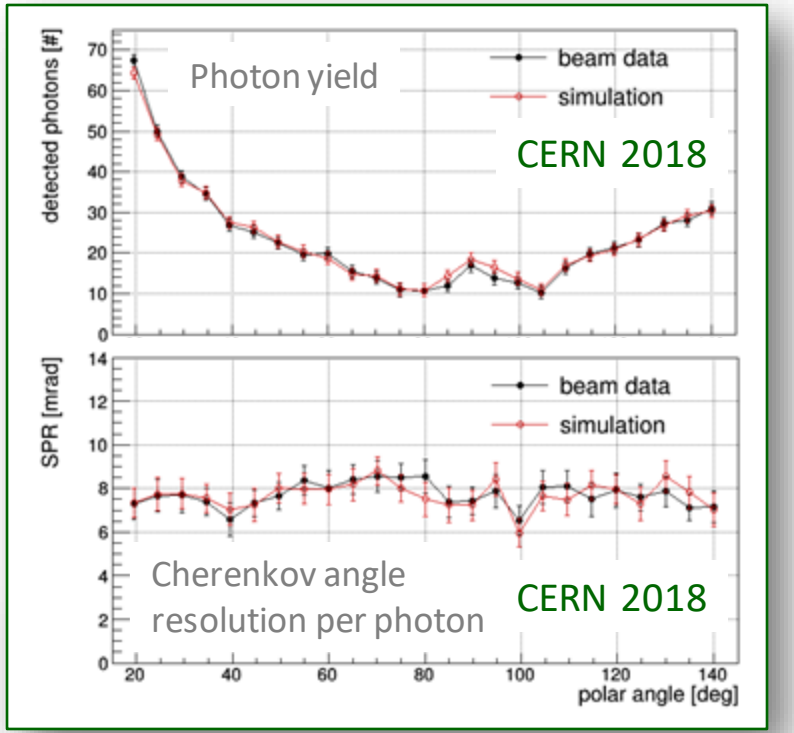
HPDIRC PROTOTYPE: DEVELOPMENT

Technical risk: hpDIRC PID design validation

- Resolution and PID performance of system prototype
- PANDA Barrel DIRC prototype tested with particle beams at CERN (2015-18)
  (included 3-layer spherical lens – but older MCP-PMTs, larger pixels, slower electronics)
- Up to 5 s.d. p/π separation at 7 GeV/c (equivalent to 5.2 s.d. π/K at 3.5 GeV/c)
- Excellent agreement with simulation (same simulation used for hpDIRC)







HPDIRC PROTOTYPE: SIMULATION

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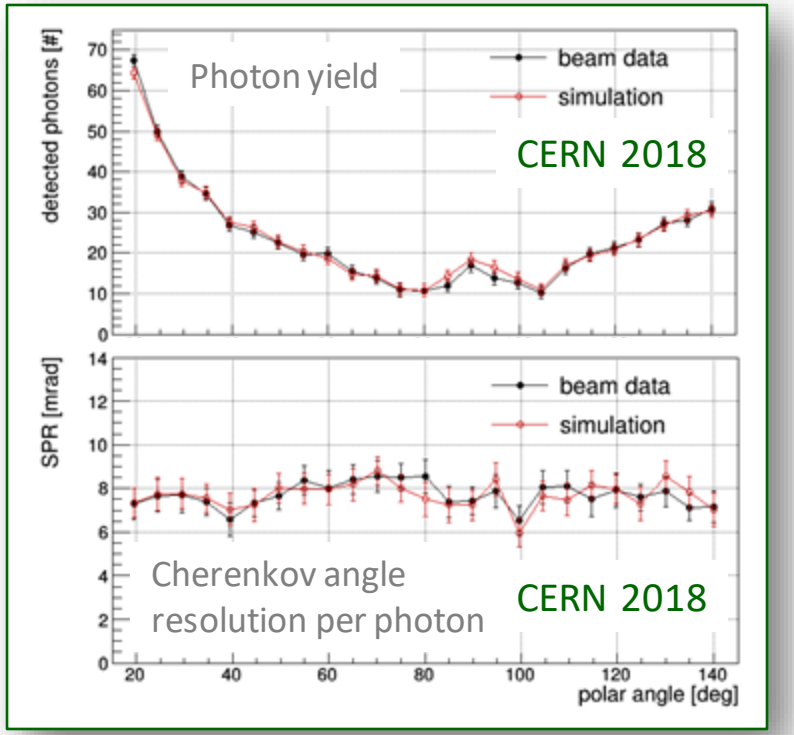
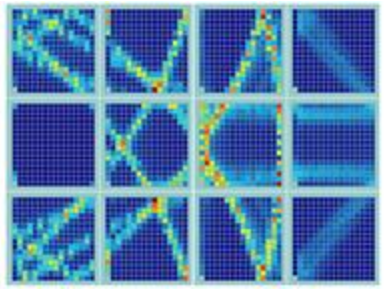


- Used this simulation to predict PID performance of upgraded hpDIRC prototype
  (new MCP-PMTs and electronics, 3mm pixels, improved PDE, 100ps timing)
- Expected π/K separation at 6 GeV/c at 20°: 3.1 s.d.
- Upgraded PANDA Barrel DIRC prototype (new sensors, new electronics) capable of hpDIRC PID performance validation in particle beams

Geant simulation of upgraded prototype

Accumulated hit pattern



π/K separation at 6 GeV/c at 20°