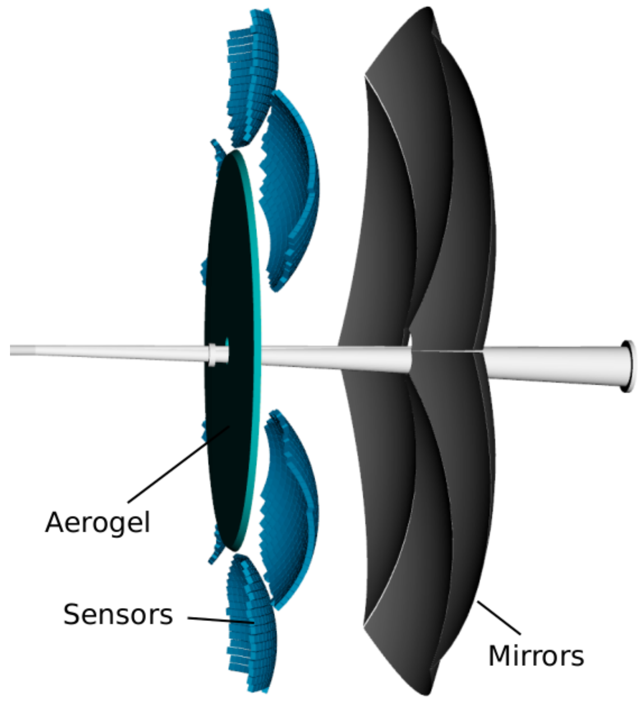
PID Systems: preTDR Status

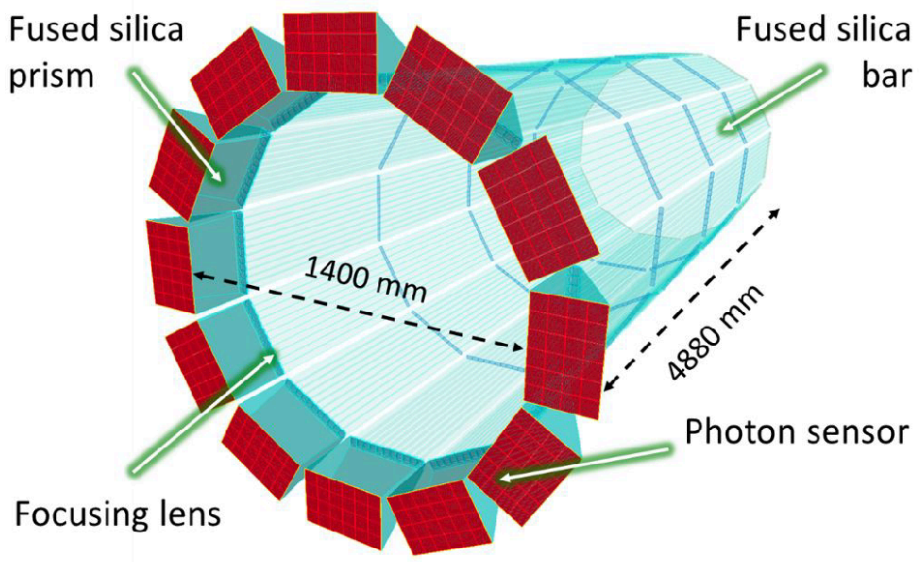
Thomas Ullrich on behalf of the PID DSCs

TIC Meeting

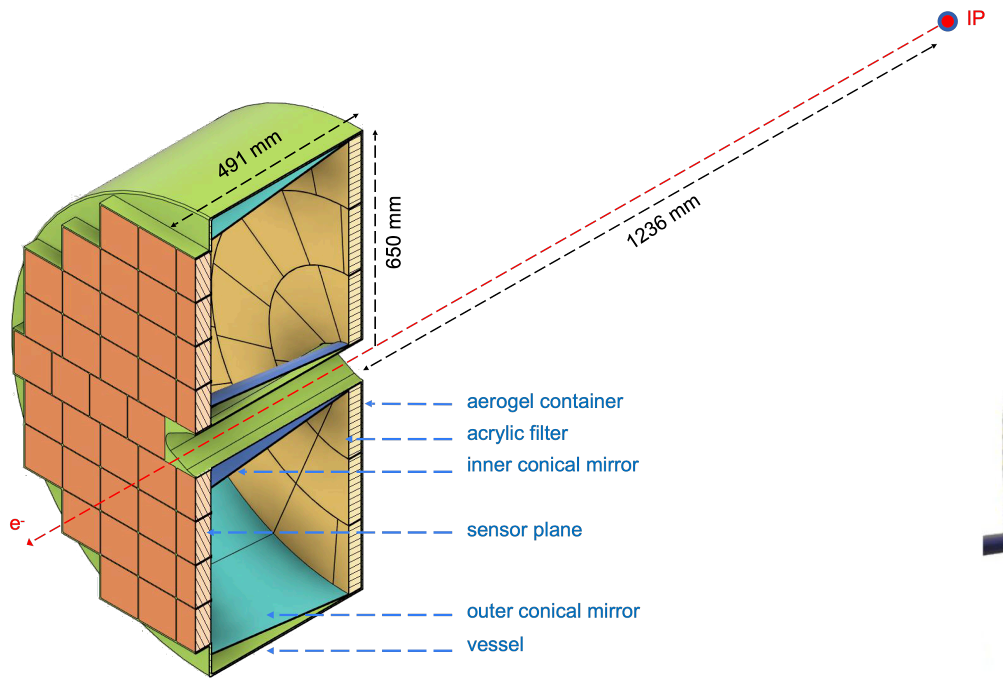
September 16, 2024



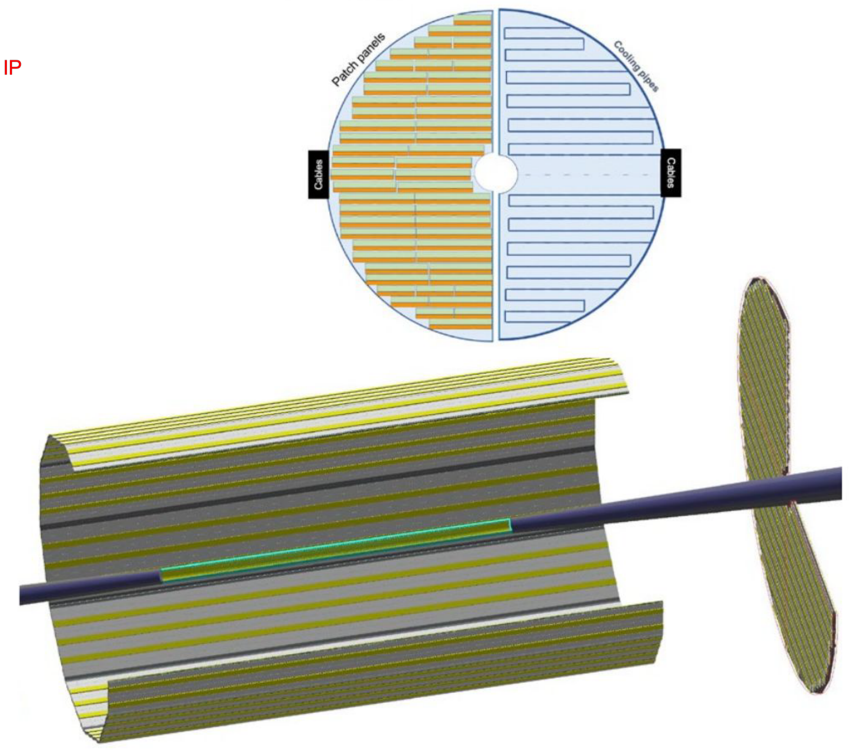
dRICH



hpDIRC



pfRICH



ToF

Recent DAC Review

- DAC Review August 28-29, 2024
- Agenda & Slides: https://indico.bnl.gov/event/24086/
- Purpose
  - Status Report from all projects (FY22-FY24)
  - Presentation of FY25 proposal
- DAC Members: C. Gerber, E. Kinney (chair), P. Krizan, A. Machado, P. Merkel, S. Miscetti, E. Oliveri, A. Papanestis, R. Poeschl, K. Wyllie, A. White
  - broad expertise inc. many aspects of PID
- PID related projects
  - eRD102 - dual RICH
  - eRD112 - Time-of-Flight & AC-LGAD
  - eRD103 - high performance DIRC
  - eRD110 – Photosensors (pfRICH)
  - (eRD109 - ASICs/FEE)

eRD102 - dRICH (Closeout)

- Challenge: covering a wide momentum range (3-50 GeV/c), operating in a high magnetic field (~1T), and fitting within limited space.
- Recent achievements: optimization of aerogel radiator; progress in development of lightweight mirrors; compact photon detection units with advanced SiPM arrays; integration of key components like the ALCOR digitizing chip; multiple TBs conducted with mixed hadron beams and various radiators.
- Main challenge for 2025: validation of real-scale prototype with component demonstrators.
- Project progressing well, aligning with 2024, 2025 goals. Key areas like PDU design show promising results
- Pending decisions: single vs. two vessel solution, definition of in-situ annealing procedures for SiPMs, and need for windows to separate different temperatures of the gas radiator and the photon detector.
- Provide material for decision on the single vs two vessel version. The performance should be simulated since, in the case of two volumes, one expects some efficiency loss, either due to photon loss at the separating wall or – in case the wall is covered with planar mirrors – due to ambiguity in reconstruction.
- Annealing procedures should be investigated, and defined; implications for the design of the r/o board (heating).
- The necessity of windows to separate regions at different temperatures (gas radiator and the photon detector)
- Present at least a vague timeline for the project at the next DAC review.

eRD103 - hpDIRC (Closeout)

- Objective of the R&D is to ensure that the required performance for ePIC can be achieved using a Cosmic Ray Telescope, which can also be used to test the completed hpDIRC bar boxes.
- Significant progress with all components of the CRT. However, none of the individual components are close to the commissioning stage, h/w available but not yet fully connected to a r/o system.
- Quartz bars from Babar, were supposed to be delivered for examination in the autumn of 2023. The report mentions arrival of the quartz bar boxes in April and examination in autumn 2024. There is no impact expected from this delay.
- CRT for testing the performance of the hpDIRC and later perform Quality Assurance on the hpDIRC boxes is a powerful tool and it’s commissioning an important milestone for eRD103.
- The delivery of the hpDIRC prototype is also an important milestone along the path of commission the CRT.
- The collaboration relies on experience and reuses techniques from the PANDA DIRC and GlueX experiments, giving them confidence and minimising risks.
- Include a rough timeline of the construction of the hpDIRC and how it fits with the current activities. Show possible bar procurement schedule and where there is float.
- Follow the development of front-end electronics more closely

eRD110 - Photosensors (Closeout)

- Funds were limited but progress made with careful consolidation of test infrastructure for timing and ageing studies.
- Test systems are ready, including illumination techniques with high timing precision.
- LAPPD tubes were tested in B-field with confirmation that increased bias can recover inefficiencies.
- Cross-talk issues on the passive interfaces for the HRPPD studied and an optimised design prepared.
- We commend the preparation of the testing infrastructure and the clear definition of the test programme.
- Positive news on the status of the EIC-HRPPD - no apparent barriers to launching the programme of detailed characterisation in the institutes.
- We commend the continuation of studies of the MPC-PMT to prove its viability as a back-up to HRPPD.
- However, that there is still significant work ahead to move from small prototype quantities to production scales for both types of devices.
- Timescales and steps towards first integration with ePIC electronics (EICROC, FCFD) not obvious – planning and coordination with electronics teams is required.
- Agreement on importance of ageing tests after observation of degradation in older LAPPD.
- Strongly recommend approval of funding though modest to conclude studies in 2025.
- Recommend to follow up on coherent oscillations/explore mitigation techniques .
- Recommend careful planning towards testing photosensors coupled to the EICROC/FCFD ASICs - critical to ensure that the specifications and performance of the ASICs are adequate for these sensors.

eRD112 - ToF (Closeout)

- Project focuses on the R&D of AC-LGADs as the chosen technology for the timing layer in the barrel and forward TOF detector, the B0 tracker, the Roman Pots, and the Off-Momentum Detectors.
- Various geometries and layouts studied, and integration with the FE ASIC was tested.
- Preliminary irradiation studies have been performed.
- FBK is being considered as a third production site to mitigate risks during the production phase.
- Project is progressing according to plan – we congratulate groups for the progress in the past year.
- Positive results with basic sensors, but some cases small margin v. requirements – concern over degradation in final detector(s). Teams are aware of this.
- Alternate sensor vendor(s) considered.
- Existing sensor studies well organized.
- Initial tests with FE ASIC have begun – various testing facilities set up across groups.
- Radiation hardness esp. wrt time and position resolution should be measured.
- As flagged in previous review, still need Information on how the sensor will be integrated into the various sub-detectors (modules, support, services), including the impact on the material budget

eRD112 - ToF II (Closeout)

- Clarifying the plans for testing the HPK strip sensors for the barrel ToF detector and the pixel sensors for the forward ToF and far-forward detectors would be beneficial.
- Strongly support the groups' intention to continue investigating factors that could degrade performance under final experimental conditions (e.g. radiation, environmental parameters such as temperature and humidity)
- Evaluate whether the current effort in sensor modeling should be extended towards a more detailed simulation of the detector response, allowing for time and spatial resolution predictions for various layouts – optimize sensor performance.
- Continue studying sensor fabrication options and quality with the currently selected vendors.
- Continue research towards developing full-size sensors to identify potential issues and assess any impact on the material budget, including sensors, bonding bases, supporting structures, and other integration materials.

dRICH

dRICH - preTDR

Premininary structure outlined

Tentative list of figures defined

Relative tasks assigned

~ 12 pages already drafted

List of Figures

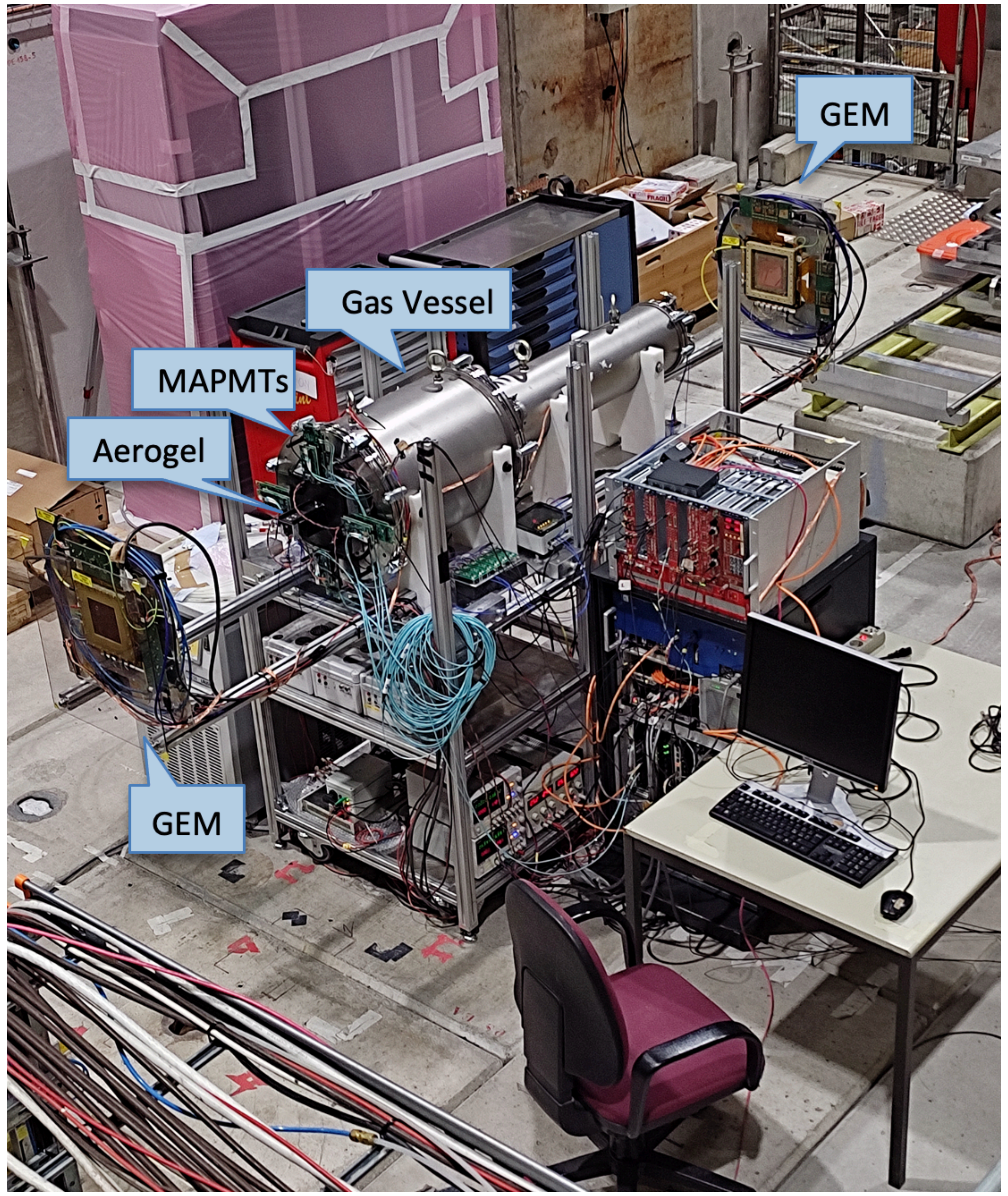
dRICH - Efforts and Timeline

- **March:** EIC R&D Day
- **May:** dRICH test-beam (extended EIC-driven photo detector)
- **June:** DAQ and ASIC review (ALCOR chip and RDO baseline spec)
- **July:** PID workfest at Lehigh
  - status of the project: https://indico.bnl.gov/event/24127/
  - dRICH tagger workfest at Lehigh
    - kick-off meeting: https://indico.bnl.gov/event/20727/timetable#20240726.detailed
- **September:** pre-TDR draft
- **October:** SiPM irradiation campaign

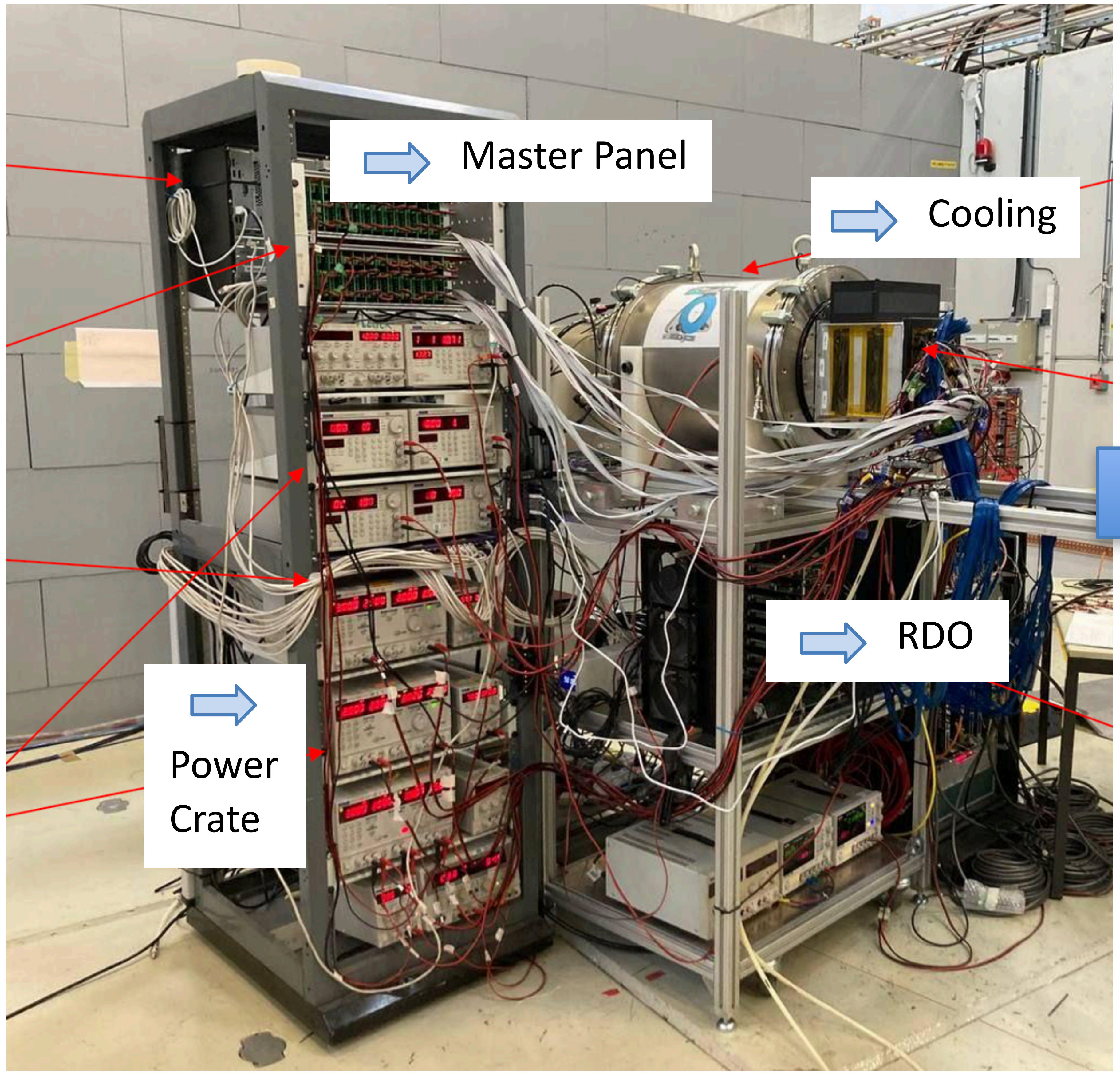
Mid ’25: Validation of real scale prototype with ePIC driven component demonstrators

dRICH Prototype Evolution

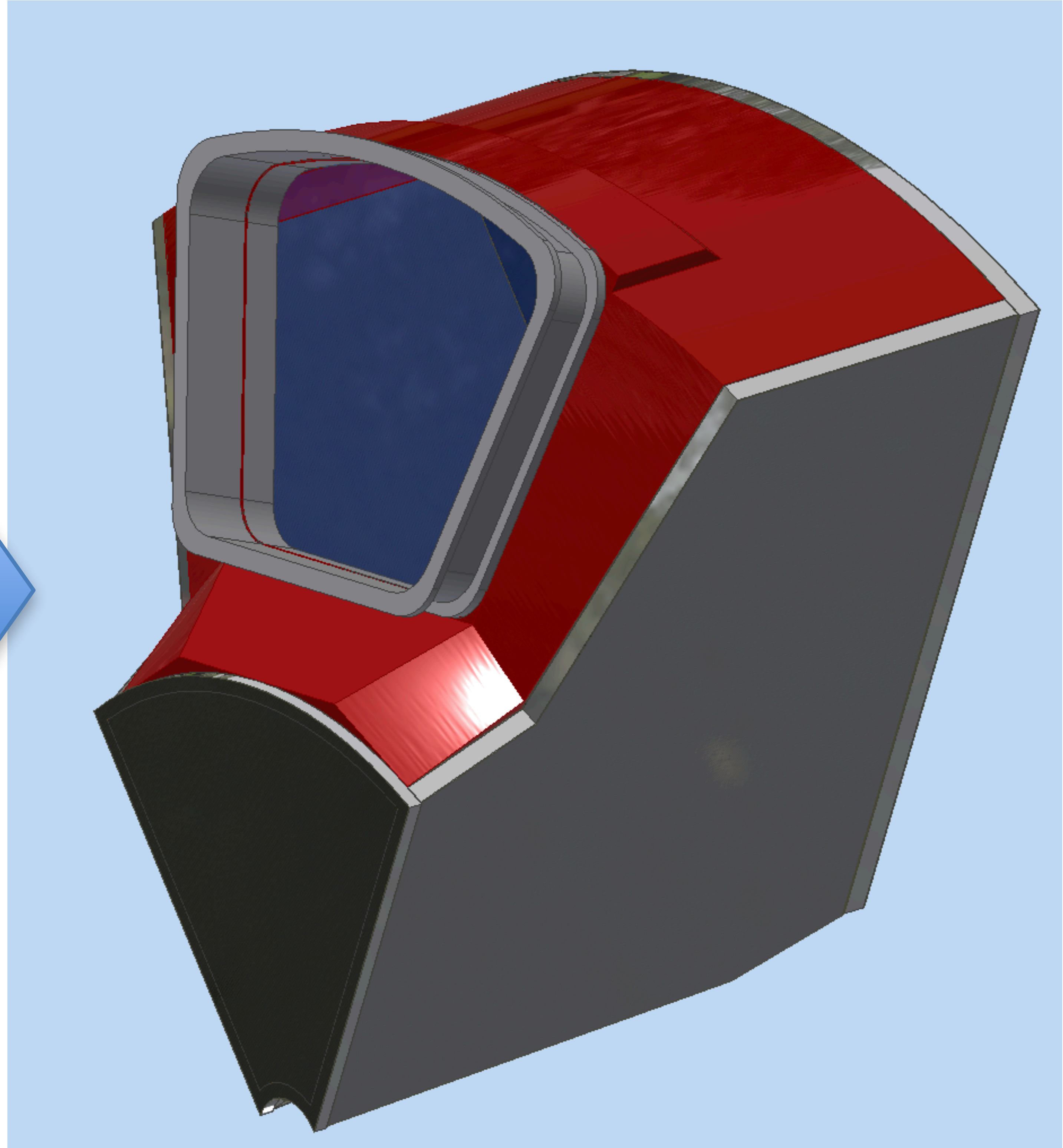
2023



2024



2025

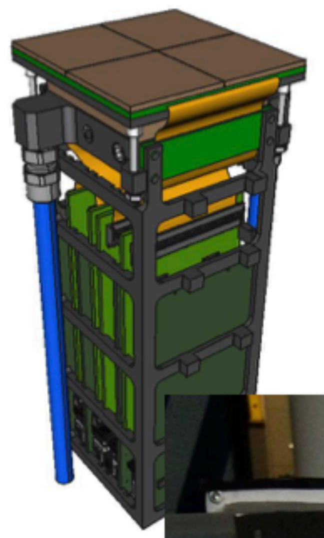


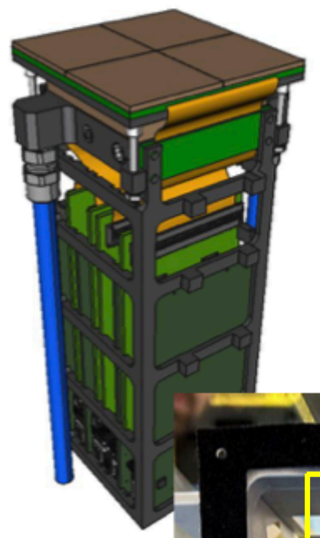
Main achievements: validation of dual radiator concept, C_2F_6 radiator gas, aerogel with optimized refractive index, ePIC driven-readout plane with SiPM+ALCOR
But: stainless steel, small mirror, small aerogel with limited ref. index, on-axis optics

Real scale prototype
Basic dRICH structure element
Realistic components & service
Off-axis optics beam test

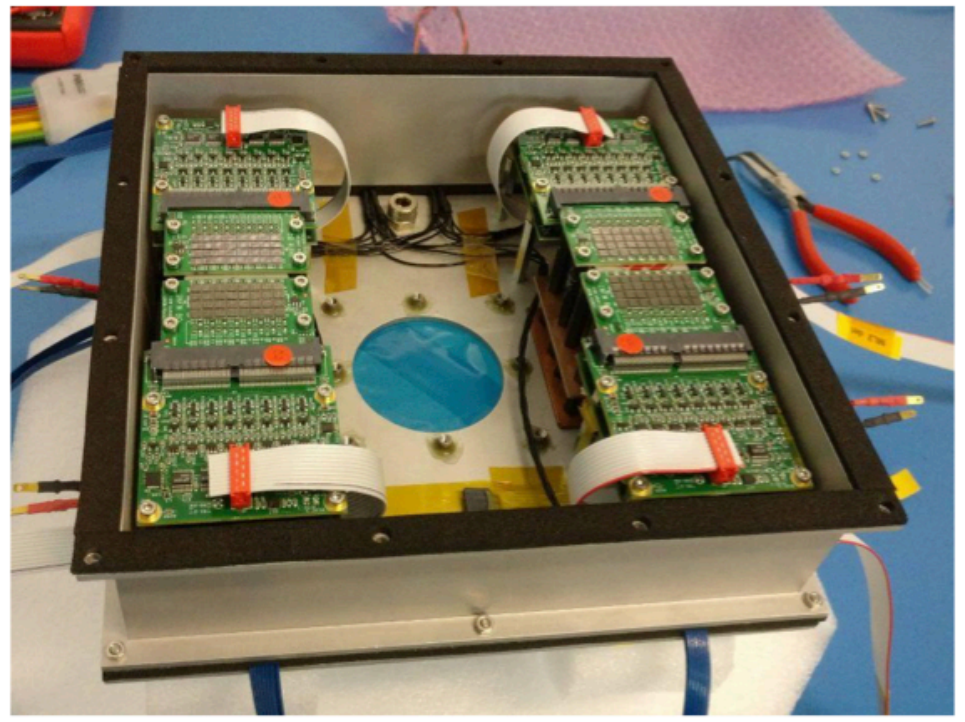
dRICH Photon Detector Evolution

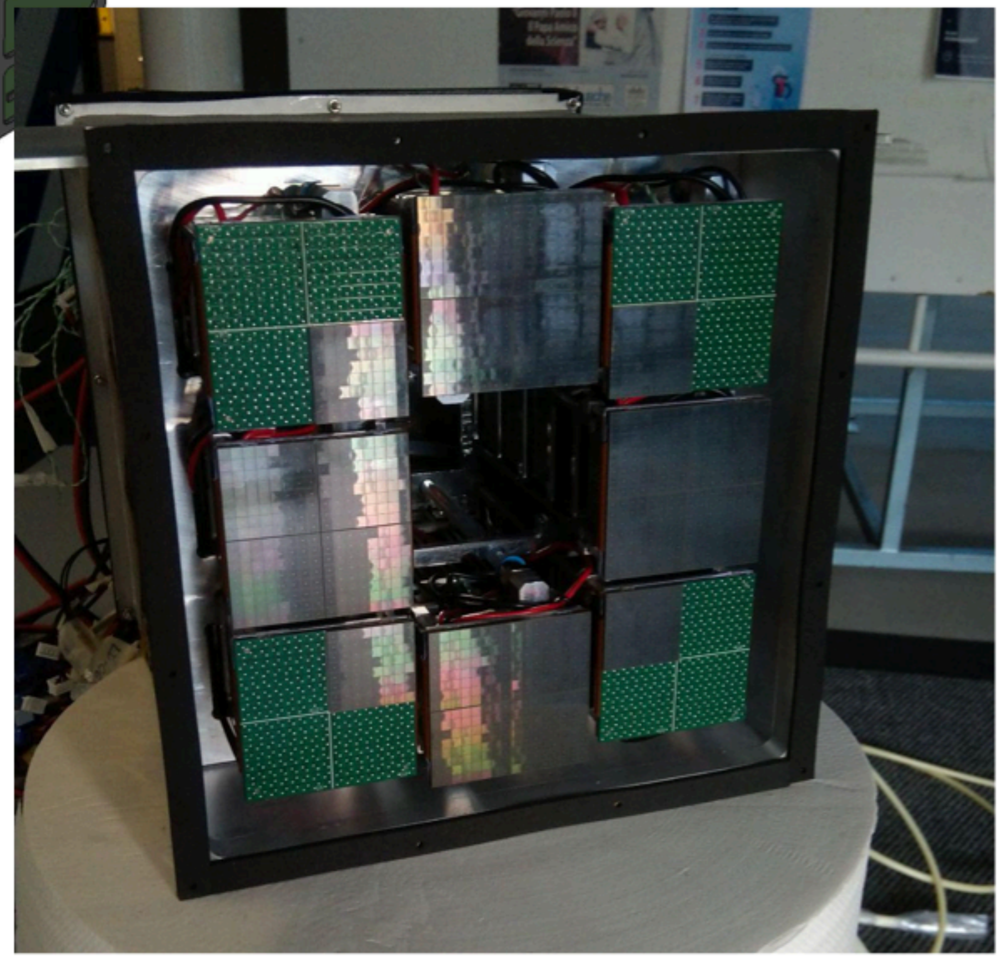
towards construction

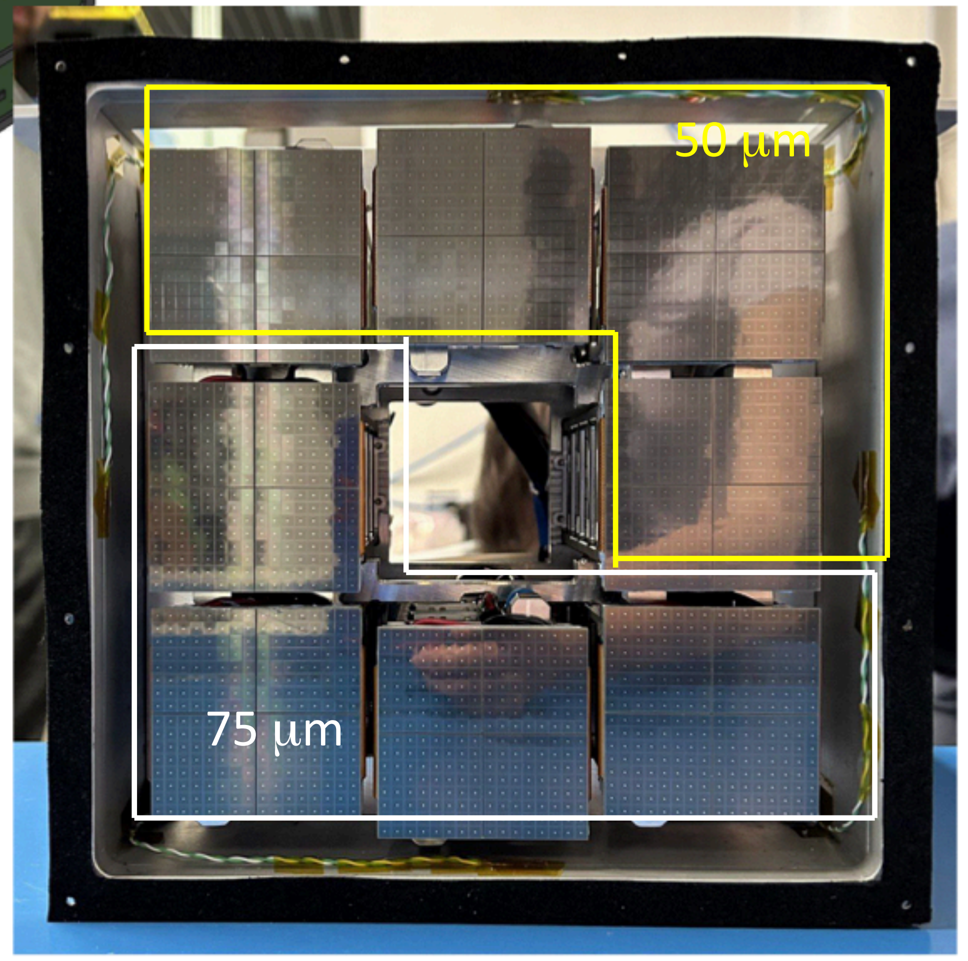


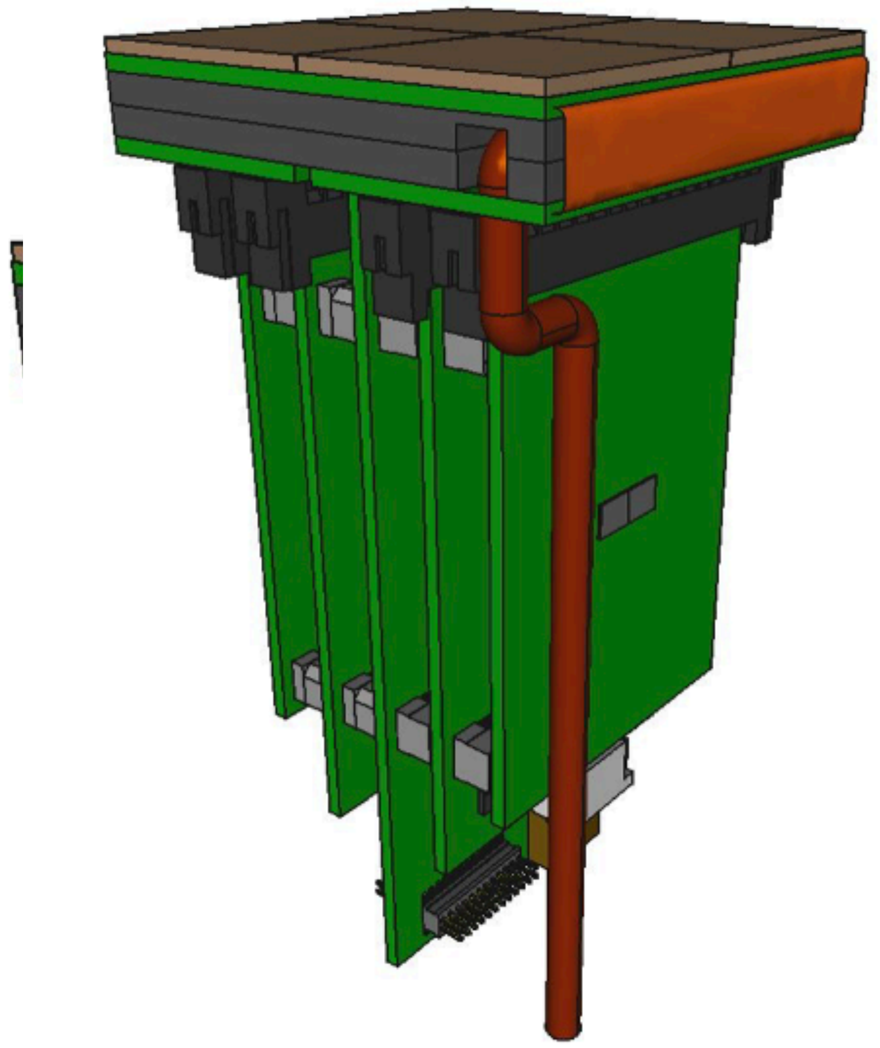


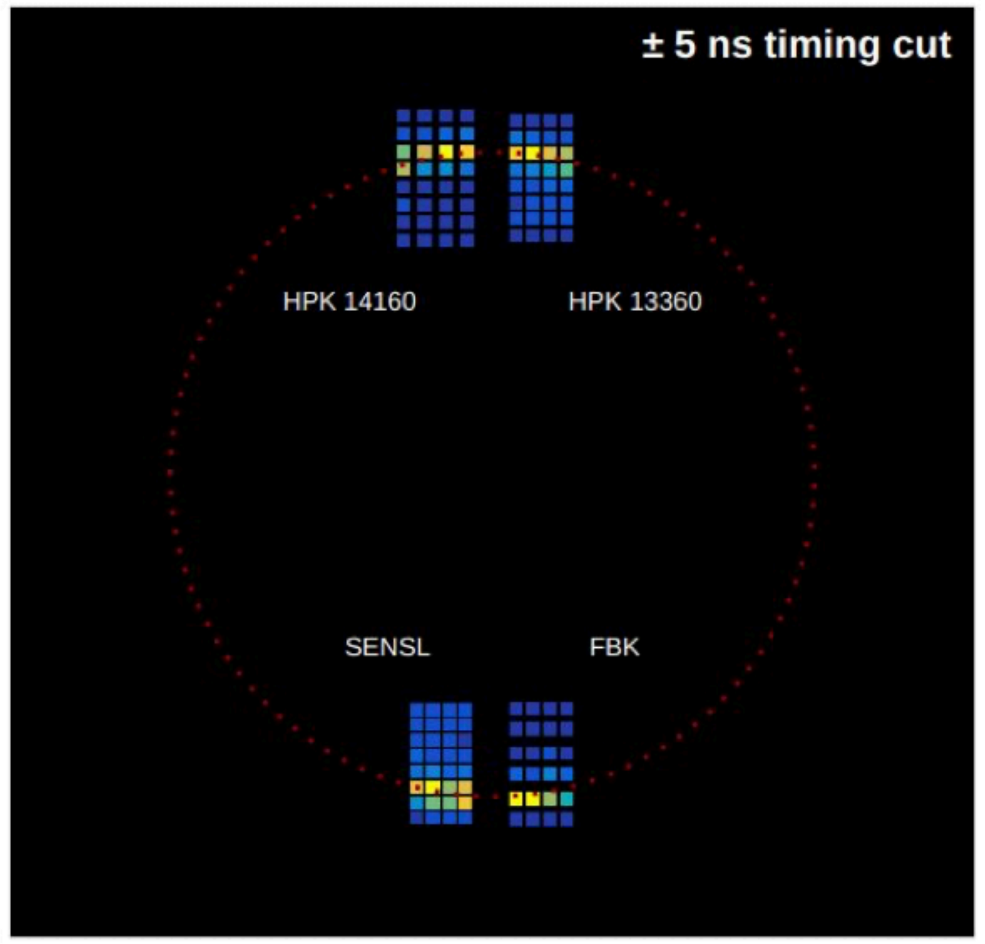
2022	2023	2024	2025
electronics v1	electronics v2	electronics v2.1	electronics v3 final prototype

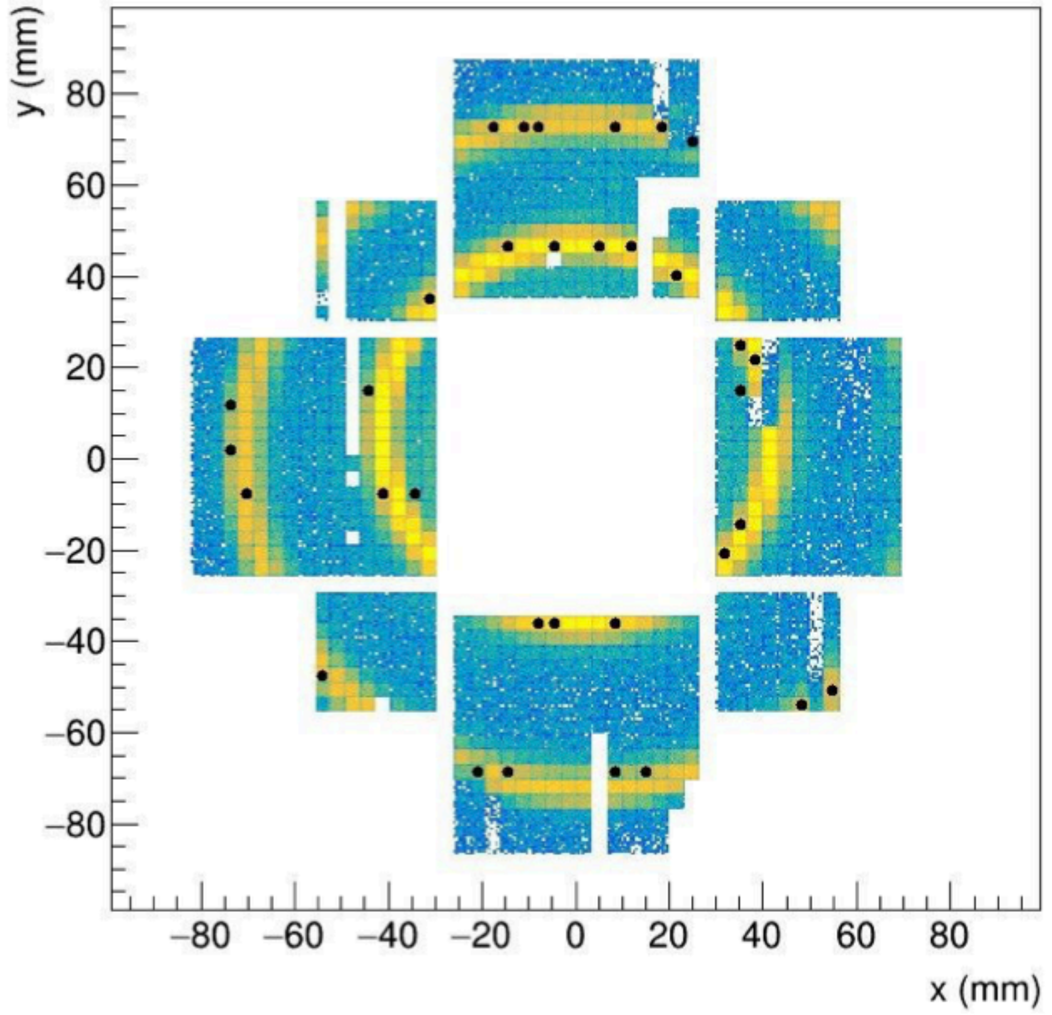


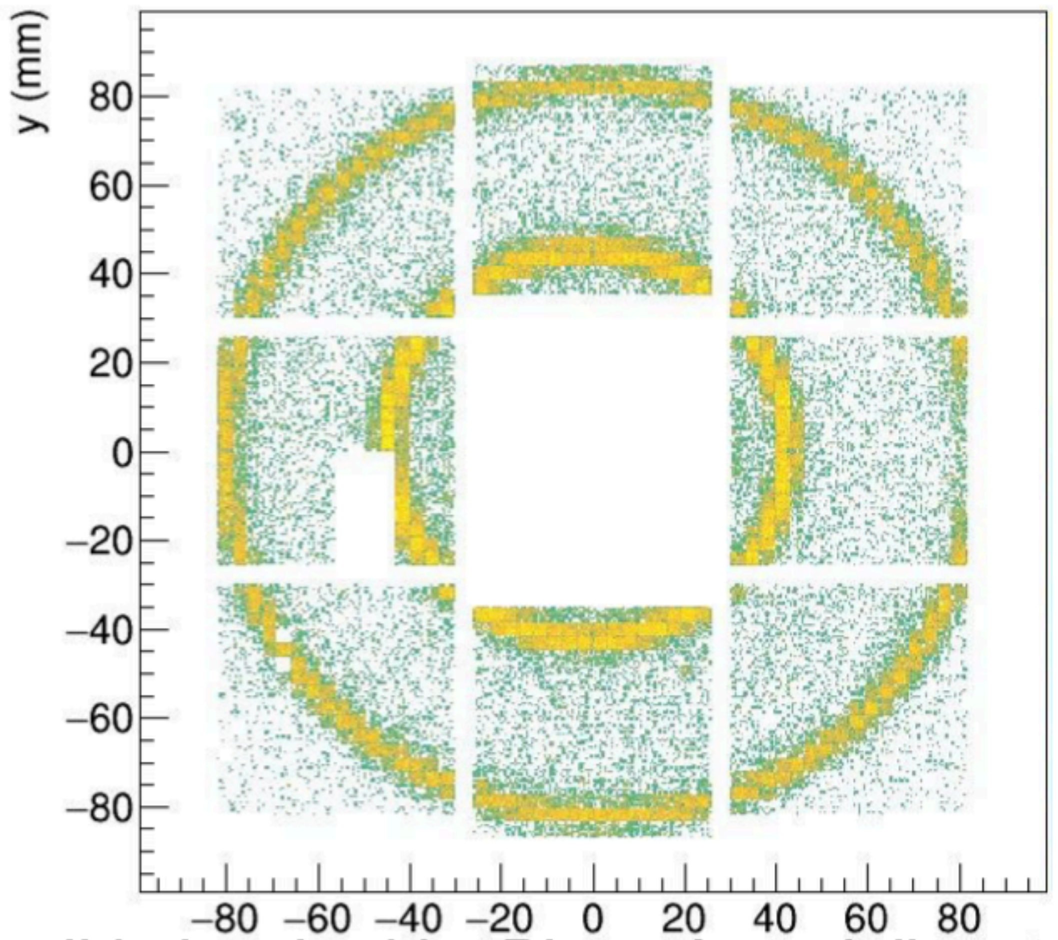












slide inspired by Pietro Antonioli

ALCOR 64ch
SiPM carrier
FEB 64
RDO

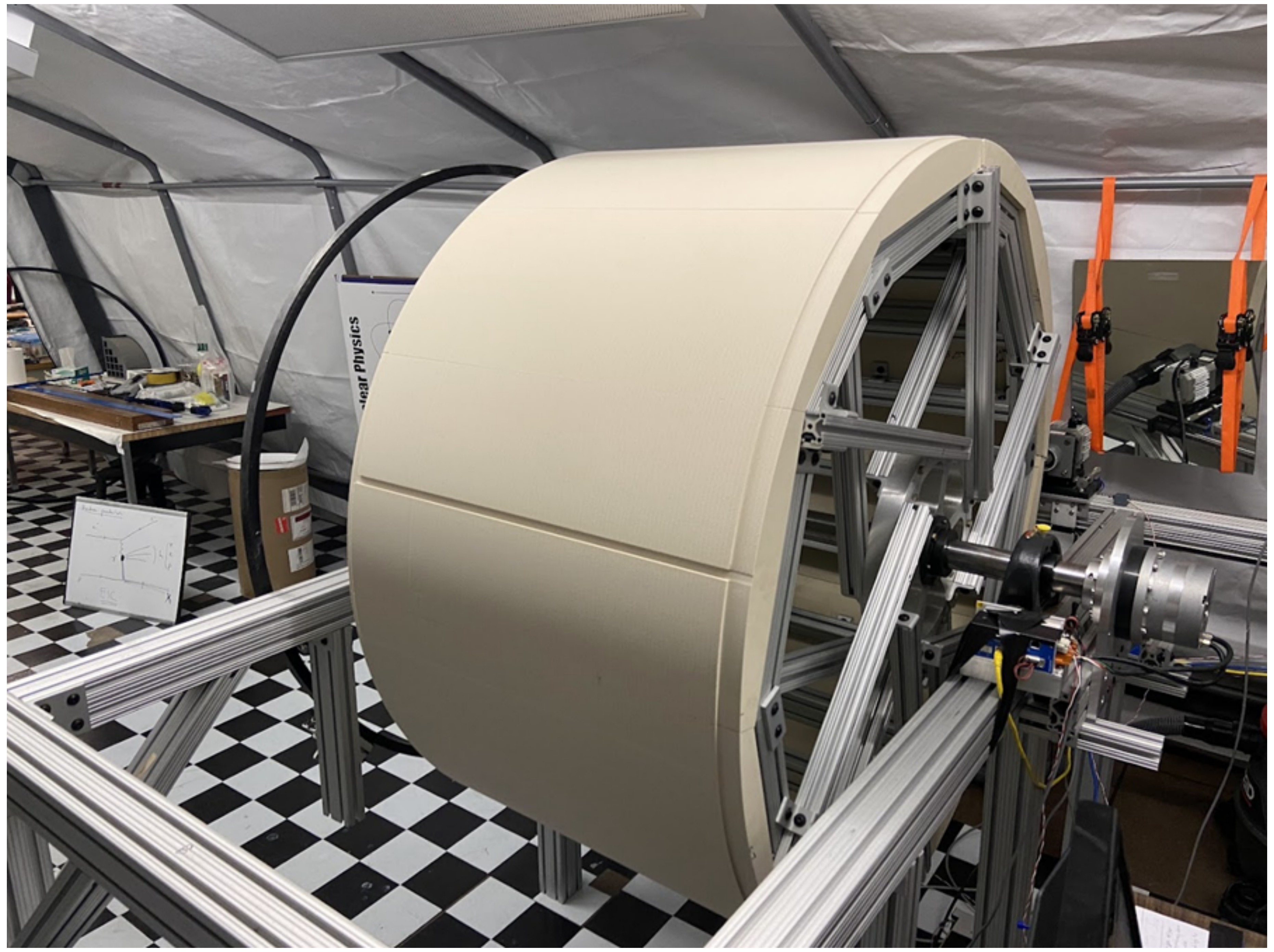
pf*RICH*

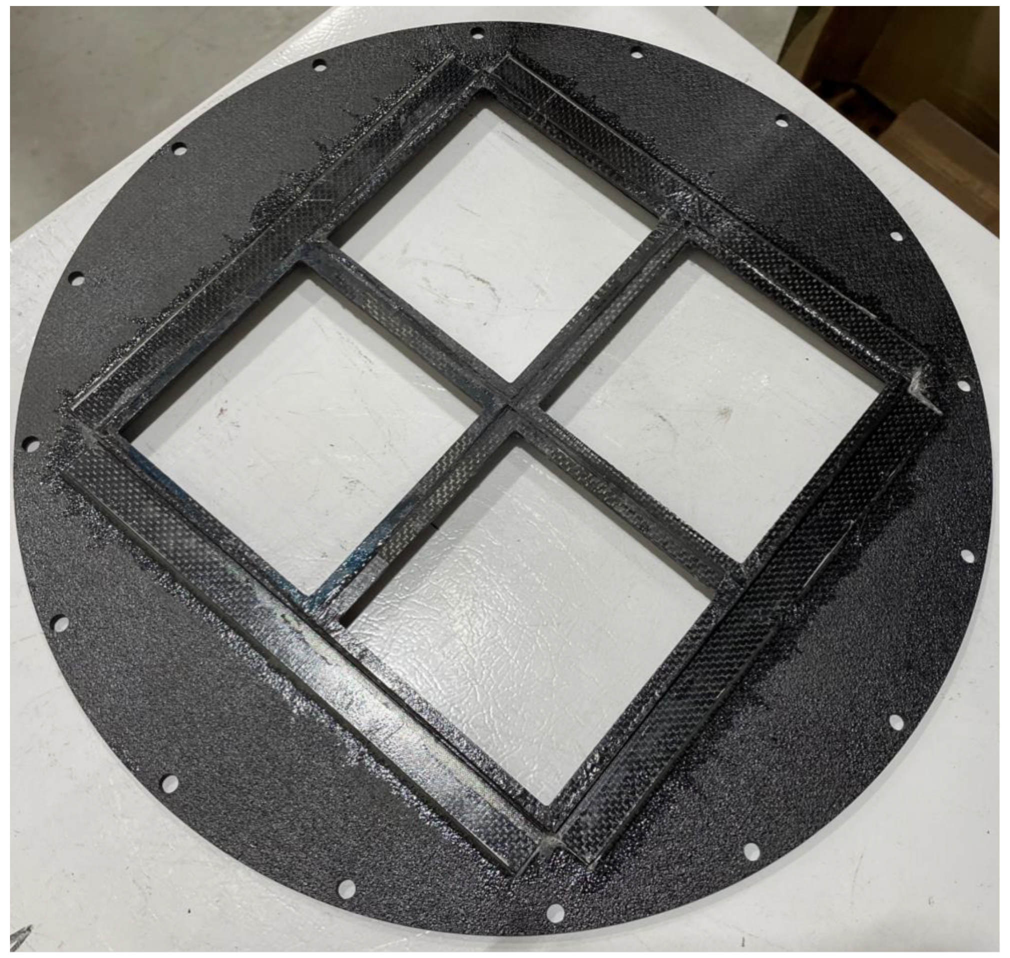
pfRICH - preTDR

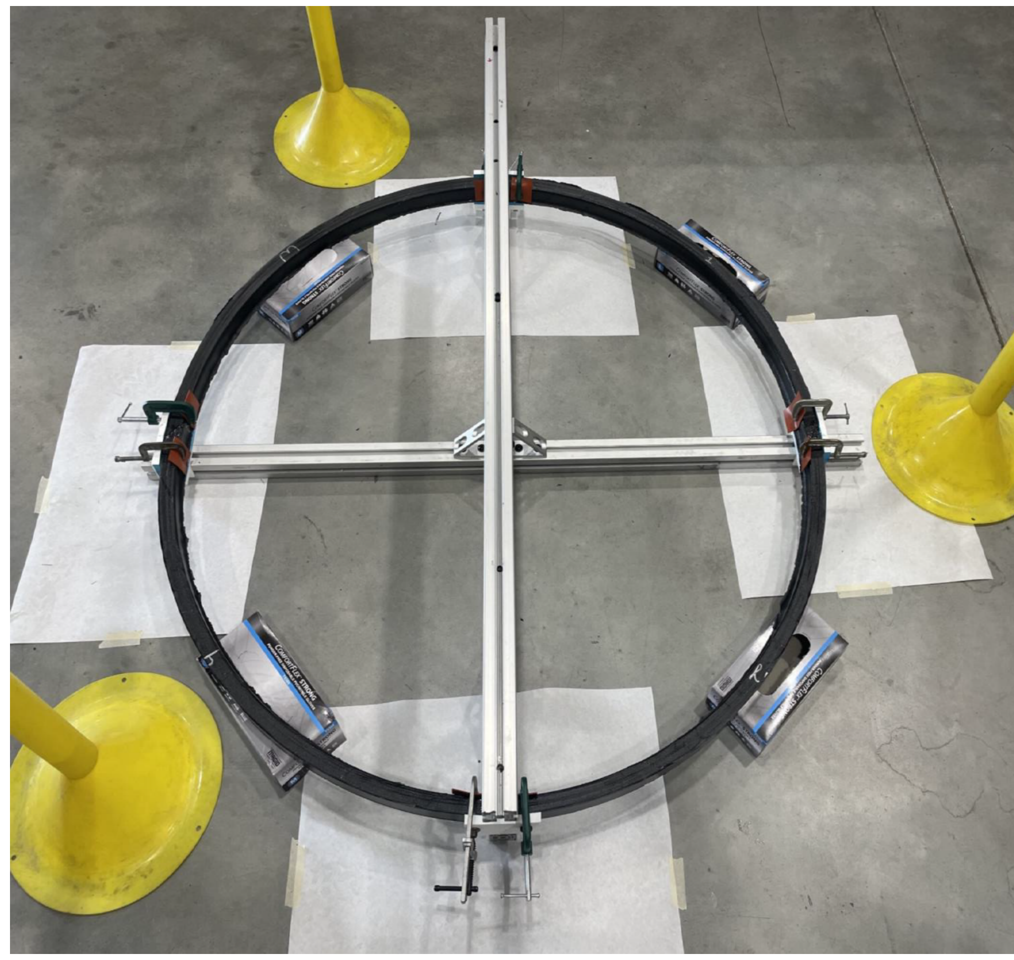
- Writing of pfRICH Pre-TDR executive summary and select supplemental material is well underway
- Text on physics requirements, device concept & description, sensors, performance and services either complete or nearly complete
- Text for bulk of remaining sections exists in supplemental material and/or existing CDR and simply needs to be condensed for the executive summary
- Work on the executive summary is mainly writing, but two sections need additional coding and analysis efforts
  - Radiation Hardness: Work is ongoing to get more accurate beam/synchrotron background maps
  - Physics Performance: Overall performance is understood from CDR studies but will redo plots using ePIC framework and LUTs (new figures ready for v1)
- Some material (like detailed construction and assembly plans) will have to remain vague as all details cannot be finalized at this stage
- Work on supplemental material proceeding as well with new detailed descriptions of aerogel, mirrors, and vessel construction
- Bottom line: should have a fairly complete v0 pre-TDR draft by the end of September

pfRICH - Vessel Work

- Fabrication of vessel and other components underway at SBU and Purdue
- Bulk of milling of the foam form for shell construction complete and detailed metrology being performed
- End-ring fabrication at Purdue continues with efforts to improve cylindrical tolerances of final pieces
- Optimization of sensor plane construction ongoing
- Various methods for sealing sensors into their enclosures are being tested, both with blanks and soon with actual HRPPDs

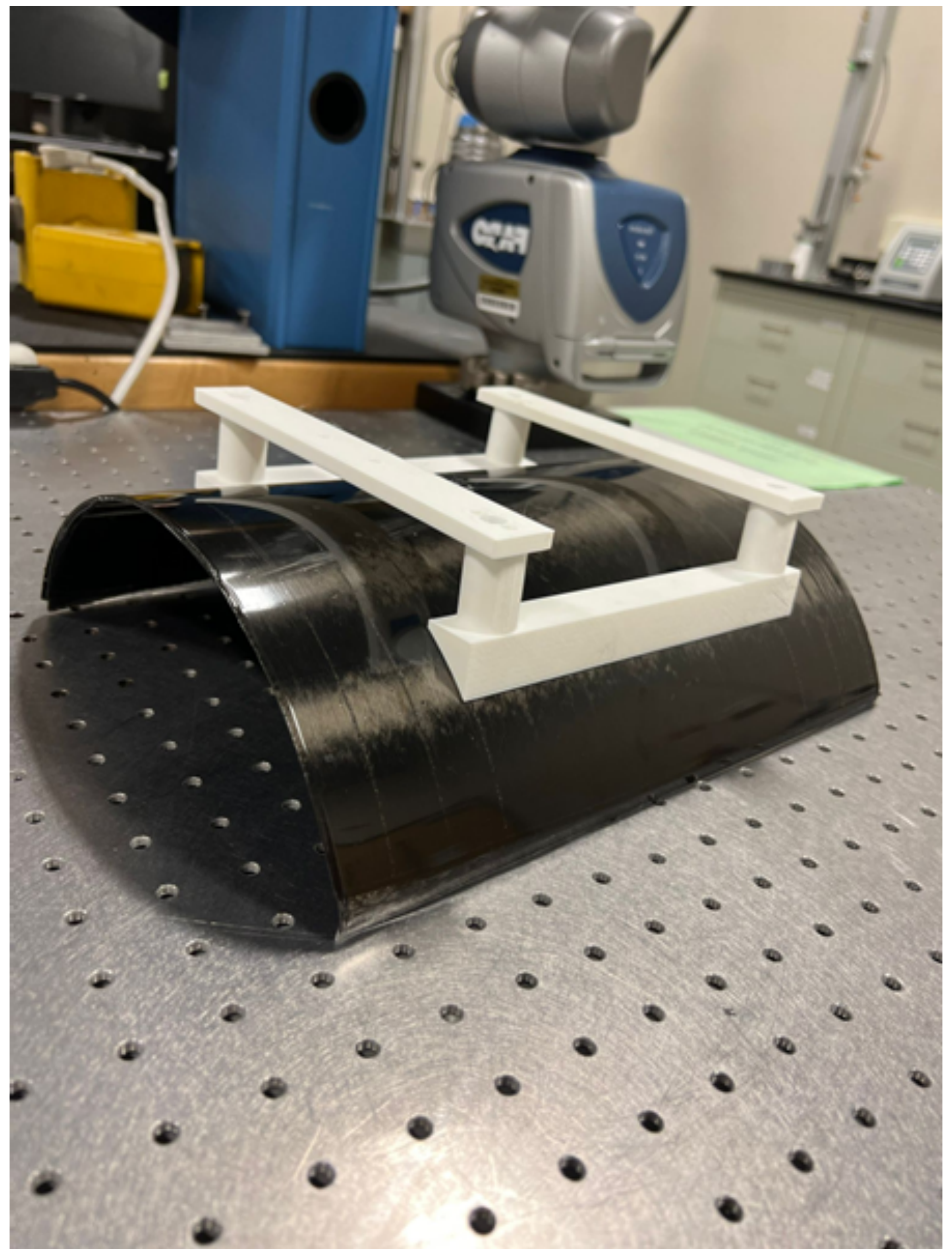


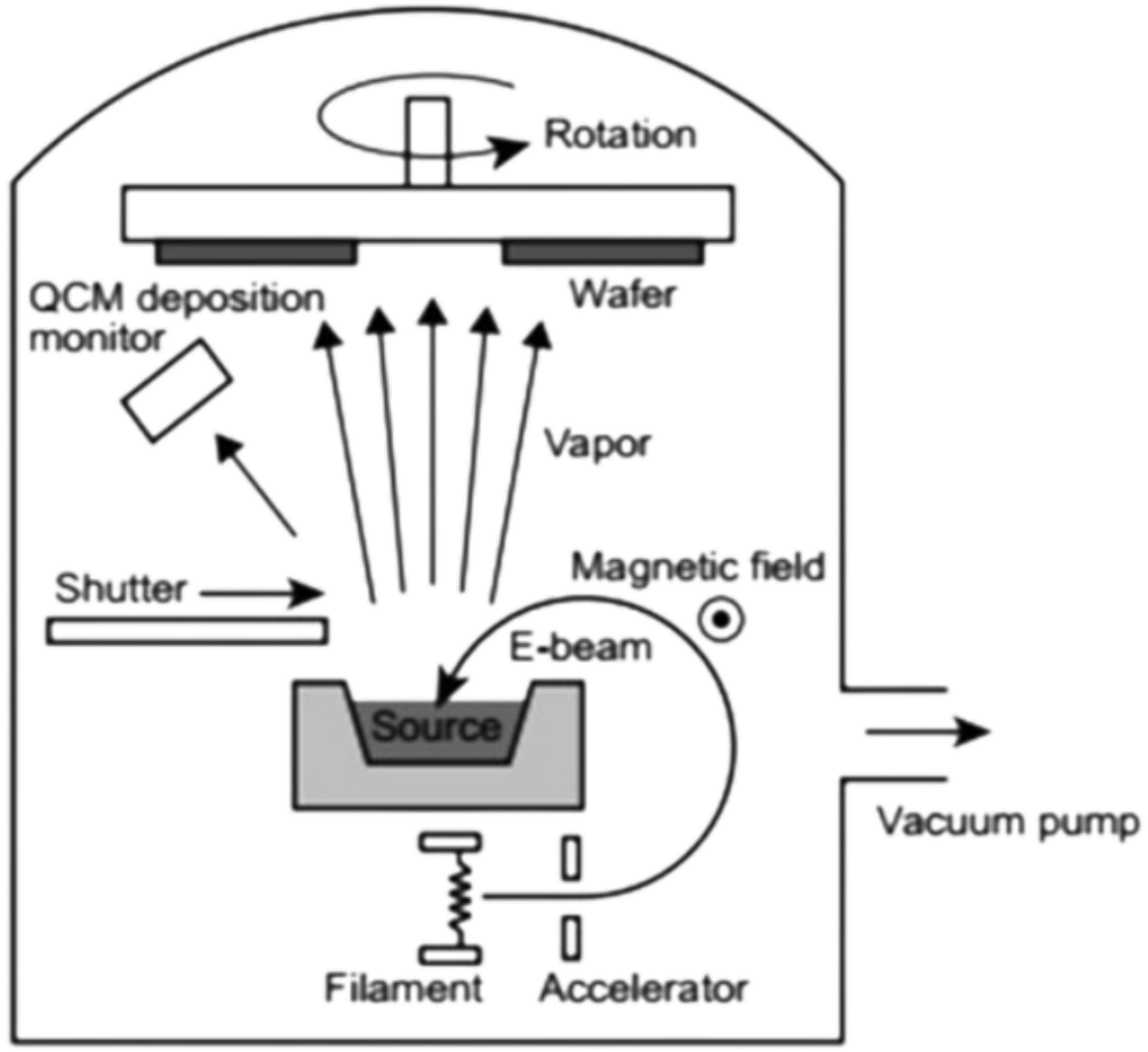


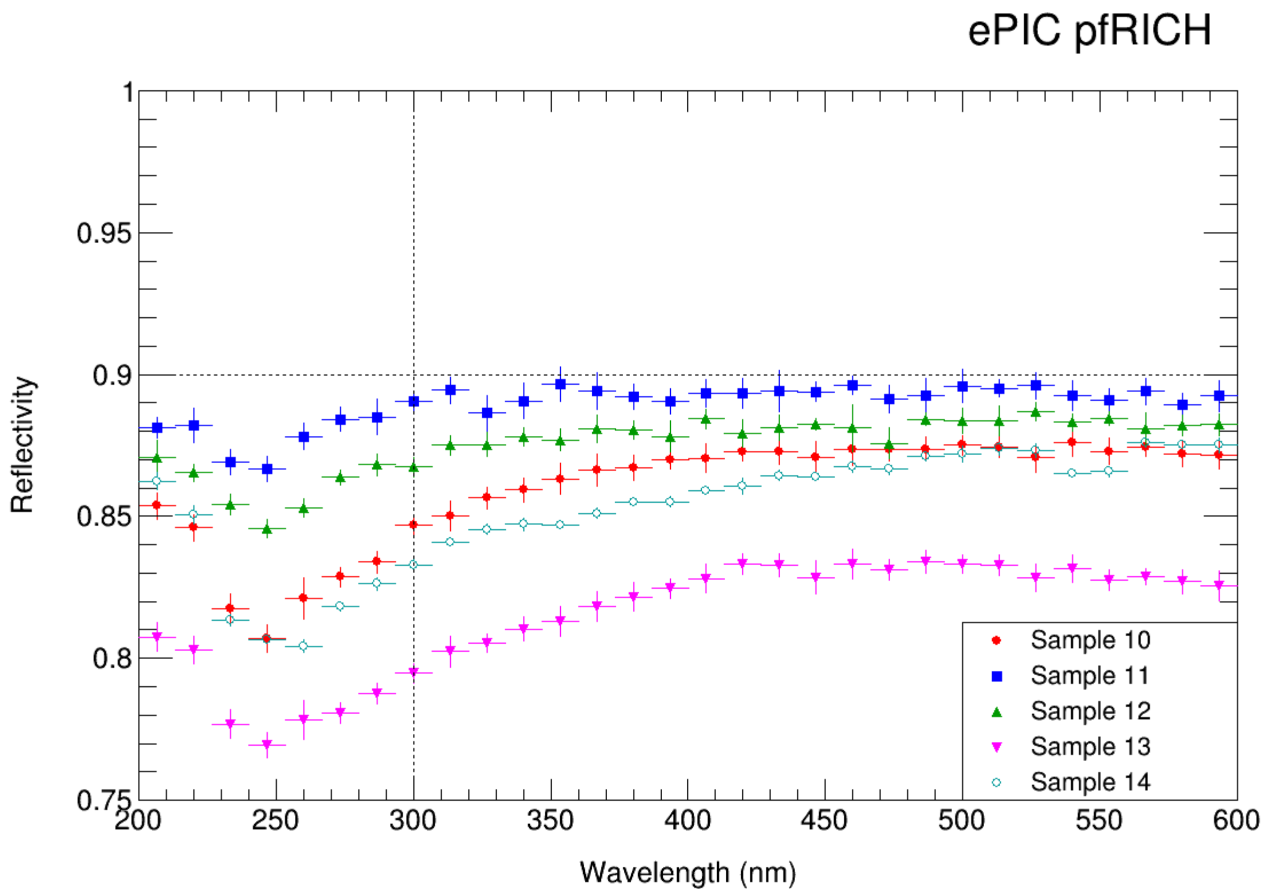


pfRICH - Mirror Work

- First curved mirror substrates delivered to SBU from Purdue several weeks ago
- Upgrades to SBU mirror coating apparatus ongoing – new cryopump, ion source, mount for full sized mirrors
- Reflectivity tests carried out at BNL show mirror samples achieve ~90% reflectivity over the wavelength range of interest
- Thermal tests of mirrors recently begun at BNL

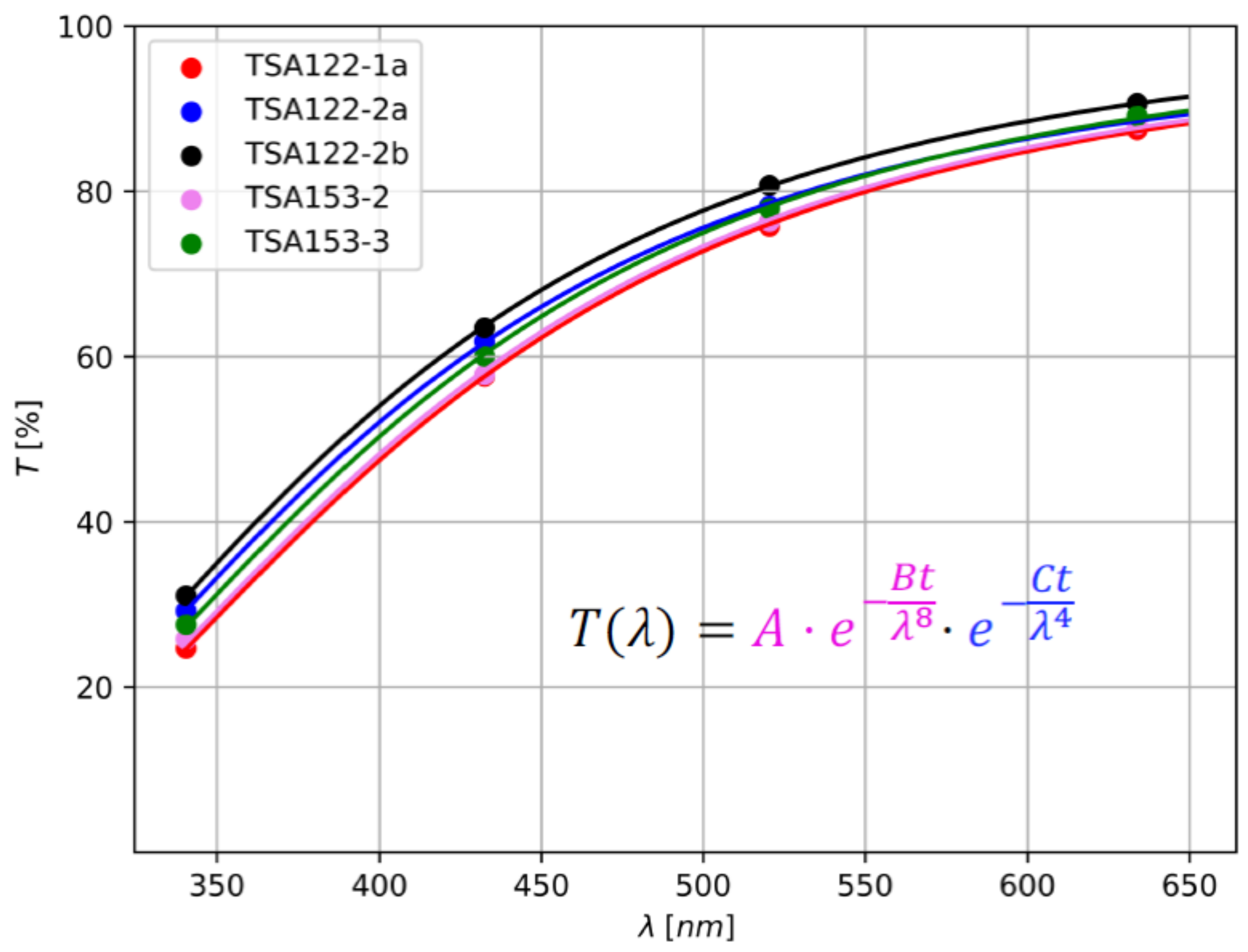


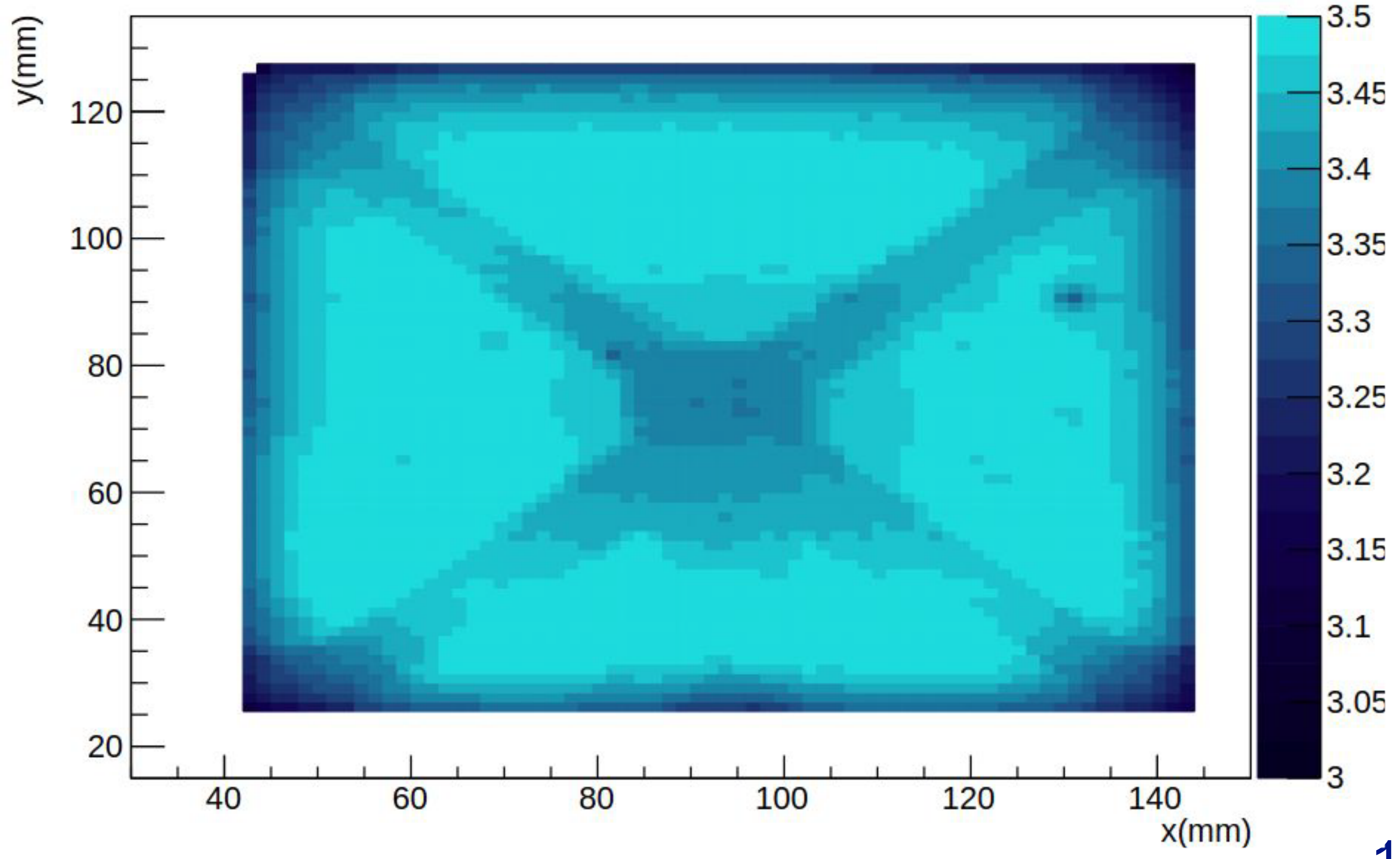




pfRICH - Other Activities

- Aerogel Evaluation
  - QA being carried out at Temple University (Matt P.)
  - Index of refraction measurements carried out and results consistent with values reported by aerogel factory
  - Transmittance also measured and in good agreement with factory values
  - New index of refraction method needed as edges of aerogel will be water-jet cut – loss of optical quality
- The pfRICH team is busy with a number of tasks related to test beam and final design realization
  - Laser monitoring system development
  - HDCROC backplane development
  - Further HRPPD sensor characterizations (timing)
  - HRPPD QE scans, aging studies, B-field tests
- Ongoing refinement of manufacturing techniques
- Software





hp*DIRC*

hpDIRC - preTDR

Using local hpDIRC Section copy shared within DSC

- Will be merged to global file once ready

Figures:

- All performance evaluation studies are done, plots available
- Figures for Mechanical section will be created with most up to date details
- Rest of figures might require slight style adjustment but in general available

Text:

- Currently working on System Description. Will start to work on Implementation section this week.

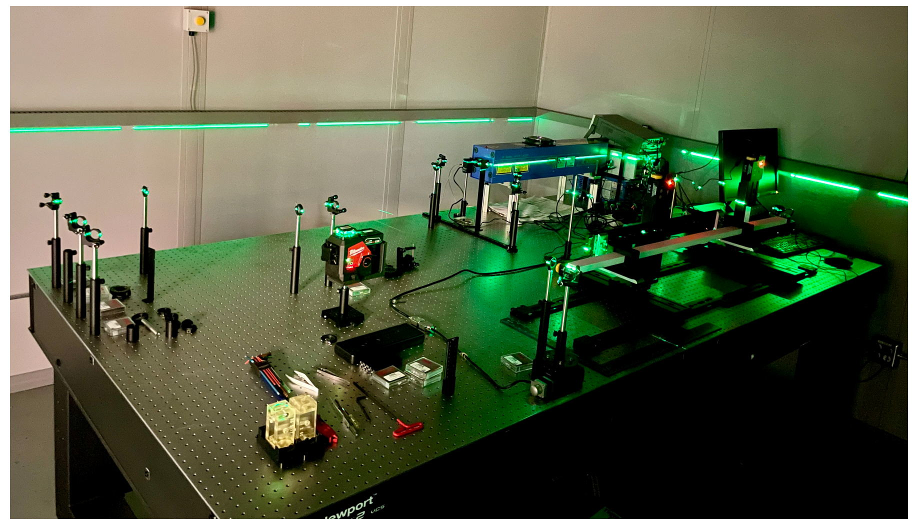
Section	Subsecion	Content	Pages	Figures
Requirements/Motivation			1	
	Performance			ZOOM into the physics coverage plot? physics event with and without hpDIRC?
				Geant/CAD fig for hpDIRC with 24 MCPs
	Integration			Bfield map (refetence to full ePIC) radiation map (refetence to full ePIC)
	Other requirements	B field, Radiation, Data Rates		Bfield map (refetence to full ePIC) radiation map (refetence to full ePIC)
System Description			4	
	Concept	hpDIRC unique aspects		
	Design	description of components, how the required performance (KPP) will be achieved		Hit pattern with Bfield on, hpDIRC with pythia event DAQ schematic?
	Performance	description of simulation and reconstruction method, CERN validation		reconstruction method plots? (combined with fish?) sim validation with CERN data standard performance plots
	Calibration	alignment - survey marks, experimental data for calibration		
Implementation			6	
	Mechanical	Design and integration, Assembly of modules, Installation		cross section (with zoom) blowup view of modules Installation sequence
	Services	nitrogen, cooling, voltage, controls and monitoring, laser calibration		Services (unless shown for full ePIC)
	Other activities needed			
	QA	CRT (Full module), Readout (Sensors + Front-end Electronics), Bars/Mirrors (Laser Lab in JLab), Prisms (?), Lenses (ODU setup)		QA fig with setups
	Timeline, workforce, work packages			schedule chart
	ES&H			
	Risk mitigation	Readout electronics, Sensor (Whatever is not tested) and HRPPD, new bars in case BaBar bars not usable		(reference to electronics and section on HRPPDs)

hpDIRC - hpDIRC Recent Activities

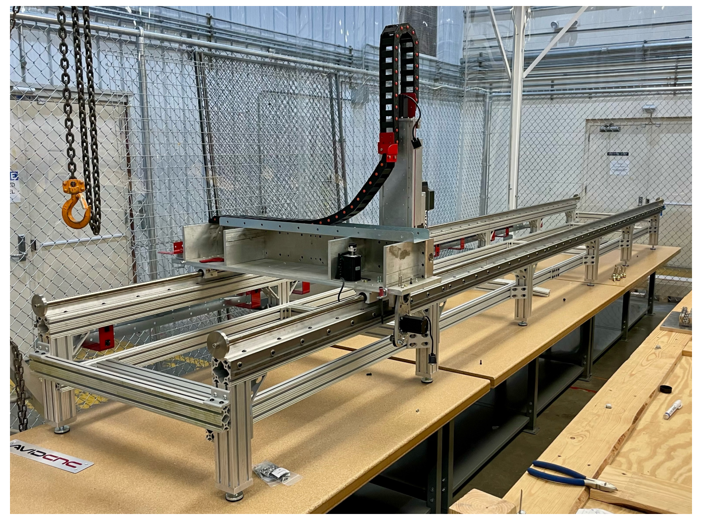
- hpDIRC prototype in Cosmic Ray Telescope (CRT):
  - CRT construction in final stage at SBU to become test bench for incremental upgrades of new components (bars, sensors, readout electronics, eventually full hpDIRC modules)
- Validation of the BaBar DIRC bar reuse:
  - Bar boxes transferred from SLAC to JLab in April 2024
  - Preparations for disassembly and QA at JLab are in advanced stage
  - Decision on reuse of bars expected by Q1-Q2/2025
- Ongoing hpDIRC studies in simulation:
  - Design optimization in final stage: narrow bars/wide plates light-guides,
    details of prism expansion volumes, sensor coverage
- Mechanical Design and Integration:
  - Progressing with details of bar boxes and readout boxes

hpDIRC prototype at SBU

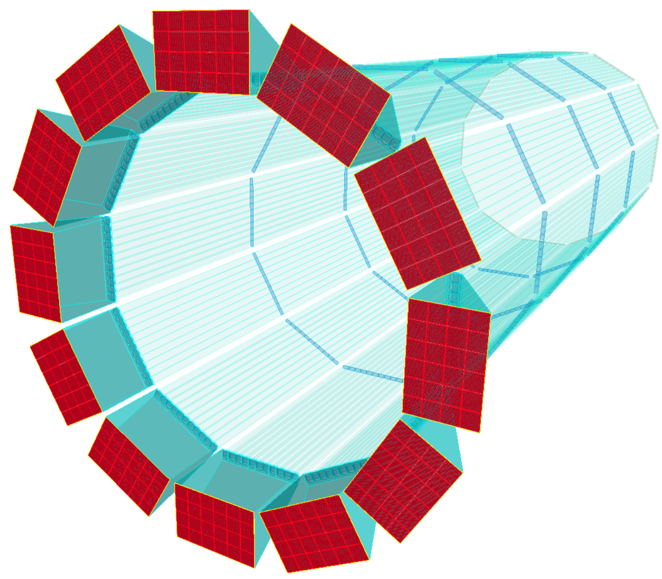
QA lab at JLab



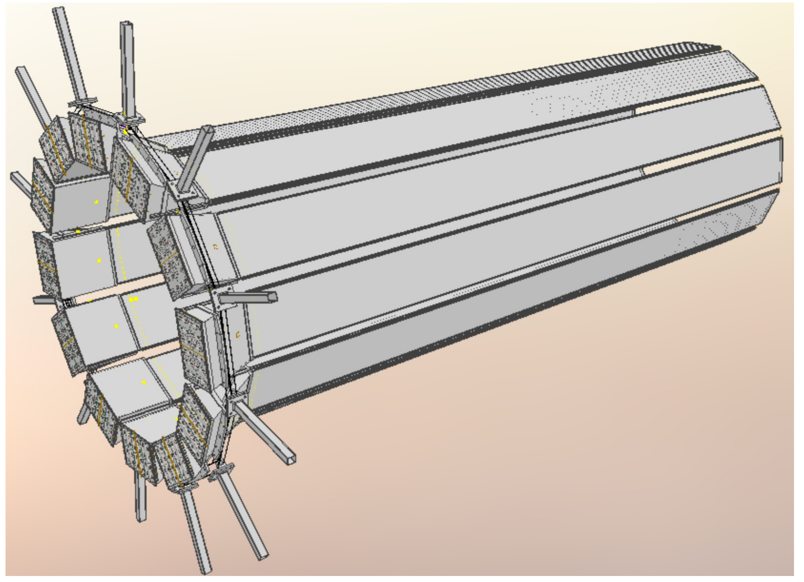
Disassembly setup at JLab



hpDIRC in Geant4



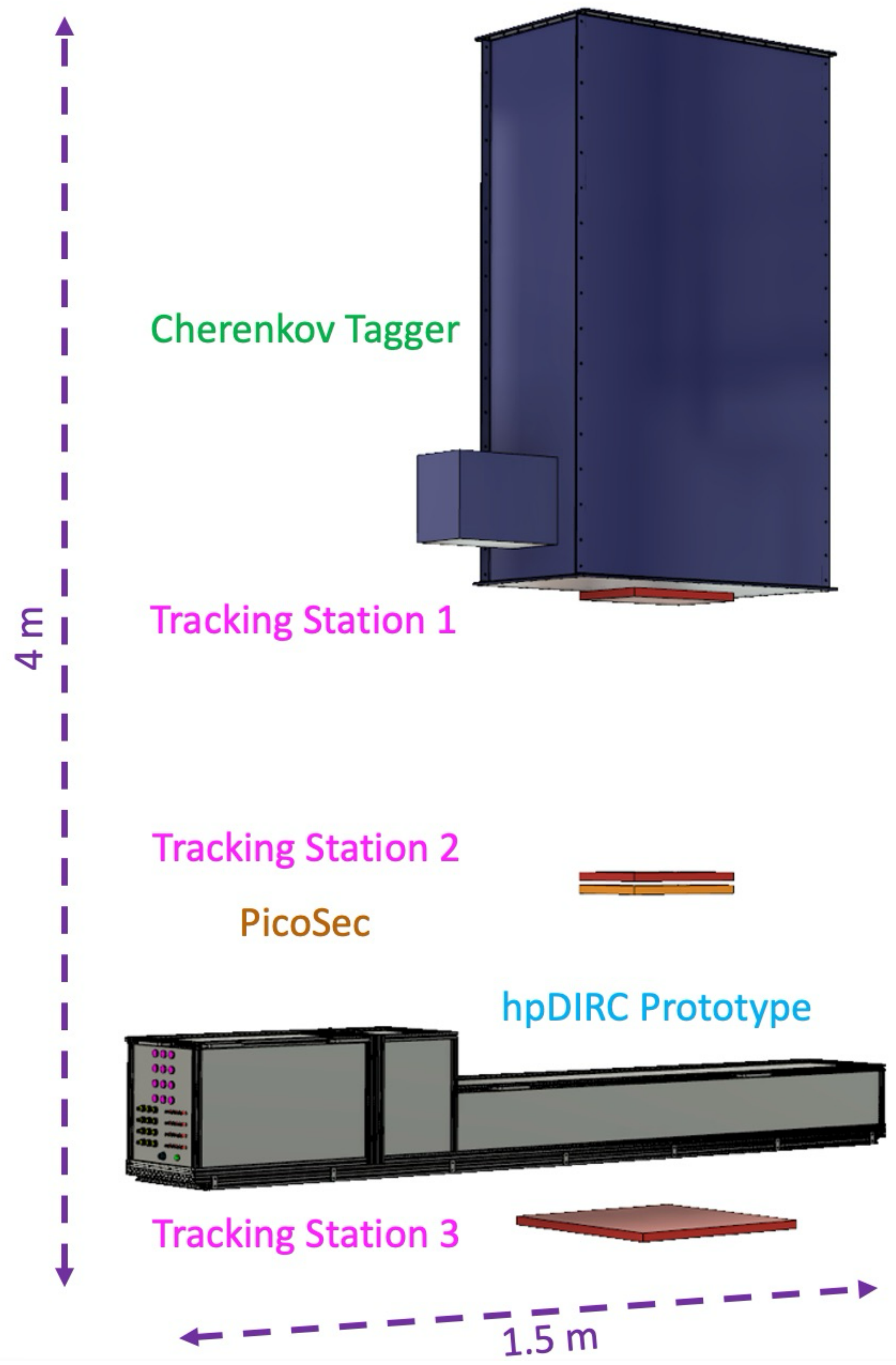
hpDIRC in CAD



hpDIRC Prototype in CRT

- Support structure completed and ready for installation of all CRT components
- Recently installed tracking stations and Cherenkov Tagger (constructed at ODU) for preliminary tests
- hpDIRC prototype:
  - Stewart platform adapted to control position and angle
  - Dark box tested for light tightness
  - Mock-up optics was used to test functionality of support system inside the dark box

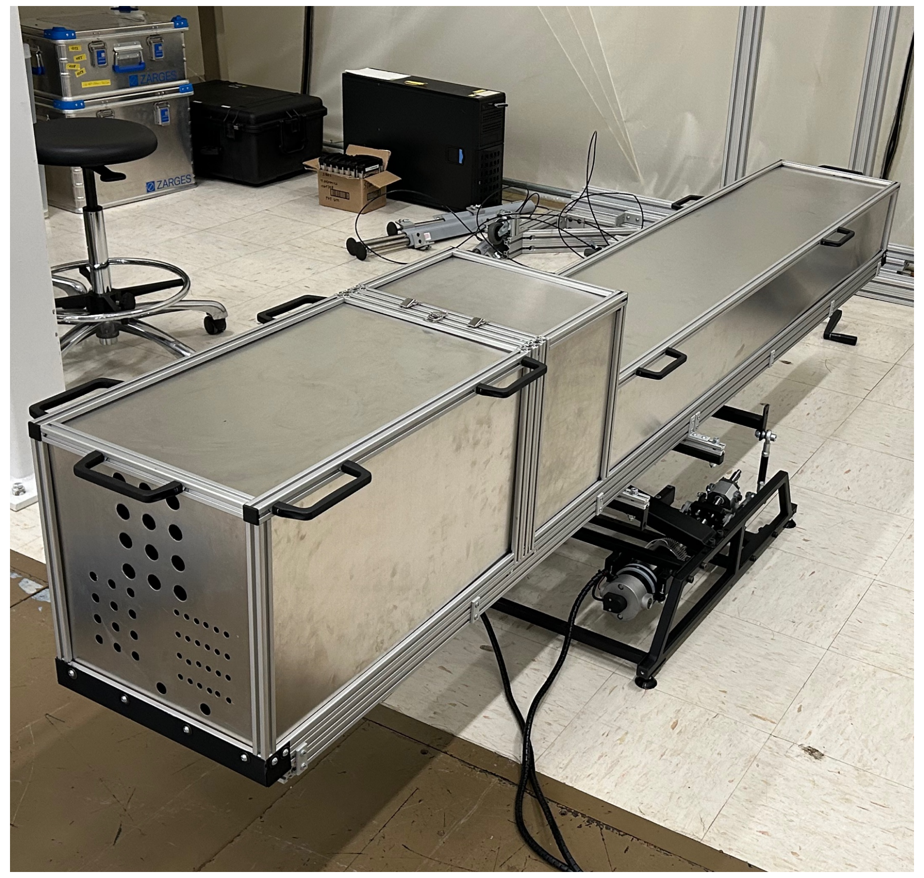
CRT setup CAD schematic



Installation of Cherenkov Tagger in CRT at SBU

Installation and alignment of CRT tracking stations

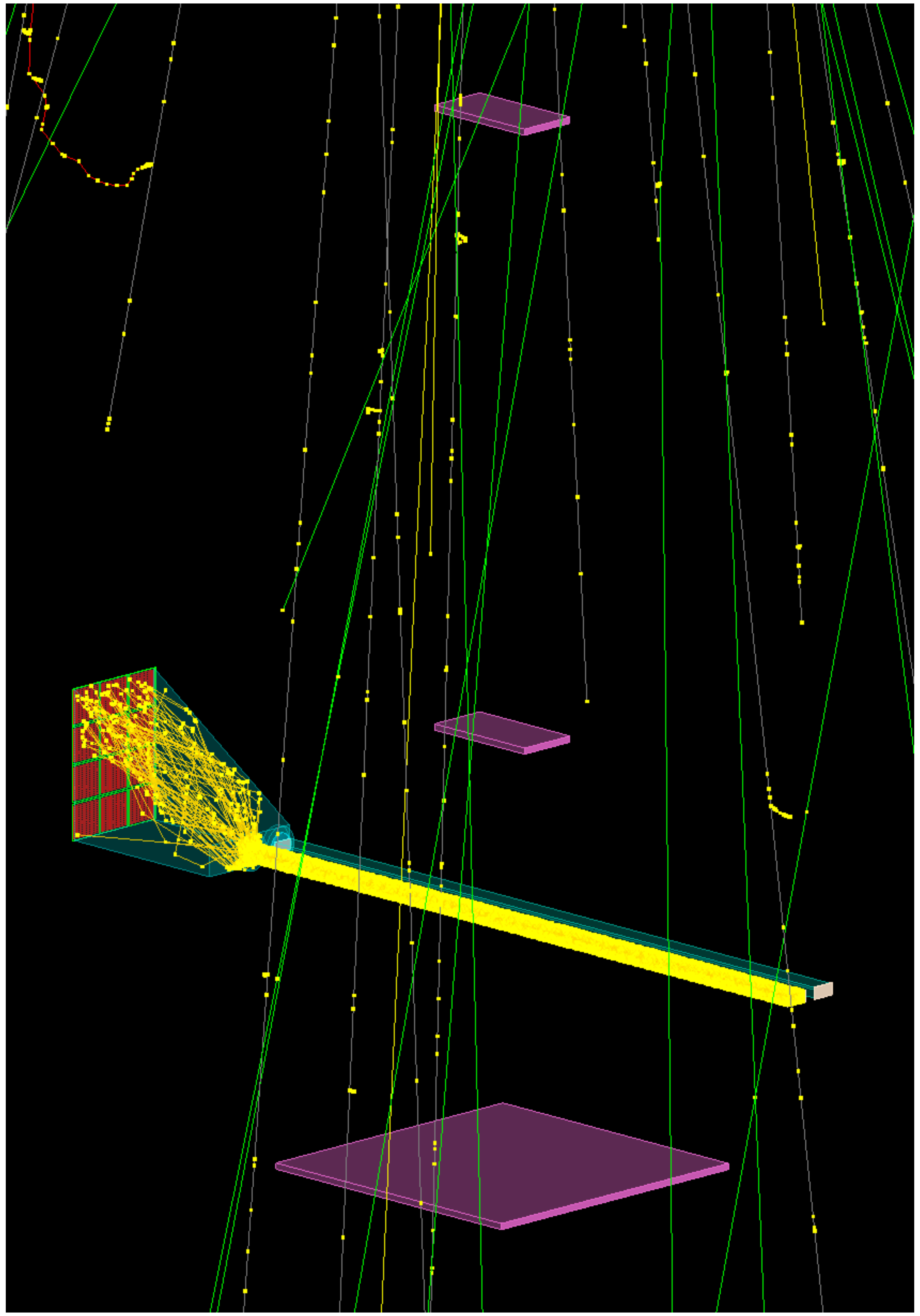
hpDIRC prototype on motion control stage



hpDIRC Prototype: Future Plans

- Commissioning of full setup starting in the Fall
  - 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
- CRT will be commissioned and operated in FY25 at SBU
- Possible transport to JLab will be evaluated by the end of FY25
- Testing a vertical slide prototype once all components are available
- Ultimate CRT goal: test of fully-assembled hpDIRC modules

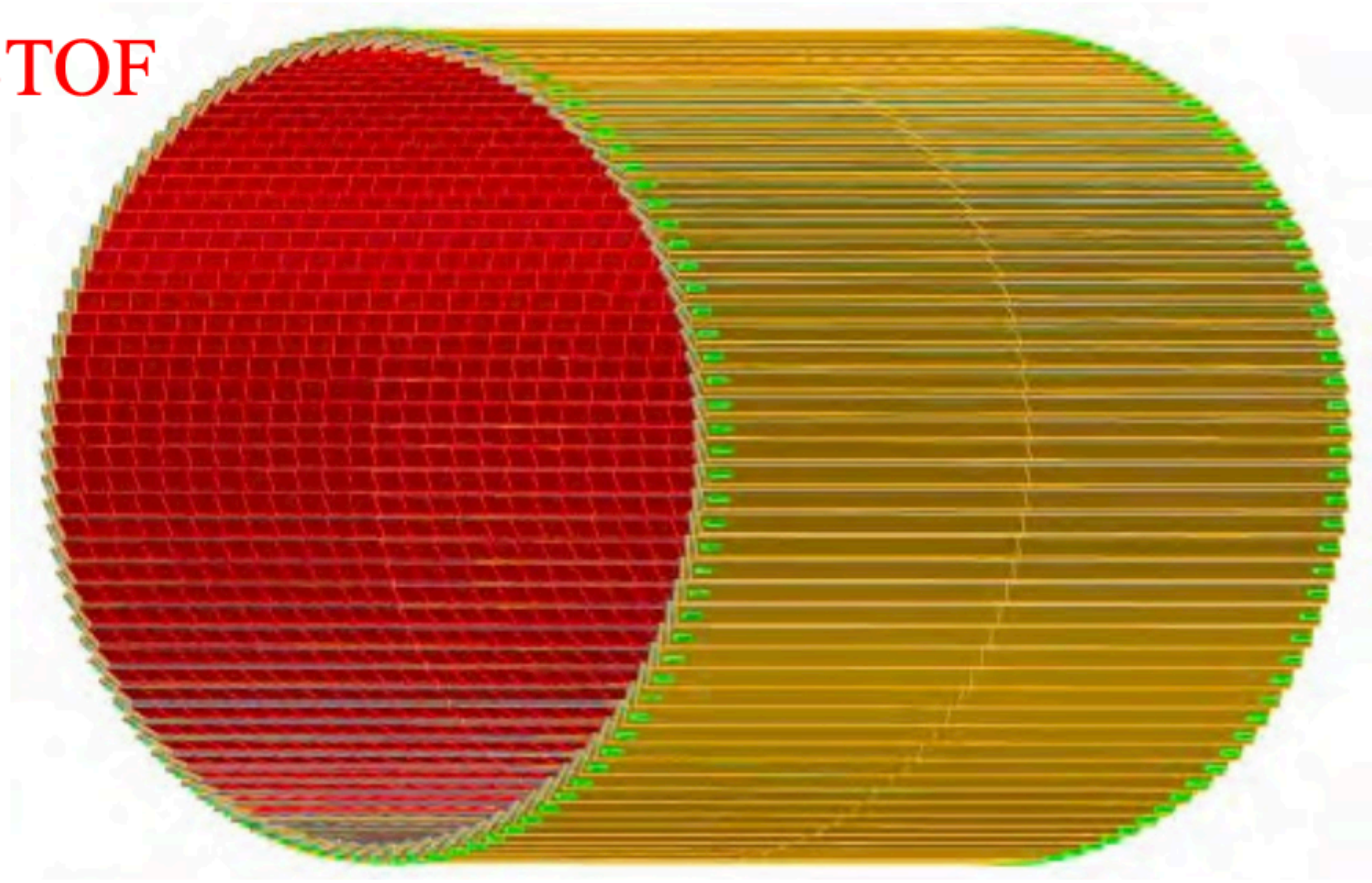
Simulation of hpDIRC Prototype with 2 bars in CRT



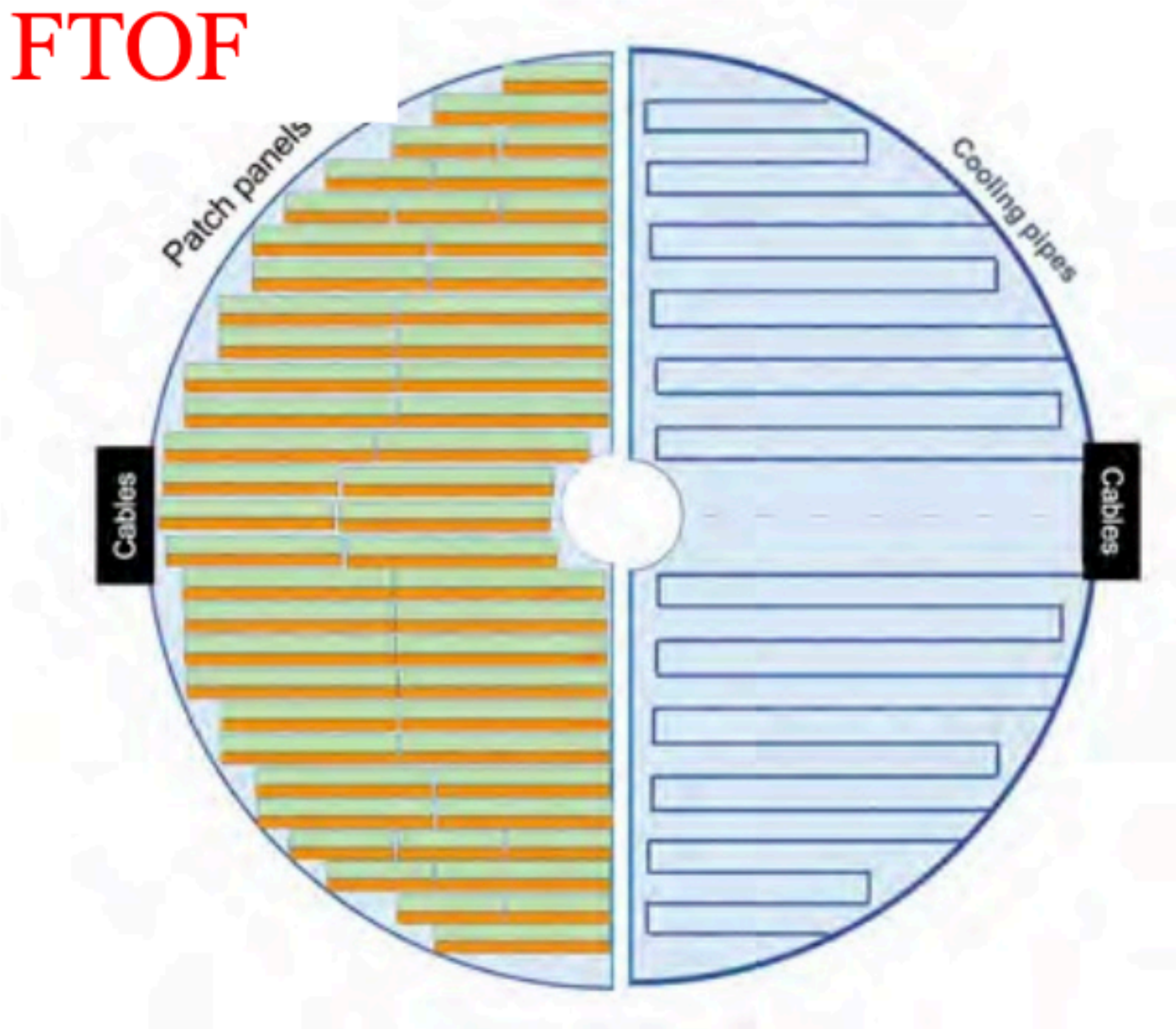
ToF

ToF - AC-LGAD

BTOF



FTOF



	Area (m^2)	Channel size (mm^2)	# of Channels	Timing Resolution	Spatial resolution	Material budget
Barrel TOF	10	0.5*10	2.4M	35 ps	30 μm in $r \cdot \varphi$	0.01 X_0
Forward TOF	1.4	0.5*0.5	5.6M	25 ps	30 μm in x and y	0.05 X_0
B0 tracker	0.07	0.5*0.5	0.28M	30 ps	20 μm in x and y	0.05 X_0
RPs/OMD	0.14/0.08	0.5*0.5	0.56M/0.32M	30 ps	140 μm in x and y	no strict req.
Lumi Tracker						

ToF - preTDR

- Copy the template from the master draft (done)
- Assign writing tasks to the corresponding experts and writing (last two weeks)
- First iteration meeting next week
- Identify remaining main tasks
- Complete first draft (before September 29)
- Key Plots:
  - Detector configurations and Key requirements
  - Realistic Performance from R&D
  - Simulations of 1/beta vs p
  - PID performance

8.3.4.1 The time-of-flight layers

Requirements

Requirements from physics: With single hit timing resolution of 35 ps from the Barrel TOF (BTOF) and 25 ps from the Forward TOF (FTOF), the TOF detector system can provide particle identification for low momentum charged particles, e.g., π-K separation at the 3σ level for $p_T < 1.2$ for $-1.3 < \eta < 1.3$, and $p < 2.5$ GeV/c for $2 < \eta < 3.7$, respectively. By combining the PID information for low momentum particles from the TOF detectors and high momentum particles from Cherenkov detectors, ePIC will have excellent PID capability over a wide momentum range in a nearly 4π acceptance, which is crucial to achieve the goals of the EIC physics program. Besides precise timing resolution, AC-LGAD sensors can also provide precise spatial resolution (30 μm), and thus aid track reconstruction and momentum determination. The requirements on the timing and spatial resolutions, as well as the material budgets (1 % and 5 % X/X_0 for BTOF and FTOF) are being evaluated in EPIC MC simulation to find the optimal configuration without over-designing these detectors.

8 *CHAPTER 8. EXPERIMENTAL SYSTEMS*

Requirements from Radiation Hardness: Simone Mazza

Requirements from Data Rates: Tonko Ljubicic

Justification

Device concept and technological choice: Add text here.

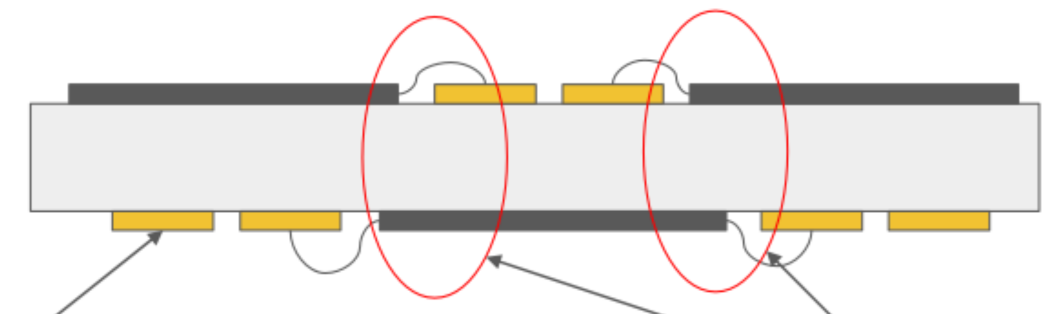
Subsystem description:

General device description: The BTOF consists of 144 tilted staves, each of which is made of two half staves with a total length of around 270 cm sitting at a radial position around 65 cm. AC-LGAD strip sensors are mounted on low mass Kapton flexible printed circuit boards (FPCs), and are wire-bonded with front-end ASICs. The FPCs are glued onto mechanical structures made from low density Carbon-Fiber (CF) materials, and bring power and input/output signals to the sensors and ASICs. The heat generated by the frontend ASICs are

Progresses Since Collaboration Meeting in July

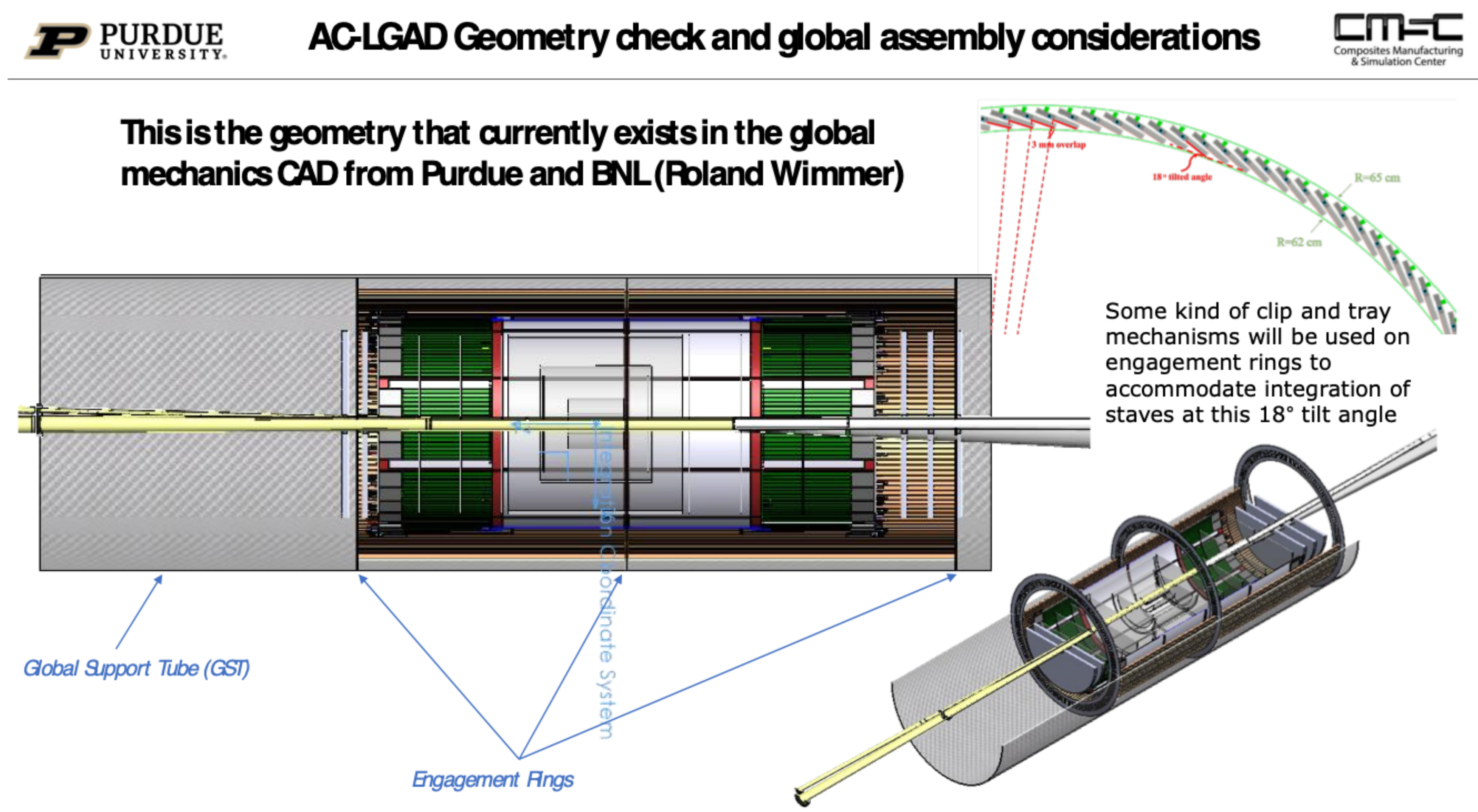
- Radiation hard test on sensors (performed)
- FY2025 R&D to PED transition crucial (eRD112+eRD109)
- BTOF double-side instrumentation of staves (decided)
- BTOF design with engagement rings (two-stave design separated at off center) with different stave lengths (which was required by other detectors?)
- BTOF services from both hadron and electron sides
- Geometry and material studies in simulation ongoing

- An alternative design can solve both of these problems if we use both sides!



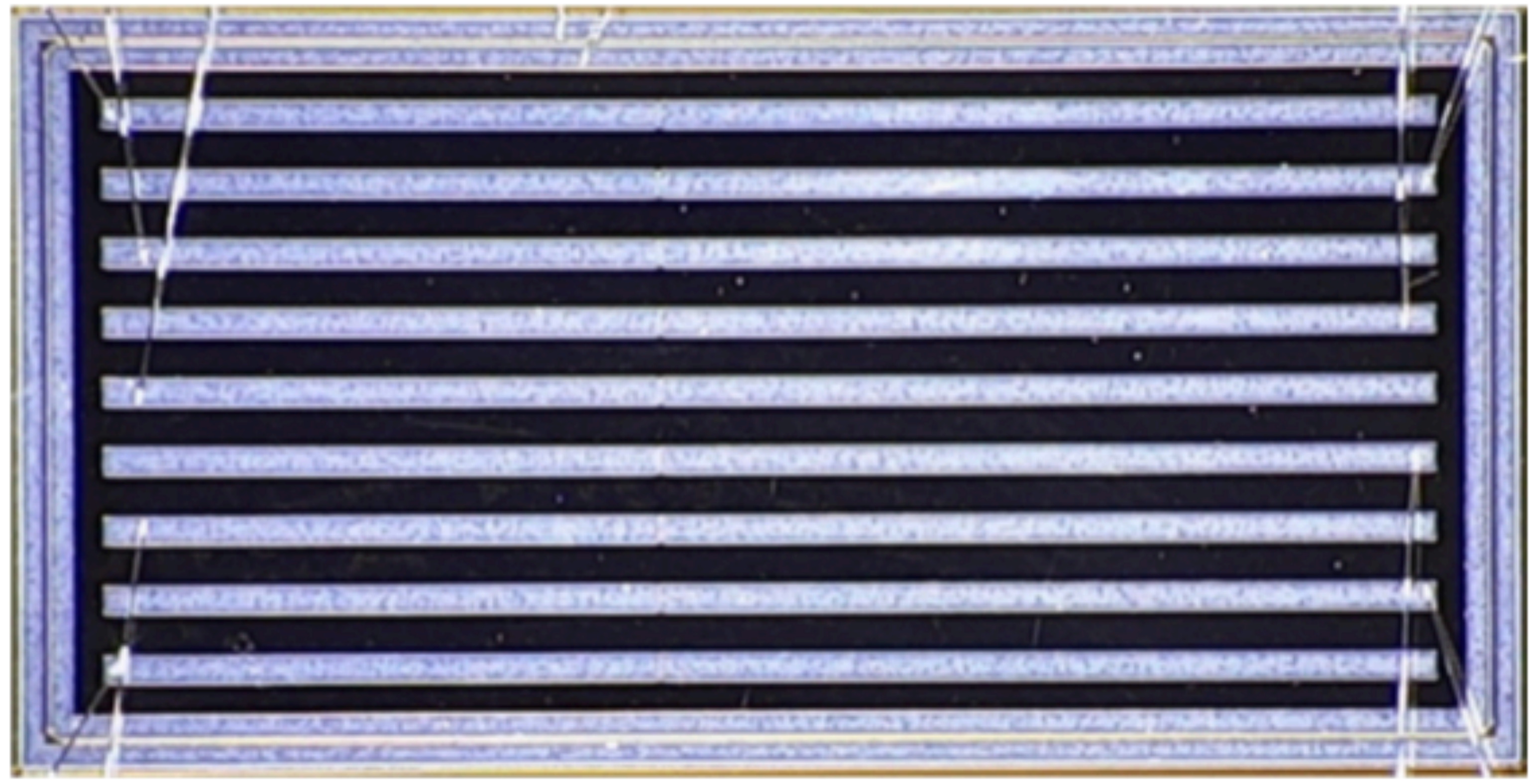
ASICs have direct contact to cooling structure → easier to cool and no temperature gradients introduced onto the sensor surface

Overlap between sensors can be chosen to eliminate acceptance gaps!

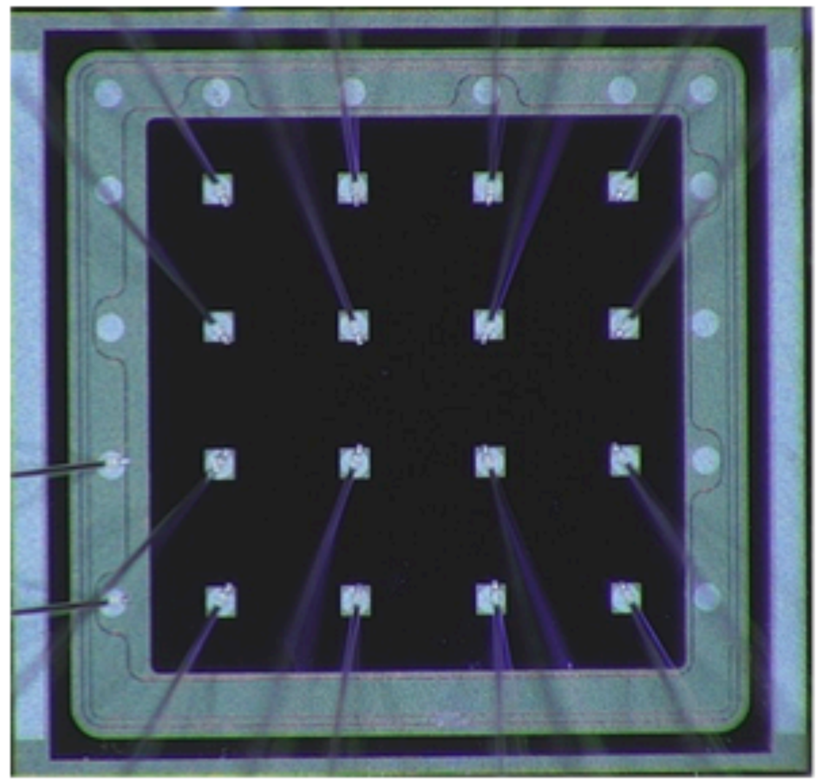


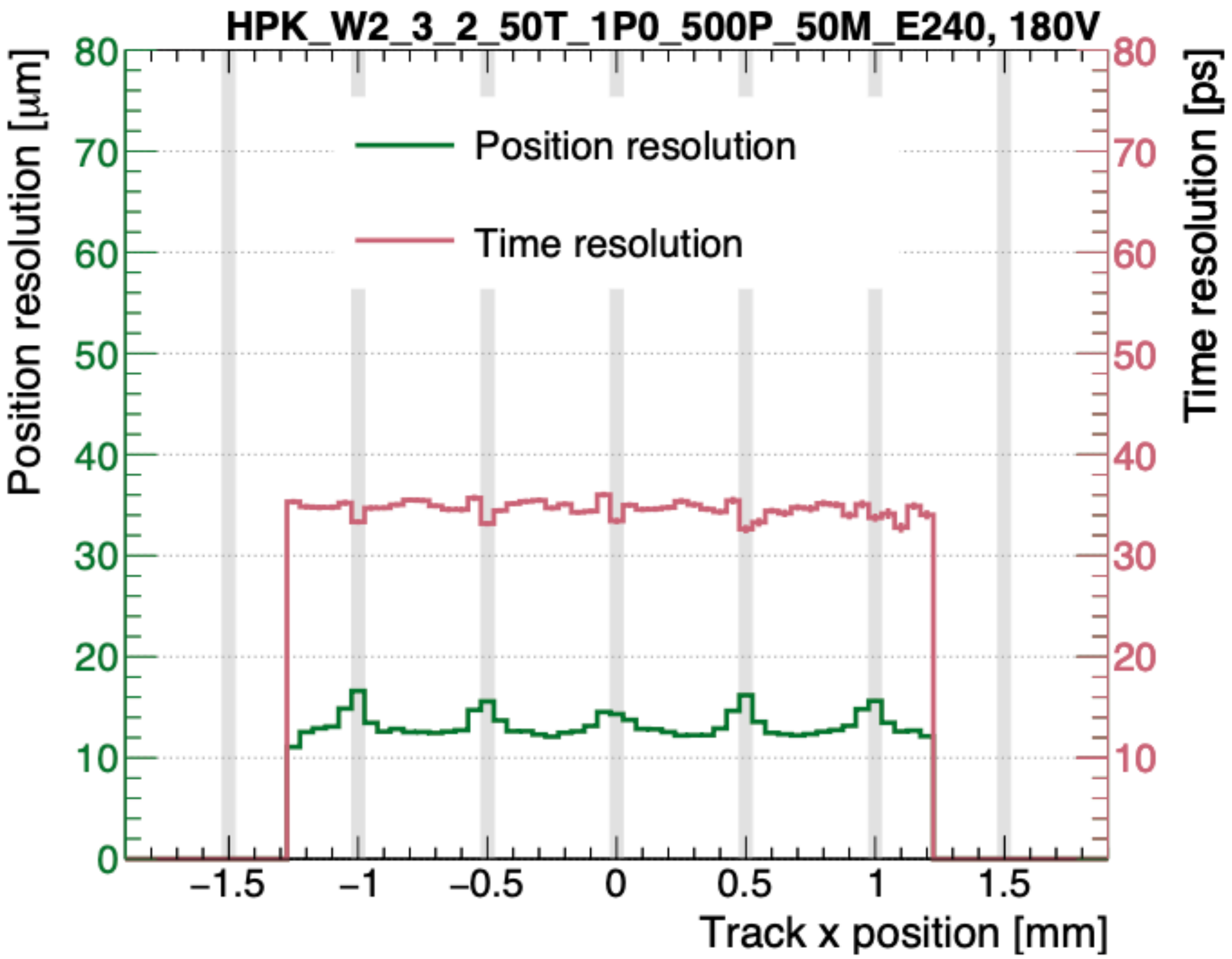
ToF: Position and timing resolutions from R&D

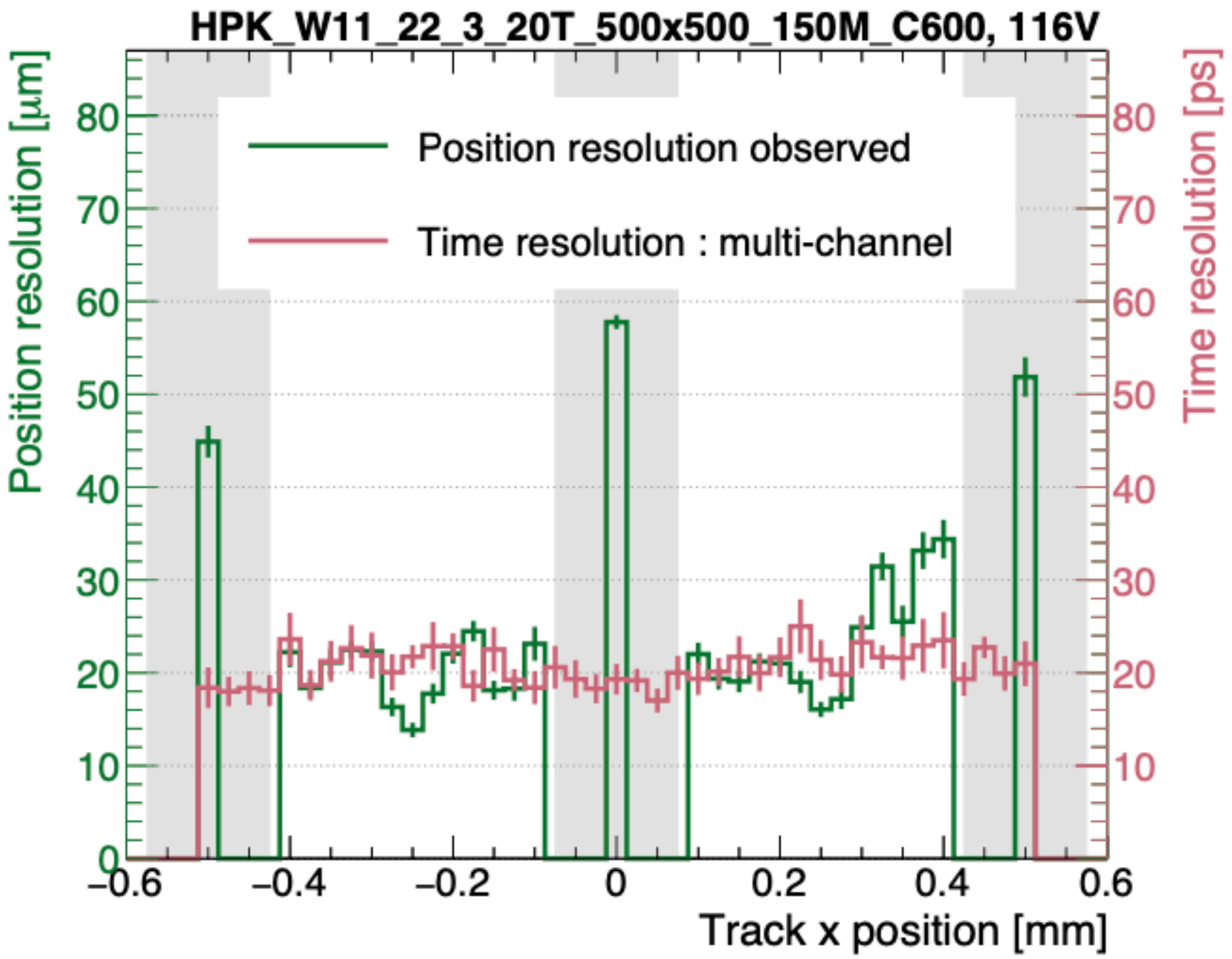
HPK Strip Sensor (4.5x10 mm^2)



HPK Pixel Sensor (2x2 mm^2)







Thank You