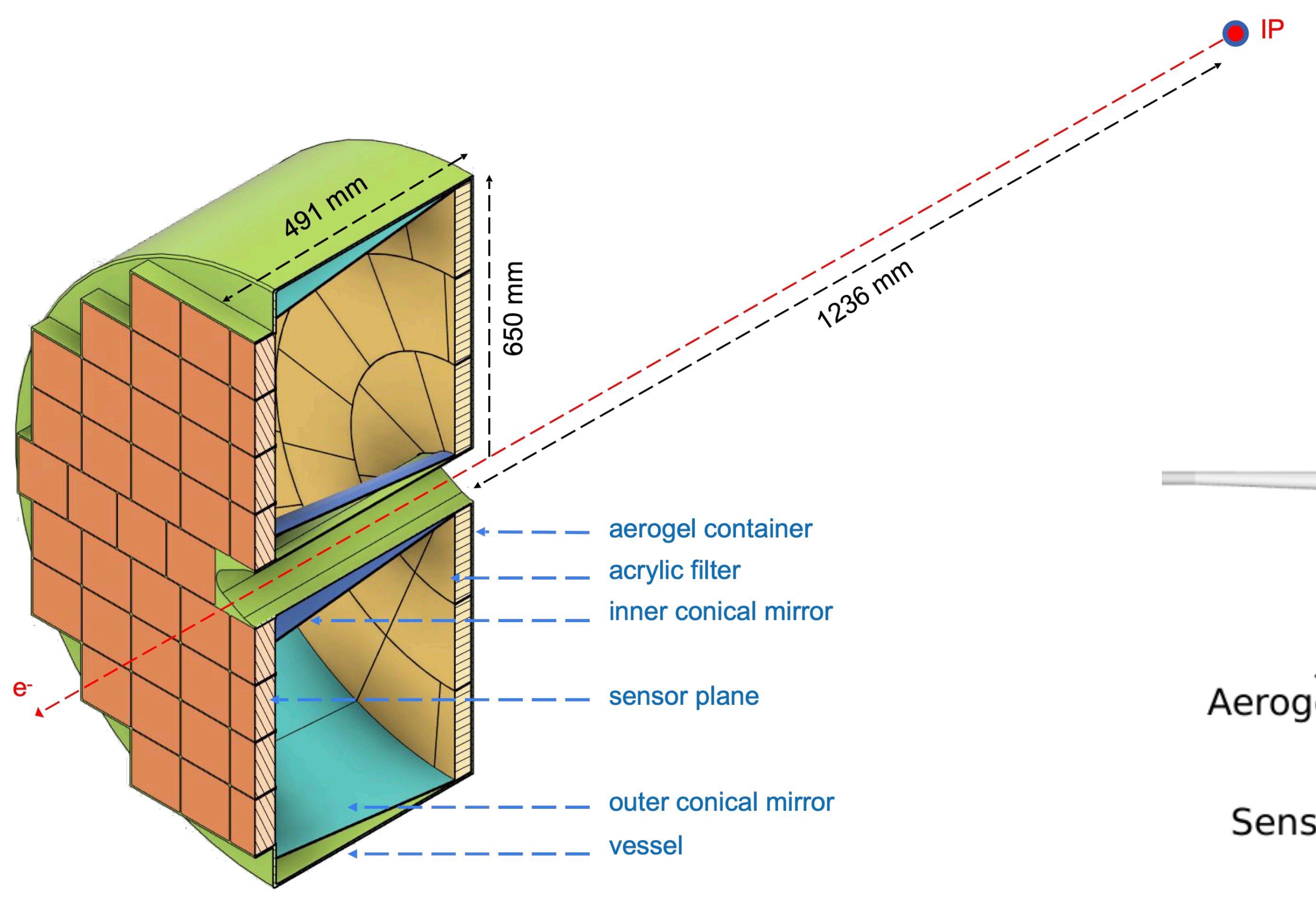
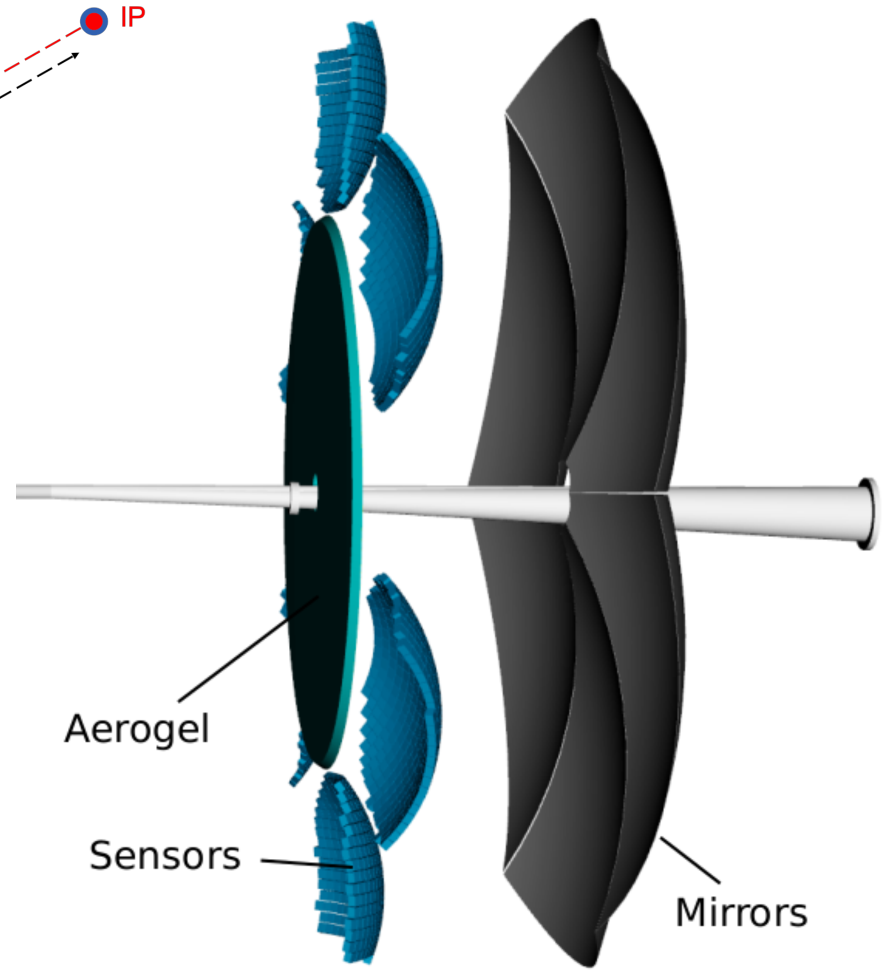
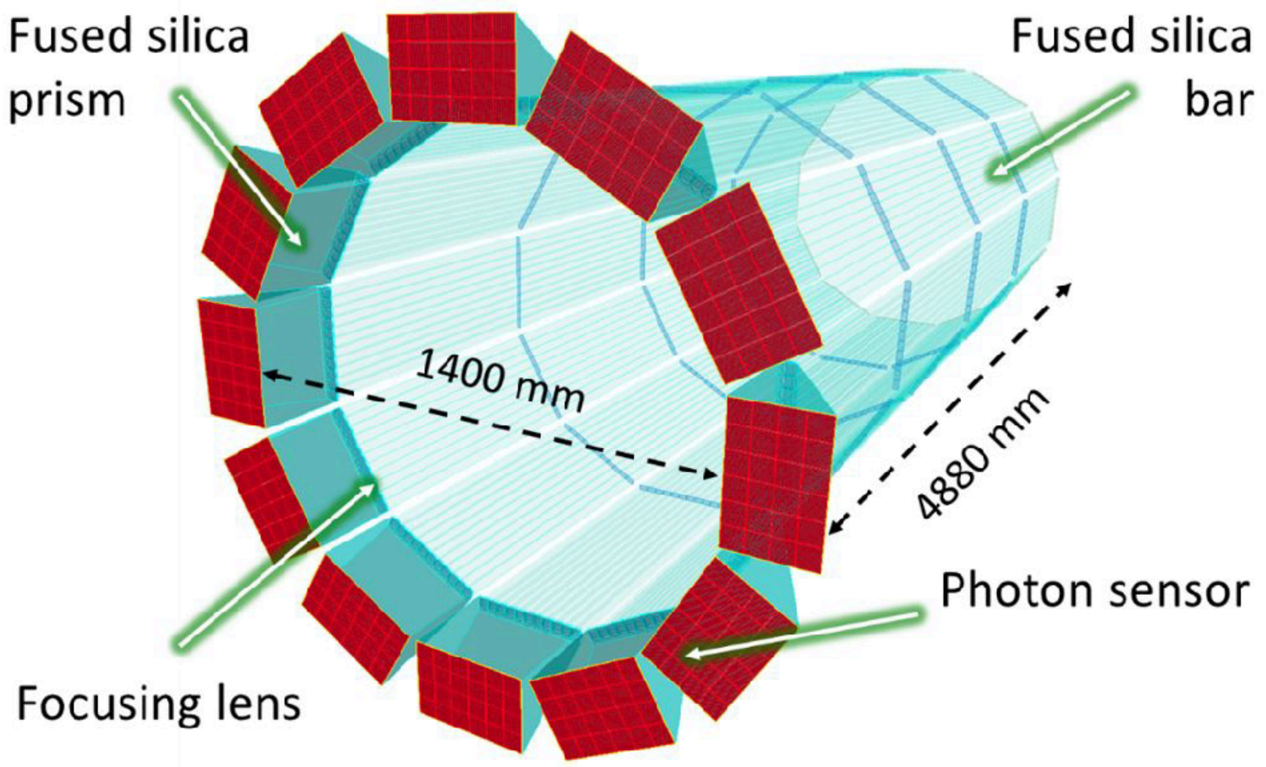
Planning for TDR effort - PID



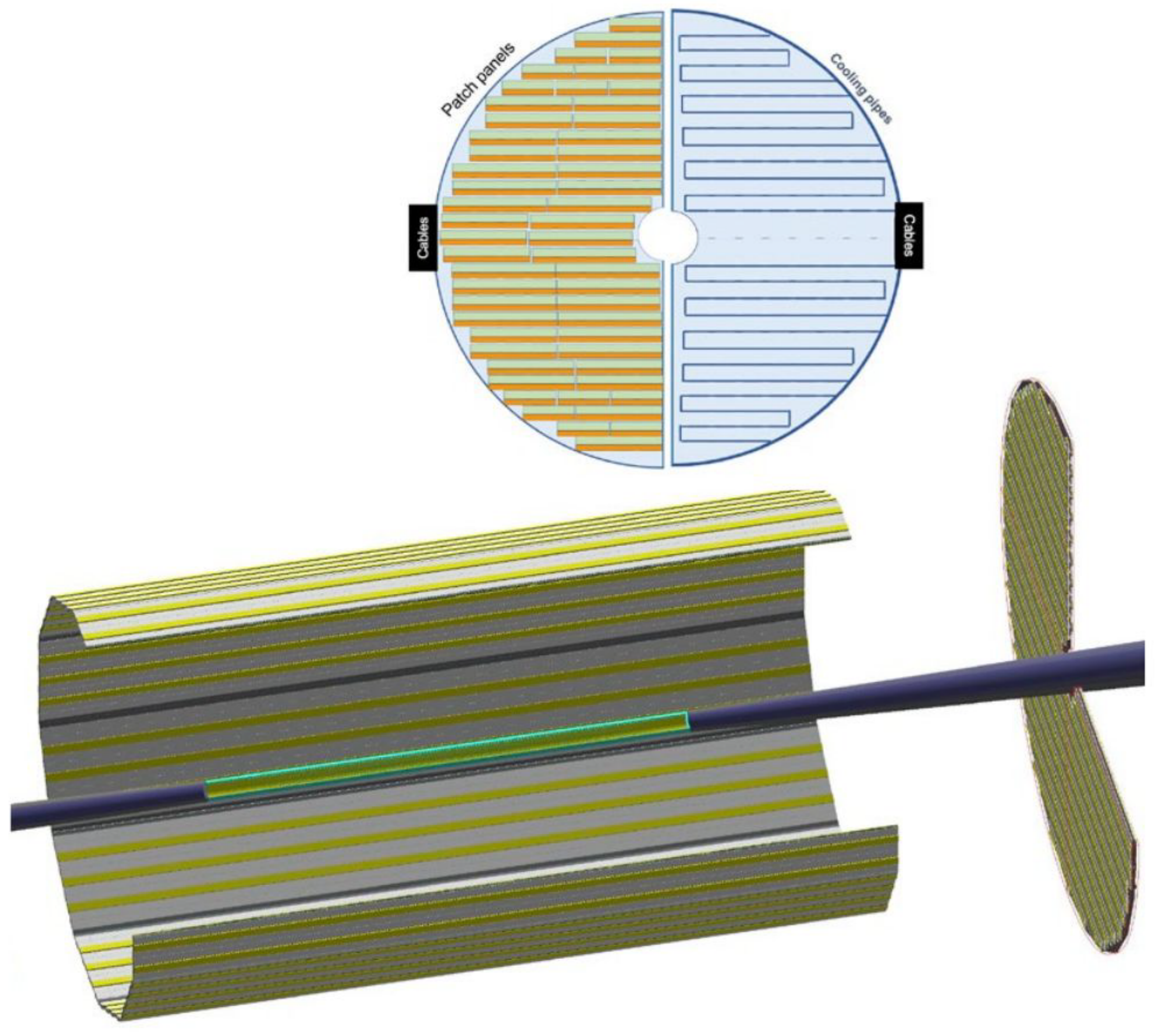
pfRICH



dRICH



hpDIRC



ToF

Thomas Ullrich on behalf of the four PID DSCs

TIC Meeting

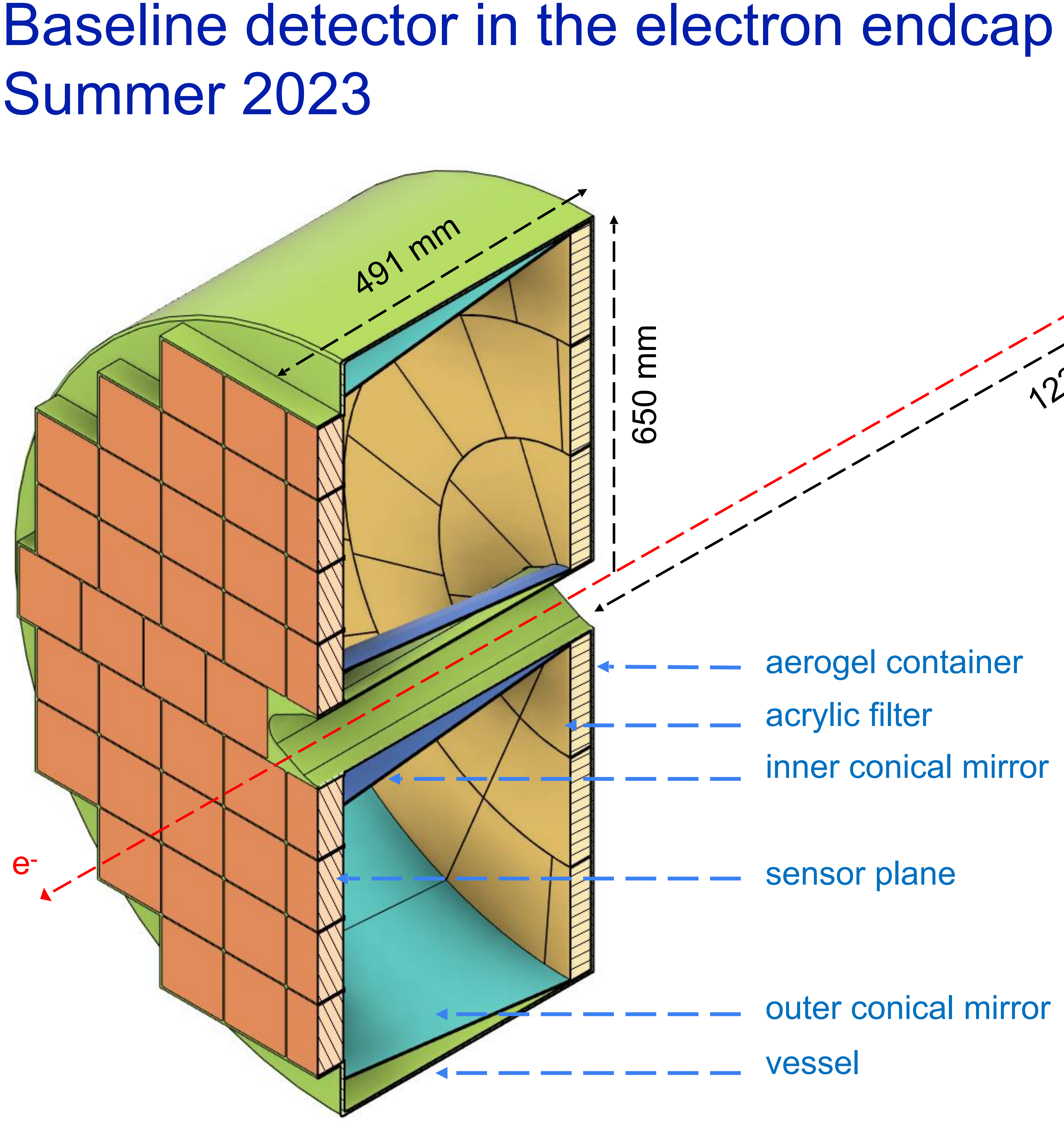
March 4, 2024

Brookhaven National Laboratory

pf*RICH*

ePIC pfRICH detector

Baseline detector in the electron endcap as of Summer 2023



- Aerogel
  - Three radial bands
  - Opaque dividers
  - 2.5 cm thick, 42 tiles total
- Vessel
  - Lightweight structure
  - Reinforced carbon fiber and 3D printed materials
  - Filled with nitrogen
- HRPPD photosensors
  - 120 mm size
  - Tiled with 1.5-3.0 mm gaps
  - 68 sensors total

pfRICH Work Packages

Engineering design oversight
A. Eslinger (JLab)

Vessel & mirrors: 3D printing & molding
A. Jung (Purdue)

Vessel: outer shell
C.-J. Naim (Stony Brook)

Mirrors: aluminum coating
W. Li (Stony Brook)

Construction coordination
C.-J. Naim (Stony Brook), Z. Tu (BNL)

HRPPD test stand
P. Garg (Yale)

Aerogel QA station
M. Posik (Temple)

HRPPD QA station
A. Kiselev (BNL)

MCP-PMT test stand
R. Montgomery (Glasgow)

Standalone GEANT software & modeling
A. Kiselev (BNL)

Software support in ePIC framework
BNL NPPS group, K. Kauder (BNL)

Physics modeling
B. Page (BNL)

DAQ software & firmware
… (BNL)

Gas system
P. Shanmuganathan (BNL)

HV & LV systems
T. Camarda (BNL)

Cooling system
D. Cacace (BNL)

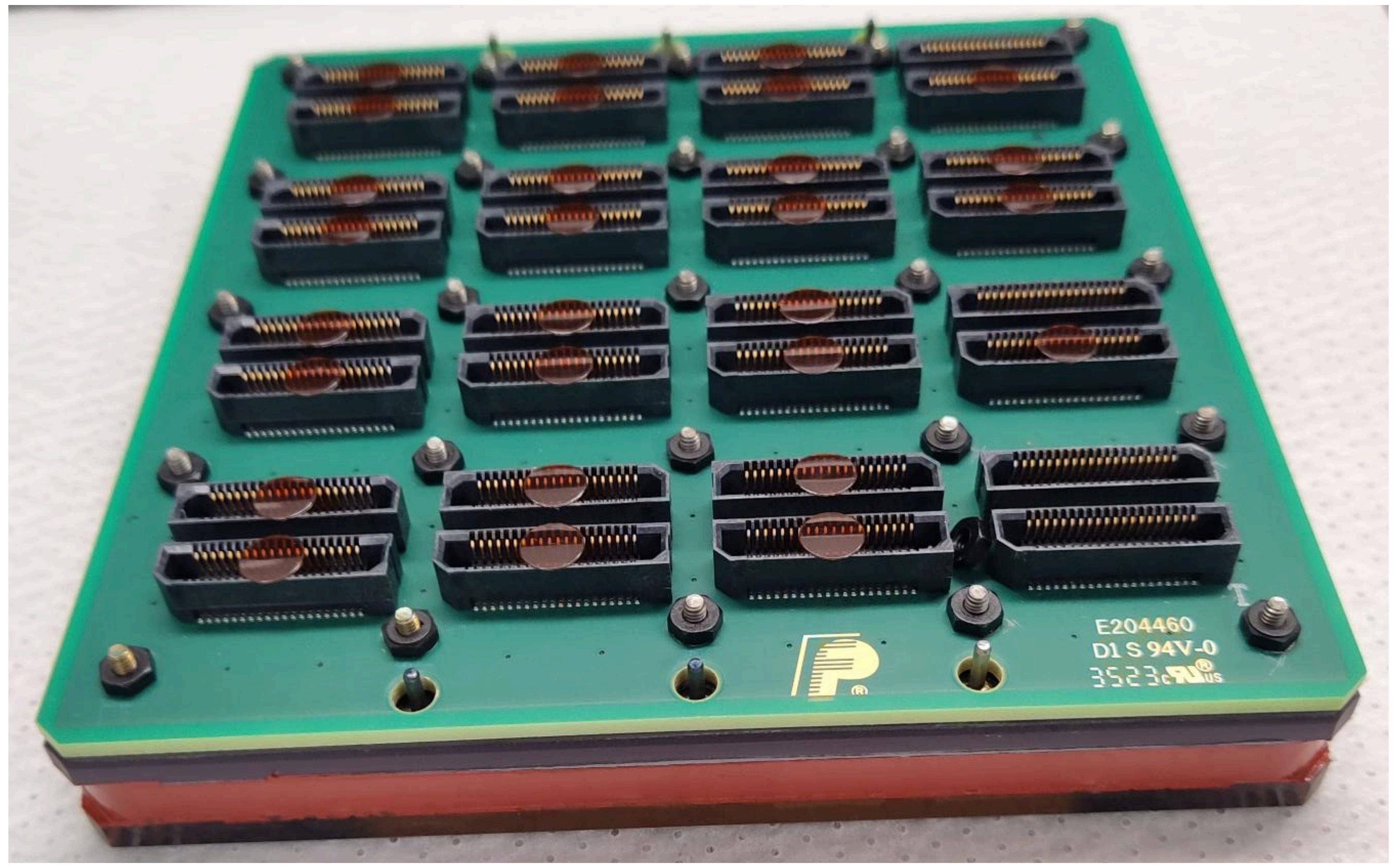
Light monitoring system
F. Barbosa (Jlab)

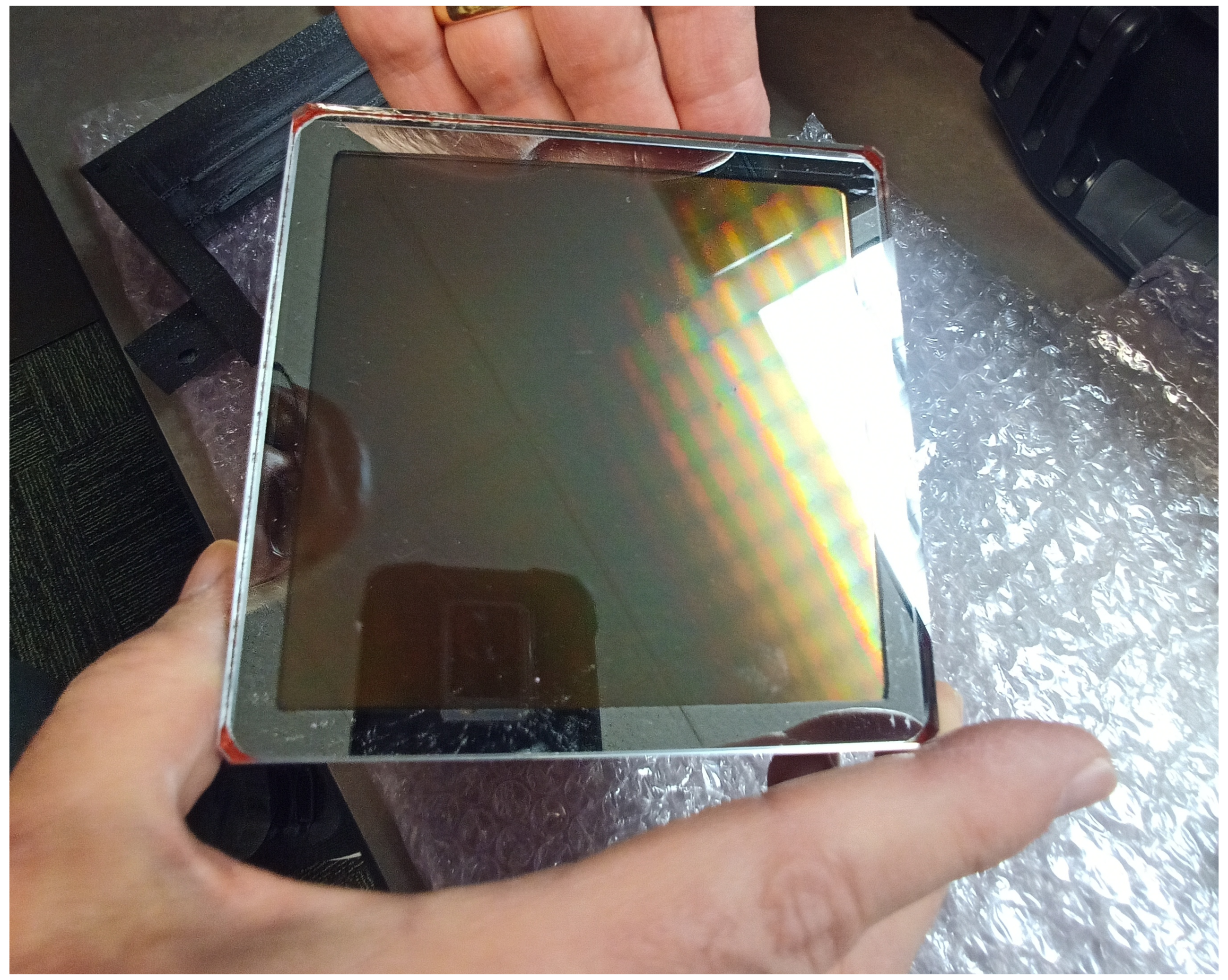
Frontend electronics
… (Debrecen)

Mirror QA station
… (BNL)

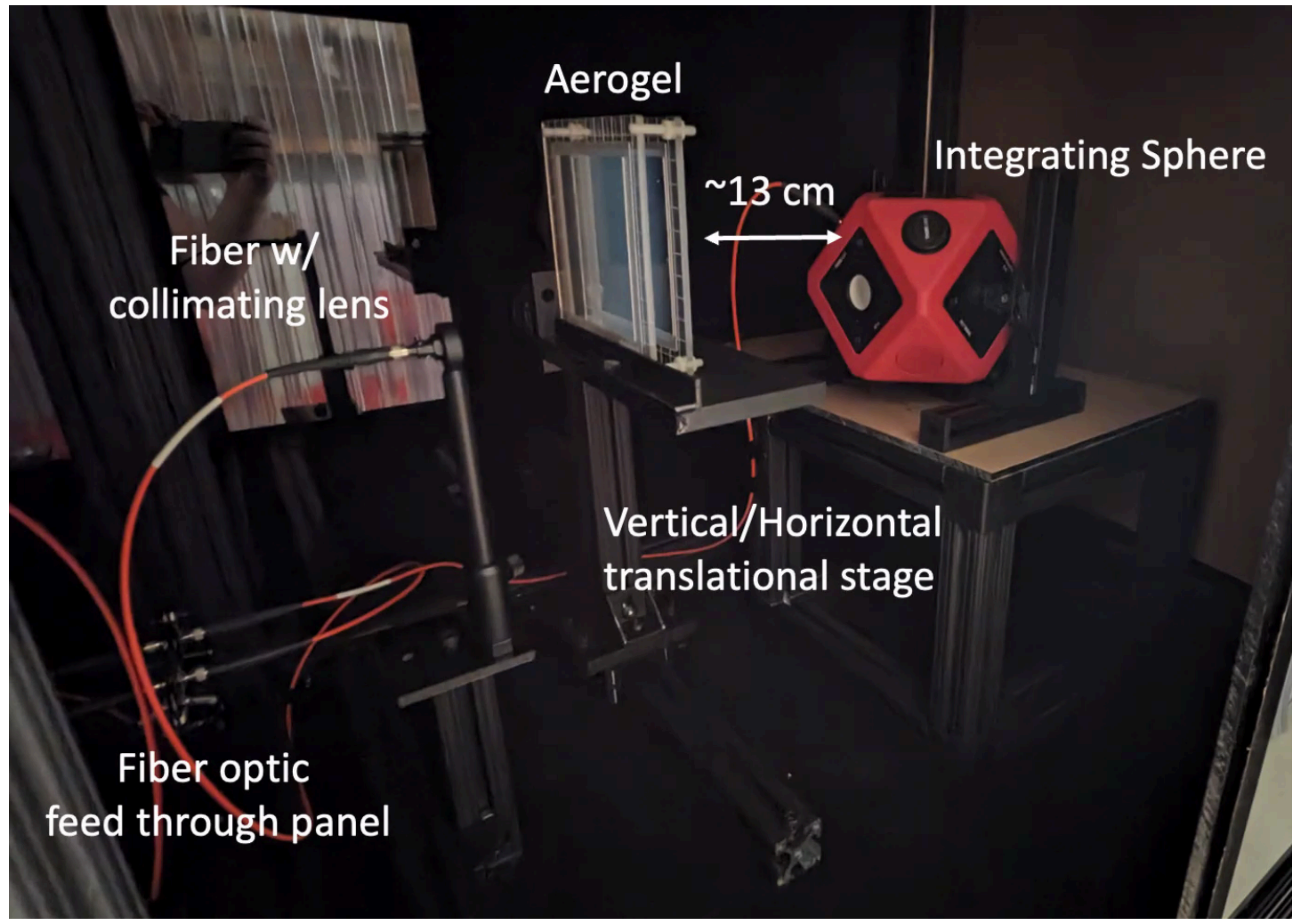
Lab / Test Beam / Prototyping

	M	A	M	J	J	A	S	O	N	D	Comments
Aerogel characterization @ Temple	x	x	x	x							Transmission, refractive index, other
HRPPD characterization @ BNL		x	x	x	x	x					Surface scans: QE, PDE, gain, timing
HRPPD B-field study @ Argonne					?						eRD110 [defined by HRPPD delivery time]
HRPPD ageing study @ INFN Trieste							?	?			eRD110 [defined by HRPPD delivery time]





EIC HRPPD #1



Aerogel QA stand @ Temple

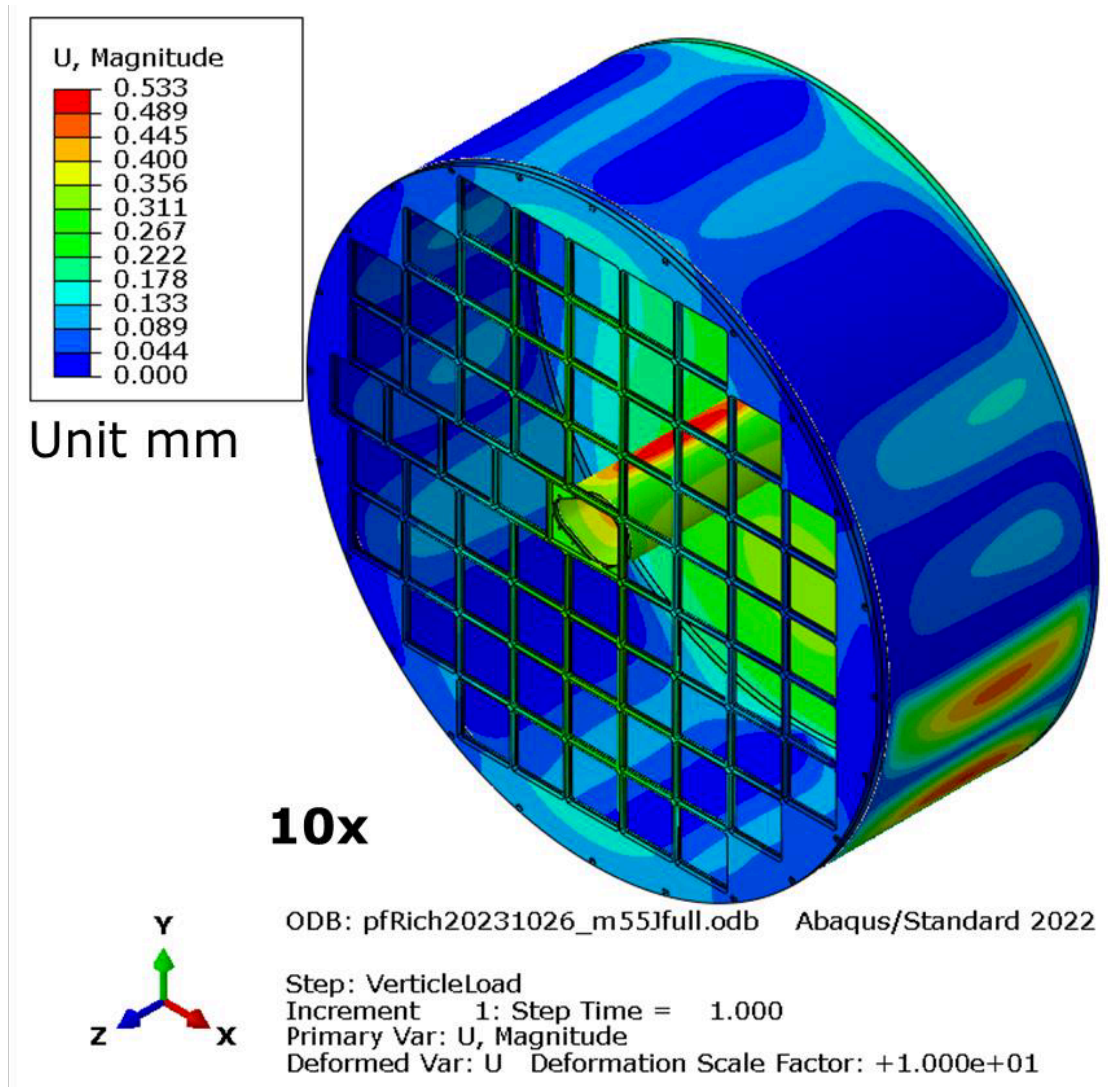
No beam tests for the pre-TDR stage (2024)

Lab / Test Beam / Prototyping

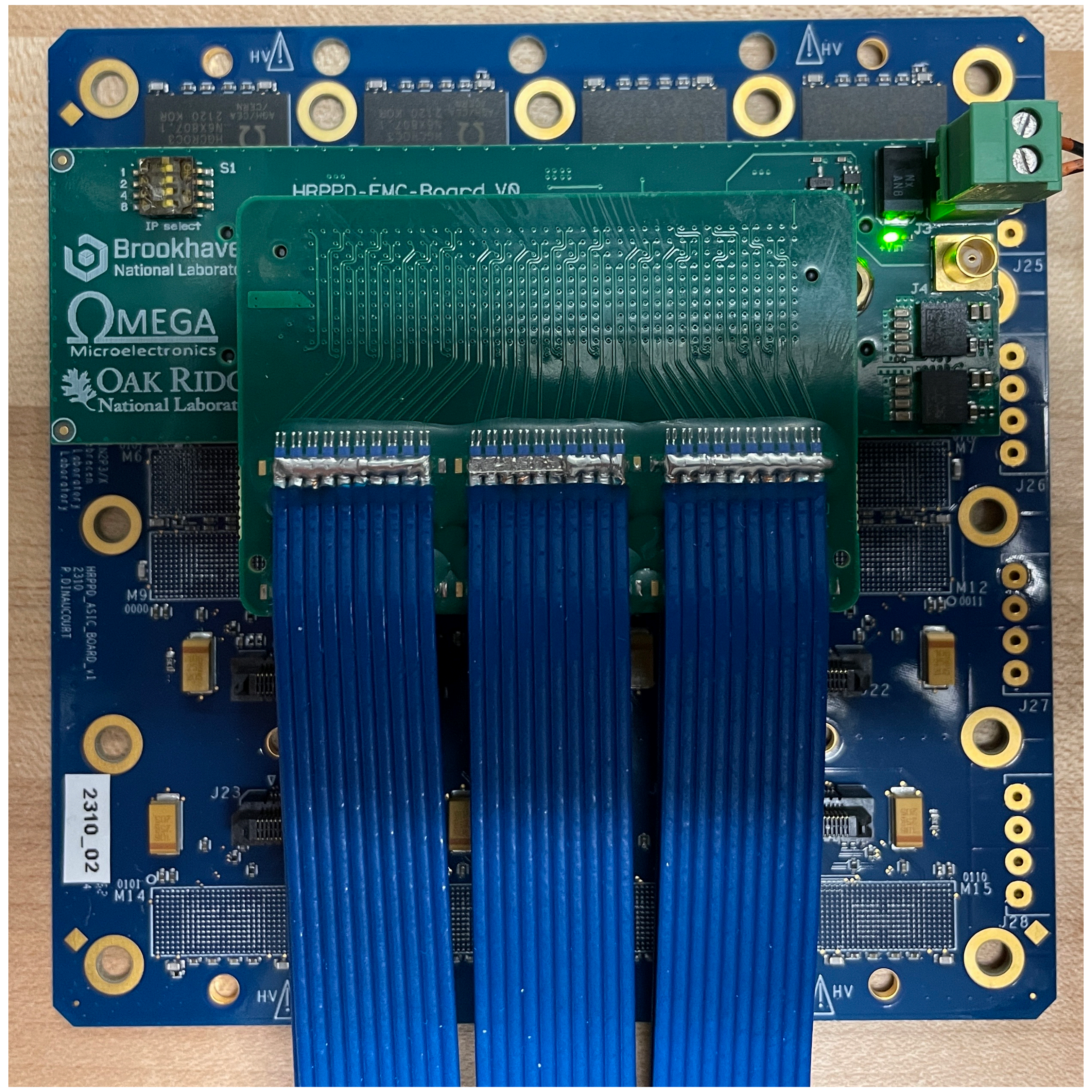
	M	A	M	J	J	A	S	O	N	D	Comments
Other MCP-PMT evaluation @ Glasgow		x	x	x	x	x					eRD110
Mirrors 1st article @ Purdue & Stony Brook	x	x	x	x	x						Funded PED proposals
Vessel 1st article @ Purdue & Stony Brook	x	x	x	x	x						Funded PED proposals
ASIC FE V0 work (I2NP3/Debrecen/BNL/ORNL)	x	x	x	x							A new PED proposal in works

Mandrel assembly started

First mirror samples



Vessel FEA work



ASIC backplane

Reconstruction Software & Simulations

	M	A	M	J	J	A	S	O	N	D	Comments
Standalone code refinement	x	x	x	.	.	.	.	.	.	.	ML add-on, timing code update, etc
Aerogel / HRPPD / mirror parameterizations			x	x							Once lab test data is available
Geometry porting to dd4hep											Pretty much completed
Optics configuration porting to EICrecon	.	.	?	?	?	.	.	.	.	.	Low priority (not needed for a pre-TDR)
IRT 2.0 interface to EICrecon	.	.	?	?	?	.	.	.	.	.	Low priority (not needed for a pre-TDR)

pfRICH geometry update & Co	x	x	.	.							Minor changes required; B field, etc
LUTs for ePIC simulation campaigns	x	x	x	x	.	.	.	.			Up until a pre-TDR input is frozen
Basic single-track performance confirmation	x	x	x	x	x	.	.	.	.		Follow reconstruction code updates
Background studies			?	?							TBD
Multi-track DIS event performance studies	.	.	.	.	.						Reconstruction code update required
pfRICH PID SIDIS money plots				?	?						Repeat March 2023 studies
Tracking resolution effects		x	x	x					x		

Engineering Design

	M	A	M	J	J	A	S	O	N	D	Comments
Outer vessel shell											Completed
HRPPD (rear) sensor plate		x	x								Assuming PED completion by August 1st
Front vessel plate & aerogel support		x	x	x							*ditto*
Inner (beam pipe) vessel wall			x	x							*ditto*
Mirrors	x	x	x								*ditto*
Installation concept; support structure	.	x	x	.	.	.	.	.	.		TBC; an ongoing effort
Gas system	x								x		Preliminary design exists
HV system		x	x	x					x		*ditto*
LV system									x		*ditto*
Cooling system									x		*ditto*
Front end electronics											2024 focus: analog FE evaluation
DAQ interface											Once RDO for EICROC is conceptualized
Slow Control											TBD

Integration and services work depends on the EIC Project timelines
Continuous support by EIC Project engineers is essential

pfRICH Summary

- Lab test and design work is ongoing
- No beam tests in 2024; focus on lab evaluation of the components (HRPPDs / aerogel / etc)
  - Assume this is sufficient for a PID subsystem PDR in Summer 2024
- Early Spring 2025: a first Fermilab beam test, for CD-2/3 (TDR) purposes
  - And then will be waiting for EICROC for a final (full chain) beam test
- A standalone GEANT software suite exists
  - A complete implementation of pfRICH geometry, optical photon propagation, event-level reconstruction
- Pre-TDR (60% readiness) drafting: recycle the CDR-style document prepared for the March 2023 ePIC Backward RICH review and update it accordingly
- TDR (90% readiness) drafting: first half of 2025

pfRICH (pre)TDR work is ongoing & no apparent showstoppers

d*RICH*

dRICH TDR Plan

The timescale is aggressive due to the limited manpower
A 60% readiness within 2024 is realistic, a 90% readiness appears challenging

dRICH @ 60% : Design of major components (mechanics, readout)
No hardware real-scale demonstrators
Realistically achievable in 2024

dRICH @ 90% : Hardware real-scale demonstrators (mechanics, readout)
Design refinement based on hardware tests
Realistically achievable during 2025 (1st half)

Left over: Aerogel (mass production) and SiPM (temperature treatments)
Detail of ancillary systems
may require longer engineering to reach best performance

Engineering Design - Mechanics

Structure:	Shell & Integration	March
	Inner Structure	July
Cooling:	Insulation / Services (preliminary)	April
	Insulation / Services (realistic)	November
Detector:	Detector box	June
	Services (power)	April
Infrastructure:	Installation tools / Services lines	After summer
Protoypes:	Existing (single component performance)	March-June
	Real-scale (realistic components, integration, mechanics, cooling)	After summer

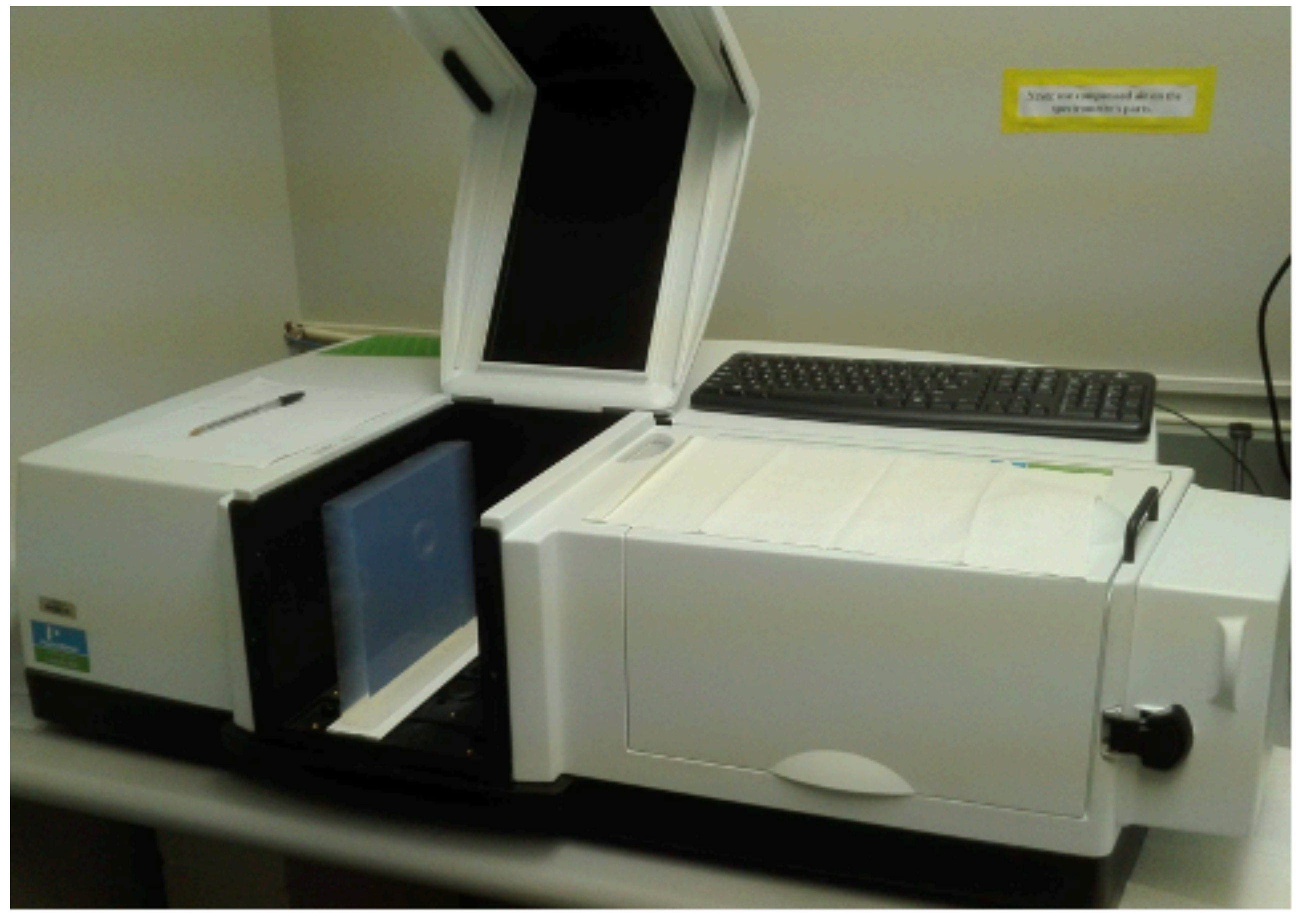
Engineering Design - Readout

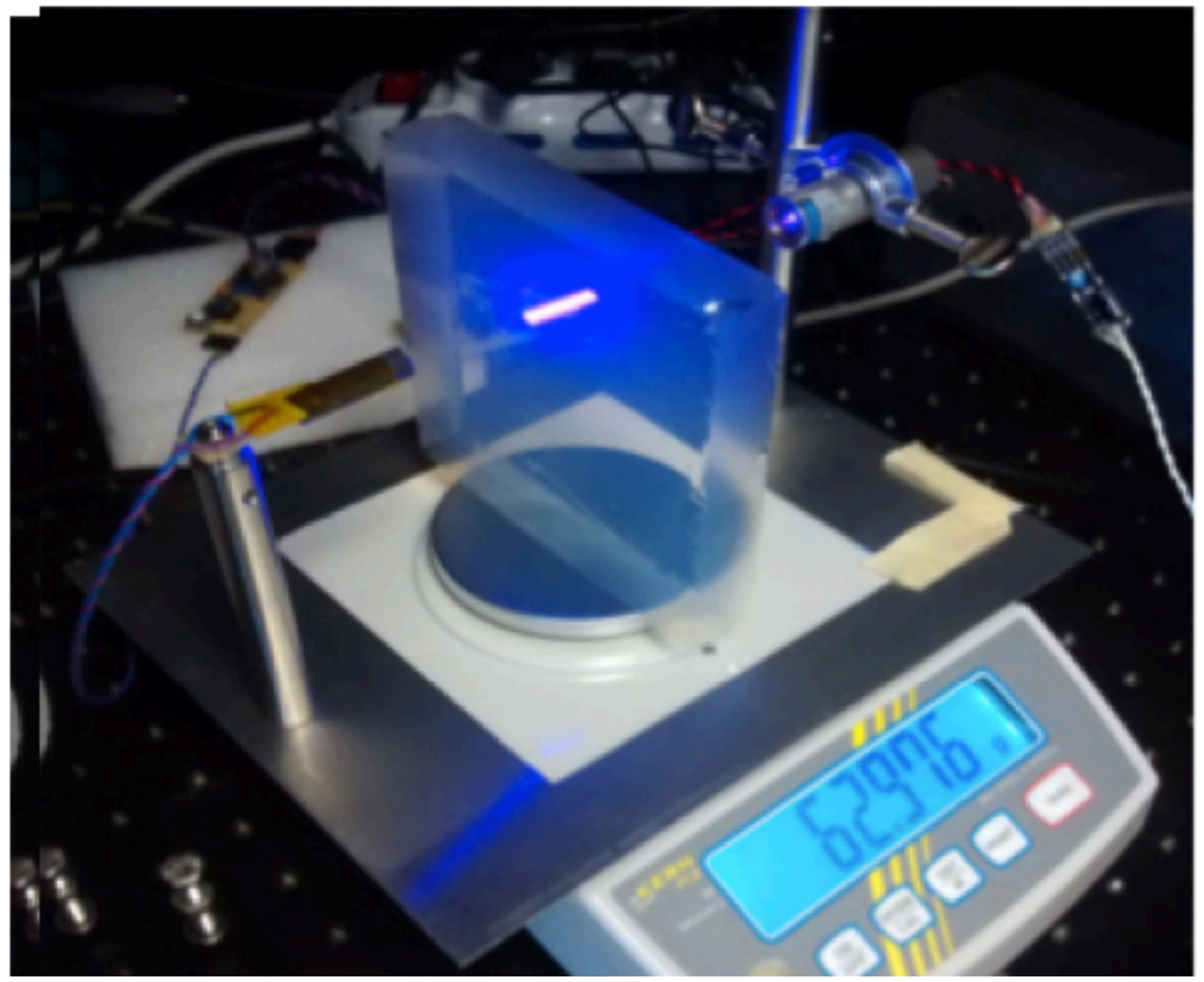
Front-end:	RDO Design	May
	ALCORv64	July
	FEB Design	December
DAQ:	General scheme	April
	Data L1 & L2 Reduction (preliminary)	July
	Data L1 & L2 Reduction (refined)	October
Services:	Power distribution	April

Assumption: readout design in 2024 but hardware realization in 2025

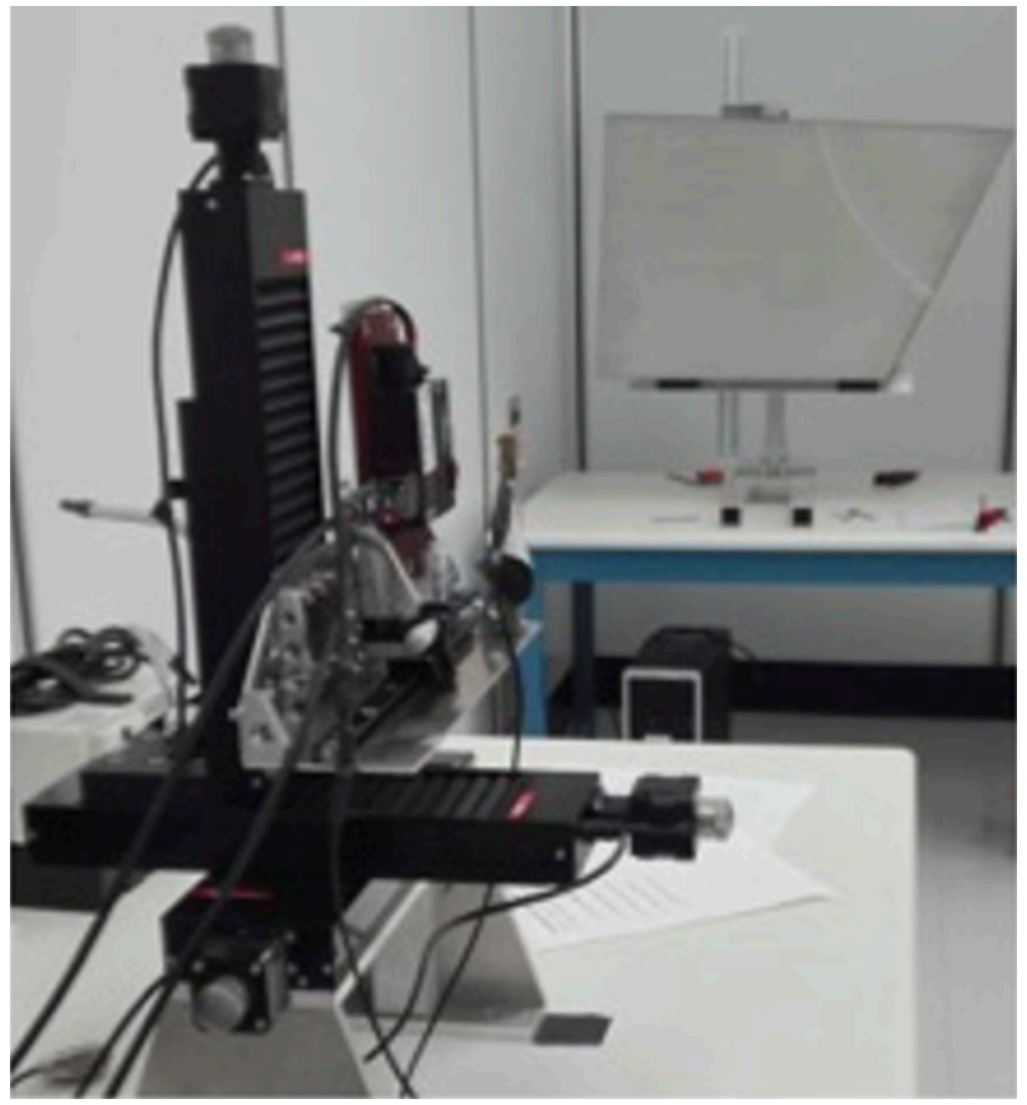
Quality Assurance & Simulation

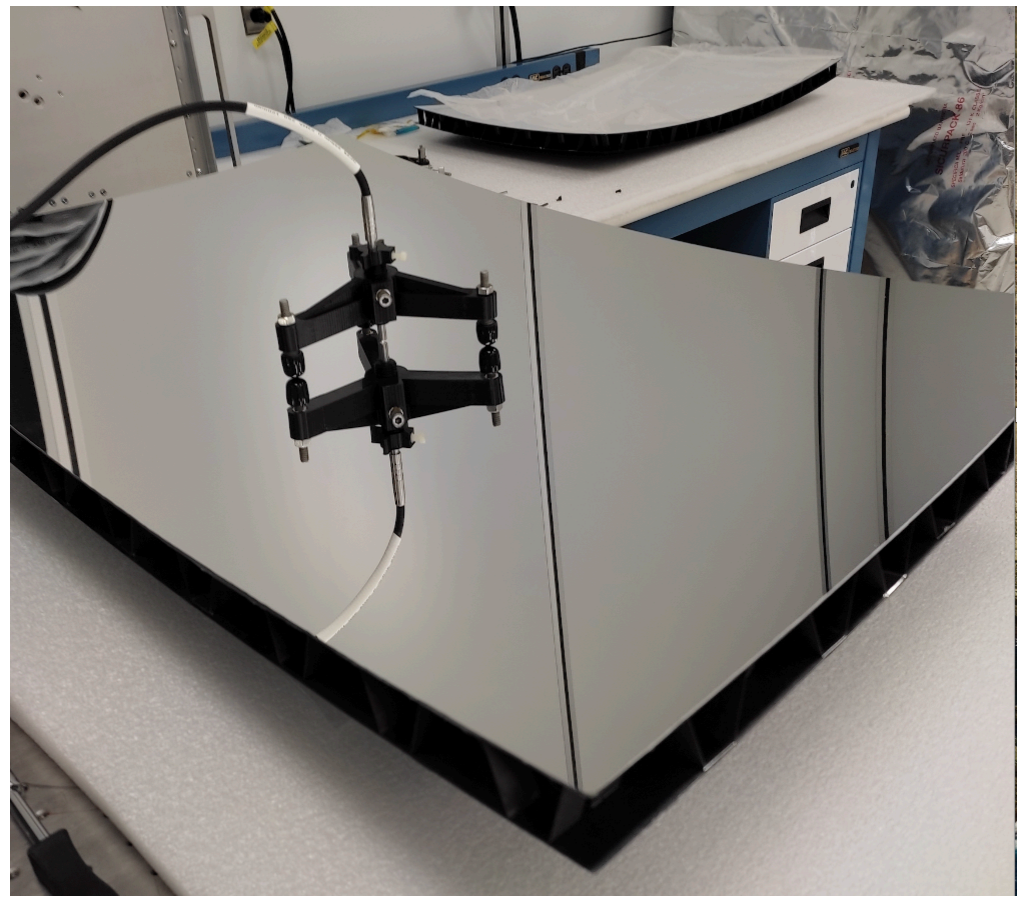
Aerogel: Temple - BNL - INFN



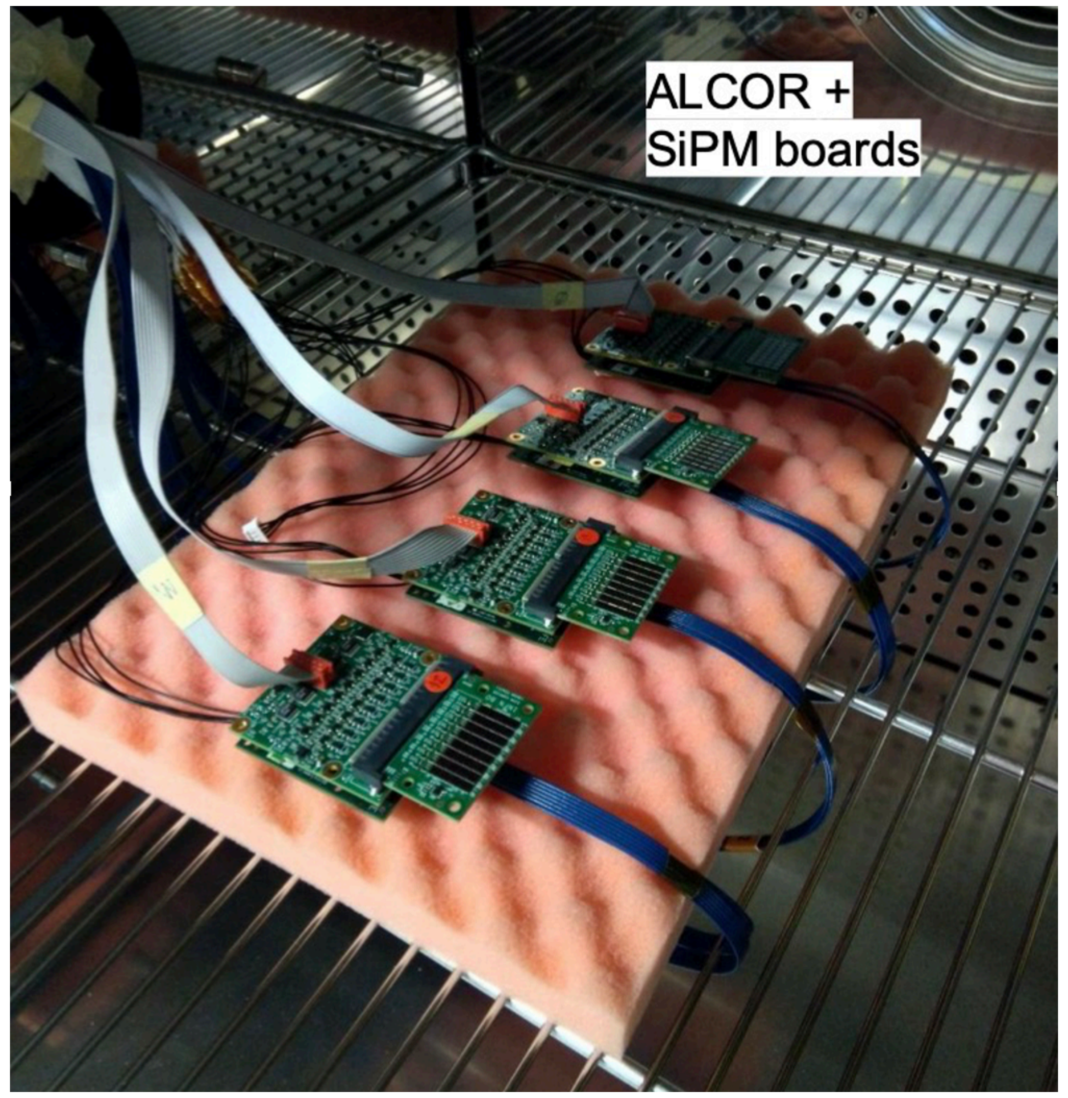


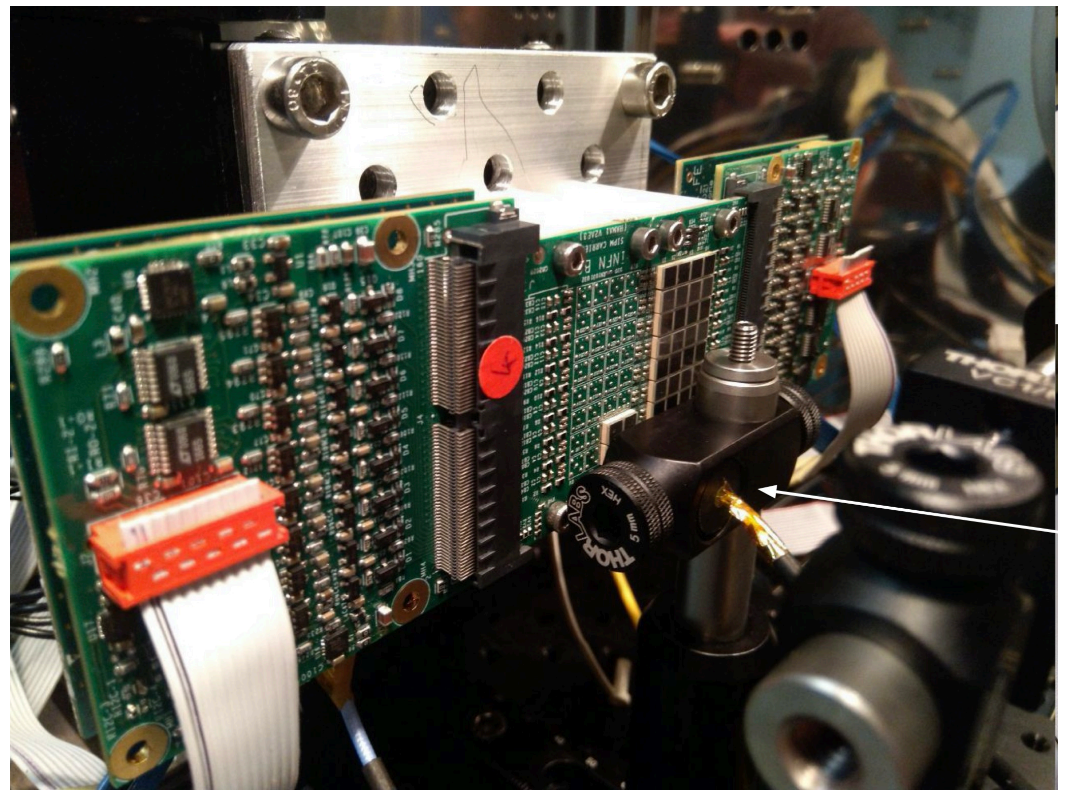
Mirror: JLab - Duke



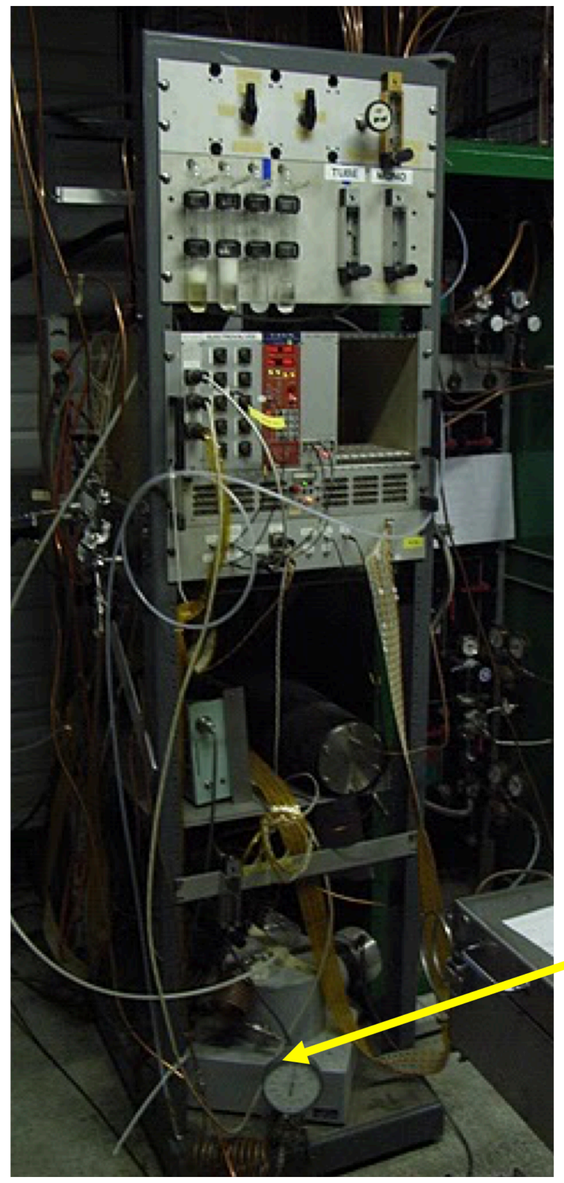


Sensors: INFN

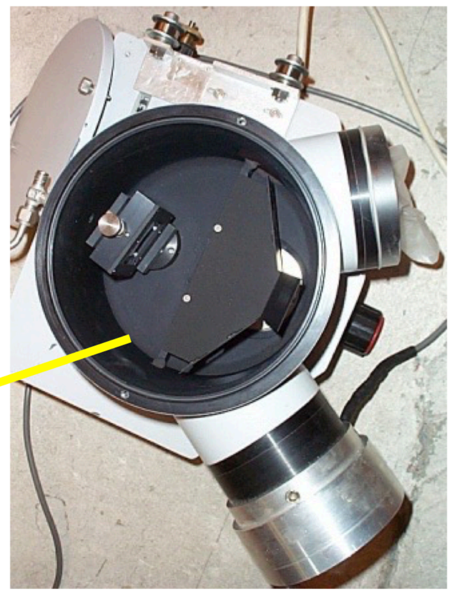




Gas: INFN - CERN



Deuterium UV lamp, Monochromator system, 1.6 m column for gas transparency measurement



dRICH simulation on track: already running within ePIC framework and supported by lab characterization & beam tests

Needed Resources

The timescale is aggressive due to the limited workforce.
A 60% readiness within 2024 is realistic, a 90% readiness appears challenging

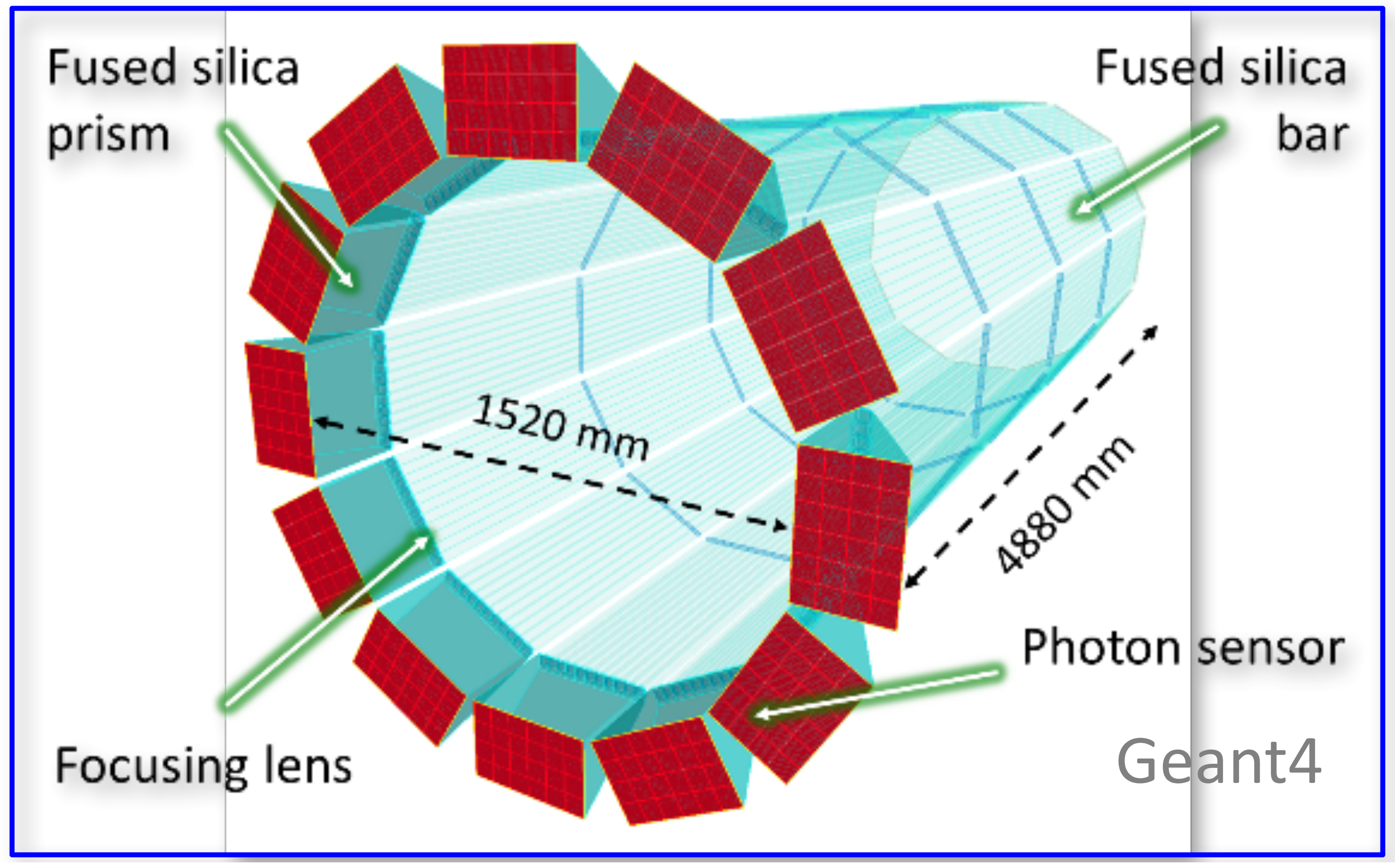
Mechanics:	Limited manpower Searching new personnel at INFN Help needed from the EIC Project
Gas:	Safety & infrastructure Help needed from EIC Project & CERN experts
DAQ:	Data reduction & interaction tagger Help needed from EIC Project
Quality Assurance:	Manpower & test stations in US Help needed from EIC Project & within RICH Consortium
Simulation:	Pattern recognition and global PID Help needed within RICH Consortium

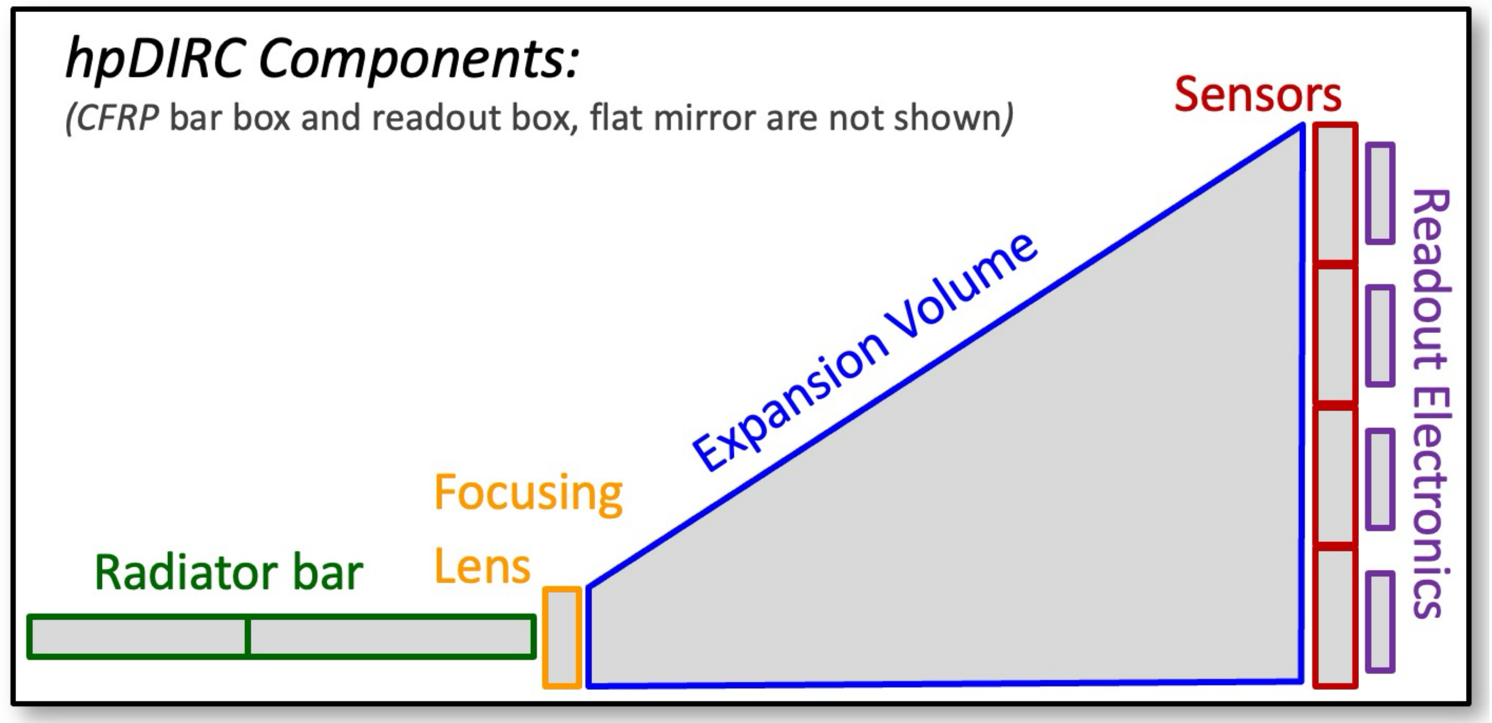
hp*DIRC*

hpDIRC Overview

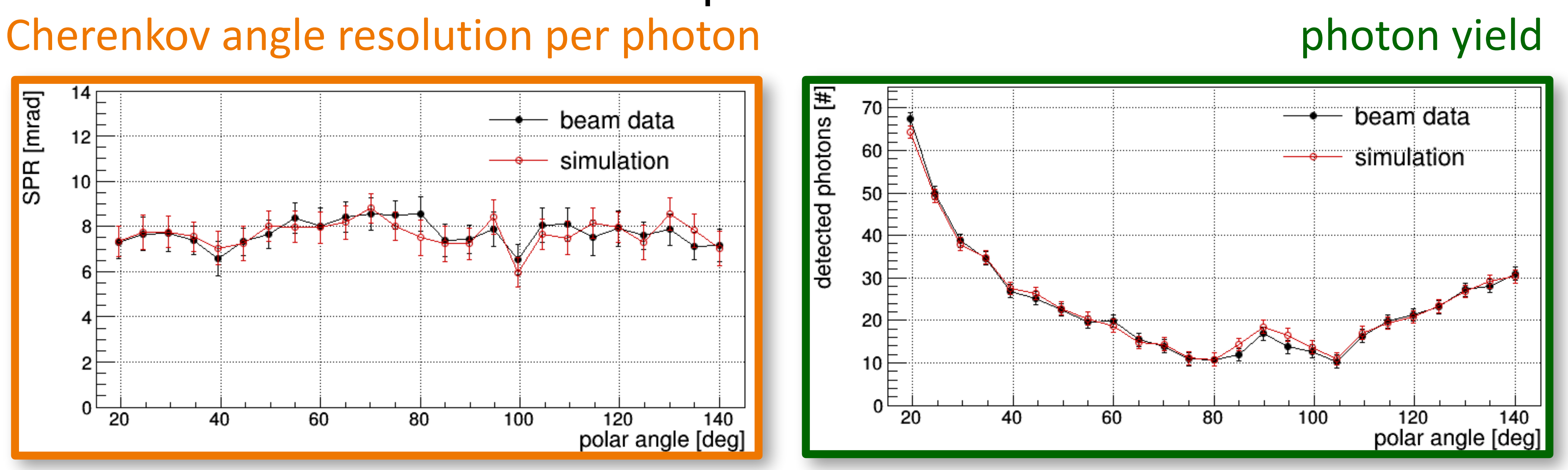
Compact fused silica prisms, narrow bars, 3-layer spherical lenses

- 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
  - joint EIC/PANDA CERN beam tests 2015-2018
- Still setting up the TDR planning/writing process
  - Several key decision to be made this summer/fall
  - Today: status and plan for the coming months



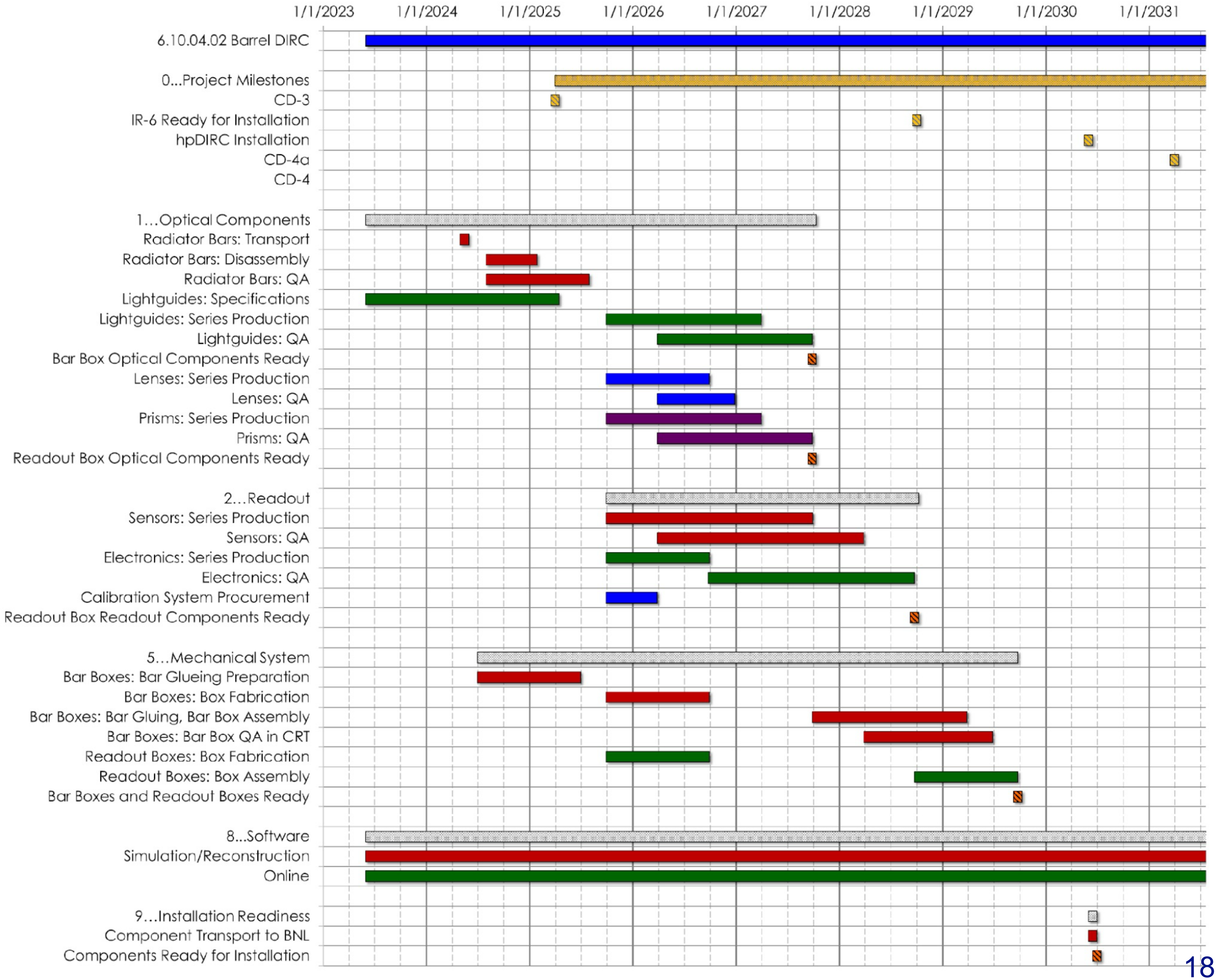


Beam data/simulation comparison for 2018 CERN beam test



Initial High-Level Schedule

- Initial hpDIRC schedule consistent with EIC project schedule
- More detailed plan with breakdown into realistic work packages and institutional assignments in preparation
- Finalizing plans for week-long in-person hpDIRC annual meeting and workfest at JLab in May, with several days dedicated to TDR planning/writing
- hpDIRC workforce adequate for TDR writing, needs to be increased for the next stage (construction, QA, installation)



BaBar Bars

- Validation of reusing BaBar DIRC radiator bars is the next crucial step towards TDR readiness
- DIRC labs are in preparation at JLab for disassembly, validation of the mechanical and optical quality, and storage
  - Transportation of bar boxes starting April 8th, 2024
  - Disassembly into individual bars to start in May 2024
  - Validation of optical quality in laser lab in summer 2024
  - Expect decision on reuse of the BaBar bars by fall 2024
- Invaluable support from JLab management, DSG group, and EIC-hall technician team
- Simulation study of optimum light guide optics underway
  - bars or plates for coupling the reused BaBar DIRC bars to the lenses/prism (EICGen R&D)

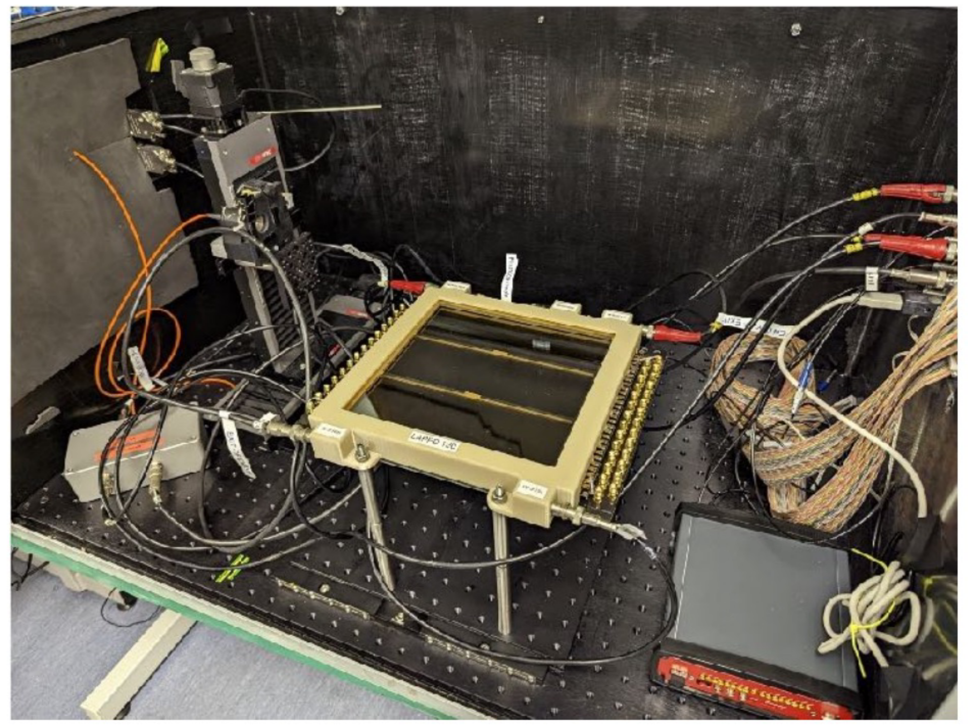
BaBar DIRC bars and bar boxes in SLAC

DIRC labs under construction at Jlab

hpDIRC Hardware Tests

- Series of beam tests with complex DIRC prototypes at CERN from 2015-2018, successful validation of performance and simulation code, no additional beam tests required
- Focusing properties of 3-layer lens validated in CERN beam test and on ODU test bench
- Radiation hardness of materials for bars, lenses, prisms, glue verified
- 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 (R. Montgomery et al.)
- Readout electronics
  - eRD109 is testing two options, FCFD ASIC with 128 channels and the EICROC with 1024 channels
- Cosmic Ray Telescope (CRT) at SBU will serve as test bench for incremental upgrades of new components (bars, sensors, readout electronics, eventually full hpDIRC modules)

Setup at Glasgow



DIRC lab/CRT space at SBU

hpDIRC Simulation

Stand-alone Geant4 Simulation

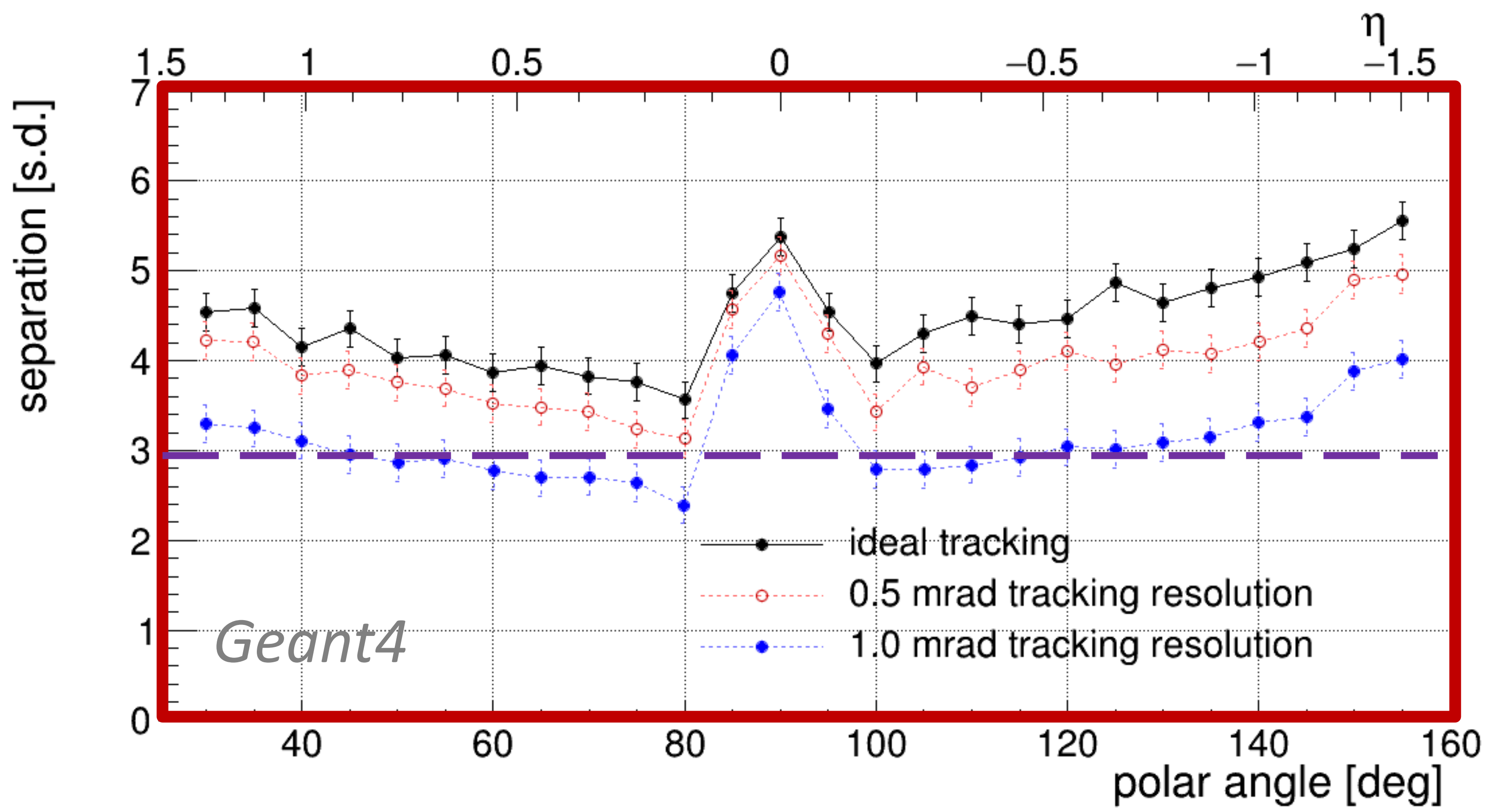
- Used for initial design, cost/optimization studies, and to test novel design options
- Realistic optics, geometry, and material properties – based on prototypes and experimental data, wavelength-dependent material properties and processes
- Validated with test beam data
- Fast sim/parametrization is being adjusted to agreed format, to be gradually improved
- Alternative reconstruction algorithms are under development
- Updated properties of sensors, optical quality of bars can be easily added when available (eRD110, eRD109, bars studies in summer 2024)

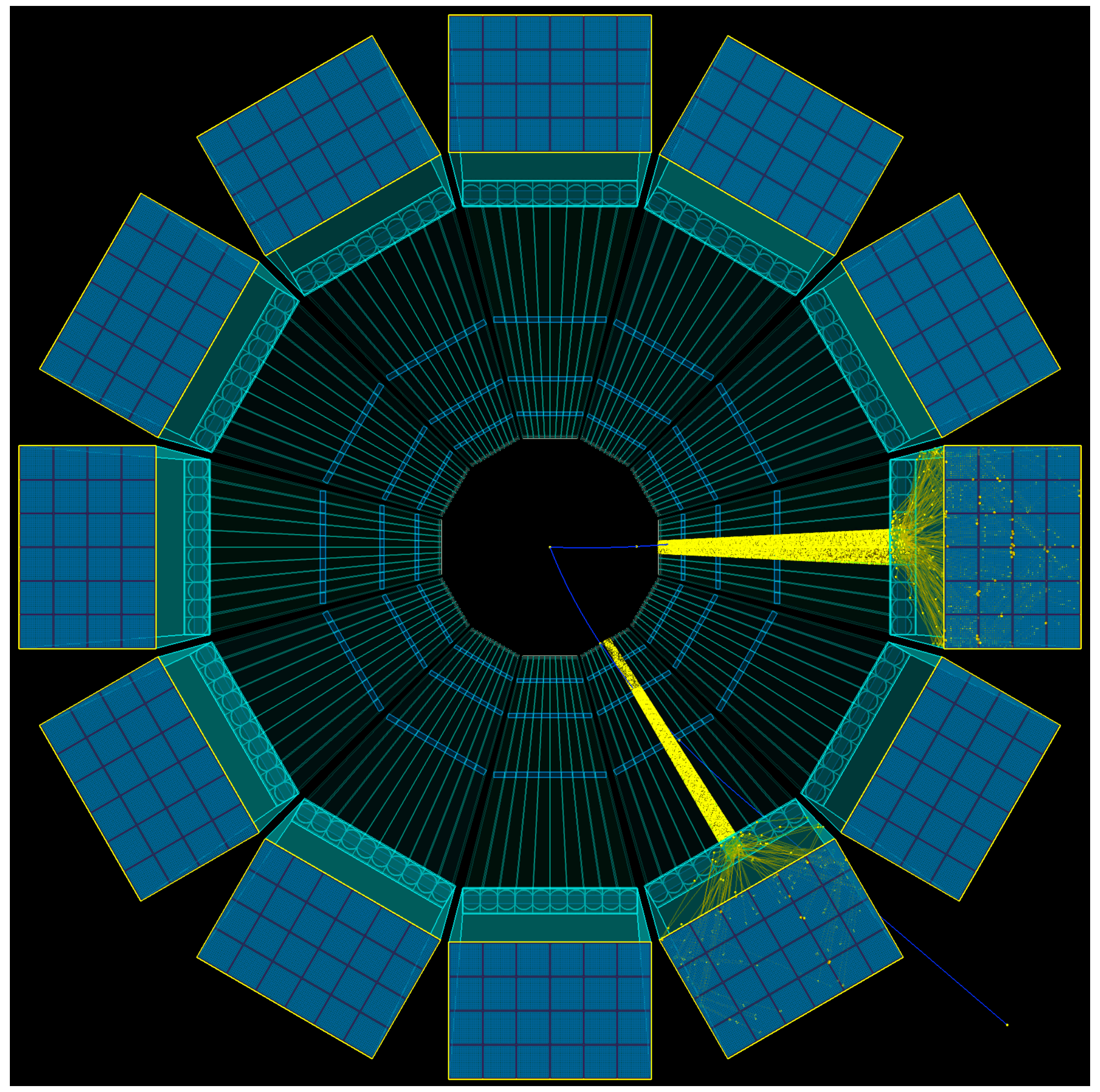
Full ePIC Simulation:

- Enabling full reconstruction chain with all other subsystems is in progress
  - modification to digitization and efficiencies, allowing generation of LUTs and PDFs

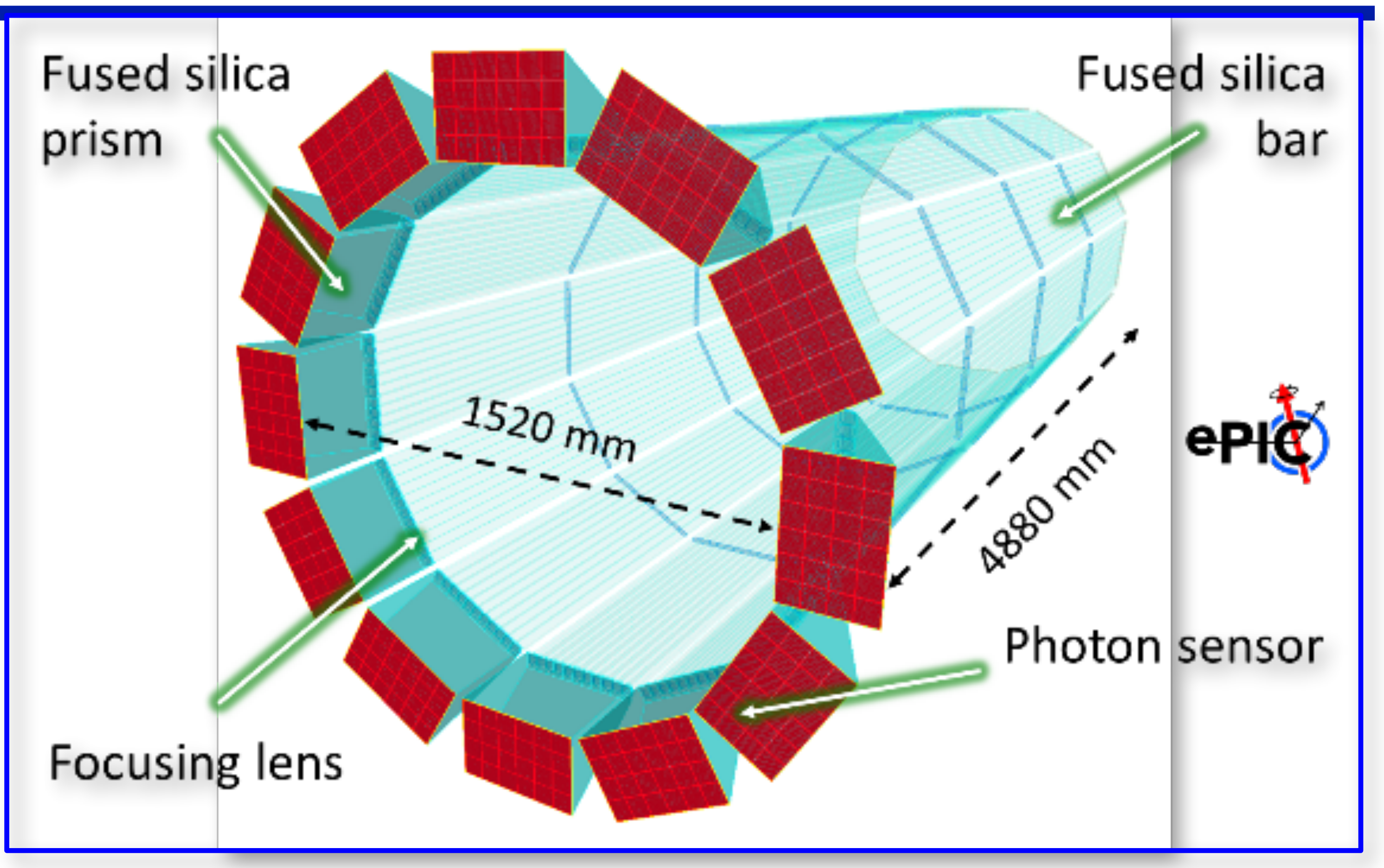
Performance studies for TDR will be based on Yellow Report requirement for tracking angular precision at high momentum (6 GeV/c)

π/K separation power at 6 GeV/c





hpDIRC Status

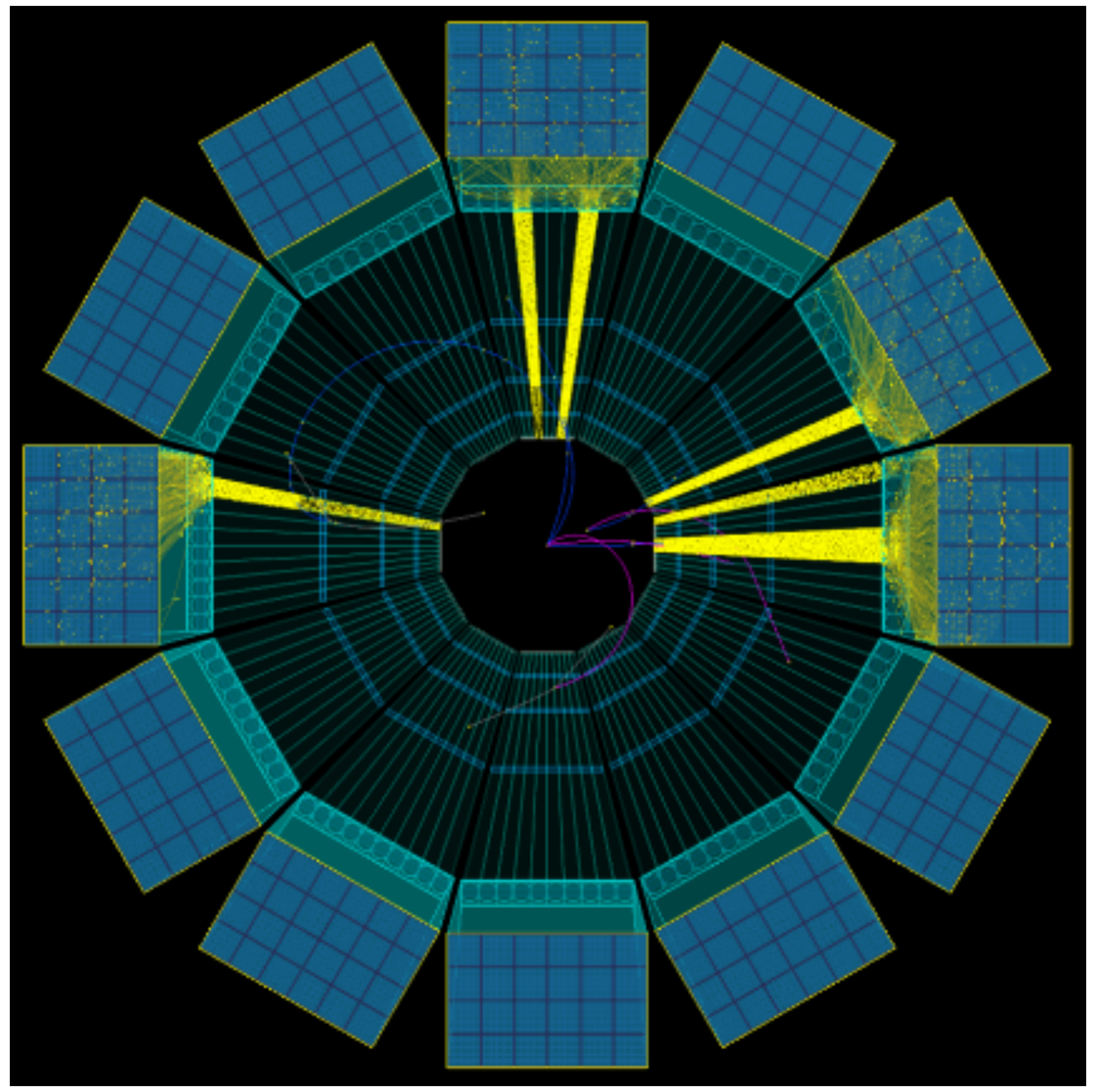


Simulation status:

- Detailed stand-alone simulation validated with test beam
- Performance evaluated with magnetic field, Pythia events, multiple tracks in event
- Fast sim/parametrization is almost ready
- hpDIRC is implemented into full ePIC stack, integration with EICRecon advanced

Hardware status:

- Radiation hardness of material for bars, prisms, lenses verified
- No additional prototype beam tests needed for performance validation
- New CRT at SBU (eRD103) will be used for integration of components near-term,
  QA of fully assembled hpDIRC modules long-term

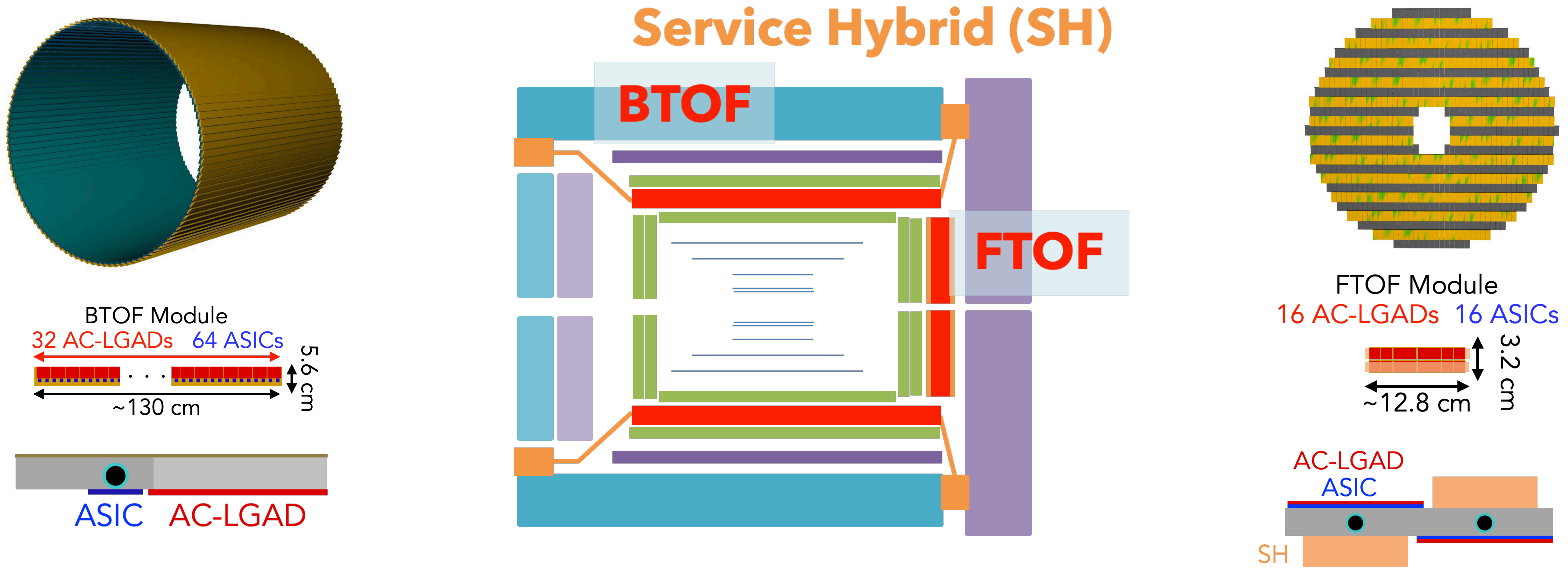


Main remaining challenges for the TDR:

- Decision about reusability of BaBar DIRC bars and required new optics for light guide section (narrow bars/wide plates)
- Selection of the sensors and readout electronics (eRD110, eRD109)
- Complete work on mechanical design, integration, installation
- Writing of the TDR chapters

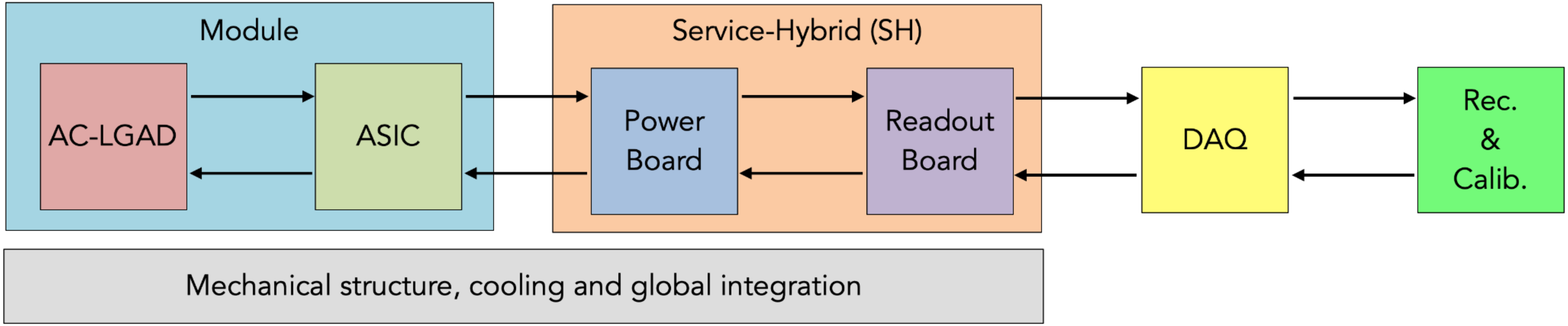
ToF

Recap of Barrel-TOF (BTOF) and Forward-TOF (FTOF)



- Strip-type and pixel-type AC-LGAD are used for BTOF and FTOF, respectively
- FCFD and EICROC are used for strip-type and pixel-type AC-LGAD readout, respectively
- BTOF SH is placed in a different place from sensor+ASICs, but FTOF SH is placed in front of sensor+ASICs

Overview of TOF System and Its Components



BTOF

- Strip-type AC-LGAD
- ASIC (FCFD)
- Sensor-ASIC integration
- Module
- Service-Hybrid
- Mechanical structure
- Global integration

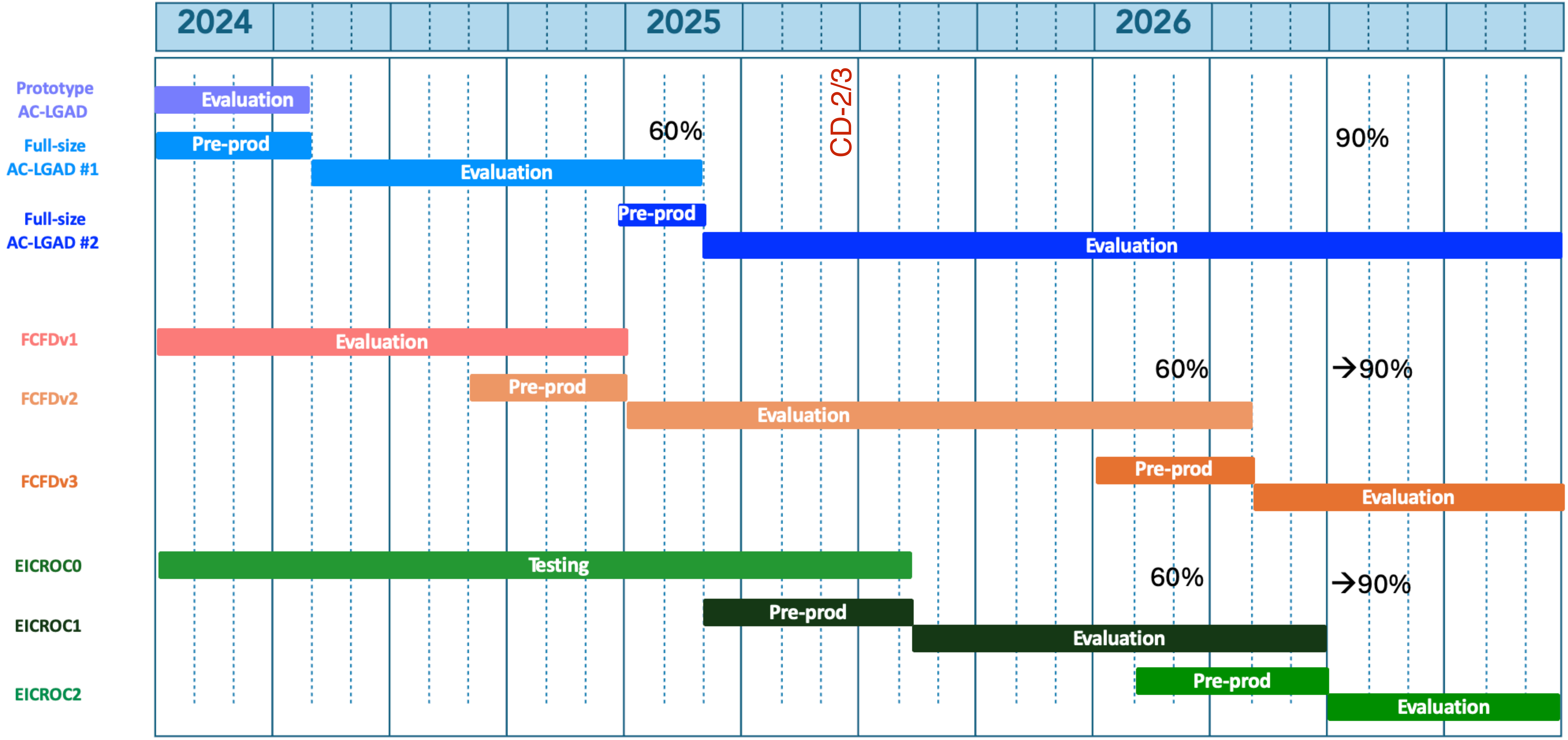
FTOF

- Pixel-type AC-LGAD
- ASIC (EICROC)
- Sensor-ASIC integration
- Module
- Service-Hybrid
- Mechanical structure
- Global integration

Common system

- DAQ
- Cooling
- HV & LV
- Software (Rec. & Calib.)
- Slow control (HW & SW)

Schedule of Sensors and ASICs



Mechanic and Support Structures

- FY24—FY25 Q1
  conception design, prototyping and pre-production
- Schedule for
  - BTOF support + interface
  - BTOF Staves
  - FTOF

Andreas Jung

TASK DESCRIPTION	Milestone	EARLY DELIVERY (BNL)	DOE CD2/3	PLAN START	DURATION	PLAN END	TYPE	2024 / 2025 / 2026
TOF LGAD support + interfaces (for now assume half cylinders)		**1/1/28**	**10/1/28**	7/5/25	25.5	8/5/27		This is now taken from actual Purdue step-wise gantt
Pre-production & Prototype, earliest for final parts of supports available				3/12/24	10.0	1/12/25	P	
Finalize BCs, Loads, design				1/12/25	4.0	5/12/25	B	
Sched. CNC Time				5/12/25	1.0	6/12/25	P	
Purchase Consumables				6/12/25	1.0	7/12/25	X	
Practice Layup				7/12/25	2.0	9/12/25	P	
Final prototype, final design for insertion tests				9/12/25	2.0	11/12/25	B	
Final Manufacturing FEA				11/12/25	2.0	1/12/26	B	
Final adjustments to manufacturing				1/12/26	2.0	3/12/26	B	
3D print sub-parts				3/12/26	1.0	4/12/26	G	
Tool Preparation & Machining				4/12/26	2.0	6/12/26	G	
Half-cylinder layup				6/12/26	1.0	7/12/26	G	
Cylinder Assembly				7/12/26	0.5	7/12/26	G	
QA/QC + loading				7/12/26	1.0	8/12/26	Y	
Half-cylinder layup & Assembly				8/12/26	2.0	10/12/26	G	
QA/QC + loading				10/12/26	1.0	11/12/26	Y	

TASK DESCRIPTION	Milestone	EARLY DELIVERY (BNL)	DOE CD2/3	PLAN START	DURATION	PLAN END	TYPE
TOF LGAD staves (cost savings via NCKU machine shop possible)		**1/1/28**	**10/1/28**	1/1/25	17.0	6/1/26	
Pre-production & Prototype, earliest for final stave available				3/7/24	10.0	1/7/25	P
Finalize design & choice				4/7/25	2.0	6/7/25	B
Purchase Consumables				6/7/25	0.5	6/7/25	X
Practice Layup				6/7/25	0.5	6/7/25	P
QA/QC				6/7/25	0.5	6/7/25	Y
Layups 1 to 72				6/7/25	2.0	8/7/25	G
Layups 72 to 144				8/7/25	2.0	10/7/25	G
Layups > 144 (spares)				10/7/25	2.0	12/7/25	G
Pipe preparation				12/7/25	2.0	2/7/26	G
Assembly/Gluing				2/7/26	2.0	4/7/26	G
QA/QC				4/7/26	0.8	4/7/26	Y

TASK DESCRIPTION	Milestone	EARLY DELIVERY (BNL)	DOE CD2/3	PLAN START	DURATION	PLAN END	TYPE
TOF LGAD endcap (for now standard sandwich structure)		**1/1/28**	**10/1/28**	9/3/25	19.0	4/3/27	
Finalize loads/BCs				9/3/25	4.0	1/3/26	P
Current Design Review				1/3/26	0.5	1/3/26	B
Final FEA & Coolant pipe layout				1/3/26	0.5	1/3/26	B
Tool Preparation & Machining				1/3/26	0.5	1/3/26	P
Practice Layup				1/3/26	1.0	2/3/26	B
Final Manufacturing FEA				2/3/26	0.5	2/3/26	B
3D print sub-parts				2/3/26	1.0	3/3/26	G
Final adjustments to manufacturing				3/3/26	1.0	4/3/26	G
First wedge layup				4/3/26	1.0	5/3/26	G
First wedge part prep				5/3/26	1.0	6/3/26	G
Tool Preparation & Machining				6/3/26	0.5	6/3/26	G
Remaining wedges layup				6/3/26	1.0	7/3/26	G
Remaining wedges				7/3/26	2.0	9/3/26	G
Endcap assembly				9/3/26	2.0	11/3/26	G
QA/QC + loading				11/3/26	2.0	1/3/27	Y

Component	Current status	R&D	PED	Beam Test	60%	90%
Sensors	prototyping: 1st HPK prototype tested; 2nd HPK production in prep.; 1st FBK prototype in prep.	eRD112 FY22 eRD112 FY23 eRD112 FY24-26		2022, 2023, 2024	FY25 Q2 (2nd HPK)	FY26 (3rd HPK)
ASIC	Prototyping: FCFDv0 and FCFDv1 for BTOF, EICROC0 for FTOF	eRD109 FY23 eRD109 FY24-26		2024	FY25 Q2 (FCFDv1,EICROC1)	FY26 (FCFDv3, EICROC2)
Module Flex PCB	Prototyping: long PCB	eRD109 FY23 eRD109 FY24	2026	2025-	FY24 Q4 (M2M, M2SH)	FY26 (full-length integration)
Module CF structure	Prototyping: BTOF stave produced, thermal simulation underway	eRD112 FY23			FY25 Q2 (full-length stave)	FY26
Module Assembly	Prototyping: Sensor/ASIC integration, Interposer	eRD109 FY24 eRD112 FY24	In prep.	2025-	Thermo-mechanic prototype FY24	Fully functional module FY26
Global support structure, Cooling	Conceptual design		Active		FY25 Q2 (1/12 with staves)	FY26 Q1 (1/12 FTOF wedge)
Service Hybrid	Prototyping: board layout	eRD109 FY24		2025-	FY25 Q1 (with ETROC2)	FY26 (final layout & ASIC)
Backendelectronics, Power supplies	Possible PS models identified	N/A	N/A		Design in FY24 (with project)	Purchase/test one in FY25
Software and simulations	Geometry and material in DD4HEP, have TOF PID, tracking δp	N/A	N/A	N/A	PID LUT in global framework in FY24	Refined material and responses in FY26

Critical Paths & Need for Additional Resource

- FCFD ASIC development and testing for BTOF (FNAL+LBL PED?)
- BTOF+FTOF module assembly (UCSC+ORNL+Purdue PED?)
- Long Flexible Print Circuit Board for BTOF staves (ORNL+Nara+RIKEN)
- Software+simulation:
  detector response + realistic material (additional institutions?)

Summary

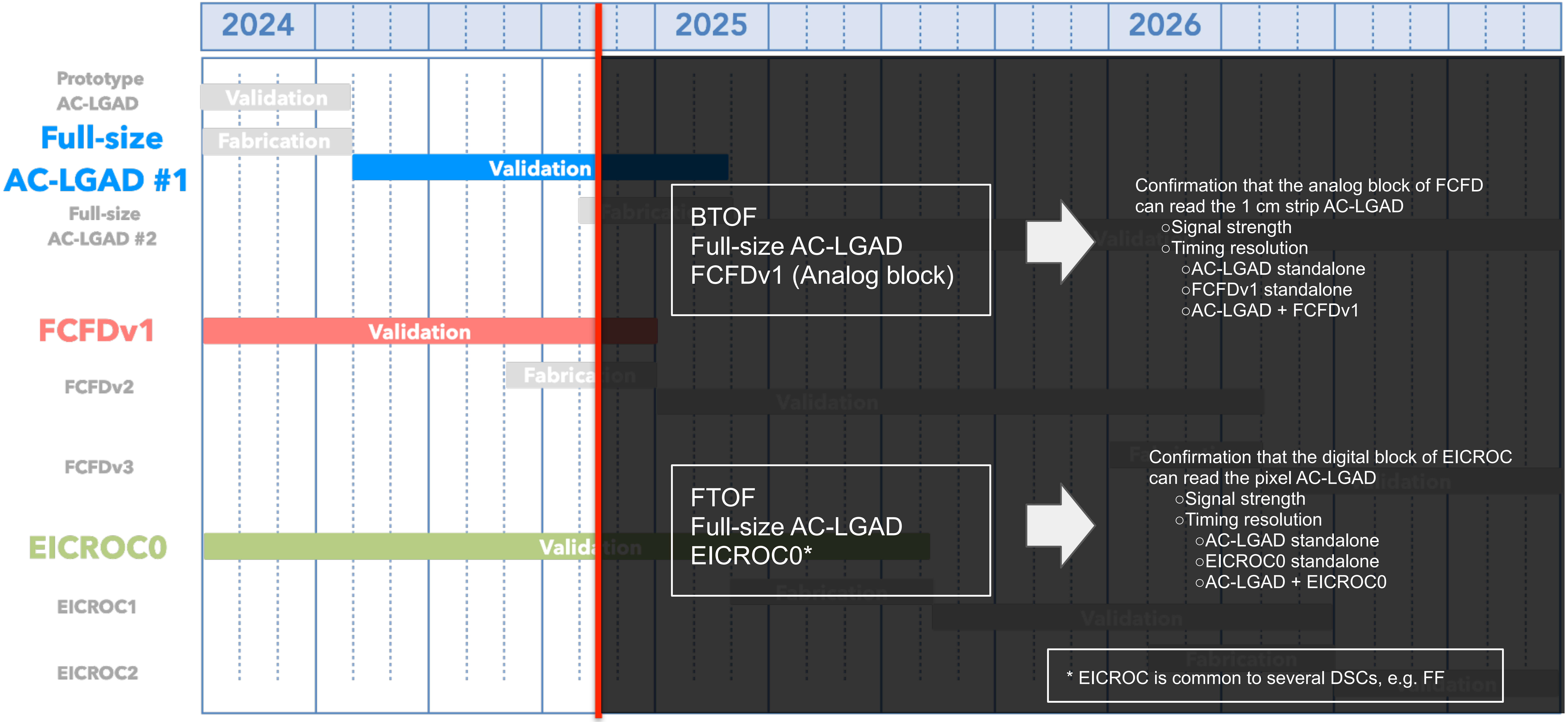
Take Away Message

- Overall all PID detectors are on track for pre-TDR/TDR
- Even some critical items cannot be considered showstoppers
  - e.g hpRHIC bars, pfRICH HRPPD, …
- Each DSC has solid participation but personnel is still needed on various efforts
- The apparent bottleneck at the moment is the integration of the stand-alone software into EICRecon
  - Well on it’s way but will not be in, tested, and verified for pre-TDR
- 60%, 90% Readiness: Sensors for ToF (AC-LGAD) will reach 90% late, as is the case for several ASICs used in PID detectors. This does not effect the readiness of other components

Backup Slides

ToF

Schedule of sensors and ASICs



Strategy for the TDR (ASIC)

- BTOF digital block demonstration is in need (a concern)
  - It is important to show that "we can't show it now, but we will definitely be able to do it shortly”
  - It is necessary to fully understand and demonstrate the individual characteristics in pre-TDR
    - Characteristics of sensor, FCFD's analog block, and the combined performance
  - The FTOF study will help to corroborate the story
    - Successful signal readout of FTOF means "complete understanding of the AC-LAGD → analog → digital chain"
    - This knowledge shows that we have the technology to extend analog blocks to digital blocks while keeping a good timing resolution
  - Investigating the availability of other ASICs (e.g. HGCROC) is also important

- The beam test at DESY is scheduled for June
  - It is a good opportunity to show performance of the sensors and ASICs with realistic environment
  - Real MIP beam is mandatory to evaluate realistic performance
  - Before the beam test, the lab tests, e.g. radiation source and IR laser, is necessary
    - Gain uniformity, temperature dependence of gain, timing resolution, spatial resolution, and power consumption

Strategy for the TDR (Module Assembly)

- Manufacturing a long (~1.3m) FPC for the BTOF stave is a concern
  - This is probably the most problematic R&D element except the ASIC because there are not many examples of such a long FPC being utilized in HEP
  - Nara Women's University and RIKEN, which have experience in developing approximately 1.3m FPC with a low material budget (O(1%) X/X0) for sPHENIX silicon strip sensor detectors, have agreed to support the development (in eRD109 should be added here)
  - It is necessary to specify the required performance and demonstrate that we have the experience/technology to make it
  - However, it is not clear if it can be used in this case, so this is an urgent item to be clarified
  - FPC R&D is covered by eRD109

- Sensor-ASIC integration
  - Several bonding strategies are planned, e.g. bump bonding, wire bonding, and using interposer
  - Adjustments are needed, but these are established techniques
  - Add bump bonding risk
  - It is important to show that these methods can be applied geometrically to sensors and ASICs bonding
  - Need to understand the application limits of each method (feedback to the ASIC R&D)
  - At least the first design of the interposer is required

- Modules
  - It is necessary to show how each component is attached and the total amount of material budget is acceptable

Strategy for the TDR (Cooling+Service Hybrid)

- Cooling system
  - It is necessary to finalize the evaluation of power consumption and the tolerable temperature range of each component
  - It is necessary to determine the cooling method of BTOF SH (water cooling is used for Sensor + ASIC)
    - In the case of FTOF, the service hybrid (SH) is cooled at the same time as the sensor + ASIC, but in the case of BTOF, the SH is installed in a separate location from the sensor + ASIC.
  - A long and a long-winding cooling pipe are used for BTOF and FTOF, respectively, so it is needed to check the difference in cooling capacity between the inlet and outlet

- SH design
  - Data rate and power distribution scheme should be designed
  - It is necessary to show the data rate and the processing power
  - If possible data stream of AC-LGAD→EICROC→FPC→FPGA will be presented

Strategy for the TDR (Software)

- Tracking reconstruction
  - Realistic TOF structure has been implemented in the current simulation
  - FTOF material budget will be modified
  - Realistic positioning resolution will be implemented with the coming beam test results (June)
  - Support structure for the wiring between module to SH of BTOF will be implemented

- Particle Identification
  - TOF PID LUT is under preparation and its first version will be ready in a few weeks
  - Realistic timing resolution will be implemented with the coming beam test results (June)
  - Hit positioning dependence of the PID performance will not be in time for pre-TDR, but we hope in the TDR

Summary of Pre-TDR Planning

- Simulation and reconstruction
  - Tracking
  - PID
- R&D:
  - Sensor: new HPK production and Characterization, simulation, irradiation
  - Sensor-ASIC integration: interposer for BTOF, hybridization for FTOF pixel sensor-ASIC
  - ASIC: EICROC0/1, FCFDv1, HGCROC
  - Module PCB: Low-mass flexible Kapton for BTOF
  - Module structure: Low-mass CF structure for BTOF module
  - Service Hybrid: RDO + Power board
- PED:
  - BTOF and FTOF support structure
  - BTOF module prototyping in prep.
  - FTOF module prototyping?