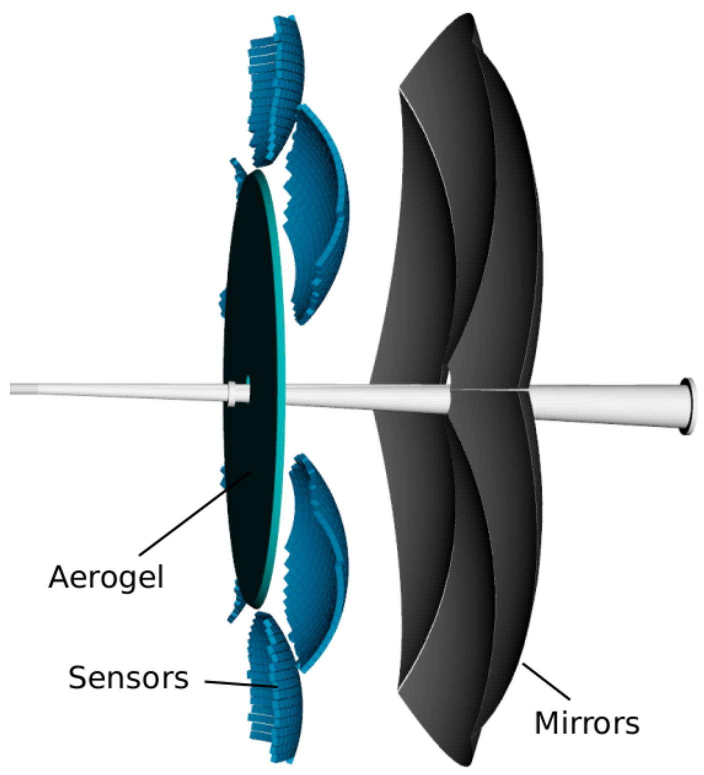
PID Working Group Meeting Report

Thomas Ullrich

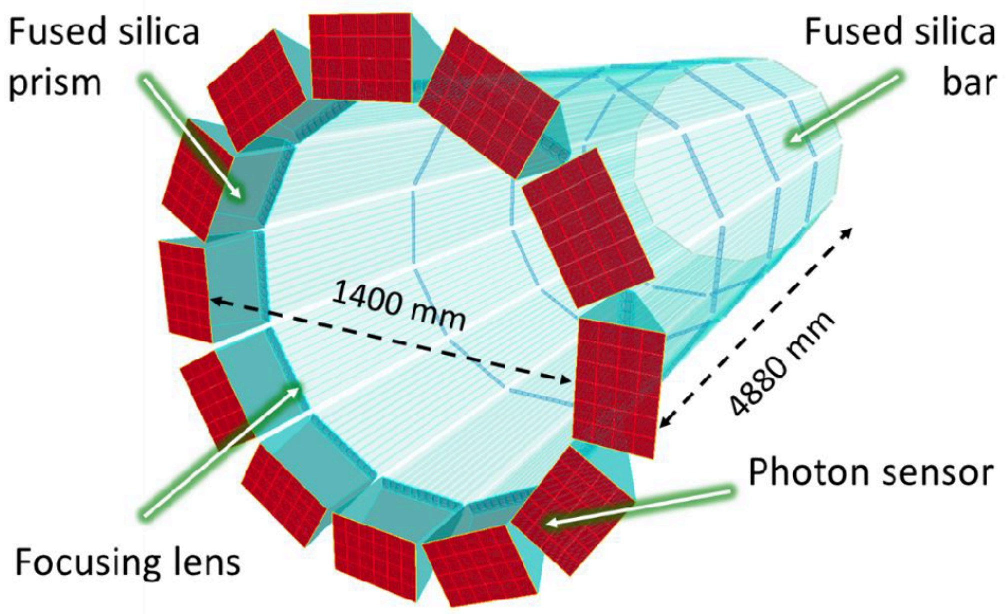
ePIC Collaboration Meeting

Lehigh University, Bethlehem, PA

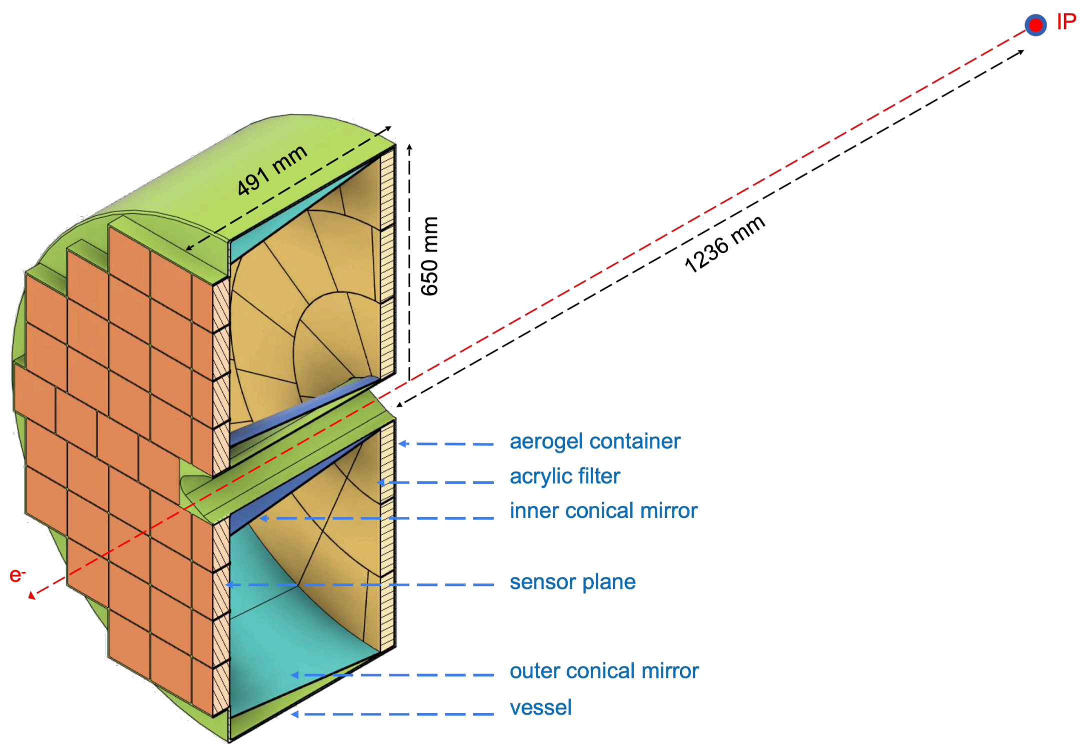
July 27, 2024



dRICH



hpDIRC



pfRICH

ToF not included here: see talk by Satoshi earlier

PID Working Group at Work

Lewis Lab 309: 23-30 in person, 12-15 remote

Extremely useful but far too short

PID Parallel Session at Lehigh Collaboration Meeting

8:00 AM → 8:05 AM **Welcome**
Speaker: Thomas Ullrich (BNL)

8:05 AM → 8:20 AM **pfRICH: Vessel Design and Construction**
Speaker: Alex Eslinger (employee@jlab.org;member@jlab.org)
pfRICH Mechanical ...

8:20 AM → 8:35 AM **pfRICH: Mirror Coating and Testing**
Speaker: Zhoudunming Tu (BNL)
pfRICH mirror

8:35 AM → 8:50 AM **pfRICH: Laser Calibration System**
Speaker: Wenliang Li (Stony Brook University CFNS)
pfRICH Laser Monit...

8:50 AM → 9:05 AM **pfRICH: HRPPD QE Determinations**
Speaker: Chandradoy Chatterjee (INFN Trieste)
chatterjee_hrppd_q...

9:05 AM → 9:25 AM **dRICH: Project Status**
Speaker: Marco Contalbrigo (INFN Ferrara)
dRICH_240725.pdf

9:25 AM → 9:45 AM **dRICH: SiPM, Front-End Electronics**
Speaker: Roberto Preghenella (INFN Bologna)
[20240725][EICUG][...

9:45 AM → 10:00 AM **dRICH: Mechanics Envelope**
Speaker: Alex Eslinger (employee@jlab.org;member@jlab.org)
dRICH Split 7-23-24 ...

9:45 AM → 10:00 AM **dRICH: Mechanics Envelope**
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dRICH Split 7-23-24 ...

10:00 AM → 10:10 AM **dRICH: Optics Optimization**
Speaker: Connor Pecar (Duke University)
dRICH_opt_ePICjuly...

10:10 AM → 10:20 AM **dRICH: RDO**
Speakers: D Falchieri, Marco Contalbrigo (INFN Ferrara)
dRICH_RDO_25Jul2...

10:30 AM → 11:00 AM **Break**

11:00 AM → 11:25 AM **hpDIRC: Preparations towards TDR**
Speaker: Grzegorz Kalicy (CUA)
240725_hpDIRCtow...

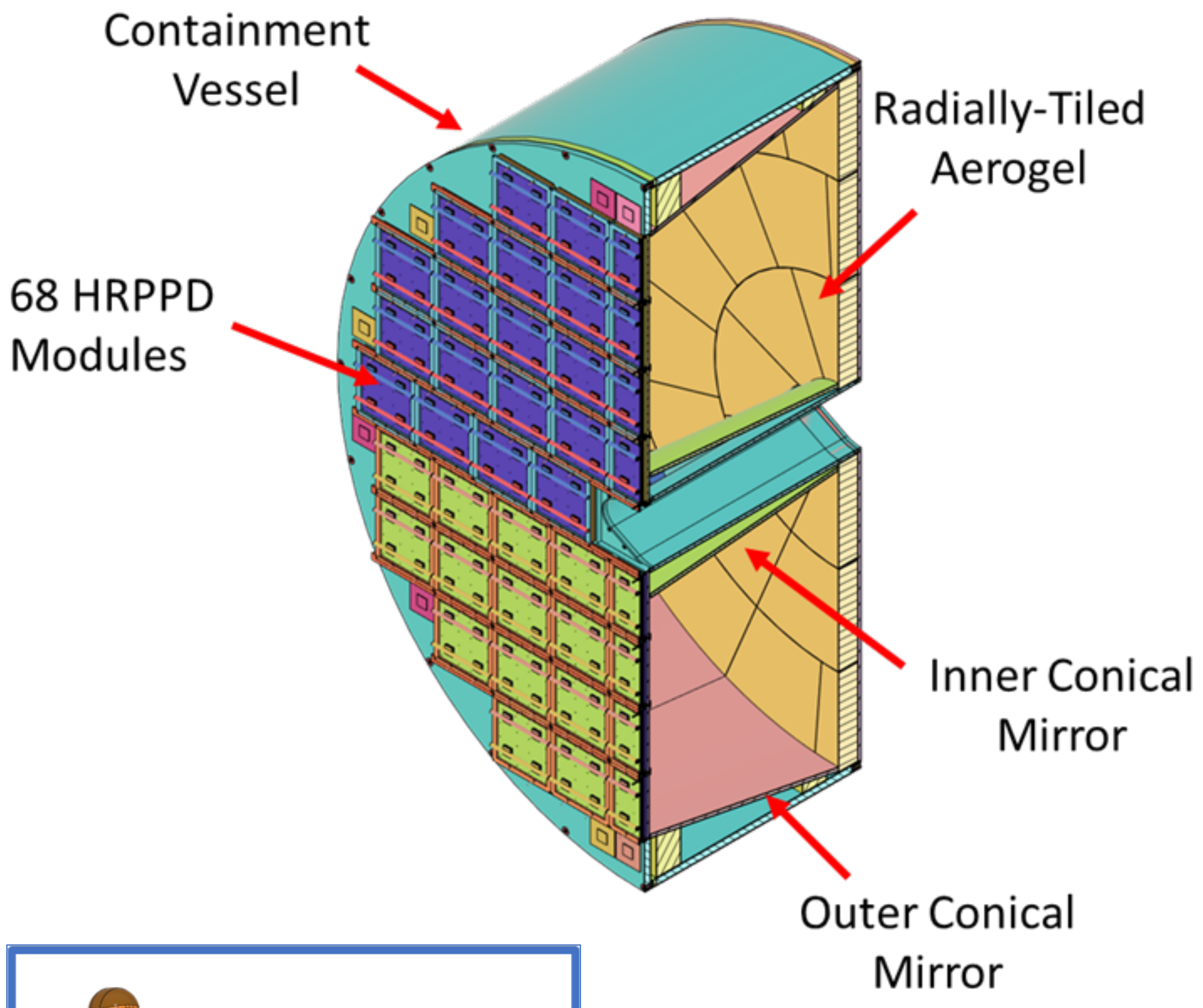
11:25 AM → 11:40 AM **hpDIRC: Mechanics, frame, bars, lenses, expansion volume**
Speaker: Grzegorz Kalicy (CUA)
240725_hpDIRCMe...

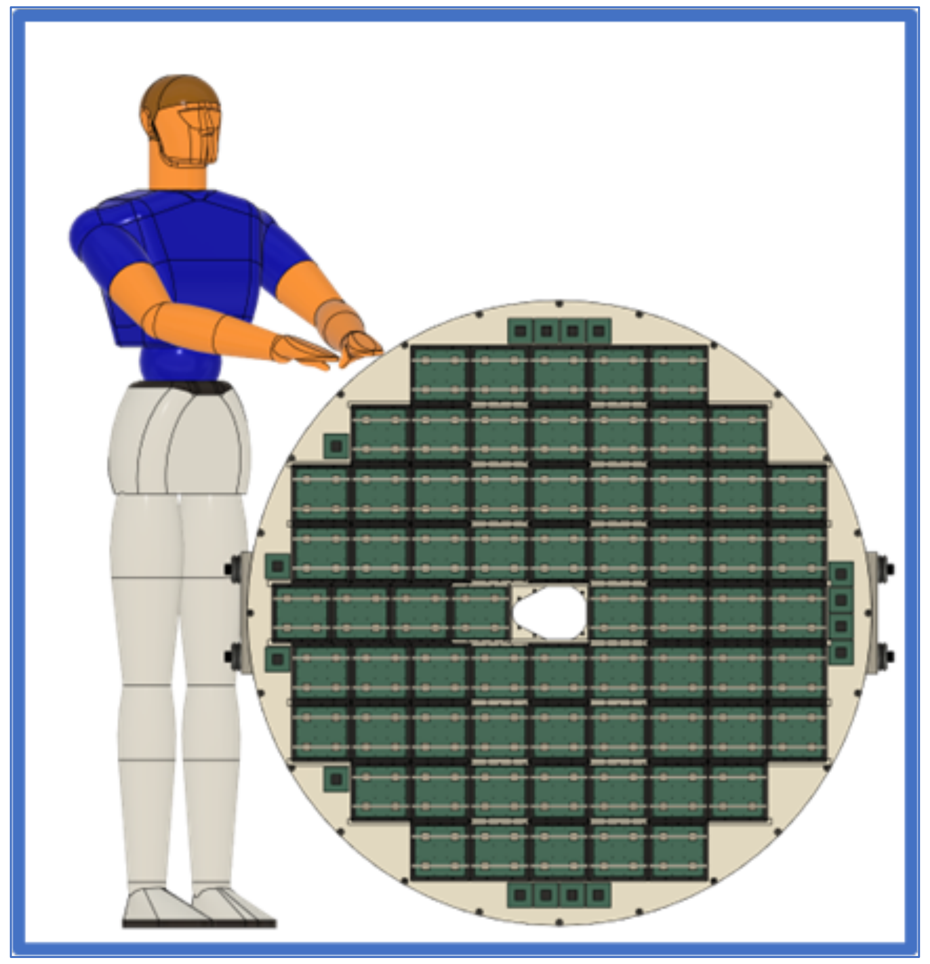
11:40 AM → 12:00 PM **ToF: Update**
Speaker: Satoshi Yano (Hiroshima University)
0725_TOF_PID.pdf

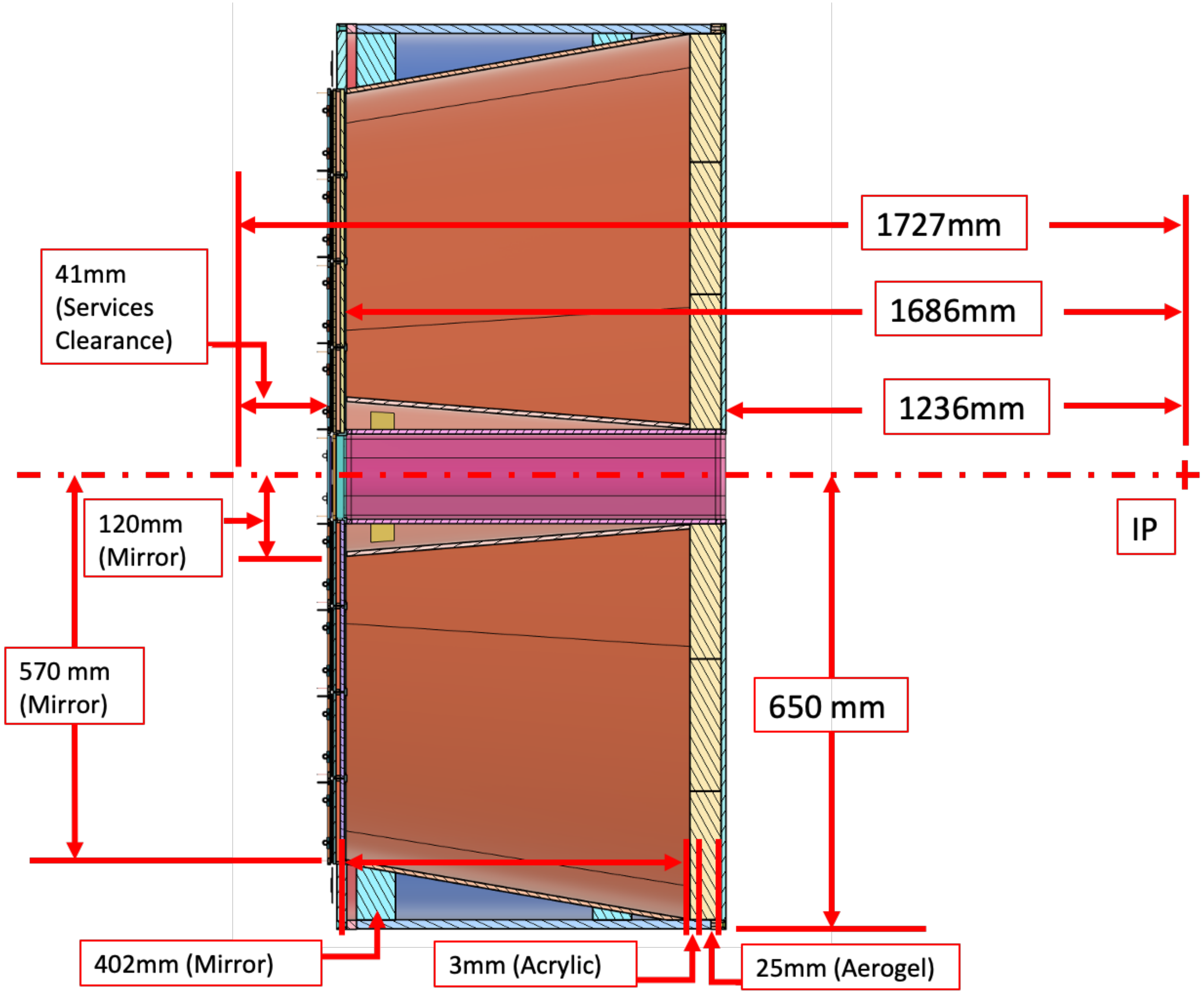
pf*RICH*

Overall pfRICH Design Converging

Alex Eslinger



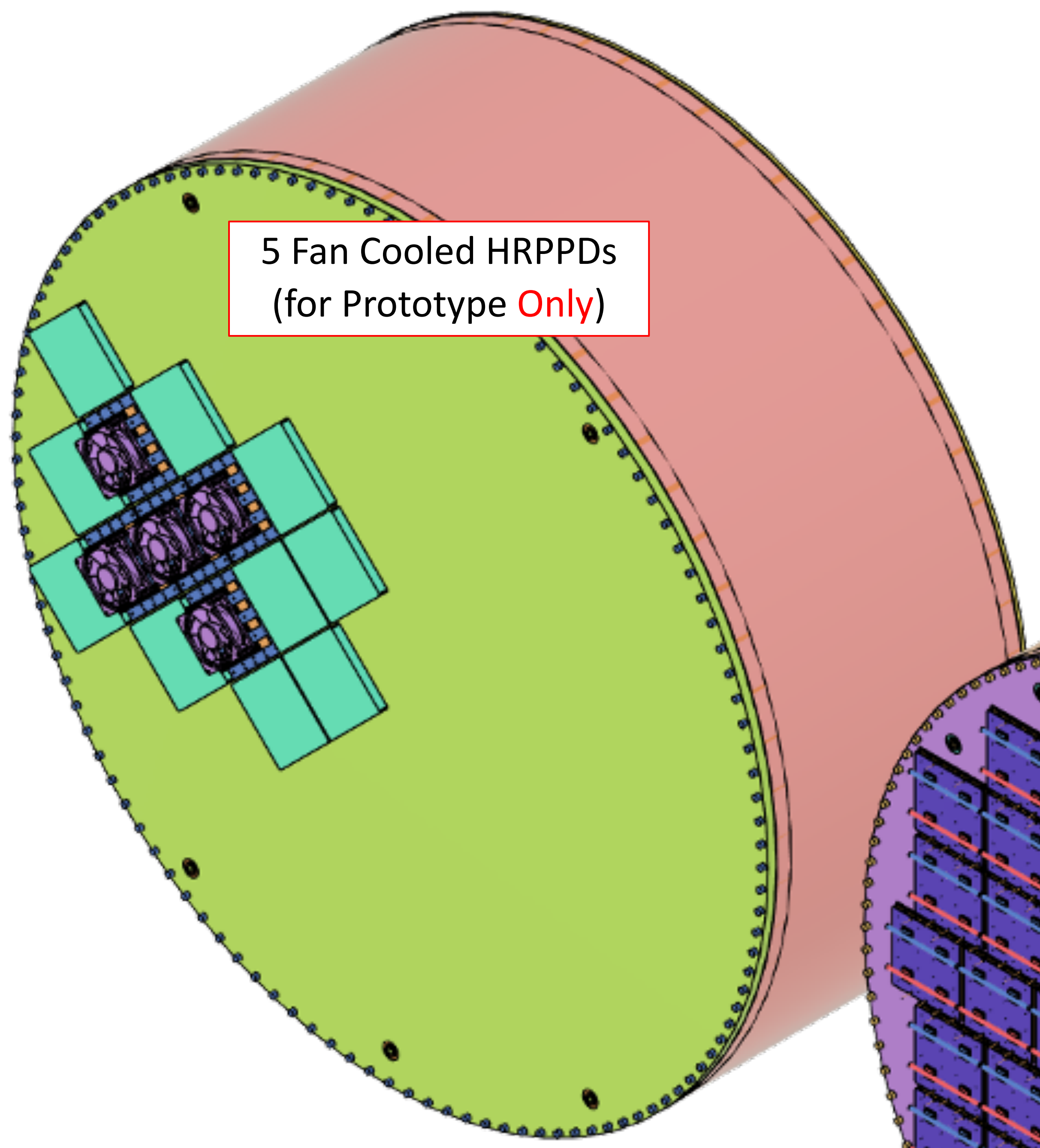




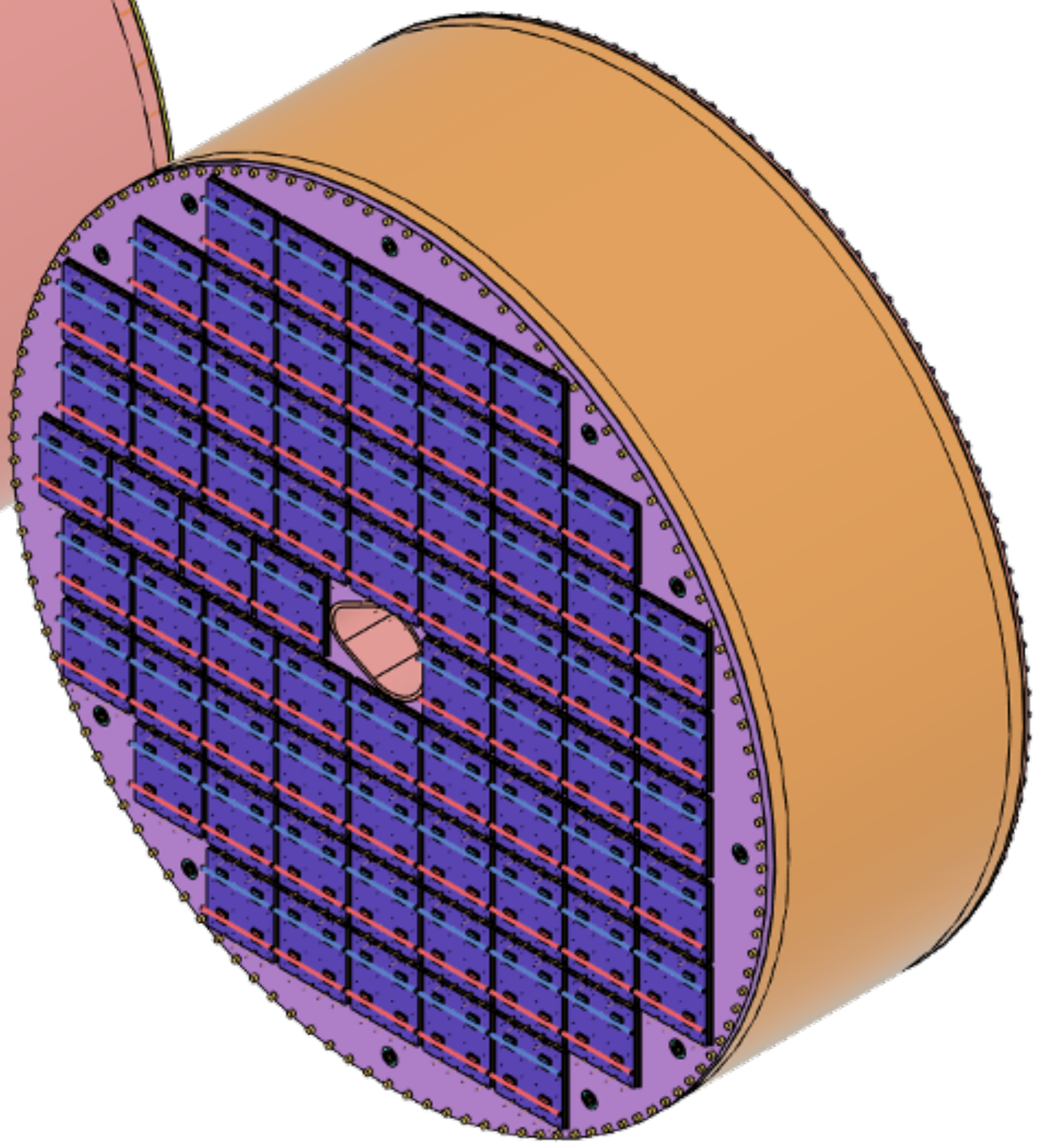
Backplane/SensorPlane

Alex Eslinger

Purdue: Sensor Plane

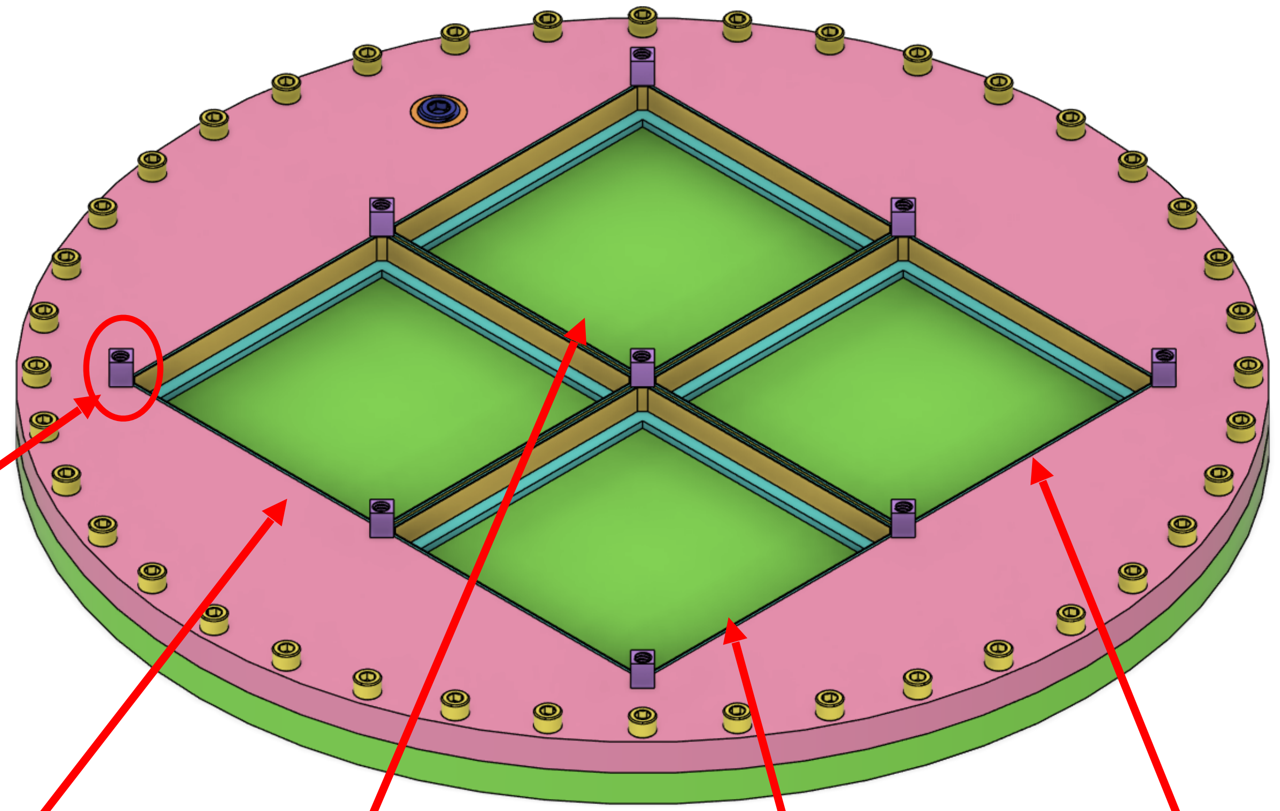


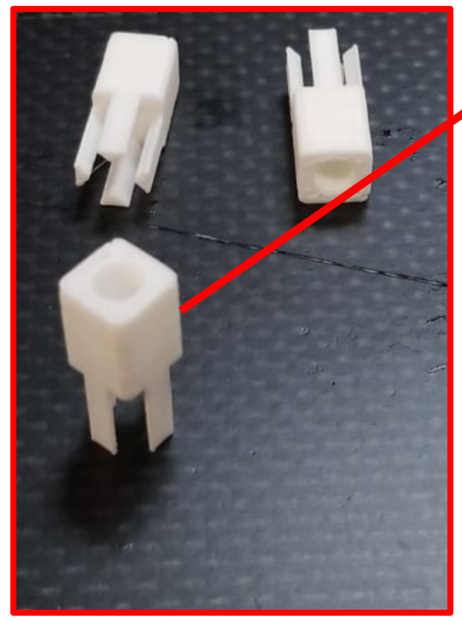
Prototype



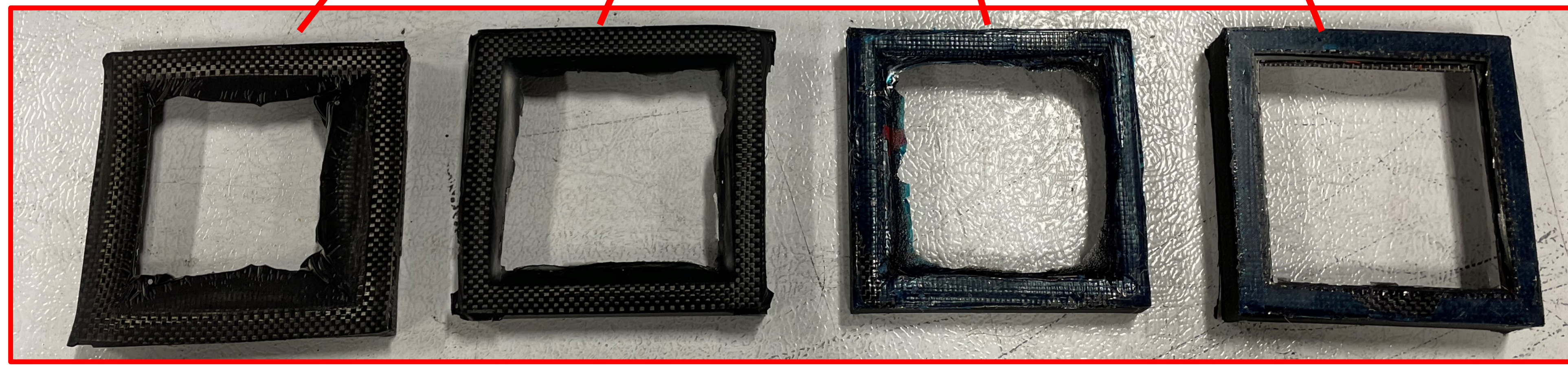
Final Design

“New Style” Sensor Plane CAD Model

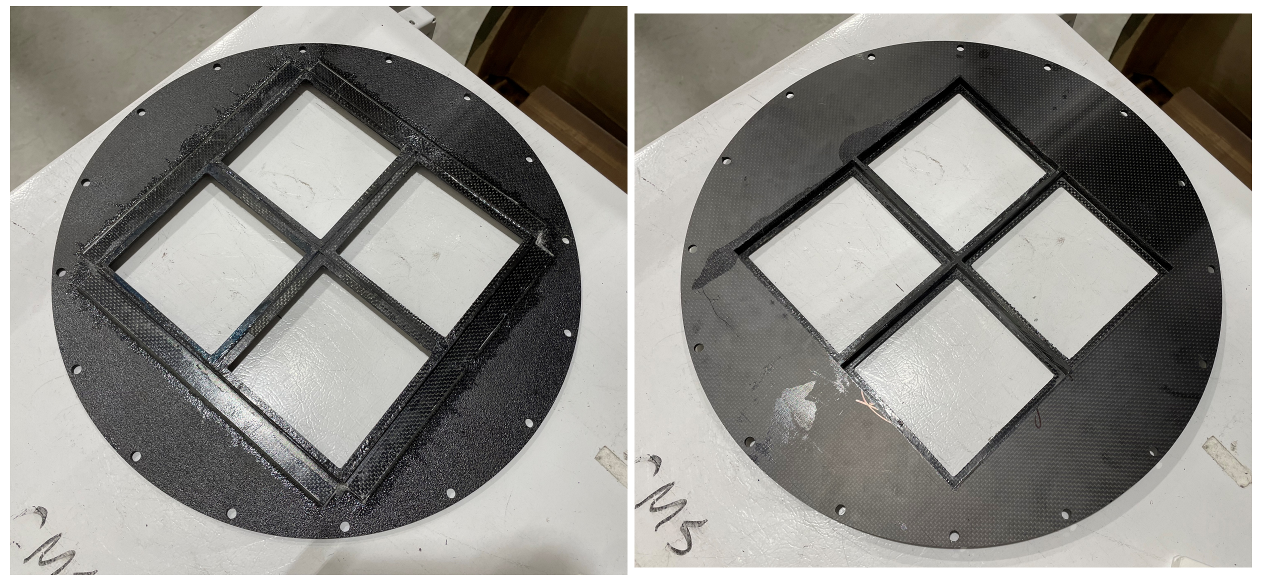




Mounting Concept



Untrimmed “Picture Frames”

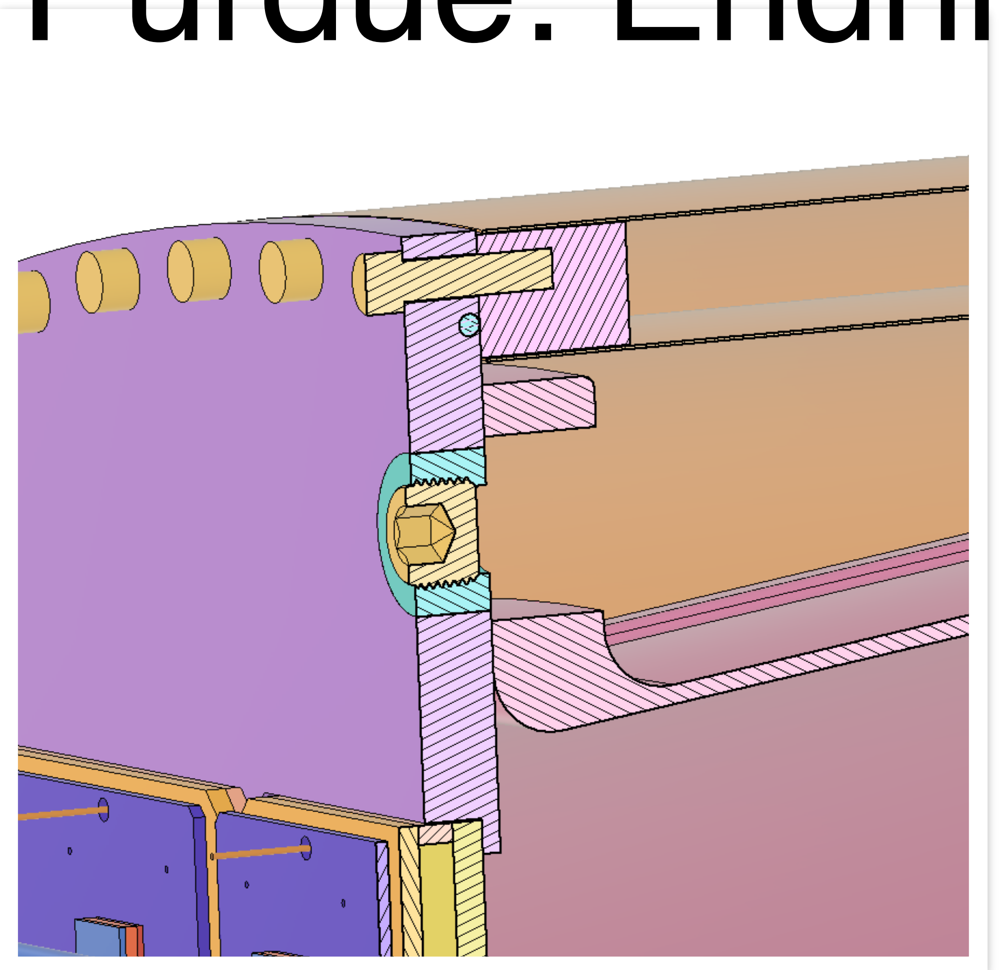


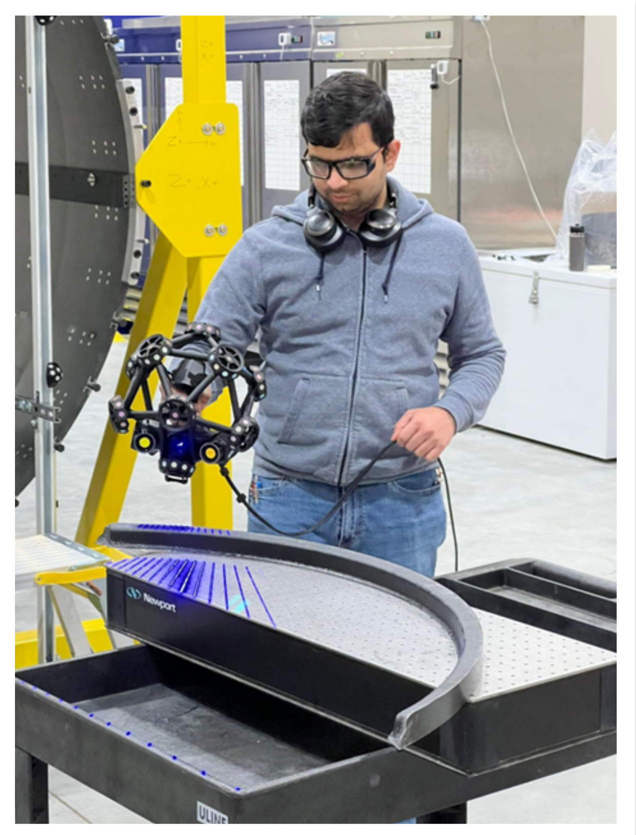
Sensor Plane Prototype
(Sealing Mock-Up)

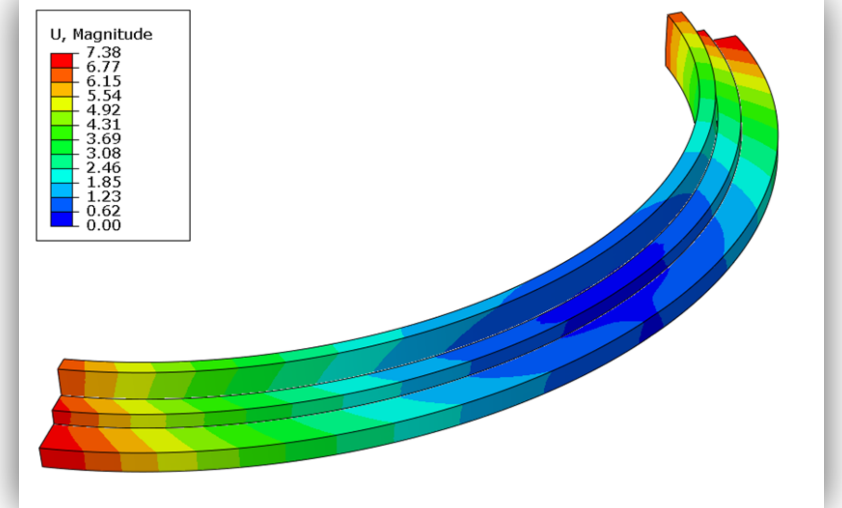
Progress on Many Fronts

Alex Eslinger

Purdue: Endrings

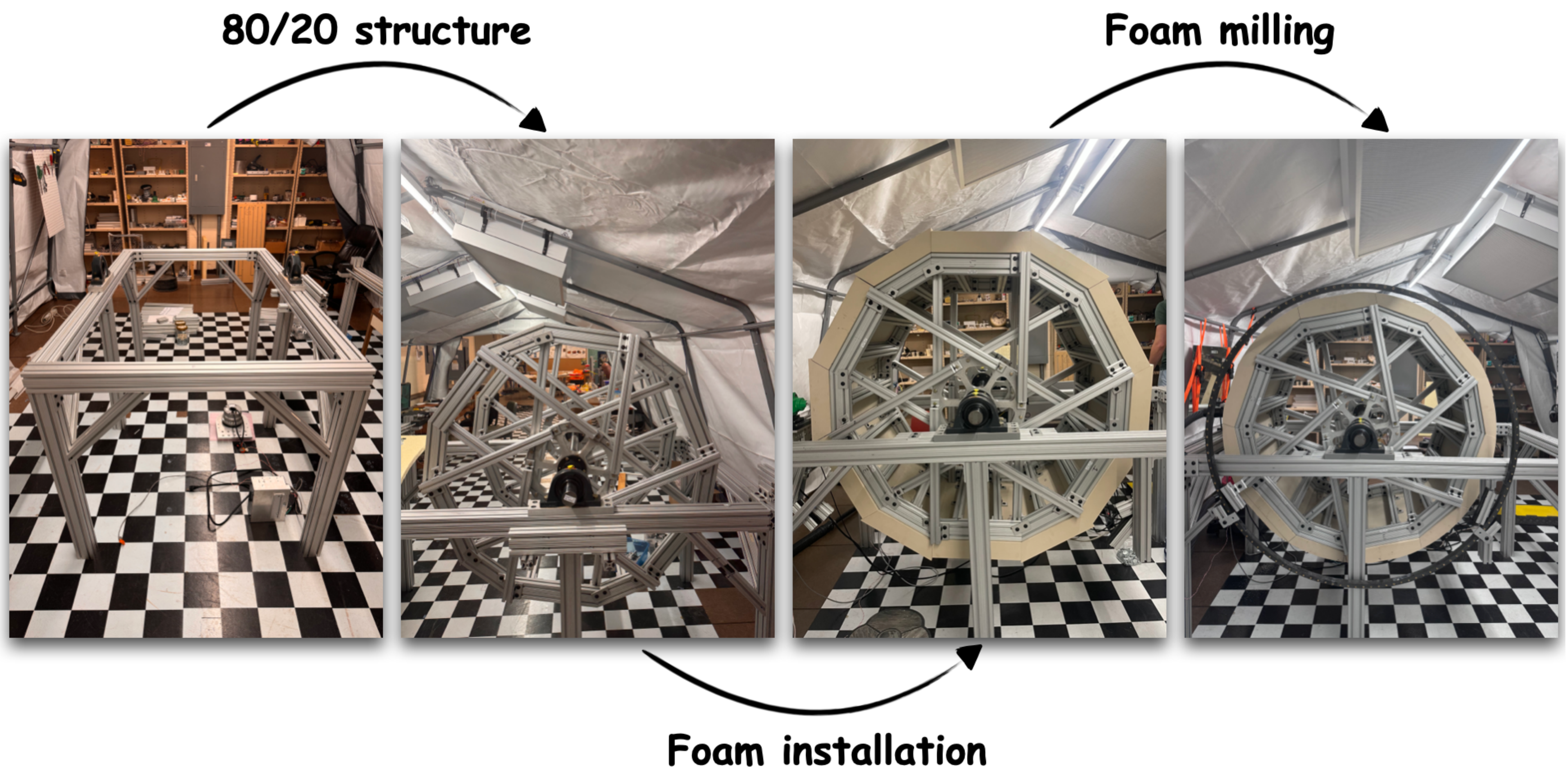




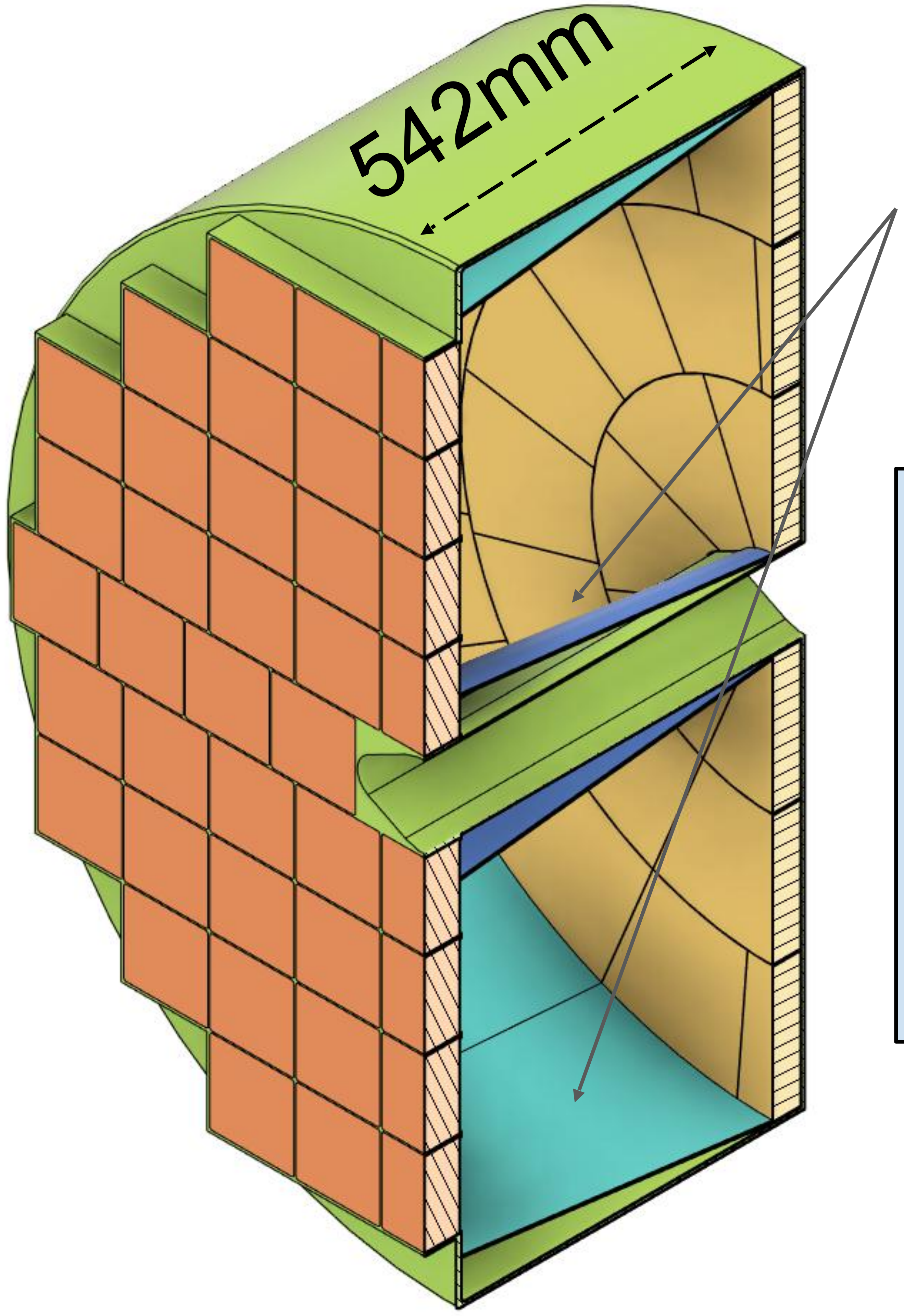


SBU: Vessel Constructions

- Tasked with creating a cylindrical shell for the pfRICH
- Use of carbon fiber sandwich material for a light, stiff, gas- and light-tight vessel wall.
- Scheduled to be completed by end of August



Mirrors for the pfRICH



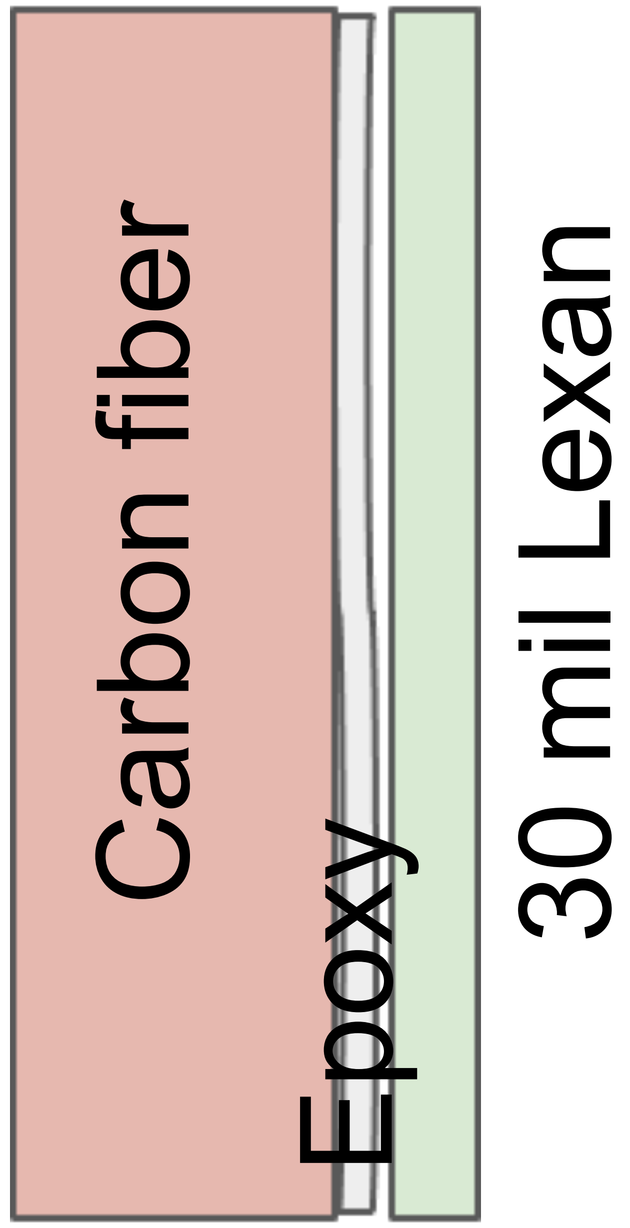
High reflectivity mirrors for photons with wavelengths 300-600 nm to improve the acceptance of the RICH detector

Requirements:
- **High reflectivity ~ 90% between 300-600 nm.**
- **Conical and lightweight**
- **Uniform coating across a large surface.**
- **Low cost - made "in house".**

True Collaboration:
- Substrate (Purdue)
- Evaporation (Stony Brook)
- Testing/QA (BNL)

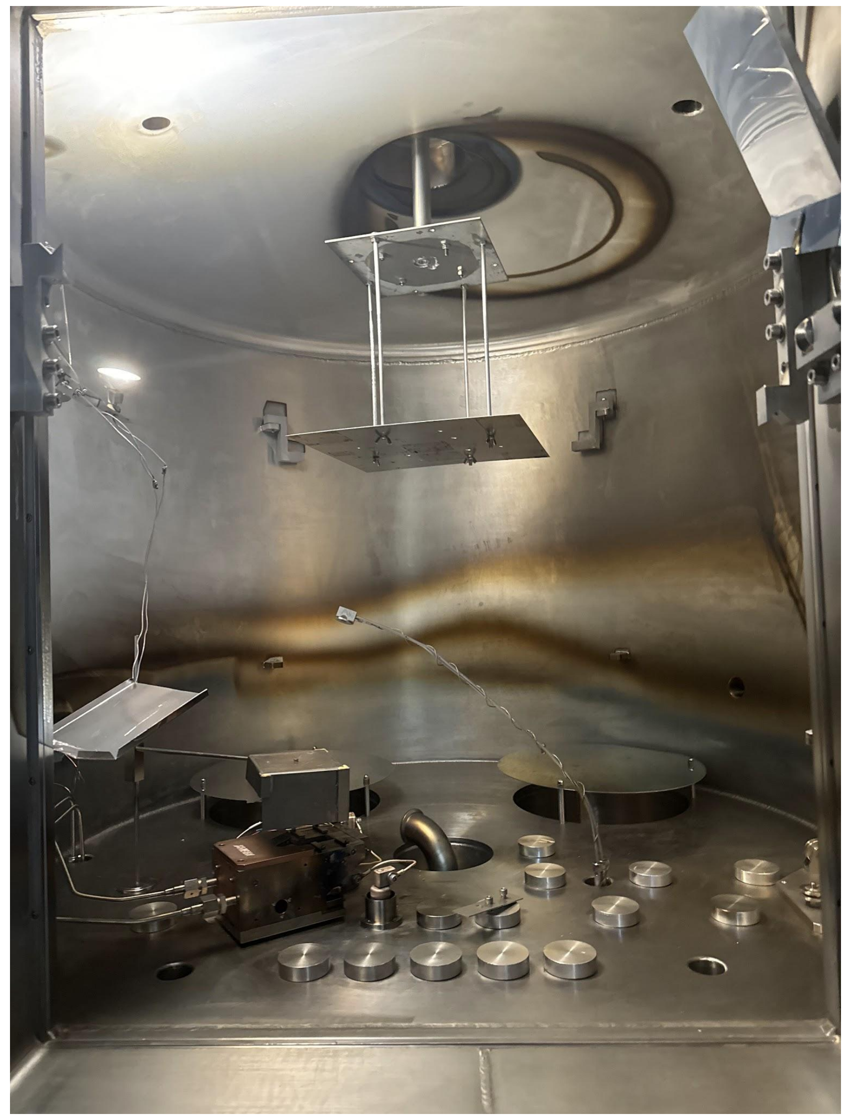
Manufacturing

Kong Tu

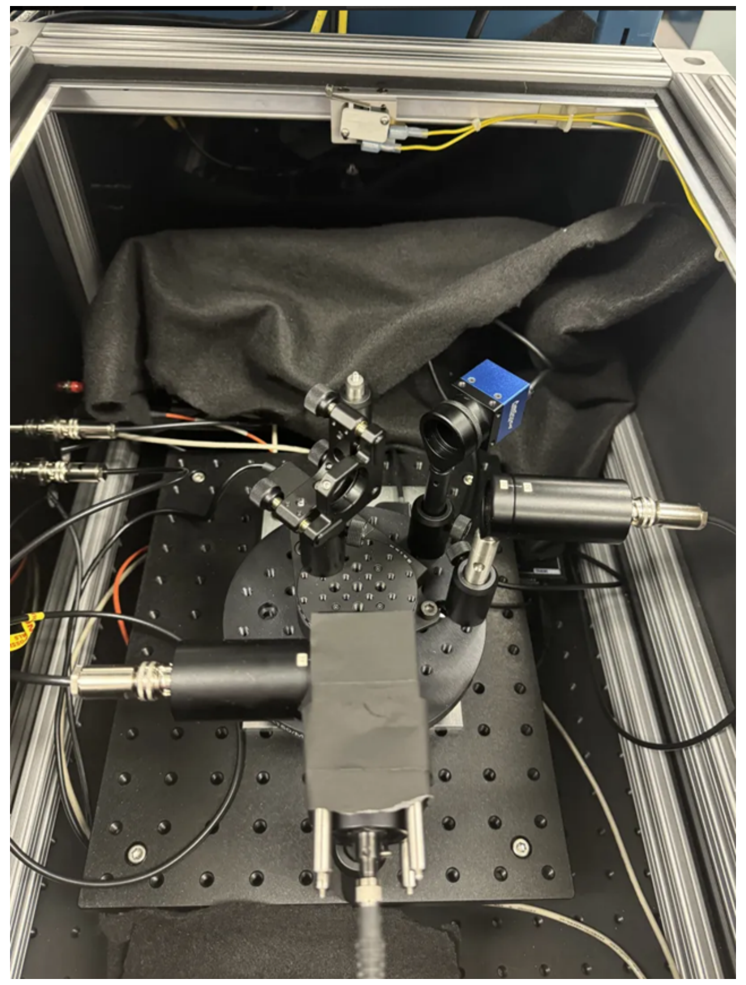


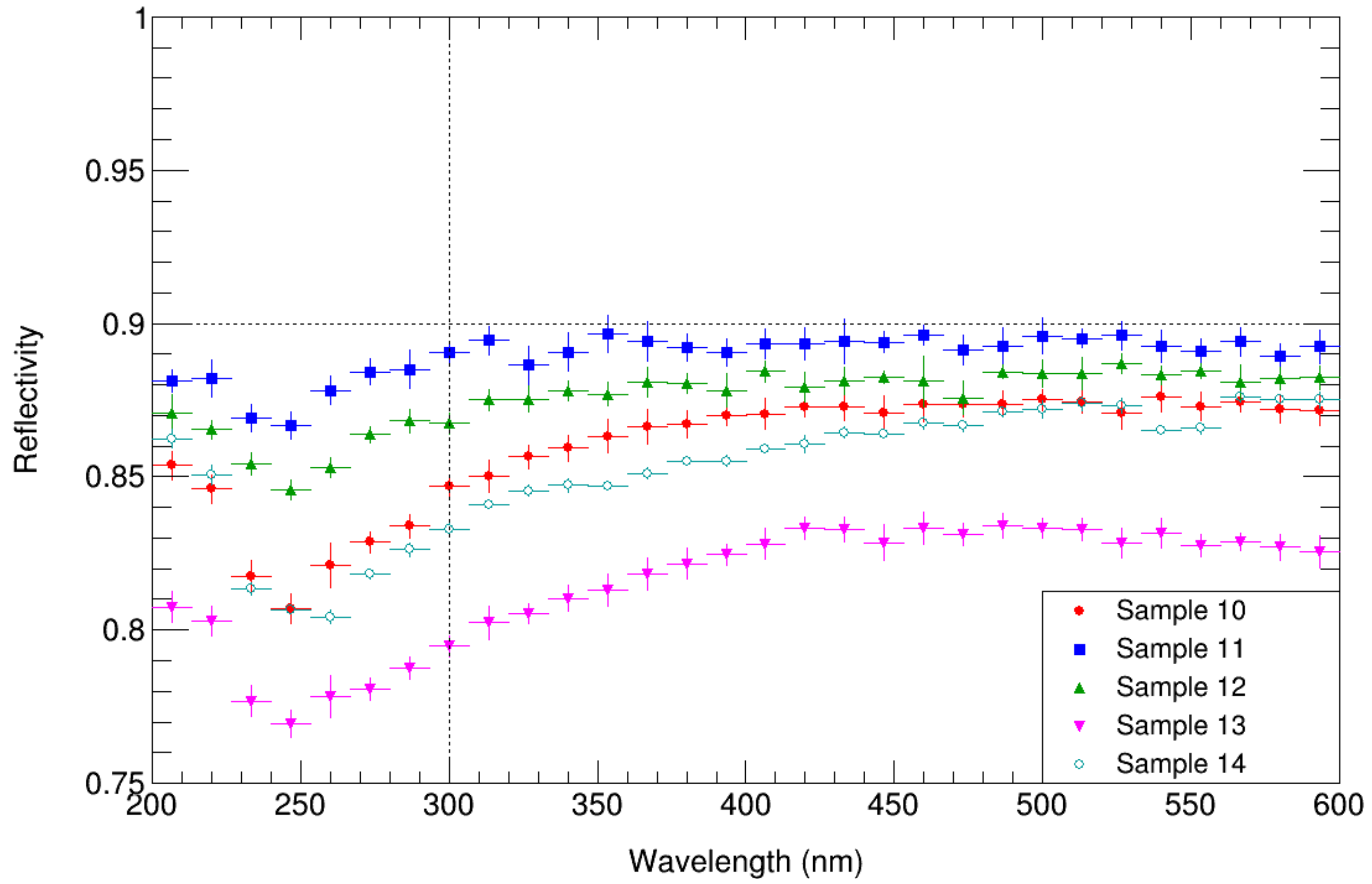
- Substarte (Purdue)
  - Carbon fiber is lightweight, strong, and rigid.
  - Lexan is flexible but has a smooth surface (~ nm level of roughness)
  - co-bonded by epoxy

- Coating in Evaporator (SBU)



- Testing (BNL)
  - Thickness
  - Reflectivity





pfRICH Laser Monitoring System

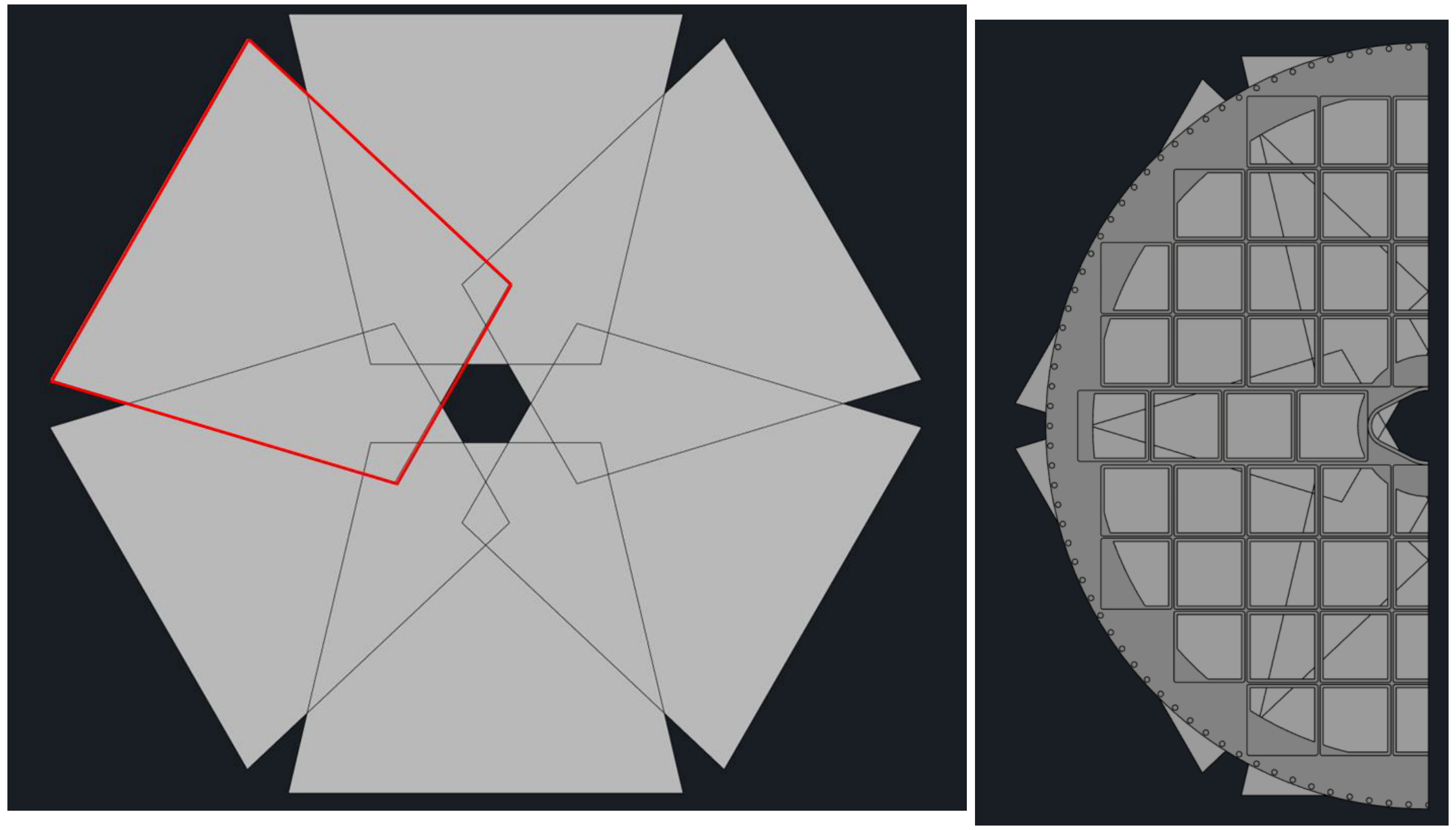
Wenliang Li

Goal of System

- Use a light source with adequate resolution to monitor timing performance of HRPPDs
- Use same light source to monitor mirror over life of experiment

Approach

- Array of 6 fibers may be used for direct illumination of HRPPDs + array 6 fibers may be used to reflect light off of the mirrors



6 fibers for direct HRPPD illumination + 6 fibers for the mirror illumination should suffice to illuminate all HRPPD pixels

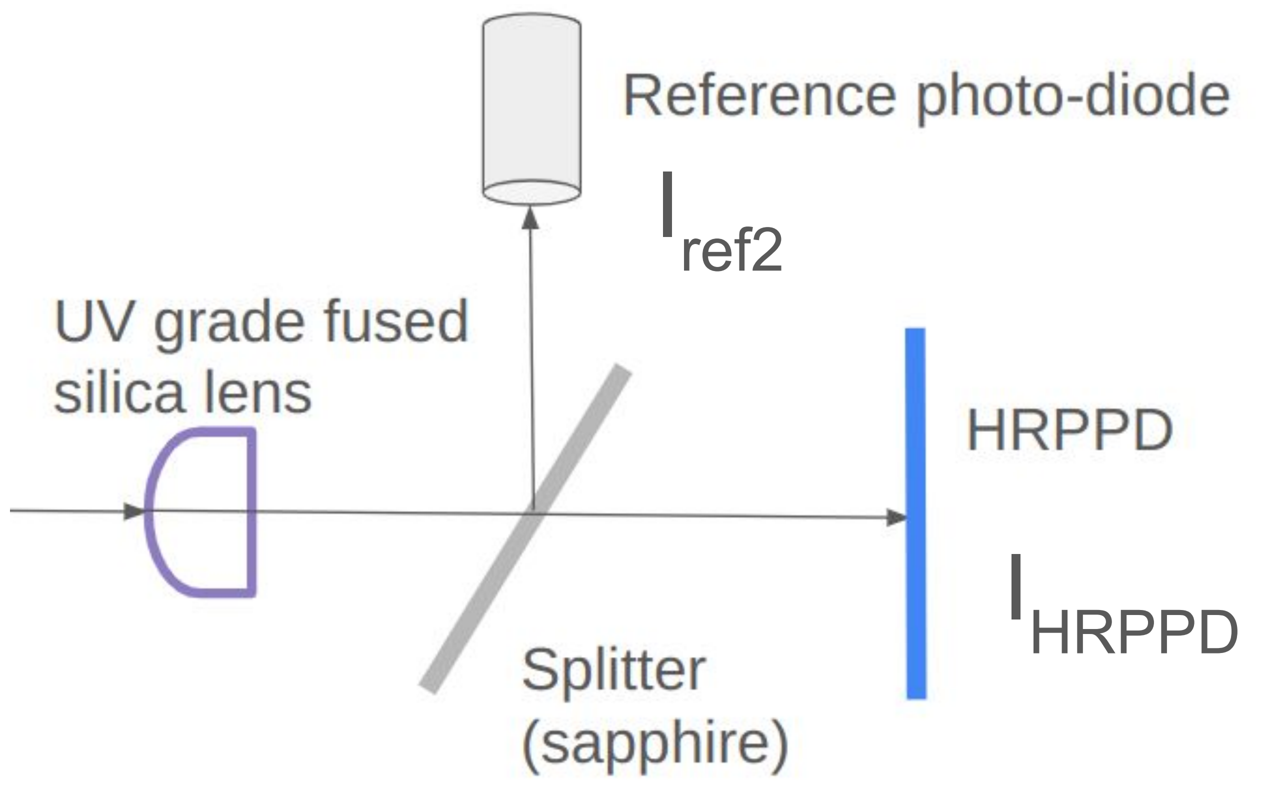
- Overall layout advanced
- Studying options for routing fibers into pfRICH vessel
- Fiber optics hardware identified
  - picosecond pulsed diode lasers, splitters, feedthroughs, fibers, diffuser
- Potential prototype for other Cherenkov systems in ePIC

Measuring QE of HRPPD

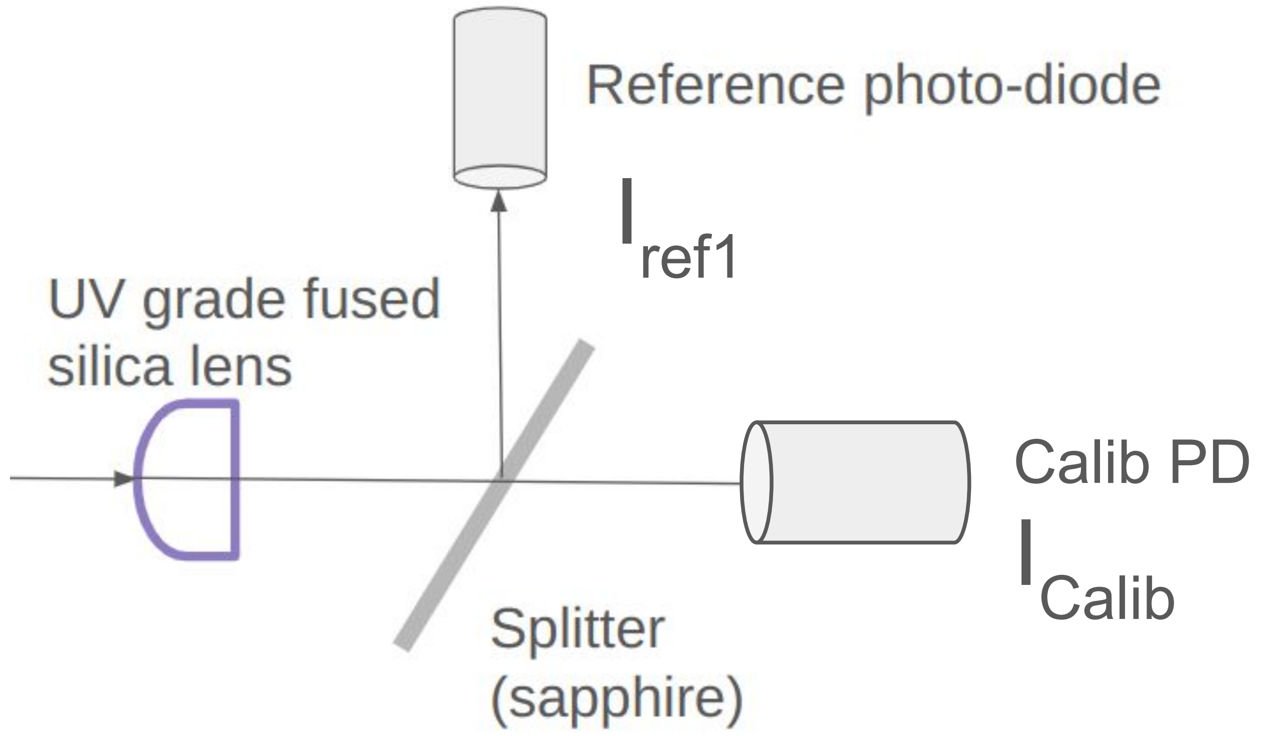
Chandradoy Chatterjee

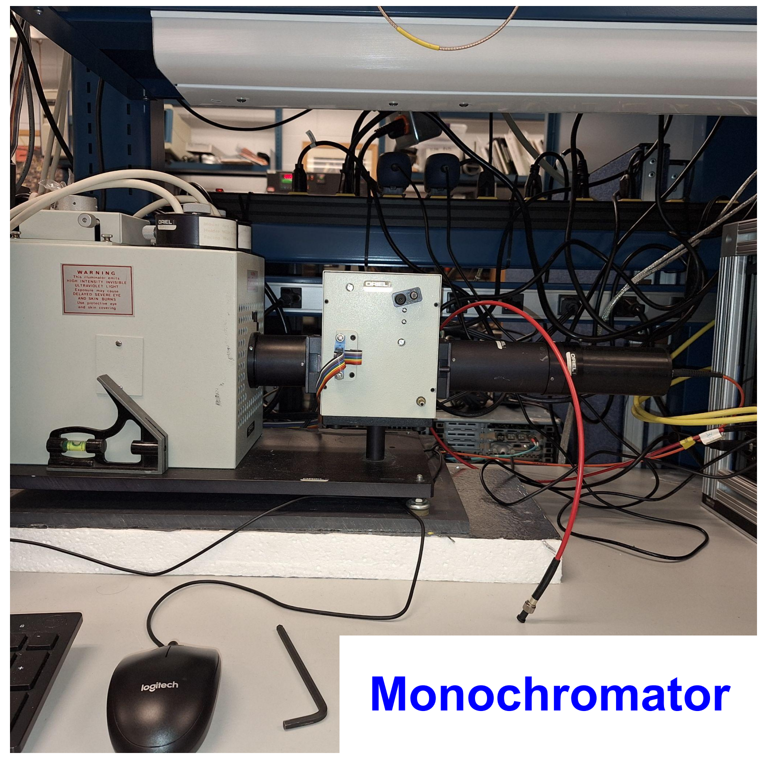
$$(QE)_{theo.} = \frac{N_{el}^{ejected}}{N_{ph}^{incident}} \quad (1)$$

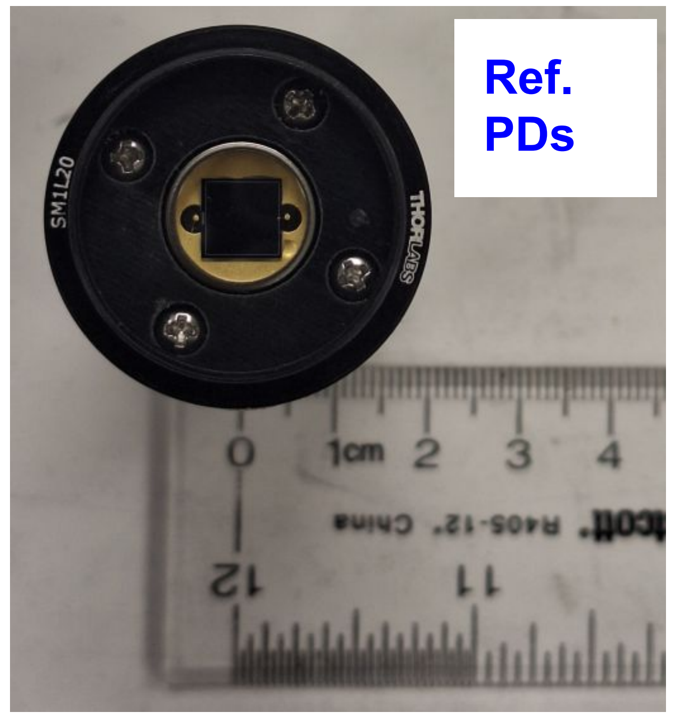
$$(QE)_{mes.} = (QE)_{calib} \cdot \frac{I_{calib}^{pc} - I_{calib}^{dark}}{I_{HRPPD}^{pc} - I_{HRPPD}^{dark}} \cdot \frac{I_{ref2}^{pc} - I_{ref2}^{dark}}{I_{ref1}^{pc} - I_{ref1}^{dark}} \quad (2)$$

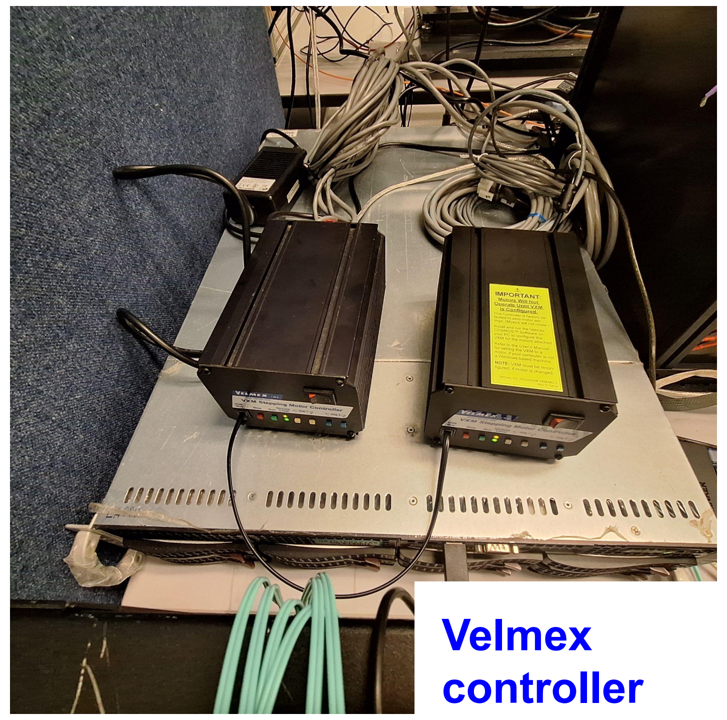


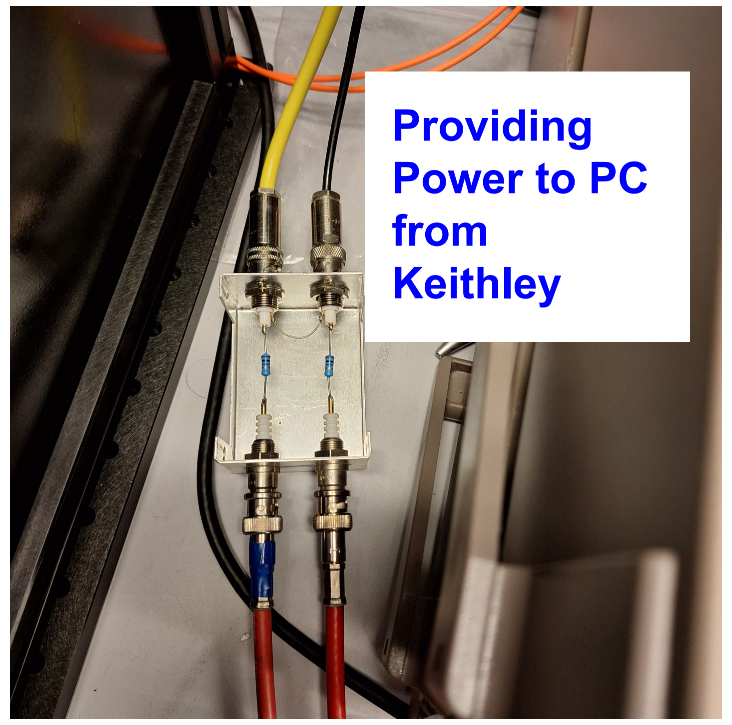
- Sources of uncertainty:
  - Determination of the photon flux
  - Fluctuation in dark current
  - Accuracy of QE of reference calibration

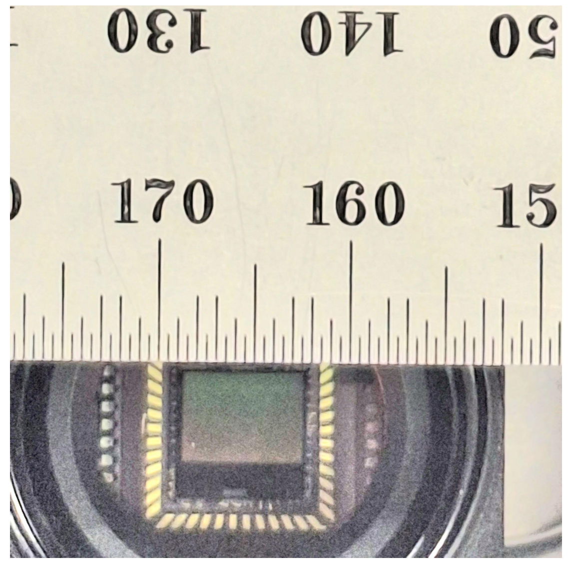











Amscope camera

HRPPD Uniformity

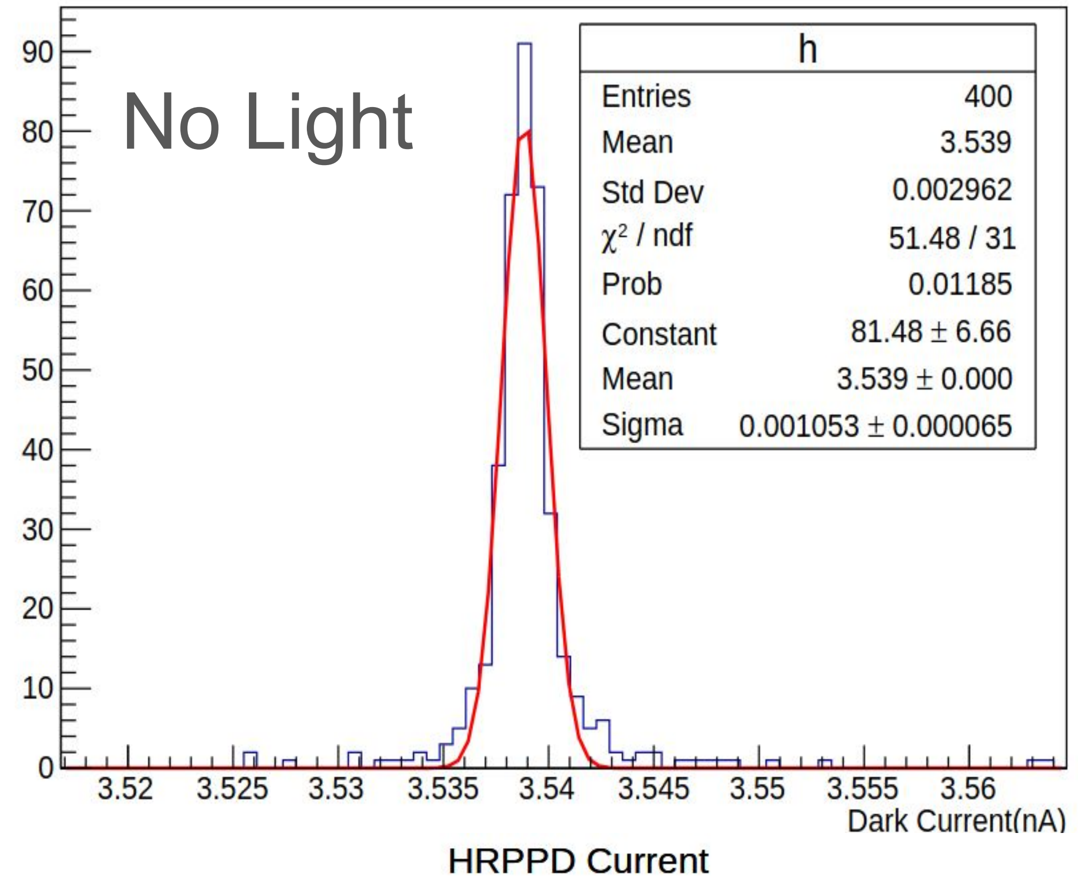
Chandradoy Chatterjee

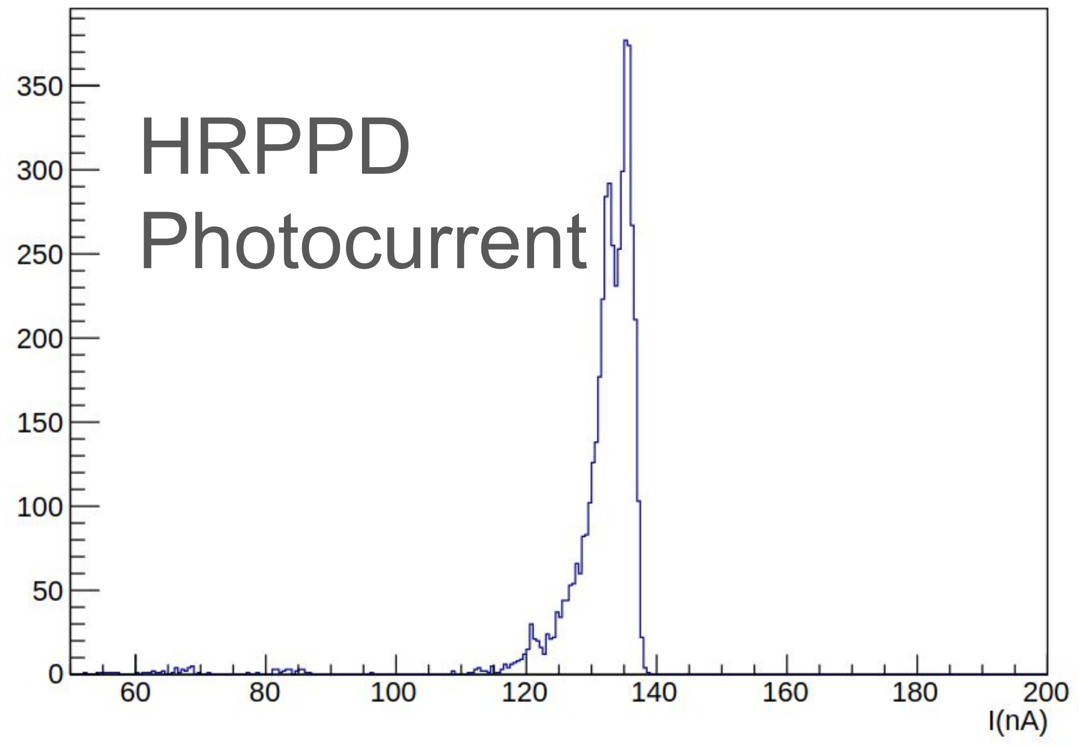
Dark currents and photocurrents

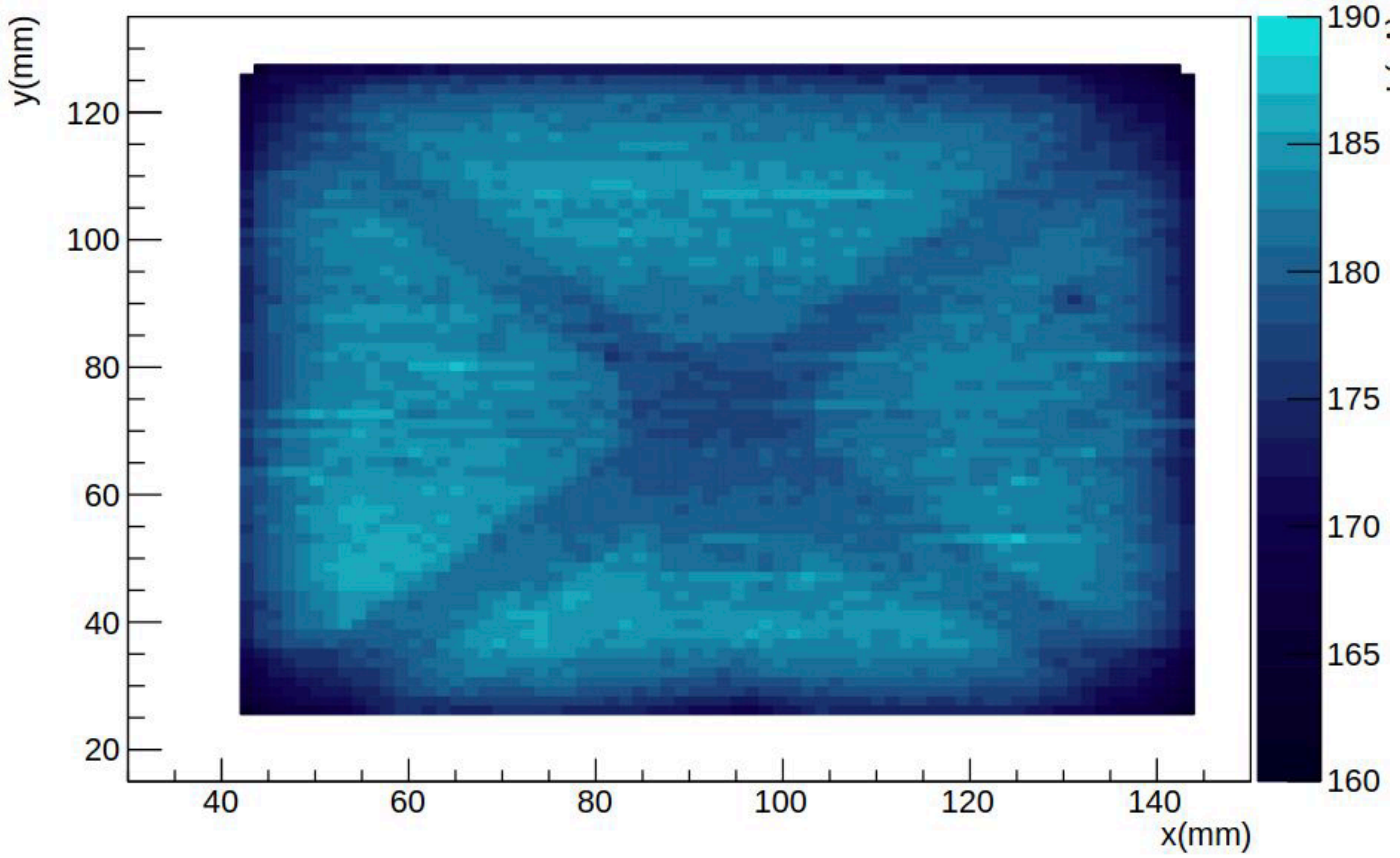
- It is known that LAPPD dark current and photocurrent are of similar values.
- In case of HRPPD the dark current is significantly smaller.

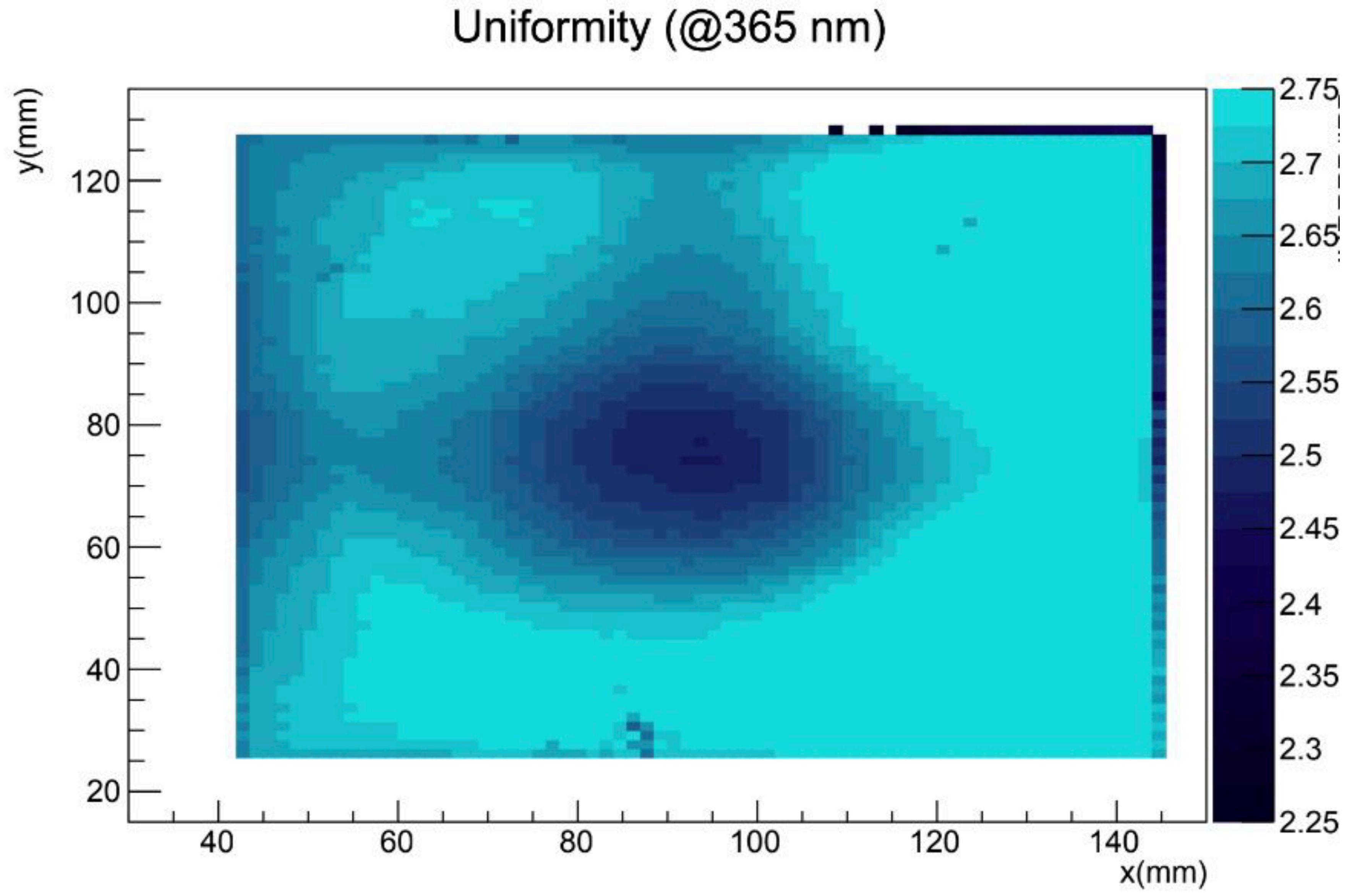
HRPPD Uniformity

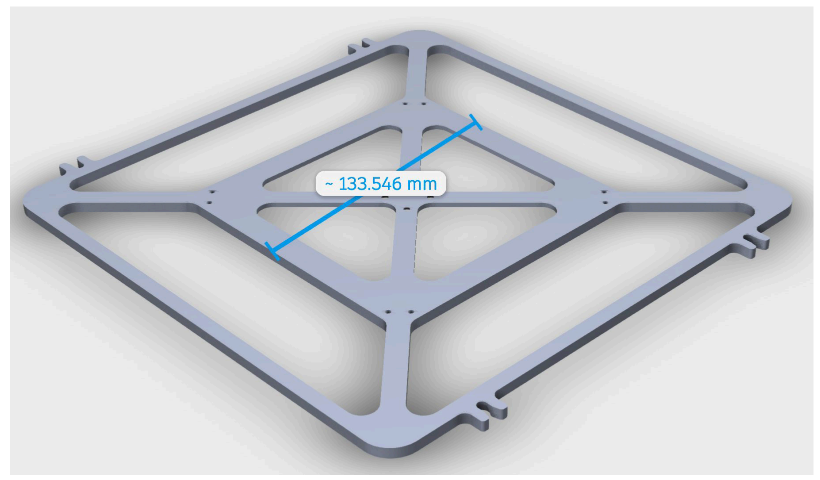
- Can clearly notice the holder structure
- Effect of different coating vessel seen







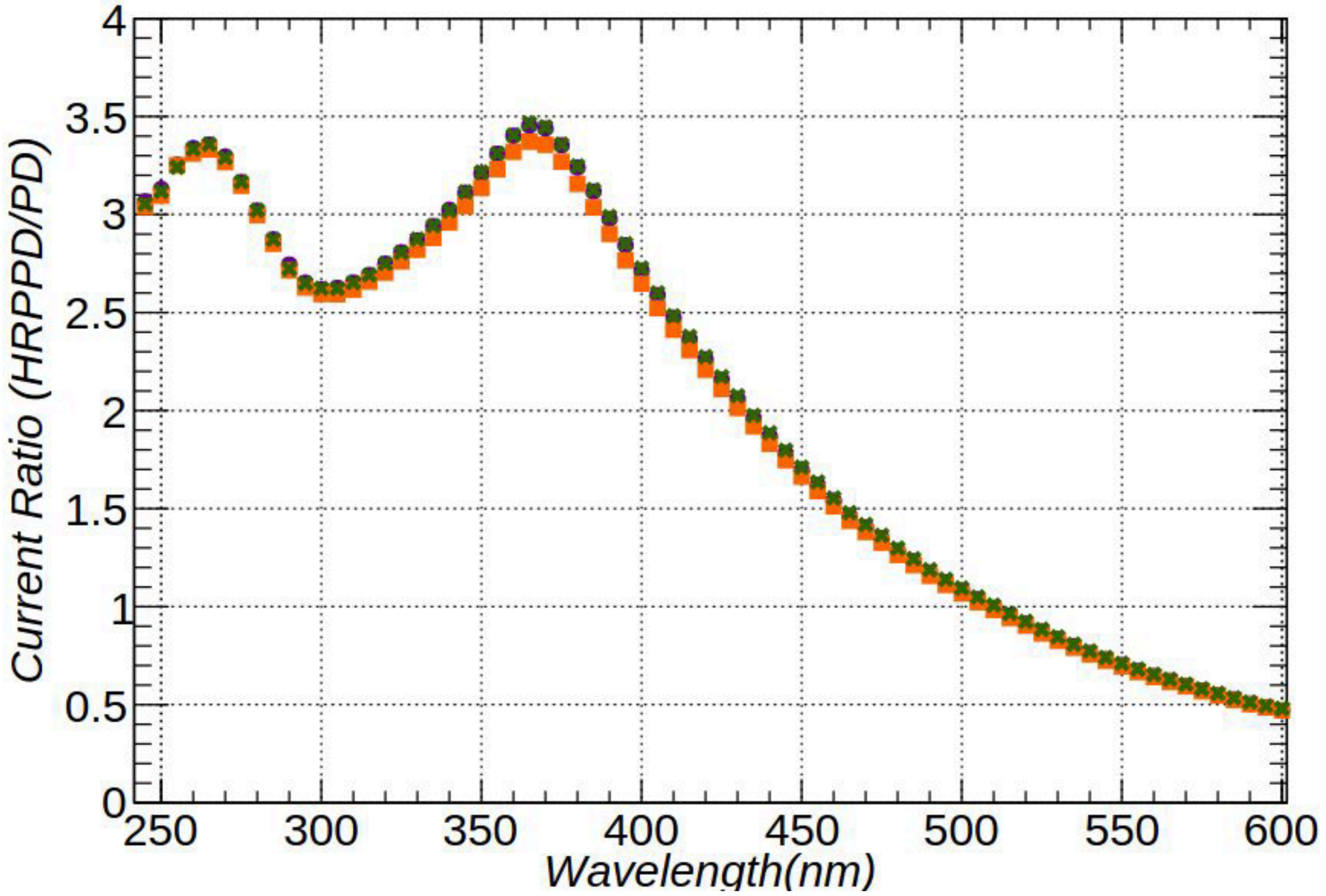


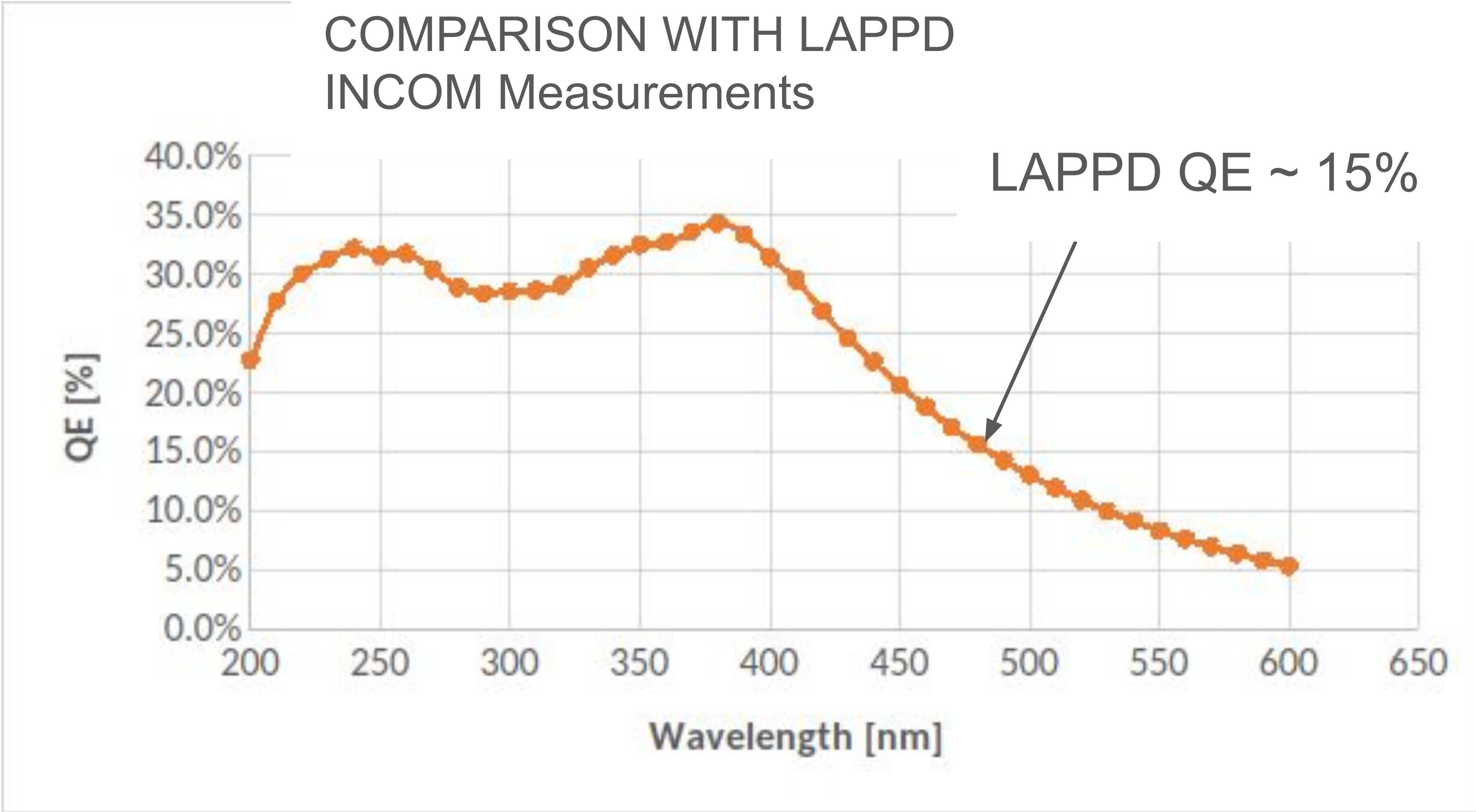


QE Status

Chandradoy Chatterjee

- Working setup has been prepared. Setup can even be used from remote.
- Three hours for a full scan of a HRPPD.
- Waiting for the calibrated photodiode. Once it arrives the **absolute** QE values of the HRPPDs will be extracted.
- So far very consistent results with INCOM has been seen.
- The active area of HRPPD measured to be 104 mm.





d*RICH*

Details on prototypes and beam
test presented earlier by Nicola Rubini

Reminder: dRICH Requirements

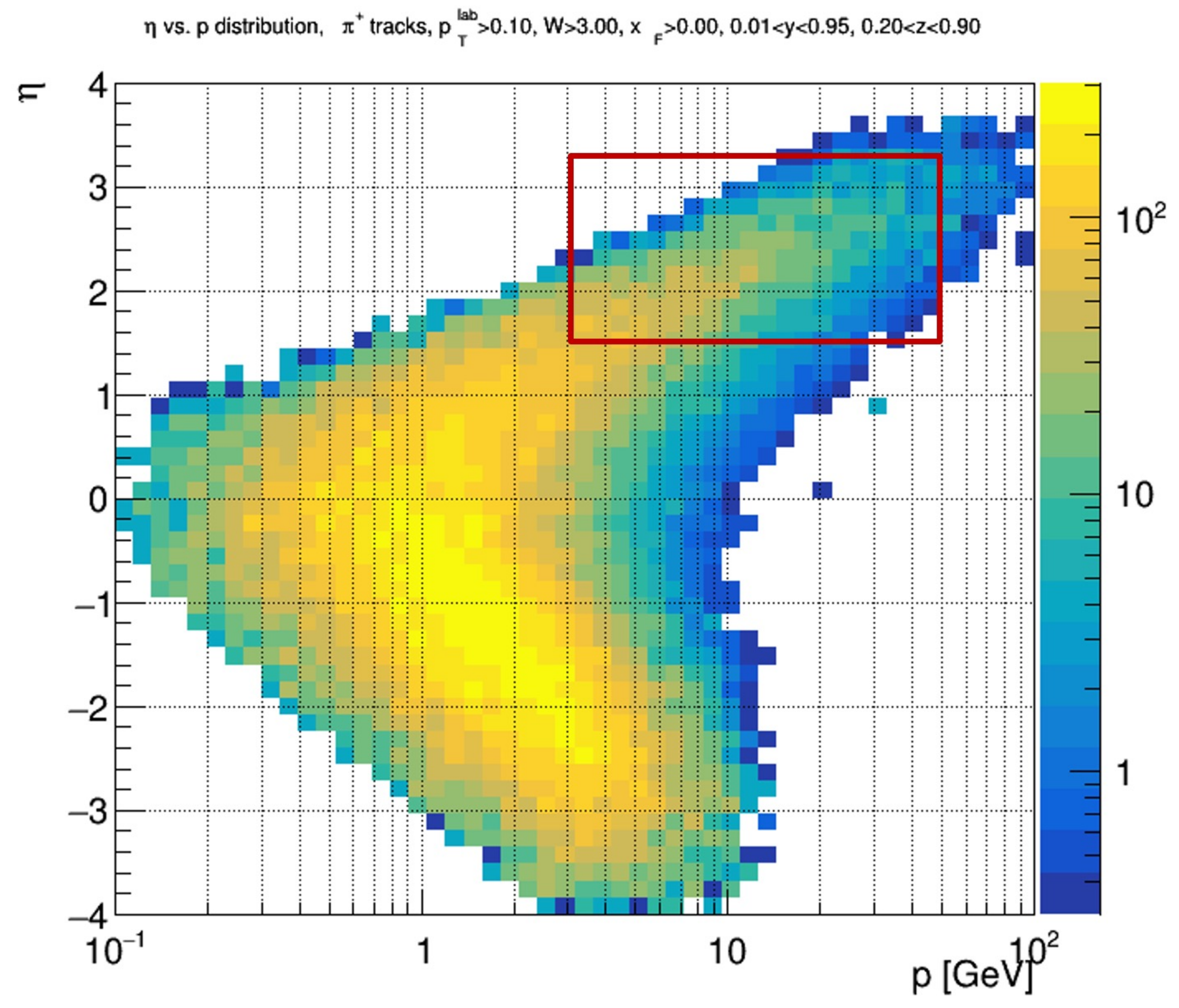
Marco Contalbrigo

Main challenges:

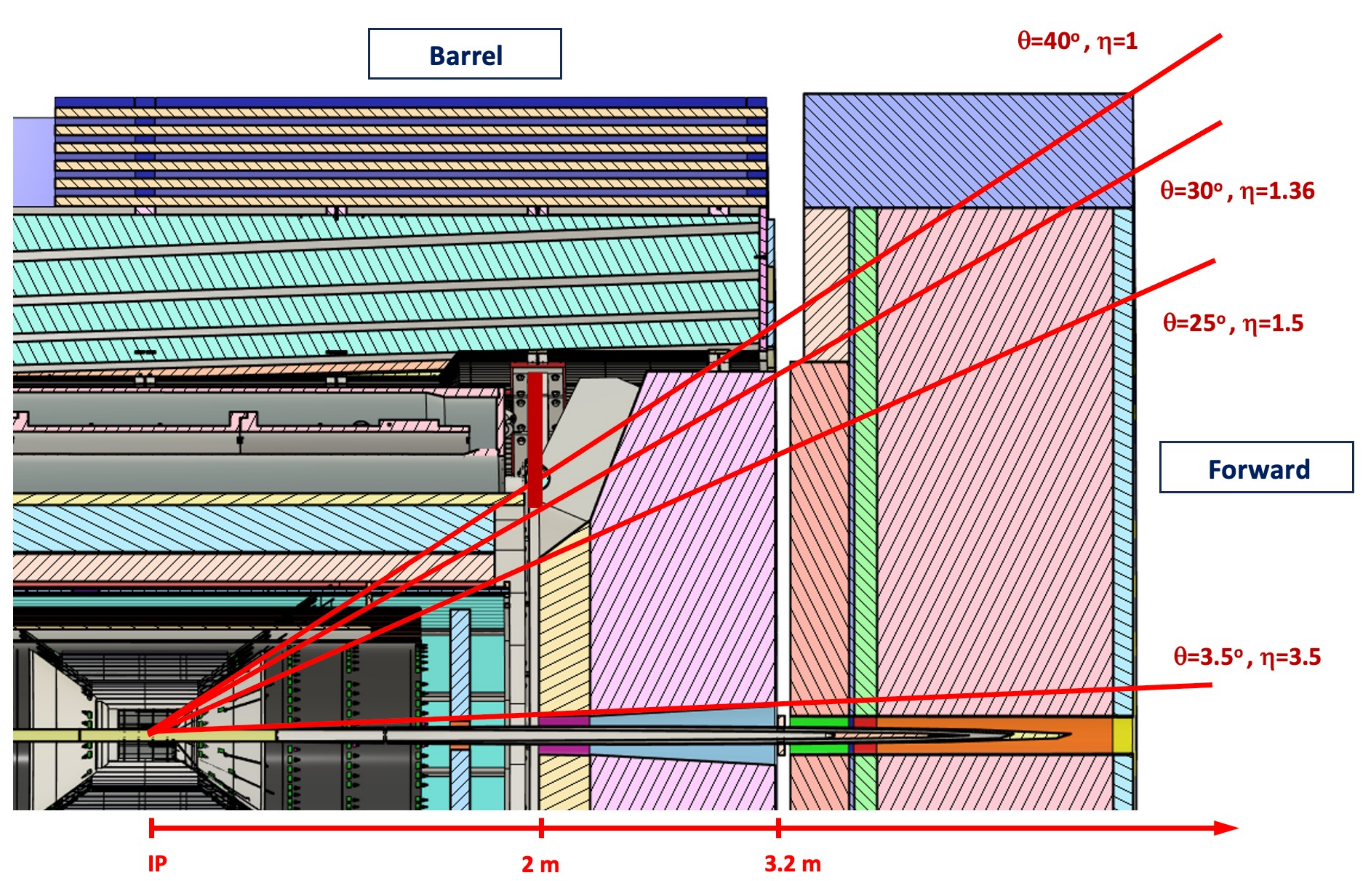
Cover wide momentum range 3 - 50 GeV/c -> dual radiator
Work in high (~ 1T) magnetic field -> SiPM
Fit in a quite limited (for a gas RICH) space -> curved detector

η	Nomenclature	Electrons and Photons			π/K/p	
		Resolution σ_E/E	PID	Min E Photon	p-Range	Separation
1.0 to 1.5	Forward Detectors	2%/E ⊕ (4*-12)%/√E ⊕ 2%	3σ e/π up to 15 GeV/c	50 MeV	≤ 50 GeV/c	≥ 3σ
1.5 to 2.0						
2.0 to 2.5						
2.5 to 3.0						
3.0 to 3.5						

Essential for semi-inclusive physics due to absence of kinematics constraints at event-level



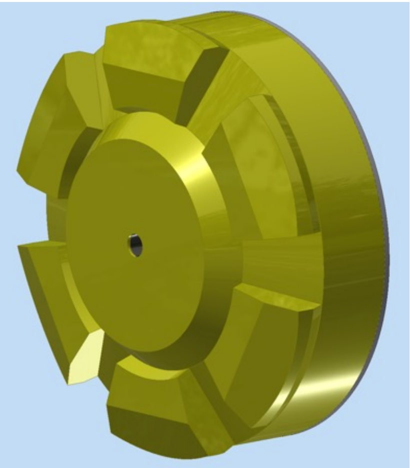
Acceptance in oseudo-rapidity defined by barrel and beam pipe

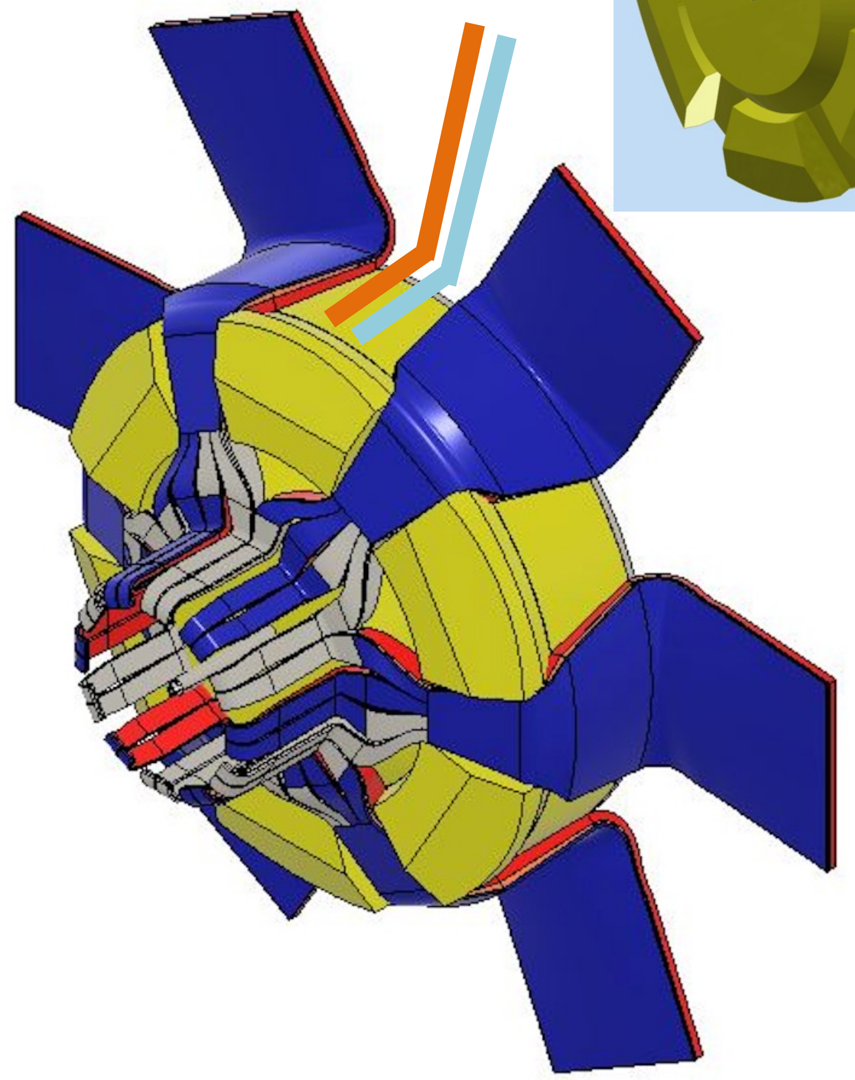


Design Progress

Marco Contalbrigo

- Φ3600 mm x L1200 mm
- Operating pressure up to 200 Pa
- Operating temperature of 22 °C

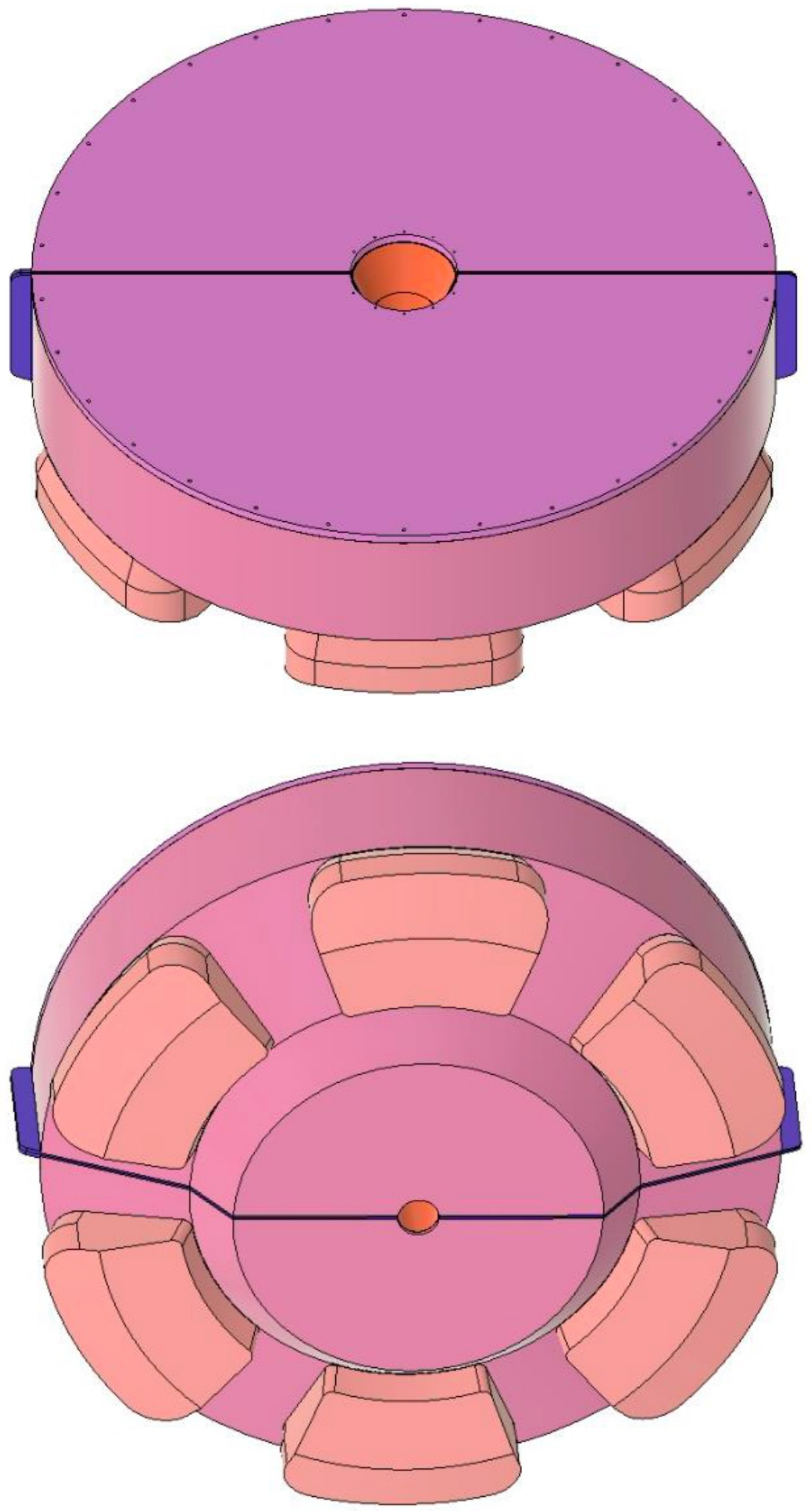




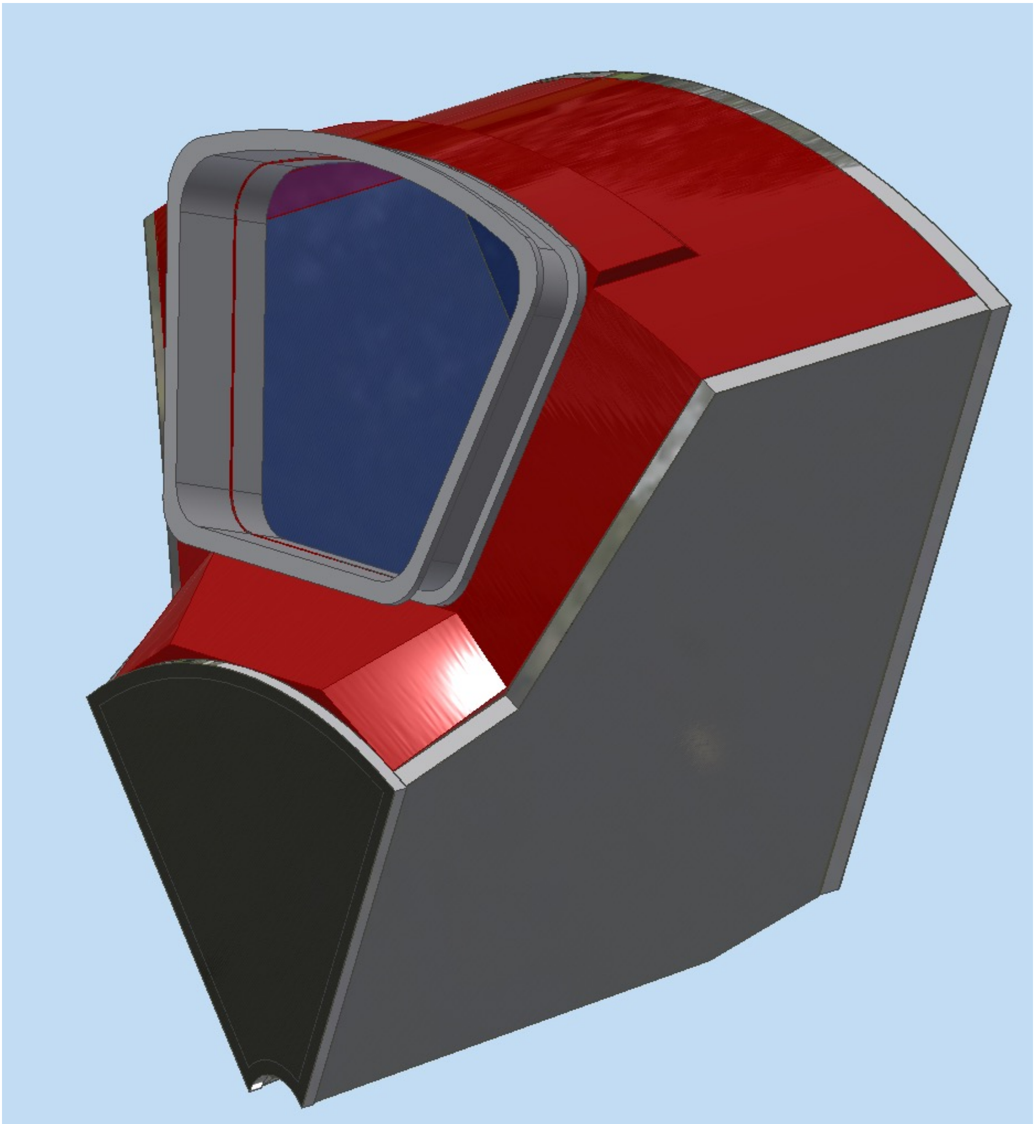
Acceptance: minimize material budget with the use of composite materials CFRP skins + honeycomb sandwich (~1 %) for windows, 1 cm bulk CFRP (~ 4 %) for round vessel

Integration:

Real scale prototype
Detector box integration
dRICH split model



Custom shell & Standard CFRP laminate foils



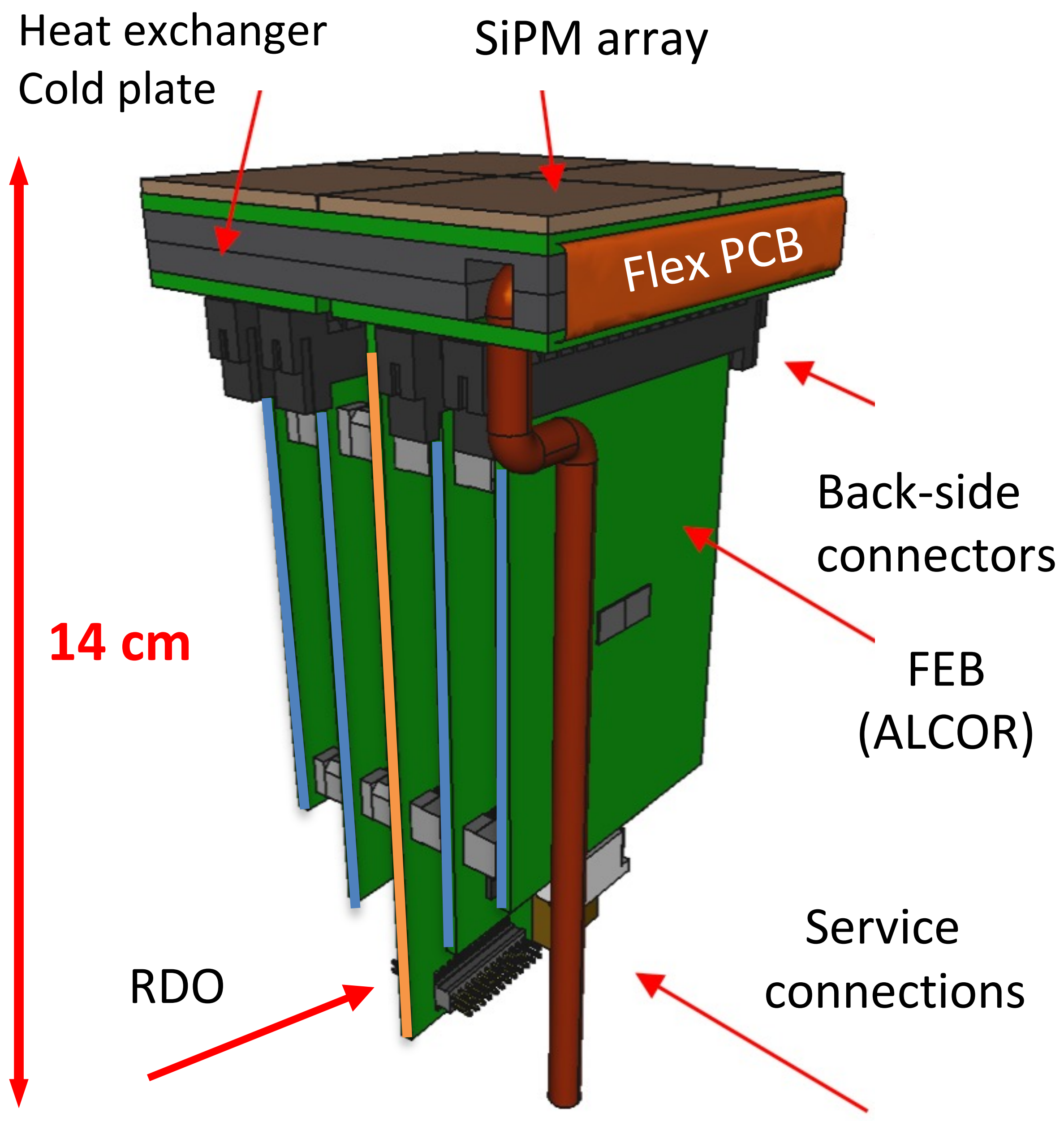
Vessel: Program towards TDR

2024: Real scale prototype

2025: Inner structure & support & Detector box & services

Photodetector:

Active area is shaped to resemble the focal surface and best exploits the focalization

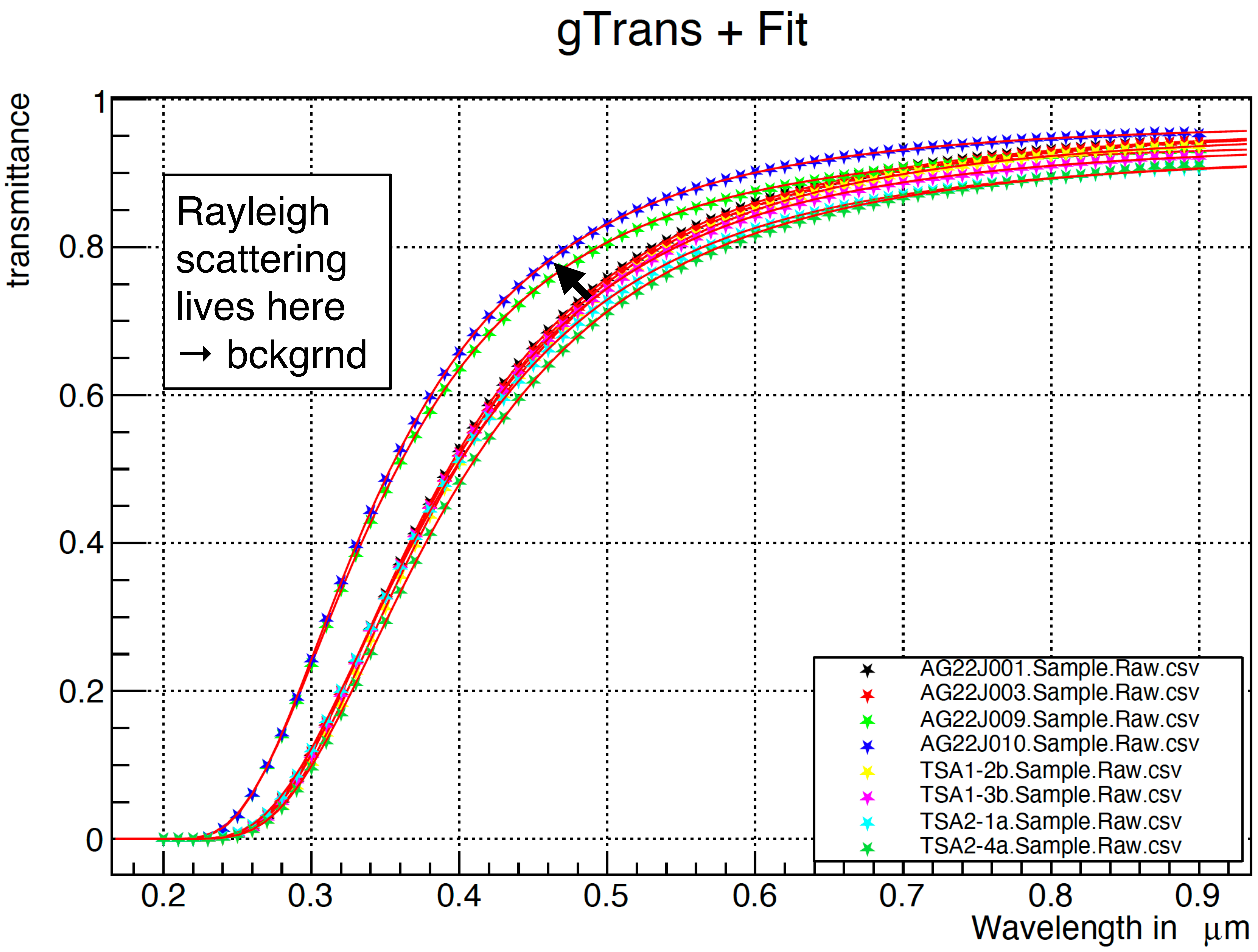


Preliminary Specs: Aerogel

Marco Contalbrigo

Optimization ongoing in the refractive index rage 1.02-1.03

New samples received from Aerogel Factory



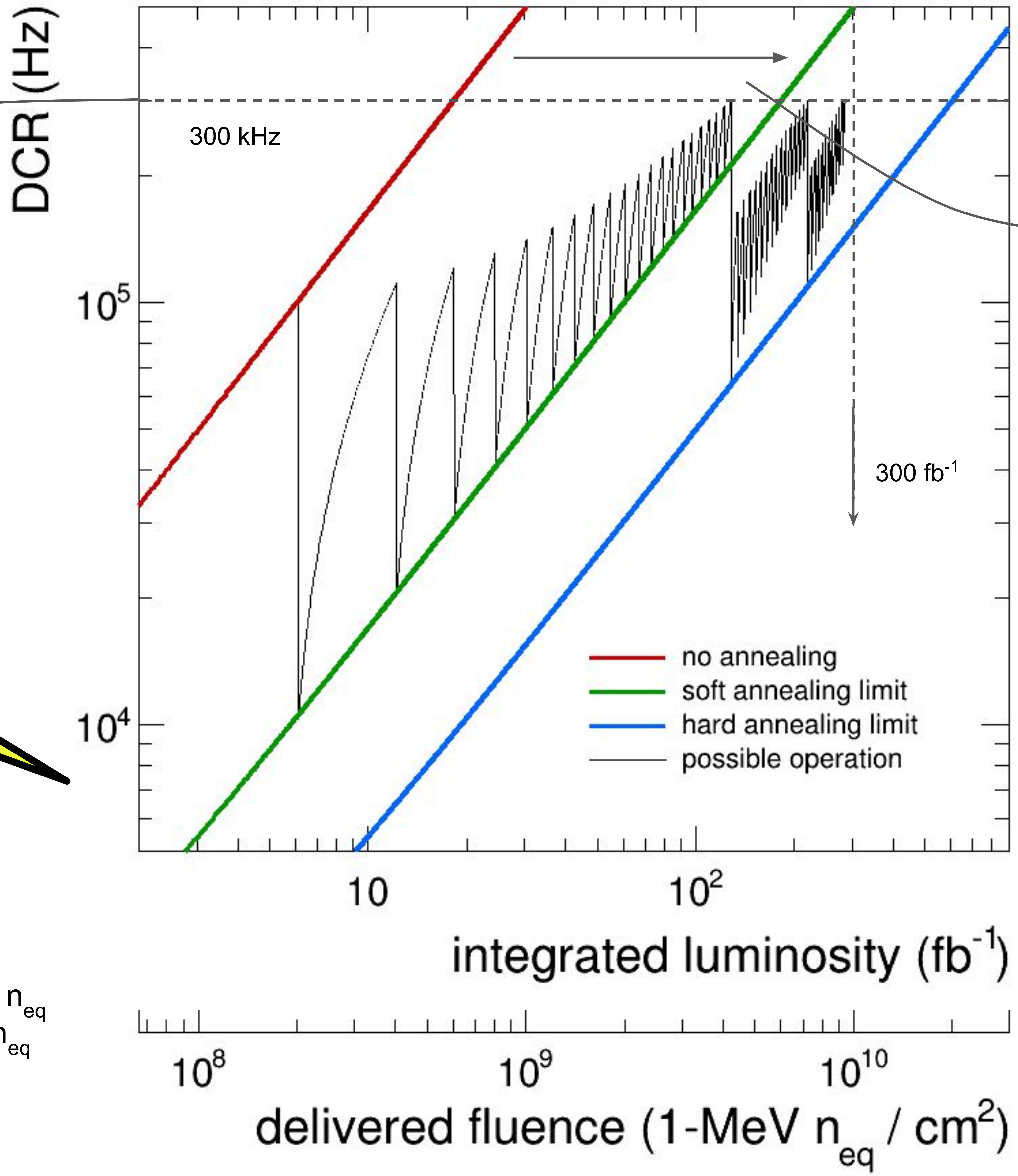
dRICH SiPM - Dark Current Rate - Ageing

Roberto Preghenella

Ageing model

Hamamatsu S13360-3050 @ Vover = 4 V, T = -30 C

max acceptable DCR for
Physics performance
~ 10 noise hits / sector within 500 ps



the "possible operation" scenario shown here has 44 soft-annealing cycles and 3 hard-annealing cycles

in-situ annealing significantly extends SiPM lifetime

up to 300 fb^{-1} without need of touching/replacing SiPM
working on optimisation of annealing protocol, maybe one could reach beyond that

model input from R&D measurements (up to 2022)

- DCR increase: 500 kHz/10^9 n_{eq}
- residual DCR (online annealing): 50 kHz/10^9 n_{eq}
- residual DCR (oven annealing): 15 kHz/10^9 n_{eq}

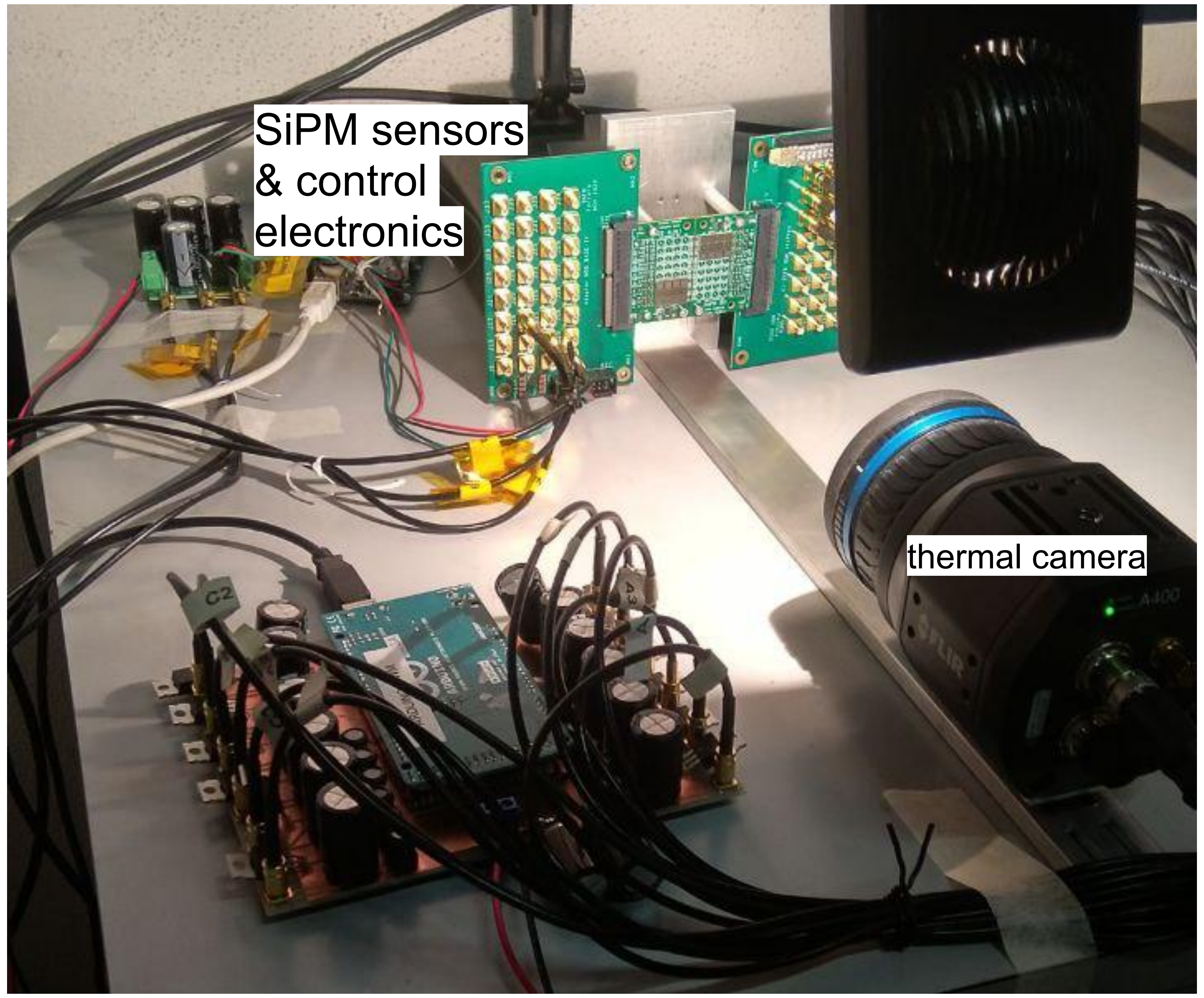
1-MeV neq fluence from background group

- 1.75 10^7 n_{eq} / fb^{-1}
- add an extra 2x safety factor

these predictions are according to present knowledge / tested solutions
there are more handles to further mitigate DCR
lower Vover, 3V
lover T operation -40 C or below

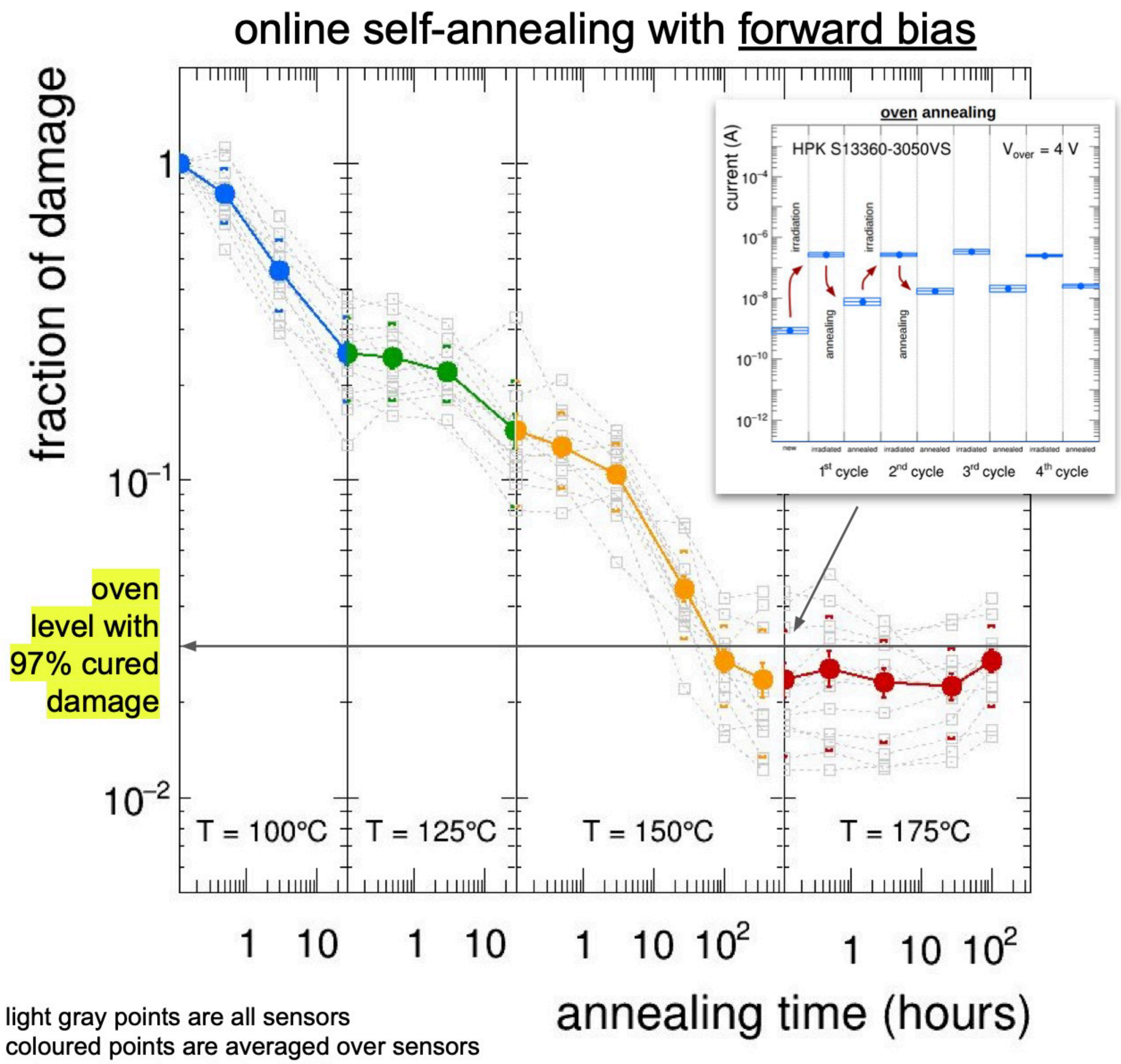
SiPM Self-Annealing

System for online self-annealing with temperature monitor and control of each individual SiPM



SiPM Self-Annealing

Roberto Preghenella

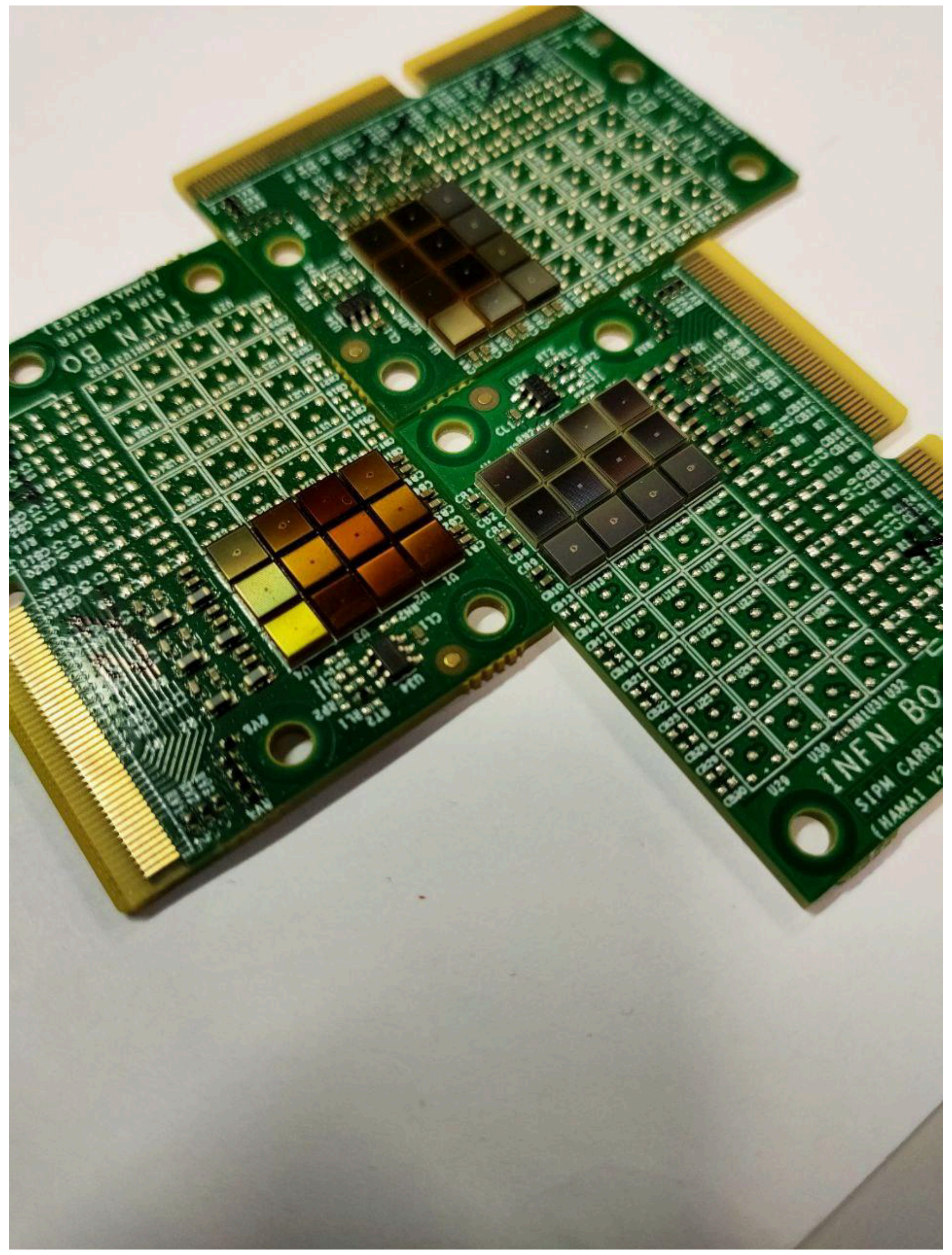


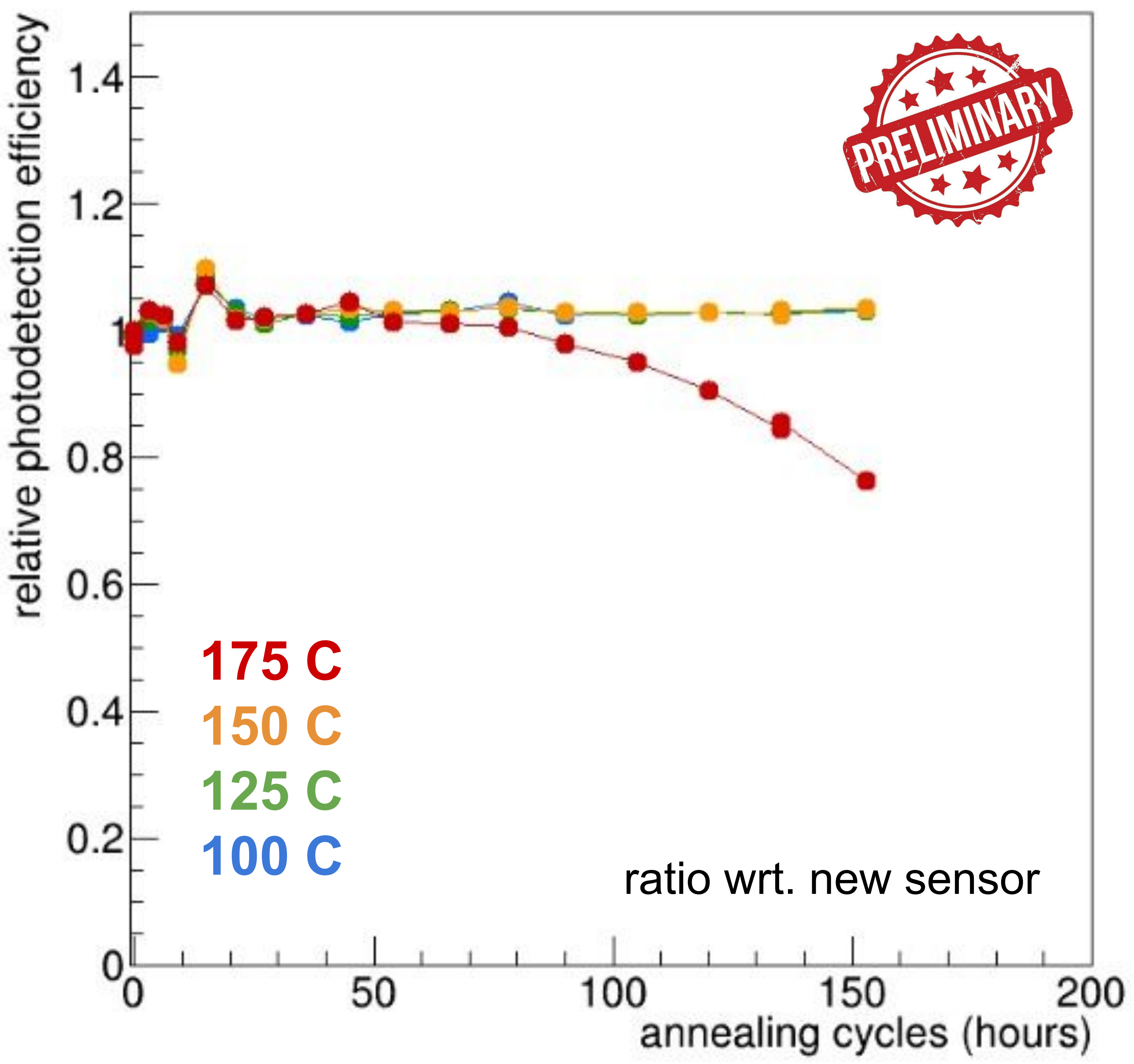
light gray points are all sensors
coloured points are averaged over sensors
coloured brackets is the RMS

- Test on how much damage is cured as a function of temperature and time
  - the same sensors have undergone self-annealing increasing temperature steps increasing integrated time steps
  - started with T = 100 C annealing
    - performed 4 steps up to 30 hours integrated
  - followed by T = 125, 150 and 175 C
- Fraction of residual damage seems to saturate at 2-3%
  - after ~ 300 hours at T = 150 C
  - continuing at higher T = 175 C seems not to cure more than that

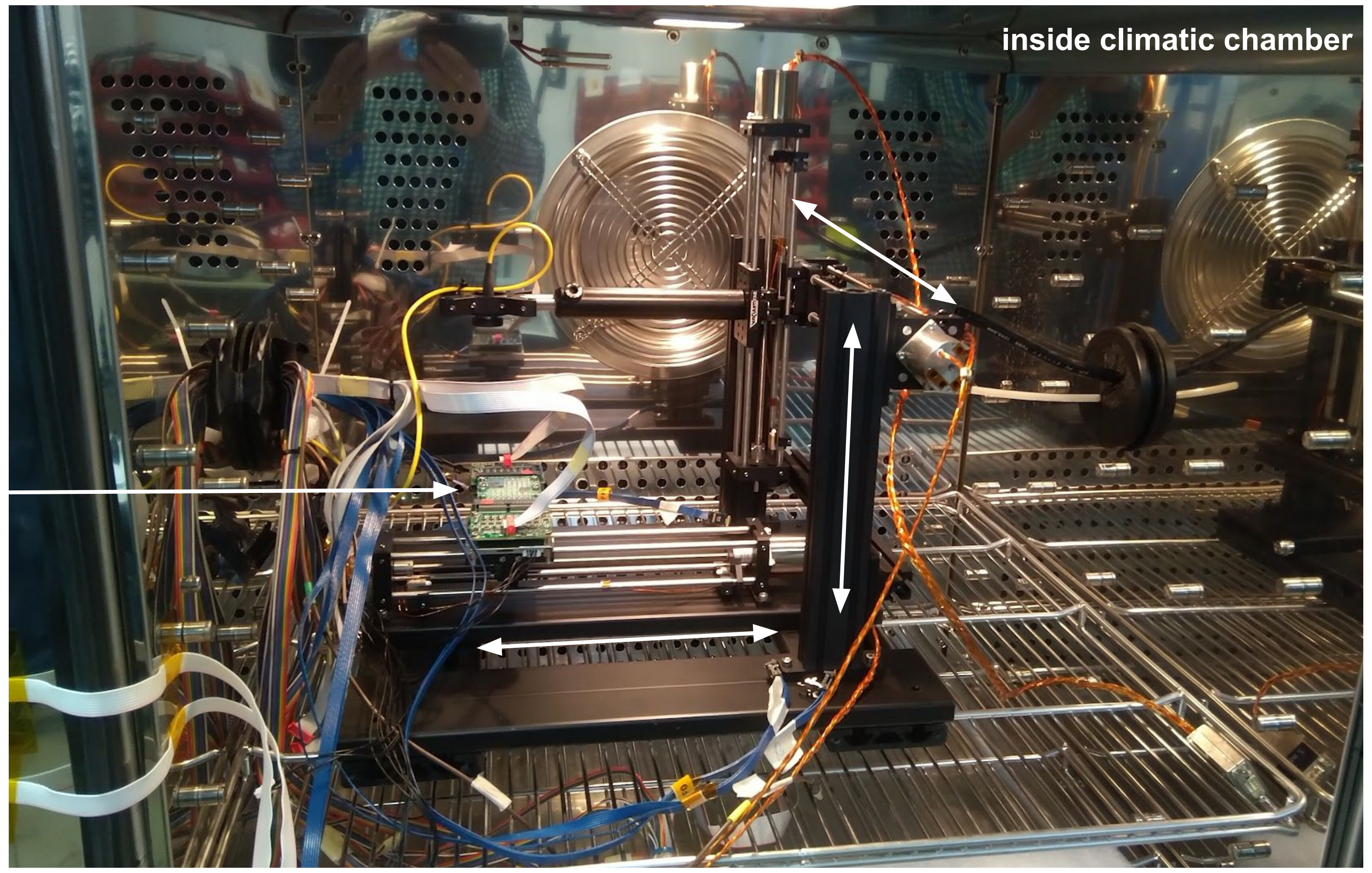
Studies of SiPM Online Self-Annealing

Roberto Preghenella





Interesting fact: annealing in oven shows different behavior

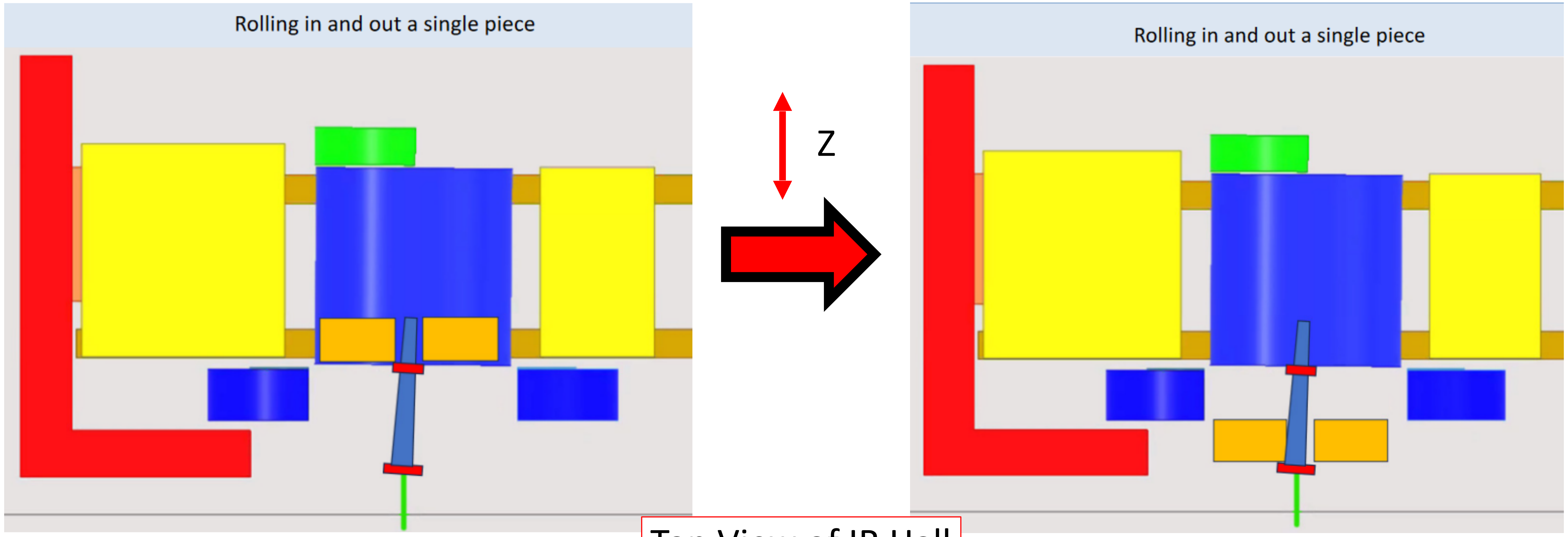


- After many hours of online annealing alterations on the SiPM windows noticed in particular in one board that underwent 500 hours of online annealing at T = 175˚ C
  - the sensors appear "yellowish" when compared to new
- Detailed studies are ongoing, preliminary results indicate efficiency loss after 100 hours of annealing at T = 175˚C. Lower temperatures unaffected up to 150 hours

dRICH Removal Considerations

Alex Eslinger

- The goal is to allow for periodic maintenance to the inner detectors in the IR without breaking the beam pipe vacuum or rolling out the barrel.
- Two scenarios are being investigated:
  - Keep the dRICH as one-piece
    - Move the dRICH back as far as practical (to the gate valve location)
    - Perform maintenance inside the barrel and on the primary dRICH electronics

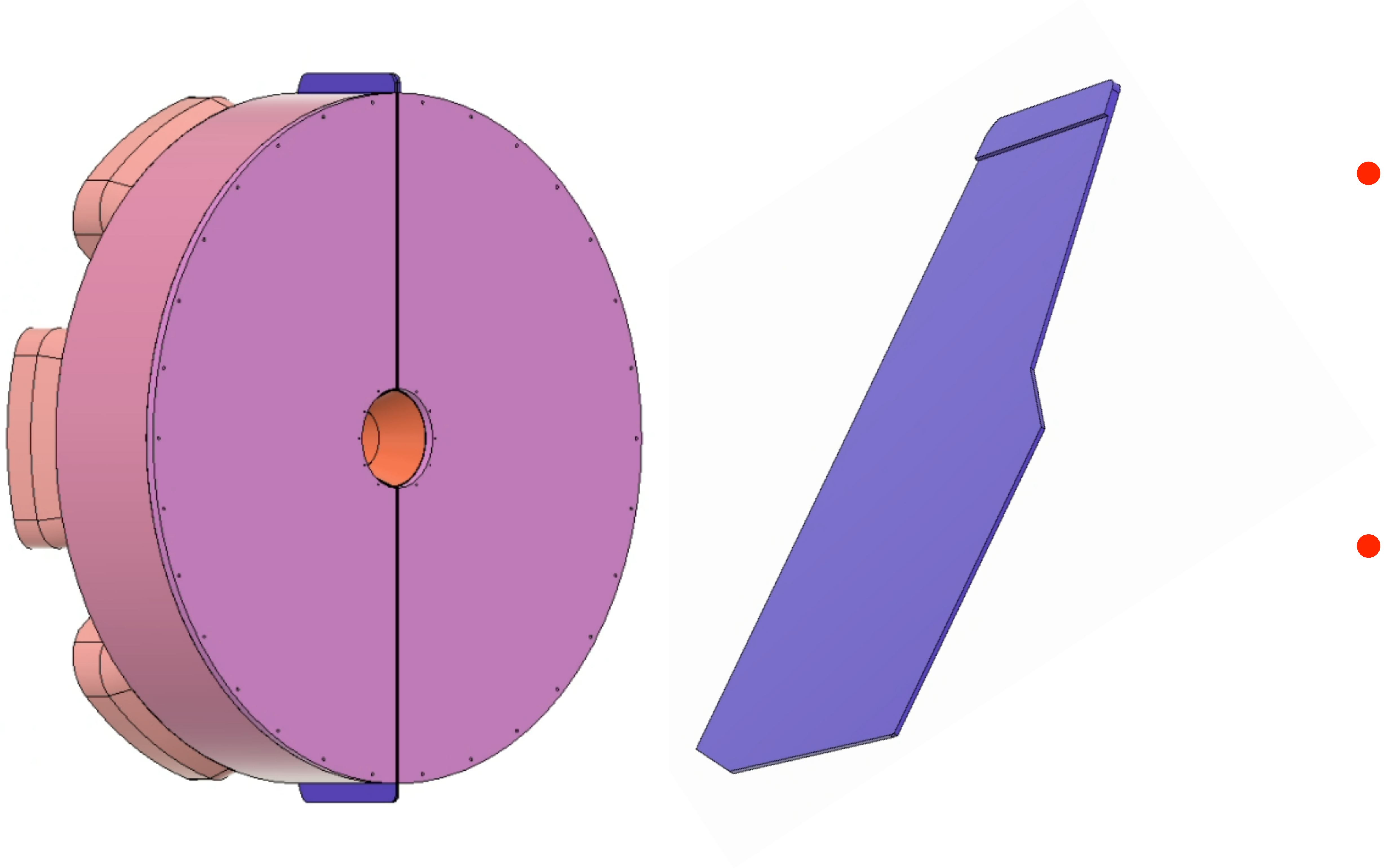


Top View of IR Hall

dRICH Removal Considerations

Alex Eslinger

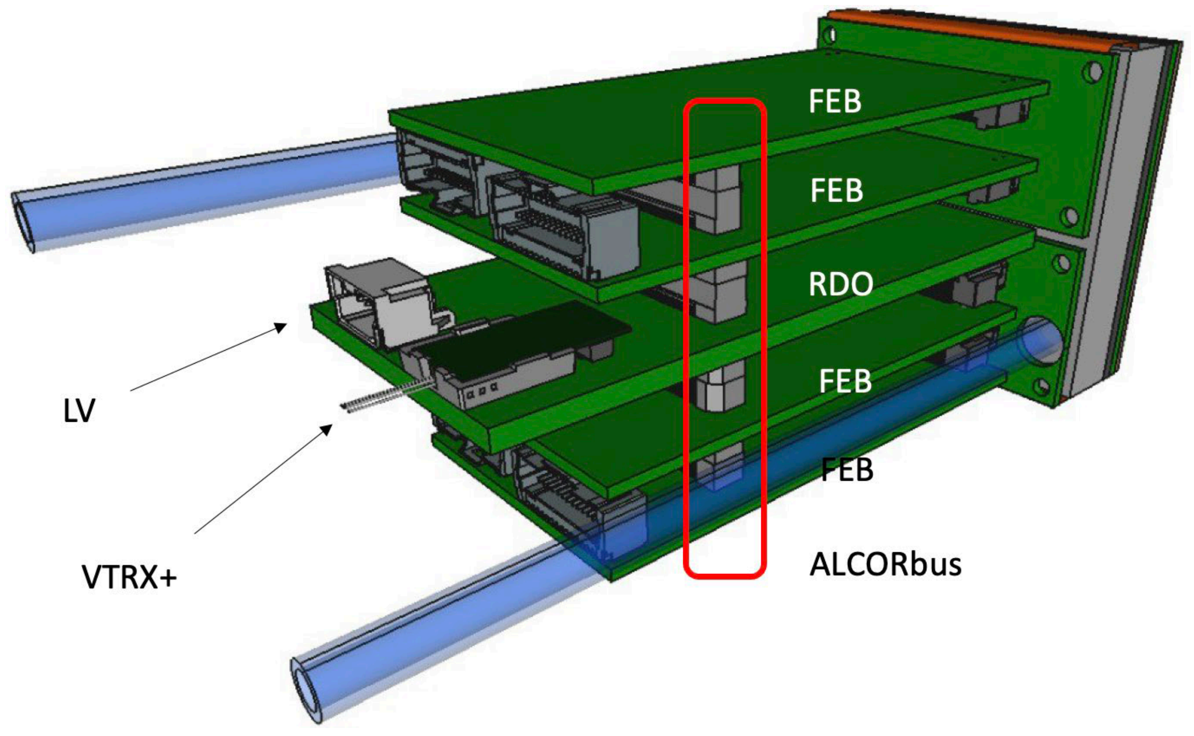
- Split the dRICH in two halves (vertically)
  - Modify the beam pipe design so that the flange is placed in front of the dRICH instead of directly behind.
  - Move the dRICH just outside of the barrel and clear the existing services
  - Split the dRICH apart and pull one or both halves out of the way
  - Perform maintenance inside the barrel and on the primary dRICH electronics

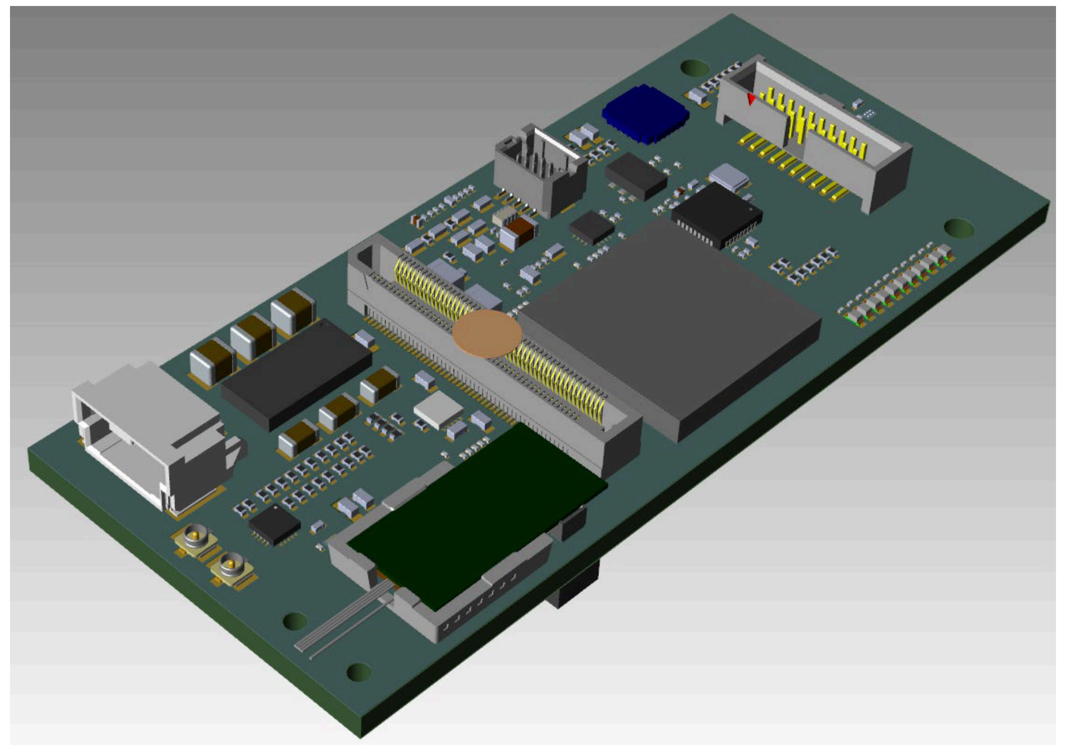


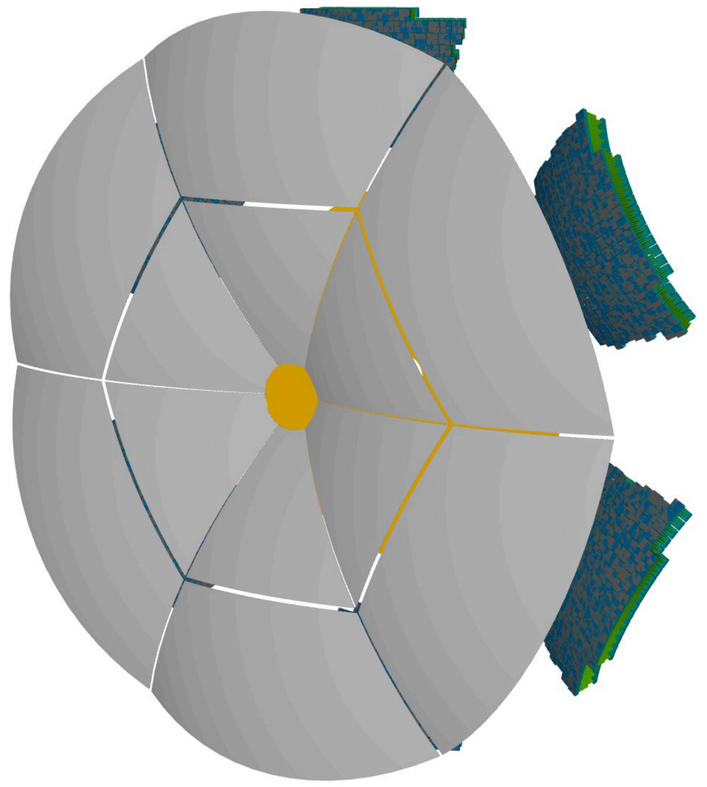
- Moving the flange to the front of the dRICH allows for the smallest bore overall. However, the dRICH will need a dividing wall for the split which may negate some of the advantages from the smaller bore.
- The CAD models for both bore options have been distributed to be used as simulation inputs to determine the best option.

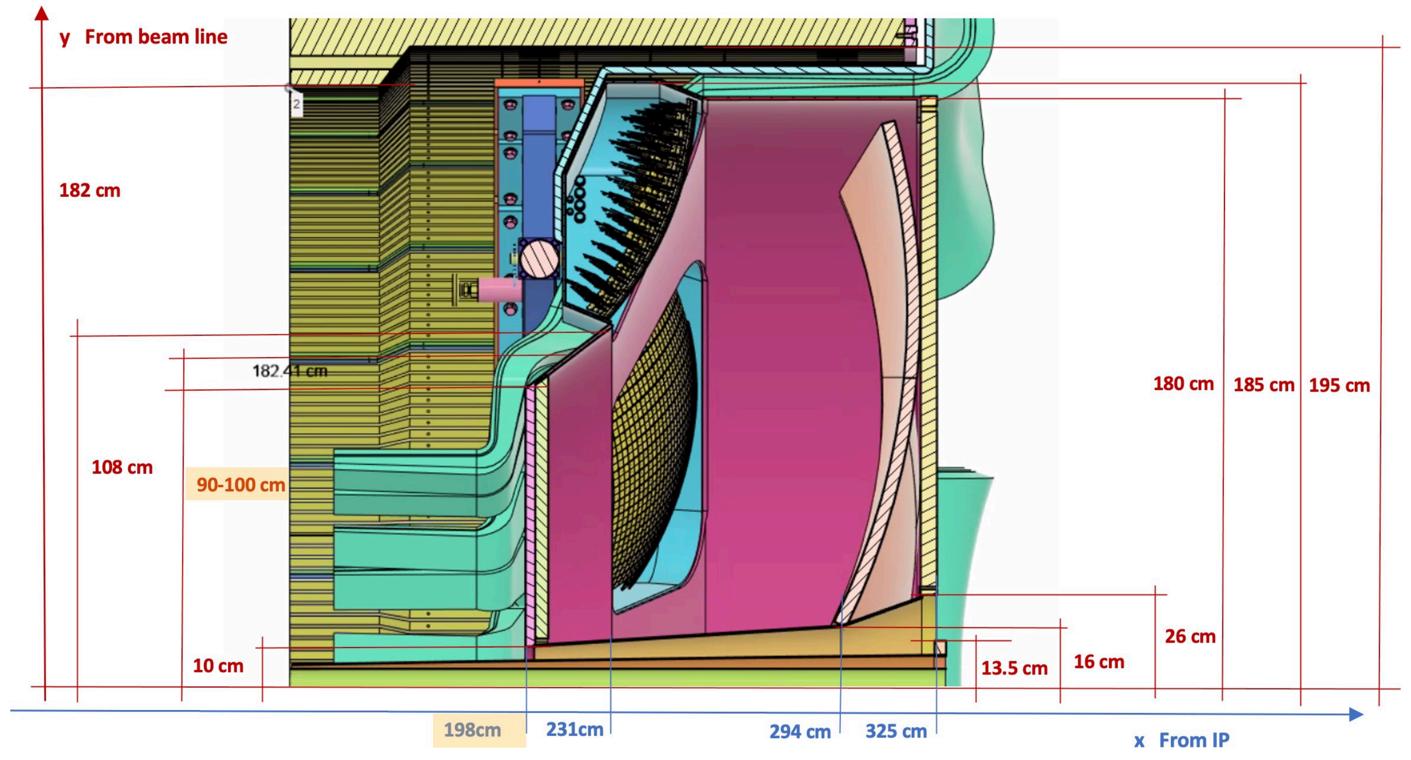
dRICH: Status on RDO and Optics

Davide Falchieri & Connor Pecar









Schematic design of dRICH RDO is almost finished

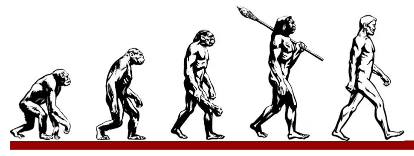
- now performing the final checks and cross-checking the most critical parts:
  - clock distribution
  - remote programmability
- the PCB layout is going to start soon
- first prototypes ready by the end of 2024
- working on the firmware in the meanwhile

dRICH optics optimization

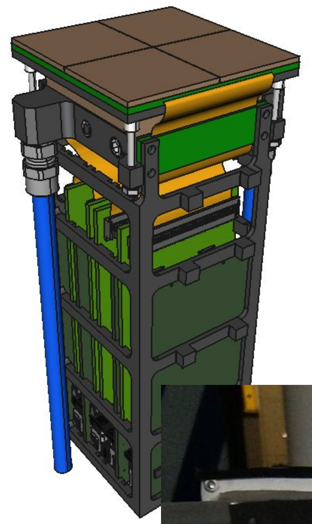
- Multi-objective Bayesian optimization framework in place and tested on single mirror design
- Updates to the IRT algorithm will allow for evaluation of a multi-mirror dRICH
- Work ongoing to optimize a two-mirror dRICH
  - First step towards fully optimizing tiling of dRICH mirrors

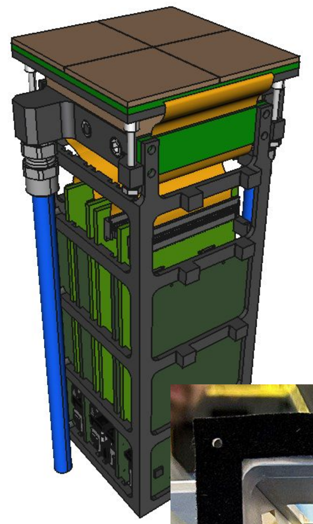
dRICH Evolution

Roberto Preghenella

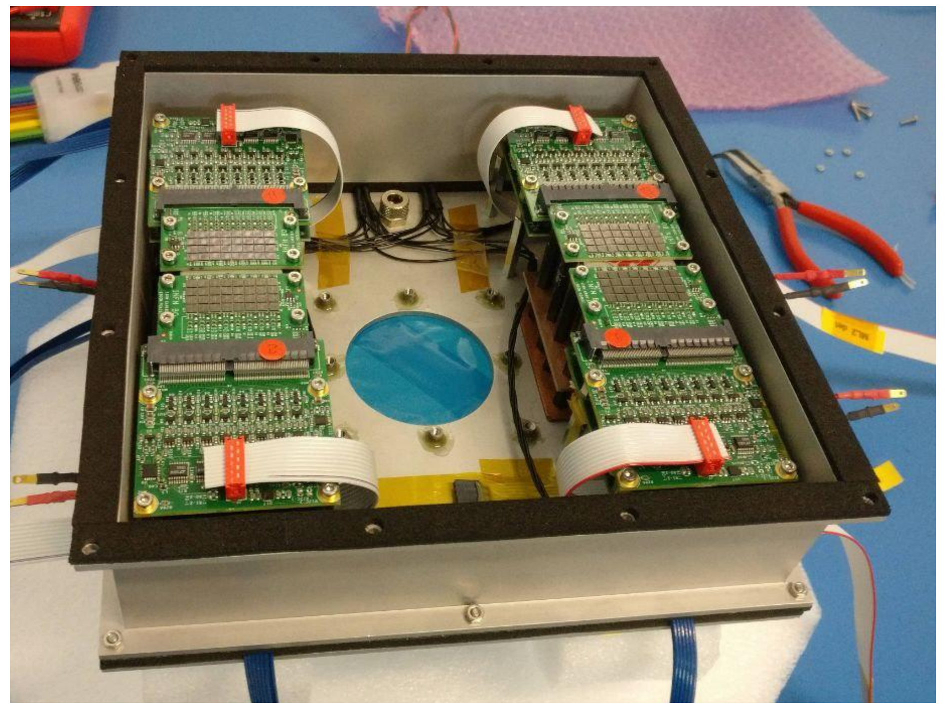


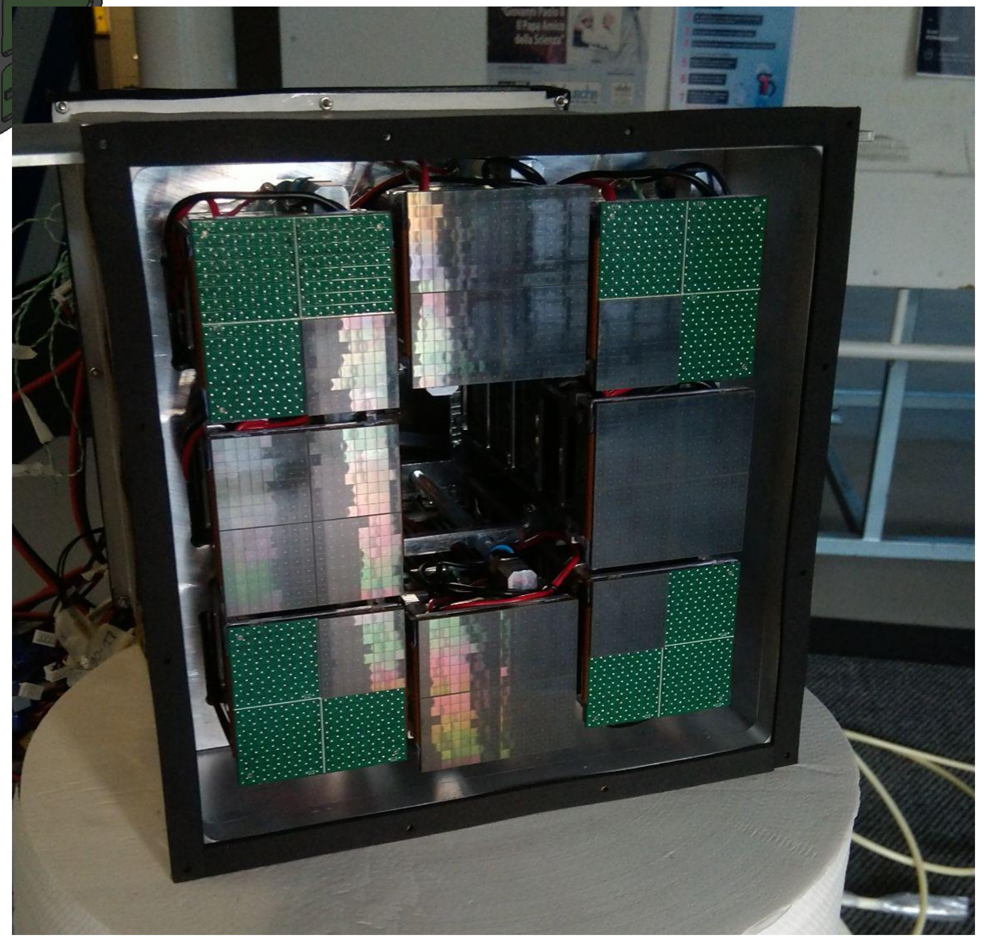
towards construction

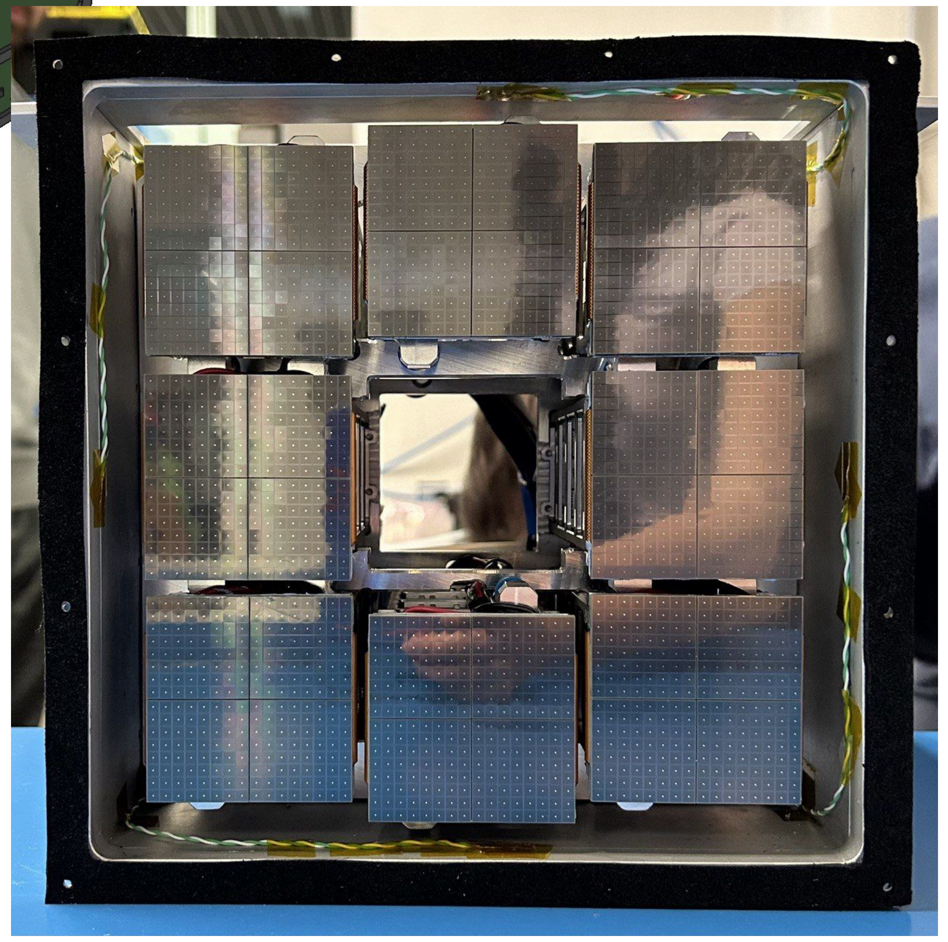


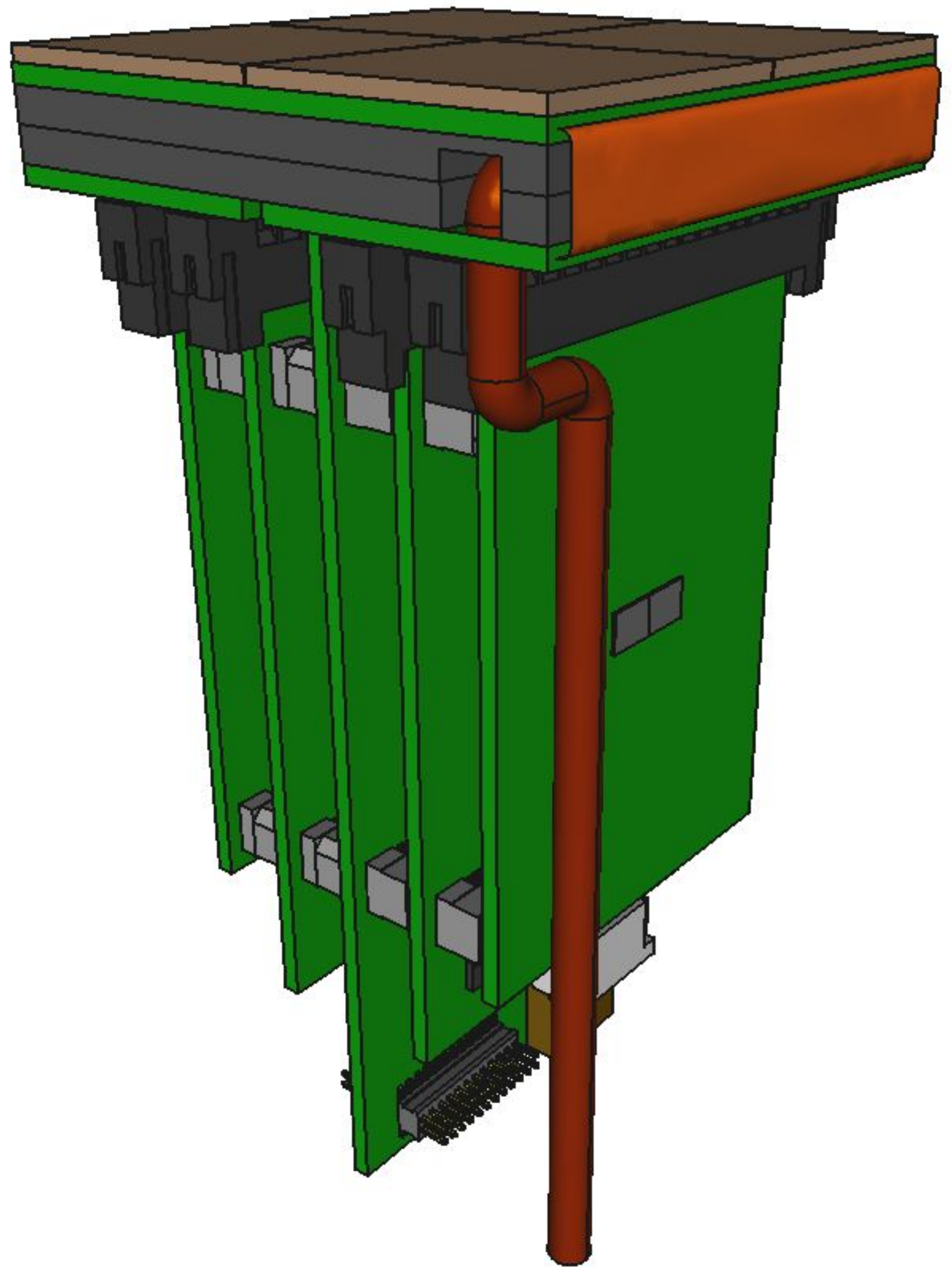


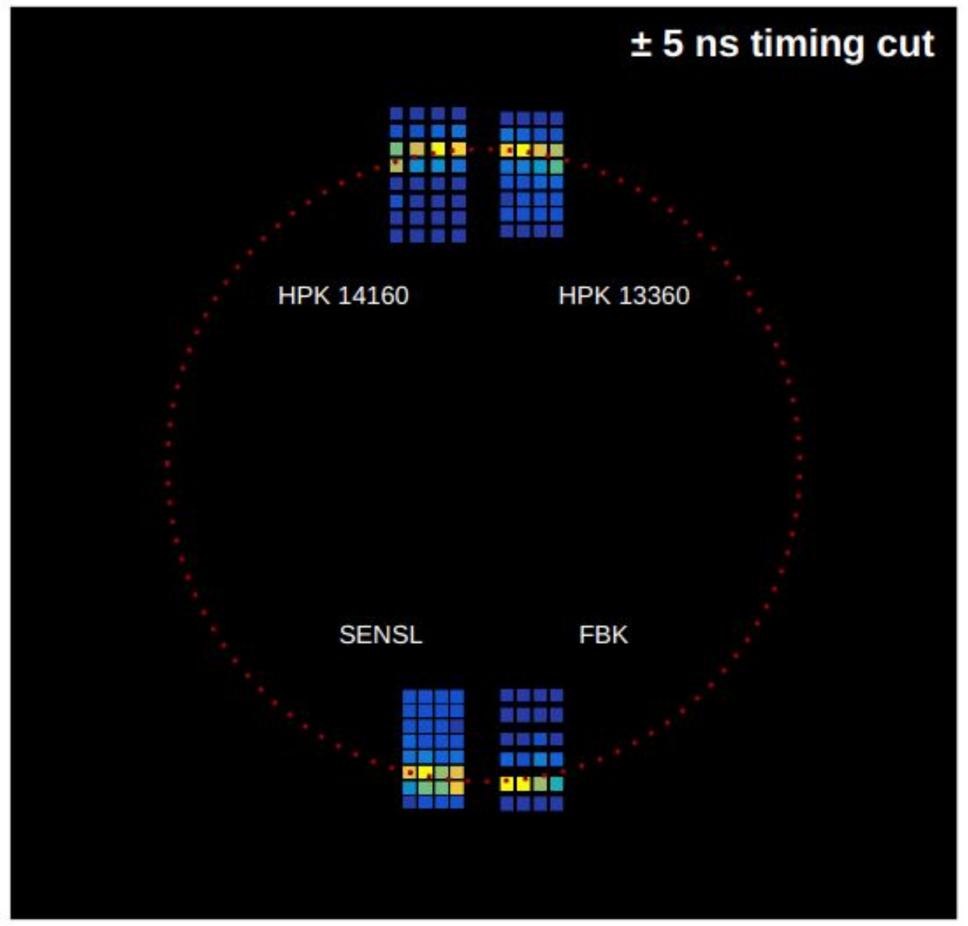
2022	2023	2024	2025
electronics v1	electronics v2	electronics v2.1	electronics v3 final prototype

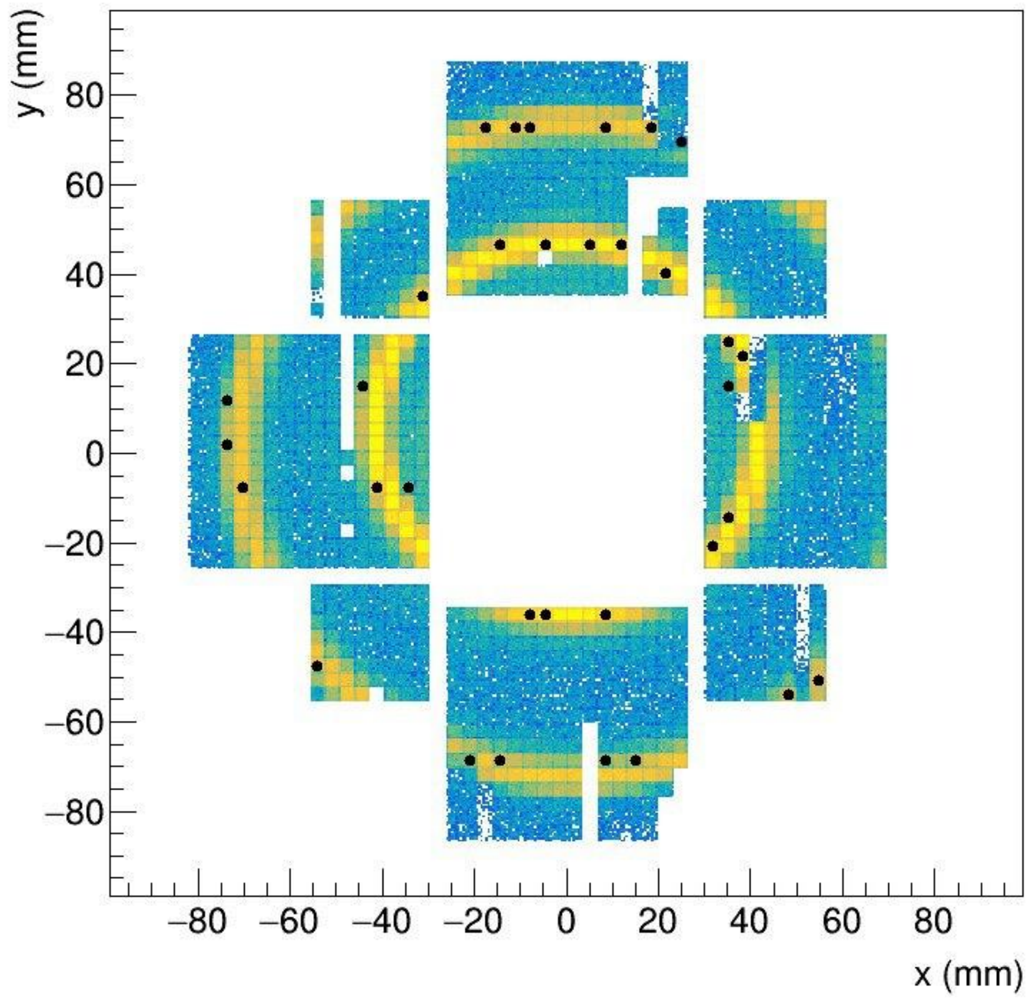


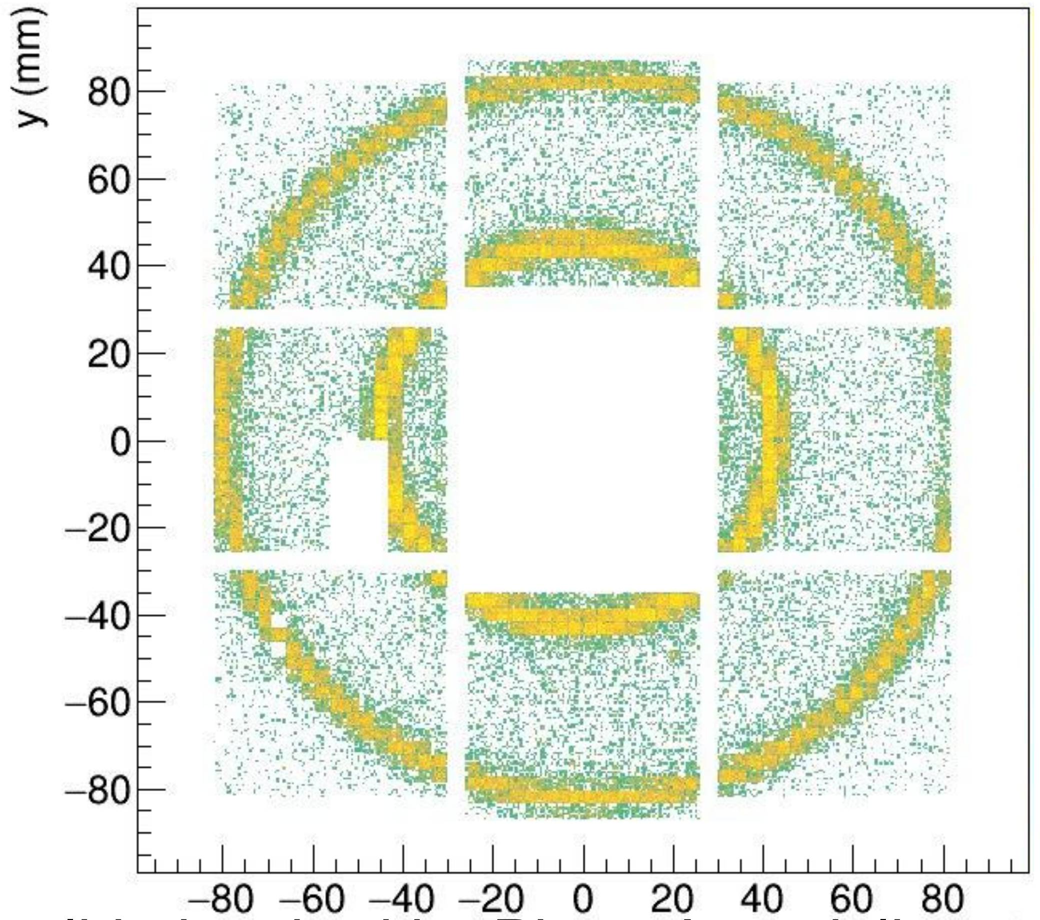










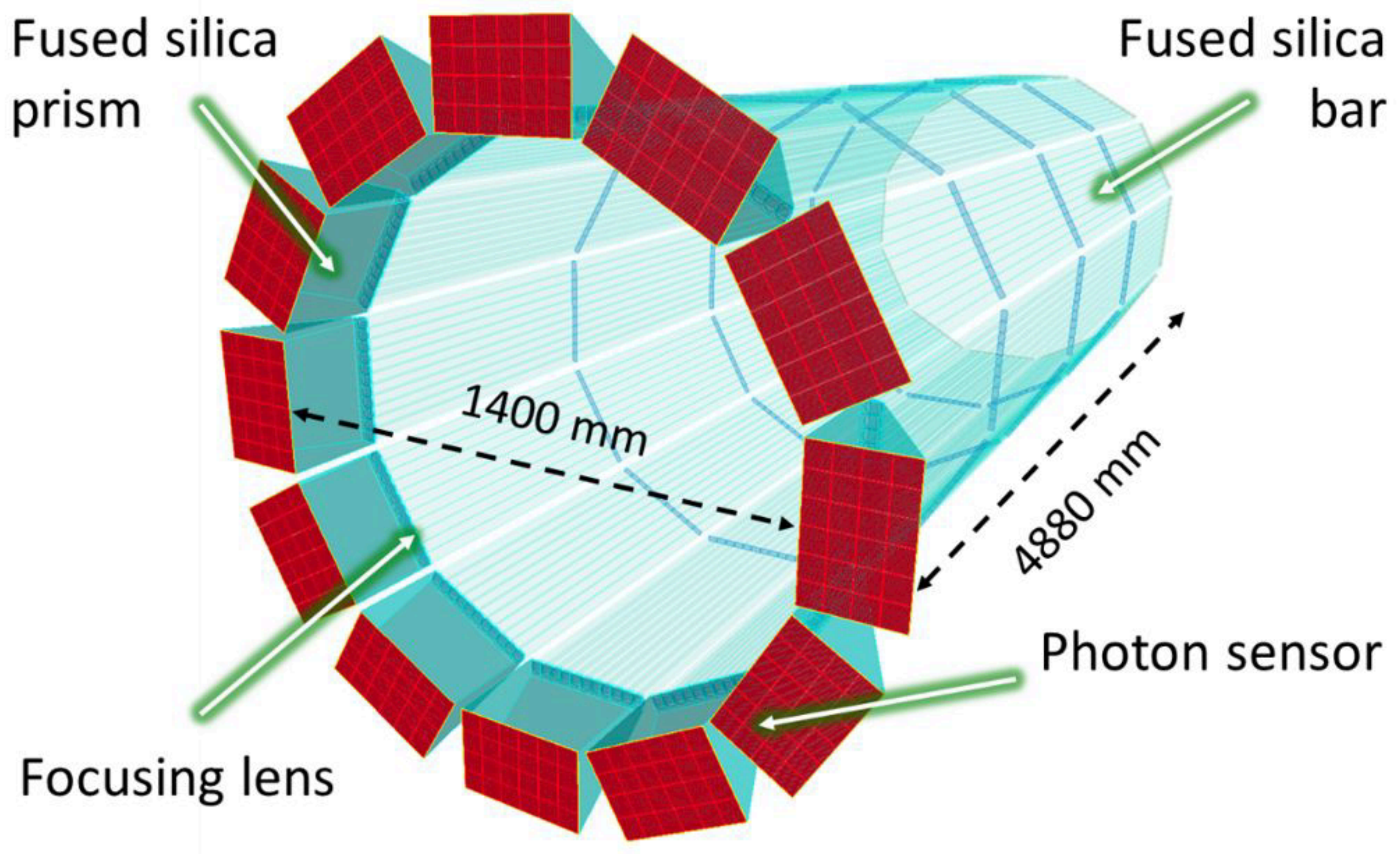


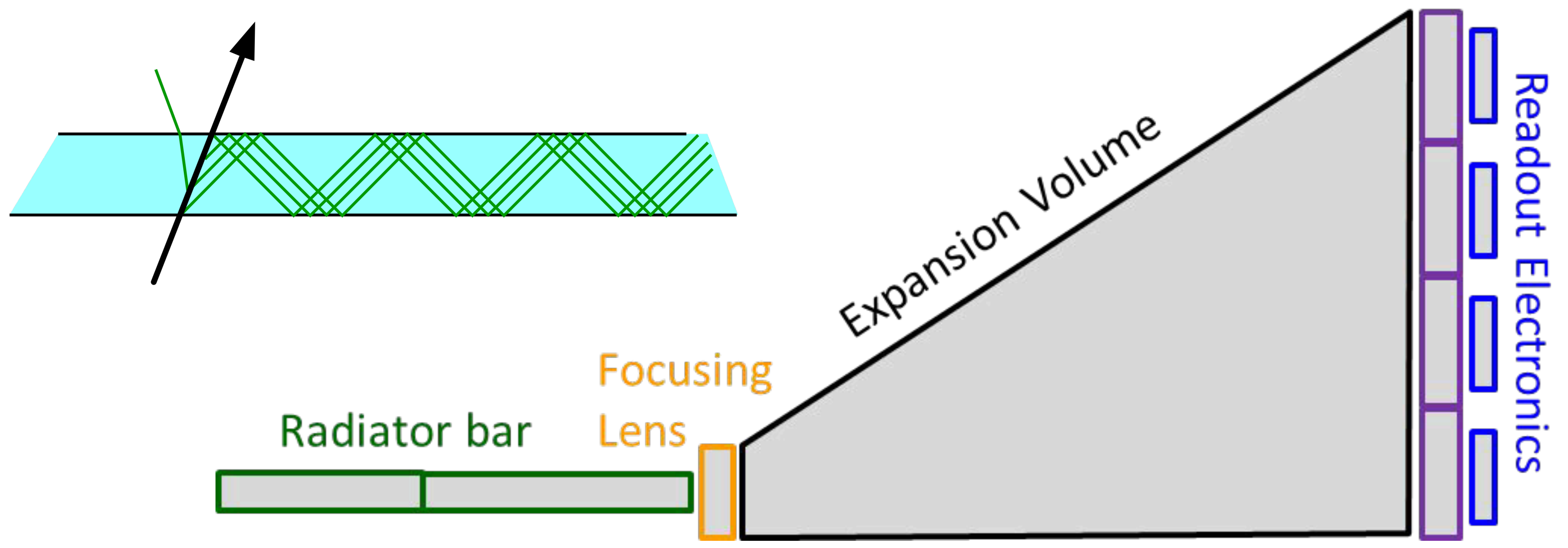
slide inspired by Pietro Antonioli

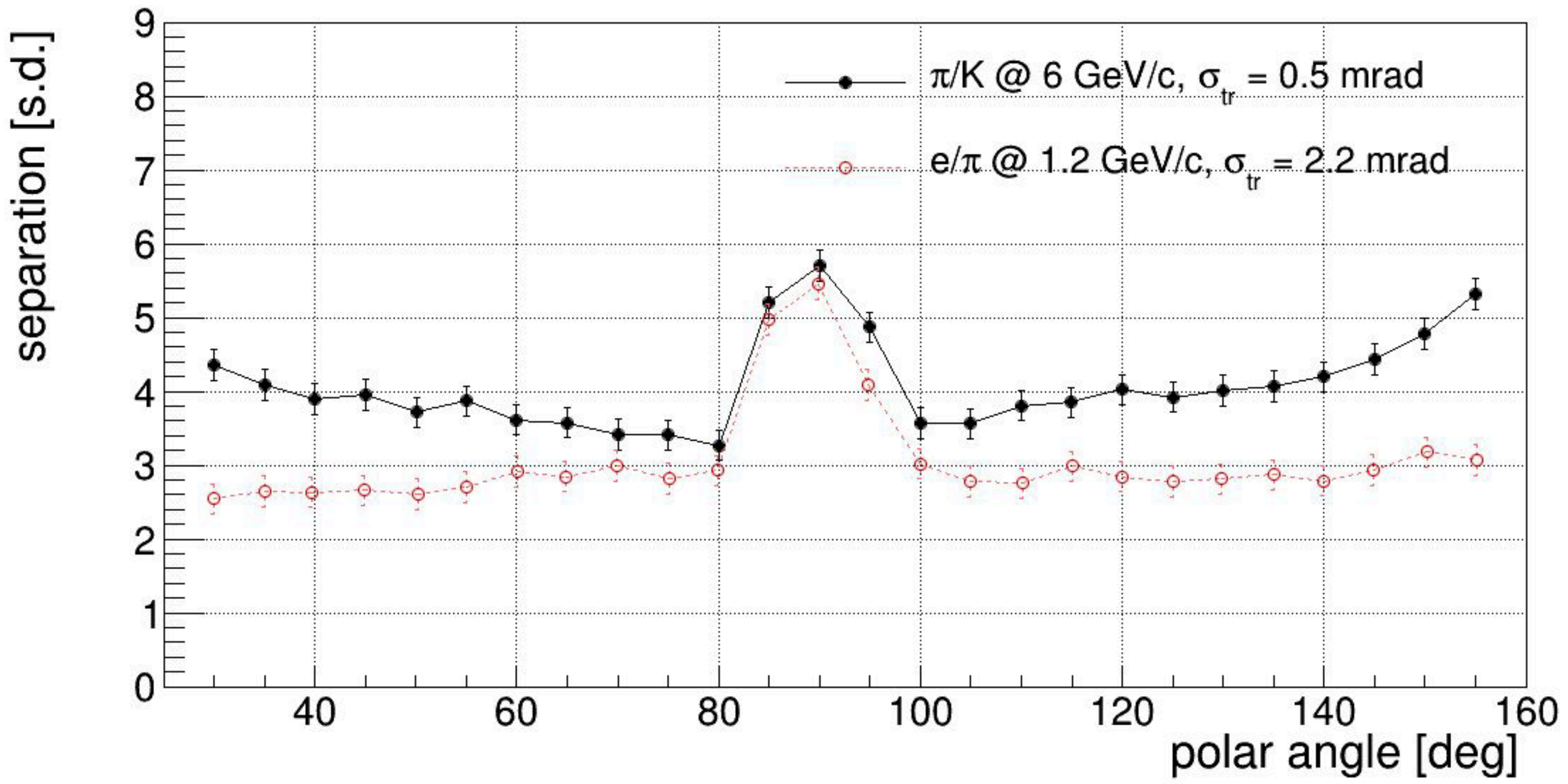
hp*DIRC*

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 is base for all hpDIRC simulation studies



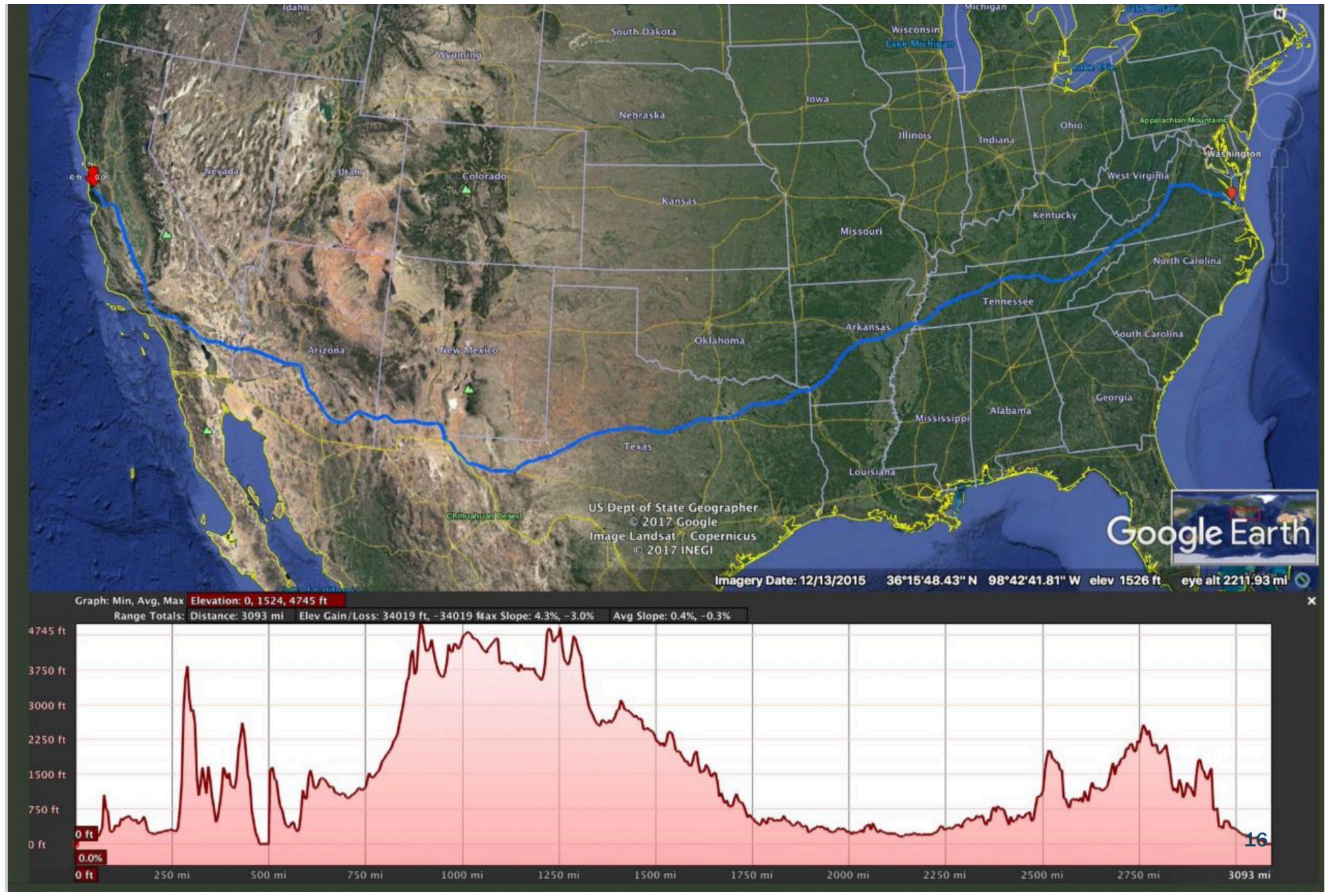


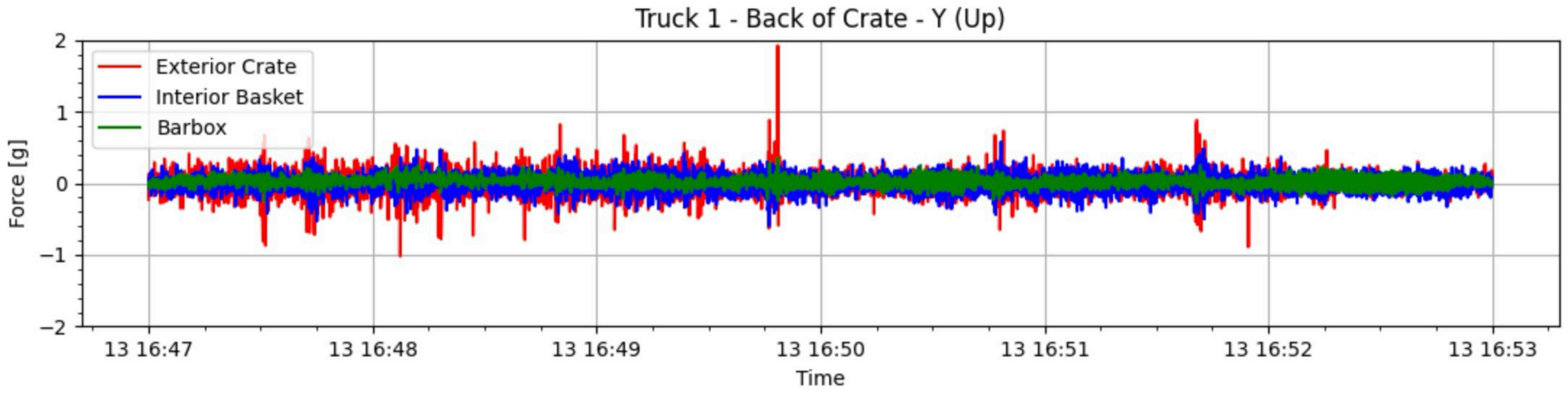


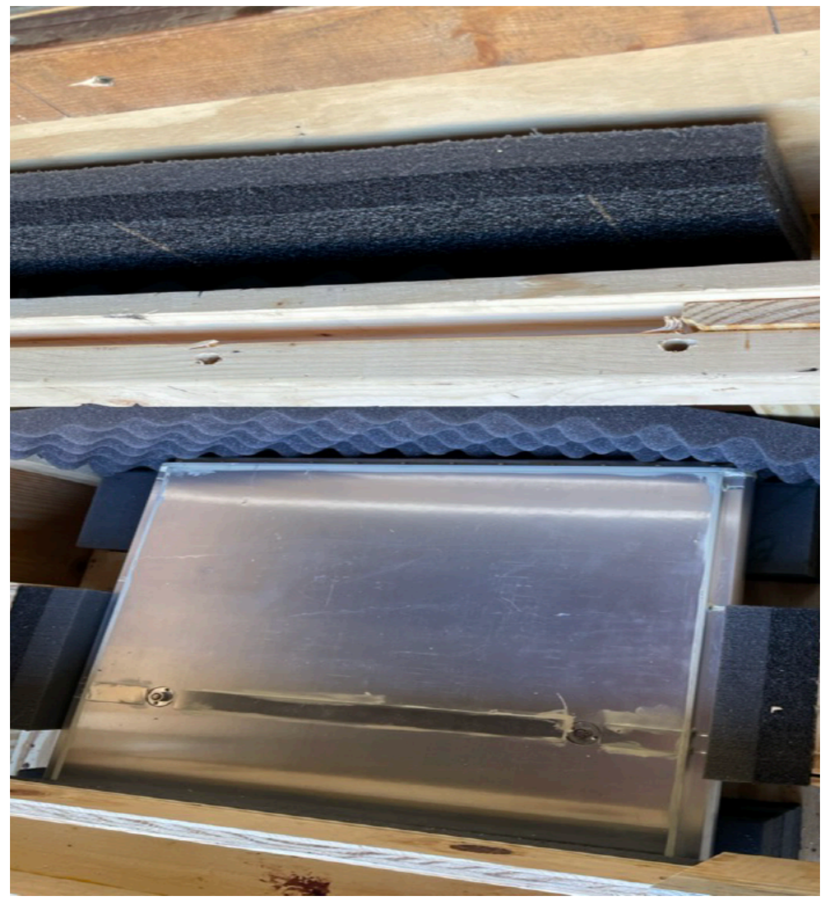
BaBar DIRC Bar Reuse

Greg Kalicy

- Successful transport of 8 DIRC bar boxes in April 2024
  - Low attitude road from SLAC, CA to JLab, VA
  - Shocks absorbing foam
  - Hydraulic shocks
  - Air shocks
  - Shock absorbing donuts
  - Air-ride, temperature control trucks
  - Goal: Keep shocks on Bar box below 1g





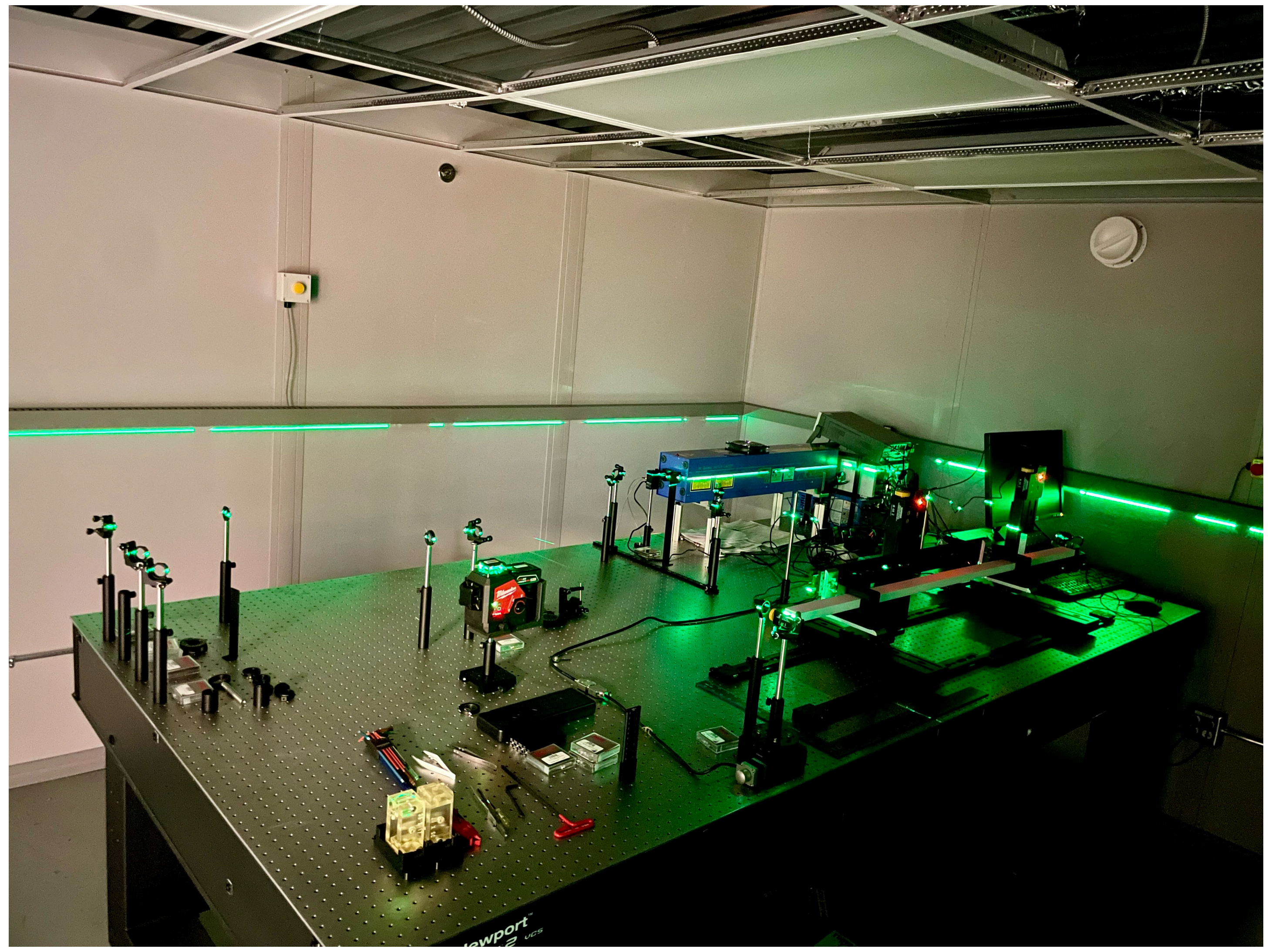


Validation of the BaBar DIRC Bars

Greg Kalicy

- Bar boxes will be disassembled into individual bars at JLab (starting in Fall)
  - Never done before
  - Aluminum covers will need to be ”opened”, glue joints between bars decoupled
- Optical quality of bars after disassembly will be evaluated in QA DIRC lab
- QA DIRC lab close to ready for commissioning
  - Reference DIRC bars from SLAC available for commissioning and as reference
- 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

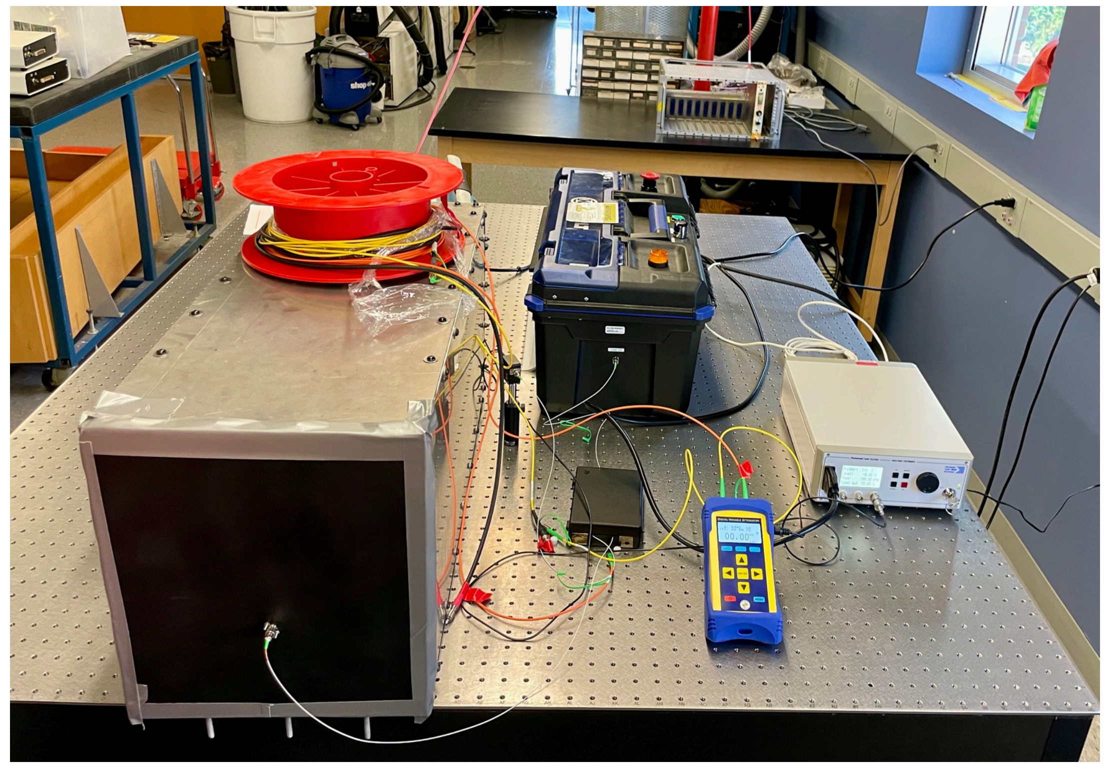
Cutting Into the Bar Box – 6 m long CNC



Cosmic Ray Telescope

Greg Kalicy

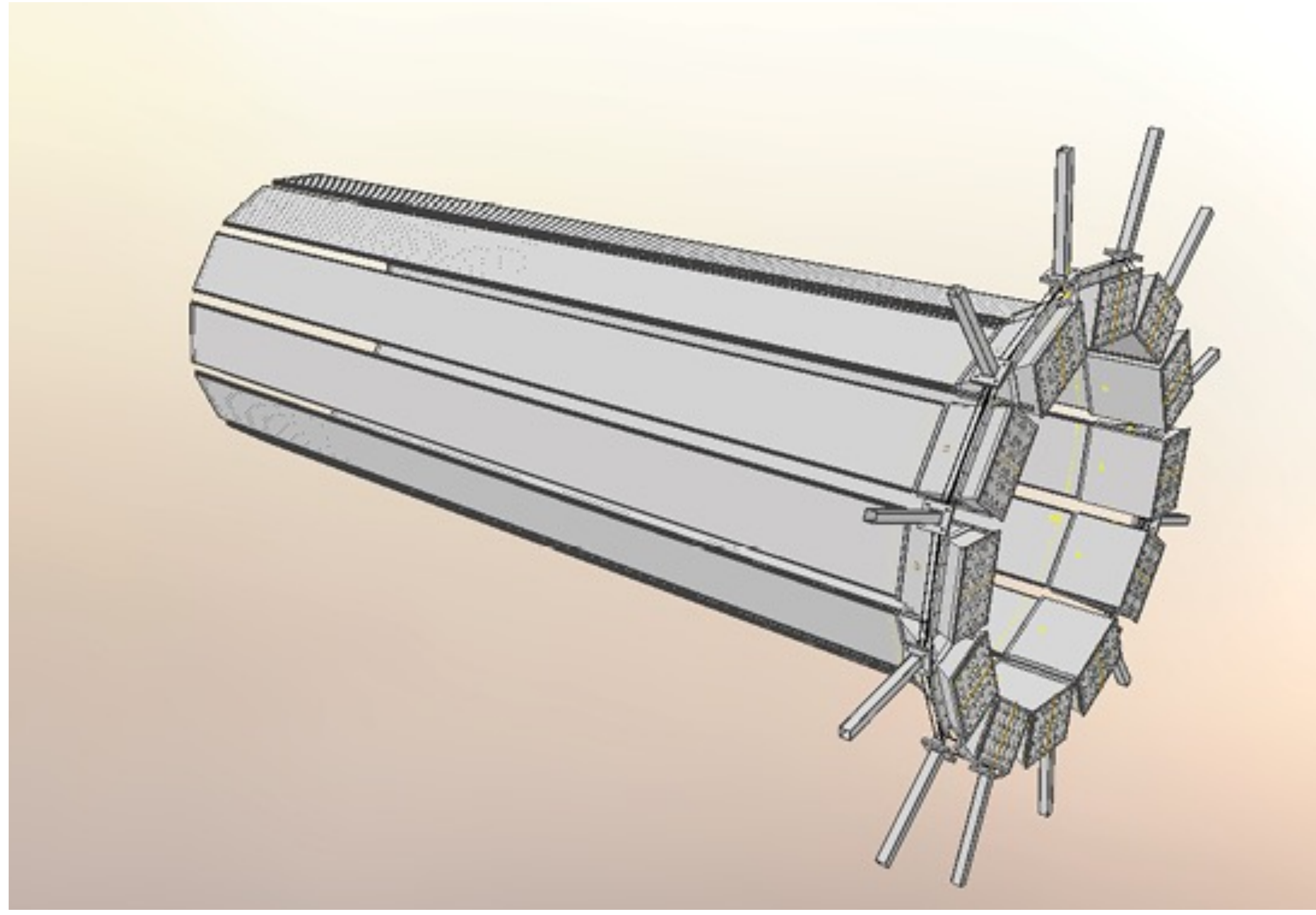
- Facility at SBU to test incremental upgrades of prototype components, performance evaluation, and QA of the assembled bar boxes
  - Initial PANDA Barrel DIRC-based prototype to commission setup
  - Modular design will allow to add new ePIC hpDIRC components once they become available
  - Cherenkov Tagger to select muons above 3.5 GeV/c
  - Three tracking stations for high-precision 3D-track reconstruction
  - PicoSec detector for event timing
  - Geant4 simulation used to optimize setup arrangement

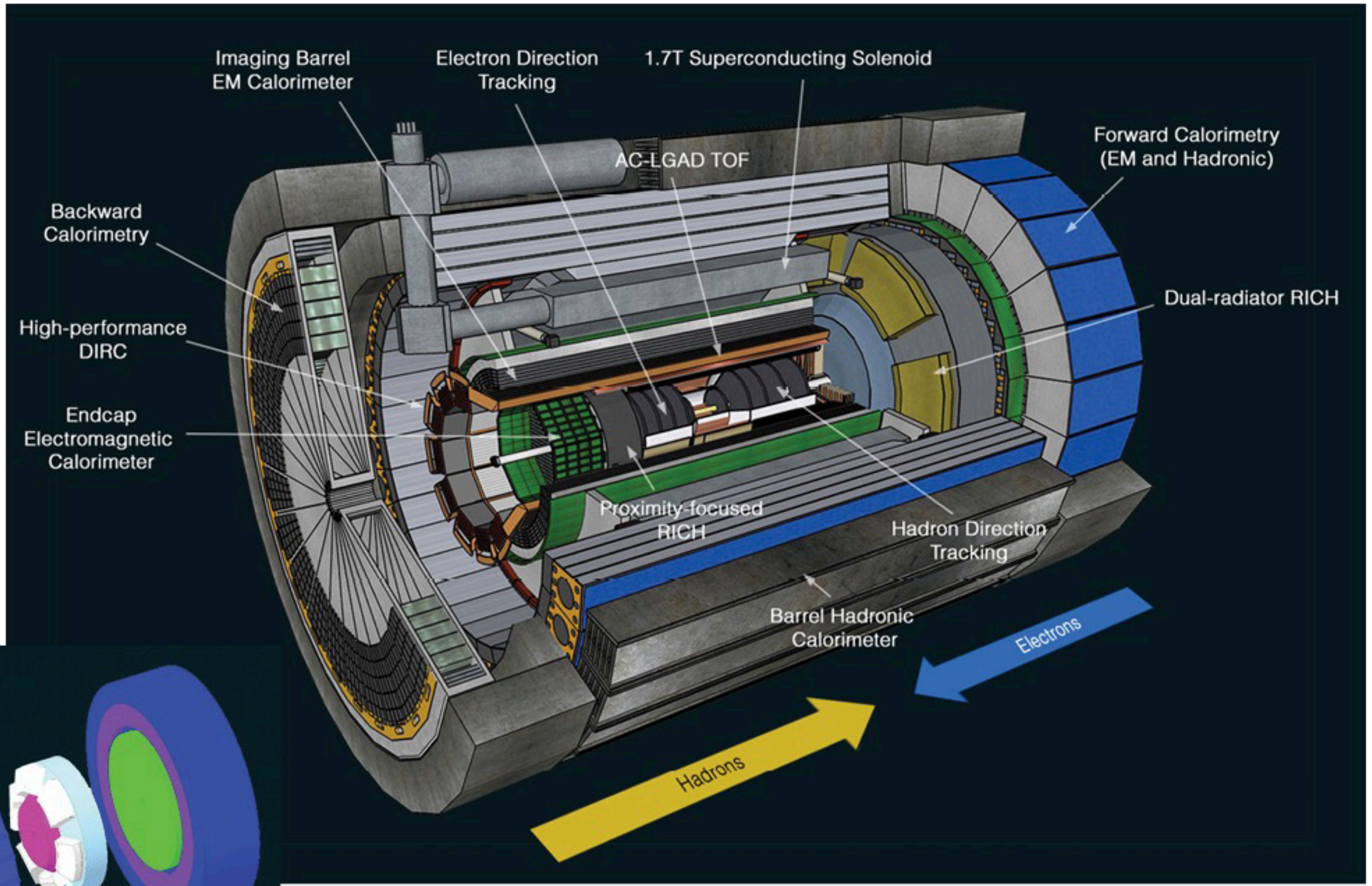


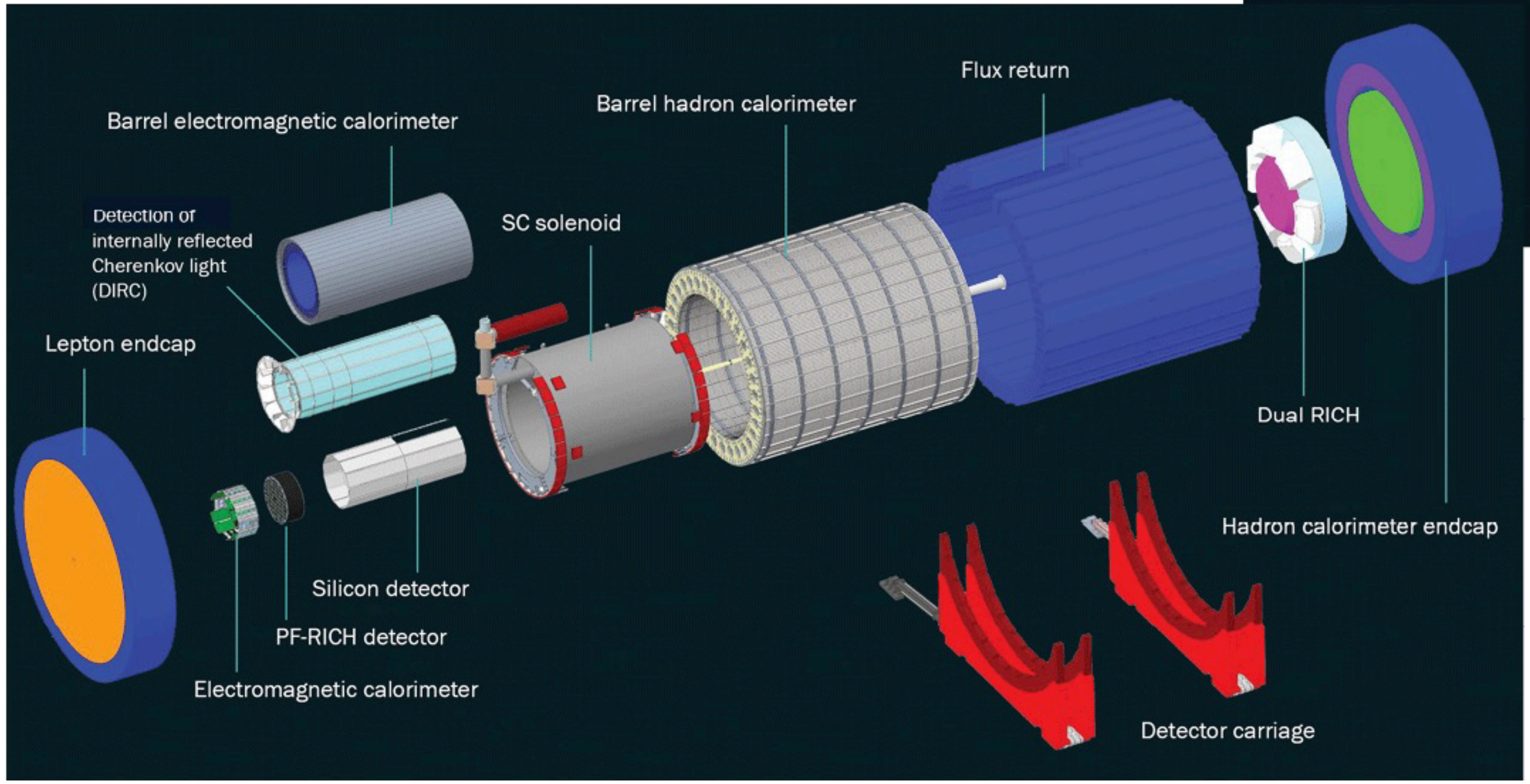
Cherenkov Tagger

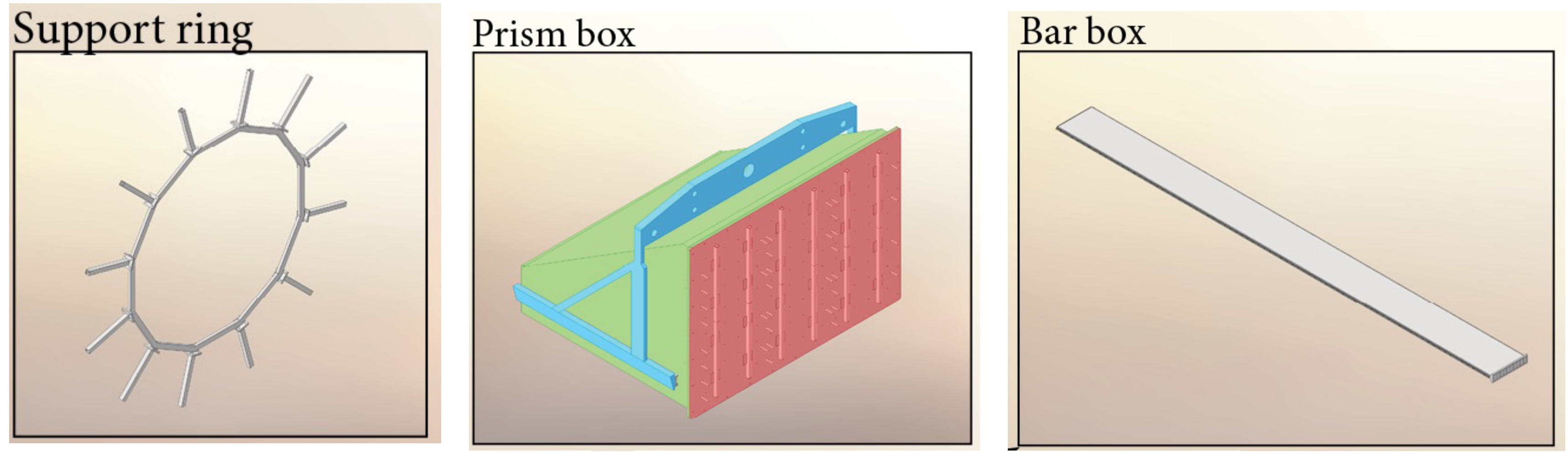
hpDIRC Integration

Greg Kalicy

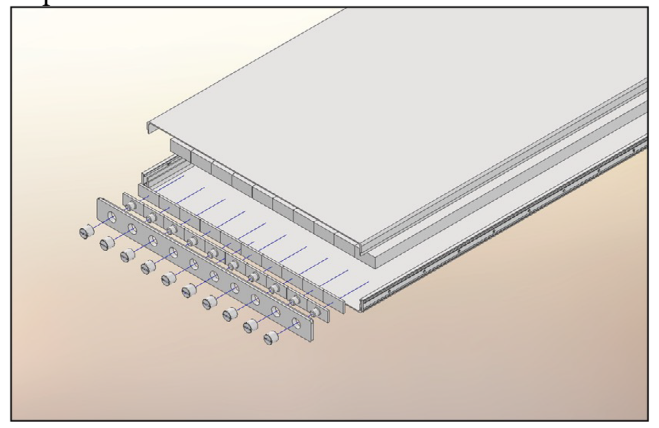




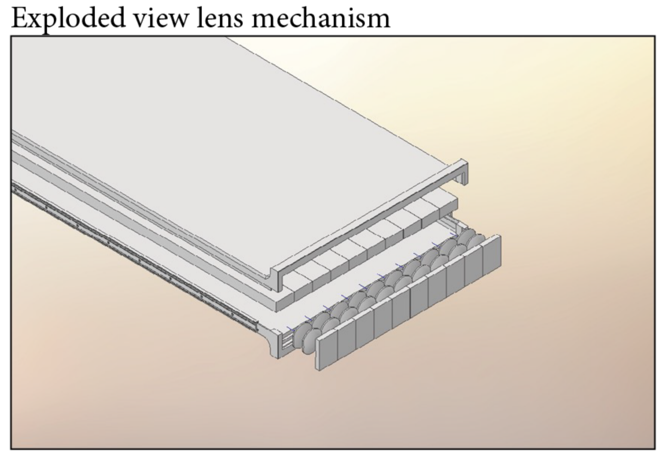


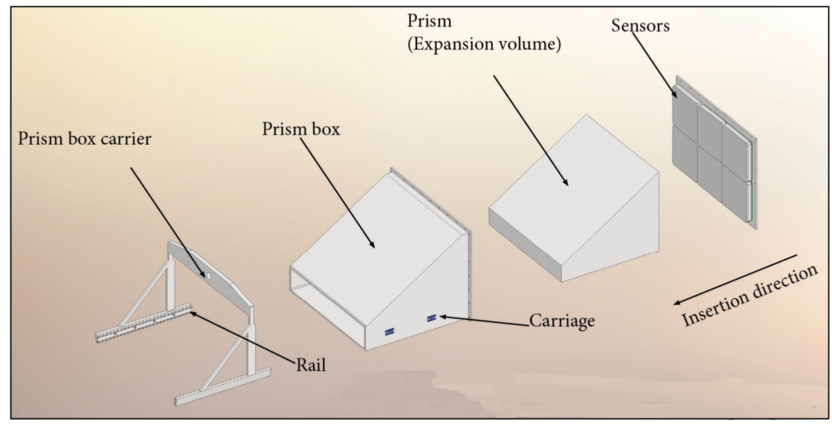


Exploded view mirror mechanism



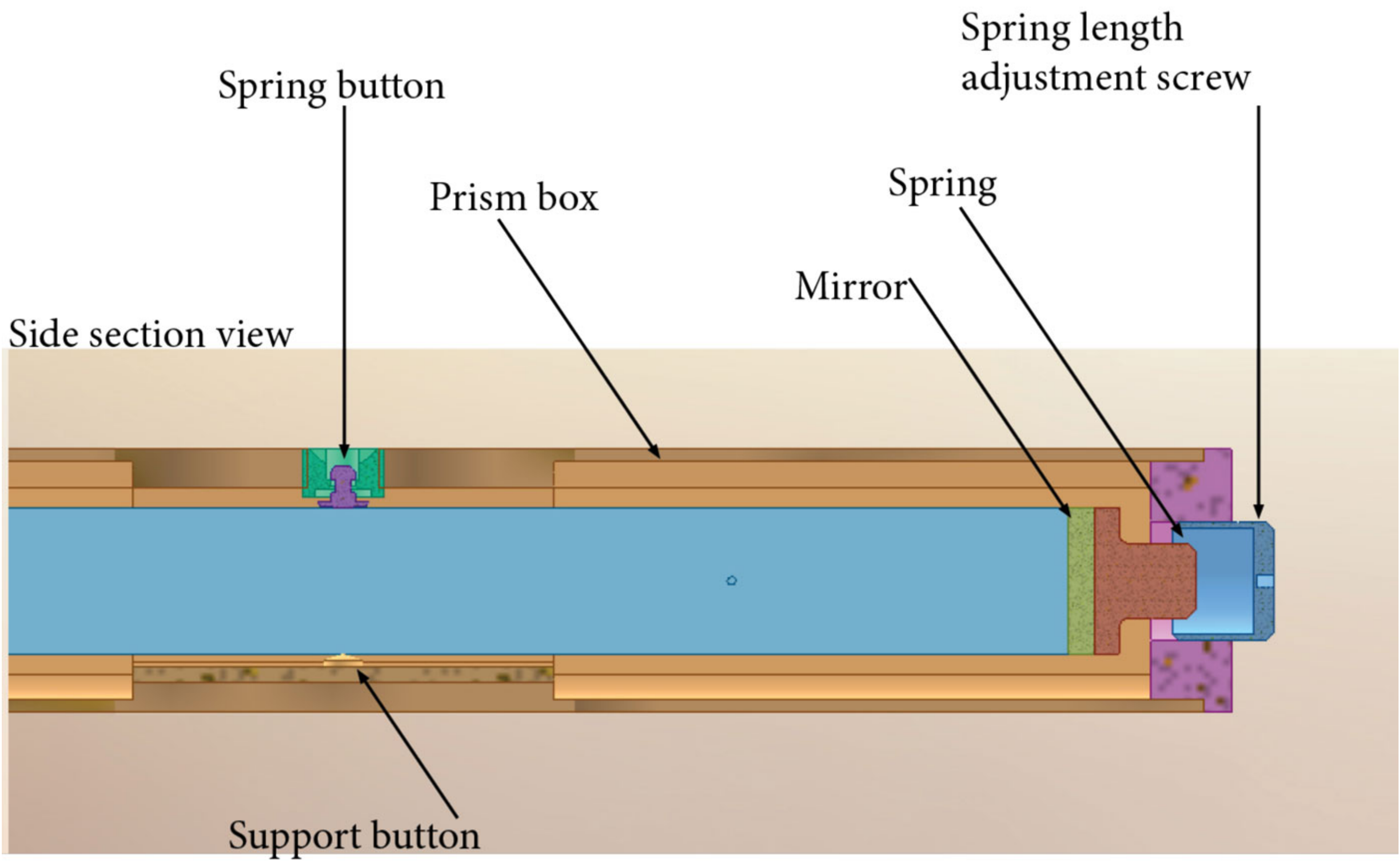
Exploded view lens mechanism

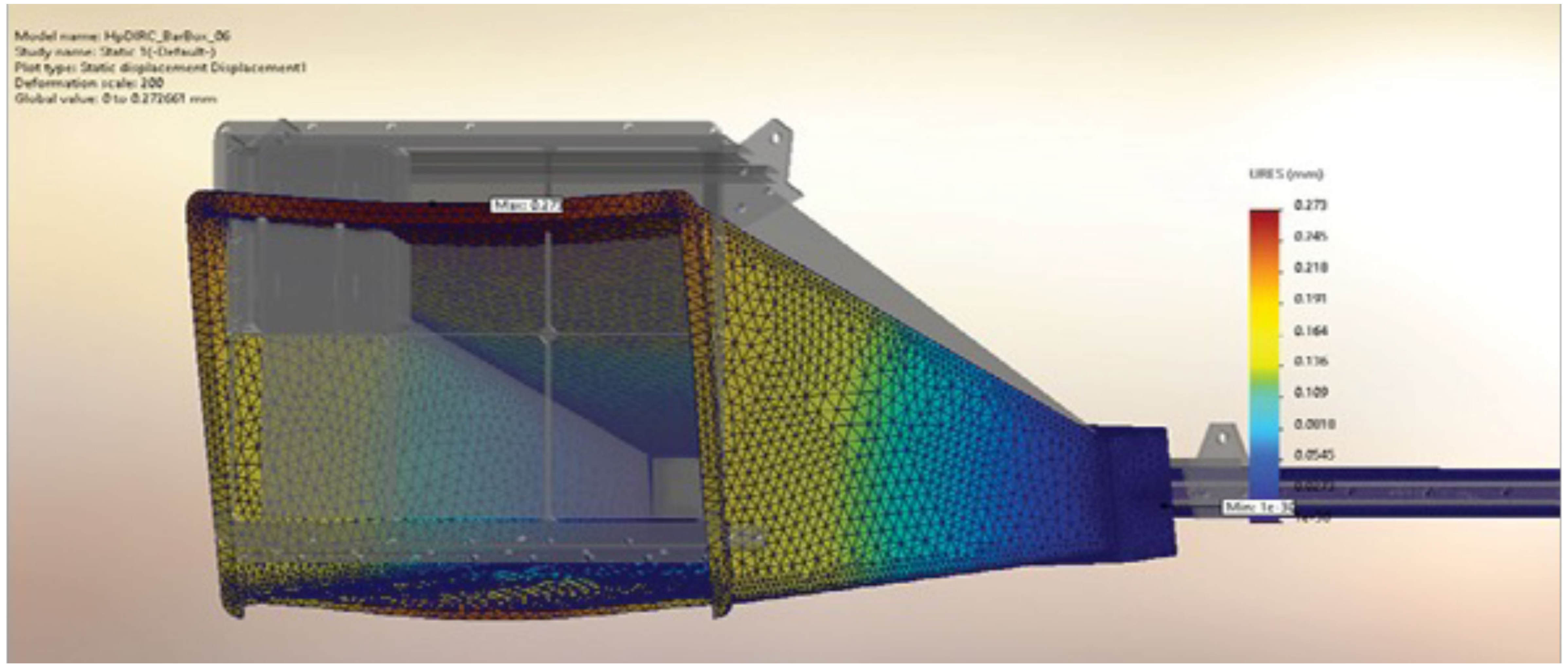




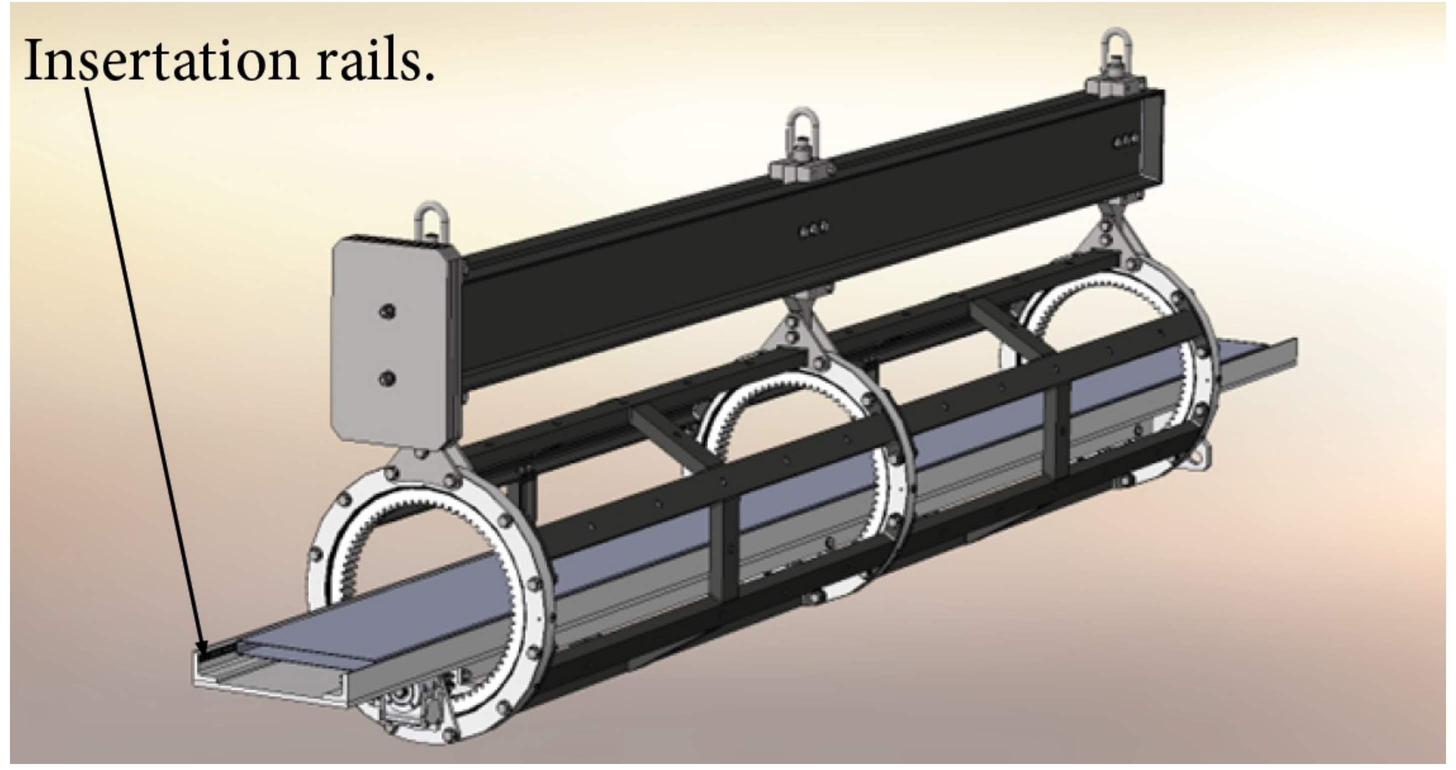
Details Matter

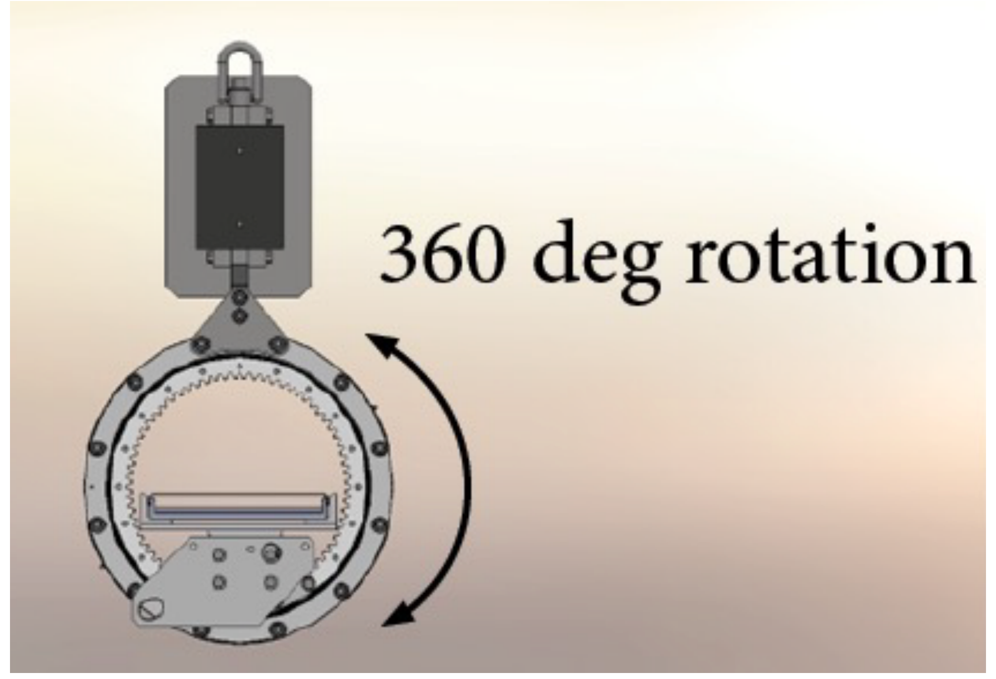
Greg Kalicy



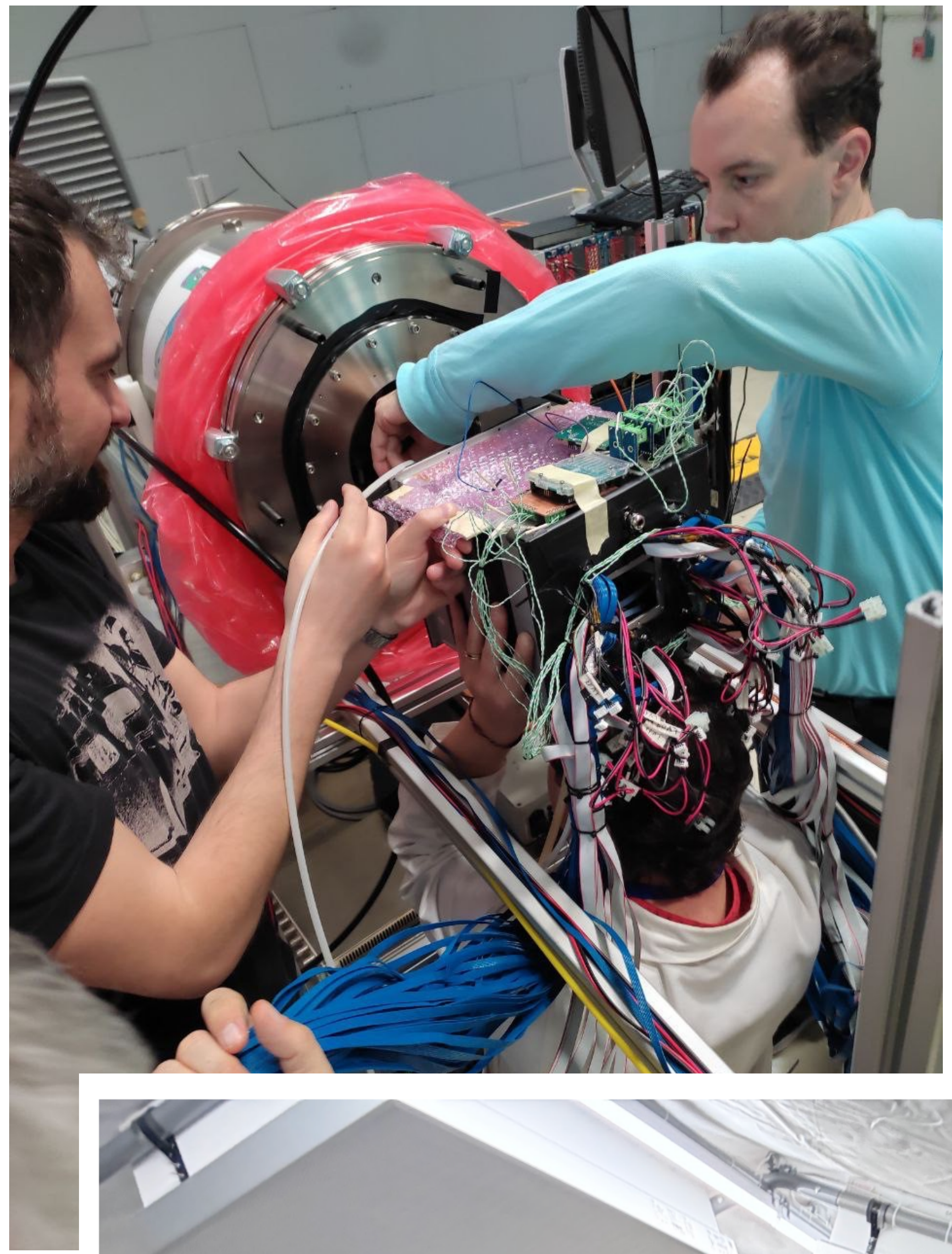


- hpDIRC construction has many components to keep bars aligned
- In initial design was designed to share support frame with inner detectors. Due to deformation by the outer EMCAL it was decided to separate MPGDs and hpDIRC.
- FEA studies in progress
  - self supporting prism box with a separate lens housing that can hold prism load
- Tricky insertion mechanism
- So far no showstoppers





Instead of a Summary …



Working towards
a common goal

ePIC