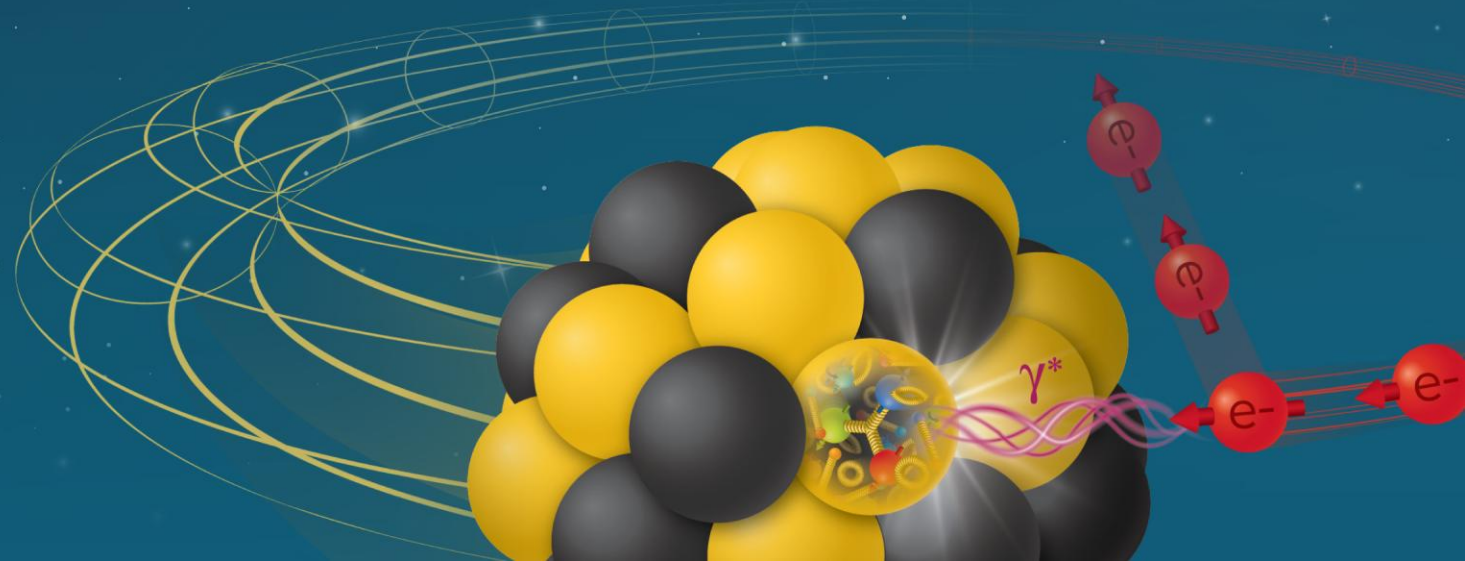


Mechanical Design Status/Discussion: Electron-Ion Collider / hpDIRC

Alex Eslinger (Jefferson Lab)

05 June 2026



hpDIRC Mechanical Discussion Context

- **Who?**

Alex Eslinger — mechanical design engineer at Jefferson Lab supporting hpDIRC and pfRICH mechanical design/integration for the ePIC detector.

- **What?**

Informal hpDIRC mechanical status discussion focused on current CAD/model state, constraints, material architecture, manufacturability, and near-term design questions.

- **When?**

hpDIRC was transferred to me from Kris in late January. Current work is focused on moving the bar box from concept-level understanding toward a validated design path.

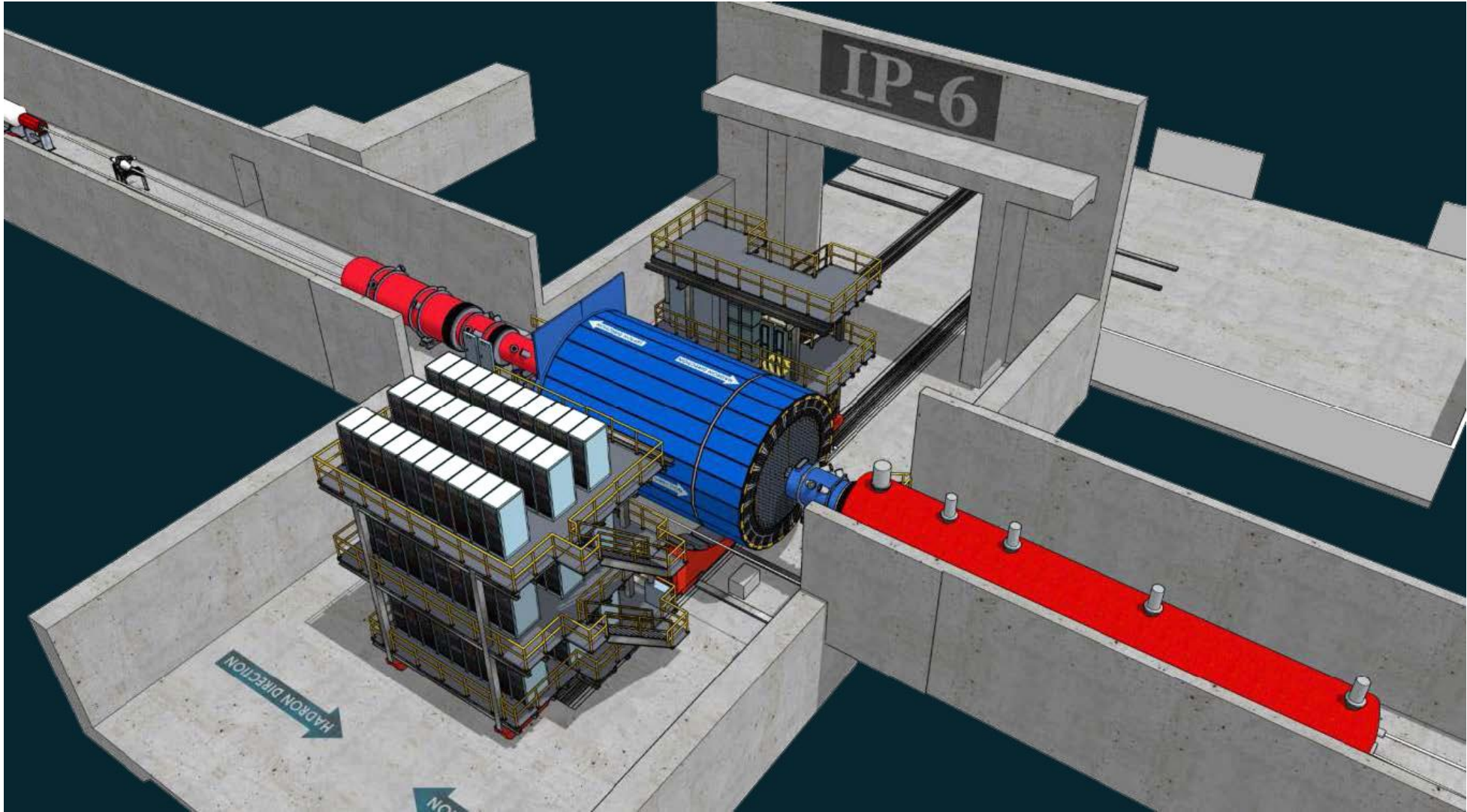
- **Where?**

The hpDIRC lives inside a tight detector envelope at IP6 at BNL for the EIC/ePIC project

- **Why?**

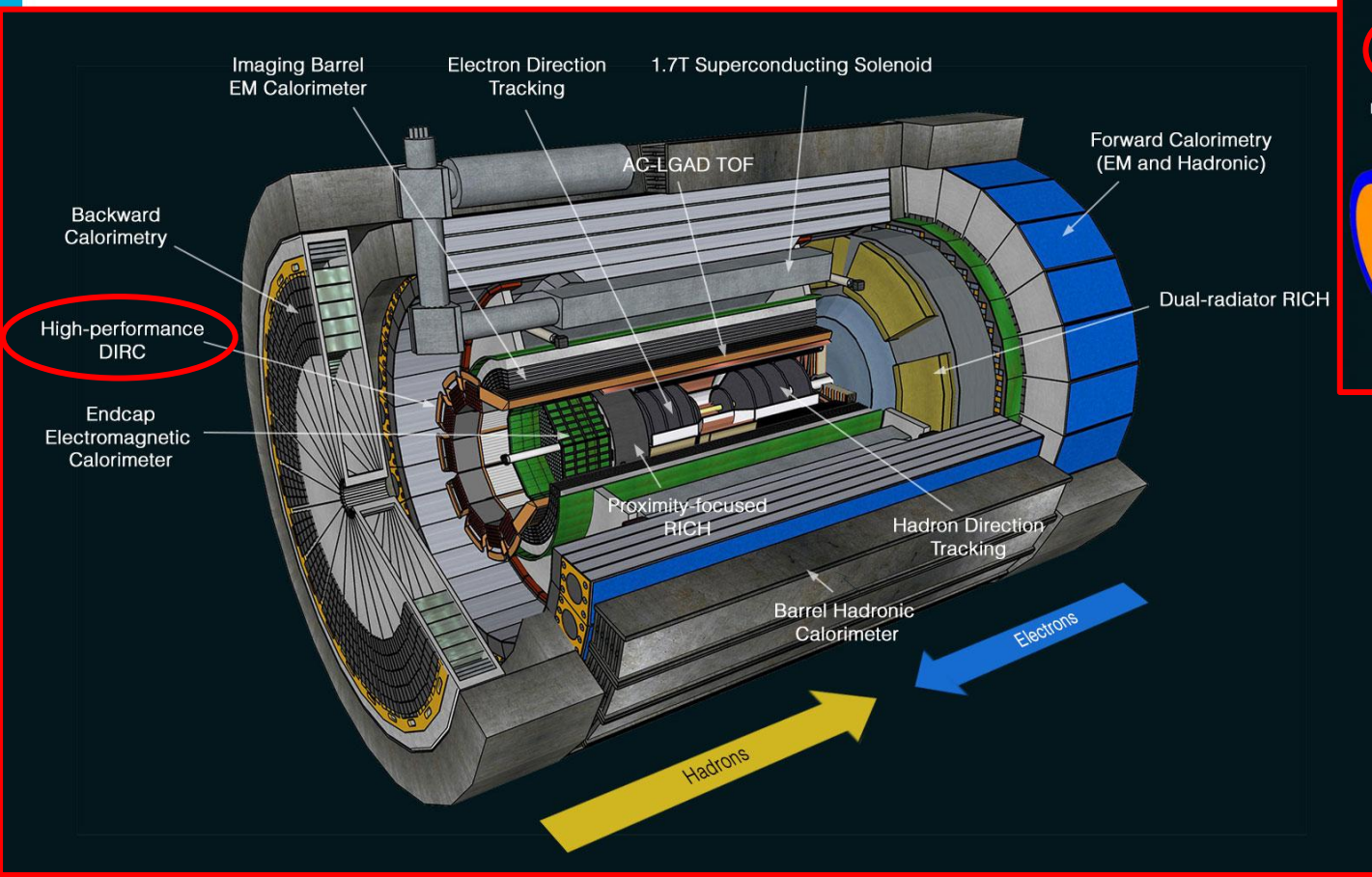
Give the team context on current work, open assumptions, and areas where feedback is needed for hpDIRC mechanical design and integration.

Global Detector Context

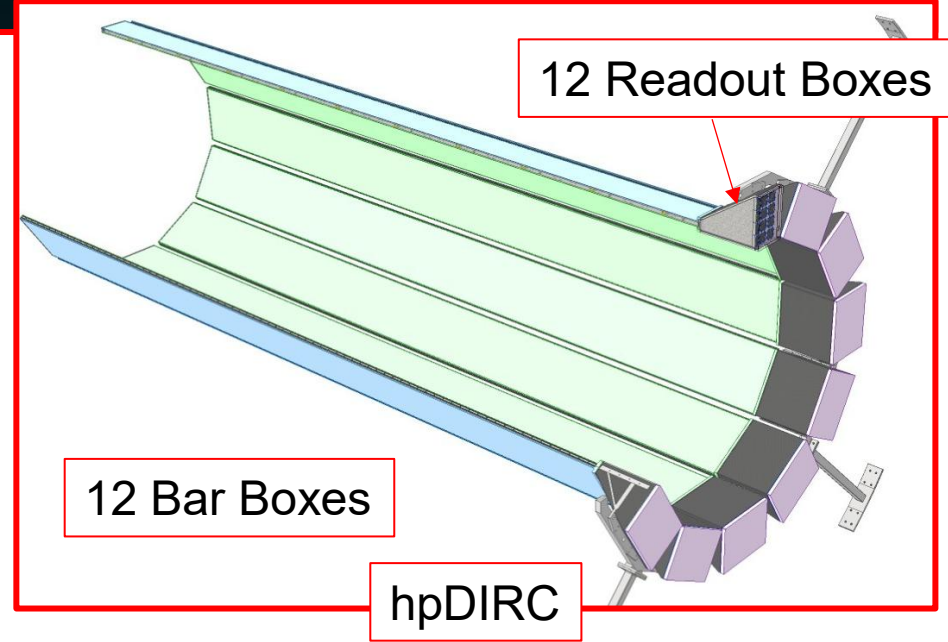
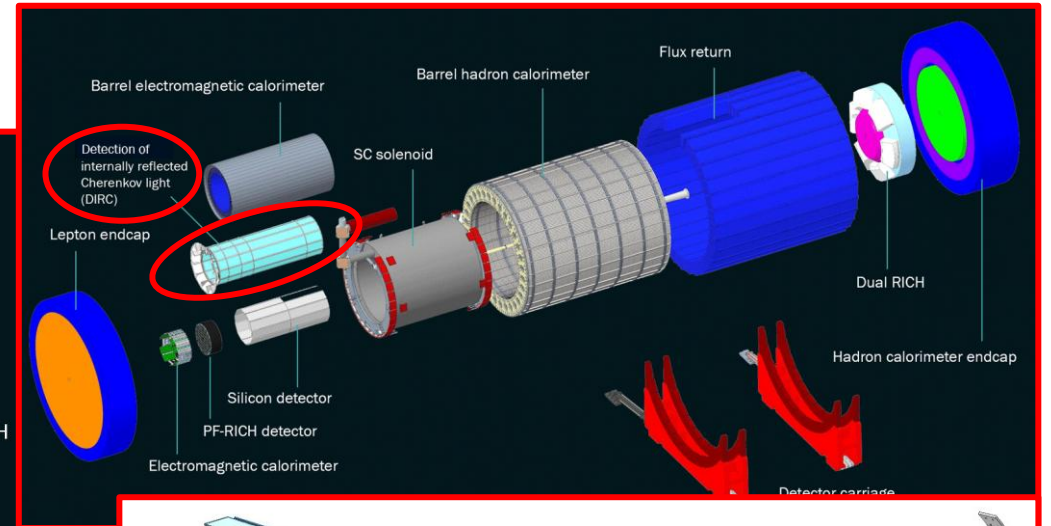


Electron-Ion Collider

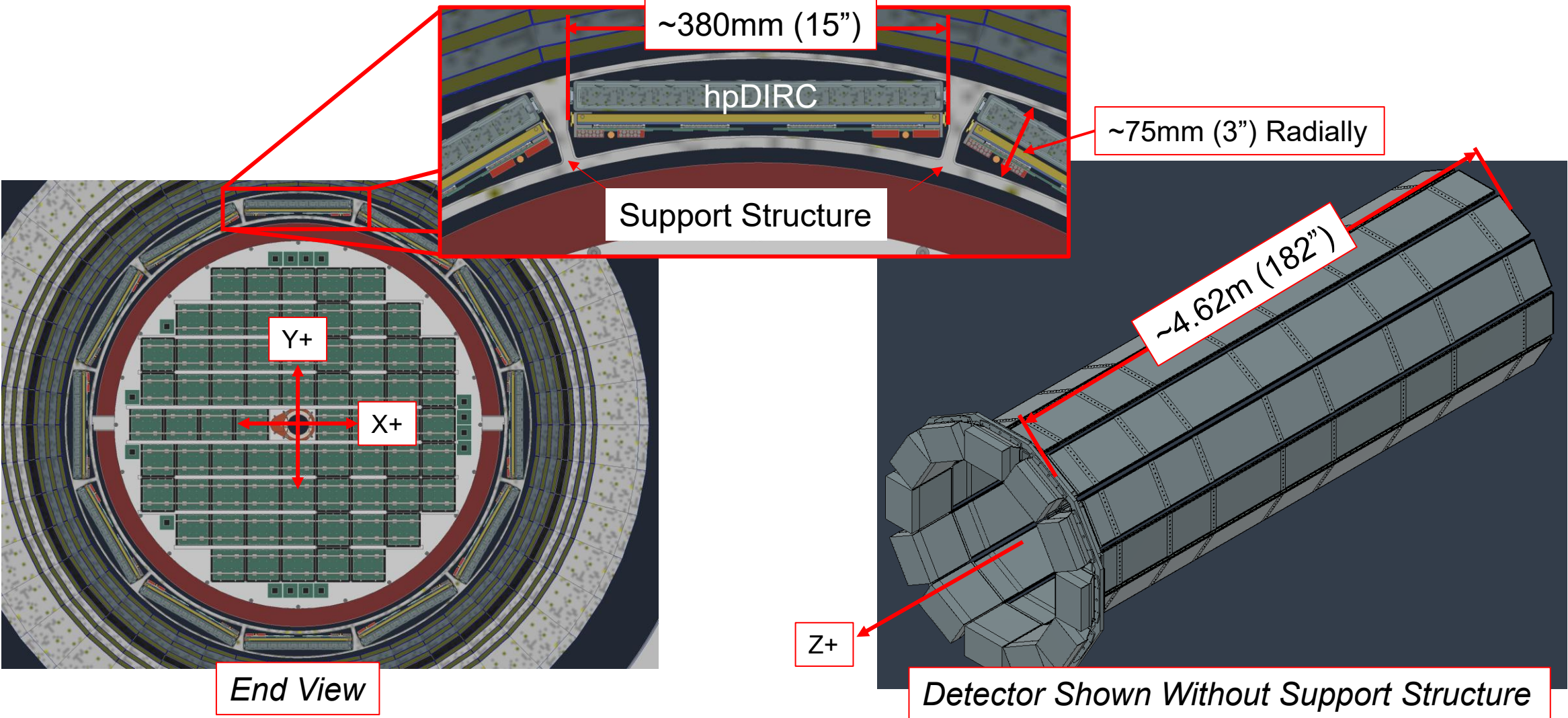
hpDIRC in Detector Context



<https://www.bnl.gov/eic/epic.php>



Available Design Envelope



Why Start With the Bar Box?

The bar box is the first architecture-level decision point.

- Defines the main structural volume inside the envelope
- Supports/locates quartz bars and optical interfaces
- Must remain light-tight with continuous N₂ flow
- Carries the aluminum / composite / hybrid material trade
- Drives buttons, rails, seals, flanges, and readout transition
- Sets stiffness/alignment assumptions for downstream design

Goal: converge on bar box architecture before maturing detailed interfaces.

Current Bar Box Design Details

Bar box scale (*working, not final*)

X: 368 mm (**14.5 in**)

Y: 31.8 mm (**1.25 in**)

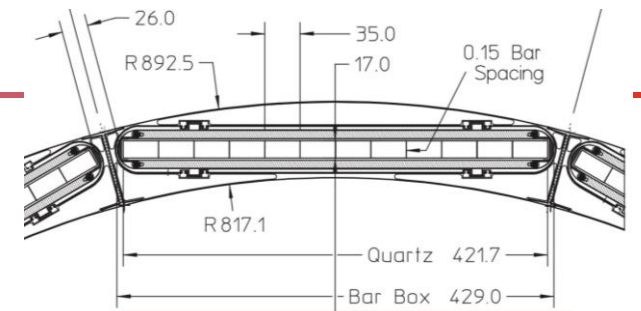
Z: 4.62 m (**182 in**)

Architecture options

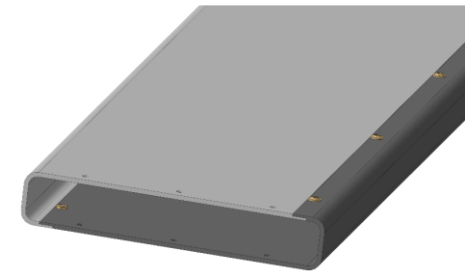
- Aluminum / BABAR-style approach
- Composite structure
- Hybrid aluminum/composite concept

Current focus

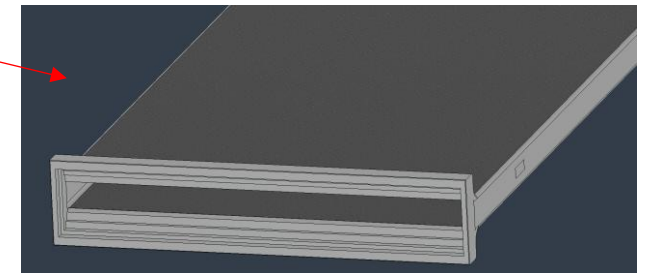
- Light-tight, long, narrow structure
- Alignment-sensitive interfaces
- Stiffness, mass, radiation length, manufacturability



BABAR Approach



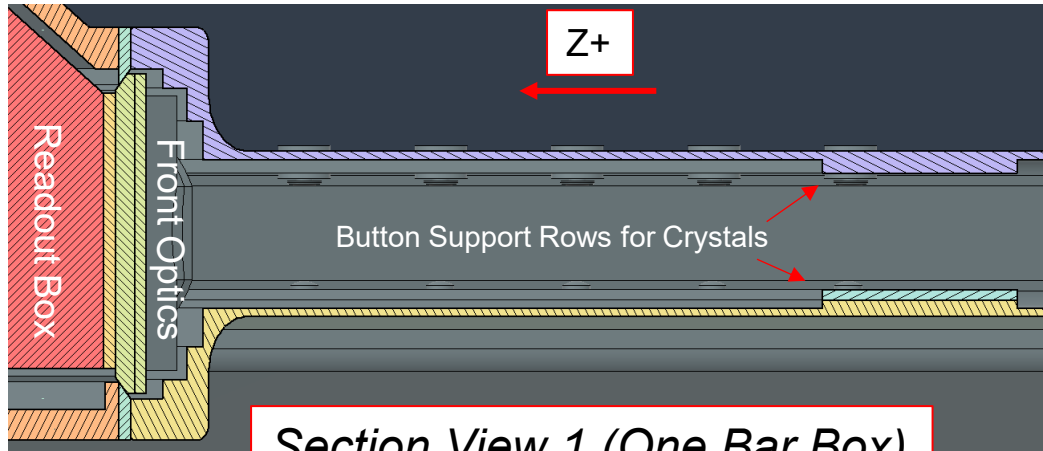
PANDA Approach



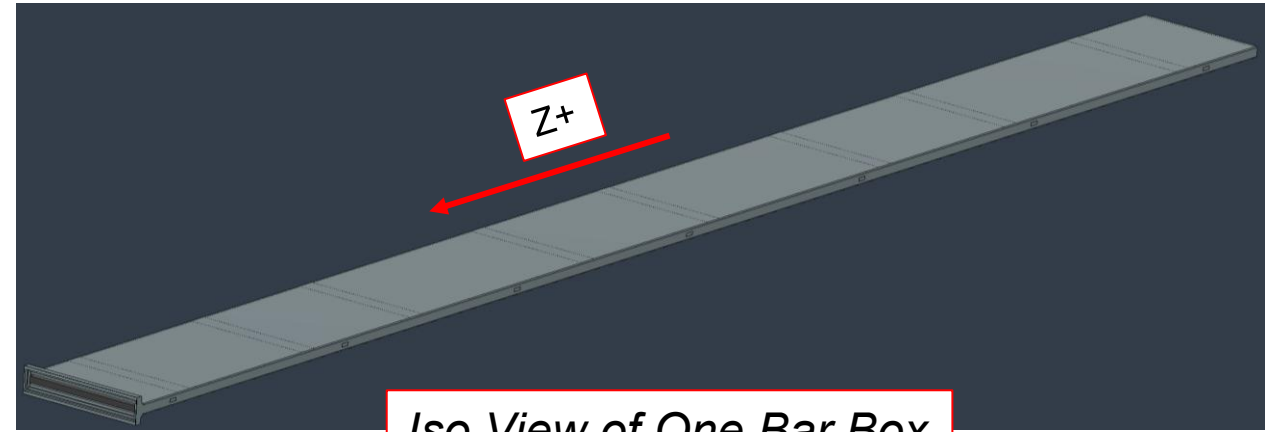
Hybrid Approach?

Near-term goal: converge on a feasible bar box architecture.

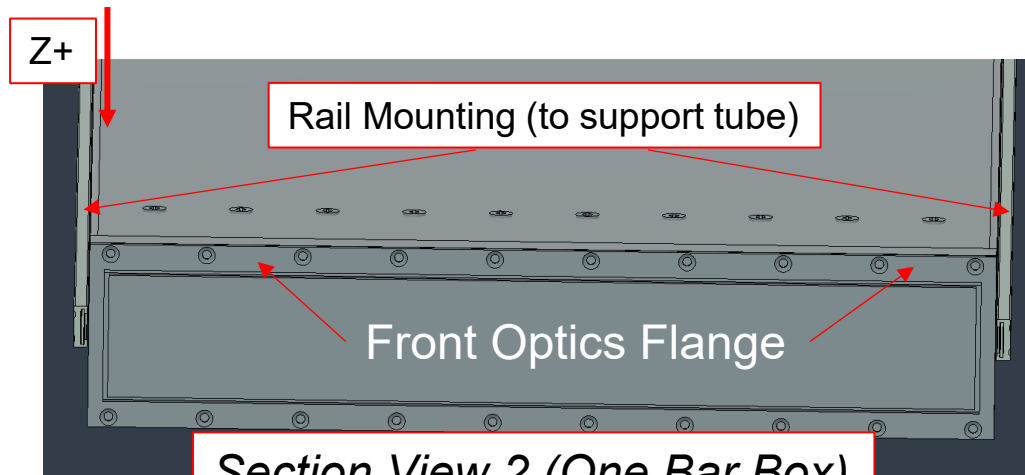
Current Geometry (Bar Boxes)



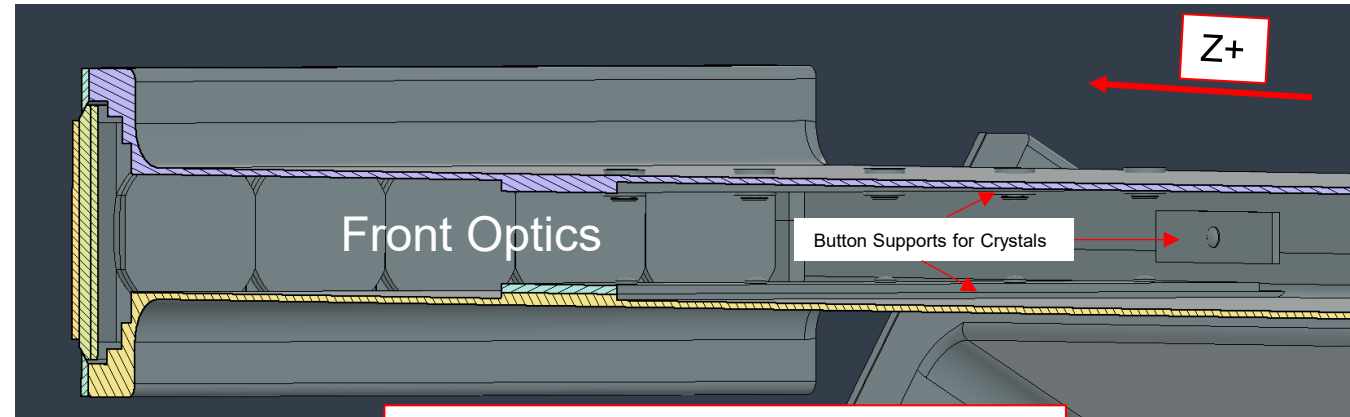
Section View 1 (One Bar Box)



Iso View of One Bar Box



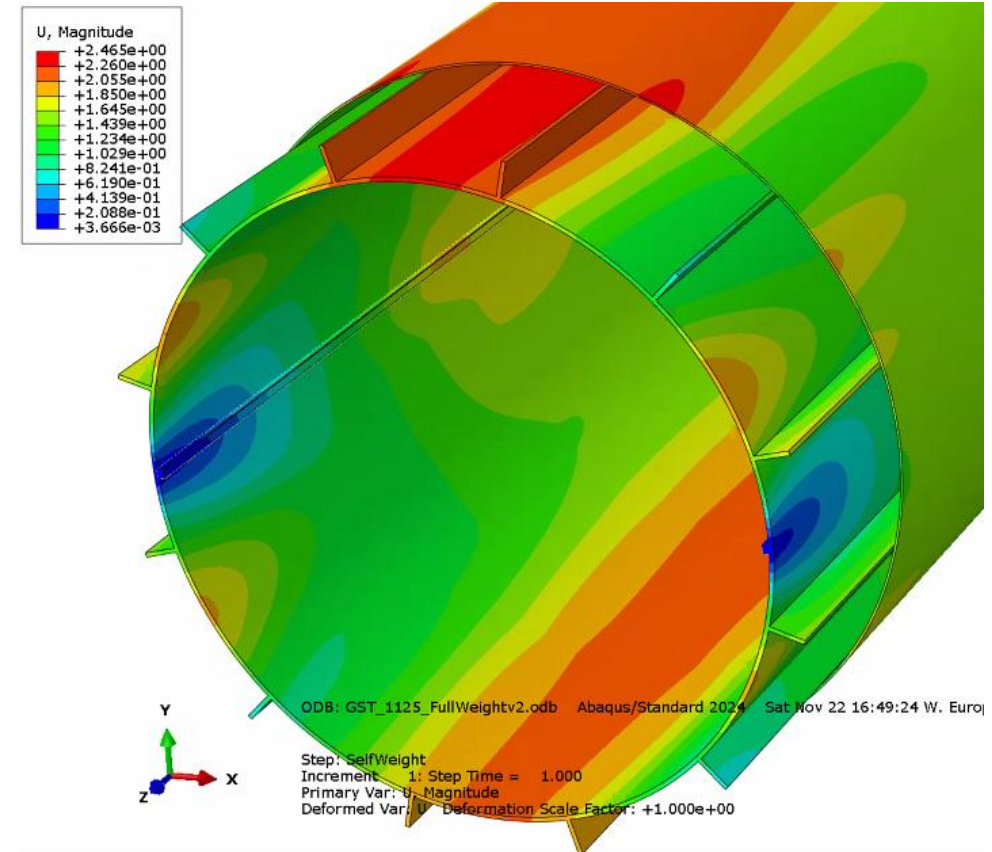
Section View 2 (One Bar Box)



Section View 3 (One Bar Box)

Current Understanding of Constraints / Needs Confirmation

| Area | Current Understanding |
|-------------------------|--|
| Z deflection | ~0.5 mm over full length |
| X deflection | Possibly <0.01 mm across crystals — needs confirmation |
| Position relative to IP | angular / positional control; calibration effects need clarification |
| BABAR comparison | ~10 mrad |
| ePIC target | ~3–4 mrad |
| Environment | radiation, magnetic field, low outgassing |
| Operations | light-tight box, continuous N ₂ flow |
| Integration | GST deflection, envelope, assembly, mass |



Current FEA used to evaluate global stiffness and support behavior

From Requirements to Reality

The constraints are coupled to the fabrication method

A bar box concept cannot be evaluated on stiffness alone. It also has to be:

- buildable and inspectable
- light-tight
- compatible with continuous N₂ flow
- low-outgassing
- acceptable for radiation length and mass
- realistic at full scale

Before pushing CAD further, I needed external input on realistic fabrication paths

SAMPE 2026 – Why I Went

What it is:

SAMPE is an advanced materials and process engineering conference focused on composites, fabrication methods, tooling, inspection, and industry capability.

Why I went:

- Identify fabrication paths and vendors relevant to hpDIRC design maturation
- Understand what composite structures industry can realistically build
- Learn which assumptions affect cost, tooling, inspection, and schedule
- Bring practical manufacturing feedback into the design before it matures too far

Outside Input / Design Takeaways

Who I have been talking to:

- Composite manufacturers identified through SAMPE outreach
- Engineer working on similar detector structures
- Internal collaborators supporting hpDIRC analysis/integration

What changed my thinking:

- Composite performance depends on laminate design, load path, and support conditions
- Flat composite panels may be lower risk than a complex all-composite box
- Interfaces may drive the design: buttons, rails, seals, inserts, hardpoints
- Hybrid aluminum/composite architecture may be worth developing as a candidate concept

Next step:

- Bring vendors a specific candidate geometry and ask what assumptions are wrong



Example SAMPE manufacturing display

What Is Well Controlled vs. Needs Attention

Well controlled / actionable now

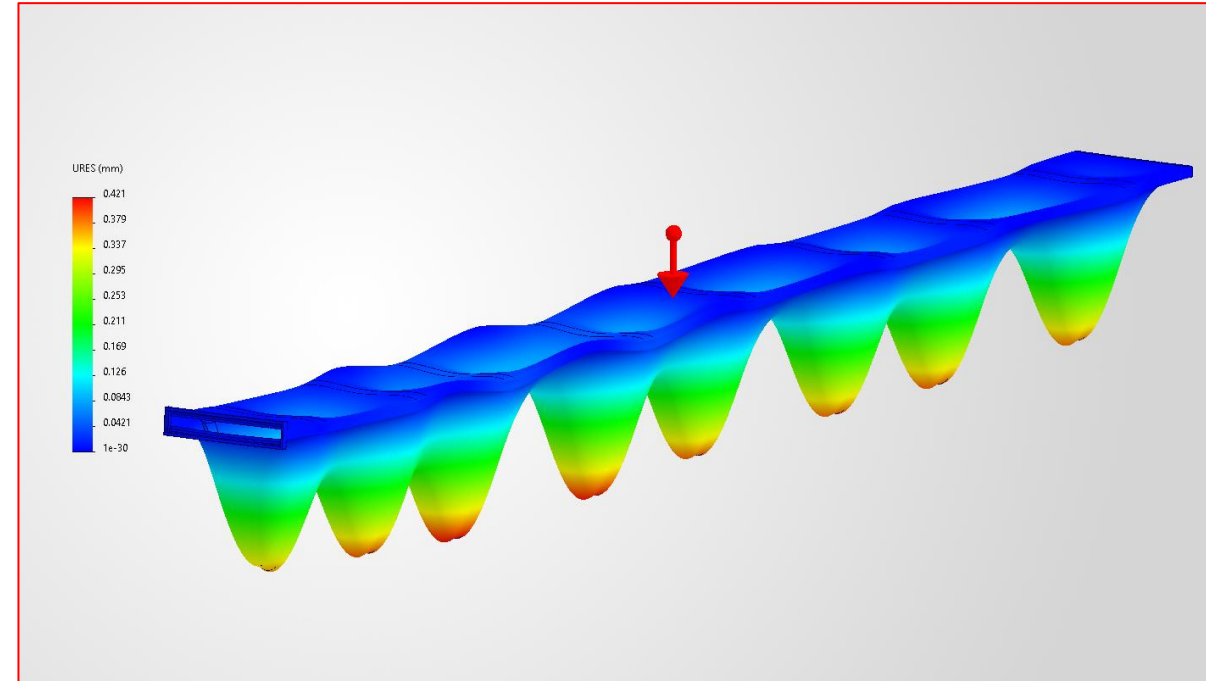
- CAD envelope development
- Bar box architecture studies
- Preliminary aluminum/composite/hybrid concepts
- First-pass structural analysis
- Vendor feedback loop

Needs attention

- X-direction deflection requirement
- What can be calibrated out vs mechanically controlled
- Radiation length sensitivity by region
- GST/support deflection interaction
- Interface strategy: buttons, rails, hardpoints, seals
- Manufacturability and inspection assumptions

Near-Term Plan

- Refine bar box CAD concept
- Develop candidate hybrid/aluminum/composite layouts
- Analyze Z and X deflection behavior
- Check interface regions and support assumptions
- Review galvanic isolation for hybrid concepts
- Re-engage vendors with specific geometry and requirements
- Compare options and recommend architecture for deeper design maturity



Rough Pass: Current Model (as-is) with 7075 Aluminum Applied

Discussion Questions

- Are my deflection/tolerance assumptions directionally correct?
- What drives the possible <0.01 mm X-direction requirement?
- What must be mechanically controlled vs calibrated?
- Where is radiation length most sensitive?
- Are there regions where aluminum is acceptable?
- Is a hybrid bar box concept worth developing?
- What should be validated first?

BACKUP

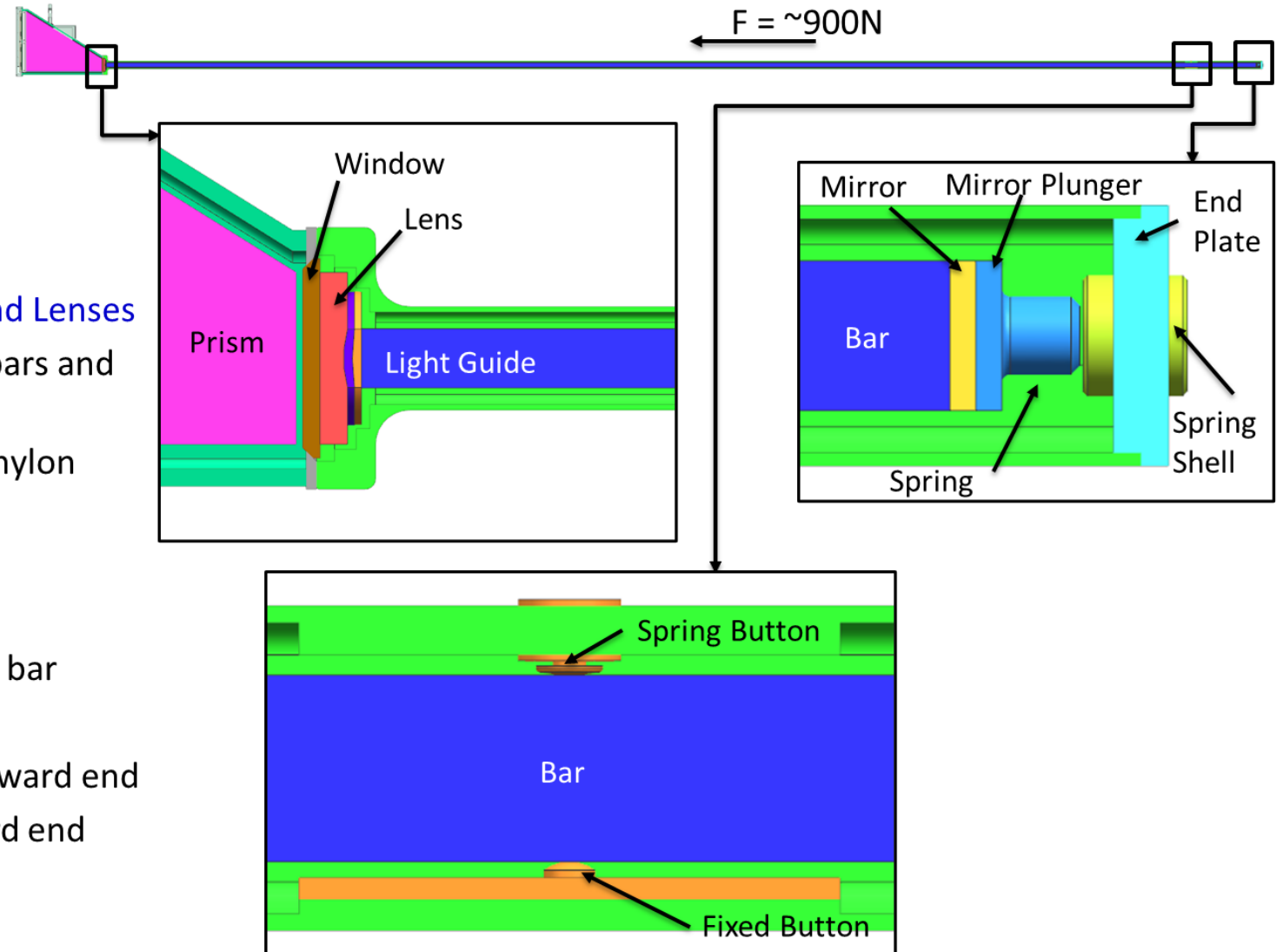
Vendor Contacts / Follow-Up Candidates

- Rock West
 - <https://www.rockwestcomposites.com>
- M4 Engineering
 - <https://www.m4-engineering.com>
- Daher Aerospace
 - <https://www.daher.com>
- Janicki
 - <https://www.janicki.com>
- Fiber Dynamics
 - <https://www.fiberdynamics.net>
- ~~Center Street Technologies~~
 - ~~<https://www.centerstreettech.com>~~
- IACMI – The Composites Institute
 - <https://www.iacmi.org>
- Coppins Industries / EB Composites
 - <https://www.coppinsindustries.com>

Bar Boxes

Bar Boxes:

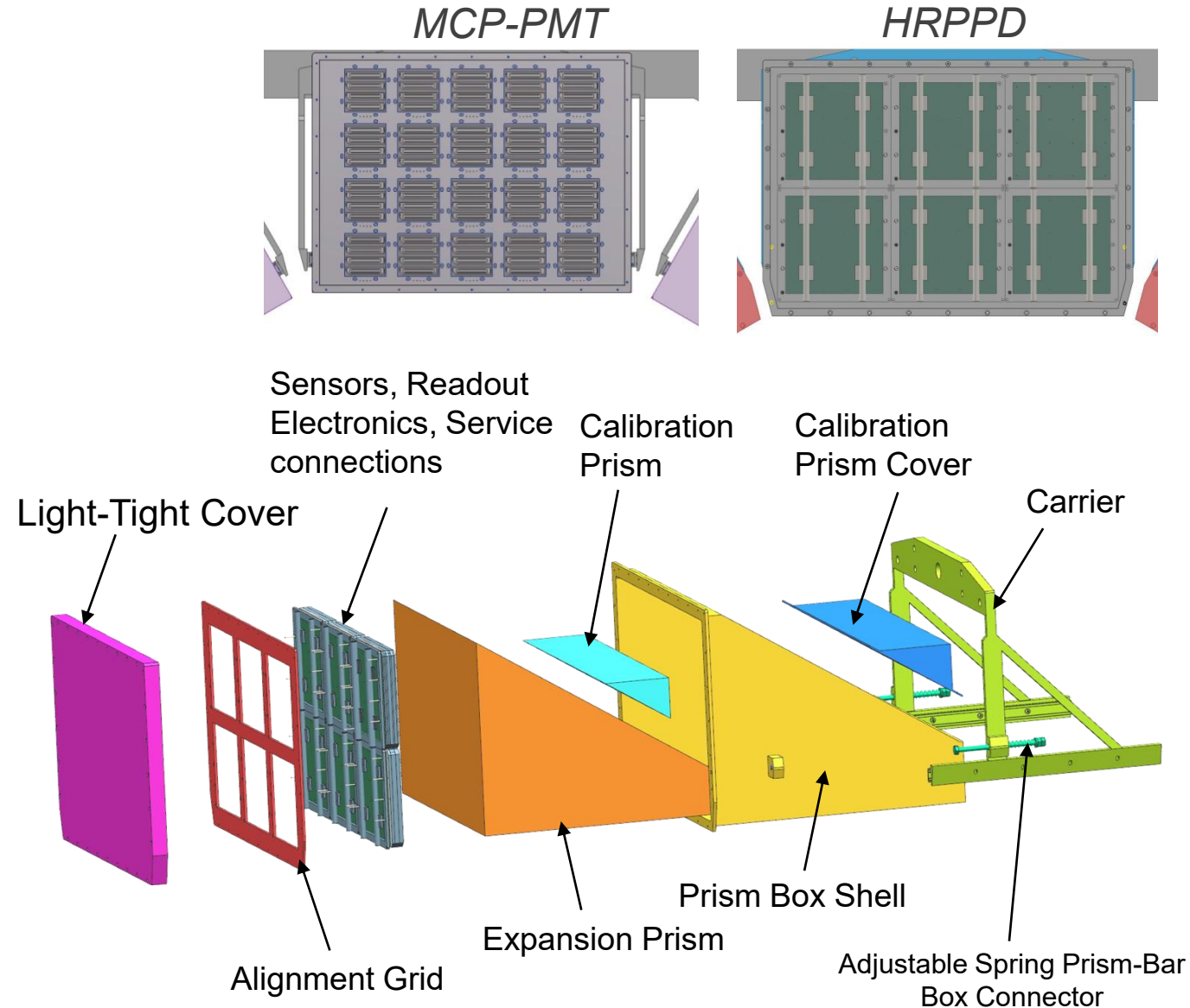
- CFRP Shell
 - Approximately 4.6m Long
 - Thickness: 1.5 mm – 3 mm (thicker in key locations)
- Contains Quartz Radiator Bars, Mirrors, and Lenses
 - 10 long bars each formed by 3 short bars and a Light Guide section
 - Radiator bars supported on rounded nylon buttons to minimize losses
- Capped on each end
 - Spring End Plate at Forward End
 - Adjustable spring assemblies for each bar
 - Maintain compression in glue joints
 - Optically transparent window at backward end
 - Counters force from springs at forward end
 - Provides gas-tight boundary



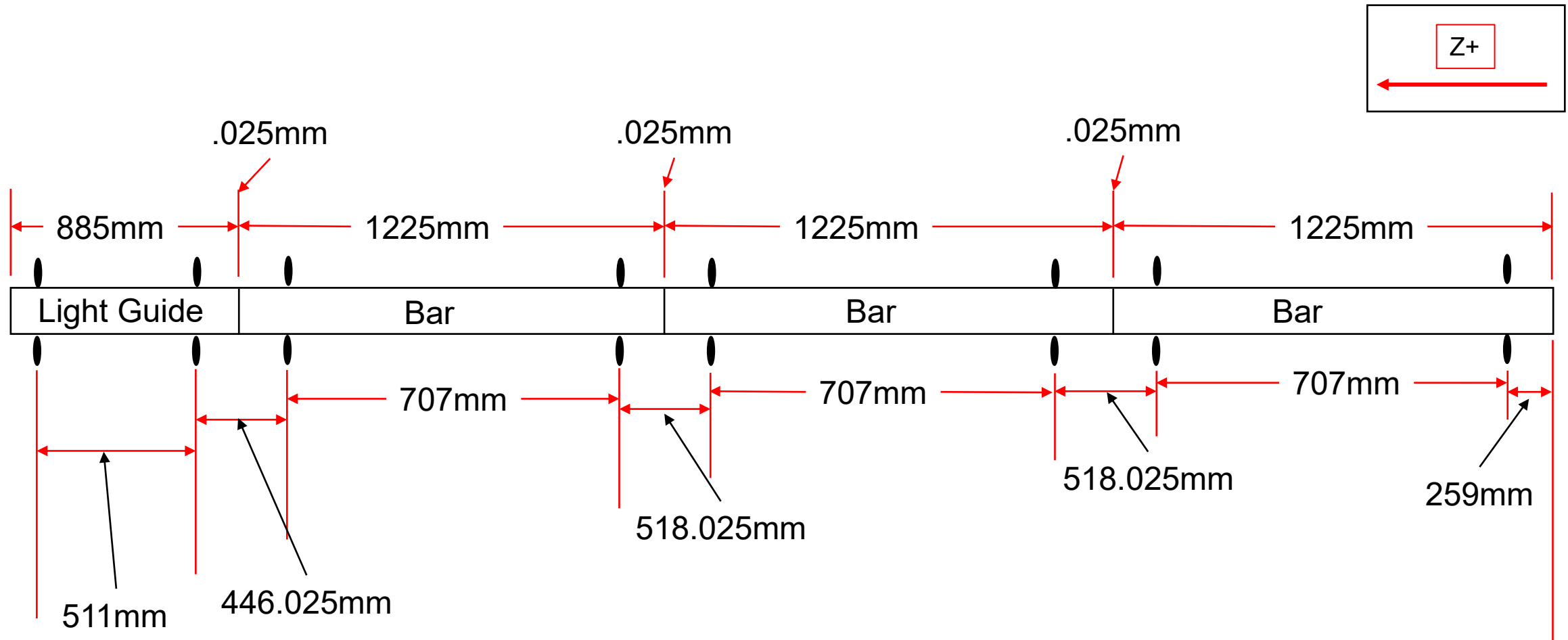
Readout Box

Readout Box

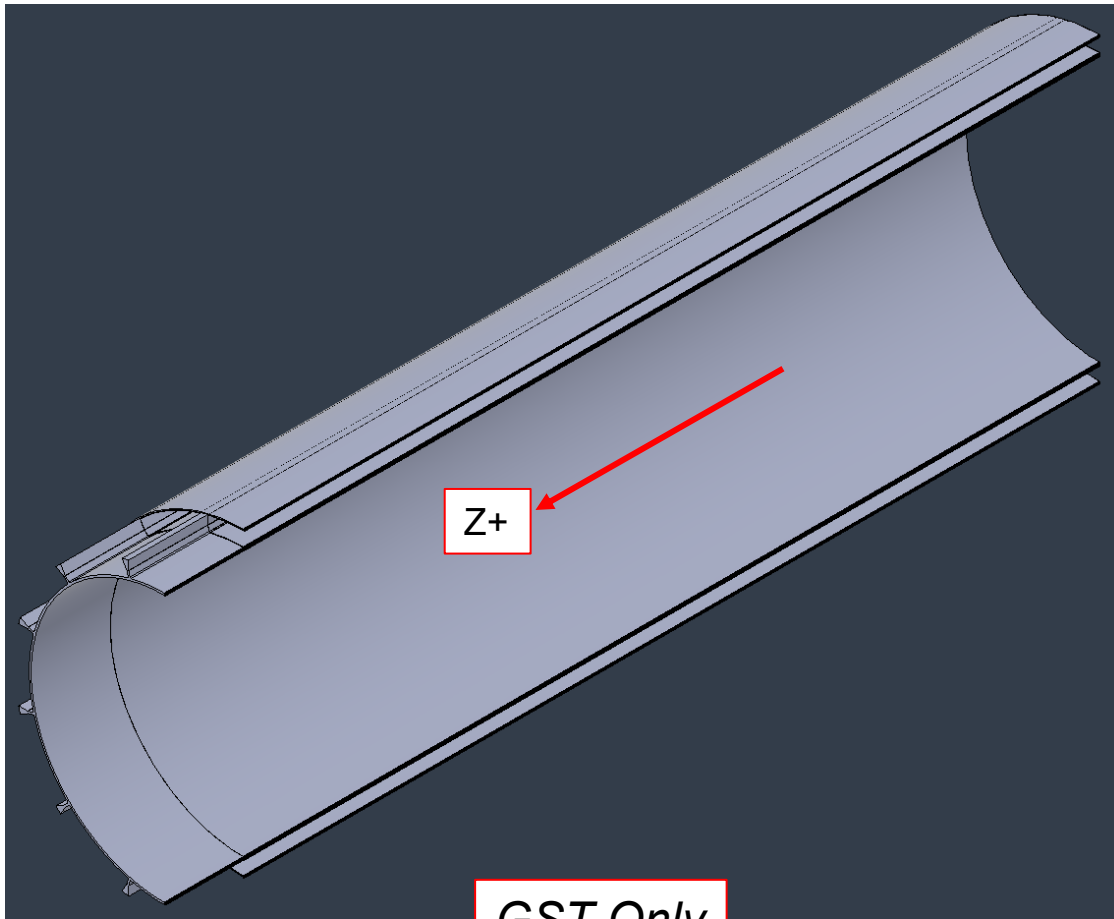
- Box shell
- Current Material: CFRP
- Current Thickness: 5 mm
- Contains expansion prism, calibration laser system
- Supports sensors, readout electronics, and associated services
- Mechanical design solutions for two sensor options:
 - MCP-PMT (baseline)
 - HRPPD
- Optical cookie connection between prism and bar box window



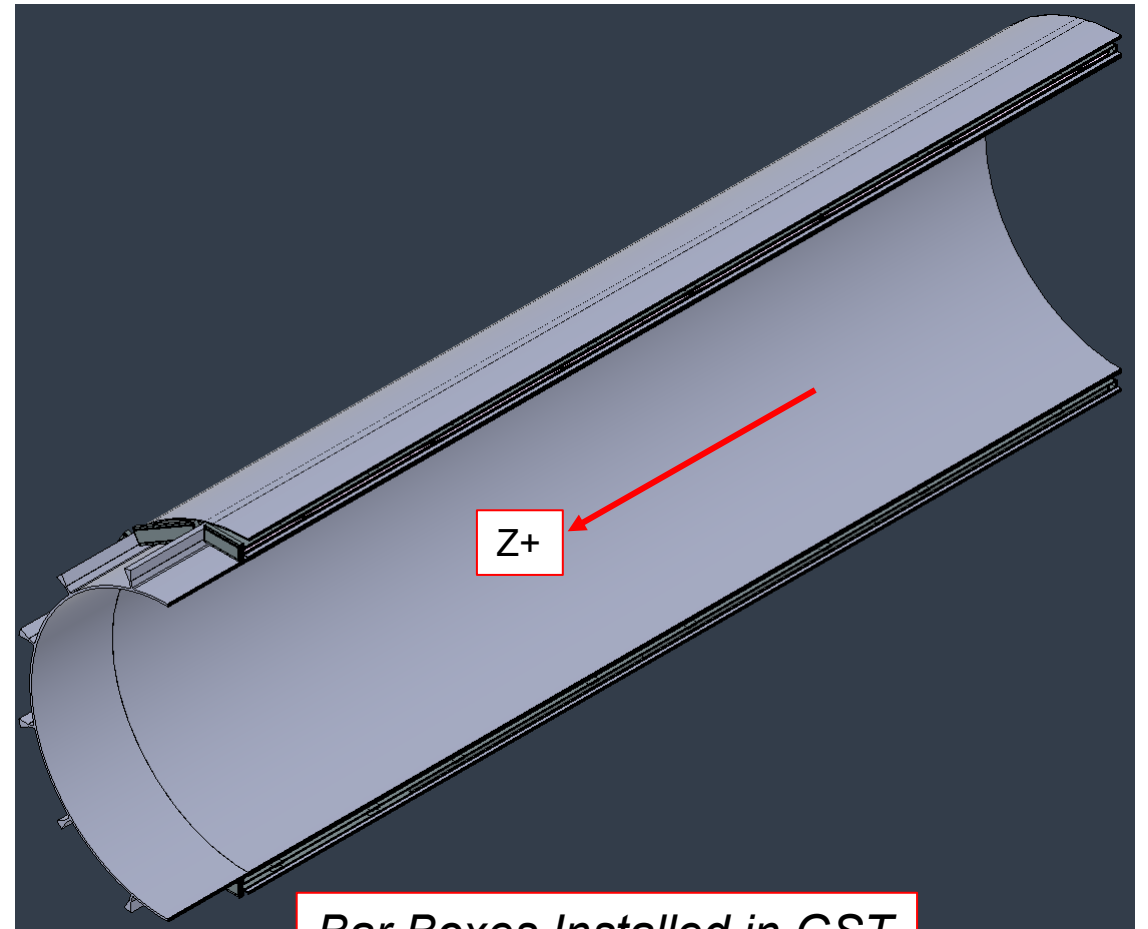
Button Supports



Support Tube (GST)



GST Only



Bar Boxes Installed in GST

General Installation Plan

