hpDIRC: GST Interface Discussion

Engineering Discussion (Dan, Rahul, Seungjoon, Sushrut)

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8/5/2026

Electron-Ion Collider

Constraints

Detector/Alignment	Optics/Physics	Structural Behavior	Environment / Compatibility	Manufacturing / Cost
Fit within the GST envelope	Maintain end-to-end optical joints between bars	Control X-direction motion at the bar support interface	Maintain dry nitrogen environment (slight overpressure)	Avoid unnecessary custom fabrication risk
Maintain required position relative to the IP	Avoid stressing glued bar/lens joints	Limit Z-axis sag/deflection over the full length	Manage humidity and sealing behavior	Use commercial processes where practical
Understand support-tube deflection and its effect on bar box alignment	Maintain no-contact condition between neighboring bar rows	Avoid twist or local deflection that disturbs optical alignment	Consider radiation exposure	Keep the design measurable, manufacturable, and cost-aware
Control how bar-box deflection couples into optical alignment	Preserve minimum residual inter-bar clearance	Support the bar stack without shifting the optical assembly	Consider magnetic-field compatibility	
Remain material-aware at detector scale	Maintain light-tightness		Consider outgassing and material compatibility	

hpDIRC Mechanical Constraints

Reuse of the BaBar fused-silica bars drives the design:

- Ten-bar stack with 150 µm nominal inter-bar gaps.
- Preserve at least 75 µm residual clearance after assembly and loading.
- Spring buttons locate the bars against fixed references at defined Z-stations.
- Critical deformation is relative motion of the support/reference planes—not rigid-body movement of the entire box.

Primary risks:

- Bar-to-bar contact
- Box twist or local width change
- Changes in button preload
- Misalignment between support stations
- Excessive axial deformation across the glued bar assembly

GST Deflection Inputs

A project target of approximately 0.5 mm deformation over the bar length has been discussed as acceptable for protecting the glue joints.

This must be treated separately from the inter-bar clearance requirement:

• Z deformation controls glue-joint loading.
• Local X/Y distortion and twist control bar clearance and button loading.
• A box can satisfy the 0.5 mm Z target and still distort locally enough to threaten the 150 μm gaps.

Needed from the loaded/unloaded GST results:
• Relative translation and rotation at hpDIRC support stations
• Local width and height change
• Twist/racking along Z
• Differential movement between rail interfaces

Requirement / Assumption Table

Item	Assumption / Requirement
Bar Box Length	~4.62m / ~14 ft
Support Interface	Current concept assumes rail/GST interface
IP Alignment	Required position relative to IP must be maintained (very tight tolerance; otherwise, recalibration is required)
Support-tube deflection	Input requested. Max deflection was quoted ~2.5mm from outdated info
Inter-bar Clearance (X)	150 microns minimum residual clearance assumed
Bar Contact	**NO**-contact condition required between neighboring bars
End-to-End Optical Joints	Must avoid stressing glued bar-to-bar joints
Lens/bar glue joints	Must avoid support loads or deformation that stresses the glue joints
Critical Motion Direction	X-direction motion at bar support interface (“Z-Stations”)
Z-axis behavior	Sag/deflection over full length must be evaluated
Gas Environment	Dry nitrogen environment required
Overpressure / Leakage	Low overpressure expected; leakage definition still needed
Light-tightness	Required
Material compatibility	Radiation, magnetic field, outgassing, humidity, sealing
Current rail component	CAD rail/slider choice not validated
Hybrid Concept Status	Promising path, not final’d or baselined

Risk Mitigation Matrix

Risk	Why It Matters	Mitigation/Validation Path
Support-tube deflection	Affects rail alignment and IP position	Use GST deflection in FEA
Rail/Component Selection	CAD slider is not validated	Compare rail options against load, clearance, length and moment needs
Hybrid structural behavior	Material split changes stiffness/load path	Run FEA with actual hybrid material distribution
X-direction motion	Can reduce bar clearance	Evaluate bar support interface displacement
Z-axis sag/twist	Can disturb optical alignment/joints	Evaluate full-length deflection modes
CTE Mismatch	Al and CF move differently with temperature	First-pass thermal estimate & joint strategy
Galvanic Corrosion	CF/Al may need isolation	Define isolation/coating/sealing solution
Gas Sealing/leakage	Dry N2 environment needs to be maintained	Define flow-in / flow-out / leakage model
Light-tightness	Optical performance risk	Detail seals, overlaps, joints, and closure features
Glue Joint Loading	Bonded optical joints must not be overstressed	Check support reactions and deformation at bar/lens interfaces
Fabrication path	Cost/Schedule risk depends on process choice	Compare CF shell vs hybrid commercial fabrication paths
Late Design Changes	Molded CF changes can be expensive	Keep panels and interfaces adjustable where practical

hpDIRC Installation

Baseline: Rail Insertion (Along Z)

- Box-mounted rails with GST-mounted rollers/carriages
- Side rails primarily support the 12/6 o'clock boxes
- Top-cover rails primarily support the 3/9 o'clock boxes
- Compact and based on the BaBar installation philosophy
- Requires controlled rail alignment over the full insertion length

Alternative: Radial Insertion (Outside-in through removable GST Panels)

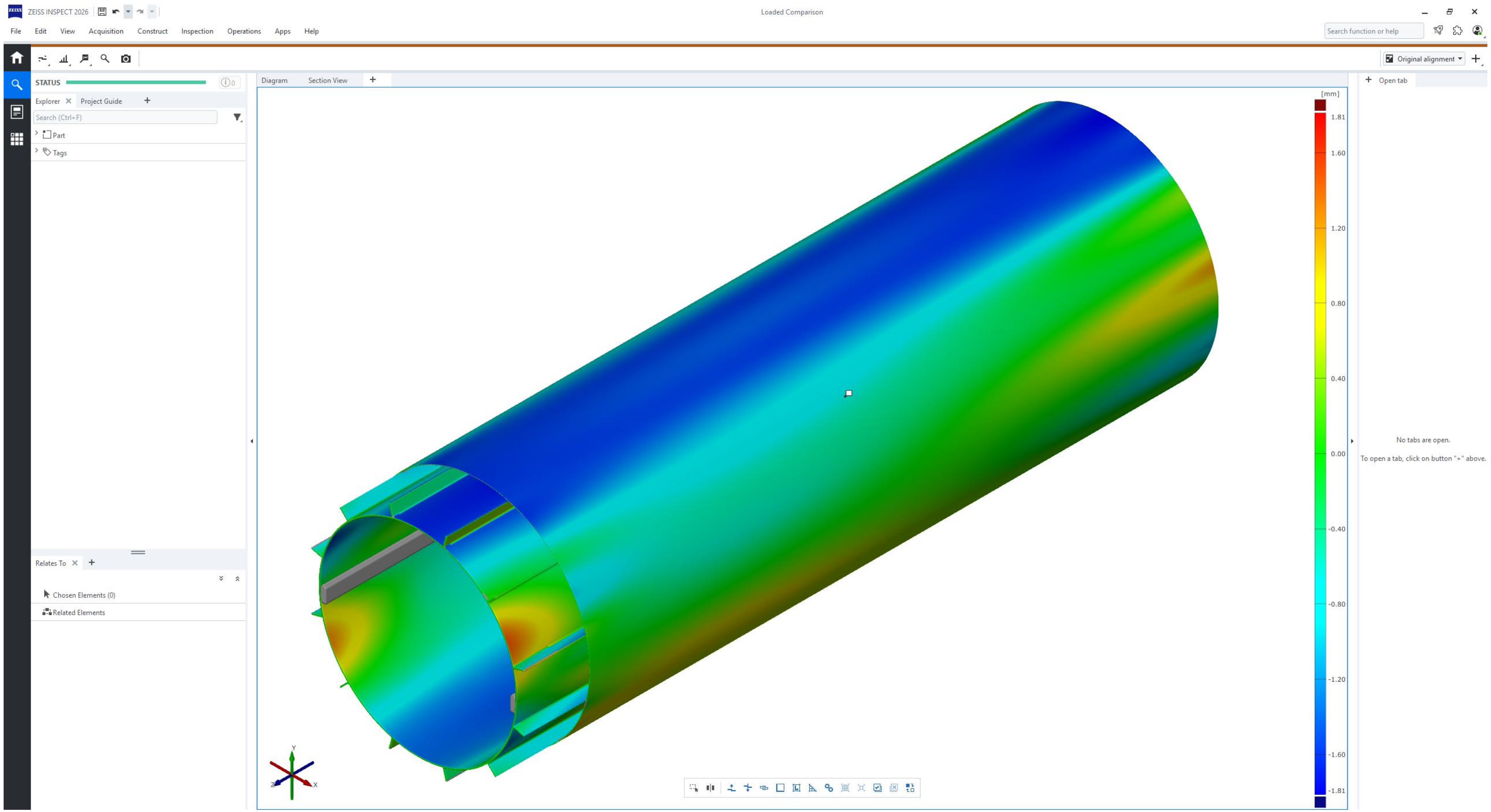
NOTE: This is being investigated and not meant to be publicly discussed until well understood.

- Insert or remove the box radially through the GST structure
- May avoid a long precision rail path
- Could simplify box installation and exceptional access
- Requires a separate final support, datum, and retention concept
- Must be evaluated against GST panel geometry, assembly sequence, available radial envelope, and handling risk

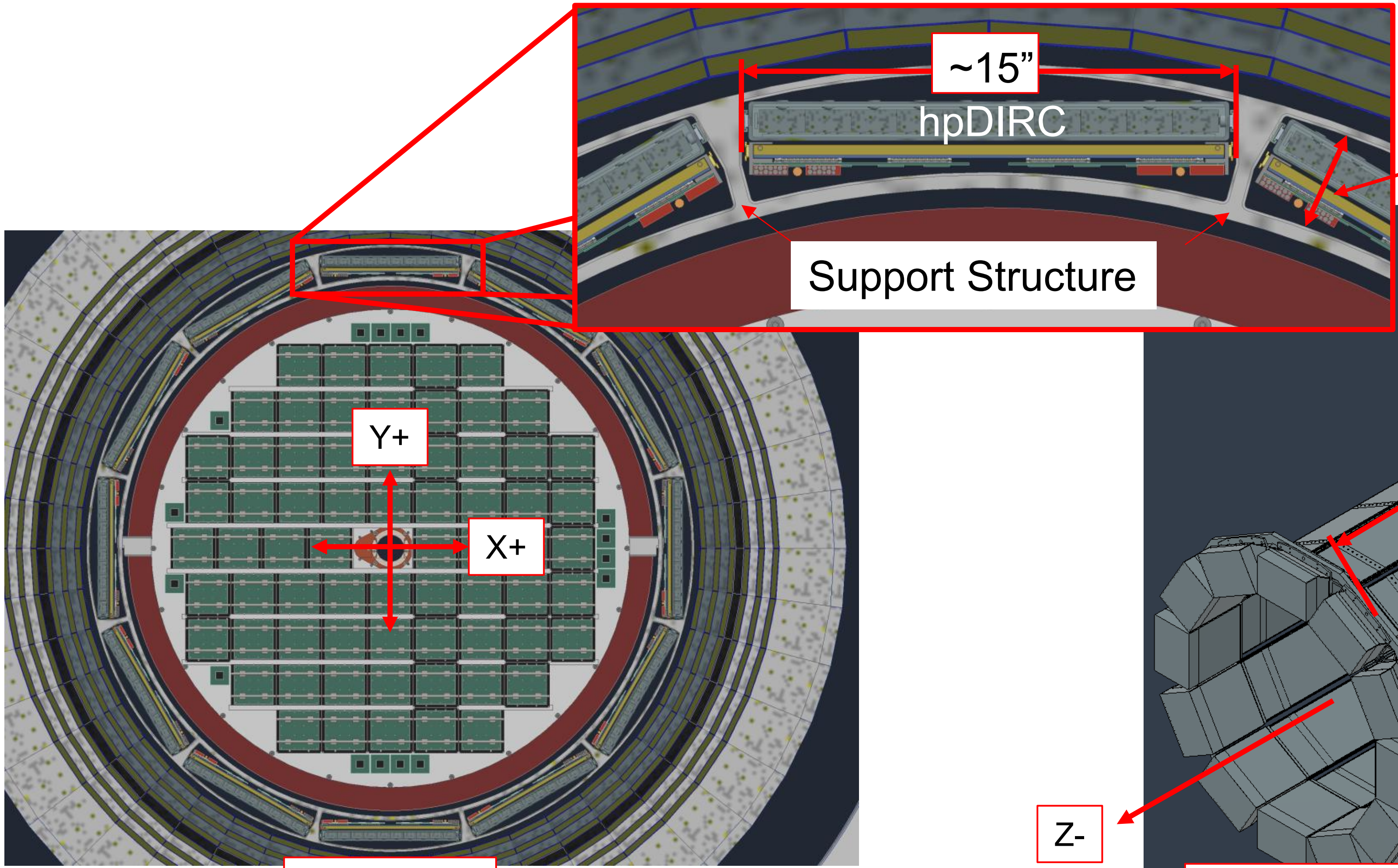
The immediate decision is whether the baseline rail insertion is credible within the current understanding of deflections.

Backup

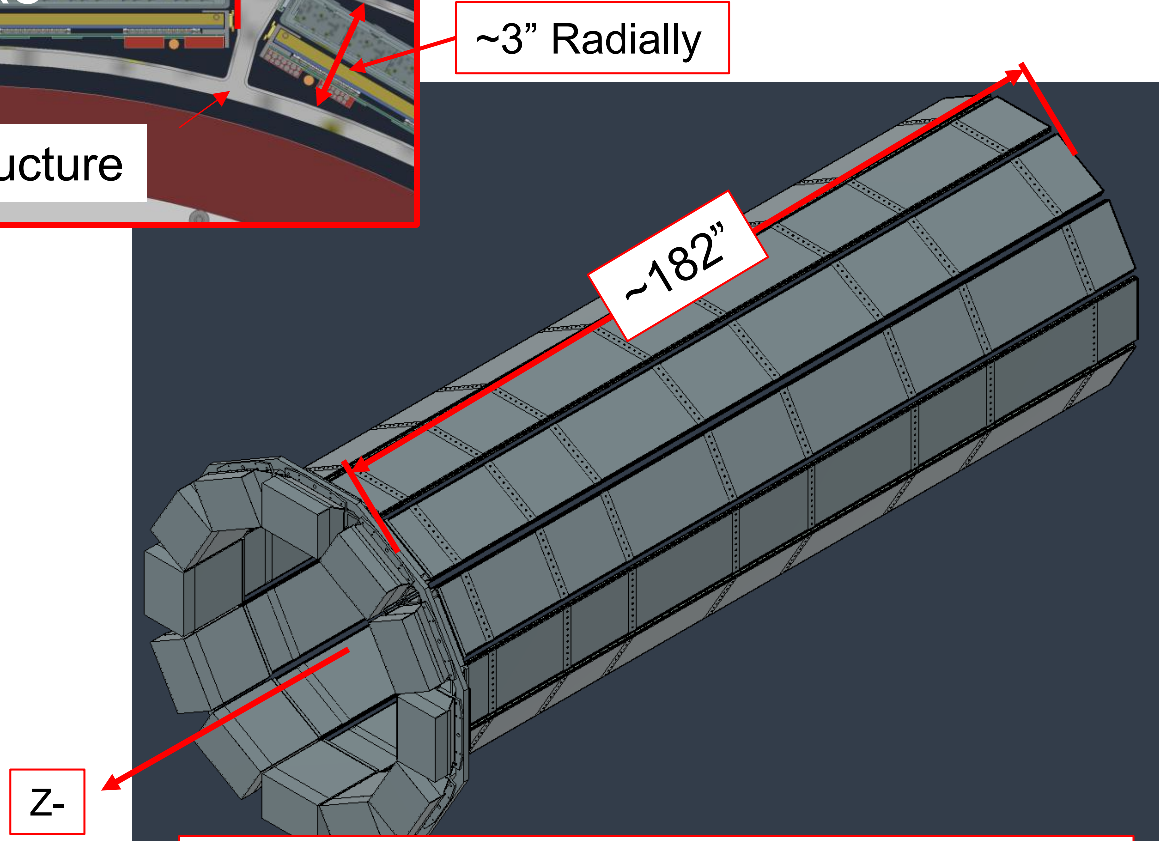
Loaded (ZOM Inspect)



Available Design Envelope

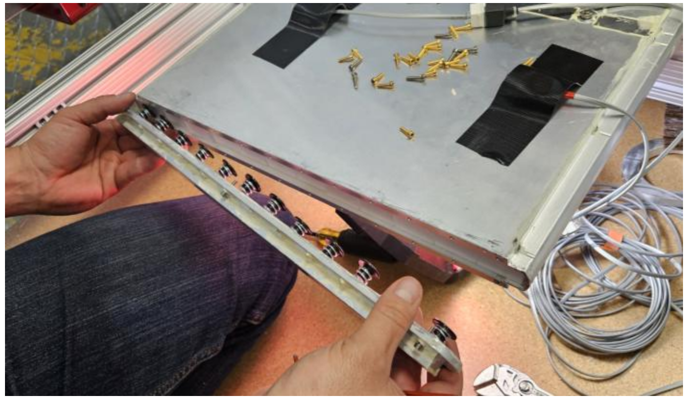


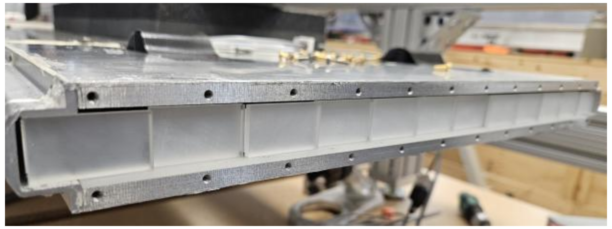
End View



Detector Shown Without Support Structure

What's in the Box?



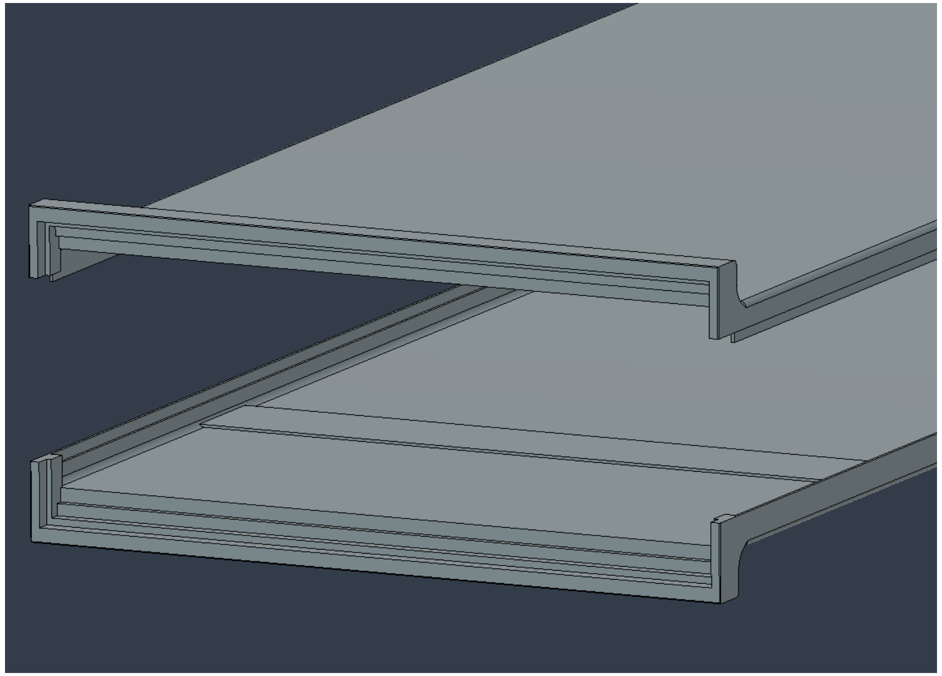


Baseline / Carbon-Fiber Concept

The baseline concept uses a primarily carbon-fiber structure for the bar box.

What it does well:

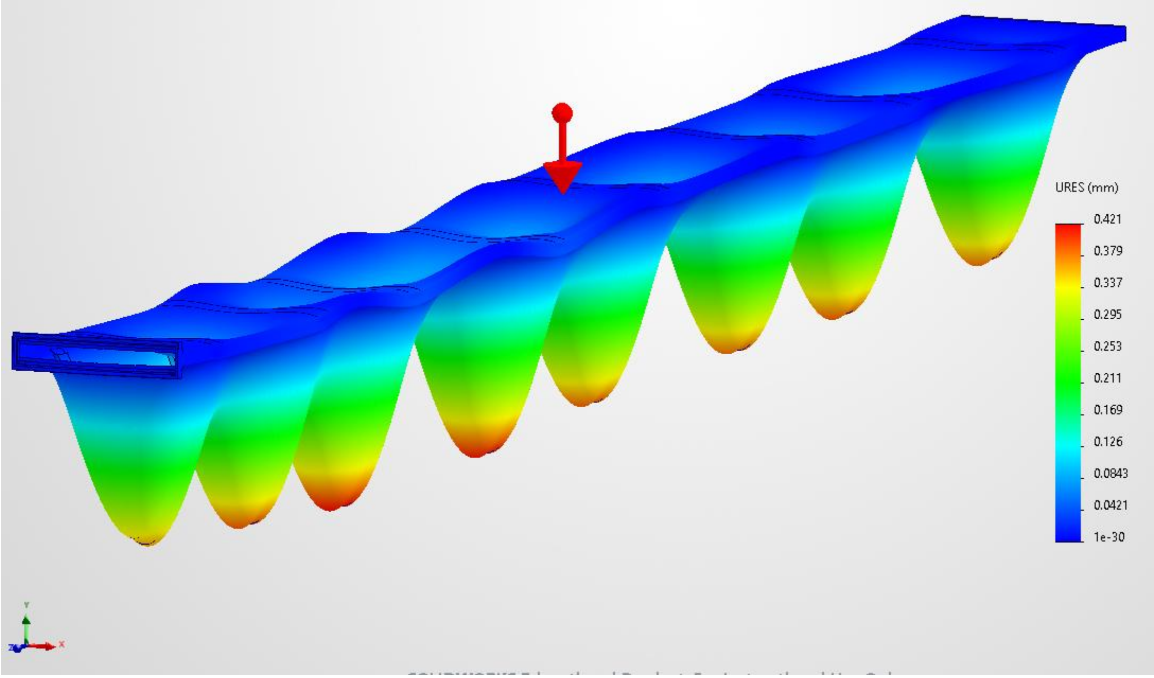
- Low material compared with an all-metal enclosure
- Good stiffness-to-weight potential
- Good dimensional stability when properly designed
- Detector-compatible direction for broad enclosure surfaces
- Avoids adding unnecessary aluminum over large areas



What still needs validation:

- Tooling, mold, and fabrication approach
- How precision datum/support features are implemented
- How button features are adjusted, fixed, and verified
- Assembly sequence for bars and lens gluing
- Gas sealing, leakage, and light-tightness details
- Local inserts, interfaces, and load introduction points
- Cost and schedule risk for full-length fabrication

All-Aluminum Study



Why it was useful:

- Simple material model for first-pass FEA
- Easy to machine, modify, and represent in CAD
- Good local precision for datum/support features
- Natural path for integrated rail or support features
- Helps identify deformation modes before detailed design

Why it is not the full answer:

- Material budget increases at detector scale
- Thermal expansion is higher than carbon fiber
- Full aluminum shell may add unnecessary mass
- Long precision structure still requires careful fabrication
- Does not automatically solve gas sealing, alignment, or assembly sequence

Key takeaway:

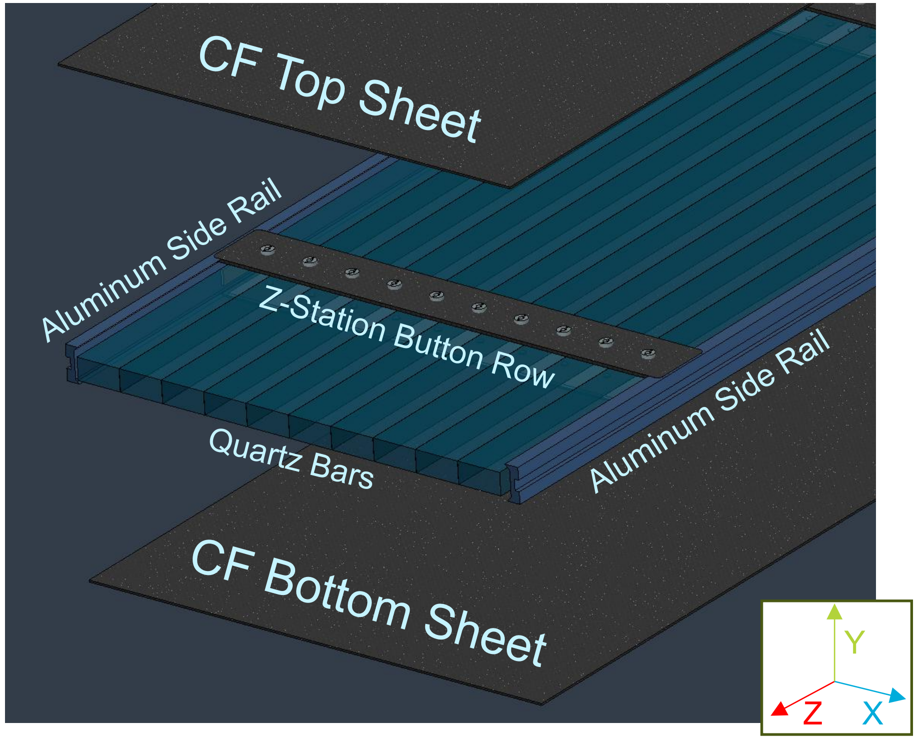
The all-aluminum model is useful for learning structural behavior, but not necessarily as the final construction approach.

Hybrid Approach

Concept:

<u>Use each material where it provides the most engineering value.</u>

- **Aluminum side members:**
  - Precision support and datum features
  - Button/preload interfaces
  - Local stiffness where loads enter the box
  - Potential integral rail/support features
  - Easier machining and design iteration
- **Carbon-fiber panels:**
  - Low-material enclosure surfaces
  - Good stiffness-to-weight potential
  - Reduced aluminum where it is not buying precision
  - Light-tight and gas-boundary surfaces, if detailed correctly
- **Why this direction:**
  - Avoids forcing one material to solve every problem
  - Keeps precision mechanical features manufacturable
  - Keeps radiation-length-sensitive surfaces low-material
  - Keeps costing, fabrication, and validation more modular



Rail Interface Opportunity

Inherited CAD condition:

- CAD appeared to use low-profile LPM17-style catalog sliders
- Existing checks appear to rely on that assumed rail concept
- Initial review raised concerns with load capacity, moment capacity, clearance, and rail length

Design opportunity:

- Since the bar box design was already being revisited, the rail interface was reconsidered at the same time
- A modified BaBar-style rail pattern was adapted to the hpDIRC box geometry
- Aluminum side extrusions can potentially act as integral rail features
- Bearing blocks may be moved outboard onto the GST/support structure

Current status:

- This is not yet a validated rail solution
- Analysis is still required
- GST/support deflection information is needed (and requested) to understand bearing-block misalignment under load