

# Global Integration

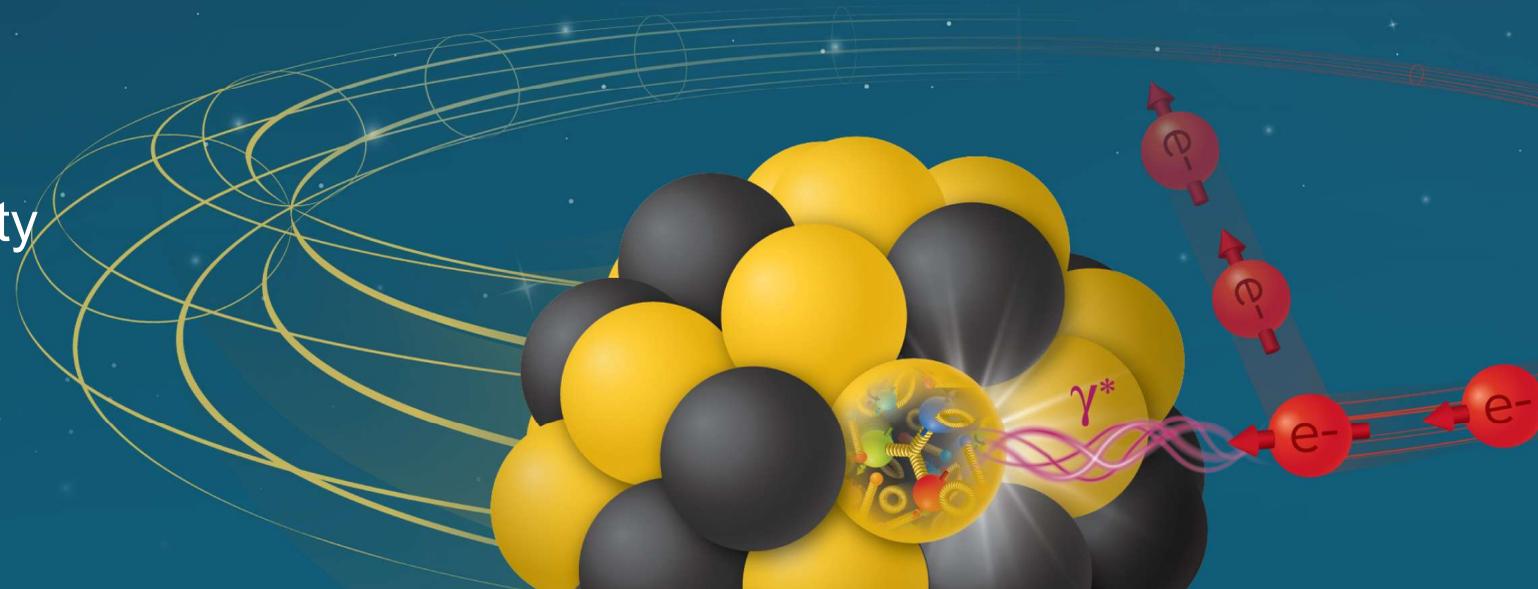
**Ben Denos**  
Engineer (Purdue University)

Andreas Jung, Sushrut Karmarkar

Incremental Preliminary Design and Safety  
Review of the ePIC MAPS Tracker

January <27/28>, 2026

Electron-Ion Collider

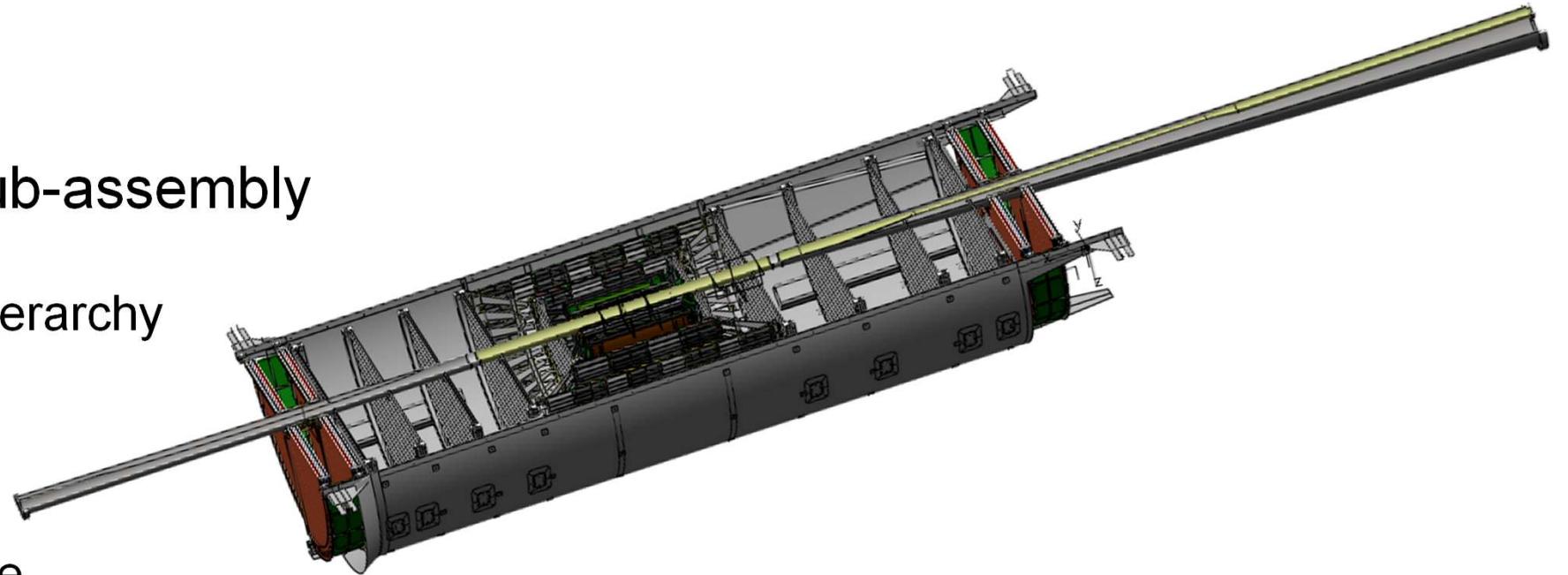


# Charges

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1. Are the technical performance requirements appropriately defined and complete for this stage of the project?
2. Are the plans for the various sub-systems appropriately documented and complete for this stage of the project?
3. Are the current plans for the detector likely to achieve the technical performance requirements, with a low risk for cost increases, schedule delays, and technical problems?
4. Are the schedule assumptions for the fabrication of the various sub-systems and assembly plans reasonable and consistent with the overall detector schedule?
5. Have ESH&Q and QA considerations been adequately incorporated into the plans at their present stage?
6. Have the recommendations from previous reviews been adequately addressed?

- Introduction
  - Management
  - SVT within ePIC
  - SVT sub-assemblies
- Beam pipe and SVT sub-assembly
  - Envelopes
  - Interfaces and support hierarchy
  - Loads
  - Services
- Integration
  - SVT integration sequence
  - Beampipe support requirements
  - Finite element analysis (FEA)
  - QA/QC of Structures
- Summary



# Regular Meetings and Updates

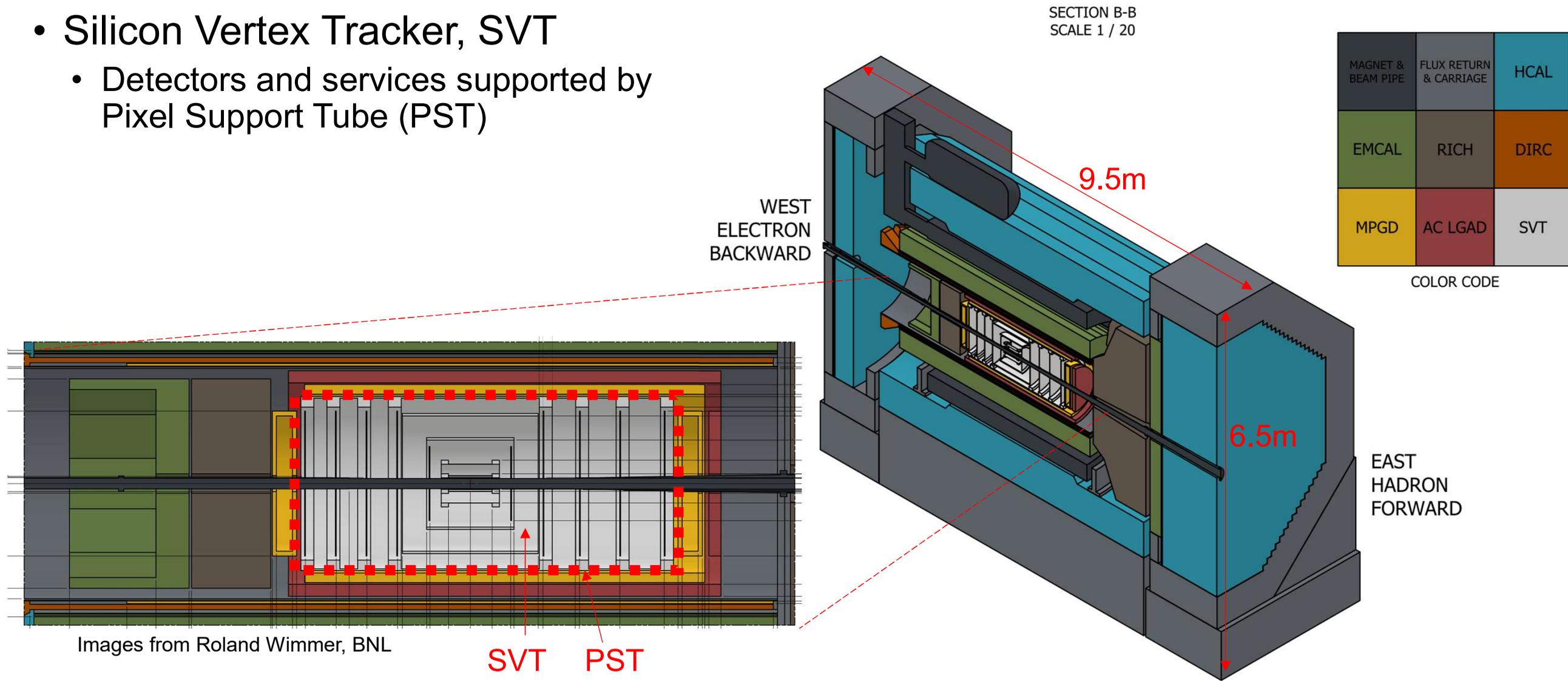
Charge 1,2

- Model and Data Sharing
  - CAD snapshots of all SVT components captured monthly in Google Drive
  - Originals or links to originals for services, loads, other common information also in Google Drive
- Communication: Meet every other week with WP4/WP6 working groups
  - <https://indico.bnl.gov/category/596/>
  - Coordinators and Co-conveners: Eric Anderssen (LBL), Andreas Jung (Purdue), Ben Denos (Purdue)
  - Inner Barrel: Rosario Turisi (INFN)
  - Outer Barrel: Georg Viehhauser (Oxford)
  - Disks, Connecting Cones, Services Routing and Integration: Nicole Apadula (LBL)
  - Pixel Support Tube, Structure Integration: Ben Denos (Purdue), Andreas Jung (Purdue)

# Introduction to Support Structure

Charge 2

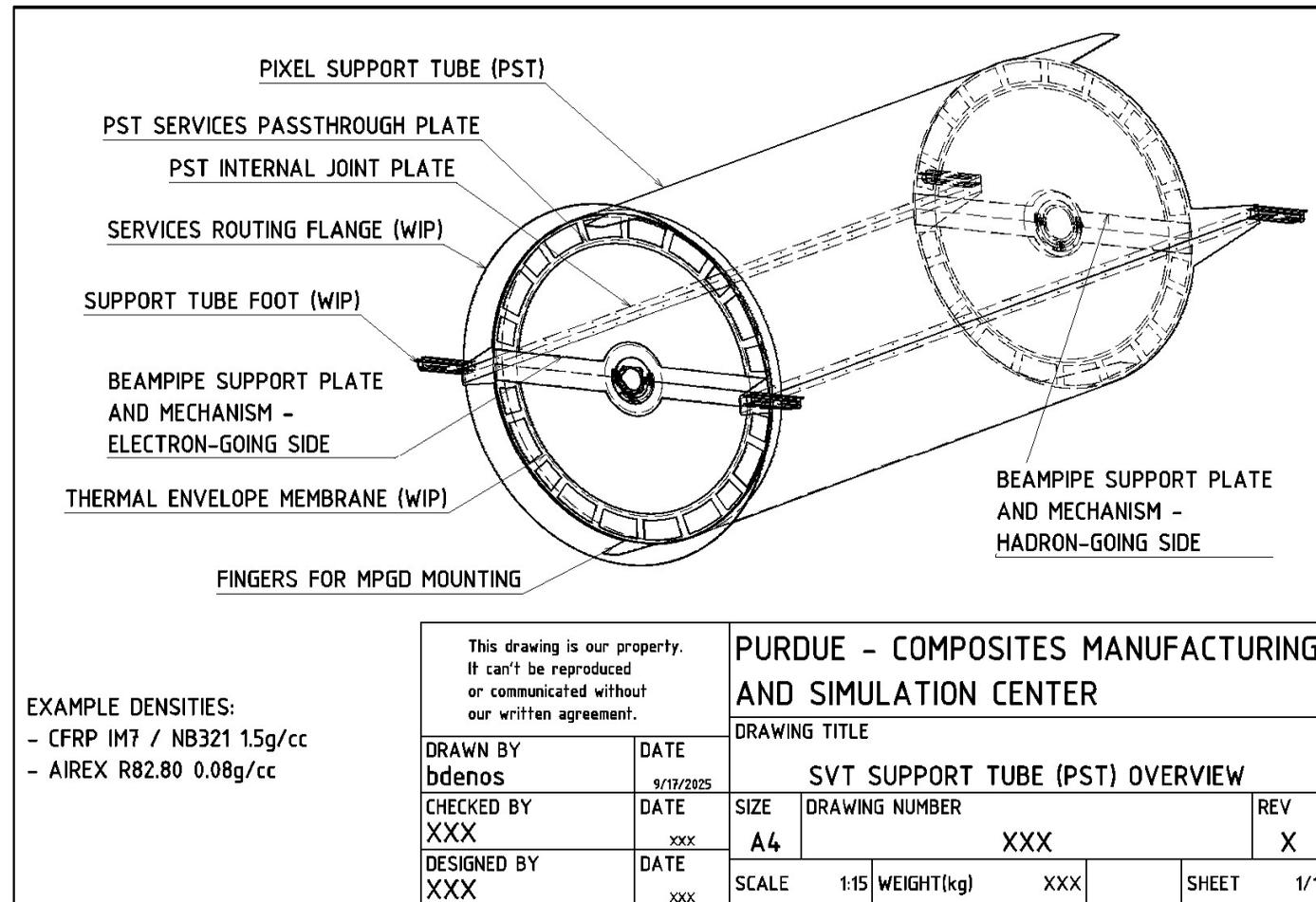
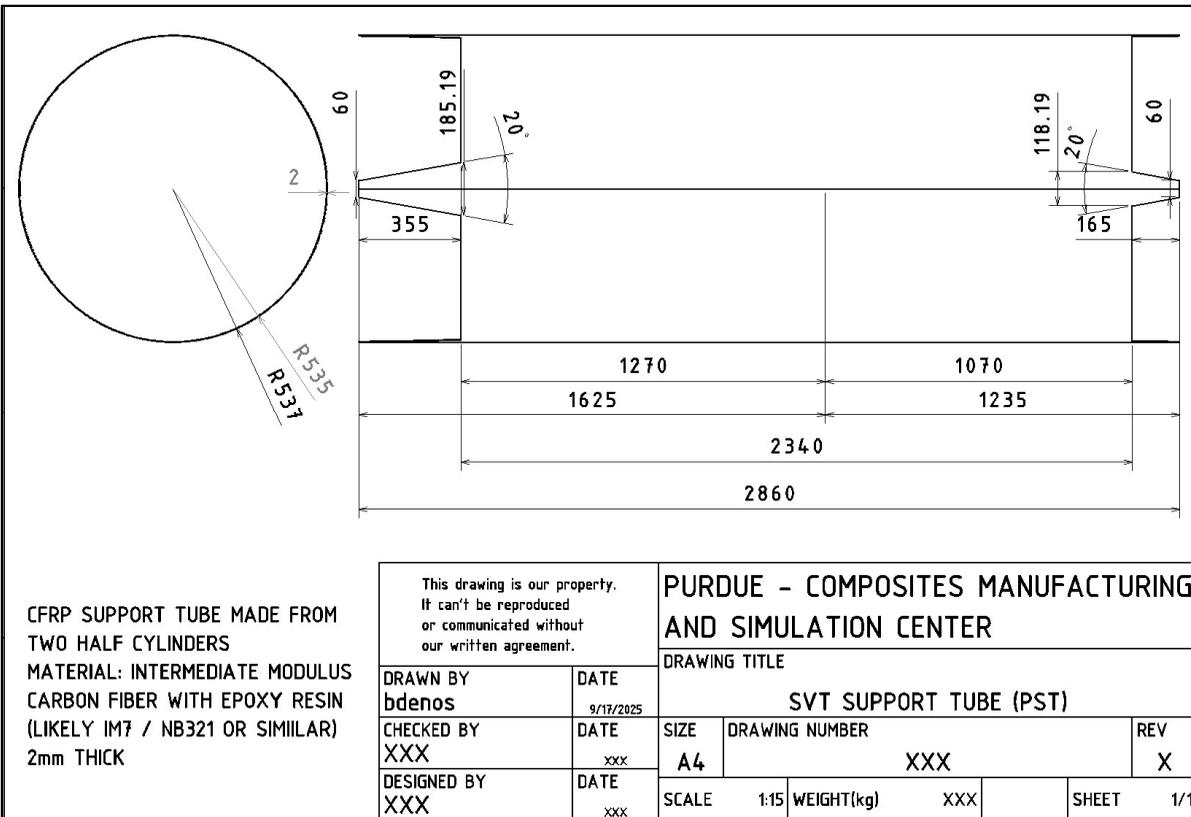
- Silicon Vertex Tracker, SVT
  - Detectors and services supported by Pixel Support Tube (PST)



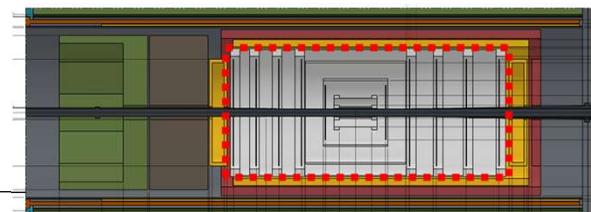
# Introduction to Support Structure

Charge 1,2

- Pixel Support Tube (PST) is 2860mm long
  - 2340mm of that is "full" cylinder
- 2mm thick CFRP laminate
- Assembled from upper and lower half cylinders
- Supports SVT, MPGD Disks
- Transfers load to GST rails via four "feet"

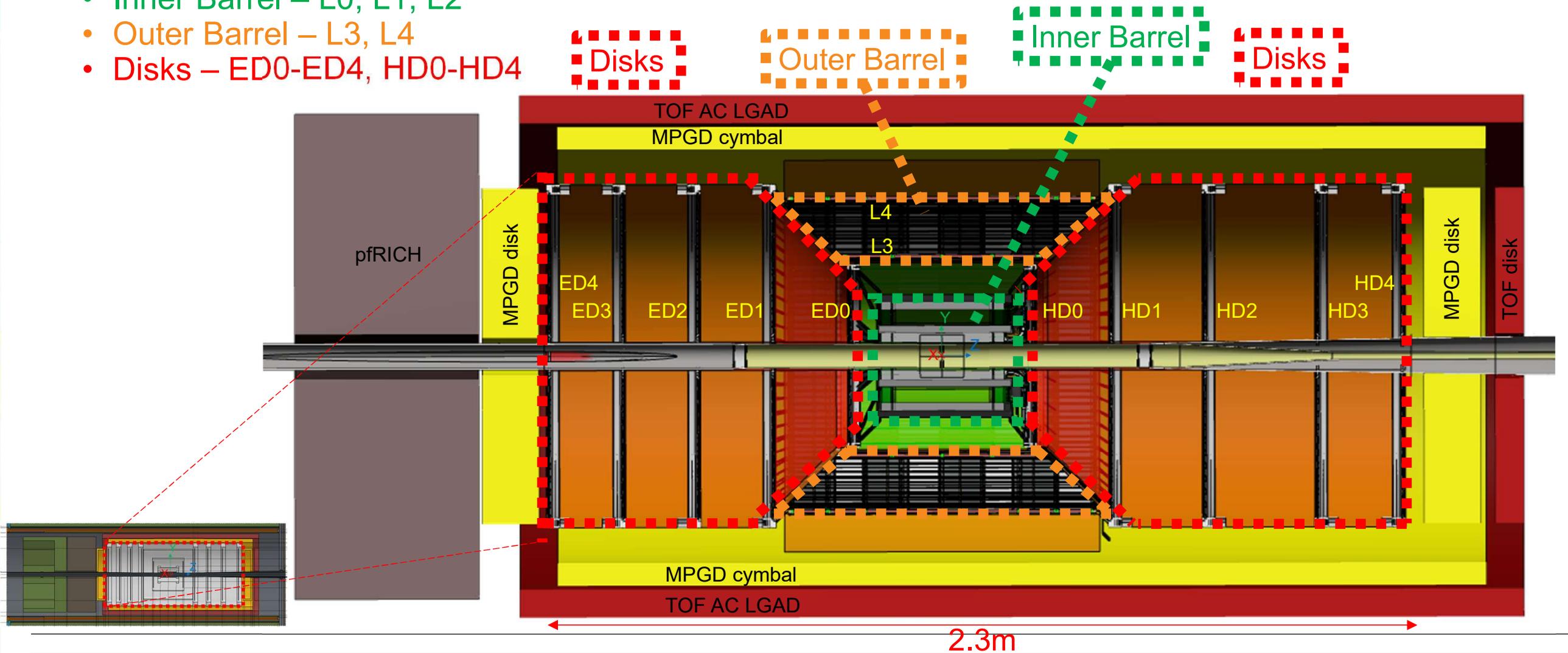


EXAMPLE DENSITIES:  
- CFRP IM7 / NB321 1.5g/cc  
- AIREX R82.80 0.08g/cc



# SVT Sub-Systems

- SVT Detectors
  - Inner Barrel – L0, L1, L2
  - Outer Barrel – L3, L4
  - Disks – ED0-ED4, HD0-HD4



# Sub-Assembly Design Status

Charge 2

## Inner Barrel

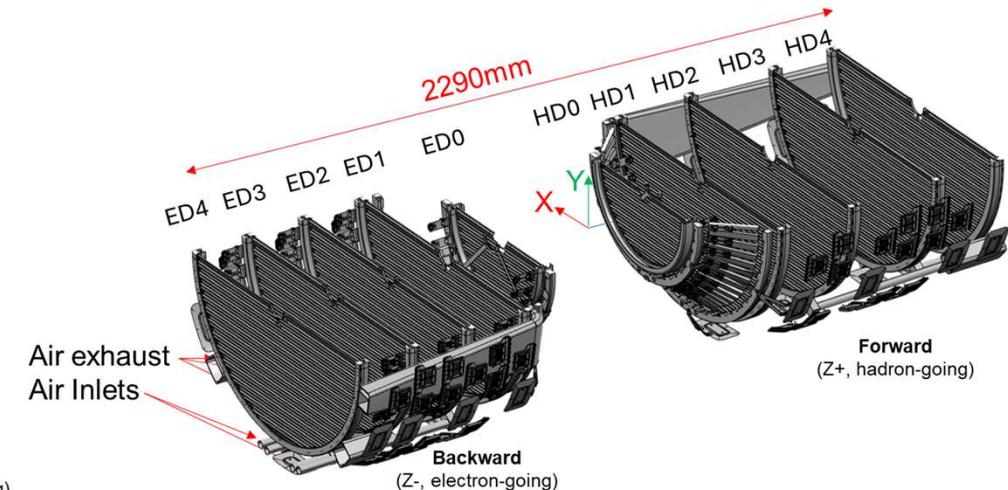
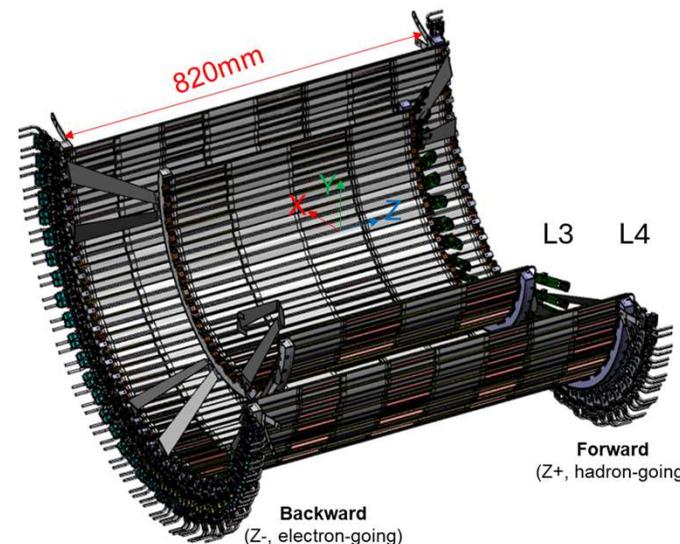
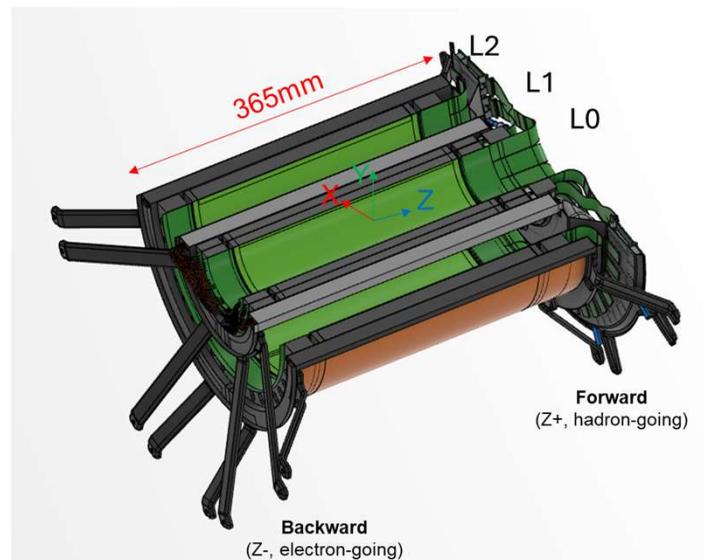
- Points of Contact
  - INFN - Rosario Turisi, Domenico Colella, Domenico Elia
- Mass Estimate ~2kg (no services)
- Model from Dec 2025

## Outer Barrel

- Points of Contact
  - UK (detector, services, controls) – Georg Viehhauser, Adam Huddart, James Glover
  - LBL (support cones) – Joe Silber, Elaine Buron
- Mass Estimate ~7kg (no services)
- Model from Jan 2026

## Disks

- Points of Contact
  - LBL - Nicole Apadula, Joe Silber, Elaine Buron
- Mass Estimate ~28kg (no services)
- Model from Dec 2025



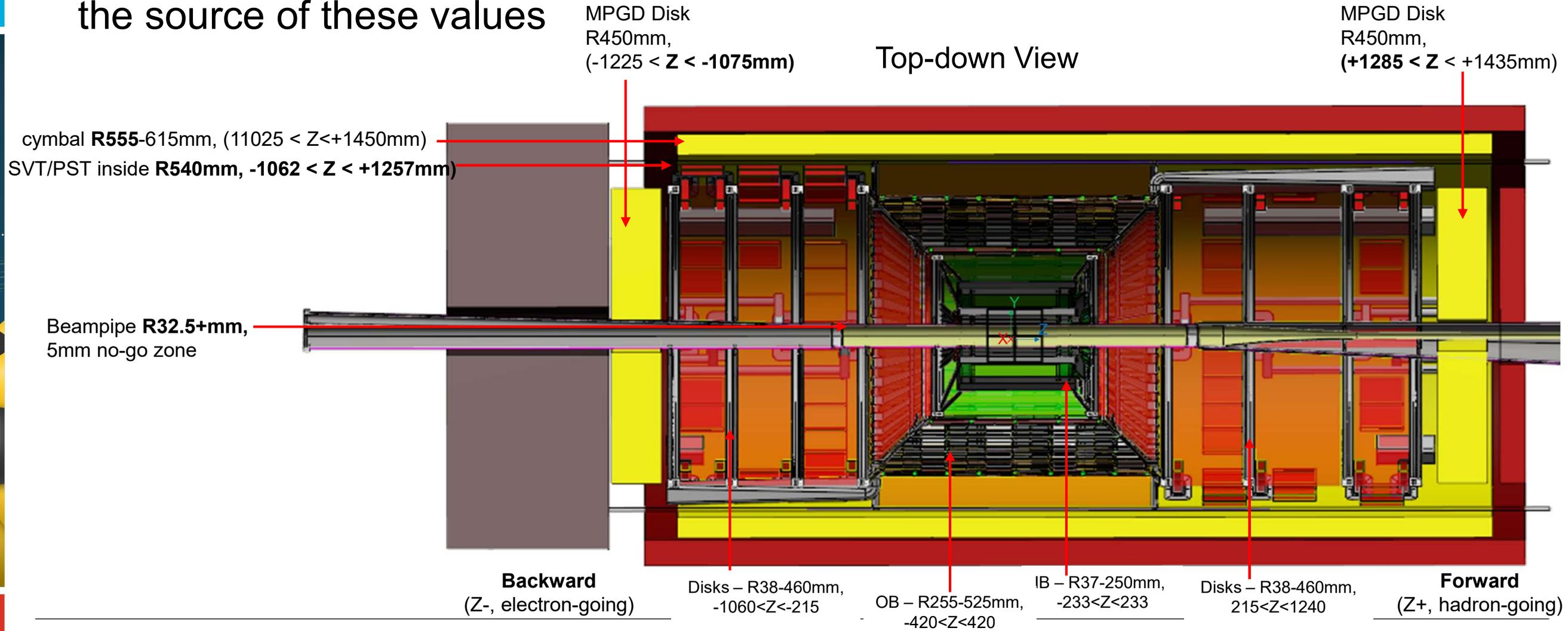
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# Presentation Section 1: Beam pipe and SVT sub-assembly

# SVT Envelopes

Charge 1,2

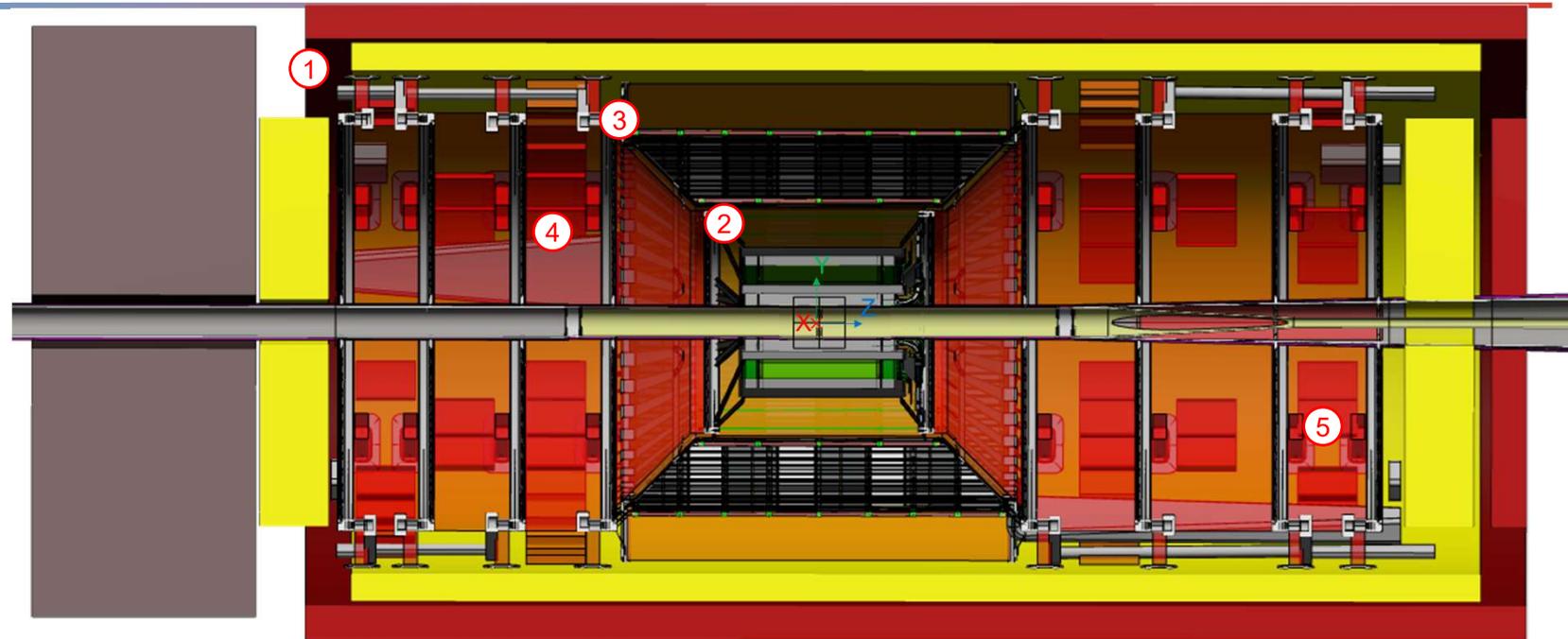
- Shared CAD assembly is the source of these values



# Envelope Interferences

Charge 1,2

- Known areas of overlap or proximity to monitor
  - At sub-assembly interfaces where supports connect
  - All seen as addressable
- 1. Services pinch point at PST exit
- 2. Inner barrel cone supports to outer barrel cone supports
- 3. Outer barrel cone supports to disk support
- 4. Control boards near air exhaust
- 5. Control boards near disk-to-PST connections (size, count, and positioning being refined)



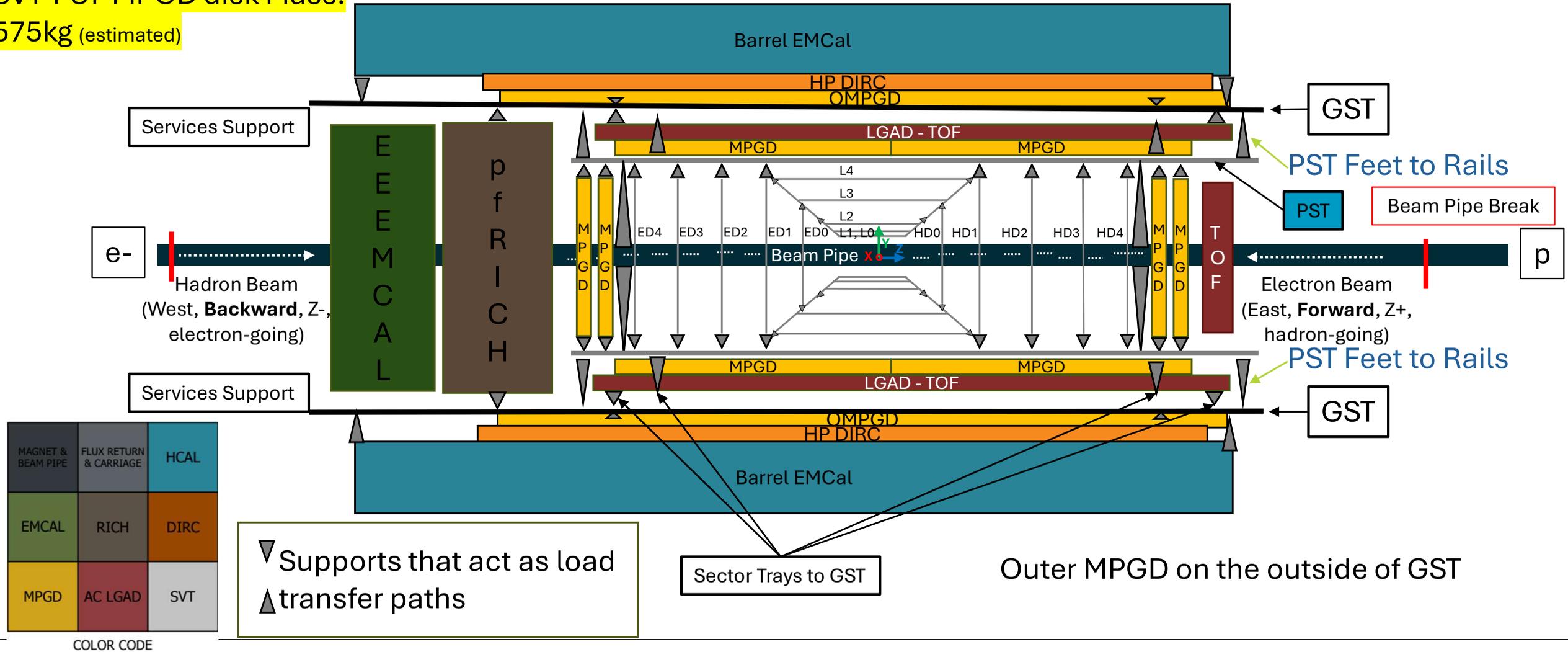
# SVT Detector Support Hierarchy Y-Z View

Charge 1,2

NOT TO SCALE

SVT-PST-MPGD disk Mass:

575kg (estimated)



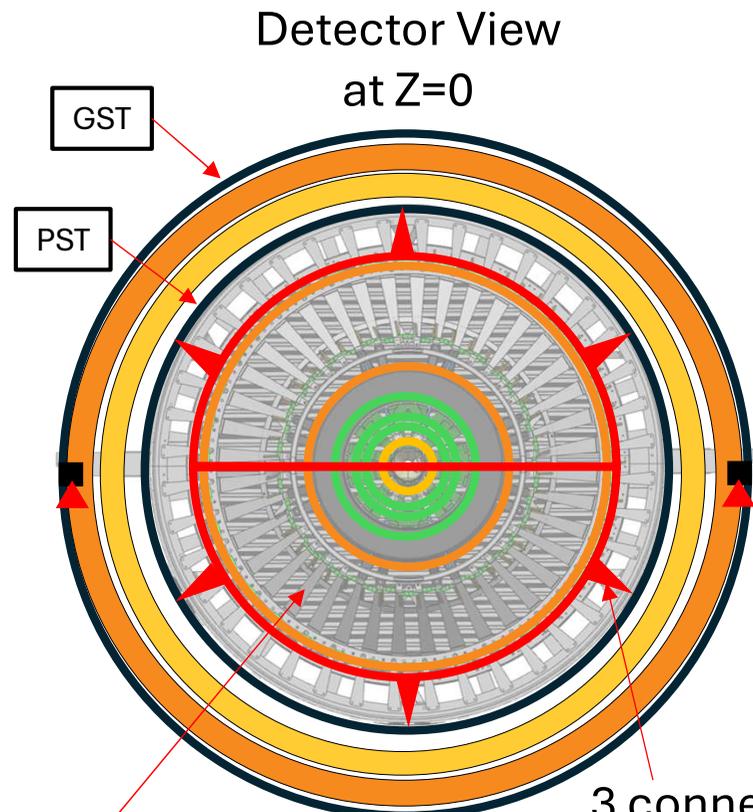
Electron-Ion Collider

ePIC SVT PDR2, January 27 and 28, 2026

Ben Denos

# SVT Detector Support Hierarchy X-Y View

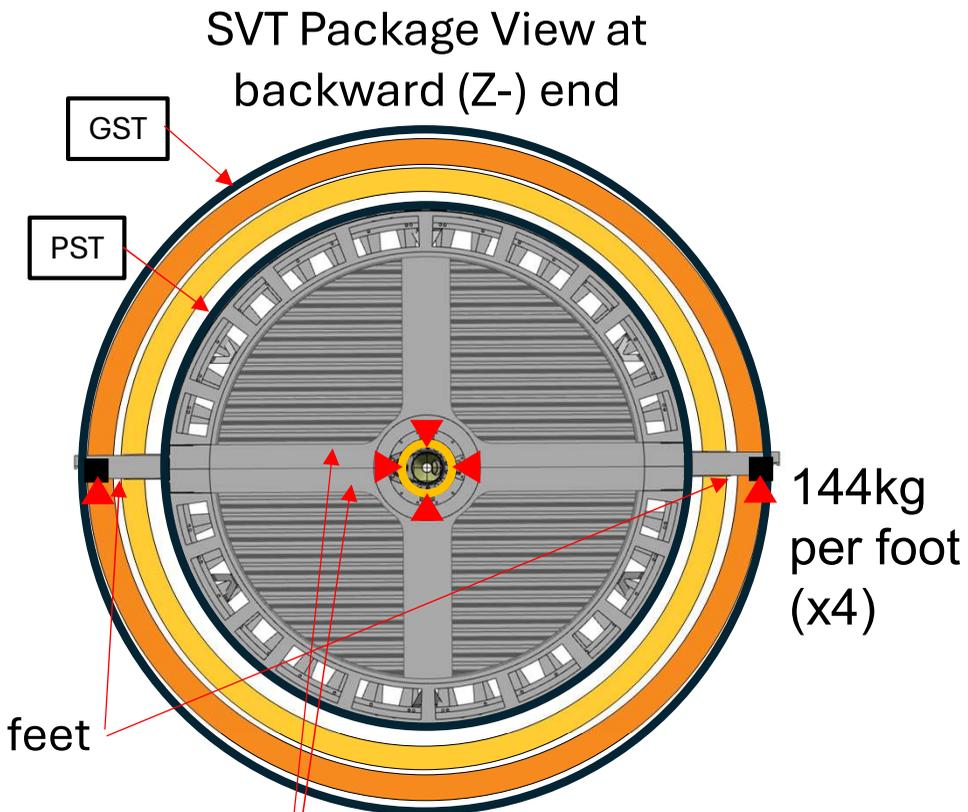
NOT TO SCALE  
 SVT-PST-MPGD disk Mass:  
 575kg (estimated)



Key:

- Beam Pipe
- Inner Barrel
- Outer Barrel
- SVT Disks
- Composite Support Tube
- MPGD cymbal
- LGAD TOF

▲ Support  
 ■ Rail



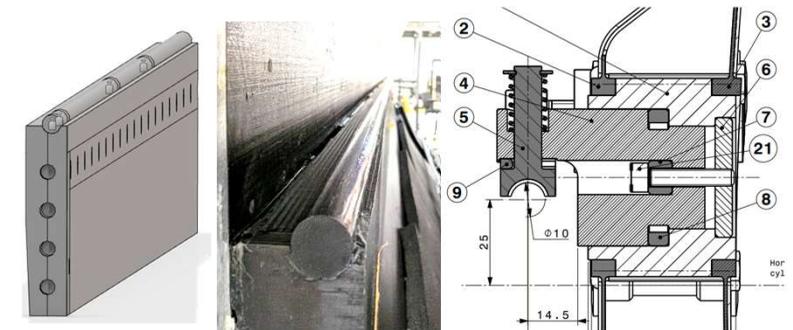
Barrel connection radial "cone" attachments seen in gray

3 connections per SVT half-disk to PST

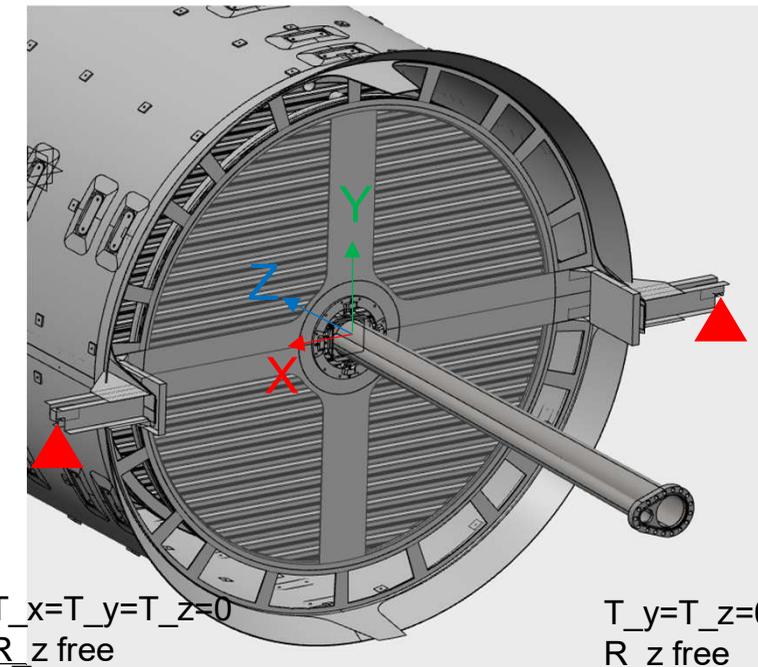
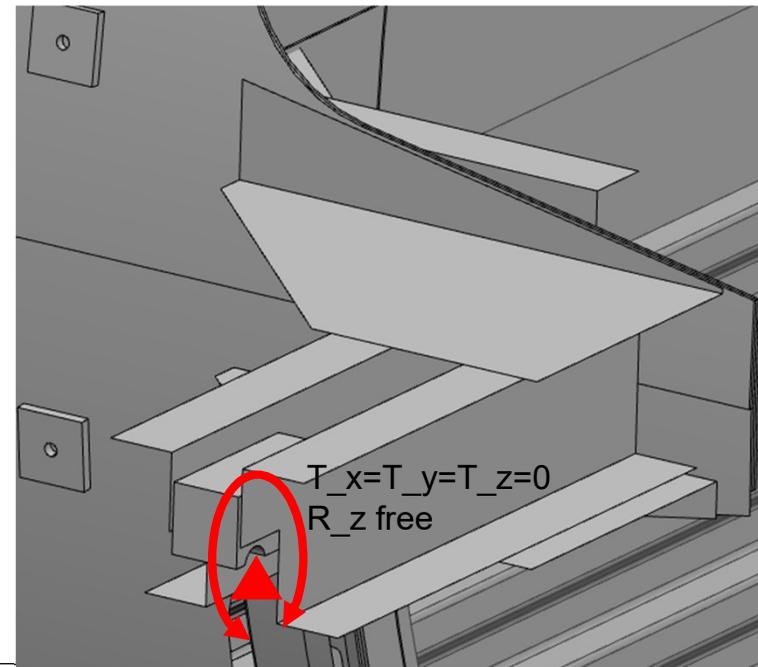
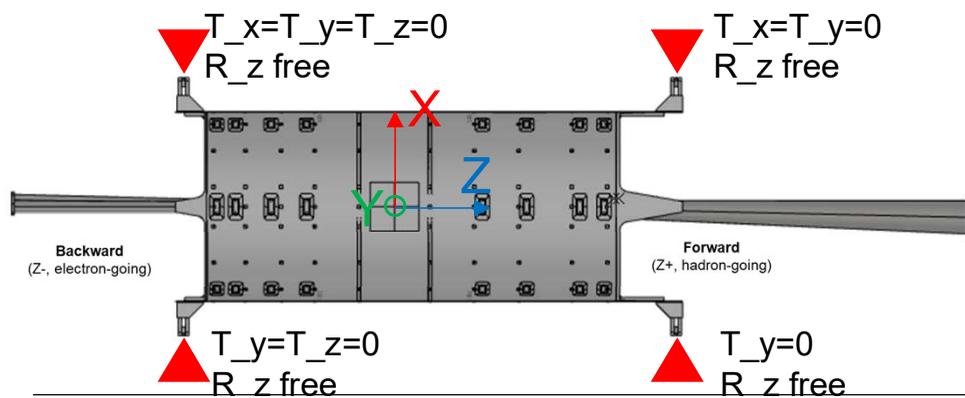
Beampipe support plates (attached to PST halves and each other)

# PST Feet

- Primary load transfer of SVT-PST-MPGD disk package: 575kg
- Two feet at each end 3 and 9 o'clock positions: 144kg each
- Extend further outward in Z to avoid cymbal and TOF
- Aluminum block with Delrin sleeve rests on GST rails
- Install after joining SVT half-cylinders, mechanical fasteners
- Z+ end removable in detector for cymbal/TOF install
- Structure needs refinement to resist twisting of PST extended "fingers"



CMS HL Upgrade BTST tracker support rails with 10mm carbon fiber rod on solid CFRP rail. [TB2S foot design](#)



# SVT Masses and Loads

Charge 1,2

- Current estimate:
  - ~350kg of detector, services
  - ~30kg beampipe
  - ~30kg PST structure
  - ~150kg MPGD disk
- ~560kg Total Package

- Table in progress

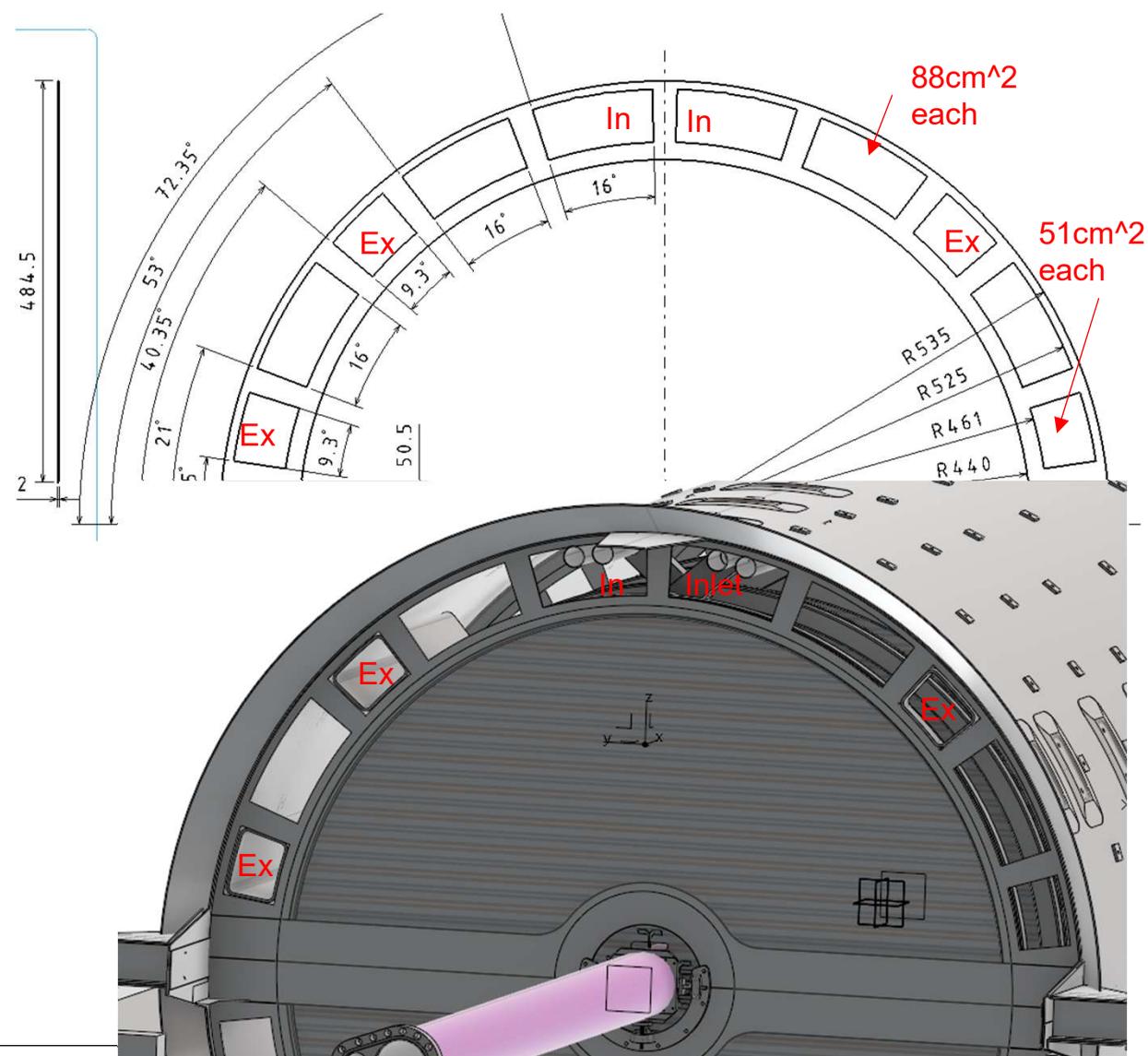
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Subsystem	Object	Mass (kg)	Equiv Force (N)	Source
Disks	ED0	2.00	19.62	Ben estimate
Disks	ED1	3.00	29.43	Ben estimate
Disks	ED2	3.00	29.43	Ben estimate
Disks	ED3	3.00	29.43	Ben estimate
Disks	ED4	3.00	29.43	Ben estimate
Disks	HD0	2.00	19.62	Ben estimate
Disks	HD1	3.00	29.43	Ben estimate
Disks	HD2	3.00	29.43	Ben estimate
Disks	HD3	3.00	29.43	Ben estimate
Disks	HD4	3.00	29.43	Ben estimate
Inner Barrel	L0	0.43	4.26	Padova estimate
Inner Barrel	L1	0.65	6.41	"
Inner Barrel	L2	0.79	7.71	"
Outer Barrel	L3	2.50	24.53	Adam notes
Outer Barrel	L4	4.00	39.24	Adam notes
<b>DETECTOR STRUCTURES TOTAL</b>		<b>36.37</b>	<b>356.82</b>	
Inner Barrel	Services in PST	20.00	196.20	Ben estimate
Outer Barrel	Services in PST	90.00	882.90	Ben estimate
Disks	Services in PST	180.00	1,765.80	Ben estimate
Inner Barrel	RDO, Cards	5.00	49.05	Ben estimate
Outer Barrel	RDO, Cards	5.00	49.05	Ben estimate
Disks	RDO, Cards	10.00	98.10	Ben estimate
<b>SERVICES TOTAL</b>		<b>310.00</b>	<b>3,041.10</b>	
<b>Air Inlets</b>		<b>5.00</b>	<b>49.05</b>	Ben estimate
<b>Air Outlets</b>		<b>5.00</b>	<b>49.05</b>	Ben estimate
<b>Beampipe</b>		<b>30.00</b>	<b>294.30</b>	<b>CAD with SS 304 and beryllium</b>
PST	Cylinder	24.06	236.00	CAD based on area
PST	Feet (x4)	4.60	45.13	CAD based on area
PST	End plates/supports	2.14	21.99	CAD based on area
PST	joint plates	1.07	10.49	CAD based on area
<b>PST TOTAL</b>		<b>31.86</b>	<b>312.59</b>	
MPGD Disk	MPGD disk E	<b>75.00</b>	<b>735.75</b>	verbal, Rosario
MPGD Disk	MPGD disk H	<b>75.00</b>	<b>735.75</b>	verbal, Rosario
<b>SVT Total</b>		<b>418.24</b>	<b>932.63</b>	
<b>SVT +MPGD Total</b>		<b>568.24</b>	<b>5,574.41</b>	

Electron-Ion Collider

# Services pass through plate

- Services cross section needed for **half of one end** is  $876/2 = 438\text{cm}^2$
- **Design at right has plenty of space**
  - Cut out area =  $825\text{cm}^2$
  - Exhaust fills  $54 \times 3 = 162\text{cm}^2$
  - Air inlets use  $5.1 \times 4 = 21\text{cm}^2$
  - Wires, services need  $343\text{cm}^2$ , have fully available:
    - $51\text{cm}^2$  (x1)
    - $88\text{cm}^2$  (x4) = 352
    - + Extra space at inlet openings also
- Alternative view, if limited to R460-511 by CBs
  - IB needs  $2.4^\circ$  of phi
  - OB needs  $14^\circ$  of phi
  - Disks need  $22^\circ$  of phi

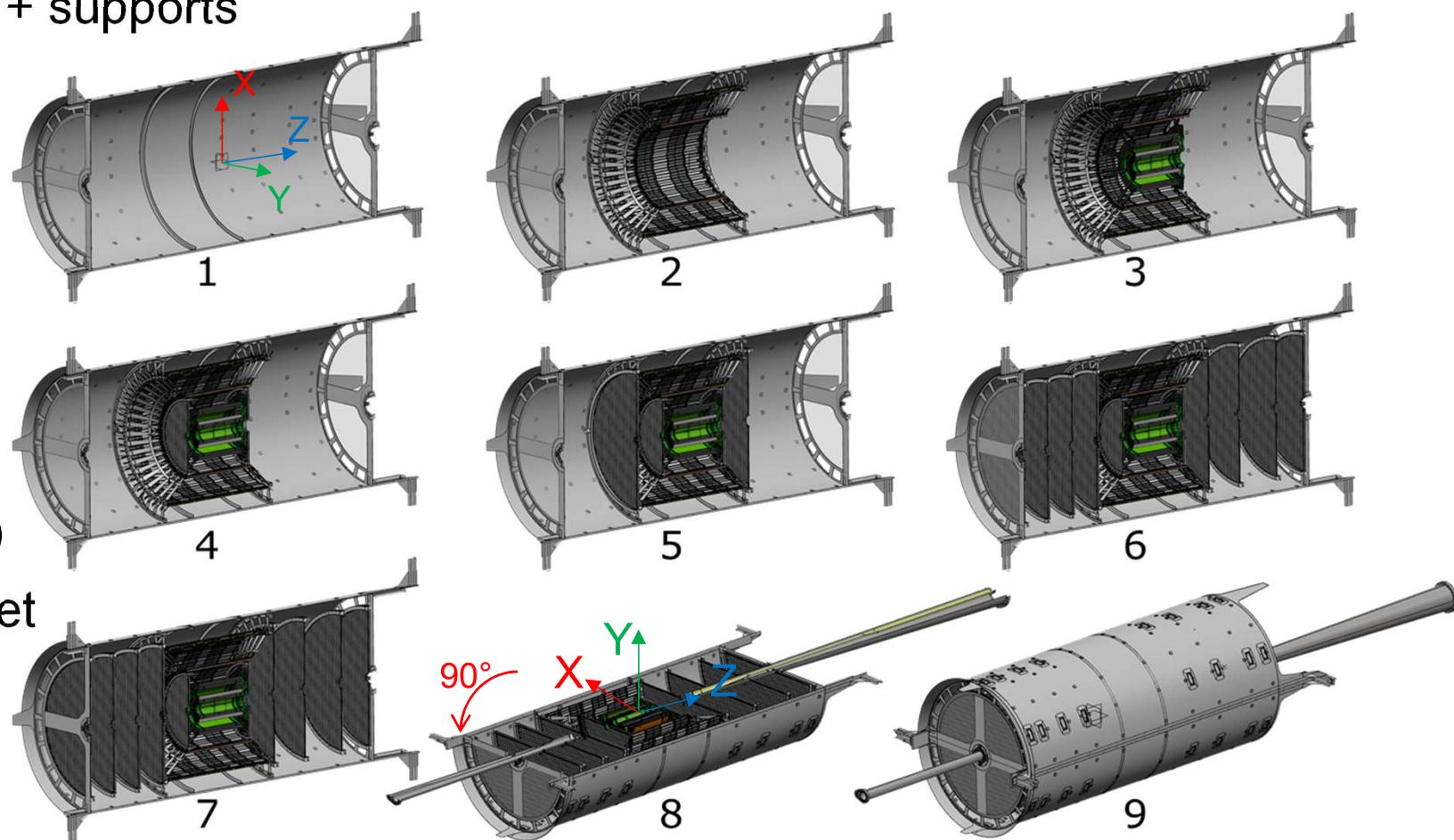


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# Presentation Section 2: Integration and Mechanical Simulation

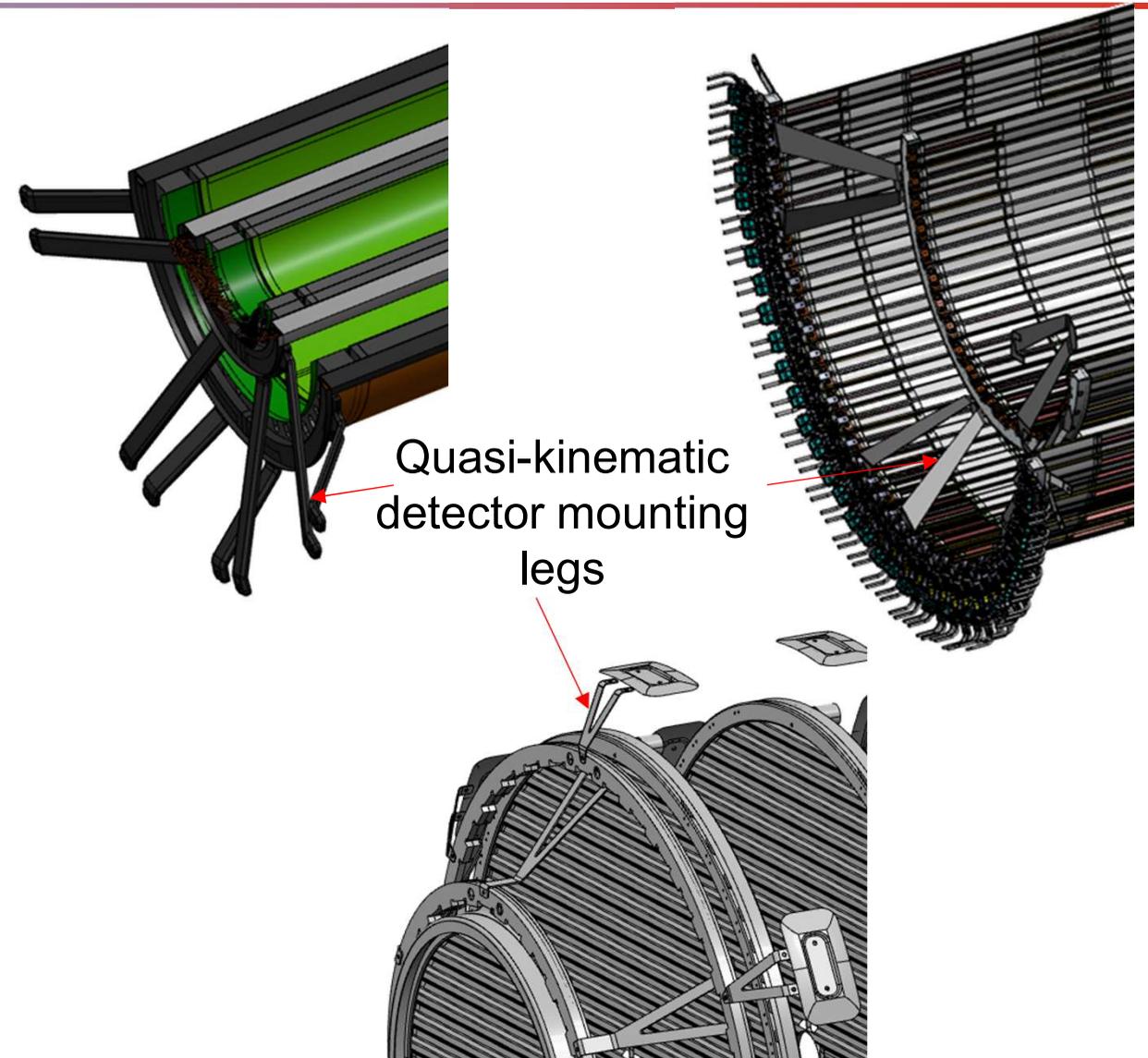
# SVT Integration Sequence

1. PST Half Cylinder secured in assembly cradle, use PST external connection points to keep shape
2. Outer barrel + boards + services + supports
3. Inner barrel + b + s
4. Disk 0 (ED0 and HD0) + b + s
5. Disk 1 on each side + b + s
6. Disk 2 - 4 on each side + b + s
7. Thermal barrier at each end
8. Beampipe install and adjust (orientation could be rotated 90°)
9. Close SVT-PST package, add feet



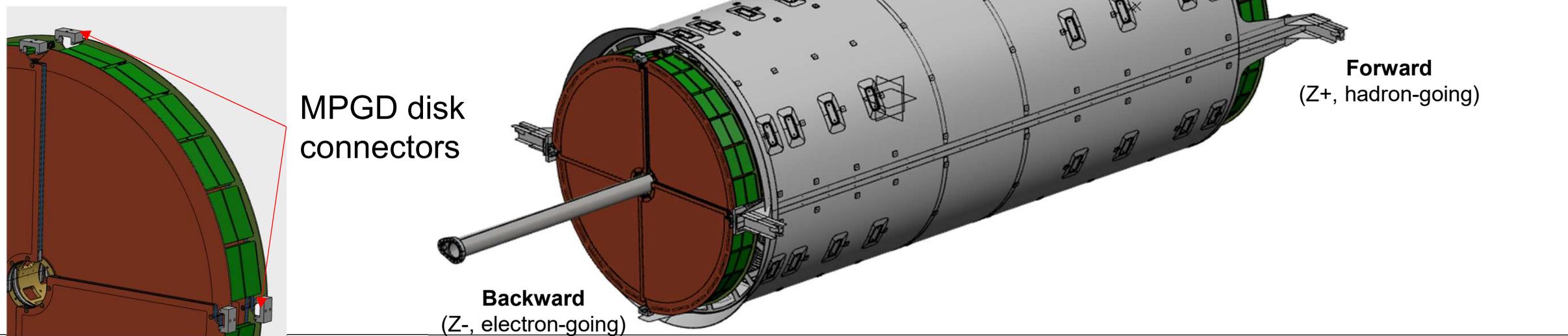
# Integration Considerations – Validate and Protect

- (Sub)system level tests of thermal, signal, cooling, etc. planned between integration steps shown
- Appropriately robust detector mount designs prevent load transfer from PST and mitigate risks from any collisions
  - Disk connecting “bipod” legs are quasi-kinematic and allow some freedom in Z direction
  - Cone connectors for barrel allow some freedom in Z direction
- Air cooling flow inside PST will need to be modeled to prevent unwelcome structure excitations
- Mockup of services guides inside and outside PST needed



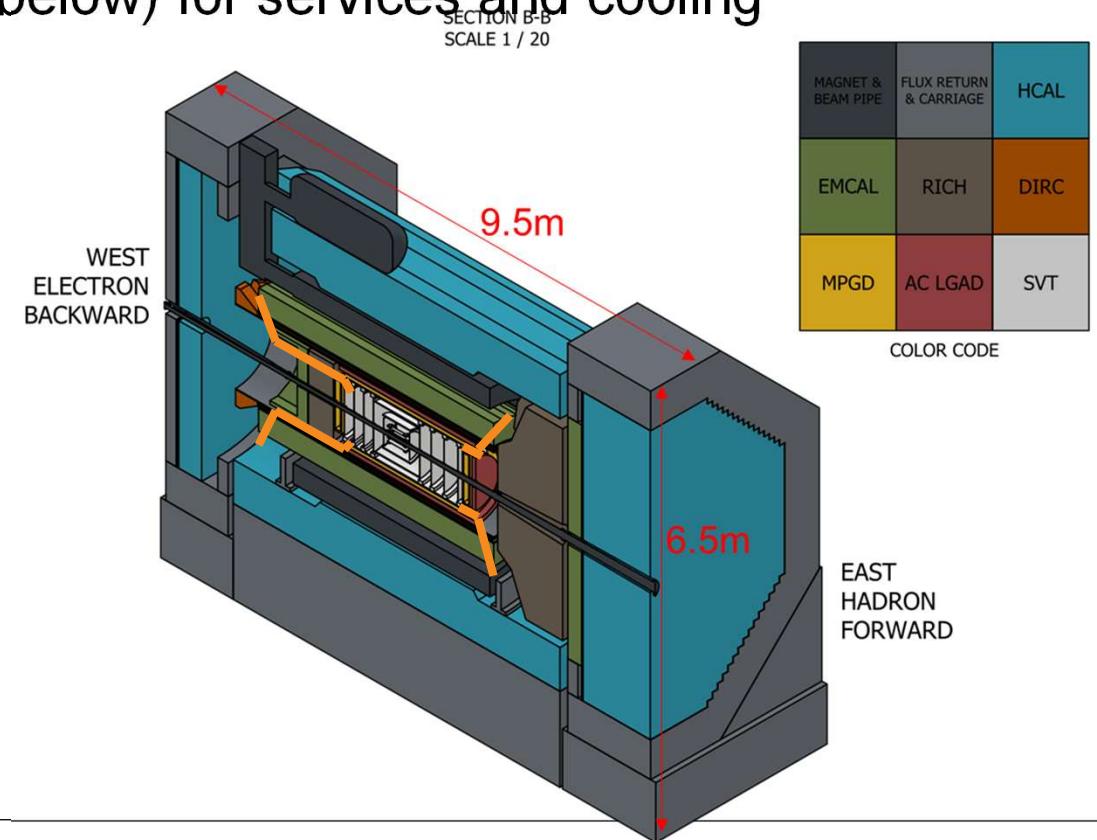
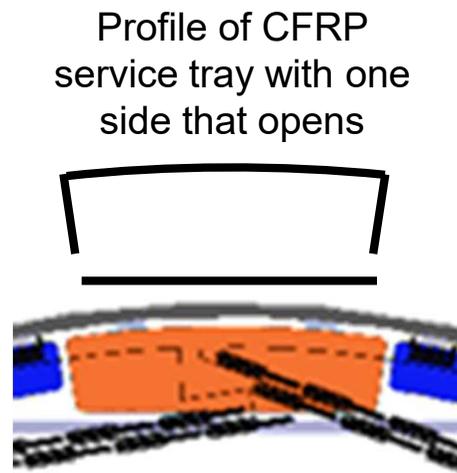
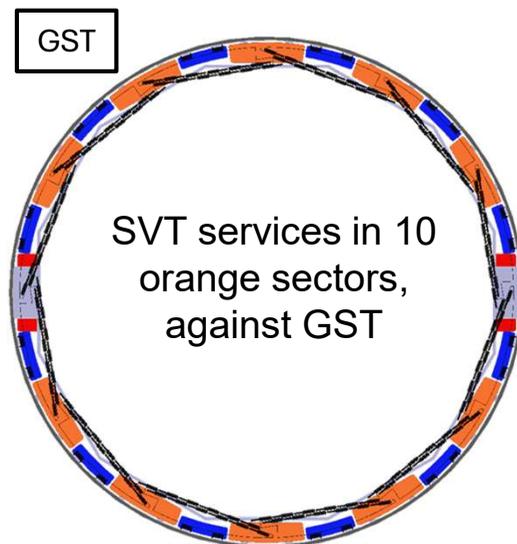
# MPGD Disks Added

- Attach to PST after SVT cylinder closed, beampipe installed
  - Carry most weight at 3 and 9 o'clock "fingers"
  - Positional attachment at 12 and 6 o'clock
- Extra 75kg at each end
- Re-measure beampipe position
  - Consider making beampipe centering mechanism accessible after this
  - OR put dummy weights in place to check final position
- Just mention locations of mount points



# Services Outside PST

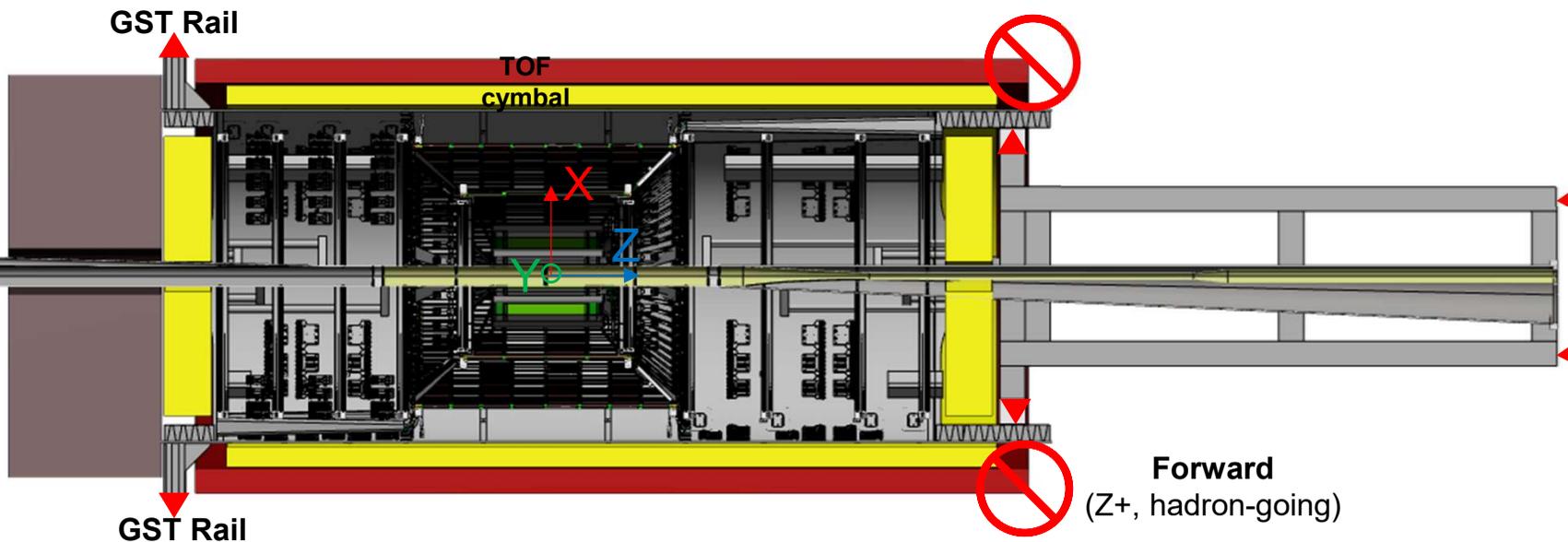
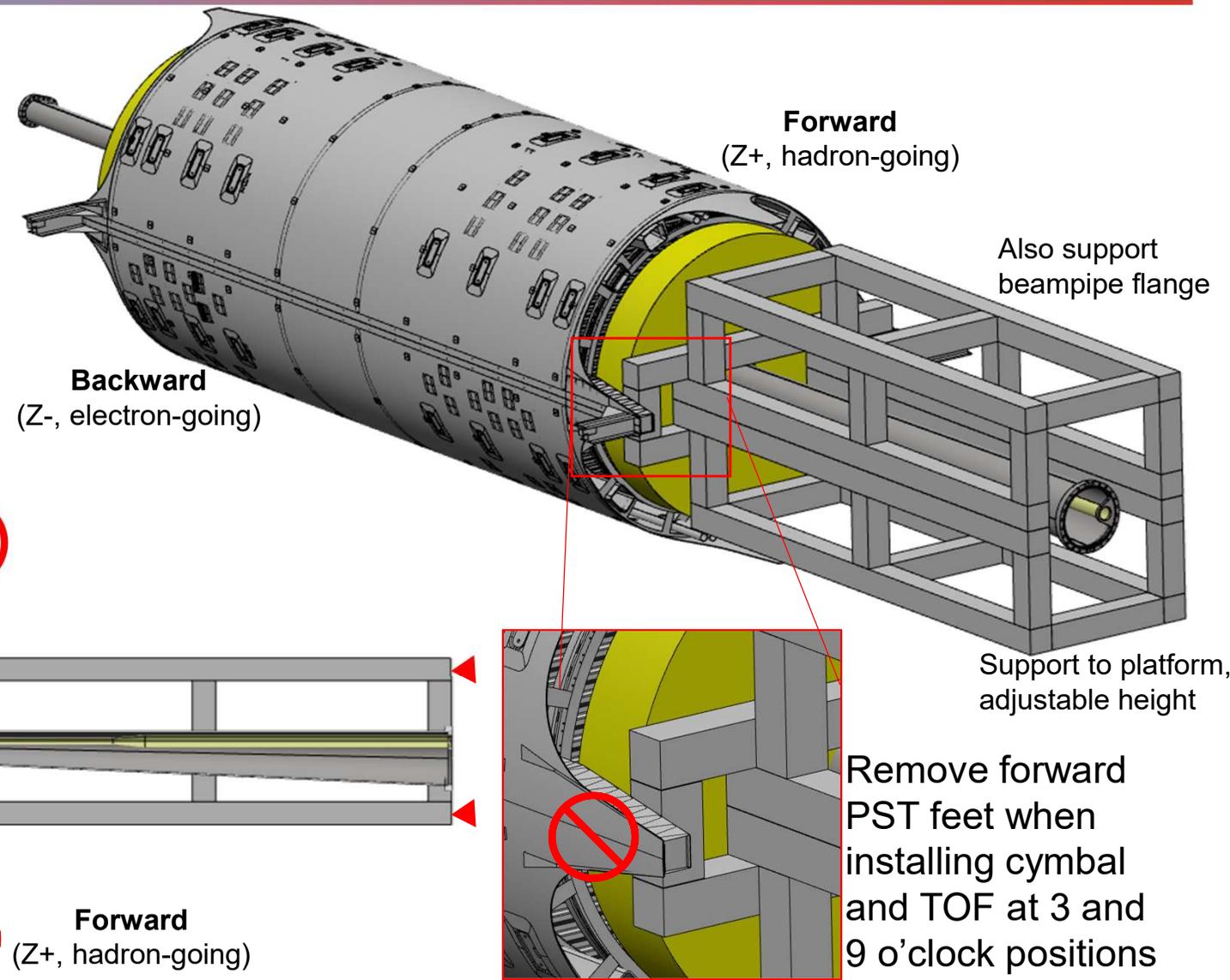
- ~100kg estimate for all services, cooling, exhaust between exit of PST and HPDIRC patch panel
  - Temporary support frames needed while assembling each SVT half
- Backward, electron-going side needs rigid supports/channels once SVT halves assembled
  - Also needs temporary support while inserting into GST
- Space for 10 sectors designated inside GST (orange, below) for services and cooling
  - See global talks
- No patch panel until outside HPDIRC



# PST Supports During TOF/cymbal Install

Charge 3

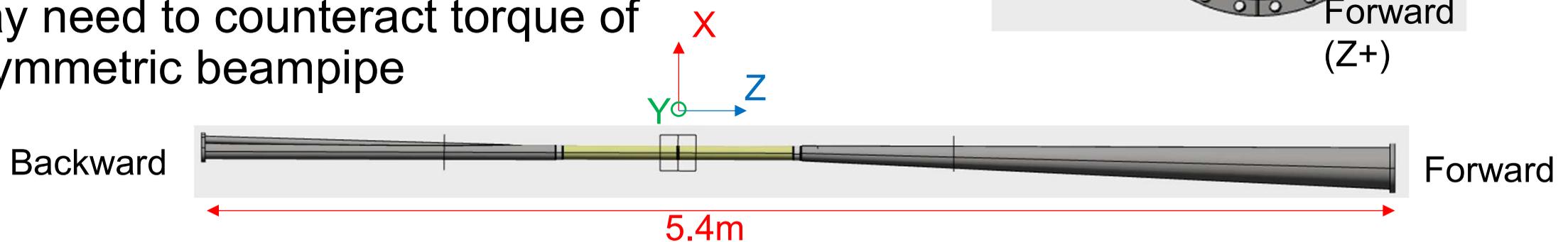
- PST “feet” on forward side need to be temporarily removed while TOF and cymbal sectors at 3 and 9 o’clock are installed
- Use temporary “tower” extension on forward end
  - May already be in place to support beampipe
- Or temporary, direct connections to GST at locations away from 3 and 9 o’clock
  - But need to avoid services already placed



# Beampipe Physical Centering Requirements

Charge 1,3

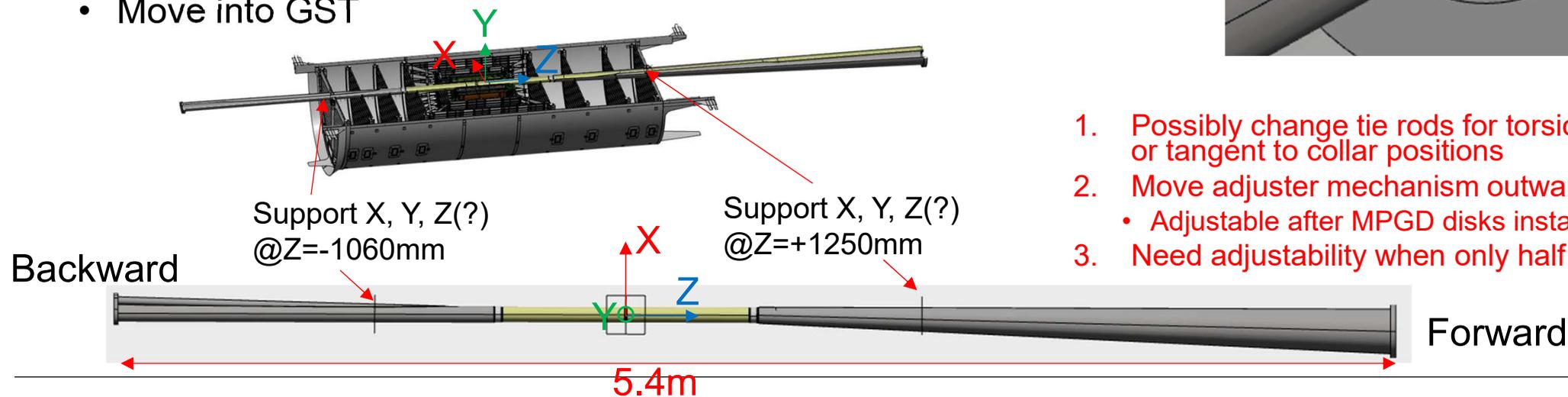
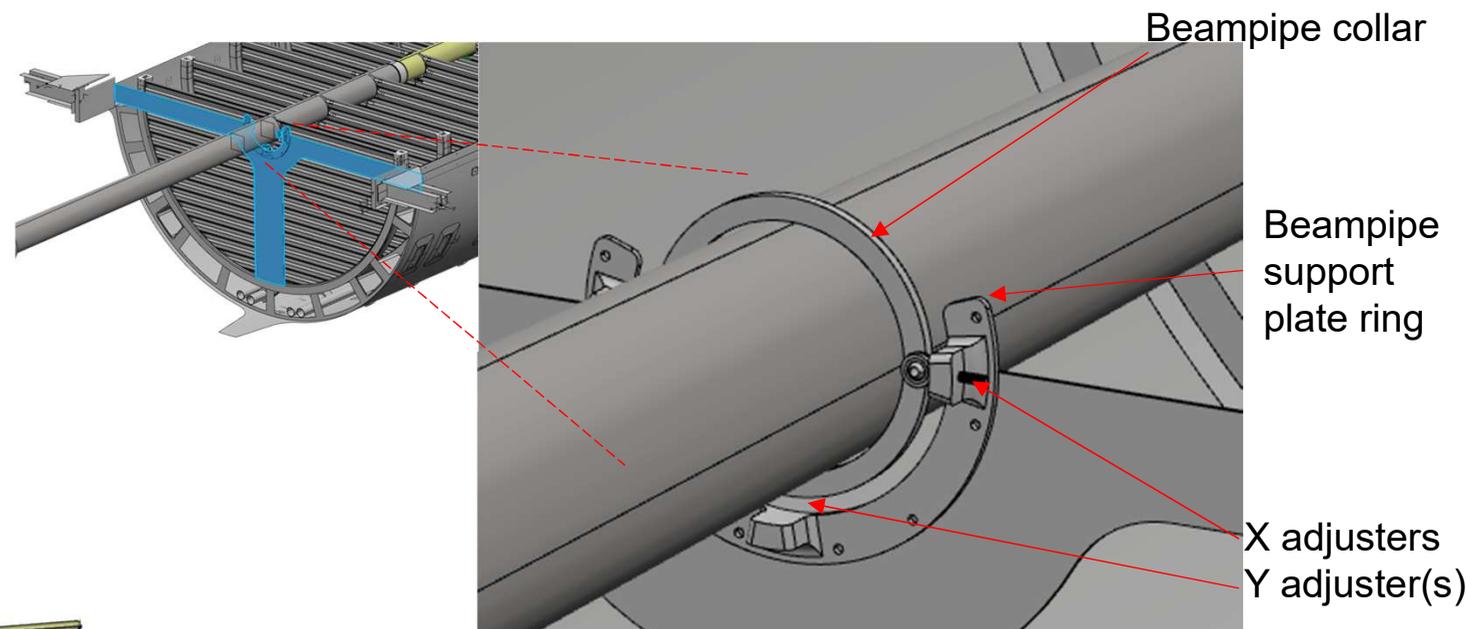
- Beryllium + Stainless Steel  
Beampipe must be installed in half cylinder and aligned to SVT at step 8 on previous slides
- Position tolerance X, Y +/-1mm , Z +/-5mm
- Rotation tolerance +/-1mrad
- Keep 5mm no-go zone around beampipe
- May need to counteract torque of asymmetric beampipe



# Beampipe Implementation in PST

- Beampipe team will weld collars at given Z locations for X, Y, and Z adjustment
  - Just outside SVT disks in Z
  - Provide adjustability – X,Y +/-3mm , Z +/-5mm
- Need to counteract torque of asymmetric beampipe
- Temporary support(s) considered for free ends
  - During SVT assembly – but allow centering
  - After complete SVT
  - Move into GST

- Initial design below



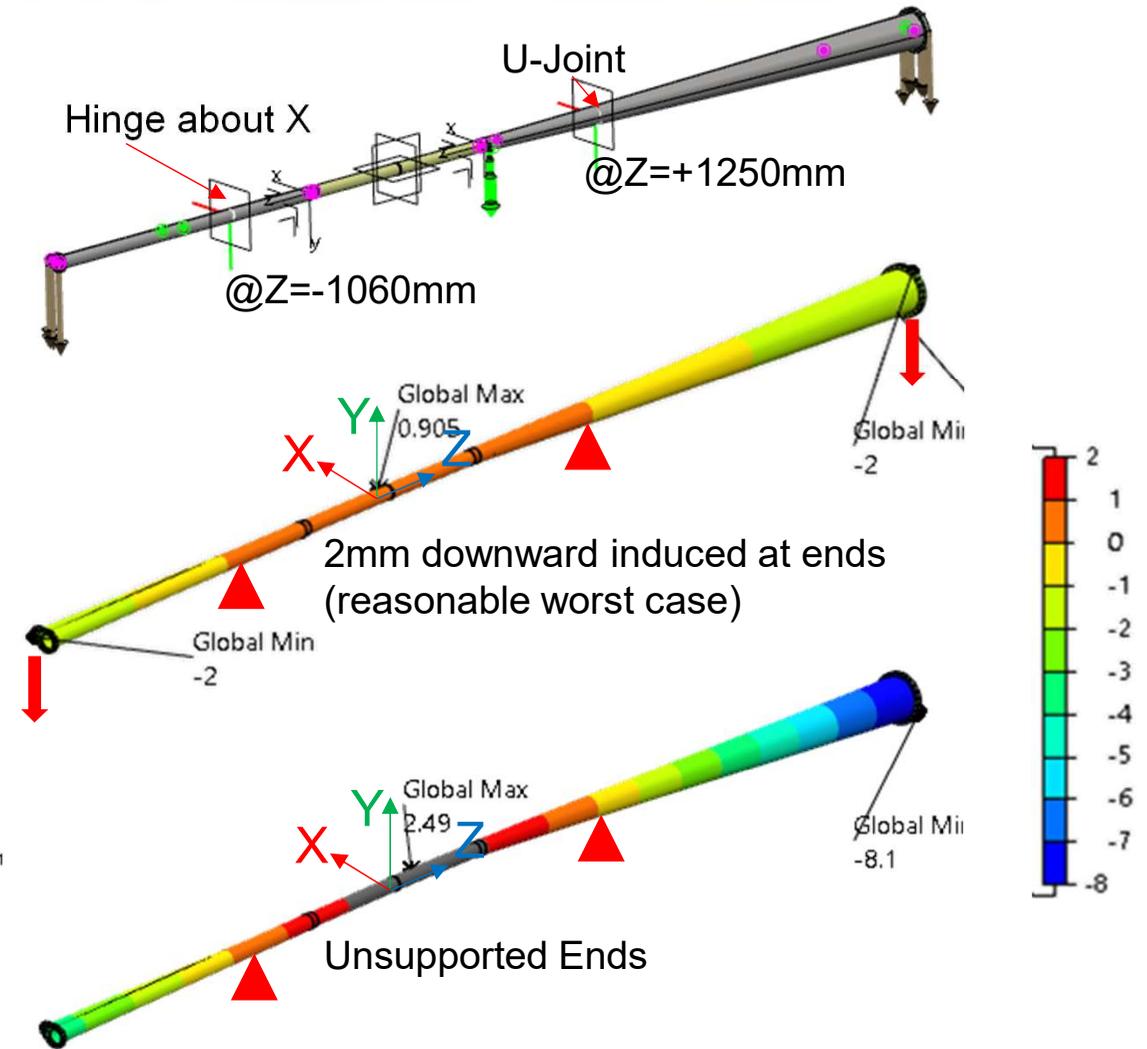
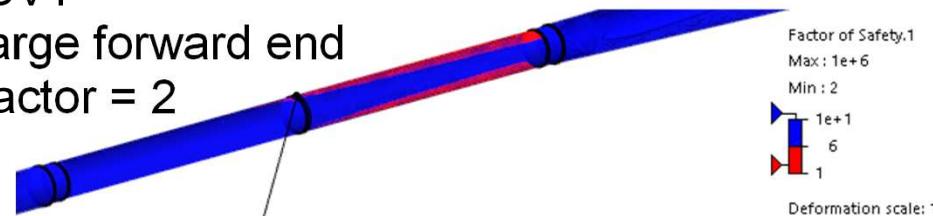
1. Possibly change tie rods for torsion control to angled, offset, or tangent to collar positions
2. Move adjuster mechanism outward in R if possible
  - Adjustable after MPGD disks installed?
3. Need adjustability when only half cylinder

# Beampipe Mechanics Simulation

Charge 3

## Model:

- 29kg total, beryllium (yellow) + 304 stainless steel (gray/silver)
- “Hinge” at backward beampipe support
- “Universal Joint” at forward beampipe support
  - Beampipe supports will likely allow some degree of pipe tilt perpendicular to beam axis
- Step 1: 2mm downward deflection induced at ends
  - +0.9mm in SVT
  - -2mm forced at both ends
- Step 2: Unsupported ends
  - +2.5mm in SVT
  - -8.1mm at large forward end
  - Min safety factor = 2
- Need to support and control flange ends better than +/-2mm to keep deflections inside SVT under 1mm



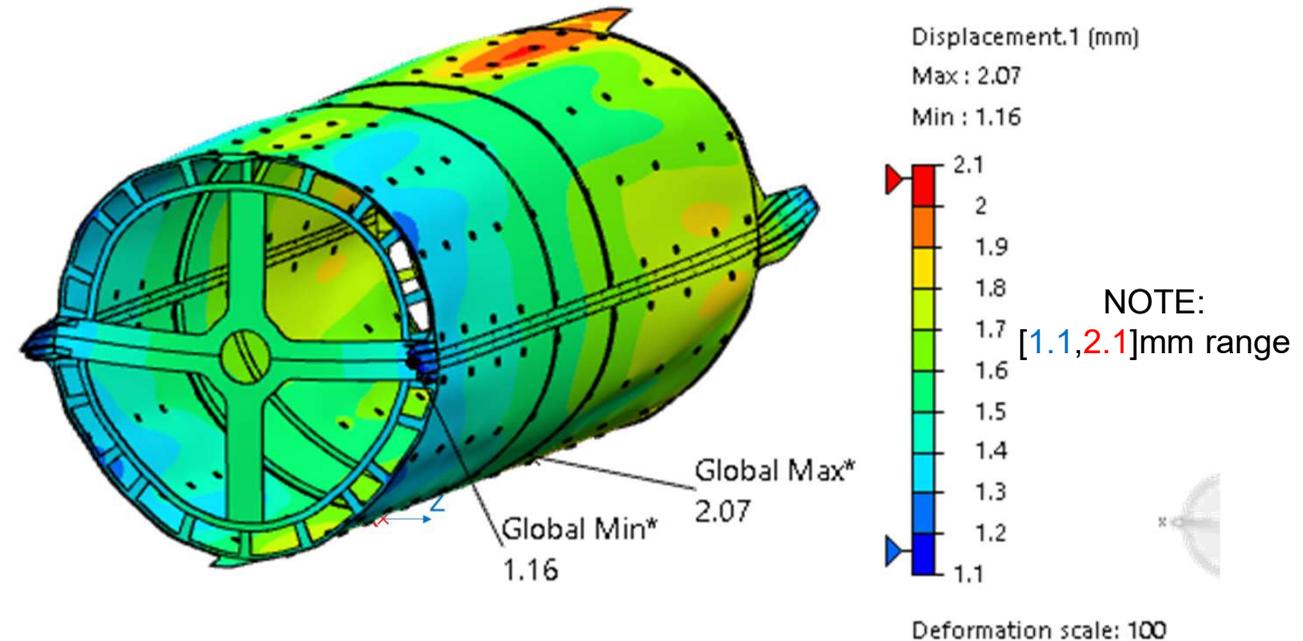
PRELIMINARY RESULTS

# Full SVT Assembly Load Mechanics Simulation

Charge 2,3

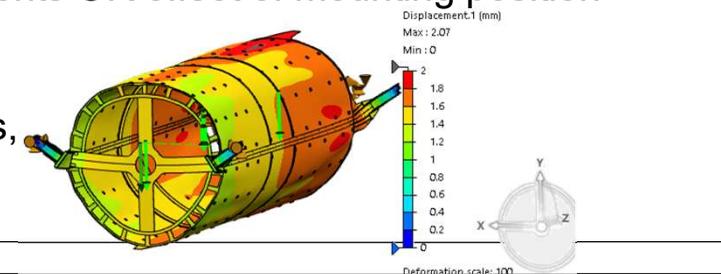
- Structure
  - 1.8mm thick IM7/F6 CFRP for PST half cylinders
  - 3.7mm thick IM7/F6 CFRP for feet structures
  - 5mm (1, 3, 1mm) IM7/F6 – Airex sandwich for beampipe support plates and services passthrough at ends
- Loads
  - 40kg detectors
  - 300kg services (now 310kg)
  - 100kg MPGD disks (now 150kg)
  - 30kg (10 backward, 20 forward) beampipe
- Boundary conditions
  - Fix X, Y at all feet contacts (hinge more realistic)
  - Fix Z at backward feet
- **<1mm target deflection for detectors achieved**
  - Largest deflections from feet twisting
    - Need to reinforce the PST “fingers” going out to “feet”
    - OR simply compensate feet position
  - Excluding feet, intra-PST deflections are [-1.1,+2.1]
    - ~1mm deflection, can improve with minor revisions

470kg loads + structure self weight  
(excluding most of the feet to show intra-tube deflection)



- 100x scale shows feet twist adds 1mm+ to overall deflection
- Explore further reinforcements OR offset of mounting position

With feet deflections,  
[0, 2]mm range

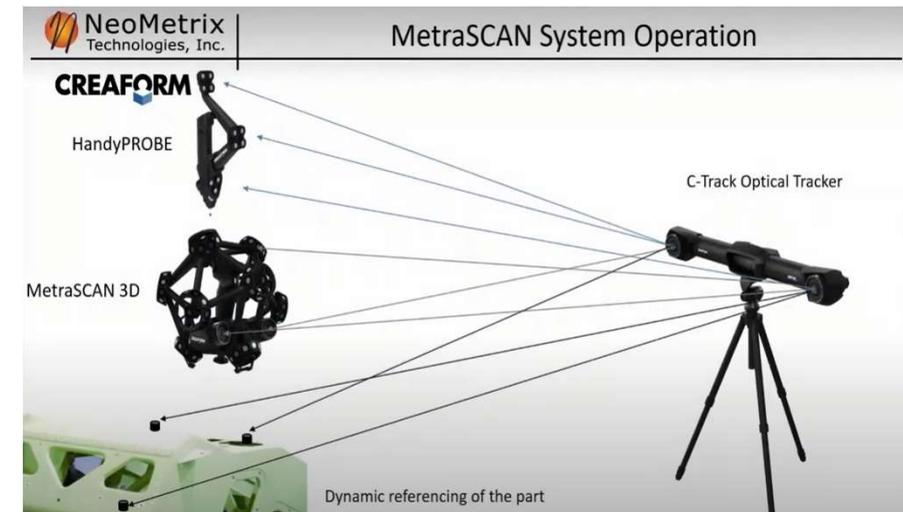


**PRELIMINARY RESULTS**

# Mechanical QA/QC and Installation Metrology

Charge 5

- Laser Scan with Creaform Metrascan up to 5m length, 0.3mm precision expected at 5m
  - **As-manufactured shapes** within defined tolerance
    - Individual components
    - As sub- and final-assemblies
  - **Loading tests** to 150% of expected loading
    - Individual components
    - As sub- and final-assemblies
    - Feasibly realistic boundary conditions
  - **Simulate** component and subassembly experiments
    - Adjust simulation BCs and add details until matching within 20% of experiments
- Simulate and measure final loading steps



# Summary

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- The designed SVT support structures and detectors fit within their designated spaces, with interfaces of concern highlighted
- Plans for individual detectors are well developed and documented, with regular snapshots of CAD models in a shared space
- Integration plans meet initial requirements for all detector groups to mitigate risk and allow for appropriate progressive system testing during assembly
- Preliminary simulations show the designed support structure providing sufficient rigidity to keep detectors safe and positioned within needs
- QA for support structures has progressive plans to ensure sub-component and assembly level success
- Steps planned before CD2 listed on next slide

# Next Steps (before CD2)

## Design Updates

- PST, refine:
  - Detector attachments to PST
  - End PST “fingers” to minimize twist/sag
  - Connection to GST, motion and adjustment
  - Beampipe support/alignment mechanism
- Services, create:
  - More detailed layout of services and boards
  - Support trays from PST to GST and out
  - Attachment points to PST and guides
- Assembly / integration cradle design
  - Ultra rigid, extruded aluminum (or similar) with CNC critical interface features
  - Support PST half cylinders outside, near designed mounting points
  - Extensions to support beampipe ends

## Finite Element Analysis

- Examine feet stresses in more detail
- Simulate feet with hinge about Z and slide in X
- Simulate half cylinder assemblies in new cradle during
  - Installation of detectors and services
  - Rotation and assembly of two halves

## Information Refinement Continues

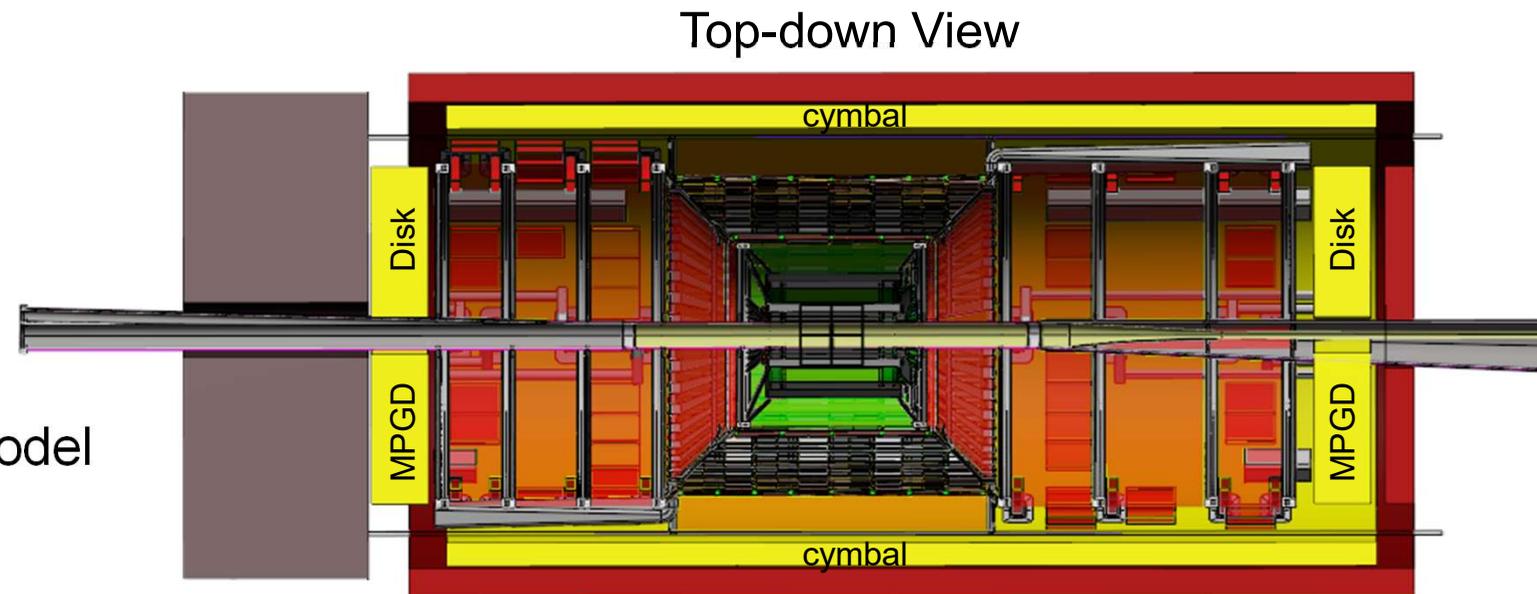
- Services and paths for each detector
- Boards (CB, FIB, SCB) for each detector
- Mass estimates for each component

# Backup

# SVT Envelopes

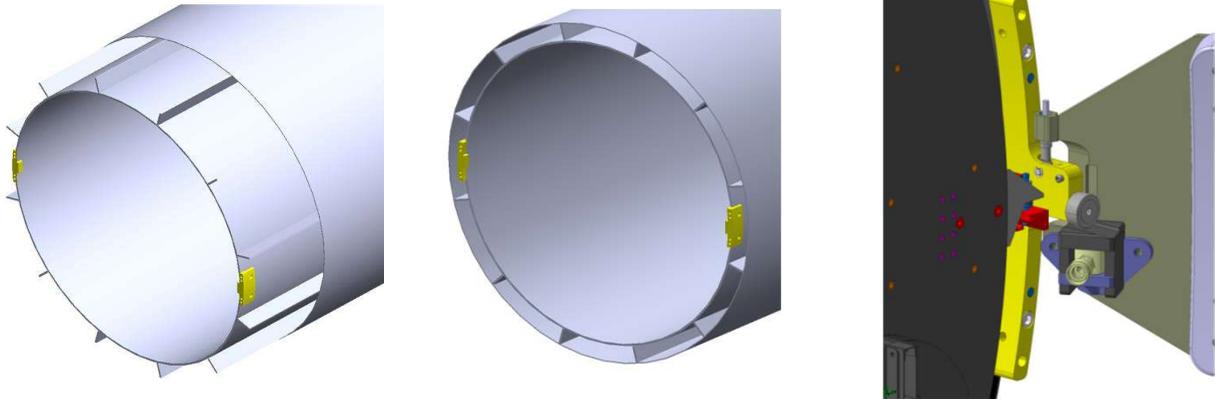
- Bounding Envelopes
  - Beampipe **R32.5+mm** – see model, keep 5mm no-go zone
  - Cymbal **R555-615mm**, ( $11025 < Z < +1450\text{mm}$ )
  - MPGD disks **R450mm**, ( $-1225 < Z < -1075\text{mm}$ ) , ( $+1285 < Z < +1435\text{mm}$ )
  - SVT/PST inside **R540mm**, ( $-1062 < Z < +1257\text{mm}$ )
  - Working within BNL shared bounds from <https://drive.google.com/file/d/114aPmcAhUPrMYnjgbfYMFClxeqjwqP77/view>

- Internal Envelopes
  - IB – R37-250mm,  $-233 < Z < 233$
  - OB – R255-525mm,  $-420 < Z < 420$
  - Disks – R38-460mm
  - Control Boards (x??) – R461-511mm
  - Air Inlet/Exhausts – see model
  - Service Paths (IB, OB, Disks) – see model
  - Disk Mounting Points – see model
- Thermal Envelope

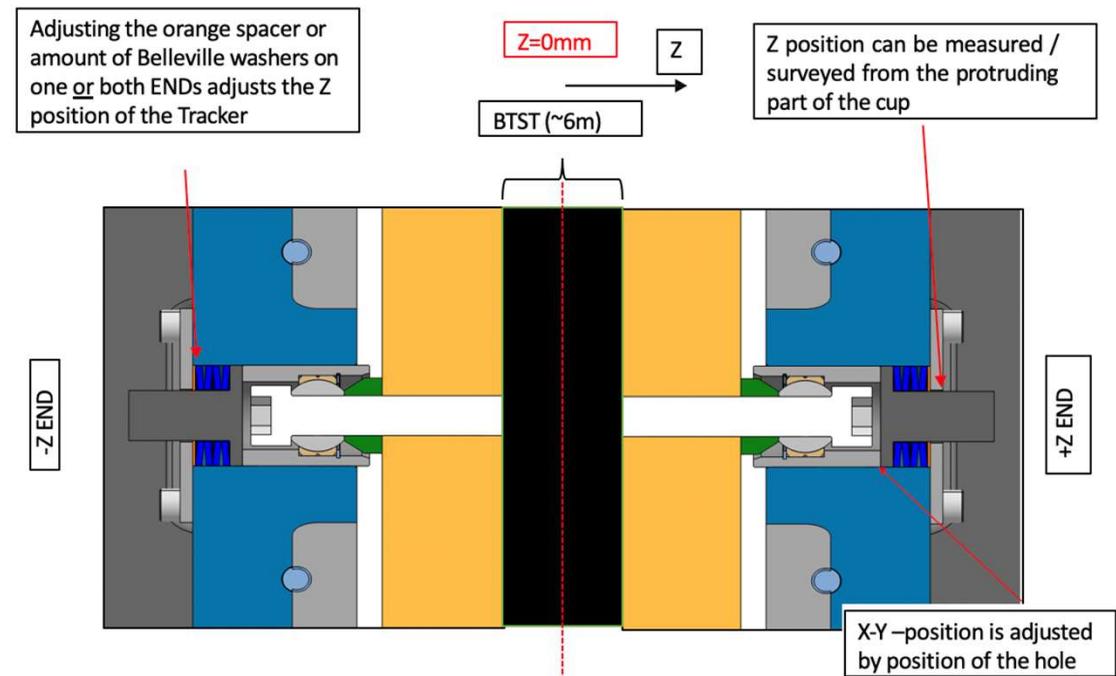


# GST tolerances/constraints and mount points

- Variety of support rails are provided by GST to support
  - PST feet
  - Mountpoints for pfRICH, EEEMCAL
  - GST itself is mounted to HCAL and EMC
  - End rings (50mm massive CRRP) to distribute load of “brackets” for GST support
- Adjustability of PST  $\pm 3\text{mm}$  and of GST  $\pm 10\text{mm}$

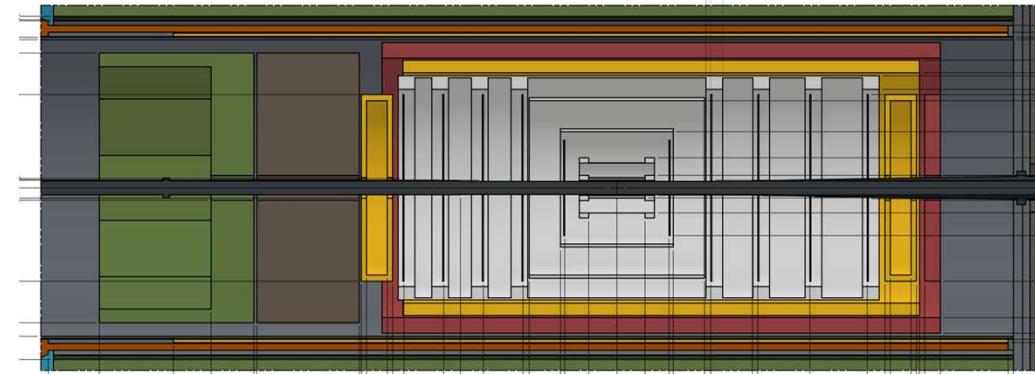


- Envelope inner radius is 715 to 725mm
- Inner installation clearance is 710 to 715 mm
- Inner cylinder (sandwich) is  $z = -1900\text{ mm}$  to  $+3125\text{mm}$
- Envelope outer radius = 805 to 810 mm
- Outer installation clearance = 810 to 820 mm (this is the clearance between GST and the barrel EMcal (BIC))
- Outer Cylinder (CFRP)  $z = -1900$  to  $+2700\text{ mm}$



# GST envelope and constraints

- Expected deflections, tolerances, geometric tolerances:
    - Deflections in final operation setup:  $\pm 2.5$  vs  $\pm 2.0$  mm
    - Manufacturing:  $\pm 1.5$ mm, Core:  $\pm 0.5$ mm & Cylindricity of 2mm
      - Face sheets:  $\pm 0.1$ mm + Core yields  $\pm 0.7$ mm max deviation
    - Geometric to fit within envelope in worst case:  $\pm 1.5$ mm
  - Envelope is  $\pm 10$ mm for insertion
    - Worst case:  $\pm 1.5$ mm  $\pm 2.5/2.0$ mm =  $\pm 4/ \pm 3.5$ mm
    - Can consider more local add. stiffening structures
- Adjustability of PST  $\pm 3$ mm in x-y and  $\pm 5$ mm in z  
→ Tolerance is  $\pm 1$ mm
- Adjustability of GST  $\pm 10$ mm in all directions  
→ Tolerance is  $\pm 3$ mm



Key:

hpDIRC

Prism

hpDIRC &  
oMPGD

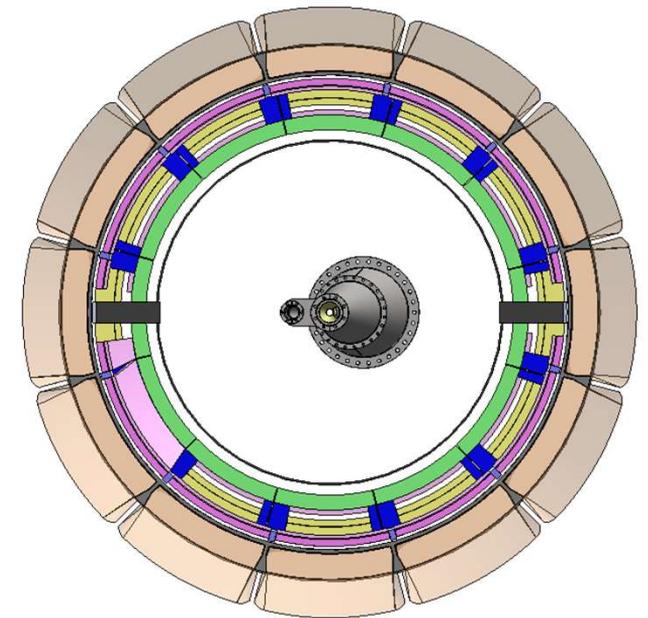
Services

Barrel TOF

iMPGD

Support  
tubes

- GST & PST



# Beam Pipe Survey and Position Monitoring

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- The central beam pipe has a tight tolerance in X and Y of +/-1mm.
- This tolerance should account for manufacturing, positional and deflection tolerances.
- Survey/inspection will give a good understanding of the manufacturing tolerances.
- Once the beam pipe is integrated into the SVT/PST, access is severely restricted, making positional information challenging.
- Some solutions we are considering are (we may implement multiple or all):
  - Constrain the beam pipe in the same way as when installed in the SVT, but in an accessible way and measure the beam pipe's deflection and translate this to external survey markers.
  - Restricting the beam pipe in the SVT at multiple locations in X and Y to minimize changes in position and surveying prior to closing the SVT halves.
  - Adding “view ports” through the PST and SVT services to make some level of survey after integration possible.
  - Add permanent distance sensors in the SVT to monitor changes in the beam pipe position.

# Beampipe Preliminary Analysis – Too rigid

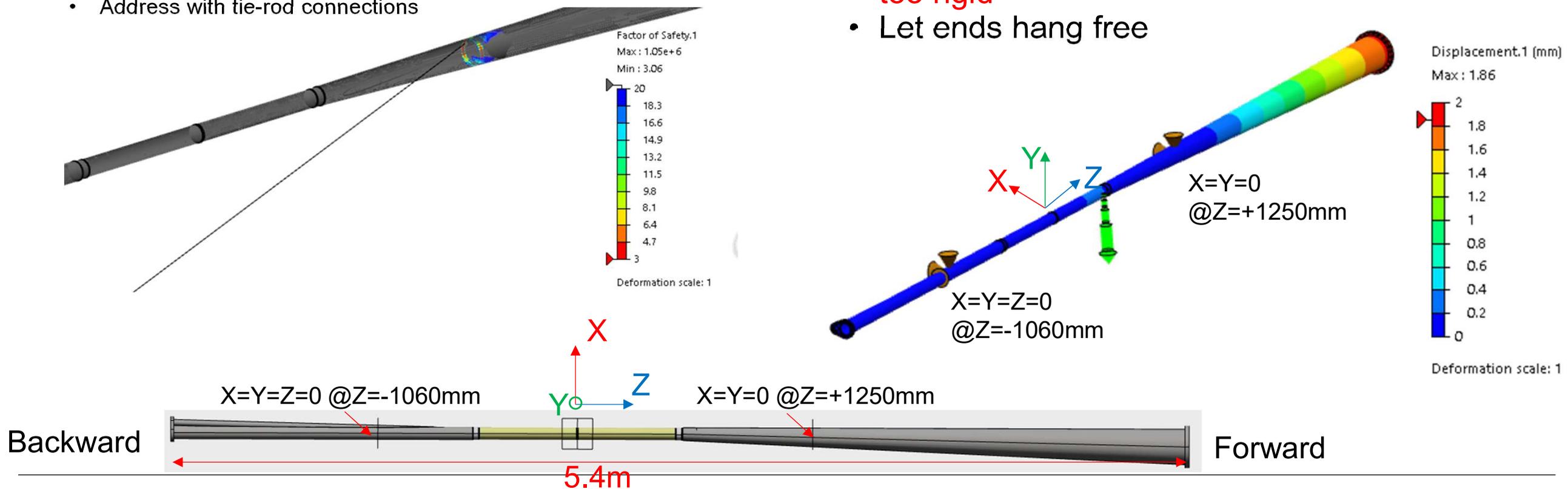
Charge 1,4

## Results / Considerations:

- Sag of ~2mm at Z+ end (if unsupported)
- Beryllium center <0.4mm deflection
- Safety factor (yield based) >3
  - Will improve with Z+ end support
- Twist (torque/moment)
  - Address with tie-rod connections

## Model:

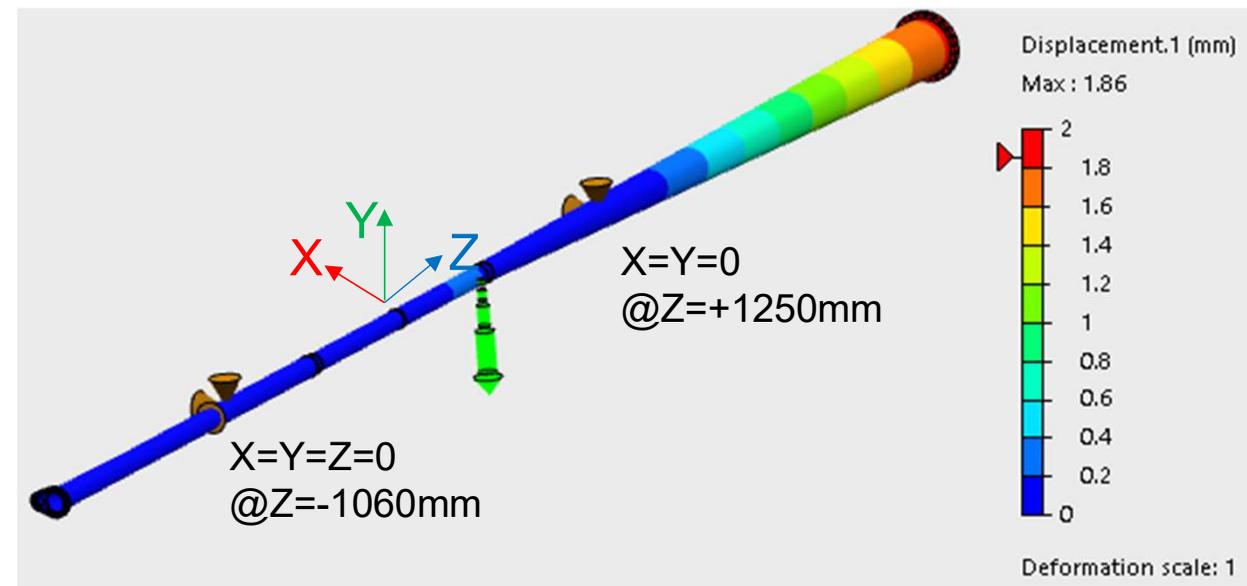
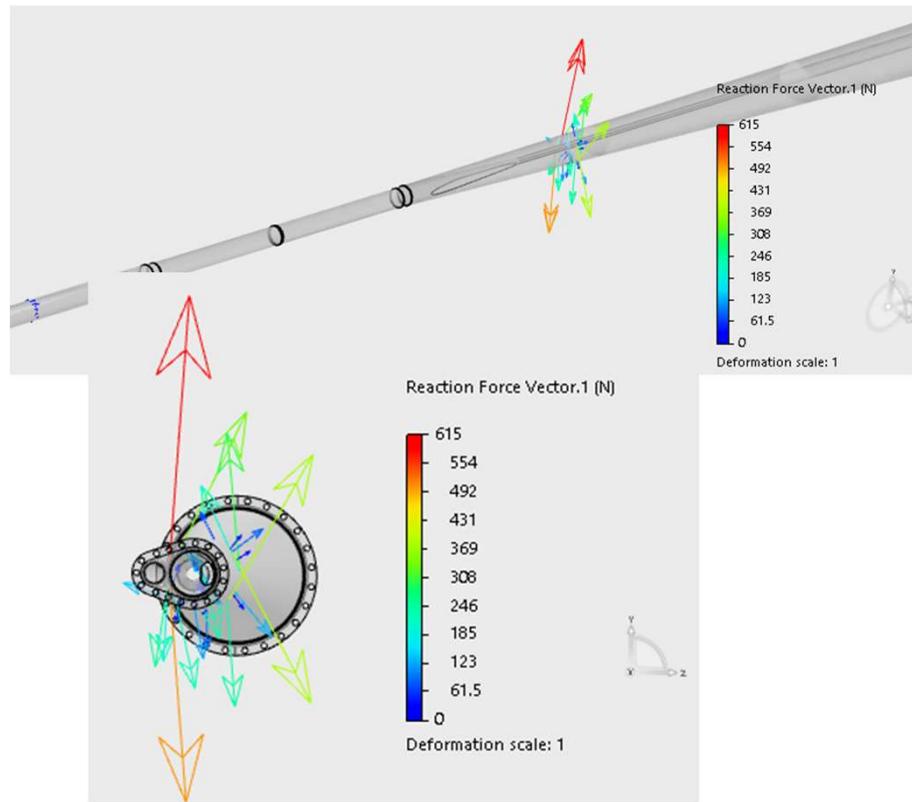
- 29kg center beryllium (yellow) + 304 stainless steel (gray/silver)
- Fixed in X, Y, Z at backward beampipe support – **too rigid**
- Fixed in X, Y at forward beampipe support – **too rigid**
- Let ends hang free



# Beampipe Preliminary Analysis – Too rigid

- Sag ~2mm at Z+ end
- Twist (torque/moment)?
- Reaction Forces

- Model:
  - 29kg center beryllium (yellow) + 304 stainless steel (gray/silver)
  - Fixed in X, Y, Z at backward beampipe support – **too rigid**
  - Fixed in X, Y at forward beampipe support – **too rigid**
  - Let ends hang free



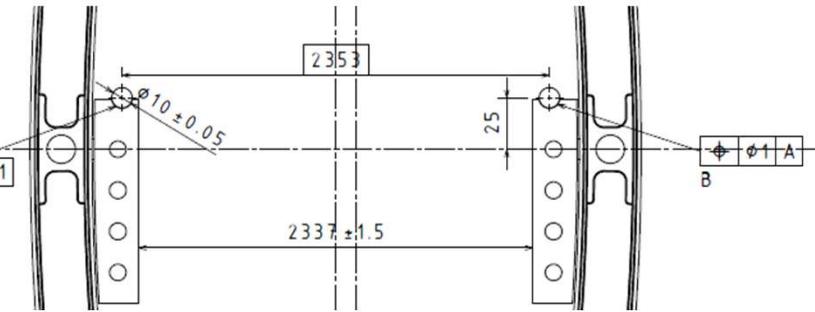
Backward



Forward

# PST Feet Mechanism Precedence

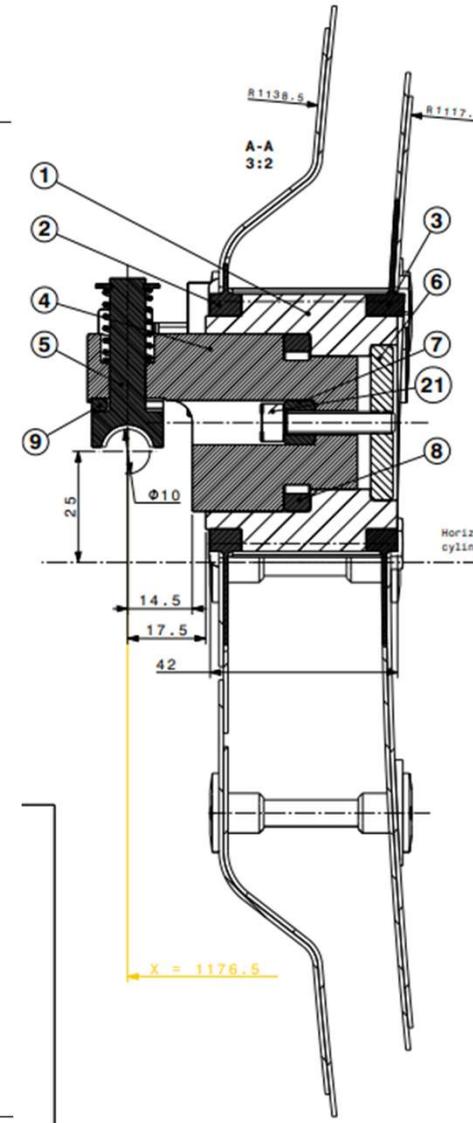
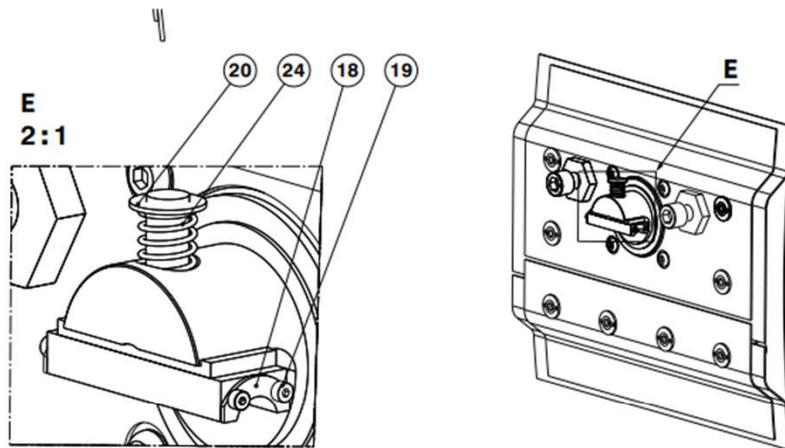
- 10mm pultruded CFRP guide rod axes within  $\pm 0.5$ mm in BTST



- CMS Phase 2 HL Upgrade TB2S to BTST rail foot support

<https://plm.cern.ch/PLM/Client/?StartItem=C&D:F11B3A9E6F294AFDAD7EA83093D0DA&B>

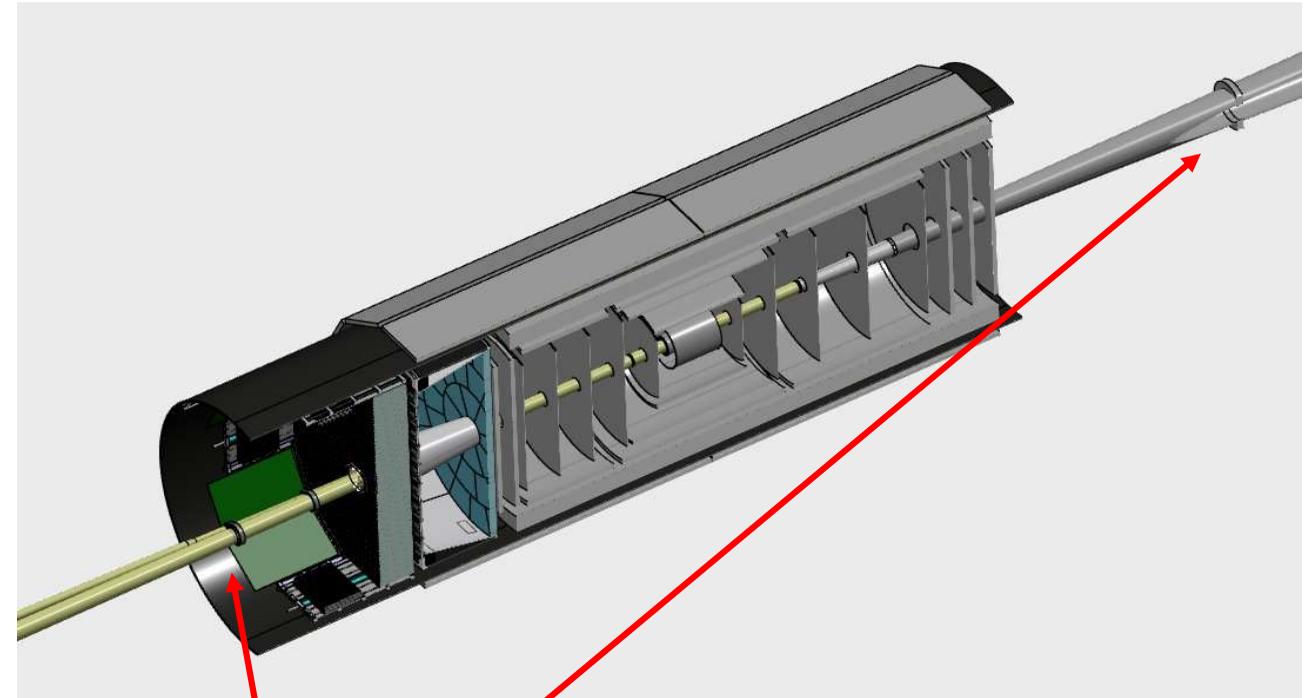
- Each foot supports up to 200kg



POS	QUANT	DESIGNATION	REFERENCE	MATERIAL	EDH SCER
05	1	SKID	CMS2TB2S0141	Alu EN AW-7075	
			ST0673724	(T6)	
06	1	Nut M5	CMS2TB2S0173	Alu EN AW-7075	
			ST1120783	(T6)	
07	1	Transversal Ext Stopper	CMS2TB2S0233	Alu EN AW-7075	
			ST1588434	(T6)	
08	1	Transversal Int Stopper	CMS2TB2S0232	Alu EN AW-7075	
			ST1588425	(T6)	
09	1	Vertical Shim	CMS2TB2S0234	Alu EN AW-7075	
			ST1212505	(T6)	
10	2	BN1593 M6 x 41.7	CMS2TB2S0253	St. Steel A2	
			ST1380028		
11	2	BN1593 M6 x 40		St. Steel A2	
			ST1380029		
12	4	BN631 M6 (0.5d)		St. Steel A4	
			ST1373700		
13	2	M12 Lifting Insert	CMS2TB2S0186	EN 1.4432	
			ST1379286	(St. Steel 316L)	
14	2	Special Machined M12 Screw	CMS2TB2S0187	EN 1.4432	
			ST1373041	(St. Steel 316L)	
15	2	BN612 M12 x 30		Steel 8.8	
			ST1379396		
16	16	M6 Clamp Nut	CMS2TB2S0188	Alu EN AW-6082	
			ST1329386	(T6)	
17	8	M6 Clamp Rod	CMS2TB2S0208		
			ST1395508		
18	2	Slide Bearing	CMS2TB2S0236		
			ST1458306		
19	4	BN612 M2x10		St. Steel A4	
			ST1458308		
20	1	CIRCLIPS BN680 Ref. 1255487		Stainless Steel	
			ST1374570		
21	1	BN612 M5x25		St. Steel A4	
			ST1324748		
22	6	Smaller Trapezoidal Washer	CMS2TB2S0209	Alu EN AW-6082	
			ST1377817	(T6)	
23	2	Bigger Trapezoidal Washer	CMS2TB2S0212	Alu EN AW-6082	
			ST1379240	(T6)	
24	1	SODEMAN Spring Ref.22010		Stainless Steel	
			ST1680426		

# Temporary supports during installation

- Need a temporary support for all services and cables of inner detector
- “Antler” design used in CMS installation of Pixel detectors



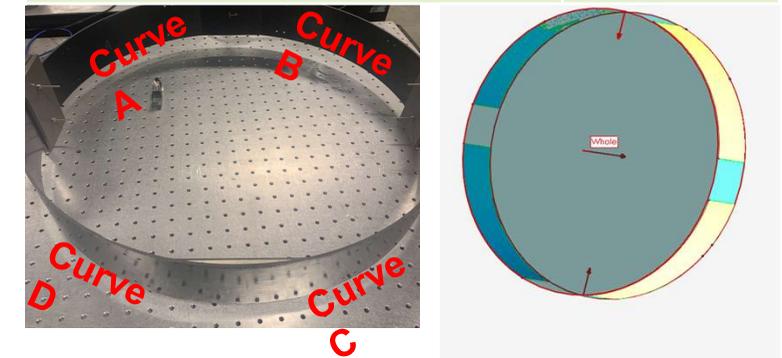
These two flanges are what needs to be kept with the assembly

# QA/QC Examples from CMS

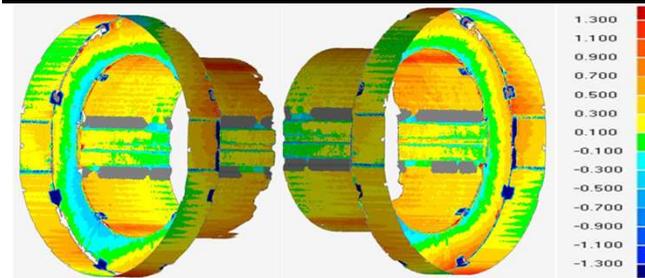
- Multiple prototypes for ITST, SC and components
  - Iteration of FEA of manufacturing method, performance under load, metrology
  - QA/QC during and at end of the process
- Prototyping using non-final materials
  - Smaller prototypes with final material, FEA driven
- Met tolerances – we typically achieve:
  - $< 500\mu\text{m}$  cylindricity (ITST, SC)
  - $50\text{-}100\mu\text{m}$  parallelism (ITST tracks)

## ITST end section cylindricity:

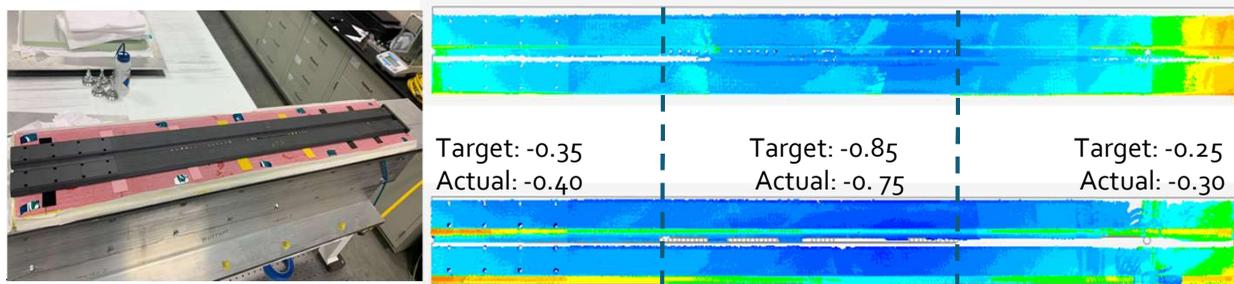
Target Diameter	606 mm
Measured dry assembled diameter	605.47 mm



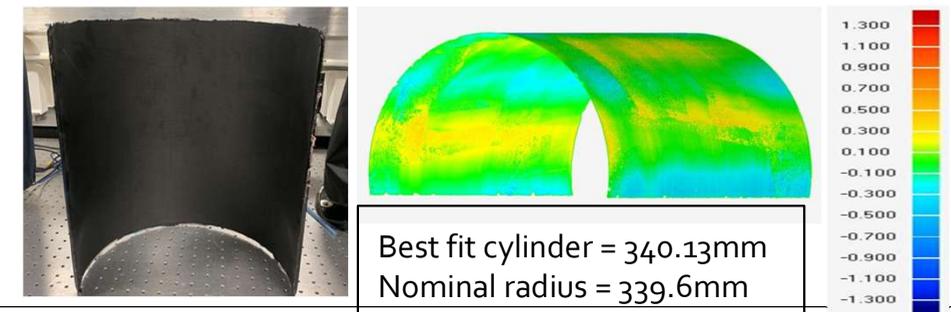
## ITST transition to mid section:



## ITST track alignment:



## SC cylindricity:



# Services for Backward (Z-) End

Charge 1,2

- Based on this SVT Services Table
- [https://brookhavenlab.sharepoint.com/:x/s/EICPublic/SharedDocs/EWtErwm\\_Is\\_tBoAbYrW\\_PJLUB3xj4ibH\\_ZNpLp7CQN13YOQg?e=g2yh1k](https://brookhavenlab.sharepoint.com/:x/s/EICPublic/SharedDocs/EWtErwm_Is_tBoAbYrW_PJLUB3xj4ibH_ZNpLp7CQN13YOQg?e=g2yh1k)
- Total cross section on backward (Z-) side = 877cm<sup>2</sup>
  - Similar on Z+ with a few Inner Barrel services added

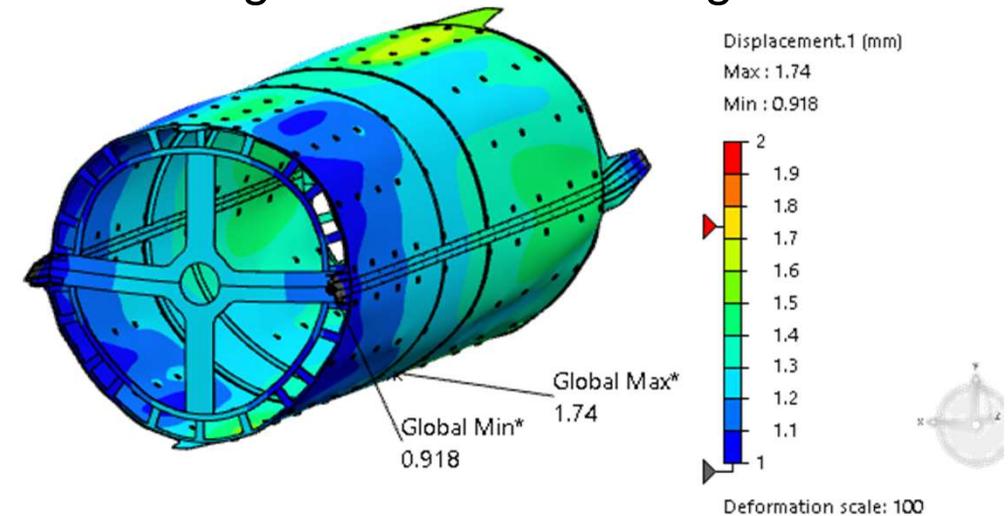
Subsystem	Type	Item	Material	Cable Specifics	Quantity	Diameter (cm)	Cross Area (cm <sup>2</sup> )	Notes
Inner Barrel	Power	LV	Multi-Conductor Cable	4 Al conductors, 18AWG	16	0.9	NA	All on the hadron side; none on the electron side
	Signal	Data	144 Fiber Cable		4	0.89	NA	All on the hadron side; none on the electron side;harnesses TBD
	Cooling	cooling	Air		2	2.54	NA	All on the hadron side; none on the electron side
	Cooling	Exhaust	Air				40.54	Preliminary estimate, <b>not subject to packing &amp; misc.</b>
Outer Barrel	Power	LV	Multi-Conductor Cable	4 Al conductors, 18AWG	93	0.9	59.16	
	Signal	Data	144 Fiber Cable		6	0.89	3.73	
	Cooling	cooling	Air		8	2.54	40.54	
	Cooling	Exhaust	Air				162.15	Preliminary estimate, <b>not subject to packing &amp; misc.</b>
Disks	Power	LV	Multi-Conductor Cable	4 Al conductors, 18AWG	185	0.9	117.69	
	Signal	Data	144 Fiber Cable		12	0.89	7.47	
	Cooling	Cooling	Air		10	2.54	50.65	
	Cooling	Exhaust	Air				202.60	Preliminary estimate, <b>not subject to packing &amp; misc.</b>
Outer Barrel / Disks FIB	Signal	Read out Fibers			NA	NA	NA	part of the fiber counts above (OB, disks) insofar external
	Power	Ext Current Source			NA	NA	NA	powered by CB (i.e. internal services, but not external)
	Cooling	cooling	Air / convection		NA	NA	NA	VTRx+ can be cooled convectively per its manual
Outer Barrel / Disks CB	Signal	Slow Control Fibers FIB	144 Fiber Cable		1	0.89	0.62	
	Signal	Slow Control Fibers FPC	144 Fiber Cable		1	0.89	0.62	
	Power	Ext Voltage Source		4 Al conductors, 18AWG	26	0.9	16.54	16 OB control boards, 36 disk control boards
	Cooling	Cooling	Water		28	0.63	8.73	Approx. 1.3 kW to be cooled
Inner Barrel SCB	Signal	Control Fibers	144 Fiber Cable		1	0.89	NA	All on the hadron side; none on the electron side;harnesses TBD
	Cooling	Cooling	Water		4	0.63	NA	All on the hadron side; none on the electron side
Inner Barrel DPB	Signal	Control Fiber	144 Fiber Cable		1	0.89	NA	All on the hadron side; none on the electron side;harnesses TBD
	Power	Bulk Power	Multi-Conductor Cable	4 Al conductors, 18AWG	16	0.9	NA	All on the hadron side; none on the electron side
	Cooling	Cooling	Water		4	0.63	NA	All on the hadron side; none on the electron side
Ground(s)						0.70	Preliminary estimate	
Interlocks						4.00	Preliminary estimate; more of a "space allocation"	
Environmental sensors						4.00	Preliminary estimate; more of a "space allocation"	
						TOTAL X1.5	876.97	Exhaust not 1.5x, only 1.0x

# Finite Element Analysis – Full SVT Assembly

Charge 2,3

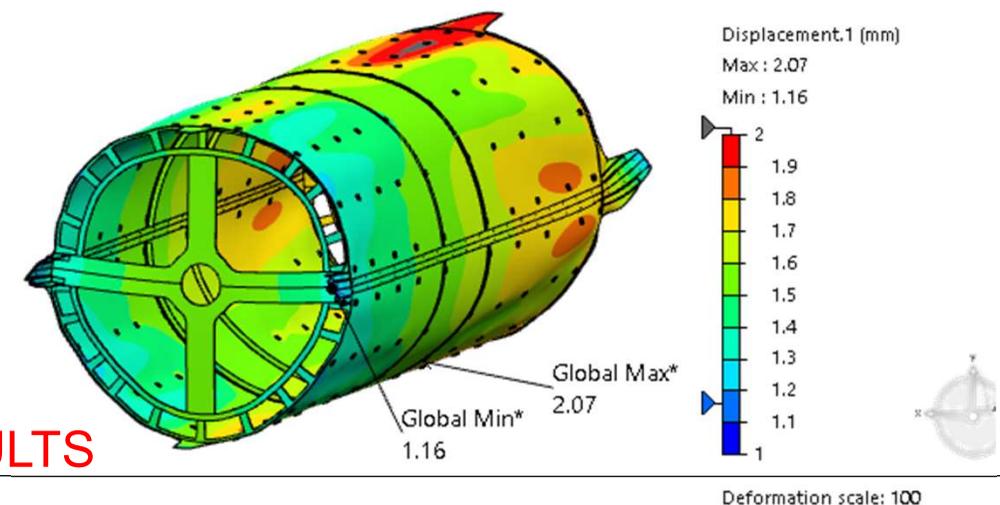
- Before adding MPGD disks (50kg at each end)
  - All SVT components, beampipe
  - exclude most of the feet
  - **PST deflections range [0.9,1.7]mm**

370kg + structure self weight



- After adding MPGD disks
  - exclude most of the feet
  - **PST deflections range [1.1,2.1]mm**
    - Only the “feet” and “fingers” sag more from MPGD

470kg + structure self weight



PRELIMINARY RESULTS