Pixel Support Tube

Concept and Design

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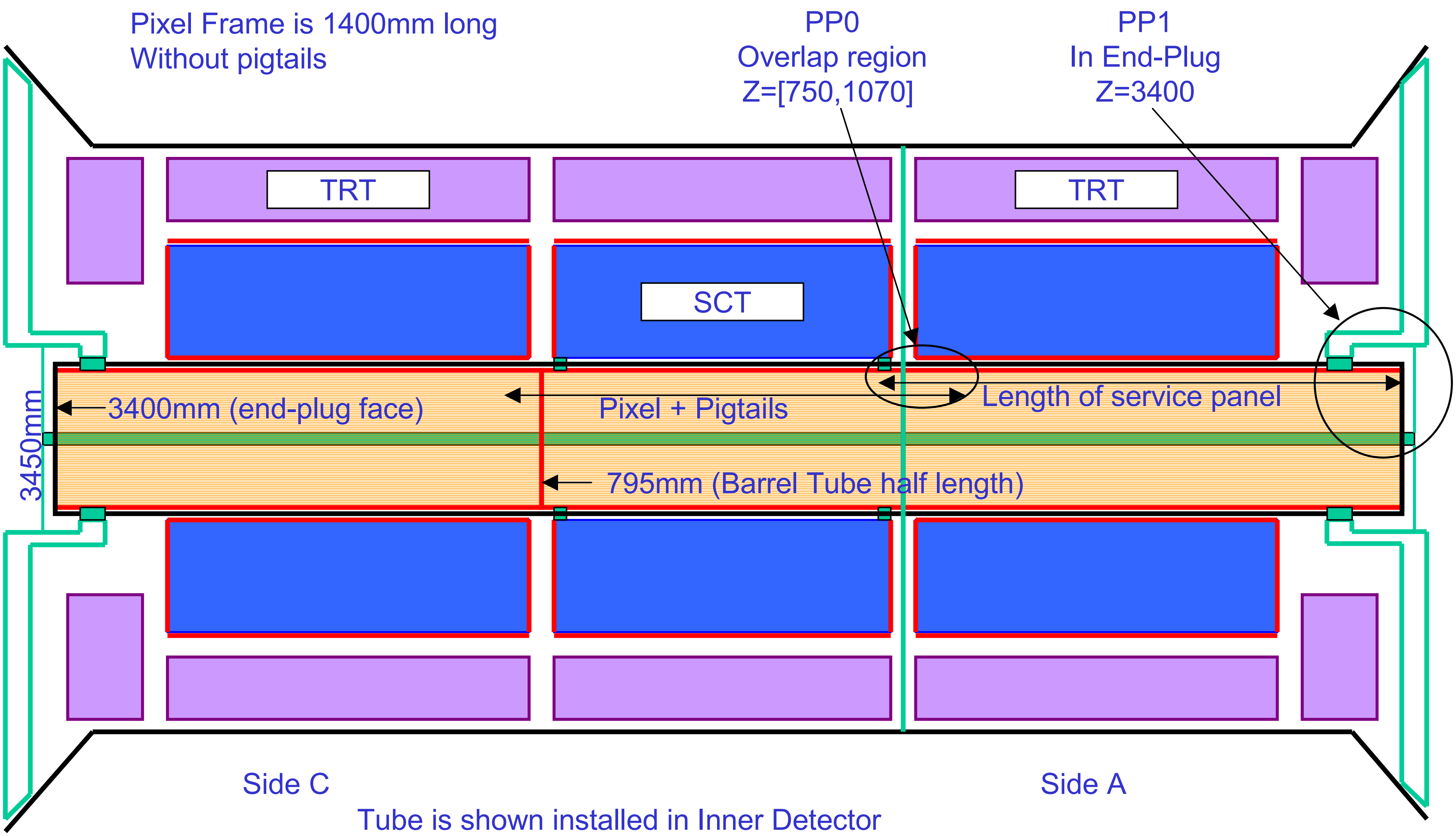
Pixel Detector

Overview

- **General Layout**
  - Delivers detector from outside ID forward using rails
  - Provides support for pixel services, and access for pixel mounts
  - Composed of barrel and two forwards
- **Interfaces**
  - Mounts to SCT barrel and the cryostat
  - Provides thermal and EMI enclosure for pixel system
  - Supports beampipe in inner detector
- **PST Design Details**
  - Rails
    - Detector and service rails
    - Service panel assembly
    - PST mockup
  - Tube Performance Issues
    - Structure and support variables
    - FEA analysis
  - PST Supports
    - Mount scheme
    - Requirements and interface block designs
    - Mount analyses
  - Tube Flanges
  - Detector Supports
  - Other interface Structures
    - Thermal/EMI enclosure (tube endplug)
    - Beampipe supports

Pixel Detector

General Layout

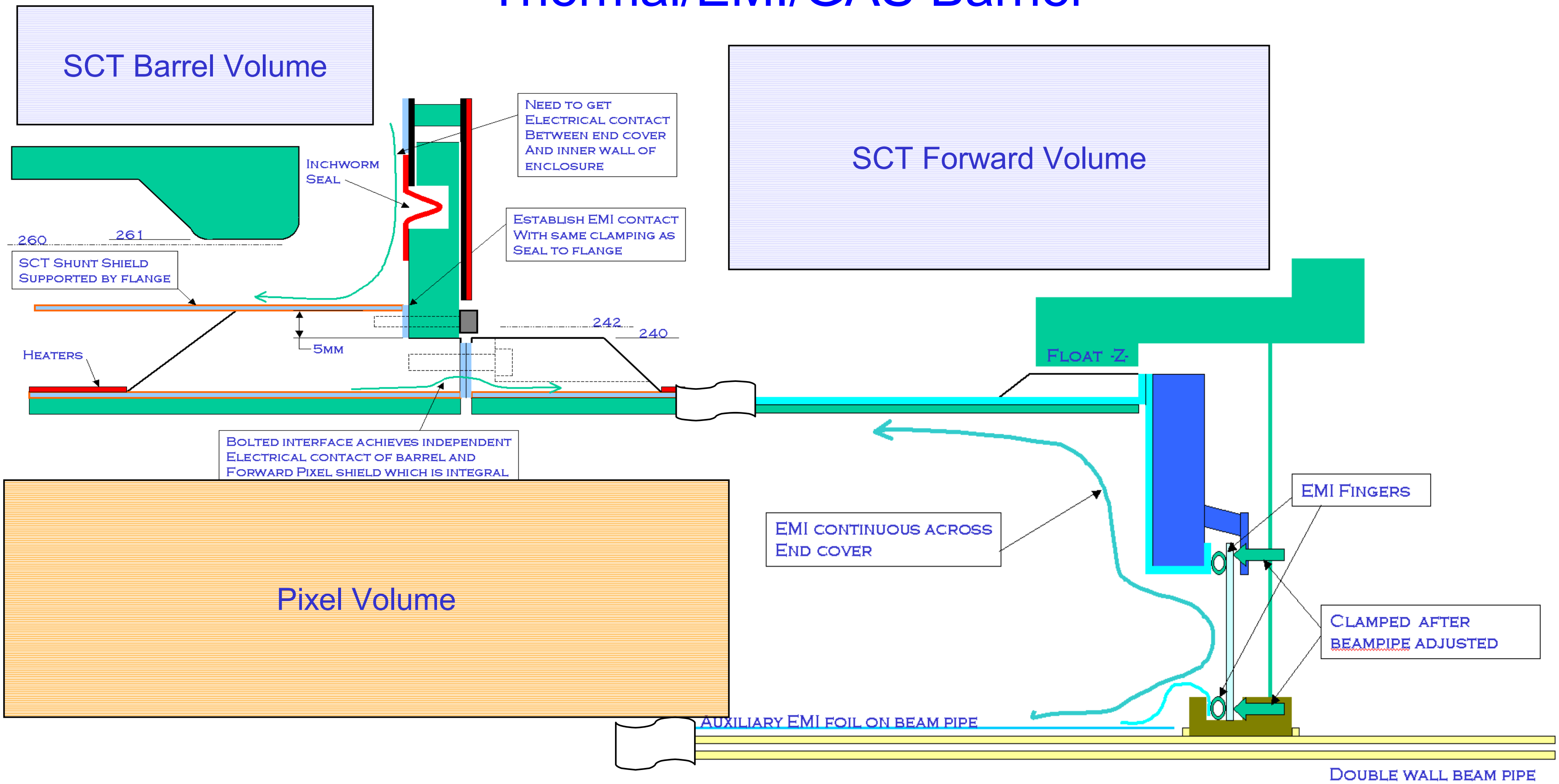


Tube is shown installed in Inner Detector

Interfaces

Pixel Detector

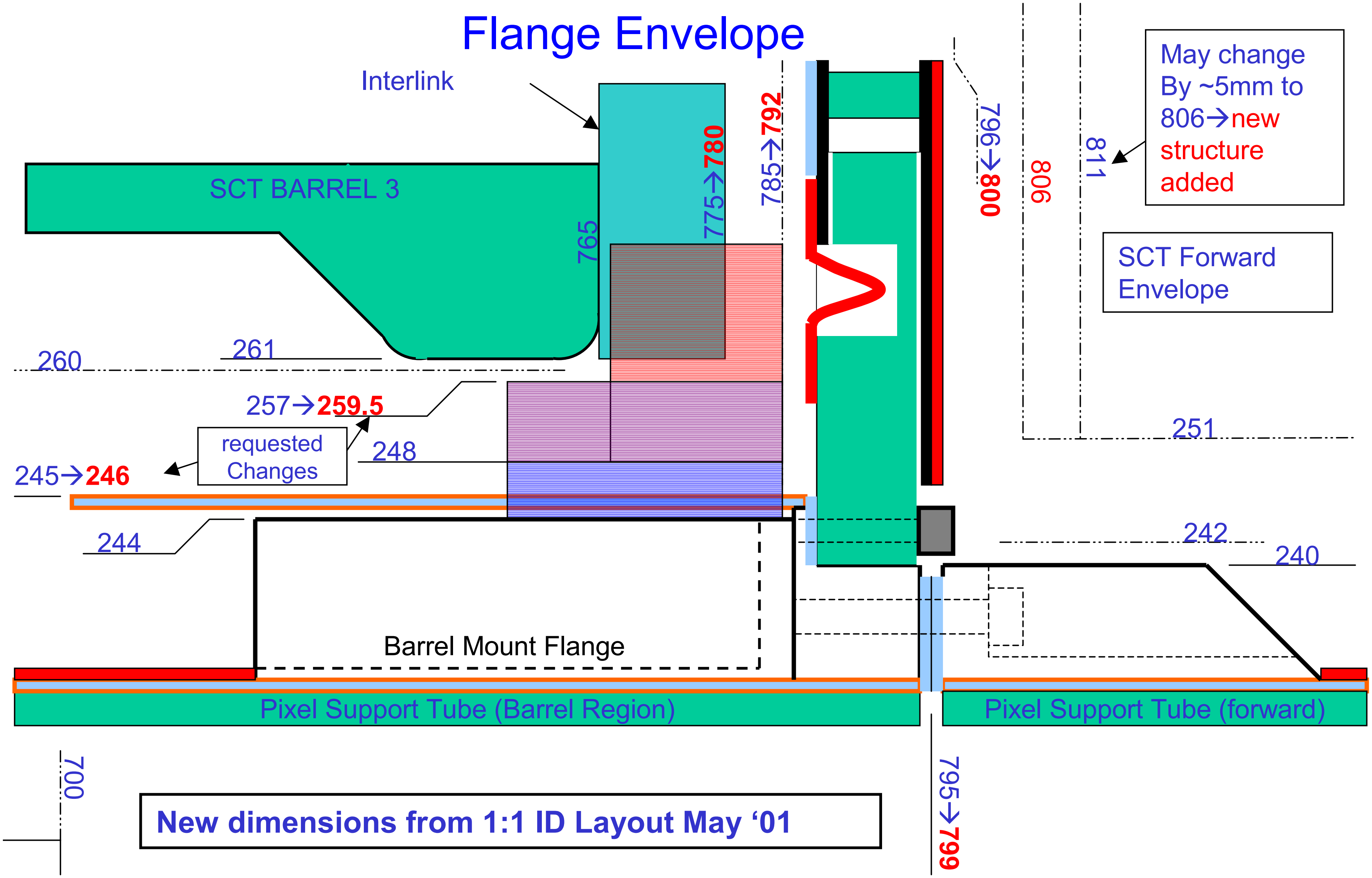
Thermal/EMI/GAS Barrier



- **Pixel Support Tube must form a closed volume with the Beam pipe – implies “end plug” structure in forward region.**

Pixel Detector

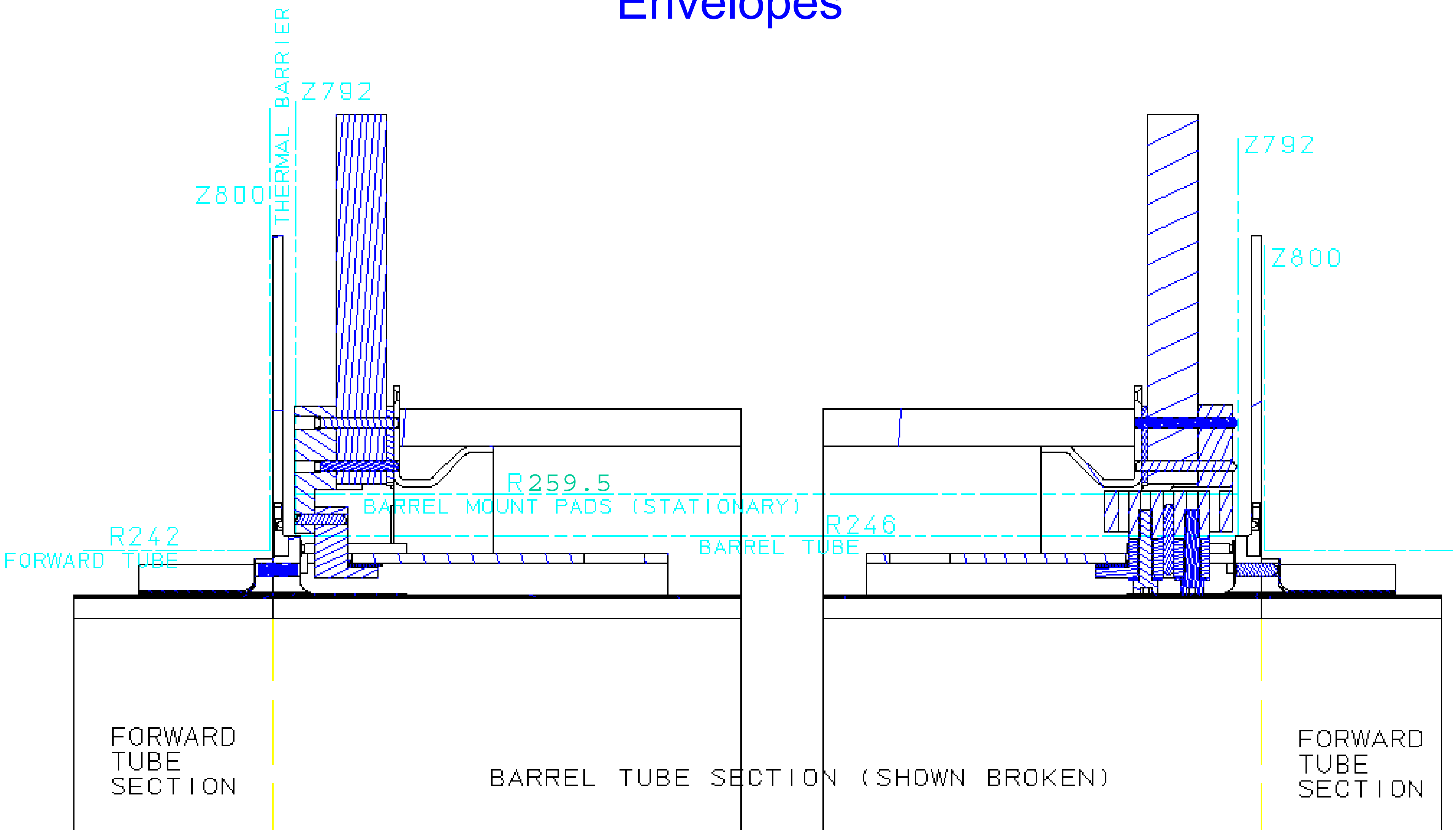
Flange Envelope



New dimensions from 1:1 ID Layout May '01

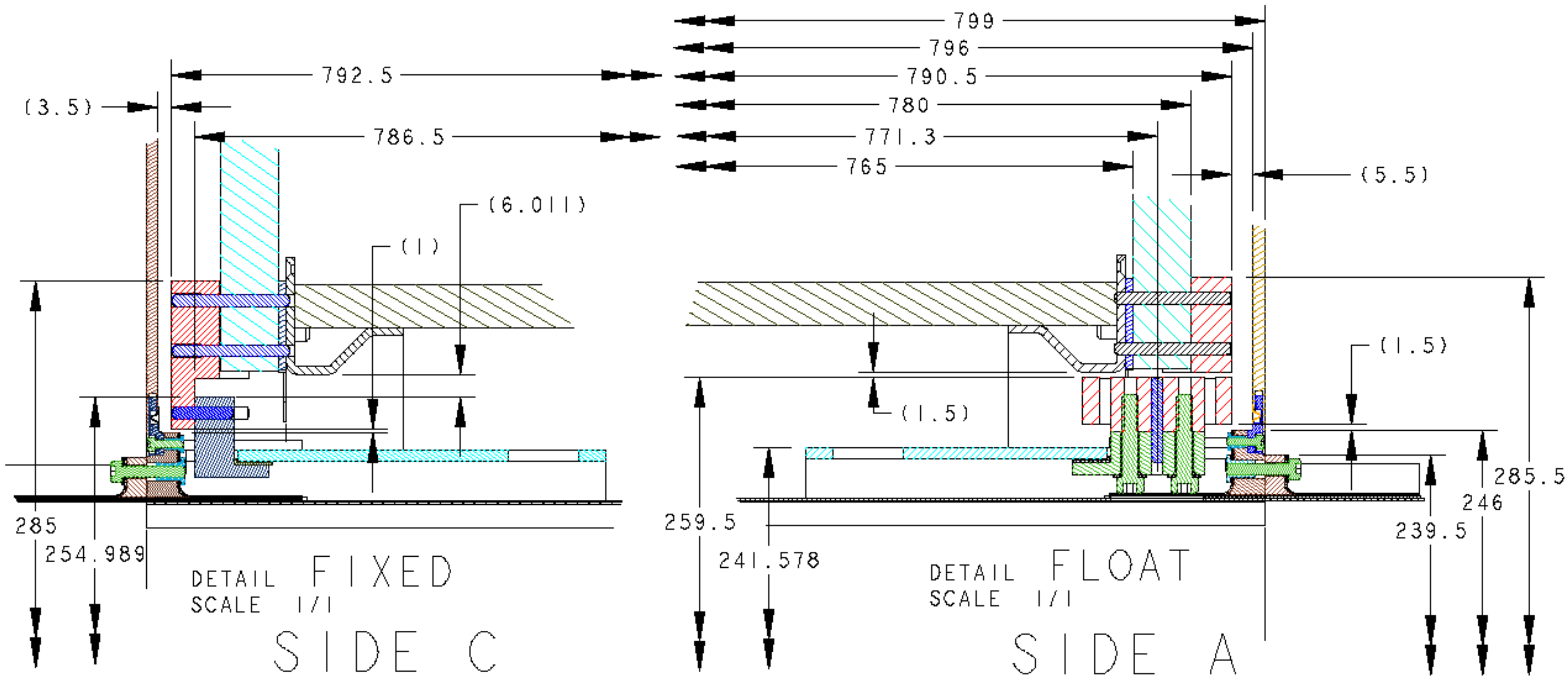
Pixel Detector

Envelopes



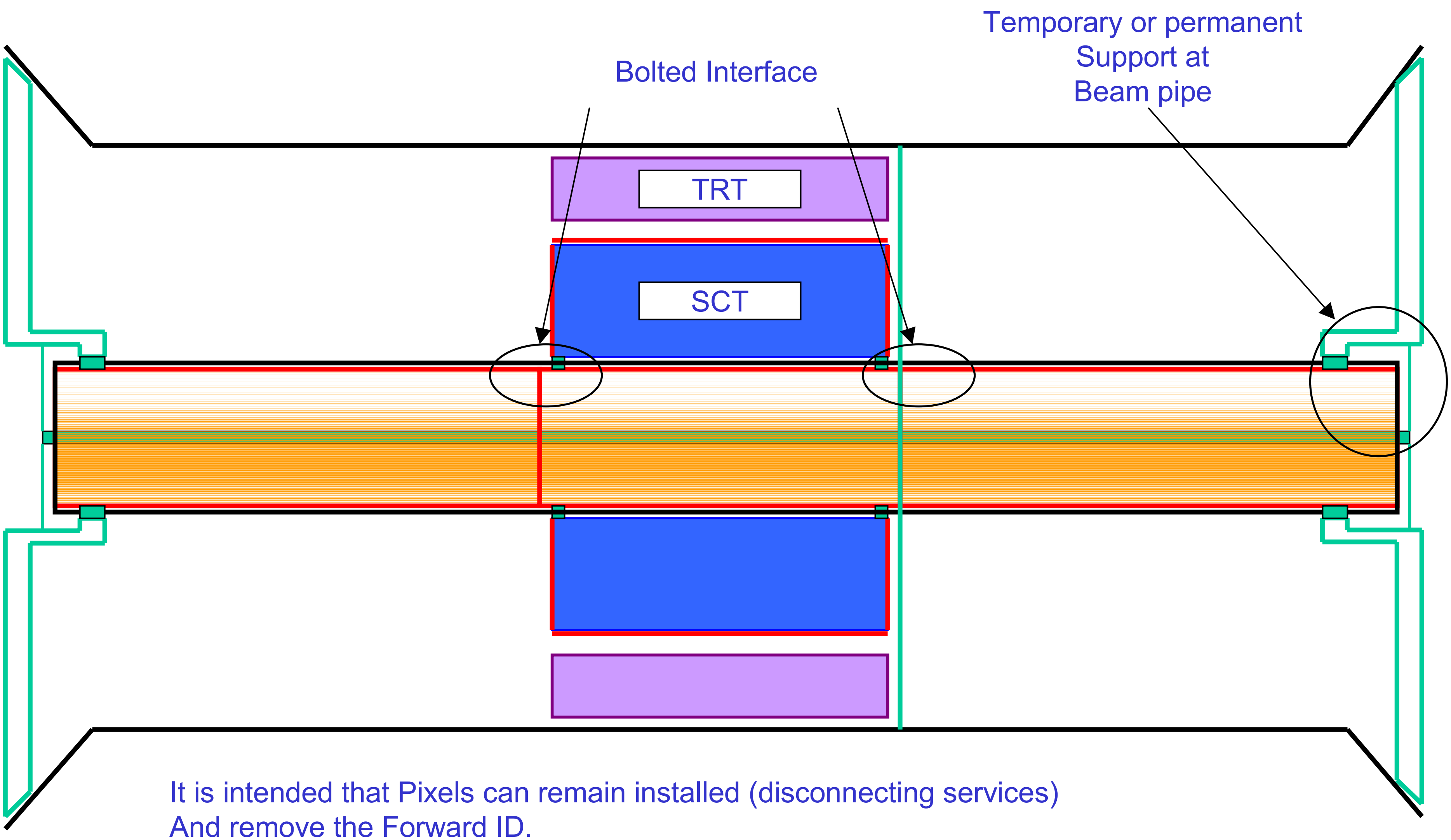
Pixel Detector

PST Cross Section



Pixel Detector

Pixel Support Tube Installed with Barrel ID



It is intended that Pixels can remain installed (disconnecting services)
And remove the Forward ID.

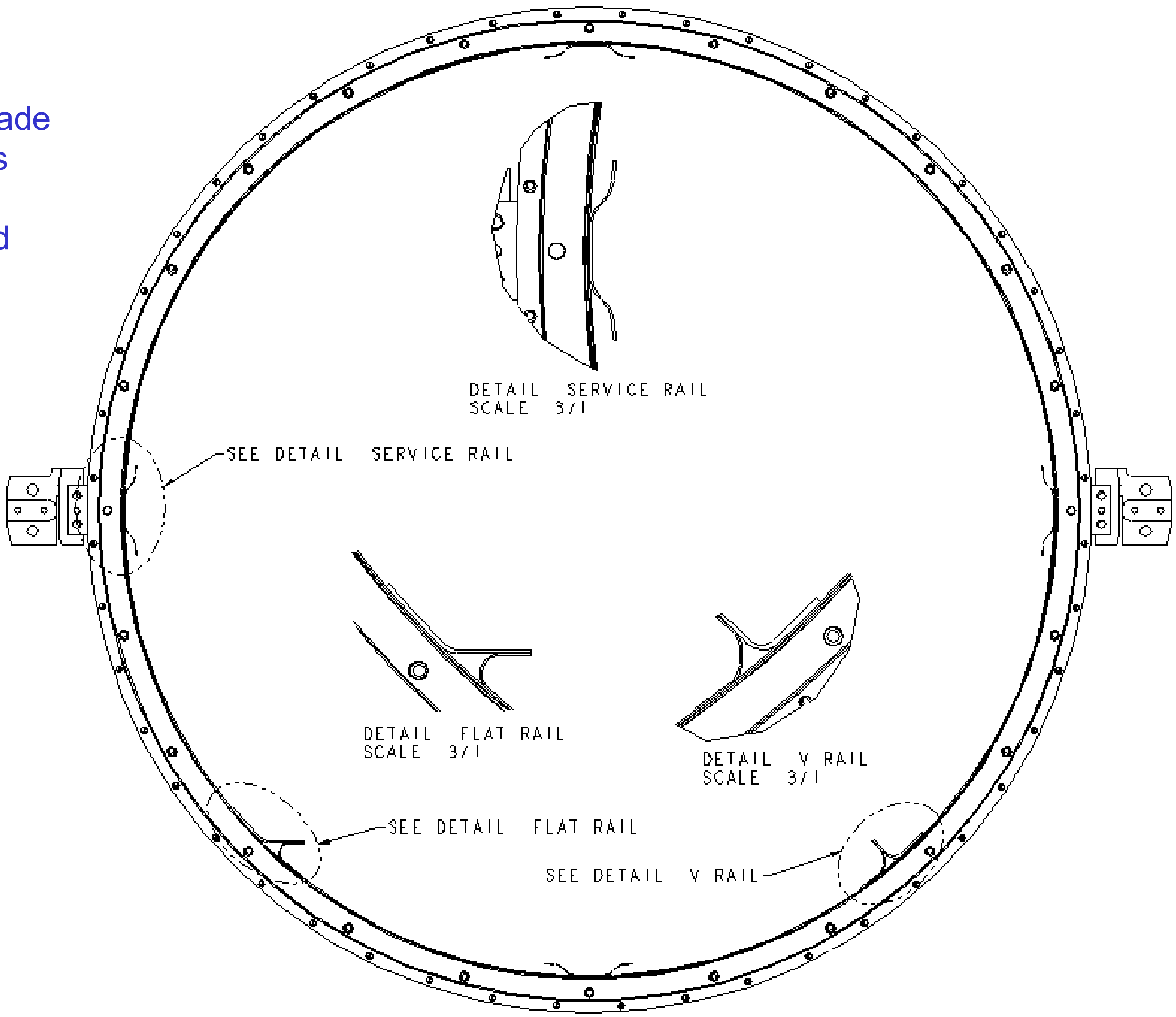
PST Design Details

RAILS

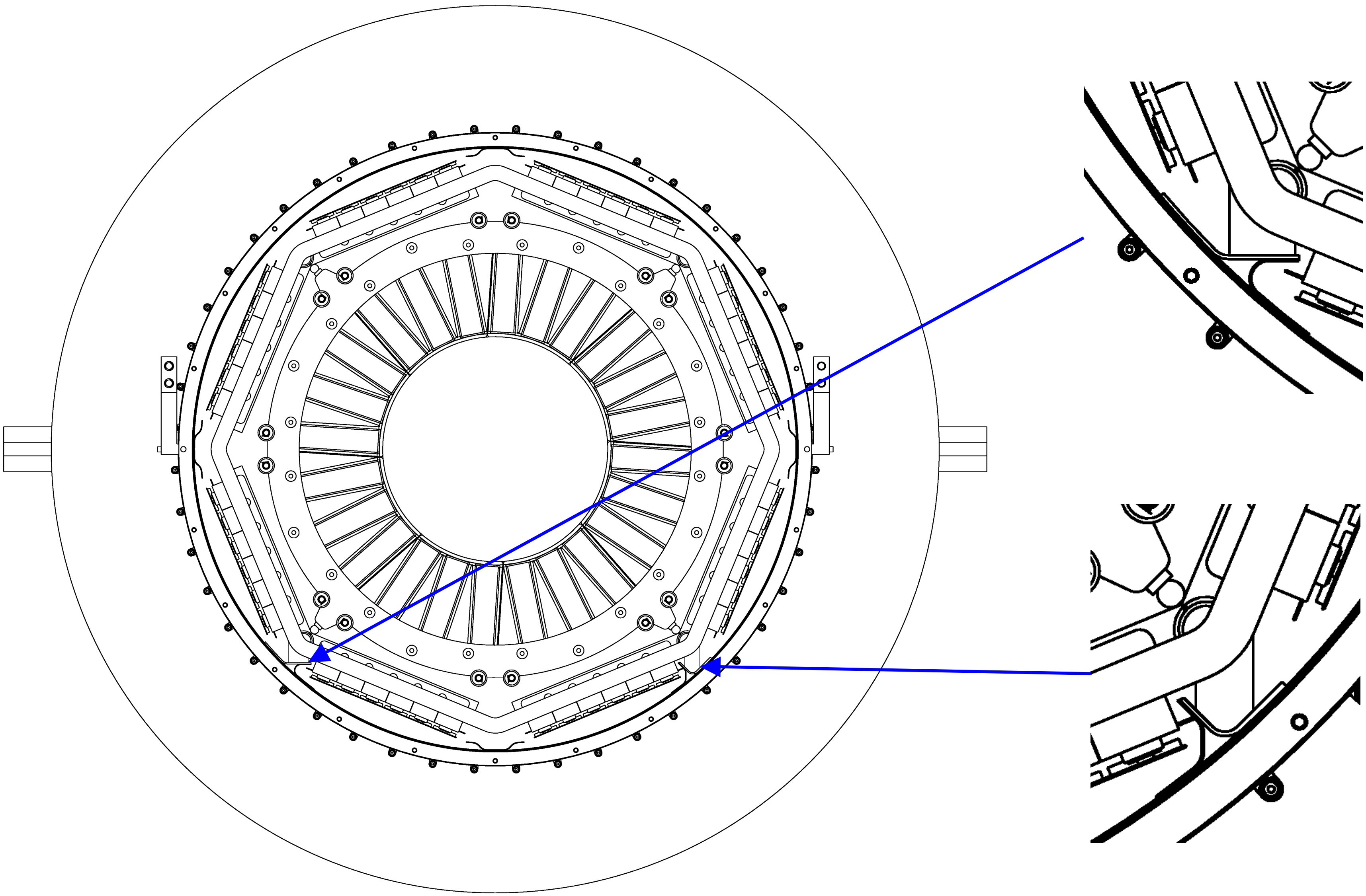
Pixel Detector

PST Rail Details

Insertion rails (flat and v)
Are bonded assemblies made
From two thin layups. This
Allows the rails to have
Closed sections (increased
Stiffness), yet use simple
Fabrication methods and
Be relatively small in
Section.

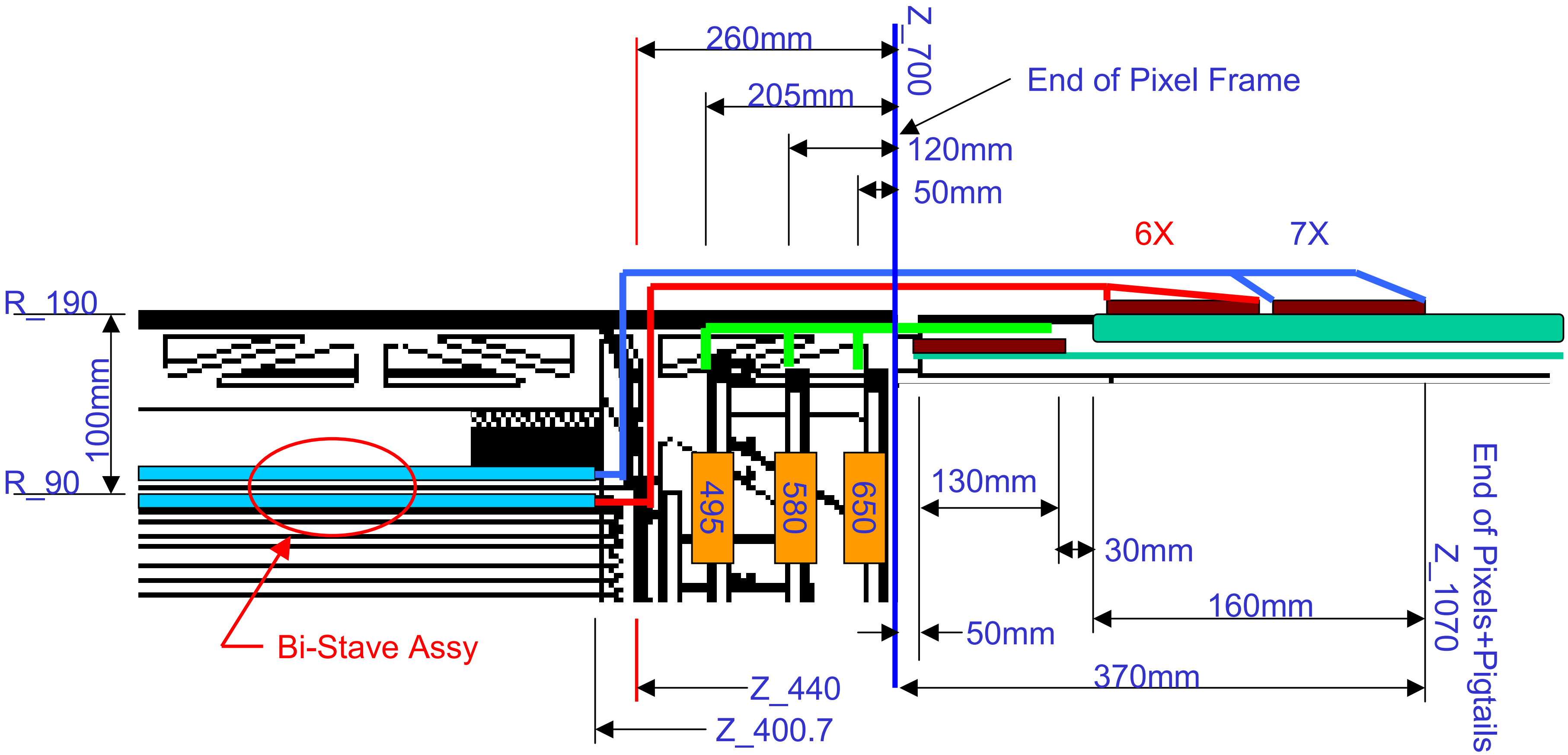


Detector and Insertion Rails



Pixel Detector

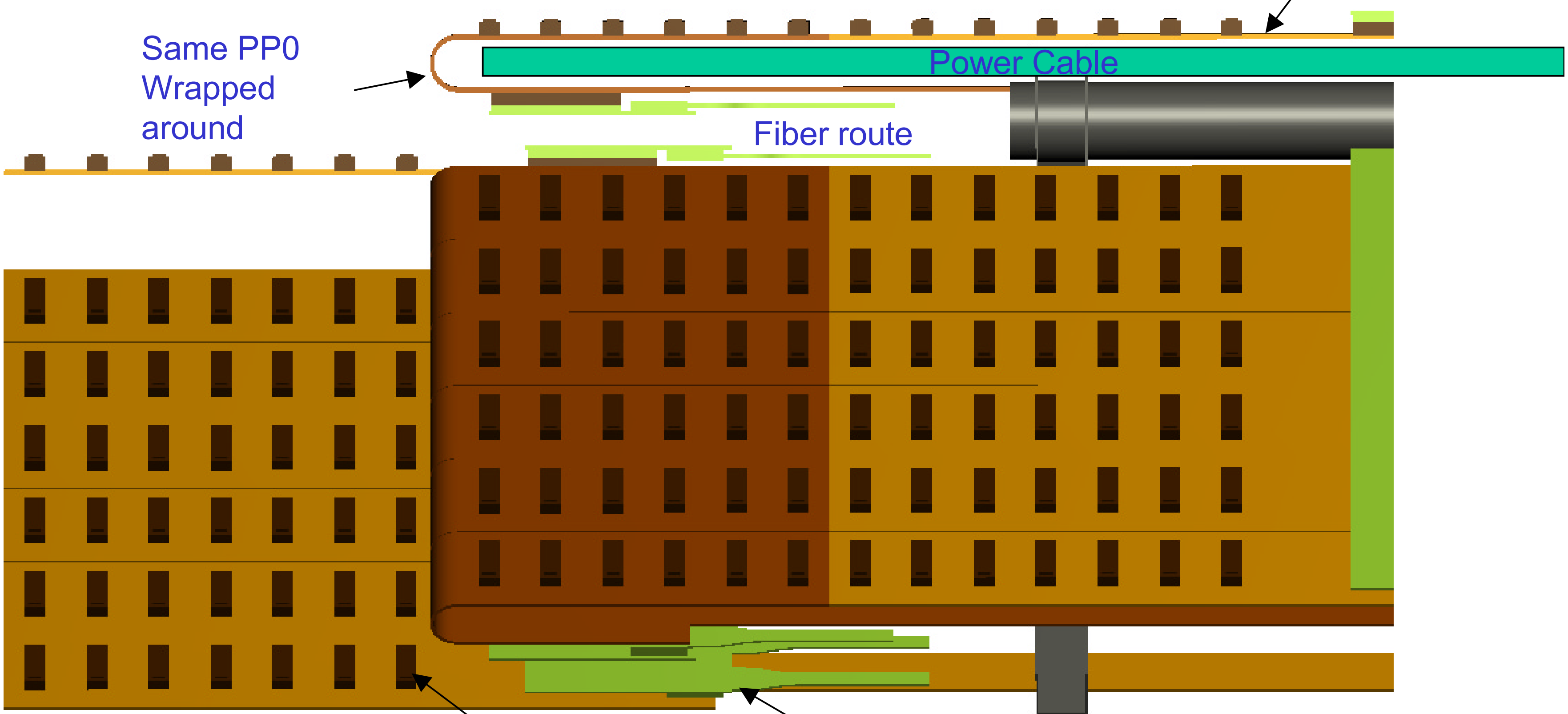
Overlap Region (PP0)



- **Radius of PP0 is approximately 180mm**
- **Starts at Z=750 and goes to Z=1070 (50mm gap between PP0 and Frame)**
- **End of Support Tube is at Z=3400mm, making the Type I panel 2.65m long**

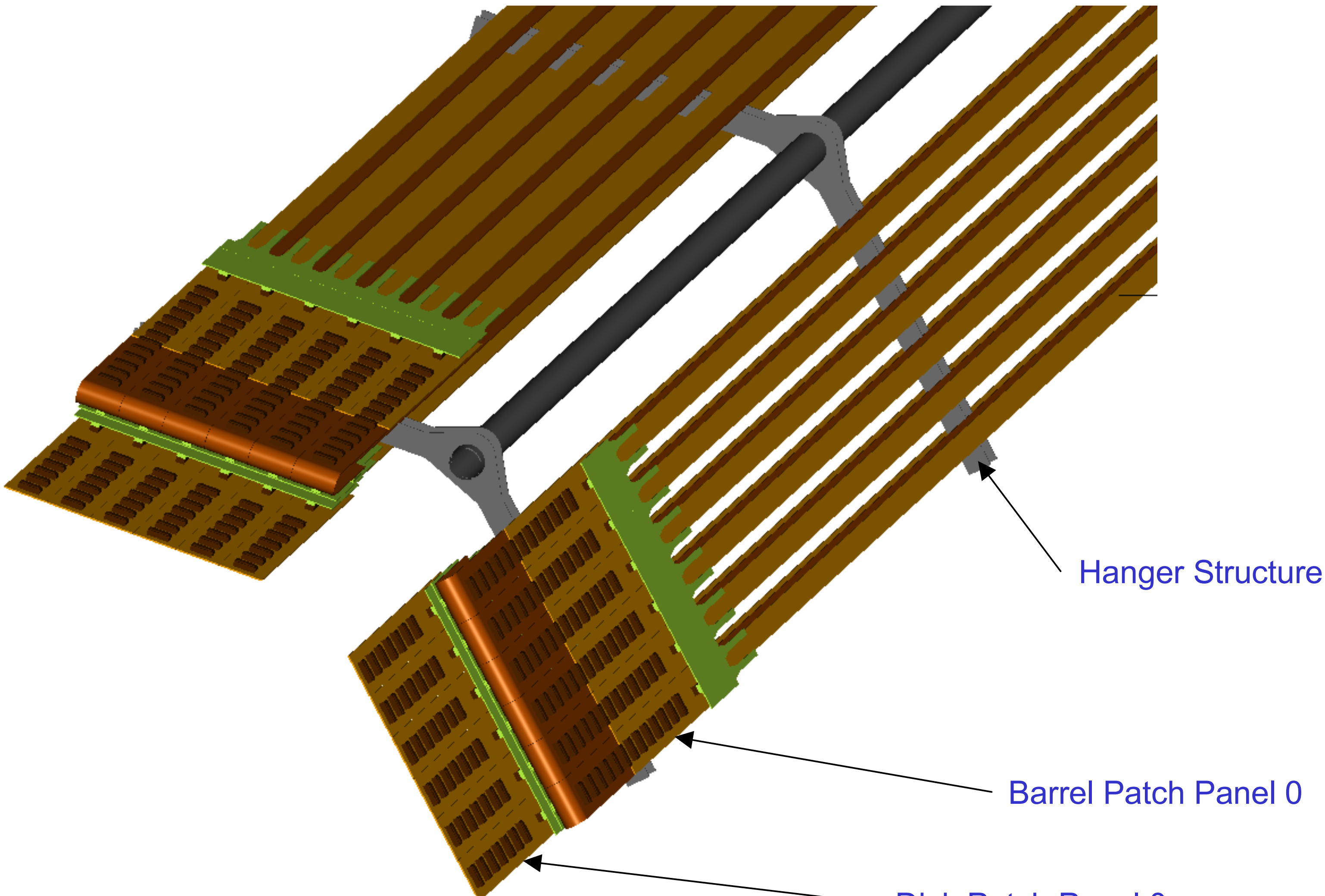
Pixel Detector

PP0 array on Service Mechanical Support



Pixel Detector

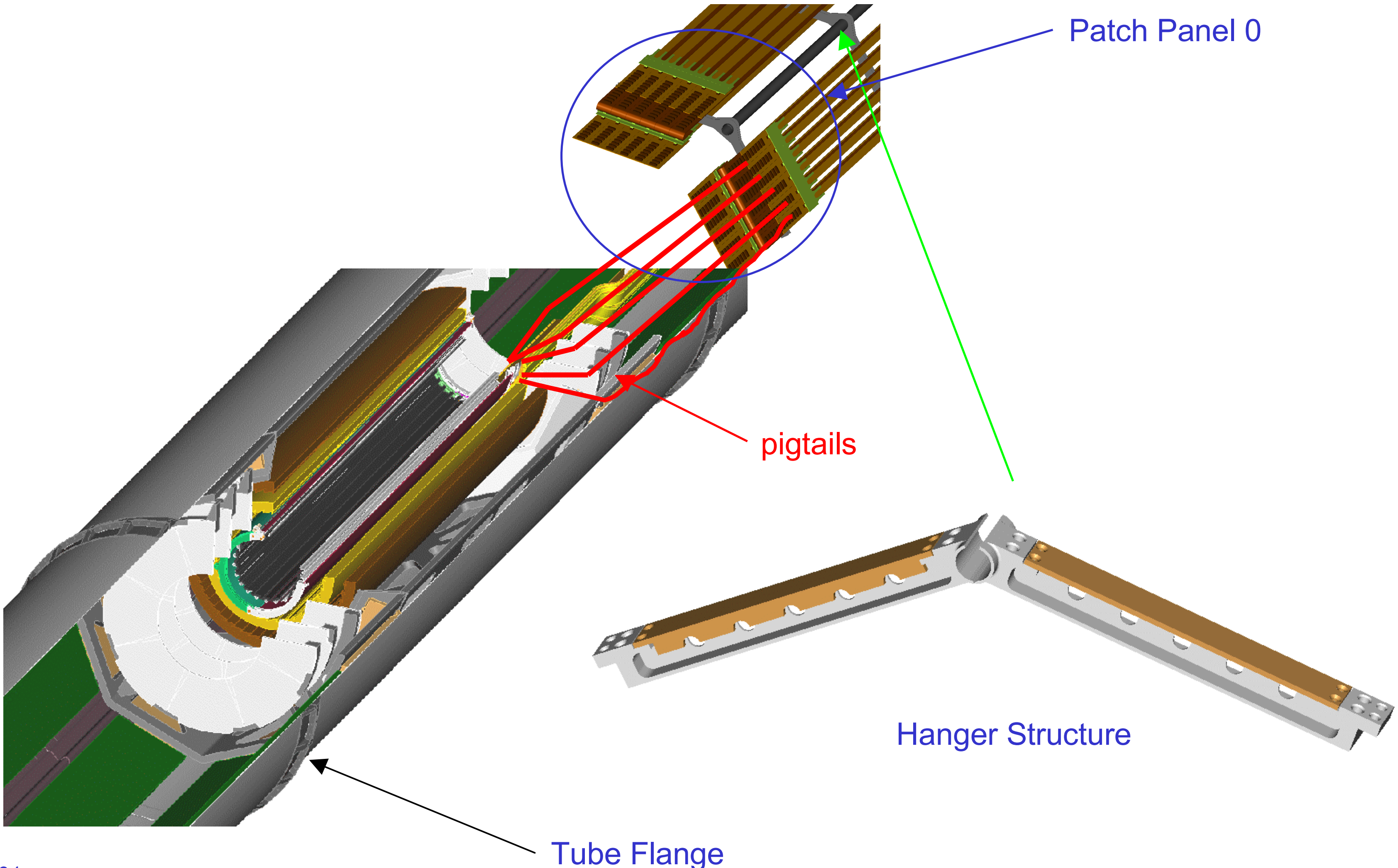
Services Mechanical Support



Structure necessary to support services during installation scheme

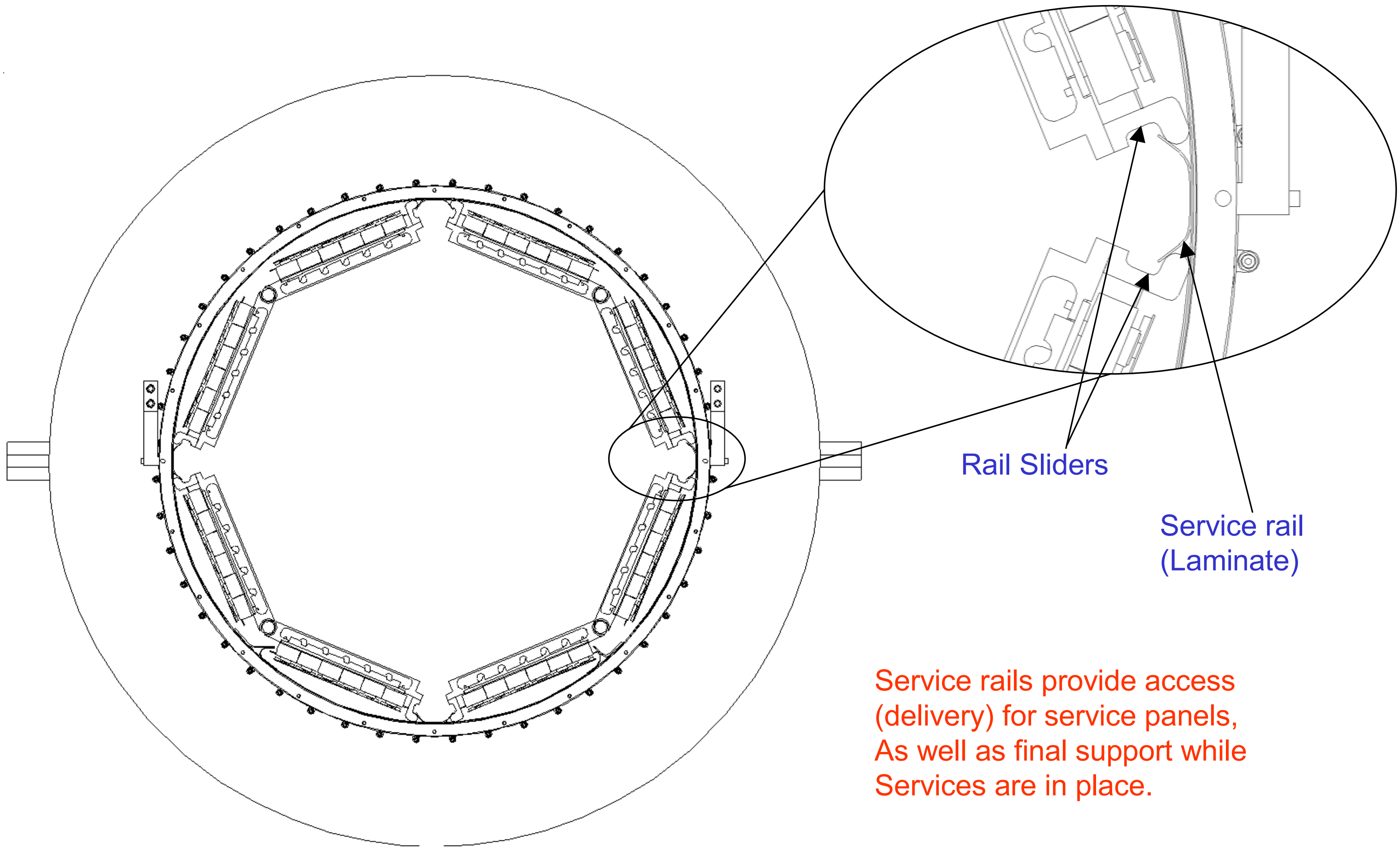
Services Mechanical Support

Structure necessary to support services during installation scheme



Pixel Detector

Services Insertion and Support



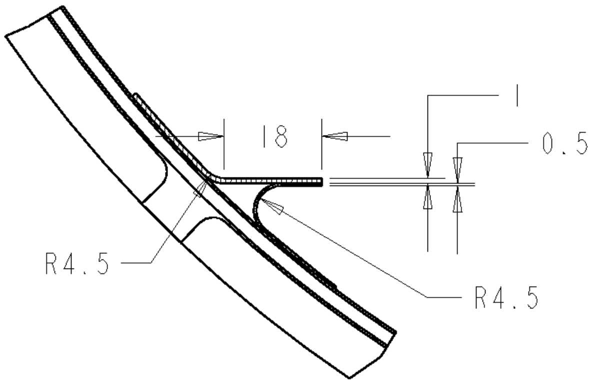
Service rails provide access (delivery) for service panels, As well as final support while Services are in place.

PST Mockup Objectives

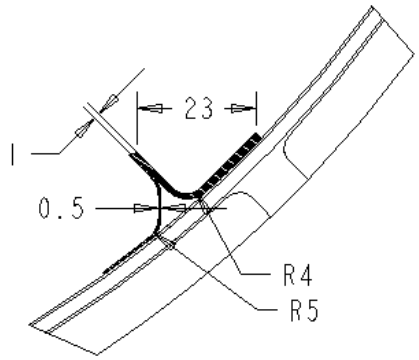
- **Mass and Envelope Geometry of final detector Frame**
  - Attempting for similar friction
  - Part of mockup effort includes friction studies of several plastics
- **At least two full quadrants of dummy service panels**
  - Initially 1-quadrant, both sides, eventually half of all services (are more needed?)
- **At least two octants (both sides) of mechanically accurate connections**
  - Needed for installation simulation
- **At least one octant of electrically active service connections**
  - This is to provide verification that terminations stay terminated through procedure
  - Might prove useful for thermal mockup
- **Provision for Dummy B-Layer installation**
  - Requires also mechanical connections for installation simulation

Pixel Detector

PST Mockup Concept



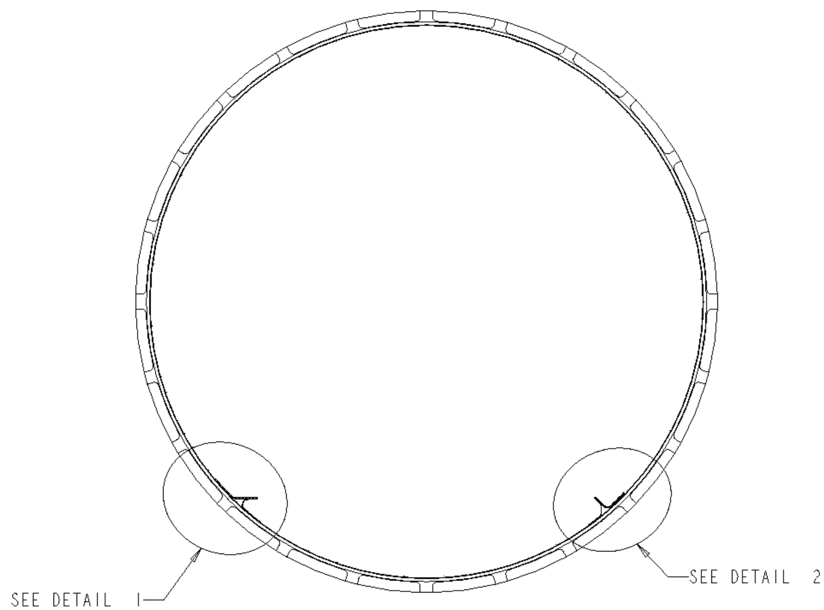
DETAIL 1



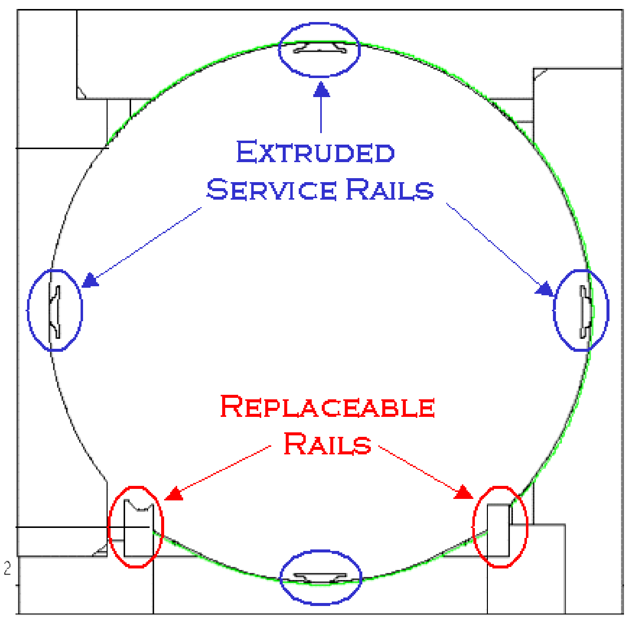
DETAIL 2

V and Flat rails were chosen to provide pseudo-kinematic support for the detector during delivery to the support points

Mockup tests rail and slider design with actual geometry

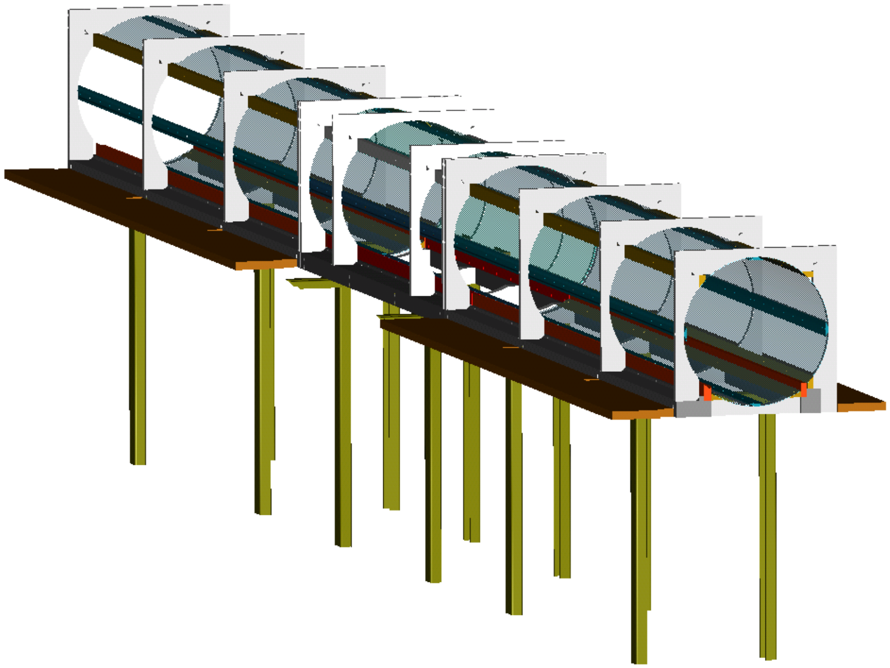


SECTION A-A
SCALE 0.375



mockup

Pixel Support Tube Mockup



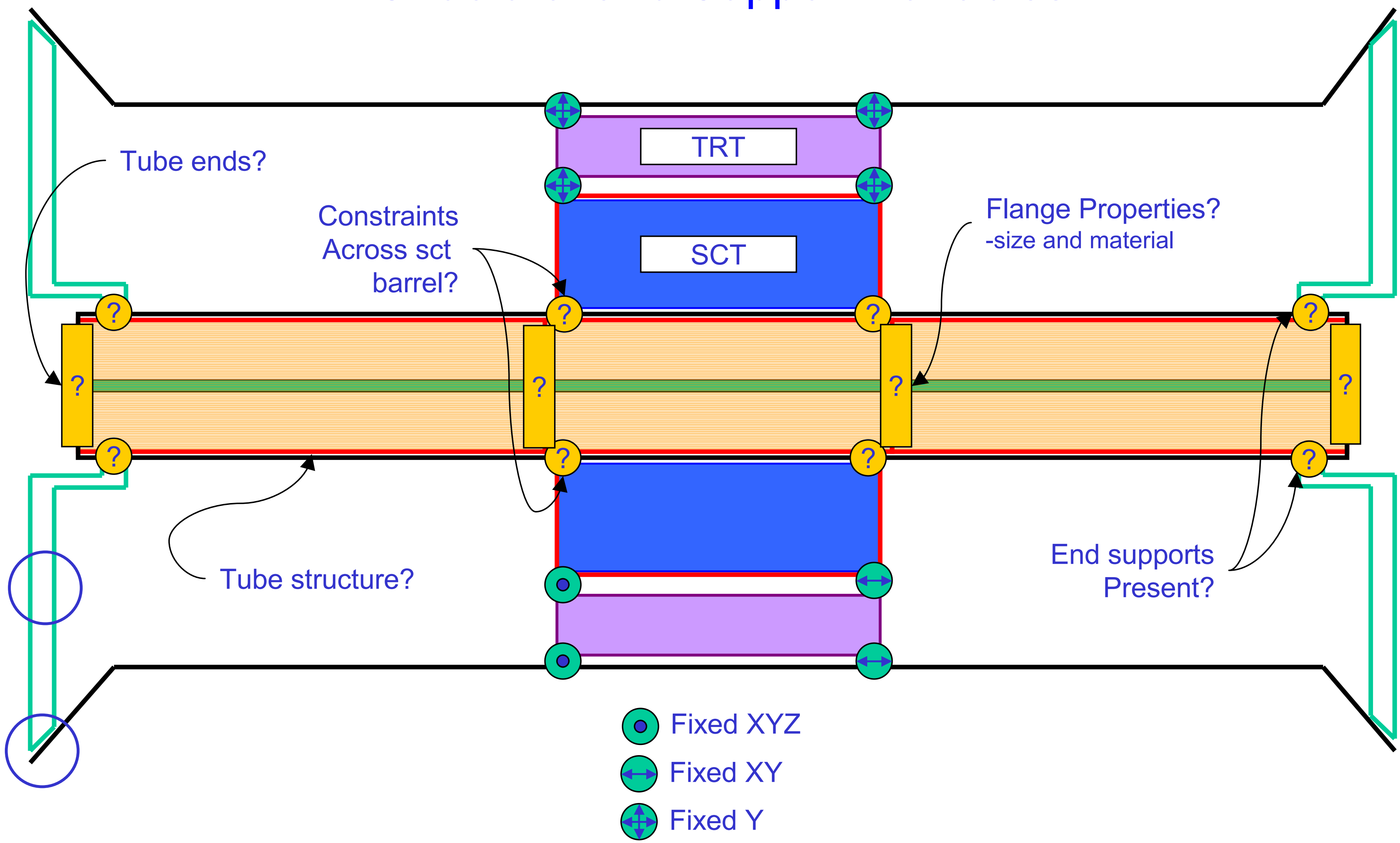
- **Mockup in three pieces to simulate independent parts of tube**
  - Goal is for full length of entire tube to simulate all installation scenarios
  - Detector rails are removable, should modification be necessary

PST Design Details

TUBE PERFORMANCE ISSUES

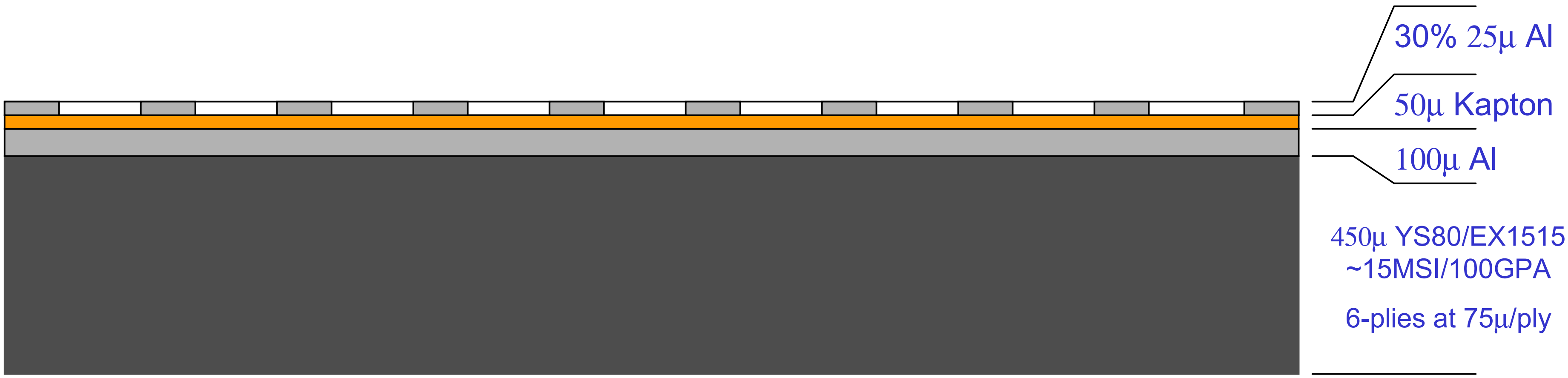
Pixel Detector

Structural and Support Variables



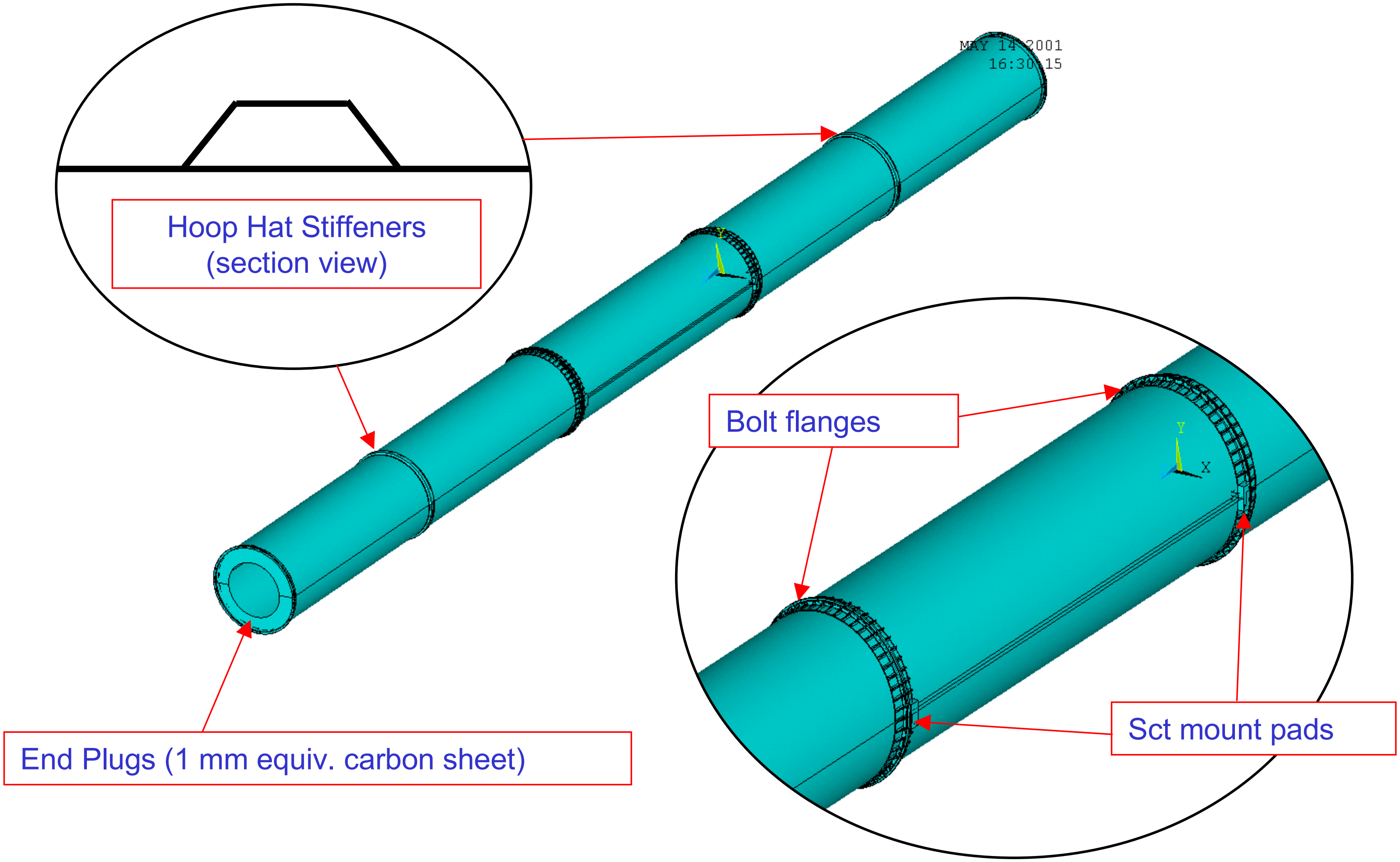
Pixel Detector

Nominal Shell Laminate



$\%X_0 = 0.045/24 + 0.01/8.3 + 0.005/24 + 0.3(0.025/24) = 0.36\%X_0$

FEA Model – Important Features

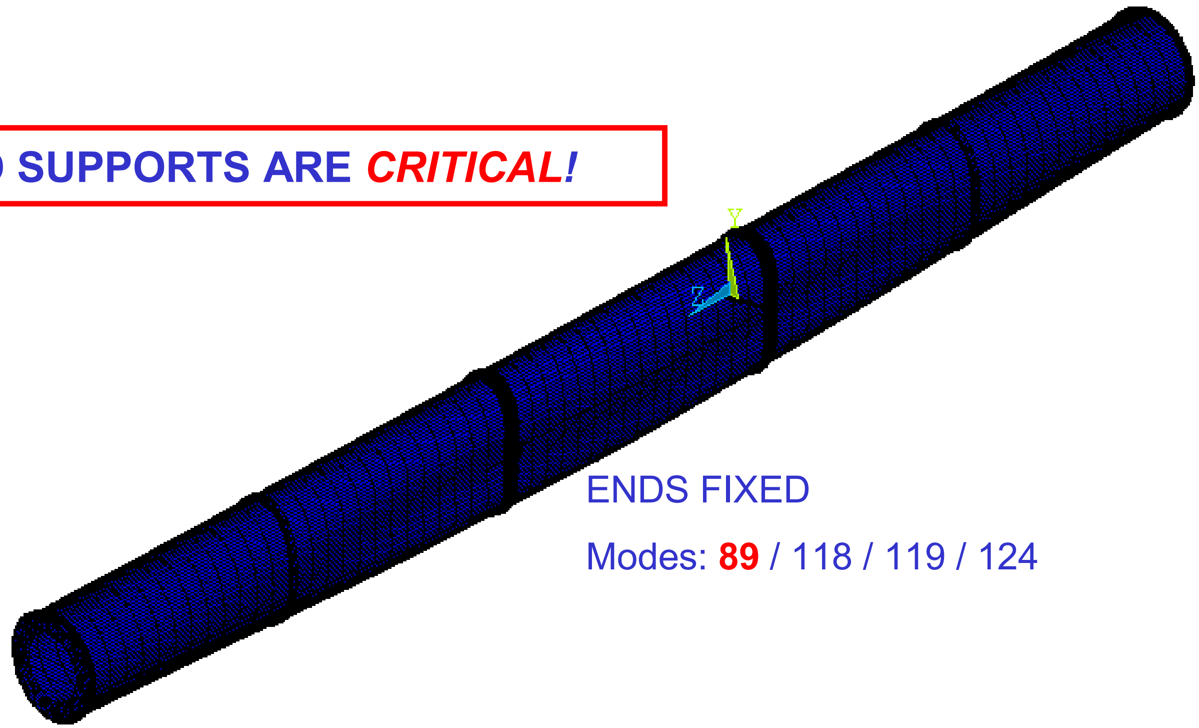


FEA Model – Effect of End Fixation

ENDS FREE

Modes: **31** / 48 / 55 / 62

END SUPPORTS ARE *CRITICAL!*



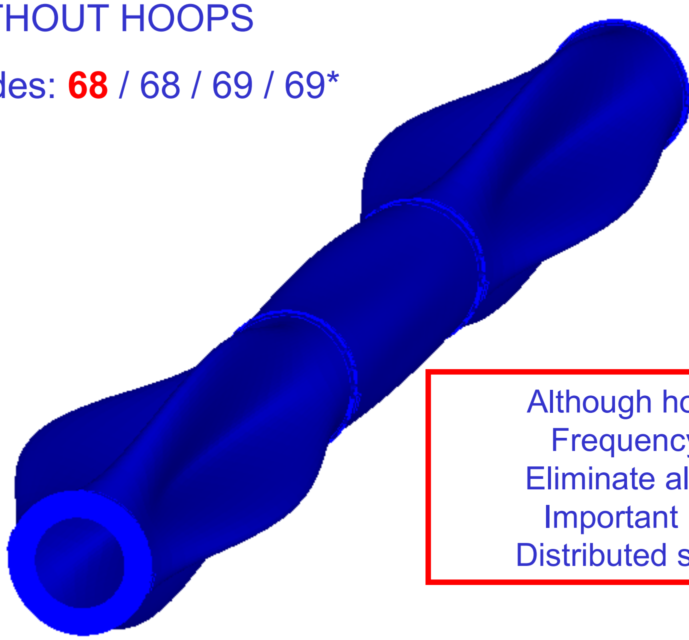
ENDS FIXED

Modes: **89** / 118 / 119 / 124

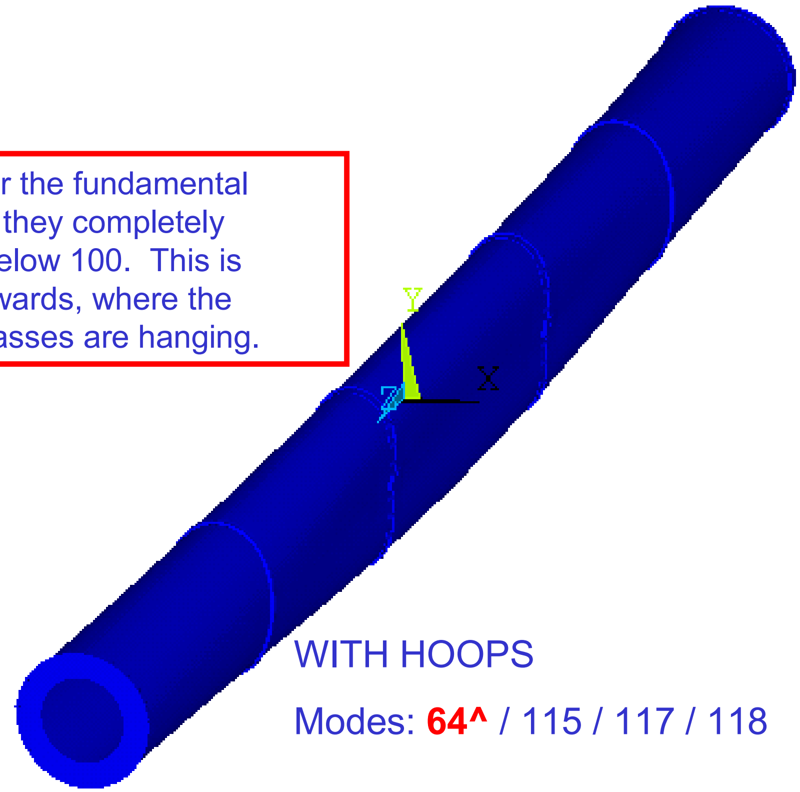
FEA Model – Effect of Hoop Stiffeners

WITHOUT HOOPS

Modes: **68** / 68 / 69 / 69*



Although hoops lower the fundamental Frequency slightly, they completely Eliminate all hom's below 100. This is Important in the forwards, where the Distributed service masses are hanging.

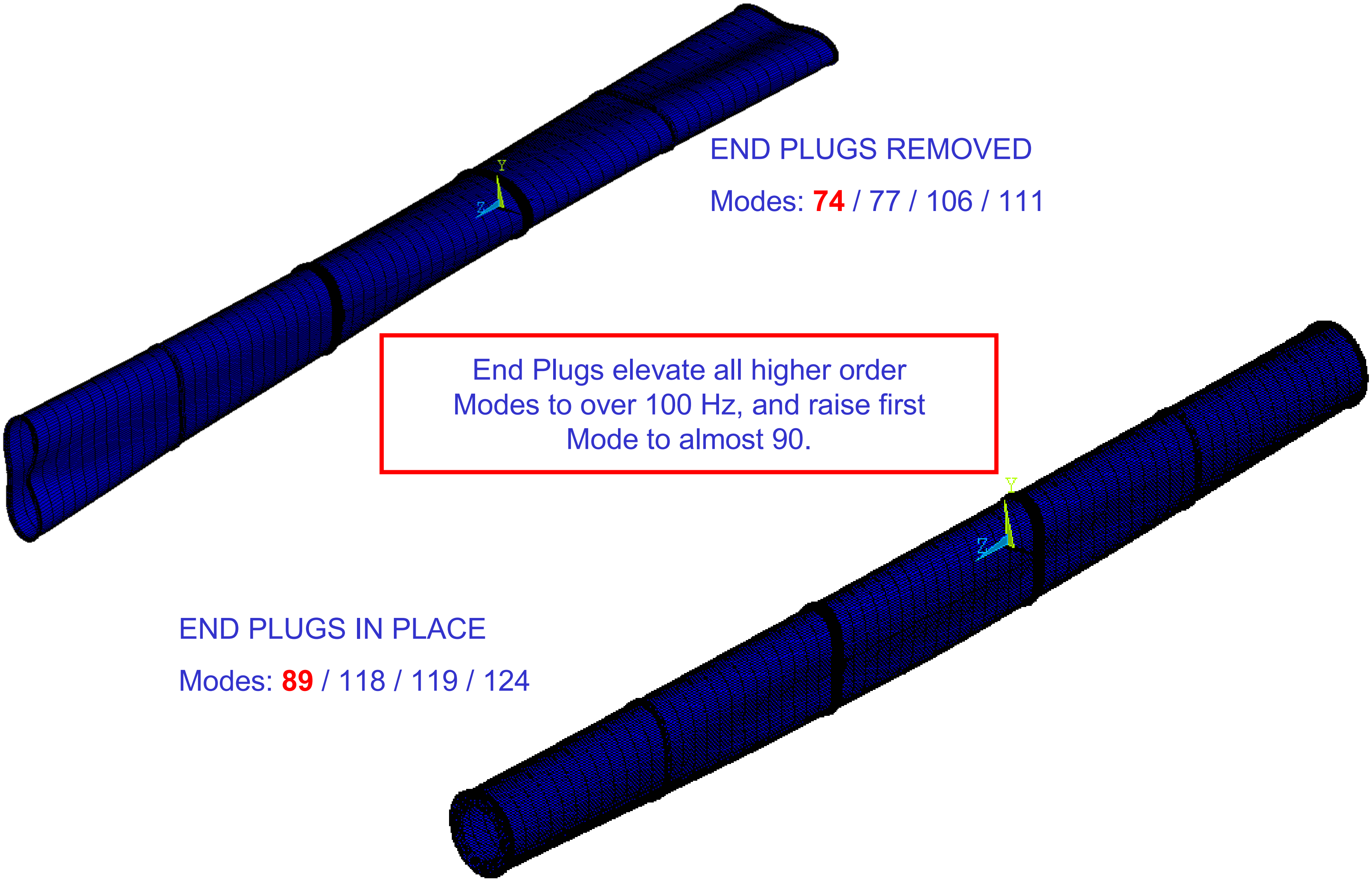


WITH HOOPS

Modes: **64^** / 115 / 117 / 118

*modes are very close in frequency,but differ in shape
^Frequencies different from previous design due to different Flange design, however, above models are same in all ways Except for the presence of hoop stiffeners

FEA Model – Effect of End Plugs



END PLUGS REMOVED

Modes: **74** / 77 / 106 / 111

End Plugs elevate all higher order Modes to over 100 Hz, and raise first Mode to almost 90.

END PLUGS IN PLACE

Modes: **89** / 118 / 119 / 124

Pixel Detector

Conclusions/Recommendations

- **Further analysis must be conducted with pixel mass**
  - However, pixels will be weakly coupled to support tube due to fixation scheme
  - Installation deflections (from gravity) appear to be low, but shell components in support tube must be analyzed
- **Recommended shell features**
  - End plugs must be structural
    - Raises fundamental frequency somewhat (~20%)
    - Raises Hom’s to above 100 Hz
  - Hoop stiffeners are needed
    - Eliminates all forward shell modes below 100 Hz (except fundamental)
    - Much more efficient than cored structure (less mass)
  - Ends MUST be supported
    - Fundamental frequency nearly triples!
    - Many Hom’s below 100 Hz are eliminated

PST Design Details

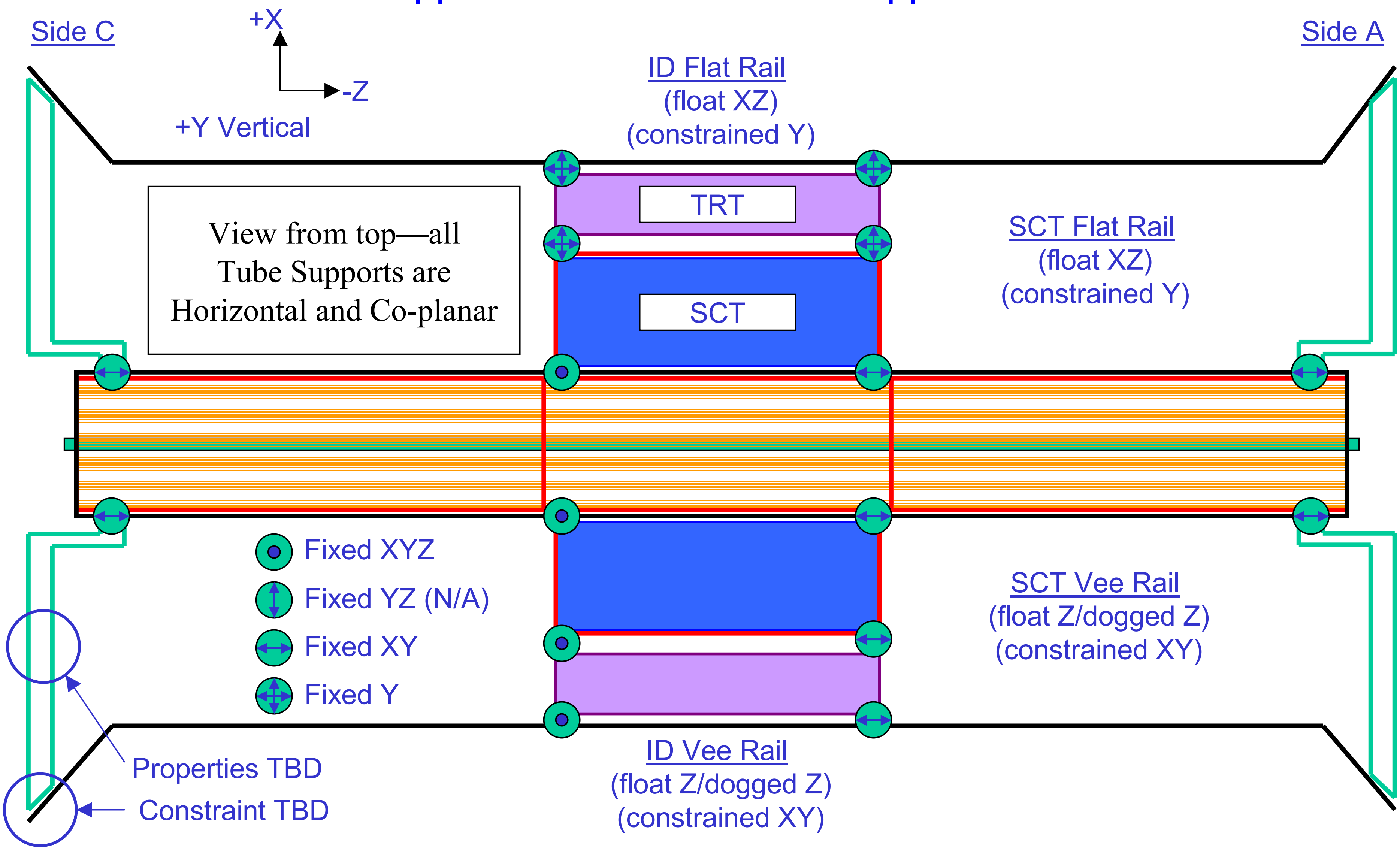
PST SUPPORTS

Mount Scheme Goals

- **Benefit from the stiffness of the SCT across the Diameter, but minimize extraneous loads:**
- **Minimize loads induced due to misalignment of mount features**
  - Each mount is potentially constrained in 6-Degrees of Freedom
  - orient “mate-up”directions with soft degrees of freedom (aligned with flexure axis where possible)
  - Use pins to locate but let bolts float until all pins are aligned
- **Minimize Internal load on SCT/Pixel**
  - CTE mis-match of very stiff objects leads to potentially high forces
  - Use of Flexures to minimize induced tension in the SCT.
- **Minimize External Load on ID Barrel**
  - Mis-match of Cryostat and Support tube yields potentially high strains
  - Use of larger flexures at Forward End Support to minimize load

Pixel Detector

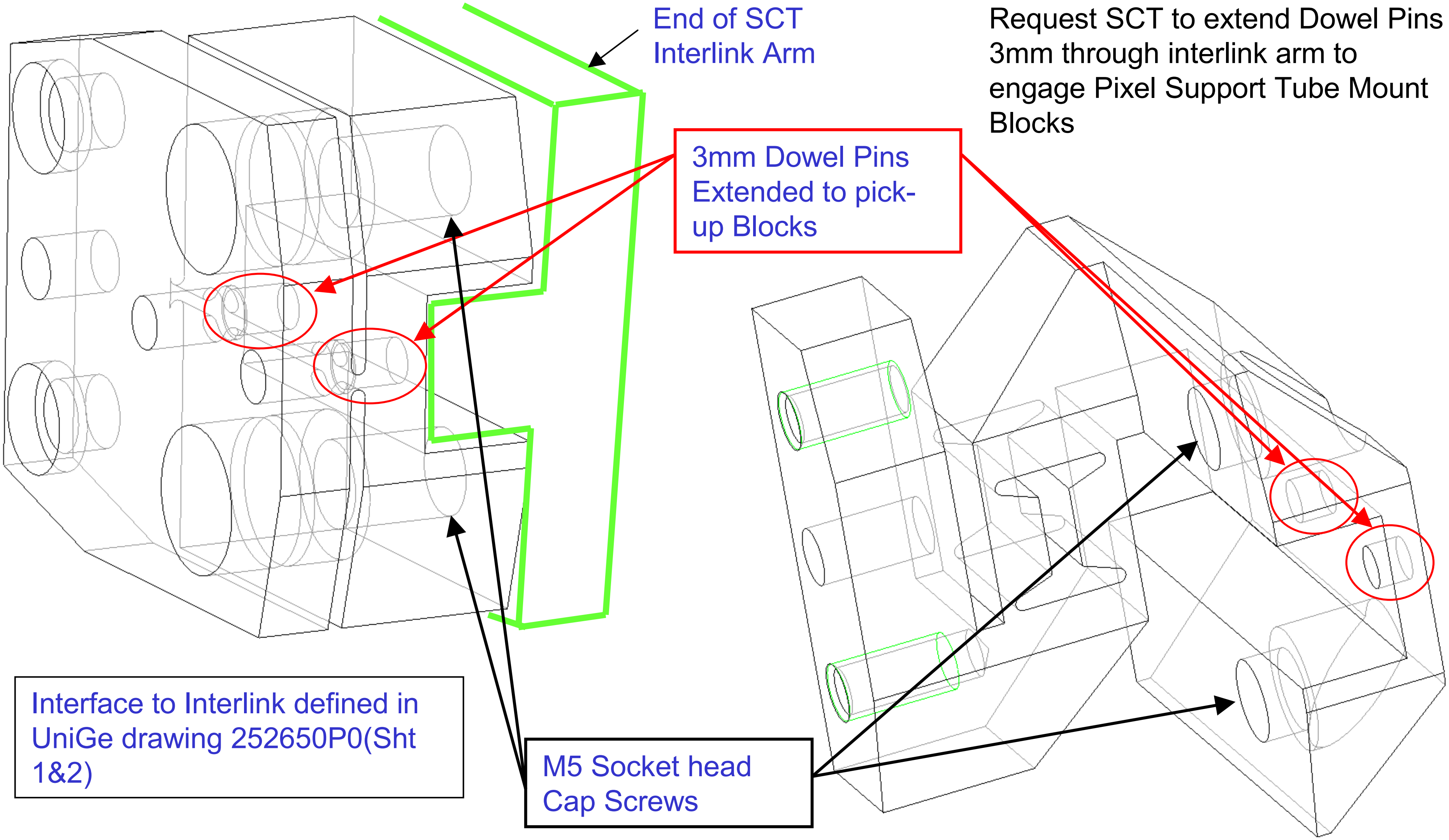
Support Condition of Pixel Support Tube



Support condition of Pixel Support Tube intends to couple in stiffness across diameter

Mount Interface to SCT Interlink

Request SCT to extend Dowel Pins 3mm through interlink arm to engage Pixel Support Tube Mount Blocks

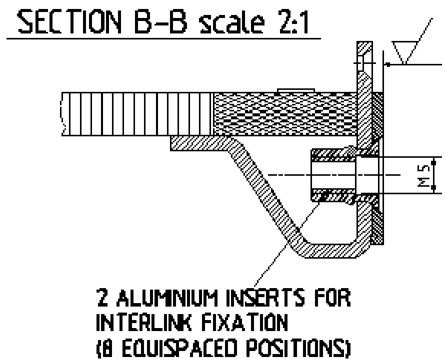


Mount blocks held in place with same M5 bolts used to hold Barrel 3 to interlink

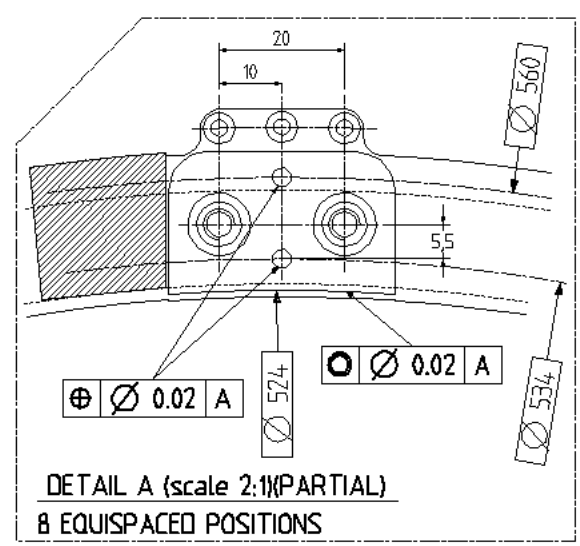
Interface to SCT Interlink

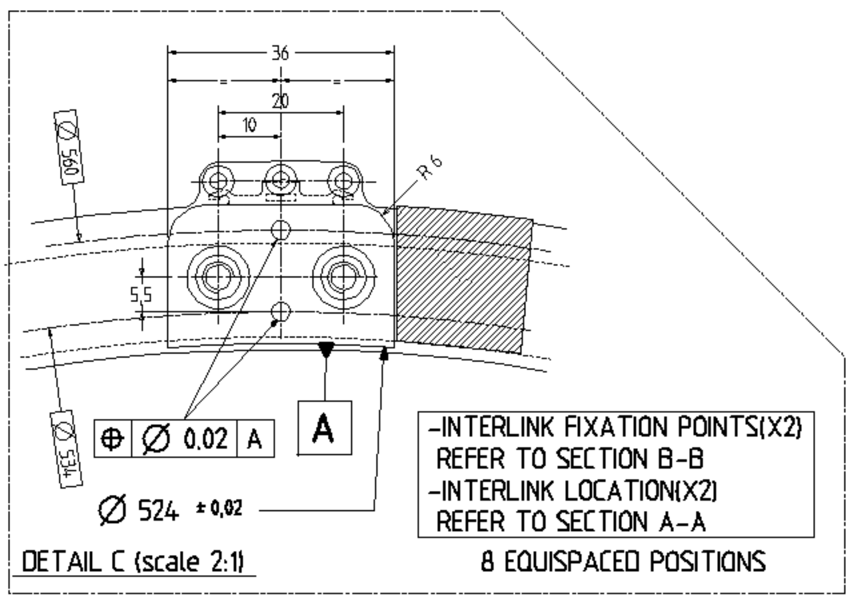
- **Pixel Support Tube is supported by Interface Blocks which are mounted to the SCT**
- **All Interface Blocks have identical interface to SCT**
  - SCT is adding additional fasteners to end of interlink for pixel/SCT mounts
  - Brief modification of the end of the interlink to accommodate
    - Extend Dowel Pins
    - Round End

SCT to Interlink Interface



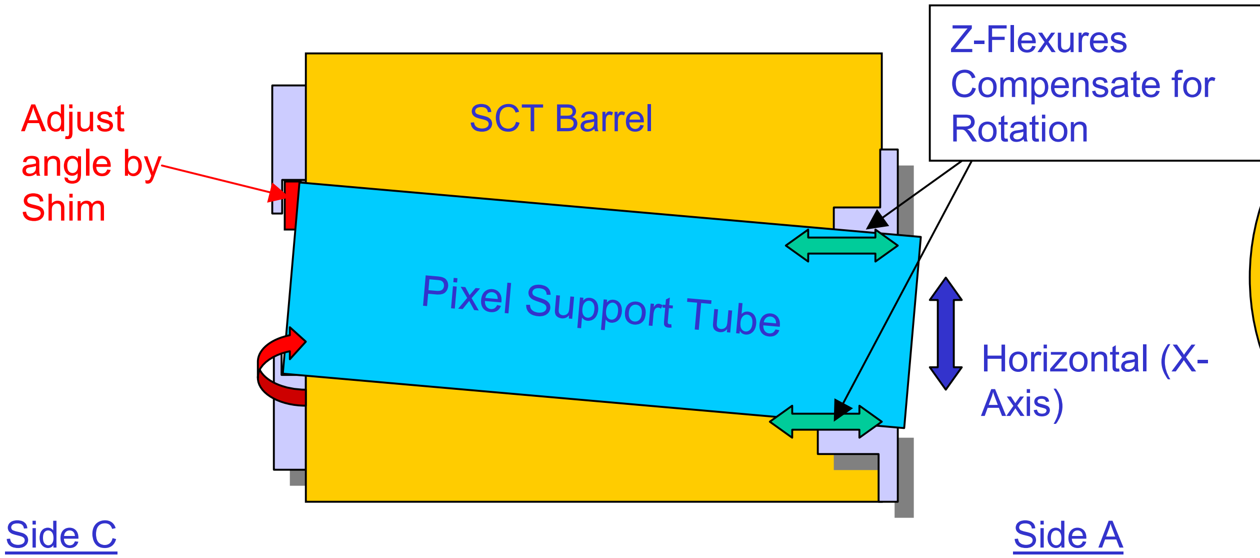
- **Absolute accuracy of Holes in SCT Barrel 3 is 20μ**
  - Is there data from the current SCT prototype indicating that this is reasonable to expect?
- **Implies that the twist in the free state is limited to 20μ**
- **Pixel Support Tube will be of same order, but hesitate to claim better than 75μ**
- **SCT is adding additional bolt holes for pixel mounting**



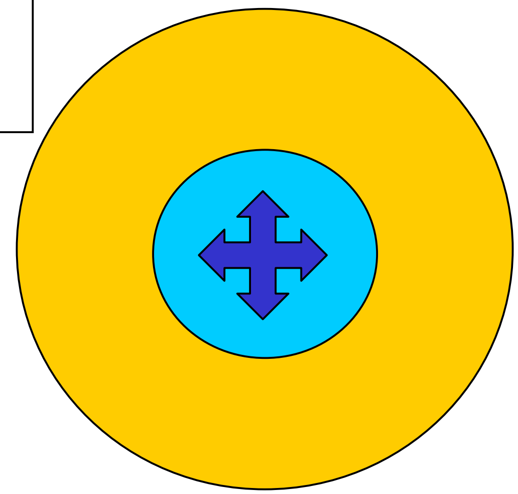


Pixel Detector

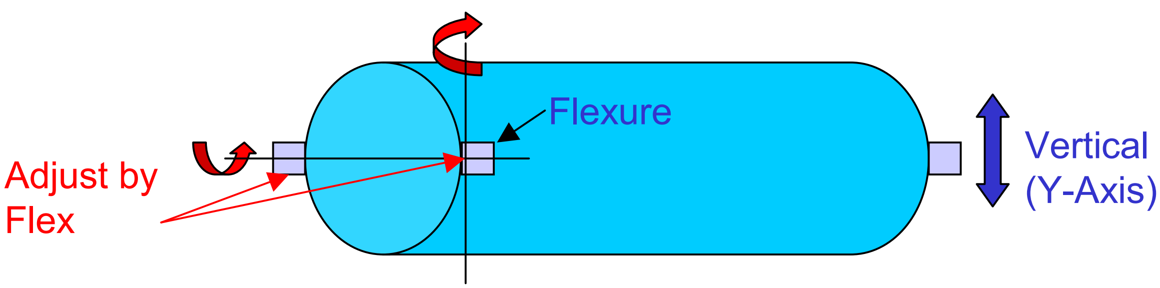
Minimize Local Loads During Assembly



Shimming one mount on side-C gives horizontal freedom on side-A



ONLY Torque about Z is over constrained

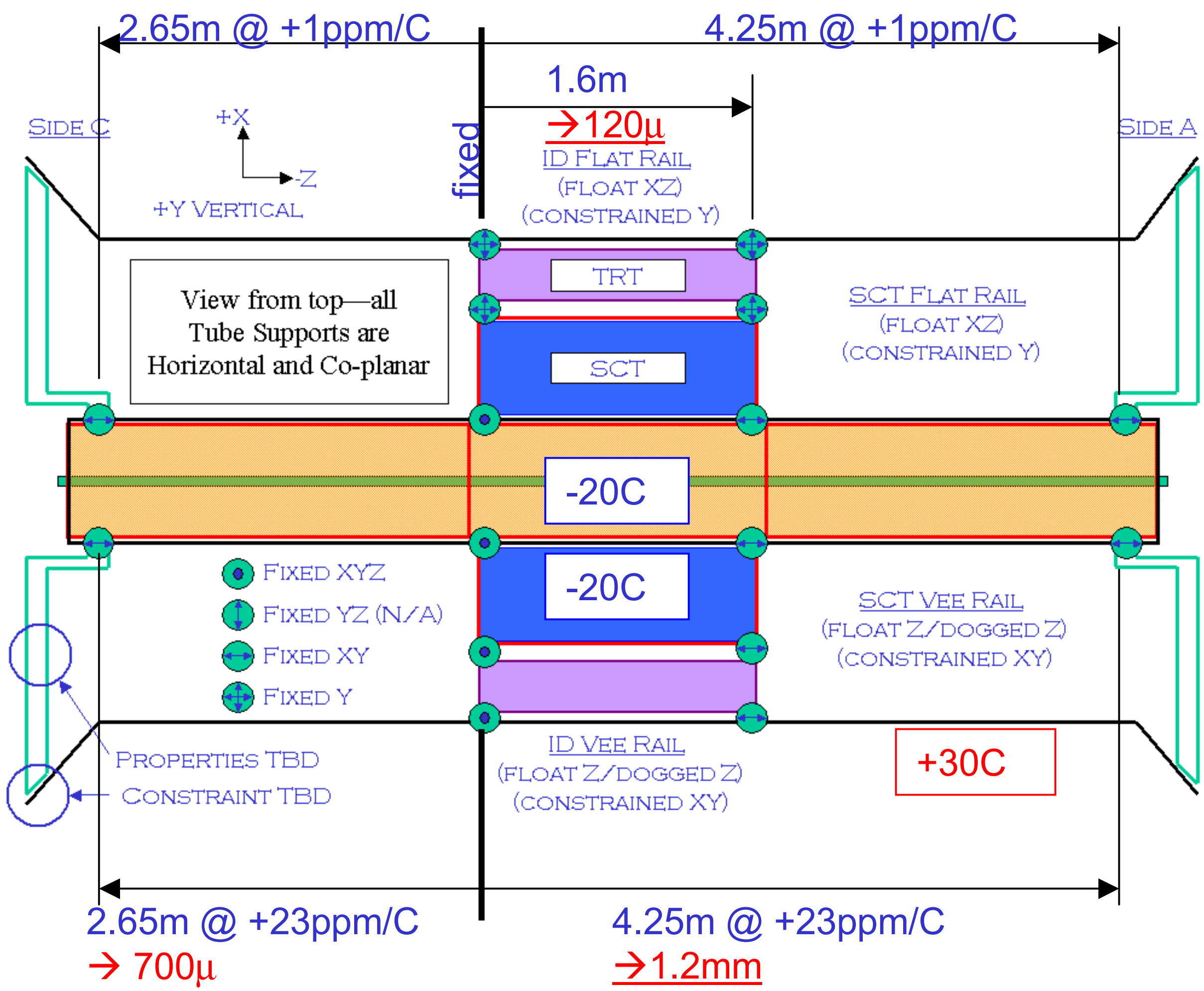


Flexure on side-C gives vertical freedom on side-A

In principle, the requirement for shimming and flexing should be minimal, in fact limited to the build tolerance

Pixel Detector

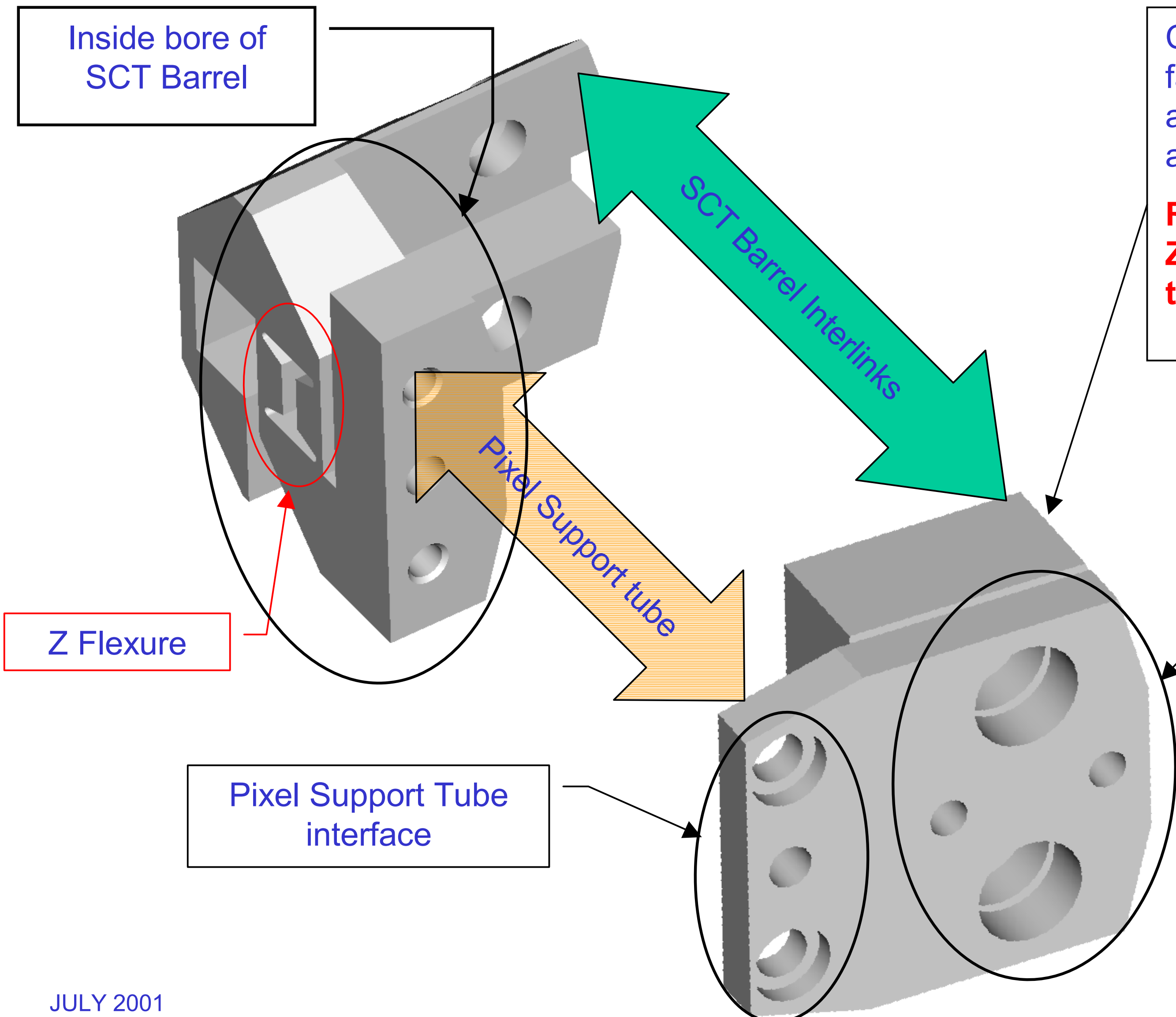
How Much Float is needed



- **Fixed Point to End of SCT yields an internal stress**
  - Due to CTE mismatch on the order of 1-2ppm/C
- **Fixed point to end of Cryostat yields an External load on the ID Barrel via the SCT**
  - There is potentially a large CTE mismatch between Cryostat and the Pixel Support Tube
  - Case where Cryostat raised 10C above no-power condition, and where Support tube CTE is unusually high (>1ppm/C)
- **Flexures need to assure minimal loads at these extensions yet remain stiff in the orthogonal directions**

Pixel Detector

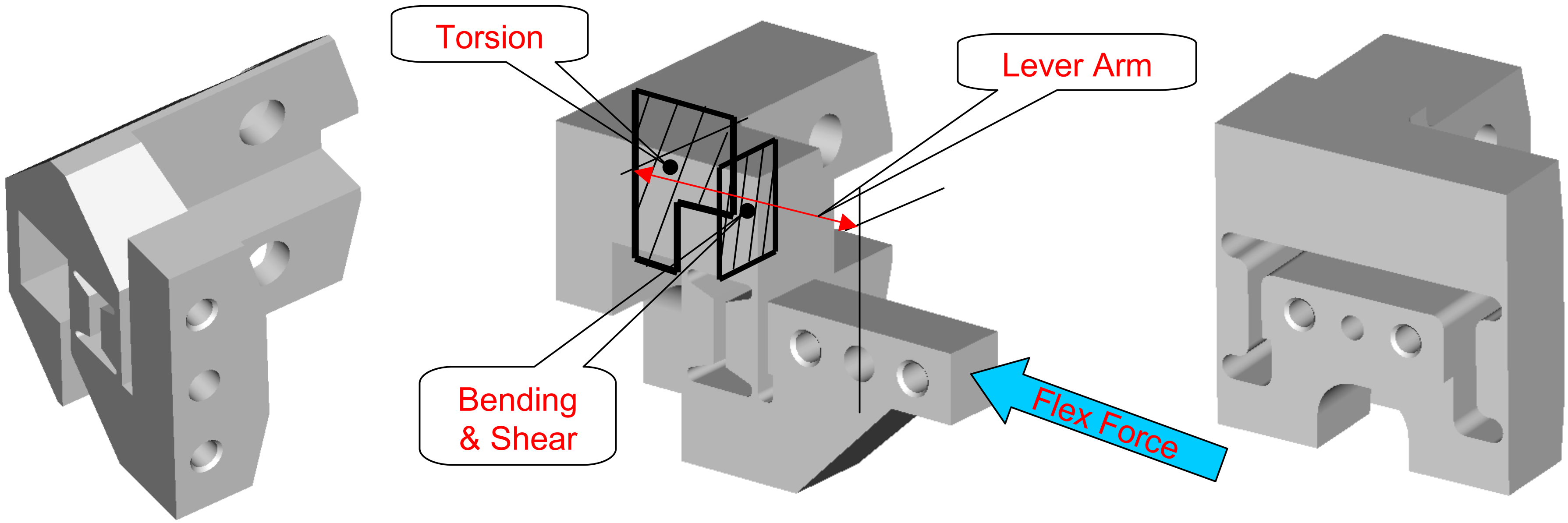
Supports Fixed or Float in Z



Can rotate parallel to mount face of Z-flexure, but rotation and vertical travel of Z-flexure are coupled

Rotate mount orientation on Z-flexure to accommodate this

Floating Mount Design Study



50g

85g

Figures of Merit

108g→80g (target)

Increased Inertias,
Rotated Mounts

Acceptable Force and
Deflection

Final Concept

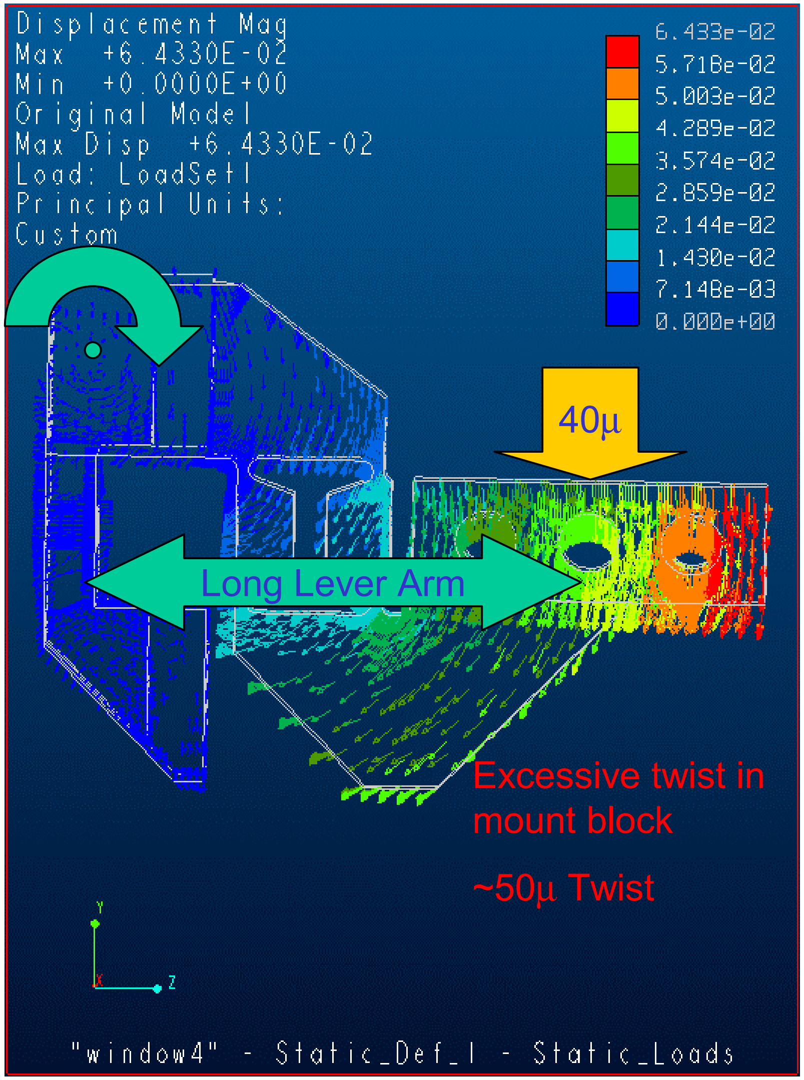
- Initial Concept
- Low Mass
- Only preliminary sizing

- Rotation of Mount Feature
- Realistic Sizing
- Developed Figures of Merit

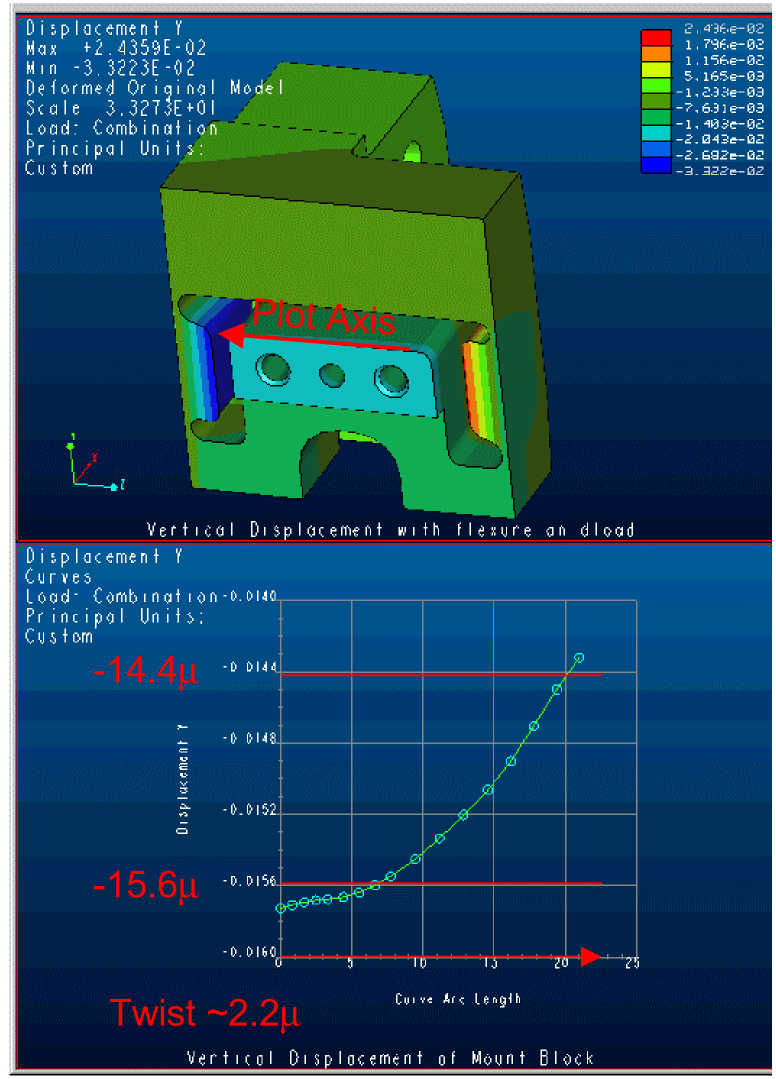
- Acceptable Deflection
- Acceptable Flex Force
- Need to Optimize Mass

Motivation for Changes

Deflection is primarily Torsion about mount section—want to reduce Lever-arm and increase Sectional Inertia

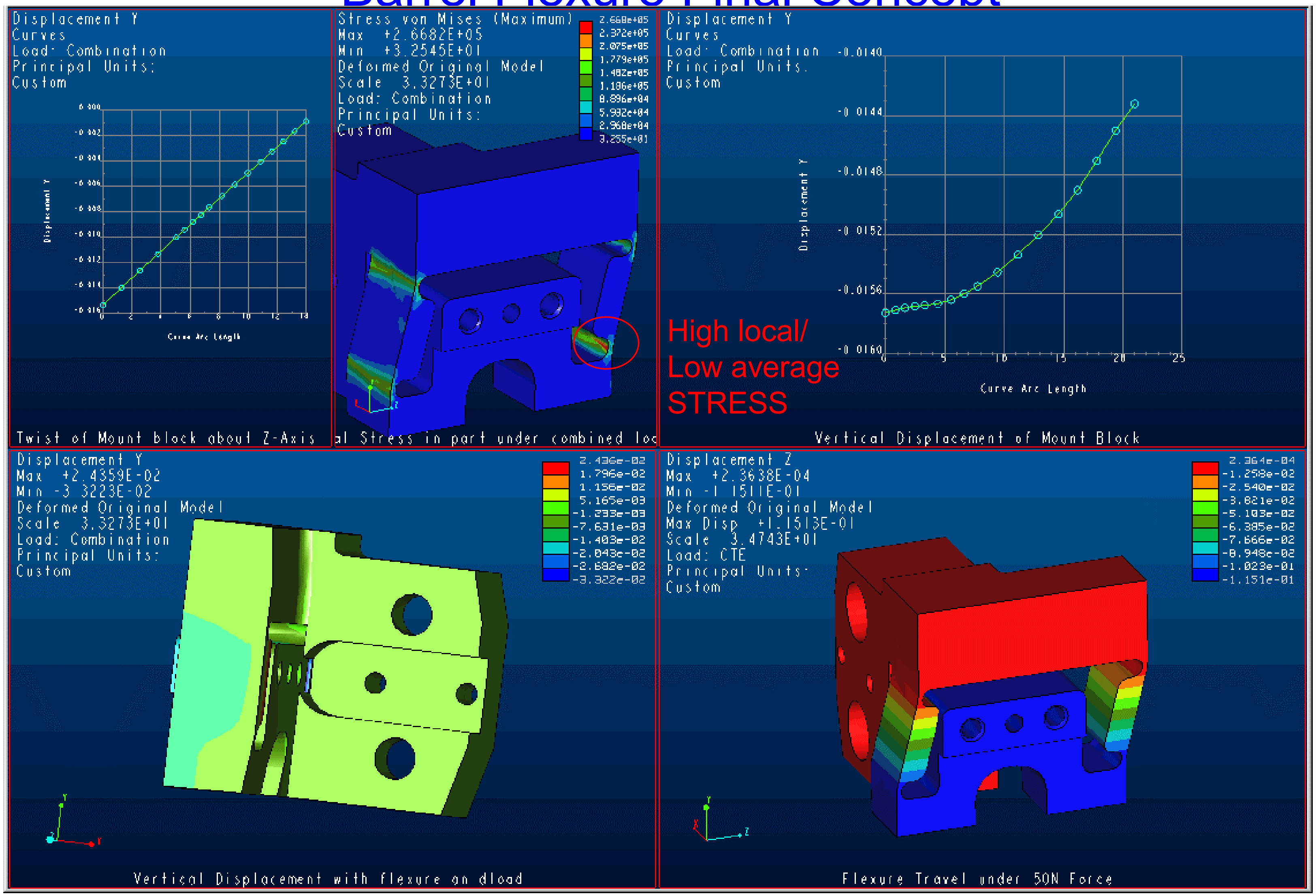


All of these are Free deflections, real constraints restrict some of these motions yielding 30-50% reductions in deflections



Pixel Detector

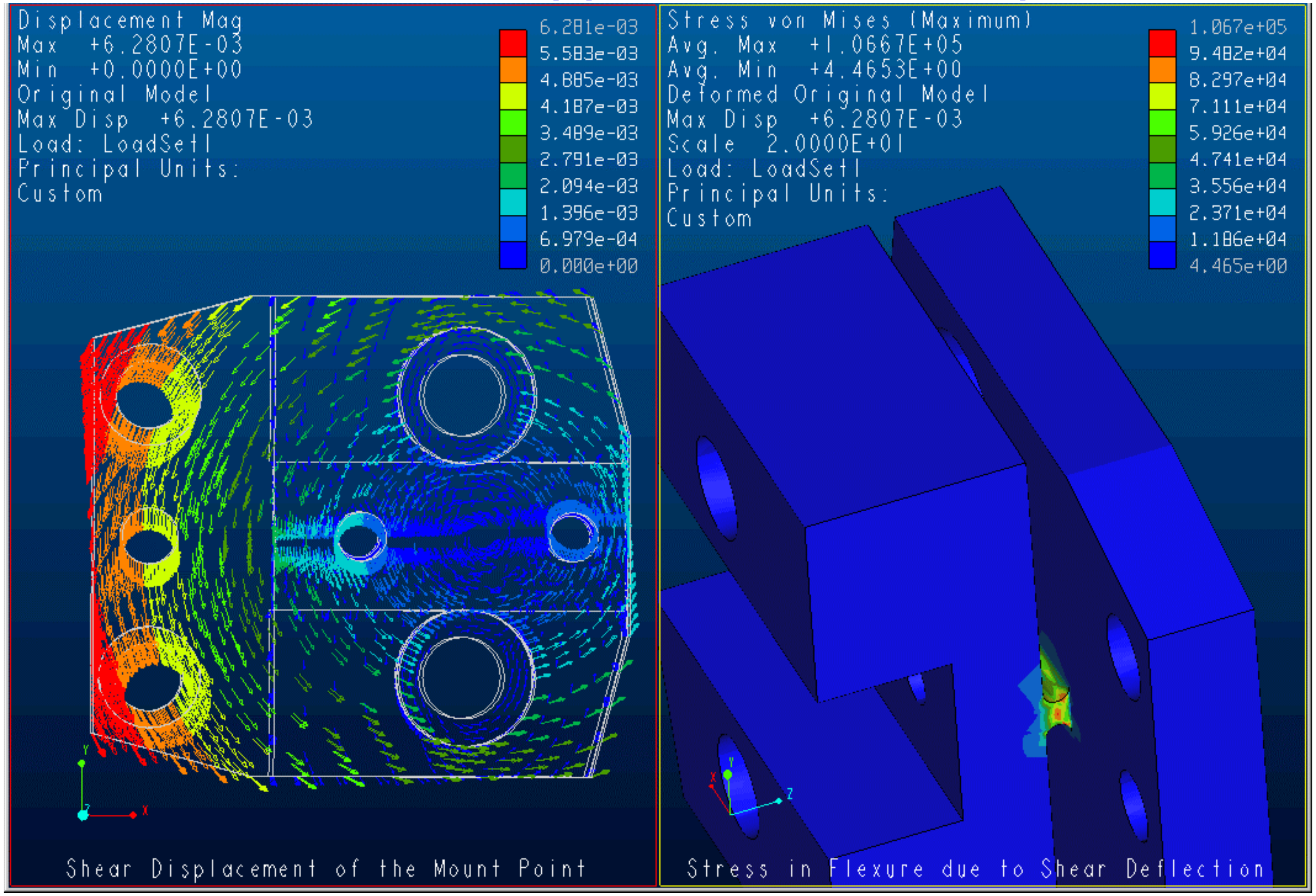
Barrel Flexure Final Concept



Results →50N force at full potential travel (115µ)
→Highest Stress <35% Yield Ti6Al4V
→14.5µ Vertical Deflection relative to SCT

Pixel Detector

Fixed Support Final Concept

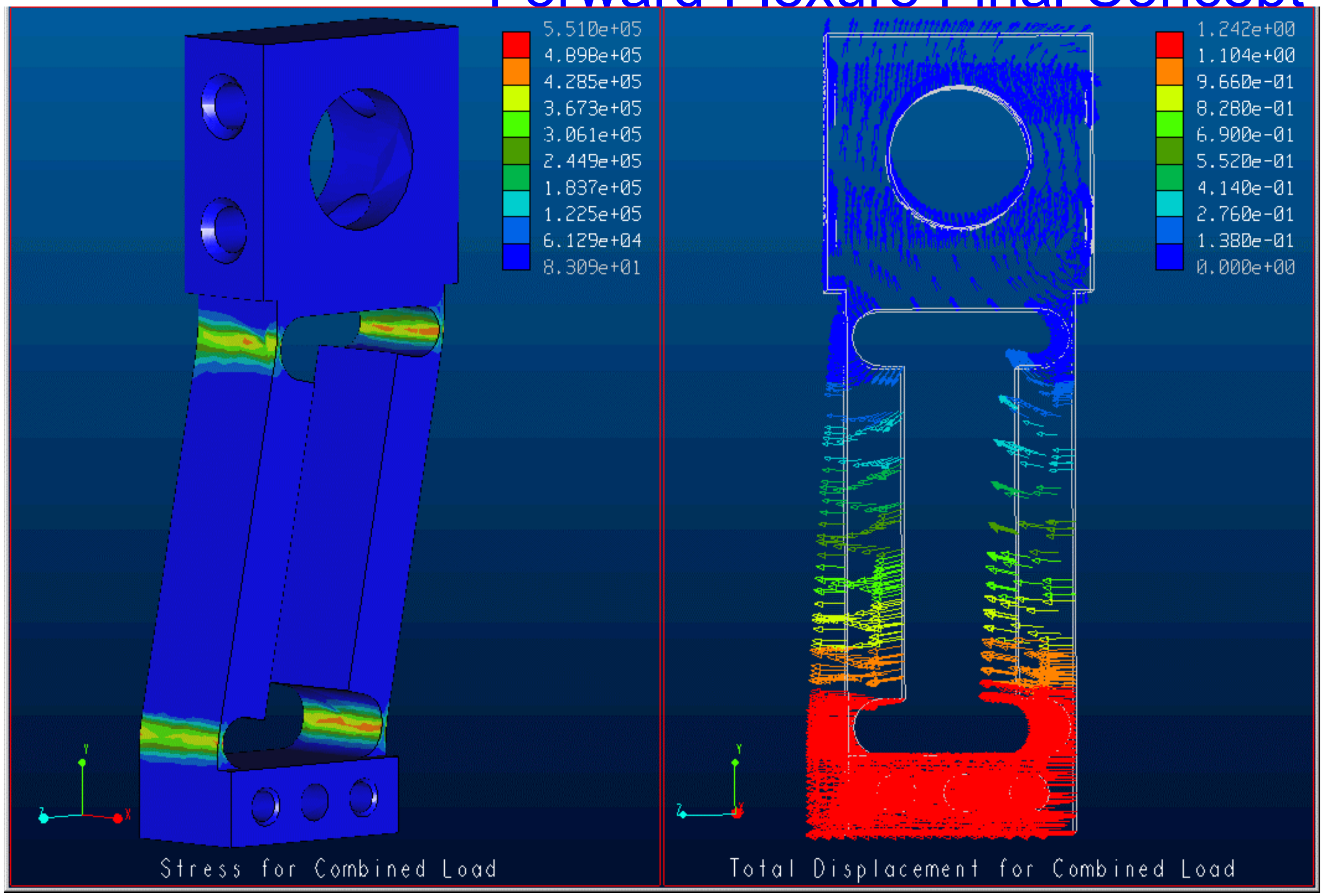


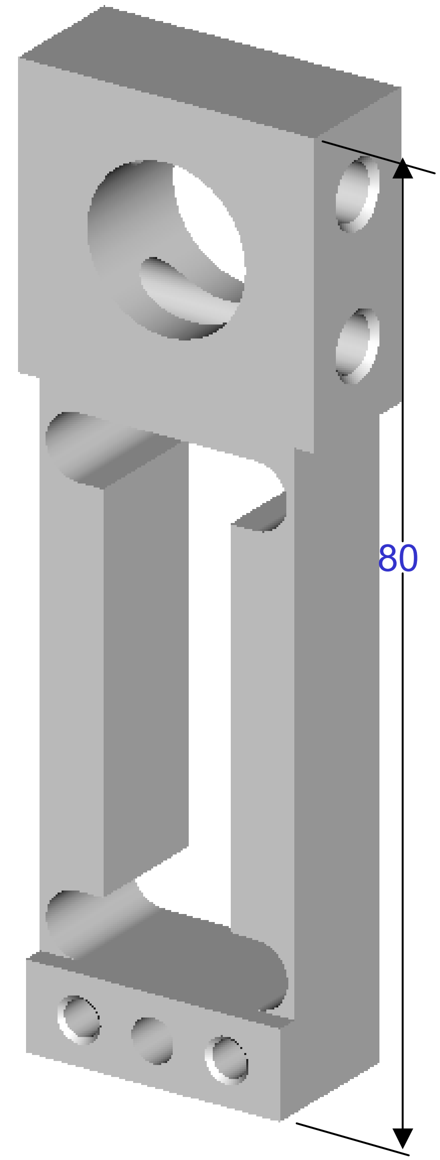
Results →5m vertical displacement relative to SCT
→very low stress design—even at full flex (not shown)

Flexure may not be needed depending on expected Build Tolerances—can easily make blocks without

Pixel Detector

Forward Flexure Final Concept





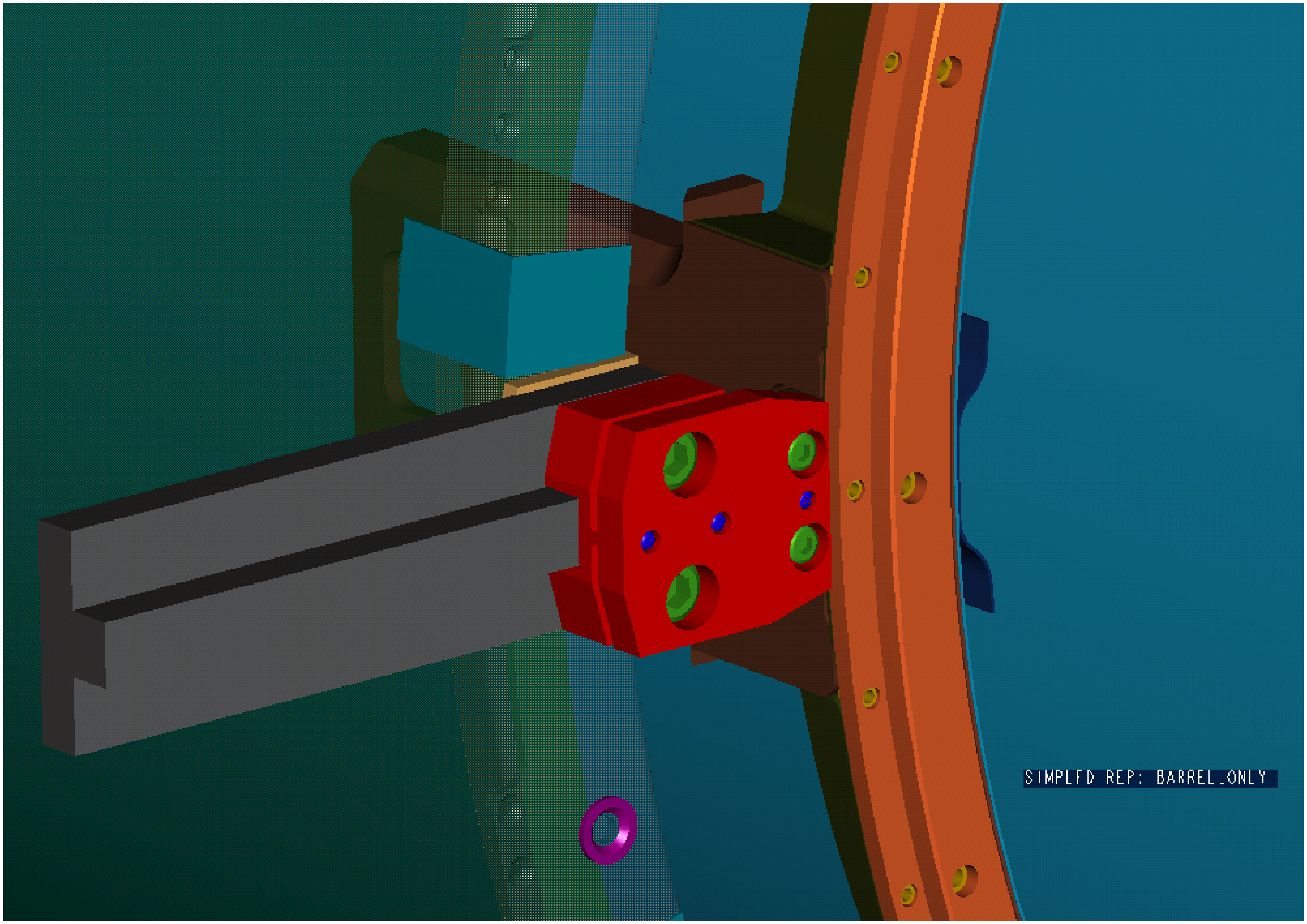
Results →37.5N load at full 1.24mm travel (this is an external load)
→Stress is high-ish in the 65% yield range—not worrisome
→Vertical displacement limited to 5µ

It is unclear if 1.2mm is needed, but flexure length is easily modified

Comparison of Performance to Req.

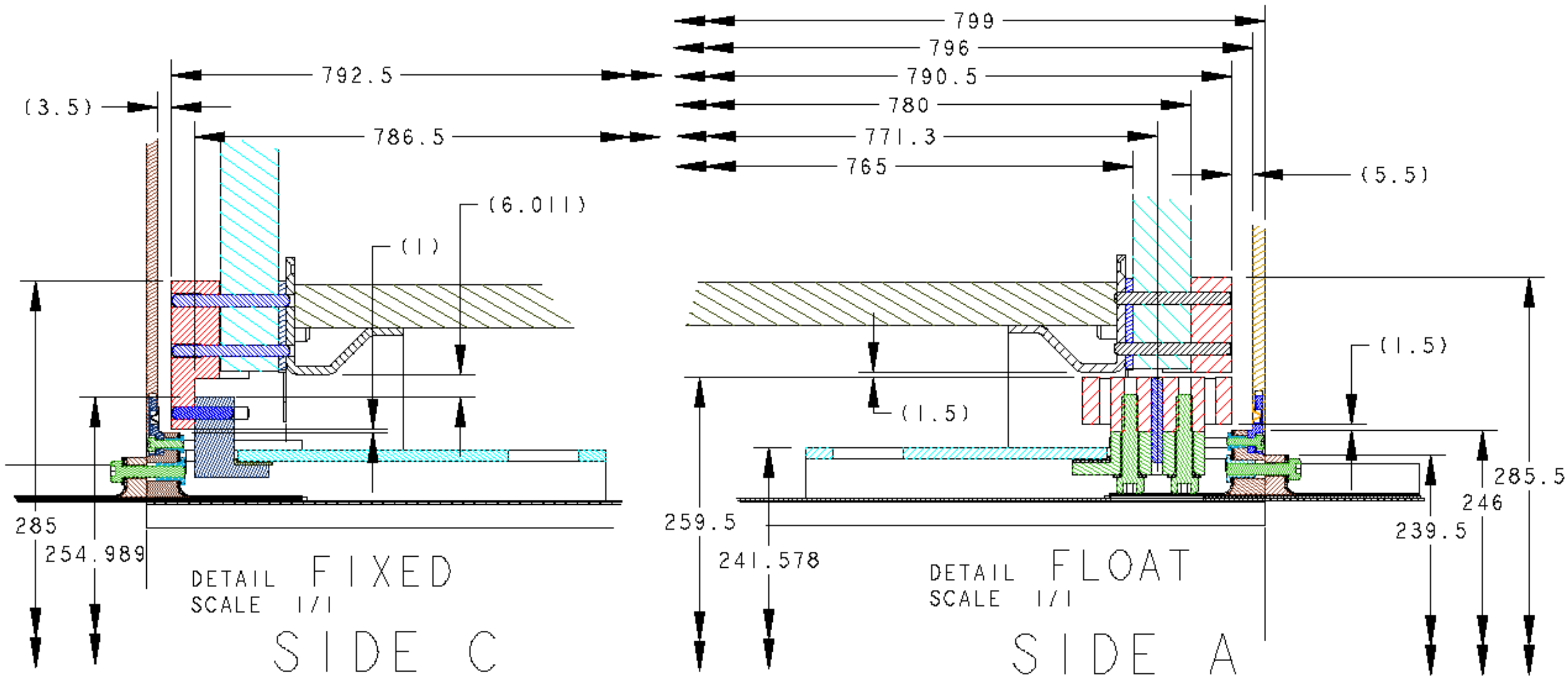
- **Fixed Support**
  - Small rotation—less than 10mmN moment
  - Vertical Deflection less than 5μ
- **Barrel Z Flexure**
  - Full Z-Travel of 120μ—force less than 50N
  - Vertical Deflection of 14.5μ
  - Would like to reduce both if practical
- **Forward End Support**
  - Full Z-Travel on Side A of 1200μ—force less than 38N (31.25N/mm)—external force on ID Barrel
  - Vertical deflection of less than 5μ
- **Internal Tension Load on SCT in Z of up to 100N (two flexures)**
  - Requires Full Temperature excursion of –40C is seen and 2ppm/C CTE mis-match
    - Compared with 30Kg mass load, 2X preload on contact and friction coefficient of 0.3 (30X9.81X2X.3)=175N Stiction load
- **Potential External Z Load on ID Barrel of 30N**
  - Side A strain is large, but partially cancelled by Side C which is shorter
    - Side A=(2X37.5N) Side C=-(2X22.5)
  - Requires Both 10C raise in Cryostat Temp (+1mm) and positive 1ppm/C support Tube @ negative 20C (anything less is smaller strain)

Pixel Detector



Pixel Detector

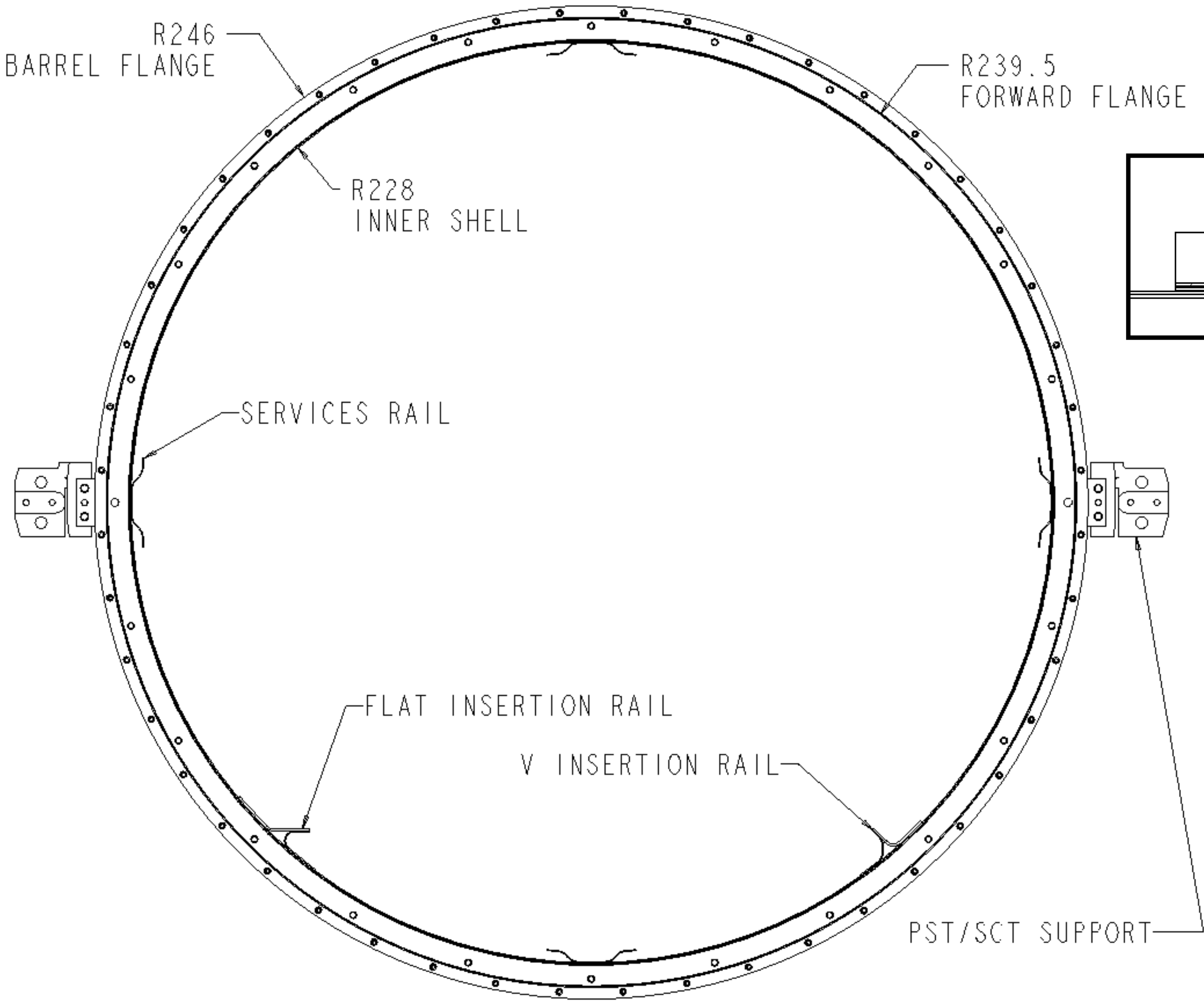
PST Cross Section

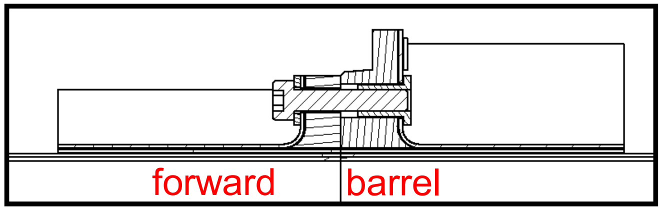


PST Design Details

TUBE FLANGES

Support Tube – Flange Details

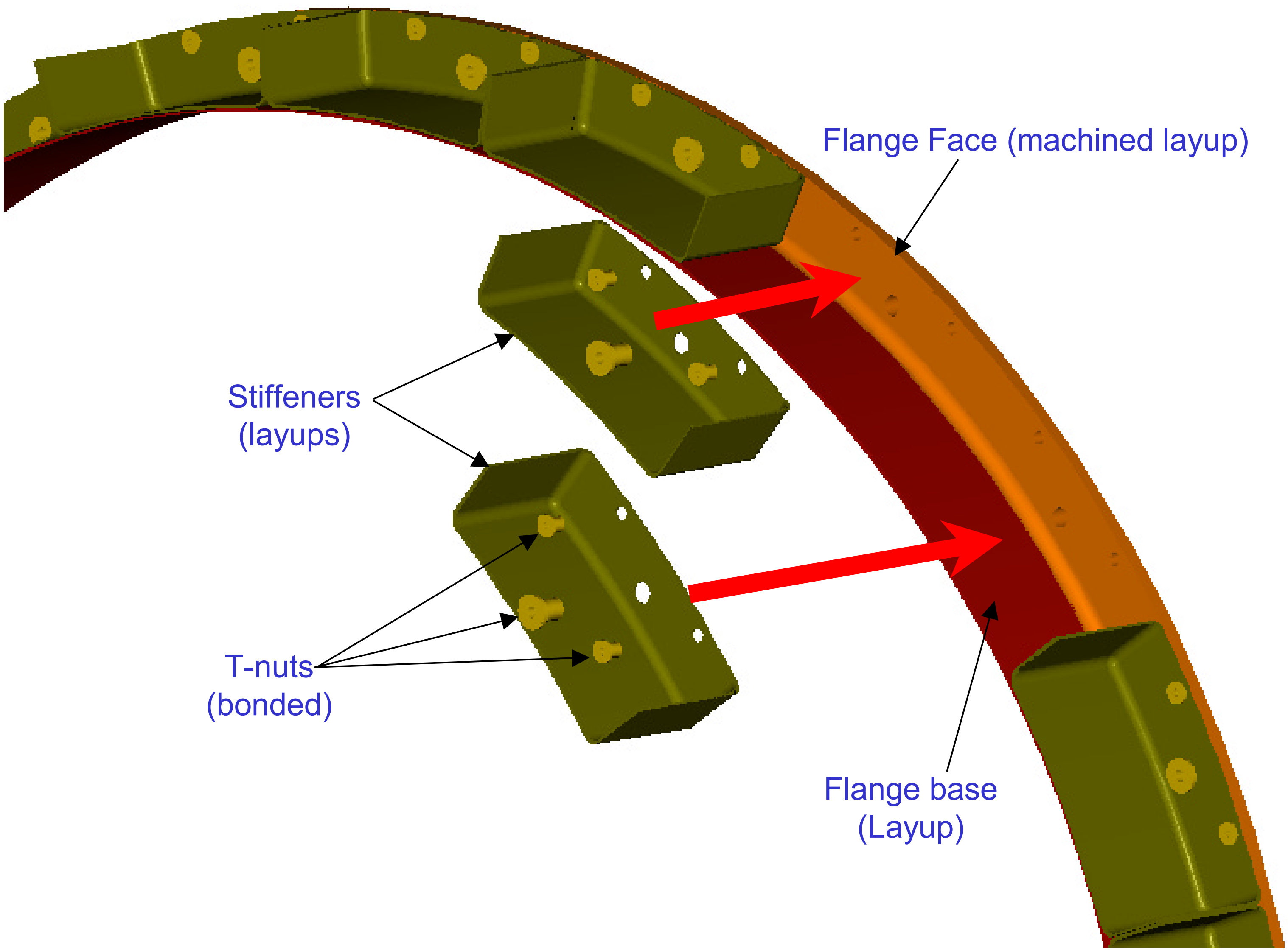




Flange x-section detail

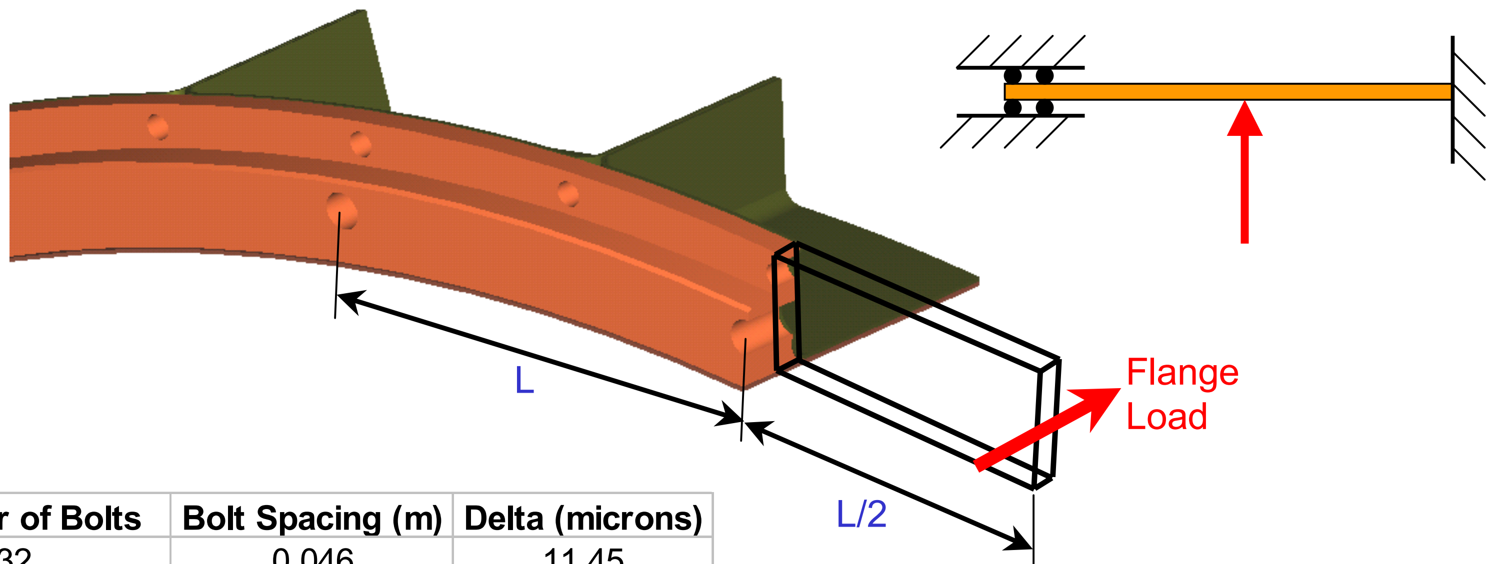
End view of barrel flange
(forward flanges have no Mount bosses and no gas seal features – see below)

Support Flange Bonded Assembly



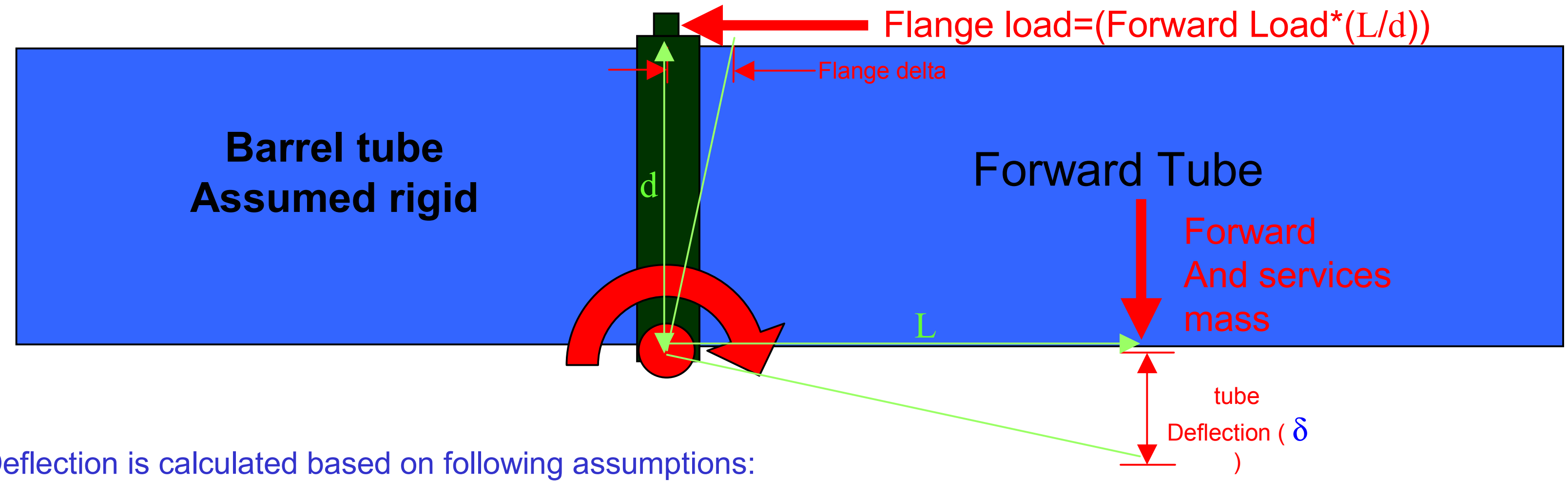
Flange Bolt Spacing Calculations

Flange is conservatively modeled as a simple beam:
- modeled as guided beam with length of bolt spacing/2
- cross section is assumed to be smallest flange section (forward)
- flange force given by support tube loads (next slide)



Number of Bolts	Bolt Spacing (m)	Delta (microns)
32	0.046	11.45
40	0.037	5.86
48	0.031	3.39
56	0.026	2.14
64	0.023	1.43

Flange Bolt Spacing Calculations (cont.)



Tube Deflection is calculated based on following assumptions:

- forward tube pivots rigidly about bottom of flange
- total forward tube mass (including services) is cantilevered
- full flange load is taken by upper bolts only (3 bolts)
- all structures rigid

Frequency is estimated based on tube deflection using $f=(1/2\pi * (g/\delta)^{1/2})$

Number of Bolts	Delta Tube (microns)	Frequency
32	64.55	62.64
40	33.05	87.55
48	**19.13**	**115.08**
56	12.04	145.02
64	8.07	177.18

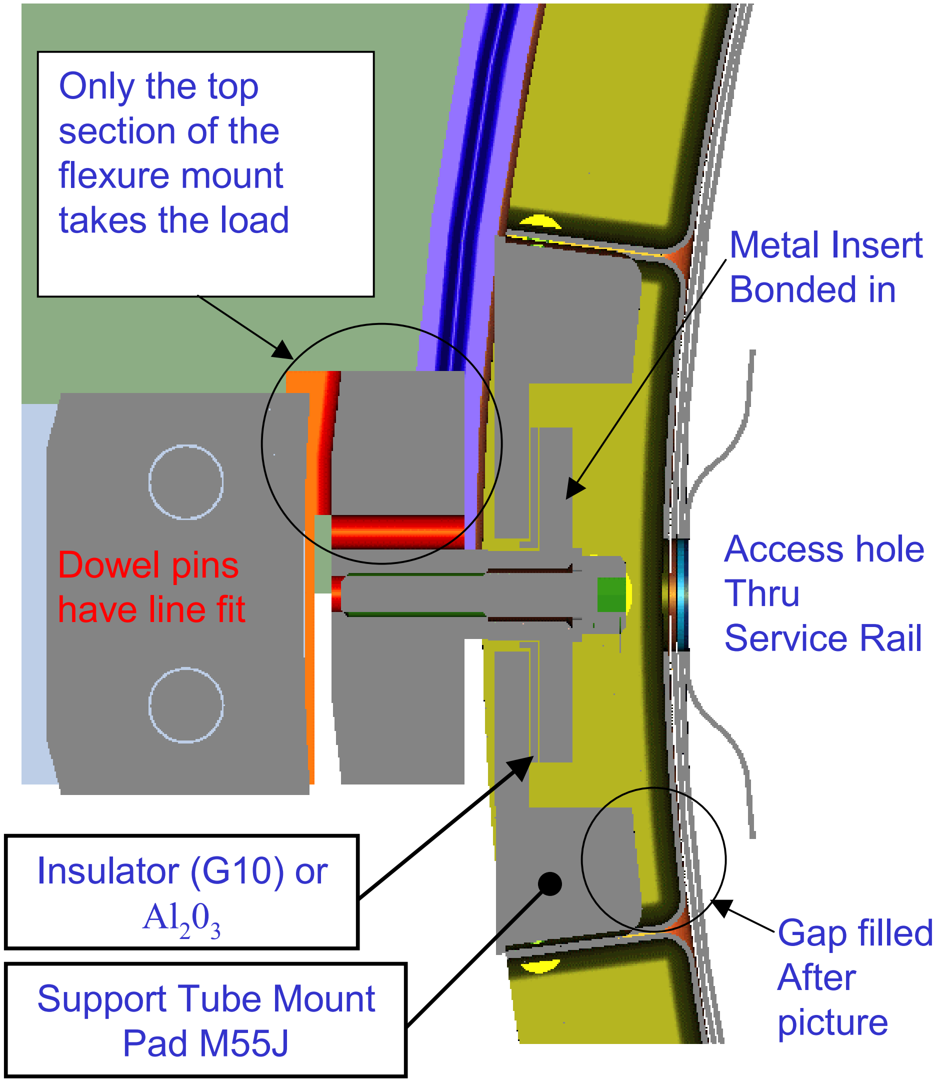
desire frequency > 100 Hz
number at left assumes no ribs
-ribs act like bolt constraints
-evenly spaced ribs allow half the number of bolts

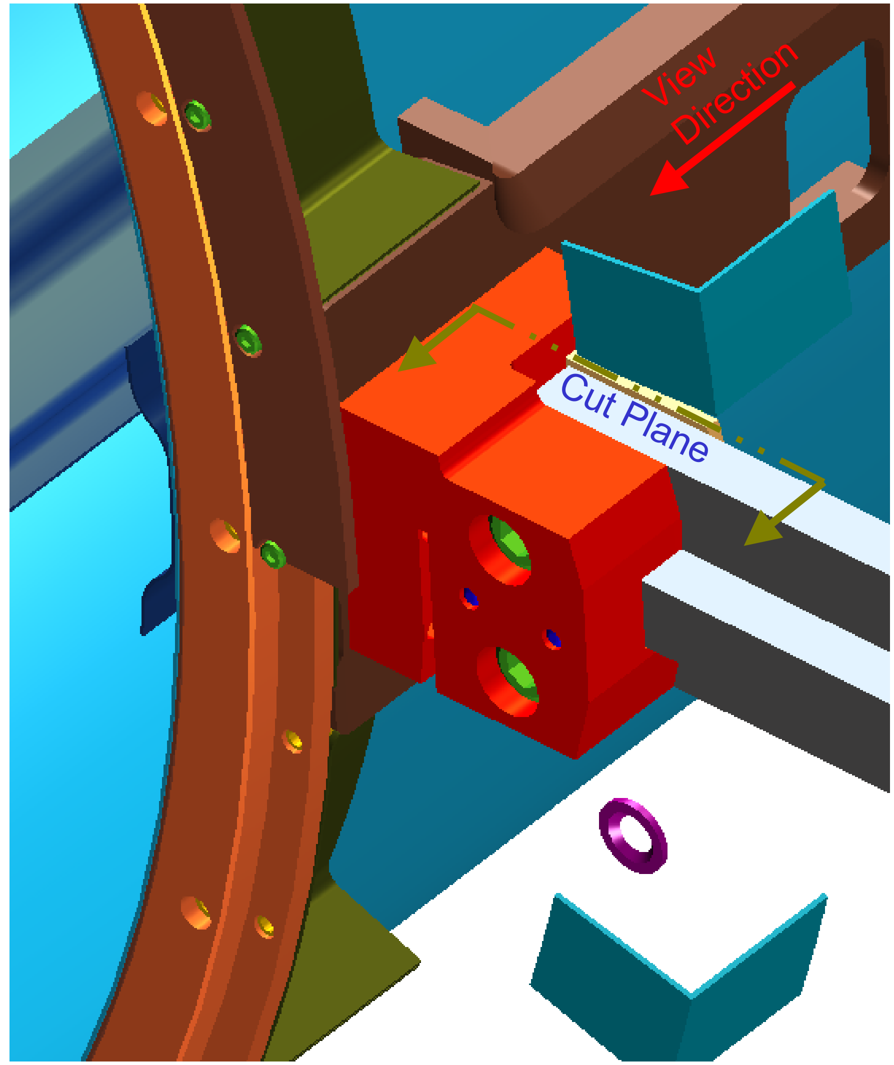
Design for 24 bolts in flange

Sizing Check on Flange

- **Flange dimensions are largely geometry driven—made as small as possible that will still fit bolt heads and threads…**
- **Wanted to verify that pushing the flange to this limit would still allow adequate coupling between Barrel and Forward Pixel Support Tube**
- **Flange modeled using beam approximations—analysis also checked number of Bolts necessary**
- **Flange will later be modeled in FEA to verify hand calculation**

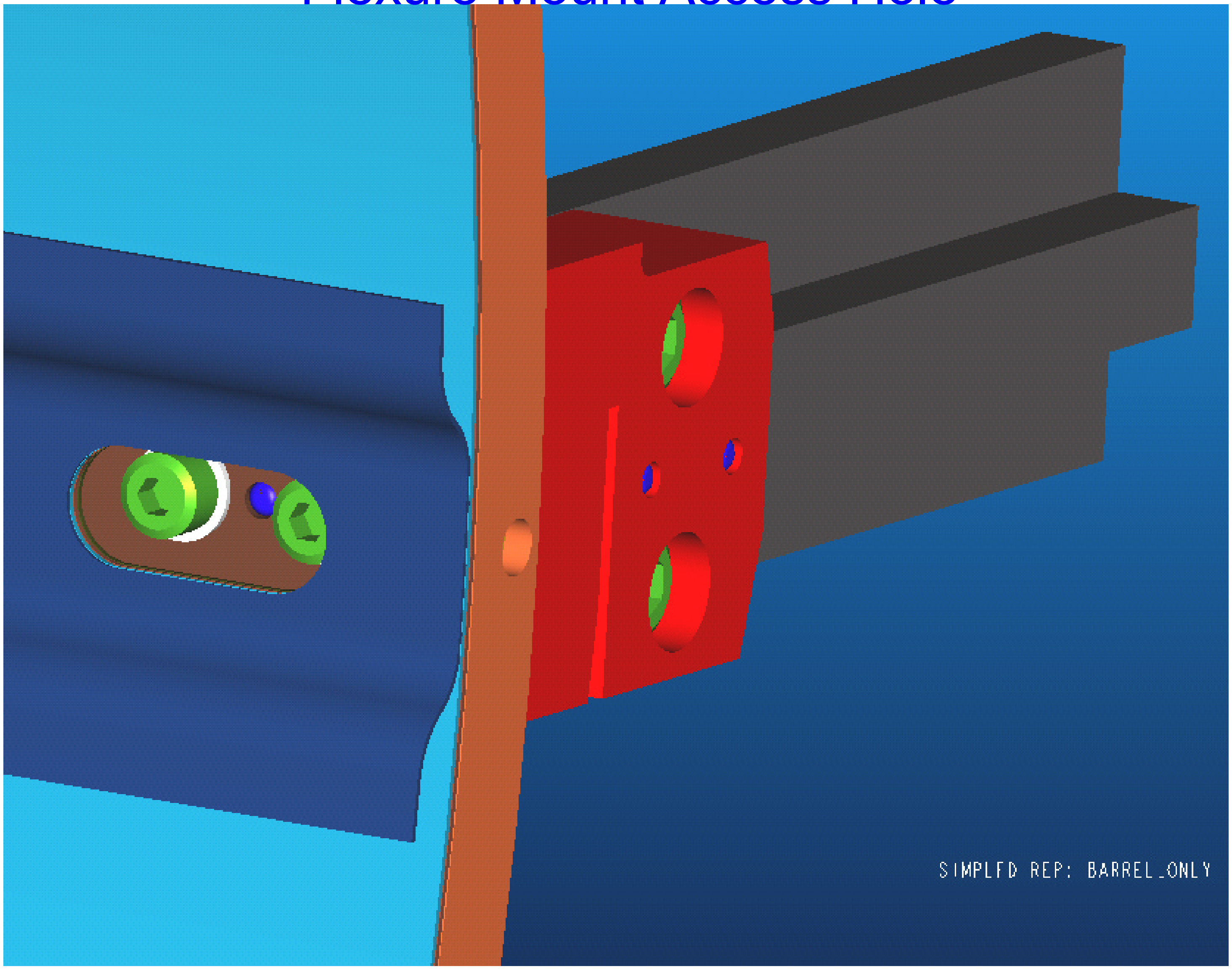
Z-Flexure (Side A)





Pixel Detector

Flexure Mount Access Hole

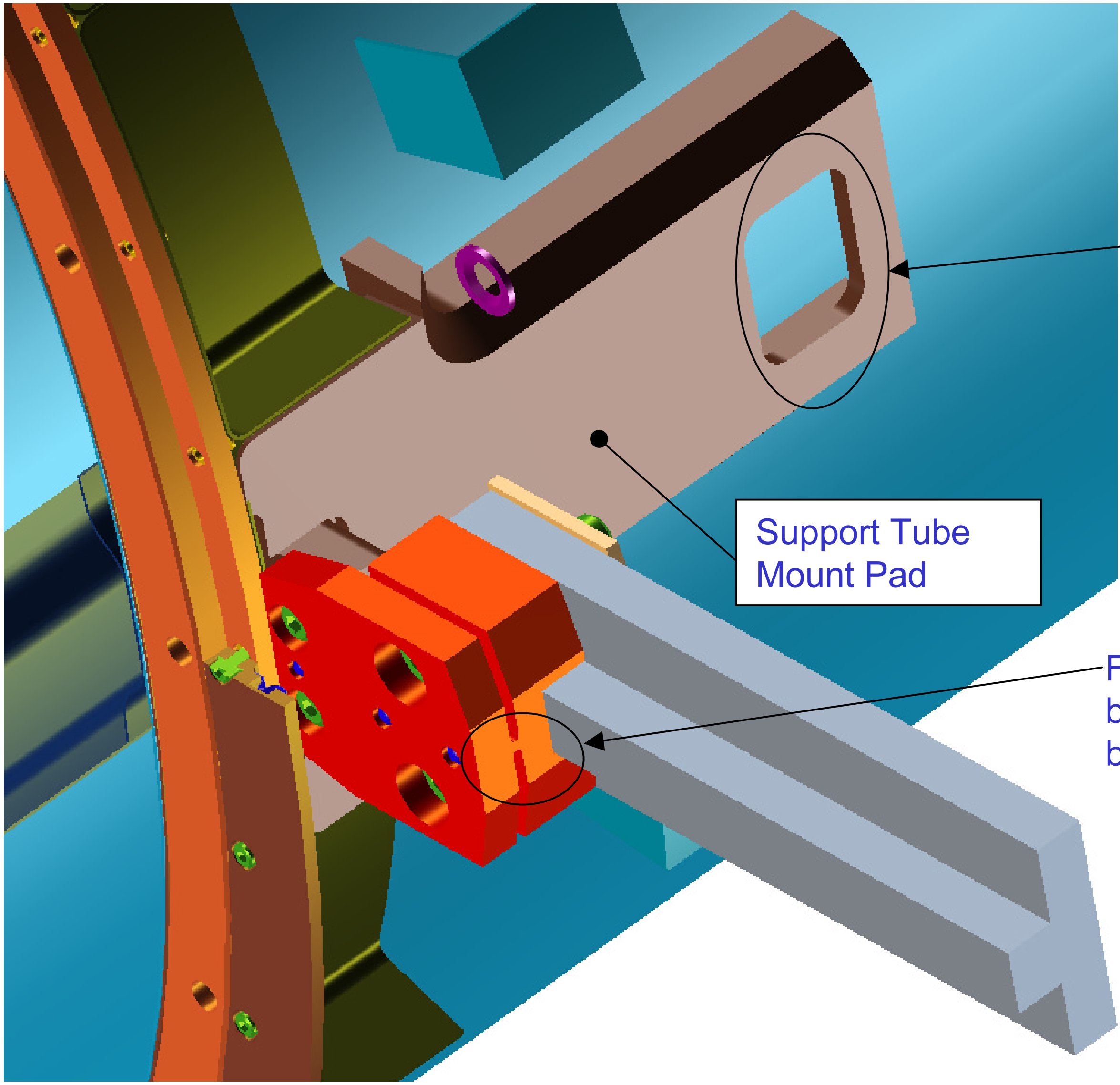


PST Design Details

DETECTOR SUPPORTS

Pixel Detector

Fixed End Support



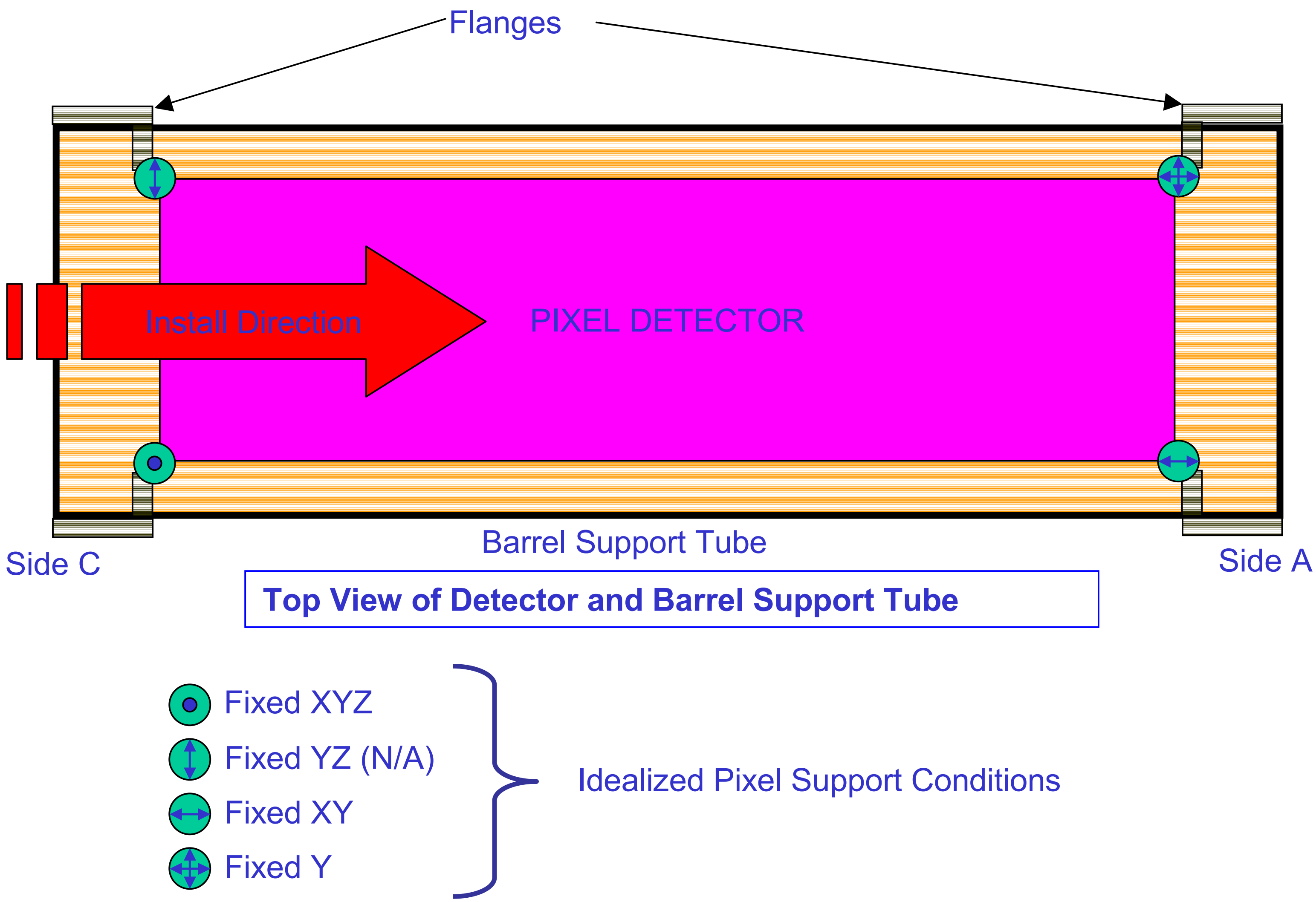
Pixel Mount will bond to Mount pad and penetrate the support tube shell through the rail

Hole in Pad is shown in proper location

Fitting flexure in envelope between interlink and thermal barrier is challenging

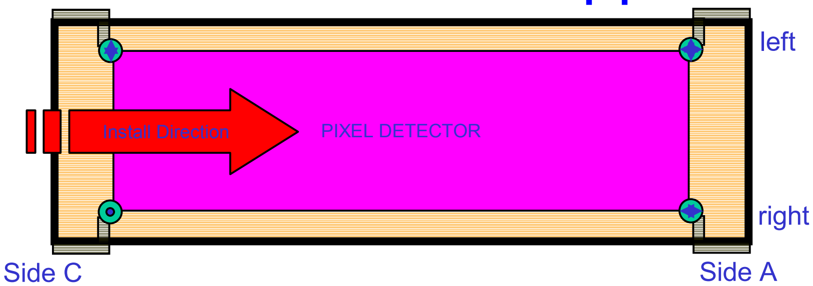
Pixel Detector

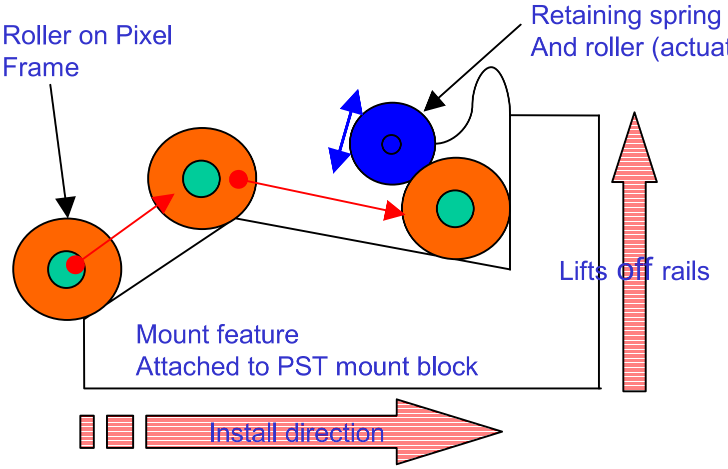
Pixel Detector Support Conditions within Support Tube



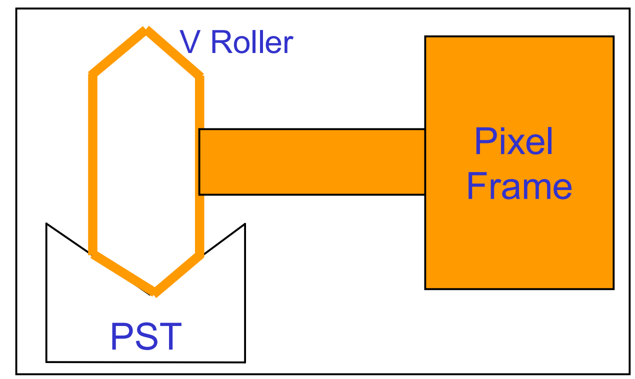
Top View of Detector and Barrel Support Tube

Pixel Detector Supports

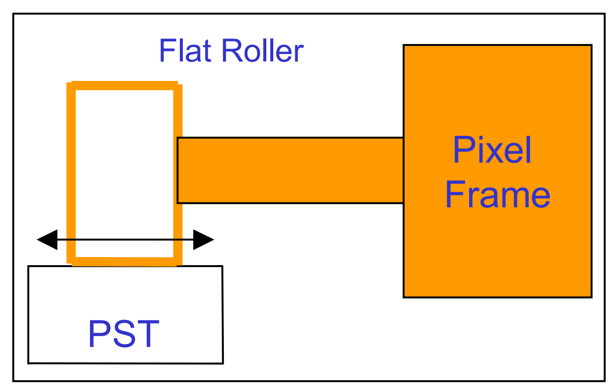




Side C
(side A similar, But no hard stop)

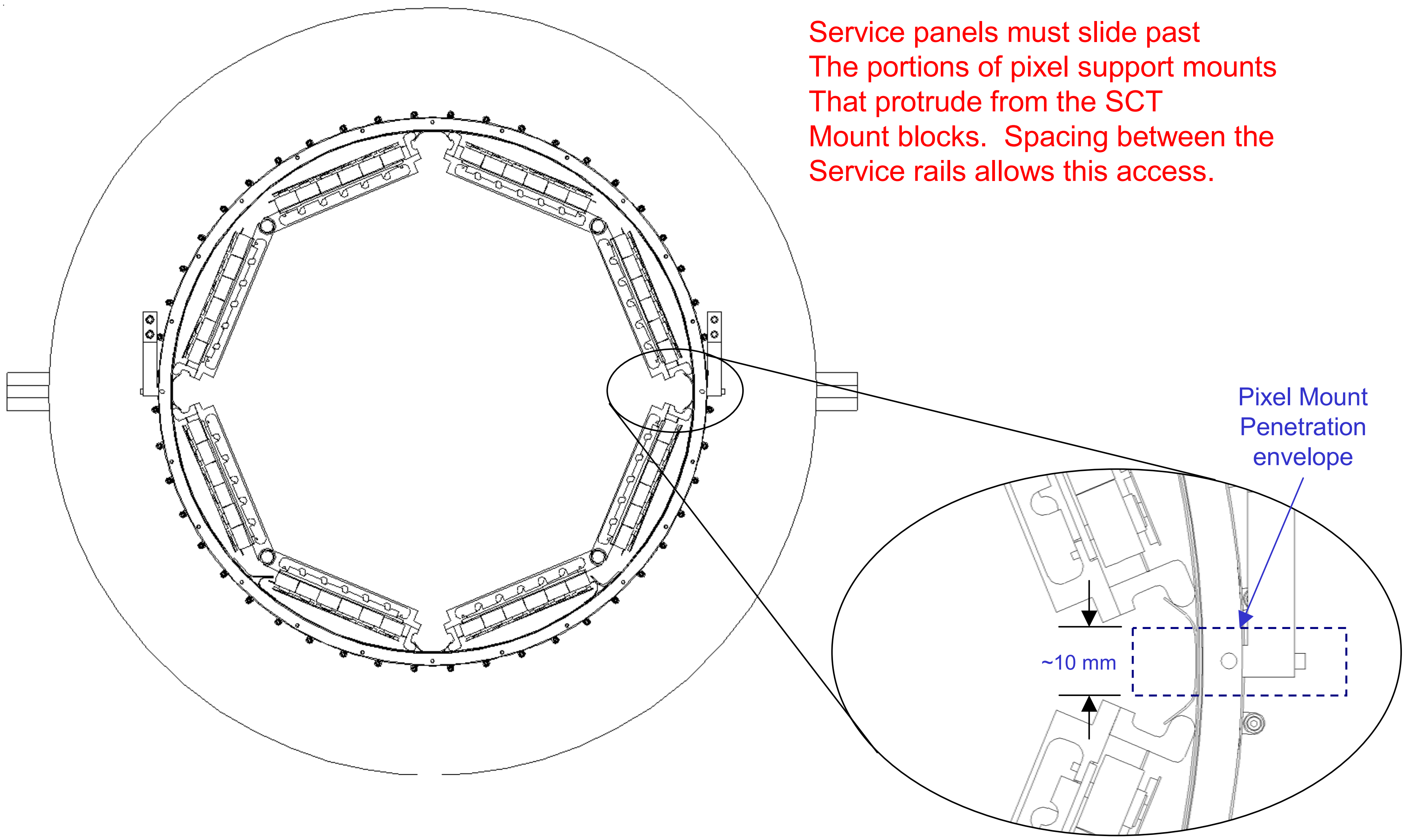


Right Side
(No X Float)



Left Side
(X Float)

Pixel Support Mounts



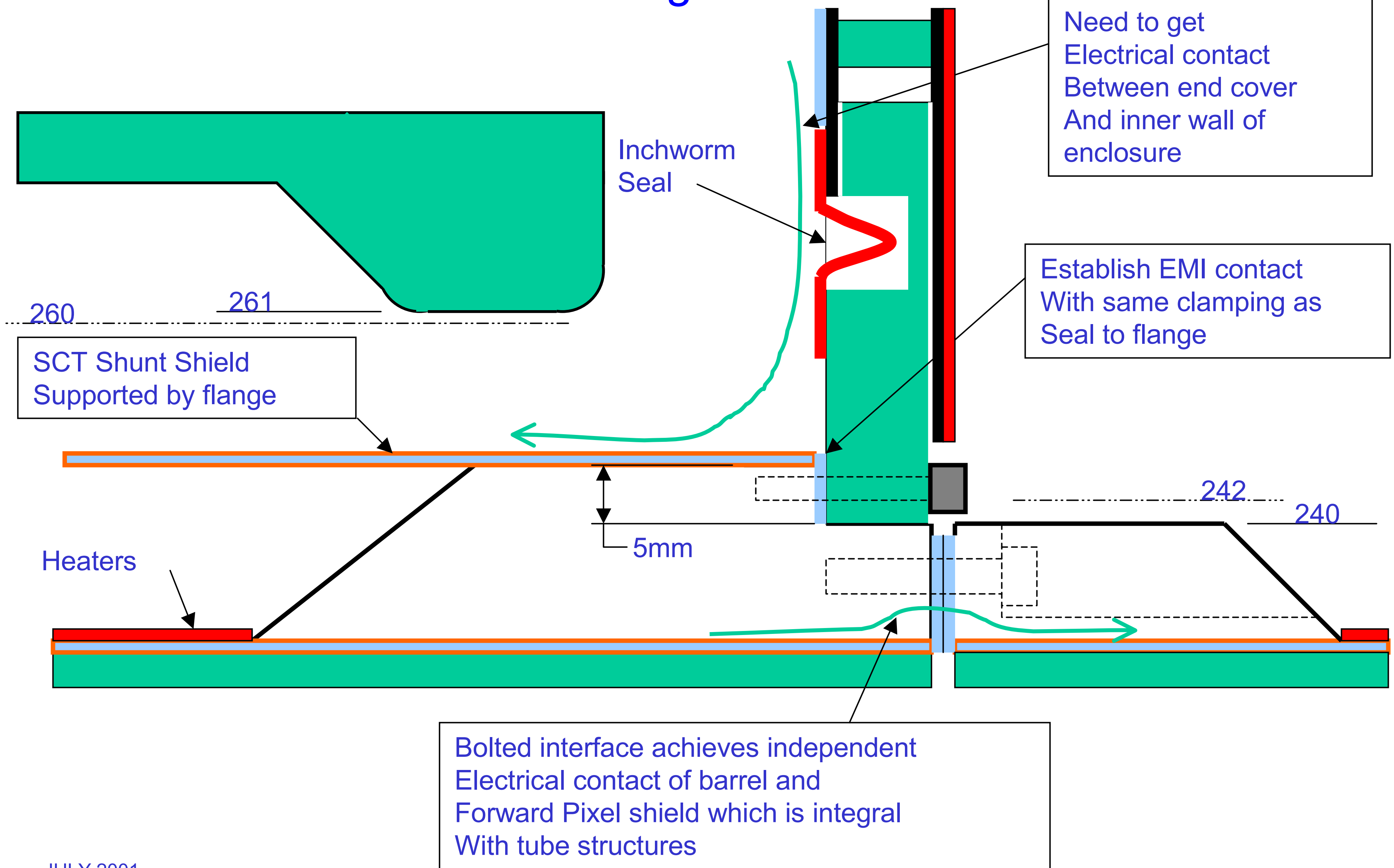
Service panels must slide past
The portions of pixel support mounts
That protrude from the SCT
Mount blocks. Spacing between the
Service rails allows this access.

PST Design Details

OTHER INTERFACE STRUCTURES

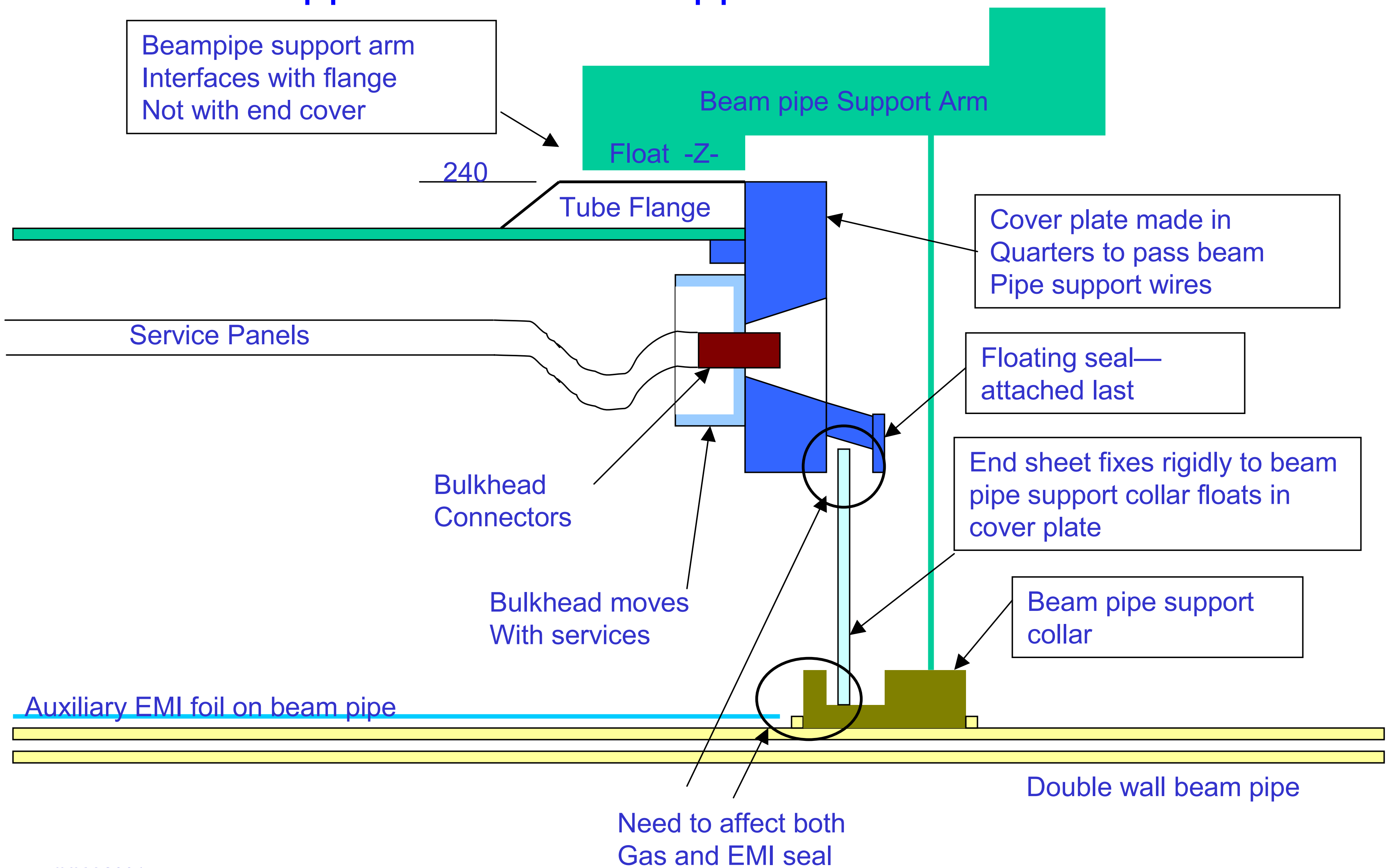
Pixel Detector

Flange Area



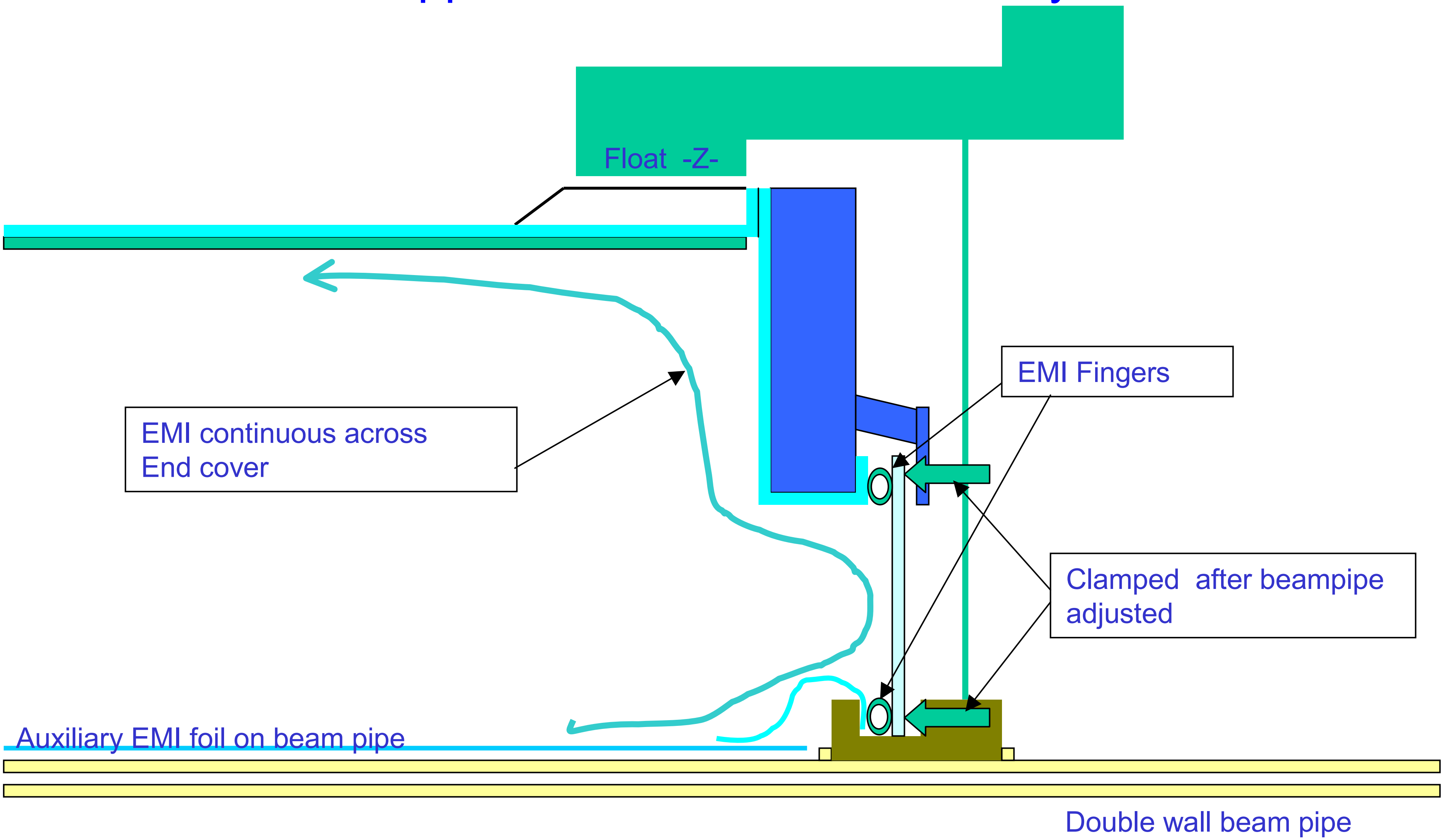
Pixel Detector

Support Tube End Support and Penetration



Pixel Detector

Support Tube End EMI continuity

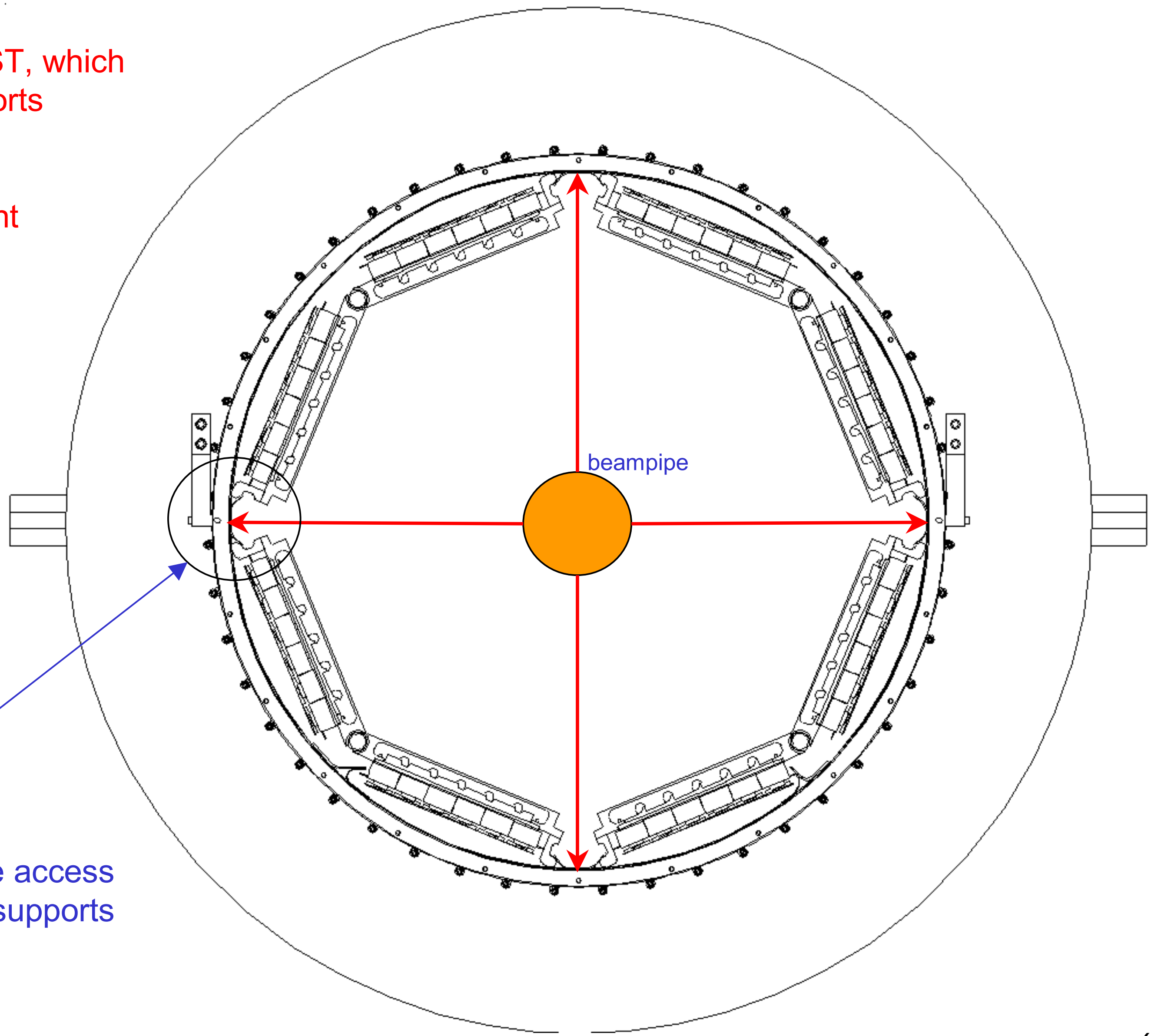


Beampipe Supports

-Beampipe is supported by PST, which
Requires that beampipe supports
Have access to insertion rails.

-Supports must allow alignment
of beampipe by up to 9 mm in
Radius.

-Design concept has not
Yet been developed.



Rail spaces provide access
For potential beampipe supports

Conclusions

- **PST Design is very young**
- **Analysis and detail design are progressing**
- **Much work still needs to be started**
  - Beampipe support scheme
  - End plug design
  - Pixel mounts
  - Installation sliders (friction analyses underway)
- **Much work still needs to be completed**
  - Tube analysis
  - Flange design
  - Prototypes
    - Shell
    - Flanges
    - Mount blocks
    - Sliders
- **Prototyping to begin at LBNL this summer**