PLR Design, Fab, and Servicing Overview

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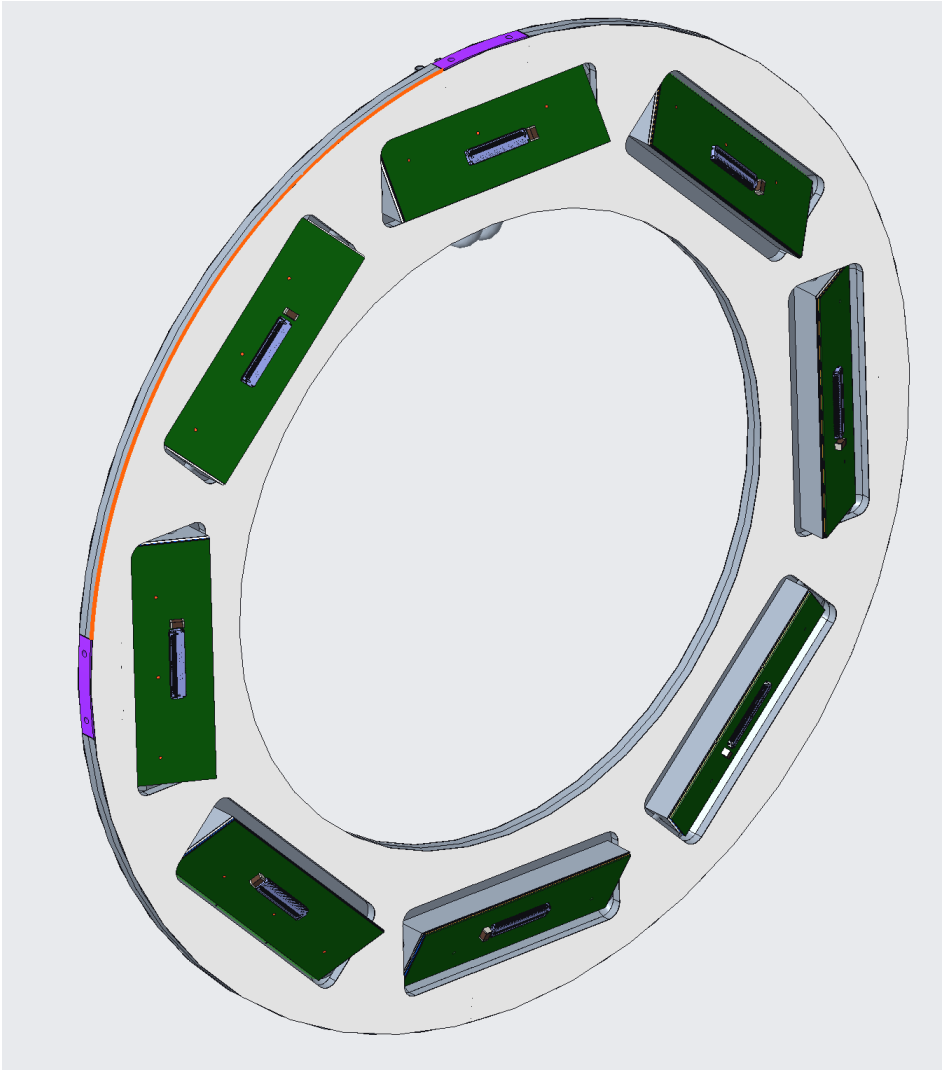
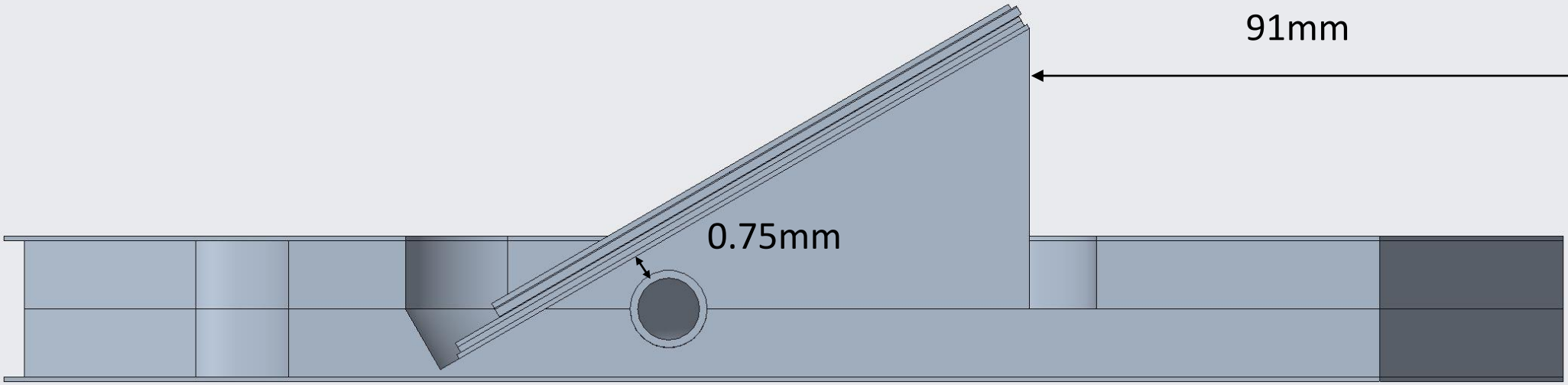
Summary

- PLR Ring is based on a simple philosophy – provide necessary PLR functionality while minimizing need for new designs/parts
- PLR Ring is based on a standard Quad Ring
  - Maintains pipe shape
  - Maintains overall dimensions
  - Maintains basic machining
  - Only addition is additional machining (during same setups) and bonding on “Wedge” Parts
- Thermal performance is dependent on several factors
  - Wedge angle
  - Facesheet-pipe distance
  - Lateral wedge position (i.e. radius since pipe radius is fixed)
  - RIng thickness
- We have confirmed thermal performance in FEA with some reasonable assumptions, but this is an initial study and should probably be updated

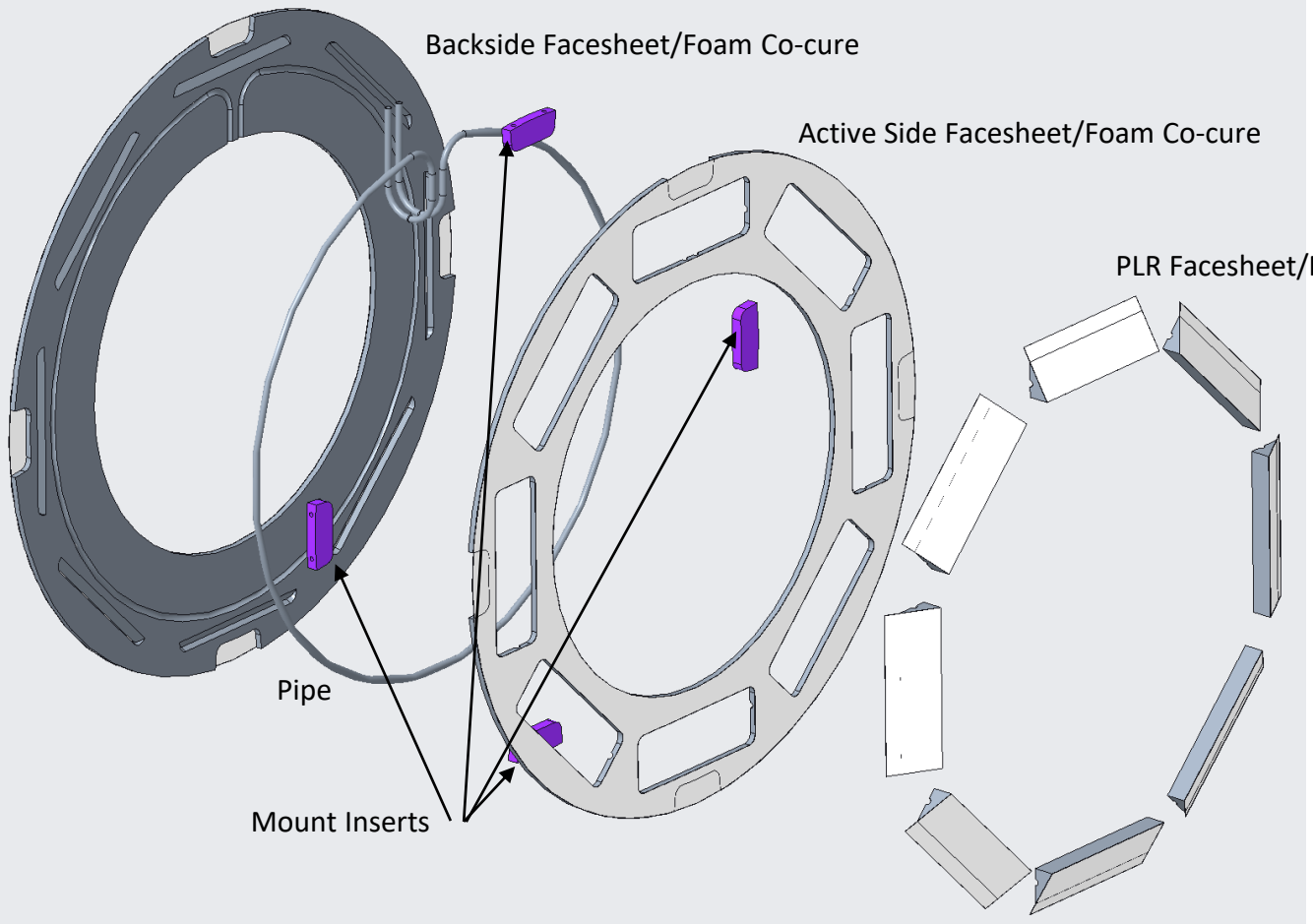
PLR Ring



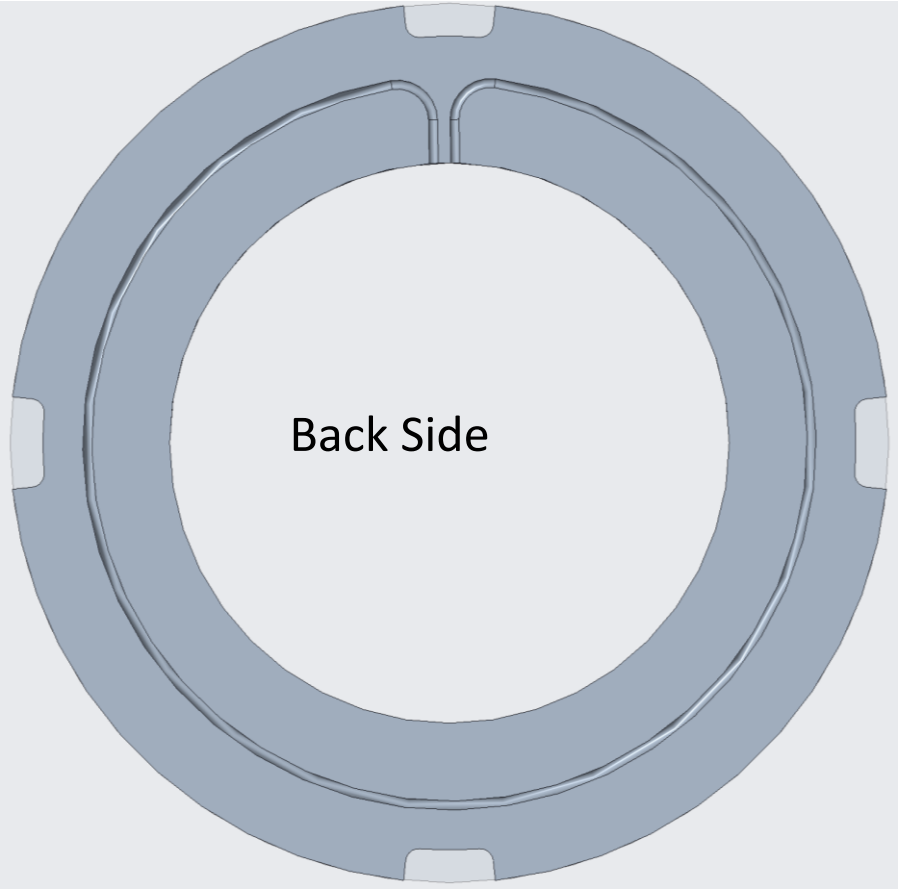
Ring Cross Section

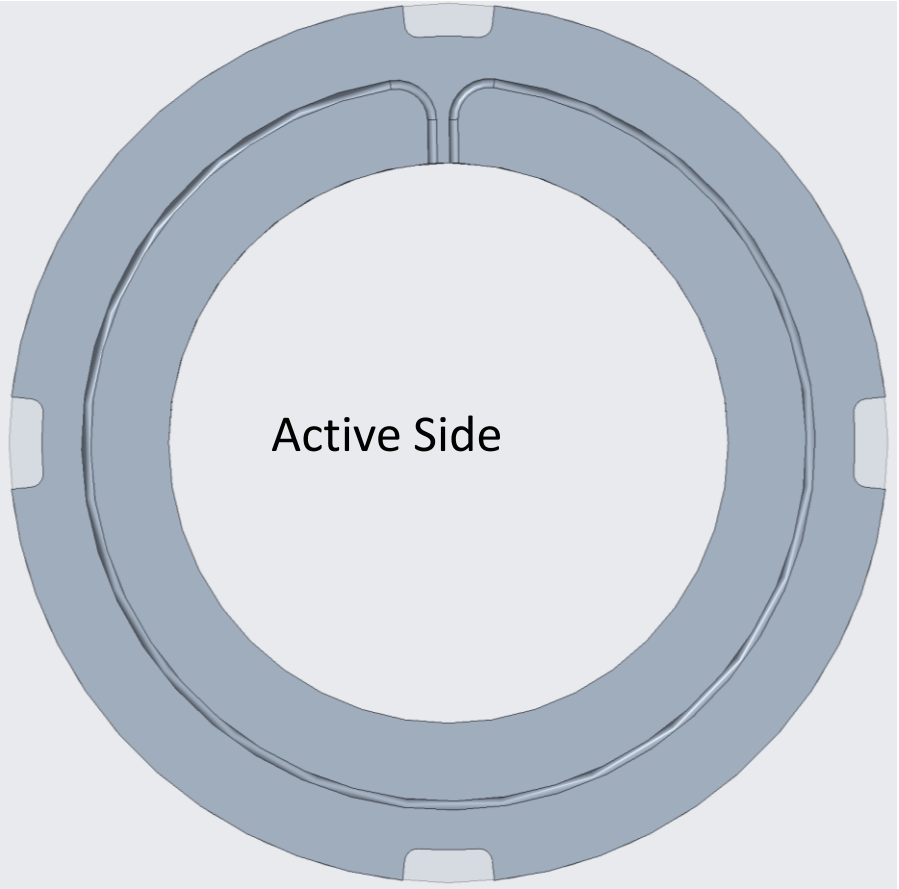


Exploded Assembly

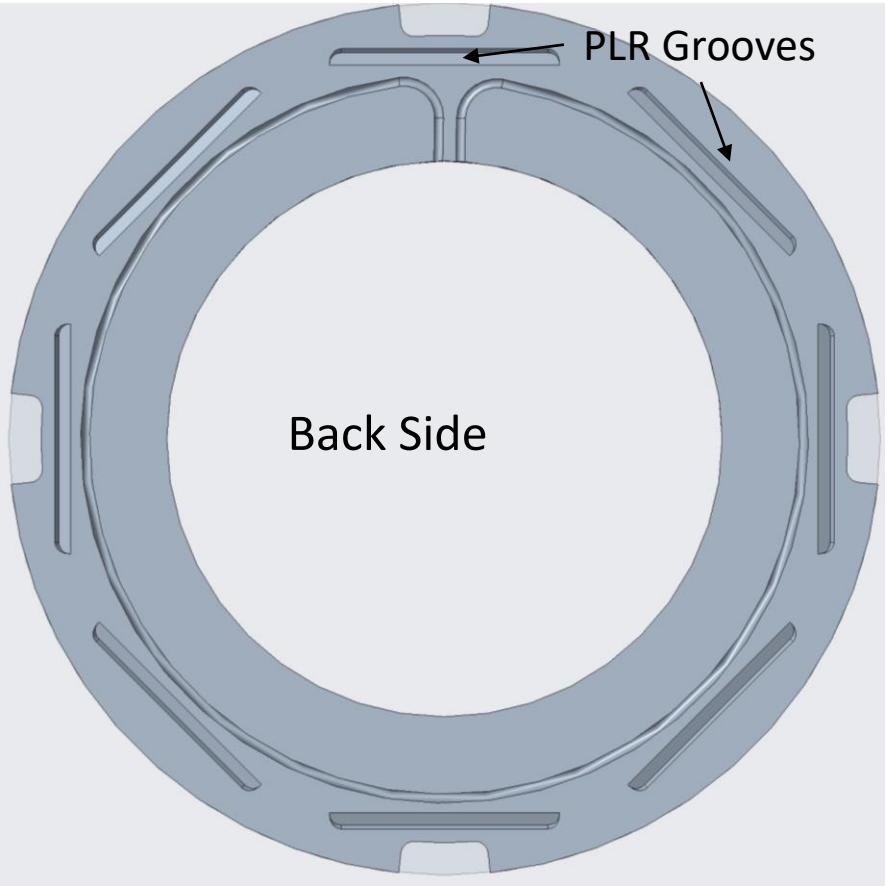


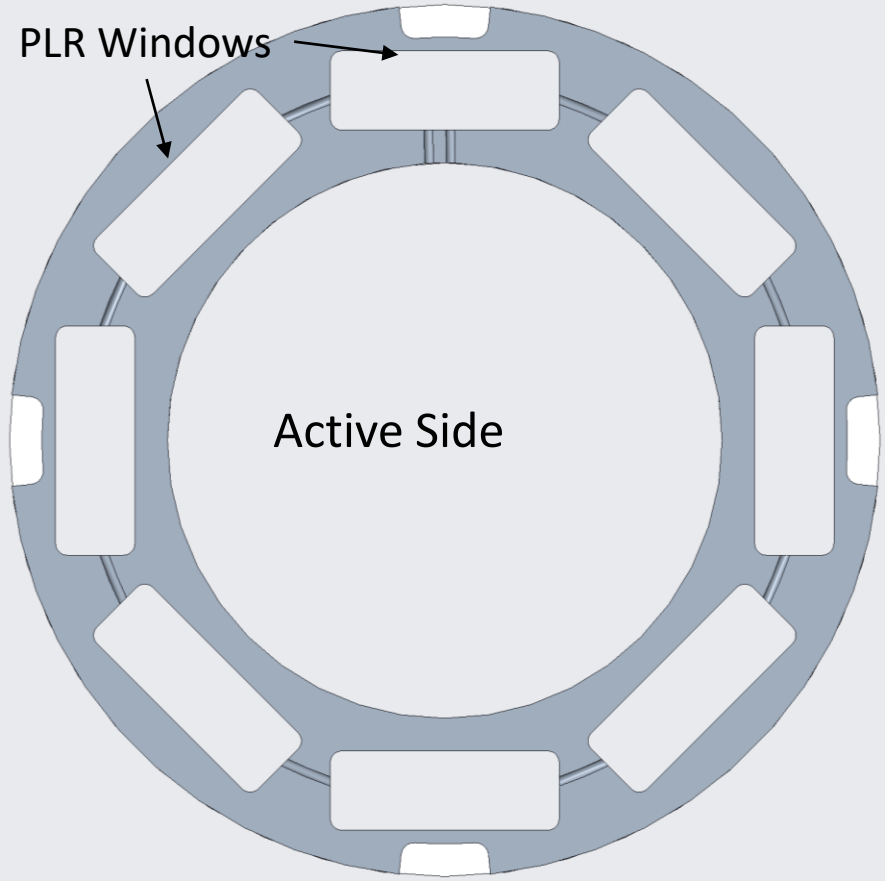
Step #1 Make Regular Quad Ring Blanks



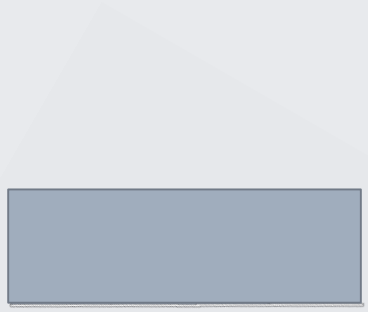


Step #2 Machine PLR Features

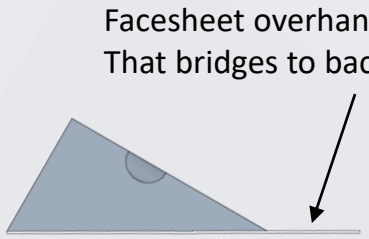




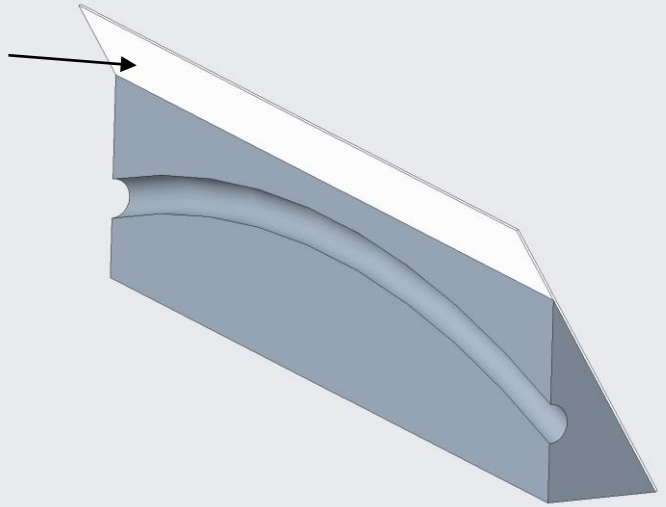
Step #3 Wedge Machining



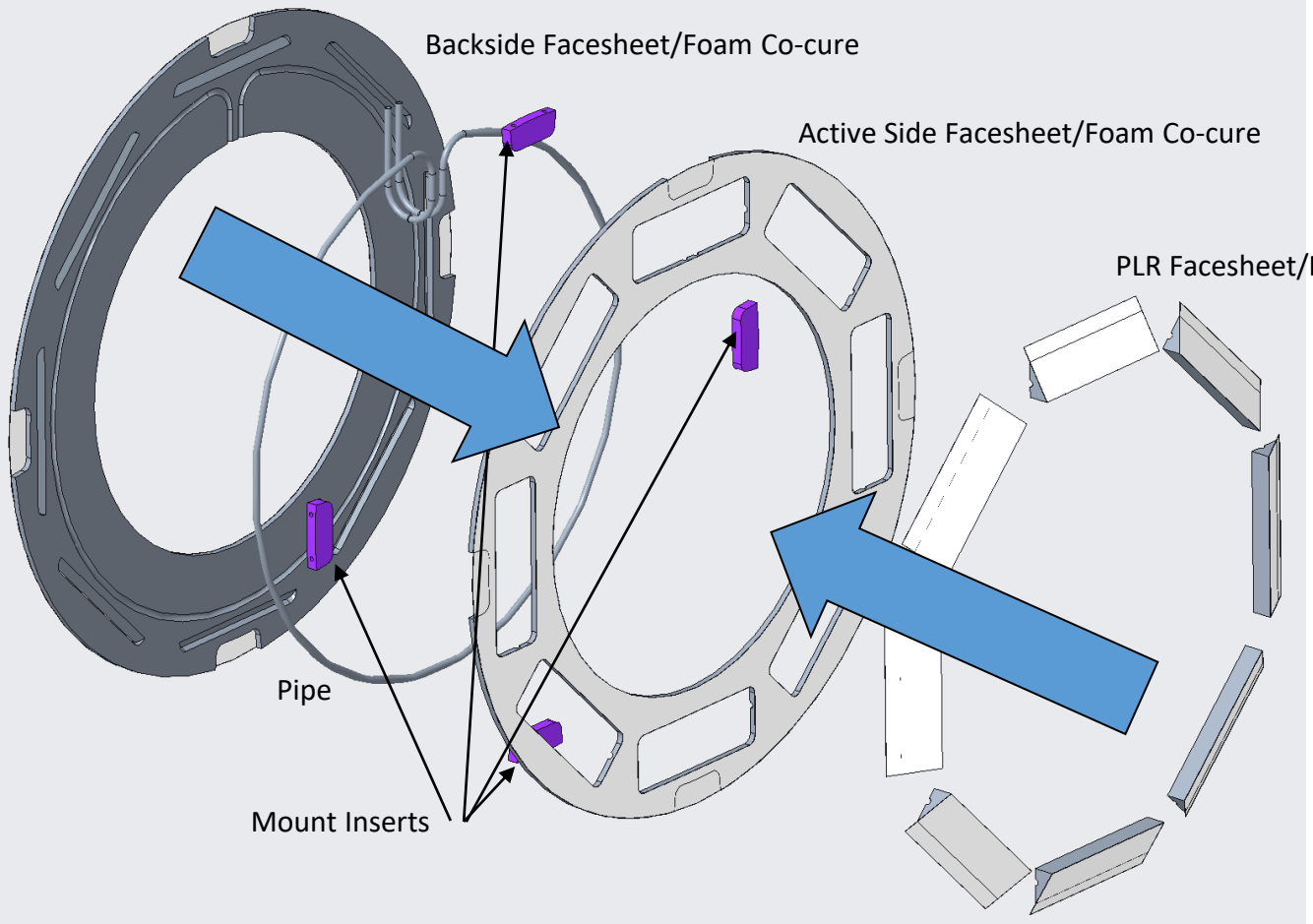
Co-cure blank



Machined wedge



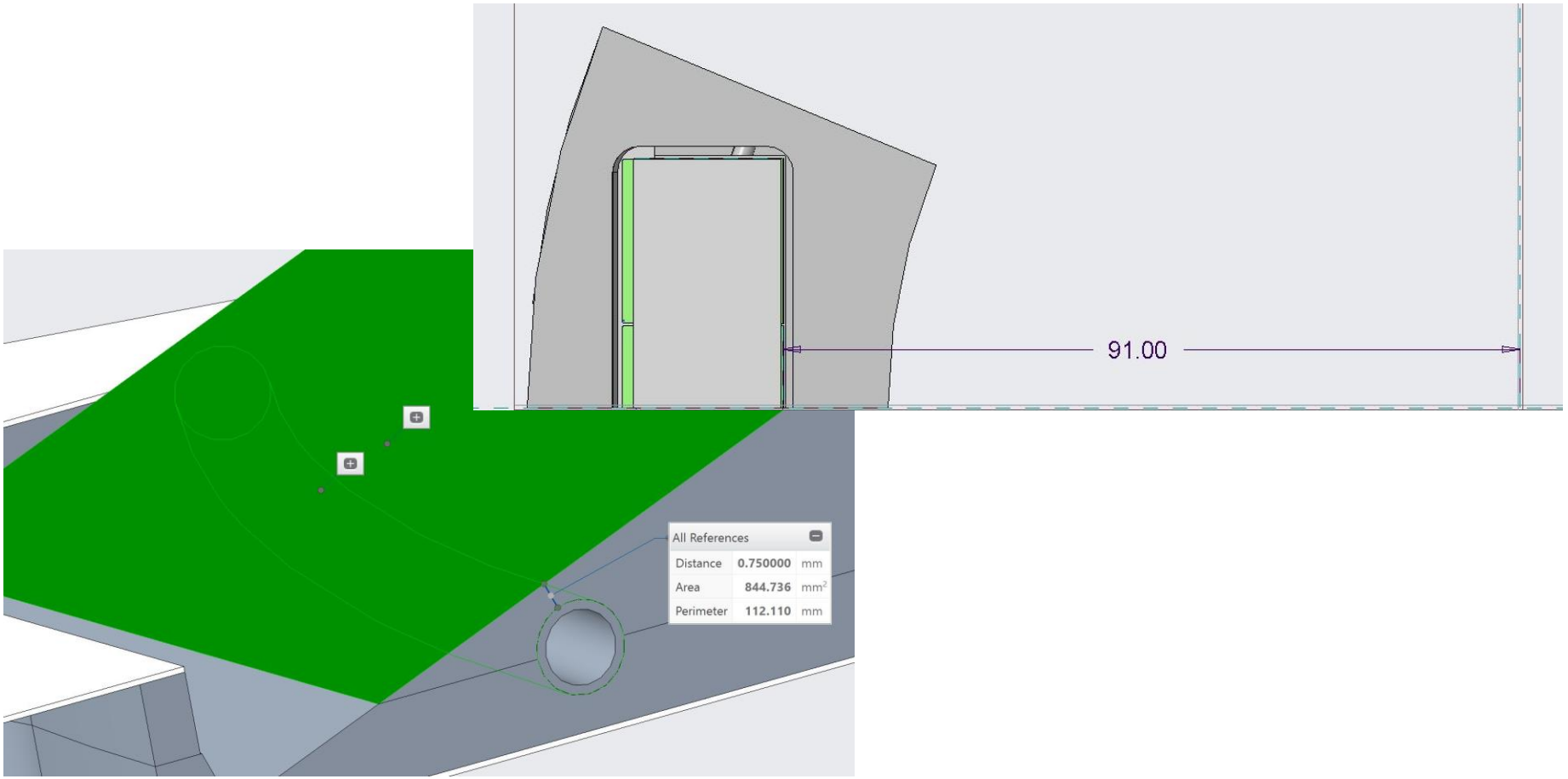
Assembly – all in one bonding operation



FEA Boundary Conditions

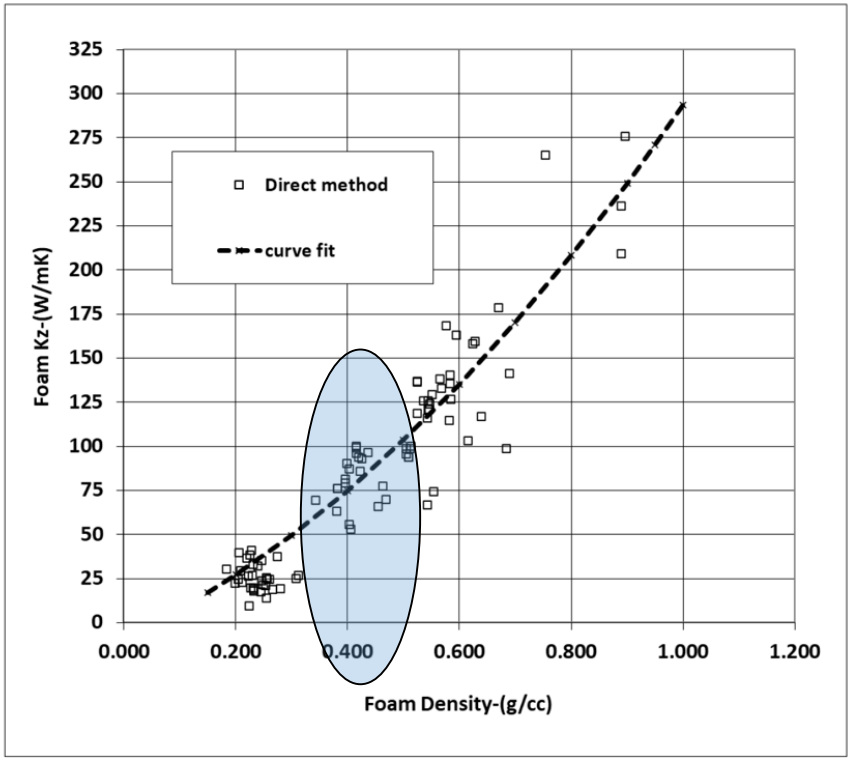
- Variables
  - Distance between facesheet and pipe
  - Radial placement of module
  - Power
    - Normal Operation
    - Failure of 1 chip
- Analysis here addresses:
  - 0.75mm between facesheet and pipe
  - Radial placement 91mm
  - 30 degree wedge angle
  - The two power conditions

Geometry Assumption for FEA

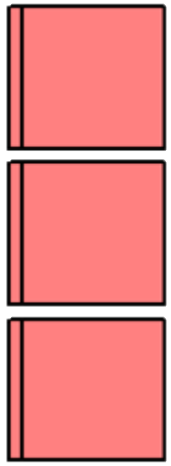
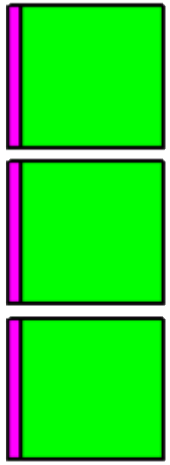
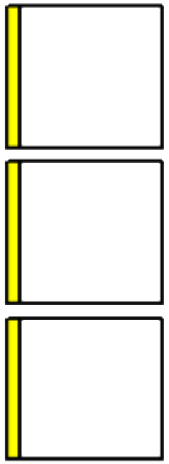
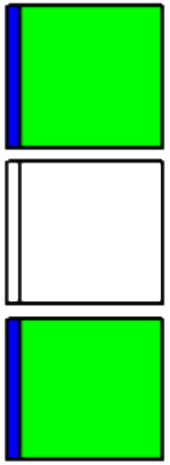


Assumed Material Props

- ”Normal” values for facesheets
- Foam k of 40 W/mK
- Glue k of 2 W/mK
- Hybrid k of 0.8 W/mK (Kapton)
- Both foam and glue should probably be better than this
- However, glue between pipe and foam was neglected



Power Cases

	CASE 1	CASE 2	CASE 3	CASE 4
	Homogenous Power Dissipation	**Normal Operation** (with 20% Current Headroom)	**No Configuration** (with 20% Current Headroom)	**One FE Open** (with 20% Current Headroom)
3D Modules (triplets)				
		NORMAL		FAILURE

Power Loads

		FE Power Dissipation (W/cm²)							
		Case 1		Case 2		Case 3		Case 4	
		Matrix	Periphery	Matrix	Periphery	Matrix	Periphery	Matrix	Periphery
Outer Barrel		0.7	0.7	0.29	3.56	0.0	6.63	0.29	7.09
Outer Endcap		0.7	0.7	0.29	3.85	0.0	6.93	0.29	7.57
Inner System	L0	0.8	0.8	0.33	4.16	0.0	7.72	0.33	10.60
	L1	0.8	0.8	0.30	3.75	0.0	6.96	0.30	7.48

L1 Radius, but L0 failure mode (triplet)

Other Loads

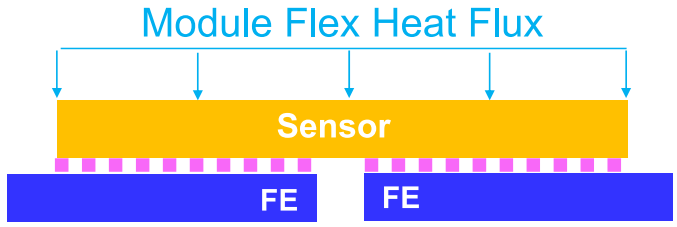
Sensor

Layer	Sensor Type	Sensor Thickness, t_{sensor} [µm]	T_{ref} [°C]	E_g [eV]	k_B [eV/K]	V_{bias} [V]	Q_{ref} [mW/cm^2]
0	3D	250	-25	1.23	8.6173E-05	**200**	**44.8**
1	Planar	100	-25			**520**	**13.3**
2	Planar	150	-25			**500**	**12.5**

Flex

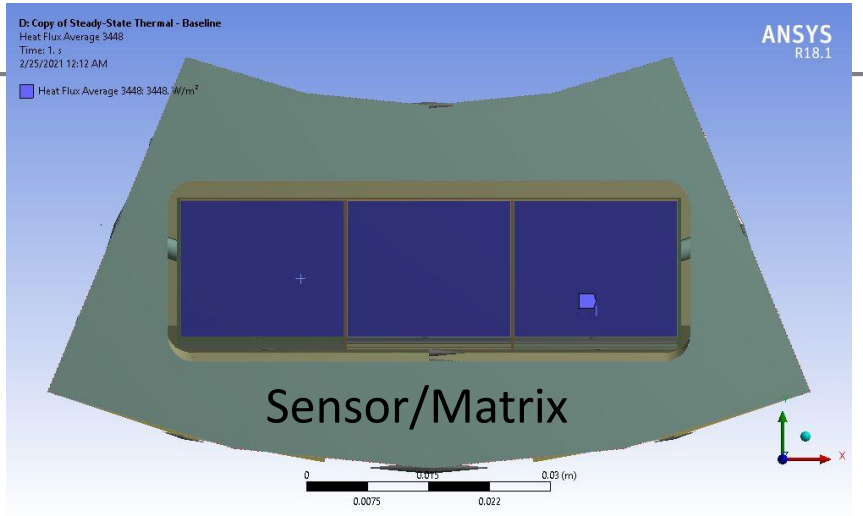
Layer	Power Applied to Sensor (flex) [W/cm^2]
0	0.092
1	0.077
Outer Endcap	**0.021**
Outer Barrel	0.070

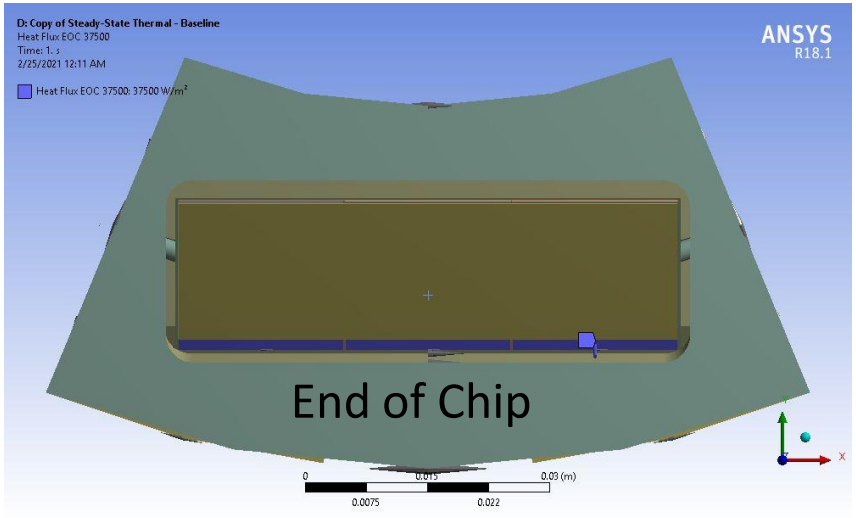
These values correspond to the worst case for each subsystems and include a **1.25 safety factor**

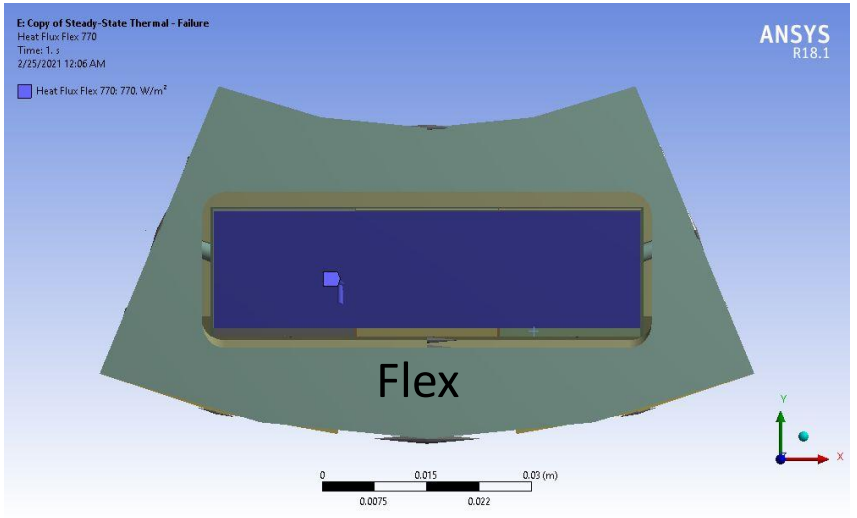


“Normal” Operation Case

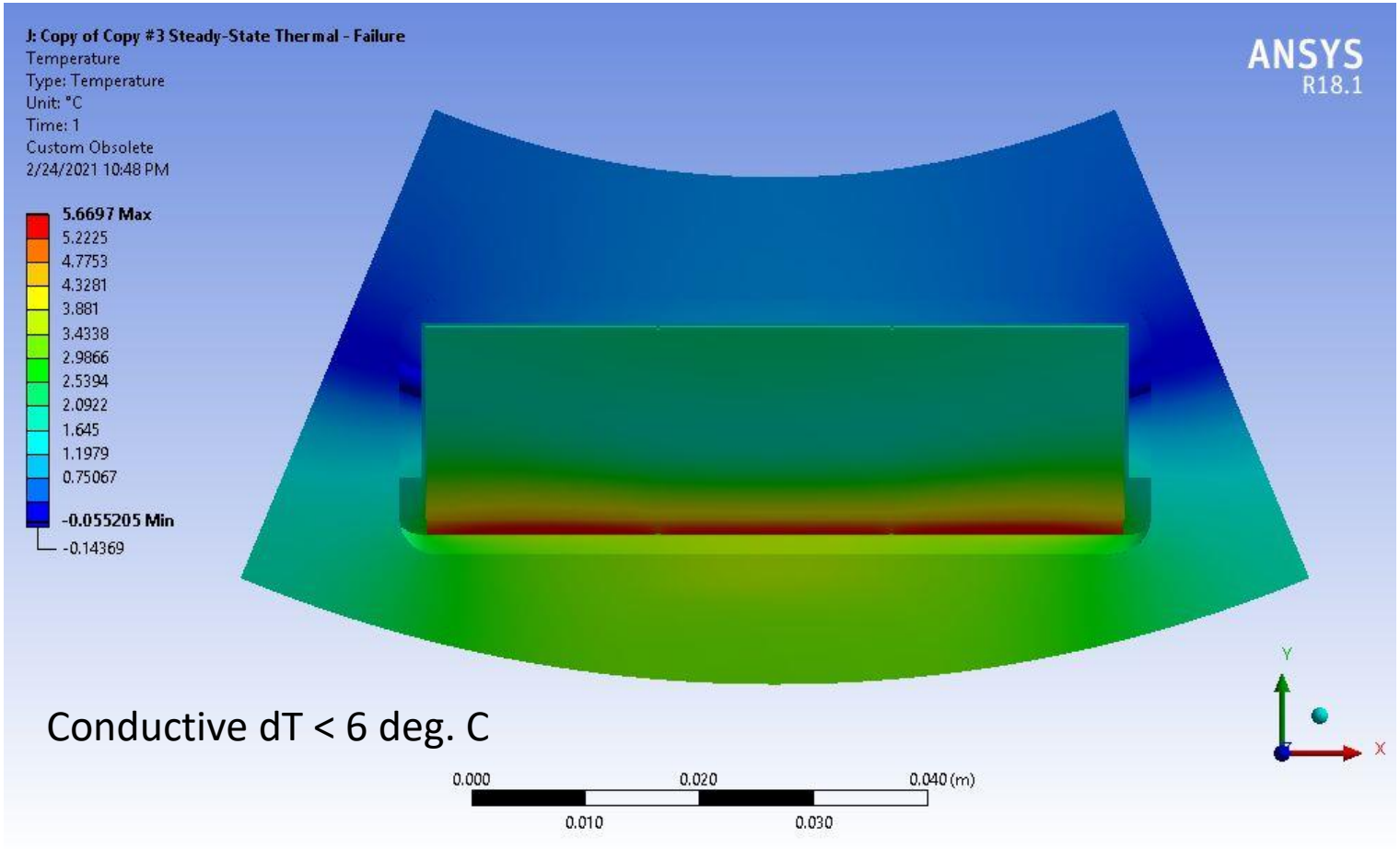
End of Chip – 37500 W/m2
Flex – 770 W/m2
Sensor/Matrix – 3448 W/m2





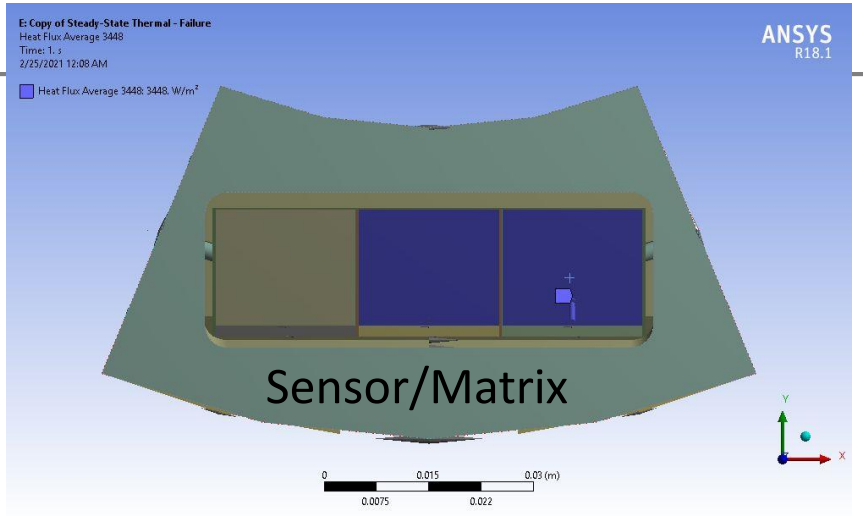


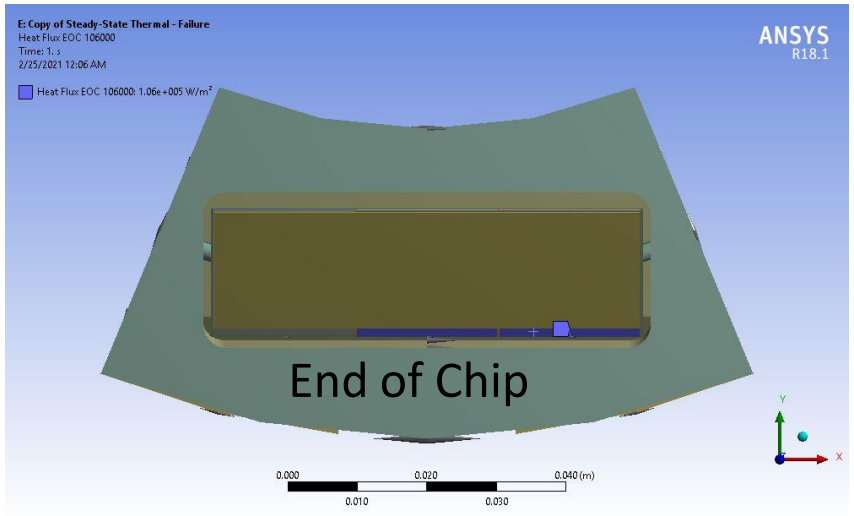
Normal Case - Results

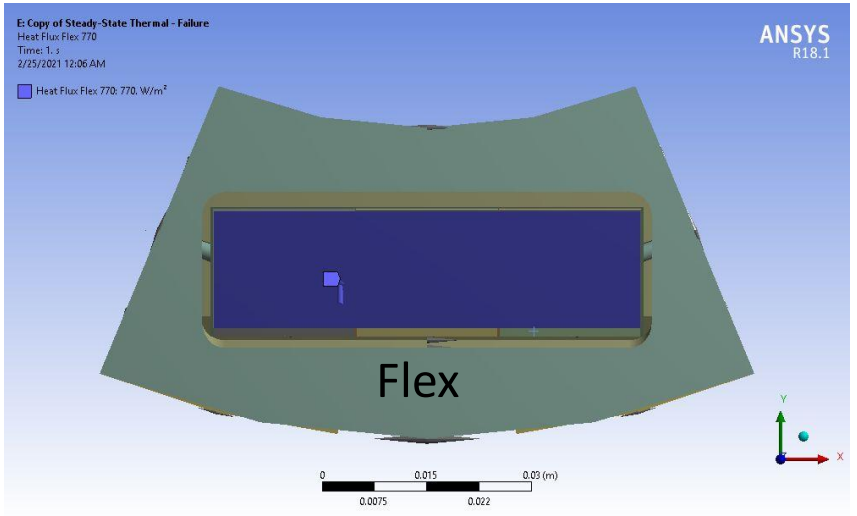


“Failure” Case

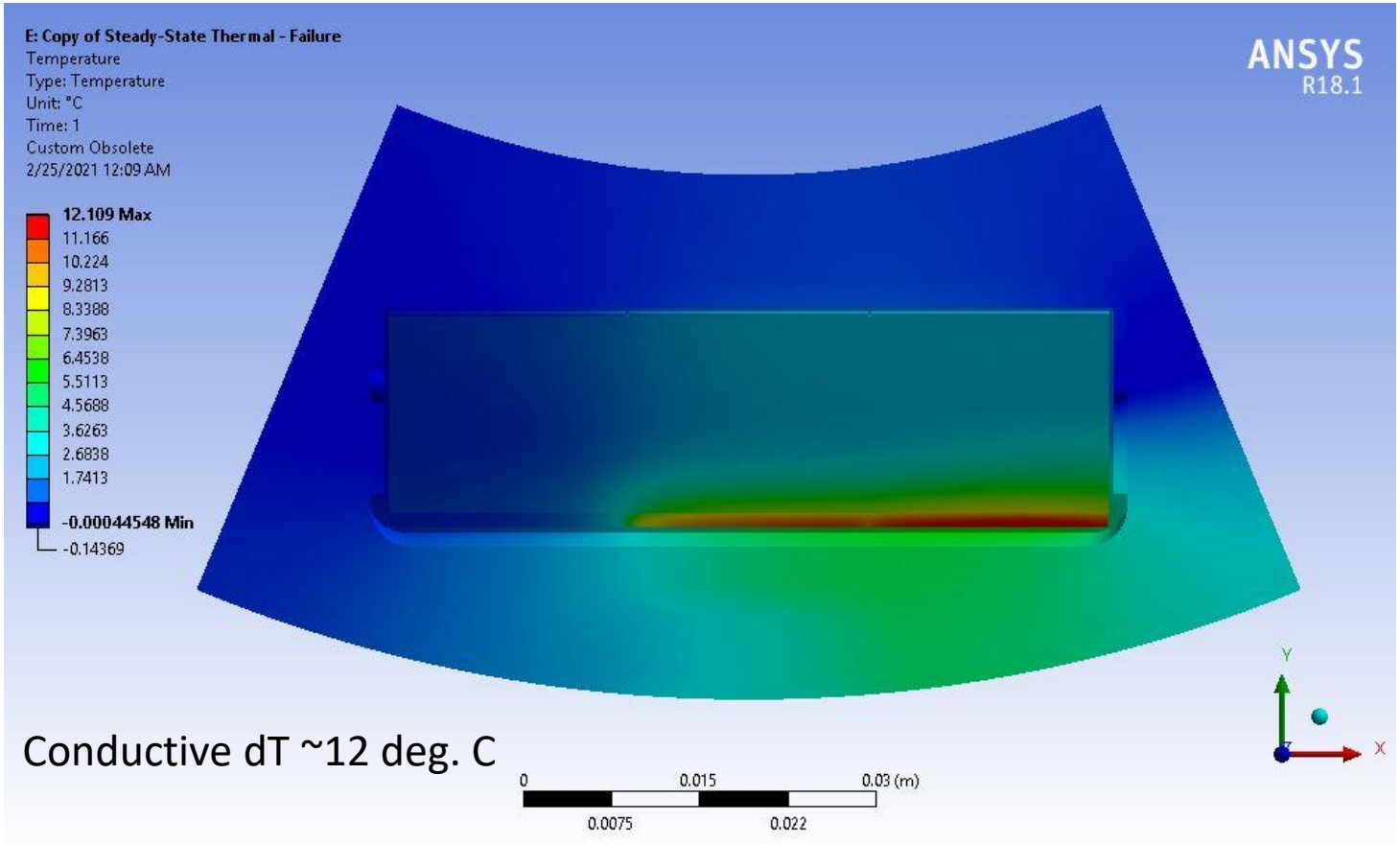
End of Chip – 106000 W/m2
Flex – 770 W/m2
Sensor/Matrix – 3448 W/m2







Failure Case Results



Conductive dT ~12 deg. C

Analysis Summary

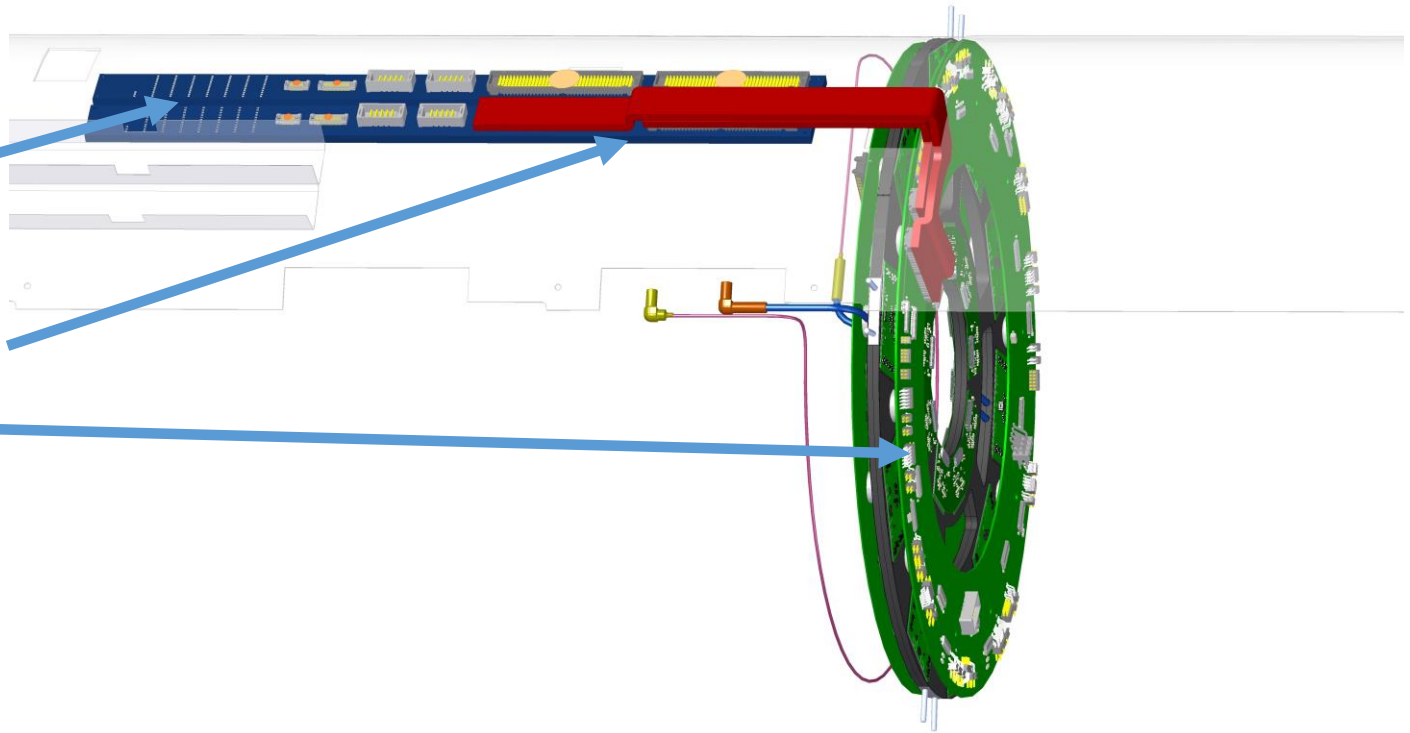
- Despite lack of glue between pipe and foam, this study seems conservative
  - Foam should be higher than 40 W/mK
  - Glue should be higher than 2 W/mK
- Due to wedge shape, distance between pipe and module has less effect than in flat ring → maintain 0.75mm spacing
- In future, must do sensitivity study on glue K, foam K, and foam/pipe interface
- This beginning study seems adequate at this phase to demonstrate that ring design is viable
  - dT limit of 10 is well respected in normal operation case
  - Only slightly exceeded in failure case, which is seen as extremely unlikely

General PLR Servicing Approach

- Servicing scheme should follow, as much as possible, the standard servicing scheme for the inner system rings
- At the PLR IDR in Mar 2021, there was still some uncertainty as to how closely that would work
- The general concept, however, is clear
  - PLR modules on one side of ring
  - 2x Ring flexes on other side of ring
  - Pigtails from modules wrap under ring to the flexes
    - Probably need new pigtails
  - Ring flexes are connected through the Ring-PP0 jumper to PP0
  - Need a new powering connection (flex or wire)

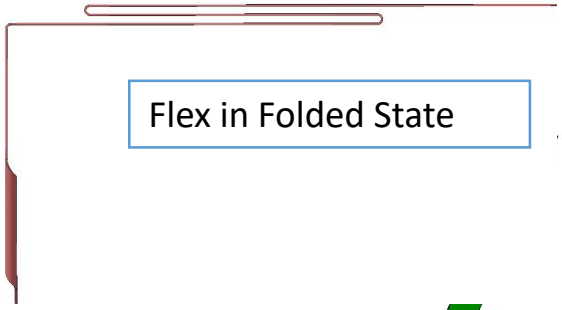
Basic Endcap Ring Components

- Not Shown
  - Quad Module Data Flex
  - Triplet Module Data Flex



- PP0
- Type-0 to PP0 Flex
- Rigid Ring (“Flex”)

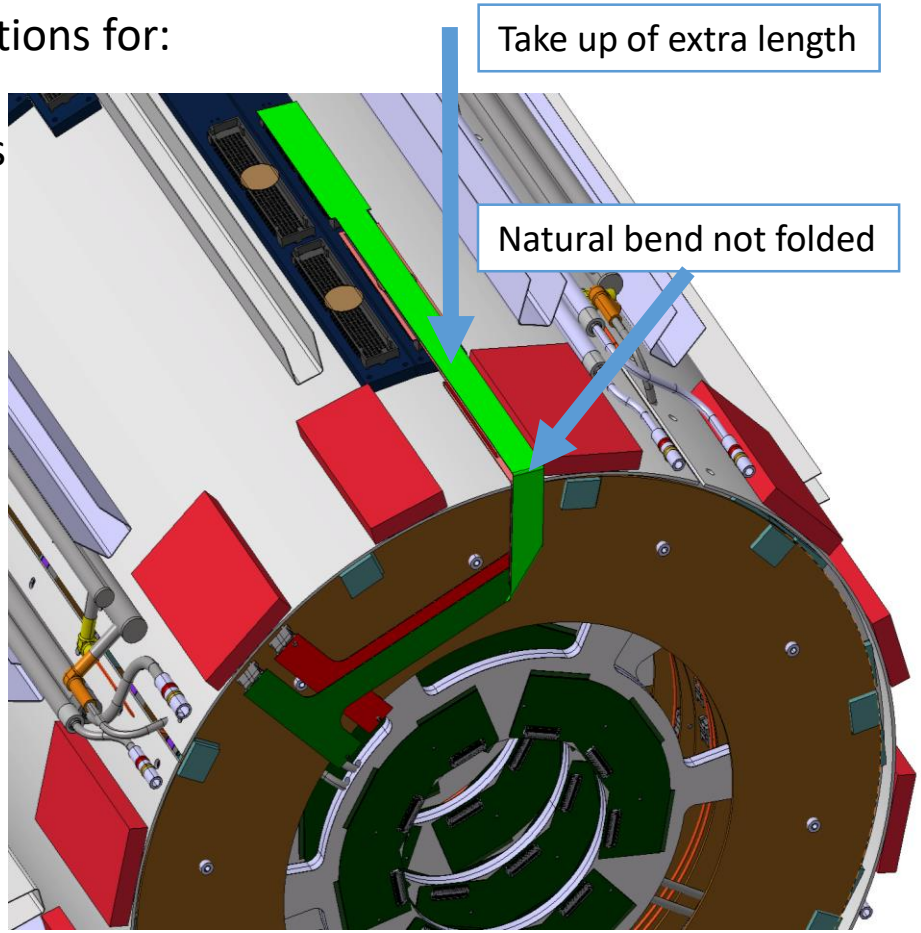
Current Ring to PP0 Concept

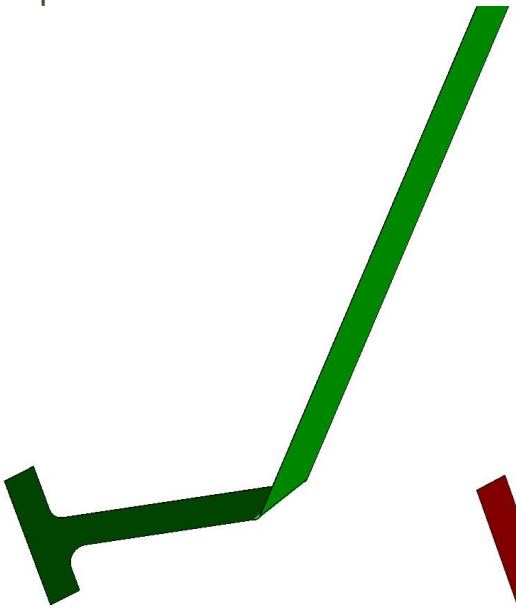


Flex in Folded State

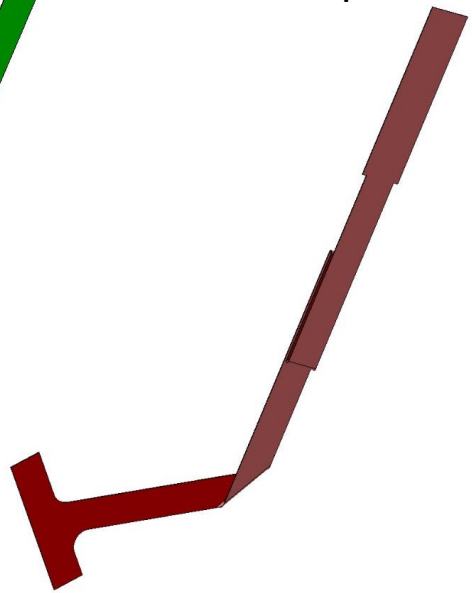
One Flex contains connections for:

- 52 differential pairs
- 2 serial power chains
- 5 High Voltage Lines
- 1 interlocks
- 1 Mops Channels



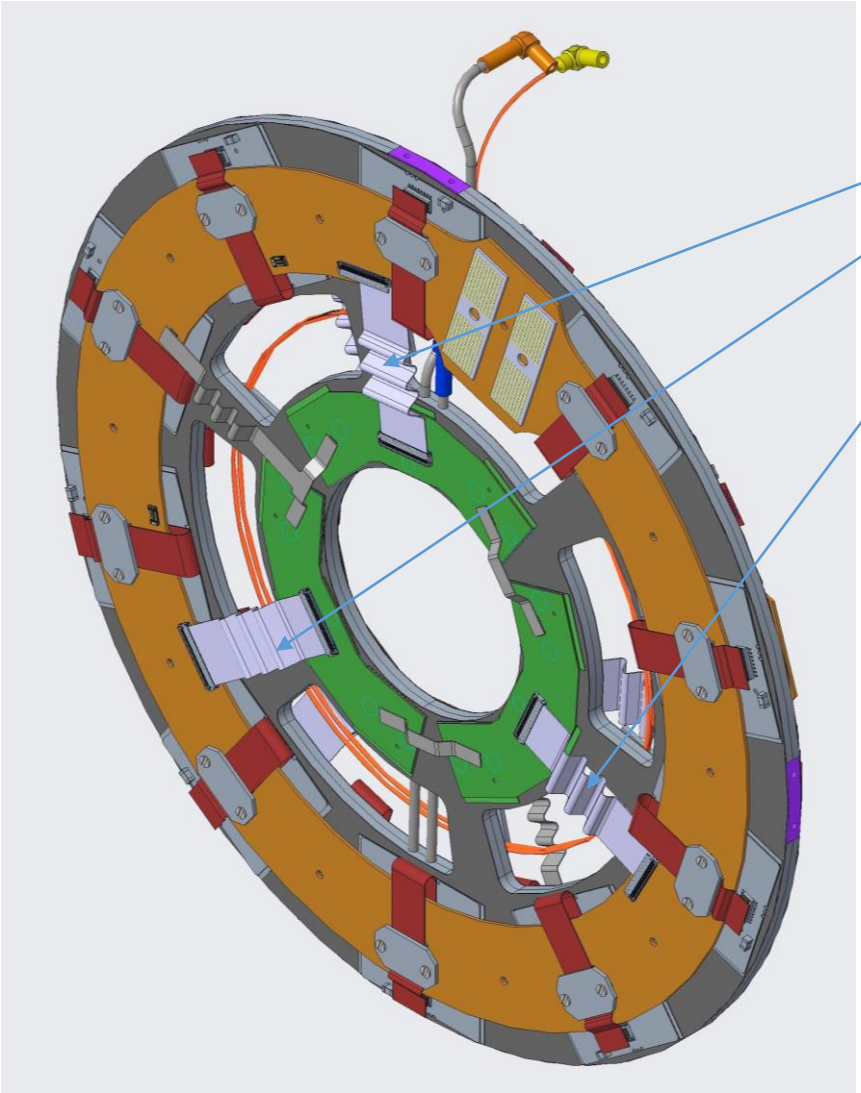


Back Flavor

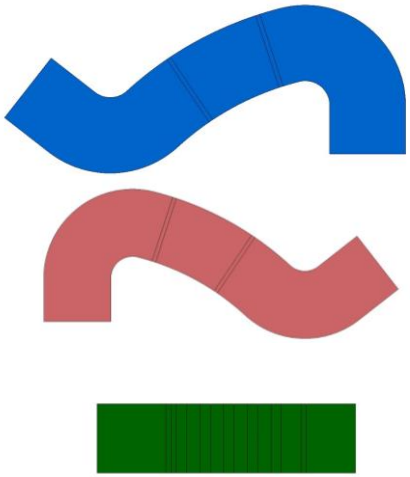


Front Flavor

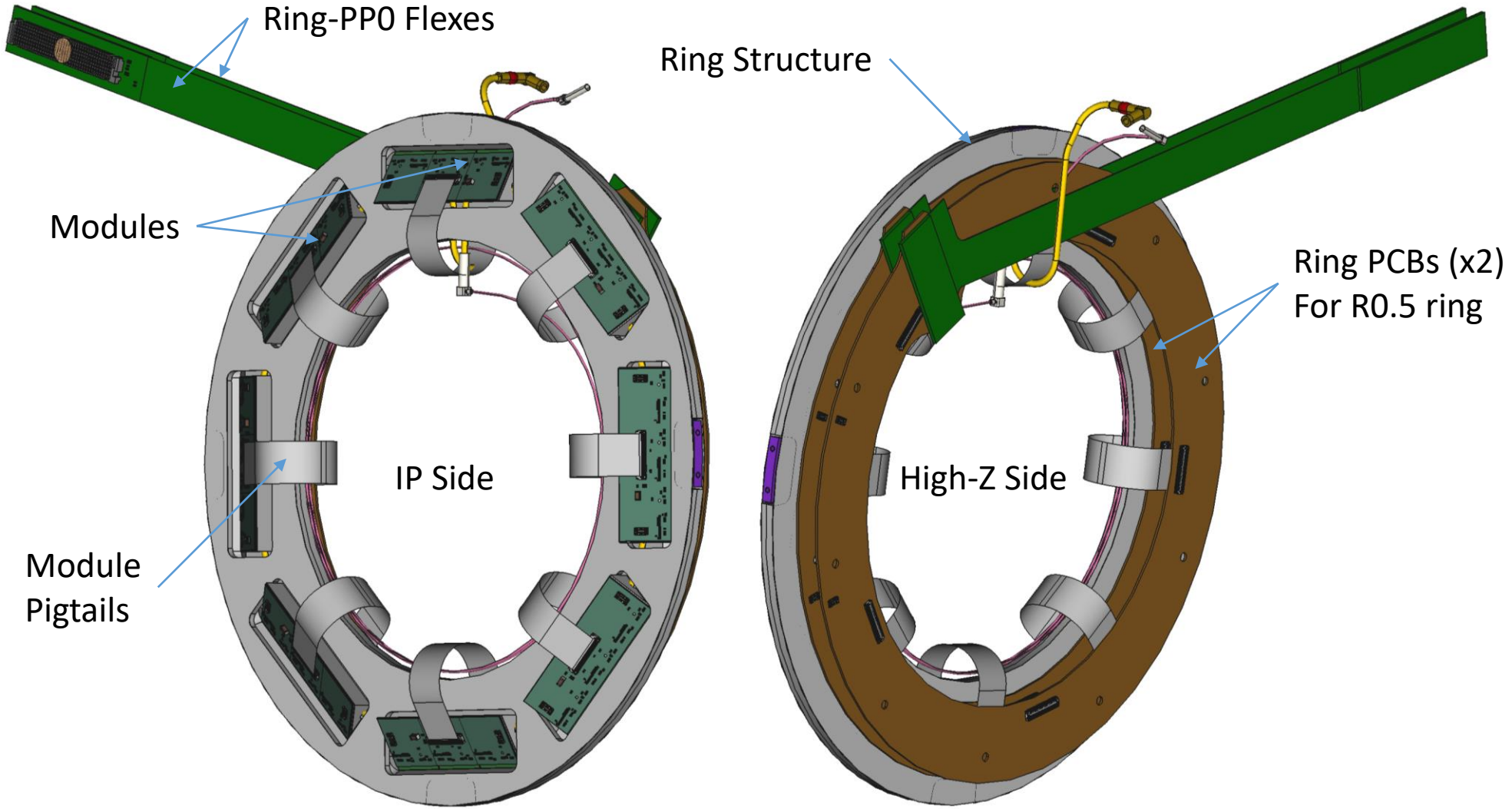
Triplet Pigtails



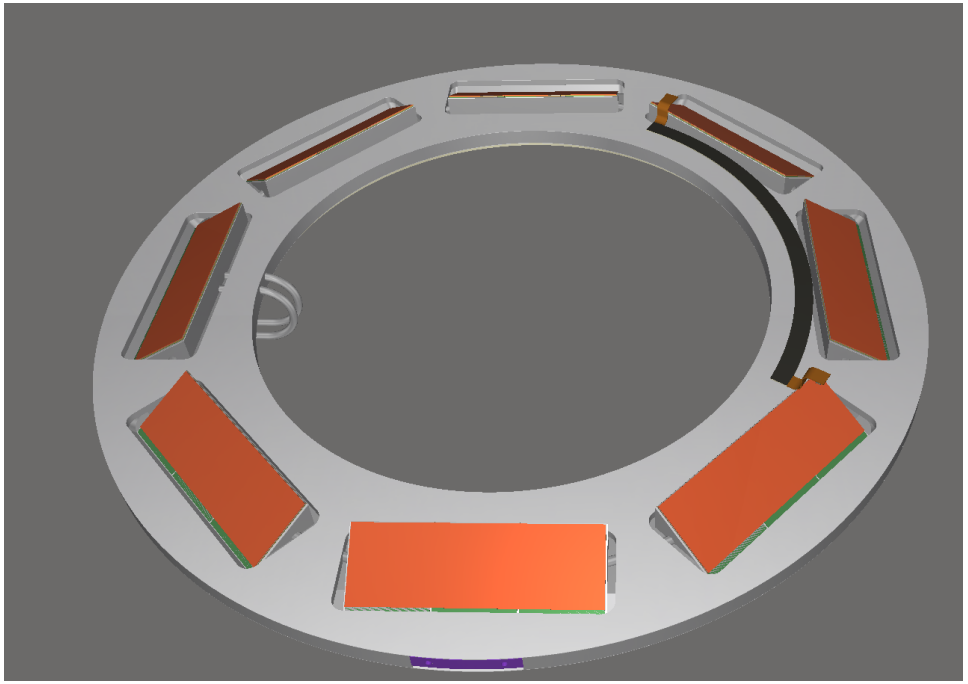
- Straight version shown here (with flexible length)
- Two other “right” and “left” flexes exist
- Some combination of these could potentially work for PLR…



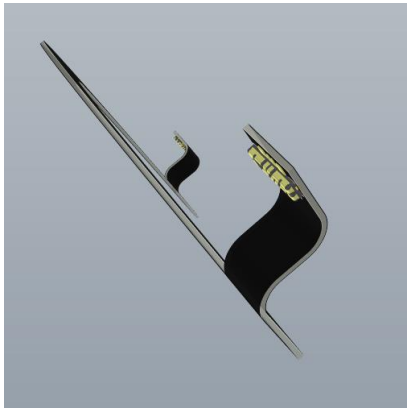
General PLR Servicing Approach



Power Flex for PLR



- The black flex connects the output of one module to the input of the next
- A separate flex (or round wire interface) will have to be designed to connect the two serial power chains to the ring



Servicing Options

- Since the services FDR, the situation is much more clear, and some choices have been made that potentially facilitate the PLR design and servicing
  - → There is now only 1 PP0 design for the IS Endcap, and it contains 104 transmission line pairs (enough for the PLR in any possible scenario)
  - → There is now only one type of Ring Flex to PP0 jumper, so no matter what “slot” the PLR is installed into in the endcap, one type of flex should work
  - → Module pigtails for PLR, while not identical to the pigtail concept for the IS Endcap, can probably profit from the “flexible” concept to minimize risk and or new design iterations
- The closest analog to the PLR is the Intermediate Ring Flex
  - However, only services 5 triplets
  - Only services 3 lanes per chip
- There are two major options for how to service the PLR, shown on following slides

Servicing Options – New Ring or No New Ring

- New Dedicated PLR Ring Flex
  - Services 8 modules in two Serial power chains (4 ea.)
  - 1 command line per module
  - 4 data lines per chip
  - Total of 104 lines, compatible with 1 PP0
- Can maintain Ring to PP0 jumpers as in rest of endcap
- Can potentially (this must be carefully checked) reuse pigtails from coupled or intermediate rings. At the least, design is VERY similar (but potentially longer)

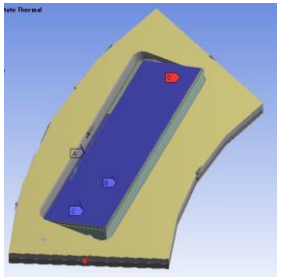
- Reuse TWO intermediate ring flexes
  - Service 4 of 5 modules per flex. One flex per Serial power chain
  - 1 command line per module, standard
  - 3 data lines per chip
  - Total of 40 lines, compatible with ½ of a PP0
- Can maintain Ring to PP0 jumpers as in rest of endcap
- Will probably need to re-design module pigtails to match 4/8 modules to 5x Ring Flex

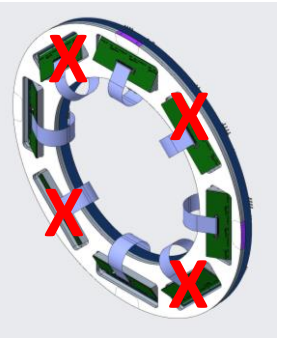
Servicing Options Summary

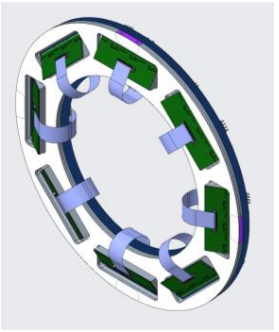
- Two major decisions have been provisionally made
  - 3 ~~or 4~~ lines per chip
  - ~~New or~~ Re-used Ring Flexes
- These choices ~~have ramifications on the flexes that must be made (including rigid ring “flex”) and~~ allow the reuse of existing components and therefore reduce cost and risk

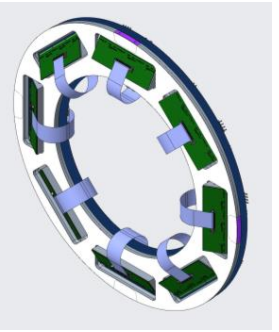
Proposed Proto, Pre-prod, Production Scope

- Prototyping
  - Fabricate one wedge assembly with pipe
  - Mount one RD53 module (or ITkPix if available)
  - Operate cold under CO2 (but without capillary)
  - Test TFM, thermal operation, etc.
- Pre-Production
  - One full mechanical ring
  - Mount 4 alternating modules (ITkPix, one serial power chain)
  - Connect to one ring flex (nominally the Intermediate ring flex)
  - Operate cold to test TFM, thermal operation, etc.
  - Thermally cycle 50 times to OTR
- Production
  - Two full mechanical rings, capillaries
  - Full complement of 16 modules
  - Four intermediate ring flex
  - Four Ring-PP0 jumpers
  - 2 PP0-Twinax bundle assemblies
  - 16 module pigtails









Summary

- Advancement of Ring and Services designs in past years (since IDR) have allowed us to conceive of a PLR with more certainty in details
  - No need for new PP0 is major cost and risk saver
  - Possibility of PLR with no new flexes (note that this is NOT a done deal) offers real savings and risk reduction
  - Hand assembly is a major saver of time and cost
- In order to validate this approach we must know
  - Can PLR survive with 3 lines per chip?
  - Is hand assembly and placement accuracy good enough for PLR?
    - This can be analyzed in near term
    - Initial thoughts are that it must be, but won't know for sure until we make prototypes and do some analysis
- All indications are so far positive, but work needs to be done to validate PLR approach and that it will have minimal impact on IS Endcap progress