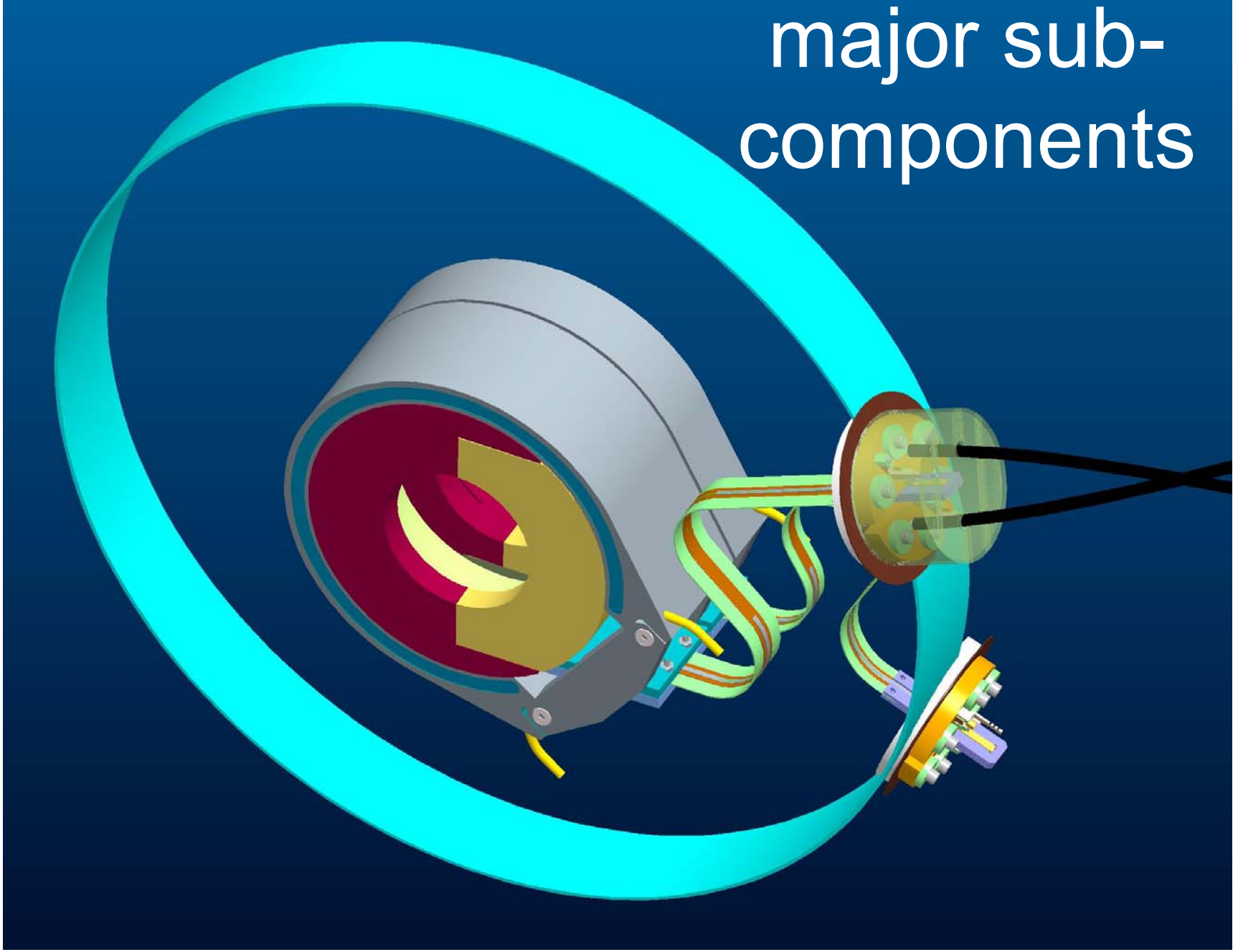
SRF Solenoid Assembly Second Design Review

Stephen Plate

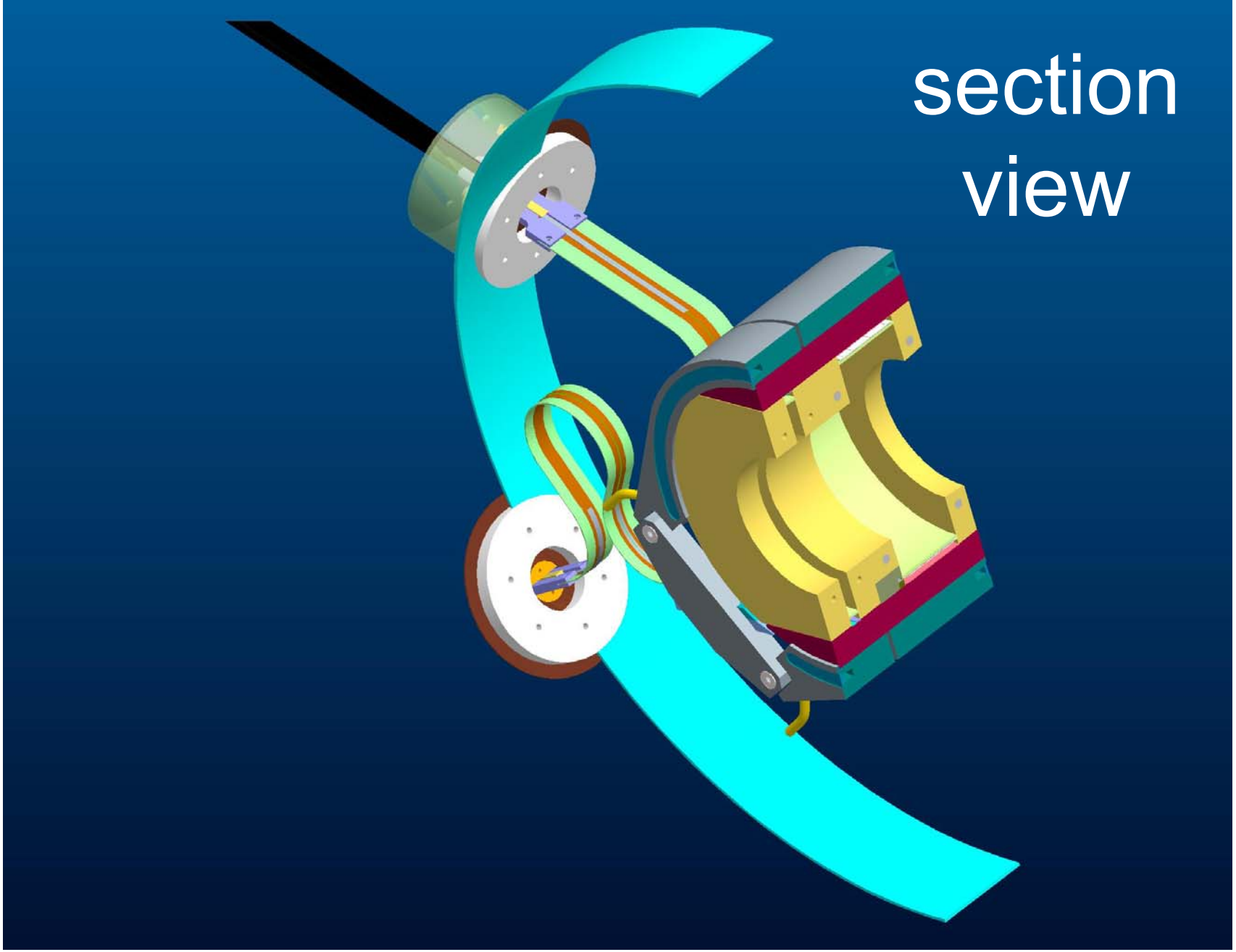
Outline

- Main & Auxiliary solenoid coils (5K)
- HTS Flexible Leads & Splices
- Main & Auxiliary steel yokes & yoke clamps
- Heat stationing on shield (77K)
- Cooling

major sub-components



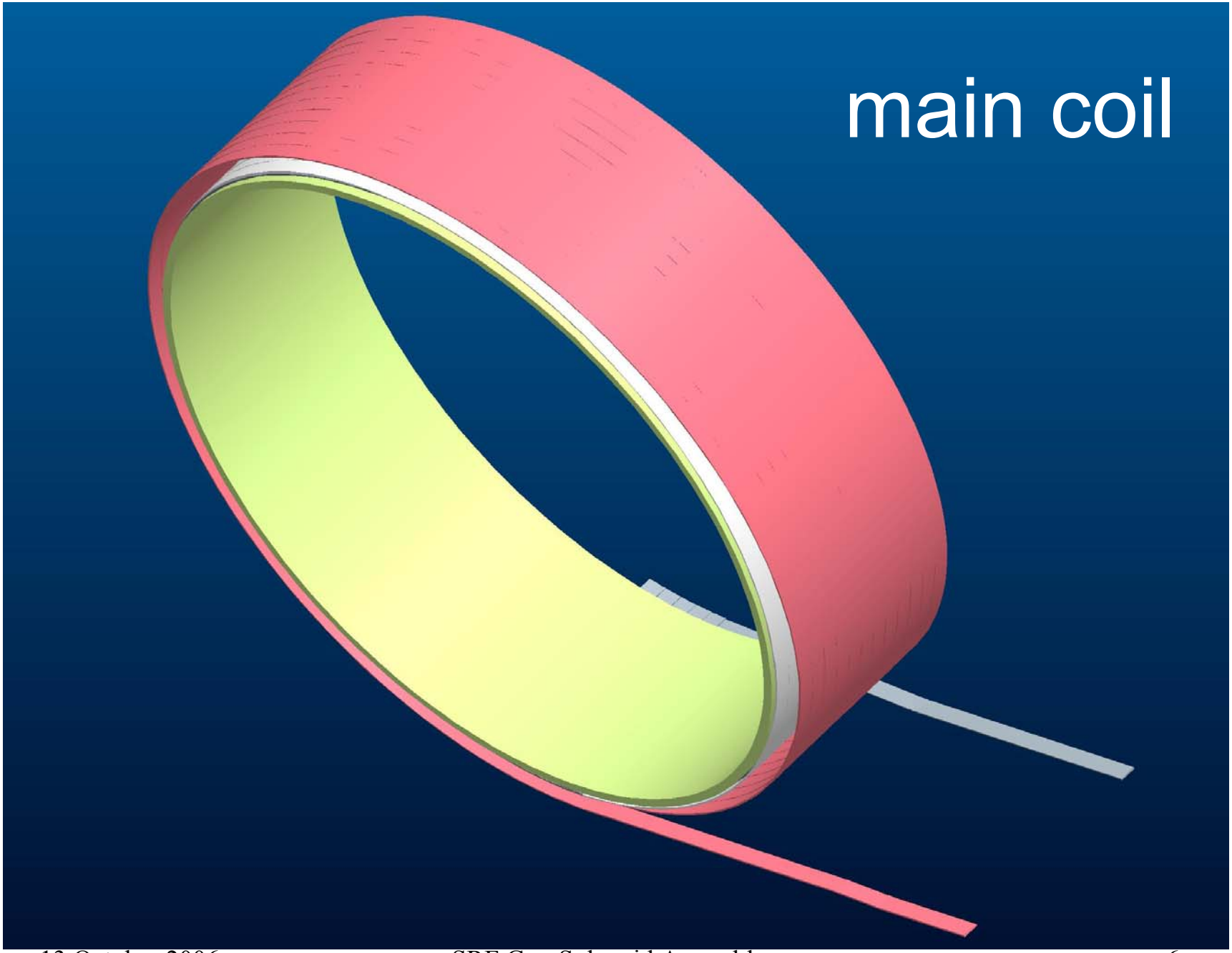
section view



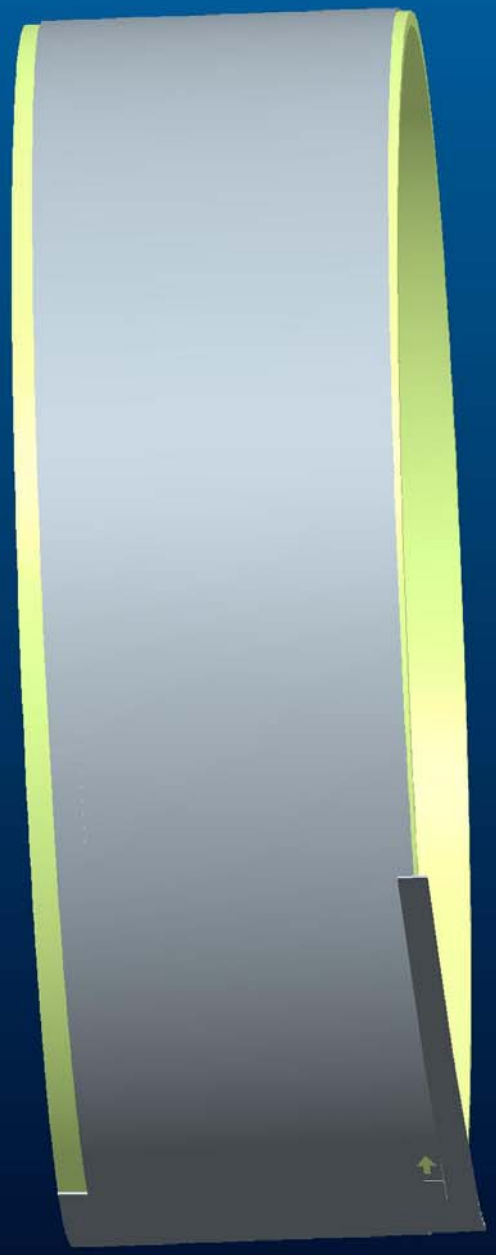
Main Coil

- Level-wound (traverse back and forth)
- 15 layers (odd number req'd), 12 turns per layer
- Operates at ~5K; conduction cooled through contact with yoke
- Wound directly on copper bobbin (radiative heat transfer from bobbin ID to beam tube aids cooling)

main coil



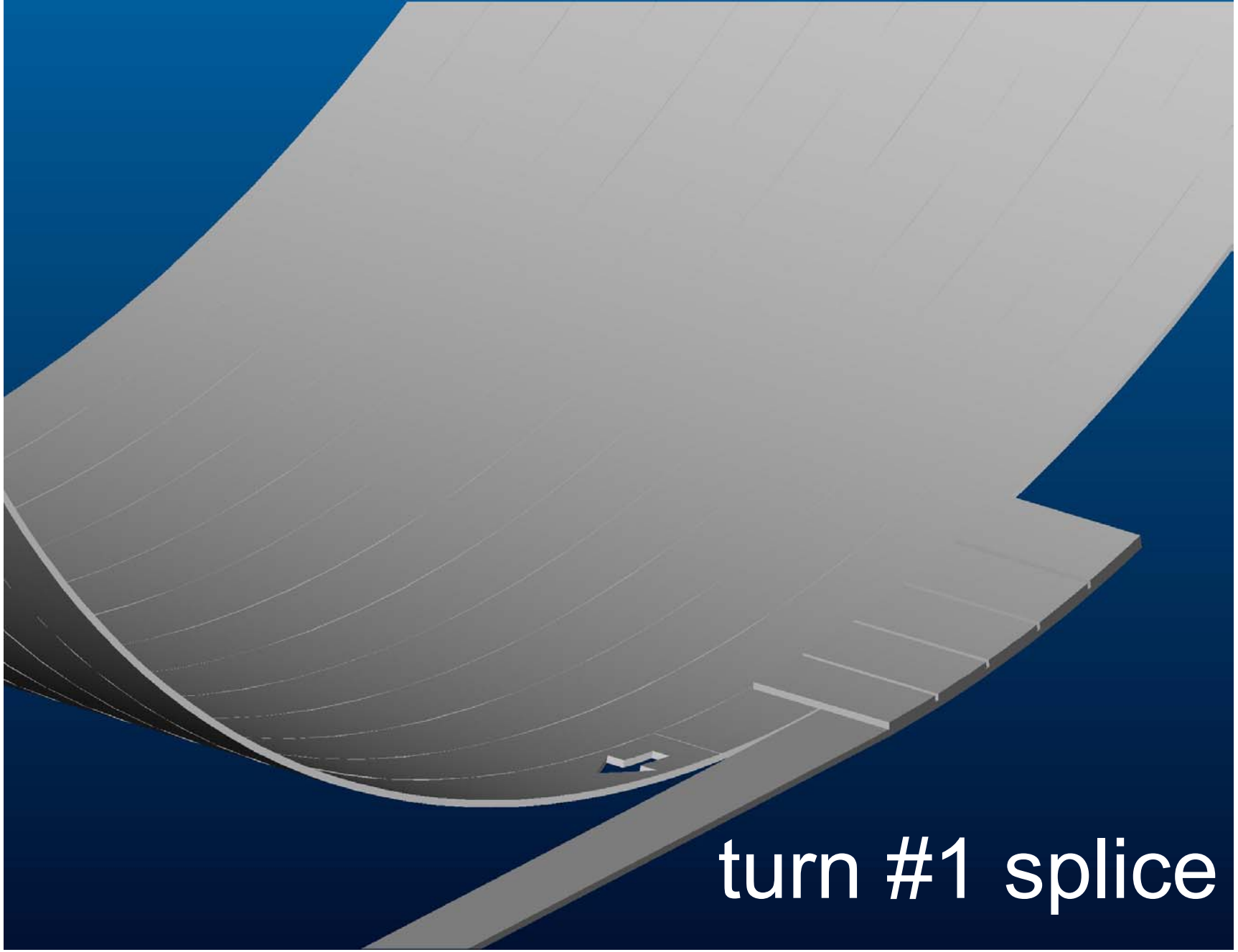
layer 1



filler

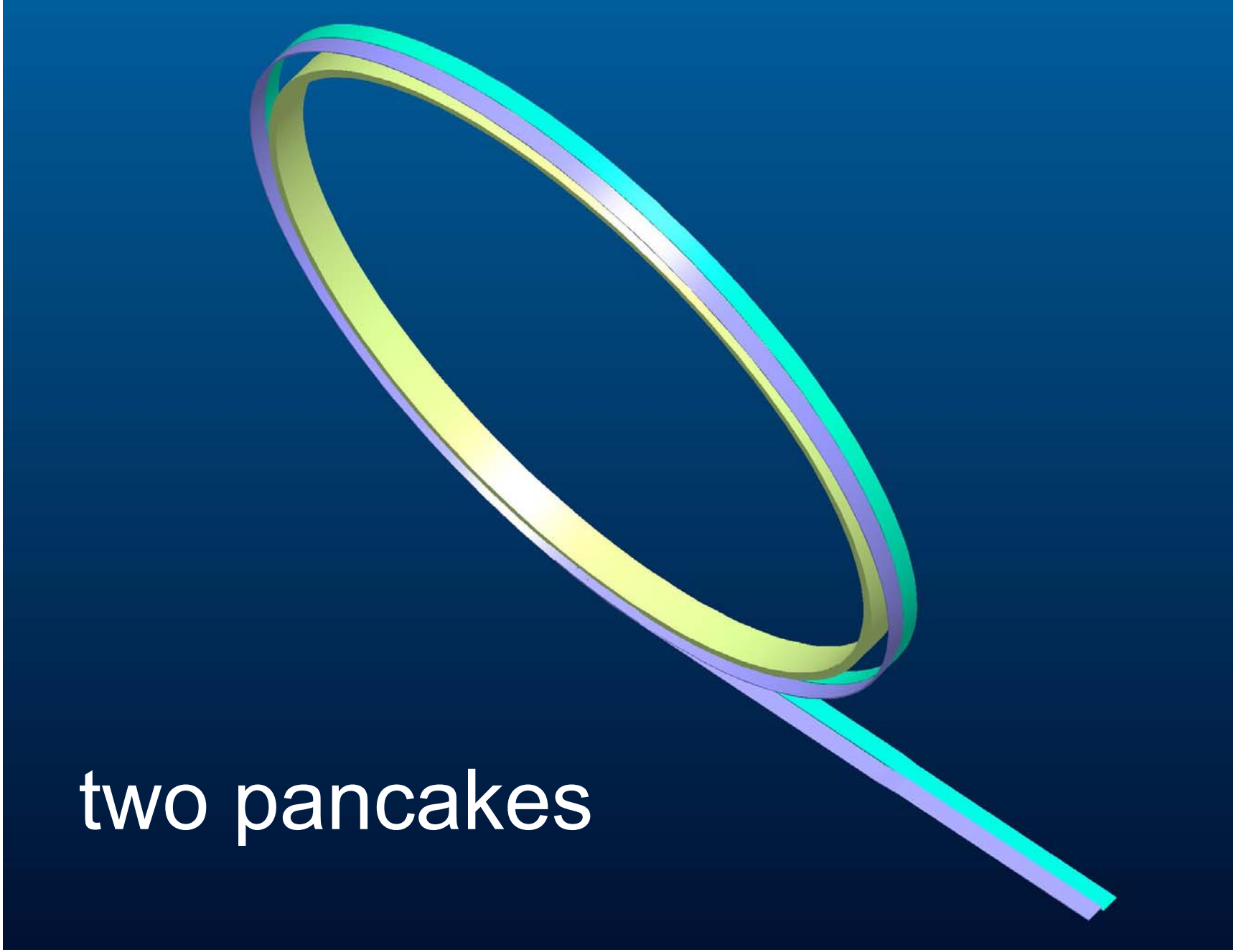
Main Coil Inner Layer Splice

- Splice lead to inside starting turn
- 10 transverse pieces (only 5 shown)
- Leads exit tangentially and parallel

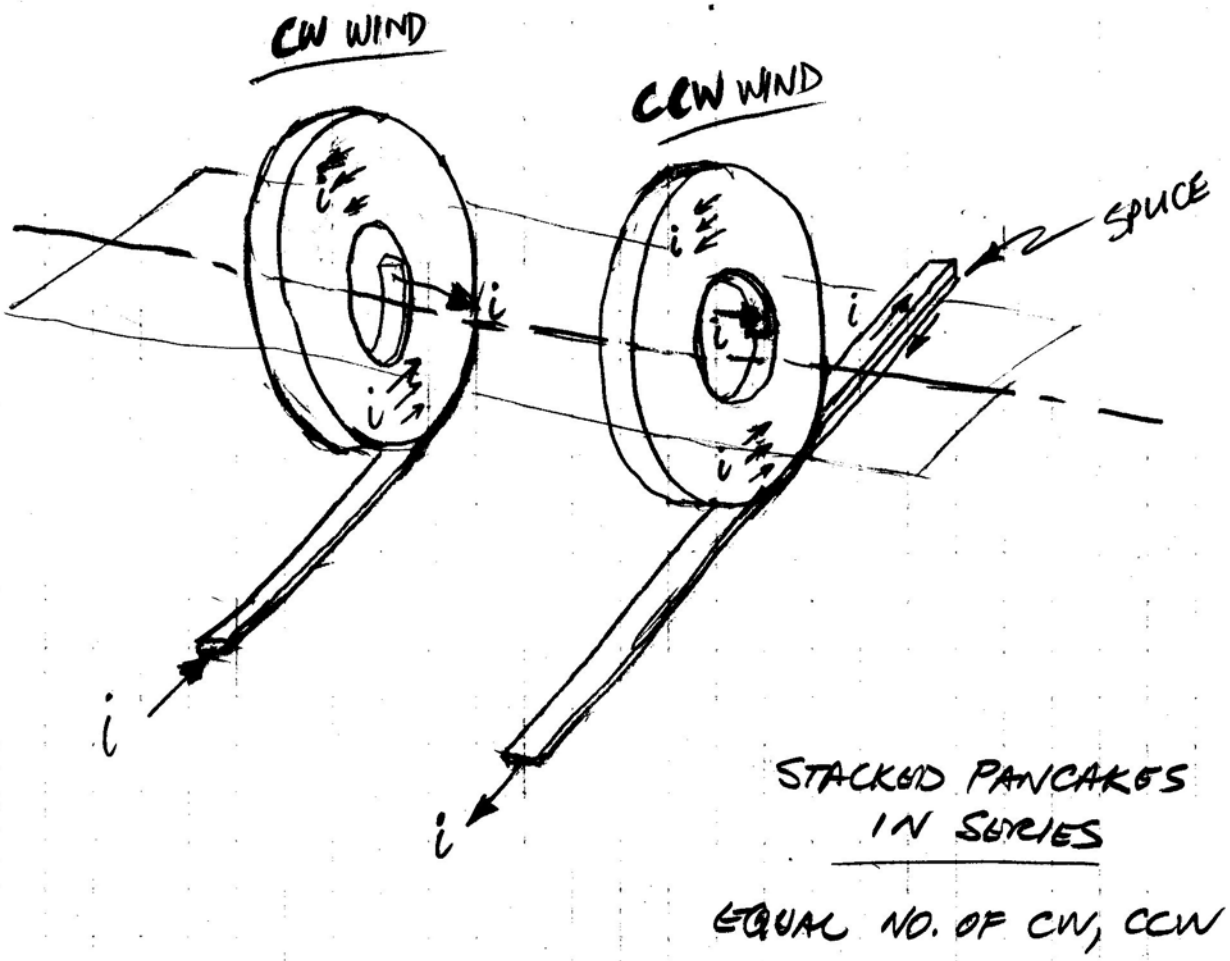

turn #1 splice

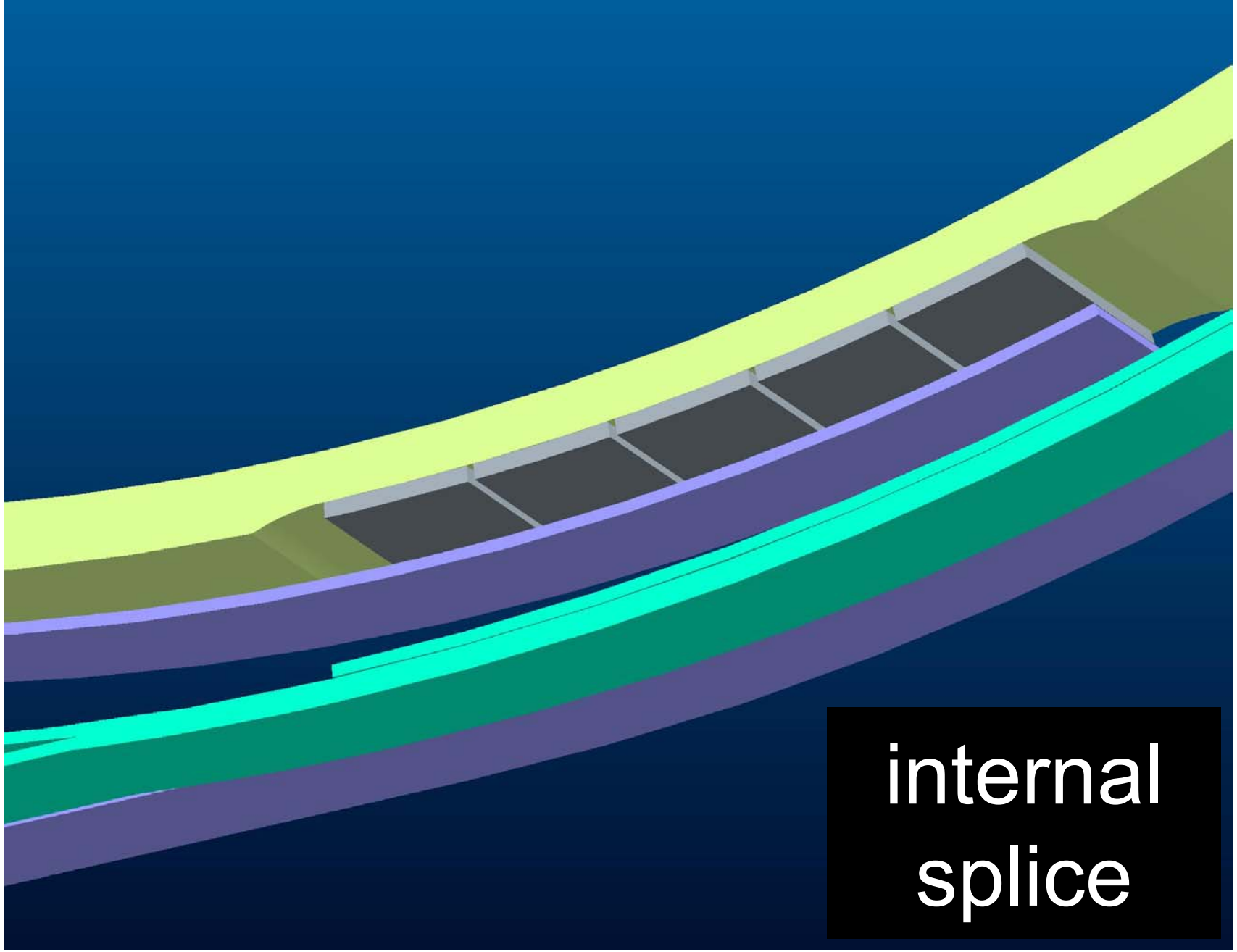
Auxiliary Coil

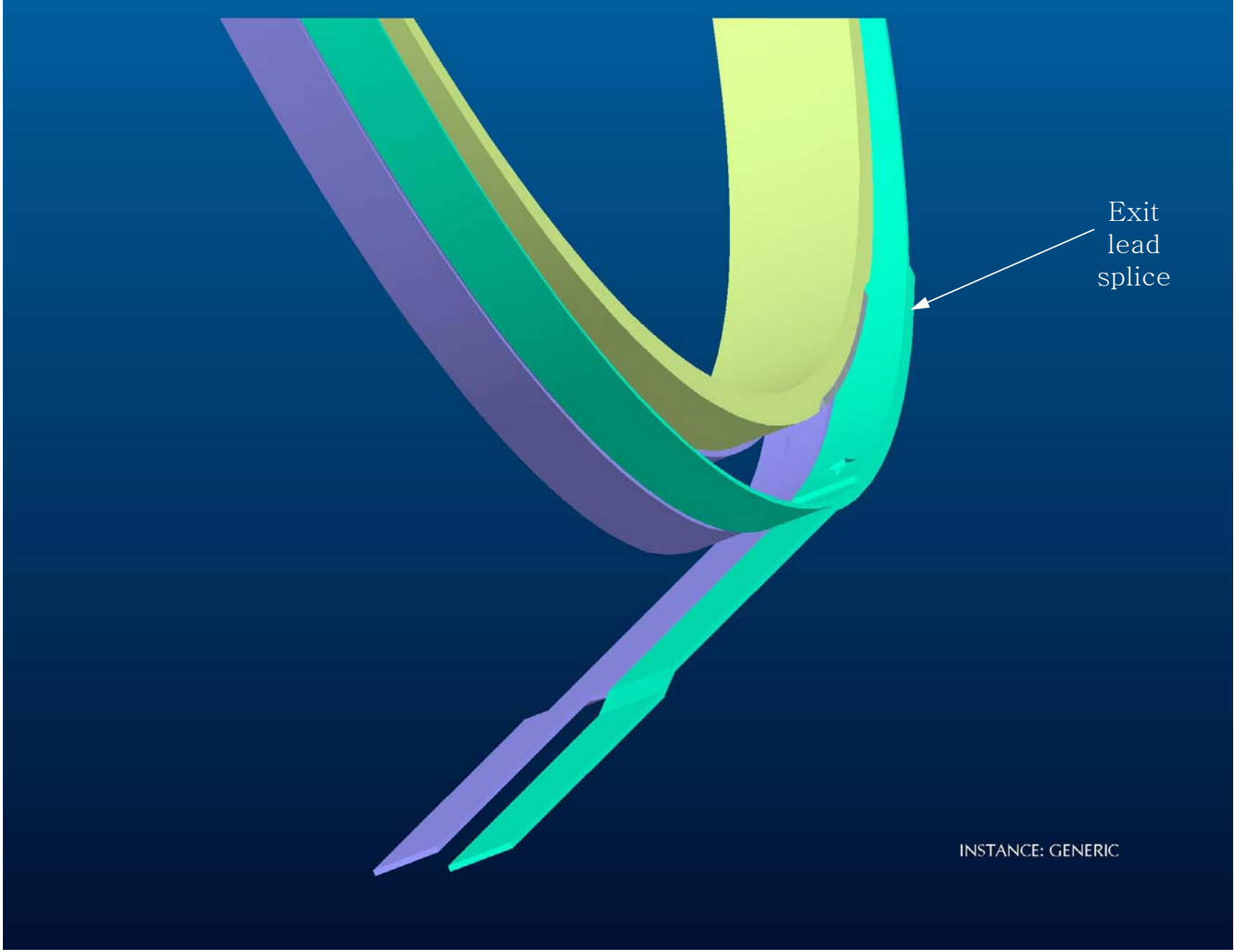
- 15-turn pancakes (two)
- Internal coil splice
- Leads exit tangentially and parallel


two pancakes

internal coil splice

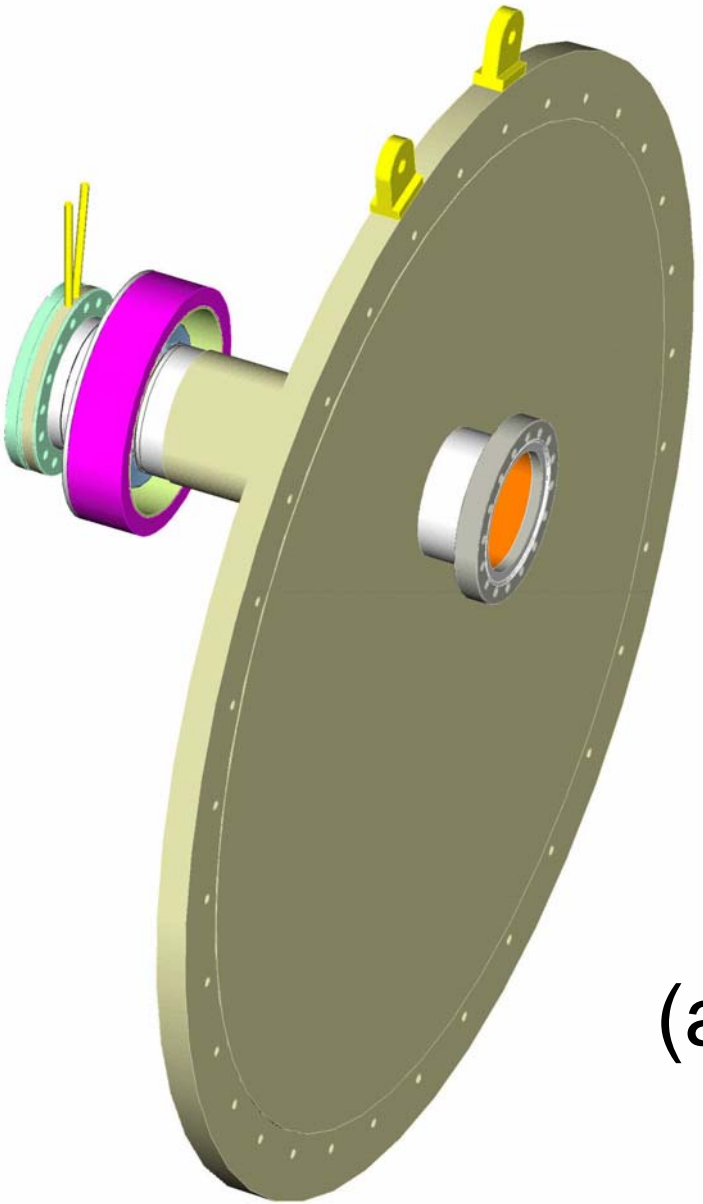



internal
splice

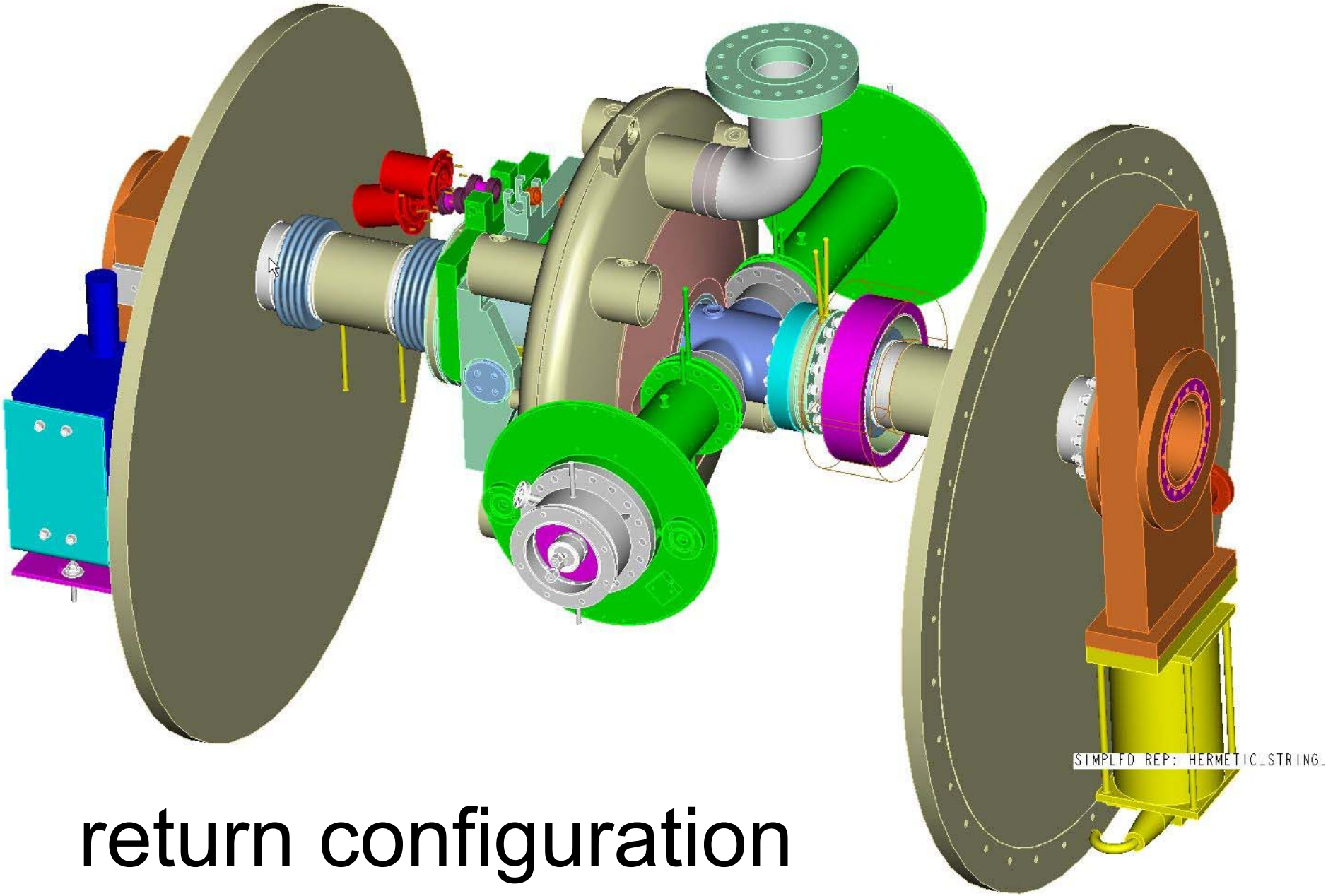

Exit
lead
splice
INSTANCE: GENERIC

Ship to J-Lab

- Ship partial assembly to J-Lab
- Tooling for support not shown; aux coil not shown
- Build hermetic string
- Ship back



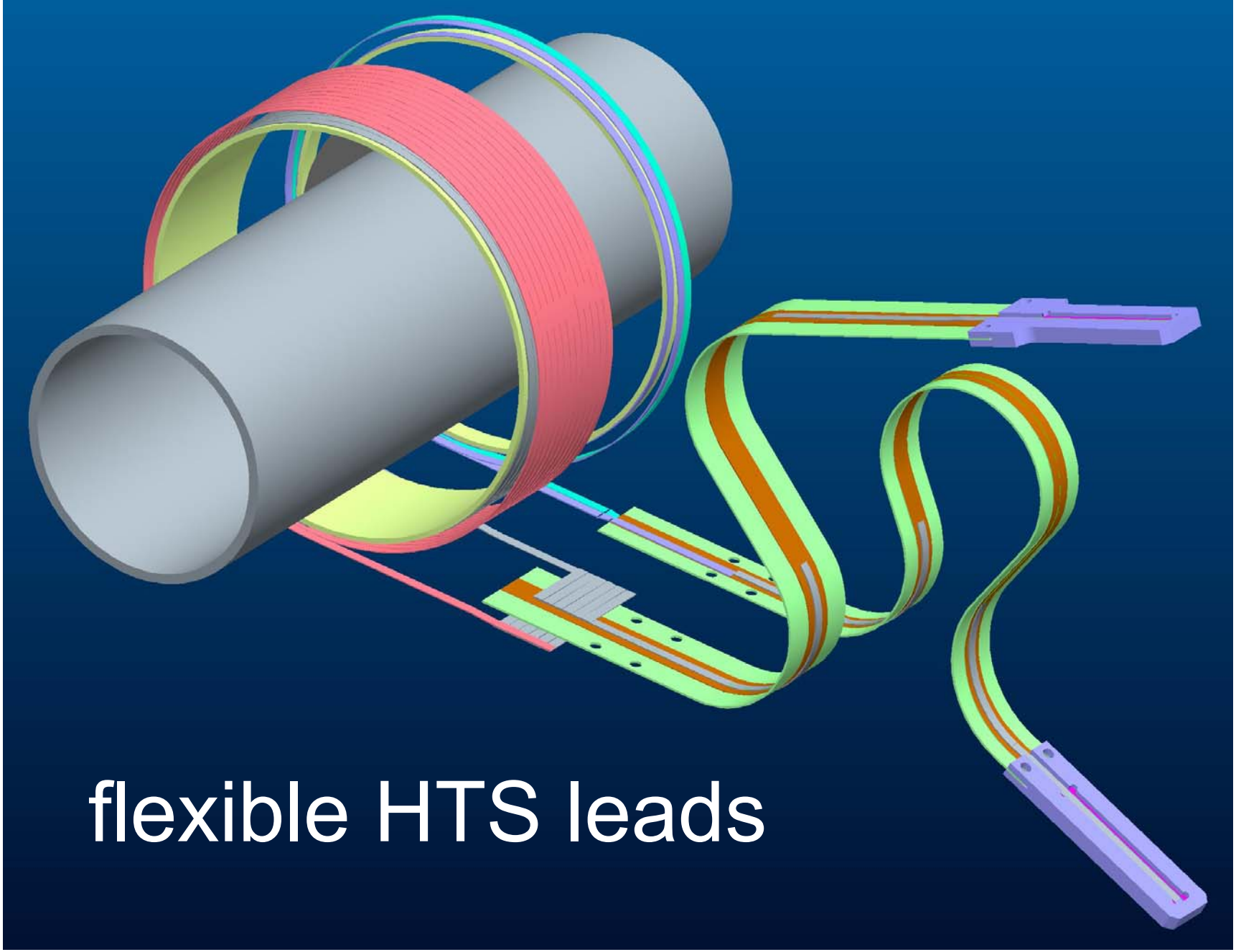
as shipped
(aux coil not shown)

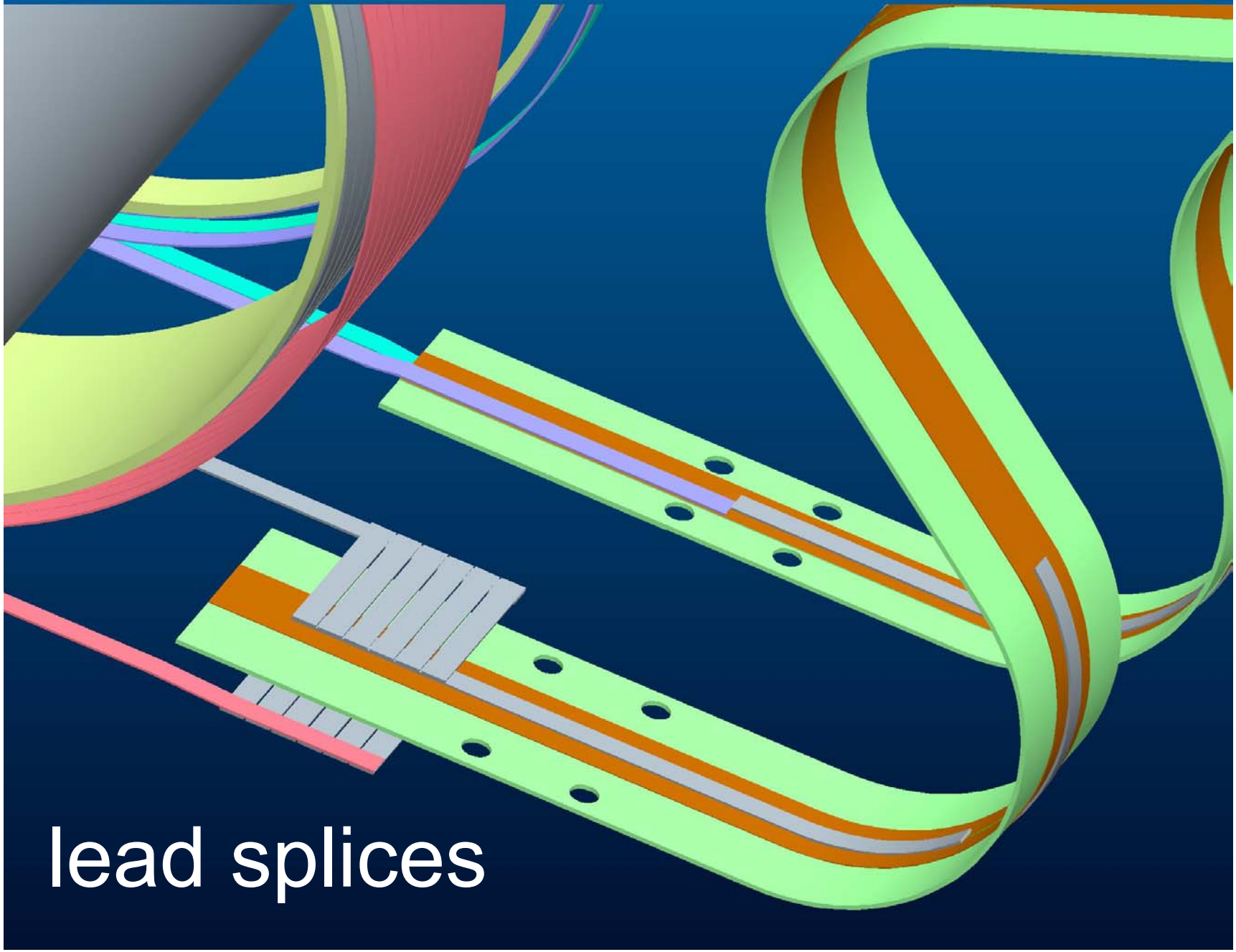


return configuration

Flexible HTS Leads

- Laminated G-10 sheet, .015 thick each
- Kapton tape
- HTS lead with Kapton over top
- Motion
  - Largest motion occurs at assembly of parts
  - Cooldown, radial = .011 inches cooldown
  - Cooldown, axial = +/-0.043 max (fully cold shield with warm beam tube & vice versa)


flexible HTS leads


lead splices

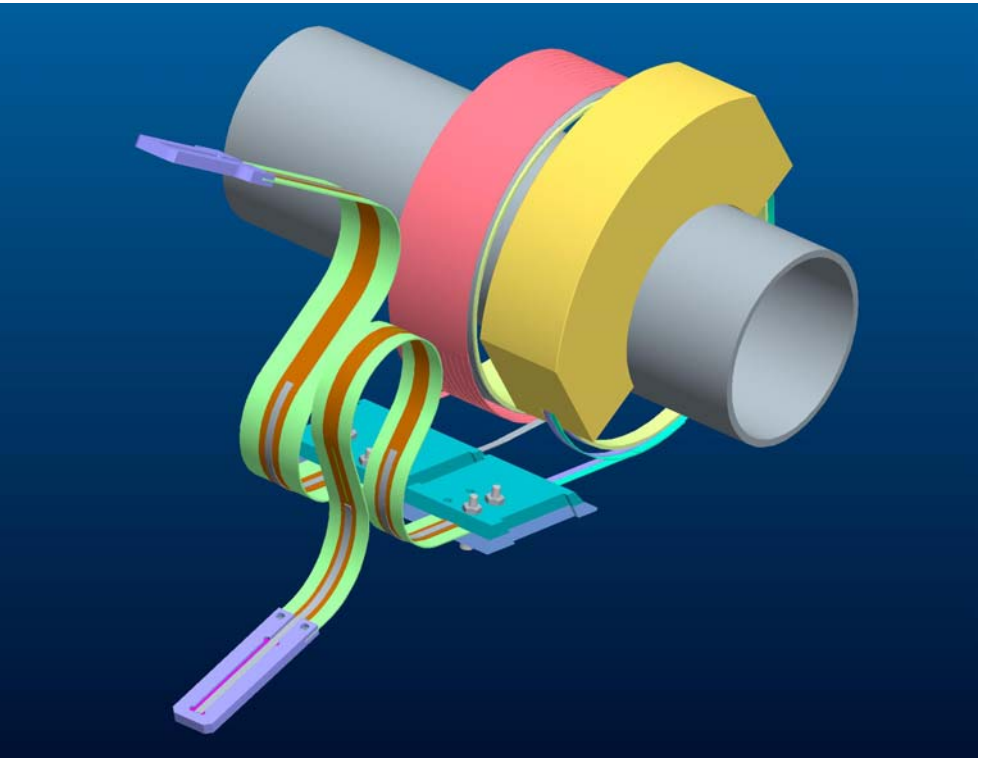
Splice Clamps

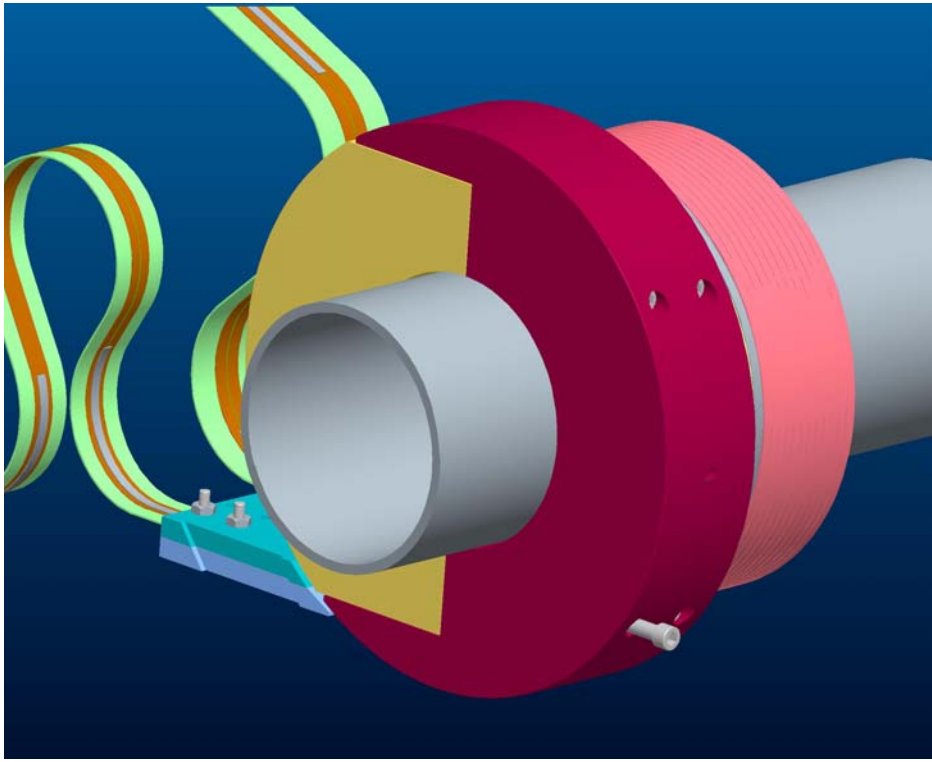
- Add voltage taps to joint
- Electrically test joints
- Insulate/protect with G-10 splice clamps

Steel Yokes

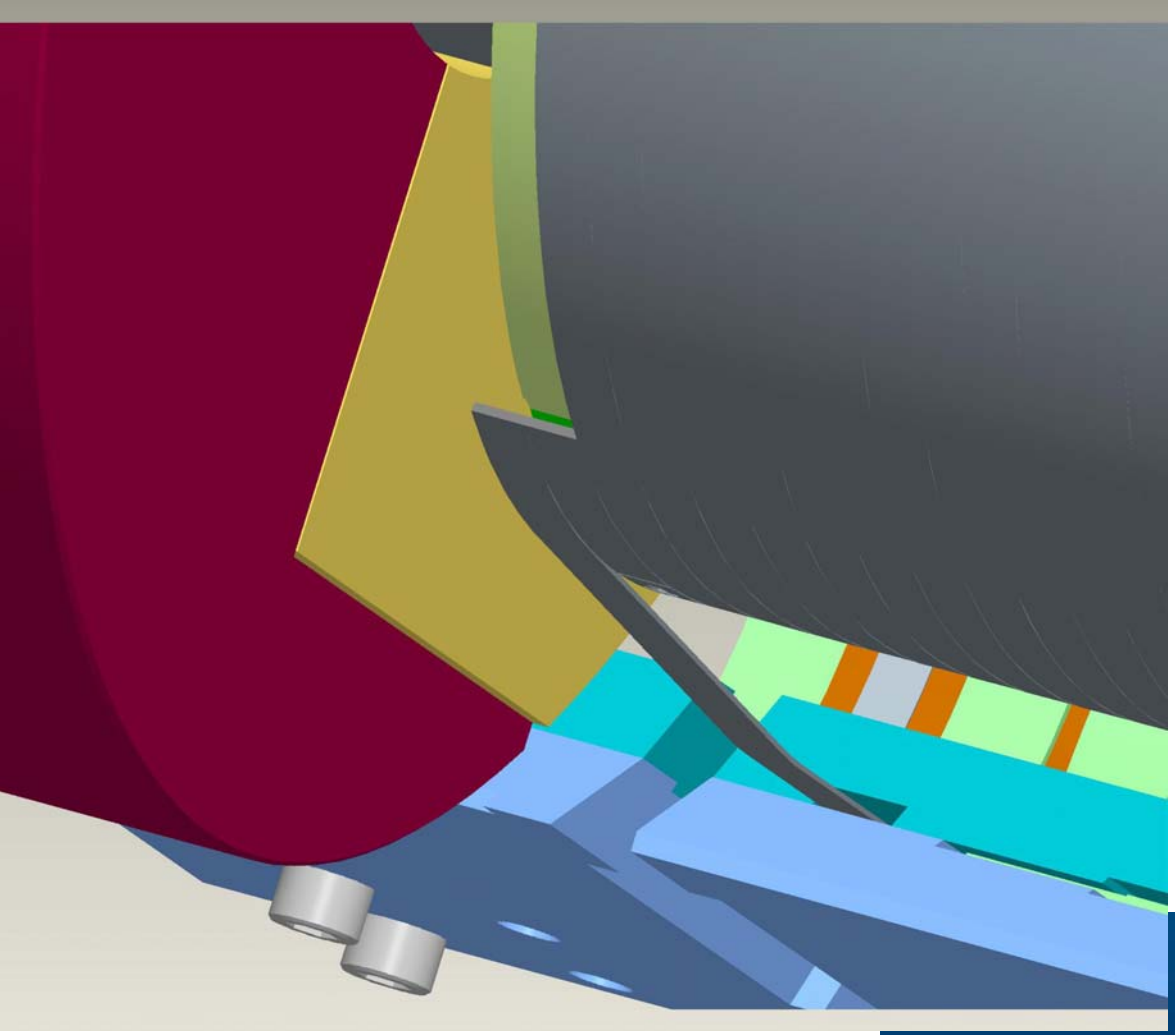
- Main yoke 9” diameter, 3.8” wide
- Aux yoke 1.9” wide

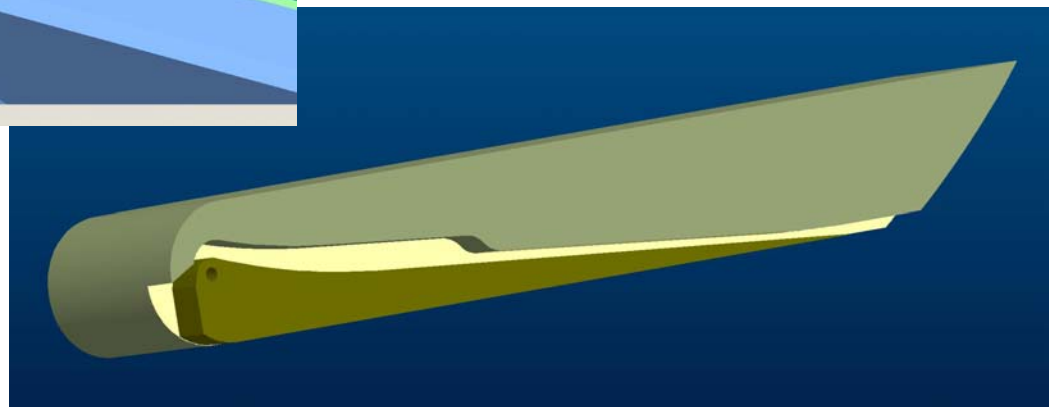
aux yoke assembly

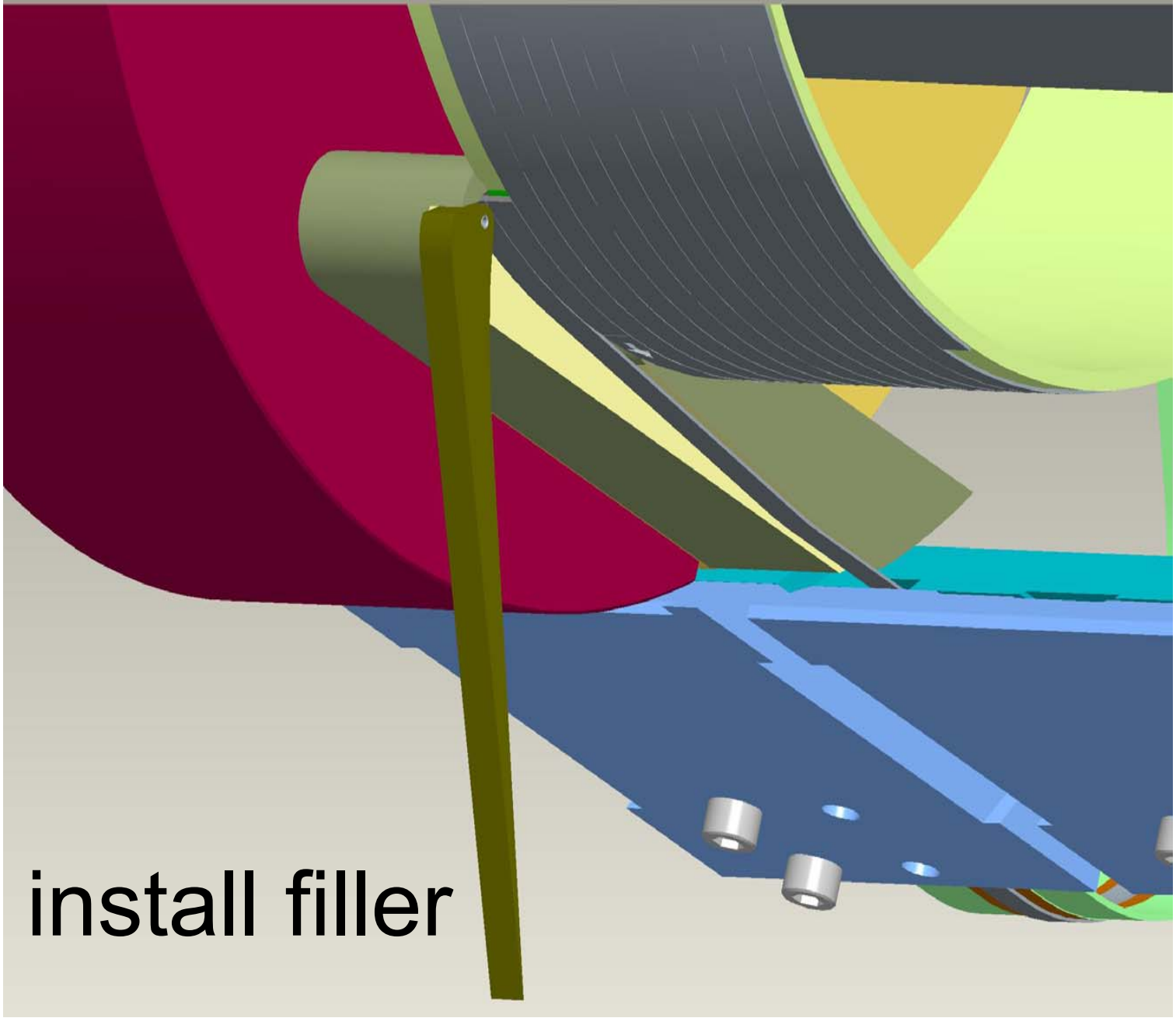


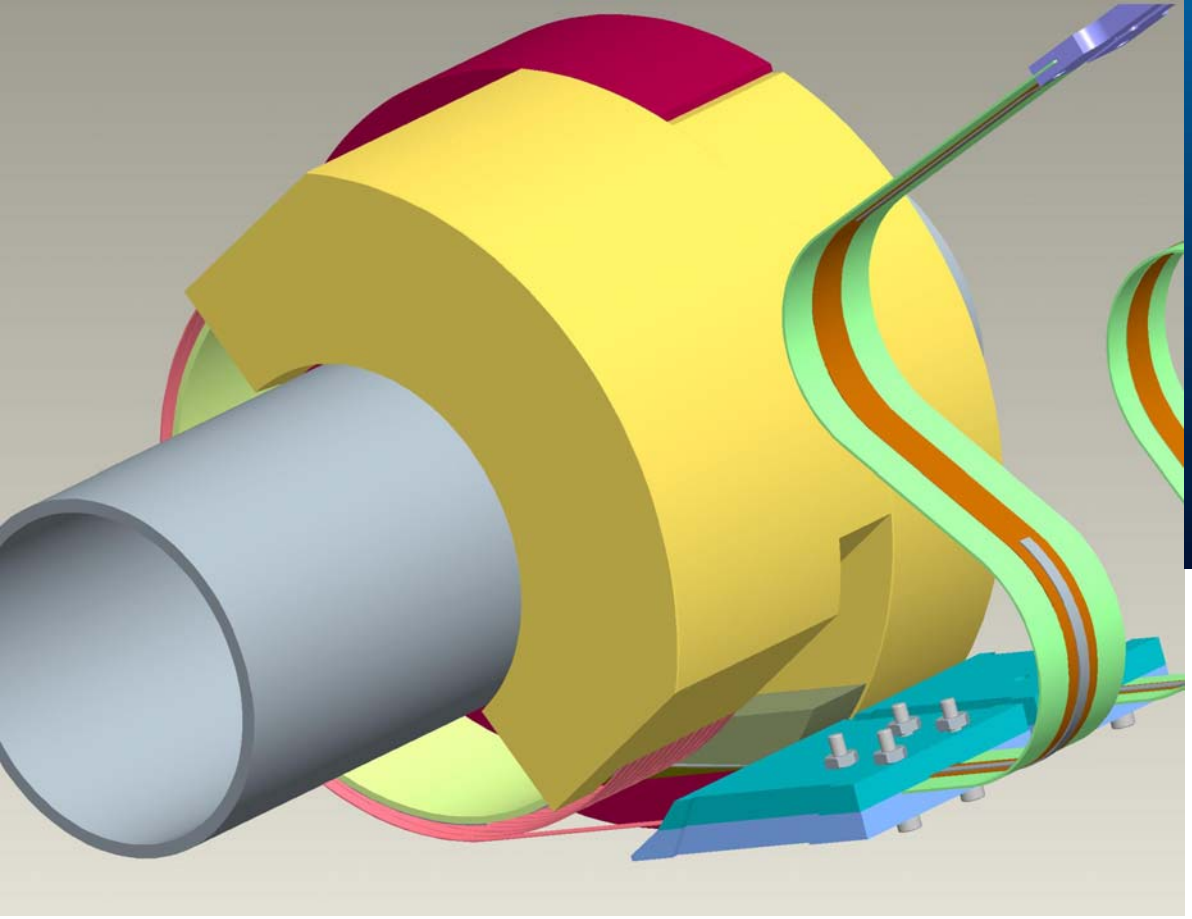


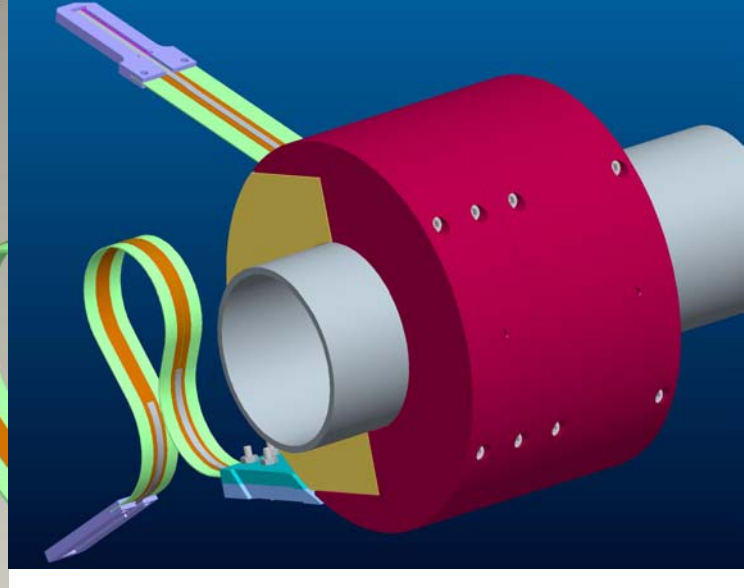
yoke splice & filler



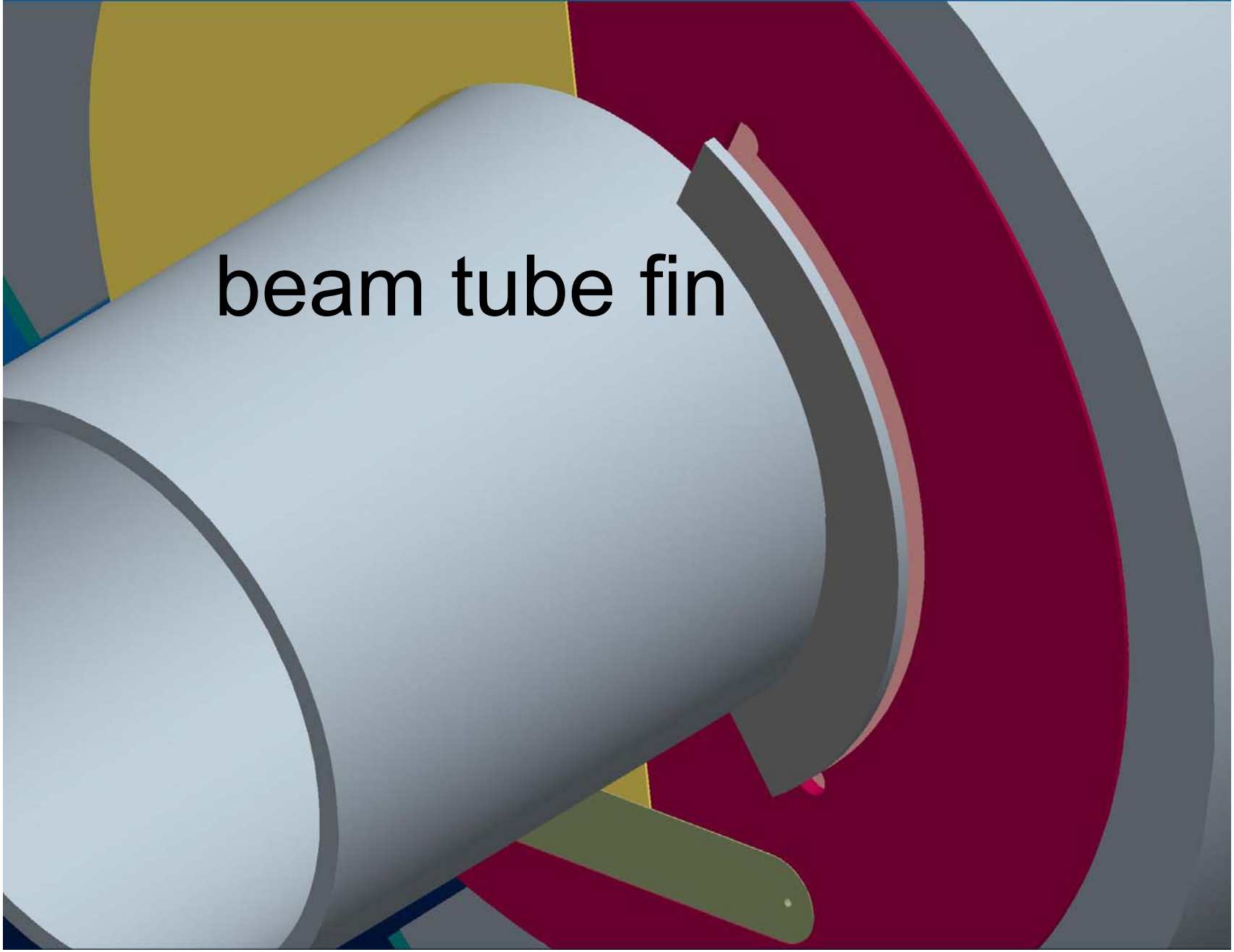


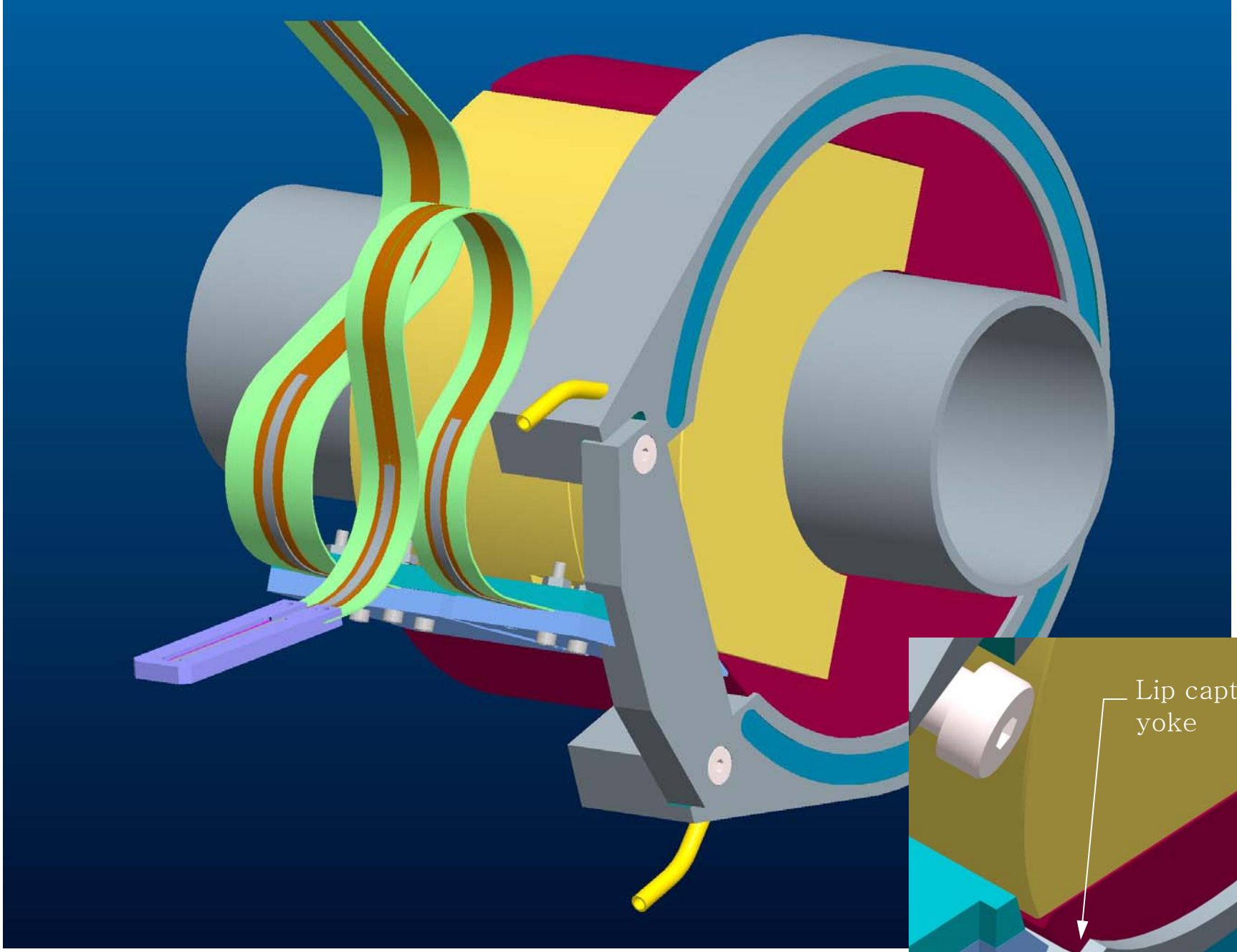

install filler



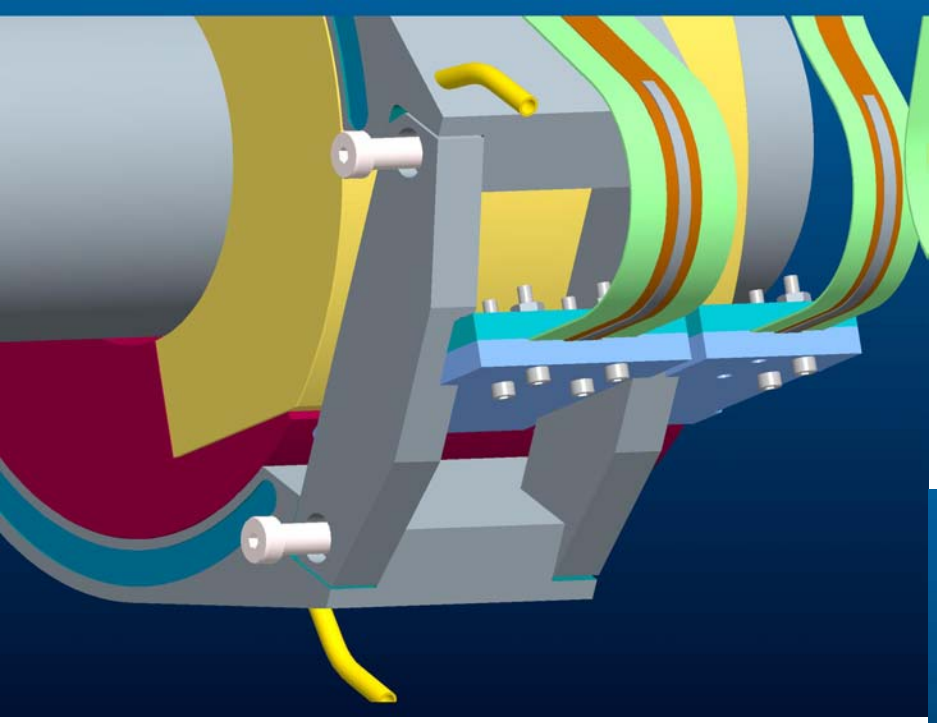


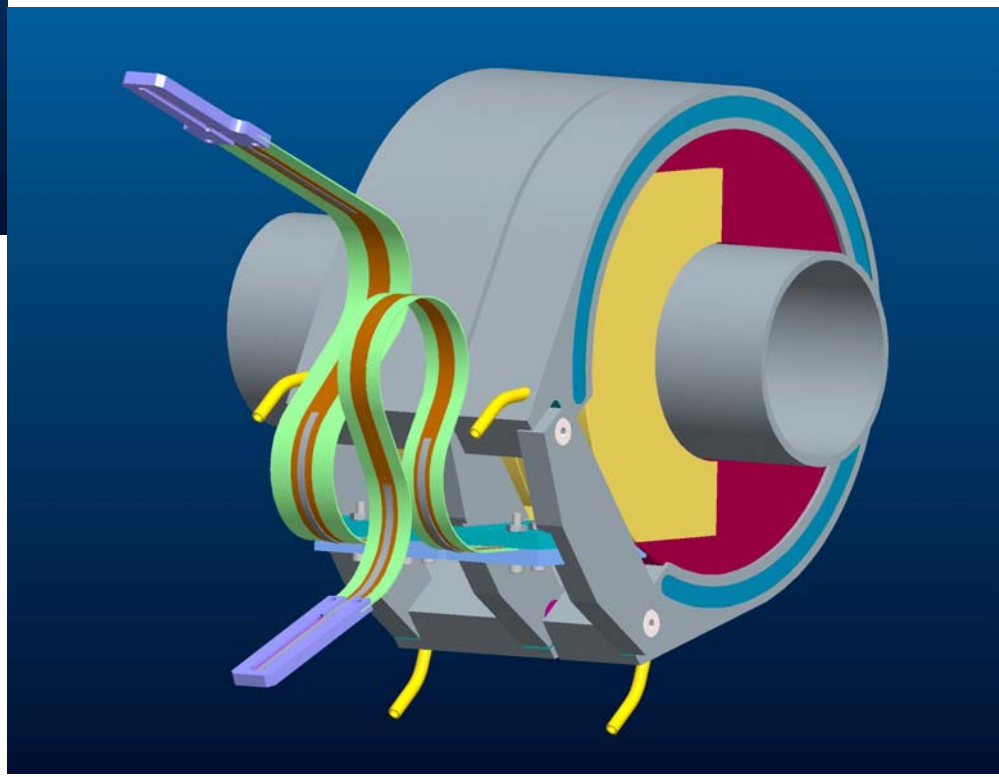
main yoke assembly


beam tube fin


Lip captures
yoke

clamps installed

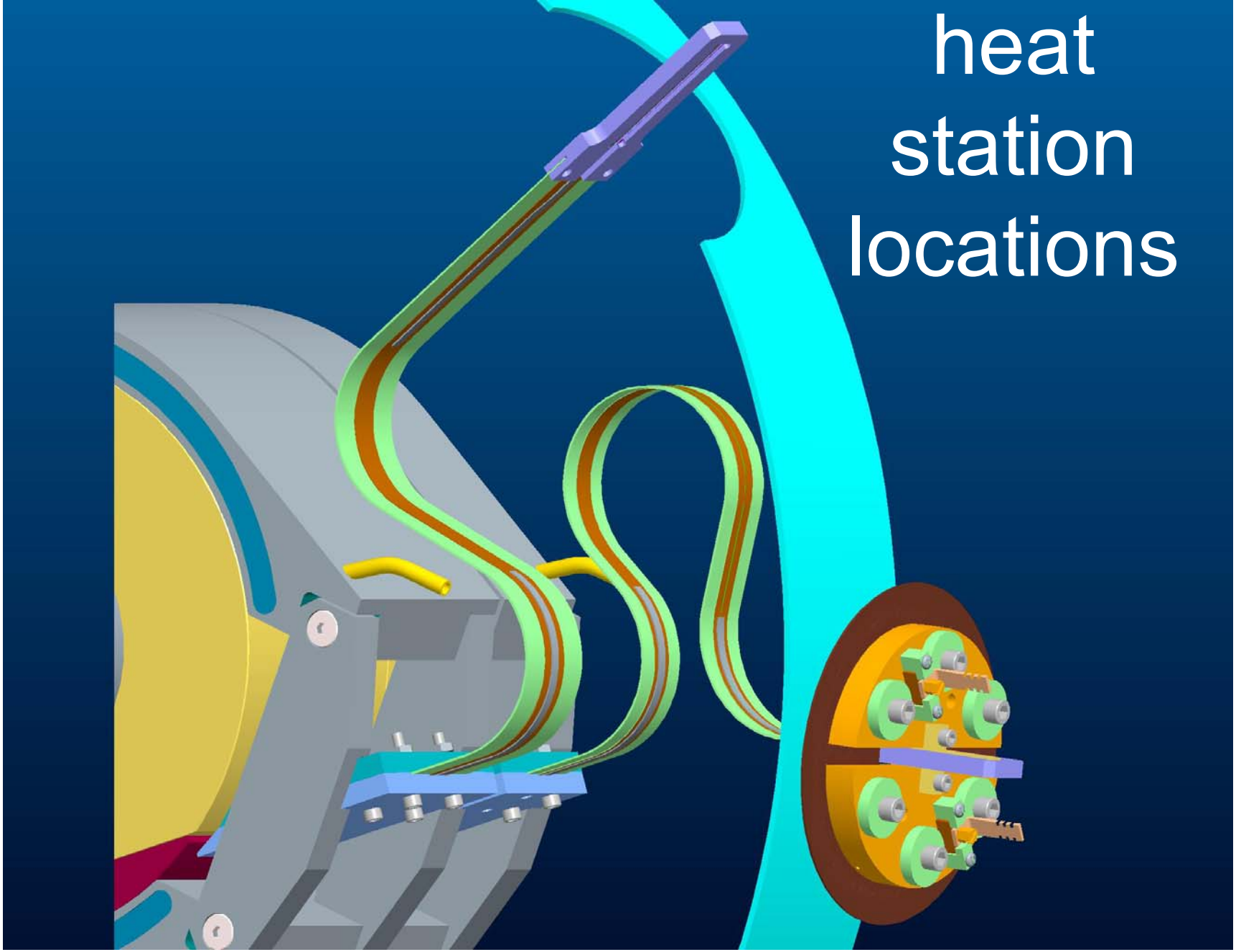




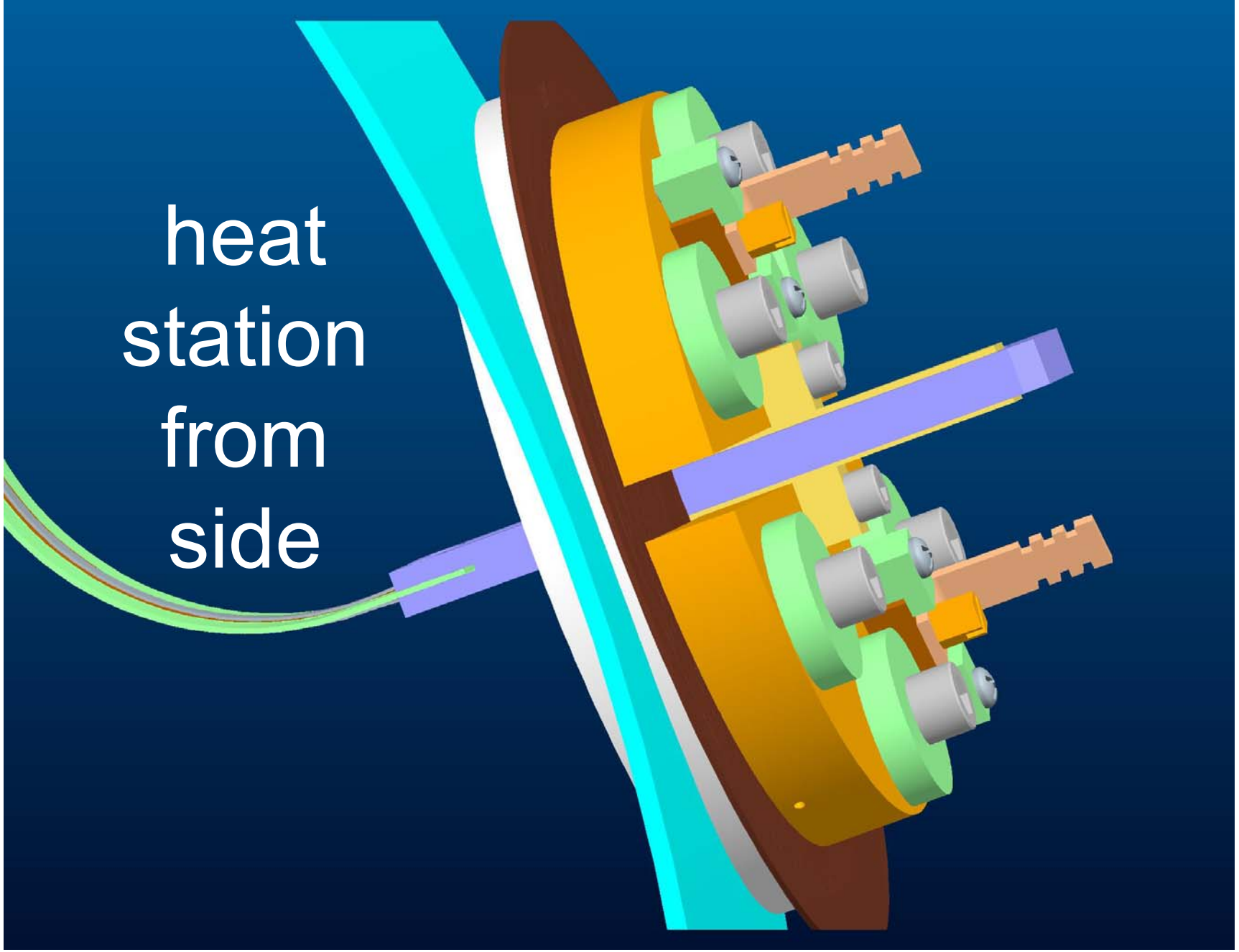
Heat Stationing of Leads

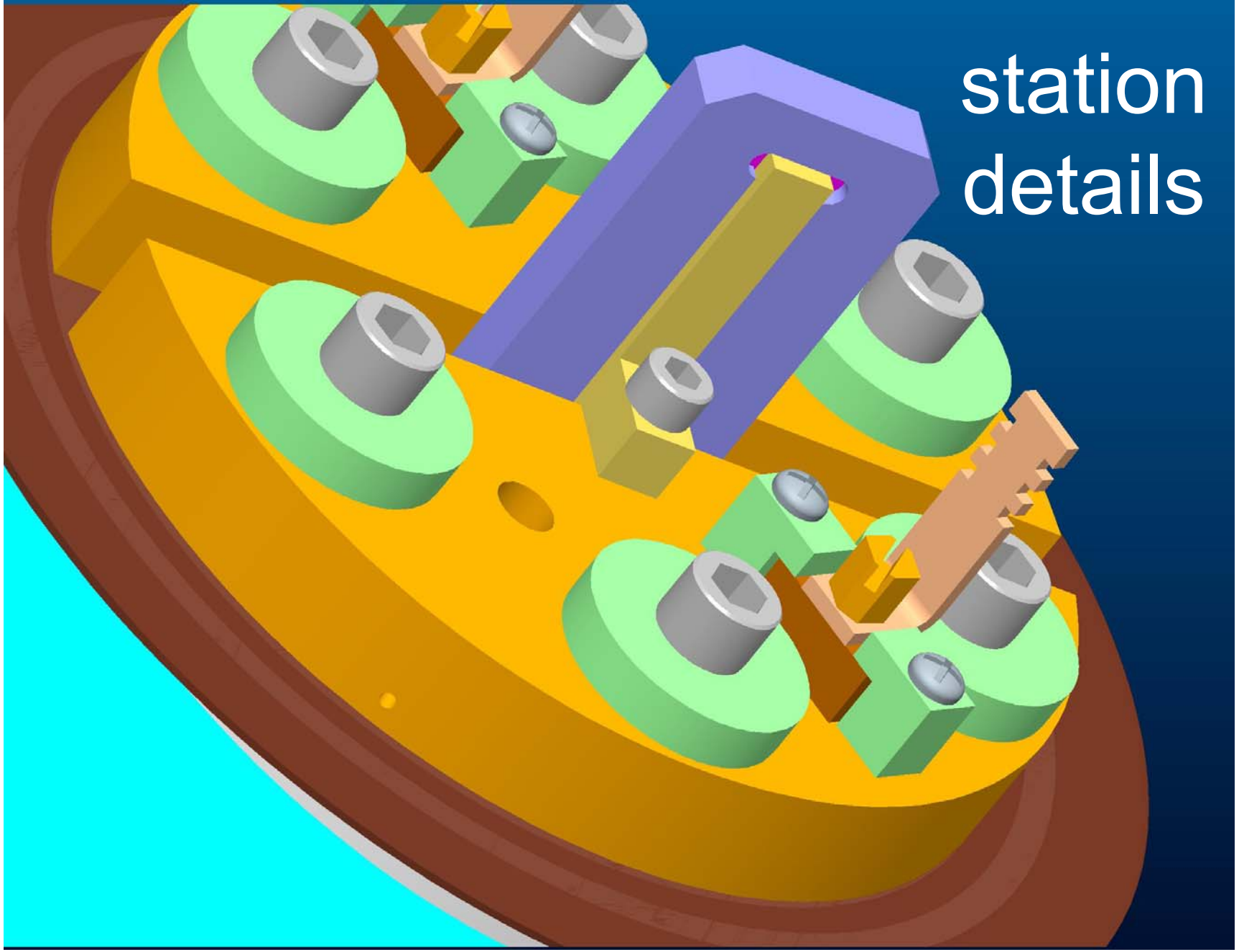
- Heat shield at 77K
- Aluminum or copper boss in shield
- Copper terminals thermally connected to boss, but isolated electrically

heat station locations



heat station from side




station
details

Cooling

- Assumptions:
  - Helium at 1 Atm is used
  - Helium flow rate is ~0.1 g/sec
  - Coil/yoke materials can be represented by copper (H_{cu}=79.6; H_{fe}=81.1 at 300K)
  - No heat transfer inefficiencies at interfaces

Cooldown Time Spreadsheet

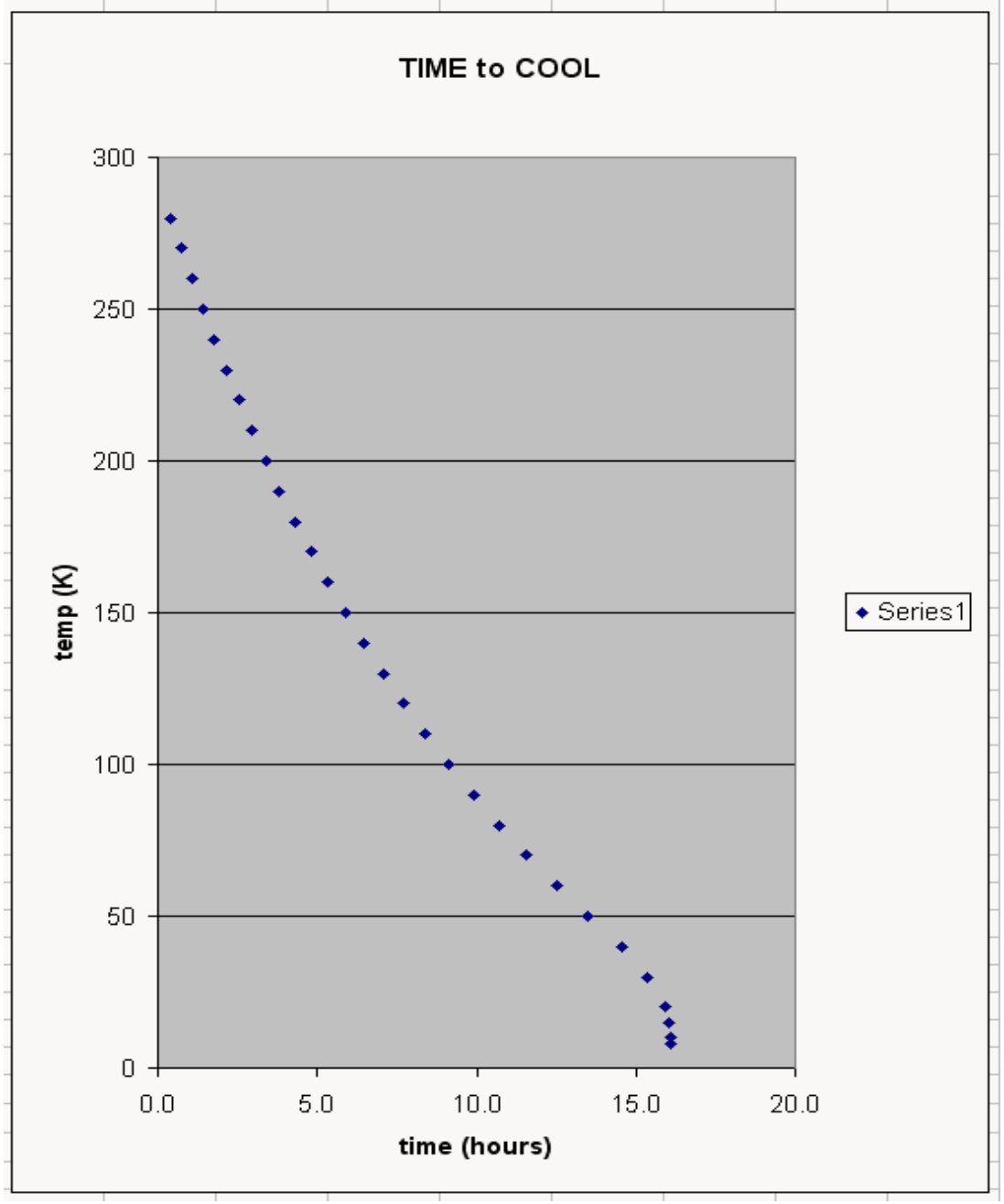
Helium Cooldown from Room Temperature to 4 K

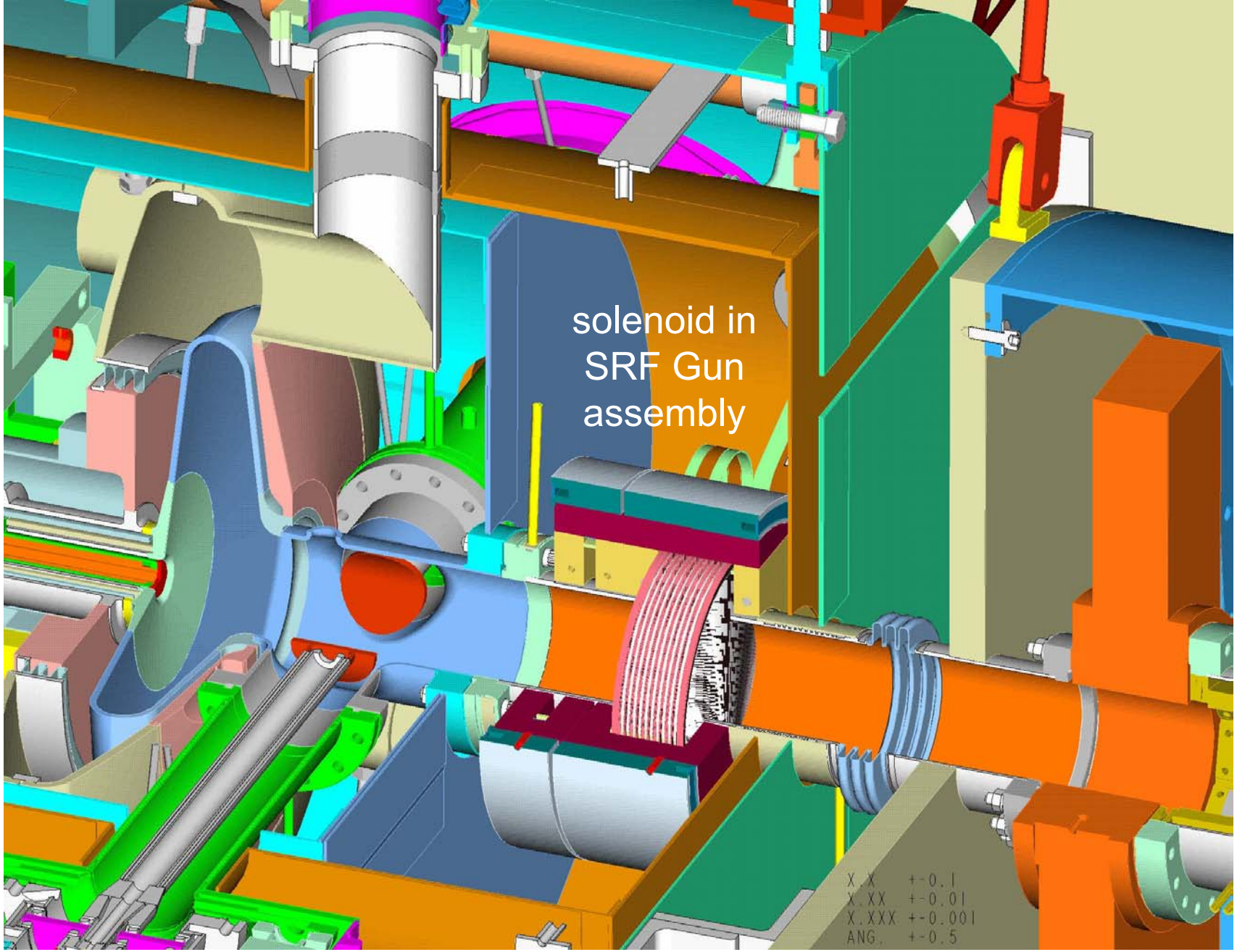
Use Iwasa eq. 4.7, p. 123		Helium properties at 1 Atm			
Sat. Liq. enthalpy@4.2K, J/g	9.71				
Sat. Liq. density, g/cm^3	0.1250		density of copper =	0.32	lb/in^3
Unit Mass (Cu), g	1,000,000		=	8865600	g/m^3
Vol (Cu), m^3	0.111607143				
Magnet mass, kg	40.0				
Helium mass flow rate, g/sec	0.1		Helium volume flow rate=	0.8	cm^3/sec

		Sp Heat of Copper			ENERGY TO BE REMOVED		COOLING AVAILABLE	TIME
			Enthalpy (= integral specific heat)		(enthalpy change x mass)	Enthalpy of Helium	enthalpy change (at T minus ~20K WRT sat liq) x mass flow	293K to T
T, K	dT, K	c(Cu), J/m^3-K	Integral [c(Cu)], J/m^3	Integral [c(Cu)], J/g	J	h(He), J/g	J/sec	hours
4.2						9.7		
5	0.8	1,418	1,134	0.0001	10	38.5		
6	1	2,254	3,389	0.0004	39	43.8		
8	2	4,285	11,959	0.0013	67	54.2	3	16.1
10	2	7,419	26,797	0.0030	564	64.7	3	16.1
15	5	24,998	151,789	0.0171	1,452	90.8	4	16.0
280	10	3,364,160	660,789,915	74.5341	153,395	1,469.5	136	0.4
290	10	3,399,845	694,788,365	78.3690	46,187	1,521.3	141	0.1
293	3	3,412,314	705,025,307	79.5237		1,536.8		

Many rows hidden
Excel iteration

Helium cooldown time to 4.2K: ~16 hours




solenoid in
SRF Gun
assembly
X.X +-0.1
X.XX +-0.01
X.XXX +-0.001
ANG. +-0.5

Further Work

- Tweak yoke dimensions to match coil OD
- Add instrumentation
- Coordination meetings with AES / J-Lab on clearances during assembly
- Auxiliary coil splice details
- Flex lead details and test
- Finish modeling
- All drawings for shops fab
- ACTION ITEMS: beam tube fin or other alignment method?; stray field on flex leads=motion?