



Cold Mass Assembly Status

Sandor Feher



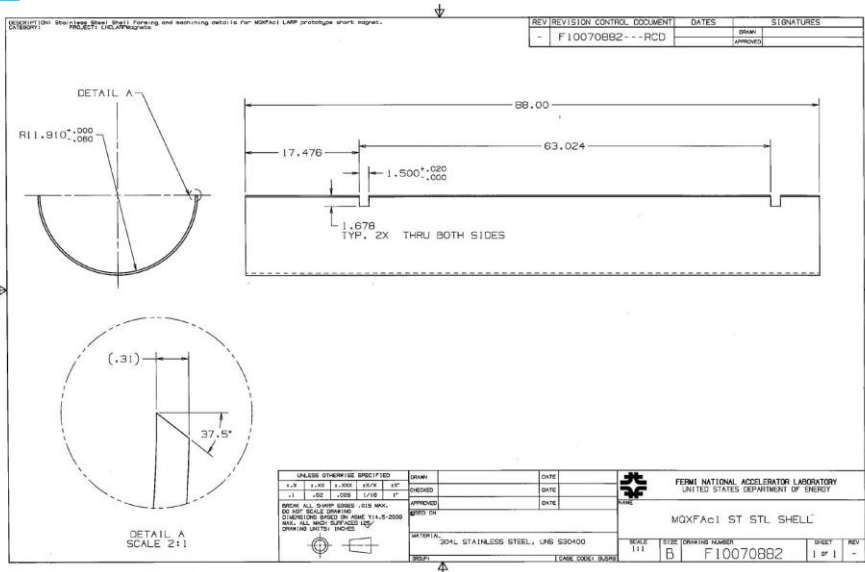
Outline

- MQXFS1d preparation – Shell Welding test
- Magnet and Cold Mass Handling
- Bus Design
- Infrastructure – ICBA
- LQXFA/LQXFB Questions
- Schedule

Shell design validation

In the short model program the plan is to verify the shell design by using MQXFS1d

- Goal for the test of MQXFS1d:
 - Verify the welding procedure
 - X-ray examination of the weld
 - Leak check
 - Stress measurement and analysis using strain gauges
 - Quench test of the magnet – no mechanical induced degradation
 - Interference between the shell and coil will be controlled



10 m long empty shell welding test

- Check the deformation of the shell
- Additional info about the shrinkage

MQXFS1d – shell design validation

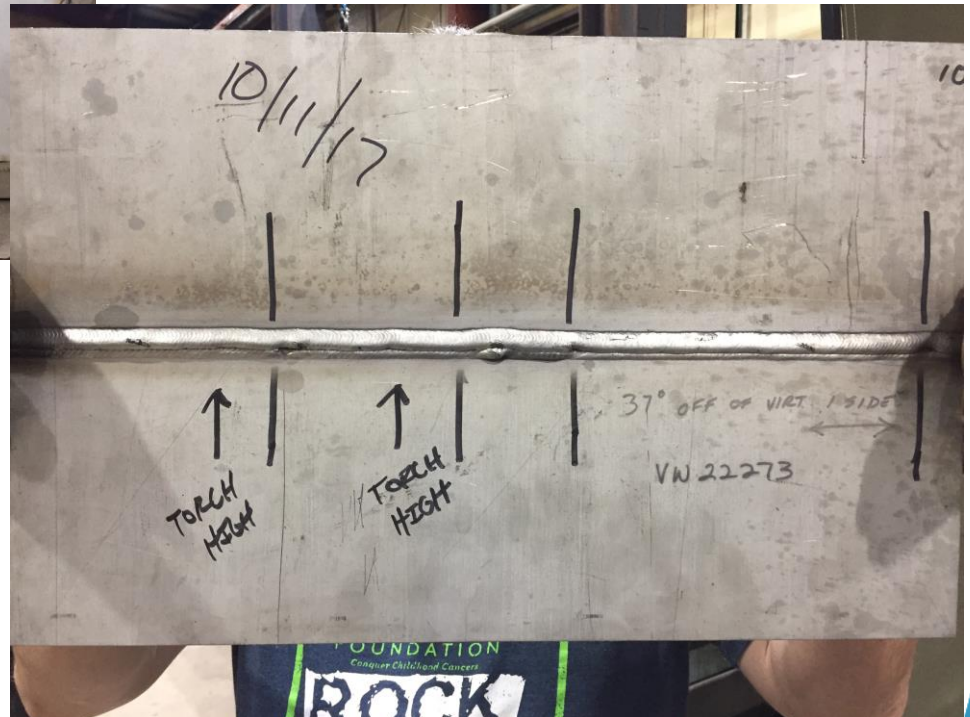
- 2x Identical BUG-O Systems procured for simultaneous welding of both longitudinal welds (GMAW DC pulse mode).



MQXFS1d – shell design validation



Root Pass – sample plates tacked to base prior to welding

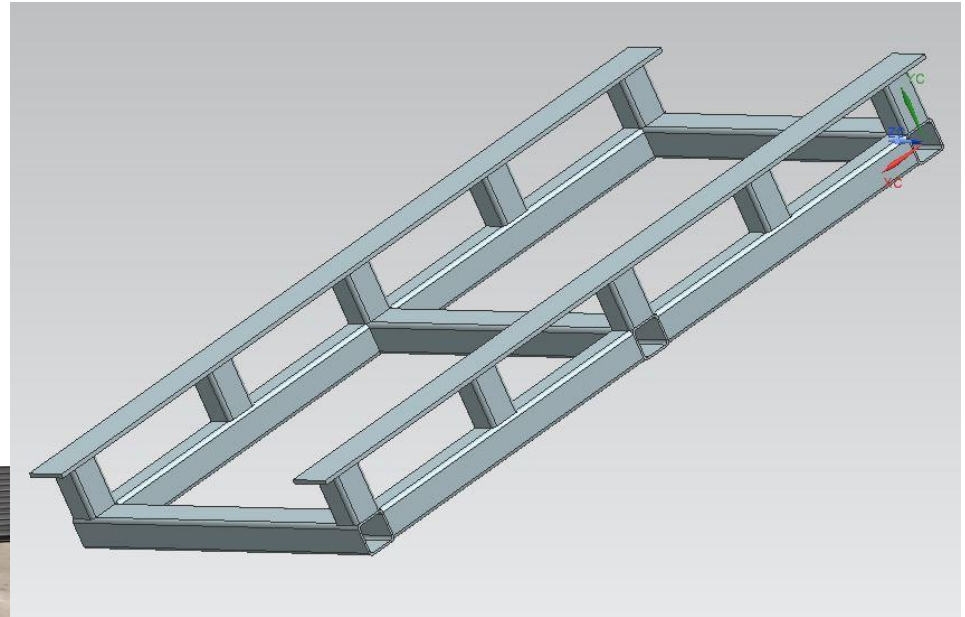
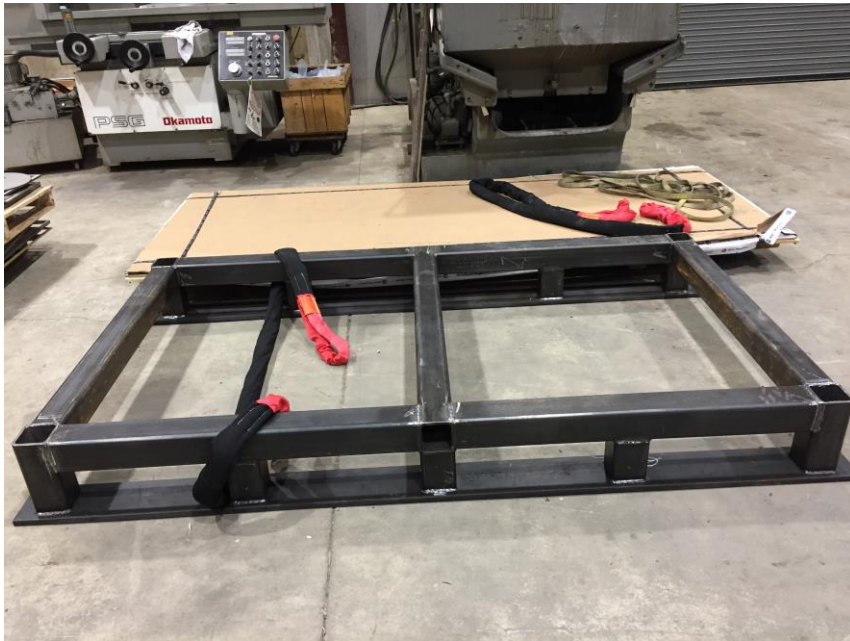


Sample w/ 3 passes complete.
Work on optimization of speed &
Min. Heat input

MQXFS1d – shell design validation



MQXFS1d – shell design validation



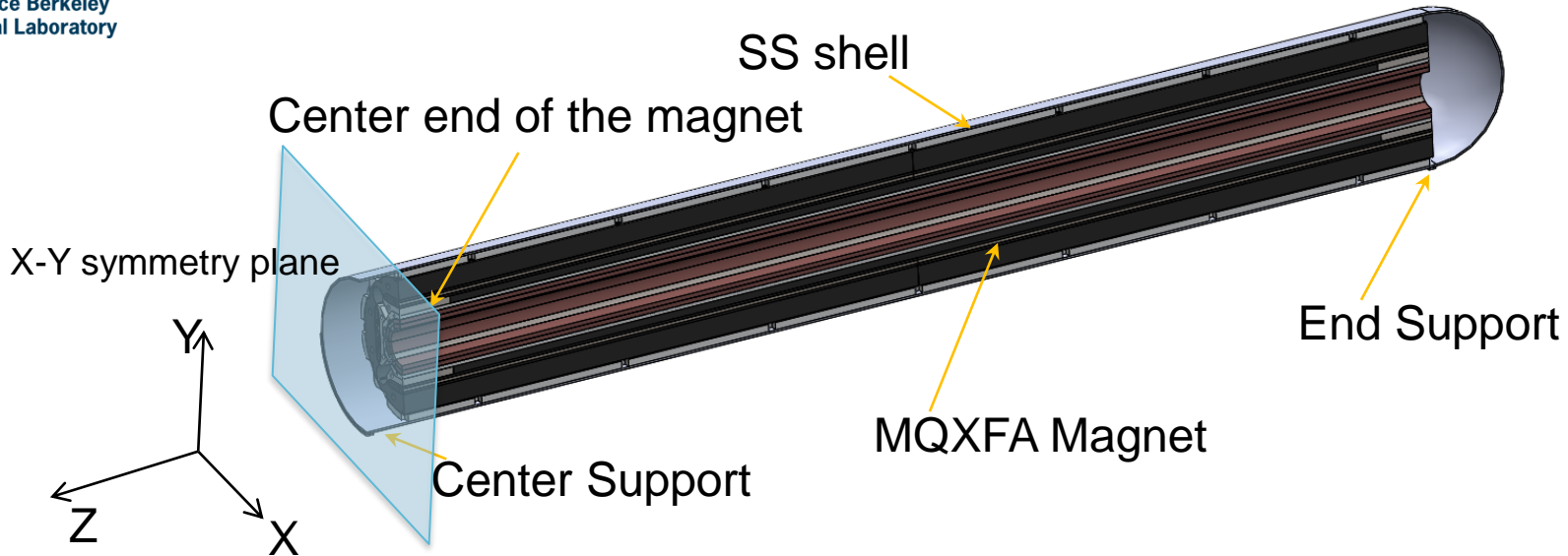
Weld Requirements

- The cold mass weld procedure will follow both Fermilab's and CERN's safety regulations:
 - To satisfy pressure vessel safety, the Fermilab Environment, Safety and Health Manual chapter 5031 for pressure vessels and ASME B&PV Code Section VIII div.1 rules shall apply to all cold mass design and fabrication.
 - Each HL-LHC work package will be subject to safety requirements specified in a CERN "Launch Safety Agreement (LSA)" document. This LSA will specify the CERN safety rules and host state regulations applicable to the systems/processes and the minimal contents of the Work Package safety file needed to meet the Safety Requirements. The LQXFA/LQXFB cryostat assembly must comply with CERN's Launch Safety Agreement (LSA) for IR Magnets.

Magnet and CM Handling

- Extensive study have been performed by Heng Pan → safe lifting points and procedure for the magnet and for the Cold Mass
- This will guide our design for the lifting fixture that need to accommodate lifting magnet, Cold Mass and Cryostat Assembly
 - The fixture → Multipurpose fixture

MQXFA Cold Mass 3D model



- The He shell is modelled as SS cylinder with dome heads.
- The model is half symmetric in length direction, the end of the yoke (the center end of the magnet in the picture) is 170 mm from the symmetry plane.
- The purpose of this analysis is to see if the bending of acceptable or not based on the following criterion:
 - (a). Coil strain limit---less than 0.05%
 - (b). Avoid separation in yoke stacks --- the axial stress on yoke should be less than 3.6 MPa

Model description

- The magnet model is used in the MQXFA1 magnet handling analyses, reviewed in “MQXFA1 Lifting and Handling Review” (Mar 16th,2017)
 - Symmetric to X-Y and Y-Z planes.
 - No preload operations in the model.
 - Magnet displacement is fixed in Z direction.

Assumptions:

- The lamination stacks and coils are simplified as homogeneous blocks.
- The center end of the magnet is constrained in Z direction to simulate the center hard connections between the two magnets.
- Neglect the axial clamping forces of yoke, pad, and collar stacks.
- Use “no separation” contact elements in the interfaces between the magnet structure parts to achieve better convergence.

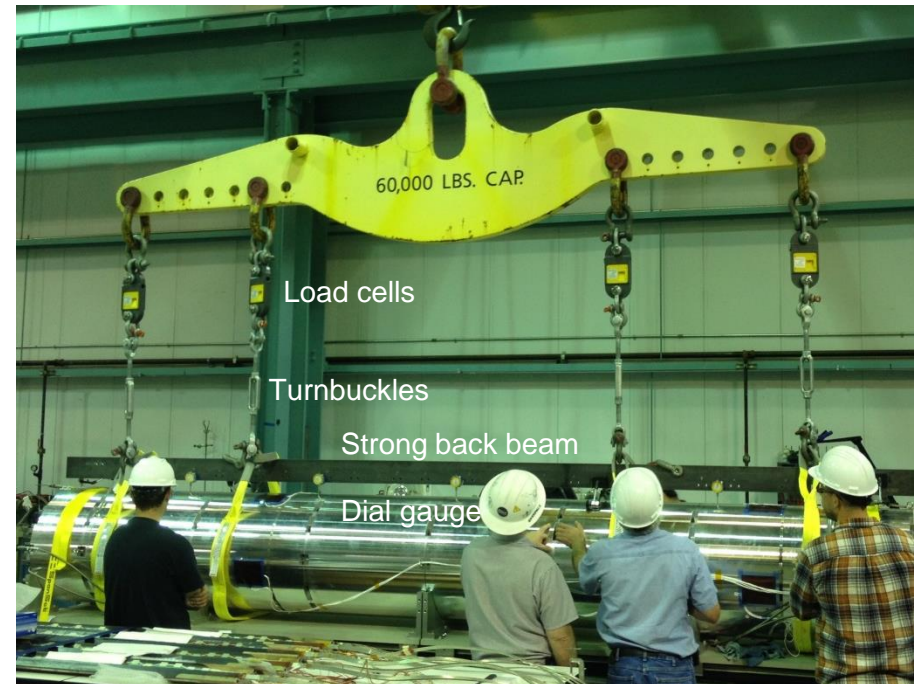
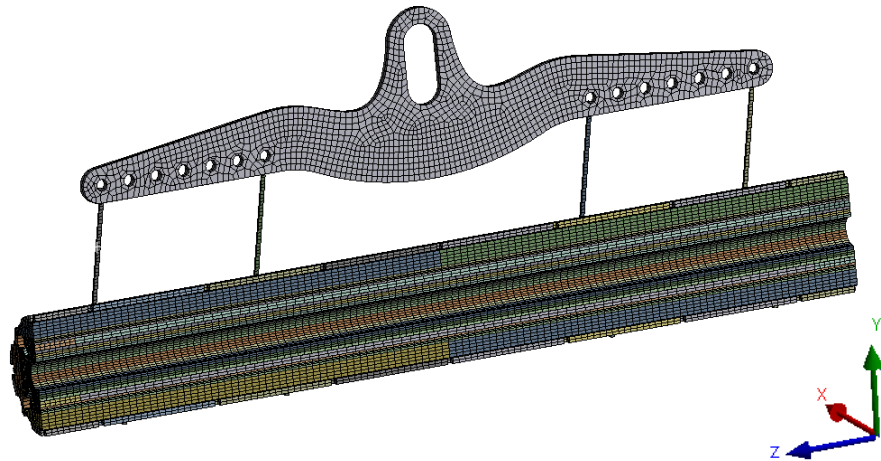
Contact	Assumption
Pole and coils	Bonded
Coil mid-planes	*No-separation (sliding allowed)
Coil and fillers	No-separation (sliding allowed)
Collar and polekey	No-separation (sliding allowed)
Collar and fillers	Bonded
Collar and pad	No-separation (sliding allowed)
Pad and masters	No-separation (sliding allowed)
Yoke and masters	No-separation (sliding allowed)
Yoke and shells	No-separation (sliding allowed)
Shell segments	**Frictional, 0.2 friction coefficient
Masters and load keys	Bonded
Shell and lings	No-separation (sliding allowed)

*Note: “**No-separation contact**”: does not allow separation on the interface, but allows interface frictionless sliding.

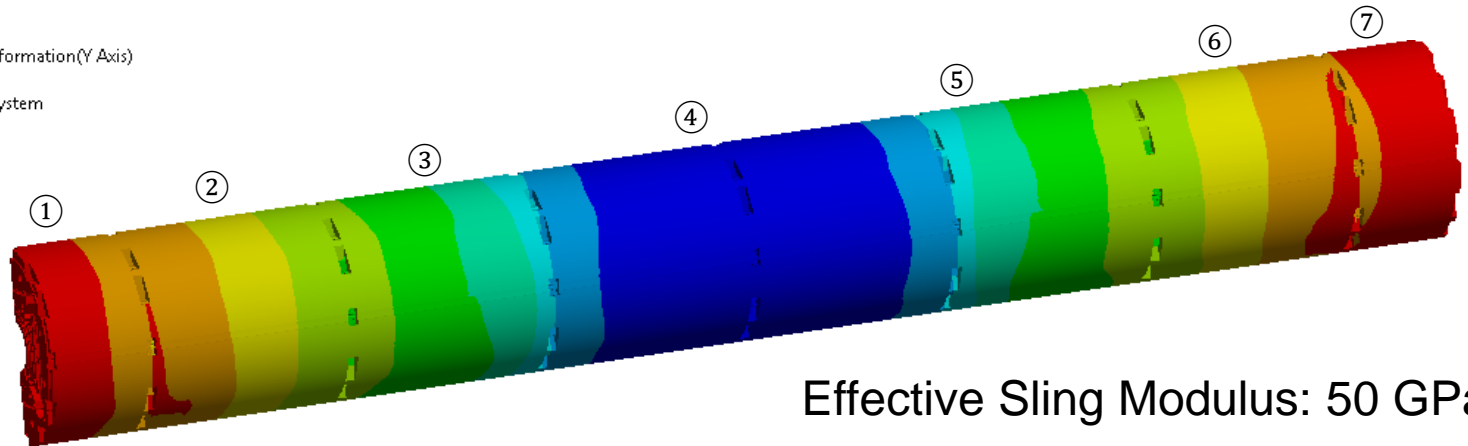
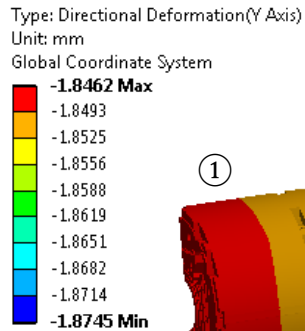
Because the structure parts are primarily subject to compression, this “no separation” assumption is appropriate. Note that the overall model stiffness is lower than in the real magnet due to the “frictionless” sliding contact assumption; the results are therefore conservative.

** “**frictional**” elements allow for separation normal to interface

Verification of the model



- A lifting test was performed with a strong back beam, and dial gauges.
- The total weight was 14650 lbs in the test. The magnet was assembled with dummy coils, which made the entire magnet ~1000 lbs lighter than with real coils.



Effective Sling Modulus: 50 GPa

Test results:

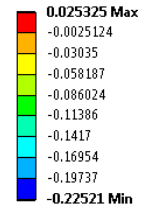
	Gauge ① (RE)	Gauge ②	Gauge ③	Gauge ④	Gauge ⑤	Gauge ⑥	Gauge ⑦ (LE)
Deflection	-0.001"	0	-0.001"	-0.001"	+0.0015"	-0.0005"	0
Calculate d	-0.00012"	-0.0003"	-0.00074"	-0.00011"	-0.0006"	-0.0005"	-0.0001"

- Gauge 5 does not have correct initial setting.
- The overall deflection is smaller than the simulations --- the structure is much stiffer than the model when applied preloads.

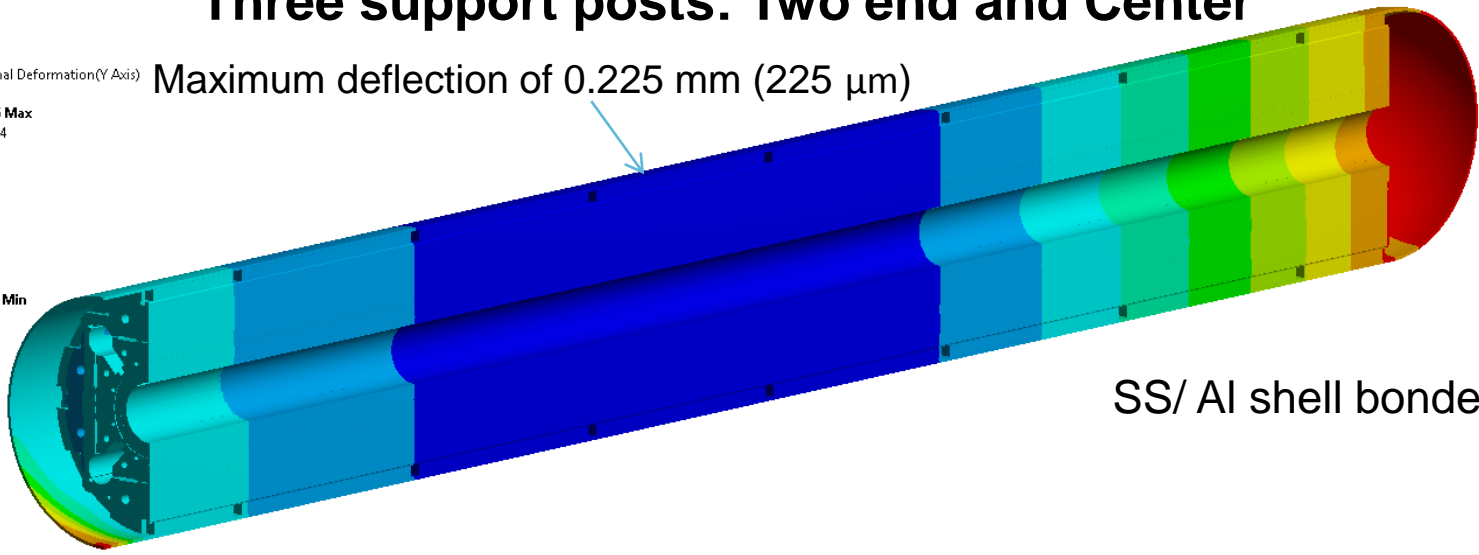
Vertical deflection

Three support posts: Two end and Center

Type: Directional Deformation(Y Axis)
Unit: mm

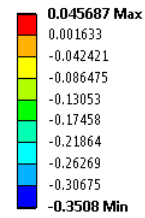


Maximum deflection of 0.225 mm (225 μ m)

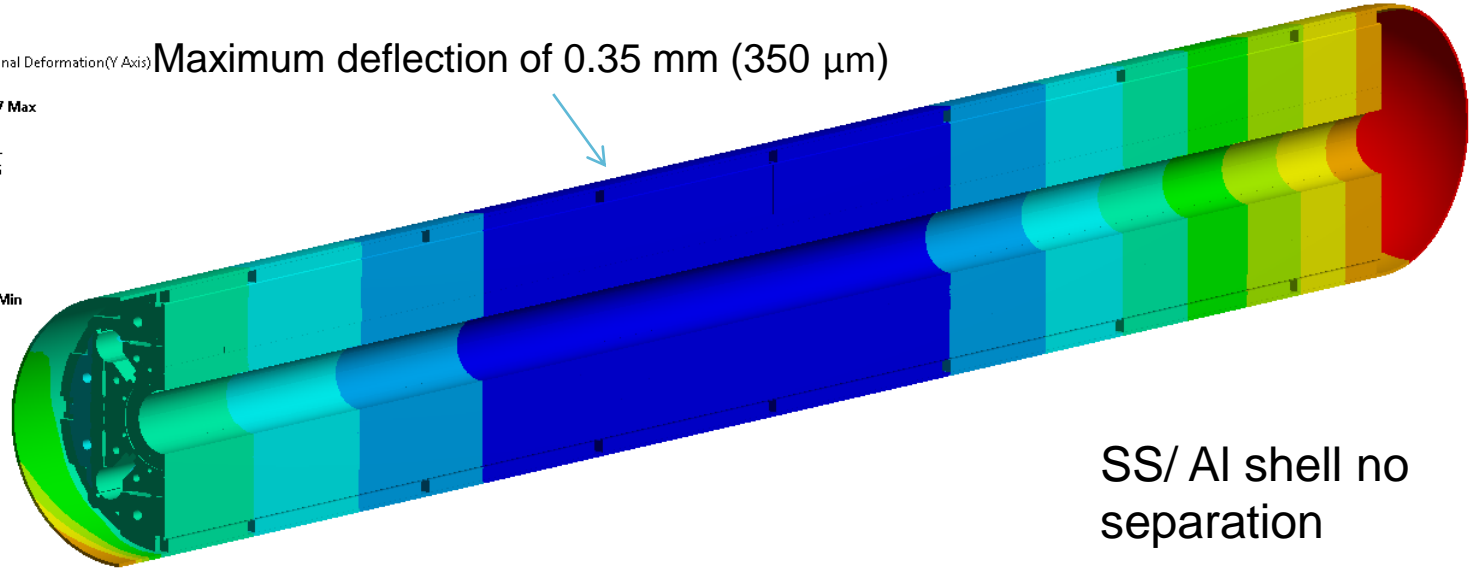


SS/ Al shell bonded

Type: Directional Deformation(Y Axis)
Unit: mm



Maximum deflection of 0.35 mm (350 μ m)



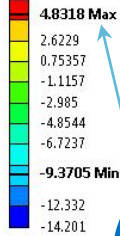
SS/ Al shell no
separation

Axial stress in yoke

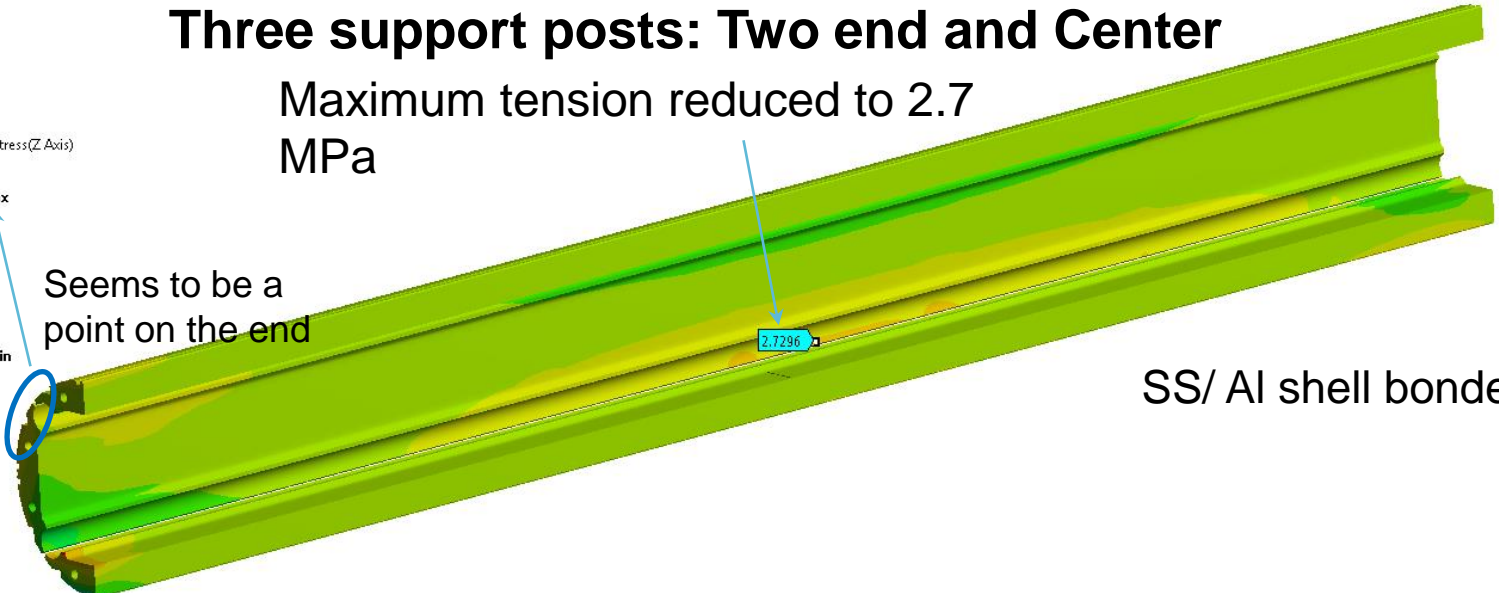
Three support posts: Two end and Center

Maximum tension reduced to 2.7 MPa

Type: Normal Stress(Z Axis)
Unit: MPa

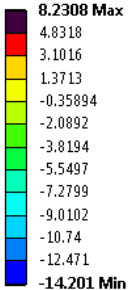


Seems to be a point on the end

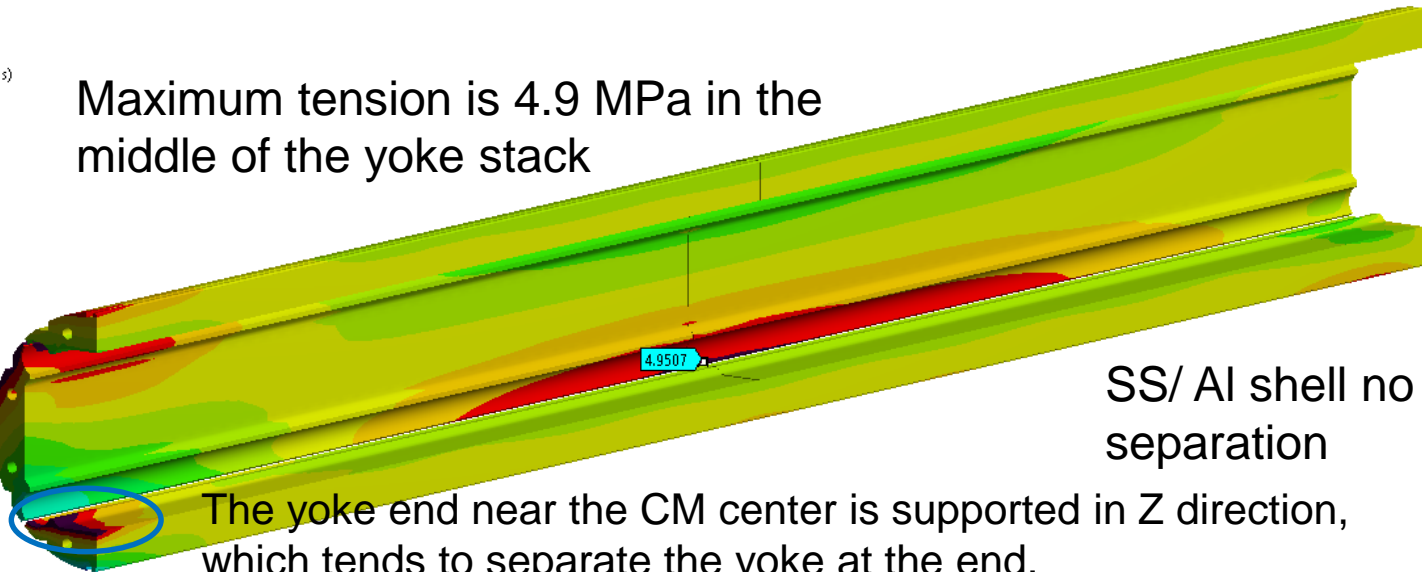


SS/ Al shell bonded

Type: Normal Stress(Z Axis)
Unit: MPa



Maximum tension is 4.9 MPa in the middle of the yoke stack



SS/ Al shell no separation

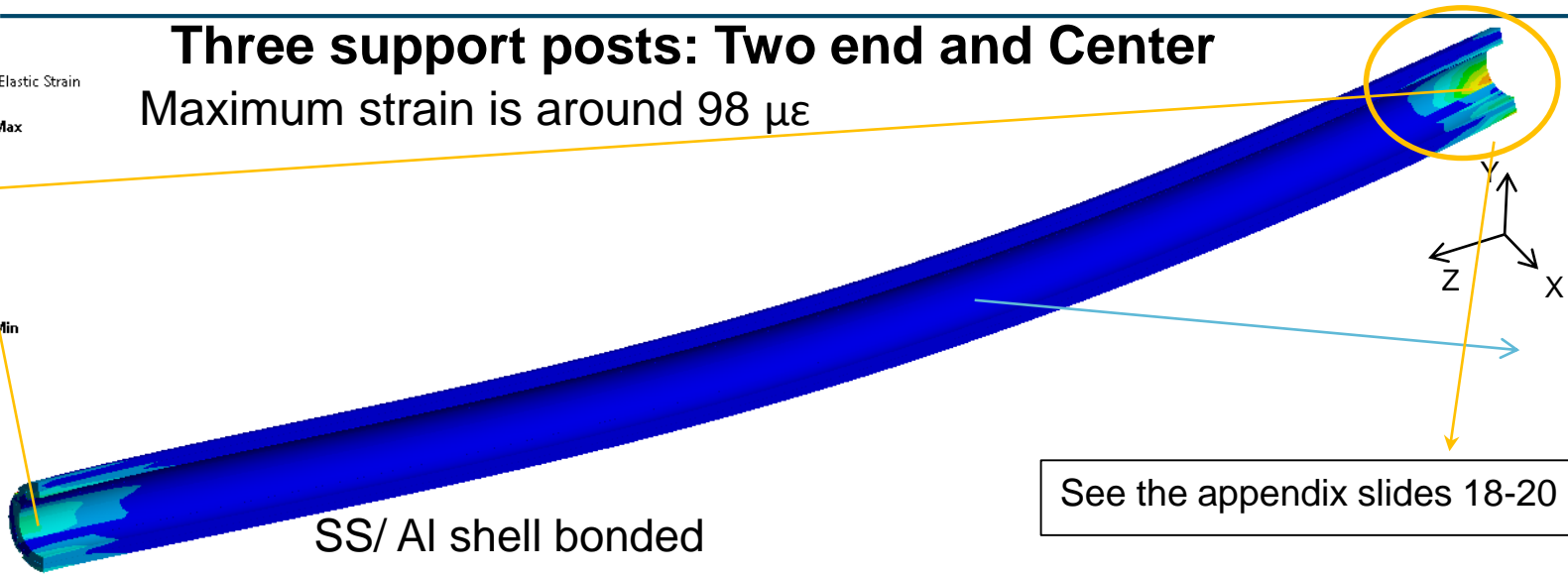
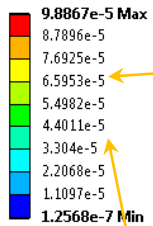
The yoke end near the CM center is supported in Z direction, which tends to separate the yoke at the end.

Equivalent strain in coil

Lawren Nations

Three support posts: Two end and Center
 Maximum strain is around $98 \mu\epsilon$

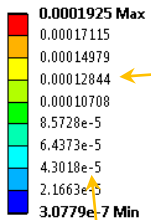
Type: Equivalent Elastic Strain
 Unit: mm/mm



See the appendix slides 18-20

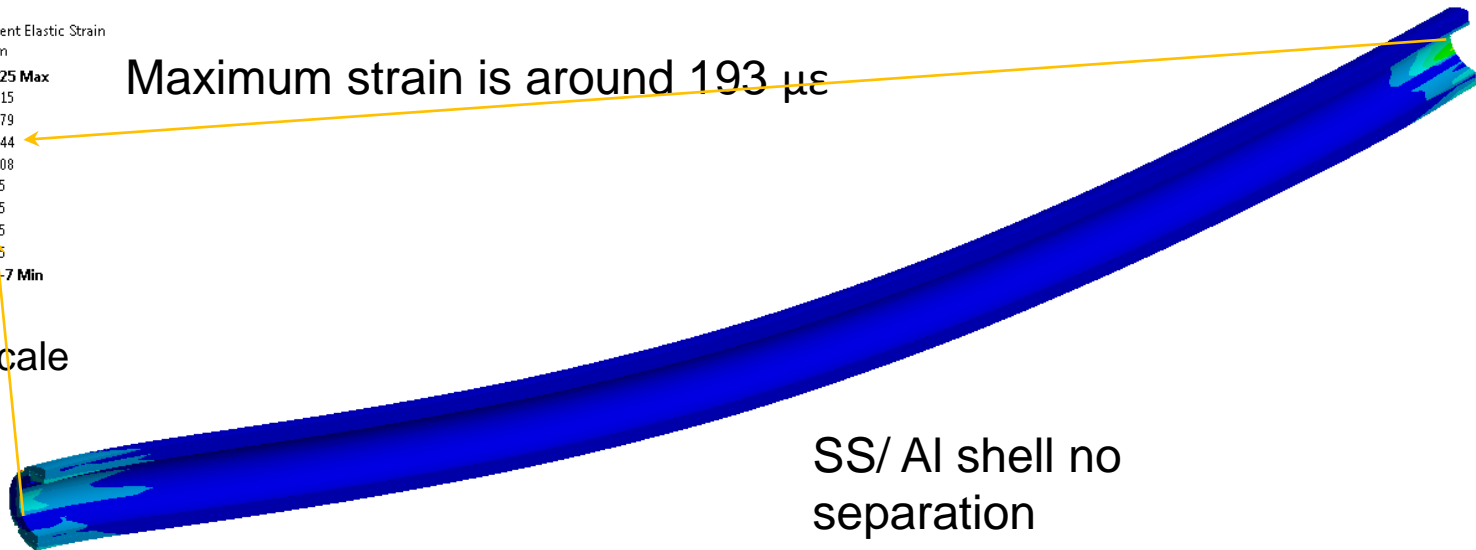
SS/ Al shell bonded

Type: Equivalent Elastic Strain
 Unit: mm/mm



Maximum strain is around $193 \mu\epsilon$

1000X scale

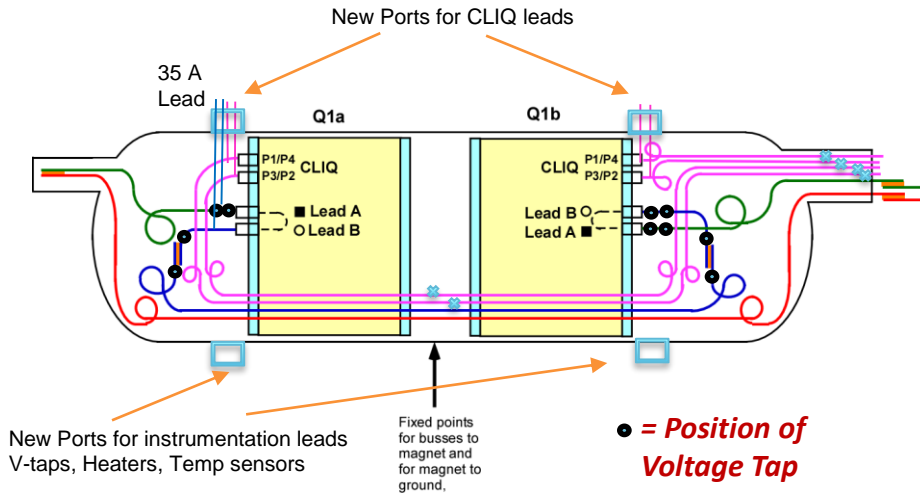


SS/ Al shell no separation

Magnet and CM Handling

- **Simulation conclusions:**
 - The stress in the real magnet should be between the bonded case and the no-separation case.
 - Without the center support, the yoke stacks are likely separate; This is an important criteria for lifting the magnet but not for the Cold Mass.
 - Coil strain in both cases (two and three point support) is in the safe range.
 - It is OK up to 2.5 g acceleration.
- **Consequences for lifting operation and lifting fixture design:**
 - Magnet will be lifted at 4 points.
 - Cold Mass before the shell is welded (moving between tooling stations) will be lifter at 8 points.
 - Welded Cold Mass will be lifted at 3 points.
 - Complex adjustable lifting fixture needed.

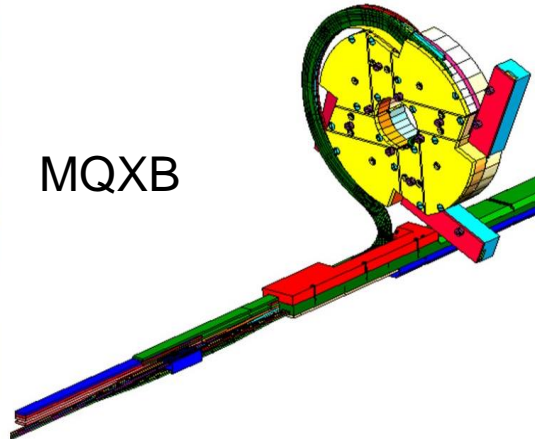
Main Bus Design



- The bus design and the expansion loop design for the LMQXFA cold mass will be similar to the design implemented on the previously built MQXB cold masses.
- V-taps will be used for magnet protection and for splice measurements.

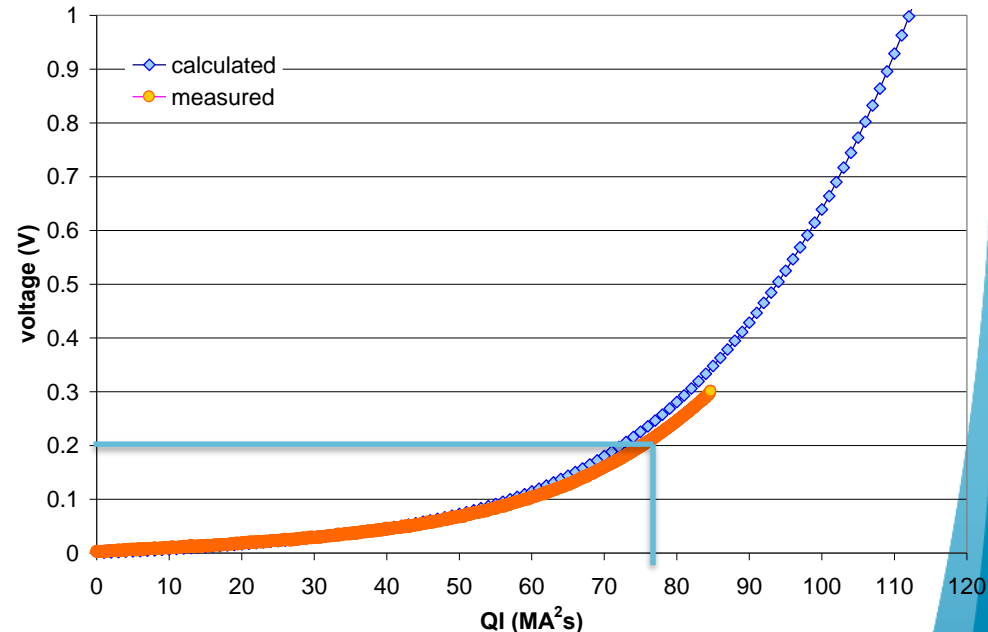
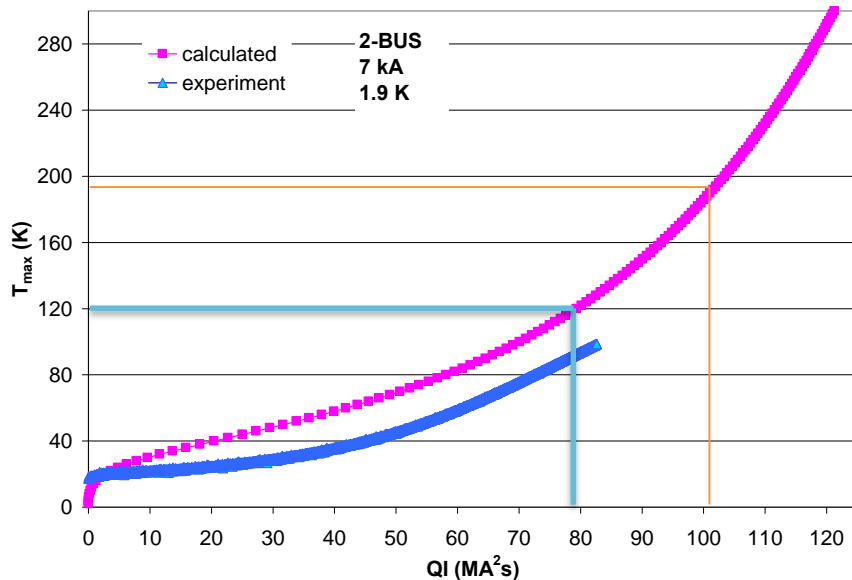


MQXB



Main Bus Design

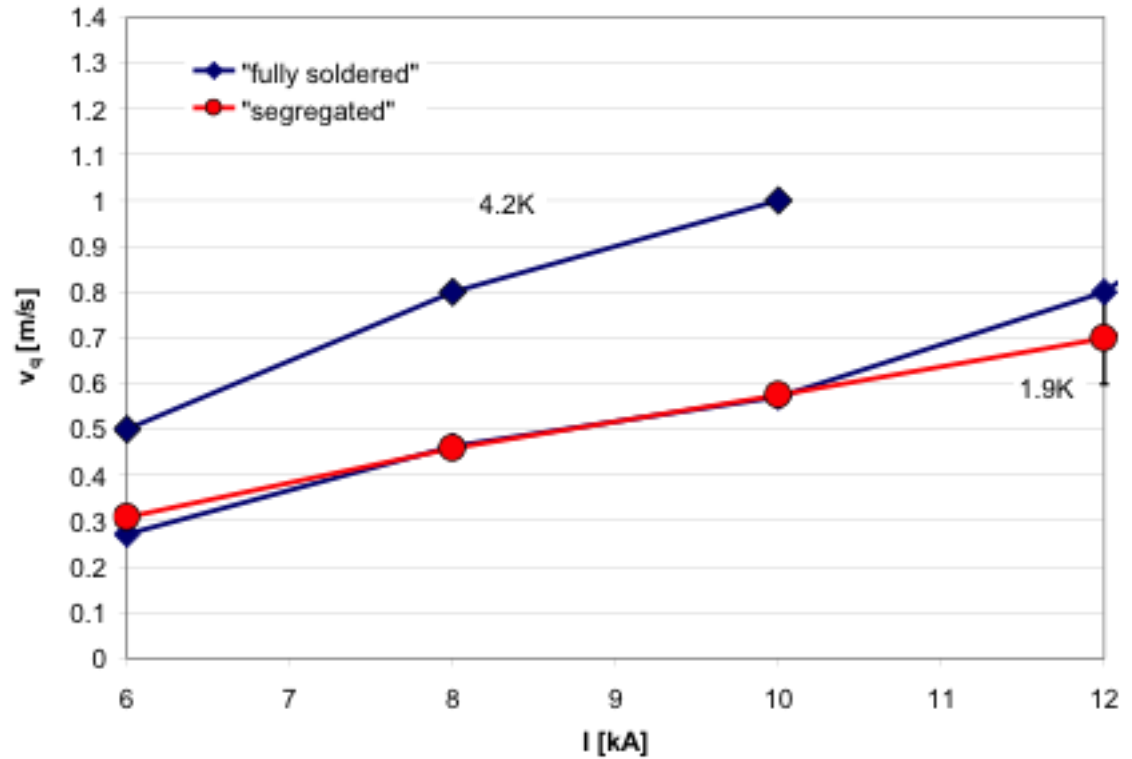
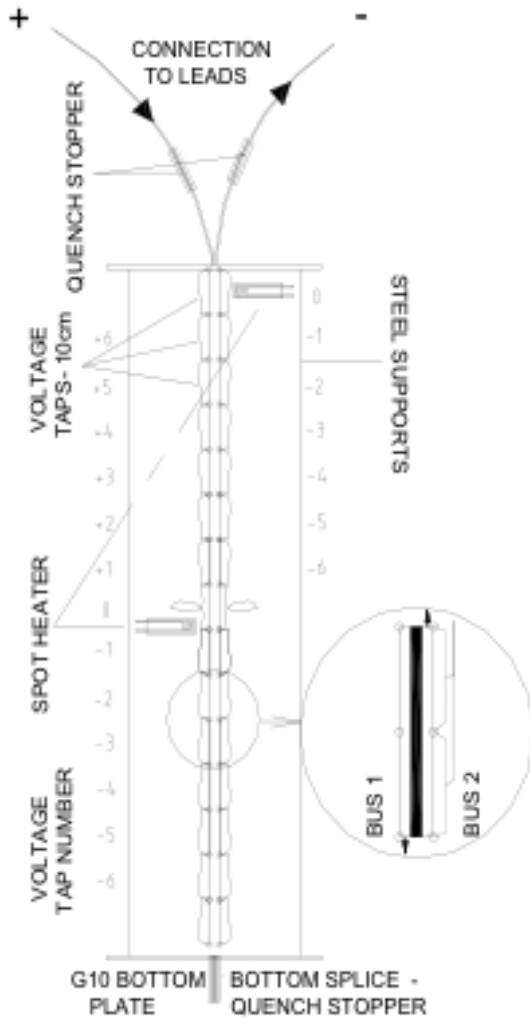
	Width (mm)	Thickness (mm)	A (mm ²)	A _{cu} (mm ²)	Cu/Sc	I _c (kA) @ 3.5 T, 4.2 K
2 bus (2 MQXB Cable)	15.4	2X1.45	40.8	23.07	1.3	60
2 LHC cable with 34 strands d=1.065 mm	18.15	2x1.92	60.6	37.3	1.6	>60



Self field data

200 mV detection threshold and additional heater effectiveness of 20 MIITs => Hotspot Temp < 200 K

Main Bus Design



Quench propagation velocity measurements on the LHC IR quadrupole bus-bar prototypes.

Two side different bus configuration:

Fully soldered



Segregated

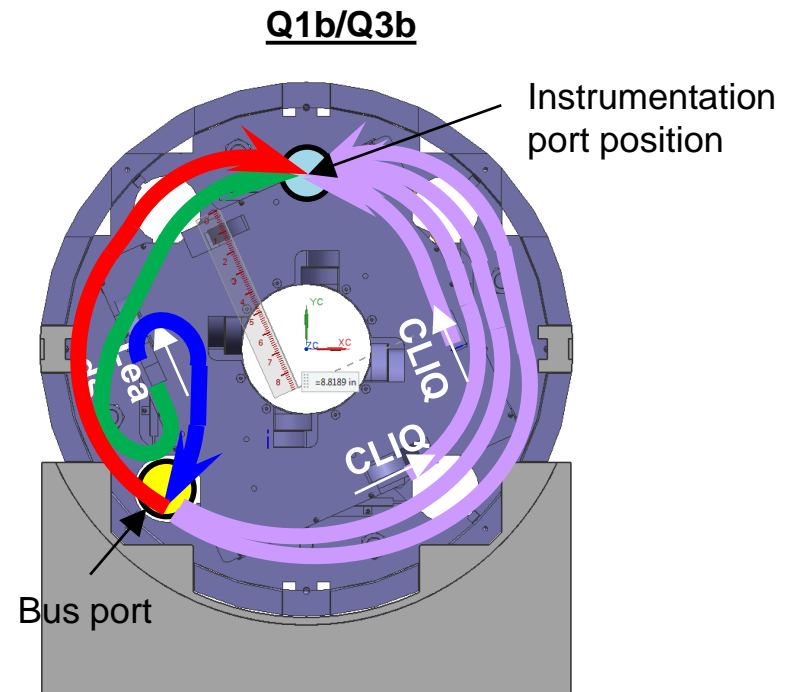
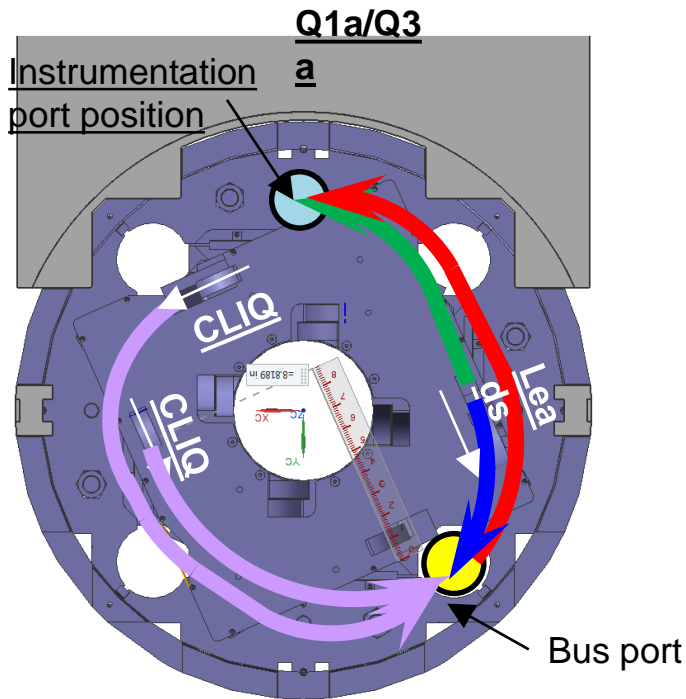


← 10 mil Kapton

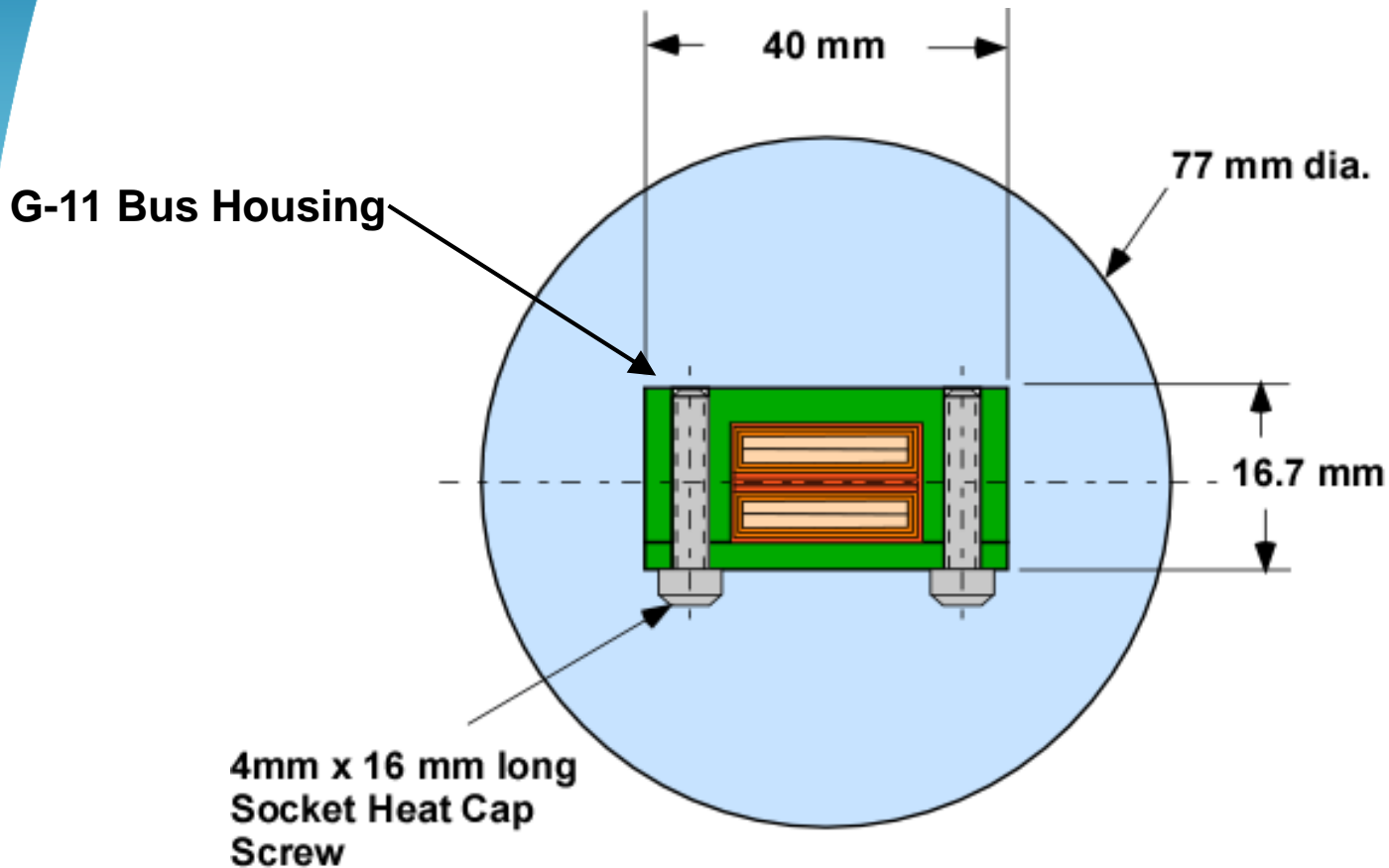
Q1 End View (same as Q3)

Conceptual design of expansion loops and bus configuration was completed and is shown below.

Since the bus port is not placed symmetrically with respect to the cold mass, there will be two different bus loop configurations on the face of the cold mass.

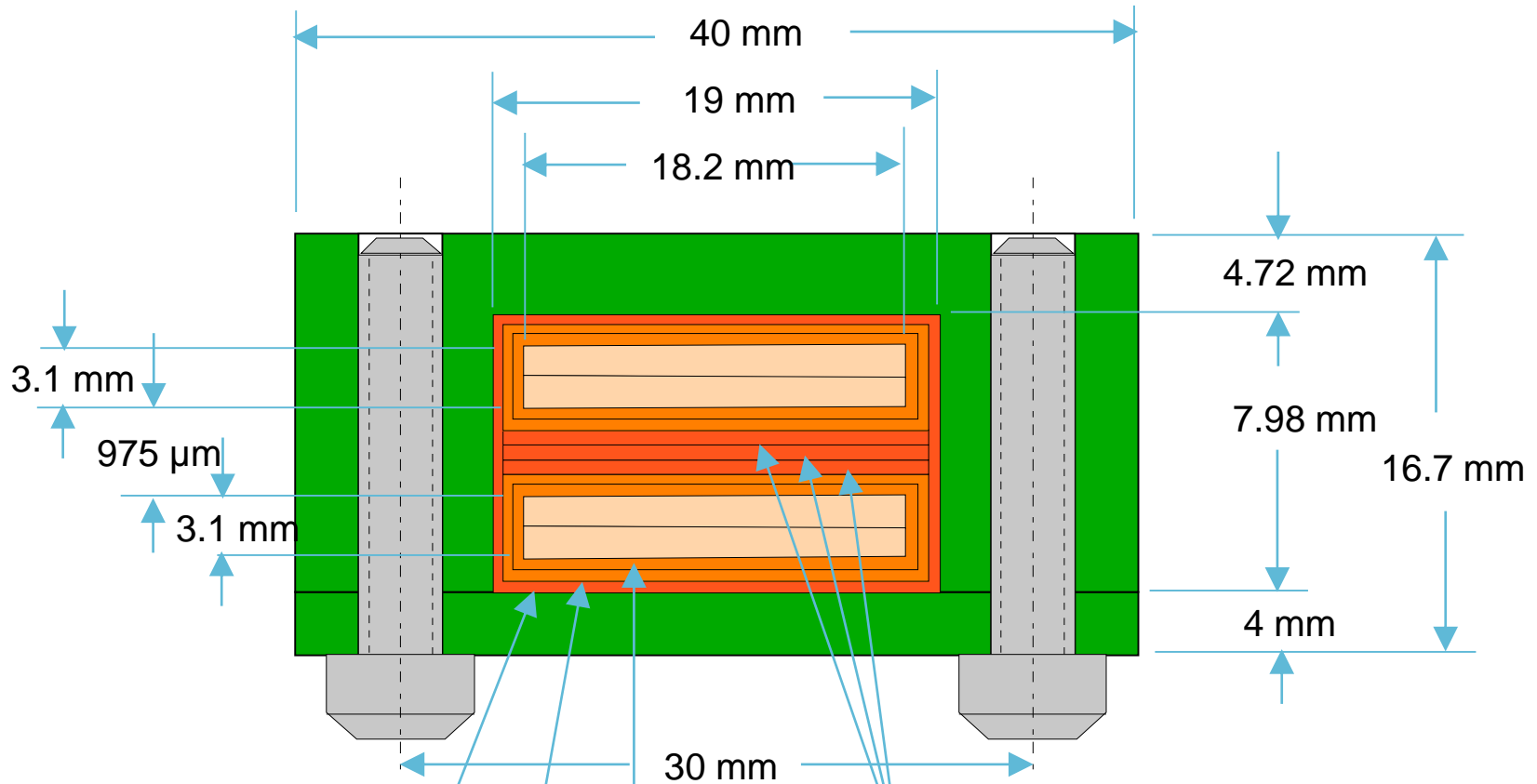


Main Bus Design



- The bus: two LHC IR cable will be fully soldered together
- Special spider support in the cooling channel for the magnet
- Loop design: two cable will not be soldered – wrapped tightly

Main Bus Design



1 layer of 50 μm thick Kapton
with 50% overlap = 100 μm

1 layer of 50 μm thick Kapton
with 66% overlap = 150 μm

30 mm

3 layers of 125 μm thick Kapton = 375 μm

1 layer of 50 μm thick Kapton with 66% overlap = 150 μm

Main Bus Design and Plans

Mockup

Assembly of a mockup, which will include both bus loop configurations and a through-bus, is beginning.

- Space has been allocated in Industrial Building 3, and a dedicated technician has been assigned.
- Models have been obtained (from Mike Solis) of all the magnet end and splice connection box assemblies.
- Cable for power leads has been obtained.
- Drawings of connection box and end plate assemblies for mockup have been completed.

Still need to:

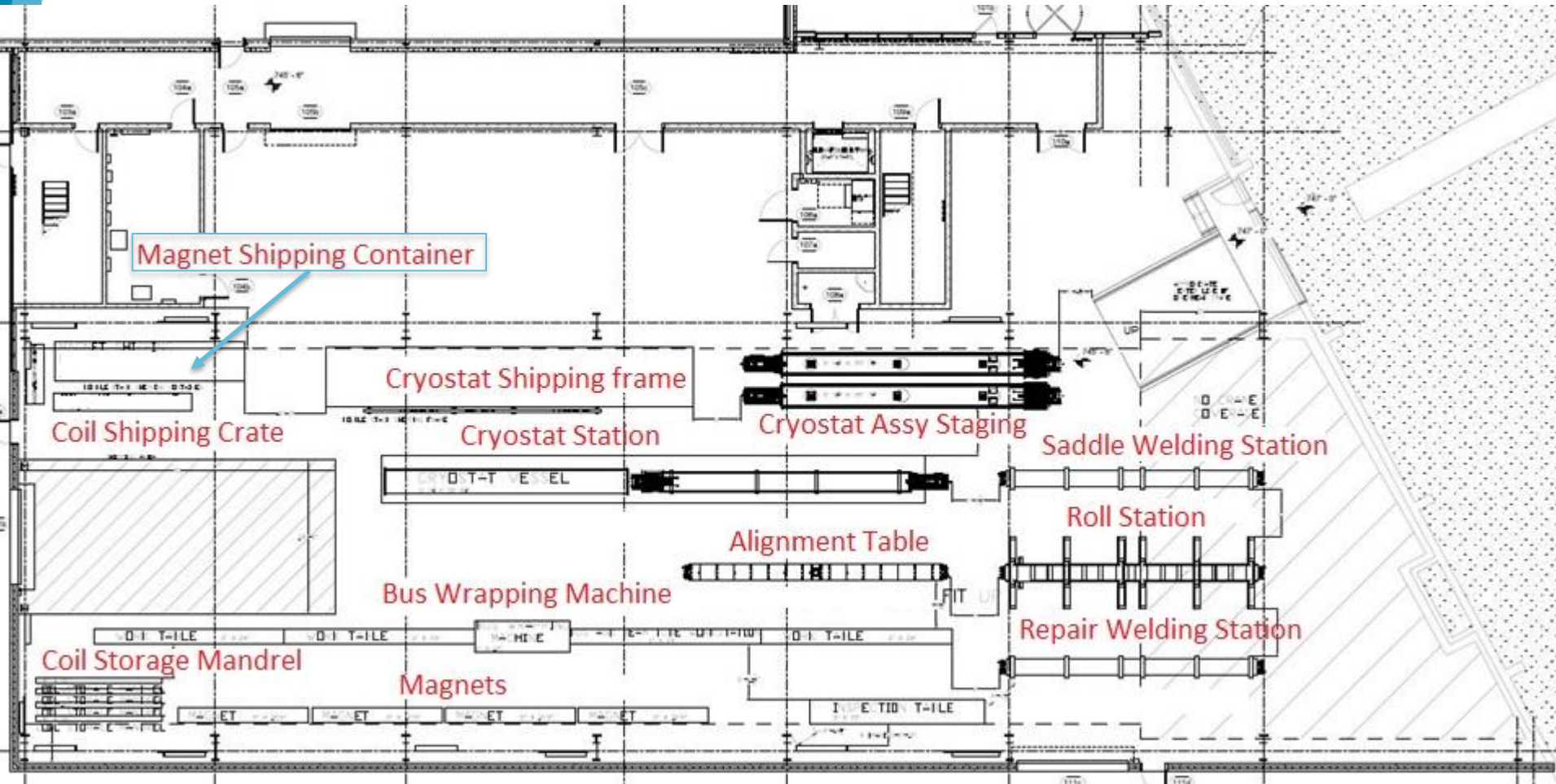
- Receive mockup parts.
- Obtain end dome model and add this to the mockup.
- Order through-bus port for mockup.
- Design through bus after confirmation of CLIQ lead configuration.
- Obtain CLIQ leads for mockup.
- Build mockup.
- Form power leads and CLIQ leads.
- Insert through bus port on mockup and short model.
- Assess results.

Plan of a Bus Test

- Use the MQXFS1e magnet – insert into the cooling channel.
- Make short section of the bus.
- V-taps, Spot Heaters, Temperature sensors.
- Quench propagation velocity, MIITS studies.

Infrastructure Availability

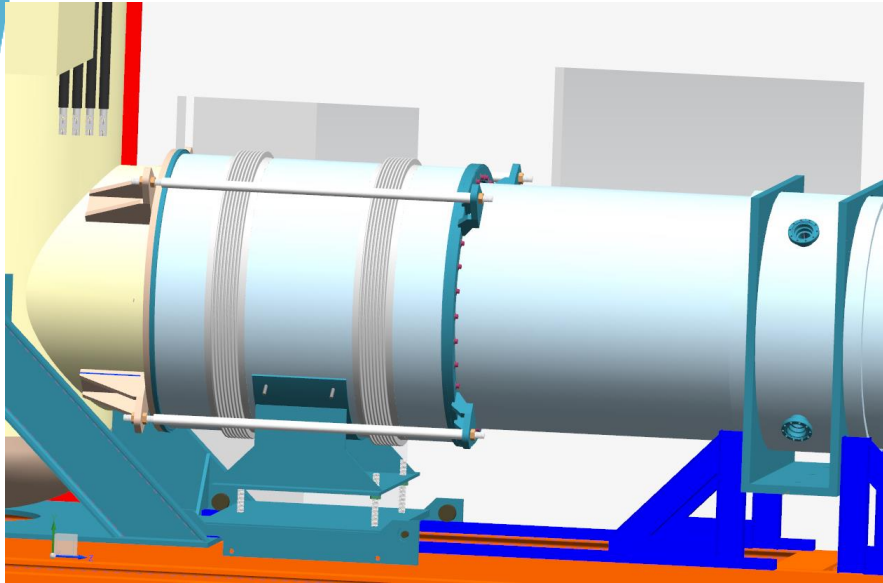
Fabrication Floorplan has been developed
Site: ICBA - a new Building is being built



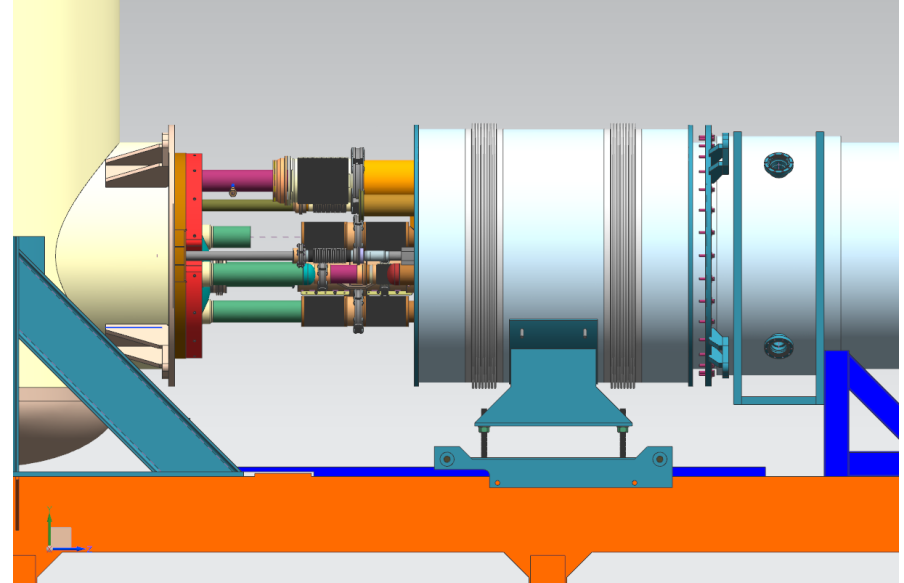
LQXFA/LQXFB Questions & Current Assumptions

- Current Assumptions
 - Flange interface is the same as previous LHC IR Magnet test configuration including:
 - Sliding interconnect bellows that moves into position.
 - Clamp connection that interfaces with the bellows/interface boxes on Test Stand 4.
 - Vacuum Vessel support post positions have not changed.

Previous Configuration

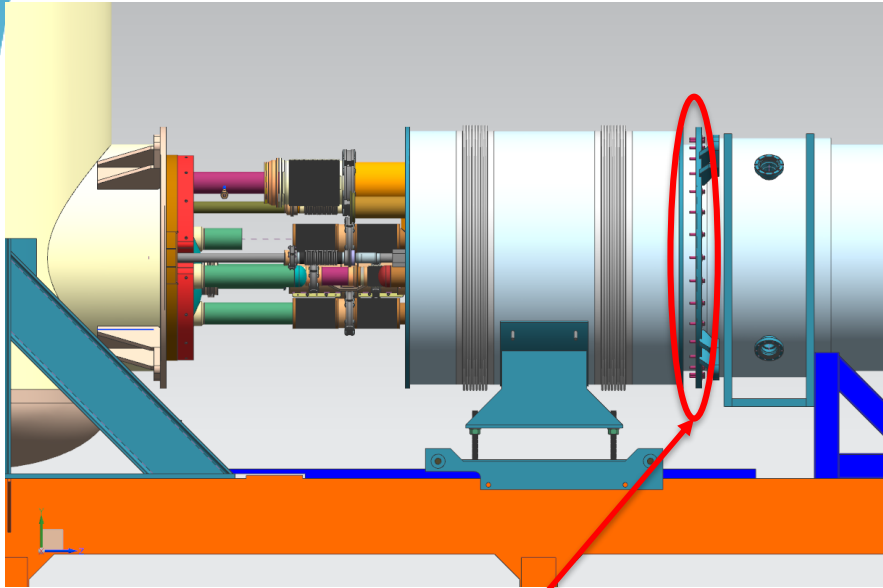


Q2P1 Interface Connection (closed)

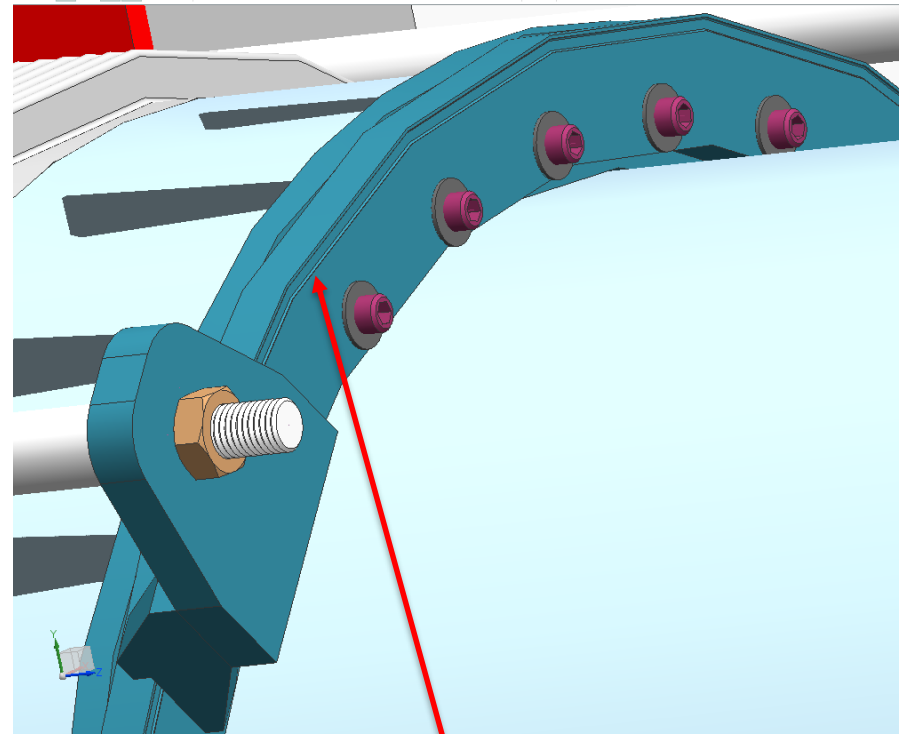


Q2P1 Interface Connection (open)

Previous Configuration



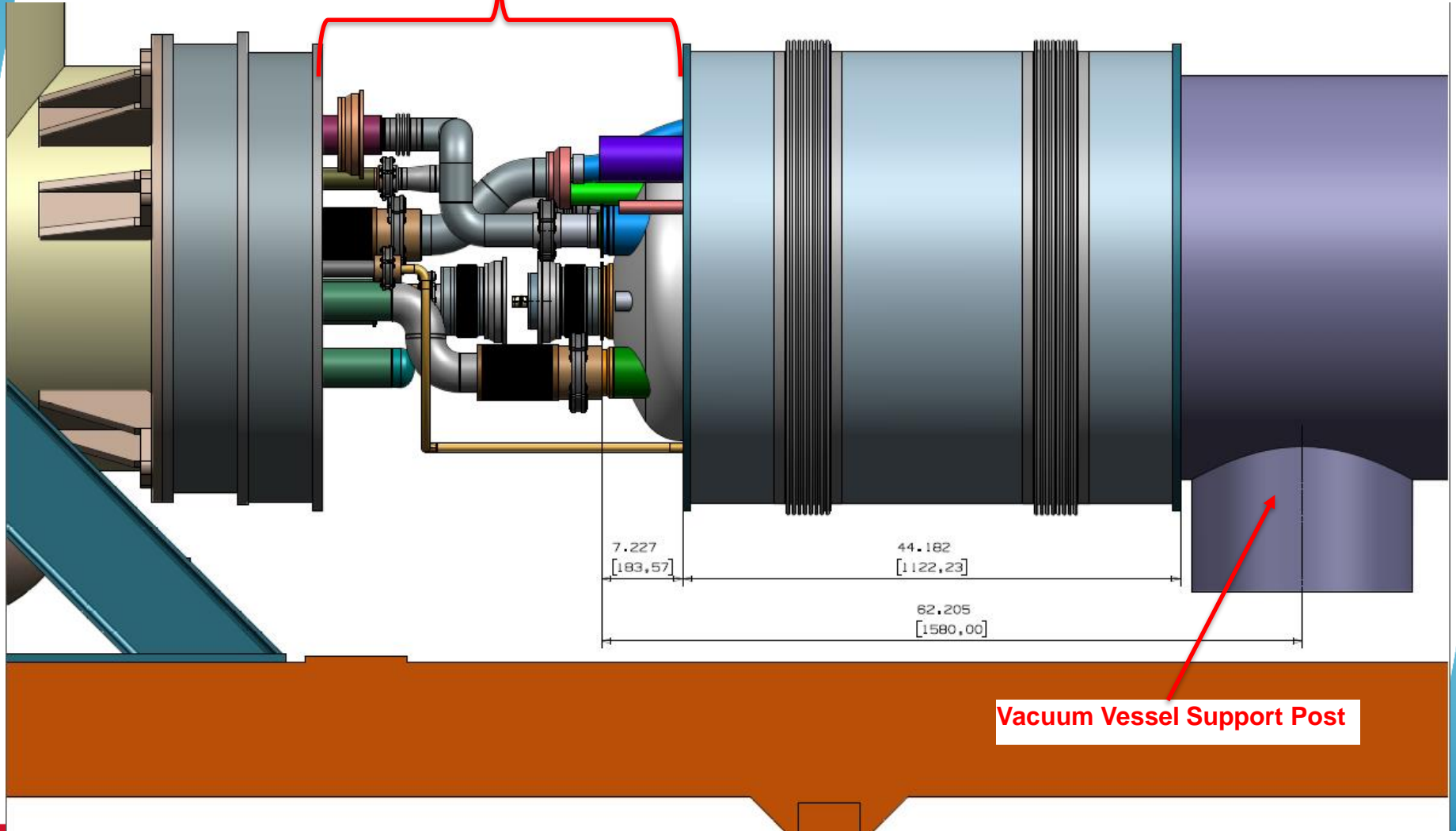
Sliding Interface flange (moved out of position to access interface piping).



O-ring clamp interface to bellows/interface-box.

New Configuration (preliminary)

Opening required to access interconnect piping



Vacuum Vessel Support Post

Potential Considerations for Instrumentation Port

1. Length of bellows/interconnect-boxes.
2. Minimum clearance requirements in “open” position.
3. Location of vacuum vessel support posts.
4. The profile (height) of the instrumentation connector assemblies.

Schedule

- Prototype Cryo-assembly (Full magnet) ready for testing: **August 1, 2019**
- Prototype Cryo-assembly Fabrication start date: **October 23, 2018**
- Important Milestones for CM prototype:
 - Interface specifications need to be completed ~ January, 2018
 - Parts need to be received by Fermilab: some of them **October 5, 2018**
 - CM Tooling to be ready for installation by October 1st, 2018
 - CM Tooling Design to be ready by April 30, 2018
 - CM tooling fabrication – ordering part/equipment by May 31, 2018
- Important Milestones for Cryostat prototype:
 - Start of the Cryostat tooling at FNAL: **May 6, 2019**
- Important Milestones for Stand 4 Test facility:
 - Interface specifications – to be able to make the relevant shuffling unit: January, 2018

Note: Early dates to accommodate design adjustments.

