Status and plans of LMQXFA cold mass

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8th HiLumi Collaboration Meeting – CERN, Oct 2018

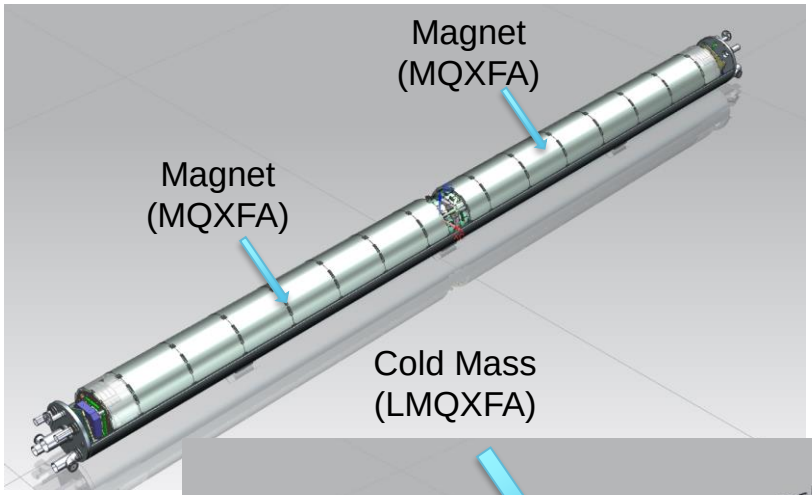
Outline

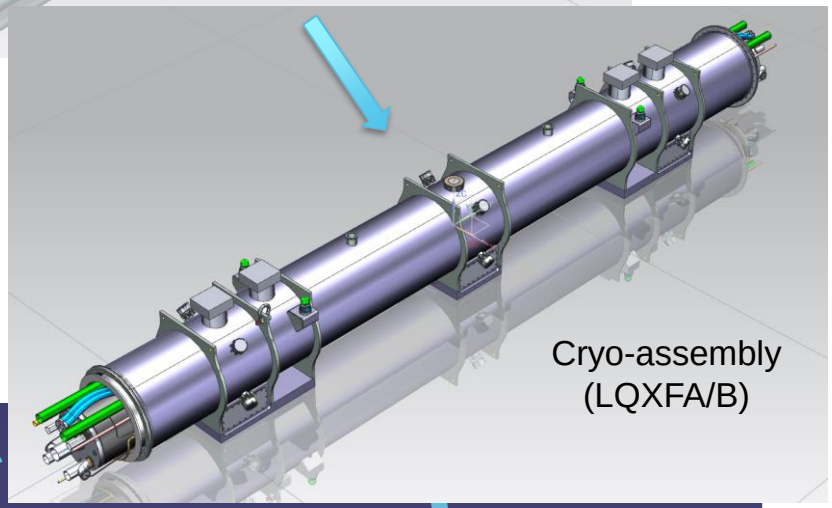
- Scope
- Functional Requirement Specifications
- Strategy
- Bas bar design and validation status
- Cold Mass Tooling design status
- Cold mass design status
- Future plans

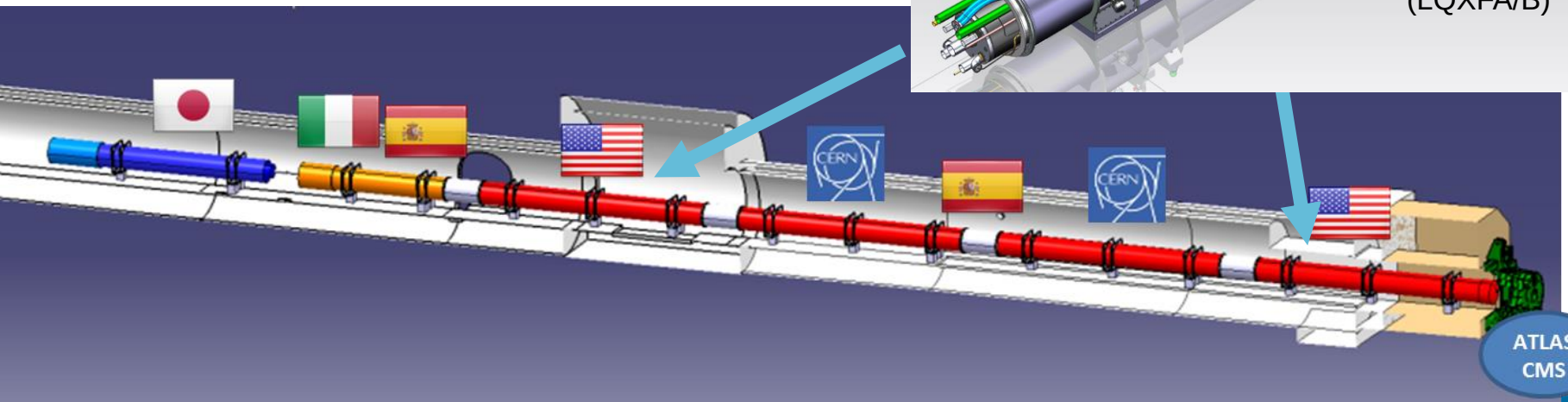
Scope of AUP Q1/Q3 Cryo-Assemblies

12 Q1/Q3 Cryo-Assemblies

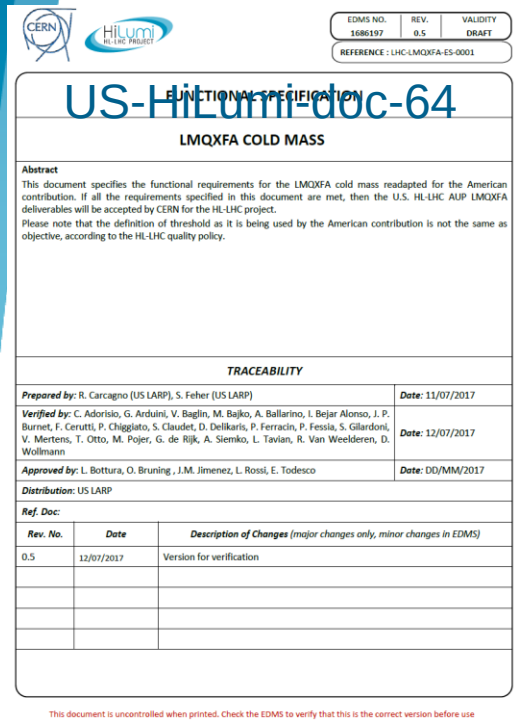
- 1 prototype (not tunnel bound)
- 1 pre-series
- 9 series production
- re-building one Cryo-assembly assumed







Performance Requirements



EDMS NO.	REV.	VALIDITY
1686197	0.5	DRAFT

REFERENCE : LHC-LMQXFA-ES-0001

US-HiLumi-doc-64

FUNCTIONAL SPECIFICATION

LMQXFA COLD MASS

Abstract

This document specifies the functional requirements for the LMQXFA cold mass readapted for the American contribution. If all the requirements specified in this document are met, then the U.S. HL-LHC AUP LMQXFA deliverables will be accepted by CERN for the HL-LHC project.
Please note that the definition of threshold as it is being used by the American contribution is not the same as objective, according to the HL-LHC quality policy.

TRACEABILITY

Prepared by: R. Carcagno (US LARP), S. Feher (US LARP)	***Date:*** 11/07/2017
Verified by: C. Adorisio, G. Arduini, V. Baglin, M. Bajko, A. Ballarino, I. Bejar Alonso, J. P. Burnet, F. Cerutti, P. Chiggiato, S. Claudet, D. Delikaris, P. Ferracin, P. Fessia, S. Gilardoni, V. Mertens, T. Otto, M. Pojer, G. de Rijk, A. Siemko, L. Tavian, R. Van Weelderen, D. Wollmann	***Date:*** 12/07/2017
Approved by: L. Bottura, O. Bruning , J.M. Jimenez, L. Rossi, E. Todesco	***Date:*** DD/MM/2017
Distribution: US LARP	
Ref. Doc:	

Rev. No.	*Date*	*Description of Changes (major changes only, minor changes in EDMS)*
0.5	12/07/2017	Version for verification

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Engineering & Equipment Data Management Service (EDMS)

- **Cold Mass Functional Requirement Specifications (FRS)**
  - CERN approved – EDMS No 1686197 (28/07/2017) under revision control
  - AUP accepted
- Requirements are classified into two groups:
  - Threshold requirements (CM 27) are requirements that contain at least one parameter that the project must achieve.
  - Objective requirements (CM 4) are requirements that the project should achieve and will strive to achieve.
- All requirements are traceable

US HL-LHC AUP

Strategy

Before production validation of the CM design:

- Short model magnet equipped with SS shell and tested
  - Successfully completed the cold test; no performance degradation observed due to the shell installed onto MQXFS1d
  - Learned how to mount the shells and how to perform welding
- Empty shell welding test
  - Validate the welding procedure before it is applied to prototype CM
  - Validate welds and welders
  - Observe deformation due to weld; virtually unsupported shell
- Bus bar mock up
  - Short model of the bus routing including expansion loops
- Short bus bar test using MQXFS1e
  - Fully constructed short bus bar is inserted into the short magnet and cold tested
- Cold Mass fabrication tooling development
  - Special requirements for handling the magnets and the cold masses
- Fabricate the prototype CM and test it horizontally in the the CERN provided cryostat
- Lesson learned applied to production CM fabrication

Empty shell welding test status

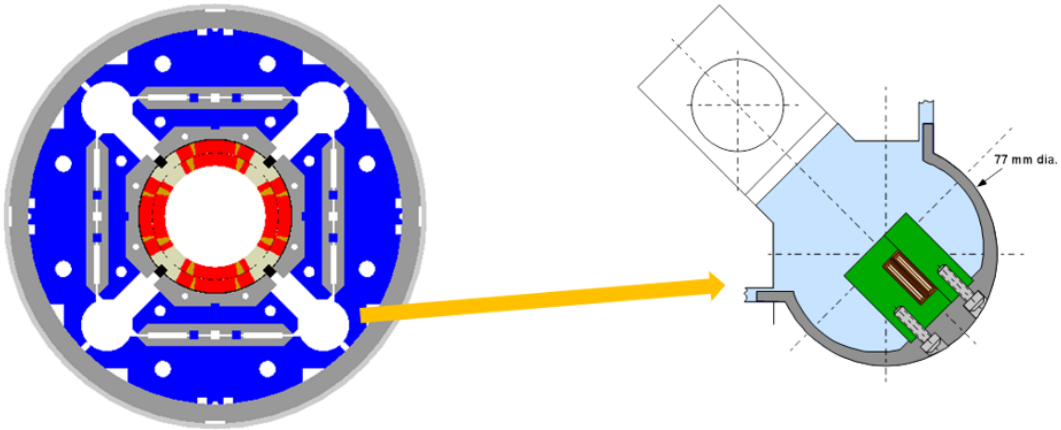
All the pieces and parts for the weld test are in house

Expected the weld test to start right after the collaboration meeting

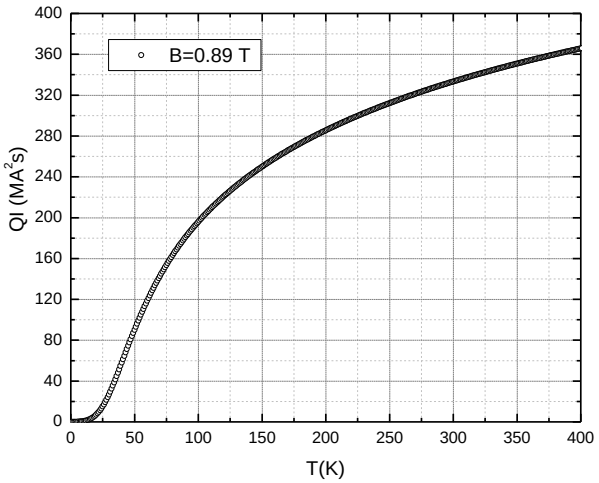
Bas bar design

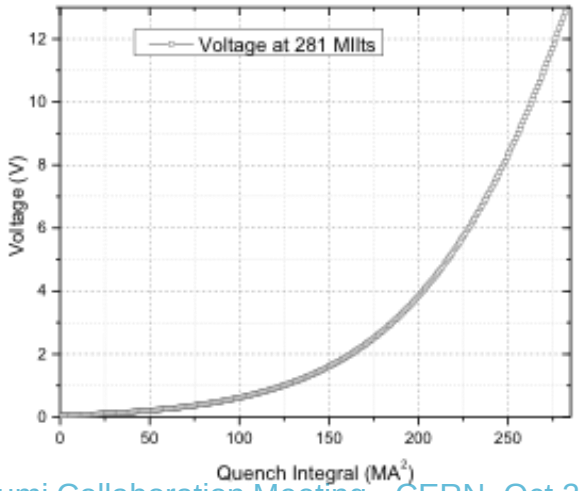
Has been completed

- Two LHC dipole cable soldered together
- 3 layers of 0.125 mm thick Kapton between buses, two layers of 0.050 mm Kapton with 66% overlap surrounding each bus and one layer of 0.050 mm Kapton with 75% overlapl around the entire bus.
- G10 housing with special SS spider support



	Entire bus	Cu	NbTi	Cu/Sc
Area (mm^2)	60.57	37.55	23.01	1.65



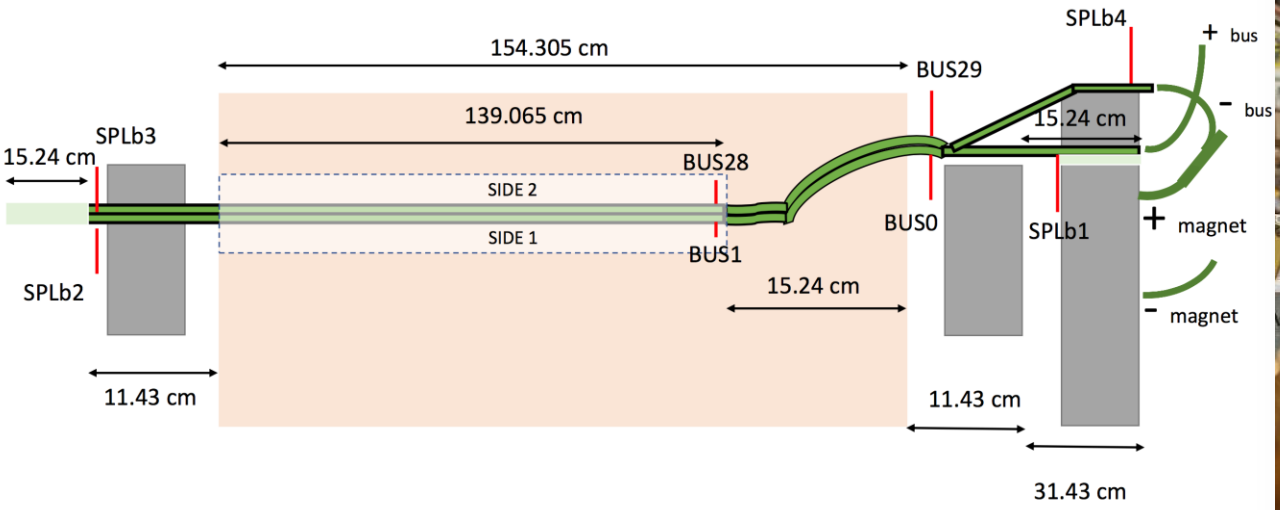


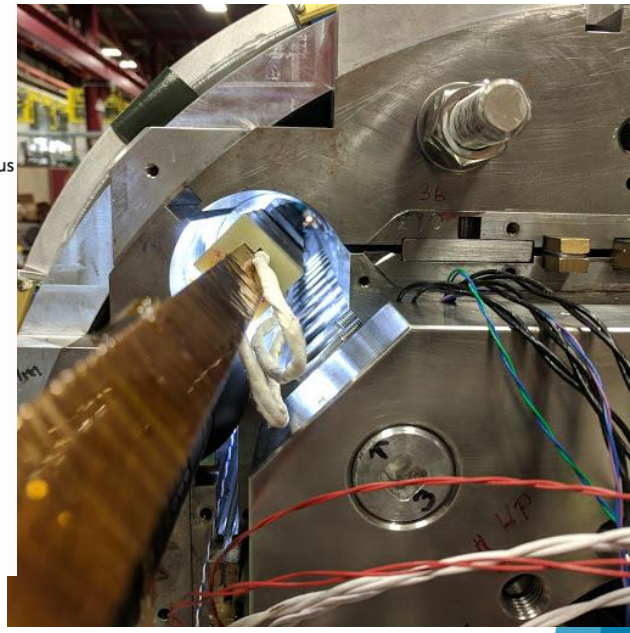
Baldini's calculation at nominal current; plenty of margin

- Over 6K of temperature margin
- High detection voltage threshold can be used
- low temperature rise

Bus bar validation

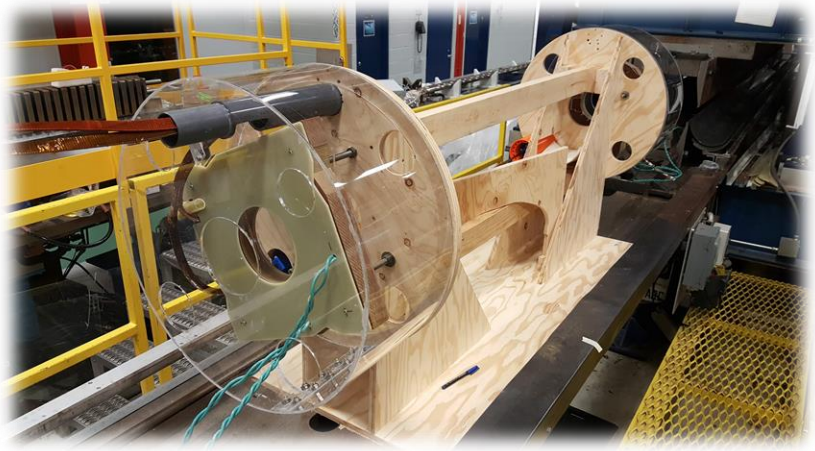
- MQXFS1e test using short bas bar
  - Instrumented with V-taps, temperature sensors and spot heater
  - Test is underway expect to start next week
  - Adequate support (no spontaneous bus quench), Quench velocities, QI, temperature margin, splice joint resistance

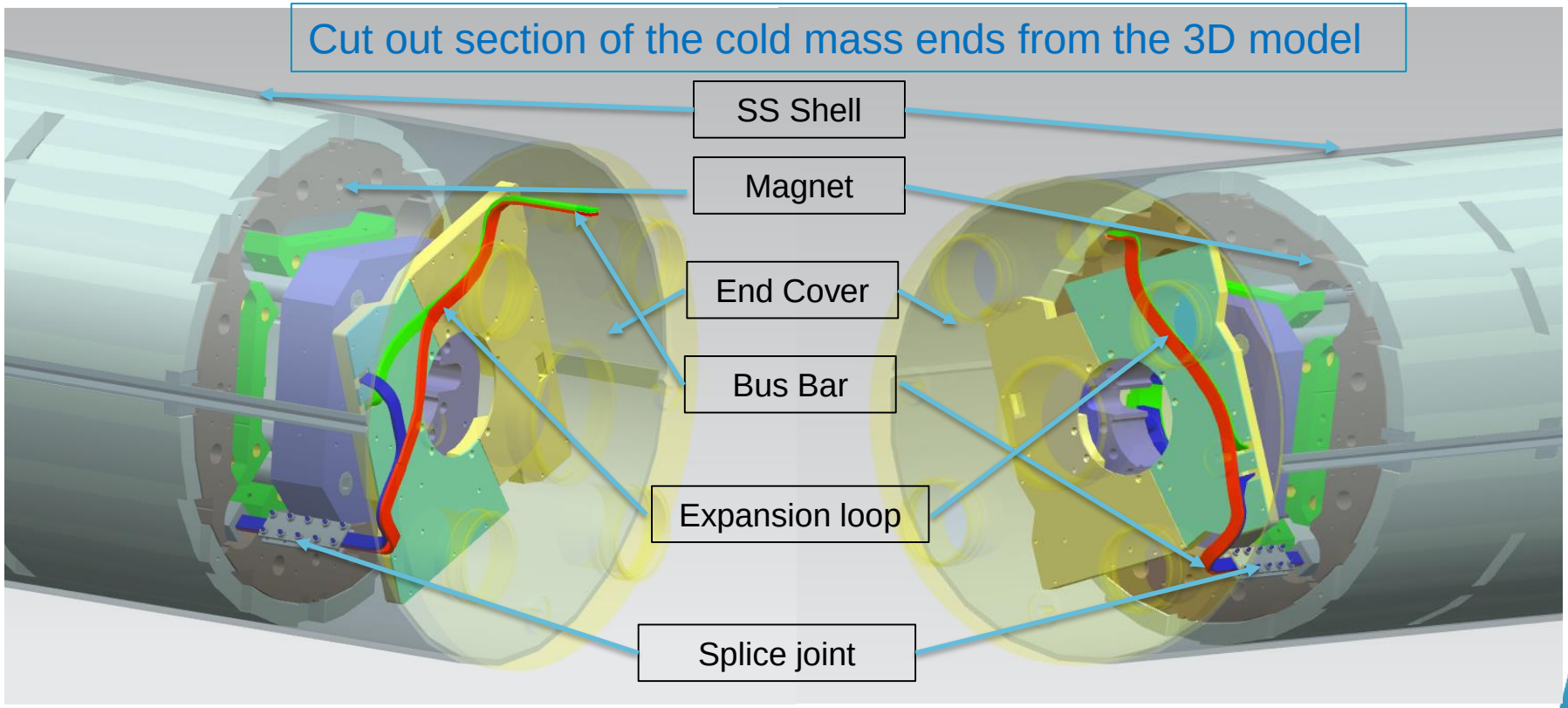




Bus Bar Mock-up

- Expansion loop still under development
  - Space constraints (65 mm space)
  - Lack of cable to be used for Mock-up
  - Length of the magnet leads

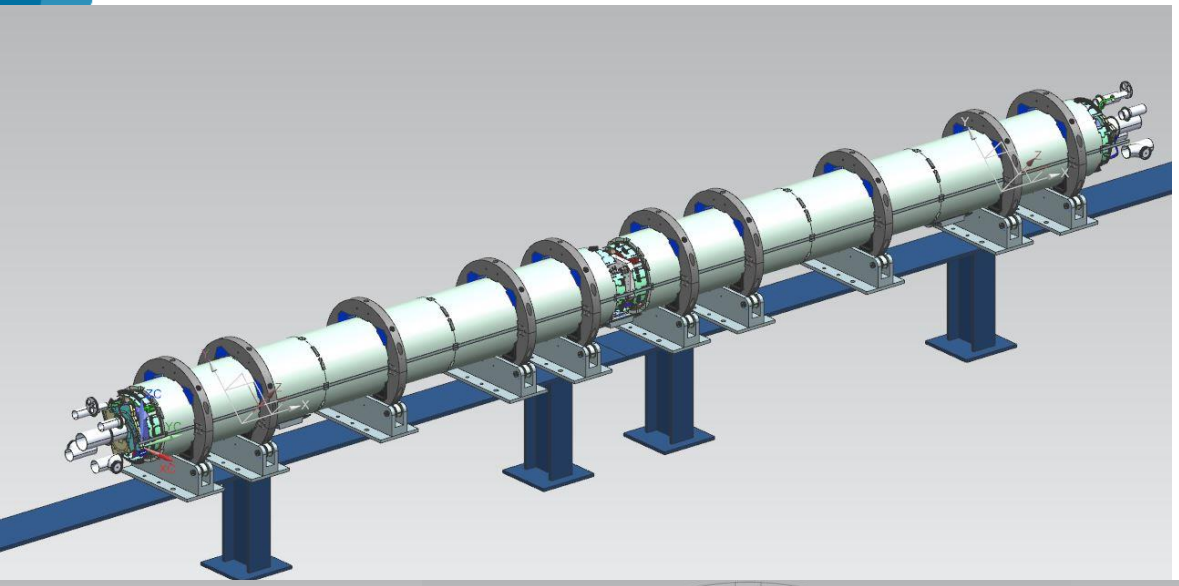




Cold Mass Tooling

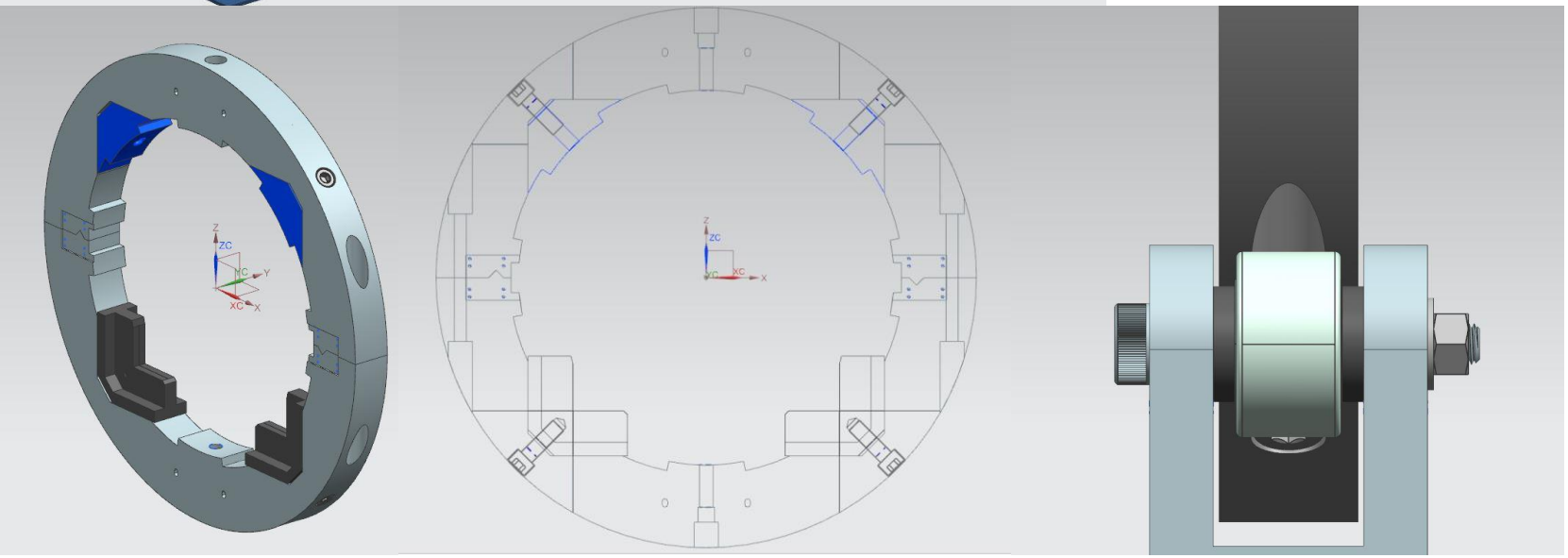
- Magnet Handling requirement drives the tooling design
  - Even lifting using four points – no greater than 200 lb difference between lifting points
  - Putting the cold mas down; at least four points to be used evenly – no more than 0.26 mm deflection allowed between resting points
- CM tooling:
  - Initial magnet survey station – magnet alignment is checked at arrival before removing the magnet from the shipping frame
  - Magnet and Cold Mass Alignment and Rolling Station
  - Welding station
  - End cover tooling
  - Cold Mass support (saddle) tooling

Alignment and Rolling Tooling

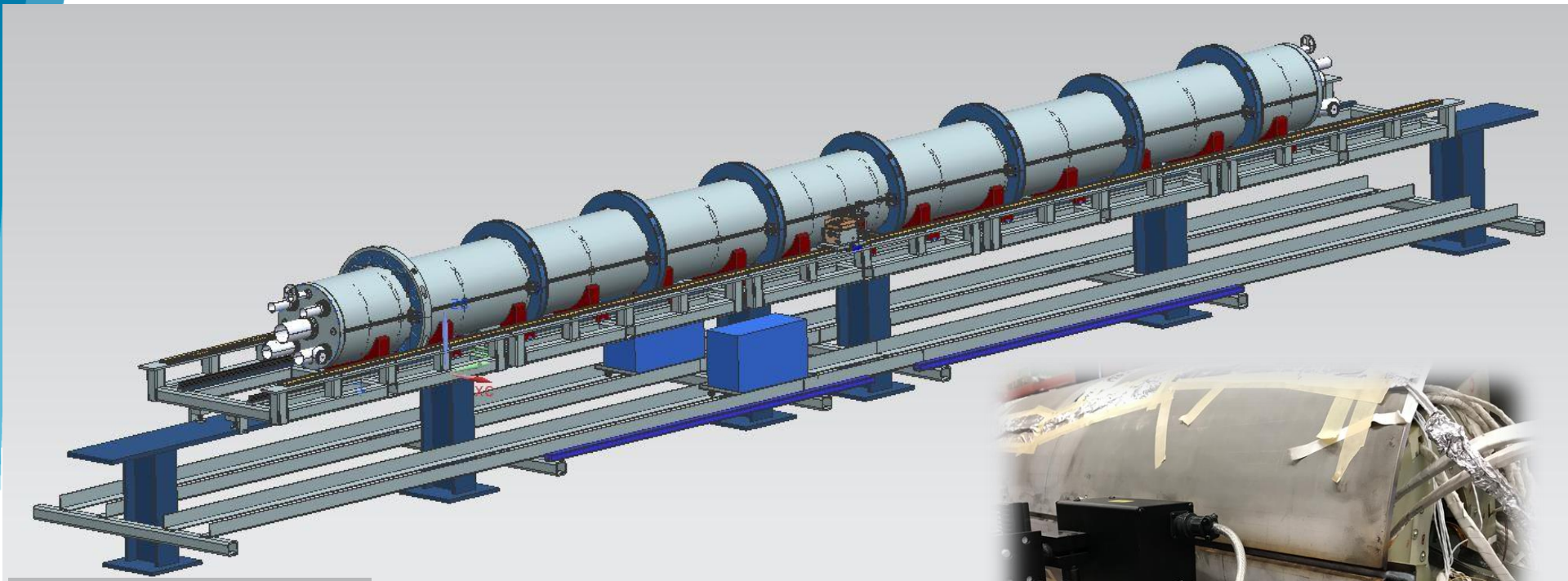


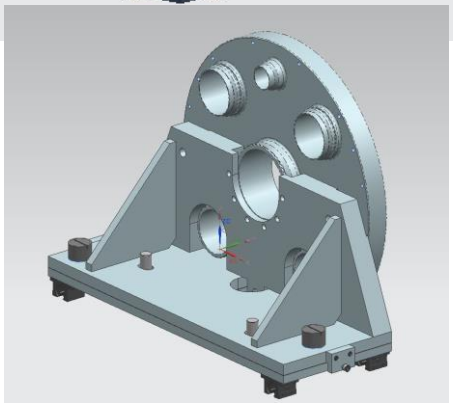
Combined tooling design

- Rollers carefully aligned – under weight
- Clamps mounted to both magnets
- Clamps aligned to rollers
- Half shell mounted and tacked
- Rolled over the half shell assembly
- The second half shell is mounted and tacked



Welding Station and End Cover Tooling





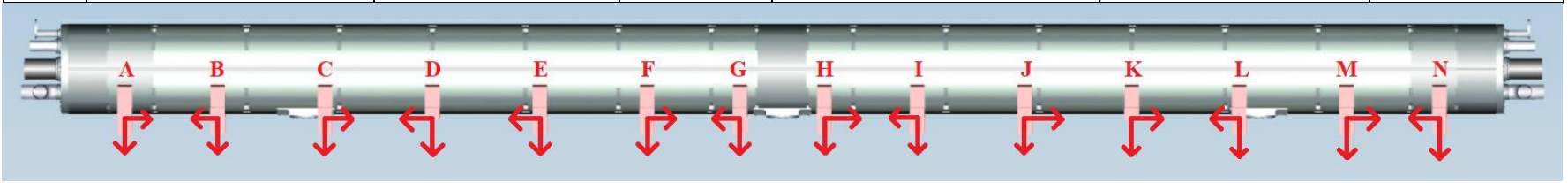
End Cover tooling is also will be used to insert the beam tube

MQXFS1d Shell Welding

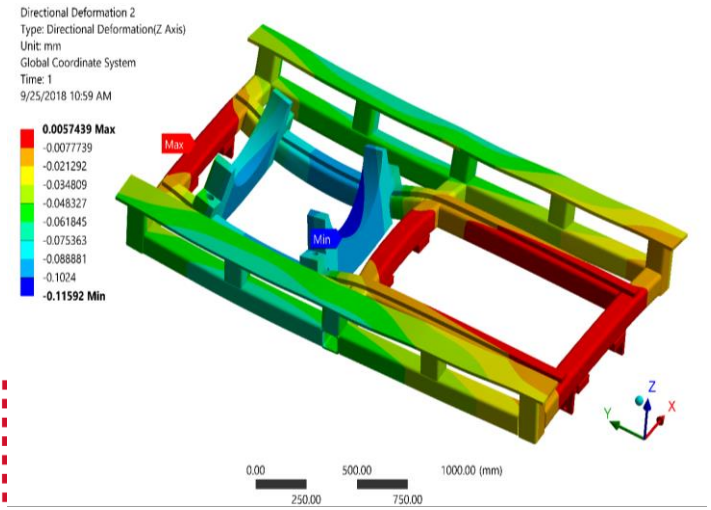
Welding tooling FEA

Summary table

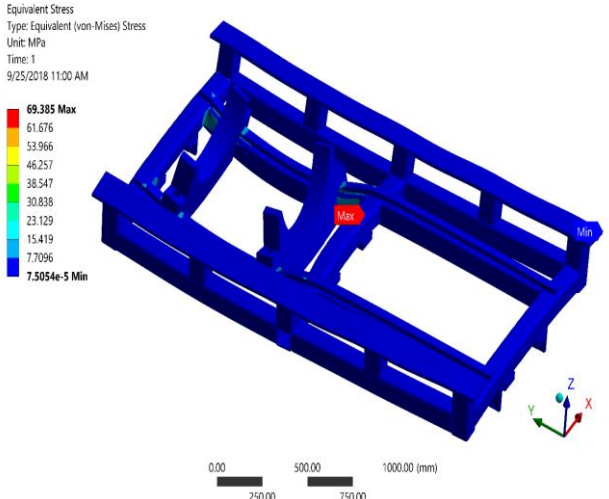
Support	Horizontal Deformation (mm)	Vertical Deformation (mm)	Weld Station	Maximum Equivalent Stress (MPa)	Maximum Weld Stress (MPa)	Weld Saftey Factor
A	0.041	0.116	1	69.3	98.8	1.64
B	0.058	0.101				
C	0.025	0.102	2	42.9	96.8	1.67
D	0.005	0.019				
E	0.024	0.105				
F	0.058	0.094	3	84.7	99.1	1.63
G	0.030	0.120				
H	0.030	0.120				
I	0.058	0.094				
J	0.020	0.097	4	43.6	97.0	1.67
K	0.004	0.015				
L	0.021	0.093				
M	0.041	0.116	5	69.4	99.2	1.63
N	0.057	0.100				



The design is within the needed tolerances and allowable stresses



Weld station 5
Deflections and
Equivalent Stresses



Stress Analysis of the LMQXFA Cold Mass under 2 Mpa Internal Pressure

This analysis shows that the stresses in all components are within the limits imposed by ASME Section VIII. The only modification suggested is to engineer compliance into the tack blocks to decrease their stress under the pressure loading.

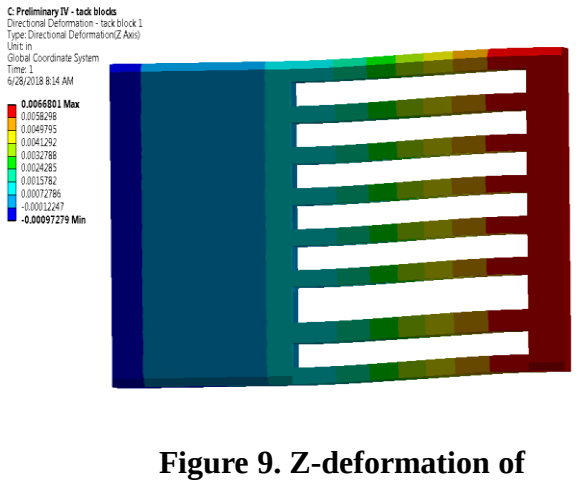
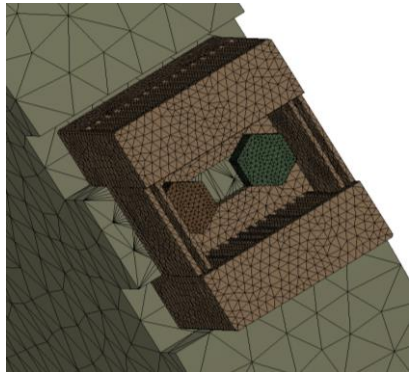
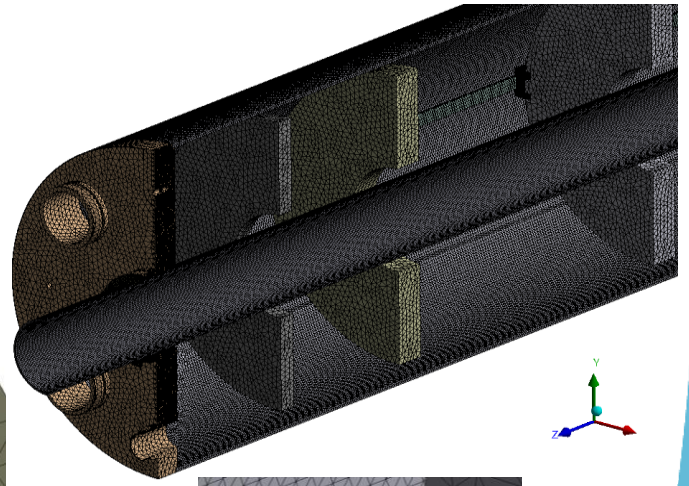
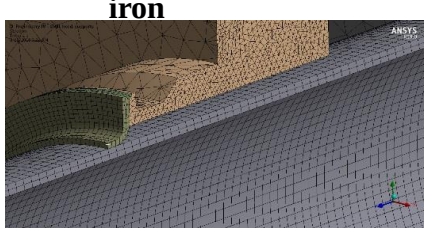


Figure 9. Z-deformation of compliant half tack block

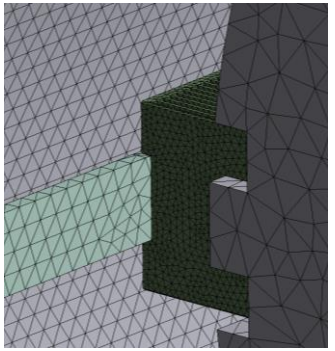


Tack block screwed to iron





Head/beam pipe junction



Tack block and backing strip

Analysis being redone using the revised new End Cover design with tapered hole for the bus bar

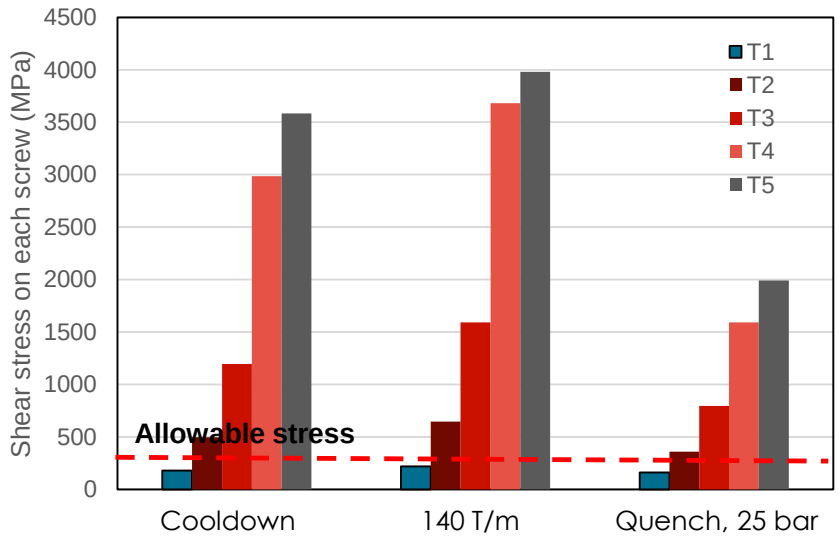
ΔUz Between the SS Shell and the yoke

0.2 mm welding shrinkage in half SS shell (SS shell barely contacts the structure after cooldown): Displacements below are from half length of the magnet.

- **Cooldown** ---- the SS shell shrinks more in cooldown.
  - The relative axial displacement ΔUz is 0.43 mm.
- **Powered at ultimate current** --- The elongation of the magnet structure is about 0.13 mm at the ultimate current.
  - Magnet elongation increases the SS shell stretch.
  - ΔUz =0.43 mm+0.13mm=0.56 mm.
- **Quench**---The SS shell stretches by about 0.36 mm in the axial direction.
  - The internal pressure releases the SS shell stretch.
  - ΔUz =0.56mm-0.36mm=0.2 mm

Shear stress in Each Screw

- The shear stress on screws is much higher than the allowable stress of M8 bolts.



Axial compliance would be necessary to reduce the axial loads on the screws of the tack blocks.

Infrastructure Availability

ICBA at FNAL

Utilizing a newly built infrastructure:

- ICBA new building at FNAL construction has started to accommodate adequate through-put of Cold Mass and Cryostat assembly work
  - Notice to proceed was on April 18th, 2018
  - goal: partial beneficial occupancy in February, 2019

Cold Mass Near Future Plans

- Project – prepare for the CD-2/3b DOE review held in December
  - FRS needs to be approved
- Empty shell welding test to be completed in October 2018
- MQXFS1e bus bar validation test at VMTF to be completed in October 2018
- Tooling design complete in November 2018
  - FEA complete for the alignment and rolling tooling
  - FEA complete for the End Cover tooling
- Tack block issue to be resolved in November 2018
  - New tack block design
  - FEA complete with the new tack block design
- Finalize the bus bar mock up with LHC cable in November 2018