Status of LQXFA cold mass, cryostating and cold test

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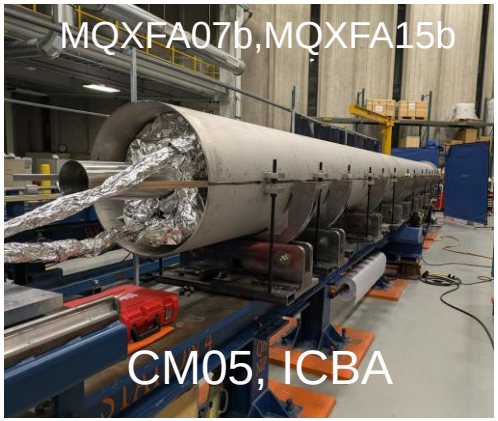
Outline

- Cold Mass and Cryo-assembly production status
- Cold Mass and Cryo-assembly production achievements and challenges progress
- CA02 test status and results

Cold Mass & Cryostat Assembly Status

- CA01 accepted by CERN.
- CA02 IB1 test completed, warm up in progress.
- CA03 prep for combination pressure/leak test.
- CM04 capillary tubes are next.
- CM05 ready for longitudinal shell welding.
- CM06 MQXFA13b has been shipped to FNAL

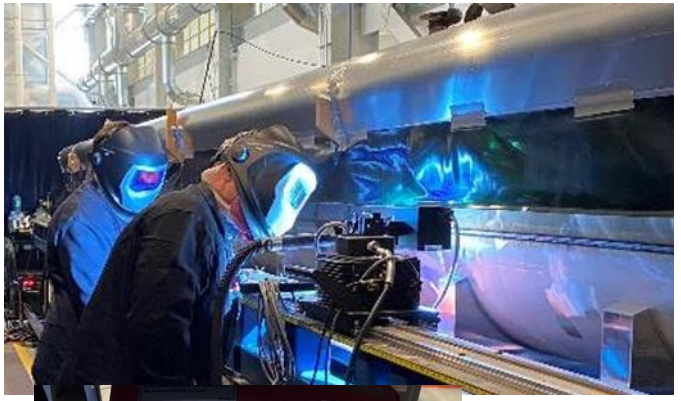
	Qa	Qb	Weld	Cryo	Test	Ship
CA01	✓	✓	✓	✓	✓	✓
CA02	✓	✓	✓	✓	✓	
CA03	✓	✓	✓	✓		
CA04	✓	✓	✓			
CA05	✓	✓				
CA06	✓	✓				
CA07						
CA08						
CA09						
CA10						

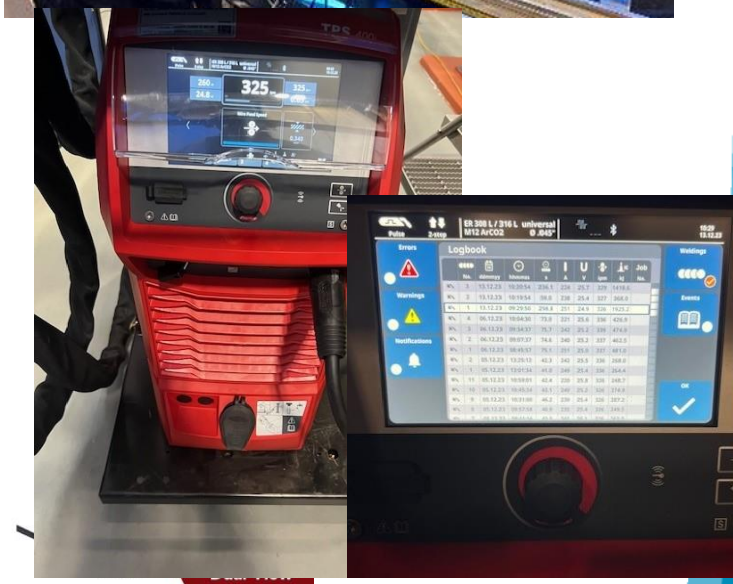


Cold Mass Production Achievements and Challenges

Welding

- It was a long process to converge
  - Approved procedure applied first on CM02
- Bought new Fronius power supplies. They are better suited for the foreign weld wire (stable arc) & provides a data log.
- Ultrasonic Test (UT) results have been exceptionally better since updates. CM-02 & CM-03 passed with minimum to no weld repairs.
- Internal Weld Inspections are now completed with an inspection Borescope (newly purchased) by a Certified Weld Inspector (CWI).



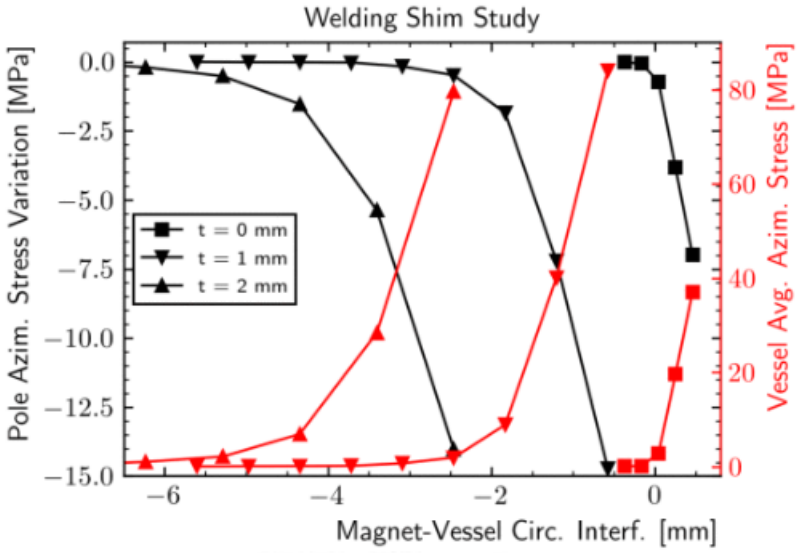


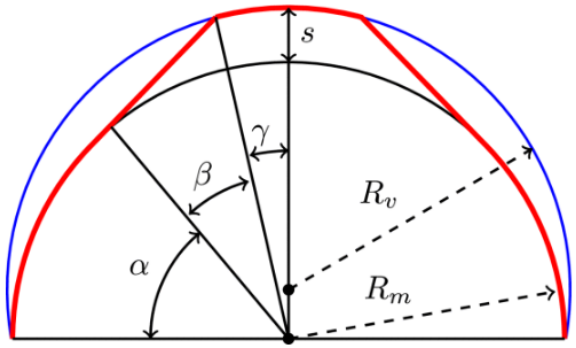
Yateks P+ Series Industrial Video Borescope 6.0 mm OD Dual View

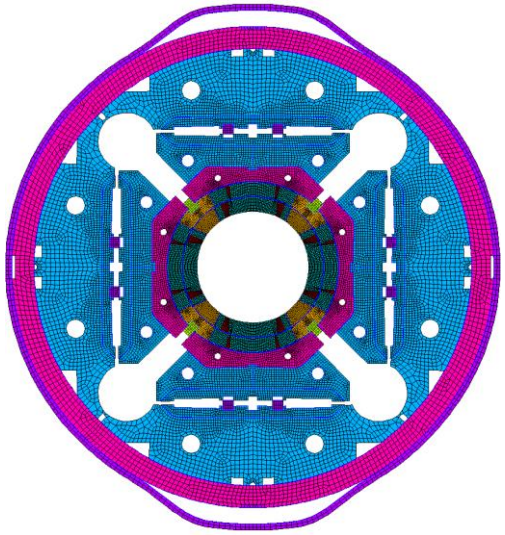
Cold Mass Production Achievements and Challenges

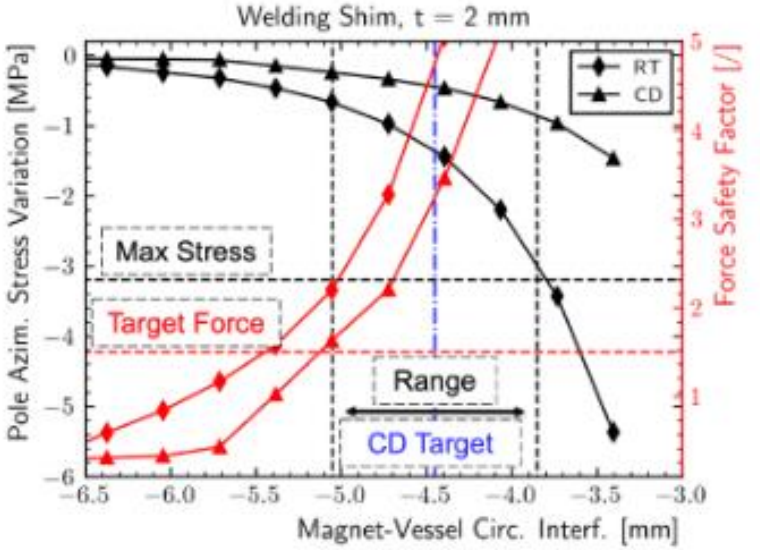
Starting with CM02 we are using the welding shims

- 2 mm target value for the shims were used (proposed by the analysis presented at MT 28) to calculate the SS vessel circumference based on the measured magnet circumference values
- It was important to machine and measure the shell correctly







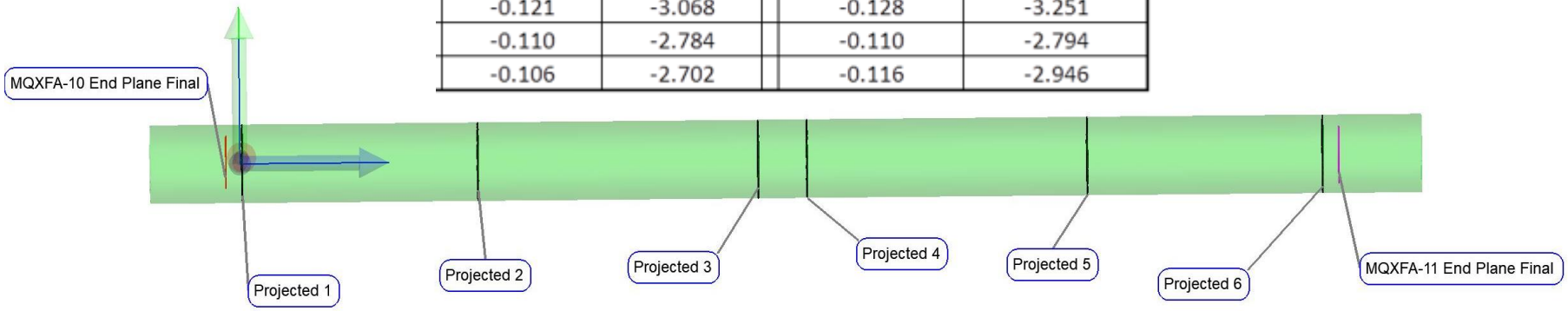


Cold Mass Production Achievements and Challenges

CM02 strain measured by survey

- Six locations along the cold mass it is measured the circumference of the SS shell before and after welding
- The same six locations the weld shrinkage is measured as well
- The average weld shrinkage of the six values -3.009 mm
- The average circumference change of the six values -2.995 mm

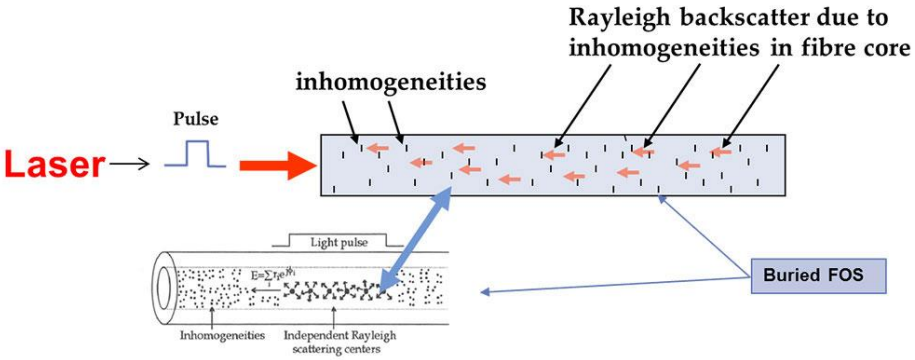
sum of chords changes		Punch mark distatnce changes	
(inch)	(mm)	L+R sum (inch)	L+R sum (mm)
-0.125	-3.186	-0.118	-2.997
-0.121	-3.064	-0.121	-3.073
-0.116	-2.950	-0.118	-2.997
-0.121	-3.068	-0.128	-3.251
-0.110	-2.784	-0.110	-2.794
-0.106	-2.702	-0.116	-2.946

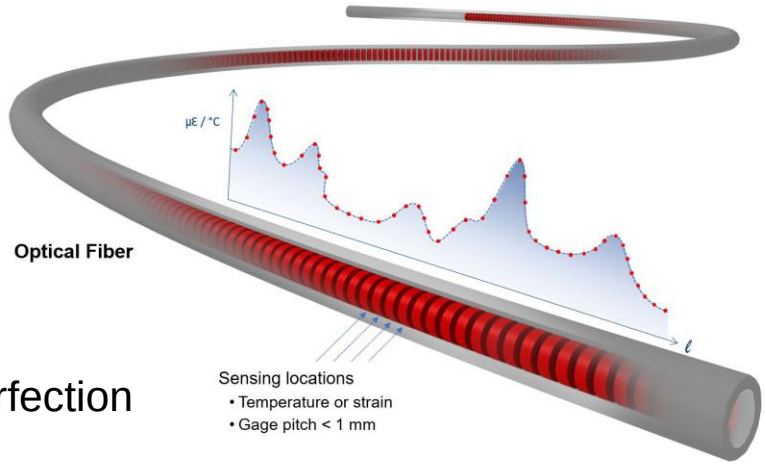


Cold Mass Production Achievements and Challenges

CM02 strain measured by strain gauges

- High-definition distributed fiber optic sensors are used

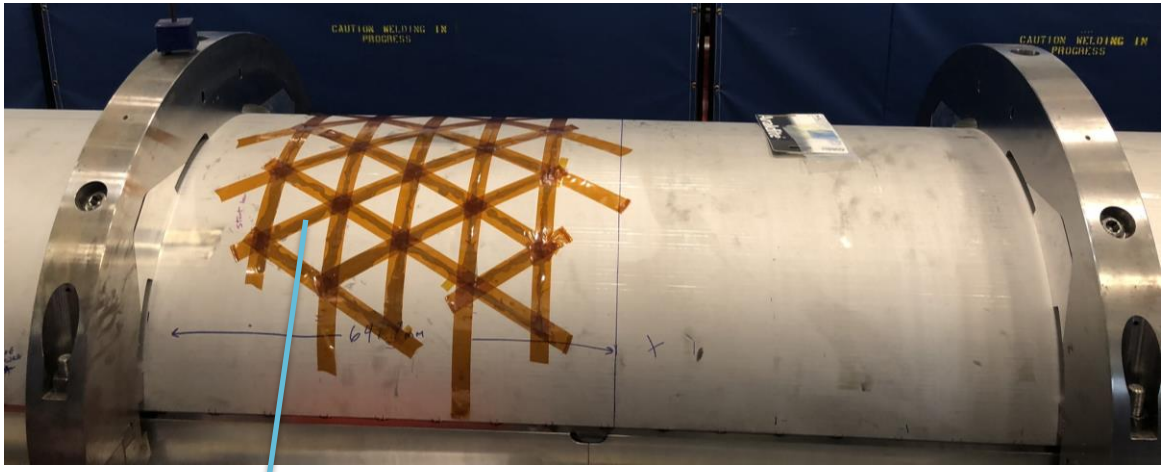


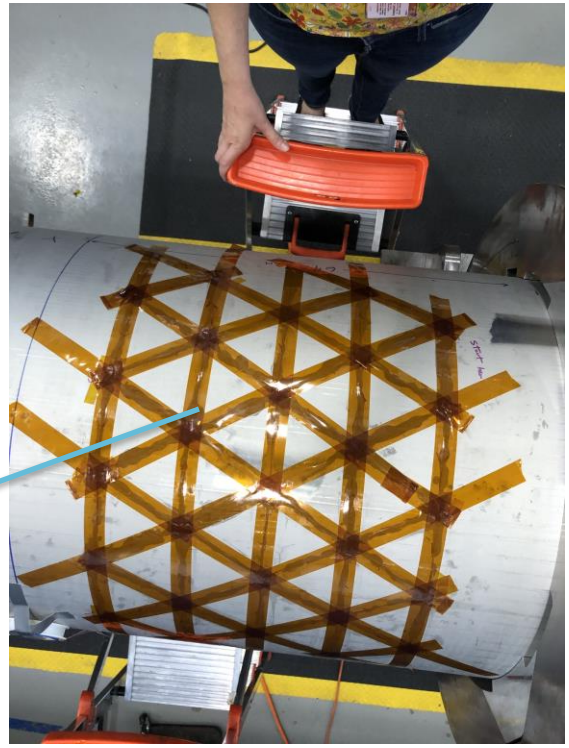


- Use Rayleigh backscattering from random imperfection
- Can be used as strain and temperature sensors
- Highest spatial resolution can be 0.65 mm
- Sensor length can go up to 20 m (30000 measuring points)
- Highest sample rate is 250 Hz with some length limitation

Cold Mass Production Achievements and Challenges

CM02 strain measured by strain gauges

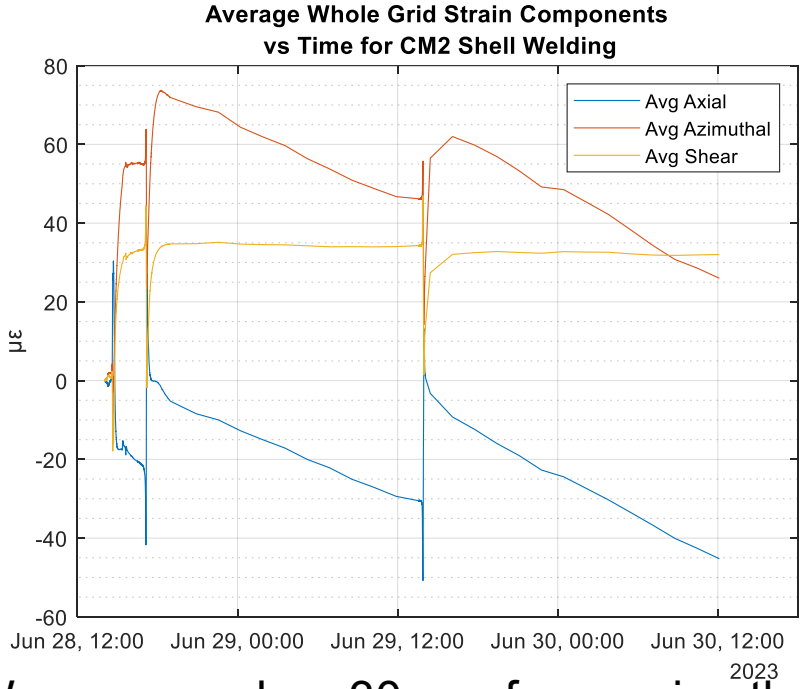


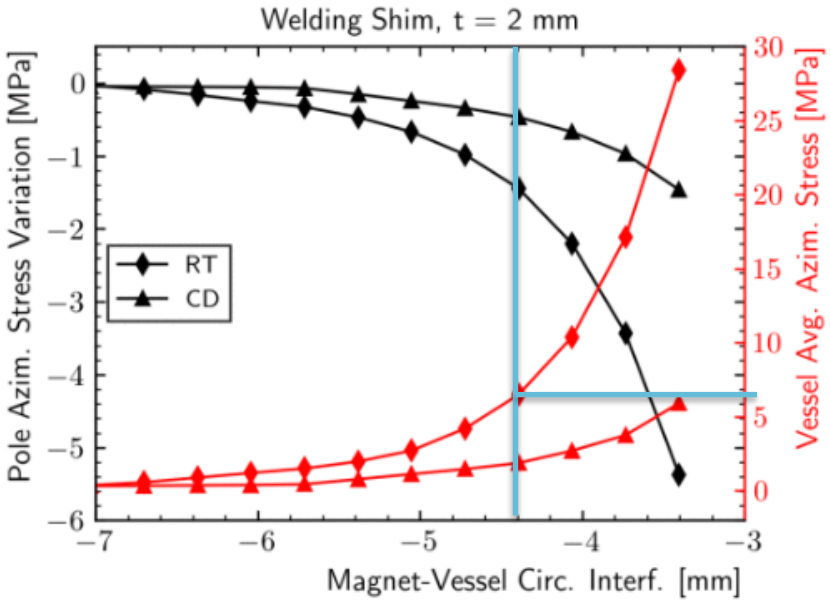


One 10 m long fiber
One 20 m long fiber (broke)

Cold Mass Production Achievements and Challenges

CM02 strain measured by strain gauges





We measured a ~30 με of avg azimuthal strain after the third welding pass in CM02. The presence of shims has reduced the stress value
Using the average azimuthal strain on the SS shell and a value of 200 GPa for stainless-steel Young modulus: 6 MPa SS stress in average. Good agreement with the target value.

Cold Mass Production Achievements and Challenges

Magnet alignment using Stretched wire technique

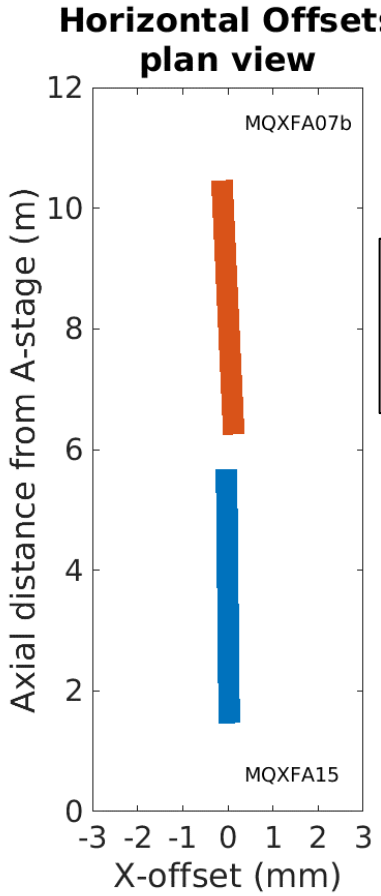
- Stringent requirement and tough measurement

Cold Mass Production Achievements and Challenges

Magnet alignment using Stretched wire technique

CM05 with final roll adjustment

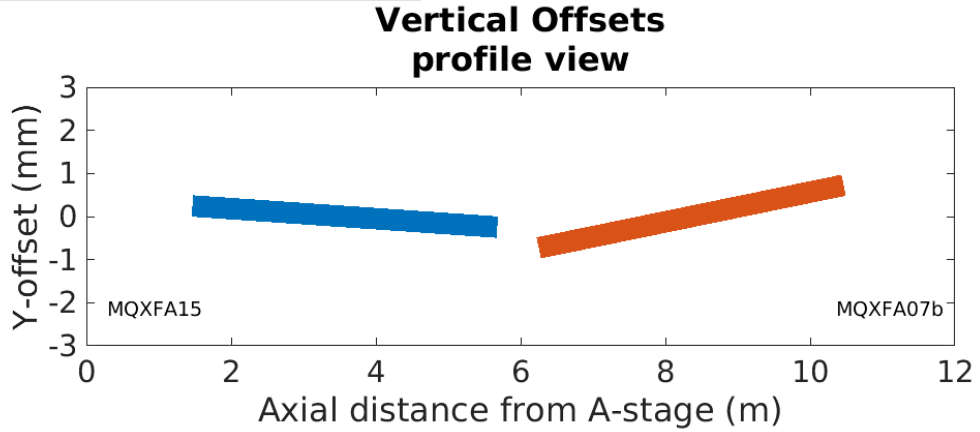
Alignment Relative to MQXFA15/MQXFA07b Average Center Line
07Aug2024 - Initial Meas. - after Zcen repositioning



MQXFA15 Lead End: X= 0.031, Y= 0.245 mm
MQXFA15 Interface End: X= -0.031, Y= -0.245 mm
MQXFA07b Interface End: X= 0.132, Y= -0.727 mm
MQXFA07b Lead End: X= -0.132, Y= 0.727 mm

A15 roll angle = -0.41 mrad
A07b roll angle = -0.07 mrad
Delta angle = 0.33 mrad
Ave angle = -0.24 mrad

A15 Z-dist A-stage to magnetic center = 3.5664 m
A07b Z-dist B-stage to magnetic center = 3.5588 m
Z-dist A15 to A07b = 4.7895 m (Lw=11.9147 m)

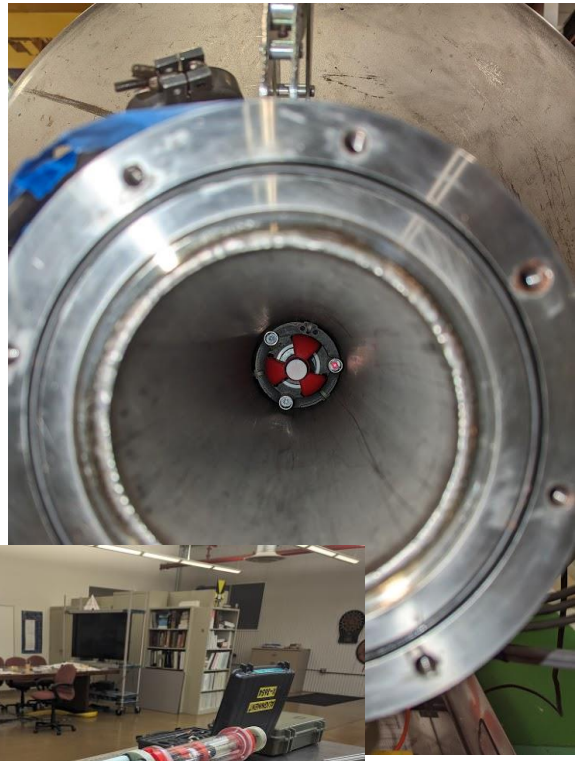


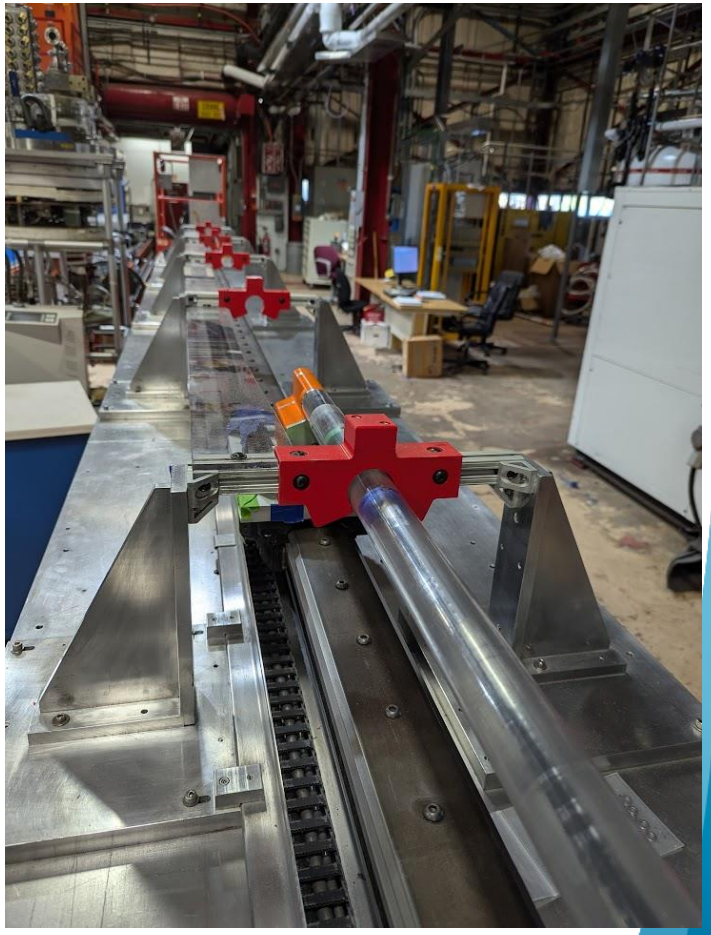
SSW_R_20240807_153720_AC_PitchYaw, SSW_R_20240807_161914_AC_PitchYaw

Cold Mass Production Achievements and Challenges

Magnet Measurements using LT

- Magnetic length, magnetic center and magnet separation

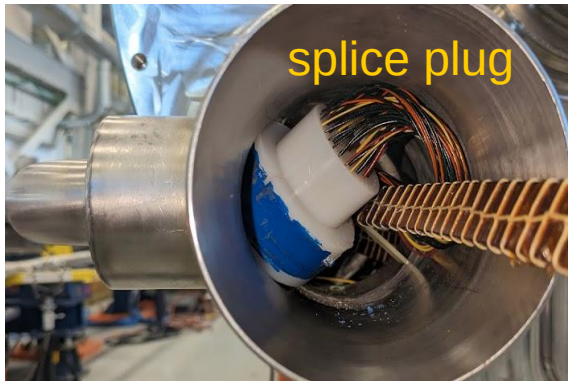


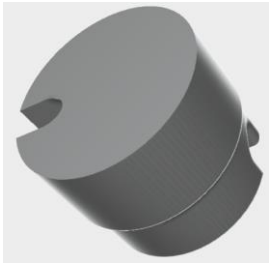


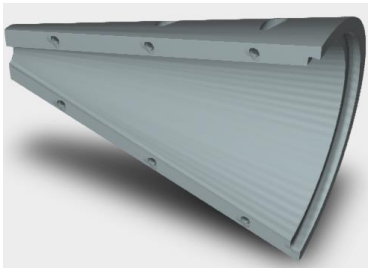
Cold Mass Production Achievements and Challenges

Cold Mass Lesson learned

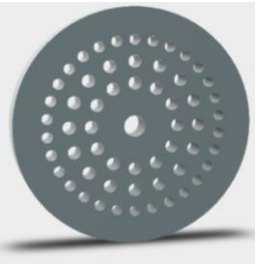
- Capillary tube – too many wires for tube diameter made it difficult to pull the wires through the 4 m long capillary causing the splice plug to be out of position in the cold mass tee.
  - Re-routed RTD instrumentation wires to reduce wire count in capillary tube.
  - Developed 3D printed tools to aid in wire alignment and wire pulling through the capillary tube.
  - Improved the wire splice robustness using barrel splice design, DocDb-4974.
  - Adopted CERN's water hipot procedure to test wire insulation integrity.







3D printed tools for wires



Cryo-assembly Production Achievements and Challenges

- Both CA02 and CA03 installation went very well
  - Lesson learned from CA02 was implemented in CA03
  - Essentially no major traveler revision was required for CA03
  - FSI target installation method was optimized using surveyors
  - Final positioning of the CM inside the cryostat procedure has been fine tuned using surveyors' measurements
- Combination pressure/leak test procedure has been developed with CERN and it has been approved both sides.
  - New pumping system has been procured and it is under installation
  - For CA02 still the leak test was not conclusive due to the contamination of the pumping system that was borrowed from the test facility

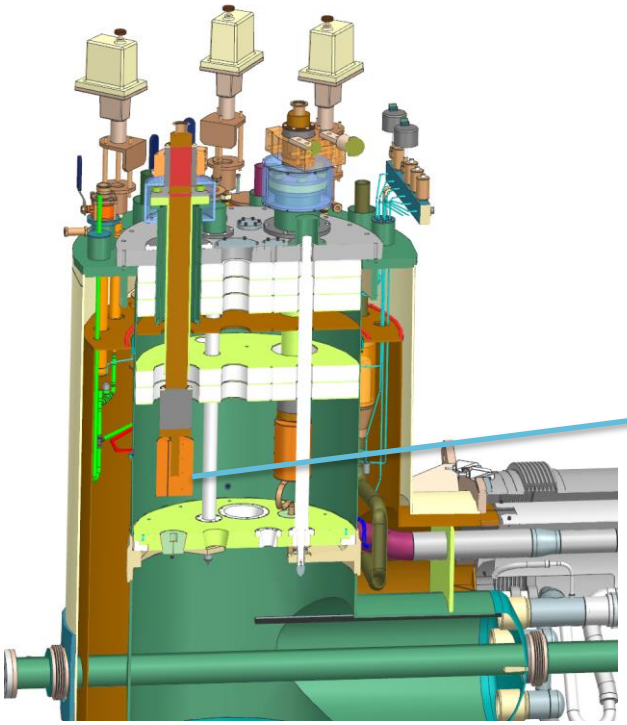
Cryo-assembly Production Achievements and Challenges

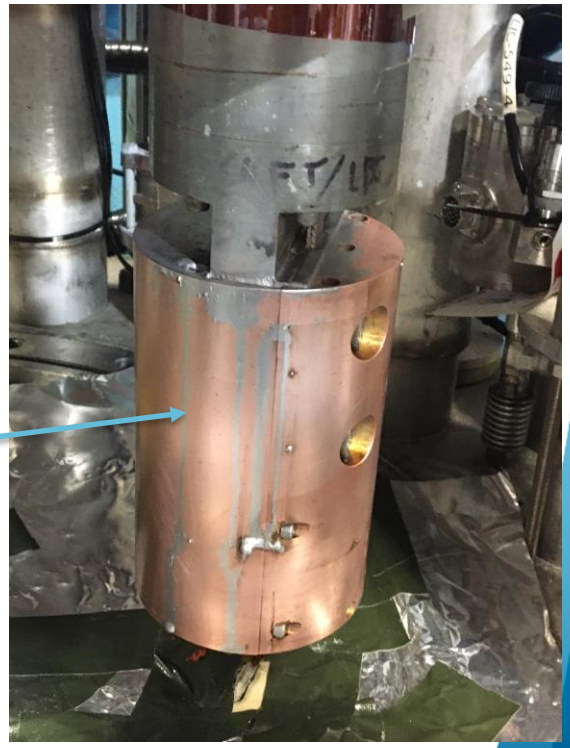
CA02 IFS Head to Flange Misalignment

- Root cause: IFS Assembly was cut at weld due to incorrect wiring.
- Corrective action: Wiring schematics were adjusted to correctly illustrate the orientation of the wiring.
- Made wire solder connections using new IFS head and welded in place.
- After welding there was a misalignment of the new IFS and the existing lower flange that was slightly distorted from the original weld.
- The issue meets requirements of ASME B&PV Code Sect. VIII div.2 and can be operational at FNAL, however, it does not meet ISO requirements and escalated to an NCR (LHC-QQXFA-QN-0012 (ver.1).

CA02 Test Status

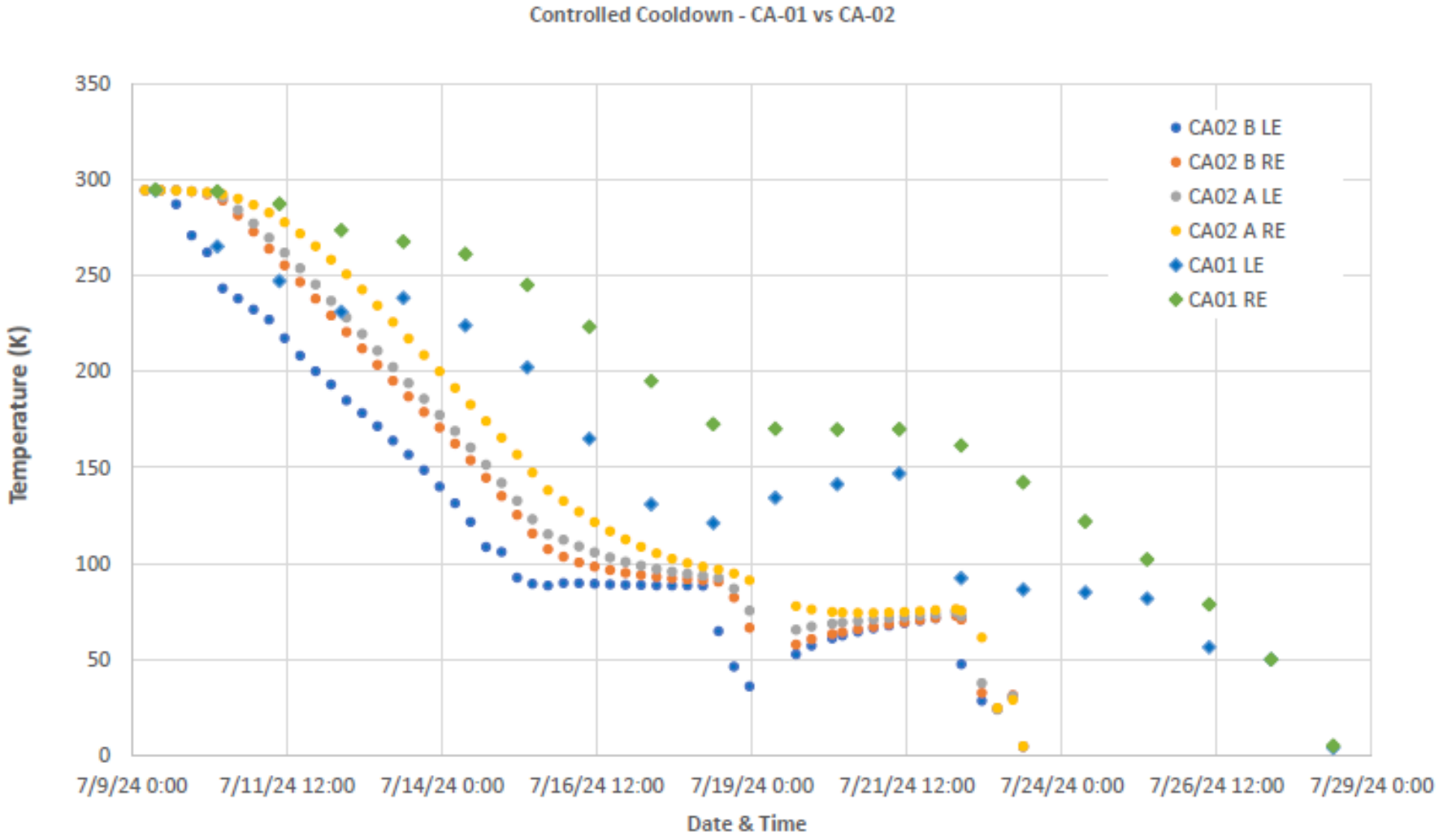
- The second pre-series cryo-assembly CA02 test is almost complete; so far, the test is very successful though the cryogenic facility was not able to satisfy the requested LHe delivery capacity on time; contributed a lot of delay to finish the test
- The test facility modifications/improvements were successfully completed
  - Added a heater to the He vapor suction line
  - New improved splice between the Power lead flag and the superconducting cable joint





CA02 Test Status

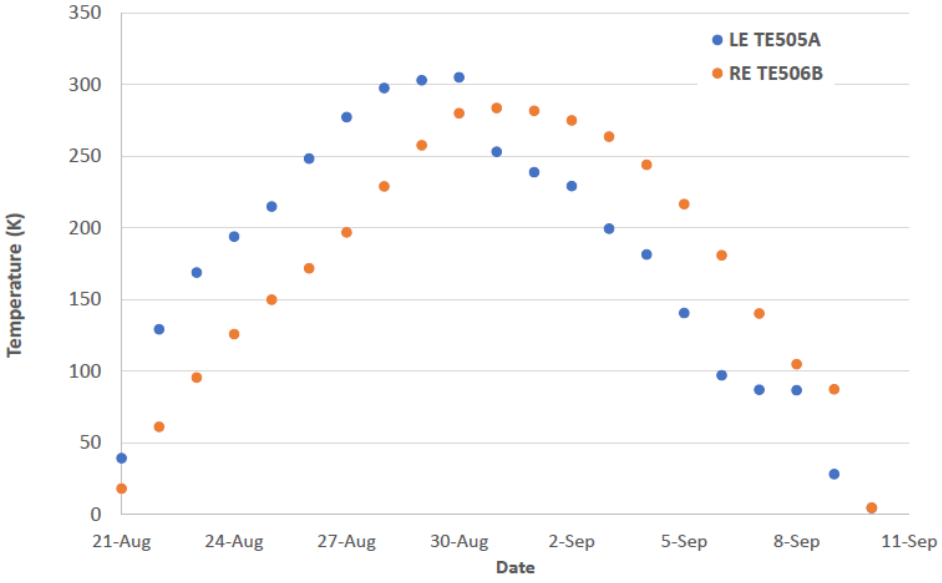
Controlled Cool Down

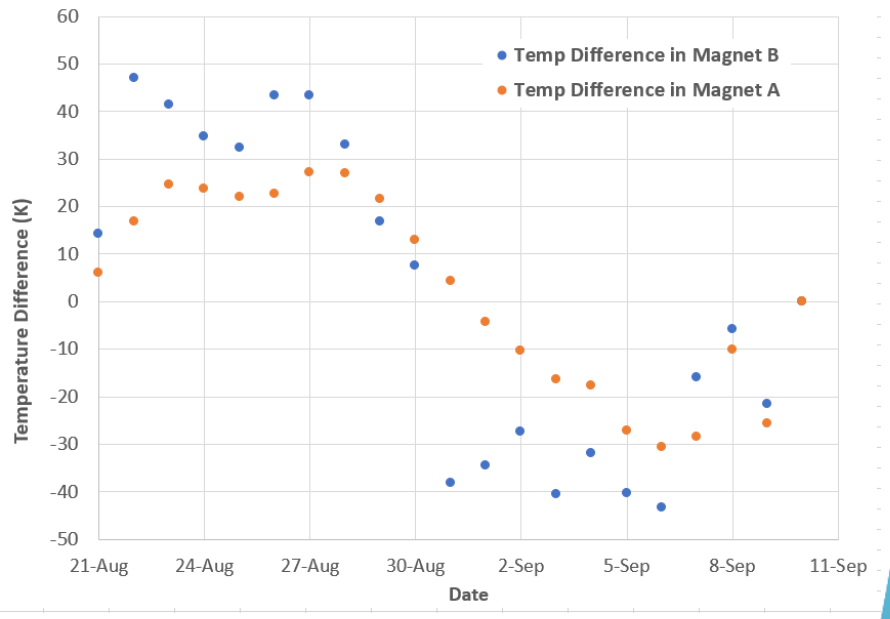


CA02 Test Status

Controlled Cool Down

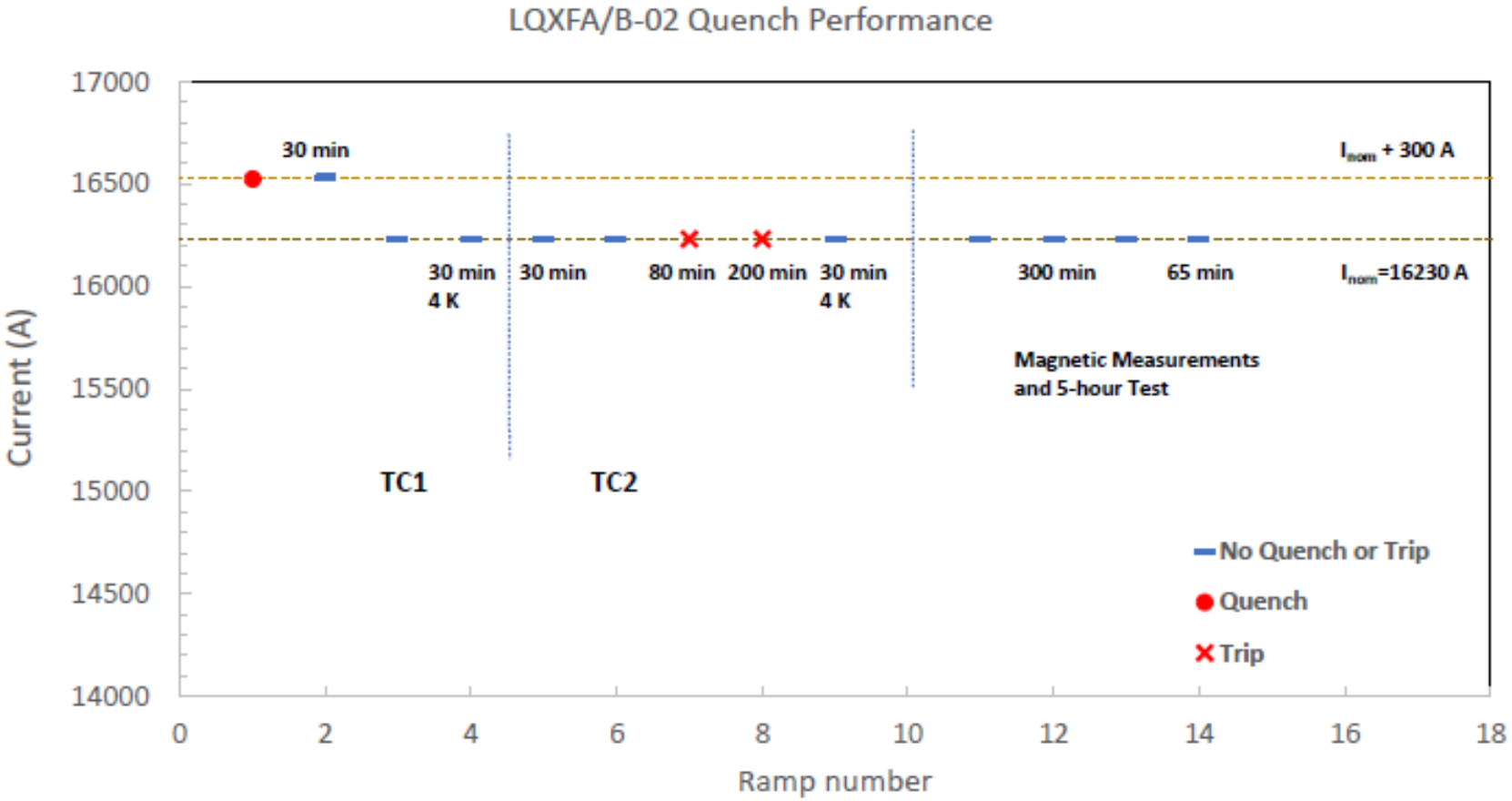
- Controlled warmup and cooldown requires 50 K temperature difference between the magnet ends
- TC was achieved within 19 days; there is still room for improvements





CA02 Test Status

- CA02 cold test results are satisfactory
  - Excellent vacuum pressure at cold 10^{-7} torr
  - Only one spontaneous quench; two trips – PS phase back glitch
  - Holding current test up 300 min successful

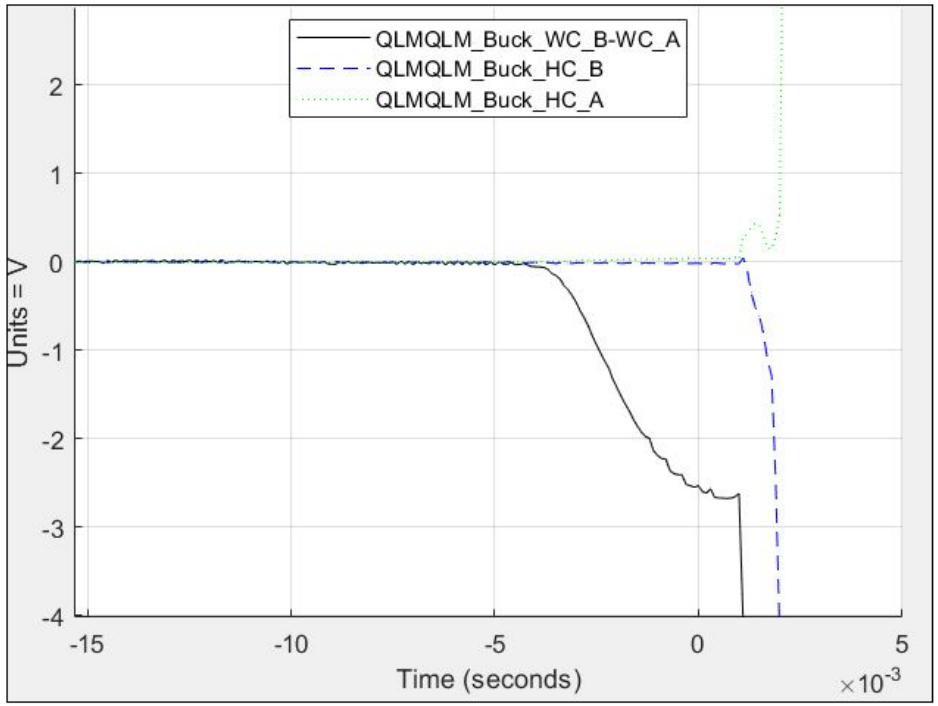


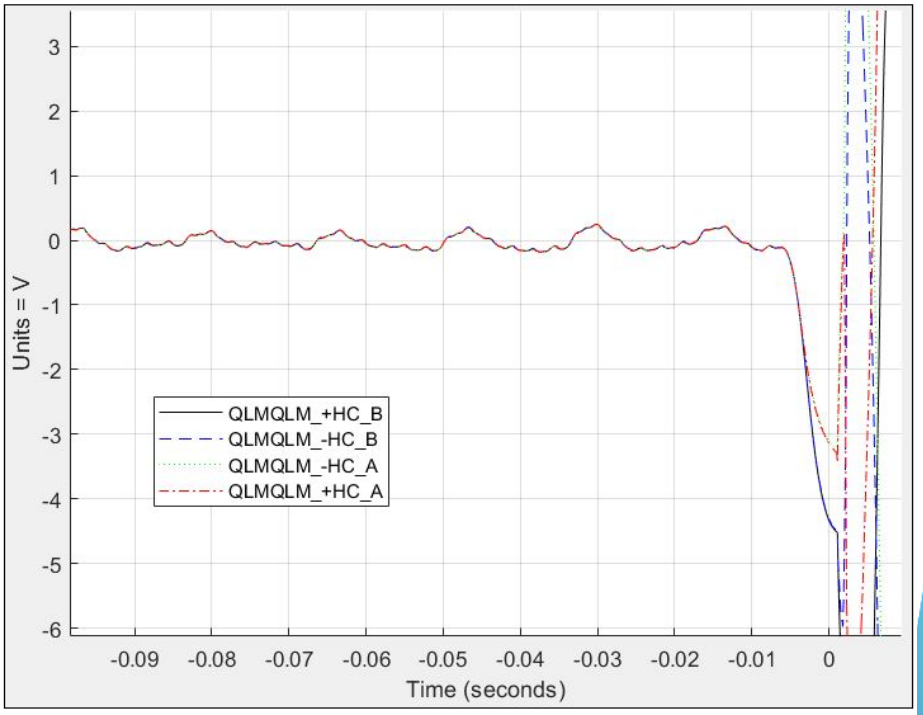
Conclusions

- Cold mass production and Cryo-assembly production progressing well
- Lesson learned implemented and installation speed is gradually increasing
- Lot of challenges were solved successfully
- CA02 test close to completion; only warm up is required
- CA02 cold test results are satisfactory

Backup slides

Trip


QLMQLM_Buck_WC_B-WC_A
QLMQLM_Buck_HC_B
QLMQLM_Buck_HC_A
Units = V
Time (seconds)
×10^-3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QLMQLM_-HC_B
QLMQLM_-HC_A
QLMQLM_+HC_A
Units = V
Time (seconds)