



**High
Luminosity
LHC**

2m Model Magnet Development of D1 and Plans

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2m-long Model Magnet - Overview

Single-layer coil, 4-split spacer collars, collared yoke by keying

$\phi 60$ mm HX hole

Notches and $\phi 34$ mm holes for iron saturation effects

Helix cooling channel

4 split stainless steel spacer collars: NSSC130S

Shell: SUS304L

Same outer-interface for J-PARC SCFM jigs

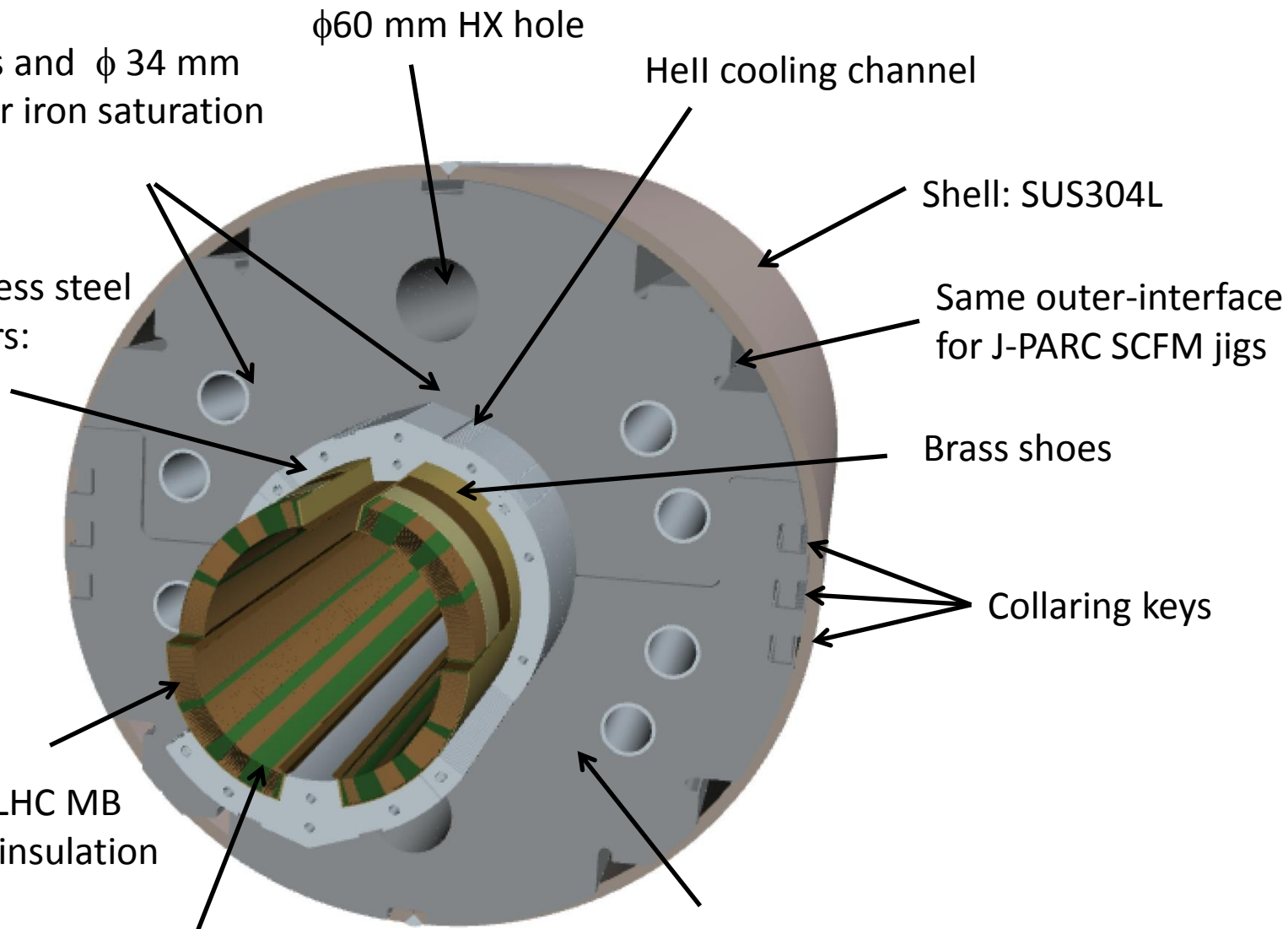
Brass shoes

Collaring keys

NbTi SC cable (LHC MB outer) + Apical insulation

Radiation resistant GFRP (S2 glass + BT resin) wedges

Horizontal split iron yoke: low-carbon steel (EFE by JFE steel) ²



Deliverables and Near-term Plan

***One 2m long model magnet will be built and tested at KEK.
The second model development is also planned.***

Up to now, one 2m long test coil was fabricated and the coil size measurement has been done.

- Dec. 2014 A short mechanical model
- April 2015 1st 2m long model
 - Field optimization by ROXIE and end spacer design are underway.
 - Coil winding would start at Jan. 2015.
- June 2015 Commissioning of test stand
 - A new header (cryostat flange) for D1. To be inspected by local government.
 - A new pair of 15kA CLs
 - Upgraded 15kA P/C and buses
- Sep. 2015 Cold test of 1st model
- Dec. 2015 2nd 2m long model
- Feb. 2016 Cold test of 2nd model

SC Cable Supply & Schedule

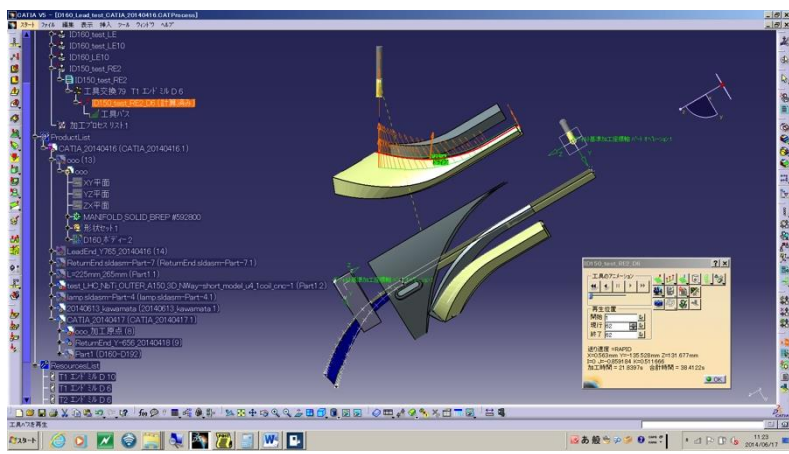
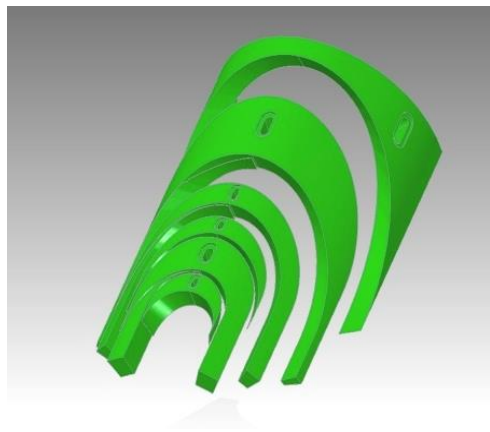
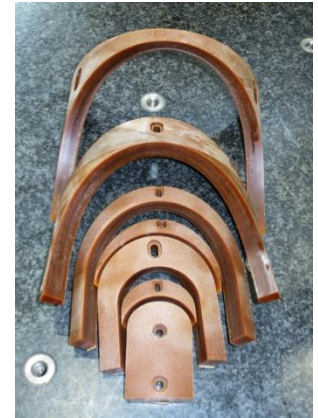
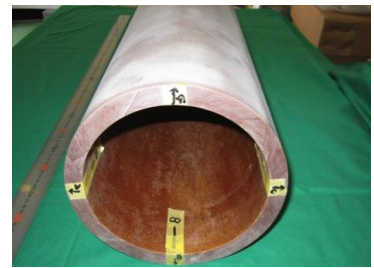
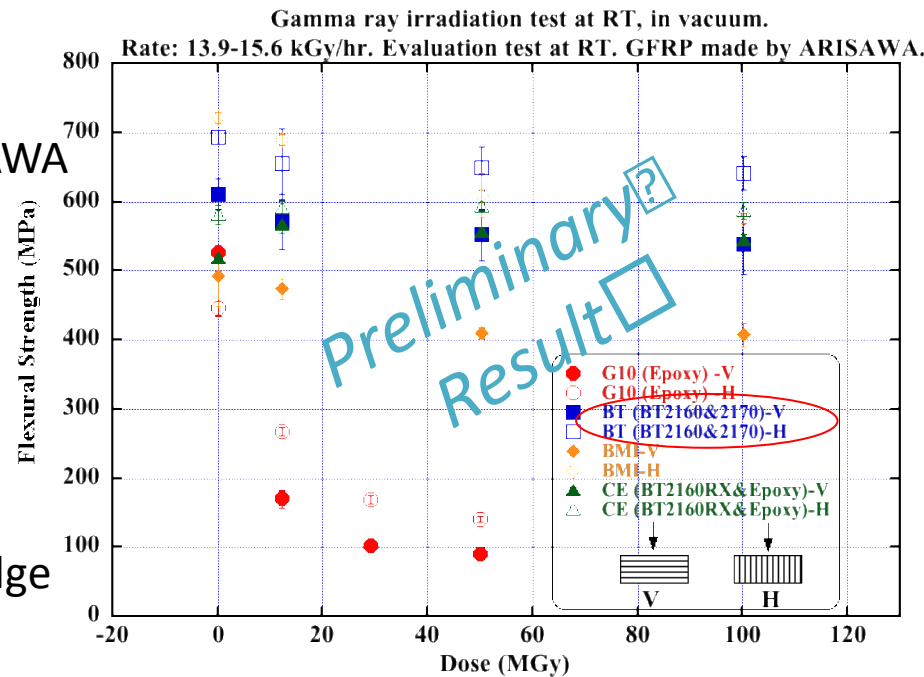
NbTi LHC MB outer cable supplied by CERN for the new D1 .

Delivery Date	Objective	Requirement	Remark
Feb. 2013	10 stack meas. (a piece length > 0.3 m)	~50 m w/ MB type insulation	Both MB inner and outer cables w/ MB type insulation
Jan. 2014 May 2014	1 practice coil* + 2 real coils for the 1 st 2-m long model + 1 spare coil	220 m** x 4	LHC MB outer cables w/ MB type Apical insulation
April. 2015	2 practice coils + 2 real coils for the 2nd 2-m long model	220 m x 4	LHC MB outer cables w/ MB type Apical insulation
JFY2016 (prospect)	6 or 7 full-scale magnets + 4 practice/spare coils	600-640 m x 18	LHC MB outer cables w/ MB type Apical insulation



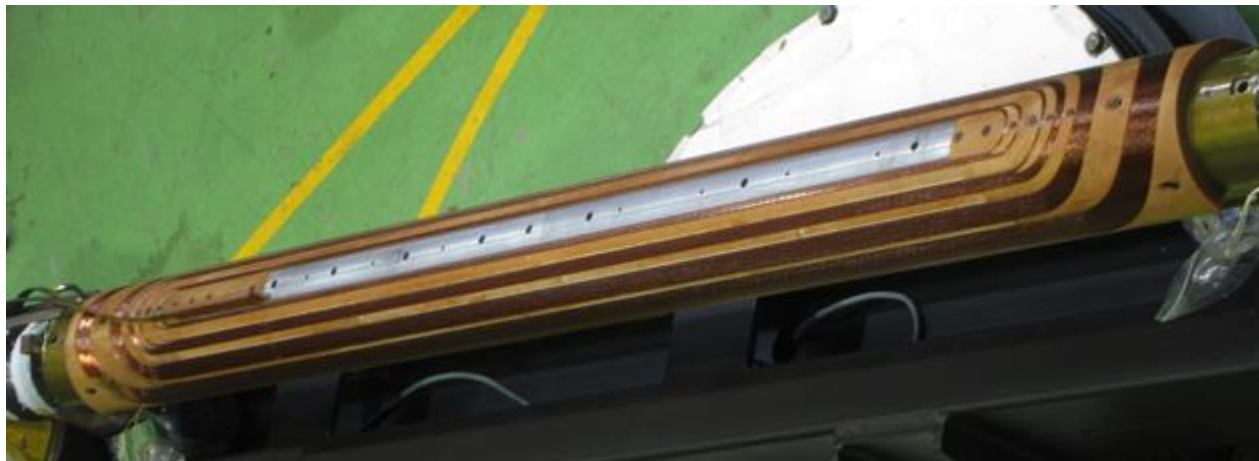
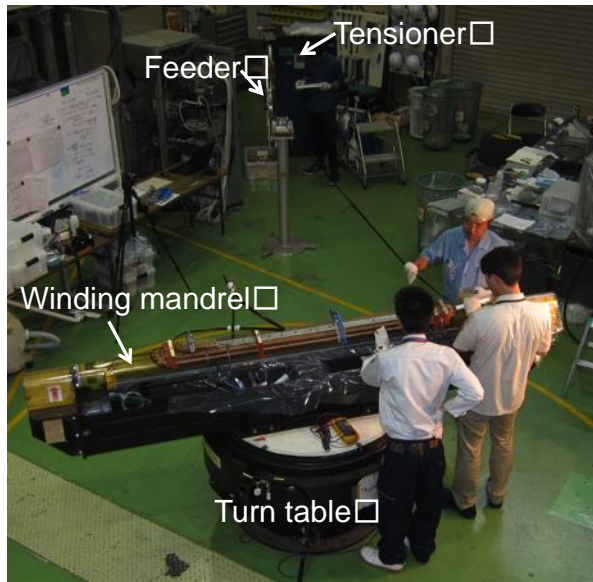
GFRP End Spacers, Wedges

- GFRP: MGC BT2160/2170 + S2 glass by ARISAWA
 - Radiation resistance beyond 50 MGy
 - similar modulus as G10: 29 GPa
 - But 30 % higher mechanical strength
- End-spacers: manufactured in-house
 - Design by ROXIE
 - Modeling with NX, Drawing with Solid Edge
 - CAD/CAM CATIA V5
- Wedges
- Adhesion: Cyanate Ester (MGC BT2160RX)



2m Model Coil

Demonstration of coil fabrication with a first 2m (test) coil.



The detail of test coil fabrication is presented by M. Sugano.

QPH & Spot Heater

- QPH might not be necessary for the D1 because peak temperature is estimated to be 300K by a conservative scenario.
- Quench Protection Heater (0.25 mm thick) for model magnet R&D
 - Still searching for manufacturer in Japan.
 - Possibility of supply from CERN
 - Necessity??
- Spot heaters will be implemented in the model magnet for the quench protection study.
 - higher field at the straight section
 - lowest field at the coil end (probably at lead-out)
- CLIQ might secure the quench protection?
 - Experimental study with the 1st model magnet

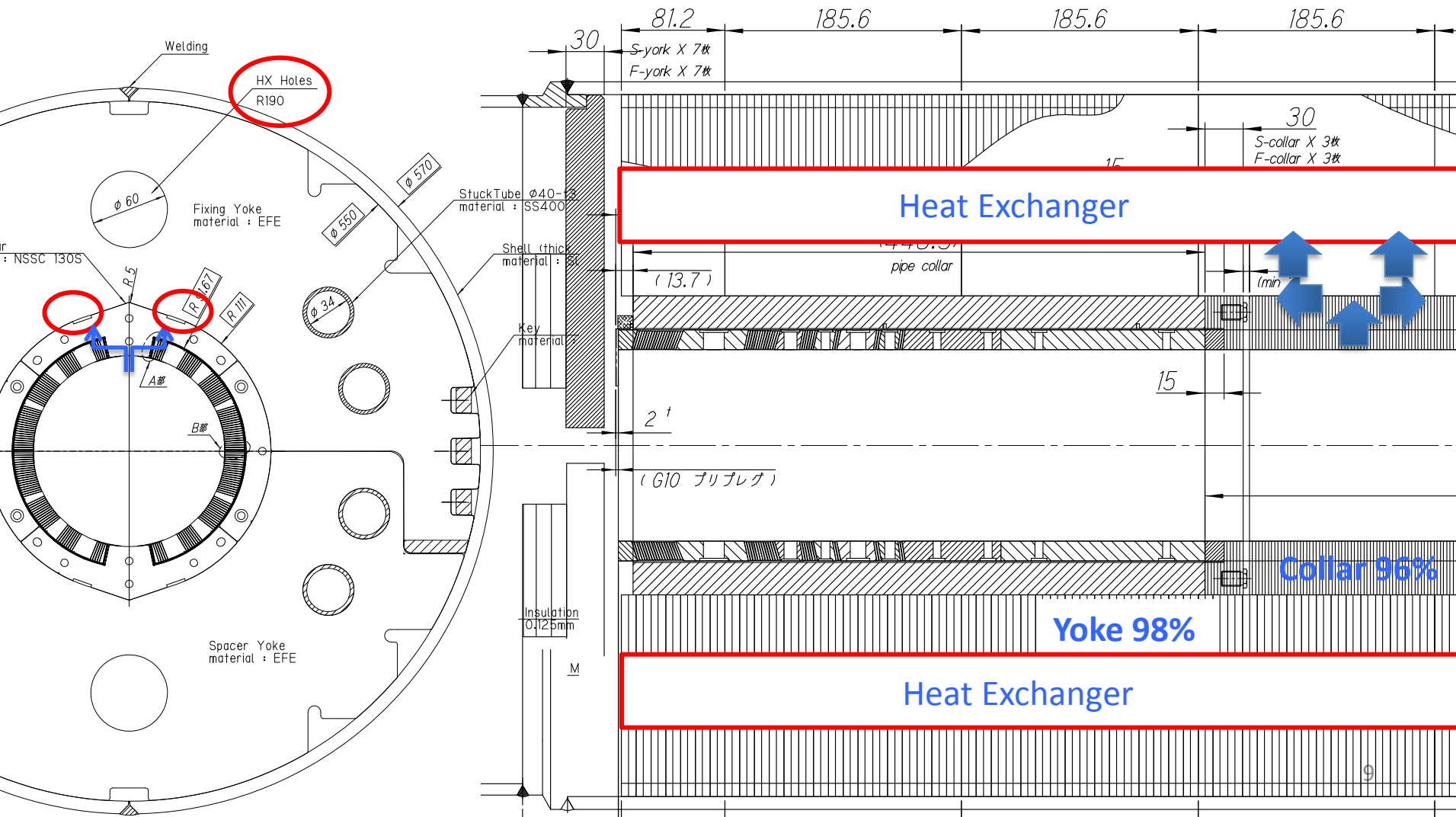
Requirement for Cooling

Suggestion by Rob:

- ◆ 2 x $\phi 57$ Hell HXs
- ◆ Radial gap of 4 % up to HX holes.
- ◆ Longitudinal free area >100cm²

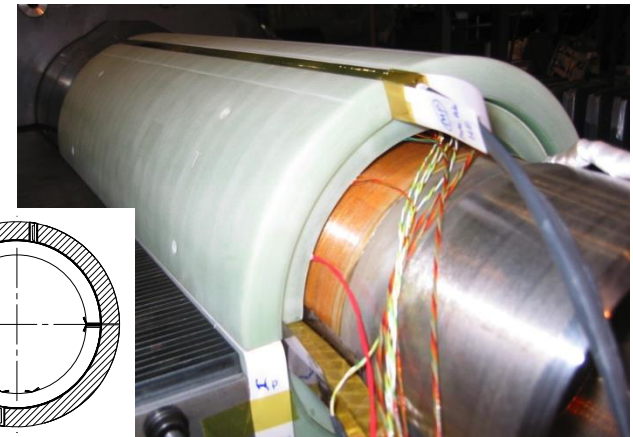
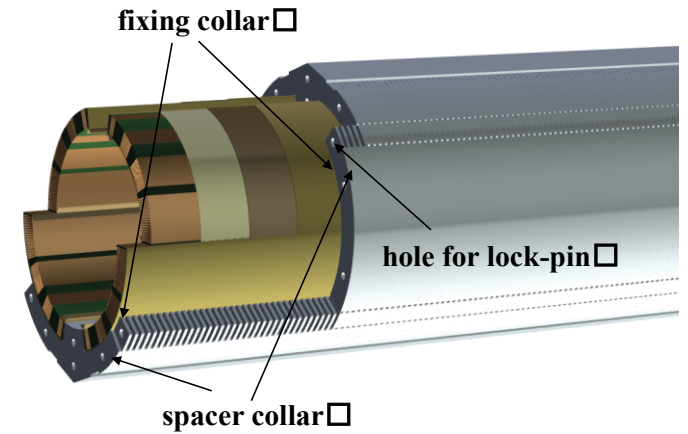
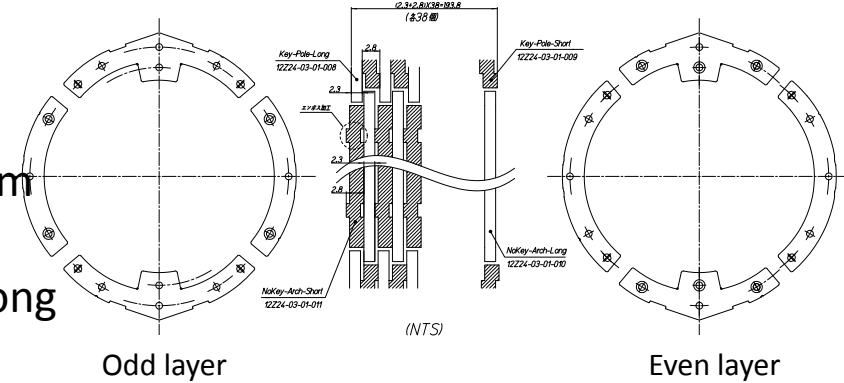


- New 2 HX holes: $\phi 60$ @R=190
- Collar lamination w/ 0.2mm gap by emboss
- Longitudinal grooves on collar: $d2 \times w20$, both sides of triangle notch.
- Yoke packing factor of 98 %
- Free area: 153 cm²



Collars

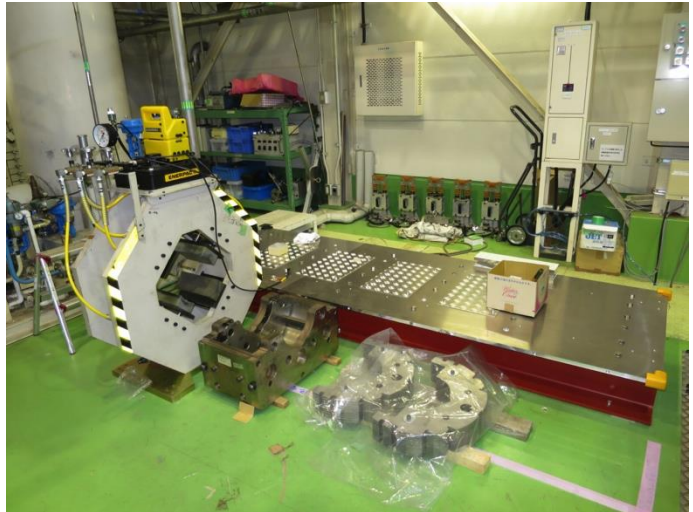
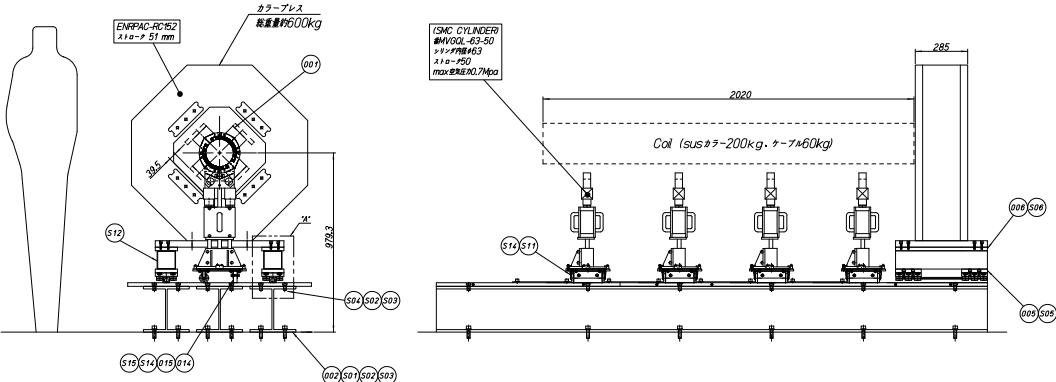
- Stainless steel: NSSC 130S (same as YUS130S)
 - 12 tons of NSSC-130S sheets (2.3mm & 2.6mm thick) delivered. This can cover the model magnet development and >30% of the 7-m long full-scale magnets production.
 - Specification, once set for the LHC MB, is fulfilled. Very low permeability of 1.002 confirmed at RT/4.2K.
- 4-way split collar concept for the dipole coil to avoid the unwanted warp at the fine-blanking process.
 - Collars work as spacers between the coil and the yoke.
 - A sub-stack of the collars is laminated by the 2.3mm thick “fixing collar” and the 2.6mm thick “spacer collar”. Similar with MQXA.
 - Four sub-stacks are connected by lock pins and provide the coil pre-stress below 5 MPa.
 - Emboss of 0.2mm
- Procurement of fine-blanking dies is on-going.
- Radiation resistant GFRP collar at lead end, same design concept as the J-PARC SCFM.



e.g.) GFRP collar to clamp the ramp box and the lead-out on the single layer coil for J-PARC SCFM.

Collaring Press and Mandrel

- Horizontal collaring press in preparation.
 - coil pre-stress below 5MPa.
 - coil deformation controlled by the collaring mandrel.



- Demonstration of collaring mandrel
 - 3D rapid prototyping.
 - Main mandrel can be removed by using “Flat Roller” after yoking.

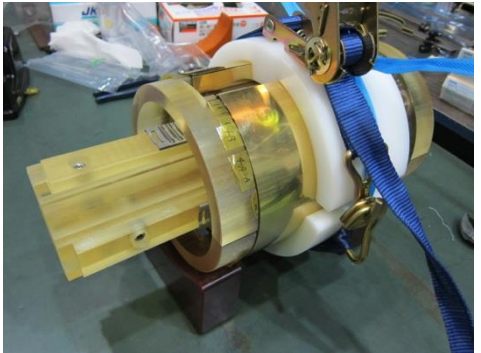
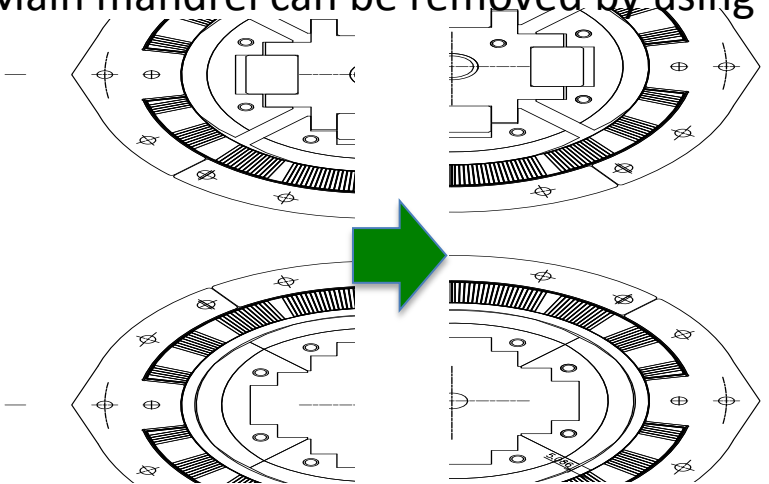
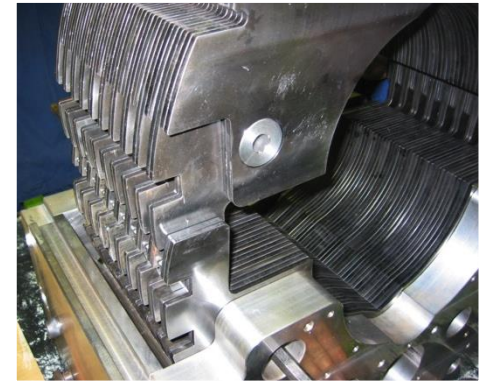
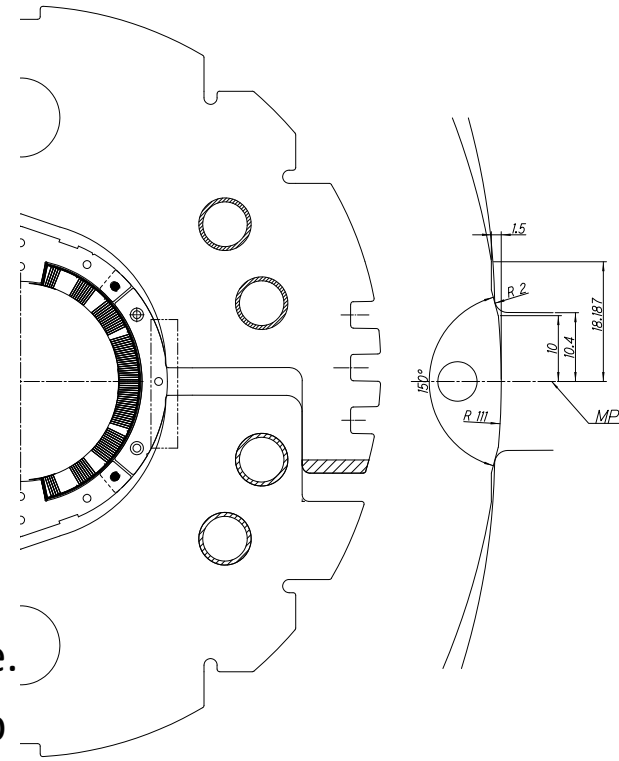


図	名	比例	材料	製法	備考
1	コラープレス	1:1	SS400	3Dプリンタ	
2	コラープレス	1:1	SS400	3Dプリンタ	
3	コラープレス	1:1	SS400	3Dプリンタ	
4	コラープレス	1:1	SS400	3Dプリンタ	
5	コラープレス	1:1	SS400	3Dプリンタ	
6	コラープレス	1:1	SS400	3Dプリンタ	
7	コラープレス	1:1	SS400	3Dプリンタ	
8	コラープレス	1:1	SS400	3Dプリンタ	
9	コラープレス	1:1	SS400	3Dプリンタ	
10	コラープレス	1:1	SS400	3Dプリンタ	

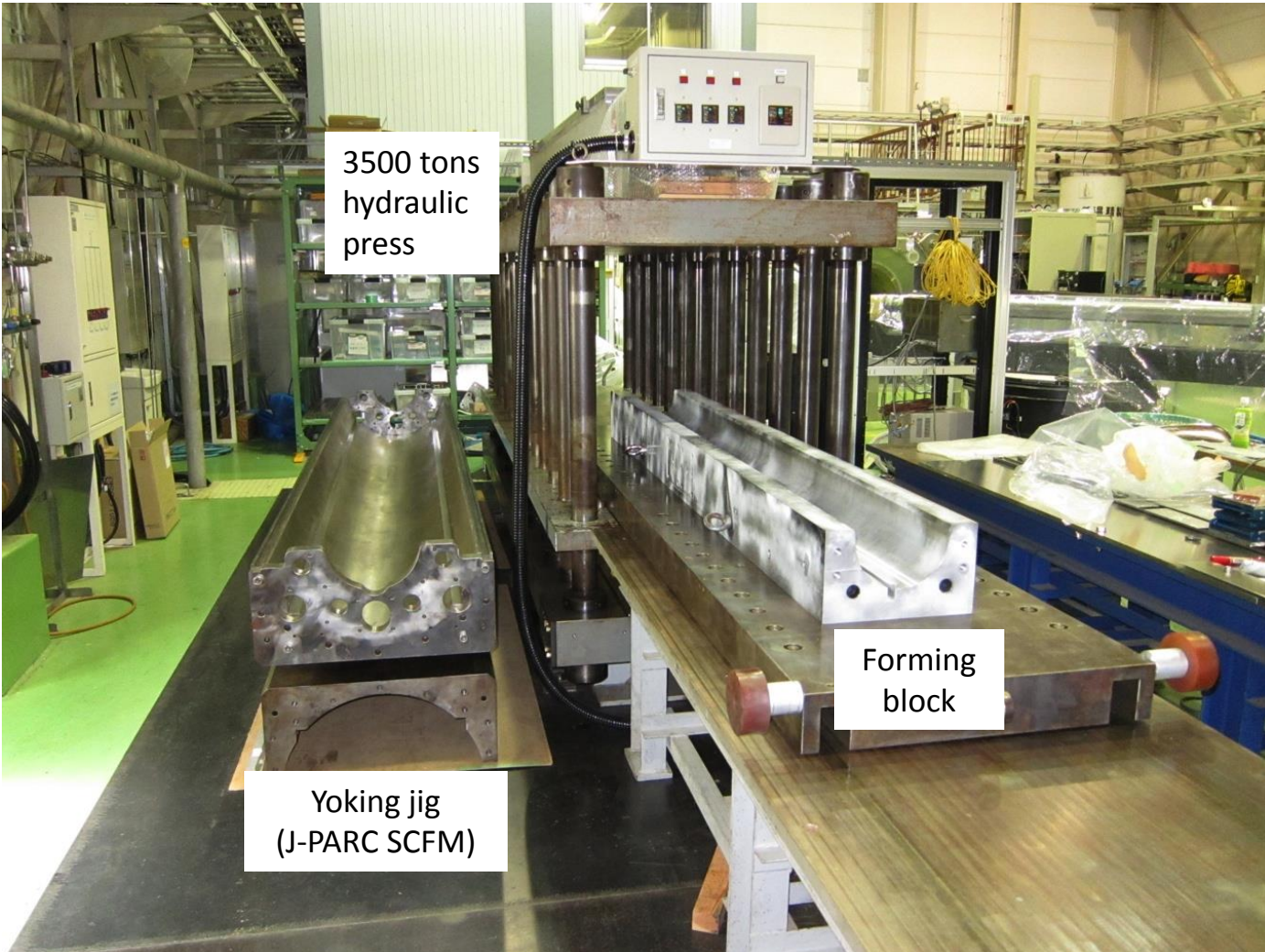
Yokes

- Low carbon steel: EFE by JFE steel
 - 15 tons of EFE sheets (5.6mm & 6mm thick) delivered for the model magnet.
 - Another 15 tons will be procured within this year.
 - Y.S.: > 240 MPa. Magnetic property: OK.
- Yoke is locked by 3 keys at each side. The coil pre-stress of 90-100 MPa will be given by the yoking.
- Mechanical short model study: Demonstration of mechanical structure
 - Concept of 4-way split collars and pre-alignment feature.
 - Increase of thickness difference (5.6mm & 6.0mm): help for yoke stacks assembly.
 - Coil pre-stress measurement at assembly and cool-down to LN₂ temperature
- For model magnet:
 - KEK placed an order of fine-blanking dies. Yoke stacks will be delivered by Feb. 2015.
 - Holes on the yoke sheet are not finalized and will be machined for the model magnets.



assembly of top and bottom yoke stacks for J-PARC SCFM

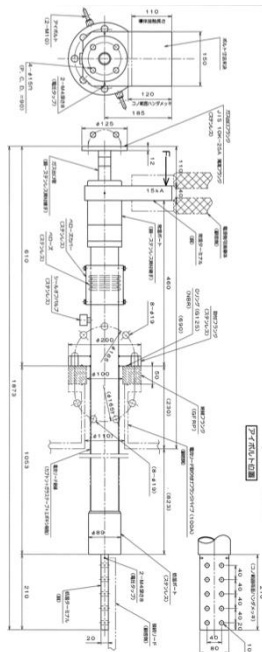
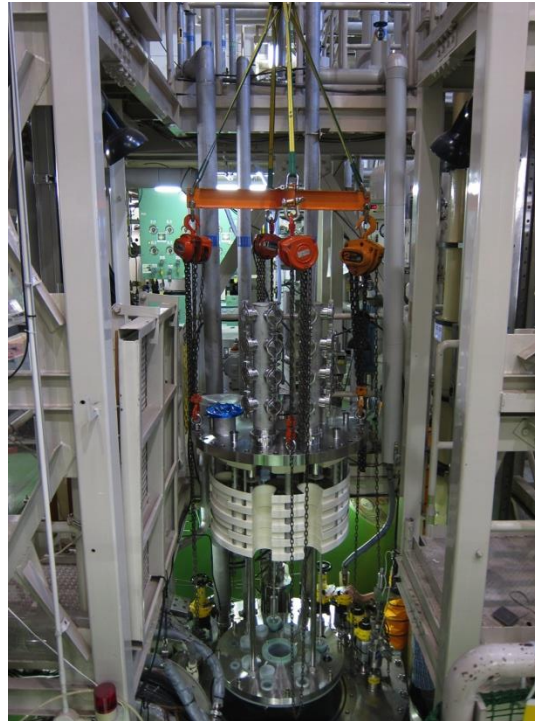
Presses, Jigs



3.6 m long hydraulic press for coil curing and yoking is ready.

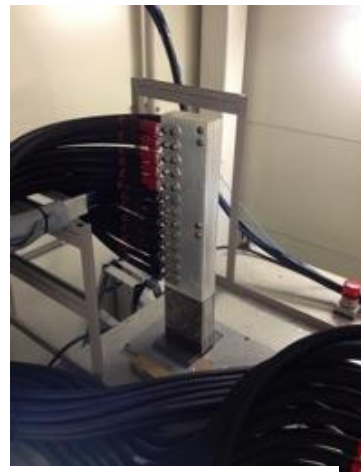
Preparatory Work for Cold Tests

- Modification and procurement of the cryostat for “12 kA, 150 mm aperture” D1 magnet.
 - Old Spec. of 9m-deep vertical cryostat: 7.5kA, 70 mm aperture dedicated for MQXA.
 - New header w/ larger warm bore.
- New 15 kA CLs to be delivered in March 2015
- Upgrade of PC and bus lines. (7.5 kA >> 15 kA).
 - New 15kA-DCCT procured by KEK is being calibrated at CERN.
 - New dump resistor of 75 mΩ with grounding at the middle.
- New DAQ systems



New 15kA-CLs

New header, cold tube, quench antenna



New 15kA bus lines

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