

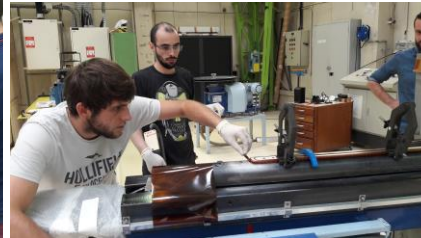


Status of MQYYM

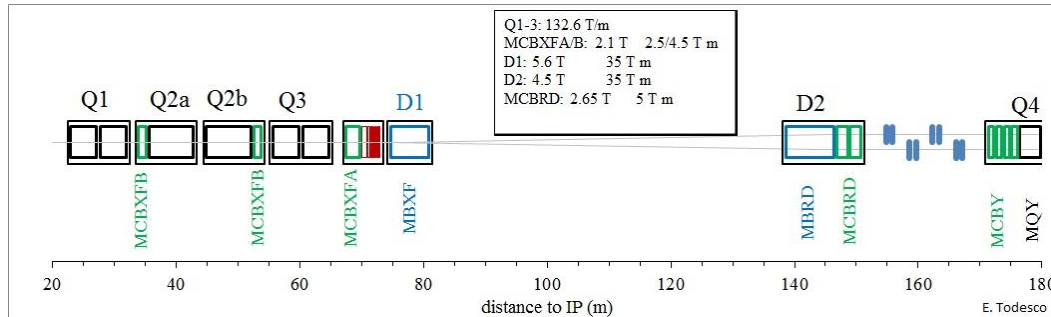
Helene Felice for the MQYYM team

CEA: D. Simon, M. Segreti, S. Somsom, R. Machado-Correia, R. Godon, E. Pepinter, Y. Rabi, J.M. Gheller, D. Bouziat, P. Graffin, G. Minier, H. Neyrial, J.M. Rifflet

CERN: : A. Foussat, J. C. Perez, N. Bourcey, L. Fiscarelli, O. Dunkel, G. Kirby, J. Fleiter, E. Todesco, M. Guinchard, P. Gros-Claude, P. Viret



History of MQYY development

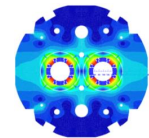


Q4 is the LHC MQY, double aperture quadrupole with 70 mm aperture

Layout of the magnets close to the interaction point

Initial HL-LHC baseline: use of **MQYY**, a new double aperture quadrupole with 90 mm aperture

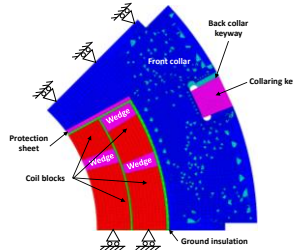
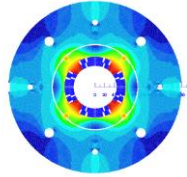
- **2011**: CEA- CERN initiative (J.M. Rifflet et M. Segreti) within the High Lumi design study (FR contribution)
- **March 2014**: CERN/CEA collaboration agreement => activities on MQYY (WP2)
- **September 2015**: Formal decision to change the cable
- **June 2016**:
 - **Decision to keep MQY to reduce cost (MQYY out of the baseline)**
 - Decision to continue with the development of MQYY short model and prototype
 - Updated CEA-CERN collaboration content: **Single aperture model MQYYM** developed by CEA and CERN
 - Parallel development: **two prototypes** developed in the QUACO initiative



Short Model and Prototypes

2 different paths

MQYYM Expected to be assembled and tested by mid 2019



11/2016

11/2017

08/2018

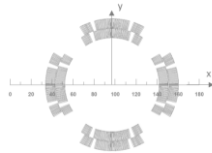
05/2020



Concept. Design
PHASE 1
4 months
11/2016 to 03/2017

Engineering Design
PHASE 2
13 months
07/2017 to 08/2018

Manufacturing
PHASE 3
18 months
11/2018 to 09/2020

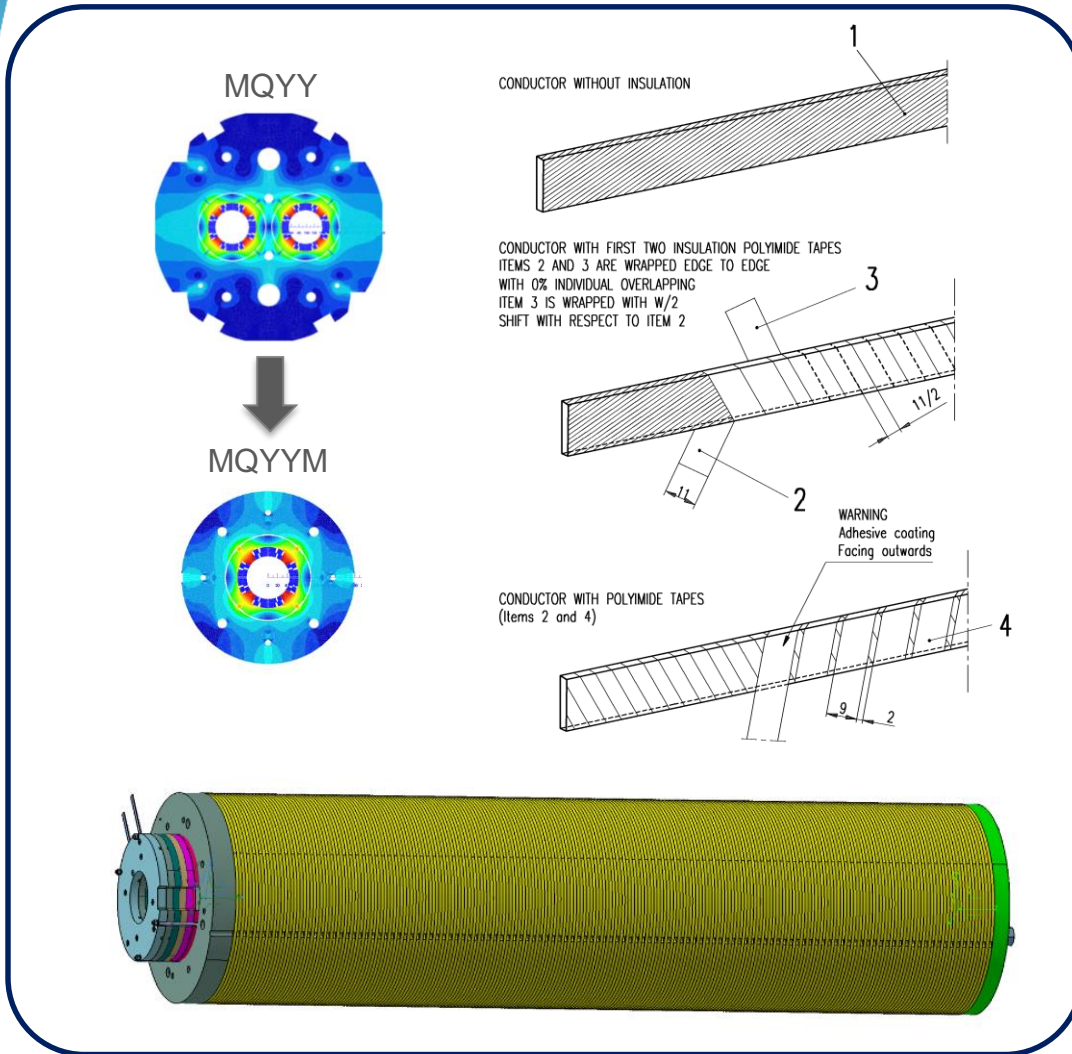


- Baseline magnetic design **provided but not imposed**
- ROXIE provided without the BEM FEM module
- Mechanical support structure design **up to companies**

see D. Simons talk



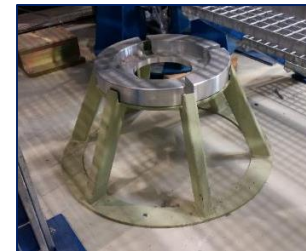
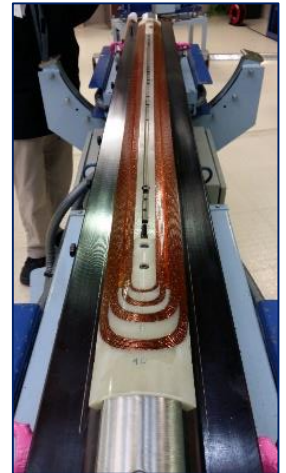
Overview of MQYYM



Physical length	1350 mm
Magnetic length at 1.9 K	1204 mm
Outer diameter	360 mm
Bare cable width	8.8 mm
Bare cable thickness	0.77/0.91 mm
Insulation thickness at nominal	0.080 mm
Short sample current	5980 A
Operating Gradient	120 T/m
Operating current	4550 A
Bpeak at operation	6.42 T
Loadline margin	23 %
Prestress level	60 MPa

MQYYM Manufacturing plan

- **Conductor from CERN**
 - Insulated conductors for 10 coils at CEA
- **Coils fabricated at CEA/Saclay**
 - Winding and polymerization
 - Coil instrumentation
- **Assembly will be performed at CERN (927) by CEA team supported by 927 team**
 - Collaring using 927 collaring press
 - Connection box assembly
 - Yoking
 - Warm Magnetic measurements
- **All components designed by CEA**
- **All interface tooling or specific tooling designed by CEA.** Design is supported/reviewed by N.Bourcey and J.C. Perez
 - Winding tooling
 - Assembly tooling (based on CERN existing tooling)
 - Coil measuring tooling (based on CERN existing tooling)
 - GPI forming tooling
 - ...
- **Procurement**
 - < 5 kCHF: order placed directly by CEA
 - > 5 kCHF: procurement through CERN but followed by CEA
 - Writing of a CERN spec by CEA team
 - Nordine Azizi / Arnaud Foussat (CERN)
 - Hubert Neyrial / H el ene Felice (CEA)



Most of the orders

H. Felice for the MQYYM team

Coil Fabrication status as of Nov 2017

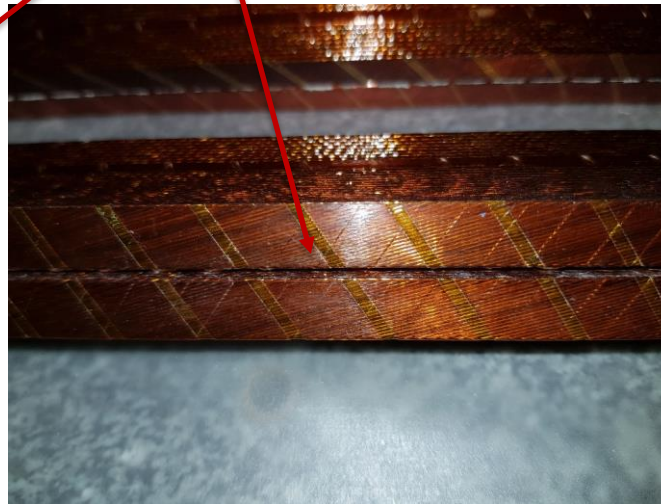
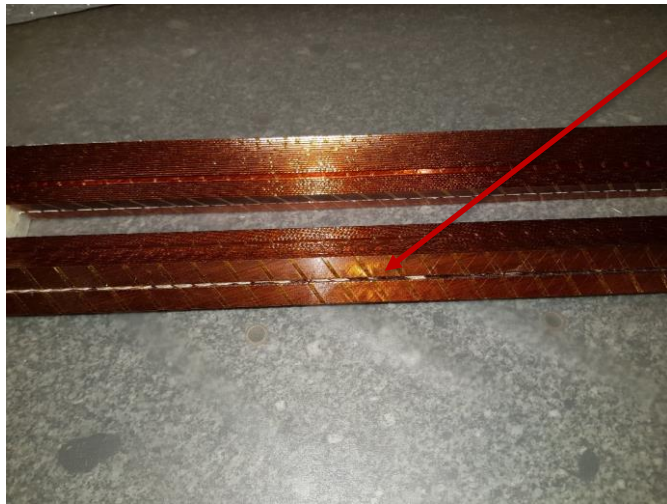
	Fabrication dates
Coil 0	22/03-27/04/2017
Coil 1	17-31/07/2017
Coil 2	4-14/09/2017
Coil 3	15-29/09/2017
Coil 4	23-31/10/2017



- Initial plan in agreement: 10 coils
- Cable at CEA for 10 coils
- End parts manufactured for 8 coils (coils 0 to 7)
- 5 coils made: coil 0 + coils 1 to 4

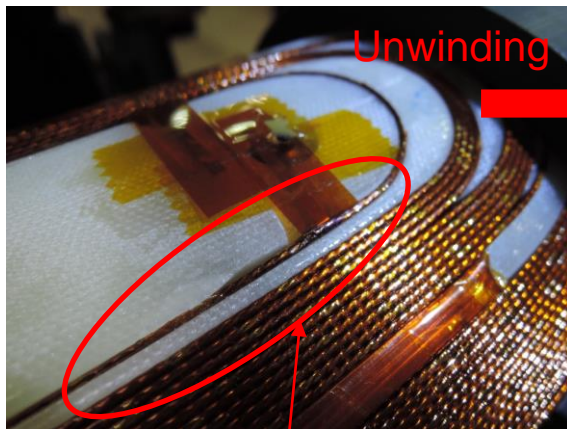
Coil Fabrication status

	Conforme	Electrical tests	Non-conformity	Possible repair	Risk
Coil 0	No	Not conform	Practice coil, vtap practicing	No	
Coil 1	No	OK	Damaged insulation and 1st set of end spacers	No	
Coil 2	Yes	OK			
Coil 3	Yes	OK			
Coil 4	No	OK	Ends with low compaction	Filling of the ends	Low
Coil 5	No	Not tested	Damaged interlayer insulation in the straight section	Filling in the area where the insulation has been torn	High

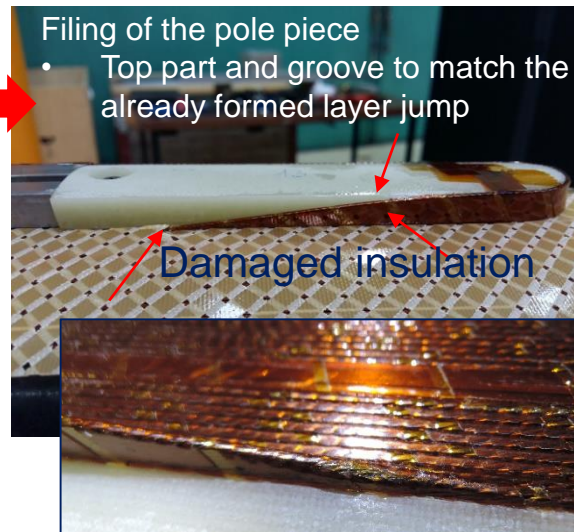


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	Conforme	Electrical tests	Non-conformity	Possible repair	Risk
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Coil 4	No	OK	Ends with low compaction	Filling of the ends	Low
Coil 5	No	Not tested	Damaged interlayer insulation in the straight section	Filling in the area where the insulation has been torn	High
Coil 6	No	Not tested	Mispositionned Layer jump Layer 2: unwound and rewound	No	Medium



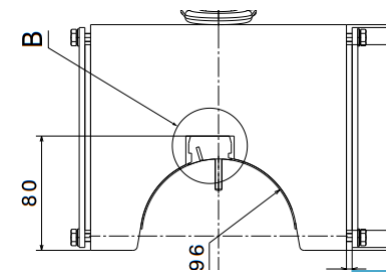
Layer jump is mispositionned
G11 seems weakened locally



- At QA step: notice an issue with the layer jump
- Decision to unwind layer 2
- Damaged insulation repaired and layer rewound

Coil Fabrication status as of April 2018

	Conforme	Electrical tests	Non-conformity	Possible repair	Risk
Coil 0	No	Not conform	Practice coil, vtap practicing	No	
Coil 1	No	OK	Damaged insulation and 1st set of end spacers	No	
Coil 2	Yes	OK			
Coil 3	Yes	OK			
Coil 4	No	OK	Ends with low compaction	Filling of the ends	Low
Coil 5	No	Not tested	Damaged interlayer insulation in the straight section	Filling in the area where the insulation has been torn	High
Coil 6	No	Not tested	Mispositionned Layer jump Layer 2: unwound and rewind	No	Medium
Coil 7	No	Not tested	IL Damaged insulation and possible overcompression of a turn	No (inner layer unwound to reuse the outer layer cable)	



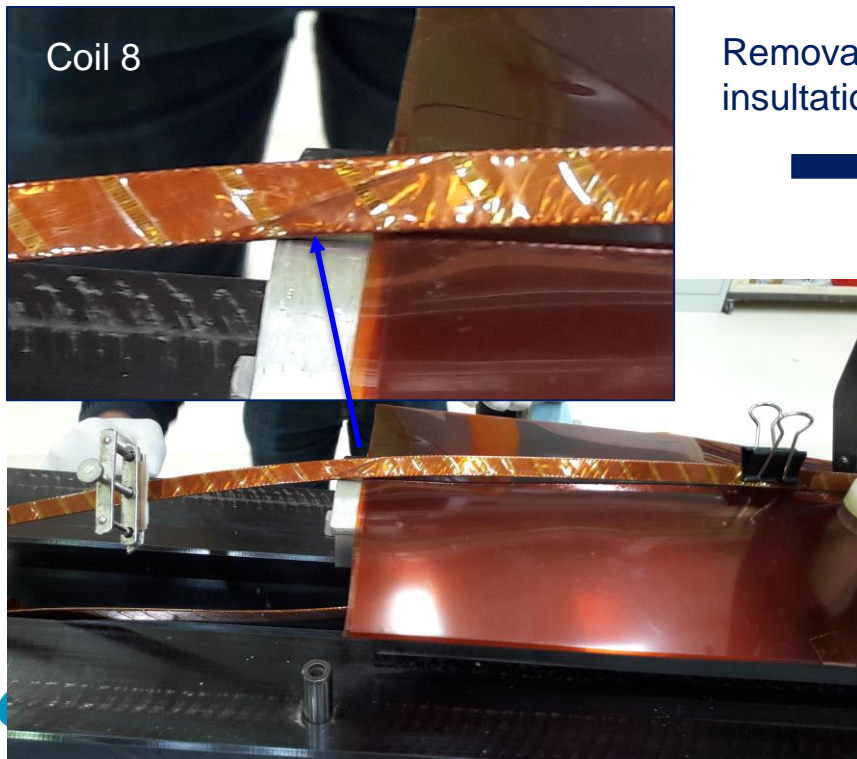
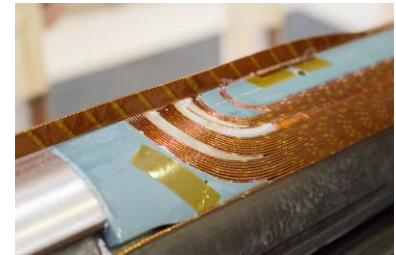
Coil Fabrication: end of the story

Decisions made in April 2018

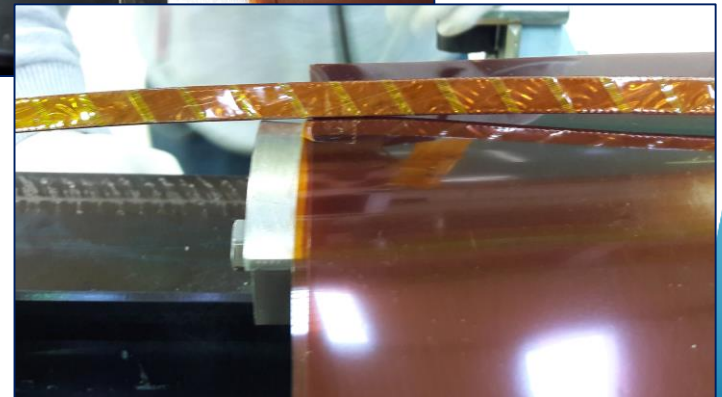
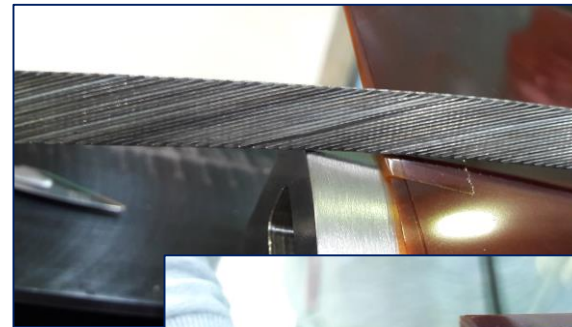
- Agreement to make two additional coils (back to initial agreement)

Follow-up actions

- Procurement of End parts for coil 8 and 9
- Workshop unavailable from May to Early July 2018
- Next steps :
 - Validation of the repaired curing mold (blue stone parts) →
 - **Coils 8 and 9 fabrication targeted by end of september 2018**



Removal of insulation



Coil Fabrication status as of Oct 2018

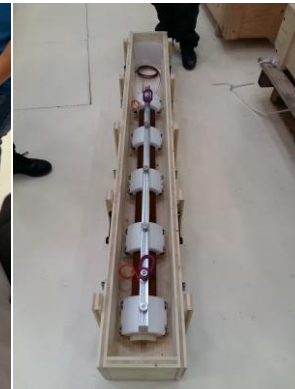
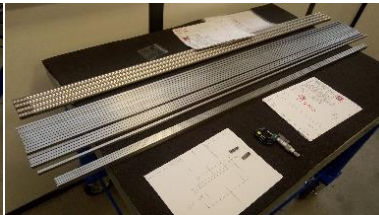
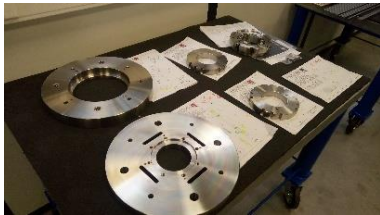
	Conforme	Electrical tests	Non-conformity	Possible repair	Risk
Coil 0	No	Not conform	Practice coil, vtap practicing	No	
Coil 1	No	OK	Damaged insulation and 1st set of end spacers	No	
Coil 2	Yes	OK			
Coil 3	Yes	OK			
Coil 4	No	OK	Ends with low compaction	Filling of the ends	Low
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Coil 6	No	Not tested	Mispositionned Layer jump Layer 2: unwound and rewind	No	Medium
Coil 7	No	Not tested	Damaged insulation and possible overcompression of a turn	No (inner layer unwound to reuse the outer layer cable)	Unwound after decision to make 2 more coils.
Coil 7 mock up	Validation of the curing sheet repair				
Coil 8	No	Not tested	Popped strand	repaired	Very low
Coil 9	Yes	Not tested			

Pending electrical QA => assembly of MQYYM with coils 2/3/8/9 (coil 4 spare)

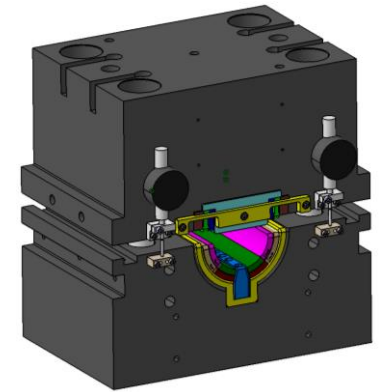
Status on components and tooling procurement

Components	Status
End parts	Procured for 8 coils (2 + 6) Procured for additional 2 coils
Cu wedges	Procured for 10 coils
Interlayer insulation	Procured for 10 coils
Collar	Procured / at CERN
Yoke	Procured / at CERN
End flanges	Procured / at CERN
Keys, tie rods...	Procured / at CERN
Connection box + G11 components	Procured / at CEA and CERN
Collaring shoe and protection sheets	Procured
Traces	Available

Tooling	Status
Coil fabrication tooling	Completed in 02/2017
Magnet assembly tooling	Delivered at CERN early 03/2018
GPI forming tooling	Delivered at CERN early 10/10/2018
Coil rigidity measurement tooling	Partially delivered (DMP)
Splicing tooling	Delivered at CEA
Coil Transportation tooling	Delivered at CEA
Aperture support	Delivered at CEA
Magnet transportation tooling	On order, delivery planned by the end of october at CERN
Magnet tilting tooling	



Focus on critical path

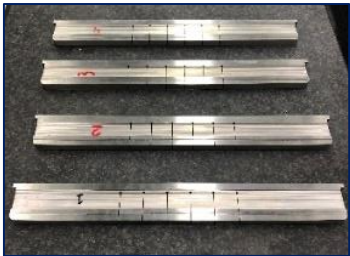


Critical path related to the coil rigidity measurement tooling

- Initial delay due to late order
- Order placed on Dec 7th 2017 with FMI, Netherlands
- FMI broke the contract at the end of January 2018

Actions implemented

- New order with DMP placed on May 7th 2018 after successful prototyping phase
- Kick-off meeting held on June 5th 2018 (CEA team + J.C. Perez)
- Attempt to optimize the schedule at DMP by requesting parts 8 in priority
 - Targeted Delivery: End of September 2018
 - Effective delivery of critical parts: Oct 15th 2018, non critical parts on their way

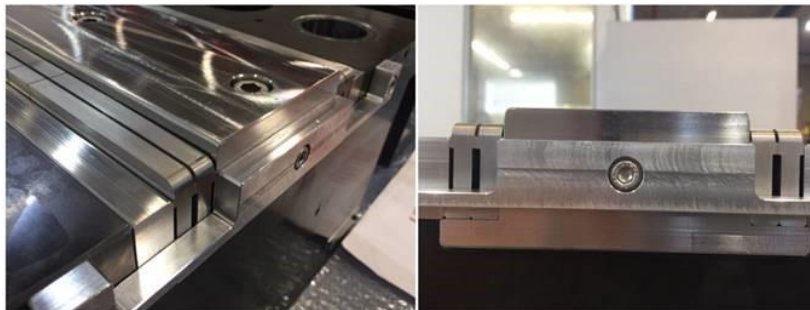
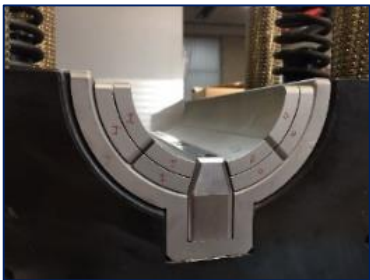


Ongoing work

- Instrumentation and calibration of the measuring bars by M. Guinchard's team => by end of November

Next steps

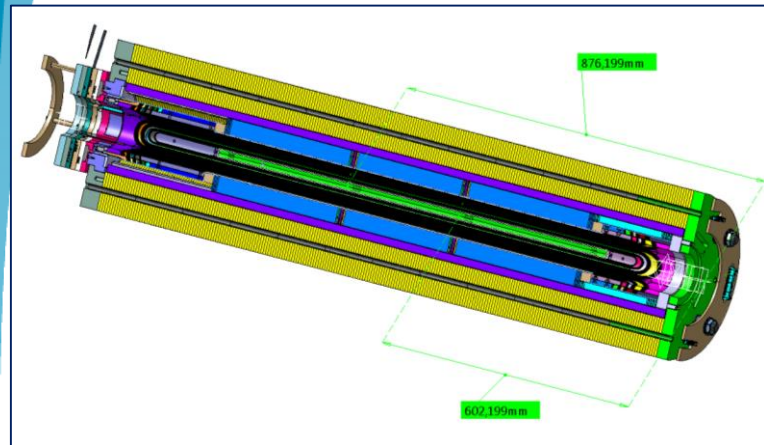
- Tooling set up in 927 and coil measurements in December 2018



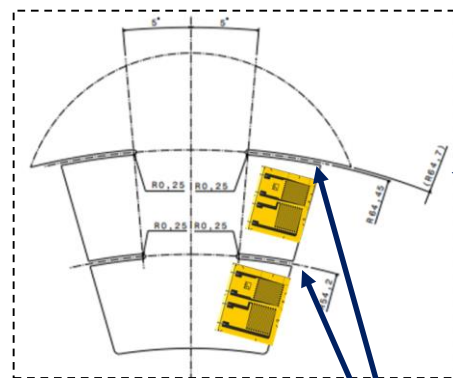
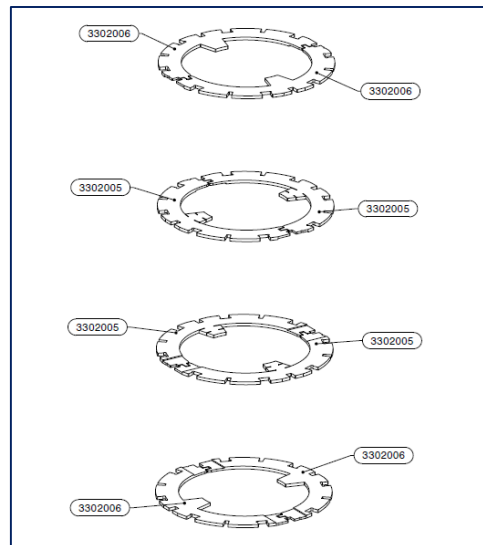
Status on assembly preparation

- **Collar instrumentation**

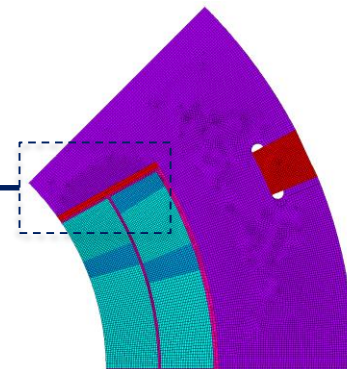
- Planned from Oct 29th to Nov 2nd => In M. Guinchard's lab with support from CEA tech R. Correia Machado



- Wiring diagram for pigtailed in preparation
- Agreement that
 - CERN is taking care of everything from SG to instrumentation plate
 - CEA takes care of everything from Instrumentation plate to HBM DAQ

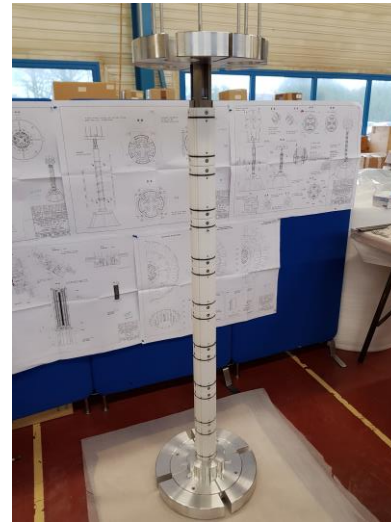
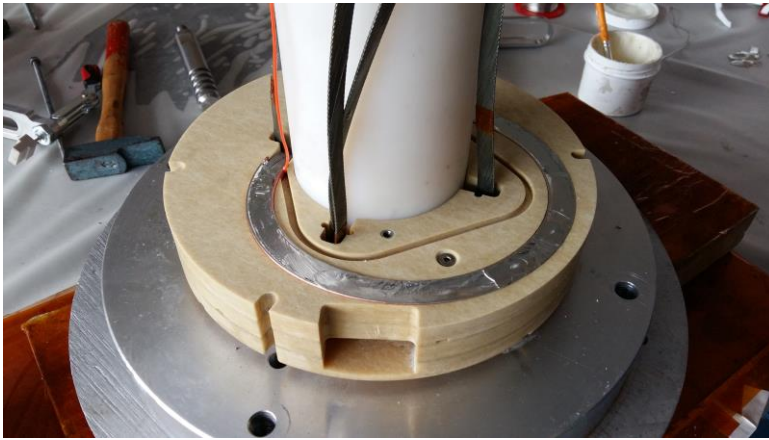


Introduction of slits (thank you N. Bourcey)



Assembly preparation (II)

- **Components preparation**
 - Collaring shoe => rolled at CERN (thank you A. Foussat, Adrien Morel, Damien Foresy)
- **Splice box**
 - Ongoing practice of our technical crew on a spare splice box



- **Assembly tooling at CERN**
- **GPI forming tooling at CERN**
 - CEA technical crew at CERN next week to practice on the Kapton forming tooling

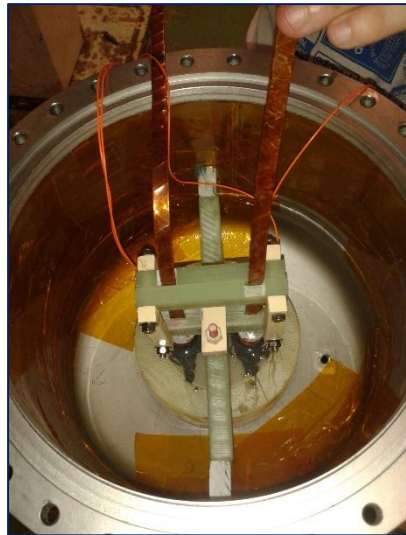
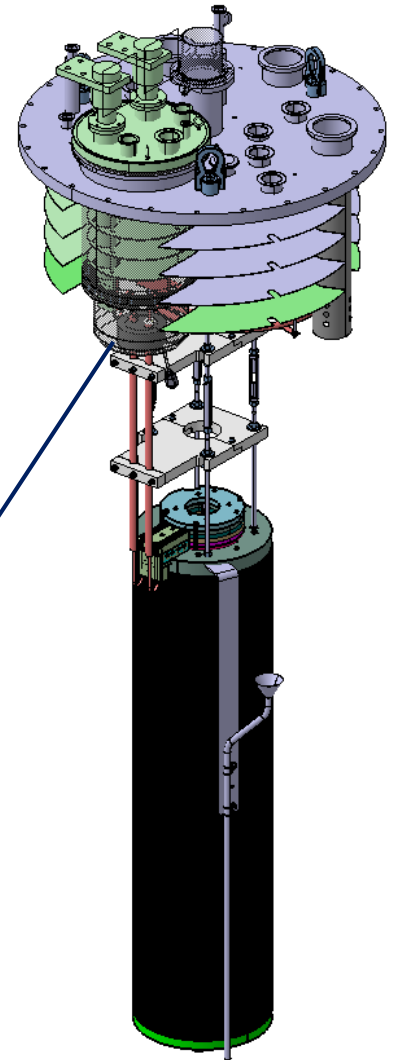
MQYYM: preparation of the test facility

Cryogenic facility

- Effort carried out by J.M Gheller
- CEA 8 m vertical cryostat equipped with a 3 m long « sock » (tank)
- Adaptation of an existing top plate
- Saturated LHe bath at 1.9 K 23 mbar => some ungoing check to ensure electrical integrity

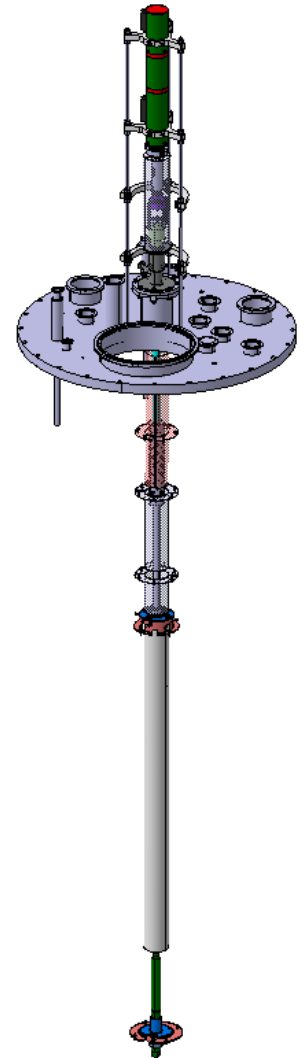
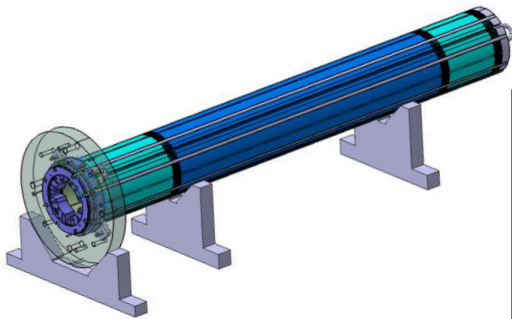
Data acquisition and magnet protection

- Effort carried out by Denis Bouziat + another group at CEA (DIS)



Plan for Magnetic Measurements

- **Cold** Probe, rotating unit and DAQ system will be provided by CERN
- Agreement on a probe: 47 mm in diameter, 5 modules of 222 mm in length
- Main difference identified between CERN and CEA facilities:
 - CERN: **pressurized** bath
 - CEA: **saturated** bath (23 mbar)=> Design of a sealed system using the cold probe provided by CERN
- Agreement on the fact that the operation of the system will be done by CEA (supported/trained by CERN)
- Training of Damien Simon on magnetic measurement acquisition system: started
- Strong support from L. Fiscarelli and O. Dunkel



Schedule

▸ Coil fabrication	287 jours?	Ven 21/07/17	Ven 05/10/18
Connection box assembly training	1 sm	Lun 15/10/18	Ven 19/10/18
▹ Tooling and components procurement	377 jours?	Lun 24/04/17	Lun 12/11/18
▸ Assembly tooling	153 jours	Mer 12/07/17	Mer 28/02/18
▸ Collars (HV Wooding)	114 jours?	Mer 10/05/17	Lun 16/10/17
▸ Yokes (HV Wooding)	63 jours?	Lun 07/08/17	Mar 07/11/17
▸ connexion box (2) (Roechling)	202 jours	Lun 09/10/17	Lun 27/08/18
▸ Coil parts (6 sets) (Tosti)	68 jours	Lun 24/04/17	Mer 26/07/17
▸ Coil parts (2 final sets) (Tosti)	68 jours	Jeu 01/03/18	Lun 04/06/18
▸ protection shims and collaring shoe	78 jours	Lun 16/10/17	Lun 19/02/18
▸ magnet components (key, flanges) (SMP Scalco)	84 jours	Lun 18/06/18	Ven 02/11/18
▸ Splicing tooling (Nicot)	107 jours	Lun 06/11/17	Mar 17/04/18
▸ GPI tooling (gavard)	216 jours	Lun 16/10/17	Ven 21/09/18
▸ Coil shipping tooling (gavard)	170 jours	Lun 06/11/17	Lun 16/07/18
▸ Magnet shipping tooling/crate (Aratz)	186 jours	Lun 15/01/18	Mar 23/10/18
▸ aperture handling/ MM tooling (nicot)	150 jours	Jeu 15/02/18	Jeu 04/10/18
▸ measuring coil tooling (DMP)	343 jours	Ven 09/06/17	Lun 12/11/18
▸ Trace fabrication	175 jours	Mer 26/07/17	Ven 13/04/18
▹ Assembly preparation and assembly	79 jours?	Lun 15/10/18	Jeu 14/02/19
Assembly of the assembly tooling (at CERN)	1 jour?	Mer 07/11/18	Jeu 08/11/18
Coil measurements + set up	1,5 mois	Mar 13/11/18	Lun 07/01/19
soldering/wiring of the trace	3 jours	Lun 05/11/18	Mer 07/11/18
GPI preparation	5 jours	Lun 15/10/18	Ven 19/10/18
▸ Collaring	64 jours	Lun 15/10/18	Jeu 24/01/19
electrical integrity tests	1 jour	Ven 25/01/19	Ven 25/01/19
Magnetic measurements	5 jours	Ven 25/01/19	Jeu 31/01/19
Yoking	5 jours	Ven 01/02/19	Jeu 07/02/19
Connection box assembly	1 sm	Ven 08/02/19	Jeu 14/02/19
Warm magnetic measurement with yoke	2 sm	Ven 15/02/19	Jeu 28/02/19
Shipping of the magnet to CEA	1 jour?	Ven 08/03/19	Ven 08/03/19

▹ measuring coil tooling (DMP)	Ven 09/06/17	Lun 12/11/18
Design (CFT + design work)	Ven 09/06/17	Jeu 12/10/17
CFT	Ven 13/10/17	Mar 21/11/17
order placed	Jeu 07/12/17	Jeu 07/12/17
FMI order cancellation	Lun 29/01/18	Lun 29/01/18
Strategy discussion	Lun 29/01/18	Ven 16/02/18
raw material at DMP	Ven 23/02/18	Ven 23/02/18
Prototyping at DMP	Ven 23/02/18	Jeu 12/04/18
order on hold at CERN by project	Ven 13/04/18	Lun 07/05/18
parallel prototyping at Gavard	Mer 14/02/18	Mar 13/03/18
fabrication by DMP	Mar 08/05/18	Mar 02/10/18
inspection visit (DS)	Ven 05/10/18	Ven 05/10/18
rework of parts	Lun 08/10/18	Ven 12/10/18
Delivery at CERN	Lun 15/10/18	Lun 15/10/18
part validation/instrumentation	Mar 16/10/18	Lun 12/11/18

▹ Collaring	Lun 15/10/18	Jeu 24/01/19
collars instrumentation	Lun 15/10/18	Ven 02/11/18
assembly on vertical stand	Mar 08/01/19	Jeu 17/01/19
Collaring on press + key welding	Ven 18/01/19	Jeu 24/01/19

MQYYM : Summary and NEXT steps

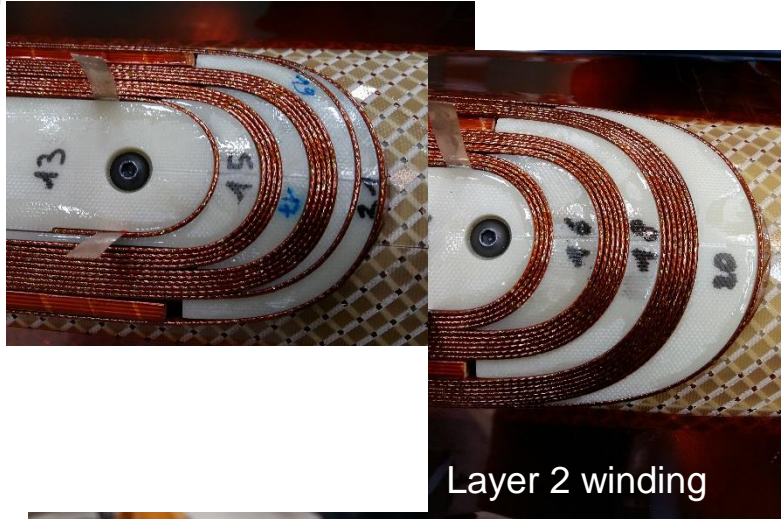
SUMMARY

- **MQYYM components procurement completed**
- **MQYYM tooling procurement close to be completed**
- **All coils are completed**
 - Pending Electrical measurements
- **Coil rigidity measurement tooling on the critical path**
- **Assembly preparation on track**
- **Mechanical instrumentation defined**
- **The best is done to keep a reasonable schedule:**
 - Tight connection between CERN and CEA teams

NEXT STEPS

- **Proceed with MQYYM assembly**
- **Magnet shipped to CEA in March 2019**

Fabrication: coil 0

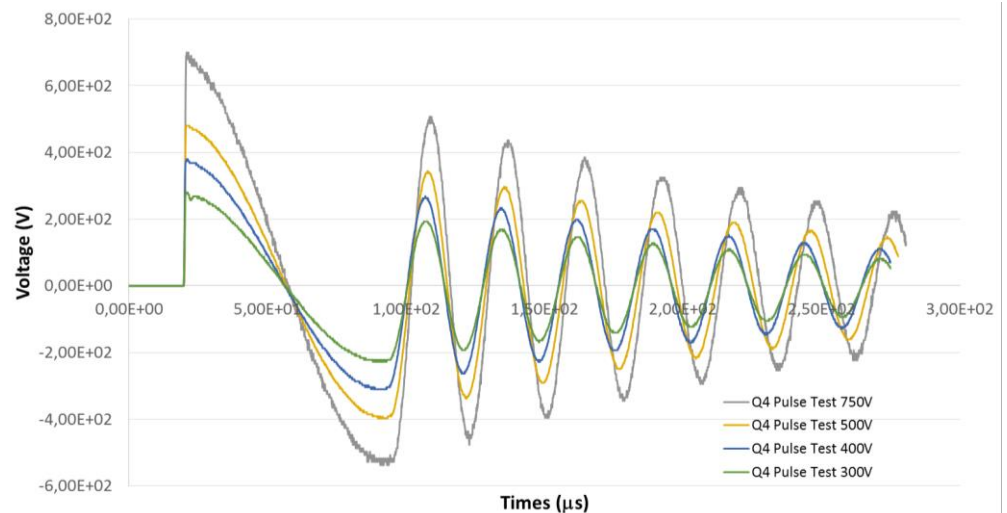


Layer 2 winding



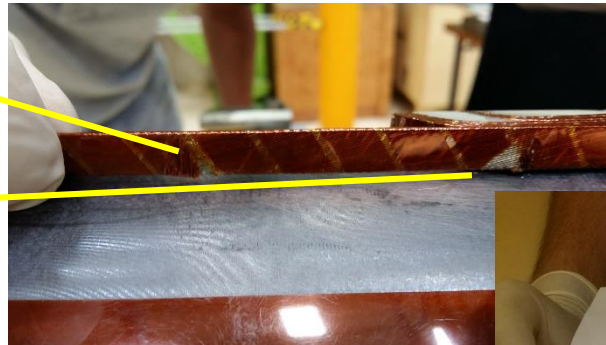
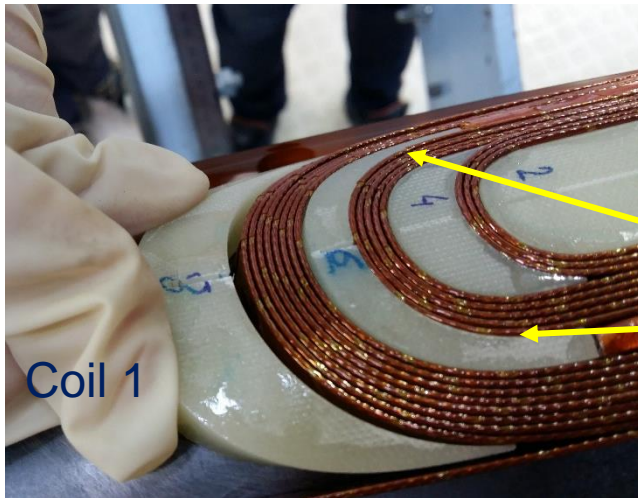
Soldered vtaps

- Good matching of the coil parts with the winding
- **CuBe Broken flags** after polymerization
=> Require smoothing of the sharp edges to avoid damaging the flags
- Impulse test showing change of frequency as V increases
=> Turn to turn weakness?
=> likely due to the weld of the vtaps using Tin Indium solder (fusion T < polymerization T!)



Coil 1

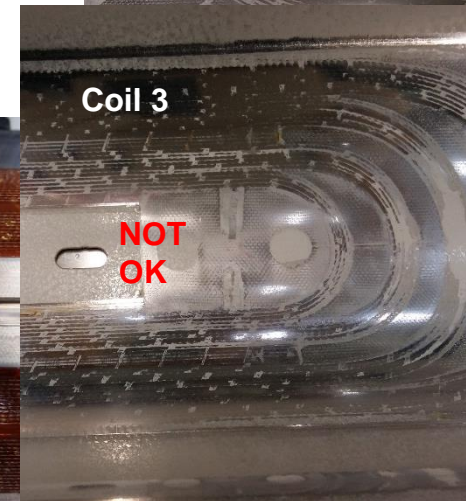
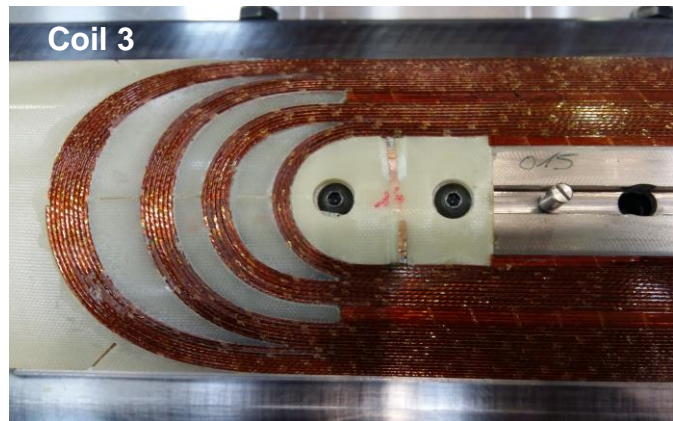
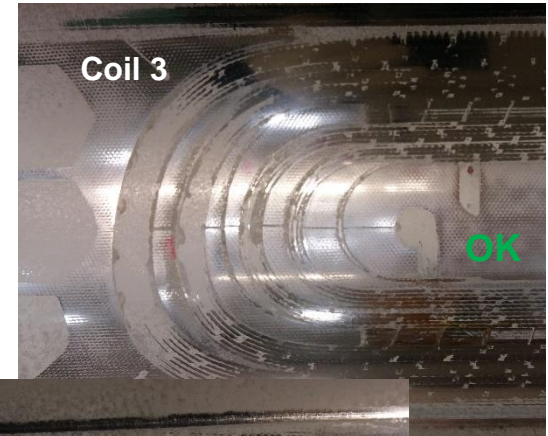
- Vtaps:
 - narrower CuSn_6 flags and SnAg solder
 - Grooves added in the end part
- **Slit** in some of the spacers, filled with G10 pieces before polymerization
- Finalization of procedures for insulation of angular wedges



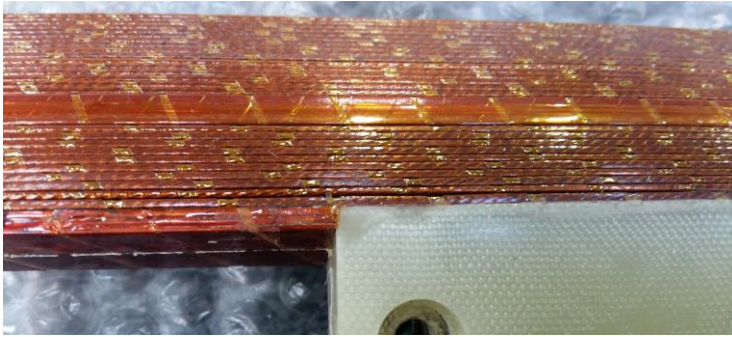
Coil 2 to 3



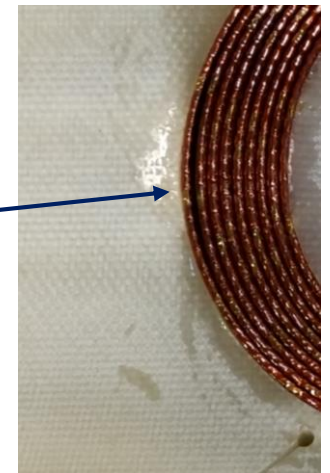
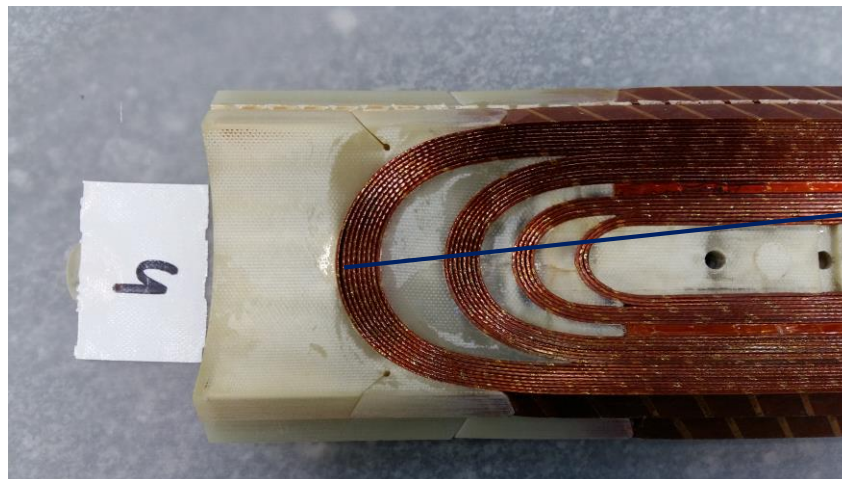
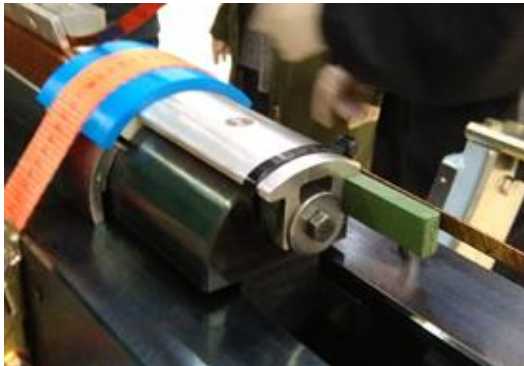
- No major issue during coil fabrication of coil 2 and 3
- Concern on vtap flags: grooves are not deep enough => some compression of the taps



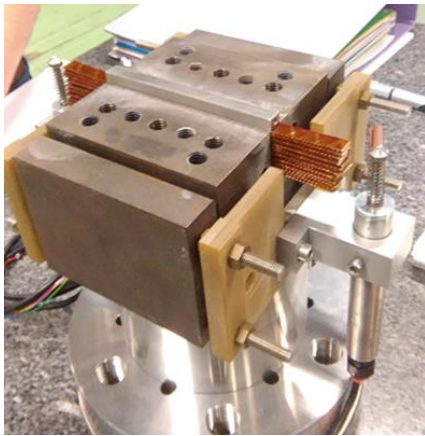
Coil 4



- Vtaps/endpart groove problem solved
- But :
- Unglued turn on the outer layer => adhesive missing? Unexpected cleaning?
- gap in the last but one turn in the RE IL: investigation ongoing. Last turn winding tension relaxation after lead cutting is suspected



Supporting activity: Ten Stacks Measurements at CEA



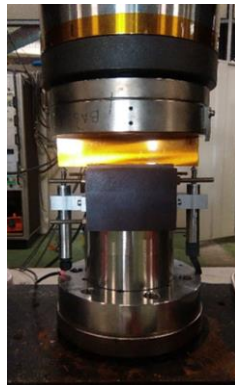
Objective 1: Rigidity measurement

Stack size	Avg Rigidity (GPa)
NS - 0.1 mm	7.3
NS	7
NS + 0.1 mm	6.9

Cross-check ongoing at CERN
+ at cold
+ creep (change of dimension under constant compression)
+ stress relaxation (change of compression under constant dimension)

Stack of 18 conductors cured at:

- Nominal size
- NS - 0.1 mm
- NS + 0.1 mm



Objective 2: Curing shim choice

