MBRD status:
MBRDS1 and MBRDP1

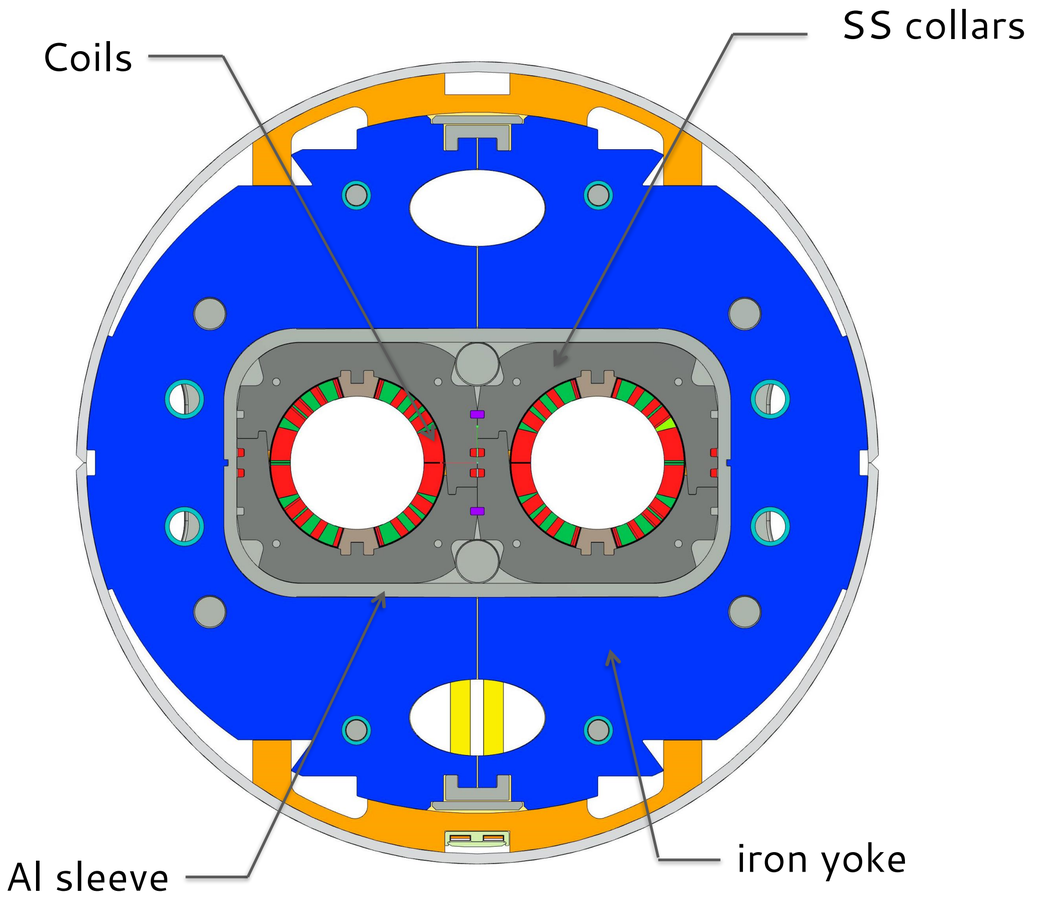
Andrea Bersani o.b.o.
INFN Genova group

MBRDS1 2019 summary

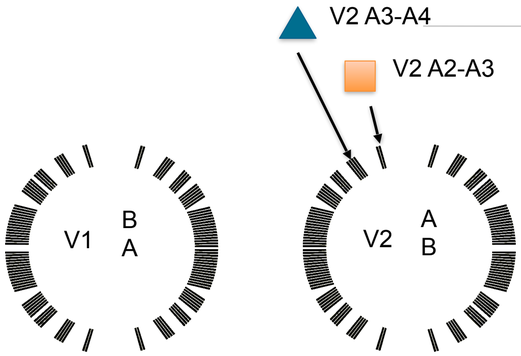
- MBRDS1 was tested at CERN at the end of 2018
- "Anomalous" training was reported
- A single aperture was tested at a scaled current
  - this test was successful
- A major damage on the pole exit of a coil was found
- A new coil has been wound
- The magnet has been re-assembled
- We hoped to manage to deliver the magnet at CERN at the beginning of October, but a small additional delay arose last week

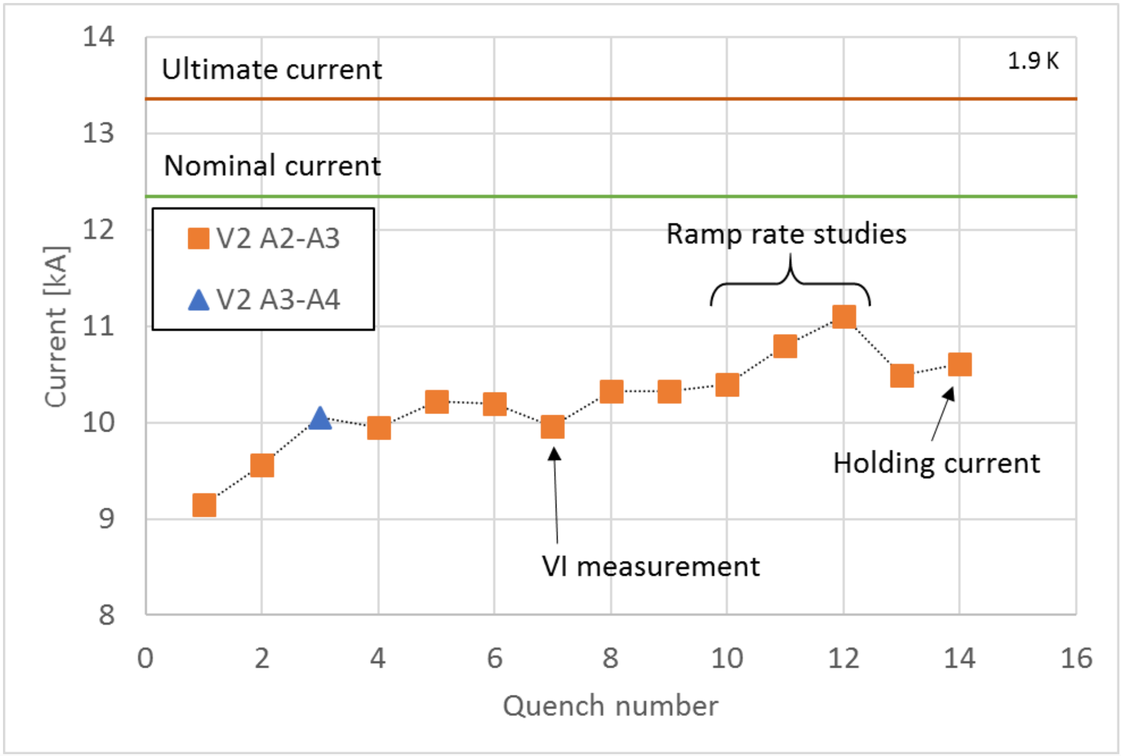
The short model

- 1.6 m long model for MBRD
  - bending recombination dipole
  - two 105mm dia. apertures
  - 4.5 T central field
- No support and shell
- To be tested at CERN
- Delivery foreseen at February 2018
- Actual delivery at October 2018
  - delay mostly due to design changes and material procurement



MBRDS1 cold tests





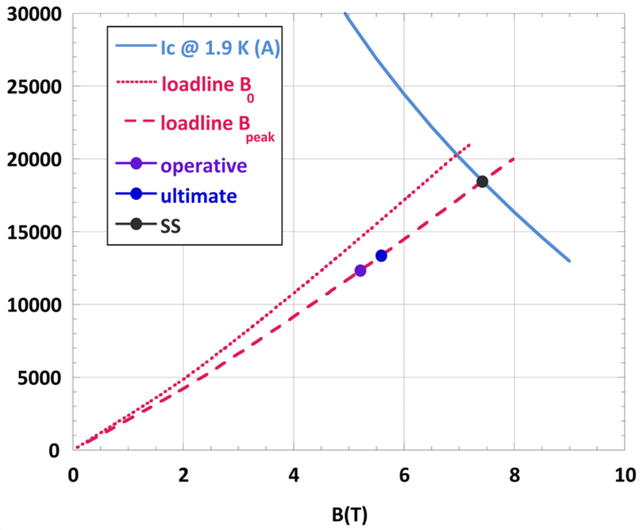
- All quenches but one in the same location
- "Small" training effect observed
- Negative precursor of the ■ quenches
- Damage on the cable expected in V2
  - fifth block, were a short circuit was detected during construction
- Further tests were performed on V1 alone
  - Data: courtesy of F. Mangiarotti

Tests on V1: preparation

- To keep comparable stress and field on cable, nominal and ultimate current were scaled

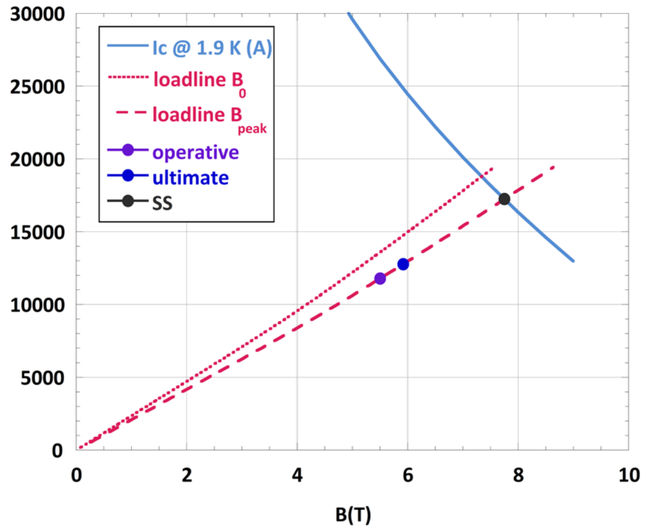
double aperture

- I_{nom}=12340 A, B_0=4.5 T
- I_{ult}=13357 A, $B_{0\ ult}$=4.82 T
- B_{SS}=7.42 T, I_{SS}=18468 A
- loadline fraction:
  f_{nom}=66.8%, f_{ult}=72.3%



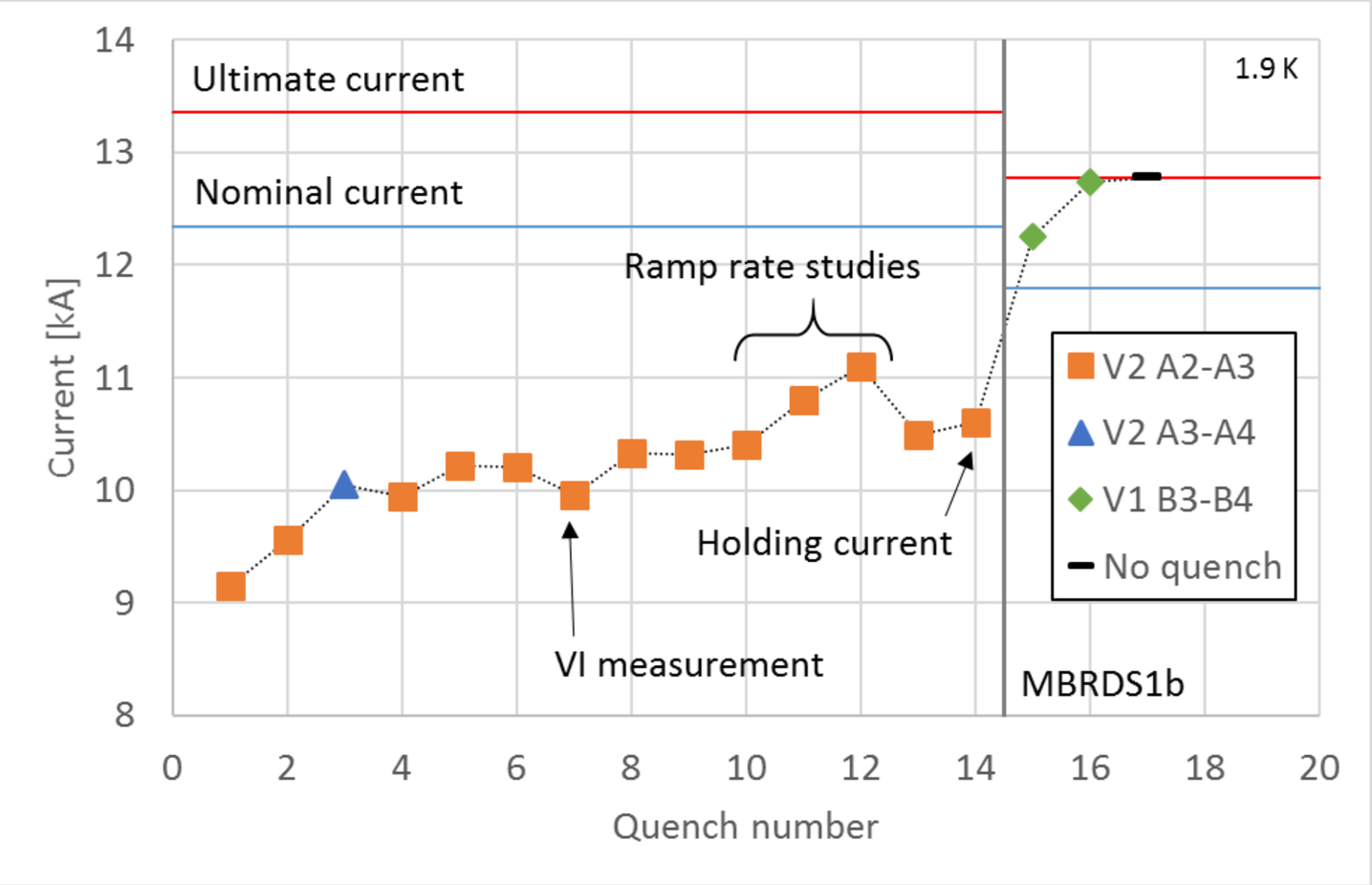
single aperture

- I_{nom}=11800 A, B_0=4.85 T
- I_{ult}=12780 A, $B_{0\ ult}$=5.21 T
- B_{SS}=7.75 T, I_{SS}=17243 A
- loadline fraction:
  f_{nom}=68.4%, f_{ult}=74.1%



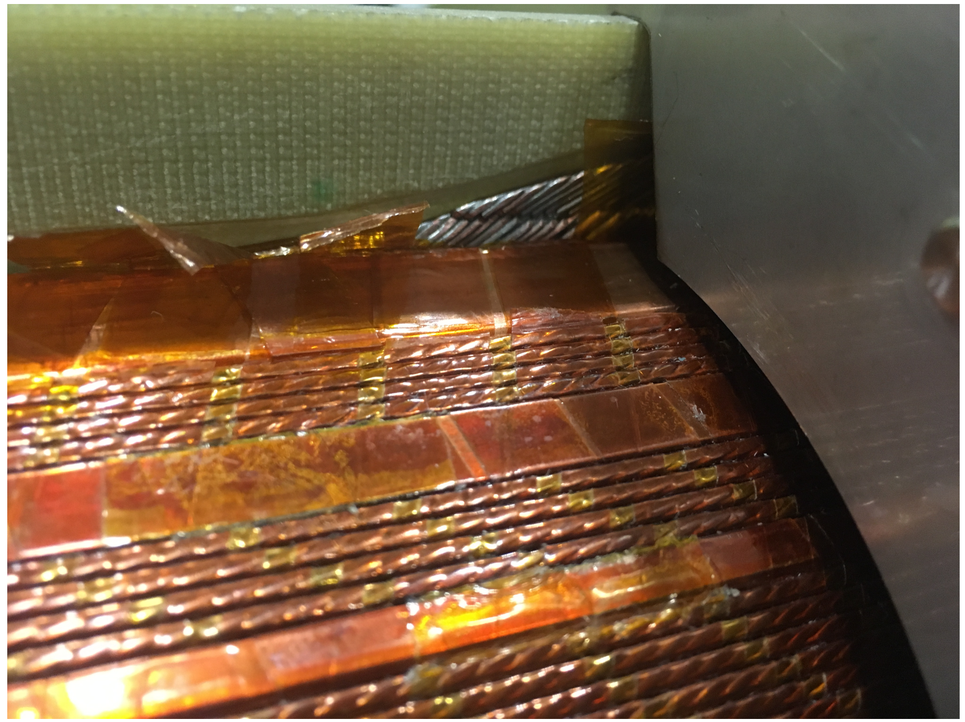
Tests on V1: results

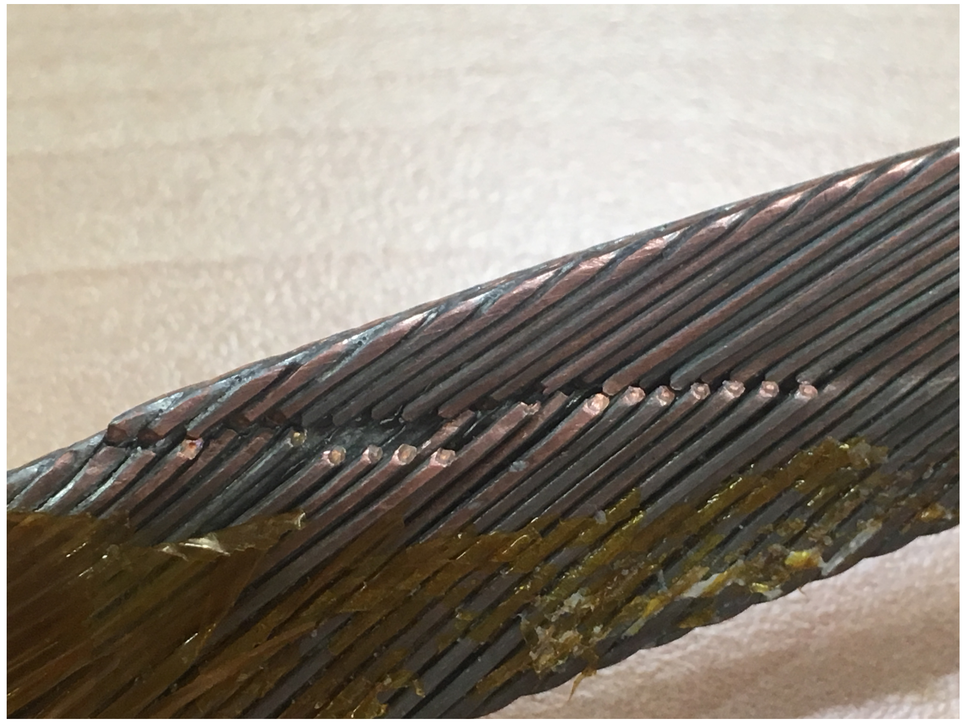
- V1 reached the ultimate current within two quenches
  - first quench directly above scaled nominal and tens of A below original nominal current
- At the third energisation the magnet held ultimate current for more than a hour
- The magnet reached ultimate at 400 A/s without quench



MBRDS1 V1 damage

- Coil A of aperture V1 was deeply inspected after magnet dismounting
- At the pole cable end a major damage was observed
- Several corrective actions have been decided to mitigate this issue

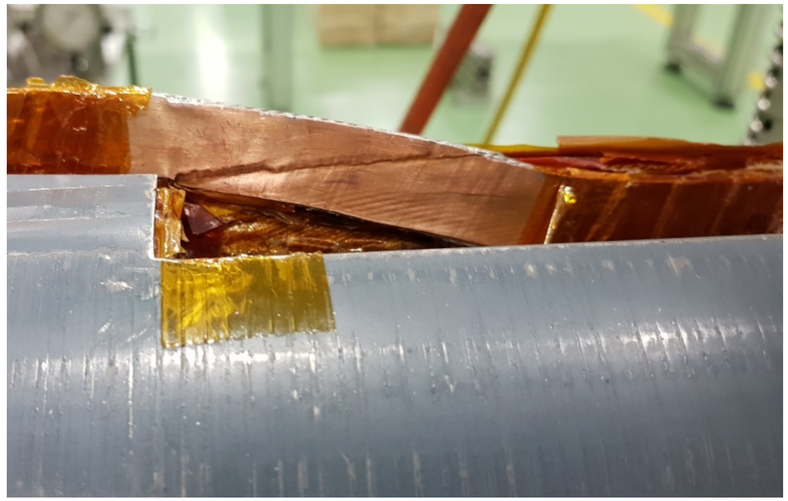


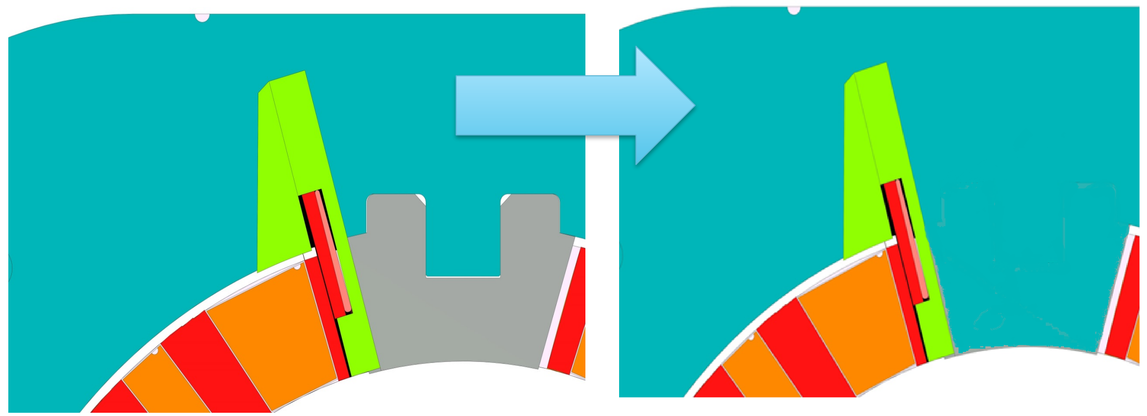


Corrective actions

- Decision for a traditional collar with integral pole
  - the detachable pole has been identified as potentially risky in case of misalignment

- Re-design of the G11 protection box the the cable end
  - the collar is weakened by the slot to allow the cable routing: minimisation of the cross section is mandatory





Review at CERN (March 2019)

- We underwent an international review on March 2019
- The non conformity and the overall design have been investigated in detail
- Several further modifications have been introduced
  - the shape of the iron yoke for prototype and series has been changed to avoid the polymer spacers
  - the design has been optimised to take into account the measurements on the built coils and the differences with the nominal values
- Particular care has been put on the mechanical measurements via strain gauges

Replacement of V2 coil A

- A completely new coil has been wound
- It came out to be slightly larger than nominal (0.43mm along the transverse section)
  - all the other coil were indeed 0.2 to 0.3 mm larger than nominal
- Most of V2 ancillary parts have been replaced
  - ground insulation
  - G11 protection boxes
  - voltage taps and strain gauges
- Steel shield were reused
- Quench heaters were removed after the first collaring

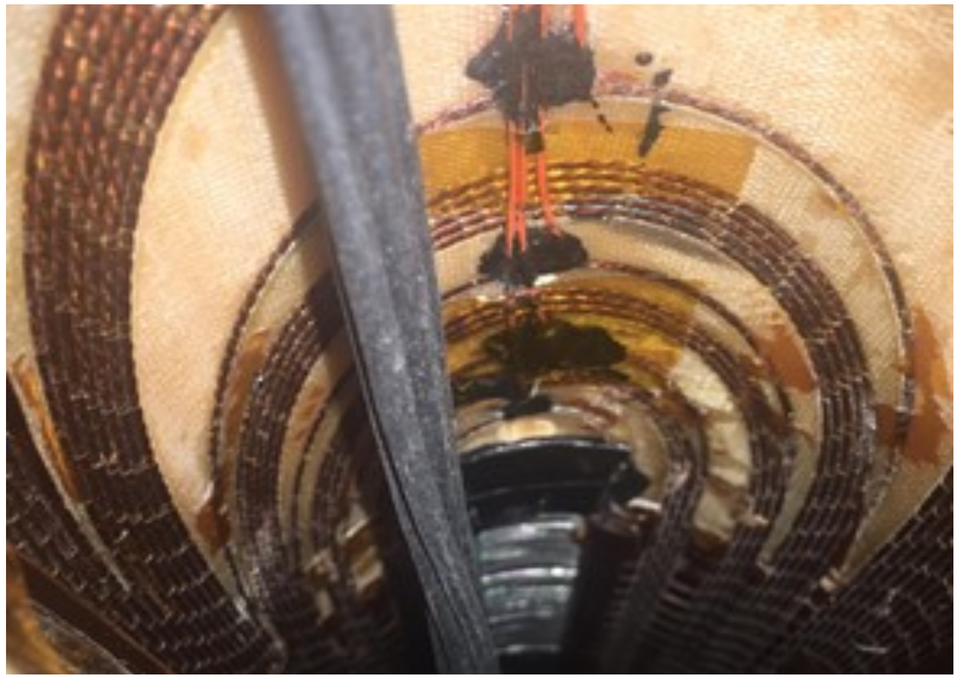
V2 new collaring

- Due to the larger size of the coil, pressure was higher than in previous collarings
  - new coil A is the largest
  - shimming in V1 was by mistake smaller than the design one, in V2 we decided to put the nominal thickness (0.2 mm instead of 0.05)
  - tapered fillers sat coil ends have possibly been dimensioned too thick

Size of actual coil wrt nominal	V2 aperture		V1 aperture		V2 repaired	
Measures in mm	A01	B02	A02	B01	A01 rev	B02
Connections side	+0.11	+0.37	+0.37	+0.32	+0.40	+0.37
Centre	+0.26	+0.36	+0.39	+0.34	+0.43	+0.36
Opposite to connections side	+0.15	+0.33	+0.31	+0.27	+0.29	+0.33
Collaring force (t)	540		550		640	

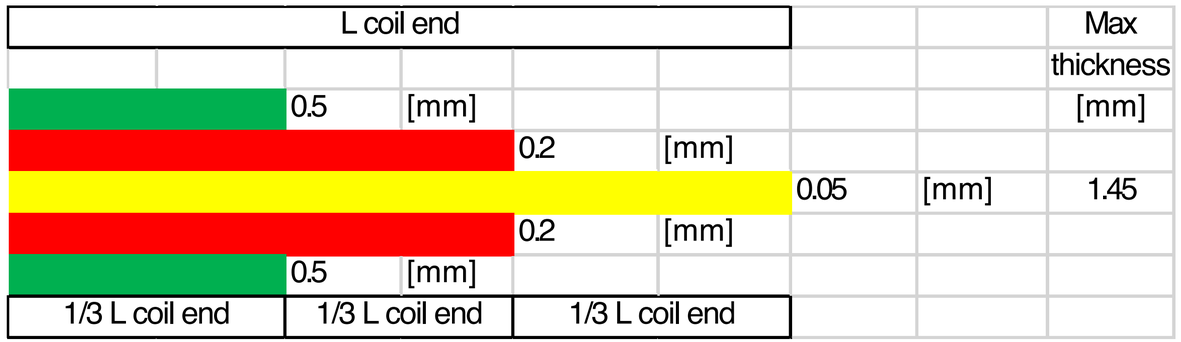
V2 new collaring issues

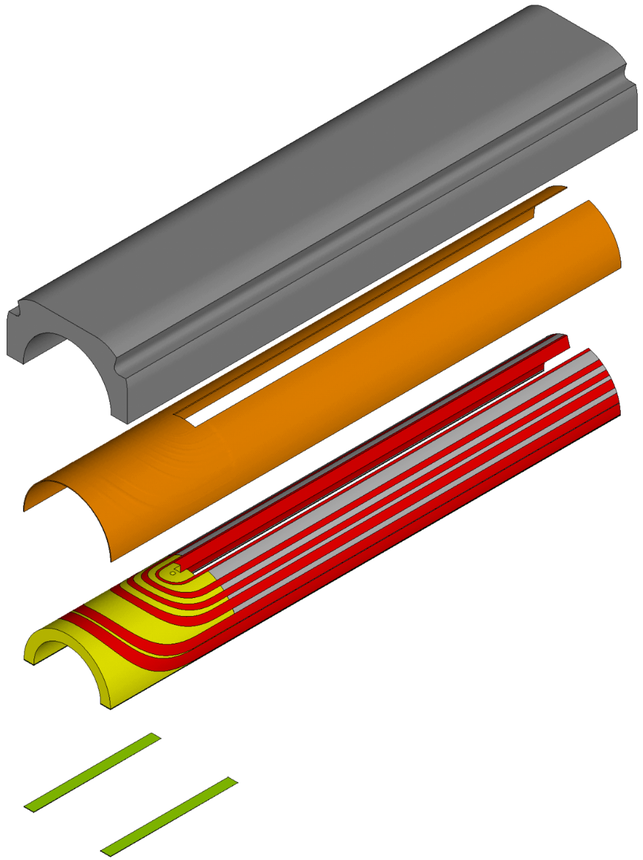
- Due to higher pressure, significant G11 delamination has been observed on the pole
- After inspection, minor delamination has been observed in all the other coils
  - modification in the pole design has been instroduced
- Repairing has been performed in presence of INFN personnel



Indications for the prototype

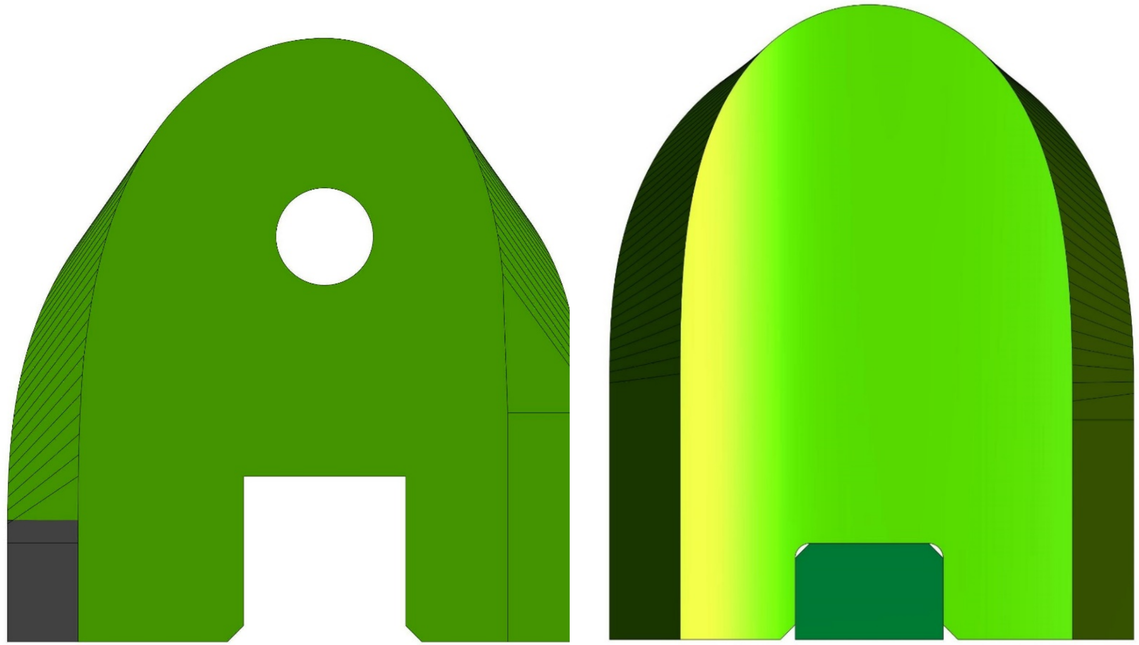
- New mockups of the coil will be built and new calculations performed to optimise the thickness of the cured coils
  - all the model ones were larger than the nominal
- No hole will be present in the poles
- G11 cable exit protection will be modified
- Mid-plane shims will be recalibrated





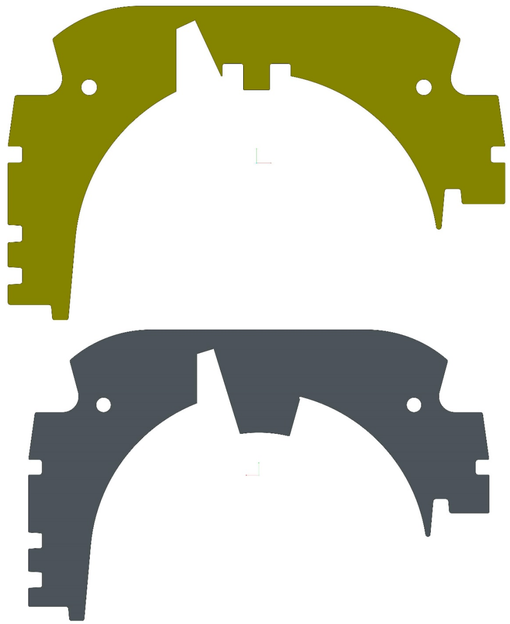
Pole end spacer

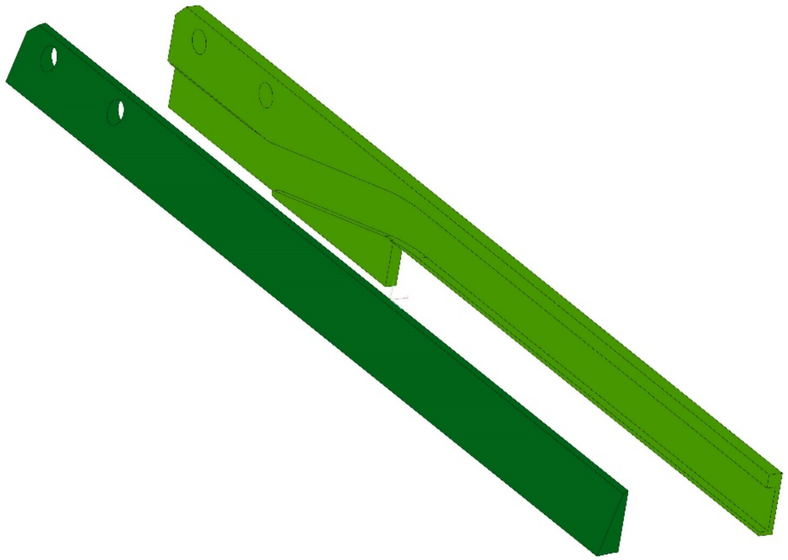
- The pole end spacer features in the model a hole and a slot for positioning
- The hole turned out to be unessential and will be removed
- The slot is needed for alignment and will be filled with G11 and Stycast
  - with detachable poles it was used to align the stainless steel pole

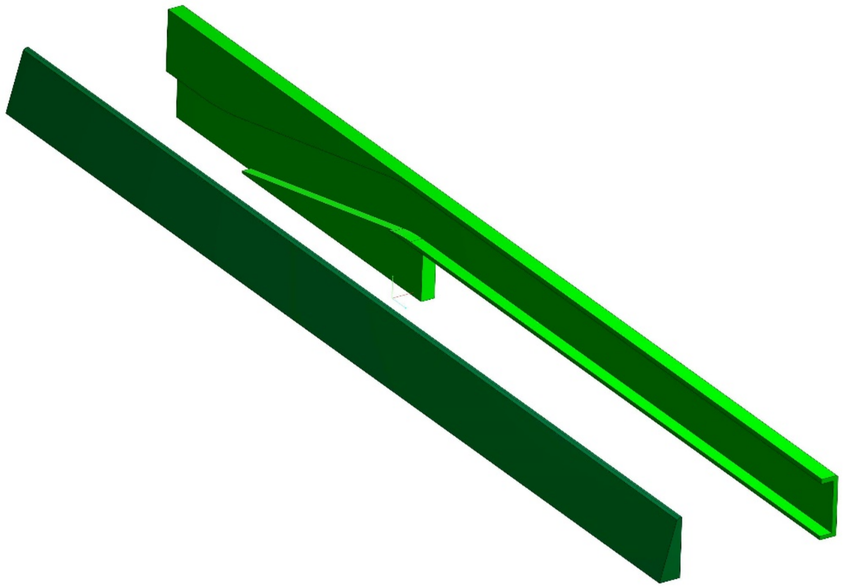


G11 cable end protection

- The thickness has been reduced to minimise the slot in the collars
- A tapering of the box is being studied to have an increasing slot area in the collars
- The S of the cable is placed ~10mm before to reinforce the box
- Insulation reinforcement is being studied on the exit





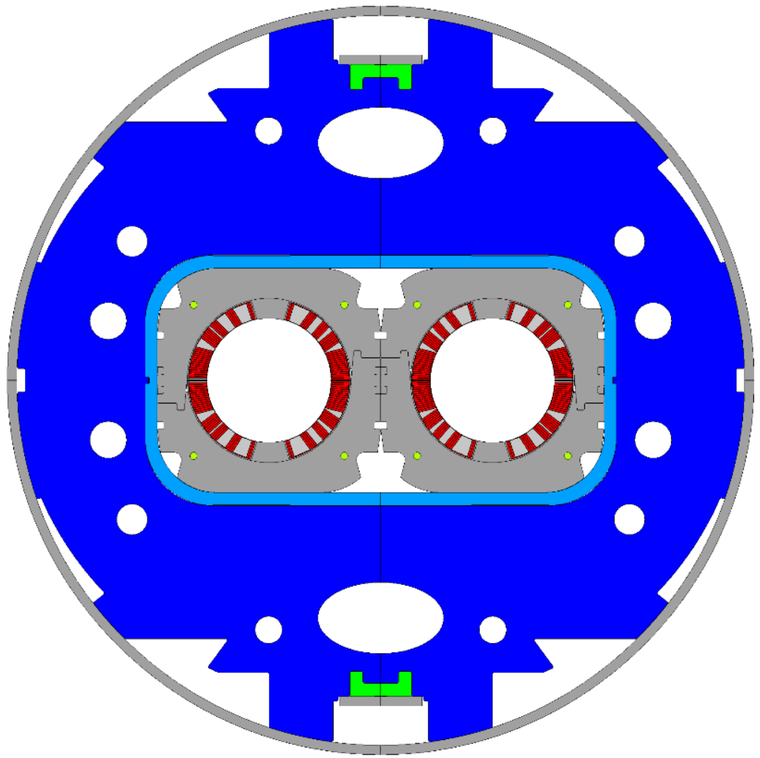


Model perspectives

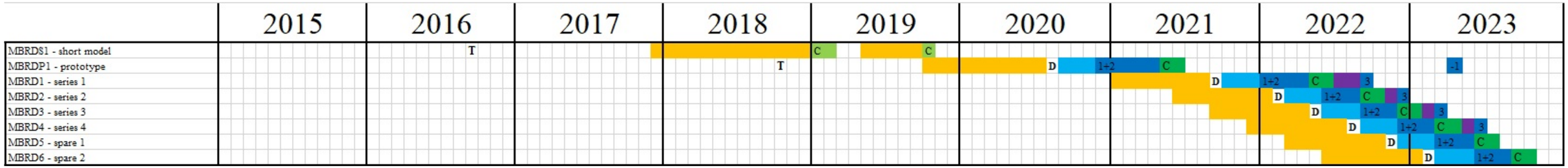
- The short model is being repaired after a major fault last spring
- Several parts have been replaced
  - collars on the connection side end have been replaced with new ones
- Mid-plane shims will be reduced as in V1
  - this will bring suboptimal field harmonics
  - simulations have been performed and the match is good
  - design consistency can be validated
- We are waiting from ASG for an ultimate time estimate for the delivery at CERN
  - reasonably we expect to have the model at CERN before end of November

Way to the prototype

- The contract for the prototype has been signed in March 2019
- The material procurement started and the delivery of cable wedges and end spacers is foreseen by the end of this month
  - construction will start as soon as possible
- The design phase is almost finished
- The contract has been extended to the series



Prototype and series tentative schedule



- The delivery of the short model is expected by the end of November at the latest
- The construction of the prototype is expected to start in the next few weeks
  - the needed parts for the start of the first winding have been ordered last summer
- The masterplan is considered solid and we are confident any unexpected problem has already shown up in the model construction and test

Thanks for your attention!