Plan for the series of HO Correctors

8th HL-LHC Collaboration Meeting
15-18 October 2018

M. Sorbi
INFN-LASA, Milan

CERN, 18 October 2018

Addendum for series construction

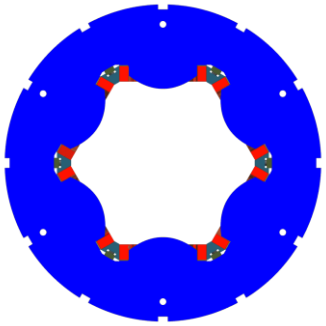
ADDENDUM No. 2 KE3085/TE/HL-LHC
to
FRAMEWORK COLLABORATION AGREEMENT KN3083
between
THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)
and
Istituto Nazionale di Fisica Nucleare (the "Institute")
concerning

Collaboration in design, procurement and testing of the high-order orbit corrector superconducting magnets in the framework of the High Luminosity upgrade for the LHC at CERN

- In November 30, 2017 has been formally approved the Addendum for the construction and test (at LASA) of the series of "High Order" corrector magnets

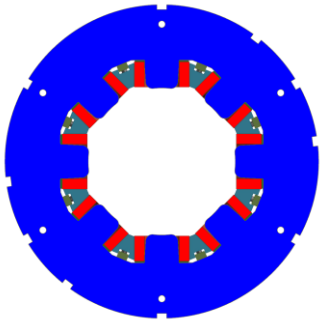
Magnet zoo (series)

OD=320 mm



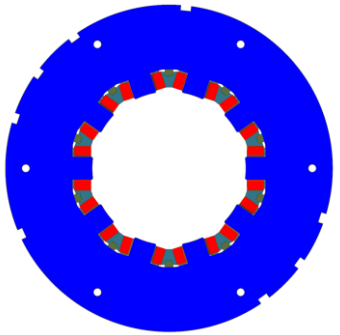
Sextupole: **12 magnets**

OD=320 mm



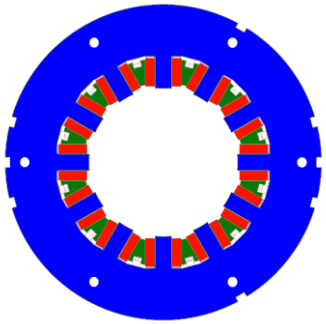
Octupole: **12 magnets**

OD=320 mm



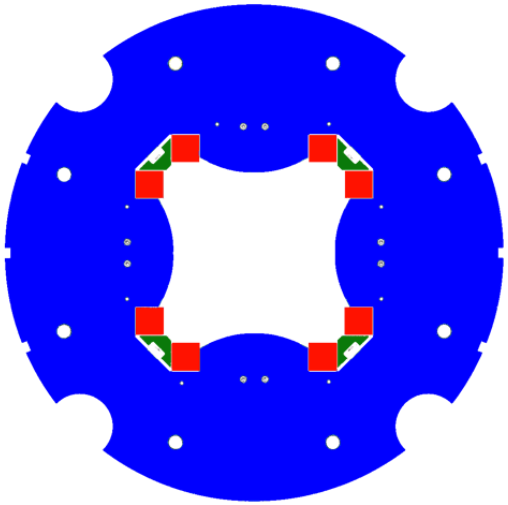
Decapole: **12 magnets**

OD=320 mm



Dodecapole: **6 +6 magnets**

OD=460 mm



Skew quad: **6 magnets**

TOTAL MAGNET N. **54**

EDMS NO.	REV.	VALIDITY
1963788	0.5	DRAFT

REFERENCE : LHC-M-EC-0002

HL – LHC Engineering Change Request
CHANGE OF QUADRUPOLE, SEXTUPOLE, OCTUPOLE AND DECAPOLE CORRECTORS INTEGRATED FIELD

ECR DESCRIPTION

WP Originator	WP3	***Process***	Design
Equipment	MCQSXF, MCSXF,MCSSXF,MOXF,MOSXF, MCDXF, MCDSXF	***Baseline affected***	Corrector package cold mass
Drawing	-	***Date of Issue***	2018-04-10
Document	-	***CI responsible***	E. Todesco, M. Sorbi
WPs Affected	WP3, WP2, WP7, WP15	***Reference Document***	TDR Version 0.1

Detailed Description

It is proposed to increase the strength of the high order correctors of order 3, 4 and 5 by 50% through an increase of total length of these magnets in the corrector package of 320 mm (see table below). The skew quadrupole corrector strength is reduced by 30%, partially compensating for the length increase (200 mm out of 320 mm). The remaining 120 mm are recovered in the cold mass through optimization of the design with no impact in the total length and dimension of the cryostats

Magnet name		Integrated field at R_{ref}=50 mm (T m)		Magnet coil length (mm)		Magnet length (mm)	
		Baseline	New value	Baseline	New value	Baseline	New value
Skew quadrupole	MCQSXF	1.000	0.700	728	528	814	614
Normal sextupole	MCSXF	0.063	0.095	132	192	194	254
Skew sextupole	MCSSXF	0.063	0.095	132	192	194	254
Normal octupole	MCOXF	0.046	0.069	119,6	169,6	183	233
Skew octupole	MCOSXF	0.046	0.069	119,6	169,6	183	233
Normal decapole	MCDXF	0.025	0.037	118,6	168,6	183	233
Skew decapole	MCDSXF	0.025	0.037	118,6	168,6	183	233
Normal dodecapole	MCTXF					575	575
Skew dodecapole	MCTSXF					200	200

Reasons for change

This is a mitigation measure in case of larger multipoles in the quadrupoles of the triplet and to provide some margin to compensate for possible failures of the corrector circuits. In particular a4 and b5 measured in the first models were larger than expected, and not correctable through magnetic shimming. The target values for the field quality of the triplet remain unchanged, as well as the strategy for correcting the b3 using magnetic shims.

Impact on Cost, Schedule & Performance

The impact on cost is estimated to less than 5% of the total magnet cost (material and manpower) estimated by INFN-LASA collaboration. A more refined estimate will be available before the end of 2018.

There is no impact on schedule.

The reduction of the skew quadrupole strength is acceptable, given the tolerance of ±1 mrad in the alignment of the quadrupole average axis w.r.t. reference orbit as discussed in WP2 meeting https://indico.cern.ch/event/718322/ .

The proposed increase of the magnetic length of the higher order correctors relies on the availability of accurate magnetic measurements (within few tenths of a unit) that are considered to be achievable given that all the triplet magnets will be measured at cold at CERN as discussed at the WP2 meeting on 13/3/2018.

- In April 2018 an “Engineering Change Request” has been requested by CERN,
- Increased magnetic (and geometric) length of 3+3 magnets and decreased the 4-pole skew.
- The variation for the 4-pole skew has been integrated also for the prototype (in “running”, the firm accepted the modification request)
- In series production we will have some magnets longer than prototypes

Addendum for series construction

1.2 Work package milestones and deliverables

Milestones:

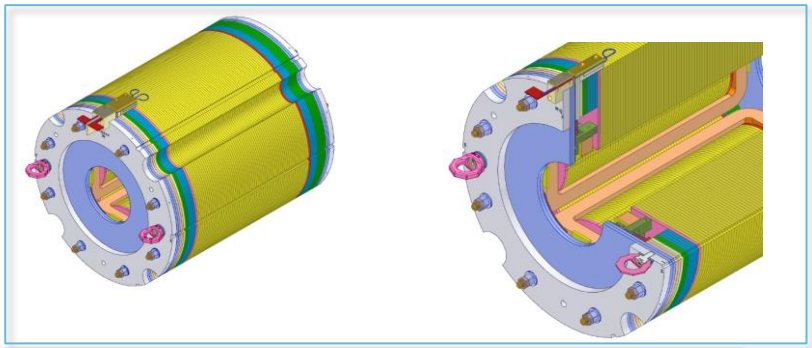
M1.1	Engineering Design of the series completed	July 2018
M1.2	First coil wound	May 2019
M1.3	First batch delivered to INFN-LASA for test (2 magnets per type)	November 2019
M1.4	Second batch delivered to INFN-LASA for test (2 magnets per type)	July 2020
M1.5	Third batch delivered to INFN-LASA for test (2 magnets per type)	March 2021

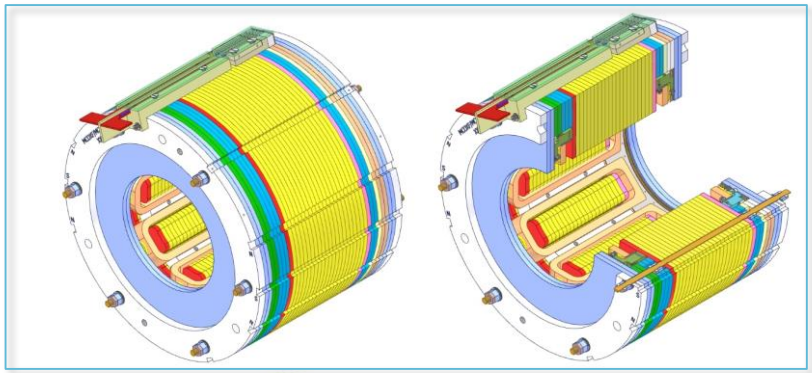
Deliverables:

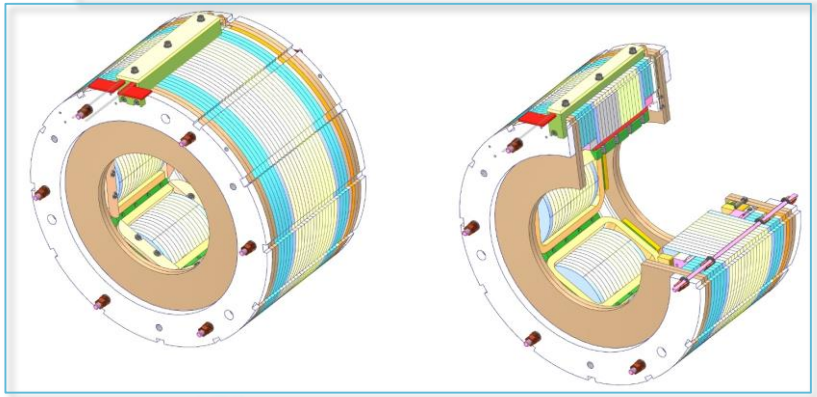
D1.1	Award for the contract of the series construction	January 2019
D1.2	First tested batch delivered to CERN (2 magnets per type)	March 2020
D1.3	Second tested batch delivered to CERN (2 magnets per type)	November 2020
D1.4	Third tested batch delivered to CERN (2 magnets per type)	June 2021

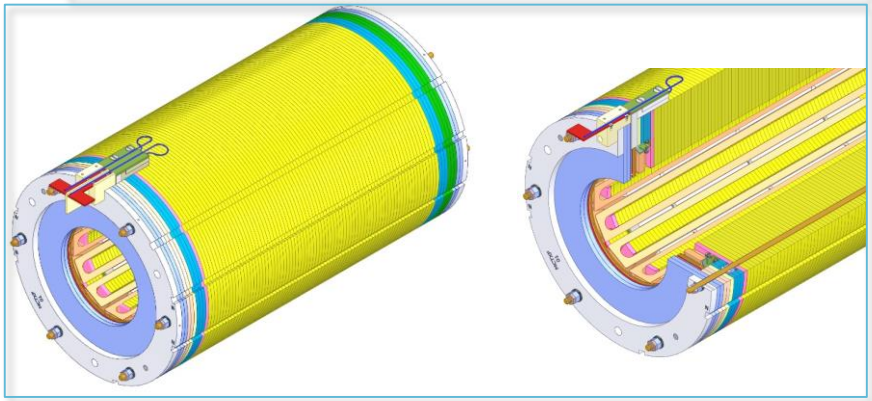
- The first Milestone M1.1 has been respected.
- We are on the road to respect the first delirevable D1.1

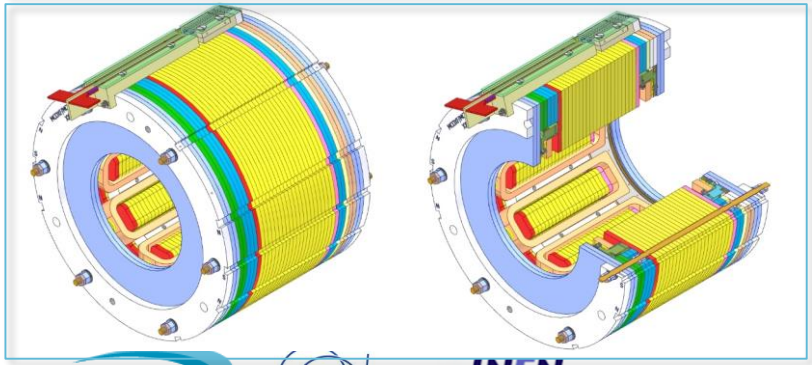
3D and 2D drawing for each magnet ready

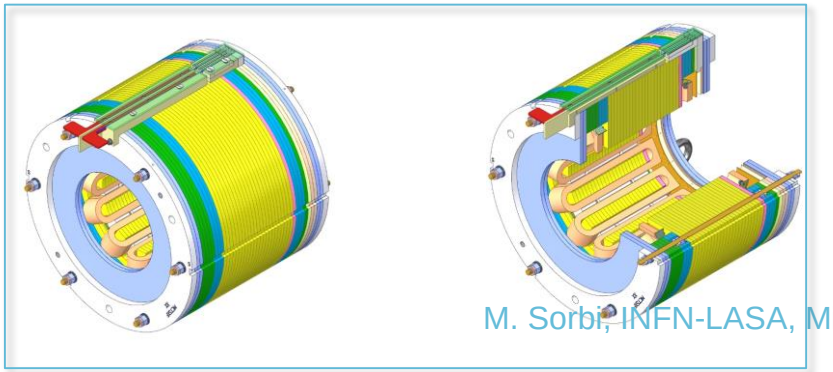




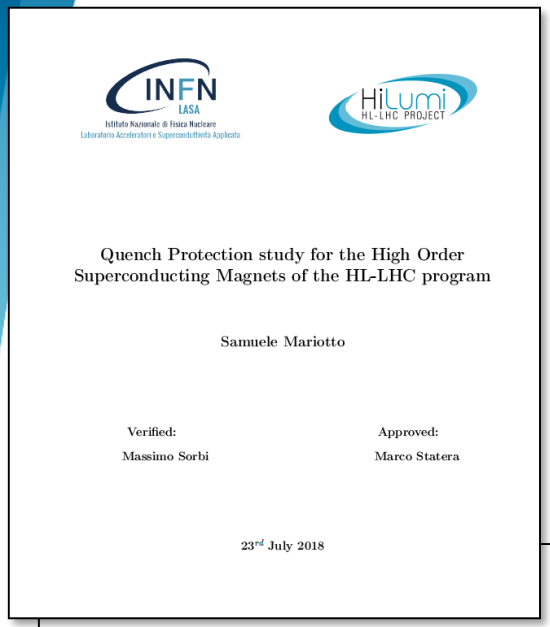








New protection study



INFN LASA
Istituto Nazionale di Fisica Nucleare
Laboratorio Acceleratori e Superconduttività Applicata

HiLumi HL-LHC PROJECT

Quench Protection study for the High Order Superconducting Magnets of the HL-LHC program

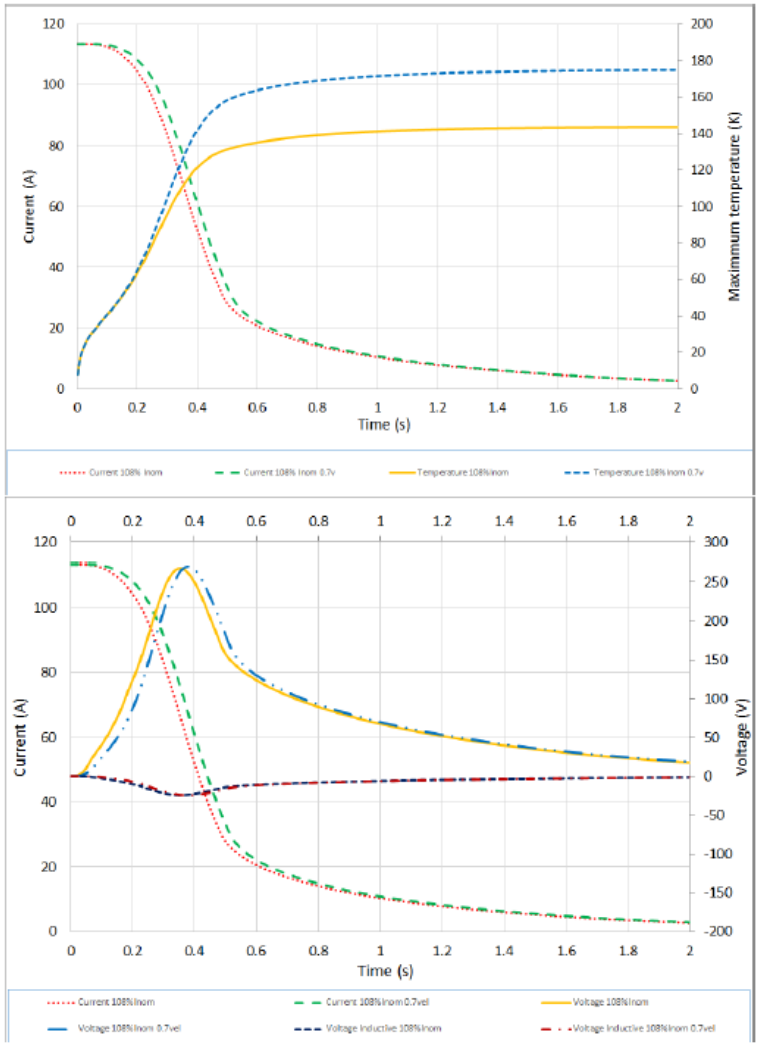
Samuele Mariotto

Verified: Massimo Sorbi

Approved: Marco Statera

23rd July 2018

Contents



Normal-12-pole quench study

- $V_{max} < 300$ V
- $T_{max} < 200$ K

All magnets (except 4-pole):

- No-R_{dump}
- $\Delta t_{delay} = 180$ ms

4-pole:

- Conventional QDS (Va-Vb)
- $R_{dump} = 1.5\text{-}3\ \Omega$

Conductor for series construction

INFN – SEZIONE DI MILANO
Laboratorio Acceleratori e Superconduttività
ANNEX A – Technical Specification

Milano, 24/04/2018

NbTi insulated wire for the HiLumi High Order corrector magnets

1. Introduction

Specification of the wire for the High Order (HO) correctors series production for the HiLumi project.

2. Characteristics

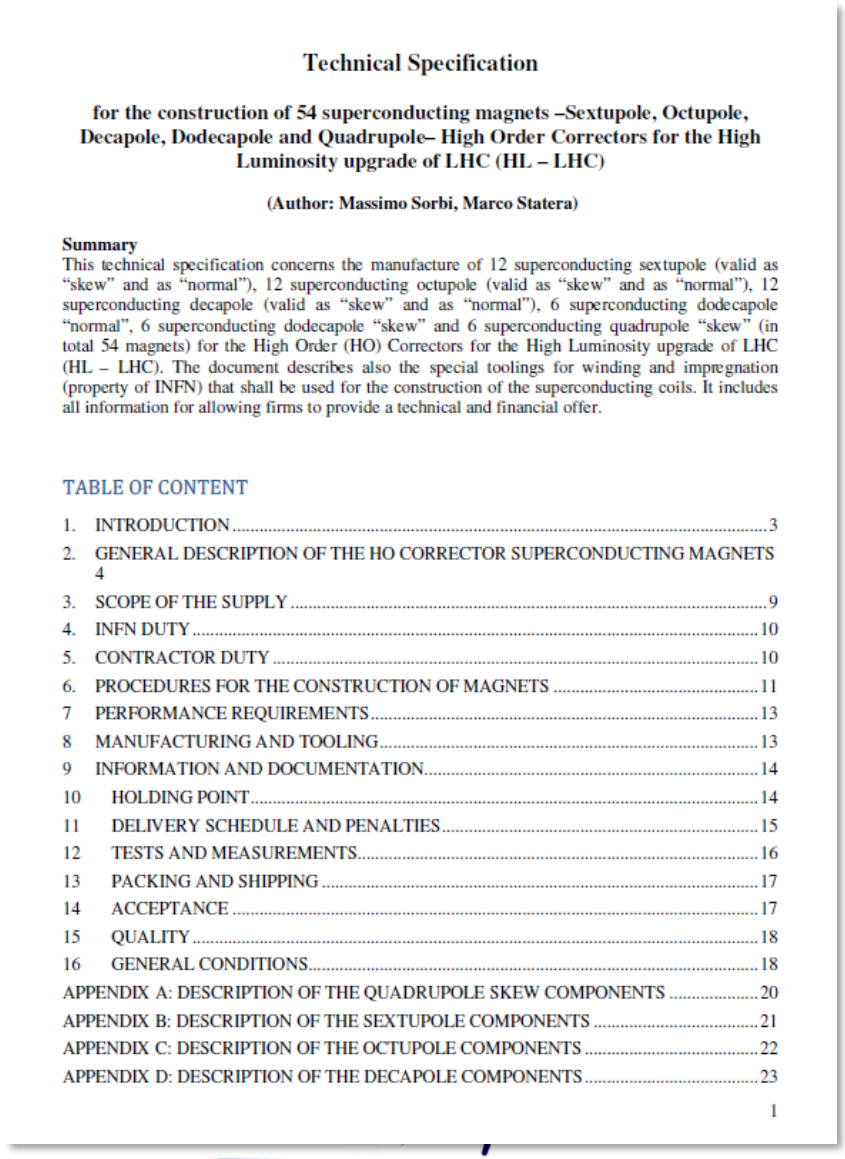
PARAMETER	units	Wire type A	Wire type B
Dimension bare	mm	0,500+-0,005	0,700+-0,005
Dimension insulated	mm	0,640+-0,005	0,840+-0,005
Insulation	-	S2 glass / type 493	S2 glass / type 493
Cu : NbTi ratio (minimum)	-	2.1	2.1
Filament diameter (maximum)	µm	5	7
Twist (maximum)	mm	15	15
Ic (at 4,2 K, 5 T) (minimum)	A	170	330
RRR (minimum)	-	100	100
n-value (minimum)	-	30	30
Minimum length per spool	km	5	6
Maximum length per spool	km	15	15
Total quantity option 1	km	95	39
Total quantity option 2	km	95	32
Delivery 1 (40%)	months	7	7
Delivery 2 (60%)	months	10	10

The offer must foresee two options with different total quantity for the Type B conductor. Only one option will be ordered. The basis of the call for tender refers to a single option.

3. Remaks and other request

- The conductor order has been launched in advance respect the series construction
- About 130 km of NbTi conductor
- The tender for the procurements of conductor has been launched in June 2018
- Formal assignment in Sep. 2018 (Bruker EAS)
- Contract to be signed in October 2018
- First units delivered in May 2019

Construction of the series



Technical Specification

for the construction of 54 superconducting magnets –Sextupole, Octupole, Decapole, Dodecapole and Quadrupole– High Order Correctors for the High Luminosity upgrade of LHC (HL – LHC)

(Author: Massimo Sorbi, Marco Statera)

Summary
This technical specification concerns the manufacture of 12 superconducting sextupole (valid as "skew" and as "normal"), 12 superconducting octupole (valid as "skew" and as "normal"), 12 superconducting decapole (valid as "skew" and as "normal"), 6 superconducting dodecapole "normal", 6 superconducting dodecapole "skew" and 6 superconducting quadrupole "skew" (in total 54 magnets) for the High Order (HO) Correctors for the High Luminosity upgrade of LHC (HL – LHC). The document describes also the special toolings for winding and impregnation (property of INFN) that shall be used for the construction of the superconducting coils. It includes all information for allowing firms to provide a technical and financial offer.

TABLE OF CONTENT

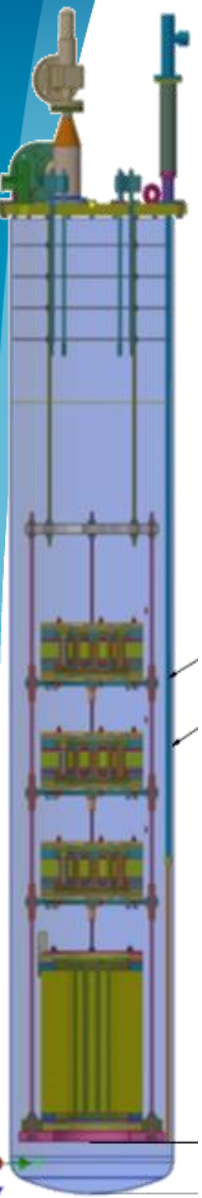
1

- The engineering design of the series completed as scheduled in July 2018 (**M1.1**)
- Technical and Contractual documents for the tender completed
- Approval by INFN Executive Board in mid July 2018
- Launch the tender in Sept. 2018
- Closing time for offers end of October
- Formal assignment in Dec. 2018
- Signature of contract. Jan. 2019 (**D1.1**)

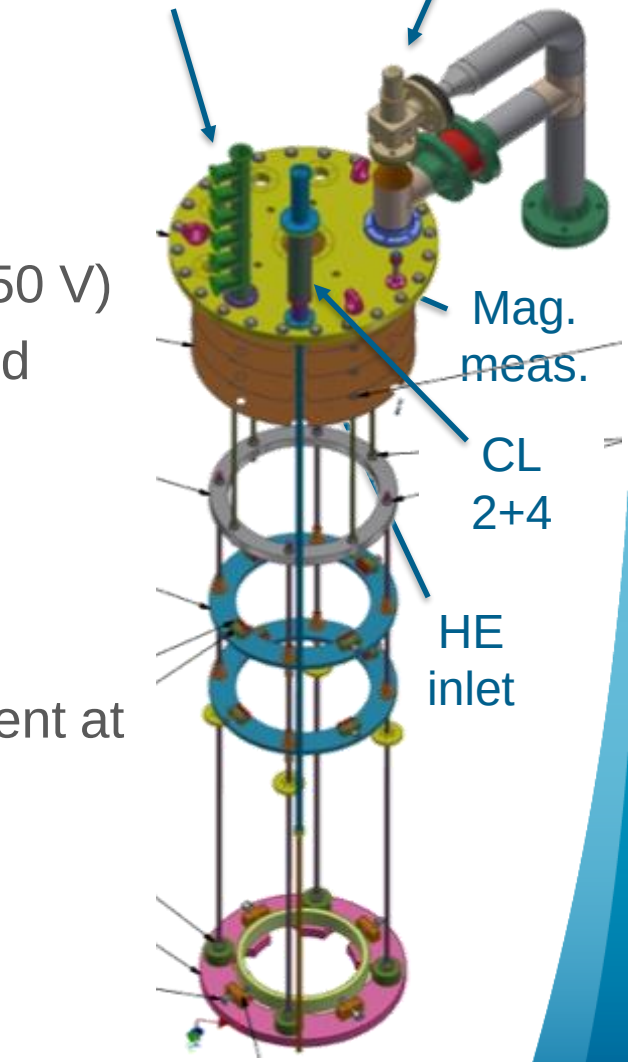
Hold point for series construction

- An **Hold Point** has been set after the delivery to LASA of the first set of 9 magnets (an entire string of correctors)
- We want to test at least the modified magnets (6-pole, 8-pole, 10-pole) to verify the requested modification
- The production has to be stopped for 2 months
- This allows to have a first set of 9 magnets on time or earlier (at CERN in Jan. 2020)
- The other sets will have a delay of 3 months respect to the original schedule (last delivery to CERN in Sept. 2021)

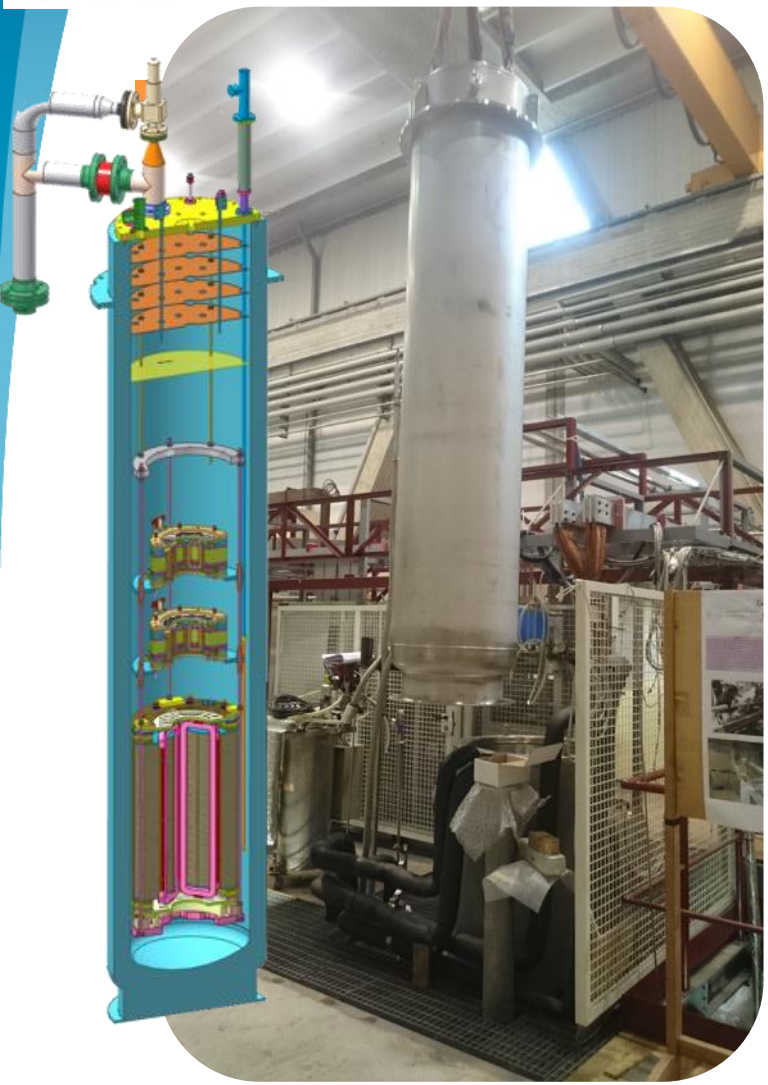
TEST STATION UPGRADE AT LASA

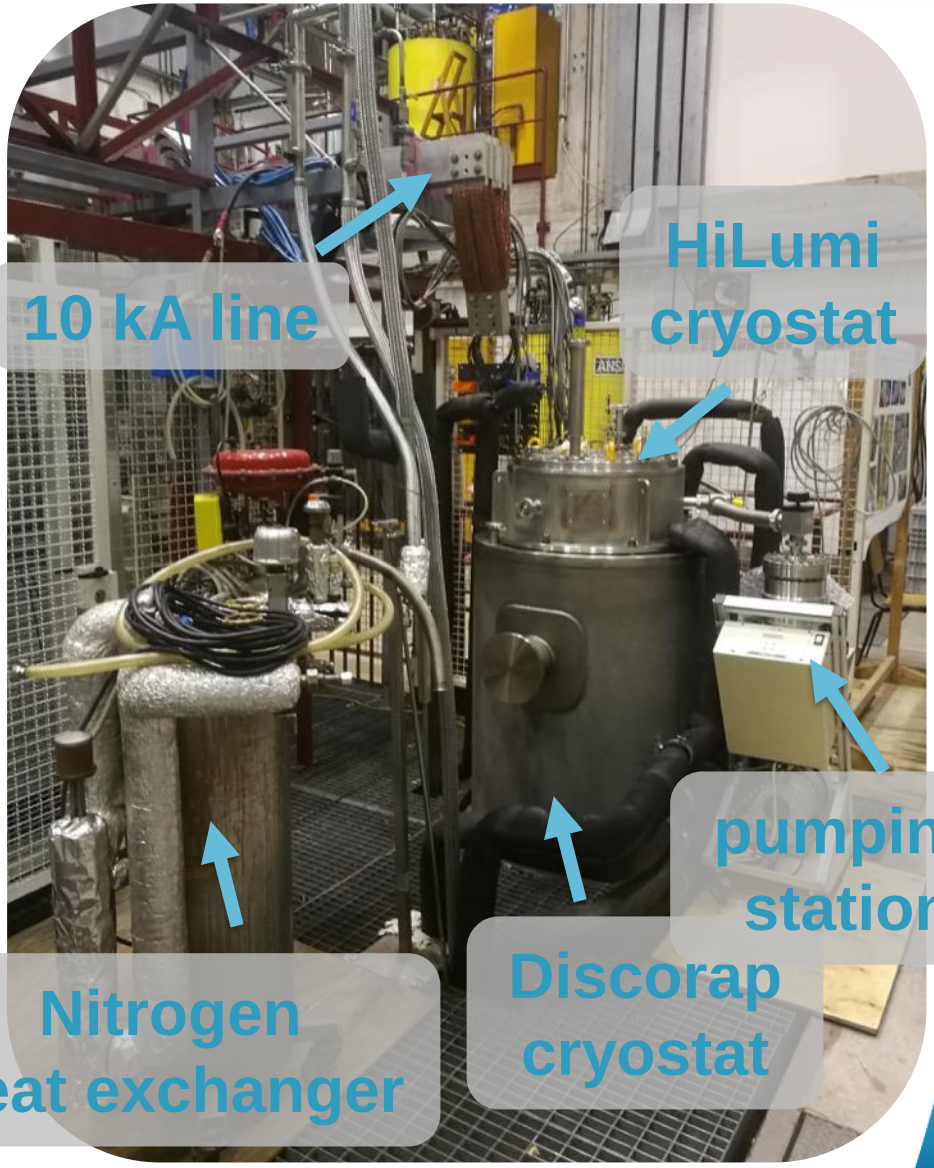


- New cryostat for testing MCTXFP1 (12P), MCQSXFP1 (4P) and then for HO series magnets
- New power supply for magnet test (200 A, 50 V)
- New main switch for power supply (fast solid state switch, $\Delta t<1$ ms)
- New acquisition system for test monitoring
- New controlled system to control cooling/warming of magnets
- Suitable for system of magnetic measurement at low temperature (supplied by CERN)
- Installation already completed and commissioned in 2018



Test station

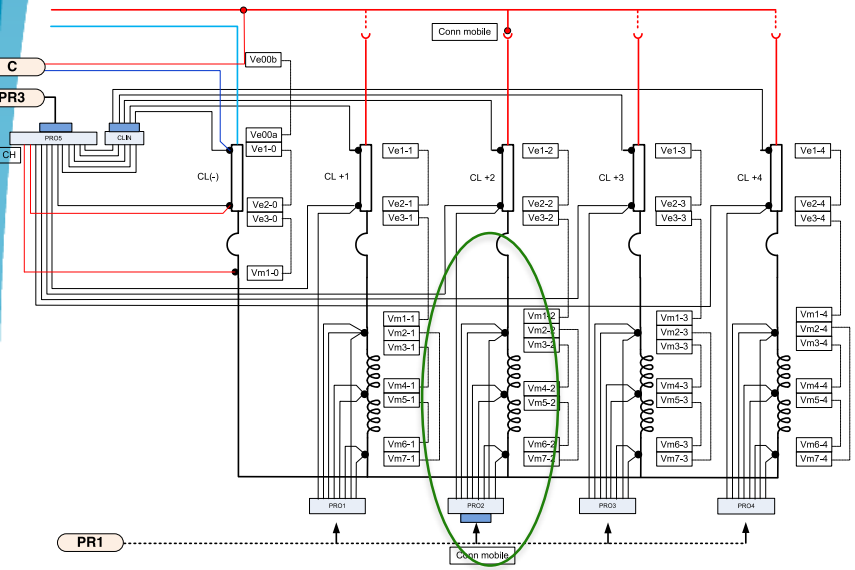




Test station

SOFTWARE

- Quench protection
- Fast DAQ
- Slow control

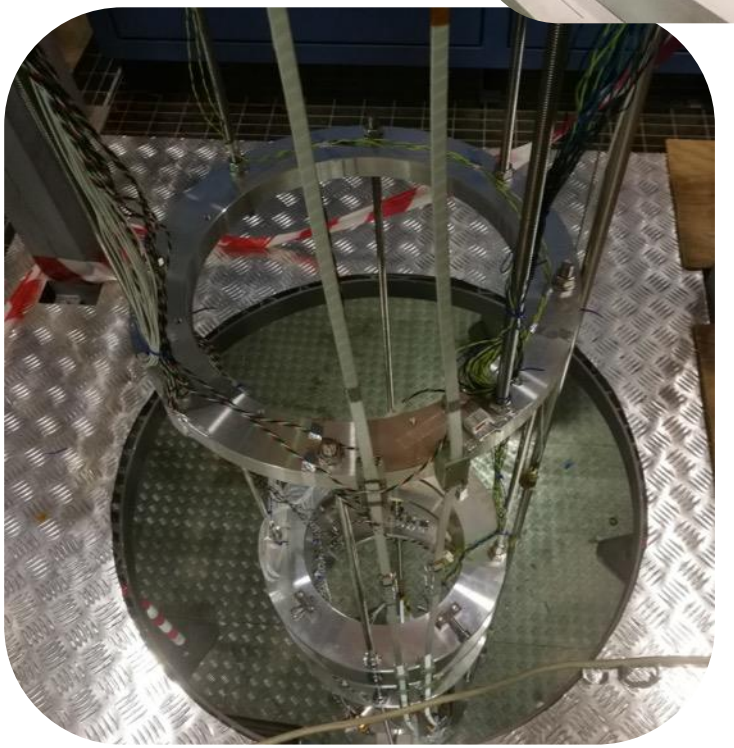


Each HO corrector

- 1 common CL + bus bar
- 1 dedicated CL + bus bar
- 3 voltage taps

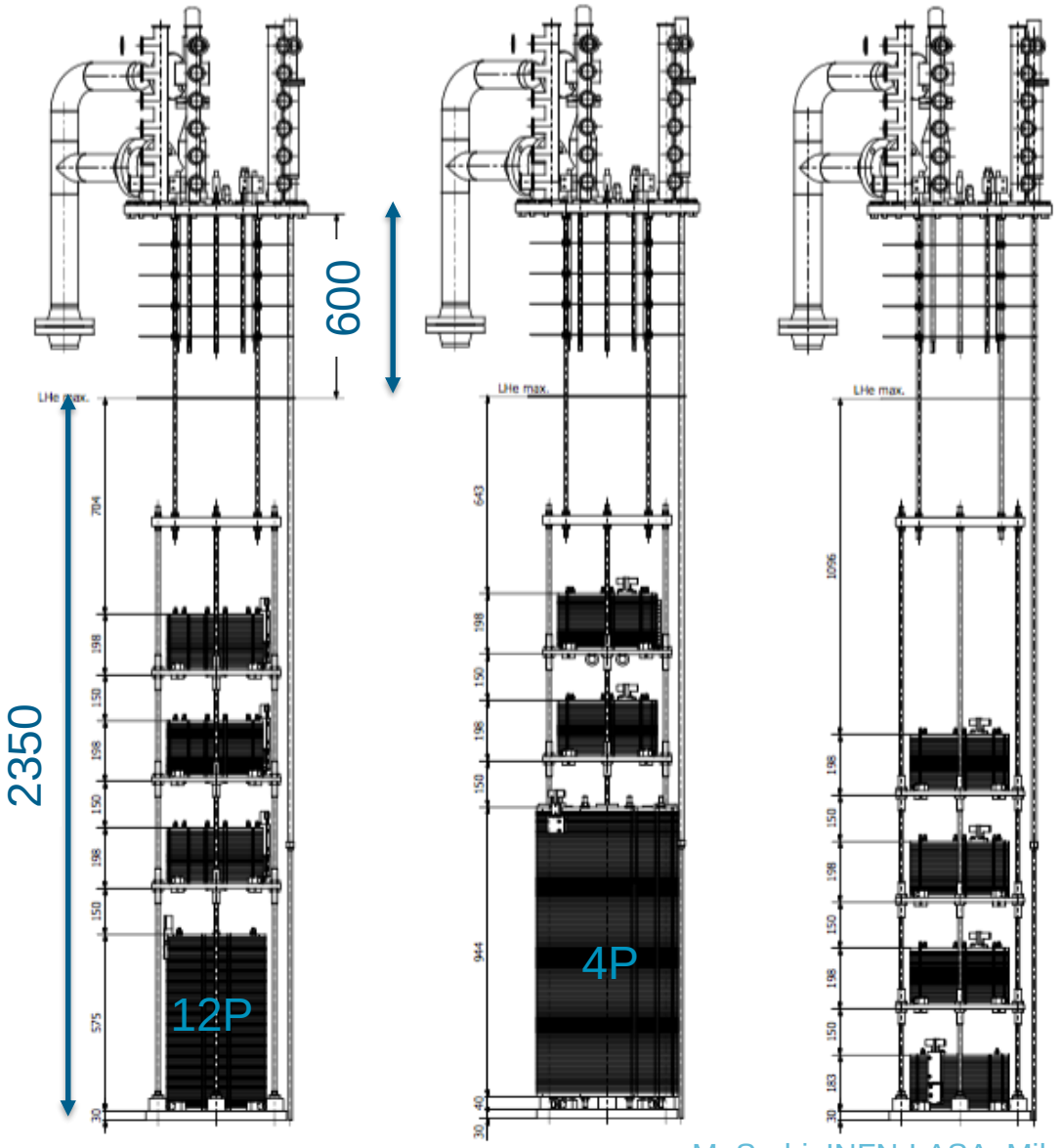
CABLING

MECHANICS
BUS BARS



CONFIGURATIONS FOR SERIES TEST

- In production are necessary 3 batches:
  - 18 magnets
  - 2X4P 2X12P
  - 5 cool-downs
- Different possible configurations for housing the magnets of each batch
- The flange is designed for housing the magnetic measurement system
- The tests will be performed at 4.2 K



M. Sorbi, INFN-LASA, Milan

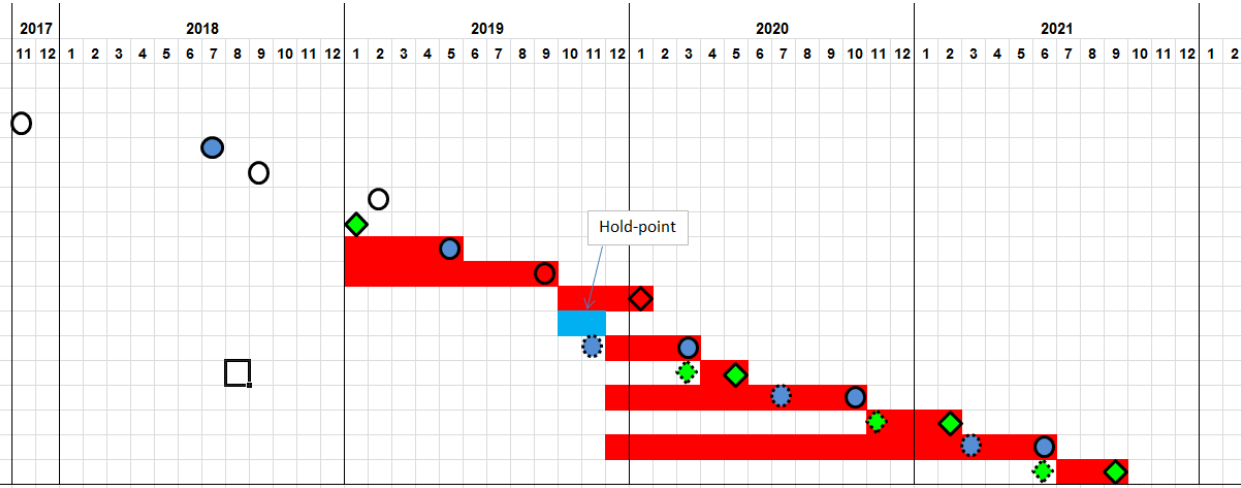
Conclusion

- The INFN activity for the HO corrector series (54 magnets) is on the track.
- Contract for 130 km of conductor almost completed.
- Final engineering and detailed design completed for all 5 magnets type.
- Tender for construction well launched.
- The LASA test station has been upgraded to manage the series test.
- First batch of magnets expected for test at LASA in Nov 2019.
- ….
- Last batch of magnets delivered at CERN in June 2021.

Schedule of completion of series

HO Correctors series for HL-LHC

			Project for Magnet Construction
		Nov. 2017	Formal approval of Addendum n.2 KE3085/TE/HL-LHC
M 1.1		Jul 2018	Engineering design of series completed
		Sep 2018	Award of contract for conductor purcharse
		Feb 2019	First delivery of conductor
	D 1.1	Jan 2019	Award of the contract for series construction
M 1.2		May 2019	First coil wound
M 1.3a		Sep 2019	1st set of 9 magnets at LASA
	D 1.2a	Dec 2019	1st set of 9 magnets delivered at CERN after test
			Hold-point for checking "new length"
M 1.3		Mar 2020	2nd set of 9 magnets at LASA
	D 1.2	Nov 2020	2nd set of 9 magnets delivered at CERN after test
M 1.4		Mar 2020	3rd and 4th set of 9+9 magnets at LASA
	D 1.3	Mar 2021	3rd and 4th set of 9+9 magnets delivered at CERN
M 1.5		Mar 2020	5th and 6th set of 9+9 magnets at LASA
	D 1.4	Mar 2021	5th and 6th set of 9+9 magnets delivered at CERN



Notes