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
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)

- Sextupole: 12 magnets
- Octupole: 12 magnets
- Decapole: 12 magnets
- Dodecapole: 6 +6 magnets
- Skew quad: 6 magnets

TOTAL MAGNET N. 54

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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

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### HL – LHC Engineering Change Request

**CHANGE OF QUADRUPOLE, SEXTUPOLE, OCTUPOLE AND DECAPOLE CORRECTORS INTEGRATED FIELD**

<table>
<thead>
<tr>
<th>WP Originator</th>
<th>WP3</th>
<th>ECR DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>MCQSF, MCQSF, MCQSF, MCQSF, MOZSF, MOZSF, MOC1YF, MOC1YF, MOC1YF</td>
<td>Magnetic length of 3+3 magnets and decreased the 4-pole skew.</td>
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<tr>
<td>Drawing</td>
<td>-</td>
<td>Date of issue: 2019-04-10</td>
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<tr>
<td>Document</td>
<td>-</td>
<td>Responsible: E. Todesco, M. Sorbi</td>
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<tr>
<td>WPs Affected</td>
<td>W93, W93, W97, W915</td>
<td>Reference Document: TDR Version 0.1</td>
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</table>

#### 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 50%, 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 cryostat.

<table>
<thead>
<tr>
<th>Magnet name</th>
<th>Integrated field at Rs=50 mm (T.m)</th>
<th>Magnet coil length (mm)</th>
<th>Magnet length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skew quadrupole</td>
<td>Baseline: 1.000, New value: 0.700</td>
<td>Baseline: 728, New value: 528</td>
<td>Baseline: 614, New value: 614</td>
</tr>
<tr>
<td>Normal octupole</td>
<td>MCQSF: 0.046, New value: 0.069</td>
<td>Baseline: 119.6, New value: 169.6</td>
<td>Baseline: 183, New value: 233</td>
</tr>
<tr>
<td>Skew octupole</td>
<td>Baseline: 0.046, New value: 0.069</td>
<td>Baseline: 119.6, New value: 169.6</td>
<td>Baseline: 183, New value: 233</td>
</tr>
<tr>
<td>Normal decapole</td>
<td>MCQSF: 0.025, New value: 0.037</td>
<td>Baseline: 119.6, New value: 168.6</td>
<td>Baseline: 183, New value: 233</td>
</tr>
<tr>
<td>Skew decapole</td>
<td>Baseline: 0.025, New value: 0.037</td>
<td>Baseline: 119.6, New value: 168.6</td>
<td>Baseline: 183, New value: 233</td>
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<tr>
<td>Normal deca-polar</td>
<td>MCTSF</td>
<td>Baseline: 515</td>
<td>Baseline: 515</td>
</tr>
<tr>
<td>Skew deca-polar</td>
<td>MCTSF</td>
<td>Baseline: 200</td>
<td>Baseline: 200</td>
</tr>
</tbody>
</table>

#### 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 mm in the alignment of the quadrupole average axis w.r.t. reference orbit as discussed in WFP2 meeting https://indico.cern.ch/event/716222/.

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 WP1 meeting on 1/3/2018.
The first Milestone M1.1 has been respected.
We are on the road to respect the first deliverable D1.1
3D and 2D drawing for each magnet ready

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New protection study

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

All magnets (except 4-pole):
- No-$R_{\text{dump}}$
- $\Delta t_{\text{delay}} = 180$ ms

4-pole:
- Conventional QDS ($V_a-V_b$)
- $R_{\text{dump}} = 1.5-3$ Ω

Normal-12-pole quench study

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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

- 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

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Test station

- 10 kA line
- HiLumi cryostat
- Discorap cryostat
- Nitrogen heat exchanger
- Pumping station

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Each HO corrector

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

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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**

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<tbody>
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<td>Nov. 2017</td>
<td>11</td>
<td>12</td>
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<tr>
<td>M 1.1</td>
<td>Jan 2019</td>
<td></td>
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<tr>
<td>M 1.2</td>
<td>Sep 2019</td>
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<tr>
<td>M 1.3a</td>
<td>Dec 2019</td>
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<tr>
<td>D 1.1</td>
<td>Jan 2020</td>
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<tr>
<td>M 1.4</td>
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<tr>
<td>M 1.5</td>
<td>Mar 2020</td>
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<td>D 1.2</td>
<td>Dec 2020</td>
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<tr>
<td>D 1.3</td>
<td>Mar 2021</td>
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</tr>
<tr>
<td>D 1.4</td>
<td>Mar 2021</td>
<td></td>
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</tbody>
</table>

- **M 1.1**: Formal approval of Addendum n 2 KE3085/TEHL-LHC
- **M 1.2**: Engineering design of series completed
- **M 1.3a**: Award of contract for conductor purchase
- **M 1.4**: First delivery of conductor
- **D 1.1**: Award of the contract for series construction
- **M 1.3**: First coil wound
- **D 1.2**: 1st set of 9 magnets at LASA
- **M 1.4**: 1st set of 9 magnets delivered at CERN after test
- **M 1.5**: Hold-point for checking "new length"
- **D 1.3**: 2nd set of 9 magnets delivered at CERN
- **D 1.4**: 3rd set of 9 magnets delivered at CERN
- **D 1.5**: 4th set of 9 magnets delivered at CERN
- **D 1.6**: 5th set of 9 magnets delivered at CERN

**Notes**

- **Actual in KE3085**
- **Milestone**
- **Deliverable**