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Horizon 2020 Research and Innovation Framework Programme, Research and Innovation Action

MEETING MINUTES

VIDEO MEETING

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Participants:	**CEA**: Maria Durante, Michel Segreti, Etienne Rochepault, Clement Lorin; **CERN**: Daniel Schoerling (Scientific Secretary), Davide Tommasini, Bernardo Bordini, Susana Izquierdo Bermudez, Alexandre Louzguiti, Jose Ferradas Troitino; **CIEMAT**: Fernando Toral; **INFN**: Stefania Farinon, Alessandra Pampaloni, Alessandro Ricci, Samuele Mariotto, Riccardo Valente, Marco Prioli, Massimo Sorbi; **PSI**: Bernhard Auchmann; **TUT**: Tiina-Maria Salmi; **Twente**: Marc Dhallé; **UoG**: Excused.
Link to Indico:	https://indico.cern.ch/event/774170/

Executive summary

The meeting is focused on assessing the status of the WP5 work with respect to deliverable and milestones, which includes the FCC Conceptual Design Report (CDR). The AOB part of the meeting is focused on the consideration of Nb_3Sn reversible degradation in the FCC main dipole.

Davide Tommasini: Status of the FCC CDR , and next steps for completion of the "long version"

D. **Tommasini** presents the status of both the short and long versions of the FCC CDR.

The short version is currently in preprint status and consists of 11 pages, focused on the baseline design of the FCC main dipoles. It also mentions the alternative designs of the main dipole; one page is dedicated to the design of the main quadrupoles and another one to that of the other magnets.

Regarding the long version of the CDR, D. **Tommasini** indicates that the WP5 contribution should contain about 30/40 pages on the FCC magnets, with parts focused on the electromagnetic design, the 2D mechanical design, etc. In order to optimize the writing of this contribution, D. **Tommasini** suggests the following strategy: all WP5 contributors should review the template currently available on Indico which has been prepared by **A. M. Fernandez Navarro, J. Munilla and F. Toral**, so that the WP5 contribution can be written in parts – and thus in parallel – before assembling. The target fixed for the writing of this contribution is mid or end of January.

Davide Tommasini: Status of EuroCirCol WP5 with respect to deliverables and milestones

D. **Tommasini** states that WP5 has currently achieved 3 of its milestones out of 5 and that the remaining 2 milestones should be reached by April and May 2019 respectively; these milestones are detailed in Table I. In addition, he also indicates that 3 of the WP5 deliverables out of 4 have already been accepted by the European Commission and that the remaining deliverable should be produced by April 2019; these deliverables are detailed in Table II.

Table I: Status and content of WP5 milestones

Title	Start date	Due date	Description
WP group established and hiring complete	01/06/2015	01/11/2015	The working group covering WP5 (High-field accelerator magnet design) has been formed, WP and task leaders have been identified and technical staff has been appointed.
Baseline specifications and assumptions for accelerator magnet	01/06/2015	01/04/2016	Preliminary set of specifications for an accelerator main dipole magnet in terms of physical and performance characteristics as well as design constraints. Target goal ranges for the final design and priority indications for individual characteristics to be studied in greater detail. Report released on project document management system.
Specifications for conductors and proposed conductor configurations	01/10/2017	01/04/2018	Report on the required physics and performance characteristics of the superconducting cables or their constituents, setting the performance targets for the industrial production requirements at large scale in view of the required accelerator dipole magnet. The specification is made available on the project's document management system.
High-field accelerator dipole conceptual design report	01/04/2018	01/04/2019	Consolidated design work consisting of drawings, functional and performance specifications for a dipole model sufficiently long (~1.5 m) to make relevant qualification measurements on performance, field quality and protection in a follow-up project.
Report on recommended follow-up R&D	01/11/2018	01/05/2019	Gap analysis between findings of the study, towards a realization project: Portfolio of suggested R&D topics related to superconducting accelerator magnets. In addition to the main dipole magnet model, present a list of required accelerator magnets and indicate their baseline physical and performance characteristics along with an assessment of feasibility, realisation risk and relative cost.

Table II: Status and content of WP5 deliverables

Title	Start date	Due date	Description
Overview of magnet design options	01/08/2015	01/11/2016	This document describes the design options for 16 T superconducting dipole magnets for the FCC hadron collider explored in the frame of the activities of WP5. All options have been considered under comparable assumptions and managed using the same tools to ensure a correct judgement and comparison of their relevant pros and cons. Three baseline design configurations have been explored: 1) block-coils, 2) cosine-theta and 3) common-coils. A fourth option, the canted cosine-theta, has been initiated by Swiss (PSI, not part of EuroCirCol) and US (LBNL, EuroCirCol partner) laboratories. The studies show that, adopting a reference margin to the load line of 14 % and with reasonable assumptions on the conductor performance, the total amount of conductor needed for the entire collider is between 7.5 and 10 ktons. depending on the option. The cosine-theta uses less conductor and the canted cosine-theta uses the largest amount. The characterisation of the magnet design options is complete and the work to finalize and compare these options in the subsequent deliverable D5.2 (identification of preferred dipole design options and cost estimates) has started.
Identification of preferred dipole design options and cost estimates	01/02/2017	01/08/2017	Detailed description of the preferred baseline design with its expected performances. Analysis of the individual merits and risks of the different, initial design options and justification for selection. The deliverable includes expected field levels, field errors and a cost estimate, which serve as input for the arc design consolidation. A summary of the technical expert advisory committee review is included. Description of requirements, constraints and impacts on environment, ancillary systems, arc, interaction region and cryogenic beam vacuum system.
Cost model for dipole magnet	01/03/2017	01/09/2018	Description of the model, reference data used as basis, any assumptions, constants and parameters that can be used to tune the benefit versus cost ratio. Major cost drivers and potentials to control costs will be indicated. The model includes three baselines: optimistic, likely and conservative.
Manufacturing folder for reference design dipole short model	01/04/2017	01/04/2019	Collection of all drawings, material and element specifications, assembly procedures. Calculation files indicating relevant design and analysis notes. Quantity and cost indications for materials and components required for production. Production quality requirements with tolerances.

Daniel Schoerling: Program for the next joint EuroCirCol-USA MDP meeting

D. **Schoerling** states that the next joint EuroCirCircol-US MDP meeting will consist of 10 minutes presentation that will aim at summarizing the work achieved by the different institutes included in WP5, i.e. FNAL, LBNL, CERN, CEA, CIEMAT, INFN, PSI, University of Patras, University of Tampere. It has been agreed that this meeting will take place on the 3rd of December at 5 pm.

Daniel Schoerling: Ideas for promoting a forum of discussion beyond the EuroCirCol

After the end of EuroCirCol, i.e. after March 2019, D. **Schoerling** proposes that the member institutes of WP5 and the institutes of the US Magnet Development Program (MDP) keep meeting informally by videoconference every one or two months in order to ease the knowledge sharing on high-field magnets for circular colliders. Since these meetings would be informal, the members list could easily be extended. Moreover they should occur at about 5-7 pm to match the working hours of institutes from the US and Europe. Finally, the FCC week would still go on at the same frequency, i.e. once per year.

AOB : Discussion on how to consider the effect of reversible Nb_3Sn degradation in 16 T dipole magnets

E. **Rochepault** presents a study on the impact of the stress on the critical current of a Nb_3Sn magnet: the Block Coil version of the 16T FCC dipole serves here as an example. To perform this study, he has used the following constitutive law which links the transverse pressure applied on the coil to the critical current reversible degradation:

$$I_c(B,S) = C\, B^{-0.5}\, {B_{c2}^{*}}^{0.5} \left[1-\left(\frac{S}{S_{max}}\right)^{a}\right]\left(1-\frac{B}{B_{c2}^{*}\left[1-\left(\frac{S}{S_{max}}\right)^{a}\right]}\right)^{2}$$

where I_c is the critical current, B is the magnetic field and S is the stress.

According to this study, it appears that if the magnet (block-design) is not sufficiently preloaded, too large reversible degradation of the critical current can be obtained. Indeed, E. **Rochepault** explains that, when the preload is sufficiently high, the stress in the high magnetic field region of the coil is smaller than with lower preload. Therefore, when the preload is sufficiently high, the reversible degradation has no impact on the critical current of the magnet. Nevertheless, there also exists a limitation to high preloads as they can lead to irreversible degradation, in particular after cool-down. B. **Bordini** summarizes this study stating that there is a short window of interference (i.e. preload) where there is no reversible current degradation; E. **Rochepault** agrees with this statement. These calculations were done for the block-design and refer to the high-field region (which is closest to the critical line). For this design type, the high-field region does not coincide with the high-stress region. This plot shows also implicitly that the expected reversible degradation in the high-stress region, is expected not so large that it limits the performance (although the expected critical current density is considerably reduced).

S. **Farinon** asks E. **Rochepault** how the values of the magnetic field B and stress S are selected in an element of the FEM model to evaluate the local critical current $I_c(B,S)$; he answers that the magnetic field B and stress S are averaged over each element of the model and that this requires a fine 2D meshing with plane stress condition.

B. **Bordini** stresses the fact that the strain (and not the stress) is actually the physical property that affects the critical current of Nb_3Sn. For this reason, he states that in the formula of the critical current above, the strain should be used instead of stress; E. **Rochepault** agrees with him. D. **Tommasini** indicates that the critical current measurements were done varying the stress S, and thus directly knowing the stress instead of strain, so he suggests to keep this approach for the moment. B. **Bordini** states that the strain of the conductor can be readily derived from the stress applied on the conductor, referring to the work done by G. **Vallone**. For this reason, a presentation by G. **Vallone** about the link between the stress on cable and the strain on Nb_3Sn filaments is scheduled on February 5th, 5 pm-7 pm.

After a general discussion, it has been agreed to consider the study of E. **Rochepault** as a first useful approach, and, for the time being, the reference Nb_3Sn conductor is RRP-like, i.e. with the parameter $a = 3.7$.