52th Meeting of the HL-LHC Technical Coordination Committee – 21/06/2018

Participants: C. Adorisio, A. Apollonio, G. Arduini, V. Baglin, F. Bertinelli, O. Brüning (chair), H. Burkhardt, R. Calaga, O. Capatina, S. Claudet, R. De Maria, D. Delikaris, P. Fessia, J. Gascon, M. Giovannozzi, S. Gilardoni, R. Jones, G. Kirby, H. Mainaud Durand, M. Martino, M. Modena, T. Otto, D. Perini, A. Poyet, S. Redaelli, F. Rodriguez Mateos, A. Rossi, J. Serrano, D. Wollmann, M. Zerlauth.

Excused: Y. Papaphilippou.

The slides of all presentations can be found on the website and Indico pages of the TCC.

The minutes were approved, with no actions to follow-up.

S. Claudet requested to add an AOB to the agenda concerning the ongoing discussions on the updated cooling requirements for the 11 T magnet.

Hollow e-lens layout and cathode development – D. Perini – slides

D. Perini reminded the TCC about the working principle of the hollow e-lens. A hollow e-beam interacts with the circulating proton beam for halo cleaning. The interaction region of the proton and electron beam extends over 3 m and the electron current should be 5 A. Such a high electron current poses significant challenges for the cathode design. A system of superconducting solenoids cooled at 4.5K generates the magnetic field to tune the beam size and steer the trajectory of the hollow electron beam. The e-lens is conceived to work both at injection energy and flat-top energy, which requires an adjustable size of the hollow e-beam.

D. Perini presented the current magnetic field configuration, featuring two main 5 T solenoids, plus additional solenoids for bending and correctors for beam steering. The powering configuration including the preliminary estimate of the number of circuits was presented. Upon a question from O. Brüning, G. Kirby explained that the main solenoids cannot be powered in series for protection reasons due to the large stored energy. M. Martino pointed out that what was reported in the presentation looks different from the previously discussed assumptions. F. Rodriguez Mateos commented that these assumptions have not been discussed yet in the Magnet Circuit Forum (MCF) and suggested taking this topic to the MCF soon for review with all involved colleagues. O. Brüning agreed and explained that a baseline design was needed to already start the first discussions for seeking in the following potential in-kind contributions, nevertheless the protection studies should be finalized.

ACTION: F. Rodriguez Mateos should report in the TCC the outcome of the circuit layout and protection studies for the hollow- e-lens after discussions in the MCF.

D. Perini mentioned that a solution to integrate BPMs in the design was identified in collaboration with BI colleagues. The inclusion of a double gun is under consideration, for redundancy (and hence availability) reasons as well as to be possibly used for MDs and tests. R. Calaga pointed out that the impact of this on space reservation should be carefully evaluated in point 4. D. Perini commented that the baseline design is fitting in the allocated space from integration, while the double gun solution could still be optimized.

D. Perini recalled the main changes to the design since November 2017, the main one being the increase of magnetic field in the main solenoids from 4 T to 5 T. Once the 3D models will be available, the discussions with possible suppliers could start (in a few weeks).

T. Otto asked if the magnets will be powered down during access. D. Perini confirmed the magnets will not be powered during access, but access will be carried out with helium inside the magnets (which is an identical procedure with respect to all other LHC magnet circuits).

D. Perini presented the status of the cathode development programme, in collaboration with Fermilab and Beijing University of Technology. The goal of the development is to decrease the cathode surface and to decrease the operating temperature (to increase the cathode lifetime). Upon a question from O. Brüning, D. Perini explained that the development programme should be completed by next year. D. Perini reported that the first test results are encouraging and that further tests (first real size Scandia doped cathode) will be carried out in the coming weeks at Fermilab.

O. Brüning asked if the dependence of the cathode lifetime on temperature is known. D. Perini explained that this dependence is not fully known, but there is clear evidence that decreasing the temperature increases the lifetime. So far about 3000 h of lifetime were reached (with the cathode still under test). The cathode lifetime is expected to be at least 10000 h, to be confirmed after the end of the tests.

S. Claudet added that also the cryogenic cooling optimization for the design is progressing well.

F. Bertinelli pointed out that the fabrication of pressured vessels will pose severe constraints on the suppliers, this is a point to be followed up very closely with the suppliers.

Hollow e-lens magnet system and protection – G. Kirby - slides

G. Kirby reported on the status of the design of the magnet system and related protection considerations. The design of the two main solenoids is in the fine tuning stage. Mechanical forces are being quantified and field maps are available for beam dynamics studies.

The effect of stray field on the beam dynamic needs to be evaluated, as the proposed design implies higher stray field than in typical LHC magnets, also impacting the 2nd beam line beside the hollow e-lens.

Concerning quench protection of the 5 T solenoids, G. Kirby concluded that the baseline is to have active detection and an energy extraction system. This could be implemented either by classical resistors or Metrosil, the latter offering an increased energy dissipation wrt to classical resistors. As an alternative, a fully passive solution based on high purity aluminium quench propagation strips is under study. For all other magnets, protection is not expected to be a problem and therefore a fully passive protection is assumed. O. Brüning asked if quench heaters are needed for the main solenoids, G. Kirby confirmed this is not the case.

M. Modena asked if from the mechanical design point of view any critical points have been identified. D. Perini commented that the present design is already taking into account all the mechanical constraints.

O. Brüning thanked on behalf of the project all people involved in the design studies for the work towards the potential inclusion of the hollow e-lens in the HL baseline.

Crab cavity test programme in the SPS – R. Calaga - slides

R. Calaga reported the status and first results of the crab cavity tests in the SPS.

After the first cool-down conditions have been stable at 4.5 K since 21st April. On May 2nd, the crab cavity assembly was tested (position, cavity movement, interlocks) and everything worked as expected. RF conditioning is currently limiting the operating voltage. There has been an increasing pressure trend in May, so the operating voltage is limited in order not to exceed 5e-8 mbar in the CC vacuum.

During the first SPS MD block devoted to the CC, protons circulated for the first time in the crab cavities. A voltage scan was performed and the longitudinal beam profile showing the crabbing effect was reconstructed. Efforts were devoted to achieve the synchronization between the main SPS RF system and the crab cavities.

In a second MD, nominal bunches were used at 26 and 270 GeV. Phase scans were performed for cavity 1 (1 MV), while the voltage in cavity 2 was limited by the cavity vacuum. It was discovered that antenna signals require filtering to suppress the direct beam induced signal, some work is required for this on the LLRF side. Orbit scans were also performed to identify the electrical center, but the measurements were not conclusive, they should be repeated with higher beam current. Emittance measurements didn't show any systematic effect of the crabbing on emittance in the 20 s SPS cycle (which is however very short compared to LHC).

A first attempt to measure the a3 multipolar component of the crab cavities was carried out but the beam was lost crossing the vertical tune resonance. After setting the correct cycle start voltage to 270 GeV equivalent, the beam circulated without problems. M. Zerlauth asked what interlock channel dumped the beam, R. Calaga explained that the beam was not dumped, it was simply lost.

The peak power in the HOMs was estimated to be below 100 mW, no problems observed.

The next MDs are foreseen in July, in less than 2 weeks 2 K operation should be possible and the LLRF will be fully deployed, allowing for tests with higher intensity once all relevant

machine protection tests are completed and appropriate mitigation measures against fast failures are in place. In total of six more dedicated MD blocks are foreseen for crab cavity tests.

AOB: ECRs for space reservation for BBLR wire compensator – A. Rossi - slides

A. Rossi reminded the TCC about the possible use of Beam-Beam Long-Range (BBLR) wire compensators for HL-LHC to increase the dynamic aperture and the operational flexibility at reduced crossing angles. The scope of the ECR is to update the space reservation in IR1 and IR5 for the BBLR wire compensator (from half-cell 4L1/5 and 4R1/5 to 5L1/5 and 5R1/5) and to ask for support for the remaining studies to be finalized (FLUKA, machine protection, mechanical design, vacuum, impedance, collimation). The selected position satisfies all requirements for both round and flat optics. Space reservation should also include space for the racks in the URs. O. Brüning pointed out that in case cores are needed between the tunnel and the new HL galleries, this should be communicated to P. Fessia, as a possible reduction of the number of cores is under discussion for savings on civil engineering. A. Rossi explained that according to P. Fessia this would not be needed, provided that the volume for cabling required for the BBLR wire compensator is within the error margin of the estimated cabling required for other systems.

O. Brüning commented that the TCC supports this activity as a backup option so the space reservation can be kept, but the BBLR wire compensator is still not part of the baseline. He suggested quantifying the resources required for the remaining studies to be performed and checking with WP leaders their support for these studies.

A. Rossi mentioned the potential space conflict with possible forward physics experiments. O. Brüning commented that at the moment no official discussions have started on this.

D. Perini asked if it was considered making the BBLR compensator superconducting to reduce its size in case of space issues. A. Rossi replied this would be possible but the object would become more bulky. S. Gilardoni added that this object will directly see the beam halo, so in case it should be designed with very big margins.

G. Arduini pointed out that the ongoing discussions on the possible movement of Q4 and Q5 towards the arc (although the relative distance between the two will be kept) could potentially have an impact on the LRBB compensator as well, so this aspect should be checked.

Implications of additional cooling requirements for the 11 T magnet – S. Claudet

S. Claudet mentioned the recent discussions on the heat loads for the 11 T dipole, which according to the latest estimates could be up to a factor 10-20 times higher than initially foreseen (depending on particle species and timescale of the heat deposition). Despite the cryogenic cooling layout being designed with margins, these will not be sufficient to cope with the estimated increase. This has an impact on the design, with additional cooling channels

possibly to be envisaged. S. Claudet recommended treating this topic in the TCC in July, as the design has to be finalized in August.

S. Redaelli commented that the scenarios in which the heat load would be 10-20 times higher should only be in case of combined failures, so the risk should be low. Nevertheless, if possible, the design change should probably be done anyway as it would improve the quench limits.

ACTION: F. Savary and S. Redaelli should report in July on the implications of additional cooling requirements for the 11 T magnet.