26th Meeting of the HL-LHC Technical Committee

Participants: C.Adorisio, V.Baglin, M.Bajko, I.Bejar Alonso, L.Bottura, O.Bruning (chair), R.Calaga, O. Carpata, D. Duarte Ramos, M. Fitterer, P. Fessio, M.Giovannozzi, B. Giraolino , M. Guinchard, R.Jones, W. Hoefle, T.Otto, S.Redaelli, F.Savary, L.Tavian, J.Ph.Tock, R.Tomas, R.van Weelderen, M.Zerlauth

Excused: J.Uythoven, D.Wollmann

The slides of all presentations can be found on the website and Indico pages of the TC:

HL-LHC PLC/TC homepage: https://espace.cern.ch/HiLumi/PLC/default.aspx

Indico link: https://indico.cern.ch/event/373545/

O.Bruning opened the meeting and announced that the minutes of the previous meetings would be distributed and approved for the next TC meeting. He recalled an action defined during the last meeting, related to the input to the latest optics from the LBDS team. J.Uythoven confirmed offline that he will discuss with the optics team and report back on this action in the TC of the 8th of October.

The TAXS aperture has been increased back to 60mm (with reservations from H.Burkhardt who reminded that such increase would come with a higher exposure and risk for the experiments). S.Redaelli commented that discussions are ongoing on this subject, and that the outcome will be reported back to a TC in due time.

M.Giovannozzi confirmed that the argument of H.Burkhardt is that a maximum of closure of the TAXS provides better protection of the experiments. In the worst case, the experiments might become a tertiary collimator intercepting showers of the TAXS.

B.Giraolino confirmed that discussions have started converging, and that we could expect a statement during the next PLC of 24/09 to present the final value to be adopted. M. Giovanozzi confirms that currently in the TDR of WP2 the baseline for the TAXS aperture is still 60mm.

Update on the 8b+4e parameter list, R.Tomas Garica – slides

R. Tomas summarized the performance reach of the 8b4e parameter set, which represents an interesting fallback solution in case (HL-)LHC operation will remain challenging due to persisting electron cloud, resulting heat load and preservation of beam quality. This production scheme allows partial compensation of the missing four 4 bunches with larger bunch intensity and lower emittance due to less splitting operations when produced in the injectors.

The given estimates are done based on achievable parameters of the LIU project (which is different from the HL-LHC baseline which represents the ideal performance target). The turnaround time was slightly increased to 183', following a slightly longer SPS ramp for HL-LHC beams.

R.Tomas outlined a few improvements which were done to the simulation code to include the actual H/V crossing plane, IBS growth times from MAD instead of an approximation formula, and general cc settings and flat leveling options.

R.Calaga asked whether the longitudinal emittance blow-up of 30% is a desired value (requiring a controlled blow-up) and whether the bunch length needs to be kept constant. R.Tomas confirmed that it should ideally be kept long to minimize IBS and the transverse blow-up during the ramp.

The 8b4e scheme has around 30% fewer LR interactions, which would allow for a reduced crossing angle. For the simulations, 9 sigma and a beta*=15cm were chosen to alleviate the CC voltage and be in line with the HL-LHC baseline scenario.

Due to the higher bunch intensities, 8b4e requires leveling at a lower luminosity to maintain the same pile-up. With the above assumptions, the 8b4e performance in terms of integrated yearly luminosity is some 20% below the LIU-compatible case (which itself is some 6% below the HL-LHC baseline). It was noted that beta* and emittance have only little impact on the 8b4e performance.

Decision: O. Bruning recommended using the same beta* as for the HL baseline to keep the performance reach comparable. The parameter set should assume the same nominal HL-LHC crossing angle, with an additional footnote adding that a further reduction of the crossing angle would be possible due to the smaller number of LR interactions.

Discussion

R.Calaga questions whether the 30% less LR interactions can directly be translated into a reduction of crossing angle, as the head on tune-tune shift will be (slightly) bigger (and hence should be taken into account).

O.Bruning enquired for the current MD plans for 8b4e as this scheme represents a very important backup scenario (not only for e-cloud and heat load but e.g. also for UFO behavior with this filling scheme). R.Tomas answered that a request was submitted but not included in the MD programs yet; this should however be given higher priority for the next MD block.

Observation of ground motion in the LHC, M.Fitterer – slides

M.Fitterer recalled the measurements of the inner triplet (IT) Eigen-frequencies presented to the 16th HL-LHC PLC by M.Guinchard, revealing a first horizontal mode around 10Hz and a first vertical mode around 23Hz which could lead to an amplification of ground motions of up to a factor of 100 by the mechanical structure of the IT. Measurements are performed from a noise input to the feet onto the beam center. O.Bruning recalled that the measurement was done on an open cryostat, which might reveal different results than in the machine (with a closed and filled mechanical structure). M.Guinchard explained the non-symmetry between lateral and transversal cross talk with the non-symmetry of the cryostat which prevents a symmetric cross talk into the opposite plane.

In the machine, the beam spectrum during the squeeze was recorded using the ADT and the DOROS BPMS (whereas the latter imply a low-pass filter at around 100Hz). A change in amplitude of the measured orbit spectrum would almost certainly be related to a movement of the IT. An eventual misalignment of the triplet would further increase the sensitivity to ground motion during the squeeze. The closed orbit distortion is hereby proportional to the maximum beta function in the triplet.

Measurements where done during 2 MD fills (4037 for IR aperture measurements at small beta, 4033 for optics commissioning) and compared with two standard physics fills (3974 with 152b and 3986 with 296b). O.Bruning commented that without averaging one obtains a lot of noise during the squeeze.

The measurements indicate a peak at 20Hz in the vertical plane that correlates well with the measurements of the IT Eigen-frequencies. In the horizontal plane, peaks at 4.5 Hz and around 10 Hz are visible. The 10 Hz peak could be correlated with the first horizontal Eigen-frequency, but as no change in amplitude is observed during the squeeze, other sources then the triplet can not be excluded.

A comparison with a 2010 measurement performed with the ADT by D.Valuch and W.Hofle was shown, revealing an identical peak appearing around 20Hz.

An attempt to investigate an eventual scaling of the peak with beta* was done, but failed to reveal convincing evidence.

During flat top for the normal physics fill 3974, additional peaks are observed mainly with the DOROS BPMS. These peaks are though not present in other spectra and also moving peaks were observed in other measurements. One explanation for the appearance and disappearance of the peaks could be the orbit feedback, which is active at flat top and during the squeeze. The ADT data for physics fills shows consistently a peak at 10 Hz in the horizontal plane at flat top and squeezed, and at 20 Hz in the vertical plane only squeezed.

In summary: DOROS and ADT data yield consistent beam spectra, independent whether feedbacks are switched ON or OFF. The 20 Hz peak seems clearly related to the IT Eigen-frequency as it is not present at high beta *. An additional 10Hz bump is visible at high and low beta*.

W.Hofle confirmed that the 20Hz peak has also been seen during tune measurements through observing a tune modulation at this frequency, probably because the triplet variation also induces a tune change and not only an orbit change. M. Guinchard commented that these frequencies mainly originate from longitudinal oscillations, as no 'squashing' of the triplet is possible at such low frequencies.

An FFT of BLM data dumps was attempted to average as well over lower frequencies, however better longer data buffers time resolution would be required for a significant this data analysis.

R.Tomas added that the 10Hz effect is already visible in the regular BPMs (not the 20Hz though), however only data with squeezed beams was analyzed.

O.Burning commented that it would be interesting to extend the analysis as well to beta*= 15cm to assess if there is some scaling and additional amplification.

Action: In view of the results, M.Fitterer highlighted the importance of an according design of the cryostat to minimize as much as possible an eventual amplifications of Eigen-frequencies.

R.Jones reminded that one should not forget the other peaks in the spectrum which are already higher than the ones we know from the IT Eigen-frequencies.

First results from June Test of 11T single aperture model, F.Savary – slides

In the beginning of his presentation, F.Savary confirmed that the action related to the confirmation of the final collimator jaw length has been followed up. The length is confirmed to be 60cm, which has been discussed and approved in the 51st ColUSM meeting (Minutes)

The 11T single aperture model MBHSP102 is composed of 2 individual coils, denominated coil 106 and coil 108. The conductor for the new coil 108 was found to be much better thanks to more adequate HT parameters (larger critical current and larger minimum RRR).

The test plan consisted of an initial training at 1.9K, including a thermal cycle, first ramps to the first target current of 12.5kA, followed by final training to 12.8kA and various powering tests (e.g. ramp rate dependence). In a second phase, magnetic measurements of transfer functions, multipole components, and integral field followed and were terminated by protection studies (including quench heater performance).

Some 20 training quenches were required to reach the target value of 12.8kA, dominated by the less performant coil 106. Coil 108 only required 4-5 (de-)training quenches. F.Savary showed the training curve of the model MBHSP102, indicating a longer training of coil 106 wrt to coil 108. For coil 106, the first 3 quenches were located in the end parts of the coils, before moving to various locations in the straight part and the ends. No particular weak point was identified in the assembly. A comparison with the initial model MBHSP101 shows a clear improvement for quench behavior.

In terms of ramp rate dependence, no quenches occurred up to ramp-rates of 200A/s; when ramping the model with 300A/s a quench occurred at 10.8kA.

Stress level measurement were performed in order to optimize future coils by applying corrective pre-stresses. Transfer function measurements show a good correlation with the 2D ROXIE model for currents above 2kA.

O.Bruning enquired whether the difference between 2D model and measurements can be associated to decaying field components. L.Bottura confirmed that such decays exist and noted that not the full measurement curve is shown in the left plot of slide 17 (but visible on the right plot).

For the allowed multipoles, emphasis was given to the b3, b5 and b7 component: During ramping b3 changes by ~22 units. A good correspondence with ROXIE simulations was found, but a certain offset of measurements wrt to the model is present which is not yet fully understood. On the first model the b3 components was in the order of 5-5.5 units, for the 2nd one we are just below 12 units.

M.Giovannozzi asked whether the spool-piece sextupole magnets (MCS) will still exist in these 11T dipoles. F.Savary confirmed that the 11T assembly will maintain the current corrector package. The corrector will be – as presently – powered in series with the existing MCS circuits of the arc.

For protection purposes, quench heaters are installed in the high and low-field region. An important particularity of coil 108 is that it has a ground wrap between the quench heater and the outside surface of the outer layer (0.1mm S2 glass). Coil 106 has no ground wrap which naturally yields in a much better contact of the QH with the coil.

Several measurements of QH delay as a function of the magnet current was performed (for a QH current of 150A). As expected, measurements show bigger delays for coil 108, which also shows to be less efficient. The energy dissipation in the inner layer is also found to be smaller than for coil 106.

In conclusion, the 2nd short model showed a rather fast training curve up to nominal current, with a few detraining quenches in coil 106. Only 4 quenches were observed in coil 108, which is consistent with the better quality/performance of the used cable. The magnet could be operated stably at nominal current during 10 hours.

The TF is in agreement with predictions, the model however overestimates saturation effects. The offset on the allowed multipoles remains to be understood.

The important differences of quench protection in the two conductors and coil insulation layout complicates the quench protection analysis. The behavior of coil 106 is very reproducible in aperture MBHSP101 and MBHSP102. The heater performance in coil 108 is delayed as expected (but very close to coil 107 measured in MBHSP101 with the same insulation layout). It was also found that the heater efficiency is lower than expected. There is no clear reason yet to explain the differences between low-field quench heater delays observed in coil 107 and 108

F.Savary concluded by referring to more information available on two Indico links (MBHSP102 – Part1, MBHSP102 – Part2).

The next model MBHSP103 is nearly finished, and expected to be installed in the SM18 test bench in around 2 weeks from now. This model – if it performs well – could become the 2nd assembly of the first 2in1 assembly. Testing of this 3rd model will start in 5-6 weeks.

Discussion

O.Bruning noted that the offset of the multipoles could be corrected with the standard correctors in the arc.

F.Savary commented that the size and geometry of the coil is not yet in nominal dimensioning, currently shimming had to be used to compensate for imperfections. Additional work is required to fully master the production process.

L.Bottura warned about false expectations wrt to further improvements of the cable performance. MSC has to procure the wires today in order to be ready for LS2. This wire will determine the persistent currents, hence no big changes are expected wrt to the current measurements.

O.Bruning confirmed the baseline for the 11T dipole installation, namely to be ready with 1 full assembly for the start of LS2, with a second one being completed in the course of LS2. The final location of installation still needs to be decided between IR2 and IR7 as a function of the planned proton and ion quench tests.

AOB

P.Fessia reported on a newly discovered integration constraint for the cryogenic connection of the cc between the D2/Q4. Today there is not sufficient space available, hence the final design of the sc link and its connection are missing. The solution studied today is to move the connection, a more detailed report on this issue will be part of the Layout update given by P.Fessia during the PLC on the 24th of September.

Next TC on the 17th of September.