Minutes of the 123st WP2 Meeting held on 12/06/2018

Participants: S. Antipov, G. Arduini, X. Buffat, R. De Maria, F. Giordano, M. Giovannozzi, G. Iadarola, D. Kaltchev, N. Karastathis, S. Kostoglou, E. Metral, N. Mounet, A. Oeftiger, S. Papadopoulou, Y. Papaphilippou, F. Plassard, A. Ribes Metidieri, M. Sabate, B. Salvant, K. Skoufavis, G. Sterbini, F. Van der Veken

AGENDA:

1 GENERAL INFORMATION (G. ARDUINI)

The minutes of the previous meeting have been circulated and approved. **Gianluigi** inquired about the follow-up of several action items of the previous meeting. **Massimo** reported on starting collaborating on a study of nonlinear field effects with Barbara Dalena and Thomas Pugnat at CEA.

For impact of Quench Protection System (QPS) on circulating beam it is important to (1) understand if there is any evidence of higher BS impedance (if possible, perform an MD) and (2) check what thickness of Cu would be needed to explain the experimental beam position data. **Riccardo** made a comment that what matters is the product of the two. Using the design values of coating thickness and conductivity, a factor of 13 is missing. According to the plot, circulated earlier by **Benoit**, the effective thickness of Cu layer is measured to be 50 µm instead of 70 µm, still leaving a factor of 10 missing. **Benoit** pointed out that no impact can be measured with bunch trains at injection due to low frequencies of coupled-bunch modes and low thickness of the coating. **Gianluigi** proposed to perform an MD with single bunches at injection. **Gianni** recalled that a beam screen of one of the magnets from Sector 1-2 is being studied. **Benoit** noted that the study needs to be done at cold temperature and at different frequencies, not DC only. **Gianluigi** suggested asking Mauro about the measured thickness of Cu coating. **Benoit** added that surface contamination is also of interest.

Sergey reported that an update on crab cavity HOMs had been received from Rama and Jamie. The mode shunt impedance for DQW design increased, exceeding the limit of 1 MΩ/m. **Gianluigi** requested an update on the HOM strength and their impact on stability at one of the future meetings.

ACTION (Impedance team): Propose and conduct an MD to measure the Beam Screen induced tune shift at Injection and test the conductivity of beam screen coating.

ACTION (Benoit): Check the measurement data on Cu thickness and its contamination.

ACTION (Jamie, Sergey): Provide an update DQW HOM strength and their impact on beam stability.

2 OPTICS VERSION 1.4 (R. DE MARIA)

A new version of the optics is a work in progress. **Riccardo** presented a summary of the changes in LHC layout and its optics and then covered in detail several key changes. Summary of changes in the layout: 2 crab cavities (CC's) per IP instead of 2+2 optional, change to Q4 and Q5 orbit correctors; remote alignment system that allows the machine to be realigned during beam commissioning; extended D1 dipole beam screen (length under discussion); new specifications for several tertiary collimators; changes in the triplet package.

Summary of changes in the optics: dedicated optics, optimized for 7 TeV; new aperture estimates thanks to the remote alignment; IR4 optimized for installation of an electron lens; IR6 optimized for TCDQ gaps, Q5 strength.

The HL-LHC TCLX and TCPH collimators require a max gap larger than 80 mm to accommodate the beam halo and orbit tolerances, but the best HL-LHC design allowed only 60 mm (as in the LHC) due to larger second beam pipe and reduced separation. To allow a larger stroke, a new design with an elliptical beam pipe (65/80 mm) is proposed, which utilizes the asymmetry in the aperture. Remote alignment allows further reducing the aperture, decreasing the stroke to below 40 mm and making it mechanically feasible.

For flat optics v1.3 the aperture is limited by the triplet (with tolerances at 12.7 rms beam size (σ) and 15.5 σ without tolerances). In v1.4 thanks to remote alignment ground motion and fiducialization tolerances can be reduced from 2 to 0.5 mm. A detailed orbit error model from Davide Gamba reduces the tolerance requirements from 2 mm to 1 mm. A recipe has been created to compute a smooth beam envelope aperture for the layout of vacuum apertures.

An important step in the further analysis is to compute the phase advance tunability. It gives a valuable input for beam lifetime studies. The analysis has to be done in a loop with IR4/6 optimization. After the optimization has been completed one can finalize the choice of crossing planes. A request to move the Q4 and Q5 by 3 m towards the arc has been made by S. Claudet to optimize the cryogenics lines in the matching section. This will require further optics studies and for that the presentation of the optics V1.4 at the TCC will be postponed. The release of the new version of the optics will be delayed unlit the finalization of the cryogenic layout.

- On the crossing plane in IP1/5, **Riccardo** emphasized that at this point a decision on the crossing plane in IP1/5 has to be made. **Gianluigi** recalled that for round optics a vertical (V) crossing in IP5 and horizontal (H) in IP1 is optimal to place the aperture bottleneck in the V plane in IP5 where it is more difficult to optimize the MKD-TCT phase advance. **Riccardo** agreed, but noted that the situation is reversed for the flat optics, both with CC's and without, because in flat optics the aperture bottleneck is in the parallel separation plane. The choice of crossing planes also has an impact on the forward physics, potentially eliminating one of the experiments. **Gianluigi** inquired about back-up options in case there are issues with CC's. **Riccardo** replied that without the crab cavities would be better to invert the crossing plane: V in IP1 and H in IP5. From the optics point of view, there is no limitation on the crossing plane; the planes can be swapped if needed. **Riccardo** proposed to evaluate the β* reach with and without CC's for all options.

- **Yannis** noted an upcoming ECR for the wire compensator where it is planned to request a space of 3 m. **Riccardo** replied that the corresponding space is allocated in IR1 and 5 and noted that the some requirements for non-baseline equipment might be in conflict.
- **Gianluigi** inquired if a test of Q7 at ultimate current shall be made. **Riccardo** agreed .that it is a good moment to perform a test; the matter has to be presented at TCC, preferably by the end of June.
- For the new tertiary collimators that utilize elliptical chamber geometry, a question arose on their impedance. **Benoit** suggested simulate and study the impedance, including the round-to-flat transitions as soon as the design is finalized, and noted that it is important not to create RF cavities.
- For the layout of vacuum apertures, **Gianluigi** pointed out the risk of fixing the wrong aperture. **Riccardo** replied that iterations are ongoing between the alignment and the optics, a discussion has started between remote alignment and alignment WG's. **Gianluigi** inquired when the design has to be frozen. **Riccardo** replied it has to happen by September otherwise the matching section cannot be closed.
- **Gianluigi** asked if there are any compatibility issues with a lower β* in IP8 (1.5 instead of 3). **Riccardo** replied that there are no issues form the optics side and the lower β* can be put in the OP scenario after confirming the lifetime. **Yannis** confirmed the lifetime is OK.
- **Sergey** asked whether there is a significant change in β-functions at the collimators and crab cavities. **Riccardo** replied the β-functions at the CC's may change by 10-15% in some pushed configurations. The β-functions at primary and secondary collimator, which are the most critical for coherent beam stability, are not changing significantly.

ACTION (Riccardo): evaluate the β* reach with and without CC's for all options for the two possible orientation of the crossing angles.

ACTION (Riccardo): Bring up the test of Q7 at the full current at the TCC

ACTION (Riccardo): Verify that all pending actions for the optics are included in v1.4 optics

ACTION (Benoit): Evaluate the impedance of the new tertiary collimators

3 STUDIES OF PACMAN EFFECTS IN THE HL-LHC (A. RIBES METIDIERI)

A PACMAN bunch in a filling scheme is bunch missing a long-range or a head on interaction with the other beam. The missing interaction affects bunch's tune, chromaticity, orbit, linear coupling and may impact its stability. The need to reevaluate PACMAN effects for HL-LHC comes from a stronger focusing in the Interaction Points and a greater beam intensity. In order to do that a strong-strong self-consistent model has been implemented in the tracking code TRAIN that uses 2^{nd} order transfer maps to integrate particle motion. An analysis has been performed for the Nominal and Ultimate operational scenarios of HL-LHC.

For the Ultimate scenario, the peak-to-peak deviation of the orbit amounts to nearly 700 μm due to the missing collisions. The maximum tune shifts are within 10^{-3}. The impact on chromaticity is small before collision - less than on unit. When in collision, the missing head-on interaction has a rather large effect on chromaticity – several units of Q', its impact on beam lifetime has to be assessed.

- **Riccardo** suggested using a half of the total orbit spread – less than 0.5 mm – as a figure of merit for aperture considerations. **Xavier** replied that it needs to be discussed with the collimation team. **Gianni** proposed adding the PACMAN orbit spread to the orbit tolerances. **Riccardo** replied that this can be done, but noted that the effect is comparatively small – less than 0.1 rms beam size (σ). **Gianluigi** asked to circulate the results with other WP's so that they could estimate the impact on their tolerances.
- **Gianluigi** inquired about the sensitivity of results to the orbit errors with respect to the nominal. **Xavier** replied that the main concern is the linear coupling, since it is very sensitive to even small deviations. Defining the tolerances is the main part of the future work on the project. An MD is planned to measure the coupling on PACMAN bunches. **Riccardo** added the results should as well be sensitive to the bias of the crossing that also introduces linear coupling.
- During the discussion of improvements done in the TRAIN code **Gianluigi** asked whether the filling pattern assumed in the simulations correspond to that considered in the operational scenario (different for Beam 1 and Beam 2). **Ariadna** confirmed, noting that previously TRAIN contained a bug such that filling pattern was considered to be the same for Beam 1 and Beam 2. **Yannis** asked about the number of long-range interactions considered. **Ariadna** replied 36-37 interactions per cycle were used for the study.
- **Gianni** asked if the filling scheme can be optimized to reduce the PACMAN effects. **Xavier** replied positively, but noted that this will have an impact on the number of collisions in IP2 and 8.

ACTION (Xavier, Ariadna): Summarize the results in a note and circulate the findings with other WP's
ACTION (Xavier, Ariadna): Check if the filling scheme can be optimized for the number of collisions in IP2,8 to lower the effects on PACMAN bunches.
ACTION (Xavier, Ariadna): Study the impact of orbit errors on linear coupling of PACMAN bunches and define the tolerances.

4 BEAM STABILITY IN THE HL-LHC: AN UPDATE (X. BUFFAT)

Xavier provided an update on coherent beam stability with beam-beam interaction. For the impedance-driven instabilities, the beam-beam interaction can substantially reduce the stability margin during the squeeze and as the beams are brought into collision. A proposed combined Ramp and ATS (Achromatic Telescopic Squeeze) scheme allows attaining a large stability margin via enhancement of beta functions at the octupoles. A telescopic index of 2.2 is needed to provide stability throughout the cycle after the complete collimator upgrade; without the upgrade the required telescopic index increases to 4.2. Riccardo has provided optics with a telescopic index of 3.3 for different values of the β* and covers all scenarios already starting from LS2 collimator upgrade.

Instabilities with high latency times, up to 40 min, are observed in LHC below the theoretical octupole threshold. These high latency instabilities are attributed to the noise (coming from the feedback system and power converter ripple) affecting the beam distribution and changing the stability diagram. Machine studies are planned to investigate the effect of feedback noise on beam stability.

Regarding beam-beam driven instabilities, a full 6D coherent numerical simulations were performed using an improved COMBI code (master thesis work of L. Barraud). Simulations show that an instability may arise in certain conditions due to synchro-betatron coupling. Synchrotron sidebands might introduce Landau damping of the instability, as predicted by Yu. Alexakhin. Simulation results show no potential problems for the current HL-LHC operational (OP) scenario. At the full intensity, the mode coupling instability can occur only at a small enough beam-beam parameter that is only reachable at the very end of the fill, where the bunch charge is reduced due to the intensity decay during the cycle.

- **Elias** proposed checking the stability with the beam-beam interaction during the offset levelling at low β* where the instability might be important. **Gianluigi** pointed out the offset levelling is not foreseen in the present OP scenarios, but it is important to know whether this is an issue and a potential limitation.
- **Gianluigi** emphasized that it is important to know if it is acceptable to go into collision with an ATS index of 3.3, and, in particular, whether there are any significant negative effects on DA. If this is the case then the collimator upgrade in IR7 could be limited to the Long Shutdown 2 (LS2) collimator subset. **Xavier** noted that the scheme can be tested during the Run III. **Riccardo** proposed trying some optics optimization to push the telescopic index to 3.3. **Elias** noted that it may be safer to remove the source of impedance rather than taking risks associated with mitigation of resulting instabilities.
- **Gianluigi** raised a question what options are left if we cannot run with an ATS index of 2.2 (required for beam stability throughout the cycle with the full collimator impedance reduction) for DA considerations. **Xavier** proposed relaxing the collimator settings to gain additional aperture. **Gianluigi** noted that one can also collapse the separation bumps faster.

ACTION (Yannis): Check the impact of high telescoping index up to 3.3 on the beam lifetime for ultimate and nominal scenario before going in collision and in collision.

ACTION (Xavier): Check the stability with the beam-beam interaction during the offset levelling at low β*.

5 SYNCHROTRON RADIATION AND E-CLOUD CONSIDERATIONS FOR THE 11T DIPOLES (G. IADAROLA)

One 15-m-long LHC dipole MB will be replaced with two 5.3-m-long stronger magnets MBH. The resulting increase in synchrotron radiation power of 4 W is negligible compared to the present cooling capacity of 8 kW/arc. The change is unlikely to impact electron cloud build-up because (1) the increase in the number of photoelectrons is marginal; (2) the HLLHC chamber geometry is very similar to that of LHC.

- **Gianluigi** mentioned an ongoing discussion on the possible increase of energy reach up to 8 TeV and asked to estimate the impact of higher energy. **Gianni** replied that the tools are ready and the study can be done.

ACTION (Gianni): Study the effect of possible increase in energy reach up to 8 TeV on the synchrotron radiation and e-cloud build-up

.

6 ROUND TABLE

Next meeting will be held on the 3rd of July.

Following up on the DQW HOMs, **Jamie** is checking the simulations, taking into account all HOM couplers and the pick-up on the beam port that may also couple to some HOMs. He suggests, first, verifying the impact on beam heating and stability and finalizing the HOM coupler design and then proceeding with the multipole calculations as they are computationally complex.