LHC Studies Working Group
Notes from the meeting held on 8 November 2011

The meeting was dedicated to the presentation of the preliminary results of LHC MD#4 (Oct 30 - Nov 4). The agenda and slides can be found at the following link: https://indico.cern.ch/conferenceDisplay.py?confId=161034

It was mentioned that due to the two long stops during the MD period (SPS dump kicker problems and LHC cryogenics), the schedule had to be changed and re-prioritized on short notice and some planned MDs could not take place: all MD teams are thanked for the understanding and the cooperation.
On the matter of 2012 MD requests, new requests will have to be handed in, and 2011 requests will not be taken into account. The request form will be modified and circulated, indications about past achievements will have to be included in the form. Given that there will be a presentation on 2012 MDs at the Evian workshop (12-14 Dec), **requests for 2012 should be handed in by 8 Dec** (next LSWG).

1. ATS MD (S. Fartoukh)

The ATS optics scheme consists of an "almost" standard squeeze (*pre-squeeze*) acting on the matching quadrupoles of IR1 and IR5, and a continuation (*squeeze*) acting on the IPQs of IR2/8 for squeezing IR1 and IR4/6 for IR5 and inducing β-beating bumps in sectors 81/12/45/56. The β* at end of the second step is equal to the pre-squeeze β* times the increase of the β function in the arc. During the squeeze, the chromatic correction is achieved by the β-beating induced in the arc. The limit for the minimum possible pre-squeeze β* is given by the maximum current for some RSDs (300 A at 3.5 TeV, i.e. 600 A at 7 TeV). Note also that the margin on the Q6 power supplies in IR1 and 5 was only 20 mV (single quadrant power supply, required voltage should be always positive), and this will be reduced further for the nominal optics at 55 cm. For this third 2011 MD, the pre-squeeze β* was pushed to its limit of 40 cm, and the plan was to activate the telescopic part to reach 10 cm in both IR1 and IR5 (no crossing angles and parallel separation on). Unfortunately the beam was lost when preparing the telescopic part towards 10 cm due to the trip of several IPQs. This was due to the fact that two different sets of knobs were to be used to correct Q, Q' and coupling in the pre-squeeze and squeeze. The use of two different knobs is not presently an available feature in the tune feedback, so that the real time trims in the RQTs and RSs were set to zero at the change of knob and the too big variation in trims caused the QPS to trip. F. Zimmermann asked whether it is possible to use only the reduced set of quadrupoles since the beginning. R. Steinhagen answered that the tune feedback cannot keep memory of the history of two different knobs and commented that one possibility would have been to transfer the RT trims into LSA first, and then change the knob. It was noted that a substantial amount of work was needed to prepare this MD, to generate the optics, to create sequences and the hypercycle, to implement additional functionality in LSA. After the successful initial dry run, injection and ramp with probes were straightforward as they profited from the experience of the previous MD sessions. The β-beating was measured and corrected online at 40 cm (brought down to <20%, main source possibly a longitudinal misalignment of triplet in IR5).

The coupling could be easily corrected with the global knobs (to be recalculated and optimized for future iterations) and a clear source was identified in IR5. The chromatic variation of the tune at 40 cm was measured, and the linearity is better than 10^{-3}, but the off-momentum β-beating could not be measured due to lack of time. The dispersion coming from the arc is amplified in the low β insertion with the square root of the β, so it becomes more visible when the β* is reduced further: at 40 cm, the linear imperfections coming from the arcs became visible in the dispersion. The V dispersion is better than the H dispersion thanks to the sorting of the main bends for the random a2 performed at the time of installation; the H dispersion starts to be non negligible, but a priori it is still correctable (recall that the main quadrupole sorting based on random b2 was optimized for β-beating only). Note that this effect will worsen when the crossing angle is introduced. The ATS studies for 2011 can be considered successful for the achromatic part, which was demonstrated until 40 cm with good tune linearity, and for the telescopic part until 30 cm in IR1. More MD time will be requested in 2012. R. Assmann recalled that this optics paired with tight collimator settings provides a way to reach a pile-up of ~100. F. Zimmermann asked whether IP2 could be squeezed also according to this scheme, S. Fartoukh answered that it has not been studied yet and the phase in IP2/4/6/8 would have to be optimized: still he guessed that to 3 m it should be possible, further might be difficult.

2. p-Pb feasibility study (J. Jowett)

The first part of the p-Pb feasibility test was presented. Several hours were spent in setting up and debugging without beam. The first injections of Pb of 2011 were performed, and a maximum of 4 Pb bunches in the presence of 304 p bunches were stored at injection energy (the target was 500 p bunches but was not reached due to a problem with the filling scheme). One important result is the fact that the Pb single beam lifetime was not worse because of the presence in the machine of p bunches. A ramp with 2 Pb and 2 p bunches was successfully performed and the RF was cogged at flat top energy. The second part of the feasibility test (tentative date: 16 Nov) aims at ramping some Pb bunches in the presence of many proton bunches and bring them into collisions (possibly declare "stable beams"). J. Uythoven asked how many bunches are planned to be used in the second part of the study, J. Jowett answered that only few bunches are being considered.

3. RF gymnastics for p-Pb (P. Baudrenghien)

The LHC features 2 completely independent RF systems and for this MD they were decoupled and operated separately. For the same magnetic field in the main dipoles, two different RF frequencies are required at injection and along the ramp to keep both beams centered in the rings. The RF frequency difference is about 4.6 KHz at injection energy and 76 Hz at 3.5 Z TeV. During the ramp the radial feedback was successfully operated independently in each ring. At the flat top, the two rings were moved onto a common frequency in order to provide the experiments with a fixed collision point: for this, the proton frequency was lowered by 38 Hz (orbit shifts to the outer part of the vacuum chamber by 0.4 mm) and the lead frequency was increased by 38 Hz (orbit shifts to the inner side of the vacuum chamber by 0.4 mm). The manipulation did not create noticeable losses. Next, RF cogging had to be performed in order to move the collision point to the center of the detectors. A longitudinal displacement of about 30 us was applied to have the bunches sitting in bucket 1 collide in the centers of ATLAS and CMS as per convention (ring 2 was cogged during this MD). The maximum frequency offset is 10 Hz per bump resulting in a maximum of 1.5 us/min; this might be increased in the future to make the cogging faster. A list of pending RF issues was presented, including a sequencer task to move the frequencies to the common value and an application to drive the frequency bumps that center bucket 1 in the center of IP1 and 5 based on RF measurements (ATLAS' BPTX was used during the MD). J. Uythoven asked whether the orbit being off centre might be a problem for the collimators or machine protection. R. Assmann answered that eventually losses at IP3 will be observed, but there is enough margin (6 σ).

4. Emittance evolution with p-Pb (R. Versteegen)

Preliminary results of beam 2 emittance measurements were presented, comparing wire scanner results and BGI data (for which a rough calibration had been performed by M. Sapinski). A comparison with IBS expected growth rates will be performed later. The horizontal emittance growth was measured to be 0.010 um/min with the wire scanners and 0.008 um/min with the BGI. The ADT seemed to have a positive effect on the V plane mostly. J. Jowett added that probably the damper causes IBS to couple into the V plane. A shorter bunch length gives a higher growth rate (0.016 to 0.025 um/min for a later fill). A. Burov commented that given the very linear curve for the emittance growth at injection, IBS is not the only phenomenon involved, but possibly scattering on residual gas also plays a role. J. Jowett added that the main purpose of the MD was to verify whether there was an effect on emittance growth from the moving beam-beam kicks coming from the presence of the proton bunches, so that also this effect should be taken into account. For the ramp fill, data was acquired only at the flat top, and no significant growth was observed during the RF gymnastics (comparison to the BSRT data will be carried out later).

5. Optics near the half integer tune (G. Vanbavinckhove)

Prior to the measurement, the aperture around IP5 was estimated for both nominal and half integer tune optics and the differences were found to be small. The β-beating was measured and corrected around the whole machine, particularly successful was the case of beam 1 vertical for which it was brought down to 15% from 60%. For beam 1, 128 correctors were used, out of which kq4.r5 had the strongest kick (K_1 = 3 10^{-5} m^{-2}), while for b2 the strongest kick was for kq6.r7 (K_1 = 2 10^{-5} m^{-2}). The losses for beam 1 and 2 were analysed before and after optics correction: the stopband for beam 1 was narrower than for beam 2 (possibly explained by the different emittance). Both stopbands were wider after correction than before, which might require further studies. To be noted that the nominal optics at injection was measured and was found to be more stable in 2011 (measured in Feb and Oct) than in 2010. R. Assmann recalled that close to the half integer there is larger space in the tune diagram and this allows for a smaller crossing angle and asked whether the optics is useable. G. Vanbavinckhove answered that a few iterations could improve the optics further, J. Wenninger added that before this new optics can be used machine protection issues have to be reviewed. F. Zimmermann added that the long-range beam-beam limit should be studied for this working point. R. Calaga commented that the optics corrections would have to be good over the full tune footprint. R. Steinhagen commented that the MD was important in showing that there is no obvious showstopper for the new working point. F. Zimmermann asked about the different number of BPMs in the different measurements. R. Tomas answered that the number of functioning BPMs decreased over the year: there were only ~1% of bad ones in the beginning of the year, while later their number increased despite the rephasing.

6. BI MD (A. Rabiller)

The time for the BI MD was cut short by the long faults, but still some useful data were acquired for the BSRT, the matching monitor and button BPMs. Concerning the BSRT, data were acquired for the calibration of the optical magnification versus camera position. R. Assmann asked whether absolute emittance measurements will be available after this MD and A. Rabiller answered that a few more tests still have to be done (differentiation of dipole and undulator contributions, magnification curve, etc). The matching monitors were validated: a scan of intensity was performed to check the sensitivity of the system (1.2-8e10 ppb), while for the timing delays more studies are needed. Achromatic lenses will be installed during the shutdown which will improve the aberrations in the system. R. Steinhagen presented the results of the analysis of BPM correction data performed by A. Nosych. The higher order corrections are available but so far not applied to simplify the BPM commissioning. These corrections are non-negligible for beam positions above square root of +/-4 mm (for large apertures can give errors up to 1 mm). A small scan was performed in pt 4 to evaluate whether these errors can be measured, 20-50 um were expected from simulation and are compatible with the measurement. Further studies at larger deviation (7-10 mm) are the next step. J. Wenninger commented that a precision to 1% of the bump would be needed, including information about the optics. R. Steinhagen answered that the absolute value would not be used, and it would be assumed only that the increment is linear.

6. UFO MD (T. Baer)

This MD concentrated on studying possible UFOs at the MKQ, the delay between UFO occurrence and MKI kick and the influence of ecloud solenoids. A total of 120 pulses for MKIs and MKQs were studied. UFOs at the MKI.5R8 were more than at the MKI.5L2 (only 3 in 2 hours), at times multiple events were observed. Sometimes vacuum spikes were observed after the MKI pulse. No UFOs were measured around the MKQs (pulsed 34 times), interesting information as the MKQ as a metalized vacuum chamber, while the MKI have a ceramic one. F. Zimmermann asked how many UFOs are expected at the MKQ if the rate is the same as for the MKI, taking into account a scaling with the length of the kickers. J. Uythoven answered about half the number observed at the MKIs, therefore quite a number. The BLM study buffer is about 11 s long (for comparison, the IQC buffer is 20 ms long) and provides vital information about temporal and spatial distribution as well as amplitude of UFOs after the MKI pulse. Thanks to this buffer, UFOs were observed to happen between 12.8 ms and 500 ms after the kick: as a gravitational force alone would predict a delay of 62 ms, it can be deduced that also electromagnetic forces are involved in the UFO dynamics. Note that a small part of BLM activity after the MKI pulse is probably due to cross talk generating noise in the BLMs. R. Assmann suggested verifying this by pulsing the MKI without beam. The beams were dumped prematurely due to losses at injection due to missing injection cleaning. This triggered the question of whether an injection interlock should be put in place (SIS) in case the injection cleaning is off. No data could be taken on asymmetric pulses between the individual MKIs, and the UFO distribution between the individual MKIs from BLM data will be analysed offline. F. Caspers added that there are hints that highly isolating surfaces seen by the beam create all sorts of problems.

6. TDI impedance and observations (B. Salvant)

Pressure and temperature increases in both TDIs during physics fills were observed and are clearly beam induced. Increasing the TDI gap (from +/-20mm to +/-55mm from fill 2219) damped the pressure increase, but not the temperature increase, and decreasing back the TDI b2 gap (back to +/-20mm for fill 2261) led back to higher pressure. Since most of the heating and pressure issues had been studied during physics fills, it was decided to concentrate on TDI impedance measurements during the allocated MD time. E. Metral added that while pressure effects disappeared, temperature increases were still there. Single high intensity bunches (~2.6e11 ppb) were used to measure the tune shift while changing the TDI gap (the same approach had been followed with physics beam but the tune shift could not be measured then). A clear V tune change was observed for both beams, while on the H plane a small tune change was observed only on beam 1. It was calculated that the total effective vertical impedances of TDI.2 and TDI.8 are very similar and larger than predicted (as already observed in 2010), comparable to the total impedance budget at injection (2/3 MΩ/m is the quoted total impedance budget at injection, 30 MΩ/m is the budget at 7 TeV, 8 MΩ/m at 3.5 TeV). R. Assmann added that for the comparison between 2010 and 2011 data, significant error bars should be added to the plot. The measurements seem indicate a total transverse impedance of 4.9 MΩ/m, which is larger than expected by a factor 3 to 4 at 3.7 mm half gap (nominal: 4.7 mm). E. Metral suggested that the measured values could maybe be explained by a coating degradation (missing coating would give 7 MΩ/m). R. Assmann commented that maybe the geometric impedance estimation is not perfect, as there are issues also with non-coated elements (e.g. TCTVB). F. Caspers commented that the surface roughness can contribute with a factor 2-3 to the resistance. The degradation of the pressure during 2011 could be explained by a degradation of the 3 um Ti coating on the hBN blocks. RF stable phase error shifts corresponding to TDI jaw movements were recorded and from these the longitudinal impedance could be inferred, a detailed analysis will follow.

The next meeting is devoted to a preliminary discussion on the MD requests for 2012, meeting to be held in 30-7-010 on Thursday 8 Dec at 9:00 (note unusual time and place).

Giulia Papotti

List of participants

ASSMANN	Ralph Wolfgang	BE-ABP-LCU
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Excused: G. Arduini, M. Giovannozzi.