152nd meeting of the LHC Collimation Study Group

26.11.2012

Present: R. Bruce (RB) [chairperson], G. Valentino (GV) [scientific secretary], O. Aberle (OA), C. Adorisio (CA), F. Carra (FC), D. Deboy (DD), M. Deile (MD), M. Gasior (MG), L. Keller (LK), L. Lari (LL), N. Mariani (NM), T. Markiewicz (TM), A. Marsili (AM), L. Nevay (LN), A. Nosych (AN), E. Quaranta (EQ), S. Redaelli (SR), J. Wenninger (JW), D. Wollmann (DW).

1. List of Actions from this meeting

- Follow-up meeting in January 2013 to discuss a plan for overall maintenance and monitoring of the collimators for LS1, such as the roller screws and the follow-up of the heating issue with the TCP.B6L7.B1.

2. G. Valentino: Preliminary Results from SPS BPM-equipped Collimator MDs

- GV presented the beam tests performed in the SPS using the prototype BPM-equipped collimator.

- GV reminded that the BPM-equipped collimators are necessary to provide faster alignment, online monitoring of the beam position at the collimators, and an improved β* reach.

- The general motivation for the MDs is to determine the remaining requirements for operation of the new BPM-equipped collimators in the LHC after LS1. The objectives of the MDs in October and November 2012 are to demonstrate that the collimator can be aligned automatically and quickly, and to obtain more statistics for the BPM non-linearities from collimator scans.

- GV reminded that the non-linearity in the BPM measurements depends on the gap between the BPMs and the beam offset. Hence, a higher-order polynomial is required to obtain the corrected orbit.

- AN performed a 2-D surface fit to simulated BPM readings for various beam offsets and BPM gaps. The simulations were done using CST particle studio. The corrected beam position is then calculated from a fifth-order polynomial, which allows for an accuracy below 1% of the BPM aperture, for beams with less than 20% beam offset and jaw gaps in the range of 2 mm to 60 mm.

- The BPM data is acquired from an electronics box in the SPS tunnel via UDP packets. The data rate is 10 Hz, and one 24-bit sample is sent per packet.

- GV presented an algorithm to align the collimators around the jaw. As the fit coefficients were unknown, the BPM response was assumed to be linear with beam offset and BPM gap, and hence the algorithm requires a few iterations to successively approximate the aligned jaw positions. A new control tab was added to the control application to set the alignment parameters, such as the time interval between iterations and the alignment accuracy or algorithm stopping point. An automatic collimator scan algorithm was also implemented to speed up the BPM measurements at various beam offsets and BPM gaps during the MD.

- RB asked when the algorithm considers the jaw aligned and what the precision is on the final alignment. GV replied that presently the accuracy is about 10 μm.

- Two MDs were held, on the 18.10.2012 and the 05.11.2012. A single LHC-type bunch was used, with coasting beam at 270 GeV. A third MD is planned for the 05.12.2012, where multiple bunches will be used to observe the BPM measurements with primary and secondary loss showers.

- GV then presented the MD results. In the first test, the jaw corners were moved individually to observe the BPM signal response. The signal of a particular jaw button was noted to increase slightly when the opposite jaw was moved out, due to the non-linearities.

- A maximum difference of 150 μm was found between the beam centres measured with BLM-based and BPM-based alignment. The alignment using feedback from the BLMs was performed with 100 μm steps. The time taken to complete an automatic BPM-based alignment varied from 18 to 100 seconds, depending on the alignment parameters. The alignment time was found to be independent of the initial jaw positions, but as expected is heavily dependent on the time interval between steps and the alignment accuracy.

- GV compared the measured and simulated non-linearities in the BPM measurements. The measurements were obtained from collimator scans around the beam, while in the simulations the beam was moved within the jaws. MG commented that the oscillating behavior at small amplitudes of the beam position is due to the finite error of the reading in the denominator, while the reading itself goes to zero. RB commented that it would be good to redo the simulations for the exact same range in orbit as in the measurements.

- SR asked about the observed drifting of the center with the gap. MG replied that this drifting is fully understood and can be cured by quickly re-aligning the collimator at the new gap. SR mentioned that it would be good to demonstrate this in the MD.

- The next MD is foreseen for 05.12.2012. In this MD, a vertical bump will be placed at the collimator to assess the effect of vertical orbit drifts on the BPM non-linearities in eventual LHC operation. MG has installed a switching box in the SPS tunnel to determine the individual errors (offset and gain) in the electronics of the 4 BPMs. The automatic collimator alignment will be performed using the fifth-order polynomial and the 2-D fit coefficients provided by AN. A functional specification will be drawn up for LHC operation in early 2013.

- JW commented that the orbit bump amplitudes achievable in the SPS should be checked beforehand.

- SR commented that the BPM non-linearities are not so important for the alignment, but more for online orbit monitoring.

- MD asked whether the BPMs were of the standard type already installed in the LHC. MG replied that the buttons had a completely new design.

3. S. Redaelli: Overview of collimation activities during LS1

- SR presented the planned LS1 activities targeted at enhancing the operational efficiency, improving the collimator layout and optimizing the location and distributions of losses. The various activities were individually discussed in detail at the collimation upgrade management and collimation working group meetings in 2012.

- The TCTs in all IRs and the TCSGs in IR6 will be replaced by collimators with a new design, in which the BPMs are embedded in the jaws. This was approved by the LMC in September 2011. Two other activities were approved by the LMC on 07.11.2012, related to improved TCL layouts in IR1 and IR5, and additional passive absorbers in IR3.

- The present TCTVB in IP8, which has a two-beam design, will be replaced by a vertical TCT collimator close to the existing horizontal TCT, as was done for the TCTVB in IP2 in the 2011-2012 winter shutdown. The main motivation for the replacement is to allow the use of the BPM-integrated design. SR mentioned that only collimators with a single-beam design are currently being produced, and that the replacement will improve the vacuum layout by removing the VMTSA modules, which was giving concerns for impedance and heating.

- Other works currently being defined (but not yet finalized or approved) include new active TCLA absorbers in IR6, which will provide improved magnet protection in case of an asynchronous dump and a better Q4 cleaning, as well as the crystal experiment in IR7. The installation of the hollow e-lens as a halo scraper has been postponed for after LS1. The TDI upgrade is foreseen for after LS1, and although it is not part of the collimation project, several design features might be reused and an optimized strategy for production must be developed.

- The engineering specifications are currently being prepared for an upgrade of the ventilation system in IR7. SR asked whether OA is involved in the discussions. OA replied that he is not, and SR mentioned that he will ask S. Roesler to add OA to the list of people involved.

- SR presented the recent results from the SPS beam tests, where a prototype algorithm for aligning the collimator jaws with feedback from the BPMs was tested successfully. The algorithm managed to align the collimator in under 20 seconds, with an accuracy of 10 μm. This algorithm will be improved and used to align all the BPM-equipped collimators after LS1.

- Collimator production is currently ongoing. The contract assignment and budget approval for the industrial production of the 16 TCTPs was achieved by March 2012, and four collimators will be installed per month starting in February 2014. On the other hand, the 2 TCSPs are being produced in-house, and should be installed in September 2013. A couple of issues presently under investigation include the poor vacuum of the ferrite, where and improved thermal treatment at 1000 degrees Celsius is currently under test, and BPM cable production, which must start as soon as possible to ensure cable availability. The BPM cabling for the 18 new collimators and the IR8 layout change have been fully approved for implementation in LS1. The production is for the moment on the right track: a half-meter jaw prototype is expected before the Christmas stop. This will validate the gold-based grazing choice before the full production starts.

- SR summarized the design and operation of the TCL collimators in IR1 and IR5. Initially, two TCLs per beam were foreseen for cells 4 and 5. These collimators have the same design as the TCT, but are made of copper rather than tungsten. Their scope is to protect the machine from collision products from ATLAS and CMS. Only the TCLs in cell 5 (TCL-5) were installed, as the TCL-4s, although ready for installation, would have overlapped with the TOTEM Roman Pot station in the same cell. The TCL-5s were used in for physics only as from the start of the 2012 run. The present TCL layout was re-evaluated in Spring 2012, to take into account the operational experience, simulations and new requirements of the forward physics community.

- Commenting on the new experiment requirements, SR mentioned that there is a request to change the TCL layout in IR1 to install the forward detector (AFP). The proposal from ATLAS, if the AFP is approved, is to install the TCL-4 and use it at nominal settings, install a new TCL-6 collimator in front of the Q6, and maintain the TCL-5 and open it when the AFP needs to take data. The requests need more studies before being approved. CMS also plans an update of the forward physics detector, however the requests have not yet been outlined in an ECR document.

- Updated simulation results for the TCL layout in the IRs were presented by F. Cerutti and L. Esposito in a previous collimation working group meeting on the 30th July. For nominal 7 TeV luminosity, the D2/Q4 magnets are unlikely

to quench, but protection is still needed for the Q5 using a TCL-4 or TCL-5. The TCL-4 is more efficient than the TCL-5 in protecting the matching section down to Q7, although the TCL-5 reduces the losses in the dispersion suppressor. The assessment of the need of a TCL-6 requires more simulations. In addition, the TCL-6 would be a new collimator, and is more difficult to insert in the present layout.

- The approved TCL strategy for LS1, in agreement with ATLAS, CMS and TOTEM, is to have symmetric layouts in IR1 and IR5. The TCL-4 will be installed in both IRs, and the TCL-5 will be kept operational at the current locations. The infrastructure for an installation of the TCL-6 will be prepared, however the installation is subject to the timely availability of the new TCTPs. Detailed integration studies are currently ongoing (A. Rossi is following this up).

- SR reminded that presently there are 3 passive absorbers in IR7 and 1 in IR3, per beam. Their scope is to improve the lifetime of warm dipoles (IR3 and IR7), and the quadrupoles (IR7 only). The operational experience of 2011 indicates that the doses in the Q5 magnet in IR3 is much higher than expected, and is comparable with the doses observed in IR7. The Q5 in IR7 is already protected as much as possible, and should be replaced after around 10 years of operation according to the design assumptions of beam losses (to be reviewed in light of the new operational experience). The IR3 Q5 was expected to survive for the LHC lifetime without dedicated passive absorbers.

- An IR3/IR7 dose sharing of 30% was estimated from beam losses measured during the 2011 run (5 fb^{-1} at 3.5 TeV with relaxed collimator settings). Similar doses were measured at the Q5 in both IRs for B1. On the other hand, in the first 6 months of operation of 2012 (7 fb^{-1} at 4 TeV with tight collimator settings), a dose sharing in IR3/IR7 of less than 5 % was measured. The estimated doses to the MQW are close to those predicted by FLUKA. In particular, the Q5 in IR7 with passive absorbers might reach the damage level after LS2, while for IR3 there is no further protection needed if the present dose sharing is preserved. On the other hand, if we go back to the dose sharing in 2011, the IR3 Q5 might be at the damage limit after LS2 if no protection is added.

- Local protection in IR3 will improve the doses in the Q5 by an expected factor of 2 to 5. This will be confirmed by detailed simulations at a later stage (RB, EQ + FLUKA). The decision to add a passive absorber in front of the Q5 during LS1 was approved by LMC. No new cabling will be required, as a few spare channels from the temperature sensors can be used. The new collimator can be connected to the existing water cooling circuits of nearby collimators. Vacuum works are however required to fit the new absorber. The cost for the in-house production of the 2 passive absorbers will amount to 200-250 kCHF, and the production will be funded by the consolidation budget available as from 2014. The proposal to re-use a TCT, which will be replaced by a Phase-II BPM-equipped collimator, as an absorber in the TCSM slot to protect the 3rd Q5 magnet is currently being considered.

- In the concluding remarks, SR commented that the old TCTs, which will be replaced by a new Phase-II BPM-equipped collimator, can be reused as a TCL-6. FC commented that the TCL is identical to the TCT, albeit without the tungsten inserts (copper jaw). The TCTs are also harder to cool down, due to the thermal conductivity of tungsten. SR asked whether this is the case also for the TCLs. OA replied that the TCL is a single block of material. FC asked whether an estimate of power deposition has been done. SR commented that the power deposited in a TCL-6 will be very low, as most of the power deposition will occur in the upstream TCL. The exact figures must be determined from dedicated simulations. FC remarked that the estimated power deposition of 10 W is quite low, as normally 200 W are considered for the standard TCTs. SR pointed out that AM is currently working on a solution for the TCL integration.

- Other pending activities requiring urgent follow-up include the possibility to increase the protection of the Q4 in IR6, which is currently under discussion with the dump team, and the approved crystal installation in IR7, which requires the layout to be frozen soon.

- OA asked whether there are any estimates on the heat load and cooling for the new passive absorbers in IR3. SR replied that this can be inferred from measured beam losses. In a worst-case scenario, the magnet in IR3 received 30% of the load received in IR7. For the same design, one would expect that the load in IR3 cannot be more than that of IR7, but this will be confirmed by simulations by RB and EQ together with the FLUKA team.

- RB reminded that earlier on in 2012, there were issues with jaw roller screws, which were worn out, and heating on the TCP.B6L7.B1. RB asked OA if there were more detailed studies for LS1 to investigate these issues further. OA replied that all roller screws will be checked, using both visual inspections and sound measurements, as was already done for a subset of the collimators during a previous technical stop. The TCP heating problem is still not fully understood. Investigation is currently limited as the TCP is quite hot. The current proposal is to replace it with a spare during LS1. SR mentioned that the LMC had asked for a mini-review on the issue with the worn-out screws, and a follow-up meeting should held early next year with a presentation by OA or R. Losito, to show the plan for overall monitoring and maintenance of these mechanical parts. The re-commissioning and maintenance of the collimation system remains the top priority for LS1.

- NM remarked that most of the present collimators are equipped with carbon composite jaws, whose impedance properties decrease with radiation. It would be interesting to perform tests to measure their properties after a few years of operation. SR replied that a Machine Development (MD) test will be held on 27.11.2012 to verify if the resistivity has degraded.

- Coming back to the heating issue with the TCP, SR suggested that we could consider replacing it with a spare collimator, and see how much can be learnt without destroying the original TCP.