Stefano Redaelli, 25-04-2007

85^{th} Meeting of the LHC Collimation Working Group, April 23rd, 2007

Present: Ralph Assmann (chairman), Giulia Bellodi, Alessandro Bertarelli, Chiara Bracco, Francesco Cerutti, Bernd Dehning, Massimo Giovannozzi, Verena Kain, Daniel Kramer, John Jowett, Marco Mauri, Laurette Ponce, Valentina Previtali, Stefano Redaelli (scientific secretary), Mariusz Sapinski, Lucia Sarchiapone, George Smirnov, Rüdiger Schmidt, Thomas Weiler.

1 Comments to previous minutes

S. Redaelli quoted an open issue from the meeting of March 5th, 2007. The normalization of halo loads on the TCDQ in case of one-sided cleaning system shows contradictory results. For one of the two cases considered for single TCP's loads are smaller than for the perfect case with two jaws. This issue is under investigation (T. Weiler, L. Sarchiapone).

2 A.O.B

R. Assmann commented that the collimation phase II studies requested by the DG's *white paper* have been received well by the Scientific Policy committee. If this preliminary positive feedback is confirmed and these studies are indeed supported, R. Assmann will coordinate the set-up of the Phase II studies.

3 Planning for the 2007 SPS MD's (S. Redaelli)

Following up an open action from last meeting of March 19th, 2007, S. Redaelli reported on the plans for the 2007 SPS MD's with beam. Even though the collimation project did not ask for dedicated MD time, we received two requests of using the collimator prototype installed in LSS5: The (1) BLM team wants to perform beam loss studies with the LHC-type monitors and the (2) LHC-ion team proposed to study beam loss patterns of ion beams after interaction with the collimator jaw materials. E. Métral presented at the last APC meeting of April 20th a first tentative MD planning, according to which the collimator controls need to be operational by **September 2007** (see details on Stefano's slides).

However, Bernd Dehning commented that the BLM team would like to have the collimator **operational during summer**. Bernd's team will send the date for when the controls need to be operational, which will be transmitted to Roberto Losito's team (Action for S. Redaelli).

Rüdiger Schmidt commented that he would like to perform an experiment at the SPS to assess the assumptions of LHC machine protection in case of **quadrupole failures**. Rüdiger proposed that the collimation and BLM teams should be involved. Further thoughts are required and Rüdiger suggested that Andres Gomez Alonso should report the details of a possible experiment at one of the next meetings of the collimation working group. The collimation working group fully supported this project. S. Redaelli warned that requests of additional MD time should be transmitted as soon as possible to E. Métral because the 2007 planning is already full and it might be difficult to fit in it new proposals.

4 Collimator settings during the energy ramping (C. Bracco)

C. Bracco discussed the collimator settings during the energy ramping from 450 GeV to 7 TeV. First Chiara reminded the limitations of the present Phase I collimation system, which according to tracking simulations can only stand about 45 % of the nominal beam intensity. The limitation comes from the losses in the dispersion suppressor magnets downstream of the betatron cleaning insertion (the collimator impedance imposes similar limitations on the total beam intensity but this was not discussed here). Chiara also reviewed the calculations of local cleaning inefficiency and enumerated a number of other known types of imperfections that will further reduce the system performance.

An operational challenge for the LHC will be to control the collimator position during the energy ramping. In order to ensure the best cleaning and protection performance, the collimators should be kept at the canonical 6/7 sigma opening throughout the energy ramp. This scenario imposes challenging operational tolerances. Operationally it would be much simple to keep the collimators at the injection settings and in fact this option has often been proposed as a "relaxed" commissioning scenario. However, Chiara's simulations show that if the injection settings (gaps in millimeters) are maintained during the ramp, the achieved cleaning performance at 7 TeV is not adequate. Local losses in several superconducting magnets all around the ring are close or even above the assumed quench limit. C. Bracco concluded that, the closer the collimators are to the cold aperture, the larger are the local losses in the machine aperture. To some extend, this conclusion is independent of the normalized betatron aperture. Therefore, in order to increase the cleaning efficiency, **the collimators must be moved during the ramp**.

C. Bracco simulated various cases to find optimum settings for the collimators during the ramp. In order to easy the collimator operation during the LHC commissioning, the operational positioning tolerances should be relaxed if possible. As the most challenging requirement is imposed by the small retraction between primary and secondary collimators (1 sigma $\approx$ 200 $'mu$m at 7 TeV), Chiara proposed to increase the TCP/TCS retraction with respect to the nominal settings. Chiara investigated the option of moving the primary collimators by keeping them at a normalized aperture of 6 sigmas during the ramp while **keeping the secondary collimators at a constant retraction from the primaries**. At 7 TeV one would end up with TCS's at about 10 sigmas. This option, proposed for the first time by R. Assmann in Chamonix 2005, seems quite promising because larger gaps of the secondary collimators also help reducing the machine impedance. The cleaning performance is only reduced by a factor 2 with respect to the nominal cleaning at 7 TeV for the Phase I system.

In order to better understand the cleaning performance during the ramp, C. Bracco produced curves of **quench limit versus energy** starting from inputs provided by Bernd Dehning's team (data used to define the BLM thresholds versus beam energy). By folding together the information on the magnet behaviour, on the effective shower length from lost protons and time duration of losses, one obtains an power law for the reduction of quench limits versus energy. By using these curves of quench limit versus energy C. Bracco concluded that, without moving the collimators from their injection settings, on paper one can stay below the quench limit during the energy ramp up to approximately **2.5 TeV**. This is a relevant result for the commissioning because it suggests that one can wait for the end of decay and snap-back effects before moving the collimators.

R. Assmann reiterated that, according to C. Bracco simulations, the "relaxed" ramp settings that consist of leaving the collimators to their injection settings in millimetres are not an promising option, not even for earlier commissioning phases. We must somehow close the collimators as we increase the beam energy. The driving physics behind this problem is that protons that loss energy by single diffractive scattering are not absorbed into the collimator jaws but are lost in the cold dispersion suppressor. Closing the primary collimators to small gaps during the ramp also implies that the betatron squeeze must worked out with primary collimators very close to the beam orbit. It will be very challenging to control the orbit in the cleaning insertions to the required level. Another option could be to start the betatron squeeze during the energy ramp.

Bernd Dehning asked if the results presented by C. Bracco are statistically relevant. Can one exclude from these simulations that there are other hot spots close to or above the quench limits? R. Assmann replied that this is the case. The statistics uncertainty on single loss locations (less than one particle lost in one bin out of 5 millions tracked) is relevant.

Rüdiger Schmidt reminded that the idea of moving the primary collimators close to the beam during the ramp has always been the preferred solution for protection because it would allow detecting early on unsafe conditions. However, R. Assmann pointed out that now it seems that this is the only option we have. If we could relax the settings for protection reasons, this will no longer be possible due to cleaning.

5 Aperture validation for 2-in-1 collimator design (T. Weiler)

T. Weiler summarized the analyses performed by J.B. Jeanneret on the aperture of the **2-in-1 vertical collimators** that are located in IP2 and IP8. These are special TCLI and TCTV collimators that are located in the region with two beams in the same pipe. The design of these elements has just been finished and we are ready for production.

T. Weiler reviewed the layout of the location where these TCLI's and TCTV's will be installed and their mechanical design. The aperture studies are done to assess the available aperture for the non-collimated beam. The following scenarios are considered in simulations: injection optics at 450 GeV and squeezed optics with $\beta^* = 2$ m in IP8 and $\beta^* = 10$ m in IP2 at 7 TeV.

The details of the aperture simulations are reported in T. Weiler's slides at pages 6 and 7. With the nominal alignment it is found that in several operation scenarios the clearance for the non-collimated beam is up to two sigmas below the LHC design criteria of 7 sigmas (n_1 units). However, it is possible to achieve the design value by moving the whole collimator tank horizontally outside of the beam pipe centre. This could be done with the fifth collimator motor that provides transverse movement of the full tank. However, J.B. Jeanneret proposed to install the critical 2-in-1 collimators with an offset of **3 mm**, which would allow recovering the nominal 7 sigmas clearance for all critical cases. This option will be considered.

R. Assmann commented that the operation of these devices will be extremely complex. Rüdiger Schmidt certainly agrees and suggested that for future presentations one should try to prepare some illustrations for the people that are not well aware of the topics.

Reporting a message from Alexej Grudiev, S. Redaelli warned that these 2-in-1 collimator will be very critical for the machine impedance. Alexej asked if it would be possible to have a vertical metal "wall" in the centre of the collimator, as a separation between the two beams, to reduce the free volume. This option is certainlt not feasible. In addition, R. Assmann stated that the final drawings (that are ready for production) got the stamp from the "impedance police" when feedback was asked by Manfred Mayer.

John Jowett said that there are special knobs to move the transverse IP position which were used for example to improve the available aperture in the IR's at either sides of the IP. Could this be of any use to improve the situation? This option remains to be assessed.

6 Triplet aperture at 7 TeV during betatron squeeze in IP1 and IP5(T. Weiler)

T. Weiler presented the results of simulations of triplet aperture in IP1 and IP5 during the betatron squeeze. Thomas used the aperture module into `MADX` to perform these calculations for the squeeze scenarios from $\beta^* = 17m$ (injection optics optics at 7 TeV) to $\beta^* = 0.55m$. Preliminary results were also presented LCU section meeting of March 12th, 2007. The latest simulations include updated tolerance tables for the magnet alignment ("as-measured" data from the measurements on surface).

The simulations by T. Weiler show that, if the squeeze is started at 7 TeV (and not at intermediate energies during the ramp), the triplet becomes the aperture bottleneck of the machine for values β^* below about **5-6 m**. For larger values of β^*, the triplet aperture is larger than the arc aperture and therefore the triplet protection with the TCT collimators might not be necessary. This is an important input that will be used to operate the TCT's during the betatron squeeze.

T. Weiler also commented that there are small differences between the results for B1 and B2 in IP5, which are not expected because the optics should be symmetric. These differences are under investigation with Thys Risselada.

The next meeting will be May 7th, 2007.