Stefano Redaelli, 09-05-2006

69$^{\text{th}}$ Meeting of the LHC Collimation Working Group, May 8, 2006

Present: Ralph Assmann (chairman), Giulia Bellodi, Dariusz Bocian, Chiara Bracco, Hans Braun, Bernd Dehning, Alfredo Ferrari, Daniel Kramer, Simone Gilardoni, Brennan Goddard, Andres Gomez Alonso, John Jowett, Manfred Mayer, Laurette Ponce, Stefano Redaelli (scientific secretary), Guillaume Robert-Demolaize, Stefen Roesler, Alexander Ryazanov, Mario Santana-Leitner, Lucia Sarchiapone, George Smirnov, Rüdiger Schmidt, Markus Stockner, Vasilis Vlachoudis, Thomas Weiler.

1 A.O.B.

- R. Assmann announced that the funding request for LHC collimation R&D studies within the FP7 Europen program was not approved by the DG.
- R. Assmann announced that is has been decided to **reduce the maximum collimator full gap** from 60 mm to **58 mm**. This design change has been adopted because with the previous design the company could not reliably manufacture the RF fingers. All LHC collimators will be affected except the transfer line collimators, which do not have RF fingers.
  Everybody agreed that the impact on the LHC is expected to be negligible.

2 Proposed BLM locations based of ion studies. (G. Bellodi)

Following up a pending action from last meeting, Giulia Bellodi revised the proposed BLM locations at IR7 based on ion collimation simulations. The list of proposed locations can be found in Giulia's slides. Identifying suitable BLM locations for ions is more critical than for protons because the ion-induced showers are shorter and hence more difficult to detect (typically, $\approx$30 cm starting from the impact point instead of a few metres for protons). It is noted that we discuss here about BLM for quench protection and not for collimator alignment.

Taking into account the simulation uncertainty ($\pm$2m in the peak location) G. Bellodi proposed additional BLM locations at longitudinal spacing ranging from $\approx$2.5 m to 3.75 m. In total, she proposes 37 monitors for beam 1 and 44 monitors for beam 2 in the dispersion suppressors downstream of IR7. These monitors should be installed in the vicinity of the bending dipoles (the standard monitoring of the quadrupoles does not change). Since 8 monitors per beam were already foreseen based on the proton loss patterns (provided by the ABP collimation team), G. Bellodi's proposal implies **29 additional BLM's for beam 1** and **36 additional BLM's for beam 2**. The difference for the two beams is explained by the fact that in simulations beam 2 shows losses in the cell 19, which are not expected for beam 1.

Bernd Dehning stated that the electronics for the BLM signal pick-up is available. However, the proposed additional monitors were not accounted for in the original budget. Additional monitors must be ordered before the end of the series production, which will run until early 2007. For the moment, approximately 200 spares are foreseen, without taking into account the ones for the phase II collimation.

Rüdiger Schmidt suggested that, if one could trust the relative height of the simulated loss peaks of different ion species, one could install more BLM's at the locations where large losses are expected and extrapolate the deposited energy at other locations based on simulations. However, the ion cross sections are not known precisely enough to reliably perform this extrapolation (A. Ferrari, H. Braun).

J. Jowett commented that the early scheme will certainly give the opportunity to better understand the loss patterns. Could we move the monitors between 2008 and 2009 if we figured out that other locations are more sensitive than the ones chosen now? Bernd replied that this should not be a problem. However, it is better to agree as soon as possible on a set of proposed locations to be entered in the database. R. Assmann suggested that, were there are no peaks according to simulations, we could reserve BLM locations for the LHC in database but not actually install monitors from LHC startup.

According to G. Bellodi's simulations, a fairly large loss peak is found at the missing dipole. Here, G. Bellodi did not propose to add any BLM. R. Assmann asked if we need no monitor this location. R. Schmidt replies that quenching some bus-bar at the missing dipole location is less likely than to quench a magnet. However, he believes that, for the sake of understanding better the simulated loss profiles, it is certainly a good idea to monitor the locations where large losses are expected. There was a general agreement that some monitors should be added there as well. After the meeting, l. Ponce confirmed that this is the case.

R. Schmidt also commented that temperature measurements are presently under investigation as a possible way to monitor steady losses (discussion in the machine protection working group). These measurements could be carried out also in this region. R. Assmann said that the temperature might not be the best way to analyse losses because lifetime, and hence the temperature increase from losses, can vary rapidly.

To conclude the discussion R. Assmann proposed that the final decision should be taken at the next meeting. As a general figure, is looks like we need an **additional 100 BLM** for ions, which are not included in the BI budget. This also includes possible additional monitors at the interaction regions. R. Assmann proposed that (1) B. Dehning should investigate the impact on the BLM project and (2) G. Bellodi should try to perform more detailed studies on the effect of the orbit errors on loss locations. There was a general agreement that, for more detailed studies of loss locations, the effect of the orbit should be taken into account, possibly by just shrinking the aperture at some locations by the allocated budget for orbit and beta-beat of ≈ 5 mm (R. Assmann).

R. Assmann also asked about the loss locations at injection. In this case, ion losses are less critical because we are well below the quench limit. H. Braun also noted that at injection the loss peaks are much broader than at 7 TeV and hence a tight longitudinal coverage is only needed at top energy.

G. Bellodi also brought up a question on momentum cleaning for the collimation experts: She started simulations with primary proton impacts on the TCP's of IR3 and found that most of the particles are lost in the TCTH of IR5 (for beam 1). Can we understand this result. This will be followed up off-line with the ABP experts.

<u>Actions</u>: (1) Estimate effect of orbit and beta-beat tolerance on the ion loss locations (G. Bellodi) and (2) assess the impact of the proposed additional BLM's on the BI budget (B. Dehning).

3 FLUKA simulationa of TCDQ halo loads (L. Sarchiapone)

Lucia Sarchiapone presented the results of FLUKA simulations on TCDQ halo loads. The model includes the TCDQ and the downstream TCSG and also a detailed modelling of the superconducting magnets further downstream. Simulations are carried out using as an input the distribution of halo beam particles into the TCDQ and TCSG Carbon jaws, as it is calculated by the ABP collimation team (data provided by T. Weiler). All the relevant collimators are taken into account: the simulation setup at 7 TeV takes into account TCP's, TCS's, TCLA's, TCT's, TCLP's and TCDQ elements. A perfect machine is considered. Data for both beams are available but these studies were focused on beam 2, which gives the worst case because for beam 2 the IP6 is immediately downstream of the betatron cleaning.

L. Sarchiapone found that, with nominal magnetic fields, up to **60 mW/cm^3** are deposited in the TCDQ jaw and approximately **20 mW/cm^3** in the TCSG jaws. The maximum peak deposited energy in the coil of the superconducting magnets is **3.1 mW/cm^3** for the MQY (Q4) and **2.3 mW/cm^3** for the dipole corrector MCBY. These values are close to the assumed **quench limit of 5.0 mW/cm^3**. This does not leave a large margin also because simulations are carried out with no optics information and assuming a perfect cleaning. Is is noted that for **beam 1** the expected deposited energies are approximately **100 times less**.

A study of the effect of the MBCY powering of the deposited energy shows that losses in the coil are reduced by a factor 2 the corrector is powered to the 10 % of its nominal current.

Alfredo Ferrari stated that the achieved safety margin is certainly not enough because we are too close to the assumed quench limits. Bernd Dehning agreed and in fact he reminded everybody that, according to the LHC design criteria, one should try to stay below one third of the quench limit.

Brennan Goddard said that it would be interesting to study the halo loads in the TCDQ area with a **reduced collimation system** (e.g. with less secondary collimators). This could set a limit of maximum beam intensity before commissioning the full collimation system. These studies require input from the ABP collimation team, who provide halo loads on the TCDQ/TCSG jaws. R. Assmann replied that these studies are being carried out in detail by C. Bracco. Chiara will provide as soon as possible the new inputs.

R. Assmann commented that it would also be interesting to study the halo loads on the TCDQ for a one-sided collimation system. We always assume that both jaws of each collimator are in place but in reality one of the two jaws will always be closer to the beam, possibly resulting in a one-sided system. R. Assmann proposes that T. Weilerprepares inputs for this case.

Both proposed studies require follow-up from L. Sarchiapone, who should run FLUKA simulations with the new provided inputs. Lucia said that any additional study will require approximately 1 week of CPU time and a few days for the analysis. S. Redaelli commented that, if the impact distributions on the TCDQ/TCSG jaws do not change significantly with a reduced collimation system, one can re-scale the FLUKA results without necessarily running again the full simulations.

<u>Actions</u> (ABP inputs followed-up by L. Sarchiapone FLUKA simulations): calculations of deposited energy from halo loads in the TCDQ elements in case of reduced collimation system: (1) missing secondary collimators (C. Bracco) and (2) one-sided cleaning (T. Weiler).

4 Followup studies (A. Ryazanov)

Alexander Ryazanov from the Kurchatov Institute gave a status of the calculations of radiation damage to the LHC collimator materials from impacting proton beams. The developed models and simulation tools use FLUKA results as inputs (energy deposition from proton impacts) to study the generation and the development of atomic cascades and sub-cascades. This phenomenon can eventually induce permanent atomic dislocations that determine the material damage. The aim of this study is to calculate the equivalent DPA (*displacement per atom*) of the collimator material in various experimental conditions. This will provide hints on the expected survival time for the LHC collimators before replacement.

A. Ryazanov presented various illustrative examples of cascade generation from impacting protons at low energy. This shows the potential of the tools that are being setup (see Alexander's slides for details). Examples of the generation rate for point-like defects from 7 TeV proton beams were also shown but not discussed in detail. This will required more discussion among the people interested, which will take place during this week (Alexander will leave CERN at the end of this week).

There was some discussions about the way DPA can be calculated. A. Ryazanov showed calculations carried out in the case of full bunch impacts at 7 TeV. He stated that the time structure of the impacting bunches is important to calculate resonant effect with the material structure. R. Schmidt said that this scenario is not the most interesting for the LHC. We would rather like to have and equivalent damage per impacting proton, to be rescaled with the total number of protons that are expected to hit the collimator jaws. The parameter of interest for us is the yearly DPA but according to A. Ryazanov this cannot be calculated *per impacting proton*. The discussions will continue off-line.

The next meeting will be May 22nd, 14h30.

Action Items:

- ▷ Follow-up of the definition of BLM locations for ions: Actions for next meeting of May 22nd: (1) estimate effects of orbit on loss maps (G. Bellodi) and (2) figure out the impact of approximately 100 additional monitors for the ion program. The aim is to provide one coherent proposal for the integration of monitor.
- ▷ Why is the momentum halo is entirely lost at the TCTH of IR? (G.Bellodi, H. Braun and ABP team).
- ▷ (1) Loss maps and proton inelastic impacts at the TCDQ for a one-sided collimation system (T. Weiler). (2) Loss maps and proton inelastic impacts at the TCDQ for a reduced collimation system with less TCSG's (C. Bracco). New inputs from ABP to be used for updated estimates of the halo loads at the TCDQ elements and at the downstream superconducting element (L. Sarchiapone).