Stefano Redaelli, 03-02-2005

50^{th} Meeting of the LHC Collimation Working Group, January 31, 2005

Present: Oliver Aberle, Gianluigi Arduini, Ralph Assmann (chairman), Alessandro Bertarelli, Helmut Burkhardt, Fritz Caspers, Nuria Catalan Lasheras, Samy Chemli, Alfredo Ferrari, Alexej Grudiev, Verena Kain, Tom Kroyer, Roberto Losito, Matteo Magistris, Catherine Magnier, Manfred Mayer, Andy Presland, Paul Proudlock, Christian Rathjen, Stefano Redaelli (scientific secretary), Stefan Reosler, Adriana Rossi, Guillaume Robert-Demolaize, Mario Santana Leitner, Daniel Schulte, Peter Sievers, Ralph Steinhagen, Katerina Tsoulou, Roger Valbuena, Vasilis Vlachoudis.

1 A.O.B.

Ralph Assmann (RA) announced that, from now on, the LHC collimation working group meetings will be held on Monday afternoon instead of Friday like it was last year. The meetings will still be held in the J. B. Adams room (864-2-B14).

2 Status of energy deposition studies at IR7 (M. Magistris)

See slides at http://www.cern.ch/lhc-collimation/files/MMagistris_2005-01-31.pdf

2.1 Results of latest simulations

Matteo Magistris presented the latest results of energy deposition studies at IR7. The FLUKA model of the insertion region contains now **up to 5 absorbers**. The first three absorbers are located upstream of the first MQTL (the first and the third are vertical, the second is horizontal) whereas the other two absorbers are placed between the dogleg dipole D3 and the dispersion suppressor (one horizontal and one vertical). The exact positions and the orientation are summarized in the following table.

Name	Position [m]	Type
`TLC.A6R7.B1`	20148.33	V
`TLC.C6R7.B1`	20179.29	H
`TLC.E6R7.B1`	20213.00	V
`TLC.B7R7.B1`	20236.65	H
`TLC.A7R7.B1`	20251.65	V

Various installation scenarios have been simulated by considering the cases of 2, 3, 4 or 5 absorbers. For each case, the peak deposited energy is calculated in the coils of the superconducting magnets. It is found that, if all 5 absorbers are included, the peak deposited energy in the superconducting coils stays **below the 2.1 mW/cm^3**, i.e. a factor 2.5 below the assumed quench limit of 5 mW/cm^3. With 4 absorbers, the maximum value is 2.5 mW/cm^3.

2.2 Discussion

RA commented the simulations should be updated to implement the contribution of the tertiary halo particles developed in IR7. This is done for the energy deposition studies at IR3. Guillaume Robert-Demolazie is working on implementing the additional absorbers on the simulation program for halo generation and tracking and he should be able soon to provide the particle distribution for the tertiary halo.

Stefano Redaelli asked over which coil volume the peak deposited energy is evaluated. This may have an effect on the quench performance because, depending on the volume where the energy is released, the response of the superconductor could be different. AF answered that the typical length of the proton induced shower is of the order of several centimetres. The density of deposited energy if fixed by the shower properties (the volume over which the energy is released cannot be smaller than the volume where the shower develops) and this is what is used in the simulations.

MM said that the FLUKA team is now preparing a report on the energy deposition studies at IR7. He asked if there is some special request for information that should be included in this report. RA replied that the attention should be focused on the definition of a minimal layout required to achieve the design goal (5 mW peak deposition in the superconducting coils). Certainly, the report should include the deposited energy in each element. In addition, the contribution form tertiary halo should also be included. No other requests were asked.

2.3 New proposed layout for the absorbers at IR7

The proposed locations for the two absorbers downstream of the dogleg conflict with existing equipment. Notably, one absorber is superimposed to an existing DFB and the other to a DQR. As alternative solution, Roger Valbuena proposed to install only one absorber instead of two. Space could be made available downstream of the DFB by superimposing two of three DQR's. Other solutions do not seem to be compatible with the already installed equipment. The FLUKA team is asked to evaluate the cleaning performance of the proposed layout with one absorber. RA asked if we should keep the horizontal or the vertical. AF replied that it seems that for optimizing the losses in the dispersion suppressor, it will be better to keep the horizontal absorber. Simulations will tell if this is indeed the case.

The new absorber location will not be optimized for absorbing the shower products. RA said that if the performance was not satisfying, one could consider reducing the absorber gap below the standard $10\,\sigma$ value. This option should be considered in the new simulations. However, Alessandro Bertarelli said that one should be careful in reducing the opening. The absorbers are made of metal and could warm up too much if they were set too close to the beam.

Paul Proudlock is worried because the the proposed location foresee to have an absorber close to the RR regions. He asked to calculate the new radiation doses for this layout. Katerina Tsoulou will run some simulations and present the results in two weeks at the next collimation working group meeting.

Action: Calculate the deposited energy in the superconducting magnets downstream of IR7 with the new proposed layout with 4 absorbers (possibly, by trying gaps below the standard $10\,\sigma$ settings) (FLUKA team).

Action: Estimate the radiation doses at the RR's with the new proposed layout of the absorbers (Katerina Tsoulou).

3 Total number of collimators and absorbers (R. Assmann)

See slides at http://www.cern.ch/lhc-collimation/files/RAssmann_2005-01-31.pdf

Ralph Assmann gave an updated report on the total number of collimators and absorbers in the LHC. Guillaume Robert-Demolaize (GRD) has prepared installation scripts to include the updated information of the various element in the LHC lattice version V6.5. Tables with the complete list of elements are now available (see RA's slides) and will be soon posted on the collimation project web page.

Adriana Rossi asked how many different types of vacuum connectors will be required. RA answered that all collimators have the same connection type as the TCS collimator, except the TCLI and TCT that are located close to D1 magnet (a total of 6 elements).

Action: Post the updated table of LHC collimator on the collimation web (R. Assmann, G. Robert-Demolaize)

4 Connection tests of ultra high vacuum flanges (C. Rathjen)

See slides at http://www.cern.ch/lhc-collimation/files/CRathjen_2005-01-31.pdf

Christian Rathjen (CR) described the results of various tests carried out on the flanges for ultra high vacuum (UHV) connections. Two different flange design have been compared: one built by `EVAC` and the other by `MKT`. The test were focused (1) on verifying the reliability of the two designs, (2) on estimating the required time for replacing the flanges (important for the radiation issue in the cleaning insertion), (3) on verifying the behaviour during bake out and (4) on testing the effect of asymmetric flange heating. 40 installation tests were carried out on a total of 10 flanges (5 per manufacturer). In addition, 7 bakeout cycles were performed. Both flange types proved to be very reliable: no leak problem was encountered due to problems with the flanges (one leak was induced by a defect of the Copper joint). The vacuum tightness was maintained without problems also with asymmetric heating of the flange (a hot spot was generated on one flange side with a burner flame at 300 degrees). The price is also similar for the two options (difference of 5 % between the two manufacturers). On the other hand, the `MKT` design is smaller and much easier to install. CR concluded that the `MKT` design is indeed the best technical choice for the LHC. RA concluded that we should then go ahead with the series production.

In addition, CR also commented on the pumping modules for the collimators. There are some critical locations were the available space between collimators and near-by elements is limited and this makes difficult to prepare the vacuum connectors (in particular, there is a critical location at IR3, where two secondary collimators are installed between Q5 and Q6). CR said that it would be very helpful to move the collimators (shifts below 1 m) to optimize the interconnections. RA said it would be much better not to modify the layout of the cleaning insertion, which has been frozen after a very detailed matching of the optics to optimize the cleaning performance. Displacements of ≈1 m could be too big. However, this possibility should be discussed in case no other solution is found.

Manfred Mayer asked if it is possible to eliminate the pumping module between the collimators at IR3 that cause problems. VAC should verify if this option could actually be a solution.

5 Tune measurements at the SPS with different collimator gaps (M. Gasior)

See slides at http://www.cern.ch/lhc-collimation/files/MGasior_2005-01-31.pdf

Marek Gasior reviewed the tune measurements performed at the SPS with different collimator settings. Two prototype of new measurement devices have been used: (1) a base-band tune measurement (BBQ) and (2) 245 MHz system. Notably, the system (1) provide tune measurements of unperturbed beam (no beam excitation is required). Both devices could measure the tune shifts as small as 10^{-4} induced by movements of the collimator jaws. The two measurement devices are in good agreement.

By measuring the tune for different values of collimator gaps, the tune dependence on the collimator gap was established. By averaging the spectra of the beam oscillations, a precision of 10^{-5} was achieved for the tune estimate. This is the first time that the effect of the collimator gap on the tune is measured with this precision.

RA welcomed the nice measurements presented by MG. Since no bad surprises are found, we can keep the uncoated carbon-carbon option for the jaw material. RA suggested that we should write a journal paper on these results.

6 Simulations of trapped model of the LHC collimator (A. Grudiev)

See slides at http://www.cern.ch/lhc-collimation/files/AGrudiev_2005-01-31.pdf

6.1 Simulation results

Alexej Grudiev (AG) presented the simulations of trapped modes of the LHC collimator. The simulations tools have been cross-checked with the trapped mode measurements with beam performed at the SPS by Fritz Caspers (FC) and Tom Kroyer. The comparison shows a fairly good agreement between simulations and measurements. Notably, the measured frequency dependence of some modes as a function of the collimator gap and a coupling at frequencies of around 0.6 GHz and 1.2 GHz are nicely reproduced by the simulations.

For the nominal LHC intensity (2808 bunches, 16 nC), AG predicted that the second $m = 0$ mode at **1.24 GHz** will dissipate **32 W** in the collimator, **4 W** of which will be absorbed by the RF fingers. The first mode at 0.6 GHz is instead not an issue. A perfect contact resistance is assumed for the RF contacts.

AG also calculated the effective longitudinal and transverse impedance of the collimator. From the simulation, he could identify the modes from various collimator components. The highest transverse impedance is induced by the transition modes and by the gap modes. Some examples of the calculated impedance and a table with the mode parameters can be found in AG's slides.

6.2 Discussion

Fritz Caspers said that the heating of the RF fingers my be critical and should not be neglected. Temperature increases should be kept below 100-150 degrees. RA said that the heating should be compared with what is induced by the electromagnetic shower in the collimator. His feeling is that the quoted 4 W are small with respect to the contribution from the impacting particles and hence might be negligible. RA also commented that, thanks to the excellent work of Sergio Calatroni and co-workers, the RF contact resistance has been reduced by almost a factor 10.

AG said that in his model the RF fingers are made of Copper. Alessandro Bertarelli (AB) replied that they are actually made of Copper/Beryllium and hence the model should be revised. There were several concerns that this could induce differences up to a factor 10 in the dissipated energy (FC, MG). Therefore, AG should update the model to take into account the correct material. AB also asked if 4 W deposited on the RF fingers are symmetrically distributed or if some fingers get heated more than the others. It was agreed that AG will address these two items and present its results in two weeks at the next collimation working group. RA stressed that we need to now as soon as possible if the RF finger design has to be changed. For example, FC proposed to consider the possibility of installing some ferrite close to the RF contacts in order to damp the dangerous modes. The various options should be discussed at the next meeting after having seen the new simulation results.

Manfred Mayer asked if from simulations one can understand if the top and bottom RF contacts between the jaws and the vacuum tank are absolutely necessary. AG replied that in his opinion they are indeed mandatory in order to avoid low frequency mode and their multipoles. FC said that one could avoid the RF contacts by properly installing some ferrite to damp the modes. RA agreed that it would be useful to perform some simulations to verify if this could be an option. Nevertheless, this topics has lower priority than the estimate of heating of the RF fingers, which should be ready in two weeks.

7 Measuring the beam size by scraping the beam with the collimator? (S. Redaelli)

See slides at http://www.cern.ch/lhc-collimation/files/SRedaelli_2005-01-31.pdf

Stefano Redaelli (SR) reported on beam size measurements carried out at the SPS by scraping the beam with the collimator. This method can provides a measure of the beam size at the collimator location. Indeed, the local measure of the beam size could potentially be a very useful tool to adjust the jaw depth during the commissioning of the LHC collimation system. Unfortunately, no dedicated measurements were performed at the SPS. Nevertheless, SR found some interesting cases that can provide useful information.

The beam size measurements are based on the following principle. By scraping the beam with one collimator jaw, one observes a reduction of the beam intensity. The profile of the beam current reduction as a function of the jaw depth with respect to the beam centre depends on the transverse beam distribution. For Gaussian beams, this profile is also Gaussian and it turns out that one can infer the beam size with a Gaussian fit. SR did this exercise for a few cases where the measurement data are sufficiently clean. It is found that the fitted values of beam size agree well with the values calculated from the emittance measurements. This is the case both for LHC type beams (batches of 72 bunches, with 25 ns spacing) and also for single bunch measurements.

SR concluded by stating that in principle this method could be used also at the LHC for setting the collimators depth at any location (the case with non-zero dispersion, neglected for the analysis of the SPS data, will need to be taken into account). However, SR also noted that this method could only be used for low-intensity beams (pilots). How the measured value changed for higher intensity beams remains to be understood.

RA commented that this measurements provide a destructive estimate of the beam size. One never knows what happens at the next injection! SR agreed but also stated that in any case, the method could be used to measure the local beta-function at each collimator location, provided that the beam emittance is known.

Action Items:

- ▷ Post on the web the updated tables with the final number of LHC collimators and absorbers (R. Assmann, G. Robert-Demolaize).
- ▷ Include the contribution of tertiary halo in the energy deposition studies at IR7 (FLUKA team, R. Assmann, S. Redaelli, G. Robert-Demolaize).
- ▷ Assess the performance of the new absorbers locations proposed by R. Valbuena, that foresee 4 absorbers instead on 5 (possibly considering absorber gaps below $10\,\sigma$) (FLUKA team)

- ▷ Estimate the radiation doses at the RR's with the new proposed layout of the absorbers (Katerina Tsoulou).
- ▷ Update the HOM's simulations by addressing the following issues:
  (1) RF finger are made of Copper/Beryllium and not of Copper;
  (2) How is the dissipated energy distributed among different finger?
  (3) Could one eliminate the RF contact between jaw and tank (top and bottom) by installing some ferrite to damp low-frequency modes?
  The results of (1) and (2) should be presented at the next collimation working group, in order to freeze the collimator design (A. Grudiev).

The next meeting will be February 14, 14:30, Adams room.