Verena Kain, 2003-03-18

22nd Meeting of the LHC Collimation Working Group, March 14, 2003

Present: Oliver Aberle, Helmut Burkhardt, Luca Bruno, Peter Sievers, Verena Kain (scientific secretary), Francesco Ruggerio, Vasilis Vlachoudis, Ralph Assmann (chairman), Brennan Goddard, Jan Uythoven, Rudiger Schmidt, Bernd Dehning, Markus Brugger, Mike Lamont, Miguel Jimenez

1 Follow-up on Action Items

Action items such as *review on vacuum issues for carbon*, *e-clouds*, ...from the last sessions will be treated in the Collimation Project Meeting (CPM).

1.1 Contribution to Impedance from LHC Collimators

FR quoted F. Caspers on the difficulty of doing impedance measurements in the lab (via wakefields). He pointed out that in the SPS where the impedance is already big, additional impedance of a collimator would only be a small perturbation (gaps between collimators jaws and beam, as small as in the LHC, cannot be set up). The question of impedance in connection with collimation will be looked at in the LTC on March 19, 2003.

2 Outcome of Chamonix

2.1 Urge for progress of specification for transfer line collimation

The specifications should be ready by June 2003 and must assume as worst case scenario a full SPS batch ($\sim$ 280 bunches) on the jaw. The system will be mainly specified for damage protection, quench protection will be a side aspect. HB proposes fully movable jaws, which is commonly supported. The budget was foreseen for a fixed collimation system, movable jaws will increase the budget. HB mentions that the simulations, currently done with MAD-X, must be coupled with scattering routines (K2?) for reliable results. As a first approach protection schemes should be set up without scattering routines as progress is important. RA said that simulations and resulting specifications should take into account the whole injection with TCL-collimators plus one turn in LHC.

Action Items:

- ▷ Specifications for transfer line collimation by June 2003 (HB)
- ▷ Requirements on racks, cables and space must be defined or respectively reservations must be checked (OA, LB $\rightarrow$ CPM)

2.2 Maintenance of collimators

In order to specify repair and maintenance procedures of the collimators answers to the following questions must be found.

1. How often do collimators have to be replaced/repaired?
2. How long does it take to replace/repair a collimator?

Under the constraints

- that personnel must not be exposed to irradiation larger than 5mSv/y (SR)
- and that the dose in the collimation insertions is expected to be almost everywhere larger than 100 μSv/h which requires formal justification and optimization for access (SR)

remote handling will be discussed. If it turns out that remote handling is necessary, a design has to be laid down.

PS brought up a discussion about the vacuum situation during changing collimators. MJ mentioned that with the present layout of the insertion changing of the collimators would mean to lose the vacuum over a length of about 100m (approximately the half-length of the cleaning insertion). PS asked whether additional valves or remote controlled flanges could be installed. During the discussion RA mentioned that the warm magnets in this area could fail more often due to more irradiation from the scattering at the more transparent collimators. Another question brought up by RA is "What is the procedure if one of the motors of the fully movable jaws gets stuck?".

Action Items:

- ▷ Answers for question 1 and 2 from above (OA, LB → CPM)
- ▷ Vacuum system: does it make sense to install additional valves in the cleaning insertions in order to restrict the deterioration of vacuum to smaller areas during collimator maintenance? (MJ)

3 MAC – Machine Advisory Committee

RA had a talk leading to questions on impedance, cooling of collimators to reduce their resistivity and the longitudinal distribution of losses. The need for experimental tests, for instance at fusion facilities (SANDIA), was indicated.

Action Items:

- ▷ More detailed study of longitudinal distribution of losses (TBD).

4 PAC03, HALO workshop

The main goal of the PAC03 as well as the HALO workshop for the LHC collimation studies shall be:

- presenting the status of the LHC collimation system
- getting advice
- getting names of experts for possible invitation
- finding out possibilities for experimental tests

4.1 PAC03

The talk "Designing and Building a Collimation System for the High-Intensity LHC Beam" has been selected as oral presentation and will be presented by RA. Several other posters will be presented.

4.2 HALO workshop

RS, JBJ and PS will participate. RS's talk will cover the same topics as his talk at Chamonix which focused on machine protection issues but will stress more the role of collimators and absorbers in the LHC. PS will give a talk on the status of material studies. JBJ will present the system layout, news on abort cleaning, radiation- and BLM-studies. Details will have to be finalized.

5 Collimation of Ions – collaboration with BNL (RA)

The goal of such a study would be to compare experimental observations at RHIC with predictions. This will help us to assess the realistic errors in our predictions for the LHC (e.g. due to incomplete models). See slides at http://lhc-collimation.web.cern.ch/lhc-collimation/files/CWG22_ions_ra.pdf.

At the same time RHIC considers improving their one-stage collimation system which presently consists of one vertical and one horizontal single jaw copper collimator for each ring.

VK talked about her experience with RHIC-collimation. The collimator jaws have to be adjusted very cautiously, as the scatter products and ion fragments can easily quench magnets downstream of the scraper.

People willing to contribute at CERN are RA, AF, VK, PS and VV, who will provide FLUKA simulations as well as particle tracking through the RHIC lattice to predict loss locations and compare results with RHIC data. Input from RHIC is required. People from BNL involved in the collaboration are Wolfram Fischer, Angelika Drees and Ray Fliller.

The relevance of RHIC results for LHC in ion collision mode still has to be discussed. LHC requirements are more stringent.

Action Items:

- ▷ Sacttering of ions through the collimator jaw (AF, VV)
- ▷ Discussion on tracking tools for simulations, setting up the tools for the RHIC lattice (RA, VK)

6 A Three Stage Cleaning System with Improved Robustness and Impedance for the LHC (RA)

RA presented his ideas on how to cope with the problems of LHC collimation. He first summarized other possibilities to relax requirements. See slides at http://lhc-collimation.web.cern.ch/lhc-collimation/files/CWG22_3stage_ra.pdf.

6.0.1 Shortening the re-trigger of the dump kicker magnet

Shortening the re-trigger time of dump kicker in case of a prefire of one module would reduce the number of protons with amplitudes between 5 and 10 σ_x by a maximum factor of 4 (currently: 20 bunches).

6.0.2 Anti-Kicker

An anti-kicker at the dump kicker magnet would give a similar improvement as shortening the re-trigger time of the kicker.

6.0.3 Fixing the phase advances between the dump kicker and primary collimators in IR7

In the present layout the phase advance (minus Nπ) between the dump kicker magnet and the primary collimators is 165° for beam1 and 132° for beam2. In the situation of beam1 the phase advance of approximately 180° would make the beam miss the primary and be swept over secondary collimators in case of a dump kicker failure. A cure would be to fix the phase advance such that all beam would impact on the primary horizontal betatron collimator. Then the secondary collimators could be possibly made short and thus more robust. For beam 2 the beam goes through the momentum collimation first before getting to the betatron cleaning insertion. It has to be made sure that the beam impacts first in IR7 which means fixing the phase advance between dump kicker and primary collimator in IR3 also.

Fixing the phase advances does not give any improvement for injection errors and will constrain the operational flexibility of the LHC. Hence this option is less attractive.

6.0.4 TCDQ at 6σ

BG and RS proposed to put the TCDQ at 6σ to make sure that in case of a dump kicker failure the beam would be captured by this absorber. The large beta function of 550m at this location, meaning a bigger beam, would favor the proposal in terms of energy density. RA pointed out that with a TCDQ at 6σ without secondary collimator afterwards the cleaning inefficiency would most probably be very poor. Furthermore the 10m-length of uncoated carbon, which is required to protect Q4, would create significant resistive impedance.

Putting the TCDQ closer than 10σ is still worth thinking about. Another advantage of such a consideration would be concentrating beam loss during a dump failure at one position in the ring (RS).

6.1 A Three Stage Cleaning System

RA presented two approaches for solving the problems (material, tight mechanical requirements, impedance) of the current collimation system. The principle in common for the two schemes is additional collimation at the triplets and setting the secondary collimators (in IR7) further out.

6.1.1 First Approach

The largest contribution to the impedance stems from the secondary collimators (in IR7: 4 primary collimators [0.2 m length each] compared to 16 secondary collimators [1m length each]). Moving the secondary collimators further away from the beam reduces the impedance.

A possibility to guarantee robustness for injection errors as well as dump kicker failures and an improvement of a factor of 3-4 in impedance is to use short (in the order of some cm) carbon primary collimators at 6σ and secondary carbon collimators of 100cm length. The transverse setting of the secondary collimators at injection energy is 7σ (450 GeV) and remains unchanged at 7 TeV with unsqueezed optics. With squeezed optics they are moved to 10σ (7 TeV). Short primary collimators are not destroyed during impact of irregular beam loss. To protect the triplets and maintain cleaning efficiency additional copper collimators at 10σ (proposal 50 cm) would be needed at the triplets.

6.1.2 Second Approach

The impedance could be reduced even further by using a **hybrid** system. Using secondary collimators of copper at 7 TeV (50 cm, 10 σ) and secondary collimators of carbon at injection energy as well as at 7 TeV with unsqueezed optics (50 cm, 7 σ at injection energy) could do the job. Carbon secondary collimators during injection are needed to guarantee protection against injection errors. Additionally tertiary collimation at the triplets as in the first approach would be needed and primary collimation would also look as described above. This approach would only work with having the secondary copper collimators in the shadow of the TCDQ (10σ).

The cleaning efficiency of short primary collimators would be worse by a factor of 2 to 3 for a jaw length of 1 cm. On the other hand they are much more robust and no adjustment of the collinearity between beam and jaw would be needed.

With secondary collimators at 10σ the secondary halo would extend to 13σ with the present phase advances between primary and secondary collimators. Phase advances should be reoptimized for the new settings to obtain further improvement.

The $n_1 : n_2 = 6 : 10$-system would make operation easier and relax set-up and mechanical tolerances (n_1, n_2 are the normalized transverse setting of the primary and secondary collimator). Whereas a $n_1 : n_2 = 6 : 7$-system could tolerate transient orbit changes of 0.25σ and a transient beta beat of 8%, it would be about 1σ and 40% for the $n_1 : n_2 = 6 : 10$-system.

6.1.3 Conclusion and further Comments

The **hybrid** system with collimators at the triplets looks promising. It offers possibilities for optimization cleaning efficiency versus impedance and robustness. The tolerances are less stringent. Details still have to be worked out. Possibilities for collimators at the triplets or D1 have to be checked. Another question is routine operation with low lifetimes with copper secondary collimators.

There is still the possibility of using beryllium, which would make the situation easier as no hybrid system might be needed. Simulations for material quantities and characteristics of beryllium under extreme conditions are being carried out. If the copper (or other metallic) collimators do not fulfill the requirements for normal operation, beryllium is still an option.

With collimators at the triplets more radiation at the triplets can be expected. The increase of the background due to scattering and showering at the tertiary collimators is said to be negligible (RS) compared to background from the collisions at the IP. Detailed studies are required.

The proposed hybrid collimation system is coupled with the TCDQ setting (secondary collimators in the shadow of the TCDQ). JBJ mentioned that as the dump kicker deflects in the horizontal plane and the TCDQ therefore scrapes in the horizontal plane one could think about putting only horizontal secondary collimators in the shadow of the TCDQ and thus restore the cleaning inefficiency of previous collimation systems. If metallic secondary collimators are used in a hybrid system it might be possible to put the vertical and skew collimators closer to the beam than 10σ without increasing the impedance too much (there will be some unavoidable increase of impedance).

The TCDQ consists of one jaw only. A simple collimator jaw on the oppositing side could make its set-up more secure (JBJ, RS).

Action Items:

- ▷ Possibilities for tertiary collimators at the D1 must be checked (OA)
- ▷ Optimizing parameters for the hybrid system in terms of cleaning inefficiency and impedance (RA, DK)
- ▷ Irradiation studies for triplets with tertiary collimators (TBD)
- ▷ Material studies for hybrid system (copper secondary collimator at normal operation with low lifetimes), including beryllium as a possible choice (PS, AF, VV, OA, LB)

- ▷ Showering studies in tertiary collimators for estimation of background at experiments (TBD)
- ▷ Simulations for beam impact and material studies for TCDQ after prefire of a kicker module and also for routine operation (BG, RA, VV, AF)

The next meeting will be on March 28, 2003.