Verena Kain, 2003-06-18

27^{th} Meeting of the LHC Collimation Working Group, June 13, 2003

Present: Ralph Assmann (chairman), Hans Braun, Brennan Goddard, Jean-Bernard Jeanneret, Verena Kain (scientific secretary), Barbara Holzer, Oliver Brüning, Bernd Dehning, Helmut Burkhardt, Nuria Catalan Lasheras, Gianluca Guaglio, Christian Rathjen, Miguel Jimenez, Vasilis Vlachoudis, Peter Sievers

1 Graphite and C-C materials for UHV applications (M. Jimenez)

See slides at http://www.cern.ch/lhc-collimation/files/MJimenez_13Jun03.pdf.

M. Jimenez (MJ) showed the results of a recent experiment to test vacuum properties of graphite and C-C. Static outgassing before and after bake-out (24 hours at 250°), thermal outgassing stimulated by e^--bombardment (3 minutes, heating power: 175 W, sample size: 14 cm^2, reached temperature: 1050°, pumping speed: 40 l/s) were analyzed. The investigated samples were not braced or clammed, all surfaces were free.

After a heat treatment of 2h at 1000° C-C has the same outgassing rate as graphite. Outgassing holes in graphite did not lead to improvement. The outgassing rate due to thermal outgassing for C-C (after 24h in situ bake-out at 250°) showed as good results as Cu or ceramics and is acceptable for LHC (outgassing rate: $3 \cdot 10^{-12}$mbar $\cdot$ l/s $\cdot$ cm^2). The gas composition after the e^--bombardment at 1050° might be problematic, as it mainly consists of CH_4 and CO having a high ionization cross section. The recovery after heating is compatible with the refilling of the LHC (outgassing rate increase of 4 orders of magnitude at 1050° and 3 orders of magnitude recovery after 1.5h; the recovery improved after repeated bombardment).

MJ pointed out that 1000° heat treatment is necessary. The duration of this treatment depends on the thickness of the material. It is important to decide on a layout of the collimator blocks as soon as possible to have furnace time allocated or to decide on using a furnace outside of CERN. Other equipment is in need of the CERN furnace, too. In situ bake out at least at 250° for approximately 24 hours is also mandatory. P. Sievers (PS) asked whether the whole assembly (collimator blocks with the collimator mounting,. . .) has to be put into the furnace. MJ replied that only the collimator blocks have to be baked out; after the assembly under normal vacuum handling there would be in situ bake out.

There is an interlock on the power supplies of the ion pumps for a pressure of $5 \cdot 10^{-5}$ Torr, thus the pressure rise due to thermal outgassing from heating caused by beam losses should be below that. The power supplies of the pumps are turned off if this pressure value is exceeded (due to for example thermal outgassing). Without any further complication it should be possible continue operation immediately afterwards and start up the pumps after the vacuum has improved. J.B. Jeanneret (JBJ) and MJ made clear that in order to give realistic numbers the pumping speed, the surface of collimators being hit and the time structure of the loss at the collimators has to be taken into account.

R. Assmann (RA) reported news from L. Vos and F. Ruggiero that 10μm of Cu coating on C would reduce the average impedance by a factor of 5. According to MJ a structure like this would need longer bake out time. PS wanted to know whether such a structure can stand heat treatment temperatures up to 1000°. MJ answered that heat treatment would be done on the jaws before coating.

JBJ brought up a discussion on where to put the pumping stations, either 2 stations on each side of the collimator (1) or one directly on the collimator (2). According to JBJ the pumping efficiency would be improved for (2). MJ remarked that he prefered (1) because of radiation issues. In general, he said, it depends on whether the pumping station has to be dismounted during collimator removal. If yes, he added, the personal would get too much dose. The decision on the pumping station scheme shall take this into account. RA remarked that we still need an estimate for electron clouds to see whether additional cleaning electrodes are necessary.

Action Items:

- ▷ Summary/report on conditions of experiment (MJ)

2 3D studies of collimators between the MQWs (C. Rathjen)

See slides at http://www.cern.ch/lhc-collimation/files/CRathjen_13Jun03.pdf.

C. Rathjen (CR) presented 3D views on the collimation insertion. The aim of the 3D studies was to investigate intervention and installation issues. The drawings were based on the information they had so far. B. Dehning (BD) pointed out that the available transverse space is tight. Space for motors was not taken into account. CR said that for exchanging collimators in the external beam line the internal beam line must be removed. The additional time must be added to the intervention time. PS added that this depends on the design and proposed gantries removing the collimators vertically. MJ replied that there might not be enough space vertically.

MJ said that in case of an intervention the vacuum of 100m is broken. RA asked whether additional valves could be placed. This is a question of reliability of valves compared to collimators MJ replied. Valves are very sensitive to radiation. Having to maintain valves in highly radioactive area too often should be avoided. RA then wanted to know whether all collimators, which are in this 100m of broken vacuum, have to baked out again afterwards. MJ answered: in general yes. The operations crew would have to decide on case by case basis.

PS asked about the weight of the ion pumps. MJ said that it depends on the pumping speed (20-30kg for 30l/s).

There are BPMs after each quadrupole assembly. CR would like to have them put at other locations than near collimators which would ease maintenance. Finding the right bellows might be problematic. These transition pieces between elliptical aperture and something which is defined by the collimator must be suitable for a pumping station and have the right length.

3 Present Status of Proposal for the LTC (RA)

3.1 News on Radiation Studies from M. Brugger (MB)

See slides at http://www.cern.ch/lhc-collimation/files/RAssmann_a_13Jun03.pdf.

RA showed the good news on dose rates in connection with intervention in the collimation area simulated by MB and S. Roesler. Cases were studied for C-C unshielded and shielded and Cu unshielded and shielded each after 1 year of normal LHC operation after 1h as well as one day of cooling time for a primary collimator and also a secondary collimator. The assumptions on total intervention time are based on: access-walking (both ways): 500s, opening of the shield: 15 min, intervention: 1h, opening of the shield: 15min. Equipment shall be designed to have less than 5 mSv/h for easy handling.

The maximum dose rates resulted for a primary collimator after one hour of cooling range from 2 to 5 mSv, for secondary collimators it is below 1 mSv. These dose rates are below the numbers by G. Stevenson (15 mSv/h) demanding full remote handling as MJ remarked. PS remarked that vacuum issues and check of He leakage are not included in the intervention time. He also wanted to know how long the machine would be down after collimator maintenance. MJ replied that for vacuum issues together with bake out it would be 10h. MJ insists on having accurate numbers as the people of the vacuum crew must not take more than 1 mSv per day. High intervention frequency and high dose rates in the collimation section could cause a shortage of vacuum personal.

3.2 News on Phase 1 and Phase 2 of LHC collimation

See slides at http://www.cern.ch/lhc-collimation/files/RAssmann_b_13Jun03.pdf.

RA gave a summary on the different phases, discussed the exposed collimators for irregular and regular failure scenarios in IR3 and IR7 for injection energy and at 7TeV, presented the optics and settings of the different phases in detail, proposed a installation schedule and talked about testing possibilities.

3.2.1 The different Phases of the LHC collimation system

The different phases were already described in the minutes of the last meeting (May 30, 2003). Additional comments:
In 2007 Phase 1 will be installed. Phase 1b (relying on optional Cu coating and/or tertiary collimators at the triplets) might be foreseen for 2008. It would not require any additional hardware and push the performance and β^* to their limits. Phase 1 will likely limit the performance. The triplet aperture must be increased (13.5σ). The collimator layout will be based on the LEP-collimator design. Phase 1 does not rely on the TCDQ shadow. In IR3 and IR7 42 collimators will be installed (instead of 54). 16 additional collimators will be put at the D1 magnets on each side of the IP in the vertical plane as well as the horizontal plane. They act as tertiary collimators to protect the triplets (not for cleaning). Additional place holders will be in the primary collimator tanks for crystal collimators. Together with the 8 TCL collimators 66 collimators will make up the phase 1 collimation system. The number of absorbers used for damage and quench protection remains so far unchanged, but should be verified for the new system. Whether spoilers and scrapers for machine protection are needed has not been investigated yet.

According to JBJ momentum collimators at top energy do not have to be moved further in than 11σ. RA proposed to put them at $15/18\sigma$ or even further out (abort cleaning has to be checked). Whether the number of momentum collimators (7 so far) can be reduced has to be investigated. Alternative materials for the secondary collimators in IR3 and for some skew collimators in IR7 are either Al, Ti or C with Cu coating.

In phase 2 metallic hybrid elements will be put at all positions of secondary collimators. Phase 2 relies on the TCDQ for the horizontal secondary collimators and on cleaning from tertiary collimators at the triplets. It will only be used for physics, during injection there will always be the phase 1 set up. At injection energy all the hybrid elements are open. Horizontal hybrid collimators have to sit at least at 10.5σ all the time. For known phase advance some of these H collimators can be closed more, if irregularly dumped beam cannot hit them. Materials for the hybrid collimators can be Be, C-C with Cu coating (coating might fall off), Al, Ti or Cu doped C, using conventional technology (MJ remarked that Al promotes the development of electron clouds). Another possibility is metallic stripes/tapes on conventional jaws. If it turned out that one has to cope with regular failure and damage advanced technology like rotary metallic collimators, consumable jaws might be discussed. O. Brüning (OB) stated that it might be useful to try to find out whether phase 2 is absolutely necessary for nominal operation. What is the increase of impedance if a certain percentage of collimators lost the coating in e.g. a dump failure case? N. Catalan Lasheras wanted to know whether the additional length of the tapering has been included in the stated lengths of the collimators. RA replied that the tapering of 20cm on each side of the collimator is not included in this length.

In 2010 (third phase) 4 TCL collimators at the high luminosity experiments will be installed.

In total there will be 26 more components installed in the LHC than in the initial baseline spread over a period of 4 years resulting in a total number of 92 collimators.

3.2.2 Exposed collimators during different failures

All the tables can be found under the URL given above.
The skew collimators in IR7 can also be hit as they are not always "skew" (tilts for example $\sim 10°$). At injection energy up to higher energies momentum collimators – when at $8/9.3\sigma$ – can be affected by an irregular dump. At injection energy oscillations from TL, SPS or injection elements can lead to beam loss at the momentum collimators.

3.2.3 Installation Schedule, Testing Possibilities, AOB

In 2007 66 collimators and 16 or more additional devices such as absorbers and scrapers will be installed. In 2008/9 22 additional collimators (hybrid collimators) will be put into the LHC. In 2010 the 4 TCL collimators will be placed.

Different testing possibilities were discussed (see slides). The LHC MAC had proposed to get in contact with Sandia to test the robustness of collimator jaws. No contact could be established so far. The SLC beam at SLAC could be used for impedance measurements along with robustness tests. JBJ mentioned that protons from the booster can be used for resistivity tests of the collimator jaws. RA noted that no efficiency predictions for ion collimation exist so far. Ion collisions can result in large $\Delta p/p$. Where are they lost, in the dispersion suppressor (H. Braun)?

CR and MJ were worried about beginning installation of equipment and fixing cable lengths in the collimation insertions. The finalization of IR3 and IR7 will not be done before the end of this year (arc 6/7 does not take part in the octant test). Until then everything can be moved in these insertions according to RA. This was discussed in December 2002.

V. Kain and RA investigated the phase advances between the collimators in IR7 and built the optics for a 45° system (20 collimators as in the old system: 4 primaries, 16 secondaries, 4 collimation planes [vertical, horizontal, 2 skew]; every 45° phase advance a collimator for each collimation plane; beta function and overall phase advance approximately as in the old system). Preliminary results gave a slightly better cleaning efficiency. Thus RA thinks that the efficiency rather depends on the tails created in the scattering than phase advance conditions (longer collimators?). OB remarked that it might be difficult to include beam2 in the studies because of shared quadrupoles.

4 TCDI (Transfer Line Collimator) Concept (H. Burkhardt)

See slides at http://www.cern.ch/lhc-collimation/files/HBurkhardt_13Jun03.pdf.

H. Burkhardt (HB) talked about the present concept of the transfer line collimation (for TI2 and TI8). It consists of 4 collimators per line (at the septum and 90° downstream, horizontal and vertical) plus an optional momentum collimator at the beginning of each line. To have enough dilution the collimators' length is proposed as 3m (this has to be discussed), 4m space reservation. Elliptical collimators set at 5σ based on 3.5μm normalized emittance and $3 \cdot 10^{-4}$ energy spread might be used. JBJ wanted to know why the momentum collimator is optional. HB replied that he would rather rely on the SPS as energy spectrometer. RA thinks that momentum cleaning in the transfer line is useful. JBJ added that the momentum collimator should be at the end of the line to do a proper job.

For his simulations HB used MAD-X as tracking tool. The collimators in the TL are treated as black absorbers. He would like to have help on setting up tools to include shower development. OB asked why he did not use RA's version of SIXTRACK with the K2 scattering module. RA replied that K2 is only useful for treating primary protons being scattered in the jaws. No shower calculations are done. As the TL collimation must protect but not clean, the destructiveness of showers must be investigated. These studies will be done in a future iteration.

Collimators at 45° and 135° phase advance might be useful (additional 4 collimators). These collimators could be made shorter (JBJ). HB proposed 45° collimators as an upgrade option and to concentrate all effort now on getting the baseline TL collimation going.

Different collimator schemes (V-shaped collimators,...) were discussed. Collimators must be compatible with operation issues (beta-beating, different emittance, tunability, optics flexibilities, ...). Tolerances on optics (matching of beta function, dispersion, ...) must be specified. The advantage of elliptical collimators is cost (B. Goddard).

OB wanted to know how many "shots" the collimators can stand if for example one of the pulsed power converters has the wrong timing. BG replied that whenever there is something wrong one goes back to pilot bunch injection.

Following HB's proposal RA summed up: there is a sound baseline of 4 collimators in each transfer line. They should be ready for the injection tests. The 45° collimators are an interesting upgrade option, which should be pursued.

5 Collimation, materials, failure modes – II (JBJ)

See slides at http://www.cern.ch/lhc-collimation/files/JBJeanneret_13Jun03.pdf.

Momentum cleaning collimators are all horizontal or with little skew. Thus they should be out of MKI failure range at injection and MKD failure at top energy with n_1 at least 11 (to avoid scraping stable particles which are at the edge of the bucket, see talk of JBJ at 26th meeting). A MKD failure at injection should be OK with Al jaws according to JBJ (ATB check needed) and also normal operation. Al contributes to impedance reduction and therefore might enable to put the IR7 collimators closer to the beam. For the usage of Al jaws decent control of amplitude excursions in the transfer line must be guaranteed.

JBJ wanted to know whether combined failures in the horizontal and vertical plane are likely to happen in the TL. HB replied they are very unlikely. He also mentioned that if the downstream septum goes wrong that there is no protection at all from the TL.

6 Request for Beam Loss Simulations

See slides at http://www.cern.ch/lhc-collimation/files/BDehning_13Jun03.pdf.

BD requested input for BLM studies.

- Number of loss locations in the arc and long straight sections for the same failure event
- What is the correlation of losses (combination of detector signals in the arc)?
- What are the most probable loss locations?
- Spread of losses

The next meeting will be announced.