Verena Kain, 2003-05-30

26^{th} Meeting of the LHC Collimation Working Group, May 30, 2003

Present: Ralph Assmann (chairman), Hans Braun, Brennan Goddard, Jean-Bernard Jeanneret, Verena Kain (scientific secretary), Mike Lamont, Rudiger Schmidt, Graham Stevenson

1 Comments on Minutes of Previous Meeting

In the last meeting MB reported on the status of Radiation Studies in IR7. All results referred to one day of cooling after the end of irradiation.

Shielding: MB concludes that locally the radiation situation gets worse with shielding but without shielding more energy is deposited in downstream installations (e.g. magnets, pumps). Thus no shielding most probably does not necessarily mean improvement but rather moving energy deposition to other locations. Problems could arise at downstream elements (e.g. quench of cold magnets). Therefore, careful studies will be necessary in order to optimize the design for the least possible dose rates and protection of equipment.

In the last minutes it was mentioned that dose rates would imply that people must not stay near the wall more than 1h per month. To give a correct statement concerning the situation in the tunnel one should rather say: the expected dose rate coming from the wall is rather uniform in the whole tunnel and will reach - depending on the cooling time - high values, which severely limit the duration of possible exposure. Therefore, thorough planning and optimization will be crucial for all maintenance work to be performed in this area.

It takes at least three days of cooling until the dose rate contribution coming from the tunnel wall becomes negligible compared to the induced activity in the shield, the collimator or the beam pipe.

For the upcoming LTC meeting, it is agreed to have results for C and Cu collimators for cooling times of 1h, 1d, 3d and 1month. Hereby, the simplified simulation approach will serve for most estimates comparing the two materials. The more realistic case will underlie these results pointing out the influence of e.g. downstream equipment or geometry effects of the collimators. Based on the obtained results, combined with a first rough estimate on intervention times and frequencies, a basic estimate of personal exposure to radiation will be given.

In the last meeting JBJ remarked that a long term policy was needed to survey shielding material supplies. He has recently mentioned this to the TCC.

JBJ's information on the fact that the parasitic dispersion which could be used to sweep out ion fragments from the IPs is only a marginal effect stems from Stephane Fartoukh.

For clarification: RS's statement of 2 to 3 collimator repairs per year was an intuitive guess. According to OA it is 5 minutes per 2 weeks for motor exchange and 2 hours for collimator exchange (frequency undefined). A more realistic number for the frequency of repairs may be derived by giving the technical engineers numbers of the frequency of beam failures.

See slides at http://www.cern.ch/lhc-collimation/files/HBraun_30May03.pdf.

Hans Braun calculated the fragmentation of ions. He investigated ^{208}Pb on graphite and found out that after the fragmentation the ratio Z/A remains very much the same as for the initially impacting ions. Thus the question of heating stemming from ions in addition to heating from protons should also be investigated. RS quoted N. Mokhov saying that there was no program so far treating ions in material properly. GSI and their tools is still an option. RA had given ion input with the different bunch spacing and density to AF to produce FLUKA results within the next 1 to 2 weeks. RA quoted AF who said that the physics in FLUKA should be suitable for the 450 GeV ion case, for 7 TeV an extrapolation is used.

2 Towards a Proposal for the LTC on June 25^{th} (RA)

See slides at http://www.cern.ch/lhc-collimation/files/RAssmann_a_30May03.pdf.

At the LTC meeting on June 25 there will be talks on FLUKA results by VV, material studies and design based on the LEP design by OA, maybe a statement on the impedance by FR and the vacuum group. RA will present a proposal for the LHC collimation system. RA informed the CWG on his view for the presentation at the LTC based on the results presented at the CWG and the CPM over the past half year. This view has been discussed with the engineers involved. 2 phases of the collimation system were introduced. In order to have a system ready for installation in 2007 immediate collimator design and construction is crucial. Thus the proposal for the LTC could be to build phase 1 with additional space reservation for a more elaborate phase 2 hybrid system. Phase 1 of the LHC collimation system must be compatible with the LHC schedule and 10-25% of nominal luminosity.
The first phase shall be a maximum robustness, minimum cost start-up system for early LHC/injection/ramp. The luminosity reach of the LHC would be reduced, cleaning and protection at the triplets could recover part or most of the reduction.
After the first run a more delicate system for nominal/ultimate performance could be installed. The goal for the second phase is low impedance and good efficiency. The less robust system would only be used in stable physics towards the end of the beta squeeze and with squeezed optics and would rely on the TCDQ to protect the secondary horizontal collimators.

2.1 Results on Material Studies:

Material studies are based on two impact scenarios:

- 8 bunches at 7 TeV (irregular dump)
- 1 full batch at injection from TL oscillation or injection kicker failures
  Transfer line collimation should cut at 5σ. With having collimators only in two planes as proposed so far, 7.05σ oscillations might escape. The injection kicker jitter adds another σ, thus 8σ oscillations could get into the LHC and collimators at 6/7 σ could be hit. RS mentions possibilities to improve this situation by either putting a third collimator into the transfer line or by collimating down to 4σ. BG adds that a factor of 2 of improvement might be possible in the kicker case (50% of a batch lost instead of 90%).

FLUKA and ANSYS with dynamic stress calculations show that materials with Z higher than C or Be are not robust enough, Be behaves well up to a length of the jaw of 0.02m. The material of choice could be fiber reinforced carbon (C-C), where 0.2 m and 1 m are OK. For Cu doped C no manufacturer could be found. So far no results on e-clouds exist. For slow losses ($4 \cdot 10^{11}$ p/s) C-C as well as Be is OK; even Al up to 0.2m might do the job.

2.2 Phase 1

The system shall be sufficient for injection/ramping up to nominal energy with reduced intensity and larger β^*.

- Best **robustness** could be guaranteed with C-C jaws (primary collimators: 0.2m, secondary collimator: 1m). The design of the collimators could be based on the LEP design. No results for C-C from the vacuum studies exist so far. It is expected to behave even better in outgassing tests than C because of a smaller grain size.
- **Impedance:**The impedance could be reduced by removing 6 collimators from the present scheme of collimators in IR7 (the last skew primary collimator and 5 secondary collimators). JBJ had proposed to remove the second skew family (1 primary and 4 secondaries). This approach might produce better results than the brute-force empirical approach by RA. At half intensity impedance would still be a factor 3.5 too high. The impedance is OK for injection and ramp. For physics the collimators might have to be re-tracked to 10.5σ (for half intensity) leading to increased β^* and reduced luminosity reach by less than a factor 2. Tertiary collimators at the triplet could recover the luminosity reach.

  For full intensity physics the feedback might help further. The best solution is to rely on hybrid low impedance secondaries as they might be installed in the second phase.
- The **efficiency** (5.4e-3) of the reduced system is roughly the same as of the old Al/Cu system (4.9e-3). The impact parameters of the reduced system are in general larger. Nevertheless, the efficiency is somewhat reduced by eliminating collimators, which is done only to improve the impedance.

ML comments that “phase 1” is not compatible with FR’s plans for the luminosity and β^* in year 1 of LHC.
RS thinks that RA should have an additional slide for the LTC to make clear that a C collimation system would be the starting point with further reduction of the impedance in the following system.
RA got different numbers on the loss distribution at horizontal secondary collimators than JBJ. The numbers of JBJ were given to MB for his FLUKA calculations. A further study is needed.
For the hybrid system (second phase) metallic collimators will be needed to be able to move the collimators closer to the beam. BG remarked that we cannot be sure that the second phase will work. RA is confident as there are several options

- Be: the impedance would be reduced
- coated C (according to JBJ, who quoted LV, a layer of at least 100μm would be needed)
- consumable collimators

2.3 Further Work to be done:

Action Items:

- ▷ Optimization in terms of number and length of collimators
- ▷ Predict loss rates at tertiary collimators and TCDQ
- ▷ Predict cleaning efficiency of three-stage collimation system
- ▷ Solution for hybrid phase compatible with slow losses (Cu is not OK, Be?, consumable collimators,...)
- ▷ budget estimation
- ▷ Identify less impacted collimators which might be made of metal
- ▷ Putting thin spoilers at chosen locations for machine protection and as scrapers?

2.4 Shadow Study

See slides at http://www.cern.ch/lhc-collimation/files/RAssmann_b_30May03.pdf.

RA investigated the transparency of a pencil beam impacting at 7σ. He found out that secondary collimators provide good shadow (not clear whether it is sufficient for Cu), but we cannot rely on the shadow from primary C collimators. Primary C collimators leak 60% of the primary beam and downstream collimators can be hit by $\sim$50% of perturbed beam, which agrees unfortunately with the assumption of possible impact on secondary collimators. BG is worried about the fact that more than 50% of beam could come back to the TCDQ. JBJ replied that one could think about 50cm long C primary collimators leading to less transparency and less load on secondary collimators. The secondary collimators could also be made shorter in this case and thus improve the impedance.

3 Collimation, Materials, Failure Modes (JBJ)

See slides at http://www.cern.ch/lhc-collimation/files/JBJeanneret_30May03.pdf.

3.1 Momentum Cleaning

Because of the non-zero beta function the primary collimator and the 6 secondary collimators in IR3 serve as combined momentum-betatron cleaning collimators. The population of the abort gap is directly proportional to the cut δ_{cut} of the primary collimator in IR3. The minimum transverse setting for the primary collimator is 11σ at top energy, which protects the collimators against MKD failures. RA thinks of moving the collimators even further out (15σ) and use C collimators.

3.2 Transfer Line

JBJ comes back to the question whether it is possible to have a full batch at a single amplitude. Problems in the transfer line shall not be exported to the LHC. RS remarks that the transfer line is not in the LHC interlock system. ML replies that it is fed back into the SPS interlock system. BG adds that if the injection septum trips a full batch is kicked to the same amplitude and the oscillation is transported into the LHC.
JBJ refers once again to the fact that with the amplitude's cut in two planes at 5σ still amplitudes of 7.05σ are possible and wants the possibilities checked for a third 45° collimator with a length from 0.5m to 1m. Whether C is OK for a such a length depends on the beta function, RA adds.
Having a skew collimator in addition would reduce the maximum amplitudes getting through the transfer line collimation to 5.4σ. RA mentions that with an additional σ at the injection kicker amplitudes of $\sim 6.5\sigma$ are still possible (and collimators at 6σ can be hit). BG replies that due to the sweep at the kicker the situation is less severe. RS wants the length of $\sim$5m of the elliptical collimators in the transfer line reviewed.

Action Items:

- ▷ Check possibilities for skew collimators in the transfer line.
- ▷ Which length shall the transfer line collimators have?

3.3 MKI Flash-over

JBJ wants to know whether this failure is "cured". BG replies that this is an inherent feature of this magnet, despite possibly adding more electronics and improvements of the contacts (lowering impact from ∼90% to ∼%50 of a batch). This failure scenario is said to happen once in 10 years and is anyway only one of the scenarios for a full batch impacting on the collimators.

3.4 JBJ's favored baseline for collimators/materials

JBJ's considerations are based on having "cured" the MKI flash-over failure scenario and improvement of the transfer line collimation. The primary collimators in IR7 shall then sit at 6σ, the one in IR3 at 11σ. The second set of skewed collimators (1 primary + 4 secondary) can be reconsidered. Fewer jaws means less budget and easier operation and maintenance. To improve the impedance Be could be chosen as material except of the horizontal collimators. To protect these against dump-kicker failures they should be made of C. Tertiary collimators at the experiments are useful although not mandatory. If using C and Be at 6 and 7σ the performance would not degrade, less activation of tanks and surroundings could be expected.

According to RS it is not important to fix everything by now but rather to come to an agreement on a basic concept for designing. This basic concept should be kept as flexible as possible in terms of materials. RA replies that if we were to use controversial Be as collimator material then people have to be informed at the LTC. JBJ insists on having data presented by OA and LB on ANSYS calculations for Be before deciding anything.
RA proposes to relax the slow loss requirement on the collimators by a factor of 10 (allowing for example to run at quench limit). RS means it to be no problem as it is a question of operation.
RA thinks it is important to decide on spoilers before the LTC to have it foreseen in the budget if they turned out to be necessary.
RS raises the question of fixing the tune between IR6 and IR7 to have the possibility of making less exposed collimators out of other materials and improving the impedance. According to JBJ, Oliver Brüning and Stephane Fartoukh used to stay that locking the phase between IP6 and IP7 would not be impossible. RA counters that the collimation system already has to meet lots of constraints and causes inflexibility as everything is pushed to the limit. RS replies that fixing the phase would at least ease the impedance problem.

Action Items:

- ▷ Is it reasonable to fix the phase between IP6 and IP7?

The next meeting will be on June 13, 2003.