Stefano Redaelli, 11-10-2005

64$^{\text{th}}$ Meeting of the LHC Collimation Working Group, October 10, 2005

Present: Oliver Aberle, Ralph Assmann (chairman), Chiara Bracco, Markus Brugger, Bernd Dehning, Alfredo Ferrari, Massimo Giovannozzi, Brennan Goddard, Matteo Magistris, Laurette Ponce, Andy Presland, Suitbert Ramberger, Stefano Redaelli (scientific secretary), Guillaume Robert-Demolaize, Adriana Rossi, Vasilis Vlachoudis.

1 Updated layout of the IR2 and IR8 (B. Goddard)

Brennan Goddard presented the recent layout modifications at IR2 and IR8, in the region of the TCTVB and TCLIA collimators. These are the two-beam design collimators located in the region with common beam pipes for beam 1 and beam 2. The proposed modifications optimize the vacuum interconnection layout and involve collimator **longitudinal shifts of tens of centimetres**, which have a negligible impact on cleaning and protection performance. The new optimized layout requires non-standard vacuum transition pieces and the additional cost will be shared between the TCDD and the collimator project. An ECR with the new layout is under approval and will be soon available. See also the EDMS document number **633431**.

2 Radiation limits for normal conducting magnets at IR3 and IR7 (S. Ramberger)

2.1 Estimated radiation limits

Suitbert Ramberger (SRa) reviewed the radiation limits for the normal conducting dipoles (MBW's) and quadrupoles (MQW's) of IR3 and IR7. Radiation limits are defined on the basis of experimental results carried out on samples of the **epoxy resin** used as insulator for the coils. The expected radiation doses at the LHC are calculated from energy deposition studies from the FLUKA team (see next section). It was mentioned that the FLUKA model has been thoroughly compared with the real magnet geometry. A 2D map of the magnetic field in the magnet cross-section has been prepared and will be implemented in future simulations.

For the MBW's, the critical location is the magnet front part, were the coil passes over the vacuum chambers and gets very close to the circulating beam (see SRa's slides). Here, the insulator is directly exposed to the secondary showers generated in the primary collimators, placed a few metres upstream of the MBW's. SRa also mentioned that there is a block of epoxy inserted between the top and bottom MBW coils (see slides). This epoxy has only a mechanical role and its radiation resistance is less critical. Radiation damage in the coil epoxy can lead to short-circuits that would immediately compromise the functioning of the magnet. The epoxy spacer could loose its mechanical properties due to high radiation doses and lead to large displacements and scouring movements of the coil.

Experimental tests suggest that the epoxy resin used for the MBW's can stand up to a total dose of approximately 25 MGy before a significant deterioration of its mechanical properties (measurements without forces, dose rate of 6kGy/hour). The extrapolation to the lifetime of the epoxy/glass fibre composite in the MBW is not straightforward. SRa believes that the **MBW's** limit is between **35 MGy** and **80 MGy**. Experimental results for the **MQW magnets** were gained at various dose rate levels of 0.2, 0.5 and 180 kGy/hour. A life-time limit of **30 MGy** to **50 MGy** appears to be reasonable. Based on the present understanding, SRa concluded that the the design of the cleaning insertion should aim at a **maximum dose of 30 MGy**. For a lifetime of ten years, this corresponds to a **maximum annual dose of 3 MGy/year**.

SRa concluded by saying that the CERN experience with operating machines is somehow inconclusive because at the LEP only one dipole had to stand an integrated dose of up to 100 MGy and magnets in the SPS north area were made with special insulator material. Differences of materials, radiation type and dose rates make it difficult to extrapolate experiences at existing accelerators to the LHC case.

2.2 Discussion

Ralph Assmann (RA) asked if the activation of the magnets could be important for the coil lifetime. Alfredo Ferrari (AF) and Markus Brugger (MB) agree that this auto-irradiation will be negligible with respect to the contributions of the secondary showers from the collimators.

RA asked if there are calculations of the **electromagnetic forces** during the magnet powering. This could be relevant in particular if the epoxy spacers between the coils were damaged by radiation. Could coil displacements affect the magnetic field and hence the beam dynamics? SRa replied that this kind of calculations are not available but he can do them (**Action**). However, he excludes significant perturbations of the beam because the field quality is mainly determined by the yoke geometry rather than by small coil displacements.

Vasilis Vlachoudis asked if the quoted radiation limits refer to average doses in the coil or to single hot spots. SRa replied that what matters are indeed hot spots because damage in small areas of the epoxy are enough to induce short-circuits. The quoted limits are set for local radiation peaks anywhere in the coil volume.

Stefano Redaelli (SR) asked if the direct proton losses on the magnet chambers, which are significant at injection energy, could be an issue. This effect has never been simulated. RA and AF replied that the injection losses on the collimators are taken into account in the estimate of total proton losses per year. Injection losses are converted into 7 TeV equivalent losses. Direct proton losses on the vacuum chambers are not included but RA and AF think that this contribution should be small compared to the losses at 7 TeV.

There was a general agreement that the design of the MBW dipoles is not optimized for the high radiation environment expected at the LHC. RA and SRa agree that, if the MBW lifetime proved to be a serious issue, in the first years of LHC operation one should invest some time to optimize the magnet design in view of possible replacements.

3 Radiation doses at the MBW of IR7 (M. Magistris)

Matteo Magistris (MM) presented the latest results of radiation doses at the MBW's of IR7 with a **passive absorber**. This absorber is modelled as 1 m long block of **steel** placed shortly upstream of the first MBW module. Various sizes and shapes of the absorber aperture have been considered as a play parameter to minimize the energy deposited in the magnet. As an input for FLUKA, the locations of inelastic impacts within the collimators was have been used. This data is provided by the ABP collimation team and have been obtained for the latest layout version with **60 cm primary collimators**. Horizontal and vertical halos are considered separately. The simulations presented here refer to the worst case (horizontal).

The simulation results show that by using a passive absorber with a elliptical aperture as small as the MBW vacuum chamber, the total deposited energy can be reduced by approximately a **factor three**, from 32 kW to about 11-13 kW. It seems difficult to further reduce the deposited energy unless apertures smaller than the vacuum chamber are used. The proposed geometry allows reducing the **peak maximum dose** in the coil by a **factor 25-30**. However, the peak dose in the coil is still of approximately **10 MGy/year**, i.e. **a factor three larger than the MBW limits** (see previous section). Therefore, a further reduction by a factor $\approx$ 10 would be desirable.

AF believes that there is still some room for improvement by changing the geometry of the absorber. AF believes that the largest effect comes from the region very close to the

MBW coil. therefore, it could be beneficial to (1) run simulation with an absorber directly in contact with the MBW (in the presented simulations, there was a 10 cm space). AF also proposed (2) to run simulations also with 0.5 m and 2 m long absorbers to see how the MBW dose scales with the absorber length. If the situation cannot be improved with modifications of the geometry, one should then (3) try different absorber materials. Possible, Tungsten could be placed in the hottest absorber locations only, if needed. RA proposed that we should also consider the option of (4) using vertical movable object like the TCLA's. It was agreed that future studies should address the four aforementioned items.

4 Ozone production at IR7 (A. Presland)

Andy Presland (AP) presented simulation results of **Ozone production** at IR7. The production of Ozone, which is corrosive and can reduce the lifetime of various accelerator components, was found to be an issue in other accelerators like LEP. AP's simulations are based on the theoretical formulation and of the empirical constants provided in the **LEP Note 379**. More recent information is not available. Simulation results indicate that the density of Ozone is of approximately 2.2×10^{-3} ppm (parts per million) in the tunnel. The Ozone density in the 'enclosed' areas of IR7 (see tunnel layout in AP's slides) can be up to 70 times larger, i.e. up to 1.4×10^{-1} ppm. The saturation times are of approximately 25 minutes (tunnel) and 300 minutes (enclosed areas).

It was agreed that we should now try to figure out what are the limits for the survival of the IR7 components. Oliver Aberle (OA) will follow this up. In addition, RA proposed to calculate the density of Ozone versus air speed in the tunnel. AP will follow this up.

5 A.O.B.

1) RA have received the drawings for the **vacuum interconnects** for approval. OA will check he drawings. RA asked if the compatibility with the BLM locations has been verified. Adriana Rossi replied that this is the case. Bernd Dehning requested to further check the drawings before the final approval.

2) RA announced that an internal CERN review of the **collimator machanical movements and stepping motors** has been organized for the 4th of November, 2005.

3) Bernd Dehning requested the simulation of **deposited energy at the BLM locations**, including the cross-talk between different collimators. The FLUKA team will provide these data.

4) Bernd Dehning also requested larger statistics in the beam loss data, as provided by the ABP collimation team. RA proposed that Chiara Bracco, a PhD student that joined the team in summer 2005, should look into this issue. She will simulate loss maps in case of a failure scenarios with secondary collimators getting close to the beam.

5) Bernd Dehning also requested to have loss maps studies for **beam 2**. RA confirmed that this issue is becoming urgent for several studies. The setup of the tracking model for beam 2 is under responsability of the ABP/LOC section. Massimo Giovannozzi said that the setup of the `MADX` model has been properly done and will be discussed at the LOC section meeting of October 11th, 2005 (see `http://slap.web.cern.ch/slap/LOC_meetings/2005/meetings.htm`). The `SixTrack` model will come in the next few weeks and will be provided to the ABP collimation team for loss maps studies.

The next meeting will be October 24, 2005 (J.B. Adams room).

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Action Items:

- ▷ Calculate the force on the MBW coils and on the epoxy spacers during field ramping (S. Ramberger).
- ▷ Make sure that the IR3 simulation of deposited energy in the MBW take into account the correct magnet geometry (R. Assmann with J.B. Jeanneret and IPHE team).
- ▷ Follow-up of simulations of radiation doses at the MBW: (1) scaling law for deposited energy versus absorber length; (2) simulations with absorber in direct contact with the MBW coil; (3) Try different material (possibly, layers of Tungsten in the critical locations and rest in steel); (4) try for the passive absorber the same geometry as the active TCLA's. (**fluka** team).
- ▷ Review simulations of Ozone production to solve discrepancies between saturation value and 'typical' value (A. Presland).
- ▷ Ozone production at IR7 versus air ventilation speed (A. Presland).
- ▷ How much Ozone can we tolerate for the collimator survival? (O. Aberle).
- ▷ Check drawings of vacuum interconnects (O.Aberle, R. Assmann).
- ▷ Provide deposited energy at the BLM locations, including cross talk from different collimators (**fluka** team).
- ▷ Larger statistics on beam loss maps (ABP collimation team).
- ▷ Setup of beam 2 tracking for beam loss studies (ABP/LOC section should provide input to the ABP collimation team).