Stefano Redaelli, 03-11-2004

45^{th} Meeting of the LHC Collimation Working Group, October 29, 2004

Present: Oliver Aberle, Ralph Assmann (chairman), Igor Bayshev, Frederik Bordry, Markus Brugger, Nuria Catalan Lasheras, Enrico Chiaveri, Bernd Denhing Alfredo Ferrari, Jean-Bernard Jeanneret, Igor Kurochkin, Barbara Eva Holzer, Markus Brugger, Mario Santana Leitner, Matteo Magistris, Paul Proudlock, Suitbert Ramberger, Christian Rathjen, Stefano Redaelli (scientific secretary), Stefan Roesler, Markus Stockner, Guillaume Robert-Demolaize, Roger Valbunea, Vasilis Vlachoudis.

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

See slides at http://www.cern.ch/lhc-collimation/files/MMagistris_2004-10-29.pdf

1.1 Simulation set-up

Matteo Magistris (MM) presented the status of the energy deposition studies at IR7. The goal of these studies is to define number and positions of additional absorbers for the tertiary halo which escapes the collimation system at IR7. Simulations are carried out with FLUKA by using a detailed model of all the relevant components of IR7 (amongst others, included are warm and cold magnets, primary and secondary collimators with correct opening/angles). The magnetic field in quadrupoles and dipoles is also considered to track the particles in the shower. The particle distributions at the primary collimators are provided by RA. The particle's trajectories are then tracked through IR7 by taking into account the lattice magnets and the collimators. The following beam loss scenario has been considered: beam lifetime of **0.2 hours**, corresponding to 4×10^{11} p/s lost in the primary collimators. It is assumed that 90 % of the protons are lost at IR7 and that the rest is lost somewhere else in the LHC ring.

In order to prevent superconducting magnets to quench, the deposited energy in the superconducting coils should stay below the quench limit of $\mathbf{5\,mW/cm^3}$. It is found that this corresponds to approximately 1 W in the total volume of the coil.

The absorbers are assumed to have the same geometry as the secondary collimators but they are made of Copper instead of Carbon, which provides a better absorption of the tertiary shower generated in the cleaning section. Four possible locations have been considered for the installation of the absorbers (see a detailed drawing in MM's slides). A critical issue for the energy deposition studies is the CPU time required to consider the possible combinations of absorber types (horizontal or vertical), locations (four different cases) and four halo types (horizontal, vertical, skew or all together). The two following approaches have been considered to reduce the CPU time of the IR7 absorber studies:

- Reduce the amount of information provided by FLUKA: this allowed reducing the CPU time required for tracking 1 proton from 120 s to 1.6 s. It is intended that, once the absorber positions and types will be finalized, simulations will be performed to provide the complete sets of outputs required for the various studies.

- Fast simulations have been run for the various considered cases in order to figure out the most interesting case studies. Results with poor statistics are in most cases sufficient to exclude the uninteresting cases.

It has been found that the most significant case to look into in detail is the case of horizontal absorbers with the horizontal halo scenario. This case provides the most critical case in terms of energy deposited in the magnets. The best location for the absorbers is the drift downstream of the second dog-leg dipole (D4). More detailed studies have been carried out with larger statistics to study in detail this case.

1.2 Number and location of the absorbers

The conclusion of the optimization of number and location of absorbers at IR7 is that **three absorbers per beam** are enough to stay below the quench limit of the first superconducting magnet (Q6). The longitudinal positions and the type of absorber (horizontal or vertical) for the beam 1 are summarized in the following table. Symmetric location with respect to IP7 are proposed for the beam 2. It is assumed that the absorbers have the same design as the secondary collimators and their jaws are made of copper. These are preliminary locations that have to be optimized and integrated in the layout.

	Distance from IP7 [m]	Type
1)	154.17	Vertical
2)	185.13	Horizontal
3)	218.92	Vertical

1.3 Deposited energy with absorbers (preliminary results)

The analysis of the simulation results is performed Cartesian binning as well as by region: this allows calculating the total deposited energy in each component of the various elements (collimators, warm and cold magnets, etc.). With the absorber location given in the previous section, it is found that all the six magnets of the Q6 superconducting quadrupole can be kept below the quench limit! The maximum deposited energy is of the order of **1 to 3 mW/cm**^{3}. With two absorbers only, the energy would be of the order of **3 to 5 mW/cm**^{3}, i.e. very close to the quench limit.

1.4 Discussion

Ralph Assmann welcomed the good results achieved in the last weeks by the FLUKA team. It is a very good new that we can stay below the quench limit with only 3 absorbers at IR7!

Igor Bayshev asked what is the size of the bins used in the FLUKA simulations. He stated that ideally one should use the same size as the dimension of the superconducting cable (a smaller size would be useful for the energy deposition studies). AF replied that this is the case.

Stefan Roesler asked if the proton interactions are forced on the primary collimators only or also in the downstream elements. Vasilis Vlachoudis replied that this is not the case: the protons interacts also with all the downstream secondary collimators. In addition, the magnetic field of dipoles and quadrupoles is also taken into account.

Igor Bayshev pointed out that only Q6 was considered as a figure of merit for the efficiency of the new absorbers. Actually, also the downstream superconducting magnets should be considered before finalizing the absorber locations. AF agrees.

Action: Study the energy deposition on the superconducting magnets downstream of Q6 (FLUKA team).

Igor Bayshev also asked whether the superconducting multipole correctors included in the quadrupole cryostat at IR7 have been included or not.

Action: Check if the multipole correctors are included in the FLUKA model of IR7 and estimate the deposited energy in these magnets (FLUKA team).

Paul Proudlock asked news about the radiation level at the RR's. In the last weeks this issue has focused the attention of various people because some estimates of radiation level at the RR's suggest that the radiation may be 100 times larger than expected. This might have an impact in the IR7 layout because, if the radiation level is too high, the option of shielding the RR's could be considered. However, the mentioned simulations were carried out without the additional absorbers. There is an urgent need of getting new estimates with the proposed absorber location. Alfredo Ferrari says that can be ready in two weeks. It was agreed that the new results will be discussed at the next Collimation Working Group meeting.

Action: Estimate of the radiation level at the RR's with the new absorbers (FLUKA team).

RA asked what is the deadline for freezing the layout at IR7. Paul Proudlock answered that it should be finalized by the end of this year. The installation at IR7 will start sooner than originally foreseen and it is mandatory to freeze the positions of the new absorbers as soon as possible. Alfredo Ferrari believes that it should be achievable to get all the required studies in time.

RA also asked what is the status of the shielding at IR7. PP replied that the possibility of shielding IR7 with steel was reconsidered after the latest estimates of radiation doses at IR7. However, it seems that this option has been excluded again because the steel would activate too much. Basically, the validity of the conclusions of the Collimation Working Group has been confirmed. PP said that other options are been considered. For instance, cables will be put close to the tunnel inner wall, as far as possible from the activated areas and precautions will be taken to lower the intervention times at IR7. PP also commented that the results at TI8, which showed a lower heating than expected, are somehow encouraging for the LHC!

Regarding the radiation level at the RR's, Igor Bayshev pointed out that it is also important to think about the total number of impacting protons expected at IR7. It is mandatory to properly estimate this number in order to get reliable predictions for the radiation level at the LHC.

2 Absorbers at IR3

2.1 Review of the energy deposition studies at IR3 - proposed locations for tertiary halo absorbers (I. Bayshev)

See slides at http://www.cern.ch/lhc-collimation/files/IBayshev_2004-10-29.pdf

As a short introduction to the talk of Igor Kurochkin, Igor Bayshev reviewed the studies of energy deposition at IR3. These results were presented in detail at the 39th Collimation Working Group meeting (June 4th, 2004) and at the LHC collimation external review. Absorbers are required at IR3 to catch the tertiary protons that escape the collimation system and the products of the showers developed in the collimators. Otherwise, the superconducting magnets downstream of the momentum cleaning section could quench. The absorbers must be made with an high Z material, like for example copper, in order to stop the gammas produced in the upstream collimators. The design can be the same as the secondary collimators.

The following table summarizes the proposed locations of the active absorbers, as presented in the 39th Collimation Working Group meeting.

Location	Plane	Dist. from IP3	Jaw length	Required space
Upstream of D3	Vert.	90.5 m	1 m	2 m
Upstream of D3	Horiz.	92.5 m	1 m	2 m
Inside the dog leg	Horiz.	176.5 m	1 m	2 m
Upstream of Q7	Horiz.	248.5 m	1 m	2 m

By introducing these absorbers, the total deposited energy in the superconducting magnets downstream of the momentum cleaning is reduced below the quench limit of the superconducting coils. However, the new configuration induces a larger heating of some magnets, notably of the dog-leg dipoles (D3). This effect is mainly induced by the increased length of the primary collimators (from 0.2 m to 0.6 m), which as been proposed to improve the overall efficiency of the momentum cleaning insertion with absorbers. Additional passive absorbers will be implemented to locally protect magnets that might otherwise get too large doses.

2.1.1 Discussion

RA asked to Christian Rathjen if there is any problem for the installation of the active absorbers at the proposed location. CR answered that in principle there should be no problem. However, at the last Insertion Working Group (October 13th, 2004), Rob van Weelderen stated that the proposed location for the absorbers might interfere with some current leads which have to be installed between Q6 and D4. This issue has to be followed-up with high priority. Ralph Assmann will meet Rob van Weelderen as soon as possible to discuss about that.

Action: Follow-up the space request to insert the new absorbers at IR3 in the LHC layout version 6.5 (Ralph Assmann, Bernard Jeanneret, Rob van Weelderen, Christian Rathjen).

2.2 Passive absorbers at IR3 (I. Kurochkin)

See slides at http://www.cern.ch/lhc-collimation/files/IKurochkin_2004-10-29.pdf

Igor Kurochkin presented the results of recent energy deposition studies in the momentum cleaning insertion IR3. The primary goal of these study is to define positions of some passive absorbers to locally protect some magnets which is irradiated too much. Notably, the dose on the `MBW.C3` dog-leg dipole downstream of IR3 is increased from 6 MGy to **14 MGy** in the new layout with 4 absorbers and 0.6 m long primary collimators if no passive absorbers are used (see previous section). This value is too close to the maximum allowed dose of **50 MGy** (see next section for an update on the specifications for the MBW magnets).

The simulation scheme is the same as the previous studies. The STRUCT code is used to generate a map of primary inelastic interactions on the jaws of the primary collimators. The hadron and electromagnetic cascades development is simulated using the Monte-Carlo code MARS. The annual doses to the magnet coils are estimated from calculated energy deposition density assuming primary losses of 10^{16} protons per year (7 TeV). The power dissipated in collimators, active absorbers, beam pipes and flanges is estimated from the energy deposition density in the assumption that the loss rate is 3×10^9 protons per seconds, which corresponds to a beam lifetime of **30 hours**. Hence, the power deposition is **30 times larger** than the given numbers for the case of a beam lifetime of **1 hour**. The energy deposition density calculations have been performed for three different setups: (1) with no active absorbers; (2) with active absorbers and no passive absorbers; (3) with both active and passive absorbers.

The passive absorber is big block of **steel** that surrounds the beam pipes. In the study presented here, IK considered a **1 metre long absorber**, placed **0.5 m** upstream of the

D3 dipoles. The transverse dimensions of is $\mathbf{1{\times}0.7\,m^2}$ (horizontal×vertical). The inner dimensions are set by the size of the vacuum chamber to $\mathbf{6.7{\times}5.2\,cm^2}$. One absorber per bean line is required.

IK found that, if the passive absorber in from of D3 is included, the radiation dose is reduced from 14 MGy to **2.7 MGy** (doses are normalized to 10^{16} inelastic proton interaction per year). The dose is reduced by more than a factor 5 with respect to the case without passive absorber. The doses to the coils of all other warm magnets do not exceed a value of 2 MGy per year. The doses to the coils of the superconducting magnets Q6 and Q7 are lower than 100 kGy per year.

The simulation model allows studying in detail the doses absorbed by the various components of collimators and magnets. For example, it is found that the fourth secondary collimators absorbs **77.8 W**. The vertical active absorbers gets **206.9 W**. For a beam lifetime of **1 hour**, the quoted energies correspond to energies six times larger: **2.33 kW** and **6.21 kW**, respectively. It is noted that the total power dissipated in the active absorbers (TCL) is a 1.5 times higher than in TCP and TCSs

2.3 Update on the survival of MBW's at IR3 (S. Ramberger)

Suitbert Ramberger reported about some measurements carried out on the coils of the warm magnets foreseen for the collimation regions. It has been found that the epoxy used in the magnet coils shows severe radiation damage for doses above **30 MGy**. However, other effects such as current cycles and temperature distributions which lead to stresses on the coils have also to be taken into account.

2.4 Discussion

RA welcomed the results by IK. We have now a fully protected IR3!

RA asked if the passive absorbers must really be as big as stated by IK. IB and JBJ replied that the proposed transverse dimension of the absorbers are not bigger than the dimensions of the MBW's. In addition, the bigger absorber is better for the passive protection of the magnet. Stefan Roesler said that increasing the size also helps in terms of remanent doses left on the absorbers. Suitbert Ramberger said that making the absorber longer could help for its transportation because 1 m i too short for using the vehicle foreseen for the MBW's. These arguments convinced RA that we can keep the proposed dimensions for the passive absorbers and possibly envisage to make them larger if required.

JBJ suggested that one could foresee to put a passive absorber in front of each critical element. RA replied that this should not be our baseline. We should start with the minimal required setting of absorbers, which ensures the desired protection. We should nevertheless reserve space in front of some critical elements for possible further upgrades of the system.

Ralph Assmann also proposed to estimate what is the additional energy deposited in the jaws of the secondary collimators at IR3 induced by a the longer primary collimators (0.6 m instead of 0.2 m).

3 A.O.B.

- Stefano Redaelli reported a message from Oliver Brüning about the shutdown of the CERN control systems. At the end of November 2004, the CERN control systems will be shutdown because all the machines will be moved to the CERN Prevessin site, where the LHC control room is being built. As a consequence of that, the beam data will not be available for two months (December 2004, January 2005). Therefore, all the data acquired during the collimators MD's at the SPS must be got before the end of November.

- RA commented on the successful collimator MD's at the SPS. The only test that remains to be carried out is the robustness test at TT40. This was scheduled for Monday 25th October but was not performed because a beam loss at TT40 damaged the vacuum chamber and a quadrupole, which has to be changed. According to the information provided by Jorg Wenninger, the vacuum chamber should be repaired on Wednesday 3rd November. On Saturday 6th test will be performed to verify if the extraction of the full intensity LHC beam can be safely achieved. Upon the results of these tests, it will be decided whether it will be possible to perform the collimator robustness test on Monday 8th November.

The next meeting will be announced.

Action Items:

▷ Study the energy deposition on the superconducting magnets downstream of Q6 (FLUKA team).

▷ Check if the multipole correctors are included in the FLUKA model of IR7 and estimate the deposited energy in these magnets (FLUKA team).

▷ Estimate of the radiation level at the RR's with the preliminary absorbers locations (FLUKA team).

▷ Follow-up the request of space for the active absorbers at IR3 (Ralph Assmann, Bernard Jeanneret, Rob van Weelderen, Christian Rathjen).

The next meeting will be announced.