Stefano Redaelli, 25-09-2004

43^{nd} Meeting of the LHC Collimation Working Group, September 20, 2004

Present: Oliver Aberle, Ralph Assmann (chairman), Hans Braun, Markus Brugger, John Jowett, Nuria Catalan Lasheras, Enrico Chiaveri, Alfredo Ferrari, Barbara Eva Holzer, Mike Lamont, Laurette Ponce, Andy Presland, Mario Santana Leitner, Matteo Magistris, Suitbert Ramberger, Christian Rathjen, Stefano Redaelli (scientific secretary), Guillaume Robert-Demolaize, Katerina Tsoulou.

1 Correction of previous minutes

The first version of the minutes of the 42^{nd} Collimation Working Group did not include the slides of the presentation by Markus Brugger on status of radiation impact studies at IR7. The slides can actually be obtained directly from MB upon request. The minutes have been corrected to include this information.

2 Radiation levels in the regions UJ76, RR73, RR77 (K. Tsoulou)

See slides at http://www.cern.ch/lhc-collimation/files/KTsoulou_2004-09-20.pdf

2.1 Simulation results

Katerina Tsoulou (KT) presented some results on the radiation levels in the UJ76, RR73, RR77 regions. Simulations are performed without taking into account the required absorbers for tertiary halo at IR7, whose position is being finalized by the FLUKA team (see next section). In any case, AF believes that the absorbers will not significantly reduce the dose level of the RRs.

It is found that the doses in the RR regions are larger than expected. The 1 MeV neutron equivalent flux at UJ76 is approximately $1.8\times10^{9}/\mathbf{cm}^2/\mathbf{year}$. For RR73 and RR77, dose of approximately $1.7\times10^{10}/\mathbf{cm}^2/\mathbf{year}$ are expected. Only air regions are taken into account. The spectum of the particles expands up to around 10 GeV. The number of hadrons with energy larger than 20 MeV is 100 times larger at the RRs than at IP1 and 5!

2.2 Discussion

Alfredo Ferrari commented that the results presented by KT show that the radiation at at RRs is an important issue. It is not going to be easy to reduce the dose by a significant factor. For sure the tertiary halo absorbers at IR7 cannot do that!

Enrico Chiaveri said that before deciding what actions to take it is mandatory to understand what is the dose limit that the equipment at the RRs can stand. We should than study what can be improved by the introduction of absorbers at IR7 and then decide if additional shielding is required.

RA asked if it is possible to shield the RRs by putting blocks of concrete in the tunnel. According to AF, a minimal thickness of approximately 2 metres would be required. This seems a possible solution for reducing the radiation doses at the RRs of IR7.

3 Status of energy deposition studies at IR7 (M. Santane Leitner)

See slides at http://www.cern.ch/lhc-collimation/files/MSantana_2004-09-20.pdf

Mario Santana Leitner (MS) discussed the status of energy deposition studies at IR7 and the progress since the last update from the Collimation Working Group of September the 3rd. The goal of these studies is to define the locations of the additional absorbers to stop the showers generated in the secondary collimators.

3.1 Follow-up of pending actions from last WG

The following items have been addressed on the basis of the requests/comments at the last meeting:

1) In the FLUKA model of the secondary collimator, air was inserted instead of vacuum in the connection pipe from the collimator tank and the flange. This bug is now fixed. The differences in the simulation results are negligible.

2) As asked by Alessandro Bertarelli, files with the total deposited energy in the collimator versus longitudinal direction has been provided as an input for the ANSIS calculations.

3) A directory has been created in the cluster of the FLUKA team with the various outputs of the collimator simulations for IR7. A "read me" file explains the contents of these files. The directory is:
`/home/LHC/IR7`

3.2 Status of studies of absorbers at IR7

Regarding the studies on the absorber locations, no reliable results is available today because a crash of the computer cluster used for the FLUKA simulations has prevented collecting the required statistics. The cluster should be repaired within a couple of days at most. After that, the lost jobs will we be launched again and results will the be available within a few days. The simulation setup includes two absorbers (horizontal and vertical) in four different locations per each beam. The absorber aperture is set to 10 sigmas (the optical sigma, $\sqrt{\beta\epsilon}$, is used).

3.3 Discussion

Matteo Magistris (MM) pointed out that the estimate of the energy deposited in the superconducting coils requires much statistics because the fluxes in a small volume far from the collimators have to be calculated. Many seeds for the shower generation have then to be considered, which demands much CPU time.

Alfredo Ferrari (AF) commented that from the preliminary results, it appears clear that there is a considerable amount of energy that escapes from the collimator system towards the downstream components. It seems that the absorbers at the proposed (preliminary) locations can reduce by at least a factor 10 the energy that escapes from the collimator system. More statistics will validate these results.

Stefano Redaelli (SR) asked whether there is still room to play with the absorber positions or the proposed locations are constrained by the available space. AF replied that in principle an optimization can be carried out to optimize the performance. However, it should be kept in mind that the absorber positioning in not critical to the few metre level and hence it makes sense to consider at first the positions which are not space constrained in the present layout. It was strongly recommended not to modify the IR7 layout!

Regarding the problem of available CPU encountered due to the crash of the FLUKA cluster, RA pointed out that a considerable CPU power is now available for the collimation team. This has been setup in the ABP group but can be used by the FLUKA team if needed. If the cluster is not fixed within a couple of days, AF and co-workers should contact Guillaume Robert-Demolaize or Stefano Redaelli to use the collimator CPU's until the cluster of the FLUKA team will be repaired.

RA strongly recommended to follow the definition of server space with all the FLUKA inputs of the IR7 simulations! A link to this directory should be included into the collimation web page. RA also proposed to have a complete list of the different components included in the model, which could then be modularly used by other users.

4 Status of collimator tests at SPS/TT40 (O. Aberle)

See slides at http://www.cern.ch/lhc-collimation/files/OAberle_2004-09-20.pdf

Oliver Aberle (OA) commented on the status of the installation for the collimator tests with beam. The following tests will be carried out:

- SPS test to check the operation a real collimator (with RF contacts) with beam.
- TT40 test to check the robustness of the collimator design and materials.

The installation in the machines was done on August the 18th without major problems. A water leak in the SPS was found and immediately repaired. There was also a problem in the in the installation of the collimator due to a systematic error of 10 mm in the element positions as included in the data base. This is also been fixed.

The installation at TT40 is not completed yet. Several accelerometers and a microphone to measure mechanical and sound vibrations induced in the collimator by the beam have also to be installed. SR is following up this installation. A PC, $\approx$500 m of cables and some mechanical pieces have been ordered and the preparation and the installation of this equipment have to be followed up.

Action: Follow-up the installation of accelerometers and microphones in the collimator at TT40 (Stefano Redaelli).

4.1 Discussion

EC asked why we need PCT temperature sensors in the TT40 collimators. RA replied that we are very interested in monitoring the temperature versus time when the beam impacts onto the collimator jaw. We are also interested in studying the required time for the collimator to recover the initial temperature, to study the efficiency of the cooling system.

RA asked if all the required material for the collimator tests with beam is available. OA replied that everything is under control and no other equipment is required, with the exception of the mentioned equipment for the accelerometer tests. SR also commented that he required additional material is been ordered.

RA commented on the recent problems about the installation of the windows at TT40. Originally, it was foreseen to install a Be-Ti windows. This was not done because this windows was not prepared in time and a Ti window has been installed instead. There are concerns about the heating of Ti, which may not stand the foreseen beam intensity. If this is not going to be the case, we will be forced to operate with lower intensities, which is completely useless for our robustness test (RA)! RA believes that we should definitely try to get a Be windows. EC agrees because we cannot work too close to the stress limit of Ti. RA encouraged AF to perform a simulation to verify if the Be option is okay. This results can be provided in a few hours (AF) if the window thickness is known. Also the correct diameter has to be taken into account to estimate if the windows can survive. OA commented that Miguel Jimenez is following this issue up and hopefully he will propose a solution soon!

Action: Follow-up the installation of the windows at TT40 (Ralph Assmann, Oliver Aberle, FLUKA team)

5 Calibration of the collimator motors for the SPS and TT40 prototypes (S. Redaelli)

See slides at http://www.cern.ch/lhc-collimation/files/SRedaelli_2004-09-20.pdf

Stefano Redaelli (SR) presented the results of the various measurements carried out in the laboratory and at the metrology to characterize and calibrate the movement of the collimator jaws.

5.1 Sensor installation in the collimator prototypes

Each collimator prototype contains four stepping motors (two per jaw) which can be independently moved. The LEP motors are used for the prototypes but this is not the final choice that will be used in the LHC collimator production (the final motor type has yet to be defined). Each collimator contains a total **14 devices**, which have to be controlled/read from the control room:

1) 4 motor that move the jaws(2 per jaw);
2) 4 resolver (1 per motor) that count the motor turns;
3) 4 devices to measure directly the jaw position, in correspondence of each motor location;
4) 2 devices to measure the collimator opening, at either side of the collimator (UP and DOWN).

Schemes with the detailed sensor installation are given in the SR's presentation. The SPS and TT40 collimators are equipped with different sensor types. It is noted that the devices of (3) and (4) can be either potentiometers or LVDT's (measurement ranges from 40 mm to 60 mm are available for both types of sensors). It is also noted that the resolvers count the steps of the motors upstream of the mechanical structure and therefore they are not in direct contact with the jaws. The exact jaw position with respect to the beam can be provided reliably by the external measurement devices, after a proper calibration. The operation of the collimator from the control room should be based on the measure of jaw positions from the external sensors.

5.2 List of performed tests

The following test have been performed for each collimator (see SR's presentation for details):

1) Calibration of single motors and resolvers before the installation in the collimator;
2) Verification of the correct functioning of jaw displacements with open collimator (measure of jaw position versus motor settings/resolver readings);

3) Calibration at the metrology of jaw positions with respect to the ideal beam trajectory (fiducialization).

In addition, it was foreseen to repeat the calibration (3) with long cables (300 m), as will be used in the tests with beam at the SPS and TT40. This re-calibration is crucial for assessing the correct sensor functioning/read-out in the realistic experimental conditions. Unfortunately, the calibration with long cables could not be carried out because the cables were not delivered in time.

5.3 Sensor calibration

The motor and resolver calibration before installation and the measurements campaigns with open collimators have been carried out with high resolution gauges (*palmer*) by SYLVAC. This sensors have a resolution of 1 micron and a maximum error below 5 microns over a range of 50 mm or 100 mm, depending on the model. The use of these high-performing measurement devices was suggested by Antonio Marin (TS-SU), who initially borrowed one to us. SR and RA proposed to buy some of these sensors for the laboratory tests with collimators. Now we have 6 palmer, 4 of which can be connected to a PC for a fast data acquisition.

The results of the calibration of single motor show that the motors are fairly precise for relative displacements: a maximum error below 15 μm was measured over the full-range of the jaw displacement (35 mm). Nevertheless, the stepping motors may loose steps and hence do not provide reliably a measure of the jaw positions over long times (they are precise only for relative displacements with respect to a known position). The resolvers count the number of steps and can detect step losses. However, the resolvers show absolute errors up to 80 μm (the expected error was 5 μm).

The measurements with open collimators show a good functioning of the mechanical structure that transmits the motion from the motors to the jaws. The the jaw position versus motor setting response is linear within a good approximation. The mechanical plays were measured by performing hysteresis loops of $\pm 100\,\mu$m with steps of 10 μm. It was found that the SPS prototype has typical mechanical plays up to 40 μm whereas the TT40 prototype have plays typically below the 10 μm level.

The measurements at the metrology allowed calibrating jaw positions and gap openings with respect to the ideal beam trajectory. The results of the detailed calibration curves performed for both collimators are given in SR's slides.

5.4 High-resolution gauge tested at TT40

SR commented on the installation of a high performing palmer by SYLVAC in the TT40 prototype. This devices has resolution of 0.1 μm and an absolute of 0.4 μm over a measurement range of 50 mm. However, the company does not know about the sensor response in a radiation environment. They believe that there should be no components sensitive to radiation inside the sensor, but they have never verified its functioning with radiation. SR proposed to install one palmer in the TT40 prototype. The company HHW (vendor that provided us the palmers by SYLVAC) has agreed to provide to us one sensor for free (the commercial price is approximately 3000 CHF), especially re-calibrated with cables of 30 m for the collimator test. We only payed 80 % of the acquisition box (1600 CHF in total). The palmer has been successfully installed on August the 18th. The software for the data taking has been prepared by Giovanni Spiezia, a student from the University of Naples who works with SR and Alessandro Masi (AT-MTM) on the accelerometers for the TT40 test. The palmer was installed at TT40 on August the 18th and the software has been tested during the recent access of September the 6th. The sensor and the data acquisition proved to work well (SR showed the first acquired data). The remote control of the software (sensor zeroing, data storage, resolution setting, acquisition frequency setting), was tested in laboratory but remains to be assessed in the TT40 tunnel environment.

5.5 Conclusions

In conclusion, SR commented that:

- The resolvers cannot be used to precisely monitor the jaw position because they are not in direct contact with the jaw but only count the motor steps upstream of the mechanical structure. In addition, they have a systematic absolute error of the order of 80 μm.
- The used potentiometers have a resolution of 40-50 μm, as expected from the manufacturer specifications. A type with a 20 μm resolution has also been tested.
- In the laboratory tests, the LVDT's show a resolution up approximately 15 μm. However, there are concerns about their use in the LHC because the require a re-calibration with long cable, to be periodically repeated (500 sensors, radiation environment!).
- For all sensors, the actual resolution in the tunnel environment remains to be figured out.
- The mechanical plays are typically below the 40 μm for the SPS prototype and 10 μm for the TT40 prototype.

SR concluded his presentation by reminding that the calibration curves have yet to be implemented in the data acquisition program of LVDT's and palmers (Action: SR, FD, OB) and the re-calibration of the LVDT's have to be done (FB). The update of the MIDI software have to be followed up and make available before the October 11th (FD, OA). Some problems were encountered with the preliminary reading test from potentiometers and LVDT's. This has to be followed up as well. Finally, for the prototype 3 it has to be decided which sensors have to be installed, what measurements have to be carried out and which man power will be allocated for these tests (OB, RA, EC).

In conclusions, SR stated that in the controlled laboratory tests it was possible to know/reproduce the collimator jaw positions within the 50 μm level. Together with a typical surface flatness of approximately 40-60 μm, this would give a total control of the jaw position in the LHC not below the 100 μm level, corresponding to 0.5 σ at top energy. This would limit the achievable β^* if it was not possible to go to the required level of 20 μm (RA). In addition, it is very important to verify which knowledge/control of the jaw position will be achievable in the real accelerator environment at the SPS/TT40 tests.

Action: Test/follow-up the data taking of the sensors in the collimators at the SPS and TT40 (Fabrice Decorvet, Oliver Aberle, Michel Jonker).

Action: Implementation of the calibration curves in the Siemens software for the data acquisition (Fabrice Decorvet, Stefano Redaelli).

Action Items:

▷ Installation of a microphone and several accelerometers in the collimator at TT40 for measurements of beam induced collimator vibration (O. Aberle, A. Masi, S. Redaelli)

▷ Follow-up the installation of the new windows at TT40 (R. Assmann, O. Aberle, E. Chiaveri, FLUKA team)

▷ Verify the functioning of sensors for position and temperature measurements of the collimators at the SPS and TT40 (F. Decorvet, O. Aberle, M. Jonker).

- ▷ Implement the calibration curves from metrology measurements in the software for the position data acquisition for the collimators at the SPS and TT40 (F. Decorvet, S. Redaelli).

The next meeting will be announced.