Stefano Redaelli, 09-05-2005

57^{th} Meeting of the LHC Collimation Working Group, May 2, 2005

Present: Oliver Aberle, Ralph Assmann (chairman), Pavel Belochitskii, Nuria Catalan Lasheras, Gianluca Guaglio, Igor Kourotchkine, Jacques Lettry, Manfred Mayer, Alessandro Masi, Matteo Magistris, Laurette Ponce, Stefano Redaelli (scientific secretary), Guillaume Robert-Demolaize, Stefan Roesler, Giovanni Spiezia, Rüdiger Schmidt, Peter Sievers, Vasilis Vlachoudis.

1 Update on collimation system studies using SixTrack (G. Robert-Demolaize)

See slides at http://www.cern.ch/lhc-collimation/files/GRD_2005-05-02.pdf

1.1 New features of the code and simulation setup

Guillaume Robert-Demolaize (GRD) reported on the latest developments on the tracking simulation and beam loss studies for the LHC collimation system. The work has be carried out with Ralph Assmann and Stefano Redaelli. A comprehensive description of the new tools will also be given in a paper submitted to PAC2005. Simulations are performed with a modified version of `SixTrack` that include the scattering routine `K2` for treating the interaction between beam protons and collimator jaws. GRD has implemented in the simulations all **primary**, **secondary** and **tertiary collimators** , all **absorbers** and all **diluters** presently included in the LHC layout (only the scrapers are not included, because their design is not yet available). In total, 71 collimators can now be treated (Phase-I + Phase-II collimators). This represents a major change with respect to the previous simulations, which included primary and secondary collimators of IR7 only, and **advances considerably the state-of-the-art simulations of the LHC collimation system**. It is noted that the inclusion of additional elements, which are presently not included in the Phase-I and Phase-II collimation system is straightforward.

GRD also pointed out that the new modified version of `SixTrack` is now available in the CVS repository of `SixTrack` and everybody interested in welcome to use the codes. A complete user's manual is under preparation. Frank Schmidt (AB-ABP) and Eric McIntosh (IT-DES) helped considerably in the implementation of the final version of the code. **The code is know completely portable** and is available for any user.

In addition, the latest `SixTrack` version also include a routine to produce the list of all inelastic impact inside the collimator jaws. This will be used as input for the FLUKA simulations of energy deposition studies in the cleaning insertions and in other locations of the LHC ring.

Simulations are performed by assuming an average impact parameter of the beam protons on the primary collimators. The chosen value is derive by studies on particle diffusion that were carried out by RA *et al.* This approach is used because, for CPU reasons, it is not possible to simulate at every run the outwards particle diffusion from the beam centre.

1.2 Preliminary simulation results

GRD shows some preliminary results obtained for the 450 GeV and 7 TeV cases. The comparison with the previous simulation results including only the IR7 collimators shows that with the complete layout the losses in the cold sections are greatly reduced. This is mainly induced by the new active metallic absorbers (TCLA's), which have recently been included in the layout. However, it is now noticed that the **losses at IR2** are **considerably increased** at injection by the **TDI**, whose nominal setting is $6.8\,\sigma$. The TDI intercepts the secondary beam halo and this explains the increase losses.

Future studies will be focused on studying in detail the contributions of various halo type (horizontal vertical and skew), on including more realistic halo types (e.g., finite beam sizes, momentum errors) and on adding imperfection to the optics and to the collimation system alignment.

1.3 Discussion

RA congratulated the achievements of GRD. We know have a very powerful tool to realistically study the performance of the LHC collimation system and also to perform various other tracking studies.

RA commented that the losses in the arc downstream of IR7, which are not completely cured by the active absorbers, are induced by **energy errors** of the halo particles that escape the betatron cleaning insertion (errors up to 20-30 % are expected due to diffractive scattering). These losses cannot be further reduced by the present system because the IR7 insertion is not designed to catch the momentum halo (small dispersion). This is an intrinsic limitation of the system that will probably limit the LHC performance. There is some hope that with the metallic Phase-II collimators (high-Z) the loss peaks could be reduced due to the better cleaning performance.

Ruediger Schmidt and Nuria Catalan asked some details of the assumed particle **diffusion models**. GRD replied that in his simulations, the average impact parameter is chosen in agreement with some detailed studies of diffusion processes performed in the past by RA *et al.* There was a general agreement that this studies **should be reviewed for the new optics** and to make sure that the simulation assumptions are correct.

Concerning the problem with the **TDI**, which dilutes the secondary halo particles before they are absorbed in the betatron cleaning insertion, RA commented that this is a expected problem due to the tight settings of the TDI. Detailed FLUKA simulations should be used to asses the impact of this problem and a re-discussion of the TDI settings should be carried out in collaboration with the injection WG to find a solution.

Once again, it was mentioned that the assumed **quench limits** should be revised based on the new inputs from the magnet builders. Ruediger Schmidt said that the proceeding of the magnet quench workshop, recently held at CERN, will be ready soon.

Ruediger Schmidt suggested that GRD's presentation should be repeated at the injection working group in order to pass the information to the involved people and to show what can be now simulated with the presented tracking tools.

2 Collimator sound and vibration measurements at TT40 (G. Spiezia)

See slides at http://www.cern.ch/lhc-collimation/files/GSpiezia_2005-05-02.pdf

Giovanni Spiezia (GS) presented results of the sound and vibration measurements performed on the collimator prototype at the TT40 robustness test in November 2004. GS is a student of the University of Naples and he spend 5 month at CERN (AB-ABP, under the supervision of Stefano Redaelli) to work on these experiment. After taking his *Laurea*, GS has come back to CERN for a stage of 4 month (1) to finalized the data analysis of the vibration measurements (1 month) and (2) to work with Roberto Losito on an automatic calibration system for the collimator motors (3 months).

It is noted that the results of the sound and vibration measurement campaign will be soon published in a paper at PAC2005.

Sound and vibration measurements have been carried out by means of one microphone and seven accelerometers. Measurements have been performed in two experimental conditions: (1) for increasing beam intensity (0.8×10^{13} p to 3.2×10^{13} p) at a fixed beam impact parameters; (2) for increasing beam impact parameters (1 mm to 6 mm) at maximum beam intensity. These measurement procedures were repeated for both collimator jaws (Carbon-Carbon and Graphite).

The main challenge of the experiment was the high radiation environment in the vicinities of the collimator. This required the development of a fully remote system for the data acquisition. Details on the architecture of this system and of the various developed software can be found in the GS's slides.

The main conclusion of the experiment is that sound and vibration measurements have **successfully** been used to **detect impacts** of high intensity, 450 GeV proton beams on a LHC collimator prototype. The system could be used to detect beams impacting on the collimator and distinguish them from impacts on other closed-by elements, such as beam absorbers. **The measurement system can in principle be used at the LHC** to detect beam impacts and, hence, possibly damaged collimators. Nevertheless, a better understanding of the sensor systematics in presence of **instantaneous radiation bursts**, in particular the effect on the transmission cables, and a optimization of the system architecture would be required for the usage in the LHC. The measurement indicate that during the few hundreds of milliseconds after the beam passage the signal of the various sensors is not well understood but it seems not usable. This aspect is under investigation with the manufacturer.

Measurements at different beam intensities and beam impact depths show increasing sound levels and are in qualitative agreement with the expectations. Vibration measurements after beam tests did not indicate significant changes of the collimator jaw mechanical structure, which is in agreement with visual inspections of the prototype. The oscillation frequencies excited by the beam have been identified as vibrations of various collimator components, e.g. bellows or vacuum tank.

2.1 Discussion

RA congratulated the people involved in these measurements, in particular GS for his excellent work and for his recent master degree *cum laude*. RA said that, following these encouraging first results, it was decided to install cables for **four microphones at IR3**. The microphone installation at IR7 is still under discussed but it was agreed to install microphones also there. For the accelerometers, a better understanding of the influence of radiation is required before deciding upon their installation into the LHC collimators.

The presentation by GS triggered several discussions. Jacques Lettry (JL) asked if it is really legitimate to neglect the first part of the signal, as it was done by assuming that the some radiation effects were dominating the signal. Stefano Redaelli (SR) replied that detailed studies were carried out on the time signal and the measured signal did not show significant correlation with other parameters (beam intensity, beam impact depth inside the jaw). On the other hand, the proposed analysis that neglects the first part of the signal show expected correlations with beam intensity and depth and the frequency analysis is consistent with the laboratory tests. In addition, SR said that similar wave forms of the time signals are measured with impacting beam on the collimator jaw and on the TED, whereas the vibration spectra are different. This suggests that the meaningful part of the signal is after the first signal spike. In conclusion, SR believes that neglecting the first part of the signal is legitimate, at least until one cannot quantify in detail the radiation contribution on the sensors themselves and on the cables.

JL also asked how one envisages to used this kind of system in the LHC, with a bunch time structure completely different than the pulsed transfer line were the test was carried out. SR replied that this system was investigated as a possible tool to detect single beam impacts in case of accident, in order to identify the hit (and possibly damaged) collimators. Microphone will not be useful during the standard LHC operation with stable circulating beams.

JL said that in principle one could identify every single LHC collimator from the frequency spectrum of the sound produced in case of excitations. This could indeed be used as a tool to distinguish one LHC collimator from another in case of beam impact. SR agrees that this is in principle possible. However, SR believes that it would be tricky to characterize all collimators because there are indication that most of the sound signal comes from various components of the collimator mechanical structure (bellows, vacuum tanks, ...), which are the same for all collimators.

Peter Sievers suggested to perform laboratory measurements to identify the resonance of the collimator jaw and compare this with the spectra measured during the beam test. SR replied that these measurements are indeed foreseen. It was not possible to perform them before the tests with beams, even if this was the preferred solution to calibrate the system, because the collimator prototypes were already installed in the SPS/TT40 tunnel when the activity was started. The SPS prototype has still vacuum and direct measurements on the jaw will be performed as soon as the vacuum tank will be opened.

3 Phase-2 collimation studies at SLAC and CERN - preliminary thoughts (R. Assmann)

See slides at http://www.cern.ch/lhc-collimation/files/RAssmann_2005-05-02.pdf

RA presented some preliminary thoughts on the Phase-II collimation studies. RA stressed that these studies should be started as soon as possible in order to be ready in 2010/2011.

The colleagues from the US-LARP collaboration are doing a great jobs for the design of a rotating collimator and they committeed to built a prototype to be installed and tested into the LHC (see details in RA's slides). CERN should investigate other alternative solutions to go beyond Phase-I collimator. This requires starting the studies soon (not later than this summer).

RA welcomed everybody to participate in these studies, possibly with "crazy idea" to investigate. Nevertheless, it is clear that the studies on the Phase-II collimators should not delay the production of the Phase-I collimation system, which stays the highest priority.

4 Order of cables for IR3 collimators (A. Masi)

See slides at http://www.cern.ch/lhc-collimation/files/AMasi_2005-05-02.pdf

Alessandro Masi (AM) presented the list of cables ordered by Roberto Losito for the IR3 collimators. The complete list is available in AM's slides. RA encouraged everybody to check in detail the list, which contains all the cables which are under responsibility of the collimation project.

AM pointed out the the cabling at IR3 will start on May 8th, 2005. Installations at the point 8 will start approximately one week later.

RA commented that the cable order does not include yet the radiation **hard cables** which are foreseen to be used for the very last few metres close to the collimators. This issue needs follow up.

The next meeting will be May 9th, J.B. Adams.