Stefano Redaelli, 19-09-2005

63rd Meeting of the LHC Collimation Working Group, September 16, 2005

Present: Ralph Assmann (chairman), Alessandro Bertarelli, Chiara Bracco, Alessandro Dallocchio, Alfredo Ferrari, Jacques Lettry, Manfred Mayer, Stefano Redaelli (scientific secretary), Guillaume Robert-Demolaize, Mario Santana Leitner, Rüdiger Schmidt, Peter Sievers, Roman Wilfinger.

1 Shock wave propagation near 7 TeV proton beam in the LHC collimator materials (A. Ryazanov)

1.1 Simulation results

Alexander Ryazanov (AR) from the Kurchatov Institute presented preliminary results on the effect of 7 TeV proton beam impacts on the LHC collimator materials. This study is being carried out at the Kurchatov Institute in the framework of a collaboration with the CERN collimation and machine protection projects. The main goal of the study is the understanding of the variation of material properties under irradiation of the LHC beams, which is crucial to calculate, for example, the lifetime of the carbon collimator jaws. Overview talks with the plans for this collaboration were discussed at the collimation working group meetings of March 21st, 2005 and of December 10th, 2004.

AR presented the preliminary results of a detailed simulation program setup by his team to model the various physics mechanisms of interest, such as ionization, electronic excitation and energy coupling between the electron and ion subsystems within the material. These effects are excited by the interaction of the proton beam with the materials. The time-scales of interest range from below a microsecond to some milliseconds. Details of the model are available in AR's slides. So far, Carbon and Copper have been considered. It is noted that the simulations use **empirical formulas** to model material properties like the specific heat of electron and ion subsystems. As an input of AR's program, the FLUKA **outputs** provided by the CERN team are used to calculate the **deposited energy** per unit volume and the **number of electrons** produced by ionization. It is also noted that the results presented have been obtained for a cylindrical target mass. The complex geometry of the collimator jaws is not yet taken into account.

AR showed some results obtained with his simulation code. In particular, he discussed the time evolution of temperature, pressure waves and sound velocity up to the first milliseconds after the proton impact. Studies so far have been focused on the Carbon material but some results were also presented for Copper. See AR's slides for detailed graphs.

Plans for the next studies include simulations of the so-called Coulomb explosion, induced by the mutual repulsion of the negative charges created by ionization at the proton passage in the material. This phenomenon is supposed to play an important role in the creation of micro-damages in the material and hence requires further studies. The effect of Coulomb explosion will be modelled by using the distribution of electrons calculated with FLUKA.

AR concluded that a model, which contains all the physical mechanisms of interest, has been successfully setup at the Kurchatov Institute. The preliminary simulation results are very interesting. In particular, AR believes that this tool goes beyond what can be done by ANSYS, which takes into account only the thermal properties of the materials but not the actual atomic motion. This is therefore a powerful tool that will allow performing detailed studies of the time-dependent behaviour of the LHC collimator materials irradiated by high-energy proton beams. Next studies will be focused on (1) understanding the effect of the Coulomb explosion and (2) on modelling the time structure of the LHC bunches, in order to investigate if resonance due to electromagnetic coupling could be induced.

1.2 Discussion

The collimation working group welcomed the interesting results presented by AR. It was agreed that the results of next studies should be presented by using the units of the SKM unit system because the presented results were not easy to compare with the ones obtained here.

Action: Convert the presented results in SKM unit system (A. Ryazanov).

Alessandro Bertarelli (AB) commented that with ANSYS one cannot model different effects than what have been presented by AR. AR agreed and stressed that (1) variation of density; (2) atomic velocity and (3) electromagnetic effects cannot be taken into account in ANSYS. However, **A. Bertarelli** believes that, since the energy deposition from protons is basically instantaneous, **all the relevant mechanisms could be simulated with** ANSYS. Notably, the development of **shock waves** can also be modelled taking into account thermal effects only. Peter Sievers agreed and stated that, from the macroscopic material properties calculated with ANSYS, one might obtain the same outputs (local velocities, pressures, temperature) as it is calculated by A. Ryazanov. AR disagrees and believes that shock waves are due to ion motion and therefore can only be simulated properly if the atomic dynamics is taken into account.

Stefano Redaelli asked if it is possible to switch off the effects that are not taken into account in ANSYS. Then, it should be possible perform a comparison between the two codes for a given test study. Everybody agreed that such a comparison should be carried out. In particular, AB also stated that such a comparison would be very useful to understand the relevance of the contributions of the effects which cannot be modelled by ANSYS.

Action: Compare the code with ANSYS by switching off the effect that in ANSYS cannot be taken into account (A. Ryazanov, A. Bertarelli).

Mario Santana Leitner asked if it is possible for AR to simulate geometries more complex that a cylinder. AR replied that is possible but requires a considerable effort. Modelling the collimator jaw would require changing coordinate system from cylindrical to Cartesian. It was agreed that should be done.

Action: Setup simulations with the real collimator geometry (A. Ryazanov).

Jacques Lettry (JL) asked if it is possible to model the surface velocity. Several measurements of surface velocity of targets with impacting proton beam, as measured with laser techniques, have been carried out by JL and co-workers and could be used to benchmark the simulation results. AR replies that the model can indeed provide the surface velocity. It was agreed that a validation of the code with experimental results would be very profitable. JL stated that, if there are not usable data available, a dedicated beam test should be foreseen for next year. This requires follow-up by the people involved (JL, RA, AB).

Action: Investigate the feasibility of a dedicated target beam test to validate the code of AR (R. Assmann, J. Lettry, A. Bertarelli).

JL also asked the cell size used in AR model and the required CPU time. AR replied that cells of approximately 1 micrometer are used and the the required CPU time per simulation is of the order of one day.

The next meeting will be announced.

Action Items:

- ▷ Convert the presented simulation results in SKM unit system (A. Ryazanov).
- ▷ Compare the code with ANSYS by switching off the effect that in ANSYS cannot be taken into account. In particular, the relative weight of the effects taken into account by Ryazanov's team should be compared with the purely thermal ANSYS results (A. Ryazanov, A. Bertarelli).
- ▷ Setup simulations with the real collimator geometry (A. Ryazanov).
- ▷ Investigate the feasibility of a dedicated target beam test to validate the code of AR (R. Assmann, J. Lettry, A. Bertarelli). Compare simulation results with the experimental data already available (J. Lettry and co-workers, A. Ryazanov).