Stefano Redaelli, 28-06-2007

87$^{\text{th}}$ Meeting of the LHC Collimation Working Group, June 15th, 2007

Present: Ralph Assmann (chairman), Giulia Bellodi, Dariusz Bocian, Chiara Bracco, Roderik Bruce, Bernd Dehning, Andres Gomez Alonso, Daniel Kramer, Michel Jonker, Luisella Lari, Marco Mauri, Pierre Pugnat, Valentina Previtali, Stefano Redaelli (scientific secretary), Mariusz Sapinski, Lucia Sarchiapone, Andrzej Siemko, Rüdiger Schmidt, Markus Stockner, Jörg Wenninger, Igor Yazynin.

1 Update on quench limit measurements (D. Bocian)

The meeting of today was a joint meeting of the LHC collimation and machine protection working groups. Dariusz Bocian presented the latest estimates of quench limits for various LHC superconducting magnet types. This is a follow up of the studies already presented at the 74th meeting of the collimation working group, held on July 17th, 2006.

D. Bocian started with some detailed introductory slides. He reviewed the design of the LHC superconducting magnets, with special emphasis on the main dipole magnets (MB's), and the mechanisms for heat flows in the magnet coil. A detailed description of heat flow between metal parts of the cable, helium inside cable, insulation, helium outside of cable and outside of the coil was presented. Dariusz stressed the importance of helium channel between coil and cold bore for thermodynamic structure of the magnet at steady state heat and 1.9 K helium bath temperature. After transition from He II to He I this channel becomes barrier for the heat transfer instead heat evacuation channel and it decrease quench limit due to the change of heat flow scheme in the magnet. It is important to understand in detail these mechanisms because different simulation set-ups need to be prepared for the various scenarios. For example, for the same heat source, the heat flows will follow different paths if the magnets are operating at 1.9 K or at 4.5 K (see the example in slide 11). Next Dariusz reviewed the cross-sections of the magnets types that he is simulating, notably the MB, MQ, MQM and MQY families. For each family, field distributions and temperature profiles in the coils were shown.

The simulations of heat propagation are based on the analogy between the thermal and electrical circuits. This is described in details in D. Bocian's slides. The network model includes the relevant superconducting cables and insulation layers. Dariusz briefly reviewed the results of measurements that were performed to validate the network model. The measurements are performed as it follows. The coil is heated by powering the quench heaters with a DC current to reach the steady state heat loads. Then, the current in the coil is ramped until the magnet quenches. This experimental set-up does not allow validating the network model at injection energy due to the limited power of the quench heaters. The agreement between simulations and measurements is below 15 %. That is why a new experimental setup - Internal Heating Apparatus (slides 25-27) - has been developed and used in the measurements. The preliminary results (slide 27) are very promising and allow scanning the magnetic field from the injection through nominal up to ultimate values. Currently measurements with IHA are on standby because of cryogenic problems in SM18.

D. Bocian presented the simulated quench limits for various magnet types by assuming four scenarios for the geometry of the beam-induced deposited energy in the coil: (1) Homogeneous distribution; (2) concentric beam loss profile; (3) Gaussian beam loss profile and (4) beam loss in a small coils volume. For the MQM and MQY magnets (operating temperature of 4.5 K) the preliminary quench limits for nominal 7 TeV current and Gaussian beam loss profile are **6 mW/cm^3** and **8 mW/cm^3**, respectively. For ultimate current powering and Gaussian beam loss profile, the limits are reduced to 4 mW/cm^3 and 5 mW/cm^3. These estimates assume a realistic distribution of losses in the coil. Dariusz pointed out that, if the homogeneous energy deposition is assumed, the estimated quench limits are reduced to

3 mW/cm^3 and 2 mW/cm^3 for MQM and MQY, respectively. *Preliminary results* for the MB's suggest that the quench limits for concentric beam loss profile are about 15 mW/cm^3 at powering current of 11.3 kA.

Additional measurements are foreseen to further investigate the reliability of the model. With respect to results previously reported, a new experimental set-up has been tested: the heaters were now also located in the inner side of the magnet aperture to simulate better the energy deposition from beam losses. Temperature sensors placed close by allow checking when the steady conditions are actually reached. In addition, other effects such as the transient loss scenario and the temperature dependence of the Copper wedge resistivity will also be taken into account. New results are expected within a few months.

A. Siemko commented that the measurement program might not be completed due to lack of resources in the AT department. The fellowship of D. Bocian could not be extended by more than two months because these studies were thought to be too academic. Some support from the AB department would have been welcome. The collimation and machine protection working group endorsed the continuation of these important studies, which will be crucial to understand better the beam induced quenches at the LHC. An AT seminar will be organized in mid-July where Dariusz will present his results.

2 Losses from wire scanners (M. Sapinski)

Mariusz Sapinski discussed the energy deposition in the superconducting magnets of IP4 induced by the wire scanners. The magnets concerned are the D4 and the Q5, which sit at about 34 m and 46 m from the wire location, respectively. Previous studies were performed in 1997 by J. Bosser and C. Bovet (LHC Project Note 108). New calculation have started in order to assess the operational range of the wire scanners with the final IP4 layout.

The layout around the wire scanners, the details of the simulations of deposited energy and the wire parameters can be found in M. Sapinski's slides. GEANT 4 is used for the energy deposition studies. The outcome of this study is that the wire scanners can be used at 7 TeV with up to a total beam intensity of 10^12 protons. However, by taking into account the various relevant sources of errors, the conservative assumption to take **one nominal bunch** as maximum safe intensity before quenching Q5 was suggested. A larger statistics in the simulations could enhance the simulation accuracy. Possible options to increase the operational range could be to use a faster scanner or a thinner wire.

R. Assmann suggested that, as a future update, we could envisage to install wire scanner in front of the primary collimators. The collimation system downstream of the wire would then take care of the losses induced by the interaction of the wire with the beam. Bernd Dehning commented that the radiation levels in the collimation regions might be too high for the wire scanner electronics.

The next meeting will be announced.