Stefano Redaelli, 09-03-2005

52nd Meeting of the LHC Collimation Working Group, February 28, 2005

Present: Ralph Assmann (chairman), Hans Braun, Fabrice Decorvet, Bernd Dehning, Ilias Efthymiopoulos, Alfredo Ferrari, Gianluca Guaglio, Barbare Eva Holzer, Michel Jonker, John Jowett, Roberto Losito, Daniela Macina, Matteo Magistris, Mario Oriunno, Suitbert Ramberger, Stefano Redaelli (scientific secretary), Stefan Roesler, Guillaume Robert-Demolaize, Alexander Ryazanov, Mario Santana Leitner, Rüdiger Schmidt, Peter Sievers, Katerina Tsoulou, Vasilis Vlachoudis.

1 Trip report from RHIC (H. Braun)

See slides at http://www.cern.ch/lhc-collimation/files/HBraun_2005-02-28.pdf

In January 2005, Hans Braun (HB) spent one week at RHIC to (1) get information on how the ion collimation is performed there and (2) to cross-check the simulations of his code ICOSIM, which he used for the LHC ion simulations. RHIC was performing Cu runs during HB's visit.

From the original 1-stage collimation system, RHIC has upgraded the system and now a full 2-stage system, with 2 horizontal and 2 vertical secondary collimators, has been installed. The primary collimators are 45 cm long, "L" shaped blocks of Copper and are located in a warm section between the triplet and the dispersion suppressor. Three or four secondary collimators are installed in the same warm section, separated only by drift spaces from the primary collimator. One vertical secondary collimator is installed in another warm section downstream of the arc of superconducting magnets. All secondary collimators are singled sided 45 cm long copper blocks. The collimators are aligned with respect to the beam by moving the whole vacuum tank. As far as HB could say, no angle adjustments were carried out. The adjustment of the various collimators is done with an automatic software, which moves the collimators one after the other (starting from the outermost) on the base of the BLM system. This software was not really used during the week of HB's visit.

The benchmark of the ICOSIM program was carried out by comparing the measured loss maps with the simulation predictions. Measurements of beam losses at RHIC are performed with BLM's all around the ring. During the standard operation, the BLM's cannot distinguish between losses coming from the two rings. Loss maps from one ring only can be obtained in some cases when the abort gap is cleaned before beam abort. Unfortunately, only two such cases were available and could be used by HB. The available statistics is therefore poor and more detailed studies would require a larger amount of loss data. Nevertheless, the preliminary comparison results are encouraging. HB's program could reproduce losses in several locations where the BLM's showed large spikes. It is noted that the absolute amplitude of losses is used as a free fit parameter and cannot be reliably estimated from simulations only. For future comparisons, it would be desirable to have more controlled experimental conditions, such as for example loss maps induced by one collimator only.

Mario Santana Leitner asked if HB is aware of any energy deposition studies carried out for RHIC before commissioning. HB replied that something was done for the positioning of the BLM's but no detailed studies on energy deposition in magnets were performed. In any case, the BLM threshold are set based on the experience and not on the simulation results.

2 FLUKA inputs for accident case scenarios (S. Redaelli)

See http://lhc-collimation-project.web.cern.ch/lhc-collimation-project/AccidentInput.htm

Stefano Redaelli presented a new web page that has been setup to provide the FLUKA inputs for various accident cases at 450 GeV and at 7 TeV. The considered scenarios are the reference cases discussed, for example, in the Chapter 18 of the LHC design report: (1) a **full injection batch** of 288 bunches impacting on a collimator; (2) impact of **8 bunches at 7 TeV** due to a mis-firing of the extraction kicker with circulating beam. For each scenario, the corresponding particle distributions are generated at the beginning of some IR7 collimators. These particle distributions are matched in phase-space with the local optics functions and hence are suitable for the FLUKA tracking along IR7, which takes into account the magnetic elements. For the time being, particle distributions are given for the collimators which are expected to be at the worst locations. The first simulation results shall confirm if these assumptions are correct or suggest more interesting cases for future studies.

3 A high resolution capacitive gauge for measuring collimator jaw positions - Results of TT40 test (S. Redaelli)

See slides at http://www.cern.ch/lhc-collimation/files/SRedaelli_2005-02-28_1.pdf

Stefano Redaelli (SR) presented the experimental results obtained at TT40 for a high resolution capacitive gauge used to measure the collimator jaw position. The installation of this sensor and the functioning principle of its data acquisition system were already presented by SR at the 43rd collimation working group meeting of September 20th, 2004. The installation of the capacitive gauge was proposed by SR following up the test bench experience of jaw calibration for the SPS and TT40 collimator prototypes. Then, capacitive gauges were used to calibrate the single collimator motors and the assembled collimator jaw. A more professional version of these gauges, suitable for the installation in a high radiation area and for remote data acquisition, was installed in the TT40 collimator prototype. The advantage of these capacitive sensors is that they have a sub-micrometer resolution, i.e. up to more than 100 times better that the other position sensors used for measuring collimator gaps and jaw positions in the SPS and TT40 prototypes.

The data acquisition system software has been setup by Giovanni Spiezia, a student from the Naples University who has worked with SR on the sound and vibration measurements of the collimator at TT40. Alessandro Masi from AT division helped to setup the data acquisition software. The software allows to remotely set various parameters of the capacitive gauge (zeroing, resolution, acquisition frequency, ...) and was used in the control room for the on-line plotting of the jaw position and for the data logging.

The TT40 tests were very successful. The capacitive position sensor worked as expected and allowed taking data during all the performed measurement campaigns. The data acquisition software provided an on-line displacement of the jaw position in the control room as well as a data logging for the later analysis. SR showed a few examples of acquired data. The capacitive gauge measurements agree with the motor settings within the 0.5 %. The measurements with the external sensor allowed estimating the mechanical play of the jaw, which is At the measured location, a play of $13 \pm 3\,\mu$m was measured, which is consistent with what was measured in the test-bench calibration before installation (see SR's presentation).

SR concluded that, on the base of the experience at TT40, the used capacitive gauges should be definitely considered as an interesting option for the jaw position measurements at the LHC. Even if several items remains to be addressed, SR believes that for most of the critical issues (remote control, electric stability, radiation hardness, ...) this sensor is not more critical than the other proposed solutions but it offers a much better performance in terms of resolution. Costs of a possible series production and the short time left for R&D are certainly the most serious problems. SR has introduced to Roberto Losito (RL) the link person of the HHW company that sells the capacitive sensors tested at TT40. There was a first meeting before the Christmas break and in two weeks RL will meet the seller to discuss the possibility of using these sensor in the LHC collimators.

4 Collimator jaw position control (R. Losito)

See slides at http://www.cern.ch/lhc-collimation/files/RLosito_2005-02-28.pdf

Roberto Losito (RL) presented his views on the collimator jaw position control system for the LHC. He gave a review of the various possible options that could be suitable for the LHC requirements. A resolution of around 20 μm should be achieved in order to precisely adjust the collimator jaws at 7 TeV, when the beam size is as small as 200 μm. The main challenges are the very high required reliability with limited maintenance, the radiation hardness (sensors must withstand 3 to 4 MGy per year), the signal transmission over long distances (up to $\approx$ 1500 m long) and the the electrical stability and reproducibility of the signals over long periods. It is also noted that a critical issue is also the short time before the end of the collimator production. The final choice for the collimator jaw position control must be taken as soon as possible.

The general philosophy for the collimator jaw position control is the same that was tested in the collimator prototype used at the SPS and TT40. **Stepping motors** will be used to move jaws. Two motors per jaw will enable adjusting jaw position and angle with respect to the beam. The motor steps will be **counted** by some devices upstream of the mechanical structure, in open loop mode (no feedback from the jaw position measurement). Then, **position sensors** will be used to directly measure the jaw position and the collimator gap. RL assumes that an accurate calibration at metrology is performed before installation.

Details of the various sensors considered by RL can be found in his slides. RL came out with two possible scenarios for the LHC:

1) **Contact rotary encoders** are used to measure the motor turns and **LVDT's** are used for the jaw position measurement. This solution can ensure an accuracy of 5 μm for the jaw positioning and a measurement accuracy of 30 μm of the collimator gap.

2) **Resolvers** are used to measure the absolute motor angle and **LVDT's** are used for the jaw position and to provide a reference home position (the zero of the LVDT) for the re-calibration over long time periods. This solution can ensure an accuracy of 20 μm for the jaw positioning and of 30 μm for the collimator gap.

The scenario (1) is the preferred solution but there may be some problem in getting the rotary encoders because the company that produces them has stopped their production. If no other similar sensors are found on the marker, the scenario (2) should be pursued.

It is noted that RL did not take into account the effect of mechanical play for the moment. It is assumed that they can be quantified at the metrology and properly taken into account in the measurements.

4.1 Discussion

During the presentation of RL it was mentioned that the LVDT manufacturer provides much larger values for the sensor accuracy. Estimates that take into account the **electronics stability** and the **sensor conditioning** predict an overall total measurement error in the 100 μm to 200 μm range. RL has discussed this problem in detail with the manufacturer and he has concluded that the intrinsic sensor performance is much better. The quoted overall error is actually driven by problems with the electronics. Therefore, RL is confident that with a proper signal treatment one can achieve accuracy in the **tens of micrometer range**.

In any case, the LVDT's should be mainly used to provide a precise home position, which should be very reproducible in time. The precision on the zero voltage is in the micrometer range and should not drift in time if a proper electronics is used.

RA said that both proposed scenarios are **acceptable for the LHC requirements**. The scenario (1) is better because it ensures a better accuracy in the jaw position but also the scenario (2) would be acceptable. A measurement accuracy of 30 μm should be enough to operate the LHC collimator. RA also stressed that for us it is very important to have a good **reproducibility** of the collimator settings. We want to be able to reproduce a given setting with high accuracy, for example for different fills. RA also stressed that is is important to go ahead with high priority in pursuing the proposed scenarios. Simultaneously, an experimental validation of the sensor performance must be started. The SPS/TT40 experience showed that it is very important to **perform tests in experimental conditions** as close as possible to the LHC environment. Long cables should be used to estimate their effect on the position measurements.

RA also pointed out that the SPS and TT40 collimator prototypes, which were basically equipped as proposed for the LHC, did not show encouraging results with respect to the jaw position measurements. The tested sensors did not provide useful measurement (with the exception of the capacitive gauge discussed in the previous section) and we could only measure the jaw position by relying on the motor settings. It has been shown that this was a problem in the electronic settings and not in the sensors themselves.

In his presentation, RL stated that in principle the stepping motors can deliver **steps in the sub-micrometer range**. Stefano Redaelli commented that the experience with the LEP motors used for the collimator prototypes, which in principle had a 5 μm minimal displacement size, it was not possible to see steps below the 10 μm level. This was not related to the mechanical play of the jaw rather to some intrinsic problem of the motor. Certainly, this experience cannot be extrapolated for the motors to be used in the LHC but nevertheless SR doubts that sub-micrometer resolutions can be achieved by improving the electronics that control the motor.

SR also commented that the colleagues from the Survey group have some experience with the use of **LVDT's at LEP**. A. Marin (TS-SU) was in charge of these sensors and his experience tells that LVDT's are **good for laboratory application but not in a big machine**. In LEP, a manual zeroing of each sensor was performed every year to compensate electronics drifts. RL replied that the LVDT's should mainly be used to provide the reference home position, which can be precisely found remotely. This will be sufficient to set the reference for the motor settings and for the motor step measurement devices, which then will be used to measure the jaw position.

Michel Jonker said that it should not be forgotten that the **acquisition frequency** of the position sensors is also important. The promised accuracy should be ensured for acquisition frequencies of at least 100 Hz. RL replied that for the proposed electronics he sees no problem at all for this low acquisition frequencies. The measurement accuracy should not be affected by operating at acquisition frequencies around 100 Hz.

Mario Oriunno (MO) commented on the experience that he had for the position control of the roman pots. With the LEP resolvers and motors they could achieve an **accuracy of** $\pm$**100** μ**m**, which is consistent with the collimator prototype experience (RA and SR confirmed that the LEP resolvers showed systematic errors up to 100 μm). MO also said that an important problem that they had to face with the roman pots was the **RF noise** induced by the motor and resolver cables. It is known that this could also be an issue for the LHC. For the collimator cables, there should be enough space to separate the power and control cables from the cables for the measured signals (see, for example, the IR7 infrastructure layout discussed at the collimation working group meeting of February 14th, 2004).

The next meeting will be March 14th, 14:30, J.B. Adams room.