Stefano Redaelli, 03-10-2006

76th Meeting of the LHC Collimation Working Group, October 2nd, 2006

Present: Ralph Assmann (chairman), Giulia Bellodi, Alessandro Bertarelli, Chiara Bracco, Hans Braun, Roderik Bruce, Helmut Burkhardt, Alessandro Dallocchio, Marek Gasior, Barbara Eva Holzer, Verena Kain, R. Jones, M. Jonker, Elias Métral, Laurette Ponce, Stefano Redaelli (scientific secretary), Herta Richter, Federico Roncarolo, George Smirnov, Ralph Steinhagen, Thomas Weiler, Roman Wilfinger, Frank Zimmermann.

1 Collimator tests with beam - scope and priorities (R. Assmann)

This collimation working group meeting was dedicated to the preparation of the collimator tests with beam at TT40 and SPS. R. Assmann opened the discussion by reviewing scope and priorities of these test and by describing the beams that will be used for these tests. The TT40 test main priority is to **assess the robustness of the collimator design against the LHC injection failure scenario** (one full SPS batch of 288 bunches impacting on the secondary collimator jaw). In addition, but with lower priority, we also want to perform measurements of the **jaw vibrations** during and after beam impacts. These measurements will be performed with a laser vibrometer and will be used to benchmark the FLUKA and ANSIS predictions of the thermo-mechanical behaviour of the collimator. During this test we will also repeat the **sound and accelerometer measurements** of the collimator during beam impact as in 2004 but with different electronics. The goal of these measurements is to investigate whether these sensors can be used in the LHC to find collimators hit by the beam in case of major failure scenarios.

The SPS test with circulating beam is a **control test** that is aimed at testing as much as possible low-, middle- and high-levels of the LHC collimator control infrastructure. In addition, we will try to investigate in more detail (1) **proton beam losses** induced by the collimator, (2) **collimator impedance** and (3) **vacuum** behaviour of the collimator with stored beams. The items (1) and (2) will complement the promising results of the 2004 measurements. The item (3) requires follow-up because the 2004 experience was basically inconclusive.

R. Assmann also announced that C. Bracco and S. Redaelli will follow-up the preparation of a **detailed planning**, which should be ready by **October 23rd** for a final iteration before the MD dates. We remind that, according to the present MD planning, the SPS MD's will be performed on **October 31st** and **November 7th** and the TT40 will be performed on **November 9th**. A reserve date for the TT40 test is fixed for November 16th.

1.1 Discussion

R. Wilfinger said that, in case the radiation doses during the TT40 test will be unbearable for the laser vibrometer, we should stop the test, let the area cool down for a few days, recuperate the laser and then repeat the test in the reserve date the following week. R. Assmann does not agree: if everything works well on the first MD date, we should not risk to postpone the main priority measurement to the last MD slot. V. Kain commented that a new shielding has been proposed for the laser, which should make sure that this equipment stays protected throughout the TT40 tests.
Followup after the meeting (Oct. 17th, 2006): In a dedicated meeting among the people involved it was agreed that: in case RP vetoes any access during the MD data, the laser will be left in the tunnel and MD will continue.

S. Redaelli commented that it is important to agree on a measurement plan for the TT40 MD. Even in the assumption that the laser survives for high intensity shots, we should agree on the order in which the measurements should be performed (do first all the laser

measurements at low intensities and the go to higher intensities or go as soon as possible to high intensities and that measure in more detail the vibration in the spare time?).

On behalf of G. Arduini, who excused himself for not being able to attend this meeting, S. Redaelli asked the question whether we need high intensity beams at for the SPS tests (high intensity means more that 16 nominal LHC bunches). R. Assmann replied that this basically depends on the measurement program vacuum and impedance. E. Métral commented that he believes that for impedance measurements high intensities are not necessarily required (see later). M. Jimenez will be contacted to see which vacuum measurements could be performed. Followup after the meeting (Oct. 3rd, 2006): M. Jimenez stated that AT-VAC is not interested in performing vacuum measurements during the SPS collimator MD's.

R. Steihagen, stated that so far it has not been foreseen to setup the orbit feedback during the collimator MD, as it was done in 2004. Non tests at the SPS were foreseen because in 2004 enough was learned in view of the LHC. Without feedback, R. Steinhagen expects an orbit stability of about **100 μm in 15 minutes**. R. Assmann commented that this might be too much for us. R. Jones stated that the feedback hardware is in principle still available and it is not excluded to set the feedback up for the collimator MDs. Followup after the meeting (Oct. 10rd, 2006): It has been verified that the orbit feedback cannot be implemented for the SPS tests this year.

2 Simulations of 450 GeV failure case (A. Bertarelli)

A. Bertarelli presented the simulation of thermo-dynamic transient behaviour of the collimator jaw after a full SPS batch impact. A. Bertarelli reminded that a permanent deformation of the jaw was found after the robustness test in 2004. On paper the problem was solved by replacing a Copper plate behind the jaw with an Inconel plate but this should be verified experimentally. A. Bertarelli described the detailed ANSIS model used to predict the jaw transient dynamics. According to simulations, the final design might experience a permanent deformation of **at most 16 μm**. On the other hand, a **maximum displacements during the transient** is expected to be of the order of **1.5 mm** (centre of the jaw). Note that at the ends of the jaw, the jaw tends to open up (carbon moves away from the support structure behind it). A. Bertarelli stressed that we should **measure at the centre of the jaw** in order to see the largest effect. Simulations are carried out for this case and for the jaw extremities.

The highest modes of interest are expected at about **30-40 kHz** and hence A. Bertarelli proposed to perform most of the measurements at an acquisition frequency of 100 kHz. Also slow measurements should be performed to see final deformation, if any. Following up discussions carried out off line with A. Dallocchio, C. Bracco and S. Redaelli, A. Bertarelli proposed to measure at high acquisition frequencies the shots of lower intensity (where no permanent deformation is expected) and at lower frequencies the shots at highest intensities (when deformation might occur). If time and radiation issues permit, more measurements could be performed (e.g., by repeating measurements at the jaw extremity and not only at the jaw centre).

The most relevant case is expected to be the one with 5 mm beam impact depth. This is what has been considered in simulations. It was noted that a scaling to smaller impact parameters is not obvious and therefore new simulations should be done to predict other impact cases with the required accuracy.

A. Bertarelli said that, as a safety margin, the simulation results should be trusted within 15 to 20% for the determination of the mode frequencies. It should not be forgotten that various approximations have been assumed (see page 11 of Alessandro's slides). A. Bertarelli also pointed out that, in order to predict what will be measured by the laser vibrometer, one should add to the results presented in his slides the movement of the overall structure,

which is not modelled in the ANSIS model. Data presented are relative displacements with respect to a non-moving support.

2.1 Discussion

Replying to a question by H. Braun, A. Bertarelli commented that the simulation results were in good agreement with the findings of the 2004 test. The transients could not be measured and hence no comparison is available. Simulation results were even slightly conservative in the prediction of the permanent deformation (30% less than measurements).

R. Wilfinger commented that A. Bertarelli should be around during the beam tests to provide an immediate feedback on the measurements.

R. Assmann welcomed the conclusion that, in order to assess the simulations, it seems that there is no need of many additional shots to be taken. We will need to test few acquisition frequencies and only two locations.

S. Redaelli commented that, according to drawing presented in other meetings, he understands that it will not be possible to measure the jaw centre, as A. Bertarelli suggested, because the tank will have 4 windows equally spaced along the jaw and the two central windows are located at 1/3 and 2/3 of the jaw length. A. Bertarelli said that he would have preferred to be contacted before the decision was taken. He thinks that by measuring off-centre, one will pick different modes than the ones that he presented. Simulations might have to be re-done. R. Assmann will ask I. Efthymiopoulos to send to A. Bertarelli the detailed drawings.

3 Installation and safety issues for the TT40 test (V. Kain)

V. Kain presented the detailed list of dates for the last collimator installation in TT40 and also gave link to a web page that she has setup on the TT40 extraction commissioning. See Verena's slides for details.

The shielding for the laser vibrometer has been designed. On paper he will provide enough protection throughout the extraction tests. It is also designed to provide a quick laser head removal in case of fast intervention if the radiation doses become to high.

V. Kain also commented that I. Efthymiopoulos, who is in charge of the setup of the collimator test, said that the collimator will not be baked-out and that pressure tests of the cooling pipes will be performed at 60 bar. This seems enough because the pipes are designed to stand up to 100 bar but will not leave much margin in case impact parameters significantly larger than 5 mm will be accidentally achieved (A.Bertarelli).

V. Kain sees an issue for the beam loss monitor installation. However, E.B. Holzer comments that the installation layout has been defined. Two hours will be need for the installation of 2 BLM's. This can be performed in parallel to other on-going installation works. Followup after the meeting (Oct. 18th, 2006): It was finally agreed to install 4 beam loss monitors in the vicinity of the collimator. This setup is similar to what we had in 2004.

V. Kain also stressed that we must make sure that the jaw will be retracted in the full out position after the tests, in order not to interfere with the following CNGS operation. This should not be an issue because the jaw feature the auto-retraction system.

V. Kain asked if we can accept the risk of having retro-reflector tapes glued on the collimator surface that faces the beam, as it is required to perform the laser vibration measurements. R. Assmann stated that we can accept the risk that they fall because this should not have an impact on the vacuum. A. Bertarelli asks if this tape can pollute the measurements. R. Wilfinger replied that this cannot be the case. He will certainly be able to figure out from the measurements if something is going wrong with the tape.

V. Kain proposes to set an upper limit to the total intensity to 2×10^{15}, which corresponds 50 high intensity shots. There is a factor 2 margin margin with respect to was is needed in

principle for the robustness test. R. Assmann agrees however states that in cases of problems this limit should be discussed again in due time.

V. Kain concluded by asking what will be the order of the performed measurements. R. Assmann replied that we will come up with a detailed plan for the overall MD, in order to be fully prepared in the date of the MD. C. Bracco and S. Redaelli will provide a detailed planning for the MD day.

R. Assmann pointed out that we must ask Ilias to equip all 4 measurement locations for the laser vibrometer, in case there is spare time and we want to perform additional measurements.

S. Redaelli asks if there is a limit to the total number of bunches that we can send on the collimator. Does the permanent deformation adds up at every shot? It this was the case, we should be careful in sending too many low-intensity shots. A. Bertarelli replied that for low intensity there should be no problem because we do not reach the plastic deformation limit.

4 Collimator controls (M. Jonker)

M. Jonker described in detail the hardware of the collimator control infrastructure that will be tested in he SPS tests. He stressed that we will test as much as possible of what will finally be used at the LHC. Even if the installation of the LSS5 collimator prototype is different than at the LHC (motors and position sensors are not the final models), all the electronics will simulate what we will have at the LHC and hence the test is still very useful.

M. Jonker stressed in particular that the **PXI electronics** will be tested. This is a technology that is not standard at CERN but seems very promising for the collimators (according to detail comparative studies carried out by A. Masi). Depending on the SPS results, in November it will be decided whether this technology will finally be adopted for the LHC.

M. Jonker also commented on the positive results of first collimator control dry-run, which was carried out last week. We demonstrated that the basic control architecture and the various communication channels work well. Even if several issues remain to be addressed before the MD's, we have seen that there are no major show-stoppers for the collimator control.

5 Impedance measurements (E. Métral)

E. Métral collected various ideas from impedance experts and proposed some measurements to carry out during the SPS collimator MD. Elias reminded the good achievements of 2004: the coherent tune shift (imaginary part of the impedance) was successfully measured and the theoretical predictions are in good agreement with the theory (see Elias's presentation at the collimation working group meeting of July 17th, 2006). New measurements should be focused on the **real part of the impedance**, which requires measuring damping or growth rate of instabilities.

Since last results presented by E. Métral last July, there are now new simulation results obtained by G. Rumolo, who implemented the collimator wake-filed in the HEADTAIL. The simulation results are in excellent agreement with the previous theoretical results and with the measurement results. In addition, these simulations allow disentangling the various impedance contributions from each other and allows predicting the time development of the impedance-driven instability, as could be measured with multi-turn beam position measurements. See details in E. Métral's slides.

Based on the predictions of the HEADTAIL code, E. Métral and G. Rumolo have found sets of measurement conditions that in principle could allow us to measure the "inductive by-pass" effect and/or "thick-wall" effect with **a single bunch**. They propose to perform

measurements with a single bunch with collimator half-gaps of 0.5 mm. For larger gaps, it will not be possible to distinguish between the instability rise induced by the collimator and by the rest of the SPS impedance sources. It will certainly be a challenge to measure growth rates in these experimental conditions, also because the expected growth of ≈ 200 μm is at the limit of the BPM resolution for the proposed beam intensities (R. Steinhagen).

The conclusion by E. Métral is that we can hope to measure the relevant collimator impedance effects by going to high energy and by testing the smaller achievable collimator gaps. Other possibilities (measurements at lower energies with larger collimator gaps, measurements with higher beam intensities) need more investigations.

E. Métral also commented on an idea H. Burkhardt to measure damping of beam oscillations rather than growth rise time. This can by done by working at negative chromaticity and by measuring the damping time after kicking the beam. This method is equivalent to the measurements of instability rise time with positive chromaticity but has the advantage that it is not destructive: many measurements can be repeated with the same coasted beam.

E. Métral also commended on tool bechmarking which is ongoing with the colleagues from GSI. Their latest results show a qualitative agreement with the theory that has been developed at CERN. However, there are about 4 order of magnitude difference in the absolute value of the predicted impedance. This difference is under investigation. Follow-up after the meeting (Oct. 13th, 2006): The four orders of magnitude difference was induced by a wrong simulation setup in the GSI simulations: a 27 km long collimator was used. Now the results are in good agreement with the CERN theory.

5.1 Discussions

R. Assmann reminded that the smaller collimator gap for the SPS prototype is about 1 mm. The anti-collision gaps prevent achieving smaller gaps.

F. Zimmermann commented that the measurements of instability rise time failed in the 2004 tests because the SPS was not sufficiently stable and we could not disentangle the effect of the collimator from other sources of beam instability. This year the stability must be better in order to perform the measurements proposed by E. Métral.

F.Zimmermann would rather try to measure the impedance at lower energy (60 GeV) because he expects that at lower energy the impedance kick from the collimator could have a larger effect. This option clearly requires more understanding.

R. Steinhagen asked which accuracy is required for the chromaticity knowledge. E. Métral responded that this is not a critical parameters for the instability rise time.

F. Zimmerman also proposed to change the tune, which at the SPS was chosen to make the machine as insensitive as possible to instabilities. One could try for example to go closer to the integer below to amplify the impedance effect. E. Métral replied that by changing the tune one would increase all the impedance effects (nobly, also the broad band contributions of other components than the collimator). It is not clear that we could gain because it might still be very difficult to disentangle the effect of the collimator only.

R. Assmann agrees that we should try to perform measurements at high energies with the smallest gaps (as close as possible to the LHC conditions). Even if these measurements seem very challenging, we should try to focus on the conditions that are closest to the LHC operational case, unless there are solid proposals of alternatives to measure the inductive "by-pass" effect.

Nevertheless F. Zimmerman insisted that the measurements at 60 GeV could be potentially interesting. R. Assmann then proposed to have from Gianluigi Arduini an estimate of how long it could take to setup stored beams at 60 GeV. If this setup will not be too long and will not jeopardize other important measurements, we could try to follow this approach as well.

F. Zimmerman also suggested to try and change the bunch length.

6 Beam loss studies during the SPS MD (S. Redaelli)

S. Redaelli discussed requirements and new proposals for beam loss studies during the SPS collimator tests. This does not include the beam loss studies performed with dedicated LHC-type monitors installed in the vicinity of the collimator. Stefano's talk was rather focused on other studies to go beyond what we achieved in 2004. Notably, Stefano proposed:

- To perform **fast beam loss measurements all around the SPS ring**. This was also done in 2004 to benchmark the LHC simulations tools (`sixtrack` version for collimation studies and aperture model). See S. Redaelli's presentation at the APC meeting of February 16th, 2006. These measurements require fast acquisition of the 216 BLM's mounted at each SPS quadrupole. Following up S. Redaelli's request, F. Follin (AB-OP) has implemented BLM acquisition at 50 Hz in the beam loss software. This measurement are available since July this year. The software is being migrated to FESA but the functionality will be kept (S. Redaelli will follow this up).

- **Fast beam current measurements during full beam scraping** with the collimator jaw. This measurement provides the local beam position and size at the collimator through Gaussian fit of the beam current profile versus collimator jaw position (see S. Redaelli presentation at the collimation working group meeting of January 31st, 2006). All the required tools are in place to perform this measurement.

- **Aperture scans with scraped beams**. This method was proposed by R. Assmann and S. Redaelli to speed-up the aperture measurements at the LHC. An experimental validation at the SPS would be very valuable. The required tools are available and the required time is of the order of two hours.

- Additional measurements of long decay of beam loss tails could be also performed to verify the theory proposed by H. Braun at the collimation working group meeting of April 4th, 2006. This can basically be done in parallel to other beam loss measurement (BLM signal should be acquire for some minutes without moving the collimator jaw).

S. Redaelli concluded by saying that the most of the proposed measurements will have a minor impact on the MD planning. He recommends that fast loss measurements and full beam scraping with the collimator should be performed systematically **at the end of each coast**, when the beam position with respect to the collimator jaws will be well known. The aperture scan will require some dedicated time but this seem a good investment because the outcome for the LHC could be significant.

F. Zimmerman suggested that the measurements with full beam scraping should be repeated by using alternatively both collimator jaws.

H. Braun stressed that for the benchmarking of his theory I would need to have the integrated loss signal within a specified frequency range. B.E. Holzer confirmed that this is what the LHC-type BLM will provide (acquisition frequency of 1 Hz).

The next meeting will be announced.