120th Meeting of the LHC Collimation Study Group

August 30, 2010

Present: R. Assmann (chairman), A. Nordt (scientific secretary), R. Bruce, D. Wollmann, O. Aberle, G. Bellodi, T. Markiewicz, V. Parma, J. Wenninger, F. Burkart, M. Cauchi, H. Day, J.L. Grenard, A. Dallocchio, V. Boccone, F. Cerutti, T. Mertens, A. Ryazanov, R. Folch, F. Caspers, G. Smirnov, G. Valentino, J- Ph. Tock, T. Baer, Y. Levinsen, H. Burkhardt, E. Holzer, E. Nebot, E. Metral.
Excused: A. Masi , S. Redaelli, A. Bertarelli.

1 Comments to the minutes

No comments on the previous minutes.

2 Agenda of this meeting

1. Regular collimation status reports:
   a) Hardware and tunnel activities
   b) Remote and beam commissioning
   c) Phase II activities at CERN
   d) Phase II activities at SLAC
   e) Cryo-collimators integration and interfaces
   f) FLUKA work
   g) Further Remarks in General

2. Special reports :
   a) Updates on Loss Maps – D. Wollmann, BE/ABP
   b) Updates on Halo Scraping – F. Burkart, BE/ABP
   c) Simulation of Loss Maps from Dust Particles – Y. I. Levinsen, BE/ABP
   d) Status of Analysis of the Beam Dump triggered By Fast Losses on 25-08-2010 – A. Nordt, BE/BI

3 List of actions from this meeting

Action	People	Deadline
Hierarchy study for scraping events	F. Burkart	
Study the 'timed loss maps' for the 'events' in more detail and simulate loss maps from laser wire scans.	Y.I. Levinsen	
Verify the different results for local inefficiency measurements (see talk Daniel Wollmann)	D. Wollmann, S. Redaelli	
Analysis for loss maps using smaller running sums for the BLM data	D. Wollmann	
Follow up for the PM analysis for fast losses	A.Nordt	

(Complete list at http://lhc-collimation.web.cern.ch/lhc-collimation/action.htm)

The next meeting will be on September 20th.

Minutes of the meeting

1 Regular collimation status reports

1.1 Hardware and tunnel activities (O. Aberle EN/STI)

- Oliver reported about the plans for the technical stop from 30th of August until 2nd of September 2010. The collimation control system in IR3 and IR7 will be checked. Temperature sensor tests are foreseen in IR2 and IR8 (cables will be tested and the readout chain). Furthermore it is foreseen to install a shielding for a collimator in UJ22 (TCDIH.29205) in order to avoid injection losses seen on Q5-Q8.

1.2 Phase II activities at CERN (R. Assmann BE/APB)

- Ralph reported about the status of the fabrication of the dispersion collimators. The manufacturing of the prototype is ongoing and progressing.

1.3 Phase II activities at SLAC (T. Markiewicz, SLAC) – see slides

- Tom presented the latest SLAC RC status report and the activities since 19th of July 2010.
- The tests of the right hand drive have been successful. And the tests of the left hand drive revealed problems that "pawl" could not "hide". The left and right are different as the left jaw rotates CW while the right jaw rotates CCW.
- These problems revealed themselves on 21st of July 2010. Several facets were rotated while the Cu tube was twisted and the ceramic race on one of the two bearings on the actuator failed under the load.
- There were several fundamental problems: the load rating of races of ceramic bearings was not appreciated. It has to be noted that each drive has 16 10mm OD / 5 mm ID races. Ceramics was chosen because of the thermal expansion characteristics and because they guaranteed not to cold weld in vacuum. The solution for this load problem on the ceramics bearings is to replace all bearings (as well as the spline gears, bevel gears and the worm drive) with ion-deposited W-S_2 stainless bearings.
- Note: Fritz was asking why they did not use Rhodium coated bearings. Rhodium is known for its good conducting resistance.
- Another problem is that the shafts supported on one end can tilt under load. The solution here is to use thrust bearings.
- It had been always planned to spot weld all screwed and pinned parts as part of the final assembly procedure. But several problems occurred: the rotation drive mounts via two screws on a tab on one half of the split bearing that houses the main shaft support and Aluminium nuts were used to attach the shaft temporarily. Under load the tab rotates as the worm pushes against it especially if the nuts are not tight enough. A solution for the pre-weld tests is to elaborate the clamp referenced to the steel support shaft to prevent any rotation as well as any tilt. Also the gears pinned in place with "rolled pins" are not very strong. The solution is to replace 6 out of 7 pins with solid stainless pins (the 7th rolled pin acts as a "fuse" to protect the housing and will therefore not be replaced).
- Tom also reported about the tests with the measurable torque. The lever arm (16`` with a weight of 13.36 lbs.) with a scale provides measurable torque for systematic studies. 214 inch-pounds are available at the moment (with the current weights). The measurements of torque required to overcome friction of the split race support bearing (50in#) and to bend the copper tube (14 in#). This makes 64 inch-pounds in total.
- In order to simulate welded fixtures, a clamp has been used. The clamp is registered to sides to the steel support in order to prevent rotation and to the top of the support in order to prevent tilt. A thrust bearing between the 40-tooth ratchet and the housing prevents a tilt of the ratchet under load.
- Also the most recent test results were presented. On 27th of August 2010 4 out of 7 rolled pins were replaced with solid stainless pins, the clamp, thrust bearings and stainless bearings. The pawl fails at 150 inch-pounds torque and the rolled pin holding the first bevel gear shears at 204 inch-pounds.
- The immediate plan is to improve the L drive unit: replace rolled pins on the ratchet axle with solid stainless; replace the pawl with a more classic design where a radial spring causes a "dog" to engage the ratchet tooth and test the unit to ~400 inch-pounds.

- Then these changes will be implemented on the R unit and they will be tested as well. Afterwards a final assembly and welding and testing and alignment in a clean room can be performed using ion-deposited W-S_2 parts. Afterwards a bake-out will be made and finally the shipping can be done.

1.4 Cryo-Collimators integration and interfaces (V. Parma TE/MSC)

- Vittorio reported that the final decision about the length of the cryo collimators was taken and it will be 4.5m.

1.5 FLUKA work

- F. Cerutti mentioned that the FLUKA team is setting up simulations (referring to the actual *Phase 1* collimation system) in order to evaluate the impact of imperfections (i.e. magnet transverse displacement) on power deposition in the cold magnets, following the optics simulations on the same topic reported in the thesis of Chiara Bracco. There a loss increase of almost one order of magnitude with respect to ideal machines conditions, was reported.
- Furthermore F. Cerutti raised the issue of the beam tube shielding for the new and shorter connection cryostat upstream of Q11 in the *Phase 2* layout. Such a shielding (i.e. 16mm stainless steel around the beam pipe) is in place in the actual connection cryostats, according to the LHC-LE-EC-00012 document (EDMS 695451).
- The question whether the shielding is needed also for Phase 2 was raised. For Phase 2 it is foreseen to install DS collimators and shorter connection cryostats. One important goal of the shielding, according to the mentioned document, is to protect Q11 from the beam losses induced shower that would not be caught due to the fact that the cryostat is empty, and would impact the front face of the quadrupole.
- Using as input the *nominal* halo simulated by Thomas Weiler for Phase 2, FLUKA calculations do not predict any significant power deposition on Q11, thanks to the pair of new collimators in the area.
- Ralph and Joerg excluded the possibility of *erratic* losses not caught by these collimators.
- On this basis, the conclusion was that the shielding in the new connection cryostats is not worthwhile.
- For the DS collimators the technical specifications have to be submitted until 6th of September 2010.

1.6 Further Remarks in General

- Ralph introduced Marija Cauchi. She will do simulation work. Gianluca Valentino was introduced as well as new student. Florian Burkart is a new technical student of Ralph and he will work on heavy ion beam losses.
- Jorg W. introduced his new PhD student Tobias Baer.

2 Special topics

2.1 Update on Loss Maps (D. Wollmann, BE/ABP) – see slides

D. Wollmann presented his updates on the latest loss maps studies

- A set-up qualification since the last set-up of the full collimation system has been done in the period from 12.06.- 22.06.2010.
- At 3.5TeV and stable beams conditions (β*=3.5m) the following qualifications have been performed:
    1) 18.06. β-tron losses ver/hor both beams, momentum losses B1+B2 (+1000Hz)
    2) 28.07. β-tron losses ver/hor both beams
    3) 11.08. β-tron losses ver/hor both beams
    4) 13.08. momentum losses B1+B2 (-1000Hz) (broken hierarchy found)
    5) 17.08. momentum losses B2 (-1000Hz) (broken hierarchy found)
    6) 27.08. β-tron losses ver/hor both beams, momentum losses mainly B2 (+900Hz).

- At 450 GeV and injection optics (β* =10m) momentum losses were studied on 24.08. for B2 (-1000Hz).
- Daniel presented the local cleaning inefficiency for the β-tron loss studies from 11.08.2010 (ver/hor both beams) for the full ring and zoomed views on IR7 and IR3.

- In IR7 we have a factor 5000 difference between cleaning inefficiency at the TCP and Q8. The hierarchy was not broken for this event.
- In a next step he presented the momentum losses for the event on 13.08. at 08:57:12 (B2 dominating, B1 and B2 equal, B1 dominating) for -1000Hz for the full ring.
- A breakdown of the hierarchy in B2 for particles with higher momentum could be observed. The TCSG.B5L3 became primary.
- Ralph added that the TCSG was at 4σ and the TCP at 6σ. Vittorio mentioned that it would be interesting to see the absolute losses as well, and Ralph said it is difficult to quantify.
- Alessandro asked how the broken hierarchy can be explained: was it a wrong collimation set-up, orbit, etc? The answer was that this could be caused by systematic beam effects in the beam or maybe this effect was there always but was not realized. The first time it was realized was on 13th of August.
- Joerg added that he checked all the beam dumps in August in detail and he has not seen this. He recommended, to keep the current orbit settings.
- Daniel presented a summary about the development of the β-tron cleaning inefficiency (for BLM signal in the 1.3sec integration time, i.e. RS09) for four different measurements (18.06., 28.07., 11.08., 27.08.).
- For B1-H (Q8.R7) the inefficiency ranges between 1.62e-4 and 2.63e-4, except for one measurement on 11.08., where it was 5.46e-4 and for B1-V (Q8.R7) the inefficiency ranges between 1.12e-4 and 2.56e-4
- For B2-H (Q8.L7) the inefficiency is between 2.6e-4 and 6.08e-4 and for B2-V (Q8.L7) it varies between 1.72e-4 and 2.03e-4.
- In several cases two values are given in the table, standing for two measurements at this day (e.g. cross resonance forth and backwards). The deviation between the forth and backwards resonance crossing is maximum 10%.
- Furthermore there is a small discrepancy between the results from Stefano and Daniel. They will investigate this in order to find the source of the deviation.
- Daniel showed a plot where he summarizes all the results. All cleaning inefficiency values are within 1 and 3e-4, except two values, where in one of them a discrepancy between Daniel's and Stefano's result was found and in the other case the beam was dumped directly after this loss.
- Then he presented the development of the β-tron leakage to the TCT's in IR1 for the losses of the BLM's within the 1.3sec integration time.
- The minimum is at 1.5e-6 local inefficiency for B1-V at TCTVA.4L1 and the maximum value is 8e-5 for B2-H at TCTVA.4R1. There is a tendency of increasing values for the different measurements for B1-V TCTVA.4L1, B1-H TCTVA.4L1, B2-V TCTH.4R1, B2-H TCTH.4R1, except for the last measurement.
- For B2-H TCTVA.4R1 the local inefficiency is at around 7e-5, except for one value at ~6e-6. For B2-V TCTVA.4R1 the values are almost constant on a level of 6e-5 and for B1-V TCTH.4L1 the local inefficiency is at 4e-6 up to 6e-6, except for one value at 1.5e-5.
- Then a summary plot for the development of β-tron leakage to the TCT's in IR5 was presented. All values are within 5e-6 and 1e-4.
- In general the local inefficiencies seem to have less deviations from one measurement to the other than for the local inefficiencies to the TCT's in IR1.
- In total there were 4 qualifications with β-tron losses made since the last full set-up of the collimation system on 22.06.2010 and there were 4 qualifications with momentum losses (+1000Hz, B1+B2; -1000Hz B1+B2; -1000Hz B2;+1000Hz B2).
- The limitation on the dispersion suppressor on Q8 is less than 6.1e-4, i.e. the cleaning efficiency is more than 99.939%.
- The hierarchy was broken in B2 for particles with too high momentum. This broken hierarchy causes additional losses into the TCT's of IR1, IR2 and IR8 and a leakage to the cold aperture in case of a momentum gain of the particles. The leakage to IR1 and IR5 TCT's was comparable to the earlier measurements (same order of magnitude).
- Daniel will have a look to other (faster) integration times for the BLM loss data. Currently only the 1.3sec integration time has been analyzed.

2.2 Updates on Halo Scraping (F. Burkart, BE/ABP) – see slides

F. Burkart presented some first analysis results for the end of fill studies on 25.08.2010.

- The TCP.D6R7.B2 (ver) was used to scrape into the halo until the beam was dumped. The beam size was σ=0.270mm and the intensity $3.95x10^{12}$ protons.
- The left jaw had been moved into the halo with a step-size of 10 microns every 4 seconds.
- Florian presented the BLM losses (1.3sec running sum) versus jaw position. The losses are increasing with jaw position and the beam was dumped when the losses were ~0.06Gy/sec (jaw position ~-0.2mm). The beam intensity is decreasing with jaw position.
- Another halo scraping was done on 27.08.2010 with TCP.C6R7.B2 (hor). The beam size was σ=0.279mm and the intensity was $4.85x10^{12}$ protons.
- The jaw position is not stored in the measurement or logging database. The reason for the missing data should be found. But the initial and final jaw positions are known from the test as well as the step-size and step-number. At the beginning of the set-up the left jaw was at 1.779 and the right at -2.729. For the centring the left jaw was moved 40-50 microns and the right jaw was moved 200-250 microns. The centred position was then for the left jaw 1.729±10 microns and for the right jaw -2.479±50 microns.
- For the test the left jaw was moved with -5micron steps every 4 seconds. In total 113 steps could be made before the beam was dumped.
- The BLM losses versus jaw position show as expected increasing losses with increasing step-number in jaw position. The highest loss observed was 0.008Gy/sec for the 1.3 sec integration time.
- Compared to the test from 25.08.2010 the losses were smaller by a factor of ~10 and the number of steps that could be made was higher for the test done on 27.08.2010.
- It was mentioned that the hierarchy study Daniel W. did, should be done as well for the scraping events.

2.3 Simulation of Loss Maps from Dust Particles (Y.I. Levinsen, BE/ABP) – see slides

Y.I. Levinsen presented latest results on simulations of loss maps from dust particles.

- In order to perform the simulations he is using the collimation tracking module from Sixtrack being extended with a "beam-gas module". In Mad-X the pressure markers are placed at locations where one expects the beam to collide with the gas or other objects. When these markers are reached, the beam-gas subroutine is called and particles coordinates are changed accordingly.
- The collision events are read from an external file (a simple ASCII format) and then Monte Carlo simulations are done with DPMJET.
- The beam-gas branch is available in the git repository (/afs/.../ylevinse/scratch1/public/git/sixtracksvn-git/).
- Until the 30^{th} of August 7 events have caused a beam dump mostly during stable beam conditions, which might originate from dust particles falling through the beam. These were fast losses with a rise time of 1-2ms.
- By inserting specific scattering locations into the beam-gas module manually at the location where one expects a local dust particle or other objects, it is possible to simulate loss maps for such an event.
- These loss maps then can be compared to actual measured data in order to see how well simulations and measurements do agree.
- The events tagged as "event 3 and event 4" are simulated, both were originating on beam 1.
- The simulation does not assume a specific obstacle type or shape it could be e.g. a local vacuum bump as well. What has been simulated is proton on proton at rest, since this assumption should be sufficient enough for a first approximation.
- Further assumptions are β*=2m, to have the TCT's at 15σ and to have 10^7 collisions with the object.
- Yngve presented the global losses around the ring for event 3 as well as the local losses downstream of the 'obstacle point'.
- The simulated local losses are in very good agreement with the measured losses for event 3. It was suggested to try to move the location of the losses slightly in order to see how well one would know the origin of the event.
- To the first order it seems that one cannot see significant differences from different locations between the 2 dipoles. The first loss spike seems to come at the first dipole downstream of the location one is choosing.
- It is also possible to get 'timed loss maps', i.e. to test the time dependency.
- All the information about the loss origin is saved. This is necessary when one wants to rescale the loss maps for adjusted pressure maps etc. Then it is possible to get 'timed loss maps' from an object falling through the beam. In certain cases, it is shown that some BLM signals were delayed. This could potentially be coming from a dust particle touching different parts of the beam.

- Yngve presented the time dependent loss maps for particles falling through the centre of the beam as well as for particles falling through one side of the beam.
- It is possible to learn more by studying the time dependencies in more detail. The study will be extended with simulations of loss maps from laser wire scans. This will be a good benchmark of the beam-gas module and valuable to the machine protection studies.
- F. Caspers said one should take into account also other particles than dust. It is possible to have even 1mm particles in the beam pipes. Also vaporizing dust could be a candidate, and one question is how to exclude that we have vaporizing dust in the machine? With increasing intensity and energy the possibility to have "dirt" interacting with the beam is increasing.
- Joerg added a comment on the paper from Frank Zimmermann about "Interaction of Macro-Particles with LHC Proton Beam". But maybe it is not enough to take only gravitational effects into account or interaction because of different charges etc. The dynamics of such particles falling through the beam can become quite complex. Maybe it is worth simulating the tails as well.
- More detailed analysis and simulations are needed in order to understand these events.

2.4 Status of Analysis of the Beam Dump triggered by Fast Losses on 25-08-2010 (A. Nordt, BE/BI) – see slides

A. Nordt presented some first preliminary results for the halo scraping event from 25.08.2010.

- The TCP.D6R7.B2 (ver) was used to scrape into the halo until the beam was dumped. The beam size was σ=0.270mm and the intensity 3.95×10^{12} protons.
- The left jaw had been moved into the halo with a step-size of 10 microns every 4 seconds (see slides from F. Burkart for other details on this event).
- The post mortem buffer that is used within the post mortem playback GUI consists of 2048 bins a 40µsec, i.e. this buffer has a length of 0.082 sec. The BLM group is storing longer PM buffers with at least 43900 bins a 40µsec for testing reasons. The length of those buffers is then minimum 1.72sec.
- These longer PM buffer data can be used in order to see what happened 1.7 sec before the beam was dumped.
- The losses for all TCP BLM-monitors in IP7 were presented (i.e BLM losses during the 40µsec running sum). The highest losses were observed at TCP B2I10 C6R7 B2 and TCP B2I10 A6R7 B2 (~0.23-0.25Gy/sec) and not on TCP B2I10 D6R7 B2 (the one sitting next the TCP that was moved) (~0.12Gy/sec).
- One can clearly see the start of the scraping, since the losses are increasing rapidly from 0.01 Gy/sec up to 0.25Gy/sec.
- It has been not understood so far, why oscillations with a period of ~0.2sec did appear before the TCP had been moved. The oscillations during the movement have a period of ~0.02sec. But these oscillations are not 'stable' or equal in frequency. A further investigation is needed in order to determine the exact periodicity. After 0.2 sec after the movement has started the losses are decreasing to 0.1Gy/sec. And after another 0.3sec the losses decrease even more to 0.06Gy/sec until the beam was dumped (0.2sec after the last decrease of the losses).
- Then the losses on the monitors that triggered the dump (i.e. all monitors that were above threshold for any running sum) was shown. Many cold magnet monitors went above threshold during this event (04L6 and 06R6 MQY monitors) as well as a warm magnet monitor (MBWA E5R7). It is always clearly visible when the movement of the TCP started.
- Then the losses on all TCSG monitors in IP7 were shown and also here one can see oscillations already before the movement. When the movement started the losses were increasing from 0.001Gy/sec up to 0.006Gy/sec. The period during the movements seems to be as for the TCP monitors (i.e. 0.02sec). The decrease of the losses until the beam was dumped happened on the same time scale as for TCP monitors.
- A more detailed analysis of this event and on the halo scraping done on 27.08.2010 is needed and will be presented in the next collimation WG meeting.