122th Meeting of the LHC Collimation Study Group

November 08, 2010

Present: R. Assmann (chairman), A. Nordt (scientific secretary), S. Redaelli, R. Bruce, D. Wollmann, G. Bellodi, T. Markiewicz, J. Wenninger, M. Cauchi, V. Boccone, F. Caspers, G. Valentino, J- Ph. Tock, E. Holzer, E. Nebot, J. Jowett, F. Carra, K. Foraz, O. Aberle, D. Macina, M. Brugger, E. Page, J.P. Corso

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

2. Special reports :
   a) News on Ion Loss Maps – G. Valentino, BE/ABP
   b) LHC Ion Loss Maps – G. Bellodi, BE/ABP
   c) Modification of the LSS2 – D. Macina, EN/MEF
   d) Modifications in LSS2 and Impact on the Vacuum System – E. Page TE/VSC, JP Corso EN/MEF, O. Aberle EN/STI
   e) Results from the TCP D6L7 B1 Test on 25-10-2010 – A. Nordt, BE/BI

3 List of actions from this meeting

Action	**People**	**Deadline**
Are additional absorbers needed in IR 3 and IR7	V. Boccone	
Study the ion loss maps in more detail and eventually re-do the simulations with more statistics and more turns	G. Bellodi, G. Valentino, S. Redaelli	
Detailed integration and installation of the TCTVA (LSS2 implementation)	Coll. Working Group	
Follow up for the collimator movement and vacuum losses	A.Nordt	

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

The next meeting will probably take place next year (2011) and has not been scheduled yet.

Minutes of the meeting

1 Regular collimation status reports

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

- Oliver reported that there are no problems so far in the tunnel.
- During the Ion run sometimes a leakage up to 30% into the ARC was observed.

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

- Vittorio B. reported about the progress concerning the design of the DS collimators. The FLUKA calculations will and need to be re-done, as well as the energy deposition studies and the bus-bars have to be implemented in the simulations.
- Markus Brugger was asking whether additional absorbers are needed in IR 3 and IR7 and Vittorio says he would follow this up.
- There will be a general design meeting on 22nd of November 2010; an invitation will be sent soon.

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

- Tom presented the latest SLAC RC status. He gave a summary of the last 6 month:
- At CM14 J. Smith showed pictures of one of the 2 jaws mounted and the rotation drive functioning. The 6 month of lab tests uncovered: deficiencies in the primary and RF bearing designs, deficiencies in the design of the drive unit and related hardware and there were problems with the testing setup (slippage of parts prior to final welding). There were multiple cycles of tests, failures, redesigns, manufactures, installations and retests, so that the promised shipping date of 1st of August 2010 was missed. The prototype was rebuilt and finally moved from test lab into the vacuum clean room on 28th of October 2010. In the clean room the final welding, assembly, bake out and testing was then done. The bake out should be over around (or before) Christmas and the shipping can be done in January 2011.
- Oliver mentioned that a final installation in the SPS can be done only until 4th of February 2011. If the shipping will be made in January, the installation is most probable not possible before the start-up in 2011.
- Tom gave a punch list of work that is still required: welding of the bellows to plate and jaw supports to bellows; the installation of all final parts, like the rotation drives with a new larger diameter W-S_2 impregnated bearings and shafts, like the rebuilt of the primary jaw-support bearings and their housings, like the ancillary parts which hold thermistors and prevent ‘oil-canning’ of the RF shields. Furthermore the welding of the cooling tubes into their feed throughs is missing so that all rotation tests from this point on cause the tubes to twist. Also the rotation, resistance and alignment tests are missing and the tests under vacuum after the vessel is cover welded. Concerning the vacuum bake out and the RGA scan, estimated 3 weeks are needed to achieve the 9-scale vacuum. And finally the post bake out rotation tests have to be done.
- In the last CWG Tom presented the setup toapply arbitrarily large torque to test the rotation drive and at many time the expected torque was required. A clamp was installed to prevent the rotation of the drive unit during testing the prior to its final welding. On 1st of September the Geneva drive axle broke at ~300 inch-pounds of torque. The drive therefore was rebuilt and tested on 16th of September with 440 inch-pounds. A large thrust bearing was added at the end of axle to prevent any bending and the Geneva drive was exchanged for a pair of 1:1 gears (this reduced the load by a factor of 3). Additionally the 5mm molybdenum shaft (and 2 bearing sets) was replaced by 6mm steel and larger bearing sets. Tom presented a plot showing the safety factor on torque required: torque required to twist annealed copper tube. There are 30 inch-pounds needed to bend each of the 1 m tubes for 360 degrees and 40 to rotate the jaw on moly split ring 1mm ceramic ball support and 100 in total for this configuration.
- It turned out that the 1mm ceramic balls have crawled on top of each other and have frozen the bearing (note scuff marks in housing and axle butt). Because of this they switched out the primary ceramic support bearing in favour of a 20mm/42mm classic steel bearing. These new bearing were put in place in temporary aluminium housing on 1st of October 2010 and it was found that the jaw now rotates freely with 0 torque required.

- The 3rd generation pawl was installed on 6th of October 2010.
- The stepped block to fine tune the length of the stroke required to ratchet a tooth was installed on 13th of October 2010.
- The shoulder on the worm gear to prevent sliding prior to final pinning was put in place too. The flattened 1mm Rhodium coated SS ball bearings in thrust bearing are now replaced with 1.3mm ceramic balls. On 22nd of October 2010 an anti rotation clamp was added.
- At the end of the lab tests they found the following results: the rotation drive operates at 0-300 inch-pounds torque (10 times higher than expected load) without the 'double-ratchet', never missing ratchet and the actuator height, initial position, length of the stroke and reliable pawl operation are all critical.
- The jaw rotation within 1/384 clicks of 20 degrees after the rotation of one facet shows that the worm gear must not slip (now held by a set screw and a shoulder) and that the primary bearing housing to which the rotation drive mounts must not rotate: held now perpendicular to the support shaft via flats milled in the piece and they will be eventually welded.
- Tom showed some pictures concerning the disassembly and move to the vacuum lab of the $W\text{-}S_2$ coated parts being bagged and ready for transport.
- The next steps are the following: the SLAC vacuum group will handle all final cleaning and welding (all the required fixtures do exist). The risks are: many final version pieces are still required (single in-house craftsman is only available); achieving the 1 nanoTorr in a finite bake time and the operation in vacuum after the bake out.
- At CERN the location will be prepared for quick plug and play installation (Fred Loprete is there from 25-29th of October 2010 to verify interfacing issues). Ideally the installation in SPS should take place before 4th of February 2011 (if not we wait for the SPS MD period later in 2011).

1.4 Cryo-Collimators integration and interfaces

- No news or problems.

1.5 FLUKA work

- Vittorio also reported about the progress about the work concerning the asynchronous beam dump and the loss studies in the injection regions. He was asking where the results should be presented.

2 Special topics

2.1 News on Ion Loss Maps (G. Valentino, BE/ABP) – see slides

G.Valentino presented latest news in the ion run, the ion collimation setup and measured ion loss maps.

- Gianluca presented loss maps at injection (betatron losses V B1, at 2010.11.05 at 10:55:34 LT, H at 11:04:11 LT, B2 V 11:09:37 LT, H 11:14:28 LT, momentum losses B1 neg. offset at 11:42:13 LT, B2 neg. offset 11:53:44 LT and 11:59:43 LT, B1 pos. Offset 12:08:13 LT, B2 pos. Offset 12:11:18 LT and 12:18:10 LT, betatron losses at 3.5TeV before squeeze V B1 17:09:13 LT, B2 V 17:14:04 LT, momentum losses at 3.5 TeV B1 pos. Offset 17:20:07 LT, betatron losses B1 H 19:18:26 LT, B2 H 19:24:01LT, momentum B1 and B2 neg. offset 19:26:20 LT, and after squeeze at 3.5 TeV betatron losses B1 V on 6th of November at 07:33:34 LT and 07:46:05, B1 H 07:36:00, and 07:45:11 LT, B2 V 07:37:50 and 07:43:46 LT, at physics conditions for B1 V 7th of November 2010 at 22:08:02 LT, B2 V 22.14:58 LT, momentum losses for B1 and B2 neg. offset 22:23:17 LT, B1 H betatron losses 8th of November at 02:47:50 LT, B2 H 02:49:39 LT, momentum B1 and B2 pos offset 03:03:27 LT).
- The loss maps he presented showed a clear leakage into the arc and high losses in the arc (for momentum losses with ± 1000 Hz).
- The losses in the arc have to be investigated in more detail since this could lead to a high radioactive exposure on the cold magnets there.
- The losses in IR3 are almost as high as in IR7 what is not the case at all for protons.
- It has to be verified whether for this case the hierarchy of the collimators was broken or not.
- But the orbit for B1 (vertical) was stable during this measurement.
- The hierarchy for B2 was broken.

- B1 and B2 show similar effects during the operation with ions. The factor between TCP and TCSG for B2 was 5.
- The leakage into the dispersion suppressor was worse than expected and was on a level of 1-2% what is 100 times worse than for proton runs. This could lead to a high energy deposition in the superconducting magnets.
- Stefano mentioned that the loss maps for the off momentum measurements are worrisome. A follow up will be made.
- There was the question whether the FLUKA team could investigate the ion loss maps in more detail in order to understand the effects.

2.2 LHC Ion Loss Maps- First Observations and Simulation References (G. Bellodi, BE/ABP) – see slides

G. Bellodi presented the first LHC ion loss maps and corresponding simulation references.

- Giulia presented the loss maps from the betatron losses on B1 at 450 GeV (horizontal and vertical, stable beam) taken on 5th of November 2010 at 11:04:11 LT (H) and 10:55:34 LT (V). The highest losses were in IR7 as predicted by simulations. The simulations were showing some (smaller) losses in IR1 and IR3 as well what was confirmed by the measured loss maps. Also a zoomed picture of these loss maps confirmed the prediction by the simulations.
- For the B2 loss maps however the situation is different and the losses in IR3 are higher (about a factor 20-30) than for B1 losses, but the losses in IR7 are still higher than in IR3. These loss maps do agree with the results from the simulations. The data were taken on the 5th of November 2010 at 11:14:28 LT (H) and 11:09:37 LT (V), both for stable beam condition at 450 GeV.
- Then loss maps for momentum losses B1 were shown (for data on 5th of November at 12:08:13 LT at 450 GeV , +VE pos. offset and at 11:42:13 LT at 450 GeV +VE neg. offset). The highest losses were measured in IR3 for both cases. The losses in the arc and DS for negative momentum offset are much higher than for the positive momentum offset, where the losses are restricted to the IPs (3,4,5,6,7). The simulations are in good agreement with the measurements and the losses in the arc were predicted as well as the highest losses in IR3.
- The B2 momentum cleaning loss maps at 450 GeV were taken at 12:11:18 LT (pos. Offset) and at 11:53:44 LT (neg. offset). In both maps the highest losses occurred in IR3. For the positive momentum offset one can see also high losses in IR7 whereas this is not the case for the negative offset momentum. In this case the simulations predicted for both cases high losses in IR7 and less losses in IR3. The difference between measurements and predictions can be due to the low statistics that were used for the simulations.
- Giulia gave a summary of the first observations for ions at injection energy:
    1. Betatron cleaning inefficiency: leakage to the DS is 05-2%, the experimental IR's are clean, the leakage to the arcs is 0.1% and RF is clean.
    2. Momentum cleaning inefficiency: the leakage to the DS is 0.5-4%, the experimental IR's show 10% (TCTH in IR1, B2) and 1% (TCTH in IR5, B1), the leakage to the arcs is 0.3% and the RF insertion shows 0.5%.
- The assessment is: loosing about a factor 50-100 in cleaning efficiency for ions compared to protons, what is expected (ion fragmentation and dissociation). The main losses occur in predicted locations, namely the DS magnets. Maybe the losses occur somewhat earlier in space than expected. There is a large 10% leakage into IR1 from IR3 losses for B2 and it is not clear what ion species escapes IR3 and travels to IR1. This has to be analyzed in more detail.
- The following loss maps were taken at 3.5 TeV. First she showed the betatron cleaning for B1 (V and H) Highest losses were measured in IR7 as predicted and high losses were seen in IR3 (also as predicted). The leakage to IR3 was around 15%. Interesting is the Q10 in R2: 2e-4 leakage to this quad was observed. For B2 again the highest losses were seen in IR7 and IR3, losses in the arc for both cases (H and V) were seen what was predicted by the simulations as well. At the TCT the losses were very small, only the TCTH in IR5 was at a 1e-5 level. The leakage into the DS went up to 3% and the leakage to IR was around 30%.
- The following results were presented for B1 observations for the off-momentum ion loss map (-1000Hz): the leakage to the DS in IR was 3%, leakage to IR7 was 0.1%, TCTH.4R1 0.5% leakage, TCTH.4L5 0.3% leakage, TCTH.4R2 0.02% leakage, TCSG in IR6 0.3% leakage, Q10.L2 0.02% leakage, Q20.L5 0.01%

leakage and the leakage for DS of IR7 was 0.01%. B1 and B2 positive momentum loss maps the simulations showed the highest losses in IR3 what was confirmed by the measurements.

- In general: the leakage into the arc was predicted by the simulations and can be seen in various loss maps. There is factor 5 difference between simulations and measurements. This can be partially explained by the fact that the statistics were very small. A follow up is needed in order to understand the losses in more detail and their origin. Maybe it will be needed to re-run the simulations with more statistics and more turns in the machine.

2.3 Modification of the LSS2 to Solve the TCTVB-ZDC Interference (D. Macina, EN/MEF) – see slides

D. Macina presented the latest results on the modification of the LSS2 structure to overcome the TCTVB-ZDC interference.

- In a first step Daniela presented an overview of the collimation scheme in IR2, including the movable collimators for protection at injection (only in the vertical plane) like TDI (V), TCDD(V) and TCLI (V), also the TCTH (horizontal plane) and the TCTVB (vertical plane) are shown in this schematic drawing.
- There is interference between the ALICE ZDC signal and the TCTVB. The ZDC will measure the total energy and the centroid of the non-interacting (spectator) nucleons. Parts of the spectator nucleons are intercepted by the TCTVB jaws introducing a systematic error which depends on the machine parameters.
- Between the 2 TCTVB jaws we have a distance of 13mm ± 13.7σ. The 3σ spectator neutron spot is well positioned between the 2 jaws in case of the xing angle of 0μrad but not for 100μrad.
- The solution for this problem is to reproduce the same layout as in IR1/IR5. This includes the displacement of the Y chamber ≤1.36m but is limited by aperture considerations.
- A note is in preparation by J.Jowett, R. Appleby and J. Uythoven and will be published soon.
- How will this be organized? EN/MEF will coordinate the project and is responsible for the layout change. The collimation working group is responsible for the detailed integration and installation of the TCTVA. In order to proceed towards an ECR EN/MEF needs to know if the integration of the TCTVA in 1.36m is compatible with the TCT requirements (see the presentation from JP Corso, E. Page and O. Aberle).

2.4 ALICE-ZDC Modification: New Beam Vacuum Layout for TCTVA Integration 4L2 and 4R2 (E. Page TE/VSC) see slides

E. Page presented the planned modification of the LSS2 structure and the impact on the vacuum system.

- Eric presented an overview of the current situation in 4L2 and showed on technical drawings where the TCTVA will be implemented. The constraint for such insertion is the space available there, only 1360mm are available and the collimators must move along their 5th axis towards IP2 (ALICE).
- 4L2 and 4R2 are symmetric for the integration but the mechanical aperture is different between 4L2 and 4R2 around the Y chambers. For 4L2 the apertures are 80 to 80 mm (VTCYD chamber) and for 4R2 the apertures are 65 to 80mm (VTCYB chamber).
- Also around the BPMs the mechanical aperture is different in 4R2 and 4L2. In 4L2 it is 80 to 80 mm (BPMWI) and in 4R2 it is 80 to 63mm (BPMWB).
- Therefore it is needed to build new vacuum elements for 4L2:
    1. VMTBA is a collimator module with an aperture of 80 mm, L=220mm, the bellow connected on the collimator side accepts the 5th axis motion.
    2. VMTQC is a collimator pumping module with an aperture of 80 mm, L=460mm, the bellow connected on the collimator side accepts the 5th axis motion.
    3. VCRLP is a vacuum chamber (circular, LSS ID67) with an aperture of 67mm, L=3800mm.
    4. The integration issues are: the connections of QCF100 (flanges) require space for a MKT collar with diameter 230mm and thickness 35mm. The thickness of the bake out envelop for the VCRL% chamber is 5mm which means a total outer diameter of 70+10=80mm.
- Also for 4R2 new vacuum elements have to be created:
    1. VMTBB is a collimator module with an aperture of 80 to 63 mm, L=220mm, the bellow will be connected on the collimator side accepts the 5th axis motion.
    2. VMTQD is a collimator pumping module with an aperture of 80 to 63mm, L=460mm, the bellow connected on the collimator side accepts the 5th axis motion.

3. VCRLP is a vacuum chamber with an aperture of 67 mm and L=3800mm, it is the same chamber as for 4L2.

- The vacuum elements that are necessary for inserting the new TCTVA are 4 modules and 2 chambers. Most of the components are available from the stock which needs to be completed. The time necessary to produce these elements is about 3 month (from drawings to reception).
- For the collimator and ID800 area the steps necessary for the installation for one sector are: venting of the vacuum sector, displacement of the moving elements (TCTH, modules, VCTY_, VCTCR, VCDGA + supports), the installation of the old support to the new location + installation of new supports (new modules), installation of the new modules and the new VCDG_ chamber, the survey of the moved and installed elements, closing of the sector, pumping and leak detection, bake out installation, bake out and NEG installation, bake out de installation and cleaning of the area. The time to ensure this work (one side) is about 1.5 month with 3 people.
- The new vacuum layout ensures the ZDC movement for 1360mm down to the IP and the new vacuum layout and special fabricated components allow the 2 collimators 5th axis motion.
- For the production and planning for the collimators area 3 month are needed and for the ID800 area 4.5 month are needed. For the installation 1.5 month for vacuum sector A4L2.C and A4R2.C each are needed.
- There was the question whether the TCDD is open all the time or not? This has to be checked.
- Oliver pointed out that the cabling has to be done as well.
- All aperture changes will be precisely documented in the ECR to be able to keep track.

2.5 Results from the TCP.D6L7 Test on 25-10-2010 (A. Nordt, BE/BI) – see slides

A. Nordt presented some first preliminary results for the TCP scraping test from 25.10.2010.

- The TCP.D6L7.B1 (V, B1) was used to scrape until it reached its position limit. The position thresholds were not changed for a maximum safety. The interlock worked as specified and the beam was dumped at 14:07:49 LT. The increment was done with 5µm every 3 seconds. We got tail data for B1 from 2.045mm to 1.642mm (exploring 1sigma of tail).
- Beam 1 intensity was 42.62e12p and B2 intensity was 39.75e12p, beta star was 3.4m.
- Highest losses were seen on BLMs sitting on 06R6 MQY in RS01-RS05 and 04L6 MQY in RS01-RS05.
- The stepwise movement of the collimator jaw during 4 minutes caused a maximum loss of 0.1Gy/sec for RS05 (2.56ms integration time).
- Plots for the beam intensity and jaw position were shown.
- The BLM sitting next to the TCP was compared with vacuum losses, where a pressure gauge in 51 m distance was used for comparison. The vacuum losses can be directly correlated with the beam losses and the 'spikes' appear at the same moment in time (losses were investigated for RS09=1.3 sec integration time).
- Then the jaw position (GU) was overlaid with the beam losses and every 0.005 and 0.015mm a 'spike' in the BLM was seen (losses for RS09). For the jaw position (GD) a spike was seen every 0.01mm.
- Correlating the vacuum losses with the jaw position shows a stepwise increase in the vacuum from 5e-10mbar up to 2.1e-8mbar corresponding to the TCP movement.
- Vacuum losses and beam losses show at the same time an increase and decrease ('spikes') and seem to be correlated with each other, i.e. the question arises whether the vacuum losses have their origin from the jaw position or not.
- Annika investigated also the expert post mortem BLM data (1.7 sec with a 40µsec resolution from before the beam was dumped). Here one can see that the losses at all the TCP BLMs appear with a frequency of 0.2 sec.
- It needs to be verified if the vacuum losses have their source in the collimator jaw movement and if there is any out gassing. Also temperature fluctuations of the collimator step motor could be investigated in order to verify whether the decrease in vacuum originates from the movement or not.