121th Meeting of the LHC Collimation Study Group

October 25, 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

2. Special reports :
    a) 3.5 TeV Simulations of Losses and News on beta star limits from Collimation – R. Bruce, BE/ABP
    b) Operational Performance – D. Wollmann, BE/ABP
    c) Ions: Needs for Collimation – G. Bellodi, J. Jowett BE/ABP

3 List of actions from this meeting

Action	**People**	**Deadline**
Follow up the different FLUKA simulations	FLUKA team	
Analyse in more detail beam losses for different integration times of the BLM signal	D. Wollmann	
Compare inefficiency values with Stefanos results	D. Wollmann,S. Redaelli	
Follow up for the ion run	J. Jowett, G. Bellodi	

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

The next meeting will be on November 8th.

Minutes of the meeting

1 Regular collimation status reports

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

- Oliver reported about a problem with one TCLA collimator, where the motor was malfunctioning. It was decided to disable this TCLA. The problem has been solved in the meanwhile and this collimator will be enabled again asap.

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

- Ralph mentioned that a general meeting concerning the upgrade projects is planned. A detailed agenda and time and place will be sent around soon. All work packages have to be prepared for 2013. There will be also a high luminosity LHC project.
- JP Tock mentioned that the short connection and the vessel design are done. The pictures will be sent around and he said that this is a challenging task.
- The phase II first prototype will be ready by end of January 2011. The R&D concerns development of diamond and other standard materials. There will be a workshop concerning shockwaves.

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

- Tom reported that the rotation mechanism is not robust enough and that it has to be rebuilt, except the housing. All bearings that are non-tungsten will be de-sulfided. The time of shipping is not set yet.

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

- No news or problems.

1.5 FLUKA work

- TCT simulations were done with shooting a pencil beam to one jaw and the results were given to Federico. Allessandro was asking whether they saw a temperature increase and the energy deposition results will be given to him.
- The cooling pipes seem to be safe, but this is a preliminary result.
- The TCT will be added to the asynchronous beam dump scenario.
- Ralph mentioned that Maria should be involved in these calculations.
- Priorities were given as follows:
    1. Asynchronous beam dump: no results yet, but work was started
    2. Injection line: Vittorio started
    3. Imperfections of the beam (i.e. misalignment): Results are expected within the next 3 weeks , the losses at perfect case will be investigated and will be crosschecked with BLM measurements.

2 Special topics

2.1 Simulations with SixTrack of Loss Pattern at beta start=3.5m (R. Bruce, BE/ABP) – see slides

R. Bruce presented results from simulations with SixTrack for loss patterns at β*=3.5m.

- SixTrack simulations (combining optical tracking and particle-matter interaction in collimators) were previously used to estimate the performance of the nominal LHC collimation system.

- A simulation of the present machine provides a very valuable benchmark. And a comparison with measurements gives a better understanding of the machine performance and the simulations accuracy.
- The output of the SixTrack simulation is used as starting point for other problems (e.g. simulations of the experimental background).
- Roderick was presenting the present machine conditions that he is using in his simulations: in IR7 he assumes the primaries being at 5.7σ, the secondaries at 8.5σ, the absorber at 17.7 σ, dump protection at 9.3-10.6 σ, the tertiaries at 15 σ and the aperture at 17.5 σ. The collimator TCLA.B5L3.B2 is deactivated.
- The optics he used comes from MAD-X: with β*=3.5m in all IPs and the thin lens optics were used to create the SixTrack input (good agreement in β function could be achieved, with some smaller deviations in the dispersion suppressor).
- As initial distributions the following settings were used: a pencil beam directly on IR7 horizontal or vertical primary or a flat distribution in the halo plane (with a spread of 0.0015 σ around 5.7 σ) with a Gaussian cut at 3 σ in the other transverse plane and an energy spread of 1.129e-4. The results from these distributions are very similar: in the following he was showing only the results from pencil beams.
- The simulations were done for B1 and B2 and the results for both beams are very similar, so that only B1 results are shown.
- 6.4e6 primary particles per simulation were used with a resolution in local cleaning inefficiency of 1.5e-6/m. The statistical uncertainty is then the square root of number of counts in each bin.
- In total 8 simulations were launched (H and V, 2 beams, 2 distributions).
- Roderick presented the results for the horizontal halo (B1). The global inefficiency is around 1.1e-3 and the highest cleaning inefficiency in the cold region is 2.7e-5. Highest losses are seen in IR7 and IR3 and IR8.
- For vertical halo B1 the global inefficiency is 8.2e-4 and the highest cleaning inefficiency in the cold region is around 2.3e-5. The highest losses occur in IR7 and IR3 as well as in IR8.
- In a next step he showed the comparison with a measured loss maps for horizontal B1, where the data were taken on 18th of October 2010. The measurements do agree well with the simulations except that the measured TCT losses are much higher than simulated, what might be partially be explained by low statistics. In a zoomed version of this comparison-plot one can see that the losses on TCSG.A6L7.B1 in the simulation are smaller than on the TCSG.B5L7.B1, what does not agree with the measurements. The measurements show the opposite effect. The measured warm losses are order of magnitude higher than in the simulations. The question was arising whether the BLMs there see showers. This has to be investigated in more detail.
- The highest cold peak from the measurements is 2e-4 what is almost a factor 10 above the simulation result. But in the simulation no imperfections were used and these results are consistent with earlier results. The measured and the simulated highest cold peaks were found within 37m. The TCT leakage is much lower in the simulation (up to 1 order of magnitude). The vertical TCTs in IR2 and IR5 see higher losses than the horizontal TCT with the vertical halo. This was confirmed by the measurements. The leakage to IR3 is accurate within 50%. The deviations of smaller peaks, though too low statistics to study these (very small) losses. With the TCT at 15 σ, the losses in TCTs in IR1 and IR5 are lower by a factor ~80 compared to the 7 TeV simulations by Thomas with TCT at 8.3 σ.

2.2 TCT Margins and Minimum β* (R. Bruce, BE/ABP) – see slides

R.Bruce presented results for TCT margins and a minimum β*.

- The present TCT settings are based on aperture calculations using the n1 method, where n1 is the maximum acceptable primary collimator opening in units of beam σ, that still provides a protection of the mechanical aperture against losses from the secondary beam halo.
- N1 has been calculated with MAD-X, taking into account an ideal aperture and optics. Then misalignments were added, the β-beat and orbit offsets within given tolerances. These assumptions may results in too pessimistic results.
- An alternative method is the use of aperture measurements performed at injection and scaling laws to calculate aperture at top energy.
- As it will be shown in this presentation it is not possible in a general case, but can be done in the LHC triplet due to the special geometry of the problem.

- Global aperture measurements were performed in September 2010 and as a result Roderick presented the following numbers: For B1 (horizontal) it is 12.5 σ and vertical it is 13.5 σ. For B2 vertical it is 14 σ and horizontal it is 13 σ. A pessimistic assumption is that the triplet aperture must be larger than the global aperture.
- Roderick explained detailed the calculation procedure: first the s-value of the limiting aperture is found with MAD-X (h and v), then it is assumed that the injection aperture is equal to the global limit. Because of the geometry, only one plane matters. Afterwards one can scale the beam size to pre-collision (larger β_x and y) and add the orbit offsets in the relevant plane from MAD-X. He showed the equation used for this calculation and this equation then has to be solved for top energy aperture. Like this a 2D problem is reduced to a 1D problem.
- The described calculation assumes the same β-beat at this s-location at injection and squeeze and the orbit shift is given by MAD-X. Worst case scenario is to assume the β-function to be larger by a factor λ at squeeze and smaller by λ at injection. Then one can include an additional orbit offset δu and solve the equation again for aperture at squeeze. On the other hand one has to note that the assumption that the global limit occurs in the triplet is already very pessimistic.
- Two sets of calculations were performed: a) with λ=1 and δ=0 (more optimistic case) and b) with λ=1.1 (20% beta beat) and δu=1mm.
- For each set the calculated TCT settings assumed 2.5 σ margin to the aperture in the configurations β=2,2.5,3,3.5m. All experimental IR were considered and both beams. The horizontal and vertical planes were treated separately to get rid of the problem where the aperture bottleneck jumps between different s-locations. The bottleneck in the separation plane (normally the limiting one) is always in the triplet of the incoming beam, the bottleneck in the crossing plane is on the outgoing plane.
- The aperture margin in the separation plane can be increased if the top energy separation is reduced from 2mm to nominal 0.7mm. Both values of separation were included in the calculation.
- As a preliminary result for B1 and case a), the TCT σ for separation of 2mm is 14.9 σ and for separation of 0.7mm it is 14.9 σ. For case b) and B1 the corresponding values for the same separation values are 15.0 σ and 14.3 and 12.6 σ.
- A more detailed measurement of the local triplet aperture at injection could be useful to refine the presented calculations.
- With no difference in beta beat and nominal orbit shifts we can squeeze to β*=2.5m keeping the present TCT settings and approximate margins. We can also squeeze to 2.0m keeping the present TCT settings and approximate margins if the separation is reduced to 0.7mm.
- With 20% beta beat and 1mm additional orbit shift we can squeeze to 2.5m if the separation is reduced to 0.7mm and the TCTs are moved 14.3 σ (or if the margin of the TCT aperture is reduced by 0.7 σ).
- To squeeze to β*=2m the TCTs would have to move in to 12.6 σ or we have to reduce the margin between the TCT and the aperture.
- We could try a configuration that seems realistic (i.e. β*=2.5m). Start with low intensity, do loss map and maybe asynchronous dump test. If the triplet aperture is protected by the TCT, this configuration can be used during operation.

2.3 Operational Performance (D. Wollmann, BE/ABP) – see slides

D. Wollmann presented latest results on operational performance.

- In a first step Daniel presented an overview of the collimator settings for the different types of collimators.
- The cleaning efficiency and the correct hierarchy of the collimation system are regularly qualified by intentionally creating slow losses. The β-tron losses are created by crossing a 3rd integer tune resonance and the momentum losses by changing the RF frequency by ± 1000 Hz. Such tests are performed with one nominal bunch at 3.5 TeV and stable beams conditions. In order to do so, dedicated fills are needed and the qualification of the collimation system is needed on a regular base in order to check the validity of the setup and in order to track the changes in the cleaning efficiency over time.
- Daniel presented the loss map for B1 (v) for betatron losses at 3.5 TeV with a β*=3.5m, where the data were taken on 11th of August at 12:03 LT with a zoom into IR7 and IR3.
- Then he presented a summary about the development of the betatron local cleaning inefficiency (leakage into the cold aperture Q8 in IR7). The BLM data used for this analysis were the RS09 data (i.e. 1.3 sec integration time). Collimation setups were made in mid of June 2010 and mid September 2010. The design inefficiency for phase I is 4.5e-5 with imperfections of 5e-4.

- As a result one can see that the local cleaning inefficiency varied between 1.26e-4 and 6.08e-4. There is no clear trend of an increasing inefficiency. One value (data from 11th of August was measured to be around 5e-4 for B1-h what might be explained with a dump a few seconds after this measurement was taken (seen also in the TCTH and TCTV).
- Daniel started an analysis of losses during stable beam condition and is investigating the development of losses, the cleaning inefficiency and in which stage of operation the highest losses appear. He is comparing the losses for different BLM integration time signals (80µs, 0.64ms, 10.24ms and 1.3s). The run he presented in this meeting was done on 16th of October 2010 between 2:30-3:24 with 312 bunches in the machine. He was first showing the change of intensity during the stable beam condition and then the losses for different BLMs around the primary collimators in IR7 during collision, stable beams and beam dump for the different integration times mentioned above. The highest losses for this collection of BLMs were seen around the TCHSH monitors. Furthermore he presented the local cleaning inefficiency for this time period. The highest losses in general appear when the beams are put into collision, during the stable beam period the losses stay constant for each running sum and the local cleaning inefficiency in the cold aperture (Q8) increased after the beam were put into collision and stayed constant during the stable beams condition.

2.4 Preparation for Ions in the LHC (G. Bellodi, BE/ABP) – see slides

G. Bellodi presented the planning for preparation of the ion run.

- First Giulia presented an overview of the beam parameters to be used during the planned ion run (like bunch spacing=1350ns, β*=3.5m, Pb ions/bunch are 7e7, transverse .norm. emittance is 1.5µm, initial lumi is 0.7-1.26e25cm-2s-1, stored energy is 0.2-0.4MJ).
- Concerning the initial settings: the first setup will be made with 2 bunches per beam what is still safe for 3.5TeV. The nominal filling scheme has still to be finalized, a factor of 2.5 SBF reduction has been agreed on.
- The ramp and squeeze functions are ready in a dedicated hypercycle and most of the settings will be kep identical to protons except for RF, xings and collimation. The xing angle settings have to be maintained as for protons through injection, ramp and squeeze. The change to ion settings will be done at the end of the squeeze. The IP settings for ions are: LHCb and ALICE spectrometers are ON and 0 µd for IP1/IP5 and 140µrad for IP2 and 100µrad for IP8.
- For the orbit checks it is planned to do a cross calibration of the orbit reading with protons:
    1. Inject high intensity p bunch (Low BPM sensitivity)
    2. Correct against reference orbit
    3. Inject low intensity p bunch and record orbit (high BPM sensitivity)
    4. Inject an ion bunch and check that orbit is the same
    5. Define it as ions reference orbit
- Then a test ramp will be made with safe ion beam, collimators at injection settings and OFB on to establish the reference orbit up to high energy. During the squeeze the same orbit reference will be used as for protons and measure the optics.
- The ramp will be made with the same collimator settings as for protons until the end of the squeeze and the the xing angles at the IPs will be set up as well as the TCTs around the collision orbit. Only one collimator setting is needed at top energy. Concerning the shadowing of the ALICE ZDCs, the TCTVBs will be at 23mm. Loss maps will be taken at 3 critical points (IR3 and IR7) which needs 3-4 fills (injection, end of squeeze and collision).
- Giulia presented the simulated loss maps for ion runs for B1 in IR7 were highest losses are expected. The aperture losses are expected to be smaller than 0.04W/m. Also she showed the loss maps for collision where the aperture losses are expected to be less than 1W/m. She showed the results for different collimator settings.
- Then she presented the detailed commissioning planning for the ion run as well as the time needed to set up the machine.