Verena Kain, 2003-12-03

33rd Meeting of the LHC Collimation Working Group, November 28, 2003

Present: Ralph Assmann (chairman), Brennan Goddard, Verena Kain (scientific secretary), Helmut Burkhardt, Peter Sievers, Jan Uythoven, Rüdiger Schmidt, Vasilis Vlachoudis, Bernd Dehning, Hans Braun, John Jowett, Stefan Rösler, Mike Lamont, Jean Bernard Jeanneret, Oliver Aberle, Christian Rathjen, Eva Barbara Holzer, Elias Metral

1 Collimation of Lead Ions (H. Braun)

See slides at http://www.cern.ch/lhc-collimation/files/HBraun_28Nov03.pdf.

H. Braun (HBr) presented first results for collimation with lead ions based on his simulation tool ICOSIM.

Proton collimation and ion collimation differ in various aspects. Due to a factor of 100 less beam current and power for ions compared to protons impedance and additional activation for ion collimation should be minor issues. Beam induced desorption still has to be investigated. HBr mentions that it might be worse for ions and refers to experiences at RHIC. However, preliminary news of a recent experiment by E. Mahner in the SPS showed less dramatic increase than expected.

Also with ions the collimator jaws have to be sufficiently robust to make them withstand mishaps. The FLUKA calculations of V. Vlachoudis for a dump kicker single module prefire predict that the energy deposition in graphite at the impact face of the jaw is almost equal to the proton case. This observation is explained by ionization which is approximately 100 times larger for ions than for protons, despite a beam power of a factor of 100 less in the ion beam.

HBr's simulation tool ICOSIM reads in the lattice functions of the LHC produced by MAD-X. Another program linked to ICOSIM generates cross section tables for the fragmentation processes during the ion-matter interactions in the collimators (program: RELDIS & ABRATION/ABLATION of Igor Pshenichnov). The tracking in ICOSIM uses linear transfer matrices including chromaticity in quadrupoles to leading order and sextupoles in thin lens approximation. The aperture model is based on version V6.4. All apertures are approximated by ellipses. Hitting a TCP or TCS sets the flag for the treatment with the fragmentation code. The actual impact location is calculated via interpolation and the effective path-length through the material is determined with: $L_{eff} = b/(\Theta - x')$ (b: impact parameter, Θ: angle of collinearity of jaw, x': angle of particle). No backscattering is assumed. The output are loss patterns and collimation efficiency.

One of HBr's plots showed that conversion into daughter nucleus ^{207}Pb is most probable. P. Sievers asked whether a Pb ion having lost one neutron only in the collimation section could make another turn. HBr replied that it would stay within the acceptance of the machine, outside the bucket, and would be lost in the momentum cleaning area.

The diffusion speed which is needed to lose the particles on the TCPs (linear tracking from TCP to TCP and around the ring with slow increase of amplitude until all particles have hit a TCP) is still an open question. For simulating diffusion due to IBS, residual gas scattering etc. HBr sampled a distribution for impact parameters (0-800nm) at the primary collimators. R. Assmann (RA) would assume a diffusion speed of 1nm/turn.

For injection as well as for collision energy most of the ions impact on the second skew primary collimator. This is by the way the collimator which was thought of to be removed from the collimation scheme. Concerning losses downstream of the betatron cleaning insertion the dispersion suppressor next to IR7 is exposed to maximum heat load for both injection and collision (for injection energy it is the only area where ions are lost). The maximum load occurs at the MQ.11, where the dispersion peaks. While the numbers stay below the threshold for the injection case, the maximum heat load for continuous losses corresponding to a local collimation inefficiency of $2.7 \cdot 10^{-3}\mathrm{m}^{-1}$ is exceeded at several locations in the dispersion suppressor for collision energy. (The limits are 8.5W/m or alternatively 100W/cell.) Both simulations were done for assuming a lifetime (due to non IP beam loss mechanisms) of 20 minutes, which is still larger than 0.2h which is used for protons to define maximum loss rates.

HBr concluded that the simulations showed that in the ion case the 2 stage collimation does not work due to basic physics principles. This is true for daughter nuclei with A close to 208, the TCS might still have a function for catching the low energy showers. The poor collimation efficiency and significant losses in the dispersion suppressor could mean that for nominal ion parameters the lifetime (due to non IP beam loss mechanisms) would have to be at least higher than 20 minutes. Early ion scheme and injection seem to be OK.

R. Schmidt (RS) remarked that the uncertainties in the assumed maximum beam loss rates are a critical issue for these studies. J.B. Jeanneret (JBJ) said that HBr should try to find out what the minimum lifetime is that is still standable. RA added that small lifetimes for short times cannot be excluded, maybe one should think of installing additional absorbers. H. Burkhardt (HB) mentioned the thin scrapers in the SPS, which might be thick enough for being damaged by ion impact. HBr replies that the beam power is sufficiently small in the SPS.

2 First thoughts on BLMs for the LHC collimator tests in 2004 in the SPS and TT40 (E.B. Holzer)

See slides at http://www.cern.ch/lhc-collimation/files/EBHolzer_28Nov03.pdf.

The talk of E.B. Holzer (EBH) summarized the existing BLM infrastructure in the SPS and TT40, test possibilities for the BLM system (hardware, calibration) and possibilities for verification of physics models (predictions of particle flux and shower distribution).

In the SPS one monitor is installed next to each quadrupole. Electronics, chambers and supports are available for temporary installation of additional chambers. But the existing chambers and their electronics will be in saturation for the beam intensities proposed for the TT40 collimator test. Secondary emission chambers (SEM) could be used there (they would also be useful for the material test to record loss patterns). It is not clear whether a prototype of the SEM detector will be available by the time of the tests. Another problem might be manpower for additional preparative simulations. Data on topology of losses (longitudinal distribution of losses) for the experiment in the ring will not exist for comparison with test results.

Testing the hardware of the chambers is useful (e.g. measure maximum current of the ionization chambers to design the protection of the readout electronics). However, uncertainties of calibration might not be sorted out with the tests; she mentioned the quench level uncertainty and physics models uncertainties in the simulations.

A cross-check of MARS and FLUKA was not felt to be of priority. JBJ mentioned that the discrepancy between the two codes concerns most certainly diffractive physics at LHC top energy.

RA proposed to install 5 BLMs around the collimator in the ring (1 on top, 1 upstream, 3 downstream). In this way loss distributions could be investigated. The usage of BLMs together with the collimator test in the SPS ring will help to get experience with operational aspects such as aligning collimators with BLMs. It was thus agreed on the usefulness of having BLMs for the collimator test in the ring. The question of physics models could be addressed in the TT40 tests where the geometry and input conditions for the simulation are less complicated, the results should be more easily interpretable.

3 TDI setting and protection (B. Goddard)

See slides at http://www.cern.ch/lhc-collimation/files/BGoddard_28Nov03.pdf.

B. Goddard (BG) presented the results of his calculations for TDI settings. The TDI is a vertical absorber at nominally 90° phase advance from the vertically kicking MKI in IR2 and IR8. Its two jaws are set symmetrically around the injected beam and are in position during injection only.

The TDI setting is ideally between the extent of the secondary halo (7.88σ and the vertical aperture limit (8.2σ). Its purpose is to protect the LHC from mis-kicked injected beam.

In order to be able to exclude the loss of protection due to phase errors between the MKI magnets and the TDI, TCLI collimators have been proposed at $360 \pm 20°$ from the TDI. The location at Q7 (+20°) is no longer available because of an interference with a DFBX.

BG checked the protection functionality of the TDI with and without TCLIs. He also looked at TDI plus one TCLI at 360° from the TDI (the 1m long TCLI can be positioned more precisely than the TDI). His studies included realistic errors:

- position/angle error of injected beam: $\pm 0.2\sigma$
- phase error between MKI and TDI: $\pm 0 - 20°$
- precision between orbit and TDI/TCLI: ±0.1mm
- mechanical error of TDI (surface roughness,...): ±0.2mm
- mechanical error of TCLI: ±0.075mm

The damage limit he assumed for his calculations is 2% of a full batch (288 nominal bunches). This number is stemming from a talk by JBJ at the LCC in November 2001 and the project-note 141 by JBJ and O. Brüning . The expected rate of MKI flashovers is 1 flashover per 8 magnets per year (according to a measurement of 1 prototype magnet), the deflection per MKI cell is 1.09σ with 33 cells per MKI magnet and there are "two dangerous kick regions" (leading to impact on either the upper jaw or the lower jaw of the TDI).

His conclusions:

- no TCLIs and assuming:
  - phase errors between MKI and TDI smaller than 10°
  - setting of the TDI at 7.7σ (minimum real position at 7.2σ)

  Probability for a damage due to MKI flashovers: once in 5 years
- one TCLI at 360° from the TDI and assuming:
  - phase errors between MKI and TDI smaller than 20°
  - setting of the TDI at 7.7σ (minimum real position at 7.2σ)

  Probability for a damage due to MKI flashovers: once in 20 years
- two TCLIs and assuming:
  - phase errors between MKI and TDI smaller than 20°

– setting of the TDI at 7.9σ (minimum real position at 7.4σ)

Probability for a damage due to MKI flashovers: once in 40 years

(These results assume a perfect phase advance between the MKI and the TCLI.) It has to be checked whether it is possible to advance the TDI as far as 7.2σ (particle load on TDI, effect on collimation, activation and heating of TDI, possibility of inducing quenches in the insertion, etc.). The maximum possible phase error between the MKI and TDI for a single pass of the injected beam also has to be analyzed.

The TCLI location at Q6 (340° or 360°) is available, the reservation of the location should be checked. The only other possible location for an additional TCLI seems to be next to D1 (180° + 20°), downstream (for the injected beam) of the insertion. This position was foreseen for the TCTs (tertiary collimator). It has to be investigated whether the TCT could replace one TCLI during injection.

The setting of the TDI must be consistent with the collimation system, it restricts the operating range of the collimation system during all operation modes of injection (e.g. $\mathrm{n}_1 \leq 6\sigma$, $\mathrm{n}_2 \leq 7\sigma$).

4 Study of loss distribution with detailed aperture model (V. Kain, E.H. Holzer)

See slides at http://www.cern.ch/lhc-collimation/files/VKain_28Nov03.pdf.

V. Kain (VK) reported about the environment which had been set up for particle tracking studies with a detailed aperture model together with EBH.

The aperture model includes every change of aperture (at transition pieces, beamscreens outside of magnets, BPMs, bellows,. . .) in the dispersion suppressor and the arc downstream (for beam 1) of IR7. MAD-X is used to install in total 1288 additional markers with aperture information into the LHC sequence V6.4.aperture.seq (first marker at ∼235m from the IP7, last marker at ∼2845m from IP7). The tracking is done with the MAD-X tracking module, thus errors (orbit, misalignment, etc.) can be conveniently included in the simulations.

The output of the environment are longitudinal loss distributions (number of lost particles per m: $\mathrm{N_{lost}(s_i)}$), a list of all hit elements, the coordinates of the lost particles at each element with losses and the dilution length (the length over which particle losses are distributed). The dilution length is calculated as the total number of losses over the peak loss per m ($\delta\mathrm{l} = 1\mathrm{m}$).

$$\mathrm{L_{dil}} = \frac{\sum_\mathrm{i} \mathrm{N_{lost}(s_i)}}{\mathrm{maxN_{lost}(s_i)}/\delta\mathrm{l}}$$

The environment was tested with test particle configurations for collision energy (uniform distributions in x (y=0) or y (x=0), uniform distribution in x and y, with or without energy offset of particles). Cuts of amplitudes in phase space with and without energy offset of particles, comparison of loss locations with locations of minimum available mechanical aperture, loss distributions, etc. were investigated. No machine errors were included. The more dimensions were added to the initial distribution (horizontal, vertical, energy offset), the longer the dilution length became. The maximum dilution length of 17.6m was obtained for an uniform initial distribution in x and y plus energy offset ($\sigma_\delta = 0.001$). For this case 52% of the hit elements were quadrupole magnets and 40% were dipole magnets; The other loss locations were elements like beamscreens outside of the magnets and transition pieces.

These are preliminary results and will change with realistic initial particle configurations. RA will generate halo data at 450GeV which will be used to define the dilution length for the collimation system. L_{dil} defines the required cleaning inefficiency for a given quench level ([p/m/s]) and maximum loss rate ([p/s]). L_{dil} is assumed to be 50m for the time being.

5 AOB

The question of radiation damage to BI equipment caused by backscattering in the proximity of the collimator test location in TT40 was raised. Results should be available as soon as possible.

J. Uythoven mentions an additional CNGS-beam extraction, which might coincide with the planned collimator and material tests and preparations for the tests. This issue will be followed up.

E. Metral showed briefly the promising results of the impedance study for the new optics layout of IR7. He confirmed the prediction of an impedance improvement of a factor of 3. For $n_1 = 7$ the stability diagram showed that the LHC can be run with nominal parameters. See slides at http://www.cern.ch/lhc-collimation/files/EMetral_28Nov03.pdf.

The next meeting will be announced.