Minutes of 10^{th} Collimation Upgrade Specification Meeting

Participants: A. Bertarelli (AB), R. Bruce (RB), R. de Maria (RdM), L. Lari (LL), T. Markiewicz (TM), A. Marsili (AM) (scientific secretary), D. Mirarchi (DM), V. Previtali (VP) (Fermilab), E. Quaranta (EQ), B. Yee Randon (BYR), S. Redaelli (SR) (chairman), A. Rossi (AR), B. Salvachua (BS), D. Wollmann (DW).
Remote: R. Appleby (RA), R. J. Barlow (RJB) (Huddersfield University), J. Molson (JM), M. Serluca (MS), G. Stancari (GS), A. Toader (AT).

Indico event here.

1 The electron lens: fundamentals and first simulations (V. Previtali)

Slides are available at this link.

1.1 Summary of the presentation

VP introduced the concept of an ideal hollow electron lens from the point of view of the proton beam, and its effect on the 7 TeV LHC beam. The electron lens used at the Tevatron has a current of 1.2 kA and an extraction voltage of 5 kV. All simulations were done with SixTrack. This study is aimed at assessing if this hardware could be used with the LHC beam parameters. For this purpose, VP added an hollow e-lens routine in SixTrack to study systematically the effect of this device on the particle dynamics.

An ideal electron lens is a cylindrical distribution of uniformly distributed electrons. It is symmetrical and centered around the beam, and confined between two radii. The electrons and protons would travel in opposite directions, leading to a sum of electric and magnetic forces directed always radially inwards. The resulting field is non-linear and can not be expressed as a multipole. The effect on the protons traveling through the electron lens is the one of a kick always directed inwards like the force and increasing the proton phase x'. Depending on the phase at which the kick happens in the normalised phase space, it can increase or decrease the particle amplitude. The normalised phase space is then divided into four quadrants in which the amplitude will be increase or decreased. The probability to increase or decrease the amplitude of the particle is the same.

In DC mode (electron lens always switched on), there is no effect in average on the particle amplitude, i.e. there is no additional diffusion that causes losses of halo particles. Other effects can take place: the electron lens generates a tune shift that might lead the particles into a resonance; and it could deform the phase space. The tune variation is small ($\simeq 10^{-4}$), always positive, and depends on the initial conditions of the particles. Simulations showed that the effect on the phase space is negligible. In DC mode, the considered electron lens would not be effective for the LHC case 7 TeV, no collision.

In AC mode, two possibilities were be considered: the resonance mode, when the electron lens varies at the same frequency as the oscillations of the particles in the transversal plan; and a white noise, where the electron lens is switched on and off randomly. In resonance mode, the electron lens is only switched on when it gives a kick in the same direction as x'; that is, in the top left and bottom right quadrants of the normalised phase space. The resulting effect is that particles with different tunes will respond to different excitation modes. Once a particle is excited, it is lost on roughly 10^4 turns ($\simeq 1\,\text{s}$). In white noise mode, the electron lens is used as a slow diffusion enhancement. The maximum change of amplitude over one turn is $\simeq 1\%\,\sigma$. The amplitude slowly increases and the particles are lost in 10^4 to 10^7 turns (1 s to 1 min).

In conclusion, the SixTrack simulations of an ideal electron lens were presented, with three different operation modes. The DC mode is not effective for the studied case; the resonant mode leads to a scraping over a few seconds; and the diffusive mode creates a scraping over the scale of a minute.

1.2 Discussion

SR welcomed this new results. They indicate clearly that the available hollow e-lens used at the Tevatron could be used at the LHC.

GS noted that the considered electron lens is not very effective in DC mode for the considered LHC case. On the other hand, he pointed out that the increase of amplitude and tune change could couple to existing machine non-linearities to give a measurable effect also in this DC mode configuration. The change of amplitude caused by the electron beam can indeed cause the particles to explore different non linear regimes. This effect was measurable at the Tevatron. Giulio commented that a proper treatment of these effects will require more complex models that what was presented here (taking into account strong sources of non linearity).

GS also pointed out that it could be possible to increase further the current of the present hollow lens, if needed.

D. Wollmann asked what is the fastest speed of losses that could be excited. VP replied that this has to be studied in detail but probably 500-1000 turns could be achieved. This would clearly require a validation from the machine protection side before installation in the LHC.

SR asked if these simulation results are confirmed by the simplified simulations with LifeTrack by A. Valishev. GS replied that Sasha's simulation results are expected in a few days.

LR asked if one could have a bunch-by-bunch excitation to compensate the tune shifts beam-beam effects at the LHC. This would required a "filled", rather than hollow, beam. GS replied this this is possible in principle. This was initially planned for the Tevatron but did not work as expected (electron beams were used to clean the abort gap).

2 Loss maps simulations with Merlin (J. Molson)

Slides are available at this link.

2.1 Summary of the presentation

JM presented Merlin, a C++ library for accelerator physics. It provides a modular design made out of three sections: lattice design, tracking, and physics processes. The lattice creation can be loaded from MadX or XTFF format. All elements and all characteristics can be manipulated individually: aperture, field, alignment, wake, etc. Merlin can track particles or moments along the accelerator and within individual elements. Physics processes can be added on top of the tracking, such as synchrotron radiation, collimation, wake fields, etc. The physics processes are applied during tracking. Merlin can take many accelerator errors: offset in x, y, s and tilt, additional multipoles, etc. Merlin has been extended to allow simulation of collimation cleaning at the LHC, offering similar functionality that what is provided by SixTrack. Another of Merlin's strong point is the parallel running: it can run parallel copies of the same binaries which interact.

JM presented some comparisons between the results of Merlin and those of SixTrack, for the 2012 4 TeV LHC loss maps. The optics input calculated by Merlin or by MadX are exactly the same. The simulated loss maps look very similar. Detailed comparisons between the two tools must be done offline. For this purpose, JM and MS will be visiting CERN next week for a few days.

JM presented the different aspects of scattering physics used in Merlin, including elastic scattering and single diffractive scattering. The range of interest is for beam energy between 450 and 7000 GeV. JM presented the fits of all appropriate existing pp and $p\bar{p}$ data for different energies.

In conclusion, the Merlin code can now generate the same LHC loss maps as SixTrack, in its scattering mode. In addition, the implementation of new scattering fits is now almost complete, as well as new material classes to simulate new collimator designs.

2.2 Discussion

SR asked if the simulations are also available for B2. JM replied that there should be no problem to set them up but this was not yet tried. SR also asked if the location of losses are also checked outside the volume of magnetic elements (i.e. in the parts that are considered as drifts in MADX). JM replied that this is the case. Checks can be done with arbitrary space resolution.

SR and RB commented that it would be nice to compare systematically the effect of the different scattering routines on the loss map results. Based on the outcome of these results, we could consider to upgrade the SixTrack models accordingly. The assumption adopted so far is that small difference in the scattering routines are smaller compared to other effects of imperfection and errors, which are properly implemented in SixTrack.

SR asked if one can run tracking simulations with Synchrotron radiation for proton beams. JM replied that this is the case. SR commented that this could be considered as an option for EQ, who is working on modeling the IR3 cleaning in various conditions.