Session summary: IR upgrade II (afternoon)

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The session was devoted to crab cavities and beam-beam effects. A total of 5 presentations were made.

R. Tomás, CERN, reported on a “Crab cavity IR design with 8 mrad crossing angle”. The basic parameter of this design are $\beta^* = 0.25$ m, $\theta = 8$ mrad, $L^* =$ 23m, 0.53 m of cavity radius (R. Calaga’s design), and 25 m of available space per ring. Compared to the current IR layout, additional quadrupoles and dipoles are required. The magnets in the design can be built with NbTi technology, the Q1 quadrupole is the most challenging magnet. The dynamic aperture of the lattice is dominated by the magnetic field errors in the large dipoles, and local correctors are required. A factor of 2 in luminosity can be gained from the optics, while long-range beam-beam effects become negligible.

R. Calaga, BNL, presented “Crab cavities in LHC”. After reviewing the history of similar cavities from 1960 to today, global vs. local crab compensation schemes were discussed. KEKB uses a global scheme. In the LHC a global scheme with a crossing angle larger than 2 mrad is not possible, in the range between 4-6 mrad unusual separation quadrupoles would be needed. At 8 mrad, the design can be simplified again. For an 8 mrad crossing angle and a frequency of 400 MHz, about 100 MV are required. Estimates for the required noise level look pessimistic currently. A fair amount of R&D would be required to develop the crab cavities. There is, however, some overlap with the crab cavity R&D effort for the ILC.

J. Tückmantel, CERN, showed “Technological aspects of crab cavities”. With a frequency of 400 MHz and the present horizontal separation of the beams only vertical kicks can be provided. For horizontal kicks a different cavity shape, or more separation between the rings is needed. The Nb on Cu technology may be an option for the crab cavities, if the film quality for the desired shape can be validated. A n-cell cavity (n small) and N cavities per transmitter should also be possible, with with somewhat higher noise. The effect of the different noise sources (amplitude, phase, also between cavities) has to be analyzed in more detail to find the best technical solution. It is also not yet clear if it is a real problem that each bunch has its individual phase. The requirements for the noise level is an order of magnitude beyond present technology. While this does not exclude the technology, some caution should be exercised.

K. Ohmi, KEK, rendered a presentation on the “Beam-beam effect with external noise in the LHC”. Weak-strong and strong-strong simulations are uses to evaluate the noise effect. High-statistics simulations are needed to distinguish an emittance growth time of 1 day from noise. Two types of noise were studied: orbit fluctuations at the collision point, and orbit diffusion and damping. Both types of noise can be created by noise in the crab cavity rf system. For the first type of noise, a tolerance of $\delta x/\sigma_x = 0.2\%$ is obtained from a weak-strong simulation, and requiring an emittance growth time of 1 day. The noise correlation time in this simulation is 1 turn. In a strong-strong simulation, the tolerance is only $\delta x/\sigma_x = 0.1\%$ for 1 turn of noise correlation time, but $\delta x/\sigma_x = 1\%$ for 100 turns. A comparison with a calculation using a formula developed by T. Sen shows agreement within about a factor 2. For a luminosity lifetime of 1 day, this gives a tolerance of $\delta x = 0.2$ μm (0.012 σ) and $\delta\phi = 0.5$ deg for a noise correlation time of 100 turns, and a 10 times tighter tolerance for a noise correlation time of 1 turn. For the second type of noise, a strong-strong simulation gives a tolerance of $\delta x_{kick} = 0.0002\ \sigma$ for $G = 0.1$ (see paper for explanation), $\delta x_{mon} = 0.1$ %, and again a luminosity lifetime of 1 day.

V. Shiltsev, FNAL, posed and answered the question: “LHC electron lenses: what are they good for?”. An electron lens can be seen as a frozen electron cloud. The parameters of an electron lens that can be controlled include current, diameter, length, position, timing, velocity, shape, angle, and direction. In the Tevatron an electron lens has been proven to reliably induce emittance growth and remove unwanted beam in the abort gap. In 5 years (or more than 1000 physics stores), no store was aborted because of the electron lens. More recently a second lens was added, which acts on selected bunches in almost every physics store, and has not caused operational problems. Possible used of an electron lens in the LHC include head-on beam-beam compensation, beam stabilization through the controlled introduction of tune spread, soft hollow collimation, and beam conditioning. RHIC is a good test bed for head-on beam-beam compensation with electron lenses.

An LHC upgrade with crab cavities poses a number of technological challenges, and the IR modification for a large crossing angle would reduce the luminosity if the crab crossing scheme does not work. Experience with the KEKB crab cavity, soon to be in operation, will be very useful in further evaluating this option. But even if a large crossing angle with crab cavities is not considered for the first LHC IR upgrade, it may be still be a viable option for a second upgrade. Furthermore, crab cavities can also be useful for small crossing angles with magnets integrated in the detectors, without the risk of a luminosity downgrade should the crab scheme not work. Electrons lenses in the Tevatron are by now an operational device. For consideration as a beam-beam compensator, the demonstration of the functionality in operation would be desirable. For this, RHIC could serve as a test bed.

I am grateful to the speakers and the other participants for discussions and comments.

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