13.10.2 Long-Range Beam-Beam Compensation

Due to the small bunch spacing, the LHC beams experience 15 'near-misses' on each side of each collision point. In IP1 and IP5, the beam separation is 9.5σ on average. In the other two collision points, the normalized separation is larger and their contribution to the long-range beam-beam effect can be neglected. The non-linear part of the long-range interactions appears to be the dominant mechanism for single particle instability [13.10.2-1], even though the tune spread is small enough (footprint criterion). A very fast diffusion in amplitude is observed for beam amplitudes of 6 to 8σ.

The topology of the long-range interactions in LHC makes it possible to devise a simple but accurate weak-strong model where the weak beam, assumed round, is perturbed by currents flowing in wires on either side of the crossing points (strong beam). This model leads naturally to a compensation system [13.10.2-2] made of genuine wires excited by a constant current for the compensation of the normal bunches or by a pulsed current in an option where the PACMAN bunches would be individually corrected.

These wires run along the beam at positions where the beams are already in separate channels. They should be placed between the two channels for a horizontal crossing and above or below for a vertical crossing. The beam-wire distance should be equal to the beam separation at the long-range interaction points (9.5σ). Studies of robustness show that they can be further retracted to 12σ, i.e. well in the shadow of the collimators. The wire excitation is 80A×m on each side of each crossing point. The β-function is not relevant (provided it is the same in both planes). The phase advance between the perturbation and the correction must be as small as possible to correct all non-linear terms and not only the detunings. The strong focusing of the LHC low-β sections allows suitable positions to be found at 112m from the crossing points. They have been reserved. The phase shift is only 2.6 degrees and the beam channels already sufficiently separated. Numerical simulations [13.10.2-3] show that particles up to 7σ are stabilized by the compensation system, i.e. all particles within the collimator acceptance. The robustness of the scheme appears high for all dc effects (errors in excitation and position). The ripple must not exceed 1 per mil to prevent heating the beam.

A 1.25mm radius (about 1 beam σ) hollow Cu wire was installed in the SPS to exercise both the physics and the technology. The wire is brazed on alumina insulators themselves brazed on stainless steel supports. Each of the two devices has an active length of 60cm. The high current density (~100 A/mm2) requires cooling. Water cooling was chosen for the SPS to meet a tight schedule. Purely passive cooling by conduction appears possible and is preferred for LHC, unless super-conducting wires can be used. The onset of strong diffusion in a situation representing the nominal LHC seems now detected [13.10.2-4]. Confirmation will be obtained in 2004 by adding other such devices to compensate the perturbation in a situation close to that of the LHC.

REFERENCES

[13.10.2-1] Y. Papaphilippou, F. Zimmermann, 'Weak-strong beam-beam simulations for LHC', CERN-SL-99-039 AP, 1999.

[13.10.2-2] J.P. Koutchouk, 'Correction of the Long-Range Beam-beam Effect in LHC', IEEE PAC2001, Chicago (2001).

[13.10.2-3] F. Zimmermann, `Weak-strong simulations studies for the LHC long-range beam-beam compensation', Proc. of beam-beam Workshop, Fermilab, June 2001.

[13.10.2-4] J.P. Koutchouk, J. Wenninger, F. Zimmermann, in work.