Observation of dynamic transverse emittance exchange in SIS-18

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The theory of linear coupling and the consequent dynamic emittance exchange is well known [1]. Transverse beam emittance exchange due to linear coupling was observed in SIS-18 during regular accelerator operation. Skew-quadrupoles are installed at GSI SIS-18 to control and utilize the linear coupling e.g. for optimization of the injection efficiency [2]. However, these skew-quadrupoles are not used during the normal operations, and any linear coupling due to misaligned magnets is usually neglected. Careful measurements were performed to verify the role of tune crossing on this exchange process. Preliminary attempts for compensation of linear coupling were made, using the emittance exchange as a diagnostic observable.

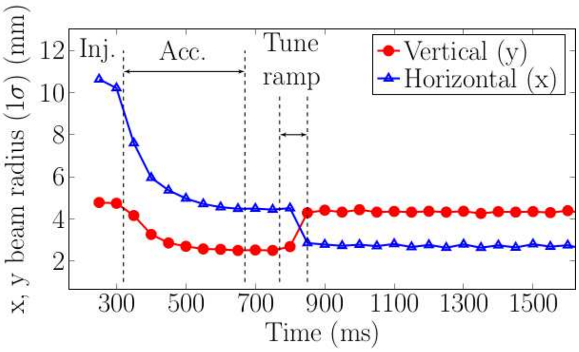

Figure 1: Evolution of the beam radii during the acceleration cycle during the high intensity operations at SIS-18.

Figure 1 shows the evolution of horizontal and vertical beam dimensions measured using an Ionization profile monitor (IPM) during the acceleration cycle for a high intensity (10^{10} stored particles) N^{7+} beam in the slow extraction mode. The high intensity working point at injection is $Q_x = 4.16$ and $Q_y = 3.29$. On the extraction flattop, the horizontal tune was ramped from $Q_x = 4.16$ to $Q_x = 4.33$ in $\approx$ 100 ms for the resonant slow extraction. Simultaneous transverse Schottky measurement established that the tune crossing and thus the linear coupling was the cause of this exchange. Figure 2 (top) shows the time evolution of the transverse beam profile before and after the exchange.

In follow-up measurements during summer 2014, emittance exchange was regularly observed due to tune crossing. This emittance exchange due to "residual" linear coupling is undesired since it led to beam losses when the vertical aperture could not accommodate the larger vertical beam due to emittance exchange. Therefore, first attempts for compensation of linear coupling were performed. The emittance exchange served as an online diagnostic for linear coupling. A scan of relative strengths of the two skew-quadrupoles was made such that, a compensation vector opposite to the natural skew error was constructed. Figure 2

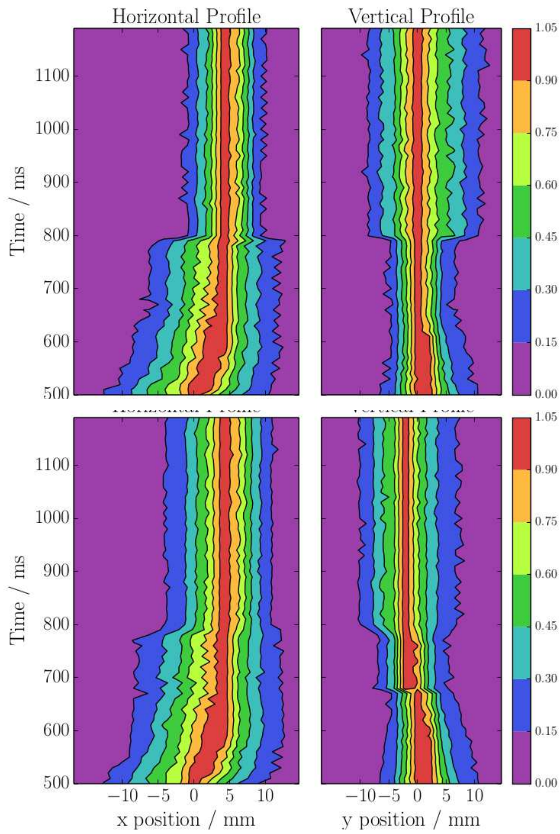

Figure 2: Horizontal and vertical beam profile evolution during the emittance exchange process for uncompensated (top) and compensated (bottom) linear coupling.

shows a comparison of transverse beam profile evolution with (bottom) and without (top) compensation. The plot shows the emittance exchange and a partial compensation of linear coupling. The reasons for partial compensation of linear coupling are unclear. Perhaps, the minimum strength of skew quadrupoles was too strong for construction of appropriate compensation vector. Linear coupling has been utilized beneficially at several synchrotrons and a better control of linear coupling is foreseen at SIS-18.

References

[1] A. Franchi et al., "Emittance sharing and exchange driven by linear betatron coupling in circular accelerator", PRST-AB 10, 064003 (2007)

[2] W. Daqa et al., "Linear Coupling With Space Charge in SIS18", Proceedings of IPAC10, Kyoto, Japan (2010)

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