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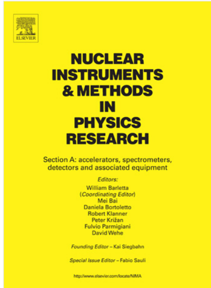

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Injection optimization through generation of flat ion beams

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Abstract

An excellent interfacing between injector linac and synchrotron is mandatory to provide ion beams of unprecedented intensities and qualities. One consequence of the single-plane Multi-Turn Injection (MTI) is that the required injection emittance for the injection plane (usually the horizontal one) is very demanding; to the other plane not. Re-partitioning of the injected beam emittances, i.e. round-to-flat transformation would increase the injection efficiency. This benefit effect to the MTI performance of a smaller emittance has been measured as a function of the amount of flatness of the beam. An excellent agreement between simulation and measured injection performance as a function of the injected emittance was achieved thanks to fast adjustment of the beam flatness without changing other beam parameters.

Keywords: injection, loss, round-to-flat transformation, emittance reduction

1. Introduction

For heavy-ion synchrotrons an efficient injection from the injector linac is crucial in order to reach the specified currents using the available machine acceptance. The FAIR heavy-ion synchrotrons are operated with intermediate charge state ions in order to increase the space charge limit. Therefore, stripping injection is not an option and the injection has to respect Liouville's theorem for the chosen charge state - avoiding the already occupied phase space area. To reach the space charge limit the multiplication of the injected current should be as large as possible. Beam loss during Multi-Turn Injection (MTI) must not exceed the limits determined by machine protection or vacuum requirements. Especially for low energy and intermediate charge state ions, beam loss can cause vacuum degradation and corresponding reduction of beam lifetime [1–4]. Beside the space charge limitation the loss-induced vacuum degradation is an important key intensity limiting factor. It exists an intensity threshold, where a further increasing of the injected intensity reduce the extracted intensity. This intensity threshold is lowered by injection loss [5]. In order to improve the MTI performance of the SIS18 synchrotron at GSI and define a range of suitable injector brilliances for given initial loss a genetic algorithm based optimization has been used [6]. The optimization resulted in a significant improvement of MTI performance and subsequent transmission for intense beams. However, the required MTI brilliance should be reachable for the injector linac.

One consequence of single-plane MTI is that the effective acceptance in the injection plane (usually the horizontal one) is reduced w.r.t. the acceptance in the other transverse plane. The two transverse emittances of the injected beam are generally similar to equal. The case may rise that the injected beam emittance is within the vertical acceptance budget but not within the horizontal acceptance budget for high MTI performance, although the product of its two emittances is lower than the product of the two effective acceptances. The MTI performance is thus reduced by not favorable emittance partitioning of the injected beam rather than by the product of the two emittances. Re-partitioning of the beam emittances, i.e. round-to-flat transformation allows to eliminate this reduction in injection efficiency.

For electrons round-to-flat transformation has been proposed in [7] and it was demonstrated experimentally in [8–10]. For ion beam lines instead it has been conceptually proposed in [11]. It turned out this EMTEX (EMittance Transfer EXperiment) beam line has very appealing features as performing the emittance partitioning by adjusting just one single magnetic field value, preserving the Twiss-parameters of the re-partitioned beam [12]. This preservation is derived analytically in [13] and it has been measured in [14]. Other transverse emittance reduction techniques, like beam collimation for instance, do not have this advantage.

This paper is on injection of such an re-partitioned