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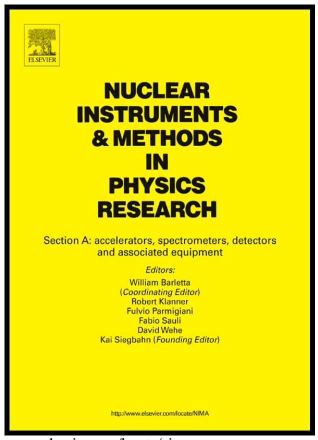


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PII: S0168-9002(16)31236-0
DOI: http://dx.doi.org/10.1016/j.nima.2016.11.069
Reference: NIMA59488

To appear in: *Nuclear Inst. and Methods in Physics Research, A*

Received date: 24 June 2016
Revised date: 30 November 2016
Accepted date: 30 November 2016

Cite this article as: S. Appel, O. Boine-Frankenheim and F. Petrov, Injectior optimization in a heavy-ion synchrotron using genetic algorithms, *Nuclear Inst and Methods in Physics Research, A* http://dx.doi.org/10.1016/j.nima.2016.11.069

# Injection optimization in a heavy-ion synchrotron using genetic algorithms

S. Appel[a,*], O. Boine-Frankenheim[a,b], F. Petrov[b]

[a]*GSI, Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany*
[b]*Technische Universität Darmstadt, Schlossgartenstraße 8, 64289 Darmstadt, Germany*

**Abstract**

The control of the beam loss induced dynamic pressure is one of the most challenging problems for synchrotrons operated with high intensity beams of intermediate charge state ions. This loss-induced vacuum degradation and associated life-time reduction is one of the key intensity limiting factors. Beam loss during Multi-Turn Injection (MTI) can trigger the pressure bump instability. An optimized injection can relax the dynamic vacuum problem, but is also crucial to fill optimal the available machine acceptance. A numerical model has been developed to describe the intensity limitation due to loss-induced vacuum degradation. In order to optimize the multi-turn injection for given initial losses, a genetic algorithm based optimization has been performed. For the SIS18 synchrotron at GSI the optimization resulted in a significant improvement of MTI performance and subsequent transmission for intense beams. A range of suitable injector brilliances for given initial loss could be defined. This information is crucial for the layout of the injector upgrade for FAIR. The effect of transverse space charge force on MTI has been included in the optimization studies.

*Keywords:* injection, loss, vacuum degradation, performance, genetic algorithms, space charge



## 1. Introduction

The present study focuses on the injection optimization of the heavy-ion synchrotron SIS18 for intermediate charge state ions. The SIS18 will serve has a booster in the FAIR facility to provide ion beams of unprecedented intensities and qualities. An optimized interface between injector linac and synchrotron is mandatory to achieve this goal. The brilliance, which relates the provided beam intensity to the beam emittance, is the adequate parameter for defining the beam requirements at injection for a given injection loss, see Fig. 1. This information is crucial for the layout of the injector upgrade for FAIR [1].

The bottleneck, which can significantly reduce the heavy-ion synchrotron performance is the loss-induced vacuum degradation (VD). Unfortunately, for intermediate charge state ions beside the space charge limitation the loss-induced vacuum degradation is an important key intensity-limiting factor. Although over the years an intense and successful upgrade program has been implemented, the observed vacuum degradation is still a serious problem for SIS18. This process, also called dynamic vacuum, can reduce the beam lifetime significantly [2–4]. Therefore the beam loss during multi-turn injection (MTI) must not exceed limits determined by vacuum requirements.

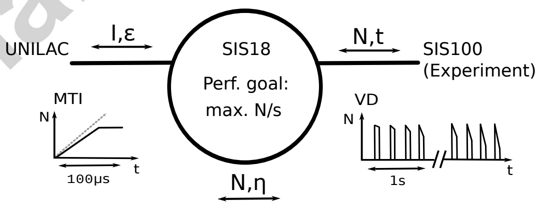


Figure 1: Location of SIS18 along the ion beam production chain and the beam parameter interfacing. The SIS18 receive due to a Multi-Turn Injection (MTI) heavy ions form the injector UNILAC and transmit the ions over four acceleration cycles (so-called ion super-cycle) to the SIS100. The loss-induced vacuum degradation (VD) leads to transmission reduction.

Because of the flexibility of SIS18 in providing a broad range of ions, non-Liouvilian injection schemes can not be employed and the MTI has to respect Liouville's theorem avoiding the already occupied phase space area. To reach the intensity limit the multiplication factor of the injected current should be as large

*Corresponding author
*Email address:* s.appel@gsi.de (S. Appel)