# Optimization of the multi-turn injection

*S. Appel*[1], *O. Boine-Frankenheim*[1,2], *L. Groening*[1], *Y. El Hayek*[1], *M. Maier*[1], *C. Xiao*[1]
[1] GSI, Darmstadt, Germany, [2] TU, Darmstadt, Germany

The multi-turn injection (MTI) into the SIS18 is one of the bottlenecks for providing ion beams of unprecedented intensities and qualities for FAIR. An optimized injection is also crucial for an excellent interfacing between injector linac and synchrotron. The loss-induced vacuum degradation and associated life-time reduction is one of the key intensity limiting factors for SIS18. Beam loss during injection can trigger the pressure bump instability. An optimized injection can relax the dynamic vacuum problem, but is also crucial to reach the synchrotron intensity limit by a large multiplication of the injected current. For the SIS18 the optimization with genetic algorithms (GA) resulted in a significant improvement of MTI performance and subsequent transmission for intense beams [1]. A loss-free or low-loss injection over many turns were identified. The dependence between gain factor and injection loss is shown in Fig. 1. GA optimization found a much better MTI performance than the previous simulation studies in [2]. Space charge results in a similar MTI performance, but with different injection settings. Using a global residual gas pressure and beam lifetime model together with the optimized multi-turn injection a range of injector brilliance could be defined. This crucial information gives more flexibility for the injector upgrade layout for FAIR [3] and allow an excellent interfacing between injector linac and synchrotron. One consequence of the single-plane 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. The injection performance has increased significantly up to about 30% shown in Fig. 2. 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 [4]. The flat beam injection scheme is a scenario for an additional upgrade of the existing UNILAC which may be necessary if the other upgrade measures [3, 5] including a well optimized injection turn out to be not sufficient to reach the beam parameters imposed by FAIR.

Further opportunity to enhance the MTI performance is to injected into both space phase planes. One possibility is to used skew quadruples during injection to couple both planes. The other is to rebuild the SIS18 injection section and transfer channel for the advantage of two-plane injection. Injection optimization simulation studies with this mentioned methods are ongoing. After the undergoing construction work at SIS18 has been finished, it is planned to test an online injection optimization with the new implement and more flexible control system. First online GA optimization test as been already performed at CRYING injector [6].

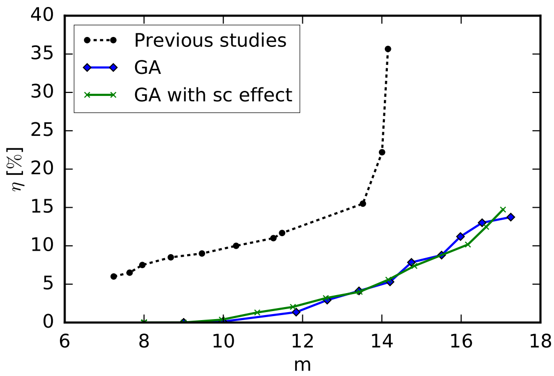


Figure 1: The GA optimization found much better MTI performance than the previous simulation studies [2].

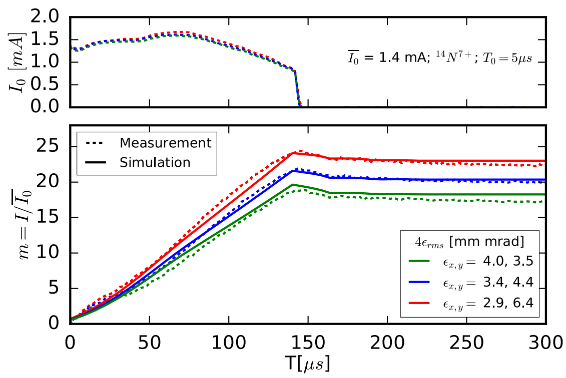


Figure 2: MTI optimization through emittance transfer.

## References

[1] S. Appel, el al, Nucl. Instr. and Meth. A 852 7379 (2017), http://dx.doi.org/10.1016/j.nima.2016.11.069.

[2] S. Appel, O. Boine-Frankenheim, arXiv:1403.5972 (2014).

[3] L. Groening et al, PRL 113, 246802 (2014)

[4] S. Appel, et al, Injection optimization through generation of flat ion beams, submitted to Nucl. Instr. and Meth. A (2017).

[5] L. Groening et al, Upgrade of the Universal Linear Accelerator UNILAC for FAIR, Proc IPAC2016 (2016).

[6] S. Appel et al, Automatized Optimization of Magnet Settings using Evolutionary Algorithms, Proc IPAC2017 (2017).

DOI:10.15120/GR-2017-1 