Ion Beam Collimation for the FAIR Synchrotron SIS100

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Abstract

The two-stage collimation system for the SIS 100 synchrotron has to operate with protons as well as with light and heavy fully-stripped ions (\(\text{H}^+\), \(\text{He}^{10+}\), \(\text{Au}^{79+}\)). The concept and basic design features of the betatron halo collimation system in SIS 100 were developed previously for proton operation. The main task of the presented work is to compare the efficiency of proton and ion beam collimation. For this purpose multi pass tracking of halo particles was performed using MAD-X (including the simulation of scattering process and energy loss in the collimators using the ATIMA code). The collimation efficiency as a function of the ion species together with the detailed beam loss distribution along the ring circumference are presented.

Simulation of collimation efficiency

(i) Angular distribution of the ions scattered in the primary collimator is approximated as Gaussian with the r.m.s. width calculated using the Moliere theory of multiple Coulomb scattering by ATIMA code [3].

(ii) The stopping power in a material is calculated using Bethe-Bloch formula. For calculations of the stopping power of high relativistic heavy fully-stripped ions ATIMA code use Lindhard and Sorensen theory [4], which imply several corrections to standard formula.

(iii) Tracking of halo particles in MAD-X [5] with given accelerator optics and physical aperture.

Motivation

Beam halo is non-Gaussian tails of a beam. It occurs due to beam imperfections (e.g. instabilities, ISIS beam mismatch) and machine imperfections (RF noises, magnet errors and misalignments).

The two-stage betatron collimation system [7] consists of the primary collimator (thick foil) which scatters halo particles and the secondary collimators (bulky blocks) which absorb the scattered particles. Some particles may escape collimators after single pass and be lost in the lattice or be scattered again in the collimation system.

Principles of collimation

The concept of two-stage collimation is considered for protons and fully-stripped ions. The primary collimator is a 1 mm thick tungsten foil. The secondary collimators are 40 cm long blocks. The primary collimator have a rectangular aperture with movable jaws.

Collimators in SIS 100

Taking into account technical aspects of SIS 100 synchrotron [2], the following design of the collimation system has been developed:

- Primary collimator has a rectangular aperture with movable jaws.
- The primary collimator is a 1 mm thick tungsten foil.
- The secondary collimators are 40 cm long blocks.

Impact parameter

The impact parameter \(\beta\) is the typical transverse offset from the edge of a primary collimator jaw for the particles impacting the collimator. The impact parameter is proportional to the size of the emittance growth. The slope of the beam envelope at the location of the primary collimator gives different effective thickness of the foil for different impact parameter.

Effect of lattice errors

To estimate the influence of the lattice errors on the collimation performance the closed orbit distortion was included in the particle tracking simulations. Closed orbit distortion with r.m.s. value of 6.8 is a result of transverse positional error of magnets edges.

Conclusion

It has been shown that conventional method of betatron halo collimation can be applied for fully-stripped light and heavy ions in the SIS 100 synchrotron. The main reason of higher level of ions leakage with the growing mass number is the increasing momentum losses. After certain level of momentum losses a halo particle in an accelerator could not make one turn to be scattered by the primary collimator again.

References

2. P. Spiller et al., "Status of the SIS 100 heavy ion synchrotron project at FAIR", IPC/13, Shanghai, May 2013, THPGO111.