Parameters of Electron Cooled Ion and Antiproton Beams in the NESR

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The NESR ring of the FAIR project [1] will store highly charged radioactive and stable ion beams for internal experiments and decelerate ions and antiprotons for transfer to FLAIR. A powerful electron cooling system has been designed [2], covering the full energy range (740-4 MeV/u) for ions and allowing intermediate cooling in the range 800-30 MeV during the deceleration of antiprotons. It will provide highest phase space density of the stored beams, compensate the diffusion of the beams during deceleration and support the accumulation of RIBs in order to achieve maximum luminosity for the collider mode [3].

Beam dynamics studies have been performed to estimate cooling times and beam parameters in the NESR, which are needed (i) for ring design studies e.g. optimization of deceleration and accumulation schemes, definition of RF systems and cycle times, (ii) by the experiments and (iii) by the users of extracted beams. The BETACOOL code [4] was used to investigate the dependence of the cooling time and the equilibrium parameters (transverse emittances and momentum spread) of the electron cooled beams on the initial beam parameters, for realistic operation parameters of the electron cooler [5]. Parkhomchuk's formula [6] with an effective electron velocity corresponding to magnetic field misalignments of 5×10^{-5} is used for the cooling force and the Martini model [7] for Intrabeam Scattering. A magnetic field strength of 0.2 T in the cooling section was assumed.

For ion beams at the maximum injection energy of 740 MeV/u, cooling times of less than 0.5 s were calculated, if the pre-cooled beam from the Collector Ring (CR) is cooled with an electron beam of 1 A. An example is shown in Fig. 1. Even if momentum spread and emittance are twice as large as the design value of the CR, the cooling time does not exceed 1.5 s. Thus, the experiments can fully benefit from the planned cycle time of 1.5 s of SIS100. For the deceleration mode, similar calculations were made at the intermediate and lowest energies at which electron cooling is applied [5]. Due to space charge limitations for highly charged ions at the lowest energy of 4 MeV/u, a maximum intensity of 5×10^7 cooled ions is estimated. This intensity limit is further reduced, if the beam is compressed into a short bunch for transfer to FLAIR.

The conditions for electron cooling are less favorable for antiprotons which are injected at 3 GeV, at larger momentum spread and emittance [1]. Due to their low charge the cooling time can be of the order of minutes as shown in Fig. 2. An adiabatic growth of the beam parameters is assumed during the deceleration from 3 GeV to 800 MeV. The cooling time for antiprotons with a deviation of 1σ of the distribution after stochastic pre-cooling in the CR is 150 s, even with an electron beam current of 2 A. If the experiments request deceleration cycles below 1 minute, better pre-cooling must be achieved. This should be possible by additional stochastic cooling in the RESR.

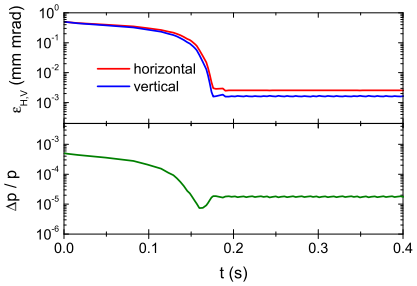

Figure 1: Simulation of electron cooling of a coasting beam of 10^8 $^{132}Sn^{50+}$ ions at 740 MeV/u. The initial beam parameters correspond to the pre-cooled beam from CR. Electron beam current: 1 A.

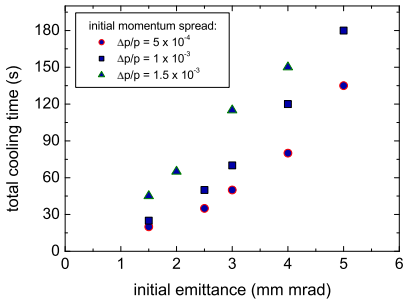

Figure 2: Total cooling time for antiprotons at 800 MeV as a function of transverse emittance and for different initial momentum spreads. Electron beam current: 2 A.

This study also confirmed the necessity of a high-quality magnet system and of electron currents of up to 2 A for fast cooling of short-lived isotopes. However, short cooling times crucially depend on the beam parameters after pre-cooling in the CR and RESR.

References

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