LAYOUT OF A NEW EXPERIMENTAL STORAGE RING NESR AT GSI

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Abstract

A new experimental storage ring (NESR) is part of the new beam facility proposed recently for GSI. The NESR will serve experiments with rare isotopes as well as atomic physics experiments. Additionally the NESR shall be capable to accumulate 7×10^{10} antiprotons per hour by applying stochastic cooling. The lattice has to provide maximum space for the different experimental installations and has also to fulfill the requirements of the stochastic cooling system. This contribution presents the conceptual design as well as lattice studies relevant for the different tasks of the ring and first beam dynamic calculations.

1 CONCEPTUAL DESIGN CONSIDERATIONS

The NESR will be a part of the future facility which is proposed by GSI [1]. As a multi purpose machine this ring will serve several tasks.

The higher intensity of secondary beams provided by the new facility will allow new kinds of experiments. One main task of the NESR are collision experiments between circulating bunches of rare isotopes and counter-propagating electron bunches circulating in an electron storage ring. The goal of this experiment is the determination of nuclear charge radii and charge distributions. Besides this, an internal target and an electron cooler will be available for experiments. Additionally the NESR offers the possibility to decelerate the rare isotope beams.

Atomic physics experiments at the NESR will focus on interactions with an internal gas-jet-target and free electrons in the electron cooler. An additional electron target will allow experiments with cooled ions and electrons of adjustable relative velocity. Atomic physics experiments will also benefit from the possibility to decelerate beams of highly charged ions in order to reduce Doppler effects.

The layout of the new facility foresees as a third task of the NESR the accumulation of antiprotons. After production by an intense proton beam and stochastic precooling in the new collector ring CR [2] batches of up to 8×10^{7} antiprotons are transferred to the NESR at 3 GeV with a cycle time of 5 s. Accumulation over several hours will allow the generation of very intense antiproton beams of up to 10^{11} particles (7×10^{10} antiprotons per hour). The accumulation scheme will employ longitudinal stacking using a stochastic cooling system for beam cooling. The accumulation process will be followed by the transfer of the antiprotons to the new synchrotron SIS100 for further acceleration to the energy required for experiments in the new storage ring HESR [3].

Ions and antiprotons will be injected along the same transfer line. This means the polarity of all ring and beamline elements has to be reversible. Changing the species will require considerable hardware modifications. Therefore the typical time period with one of the two species will be months rather than weeks.

2 LAYOUT OF THE NESR

The New Experimental Storage Ring is designed with a rectangular shape providing maximum space for experiments. Four long straight sections are foreseen for the main experimental installations. Each straight section has a magnet free space of 18 m. Figure 1 depicts the layout of the NESR. The main ring parameters are listed in Table 1.

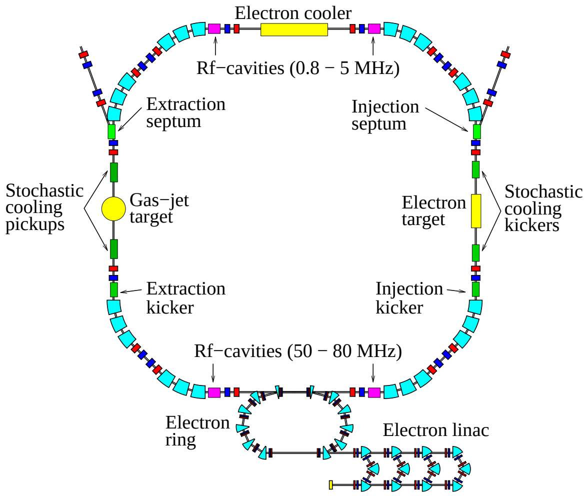

Figure 1: The NESR layout foresees a rectangular shape with four straight sections for the main experimental installations.

The NESR has a circumference of 208.5 m. The magnetic structure consists of 24 dipole and 32 quadrupole magnets. Although normal conducting dipole magnets could be used, also advantages of superconducting magnets are investigated. In both cases the maximum field strength will amount to 1.6 T. Due to the maximum bending power of 13 Tm the maximum ion energy for the reference particle ($A/q = 2.7$) will be 784 MeV/u. Acceptances amount to 100 mm mrad in the horizontal and 50 mm mrad in the vertical plane. These values will be obtained for a maximum momentum spread of ±2 %. Horizontal and vertical tunes of 3.8 will allow operation away from dangerous resonances. In order to correct the natural chromaticity 16 sextupole magnets – four in every arc – have to be installed. The chosen sextupole setup is shown in Figure 2.

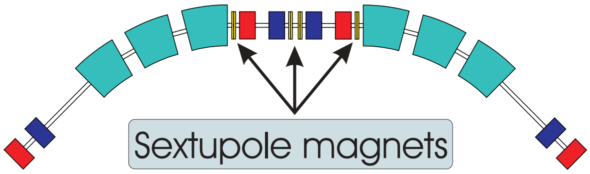

Figure 2: Four sextupole magnets are located in every arc in order to correct the natural chromaticity.

Injection and extraction are located on opposite sides of the ring (see Figure 1) using full aperture kickers. Septum and kicker magnets for injection and extraction will be identical.

Table 1: NESR Parameters

Circumference [m]	208.5
Maximum bending power [Tm]	13
Maximum ion energy (A/q = 2.7) [MeV/u]	784
Maximum antiproton energy [GeV]	3.07
Number of superperiods	4
Length of straight sections [m]	18/3
Horizontal acceptance [mm mrad]	100
Vertical acceptance [mm mrad]	50
Momentum acceptance [%]	±2
Horizontal tune	3.8
Vertical tune	3.8
Transition energy	5.61
Natural horizontal chromaticity	-8.72
Natural vertical chromaticity	-6.72

Two different rf-system will be installed in the NESR. The first system operates at frequencies between 0.8 and 5 MHz, the second one between 50 and 80 MHz. While the first system will be used for operations such as beam accumulation and deceleration, the second system is necessary for the generation of short bunches for electron scattering experiments. Up to 60 ion bunches have to be stored in the NESR and will be collided with electron bunches.

Precooled rare isotopes will be injected at an energy of 740 MeV/u after stochastic cooling in the collector ring. For some experiments lower energies in the range of 100 MeV/u to 200 MeV/u are required. In order to use an injected beam of short lived nuclei efficiently the deceleration time must not exceed 1 s. Therefore a ramping rate of 1 T/s is foreseen.

Figure 3 depicts the horizontal and vertical beam envelopes ($\varepsilon_h = 100$ mm mrad, $\varepsilon_v = 50$ mm mrad, $dp/p = \pm 2$ %) as well as the dispersion function over one quarter of the ring. The four straight sections of the NESR are dispersion free. The maximum dispersion of 3.4 m is reached in the arcs. The beta functions in the straight sections amount to 8 m in the horizontal and 10 m in the vertical plane.

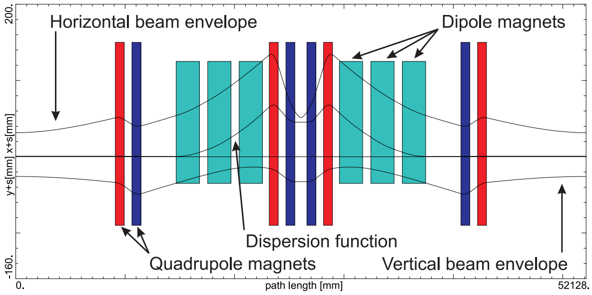

Figure 3: Beam envelopes and dispersion function over one quarter of the NESR.

These values are appropriate for many experiments. However, especially for electron scattering experiments smaller beta functions are essential. Therefore additional quadrupole magnets have to be installed to provide the required beta functions at the interaction point. Figure 4 shows an example for the ion optics around the interaction point. The beta functions amount to 1.5 m in the horizontal plane and to 0.15 m in the vertical plane.

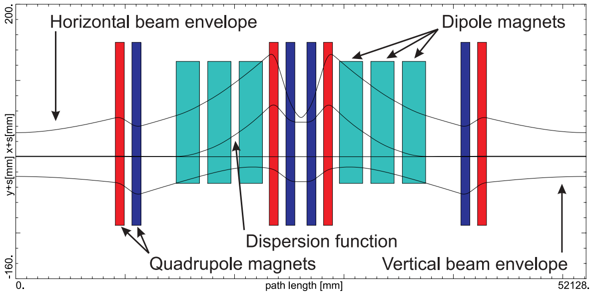

Figure 4: Ion optics around the interaction point. Additional quadrupole magnets will provide low beta functions at the interaction point.

In order to get a first estimation of the useful aperture dynamic aperture calculations using the MIRKO code have been carried out. These calculations have taken only the sextupole components into account.

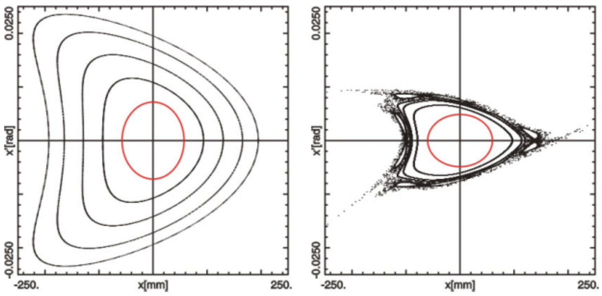

Figure 5: Dynamic aperture for normal operation (left) and operation in collider mode (right) calculated with MIRKO.

Figure 5 shows the calculated dynamic aperture in the xx'-plane for the normal operation mode (left) and the electron nucleus collision mode (right). The geometric acceptance for dp/p = 0 is drawn in red. It amounts to 400 mm mrad for normal operation and to 300 mm mrad for operation in the collider mode. The dynamic aperture which is very large in the normal operation mode shrinks due to the influence of the additional quadrupole magnets if the ring will be operated in the collider mode. To determine the dynamic aperture more precisely misalignment and field errors have to be included.

3 EXPERIMENTAL INSTALLATIONS

An essential installation for most experiments in the NESR will be the electron cooling device. The basic design of the NESR electron cooler will be very similar to the design of the one which is installed in the existing Experimental Storage Ring ESR [4, 5] at GSI.

Table 2: NESR Electron Cooler Parameters

Maximum acceleration voltage [kV]	450
Maximum electron current [A]	2
Electron beam diameter [mm]	25
Magnetic field [T]	0.2
Transverse electron temperature [eV]	0.1
Length of cooling section [m]	4
Field straightness $B_{\perp}/B_{\parallel}$	5×10^{-5}

The major modification will be the increase of the electron energy to 450 keV according to the higher ion energies. As a consequence a magnetic guiding field of 0.2 T has to be applied and a field straightness in the cooling section of 5×10^{-5} is required in order to have strong magnetized cooling. To achieve short cooling times the length of the cooling section will be 4 m and a maximum electron current of 2 A will be applied. A transverse electron temperature of 0.1 eV should be achieved.

As mentioned before, the electron scattering facility will be one of the main experimental installations of the NESR. This facility consists of an electron storage ring and a full energy electron linac. The circumference of the electron ring amounts to 50.23 m and provides electrons with energies between 200 MeV and 500 MeV. A working point at a horizontal tune of 3.8 and a vertical tune of 2.8 is chosen. Emittances in both planes are 0.05 mm mrad, the momentum spread amounts to only ±0.018 %. The conceptual design of electron facility and interaction region was done in collaboration with BINP in Novosibirsk [6]. With this setup luminosities of up to 1×10^{28} $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ in electron-ion collisions are expected. However, the layout of the interaction region still has to be optimized. The length of the magnet free space varies between 1 m and 4 m for the different designs. The final decision about the layout depends mainly on the type of detector which will be installed at the interaction point.

The other important experimental installation is the internal target. This target will either be a gas jet target like the one which is installed in the existing ESR [7] or a pellet target. Available target materials at the ESR gas jet are all gaseous elements from hydrogen to xenon. Target densities are in the range from 10^{12} to 10^{14} particles/cm^3.

4 CONCLUSION AND OUTLOOK

The NESR layout which is presented in this paper is just preliminary. Although many tasks can be fulfilled with this design, the antiproton accumulation scheme still has to be worked out. The key problem in this connection is to fulfill the requirements of the stochastic cooling system which is necessary for accumulation of antiprotons. The lattice has to be changed in such a way, that the NESR is able to fulfill all the other tasks.

The next steps in the NESR layout are calculations concerning higher order corrections, the dynamic aperture and also beam dynamics. The beam dynamics calculations will focus on cooling times and equilibrium beam parameters.

R & D work will focus on the development of a 450 keV electron cooler, a stochastic cooling system for antiprotons and the layout of the electron scattering facility.

5 REFERENCES

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