ANTIPROTON ACCELERATION AND DECELERATION IN THE HESR

B. Lorentz[#], T. Katayama, A.Lehrach, R. Maier, D. Prasuhn, R. Stassen, H. Stockhorst, and R. Tölle
Forschungszentrum Jülich GmbH, D 52425 Jülich, Germany.

Abstract

The High Energy Storage Ring (HESR) is a part of the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt [1,2]. The ring is used for hadron physics experiments with a pellet target and the PANDA detector, and will supply antiprotons of momenta from 1.5 GeV/c to 15 GeV/c. To cover the whole energy range a flexible adjustment of transition energy and the corresponding γ_{tr} value is foreseen. For injection and accumulation of antiprotons delivered from the CR at a momentum of 3.8 GeV/c (γ=4.2), the HESR optics will be tuned to γ_{tr} =6.2. For deceleration down to a momentum of 1.5 GeV/c this optic is suitable as well. Stochastic cooling at an intermediate energy is required to avoid beam losses caused by adiabatic growth of the beam during deceleration. For acceleration to 8 GeV/c (γ =8.6) the optics will be changed after accumulation of the antiproton beam to γ_{tr} =14.6. For momenta higher than 8 GeV/c the beam will be debunched at 8 GeV/c, optics will be changed to γ_{tr} =6.2, and after adiabatic rebunching the beam will be accelerated to 15 GeV/c (γ=16). Simulations show the feasibility of the described procedures with practically no beam losses.

INTRODUCTION

The High Energy Storage Ring HESR is dedicated to the field of high energy antiproton physics with high quality beams over the broad momentum range from 1.5 to 15 GeV/c to explore the research areas of hadron structure and quark gluon dynamics, e.g. non perturbative QCD, confinement, and chiral symmetry. An important feature of the new facility is the combination of phase space cooled beams with internal targets which opens new capabilities for high precision experiments.

Wide international collaborations (e.g. PANDA [3]) with a rich scientific program are working on new experiments with antiprotons in the energy range between the CERN Antiproton Decelerator AD and the Tevatron energies.

Special equipment enables the high performance of this antiproton machine, which will make high precision experiments feasible that are not possible up to now. Key tasks for the design work to fulfil these requirements are:

- multi harmonic RF cavities [4],
- high sensitivity stochastic cooling pickups for the frequency range 2-4 and 4-6 GHz,
- powerful beam cooling systems to counteract beam heating (from beam target interaction and intra beam scattering) to achieve high luminosity and high beam quality.

Stochastic cooling will be used for the injection and accumulation process and to counteract the beam heating caused by the target of the PANDA experiment.

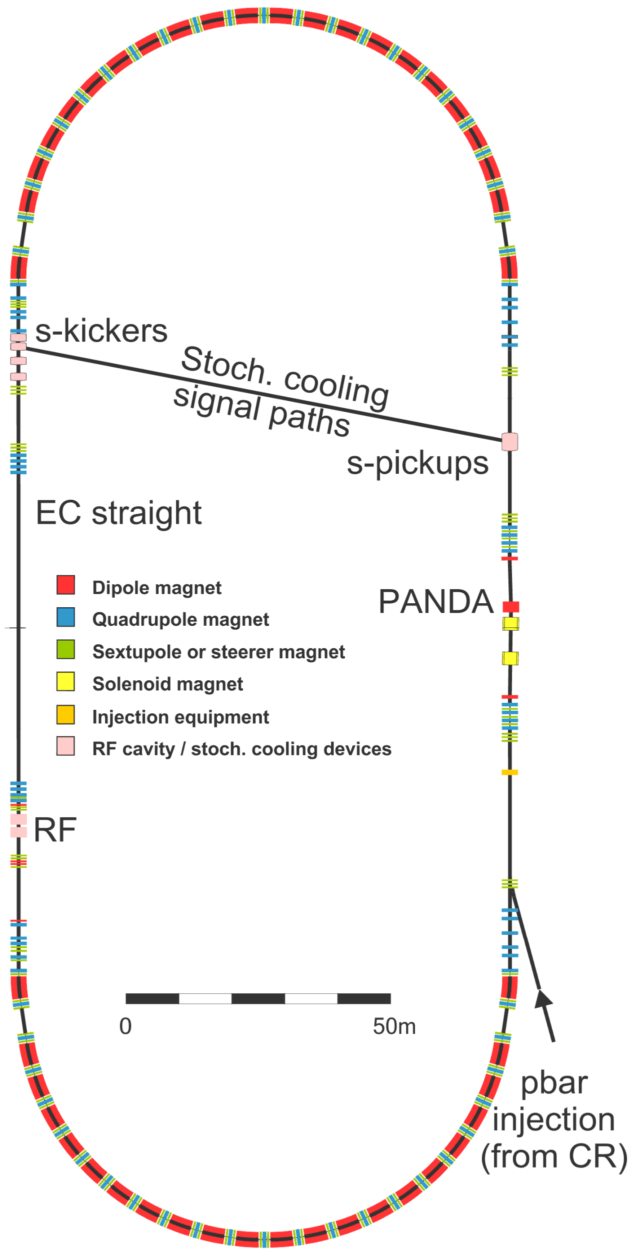

Figure 1: Schematic view of the HESR ring, the target position for PANDA is in the middle of the right straight section. Injection is placed on the bottom right, positions of stochastic cooling pickups and kickers are indicated.

[#] b.lorentz@fz-juelich.de

Table 1: Lattice Properties

lattice type	FODO with dispersion suppression
magnet type	normal conducting
number of dipoles	44
length of dipole	4.2 m
dipole field	0.17 1.7 T
deflection angle	8.2 deg,
number of quadrupoles	50 (arcs) + 34 (straights)
quadrupole length	0,5 m
max, gradient	25 T/m
working point	7.61
arc $\beta_{xy}^{max,}$	24 80 m
$D_x^{max,}$	2 8.5 m
straight $\beta_{xy}^{max,}$	490 m 110 m
target β_{xy}	1 5 m
cooler β_{xy}	25 200 m
chromaticity ξ_{xy}	20 to 10
transition γ_{tr}	6.2 – 25
arc length	157 m
ring length	576 m
Injection	150 m long bunches from CR at 3.8 GeV/c
horizontal/ vertical geometrical acceptance	4 / 4 mm mrad for β_{target} = 1m 15 / 15 mm mrad for β_{target} = 5m
relative momentum acceptance	$\pm 2.5\times10^{3}$
dipole ramp rate, energy change / turn	25 mT/sec, 400 eV
rms beam size (radius) at target	~1 mm

The lattice type chosen for the HESR consists of normal conduction dipole and quadrupole magnets. The arcs consist of a FODO type lattice structure. To achieve dispersion free straight sections, an option with dispersion suppression at the exit of each arc is foreseen. Fig. 1 and Table 1 show a view ot the anticipated ring arrangement and the lattice properties.

Lattice Structure in the Arc Sections

For a regular FODO lattice in the arcs, the value of transition energy would be located inside the energy range of the ring. However, this can be overcome by dividing the focussing and defocusing quadrupole families in the arcs into several sections with different focussing. The transition energy can then be moved outside the HESR energy range. To still be able to reach zero dispersion in the straights a well-known dispersion suppression scheme can be applied. In the last FODO cell of each arc, one dipole is removed, and the missing bending power is distributed equally to the rest of the dipole magnets in the arc (examples in Figs. 2 and 3)

Lattice Structure in the Straight Sections

In each straight section the focussing structure consists of four quadrupole triplets. This allows telescopic operation of the straight sections with a betatron phase advance of 2π in the horizontal and vertical plane on either side of the HESR ring. For higher flexibility in adjustment of beta functions at target and electron cooler, the triplets can be operated away from the telescopic setting.

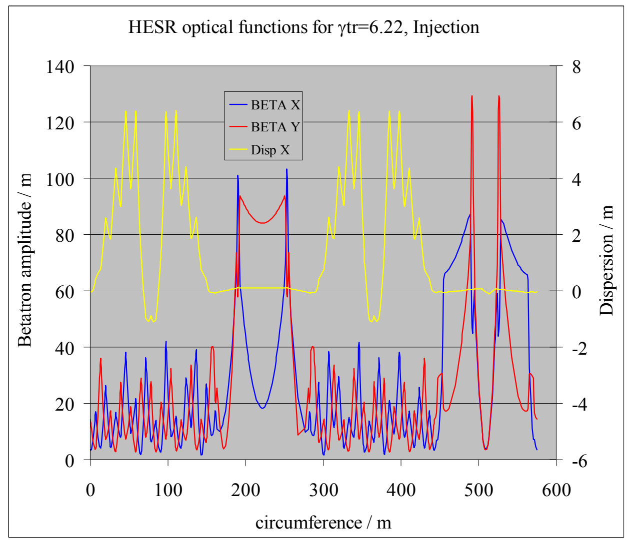

Figure 2: Optical functions for the HESR magnet lattice with dispersion suppression for transition energy of γ_{tr}=6.22. Shown are the horizontal betatron amplitude β_x (blue), the vertical betatron amplitude β_y (red), and the horizontal dispersion D_x (yellow) along the ring.

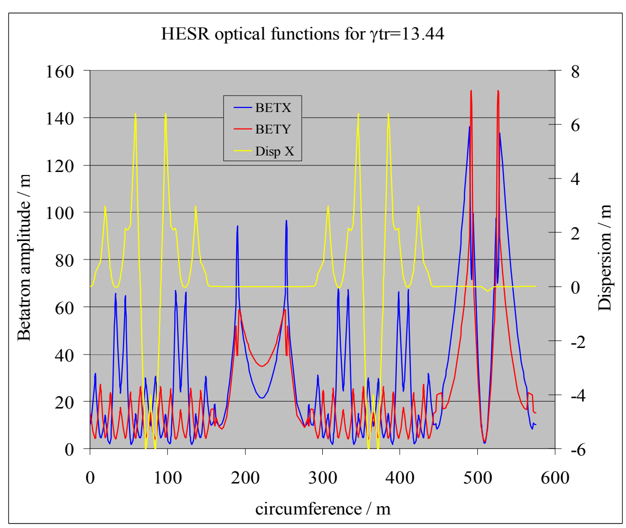

Figure 3: Optical functions for the HESR magnet lattice with dispersion suppression for transition energy of γ_{tr}=13.4. Shown are the horizontal betatron amplitude β_x (blue), the vertical betatron amplitude β_y (red), and the horizontal dispersion D_x (yellow) along the ring.

ISBN 978-3-95450-168-7

Acceleration

For acceleration of the antiproton beam, the optics with γt =14.2, to allow acceleration to about 8 GeV/c. For acceleration to higher energies the beam will be debunched at 8 GeV and the beam optics changed to γt=6.2. As simulations show, rebunching and acceleration to 15 GeV can be accomplished with particle loss well below 1 % (Fig. 4).

Deceleration

Deceleration of the antiproton beam will be done using the injection optics with γt =6.2. Adiabatic growth of the beam would lead to particle loss (Fig. 5), this will be avoided by applying stochastic cooling at an intermediate flattop energy of about 2 GeV (Fig. 6).

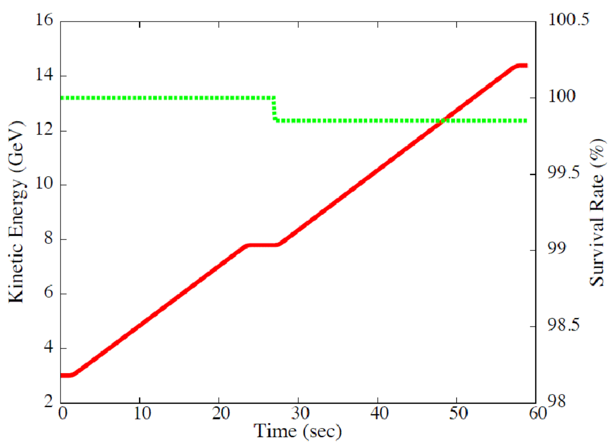

Figure 4: Simulation results for survival rate and energy acceleration versus time in cycle.

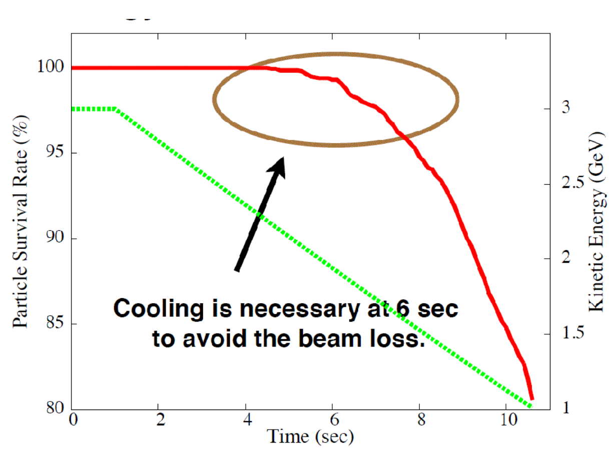

Figure 5: Simulation results for survival rate and energy versus time in cycle during deceleration without stochastic cooling.

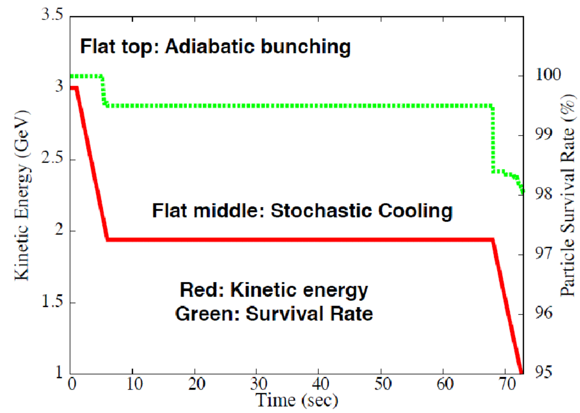

Figure 6: Simulation results for survival rate and energy versus time in cycle during deceleration with stochastic cooling at an intermediate energy of about 2 GeV.

REFERENCES

[1] Facility for Antiproton and Ion Research, https://www.gsi.de/forschung_beschleuniger/fair.htm

[2] The FAIR project, http://www.gsi.de/fair/

[3] The PANDA experiment, http://www-panda.gsi.de/

[4] R. Stassen et al, http://accelconf.web.cern.ch/AccelConf/IPAC2013/papers/mopea016.pdf