HESR AT FAIR: STATUS OF TECHNICAL PLANNING

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Abstract

The High-Energy Storage Ring (HESR) of the international Facility for Antiproton and Ion Research (FAIR) at GSI in Darmstadt is dedicated to Strong Interaction studies with antiprotons in the momentum range from 1.5 to 15 GeV/c. Powerful phase-space cooling is needed to reach demanding experimental requirements in terms of luminosity and beam quality. Status and details of technical planning including cryogenic concept will be presented.

INTRODUCTION

The QCD front end of the antiproton branch of the FAIR facility is covered by the High Energy Storage Ring HESR. Encouraged by GSI requests FZJ is now designing the HESR as a superconducting machine and is prepared contribute it to FAIR. The HESR consortium also includes the Uppsala group who is responsible for the electron cooler. The HESR covers a momentum range between 1.5 GeV/c and 15 GeV/c. The injection energy is fixed at 3.8 GeV/c. The antiprotons are ac-/decelerated to the desired momentum. The HESR is equipped with electron and stochastic cooling systems to provide excellent beam quality to the experiments. At the target point (PANDA [3]) the betatron amplitudes have to be variable between 1 and 20 m, at the electron cooler they have to be variable between 25 and 200 m. All installations allow a later extension of the experimental program to polarized antiproton physics.

Careful inspection of the mounting situation showed that the beam would cross the beam pipe a few cm after the coil head for straight magnets of 1.8 m length. This finding together with the tight aperture budget in the arcs led to the decision to use bent magnets instead of straight ones, and to decrease the number of dipole magnets at the same time. The arcs now consist of 4 unit cells each with 4 dipole magnets per cell as shown in Fig. 1. All other features of HESR as described in [1] can be maintained.

SC DIPOLE MAGNETS

The dipole magnets are developed based on the well established RHIC-D0 magnets. A industry study showed that a bending radius of 15.3 m is feasible, if the magnet is being manufactured in a bent way right from the beginning. Further details of bent sc magnets are given in [2]. The main parameters of the dipole magnets are summarized in Table 1.

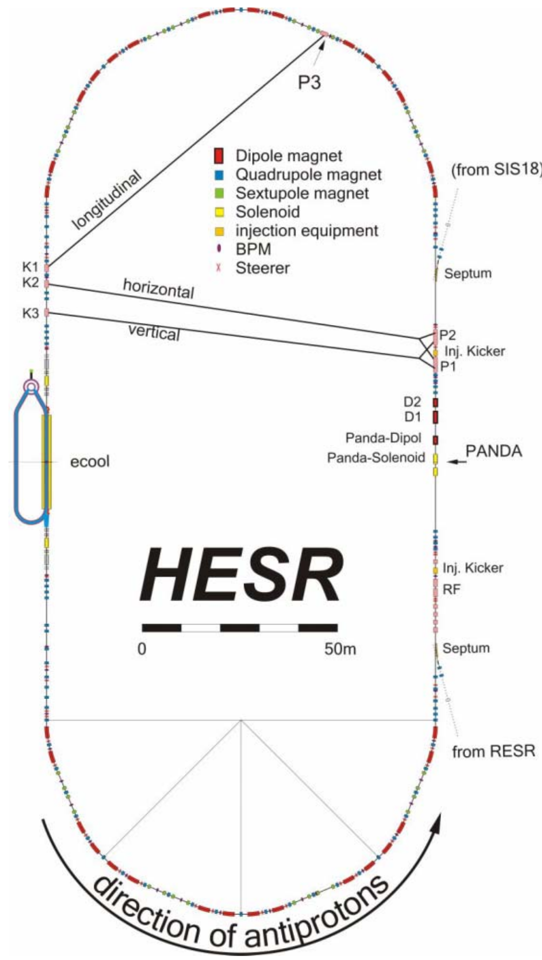

Fig. 1: Layout of HESR

Table 1: Parameters of HESR dipole

type	cos-theta, coil arrangement from RHIC-D0, coil heads from RHIC-D0
coil aperture	50 mm radius
$\lvert\Delta B/B\rvert < 10^{-4}$	35 mm radius up to 2500 A
bending radius	15.278 m
B_{max}	3.3 T for 50 Tm (3.6 T for 55 Tm)
B_{min}	0.3 T
I_{max}	5300 A (3.6 T)
ramping rate	< 25 mT/s
cable	Rutherford 30 strand (as RHIC D0)
cooling	forced flow

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op. temperature	4.2 … 4.5 K
number	32 + 1 for online measurements

CAVITIES

Two different cavities are needed in the HESR. An acceleration cavity which also can be used for bunch rotation, and a barrier bucket cavity to compensate for the mean energy loss of beam target interaction. The prototype tank of the low-power cavity (Fig. 2), which is intended for providing the barrier bucket is presently being prepared for installation in COSY for beam tests to verify the interplay of barrier bucket operation and stochastic cooling performance. The prototype tank of the high-power cavity is close to completion. All necessary magnetic alloy cores passed successfully the acceptance tests.

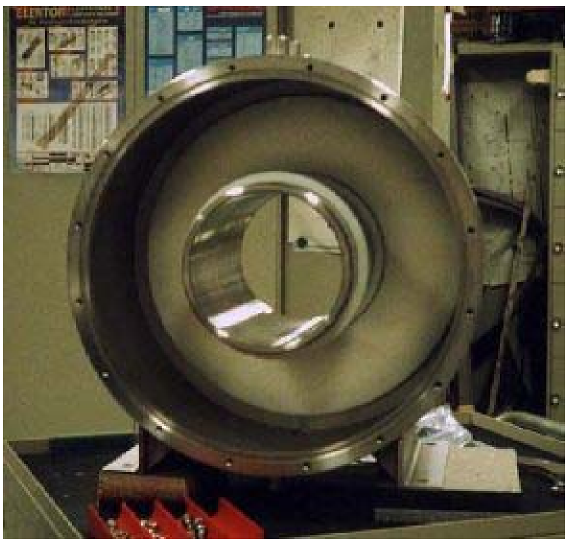

Fig. 2 Low-power barrier bucket cavity tank

STOCHASTIC COOLING

Detailed numerical and analytical investigations of the Fokker-Planck equation for longitudinal filter cooling including an internal target have been carried out to demonstrate the stochastic cooling capability at the HESR. To gain confidence in the model predictions experimental stochastic cooling studies with the internal ANKE target under realistic conditions for longitudinal cooling were carried out at the cooler synchrotron COSY. The cooling model receives a remarkably good agreement with the experimental results at COSY. The beam target interaction is well described by the model through the quantities mean energy loss and mean square relative momentum deviation per turn. Both quantities can be measured. The good agreement of the model with the experimental results at COSY gives a safe confidence that the model will also fairly well predict the cooling properties of the HESR at the FAIR facility.

The choice of the filter cooling technique at the HESR restricts the usable bandwidth to (2-4) GHz for longitudinal cooling. The same bandwidth is also envisaged for transverse cooling. Two different coupler designs have been developed together with appropriate combiner boards: a) $\lambda/4$ printed loop structures and b) ring-slot coupler, both for the envisaged frequency range.

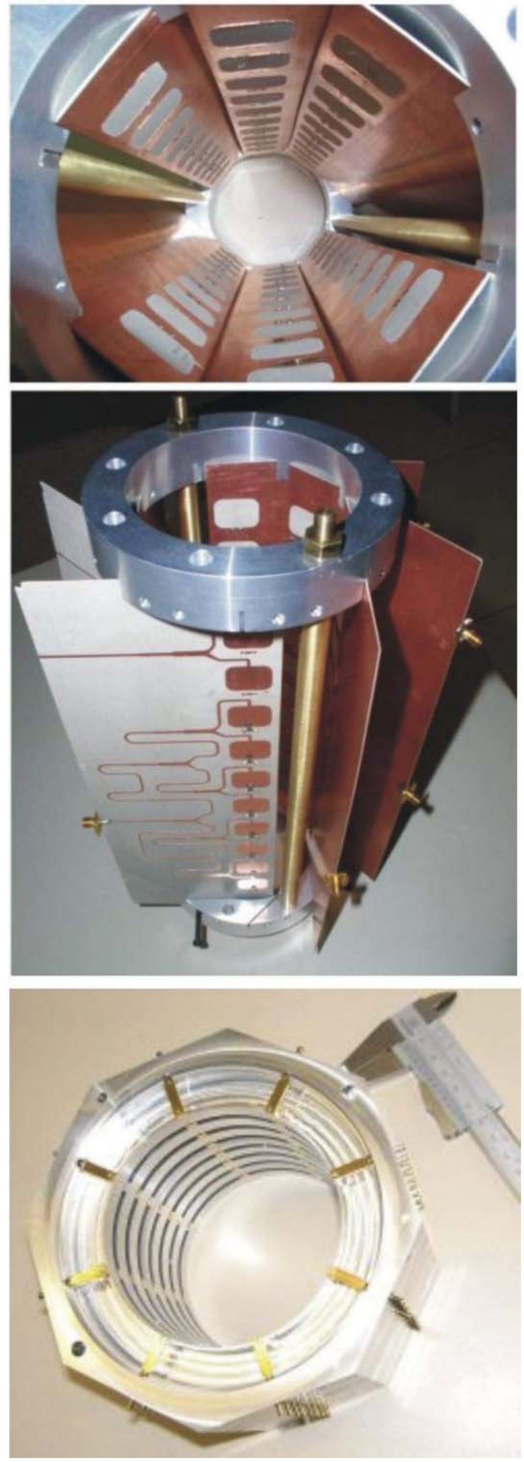

Fig. 3: Axial (top) and total (middle) view of the $\lambda/4$ printed loop couplers. Bottom: Ring-slot coupler

HIGH-ENERGY ELECTRON COOLING

The layout of the high-energy electron-cooling system [4] now includes only one single 90° bend before the 24-m electron-cooling straight section, see figure 4.

Prototypes of components of electron-beam diagnostics and of magnetic-field measuring system are being assembled and will be tested in the autumn this year.

Simulations employing a slightly "tilted" electron beam shows promising results.

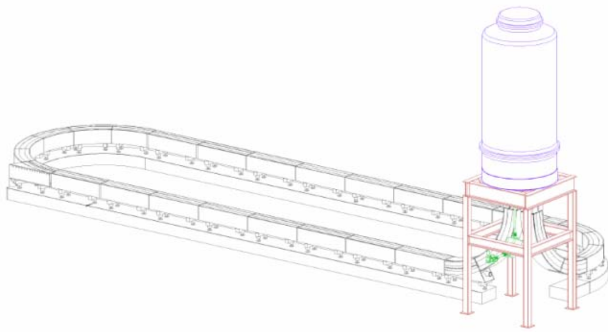

Fig. 4: High-energy electron-cooling system

FLOOR SPACE MANAGEMENT

Right from the beginning of the planning for HESR efforts were made to automatically assign a contour to each component of the synchrotron. For each element an entry in a database is available and allows to electronically generate the floorplan from the MAD survey output. A sample zoom is shown in Fig. 5.

Fig. 5: Zoom of present HESR floor plan. D - dipole magnet, OC - orbit corrector, Q - quadrupole magnet, S - sextupole magnet. Not all He-covers and beam pipes shown. Further details will be added according to the progress of the project.

CRYOGENIC CONCEPT

All the superconducting magnets in the HESR are located in the two arcs of the ring, whereas most of the devices in the straight sections do not require cryogenic cooling. The only exception is the PANDA superconducting solenoid, whose cryogenics is overseen by the experimental group.

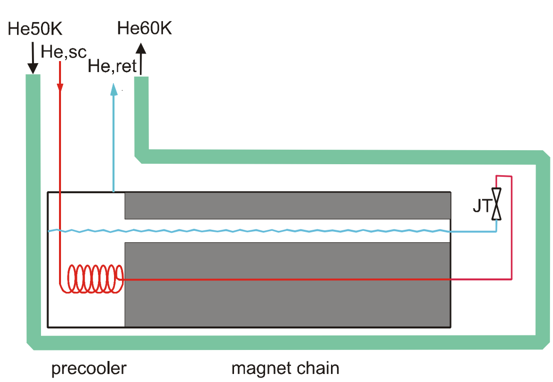

Fig. 6: Scheme of the cooling Helium flow through the cold mass

To save longitudinal space, in each of the two arcs all the magnets are enclosed in a single, long cryostat, and are cooled in series. The cold mass inside the cryostats is fragmented to allow easier assembly.

Supercritical helium at a pressure of 3 bar acts as a coolant for the magnets. At the end of the magnet string, a Joule-Thompson expansion of the supercritical helium produces two phase helium, which backflows in a heat exchanger tube within the magnets and provides continuous recooling for the supercritical helium flow. To improve stability, the supercritical helium is circulated through a pre-cooler adjacent to the first magnet before being forced through the magnet string (Fig. 6).

The heat load from 300 K is intercepted by a thermal shield cooled by the circulation of pressurised helium gas at about 50 K (Fig. 7). The expected heat load at 4.5 K is 1500 W in total for the two cryostats, requiring approximately 77 g/s of evaporating helium.

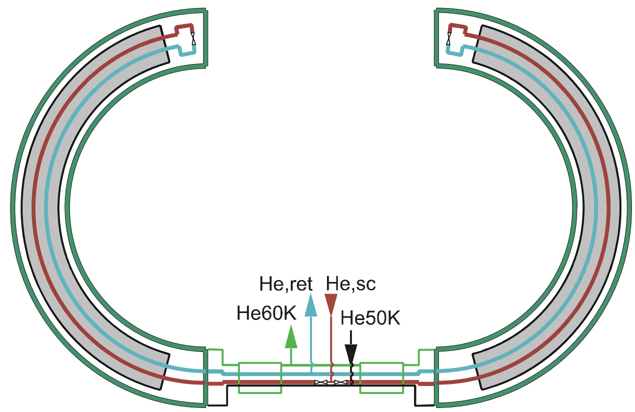

Fig. 7: Cooling scheme for the HESR

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