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INJECTION KICKER FOR HESR AT FAIR USING SEMI-CONDUCTOR SWITCHES*

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Abstract

The High Energy Storage Ring for Antiprotons (HESR) is going to be built at FAIR in Darmstadt on the extended GSI campus. It will receive the antiprotons via the Collector Ring (CR). Using a barrier bucket, the circulating particles will be compressed into one half of the circumference. New particles have to be injected into the remaining half. Thus rise and fall time must not exceed 220 ns each with a flat top of 500 ns. A kick angle of 6.4 mrad is required at 13 Tm magnetic rigidity. The system must allow pole reversal for injection of positively charged particles. With a voltage lower than 40 kV a semi-conductor based pulser is going to be realized. Boundary conditions and the status of preparatory work are described. Simulation results and available measurements are presented.

INTRODUCTION

The HESR is a synchrotron and storage ring which is being built for FAIR on the GSI campus in Darmstadt in Germany. The Institute of Nuclear Physics 4 at Forschungszentrum Jülich (FZJ) has the overall responsibility for the complete HESR and will install it at the FAIR site when the buildings are ready. HESR will allow handling particles whose magnetic rigidity is in the range of 5 – 50 Tm. For protons or antiprotons this corresponds to momenta (energies) between 1.5 and 15 GeV/c (0.87 and 14.8 GeV), and for bare Uranium this corresponds to 579-5797 MeV/u/c. Injection is designed to operate at 3 GeV which is the production energy of antiprotons (12.76 Tm) to be injected via the collector ring CR which is needed for initial cooling. The injection equipment will be able to inject particles carrying positive or negative charge. For antiprotons each injected bunch might contain up to 10^8 particles, for heavy ions the intensity will be less.

INJECTION PROCESS

As the accumulator ring RESR will be postponed by several years, the proposed way of antiproton beam accumulation for the HESR is to use the already designed stochastic cooling system and the barrier bucket (BB) cavity of the HESR. The BB cavity of the HESR is used to separate the circumference of the HESR ring into two equal regions, one reserved for the injected beam and the other one for the accumulated beam. A beam bunch of 10^8 antiprotons delivered by the CR is kick-injected every 10 seconds into the central part of the two full wave barrier pulses (Fig. 1). The injection kicker rise time is 220 ns and the flat top time is 500 ns (Fig. 1). Just after beam injection the barrier voltages are switched off and the beam becomes coasting with a revolution period of 2 µs. Fast filter stochastic cooling is continuously applied during the whole accumulation process to avoid beam dilution due to Schottky noise diffusion. In the well cooled coasting beam again two full-wave barrier voltages are excited adiabatically and the right hand voltage moves to the injection position within the period of 0.5 sec. A new particle free gap with 1 µs duration for the injection of the next bunch is available. This procedure is repeated 100 times (1000 s) until 10^{10} antiprotons are accumulated. The beam accumulation and cooling processes have been studied in detail in [1, 2] and the corresponding proof of principle experiment has been successfully carried out at the GSI [3].

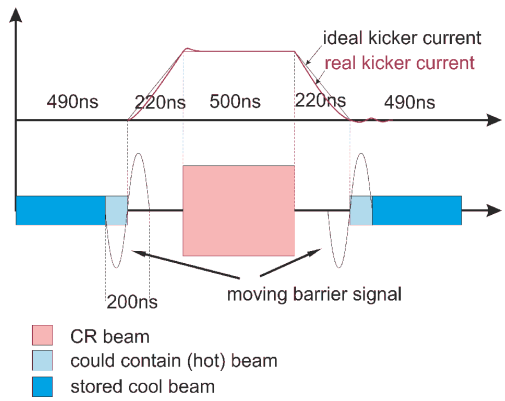

Figure 1: Injection timing of HESR.

SYSTEM DESIGN AND PARAMETERS

Preparatory studies at FZJ were carried out to specify mechanical properties, magnet properties and pulser properties. System design and the vacuum system are covered by FZJ, whereas the subsystems magnet and pulser are in the responsibility of the contractor. Requirements to build the coil (one single winding) with two horizontal slits on each side of the magnet and to make provisions to later install an eddy current strip (copper) into the slit in the bottom yoke have been accepted by the contractor (reduction of longitudinal impedance) [4]. The strip can be installed provided that in-vacuum dielectric tests are convincing.

The injection kicker system will have to deflect the incoming beam by 6.4 mrad using 4 individual 36 cm long

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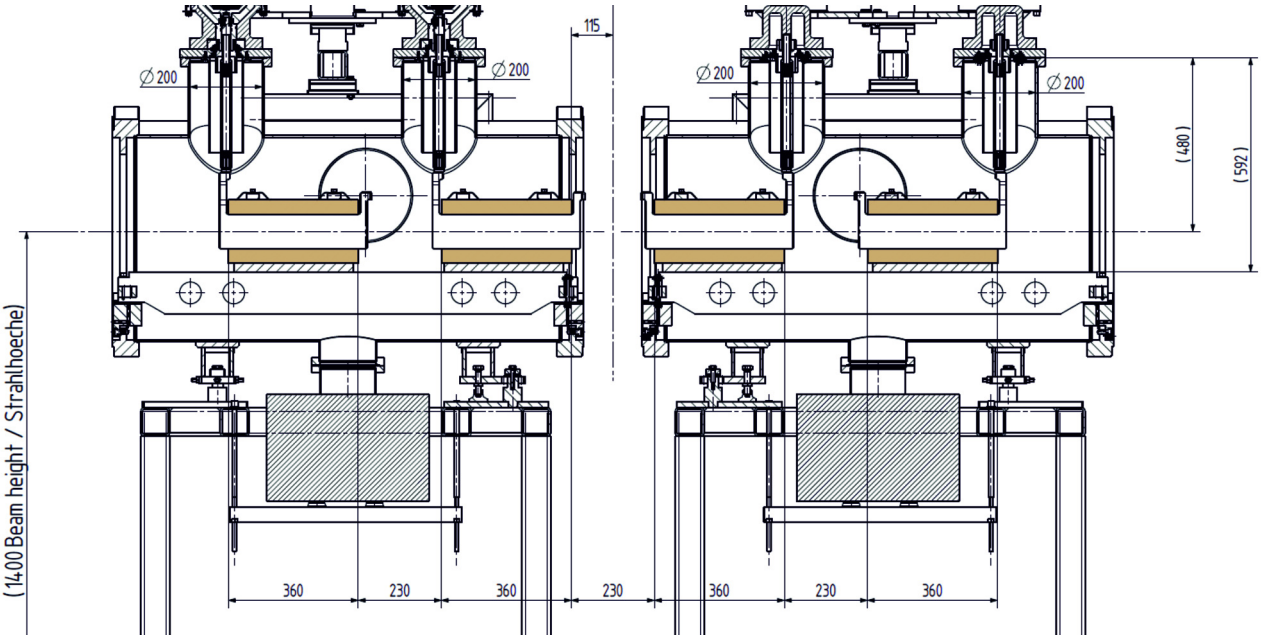

Figure 2: Mechanical layout of the injection kickers including vacuum tanks. During bake-out the termination resistors (top, not completely shown) can be disconnected and lifted without breaking the vacuum.

ferrite magnets, each connected to one pulser. All relevant parameters have to be optimized to ensure that the sum of rise and fall time does not exceed 500 ns.

Maximum field integral of each magnet is 27 Tmm which is sufficient to allow kicking the beam onto the correct trajectory. Less than 4700 A are necessary to do the job. The magnet design is accepted and the magnets are in production at the contractor. The company proposed a Blumlein circuit requiring a driving voltage of 40 kV and develops a pulser using state-of-the-art semiconductor switches. Similar pulsers are in use e.g. at SOLEIL [5]. The connection between magnet and HV feedthrough is done in stripline technique. Extensive studies to further minimize the stray inductances throughout the whole system including pulser geometry are going on at the contractor.

VACUUM TANKS

FZJ designed the mechanical layout of the injection components and manufactures the vacuum tanks, see Fig. 2.

For use in HESR, two magnets each will be mounted into one tank. The orientation of the magnets leads to a first order cancellation of unwanted field components. FZJ will acquire 3 tanks. The first one will be used as a test tank (delivery to FZJ delayed to end of May 2015) for test measurements and performance verification. FZJ will assemble all further mechanical parts (support structure for the magnets including position control) and will integrate an automated heating and pumping system.

The complete assembly including heating jackets will be shipped to Sigmaphi in summer 2015 for system tests. A sketch of the full assembly is shown in Fig. 3. In this tank, only one magnet is installed for system tests. On

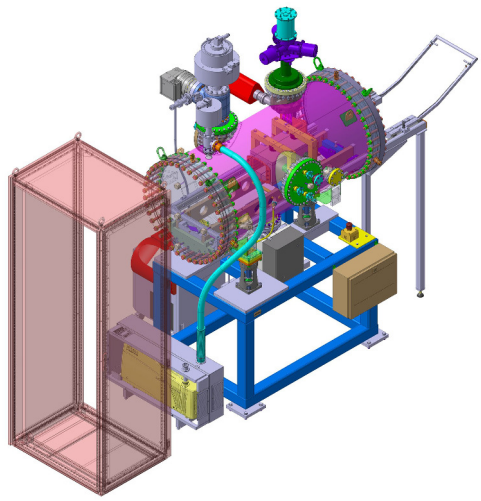

Figure 3: Test tank for the HESR injection kickers as to be delivered to the contractor. For detailed description see text.

the right hand side a tool for inserting the 75 kg magnet is shown. The cabinet will house the vacuum and heating control equipment. The termination resistors on top of the HV feedthrough are indicated. Their number (here: 3) depends on the choice of the cable impedance. For the test tank numerous heating cycles are expected. After acceptance of the magnets they will be mounted into the clean 'production' tanks which will be installed into the HESR.

MAGNET ASSEMBLY

Some details of the magnet assembly are shown in Fig. 4 together with all current bearing parts including cabling. The exact number of cables might still vary. Pole reversal

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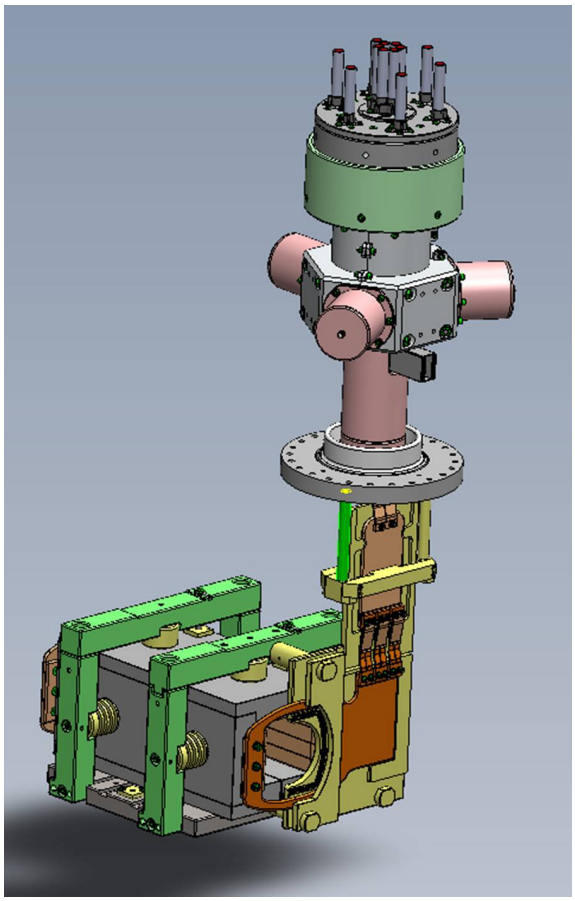

Figure 4: Kicker magnet assembly with stripline connection within vacuum tank to the feedthrough. The cable terminal shown is intended for the mock-up and might change for the 'production version' of the kicker.

can e.g. be accomplished by changing the cables on top from the inner circle to the outer circle and vice versa. The current sensor is located at the box below the hexagon. The circular disc in the middle is the high voltage feedthrough. The ferrite parts of the magnet (grey blocks) are fixed mechanically by springs pushing from the surrounding frames (green). The lower yoke will be split to investigate whether insertion of a 2 mm copper strip can be useful for reducing the longitudinal impedance of the magnet.

MEASUREMENTS

The scheduled measurements on the prototype performance are delayed as (i) the vacuum vessel is still in fabrication and (ii) the ferrite blocks had to be shipped back to the manufacturer for cleaning. The measurements are re-scheduled for summer 2015.

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