Operational Characteristics of the COSY Electron Cooler

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Abstract

The COSY electron cooler has been designed, constructed and tested during the years 1989 to 1992. After magnetic field measurements and corrections the electron cooler was mounted in a test position outside the COSY ring for first electron beam experiments. In February 1993 the electron cooler was moved into the COSY ring. First cooling experiments took place during spring and summer 1993. Results of the comissioning and the first cooling experiments will be presented.

1. INTRODUCTION

The COSY electron cooler is designed for electron energies between 20 and 100 keV and an electron current of up to 4 A. With these parameters COSY is able to provide high brillance proton beams at low energies between 40 MeV and 180 MeV. The maximum flux of the solenoidal field of the electron cooler amounts to 0.15 T. Results of the longitudinal and transverse magnetic field measurements and corrections are presented in Section 2.

Gun and collector conditioning took place in the test position outside the COSY ring. Results of the electron beam tests are described in Section 3.

The first cooling experiments in COSY were carried out at an energy of 38 MeV protons corresponding to 20 keV electron energy. Momentum cooling was obeserved with longitudinal Schottky spectra, the transverse cooling with H^0-detectors. Cooling results are presented in Section 4.

2. THE MAGNETIC FIELD

The magnetic field configuration consists of three solenoids and two 90° toroids. The solenoids are constructed similar to the IUCF design with iron rods as magnetic yoke. This design allows an easy access to the magnets to mount additional steering and correction coils. The two 90° toroids are splitted into a 55° and a 35° toroid each. Their mechanical layout is similar to the CELSIUS toroids. All main magnets are connected in series to one power supply which also feeds the compensation solenoids in the COSY ring. The final adjustment of the different currents for each of the magnets is done by active shunts. In this way the ripple of the main power supply does not change the current ratio of the individual magnets, which decreases the requirements for the tolerances, especially for the compensation solenoids.

The expected field decrease in the transition regions between the solenoids and the toroids is compensated by separate gap coils. The longitudinal magnetic field was measured with a Hall probe drawn through the magnet system [1]. Fig. 1 shows the magnetic field deviations on the electron beam axis along the whole magnetic system from the gun to the collector solenoid. The active shunts and the gap coils are set to the optimum values for a magnetic field of 0.12 T. The field deviations are below 10^{-2} which is in agreement with the specifications. The large deviation at the transition between collector toroid and collector solenoid is due the fact, that we did not care about the electron beam quality in front of the collector. Therefore we did not install a gap coil at this transition. The remanent field of the cooler magnets amounts to 10^{-4} T, the reproducibility of the magnetic field after a rapid switch-off is better than 10^{-3}.

High requirements have to be fulfilled by the tranverse field in the drift region, because any angular deviation from the pure longitudinal field simulates a higher temperature of the electron beam and increases the cooling time. For the transverse magnetic field measurements we used the same method as it was used at the TSR cooler in Heidelberg [2]. A soft iron magnetic needle mounted perpendicular on a

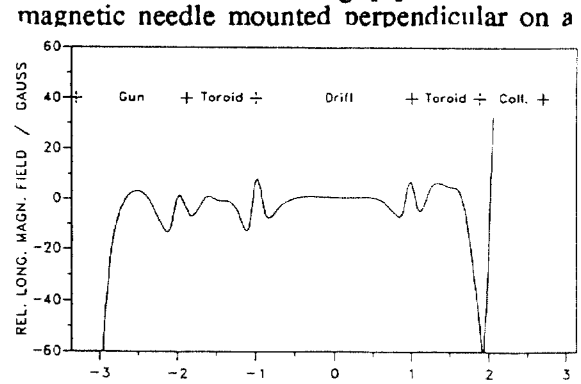

Figure 1: The longitudinal magnet field deviations at a level of 0.12 T.

small mirror orientates itself freely in space due to a cardanic suspension. This mirror was drawn through the drift solenoid by a rod made of balsa wood. The soft iron needle adjusts itself exactly along the magnetic field lines. An electronic autocollimator registers the angle deviations of the mirror. This directly gives the ratio between the tranverse and the longitudinal magnetic field at the measurement position. Though the deviations were already as low as $3 \cdot 10^{-4}$, we added saddle coils with continuously varying angle according to the field deviations. The field error coils consist of 3 windings fixed on a plastic sheet, which could easily be mounted onto the coils of the drift solenoid due to the "open" construction. With these error coils we were able to suppress the transverse field component to less than 10^{-4} in an effective cooling region of 1.5 m [3].

3. ELECTRON BEAM TESTS

The first electron beam tests were made in an offline position outside of the COSY ring. This enabled us to check the different electron beam conditions without disturbing the comissioning of the storage ring itself. The vacuum system of the COSY electron cooler is not yet baked, so we achieved a vacuum of 10^{-9} hPa without electron beam, increasing to $5 \cdot 10^{-8}$ hPa with electron beam on. The conditioning of the electron cooler was done within 2 days, resulting in a stable operation at 100 keV and 1.5 A. At lower energies up to 25 keV electron currents up to 3 A were possible. These current limitations are due to the pressure increase of the unbaked vacuum system. The electron gun with the adiabatic acceleration allows an independant adjustment of the electron energy with the acceleration voltage and of the electron current with the gun anode voltage. The measured gun perveance of 0.88 μP is in good agreement with the EGUN-result [4] of 0.9 μP.

Fig. 2 displays the results of our collector efficiency measurements. We varied the collector voltage between 5 kV and 7.5 kV and the current of the collector end coil between 0 A and 6 A. The collector anode voltage was set to the minimum value to avoid beam reflection. The graph clearly shows a possible collector efficiency of better than $2 \cdot 10^{-4}$. The influence of the collector end coil is much more efficient than a higher collector voltage [5].

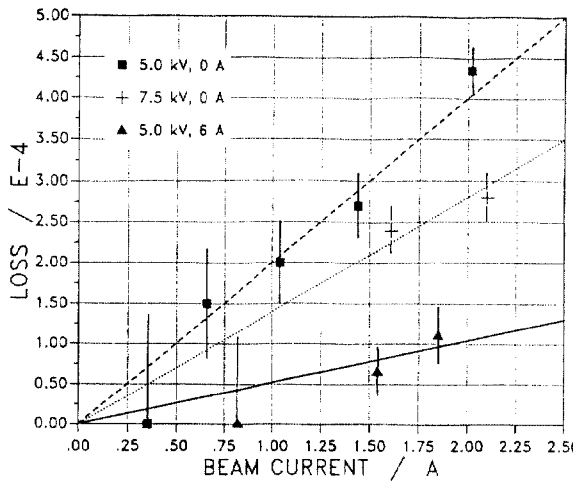

Figure 2: Electron loss as function of the electron current, varied are the collector anode voltage and the collector end coil current.

4. COOLING RESULTS

After the electron beam tests in the offline position the electron cooler was moved into the COSY ring during a 4 weeks shutdown in February 1993. Fig. 3 shows the electron cooler and the compensation solenoids in their final position in the COSY tunnel.

Our cooling experiments so far were carried out at injection energy, i.e. 38 MeV protons. A few tests were made to check the electron beam conditions after the reinstallation of the electron cooler. Then we adjusted the proton correction steerers and the quadrupoles in the cooling telescope to compensate the magnetic disturbance of the cooler magnets to the storage ring. It turned out that the steering of the proton beam and the electron beam could be handled nearly independant to each other. By this it was a rather easy task to adjust the proton and the electron beam directions to better than 0.3 mrad. After a fine adjustment of the electron energy beam cooling could be detected. Even with electron currents between 50 mA and 250 mA cooling times of 5 to 10 sec were observed. The first observations of cooling were made by looking at the bunch length reduction observed with the sum signal of a beam position monitor. The longitudinal Schottky spectra indicated a momentum spread reduction from $2.5 \cdot 10^{-3}$ to less than 10^{-4} for 10^9 protons. An increase of the electron current to 400 mA lead to proton beam instabilities, whereas with 250 mA the proton lifetime was increased from 50 sec without cooling to 5 min with cooling.

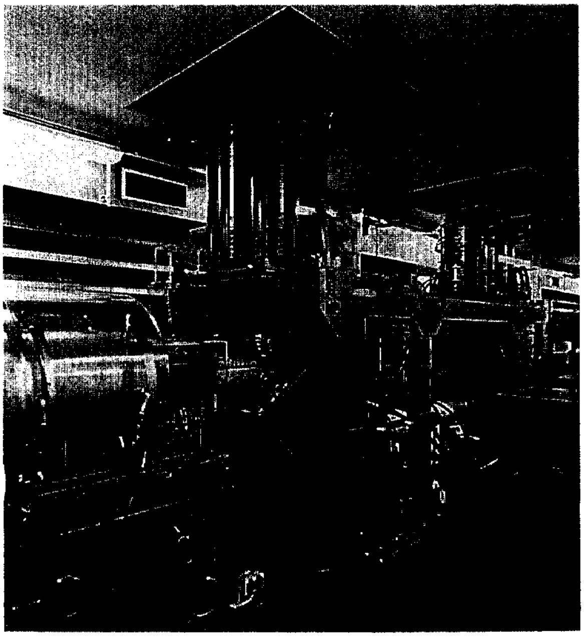

Figure 3: The electron cooler in its final position in the COSY tunnel

After installation of our H^0 diagnostics, a two-dimensional multiwire proportional chamber behind the exit of the first bending magnet, we were able to measure the transverse beam profiles in the cooling region. Figure 4 shows the horizontal and vertical beam profiles 1s, 3s and 6 s after injection. The axes are calibrated in mm. The cooled beam emittance may be calculated according to formula 1:

$$\varepsilon = \frac{w^2}{\beta_c + d^2/\beta_c} \qquad (1)$$

Here, β_c is the betafunction in the cooling region, 6 m in the horizontal and 18 m in the vertical plane, d is the distance between cooling region and the H^0 diagnostics, for COSY 25 m, and w is the measured H^0 profile width. With these values we estimate a cooled beam emittance of better than 0.4 π mm mrad. The uncooled beam emittance is in the order of 25 π mm mrad.

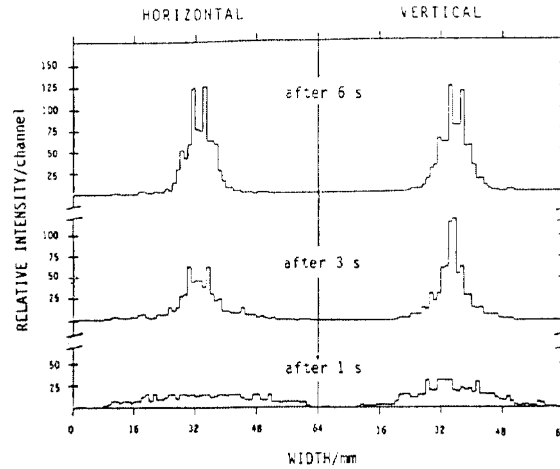

Figure 4: Horizontal and vertical H^0 spectra of the cooled proton beam in COSY

Detailled drag force measurements, acceleration of the cooled beam and cooling at higher energies is scheduled for the second half of 1994.

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