STATUS OF THE 2 MEV ELECTRON COOLER FOR COSY / HESR

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Abstract

The 2 MeV electron cooling system for COSY-Jülich is being built to boost the luminosity in presence of strong heating effects of high-density internal targets in the entire energy range. The 2 MeV cooler is also well suited in the start up phase of the High Energy Storage Ring (HESR) at FAIR in Darmstadt. It can be used for beam cooling at injection energy and for testing new features of the high energy electron cooler for HESR. The design and construction of the cooler is accomplished in cooperation with the Budker Institute of Nuclear Physics in Novosibirsk, Russia. The infrastructure necessary for the operation of the cooler in the COSY ring (radiation shielding, cabling, water cooling etc.) is established. The electron beam commissioning at BINP Novosibirsk started in May of 2011. First results are reported. Final commissioning at COSY-Jülich is planned for the end of 2011.

INTRODUCTION

The new generation of particle accelerators operating in the energy range of 1-8 GeV/u for nuclear physics experiments requires very powerful beam cooling to obtain high luminosity. For example the investigation of meson resonances with PANDA detector requires momentum spread in antiproton beam, which must be better than 10^{-4}. To obtain such a momentum spread cooling time in the range of 0.1- 10 s is needed. The 4 MeV electron cooler at the RECYCLER ring (FNAL) [1] achieves cooling time about 1 hour. The new cooler for COSY should provide a few orders of magnitude more powerful longitudinal and transverse cooling which requires new technical solutions. The basic idea of this cooler is to use high magnetic field along the orbit of the electron beam from the electron gun to the electron collector. In this case high enough electron beam density at low effective temperature can be achieved in the cooling section.

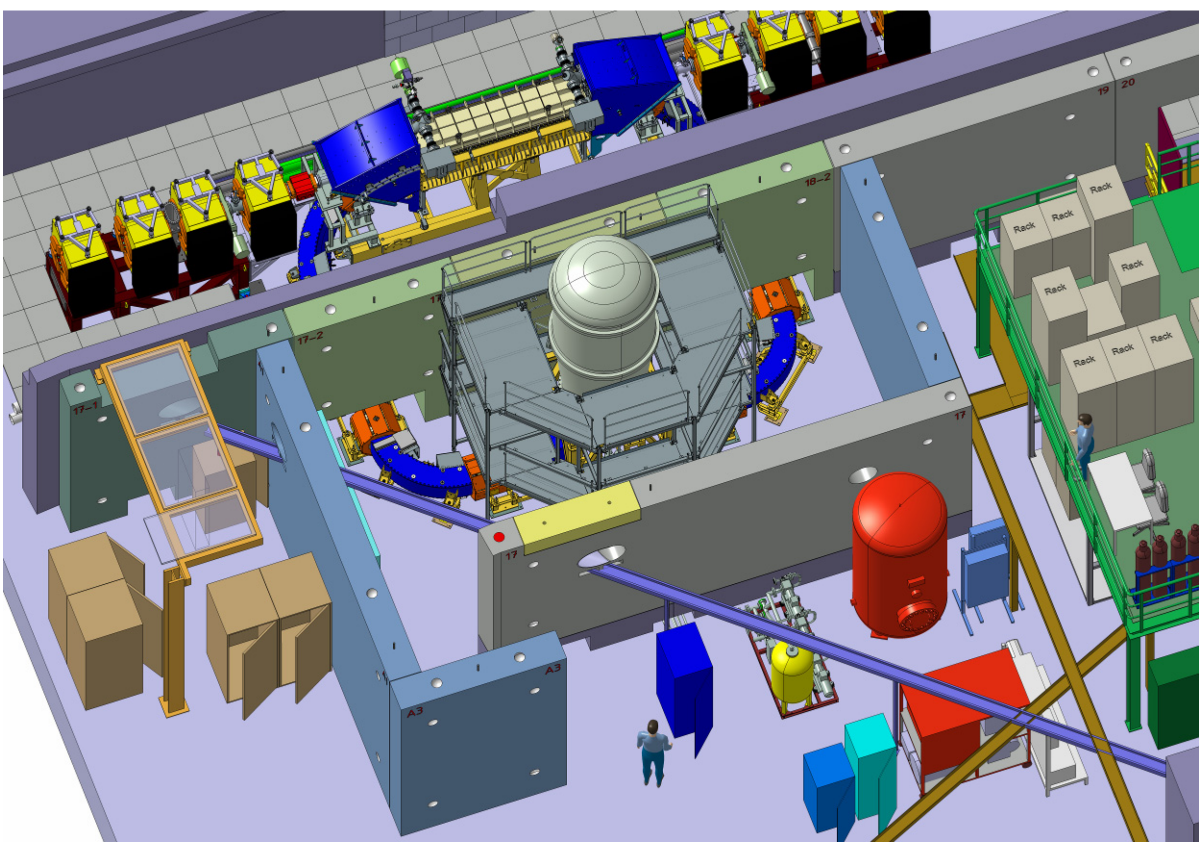

Figure 1: A 3D model of the 2 MeV electron cooler to be installed in COSY.

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BASIC DESIGN FEATURES

The basic parameters of the COSY cooler are listed in Table 1 [2]. The length of the cooling section is given by the space available in the COSY ring.

Table 1: Basic Parameters of the 2 MeV electron cooler.

Energy Range	0.025 ... 2 MeV
High Voltage Stability	$< 10^{-4}$
Electron Current	0.1 ... 3 A
Electron Beam Diameter	10 ... 30 mm
Length of Cooling Section	2.69 m
Toroid Radius	1.00 m
Magnetic Field (cooling section)	0.5 ... 2 kG
Vacuum at Cooler	10^{-9} ... 10^{-10} mbar

In Fig. 1 the layout of the COSY 2 MeV cooler is shown. The main features of the cooler are [2]:

1. The design of the cooling section solenoid is similar to the ones of CSR (IMP) and LEIR (CERN) coolers designed by BINP [3,4]. However, for the 2 MeV cooler the requirement on straightness of magnetic field lines is so high ($\Delta\theta < 10^{-5}$) that a system for control of magnetic field lines in vacuum becomes necessary.
2. For suppression of high energy electron beam losses at IMP and LEIR coolers electrostatic bending was used [5]. The shape of the 2 MeV transport lines, however, dictates a different approach. The collector (inside the HV terminal) will be complemented by a Wien filter to suppress return electron flux.

STATUS OVERVIEW

Fig. 2 shows the cooler being assembled in Novosibirsk [6]. The electron beam transport channel from the bottom of the high voltage vessel to cooling section and back to the high voltage vessel is assembled and vacuum tested. The leakage rate is better than $2 \cdot 10^{-9}$ mbar·l/s. The high voltage vessel is not completed yet. The measurements of the magnetic field along the electron beam orbit from gun to collector are finished [7]. An in-vacuum system for measuring magnetic field straightness in the cooling section is installed. The cascade transformer is assembled and the characteristics of the low voltage generator were studied. The ceramic acceleration and deceleration tubes are completed. Electronic components for the high voltage sections are tested on two sections, however production of 33 sets is still in process and should be finished in September 2011. The electron gun and collector with Wien filter are tested on a dedicated test bench, see Fig. 3 [8, 9]. The perveance of the electron gun of 9.5 $\mu A/V^{3/2}$ corresponds to the calculation. The Wien filter for suppression of the secondary emission from the collector was tested successfully. Problems with Penning discharges for high voltages were observed. Conditioning under high voltage and vacuum improvements increased discharge threshold. Collector efficiency is better than 10^{-5}. As first stage, the high voltage terminal can be installed in the high voltage vessel.

In the COSY ring the section for installing the cooler is prepared [10]. The position of one bumper is changed. The beam pipe diameter in this section is reduced to 100 mm, the value corresponding to diameter of the vacuum chamber inside the cooling section. Additional steering coils were installed on the quadrupoles for orbit correction [11]. New concrete radiation shielding walls with two large openings for the electron beam transport line are installed. After the summer shutdown COSY is fully operational. The SF_6 gas system is delivered, the power supplies are ordered.

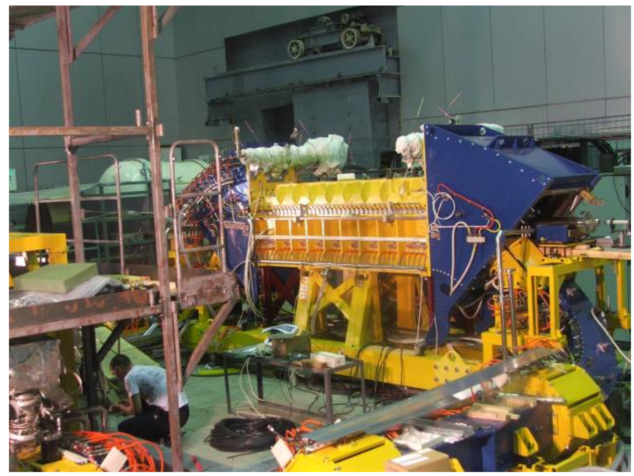

Figure 2: Assembling the 2 MeV electron cooler at BINP.

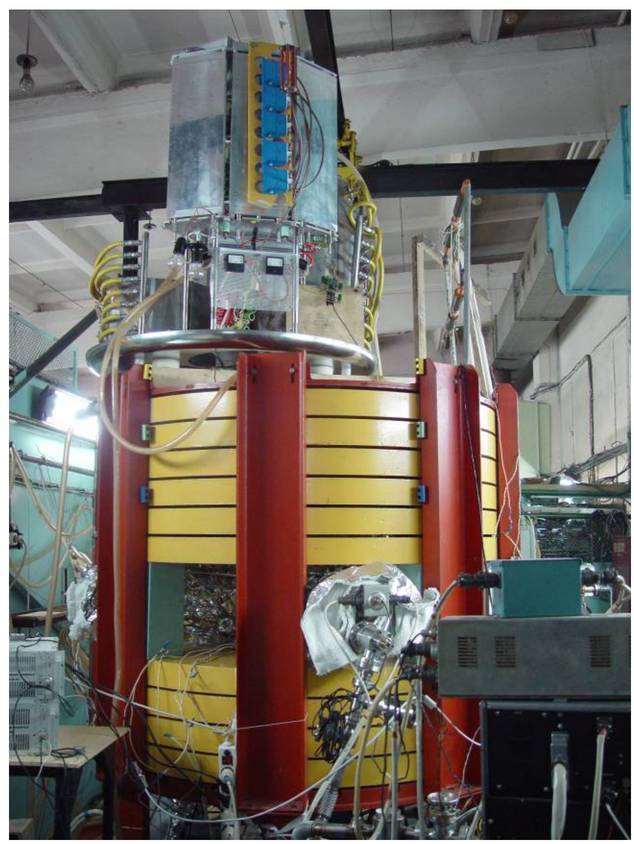

Figure 3: Electron gun and collector test bench at BINP.

MAIN COMPONENTS

Magnetic System

The main component of the magnetic system is the cooling solenoid. To satisfy the requirements on straightness of the magnetic field, the cooling solenoid is assembled from numerous short coils. The required field quality is achieved by mechanically adjusting the angles of individual coils.

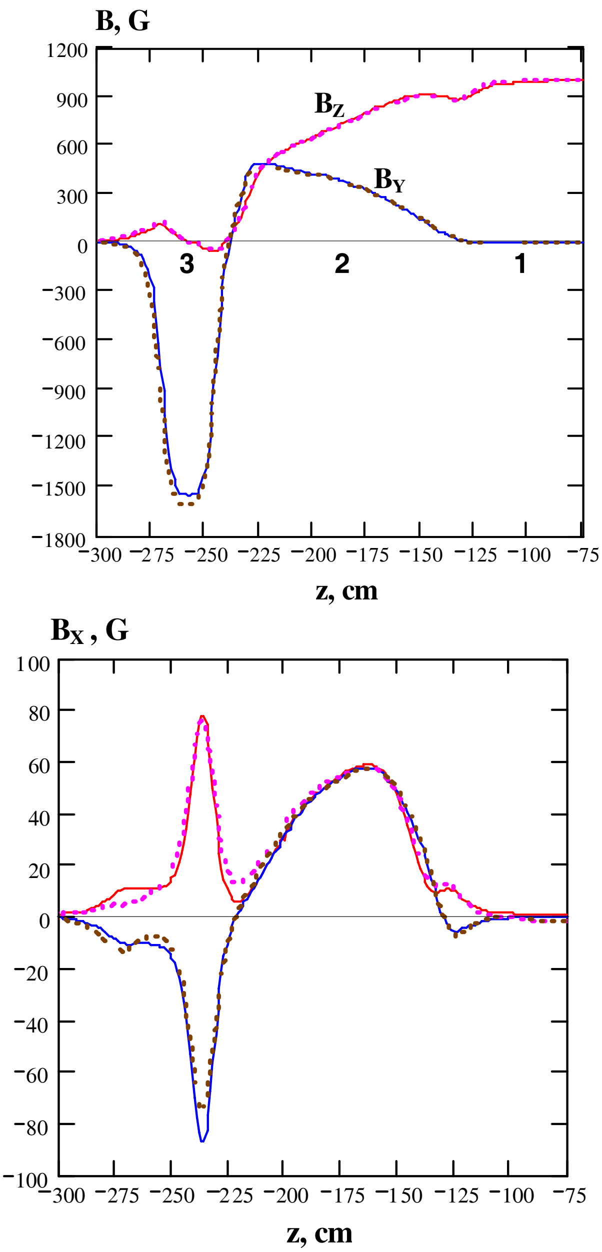

Figure 4: Longitudinal B_z and vertical B_y magnetic field components (upper plot) and horizontal B_x component along two lines with x = ± 2 cm, y = 0 (lower plot) versus cooling solenoid axis z. Dots represent measured curves, solid lines- computed curves (MAG3D). The origin is determined in the centre of the cooling solenoid (z = -75 cm). 1-cooling solenoid, 2-toroid, 3-dipole corrector.

Dipole magnets are installed along the proton orbit for compensation of the vertical field action on protons by the toroids. For better compensation of transverse components of magnetic field generated by current leads, two types of coils with opposite direction of winding are used. Magnetic field measurement along the electron beam orbit from gun to collector was performed by a set of calibrated Hall probes, which were located on a carriage. Representative parts of the magnetic system were selected for measurements. Longitudinal, normal and binormal magnetic field components are measured. Each component is measured at four different points that gives information about dipole and gradients of these field components. In Fig. 4 the magnetic field components along the path of the ion beam (cooling section, toroid, correction dipole) as example of measurements are shown.

High Voltage Terminal

The high voltage terminal is supported by a column consisting of 33 identical high voltage sections. The whole assembly is placed inside a vessel filled with SF_6 under pressure up to 10 bar. Each HV section contains two coils providing guiding magnetic field for acceleration and deceleration tubes and the high voltage power supply generating up to 60 kV. Each section is powered by a separate winding of the cascade transformer. Total power consumption of one section is about 300 W. The high voltage vessel is produced in Germany. In case of high pressure of 12 bar SF_6 there is a deformation in the bottom flange of some mm, which is taken into account by the mechanical design (see Fig. 5) [12].

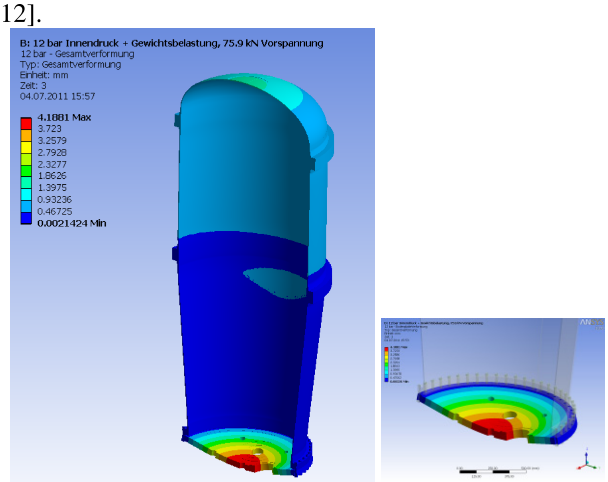

Figure 5: Mechanical stresses and deformations of the high voltage vessel.

Cascade Transformer

The power supply of the regular high voltage sections, high voltage terminal and collector is based on the concept of a high frequency cascaded resonant transformer. The system consists of 33 transformers with cascaded connection. At time of first testing high level of heating of stainless steel rings enclosing the cascade transformer was observed. Initial testing showed a 1.2 kW loss at each transformer. After coating the stainless steel with copper (by galvanic process) the power losses decreased to 464 W according to the difference of cooling oil temperature

Beam Diagnostics

For measurement of the electron beam position 10 pickups (5 in the beam line from gun to the cooling section and 5 from cooling section to collector) are foreseen. 2 pickups are installed in the cooling section for measuring the proton as well as the electron beam positions. The last two ones have a special design due to the fact that the in-situ magnetic field measurement system needs space for the magnetic sensor which is mounted on the cart moving along the solenoid axis. Each pickup consists of 4 sectors. To study the dynamics of electron cooling in a synchrotron only non-destructive instrumentation can be used. Beam diagnostics based on recombination is usually used to optimize electron cooling of protons (H^0-diagnostics). In some cases insertion devices may prevent the H^0 particles from reaching the detector (e.g. ANKE detector at non-zero position in the COSY ring). In the future HESR ring, for example, this technique is not applicable due to antiprotons being accelerated. An Ionisation Profile Monitor delivers real time data in both transverse planes allowing detailed analysis of beam profile evolution in COSY. Attempts to use scintillation of residual gas to measure beam profiles were very promising. So ionisation and possibly scintillation profile monitors become vital for optimization of electron cooling of antiprotons. The IPM was designed at GSI keeping the requirements for the future FAIR machines in mind [13]. The ionisation products are guided to a position sensitive detector by transverse electric field. An arrangement consisting of an MCP stack (100x48 mm^2), a luminescent screen, and a 656×494 pixel CCD camera is used to detect ions in high resolution mode. The IPM actually contains two identical units to provide simultaneous measurements in both, horizontal and vertical, planes. The IPM is installed in COSY in the arc downstream of the cooler telescope. The data acquisition software was developed at FZJ with an emphasis on real-time display of beam profiles. The software also performs fitting and plots beam width and position vs. time. The beam current measured by the beam current transformer (BCT) is also displayed. A Scintillation Profile Monitor (SPM) is being developed at COSY as a robust and inexpensive alternative to the IPM. The disadvantage of much lower event rate compared to the IPM and thus the necessity to locally add nitrogen to the residual gas is compensated by the much simpler mechanical design of the SPM. The light emitted by the gas in the vacuum chamber is focused by a lens onto a multichannel photomultiplier (PMT) array (Hamamatsu 7260-type, 32 channels, $0.8 \cdot 7$ mm^2 photocathode, 1 mm pitch). The readout is performed using a multichannel current digitizer, developed at iThemba LABS [14]. The problem of low rate of scintillation events detected by a multichannel photomultiplier is coped with by injecting small amounts of pure nitrogen into the SPM vacuum chamber. This leads to a temporary local pressure bump of no more than an order of magnitude. A commercially available piezo-electric dosing valve allows good control over the amplitude and duration of the pressure bump. Since the average pressure in the machine is hardly changed, the method is fully compatible with experiment operation [15.] A method using Thomson scattering is proposed to measure the electron beam profile in the cooling section [16].

SUMMARY

The main components of the 2 MeV electron cooler are manufactured and the whole system is now being assembled at BINP Novosibirsk. The commissioning with electron beam starts end of summer 2011. The installation at COSY is expected in winter 2011. Since the straightness of magnetic field in the cooling section needs to be better than 10^{-5} an in-situ magnetic field measurement system was installed. Diagnostic tools for optimisation of the electron cooling system were developed and tested. Modifications to the COSY ring and its infrastructure were done.

ACKNOWLEDGEMENTS

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