PROGRESS OF THE 2 MEV ELECTRON COOLER DEVELOPMENT FOR COSY- JÜLICH/ HESR

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Abstract

The 2 MeV electron cooling system for COSY-Jülich was proposed to further boost the luminosity in presence of strong heating effects of high-density internal targets. The energy is chosen to cover the full energy range of COSY. 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 at 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 that 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.

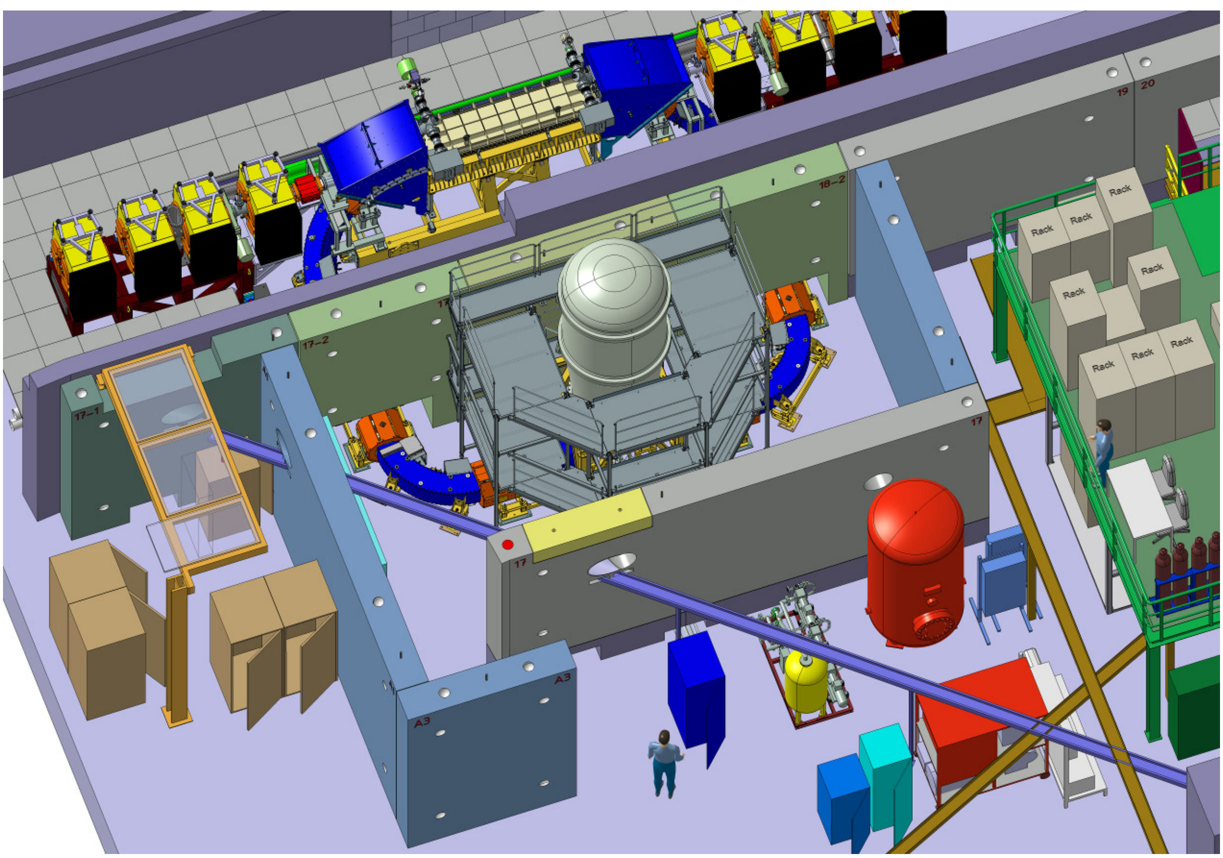

Figure 1: Integration of the 2 MeV electron cooler in COSY.

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BASIC DESIGN FEATURES

The basic parameters of the COSY cooler are listed in Table 1 [2,3]. 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:

1. The design of the cooling section solenoid is similar to the ones of CSR (IMP) and LEIR (CERN) coolers designed by BINP [4,5]. 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 [6]. The shape of the 2 MeV transport lines, however, dictates a different approach. The collector (inside the HV terminal) is complemented by a Wien filter to suppress return electron flux.

MAIN COMPONENTS

Magnetic System

The main component of the magnetic system is the cooling solenoid (Fig.2) where electron and proton beams share the same orbit. 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. 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 the electron gun to the collector was performed by a set of calibrated Hall probes, which were located on a carriage [7]. 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. 2 the magnetic field components along the path of the ion beam (cooling section, toroid, dipole corrector) is shown. The same components measured along the electron path (cooling section, toroid, transition section) is shown in Fig. 3

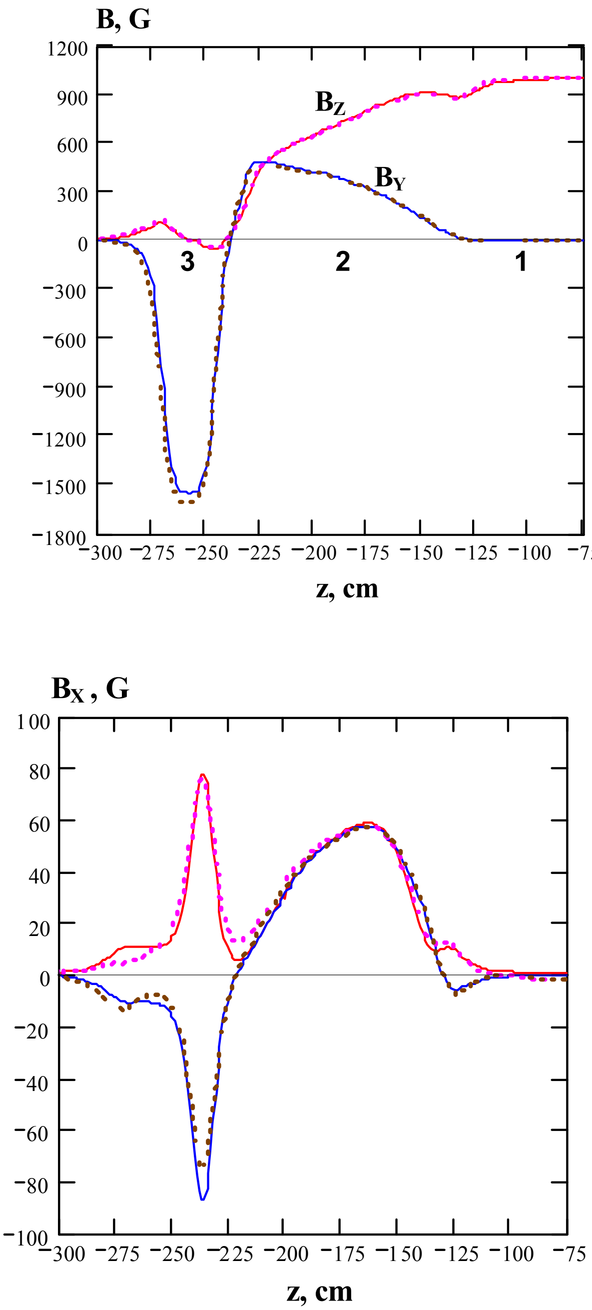
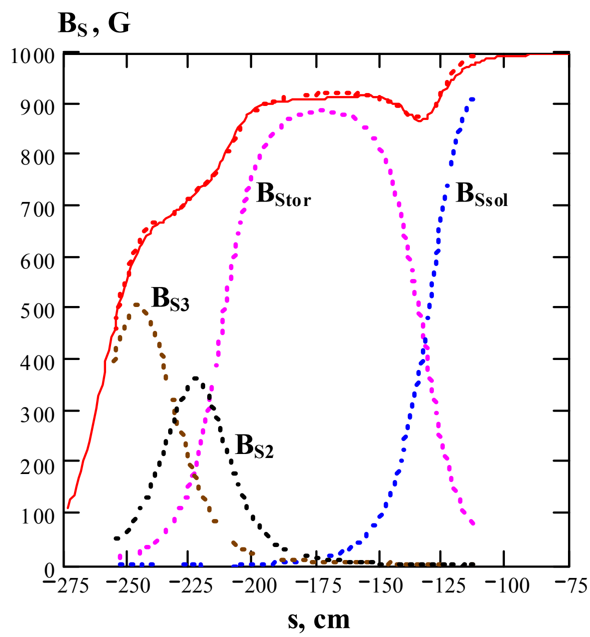


Figure 2: Longitudinal B_z and vertical B_y magnetic field components (upper) and horizontal B_x component along two lines with x = ± 2 cm, y = 0 (lower) versus cooling solenoid axis z. Dots-measured curves, solid lines-computed curves (MAG3D). The origin is determined in the centre of the cooling solenoid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



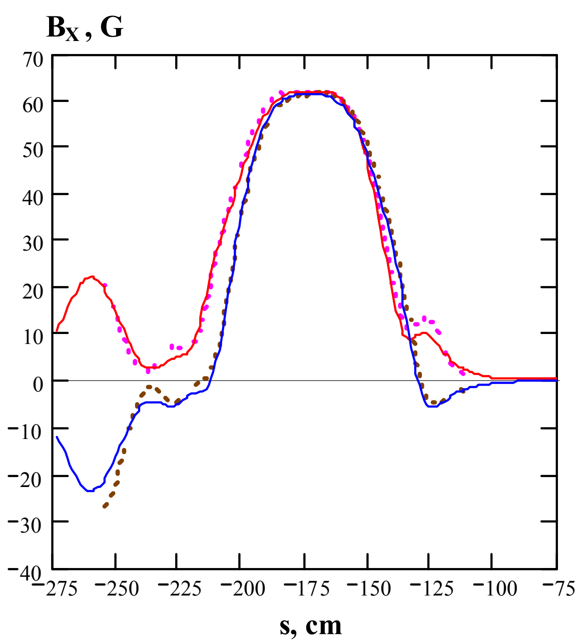


Figure 3: Longitudinal magnetic field component B_s and its constituents (upper) and horizontal B_x component along two lines with x = ± 2 cm, y = 0 (lower) versus cooling solenoid axis z. Dots-measured curves, solid lines- computed curves. The origin is determined in the centre of the cooling solenoid (z = -75 cm). B_{Stor}- toroid component, B_{Ssol}- cooling solenoid, B_{S2}-, B_{S3}- components of two and three coils of the transition magnet.

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.

Cascade Transformer

The basic idea for power supply of the regular high voltage sections, high voltage terminal and collector is 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 inclosing the cascade transformers was found. Initial testing showed a 1.2 kW loss at each transformer. After coating the stainless steel with copper (by galvanic process) the power decreased to 464 W. The heat loss was determined by measuring the oil temperature of the cooling system.

SUMMARY

The main components of the 2 MeV electron cooler are manufactured and the whole system is now assembled at the test bench in BINP Novosibirsk. The commissioning with electron beam started in August 2011. The installation at COSY is expected in December 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 is being built. Diagnostic tools for optimisation of the electron cooling system are developed and tested. Modifications to the COSY ring itself and its infrastructure were done.

ACKNOWLEDGEMENTS

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