STATUS OF 2 MEV ELECTRON COOLER 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 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 project is funded since mid 2009. The design and construction of the cooler is accomplished in cooperation with the Budker Institute of Nuclear Physics in Novosibirsk, Russia. The production of 90% of the cooler components was complete by the end of 2010 at BINP. The space required for the 2 MeV cooler was made available in the COSY ring during the summer 2010 shutdown. The infrastructure necessary for the operation of the cooler in the COSY ring (cabling, water cooling etc.) is established.

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 an internal hydrogen target with effective thickness 4×10^{15} atoms per cm^2 and 10^{10} – 10^{11} antiprotons at 15 GeV circulating in the HESR. In this case the peak luminosities ranging from 2×10^{31} to 2×10^{32} cm^{-2}s^{-1} are achievable. These experiments allow observing meson resonances in proton-antiproton annihilations. Resolution of the experiments is limited by 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.

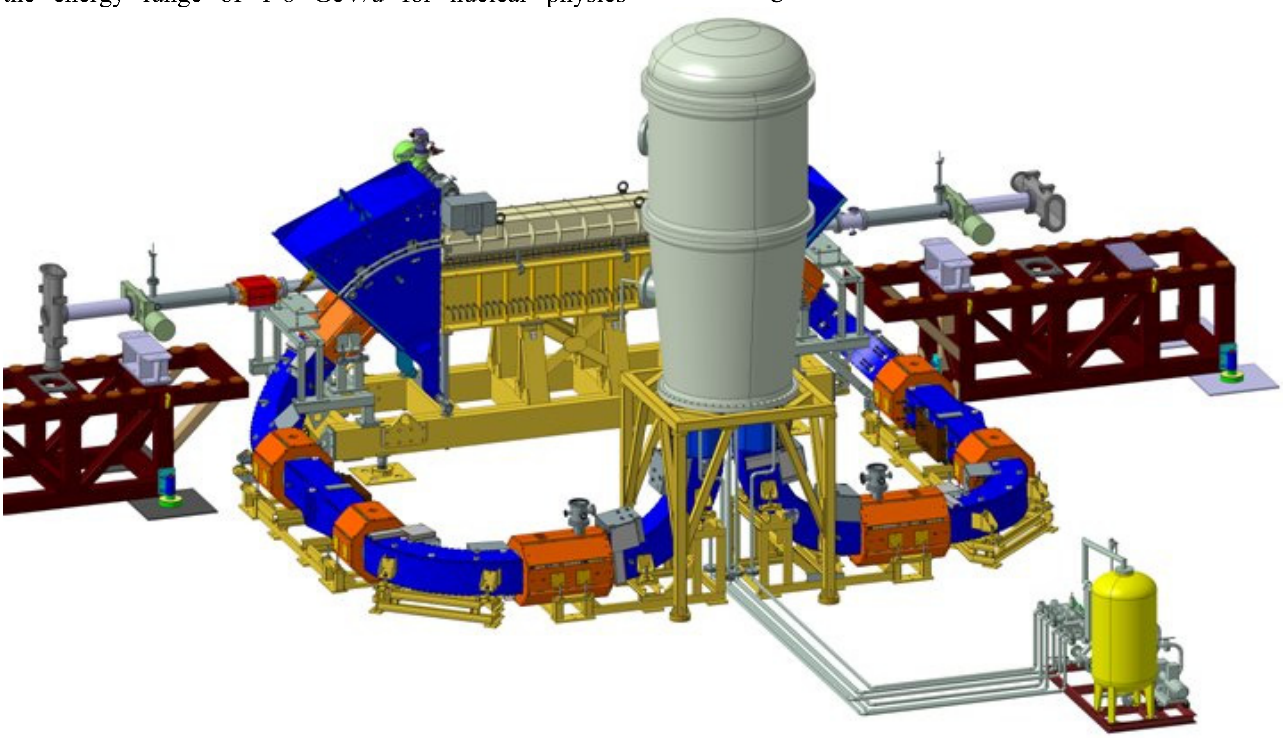

Figure 1: Layout of the 2 MeV electron cooler for COSY.

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BASIC DESIGN FEATURES

The basic parameters of the COSY cooler are listed in Table 1. 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 [2, 3]. 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 [4]. 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.

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. Measurements of the transverse components of the magnetic field are intended to be carried out by a probe similar to the one described in [3].

High Voltage Terminal

The high voltage terminal is supported by a column consisting of 33 identical high voltage sections (fig. 3). 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.

Figure 2: Toroid and cooling section.

Each section is powered by a separate winding of the cascade transformer. Total power consumption of one section is about 300 W. A new feature of the electron gun is a control electrode split in 4 parts for independent modulation in 4 sectors of electron beam. Using such modulation it is possible to monitor the beam size and rotation using the pickup electrodes. A system for suppression of secondary electron flux based on Wien filter is added to the electron collector. Here the beam moves in crossed transverse electric and magnetic fields.

Cascade Transformer

For the last few years the COSY-BINP collaboration was testing prototype elements for the magnetized cooler at high voltage. The turbine electro generator driven by compressed gas feeding magnet coils along the HV column was tested [4]. For the 2 MeV electron cooler a cascade transformer is chosen now to power components at high potential. The energy range of the 2 MeV cooler is very broad from 24 keV to 2 MeV. In this case the electron optics of the accelerating tube should be very flexible. So, the continuous longitudinal magnetic field is preferable. The generation of such field demands the large number of independent solenoid coils located in each section. The solution based on a cascade transformer is expected to be more reliable since no moving parts are present. For this reason the reliability of this design depends on electrical strength only. However, the cascade transformer design also has disadvantages. An issue inherent to all cascade solutions is related to power transfer efficiency. The total power consumed by all sections is passed through the first one. That is why the power efficiency of the sections should be very high in order to keep the power losses reasonable. Moreover, the required number of HV sections appears to be close to the upper limit for such systems. The transformer column and a prototype of one section are shown in Fig. 4 and Fig. 5.

For 4 or 8 MeV electron cooler with lowest electron energy of about 500 keV it is possible to use smaller number of optic elements (e.g. Fermilab cooler [5] or Swedish project [6]).

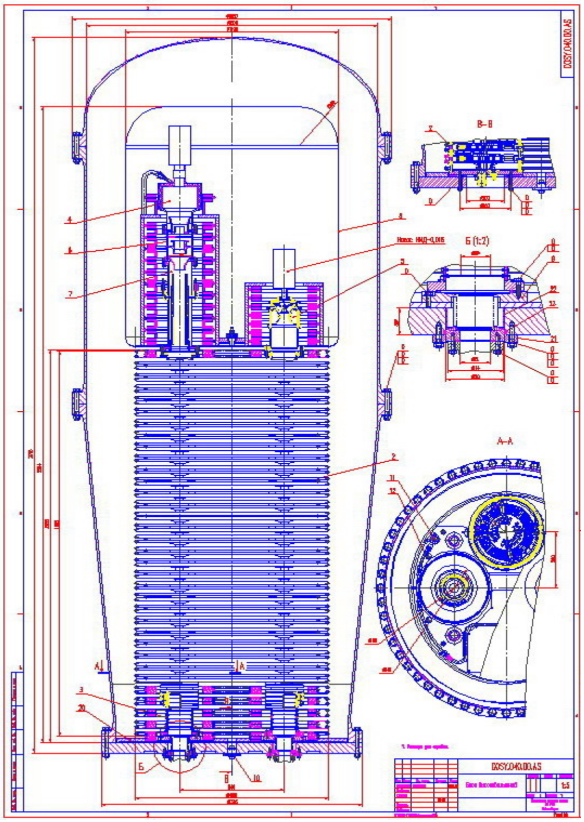

Figure 3: High voltage terminal with electron gun and collector inside the pressure vessel.

This regime of the cooler operation can be checked with the 2 MeV COSY cooler by turning off some magnet power supplies. For higher electron energies the concept of turbines will be further developed.

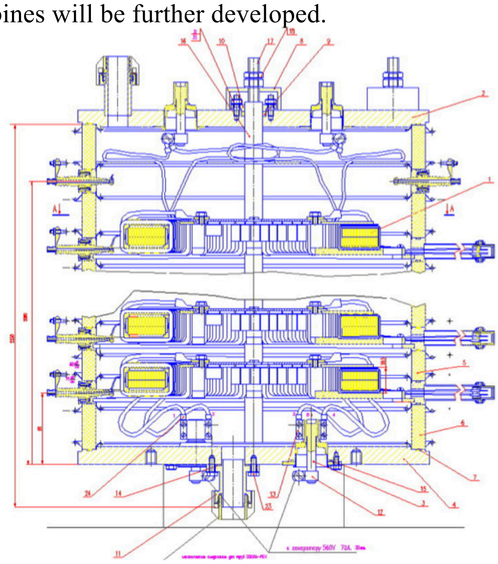

Figure 4: High power cascade transformer.

The transformer column has a spark-gap system for safety in case of gas breakdown. The inner diameter of a transformer section is 20 cm, the outer diameter - 28 cm and the height 2 cm. The design value of energy-transfer power amounts to 40 kW. Oil is used as isolation and cooling medium.

Figure 5: Prototype of the transformer section.

SUMMARY

The main components of the 2 MeV electron cooler are manufactured in the BINP machine shop. The commissioning with electron beam starts in summer 2011 in Novosibirsk. The installation at COSY is expected in autumn 2011. The pressure vessel is available at BINP. A second vessel is now in production in Germany. The HV system is modular. It is based on a resonant cascade transformer providing power to multiple HV sections at different electrical potential. A Wien filter is intended to improve collector efficiency. 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 as well. Diagnostic tools for optimisation of the electron cooling system are developed and tested. Modifications to the COSY ring itself and its infrastructure to make space available for the cooler were done.

ACKNOWLEDGEMENTS

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