STATUS OF THE 2 MEV ELECTRON COOLER FOR COSY JUELICH

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Abstract

The design and construction of the 2 MeV electron cooling system for COSY-Juelich is proposed to further boost the luminosity in presence of strong heating effects of high-density internal targets. In addition the 2 MeV electron cooler is an important step towards the high energy electron cooler for the High Energy Storage Ring (HESR) in the FAIR project. The design of the 2 MeV electron cooler will be accomplished in cooperation with the Budker Institute of Nuclear Physics in Novosibirsk, Russia. A newly developed prototype of the high voltage (HV) section, consisting of a gas turbine, magnet coils and HV generator was successfully tested. Special emphasis is given to voltage stability which must be better than 10^{-4}. First experiments with three HV sections, installed in a pressure vessel filled with SF_6 gas are reported.

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 to study meson resonances in proton-antiproton annihilations. Resolution of the experiments is limited only by momentum spread in antiproton beam, which must be better than 10^{-4}.

The average momentum losses dp/pdt on such a target (for 4 GeV antiprotons) will be about $4\cdot10^{-6}s^{-1}$ and the heating rate of momentum spread by fluctuation of ionization losses will be near $dp^2/p^2dt = 2\times10^{-9}s^{-1}$ To obtain momentum spread of $10^{-5} – 10^{-4}$ cooling time in the range $\tau_{cool} = 2(dp/p)^2/(dp^2/dt/p^2) = 0.1 \div 10s$ 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 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. For example the electron beam density of 2×10^8 cm^{-3} (6 mm beam diameter and 1.5 A of current) magnetized with longitudinal magnetic field of 2 kG will have 2.7×10^6 cm/s drift velocity in the beam reference frame. This velocity allows (in principle) to have cooling time near 0.1 s for the low angular spread ($\Delta p_{\perp}/p = 10^{-5}$) beam.

BASIC DESIGN FEATURES

The basic parameters for the COSY cooler are listed in Table 1. The restrictions are given by the space available in the COSY ring. The height is limited to 7 m by the building.

Table 1: Basic Parameters and Requirements

COSY 2 MeV Electron Cooler	Parameter
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	2-3 m
Toroid Radius	1.25 m
Magnetic Field (cooling section)	0.5 ... 2 kG
Vacuum at Cooler	10^{-8} ... 10^{-9} mbar
Available Overall Length	6 m
Maximum Height	7 m
COSY Beam Axis above Ground	1.8 m

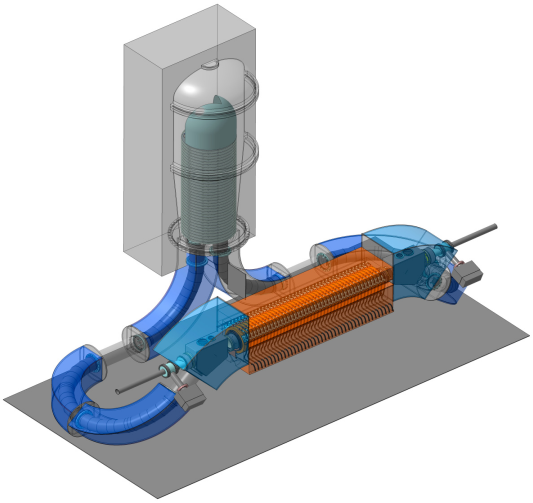

Figure 1: Layout of the 2 MeV electron cooler for COSY.

In Fig. 1 the layout of the COSY 2 MeV cooler is shown. The cooler HV terminal is installed inside the pressure vessel filled with SF_6 gas. 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 [2,3]. However, for the 2 MeV cooler the requirement on the straightness of magnetic field lines is so high ($\Delta\theta < 10^{-5}$) that a system for monitoring the magnetic field lines in vacuum becomes necessary.

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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 modified to suppress return flux. A new low energy line in front of the collector with electrostatic field or 180 degree bending can be used .

PROTOTYPE ELEMENTS STUDY

For the last few years the COSY-BINP collaboration was studying prototype elements for the magnetized cooler. The turbine electro generator driven by compressed gas feeding magnet coils along the HV column was tested. This gas is used to produce power for individual sections and, at the same time, to cool the 500 Gauss coils (Fig. 2).

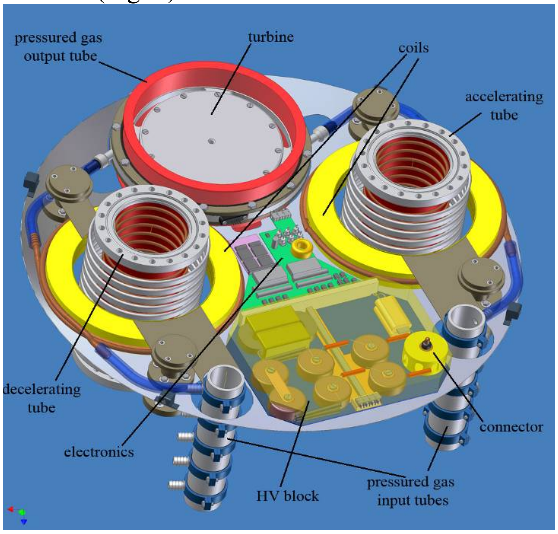

Figure 2: Preliminary design of the HV section with magnet coils around the acceleration and deceleration tubes.

For experiments with HV sections in pressurized SF_6 gas we used the same vessel as used for 1-1.5 MeV industrial accelerator of ELV type (Fig. 3 and Fig. 4). The height of a single HV section equals 4 cm while the gap between them is 2 cm. The results of HV tests are shown in Fig. 5 and Fig. 6.

Figure 3: Pressure vessel used for HV section testing.

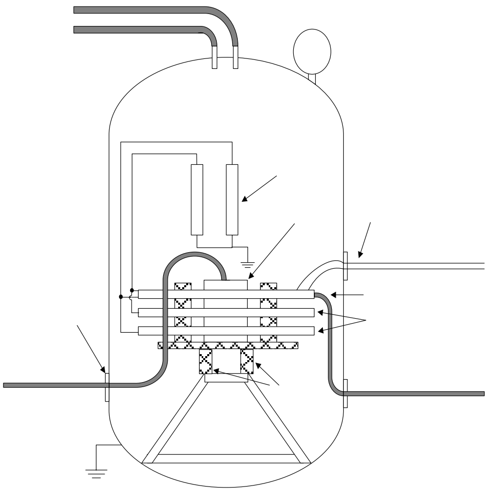

Figure 4: HV test setup.

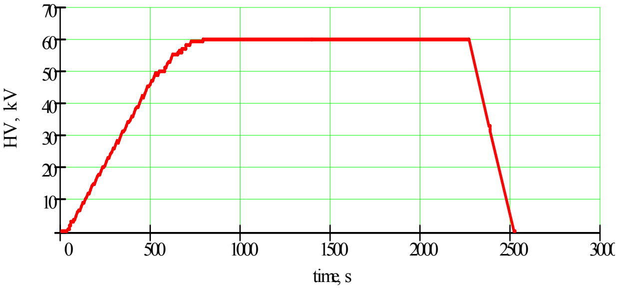

Figure 5: Voltage between sections in SF_6 (1.6 atm.).

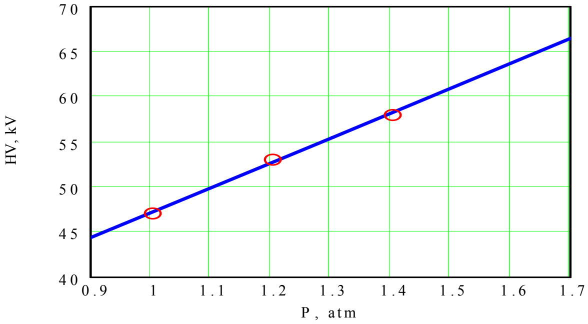

Figure 6: Discharge voltage versus SF_6 pressure.

Fig. 6 shows the measurement of discharge voltage between HV sections for different SF_6 pressure. Linear extrapolation (blue line) shows that the discharge voltage at 1.6 atm is 63 kV which is higher than the design output of the HV source (60 kV). From these experiments it is clear that SF_6 gas isolation works well for the chosen HV section design. HV stability was measured using an ADC installed in the HV terminal. In Fig. 7 relative HV stability is shown.

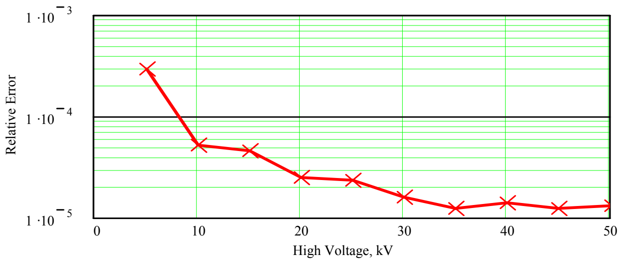

Figure 7: Relative HV stability versus HV value.

In Fig. 8 voltage between sections at 1.2 atm. of SF_6 is shown.

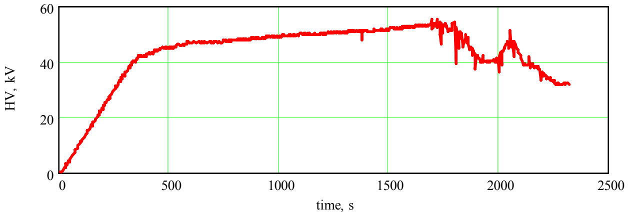

Figure 8: Voltage between sections in SF6 (1.2 atm.).

There is ripple which appears at higher voltage and does not vanish when the voltage is decreased. The most probable explanation of the effect is the appearance of regions of ionized gas after the first spark. After that sparks in this region appear more often and at lower voltages. Similar behavior can be observed at 1.4 atm. (Fig. 9).

At high values of voltage, which are close to maximum, sparks appear. Maximum voltage reached for this pressure (1.4 atm) is 58 kV. Stable operation is possible at 56-57 kV. To estimate the coil temperature, the coil resistance was measured during the experiments. Using the equation for dependence of coil resistance on temperature $R = R_0(1+\alpha\Delta T)$ one can estimate the average coil temperature (for copper α=0.0038 [1/K]).

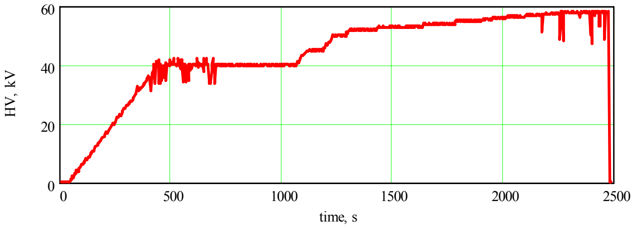

Figure 9: Voltage between sections in SF_6 (1.4 atm.).

The evolution of the coil temperature is shown in Fig. 10. The coil temperature increase (reconstructed from coil resistance) is acceptable. There is no dependence of the temperature on conditions in the vessel. It proves that coil cooling provided by gas flowing in tubes is much stronger than cooling by convection.

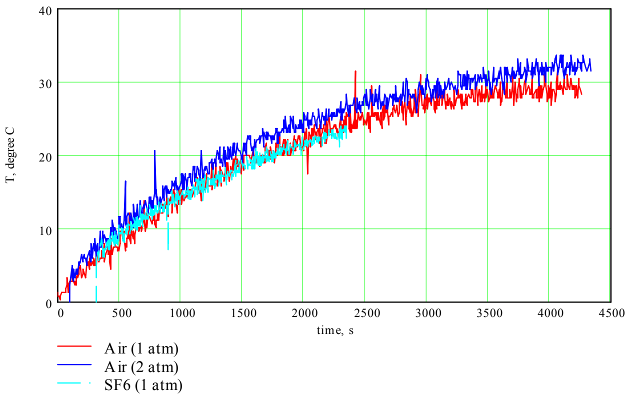

Figure 10: Average coil temperature calculated from resistance minus room temperature for different conditions in the vessel. I=1.3 A.

SUMMARY

The HV section prototype was successfully tested under different gas mixtures and pressures in a test bench at BINP. The specified voltage stability of better 10^{-4} was reached. The magnetic field in the coils of a single section reached the required value of 500 G. The specified high voltage of 60 kV per section was reached with required stability under SF_6 pressure of 1.6 atm. In the next step more of such high voltage sections will be combined and long life time and reliability will be investigated.

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