STATUS OF THE 2 MeV ELECTRON COOLER DEVELOPMENT FOR COSY-JUELICH

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Abstract

The design and construction of a 2 MeV electron cooling system for COSY-Juelich is proposed to further boost the luminosity even with strong beam heating effects of high-density internal targets. In addition the 2 MeV electron cooler for COSY is intended to test some new features of the high energy electron cooler for HESR at FAIR in Darmstadt. 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 section, consisting of a gas turbine, magnet coils and high voltage generator including electronics was successfully tested. Special emphasis is given to voltage stability better than 10^{-4}. Results of first experiments with three combined high voltage sections, arranged in a SF_6 pressurized gas tank are reported.

INTRODUCTION

The COSY synchrotron accelerator and storage ring provides unpolarized and polarized proton or deuteron beams for internal or external hadron physics experiments in the momentum range from 300 MeV/c to 3.7 GeV/c [1]. Electron cooling is applied at low energies, at present mainly at injection energy, to prepare low-emittance beams to be used after acceleration and extraction for internal and external experiments. Stochastic cooling, covering the momentum range from 1.5 GeV/c up to the maximum momentum, is used to compensate energy loss and emittance growth at internal experiments. Future experiments at COSY require higher luminosity (> 10^{32} cm^{-2} s^{-1}). There are two possible ways of achieving it i) increasing the bandwidth of the stochastic cooling system and/or ii) electron cooling up to maximum momentum. For operation with thick internal targets, fast (magnetized) electron cooling is the only technically feasible solution. For electron cooling up to maximum momentum of COSY an electron cooler up to 2 MeV electron energy has to be developed together with the Budker Institute in Novosibirsk [2,3].

PROPOSED 2 MeV ELECTRON COOLER

Basic Parameters and Requirements

The basic parameters and requirements are listed in Table 1. The most important restrictions are given by the available space at the COSY ring itself. The height is limited by the building to 7 m, the length of the cooler in beam direction by the existing electron cooler and the ring itself to 3 m. The acceleration of polarized beams at COSY has to be taken into account. Space for compensating magnets is needed to achieve conservation of beam polarisation.

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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	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	7 m
Maximum Height	7 m
COSY Beam Axis above Ground	1.8 m

Preliminary Technical Design

The proposed electron cooler consists of a high pressure vessel with electrostatic acceleration and deceleration columns, two bending toroids and cooling section. The preliminary layout of the cooler is shown in Fig. 1 [3]. The basic features of the design are i) the longitudinal magnetic field from the electron gun to the collector, in which the electron beam is immersed, ii) the collector and electron gun placed at the common high voltage terminal and iii) the power for the magnets surrounding the accelerating and decelerating columns is generated by gas driven turbines. The electron beam is accelerated to the energy up to 2 MeV. After that the electron beam is bent in the toroid and is guided to the cooling section. After passing the main solenoid the beam is returned to the electrostatic column. Here it is decelerated and absorbed in the collector located in the head of the electrostatic column. Each toroid consists of two parts. The first one bends the magnetized electron beam 90° in the vertical plane. The second one bends the beam 180° in the plane, which is inclined 45° to the vertical plane. Such a complicated 3-D geometry provides compactness of the system. The dipole kick for protons in the bending toroids near the cooling section will be compensated by dipole magnets which will be installed as close as possible to the large toroid coils. The centrifugal drift on the other hand, caused by the curvature of the magnetic force line can be compensated by the electrostatic plates installed inside the toroids. Additional short electrodes installed at the edges of these plates can improve the electric field quality. Electrostatic bending is used for better recuperation efficiency [4,5].

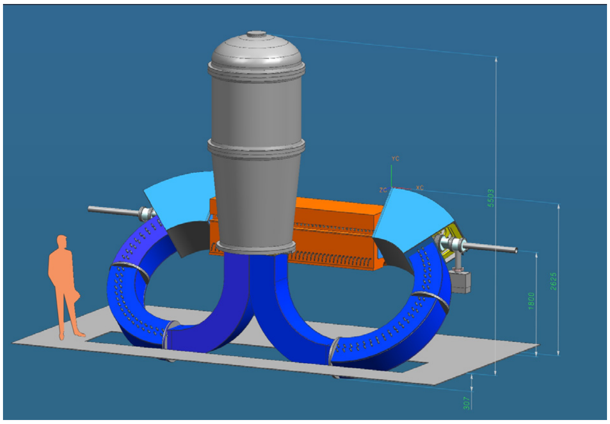

Figure 1: Layout of the proposed 2 MeV electron cooler for COSY.

PROTOTYPE OF THE HIGH-VOLTAGE SECTION

High Voltage System

Each high voltage section of the 2 MeV electron cooler (Fig. 2) contains: high voltage power supply, coils generating the magnetic field along the acceleration and deceleration columns, low voltage power supply and control units. Each section has two high voltage power units generating 30 kV each. Using two HV units allows decreasing the voltage across the insulation inside each section from 60 kV to 30 kV. The voltage between the sections amounts 60 kV. The whole 2 MV column consists of 34 sections. The electric field between the sections will be 30 kV/cm. To suppress sparking SF_6 gas pressure of about two bars is sufficient. Special measures must be taken to prevent destruction caused by sparking. Accelerating rings are surrounded by collar rings. Gas driven turbines with integrated electric generators are being developed for powering the high voltage sections and the magnet power supplies. A compressor at ground potential will pump SF_6 gas from the vessel, compress it and feed it to a thermo exchange chamber and gas filter. After this the pressurized gas is directed with plastic tubes along the high voltage column.

Turbine

The turbine generator consists of a gas turbine with 24 permanent magnets and a stator with 36 coils. The coils are connected in three series lines so that the generator produces three-phase AC power. The nominal frequency depends upon loading current and is expected to be close to 2 kHz. This high frequency of AC power enables deploying the transformers and smoothing capacitances of reasonable size inside the power supply.

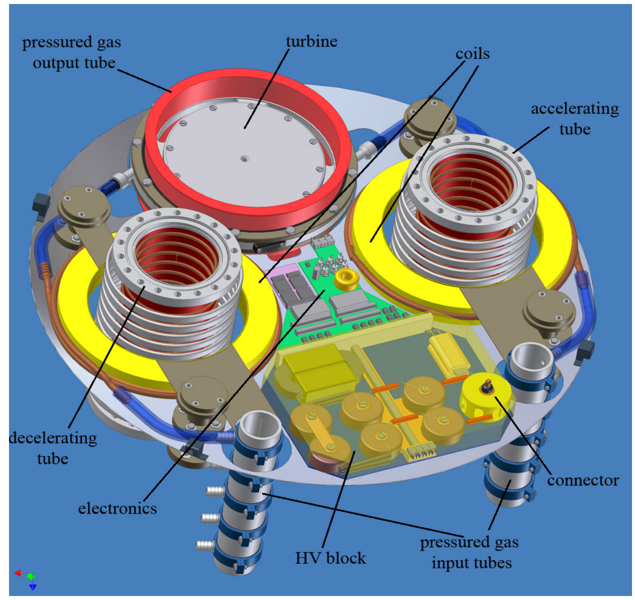

Figure 2: Layout of a complete high voltage section.

The maximal electric power produced by the generator during preliminary testing was 670 W. The power production efficiency of the turbine was 10%. The electronics board and the PID regulator are described in more detail in [6].

High Voltage System Test Bench

To test HV sections in pressured gas a dedicated test bench was built (Fig. 3) [7].

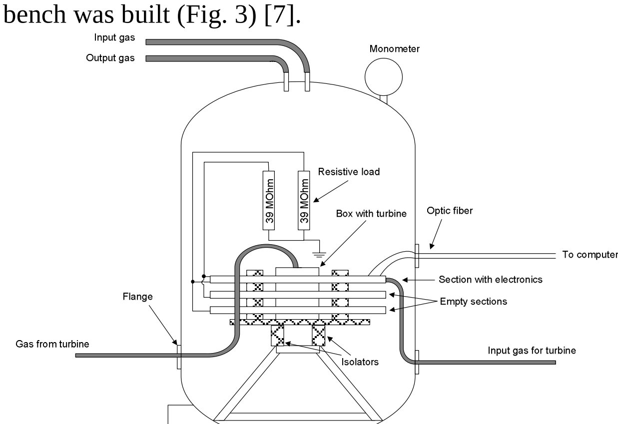

Figure 3: High voltage section test bench.

The pressure vessel is 207 cm high and 121 cm in diameter. Three sections (one section with electronics and magnet coils and two empty sections) were placed in the pressure vessel. Inside the vessel the sections were arranged on an isolating table. The section equipped with electronics was placed on top. Resistive load, consisting of two 39 MΩ resistors in series, was attached to the output of the high voltage power supply. Middle point between resistors was attached to the ground. High voltage outputs were also connected to two empty sections. Control electronics of the section is connected to a computer via optic fiber. The gas is transported to/from the turbine via plastic tubes.

High Voltage Stability

To test the stability of the high voltage several experiments were made. The high voltage stability was measured using an ADC. In Fig. 4 and 5 absolute and relative stability of the high voltage is shown.

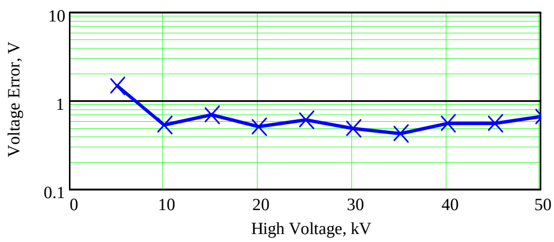

Figure 4: Absolute stability of the high voltage.

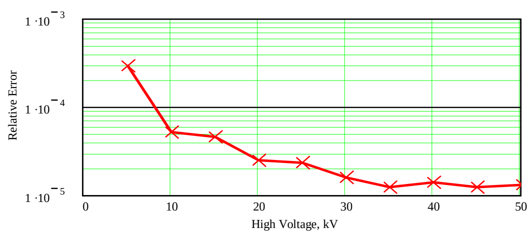

Figure 5: Relative stability of the high voltage.

Experiments with Gas Mixture and Pure SF_6

A mixture of SF_6 and air was made in the vessel (an amount of SF_6 was added to increase the pressure by 0.2 atm to 1.2 atm). First measurement was made to compare such mixture with air under the same pressure [7].

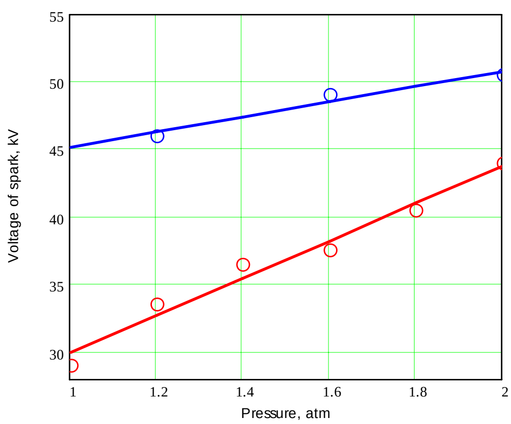

Figure 6: Dependence of spark voltage between sections on pressure. Red – measurement in air, blue – measurement in gas mixture (air + SF_6).

In experiments with gas mixture a voltage of 50 kV between sections was reached. In case of pure SF_6 60 kV was achieved (see Fig.7).

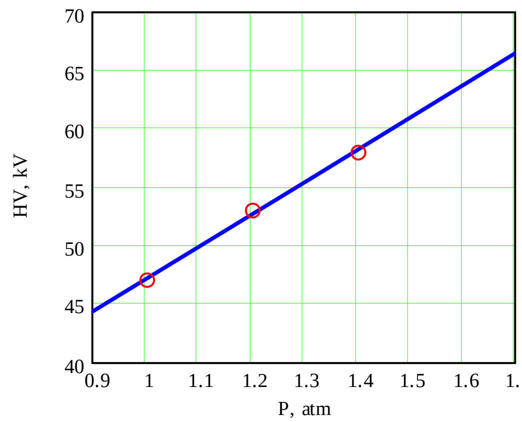

Figure 7: Discharge voltage versus SF_6 pressure.

Assuming that the measured points lie on a line we can estimate the maximum voltage for 1.6 atm SF_6 to 63.5 kV.

SUMMARY

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

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