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HIGH VOLTAGE COOLER NICA STATUS AND IDEAS

V.B. Reva[1], M.I. Bryzgunov, A.V. Bubley, A.D. Goncharov, N.S. Kremnev, V.M. Panasyuk, V.V. Parkhomchuk[1], V.A. Polukhin, A.A. Putmakov BINP, Novosibirsk, Russia
[1]also at Novosibirsk State University, Novosibirsk, Russia

Abstract

The new accelerator complex NICA [1-2] is designed at the Joint Institute for Nuclear Research (JINR, Dubna, Russia) to do experiment with ion-ion and ion-proton collision in the range energy 1-4.5 GeV/u. The main regime of the complex operation is ion collision of heavy ion up to Au for study properties of dense baryonic matter at extreme values of temperature and density. The planned luminosity in these experiments is 10^{27} $см^{-2}·c^{-1}$. This value can be obtained with help of very short bunches with small transverse size. This beam quality can be realized with electron and stochastic cooling at energy of the physics experiment. The subject of the report is the problem of the technical feasibility of fast electron cooling for collider in the energy range between 0.2 and 2.5 MeV.

SETUP DESCRIPTION

The NICA collider for study nuclear physics at range of relativistic physics 1-4.5 Gev/u requires powerful electron cooling system to obtain high luminosity. The basic idea of this cooler is to use high magnetic field along all orbit of the electron beam from the electron gun to the electron collector. At this case we have chance to have high enough the electron beam density at cooling section with low effective temperature The schematic design of the setup is shown in Figure 1. The electron beam is accelerated by an electrostatic generator that consists of 42 individual sections connected in series. Each section has high-voltage power supplies with maximum voltage 60 kV and current 1 mA. The electron beam is generated in electron gun immersed into the longitudinal magnetic field. After that the electron beam is accelerated, moves in the transport line to the cooling section where it will interact with ions of NICA storage ring. After interaction the electron beam returns to electrostatic generator where it is decelerated and absorbed in the collector. Because the NICA is collider there are two electron lines for both ion beams located up and down. Both electron coolers are independent from each other.

The optics of 2 MeV cooler for NICA is designed close to the COSY high-energy coolers [3]. The motion of the electron beam is magnetized (or close to magnetized conditions) along whole trajectory from a gun to a collector. This decision is stimulated by requirement to operate in the wide energy range from 200 keV to 2.5 MeV. So, the longitudinal field is higher then transverse component of the magnetic fields. The essential challenge of this design is low value of the energy consumption of magnetic field 500-700 kW for both coolers. So, the volume of copper in the coils is maximum as possible taken into account the small distance between beam lines. This distance is 32 cm.The length of the linear magnets is defined by the necessity to locate the electrostatic generator outside the shield area of the storage ring.

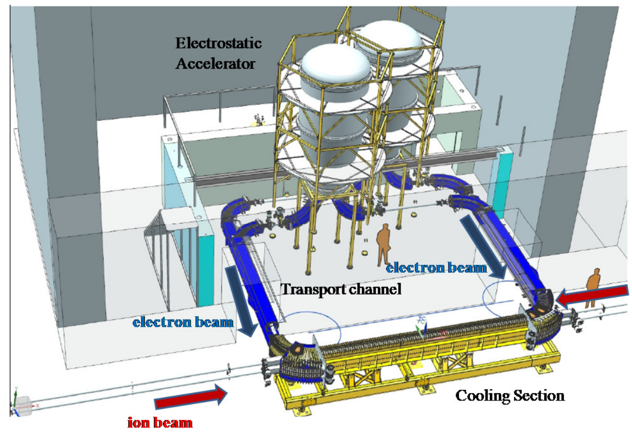

Figure 1: 3D design of 2 MeV COSY cooler.

The vacuum chamber will be pumped down by ion, getter and titanium sublimation pumps. The typical diameter of the vacuum chamber is 100 mm and the aperture in the transport channel and cooling section is close to this value. The diameter of the accelerating tube is 60 mm. The main parameters of NICA cooler can be found in Table 1.

Table 1: Specifications of NICA Cooler

Parameter	Value
Energy range	0.2÷2.5 MeV
Number of the cooling section	2
Stability of energy (ΔU/U)	$\le 10^{-4}$
Electron current	0.1÷1 A
Diameter of electron beam in the cooling section	5÷20 mm
Length of cooling section	6 m
Bending radius in the transport channel	1 m
Magnetic field in the cooling section	0.5÷2 kG
Vacuum pressure in the cooling section	10^{-11} mbar
Height of the beam lines	1500/1820 mm
Total power consumption	500-700 kW

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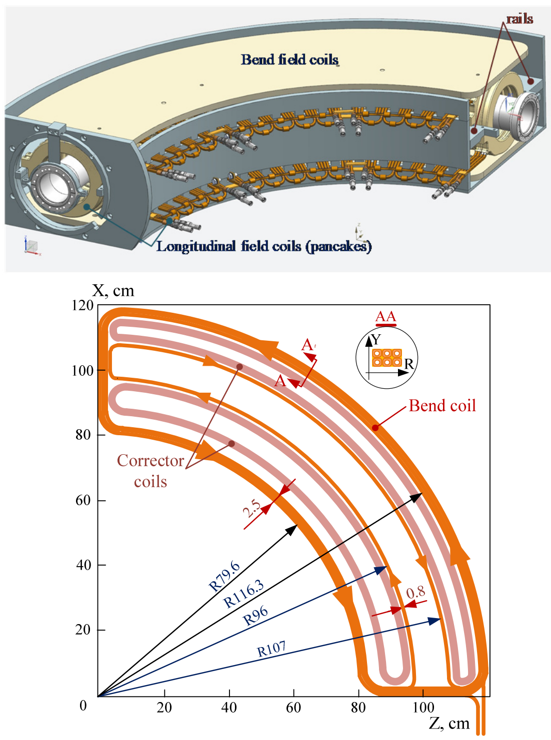

Figure 2: Design of bending magnets.

MAGNETIC SYSTEM

The magnetic field in the accelerating tube is taken 500 G and this value is related to the maximum power that can be transfer to a high voltage potential with help of the cascade transformer. The value in the transport channel is located in the range 0.5 kG – 1 kG. The energy 2.5 MeV is high enough in order to don't have the complete adiabatic motion of the electrons because the magnetic field of the bend elements is chosen to provide the length of bend equal to integer number of Larmour lengths. In such case the kick on entry to bend is compensated by kick on leaving and the excitation of the transverse motion of the electron is small. So, it is convenient to change the longitudinal magnetic field according to the electron momentum. At attainment of the maximum magnetic field the transition to another integer number is implemented. Figure 2 shows the design of the 90° bending magnets. It consists of coils of the longitudinal magnetic field and coils of the bending field. The last shows separately on the bottom picture. The curve of the bending field should be very close to the centrifugal force $Fc=pV/R$ (see Fig. 3). In this case the oscillation of the transverse motion of electrons is minimal. To decrease heating of the beam after transition through a bend, the length of the bend should be equal to integer number of Larmor length. In such a case kick on entry to bend in compensated by kick on leaving (see Fig. 4). Also field index $n=0.5$ is required in order to prevent changing transverse shape of the electron beam. The field index is produced with help of bend coils with special shape.

It is clear that it is possible to set one value of energy of electron beam and to adjust cooler optics for this energy in order to avoid high temperature of the electron beam in cooling section. But wide range of operating electron energy means that optics of the cooler must be easily adjustable for all energies. One method of realization of such system is to adjust optics manually for every value of energy. Number of parameters and correctors in our system allow us to do this, but this method is very time consuming. There is easier method which was proposed for this system. The idea of the method is to change magnetic field in the cooler synchronously with beam energy.

The magnetic field in the cooling section is taken 2 kG in order to have the maximum Larmour oscillation (~ 20) of the electron during its interaction with ion in order to have the magnetized Coulomb collisions even the highest electron energy 2.5 MeV. The cooling section consists of units with length 1 m. Each section contains coils of the longitudinal magnetic field, the correction coils of the transverse field, magnetic shield and magnetic shield support. Each vacuum section inside unit contains the BPM. So, the rough regulation of the magnetic force line is possible as result measurement of BPM with electron and ion beams. The ion beam is used as base line for the electron beam. The vacuum tube can be covered by NEG coats or contains NEG modules. The preliminary design of the cooling section is shown in Figure 5.

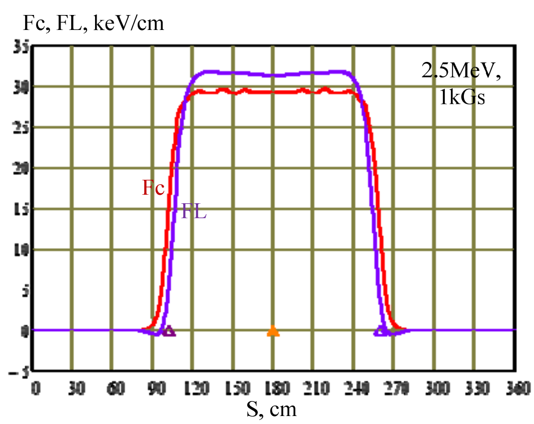

Figure 3: Centrifugal and Lorentz forces in 90 bend magnets.

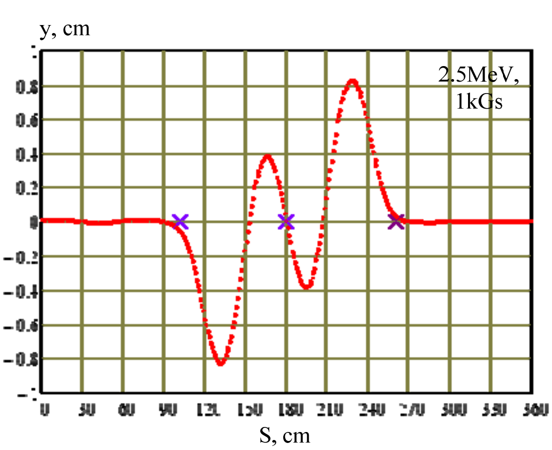

Figure 4: Oscillation of orbit in the bending magnet.

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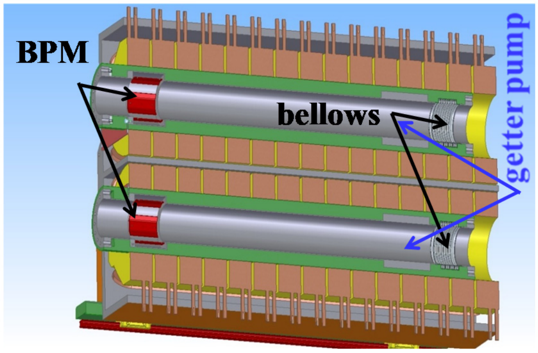

Figure 5: Design of the cooling section.

ELECTROSTATIC ACCELERATOR

The design of the electrostatic accelerator is shown in Figure 6. The accelerating column consists of 42 identical high voltage sections. The column with high voltage terminal is placed in special vessel which was filled with SF6 under pressure up to 10 bar. The section contains two magnetic coils producing guiding magnetic field for acceleration and deceleration tubes and the high voltage power supply producing up to 60 kV. Total power consumption of one section is about 300 W. The coils and the electronic components are cooled with transformer oil. Electrostatic accelerator of NICA cooler. It is divided on two parts. The middle section contains of vacuum pumping, BPM, correctors and mechanical support.

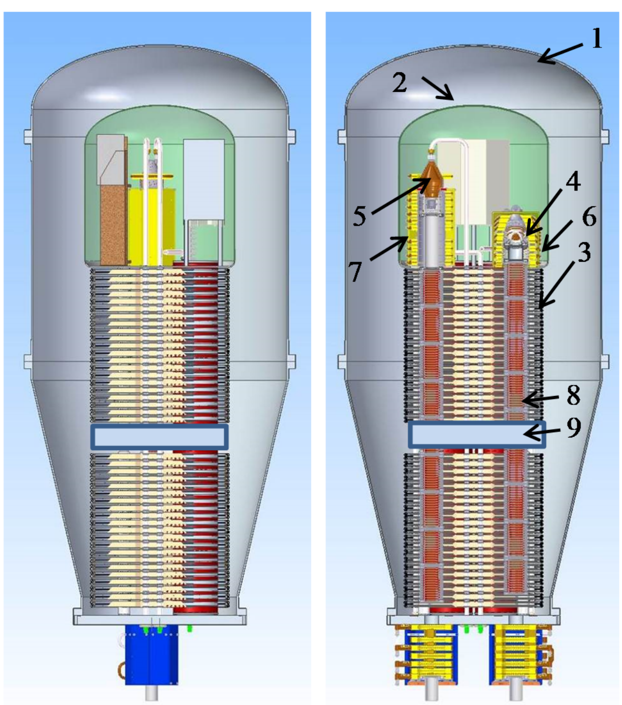

Figure 6: Design of the electrostatic accelerator of NICA cooler. High-pressure vessel for SF_6 is 1, high-voltage terminal (HVT) is 2, ihigh voltage section is 3, electron gun is 4, electron collector is 5, magnetic system of the electron gun is 6, magnetic system of the electron collector is 7, acceleration tube is 8, middle section is 9.

The key problem of the accelerating/decelerating column is transfer energy to 42 sections, gun and collectors are located at high voltage potential. The base idea of the power supply is based on idea of a high frequency cascaded resonant transformer. The system consists of 42 transformers with cascaded connection. The electrical energy is transmitted from section to section from the ground to high-voltage terminal. Along this way the energy is consumed by the regular high-voltage section. The main problem of such decision is leakage inductance of the transformers. They are connected in series and the voltage from power supply is divided between inductance leakage and a useful load. In order to solve this problem the special compensative capacitance is used. This type of the transformer was used in COSY electron cooler [4]. Its length was 2 m and diameter 0.38 m. The length of NICA cooler is larger and power consumption is larger too. Because two transformer column was decided to use. One for collector and the other for the HV sections. Moreover each transformer column is divided by two in the middle section with technological point of view. In this case the transformer length is about 1.3 m that is more convenient for assembling and commissioning. Total length of one transformer column is about 2.6 m.

CONCLUSION

The many problems of the electron cooler at 2.5 MeV (modular approach of the accelerator column, the cascade transformer, the design of the electron gun with 4-sectors control electrode, Wien filter etc) was experimentally verified during commissioning in COSY. But there is enough new decision induced by the problem of cooling two ion beams in the collider mode. At the end of work the NICA collider will obtain a powerful system of the cooling for luminosity improve.

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