LOW ENERGY COOLER FOR NICA BOOSTER

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Abstract

Low energy cooler for NICA project is being currently designed at BINP in collaboration with JINR. From the point of view of its features it is similar to previous low energy coolers manufactured at BINP, i.e. equipped with variable electron beam, electrostatic bending, high precision solenoid etc. The article describes some technical solutions applied to the cooler design.

INTRODUCTION

NICA is abbreviation of one of the most challenging recent Russian project in high energy physics [1]. It is going to be largest heavy ion collider ever been built in Russia. It contains a number of complicated systems and subsystems. One of them is heavy ion booster which is located at the existing hall of former synchrophasotron, and new magnetic elements sit inside old giant iron yokes [2]. Low energy cooler is quite important element of the booster which provides sufficient improvement of the ion beam quality.

Main specifications of the cooler are listed below:

ions type	p+ up to $^{197}Au^{31+}$
electron energy, *E*	1,5 ÷ 50 keV
electron beam current, *I*	0,2 ÷ 1,0 Amp.
energy stability, *ΔE/E*	$\leq 1\times10^{-5}$
electron current stability, *ΔI/I*	$\leq 1\times10^{-4}$
electron current losses, *δI/I*	less than 3×10^{-5}
longitudinal magnetic field	0,1 ÷ 0,2 T
inhomogeneity of the field, *ΔB/B*	$\leq 3\times10^{-5}$
transverse electron temperature	≤ 0,3 eV
ion orbit correction:	
displacement	≤ 1,0 mm
angular deviation	≤ 1,0 mrad
cooling section length (effective),	1940 mm

The requirement for vacuum condition in not very strict (10^{-11} mbar), on the other hand the cooler is the only 'warm' element, since all magnets of the booster are superconductive. This leads to some difficulties in design of junctions of different types of elements.

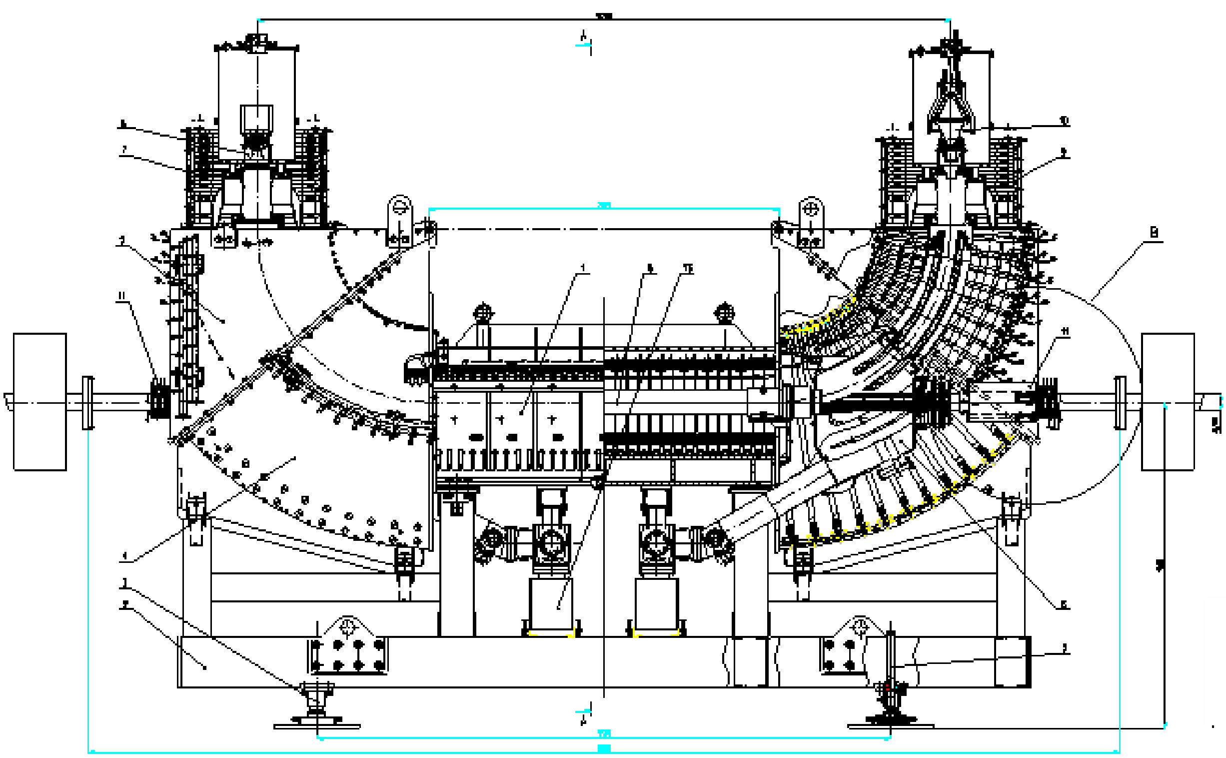

Fig.1 The general layout of the cooler.

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COOLING TIME SIMULATIONS

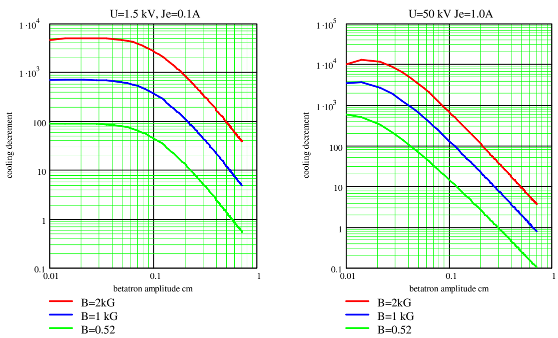

Fig. 2. Comparison of the cooling process for different energies of the electron beam 1.5 kV on the left, 50 kV on the right (electron current 0.1 A).

One can see that it is possible to achieve the cooling time better than 1s for gold ($^{197}Au^{31+}$) ion beam with the emittance of 5 mm×mrad, either for low and high energies. Strong magnetic field, required for the fast cooling, may cause some problems for low energy cooling. This should be studied after the booster optics and magnetic correction is complete.

ELECTRON GUN AND COLLECTOR

The electron gun design is based on the slightly changed gun previously used for CSRe,CSRm [3] and LEIR coolers. The only difference is the four-sector control electrode (fig.3) with separate feeding of all sectors via additional feedthroughs. This small change, nevertheless, opens a new possibility for non-axially modulation of the electron beam profile, which could be used in some applications [4].

One more perspective is to use the gun as 3D kicker [6].

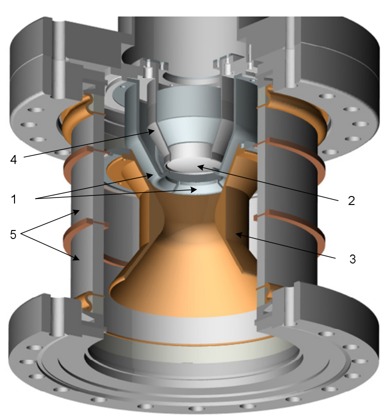

Fig.3 The sketch of the electron gun with four sectors control electrode. 1 – four-sector control electrode, 2 – oxide cathode, 3 – anode, 4 – cathode housing, 5 – ceramics.

Since the electron gun of the cooler is embedded in longitudinal magnetic field, its characteristics depend on field strength. Emissive ability of oxide cathode (2) is about 0.5 A/cm^2, so the maximum possible current is about 3A for 29 mm cathode diameter. Another important characteristic of the gun is the electron transverse temperature, which entirely determines cooling process. One of the tasks for cooler's electron guns design is keeping the transverse temperature as low as possible.

The scheme of the collector is shown on fig. Passing the accelerating tube (1) the electrons go through pre-collector electrode (2) and suppressor (3), after that enter the collector (4). The suppressor electrode forms electrostatic barrier, which catches low energy secondary electrons inside the collector. Its potential is chosen near the cathode potential. Primary electrons slow down quite strongly, and secondary electrons, loosing a part of their energy due to interaction with collector inner surface, are reflected back to collector quite effectively. Pre-collector electrode forms a 'surface' of the potential barrier. Usually it is equal to the collector potential (because of symmetry), but might differs. The coils and magnetic screen generate required shape of magnetic field to distribute the electron flux over collector internal surface [5].

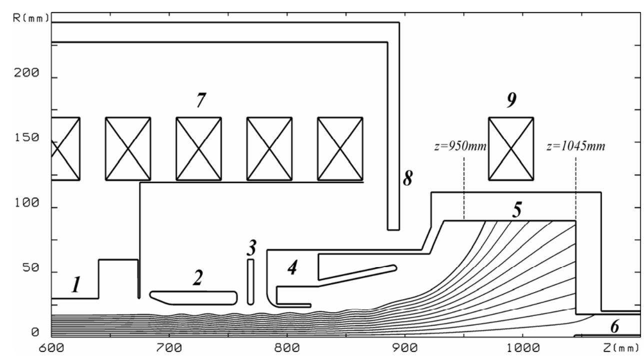

Fig.4. Collector scheme. 1 - accelerating tube, 2 - pre-collector electrode, 3 – suppressor, 4 - collector entrance, 5 - internal surface, 6 - pumping tube, 7 and 9 - coils for longitudinal field, 8 – magnetic screen.

ELECTROSTATIC BENDING

The effectiveness of electron collectors designed at BINP is about $10^{-3} \div 10^{-4}$ that doesn't provide required electron current losses, which is very important for heavy ion rings. To improve the situation the electrostatic bending proposed to be used. Since all reflected electrons are captured with the collector in a presence of the electrostatic drift compensation, current losses are extremely low (tree orders of magnitude less than without it) [8]. On the other hand, the electrostatic plates attract low energy ions originated from residual gas ionisation. This is also quite important to reduce undesirable losses. For example, special electrostatic plates had to be installed at COSY cooler to avoid this [9].

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MAGNET SYSTEM

The magnet system of the cooler is similar to other low energy coolers design. The only difference is rather strict requirement for the field homogeneity at cooling section, which is typical for the high energy cooling systems. So some technical solutions of the COSY cooler are going to be applied [9]. Probably, in-vacuum field measurement system has to be installed [7], which is undesirable due to its complicity in operation and an extra space along the ring is required for the measurement equipment.

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