High voltage electron cooling in ion colliders

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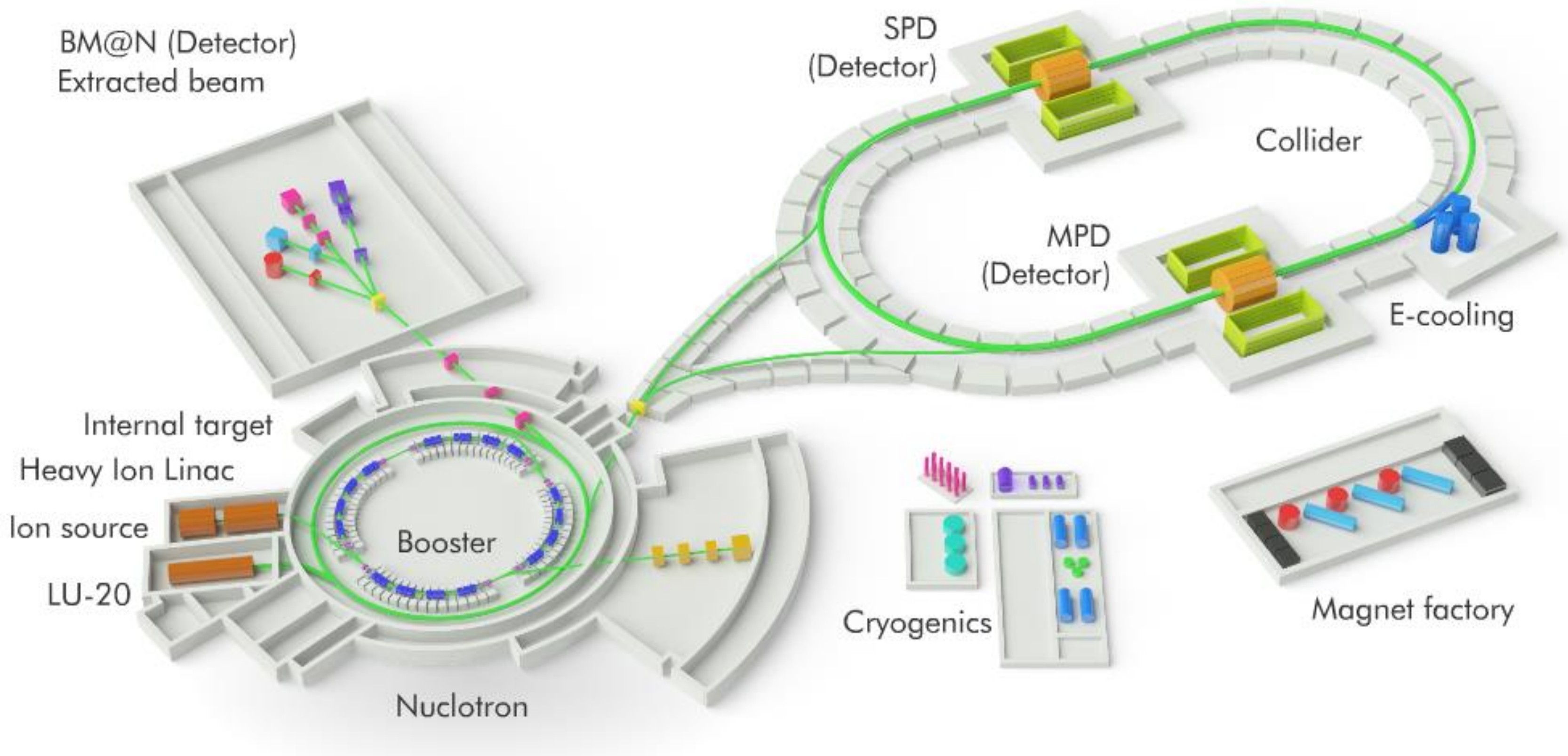
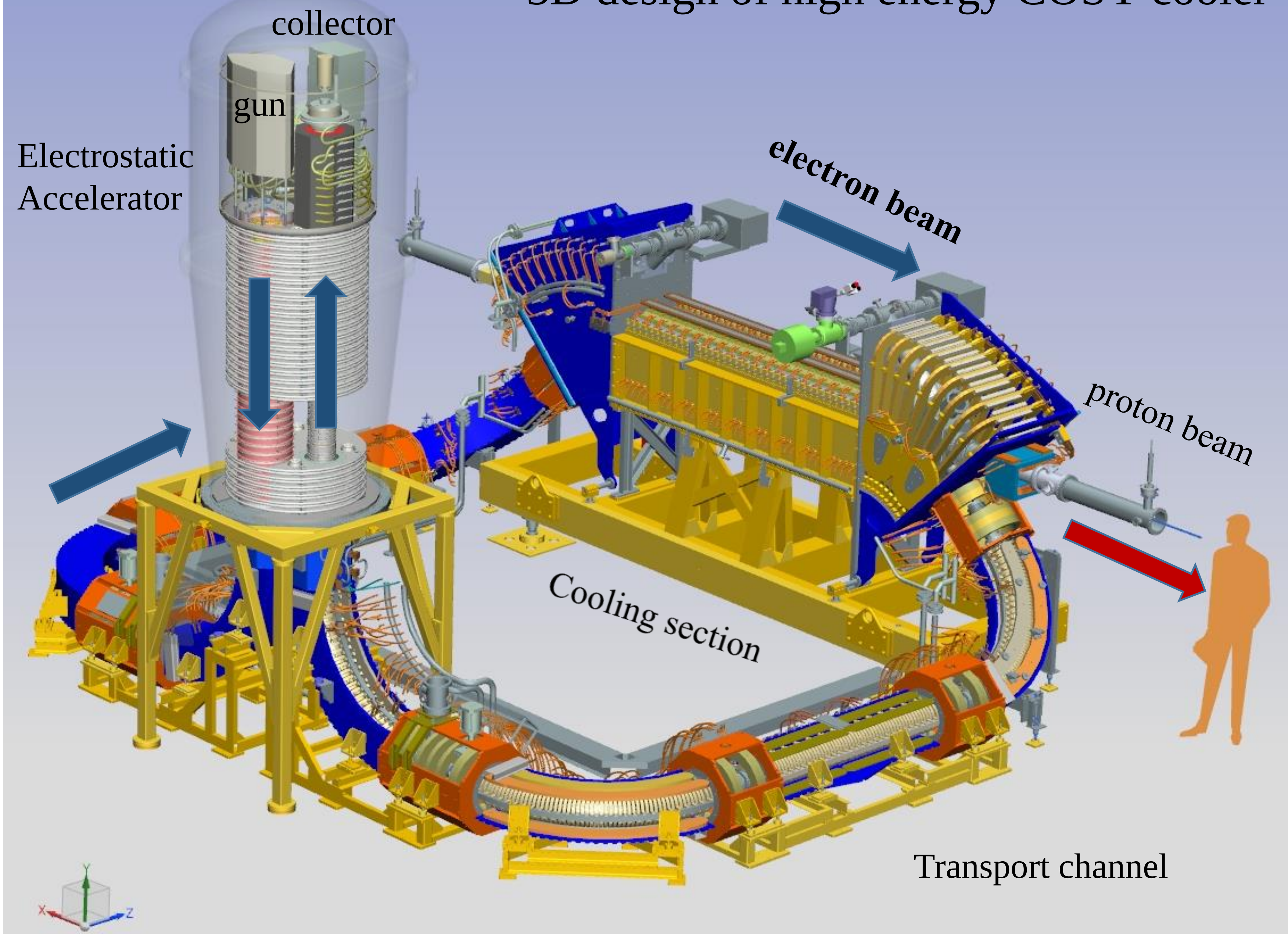
NICA project

The NICA (Nuclotron-based Ion Collider fAcility) complex is aimed in the study in the laboratory of the properties of nuclear matter in the region of the maximum baryonic density



3D design of high energy COSY cooler



Main feature of cooler COSY

1. Classical design with longitudinal magnetic field;

-very wide range of the operation, the preferable smallest energy is 25 keV, it is injection energy;

2. Section-module principle of the design of the electrostatic accelerator;

-each section contains the high-voltage module and coils of the magnetic field;

3. Possibility for on-line control of the quality of the magnetic field

- in order to have high cooling rate;

4. Cascade transformer for power supply of the HV sections;

- smooth longitudinal magnetic field along accelerated tube demands power to many coils;

5. Electron Collector with Wien Filter

-in order to have small leakage current from the collector

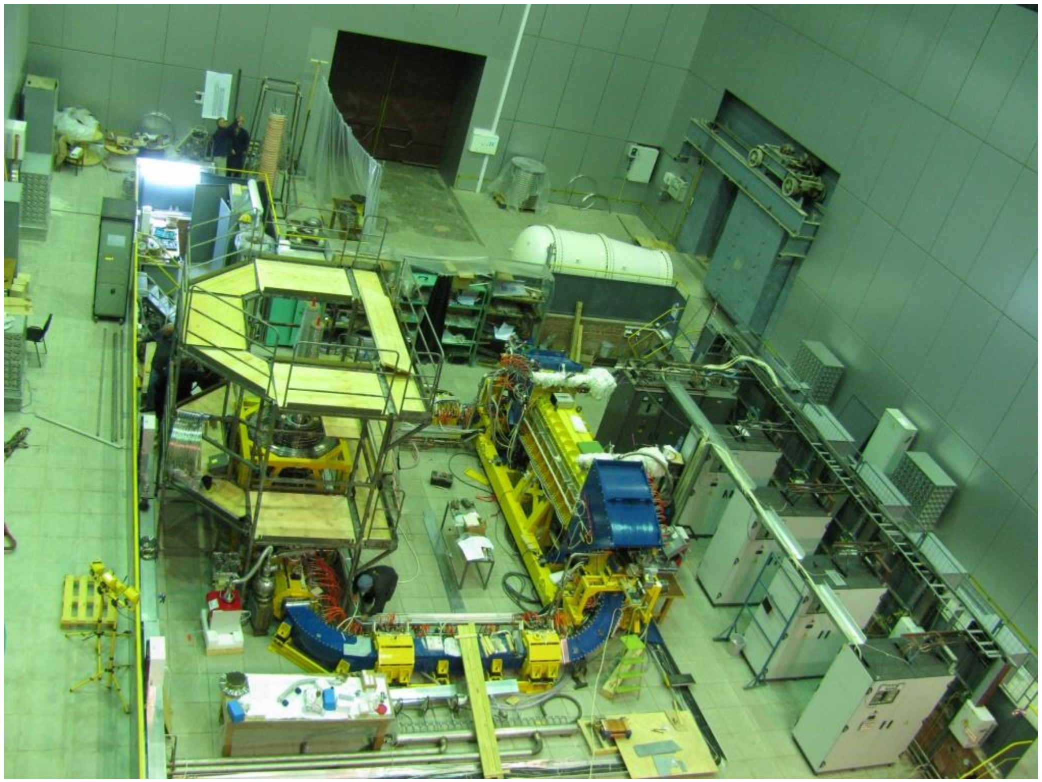
6. "Magnetized" electron motion

7. "4-sectors" electron gun for diagnostics of the electron beam motion

2 MeV Electron Cooler	Parameter
Energy Range	0.025 ... 2 MeV
Maximum Electron Current	3 A
Cathode Diameter	30 mm
Cooling section length	2.69 m
Toroid Radius	1.00 m
Magnetic field in the cooling section	0.5 ... 2 kG
Vacuum at Cooler	10^{-9} ... 10^{-10} mbar
Available Overall Length	6.39 m

Electron cooling system for COSY

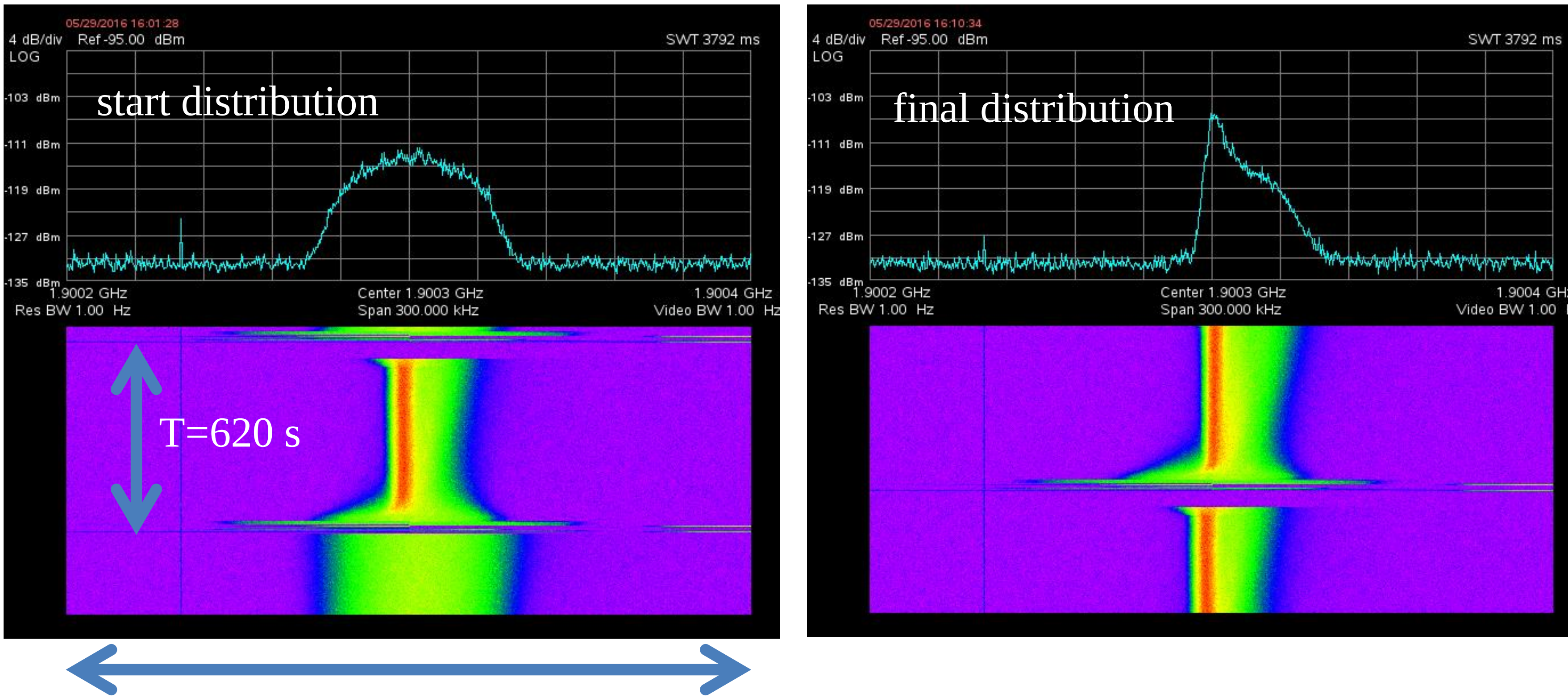
Novosibirsk



Germany

Cooling results from COSY

Electron energy 909 keV, proton energy 1.7 GeV, Ie=0.5 A

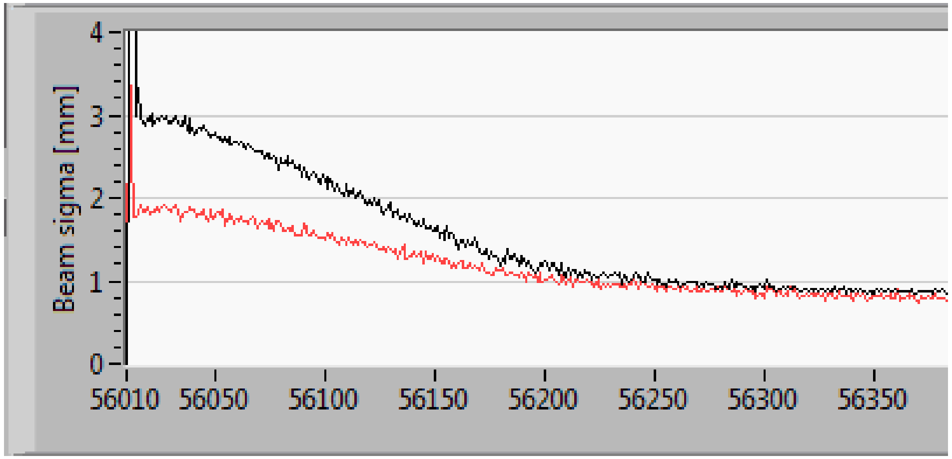


$\Delta p/p = 2.4\ 10^{-3}$

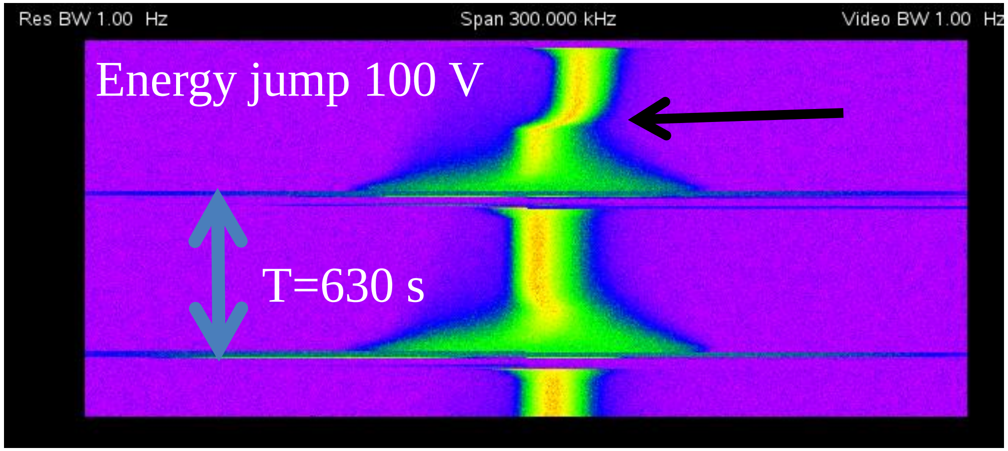
Cooling decreases longitudinal spread to about $5\cdot10^{-5}$.

Cooling results from COSY

Example of the transverse cooling. $N_p=3\cdot10^8$, $I_e=0.8$ A, $E_e=909$ keV.

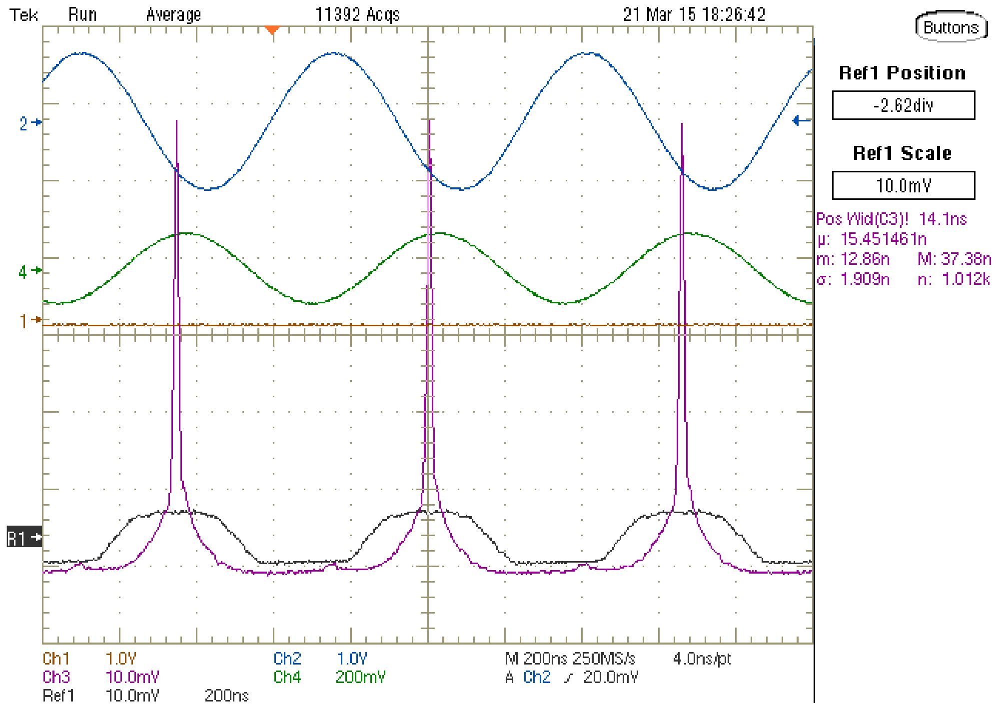


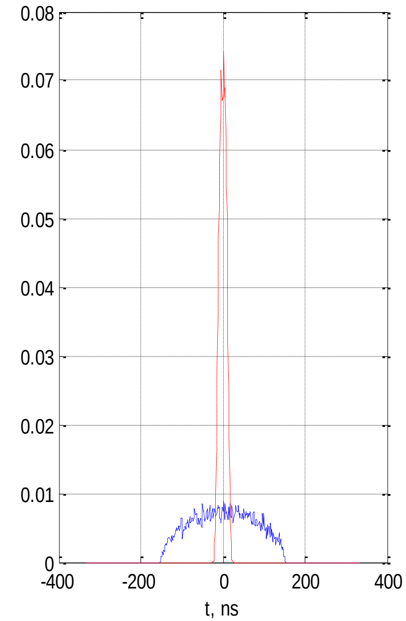
One of the first experiment with electron energy 1.26 MeV. $E_p=2.3$ GeV. $I_e=0.5$ A



Cooling simulations for COSY

Cooling of bunched proton beam on COSY. Electron energy 908 keV. Electron current 0.5 A. U_{RF}=200 V.





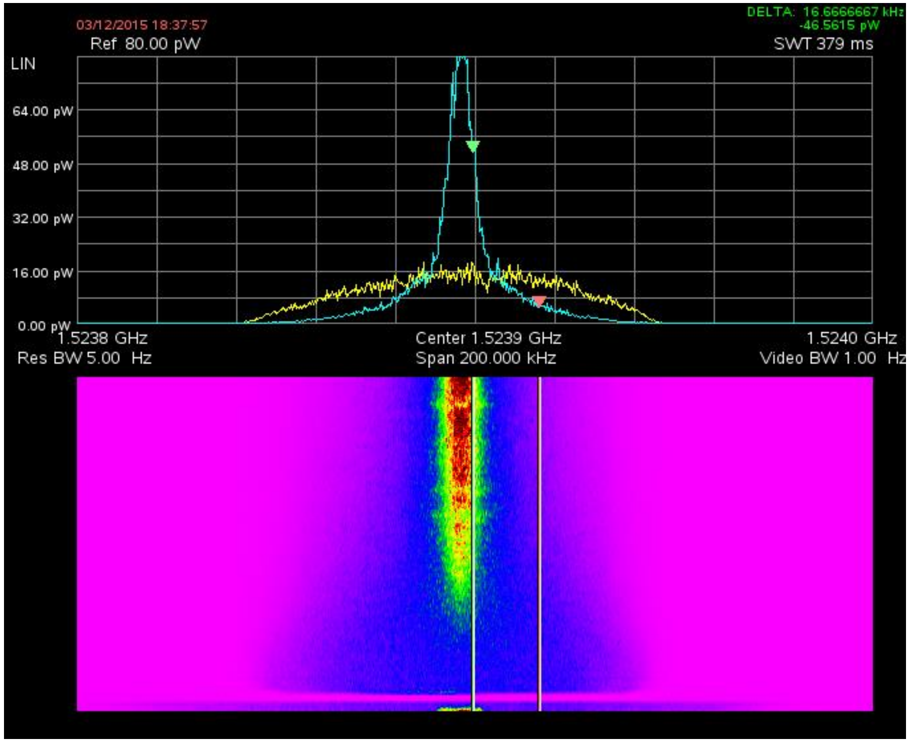
Measurements

Simulations

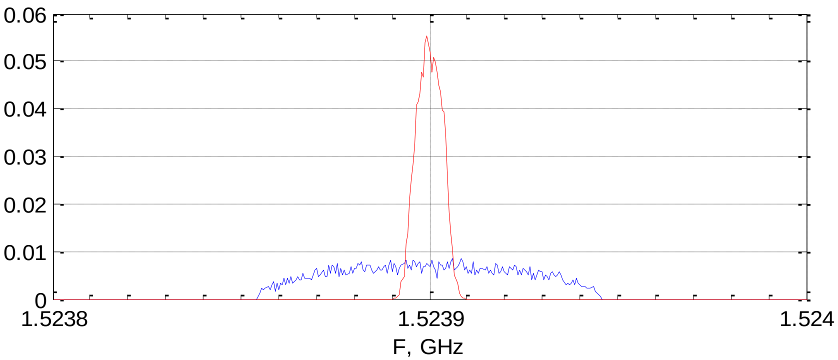
Cooling simulations for COSY

The same experiment with cooling of bunched proton beam on COSY. Momentum distribution.

Measurements

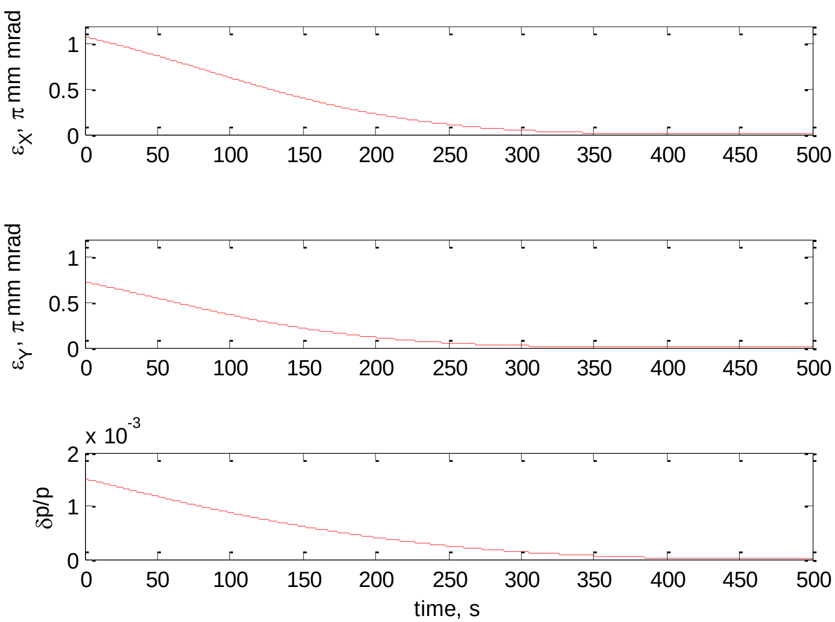


Simulations

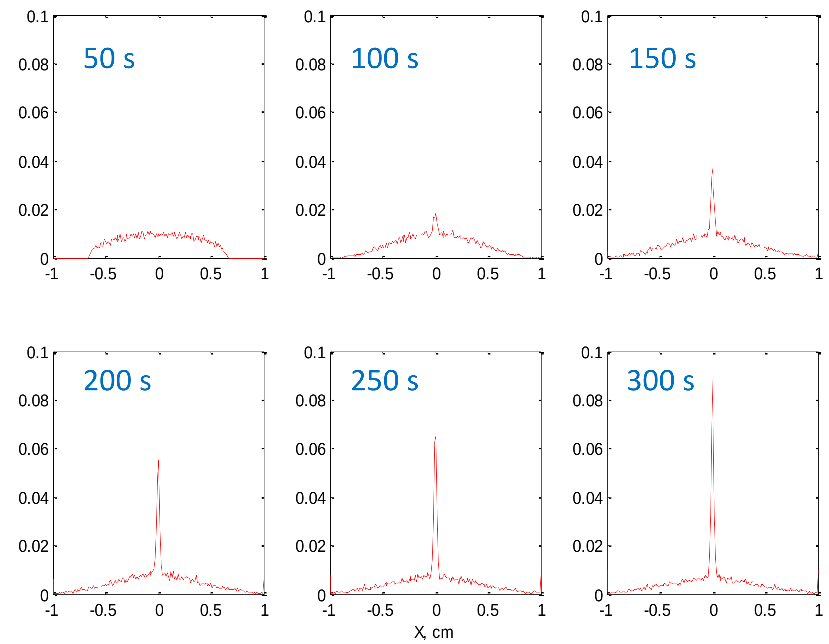


Cooling simulations for NICA collider

Cooling simulations of coasting beam. Ions $^{197}Au^{79+}$, Ei=4.6 GeV/u.
Ie = 1 A, Ee=2.5 MeV, Re=0.4 cm.



Ni=0

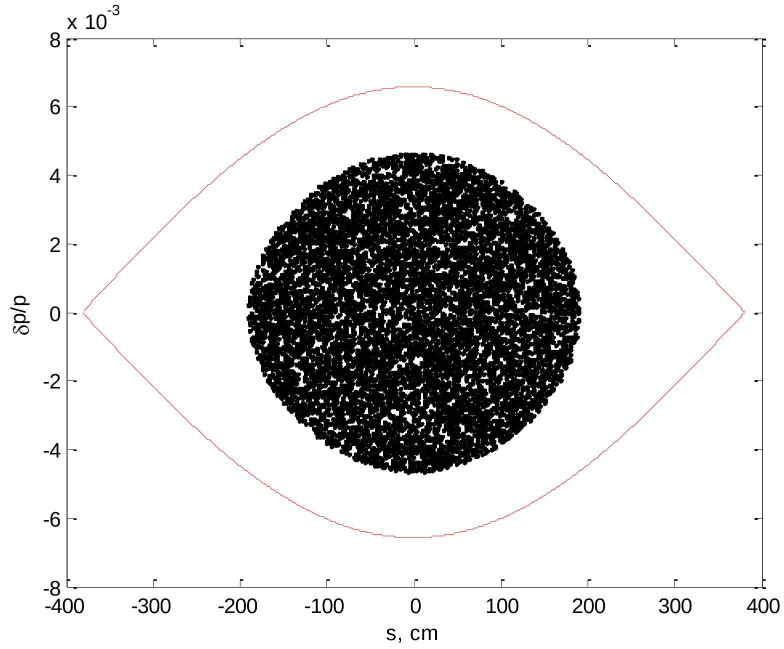


$Ni=22\cdot2.3\cdot10^9$

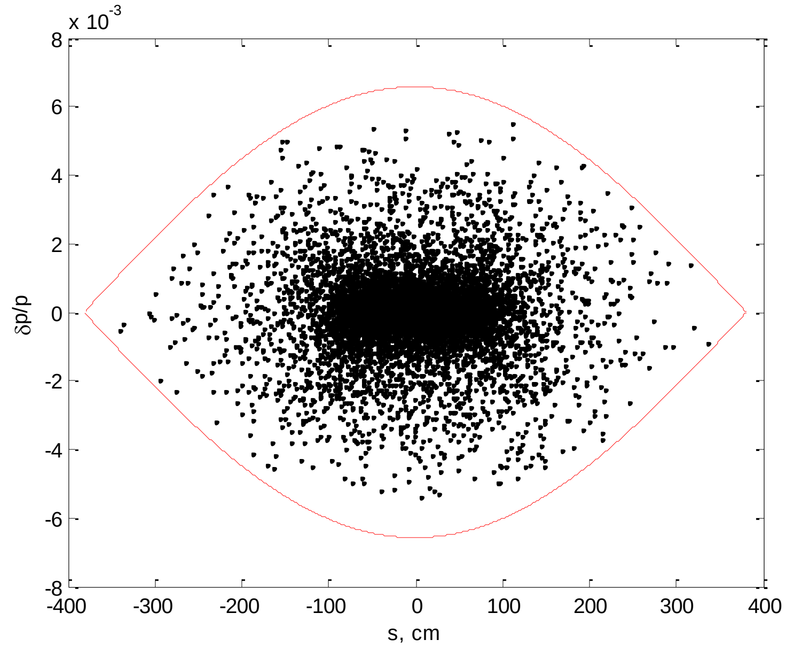
Cooling simulations for NICA collider

Electron cooling will work during beam collision experiment and cool bunched ion beams.

Simulations of bunched ion beam cooling. Ions $^{197}Au^{79+}$, Ei=4.6 GeV/u.
Ee=2.5 MeV, Ie=1 A, Re=0.4 cm, Ni=$2.3 \cdot 10^{9}$. h_{RF}=66, U=0.6 MV.



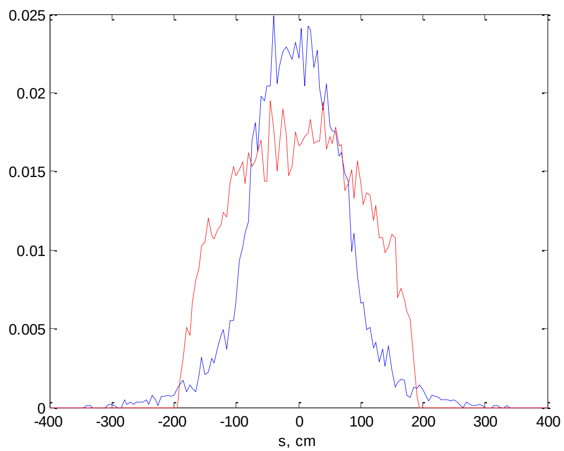
Before cooling

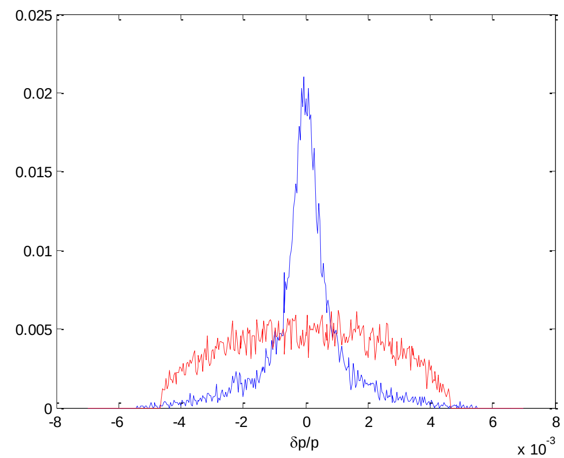


After 160 sec

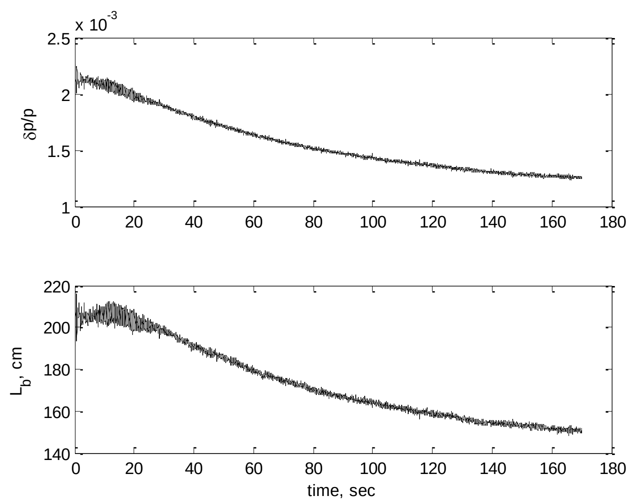
Cooling simulations for NICA collider

Cooling of bunched beam. Red – initial distribution, blue – after 160 sec.



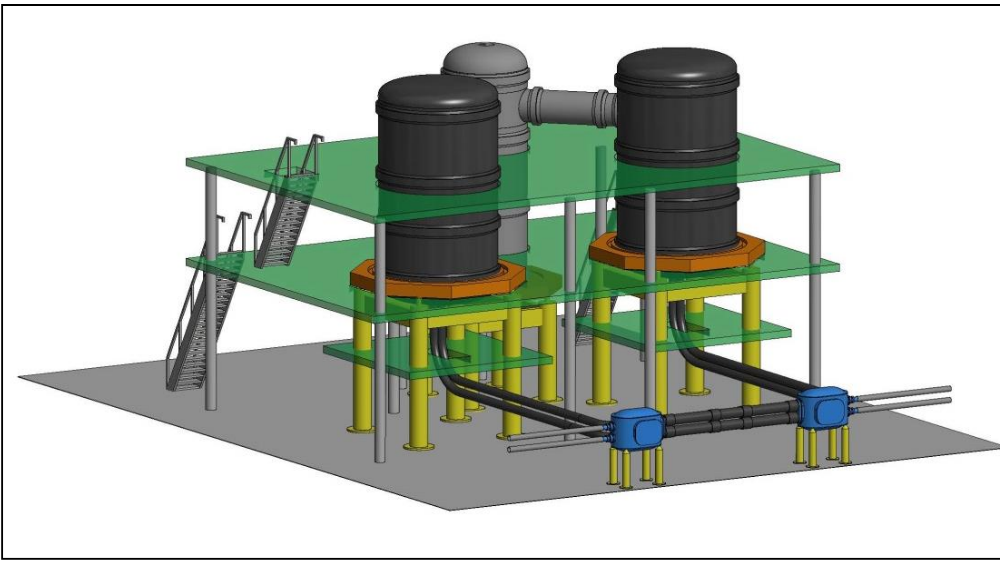


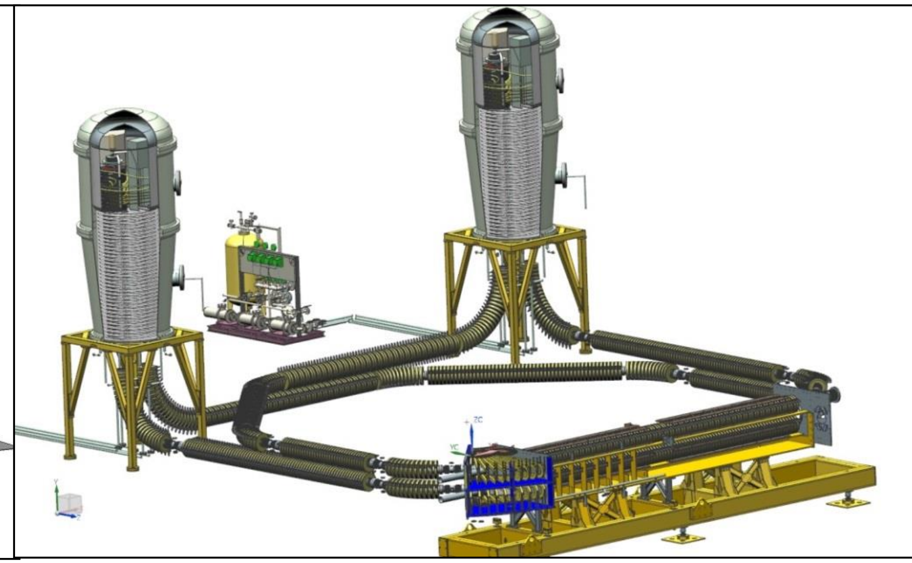
Dependence of rms parameters on time.



Construction of the NICA cooler

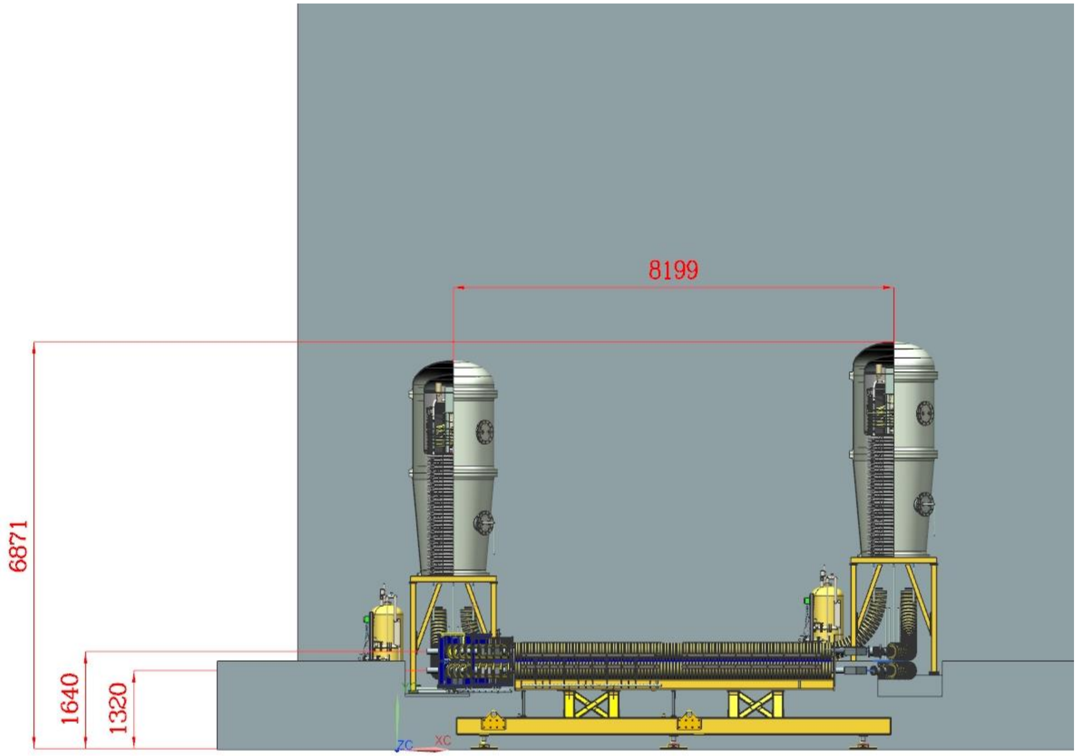
The electron cooling system will cool two colliding beam independently. It mean that it consists of two independent cooling systems.





JINR proposal with additional tank for generation of HV

BINP proposal based on construction of COSY cooler

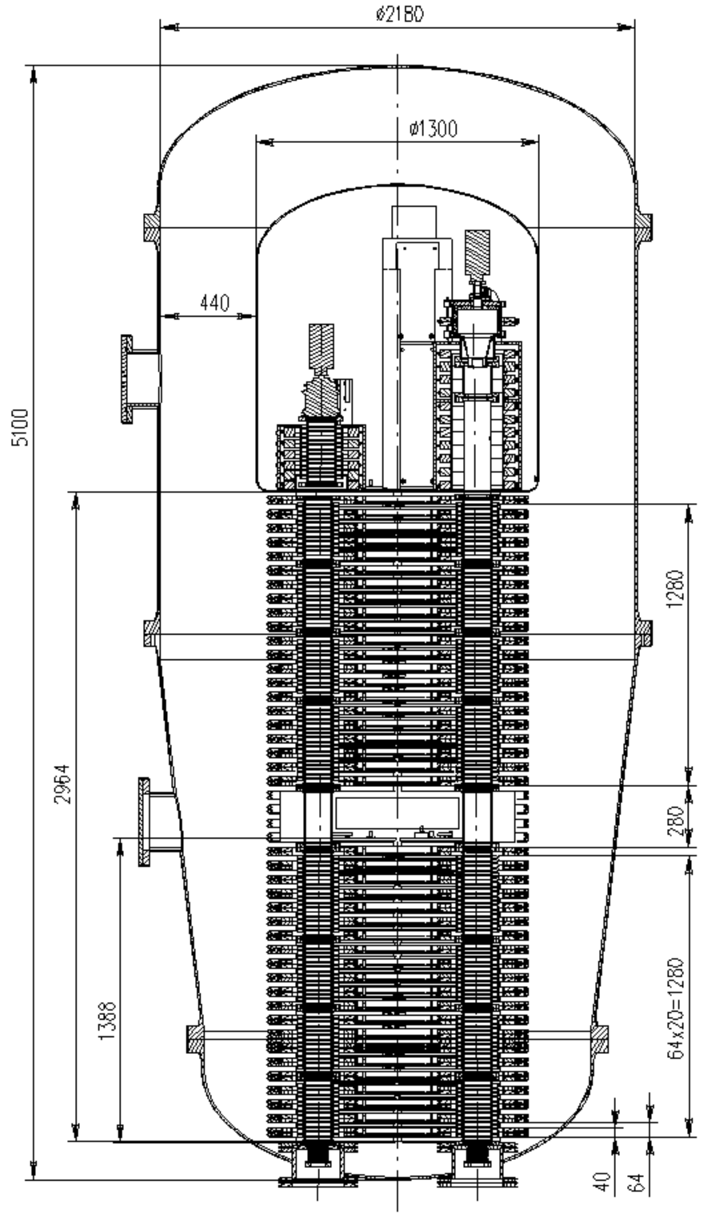


Sketch of the NICA HV electron cooling system with sizes.

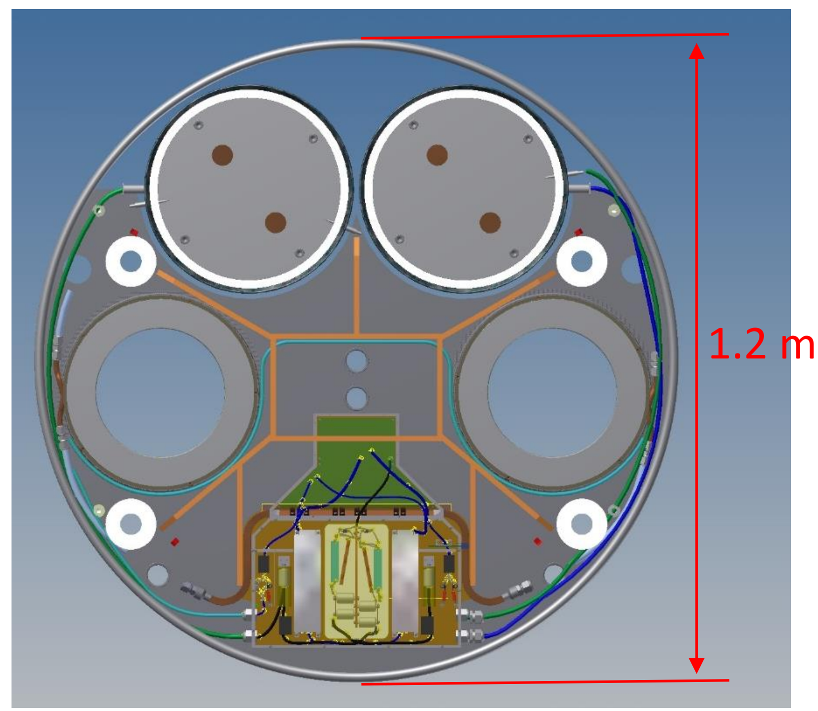
Main parameters of the electron cooling system

Electron energy, MeV	0.2 ... 2.5
High voltage stability, $\Delta U/U$	$\leq 1 \cdot 10^{-5}$
Electron current, A	0.1 ... 1
Electron beam diameter in the cooling section, mm	5 ... 20
Cooling section length, m	6,0
Bending radius in transport channels, m	1-1.3
Magnetic field in cooling sections, kG	0.5 ... 2
Vacuum pressure in cooling section, mbar	10^{-11}
Height of lower beam, mm	1500
Height of higher beam, mm	1820
Power consumption, kW	≤ 500

HV column of the NICA cooler

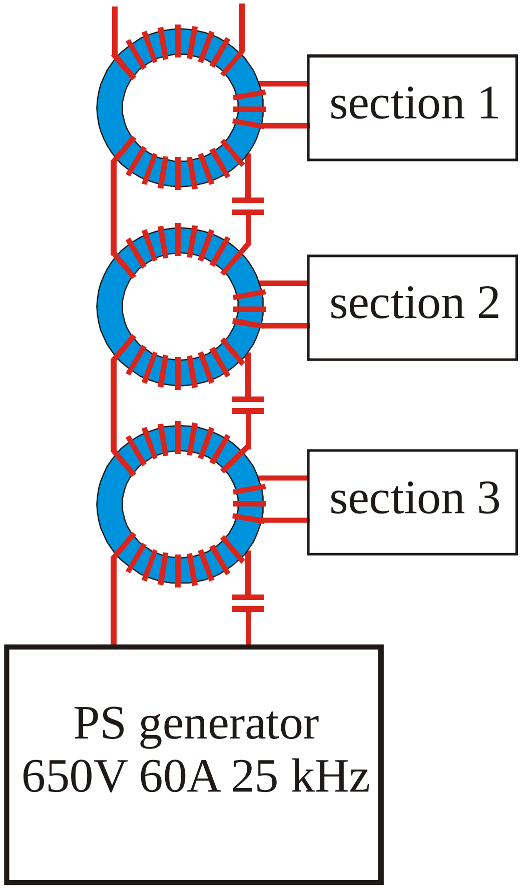


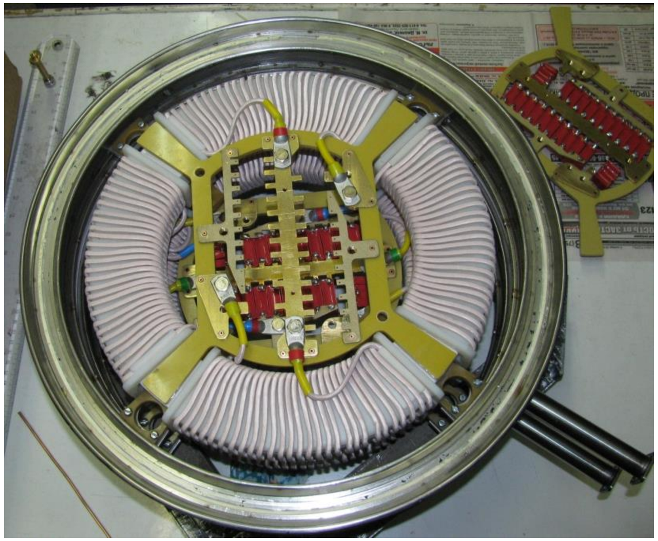
The electrostatic column consists of 42 identical sections. Each section contains HV power supply for up to 60 kV and two supplies for magnetic coils of two electrostatic tubes.



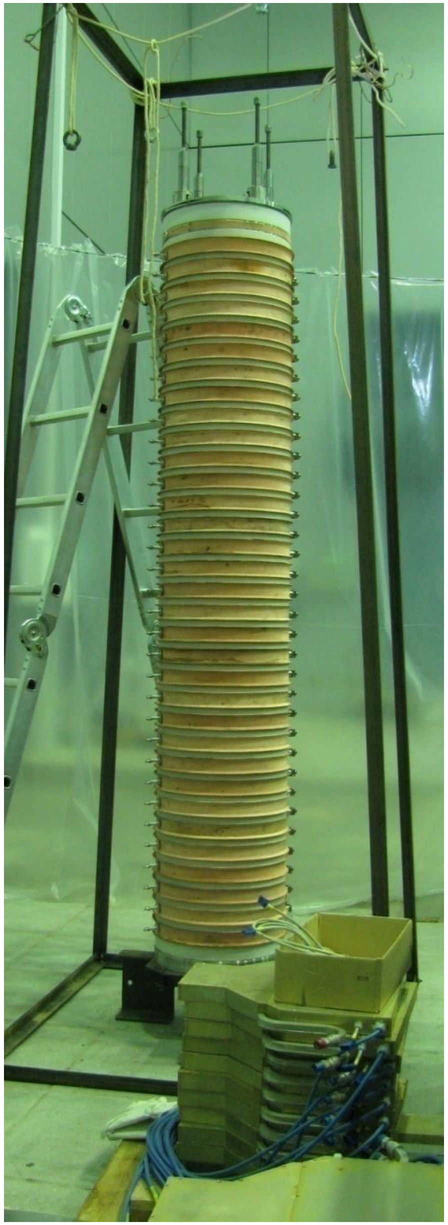
Cascade transformer

Every HV section and HV terminal is powered with the help of special cascade transformer.



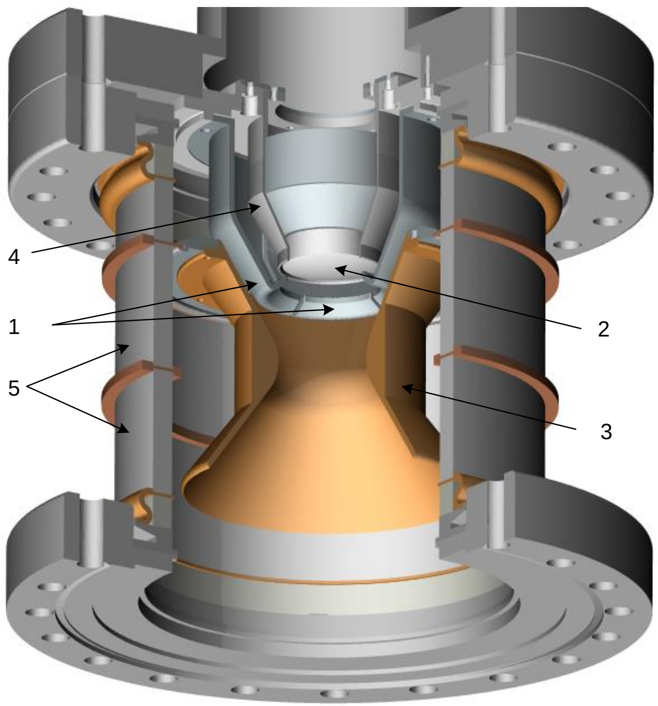


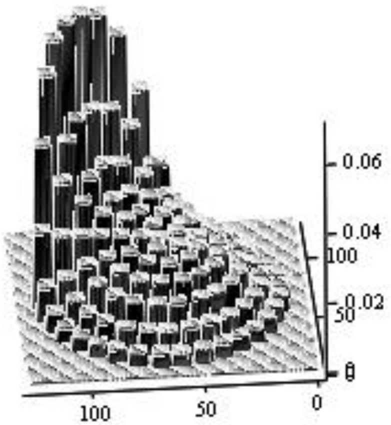
One section of the transformer



Electron gun

Electron gun with 4 sector control electrode gives possibility to measure not only beam position but also beam shape.

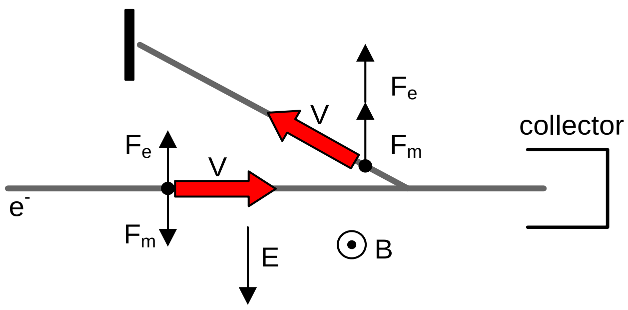




Simulated current distribution for modulation on one sector

Electron collector

Principle of the collector work

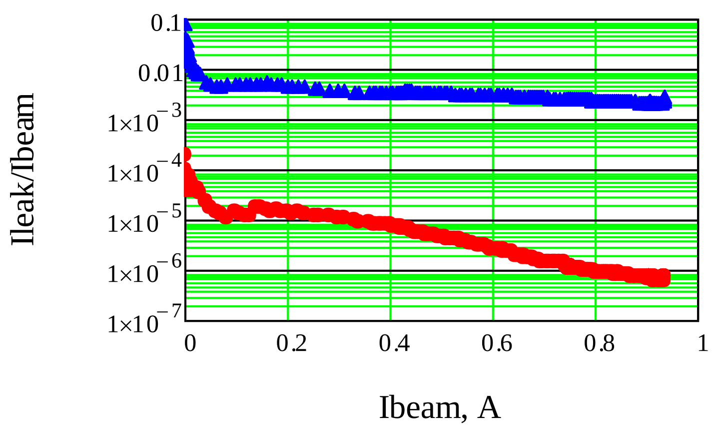


primary beam

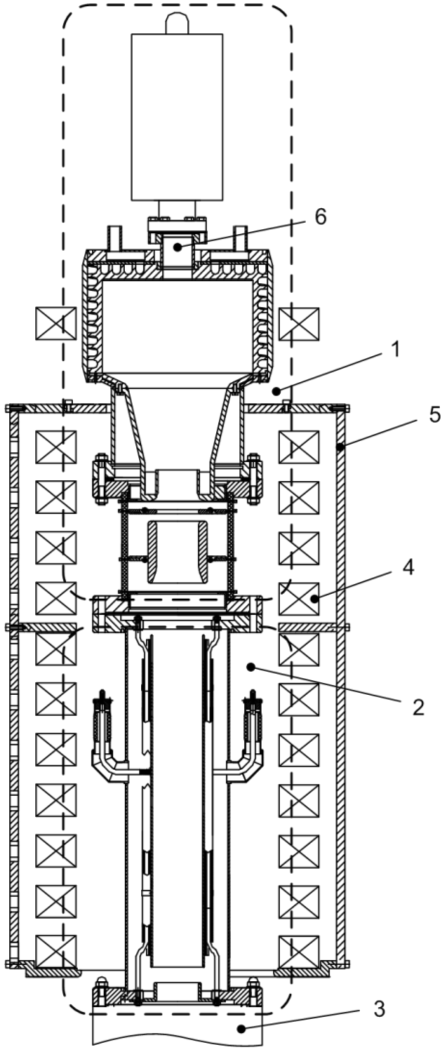
$$\vec{F}_{\perp} = e\vec{E} - \frac{e}{c}\left[\vec{v} \times \vec{B}\right] = 0$$

secondary beam

$$\vec{F}_{\perp} = e\vec{E} + \frac{e}{c}\left[\vec{v} \times \vec{B}\right] \neq 0$$



Collector efficiency, measured on COSY cooler



Collector for COSY cooler

Thankyou for your attention!