РОСАТОМ

РФЯЦ ВНИИЭФ

ИЯРФ

ГОСУДАРСТВЕННАЯ КОРПОРАЦИЯ ПО АТОМНОЙ ЭНЕРГИИ «РОСАТОМ»

PROGRESS IN CW MODE ELECTRON RESONANCE ACCELERATOR BETA-8 DEVELOPMENT

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Electron resonance accelerator BETA-8

- Electron accelerator BETA-8 is developed to perform radiation researches and radiation tests of large-size objects in a wide energy range of accelerated electrons
- It will be possible to study and elaborate with its aid the technological processes requiring high power and high values of absorbed dose of electron radiation and bremsstrahlung

There are designed, produced and tested the basic elements of the accelerator:

- Coaxial accelerating cavity
- System of HF power supply
- Unit of HF power input to the cavity
- Feeder (line of HF power transport)
- HF electron injector
- Deflecting electromagnets
- Vacuum system and thermal stabilization system
- Automatic control system

Design parameters of the accelerator:

- Values of accelerated beam output energies.....1.5, 4.5, 7.5 MeV
- Average beam power.....300 kW
- Operating resonance frequency.....99.9 MHz
- CW and pulse-periodic mode

Cavity of accelerator BETA-8

- At a level of HF power supply equal to 180kW there can be obtained a electron beam with the average power up to 15 kW and energy up to 7.5 MeV

- Energy increase – multiple beam pass at a median horizontal plane of the cavity
- Beam return to the cavity – deflecting magnets outside the cavity

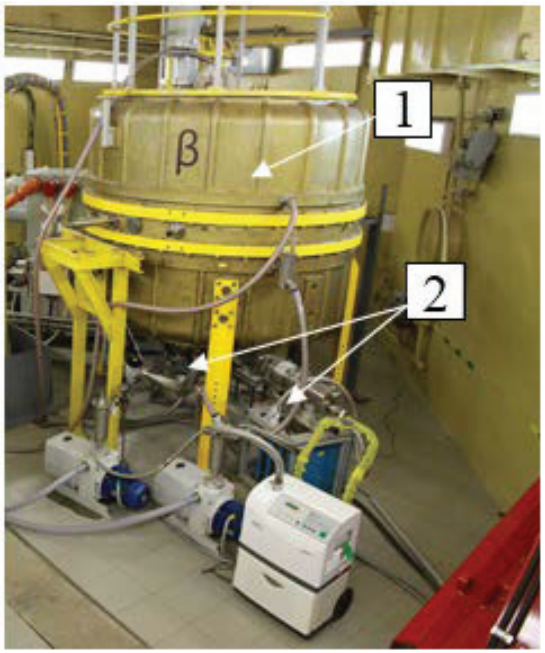


Fig. 1 – Accelerator BETA-8:
1 – cavity; 2 – exhaust cart

- At HF power supply at a value of 165 kW there is set electromagnetic oscillation in the cavity to provide electron energy ≈ 1.5 MeV

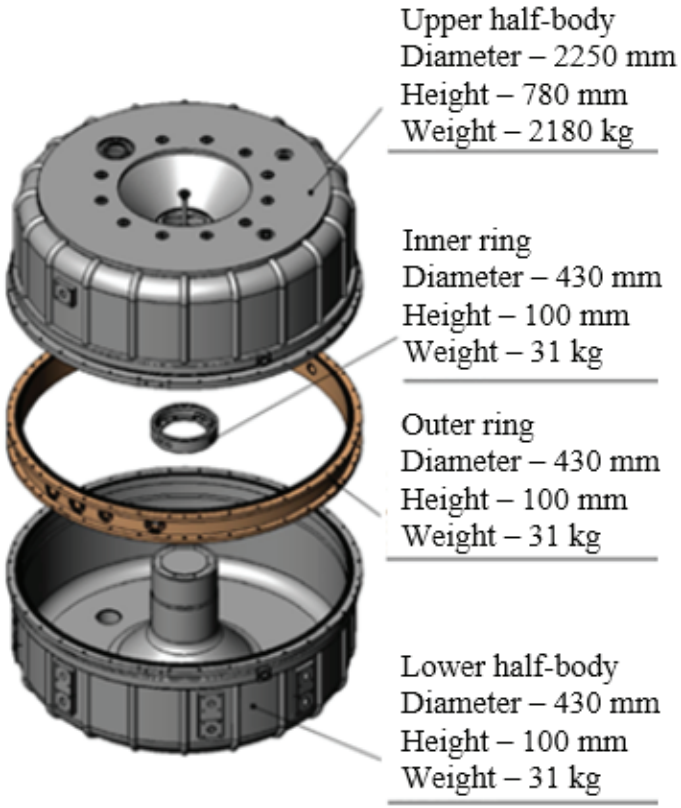


Fig. 2 – Accelerator cavity

System of HF power supply

- The system of HF power supply is designed to achieve CW power of 540 kW
- The system of HF power supply represents three single-type generator modules and a HF power summator

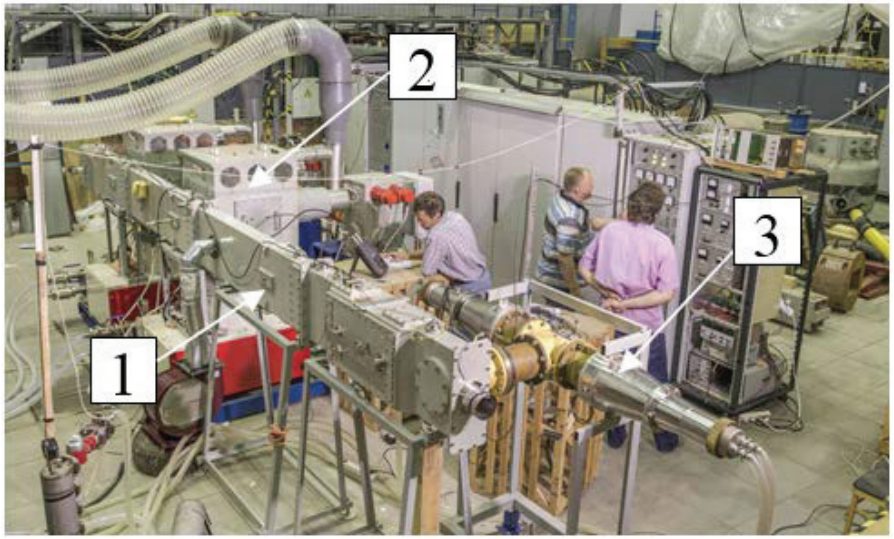


Fig. 3 – System of HF power supply:
1 – HF power summater;
2 – generator module;
3 – matched load

- One module provides getting of CW power of 180 kW at frequency range of 95 – 105 MHz
- Generator output is a 50Ω coaxial air line

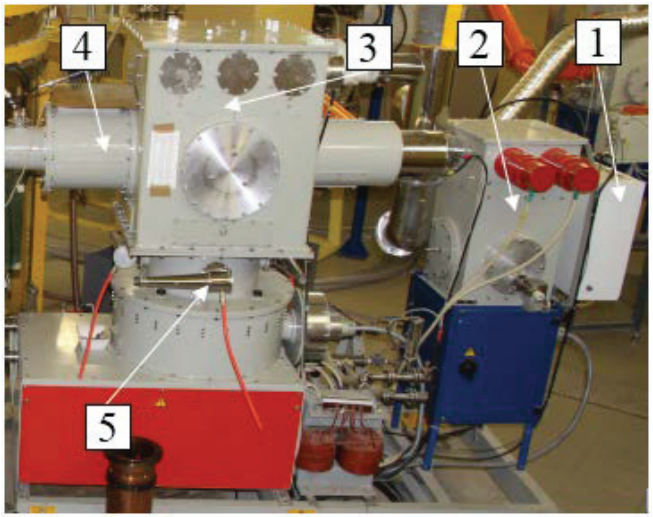


Fig. 4 – HF generator:
1 – preamplifier;
2 – cascade on tetrode GU-92A;
3 – output module on tetrode GU-101A;
4 – output of HF power;
5 – loads to suppress parasitic oscillation modes

UPI and feeder

UPI matches HF power supply and accelerating cavity

- Operating frequency of UPI.....98 ÷ 102 MHz
- VSWR..... ≤ 1.3
- Feeding HF power.....up to 600 kW

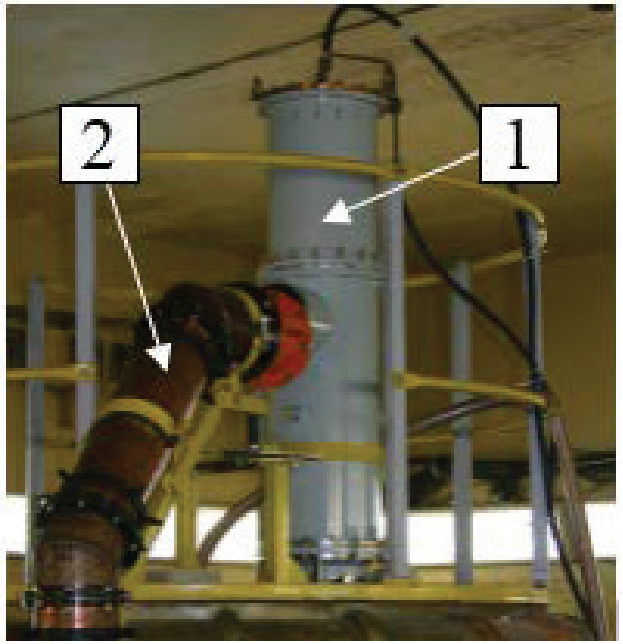


Fig. 5 – UPI:
1 – Unit of power input;
2 – coaxial feeder

The line of HF power transfer represents air-filled coaxial feeder with wave resistance 50 Ω

- Transmission of signal with the average power up to 600 kW
- Range of operating frequency.....98 ÷ 102 MHz
- VSWR.....1.15 at matched load operation

Fig. 6 – Coaxial feeder

Injection system of accelerator BETA-8

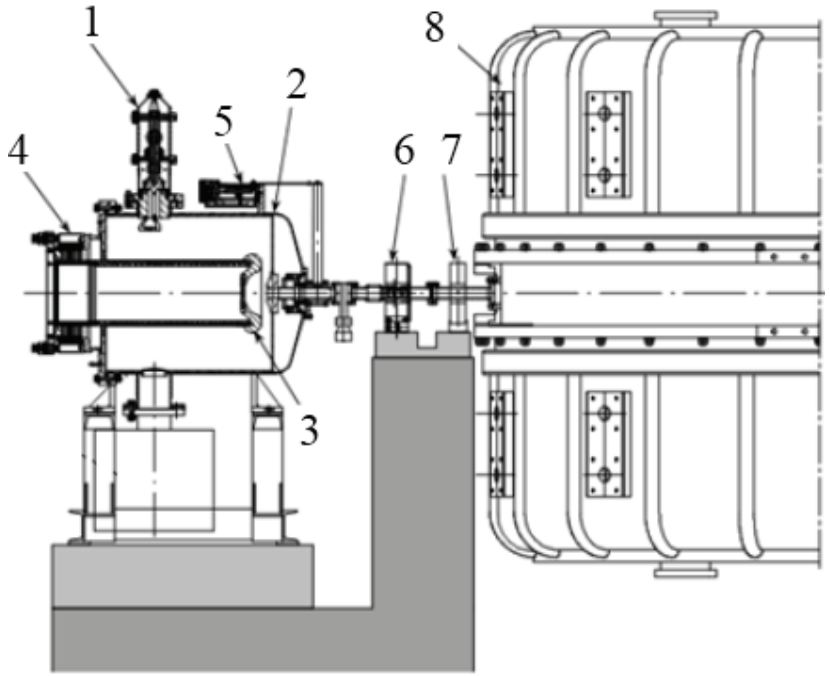


Fig. 7 – Injection section:
1. Unit of HF power input to the injector cavity
2. Coaxial injector cavity
3. Cathode unit with focusing electrode
4. Device of rough frequency control
5. Device of fine frequency control
6. Focusing solenoid
7. Magnetic quadrupole lens
8. Accelerating cavity

Basic characteristics of injector:

- Maximal average current.....40 mA
- Electron energy.....50 – 100 keV
- Bunch duration.....0.7 – 1 ns;
- Maximal repetition rate of bunches.....100 MHz

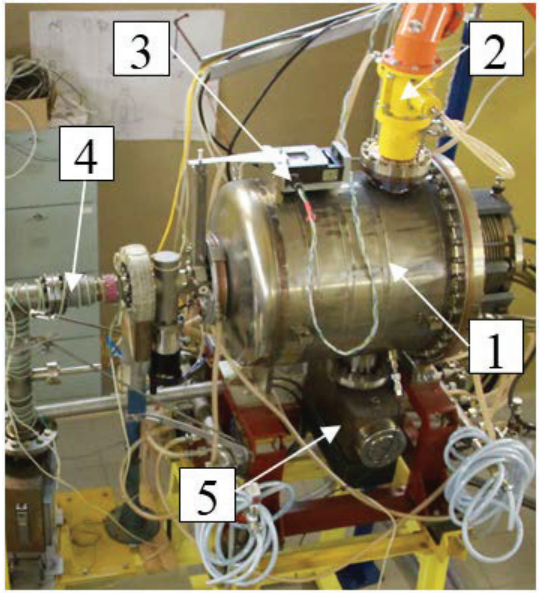


Fig. 8 – Electron injector : 1 – injector cavity;
2 – UPI; 3 – device of cavity frequency tuning;
4 – high-vacuum pump;
5 – channel of beam transport

System of beam magnetic guidance in accelerator BETA-8

The system of magnetic guidance can be conditionally divided to two parts:

- Recirculation of accelerated beam
- Beam transport to the experiment site

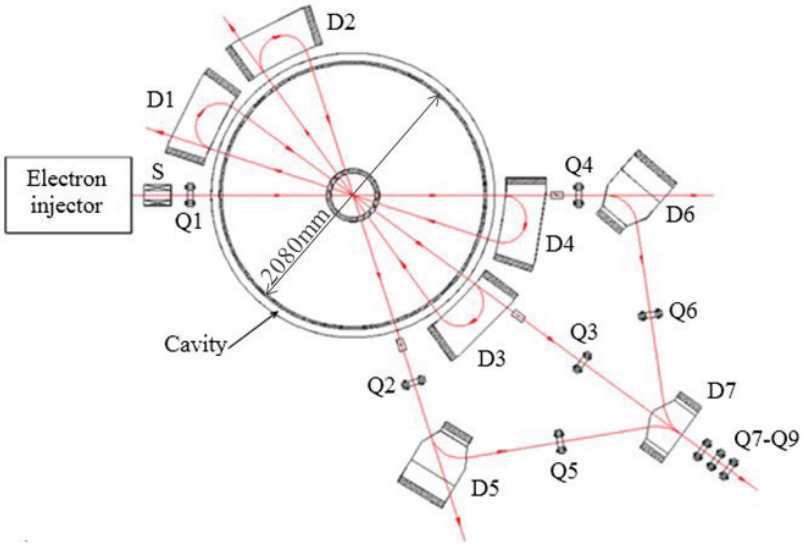


Fig. 9 – Diagram of beam magnetic guidance:
– beam travel direction;
D1 – D7 – deflecting dipole magnets;
S – system of solenoids;
Q1 – Q9 – quadrupole magnetic lenses

Designed parameters of the beam system magnetic recirculation:

Parameter	Magnet			
	D1	D2	D3	D4
Average energy of deflected electrons, MeV	1.5	3.5	4.5	6.5
Magnetic field induction at an area of homogeneous field, mT	37	67	97	125
Pole gap width, mm	50	50	50	50

Designed parameters of the beam transport section magnets:

Parameter	Magnet			
	D6	D5	D7	
Average energy of deflected electrons, MeV	1.5	4.5	1.5 and 7.5	
Magnetic field induction at an area of homogeneous field, mT	25	96	17 for 1.5 MeV	65 for 7.5 MeV
Pole gap width, mm	50	50	50	

Simulation of beam magnetic guidance in accelerator BETA-8

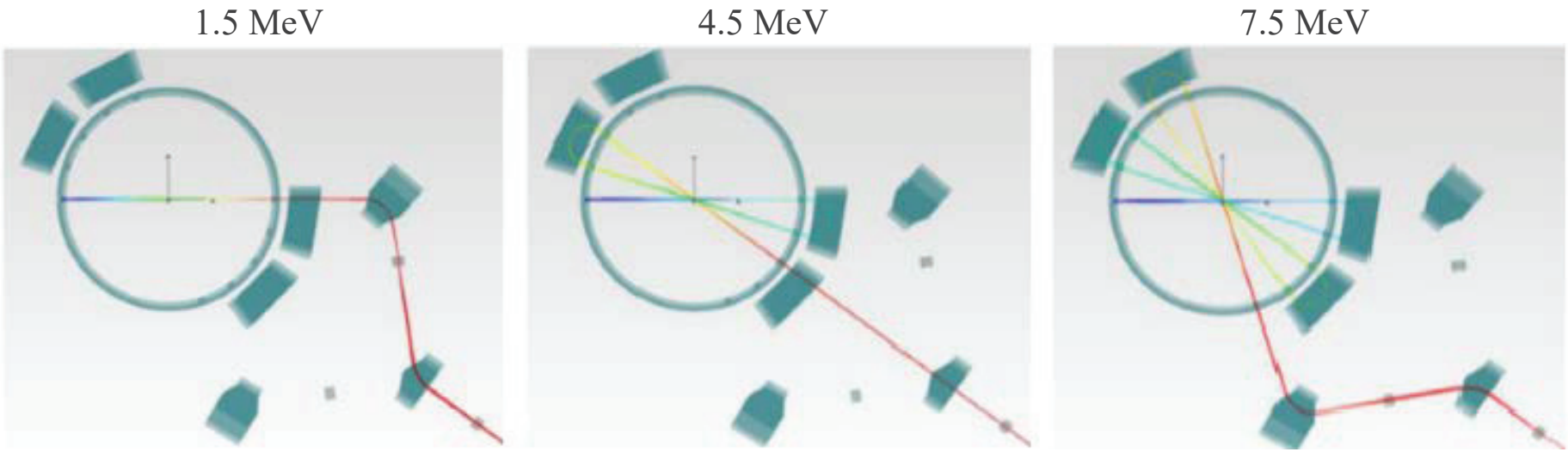


Fig. 10 – Three versions of beam magnetic guidance depending on output energy of electrons

Conditions of five-fold beam guidance through the accelerating cavity:

- Expected beam diameter at the output from the cavity.....≈ 10 –15 mm
- Beam transverse emittance.....≤ 50 mm·mrad
- Energy spread at turning segments..... ≤ 6 %
- Ultimate phase length of the bunch at its injection to the cavity.....40º (1.1 ns)

A model of the system of beam magnetic guidance in accelerator BETA-8

At guiding a 300 kW beam the losses of electrons in the cavity walls and vacuum chambers of the magnetic guidance system should be minimal

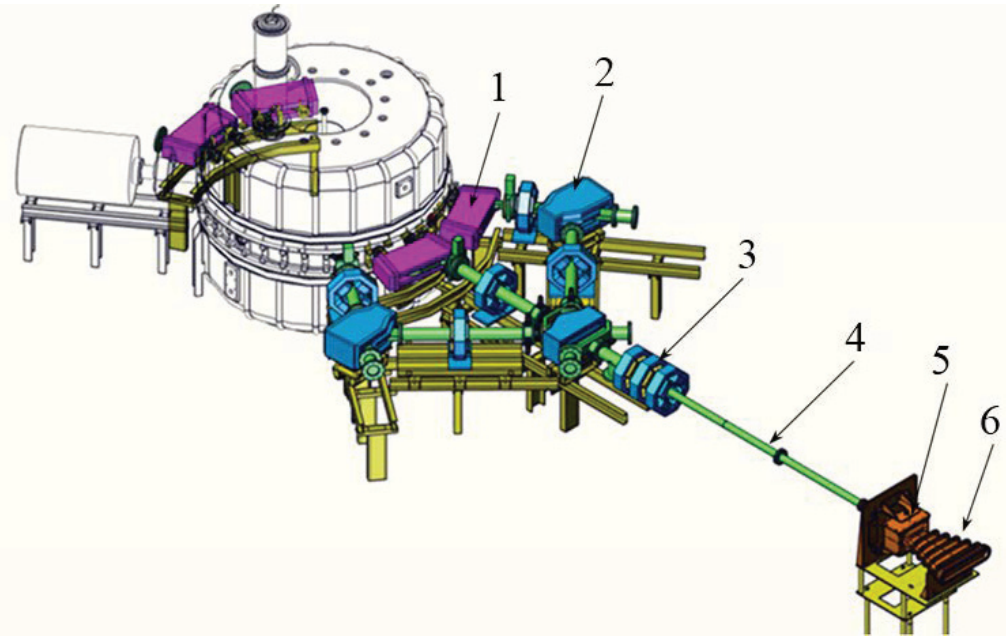


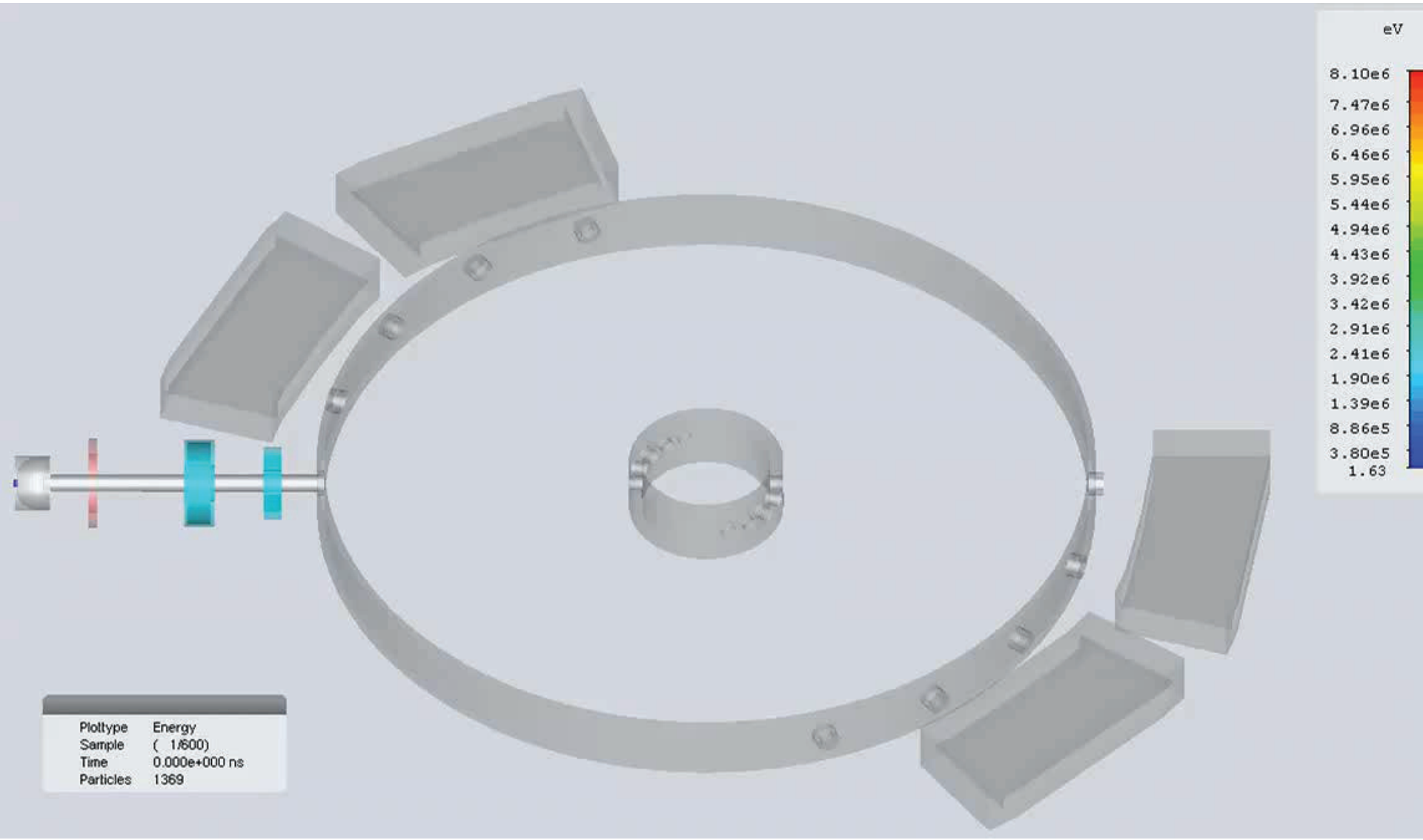
Fig. 11 – a model of the system of beam magnetic guidance: 1 – beam recirculation magnets; 2 – beam transport magnets; 3 – quadrupole lenses; 4 – vacuum channel of beam guidance; 5 – scanning magnet; 6 – output device

- Four identical dipole magnets are responsible for the accelerated beam recirculation (1)
- Transport of the accelerated beam with the average energies of 1.5, 4.5, 7.5 MeV is implemented with the aid of beam transport magnets (2)
- Magnet quadrupole lenses have got identical design and are aimed at beam focusing (3)
- Drift channels are sufficiently long and the need for additional focusing lenses can be revealed after the start with the beam

Conclusion

1. At this stage of creating the BETA-8 accelerator at decreased HF supply power (up to 180 kW) and electron beam there should be experimentally elaborated key physical principles of accelerator operation.
2. There are developed and tested basic assemblies of accelerator BETA-8:
   - cavity with UPI and feeder
   - HF generator
   - HF injector
   - On the technological systems there are obtained stable design parameters at the operation with the automated control system
3. The developed system of electron beam magnetic guidance in accelerator BETA-8 is described. There are demonstrated the computed trajectories and beam parameters criteria for each of the operating energy values 1.5, 4.5 and 7.5 MeV obtained as a result of three-dimensional simulation of electrons dynamics in the accelerator.
4. The BETA-8 accelerator can be brought to design output parameters through the increase of HF power up to the expected level of 540 kW.

Thank you for your attention!


eV
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7.47e6
6.96e6
6.46e6
5.95e6
5.44e6
4.94e6
4.43e6
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3.42e6
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Plottype Energy
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Particles 1369