

NSC KIPT ACCELERATOR ON NUCLEAR AND HIGH ENERGY PHYSICS

I.S. Guk, A.N. Dovbnya, S.G. Kononenko, A.S. Tarasenko, National Science Center “Kharkov Institute of Physics and Technology”, 1 Academicheskaya St., Kharkov, 61108, Ukraine
 M. van der Wiel, J.I.M. Botman, Technische Universiteit Eindhoven, Den Dolech 2, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Abstract

One of the main reasons for the departure of specialists in nuclear physics and related fields of physics from Ukraine is the absence of up-to-date accelerators making possible investigations to suit the international requirements in this field of knowledge. Investigations at a qualitatively new level can be performed by creating the accelerator that will incorporate the latest technological achievements in the field of electron beam acceleration on the basis of a superconducting TESLA accelerating structure. This structure permits the production of both quasi-continuous polarized electron beams required for ingenious experiments to verify current theoretical models of nuclear matter interaction, and supershort pulsed beams of electrons with a high current for studies into FEL and neutron physics. The new facility is expected to provide the possibility for the researchers from other countries to perform investigations that would be of interest for them, thereby contributing to the integration of the efforts of Ukrainian scientists and the scientists of the world community.

VARIANTS OF RECIRCULATOR STRUCTURE

The choice of a high-frequency system is of vital importance for the accelerator. The analysis of present-

day developments shows the superconducting TESLA accelerating structure (devised at DESY and operated in the continuous mode) to meet our requirements most adequately. The attainment of a 35 MeV/m accelerating gradient in a standard nine-cell cavity in 2003 [1] gives grounds for us to be oriented in future to this accelerating structure.

It was decided that the setup should be located in the 37x9 m² target hall of the LU-2000 accelerator [2] (see also fig. 3).

From the proposed program of research at the setup [2], the highest energy of accelerated electrons must lie in the range between 400 and 700 MeV.

Consideration was given to two variants of the accelerator structure, which take into account the availability of magnetic equipment and its components, and also, the existing developments of cryostat designs.

Variant 1

In view of the available floor area, we have chosen a planar arrangement of magnetic elements with four switching magnets and two acceleration gaps [1, 2] (see Fig. 1).

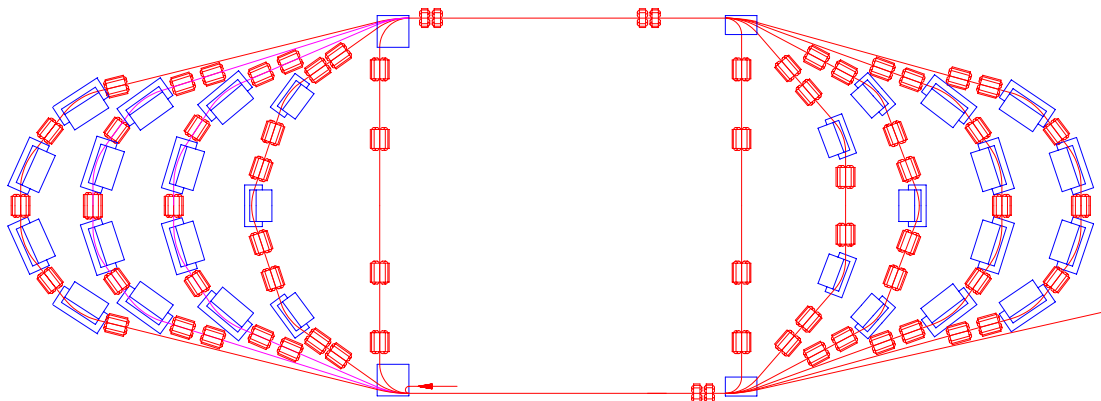


Figure 1: Recirculator lay-out in variant 1.

A beam of 10 MeV energy will be injected into a straight section of the recirculator. The length of straight sections was chosen from the consideration of arranging there two TESLA sections in a cryostat. The accelerating gradient is expected to be ~ 18 MeV/m.

In the arcs, there are two types of magnets to be used: 1) for an energy up to 191.8 MeV (eight out of ten magnets from the EUTERPE storage ring, turned over to the NSC KIPT by the Technische Universiteit

Eindhoven); and 2) for energies between 191.8 MeV and 410 MeV (20 magnets specially designed for the given setup).

For beam focusing, 69 quadrupole lenses are to be used (32 of them come from the EUTERPE storage ring).

A further increase in the number of arcs in order to enhance the final electron energy is impossible without developing new types of magnetic elements.

Variant 2

In the second variant (Fig. 2), 12 TESLA sections are chosen for the accelerating system. They will be positioned in a standard 15.927 m long cryostat devised for the TESLA collider. The accelerating gradient is to be

20 MeV/m. The first turn of beam is realized with the use of 10 dipole magnets of the EUTERPE storage ring (B1), the second turn - by means of 10 magnets B2 (Fig. 2). Twenty quadrupoles are required for the beam focusing.

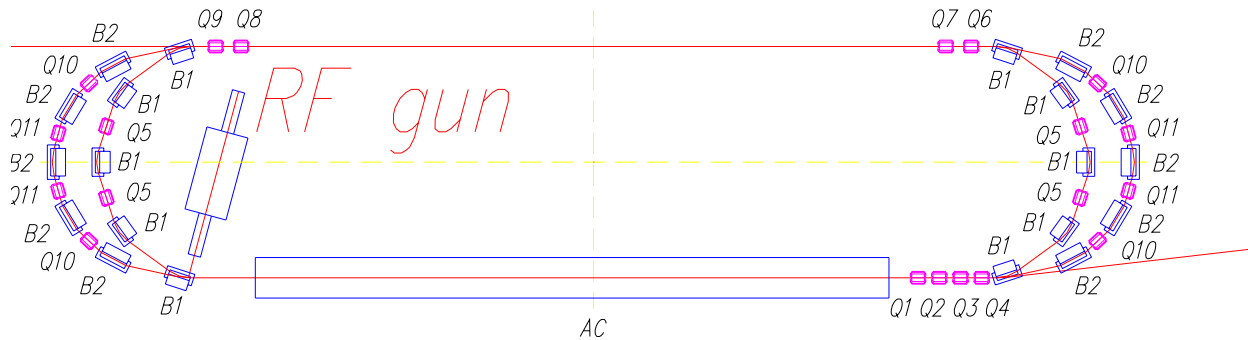


Figure2: Recirculator lay-out in variant 2.

Two injectors necessary for experiments with both polarized beams and short bunches can be arranged inside the recirculator space in the orbital plane. The layout of the recirculator and the scheme of beam ejection to the experimental rooms are shown in Fig. 3.

The 10 MeV beam from the injector is bent by the magnet (Fig. 2), gets a 240 MeV gain in the accelerating structure and may be used in SP-103 hall. With five magnets switched on, the beam can be directed to the neutron target (Fig. 3). As five more magnets of the first

ring are switched on, the beam will pass through the accelerating structure for the second time, and on attaining an energy of 490 MeV may be used in SP-103 hall. If the first five magnets of the second ring are switched on, the beam may be used in the reload room, in the neutron target area, and with switching on the next two more magnets of this ring the beam may be directed to the LU-2000 accelerator room. With all the magnets of the second ring switched on, a beam with an energy of 730 MeV may be guided to SP-103 hall.

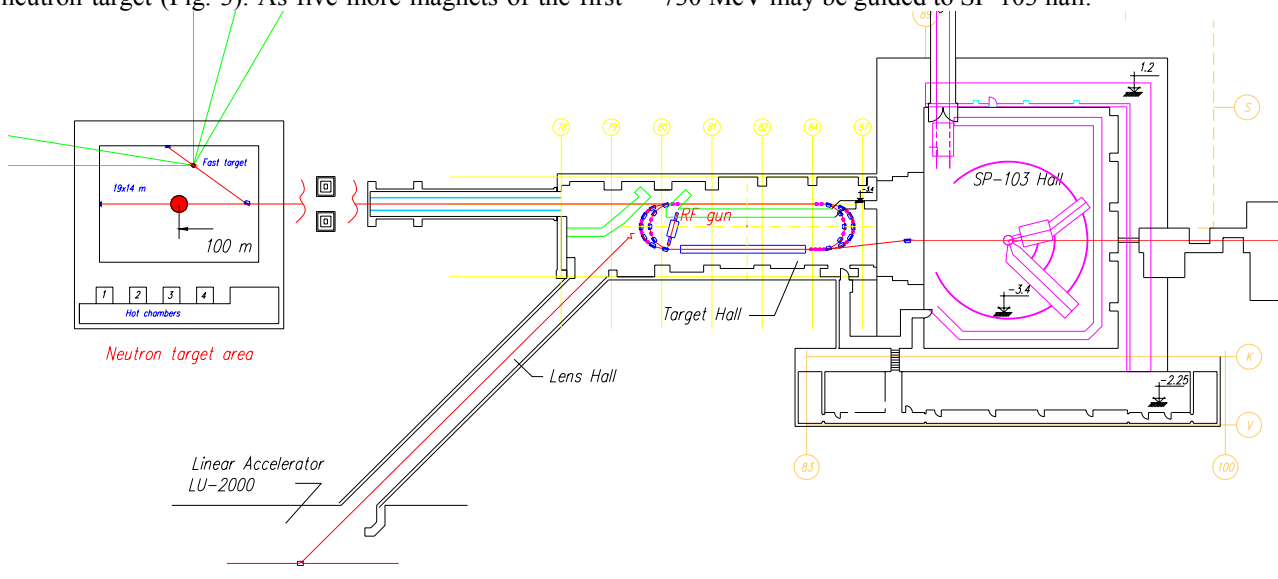


Figure 3: General view of a complex.

The FEL undulator can be installed either in a free straight section of the recirculator or in SP-103 hall, in the lens hall, or in the reload room.

CONCLUSIONS

The main parameters of the recirculator variants considered are presented in table 1. The first variant calls for the development of three new types of dipole magnets

and one type of quadrupole magnets and, correspondingly, the associated equipment for their manufacture. This will certainly affect the cost of the magnetic system. The available quantity of magnetic elements of the EUTERPE ring (provided that the switching magnets will be manufactured) will be sufficient only to attain an output energy of 210 MeV.

The magnetic system of this variant is bulky, congested with a great number of quadrupole lenses, and requires a few types of power supplies. The necessity of installing positioning magnets, beam position sensors complicates still more the arrangement of the equipment in the arcs of the recirculator. The beam injection scheme is also more complicated, because all the injectors must be placed beyond the orbital plane of the recirculator for the lack of space in the plane of beam motion.

The second variant calls for the development of one type of dipole magnets, the number of available quadrupoles being sufficient to provide focusing in both the arcs and the beam transport line. The 490 MeV energy can be attained without any development of new magnetic elements. Starting of the setup with this energy as a first

stage of creating the design facility will permit the fulfillment of the physical program planned.

The cost of the HF system for variant 2 is nearly three times higher than the cost of the system for variant 1.

At the present stage of development, variant 2 seems more preferable. Its advantages consist, first of all, in the simplicity of the magnetic system, in no necessity to design and manufacture a great number of new types of magnetic elements, that would considerably delay putting the setup into operation for the physical program. So, this factor substantially makes up for a high cost of the HF system. Owing to a less number of recirculations, the second variant will make it possible to obtain a much higher current at the exit of the accelerator. With this accelerator as the basis, an intense neutron source and a powerful FEL can be created.

Table 1: Recirculator parameters

Parameter	Variant 1 ($E_{\max} = 410$ MeV)	Variant2 ($E_{\max} = 730$ MeV)
Injection beam emittance, π -mm-mrad	0.05 – 0.295	0.05 – 0.295
Energy spread of the injection beam, %	0.0578 – 0.129	0.0578 – 0.129
Number of accelerating sections	4	12
Number of cryogenic modules	2	1
Energy gain for single pass, MeV	36,36	240
Number of 180° bends of the beam	9	4
Length of large straight sections, m	5,129	19
Total number of dipole magnets	28+4switching	20
Highest field in dipole magnets, T	1,27	1,345
Dipole magnet lengths, m	0.51; 0.66	0.51; 0.66
Vertical aperture of dipole magnets, cm	2,5	2,5
Pole width, cm	12	12
Number of quadrupole magnets	69	20
Maximum gradient in quadrupole magnets, T/m	4,5	6,5
Length of quadrupole magnets, m	0.3 (63 units), 0,1 (6 units)	0,3
Diameter of quadrupole magnet aperture, cm	5	5
Total length of the recirculator, m	150.52	130.95
Emittance at exit point of the accelerator, π -mm-mrad	0.00125 – 0.0074	0.0007 – 0.004
Energy spread, %	0.00144–0.00324	0.0008–0.00176
Highest value of beam envelope, X, Z, cm	± 0.35	$\pm 0.65; \pm 0.2$

REFERENCES

- [1] Lutz Lilje, High gradients in TESLA nine-cell cavities, // TESLA collaborating Board Meeting, Frascati, 28 May 2003.
- [2] A.N. Dovbnya, I.S. Guk, S.G. Kononenko, M. van der Wiel, J.I.M. Botman, A.S. Tarasenko, Choice of the basic variant for the NSC KIPT accelerator on nuclear and high energy physics, PROBLEMS OF ATOMIC SCIENCE AND TECHNOLOGY. 2004. № 1. Series: Nuclear Physics Investigations (42), p.16-18.
- [3] A.N. Dovbnya, I.S. Guk, S.G. Kononenko, F.A. Peev, M. van der Wiel, J.I.M. Botman, A.S. Tarasenko, Magnetic structure of the NSC KIPT nuclear-and-high-energy-physics electron accelerator at 400 MeV, PROBLEMS OF ATOMIC SCIENCE AND TECHNOLOGY. 2004. № 2. Series: Nuclear Physics Investigations (43), p.9-11.