STATUS OF DEVELOPMENT OF THE PROJECT OF THE MULTIFUNCTIONAL ACCELERATOR COMPLEX OF THE NSC KIPT

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The results of the development of the multifunctional accelerator complex of the NSC KPTI are presented. The magneto-optical structure of the recirculator, which is the basis of the complex, is given, which ensures the production of an electron beam with a maximum energy of about 600 MeV when the beam passes through the superconducting accelerating structure three times, is considered. Variants of obtaining beams of electrons, gamma quanta, positrons and neutrons for performing fundamental and applied research in the field of nuclear physics and energy, solid-state physics, and nuclear medicine are considered.

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INTRODUCTION

The purpose of the development and construction of the multifunctional accelerator complex of the NSC KPTI is to create a material and technical base for the revival of nuclear physics research and the basis for training specialists in this field in Ukraine [1-3]. As the analysis showed, currently only four electron accelera tors are operating in Ukraine: the technological acceler ator LU10 at an energy of 10 MeV, the accelerator LU 30 at an energy of 30 MeV, the accelerator LU 40 at the NSC KPTI, whose operation was restored after the damage caused by the war, and the microtron M 30 at an energy of 25 MeV at the Institute of Electron Phys ics, National Academy Sciences of Ukraine, Uzhhorod. These accelerators were created more than 60 years ago and have long ceased to meet the requirements of mod ern nuclear physics research.

The lack of accelerators and nuclear physics facili ties built on the basis of the latest technologies has led to a catastrophic decline in the training of specialists in the field of nuclear physics research, which is extremely necessary for maintaining the nuclear energy industry of Ukraine [4, 5]. This also excludes the access of Ukraini an scientists to the creation of modern accelerators for the needs of science and nuclear technologies both in the country and in the world. The conceptual design of the facility was based on world achievements in the development of accelerator technologies based on superconducting accelerating structures [2, 3], as well as the experience gained in the process of developing the basic accelerator facility of the NSC KPTI for nuclear physics and high energy physics based on the SALO recirculator project [6].

1. RECIRCULATOR

The general view of the recirculator is presented in Fig. 1. The magneto-optical structure of the recirculator and its main characteristics are described in detail in [7]. A beam with an energy of 29 MeV can be injected into the accelerating structure of the recirculator (Fig. 2). It consists of the energy of the injector, which in the high-charge mode can accelerate the beam to 4 MeV [8], and the energy gain to 25 MeV due to the superconducting accelerating module [9], which is used in the injector complex.

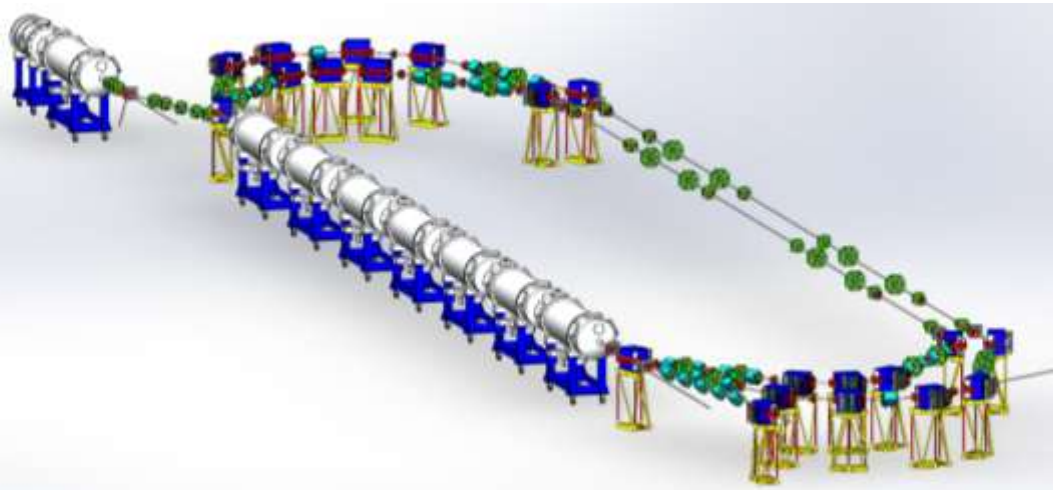

Fig. 1. General view of the magneto-optical structure of the recirculator

Further, the beam in seven accelerator modules will be able to gain energy of 175 MeV. To further increase the energy, two magnetic rings are used, with the help of which the beam passes through the accelerator two more times. The maximum electron energy can be increased to 554 MeV.

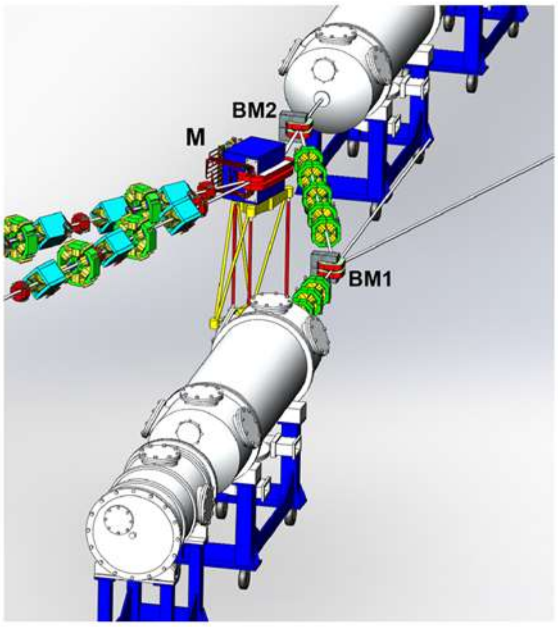

Fig. 2. Injection of electrons into the accelerator

The cross-section of the beam at the output of the second magnet of the output channel (beam energy E = 554 MeV) is presented in Fig. 3 [7].

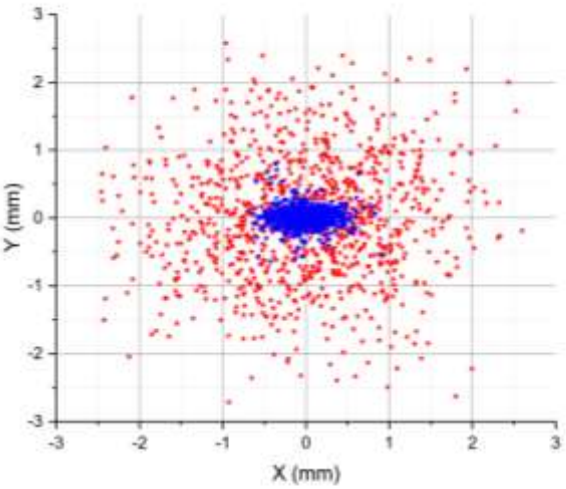

Fig. 3. The beam with the highest energy at the output of the output channel

The energy spectrum of the beam with maximum energy is presented in Fig. 4.

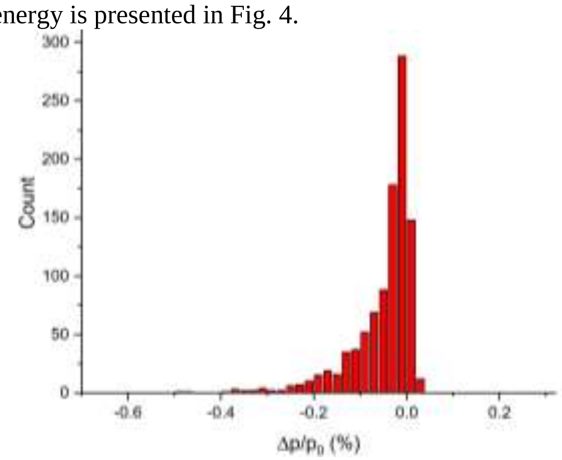

Fig. 4. Spectrum of the beam with the highest energy

2. WHAT BEAMS CAN BE OBTAINED FOR PHYSICAL RESEARCH

ELECTRONS

The electron output channels can produce beams in a wide range of energies.

As can be seen from Fig. 2, in addition to injection into the recirculator, it is possible to use quasi-continuous beams with an energy of 29 MeV and a current of about 1 mA for radiation treatment of materials and production of medical isotopes.

Another channel with such energy will make it possible to create a source of positrons for Positron Annihilation Spectroscopy, which allows studying the smallest atomic defects in crystals, metals, semiconductors and polymers, such as voids in the nanometer range, as well as chemical structures in liquids and biological systems.

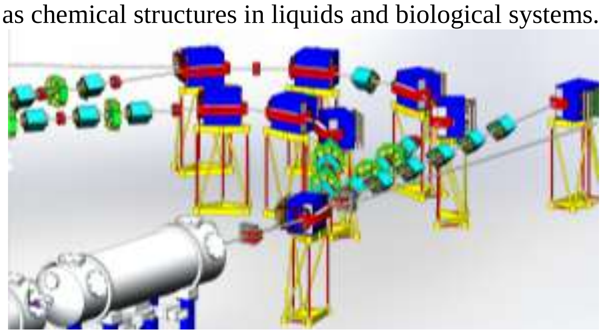

Fig. 5. Possible electron extraction channels for nuclear physics research

On the basis of the channel with the maximum electron energy, a complex of magnetic spectrometers for nuclear physics research can be placed, as well as a free electron laser.

By switching off the fourth magnet of the second recirculation ring (Fig. 5), an additional channel can be organized for research with energies up to 380 MeV.

All electron output channels are presented in Fig. 6. Switching off the third magnet of the first ring makes it possible to inject a beam with an energy of 200 MeV into the synchrotron radiation source - an electron ring with an energy of 1.2 GeV [14].

NEUTRONS

As can be seen from Figs. 5 and 6, a direct beam with an energy of about 200 MeV can be used in a pulsed neutron source [10].

The superconducting injector of the complex in the high-charge mode will accelerate electron bunches with a charge of 1 nanocoulomb, a length of 15 ps with a frequency of about 500 kHz. The average current at the injector output in this mode will not exceed 0.5 mA. After acceleration in a linear accelerator, the electron energy will reach 200 MeV.

One electron with an energy of 200 MeV in a uranium target generates ~0.14 neutrons. The total average neutron flux at the output of the neutron channel will be 4.4×10^{14} s^{-1}. The pulsed flux will reach 6×10^{19} n/s. Such beam parameters, as demonstrated in works [11,12], allow, due to the short electron pulse and small target size, to obtain neutron fluxes on short flight bases that are not inferior to installations with proton accelerators.

POSITRONS

In recent years, the number of positron spectrometers in various scientific centers has increased dramatically. This is due to the fact that positron annihilation provides information about the structure of matter that is not available for study by other experimental methods.

In [13], the creation of a positron source for annihilation spectroscopy is considered in detail. In the proposed structure of injection into the recycler [7], a beam with an energy of 29 MeV can be used for this, which interacts with a tantalum target. Due to the time structure of the electron beam, it is possible to obtain pulsed positron beams with a bunch length of about 5 ps.

To obtain positrons with high energy, a converter is used, located in front of the dipole magnet VM1 (see Fig. 2). The positron beam, which is captured by the magnetic system of the injection channel, which consists of dipoles VM1, VM2 and five quadrupoles, is accelerated to an energy of 181 MeV. This beam can be output to an experimental setup located on the direct channel. The use of the magnetic system of the first recirculation ring will allow increasing the positron energy to 356 MeV and outputting the beam through a special channel to the experimental setup.

More detailed parameters of the positron beam are given in [13].

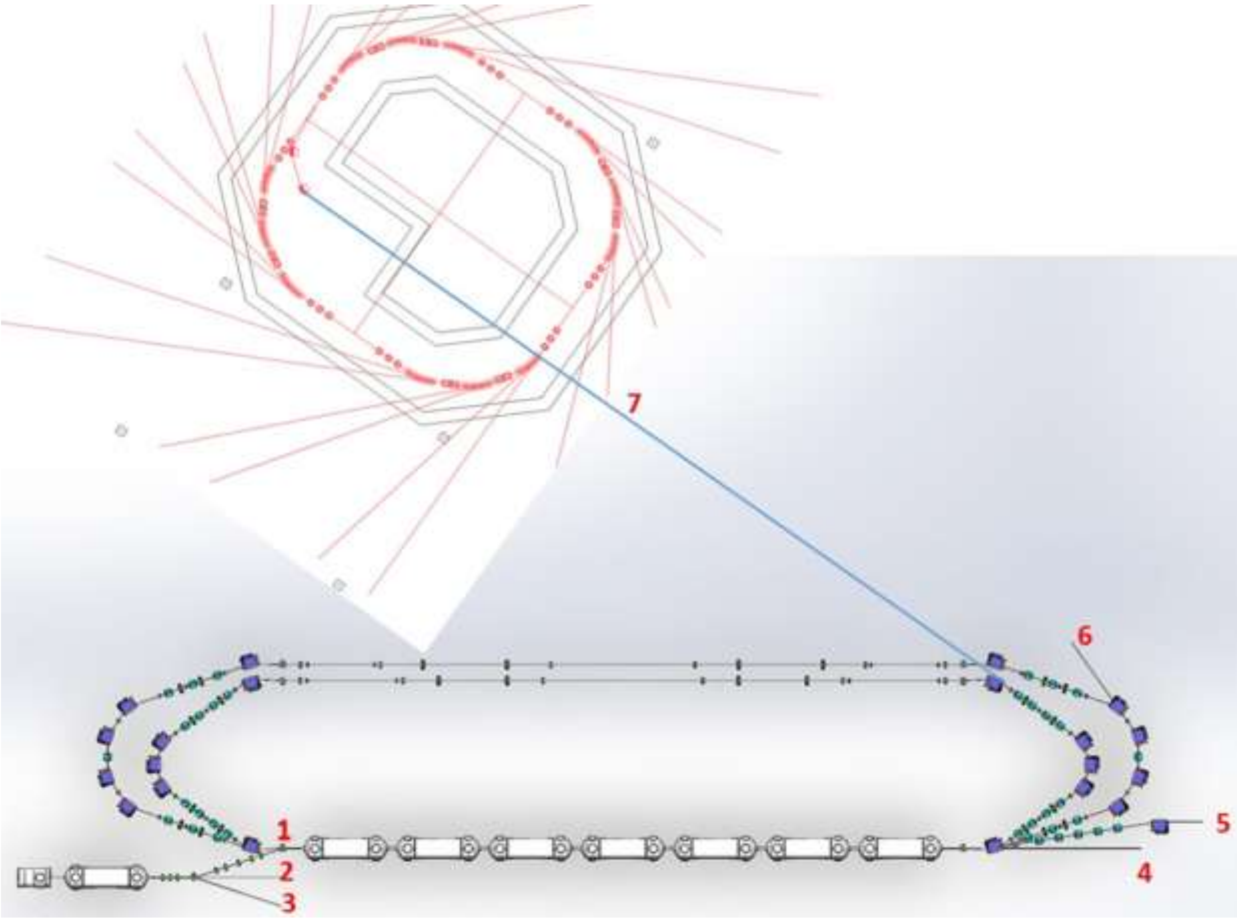

Fig. 6. General view of the electron output channels. 1. Energy up to 29 MeV, injection of electron and positron beams into the recirculator. 2. Energy up to 29 MeV, for work with radiation technologies, production of isotopes for medicine, etc. 3. Energy up to 29 MeV, for creating a positron source for positron annihilation spectroscopy. 4. Energy up to 200 MeV, for the target of a pulsed neutron source. 5-6. Maximum energy 555 and 380 MeV, nuclear physics research, free electron laser. 7. Energy 200 MeV, injection into the accumulator, synchrotron radiation source with an energy of 1.2 GeV

GAMMA QUANTA

The most common method of generating such radiation is the process of "bremsstrahlung", in which a beam of electrons (positrons) is directed into a substance (for example, a metal target), losing energy during collisions with atoms and releasing this energy in the form of radiation.

The nature of such radiation can be dramatically changed using a single-crystal target. In this case, depending on the orientation of the target relative to the beam of electrons (positrons), polarized quasi-monochromatic coherent radiation, as well as channeled radiation, can be obtained. For a positron beam, annihilation radiation is additionally formed when passing through the target. To distinguish annihilation radiation from the background of bremsstrahlung radiation, their different angular dependence was used.

Positron channeling leads to a significant increase in the contribution of annihilation radiation to the total spectrum of positron radiation moving along the crystallographic axis of the single crystal [15].

CONCLUSIONS

The performed calculations of the beam parameters of the multifunctional accelerator complex of the NSC KPTI demonstrated the possibility of conducting a large volume of research in many fields of science using nuclear physics methods.

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