CHOICE OF THE BASIC VARIANT FOR THE NSC KIPT ACCELERATOR ON NUCLEAR AND HIGH ENERGY PHYSICS

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Present worldwide (and European) developments and requirements in nuclear physics, related in particular to nuclear power needs, call for the development of a new generation of accelerators for the realization of this research. We propose to construct a facility at NSC KIPT, which produces continuous electron beams in the energy range of 5 to 400 MeV with a current up to one hundred microamperes. This facility is foreseen to provide both un-polarized and polarized electron beams of small emittance.

World trends in accelerator developments indicate that the NCS KIPT accelerator should be a superconducting linear accelerator working in continuous mode, or an accelerator with beam recirculation. In both cases it is most expedient to use accelerating structures of the TESLA type.

Estimations of capital expenses and operational costs for construction and operation of either the linear accelerator or the recirculator accelerator point to significant advantages of the second option. An advantage of the recirculator accelerator is also the opportunity to increase the energy in steps, according to the availability of financial means.

Simulations of the particle movement in the recirculator accelerator, have shown that the output beam parameters satisfy all modern requirements on electron beams, as specified by the research that will be carried out using this facility.

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1. INTRODUCTION

In the first 80 years of accelerator development the majority of constructed electron linear accelerators and synchrotrons in the energy range of 100…2000 MeV has exhausted the opportunities of their use in nuclear physics because of the small pulse duration with respect to the pulse repetition period. The second life for these accelerators was promised by the use of beam stretchers.

About 15 projects of such installations have been proposed. By 2002 only six projects were realized. At present, two of the installations in operation have stopped and have been disassembled; the nuclear physics research is going on only at three installations [1-3]. During the last ten years basically recirculators have been used for experiments with electrons. These were created using acceleration technology on the basis of superconductivity, and also using warm accelerating systems. The extraction of electrons from these facilities, in comparison with stretchers, does not represent essential difficulties: JLab, MAMI, S-DALINAC [4-6].

The last achievements in the high technology fabrication of accelerating structures for TESLA [7] allow to obtain an accelerating gradient near 35 MeV/m. Use of this structure for operation in a continuous wave (CW) mode allows to design a sufficiently compact accelerator with an energy of about 400 MeV, with a continuous beam and with the appropriate parameters for nuclear physics research. The same mode of operations using an injector with very short bunches allows to create either a free electron laser with high brightness or a neutron source with unique characteristics.

Already projects using accelerating structures of the TESLA-type in CW mode for free electron lasers in the x-ray range of wavelengths have appeared [8.9]. The first turn of the 40 MeV superconducting linear accelerator ELBE is realized [10]. It is intended for use in nuclear spectroscopy, radiation physics, neutron physics and as the free electron laser in the infra-red area of the spectrum.

The linear accelerators LU-2000 and LU-300, constructed at KIPT in the sixties of the last century, have become outdated and do not answer the requirements of modern physical experiments. A new particle accelerator installation with 400 MeV electron energy is proposed at NSC KIPT on the basis of available capital structures, using the newest technological achievements in the field of acceleration of electron beams. (If a management of the tendencies in development modern accelerator base for reception of continuous electron beams,??) On the basis of modern accelerator developments regarding continuous electron beams, this installation should be either a superconducting linear accelerator working in CW mode, or a recirculator on the basis of TESLA-type superconducting accelerating structures.

Estimations of costs and other characteristics of the proposed accelerator are based on information about the accelerators in the BESSY SASE-FEL [8] and TESLA [11] projects, using the same structure.

2. 400 MeV SUPERCONDUCTING ELECTRON LINAC

Most suitable for accommodation of the linear accelerator is the lens corridor and target hall at NSC KIPT (see fig.1). This is because these areas adjoin the SP-103 hall where the magnetic spectrometer is located, and also building 46, which can be used for accommodation of the control of theaccelerator complex, and for equipment necessary for physics research on the beams (for beam dynamics research or for research making use of the electron beams?). The SP-103 hall can be used both for accommodation of new spectrometers, and for free electron lasers activities.

For obtaining 400 MeV energy using a quite achievable gradient of 15…20 MeV/m about 20 standard accelerating structures have to be used. For obtaining the necessary final energy, two modules of the TESLA accelerating structures are sufficient, as one module consists of 12 units with a total length of 15.927 m [11] (???).

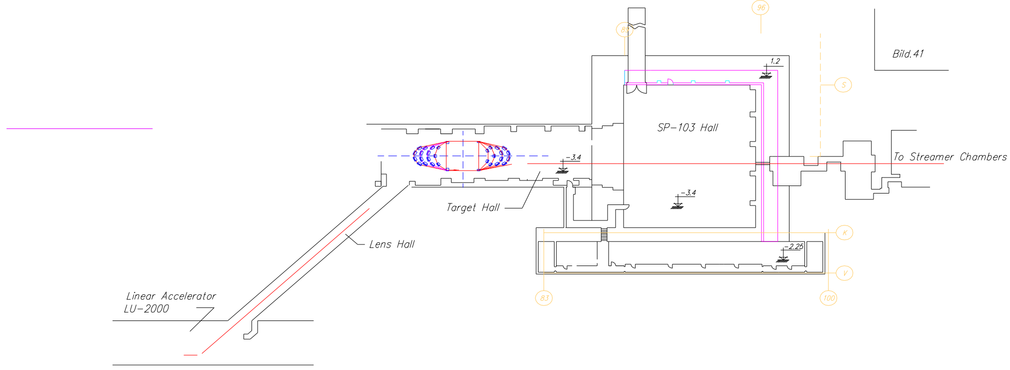

Fig. 1. Experimental setup at LU-2000 output

The minimum rf-gun length with 25 MeV pre-accelerator would be about 4 m. In this way, the minimum building length for housing the accelerator should be 36 m, so that with additional hardware it must be no shorter than 40 m. For this reason, there are two options for housing the accelerator: in the lens hall and in the target hall with displacement of the accelerator axis relative to the existing beam pathway. The latter is necessary in order to place a part of the accelerator in the re-loading tunnel, since the length of the target hall is smaller than needed. The existing re-loading does not permit to place a module of 16 m long in the bunker, however, if one lengthens the existing hatchway by 12 m, this problem should be solved. A study of the positioning of the proposed TESLA accelerator in the tunnel indicates that the transverse cross-section of the considered premises can accommodate the accelerator.

The cost of one TESLA accelerating structure in the accelerator together with the infrastructure required to run this system (power, vacuum, cryogenic, high-frequency, control, etc.), as follows from the assessment of other references [8,11,12], by mass manufacture amounts to 100-215 thousand euro.

From budget costs of the TESLA accelerator, based on expenses for the construction of TTF, it follows, that the capital expenses for purchase of the main accelerating modules and RF system of the TESLA accelerator make 51% of all capital expenses, and the cost of annual operation of the accelerator, i.e. expenses for the electric power, regular klystron replacement or restoration, helium loss under working condition of the accelerator of 5000 hours per one year make 7% of these expenses.

The capital expenses for the 400 MeV linear accelerator will amount to more than 6 million euro, and annual operational charges - 420 thousand euro. The beam power of such an accelerator will be about 40 KW. The power of cryogenic losses is more than 630 W at a temperature of 2K. Yet, power expenses on the cryogenic system will be dominant, and for this reason the total power used by the accelerator will exceed 2.5 MW.

3. 400 MeV RECIRCULATOR WITH SUPERCONDUCTING ACCELERATING STRUCTURE

Accelerating structures costs of the linear accelerator form the largest part of the common capital expenses of the construction of the installation. Using a beam circulation scheme allows to reduce length, and, hence, cost of the accelerating system.

Let us consider a 400 MeV recirculator, using the magnetic equipment from the EUTERPE electron ring [13].

The recirculator is supposed to be placed in the LU-2000 target hall and beam extraction is to be in SP-103 hall (see fig.2).

As the accelerating system is placed in the straight sections of the recirculator, two TESLA structures are supposed to be used in which the beam receives a 36 MeV gain of energy. The recirculator magnetic structure is considered in ref. [14].

At a beam power of the accelerator of 40 kW, the capacity of recirculator magnetic system will not exceed 170 kW. The capacity of the refrigerator should make about 280 kW. Costruction cost of the recirculator magnetic system is estimated at 280 thousand euro.

4. CONCLUSIONS

The comparison of two variants of installation shows essential recirculator advantages, lower capital expenses for the construction of the accelerator, and smaller expenses for operation.

Use the of the recirculation circuit version of the beam allows consistently increasing the maximal energy in the installation in the process of increasing volume of means found for the realization of the project, creating

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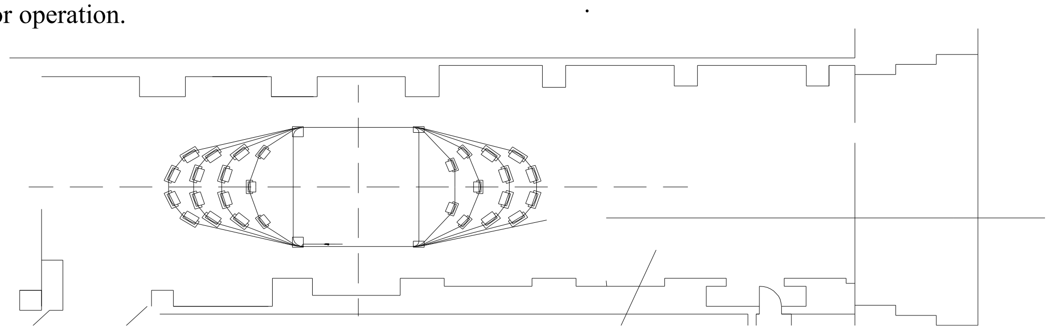

Fig.2. Recirculator layout in the LU-2000 target hall

on each stage an opportunity for realizing experiments with the beam. So, with the presence of the 10 MeV injector and the first distributing magnet, the beam can be guided to the SP-103 hall and to the lens corridor. After installation of the first accelerating module of 36 MeV in the straight sections of the recirculator the opportunity of working with a beam up to 46 MeV in the SP-103 hall will appear. After installation of all four distributing magnets it is possible to work with the beam with this energy in the overload hall and lens corridor. The installation of the accelerating module in other straight sections will allow lifting the beam energy in these workstations up to 83 MeV. The installation of magnetic elements of the EUTERPE-ring will allow receiving 192 MeV energy in the SP-103 hall and 228 MeV in the overload and lens halls. The complete installation of 5 arcs with 4 magnets in every arc will allow getting 410 MeV energy in SP-103 hall and a little bit lower energy in other halls.

The injector replacement will allow effectively to use the accelerator for nuclear physics, as free electron laser and as a neutrons source.

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ВЫБОР ВАРИАНТА БАЗОВОЙ УСКОРИТЕЛЬНОЙ УСТАНОВКИ ННЦ ХФТИ ПО ЯДЕРНОЙ ФИЗИКЕ И ФИЗИКЕ ВЫСОКИХ ЭНЕРГИЙ

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Предлагается создать в ННЦ ХФТИ установку для получения непрерывных пучков электронов в диапазоне энергий 5…400 МэВ с током до нескольких сотен микроампер с использованием сверхпроводящей ускоряющей структуры TESLA. На установке предполагается получать как обычные, так и поляризованные пучки электронов с малым эмиттансом.

ВИБІР ВАРІАНТА БАЗОВОЇ ПРИСКОРЮВАЛЬНОЇ УСТАНОВКИ ННЦ ХФТІ ПО ЯДЕРНОЇ ФІЗИКИ ТА ФІЗИКИ ВИСОКИХ ЕНЕРГІЙ

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Пропонується створити в ННЦ ХФТІ установку для одержання безперервних пучків електронів в діапазоні енергій 5…400 МеВ зі струмом до декількох сотень мікроамперів з використанням надпровідної прискорювальної структури TESLA. В установці будуть одержані як звичайні, так і поляризовані пучки електронів з малим еміттансом.