The Regional Center for Proton Therapy on the Basis of Yerevan Electron Synchrotron

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Abstract

At Yerevan Physics Institute (YerPhI) it has been proved that the existing synchrotron allows to accelerate both electrons up to 6 GeV and protons up to 250-500 MeV. The aim reconstruction is the establishment of the Regional Center for Proton Therapy (YerCPT) on the basis of Yerevan Synchrotron. The transition to the proton mode implies the minimal of the possible changes of the accelerator which will mainly touch upon the injector and RF system. This injector itself can be used as an instrument and for production of radionuclides for medicine.

1. INTRODUCTION

The Yerevan Electron Synchrotron has been operating since 1967. It is a rather unique device on base of which the significant center of physical researches has been created. The fundamental scientific research program [1] for the current decade has been developed.

This program also includes the accelerator systems and devices development to provide protons acceleration up to 250-300 MeV. It will allow to use 4.5-6 GeV energies electrons for fundamental physics researches, as well as tumor diseases treatment, radionuclides production and so on.

The presented talk is based on "The Project of the Proton Therapy Center (PTC) on the Base of Yerevan Synchrotron"[2].

The Yerevan Synchrotron is the biggest accelerator in the south region. The idea to design and manufacture PTC at Yerevan Synchrotron is based on the fact that there are qualified personnel and good infrastructure. Besides there will be a little additional building work mainly for the medical rooms construction.

The PTC design must include maximum of existing apparatus of YerPhI. The protons must be accelerated in synchrotron whose accelerating and magnet supply systems must be developed. Besides, the electron ring systems will be developed too and the number of unified (electrons and protons) extracting channels will increase.The medical rooms(MR) equipment and their arrangement on account of the existing buildings has been designed.

2. THE MAIN FEATURES OF PTC

Protons maximal energy	250 MeV
Protons minimal energy	60 MeV
Average current	5 mA
Injection energy	12 MeV
Injected beam duration	5 μsec
Ejected protons number *(particles per pulse)*	10^{10}
Acceleration cycle frequency	4 Hz
Energy gain per turn	5 keV
Accelerating voltage amplitude	10 kV
Accelerating voltage quantity	4
Accelerating station number	6-8
Injected beam energy spread	0.5%
Ejected beam energy spread	(0.1-0.4)%
Number of medical room	6

3. PTC SYSTEM MAIN DEVICES

3.1. Accelerating devices

The basic novelty in PTC project is the injector and preinjector devices with their supply system, ring accelerator accelerating modules with driving generator, and the proton mode ring electromagnet supply system.

The proton injector И-12 is a linac. Its operating frequency is chosen 425 MHz due to existing structure and to minimize accelerating system sizes for its installation in the electron injector room. It consists of four cavities. The protons are accelerated from 100 keV to 2 MeV in the first cavity, which is made by RFQ scheme. The other cavities, done by DTL scheme, accelerate the protons up to 12 MeV. Beam current and position pickups as well as the focusing units are installed in the interactive space. The pulse duration is 5-10μsec, the frequency - 4 Hz, and the current is 5 mA at $\pi \bullet 10^{-5}$ m radian emittance. The operation mode of 50 mA current and 50 Hz frequency is also considered. This mode is used for the injector independent operation to the radionuclides production. The injector system includes the control system providing switching and controlling of all injector devices, the supply and thermostatic systems.

The preinjector provides 100 keV energy protons at pulse current of 10 mA (first mode) and 50 mA (second mode). Ion source of duaplasmatron type operates in discharge ignition pulse mode at 50 Hz frequency synchronized with the feeding pulse of 100 kV high accelerating voltage. The protons are accelerated in two spaces between the earthen and accelerating electrodes.

The accelerating system consists of a driving generator and 8 accelerating modules 6 of which are operational and 2 in reserve. They are located uniformly along the ring. Each accelerating module consists of 2 half-module each being coaxial and shortened on the end. The inner space of the coaxial is filled with the ring cores wound of amorphous iron band. The half-modules are antiphase excited and 1.67 kV accelerating voltage is created between them to provide on six modules the total 10 kV. The frequency is changed in the range of 0.876 - 3.6 MHz, and the amplitude is changed by program according to the beam feedback signals. The mode and parameters control is provided by accelerator control computer data.

Electron and proton beams input system is totally unified by the existing analyzer development and an additional bending magnet installation.

The ring electromagnet supply system excites the field of $2 \bullet 10^{-2}$ T in the electromagnet gap at the injection with the linear rise during acceleration (100 msec) up to 0.048-0.107 T and 1-3% discreteness. The cycle frequency is 4 Hz. The stabilized thyristor rectifiers with the ripple damping filters are used as an electromagnet power supply.

This system is linked with the PTC control system via sequential multiplexer communication channel.

3.2. The Control and Measurement Systems

The PTC basic features is the requirement of the beam radial position stabilization during the extraction at the effect of the local distortions induced by magnetic bump. So, the radial position pickups must be installed out of the bump influence area. The corrected signals of the pickups go to the corresponding inputs of the driving generator and form the beam feedback to damp synchrotron oscillations.

B-timer generates 12 signals in 12 independent channels to provide magnetic field synchronization during the acceleration cycle. These signals also depend on the final magnetic field value given by the computer control system.

The PTC has a beam diagnostic system which includes:

a. Beam profile and emittance measuring system operated at the injector and preinjector inputs and outputs as well as at the fast and low extraction channels (the beam profile can be measured at any time of acceleration).

b. The system detecting the beam position by its radial and phase projections. The system is matched with the signals of beam feedback, control and medical control systems.

c. Beam current measuring system with ± 1% accuracy.

PTC control system with its subsystems is designed on the base of [3,4]. It provised the operation reliability and stability as well as excludes the possible mistakes of the personnel. The control system consists of two levels. The low level controls the data collecting and the processes which are strongly connected with the acceleration cycle, releasing the upper level computers of the real time operation. The low level contains 15 microcomputers, and upper level uses 3 IBM PC/AT linked in accelerator control local net. One of upper level computers controls the whole PTC operation, and two others control the injector and synchrotron. The system is designed in CAMAC standard.

4. MEDICAL ROOMS

The proton beam extraction devices are unified with the electron beam extraction system and increase the number of the extraction channels by two, one for slow and one for the fast extraction.

Proton beam transportation into the medical rooms is realized by means of quadropoles, bending and correction magnets.

According to the various requirements of tradition equipment there are 4 medical rooms for the patients with different localization of diseases:

- for irradition of brain tumors, hypopsis and aneurysm;
- for irradiation of eye tumors (melanoma);
- for irradiation of prostatic adenoma and womb tumors;
- for irradiation of the other body parts tumors - lungs, skin melanoma, etc. by the rotating beam.

Besides, there will be 2 experimental rooms for the irradiation mode improvement and medical-biological researches as well as short-lived isotope production, used in X-ray emission and positron tomography. All the rooms will be located in the existing buildings of YerPhI to minimize the expenses.

5.THE RADIONUCLIDES PRODUCTION

As already has been told the accelerator in proton mode will produce enough dense proton beam (10^{10} p/bunch) at 60-300 MeV energies. Evidently, having the radio-chemical technique, it is possible to produce the large scale of short-lived radioactive isotopes used in the medicine as well as in other fields of science and technology. It must be noticed, there is no such a center in the region.

The medical-purpose radioisotopes can be produced on the beam of proton injector at the energies up to 12 MeV. The possible reactions of this energies range can be processes of *(p,n)*- type reactions ($^{86}Sr \rightarrow ^{86g,m}Y$, $^{94}Mo \rightarrow ^{94,m}Tc$, $^{62}Ni \rightarrow ^{62}Cu$ *etc.*) . These isotopes are effectively used in the positron emission tomography.

The proton injector can operate independently of the synchrotron electron mode operation. So, the arrangement of the technological room at the injector can sufficiently increase the efficiency of the isotope production.

6. CONCLUSION

The estimation shows that the creation of PTC on Yerevan Electron Synchrotron base, with its developed infrastructure, determines the low construction expenses and their fast compensation. The cost will be to an order lower than the one of similar systems constructed now in the USA. Under favorable conditions PTC can operate in 2-2.5 years,

7. REFERENCES

[1] "The Technical Modernization and Development Program of Yerevan Electron Synchrotron in 1987-2000", Ed. by Amatuni A.Ts., YerPhI, State Committee of Atomic Energy of USSR, Yerevan, (1987).

[2] "The Project of the Proton Therapy Center on the Base of Yerevan Synchrotron", Moscow-Yerevan, (1993).

[3] "The Technical Proposal of the Center by OPUS-1 Theme", Moscow, (1989).

[4] "Loma Linda University Medical Center Proton Therapy Accelerator. Engineering Design Report.", FNAL, Preliminary Issue, Feb. 4, (1987).