MEASUREMENT OF THE PROTON BEAM PROFILE VIA AN ACTIVATION METHOD OF DIAGNOSTICS*

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Abstract

In The Budker Institute of Nuclear Physics the accelerator-based source of epithermal neutrons was invented and now operates to be used in the boron neutron capture therapy. Neutrons on the facility are generated during the threshold reaction ^{7}Li(p, n)^{7}Be which occurs when the proton beam is thrown on the lithium target. To control the neutron output it is necessary to monitor the parameters of the accelerated proton beam. The spatial distribution of the accelerated proton beam was measured exactly on the lithium target, using an activation method of diagnostics.

INTRODUCTION

The principle of operation of the facility is as follows. The negatively charged ion beam is generated on the ion source, then it is injected in the tandem accelerator with vacuum insulation. After a recharge of H^- beam into positively charged protons in the recharging gas target a proton beam is formed, which is accelerated to doubled potential of the high voltage electrode. On the lithium target as a result of a threshold reaction ^{7}Li(*p, n*)^{7}Be the neutron flux is generated [1]. General view of the accelerator is shown in fig. 1.

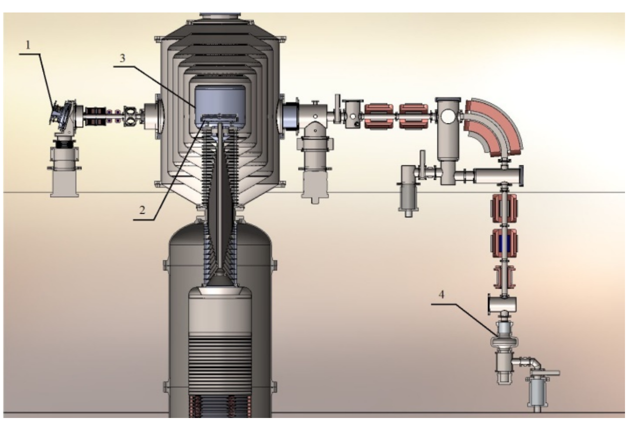

Figure 1: Vacuum insulation tandem accelerator. 1 – H^- ion source, 2 – gas recharging target, 3 – high voltage electrode, 4 – lithium neutron-generating target.

As a result of an interaction between protons and lithium on the neutron-generating target an accumulation of the radioactive isotope of beryllium takes place. It was proposed to track down an area of the beryllium storage in order to restore a profile of the proton beam.

THEORETICAL FOUNDATION

The neutrons are generated during an inelastic scattering of 2 MeV proton beam on the lithium nuclei according to the reactions [2]:

$$^7Li + p \rightarrow\ ^7Be + n - 1{,}646\text{ MeV},$$
$$^7Li + p \rightarrow\ ^{7*}Be + n - 2{,}076\text{ MeV } (\sim 10\%),$$
$$^{7*}Be =\ ^7Be + \gamma + 430\text{ keV}.$$

The process of an inelastic scattering is characterized by the resonance energies: 1.05, 2.05, 2.25 MeV, which are close to the threshold reaction of the neutron generation 1.882 MeV. The flux of gamma-quants with the energy of 0.478 MeV is equal to the flux of neutrons. To decrease the gamma-quants flux the thin layer of lithium is sprayed to the copper substrate.

After an experiment there is a radioactive isotope ^7Be is accumulated, which has a half-life of 53.6 days. The tracking of gamma-quants with the energy of 478 keV, released during the beryllium decay, could serve an alternative way of the proton beam profile measurement in an accelerating part of the facility. To implement such a method the gamma-spectrometric complex was involved, that consists of the scintillation NaI-detector, which was pre-calibrated for energy, and the lead shielding with the collimation hole of 8 mm. The measurement of gamma-radiation is carried out after an experiment, remotely from the facility.

With the penetration of ionizing particles in the scintillator material the flash of luminescence occurs, then it is converted into a pulse of electrical current by the photomultiplier, finally the electronic system records it.

RESULTS OF EXPERIMENTS

For the restoring of the beam profile the neutron-generating target was imposed a proton beam influence during 25 minutes. The measurement of gamma-radiation was carried out one week later after an experiment, in order to exclude the short-lived gamma-quants.

The lithium target substrate is moved in increments of 1 cm before the collimation hole of the lead shielding (the center of the target is the point [0;0] in the figure 2), in this way the counting speed was determined in the line of a full absorption. The luminescence intensity distribution on the target surface, defined as the number of recorded events to the time of statistics collecting, is shown in fig.2.

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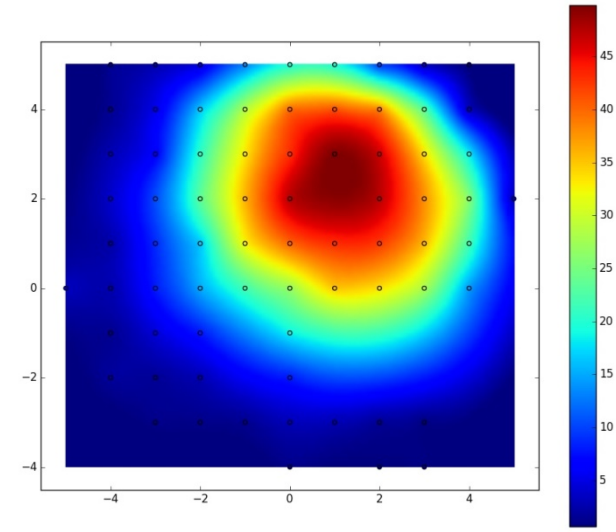

Figure 2: Ttransverse beam profile, registered on the lithium target.

As it follows from the obtained distribution, the proton beam shape is round. The width on the level of "e" times decrease of the luminescence intensity is about 48 mm. This result is in a good agreement with the results of numerical calculation, in which the focusing element is a bending magnet in the transport part of the facility. The beam with 1 cm radius and maximum angles of 1.6 mrad was used as a source. Also the calculation takes into account the same conditions, as it is on the real facility. According to the calculation, made by A.M. Dolgov and V.A. Kiselev, transverse beam size was about 40 mm at the distance of 200 cm to the bending magnet. The result of calculations is shown in the figure 3.

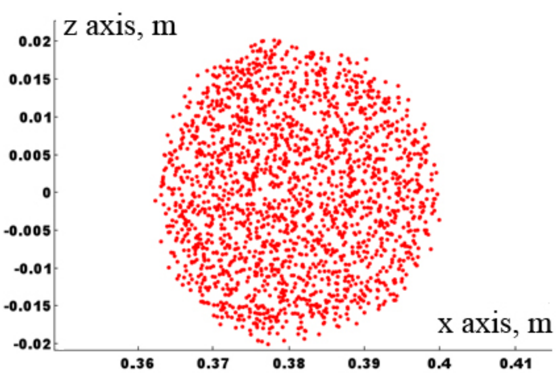

Figure 3: Transverse beam profile at the distance of 200 cm to the bending magnet.

CONCLUSION

In The Budker Institute of Nuclear Physics the research to obtain a high-current proton beam is pursued in the tandem accelerator with vacuum insulation.

The innovative diagnostics on the gamma-spectrometric complex was implemented in order to monitor the proton beam profile on the lithium neutron-generating target. The shape, size and profile of the beam were successfully determined, also this result corresponds to the numerical calculation.

Such method of diagnostics could allow to estimate the full neutron flux, the amount of neutrons, judge the target state and restore the proton beam profile. According to the attractive capabilities, the prospects are to develop this method and apply it continuously.

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