Excitation function $^{14}N(n,t)^{12}C$ in fast neutrons energy region

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Abstract

In this work experimental investigation of $^{14}N(n,t)^{12}C$ reaction is described. The ionizing chamber with Frisch greed was used for reaction products spectroscopy. Working gas of the ionizing chamber contained ~3% of nitrogen. This gas we used as target where investigated reaction took place. Using of digital signal processing methods allows us to select the signals correspond to (n,t) reaction from large number of background events. $^{14}N(n,t)^{12}C$ reaction cross section experimental data for is presented in this work.

Introduction

One of the possible fuel types for advanced nuclear reactors is nitride fuel. This kind of fuel has a lot of advantages - nitride fuel is high-density, has good heat conductivity that provides rather low temperature of fuel elements at operation and it, in turn, has positive effect for safety. Nevertheless there is a big problem which connected with an additional tritium source from ^{14}N (n, t) ^{12}C reaction.

Tritium leaks in the environment because it has a high mobility and easily penetrate through constructional materials. Tritium is dangerous for personnel of nuclear stations because it can easily replace light hydrogen isotope in human body and it can create inner radiation source.

The set of experimental data for ^{14}N (n, t) ^{12}C reaction available from the literature as well as different theoretical estimations show big discrepancy. In this condition only new experimental research of $^{14}N(n, t)^{12}C$ reaction cross section based on modern techniques can provide sufficient precision for this value.

Experimental method

In present work measurement of section of $^{14}N(n, t)^{12}C$ reaction were executed on accelerator EG-1 of IPPE. Neutrons were generated in D (d, n) reaction on a firm titanic target, which thickness is 1 mg / cm^2. Measurements were executed for 37 various neutron energies in an interval from 5.1 to 7.0 MeV.

Cross section research was carried out using doubled ionizing chamber with a common cathode. The main ionization chamber with Frisch grid was used as detector of the events of neutron interaction with nuclei of nitrogen. A parallel plate chamber which contains a thin solid ^{238}U layer was used as neutron flux monitor (fig. 1).

Signals from various electrodes of the chamber were amplified and then were digitized with the help the wave form digitizer – LeCroy 2262. The further processing of signals was made by means of programs. The information on amplitudes of anode and cathode signals, and also the moments of the beginning and the ending of these signals was taken during processing. Joint analysis of this information allowed us to define charged particle energy, place of event occurrence in the interelectrode space and charge collecting time (charge is formed by a particle).

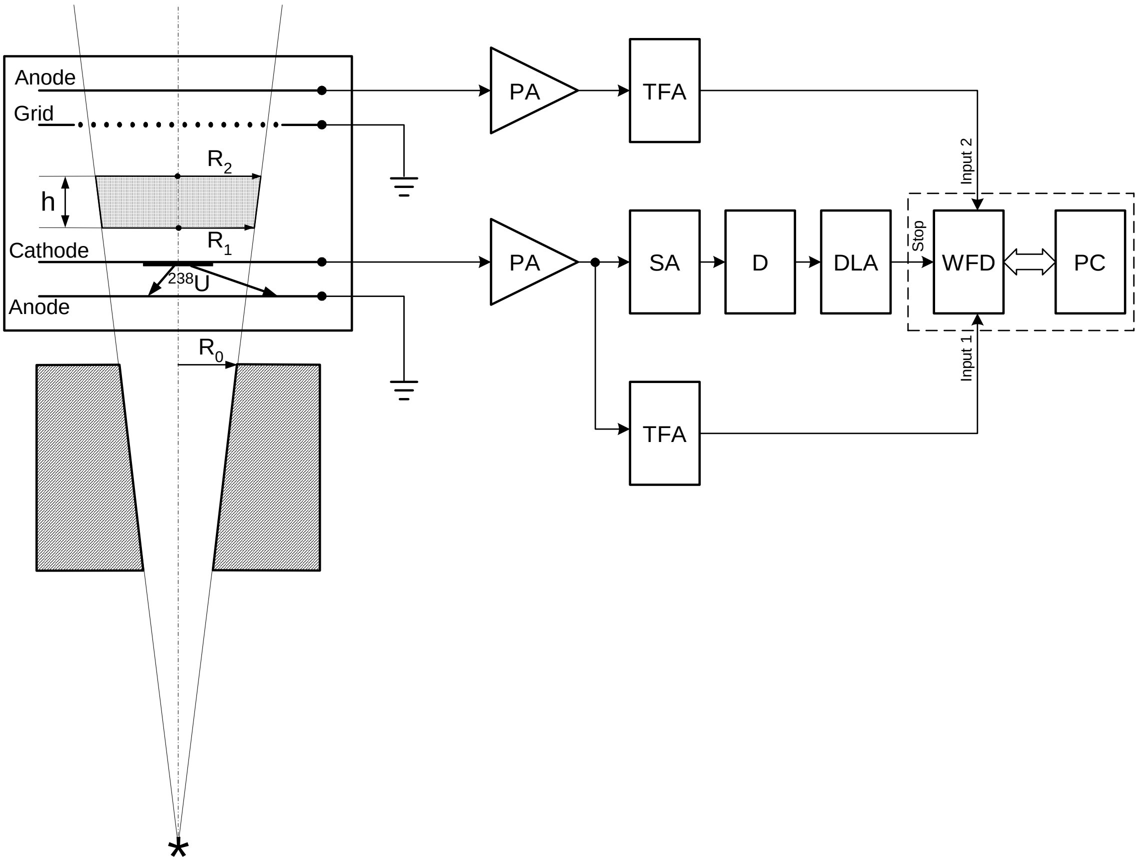

Figure 1. Block diagramme of experimental setup. DA – preamplifier, TFA – timing filter amplifier, D – discriminator, SA – spectroscopy amplifier, DLA – delay line amplifier, WFD – waveform digitizer, DC – personal computer.

Chambers were filled by 97%Kr + 3%N_2 gas mixture. The nitrogen contained in working gas was a target for neutron interactions. Gas target use has allowed us to considerably increase nuclei number in the investigated sample and hence, to reduce time of measurements. Use of fast neutron collimation together with signal digital processing methods has allowed us to allocate a certain gas cell in the sensitive volume of the chamber. So we can take in consideration events that happen in the cell only. One of the main advantages of such approach is that accurate choice of the gas cell size and position makes it possible to suppress wall effect practically. Number of nitrogen atoms in can be easily calculated for fixed gas cell using simple gas laws.

It should be noted especially that the increase time of anode signal bears in itself type of the registered particle information. For example, free path and time of charge collecting for proton appears much more than for α-particles of the same energy. In this work it was possible to use this principle for particles division on type and to reduce a background arising from parasitic reactions in working gas and on detector electrodes. In Fig. 2 the spectrum of anode signals received from the detector (top part of figure). In the bottom part of figure 2 the same spectrum after suppression of a background is given. Really, only after background suppression it is possible to observe a number of lines related to α_2, α_3 channels of ^{14}N (n, α) reaction and the channel of reaction with tritium emission which is the subject of the current research. Application of powerful digital methods of suppression of the background, which is not used in other works, essentially has allowed to improve the situation with definition of number of events correspond to the channel of reaction (n, t).

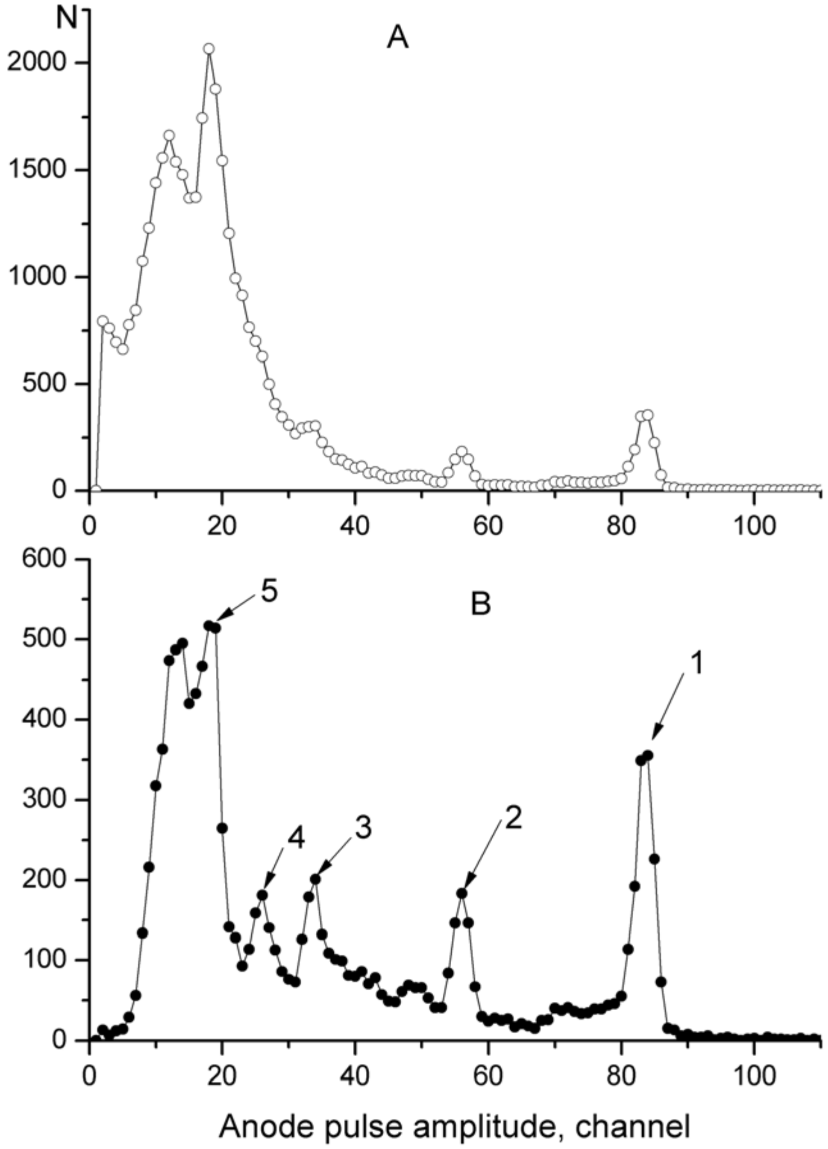

Figure 2. Energy spectrum for: A – all events; B – after selection. 1-^{14}N(n,α_0), 2- ^{14}N (n,α_1), 3-^{14}N(n,t), 4-^{14}N (n, α_2), 5-^{14}N(n, α_3).

Experimental results

14N (n, t) reaction cross sections data that is obtained in this work are shown in fig. 3 and fig. 4. On the fig.3 new data and experimental data available from the literature [1-4] are shown. On the fig.4 our experimental data is plotted together with different libraries estimations (ENDF/B VII, BROND, and JENDL). In average, for neuron energy range 5.6-7 MeV our cross section data level in 2-3 times less then other authors' one. For low neutron energy range (5.25-5.6 MeV) value of cross section significantly higher then Bonner group data [1].

Additionally our energy dependence of 14N (n, t) reaction cross section is different from other authors' one. In our data set we don't observe the well shaped resonances in (n, t) reaction cross section for energy 5.66, 6.05 and 6.7 MeV predicted by ENDF/B VII library (see fig.4).

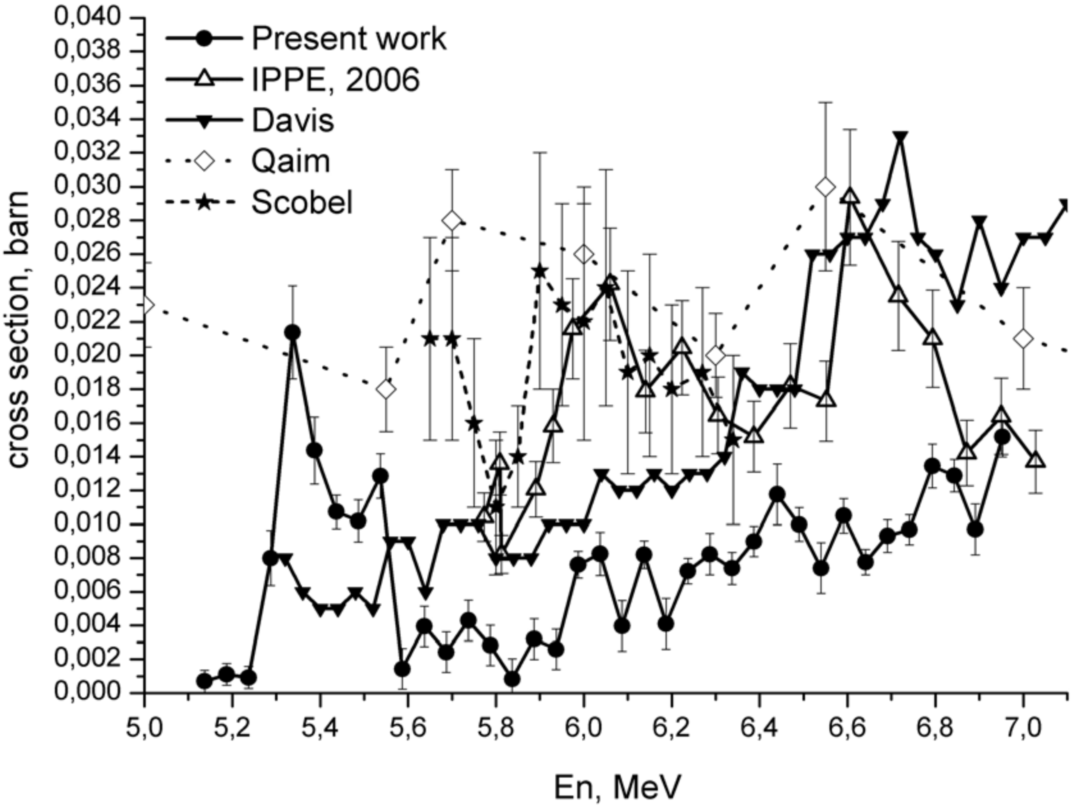

Figure 3. $^{14}N(n,t)^{12}C$ reaction cross section in comparison with experimental data of other authors.

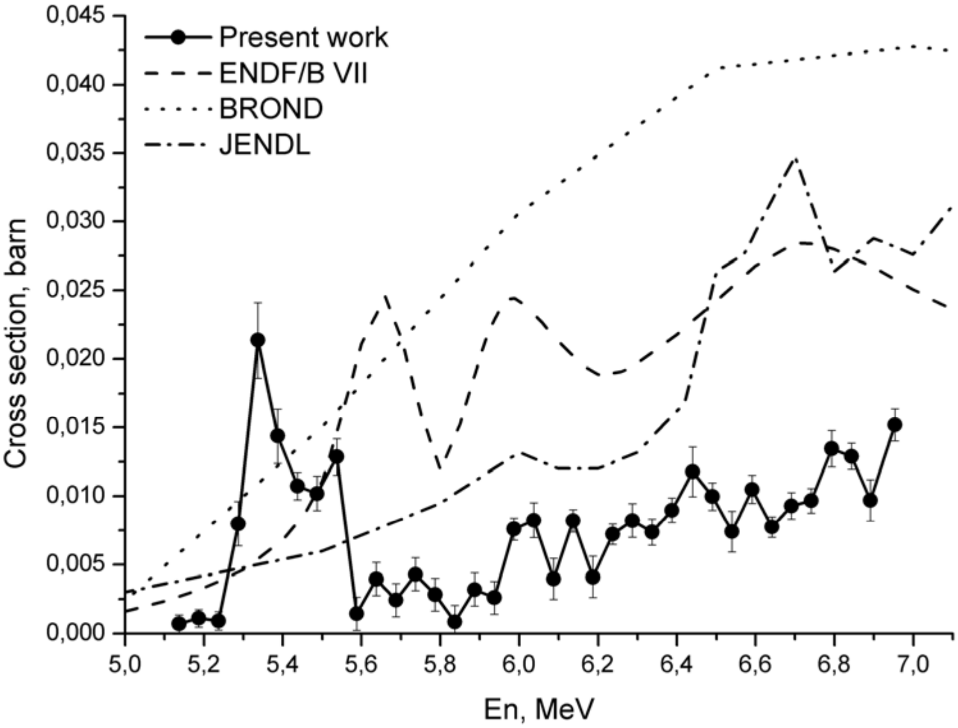

Figure 4. $^{14}N(n,t)^{12}C$ reaction evaluated cross section in comparison with experimental data.

At the same time in our cross section data we have clean peak for energy 5.4 MeV which is not presented in available estimations. The same structure we can see in tendency of data, predicted by ENDF/B VII library, but a peak position on a energy scale essentially differs (250 keV).

Conclusion

In this work was used a set of new methods which allows us significantly reduce a background and improve reliability for number of $^{14}N(n,t)$ events definition. As effect – background suppression for developed spectrometer is much better than for the others were used before. The obtained results strongly differ from other authors' data accessible from the literature. None of the available theoretical estimations can describe energy dependence for cross section obtained in this work. Only additional experimental and theoretical effort can solve the problem of $^{14}N(n, t)$ reaction excitation function behavior.

References

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