Angular Distribution of Neutrons Around Thick Beryllium Target of Accelerator-Based 9Be(d, n) Neutron Source

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An experimental work and simulations were carried out to determine the angular distributions of neutrons and yields of the $^9Be(d, n)$ reaction over all angular range (360 deg) on a thick beryllium target as an accelerator-based neutron source at incident-deuteron energy 13.6 MeV. The neutron activation method was used in the experimental part using aluminum and iron foils as detectors to calculate the neutron flux. The Monte Carlo neutral-particles code (MCNP5) was used to demonstrate and simulate the neutron distribution, also to understand and compare with the experimental results. The neutron energy spectrum was computed using the projection angular-momentum coupled evaporation code PACE4 (LISE++) and the spectrum was adopted in MCNP5 code. Two experimental ways were used, one with beryllium target and another one without the beryllium target, to evaluate the neutron flux emitted only by the beryllium target. Typical computational results were presented and are compared with the previous experimental data to evaluate the computing model as well as the characteristics of emitted neutrons produced by the $^9Be(d, n)$ reaction with a thick Be-target. Moreover, the results can be used to optimize the shielding and collimating system for neutron therapy.

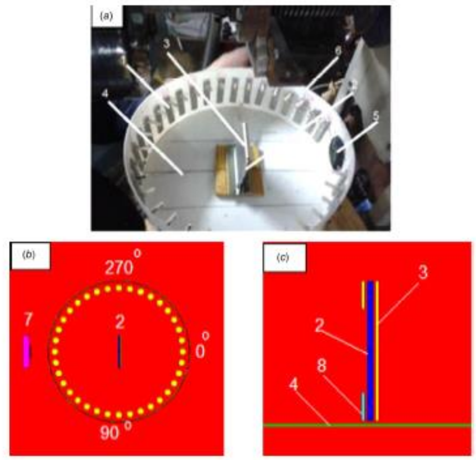

Fig. 1 The setup of experiment: (*a*); 1—Al foils, 2—beryllium target, 3—Al disk 1 mm thick in the opposite irradiated side of the beryllium target, 4—the plastic holder, 5—the hole for incoming deuteron beam, 6—four iron foils fixed on the outer back-side of the plastic holder, (*b*) and (*c*); drawings from MCNP5 code for the geometry and elements of the experiment, 7—the beam channel, (*c*); clear view of the components beside the target, and 8—iron holder

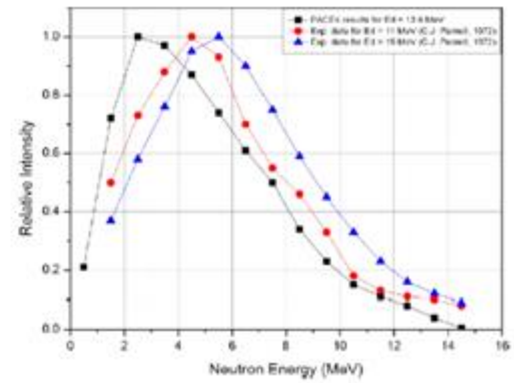

Fig. 3 The results of PACE 4 code simulation of neutron energy spectrum of the reaction $Be^9(d,n)$ for E_d = 13.6 MeV and 0 deg emission compared to experimental data taken from (C. J. Parnell, 1972) [1]

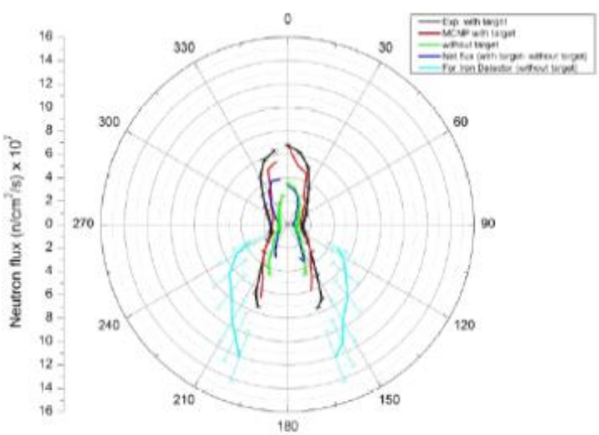

Fig. 4 The polar distributions of neutrons produced at the center of this circle where the Be target is positioned [with error bars]. The Fe foils at positions 115deg, 155deg, 205deg, and 245deg, while the other points of Fe curve are extrapolated. The MCNP results were represented here by the red curve.

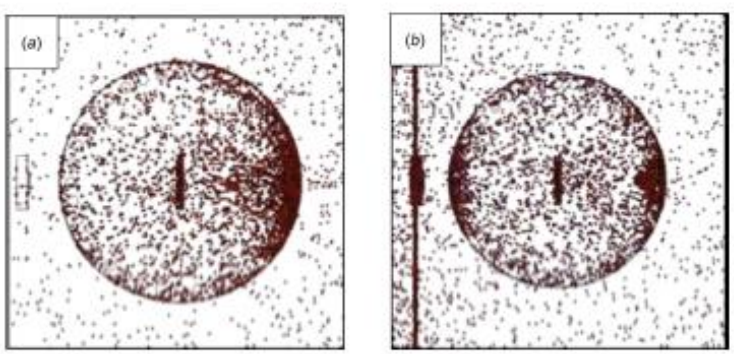

Fig. 6 The MCNP5 windows of simulated results of angular distributions of neutrons produced by (*a*) one source (the beryllium target at the center) and (*b*) two sources (one is the beryllium target at the center and another one at the end of deuteron beam canal). The dots refer to the neutron particles.

References

In this paper, an angular distribution of fast neutrons emitted by the source $Be^9(d,n)$ over 360 deg has been evaluated. The results showed that the maximum neutron fluxes are at 0 deg and 180 deg with respect to the deuteron beam direction. Whereas the minimum found to be at 90 deg and 270 deg as theoretically expected and agreed with the experimental and simulated results as in Refs. [2] and [3]. The unexpected existence of non-negligible values of neutron fluxes detected by Al- and Fe-foils in the frontward and backward directions with respect to the target without the existence of the beryllium-target can be explained by the collisions between the deuteron ions and the surrounding air and the thin Al-foil located at the end of beam canal. The highly scattering

[1] C. J. Parnell, Brit. J. Radiol. 45_ (1972), p. 452.). [2] S.T. Butler, Angular distributions from (d, p) and (d, n) nuclear reactions, Proc. Roy. Soc. (London) A208, 559 (1951). [3] A. B. Bhatia et al, XLV. Angular distribution in (d, p) and (d. n) reactions, Phil. Mag. 43, 4. 83 (1952).