

and shutdown states, this study employs a “two-step method.” The findings demonstrate that the high dose rate area, reaching several tens of Sv/h, is concentrated within a 2-meter space in the central region above the subcritical reactor during operation. Table 1 presents the radiation dose rate distribution in the personnel detention area under three distinct scenarios following six months of continuous operation of CiADS.

The induced dose is mainly caused from beam tube activation during CiADS operation. According to simulation results, we suggest that the operation and maintenance of equipment in top region of the reactor should be carried out at a proper time, such as after 1 day of beam shutdown. And we also recommend to select appropriate radiation protection measures, such as removing beam tube or increasing shielding, to further reduce the radiation dose to minimize the exposure of the staff.

The induced dose primarily stems from the activation of the beam tube during CiADS operation. Based on simulation results, we recommend conducting the operation and maintenance activities of equipment in the upper region of the reactor at an appropriate time, such as after a one-day period of beam shutdown. Additionally, we advise the implementation of suitable radiation protection measures, such as the removal of the beam tube or the augmentation of shielding, to further reduce the radiation dose and minimize staff exposure. These recommendations are essential in ensuring the safety and well-being of personnel involved in CiADS operations.

6 - 18 Measurement of the ^{252}Cf Neutron Spectrum and the Cosmic-ray Neutron Spectrum

Wen Zhiwen, Luo Peng, Xu Junkui and Song Shiyu

The extended-range multi-sphere neutron spectrometer (EBSS) was used to measure the ^{252}Cf neutron spectrum and the cosmic-ray neutron spectrum. It consists of seven polyethylene-only spheres and seven extended-range spheres. The neutron multipliers of the extended-range spheres embed concentric shells of lead, copper and tungsten.

Based on the direct neutron count rates and the corrected response functions, the neutron spectrum of the ^{252}Cf source was unfolded by the unfolding codes. The unfolding codes were provided by the China Institute for Radiation Protection. The neutron spectrum was calculated with the unfolding codes according to Eq. (1). M represents the neutron count rate, i is the sphere number, j is the energy bin number, Φ is the neutron fluence.

$$M_i = \sum_{j=1}^{nE_n} R_{i,j} \cdot \Phi_j \quad (1)$$

Since the number of the spheres is less than the number of the energy bins, in the condition of the default spectrum, the unfolding codes iteratively solve the ‘few channels’ problem based on linear least squares method. The default spectrum is the ISO8529-1 standard ^{252}Cf neutron spectrum. The default spectrum was scaled to the same total fluence rate of the unfolding spectrum. Figure 1 shows that the unfolding neutron spectrum agrees very well with the ISO 8529-1 standard ^{252}Cf neutron spectrum. Since there were scattered neutrons present even after the shadow cone subtraction, the experimental bins are higher than the ISO data for neutron energy below the peak and lower for energy above the peak.

For the cosmic-ray neutron measurement, the geographic location, atmospheric depth and altitude of the measurements are 36.3°N , 103.54°E , $833.6 \text{ g}\cdot\text{cm}^{-2}$ and 1 614 m, respectively. Each sphere was placed at 1.5 m above the roof floor. Each sphere was measured for 8 h and the count rate data from the cosmic-ray neutrons were saved at every fixed time interval (1 h). The statistical uncertainty of each sphere is about 3%. The cosmic ray neutron spectra at each altitude were almost the same in their shapes^[1] and the cosmic-ray neutron spectrum at sea level measured by Goldhagen^[2], *et al.* was employed as the default spectrum. The cosmic-ray neutron spectrum is obtained by unfolding the measured counting rates with the corrected response functions. The default spectrum was scaled to the same total fluence rate of the unfolding spectrum. Figure 2 shows that they are in quite good agreement. The major peaks of thermal neutron region, evaporation peak around 1 MeV and peak around 100 MeV caused by nuclear spallation reaction are clearly observed. The total neutron fluence rate determined from the unfolding spectrum is $0.028 \text{ cm}^{-2}\text{s}^{-1}$ which is close to the value measured by Kowatari, *et al.* at the altitude of 1 660 m in the Mt. Fuji Area.

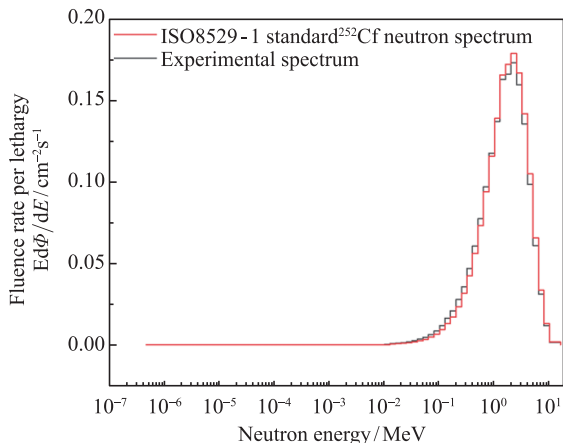


Fig. 1 (color online) Comparison of unfolding ^{252}Cf neutron spectrum of the EBSS and the ISO 8529-1 standard ^{252}Cf neutron spectrum.

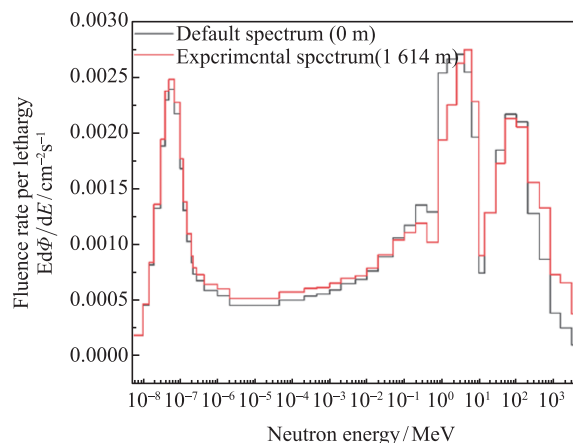


Fig. 2 (color online) Comparison of the experimental spectrum and the default spectrum obtained by Goldhagen, *et al.*

References

- [1] M. Kowatari, K. Nagaoka, S. Satoh, *et al.*, J. Nucl. Sci. Technol. 42(2005)495.
- [2] P. Goldhagen, M. Reginatto, T. Kniss, *et al.*, Nucl. Instrum. Meth, 476(2002)42.

6 - 19 Excitation Functions for Fast-neutron Induced Reactions on Zinc

Liu Bingyan, Tian Guoyu, Han Rui, Shi Fudong, Sun Hui, Zhang Zekun and Chen Zhiqiang

Zinc is important in reactor to decrease the radiation fields and primary water stress corrosion cracking^[1].

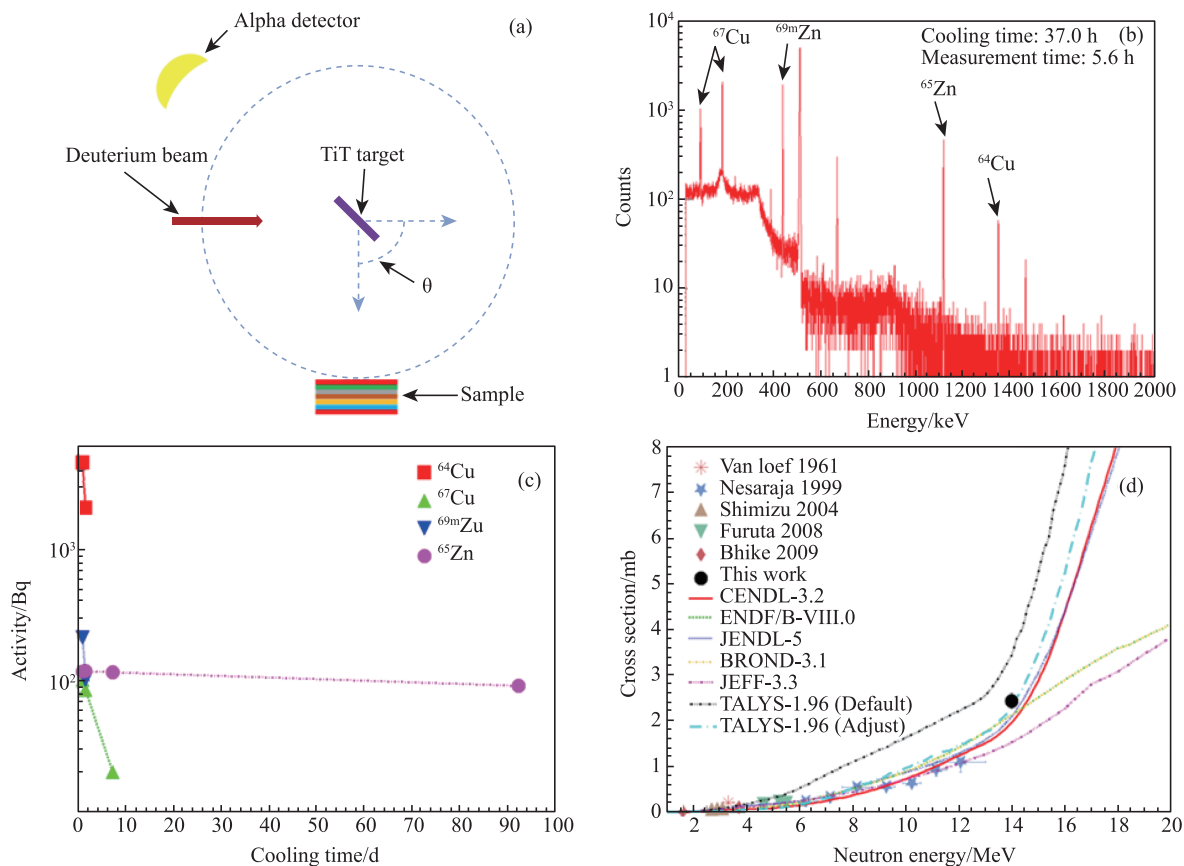


Fig. 1 (color online) Schematic view of the experimental setup (a), Typical γ -ray spectra of irradiated Zn sample (b), activities of measured radionuclides with different cooling time (c) and excitation function of the $^{112}\text{Sn}(n, x)^{111}\text{In}$ reaction (d).