by using foil activation methods. Besides, theoretical result of TALYS-1.95 code with default models and evaluated nuclear data of the ENDF/B-VIII.0, PADF-2007 and JENDL-4.0/HE libraries were compared with experimental values.

Neutron induced reactions are very important for ADS and radiation safety. Metal tin or tin alloys play important roles in the application of nuclear technology. Tin is the potential structural material of first wall for a fusion tokamak reactor (Budaev, *et al.*, 2020). Nb_3Sn is used in the superconducting radio frequency cavities due to the excellent performance in acceleration gradient and operating temperature. Cross sections of the ^{112}Sn(n, x)^{111}In, ^{114}Sn(n, 2n)^{113}Sn, ^{nat}Sn(n, x)^{117m}Sn and ^{124}Sn(n, 2n)^{123g}Sn reactions have been measured by using the activation technique at 13.6 MeV neutron energy[7]. The irradiation was carried out at the K-400 Neutron Generator at China Academy of Engineering Physics. The experimental data are compared with the corresponding evaluated nuclear data from the ENDF/B-VIII.0, JENDL-4.0/HE, BROND-3.1, CENDL-3.2 and JEFF-3.3 libraries and TALYS-1.95 calculation.

High energy density physics experiments were performed at nuclear data experimental terminal of HIRFL-CSR at IMP. APD readout $LaBr_3$ and CsI detectors were developed for the measurements of high intensity gamma rays. The energy spectra of gamma rays were measured with or without strong magnetic field (5 T) using 150 MeV/u intense Bi beam bombarded on several targets. The neutron yields were measured with or without strong magnetic field (10 T) using 430 MeV/u ^{78}Kr beam bombarded on several targets by activation method.

References

[1] H. Sun, R. Han, B. Liu, et al., Applied Radiation and Isotopes, 190(2022)110474.

[2] X. Zhang, Z. Chen, R. Wada, et al., Nucl. Instrum. Meth. B, 516(2022)48.

[3] J. Yan, B. Liu, Y. Gong, et al., Nucl. Instrum. Meth. B 510(2022)49.

[4] H. Sun, B. Liu, R. Han, et al., Eur. Phys. J. A, 58(2022)256.

[5] Y. Gong, B. Liu, Z. Wen, et al., Nucl. Instrum. Meth. B, 519(2022)15.

[6] B. Liu, R. Han, H. Sun, et al., Eur. Phys. J. A, 58(2022)17.

[7] B. Liu, G. Tian, X. Yangon, et al., Applied Radiation and Isotopes, 184(2022)110209.

6 - 17 Study on Radiation Field of the Coupling Region in CiADS

Song Shiyu and Luo Peng

There is complex spatial structure design and radiation source in the coupling region of CiADS, which is also one of the most important areas in radiation protection design. Radiation sources term mainly includes subcritical reactor leaking particles and beam loss particles, this paper adopted “two-step method” to study the radiation field distribution of CiADS in the status of operation and shutdown. Result shows that the high dose rate area (several tens Sv/h) is concentrated in the 2 m space of the center region above the subcritical reactor during operation. Table 1 shows that the radiation dose rate distribution in the personnel detention area under three situations after 6 months continuous running of CiADS.

Table 1 The inducing dose rate (μSv/h) distribution after CiADS shutdown.

Cooling times	1s	2h	1d	7d
Don’t remove beam tube and don’t increase the shield	1953	1216	411	338
Remove beam tube and don’t increase the shield	946	541	77	59
Don’t remove beam tube and increase the shield	859	523	91	70

The coupling region of the Compact Intense Accelerator-Driven System (CiADS) exhibits a complex spatial structure design and encompasses significant radiation sources, making it a crucial focal point in the design of radiation protection measures. The primary radiation sources in this region primarily consist of subcritical reactor leaking particles and beam loss particles. To investigate the radiation field distribution of CiADS during operational 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.

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

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 g·cm^{-2} and 1 614 m, respectively. Each sphere was place 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 cm^{-2}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.