ANIMMA 2021
Prague, Czech Republic June 21-25, 2021

Contribution ID: **15** Type: **Oral presentation**

#07-15 Characterization of Inelastic Proton Scattering on Carbon for Active Interrogation Applications

Wednesday, June 23, 2021 3:40 PM (20 minutes)

Passive detection of special nuclear material is challenging because of its inherently low rate of spontaneous emission of penetrating radiation, the relative ease of shielding, and the fluctuating and frequently overwhelming background. Active interrogation, the use of external radiation to increase the emission rate of characteristic radiation from special nuclear material, has long been considered to be a promising method to overcome those challenges. Current active-interrogation systems that incorporate radiography tend to use bremsstrahlung beams, which can deliver high radiation doses. Low-energy ion-driven nuclear reactions that produce multiple monoenergetic photons may be used as an alternative. The inelastic scattering of protons on carbon —specifically, ^{12}C(p,p′)^{12}C —is one such reaction that could produce large yields of highly penetrating 4.4- and 15.1-MeV gamma rays. The gamma-ray energies produced by this reaction would provide higher penetration capability than existing bremsstrahlung systems (photon-energy endpoints of 6 and 9 MeV) while enabling robust material discrimination by means of dual-energy photon radiography. This reaction does not directly produce neutrons below the approximately 19.7-MeV threshold, and the 15.1-MeV gamma-ray line is well matched to the photofission cross-section of ^{235}U and ^{238}U. Rate and spectral measurements were made with liquid organic scintillators and NaI(Tl) scintillators, while the radiation dose was measured using thermoluminescent dosimeters. We use Geant4 simulations to simulate the detector responses and background radiation production in the experimental area, which allows the estimation of the yields of the 4.4- and 15.1-MeV gamma rays from near the reaction threshold up to 30 MeV. The yields in all experimental configurations are greater than in a comparable deuteron-driven reaction that produces the same gamma-ray energies and which has been considered for use in active interrogation —^{11}B(d,nγ)^{12}C. However, a significant increase of the neutron radiation dose accompanies the proton energy increase from 19.5 to 30 MeV. This source could potentially address some of the key technical specifications required for new active-interrogation systems. By taking advantage of the emission of gamma rays into a large solid angle, even multiple cargo scanning streams may be feasible with a single source, thereby increasing the container throughput. With no direct neutron production at proton energies below 19.5 MeV, the ^{12}C(p,p′)^{12}C reaction should further reduce the neutron-shielding requirements and lower the total radiation dose imparted to cargo.

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Session Classification: 07 Nuclear Fuel Cycle, Safeguards and Homeland Security

Track Classification: 07 Nuclear Fuel Cycle, Safeguards and Homeland Security