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Triple angular correlations in inelastic nuclear collisions with gamma-ray emission: astrophysical aspect

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Inelastic nuclear collisions accompanied by gamma emission from excited nuclei serve as a valuable source of information regarding nuclear reaction mechanisms and the characteristics (energy, spin, parity) of nuclear levels. Notably, however, gamma radiation resulting from such collisions - occurring not only on the Sun but also on other stars - can be detected on Earth (see, e.g., [1]). The intensity of this radiation allows for an assessment of the concentration and energy of the colliding particles within stellar atmospheres. In principle, further information regarding the fluxes of colliding particles can be obtained, as the energy (frequency) of gamma quanta emitted in a specific direction depends on the trajectories of the colliding and outgoing particles. As a step toward acquiring such data, the characteristics of gamma radiation emitted at various angles relative to the reaction axis in the inelastic scattering of protons (with energies ranging from 5.44 to 25 MeV) by the ^{12}C nucleus was calculated in [2] (the 2^+ state 4.439 MeV was excited). The calculated gamma-line shapes (intensity versus energy) showed good agreement with the results of earlier measurements.

Evident expression for the differential cross section of the analogous $^{12}\text{C}(\text{n},\text{n}'\gamma)$ reaction—involving excitation of the same 4.439 MeV state—is presented in a recent study [3], alongside the results of measurements of this cross section. Using a more general approach to describing angular correlations—based on functions of three vectors that are independent of the choice of coordinate axes, as first described in [4]—we derived the double-differential cross sections for both the $^{12}\text{C}(\text{n},\text{n}'\gamma)$ reaction and the analogous $^{12}\text{C}(\text{p},\text{p}'\gamma)$. In our view, differential cross sections expressed in terms of such vector functions are better suited for calculating gamma-line shapes. This approach to describing triple angular correlations can be extended to other similar reactions, including those of astrophysical significance.

References 1. D.J. Forrest, R.J. Murphy. Solar Physics, 1988, v. 118, iss. 1, p. 123-135. 2. J. Kiener. Phys. Rev. C, 2019, v. 99, iss. 1, 014605. 3. P. Filonchik et al. Int. J. Mod. Phys. E, 2024, v. 33, iss. 12, 2441020. 4. L.C. Biedenharn. Pure and Applied Physics, v. 9 (Nuclear Spectroscopy, Edited by F.Ajzenberg-Selove), part B, 1960, section V, subsection C, p. 732 (Academic Press, New York and London).

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