Contribution ID: **66** Type: **not specified**

Muonic X-ray and spherical encoding-based ICF target element imaging

The elemental distribution in inertial confinement fusion (ICF) targets critically influences their fusion performance. However, existing detection technologies struggle to simultaneously achieve deep penetration, non-destructive analysis, and micron-level resolution. This project proposes a novel method combining muon-induced X-ray emission (MIXE) with spherical coded imaging to overcome the technical limitations in high-precision elemental distribution detection for ICF targets. The method involves irradiating targets with a muon beam to generate characteristic X-rays, which are modulated by a coded spherical aperture to form encoded signals on the detector. Microscale elemental distribution is then reconstructed through deconvolution and CT algorithms. The research encompasses: 1) establishing a physical model for characteristic X-ray emission induced by muons, based on the design parameters of China’ s upcoming high-intensity muon source and typical ICF target elemental distributions; 2) optimizing the spherical coded imaging system and reconstruction algorithms; and 3) quantitative calibration of oxygen distribution in targets (targeting spatial resolution ≤5 μm and density measurement uncertainty ≤0.2 at.%). By integrating the advantages of MIXE and spherical coded imaging, this method enables non-destructive, deep-layer detection of multi-element distributions, addressing the limitations of traditional techniques in surface analysis and sample irradiation damage. The project not only serves the demand for high-precision elemental detection in ICF targets but also provides technical support for China’ s first high-intensity muon source facility, driving methodological innovation in particle detection technologies under extreme conditions.

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