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Fission Neutrons Multiplicity Distribution Reconstruction Techniques

Nuclear fission is one of the most important phenomena in nuclear physics, with broad practical applications. While it is well-studied for applied needs, numerous open questions remain in fundamental research. Spontaneous fission (SF) is one of the primary decay modes in the transfermium ($Z \geq 100$) and super-heavy element (SHE) regions. However, most available experimental data have been collected for isotopes up to californium ($Z \leq 98$), while data for heavier nuclei remain scarce.

Experimental studies of SF properties in the SHE region face multiple obstacles, such as short half-lives requiring online measurements and extremely low formation cross-sections necessitating highly efficient setups due to limited data yields. The primary SF characteristic—mass or isotopic distributions of fission fragments—cannot yet be measured with high efficiency. Other critical properties include total kinetic energy (TKE) and prompt neutron multiplicity distributions (PNMD). Most existing detector setups for SHE studies rely on silicon strip detectors, which struggle to measure TKE accurately due to the amplitude deficit effect. In contrast, PNMD can be measured with relatively high efficiency using large arrays of ^{3}He counters or similar solid-body neutron detectors.

The single-neutron detection efficiency for such detectors typically ranges near 50% and rarely exceeds 70%. This sub-100% efficiency distorts the measured PNMD shape compared to the true distribution, requiring a reconstruction procedure. Currently, the most widely used method is the simple yet powerful Tikhonov regularization technique, which incorporates prior information via a linear operator and regularization parameter. However, optimal selection of the regularization parameter remains a topic of debate. Monte Carlo methods offer a second approach, enabling the incorporation of arbitrary nonlinear detection efficiencies and potentially outperforming traditional methods for low-statistics data.

This talk addresses the optimal strategy for selecting regularization parameters in Tikhonov methods, discusses previously unreported technique artifacts, and proposes solutions. Additionally, it explores the often-overlooked impact of detection efficiency uncertainties on results. Finally, Monte Carlo methods are examined for their applicability to induced fission studies, where PNMD measurements are limited by low, energy-dependent neutron detection efficiencies but collected statistics are high.

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