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Systematics of the mass-asymmetric fission of excited nuclei from ^{176}Os to ^{206}Pb

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ABSTRACT

The competition between the dominant mass-asymmetric and rarer narrow mass-symmetric fission modes in actinide nuclei are controlled by deformed and spherical shell effects. The low energy fission of $^{180}_{80}$Hg was recently observed to be strongly mass-asymmetric, indicating that despite spherical shell gaps in fragments around $^{90}_{40}$Zr, the system does not fission mass-symmetrically. Several theoretical approaches have been used to explain this unexpected result.
To investigate the underlying mechanism, systematic measurements of fission mass distributions for isotopes of Os, Pt, Hg and Pb, formed in fusion reactions with p, ^{12}C, ^{32}S, ^{40,48}Ca projectiles, have been made for excitation energies above the fission saddle-point (E^*_{eff}) between 2.8 and 28.2 MeV. Evidence for mass-asymmetric fission is widespread, manifested as flat topped mass distributions or significant deviations from a single Gaussian shape. The systematic trends seen cannot be attributed to quasifission. Comparing two-Gaussian fits at a wide range of E^*, it is concluded that the fit centroids reflect the low energy character of mass-asymmetric fission in the sub-lead region.
Quantitative comparisons were made with microscopic calculations by Scamps and Simenel (2019) [33] of fission mass-asymmetries attributed to the influence of shell gaps in both neutrons (N=52, 56 for compact octuple deformations) and protons (Z=34 and Z=42, 44, 46 with large quadrupole deformations). For the predominant fission mode in the calculations, having one elongated and one compact fragment, the results are in extremely good agreement with all experimental values. This provides strong support for both the calculations, and the exploration of mass-asymmetric fission systematics through heavy ion fusion reactions. The total kinetic energy distributions for ^{176}Pt and ^{180}Pt do not show any evidence of a low TKE mass-symmetric fission mode, as had been reported for ^{178}Pt by Tsekhanovich et al. (2019) [39].

Nuclear fission is a large scale collective rearrangement of a microscopic system which involves a subtle interplay of collective and single particle effects. Though fission was discovered [1,2] more than eighty years ago, there are many fundamental questions that are not yet fully understood [3]. Apart from its significance as a fundamental nuclear phenomenon, fission is important in the astrophysical *r* process [4,5], the creation of heavy [6] and medium heavy [7] nuclei, the creation of nuclei far from stability [8], in power production and in the synthesis of radio-isotopes — all these demand a clear understanding of the fission process.

One of the key characteristics of fission is the fragment mass distribution. In the spontaneous and low energy fission of actinide nuclei, the fragment mass division was observed to be asymmetric at the time of discovery, unlike the symmetric mass splits predicted by the liquid drop model [9,10]. An early proposed explanation [10–12] was the extra binding energy of fragments with completely filled spherical proton and neutron shells at Z=50, N=82

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