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High-Resolution Gamma-Ray Spectroscopy of ^{136}Ba: Implications for Neutrinoless Double Beta Decay

Neutrinoless double beta decay ($0\nu\beta\beta$) is a rare nuclear process predicted by beyond-Standard Model theories, offering crucial insights into the nature of neutrinos and lepton number violation. A confirmed observation of $0\nu\beta\beta$ would establish the Majorana nature of neutrinos and provide constraints on their absolute mass scale. Among candidate isotopes, the decay of ^{136}Xe to ^{136}Ba is extensively studied in large-scale experiments such as EXO, KamLAND-Zen, nEXO, and PandaX. However, to date, experiments have only set lower limits on the decay lifetimes [1].
A significant challenge remains in the precise determination of nuclear matrix elements (NMEs), which introduce uncertainties in extracting neutrino properties from measured decay rates. Theoretical predictions of NMEs vary considerably [2], highlighting the need for improved nuclear structure data.
This study investigates the nuclear structure of ^{136}Ba, the daughter nucleus of ^{136}Xe, through high-resolution gamma-ray spectroscopy using the FIPPS array at ILL. The focus is on low-spin states in ^{136}Ba populated via the ^{135}Ba(n,γ)^{136}Ba reaction, with particular emphasis on the characterization of low-spin 0^+ states. These states play a fundamental role in $0\nu\beta\beta$ decay transitions but remain incompletely understood.
The level scheme of ^{136}Ba has been studied through ^{136}Cs β decay and ^{135}Ba(n, γ) reaction experiments. Although several (n, γ) studies have been conducted, the only published data dates back to 1969 [3]. More recently, a study of the ^{138}Ba(p, t)^{136}Ba reaction [4] identified several previously unknown 0^+ states in ^{136}Ba. The high statistics of this experiment will allow for a significant expansion of the existing data set.
The experimental setup consisted of 16 HPGe clover detectors with anti-Compton shields, achieving an efficiency of 3.5% at 1.4 MeV and an energy resolution of ~2 keV at 1.3 MeV. The experiment employed a thermal neutron beam from the ILL reactor with an intensity of ~10^7 n/s/cm^2 [5]. The results will highlight newly identified transitions and spin assignments for states up to 5 MeV in excitation energy. The coincidence method was used to assign new decay lines by analyzing γγ matrices, while spin assignments were determined through angular correlation analysis of coincident γ rays, referencing existing literature on tentative spin values and mixing ratios.
Additionally, the findings will be compared with theoretical calculations to provide further insights into the nuclear structure of ^{136}Ba. Lifetime measurements will be conducted to reduce uncertainties and provide new data. The vibrational and mixed-symmetry properties of ^{136}Ba (*N=80*) will also be explored to enhance the understanding of its collective dynamics. These results aim to reduce NME uncertainties, advance knowledge of $0\nu\beta\beta$, and contribute to broader nuclear structure studies.

References:

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