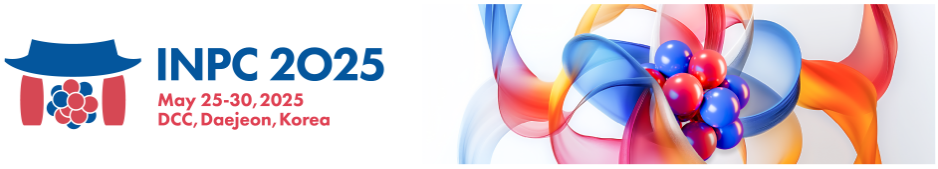

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Investigation of excited states in As-76 of interest for double-beta decay

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Investigation of excited states in ^{76}As of interest for $\beta\beta$ decay

In recent years, double-beta decay studies have been conducted both experimentally and theoretically, due to their potential to provide insights into neutrino properties and the conservation of symmetries. While the two-neutrino decay channel is predicted by the Standard Model and has been measured for various nuclei, the neutrino-less channel is yet to be found experimentally and is one of the best-known examples of possible beyond-standard-model physics. A measurement of this process would imply that the neutrino is its own antiparticle and would provide an accurate estimate of its mass, provided that the nuclear matrix element is known. Among many candidates, significant efforts have been made to study, theoretically \cite{Menéndez} and experimentally \cite{Agostini, Šimkovic}, the double-beta decay of ^{76}Ge to ^{76}Se. Experiments performed so far have only been able to set a lower limit on the decay lifetimes. The predicted lifetimes and decay rates vary significantly depending on the chosen theoretical description. Theoretically, the wave functions of the ^{76}Ge ground state and the ^{76}Se low-lying states play a crucial role. Additionally, theory shows that the structure of the intermediate ^{76}As nucleus plays a non-negligible role in the decay process \cite{Suhonen}. Therefore, very precise nuclear-physics data are needed to constrain the uncertainty in theoretical predictions. This work aims at studying the structure of ^{76}As, the intermediate nucleus in the $\beta\beta$ decay of ^{76}Ge.

The structure of ^{76}As was investigated in detail through the measurement of the ^{75}As(n,γ) reaction using the FIPPS+IFIN array at ILL, in Grenoble. The array consists of 16 HPGe clover detectors, each equipped with anti-Compton shields. The total efficiency of the array was around 3\% at 1408 keV, and its energy resolution was around 5.5 keV at 7 MeV. The setup used a thermal neutron beam from the ILL nuclear reactor, with an intensity of around 10^7 $n/s/cm^2$ \cite{FIPPS}. The experiment was carried out in November 2023 and lasted 14 days. The results of such experiment will be presented. These include 700 new transitions found for states up to 1.5 MeV in excitation energy, the resolution of doublets, and spin assignment of levels up to 500 keV in excitation energy. For the assignment of new decay lines, the coincidence method was used, analyzing both $\gamma\gamma$ matrices and $\gamma\gamma\gamma$ cube projections. To assign spins, the angular correlations of coincident γ rays were analyzed. The available information in literature on tentative spin assignments and mixing ratio values was used as a base for the angular correlation analysis. Additionally, the comparison of the experiment results to large-scale Shell Model, RPA and interacting boson-fermion-fermion \cite{Jolie} calculations will be presented.

The complexity of the analysis and the difficulty of linking very precise experimental results to theories lead the analysis towards a statistical approach, in complement to the level scheme analysis. Since no analysis of this kind was previously run at FIPPS, a neutron-capture test experiment was performed using the HPGe array in June 2024 using a ^{95}Mo target. The test aimed to verify the literature values obtained in previous experiments \cite{Milan96Mo}. The same analysis has been applied to ^{76}As and the results of such analysis will also be presented. To confirm the results found during the ILL experiment, and study states with higher spins, a fusion-evaporation experiment was run at IKP (University of Köln) in October 2024. This experiment exploited the HORUS experimental setup, consisting of 14 Ge detectors, among which six equipped with anti-Compton shields. The performed experiment measured the γ rays coming from a ^{76}Ge(p,n) reaction at 9 MeV on a highly enriched ^{76}Ge target. The results of the analysis of this experiment will also be presented, and compared to both neutron capture data and recently published fusion-evaporation experimental results \cite{76AsiThemba}.

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