IFIN-HH

Proposal for the TANDEM accelerator for the period

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Investigation of the $E1$ and $M2$ transition strength in $A = 35$ mirror nuclei using the in-beam fast timing technique

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The corresponding electric dipole transitions between bound states in $|T|$=1/2 mirror nuclei should have approximately equal strength. Apparently, the known decay scheme of the first $7/2^-$ state in the ^{35}Cl $-^{35}$Ar mirror pair indicate the opposite, since for almost equal gamma energies the main branch is the $(7/2^- \rightarrow 3/2^+)$ $M2$ in ^{35}Cl while in ^{35}Ar is the $(7/2^- \rightarrow 5/2^+)$ $E1$. However, only for ^{35}Cl the lifetime of the $7/2^-$ state is known (τ=45.3(6) ps), leaving place for divergent arguments regarding the influence of isospin mixing on the strength of the mirror $E1$ and $M2$ transitions originating from this level. We propose therefore to clarify this problem by measuring the lifetime of the E_x=3197 keV, $7/2^-$ yrast state in ^{35}Ar using the in-beam fast timing technique, with the Bucharest HPGe-$LaBr_3$:Ce array.

I. Scientific motivation

One of the isospin selection rules for gamma decay advanced by Warburton and Weneser [1] at the end of 60's is that electric dipole transitions in conjugate nuclei should have (almost) equal strength. This rule proved to be valid for most of the systems where experimental data is available, with only several notable exceptions like in the ^{15}N $-^{15}$O mirror pair, where the decay of the $1/2^+$ analog states at 8312 keV - 7550 keV shows a factor 400 difference for the $E1$ transition strength. Nevertheless, the 7550 keV state in ^{15}O is unbound and this fact might explain the large difference of $E1$ strength. In heavier systems a significant difference in a decay pattern of analog states involving $E1$ transitions appears in the ^{35}Cl $-^{35}$Ar mirror pair. In this last case the decay pattern of the first excited $7/2^-$ state is significantly different in each of the two nuclei, as can be seen from Fig. 1. The $E1$ and $M2$ decay branching ratios are not similar at all, while the gamma-ray energies are quite close and do not account for such a large difference if one consider that the $B(E1)$ and $B(M2)$ values are approximately equal in both nuclei.

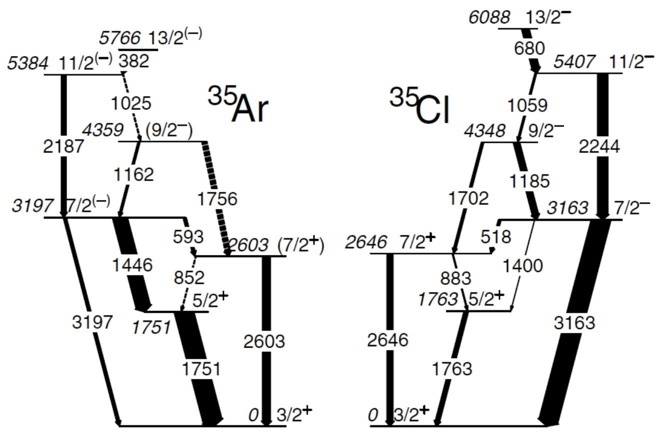

FIG. 1: Relevant level scheme of mirror A=35 nuclei (figure taken from ref. [2]) showing the very different decay pattern of the $7/2^-$ state.

This problem was discussed by Ekman et al. in ref. [2, 3], where it was supposed that the $B(M2)$=0.25 W.u. of ^{35}Cl might be approximately equal in both nuclei, while due to the isospin mixing the $E1$ matrix elements might cancel in ^{35}Cl and sum up in ^{35}Ar, leading to three orders of magnitude difference in strength from 2×10^{-8} W.u. to 3×10^{-5} W.u. The explanation was advanced with the reserve that there is no obvious reason for the assumption of identical $B(M2)$ values and the required degree of isospin mixing for the cancelation of the $E1$ matrix elements would exceed five percent, which is much more than is expected for these nuclei.

The decay of the $7/2^-$ state in the A=35 mirror nuclei was further discussed in ref. [4], where the possibility to extract the isospin mixing from the relative intensity of the $E1$ transitions in mirror nuclei was investigated. Relying on a $B(M2)$ value of 0.0032 W.u. theoretically predicted in ref. [5], they deduced about one percent isospin mixing for the A=35 mirror nuclei, which is a reasonably value. In this case, the lifetime of the $7/2^-$ state of ^{35}Ar should be around 350 ps, well within the range accessible using in-beam timing with fast scintillators.

A precise measurement of the lifetime of this state in ^{35}Ar would clarify the problem from experimental point of view, and would indicate the possible deviations from the selection rules of Warburton and Weneser [1]. We propose therefore to determine the lifetime of the first $7/2^-$ state of ^{35}Ar using the in-beam fast timing technique with the Bucharest mixed array of HPGe and $LaBr_3$:Ce detectors.

II. Experiment

The excited states in ^{35}Ar will be populated using the ^{28}Si(^{12}C,αn)^{35}Ar fusion-evaporation reaction. The cross sections for different exit channels were calculated using the CASCADE code, indicating about 20 mb for the (αn) evaporation channel at 40 MeV beam energy, which represents ~2% from the total fusion cross-section. The target will be 2 mg/cm^2 ^{28}Si on 10 mg/cm^2 gold backing, dimensioned to integrate over the optimum energy range for producing the ^{35}Ar nucleus, from 34 to 40 MeV.

The gamma rays will be detected with the Bucharest array for in-beam fast timing, consisting of 8 HPGe detectors and 11 $LaBr_3$:Ce detectors. The high-resolution Ge detectors will be used to gate on the 1751 keV transition (Fig. 1), and thus select in the scintillator detectors the decay γ-ray of 1446 keV from the $7/2^-$ state, and, eventually the 2187 keV and other gamma-rays feeding this level. The time spectrum of the decay of the $7/2^-$ level can be determined by simply gating on the 1446 and 2187 keV transitions as STOP and START in the $LaBr_3$:Ce detectors, or by gating only on the 1446 keV as STOP and whatever feeding of the $7/2^-$ level as START.

As shown in our recent work [6], by using a special technique for the processing of the timing information from the $LaBr_3$ detectors, and thus fully use the detection efficiency by adding up the contribution from all the pairs of such detectors, we can measure in this way half-lives down to 30–40 ps by the centroid shift method, there is thus a very good chance to measure the lifetime of the $7/2^-$ level if the lifetime of the level is of this order of magnitude or longer.

III. Beamtime request.

Considering the following conditions:

- beam intensity of 5 particle-nA;

- 2 mg/cm^2 ^{28}Si on 10 mg/cm^2 gold backing;

- an average ^{35}Ar production cross section of 15 mb inside the ^{28}Si layer;

- that 60% of the total gamma flux is passing through the $7/2^-$ state, based on the intensities from ref [7];

- efficiencies of about 0.006, and 0.005 for gamma-ray energies of about 1750 keV of the HPGe array, and the $LaBr_3$:Ce array, respectively,

we get a rate of about 6 triple Ge-LaBr-LaBr coincidences/hour (total full-energy peak coincidences), therefore for a 10 days of beamtime we will get around 1500 events in the triple-gated time spectrum for the $7/2^- \rightarrow 5/2^+$ transition. This level of statistics should be enough to obtain the desired lifetime with 10% precision. The statistics will be higher if the START gate is made wider, not restricted to full energy peak, with the reserve that this technique is appropriate for lifetimes above 100 ps.

We ask therefore 10 days of beam time to measure with 10% accuracy the lifetime of the yrast $7/2^-$state in ^{35}Ar.

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