Direct observation of α particle decay of the ^{16}O levels close to ^{15}N+p threshold: Do we understand the nature of the isospin mixture in ^{16}O levels?

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The nucleus ^{16}O plays a key role for the evolution of baryonic matter in our universe. Its pronounced α-cluster structure is responsible for the closing of the CN cycle through the ^{15}N(p,α)^{12}C reaction, controlling the stellar hydrogen burning in massive main sequence stars and determines the strength of the ^{12}C(α,γ)^{16}O reaction that defines the ^{12}C/^{16}O ratio in stellar helium burning, which in turn influences the burning sequence during late stellar evolution, the ignition conditions of thermonuclear supernovae, and, last but not least, the formation of organic life on habitable planets such as Earth [1].

The reaction ^{15}N(p,γ_0)^{16}O is of particular importance for modeling the CNO bi-cycle as it competes with the reaction ^{15}N(p,α)^{12}C. A very important contribution to the (p, γ_0) process is a resonant contribution from the two 1^- levels in ^{16}O at E_x = 12.45 and 13.09 MeV. These two levels are mixed in the isospin. The T=1 admixture to the lower level at 12.45 is mainly responsible for its γ width. There are two more pairs of the same spin (J=2,3) levels which are also isospin mixed (see Fig.1). Because of the importance of the ^{16}O structure for nuclear physics and astrophysics the levels in question were thoroughly investigated in different reactions [1]. The isospin mixing was evaluated using γ widths (inhibited for T=0 transitions) or α particle decay to the ground state in ^{12}C (forbidden for T=1 states) and estimated as ~20% [1]. Direct α particle decay to the first excited state in ^{12}C was observed only for the 13.3 MeV state over 50 years ago [2]. As a development of the TTIK method for low energy reactions in Astana [3], we observed various modes of decay of ^{16}O levels in the excitation region of 12.3-13.5 MeV [3]. These levels were populated in resonance ^{15}N+p reactions, using beam of ^{15}N and extended hydrogen gas target. Fig. 2 presents the 180^0 cm excitation spectra for different exit channels of the reaction. The data on the decay α widths for the T=0 and T=1 levels in

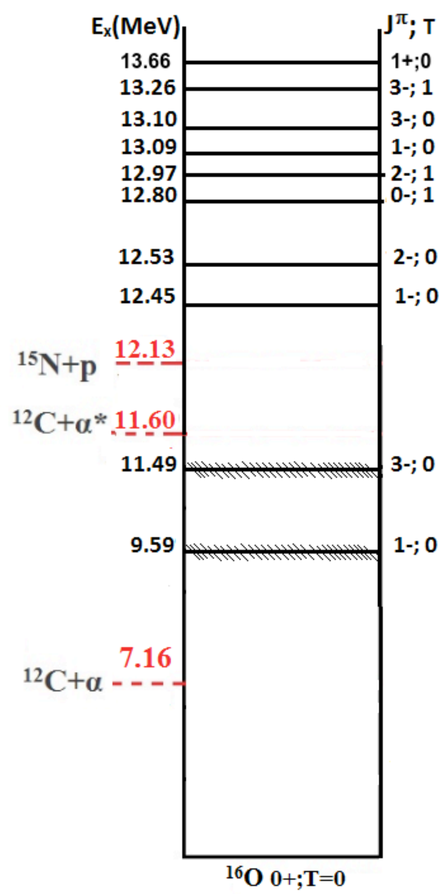

FIG. 1. Scheme of relevant levels in ^{16}O.

question are given in Table I. These data summarize our preliminary analysis and that of Ref. [1]. The single particle, limit for the α widths, $\Gamma_{\alpha 1sp}$, was obtained in Woods-Saxon potential with parameters $r_0=1.23\ fm$ ($R= r_0 x 12^{1/3}$); $r_{0C}= 1.31fm$; $a=0.65fm$; The depth of real part well was changed to fit the binding energy.

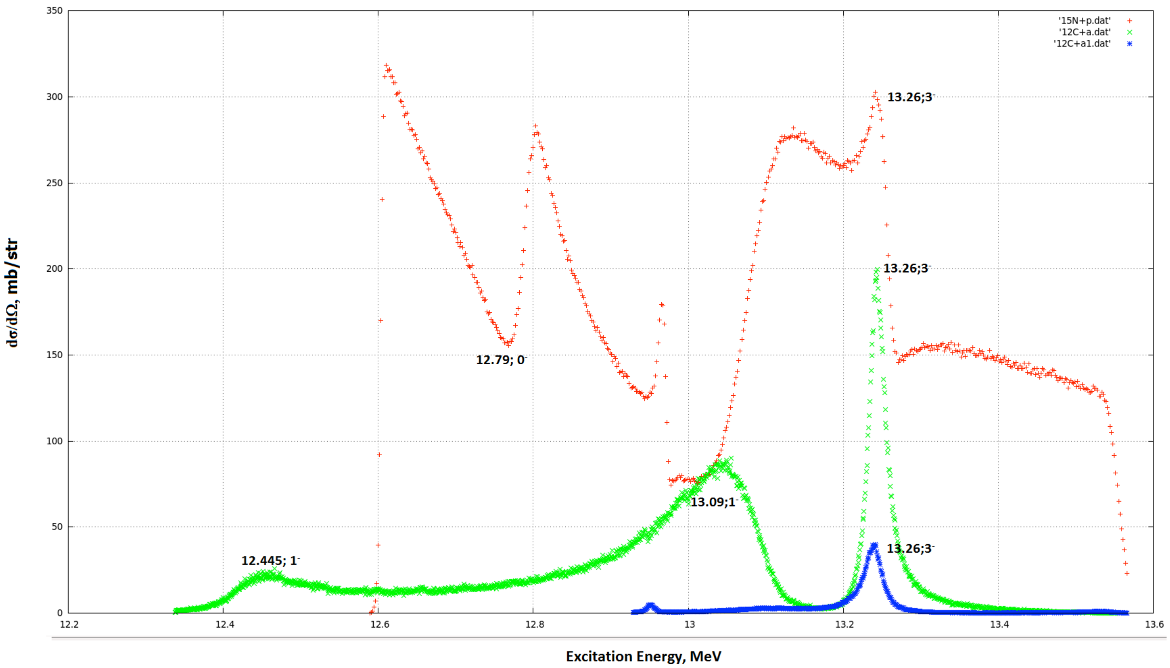

FIG. 2. Excitations functions for different channels of ^{15}N+p reaction red line : p+^{15}N ; green: α+ $^{12}C_{gr}$; blue α +$^{12}C^*$.

As it seen from Table I the reduce width for forbidden α decay of the T=1, 1^- state is even larger than that of the T=0 state. It is also seen that the isospin mixture for states with spin 2 and 3 is well over ~20% which was claimed before. It is difficult to explain the found large reduced width of the T forbidden decay. Indeed, one may consider the levels in question as manifestation of a simple shell model p1/2-d5/2 configuration. The relatively small reduced widths for α decay to the ^{12}C ground state (for the 1^- ,3^-, T=0 states) can be understood as a result of the presence of well known broad α cluster states at 9.6 and 11.6 MeV, and the 20% mixture of T=1 and T=0 states (as a result of the similar structure and close excitation energies. However, 1^-, 2^-, 3^- states with large reduced widths for the decay to the first excited state in ^{12}C are unknown in ^{16}O. One can consider the present results as a motivation for the search. The presence of 1+ level with the corresponding reduced width of 18% (Table I) can be considered as a sign of the perspective for the search.

Table I. Decay of levels in ^{16}O to the first excited state in ^{12}C.

J^{π} ;T	E^*_{16O} (MeV)	$\Gamma_{\alpha1\ exp}$ (keV)	$\Gamma_{\alpha1\ sp}$ (keV)	$\gamma_{\alpha1}$ (%)
1^-; 0	12.44	0.030	18.5	1.6
2^-; 0	12.53	0.092	29.0	3.2
0^-; 1	12.80			
2^-; 1	12.97	0.300	160.0	1.9
1^-; 1	13.09	0.580	255.0	2.3
3^-; 0	13.13	20.900	330.0	6.3
3^-; 1	13.26	10.300	420.0	2.4
1^+; 0	13.66	59.000	325.0	18.0

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