Spin assignment of the 7.57 MeV state in the unbound nucleus $^{16}$Ne*

J. Marganiec$^{1,2,3}$, F. Wamers$^{1,2,3}$, T. Aumann$^{1,3}$, L.V. Chulkov$^{1,4}$, B. Jonson$^5$, T. Nilsson$^5$, H. Simon$^3$, and the R$^3$B collaboration

$^1$TU Darmstadt, Germany; $^2$EMMI, GSI Darmstadt, Germany; $^3$GSI Darmstadt, Germany; $^4$NRC Kurchatov Institute, Moscow, Russia; $^5$Chalmers Tekniska Högskola, Göteborg, Sweden

Two-proton decay of the unbound nucleus $^{16}$Ne, produced in one-neutron knock-out from a 500 MeV/u $^{17}$Ne beam, has been studied at GSI. The beam was directed towards carbon (370 mg/cm$^2$) or polyethylene (213 mg/cm$^2$) targets. The reaction products were identified by means of position, energy loss, and Time-of-Flight measurements, using the R$^3$B-LAND setup. Coincidences between $^{14}$O and two protons provided the momentum four vectors, which were transformed into the projectile rest-mass frame, where two different sets of non-relativistic Jacobi coordinates ($T$- and $Y$-system) were used in the analysis [1].

The internal kinetic energy (the relative energy) $E_{fp}$ in the three-body system $^{14}$O+p+p (see Fig. 1), and the fractional energies in the fragment-proton ($\epsilon_{fp}$) and the proton-proton ($\epsilon_{pp}$) subsystems were reconstructed. The correlation functions normalized to unity, for the fractional-energy distributions $W(\epsilon_{fp})$ and $W(\epsilon_{pp})$ and the angular distributions $W(\cos \theta_{fp})$ and $W(\cos \theta_{pp})$, were constructed and analyzed. The required efficiency and acceptance corrections have been estimated using the Monte Carlo simulations (see Ref. [2] for details).

![Figure 1: $^{14}$O+p+p relative energy spectrum.](image)

In this case, the initial $2^+$ state emits a proton from the $d_{5/2}$ shell feeding the $^{14}$O+p in a $d_{5/2}$ shell configuration in $^{15}$F. This $2^+$ state is unstable and emits two protons. Its width is surprisingly narrow. This suggests that its structure can be more complicated than a $^{14}$O+p+p state. This state is also situated above the four proton emission threshold, which indicates a possible many-body structure. And the $^{12}$C+4p configuration with four protons in the $(sd)$ shell, could be the cause of such a narrow width of this state [3]. A special case of such a structure could consist of an excited core together with two protons, $^{14}$O($2^+)+2p$ [4]. The theoretical predictions for the position of the second $2^+$ state in $^{16}$Ne are $E^* = 4.2$ MeV [5] or $E^* = 3.6$ MeV [6], both close to the known position of the second $2^+$ state in the mirror nucleus $^{16}$C [7]. From this mirror nucleus (the third $2^+$ state of $^{16}$C is at $E^* = 6.11$ MeV [8]), the investigated state is assumed to be the third $2^+$ state in $^{16}$Ne.

![Figure 2: Three-body correlations between the decay products of the $E_{rel} = 7.57$ MeV.](image)

Correlations between the decay products from the excited state at the resonance energy $7.57(6)$ MeV are shown in Fig. 2. The two peaks visible in $W(\epsilon_{fp})$ and $W(\cos \theta_{pp})$ have been associated with transition to the state at $E_{rel} = 2.8$ MeV in $^{15}$F. The results of the calculations for the assumed initial spin value $I^\pi = 2^+$ and channel spin $j = 5/2$ are shown in Fig. 2 as dashed lines. The physical background contributions are shown in Fig. 2 as dotted lines. The sum of these two contributions (solid lines) perfectly reproduces the experimental data (see Ref. [2] for details).

* Work supported by NAVI, GSI-TU Darmstadt cooperation, HIC for FAIR, EMMI and BMBF. (B.J.) is a Helmholtz International Fellow.

References