A measurement of $^7\text{Li}+\alpha$ was performed at CRIB [1, 2], as previously reported in ref. [3]. An excitation function of $^7\text{Li}+\alpha$ elastic scattering was obtained as shown in Fig. 1, and a structure with several peaks were clearly observed. We performed an analysis using an R-matrix calculation code (SAMMY-M6) to deduce resonance parameters. Initially we calculated the excitation function assuming 6 known alpha resonances shown in Table. 1. The energy, spin and parity ($J^\pi$) of each resonance were fixed to the known values [4], and the $\alpha$ width ($\Gamma_\alpha$) was deviated. For the excitation energies, the values by $^7\text{Li}+$ elastic scattering fitted by R-matrix analysis parameters in ref. [7], and $\gamma_\alpha^2$ with refs. [8] and [9], in which $\Gamma_\alpha$ was not presented explicitly. As for $\gamma_\alpha^2$, the agreement is not very good between the present work ($R=3.2$ fm), and previous results ($R=4.9$ fm [8] and $R=6.0$ fm [9]), partly because they use different $R$ to explain their data. Our measurement is considered to be quite insensitive to the total width, since the spectral widths of all the resonances are mostly determined by the experimental resolution and $\Gamma_\alpha$. Below we discuss the highest two resonances in detail.

**Resonance at 12.63 MeV**

We started the calculation with a known resonance energy of 12.55 MeV, but the measured peak appeared at a higher energy of 12.63 MeV. The state at 12.55 MeV is considered to have $J^\pi=1/2^+$ and an isospin T=3/2, being analogue of the $^{11}\text{Be}$ ground state. It was observed via $^9\text{Be}(^3\text{He}, p)$ [10], $^{11}\text{Be}(^3\text{He}, ^3\text{He})$ [11], and other reactions [4]. The assignment $J^\pi=1/2^+$ (3/2+) was proposed by a measurement of $^{10}\text{Be}(p, \gamma)^{11}\text{Be}$ reaction [12]. They measured the angular distribution of $\gamma$ rays, and concluded the distribution is consistent only with $J^\pi=1/2^+$ or 3/2+, and the former is more likely. However, a T=3/2 state is un-
expected to be observed as a strong resonance via $^7\text{Li}+\alpha$ scattering, as in the present work and in ref. [9]. The dual character (T=3/2 and 1/2) of this state, possibly suggesting a large isospin mixing, is a long standing problem and remained unsolved for a long time [12–15]. A complete understanding, including theoretical prediction for the width, is still not obtained yet. Recently Fortune [16] made a re-analysis of the data in ref. [12] and pointed out the 1/2$^+$ resonance could be much broader than considered before. To form a 1/2$^+$ resonance, the $\alpha$ particle must be coupled by $l=1$ (p-wave). Our R-matrix calculation indicates that the sharp resonance could not be formed with a p-wave, but an f-wave resonance fits the experimental result perfectly.

Considering above, the present result suggests a different point of view: The resonance observed in this work may not be the known one at 12.55 MeV, but another one having a different $J^\pi$, but located at 12.63 MeV. They might have been considered as the same resonance in some previous measurements such as in ref. [9]. The $J^\pi$ of the state can be 3/2$^+$, which was listed as a possible assignment in ref. [12]. Another suggestion made by Soić and co-workers [17] was this state can have a $J^\pi=9/2^+$ from schematics of the rotational band of an alpha cluster state. Therefore, we performed the R-matrix analysis for both cases, $J^\pi=3/2^+$, and 9/2$^+$.

### Resonance at 13.03 MeV

This resonance was observed initially via the $^{10}\text{Be}(n, \alpha)^7\text{Li}$ reaction [18], and then via $^7\text{Li}+\alpha$ inelastic scattering at 13.03 MeV [9]. Later two states at 13.12 MeV ($J^\pi=9/2^-$) and 13.17 MeV (5/2$^+$, 7/2$^+$) were introduced in the analysis of ref. [7], and the 13.03 MeV resonance was regarded as the former one [4]. Zwieglinski and co-workers [19] observed a state by the $^{10}\text{Be}(^3\text{He}, p)^{11}\text{B}$ reaction at 13.137 MeV, which is the value in the compilation [4] for the $J^\pi=9/2^-$ state. However, obviously there is a confusion on the energy and $J^\pi$ of this level, because they also mention a state with $J^\pi=9/2^-$ was not expected to be strongly excited by that reaction. After all the assignment of $J^\pi=9/2^-$ is not so evident, since no measurement is known that observed this resonance separately from other ones and determined its $J^\pi$ as 9/2$^-$. In the present analysis, we considered three possible $J^\pi$ for the levels previously observed at 13.03, 13.137 and 13.16 MeV, 9/2$^-$, 5/2$^+$, and 7/2$^+$, and only the calculation with $J^\pi=9/2^-$ resulted in a reasonable fit. A sudden fall in the spectrum at 4.4 MeV corresponds to the the highest limit of the energy acceptance of our measurement. The two highest energy points shown in the figure were excluded in the R-matrix fitting. The rest points, covering the peak cross section, were within the energy acceptance.

### References