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Abstract

A scenario is given for the formation of Ξ^- states and the transitions to states with double-Λ in anticipation of observations, especially in the KEK-E224 experiment. First, the production cross sections of Ξ^- hypernuclear states by (K^-, K^+) reactions are calculated within the framework of the distorted-wave impulse approximation. Next, the transition rates from Ξ^-hypernuclear states to possible double-Λ states are obtained, which are closely related to single- and double-Λ emissions after the $\Xi^- p \rightarrow \Lambda\Lambda$ conversion in nuclei.

§1 introduction

Recently, a new experiment concerning the (K^-, K^+) reaction was carried out using a scintillating fiber target; the data analysis is now in progress (KEK-E224) [1]. We remark here that the interactions and dynamics between the produced Ξ^- particle and the target nucleus (^{12}C) can be studied from this experiment, noting the possibility of observing Ξ^- hypernuclear states as well as their transitions to double-Λ states. The possibility of forming Ξ hypernuclei via the (K^-, K^+) reaction has been investigated [2], in which the forward cross sections for the formation of discrete Ξ hypernuclear states were simply estimated to be at the level of only 1 μb/sr. It is expected, however, that in the E224 experiment the production counts in the bound-Ξ^- region have been stored in sufficient number to observe possible peak structures. It is therefore important to perform more realistic calculations of the production cross sections of Ξ hypernuclear bound states under the kinematics of this experiment.

Once a Ξ^- hypernuclear state is formed, it should decay into some two-Λ states through the $\Xi^- p \to \Lambda\Lambda$ transition in the nucleus. There are three types of final $\Lambda\Lambda$ states: two-Λ bound, one-Λ bound and one-Λ continuum, two-Λ continuum. The analysis of the E224 data makes it possible to distinguish these three final states by observing Λ particles produced at the (K^-, K^+) reaction points. The observation of Λ particles from a Ξ hypernuclear state may be useful for obtaining information concerning the Ξ^- nucleus potential, even if no peak structure can be seen in the K^+ spectrum.

In this paper we discuss the calculation of the (K^-, K^+) cross sections for producing Ξ hypernuclear states within the framework of the distorted-wave impulse approximation (DWIA), and estimate the transition rates from Ξ hypernuclear states to possible $\Lambda\Lambda$-sticking nucleon-hole states.

§2. Production of Ξ-hypernuclei by the (K^-, K^+) reaction

It is well known that the conventional DWIA for in-flight (K^-, π^-) and (π^+, K^+) reactions can reproduce the absolute cross sections of typical peaks as well as the overall structure of both Λ-hypernuclear excitation functions [2-5]. This is mainly due to the fact that the relevant meson momenta are sufficiently large (typically $p > 700$ MeV/c) to be suitable for an impulse approximation. Based on this fact, we applied DWIA to the in-flight (K^-, K^+) reaction in order to predict the Ξ-hypernuclear production cross sections for the $^AZ(K^-, K^+)^A_\Xi Z'$ reaction, which are concerned with the E224 experiment at KEK

(^{12}C target). The DWIA differential cross section and the strength function $S(E_Y,\theta)$ are expressed in the Kapur-Peierls method [4] by

$$\frac{d^2\sigma}{d\Omega dE_Y} = \xi\Big[\frac{d\sigma(\theta)}{d\Omega}\Big]_{\rm elem} S(E_Y,\theta) \;\text{ and }\; S(E_Y,\theta) = -\frac{1}{\pi}\sum_f \mathrm{Im}\Big[\frac{N_f(E_Y,\theta)}{E_Y-\epsilon_f(E_Y)}\Big]. \quad (2.1)$$

Here, E_Y is the hyperon energy and suffix f represents a hypernuclear final state, which may be expressed by the eigenfunction $\Psi_f(E_Y) \equiv |\,{}^A_\Xi Z';\ E_Y,\ J_f T_f \tau_f \alpha\rangle$ and the eigenenergy $\epsilon_f(E_Y)$.

With Ψ_f and the nuclear target wavefunction Φ_0, the effective nucleon number $N_f(E_Y;\theta)$ in Eq.(2.1) is defined as

$$N_f(E_Y,\theta) = \langle\Phi_0|\hat{O}^\dagger(\theta)|\Psi_f(E_Y)\rangle\ \langle\tilde{\Psi}_f(E_Y)|\hat{O}(\theta)|\Phi_0\rangle. \quad (2.2)$$

Here, the transition operator $\hat{O}(\theta)$ is given by the following relevant meson waves:

$$\hat{O}^{(K^-,K^+)} = \int d^3\vec{r}\ \chi^*_{K^+}(\vec{k}_f,a\vec{r})\ \chi_{K^-}(\vec{k}_i,\vec{r})\sum_{\nu=1}^{A} V_-(\nu)\delta(\vec{r}-\frac{M_c}{M_A}\vec{r}_\nu)\ , \quad (2.3)$$

where $a \equiv M_A/M_H$ and $M_c = M_H - m_Y$. The recoil effect is taken into account in view of the large momentum transfer involved. By definition, the strength function $S(E_Y;\theta)$ covers not only the hypernuclear bound states, but also the continuum final states, which consists of the hyperon resonances and the quasi-free processes (QF). Specifically for the bound states ($E_Y < 0$) which are mainly concerned here, Eq.(2.1) tends to the ordinary expression with the effective proton number: $\frac{d\sigma(\theta)}{d\Omega_L} = \xi\left[\frac{d\sigma(\theta)}{d\Omega_L}\right]_{K^-p\to\Xi^-K^+} Z_{\rm eff}(i\to f;\theta)$.

Corresponding to the E224 experiment, we confine ourselves to the ^{12}C case. As for the nucleon radial wave functions, we first use the harmonic oscillator (HO) functions with the standard size parameter (b_N=1.65 fm), and then the appropriate Woods-Saxon (WS) potential. Here, the WS potentials for N, Λ and Ξ (used in this paper) are represented as

$$U_B(r) = V_0^B f(r) + V_{\rm LS}^B(\frac{\hbar}{m_\pi c})^2\ (\mathbf{l}\cdot\mathbf{s})\frac{df(r)}{rdr} + U_{\rm COUL}(r), \quad (2.4)$$

with $f(r) = 1/[1+\exp(r-R)/a]$ and $R = r_0(A-1)^{1/3}$ fm $(B = N,\Lambda,\Xi)$. For the Ξ potential, we adopt the values $V_0^\Xi = -24$ MeV, $V_{\rm LS}^\Xi = 1.0$ MeV, $r_0 = 1.1$ fm and $a = 0.65$ fm (taken mostly from Ref.[2]). We also try to change the depth V_0^Ξ considering the uncertainties of our present knowledge.

We simply start with the meson plane waves (PW) to obtain the reference values of the production cross sections. In order to calculate the meson distorted waves (DW), we adopt the eikonal approximation by using the 2-parameter-Fermi type nuclear density $\rho_N(r)$ and the following meson-nucleon total cross sections based on the experiment [6]:

$$\sigma_{K^-p} = 32.5 \text{ mb}, \ \sigma_{K^-n} = 25.5 \text{ mb}, \ \sigma_{K^+p} = 19.6 \text{ mb} \ \text{ and } \ \sigma_{K^+n} = 20.1 \text{ mb},$$

which correspond to an incident momentum of p_{K^-}=1.60 GeV/c and a scattering angle of $\theta_{K^+} = 0°$. It is notable that an approximation based on the empirical meson-nucleon cross sections works satisfactorily for simulating the Klein-Gordon solutions [5].

Figure 1 shows the excitation function calculated for the ^{12}C$(K^-, K^+)^{12}_{\Xi^-}$Be reaction with $p_{K^-} = 1.6$ GeV/c and $\theta_{K^+} = 0°$. Table I lists the detailed effective proton numbers for the four cases: combinations of the proton wave function (HO vs. WS) with the plane and distorted meson waves (PW vs. DW). Note that the Woods-Saxon potential with $V_0^{\Xi} = -24$ MeV accommodates three Ξ^- bound states in $^{12}_{\Xi^-}$Be of $0\tilde{s}_{1/2}$, $0\tilde{p}_{3/2}$ and $0\tilde{p}_{1/2}$.

===== Fig. 1 =====

Since the hyperon recoil momentum is considerably large (about 500 MeV/c), the kinematical condition should cause a preferential excitation of the J-stretched states, such as $|\ [0p^{-1}0p^{\Xi}]J = 2^+\rangle$. On the other hand, however, the radial wave function of the $0p^{\Xi}$ state extends more outside than in the Λ case, due to the shallower potential for Ξ. Thus, in contrast to the (π^+, K^+) spectrum, the different radial behavior from that of the $0p_{3/2}$ proton reduces the 2^+ strengths to be comparable to the $[0p^{-1}0s^{\Xi}]J = 1^-$ strength. This explains the apparently increased 1^- peak of the ground state in relative comparison with the 2^+ peak at $E_{\Xi} = -2$ MeV. In Fig.1 we use the smearing width of each peak, which simulates the $\Xi^- p \to \Lambda\Lambda$ conversion width Γ_{Ξ} obtained in the following section. It is remarkable that the conversion widths are rather small compared with the Σ case.

===== Table I =====

When one compares the DW and PW results, it can be seen that the meson wave distortion gives rise to a 1/2.8 reduction for the effective proton number estimates. Note, however, that the amount of such a reduction depends considerably on the size of the nucleus and, in fact, the reduction factors are 1/5 - 1/6 for the ^{28}Si and ^{40}Ca cases [7]. It is also notable that the use of the proton WS wave function causes a sizable increase in the calculated effective numbers.

Based on the eikonal approximation, the total effective proton number is calculated to be $Z_{\text{eff}}^{\text{Total}} = 2.99$ (DW), which should be compared with $Z = 6$. In this respect, it is interesting to estimate the strength summed over the bound states; we obtained $\sum_{bound} Z_{eff}^{DW} = (2.8 - 3.4) \times 10^{-2}$. This means that the probability of producing Ξ^- directly in the bound states is theoretically about 1% of the total Ξ^- produced in the in-flight (K^-, K^+) reaction on the ^{12}C target.

In the last column of Table I we add the calculated cross sections estimated with the experimental elementary cross section [2], $\xi(d\sigma/d\Omega)_{K^-p\to\Xi^-K^+} = 22-35$ μb/sr. The cross section for the pronounced peak of $[0p^{-1}0p^{\Xi}]$ obtained at 9 MeV excitation $(0_1^+ + 2_1^+ + 2_2^+)$ is predicted to have about 0.5 μb/sr at the forward angle. The value is about 1/40 of the corresponding strength producing Λ in the (π^+, K^+) reaction, which is due to the larger momentum mismatch and the different radial behavior of the Ξ^- wave function. If we use a deeper potential with $V_0^{\Xi} = -30$ MeV, the cross section leading to each bound state increases by about 50%: e.g. $d\sigma/d\Omega(1_{g.s.}^-)$= 0.44 μb/sr (cf. Table I). On the other hand, if we use $V_0^{\Xi} = -12$ MeV, we obtain only one bound $0s_{1/2}^{\Xi}$ state with $d\sigma/d\Omega(1_{g.s.}^-)$=0.13 μb/sr, one half of the ground-state cross section listed in Table I. Thus, the theoretical cross sections depend appreciably on the potential strength V_0^{Ξ}.

The calculation was similarly performed for the ^{16}O$(K^-, K^+)^{16}_{\Xi^-}$C reaction, and four pronounced peaks were obtained which are well separately from each other. The main feature discussed concerning the effective proton numbers for ^{12}C$(K^-, K^+)^{12}_{\Xi^-}$Be is also applicable to the latter case. We add, however, that the distortion effect increases so as to result in a smaller ratio $Z_{eff}^{DW}/Z_{eff}^{PW} = 1/3.5$ for $^{16}_{\Xi^-}$C (1/2.8 for $^{12}_{\Xi^-}$Be), and that the difference between the WS and HO proton wave functions becomes larger. The summed strength over the bound states was also evaluated to be $\sum_{bound} Z_{eff}^{DW} = (2.8-4.0) \times 10^{-2}$, while the total effective proton number is $Z_{eff}^{Total} = 3.52$ (DW). Thus, the probability of populating the Ξ-hypernuclear bound states is again predicted to be about 1% of the Ξ^- produced in the in-flight (K^-, K^+) reaction.

§3. The $\Xi^- p \to \Lambda\Lambda$ conversion in a nucleus

Zhu et al. [8] considered the production of double-Λ hypernuclei in Ξ^- atomic capture. Here, we are concerned with the Ξ^- particle in a nuclear bound state $(n_{\Xi} l_{\Xi})$ which reacts with one of the nucleons to produce two Λ particles. This process is induced by the ΞN-$\Lambda\Lambda$ strong interaction $v_{\Xi N,\Lambda\Lambda}$. We now discuss the calculation of the partial conversion widths (Γ_{bb}, Γ_{bc} and Γ_{cc}, where bb, bc and cc mean that two Λ's in bound states, one Λ in a bound state and the other Λ in a continuum state, and two Λ's in continuum states, respectively

). Their sum leads to the total conversion width: $\Gamma_\Xi = \Gamma_{bb} + \Gamma_{bc} + \Gamma_{cc}$. The corresponding probabilities are thus given by $P_{bb} = \Gamma_{bb}/\Gamma_\Xi$, $P_{bc} = \Gamma_{bc}/\Gamma_\Xi$ and $P_{cc} = \Gamma_{cc}/\Gamma_\Xi$, respectively. In the second-order perturbation we have

$$\Gamma_{bb}(n_\Xi l_\Xi) = \sum_{n_N l_N} \sum_{n_{\Lambda_1} l_{\Lambda_1}} \sum_{n_{\Lambda_2} l_{\Lambda_2}} \sum_{LST} \frac{[L][S][T]}{[l_\Xi][s_\Xi][t_\Xi]} \times \langle n_\Xi l_\Xi\, n_N l_N \mid v_{\Xi N,\Lambda\Lambda} \mid n_{\Lambda_1} l_{\Lambda_1}\, n_{\Lambda_2} l_{\Lambda_2} \rangle^2_{LST} \times \frac{\Gamma^{(h)}_{n_N l_N}}{(\epsilon_\Xi + \epsilon_{n_N l_N} - \epsilon_{n_{\Lambda_1} l_{\Lambda_1}} - \epsilon_{n_{\Lambda_2} l_{\Lambda_2}} + \Delta)^2 + (\Gamma^{(h)}_{n_N l_N})^2/4} \tag{3.1}$$

and

$$\Gamma_{bc}(n_\Xi l_\Xi) = \sum_{n_N l_N} \sum_{n_{\Lambda_1} l_{\Lambda_1}} \sum_{l_{\Lambda_2}} \int_0^\infty dk_{\Lambda_2} \sum_{LST} \frac{[L][S][T]}{[l_\Xi][s_\Xi][t_\Xi]} \times \langle n_\Xi l_\Xi\, n_N l_N \mid v_{\Xi N,\Lambda\Lambda} \mid n_{\Lambda_1} l_{\Lambda_1}\, k_{\Lambda_2} l_{\Lambda_2} \rangle^2_{LST} \times \frac{\Gamma^{(h)}_{n_N l_N}}{(\epsilon_\Xi + \epsilon_{n_N l_N} - \epsilon_{n_{\Lambda_1} l_{\Lambda_1}} - \hbar^2 k^2_{\Lambda_2}/2m_\Lambda + \Delta)^2 + (\Gamma^{(h)}_{n_N l_N})^2/4} . \tag{3.2}$$

The expression for Γ_{cc} can be written similarly. Here, $| n_\Xi l_\Xi \rangle$, $| n_N l_N \rangle$, $| n_\Lambda l_\Lambda \rangle$ and $| k_\Lambda l_\Lambda \rangle$ denote a Ξ^- hypernuclear state, a proton-hole state, a Λ-bound state and a Λ-continuum state, respectively, and ϵ_Ξ, $\epsilon_{n_N l_N}$ and $\epsilon_{n_\Lambda l_\Lambda}$ are the corresponding single-particle energies. The two-Λ states in these expressions are antisymmetrized and normalized. The $\Xi^- p$-$\Lambda\Lambda$ mass difference is denoted by Δ. The Breit-Wigner shape is taken for the distribution of a hole-excited state, where $\Gamma^{(h)}_{n_N l_N}$ denotes the width of a hole state. If $\Gamma^{(h)}_{n_N l_N}=0$, this part reduces to the δ function. It should be noted that Γ_{bb} gives the strength of the energy-conserving transition to two-Λ bound and proton hole-excited states. For $v_{\Xi N,\Lambda\Lambda}$, we adopt the Gaussian-represented version [9] of the Nijmegen model-D interaction [10]. For simplicity, we take only the $T = 0$ $^1S_0$ component, which dominates the ΞN-$\Lambda\Lambda$ coupling part. The calculated values of P_{bb}, P_{bc} and P_{cc} are quite insensitive to the choice of $v_{\Xi N,\Lambda\Lambda}$, since they are given by the ratios of the above conversion widths.

In the present calculation the single-particle wave functions of N, Λ and Ξ were obtained by the corresponding WS potentials. These wave functions are represented in the Gaussian base: Bound-state ones were solved variationally in this base. Continuum ones, normalized to $\sqrt{2/\pi}\sin(kr - \pi l/2 + \delta_l)$ asymptotically, were expanded in terms of Gaussian functions. Then, the above matrix elements of $v_{\Xi N,\Lambda\Lambda}$ were obtained from those in the Gaussian base. The WS parameters for N and Λ were taken as $V_0^N = -50.0$ MeV ($r_0 = 1.25$, a=0.53) and $V_0^\Lambda = -32.0$ MeV ($r_0 = 1.1$, a=0.60), respectively, as indicated experimentally. For the Ξ potential we also investigated the two cases of $V_0^\Xi = -24$ and -12 MeV. V_{LS}^Ξ was not taken into account. The width of $0s$ proton-hole state was taken to be 10 MeV, while that of $0p$ state was neglected and the Breit-Wigner distribution was replaced by the δ function for simplicity.

===== Table II ===== ===== Table III =====

In Table II, the calculated values of P_{bb}, P_{bc} and P_{cc} are given for each Ξ^- bound states in ${}^{12}_{\Xi^-}$Be produced by the (K^-, K^+) reactions on ^{12}C targets. The values of E_Ξ are the calculated binding energies of Ξ^-, where we have well-separated the $0s_\Xi$ and $0p_\Xi$ states ($V_0^\Xi = -24$) or only a $0s_\Xi$ state ($V_0^\Xi = -12$). The calculated probabilities of single- and double-Λ emissions (P_{bc} vs. P_{cc}) turn out to be different between the $0s_\Xi$ and $0p_\Xi$ states, and the ratio is considerably dependent on V_0^Ξ. This means that these quantities are good signals from Ξ^- hypernuclear bound states. Table III shows the partial widths $\Gamma_{ij}(n_\Xi l_\Xi \to l_N^{-1} l_\Lambda^i l_\Lambda^j)$ for two-Λ one nucleon-hole final states specified by $l_N^{-1} l_\Lambda^i l_\Lambda^j$ $(i, j = b, c)$ in the case of ${}^{12}_{\Xi^-}$Be ($V_0^\Xi = -24$), where l_N^{-1} denotes a nucleon hole state and l_Λ^i a Λ-bound ($i = b$) or Λ-continuum ($i = c$) state. Since the hole width of the $0p$ state is taken to be zero, there is no contribution from the $p_N^{-1} l_\Lambda^b l_\Lambda^b$ state. Highly-excited bound states, such as $s_N^{-1} p_\Lambda^b p_\Lambda^b$, were not taken into account. Then, the $0s_\Xi$ ($0p_\Xi$) state leads to only the $s_N^{-1} s_\Lambda^b s_\Lambda^b$ ($s_N^{-1} s_\Lambda^b p_\Lambda^b$) double-$\Lambda$ state.

Our obtained values of Γ_Ξ are found to be considerably small. One reason is that the statistical weight of the $T = 0$ ${}^1S_0$ ΞN-$\Lambda\Lambda$ interaction is small, as discussed regarding the G-matrix calculation [11]. In addition, it should be said that the ΞN-$\Lambda\Lambda$ interaction, deduced from the Nijmegen model D, is fairly weaker than that based on model F. Of course, there still remains a likelihood of having the stronger ΞN-$\Lambda\Lambda$ coupling and the larger value of Γ_Ξ, which may make it difficult to observe the peak structures of the Ξ^- hypernuclear bound states in the K^+ spectrum. Even so, it will result in some useful information concerning the Ξ-nucleus potential to observe the ratio of single- and double-Λ emissions from possible Ξ^- bound states.

§4. Outlook

In order to intensively investigate $S = -2$ systems, a new experiment (KEK-E224) concerning the (K^-, K^+) reaction was performed with a scintillating fiber target. In anticipation of observations, especially in the KEK-E224 experiment, we calculated the production cross sections of the Ξ^- hypernuclear states, as well as the transition rates from Ξ^- hypernuclear to possible double-Λ states which are closely related to single- and double-Λ emission probabilities. In our calculations the most uncertain is the potential between Ξ and the nucleus, which remarkably affects our results. In other words, we point out a possibility for obtaining the first reliable information concerning the Ξ states in nuclei by comparing our results with the E224 data. The Ξ^- hypernuclear state leads to the two-Λ bound and proton-hole excited state, which must break up into some fragments including double-Λ hypernuclei. An interesting possibility is to identify such a fragment by observing the characteristic π^- decay [12].

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Table I

Effective proton number $Z_{\rm eff}$ calculated for the ^{12}C$(K^-, K^+)^{12}_{\Xi^-}$Be reaction with $p_{K^-} = 1.6$ GeV/c and $\theta^{\rm L}_{K^+} = 0°$. The harmonic oscillator (HO; $b_N = 1.65$ fm) and Woods-Saxon (WS) potentials were employed to generate the bound-state single particle wave functions for the $[j_N^{-1} j_\Xi]_J$ configuration. DW and PW denote the results of the eikonal K-meson distortion and those of the plane wave approximation, respectively. The last column lists the cross sections (in μb/sr) which were estimated from $Z^{\rm DW}_{\rm eff}$ by multiplying the experimental elementary cross section $\xi(d\sigma/d\Omega)_{K^-p \to \Xi^- K^+} = 22 - 35$ μb/sr [Ref.2].

proton	Ξ^-	J^π $(\epsilon_\Xi - \epsilon_p)$	ϕ_N(HO)$\times\psi_\Xi$(WS) $Z^{\rm DW}_{\rm eff}$	$[Z^{\rm PW}_{\rm eff}]$	ϕ_N(WS)$\times\psi_\Xi$(WS) $Z^{\rm DW}_{\rm eff}$	$[Z^{\rm PW}_{\rm eff}]$	$(d\sigma/d\Omega)^{\rm DW}$
		(MeV)	$\times 10^{-3}$		$\times 10^{-3}$		(μb/sr)
$0p_{3/2}$	$\rightarrow 0s_{1/2}$	1^- (0.19)	7.50	[20.99]	9.60	[27.52]	0.211−0.336
	$\rightarrow 0p_{3/2}$	0^+ (9.18)	1.45	[5.21]	1.41	[5.36]	0.031−0.049
		2^+ (9.18)	7.54	[19.76]	8.72	[23.44]	0.192−0.305
	$\rightarrow 0p_{1/2}$	2^+ (9.46)	7.06	[18.48]	8.19	[22.01]	0.180−0.287
$0s_{1/2}$	$\rightarrow 0s_{1/2}$	0^+ (16.30)	1.22	[3.35]	1.78	[5.04]	0.039−0.062
	$\rightarrow 0p_{3/2}$	1^- (25.29)	2.20	[6.08]	2.96	[8.43]	0.065−0.104
	$\rightarrow 0p_{1/2}$	1^- (25.57)	1.02	[2.82]	1.38	[3.93]	0.030−0.04[illegible]
Sum over the bound states:			27.99	[76.69]	34.04	[95.73]	0.748−1.192

$Z^{\rm total}_{\rm eff} = 2.99$ for DW [6.00 for PW].

Table II

Transition probabilities from Ξ^- bound states ($n_\Xi l_\Xi$) in ${}^{12}_{\Xi^-}$Be to final $\Lambda\Lambda$ states. P_{bb}, P_{bc} and P_{cc} denote the probabilities to two Λ's in bound states, one Λ in a bound state and the other Λ in a continuum state, and two Λ's in continuum states, respectively. The Ξ^- state energy E_Ξ and the conversion width Γ_Ξ (in MeV) correspond to the depth V_0^Ξ of the Ξ-nucleus WS potential.

	$n_\Xi l_\Xi$	E_Ξ	Γ_Ξ	P_{bb}	P_{bc}	P_{cc}
$V_0^\Xi = -24$ MeV	$0s_\Xi$	-10.7	1.20	0.115	0.813	0.072
	$0p_\Xi$	-1.5	0.64	0.036	0.503	0.461
$V_0^\Xi = -12$ MeV	$0s_\Xi$	-4.1	1.07	0.041	0.765	0.194

Table III

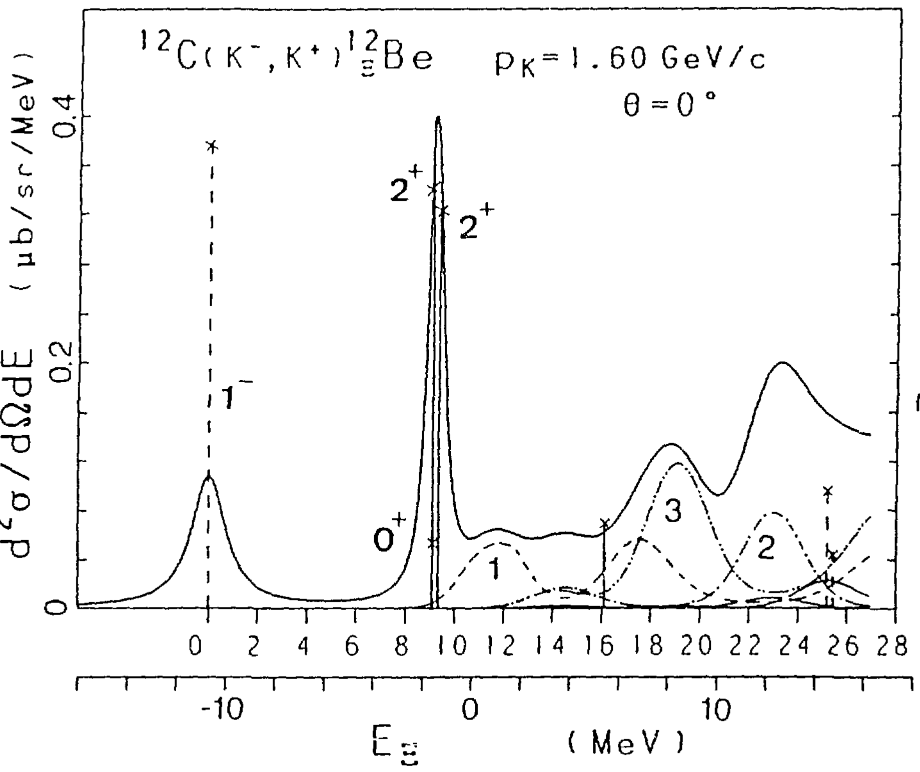
Partial widths $\Gamma_{ij}(n_\Xi l_\Xi \to l_N^{-1} l_\Lambda^i l_\Lambda^j)$ in MeV for each two-Λ one nucleon-hole final states specified by $l_N^{-1} l_\Lambda^i l_\Lambda^j$ $(i, j = b, c)$ in the case of ${}^{12}_{\Xi^-}$Be with $V_0^\Xi = -24$ MeV, where the suffices b and c mean the Λ particle in a bound state and in continuum, respectively.

$n_\Xi l_\Xi$	Γ_{bb}		Γ_{bc}		Γ_{cc}	
$0s_\Xi$	$s_N^{-1} s_\Lambda^b s_\Lambda^b$	0.138	$s_N^{-1} s_\Lambda^b s_\Lambda^c$	0.337	$p_N^{-1} s_\Lambda^c p_\Lambda^c$	0.025
			$s_N^{-1} p_\Lambda^b p_\Lambda^c$	0.053	$p_N^{-1} p_\Lambda^c d_\Lambda^c$	0.060
			$p_N^{-1} s_\Lambda^b p_\Lambda^c$	0.580	$p_N^{-1} p_\Lambda^c f_\Lambda^c$	0.002
			$p_N^{-1} p_\Lambda^b s_\Lambda^c$	0.019		
			$p_N^{-1} p_\Lambda^b d_\Lambda^c$	0.188		
$0p_\Xi$	$s_N^{-1} s_\Lambda^b p_\Lambda^b$	0.023	$s_N^{-1} s_\Lambda^b p_\Lambda^c$	0.138	$s_N^{-1} s_\Lambda^c p_\Lambda^c$	0.000
			$s_N^{-1} p_\Lambda^b s_\Lambda^c$	0.003	$s_N^{-1} p_\Lambda^c d_\Lambda^c$	0.000
			$s_N^{-1} p_\Lambda^b d_\Lambda^c$	0.017	$p_N^{-1} s_\Lambda^c s_\Lambda^c$	0.004
			$p_N^{-1} s_\Lambda^b s_\Lambda^c$	0.001	$p_N^{-1} s_\Lambda^c d_\Lambda^c$	0.003
			$p_N^{-1} s_\Lambda^b d_\Lambda^c$	0.083	$p_N^{-1} p_\Lambda^c p_\Lambda^c$	0.086
			$p_N^{-1} p_\Lambda^b p_\Lambda^c$	0.053	$p_N^{-1} p_\Lambda^c f_\Lambda^c$	0.000
			$p_N^{-1} p_\Lambda^b f_\Lambda^c$	0.025	$p_N^{-1} d_\Lambda^c d_\Lambda^c$	0.186
					$p_N^{-1} f_\Lambda^c f_\Lambda^c$	0.014

Figure Captions

Fig. 1

The excitation function $d^2\sigma/d\Omega dE$ (solid curve) for the $^{12}C(K^-, K^+)^{12}_{\Xi^-}Be$ reaction with $p_{K^-} = 1.6$ GeV/c and $\theta_{K^+}=0°$. The solid(J^+) and dashed(J^-) straight lines show the calculated effective proton numbers drawn relatively to the maximum strength indicated on the right. The conversion width Γ_Ξ and the proton hole width are both taken into account as the smearing width of each state. In the continuum region ($E_\Xi > 0$), dashed and dash-dotted curves show partial contributions from quasi-free resonances with $L = 1^-$, 2^+ and 3^-, respectively.



$^{12}C(K^-,K^+)^{12}_{\Xi}Be$
p_K=1.60 GeV/c
θ=0°
$d^2\sigma/d\Omega dE$ (μb/sr/MeV)
Z_{eff} MAX=0.01
1⁻
2⁺
2⁺
0⁺
1
2
3
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
-10 0 10
E_Ξ (MeV)
0
0.2
0.4

Fig. 1