the target nucleon to form fragments, the *exponential* nature of $F(k)$ produces the observed independence of k_0 on the mass of the ejected fragment.

Finally, we note that in the subthreshold production of antiprotons in p-nucleus collisions, Piroue and Smith[9] were led unalterably, a decade ago, to the need for an exponential form for $F(k)$. W. Frati and this author,[14] by refitting the antiproton data with $F(k)=\exp(k/k_0)/k$ and using the proper effective energy of the struck nucleon, find the value $k_0 \cong 95$ MeV/c. This provides another direct confirmation of the single-scattering hypothesis.

We conclude that "quasi-two-body scaling" gives a simple representation of a wide body of experimental data. The analyses are consistent with the hypothesis that the interactions that produce backward particles can be represented by the single scattering from an effective high-momentum distribution $F(k)=\exp(-k/k_0)/k$.

I wish to take this opportunity to thank Dr. William Frati for his splendid collaboration in our experimental work and for his encouragement and discussions during the course of this attempt to understand high-momentum distributions in nuclei. I thank D. Yang for his enthusiastic help with the computations, and R. Woloshyn and R. Amado for spirited discussions.

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[4] m_p is the projectile mass and m_Q and Q are the mass and mass number, respectively, of the detected nucleus in the generalization of Eq. (1) to nuclear projectiles and fragments.

[5] R. M. Woloshyn obtains, for elastic scattering,

$$C=\frac{s(s-4m^2)}{32\pi^2 pmE_q}\frac{d\sigma(k_{\min}\to q)}{dt}.$$

We assume that neutron- and proton-momentum distributions in nuclear matter are identical; the normalization constant $N_k=\int_0^\infty F(k)\,d^3k$ depends mainly on the low-momentum behavior of $F(k)$ and hence on A.

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Sub-Coulomb Resonances in the ^{12}C-^{12}C System through the Reaction ^{12}C(^{12}C, ^{16}O)^{8}Be

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The excitation functions of the reaction ^{12}C(^{12}C, ^{16}O(g.s.))^{8}Be(g.s.) were measured at 35° lab (~90° c.m.) and at 20° lab (~50° c.m.) near and above the Coulomb barrier ($5.75 \leqslant E_{\text{c.m.}} \leqslant 8.9$ MeV). Resonant structures were found at 5.94, 6.35, 6.69, 8.0, and 8.4 MeV. These resonant structures were correlated with those in the elastic channel. The angular distributions at 6.4, 6.65, and 8.0 MeV were measured, and the spin-parity assignments are 2^+, 2^+, and 4^+, respectively. The oxygen partial width at 5.94 MeV was determined to be 14 keV, which is as large as the carbon partial width.

Since the resonant structures in the ^{12}C-^{12}C system were first observed near and below the Coulomb barrier,[1] several experiments have been performed[2] and new information on this system has been accumulated. Theoretical work also has been forwarded to understand these structures.

In the simplest picture these resonances are represented as shape resonances in a potential well. Recent attempts to apply this picture to the ^{12}C-^{12}C and ^{12}C-^{16}O systems were reported by Park, Scheid, and Greiner[3] and by Nagorcka and Newton.[4] In other pictures, doorway-state models which are based on either nuclear molecule[5,6] or α-particle molecule models[7] have been proposed. In particular, Imanishi succeeded in reproducing the resonant structures in the ^{12}C-^{12}C system, including their carbon widths, and further predicted the spin and parity for the resonance at 6.3 MeV to be 0^+.[5] But no one has concluded as to which model is the most suitable.

We measured the ^{16}O-^{8}Be channel in an effort to get more information on the ^{12}C-^{12}C system. This channel is favorable for this purpose, considering the Q-value effect and angular-momentum matching, because the threshold energy for this channel differs by only 200 keV from that of the ^{12}C-^{12}C channel; moreover, ^{8}Be and ^{16}O are the α-conjugate nuclei which are often associated with resonant structures. However, it is very difficult to detect ^{8}Be in this low-energy region [$5.5 \leq E(^{8}Be) \leq 20$ MeV]. We detected low-energy recoiled ^{16}O particles by using a gas ΔE-E counter system.[8] In this Letter, we shall report on the resonant structures near and above the Coulomb barrier in the ^{12}C-^{12}C system through the reaction $^{12}C(^{12}C, ^{16}O)^{8}Be$.

The experiment has been performed using the $^{12}C^{3+}$ and $^{12}C^{4+}$ beams from the Kyoto University tandem Van de Graaff accelerator. The target was a carbon foil with a gold layer of a few micrograms per square centimeter. The target thickness was 15–25 μg/cm^2. Absolute cross sections were determined by assuming that the elastic scattering of carbon by gold is pure Rutherford scattering.

The excitation functions of the reaction $^{12}C(^{12}C, ^{16}O(g.s.))^{8}Be(g.s.)$ were measured in 50-keV steps for $5.75 \leq E_{c.m.} \leq 8.9$ MeV at 35° lab (~ 90° c.m.) and for $6.4 \leq E_{c.m.} \leq 8.9$ MeV at 20° lab (~50° c.m.). The result at 35° lab is shown in Fig. 1(a). Several remarkable peaks are found at 5.94, 6.4, 6.65, 8.0, and 8.4 MeV. The peak at 8.0 MeV is also found in the excitation function at 20° lab (~ 50° c.m.), as shown in Fig. 1(b), an angle which corresponds to that of a peak of $|P_4(\cos\theta)|^2$ and valleys of $|P_2(\cos\theta)|^2$ and $|P_6(\cos\theta)|^2$. The first two peaks may be the same as the ones first observed by Almqvist, Bromley, and Kuehner,[1] about which we shall discuss below in detail. The peak at 8.0 MeV may correspond to that observed in the reaction $^{20}Ne(\alpha, ^{12}C)^{12}C$ in which $L = 4$ and 6 are dominant.[9]

The elastic excitation function was also measured at 90° c.m. in 50-keV steps for $5.5 \leq E_{c.m.} \leq 9.0$ MeV. The result is shown in Fig. 1(c). Our data are similar to those of Spinka and Winkler.[10]

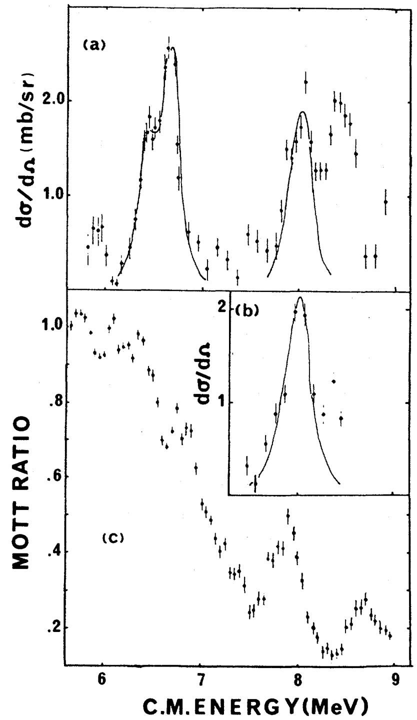

FIG. 1. (a) The excitation function of the reaction $^{12}C(^{12}C, ^{16}O(g.s.))^{8}Be(g.s.)$ at 35° lab. (b) The excitation function of the reaction $^{12}C(^{12}C, ^{16}O(g.s.))^{8}Be(g.s.)$ at 20° lab. In (a) and (b), the solid curves are the results of resonance calculations with the Breit-Wigner shape. (c) The excitation function of the elastic scattering of $^{12}C + ^{12}C$ at 90° c.m.

The resonant structures, appearing in the ^{16}O-^{8}Be channel, seem to be correlated with those of the elastic channel.

The angular distributions at 6.4, 6.65, and 8.0 MeV were measured. The results are shown in Fig. 2 and were fitted with $|P_L(\cos\theta)|^2$ by assuming these peaks as isolated resonances. The good fits shown in Fig. 2 strongly suggest that the spins and parities of the resonances at 6.35, 6.69, and 8.0 MeV are 2^+, 2^+, and 4^+ respectively. The spin of the resonance near 6.3 MeV was predicted to be 0^+ by Imanishi,[5] but recently Kondō, Matsuse, and Abe[11] pointed out that this assignment was doubtful because the observed cross section was much larger than the upper limit of the yield calculated in the case of complete absorption for $L = 0$. Our spin assignment is consistent with this latter calculation. The spin of the resonance at 8.0 MeV is also consistent with data on the reaction $^{20}Ne(\alpha, ^{12}C)^{12}C$.[9] The spin of the resonance at 5.925 MeV (in our data, 5.94 MeV) in the ^{16}O-^{8}Be channel was assigned to be 4^+ by Coo-

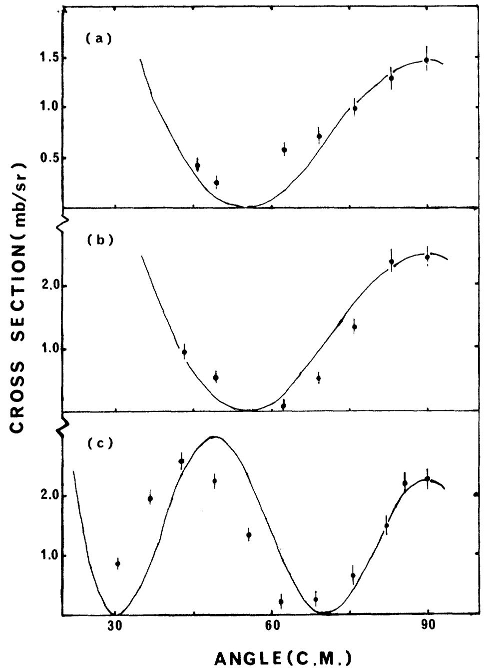

FIG. 2. The angular distributions of the reaction $^{12}C(^{12}C, ^{16}O(g.s.))^{8}Be(g.s.)$ and $|P_L(\cos\theta)|^2$ fits (a) at 6.4 MeV and $L=2$, (b) at 6.65 MeV and $L=2$, and (c) at 8.0 MeV and $L=4$.

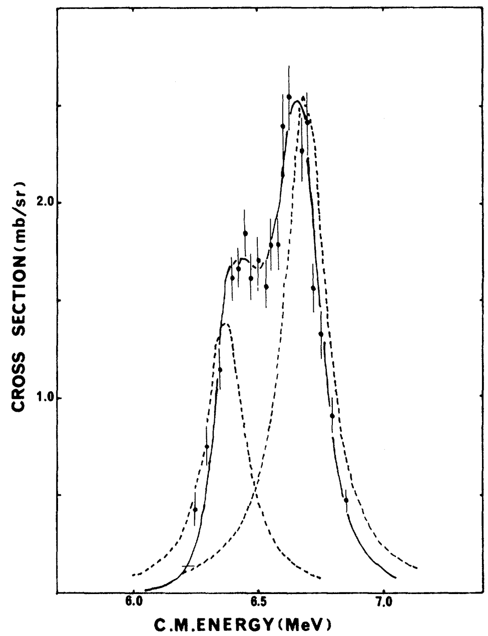

FIG. 3. The result of the calculation of the interference effect between the resonances near 6.4 and 6.65 MeV (solid curve). Each Breit-Wigner shape is shown by a dashed curve. The resonance energies are as follows: $E_1=6.35$ MeV and $E_2=6.69$ MeV.

per, Lau, and Reisdorf.[12] This result is the same as that of Almqvist, Bromley, and Kuehner.[1] Thus the resonance at 5.94 MeV can be regarded as the same one observed in other exit channels.[1]

The resonance energy of 6.35 MeV was determined as follows: In the ^{16}O-^{8}Be channel, another stronger resonance with the same spin ($J=2$) exists near 6.65 MeV. Thus these two resonances interfere and draw near each other. The calculated result taking account of this interference effect is shown in Fig. 3. The resonance at 6.35 MeV may also be the same one observed in other exit channels by Almqvist, Bromley, and Kuehner.[1]

Under the assumption that the resonances are isolated resonances with the Breit-Wigner shape, partial widths of the resonances at 5.94, 6.35, 6.69, and 8.0 MeV were deduced. For the resonance at 5.94 MeV, we obtained an oxygen partial width Γ_O of 14 keV and a reduced width $\langle\gamma_c^2\rangle$ of 9.8% for $R=7$ fm by using the carbon width Γ_C of 3.75 keV in Ref. 1. This reduced width is as large as those of the elastic channel. For the other three resonances, the partial widths were obtained in the form of the product of Γ_O and Γ_C. This product ($\Gamma_O\Gamma_C$) is determined to be 950, 2050, and 3050 keV^2 for the 6.35-, 6.69-, and 8.0-MeV resonances, respectively. These results suggest that the reduced widths of the ^{16}O-^{8}Be channel are possibly as large as those of the elastic channel. This fact shows that the ^{16}O-^{8}Be configuration, as well as the ^{12}C-^{12}C configuration, plays an important role for the sub-Coulomb resonances.

It is worth comparing the ^{16}O-^{8}Be channel with the α channel. In a recent study of the α channel, two more resonances appear at 7.71 and 9.84 MeV which have $J=4$ and $J=8$, respectively.[13] The former was found also in the ^{20}Ne-α channel but did not appear in the ^{16}O-^{8}Be channel in our measurement in which these two channels were observed simultaneously. To the contrary, the resonances at 6.69 and 8.0 MeV are not clearly seen in the α channel. Recently, in a measurement of the ^{16}O-^{8}Be channel in the energy region of $9 \leq E_{c.m.} \leq 20$ meV, [14] gross structures of a few MeV in width were found which consisted of several intermediate structures of a few hundred keV in width with the same spin, and moreover it was revealed that these gross structures might construct a rotational band. The existence of a broad rotational band like this was predicted by Arima, Sharff-Goldhaber, and McVoy[15] from an analysis of the optical potential. This prediction agrees very well with the above data. The resonances at 6.35 MeV (2^+), 6.69 MeV (2^+), and 8.0 MeV (4^+) in our data also seem to belong to this rotational band. This means that the sub-Coulomb resonances which are enhanced in the ^{16}O-^{8}Be channel are led by shape resonances.

The narrow widths, however, cannot be reproduced by the shape resonance alone. The states which overlap well with the ^{16}O-^{8}Be configuration may couple with the shape resonances to make the intermediate structures. This result may support the double-resonance mechanism.[5,6] However the state which must be coupled is not the state C*(2^+, 4.43), but the state which belongs to the second $K^\pi = 0^+$ band.[16]

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Giant Magnetic Dipole States in ^{208}Pb Observed in the ^{207}Pb + n Reaction*

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High-resolution neutron transmission and elastic-scattering measurements on ^{207}Pb have revealed a concentration of p-wave strength in ^{208}Pb which is mainly accounted for by $J^\pi = 1^+$ resonances. The sum of the ground-state radiative widths for these resonances is $\sum \Gamma_{\gamma 0} = 7.2$ eV which agrees well with a one-particle–one-hole theoretical prediction which locates a fragment of the giant $M1$ resonance at 7.50 MeV with $\Gamma_{\gamma 0} = 9.3$ eV.

The location of the magnetic dipole strength in ^{208}Pb has been the subject of a number of papers, both theoretical and experimental. From an examination of experimental works,[1-10] it is evident that uncertainty exists as to the magnitude and distribution of the $M1$ strength observed. Thus far, a major difficulty has been to obtain data which can be utilized to assign definitively levels as having $J^\pi = 1^+$.

In this work we present the results of high-resolution neutron transmission and (preliminary) elastic-scattering measurements on ^{207}Pb which allow the definitive assignment of spin and/or parity to many resonances in ^{208}Pb. Examination of the p-wave resonances between 3 and 400 keV shows a concentration of p-wave strength (i.e., a doorway state) in the vicinity of $E_n = 120$ keV which mainly arises from several resonances having $J^\pi = 1^+$. Combining our J^π assignments with the neutron-capture data of Allen and Macklin,[11] we are able to demonstrate that a significant portion of the $M1$ strength in ^{208}Pb is located within our observed doorway state.

The experimental work was performed at the