**INTRODUCTION**

Recent experiments and production of contact interactions are described, showing the importance of contact interactions in the structure of nucleons. Higher order terms, which are not included in the Born approximation, are discussed. The effect of the exchange interaction on the contact interactions is also considered. The role of contact interactions in the structure of baryons is emphasized. The interaction between nucleons is studied in detail, and the role of contact interactions in the structure of baryons is highlighted.

**REFERENCES**


involved. The ultimate goal of a 9Li experiment, however, remains the detection of the 3/2\(^+\) + 1/2\(^+\) g.s. intradoublet \(\gamma\) ray, since any determination of the spin–spin interaction (l). Unfortunately, direct excitation of the 3/2\(^+\) level in the \((K^-,\pi^-)\) reaction requires spin flip, strongly suppressed at forward angles, and indirect population from higher levels was too weak to be detected in the experiment.\(^8\)

The observation\(^8\) of the 3.1 MeV \(\gamma\) line in \(^{10}\)Be (Fig. 1b), with an upper limit of about 100 keV placed on its splitting into two components, stringently constrains the magnitude of the spin-orbit effective interaction which gives the main contribution to the splitting of the \(^{10}\)Be excited doublet:

\[
|\Delta S| \lesssim 0.04 \text{ MeV} . \tag{5}
\]

This provides the best limit\(^6\) so far on the strength of the related one-body \(A\)-nuclear spin-orbit splitting

\[
\varepsilon_p \equiv \varepsilon_{l1/2} - \varepsilon_{l3/2}, \quad |\varepsilon_p| \lesssim 0.25 \text{ MeV} . \tag{6}
\]

It is clear that the determination of the spin dependence of the \(A\)N effective interaction requires detection of several additional intradoublet \(\gamma\) transitions. Typical examples, mostly of g.s. doublets, are shown in Fig. 2 and classified according to their approximate \((1p_{1/2}^{-1},1s_{1/2})\) N\(^{10}\)A nature.\(^6\) This classification means that the three parameters of Eqs. (1)-(3) are to be disentangled from the following two combinations

\[
1p_{3/2}^{-1},1s_{1/2} : \quad \delta = \frac{2}{3} \Delta + \frac{4}{3} S_A - \frac{8}{5} T, \tag{7}
\]

\[
1p_{1/2}^{-1},1s_{1/2} : \quad \delta' = -\frac{1}{3} \Delta + \frac{4}{3} S_A + 8T . \tag{8}
\]

With the expected values given in (4), the main contribution to \(\delta\) comes from the spin–spin interaction, so a detection of any of the intradoublet \(\gamma\) lines of (a) would provide an approximate measure of \(\Delta\), particularly since \(S_A\) has been constrained by the \(^{9}\)Be measurement (Eq. (3)) and the phenomenologically unknown \(T\) was shown\(^6\) to be insensitive to the theoretical model of its determination. Of the four possibilities denoted in (a), \(^{10}\)B provides the best target choice and the most straightforward interpretation\(^5\) of an observation. A preliminary result\(^9\) for the measurement of the \(2^- + 1^-\) g.s. \(\gamma\) line in \(^{12}\)B quotes \(E_\gamma \sim 157\) keV, compared with the prediction\(^6\) \(E_\gamma \sim 170\) keV; in excellent agreement.

The phenomenologically unknown tensor interaction enters significantly in the splitting expression \(\delta'\), Eq. (8). This suggests measuring one of the \(\gamma\) lines of (b). A measurement of the \(1^- + 0^-\) g.s. \(\gamma\) line in \(^{14}\)N, of energy predicted to be \(E_\gamma \sim 84\) keV, was undertaken at BNL and the analysis of the data is in progress.\(^9\)

**WEAK DECAY OF A HYPERNUCLEI**

The weak decay of a hypernuclei is dominated, except for the very light hypernuclei, by the nonmesonic decay

\[
A + \pi^- \rightarrow A + \pi^- . \tag{9}
\]

The free \(A\) decay, \(A + \pi^- \rightarrow A + \pi^- + p\), is strongly suppressed in hypernuclei owing to the Pauli principle which excludes the low-energy recoil nucleon. The decay mode (9) cannot be studied in free space. Direct measurement of \(A\)-hypermolecular lifetimes, therefore, is of considerable interest, providing for a unique signature of this weak process. Recently, a measurement\(^1\) was undertaken at BNL by detecting relatively high-energy \((E \geq 30\) MeV\) protons and neutrons originating from the decay (9) in coincidence with production pions from the reaction

\[
^{12}\text{C}(K^-,\pi^-)^{12}\text{C} . \tag{10}
\]

The proton time of flight (TOF) spectrum from tagged hypernuclear decays was compared with a prompt TOF spectrum measured simultaneously for the inclusive reaction

\[
\pi^- + ^{12}\text{C} + p + X . \tag{11}
\]

induced by the \(\pi^-\) component of the beam. This allows a direct determination of the hypernuclear lifetime. The \(^{12}\text{C}\) excitation spectrum obtained in coincidence with those decay protons used in the lifetime measurement is shown in Fig. 3. The three mass regions shown correspond to the excitation of:

- a. \(^{12}\text{C}\) g.s. configuration \((1p_{1/2}^{-1},1s)\), followed by the decay of the \(1^- + 0^-\) g.s. \((1p_{3/2}^{-1},2s^2,2p_{1/2}^1)\)
- b. \(^{12}\text{C}\) \((1p_{1/2}^{-1},2p_{1/2}^1)\) belonging to the \((1p_{1/2}^{-1},1p)\) configuration, known\(^1\) to decay by emitting a low-energy proton to the \(5/2^-\) g.s. of \(^{12}\text{B}\), the latter decaying nonmesonically;
Table 1. Hypothesis Test Results

<table>
<thead>
<tr>
<th>H0</th>
<th>H1</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P &lt; 0.05)</td>
<td>(P &gt; 0.05)</td>
<td>0.032</td>
</tr>
</tbody>
</table>

Note: The hypothesis test results indicate that the null hypothesis \(H_0\) cannot be rejected at the 0.05 significance level, suggesting that the observed data is consistent with the null hypothesis. Further analysis is required to confirm these findings.

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Figure 2. Hypothetical Production Data in kg.

- The production data is shown in a graph format, where the x-axis represents time, and the y-axis represents production quantity in kg.
- The data points are plotted, indicating a trend in production over time.

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Discussion:

The production data shows a consistent increase in production over time, which is expected in a growing production scenario. The graph clearly illustrates the growth pattern, which can be further analyzed for predictive insights.

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Conclusion:

The hypothesis test results support the null hypothesis, suggesting no significant difference in production. Further research is needed to validate these findings with additional data points and contextual factors.

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References:

1. [Source 1](#) - Hypothesis Testing
2. [Source 2](#) - Production Data
3. [Source 3](#) - Additional Analysis

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Appendix:

- Additional tables and data points for further analysis.
- Detailed methodology for hypothesis testing and production data analysis.
moderate (less than 20% off) for Λ production when the various approximations are removed, but substantial for Λ production because of the strong pion-nuclear interaction in the (3,3) vicinity. The ENTA calculations for Λ-hypnuclear production are marked by bars in the figure. The net outcome is that Λ-hypnuclear production rates are higher by about an order of magnitude than Λ-hypnuclear production rates.

Yamazaki et al.\textsuperscript{18} recently reported a striking Λ-hypnuclear structure in the \( ^{12}\text{C}(K^-,\pi^+)\) spectrum for the reaction

\[
^{12}\text{C}(K^-,\pi^+)\frac{3}{2}^+\text{Be}
\]

with stopped kaons at KEK (Fig. 5). The mass resolution of this experiment was 1.3 MeV, allowing for a clear observation of three narrow peaks (\( \Gamma < 4 \) MeV) in the momentum range \( q=150-170 \) MeV/c. The formation rate of these peaks is fairly large, of order 1% per stopped kaon. None of the peaks observed is believed to correspond to the \( \Lambda(\pi^-) \) g.s. configuration which should have been excited with a calculated rate of about 0.5% per stopped kaon, an insufficient intensity to be observed if its width were small. One possibility is that the \( \Lambda(\pi^-) \) level is too broad to be uniquely observed, in agreement with the phenomenological analysis of Refs. 19, 20. It is remarkable that the observed narrow \( \frac{3}{2}^+\text{Be} \) states all stand out in the \( \Sigma \) continua, particularly for the \( \pi^0 \) tagging shown in the figure (this tagging ensures that the states decay by conversion \( \Sigma^+ p + \Lambda n \) and subsequently by the weak decay \( \Lambda + m^\Lambda \), not by the quasi-free mode \( \Sigma^- + \pi^- \)). Similar findings have been preliminarily reported by Hungerford\textsuperscript{21} for the reaction (12) in flight, at \( p(K^-) = 720 \) MeV/c.

Yamazaki et al.\textsuperscript{18} argued that the energy difference \( \Delta E = 4.6 \) MeV between the two lowest \( \frac{3}{2}^+\text{Be} \) peaks \( (1\text{p}_{3/2}, 1\text{p}_{1/2}) \) at \( q=164 \) and \( q=175 \) MeV/c is due to the energy splitting of the states.

\[
\begin{align*}
\text{Fig. 5. } &\pi^+ \text{ spectrum from } K^- \text{ stopped in CH}_n \text{ as taken in KEK.} \\
\end{align*}
\]

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**Fig. 6.** Relative intensities calculated\textsuperscript{22} for \( ^{12}\text{C}(K^+,\pi^+) \) at rest, for three assumed values of the \( \Sigma \)-nuclear spin-orbit splitting \( \varepsilon_p \), \( (1\text{p}_{3/2}, 1\text{p}_{1/2}) \) at 158 MeV/c be attributed almost entirely to the \( \Sigma \)-nuclear spin-orbit splitting \( \varepsilon_p \) (c.f. Eq. (6) for the corresponding situation in \( \Lambda \) hypnuclear). The shell-model calculations of Dover et al.\textsuperscript{22} raise some serious reservations about such a conclusion. Figure 6 gives the relative intensities calculated, for \( \Sigma \) residual interaction \( V(\Sigma N) \) determined from Model D,\textsuperscript{7} as a function of \( \varepsilon_p \). It is clear from (b) that although the choice \( \varepsilon_p=5 \) MeV does reproduce the two lowest peaks in \( \frac{3}{2}^+\text{Be} \), it does not leave room for a substantial \( 1\text{p}(\Sigma^-) + 1\text{p}(\Sigma^-) \) intensity in the 9 MeV region corresponding to the third observed peak (q=152 MeV/c). In fact, it has not proved possible to find a reasonable \( V(\Sigma N) \) which would place sufficient intensity to this region without over-depleting the intensity calculated for the 5 MeV region. On the other hand, increasing \( \varepsilon_p \) to about 9 MeV (Fig. 6c), as favored by straightforward interpretations\textsuperscript{23,24} of the somewhat ambiguous \( ^{16}\text{O}(K^+,\pi^+) \) data\textsuperscript{23} at \( p(K^-)=450 \) MeV/c, leads to a splitting between the two main peaks which varies linearly with \( \varepsilon_p \), but the remaining intensity around 5 MeV is depleted, again, leaving only two peaks explained. Of course, if \( \varepsilon_p \) were as large as 9 MeV, the second observed peak could tentatively be assigned\textsuperscript{22,25} to the \( d_{3/2}(\Sigma^-) \) configuration; but it is far from clear why a \( 1\text{b}(\Sigma^-) \) state should remain unfragmented and narrow, and this reservation would become even more valid if, for \( \varepsilon_p=5 \) MeV, one attempted to ascribe the origin of the third peak to an excited d(\( \Omega \)) state.

It is worth noting, Fig. 6a, that for \( \varepsilon_p \ll \Lambda \sim 5 \) MeV the energy splitting of the two calculated main peaks no longer varies linearly
which gives

\[
\frac{d_y}{d_x} = \frac{c}{x+y}
\]

Exercise: Find the partial differential equation that represents the given function.

Given:
\[
G(x, y) = x^2 + y^2
\]

Find \( E(x, y) \) such that
\[
G(x, y) = E(x, y)
\]

Solution:
\[
E(x, y) = \frac{d_x}{d_y} - \frac{d_y}{d_x}
\]

where \( \frac{d_x}{d_y} \) and \( \frac{d_y}{d_x} \) are the partial derivatives of \( G(x, y) \) with respect to \( x \) and \( y \), respectively.

Consider the process of producing a linear relation between two variables.

The linear relation is given by
\[
T_x = \frac{d_x}{d_y} - \frac{d_y}{d_x} = \frac{c}{x+y}
\]

where \( c \) is a constant.

The process can be described by the following equation:
\[
\frac{d_x}{d_y} = \frac{c}{x+y}
\]

This equation represents a linear relationship between the variables.

No external field interactions are present.

Consider the production of a linear relation between two variables.

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where \( c \) is a constant.

The process can be described by the following equation:
\[
\frac{d_x}{d_y} = \frac{c}{x+y}
\]

This equation represents a linear relationship between the variables.

Comparisons of nuclear excitation and nucleon excitation states.
\[ E \text{ (MeV)} \]

\[ 0 \quad 0 \quad 0 \quad 0 \quad 0 \quad 0 \]

\[ R/E \text{ (arb. units)} \]

The sum of the convolution component is 0 when the \( V_x \) is a discrete value. The \( I_x \) value function does not have an unbounded part \( V_x \).

\[ 0 = V_x \left( \frac{V_x}{V_x H - I_x} \right) + V_x = V_x \]

\[ \text{In the convolution component, where the } \lambda \text{ function equals } 0 \text{.} \]

\[ 0 = \int_{-\lambda}^{\lambda} \lambda \, d\lambda = 0 \]

\[ \text{Then yields exactly the same convolution term in (30).} \]

\[ \int_{-\lambda}^{\lambda} \int_{-\lambda}^{\lambda} \lambda \left( \frac{V_x}{V_x H - I_x} \right) \, d\lambda d\lambda = 0 \]

\[ \text{The sum of the convolution components is } \frac{V_x}{V_x H - I_x} \text{ is 0 when the } \lambda \text{ function equals 0.} \]

from Eq. (30) for Eq. (30) from Eq. (32) we show the convolution results.

This agrees with the convolution component term in (30).

\[ \int_{-\lambda}^{\lambda} \left( \frac{V_x}{V_x H - I_x} \right) \lambda \, d\lambda = 0 \]

\[ \text{So that this sum becomes} \]

\[ \int_{-\lambda}^{\lambda} \left( \frac{V_x}{V_x H - I_x} \right) \lambda \, d\lambda = 0 \]

\[ \lambda \]
REFERENCES


15. J. Szymanski, this volume.


