MICROSCOPIC CALCULATIONS OF $\Lambda$ SINGLE PARTICLE ENERGIES

Q.N. Usmani and M. Sami
Jamia Millia Islamia, Jamianagar, New Delhi-110025, India
and
A.R. Bodmer
Department of Physics, University of Illinois at Chicago, IL-60680, U.S.A.
and
Physics Division, Argonne National Laboratory, Argonne, IL 60439-4843, U.S.A.

We analyze the $\Lambda$ single particle energies $B_\Lambda$, obtained from $(\pi^+, K^+)$ and $(\pi^-,K^-)$ reactions\(^1\)
for hypernuclei from $A=11$ to $A=89$, in terms of phenomenological two and three body $\Lambda N$ and $\Lambda NN$ interactions which were obtained earlier from studies of $\Lambda p$ scattering, the s-shell hypernuclei and the $\Lambda$-binding to nuclear matter\(^2\). We show that the $B_\Lambda$ values can be very well explained by use of the local density approximation based on calculating the $\Lambda$-binding to nuclear matter $D$ as a function of density $\rho$, and the $\Lambda$ momentum $k_\Lambda$. Thus, we calculate $D \equiv D(\rho,\varepsilon,k_\Lambda)$, where $\varepsilon$ is the space-exchange parameter in the $\Lambda N$ potential (for details see ref. 2 & 3). The various expectation values are evaluated using the Fermi Hypernetted Chain Approximation. To take into account the fringing field the $D$ was fitted with density dependent effective $\Lambda N$ potential of the following form

$$V_{\Lambda N}(\rho,\varepsilon,r) = V_0(\rho,\varepsilon)T_2^N(r)$$

where $T_2^N$ corresponds to a $2\pi$ exchange mechanism with cutoff\(^2\).

To obtain the $\Lambda$ single particle potential the empirical nuclear density $\rho(r_N)$ for the appropriate core nucleus is folded with $V_{\Lambda N}(\rho,\varepsilon,r)$:

$$U_\Lambda(\varepsilon, r_\Lambda) \equiv \int V_{\Lambda N}(\rho,\varepsilon,\vec{r}_\Lambda - \vec{r}_N)\rho(r_N) dr_N$$

For the $\Lambda$ effective mass $m_\Lambda^*/m_\Lambda$, we calculate the difference $D(\rho,\varepsilon,k_\Lambda) - D(\rho,\varepsilon,0)$ which is then fitted with a quadratic momentum dependence. The $B_\Lambda$ values corresponding to the $\Lambda$ in the $s$, $p$, $d$ and $f$ orbitals are obtained by solving the appropriate Schrödinger equation.

We find that $\Lambda N$ and $\Lambda NN$ potentials, which give a consistent account of s-shell hypernuclei, of D, and of the $\Lambda p$ scattering data, explain very well the data (see fig.). The $B_\Lambda$ values are consistent with a purely dispersive density independent $\Lambda NN$ potential and with one...
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which also has a $2\pi$ exchange component. We find a strong correlation between $\varepsilon$ and the $\Lambda NN$ potentials; $\varepsilon \approx 0.15 \pm 0.02$ with only a dispersive $\Lambda NN$ potential and $\varepsilon \approx 0.30 \pm 0.02$ with a dispersive $\Lambda NN + 2\pi$ potential. From scattering data, $\varepsilon \approx 0.13$ to 0.38

As expected, we find $m^*/m_\Lambda$ is proportional to $\varepsilon$. For $\varepsilon \approx 0.15$, we find $m^*/m_\Lambda \approx 0.90$, whereas for $\varepsilon \approx 0.30$, $m^*/m_\Lambda \approx 0.82$. In the phenomenological fits of ref. 4), based on a zero range approximation, the $m^*/m_\Lambda \approx 0.76 - 0.80$. These small values of $m^*/m_\Lambda$ may be attributed to the use of zero range approximation.

The value of $D$ which we obtain is quite well determined and insensitive to the particular form of potential used; $D \approx 27.9 \pm 0.4$ MeV.

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References
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