Self-energy of Λ in finite nucleilinkfrontmatter.1*

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PACS numbers:

$\Lambda^{17}\Lambda$¨u

I. INTRODUCTION

?(K^-,π^-)??$\Lambda\Sigma(\pi^+,K^+)(K^-_{\rm stopped},\pi^0)$?

$YN\Lambda N\Sigma N$?$YNYN$?ü?$NNYNYN^{3\,3\,4}_{\Lambda\Lambda\Lambda}$??$YNYNG$ $YNYNYNG$?G?YN

$\Lambda^{17}_{\Lambda}GGG$?$Gk_F\Lambda$??

$G\Lambda$ö(γ,K^+)?(π^+,K^+)??ΛG?

ΛöΛ

II. COMPUTATIONAL DETAILS

A. Evaluation of the Λ self-energy

Λ??$GYNG_{YN}$

$$\mathbf{k}=\frac{M_N\mathbf{k_Y}-M_Y\mathbf{k_N}}{M_N+M_Y},$$
$$\mathbf{K}=\mathbf{k_N}+\mathbf{k_Y},$$

$M_NM_Y\Lambda M_\Lambda\Sigma M_\Sigma$?

$$\begin{aligned}\langle k'l'KL(\mathcal{J})ST_z|\,G_{YN}\,|k''l''KL(\mathcal{J})S'T_z\rangle =&\\ &\langle k'l'KL(\mathcal{J})ST_z|\,V_{YN}\,|k''l''KL(\mathcal{J})S'T_z\rangle\\ &+\sum_l\sum_{Y=\Lambda\Sigma}\int k^2dk\,\langle k'l'KL(\mathcal{J})ST_z|\,V_{YN}\,|klKL(\mathcal{J})S'T\\ &\times\langle klKL(\mathcal{J})ST_z|\,G_{YN}\,|k''l''KL(\mathcal{J})S'T_z\rangle\\ &\times\frac{Q(k,K)}{\omega_{NM}-\frac{K^2}{2(M_N+M_Y)}-\frac{k^2(M_N+M_Y)}{2M_NM_Y}-M_Y+M_\Lambda},\end{aligned}$$

$QV_{YN}YN\omega_{NM}kk'k''ll'l''KL\mathcal{J}ST_zk_F{}^{-1}\omega_{NM}--80\Lambda$ $G_{YN}G_{YN}$?[1]

$$\begin{aligned}|(k_al_aj_at_{z_a})(k_bl_bj_bt_{z_b})JT_z\rangle =& \sum_{lL\lambda S\mathcal{J}}\int k^2dk\int K^2dK\begin{Bmatrix} l_a & l_b & \lambda\\ \frac{1}{2} & \frac{1}{2} & S\\ j_a & j_b & J\end{Bmatrix}\\ &\times(-1)^{\lambda+\mathcal{J}-L-S}\hat{\mathcal{J}}\hat{\lambda}^2\hat{j}_a\hat{j}_b\hat{S}\begin{Bmatrix} L & l & \lambda\\ S & J & \mathcal{J}\end{Bmatrix}\\ &\times\langle klKL|k_al_ak_bl_b\rangle\,|klKL(\mathcal{J})SJT_z\rangle,\end{aligned}\qquad(2)$$

$\langle klKL|k_al_ak_bl_b\rangle$?

$$\langle(k_al_aj_at_{z_a})(n_bl_bj_bt_{z_b})JT_z|\,G_{YN}\,|(k_cl_cj_ct_{z_c})(n_dl_dj_dt_{z_d})JT_Z\rangle\,,\qquad(3)$$

[1] Note the distinction between k_a and k and l_a and l. With the notation k_a or l_a we will refer to the quantum numbers of the single–particle state, whereas l or k without subscripts refer to the coordinates of the relative motion.

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$$\langle (k_a l_a j_a t_{z_a})(n_b l_b j_b t_{z_b}) JT_Z | \, G_{YN} \, | klKL(\mathcal{J})ST_z \rangle \,, \tag{4}$$

??

$$|(n_a l_a j_a t_{z_a})(k_b l_b j_b t_{z_b}) JT_z\rangle = \int k_a^2 dk_a R_{n_a l_a}(\alpha k_a) \, |(k_a l_a j_a t_{z_a})(k_b l_b j_b t_{z_b}) JT_z\rangle \,, \tag{5}$$

$k_a l_a j_a n_a l_a j_a \alpha^{17}_{\Lambda} l_{a,b} j_{a,b} t_{z_{a,b}} JT_z$
??

$$\mathcal{V}_{HF}(k_\Lambda k'_\Lambda l_\Lambda j_\Lambda t_{z_\Lambda}) = \frac{1}{\hat{j}_\Lambda^{\,2}} \sum_J \sum_{n_h l_h j_h t_{z_h}} \hat{J}^2 \times \langle (k_\Lambda l_\Lambda j_\Lambda t_{z_\Lambda})(n_h l_h j_h t_{z_h}) JT_z | \, G_{YN} \, | (k_\Lambda l_\Lambda j_\Lambda t_{z_\Lambda})(n_h l_h j_h t_{z_h}) JT_z \rangle \,, \tag{6}$$

$\hat{x} = \sqrt{2x+1} n_h l_h j_h t_{z_h} l_\Lambda j_\Lambda t_{z_\Lambda} t_{z_\Lambda} = 0 \Lambda k_\Lambda k'_\Lambda$
$2p1h$??$2p1h$

$$\mathcal{W}_{2p1h}(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda t_{z_\Lambda} \omega) = -\frac{1}{\hat{j}_\Lambda^{\,2}} \sum_{n_h l_h j_h t_{z_h}} \sum_J \sum_{lLS\mathcal{J}} \sum_{Y=\Lambda\Sigma} \int k^2 dk \int K^2 dK \hat{J}\hat{T} \times \langle (k'_\Lambda l_\Lambda j_\Lambda t_{z_\Lambda})(n_h l_h j_h t_{z_h}) JT_z | \, G_{YN} \, | klKL(\mathcal{J})SJT_z \rangle \times \langle klKL(\mathcal{J})SJT_z | \, G_{YN} \, | (k_\Lambda l_\Lambda j_\Lambda t_{z_\Lambda})(n_h l_h j_h t_{z_h}) JT_z \rangle \times \pi \delta \left(\omega + \varepsilon_h - \frac{K^2}{2(M_N+M_Y)} - \frac{k^2(M_N+M_Y)}{2M_N M_Y} - M_Y + M_\Lambda \right) \tag{7}$$

$\omega \Lambda \Lambda \varepsilon_h {}^{16} klKL(\mathcal{J})SJT_z YN$?
??

$$\mathcal{V}_{2p1h}(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda t_{z_\Lambda} \omega) = \frac{P}{\pi} \int_{-\infty}^{\infty} \frac{\mathcal{W}_{2p1h}(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda t_{z_\Lambda} \omega')}{\omega' - \omega} d\omega' , \tag{8}$$

$P \mathcal{W}_{2p1h} \omega' \mathcal{V}_{2p1h} \omega \Lambda$
??$YNG2p1h$??$YN\Lambda$

$$\mathcal{V}_c(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda t_{z_\Lambda}) = \frac{1}{\hat{j}_\Lambda^{\,2}} \sum_{n_h l_h j_h t_{z_h}} \sum_J \sum_{lLS\mathcal{J}} \sum_{Y=\Lambda\Sigma} \int k^2 dk \int K^2 dK \hat{J}\hat{T} \times \langle (k'_\Lambda l_\Lambda j_\Lambda t_{z_\Lambda})(n_h l_h j_h t_{z_h}) JT_z | \, G_{YN} \, | klKL(\mathcal{J})SJT_z \rangle \times \langle klKL(\mathcal{J})SJT_z | \, G_{YN} \, | (k_\Lambda l_\Lambda j_\Lambda t_{z_\Lambda})(n_h l_h j_h t_{z_h}) JT_z \rangle \times Q(k,K) \left(\omega_{NM} - \frac{K^2}{2(M_N+M_Y)} - \frac{k^2(M_N+M_Y)}{2M_N M_Y} - M_Y + M_\Lambda \right) \tag{9}$$

??

$Q \omega_{NM}$
Λ

$$\Sigma(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda \omega) = V(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda \omega) + iW(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda \omega), \tag{10}$$

$$V(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda \omega) = \mathcal{V}_{HF}(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda) + \mathcal{V}_{2p1h}(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda \omega) - \mathcal{V}_c(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda) \tag{11}$$

$$W(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda \omega) = \mathcal{W}_{2p1h}(j_\Lambda l_\Lambda k_\Lambda k'_\Lambda \omega). \tag{12}$$

B. Solution of the Schrödinger equation

??ö$\Lambda 2p1h$ö$R_{box} R_{box}$15

$$\Phi_{iljm}(\mathbf{r}) = \langle \mathbf{r} | k_i ljm \rangle = N_{il} j_l(k_i r) \psi_{ljm}(\theta\phi) \tag{13}$$

$\psi_{ljm} j_l k_i$

$$j_l(k_i R_{box}) = 0. \tag{14}$$

$l = 0$

$$N_{i0} = \frac{i\pi 2^{1/2}}{R_{box}^{3/2}}. \tag{15}$$

??Λ

$$\sum_{n=1}^{N_{max}} \langle k_i | \, \frac{k_i^2}{2m_\Lambda} \delta_{in} + V(\omega = E_\Upsilon) \, | k_n \rangle \langle k_n | \Upsilon \rangle = E_\Upsilon \langle k_i | \Upsilon \rangle \,, \tag{16}$$

2030??$r = R_{box} R_{box}$?

III. RESULTS AND DISCUSSION

YNV_{YN}?ü?$F/D\alpha$ü
??$\Lambda k_F = 1.36^{-1} \omega_{NM} = -80 \Lambda YN$??*et al.*?*et al.* ?$\Lambda$üü
${}^3S_1 - {}^3D_1 \, {}^1S_0 \Lambda \Lambda N \Sigma N \Lambda$
$\Lambda^{17}_{\Lambda} l_\Lambda = 0$ü$\Lambda A \to \infty$?
Λ^{17}_{Λ}??ΛöGüΛ??$\Lambda 0 s_{1/2}{}^{16}$?
$2p1h \mathcal{V}_{2p1h}$??$\mathcal{V}_c$????$k_F = 1.36^{-1} HF + 2p1h G \omega_{NM} HF$
$\Lambda 2p1h$??
??ΛG??
rr

$$\mathcal{V}_{HF}(l=0,r,r') = \frac{2}{\pi} \int k^2 dk \int k'^2 dk' j_0(kr) j_0(k'r') \mathcal{V}_{HF}(l=0,k,k') \tag{17}$$

$\mathcal{V}_{HF}(l=0,r,r') r' \Upsilon_1(r)$

$$\mathcal{V}^{loc}_{HF}(l=0,r) = \frac{\int dr' r'^2 \mathcal{V}_{HF}(l=0,r,r') \Upsilon_1(r')}{\Upsilon_1(r)}. \tag{18}$$

$\mathcal{V}^{loc}_{HF}(r) \Upsilon_1(r)$
??

$$V_{WS}(r) = \frac{V_0}{1 + \exp{(r-R)/a}}, \tag{19}$$

$V_0 = -22.40 R = 3.15 a = 0.6$??$\Lambda 0.99994$
$\Lambda R a V_0(E)$??$\Lambda k k m_{k,\Lambda}$?

$$\frac{m_{k,\Lambda}(E,r)}{m_\Lambda} = \left(1 + \frac{m_\Lambda}{k} \frac{dV}{dk} \right)^{-1} = \left(1 + \frac{dV(E,r)}{dE} \right)^{-1}. \tag{20}$$

??$m_{k,\Lambda}/m_\Lambda = 0.8$
$\Lambda \mathcal{V}_{2p1h} 2p1h$??$l_\Lambda = 0 \langle \Upsilon_1 \mid \mathcal{V}_{2p1h}(\omega) + i\mathcal{W}_{2p1h}(\omega) \mid \Upsilon_1 \rangle$
??ü$\mathcal{W}_{2p1h}$üω??$\omega = 0 2p1h$??
?????????$V_0 \mathcal{V}_{2p1h} - \mathcal{V}_c$??$k$???$V_0$

$$\frac{m^*_\Lambda(E)}{m_\Lambda} = \left(1 - \frac{dV_0(E)}{dE} \right). \tag{21}$$

??m^*/m
$\Lambda l_\Lambda = 0 r$??Λ?$\Lambda -40.5 {}^3S_1 - {}^3D_1$?ü??$5-60$?$\omega = 40-9$
-25?G?
$\mathcal{W}_{2p1h}$????Λ^{16}??Λ???$\Lambda -0.2$?-2.4
Λ

IV. CONCLUSIONS

Λ_{Λ}^{17}?ü?ü$\Lambda\Lambda 0s_{1/2}{}^{17}_{\Lambda}-11.83-7.38$ü?$-12.5\Lambda$?

V. ACKNOWLEDGMENTS

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TABLE I. Partial wave contributions to the binding energy of the Λ in nuclear matter for the Jülich and Nijmegen potentials at Fermi momentum $k_F = 1.36$ fm^{-1}. Numbers in parentheses refer to the case when the coupling to intermediate ΣN is omitted in the calculation of the ΛN G–matrix. The total numbers include partial waves with total angular momentum $J \leq 4$. All entries in MeV.

	$^1S_0$	$^3S_1$–$^3D_1$	$^3P_0$	$^1P_1$–$^3P_1$	$^3P_2$–$^3F_2$	Total
Jülich	-0.6	-33.95	0.59	3.04	0.093	-31.48
	(1.61)	(-19.98)	(0.62)	(3.31)	(0.25)	(-11.93)
Nijmegen	-14.99	-8.17	0.37	3.54	-3.88	-24.35
	(-13.84)	(13.63)	(0.43)	(4.36)	(-2.92)	(0.57)

TABLE II. Single–particle energy (ε_Λ), mean–square radius (rms) and kinetic energy (T) for a Λ in the $0s_{1/2}$ state of $^{17}_{\Lambda}$O. The results are given for the Jülich and Nijmegen potentials and for two approximations to the self–energy: the Hartree–Fock (HF) and the Hartree–Fock plus the two–particle–one–hole diagram (HF+2P1H). Energies are in units of MeV and rms in units of fm.

	Jülich		Nijmegen		Exp
	HF	HF+2P1H	HF	HF+2P1H	
ε_Λ	-10.15	-11.83	-4.76	-7.38	-12.5 [**?**]]bando3
T	6.43	6.49	4.43	5.08	
rms	2.49	2.47	3.04	2.80	

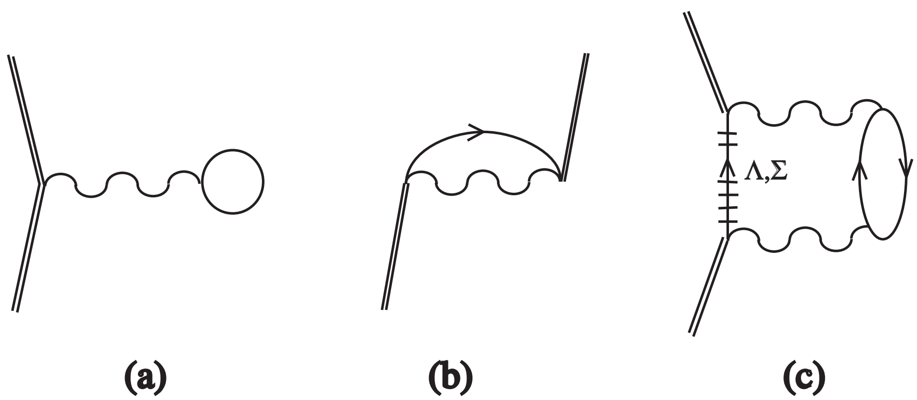

FIG. 1. Diagrams through second order in the interaction G_{YN} (wavy line) included in the evaluation of the self–energy of the Λ. Diagrams (a) and (b) represent the direct and the exchange Hartree–Fock terms, while (c) is an example of the second order two–particle–one–hole diagram. Note that the double external lines represent a Λ while the "railed" line in (c) refers to a intermediate Λ and Σ hyperon.

FIG. 2. Wave function in r–space for the Λ in the $0s_{1/2}$ state in ${}^{17}_{\Lambda}\mathrm{O}$ for the Jülich (solid line) and the Nijmegen (dashed line) potentials. For comparison we include the single nucleon wave function (dash–dotted line) in ${}^{16}\mathrm{O}$ from Ref. [26].

FIG. 3. Local single–particle potentials for a Λ in the $0s_{1/2}$ state in ${}^{17}_{\Lambda}\mathrm{O}$ employing the Jülich potential. Solid line represents the results obtained from Eq. (19) while the dashed line is the result obtained with the Woods–Saxon parametrization discussed in the text.

FIG. 4. Energy dependence of the depth of the Λ–nucleus Woods–Saxon potential for a Λ in the $l = 0$ state employing the Jülich potential. The dashed line shows the depths resulting from fitting the phase–shifts to those obtained by including only the Hartree–Fock diagram to the self–energy. Solid line is obtained by including also the two–particle–one–hole diagram in the evaluation of the self–energy.

FIG. 5. Ground state expectation value of the real and imaginary parts of the dispersive term of the Λ self–energy as functions of ω. Solid lines are results obtained with the Jülich potential while dashed lines are those of the Nijmegen potential.

FIG. 6. Local Λ–nucleus Woods–Saxon potential at different Λ energies for a Λ in the $l = 0$ state.

FIG. 7. Imaginary part of the optical potential at different Λ energies for a Λ in the $l = 0$ state.