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POLARIZATION OF Λ HYPERONS PRODUCED BY THE QUASIFREE (Π^+,K^+) REACTION ON ^{12}C

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Polarization of Λ Hyperons Produced by the Quasifree (π^+,K^+) Reaction on ^{12}C

A recent letter [1] has described the very nice determinations of the polarizations of Λ hyperons produced by the quasifree (π^+,K^+) reaction on ^{12}C at a pion momentum of 1.05 GeV/c. These polarizations were deduced from measurements of the asymmetries, with respect to the reaction plane, of the pions from the weak decay $\Lambda \rightarrow \pi^- p$. In the region of the peak in the kaon spectrum, which corresponds to the quasifree Λ production, the polarizations are in very good agreement with those calculated from the elementary Λ production reaction $n(\pi^+,K^+)\Lambda$, with the inclusion of the Fermi momentum of the target neutron in ^{12}C. The firm conclusion, that the Λ production in the ^{12}C target is characterized by the quasifree process in this region, is supported by the fact, as pointed out by the authors, that the Λ depolarization due to final-state interactions (e.g., ΛN rescattering) is expected to be small. This follows because the depolarizing "spin-orbit and/or spin-spin interactions" are known to be small for Λ hypernuclei.

My first remark strengthens this argument by claiming that *only* the spin-spin interaction causes depolarization, so that even a larger spin-orbit interaction would not be of concern. The essential point is that the constraint of parity conservation, which limits the polarization produced in a reaction to be along the normal ($\mathbf{y} = \mathbf{k}_\pi \times \mathbf{k}_\Lambda$) to the production plane, also prohibits the spin flip of this component by the spin-orbit force. Thus, e.g., the spin-orbit interaction simply scatters transverse spin-up and spin-down states differently without any spin flip. Then, since

depolarization requires some spin flip, the spin-orbit interaction does not contribute to it. More specifically, the polarization after scattering of an initially polarized spin-1/2 particle is given by

$$p_{y'} = (P_y + p_y D_{yy'})/(1 + p_y A_y) , \tag{1}$$

where p_y is the initial polarization, P_y and A_y are, respectively, the polarizing and analyzing powers of the scattering, and $D_{yy'}$ is the polarization transfer (depolarization) coefficient [2]. Since A_y and P_y are zero in forward scattering, the polarization after a small-angle rescattering due to a final-state interaction is essentially

$$p_{y'} = p_y D_{yy'} . \tag{2}$$

Then, in terms of the spin $1/2 + 1/2 \rightarrow 1/2 + 1/2$ scattering matrix (for ΛN scattering) [3],

$$M = a_{oo} + a_{yo}\sigma_y\sigma_o + a_{oy}\sigma_o\sigma_y + a_{xx}\sigma_x\sigma_x + a_{yy}\sigma_y\sigma_y + a_{zz}\sigma_z\sigma_z , \tag{3}$$

the projectile (target) spin-orbit amplitude is a_{yo} (a_{oy}) , and the a_{jj} are spin-spin amplitudes. From

$$D_{yy'} = Tr\, M\sigma_y\sigma_o M^{\dagger}\sigma_y\sigma_o / Tr\, MM^{\dagger} \tag{4}$$

one obtains

$$D_{yy'} = \frac{|a_{oo}|^2 + |a_{yo}|^2 + |a_{oy}|^2 - |a_{xx}|^2 + |a_{yy}|^2 - |a_{zz}|^2}{|a_{oo}|^2 + |a_{yo}|^2 + |a_{oy}|^2 + |a_{xx}|^2 + |a_{yy}|^2 + |a_{zz}|^2} . \qquad (5)$$

Thus, $D_{yy'}$ differs from one, thereby signaling some depolarization, only because of the spin-spin amplitudes which provide the required spin flip.

My second remark concerns the explanation for the reduction of the polarization in the higher excitation region of the spectrum, i.e., the lower kaon energy region. The authors suggest that depolarization might occur in a (subsequent) ΛN interaction at these higher Λ energies for which the nucleon could be knocked out of the nucleus. In view of the discussion above, this requires that both the ΛN scattering probability and the spin-spin interaction strength increase substantially with the increase in Λ energy. There is, however, a simple explanation for a decrease in the p_y *component* of the Λ polarization in the production process itself. In the quasifree kinematics, **y**, as defined above, is also the normal to the (π^+,K^+) reaction plane since $\mathbf{k}_\Lambda$ and $\mathbf{k}_K$ are colinear in the c.m. frame. This is not the case when quasifree production no longer applies, since then, with the three- (or more) body final state $K\Lambda X$, the Λ production plane is no longer defined. Thus, in the limit of vanishing quasifree production, the component of Λ polarization along $\mathbf{y} = \mathbf{k}_\pi \times \mathbf{k}_K$ also goes to zero. This result might then be useful in a quantitative distinction among the quasifree and other Λ–production processes.

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