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n-p CHARGE EXCHANGE AS A POLARIZATION ANALYZER OR
SOURCE OF HIGH ENERGY POLARIZED BEAMS

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A B S T R A C T

It is noted that on very simple and plausible assumptions, one may infer from the measurements of the differential cross-section at 8 GeV/c that n-p charge exchange scattering with $0.25 \leq -t \leq 0.5$ (GeV/c)² is a good polarization analyzer or, with polarized target, a source of longitudinally polarized beams.

It is the purpose of this note to point out that from the structure of $d\sigma/dt$ for n-p charge exchange scattering as measured by Manning et al. ¹⁾, one might infer that the double flip helicity amplitude may dominate when $0.25 \lesssim -t \lesssim 0.4$ (GeV/c)². This amplitude, often referred to as ϕ_4 ²⁾, has the structure :

$$\phi_4 = \langle +\frac{1}{2} -\frac{1}{2} | \phi | -\frac{1}{2} +\frac{1}{2} \rangle = \sum_j (2j+1) \beta_j d_{-1,1}^j(\theta). \quad (1)$$

Owing to parity conservation, one has

$$\phi_4 = \langle +\frac{1}{2} -\frac{1}{2} | \phi | -\frac{1}{2} +\frac{1}{2} \rangle = \langle -\frac{1}{2} +\frac{1}{2} | \phi | +\frac{1}{2} -\frac{1}{2} \rangle, \quad (2)$$

If the remaining amplitudes ²⁾ vanish, one sees from (2) that the recoiling particles from the scattering of an unpolarized beam on a longitudinally polarized target will be longitudinally polarized with polarization equal and opposite to the target polarization, while the scattered particles will be longitudinally polarized with the same polarization as the target. Corrections due to non-vanishing ϕ_i for $i \neq 4$ are of second order; the exact expressions for the longitudinal polarizations are

$$I_o \underset{\text{scattered}}{P_{\text{recoil}}} = P_{\text{target}} \left[\mp |\phi_4|^2 + |\phi_1|^2 - |\phi_2|^2 \pm |\phi_3|^2 \right] \quad (3)$$

where

$$I_o = 2 d\sigma/d\Omega = |\phi_4|^2 + |\phi_1|^2 + |\phi_2|^2 + |\phi_3|^2 + 4|\phi_5|^2. \quad (4)$$

Similarly from (2) one sees that when $|\phi_4|^2$ dominates, the reaction may be a useful polarization analyzer ³⁾.

The supposition that ϕ_4 dominates in the range $0.25 \leq -t \leq 0.4$ $(\text{GeV}/c)^2$ is based on the assumption that n-p charge exchange amplitudes behave similarly to π -p and K-p charge exchange amplitudes and decrease roughly like $e^{\sqrt{t}/2}$ with $\sqrt{t} \approx 10 (\text{GeV}/c)^{1/2}$ 4). Owing to its spin structure, ϕ_4 must vanish linearly with t as $t \rightarrow 0$. These properties lead to the conclusion that ϕ_4 has a maximum near $-t \approx 0.2 (\text{GeV}/c)^2$. [The single flip amplitude ϕ_5 must vanish like $\sqrt{t}$ as $t \rightarrow 0$ and, therefore, has a maximum near $-t \approx 0.08 (\text{GeV}/c)^2$.]

The differential cross-section 1), instead of decreasing like $e^{\sqrt{t}}$, flattens out in the region of $0.2 \leq -t \leq 0.4$. This could be due to a $|\phi_4|^2$ contribution. If so, this flattening is analogous to the small maximum in $\pi^- p \rightarrow \pi^0 n$ and $K^- p \rightarrow \bar{K}^0 n$ near $-t = 0.08 (\text{GeV}/c)^2$ which is attributed to the contribution of the spin-flip amplitude 4).

A fit to the n-p charge exchange data 5) shows quantitatively how the contribution of $|\phi_4|^2$ may account for the flattening of the $d\sigma/dt$ v. $-t$ curve in the region of $0.2 \leq -t \leq 0.4 (\text{GeV}/c)^2$. In this region, the amplitudes of Ref. 5) simply reflect the properties outlined above. Figure 3 of Ref. 5) shows the extent to which ϕ_4 may dominate the scattering.

A more detailed discussion of polarization effects in n-p (and $\bar{p}$ -p) charge exchange scattering will be given in a forthcoming publication.

R E F E R E N C E S

- 1) G. Manning, A.G. Parham, J.D. Jafar, H.B. van der Raay, D.H. Reading, D.G. Rejan, B.D. Jones, J. Malos and N.H. Lipman, Nuovo Cimento 49, 189 (1966).
- 2) M.C. Goldberger, M.T. Grisaru, S.W. MacDowell and D.Y. Wong, Phys. Rev. 120, 2250 (1960).
- 3) The differential cross-section with longitudinally polarized target (P_L) and beam polarized with polarization vector $\underline{Q}$ differs from that with unpolarized target, viz.,

$$2 \left[\left(\frac{d\sigma}{d\Omega} \right)_{P_L} - \left(\frac{d\sigma}{d\Omega} \right)_{P_L=0} \right] = -P_L \left[Q_L (|\phi_4|^2 + |\phi_3|^2 - |\phi_2|^2 - |\phi_1|^2) + Q_p \sin\phi \, 2 \operatorname{Re} \{ \phi_5 (\phi_4 + \phi_3 - \phi_2 - \phi_1)^* \} \right]$$

where

$$2 \frac{d\sigma}{d\Omega} = I_0 = |\phi_4|^2 + |\phi_1|^2 + |\phi_2|^2 + |\phi_3|^2 + 4 |\phi_5|^2$$

Q_L = longitudinal beam polarization = $\underline{Q} \cdot \hat{k}_i$

$\vec{k}_i$ = incident beam momentum

Q_p = transverse beam polarization

$\sin\phi = \hat{k}_i \cdot \hat{n} \times \hat{Q}$

$\underline{n} = \underline{k}_i \times \underline{k}_f$ = normal to scattering plane.

- 4) See, for example, L. Van Hove, Proceedings of the XIIIth International Conference on High Energy Physics, Berkeley (1966) - University of California Press;
N. Byers and C.N. Yang, Phys.Rev. 142, 976 (1966).
- 5) N. Byers, Phys.Rev. 156, 1703 (1967).