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SPIN-1 PARTICLES

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December 1984

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Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

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LBL-18881

Vector Polarization in Reactions with Spin-1 Particles*

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*This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098.

Vector Polarization in Reactions with Spin-1 Particles

In a recent Letter[1)] it was shown that in nuclear or particle reactions involving a spin-1 particle, a determination of the amplitudes can be made without measuring any polarization observables that require vector polarizations in either the initial or final state. Only Lorentz invariance of the reaction was assumed in this discussion. It was noted, however, that discrete ambiguities are not necessarily eliminated. When parity conservation is also imposed, which is the situation of the greatest practical importance, the remaining discrete ambiguities can in fact be easily seen, so we consider it important to expand on and clarify this point.

As before, we consider first the simplest master reaction with the spin structure $0 + 0 \to 0 + 1$. Parity conservation, with the product of the intrinsic parities $\pi_T=+1$, reduces the three helicity amplitudes A, B, and C (corresponding to helicities +1, 0,-1) to A=C and B=0; so the cross section alone, $\sigma = 2|A|^2$, provides the determination of A, and all polarization components are fixed and known.[2)] For $\pi_T=-1$, A=-C and $B \neq 0$, and the non-zero observables are

$$\sigma = 2|A|^2 + |B|^2 \tag{1}$$

$$\sigma p_{zz} = 2|A|^2 - 2|B|^2 \tag{2}$$

$$\sigma(p_{xx} - p_{yy}) = -6|A|^2 \tag{3}$$

$$\sigma p_{xz} = 3\sqrt{2}\,\mathrm{Re}AB^* \tag{4}$$

$$\sigma p_{y=} 2\sqrt{2}\,\mathrm{Im}\,AB^*. \tag{5}$$

One sees here that information on the imaginary part of the product of amplitudes is now attainable only from measurement of the vector polarization. Thus, from the tensor polarizations one can determine A , B , and cos ϕ, where ϕ is the phase angle between A and B. Since the sign of ϕ is not determined, there is a two-fold discrete ambiguity in the sign of the vector polarization p_y. This can be eliminated, however, by a very crude measurement, since $|p_y|$ is known.

Since the ranges of values of the polarization components in this master reaction are so restricted by parity conservation[2], it is useful to examine a reaction with the simplest spin structure for which parity conservation does not limit the ranges of the observables. This occurs for elastic scattering with the spin structure $1 + 0 \to 1 + 0$, where parity conservation and time-reversal invariance reduce the $3 \times 3 = 9$ transition-matrix amplitudes to four invariant ones, A, B, C, and D. As a generalization of eq. (5), the imaginary parts of the six bilinear products of these amplitudes can be written in terms of the observables as follows[3]:

$$
\begin{aligned}
\mathrm{Im}\, AB^* &= -\sigma K_z^{\,y} \\
\mathrm{Im}\, AC^* &= \sigma K_y^{\,z} \\
\mathrm{Im}\, AD^* &= (1/2)\sigma(A_y - K_y^{\,x}) \\
\mathrm{Im}\, BC^* &= -\sigma K_x^{\,z} \\
\mathrm{Im}\, BD^* &= \sigma K_z^{\,z} \\
\mathrm{Im}\, CD^* &= (1/2)\sigma(A_y + K_y^{\,x}),
\end{aligned}
\qquad (6)
$$

where K_i^{jk} and A_y are polarization transfer coefficients and the vector analyzing-power, respectively. The subscripts (superscripts) refer to the initial (final)-state polarization components. In analogy with eq. (5), it is seen that eqs. (6) involve initial-state vector polarization components, which must be used in order to remove the implied many-fold discrete sign amibiguity. However, it has been shown recently that determinations of, for example, $ReAB^*$, $ReBC^*$, $ReCD^*$, (which inolve only tensor polarizations) and $Im\ AD^*$ alone can eliminate these discrete ambiguities[4]. Since the determination of $Im\ AD^*$ requires only initial-state vector polarization, which is easily provided in a polarized beam, it follows that a complete determination of the amplitudes can be made from measurements of final-state tensor-polarization components alone.

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This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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