A Measure of the Polarization of High-Energy $\bar{p}$ Beam from Angular Correlation in Reaction $\bar{p}p \rightarrow \bar{Y}Y$.

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Summary. -- Angular correlation measurements in hyperon production by antiprotons in hydrogen yield a possible determination of the polarization of a high-energy $\bar{p}$ beam, to within the sign of its transverse component. The proposed method provides further a way of determining the transition matrix of the reaction, to within a similar ambiguity in sign.

1. - Introduction.

The $\bar{p}$ beams produced in large accelerators may have some polarization. Since the production of antiprotons is reflection-invariant, this polarization is known to be perpendicular to the production plane and, in the usual experimental arrangements, this direction is preserved, but the magnitude and the sign of the polarization are not known. The main purpose of this note is to show that, for beams of sufficiently high energy, the magnitude (but not the sign) of this transverse polarization is directly accessible from angular correlation measurements on the decay particles of $\bar{Y}Y$ pairs produced in the reaction

$$\bar{p}p \rightarrow \bar{Y}Y,$$

provided that the hyperon $Y$ has an asymmetric decay (e.g. $\Lambda$, $\Sigma^+$, ..., but not $\Sigma^-$). The results that we give are in fact somewhat more general, i.e.,
the correlation experiment yields a complete determination of the polarization of the $\bar{p}p$ beam, whatever it may be, to within the sign of its transverse component \(^{(1)}\), and also a determination, to within a similar ambiguity in sign, of the elements of the transition matrix $T(\theta)$ of reaction (1). (As usual we denote by $\Omega = (\theta, \varphi)$ the direction of emission of the $\bar{Y}$ in the c.m. system.)

In short the line of argument goes as follows. As shown in Sect. 3, angular correlation measurements on the decay products of the $\bar{Y}Y$ pair permit to determine all the elements of its polarization matrix $\varrho_Y$. The latter is related, through the matrix equation \(^{(2)}\)

$$\varrho_Y = T_{2p} T^*$$

to the polarization matrix $\varrho_p$ of the $\bar{p}p$ pair, which in turn depends in a simple way on the beam polarization and on the azimuthal angle $\varphi$. Resolving eq. (2), we obtain expressions for the beam polarization (Sect. 4) and for the elements of $T$ (Sect. 5) in terms of $\varphi$-averages of elements of $\varrho_Y$, i.e. in terms of measurable quantities. It is important to note that the expressions, that we give in Sect. 4 and 5, are valid for any value of $\theta$. In particular, every event may be used in the determination of the polarization with the expressions given in Sect. 4. At the end of this note (Sect. 6), however, we investigate in more detail the forward and backward production, and give simpler expressions which hold only in these cases.

The interest of angular correlations in reaction (1) has already been stressed in the literature, in connection with the peripheral model \(^{(3-4)}\). As shown in ref. \(^{(1)}\), the measurement of the transverse polarization turns out to be extremely simple, when the peripheral model holds. We want to emphasize that, in the present work, we have not restricted ourselves to any particular model, and that our results do not imply any other assumption about the mechanism of reaction (1) than the known invariance properties of strong interaction processes.

\(^{(1)}\) In particular, the longitudinal polarization, if any, is obtained with its sign. Therefore, it is possible to obtain the sign of the transverse polarization if one happens to know the sign of the ratio longitudinal to transverse. Magnets and fields, arranged in such a way as to give some longitudinal polarization to the $\bar{p}p$ beam, could achieve this result.

\(^{(2)}\) We assume as usual $\text{Tr} \varrho_p = 1$, but take for convenience a different normalization for $\varrho_Y$. $\text{Tr} \varrho_Y$ is, to within phase-space factors, the cross-section for observing the $\bar{Y}Y$ pair.
