Angular distribution technique to measure Λ^0 polarization

Julián Félix
Instituto de Física, Universidad de Guanajuato, León, Guanajuato, Mexico

Recibido el 23 de noviembre de 1998; aceptado el 15 de febrero de 1999

It is reported a technique to measure Λ^0 polarization; this technique consists on fitting to a straight line the Λ^0-decay-proton angular distributions, determined in the Λ^0 rest frame; the slope of the fit is directly related to the Λ^0 polarization.

Keywords: Λ^0; polarization; angular distribution

Se reporta una técnica para medir la polarización de Λ^0; esta técnica consiste en ajustar a una línea recta la distribución angular del protón proveniente del decaimiento de Λ^0, determinada en el sistema donde Λ^0 está en reposo; la pendiente del ajuste está relacionada directamente con la polarización de Λ^0.

Descriptores: Λ^0; polarización; distribución angular

PACS: 07.05.K; 02.50

1. Introduction

In experimental high energy physics, it is a common practice to develope techniques to analyze data and never formally report them; they pass by word of mouth between the physicists and occasionally are reinvented. This phenomenon probably happens because habitually in the letters or rapid comunications there is not space enough to make a detailed description of the used technique; for that reason, only bits, trying to describe briefly the employed technique, are given, making, sometimes, more obscure such technique.

In this paper we describe a technique to measure Λ^0 polarization. This technique mainly consists on fitting to a straight line the Λ^0-decay-proton angular distributions, determined in the Λ^0 rest mass coordinate system; the polarization is extracted from the fit slope and fit interception, knowing the asymmetry decay parameter in the channel $\Lambda^0 \to p\pi^-$.

2. The technique

In all experimental studies of Λ^0 polarization, Λ^0 is detected and analyzed through the decay channel $\Lambda^0 \to p\pi^-$ [1]; such decay occurs with $63.9 \pm 0.5\%$ of probability [3]. To determine Λ^0 polarization, or any other hyperon polarization, we need to experimentally define a coordinate system, in particular the quantization axis, with respect to which we want to measure the polarization. To define this coordinate system and to introduce some essential concepts, consider the Fig. 1. In Fig. 1a it is sketched the laboratory coordinate system; the production plane is defined by the Λ^0 momentum (P_Λ) and the beam momentum (P_{beam}), the normal to the production plane is defined by

$$\mathbf{n} \equiv \frac{P_{\text{beam}} \times P_\Lambda}{|P_{\text{beam}} \times P_{\Lambda|}}. \qquad (1)$$

For a detailed description, see Ref. 1.

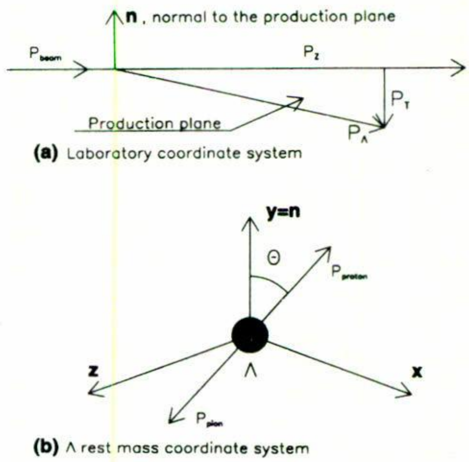

FIGURE 1. (a) Laboratory coordinate system and some useful variables are shown; the normal to the production plane is defined by Eq. (1). (b) Λ^0 mass rest coordinate system is shown.

The normal to the production plane is taken as the quantization axis; its direction is a Lorentz invariant, when the boost is made along the P_Λ direction back to the Λ^0 mass rest frame. In Fig. 1b this situation is drawn; the $\mathbf{y}$ axis is along $\mathbf{n}$ (the quantization axis), the axis $\mathbf{z}$ is along the Λ^0 momentum, and $\mathbf{x} = \mathbf{y} \times \mathbf{z}$. It is very well known that the angular distribution of the proton, in the Λ^0 mass rest frame is given by [2, 4]

$$\frac{\mathrm{dN}}{d\Omega} = N_0(1 + \alpha \mathcal{P} \cos\theta), \qquad (2)$$

where dN is the number of protons, from the Λ^0 decay, inside of the solid angle $d\Omega$, N_0 is a normalization constant, the asymmetry parameter, α, is 0.642 ± 0.013 [3], $\mathcal{P}$ is the Λ^0 polarization along the normal to the production plane, and the angle θ is defined by $\cos\theta = \hat{\mathbf{p}}_{\text{proton}} \cdot \mathbf{n}$. For a detailed derivation of this formula, see Ref. 4.

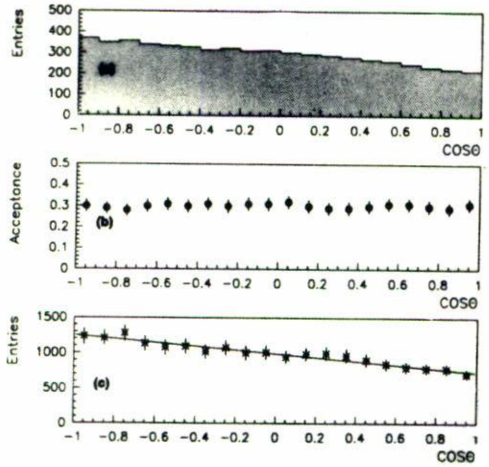

FIGURE 2. (a) $\cos\theta$ distribution of data, (b) $\cos\theta$ distribution of the acceptance, and (c) $\cos\theta$ distribution of the corrected for detector acceptance data are shown.

The polarization normally is studied as function of P_T [1], if this is the case, in each P_T bin $\cos\theta$ must be histogrammed, see Fig. 2a for an ideal example, this is a typical distribution. Before fitting to a straight line, it must be corrected for detector acceptace.

The normal technique to study the detector acceptance is the Monte Carlo technique [4]. It consists on generating a data sample (we call this the generated sample) and passing it through a computational simulated detector that truly emulates all aspects of the detector (the sample that pass the computational detector simulator is called the accepted sample); in principle if the generated sample is a good one, this accepted sample must resembles all the real distributions (P_T, x_F, P_Λ, P_{proton}, etc.), if not we must start again with another generated sample; this circle must be repeated until we get a good accepted sample. In practice this circle could be endless, very consuming time; a more manageable approach is to reproduce only the distributions used in determining Λ^0 polarization (P_T, etc.). With these two samples, the detector acceptance is defined as the ratio of the accepted data to the generated data, in each $\cos\theta$ bin. The cceptance is less than one due to the limited geometry of the detector, inefficiencies in the spectrometer devices, inefficiencies in the event reconstruction, etc. An example of acceptance is given in Fig. 2b.

To set ideas up, suppose that in the bin j of the $\cos\theta$ distribution there are R_j entries; and that for Monte Carlo studies of the acceptance, in the same bin we generated G_j events; and that from those generated events only A_j are accepted: The acceptance is defined by the ratio

$$Acc_j \equiv \frac{A_j}{G_j}. \tag{3}$$

The correction for detector acceptance must be done bin by bin in the $\cos\theta$ distribution, the corrected for acceptance distribution is the ratio of the real distribution to the acceptance, an example is given in Fig. 2c.

In other words, suppose that after the correction in the bin j we get C_j events, these are obtained by

$$C_j = \frac{R_j}{Acc_j}. \tag{4}$$

In each step, the propagation of errors must be done carefully and included in the corresponding analysis.

The corrected for acceptance distribution is the one that must be fitted to a straight line ($y = mx + b$); from the fit m and b are obtained, indeed the corresponding errors. Comparing with the Eq. (2) we obtain:

$$N_0 = b, \qquad \mathcal{P} = \frac{m}{\alpha b}; \tag{5}$$

combining in quadratures the uncertainty of α ($\Delta\alpha$), the uncertainty of the slope m (Δm), and the uncertainty in the interception b (Δb), the uncertainty in the polarization $\mathcal{P}$ ($\Delta\mathcal{P}$) is given by

$$\Delta\mathcal{P} = \frac{m}{\alpha b}\left[\left(\frac{\Delta m}{m}\right)^2 + \left(\frac{\Delta b}{b}\right)^2 + \left(\frac{\Delta\alpha}{\alpha}\right)^2\right]^{\frac{1}{2}}. \tag{6}$$

Where it is assumed that there are no correlations between those parameters. This uncertainty takes into account only statistical errors.

Ideally, it is necessary a Monte Carlo with infinite number of events; in practice to make an acceptable correction, the accepted sample must be at least ~ 3 times the real data; this is what experience tells. Also the experience shows that this technique works very well at high statistics, and begins to give sham results as statistics becomes lower.

3. Conclusions

We have presented a technique to measure Λ^0 polarization that make use of the angular distribution of the Λ^0-decay-proton in the Λ^0 mass rest frame. This technique works properly at high statistics.

Acknowledges

This work was partially supported by CONACyT, México, under Grant 458100-5-3793E.

1. J. Félix, *Mod. Phys. Lett. A* **12** (1997) 363.
2. J. Félix *et al.*, *Phys. Rev. Lett.* **76** (1996) 22.
3. Particle Data Group, *Phys. Rev. D* **50** (1994) 1.
4. J. Félix, Ph.D. thesis, Universidad de Guanajuato, México, 1994.