Effect of exotic S=+1 resonances on K^0
Lp scattering data

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We consider the effect of an exotic S=+1 Θ^+ resonance on the scattering of neutral kaons off protons. Explicit results are presented for the K^0
Lp total cross sections.

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Results from a wide range of recent experiments are now consistent with the existence of an exotic S=+1 resonance, the Θ^+(1540), having a narrow width and a mass near 1540 MeV [1]. Width determinations have been hindered by limitations on experimental resolutions, resulting in upper bounds of order 10 MeV. The quantum numbers of this state remain unknown, though a prediction of J^P = 1/2^+ was obtained in the work [2] that provided a motivation for the original search.

An examination of older K^+d and K^+p data has provided no confirmation for the Θ^+ or an associated Θ^++ state [3]. In fact, these older measurements seem to require a width much smaller than 10 MeV [4, 5, 6, 7]. Most investigations of the older data have focused on K^+d experiments from which the K^+n interaction has been extracted. The effect of Fermi motion in the deuteron is particularly important for a narrow structure, making the observation of a 'bump' in any cross section unlikely. This point has been extensively demonstrated by Nussinov [4], and by Cahn and Trilling [7].

The problems of Fermi motion can be avoided if instead one considers the K^0
Lp interaction. However, as the K^0
L is a mixture of K^0 and K^- (assumed Gaussian) having widths of order 10 MeV/c at 440 MeV/c, the latter being an estimate of the momentum spread associated with the beam used in Ref. [10]. A resonance in the D^3
0 partial wave is also included for comparison.

The measurement of Ref. [10] was reported with total cross sections calculated over 20 MeV/c bins. We have accordingly averaged over this interval, finding a further minimal reduction in the peak. Results for resonances with a range of widths are compared in Fig. 3. From Fig. 1, the most pronounced deviations from our predicted smooth behavior occur near 280 and 460 MeV/c (corresponding to C.M. energies of 1480 and 1550 MeV). The apparent 'bump' at 1480 MeV could be more than a statistical fluctuation. The PDG [12] reports a 1-star Σ(1480) based on an analysis of K^-p → K^0npπ^-, with a 3.5 standard deviation signal being seen in K^0
p. (The data of Ref. [11] does not show this structure.) Given the large experimental uncertainties, a fluctuation near 1550 MeV is only interesting in that it occurs near the expected Θ^+(1540) signal. (The overall momentum scale has a quoted uncertainty of 2%.) Here too the PDG reports a weak evidence for a nearby bump, the Σ(1560).

\[ M_{K^0_Lp} = \frac{1}{4}(Z_1 + Z_0 + 2Y_1) \] (1)

where Z_{0,1} are the strangeness S = 1, I = 0 and 1 amplitudes, and Y_1 is the S = -1, I = 1 amplitude. The Y_1 contribution dominates at low energies, the S = 1 component growing in relative importance with increasing energy. Our result for the K^0
Lp total cross section, calculated from the imaginary part of the forward scattering amplitude, is given in Fig. 1. Note that this is not a fit but rather a prediction based on analyses of other reactions.

Starting from this description of the data, we have added a narrow Breit-Wigner resonance in order to demonstrate the magnitude of its effect. In doing so, we have taken into account the fact that the incident K^0
L beam has a momentum spread, which also tends to smear out a narrow structure. In Fig. 2 we have added an S = +1 resonance, having a 5 MeV width, to the P_{01} partial wave. Here we compare the result for beam momentum distributions (assumed Gaussian) having widths of 10 and 20 MeV/c at 440 MeV/c, the latter being an estimate of the momentum spread associated with the beam used in Ref. [10]. A resonance in the D^3
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In conclusion, present $K^0 p$ scattering data are insufficiently precise to confirm the $\Theta(1540)$. However, if more precise data were to become available, with improved momentum resolution, this method would have the advantage of producing a resonance structure, unlike the $K^+ n$ cross sections extracted from deuteron target experiments which are fundamentally limited by Fermi momentum. In this case, the main limiting factor for a determination of $\Theta^+$ properties would be our knowledge of weak $\Sigma$ resonances [13].

Acknowledgments

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FIG. 1: Total cross section for $K_L^0 p$ (solid) and contributions (dashed) from $S = -1$ and (dotted) $S = +1$. Data sets from Ref. [10] (open and solid circles) and Ref. [11] (open triangles).
FIG. 2: Effect of 1540 MeV $P_{01}$ resonance of width 5 MeV for a 10 MeV/c (dashed) and 20 MeV/c (solid) momentum spread. Effect of a $D_{03}$ resonance of same mass and width (20 MeV/c spread) displayed for comparison (dotted). Dash-dotted curve gives the unmodified total cross section for $K^0_L p$. Data as in Fig. 1.

FIG. 3: Resonance signal for a 1540 MeV $P_{01}$ resonance of width 1 MeV (dotted), 2 MeV (dashed), and 5 MeV (solid), for a 20 MeV/c momentum spread. Dash-dotted curve gives the unmodified total cross section for $K^0_L p$. Data as in Fig. 1.