Strong Enhancement of Weak Amplitudes and Helicty Dependence of Proton Total Cross Sections

Lockyer *et al.*[1] have reported the helicity dependence of the 6-GeV proton total cross section on water as $(\sigma_+ - \sigma_-)/2\sigma = (2.65 \pm 0.60) \times 10^{-6}$. There are several ways to see that this is a large effect: (1) The same effect has been measured at 15 MeV[2] and at 50 MeV,[3] where it is an order of magnitude smaller, and in good agreement with potential model calculations which imply a maximum signal at 50 MeV.[4] (2) Two meson-exchange model calculations[5,6] yield predictions less than 10^{-7}. (3) The imaginary part of the helicity-dependent forward scattering amplitude implied by experiment is 10 times larger than the (purely real) forward amplitude for neutrino-nucleon charge-exchange scattering, which sets a natural scale for such amplitudes.[7]

Accepting that the reported effect is large, we may inquire whether comparably large effects have been seen in other nonleptonic weak processes. Nearly two decades ago this issue was a topic of considerable discussion.[8-11] Schwinger[8] and Feynman[11] described explicit calculations doubtless performed by others as well. We adapt Feynman's result by asking, since $\Delta I = \frac{1}{2}$ amplitudes dominate the $K \to 2\pi$ and $\Lambda \to N\pi$ decays, how much must the $\Delta I = \frac{1}{2}$ parts of the "naive" amplitudes, $(K^0 \to \pi^+ W^-) \times (W^- \to \pi^-)$ and $(\Lambda \to p W^-) \times (W^- \to \pi^-)$, be enhanced to agree with experiment? The results are a factor of 10 for the $K \to 2\pi$ amplitude, and a factor of 8 for $\Lambda \to N\pi$.

Of course, the (four-body) nucleon scattering problem is quite different from the three-body decay problem, so that one could not have predicted the large experimental effect on the basis of the known enhancements of strangeness-changing decays. However, given that example, the reported helicity dependence deserves to be treated with no less confidence than would be accorded any result from a single experiment of such difficulty. The number, though large, is quite consistent with our still imperfect knowledge of weak interactions. A similar comment applies to the large circular polarization of γ rays reported in the reaction $n + p \to d + \gamma$ at low energy.[12]

In the experimentally well established case of strangeness-changing decays, there is a substantial literature of sophisticated calculations which come much closer to agreement with observations than the simple W exchange described above.[13] Perhaps deeper study of theory for the newer experiments might reveal further cases of strong enhancement of weak interactions. Two of us (T.G. and D.P.) have undertaken such a study for helicity dependence of nucleon total cross sections.

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