Does the πNN coupling "constant" vary with energy?

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We examine a recent suggestion for an energy dependence of the pion-nucleon coupling in *pp* scattering. Hoshizaki and Tanaguchi find that this coupling increases from 13.5 at low energies to 18.5 at 800 MeV, using a *pp* partial-wave analysis method. We find large errors associated with such an extraction and no evidence for a rapid variation. The influence of a coupled $N\Delta$ channel complicates such studies.

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Knowledge of the pion-nucleon (πNN) interaction is crucial to our understanding of nuclear and particle phenomenology. The pion mediates the long-range part of the nucleon-nucleon (NN) interaction and is the most precisely measured of all meson-exchange contributions. In analyzing NN elastic scattering data, the high partial waves are usually assumed to be given by the one-pion-exchange (OPE) interaction alone. In potential-model calculations, the πNN coupling is rarely varied. Even when varied, this coupling generally remains stable within a few percent, if data below 400 MeV are analyzed.

It is therefore important to understand a recent analysis [1] in which it is claimed that the πNN coupling has an energy dependence noticeable above 600 MeV in the laboratory kinetic energy. Data analyses have utilized the OPE interaction for high partial waves far beyond 600 MeV [2]. If the claim of Ref. [1] is correct, the OPE approximation would be very poor indeed. In fact, the authors of Ref. [1] suggest that meson theory begins to break down at this energy. The suggested [1] explanation is analogous to the Landau energy in quantum electrodynamics (QED). While such problems may occur in meson theory [3], at some large value of pion Q^2, there are more modern reasons [3] (based on the properties of QCD) to expect that one would not observe this behavior.

While the model proposed in Ref. [1] may not describe a rapid variation of the πNN coupling, the existence of this behavior is a separate issue. Before proceeding, we first suggest a problem with the method of analysis [1] used by Hoshizaki and Tanaguchi. The effect of inelasticity on high partial waves is not accounted for in the OPE model they have cited. The influence of a coupled $N\Delta$ channel, which has been described recently by Fasano and Lee [4], and others [5], modifies the simple OPE contribution [6] used in Ref. [1]. The effect on partial waves beyond $^3J_7$ is significant at 800 MeV. These results imply that the coupling to inelastic channels will reduce the reliability of g^2 extractions at higher energies.

In order to directly check the results of Ref. [1], we have ignored the effects of inelasticity, and have mapped the πNN coupling against χ^2 at 800 MeV. Our results are considerably different than those of Hoshizaki and Tanaguchi. We analyzed data between 775 and 825 MeV [7], varying the cutoff for searched partial waves, and found a shallow χ^2 minimum for $g^2/4\pi = 15.56 \pm 1.04$. The uncertainty quoted here is determined from an error matrix and is probably too small. This result, when combined with the uncertainties due to inelasticity, does not support an energy-dependent coupling.

We should also note that the 800-MeV result was anomalous in an earlier analysis [8] by Hoshizaki and co-workers. In that analysis, the solution at 750 MeV (using $g^2/4\pi = 14.4$) had a χ^2/datum of 0.91, compared to 1.49 at 800 MeV. (The 665, 706, 730, and 750 MeV points from Ref. [8] are missing in the results of Ref. [1].) The χ^2/datum was significantly less than 1 for several of these single-energy analyses. This suggests that the fits may have been overparametrized. Another interesting feature of the 800-MeV solution is found if one compares Fig. 1 of Ref. [1] with Table I of Ref. [8]. The χ^2/datum for 800-MeV solutions having the same number of data and the *same* πNN coupling has changed from 1.49 in Ref. [8] to 1.2 in Ref. [1]. While no comment is made in Ref. [1], this change is likely due to a change in the number of searched partial waves.

In conclusion, we have examined the claim of an energy dependence for the πNN coupling, finding no convincing evidence for such behavior. The influence of inelastic channels greatly complicates the extraction attempted in Ref. [1].

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[3] The behavior suggested in Ref. [1] is a feature of theories lacking asymptotic freedom. However, meson theory is not valid at high Q^2, where QCD is expected to be correct. (We should also note that the coupling would vary with Q^2 rather than the incident energy.) Since, in QCD, one *does* have asymptotic freedom, this behavior will not occur. See the more modern discussion in, for example, P.D.B. Collins, A.D. Martin, and E.J. Squires, *Particle Physics and Cosmology* (Wiley, New York, 1989), Sec. 2.6.

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[7] This energy range contained 1033 data points. Only 10% of these were more than 10 MeV from the central energy, with roughly equal numbers above and below. Similar results were found for the coupling in two different fits. One took the $^3J_7$ cutoff for searched partial waves; the other used a cutoff at J=5. The χ^2/datum for our minimum was 1.5. More detailed comparisons with Ref. [1] would require knowledge of their energy bin width, and their method for describing energy dependence over this range (we have used the energy-dependence found in our global fit [2] to 1.6 GeV).

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