Determination of the πNN Coupling Constant from Elastic Pion-Nucleon Scattering Data

Richard A. Arndt, Zhujun Li, L. David Roper, and Ron L. Workman
Department of Physics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061
(Received 4 May 1990)

We have analyzed the available pion-nucleon elastic scattering data with laboratory kinetic energy below 2 GeV and have extracted the charged-pion–nucleon coupling constant. The extracted value of f^2, using fixed-t dispersion relations, is found to be 0.0735 ± 0.0015, a value in conflict with the result of Koch and Pietarinen, yet consistent with the value of the $\pi^0 pp$ coupling determined in the recent Nijmegen analysis of pp scattering data.

PACS numbers: 13.75.Gx, 11.50.−w, 21.30.+y, 25.80.Dj

In a recent analysis of the low-energy pp data, Bergervoet *et al.*[1,2] have determined the value of the $\pi^0 pp$ coupling constant. Their extracted value of the $\pi^0 pp$ coupling, which was found to be[2] 0.0749 ± 0.0007, is more than 3 standard deviations below values[3] found for the charged-pion coupling. They interpreted their result as possible evidence for a large breaking of charge independence.

Recently, Thomas and Holinde[4] have proposed an explanation based on the effect of form factors used in the calculation of Ref. 2. These authors argue that the choice of a lower cutoff mass can account for the discrepancy. This interpretation is, however, refuted by the Nijmegen group.[5]

It should be noted that these arguments for and against the existence of charge-independence-breaking effects rely on a well determined value for the coupling f^2 of charged pions to nucleons. A currently accepted value[3,6] for f^2 is 0.079 ± 0.001, determined by Koch and Pietarinen.[6]

Motivated by the controversial value of the $\pi^0 pp$ coupling constant determined by the Nijmegen group,[1,2] we have analyzed the existing $\pi^\pm p$ data below 600 MeV in order to check the value of f^2. This study was part of a larger analysis[7] of elastic $\pi^\pm p$ data to 2 GeV.

The method we have used to extract f^2 is essentially the same as that described by Koch and Pietarinen.[6] The dispersion relations for the invariant B amplitudes[6] are sensitive to the choice of f^2. We can combine an unsubtracted dispersion relation for the isospin-even amplitude B^+ and a subtracted dispersion relation for the isospin-odd amplitude B^-. From the relations $B_\pm(\nu,t) = B^+(\nu,t) \mp B^-(\nu,t)$ for $\pi^\pm p \to \pi^\pm p$ amplitudes, we obtain the result[6]

$$(\nu_B \pm \nu)\left[\mp \mathrm{Re}B_\pm(\nu,t) \pm \frac{\nu}{\pi}\int_{\nu_1}^{\infty}\left(\frac{\mathrm{Im}B_+}{\nu'\mp\nu} + \frac{\mathrm{Im}B_-}{\nu'\pm\nu}\right)\frac{d\nu'}{\nu'}\right] = \frac{g^2}{m} + \tilde{B}(0,t)(\nu_B \pm \nu)\,, \tag{1}$$

with

$$\tilde{B}(0,t) = \frac{2}{\pi}\int_{\nu_1}^{\infty}\frac{\mathrm{Im}B^-(\nu',t)}{\nu'}d\nu'\,, \tag{2}$$

where we have defined $\nu_B = (t - 2\mu^2)/4m$ and $\nu_1 = \mu + t/4m$, μ and m being the charged-pion and nucleon masses, respectively.

The relation in Eq. (1) defines a straight line with intercept g^2/m [recall the relation $g^2 = 16\pi(m^2/\mu^2)f^2$]. In order to check our method we have extracted f^2 from the Karlsruhe solution[8] for values of t between -0.1 and -0.2 GeV^2. We find the value of f^2 to be 0.079 in agreement with the result of Koch and Pietarinen.[6]

From our most recent analysis[7] of elastic πN data to 2 GeV, which we name SM90, we have repeated the above process. Our method of analysis has been described in detail elsewhere.[9] In obtaining SM90 we differ from Ref. 9 in that we have used the Coulomb rotation phase of Tromborg, Waldenstrøm, and Øverbø[10] and have constrained our amplitudes to give the scattering length values determined by Koch.[11] These modifications have little effect on the determination of f^2 over the kinematic range quoted above. We find for f^2 the value 0.0735 ± 0.0015 from data with laboratory kinetic energies below 600 MeV. If scattering length constraints are removed from SM90, the same value of f^2 is obtained. The consistency of our amplitudes with fixed-t dispersion relations is illustrated in Fig. 1 where SM90 is plotted for $t = -0.15$ GeV^2.

We have also fitted the πN data to 2 GeV with solutions that have been constrained to follow the trend of Karlsruhe[8] and Carnegie-Mellon-Berkeley[12] solutions. These solutions, which we have denoted by KV90 and CV90, respectively, give a higher χ^2 per data point than SM90 (the Karlsruhe[8] and Carnegie-Mellon-Berkeley[12] fits also exceed SM90 in their χ^2 per data point). It is interesting to note, however, that KV90 and CV90 also lead to values of f^2 consistent with SM90.

The elastic $\pi^\pm p$ database[13] below 600 MeV has in-

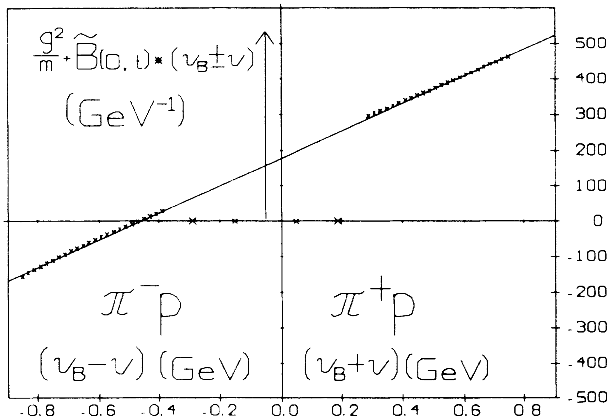

FIG. 1. Fixed-t dispersion relation for the $B\pm$ amplitudes of the solution SM90 evaluated at $t=-0.15\ \mathrm{GeV}^2$. A best linear fit is given by the solid line.

creased by 50% since 1983, the increase coming from the addition of high-precision data. These data were not available to Koch and Pietarinen[6] at the time of their analysis. It would be interesting to see the results of a revised analysis from this group. Apart from improved data, one further difference between the Karlsruhe and SM90 solutions may underlie the difference in extracted πNN couplings. The Karlsruhe solution is constrained to satisfy partial-wave dispersion relations[11] which require as input a value of the πNN coupling, thus a value of f^2 is implicitly contained in the $B\pm$ amplitudes. The solution must be iterated to find a stable value for the coupling. The solution SM90 has no such input and thus the extracted coupling is unbiased. Our agreement with the coupling found[2] from pp scattering data is satisfying in that both reactions now give a consistent value for f^2 thus removing the spectra of large charge-independence-breaking effects in the πN system.

This work was supported in part by the U.S. Department of Energy Grant No. DE-AS05-76ER04928.

[1] J. R. Bergervoet, P. C. van Campen, T. A. Rijken, and J. J. de Swart, Phys. Rev. Lett. **59**, 2255 (1987).

[2] J. R. Bergervoet *et al.*, Phys. Rev. C **41**, 1435 (1990).

[3] O. Dumbrajs *et al.*, Nucl. Phys. **B216**, 277 (1983).

[4] A. W. Thomas and K. Holinde, Phys. Rev. Lett. **63**, 2025 (1989).

[5] J. J. de Swart (private communication).

[6] R. Koch and E. Pietarinen, Nucl. Phys. **A336**, 331 (1980).

[7] R. A. Arndt, J. M. Ford, Z. Li, L. D. Roper, and R. L. Workman (to be published).

[8] G. Hohler, F. Kaiser, R. Koch, and E. Pietarinen, *Handbook of Pion-Nucleon Scattering* (Fachsinformationszentrum, Karlsruhe, Germany, 1979), Physics Data 12-1.

[9] R. A. Arndt, J. M. Ford, and L. David Roper, Phys. Rev. D **32**, 1085 (1985).

[10] B. Tromborg, S. Waldenstrøm, and I. Øverbø, Phys. Rev. D **15**, 725 (1977).

[11] R. Koch, Z. Phys. C **29**, 597 (1985).

[12] R. L. Kelly and R. E. Cutcosky, Phys. Rev. D **20**, 2782 (1979); R. E. Cutcosky *et al.*, *ibid.* **20**, 2804 (1979); **20**, 2839 (1979).

[13] A complete listing of the present database can be obtained from the authors or interactively through the Scattering Analysis Interactive Dial-in (SAID) program.