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A COMPILATION OF DATA ON THE REAL PARTS OF THE $K^{\pm} p$ FORWARD SCATTERING AMPLITUDES

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1. Introduction

The kaon-nucleon interaction has been extensively studied, both experimentally and theoretically, in the past few years. The rapid accumulation of accurate experimental data has made it possible to apply to this process many theoretical methods which had previously been used with notable success in the study of the πN interaction. In particular, forward dispersion relations for kaon-nucleon scattering /1/ have been widely used to obtain information about the values of the $KN\Lambda$ and $KN\Sigma$ coupling constants, to correlate experimental data on the real parts of the forward $K^{\pm}p$ scattering amplitudes and predict their values in energy regions where data are scarce, to resolve ambiguities in $K^{\pm}p$ phase shift analyses, and to obtain constraints on the asymptotic behaviour of the amplitudes.

Many of the methods of analyzing $K^{\pm}p$ scattering on the basis of dispersion relations require experimental information on the real parts of the forward scattering amplitudes /1-9/. The individual data points for the values of these real parts generally have rather large errors (and, even within the estimated errors, their values are often suspicious), so that reliable information can be extracted from these data only by analyzing simultaneously a large number of independent experimental measurements. It is therefore of great importance in such analyses to utilize a set of data which is as complete as possible[x].

Experimental data on the real parts of the forward $K^{\pm}p$ scattering amplitudes come from many diverse sources, and the difficulty of extracting the required information from the literature is no doubt well known to all authors who have made use of these data. Although a fairly complete list of references to the data is available/1/, no full compilation of their numerical values has been published. A recent partial compilation/7/, although extremely useful, covers only a limited energy range and omits much of the earlier data. Ref./10/ includes a summary of experimental information on the forward elastic differential cross section and total cross section for $K^{+}p$ scattering, from which some additional values of the real part of the $K^{+}p$ forward scattering amplitude can be constructed; but the information given there is also by no means complete, even for $K^{+}p$ scattering. In connection with a recent re-analysis of all available data on forward $K^{\pm}p$ scattering/9/, we have made a new, considerably more complete compilation of experimentally determined values of the real parts of the amplitudes. We present this compilation here (with the addition of some results which became available to us too late to be used in ref./9/) in a form in which the data may be used directly in dispersion relation calculations.

[x] The dangers of using an incomplete set of data are well illustrated by a comparison of the results of refs./4/ and /5/. When the original calculations of ref./4/ were subsequently revised/5/ by the inclusion of more up-to-date data on the real parts of the forward scattering amplitudes, the numerical results of the analysis changed by considerably more than the originally estimated statistical errors.

2. Determination of the Real Parts from Differential and Total Cross Section Data

The most straightforward method of determining the magnitude of the real part of the forward scattering amplitude in terms of experimental data is provided by the relation

$$(\mathrm{Re}\,F)^2 = \left(\frac{d\sigma}{d\Omega}\right)_0 - \left(\frac{q\,\sigma_{tot}}{4\pi}\right)^2, \qquad (1)$$

where $(d\sigma/d\Omega)_0$ is the elastic differential cross section in the forward direction, σ_{tot} is the total cross section, q is the c.m. momentum, and F is the c.m. forward scattering amplitude.

Good measurements of the $K^{\pm}p$ total cross sections have been made at so many energies that the values of σ_{tot} required for eq.(1) may be regarded as accurately known almost everywhere from threshold to 20 GeV (laboratory energy) for $K^{+}p$ scattering and from threshold to 55 GeV for $K^{-}p$ scattering. Several fairly complete lists of references to the data and compilations of the values of σ_{tot} are available /1,10-12/. The information given in these sources may be supplemented by the most recent experimental measurements of σ_{tot} /13-15/.

Values of $(d\sigma/d\Omega)_0$ are considerably more difficult to obtain experimentally and exist only at certain energies. Fortunately, most of the papers in the literature reporting experimental determinations of the angular distributions for elastic $K^{\pm}p$ scattering at sufficiently small momentum transfers also present an analysis of the exptrapolation of the differential cross sections to the forward direction.

Two main methods are used in practice for this extrapolation. Firstly, at energies at which the number of contributing partial waves is not too great (typically, below a few GeV), the differential cross section as a function of the c.m. scattering angle Θ is often represented in the form of a truncated series of Legendre polynomials

$$d\sigma(\Theta)/d\Omega = C\sum_{\ell=0}^{N} A_\ell P_\ell(\cos\Theta), \qquad (2)$$

where C is some fixed normalization constant, usually chosen to be $C = 1/q$. The coefficients A_ℓ are determined by a least-squares fit of the parametrization (2) to the experimental values of $d\sigma(\Theta)/d\Omega$.

The second method is usually employed for the analysis of angular distributions at higher energies, where the elastic scattering at small angles appears to have a diffractive character. In this case, the measured values of

$$\frac{d\sigma(t)}{dt} = \frac{\pi}{q^2}\frac{d\sigma(\Theta)}{d\Omega} \tag{3}$$

in a restricted range of scattering angles near the forward direction are usually fitted to an exponential form such as

$$d\sigma(t)/dt = \exp(a + bt + ct^2). \tag{4}$$

Here t is the usual momentum-transfer variable given by

$$t = 2q^2(1 - \cos\Theta). \tag{5}$$

In most cases, a good fit to the data is found by retaining only the first one or two of the parameters a, b, c in eq. (4).

3. The Data Compilation

We have found from the available literature suitable experimental data on the angular distributions of the elastic differential cross sections at 73 energies for K^-p scattering[16-35] and at 49 energies for K^+p scattering[33,36-53]. For each energy at which a reliable extrapolation to the forward direction was made in the paper originally reporting the experimental data, we used the reported value of $(d\sigma/d\Omega)_0$ or $(d\sigma/dt)_0$ for our determination of the real part of the forward scattering amplitude. However, we made use of the most up-to-date values of σ_{tot} in calculating the real parts from eq. (1); for this reason, our values of the real parts differ in many cases from corresponding values given in refs.[16-53].

In ref.[7] many of the $K^{\pm}p$ angular distributions were re-analyzed by means of the parametrization (2), and in ref.[10] some K^+p angular distributions were analyzed on the basis of the parametrization (4). In a number of cases in which no corresponding analysis was carried out in the paper originally reporting the experimental data, we therefore used the results of refs.[7,10] for our determination of the real parts.

For convenience, we have converted the real parts of the c.m. amplitudes obtained from eq. (1) to the laboratory frame, since the dispersion relations in which these data are used are normally written for the laboratory amplitudes. In Tables 1 and 2 we present, for K^-p and K^+p scattering, respectively, the magnitudes[x] of these real parts, $|D|$, and of their errors, ΔD, using the kaon laboratory momentum k as the kinematic variable. The errors ΔD take into account the estimated errors on both $(d\sigma/d\Omega)_0$ and σ_{tot} in eq. (1).

In many cases, the central value of $(\mathrm{Re}F)^2$ calculated from eq. (1) turned out to be negative, although the calculated error was large enough to allow also a reasonable range of positive values. In these cases, we set $\mathrm{Re}F = 0$ with a smaller error. If, however, it was found that no positive values were included within the error limits (this is the case at three energies for K^-p scattering), we concluded that the data on $(d\sigma/d\Omega)_0$ and σ_{tot} at the energy in question are incompatible (probably because their errors have been underestimated). Since we have no well-defined procedure for enlarging the errors in these cases, we merely indicate these points in Table 1 by means of an asterisk and no values for the real parts are given for them.

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[x] Since the Coulomb interference has generally not been observed in $K^{\pm}p$ scattering experiments, most of the signs of D are undetermined experimentally. However, these signs may be fixed unambiguously from analyses of forward dispersion relations[1,9], except for K^-p scattering in those energy regions where $|D|$ is small.

Unfortunately, fits to the angular distributions obtained in several papers used, as constraints, either (a) the optical limit in the forward direction[54,55] (assuming the absence of a real part) or (b) a value of the real part calculated from a dispersion relation[20,56]. Data based on such fits are not included in our compilation. There is, of course, no objection to the application of procedure (b) for many purposes. In fact, it amounts to the use of additional valuable information. However, values of the real parts of the amplitudes obtained in this way cannot be regarded as purely experimental and should not be used as input data in analyses of the dispersion relations.

Finally, we mention that additional information about the $K^{\pm}p$ forward scattering amplitudes is available from phase shift analyses and from low-energy effective range and K-matrix parametrizations of the scattering data. However, since many model-dependent ambiguities remain in these analyses at the present time, we do not make use of them for our data compilation.

An extended version of the present work, including a survey of the existing phase shift analyses and other parametrizations of the $K^{\pm}p$ scattering data will be given elsewhere

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References

1. N.M. Queen, M. Restignoli and G. Violini. Fortschr. Phys., 17, 467 (1969).
2. N. Zovko. Z. Phys., 192, 346 (1966).
3. G.H. Davies, N.M. Queen, M. Lusignoli, M. Restignoli and G. Violini, Nuclear Phys., B3, 616 (1967).
4. R. Perrin and W.S. Woolcock. Nuclear Phys., B4, 671 (1968).
5. R. Perrin and W.S. Woolcock. Nuclear Phys., B12, 26 (1969).
6. A.D. Martin and G.G. Ross. Phys.Letters, 26B, 527 (1968).
7. A.D. Martin and R. Perrin. Nuclear Phys., B20, 287 (1970).

8. M. Restignoli and G. Violini, Rome preprint (1970).
9. O.V. Dumbrais, T.Yu. Dumbrais and N.M. Queen, JINR preprint, E2-5216, Dubna (1970).
10. Particle Data Group, Berkeley preprint UCRL-20000 $K^{+}N$ (1969).
11. V.S. Barashenkov. Secheniya vzaimodeistviya elementarnykh chastits /in Russian/, Nauka, Moscow (1966).
12. Y. Sumi, Supplement to Progr.Theor.Phys., Extra Number, 3, (1967).
13. R.J. Abrams et al., Phys. Rev., D1, 1917 (1970).
14. R.L. Cool et al., Phys.Rev., D1, 1887 (1970).
15. J.V. Allaby et al., Phys. Letters, 30B 500 (1969).
16. M.B. Watson, M. Ferro-Luzzi and R.D. Tripp, Phys. Rev., 131, 2248 (1963).
17. P. Nordin, Jr. Phys. Rev., 123, 2168 (1961).
18. R. Armenteros et al., Nuclear Phys., B21, 15 (1970).
19. P.L. Bastien and J.P. Berge, Phys. Rev. Lett., 10, 188 (1963).
20. L. Bertanza et al. Phys. Rev., 177, 2036 (1969).
21. B. Conforto et al. Nuclear Phys., B8, 265 (1968).
22. W. Graziano and S.G. Wojcicki, Phys.Rev., 128, 1868 (1962).
23. W. P. Trower et al. Phys. Rev., 170, 1207 (1968).
24. A. Fridman et al. Phys. Rev., 145, 1136 (1966).
25. V. Cook et al. Phys. Rev., 123, 320 (1961).
26. R. Crittenden et al., Phys. Rev. Lett., 12, 429 (1964).
27. M. Dickinson, S. Miyashita, L. Marshall Libby and P. Kearney, Phys. Letters, 24B, 596 (1967).
28. J.R. Ficenec and W.P. Trower, Phys. Letters, 25B, 369 (1967).
29. M.N. Focacci et al., Phys. Letters, 19, 441 (1965).
30. J. Gordon, Phys. Letters, 21, 117 (1966).
31. J. Mott et al., Phys. Letters, 23, 171 (1966).
32. L.S. Schroeder, R.A. Leacock, R.L. Wagstaff and W.J. Kernan Phys. Rev., 176, 1648 (1968).
33. K.J. Foley et al., Phys. Rev. Letters., 11, 503 (1963).
34. M. Aderholz et al., Phys. Letters., 24B, 434 (1967).
35. K.J. Foley et al., Phys. Rev. Lett., 15, 45 (1965).

36. S. Goldhaber et al., Phys. Rev. Lett., 9, 135 (1962).
37. S. Focardi et al., Phys. Letters 24B, 314 (1967).
38. T.F. Stubbs et al., Phys. Rev. Lett., 7, 188 (1961).
39. G. Goldhaber, 4th Coral Gables Conference, 1967, p. 190.
40. R.W. Bland, G. Goldhaber and G.H. Trilling, Phys. Lett., 29B 618 (1969).
41. G. Giacomelli et al., Nuclear Phys., B20, 301 (1970).
42. W. Hirsch and G. Gidal. Phys. Rev., 135B, 191 (1964).
43. S. Andersson et al., Phys. Letters, 30B 56 (1969).
44. V. Cook et al., Phys. Rev., 129, 2743 (1963).
45. A. Bettini et al., Phys. Letters, 16, 83 (1965).
46. W. Chinowsky et al., Phys. Rev., 139B, 1411 (1965).
47. J.A. Danysz et al., Nuclear Phys., B14, 161 (1969).
48. J. Debaisieux et al., Nuovo Cimento, 43A, 142 (1966).
49. W. De Baere et al., Nuovo Cim., 45A, 885 (1966).
50. J. Banaigs et al., Nuclear Phys., B9, 640 (1969).
51. J.N. Mac Naughton, L. Feinstein, F. Marcelja and G.H. Trilling, Nuclear Phys., B14, 237 (1969),
52. Chin-Yung Chien et al., Phys. Letters, 28B, 615 (1969).
53. P.L. Jain et al., Nuclear Phys., B19, 568 (1970).
54. L. Sodickson, I. Mannelli, D. Frisch and M. Wahlig. Phys. Rev., 133B, 757 (1964).
55. C. Daum et al., Nuclear Phys., B6, 273 (1968).
56. W.R. Holley et al., Phys. Rev., 154, 1273 (1967).

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Table 1

Magnitudes of the real parts of the K^-p forward scattering amplitude in the laboratory system and their errors, as a function of the kaon laboratory momentum k. Two references are given in those cases in which no extrapolation of the differential cross section was made in the original paper reporting the experimental data; the first reference is that of the original paper, and the second is that from which we take the result of the extrapolation.

k (GeV/c)	Reference	|D|(fm)	ΔD (fm)
0.293	[16]*	----	----
0.300	[17]	0.00	0.40
0.350	[16]	0.08	1.11
0.390	[16]	0.27	0.72
0.400	[17]	0.18	1.06
0.434	[16]*	----	----
0.436	[18]	0.61	0.24
0.455	[18]	0.51	0.23
0.475	[18]	0.65	0.16
0.495	[18]	0.40	0.25
0.513	[16]	0.18	0.57
0.514	[18]	0.60	0.18
0.534	[18]	0.68	0.16
0.554	[18]	0.69	0.15
0.573	[18]	0.60	0.16
0.597	[18]	0.69	0.17
0.617	[18]	0.77	0.16
0.620	[19]	0.21	0.49

0.637	[18]	0.43	0.24
0.658	[18]	0.77	0.14
0.677	[18]	0.78	0.15
0.699	[18]	0.77	0.15
0.708	[20],[7]	0.67	0.39
0.719	[18]	0.92	0.15
0.725	[20],[7]	0.35	0.39
0.740	[18]	0.89	0.16
0.741	[20],[7]	0.33	0.39
0.760	[19]	0.49	0.21
0.761	[18]	0.86	0.18
0.768	[20],[7]	0.54	0.39
0.773	[18]	1.01	0.16
0.777	[21]	0.99	0.20
0.793	[18]	1.02	0.15
0.802	[20],[7]	0.93	0.39
0.806	[21]	1.17	0.22
0.838	[21]	1.21	0.20
0.850	[19]	1.00	0.17
0.853	[21]	1.05	0.20
0.874	[21]	0.93	0.22
0.894	[21]	1.02	0.23
0.904	[21]	1.00	0.23
0.916	[21]	0.68	0.38
0.935	[21]	0.88	0.24
0.954	[21]	0.70	0.33
0.970	[21]	0.59	0.40
0.991	[21]	0.93	0.25
1.022	[21]	0.64	0.40
1.044	[21]	0.81	0.31
1.061	[21]	0.53	0.42
1.080	[21]*	----	----

1.102	[21]	0.42	0.56
1.117	[21]	0.29	0.73
1.134	[21]	0.34	0.70
1.150	[22]	0.62	0.38
1.153	[21]	0.68	0.33
1.174	[21]	0.37	0.65
1.183	[21]	0.42	0.54
1.330	[23]	0.00	0.33
1.450	[24]	1.08	0.62
1.950	[25]	1.12	0.32
2.000	[26]	1.18	0.17
2.240	[27]	0.64	0.49
2.660	[28]	0.00	1.18
3.000	[29]	0.99	0.54
3.460	[30]	1.08	0.81
4.100	[31]	0.11	7.69
4.600	[32]	0.00	1.62
5.500	[31]	1.59	1.02
7.200	[33]	4.03	2.24
9.000	[33]	5.16	2.70
10.000	[34]	0.00	1.98
11.880	[35]	0.00	4.27
15.910	[35]	0.00	3.19

x/ In these cases, the value of $(\mathrm{Re}\,F)^2$ calculated from eq.(1) was found to be negative within the errors.

Table 2

Magnitudes of the real parts of the $K^{+}p$ forward scattering amplitude. The conventions are the same as in Table 1.

k (GeV/c)	Reference	|D|(fm)	Δ D (fm)
0.140	[36]	0.42	0.09
0.175	[36]	0.48	0.08
0.205	[36]	0.46	0.07
0.235	[36]	0.46	0.07
0.265	[36]	0.43	0.07
0.355	[36]	0.46	0.05
0.520	[36]	0.46	0.05
0.642	[36]	0.44	0.05
0.778	[37], [7]	0.47	0.04
0.810	[38], [7]	0.43	0.08
0.860	[39]	0.43	0.03
0.864	[40]	0.46	0.05
0.900	[41], [7]	0.37	0.04
0.910	[42], [7]	0.40	0.08
0.960	[39]	0.41	0.06
0.969	[40]	0.46	0.07
0.978	[41], [7]	0.43	0.05
1.060	[41], [7]	0.38	0.05
1.087	[43], [10]	0.30	0.20
1.124	[41], [7]	0.37	0.07
1.170	[44], [10]	0.50	0.13
1.200	[39]	0.46	0.08
1.207	[40]	0.47	0.07
1.215	[43], [10]	0.44	0.21
1.216	[41], [7]	0.50	0.14
1.253	[41], [7]	0.63	0.12
1.317	[41], [7]	0.49	0.08
1.372	[43], [10]	0.00	0.43
1.376	[41], [7]	0.51	0.10
1.453	[43], [10]	0.40	0.29
1.455	[45], [10]	0.78	0.04
1.477	[41], [7]	0.65	0.12
1.960	[46]	0.86	0.16
1.970	[44], [10]	0.28	0.33
2.110	[47], [10]	1.24	0.30
2.310	[47], [10]	1.20	0.30
2.530	[47], [10]	0.85	0.30
2.720	[47], [10]	1.25	0.30
2.970	[48]	1.13	0.29
3.460	[49]	0.53	0.96
3.550	[50]	0.74	0.83
4.600	[51]	0.00	1.23
4.970	[49]	1.16	0.85
6.800	[33]	2.62	1.21
7.300	[52]	3.02	0.73
9.800	[33]	3.69	0.63
12.700	[53]	6.97	1.87
12.800	[33]	5.85	0.63
14.800	[33]	7.04	0.80