Striking pattern of a strong-interaction reaction

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Previous indication that in pp elastic scattering at 6 GeV/c at all t values the reaction amplitudes in the planar-transverse optimal frame are all either pure real or pure imaginary is now strengthened and the tendency is shown to hold also for pp elastic scattering at 579 and 800 MeV.

Current conventional wisdom holds that the key to the understanding of strong interactions is at very high energies, and that at energies in the low-GeV region the situation is likely to be too complex to yield significant clues. Yet, in the absence of a dynamical theory that has sufficient predictive power to be able to describe accurately the very large amount of experimental information that has been accumulated on strong-interaction reactions in the last three decades, the search for phenomenological clues to formulate better theoretical models continues. The aim of this note is to report a further confirmation of such a clue in the form of a striking feature of at least one strong-interaction reaction.

Since the clue appears in terms of an unusual pattern of reaction amplitudes, sufficient amount of experimental information must be available on a broad variety of polarization observables before such a pattern is discernable. It is for this reason that pp elastic scattering was investigated, since such an amplitude analysis is possible for that reaction at 6 GeV/c and now also at 800 and 579 MeV.

In previous work[1] we first analyzed pp elastic scattering[2] at 6 GeV/c at one particular value of t, using the optimal formalism[3] of polarization phenomena. In such an optimal formalism the relationship between the experimental observables and the bilinear products of reaction amplitudes is as simple as possible; namely, it is represented by a string of small submatrices along the diagonal of the large matrix describing that relationship. Regardless of the values of the spins of the particles in the reaction, the size of these small submatrices are one-by-one, two-by-two, four-by-four, or eight-by-eight but never larger for any four-particle reaction, if we use the "primary" observables. From such a structure the results for observables containing some unpolarized particles can be easily constructed.

The optimal formalism contains an infinite set of different frames, each characterized by the orientations of the quantization axes of the four particles. For a parity-conserving reaction which is also time-reversal invariant and involves identical particles both in the initial and final states, the optimal formalisms can be either the transversity frame (in which the orientation of the quantization axes of all four particles is normal to the reaction plane), or one of the infinitely many planar frames, in which the orientations of the quantization axes of the four particles are in the reaction plane and are correlated.[4] A well known special case of such a planar frame is the helicity formalism in which the orientations are in the direction of the momenta of each particle. One of the infinite number of other planar frames is the planar-transverse frame in which the orientation directions are in the reaction plane but normal to the helicity directions.

Our previous work on pp elastic scattering first showed[1]

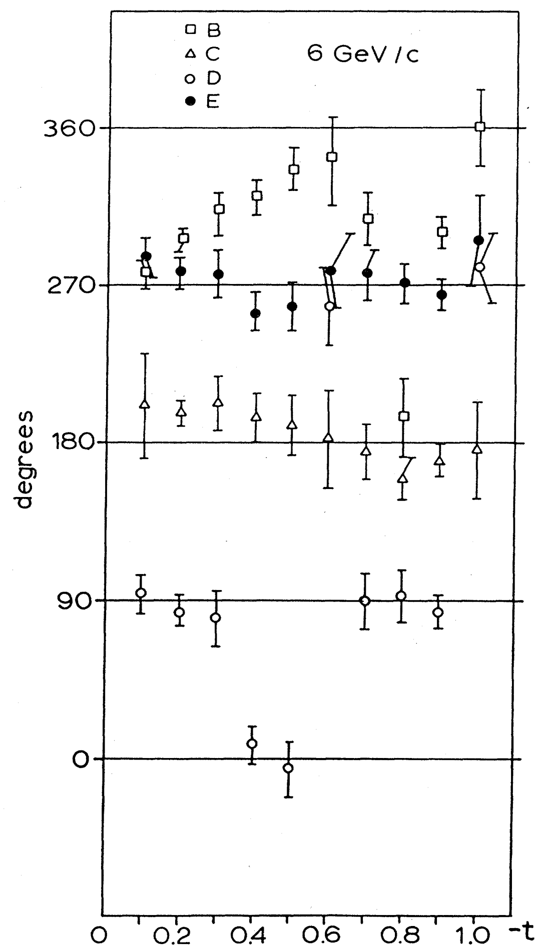

FIG. 1. The four relative phases of the five complex reaction amplitudes for pp elastic scattering at 6 GeV/c at various values of t, in the planar-transverse optimal frame.

that at 6 GeV/c and at $t=-0.6$ (GeV/c)^2 in the planar-transverse frame all five reaction amplitudes were either pure real or pure imaginary. More precisely, since the overall phase of the amplitude set is arbitrary, only the *relative* phases of the four amplitudes with respect to the fifth are meaningful quantities, so that the observation involved finding the four relative phases to be integer multiples of 90°.

Later, this observation was found[5] to hold also for the other t values at 6 GeV/c for elastic pp scattering.

Since then, we have performed an optimal amplitude analysis also on 579- and 800-MeV pp elastic scattering, using the recent experimental results from SIN (Ref. 6) and LAMPF (Ref. 7). Furthermore, we also reanalyzed the 6-GeV/c data, correcting a minor error in the previous tabulation and otherwise confirming the previous findings.

The outcome of this review of the previous analysis and of the extension of it to 579 and 800 MeV is that we find the above-described feature prevailing to an even larger extent.

The results are shown in Figs. 1–3. The first of these shows the four relative phases as functions of t for pp elastic scattering at 6 GeV/c. Figure 2 shows the four relative phases as functions of the scattering angle θ at 800 MeV, as constructed (a) from the phase shifts of Ref. 8 and (b) from the amplitudes determined directly from the data of Ref. 7. The two are juxtaposed to illustrate that the two ways of calculating the planar-transverse amplitudes are in good agreement. Finally, Fig. 3 shows the four relative phases at 579 MeV, as obtained from Ref. 6.

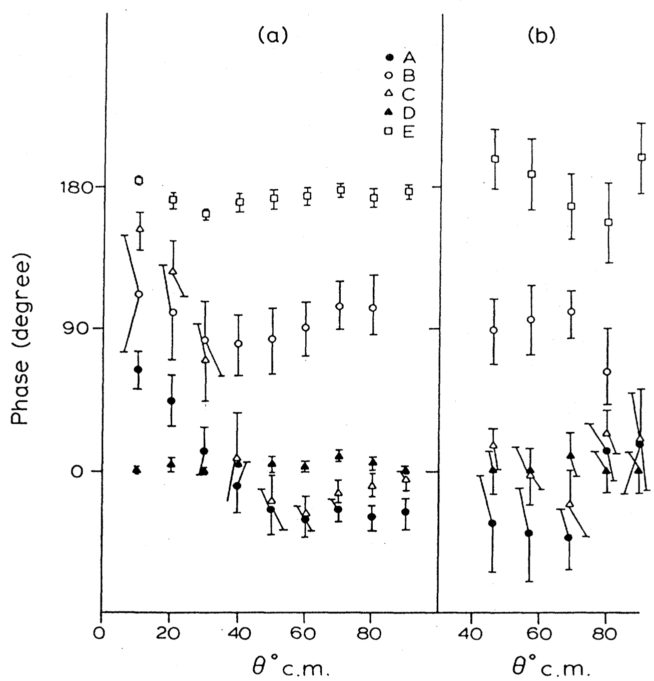

FIG. 2. The four relative phases of the five complex amplitudes for pp elastic scattering at 800 MeV in the planar-transverse frame. (a) was constructed on the basis of the phase-shift analysis of Ref. 8, while (b) was constructed from a direct determination of scattering amplitudes from the data of Ref. 7. The one arbitrary phase was chosen at each angle so that the phase of the amplitude D is approximately zero.

As the figures indicate, there is a strong tendency for the phase differences to be multiples of 90°. In terms of just counting the data points which fall on the appropriate horizontal lines within their errors, the fit at 6 GeV/c is excellent, perhaps even too good considering the meaning of the statistical error bars. The only systematic deviation of conceivable statistical significance is for B. At 800 MeV again the agreement in terms of the above criteria is excellent, though one has fewer data points and some have larger errors. Here the only conceivably systematic deviation is for A at smaller angles, but even that is marginal. Finally, for 579 MeV, the good agreement persists, with conceivably systematic deviations for the amplitude A.

It would, of course, be preferable to have more accurate measurements of the amplitude phase differences in order to establish this apparent feature more firmly. Yet, even with the present information, we believe that the pattern is striking enough to warrant attention.

We have attempted to derive this striking feature from some of the currently or previously popular dynamical models such as Regge poles or QCD but have been unsuccessful. In as much, therefore, as this feature is not caused by "accident" (something that would be extremely hard to believe), the underlying dynamical law is one that is outside our present understanding of particle physics.

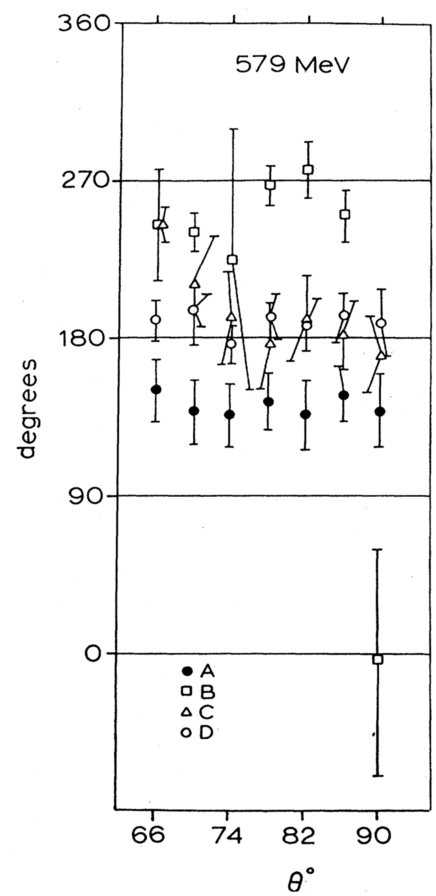

FIG. 3. The four relative phases of the five complex reaction amplitudes for pp elastic scattering at 579 MeV at various values of the c.m. scattering angle θ, in the planar-transverse frame.

Our aim in publicizing this finding at this time is manifold. First, we want to encourage the investigation of *pp* elastic-scattering data at lower energies from this new point of view. Second, similar search on other reactions would be of interest, although the candidates are few, since complete polarization data are available only on very few strong-interaction reactions. This points out our third aim, namely, to encourage the design and performance of such polarization experiments. Finally, a dynamical theory predicting such a behavior will have to be found, a task of no small magnitude.

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