Direct Reconstruction of the pp Scattering Matrix below 500 MeV, an Attempt (*).

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Summary. — We explore whether or not it is possible to use available experimental data to directly reconstruct the pp scattering matrix in three energy ranges extensively searched by experimentalists. We show that one can reasonably solve this problem in spite of its complexity and the lack of some data.

1. — Introduction.

We want to examine the old problem of the direct reconstruction of the $M$ scattering matrix from the knowledge of experimental data for the proton-proton interaction below 500 MeV which have been extensively searched by several experimental groups. Wolfenstein and Askin (1), Stapp and collaborators (2) have given expressions for the matrix elements, i.e. the scattering amplitudes, in terms of a set of experimental quantities. These expressions are invariant with respect to rotation, parity and time reversal. The above-mentioned amplitudes can be extracted from such quantities by solving simple algebraic equations since those quantities are simple bilinear combinations of these amplitudes. In order to get a complete solution spin-dependent expressions must be included. Extra theoretical assumptions must be added if some experimental data are not available.

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This way to tackle the problem is different from the method based on the phase-shift analysis (PSA) which makes use of unitarity and smoothness of all observable quantities as a function of the centre-of-mass scattering angle together with a reasonable assumption concerning the behaviour of phase shifts for the higher angular-momentum values. PSA leads to some sets of phase shifts which are faced up with other experimental data in order to select the correct solutions. But, as emphasized by Schumacher and Bethe (3), all these solutions are obtained by means of a search through the phase-shift space with random sets of initial phase shifts taken as starting points. However there is no proof that all regions of the many-dimensional phase-shift space have been completely explored. Also, phase shifts are unnatural parameters which cannot be directly determined from measurable quantities, contrary to amplitudes, and the uniqueness of the PSA solution can be proved only if one has a complete set of experiments (4).

Another method consists in solving equations involving observable quantities in order to extract the underlying amplitudes. This method is more direct and computationally simpler than those using PSA. Below the pion production threshold the uniqueness of the solution is gained using unitarity equations with a complete set of experiments (5). But this method of direct reconstruction is used in the best possible condition at energies exceeding the pion production threshold (6). We adopt this point of view and then attempt to get the amplitudes in three energy ranges of respectively (210 ÷ 213) MeV, (307 ÷ 315) MeV and (415 ÷ 429) MeV extensively searched by experimentalists.

The following difficulty arises in these energy domains: experimental information is incomplete. To obviate this lack of data we solve the algebraic equations given by observables as if all experimental quantities were available, then, by use of a minimization technique, we search the missing data leading to a solution of the algebraic system. Hence we obtain the moduli and phase differences of the various amplitudes. In order to get their real and imaginary parts it is necessary to consider one of the phases as a parameter, the value of which is given by a recent PSA (7). Then we deduce the other phases from our calculated phase differences and from moduli the real and imaginary parts that were aiming at. This procedure allows us also to make the comparison between our results and those of PSA.

In the next Section we derive the equations of the problem. We scrutinize the experimental data used in our work and give our numerical results in Sect. 3. We conclude in Sect. 4.