DIRECT RECONSTRUCTION OF pp ELASTIC SCATTERING AMPLITUDES AND PHASE SHIFT ANALYSES AT FIXED ENERGIES FROM 1.80 TO 2.70 GeV

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The direct reconstruction of the pp elastic-scattering amplitudes and fixed-energy Saclay-Geneva phase shift analyses have been carried out at 1.8, 2.1, 2.4 and 2.7 GeV where complete sets of observables have recently been measured at SATURNE II. The results of the two complementary analyses agree well at all energies and give a good description of existing data points.

NN observables can be expressed in terms of the scattering matrix elements. From there, two different approaches can be followed [1] – either a phase shift analysis (PSA) over the entire angular range or, if enough different data are available at the same angle and the same energy, a direct amplitude reconstruction (DRSA).

Assuming parity conservation, time reversal and isospin invariance, the scattering matrix [2] is written in terms of complex amplitudes a, b, c, d and e as

$$\begin{aligned} M(\vec{k}_f,\vec{k}_i) = \tfrac{1}{2}[(a+b) + (a-b)(\vec{\sigma_1},\vec{n})(\vec{\sigma_2},\vec{n}) + (c+d)(\vec{\sigma_1},\vec{m})(\vec{\sigma_2},\vec{m}) \\ +(c-d)(\vec{\sigma}_1,\vec{\ell})(\vec{\sigma}_2,\vec{\ell}) + e(\vec{\sigma}_1+\vec{\sigma}_2,\vec{n})] \end{aligned} \tag{1}$$

where $\vec{\sigma}_1$ and $\vec{\sigma}_2$ are the Pauli 2x2 matrices, $\vec{k}_i$ and $\vec{k}_f$ are the unit vectors in the direction of the incident and scattered particles, respectively, and $\vec{n},\vec{m}$ and $\vec{\ell}$ are the c.m basis vectors.

Observables will be denoted as X_{srbt} with the subscripts referring to the polarization orientation of the scattered, recoil, beam, and target particles, respectively. Any observable can be expressed in terms of the five amplitudes from Eq. 1, for instance

$$\frac{d\sigma}{d\Omega} = \frac{1}{2}[|a|^2 + |b|^2 + |c|^2 + |d|^2 + |e|^2] \tag{2}$$

$$\frac{d\sigma}{d\Omega}A_{oonn} = \frac{1}{2}[|a|^2 - |b|^2 - |c|^2 + |d|^2 + |e|^2]. \tag{3}$$

In the PSA approach the reconstruction of scattering amplitudes is possible even from incomplete sets of experimental quantities [3]. The lack of observables at some angles is compensated by an imposed smooth angular dependence. The phase shifts are determined up to an orbital momentum L_{max}. The higher-L partial amplitudes corresponding to peripheral interactions are described by the OPE approximation. At higher incident energy the value of L_{max} and therefore the number of free parameters increases. Due to the larger importance of inelastic interactions more imaginary phase shifts are added. It leads to even more free parameters, in the present energy range there are 25 to 30 parameters at each energy. The only observable directly related to the imaginary parts of the phase shifts is the total inelastic cross section. The imaginary parts are poorly constrained for large angular momenta and must be taken from models(for details see Ref. 4). Thus with increasing energy the PSA becomes more model dependent.

A DRSA is performed independently at each energy and angle, where it requires a complete set of measured observables [5] (i.e more than 9 observables). For this reason a DRSA is always limited to a small number of angles and will never become a universal tool in predicting unknown quantities. The information provided by an accurately measured angular dependence of observables is lost, or may be used indirectly to eliminate extraneous solutions. The amplitudes are determined up to a common phase. On the other hand, a DRSA is completely model independent except for the symmetry laws. It gives a pure phenomenological description of a given interaction channel without any additional conditions and has no energy limit. Since the solution at one angle is independent of those at other angles, the amplitude analysis can reveal possible anomalies in angular or energy dependences.

A way of checking the validity of model-dependent contributions to a PSA is to compare the PSA amplitude predictions with the direct reconstruction from the amplitude analysis. In this respect the amplitude analysis is complementary to the PSA. Agreement supports the PSA which may then be used to predict unmeasured quantities. A disagreement between the two methods either suggests a possible anomaly in the database, or casts a doubt on the PSA theoretical input. Comparison of PSA with directly-reconstructed amplitudes is also important at low energy close to the pion production threshold. The DRSA then provides a check of the validity of different potential models.

Using the spin-dependent data from SATURNE II [6] and the recent COSY $d\sigma/d\Omega$ data [7] PSA and DRSA analyses were performed. Results of the two complementary analyses are in good agreement at all four energies as illustrated in Fig. 1. They are also compared to the Virginia Polytechnic Institute (VPI) phase-shift predictions below 2.55 GeV [8]: one observes considerable dif-

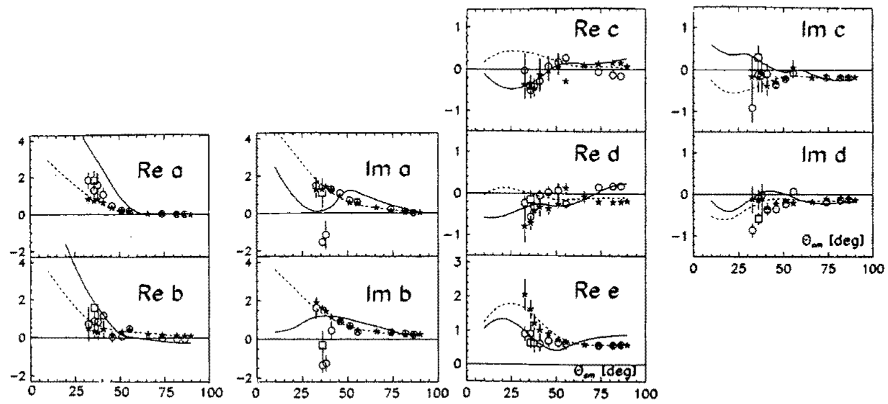

Figure 1: Direct reconstruction of the scattering amplitudes at 1.8 GeV shown as points. The solid and dashed lines are predictions from PSA analyses [8,4] respectively.

ferences which are likely due to the incomplete data base in the VPI PSA. The predictions of observables will help for planning possible future experiments, in particular at COSY. Measurements of observables at small angles are highly desirable in order to improve PSA and DRSA solutions for $\theta_{cm} \leq 40^o$.

An energy limit for the validity of the PSA method is hard to estimate. A possible way of checking the validity of model-dependent contributions to a PSA is to compare the PSA amplitude predictions with those from a DRSA.

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