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HAVE DISPERSION RELATIONS FOR THE FORWARD pp-, $\bar{p}$p-SCATTERING AMPLITUDE REALLY BEEN TESTED?

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The forward dispersion relations for the nucleon-nucleon scattering have not been proved, although they were written down a long time ago[1]. Numerous papers[2–18] have been devoted to calculations of the real parts of the pp , $\bar{p}p$ forward scattering amplitude, using a large variety of dispersion relations (see also reviews[19–21]). The comparison of predicted values of the real part of the pp scattering amplitude with the experimental ones allows one to conclude, that, on the whole, the experimental data agree well with the dispersion relation predictions. Therefore, it is claimed that the dispersion relations have been tested for the forward pp, $\bar{p}p$ scattering

In this note we would like to point out the weakness of this claim, the reasons for that being:
1) the arbitrary choice of the way in which the large unphysical region and the low-energy $\bar{p}p$ scattering region are taken into account in the calculations;
2) the arbitrary choice of the method of extrapolation of the differential cross sections to the forward direction in experimental determination of the real part of the amplitude;
3) in addition, we recall yet another snag, which is the presence of the three non-vanishing amplitudes in the forward nucleon-nucleon scattering; only one of them is spin-independent.

Let us dwell now on the listed above difficulties.

Because of the lack of polarization data (such as, e.g., total cross sections for scattering of polarized beams on polarized targets; the first experiment of this kind has lately been performed[22]) one puts under the dispersion integral the usual total cross section, which gives, via the optical theorem, the imaginary part of the spin-independent amplitude. If this amplitude could be continued into the low-energy region of the $\bar{p}p$ scattering, where σ_{tot} is difficult to be measured, and into the unphysical region, where the measurements of the amplitude are impossible in principle, the imaginary part would have been treated in a consequent way. However, because of the lack of data for the low-energy $\bar{p}p$ scattering, such a continuation (e.g., by means of the effective range approximation) cannot be carried out. This is why in the dispersion relation calculations the imaginary part of the amplitude in the unphysical and low-energy regions is sometimes decomposed into a series in which the coefficients are determined by comparison of the calculated real parts with the experimentally measured ones. An alternative way of handling of these regions is to replace the continuum of states with a set of bound states at fixed energies. Mathematically this is equivalent to replacing of a cut of an analytic function by a sum of poles (resonances); the values of their residues (coupling constants) are either fixed earlier, or found comparing the calculated values of the real part with the experimental data. One should note that the replacement of the cut with the poles is, in itself, an arbitrary procedure. Besides, both the exact number of poles-resonances and the values of their coupling constants are unknown. Therefore, it seems to us that the so-called agreement of theoretical (i.e., dispersion relation) calculations with experimental data on the real parts of the pp forward scattering amplitude means only that the parameters in various approximations of unphysical and low-energy regions of the $\bar{p}p$ scattering can be chosen so as to obtain the consistency.

We shall give now the arguments to support this point of view.

If one assumes that the observed consistency is not a mere coincidence ascribed to the large ambiguity introduced by the lack of knowledge (outside the framework of analyticity and dispersion relations) of the amplitude in the unphysical and low-energy region of $\bar{p}p$ scattering, but a regularity, it means, then, that the spin effects are small, because experimentally one measures a complicated mixture due to the additional presence of two spin-dependent amplitudes.

On the other hand, in two recent papers /23,24/ a theoretical model-independent determination of the real part of the spin-independent amplitude of the forward scattering has been carried out by means of the analytic continuation of this amplitude from the region where the phase shifts were available to higher energies. It has been shown that even to 30 GeV the absolute value of its real part is much larger (by about 50 to 100%) than of the experimental (and, therefore, spin-averaged) real part. The authors of papers /23,24/ come to the conclusion that one cannot neglect spin effects at energies as high as 30 GeV. This conclusion seems strange to us, since the "subtraction" of spin effects while extracting the real parts from the experimental data tends to diminish, and not enlarge their absolute values.

We propose now another and maybe more plausible explanation of the existing discrepancy, namely, that the experimentally determined values of the spin-averaged real parts in the medium energy range (2-30 GeV) are wrong. They have been found by extrapolation of the measured small-angle values of differential cross sections to the forward direction and by comparing the obtained values with the optical point. The exponential t-dependence of the differential cross sections, the validity of which is doubtful, has been assumed. On the other hand, if one applies the model-independent method of extrapolation /25,26/ then the absolute values of the real part can increase almost by a factor of 1.5 (see Table 3 of ref. /25/), and the existing discrepancy disappears.

Thus, starting from the results of ref. /23-26/, one can make the following conclusions.

1) The existing agreement of the dispersion relation calculations of the real part of the forward pp scattering amplitude with experimental data is, in fact, a coincidence, since the experimental values have been determined in a wrong way. The apparent consistency shows only the unreliability of the calculations, caused

by the presence of the unphysical and low-energy region of $\bar{p}p$ scattering.
2) The actual absolute values of the real part of the pp forward amplitude at medium energies are larger by a factor of 1.5-2, than the measured ones* (see review [20] for references).
3) The conclusion of authors of papers [23,24] concerning the presence of the fairly large spin effects in nucleon-nucleon scattering up to 30 GeV seems groundless.
4) The dispersion relations for the pp, $\bar{p}p$ forward scattering amplitude have been tested, at best, only qualitatively.
5) Their quantitative testing is impossible as long as there is no strict quantitative theory of the $\bar{p}p$ scattering in the unphysical and low-energy regions.
6) The measurements of the real part of the $\bar{p}p$ forward scattering amplitude are required (we stress here again the total unsuitability of the exponential law of extrapolation of the differential cross sections to the forward direction [26]). They would allow one to constrain the possible theories of the $\bar{p}p$ scattering in the unphysical and low-energy regions and, thus, would do much more good for testing the dispersion relations than the continuing measurements of the real part of forward pp scattering amplitude.

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* It would be nice to have some theoretical and experimental pros or cons independently of any dispersion relation (analyticity) considerations.

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