The "Sagara Discrepancy": Fact or Fiction?

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A few years ago, based upon their very precise experimental data for (among other observables) the elastic differential cross section (DCS) for proton-deuteron (*pd*) scattering Sagara *et al.* [1] found a systematic discrepancy in the magnitude of the cross section minimum when comparing the data with theoretical calculations. In fact, the relative difference $\Delta_{\min} \cdot = \left(\sigma_{theor}^{\min} - \sigma_{\exp}^{\min}\right) / \sigma_{\exp}^{\min}$ turned out to be rather large and positive at low energies, to change sign around 5 MeV and to become large negative at higher energies, reaching - 25% at 18 MeV. The inference that there exists another real discrepancy between experiment and theory, in addition to the notorious and well established A_y-puzzle, was, however, not very compelling as the theoretical calculations used for comparison had actually been performed for neutron-deuteron (*nd*) scattering, with only the so-called "outer" Coulomb corrections [2] added manually. Later this energy-dependent discrepancy was confirmed by Koike and Ishikawa [3], using different "realistic" nuclear potentials, but again employing the same approximation for including some Coulomb effects.

However, a long time ago in the first published calculation of *pd* scattering which treated the Coulomb potential "exactly" (*viz.*, the "outer" Coulomb corrections exactly and the "internal" ones consistently up to terms of the order α^2), Alt, Sandhas, and Ziegelmann [4] had demonstrated, albeit by using only a simple nuclear potential model, that this approximate Coulomb correction method is generally unsatisfactory and certainly can not substitute a *pd* calculation which includes *all* Coulomb effects. In addition, the DCS at 2 and 10 MeV shown there indicated a rather strong energy dependence of the failure of this approximation in Refs. [1,3] as compared to the full *pd* calculation. Indeed, at 2 MeV the "exact" DCS minimum was strongly over estimated, while at 10 MeV an underestimation was found. Hence, the above-mentioned discrepancy could very well have been an artifact of the approximation used for taking into account Coulomb effects. However, some caution must be exercised before drawing from those early calculations [4] quantitative conclusions about a possible discrepancy between theory and experiment since the nuclear potential employed there was rather unrealistic, and the minimum, as an interference effect, must be expected to be very sensitive to the finer details of the nuclear interaction model. Recently, we have published the first calculation of *pd* scattering for energies above the deuteron breakup threshold for a realistic nuclear potential [5], within the systematic screening and renormalization approach (for a review see Ref. [6]). In the meantime calculations for several more energies have been performed in our group. It, therefore, appears worthwhile to investigate whether this so-called "Sagara discrepancy" constitutes a real physical effect, or is only the result of the inappropriate theoretical description of this reaction (by an insufficient treatment of either the Coulomb [1,3] and/or the nuclear [4] interaction). In our calculations we have used the Paris potential in the PEST1 form [7], which is known to represent a fairly accurate description of the nucleon-nucleon interaction. In the figure we present the relative difference Δ_{min} between our theoretical results for the DCS minimum and some of the data of Sagara *et al.* [1]. Inspection reveals the following results:

(i) Even with a sophisticated nuclear potential model and a correct description of the Coulomb repulsion between the protons, the "Sagara discrepancy" survives.

(ii) The overall magnitude of this discrepancy is strongly reduced as compared to the calculations with improper account of the Coulomb interaction [1,3].

(iii) The earlier model calculations [4] gave a different energy dependence of Δ_{min}, thereby illustrating the sensitivity of the cross section minimum to the nuclear potential model.

(iv) For all energies considered, the present calculations yield a larger cross section minimum than experiment; i.e., $\Delta_{min} > 0$. In particular, the percentage excess in Δ_{min} has become only rather weakly dependent on energy in the range considered (from 9.3% at 5 MeV to 6.3% at 18 MeV), in contrast to the original estimates [1,3]. These results provide a strong hint that for their explanation physical effects like further inadequacies of the nuclear potential, three-body forces, etc., are called for, although the latter must be consistent with the near perfect agreement of theoretical calculations with experimental data for *nd* scattering. A plausible candidate would be a charge-symmetry breaking contribution to the nuclear force.

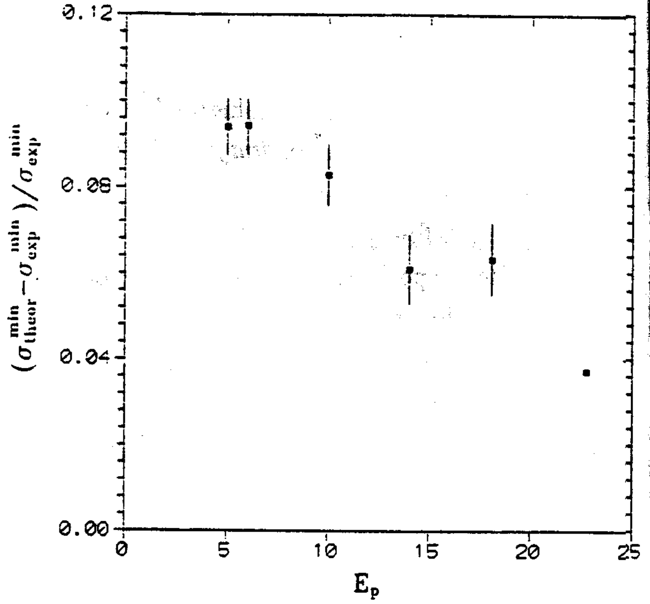

Figure 1. The "Sagara discrepancy" Δ_{min} as function of the energy.

References

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