Complete set of deuteron analyzing powers from $\vec{d}p$ elastic scattering at 190 MeV/nucleon†

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All the deuteron analyzing powers, iT_{11}, T_{21}, T_{20} and T_{22}, for elastic deuteron-proton (dp) scattering have been measured with a polarized deuteron beam at 186.6 MeV/nucleon at the angles in the center of mass system of $\theta_{\mathrm{c.m.}} = 39°$–$165°$. These data, together with our previously reported deuteron analyzing powers taken at different energies, constitute a solid basis to guide the theoretical investigations of three-nucleon forces ($3N$Fs).

Our new deuteron analyzing powers and the previously measured data at 70 and 135 MeV/nucleon together with the elastic cross section data in the energy region of interest, are compared with the results of $3N$ Faddeev calculations based on the standard nucleon–nucleon (NN) potentials[1)] alone or combined with the TM99 $3N$F.[2)] The AV18 NN potential is also combined with the Urbana IX $3N$F.[3)] Parts of the data are shown in Figs. 1a), c), and e). Predicted 3NF effects localized at backward angles are supported only partially by the data. The data are also compared to predictions based on locally regularized chiral NN potentials.[4)] The N^{4}LO chiral potential predictions are close to the semi-phenomenological NN results for the measured observables. At 190 MeV, the N^{4}LO NN predictions are generally away from the data. This would indicate the effects of $3N$F contributions that were neglected in our calculations. An estimation of the theoretical truncation uncertainties in the consecutive orders of chiral expansion (Figs. 1b), d), and f)) suggests that the observed discrepancies between this modern theory and the data could probably be explained by including chiral 3NF's in future calculations.

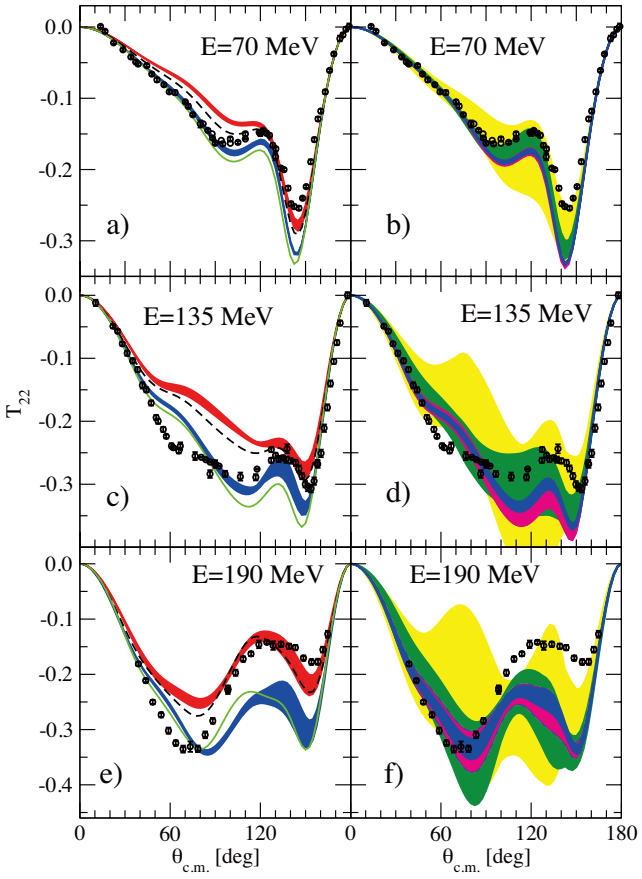

Fig. 1. Elastic dp scattering deuteron tensor analyzing power T_{22} at incoming nucleon laboratory energies of E = 70 MeV: a) and b), 135 MeV: c) and d), and 190 MeV: e) and f). In a), c), and e) the blue shaded band indicates predictions of standard NN potentials[1)] and the red shaded band indicates predictions when they are combined with the TM99 $3N$F. The dashed black curve represents the prediction of the AV18+Urbana IX combination. The solid green curve shows prediction of the locally regularized (regulator $R = 0.9$ fm) N^{4}LO chiral potential. In b), d), and f), the estimated theoretical uncertainties at different order of chiral expansion are shown by the bands of increasing width at: N^{4}LO (blue), N^{3}LO (magenta), N^{2}LO (green), and NLO (yellow). The black circles are dp data taken at RIKEN.

References

1) R. Machleidt, Phys. Rev. C **63**, 024001 (2001); R. B. Wiringa *et al.*, *ibid.* **51**, 38 (1995); V. G. J. Stoks *et al.*, *ibid.* **49**, 2950 (1994).
2) S. A. Coon, H. K. Han, Few Body Syst. **30**, 131 (2001).
3) B. S. Pudliner *et al.*, Phys. Rev. C **56**, 1720 (1997).
4) E. Epelbaum *et al.*, Phys. Rev. Lett. **115**, 122301 (2015).

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