Tensor Analysing Power Measurement in Charge–Exchange Reaction $\vec{d}\,p \to (pp)n^*$

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One major feature of the polarised deuteron charge–exchange break–up reaction $\vec{d}\,p \to (pp)n$ is that the differential cross section and the two deuteron Cartesian analysing powers A_{xx} and A_{yy} are directly related to the magnitudes of the spin–spin neutron–proton charge–exchange amplitudes, which govern the spin–transfer observables in $\vec{n}\,p \to \vec{p}\,n$ at small momentum transfers [1].

A first measurement was carried out at ANKE with a 1170 MeV polarised deuteron beam [2]. Having determined their vector and tensor polarisations before and during the acceleration of deuterons in the COSY ring, measurements of three tensor and two vector analysing powers showed that any depolarisation of the circulating beam is definitely less than 2%. The vector and tensor polarisations are typically about 74% and 59%, respectively, of the ideal values that could be provided by the polarised source.

After identifying the $dp \to (pp)n$ events, these were binned in intervals of diproton excitation energy E_{pp} and three–momentum transfer $q = -\sqrt{t}$. With a stable spin axis in the beam line oriented along the y-direction, the numbers $N(q,\phi)$ of diprotons produced at an azimuthal angle ϕ are, after correcting for luminosity with the help of the beam current monitor,

$$N(q,\phi) = N_0(q)\,\left[1+\tfrac{3}{2}P_zA_y(q)\cos\phi + \tfrac{1}{2}P_{zz}\left\{A_{yy}(q)\cos^2\phi + A_{xx}(q)\sin^2\phi\right\}\right], \qquad (1)$$

where P_z and P_{zz} are the beam polarisations for the seven different source states, $N_0(q)$ the numbers obtained with the unpolarised beam, and A_y and A_{yy} are vector and tensor analysing powers of the reaction.

The results for the two $\vec{d}\,p \to (pp)n$ tensor analysing powers are shown in fig. 1 in 20 MeV/c bins in q for two cuts in the excitation energy, *viz.* $0 < E_{pp} < 1\,$MeV and $1 < E_{pp} < 3\,$MeV. In contrast to the strong and rapidly varying tensor analysing powers shown there, the vector A_y is consistent with zero for all momentum transfers.

For low excitation energy E_{pp} of the final pp pair, and small momentum transfers, the $\vec{d}\,p \to (pp)n$ reaction mainly excites the ${}^1S_0$ state of the final pp system. This involves a spin–flip from the pn triplet to pp singlet and thus provides a *spin–filter* mechanism. In single–scattering approximation, the results depend only upon the np spin–dependent amplitudes β, γ, δ and ε. If we neglect the deuteron D–state, we expect that at low E_{pp}

$$\begin{aligned} A_{xx} &= \frac{|\beta|^2+|\gamma|^2+|\varepsilon|^2-2|\delta|^2}{|\beta|^2+|\gamma|^2+|\delta|^2+|\varepsilon|^2}\,, \\ A_{yy} &= \frac{|\delta|^2+|\varepsilon|^2-2|\beta|^2-2|\gamma|^2}{|\beta|^2+|\gamma|^2+|\delta|^2+|\varepsilon|^2}\,, \\ A_y &= 0\,. \end{aligned} \qquad (2)$$

Since in the forward direction $\beta = \delta$ and $\gamma = 0$, the value of $A_{xx} = A_{yy}$ at $q = 0$ should depend only upon the ratio of $|\beta|$ to $|\varepsilon|$, which changes smoothly with energy. However, the δ amplitude, which contains the one–pion–exchange pole, varies very rapidly with momentum transfer. Given that the dominant real part of this amplitude vanishes when q is of the order of the pion mass, it is to be expected that in this region A_{xx} should approach its kinematical limit of $+1$, as suggested by our data in fig. 1.

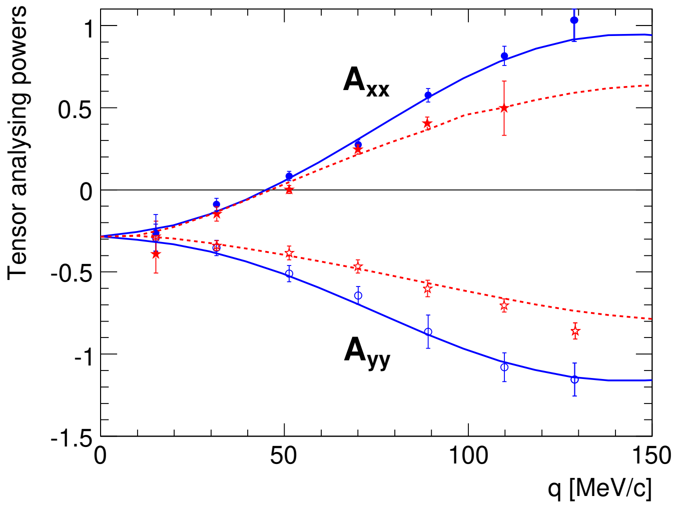

Fig. 1: Values of the tensor analysing powers A_{yy} and A_{xx} extracted for the $dp \to (pp)n$ reaction for $0 < E_{pp} <$ 1 MeV (circles) and $1 < E_{pp} < 3$ MeV (stars). The curves correspond to the predictions of the impulse approximation program, for which the input amplitudes at 585 MeV were taken from SAID; $0 < E_{pp} <$ 1 MeV (solid) and $1 < E_{pp} < 3$ MeV (broken).

The spin–triplet final states generally produce the opposite signs for the analysing powers to the singlet and so, as soon as one departs from the very small E_{pp} limit, a dilution of the A_{xx} and A_{yy} signal is predicted. This effect depends sensitively upon the final state interactions in the low energy pp system. These, together with the Paris S+D–state deuteron wave function, are included in our full analysis program

The predictions of fig. 1 were made using amplitudes from the current SAID NN phase shift solution. All the features of both A_{xx} and A_{yy} are reproduced for $q \leq 130\,$MeV/c provided that $E_{pp} < 1\,$MeV. Less dilution of the signal with E_{pp} is seen than predicted by the program, especially in the case of A_{xx}. However, due to the experimental acceptance, there is some correlation between the directions of the diproton relative momentum and the momentum transfer and the program indicates that this can lead to the observed weaker dilution.

References:

[1] A. Kacharava et al., COSY Proposal #152: *Spin Physics from COSY to FAIR*, nucl-ex/0511028.

[2] D. Chiladze et al., submitted to PR ST-AB, nucl-ex/0511052.

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