Study of the $pn \to \{pp\}_s\pi^-$ reaction near the threshold at ANKE

With the advent of chiral perturbation theory (χPT), the low-energy effective field theory of QCD, accurate calculations have become possible for hadronic reactions. The extension of the approach to pion production in nucleon-nucleon collisions requires new high precision experimental information in the near-threshold region.

Of especial interest are the processes $pp \to \{pp\}_s\pi^0$ and $pn \to \{pp\}_s\pi^-$, with the formation of a $^1S_0$ proton pair (diproton) in the final state. The measurements of $d\sigma/d\Omega$, A_y and the spin-correlation coefficients $A_{x,x}$ and $A_{x,z}$ will permit an amplitude analysis that should provide a non-trivial test of the χPT predictions. A combined study of these processes will lead to the isolation of the Low Energy Constant (LEC) d of the $4N\pi$ contact operator in χPT.

The ANKE spectrometer is particularly well suited for the study of reactions with a final diproton. The excellent resolution in the excitation energy of the proton pair, $\sigma_{E_{pp}} <$ 0.5 MeV, allows one to select the range of low $E_{pp} < 3$ MeV. This ensures the dominance of the $^1S_0$ state of the final proton pair. Single and double polarisation experiments can be conducted through the use of the polarised COSY beams and the ANKE polarised internal target.

As a first step in the proton–neutron programme, measurements with a polarised proton beam incident on an unpolarised deuterium cluster target were performed at ANKE in 2009 at a beam energy of $T_p = 353$ MeV.

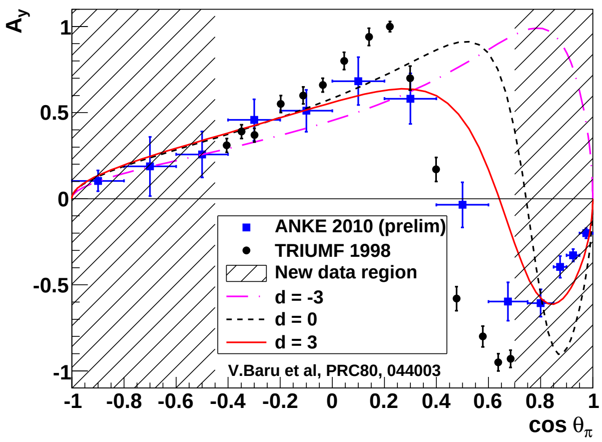

Fig. 1: A_y in the $\vec{p}n \to \{pp\}_s\pi^-$ reaction at T_n=353 MeV (blue squares). Also shown are the results of χPT calculation for $d = 3$ (red solid line), $d = 0$ (black dashed line), and $d = -3$ (magenta dot-dashed line). The data from TRIUMF are shown as black circles.

The results for the $\vec{p}n \to \{pp\}_s\pi^-$ reaction are presented in Figs. 1 and 2. The ANKE data are shown together with the results from TRIUMF [H. Hahn *et al.*, Phys. Rev. Lett. **82** (1999) 2258] and compared to the prediction of the IKP theory group [V. Baru *et al.*, Phys. Rev. C **80** (2009) 044003]. The value of LEC $d = 3$ is favoured, though it must be stressed that the pion d–waves have not yet been included in the calculations.

The results were obtained with a 40 MeV wide range of effective beam energy in the free pn-scattering, *i.e.*, $T_{\text{free}} = 353 \pm 20$ MeV. The $E_{pp} < 3$ MeV cut was imposed on the data but, to facilitate the comparison with previous results, the cross section has been recalculated for the $E_{pp} <$ 1.5 MeV cut used at TRIUMF. This was done using the Migdal-Watson approximation for the final state interaction in the $^1S_0$ proton pair. The main advantage of the ANKE measurement is the extended angular range compared to the pre–existing data.

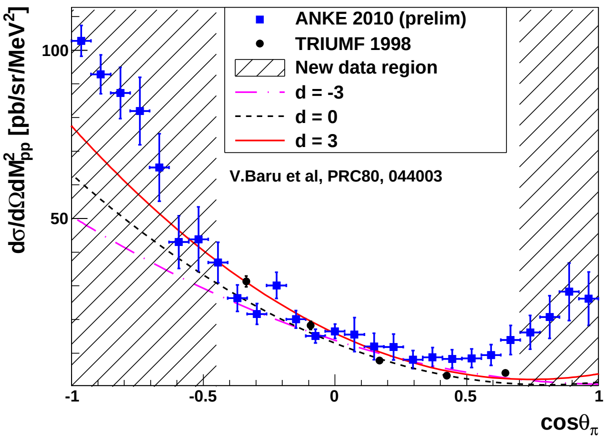

Fig. 2: ANKE Preliminary results for the cross section of the $\vec{p}n \to \{pp\}_s\pi^-$ reaction at T_n=353 MeV in the $E_{pp} <$ 1.5 MeV range. The conventions are the same as those used in the caption to Fig. 1.

The transitions involving the $4N\pi$ contact interaction correspond to the p-wave pion production in the $np \to \{pp\}_s\pi^-$ reaction. The magnitude of one of the p-wave amplitudes is fixed completely by the measurement of $(1 - A_{x,x})d\sigma/d\Omega$ for $np \to \{pp\}_s\pi^-$. The double polarisation experiment for the measurement of $A_{x,x}$ and $A_{y,y}$, scheduled for 2011, will greatly improve our knowledge of the LEC d.

This experiment will provide the most systematics-free way to fix the value of d. At the same time, the magnitude of the other p-wave amplitude and its relative phase will be deduced from a combined analysis of these results with our cross section and analysing power data for $pp \to \{pp\}_s\pi^0$ and $np \to \{pp\}_s\pi^-$, which have already been taken. Two determinations of the LEC d will therefore be possible.