# Pion production in $pN$ collisions at close to threshold energies

R. Bilger, W. Brodowski, H. Calén, H. Clement, C. Ekström, K. Fransson, G. Fäldt, L. Gustafsson, B. Höistad, A. Johansson, J. Johansson, T. Johansson, K. Kilian, S. Kullander, A. Kupsc,P. Marciniewski, B. Morosov, W. Oelert, R.J.M.Y. Ruber, J. Stepaniak,A. Sukhanov, P. Sundberg, A. Turowiecki, G.J. Wagner, Z. Wilhelmi, C. Wilkin, J. Zabierowski, J. Złomańczuk

*Uppsala, Jülich, Warsaw, Dubna, Tübingen, Łódz, London*

Isospin conservation leads to three independent $NN \to NN\pi$ total cross sections, $\sigma_{if}$, where the indices $i$ and $f$ represent the isospin of the initial and final NN pairs. The $pp \to pp\pi^0$ reaction involves only $\sigma_{11}$, and is well measured in the threshold region at IUCF and Uppsala. $\sigma_{10}$ may be extracted from data on $pp \to pn\pi^+$ ($\sigma_{10}^{np} + \sigma_{11}$) and $pp \to d\pi^+$ ($\sigma_{10}^{d}$), both extensively investigated at IUCF. The third one, $\sigma_{01}$, is poorly known at low energies; it has recently been measured for excitation energies of the final $pp$ pair up to 3 MeV at RCNP and up to 1.5 MeV at Triumf. A phase shift analysis of all $NN \to NN\pi$ experimental data below 1 GeV gives $\sigma_{01}$ values compatible with zero, whereas the analysis of the $NN$ inelastic scattering data below 600 MeV makes $\sigma_{01}$ small, but non-negligible. This cross section is of particular importance since it allows one to estimate the magnitude of the non-resonant pion production in $N-N$ collisions because the intermediate $\Delta$ is forbidden by the isospin conservation.

In this contribution we report on systematic measurements of the $pp \to pp\pi^0$ reaction at 310, 320, 340, 360, 400 and 425 MeV, and of the quasi-free $pn \to pp\pi^-$ reaction in $pd$ collisions at 320 MeV, carried out at the CELSIUS storage ring in Uppsala. Differential cross sections, $d\sigma/dq$ ($q$ is the two-proton relative momentum in the final state) and $d\sigma/d\Omega_\pi$ are extracted.

The $pp \to pp\pi^0$ distributions are described in terms of partial waves corresponding to the $Ss$, $Ps$, $Pp$, $Sd$ and $Ds$ final states. It has been found that commonly used amplitudes, derived from their simple threshold behaviour, fail to reproduce the data at the higher energies. However, in a DWBA treatment, assuming interaction ranges related either to $\pi$ or $\rho$ exchange, we find acceptable agreement, though the longer range of pion exchange provides significantly better description of the $Ps$ and $Pp$ waves.

The resulting parametrisation of the $pp \to pp\pi^0$ differential cross sections has been used to extract the $\sigma_{01}$ cross section through the relation $\sigma_{01} = 2\sigma(pn \to pp\pi^-) - \sigma(pp \to pp\pi^0)$.