A method to disentangle single meson and multi-pion production rates in the missing mass spectra of the quasi-free $pn \to pnX$ reactions

P. Moskal for the COSY-11 collaboration

The measurements of the quasi-free $pn \to pn\eta$ and $pn \to pn\eta'$ reactions are being conducted at the COSY-11 facility by registering all outgoing nucleons from the $pd \to p_{sp}pnX$ reaction and using the missing mass technique for the identification of events with the creation of the meson under investigation [1]. Subscript $_{sp}$ denotes the spectator proton, which does not take part in the reaction, and X stands for the η, η' meson, or multi-pion system. In this report we will outline a technique [2] which permits to distinguish contributions of multi-pion and a single meson production in the missing mass spectrum of the quasi-free $pn \to pnX$ reaction when it is studied via the measurement of the $pd \to pnX\,p_{sp}$ process. The technique allows also to combine events corresponding to the multi-pion production at various excess energies in order to increase statistics for the determination of the shape of the multi-pion background at a fixed excess energy.

The known momentum of the proton beam and the indirect determination of the four-momentum vector of neutron inside the deuteron at the moment of the collision permit to determine the total energy available for the proton-neutron reaction for each registered event. Therefore, the collected data can be grouped according to the excess energy with respect to the $pn \to pn\eta$ process for instance. The production of the η meson can occur only if the excess energy $Q = \sqrt{s} - m_{proton} - m_{neutron} - m_\eta$ acquires positive value. According to the above definition Q is understood as an excess energy with respect to the $pn\eta$ system. Consequently such defined Q may also be negative, and in the case of the negative values of Q only pions may be created for example via the $pn \to pn\pi\pi$ reaction.

In order to establish the form of the background it would be sufficient to determine a missing mass spectrum ($\frac{dN^\pi}{dm}$) from an infinitesimal range of any of the negative values of Q, provided that the number of events written on tapes suffices to neglect any statistical fluctuations and that the shape of the reconstructed invariant mass of pions is independent of the excess energy Q. The latter assumptions allows to express the background distribution in a convenient way as a function of the difference between the kinematical limit ($m_\eta + Q$) and the given mass m: $B(m_\eta + Q - m)$.

Being not limited by statistics one could divide the range of positive values of Q into so narrow subranges that the resultant missing mass spectrum - in each subrange of Q - would be a simple sum of the form B and a signal from the η meson. The discussed situation is depicted schematically in figure 1. The lower panel of this figure shows the method of the construction of the background. If the two assumptions mentioned above were valid, then in order to derive a signal of the η meson from a missing mass spectrum it would be sufficient to subtract a missing mass spectrum determined for negative Q after the shift of the latter to the kinematical limit (dotted line) and normalization at the very low mass values where no events from the η meson production are expected (dashed-dotted line). In such a case the contribution of the $pn \to pn\eta$ reaction could be extracted without the necessity of any assumption of the unknown distribution of the background expressed as a function of the excess energy ($\frac{dN^\pi}{dQ}$).

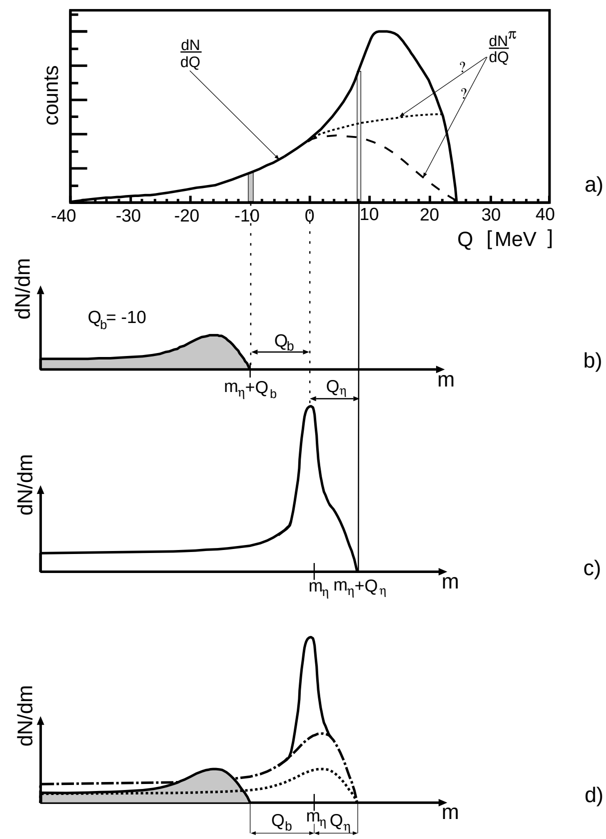

Fig. 1: a) Distribution of the excess energy with respect to the $pn \to pn\eta$ reaction plotted schematically for the beam momentum of $P_b = 2.075\ GeV/c$ [2]. b), c) Scheme of the missing mass spectra as derived for the negative (Q_b) and positive (Q_η) values of Q. d) The shape of the background in the mass spectrum for Q larger than zero can be constructed from the shape of the multi-pion mass distribution determined for Q less than zero.

However, by reviewing the experimental distribution of $\frac{dN}{dQ}$ [1] one recognizes that the obtained statistics is indeed insufficient for the derivation of the $\frac{dN^\pi}{dm}$ spectrum from the bin of Q with the width equal to the experimental resolution (FWHM = 5 MeV). Yet, the statistics can be improved significantly if all events registered with Q less than zero could be taken into account. This can be realized by adding to the missing mass calculated for a given event a value of ($Q_\eta - Q_b$) which will shift the background events measured at Q_b to the kinematical limit defined by the Q_η. In this manner one constructs the background for the missing mass spectrum obtained for $Q = Q_\eta$. The resultant modified missing mass distribution obtained from the entire data sample of negative Q values can be identified with the function $B(m_\eta + Q_\eta - m)$ needed for the derivation of the background distribution within a finite excess energy bin. For more details the reader is referred to a more comprehensive report [2].

References:

[1] P. Moskal et al., AIP Conf. Proc. **717** (2004) 907.

[2] P. Moskal, Schriften des FZ-Jülich: Matter & Materials **21** (2004) 249.