Momentum resolution of the COSY–11 neutron detector

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In order to investigate the isospin dependence of the meson production in the hadronic interactions [1], the COSY–11 [2] facility has been extended by the neutral–particle–detector. In this year, using the COSY-11 facility a measurement of the η' meson production in the proton-neutron collision has been conducted [3]. The experimental precision of the missing mass determination of the $pn \to pnX$ reaction strongly rely on the accurate measurement of the momentum of neutrons. Therefore, the resolution of the neutron momentum determination has to be established. The neutron detector is desined to deliver the information about the time at which the registered neutron or gamma quanta induced a hadronic or electromagnetic reaction. The time of the reaction combined with this information allows to calculate the time–of–flight (TOF^N) of the neutron (or gamma) on the 7.54 m distance between the target and the neutron detector, and — in case of neutrons — to determine the absolute value of the momentum (p) what can be expressed as:

$$p = m \cdot \frac{l}{TOF^N} \cdot \frac{1}{\sqrt{1-(\frac{l}{TOF^N})^2}},$$

where m denotes the mass of the particle, l stands for the the distance between the target and the neutron detector and TOF^N is the time–of–flight of the particle.

Monte Carlo studies of the quasi-free $pp \to pp$ reaction via the $dp \to ppn_{sp}$ process have been performed in order to establish the momentum resolution of the neutron detector. As n_{sp} a spectator neutron has been denoted. This reaction was chosen since it can be identified in the data taken during the previous COSY-11 measurements conducted with the deuteron beam [4], and hence the simulation results could have been corroborated by the experimental data [6]. The detection of both outgoing protons from the $dp \to ppn_{sp}$ reaction precedes via the well established method [2] and the spectator neutron is measured by the neutron detector [6].

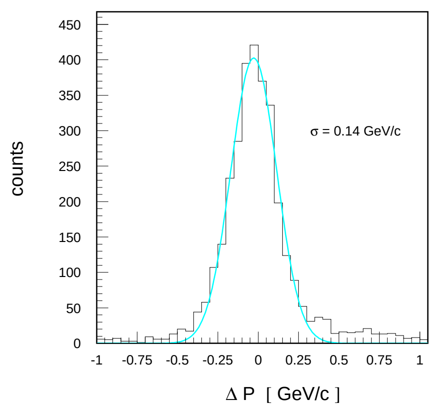

Fig. 1: Difference between generated (P_{gen}) and reconstructed (P_{rec}) neutron momenta for the $dp \to ppn_{sp}$ reaction simulated at a deuteron beam momentum of 3.204 GeV/c. At this beam momentum an average momentum of specatator neutrons is equal to 1.6 GeV/c.

Figure 1 presents the difference ($\Delta P = P_{gen} - P_{rec}$) between the generated neutron momentum (P_{gen}) and the reconstructed neutron momentum from signals simulated in the detectors (P_{rec}). The value of (P_{rec}) was calculated taking into account the time resolution of the neutron detector (σ = 0.4 ns) [5] as well as the time resolution of the S1 counter (σ = 0.25 ns). The time at which proton hit the S1 detector is needed to determine the time of the reaction in the target place. The distribution of ΔP – for neutrons possessing momentum of 1.6 GeV/c – was fitted by a Gaussian function resulting in a momentum resolution of σ(P) = 0.14 GeV/c [6]. The accuracy of the TOF^N mesurement is approximately independent of the momentum of neutron however the percentagewise the resolution of determining the neutron momentum alters significantly as its momentum changes.

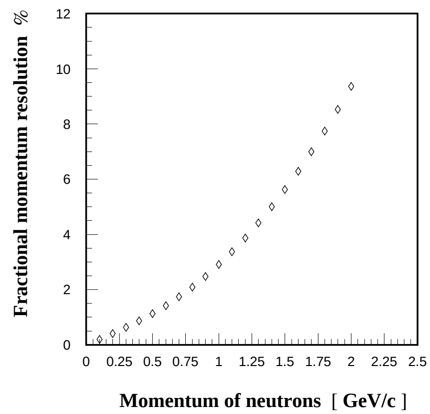

Fig. 2: Fractional momentum resolution of the neutron detector as a function of neutron momentum.

This fractional momentum resolution –which is shown in figure 2 as a function of neutron momentum – is given by the equation:

$$\frac{\sigma p}{p} = \frac{\frac{dp}{dt} \cdot \sigma_t}{p},$$

where $\sigma_t = \sqrt{\sigma_n^2 + \sigma_{S1}^2}$ accounts for both the time resolution of the neutron and S1 detectors. The result presented in figure 2 was obtained assuming that σ_n = 0.4 ns, σ_{S1} = 0.25 ns, and l = 7.54 m. The value of l corresponds to the distance between the target and the centre of the neutron detector.
This fractional resolution depends on the neutron momentum and e.g. for the neutrons produced at threshold for the $pn \to pn\eta$ reaction (p = 0.76 GeV/c) it amounts to 2% and at threshold of the $pn \to pn\eta'$ reaction (p = 1.06 GeV/c) it is equal to 3.2%

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