Evaluation of the missing mass resolution for the FRH extensions with DIRC and Time-of-Flight detectors.

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The η' mesons for the rare decays studies at the WASA-at-COSY facility will be produced in the $pp \to pp\eta'$ reaction close to threshold. The identification of the $pp \to pp\eta'$ process will be performed by means of missing mass to the two outgoing protons measured in the Forward Range Hodoscope (FRH). Due to the large background originating from the multi-pion production the statistical and systematical errors in the evaluations of the cross sections and branching ratios of the investigated decay channels will strongly depend on the resolution of the missing mass reconstruction, which in turn will depend on the precision of the reconstruction of the momentum vectors of the registered protons. At present determination of the energy of the protons is based on the energy loss measurement in scintillation layers of the FRH. The resolution achieved with the setup used at the CELSIUS facility was about 1.5% ($\sigma(T)/T$) for protons with kinetic energy lower than T = 300 MeV i.e. for protons stopped in the detector material. However, it worsen significantly for larger energies. The achieved accuracy was satisfactory for investigations of the η meson production and decay. However, it appears to be insufficient for the studies of the η' meson due to much higher background-to-signal ratio and due to higher energies of the outgoing protons than in case of $pp \to pp\eta$ reaction. For the beam momentum of P_{beam} = 3.35 GeV/c, considered as an optimum [1], for the production of the η' meson at the WASA-at-COSY facility, the kinetic energies of the protons are in range between 300 MeV and 800 MeV (see figure 1(left)).

In order to improve the accuracy of the energy determination of the forward scattered ejectiles the FRH was upgraded with two new scintillator layers each with the thickness of 15 cm [2]. The rough estimate of the energy resolution expected with the extended detector is shown in figure 1(right). With this accuracy of the energy measurement the missing mass distribution has the width of about 3.5 MeV/c^2 (FWHM) and the tails as it is seen in figure 2(left). In the simulations the contributions from the extension of the interaction region and the spread of the COSY beam momentum were not included. The overall contributions of these effects is estimated to be about 4 MeV/c^2(FWHM) [1]. In this report only the effect of the resolution of the protons kinetic energies is considered.

There are two suggestions of a possible future improvement of the accuracy of the energy measurement. One assumes installation of the DIRC detector wich would enable to determine the velocity of protons with accuracy of about $\sigma(\beta)/\beta$ = 0.003. The second scenario includes adaptation and extension of the FRH which would allow to determine the time of flight [3] for protons passing through the FRH with precision of $\sigma(TOF)$ = 100 ps [4]. In order to facilitate comparison of the TOF, DIRC and energy loss techniques we expressed properties of TOF and DIRC methods in terms of fractional kinetic energy resolution. The results are compared in figure 1(right). The figure shows that both DIRC and TOF would yield better resolution than that obtained only from the energy losses. It is also evident, that the energy resolution of the DIRC detector is much better than the TOF method. It is, however, important to note, that TOF can be determined for protons which managed to pass the whole detector (T>≈ 360 MeV), whereas DIRC can deliver signals only for protons above Cerenkov threshold which corresponds to 500 MeV. This implies that only a fraction of protons from $pp \to pp\eta'$ reaction can be reconstructed by means of the DIRC or TOF detectors.

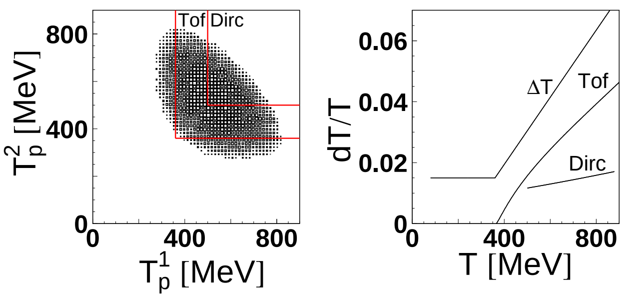

Fig. 1: **Left panel:** Kinetic energies of protons from the $pp \to pp\eta'$ reaction simulated for the beam momentum of 3.35 GeV/c. **Right panel:** Fractional kinetic energy resolution estimated for the three considered techniques.

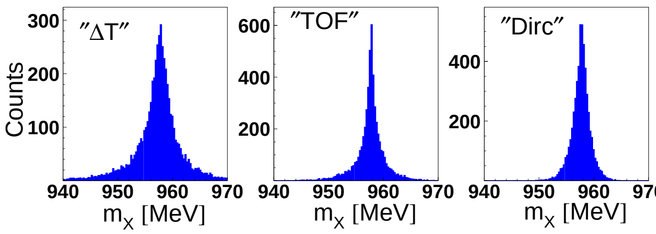

Fig. 2: Missing mass distribution for $pp \to pp\eta'$ reaction reconstructed under assumption that the resolution of the kinetic energy determination of protons will be as expected for energy loss measurement (left panel), TOF (middle panel), DIRC (right panel).

Figure 1(left) shows that at the beam momentum of 3.35 GeV/c the energy of the both protons from the $pp \to pp\eta'$ reaction can be reconstructed for only about 20% of events using the DIRC detector, and for about 70% of events using the TOF technique. In other cases the energy of one or the both protons must be determined using the energy losses. The simulations of the missing mass distribution shows that using the TOF or DIRC for the reconstruction of energy of protons would lead to improvement of the resolution of the missing mass reconstruction by about a factor of two (see figures 2(middle) and 2(right).

References:

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