## Feasibility studies of the measurement of $BR(\eta' \to \pi^+\pi^-\pi^0)$ with WASA-at-COSY

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Studies of rare decays of the $\eta$ and $\eta'$ mesons are one of the most important goals of the WASA-at-COSY physics program. For example decay $\eta' \to \pi^+\pi^-\pi^0$ was pointed out as an accurate way of extracting the quark mass difference [1]. The process is possible only by isospin-violating interaction due to $(m_d - m_u)$ term in the QCD Lagrangian and as a consequence the decay width is proportional to $(m_d - m_u)^2$. The decay has been never observed and only an upper limit of 5% (90% CL) for the branching ratio has been reported [2]. Recent calculations based on chiral unitary approach predict the branching ratio to be about 1% [3].

An attempt to observe the decay will be made with the WASA-at-COSY facility. The $\eta'$ mesons will be produced in two proton collisions via the $pp \to pp\eta'$ reaction. Due to huge background from direct production of three pions the experimental conditions must be carefully optimized. WASA detector is designed to work with maximum luminosity of $10^{32}\text{cm}^{-2}\text{s}^{-1}$. After what taking into account the detection and reconstruction efficiencies this leads to about $10^6$ $\eta'$ mesons tagged per day.

In order to find the optimum beam momentum for the measurement of the branching ratio ($BR$) for the $\eta' \to \pi^+\pi^-\pi^0$ decay we have studied the relative statistical uncertainty as a function of the excess energy ($Q$):

$$\frac{\sigma(BR)}{BR}(Q) = \frac{\sqrt{N_S + N_B}}{N_S}, \qquad (1)$$

where the $N_S$ denotes the number of the signal events and the $N_B$ indicates the number of the background events.

The values of $N_S$ were estimated based on the known total cross section energy dependence for the $pp \to pp\eta'$ reaction and the assumptions for the BR based on the theoretical predictions. The values for $N_B$ were extracted from the COSY-11 measurements [4]. The direct three pion production and the $\eta' \to \pi^+\pi^-\pi^0$ decay will be reconstructed with the best precision by using missing mass of the two outgoing protons measured in the forward detector. We have assumed that the kinetic energies of the protons will be extracted using energy loss method in the layers of the Forward Range Hodoscope and the directions are determined using the Forward Proportional Chambers. The momentum resolution of the COSY beam, extensions of the interaction region, the detection efficiency and the proton-proton final state interactions are also taken into account.

An example calculation of the branching ratio accuracy have been conducted assuming a one week experiment with luminosity L=$10^{32}\text{cm}^{-2}\text{s}^{-1}$ and five values of $BR(\eta' \to \pi^+\pi^-\pi^0)$: 5%, 2%, 1%, 0.75% and 0.5%. The $Q$ dependence of $\sigma(BR)/BR$ is shown in Fig. 1. As expected the relative accuracy nearly scales with the value of the assumed branching ratio. The optimum accuracy is achieved for the excess energies between 60 and 90 MeV, independent of the BR magnitude.

The statistical uncertainty of the branching ratio will improve with time as $1/\sqrt{t}$. The dependence for the beam momentum of $p_{beam}$=3.45 GeV/c corresponding to the excess energy $Q$=75 MeV is shown in Fig. 2. The plot shows that for the BR equal 0.5% a relative accuracy of 10% would require two months of beamtime.

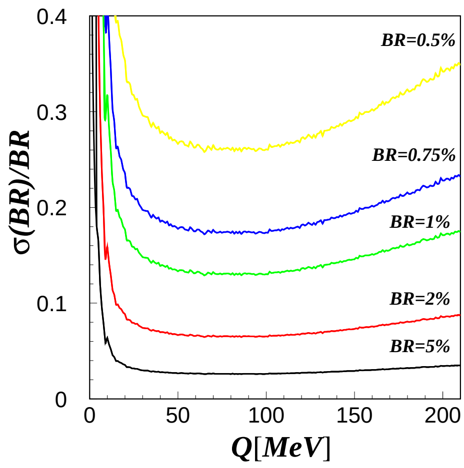


Fig. 1: The relative accuracy of the $BR$ as a function of the excess energy $Q$ for the $pp \to pp\eta'$ reaction. The results for the five values for BR are shown.

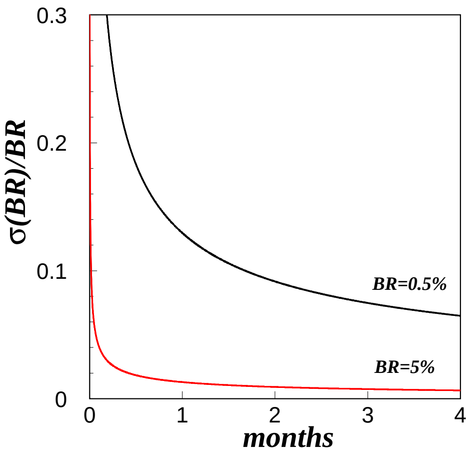


Fig. 2: The branching ratio accuracy as a function of measurement time in months.

An additional source of background, not discussed here, comes from other decays of $\eta'$ involving similar particles: $\eta' \to \pi^+\pi^-\eta$ and $\eta' \to \omega\gamma$. This background can not be suppressed using the missing mass method.

**References:**


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