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Study to characterize the production of antineutrons in high energy pp collisions through charge exchange interactions in the ALICE experiment

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Abstract

In a previous study, simulations were performed to evaluate the feasibility of antineutron ($\bar{n}$) identification and kinematic reconstruction via hadronic charge-exchange (CEX) interactions: $\bar{n}+n \to \bar{p}+p$ and $\bar{n}+n \to \bar{p}+p+\pi^0$. The target neutrons are those in the silicon nuclei of the inner tracking detectors used in LHC experiments such as ALICE, ATLAS, and CMS. GEANT4 simulations using the ALICE Inner Tracking System (ITS) as a working example were employed to develop a dedicated protocol for $\bar{n}$ identification and kinematic reconstruction. The method focuses on identifying the proton partner from the CEX interaction, a challenging task due to the presence of fragmentation protons from silicon nuclei. Momentum correlations between the $\bar{n}$ and all possible $\bar{p}p$ pairs showed that successful partner identification and $\bar{n}$ reconstruction are associated with events with minimal momentum loss. Based solely on $\bar{p}p$ observables, an efficiency of 0.006% was estimated for PYTHIA-generated pp collisions at $\sqrt{s_{pp}} = 13$ TeV.

In this work, the proposed protocol is applied to Monte Carlo pp collision samples from ALICE Run 3 to evaluate its performance under more realistic detector conditions. A preliminary CEX identification efficiency lower than that obtained in the feasibility study is obtained after incorporating the full ALICE detector geometry and background-suppression criteria. These simulations also enable a detailed characterization of background processes that mimic the CEX signal. To improve signal-background discrimination, classical one-dimensional selections are compared with a multivariable approach based on machine learning. The machine-learning selection provides significantly better signal-background separation, yielding a final CEX candidate sample with a purity of approximately 70%.

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