Study of Λ's beta decay in hypernuclei --experimental feasibility

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Content

The modification of baryon properties inside nuclei, compared to those in free space, has been suggested by the EMC effect. According to the Quark-Meson Coupling (QMC) model, the β-decay rate of a Λ hyperon embedded in a nucleus is expected to decrease by up to 20% due to changes in the spatial distributions of u and d quarks [1]. To investigate this predicted modification of baryon structure in detail, we are planning an experiment to measure the β-decay rate of the Λ hyperon in ${}^{5}_{\Lambda}\mathrm{He}$ and ${}^{13}_{\Lambda}\mathrm{C}$ at the J-PARC K1.1 beamline. The physics interest and the principle of the experiment will be presented in a separate contribution.

The β-decay branching ratio of the Λ is as small as 8.0×10^{-4}, making background events from dominant decay modes, such as $\Lambda \rightarrow p\pi^-$ and $\Lambda \rightarrow n\pi^0$, a major challenge for the measurement. To suppress these backgrounds, we will employ plastic scintillators and Cherenkov counters for electron identification, along with a segmented spherical BGO calorimeter to measure the energy and spatial distribution of β-decay electrons. Cluster analysis based on the hit pattern will be used, as the signal electrons form a single cluster, while π^0 decays primarily into two γ rays, producing two clusters. Additionally, when a π^- stops inside the BGO, neutrons emitted through absorption processes (e.g., $\pi^-pn \rightarrow nn$, $\pi^-pp \rightarrow pn$) can generate multiple clusters, providing further background discrimination. Previous Geant4 simulations have demonstrated that this cluster analysis can reject 97% of π^0 events and 92.8% of π^- events [2]. However, the uncertainty in the number of neutrons emitted during π^- absorption in the BGO remained a significant source of systematic uncertainty.

To address this, we conducted a dedicated test experiment in March 2024 at the J-PARC K1.8 beamline. A 0.4 GeV/c π^- beam was directed onto the one segment of the BGO counter, and neutrons emitted from π^- absorption were detected using adjacent segment of the BGO counter. We compared the experimental data with Geant4 simulations and incorporated the observed differences into an improved cluster analysis to assess the feasibility of the β-decay measurement. In this presentation, we report on the experimental setup for the β-decay study of ${}^{5}_{\Lambda}\mathrm{He}$ /${}^{13}_{\Lambda}\mathrm{C}$ and the latest feasibility assessment based on the test experiment results.

Reference

[1] P.A.M. Guichon and A.W. Thomas, Phys. Lett. B **773** (2017) 332.
[2] K.Kamada *et al*., EPJ Web of Conferences **271**, 01009 (2022)

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