A significant improvement in the resolution of hypernuclear levels could be attained by studying the \((K^-, \pi^0)\) reaction at rest. The new LAMPF neutral meson spectrometer can attain a \(\pi^0\) energy resolution of 200 keV. It is shown that, even today, an experiment is feasible and would shed significant light on our understanding of hypernuclei.

1. Introduction

The experimental study of lambda hypernuclei has lagged far behind the theoretical sophistication of calculations done by physicists such as Jan \(\check{Z}\)ofka, but now we can at least dream of some possible improvements which would bring experimental data up to the necessary quality. Until now the main difficulty has been the very low flux of negative kaons that has been available from existing accelerators. The pioneering studies with the \((K^-, \pi^-)\) reaction have opened a fascinating window onto hypernuclei, but unfortunately the window has crazed, yellowing glass and we cannot see through properly. Even with the successful operation of very sophisticated spectrometers, experiments have been limited by painfully low count rates and poor resolution for the energy levels in the resulting hypernuclei, typically 2 to 4 MeV. The use of the \((\pi^+, K^+)\) reaction has opened a new window with a different view, but the glass is just as poor. We shall have to wait for PILAC at Los Alamos before an energy resolution of 200 keV can be achieved \([1]\). We suggest that the \((K^-, \pi^0)\) reaction at rest can provide a similar opportunity to dramatically improve the energy resolution.

2. The \((K, \pi)\) reaction at rest

Most studies of the \((K^-, \pi^-)\) reaction have used \(K^-\) momenta in the range of 600 to 800 MeV/c to minimize the momentum transfer to the nucleus and thus help the lambda stick in the nuclear environment. For the \((K^-, \pi)\) reaction at rest, the momentum transfer to the \(\Lambda\) is about 250 MeV/c, which is considerably more than the typical Fermi momentum. The reaction thus is more similar in character to the \((\pi^+, K^+)\) reaction which has a momentum transfer of about 350 MeV/c.

Some of the earliest emulsion experiments were done at rest. There were even counter experiments, for example one at CERN with \(^6\)Li and \(^7\)Li targets which used the \((K^-, \pi^-)\) and \((K^-, \pi^0)\) reactions to produce \(^4\)H and \(^4\)He and study their gamma-ray transitions \([2]\). However a recent series of experiments at KEK have highlighted the advantages of stopped \(K\) experiments and have obtained some useful data on branching ratios and typical spectra. Of particular relevance is the
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experiment on $^{12}$C($K^-$, $\pi^-$) at rest which obtained an energy resolution of about 2.5 MeV [3]. They measured the branching ratio to be $(2.3 \pm 0.3) \times 10^{-3}$ to the $(p_{3/2})^{-1}(p)_{\Lambda}$ state in $^{12}$C and $(0.98 \pm 0.12) \times 10^{-3}$ to the $(p_{3/2})^{-1}(s)_{\Lambda}$ state. These states are clearly observed and are cleanly separated from the background. In fact in this experiment they indirectly measured the branching ratio for $^4$He($K^-$, $\pi^0$) to the ground state to be $(7.4 \pm 1.0) \times 10^{-3}$.

Now the disadvantage of the ($K^-$, $\pi^-$) reaction at rest is that the $\pi^-$ loses energy as it comes out of the target, so if the kaons stop in a relatively large volume, the energy distribution of the pions outside the target is spread out and this can be the major contribution to the final energy resolution. The ($K^-$, $\pi^0$) reaction has the advantage that the $\pi^0$ decays immediately into two $\gamma$-rays, and these do not lose energy as they traverse the stopping target.

Thus the difficulty of studying the ($K^-$, $\pi^0$) reaction is entirely focussed on the $\pi^0$ spectrometer. The quality of such devices has been radically improved with the Los Alamos design of their new neutral meson spectrometer [4] which is based on the same principles as their existing $\pi^0$ spectrometer [5]. The new device uses active converters of BGO to produce two electron-positron pairs which thus determine the position of the $\gamma$-ray very precisely. Following the converters and wire chambers are CsI calorimeters which measure the total energy of the $\gamma$-rays to about 5%. There will be 120 individual crystals of pure CsI, each one measuring $10 \times 10 \times 35 cm^3$. A schematic drawing of the device is shown in Figure 1. It turns out that the most critical measurement is the vertex position and this can be turned into a determination of the $\pi^0$ energy with an uncertainty of only 200 keV, if the effective solid angle is cut back to 1 msr. Part of this device should be tested in 1992, but the complete spectrometer will not be available until a year later.

![Fig. 1. Schematic lay-out for a $\pi^0$ spectrometer.](image-url)