Study of Σ-Nucleus Potential by the (π^-, K^+) Reaction

KEK-PS E438 Experiment

We are studying the Σ-nucleus optical potential through investigating the inclusive (π^-, K^+) spectra on several nuclear targets since it is not well-known. In nuclear medium, a Σ hyperon is immediately annihilated with a nucleon into a Λ hyperon and a nucleon. Due to this absorptive potential, the Σ-hypernuclear bound state is spread out even if it exists. In fact, spectroscopic studies in the past have failed to identify the Σ-hypernuclear states, except for a very light system, ${}^4_\Sigma$He. It seems practically hard to investigate the Σ-nucleus potential systematically through spectroscopic studies of Σ-hypernuclear structure. Therefore, the inclusive (π^-, K^+) spectrum would provide information on the Σ-nucleus potential. The spectrum shape reflects the final state interaction of Σ^- with a residual nucleus, as shown in Figure 1.

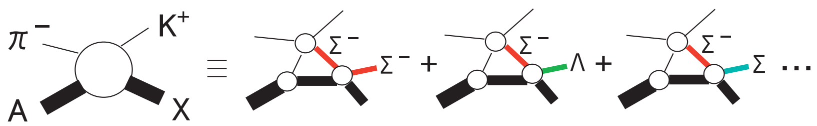

Figure 1: Diagram of the inclusive (π^-, K^+) reaction.

E438 was carried out at the K6 beam line of the KEK 12-GeV Proton Synchrotron. Pion beam momentum was chosen at 1.2 GeV/c. Scattered kaons were measured with the Superconducting Kaon Spectrometer (SKS) system. We obtained the (π^-, K^+)-inclusive spectra for five nuclear targets of C, Si, Ni, In, and Bi, as shown in Figure 2-(a)$\sim$(e).

The energy scale (horizontal axis) was calibrated by measuring the elementary $p(\pi^-, K^+)\Sigma^-$ reaction with the polyethylene (CH_2) target. The carbon spectrum in Figure 2-(a) was obtained by subtracting hydrogen contribution ("dip" in the figure) from the CH_2 spectrum. The energy resolution was found to be 1.93 MeV (FWHM). We successfully reproduced the elementary cross section measured in the previous experiment; the vertical scale (differential cross section) is thus correct.

The (π^-, K^+) reaction is almost free from back-ground event contamination. One finds significant yield in the bound region ($-B_{\Sigma^-}$<0), which demonstrates the finite strength of the Σ-nucleus potential. To obtain further information, we calculated the inclusive spectra in the framework of DWIA and compared with observed spectra. Figure 3 shows three calculated spectra for different Σ-nucleus potentials in case of Si, plotted together with the observed spectrum. Shape of each potential can be found in the right hand side. One finds that "shallow" potential does not fit the observed spectrum. Even "atom-DD" potential, having a strong repulsive core, does not reproduce the spectrum, where the potential has been extracted from the analysis of the Σ^--atomic X-ray data. We found that a strongly-repulsive potential is favored to reproduce the observed spectrum.

The present result would provide important information on investigating not only the hyperon-nucleon interaction, but also a role of hyperon in dense matter, such as a neutron star.

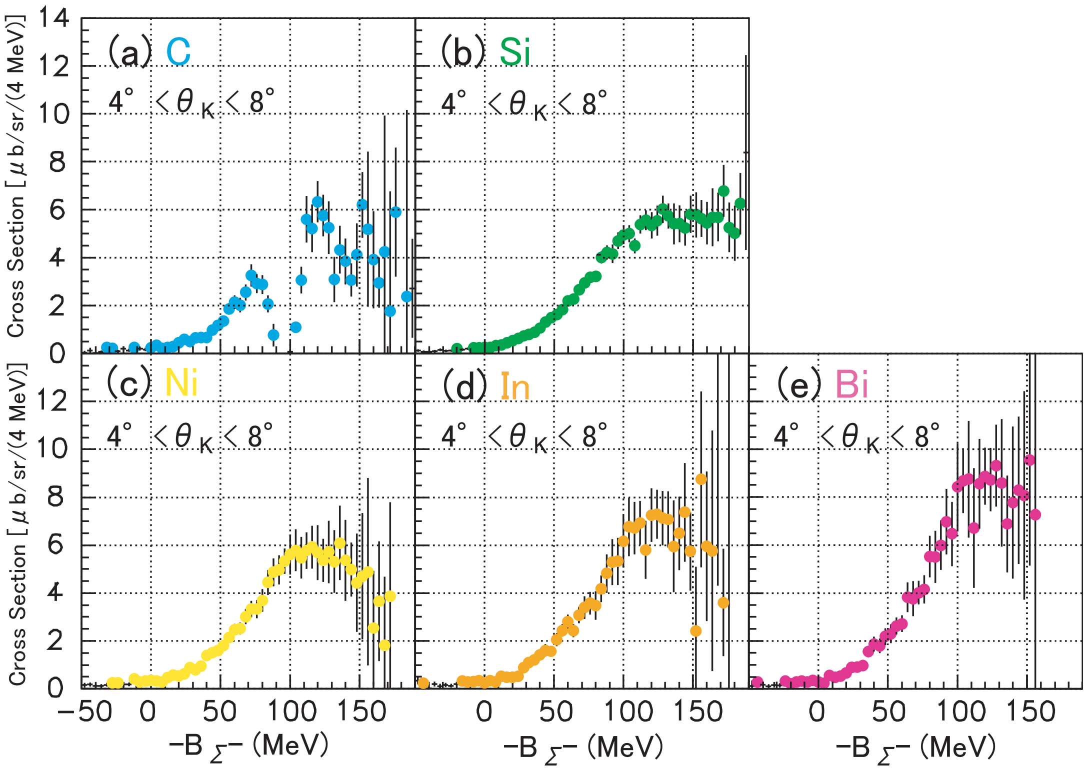

Figure 2: Inclusive (π^-, K^+) spectra on C, Si, Ni, In, and Bi as a function of the Σ^--binding energy $(-B_{\Sigma^-})$.

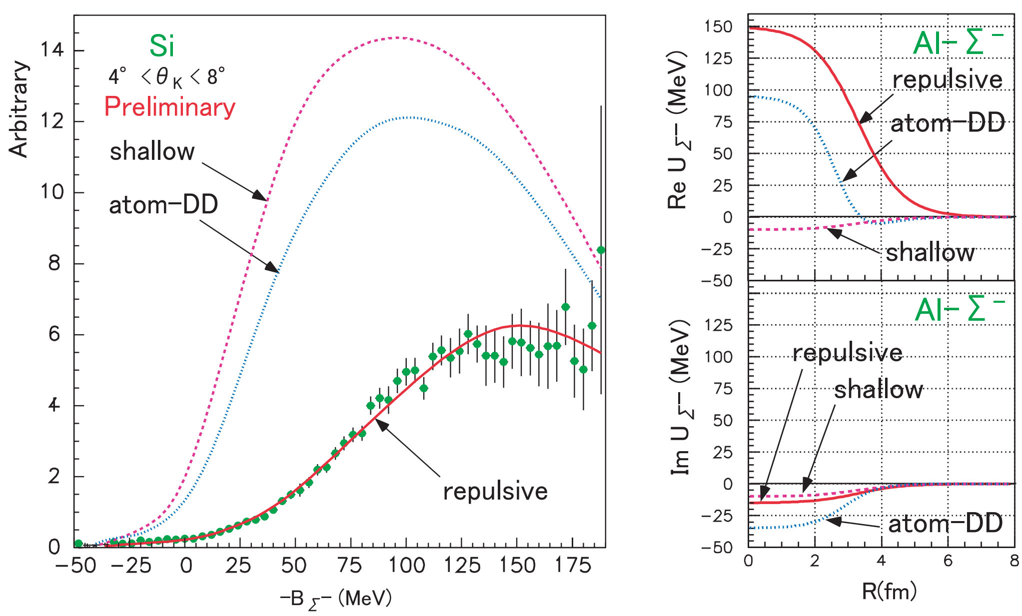

Figure 3: Calculated (π^-, K^+) spectra in DWIA (left) and the potential shapes used in the calculations (right-upper: real part, right-lower: imaginary part).