New deeply bound pionic states in Sn isotopes

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An experimental study of the ^{208}Pb(d,^{3}He) reaction at the Fragment Separator (FRS) had led to the discovery of the deeply bound pionic states $2p$ and $1s$ in ^{207}Pb [1]. In a following experiment pionic states in ^{205}Pb were populated in the ^{206}Pb(d,^{3}He) reaction. The better suited neutron hole excitation spectrum of ^{205}Pb together with an improved energy resolution of $\sim$ 300keV allowed for a clear separation of the pionic $1s$ state from the $2p$ state in the excitation energy spectrum. The data analysis of this experiment was completed, and final values for the pionic binding energies and widths for both $1s$ state and $2p$ state were determined [2]. From the pionic $1s$ binding energy and width, which is almost exclusively determined by the s-wave pion-nucleus potential, the central potential V_0 could be deduced to be $\sim$ 27MeV (repulsive) [2], which indicates a significant additional repulsion as compared to the value obtained with the free πN scattering lengths. The experiment does however not allow to decide whether this additional repulsion is due to the isoscalar or the isovector part of the interaction.

In order to experimentally separate both parts, one has to compare deeply bound pionic states in nuclei with different neutron to proton number ratio. In this respect the study of pionic states in Sn isotopes was considered particularly promising, an expectation which was supported by theoretical studies [3]. Sn has the advantage of having both a long chain of stable isotopes ranging from $A = 112$ to $A = 124$ and a well-suited neutron level scheme with low-lying $3s_{1/2}$ neutrons. This opens the possibility of populating quasi-substitutional configurations where the $s_{1/2}$ neutron is replaced by a negative pion in the $1s$ state. These configurations are preferentially formed at vanishing momentum transfer, a condition which is achieved in (d,^{3}He) transfer reactions at a deuteron incident kinetic energy close to 500 MeV.

In a beam time in May 2001 the population of deeply bound pionic states in Sn isotopes was studied at the FRS in the (d,^{3}He) reaction. The Sn isotopes $A = 112, 116, 120, 124$ were irradiated with a d beam at $T_d = 503.388\,\mathrm{MeV}$. One of the prerequisites for the experiment was a high quality of the d beam, which was delivered from SIS with an intensity of $1.5{\cdot}10^{11}$ per spill (average intensity $\sim 0.5 \cdot 10^{11}$/s), a momentum spread $\delta p/p = 3 \cdot 10^{-4}$, and a horizontal beam spot $\delta x \simeq$ 1mm. In order to achieve the aspired energy resolution of 300 keV, thin strip targets of 1.5 mm width and 20 mg/cm^2 were used. The ^{3}He energy at the FRS focal plane was calibrated by using the non-pionic ^{112,116,120,124}Sn(d,^{3}He)^{111,115,119,123}In$_{(\mathrm{g.s.})}$ reactions, and independently by using the p(d,^{3}He)π^0 reaction from a thin mylar layer attached to the downstream surfaces of the Sn targets. Fig. 1 shows the observed energy spectra (acceptance corrected) of ^{3}He in the ^{116,120,124}Sn(d,^{3}He) reactions. The three distinct peaks in the middle part correspond to the $1s$ states in ^{115,119,123}Sn, respectively. The large skewed peaks close to 371 MeV arise from the p(d,^{3}He)π^0 reaction, and are subject to a large kinematical shift and broadening. They not only assured that there was no long term drift in the experiment but also provided an independent energy calibration which turned out to be consistent with the calibration with the Sn(d,^{3}He)In reactions. Further analyses to deduce the binding energies, widths, isotope shifts and cross sections are in progress.

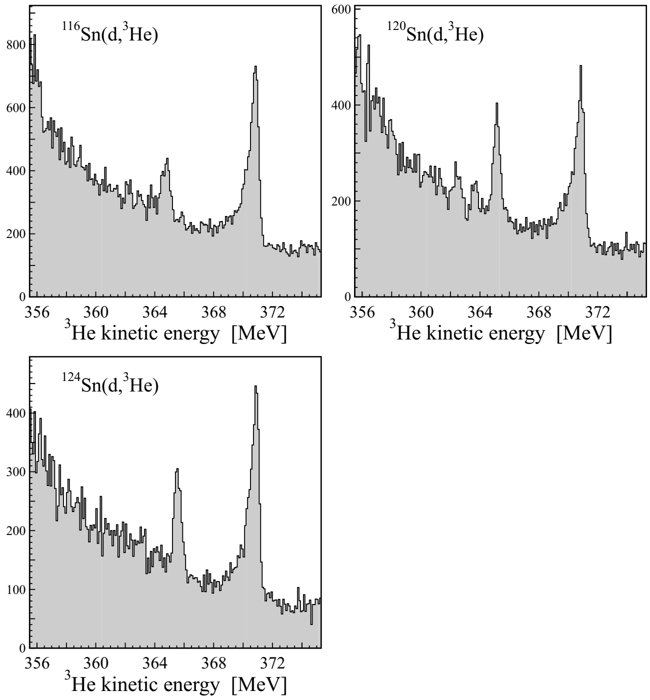

Figure 1: Acceptance corrected ^{3}He kinetic energy spectra measured in ^{116,120,124}Sn(d,^{3}He) reactions at $T_d = 503.388\,\mathrm{MeV}$. See text for further explanation.

References

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