Observation of the Pionic 1*s* State in Lead in the ^{206}Pb(d,^{3}He) Reaction

H. Gilg [a], A. Gillitzer, P. Kienle, M. Münch, W. Schott, H. Geissel [b], G. Münzenberg [b], H. Weick [b], S. Hirenzaki [c], T. Yamazaki [d], R.S. Hayano [e], K. Itahashi [e,f], K. Suzuki [e], N. Iwasaki [g], D. Tomono [g], and T. Yoneyama [g]

[a] present address: Department of Physics, University of Tokyo [b] GSI, 64291 Darmstadt
[c] Department of Physics, Nara Women's University, Nara 630, Japan
[d] Center for Nuclear Study, University of Tokyo and JSPS, Tokyo 102, Japan
[e] Department of Physics, University of Tokyo, Tokyo 113, Japan [f] present address: GSI Darmstadt
[g] Department of Physics, Tokyo Institute of Technology, Tokyo 152, Japan

Experimental studies of the ^{208}Pb(d,^{3}He) reaction at the GSI Fragment Separator FRS in recoil free kinematics lead to the first observation of deeply bound pionic states in heavy atoms [1]. Although this discovery is a major step in the investigation of pionic atoms and deepens the understanding of the pion-nucleus potential, the 1*s* and 2*p* levels were not clearly resolved. A new generation of high resolution spectroscopy of deeply bound pionic states in lead has been opened with a recent experiment at the FRS.

The spectrum of the ^{208}Pb(d,^{3}He) reaction shows a prominent peak at excitation energies below the continuum π^- emission threshold which was assigned to the $(2p)_\pi(p_{1/2,3/2})_n^{-1}$ configuration based on the comparison with DWIA calculations [2]. A shoulder at lower excitation energy next to the 2*p* peak was attributed to the $(1s)_\pi(p_{1/2,3/2})_n^{-1}$ contribution, see figure 1. Taking into account the known neutron separation energies in ^{208}Pb, the pionic binding energies were determined to be $B_\pi(2p) = 5.31 \pm 0.09$ MeV and $B_\pi(1s) = 7.1 \pm 0.2$ MeV. These results were used to deduce the effective mass of π^- in nuclear matter ($m^\star_\pi = 160 \pm 20$ MeV/c^2 for $\rho_n/\rho_p = 1.6$ [3]).

In the most recent experiment the FRS was used as a high-resolving spectrometer to study the ^{206}Pb(d,^{3}He) reaction, i.e. to analyze the momentum spectrum of the ^{3}He nuclei at the second dispersive focal plane via position measurement in coincidence with particle identification at the 4^{th} (final) focal plane [1].

The goal of the experiment was to measure the binding energy of the 1*s* state and the widths of both 2*p* and 1*s* states more precisely to improve the present parametrisations of the pion-nucleus optical potential. The ^{206}Pb(d,^{3}He)$\pi\otimes^{205}$Pb reaction was predicted [4] to be better suited for separation of the $(1s)_\pi$ and $(2p)_\pi$ levels. Besides the use of a ^{206}Pb target several experimental improvements (thinner (25 mg/cm^2) Pb stripe targets and a better stabilisation and controlling of the magnetic fields of the FRS to $\delta B/B \leq 1 \cdot 10^{-5}$) were introduced the most recent measurement which yield roughly a factor of 2 better resolution in the momentum spectrum. A comparison of the obtained spectrum and the result of the previous experiment is presented in figure 1. The instrumental Q value resolution in the new experiment is about $\delta Q \simeq 0.3$ MeV, which is mainly due to the momentum spread of the deuteron beam.

The new quality of spectroscopy is clearly visible in the shown position spectra. The pionic 1*s* component is now well separated from the 2*p* level. Obviously, this will considerably reduce the uncertainty in the determination of the pionic binding energy in the 1*s* state, which has the largest overlap with the nuclear density distribution and is therefore most sensitive to the *s* wave pion potential and the π^- mass shift in the nuclear medium. In addition, the comparison of the 2*p* binding energies in ^{207}Pb and ^{205}Pb can give information on the influence of the neutron density distribution on the deeply bound pionic states.

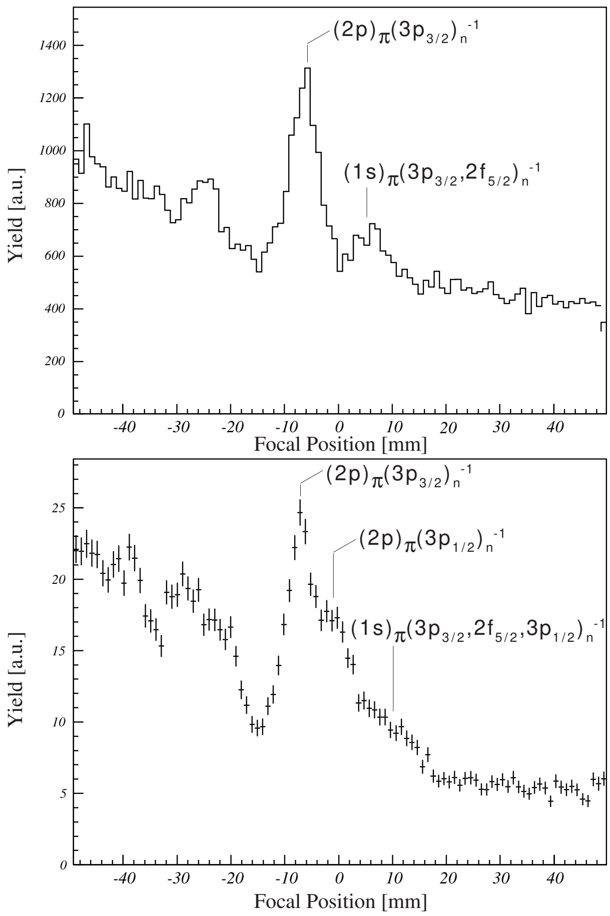

Fig. 1: Comparison of the ^{3}He position spectra obtained in the present (upper panel) and the previous experiment (lower panel)

References

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