Deeply Bound *1s* and *2p* Pionic States and the *s*-Wave Part of the Pion-Nucleus Interaction

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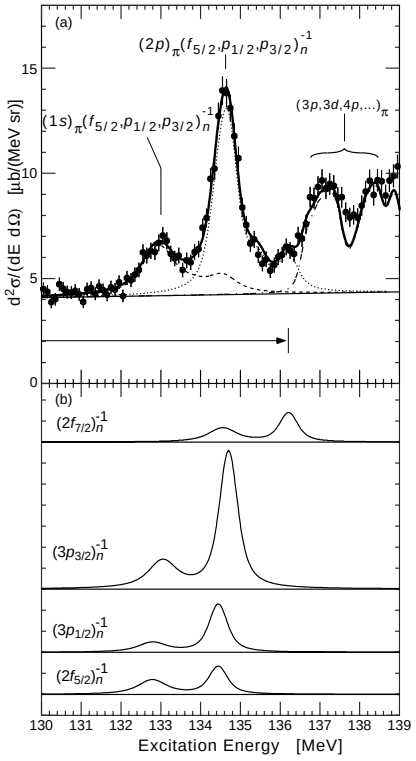

Figure 1: Measured excitation energy spectrum for the ^{206}Pb(d,^{3}He) reaction (T_d = 600 MeV) in the region of the bound pionic states. In a fit (fitting region indicated by the arrow) $(1s)_\pi$ and $(2p)_\pi$ peak are decomposed into the contributing neutron hole configurations of which the most important are $2f_{5/2}$, $3p_{1/2}$ and $3p_{3/2}$.

After the discovery of the deeply bound $(1s)_\pi$ and $(2p)_\pi$ states in ^{207}Pb in the ^{208}Pb(d,^{3}He) reaction [1] and the determination of the real and imaginary *s*-wave-potential parameters b_0 and ImB_0 from the $(2p)_\pi$ binding energy and width [2, 3], a new experiment on the ^{206}Pb(d,^{3}He) reaction was performed at the Fragment Separator (FRS). The better suited neutron shell structure of ^{206}Pb compared to ^{208}Pb and an improved energy resolution allowed for a clear separation of the $(1s)_\pi$ component from the dominant $(2p)_\pi$ peak in the excitation spectrum [4], which was not achieved in the ^{208}Pb(d,^{3}He) experiment. Accordingly the binding energy and width of the $(2p)_\pi$ state (B_{2p}, Γ_{2p}) and especially of the $(1s)_\pi$ state (B_{1s}, Γ_{1s}) can be determined with significantly higher precision.

Decomposing the excitation energy spectrum into $(1s)_\pi$ and $(2p)_\pi$ components coupled to different neutron hole contributions (Figure 1) the values B_{1s} = 6.768 ± 0.044 (stat.) ± 0.041 (syst.) MeV, $\Gamma_{1s} = 0.778^{+150}_{-130}$ (stat.) ± 0.055 (syst.) MeV, B_{2p} = 5.110 ± 0.015 (stat.) ± 0.042 (syst.) MeV and Γ_{2p} = 0.371 ± 0.037 (stat.) ± 0.048 (syst.) MeV were obtained.

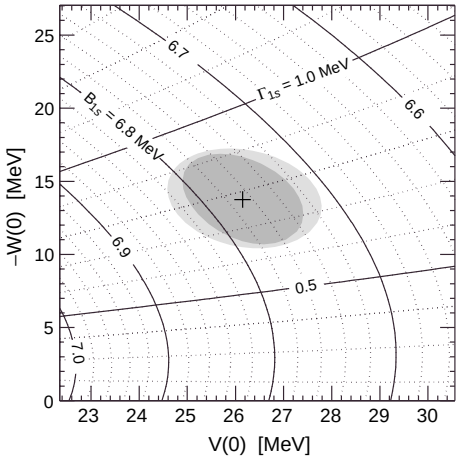

Figure 2: Binding energy and width of the $(1s)_\pi$ state in ^{205}Pb related to the real ($V(0)$) and imaginary ($W(0)$) part of the *s* - wave potential in the center of the nucleus. The *p* - wave potential is taken from a parameter set given by Seki and Masutani [5]

These quantities were used to determine the pion-nucleus *s* - wave optical potential. The most precise values for the real and imaginary part ($V(0) = 26.1^{+1.7}_{-1.5}$ MeV, $W(0) = -13.8^{+3.4}_{-3.5}$ MeV) were deduced from B_{1s} and Γ_{1s} (Figure 2). The 1*s* state has a larger sensitivity, since the pionic 1*s* wave function has larger overlap with the nuclear density distribution than the 2*p* wave function, and since the 1*s* binding energy and width are almost exclusively determined by the *s* -wave potential parameters. With the assertion that the isovector term of the π^--nucleus interaction $b_1^\star$ is modified in the medium and that the isoscalar part is induced by double scattering mainly, one can derive from $V(0)$ = 26.1 MeV for ^{205}Pb that $b_1^\star \simeq -0.125 m_\pi^{-1}$. This also indicates a reduction of the quark condensate to 72%.

References

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