The observation of deeply bound pionic states of xenon produced in the
\( \text{Xe}_{\text{nat}}(d,^3\text{He})\text{Xe}_{\text{nat-bound}} \) reaction

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The observation of a clear peak structure corresponding to the 2p state of pionic atoms of
\(^{207}\text{Pb}\) and \(^{208}\text{Pb}\) produced in \((d,^3\text{He})\) reactions at an energy of \(E_d=600\text{MeV}\) [1,2] confirmed the
theoretical prediction of the existence of deeply bound pionic states in heavy nuclei [3]. At the same
time these experiments confirmed that the 2p state is populated preferentially in the case of a lead
target in contrast to the 1s state, which is suppressed by the lack of s-state neutrons in the outer shell.
The closed shell nucleus \(^{136}\text{Xe}\) is suggested by Umemoto et al. [4], to be a particularly good candidate
as a target for observation of the deeply bound \(1s\) state in the \((d,^3\text{He})\) reaction.

Here we report on a pilot study of the production of pionic atoms of xenon in \((d,^3\text{He})\) reactions
at \(E_d=500\text{MeV}\), using natural xenon as a target. The experiment was done at the CELSIUS storage ring
energy resolution of the spectrometer was \(\leq1.2\text{ MeV}\) in the measured energy range of \(^3\text{He}\) ions.

The measured \(^3\text{He}\) spectrum from
the \(\text{Xe}_{\text{nat}}(d,^3\text{He})\text{Xe}\) reaction is shown in
fig.1a. Two peaks are observed at approximately 362 and 364 MeV. The peak
positions are in a good agreement with those
expected following the population of the \(1s\) state in odd \(A\) and even \(A\) isotopes of xenon,
respectively (fig.1b). Thus we conclude that the production of deeply bound pionic states in
the mixture of xenon isotopes has been observed in the \(\text{Xe}_{\text{nat}}(d,^3\text{He})\) reaction. An
experiment on the \(^{136}\text{Xe}(d,^3\text{He})^{35}\text{Xe}_{\text{nat-bound}}\) reaction is being prepared with an isotopically
enriched target. Based on the present results such an experiment offers very good
perspectives for a precise determination of the binding energy and the width of the \(1s\) state.

References