The Nucleon Density of ^{172}Yb and ^{176}Yb at the Nuclear Periphery Determined with Antiprotonic X–rays

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The investigation of antiprotonic X-rays allows to draw conclusions about the nucleon density at the nuclear periphery [1,2]. In an experiment at the LEAR facility of CERN antiprotons with an initial momentum of 414 MeV/c were stopped in ^{172}Yb and ^{176}Yb to study the antiprotonic–atom cascade. The strong interaction widths and shifts of the lowest observable X–ray transitions were deduced.

Due to the good statistics of the collected data forty X–ray transitions up to $\Delta n = 5$ could be observed. The experimental intensities of the transitions were compared with results from calculations of the antiprotonic cascade. The cascade calculations, based on a work by Leon [3], started below the electron cloud at n=20. The initial distribution was adjusted in order to reproduce the X–ray intensities of transitions with $n \leq 20$. Calculated and measured relative intensities were found to be in good agreement.

This good agreement and the large number of observed transitions opened the possibility to determine for the first time the widths of non–circular orbits in addition to the circular ones. Altogether three level shifts and six level widths were measured for ^{172}Yb and ^{176}Yb, respectively. In fig. 1 the results for ^{176}Yb are shown. From ^{172}Yb to ^{176}Yb the widths are slightly increasing whereas the shifts stay roughly constant.

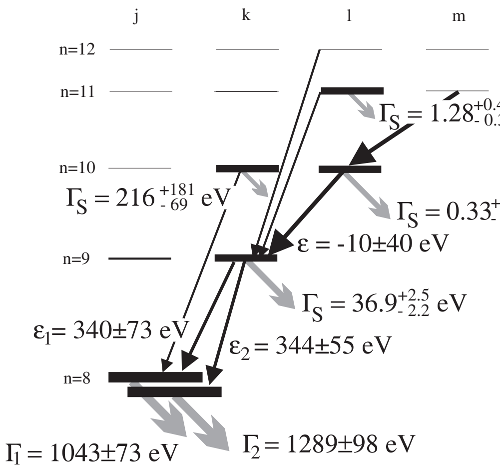

Fig. 1: Energy shifts and widths for those levels of antiprotonic ^{176}Yb which are sizeably influenced by the strong interaction. Γ_1 and ε_1: Width and shift for $j = l + 1/2$; Γ_2 and ε_2: Width and shift for $j = l - 1/2$.

From the intensity balance of the lowest populated levels, the strength of the strong interaction with the nucleus and the nuclear density was deduced. A Fermi distribution was used for the nucleon densities. With the parameters from Ref. [4] (model a) for the proton density distribution and the difference between neutron and proton radius taken as 0.13 fm [5], the difference between the neutron and proton diffuseness parameters was deduced to be (0.58 ± 0.04) fm for ^{172}Yb and (0.71 ± 0.04) fm for ^{176}Yb. The resulting nucleon densities are plotted for ^{176}Yb in fig. 2. Additionally the neutron–to–proton density ratio is drawn together with the absorption probabilities for the most interesting levels.

The method described here together with the determination of the annihilation products [6] makes antiprotonic atoms being a powerful tool to study the nuclear periphery.

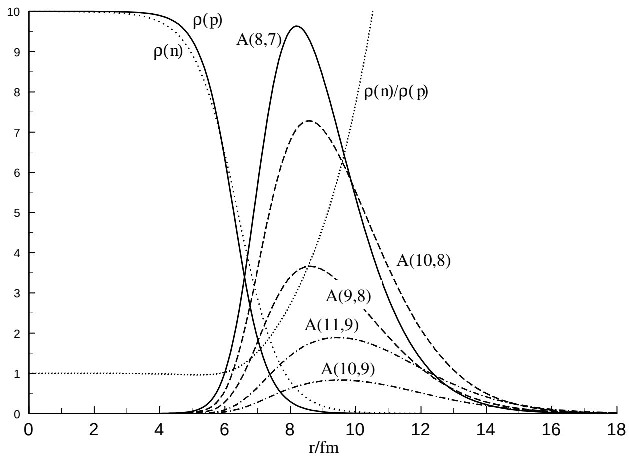

Fig. 2: Absorption probability for antiprotons A(n, l), proton ρ(p) and neutron density ρ(n), and neutron–to–proton density ratio for ^{176}Yb. The neutron and proton densities are normalized to ten in the center of the nucleus. The absorption probabilities of the levels (9,8) and (10,8) are magnified by a factor of 20 compared to that of (8,7), those of (10,9) and (11,9) by a factor of 400.

References

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