Systematic Investigation of Antiprotonic X Rays and of γ Rays after Antiproton Annihilation

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The investigation of antiprotonic x rays allows to draw conclusions about the nucleon density in the nuclear periphery [1]. In the PS209 experiment at the LEAR facility of CERN the antiprotonic-atom cascade has been studied for a large number of elements from oxygen to uranium (cf. fig. 1) and the strong interaction widths and shifts of the lowest observable x-ray transitions were deduced. For the investigated isotopes up to eight parameters could be measured [2]. For many of the investigated elements isotopic effects were found. The width and shift depends on the antiproton-nucleus interaction and on the nucleon density in the nuclear periphery, where the antiproton-annihilation takes place. The results allow to test different models of the nucleus and of the antiproton-nucleus interaction.

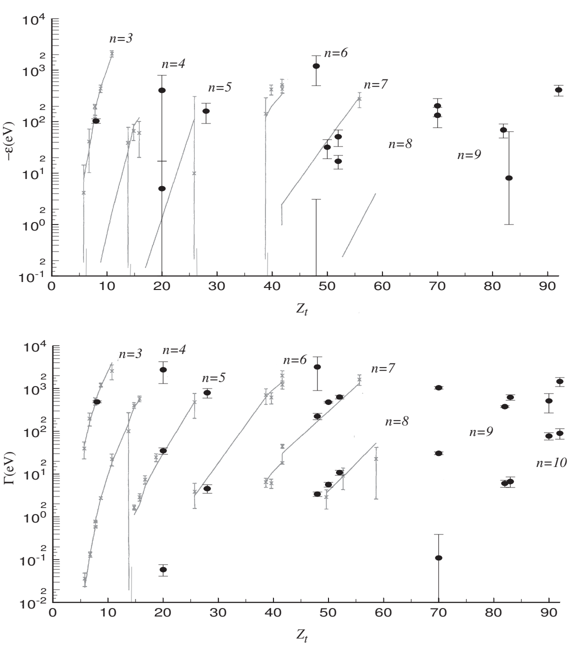

Fig. 1: Strong-interaction energy shifts and widths of antiproton-atomic levels. The grey dots correspond to measurements before the experiment PS209. The lines show the result from calculations with an effective antiproton-nucleus optical potential [1]. The black points are the new results of the PS209 collaboration.

In fig. 1 the results from the PS209 collaboration are plotted together with the data compiled in Ref. [1] from earlier measurements. More elements have been measured than in all experiments before and for most of the previously investigated isotopes the accuracy has been improved. The comparison shows qualitatively a good agreement with the simple model of an effective antiproton-nucleus optical potential. Now new calculations should follow to adjust the antiproton-nucleus optical potential to the new data and simultaneously determine the nucleon density in the nuclear periphery.

In an additional experiment prompt γ rays of residual nuclei after antiproton annihilation have been investigated. The excitation spectrum of four residual nuclei after the annihilation could be determined up to an energy of 1.3 MeV. It was found that highly excited levels are produced, which decay into the isomeric or ground state of the nucleus.

From the yield of residual nuclei with one nucleon less than the target nucleus the neutron-to-proton density ratio in the nuclear periphery can be determined [3,4]. This was done for several target nuclei. The residual $(A_{\rm t}-1)$-nuclei were detected by their γ activity. The results were compared with nucleon densities from Hartree-Fock-Bogoliubov calculations. From the comparison of measured and calculated neutron-to-proton density ratios the ratio of the imaginary parts of the effective scattering lengths of antiprotons with neutrons and protons was deduced to be 0.69±0.04 [5] (cf. fig. 2). This value is a measure for the difference in the strength of antiproton-annihilation with neutrons and protons.

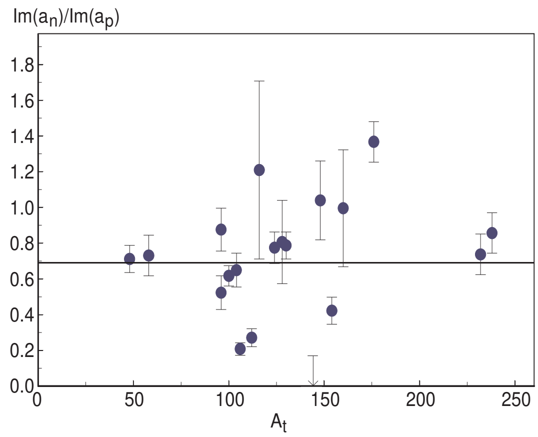

Fig. 2: Ratios of the imaginary parts of the effective scattering lengths of antiprotons with neutrons $a_{\rm n}$ and protons $a_{\rm p}$ versus $A_{\rm t}$. The line corresponds to the value 0.69.

References

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