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High precision atomic data for halo nuclei and related nuclear structure[1]

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The observation of extremely large nuclear interaction cross sections for the isotopes ^{6,8}He, ^{11}Li, and ^{11,14}Be demonstrated that one of the paradigms of nuclear structure – a constant nuclear matter density throughout the nucleus – is not necessarily fulfilled. It turned out that the large cross section of these isotopes is caused by a "halo" of dilute neutron matter around a central core nucleus that obeys the usual nuclear density. A large deformation, as another possible explanation, was soon ruled out by laser spectroscopic investigations of the hyperfine structure of ^{11}Li and ^{11}Be, showing that their nuclear moments are in accordance with a nearly spherical nucleus. Since then, a measurement of the nuclear charge radii of these exotic isotopes was considered of high importance. Only atomic isotope shift measurements can provide reliable nuclear charge radii of short-lived isotopes so far. This technique has been used on long isotopic chains of heavier elements above neon (Z=10) for decades. However, the isotope shift in light elements is dominated by huge mass-dependent shifts whereas the nuclear volume shift is only on the scale of a few 10 ppm. Semi-empirical techniques – that proofed to be successful in separating mass-dependent and finite-size effects for heavier elements – are therefore not sufficiently accurate in these cases. A clear separation of the nuclear size effect became possible only with the emergence of new techniques in high-accuracy atomic structure calculations of two-electron and three-electron systems, allowing the calculation of the mass-dependent isotope shift with accuracy of 1 ppm and better. Isotope shifts, hyperfine structure splitting and absolute transition frequencies have now been determined for all isotopes of helium, lithium and beryllium – except ^{14}Be – in several experiments at various on-line facilities world-wide. In my talk I will present a few examples for the techniques that are applied in such measurements and discuss how their results have influenced our picture of halo nuclei.

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