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Charge radii of neutron-deficient 52,53Fe produced by projectile fragmentation

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A kink at a nucleon shell closure in mean-square charge radii r2 along an isotopic chain is a distinct feature of charge radii [1], though the underlying mechanism still remains elusive. Such a feature is clearly visible in the Ca chain at the N = 28 neutron shell closure, which has been a major challenge for nuclear theory to understand [2]. In the present study, the r2 of 52,53Fe below N = 28 were determined [3] to investigate how the pattern of r2 around N = 28 changes when moving from semi-magic Ca to Fe isotopes, where the neutron-proton polarization effects are enhanced.

The 52,53Fe beams were produced by fragmentation of a 160-MeV/nucleon 58Ni beam in a Be target at NSCL at MSU. The 52Fe or 53Fe beams were selected using the A1900 fragment separator [4], thermalized in a gas stopper [5], and extracted at an energy of 30 keV. The Fe+ beam was then transported to the BECOLA facility [6] and bunched-beam collinear laser spectroscopy was performed to measure atomic hyperfine structures (hfs).

Ion beams of the transition-metal Fe are known to be notoriously difficult to produce at ISOL facilities due to long release times from thick targets. The novel scheme of in-flight separation followed by gas stopping was used in the present study for the first time for laser spectroscopy. This is a major step forward and complements such capabilities well established at ISOL facilities, where significant data on r2 have been obtained for selective elements [1].

The r2 of 52,53Fe were determined from the isotope shifts of the hfs. The multi-configuration Dirac-Fock method was used to calculate atomic factors. The obtained r2 of Fe exhibits a sharp kink at N = 28, which appears to have a similar structure to the Ca chain. The nuclear density functional theory was used to interpret the results. The underlying mechanisms of the kinks in r2 of Fe and Ca, as well as the experimental details, will be discussed.

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