EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Letter of Clarification for INTC-P-486: Collinear laser spectroscopy on chromium: from $N = Z$ towards $N = 40$

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The purpose of this letter is to address the comments raised by the INTC at the November 2016 meeting regarding the proposal INTC-P-486.

Comment 1: "The change of the charge radii trend expected at $N = 32$ is improbable."

Although the size of the $N = 32$ subshell gap is suggested to be largest at $Z = 20$ and to decrease with increasing proton number, typical signatures for a shell closure such as a high $E(2^+)$ [1] and low $B(E2)$ [2] value are still observed in Cr. Since these observations are usually accompanied by a characteristic kink in the course of the mean-square charge radii, the question whether an effect will be seen in the Cr isotopic chain is certainly valid. Recent collinear laser spectroscopy measurements of the Ca isotopes have however revealed that the charge radius at $N = 32$ is unexpectedly large [3], in contradiction with the expected decrease in the case of a shell closure. Since the shell effect should be smaller in Cr than in Ca, the INTC referees correctly remark that it is therefore likely that no change in slope of the mean-square charge radii will be seen in the Cr isotopic chain. However, we note that in order to really see a change in slope, also the charge radii beyond $N = 32$ need to be known. Furthermore, even if no effect is seen, our data will provide input to better understand the intriguing result in Ca, which currently cannot be reproduced by state-of-the-art models.

Comment 2: "Moreover, no theoretical prediction was presented, with which the experiment could be compared. . . . The INTC recommends that a letter of clarification be submitted presenting some support from theory."

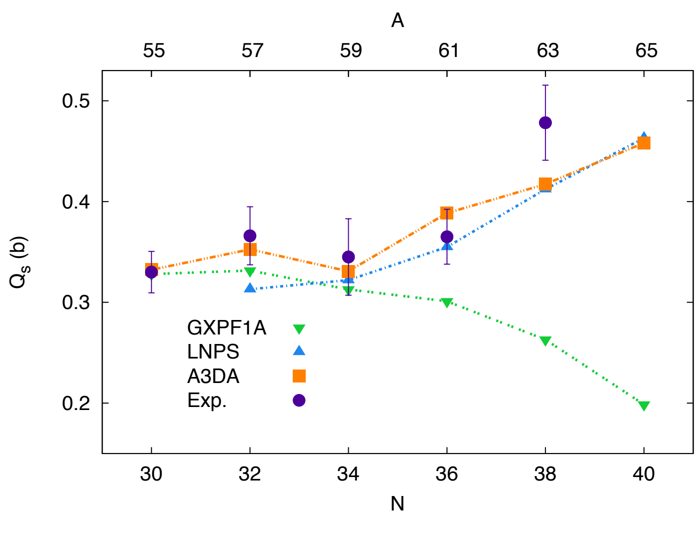

Figure 1: Experimental quadrupole moments of the Mn isotopes compared to shell model calculations using the GXPF1A, LNPS and A3DA interaction. Figure taken from [4].

So far, large-scale shell model calculations have provided the most accurate description of magnetic and quadrupole moments in this mass region. As illustrated in the recent collinear laser spectroscopy work [4–6] on Mn, one proton heavier than Cr, the LNPS

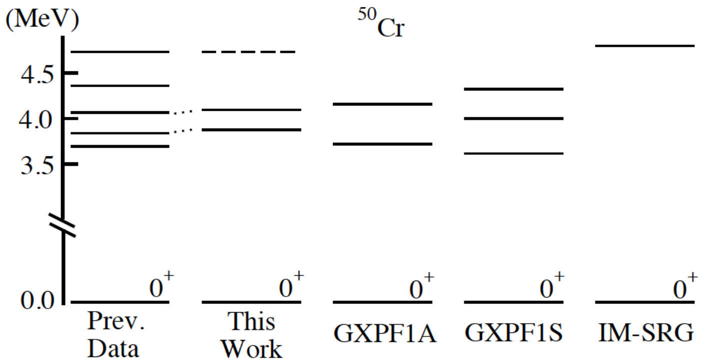

Figure 2: Experimental 0^+ spectrum of ^{50}Cr compared with several theories, such as the ab-initio IM-SRG discussed here. Figure taken from [10].

interaction [7] has proven to be very successful in the region of deformation around $N = 40$ (see Fig. 1). Alternatively, also Monte Carlo shell model calculations using the A3DA interaction [8, 9] provide a good reproduction of the observed nuclear moments in Mn. By calculating potential energy surfaces in a constrained Hartree-Fock framework using this A3DA shell model hamiltonian, also the shape evolution along the Mn isotopic chain could be studied. For the proposed Cr work, we are in contact with both theoretical groups.

In the last few years, tremendous progress in ab initio many-body methods has been made, especially in the medium-mass regime. Semi-magic nuclei up to $Z = 50$ have been calculated with large-space methods [11, 12], and a valence-space version of the in-medium similarity renormalization group (IM-SRG), based on two- (NN) and three-nucleon ($3N$) forces from chiral effective field theory, has since extended the reach of ab initio methods to ground and excited states of essentially all open-shell nuclei throughout the p-, sd-, and pf-shell regions [12, 13]. This allows, for example, the prediction of the 0^+ spectrum of ^{50}Cr [10, 13], which was found to be within a few hundred keV of experiment, as shown in Fig. 2. With NN and $3N$ forces which reproduce saturation properties in infinite matter, binding energies of all nuclei in the lower pf-shell can now be calculated [14], and the agreement with the new ISOLTRAP-measurements of the Cr-isotopes is remarkable [15, 16].

These IM-SRG calculations have also recently been extended to other operators such as charge radii and electromagnetic moments [16], but insufficient experimental data can make testing predictions across regions difficult. Therefore measurements of ground state properties of $^{48-61}$Cr will provide an excellent opportunity for further test the performance of these new calculations.

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