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Probing short range interactions in neutron rich system at ISS

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Pairing correlations are basic elements of superconductivity and superfluidity in strongly interacting quantum many-body systems. These phenomena span very different size scales, from color-superconducting quark matter to neutron stars, and very different energies, from below meV in superconductors to MeV in nuclei and 100 MeV at the quark scale. Of particular interest are superfluid fermionic states in multicomponent systems with cross-species pairing. Nuclei in this respect represent a very interesting case and indeed the existence of a coherent pn pairing state has been longly investigated with different experimental probes along the line of stability. Open question is if pairing is modified in systems with neutron excess. A recent electron and proton scattering experiment [1] has shown that nucleon in nuclei form close proximity pairs, but, that the fraction of high-momentum protons increases markedly with the neutron excess in the nucleus, whereas the fraction of high momentum neutrons decreases slightly. This effect is somewhat unexpected in the classical shell model, where protons and neutrons fill independent orbits, indicating the presence of a strong pn interaction. For more neutron rich systems, since the neutrons are occupying higher momentum orbitals a strong pn interaction will shift the protons toward more excited states across the Fermi energy surface making the proton distribution more diffuse. As an example we have calculated the proton occupancies for the gs of 68Ni comparing them with those of 56Ni. Using a Shell Model space of f7/2, p3/2, f5/2, p1/2 and g9/2 for both protons and neutrons we obtain spectroscopic factors of 7.754, 0.218, 0,021, 0.004, 0.004 for protons and 7.993, 3.933, 5.769, 0.099, 2.206 for neutrons in the case of 68Ni and 7.310, 0.595, 0.076, 0.015, 0.004 for protons and 7.313, 0.587, 0.079, 0.016, 0.005 for neutrons in the case of 56Ni. Clearly if such effect should be confirmed a revision of the role of the pn interaction would be required.
Proton stripping reactions for nuclei close to shell closures (Z=28 or 50) are suited to probe such effect. Examples are 68Ni(t,4He)67Co or 132Sn(t,4He)131In using the ISS solenoid. For a 68Ni beam (8 10ˆ5 pps at Isolde) at 9 MeV/n, cross sections of the order of several tents mb/sr are expected.

[1] Probing high-momentum protons and neutrons in neutron-rich nuclei Nature 2018 Aug, 560(7720):617-621. Doi: 10.1038/s41586-018-0400-z.

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