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Negative ion spectroscopy at CRIS-ISOLDE

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Negative ion spectroscopy at CRIS-ISOLDE

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Negative ions are unique quantum systems to probe electron correlation effects: since the Coulomb potential of the nucleus is almost entirely screened, the binding of the additional electron is primarily due to many body interactions between electrons. Consequently, negative ions are sensitive probes for electron correlation theories that go beyond the independent particle approximation. However, due to the weak binding potential, the energy gained by attaching an electron to a neutral atom, referred to as electron affinity (EA), is typically only of the order of one eV. For the same reason, negative ions typically lack bound excited states with opposite parity. Consequently, the EA is the only parameter which can be probed with high precision, typically via laser photodetachment threshold spectroscopy.

In order to study radiogenic elements, in particular those with short half-lifes, an on-line facility such as CERN-ISOLDE is needed, where elements with half-lifes larger than 30ms can be produced and delivered to experimental setups. A program to study EAs and isotope shifts utilizing radiogenic negative ions at ISOLDE was established by the GANDALPH collaboration, reaching a major milestone with the determination of the electron affinity of astatine utilizing the GANDALPH detector in 2018 [1].
Most commonly, ISOLDE uses positively charged ion beams produced by a variety of ion sources, thereby requiring considerable time and effort for the production of negative ion beams. Furthermore, the existing negative ion source only produces the halogen elements efficiently. Hence, in order to widen the scope of negative ions available at ISOLDE, efforts to convert positive ions delivered by ISOLDE to negative ions using the charge-exchange process were initiated. Initial yields of the production of uranium from charge exchange reactions by injecting a 40keV ion beam into a sodium filled charge exchange cell were performed in 2022 using the CRIS setup [2].

Following the successful tests, a beamline dedicated for negative ion beam spectroscopy, utilizing the GANDALPH detector connected to the CRIS setup was designed, expected to be commissioned for experiments by the end of 2024.

Here, we will present the status and developments of the negative ion program at ISOLDE utilizing the charge exchange production at CRIS as well as future activities including the isotope shift in the EA of chlorine, the EAs of Po, Fr and the actinide elements.

References:
[1] D. Leimbach et al., Nat Commun 11, 3824 (2020)
[2] M. Nichols et al., NIM B 41, (2023)

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