Contribution ID: **44** Type: **Oral**

Combining a cryogenic Paul trap and an electrostatic ion beam trap to explore the most exotic nuclides with high-resolution laser spectroscopy

Wednesday 15 January 2020 09:30 (30 minutes)

Collinear laser spectroscopy (CLS) is a powerful tool to access nuclear ground state properties of short-lived radionuclides by measuring the atomic or ionic hyperfine structure [1,2]. This technique uses fast (˜30 keV) beams to minimize the Doppler broadening and thus, approaching the natural linewidth which is necessary to resolve the hyperfine structure. However, in order to explore the most exotic nuclides far away from stability, more sensitive methods are needed. For this reason, the novel MIRACLS (Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy) project at ISOLDE/CERN, aims to combine the high spectral resolution of conventional CLS with high experimental sensitivity.

This increase in sensitivity is achieved by trapping ion bunches in a novel 30 keV electrostatic ion beam trap (EIBT) [3], in which the ions bounce back and forth between two electrostatic mirrors such that the laser-ion interaction time is increased with each revolution.

The combination of CLS and EIBT techniques in MIRACLS constitutes stringent requirements on the emittance of the probed ion bunches. A low energy spread (< 1 eV) to minimize the CLS Doppler broadening is as essential as a temporally narrow ion-bunch profile (< 500 ns) for EIBT operation. Moreover, the transversal emittance should be as small as possible to maintain ion trajectories parallel to the laser-beam axis over thousands of revolutions inside the EIBT.

Although specialized linear Paul traps have explored the benefits of cryogenic environments cooled by LN2 [4], conventional devices for buffer-gas cooling and bunching at RIB facilities operate at room temperature. As the emittance scales linearly with the "buffer gas temperature"[5], a compact, linear Paul trap with cryogenic cooling down to < 40 K is currently designed, to meet the emittance requirements at MIRACLS.

This presentation will introduce the MIRACLS concept, present the first results from a proof-of-principle experiment [6,7] and give an outlook to the design of a 30 keV EIBT including a cryogenic, linear Paul trap for optimal beam preparation.

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Session Classification: Precision Measurements 2

Track Classification: Precision Measurements