Negative ion production presents

Double Charge Exchange

at the CRIS experiment

Starring

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A positively charged ion beam produced at ISOLDE (CERN) is first mass separated by a high resolution separator then cooled and bunched in a linear Paul trap. The bunched beam is then guided to the Collinear Resonance Ionization Spectroscopy (CRIS) experimental setup [1].

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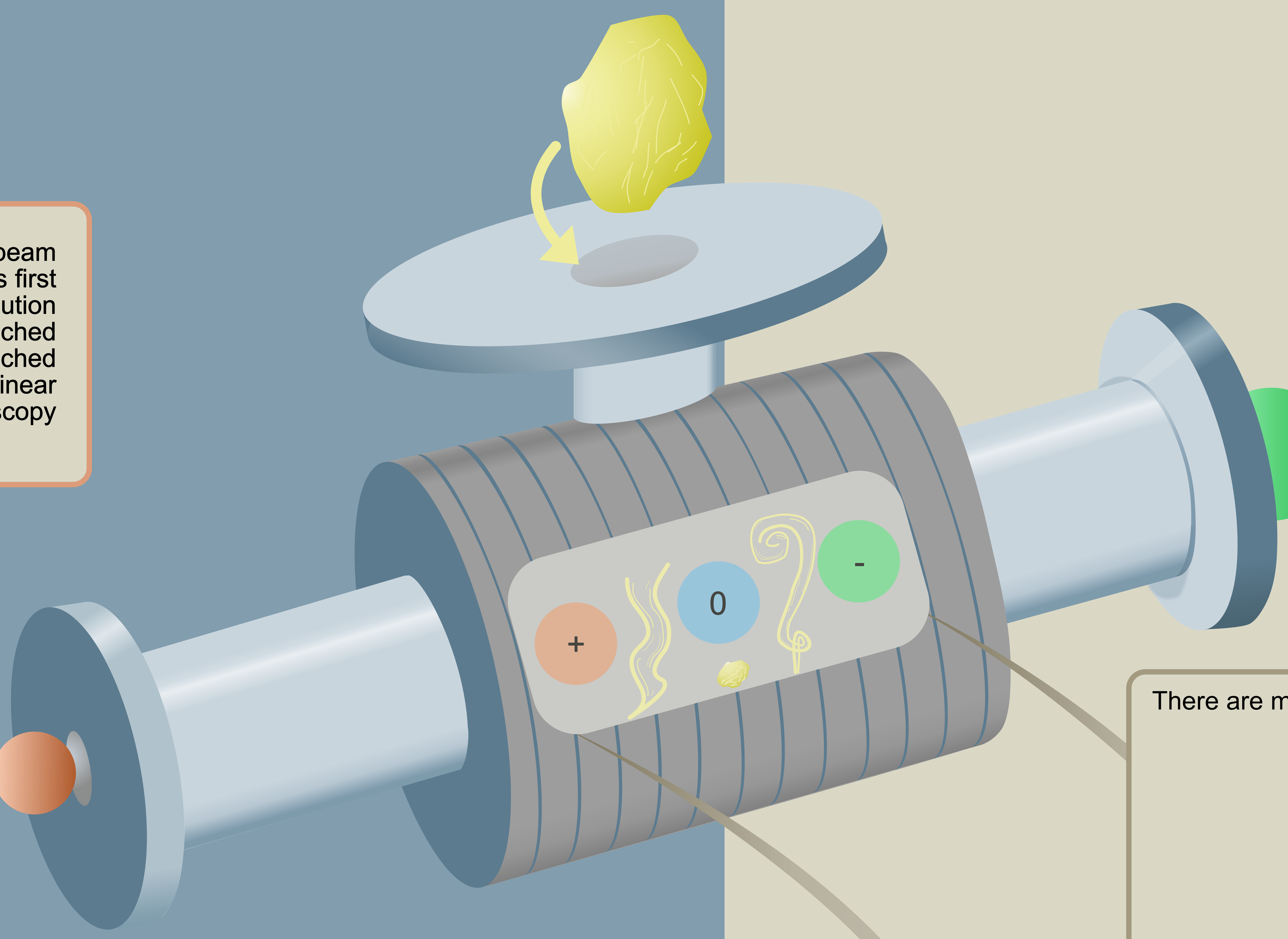
When the positive ion beam arrives to CRIS, it enters a charge exchange cell (CEC). The CEC at CRIS is filled with alkali metal (Na or K) which is then heated until the metal vaporizes [2]. A neutral atom beam is produced in the CEC from single electron capture reactions. Usually the neutral beam is used for the CRIS experiments, but this time we wanted to test negative ion production. The double electron capture process or "double charge exchange" can be seen in detail in figure 1.



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We are testing negative ion production with a CEC in preparation for electron affinity (EA) measurements at CRIS [3]. Negative ion production depends on the pressure inside the CEC because the incoming ion must gain two electrons. By changing the heating temperature, we can see how this affects negative ion production as seen in figure 2.

There are multiple reactions to consider:

$$U^+ + K \rightarrow U + K^+ + \Delta E$$

$$U + K \rightarrow U^- + K^+ + \Delta E$$

$$U^- + K \rightarrow U + K + e^-$$

Where ΔE is the difference of ionization potentials (IP), or in the case of negative ions, the EA.

Element	IP (eV)	EA (eV)
K	4.34	0.50
Na	5.14	0.55
U	6.19	0.31
Ar	15.76	-1.0

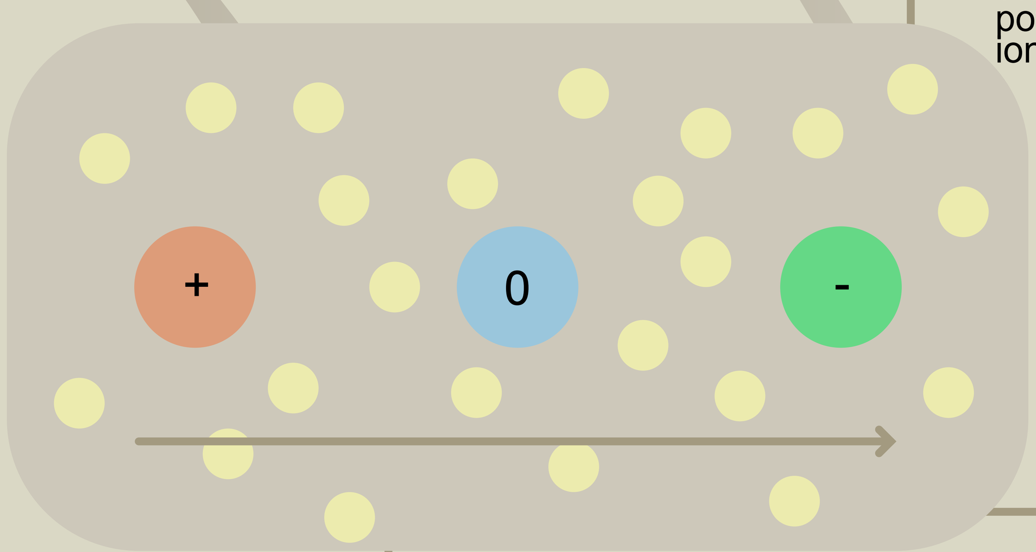

Figure 1
The double electron capture reaction process. The alkali metal vapor is represented by the yellow circles. After consideration of the reactions, IP and EA, electronic state populations and cross section for double charge exchange can be determined.

$^{238}U^-$ production in a CEC

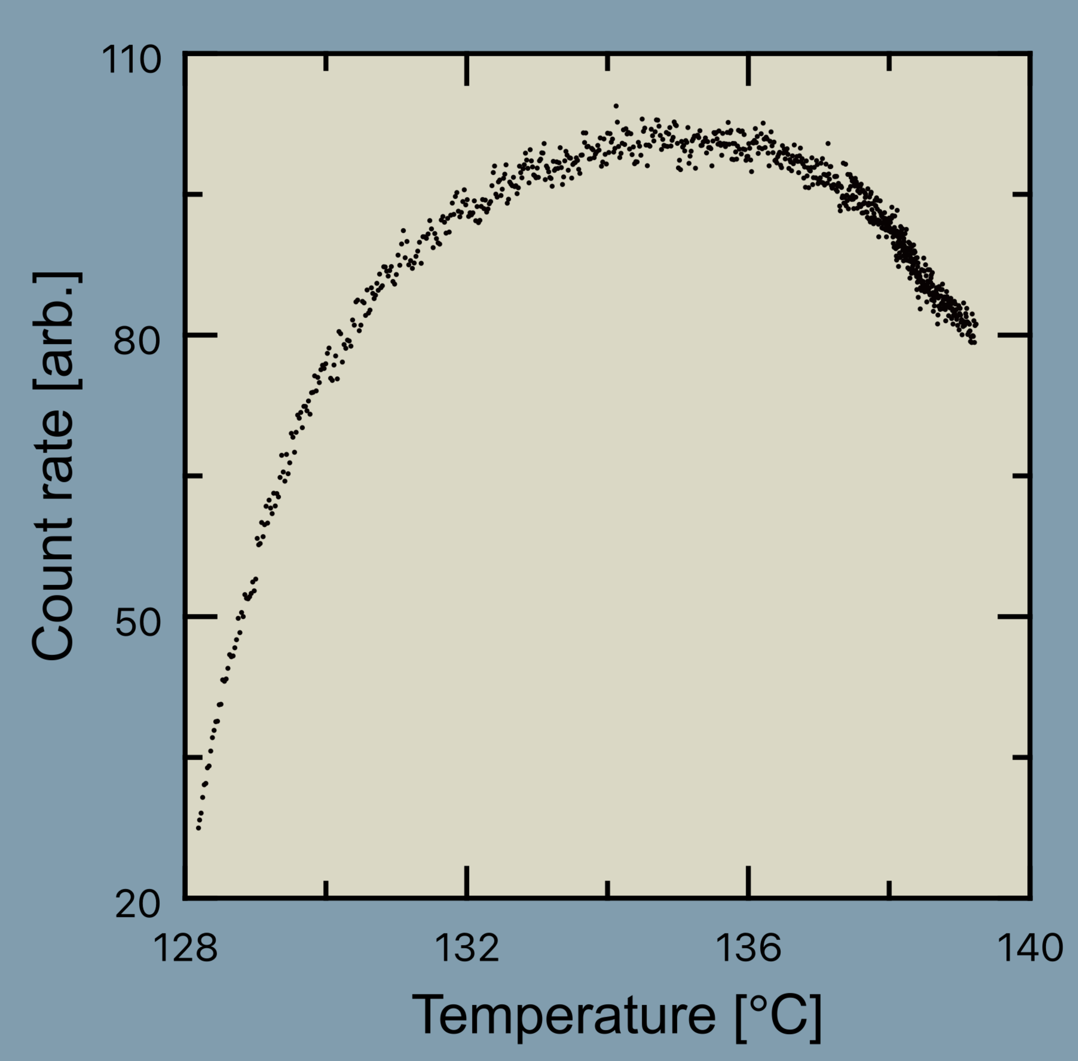

Figure 2
Temperature dependence of negative uranium production with a beam energy of 40 keV. The curve was measured both while heating and cooling the CEC with K vapor as the target. Data points were collected from count rate on a MagneToF detector.

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Now that we have successfully produced and detected negative ions at CRIS, there is tons we can do both experimentally and theoretically!

On the experiment side, producing negative ions with a CEC opens up possibilities of studying elements that are difficult to produce with a surface ion source. Next, we plan to measure the EAs for polonium and francium which have never been measured. These studies will be used as benchmarks for future studies of negative actinide elements.

Negative ions are excellent systems to study electron-electron correlation with. Therefore, studies on negative ions can be used to develop atomic theory that goes beyond the independent particle model.

Furthermore, a model for negative ion production in a CEC is being developed. This will help us understand how variables such as vapor choice, vapor temperature, and incoming beam energy affect production. We are also interested in knowing if electron correlation information can be extracted from production curves.

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References

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