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Project summary:

Radioactive ions and atoms in superfluid helium and cryogenic noble gases

(project ran from 2000 to 2008)

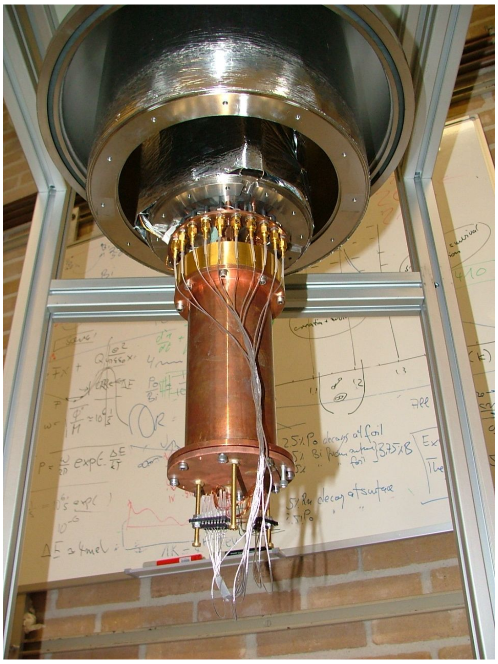
A wide variety of scientific disciplines makes use of low-energy radioactive isotopes. As in-flight radioactive ion beam facilities produce and select isotopes at high energy, ion catcher techniques to transform high-energy ions into low-energy ones are essential. Even after slowing down the energetic ions in solid materials as much as possible and with as little energy spread as possible (using energy-bunching techniques), the remaining energies are fairly high (several MeV/nucleon). These can be stopped in and extracted from stopping cells filled with noble gas, but, in the case of helium, the most-used gas, a stoppping length of up to a few meter at a pressure of 1 bar is needed for efficient stopping.

In the RIASH project (Radioactive ions and atoms in superfluid helium), we investigated the usefulness of superfluid helium as stopping medium for energetic radioactive ions/atoms. As the density of liquid helium is about 1000 times the density of gaseous helium at atmospheric pressure, it's use allows to shrink a stopping cell in the direction of the incoming beam by a similar factor. Superfluid helium instead of normal fluidic helium is considered as ions move much faster under the influence of electric fields and can thus be extracte much faster compared to normal fluidic helium.

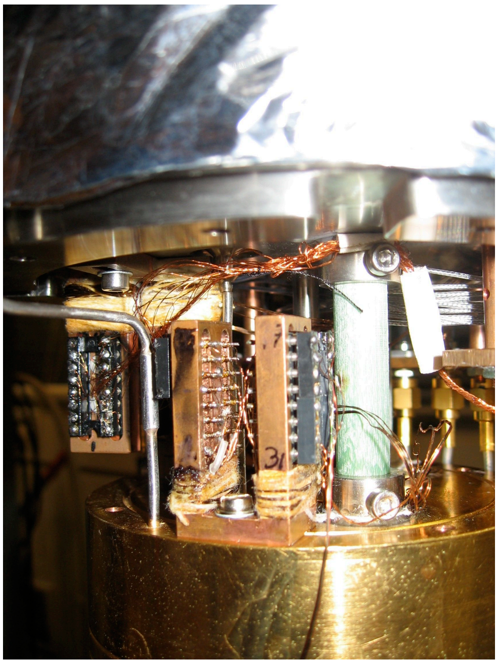
For the RIASH project. a dedicated cryostat was designed in collaboration with and manufactured by Vacuum Specials B.V. to reach temperatures of 1 K. The experimental cell and other equipment as well as the wiring of the cryostat was performed at KVI. Experiments were performed with a closed cell using 219-radon and other ions that are emitted in the alpha decay of a 223-radium source installed in the superfluid helium volume at the bottom of the experimental cell. Using a DC electric field, ions are readily transported to the superfluid helium surface; a maximum of 20% efficiency was measured. The main bottleneck in the process is the extraction of these ions from the superfluid surface. Earlier attemps to extract helium ions had proven unsuccesful. We managed for the first time ever to extract positive ions from superfluid helium an thus proved the validity of the concept of using superfluid helium as stopping cell medium.

As a side product, the experimental equipment was used to study the survival and transport of ions in the cryogenic noble gases helium, neon and argon. 100% transport efficiency was observed due to cryogenic purification of the noble gases, leading to the development of a full-scale stopping cell using cryogenic helium as stopping medium (see project above). The effect of ionization of the cryogenic helium gas was studied in experiments at the Accelerator Laboratory of the University of Jyväskylä, Finland.

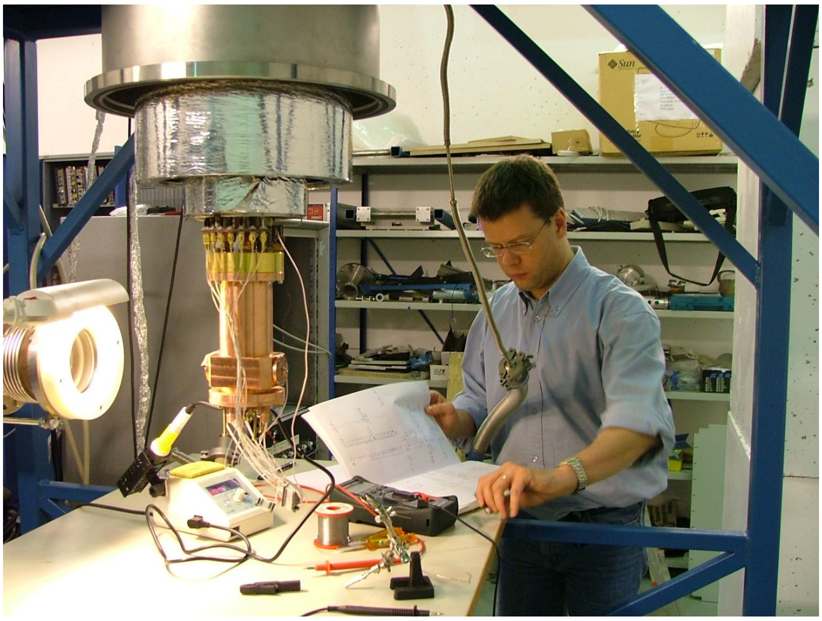
Below an impression of the stopping cell and some examples of the technology developed in this project.



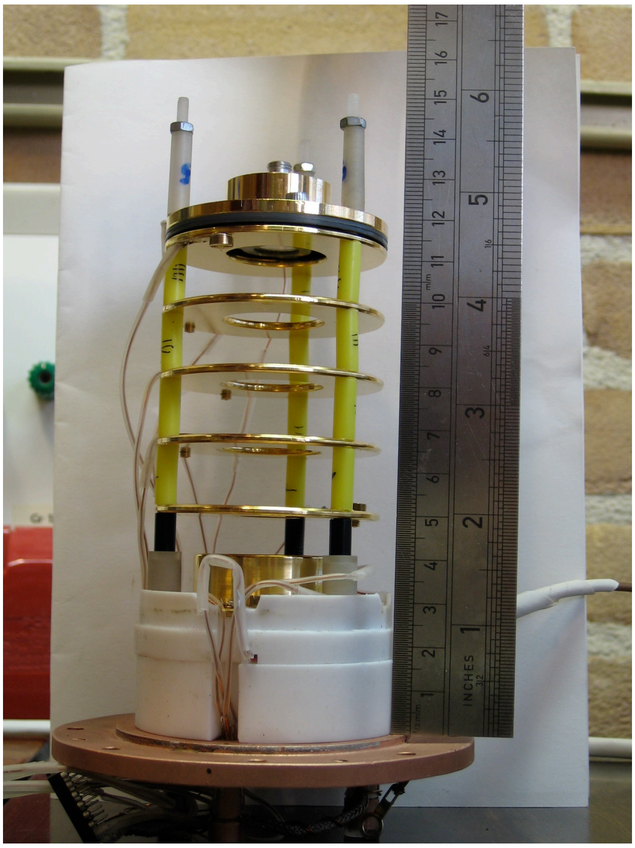
The experimental cell at the heart of the cryostat was fully designed and built at KVI. The picture shows the experimental cell attached to the 1K pot, which is attached to the liquid helium vessel. The vessel with a larger diameter is the liquid nitrogen vessel. The outer structure is the vacuum container (vacuum is needed for thermal insulation).



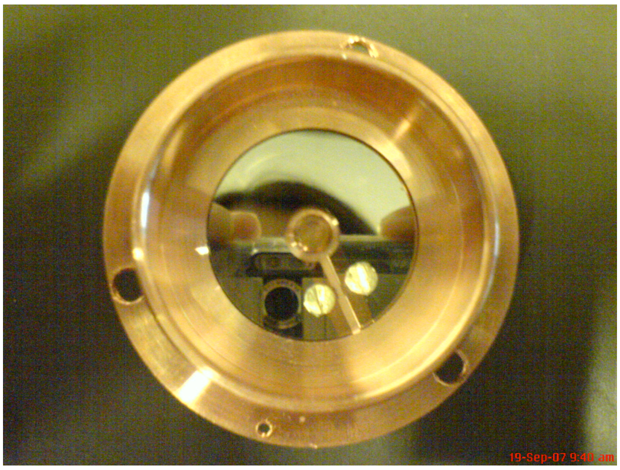
Connections between the experimental cell and the 4K liqiud helium vessel. Long and very fine (0.1 mm) wires and intermediate heat sinks are used to minimize the heat load on the experimental cell. Temperatures just below 1K were reached.



The cryostat being installed at a beam line of the Accelerator Laboratory, University of Jyväksyä, Finland. A specially designed experimental cell with thin beam entrance window is seen installed at the heart of the cryostat.



Inside of the experimental cell. Gold-plated disk-shaped electrodes provide the electric field to transport ions from the source at the bottom to the alpha particle detector at the top.



View into the bottom of the experimental cell. The radium-223 source is deposited on the central circle. The shiny surface surrounding it is an electrode used to generate second-sound waves in an attempt to enhance the transport of ions across the liquid-vapour interface. The electrode consists of a thin nickel-chromium layer vacuum-evaporated onto a quartz disk.