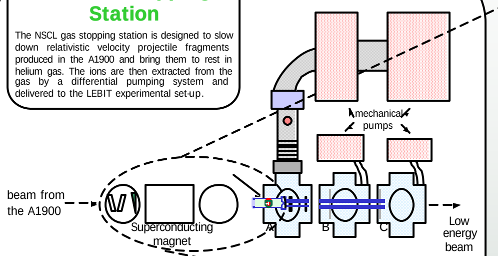
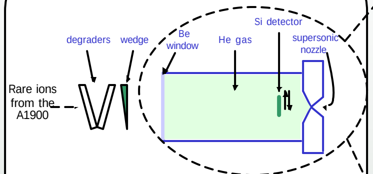
# The NSCL Gas Stopping Station

## The Gas Stopping Station

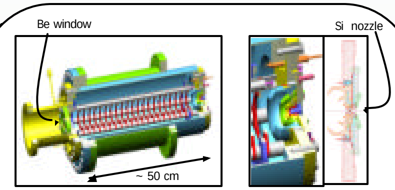
The NSCL gas stopping station is designed to slow down relativistic velocity projectile fragments produced in the A1900 and bring them to rest in helium gas. The ions are then extracted from the gas by a differential pumping system and delivered to the LEBIT experimental set-up.




## The Gas Stopping Cell




The radioactive beam passes through a pair of variable degraders positioned upstream from the gas cell, where it loses most of its energy. Next, the range of particle energies is compressed as the beam passes through a wedge. After penetrating a beryllium window, the remainder of the ion's energy is dissipated in the helium gas. The ions will be carried downstream through the supersonic nozzle by a combination of electric potentials and gas flow. A silicon detector can be placed in the path of the beam to measure the residual energy of the ions.



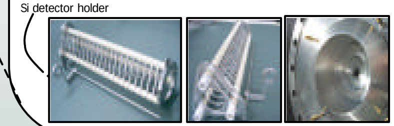

### Ring Electrodes

After passing through the beryllium window, the radioactive beam leaves the vacuum of the beam line and comes to rest in 1 bar of helium in the gas cell. The ring electrodes then provide a potential gradient which drags the ions toward the spherical electrodes and the supersonic nozzle.

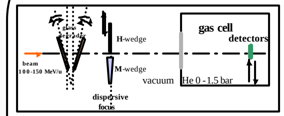
### Spherical Electrodes and Supersonic Nozzle

The spherical electrodes focus the ions in a cone-shaped field, directing them toward the center of the supersonic nozzle. Once the ions are within a few mm of the nozzle, movement through the nozzle is due to helium gas flow. The nozzle itself also has an electrical gradient

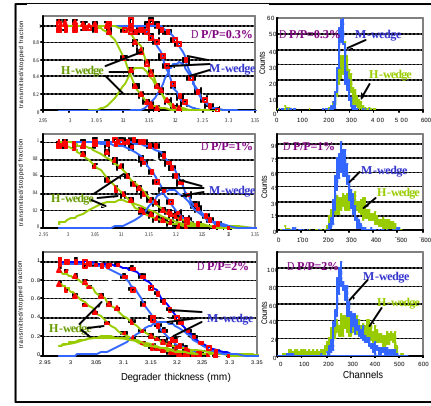
Si detector holder



## Stopping efficiency / Energy bunching



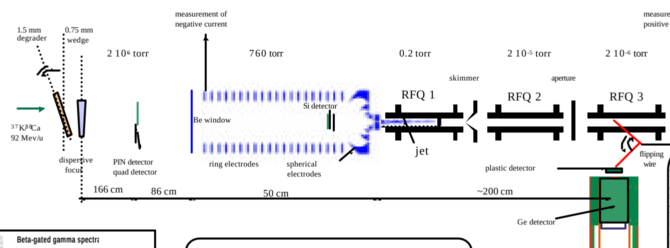

The gas stopper is a thin, less than 10 mg/cm², target. It is important to demonstrate that energetic ions can be stopped efficiently in the gas stopper. Numerous tests of the stopping efficiency were performed with various stable and radioactive beams with narrow and broad initial momentum distributions. The fraction of ions stopped in helium was measured as a function of the degrader thickness, gas pressure, position of detector in the cell and beam momentum distribution.

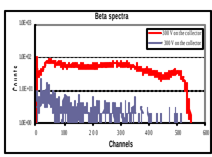


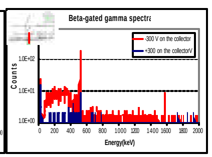

As an example, we present results of an experiment with a radioactive $^{32}$P beam produced by fragmentation of a 150 MeV/u $^{36}$Ar primary beam. The counting rate in the detectors placed inside the cell was measured as a function of the effective thickness of a glass degrader. The difference of the transmission profiles for 1 bar helium (full symbols) and for the evacuated cell (empty symbols) yields the stopping profiles (thick solid lines). The data were taken for both a shaped monoenergetic wedge degrader, M-wedge (blue lines) and homogeneous, H-wedge, degrader (green lines). The wedge degraders were placed in a dispersive focus of the beam line energy bunching. The energy bunching effect is observed in the stopping profiles and energy spectra for different values of the beam momentum distribution.

## Extraction tests

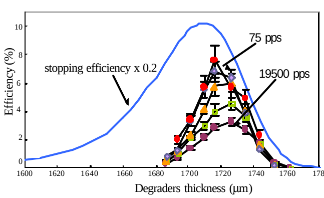
Short-lived radioactive fragments were stopped and thermalized in helium and extracted by electrical fields and gas flow. The ions were collected on a metallic wire that can be introduced in the third section of the RFQ ion guide. The decay of the ions is detected by beta and gamma detectors placed in close geometry to the collected source.



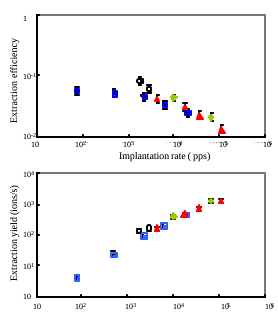




As an example, the results of tests with 92 MeV/u $^{38}$Ca/$^{37}$K are presented. The beta and gamma spectra normalized to the number of implanted fragments were taken for positive and negative voltages on the collector foil. The primary beam was cycled on/off and the data collected only during the beam off period. The red curves show the presence of the radioactive ions above the background.




The extraction efficiencies deduced from comparison of collected activity and implantation rates. The obtained extraction efficiency as a function of the degrader thickness for different implantation rates is compared with the stopping efficiency.

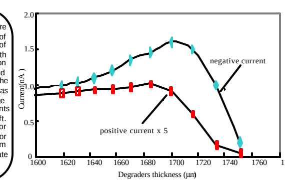



The summary of measurements of extraction efficiency is presented. Data are taken for the $^{38}$Ca/$^{37}$K beams at 0.5 % (full symbols) and 0.1% (open symbols) momentum distributions. The measurements were done for the optimum degrader thickness. As seen from the plot, the extraction efficiency drops drastically with an increase in the rate of fragments. The decrease is caused by the space charge effect of the ionized helium buffer gas.

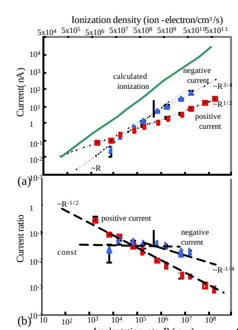
## Ionization measurements

Several measurements of ionization currents induced in helium by fast fragments were performed. The negative current was collected at the first ring electrode that had the highest positive voltage. Positive current was collected on the collection wire.

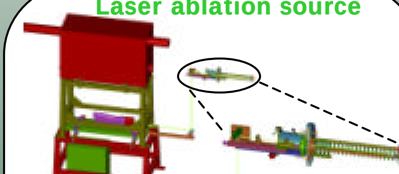
The collected negative and positive charges are observed to behave differently with variation of the degrader thickness. While the collection of electrons follows the range curve folded with some geometrical efficiency, the positive ion collection, in general, is significantly lower and further reduced at thicker degrader values. The ions are collected after drifting through the gas cell length and the nozzle. The space charge induced in helium gas by the implanted fragments causes the significant ion-loss during their drift. The same loss mechanisms are responsible for loss of the radioactive ions. Data were taken for $^{38}$Ca/$^{37}$K fragments and 0.5% value of beam momentum distribution, at an implantation rate of ~ 40000 pps.



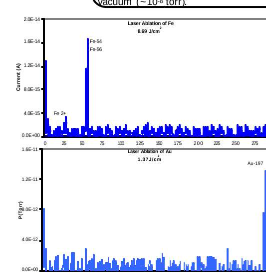

Positive and negative currents were measured at various implantation rates of a $^{48}$Ca primary beam with a final energy of 47 MeV/u before entering the gas cell window. The measured values are compared to the calculated values of induced ionization. One can observe from the ratio of measured currents to the calculated induced ionization that positive and negative currents behave differently with an increase in the rate. The ratio of the negative current to the ionization is, to first order, a constant as a function of the implantation rate. This constant reflects the efficiency of electron collection. The deviation from the linear dependence at highest implantation rates is most likely associated with screening of the drifting electrical field by induced spacecharge. The corresponding ratio of the positive ion current drops drastically with an increase in the rate of fragments. The decrease in the rate, indicating the loss mechanisms associated with induced space charge. The loss of ions is due to space-charge effects, which take place in the main drifting region and in the vicinity of the nozzle.




## Laser ablation source



A laser ablation system has been implemented for the production of metal and carbon clusters for off-line tests. These clusters are used as test ions and the carbon clusters can be used as mass references for high-precision mass measurements. Below are two plots demonstrating the laser ablation of Fe and Au under vacuum (~10⁻⁸ torr).

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