RIA gas cell/ion guide system:

A key feature of the RIA concept is the use of intense energetic heavy-ion beams with projectile fragmentation or fission as a production mechanism for beams of short-lived nuclei. This method, based on in-flight fragment separation, stopping of the fragments as singly-charged ions in an IGISOL-type helium gas cell configuration, and fast extraction, allows for a breakthrough in capabilities for a broad range of beams. The scheme combines the intrinsic advantages of in-flight fragmentation, short delay times, with those of the ISOL concept, high-quality beams of precise energy as required by experiments.

The high intensity heavy-ion beam impinges on a moderately thick target of cooled light material (liquid-lithium cooled graphite or pure liquid lithium) where the fragmentation products are created. The kinematics pushes all reaction products in a narrow forward cone where they are collected by a large-acceptance fragment separator, separated from the bulk of the reaction products, and their energy dispersion is reduced before they are slowed down at the entrance of a gas cell. It is important that the primary beam not enter the gas cell, otherwise the high ionization density creates a plasma that affects the recoil ions. This is ensured by the use of a high acceptance fragment separator which removes not only the beam but a large fraction of the other fragments also produced in the process. The transmitted recoils loose most of their energy in a high Z degrader before entering the gas cell filled with high-purity helium where they recapture electrons during the final deceleration until they come to rest. The vast majority of them will be in the singly ionized charge state due to the high ionization potential of atomic helium. The effective stopping thickness of helium in the gas cell must cover the range straggling of the reaction products for the majority of the recoil ions to be stopped in the gas. The range straggling varies for different species, the degrader material used, the energy of the reaction products and finally how well the momentum dispersion of the reaction products can be cancelled. For the parameters of the RIA accelerator and fragment separator, the resulting helium effective thickness will vary from below 0.5 atmosphere-meter for most reaction products above mass 50 amu to about 5 atmosphere-meter for the lightest neutron rich isotopes. The gas cell will therefore have a length of about a meter and operate at pressures between 0.5 and 5 atmospheres depending on the reaction products of interest. Such a cell is too large to obtain a fast evacuation time just from the gas flow as done with standard IGISOL systems. Therefore, to speed up evacuation of the ions from the cell, an electric field gradient along the length of the cell is added. It drags the ions towards the cell exit where a set of concentric electrodes help focusing them on the exit hole. At the exit hole, the gas velocity grows rapidly and pulls the ions out. This allows extraction times of the order of a few milliseconds to be attained with the large cell being proposed. The voltage gradients required to extract the ions in that time scale are determined from ion mobility data. The proposed gas cell and a scaled down 15 cm prototype operating at up to 0.5 atmosphere have been designed using an ion trajectory program developed at ANL in which the effect of the helium gas on the ion trajectories is added by a monte-carlo method treating individual ion-gas collisions and adjusted to reproduce the known ion mobility data. The scaled down version of the gas cell has been constructed at ANL and measurements performed with reaction products validate the simulations. The general layout of a possible fragment separator/gas cell assembly for the RIA project is shown in figure 1. The prototype gas cell used in the demonstration test is shown in figure 2.

The ions are extracted from the gas cell together with a large flow of helium gas (typically 5-10 SLM for the system needed here). The resulting residual pressure of helium after extraction is too large to accelerate the ions directly. They must therefore go through a differential pumping system, a so-called ion guide system, where the ions are guided by a RF structure to a region of lower pressure while the gas is pumped away by large roots blowers. This system carries the ions to a low-pressure region from where they can be accelerated in the standard fashion by the post-accelerator. This is a standard technology demonstrated at IGISOL facilities and at ANL (see figure 3) and results in much better emittance for the extracted beam.

Research and development are needed in a few key issues for the gas cell/ion guide system. The codes used to determine the different components to the range straggling need to be validated in this energy regime. The simulations of the scaling of the gas cell to larger pressures need to be tested experimentally. The ion guide system will have to handle large currents in the proposed RIA facility and means to limit the emittance growth for these large currents will have to be investigated. And finally, the issue of the ionization in the gas by the contaminant reaction products that will not be rejected by the fragment separator needs to be studied in more detail. While preliminary studies indicate that for typical situations this will not be an issue, in certain cases (where the reaction products might be too close to the primary beam to obtain full rejection of the ladder or in the advent of cases where beam powers up to 400 kW become available) this ionization effect may start limiting the efficiency that can be attained.

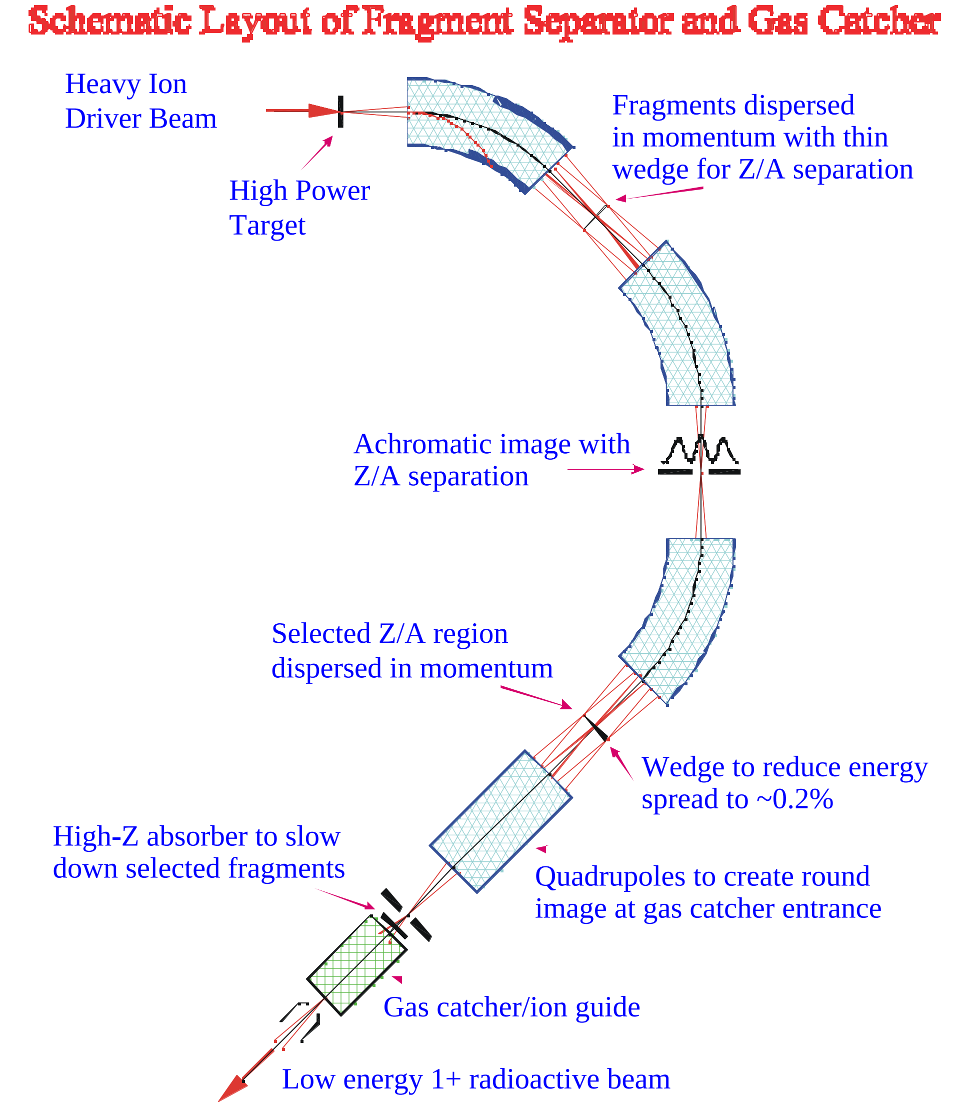

Figure 1. Schematic Layout of a Fragment Separator to collect heavy ion fragmentation products and deliver them to the gas catcher/ion guide apparatus.

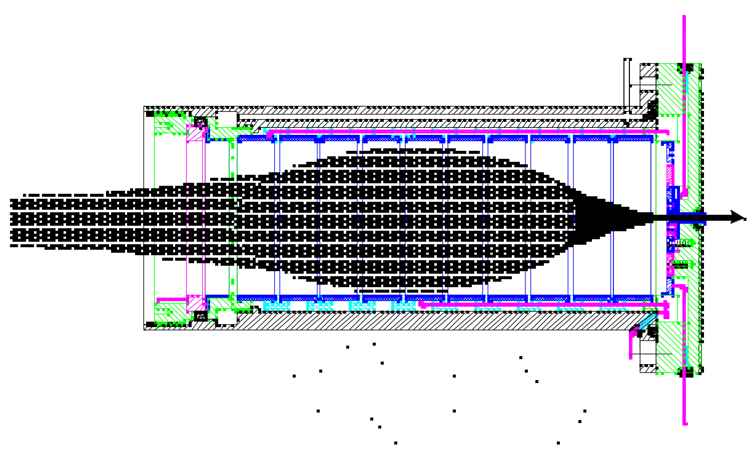

Figure 2. Drawing of the test gas cell used at Argonne to successfully demonstrate the use of RF and DC extraction fields inside the cell to guide the ions to the exit aperture. [Expanded view of the gas catcher/ion guide at the bottom of figure 1 above.]

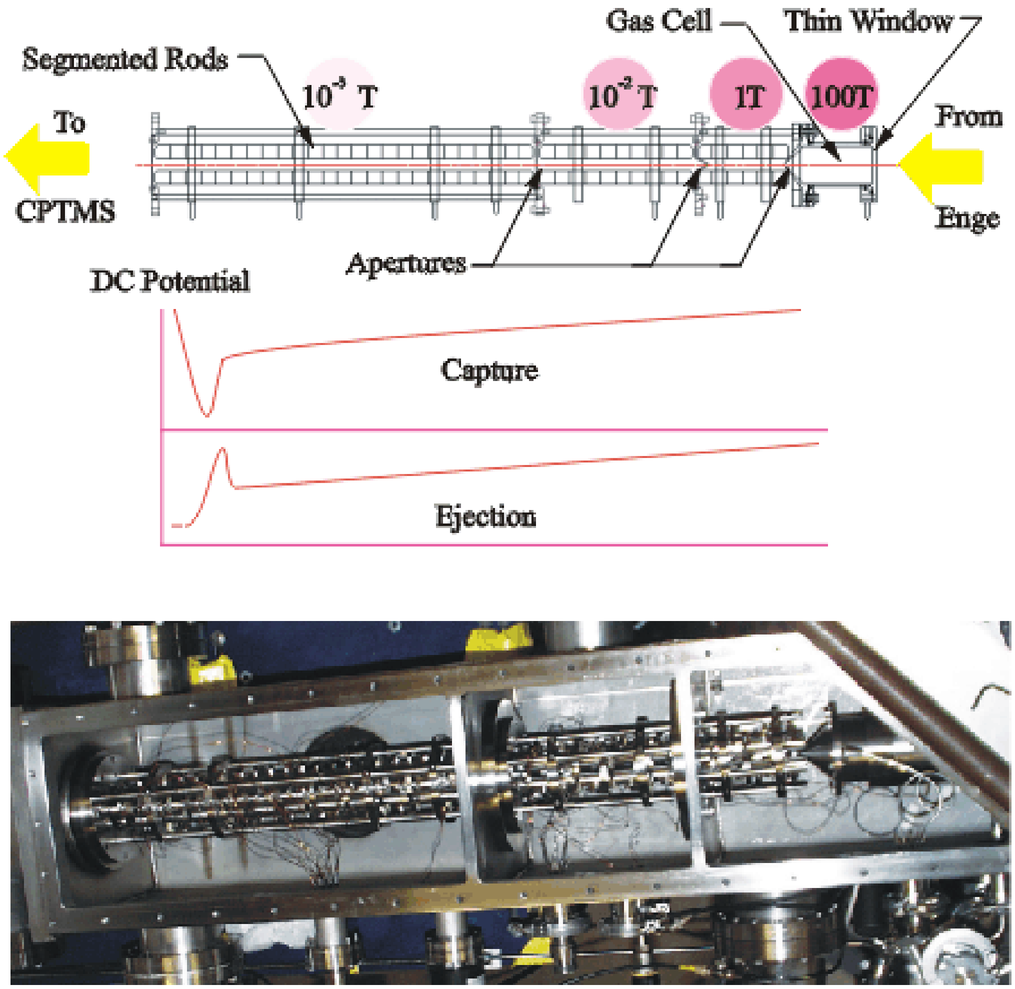

Figure 3. Schematic view (top panel) and picture (bottom panel) of the RF gas cooler system used at Argonne to stop and capture fast radioactive reaction products and extract them as a pulsed low-energy beam. The dc gradients applied along the rf structure for capture and ejection of the ions are shown in the center panel.