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DEVELOPMENT OF A RADIOACTIVE BEAMS (RB) ACCELERATOR USING AN ISOL AS A SOURCE

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Summary

High yields of separated, radioactive isotopic ions (up to 10^{11} atoms/sec per μA of incident protons) at on-line mass separators, e.g. ISOLDE at CERN (SC), make it feasible to consider using such secondary ions as projectiles for nuclear reactions. A pressing need for reaction data involving radioactive species exists in nuclear astrophysics. This requires having available projectiles ($A \leq 60$) in the energy range from about 200 keV/amu to 1.5 MeV/amu. At TRIUMF, an ISOL device is proposed using the available high proton current ($\leq$100 μA). A beam of radioactive species, extracted with about E = 60 keV from the target/ion source, would be mass analyzed and transported vertically to experimental areas for use there or to be injected into a post-accelerator. Although other possibilities are being considered, most attention so far has been devoted to a RFQ/drift tube linac combination. Parameters for one possible system are presented.

Introduction

With the advent of high current, intermediate energy proton accelerators, it has become possible to produce sufficient quantities of short-lived, unstable nuclei to allow them to be accelerated and used as heavy ion projectiles in nuclear reactions. Such nuclear reaction studies are of particular interest in astrophysics, where, for example, the hydrogen or helium fusion rates (cross-sections) with various unstable nuclei are unknown. Other interesting nuclear reactions on the neutron-rich side of the valley of stability could also be studied using accelerated radioactive beams.

Thick targets (up to 100 g/cm^2) bombarded by intermediate energy (500 MeV) protons will produce isotopes close to the valley of stability with rates up to 10^{11} atoms/μA•sec. Depending upon the nature of the target (composition, form) and the elements involved, the isotopes diffuse continuously out of the beam-heated target matrix (up to 2000°C) and can be ionized by several types of ion sources (surface ionization, plasma- and perhaps ECR-sources). Due to the high radiation fields and contamination problems, leading to sparking conditions, the singly-charged (+ or -) radioactive ions can only be extracted with voltages up to 60 kV. The ions are then transported along a beam line, mass analyzed and separated in a magnetic spectrometer, and prepared for further acceleration.

Description of the Proposed ISOL Facility

An overall layout of the proposed ISOL facility at TRIUMF is shown in Fig. 1. The proton beam (E_p = 180-500 MeV, $I_p \leq$ 100 μA) from the TRIUMF cyclotron will irradiate the target/ion source (T/IS) situated at the end of beam line 4A. The extracted ion beam passes through a dispersive stage (QQD), capable of high resolution in atomic mass ($M/\Delta M \approx 600$), with the dipole mounted vertically. Unwanted isotopic masses are removed by slits in the focal plane (switchyard). The beam for the high intensity, post-accelerator beam line is deflected electrostatically, while the beam for the high resolution line passes through undisturbed. This latter beam is brought to a zero dispersion focus by a mirror image (DQQ) of the first stage and then bent by a high dispersion magnet of about $M/\Delta M \approx 20000$ into the second floor, high resolution line. This floor contains several setups for performing low energy experiments with the selected radioactive isotopes. The high intensity beam is bent electrostatically onto the first floor (ground/post-accelerator level) and injected into the first element of the post-accelerator. Further details of the ion beam optics of this facility can be found in TRIUMF design note TRI-DN-85-68 Rev.

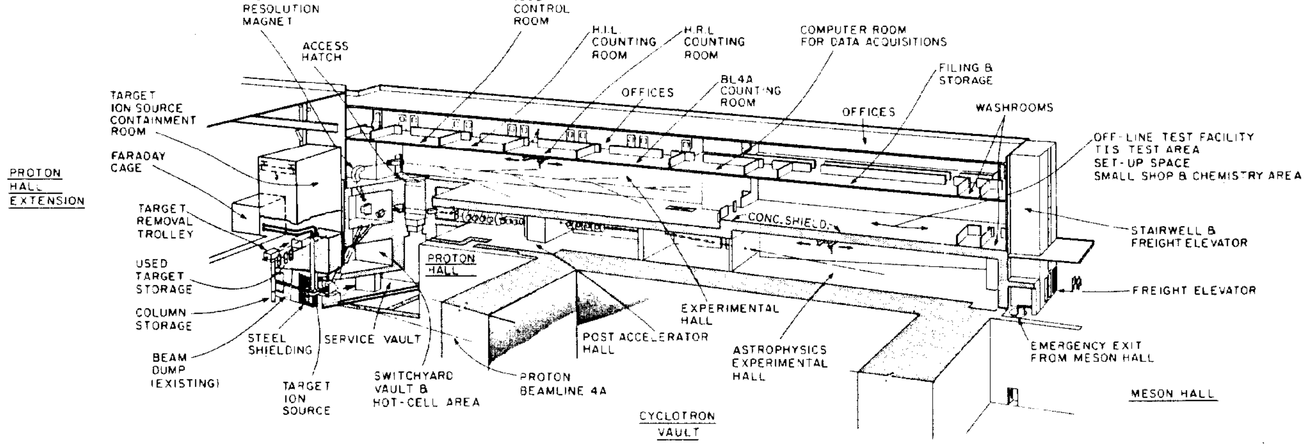

Fig. 1. Proposed ISOL Facility at TRIUMF

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The Post-Accelerator Facility

The specifications for the post-accelerator are dictated both by the ISOL-delivered beam and by demands of the nuclear astrophysics experimental studies. Table I gives an overview of the post-accelerator requirements.

At some point between 60 keV/amu and 100 keV/amu, it becomes feasible to increase the q/A of the ion beam by passing it through a thin foil or gas stripper before further acceleration in a drift tube linac. The latter could be similar in design to any of several existing heavy ion linacs, such as the UNILAC, HILAC or RILAC.

Table I. Specifications of the TRIUMF-ISOL Post-Accelerator

Parameter	Value of Range	Comments
Ion	$A \leq 60$ $q/A \geq 0.016$	singly-charged ions (+ or -) delivered by ISOL
Input Energy	$E_{total} = 60$ keV $E/amu \geq 1$ keV/amu	maximum ISOL voltage, may be raised by biasing the first section of the accelerator
Output Energy	$E_{total} = 90$ MeV $E/amu \leq 1.5$ MeV/amu	continuously variable range of $0.2 \leq E/amu \leq 1.5$ MeV/amu
Input Energy Spread	$\Delta E/E \leq 10^{-4}$	delivered by ISOL
Output Energy Spread	$\Delta E/E \leq 10^{-3}$	debunching after the accelerator
Duty Factor (RF)	100%	due to low currents delivered by ISOL
Transmission	≈50%	
Beam Current	$\leq 10^{12}$ particles/sec	low ISOL currents

A critical part of the post-accelerator is the first stage, which must capture, bunch and accelerate the singly-charged (+/-), very low velocity ($\beta \geq$ 0.0015%) dc beam from the ISOL with good efficiency. This is best accomplished by some form of RFQ, such as, for example, one built at GSI for $q/A \geq 1/130$ [1], or a low frequency version of the Los Alamos four-vane structure. A preliminary design of the later version, done at CRNL for $q/A > 0.025$, a peak field of 1.5 times the Kilpatrick criterion and an operating frequency of 23 MHz, has a calculated capture efficiency of 94% for a 0.1 π cm mrad (normalized emittence) ISOL beam [2].

As an illustration, a possible post-accelerator layout, initiated following discussions with H. Klein [3], is shown in Fig. 2, along with the associated experimental area. This system, operating at CW, would require an estimated 4 MW of RF power. A more complete discussion of initial concepts of the TRIUMF-ISOL post-accelerator can be found in TRIUMF Report TN-85-1.

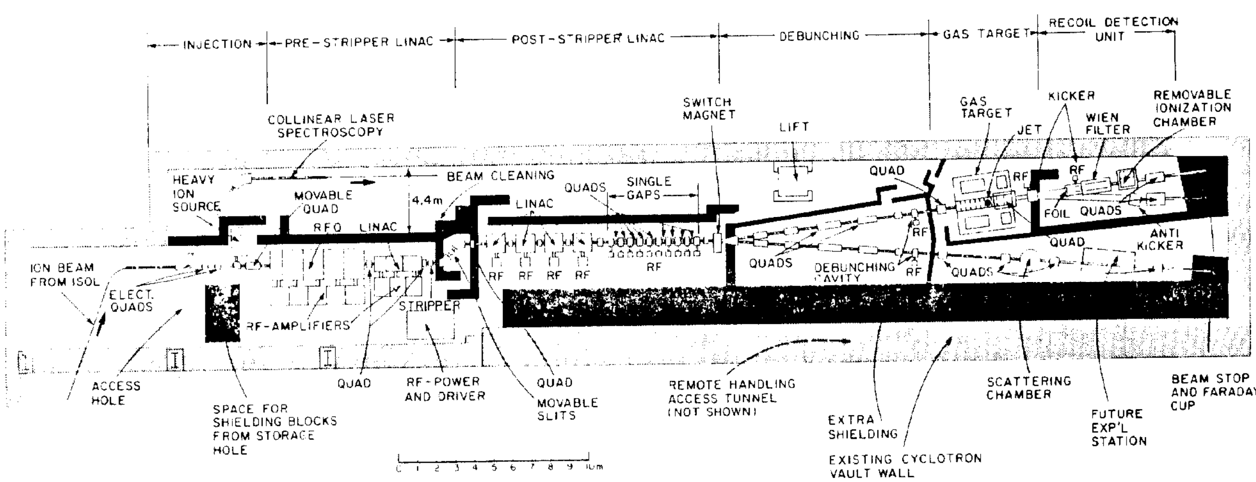

Fig. 2. General Layout of a TRIUMF-ISOL Post-Accelerator Facility

References

1. R.W. Müller, U. Kopf, J. Bolle, S. Arai and P. Spädtke, Proceedings of the 1984 LINAC Conference, Ed. N. Angert; GSI Report 84-11.

2. H. Klein, University of Frankfurt, private communication.

3. G. MacMichael and B. Chidley, CRNL, private communication.