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TRIUMF

THE TRIUMF NEWSLETTER
NEWS FROM CANADA'S NATIONAL LABORATORY FOR PARTICLE & NUCLEAR PHYSICS

TRIUMF Expands Research Capacity

PAUL SCHMOR,
ISAC DIVISION HEAD

Construction has started on TRIUMF's new ISAC II facility, an isotope Separator and Accelerator that will expand TRIUMF's capacity to conduct research in subatomic physics. The project is being funded by the BC Knowledge Development Fund and Industry Canada and is designed to increase the range of capabilities of ISAC I, TRIUMF's existing isotope separator and accelerator. Together, ISAC I and II will form arguably the world's premier on-line isotope separator (ISOL) facility.

ISAC Backgrounder

ISAC was designed to investigate the intriguing questions from elemental genesis in nuclear astrophysics, and to test our understanding of matter and the nucleus through precision studies of the nuclear and atomic properties of particular isotopes. There are approximately 300 naturally occurring isotopes. An ISOL facility such as ISAC can increase the number of isotopes available for research by an order of magnitude. ISAC can also provide rare short-lived isotopes in sufficient quantity and purity to be used as diagnostic probes for medical, industrial and condensed matter applications. The wide range of isotopes produced in ISAC allows the experimenters to choose one that matches their particular chemical and lifetime requirements.

ISAC I Capabilities

ISAC I is now in full operation. Funded in 1995 by the province of BC and Industry Canada, the building has three main technical areas: a multistory target service facility, a target vault and an experimental hall.

The TRIUMF cyclotron can transport up to 100 µA of the 500 MeV proton beam to one of two target stations in the target vault, where spallation provides a large variety of short-lived isotopes. To date, one target has been tested with the full 50 kW of beam power. Tantalum and niobium foil targets are regularly used in operation at proton currents as high as 40 µA. The target material is placed in a heated tube and a short heated-transfer tube takes vapour products from the target to an ion source.

Diffusion from the target and subsequent effusion to the ionizer depends on the isotope, but generally takes several tens of milliseconds (ms). Consequently, the technique is not efficient for isotopes having half-lives shorter than 10ms. Nevertheless, the measured yield for ^{11}Li (half-life only 8.5 ms) from a tantalum foil was 2.2×10^4 ions/s, an amount sufficient to initiate a high-priority experimental proposal.

In 2001, more than 2500 hours of RIB experiments were scheduled, with nearly 70% availability. Scheduled times will nearly double once the second target station comes into full operation, which is expected in 2003. Target material has included niobium foil, tantalum foil, silicon carbide, calcium oxide and calcium zirconate. The TRIUMF operating license currently prevents the use of thorium and uranium targets, but a license amendment application to permit their use in targets will soon be submitted. Targets and their measured isotopic yields can be obtained from www.triumf.ca/people /marik/homepage.html.

ISOTOPE	TARGET	P + CURRENT (µA)	MAX.YIELD (NUCLEI/S)
^{8}Li	Ta	40	8.3×10^{8}
^{9}Li	Ta	35	9.4×10^{7}
^{11}Li	Ta	40	2.2×10^{4}
^{20}Na	SiC/C	30	8.6×10^{7}
^{21}Na	SiC/C	30	2.7×10^{9}
^{26}Na	SiC/C	30	1.6×10^{7}
^{37}K	TiC/C	40	6.0×10^{7}
^{38m}K	$CaZrO_3$	2	1.2×10^{7}
^{74}Rb	Nb	30	1.3×10^{4}
^{79}Rb	Nb	10	4.6×10^{9}

ISAC uses a thermal ion source to ionize products from the target, particularly efficient for alkali-like elements. An ECR ion source, currently being tested for operation in the fall, will initially permit ionization of elements and molecules that are volatile at temperatures lower than about 500 K. Lasers have been useful in selectively ionizing most periodic table ele-

NEXT DEADLINE FOR PROPOSAL SUBMISSIONS:
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ments, excluding noble gases. TRIUMF will shortly announce the appointment of a laser physicist and purchase laser equipment. Initial operation of a resonant laser ion source could start in two years.

A particular isotope in a beam from the ion source is selected with a magnetic mass separator having a resolution up to $1/10^4$. These selected isotopes are available at energies up to 60 keV. They can be delivered to either a system of linear accelerators or to a variety of experimental stations through a beam line containing only electrostatic steering and focusing elements. One of these lines includes a laser-induced polarizer, which has been used to polarize ^{8}Li, ^{9}Li, ^{26}Na and ^{28}Na. Other low-energy experimental facilities include a neutral atom trap (TRINAT), a low temperature nuclear orientation station (LTNO), the 8π dectector, two general purpose stations, a polarimeter, a sample collection chamber and a ßNMR station for condensed matter studies. An isotope trap for high precision mass measurements (TITAN) is currently being designed.

A singly-charged isotope from either the target ion source (stable and RIBs), or from an off-line ion source (stable beams), must have an injection energy of 2 keV/amu for acceleration through the linacs to higher energies. (The 60 keV ion source limit currently restricts accelerated masses to a maximum of 30 amu. Installation of a Charge State Booster, or CSB, will increase the accelerated mass range up to 150.) The linacs consist of an RFQ and a five-tank DTL. The accelerated beam energy is continuously variable from 0.15 to 1.5 MeV/amu. A series of bunchers and choppers permit the time between rf beam buckets and/or the time focus at the experiment to be adjusted. The accelerated beam quality is excellent, providing beams having energy spreads less than 0.1%, selectable intervals of 28, 85 or 170 ns between beam bursts, 90% of beam through apertures 2mm in diameter, longitudinal time spreads as short as 400 ps (FWHM), and longitudinal emittances of 1 π keV/amu ns.

Two experimental facilities were designed for nuclear astrophysics measurements using accelerated beams: DRAGON and TUDA. Another general purpose station is available for users with less complex beam requirements. Capabilities can be found on the TRIUMF home page, www.triumf.ca/annrep/dragon.pdf and www.triumf.ca/annrep/tuda.pdf.

ISAC II Capabilities

In 2000, the federal government approved a second five-year budget for TRIUMF that included ISAC II, an expansion to ISAC I that allows both the accelerated mass range and final energy of the rare isotopes to be increased. In 2002, the province of BC provided $8.7M for civil construction from its $42M Knowledge Development Fund. Industry Canada, through the National Research Council, is providing about $19M for technical components. The new building will include an accelerator vault, light laboratory space, offices, counting rooms and an experimental hall. Initial operation is scheduled to begin in 2005.

When completed, ISAC will accelerate isotopes with masses up to 150 in an energy range from 0.15 to at least 6.5 MeV/amu. The new accelerators will be linacs with superconducting cavities. In collaboration with the laboratory in Legnaro, Italy, a prototype 105 MHz cavity was built and is being evaluated at TRIUMF.

Technical components for ISAC II have been ordered and are being fabricated. Delivery of most of the components for the CSB is expected in 2002. Twenty super conducting

WELCOME TO THE FIRST ISSUE OF THE TRIUMF NEWSLETTER.

THE PURPOSE OF ANY NEWSLETTER IS TO KEEP COMMUNITIES INFORMED ABOUT ISSUES RELATED TO ACTIVITIES OF COMMON INTEREST. KEEPING STAKEHOLDERS UP-TO-DATE IS ESPECIALLY NECESSARY WHEN SUCH ACTIVITIES ARE EVOLVING OR CHANGING RAPIDLY WITH TIME.

FOR A LABORATORY LIKE TRIUMF, A NEWSLETTER IS PARTICULARLY IMPORTANT SINCE THE COMMUNITY IS INTERNATIONAL, AND THE OPPORTUNITIES AND FACILITIES AT THE LABORATORY ARE RAPIDLY EVOLVING. THE MAIN ACTIVITIES OF THE LABORATORY REVOLVE AROUND THE WORLD'S LARGEST H- CYCLOTRON. THE CYCLOTRON IS UNIQUE IN ITS ABILITY TO SIMULTANEOUSLY PROVIDE MULTIPLE BEAMS OF PROTONS AT DIFFERENT ENERGIES.

AT TRIUMF, THESE PROTON BEAMS CAN BE USED FOR A VARIETY OF PURPOSES, RANGING FROM THE PRODUCTION OF INTENSE BEAMS OF PIONS AND MUONS FOR RESEARCH PROJECTS, SUCH AS PARTICLE PHYSICS AND MATERIALS SCIENCE USING THE μSR TECHNIQUE, TO CANCER THERAPY.

RECENTLY, A 500 MEV PROTON BEAM WAS DEVELOPED AS A DRIVER BEAM TO IRRADIATE THICK TARGETS FOR THE PRODUCTION OF RADIOACTIVE NUCLEI. WHEN MASS-SEPARATED, THE NUCLEI CAN BE USED FOR A VARIETY OF EXCITING NEW INVESTIGATIONS. THIS FACILITY, CALLED ISAC, IS PRODUCING SOME OF THE MOST INTENSE RADIOACTIVE BEAMS AVAILABLE ANYWHERE IN THE WORLD.

THIS FIRST ISSUE OF THE TRIUMF NEWSLETTER WILL HIGHLIGHT THESE NEW RADIOACTIVE BEAM DEVELOPMENTS AND WILL CONTAIN ENOUGH INFORMATION FOR POTENTIAL USERS TO PROPOSE AND UNDERTAKE EXPERIMENTS AT THESE NEW FACILITIES. SUBSEQUENT ISSUES WILL HIGHLIGHT OTHER ASPECTS AND PROJECTS THAT ARE UNDERWAY AT THE LABORATORY.

ALAN SHOTTER
DIRECTOR, TRIUMF

COLLABORATIONS ARE NOW BEING FORMED TO DEFINE THE EXPERIMENTAL APPARATUS OF ISAC II. OPPORTUNITIES EXIST EITHER TO JOIN THESE GROUPS OR FORM NEW GROUPS.

FOR MORE INFORMATION, CONTACT JEAN-MICHEL POUTISSOU, TRIUMF'S ASSOCIATE DIRECTOR, AT JMP@TRIUMF.CA. TO GET A LOOK AT ISAC II'S ONGOING CONSTRUCTION, CHECK OUT THE TRIUMF WEBCAM AT HTTP://AXISC4.TRIUMF.CA.

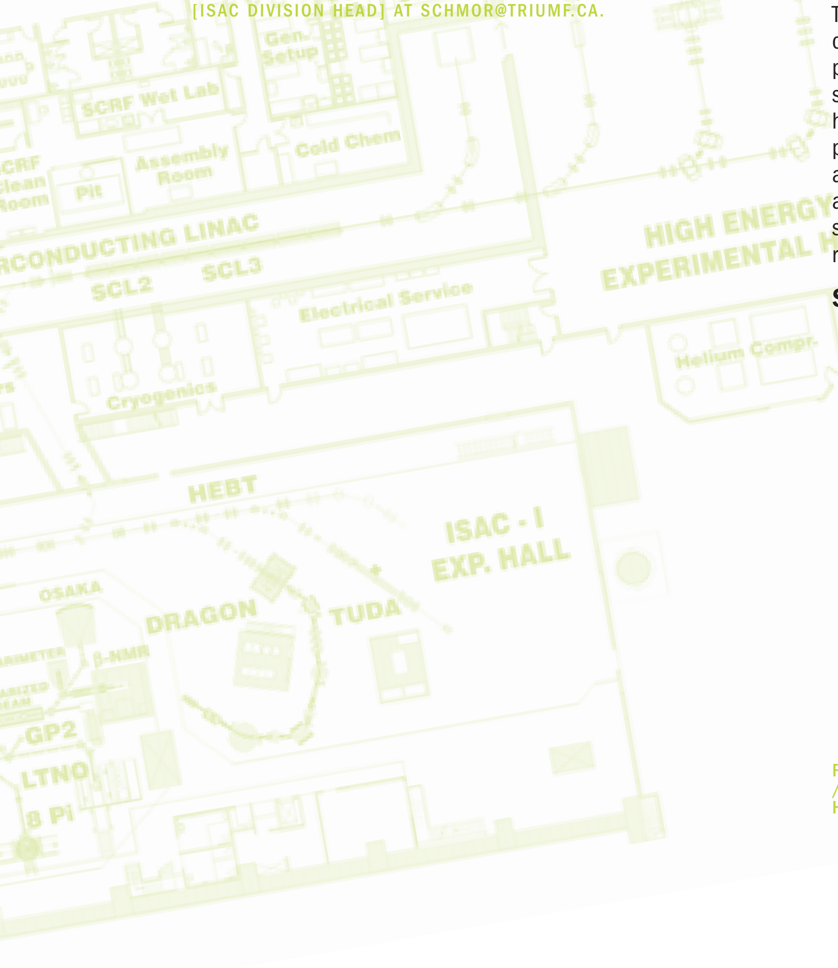
ISAC I			
	Energy Range	.15-1.5	MeV/u
	Mass Range	4-30	amu
	ΔE/E	0.1-0.5	%
ISAC II			
	Energy Range	.4-14	MeV/u
	Mass Range	4-150	amu
	ΔE/E	0.02-0.2	%

cavities for the medium beta section of the ISAC drift tube linac are being fabricated. Installation of the first four cavities into the new accelerator vault is expected in 2003.

Experiments at ISAC

ISAC is operated 24 hours per day, 7 days a week, by a team of trained operators and is intended to be easily accessible to the international community. In response to user demand, new ion sources, targets and capabilities are being developed. Experiments approved by the TRIUMF Experiments Evaluation Committee and letters of intent are being used to set the development priority. See this newsletter's insert for details on how to submit proposals or contact Jean-Michel Poutissou, TRIUMF's Associate Director, at jmp@triumf.ca.

FOR MORE DETAILED INFORMATION ON ISAC, CONTACT PAUL SCHMOR [ISAC DIVISION HEAD] AT SCHMOR@TRIUMF.CA.



DRAGON Delivers Key Measurements in First Experiment

DAVE HUTCHEON, TRIUMF SENIOR RESEARCH SCIENTIST

The DRAGON facility at TRIUMF/ISAC was designed to study nuclear reactions where a proton is captured by an unstable nucleus, with emission of gamma rays.Such radiative capture reactions are important for an understanding of explosive hydrogen burning in stars such as novae, x-ray bursters and some supernovae.

DRAGON has carried out a first experiment, using beams of unstable ^{21}Na at intensities up 500 million per second. A resonance at 212 keV was detected at rates of about 1 per hour, with background less than the signal by at least a factor of 10. This reaction affects two observable quantities of astrophysics interest, the ratio of Ne isotopes in pre-solar meteorite grains and the rate of ^{22}Na decay seen by orbiting gamma-ray telescopes. A resonance at 822 keV was also studied, complementing an observation in proton elastic scattering by the TUDA group (see www.triumf.ca/annrep/tuda.pdf).

With these first measurements, the DRAGON facility has demonstrated that it has met its design goals. The combination of intense unstable beams produced at ISAC and the sensitivity and efficiency of DRAGON is unequalled by any other laboratory in the world.

The principal challenge in making laboratory measurements of these capture processes is their considerably low rate, typically one reaction per million million beam particles. DRAGON meets this challenge by studying the reactions in inverse kinematics, where the beam is the heavy unstable nucleus and the target is hydrogen gas. The heavy products of the capture reaction recoil forward with appreciable energy, allowing them to be separated from beam particles and detected in a detector at the end of the separator. An array of detectors surrounding the gas target detects the gamma rays from the capture reaction.

SOME OF THE KEY FEATURES OF THE SYSTEM ARE:

- beams up to mass number 30 and energies between 0.15 and 1.5 MeV/amu can be delivered by the ISAC accelerators and accepted by DRAGON
- suppression of beam-related background by at least 12 orders of magnitude
- gamma detector array able to deal with background rates of several million counts per second from loss of positron-emitting beam particles in the region of the target
- windowless gas target cell 10 cm long operating at pressures up to 10 Torr
- 2-stage electromagnetic mass separator, 20 m long, consisting of 2 electrostatic dipoles, 2 magnetic dipoles, 10 quadrupoles and 4 sextupoles
- heavy recoils detected in a double-sided silicon strip detector or segmented ion chamber

FOR MORE INFORMATION ABOUT DRAGON, SEE WWW.TRIUMF.CA/ANNREP/DRAGON.PDF OR CONTACT DAVE HUTCHEON AT HUTCHEON@TRIUMF.CA.

TUDA Update

PATRICK WALDEN,
TRIUMF RESEARCH SCIENTIST

TUDA (TRIUMF-UK-Detector Array) is a general purpose scattering facility designed for use with the accelerated radioactive nuclear beams available from ISAC I. TUDA is principally (but not exclusively) designed for the detection of charged particles using silicon strip detectors. This enables the construction of highly segmented detector systems of large solid angle. Typical experiments include: $^{1}H(^{21}Na, ^{21}Na)^{1}H$, $^{4}He(^{18}Ne, p)^{21}Na$ and $^{2}H(^{18}Ne, p)^{19}Ne(4.033$ MeV).

TUDA's configuration consists of a modular vacuum chamber (length 1.5m, diameter 0.4m). An upstream flange holds the beam collimator system. A center box contains the target ladder, vacuum system ports and four large, general purpose ports. Currently a gas cell target, being developed for (^{3}He, p) experiments, is expected to be operational for winter 2003. The downstream flange is used for the electrical, gas and coolant feedthroughs. The detectors and preamplifiers are mounted on four rods arranged around the central axis of the chamber and attached to the downstream flange. The entire detector assembly can be withdrawn enabling convenient access to the detectors and instrumentation. The optics of the beam line gives a beam spot size of 2mm in diameter at the target position.

All of the pulse-processing instrumentation and data acquisition to support up to 512 discrete detector elements are housed in a stand alone counting room located close to the TUDA vacuum chamber. The room is in a Faraday cage that provides grounding and EMI/RF screening. The data acquisition system is based on a modified version of the Silena 9418/6V VME ADC and the CAEN V673 VME multihit TDC.

1) NIM A 454, 350 (2000)
2) PHYS. REV. C65, 042801 (2002)

Charge State Booster (CSB)

MIGUEL OLIVO
TRIUMF SNR. RESEARCH SCIENTIST

A charge state booster using the Electron-Cyclotron-Resonance (ECR) ion source technique has been developed at the Institut des Sciences Nucléaires (ISN) in Grenoble[1]. The method involves de-accelerating the incoming 1+ ions to thermal energies and capturing them in the plasma of an ECR source, where they are stepwise multi-ionized by collisions with the hot electrons of the plasma. The n+ ions are then extracted and accelerated.

A research collaboration program set up between ISN and TRIUMF to study the properties of the ISN-PHOENIX-ECR source as a charge breeder device suitable to the TRIUMF-ISAC facility was brought to completion in November of 2001. The result of these measurements[2] indicate that this system can fulfill the ISAC requirements in terms of breeding efficiency and breeding time for the 1+ to n+ process. A sample of some gaseous, metallic and alkaline elements relevant to the ISAC experimental programs (such as Ar, In, Ag, Zn, Sn, Sr, Ga, Co, Rb, K and Na) were studied. The results are listed in the accompanying table. Based on these results a PHOENIX booster ion source has been ordered from PANTECHNIK (France). This firm has been licensed by ISN to manufacture the source based on the ISN design.

This source will be incorporated as an extension to the TRIUMF 1+ ion source test stand in 2002-03 for further tests and in preparation to its future installation in the ISAC I hall.

For more information about TRIUMF's Charge State Booster (CSB), contact Miguel Olivo at olivo@triumf.ca.

FOOTNOTES:
1. P. SORTAIS ET AL., RNB2000 CONF. PROC., NUCL. PHYS. A VOL. 701 PP. 537-549 (2002).
2. T. LAMY ET AL., PROC. EPAC 2002 (PARIS) PP. 1724-1726

The Breeding Efficiency, η, and Time, τ, For Various Isotopes.

	η(%)	τ(ms)
$^{40}Ar^{1+/6+}$	5	100
$^{115}In^{1+/18+}$	4.6	120
$^{109}Ag^{1+/17+}$	3	75
$^{64}Zn^{1+/10+}$	2.8	50
$^{120}Sn^{1+/19+}$	4.1	150
$^{88}Sr^{1+/14+}$	3.6	125
$^{69}Ga^{1+/11+}$	2	80
$^{59}Co^{1+/9+}$	2	100
$^{85}Rb^{1+/13+}$	5	100
$^{39}K^{1+/9+}$	7.9	70
$^{23}Na^{1+/8+}$	1.8	---

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