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OPERATED AS A JOINT VENTURE

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UNDER A CONTRIBUTION FROM THE
NATIONAL RESEARCH COUNCIL OF CANADA

DECEMBER 2003

The contributions on individual experiments in this report are outlines intended to demonstrate the extent of scientific activity at TRIUMF during the past year. The outlines are not publications and often contain preliminary results not intended, or not yet ready, for publication. Material from these reports should not be reproduced or quoted without permission from the authors.

ACCELERATOR TECHNOLOGY DIVISION

INTRODUCTION

The Accelerator Technology Division is responsible for most of the engineering and design at TRIUMF, as well as support of the beam dynamics effort for international collaborations. Other responsibilities include project planning, electronic development and services, Building department and the Design Office and Machine Shop. This year, as for the past number of years, most of the available effort went into supporting the ISAC program. An indication of this is the number of new Requests for Engineering Assistance (REA) that were submitted during the year. There were 34 ISAC related jobs and 21 non-ISAC jobs in mechanical engineering and design. Figure 231 shows the distribution of REAs since they were instituted in 1995. The total may not indicate the overall level of effort required as some requests are for major projects requiring many months of effort and others can be satisfied with a few days of design time.

The Canadian Nuclear Safety Commission requires TRIUMF to develop and adopt a quality assurance program for all activities at the laboratory. A task force, which included two members of the division, was set up to develop this program. For the most part the new plan is adopting many of the policies and procedures that already exist. In some cases the documentation and formalization of the procedures will have to be improved and this will have some impact on the work of the division. Hopefully there will be an overall benefit emerging from this quality management system.

In mechanical engineering, the main job during the first part of the year was the completion of the east target station for ISAC. The system was assembled and then run off-line with a surface source for testing in August. Much of the effort then moved to the design of the cryomodules for the ISAC-II superconducting linac and specification of the refrigeration system. Some remaining work on the DRAGON spectrometer was completed and a start made on the RFQ cooler for the charge state booster.

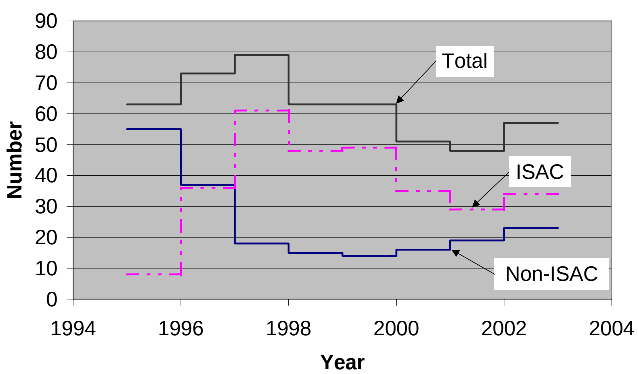

Fig. 231. Distribution of REAs since 1995.

The replacement of the BL1A triplet in the high radiation area downstream of the T2 target was a significant effort for the Design Office. This project is being coordinated by the Remote Handling group for installation in the shutdown starting at the end of the year. ISAC projects used about 60% of the design effort. The Machine Shop was fully loaded throughout the year and, in addition to the in-house fabrication work, subcontracted over 200 work packages worth about $500 K to local shops.

There were a number of projects involving TRIUMF's infrastructure role in supporting off-site experiments. An engineer has assisted the KOPIO collaboration in developing the design of the pre-radiator detector. A potential source of inexpensive extruded scintillator was found by working with a local plastics company. The pre-radiator also uses thin aluminum extrusions and possible suppliers for this were investigated. A detector stand assembly for the NPDGamma experiment at Los Alamos was designed, fabricated and delivered to Los Alamos in December.

TRIUMF personnel have been working on components for the ATLAS detector at the LHC for a number of years. Engineering and technical support has been provided by TRIUMF staff at the University of Victoria for the feedthrough project and the assembly of the hadronic endcap calorimeters into their support structure at CERN. An engineer supported by TRIUMF at Carleton University has assisted in the construction of the forward calorimeter modules and assembly and testing at CERN.

The TRIUMF collaboration on accelerator contributions to the LHC is described in another section. A study of the feasibility of a storage ring for the radioactive ions for ISAC was started as a future option for acceleration to higher energies. In addition to this work some initiatives aimed at potential collaborations on other international projects were begun. Studies of micro-bunching at the Brookhaven AGS beam for the KOPIO experiment continued. This experiment also requires upgrades to their kickers to permit higher intensity beams. A CFI grant was awarded to a UBC/TRIUMF collaboration for this AGS upgrade program. However, the grant is dependent on NSF funding of the KOPIO experiment, which has been delayed.

The Kicker group also provided assistance to the Japanese Hadron Facility in the design of a fast extraction/abort kicker for their main ring. A collaboration with this facility is being considered along with a Canadian involvement in the long baseline neutrino experiment. TRIUMF beam dynamics and kicker personnel attended a SLAC linear collider workshop and the outcome was a proposal to carry out research on the use of high power semiconductor switches to replace thyratrons in kicker systems. Towards the end of the year the Kicker group started a project, financed by an outside experimental group, to build a fast muon kicker for a muon lifetime experiment at PSI.

Field mapping the TWIST magnet was the main effort of the Magnet Measuring group during the first half of 2002. The rad-hard quadrupoles for the replacement BL1A triplet were also measured, along with a number of other magnets. A number of new magnets were designed during the year and the contract to design and build five 9 T superconducting solenoid magnets for the ISAC-II linac was awarded and is being monitored by the magnet engineer.

Hans Mertes, who was responsible for TRIUMF buildings for the past 20 years, retired and was replaced by Dragan Mitrovic. A number of maintenance and minor construction projects were carried out, including the replacement of the roof on the north wing of the main office building.

The Electronics Services group was involved as usual in a large number of support projects from cables and electronic modules for experimenters, to site communications and support of the growing number of PCs at TRIUMF. The Electronics Development group continued to provide all of the hardware installation, maintenance and upgrades for the ISAC control system as well as the development of the prototype data acquisition boards for CERN. Some secondary channel controls for the meson hall are being incorporated into a new EPICS based secondary channel control system.

BEAM DYNAMICS

In line with a recommendation in the Canadian Subatomic Physics Five-Year Plan (2001), studies have begun of the scientific potential and technical feasibility of a storage ring for the radioactive ions from ISAC. Such a ring (the ESR) has been successfully built and used at GSI Darmstadt, and others are being built, proposed or considered at IMP Lanzhou, RIKEN, TU Munich, GSI, and CERN (ISOLDE). Some of the attractive possibilities which a storage ring would open up are:

- measurement of otherwise inaccessible interactions;
- cooling of the beam, significantly improving position, time and energy resolution, and allowing the use of internal gas targets and the achievement of higher luminosities than with solid targets in the ISAC-II beam;
- acceleration to higher energies;
- direct measurement of nuclear and ionic properties (mass, lifetime, ...);
- quasi-simultaneous operation with ISAC-II experiments using the same ions;
- fast extraction of high-intensity pulsed beams for studying interactions with very low cross sections.

Three general scenarios may be considered, in order of increasing complexity and cost:

Mini:

An accumulator ring for ISAC-II beams, with no provision for cooling or further acceleration (similar in purpose to the 5 MeV/u "Recycler" proposed for the Munich Accelerator for Fission Fragments at the high-flux reactor (FRM-II).

Midi:

A storage ring for ISAC-II beams, with cooling and modest acceleration – say to four times greater energies – 26 MeV/u for the heaviest ions and 60 MeV/u for the lightest.

Maxi:

A cooler storage ring capable of handling, say, 100 MeV/u beams delivered by a further ISAC accelerator (linac or cyclotron).

For initial orientation we have considered scaled versions of the TSR at MPI Heidelberg, which has a bending power of 1.5 T-m, a diameter $D \simeq 15$ m, and charge (or momentum) acceptance of $\pm 4\%$. (It is also the basis for the ISOLDE 2.6 T-m test intersecting storage ring (TISR) design.)

The ring diameter required depends on both the maximum energy and the mass/charge ratio (A/q) of the circulating ions. If the ISAC-II beam were to be injected by stripping in a foil, and the associated beam loss could be tolerated, then the A/q for light ions could be reduced from 3 to 2 and that for heavy ions ($Z = 65$) from 7 to 3.2, allowing the bending power $B\rho$ and ring diameter to be correspondingly reduced.

Table XLIV shows approximate values for the major ring parameters for each of the above scenarios and for the TSR and TISR.

One of the main design challenges is to limit ion loss caused by scattering, energy straggling or charge exchange in the injection stripping foil, residual gas or internal target. These effects limit the acceptable thickness for each of these items, and also require the injection energy and transverse and momentum acceptances to be sufficiently high. These issues are currently being explored, with the aim of establishing a basic conceptual design (magnet lattice, injection scheme, and rf, vacuum and cooling requirements) and estimating the

Table XLIV. Storage ring parameters.

Ring	Strip injn.	Z	A/q	Energy (MeV/u)	$B\rho$ (T-m)	D (m)
TSR	No		2	30	1.5	15
Mini	No	6	3	14.6	1.6	
	No	65	7	6.5	2.5	21
	Yes	6	2	14.6	1.1	
	Yes	65	3.2	6.5	1.2	13
Midi	No	6	3	60	3.3	
	No	65	7	26	5.0	36
	Yes	6	2	60	2.2	
	Yes	65	3.2	26	2.4	20
Maxi			2	100	2.9	29
TISR			2	75	2.6	21
			2	300	9.0	66

beam performance achievable (intensity, emittance and charge composition).

Muon Acceleration in an FFAG

Muons present unique challenges for acceleration. First, muons decay; this means that acceleration must be rapid. Second, the 3D emittance of muons emitted from a production target is large; thus, unless there is strong cooling, the accelerator must have extremely large acceptance in all planes. Fixed field alternating gradient (FFAG) magnetic lattices coupled with superconducting rf cavities are a strong candidate to meet these challenges, particularly in the energy range 3–20 GeV, and there is rising interest in these machines at KEK, CERN and in the U.S. Continuing a collaboration with FNAL, we have promoted the non-scaling type FFAG and have further explored options for fixed-frequency acceleration.

Previously the problem of optimizing a single frequency was considered. With the objective of increasing the number of turns and reducing rf voltage, an algorithm that allows cavities to be grouped, and for each group to have its own optimum frequency, has now been devised. Two types of grouping were considered: ABAB and AABB, without restrictions on the number of groups or elements. The program has been applied to muon acceleration in a 300 cell FFAG with 200 MHz rf; cavity parameters were estimated based on existing CERN NC and SC designs. Comparisons were made between several grouping strategies for 5-turn and 6-turn acceleration. The ABAB type grouping typically yields larger transmission than the AABB type. However, for this machine, there are no great improvements in the performance between single-frequency and multi-frequency operation until the number of frequencies becomes large. Thanks to lattice design work at FNAL, and in part to these rf studies, the FFAG accelerator has been costed at BNL, was the subject of a recent Muon Collaboration (MC) workshop at LBNL, and is considered almost on par with the recirculating linac as part of the U.S. MC baseline proposal.

Micro-Bunching at Brookhaven AGS

It was a significant achievement to document the numerous slow-extraction simulation studies of the previous year. In these studies it was discovered that some 6% of protons, with small betatron amplitude, cross resonance without being extracted. One may choose simply to send them to a beam dump. However, by adiabatic movement of the rf bucket central momentum one may force particles to cross through resonance a second time. To keep the phase spread small, one must also ramp the betatron tune to give a resonance that coincides with the rf bucket. Several schemes of this sort were investigated, but results were disappointing. At best the ramping strategy can extract only an additional 2% of the initial beam; and the micro-bunch phase width is compromised.

RF beam loading of rf cavity

Based on the assumption of minimum reactive power and the smallest rated power tube, resonance frequency tuning and cavity power requirements for the 25 and 100 MHz systems for the proposed KOPIO experiment were estimated using beam current Fourier components calculated for a micro-bunched slow extraction. The power requirement is dominated by ohmic loss whereas the dynamic tuning range specification is dominated by reactive compensation of the particle beam current. However, due to their ubiquity at BNL, it was subsequently decided to employ a 60 kW tube, a rating 3 times greater than is required, and to reduce the tuning range by having the tube sink 20 kW of reactive beam power.

MAGNETS

In addition to contract supervision on the fabrication of the CERN twin aperture quadrupoles described in the CERN collaboration section, work was carried out on a number of other magnets during the year.

- The conceptual design of a 60 Hz steering magnet to paint the high intensity proton beam on to the ISAC targets was completed, but budget constraints have delayed the detailed design of the magnet [TRI-DN-02-1].
- The second dipole from the decommissioned M8 beam line was modified to act as a charge selector dipole for ISAC's charge state booster [TRI-DN-02-7 and TRI-DN-02-18].
- A small $X-Y$ steering magnet was designed to fit between the ISAC-II cryomodules [TRI-DN-02-17]. At year-end, construction had started on

8 magnets in the TRIUMF shop. The magnetic shielding of the ISAC-II medium beta cryomodules was studied [TRI-DN-02-20].

- Everson Electric Company (Bethlehem, PA) was contracted to design and build five 9 T superconducting solenoids for the ISAC-II medium beta cryomodules. The first magnet is expected to arrive in February, 2003.

Due to the decommissioning of the TRIUMF VAX cluster, considerable effort was spent transferring all old magnet measurement data from magnetic tapes to CDs and to the alph10 computer.

Experiment 614 – TWIST

The first half of 2002 was largely taken up with surveying the TWIST superconducting solenoid in the meson hall. A custom rotating arm survey system was built for this with capacity for 2 Hall probe arms. One probe arm has 7 Hall probes for surveying the main volume of the magnet and the other has the capability of 5 Hall probes for measuring upstream from the magnet, only the probe arm with 7 Hall probes was used for the preliminary surveys.

Another arm, with a NMR probe attached, was also attached to the rotating boom. The whole survey system can rotate through 360° and can also move along the Z axis by approximately ± 1.0 m. A second Hall probe channel will be built in early 2003, ready for further measurements. A detailed comparison was made between field maps taken for the TWIST solenoid at a field of approximately 2 T, and predictions obtained using the TOSCA 3D electromagnetic simulation code. There are twelve coils in total, comprising six inner coils and six outer coils. Three main discrepancies were identified in comparison with the TOSCA base model, namely: the measurements had an upstream-downstream asymmetry of 0.7 mT that was not predicted by TOSCA; the reduction in measured field, as one moves away from the centre of the yoke, is greater than TOSCA predictions; and a measured field asymmetry in both X and Y was not predicted. A series of TOSCA simulations, mainly by a co-op student, resulted in the following conclusions:

a) Modifying the model by moving the upstream set of inner and outer coils as well as the downstream set, by a distance of 1.8 mm along the Z-axis towards the centre of the solenoid corrects the predicted field gradient to better match the measured map;
b) A predicted upstream-downstream field asymmetry, similar to the measured asymmetry, can be achieved by appropriately scaling the current (by up to 1.7%) in three of the six inner coils of the solenoid;
c) The measured field asymmetry in both X and Y is predicted when the coils are displaced off-centre by approximately 1.5 mm in X and 1.8 mm in Y.

Detailed field maps obtained from the TOSCA simulations have been supplied for GEANT studies.

Magnet Measurements

Other magnets surveyed this year included the M8CSB dipole (charge state booster dipole), seven ex-Chalk River double steering magnets, HiTime 7 T superconducting solenoid from M15 (surveyed twice), and three radiation hard quadrupoles for 1A triplet (1AQ14, 1AQ15, 1AQ16). These triplets were measured with an 8 in. rotating coil. The 1AQ15 triplet was also measured with the survey table and a Hall probe for comparison.

Kickers

AGS KOPIO collaboration

The Kicker group carried out a conceptual design and budget estimate for upgrades to the AGS kicker systems for a Canadian Foundation for Innovation (CFI) grant submission for the proposed KOPIO experiment at Brookhaven National Laboratory (BNL). Upgrades are required to the booster extraction and AGS injection kickers in order to increase the AGS beam intensity by at least 50%.

NLC collaboration

The Kicker group are collaborating with kicker experts at SLAC carrying out research into the application of high power insulated gate bipolar transistors (IGBTs) for high efficiency, high reliability, and low cost pulsed power modulators for the Next Linear Collider (NLC) (Fig. 232). The IGBTs are stacked in series with a voltage of approximately 140 kV dc per stack. Under normal conditions the IGBTs conduct 3 kA current pulses for 3 μs, and under fault conditions the IGBTs may have to turn off currents of 6 kA or more. The aim of the power IGBT high speed switching project at TRIUMF is to understand and optimize internal designs of the IGBT so that the IGBTs can be reliably used in the pulsed power modulators. A co-op student will commence work on this project during 2003.

JHF collaboration

The TRIUMF Kicker group were approached by the JHF Neutrino Experimental group to consider the feasibility of designing a combined function extraction and abort kicker system for the Japanese Hadron Facility (JHF); at this time a design did not exist for such a kicker system. After making several suggestions for

Fig. 232. Solid state induction modulator developed at SLAC.

the combined function kicker system we were invited to be members of an international collaboration designing and constructing the combined function extraction and abort kicker system. We were invited to give a talk at the JHF Neutrino Workshop, Kyoto, Japan in September. To our knowledge, this would be the first time that a combined function kicker has been constructed. The main involvement of the TRIUMF Kicker group will be in the design of the high power semiconductor switches required for the kicker; these switches will probably require high power IGBTs. TRIUMF will also perform PSpice calculations to determine the effect of dispersion on the detailed shape of pulses created with a pulse forming cable feeding a lumped element transmission line kicker magnet. We are also recommending a 32 kV system voltage, rather than 40 kV, to increase reliability. This will involve the design of a 3-cell kicker magnet with good transmission line behaviour, using a design first proposed by TRIUMF in 1994.

An NSERC research grant has been applied for to carry out research into the high power semiconductor switches that will be required for the next generation of kicker systems.

PSI MuLan collaboration

An international collaboration plans to measure the lifetime of the muon to a precision of 1 ppm. The “MuLan” experiment will take place at PSI in northern Switzerland. The central idea employed in MuLan invokes an artificial time structure on an otherwise dc beam. The MuLan method requires a fast beam line kicker, which can turn the beam “on” and “off” at a repetition rate of up to 75 kHz: the TRIUMF Kicker group have been asked to design and build the kicker with the goal of shipping the kicker during June, 2003 and commissioning it at PSI in July, 2003. The kicker needs to run with a standard “on-off time cycle” or in a “muon on request” mode. The MuLan kicker will consist of 2 pairs of deflector plates mechanically in series, driven by 4 FET modulators. Each pair of plates is 0.75 m long. One plate of each pair is driven by a ±12.5 kV FET based modulator and the other plate is driven by a −12.5 kV modulator. The potential difference between a pair of deflector plates is variable up to 25 kV. Each modulator consists of two stacks of FETs operating in push pull mode. The specifications for the kicker demand that the rise and fall times of the deflector plate voltage is not more than 45 ns. There is a requirement for an adjustable output voltage from 0 V to ±12.5 kV per deflector plate, a minimum pulse duration of 200 ns, and adjustable repetition rate up to a maximum of 75 kHz, continuous. In addition, short turn-on and turn-off delays are required. We have developed a novel concept for the design of the MuLan kicker; a PCB containing a 1 kV MOSFET high-speed driver, power supply, and fibre optic receiver has been prototyped and is currently under test (Fig. 233). The printed circuit board layout for this design is very critical due to the fast switching times (<2 ns on the board) and the presence of kV transients that could otherwise be superimposed on low voltage fibre optic control voltages (5 V). It is planned to finalize the design of this PCB early in 2003.

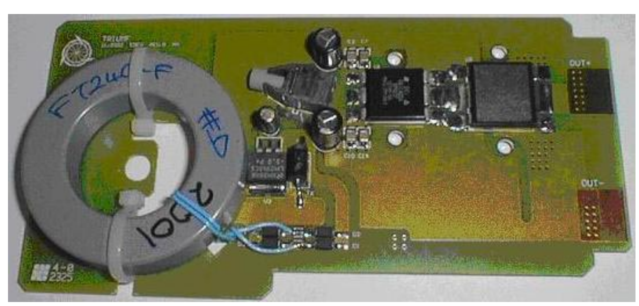

Fig. 233. Prototype PCB developed for MuLan kicker (heat sinks and fibre optic receiver shield not mounted).

MECHANICAL ENGINEERING

Mechanical engineering work at TRIUMF is initiated by the submission of a Request for Engineering (REA) form which is assessed and assigned according to the size, complexity and schedule of the task. Large, complex tasks usually require a team approach guided by a project engineer. The ISAC-II superconducting accelerator refrigeration system and cryomodules fall into this category.

During the year there were 34 ISAC REAs and 21 non-ISAC REAs submitted, along with a number carried over from the previous year.

As in the past there was continuous participation of engineering personnel in performing engineering analyses, consideration of safety related issues, design reviews, and other ad hoc engineering related small jobs.

ISAC-I East Target Station

This large project is a carry over from the previous year and was broken down into 6 major work packages as listed and briefly described below.

East module access area (EMAA)

The EMAA is the zone above the modules and below the five removable shield plugs. Although the work commenced in 2001, it could only be done during maintenance days and target changes for the west station, hence the majority of work was accomplished in this report period. A better approach to the layout of the EMAA was required due to problems with accessibility experienced in the WMAA. To correct this shortcoming, and in consultation with the target hall coordinator, a detailed design of the area was produced placing cables in cable trays, re-routing most services to maximize usable floor area, and redesigning the high voltage cage to produce a much neater entry of services to the target module and allow ease of handling during removal. The results of this work have made maintenance work easier in the EMAA, and the WMAA will be upgraded in a similar way in the future. The EMAA also houses some of the microwave equipment necessary to drive the ECR source. The power supply and controller are located in the electrical room but the magnetron, isolator and auto tuner are located on the south wall of the EMAA and connect through a wave guide to the top of the target module. The EMAA was completed and operational in the summer.

Faraday cage and HV chase

The Faraday cage is located in the electrical room adjacent to the target hall and houses the high voltage power supplies and related equipment, and the target gas supply system. Advantage was taken of an extended shutdown early in the year to accomplish a majority of the work.

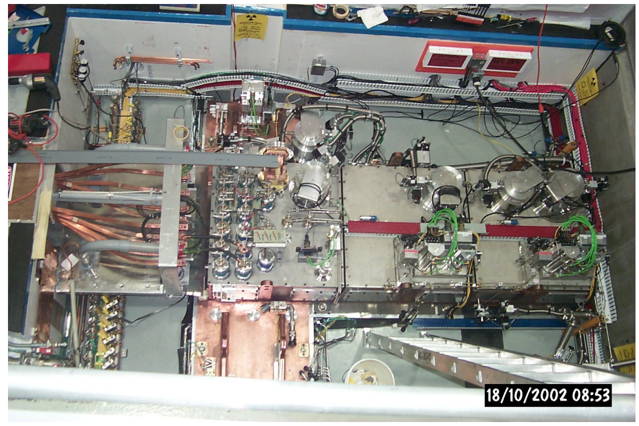

Fig. 234. View of EMAA.

A difficult task was the installation of high voltage conductors in the high voltage chase. The chase is approximately $2 \times 2 \times 20$ ft long with three right angle bends. There are ten 0.5×0.5 in. water-cooled conductors (plus a plastic tube for wires and 4 separate gas lines) that are required to be accurately installed in an H pattern to match several insulation stands in the chase and terminate in a flat array at a pedestal next to the target module. Flexible jumpers are used from the pedestal to the target module. The chase is then enclosed by shield blocks and the portion in the EMAA (Fig. 234) is surrounded by a high voltage cage. All this work was completed in the first half of the year.

Modules

The entrance and dump modules had been completed and installed in 2001. The assembly of TM2 (scheduled to be the surface source module for the east target station) and TM3 (the ECR source module) had commenced in 2001 but the difficult tasks were carried over to this report period. These included the accurate assembly of 30 tubes (0.25 and 0.375 in. diameter) into the service tray and putting them in place, and the accurate fitting of the containment box on to the bottom of the module so that it can be manipulated in the hot cell. The most formidable challenge was bending, fitting and soldering the 14 water blocks in the containment box that connect the service tray tubes to the target extraction column. This is a new, unique design that allows the complete disconnection of services between the service tray and extraction column tray so that either tray can be removed and replaced in the hot cell. This was a painstaking task in a small work space made more difficult by the fact that spacing of the tubes is crucial due to the potential differences during operation (Fig. 235). Due to the complexity of the task, it took an additional two months to accomplish beyond the original scheduled date. However, it

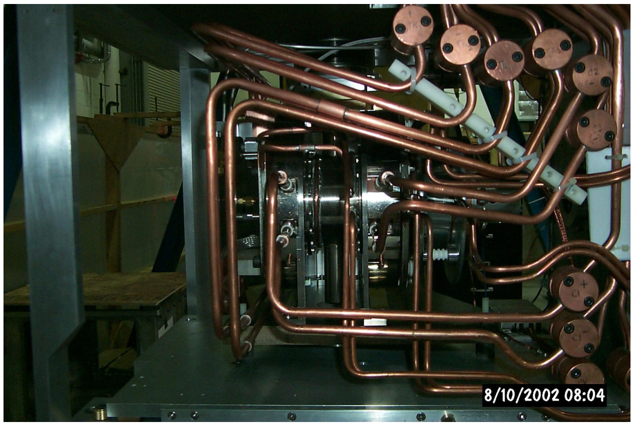

Fig. 235. TM3 water block assembly.

has proved to work well and has accepted voltages up to 50 kV to date.

The exit modules are similar to those in the west target station but incorporate the new shield plug, a slightly different containment box, and redesigned optics for compatibility with the ECR source. The two exit modules were completed in March and installed in April. Leak checking, continuity checks and diagnostic checks were then performed successfully.

TM2 (surface source) was installed in July and was leak, systems, and high voltage checked. It was available for stable beam delivery towards the end of August. This was followed by removal of TM2 and installation of TM3 (ECR source) during the first week of October. After three weeks of checks it was available for stable beam delivery in early November.

DRAGON

The remaining items of the DRAGON beam line were completed as follows:

- Modular security fence, complete with safety interlocks.
- Service platform (walkway) along the west side of the beam line. The platform was built above the cable trays of the power and controls cables using aluminum checker plates. The floor plates can be removed in sections for access to the power cables. The control cables can be accessed by simply lifting the hinged checker plate covers.
- Profile monitors were completed (see Figs. 236 and 237) and awaiting installation.
- Lead shields (about 3000 lbs each) for the charge slits and mass slits diagnostics box, complete with supports, were constructed and installed.
- Multi channel plate (MCP) was assembled and installed in the final slits diagnostic box.

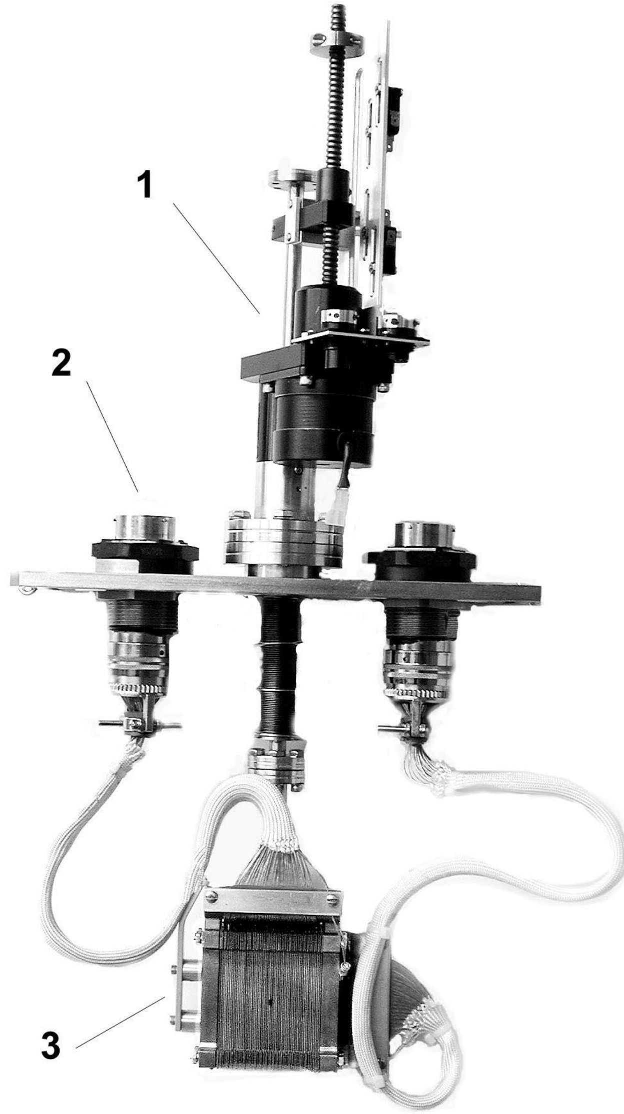

Fig. 236. DRAGON profile monitor showing actuator, vacuum feedthroughs, and monitor head.

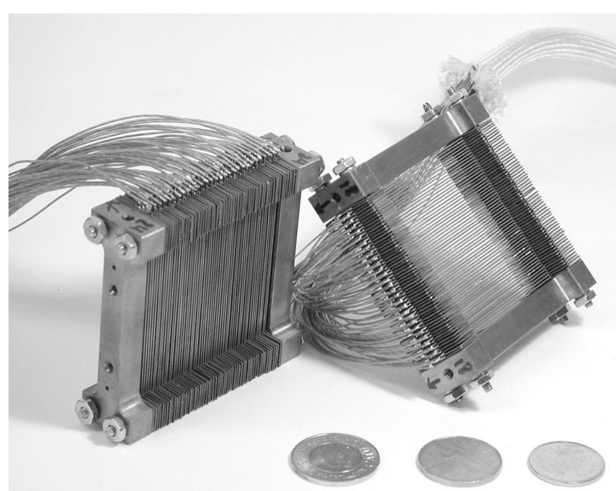

Fig. 237. DRAGON profile monitor showing $X-Y$ monitor heads.

- A universal alignment fixture was designed and built. This fixture can be used to pre-align all existing DRAGON diagnostic devices, eliminating alignment of a device in the beam line after repair or when constructing a new device on existing beam line ports.

RFQ cooler

The RFQ cooler captures low energy ion beams, cools the ions, and bunches them before injection into the charge state booster (now being constructed by another group at the ISAC test stand).

Before installing the RFQ cooler in the ISAC test stand, the device will be set up and tested in the former TISOL experimental area in the proton hall extension. The area has been cleared and an exclusion area (semi-clean room) that will house the RFQ cooler is under construction.

The RFQ cooler is a device 2 m long, built on a high voltage platform and protected by a high voltage cage.

The hardware design is about 75% complete. A design review will be done shortly in order to complete the final design and start construction. An overview of the RFQ cooler is shown in Fig. 238.

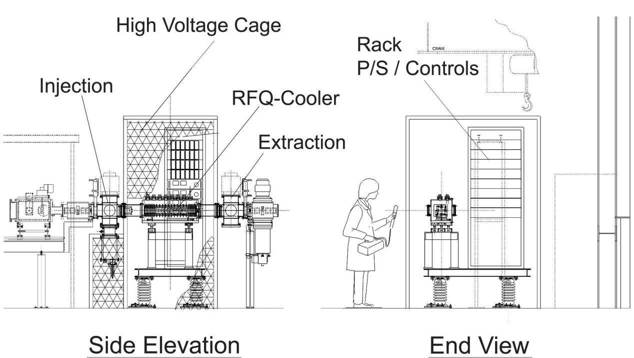

Fig. 238. RFQ cooler.

Engineering – Other

LTNO

The cold beam line of LTNO was redesigned and rebuilt to eliminate binding of the IRIS, and also to eliminate the leak that used to develop when the beam line was cooled to cryogenic temperatures.

KOPIO

Scintillator extrusion

Since a large quantity of scintillator is needed for the KOPIO preradiator, it was desirable to seek an inexpensive scintillator for this experiment as conventional cast scintillator cost would be prohibitive. Fermilab has developed a method of producing inexpensive scintillator using polystyrene and some dopants using extrusion techniques. It is also desired that these extruded pieces of scintillator contain holes in their middle plane to accommodate fibres for light collection. Using a local company, Celco Plastics (Surrey, BC), and using the Fermilab method, we have been able to produce scintillator similar to that produced at Fermilab. So far we have produced scintillator with $\frac{1}{2}$ in. $\times 1\frac{1}{4}$ in. cross section and containing 3 holes. Efforts are under way to control the shape of the holes, control the external shape of the cross section to very tight tolerances for an extrusion process, increase the width of the cross section, and hence increase the number of holes in each cross section.

Aluminum extrusions

The KOPIO preradiator requires very thin walled and very tight tolerance aluminum extrusions to provide uniform electric field to the detector wires. One company had been found in Ohio who agreed to try to make such extrusions and indeed produced some samples for the prototypes. However, when this company tried to produce thinner sections, they had trouble doing so and then couldn't even reproduce the original extrusions as the personnel who successfully produced it originally had subsequently retired. Although they are still trying to duplicate what they produced, we have started looking for alternate suppliers. Most companies shy away from this very thin and tight tolerance shape but two companies are willing to try. An order has been placed with one of them to produce what the Ohio company had originally produced.

Other projects

Design and development was carried out for a detector stand assembly with two axis position control and data acquisition system for the NPDGamma experiment at the Los Alamos National Laboratory neutron research facility. The position controlled part of the frame is called the detector array frame and it houses 48 individual cesium iodide detector crystals each weighing about 50 lbs arranged radially around the LHe target cryostat which is also held by a "TRIUMF plate" which holds everything including the "spin flipper". Delivery of the whole system was made to LANL on December 23.

Numerous other thermal, stress and other calculations were done for such things as the ISAC target heat shield, pepperpot beam stop, ISAC-II SCB cryomodule vacuum tank, LHe reservoir, ISAC-II SCB rf cavity, etc.

ISAC-II

January, 2002 marked the beginning of the involvement of engineering on the superconducting linac planned for the accelerator hall in ISAC-II. There were two major work packages assigned to mechanical engineering – (1) the refrigeration system, and (2) cryomodules. The linac is to be installed in two phases. Phase 1 involves the design, manufacture and installation of 5 medium-β cryomodules and 2 high-β cryomodules, the helium refrigeration system, and the helium distribution system to support the operation of this phase of the accelerator. Phase 2 is not at the present time completely defined, but will include an addition to the refrigeration system as well as completion of the high-β cryomodules.

Each resonator in the cryomodule required individual frequency tuning. TRIUMF has developed a design that allows both coarse and fine tuning to be accomplished by the same device and driver. A brief description is included.

Refrigeration system

The refrigeration system is composed of the following major components – an exterior helium storage tank capable of holding the entire phase 1 system inventory as a compressed gas, the main He compressor for this phase of the project housed in a separate compressor room adjacent to the experimental hall, a high pressure delivery system from the compressor to the liquifier housed in the cryogenics room adjacent to the accelerator hall, the liquifier, a turbine expansion machine producing liquid helium, the liquid helium storage dewar, the cryogenic distribution system from the storage dewar to the valve boxes (i.e. one valve box is required per cryomodule), and the transfer line between the valve box and the cryomodule. This system will obviously require a number of sub-systems for operational support that will not be listed here (i.e. He purifier system). Phase 1 (and 2) of the refrigeration system will be a 500 W at 4.5° K system based on the head load of the phase 1 components plus losses, with a suitable margin. It will have a 1000–2000 l liquid He storage dewar allowing for enough liquid He to ensure that cryomodule cooldown is rapid enough to avoid Q disease. A medium-β cryomodule cooldown will require approximately 200 l/hour for a duration of 6 hours.

Both the refrigeration system and distribution control system will be integrated into a two layer single system, consisting of a control layer handling all aspects of device control, and an operation interface (OPI) layer using the EPICS ISAC control system philosophy.

The team looking after the refrigeration system visited other laboratories involved in superconducting accelerators accumulating information, reference data, and related advice, in order to construct a specification to be sent out in a bid package to potential suppliers sometime in early 2003 with a goal of having an operational and accepted system by the end of 2004.

Cryomodules

The mechanical design of the medium-β cryomodules was initiated by the creation of a cryomodule specification based on the beam dynamics design note for relevant dimensions. A medium-β cryomodule is a stainless steel vacuum tank housing 5 cryo elements – 4 quarter-wave resonators and one 9 T solenoid. The cryo elements are supported by a rigid frame suspended from the tank lid by thin walled tubular struts in such a way as to accommodate material shrinkage during cooldown to 4.5° K. Cryo element alignment is paramount for efficient accelerator operation and must be maintained over repetitive cooldown cycles.

120 l of the liquid helium inventory of ~170 l is held in the 40 cm diameter × 159 cm long helium reservoir and connected to the cryo elements by a 3 in. tube/bellows assembly. The reservoir is supported to the lid by a central tower which also provides a platform for pressure relief valves, a burst disk and cryogenic feedthroughs. The vacuum tank is lined with sheet μ-metal in order to negate the earth's magnetic field effects. Inside this liner is the liquid nitrogen (LN_2) liner which intercepts the heat load from the vacuum tank to the cryo elements. The LN_2 liner is placed in the tank sitting on the floor and away from the μ-metal by low conductivity standoffs. The lid will also have a double liner overlapping with that of the tank proper. The lid also provides space for other feedthroughs related to diagnostics, rf devices such as resonator tuning and coupling loop tuning, heaters, temperature readout feedthroughs and the frame suspension lugs.

Tests will be performed to investigate material shrinkage and any effects it will have on cryo element alignment (other than vertical). Once material shrinkage has been allowed for, alignment of the cryo elements to the beam ports will be performed in the assembly area and each cryomodule will be delivered aligned with two external alignments for alignment in the beam line on a standard TRIUMF 3-point mounting system.

Between cryomodules there is a diagnostic box, steering magnet, a short retractable beam tube and a 2 in. valve associated with the beam port at one end of each cryomodule; the other end has only a valve and KF40 stub to match the beam tube. This allows for removal of a cryomodule from the beam line without venting the system or the cryomodule. A cryomodule will be able to be replaced by a section of beam tube allowing the accelerator to remain operational.

At the end of this report period the vacuum tank, inter-modular components and some of the support frame have been detailed for release early in 2003. The goal is to have an operational medium-β cryomodule by late 2003.

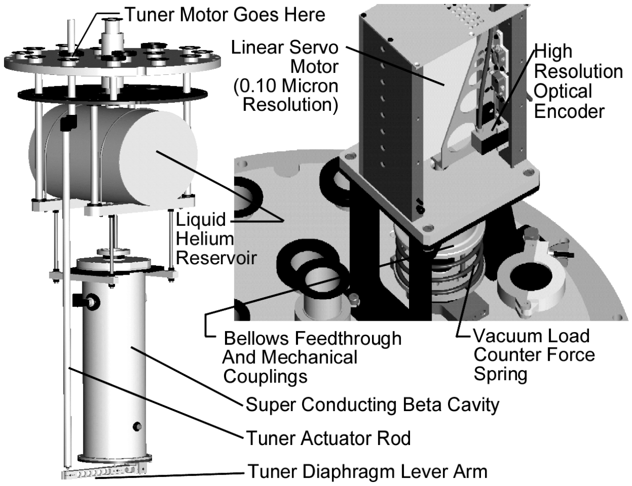

Fig. 239. Resonator tuning diaphragm and actuating mechanism.

Resonator tuning system

A new type of tuner system design was developed and tested successfully for the new ISAC-II superconducting rf cavity. This is the first known application of a direct drive linear motor actuating a tuner diaphragm of this sort to a resolution of ± 0.5 μm through a 5 ft long linkage system from outside the vacuum (Fig. 239). A special contoured tuning diaphragm with radial slots allows a coarse tuning range of $> \pm 2$ mm with an actuation load of ± 10 kg. FEA analysis was used in the design to confirm stress levels at maximum deflection and stiffness to ensure reliability and compatibility with the tuner control system.

Engineering – Victoria

Signal feedthrough project

There is continuing support for the ATLAS feedthrough project where construction of the last of 55 feedthroughs was completed towards the end of the year. All but four of these feedthroughs have arrived at CERN and staff at the University of Victoria will be supporting the integration process into the endcap cryostat of the ATLAS project at CERN. The TRIUMF laboratories at the University of Victoria will still be available to repair any damaged feedthroughs as a result of the installation process.

Hadronic endcap (HEC) module assembly table

Contributions to the ATLAS HEC production structure and manipulation tooling for the assembly of the HEC modules is ongoing. After components of the support structure were manufactured in Canada in 2001, successful delivery to CERN and final inspection were completed in early 2002.

ISAC target development

The targets designed for the ISAC target stations are currently limited to 40 μA at maximum. Additional cooling would be required after this to avoid damage to the target components. A new target has been equipped with fins to increase the surface area to increase the heat dissipation required with the increasing proton beam currents and has been tested off-line. A thermal simulation using finite element software has been conducted and the results from these analyses have closely matched the measurements in the test scenario. These results demonstrate that the new target can withstand proton beam currents up to 100 μA.

With the completion of the manufacturing and testing of ATLAS feedthroughs, the decommissioning of the laboratory space at the University of Victoria has begun, other than leaving a small area for feedthrough repair, if the need arises. At this time a high temperature vacuum test station is being introduced for ISAC target development. Existing equipment is being modified and an effusion cell is being designed to test various materials for potential use in future ISAC targets.

ISAC-II – medium β accelerator design

The University of Victoria has been providing technical support as needed while the design for the medium β cryomodules progresses. This has primarily involved calculations for the heat load on the cryomodules as well as determining the details of the flash vapourization expected of the liquid helium inside the cryogenic components if a loss of vacuum occurs inside the cryomodule tank.

General

The Engineering group at the University of Victoria has continued to provide support for beam line and equipment maintenance at TRIUMF. This has included technical drawings and calculations as required.

Engineering – Carleton

ATLAS forward calorimeters (FCAL)

In July, the FCAL 3C module was packed into a Carleton designed and constructed reusable shipping crate and transported to CERN by truck and air. The total shipping weight of the module and the protective crate was 5154 kg. Once at CERN, the module was moved into a clean room and the installation of signal readout boards was completed (Fig. 240), along with several high voltage tests (Fig. 241) designed to locate shorts in the readout anodes. A cold test, consisting of having the module in a cryostat of liquid argon, was successfully completed in November. This module is now ready for a calibration beam test scheduled for June, 2003. Construction of FCAL module 3A was completed to the point where only about 5000 tungsten anode rods remain to be inserted. This module is scheduled to be shipped to CERN in April, 2003.

Fig. 240. Installation of FCAL 3C readout boards at CERN.

Fig. 241. Testing of FCAL 3C after arrival at CERN.

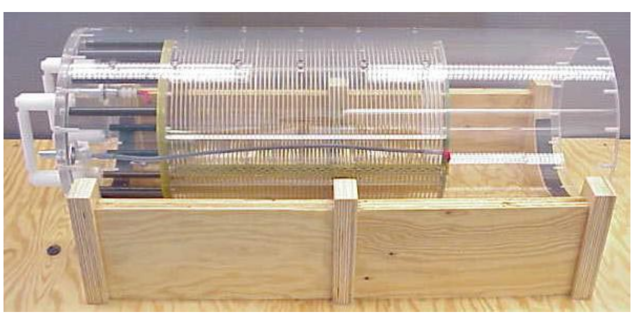

Fig. 242. "See through" TPC readout test chamber.

TPC readout test chamber

In order to test various TPC readout patterns for use in future linear colliders, a small non-magnetic TPC was designed and constructed at Carleton (Fig. 242). The chamber is housed in a 600 mm long, 222 mm diameter acrylic tube. Most of the components are non-metallic with a few that are non-magnetic materials. The chamber was sent to the University of Victoria for testing in a specially built reusable shipping container, the lid of which can also be used as an assembly stand for the inner working of the chamber.

PLANNING

This year the Planning group was involved in planning, scheduling, coordinating and expediting several sub-projects for ISAC-I (east target station, ECR source, 25 MHz cavity, Osaka beam line, and 8π); ISAC-II (BC Research facility, medium-β system, high-β system, transfer line, H-HEBT and charge state booster (CSB)); planning and coordinating activities for two scheduled shutdowns (December 22, 2001–April 17, 2002 and September 19–26); prototype chambers for KOPIO preradiator, M8 decommissioning, 1A triplet repairs and replacement. The Planning group was also involved in preparing preliminary PERTs for the rf cooler and TIGRESS.

ISAC-I

Various plans and PERTs were prepared and updated regularly with manpower estimates and analysis to identify critical areas and resolve any problems. ISAC priorities were evaluated and higher priority was assigned to: the east target station that was installed in the winter, 2002 shutdown; ECR source (to be installed in TM3 and tested with beam in November); install and commission 25 MHz buncher in spring; and expedite low energy experimental program that included the β-NMR and Osaka beam line.

Manpower planning was done, activities were coordinated and expedited, and the above goals were achieved on schedule. However, several technical problems encountered in the installation of the target module at ITE delayed the commissioning until November.

Technical details and progress on PERTed activities are described elsewhere in this report under the respective principal group. However, following is a summary of the main projects along with the major milestones achieved.

East target station

This project received high priority and had to be fast-tracked for installation in the January shutdown. The project was broken down into 9 work packages and major highlights included: 2A beam line (2A3 beam line installed in winter shutdown); Faraday cage (most work done in winter shutdown and remainder completed by summer with limited access to electrical room due to ITW beam operation); target hall (included modification and commissioning of south hot cell and alignment components and water package shielding in

March); controls (included 2A controls, target protect interlocks and RIB controls for vacuum system, beam optics and beam diagnostic systems completed in the winter shutdown).

The work on the modules required extensive Design Office and Machine Shop effort. Several design modifications were made for better manufacturability and remote handleability. Initially the plan was to make TM2 and TM3 interchangeable but later complications associated with installation of the ECR source and microwave guide and generator excluded that provision. TM3 was designated as the module for the ECR source at ITE, and TM2 with surface source at either east or west target stations. Some of the major technical challenges that took longer than anticipated included accurate assembly and installation of 30 tubes and 14 water blocks in the containment box. Consequently exit modules 1 and 2 were installed in April and TM2 (with surface source) was installed in July, followed by leak checking, fixing water leaks, and high voltage checks by September. The ECR source was tested on the test stand by September. TM2 was removed and TM3 with ECR source was installed in October, followed by checks and tests with stable beam in November.

Target conditioning box

An alternative conditioning system was designed and fabricated by January to expedite the process of changing and conditioning ISAC targets. Assembly continued till April due to lack of manpower.

Experimental facilities

The Osaka beam line was installed and tested in October/November with a new chamber and associated services. The 8π beam line with a simple chamber was commissioned with a test beam in December.

DRAGON and TUDA started commissioning with stable beam followed by RIB. Some of the major hardware items completed for DRAGON included: modular security fence with safety interlocks, service platform, lead shields for charge slits and mass slits diagnostic boxes, and universal alignment fixture.

ISAC-II

PERTs were prepared and monitored for all ISAC-II projects, and activities were coordinated and expedited to meet various milestones. Major milestones achieved for the medium-β system included: commissioning tests on Nb cavity with rf controls in June, with mechanical prototype tuner in October, and with μ-metal in November, tuner development and final design released in November, order amplifiers in December, prototype solenoid ordered in October with delivery in March, 2003. Fabricated cavities at Ezanon progressed well with delivery anticipated in January, 2003, to be followed by chemical treatment at CERN by April, 2003. Extensive effort was spent in planning cryomodule engineering. Conceptual design was reviewed in November and three designers were allocated to complete the design of the tank, lid, LN2 shield, liquid helium reservoir, frame and suspension system, intermodule zone, and jigs and fixture by March, 2003, fabricate and assemble by September, 2003, with an aim to do cold tests and test the cryomodule with rf in October, 2003. The refrigeration system is on the critical path because specifications were delayed due to lack of manpower and information.

Work continued on high-β beam dynamics, HEBT transfer line (layout, specifications and concept design of dipoles), and charge state booster (components ordered in February and received in November, design CSB stand in fall, modify analyzing magnet in December), with an aim to test the whole system on the test stand by October, 2003.

Shutdown Activities

There were two shutdowns during the year: the winter shutdown (December 22, 2001–April 17, 2002), and a short maintenance shutdown (September 19–26).

Winter shutdown

BL1A shutdown activities began in early January, with the removal of many shielding blocks from the meson hall to a temporary storage location near the Machine Shop. The original work schedule slipped a little at first because of an unanticipated need to quickly arrange two radioactive waste shipments to the AECL disposal facility to save significant money. Delays were also caused from obstacles encountered along the way – welded steel shielding in M8/T2 area, additional water leaks, new crumbling blocks. Six heavy crumbling shielding blocks were shipped to the Chalk River storage site and removal of additional hidden crumbling blocks, including some underneath the T2 cooling package was delayed to the winter, 2003 shutdown. The extent and complexity of some of the BL1A tasks, most of them in very high radiation fields, resulted in some higher than usual doses for a few workers with three receiving between 5 and 7 mSv. A total shutdown dose of 150 mSv was distributed among 110 workers.

Major jobs completed by the Remote Handling, Beam Lines, Vacuum and Diagnostics groups in the meson hall included: M8 decommissioning that involved removal of the M8 channel front end elements, shielding replacement and reconfiguration (new shielding was designed to fill the void as well as to replace some removed crumbling blocks), the *in situ* repair of three separate water leaks on all three 1A triplet magnets, repair of M20Q1 and B1 water leaks, 1AQ10 rotary collimator vacuum leak, rebuilding of the troublesome M13 beam blocker, T1 and T2 target and water package MRO, repair of 1AM8 and 1AM10 monitors, repair of vacuum leaks at 1AVA8 and M13VA1 (broken bypass line), and replacement of 1AWVA2's air cylinders.

In the vault the cyclotron lid was raised towards the end of January to minimize shutdown dose. Radiation fields were about 10% higher than last year (as predicted from the previous beam delivery schedule), and, as much as possible, remote handling equipment was used to minimize personnel dose exposure. Apart from the usual heavy schedule of routine diagnostics MRO (including work on the extraction and pop-in-probes), there was quite a lot of time spent doing centre region work where, fortunately, the fields were reasonably tolerable. This included installation of a water-cooled beam absorber in LQ1's detachable quadrant (to help maintain cool centre region temperatures during higher intensity injection), repair, relocation and addition of several thermocouples, and the refurbishment of correction plates in Q1 and Q3. At the tank periphery, work included blanking off the unused centring probe feedthroughs and the tricky job of replacing the seals on the extraction 1 gate valve.

There was also a large number of additional jobs and MRO work around the site, including replacement of PCB transformers, construction and installation of the 2A3 leg and east target station.

Fall mini shutdown

This one week of extended maintenance work had a reasonably ambitious schedule. BL1 work started when PIF finished in 1B, while vault work started a week later when proton therapy had finished. The total shutdown dose was under 5 mSv with no one exceeding 1 mSv. Major jobs completed in this mini shutdown included: diagnostics MRO (extraction probes 1 and 2A, beam line monitors including 1AM8, fast shutter), beam lines (repair M13 beam blocker and install slit box in M13 F2, remove 1BBB2 latch mechanism and repair 1BBB3 vacuum leak), power supplies (main magnet power supply relay, water hose, MRO and repair radiation damaged feedback wiring), vacuum (tank cryo pump MRO, install turbo on cryoline and swap B20, extensive BL leak checking, change 2A O-rings near 2AVM1), services (install new rf room water filter, compressor MRO, ISIS LCW pump MRO, aluminum ALCW system control valve MRO), and rf (investigate sparking, install and test new combiners, build new GAT control software, check out ISIS rf pickup from tank).

The vault was ready in time for tuning up the cyclotron as scheduled but extraction down BL1A was delayed one day to accommodate last minute work. There were a few lingering details from the shutdown affecting subsequent operation. The M13 beam blocker initially worked fine as a blocker but lost its dual purpose as a beam line gate valve, M20Q1 developed a 1 l/h water leak, and a 1AQ9 over temperature fault was not found along accessible interlock wiring. It was recognized that 1AQ9 would therefore require uncovering to determine the exact cause and in the meantime 1A would have to remain tuned with 1AQ9 off. This did not have any major impact on beam operation since it is needed with the septum to provide M11 beam. Finally, 1BBB3 needed to be removed to repair a leaking bellows, making it necessary to run with the 1B area secured until the blocker was fixed. Since the lid was not raised, there was no opportunity to replace the two dead X2C foils. A viewing through the periscope indicated that whiskers were not nicely aligned but also showed that the heavily used one was fairly good. After the usual target scans and radiation surveys, the beam intensity was increased to deliver to BL1A and BL2A2 their nominal currents followed by 40 μA to 2C4.

DESIGN OFFICE

Available hours were up 3.5% over last year to 16,160 with the addition of one full-time junior and a reduction in sub-contracted hours. With ISAC-I under development and ISAC-II being in first stage design, focus has changed.

The ISAC project received 59.5% of design hours available during the calendar year. Specifically and in order of magnitude they were: (a) target module development including TM2, TM3 ECR source and all IT east modules; (b) ISAC-II SCB cryomodule component design, HEBT transfer, cavity refrigeration and experimental prototyping; (c) LE beam transport upgrades; (d) charge state booster development for installation in the ISAC test stand; (e) off-line ion source reconfiguration; and (f) miscellaneous experimental support.

TRIUMF's main program received double the hours of last year at 29.3%. The main projects were (a) BL1A triplet upgrade, (b) cyclotron HE probe upgrades, transmission line upgrade and beam absorber, (c) μSR, (d) M13/TWIST, (e) M11, (f) ISIS, (g) safety and other projects. External projects received 6.7% with most effort concentrated on the pulse forming network, HV switches and power supplies for the CERN collaboration.

Photographic and visual art services continue to grow in support of seminars and conferences. Publications such as the annual financial report are increasingly processed in-house. Instructional aids for the lobby, models, posters and displays are being consistently upgraded. Network 2D CAD is now available through PC support. 3D is under evaluation. 70% of the legacy archive has now been scanned.

MACHINE SHOP

The TRIUMF Machine Shop, with 19 technicians and 3 apprentices, produced approximately $129,000 worth of fabricated and machined components for various on-site groups each month. The shop charge out rate is $70/hour. The distribution by TRIUMF divisions and other groups is shown in Table XLV. In addition, 228 separate work packages worth more than $464,000 were sub-contracted through the Machine Shop to local industrial companies. The Machine Shop continued to be fully loaded throughout the year with ISAC continuing to be the major user. Two older machines were replaced with a new lathe and milling machine and these were very welcome additions to the ongoing program of updating equipment.

Table XLV. Machine Shop utilization.

ISAC Development	22.29%
Science	20.14%
ISAC Operations	14.13%
Nordion	13.74%
ISAC-II	11.19%
Cyclotron	9.06%
Cyclotron Refurnishing	5.03%
CERN	2.42%
Affiliated Institutions	0.75%
NSERC	0.57%
Site Infrastructure	0.50%

BUILDING PROGRAM

The Building department was involved in the following activities:

Design and management of minor construction projects

The department carried out the following projects: laser rooms in ISAC-I extension hall and service annex, roof access stairs (Fig. 243), additional air intake openings on the ISAC-I building, and proton hall fence, for a total cost of $69,900.

Structural design and engineering review

Structural design was done for the TITAN test area tent steel frame and the 20 ton spreader beam, and engineering review was performed for the new magnet support stand (BL1A triplet).

Construction review

Besides the reviews of minor construction projects managed by the department, the construction review of the new ISAC-II facility was done on a regular basis.

Management of maintenance and repair work

During the course of the year approximately $40,000 was spent on maintenance and repair work

Fig. 243. The new aluminum roof access stairs (before and after).

at various TRIUMF buildings (the annual maintenance and repair contract consumed $31,500). A further $12,800 was spent on interior and exterior painting. The roof of the main office building north wing was replaced at a cost of $65,800.

Drawings library maintenance and services

The department continued with organizing and updating the site and buildings drawings library, and provided services of issuing drawings to many in-house clients.

ELECTRONICS SERVICES

Overview

Electronic Services had a very full year as detailed in the following sections. The personnel in the group worked on virtually all projects and experiments on site and interacted with an estimated half of the site staff. We continue to be one of the most sought out groups with information on every aspect of electronics from ordering special cables, answering obscure software questions, designing specialized modules and answering just about every PC question. We also have senior personnel that have very valuable historical information on some of the original systems installed at TRIUMF.

Electronics Shop

The Electronics Shop continues to be a major "hub" of TRIUMF. All major and minor ongoing projects are reflected in our daily shop repairs and production. The following were assembled during the year: boards and cables for CERN, flow-switch controllers for ISAC, QSX modules for ISIS, and modules for Jefferson Lab. Cables were made for all groups on site: DRAGON, site communications, PET chemistry, controls, CHAOS, TWIST, β-NMR, beam lines, Osaka, TUDA, University of Guelph, TRINAT, ITE vacuum, Expt. 871, M20, 8π and TRIUMF Stores. The shop also handled a large variety of special, one of cables that experimenters required the day before. The TRIUMF library continues to have ongoing daily support from a member of this group.

Experimental and Target Support

This group spent 80% of its time on CERN contributions including assembly of the PFNs, switch tanks, and help in laying out and testing of bias boards. Cabling of the control system for PFN testing was also done. Assistance was also given to the TWIST experiment in acquisition cabling and the design and installation of a FASTBUS cooling interlock system which has already saved the system from overheating when an air-conditioner failed to restart after a power outage. ISAC was supported with design and installation of the ITE target and dump protection system.

Site Communications

The major effort in site communications was the upgrade to the faster 100 base-T Ethernet standard. These areas included the proton hall extension ground floor and mezzanine floor, TISOL platform, trailer P, service annex ground floor and second floor, ISIS, level 264, service annex extension ground floor and second floor, trailer M, remote handling building, Safety group office, M15 counting room, proton therapy, operations control room, and the Plant group building. All documentation for this work is posted on the TRIUMF Web site. The other major project this year was the planning, specifying, tendering contracts, and ordering of data communications for the new ISAC-II building. Ongoing work included repairs to the site communication system as required, as well as assisting numerous individuals with unique requests for equipment or services.

Technical Support

A large effort of Technical Support went to the Controls group in the design and construction of a new CAMAC based 32-channel 16-bit ADC module incorporating a digital signal processor as well as a CAMAC power and diagnostic module used to monitor the health of individual crates. Another special job for the Controls group was the construction of a replacement sub-assembly for an obsolete DAC on a CAMAC module. This is an ongoing area of concern as many repair parts are not available for some of the 20–30 year old modules on site. For TWIST, some small devices were built and considerable documentation was completed. Proton therapy has a very special PLC system with no backup, so a second fast shutter PLC interface box was constructed. LTNO came in with a request for a precision interval gate generator, stable to one part in four million over one hour. This required acquisition of a specialized oscillator along with the design of a new module.

High Level Software Support

The principal task during 2002 was the development of a control system for the CHAOS polarized proton target on the M11 beam line. All data acquisition and control functions were implemented using the EPICS toolkit and employed a PLC for vacuum control, CAMAC and GPIB for data acquisition, and a Java based acquisition system (JACQ) for data analysis. The system worked well but the beam line had a number of problems. In parallel with CHAOS was the mapping of the TWIST solenoid. The JACQ application was used for this and data was successfully collected using both NMR and hall probes moving within the solenoid cavity. Some supervision of a co-op student took place in association with this work. The proton irradiation facility positioning system was improved by using the JACQ application with a custom front end, co-developed with a co-op student.

Assistance was provided to two co-op students in the development of a PLC based system destined for ISAC. One for the ISAC target implantation system and the other for the 8π TIGRESS liquid nitrogen level controls. Further work was done for TIGRESS to specify an $X-Y$ table for detector calibration. The LTNO experiment required some continuing work for the data acquisition system. This included the implementation of three new instruments into the system and several modifications to existing components.

A complete overhaul of the Bl2A extraction probe control system was completed to improve reliability. The performance was immediately obvious after implementation, and the system has operated fairly reliably since then. The tank thermocouple system was re-written to improve operation. A new kinetics 3291 dataway display exerciser tool was written for controls hardware. TRIMAC application development is still ongoing using both Fortran and C. The C systems are a good option for small CAMAC based systems requiring some automation. Investigations were made into building a measurement system for the proposed KOPIO preradiator assembly for Brookhaven. Mechanical positioning systems that could cover over 2 m and allow positional accuracy of 50 μ were researched. Automated image analysis was investigated for fine measurements in two axes using equipment borrowed from PIF. A successful byproduct was the rescue of a PIF experimenter who had lost his computer and was able to collect data as a result of this work. Problems with the M15 separator power supplies resulted in a complete cleaning of all heads and reworking the cooling system. Further work has started to build a test assembly and repair some damaged components.

PC Support/Desktop Services

This year continued to be a busy year for the department. Although the 2001 task numbers are not available for comparison, a comparison to the year 2000 shows a 56% increase to 276 software related tasks, a 40% increase to 167 network related tasks, and a decrease of 32% for the 205 hardware related tasks performed. The decrease in hardware related tasks is presumably due to a greater adherence to the hardware standards defined by this department. These standards are primarily based on reliability and compatibility. With the implementation of a hardware tracking system, it can be seen that a majority of the new Windows based PCs are following these standards.

Several major tasks were completed. A third NetWare server called NW02 was purchased and set up to provide imaging services, Web access such as iFolder, iPrint, and a Web server. A new Desktop Services Web site was created to provide an organized and easy to use help desk resource for TRIUMF staff. An AutoCAD pool of licenses was created from existing stand alone licenses to provide many users access to this application. As of December 31, 30 users are accessing the 9 shared licenses. The PC backup server software was upgraded to allow greater compatibility with Windows 2000 and to make administration easier. The number of users on the NetWare service increased from 74 to 93. Our PC backup service is now serving 42 PCs, up from 26 PCs. The number of virus scan clients has increased to 229 from 167. There has been a noticeable increase in consultations with TRIUMF staff. It is estimated that PC service fielded 3000 consultations this year. These consisted of telephone calls, visits to our offices, and impromptu meetings in hallways with staff seeking advice on every computer topic imaginable.

Electronics Repair Shop – Nucleonics

Considerable time was spent repairing the electronic controls for some of the machines in the Machine Shop, including the electron beam welding machine and numerical readouts for the lathes. Also, repairing detector electronics for E787 at Brookhaven National Laboratory, and repairing and recalibrating high-voltage power supplies borrowed from Fermilab for use in the TWIST experiment at TRIUMF were significant tasks. In total, 282 electronic devices were serviced in some way, including: 40 monitors, 96 power supplies (including 12 NIM units, 10 CAMAC units, 65 high-voltage units, of which 32 were for TWIST, and 9 other units), 64 nucleonics modules (which included 56 NIM devices and 8 CAMAC devices), 24 front end pre-ampliers and amplifiers for E787, 18 pieces of test equipment, 7 printers, and 33 other assorted electronic devices which included 7 from the Machine Shop.

ELECTRONICS DEVELOPMENT

During this year the group's main effort continued in supporting the ISAC control system design and installation along with the data acquisition board (DAB) for CERN. One member of the group was assigned to the quality assurance task force, which has been charged with creating and implementing a QA program acceptable to the CNSC. Travis Howland joined the group as a junior technician.

ISAC Support

The group provided all the hardware installation, maintenance and upgrade support for the ISAC control system. An additional 40 CAN-bus modules for power supply control, and 35 ISAC standard VME modules were installed. CAN-bus code was completed to allow the remote integrator module to communicate with the ISAC control system. Two 4-channel modules were installed on the mass separator platform and the LEBT/yield station section. The ability to read currents of less than 1 pA has improved beam optimization. Optical isolation was added to two more modules and installed on the TUDA chamber.

The ISAC test stand and OLIS controls underwent a complete rebuild to bring the original installations up to the current ISAC control system configuration.

A modification to the CAN-bus controller transition modules in the DTL/HEBT section was made to provide a cleaner installation and easier maintenance.

A temperature measurement sensor was constructed and installed in the 8π shack, and incorporated into the EPICS alarm handler.

Maintenance activities included repair of malfunctioning components as well as development of test procedures for TRIUMF built devices.

Further development on the VME back plane tester was completed. A second linked module can now test the VME back plane for open and shorts automatically.

A variable current source module was designed and built to automate test procedures for the VQSX module.

CERN

Nine new modules of the latest revision (DABIII) were delivered to CERN in July. Embedded code was written to provide additional functions for orbit batch/bunch acquisition. Two members of the group went to CERN in mid-July to integrate and test the DAB with updated CERN WBTN mezzanine modules. The integration tests with a single DAB module were completed successfully using simulated beam position signals in the laboratory. Scheduled SPS beam tests with real-time data acquisitions using multiple DAB modules were postponed until September to allow time for the completion of SPS equipment installation. Preliminary design based on the new DAB specification was started. The new module will conform to the VME-64x standard.

Engineering Support

An independent PLC system (Modicon Momentum) for the ISAC mass separator high voltage lock-up area was designed and installed according to the Safety group's requirements specification. In addition, an EPICS user interface was implemented and integrated into the ISAC operations console.

For the modular radiation monitoring system the universal detector module design was updated. Ten modules were built, calibrated and shipped to INER in Taiwan.

A gamma radiation detector for PET radiochemistry was designed and built. A photodiode produces a small (fA) current, which is amplified and filtered, producing 10 mV per fA. During testing, the noise level was measured to be 30 fA RMS. Improvements to reduce the noise are being pursued.

Three more VICA harp readout modules were produced for the TRIUMF Diagnostics group.

The Magnet/Kickers group continued to receive support with engineering, design and prototyping of their chopper systems.

The group also provided technical advice to three co-op students with other groups.

Experiment Support

A VME based Gate Logic module was developed for the μSR group. Seven modules were constructed. A third VME frequency synthesizer module was built and delivered. Modifications were completed for enhanced performance of the μSR's $\pm$1 kV pulser that was built last year. Some simulation and prototype design was completed for KOPIO high voltage power supplies.

Secondary Channel Support

A failure of the obsolete programming unit for the M9 and M15 vacuum system PLCs precipitated integrating these systems into the ISAC BL2A PLC. The M9 system move was successfully completed. Work was started on the databases and code in preparation for moving the M15 vacuum system. This move, when completed in the spring shutdown, will allow the systems to be fully supported by the new EPICS based secondary channel control system. The addition of a JAW into the M13 beam line required the group to provide a mechanism to control the movement. A temporary controller was constructed so the JAW could be used during the fall beam time. The existing M13 controller will be expanded during the next shutdown, to include this functionality.

New Hardware Designs

Several new modules were designed and built:

- A VME ADC based on the VQSX was designed, built and tested. It incorporates 8 channels of 16-bit ADC and a single channel 16-bit DAC. Any of the input channels can be routed to the DAC output for diagnostic monitoring.
- An 8-channel 12-bit DAC mezzanine card was developed for the VME VQSX module. This card provides analogue monitoring for each of the 8-current inputs.
- An upgraded water flow module was designed, specifically for ISAC requirements. This design allows calibrated flow rates to be read by the ISAC control system via CAN-bus. The board layout has been completed. Installation for the ISAC rf water system is planned for spring, 2003.
- The prototype NMR module auto tuning and pulse detection functions were successfully tested. Full functionality testing continues in parallel with the final module design.
- An accelerometer circuit was constructed in an attempt to correlate readback noise with mechanical vibration. The device is currently being used by the TRIUMF Diagnostics group.

Infrastructure

The growth of the group required replacement of its WindowsNT based file server with a faster larger system. A new system running Linux was assembled utilizing hardware RAID disks. For data security and immediate recovery the files are mirrored on a second server in a different building. In addition, daily incremental backups are performed.