TRIUMF

ANNUAL REPORT
SCIENTIFIC ACTIVITIES
2000

ISSN 1492-417X

CANADA'S NATIONAL LABORATORY
FOR PARTICLE AND NUCLEAR PHYSICS

OPERATED AS A JOINT VENTURE

MEMBERS:

THE UNIVERSITY OF ALBERTA
THE UNIVERSITY OF BRITISH COLUMBIA
CARLETON UNIVERSITY
SIMON FRASER UNIVERSITY
THE UNIVERSITY OF VICTORIA

ASSOCIATE MEMBERS:

THE UNIVERSITY OF MANITOBA
L'UNIVERSITÉ DE MONTRÉAL
QUEEN'S UNIVERSITY
THE UNIVERSITY OF REGINA
THE UNIVERSITY OF TORONTO

UNDER A CONTRIBUTION FROM THE
NATIONAL RESEARCH COUNCIL OF CANADA

OCTOBER 2001

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.

EXPERIMENTAL FACILITIES

Proton Irradiation Facility

(E.W. Blackmore, TRIUMF)

There were two extended runs of the proton irradiation facility (PIF) in August and December, with both the BL2C and BL1B test areas available. In addition there were several shorter runs at lower energies on BL2C which were used for calibrations and to allow the University of Alberta group to check the single event upset rate in their FPGA devices for the ATLAS calorimeter readout.

For the August run the users were from DREO in Ottawa, DERA in the UK, and MD Robotics in Brampton. In addition to proton runs at energies from 20 to 500 MeV, an attempt was made to use the BL4B CHARGEX facility to provide a monoenergetic neutron beam at 280 MeV. Calibration of the neutron beam had been carried out previously using the SASP spectrometer to measure the neutron energy spectrum via the (n, p) reaction on liquid hydrogen. The single event upset cross section of a memory device was measured in the neutron beam and compared with protons of the same energy. The uncertainty in the low energy neutron tail precluded a definitive result and further studies are planned. In addition a biological dosimetry experiment was carried out in which samples of human blood were exposed to high energy protons and to spallation neutrons produced by stopping 500 MeV protons in a steel block.

In December a high intensity irradiation set-up was commissioned on BL1B to permit small devices to be exposed to fluences up to 10^{13} protons/cm^2 in a reasonable time. There is a similar test set-up on BL2C for energies of 110 MeV and below. This capability permitted a group from DREO to measure the light output and I-V characteristics of quantum well LEDs when irradiated with protons from 50 to 500 MeV with fluences from 10^{10} to 10^{13} protons/cm^2.

A poster describing the 20–500 MeV proton irradiation facility at TRIUMF was presented at NSREC 2000 in Reno. Several potential new users of the TRIUMF facility were identified. The next meeting of this conference on nuclear and space radiation effects will be held in Vancouver in July, 2001. There is considerable interest in the space effects community in comparing the single event effect cross sections for protons with those of higher LET heavy ions. At the request of MD Robotics, a calculation using LAHET and a simple Monte Carlo routine was made to determine the LET spectrum of heavy ion recoils produced by protons of 50–500 MeV interacting with silicon. The result can then be used to determine the LET level that proton testing reaches as a function of incident proton energy.

Proton Therapy Facility

(E.W. Blackmore, TRIUMF)

A total of 6 patients with ocular melanoma were treated during 2000, bringing the total number treated at TRIUMF to 60. As mentioned in last year's Annual Report, the reduced number of patients in the last couple of years is due to fewer operating months of the cyclotron and to some changes in the selection criteria. Radioactive plaque therapy is carried out by the same group and is the treatment of choice if feasible. A recent review of plaque therapy carried out at the British Columbia Cancer Agency has indicated extremely good results for the treatment of ocular melanoma, and with low toxicity. Where the location and size of the tumour preclude plaque therapy, proton therapy is used.

There were no significant changes made to the treatment equipment during the year. One of the Exradin T1 calibration ion chambers developed a loose cap and had to be replaced.

μSR User Facility

(S. Kreitzman, TRIUMF)

The μSR facility coordinated a very productive year for its users during this millennial year. 19 groups (9 of which are Canadian university based) took a total of 77 beam weeks, 6 of which were for β-NMR. The beam delivery schedules that allowed for this (historically) increased availability of high intensity beam time were TRIUMF's successful endeavour to allow its user community to recoup the beam time lost in the previous year due to unanticipated shutdowns.

The major facility developments which highlighted the year were:

- Successful inauguration of the β-NMR facility.
- Application for a new magnet for the high timing resolution/high field spectrometer.
- Redesign of Helios spectrometer and stand.
- Integration of new technical and software staff.

The following report outlines these and related developments more fully.

β-NMR

The maiden voyage of the (user facility supported) β-NMR experiment occurred during this year. This ISAC experiment boasted a huge array of new systems ranging from broad-band rf field coils, ultra-high vacuum systems and cryostat, to laser pumped ^{8}Li nuclear polarization. Remarkably, the very first data run when everything was finally set up (with a ^{8}Li production rate of about 10^8/sec) produced a huge resonance with signal/noise of about 50 in only 20 seconds of data-taking. It is clear from this data that β-NMR at TRIUMF can accumulate high quality data as quickly and efficiently as its more well established μSR big brother.

Spectrometers

Helios

Helios is a general purpose 6 T spectrometer used for transverse field (below 2 T) and longitudinal field (LF) studies. In this era of increasingly small samples, prompted by intense interest in high-T_c superconductors, the capability to precisely align samples and beam trajectories and counters is essential. To this end, a highly rigid and reproducible stand has been designed for the Helios magnet (see Fig. 111) so that beam, counter and sample geometries can be precisely matched without having to manually realign after an access event into the system.

OMNI′

The increased interest in studying LF relaxation in confined materials (i.e. those systems that require relatively thick walls, such as systems under pressure) has prompted us to begin a redesign of the OMNI′ spectrometer so that it will be ideally suited to this task. This redesign will again allow the rapid set up of a rigid and reproducible counter array, with integrated shielding and cryostat support mechanisms. The system is designed to easily accommodate the majority of experiments that we historically deal with on the M9B beam line so that experimental set-ups and changes proceed much more quickly and efficiently.

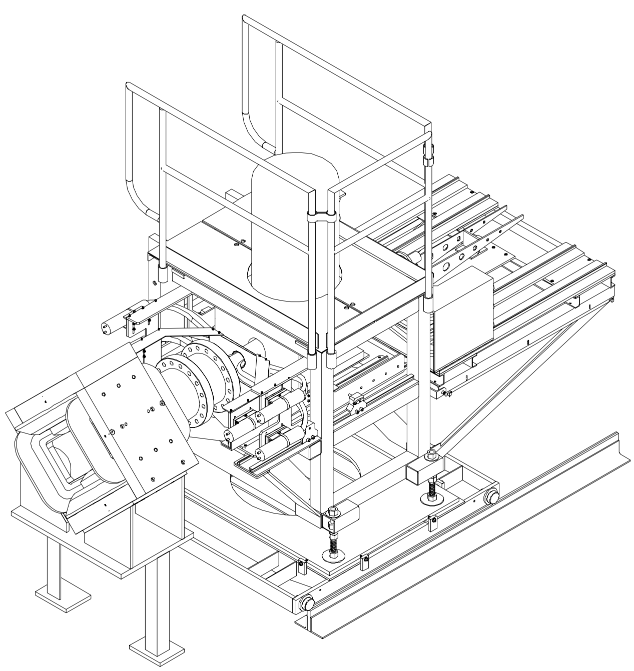

Fig. 111. The design for the new Helios stand provides a highly stable platform for superior alignment and reproducibility in the era of μSR on increasingly small samples.

It's HiTime for Belle

With the introduction of the world's only production μSR high field/high timing resolution (HTF/HTR) spectrometer over the last two years (our Belle spectrometer), not only has demand for experimental beam time on this rig burgeoned but users are also requesting experimental accuracy and precision that the Belle magnet simply cannot provide. Originally this magnet (utilized historically by Bell Labs) was loaned to us by Physikon Research to allow us to attempt building the HTF/HTR spectrometer. With technical aspects of the spectrometer (i.e. its timing resolution in high field) working well, the users have started to request magnetic field characteristics such as low drift (1 G/day) and 0.1 G homogeneity which the Belle magnet simply cannot provide. To this end a new magnet has been commissioned from American Magnetics that will exceed all the requirements that one can foreseeably require of an HTF/HTR spectrometer. This magnet's name will be HiTime and should be in service for the 2001 fall schedule.

Third generation low background inserts

Responding to user demand for effective means of carrying out clean μSR experiments on samples with sizes of the order of 1–2 mm in diameter, the facility has entered a development cycle for a new generation of low background inserts. These inserts utilize the experience gained with previous *in cryostat counter* low background systems and comprise an active collimator, muon counter, plus muon and positron vetoes; all within the cryostat in a very tight geometry. The sample is cold loadable and can be changed without system disassembly.

Software and facility documentation

Data analysis platform migration

The data analysis platform has largely been migrated to Linux based computers. All of the familiar tools, i.e. spect, fft, db, msrfit, will be available on the Linux cluster. Also, the μSR data archive has now moved to the μSR server which also provides the cpu power for the Web based portals below.

Web based data tools

Connecting to http://musr.triumf.ca/mud allows anyone to search, display and fft any data in our archive. The addition of interactive fitting is still in the works.

New look Web site

http://musr.triumf.ca will soon be officially opened as our new portal to the world.

Beam Lines

(C. Ballard, TRIUMF)

The Beam Lines group is part of the Science Division and is responsible for the installation, alignment and maintenance of the experimental facilities at TRIUMF. This year has seen the group evolve in three distinct directions. One avenue was to supply technical assistance to the existing experiments and secondary channels in the meson hall, and the other two projects were ISAC and CERN.

In ISAC, the end of 2000 saw the completion of the MEBT installation and the alignment of the DTL triplets and tanks – resulting in beam through the DTL. In parallel, the group assisted on the LEBT installation including the polarizer leading to the β-NMR platform. The next priorities were the β-NMR, 8π, DRAGON and TUDA experiments. The installation of the high voltage platform for the β-NMR experiment included the fence, interlocks and isolation transformer. The gas target was assembled for DRAGON, and the quadrupoles and bending magnets were installed in the HEBT, DRAGON and TUDA beam lines. The next major project was the assembly and alignment of DRAGON's electrostatic dipoles and installation of DRAGON's electrical, plumbing and vacuum services. The success in ISAC was, in part, achieved through the coordinated efforts of the Science Division, Cyclotron Division, and trades people with the assistance of three University of Victoria co-op students and three summer students.

In the meson hall, efforts were focused on maintenance and the preparations for the TWIST experiment in M13. The maintenance included an overhaul of the M9 separator, repairs to the M15 separator, M13 jaws, M9 beam blocker, and the TNF. The group also performed preventative maintenance on the water packages, vacuum systems and magnet interlocks. Included in the meson hall project was the ongoing technical assistance to the proton irradiation facility, proton therapy, and the experimental support in the proton hall.

The CERN Collaboration involved three technicians on two projects. The most significant of these was the beginning of the assembly of nine pulse forming network (PFN) tanks, which required the installation of a clean area with an overhead crane. This project will continue for the next five years. The other projects for CERN were the fabrication of the fast wire and fast blade scanners.

The Beam Lines group was also responsible for many of the alignment projects on site. There have been significant changes in the methods of alignment with the acquisition of the new total station which uses electronic distance measurement (EDM) and target recognition to download coordinates to a PC.

Cryogenic Targets

(C. Marshall, TRIUMF)

Ongoing experiments

Several scheduled experiments used liquid hydrogen or deuterium targets which had been built in previous years. Although only minor target improvements were undertaken, operations during 27 target-weeks of scheduled beam took up a large part of the group's efforts in 2000. Targets were in use on CHAOS (Expt. 778), parity (Expt. 761) and RMC (Expt. 864), with no extended down-times.

Design of new targets

Experiment 744: The liquid hydrogen target must operate inside the RMC detectors, allowing clean transmission of a pion beam. There must be a minimum of material along the sides of the target, where electrons of interest in the experiment exit from the interaction region. It is proposed to use a low-mass honeycomb material for the side walls. Testing of a prototype using this material has started. Entrance and exit windows will be of formed mylar.

Experiment 875: This experiment studies multiple scattering of muons in various materials, including liquid hydrogen. The liquid hydrogen target will be in the form of a cylinder with a horizontal axis, measuring 9 cm in diameter by 10 cm long, contained within a metre long evacuated scattering chamber. A conceptual design has been completed.

Computing Services

(C. Kost, TRIUMF)

Overview

Most of the approximately 800 networked devices at TRIUMF have been moved off the old FDDI token ring to the new gigabit backbone. Security concerns, hardware maintenance/upgrades, software management, and dealing with migration to a central mail system were all exacerbated by the rapid increase in the number of PC-based Linux systems. There is a strong need to minimize the number of Linux flavours and/or operating system versions in order to provide centralized software support and security. The contribution of our group to the GEANT4 collaboration continues to show benefits to all parties involved.

Modular approach to integration

Using a modular approach, our group has attempted to provide an integrated environment for the computing community. The main modules are now:

- a dual VAX-4100 VMS cluster to provide legacy support;
- public computing facilities for Linux;

- public computing facilities for Alphas running Compaq Tru64;
- a VALinux computer with DLT-8000 tape drive to provide daily site Linux/UNIX backup;
- a Linux computer with hardware RAIDed disk to provide a central mail facility;
- a Linux computer to act as the site Web server and common Linux/Tru64 software repository;
- a Linux computer to act as the site UNIX/Linux/SGI print server;
- a Windows NT computer to act as the print and file server for site PCs;
- a Windows NT computer to allow up to 15 X-sessions to run Windows applications;
- a Novell/Netware server to backup site Windows-based PCs;
- a Linux computer to provide centralized security logging.

Some of the advantages of using this modular approach were improved stability of each module, ease of management of each module, and decreased inter-dependency of the modules. A disadvantage was the increased hardware costs (albeit, hardware constitutes but a small fraction of the overall costs).

Hardware

Figure 112 shows the annual update for the growth in CPU power. The solid line shows the historical doubling every two years. Technology shifts have resulted in CPU power growth considerably larger than expected. The latest data for Pentium (i.e. Linux) now include a somewhat larger group of users than in the past, accounting for a larger than expected growth for the year 2000.

The most significant hardware change this year was the switchover from FDDI to gigabit Ethernet. Figure 113 illustrates how the 23 Nortel Networks Baystack 450-24T switches were strategically located around the site. The switchover of hundreds of network connected devices, from essentially

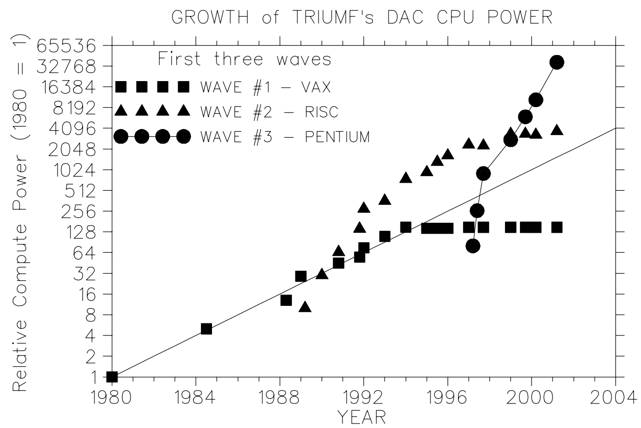

Fig. 112. Core computing growth.

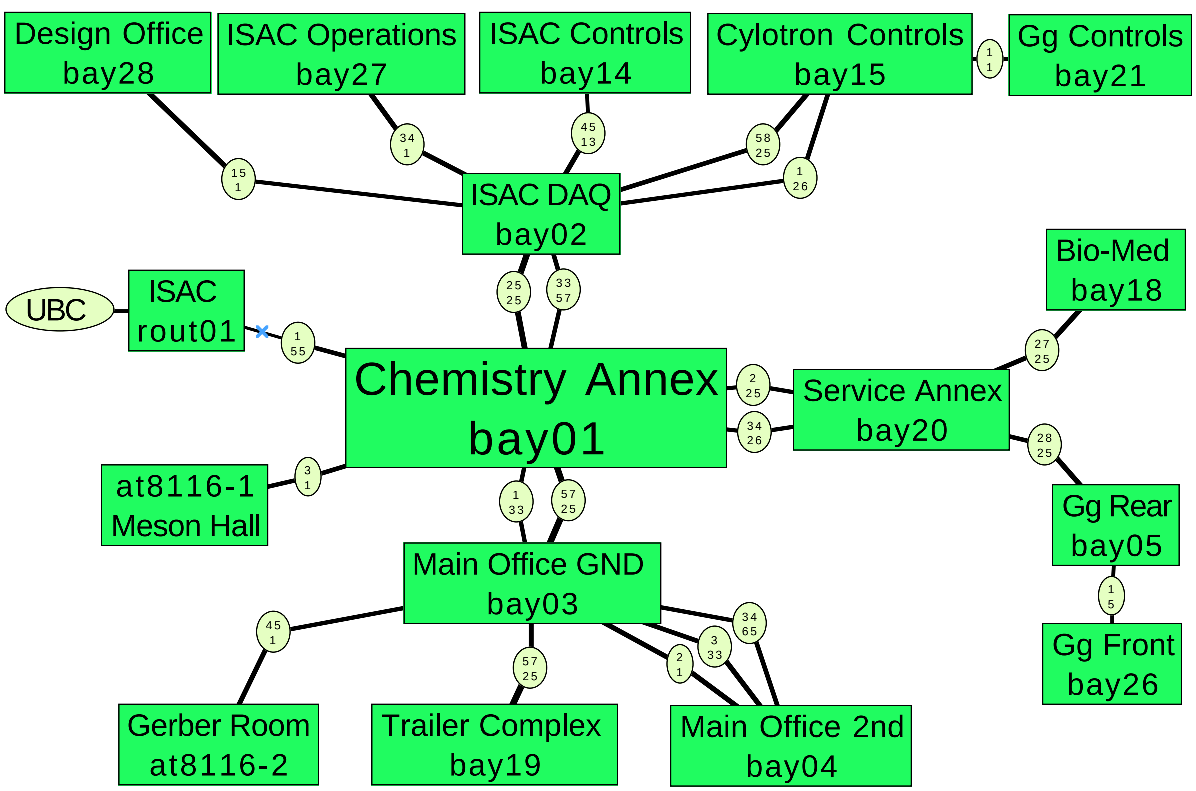

Fig. 113. Gigabit network.

10Base-T to 100Base-T connections, went very smoothly. Other significant hardware changes implemented by our group were:

- A much earlier upgrade, than was originally planned, of the RAID disks attached to our central mailer, trmail. Increases in the size of mail messages (as more of them include large attachments), as well as increased activity and diversity in the use of e-mail necessitated a tripling of the disk capacity from 18 to 54 Gbytes.
- A Dual PIII-800MHz public Linux facility was added to the existing Dual PII-450MHz, sharing both passwords and user home disk space.
- A Compaq Alpha Server DS10, running Tru64, with 768 Mb of RAM was added to allow compute intensive engineering calculations.
- Two network attached E-size inkjet printers, an HP2800CP for extremely complex graphics/drawings, and an HP500PS capable of 42 in. wide high resolution (1200×1200 dpi) colour graphics, were added to support printing poster presentations and engineering drawings.
- The Alpha based backup of UNIX systems has been replaced by a rack mountable PIII-650 VALinux machine using a single DLT-8000 tape drive and BRU software. A Web page allows users to determine when their files were last backed up.

Software developments

Web-mail and Netscape Roaming Access support were added to allow more flexibility for those accessing e-mail away from TRIUMF. Lightweight directory access protocol (LDAP) will be expanded early next year to include not only user names and e-mail addresses, but also information supplied by Human Resources on telephone and room numbers as well as placement in TRIUMF's organization chart. Users will shortly be able to upgrade their own database entries.

The two-body kinematics program Kin2Body was ported to C^{++} with an added graphical user interface (GUI). The interactive version of the beam transport program TRANSPORT, called INTRAN, was updated for Linux. The beam transport program REVMOC was updated for Tru64, Linux, VMS, and Windows9x.

GEANT4

As a member of the GEANT4 collaboration, our group continued its contribution to the Low Energy Physics, Testing and Quality Assurance, and Documentation working groups. The T & QA contribution involved various system-testing and diagnostic activities, and responsibility for the implementation of two new Web-based tools: LXR, a source code browser, and Tinderbox, an automated distributed system testing framework. These are described in more detail elsewhere in this report. TRIUMF presented a demonstration of Tinderbox at the annual GEANT4 workshop in October at Orsay, France.

Beam dynamics

A presentation on the current space charge techniques, used in the TRIUMF developed ACCSIM multi-particle tracking code, was given at KEK to collaborate on space-charge simulations. A KEK-written code was also used to study emittance growth and halo production due to non-linear space-charge resonances. Detailed comparisons made on similar runs with ACCSIM showed very close agreement between these two codes. ACCSIM was also applied to the intense-beam tracking studies of the KEK 12 GeV proton synchrotron. An intensity-doubling scheme has been proposed for this ring, which is used in the production of the KEK-to-SuperKamiokande neutrino beam.

A group member also contributed to the CERN/TRIUMF LHC collaboration in the development of an efficient and accurate treatment of image forces in space-charge simulations (reported in an EPAC 2000 paper), and the application of a fast-multipole technique, developed for ACCSIM, to study coherent beam-beam effects in the LHC. These tasks are reported in more detail in the CERN Collaboration chapter of this Annual Report.

In addition to use for KEK and CERN applications, the ACCSIM code continues to be in active use at other sites, including BNL and ORNL (for SNS accumulator ring studies), LANL (PSR studies), and Tsukuba University (Proton Therapy System).

To assist with neutrino factory studies, the synchrotron longitudinal dynamics code LONG1D was ported from DEC to IBM (AIX) use at CERN.

Physica

This popular general purpose data analysis/display program continues to evolve as bugs are fixed and new features are added:

- enhanced text match indexing in a string;
- improved binning;
- much faster input when error checking is not required;
- measures to avoid overwriting existing files;
- enhancements to the INTERP, GRAPH, and RESIZE commands.

A "bare-bones" version, written in C^{++}, is now undergoing testing on MS Windows. A few basic GUI forms and menus complement the command line interface.

Porting Physica to Alpha Linux has been problematic, but to our amazement if this FORTRAN program is compiled and linked non-shared under Tru64 Alpha the executable runs almost flawlessly on a Linux Alpha system! Only the non-essential "call system" hook fails to work. Enhancements to Physica are expected to continue in the future, especially in light of a pending agreement to "commercialize" this software. This will not impact the free access to the executable code for all member sites of TRIUMF.

WAN

Although local network bandwidth has increased dramatically, there is still a strong pent-up demand for increased throughput to remote Internet sites. The full duplex 100 Mbit fast Ethernet link to UBC remains extremely reliable. The UBC to BCNet link and beyond are still problematic.

WWW

Our group continues to provide limited support for TRIUMF's main WWW server as well as provide consultation and coordination of the many contributors to the contents of our Web site, particularly the ISAC Internal pages and the Proton Irradiation Facility Web pages.

Linux

Linux continues to increase its dominance at TRIUMF, as it has at most of the other high energy physics laboratories worldwide. A summary trip report (http://www.triumf.ca/hepix2000/trip_report.html) of the HEPNT/HEPiX Workshop at JLAB, October 30–November 2, has been put on the Web.

Redhat Linux continues to be the recommended standard at TRIUMF. Users can now subscribe to an automated daily update procedure (most of which involves security patches) for most systems running RH5.2 through RH7.0. Monitoring to a central security machine can also be enabled. Unfortunately, manpower constraints have meant that fewer than half of the Linux machines have subscribed so far.

Thin clients

After testing diskless UNIX-based PCs as X Window terminals, it was decided to instead use disk-based PCs running Redhat Linux 7.0 as X-terminal replacements. A pilot trade-in program for four X-terminals indicated that this would be a better solution since it would provide better stability than diskless systems, and the ability for the owner to more readily use the local cpu for number crunching. The effort to replace the limited (8-bit colour) and insecure X Window terminals will be accelerated in the coming years.

Security

Security "events" are on the increase at TRIUMF. To date they have not been serious. The use of security tools (e.g. openssh) is on the increase but much more still needs to be done. Traditionally TRIUMF has maintained a very open computing environment – an asset which will be difficult to give up. Increased monitoring of incoming traffic is taking place and there are plans to put a proper firewall in place next year. As well, the drive to improve the security of all local networked computers will continue as manpower allows.

Near future

- Replace Windows NT based Windows applications running on X Windows by a much faster dual-cpu Windows 2000 server.
- Wireless portals, with safety surveillance being the first to use this technology to improve efficiency and reduce manpower requirements.

Potpourri

- The dramatic decrease in cost of disk storage (≈\$10/Gbyte in 2000, which is a 1000 fold drop in just 11 years) is expected to continue at 50% every 12 months! We are seriously looking at an LTO (linear tape open) based stacker to address the resulting backup issue. Fortunately the recent site LAN upgrade to gigabit Ethernet will mitigate any network impact that would result from this large increase in backup traffic.
- Two HP9100C Digital Sender scanning units were purchased. Documents are scanned and the resulting colour PDF files can then be sent by e-mail or printed to a site printer.
- An XGA (1024×768) 1400 ANSI lumen Sony LCD projector was purchased, mainly for making PowerPoint or VHS video presentations in the auditorium.

Data Acquisition Systems

(R. Poutissou, TRIUMF)

Overview

The Data Acquisition group has continued to deploy MIDAS Linux data acquisition systems around the site. More functionality has been added to MIDAS software.

Four VAXstations were retired from active duty, two being replaced by PCs running MIDAS (parity and RMC experiments). Two more MIDAS systems were added to the detector facility. All VDACS data acquisition systems have been retired.

MIDAS software

This year the continuous development and improvement of the MIDAS software includes: a) Web-based run control flexibility such as manual trigger button, customized script button, log history button, history plot display button, slow control page hyperlink for variable modification; b) Front-end code: implementation of "Super Event" structure for dead time and disk space reduction, BOR/EOR event handling improvement; c) Extensive Web-based MIDAS documentation, http://midas.triumf.ca/docmidas/index.html; d) New application: "webpaw" providing a Web-based interface to display experiment specific PAW data. This package is actually not part of MIDAS but has been developed in conjunction with it.

Overall, MIDAS has been quite successful not only within TRIUMF but also around the world with over a dozen laboratories using it.

NOVA

The NOVA data analysis system continues to evolve to meet the needs of new TRIUMF experiments. Version 2.2 of the system was released in 2000. Enhancements in this release include the possibility of accessing the raw data directly as Floating Point or INTEGER*4 variables (in addition to the default INTEGER*2). The display package has been updated to support log plots, as well as the ability to sum adjacent channels (making it easier to view significant features in spectra with many channels / few counts per channel). Support has been included to access the event time supplied by MIDAS, which is critical for a number of ISAC experiments. The ability to repeat a command at regular intervals has been added, allowing an updating "live time" display to be implemented. A number of minor changes were made to the system to facilitate its use in a batch environment. NOVA has been fully integrated with the latest version (1.8.2) of MIDAS. Use of NOVA beyond TRIUMF continues to increase. NOVA has now been installed at Oak Ridge, Notre Dame and KVI.

ISAC systems

The ISAC experiments (i.e. Lifetime (GPS, GP2), TRINAT, LTNO, β-NMR) have been using the MIDAS DAQ package successfully as standard data acquisition. Most of the DAQ support group interventions were for small modifications of the acquisition software or hardware upgrades. Parasitic beam tests or detector tests required attention from the DAQ staff for set-up and support. Several new PCs have been deployed for off-line analysis and required some DAQ time for package installation. As a new ISAC experimental area, the TUDA shack required the installation of a DAQ.

β-NMR at ISAC

Custom hardware has been designed, implemented and successfully integrated in the β-NMR data acquisition system. It consists of a pulse programming generator (PPG) card and frequency synthesizer control (FSC) module (both in VME and fully programmable).

The simple TD-μSR software developed in 1999 was significantly upgraded, integrating the PPG and FSC modules.

β-NMR can acquire data in two modes.

- β-NMR Type 1: I-μSR data are acquired in a dead-timeless multichannel scaler and transferred to the host computer every beam cycle. The standard MIDAS data logger is used to save the data in this experiment. Banks of data read from CAMP need to be saved along with the histogram data. A front-end program was written to read data from the CAMP server CPU and send this data into the data stream. The data is also reduced and stored in a format compatible with standard μSR archives.
- β-NMR Type 2: TD-μSR data are acquired in a dead-timeless multichannel scaler and histogrammed in the front end. Data from each beam cycle are added. The standard data archiver MDARC was upgraded. Support for extra scalers was added. The on-line database was reorganized to separate MDARC's parameters from those needed by the front end. Thus MDARC becomes independent of the particular front-end program in use. This enables MDARC to be used for the future replacement of the μSR data acquisition systems in the meson hall.

μSR systems

A project was initiated to replace the μSR data acquisition systems, currently running under VMS on VAXstations, by a MIDAS data acquisition system running under Linux on a PC. This system will share many elements developed for the β-NMR experiment at ISAC.

The present run control database (RCDB) will be replaced by the MIDAS on-line database (ODB), and a user interface is needed that has the look and feel of the existing user interface. A co-op student has written a user interface in Tcl/Tk.

The ODB arrangement for μSR was planned, and a Tcl to C interface was produced to enable the Tcl code to access the ODB.

Expt. 614 slow controls

The slow controls system for Expt. 614 (TWIST) continues to evolve towards its final form. During 2000, it was decided that much of the slow controls/monitoring would be based on a programmable digital voltmeter from Hewlett-Packard. A MIDAS driver for this device has been written, and it is currently being used to monitor temperatures and pressures in a test set-up. Real time values of slow control variables monitored by this device are available from the MIDAS status page, and a time history of these variables is also available from a Tcl window accessible from this page.

RMC and parity

Both the RMC and the parity DAQ hardware were upgraded from VAX/VMS host CPUs to Linux PCs. The custom front end software was rewritten to function in a MIDAS environment with success.

Detector Facility

(R. Henderson, TRIUMF)

This year has been a very active one for the Detector Facility. The facility has been almost fully occupied with the Expt. 614 project. As expected, ATLAS modules are now in full production, so that group doesn't require a large amount of help from the facility. We continue to provide the services of Rich Maharaj to work full time on the ATLAS project. In addition, we continue to contribute significantly to the ISAC facility.

The Expt. 614 project is a sophisticated experiment which hopes to measure the Michel parameters to ten times the precision they are now known. TRIUMF members are playing a central role in this collaboration. Robert Henderson has designed the various detector modules and was largely responsible for the design of the complex "cradle" that will hold, align and service the nineteen modules in the experiment. Robert Openshaw has designed the complex gas system. Wayne Faszer has designed and built the high precision wire surveyor, and is now overseeing module assembly, testing and QC.

The larger mill in the scintillator shop was refitted as a 4-axis NC mill. Chris Stevens continues to work full time machining parts for Expt. 614, mostly G10 gas box and wire plane parts. With approximately 1.0 man-years of full time NC work performed so far, this mill refit has clearly saved the Expt. 614 project enormous machining costs. The curved scintillator pieces for $G\emptyset$ are also being machined on this NC mill.

Also in the scintillator shop, a variety of scintillators have been built, the biggest customer being the μSR group. Experiment 949 at BNL also requires several scintillator jobs. Two of these are small but highly complex assemblies. The first (B4) is nearing completion; the second, an active degrader, is part way through. This year fewer scintillators were required at TRIUMF and the shop committed to making a large number of scintillators for the $G\emptyset$ experiment at JLAB. This involves about 0.9 man-years of shop time over an 18 month period. After significant delays, the $G\emptyset$ group has finalized the design and these scintillators are now in production.

Robert Henderson and Dave Hutcheon designed a prototype ISAC beam monitor. A prototype of this monitor was built by Marielle Goyette in the facility. It uses 48 brass blades on a 1 mm pitch and was successfully tested in a low energy beam. Based on what we learnt from making this prototype, the design has been improved and a second prototype built. This unit will be mounted on the proper hardware for use in the ISAC beam line. Unless there are unforeseen problems, this project is essentially completed, except for passing on the construction techniques.

GEANT4

(P. Gumplinger, TRIUMF)

GEANT4 is a collection of software, arranged like a toolkit, and designed to accurately simulate the passage of particles through matter. Its capabilities include a powerful kernel, extensive physics models, the ability to visualize the detector, particle trajectories and hits, and the creation of a persistent detector description and persistent events. GEANT4 is written in C^{++} and exploits advanced software engineering techniques and object oriented technology to achieve transparency of a multitude of physics implementations. It replaces the successful and venerable GEANT3 package and is available for a variety of operating systems: flavours of UNIX, Linux, and Windows NT.

GEANT4 is also the name of a large international collaboration of scientists and software engineers whose mandate it is to perform production service, oversee the ongoing further development of the program, and provide user support. This collaboration superseded the R&D project, RD44, which produced the first public production version at the end of 1998. A Memorandum of Understanding (MoU) signed by all participating parties governs the formal collaboration. It is subject to tacit renewal every two years and sets out a collaboration structure defined by a Collaboration Board (CB), a Technical Steering Board (TSB) and several Working Groups. The MoU also specifies a key by which the collaboration's resources (money, manpower, expertise, and key roles and activities such as program librarian and documentation manager) are measured in Contribution Units (CU) and it further delineates how the boards are constituted depending on the CU count for each signatory. TRIUMF has a seat on both the Collaboration Board and the Technical Steering Board.

It is the CB's mandate to manage these resources and to monitor the agreed upon responsibilities among the affiliates. This body is also charged with the evaluation of proposals for the evolution of the MoU. The TSB, on the other hand, is the forum where technical matters like software engineering details and physics model implementation issues are discussed and decided, and where priority is given to user requests. Its primary tasks are the supervision of the production service and the user support, and to oversee ongoing further development of the program. The TSB is chaired by the spokesperson of the collaboration, who is appointed by and reports to the CB. The spokesperson is (re-)elected every two years by a simple majority of votes. This is also the modus operandi in general for making decisions in the two boards.

Every domain of the GEANT4 software, which corresponds to a releasable component (library), is individually managed by a working group of experts. In addition, there is a working group for each of the activities: testing and quality assurance, software management and documentation management. A release coordinator, who is selected by the TSB, heads each group. This clean overall problem decomposition makes the distributed software design and development possible in a worldwide collaboration. Every group can work in parallel, thus allowing an optimal utilization of manpower and expertise. As in previous years, TRIUMF collaborators participated in the activities of the electromagnetic physics implementation, testing and quality assurance, software management, and documentation management working groups.

In particular, one of our group took responsibility for implementing WWW-based tools to improve the system testing process. System testing involves repeated cycles of testing the GEANT4 code as a whole on all supported computing platforms and in many different usage configurations. This process is crucial to maintaining the integrity of the code during development and also to certifying the code prior to public releases.

We decided to set up a dedicated WWW server at TRIUMF to support the development of the Web-tools, which are heavily based on server-side Perl scripts. Our dual-processor Linux system was configured for this purpose and made publicly accessible via http://geant4www.triumf.ca/. Following this, the implementation of LXR (a source code browser) and Tinderbox (an automated testing and reporting tool) could proceed.

The LXR browser offers a powerful source code viewing and searching facility, with point-and-click navigation of the source tree, filename search, full-text indexing, and hyperlinked cross references for identifiers such as class names, method names, and variable names. The package was modified for the GEANT4 implementation by making some improvements to the user interface and the Web page designs, but the major customization was to support different releases and reference versions of the code through a common interface. The LXR facility is now fully operational and will be useful to G4 users, developers and testers.

Tinderbox constitutes the major part of the Web-tools development work. Originating in the Mozilla open source project, it comes to us in a rather minimal and ad hoc state, although the basic machinery consisting of test-case scripts, test-result processing, a test database, and a reporting facility, is very sound and is a good base on which to build the more diversified system-test framework we need for GEANT4. This year, Tinderbox was installed and brought to a prototype stage where complete operational GEANT4 test-cycles could be performed: (1) System tests launched on various client platforms at TRIUMF and at CERN; (2) Test progress and results (job logs) sent by the clients to the "Tinderbox server" (geant4www) at TRIUMF; (3) Messages interpreted by Tinderbox and stored in a tests database; (4) Job logs scanned and hyperlinked for compilation and link errors, run-time errors, and regression test results; (5) Tables of test results, with links to logs and developer/tester messages, displayed through any Web browser.

A presentation on Tinderbox and a live demonstration were given in October at the annual GEANT4 workshop in LAL-Orsay, and plans were made for further development to bring Tinderbox into full production. The main efforts in 2001 will be (1) to create comprehensive and portable client scripts, which must duplicate the functionality of the current rather complex and fragmented collection of scripts used in system testing, and (2) to increase the capacity of the on-line displays, which must accommodate GEANT4's large number of test platforms, test cases, and code configurations.

Collaboration highlights during the past year were the June release of GEANT4.2.0 and the December release of GEANT4.3.0. The GEANT4 collaborators are: J. Chuma, P. Gumplinger, F.W. Jones, C.J. Kost, TRIUMF; L.G. Greeniaus, Alberta.

Scientific Services

(M. Comyn, TRIUMF)

The Scientific Services group encompasses the Publications Office, Library, Information Office, and Conferences. Its activities during 2000 included: producing the 1999 Annual Report, the TRIUMF preprints, and a conference proceedings; implementing a new database system for the Library; updating the display material in the front lobby; and supporting eleven past, present and future conferences and workshops.

Publications Office

The TRIUMF Annual Report Scientific Activities has been truly electronic since 1998. Electronic files have been used throughout, from initial contributor submission, through editing, transmission via ZIP disk to the printer, and subsequent direct printing on a Xerox Docutech system. The same files are used for the WWW versions of the report which are available at http://www.triumf.ca/annrep in both Portable Document Format and PostScript file formats. Unlike the monochrome paper version, the electronic versions allow those figures which were submitted in colour to be both viewed and printed in colour. The WWW version of the 1999 report was available to readers four weeks before the printed version. During 2000, over 400 people accessed the 1999 Annual Report via the WWW. The Annual Report mailing list has been reduced and the trend is expected to continue as people become more accustomed to accessing the information over the WWW. This will result in less copies having to be printed, with subsequent cost savings.

In an attempt to aid and encourage authors to submit Annual Report contributions in the correct format, the instructions available on the WWW were condensed and simplified. The $\LaTeX\,2_\varepsilon$ skeleton file was upgraded to introduce new features, and the instructions document which all authors should consult was expanded to include details of these new features, plus additional information on the correct production of Encapsulated PostScript files for the figures.

Illegal code embedded in Encapsulated PostScript files continues to be a major problem in electronic publishing. Some software packages, such as the TRIUMF graphics routines, fully conform to the Encapsulated PostScript specifications, whereas many do not. In order to alert authors to problems encountered with files they submitted the previous year, and in an attempt to prevent similar problems recurring, a post mortem of the 180 figures in the 1999 Annual Report was produced and included on the Web site to supplement that for the 170 figures in the 1998 Annual Report. This analysis and explanation of solutions is viewed as an ongoing project which will evolve as new procedures are devised and software packages become available for editing bad PostScript code. Superior TRIUMF scientific publications should result. See http://www.triumf.ca/annrep/figures.html for details. These developments were presented to the Joint Accelerator Conference Website (JACoW) committee during the European Particle Accelerator Conference (EPAC 2000), which was held in Vienna in June, and used during the processing of the contributions to the electronic proceedings.

Final work on the camera-ready manuscripts for the proceedings of the Third International Conference on Isotopes (3ICI), held in September 1999, was completed early in the year, followed by extensive efforts to assemble and check the various sections included at the beginning and end of the proceedings. Frequent liaison with the publisher, World Scientific Publishing in Singapore, was necessary before ultimate printing and distribution to the delegates late in the year.

TRIUMF preprints are now only produced electronically, and immediately posted on the WWW at http://www.triumf.ca/publications/home.html to allow rapid dissemination of the publications. This has replaced the traditional distribution of paper copies by mail, resulting in significant cost and labour savings.

Library

The Library budget was increased in 2000 to compensate for rising journal subscription costs and unfavourable exchange rates for 2001 renewals, thereby maintaining the list of journals which have been acquired since the last cutbacks in 1998. However, the journal subscription budget and electronic access alternatives are constantly under review.

The Library made a modest number of book purchases in 2000, but continues to rely on donations for most of its acquisitions.

A new Oracle database system was fully implemented during the year. It allows accurate tracking of the journal subscription acquisitions and hence aids subsequent timely requests to publishers for any missing volumes. It also identifies any volumes which have been illegally removed from the Library, prompting requests for their return during the annual spring bookbinding exercise. UBC Library catalogue records for all TRIUMF Library books acquired since 1970 were downloaded into the database. Now all books loaned from the TRIUMF Library are entered in the database and automatic e-mails are sent to borrowers who fail to return a book after a month, followed by weekly reminders. This system has proved to be extremely successful at ensuring the prompt return of books, with the added advantage that several borrowers have also returned books which have been out for extended periods. Records for books acquired before 1970 have to be entered manually whenever they are first loaned, and all new acquisitions have to be entered. Outstanding loan reports can be generated easily.

The Library operates on a self-serve basis and manages with minimal support for day-to-day operations.

Information Office

Both Information Office and Conference personnel now reside in the Information Office located adjacent to the lobby. For three quarters of the year the functions were combined during an extended leave of absence.

The Information Office coordinated tours for over 1445 people during 2000. The general public tours were conducted by a summer student during the June to August period when tours were offered twice a day. Throughout the remainder of the year for the twice weekly general public tours, and for the many prearranged tours given to high school students and others, a small group of dedicated TRIUMF staff acted as tour guides.

During the year several new display panels were produced as part of an effort to gradually redesign the layout of the lobby and replace the existing public relations materials.

The TRIUMF Welcome Page, which is accessible directly at http://www.triumf.ca/welcome or via the TRIUMF WWW Home Page, continues to receive over 5,000 visits each year. The series of WWW pages were developed by two co-op students. They are intended to provide an overview of TRIUMF in a format understandable to the general public. The virtual tour of TRIUMF allows people to "visit" from anywhere in the world via the WWW, or to gain a good introduction before coming to TRIUMF for a real tour. The latter is particularly intended for students using TRIUMF and its science as part of school projects. The Information Office responds to any questions posed by visitors to the site. Some of the pages were updated during the year.

Various TRIUMF images found on the WWW pages are in demand for use in text books and on other Web pages. The classic shot of the interior of the cyclotron, taken by G. Roy, has featured as the picture of the week on the Web site Particle Physics Research in the UK, and was the inaugural picture of the week on the Physics Central Web site hosted by the American Physical Society.

A Sony VPL-PX20 LCD data projector was purchased for multimedia presentations in the Auditorium and other venues. The 1400 ANSI lumen device with XGA 1024×768 pixel resolution has become increasingly popular with speakers giving seminars using MS PowerPoint, Star Office, and other applications.

Support was provided to the TRIUMF Users' Group throughout the year by the TUEC Liaison Officer.

Conferences

During 2000 support was provided for the following conferences and workshops.

- Muon Source Mini-Workshop, TRIUMF, March 24–25 (40 delegates).
- Astbury Symposium, TRIUMF, April 15–16 (120 delegates).
- European Particle Accelerator Conference (EPAC 2000), Vienna, June 26–30.
- Summer Nuclear Institute at TRIUMF (SNIT 2000), TRIUMF, July 10–21 (25 delegates).
- Fourth International Symposium on Radiohalogens (4ISR), Whistler, September 9–14 (130 delegates).
- ISAC Laser Ion Source Workshop (ILISWS), TRIUMF, December 4–5 (30 delegates).
- TRIUMF Users' Group Annual General Meeting, TRIUMF, December 6–7 (60 delegates).

In addition, preparations were made for the following future conferences and workshops.

- 38th Western Regional Nuclear and Particle Physics Conference (WRNPPC'01), Chateau Lake Louise, Alberta, February 15–18, 2001.
- Particle Accelerator Conference (PAC2001), Chicago, June 18–22, 2001.
- 14th International Conference on Electromagnetic Isotope Separators and Techniques Related to Their Applications (EMIS XIV), Victoria, May 6–10, 2002.

Sudbury Neutrino Observatory
(R. Helmer, TRIUMF)

The underwater connectors used in SNO continue to operate satisfactorily in the regassed water. The rate of loss of tubes overall in the detector is about 0.6% per year; approximately half of this loss is attributable to the connector.

Simple studies carried out in a vacuum on the prototype connector fabricated last year indicated that it was subject to breakdown at a considerably higher voltage than the typical existing connectors. The improvement is mostly attributable to an increase in the distance between ground and the point where breakdown is initiated. In the connector presently in use, breakdown begins on the female side at the point where the pin enters the receptacle, then proceeds along insulator surfaces to ground on the male side. The total distance is 0.130 in. In the new design the connector was made re-entrant, eliminating the possibility of breakdown to ground on the male side and thereby forcing a longer breakdown path (0.250 in.) to ground on the female side.

This year further improvements were made by eliminating all gaps inside the connector and by increasing the distance of a possible breakdown path along insulator surfaces from the central conductor to ground on the male side at the cable entry point. The distance has been increased to 0.326 in. from 0.235 in. Six prototypes of this new design were fabricated and tests in vacuum indicated that breakdown occurs between 2900 V and 3900 V, compared with typical breakdown voltages of between 1600 and 2500 V in the connector presently in use. The highest operating voltage in SNO is 2500 V; hence it would be expected that fewer connectors of the new design would be subject to breakdown. Some further tests in vacuum are planned to investigate whether application of a dielectric grease provides any further protection. Long term tests in degassed water will then commence as it seems unlikely that the goal of achieving a breakdown voltage of 6 kV, suggested by the SNO External Advisory Committee on Connectors, can be reached without a redesign of the entire connector.

During the year it became apparent that the effort to produce a source of ^{8}Li could benefit from some support from TRIUMF. This source is needed primarily to check on the efficiency of algorithms designed to remove non-physics events from the data stream, but it has other potential uses as well. The beta-decay of ^{8}Li is the mirror of the decay of ^{8}B, the source of neutrinos from the sun which are being detected with SNO. ^{8}Li nuclei are produced via (n, α) reactions on ^{11}B using a commercial DT neutron generator located in a pit 70 m from the SNO detector. From there the radionuclei are transported in a helium gas stream to a decay chamber located in the detector. Alphas from the breakup of the daughter nucleus, ^{8}Be, are coincident with the betas and are used to tag the decay by detection of the scintillation light produced as the alphas slow down in the helium gas. Problems had been encountered in transporting the ^{8}Li over the long distance in a narrow capillary (the lifetime of ^{8}Li is 0.84 s) and in detecting the alpha scintillation light. Drawing on expertise gained from gas jet systems used in the early days of TRIUMF, the first problem was solved by increasing the capillary diameter. This in turn led to problems in source deployment, since the capillary no longer fit on the standard SNO deployment system. Some of the equipment used for deployment was therefore redesigned and fabricated at TRIUMF. The second problem was solved by painting the inside of the decay chamber with a coating of reflective paint, and light collection was further improved by coating the paint with a wavelength shifter. The source was successfully deployed in December.

Work on the scintillation light source mentioned in last year's report was put on hold during development of the ^{8}Li source. It is anticipated that the scintillation source will be completed in the coming year. An effort to redesign the ^{8}Li source to make it more suitable for testing reconstruction algorithms and providing an energy calibration point, and possibly for providing a comparison spectrum to that measured with the ^{8}B neutrinos, is also under way at TRIUMF.

Experiment 715 Off-Line;
Precision Optical Pumping
(S. Gu, UBC; J.A. Behr, TRIUMF)

In Expt. 715's (TRINAT's) off-line lab, laser trapping and cooling technology is used to polarize atoms, and hence nuclei, of the stable isotope ^{41}K, with the intent to apply the same techniques on-line to radioactive ^{37}K, which has almost identical hyperfine structure. One goal is to measure the extent to which parity is violated in the weak interaction. Wu at Columbia in 1957 first discovered parity violation in nuclear beta decay, using a dilution refrigerator to polarize the nuclei. The trapping technologies promise a major improvement: the ability to achieve high polarization and, more importantly, to measure that polarization with atomic physics probes independent of the nuclear decays.

Our recent progress has been to achieve $\geq 90\%$ nuclear polarization of ^{41}K. We start with an ordinary MOT and turn off the trap beams for 1 ms, while turning on circularly polarized light resonant with the D_1 ($S_{1/2}$ to $P_{1/2}$) transition. Absorption of this light increases the atomic angular momentum; together with random spontaneous emission, the result is a biased random walk which "optically pumps" the atoms to the maximum angular momentum $\mathrm{F} = 2$ $\mathrm{M_F} = 2$ state. In this state, both the nucleus and the atomic angular momentum are fully polarized.

The **B** field must be weak (to avoid decoupling the atomic and nuclear angular momentum) and pointed in the direction of the optical pumping light, to avoid spoiling the quantization axis. Eventually, we will turn off the MOT's quadrupole **B** field. In this first test, we left the quadrupole field on, but attenuated the retroreflected beams in the horizontal plane. The trapped atom cloud's equilibrium position then moved to finite **B** field in the horizontal plane, directed along the optical pumping axis. Then an additional uniform **B** field of 2 G was applied along that axis to move the atoms back to the original MOT centre.

If the light is completely circularly polarized and the atoms are completely polarized, the absorption of the D_1 light vanishes, because the $S_{1/2}$ and $P_{1/2}$ states have the same total angular momentum, so the atoms cannot absorb more angular momentum. The D_1 fluorescence was monitored with a CCD camera with a 1 nm FWHM interference filter to block the D_2 trap light. The D_1 light is tuned $\approx$ one linewidth to the red of resonance to minimize heating of the atoms.

So the polarizing and observing process was:

1) Leave trapping quadrupole **B** field on all the time.
2) Trap atoms with unbalanced trapping laser beams in a non-zero **B** field parallel to the D_1 light.
3) Turn off the trap laser beams for 1 ms.

4) At the same time, turn on D_1 laser and leave it on.
5) Turn off D_1 laser and restore the trap laser beams for 1 ms to retrap the atoms.
6) Go to 3 and repeat.

The time-averaged D_1 fluorescence is shown in Fig. 114 as a function of the polarization of the light as it is varied smoothly from circular to linear and back to circular by a liquid crystal variable retarder. The 5:1 fluorescence ratio between linear and circular polarized light, in a simple estimate where the main contaminant is F = 2 M_F = 1, implies that ≈92% nuclear polarization is achieved. The main depolarization process is believed to be the Larmor precession of the atoms in the MOT quadrupole field, which will eventually be turned off.

We implemented a similar scheme on the radioactive ^{37}K, and a test run achieved an average 70% polarization (90% in one direction and 40% in the other), as measured by the nuclear decay products (see the Expt. 715 report in the Nuclear and Atomic Physics section of this Annual Report).

Plans for the next year include: improving the polarization; fully probing the population of all magnetic sublevels (by stimulated Raman scattering followed by resonant fluorescence probing); beginning development of a circularly polarized dipole force trap [Korwin *et al.*, Phys. Rev. Lett. **83**, 1311 (1999)] which can trap the fully polarized sublevel with minimal dependence on circularly polarized light quality. Together with nuclear detector and vacuum chamber development, the goal is to begin parity violation measurements with radioactives in spring, 2002.

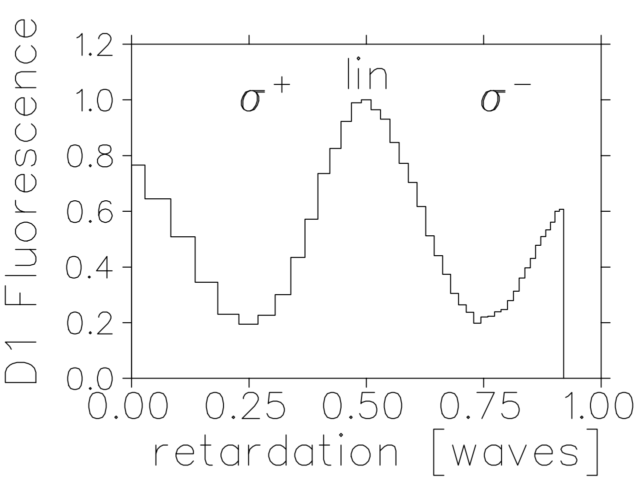

Fig. 114. D_1 fluorescence as a function of optical pumping beam polarization, showing that ^{41}K atoms are polarized. The polarization of the D_1 laser changes continuously from σ^- ($\lambda/4$ retardation) to σ^+ ($3\lambda/4$ retardation). With σ^- (σ^+) light, most of the atoms are sent to the F = 2, M_F = –2 (2) dark state, so that less fluorescence is observed. Figure 114 allows us to estimate that the polarization is ≅ 90% with σ^- (σ^+) D_1 laser light.

β-Detected Nuclear Magnetic Resonance at ISAC

(G.D. Morris, TRIUMF; R.F. Kiefl, TRIUMF/CIAR/UBC)

We are developing a beta-detected nuclear magnetic resonance (β-NMR) facility for studying materials and phenomena of interest in condensed matter physics. The initial spectrometer, designed for experiments in high longitudinal magnetic field, is virtually complete. Development of DAQ software to enable various experiments to be performed continues as we begin the experimental program.

Introduction

Nuclear magnetic resonance is a powerful experimental technique that yields information about the electronic, chemical and magnetic environment and dynamics present in materials. In the nuclear-detected techniques of β-NMR and μSR, radioactive probes are implanted and information about the local environment is revealed through the anisotropic distribution of the outgoing decay products. Specific and often unique features of these various resonance techniques make each well suited to certain experiments. β-NMR at ISAC is being developed to take advantage of the high flux of low energy spin polarized radioisotopes, particulary for experiments on ultra-thin samples over a wide range of magnetic fields and temperatures.

The scientific motivation as well as the layout and functions of the polarizer and high field spectrometer have been described in detail previously [Kiefl *et al.*, Physica **B289-290**, 640 (2000); last year's Annual Report, p.116].

Polarization

A key milestone achieved this past year has been the polarization of ^{8}Li atoms with an in-flight optical pumping technique. The largest polarization achieved thus far has been about 40%. However, the installation of a ring laser in 2001 is expected to result in a larger and more stable nuclear polarization. Developments in the polarizer section are described in detail elsewhere in this Annual Report by C.D.P. Levy *et al.*

Beam spot imaging

In order to precisely focus and steer the radioactive ion beam spot onto small samples, we have developed a CCD camera system to image the light produced when the ion beam is stopped in a piece of scintillator at the sample position. This system allows one to make adjustments to the electrostatic optical elements which define the position and shape of the beam spot in nearly real time.

This system is based on a 16-bit monochrome CCD camera (model MX516, manufactured by Starlight Xpress, UK) incorporating a cooled, low-noise CCD sensor which allows long exposures to be made. A 50 mm f 1.4 lens provides a narrow 7° field of view on the 500 × 290 pixel CCD. Peak sensitivity of the CCD occurs at 500–550 nm, close to the emission wavelength of several types of plastic and inorganic (UHV compatible) scintillation detectors.

The camera is mounted outside the UHV chamber but views the sample face almost along the beam axis through a UHV viewport and via a first surface mirror inside the UHV chamber which provides an approximately 90° bend in the optical path. The mirror is mounted on a hinge so it may be moved into position in front of the backward counter, slightly offset from the incoming ion beam.

For each ^{8}Li ion, energy is deposited in the scintillator in three ways. The initial beam energy is the smallest contribution, and the outgoing minimum-ionizing betas contribute about 100 keV on average. Most of the light will be generated by two very short-ranged α particles produced in the decay of an excited state of ^{8}Be, contributing about 1.6 MeV. Thus, the source of light within the scintillator is well correlated with the spatial distribution of implanted ions.

Exposures of about 30 s are sufficient to record the ^{8}Li beam spot with an ion flux of $\approx 10^7$ s^{-1} incident on a 0.25 mm thick Bicron BC412 plastic scintillator.

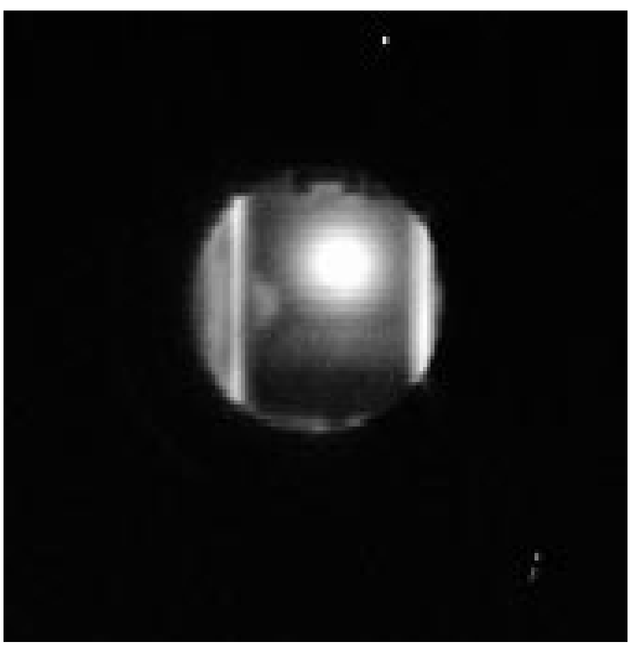

Fig. 115. An image of a slightly off-centre beam spot of ^{8}Li landing on an 8 mm wide piece of Bicron BC412 scintillator. Contrast has been adjusted to reveal the edges (bright vertical lines) of the scintillator and some of the cryostat parts; the FWHM of the spot is about 2 mm.

An example of the image of the beam spot is shown in Fig. 115. With longer exposures it is also possible to image the light produced by 100 nA beams of *stable* ions obtained from an off-line ion source.

Low energy implantation

Since the atoms in the ISAC production targets are initially thermal, they are accelerated through a potential difference of 30 kV as they are injected into the beam line which transports them to an experiment. Such a low energy allows the use of electrostatic optics in the beam line and also makes it possible to vary the implantation energy by biasing the sample to a high voltage. The design of the spectrometer takes advantage of this to enable very low implantation energies and consequently very shallow implantation depths. The entire spectrometer including the superconducting solenoid, cryostat and all the electronics are mounted on a high voltage platform so that the ion energy at the sample surface may be varied from about 1 to 90 keV. The resulting mean implantation depth ranges from about 50–3000 Å. Conventional NMR does not have sufficient sensitivity to detect a signal from the small number of atoms in such a thin layer, especially in weak magnetic fields where the low Larmor frequency would result in a very small signal in an inductive pickup coil. Experiment 897 will use this low energy and low field capability to directly probe the magnetic field just within the sample surface to make an absolute determination of the London penetration depth in superconductors in the Meissner state. Analogous μSR experiments have been performed with low energy muons (LEM) at the Paul Scherrer Institute [Jackson *et al.*, Phys. Rev. Lett. **84**, 4958 (2000)], however, the muon event rates remain at least 4 to 5 orders of magnitude lower than rates we have demonstrated at ISAC. This year, "soft landing" of ^{8}Li has been demonstrated down to 5 keV and should proceed to lower energies as tunes are developed. A long-awaited UHV-compatible replacement for the existing superconducting magnet in the high field spectrometer will be installed early in 2001. With the bakeable magnet, true UHV conditions will be reached so that low temperature experiments can be performed with kinetic energies down to about 1 keV. The electrode assembly which shapes the deceleration potential is presently being rebuilt in a more robust and more precisely aligned assembly.

RF control and DAQ

All of the electronics required to generate precise timing signals simultaneously with amplitude- and frequency-modulated rf power are now installed. A great deal of progress has been made in the software which configures and controls various types of experiments in real time.

Unlike conventional NMR, the nuclear-detected NMR techniques do not require a tuned high-Q rf coil for detecting the NMR signal. This allows the use of a broadband coil to generate the rf magnetic field and consequently one can sweep the rf frequency over a wide range – 0–40 MHz in the present design – without any need to change the coil. With appropriate modulation of the rf power, it should be possible to irradiate with several frequencies simultaneously.

Figure 116 shows the first resonance observed with the spectrometer in which ^{8}Li was stopped in a Pd foil in a magnetic field of 3 T at room temperature. During this run the beam was implanted continuously while the rf frequency was repeatedly ramped from 18.93 to 18.99 MHz in 100 Hz steps every 4 ms. Depolarization of the implanted spins occurs when the rf frequency reaches the Larmor frequency, so the resonance reflects the distribution of local magnetic field at the site of the ions. After the rf has swept over the resonance the decay asymmetry recovers as the unpolarized population of spins is gradually replaced with new, polarized ions. This mode is useful for quickly searching a range of frequencies in order to locate resonances. The width of the line in Pd was found to be about 2 kHz.

Another DAQ mode makes use of the ability to pulse the incoming beam with an electrostatic kicker and control the rf frequency and power with a pulse programmer, rf synthesizer and arbitrary function generator. In Fig. 117 the flat line was obtained with the beam polarization off, yielding a baseline which is very useful for fitting a relaxation function. The top curve shows the beta decay asymmetry in the absence of any rf power, in which the (Korringa) relaxation is known to be caused by the interaction with conduction electrons in the metal. When rf power at the Larmor frequency is applied after the beam pulse, and kept on to

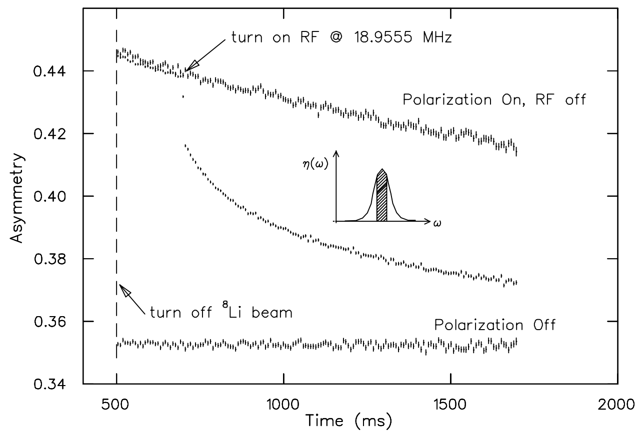

Fig. 117. Bottom curve: beta decay asymmetry without beam polarization; top: exponential spin relaxation without rf; centre: resonant depolarizaton with rf applied just after the ^{8}Li beam was switched off.

the end of the histogram, a portion of the polarization is quickly destroyed. It appears that continuous rf causes depolarization, but only of those nuclei close to the centre of the resonance line. The remaining nuclei in the wings come into resonance more slowly, probably as those ions diffuse to sites where they are subject to smaller dipolar fields.

The ability to manipulate spins with sequences of complex rf pulses is essential to many planned NMR experiments. In Fig. 118 we show a sharp step in the back-front asymmetry when a short, amplitude-modulated rf pulse is applied on resonance after the beam was shut off. The two spectra shown – with longitudinal polarization in each orientation along the z-axis – were taken by alternating the handedness of

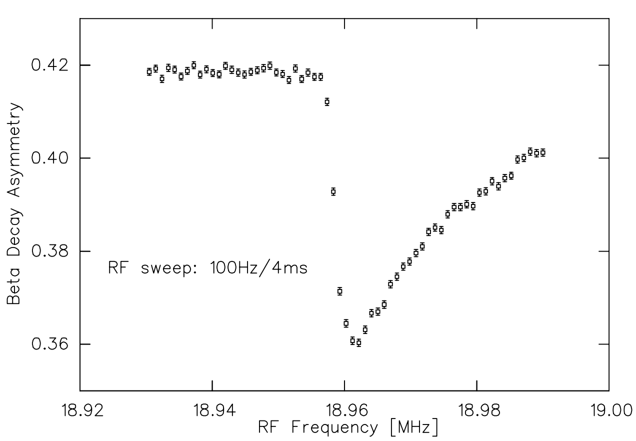

Fig. 116. First observation of resonant depolarization of ^{8}Li at ISAC. In this run the decay asymmetry was recorded while the rf frequency was rapidly swept over the resonance in a constant magnetic field of 3 T.

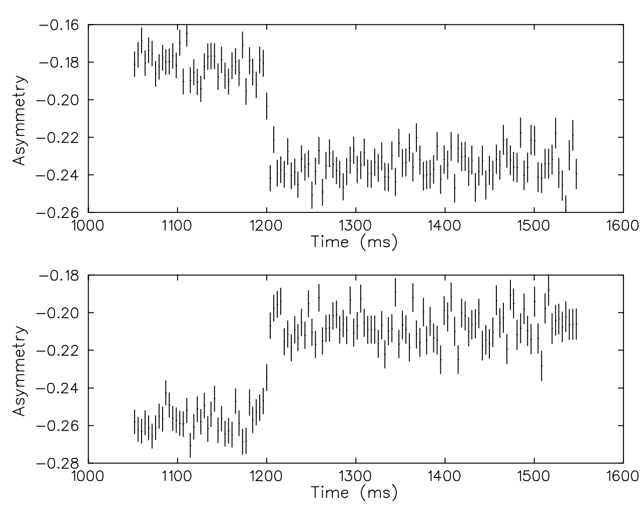

Fig. 118. Examples of time-differential spectra in which a short rf pulse was applied after the end of a pulse of beam. The step in decay asymmetry is due to precession of the spins in the rf magnetic field. Both orientations of initial polarization were acquired in the same run.

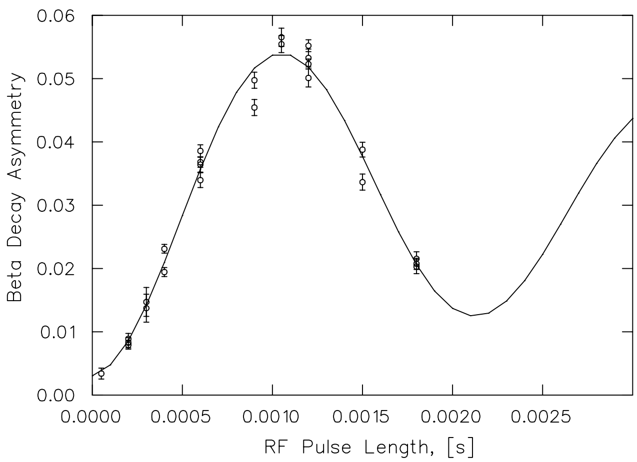

Fig. 119. Change in back-front asymmetry (the amplitude of the step in Fig. 118) as a function of rf pulse length. Asymmetry oscillates about the baseline, indicating that spins are being rotated coherently by the rf magnetic field.

the circularly polarized laser light throughout the run while routing events to the corresponding histograms. Plotting the amplitude of the resulting step in asymmetry as a function of rf pulse length (see Fig. 119), we see that the projection of the polarization along the z-axis follows a cosine dependence; spins are being flipped through 180° with a pulse of about 1 ms duration.

In summary, the first β-NMR spectrometer is virtually complete. We are currently working to optimize the polarization so that the experimental program can be carried out as efficiently as possible. Many features of the DAQ and control system are now working and more are being added. We are about to begin the first experiments on semiconductors and superconductors.

Nuclear Astrophysics with DRAGON at ISAC

(J.M. D'Auria, SFU)

Overview

The TRIUMF-ISAC facility will produce high-intensity radioactive accelerated beams of energies from 0.15 to 1.5 MeV/u and with A<31. An essential part of the experimental program with such beams is to measure the absolute rates (20%) of radiative capture reactions in which the heavy reactant is unstable and short-lived. The DRAGON facility will be used to achieve such measurements utilizing inverse kinematics, in which the beam is the heavy, radioactive nuclide, and the target is hydrogen or helium (gas). Table XVI indicates (not in order of priority) some of the reactions that are planned for study; the first reaction will be ^{21}Na$(p,\gamma)^{22}$Mg.

Table XVI. Reactions of interest (inverse kinematics/DRAGON facility).

^{13}N$(p,\gamma)^{14}$O	E805	Hot CNO cycle
^{15}O$(\alpha,\gamma)^{19}$Ne	E813	Hot CNO cycle/breakout
^{17}F$(\alpha,\gamma)^{18}$Ne		Hot CNO cycle
^{19}Ne$(p,\gamma)^{20}$Na	E813	Hot CNO cycle/breakout
^{20}Na$(p,\gamma)^{21}$Mg	E908	rp process pathway
^{21}Na$(p,\gamma)^{22}$Mg	E824	Hot NeNa cycle; ^{22}Na prod.
^{22}Mg$(p,\gamma)^{23}$Al	LOI	^{22}Na production
^{23}Mg$(p,\gamma)^{24}$Al	E810	rp process
^{23}Al$(p,\gamma)^{24}$Si	LOI	^{22}Na production
^{25}Al$(p,\gamma)^{26}$Si		^{26}Al production

The facility

Summary

The main components of the DRAGON system are a windowless, extended gas target; a two-stage electromagnetic mass separator; detectors of the heavy reaction products and detectors of the capture γ-rays. The expected radiative capture rates are of order 1 event per second for a beam intensity of 10^{10} s^{-1} or lower. The role of the DRAGON is to provide clean separation and identification of the recoiling reaction product from the relatively more intense incident beam, and to allow for the measurements of the rates of these essential reactions as a function of the energy of the incident beam.

Funding over a three year period for the building of DRAGON and its initial operation was received from NSERC (and TRIUMF) in April, 1998, while funding for the required gas target was received in 1997. In 2000, funding was received to design, build and install a BGO based gamma array around the gas target chamber. A conceptual layout of DRAGON is displayed in Fig. 120; inserted in this figure is a diagram indicating beam focusing properties at different locations. A summary of the status of the various components is provided below.

Gas target

The gas target system, including the recirculation system and the EPICS controls, was commissioned using hydrogen and helium gases, i.e. when using these gases the pressure in the inner chamber was 5 Torr, while at the upstream and downstream end chambers the pressure was of order 10^{-6} Torr. The shape of the side windows of the inner gas chamber required special design (see Fig. 121) to minimize the effects of streaming (and higher pressures) when using hydrogen gas. Approximately 4 L of X13 zeolite is used in the recirculation chamber to maintain purity of the recirculating target gas.

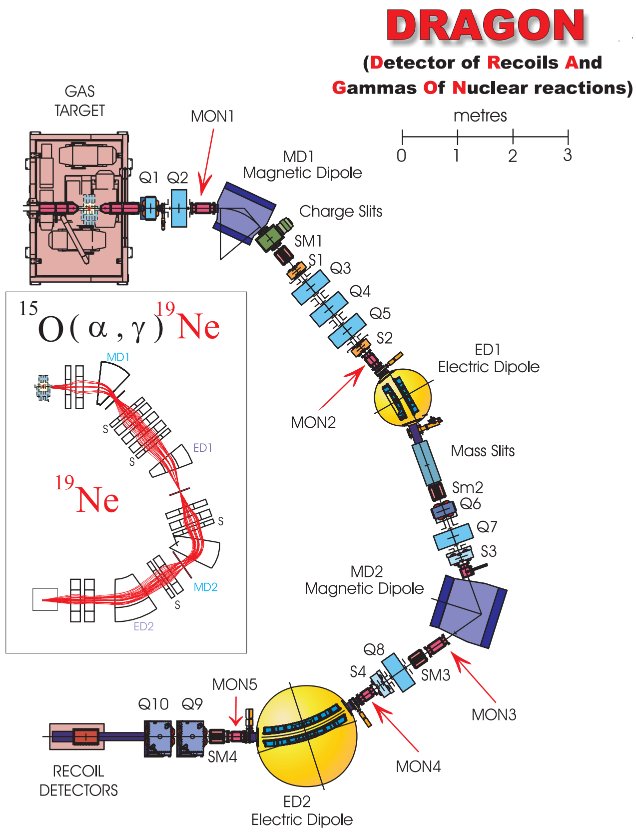

Fig. 120. Displayed is a detailed layout of DRAGON in the ISAC hall. The insert presents the calculated beam trajectory of a ^{19}Ne ion beam from the ^{15}O$(\alpha,\gamma)^{19}$Ne reaction.

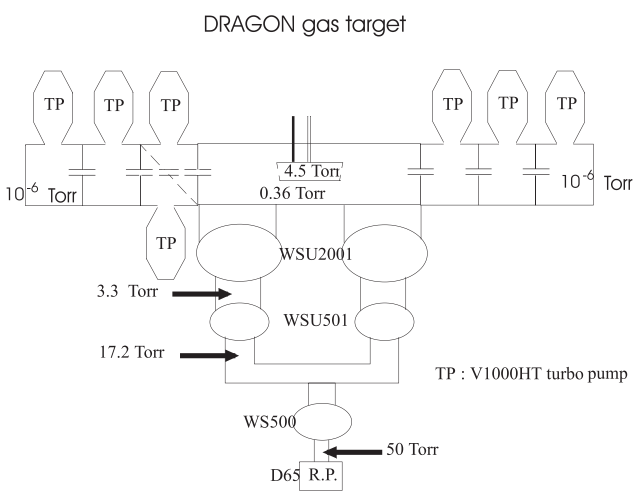

Fig. 121. Schematic representation of the DRAGON windowless gas target; measured gas (H_2, He, or air) pressures indicated.

Mass separator

The separator contains both magnetic and electrostatic dipoles in order to achieve separation of the beam and recoil product, which have essentially the same momentum. It is a two-stage device, each ending in an energy-achromatic, mass-dispersive focus. Following selection of one charge state of beam and product in the 50° magnetic dipole, an electric dipole is used to select only the product based upon its different energy. Mass dispersion of 0.47 cm/% is achieved in the first stage and 2.12 cm/% in the second stage. Each stage has 5 quadrupoles for focusing, 2 sextupoles to correct aberrations, and 2 steering magnets.

All twenty magnetic elements have been mounted on their stands in locations on the beam line. The vacuum chamber for the first dipole was installed and the second chamber is expected from the machine shop. The titanium electrodes were polished and the entire interior structure, including insulators, assembled for both sets of electrostatic dipoles.

Particle detection system

The detection system for the recoiling reaction product heavy ions consists of a thin carbon film, electron focusing, multichannel plate (MCP) detector system to provide positional and timing information, followed by a thin windowed ionization chamber (IC) with a parallel gridded avalanche counter (PGAC) as front end. This provides a second timing signal and a total energy signal. This particle detection system will provide a local time of flight for a primary mass determination. The MCP was assembled and tested successfully with an alpha source. The IC (without PGAC) was tested initially with heavy ions at Yale University, and then combined with the PGAC at the University of Notre Dame. The IC displayed resolution equivalent to an Ultra Si detector, namely 2.7% resolution with 0.9 MeV/u ^{16}O ions (4.7% at 0.2 MeV/u).

Gamma array

Funding has been received from NSERC to build a gamma detector, which will be a part of DRAGON for the first experiments in mid-2001. The detector is composed of 30 segments of BGO crystal, each segment being a hexagonal cylinder 56 mm in diameter by 76 mm long. The segments of the array will be stacked to form a closed volume around the DRAGON gas target. Capture γ-rays will be detected in coincidence with the heavy ion detected in the separator.

Prototype crystal modules were received from three suppliers and tested with radioactive sources of γ-rays. Especially important are the rate-handling capability and energy resolution of the modules. The design of the phototube base was optimized with help from TRIUMF technicians, and 31 detectors were ordered from Bicron and Scionix corporations. The Bicron detectors are more expensive and have slightly superior energy resolution. Rate-handling capability was optimized by placing a strong source of 511 keV γ-rays near each crystal and requiring minimum pulse-height shifts with varying counting rate. This test simulates the background effects expected from the small percentage of radioactive beam spilled in the target. So far about half of the detectors have been tested with radioactive sources up to 6.1 MeV γ-ray energy. NIM and CAMAC electronics were procured and tested with a version of the TRIUMF standard MIDAS data acquisition program, which runs on a PC. The electronics processes the signals from 30 independent BGO crystal channels in parallel, using fast ADCs to convert each pulse height. The maximum background rate-handling capability of each module is about 500 kcps, which translates to 15 Mcps for the whole array, if uniformly illuminated.

A mounting system, which accommodates both detectors interchangeably, has been designed and a preliminary Monte Carlo simulation of efficiency performed using GEANT. The detector layout was designed to maximize total solid angle coverage, homogenize counting rates among the detectors, and optimize z-axis sampling of a resonant γ-ray source. This last feature will facilitate monitoring of the beam energy by measuring the z-position of the resonant target gas along the beam/target intersection line. The mounting system will also allow for the positioning of a lead blanket, if deemed necessary, to reduce effects of external background. Detailed design of the mounting arrangement is under way in the TRIUMF Design Office. Present plans indicate that the entire gamma array will be installed and commissioned by the middle of April, 2001.

The work described in this section involved mainly Drs. Joel Rogers and Ahmed Hussein, and graduate student Dario Gigliotti of UNBC.

Science

^{22}Mg

In anticipation of the first study planned for DRAGON, namely the measurement of the ^{21}Na$(p,\gamma)^{22}$Mg rate, a detailed study of the levels was completed using a (p,t) reaction. The study was performed at the (now closed) University of Tokyo CNS Laboratory using the high-resolution triton spectrometer. Figure 122 displays the energies of the states that were observed; the observed precision was better than previously measured. Given the energy loss in the DRAGON gas target, it was important to know the energies with such precision. These studies have been accepted for publication in Physical Review C.

Alpha commissioning and source preparation

The initial commissioning of the DRAGON will be performed using an alpha emitter positioned just upstream of the centre of the gas target. A small magnet

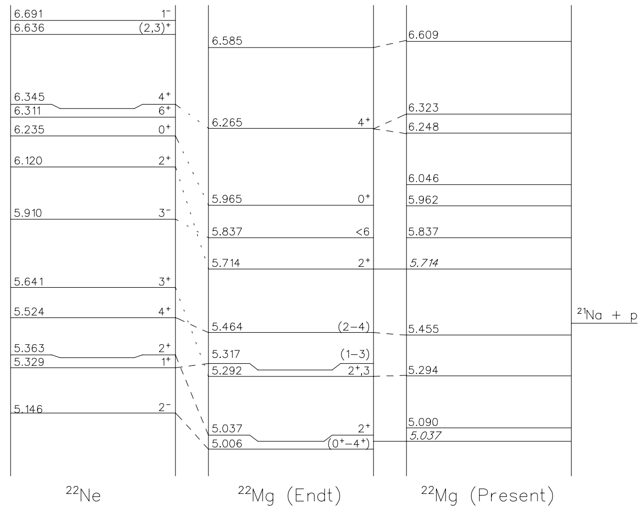

Fig. 122. Levels of ^{22}Mg as studied using a $(p,t)^{21}$Na reaction on ^{24}Mg and considered important for the $(p,\gamma)^{22}$Mg reaction.

and a set of slits positioned at the target centre will allow for the production of a deflectable, parallel beam of ^{4}He$^+$ ions to explore the characteristics of the optics of the magnetic elements in a systematic fashion. A ^{148}Gd source, which emits an alpha of 3.183 MeV, was produced at TRIUMF by the irradiation of a Sc foil on BL2A with 40 MeV protons under controlled conditions. A detailed radiochemical separation procedure was followed using the laboratory facilities of Simon Fraser University to separate gadolinium for the target material and other reaction products. The extracted gadolinium was then electrochemically deposited onto a Pt foil; the separation efficiency of the entire procedure was about 75%, but the final source strength was only 16 μCi due to some difficulties in the original production irradiation. The source was mounted on a standard alpha holder and sprayed with a thin layer of lacquer ($\sim$40 μg/cm^2).

Charge state distributions

When heavy ions traverse a gas, a distribution of charge states results. Depending upon the thickness of the gas, this distribution may or may not reach equilibrium conditions. This process affects the studies planned for DRAGON, as only one charge state will be measured using the spectrometer. Little information exists in the literature on this process for low energy, low Z heavy ions. Studies were performed using the windowless gas target system at the University of Naples Tandem Laboratory in Italy. Using beams of oxygen and sodium at energies relevant to the planned studies, resulting charge distributions were measured as a function of gas pressure. Figures 123 and 124 display some of the preliminary results.

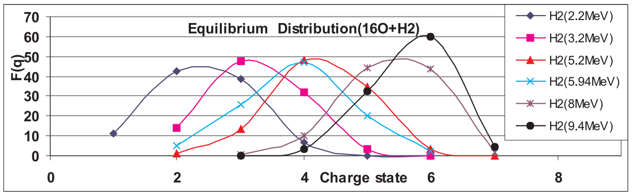

Fig. 123. Charge state distribution resulting from a ^{16}O beam in a windowless hydrogen gas target system.

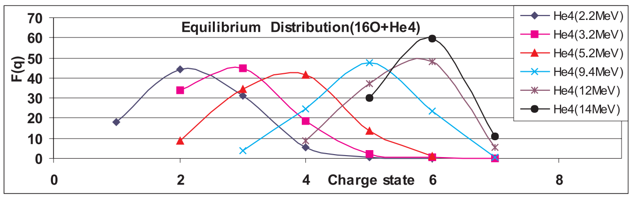

Fig. 124. Charge state distribution resulting from a ^{16}O beam in a windowless helium gas target system.

Summary

By the end of this year the DRAGON facility was approximately 80% completed. Preparations were under way to initiate commissioning of the first two sections using the ^{148}Gd alpha source positioned 50 cm upstream of the gas target centre. The emitted alphas would be detected using a Si strip detector mounted in the charge slits vacuum chamber located after the first magnetic dipole.

8π Spectrometer
(G.C. Ball, TRIUMF)

The 8π γ-ray spectrometer, designed by Canadian physicists to pursue high-spin γ-ray spectroscopy studies at TASCC, was moved to TRIUMF in March. The 8π spectrometer is a second generation instrument composed of 20 Compton-suppressed HPGe detectors, a 4π BGO γ-ray calorimeter, and a multi-element CsI(Tl) charged-particle detector array. The spectrometer is presently being modified for a vigorous program of decay studies with the non-accelerated radioactive beams available in the low energy area of ISAC-I. In these studies, the γ-rays are emitted from nuclei at rest and the Doppler broadening associated with emission from a moving source, as is typical of the experiments with accelerated beams, is no longer an issue. It is therefore possible to achieve a higher γ-ray efficiency, while retaining excellent energy resolution and peak-to-total ratio, by removing most of the inner BGO calorimeter and close-packing the 20 Compton-suppressed HPGe detectors of the 8π around the source position.

A key element of the research program with the 8π spectrometer at ISAC will be superallowed Fermi β-decay studies. A 4π array of plastic scintillators to detect positrons is also required for these studies. The <60 keV isotope-separated beams from ISAC will be implanted in aluminized mylar tape at the mutual centre of the β- and γ-arrays. Periodic movement of the tape will remove long-lived daughter activities from the vicinity of the detectors. A new LEBT has been designed to ensure a beam spot diameter of 5 mm, so that 1.27 cm wide tape will be sufficient to intercept the entire beam profile. This is achieved without the use of any slits in close proximity to the detector arrays.

The installation and commissioning of the modified 8π spectrometer is scheduled for completion by the summer of 2001. The new LEBT will be built in the fall and first experiments will begin in early 2002.

Low Temperature Nuclear Orientation
(P.P.J. Delheij, TRIUMF)

With the low temperature nuclear orientation set-up at ISAC-I, radioactive isotopes are implanted and polarized in ferromagnetic foils which are cooled to temperatures below 10 mK. As a consequence, the emitted radiation of the subsequent decay is anisotropic. This effect can be applied in studies of nuclear structure, condensed matter and fundamental symmetries.

After the first radioactive beam was delivered in the previous year, the efforts were directed towards commissioning the set-up and starting the first experiments. Two beam periods in the spring and the fall were taken. A central role in the commissioning is played by ^{79}Rb. It can be produced in abundant quantities from several production targets. Furthermore, the γ-ray decay structure provides several internal consistency checks on the measured anisotropies.

In the spring, problems with the target foil preparation led to a maximum anisotropy of 5% for the 688 keV γ-ray transition in the decay of ^{79}Rb. This is about half of the value that we obtained previously. Subsequently, problems developed with the beam diagnostics in the cryostat which reduced the efficiency of the beam delivery considerably. However, a satisfactory ^{75}Ga:^{75}Rb production ratio and intensity was still obtained (see the report on Expt. 863).

In the fall, an anisotropy of 0.110 was observed for the 688 keV γ-ray, slightly exceeding the previous large value. This proved that the problems with the target foils were solved. The beam diagnostics performed very well with a noise level of 1–2 pA on the cold Faraday cup channels in the cryostat. However, instabilities in the beam line leading to the LTNO set-up caused beam intensities to vary by a factor of 3 over timespans of a few hours. With the failure and replacement of the rf source for the NMRON scans, data with limited statistical accuracy could be acquired. Also ^{91}Rb (decaying to the ^{91}Y isomer) was implanted with acceptable intensities (see the report on Expt. 826). In this period a power outage and a dropout of the cooling water supply plagued the refrigerator system.

The experiments with ^{79}Rb gained considerable significance with the publication of the calculation of the hyperfine fields for all elements from Rb until Xe [Cottenier and Haas, Phys. Rev. **B62**, 461 (2000)]. Excellent agreement with the experimental values is shown except for Rb and Sr. The present experimental value for Rb was obtained with an integral nuclear orientation measurement. An NMRON measurement (differential nuclear orientation) can resolve this problem. Therefore, Expt. 893 was approved by the EEC for the first hyperfine field measurement of Rb in the hosts Fe, Ni and Co.

Collaborators on the LTNO are: P.P.J. Delheij, C.A. Davis, TRIUMF; B. Turrell, J. Pond, R. Kiefl, Univ. of British Columbia; K.S. Krane, P. Schmelzenbach, J. Loats, C. Stapels, Oregon State Univ.; J. Wood, D. Kulp, Georgia Inst. of Technology; P. Mantica, W. Kumarasiri, D. Groh, Michigan State Univ.; H. Haas, Hahn Meitner Inst.; S. Cottenier, K.U. Leuven.

Experiments 870, 874, 879, 900 "TUDA" TRIUMF-UK-Detector-Array

(T. Davinson, Edinburgh)

TUDA 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 [Davinson *et al.*, Nucl. Instrum. Methods **A454**, 350 (2000)]. Typical nuclear astrophysics applications are:

- elastic scattering, e.g. Expt. 879, ^{1}H(^{21}Na,^{21}Na);
- (α, p) reactions, e.g. Expt. 870, ^{4}He(^{18}Ne,p);
- studies of the 4.033 MeV state of ^{19}Ne such as:
  - Expt. 874, ^{2}H(^{18}Ne,p)^{19}Ne;
  - Expt. 900, ^{6}Li(^{15}O,d)^{19}Ne.

The TUDA apparatus can also be used for nuclear physics experiments.

TUDA's initial configuration consists of a modular vacuum chamber (length 1.5 m, diameter 0.4 m). A photograph of the chamber is shown in Fig. 125. The upstream box houses the beam collimator system. The centre box contains the target ladder, vacuum system ports and four large, uncommitted ports. The downstream box is used for the electrical, gas and coolant feedthroughs. All are connected via simple tubular sections. The modularity of the design is intended to

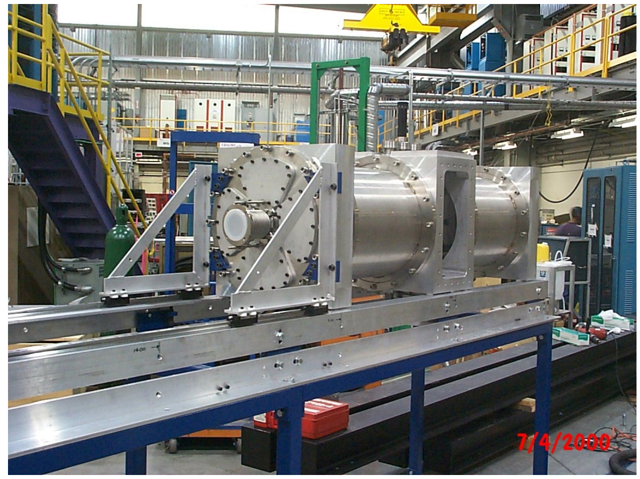

Fig. 125. Photograph of the TUDA chamber during initial assembly. The downstream flange is visible.

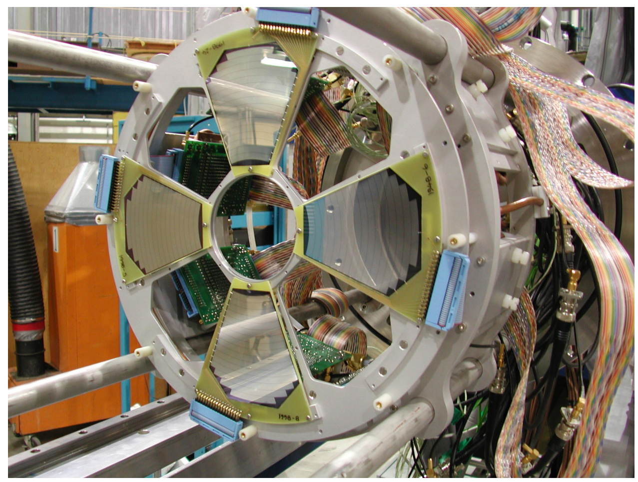

Fig. 126. Photograph of a partially installed MSL type YY1 silicon strip detector and preamplifiers within the TUDA chamber.

simplify the customization of the chamber to a wide variety of experiments. The detectors and preamplifiers are mounted on four rods arranged around the central axis of the chamber and attached to the downstream flange (Fig. 126). The entire detector assembly can be withdrawn from the chamber using a linear track system enabling convenient access to the detectors and instrumentation. The optics of the beam line have been designed to enable a minimum beam spot size of 1 mm ×1 mm to be produced at the target position. The TUDA vacuum chamber is designed so that it can be easily removed and the target position and beam line used by other experiments.

All of the pulse-processing instrumentation and data acquisition are housed in a purpose-built, standalone counting room located close to the TUDA vacuum chamber. Great care has been taken to provide clean power, high quality grounding and EMI/RFI screening from the multiple rf sources within the

ISAC-I experimental hall. The instrumentation consists of the RAL108 charge-sensitive preamplifier and the RAL109 shaping amplifier/discriminator which provide spectroscopy-level performance. Trigger logic is provided by CAMAC ECL logic modules. Detector bias is provided by a CAEN SY403 HV Mainframe (32 channels, –600 V, 0.2 mA). The data acquisition system will use a modified version of the Silena 9418/6V VME ADC (32 channel, 12-bit) and the CAEN V673 VME multihit TDC (128 channel, $\sim$0.8 ns LSB) which have been ordered and are expected to become available during the summer of 2001. In the interim, commissioning and early experiments will use the Silena 4418/V CAMAC ADC and LeCroy 3377 CAMAC TDC. Infrastructure (cabling, racks, etc.) to support up to 512 discrete detector elements from up to 32 silicon strip detectors has been installed.

TUDA collaborators include: T. Davinson, N. Farrington, D. Groombridge, A. Laird, P. Monroe, A. Ostrowski, C. Ruiz, F. Sarazin, K. Schmidt, A. Shotter, P. Woods (Univ. of Edinburgh); B. Fulton, B. Greenhalgh, J. Pearson, L. Watson (Univ. of York); N. Clarke (Univ. of Birmingham); J. Daly, J. Gorres, M. Wiescher (Univ. of Notre Dame); L. Buchmann, P. Walden (TRIUMF); A. Chen, J. D'Auria (Simon Fraser Univ.); S. Cherubini, P. Leleux (Univ. Louvain-la-Neuve); J. Hinnefeld (Univ. of South Bend); R. Azuma, J. King (Univ. of Toronto); E. Konobeevsky, M. Morodovskoy, V. Simonov, A. Stepanov, V. Zavarzina (INR RAS).