

# TRIUMF



## ANNUAL REPORT SCIENTIFIC ACTIVITIES 1997

CANADA'S NATIONAL MESON FACILITY  
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UNDER A CONTRIBUTION FROM THE  
NATIONAL RESEARCH COUNCIL OF CANADA

APRIL 1998

*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 therapy facility

(*E.W. Blackmore, TRIUMF*)

A total of 13 patients with ocular melanoma were treated during seven treatment weeks in 1997, bringing the total number of patients treated at TRIUMF to 36. The reduced number for this year is due to a combination of reduced referrals, and a decision to not treat tumours with a volume greater than 40% of the globe volume. Clinical follow-up of patients treated to date is showing that all tumours have stopped growing, and that the most serious type of complication, neovascular glaucoma, increases in frequency with the size of the tumour.

A few developments were made to the treatment system this year. A system for mounting an aluminum wedge, downstream of the patient nozzle, close to the patient's eye was implemented. Wedges with angles from 10–60 degrees can be used to modify and improve the dose distribution. After completing necessary dosimetry measurements the use of wedges was approved for patients and has been used in about half of the treatments since. A three-axis scanner was developed to replace the existing two-axis scanner. The design is much lighter and can be easily mounted on the dosimetry table. It will be commissioned early in 1998.

Several beam periods were used for dosimetry experiments involving MRI-polymer gels which can provide a three dimensional dose distribution. After irradiation of the gels, MRI scans can be used to convert the transverse relaxation rate to dose. Another dosimetry technique is being evaluated as an M.Sc. student project. A sensitive scintillation screen is viewed through a mirror by an integrating CCD camera with a frame-grabber to provide an immediate display of lateral dose distributions, or depth distributions, if the scintillator is mounted on a wedge. Linearity and sensitivity checks have been carried out and studies such as edge effects at collimators and wedges can be made very quickly.

During the December treatment week, dosimetry and a series of cell irradiations were carried out to measure the relative biological effectiveness (RBE) of 70 MeV protons as a function of depth in a spread out Bragg peak, and dose level. This is a repeat of previous RBE studies, using the sliced gel technique with cultured Chinese hamster cells, carried out by the biophysics group at the Cancer Research Centre.

### Proton irradiation facility

(*E.W. Blackmore, TRIUMF*)

The proton irradiation facility (PIF) uses the low intensity proton beam from BL1B for energies from

500 MeV to 180 MeV and BL2C-1, the proton therapy line, for energies below 120 MeV. In addition to monoenergetic proton beams, a neutron beam with an energy spectrum similar to that found for atmospheric neutrons can be produced by completely stopping the 500 MeV proton beam in a beam stop, and setting up downstream of the beam stop near the beam axis. Lower energies of protons can be used to get a different neutron spectrum.

During a three day run in March, several tests of proton fluence detectors for space applications were carried out. These detectors included ones based on measuring single event rates in well characterized devices. In addition, the response of bubble detectors to high energy neutrons and protons was measured.

A six day run in September was used by groups from NASA Goddard Space Flight Center, the Naval Research Laboratory, DERA in Farnborough, UK and DREO in Ottawa, for a number of studies with proton energies ranging from 500 MeV to below 15 MeV, and with neutron beams obtained by stopping 70, 225, 350 and 500 MeV protons. Various devices including optoelectronic devices, memory chips and proton and neutron detectors for space applications were tested. This was the most extensive use of the PIF facility since commissioning, and the groups were treated to exceptionally good beam conditions, as for most of the period they were sole users. Bonner sphere measurements were made of the neutron spectrum for 225 and 500 MeV protons stopping in steel and these are being compared to FLUKA calculations.

### $\mu$ SR user facility

(*S. Kreitzman, TRIUMF*)

#### Overview

1997 was, once again, an active year for the TRIUMF  $\mu$ SR facility. We operated at maximum capacity (i.e. using four beam lines) for the majority of the available beam time. 20 groups working on 49 active experiments took 82 weeks of beam during the year.

Visitors to the facility will have noticed a personnel change. Our facility engineer has moved over to broader responsibilities (as head of the TRIUMF beam lines technical group) and we have taken on a fabrication technician in his place. This change reflects the reality that TRIUMF as an institution is placing ever more of its efforts and emphasis on completing the ISAC construction and commissioning. Technical services, such as access to the Machine Shop, have come under extreme pressure for those established groups which must carry on the basic science program. To this

end we chose our new technician from one of the TRIUMF Machine Shop graduated apprentices, thereby allowing the  $\mu$ SR group greater access to this critical resource. Additionally, with our (previous) engineer now overseeing broader TRIUMF beam line installations and maintenance,  $\mu$ SR will be well served by having an individual so well versed in our field involved in the broader TRIUMF support infrastructure.

The facility's financial situation this year has been stable. However, we are still in a situation where major initiatives must be supported by the user community (for both equipment and capital expenditures) in order to become a reality. TRIUMF and NSERC (Natural Sciences and Engineering Research Council) support, along with the user contributions are sufficient only to provide maintenance, repair, operations and minor upgrades for the existing  $\mu$ SR infrastructure. The facility will be applying for a new MFA (Major Facility Access) grant next year from NSERC and it is hoped that the excellent science produced by the user community will be reflected in a redress of the severe cuts made to our previous operating budget.

The majority of the facility's efforts this year can be summarized as follows:

- spectrometer upgrades
- data acquisition issues and VME
- the new  $\mu$ SR clock
- $\mu$ SR equipment and beam line facilities tables.

Each of these sections is more fully described below.

### Spectrometer upgrades

#### Low background inserts

The idea of low background  $\mu$ SR has taken root with the user community insofar as groups are coming to TRIUMF with increasingly smaller samples (recently a  $0.07 \text{ cm}^2$  sample has been used) with the expectations of reasonable signal-to-background ratios. Meeting these expectations requires that those muons which do not land in the sample be rejected as efficiently as possible.

To this end a new class of low background inserts is being developed in the facility. These have muon and veto counters located inside the cryostat in a very compact geometry. The result is that any muon which passes through the muon counter and does not land in the sample, has a very high probability to register in the veto counter. Backgrounds are then caused by inefficient detection of muons in the veto counter in conjunction with the probability of a very large angle muon counter scattering event, missing the veto

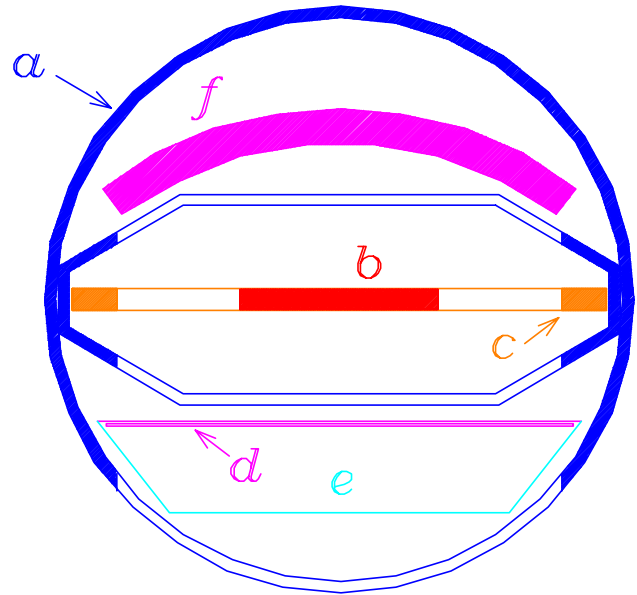


Fig. 83. Very low background standard cryogenic. Insert for ZF and LF  $\mu$ SR. a) fibreglass frame, b) suspended sample, c) sample mount, d) muon scintillator, e) muon light guide, f) veto counter.

counter entirely. The combination of these sources results in an absolute background of about 1.5% relative to the incoming rate.

A schematic diagram of one such apparatus is given in Fig. 83.

#### Belle high timing resolution spectrometer

Much work has been invested in improving this apparatus which has been designed for transverse field  $\mu$ SR experiments up to 7.5 T. At the highest fields, the Larmor precession frequency is over 1 GHz and the timing resolution of the components in the system becomes critical. To resolve a 1 GHz signal without too severe a loss in amplitude requires that the overall timing resolution of the system be kept less than 300 ps, about the time it takes light to travel 3 cm in cable or light guide. Achieving this requires a careful combination of equipment and design parameters. Firstly, the system must be kept small to minimize time delay and light attenuation from the scintillator. Naturally, a high speed scintillator must be used and matched with very fast high gain phototubes. For a multiple counter spectrometer and a magnet with no yoke (i.e. Belle) there is little choice except to use mesh dynode tubes so they can operate in the rather high fringe field of the magnet. Another design parameter found to be significant for improving the (counter) resolution to about 200 ps is that the counter geometry must be kept simple. Compound bends or shapes which create light traps in the light path are to be avoided.

Of course, without a clock that can in fact *keep up* with the frequencies involved, the above efforts would

be in vain ... a discussion of that instrument is given in a following section. Several preliminary counter designs have been tested with our old clock and precession data are presented below for an earlier design. Newer light guide designs tested in the laboratory have shown further improvements, resulting in a positron counter timing resolution of approximately 200 ps.

### Magnetic field control

Issues pertaining to magnetic field control are critical to controlling systematic effects during what can often be very long  $\mu$ SR data runs. This issue is particularly acute in high field situations. Although the best solution would be to monitor the field at the sample position, this possibility requires a complex sample/field probe switching mechanism which is somewhat incompatible with the TRIUMF facility's reliance on beam line swapable spectrometers.

Thus, field control at our facility requires that the probe, which is connected to a field stabilization feedback system, be located at a distance from the sample. For Helmholtz geometry superconducting coils (i.e. in the DR and Belle spectrometers, see Tables V, VI, VII) we have tried to place a fixed externally mounted room temperature Hall probe in the bore of the magnet, but found this approach to be unsuccessful. The downfall of this method arises because the probe is located in a very high field gradient and the systematic changes (due to ambient temperature effects) of the relative probe-sample position leads to erroneous field control measurements.

With our lessons learned, we have adopted the following method of field control in Helmholtz superconducting coils. Hall probes (with internal temperature measurement and correction hardware if required) are placed in the magnet assembly itself on a locus of constant axial field from the centre. For Helmholtz coils this is on a cone of approximately  $45^\circ$  relative to the axial direction. The location of the probe is such that its differential thermal contraction with respect to the sample is minimized. Thus for the DR the probe is placed on one of the heat shields surrounding the cold finger, and in Belle it is placed inside the magnet bore, onto which the cryostat is bolted. Test data to date seem to substantiate the efficacy of this approach.

### Data acquisition issues and VME

Changes in the data acquisition environment that began in 1996 have in 1997 taken firm root. Most significantly is the intention to remove any dependence on a Q-bus based CAMAC interface. VME based data acquisition front ends have been utilized in M15 and M20 over this past year, and this DAC implementation will shortly be the  $\mu$ SR standard at TRIUMF.

To date the VME system is simply a system motherboard with SCSI, Ethernet, IEEE488, and RS232 capability. The first two are integrated into the board itself, while the last two are added as industry packs. The SCSI port is dedicated to the control of an attached CAMAC crate. Two rpc software drivers handle the calls to the hardware attached, a CAMAC driver and a CAMP slow controls driver. We plan to further expand the motherboard's I/O capabilities with two more industry packs, one having multichannel A/D and D/A capability and the second a dual motor control. These additions will allow CAMP to include flow control and general closed loop feedback capability in addition to CAMAC, RS232 and IEEE488 channels.

None of the above system board functionality actually makes use of the VME backplane. This is reserved for the VME clock and its associated modules. The clock (see below) will have a dedicated microprocessor board whose ram acts as the histogramming memory of more conventional systems. The processor board will access the clock every 10  $\mu$ s or so (depending on the gate time of the  $\mu$ SR experiment) to readout any new data that may be present. Additionally, the clock processor board will have its own Ethernet channel (distinct from that of the system motherboard) allowing for independent downloading of the histogram information while other CAMAC and slow control functions continue.

### The new $\mu$ SR clock

Time differential  $\mu$ SR (TD $\mu$ SR) is the most common type of  $\mu$ SR experiment carried out at TRIUMF. It requires the accurate measurement of the time difference between the entrance of the muon into the sample and its subsequent decay into a positron (which is detected) and neutrinos. For the last decade TRIUMF and PSI have relied on the LeCroy 4204 TDC (time to digital convertor) for this task. This TDC is now no longer manufactured or serviced and exhibits an inherent timing resolution of about 400 ps that is considerably poorer than that required for a high timing resolution apparatus. Since these TDCs have now begun to show ageing problems a new generation was required. Even so, since the 4204 was an instrument that had been customized for  $\mu$ SR experiments, up to 1996 no obvious commercial replacement was evident.

Our objectives for the new  $\mu$ SR TDC were four fold.

1. Timing resolution and jitter below 100 ps.
2. Buffered operation to enable high data rates.
3. Bad event detection and/or rejection.
4. Easy integration into the data acquisition environment.

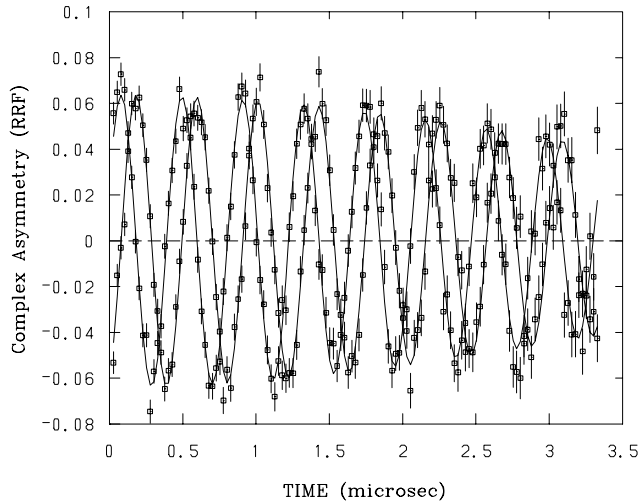


Fig. 84.  $\mu$ SR rotating reference frame time differential spectrum at 6.7 T. Two orthogonal spectra are displayed in the rotating reference frame (i.e. spectral frequency components are displayed relative to a high frequency reference) so that the precession can be viewed and assessed by eye. The relaxation of the signal envelope is indicative of the field inhomogeneity present in Belle for a  $0.64 \text{ cm}^2$  square sample area.

Fortunately in early 1997 we became aware of a project by Highland Technologies and Berkeley Nucleonics (well known for their timing hardware) to define the parameters of a new generation VME based multi-channel clock/TDC which seemed a suitable candidate for our needs. Thus, still at the design stage, we convinced (for a reasonable fee) the various parties to add additional hardware capability to their original design so that it could meet the criterion above. Specifically, the original design has been augmented with double hit detection hardware and a buffered output to allow fast data transfer without too much dead time.

This has now been accomplished and the first production models of the clock have been delivered to TRIUMF. It has a 50 ps minimum timing resolution with inherent jitter below this value for a  $20 \mu\text{s}$  gate. Because it is VME based, integration into the DAC

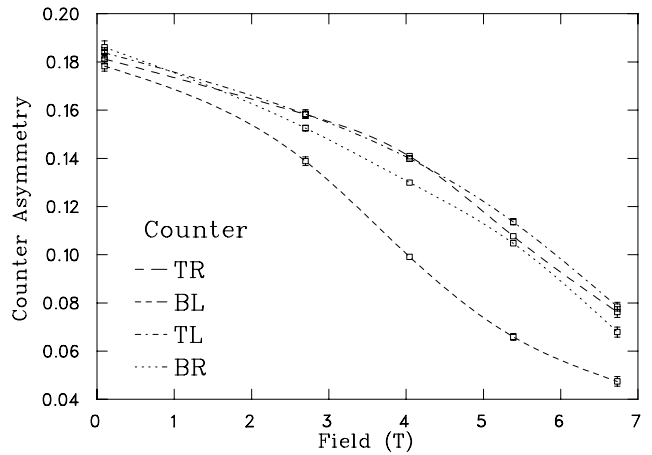


Fig. 85. Belle spectrometer individual counter asymmetry, with LeCroy 4204 clock and compound light guide bends.

systems described in the previous section is inherited. The clock has a further feature in that the internal microengine can be programmed to analyze the hit patterns so that only valid  $\mu$ SR events are passed to the output buffer. One of the TRIUMF DAC staff software engineers is intimately involved in this effort and we foresee the in-house capability of microcoding the clock. Ultimately, this will allow us the flexibility to code for other non-standard types of data filtering/routing (i.e. multiplexed  $\mu$ SR) whose needs are already presenting themselves in various experimental set-ups.

Plans to install these new clocks into all the  $\mu$ SR beam lines are now under way. Thus, over the next year the facility will finally alleviate a long standing thorn in its side and have a new generation of clocks to carry into the next decade.

#### $\mu$ SR equipment and beam line facilities tables

Following are tables of the  $\mu$ SR spectrometers and inserts. For more information consult [www.triumf.ca/msrfac](http://www.triumf.ca/msrfac).

Table V. The spectrometers:

Spectrometer	Characteristics	Experiment types
Gas cart	10 mT $\hat{y}$ , $1\pi$ counters, HH design	LTF, LLF
Omni	0.4 T $\hat{z}$ , 20 mT $\hat{x}$ - $\hat{y}$ , $4\pi$ counters, HH design	LF, TF, ZF, RF- $\mu$ Wave
Omni'	0.25 T $\hat{z}$ , 20 mT $\hat{y}$ , $4\pi$ counters, HH design	LF, TF, ZF, RF- $\mu$ Wave
LAMPF	3.5 T $\hat{z}$ , 0.5 mT $\hat{x}$ - $\hat{y}$ , $4\pi$ counters, HH design	LF, TF, ZF, RF- $\mu$ Wave
Belle	7.5 T $\hat{z}$ , $2.0\pi$ high resolution counters, HH design	TF, 1.6–300 K
Helios	6 T $\hat{z}$ , $1$ – $2\pi$ counters, SC solenoid	LF, TF, HTF, RF- $\mu$ Wave
DR	5 T $\hat{z}$ , $0.1$ – $1.5\pi$ counters, HH design	LF, TF, ZF, LLF, HTF
SFUMU	0.5 T $\hat{z}$ , $2\pi$ counters, HH design	TF high $\vec{p}$ muons
Varian	0.5 T $\hat{y}$ , $1$ – $2\pi$ counters, electromagnet	TF high $\vec{p}$ muons

TF=transverse field    LF=longitudinal field    ZF=zero field    RF=radio frequency     $\mu$ Wave= Microwave

Table VI. The inserts:

Acronym	Full descriptive name of insert	Characteristics
VGFC:Janis	Vertical gas flow cryostat : Janis	2.4–330 K
/SC	standard configuration	>100 mg & >1 cm dia
VGFC:Cryo	Vertical gas flow cryostat : Cryo Industries	2.4–330 K
/SC	standard configuration	see sample densities above
/LB	low background configuration	<100 mg or <1 cm dia
HGFC:Cryo	Horizontal gas flow cryostat : Cryo Industries	2.8–330 K
/SC or /LB	standard or low background configuration	see sample densities above
/RFss	RF solid-state configuration	10–220 MHz/1 KW
/ $\mu$ Wave	$\mu$ Wave solid-state configuration	1–2 GHz/2 W, 800 MHz/20 W
HGFC:Quant	Horizontal side access gas flow	1.55–330 K
/SB or /LB	standard or low background configuration	full LB for ZF
CFC:20 cm	20 cm cold finger cryostat - axial or side access	2.8–330 K
CFC:40 cm/ax	40 cm cold finger cryostat - axial access	2.8–330 K
CFC:40 cm/sa	40 cm cold finger cryostat - side access	2.8–330 K
HO2 cm	Horizontal oven (2 cm target)	330–900 K
HO3 cm	Horizontal oven (3 cm target)	330–900 K
HPC	High pressure cell	50 MPa
Gas cart	High volume gas target	174 L 300 KPa
RFchem	RF apparatus for liquid chemistry targets	280–325 K
/160/185/205/305	Resonant frequency specification	300 W

Table VII. Spectrometer &amp; insert compatibility guide:

Inserts	Spectrometers								
	DR	Belle	Omni	Omni'	LAMPF	Helios	SFUMU	Varian	Gas cart
Stand alone	X	X						X	
VGFC:Janis			X	X					
VGFC:Cryo			X	X	X				
HGFC:Cryo			X	X	X	X	X		
HGFC:Quant			X	X	X		X	X	
CFC:20 cm			X	X			X		
CFC:40 cm/ax			X	X	X	X	X		
CFC:40 cm/sa			X	X			X	X	
HO			X	X	X	X			
HPC			X	X		X	X		X
Gas cart									X
RFchem			X	X		X			

## Detector facility

(*R. Henderson, TRIUMF*)

The major project in the detector facility has been the construction of the BaBaR drift chamber. This involved considerable modifications and upgrade of the existing large clean room built for the HERMES project. This effort resulted in an excellent clean room, with dust counts of about 200 and temperature control to  $\pm 0.2^\circ\text{C}$ . The reduced humidity is also a requirement of the next major project, the ATLAS calorimeter modules.

The 28,768 wires of the BaBaR drift chamber have all been strung. The chamber has also been rotated to the vertical and 19 reject wires replaced. The covers were installed before Christmas, the chamber made helium leak tight, then tested with chamber gases, including a gaseous radioactive isotope as a source. This chamber is expected to be shipped to SLAC at the end of February, 1998.

A prototype ionization chamber for the ISAC DRAGON spectrometer is nearing completion. It will be tested in early 1998. Its performance will be compared with a refurbished ionization chamber borrowed from Ohio.

Construction of the KVI drift chambers has been completed and they are now being tested prior to shipment. These, like the previous MWPCs, will be used initially in the SUPERNOVA experiment.

Gas microstrip detector testing has continued in the facility. Although these types of chambers work fairly well and have been used in several experiments, they remain somewhat fragile and are difficult to make in reasonable sizes. A new detector type, GEMs (gas electron multipliers), seem to offer a better approach to applications where GMDs were used. The facility expects to begin tests on GEMs in 1998, in collaboration with other interested TRIUMF researchers.

A current-to-voltage preamp was developed for beam profile monitors on ISAC, and tested on ion-source stands. The preamps presently in use at TRIUMF have a resolution of 10 pA; this new preamp has a resolution of about 0.5 pA.

The facility published a NIM paper in 1997, describing the wire stringing machine developed for the SUPERNOVA project. This winder was used for the construction of the four MWPCs and two VDCs of this project. It is now available for subsequent chamber work. Modifications are planned to increase its precision.

The scintillator shop made fewer scintillators in 1997, but in 1998 is expected to be producing 500 adiabatic light guides for TJNAF, a project that is expected to use 14 man-months of labour. During 1997 more of the scintillator shop machine time was used on

the various wire chamber projects for BaBaR, ISAC and SUPERNOVA.

## The CHAOS polarized proton target (CPPT)

(*P.P.J. Delheij*)

This frozen spin polarized proton target is designed to operate in the CHAOS spectrometer on the pion beam lines at TRIUMF. Since the homogeneity of the spectrometer is insufficient for the process of dynamical polarization, the cryostat with the sample must be retracted from the spectrometer and inserted in the high homogeneity polarizing magnet each time the target is repolarized. To preserve the polarization during the transport a dilution refrigerator cools the sample to a temperature of approximately 60 mK. During this transfer the third (superconducting) magnet prevents to a large extent the loss of polarization (typically 0.015 for a roundtrip) with a field of 0.15 T over the target volume. This magnet is mounted on the inner heat shield of the cryostat shell. The set-up is part of the latest generation of polarized targets (with the ones at LEGS and MAMI) that leave the polarizing field completely before entering the spectrometer field. Therefore all these set-ups need to provide a small holding field during the transport, which is generated by a third magnet.

The main components of the set-up are shown in Fig. 86. The polarized sample is mounted in a cup with rectangular cross section to minimize the material in the beam that generates background. The volume is  $30 \times 25 \times 5 \text{ mm}^3$  (w x h x t). The opening angle is  $\pm 20^\circ$  vertically and two times  $160^\circ$  in the horizontal direction.

In the fall the target was operated for 8 weeks continuously, consistently with an initial polarization above 0.80 reached typically in 2 hours. Ramping of the magnets and the actual moving of the target took typically 1 hour or slightly less for a total service time of approximately 4 hours. This included for negative polarizations ramping of the polarizing magnet with the target in the inhomogeneous shoulder of the field to avoid polarization loss by the superradiance effect. The polarization decay was typically  $0.08 \times 10^{-2}$  per hour in the spectrometer field near 1 T.

Liquid helium for the dilution refrigerator flow cryostat was supplied from from a 250 l dewar through a rigid transfer line. Considerable effort was required for synchronization and alignment of the refrigerator and dewar lifts. The refrigerator dewar could be refilled with the system in any position. Liquid helium for the superconducting polarizing magnet is also transferred from this refrigerator dewar.

During 1997 the main improvements were related to preventing thermal damage to the butanol beads

# CHAOS

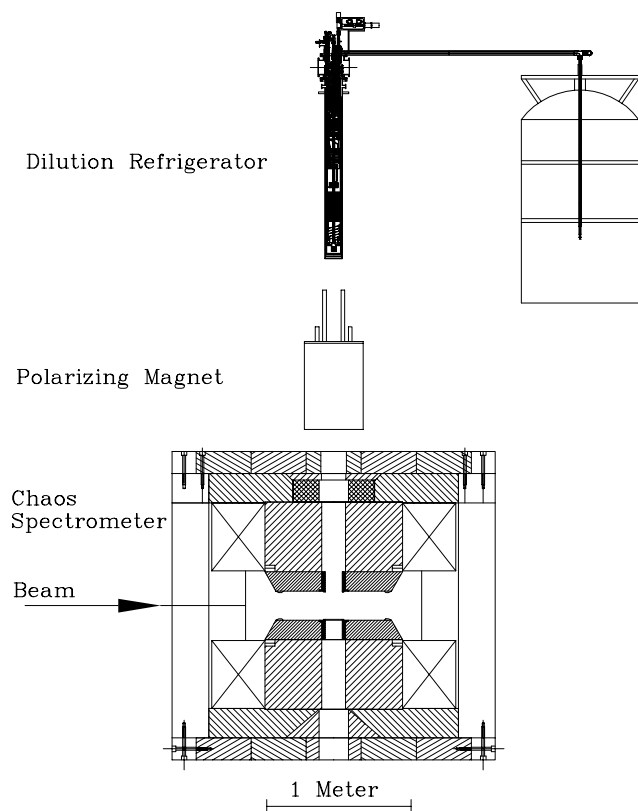


Fig. 86. Main components of the CHAOS set-up. Before the cryostat is lowered into the spectrometer, the polarizing magnet is moved sideways.

during the loading procedure. Furthermore, the signal-noise ratio of the NMR system was improved by rearranging the wiring in the target cell. The long term (1 hour) drift was reduced by placing the analogue components in a temperature controlled cabinet.

## Cryogenic targets

(*W. Kellner, TRIUMF*)

A major activity of spring and summer running was to adapt the liquid  $^3\text{He}$  target for use in Expt. 785. It was necessary to make a target which could be inserted through the long, small-diameter central bore of the CHAOS spectrometer. In collaboration with the experimenters, this was done and the target operated successfully over a 10-week running period.

The  $\text{LH}_2$  target of Expt. 704, at the SASP target location, was operated four times over the year, a total running time of 8 weeks.

There were three major runs of the parity (Expt. 497)  $\text{LH}_2$  target in February, August and December/January amounting to 11 weeks in all. The A20 cryogenerator had only a small margin of excess cooling at the start of the February run, but ran without

significant loss of cooling power until the end of the run. In August, however, the initial cooling power was lower than in February and dropped below the minimum for stable target operation part way through the running period. Between August and December runs the cooling power was boosted by addition of two CTI cold heads to the He heat-exchange loop between cryogenerator and target, with an intensive effort of design, fabrication, assembly and testing. The added cooling power permitted operation of the A20 at reduced output and the system ran with no loss of cooling power through the December/January period.

## Technical Support group

(*C. Ballard, TRIUMF*)

The Science Division Technical Support group includes two subgroups to best serve the needs of the basic program, contributions to CERN, ISAC, and special projects. Six of the ten technicians of the group form the original Beam Lines group headed up by Bob Hilton. In 1997, this core of technicians (who worked together on the original beam lines at TRIUMF) has been involved in the design of the ISAC beam lines. Their combined knowledge of the manufacture and installation of magnets, services and vacuum systems is extensive. This knowledge coupled with a preventative maintenance program provided valuable insight into the design of ISAC systems. Some innovative examples that were incorporated (through liaison with the Design Office) were the G10 insulators on the magnet cooling systems, alignment and magnet adjustment techniques, stand installation methods, beam tube installation techniques, turbo pump stands and servicing methods, access of filter systems, header locations, methods for reducing dose levels for personnel involved in MRO and key information on the diagnostics and installation of dipoles, quadrupoles and vacuum systems. Much of the success of the group has been reported elsewhere such as the extraction of beam into the front end of 2A and the general MRO of existing channels and in experimental technical support and in the manufacture of the CERN magnets overseen by George Clark. The group continued to support the TISOL experiment with target production, alignment, mechanical MRO and design collaboration.

The balance of the group headed up by Eddie Knight was involved in the conceptual design and manufacture of mechanisms used in proton therapy and in experiments on beam line 4B. Experimental support was provided for Expt. 787, parity, Expt. 704 and strontium-82 production as well as support for CHAOS and  $\mu\text{SR}$  in the meson hall. General maintenance and upgrading was done on the separators in M15 and M20 such as window replacement and conditioning. An

innovative conceptual design of a beam line window which enables changing without any loss of beam time to other groups was developed and will be implemented in 1998. Further support was provided to Gary Wait in his CERN collaboration with the "Dummy Load". TR13 shielding blocks were designed to be able to sustain an experiment running at 50  $\mu$ A continuously. Improvements were made in the TNF water package to be able to reuse old TNF resin cans with a significant cost savings. A considerable amount of time was spent in the alignment of 2A head end, 2A tunnel, target hall and the RFQ. The target hall layout for the vacuum tank feet and formwork were done so the 5 ton steel blocks from Tennessee could be placed.

### Computing services

(C. Kost, TRIUMF)

#### Overview

The "third wave" (Pentium based machines) arrived in 1997. The "first wave" constituted the

VAX/VMS based machines of the 1980's, while the "second wave", based on the RISC architecture starting around 1990, crested this year and is expected to be overpowered by Pentium based machines in a time spanning just 2 years. Imagine what the "fourth wave" will be like! Thus, the migration to Pentium based machines, mostly running LINUX, formed the main thrust of this year's transitions. However, all did not go as smoothly as in previous years due to:

- changeover in a key staff member
- security concerns
- decreased reliability of vendor software,
- lack of proper vendor support and
- increased complexity of software management.

As a result, maintaining stability within the existing computing infrastructure will be a key challenge for 1998.

#### Hardware

Figure 87 shows the state of TRIUMF's computing

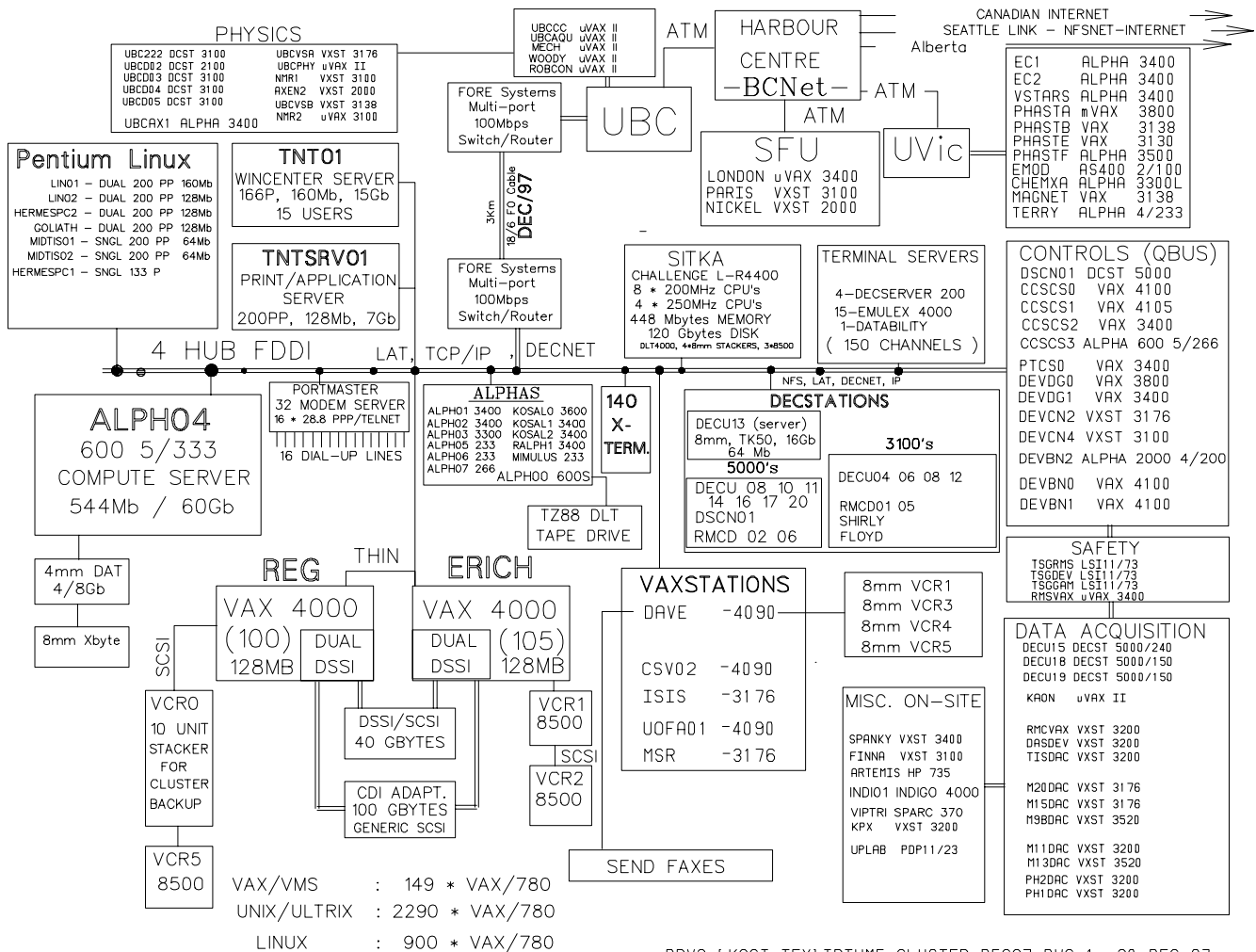


Fig. 87. TRIUMF computing facility.

facilities in December from Computing Services' point of view. After approximately 30 years of use, all accounts to the campus MTS system were closed down as UBC support of MTS will be withdrawn in early 1998. To continue the trend of previous years many of the ULTRIX based DECstations were phased out. Minimal support of this platform will be provided as the remainder dwindle over a number of years. The dual-4100 based VAX/VMS cluster remains a reliable, low-maintenance work-horse for many users, the only significant change being the addition of 40 Gbytes of disk space bringing the total to about 160 Gbytes.

The single ALPHA server alph04 (an ALPHA station 600 5/333), upgraded to 544 Mbytes of memory and having over 60 Gbytes of disk space, continues to provide the bulk of public UNIX support at TRIUMF. A 200 MHz Dual-Pentium Pro with 256 Mbytes of memory and 20 Gbytes of disk space, and running Redhat LINUX, was installed early in the year. With increasing software availability and as users became familiar with the LINUX world, the usage of this platform increased rapidly throughout 1997. This pace is expected to accelerate in 1998. The Windows NT platform is still a minor, although rapidly increasing factor.

Figure 88 shows our annual update for the growth of CPU power.

As in previous years, attendance at the HEPix meetings enabled us to share our computing experiences with other high energy physics labs (see URL [http://www.triumf.ca/hepix97/site\\_report.html](http://www.triumf.ca/hepix97/site_report.html)).

The Windows-NT server, running the Wincenter product which allows up to 15 simultaneous users on Xwindow terminals to run PC software, although still very popular, is showing some additional limitations as it becomes increasingly difficult to maintain stability with a constant stream of Microsoft upgrades and bug fixes. This is due to lack of product

robustness/compatibility largely attributable to the fact that both the operating system and application software were not designed to operate in a multi-display, multi-user environment. It is expected that Microsoft will provide integrated X-support for their NT platform in 1998/99. The use of "thin-PC's" supporting Xwindows (so-called NetPCs) is likely to provide more choices for 1998.

Of the over 700 devices connected to TRIUMF's LAN some 50 VXT and 140 NCD are Xwindow terminals. Due to their wide use in the controls environment, PC support has traditionally been provided by the Electronics Services group. With PC's becoming more powerful/cheaper there is a clear trend, in the general user community, to once again purchase them over X-terminals in spite of their increased management costs. This has strained both the traditional support group and our Computing Services group which, of necessity, is taking a more "centralized" support model for PC's. Thus their management will be largely down-loaded to the end-user, with the result that the overall scientific productivity is likely to suffer.

An Apple 7300/180 with 80 Mb of memory was purchased to accommodate those using this format at the PAC'97 conference. As a result of its stability, productivity, and simplified software management, and our experience with this relatively rare (at TRIUMF) platform, some others have started purchasing them instead of PC's.

### LAN

The local-area network, with its fibre-base FDDI backbone has proven to be quite stable. The site will slowly migrate to 10baseT/100BaseT as demand grows.

### Telecommuting

Offsite access to TRIUMF from home continues to grow at a modest pace. This may change rapidly as local cable and telephone companies introduce high speed access at reasonable rates.

### ISAC and the internet

A fifth "spoke" in TRIUMF's FDDI ring was purchased to facilitate both an upgraded internet link to UBC and the planned ISAC local area network.

In 1997 we needed to address two requirements to modify our site network and its link to the outside:

- to install the connection and routing capability to use the newly installed fibre link from UBC to our site to its full potential.
- to provide the network infrastructure for the ISAC facility.

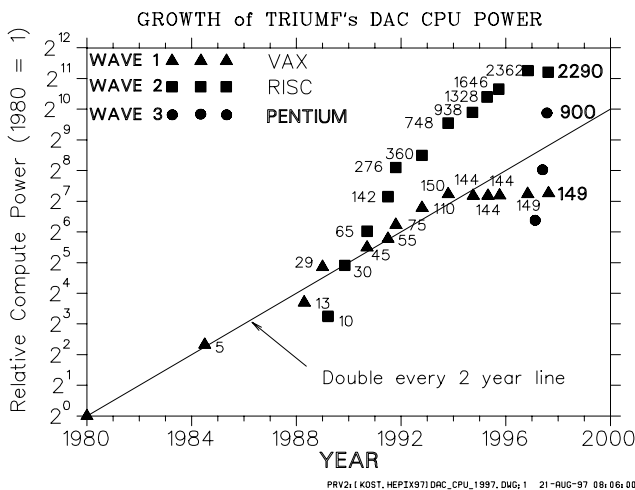


Fig. 88. DAC computing growth.

After studying various options, a cost-effective coherent solution was chosen which met both these requirements. It takes advantage of current 100baseT technology used in our new fibre link from UBC, is readily adapted to accommodate our existing FDDI network, and is scalable to the needs of ISAC as it comes into operation as well as new demands from the rest of the site.

This solution is based on the PowerHub 7000 from Fore Systems, the same equipment used to serve the rest of the UBC network. Some of the reasons for choosing Fore are:

- UBC has several of the Fore PowerHubs in place already and we can share expertise and support.
- provides the technical functions to connect to the new fibre and allow high speed switching (100baseT) connectivity on site.
- scalable – expansion capability can be purchased as needed.

The initial configuration, being commissioned in a temporary location in the main office building, consists of the PowerHub 7000 with various modules to connect it to the internet, the rest of TRIUMF and basic services for ISAC. When cable and fibre services in the new building are ready it will be installed there in 1998, and currently planned expansion will provide services to ISAC controls and data acquisition areas.

Figure 89 shows the planned configuration, set for completion in 1998.

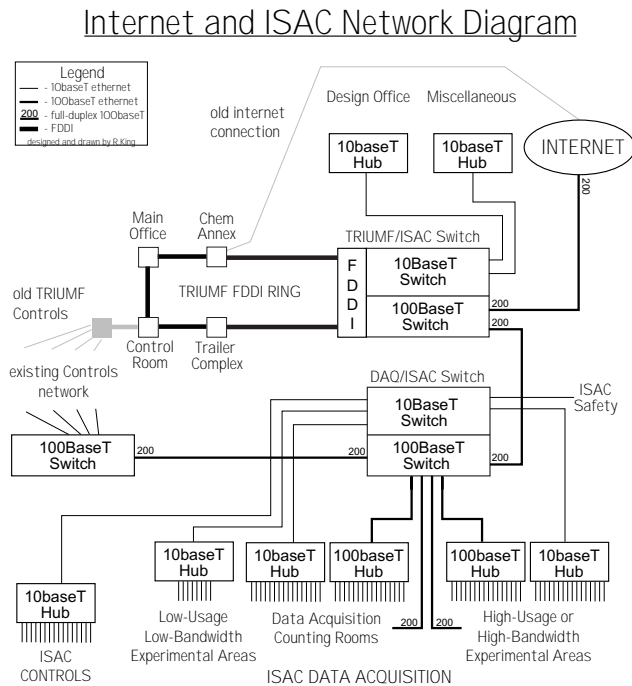


Fig. 89. Internet and ISAC network.

## WAN

In April, CA\*net folded as a provider of internet backbone services in Canada. It was replaced by a commercial service provider. Bell Advanced Communications established the Bell Internet Transit Service (ITS) for Canadian Internet Service Providers to access the internet at Canadian points of presence. (See <http://www.bacits.bell.ca>.) The points of presence (POP) are located in Vancouver, Calgary, Regina, Winnipeg, Toronto, Montreal, Fredericton, Halifax, St. John and Charlottetown – special arrangements provide access to Yellowknife and Whitehorse. This ITS network utilizes BAC's ATM Network Services. BCnet and most other regional providers chose to go with this new arrangement while the Quebec universities chose a different provider. Connections to international partners were either extremely good or extremely bad depending on what provider is used by the international partners. To improve connections to some of our most important partners in the HEP world, HEPcan uses an NSERC grant to fund private connections. Since the end of December, HEPcan is supporting one tenth of the costs of a dedicated link between CERN and the US and one half of the costs of a dedicated link between Montreal and Princeton for connection to ESnet (US DOE labs). Connection to DESY remains poor. Connection to KEK has been good since September.

In 1997, the federal government continued funding CA\*net II (see <http://www.canarie.ca/>). CA\*net II is a CANARIE partnership of Canada's leading universities, research institutions, industry and carriers. The CA\*net II initiative closely parallels the US NGI (next generation internet) and Internet 2 initiatives. CA\*net II will connect up to 13 GigaPOP's with a high performance IP/ATM network which in turn will connect most of Canada's major universities and research institutions through regional advanced networks (RAN)s. UBC has just been connected to the GigaPOP in Vancouver. CA\*net II is connecting to international high speed networks in Chicago at the STAR TAP. At this moment, ESnet is also connecting there but our European partners are not.

## Image processing station

The image processing station, described in last year's Annual Report, has proven very popular. Limiting access to times when assistance could be provided has constrained its usage, although this also assured reliability. The local colour inkjet printer was upgraded to a higher resolution/speed, while a 600 dpi colour Lexmark 1275 laser printer, purchased through a shared arrangement with the accounting department, was added to the network for the speedier production

of overhead transparencies. The 133 MHz Pentium, with 128 Mbytes of memory will need to be substantially upgraded as user requirements continue to become ever more demanding.

## Software developments

### GEANT4

Two members of our group were active participants in the GEANT4 international collaboration, aimed at creating a detector simulation tool kit for the next generation of HEP experiments. Their efforts were mainly directed to the development of low and medium energy hadron physics process and cross section classes. Detailed elsewhere in this report is TRIUMF's significant, and very visible contribution to this high profile, leading edge programming project. This commitment will be maintained for at least another year. Thereafter efforts will be diverted more towards applying this valuable tool than to its development.

### Supported platforms

The number of machines and operating systems supported by our group continues to grow, creating significant challenges in the areas of software porting, code management, software packaging and distribution. This year CVS-based source-code management was implemented for a number of the larger packages. The increased popularity of LINUX prompted a major effort towards porting PHYSICA, GPLOT, EDGR and some other popular programs to this environment, utilizing the g77 and gcc compilers. The GPLOT library was also compiled and made available for users of Absoft Fortran. The list of supported platforms follows:

DEC ALPHA (Digital UNIX)	DEC ALPHA (VMS)
DECStation (ULTRIX)	DEC VAX (VMS)
SGI (IRIX)	INTEL (LINUX)
HP (HP-UX)	IBM (AIX)
SUN (SUNOS)	SUN (Solaris)

### RELAX3D, ACCSIM ...

To satisfy user community demands, a major upgrade (scheduled for release in 1998) was undertaken for the 3-D Laplace/Poisson solver RELAX3D, including the addition of a Tcl/Tk based graphical user interface based on a unique process communications package called "Expect". Together with improved problem set-up facilities, the interface streamlined the use of RELAX3D and particularly enhanced the visualization and interpretations of results through either the built-in plotting package or links to external visualization programs such as MATLAB. A paper and poster on this work was submitted to the 1997 Particle Accelerator Conference (PAC'97).

The development of ACCSIM, a multiparticle tracking and simulation code, (details reported in the CERN Collaboration section of this Annual Report) continued at a level of 0.2 FTE. There was also some collaborative work with BNL, in support of the accumulator ring studies for the US National Spallation Neutron Source, and at KEK, where simulations were developed for the booster ring of the Japanese Hadron Facility. A review paper and poster on ACCSIM was submitted to PAC'97.

A number of TRIUMF-developed programs, INTRAN, PHYSICA, EDGR, ACCSIM, and RELAX3D were demonstrated by members of our group at PAC'97.

### WWW

Our group continued to provide software management services for TRIUMF's main Web server, and to provide consultation and coordination with the many contributors providing content for our Web site. The growth in server content and usage continued unabated, with over 10,000 hits per day by the end of 1997. It is hoped that, with improved optic-fibre links (running at 100 Mb/s) and the advent of Internet-2/Canet-2, improved connectivity to other HEP sites will take place in 1998.

Two "live" cameras, updating images every five minutes, allowed interested parties world-wide to view the construction (both interior and exterior) of the ISAC facility via the URL [http://www.triumf.ca/web1\\_advax/ISAC-current.html](http://www.triumf.ca/web1_advax/ISAC-current.html).

### Security

The DLT drive provided reliable backup to over 30 computers. However, no such centralized service is as yet provided for the many PC/Windows systems. As the year came to a close a number of computers (mostly SUN and LINUX systems) were found to be compromised (by users external to the TRIUMF site). The open computing environment that the TRIUMF community has been accustomed to may need to be radically altered in the near future. As more "hostile" users connect to the world internet, some important programming projects may need to be delayed in order to deal with what is rapidly becoming a global epidemic of unauthorized usage of computing/telecommunication resources.

### Summary

Migration away from the traditional (software/hardware integrated) vendor based computing environment continues to be both challenging and exciting. The question for 1998 is "Will these non-integrated vendors deliver reliable hardware and software"?

## Data acquisition systems

(*R. Poutissou, TRIUMF*)

### Overview

During 1997, the Data Acquisition group continued to maintain the standard VMS VDACS/ $\mu$ SR data acquisition systems and the special RMC data acquisition system while the new MIDAS system became operational on CHAOS and TRINAT DAQ systems.

### MIDAS software

In the first half of the year, the MIDAS data acquisition system was heavily tested on a variety of different computer platforms as well as used in small test labs. Based on this work, a list of improvements was established. In order to address them, Dr. Stefan Ritt, main author of MIDAS, was invited to spend some time at TRIUMF. The collaborative work was very fruitful. Almost all of the desired improvements were implemented which gave birth to a first release and distribution of the MIDAS package. The improvements included in particular: a security option, front-end ring buffer, front-end interrupt handling and transfer speed increase.

Besides these main tasks, several aspects of the package were revisited in order to simplify its use like: package installation, monitoring tools and user code interface. MIDAS is currently distributed under version 1.03. The CHAOS group used MIDAS for their entire beam time without problem and several user specific applications were developed. Goals established last year regarding MIDAS operation under other operating systems have been reached i.e.: VMS and MS-DOS MIDAS front-ends, MIDAS + PAW under NT and Linux and stand-alone data acquisition with CAMAC under NT have been installed and successfully tested. Complete MIDAS documentation is currently under construction. Other projects have been carried out such as: a CAMAC driver for Linux systems using the DSP004, Kinetics 2926 and 2927 CAMAC PC interfaces, DMA studies under VxWorks, and Tcl/Tk run control application.

### NOVA software

Various minor but significant improvements to the NOVA analysis system have been implemented during the past 12 months. The XWindows display package continues to evolve – colour displays are now implemented for 2-D histograms, which are particularly useful for TRINAT experiments. The hard copy printer drivers have been upgraded to directly support postscript and data compression (resulting in a substantial decrease in the time required to generate a hard copy of a plot). In addition, a preliminary version of a TCL interface for NOVA has been imple-

mented. An ASCII file input event driver has been implemented, allowing Monte Carlo generated data to be analyzed using NOVA.

All NOVA-based experiments at TRIUMF are now using version 2.0 of the program. Because of various incompatibilities in (and rapid evolution of) the MIDAS system, the parity experiment had been the single experiment which was still using the old version of NOVA. MIDAS has now stabilized to the point where it was possible to upgrade all of the parity software to the latest version of NOVA.

### $\mu$ SR systems

A new 8 channel VME-based TDC V680 with a maximum resolution of 49 ps and a jitter less than 200 ps plus timer base jitter was purchased from BIRA/Highland. Concerted efforts of  $\mu$ SR experts and DAS personnel made it possible to test successfully a prototype system on M20 last fall. The timing histograms are built in the memory of our standard MVME023 CPU running VxWorks. The CPU also controls the TDC. This type of TDC will replace the old LeCroy 4204 TDC's and CES HM21612 histogramming memories. LeCroy no longer produces or services this type of TDC. The intention is to equip M15, M20 and M9B with such TDC's in the coming year.

Since front-ends of M15 and M20 had been moved last year to VME based CPU's connected via Ethernet, it became possible to use non-QBUS VMS machines as host. M15DAC and M20DAC were upgraded from VAX 3520s to 3100/76 VAX stations to double the CPU power. The change was relatively simple due to the similarity of the hardware. The 3520s were then available to upgrade M9BDAC and M13DAC from 3100s. This was done, but turned out to be very time consuming.

A driver for a new instrument (Lakeshore 450 Gaussmeter) was written and used by  $\mu$ SR, as were minor additions to an existing driver (for Group3 Digital Teslameter).

### Support for FASTBUS

The software support for reading out FASTBUS TDC1877 modules for Expt. 614 was completed and tested for the first time during the prototype chambers beam tests in August. The readout system used a Struck SFI FASTBUS card with a MVME-162 CPU running VxWorks and MIDAS as the DAQ software.

### Support for SNO

The TRIUMF DAQ group has provided considerable assistance to the SNO DAQ effort in preparation for turn on of the experiment. During the summer and fall of 1997, Peter Green implemented an Ethernet driver to connect a VME-based embedded CPU

(located underground) to the main DAQ computer on the surface. In addition, he provided considerable assistance in implementing and debugging the main event switchyard (dispatcher) which is responsible for distribution of raw event information to a heterogeneous collection of analysis computers (Sun, DEC ALPHA and Macintosh) which are primarily responsible for real-time analysis and monitoring of the SNO data stream. Both of these pieces of software have been implemented and demonstrated to operate reliably.

#### Custom hardware

Andrew Daviel worked on the design and specification of a system to improve the signal/noise of UTC data for the rare kaon decay experiment (Expt. 787) at BNL. The system consists of a number of complex programmable logic elements implemented in Altera FPGA's and designed to interface with commercial FASTBUS TDC units.

#### Scientific services

(*M. Comyn, TRIUMF*)

The Scientific Services group, created at the end of 1995, is responsible for the Information Office, Publications Office, Library and Conferences.

#### Information office

The year began with the launch of the TRIUMF Welcome Page, which is accessible directly at <http://www.triumf.ca/welcome> or via the TRIUMF WWW Home Page. The series of WWW pages were developed by two co-op students over the preceding eight months. 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 site received over 5,000 visits during the first year. The Information Office responds to any questions posed by visitors to the site.

The Information Office coordinated tours for 2,604 people during 1997, requiring 306 tour guides. The majority of public tours were conducted by a summer student during the May–August period when tours were offered twice a day.

Both the 1995–96 and 1996–97 TRIUMF Annual Financial & Administrative Reports were published during the year. In addition, new public relations material was developed and published.

#### Conferences

During 1997 support was provided for the following conferences and workshops.

- Workshop on Experiments and Equipment at Isotope Separators (WEEIS), Harrison Hot Springs Hotel, April 26–29.

- 1997 Particle Accelerator Conference (PAC'97), Hotel Vancouver, May 12–16.

This conference constituted the major workload for the Scientific Services group, throughout the year, in all areas.

- Seventh International Symposium on Meson-Nucleon Physics and the Structure of the Nucleon (MENU'97), UBC, July 28–August 1.

- 1997 Fall Meeting of the Division of Nuclear Physics of the American Physical Society (DNP'97), Chateau Whistler, October 5–8.

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

- HERMES collaboration meeting, TRIUMF, February 9–13, 1998.

- 35<sup>th</sup> Western Regional Nuclear and Particle Physics Conference (WRNPPC'98), Chateau Lake Louise, Alberta, February 13–15, 1998.

- Workshop on Accelerator Operations (WAO'98), TRIUMF, May 18–22, 1998.

- XXIX International Conference on High Energy Physics (ICHEP'98), UBC, July 23–29, 1998.

- 7<sup>th</sup> Annual Meeting of the Canadian Chapter of the International Isotope Society, UBC, May 20–21, 1999.

- 14<sup>th</sup> International Conference on Electromagnetic Isotope Separators and Techniques Related to their Applications (EMIS-14), 2001.

#### Publications office

TRIUMF preprints are now produced electronically, wherever possible, and posted on the WWW at <http://www.triumf.ca/publications/home.html> to allow immediate dissemination of the publications. This has replaced the traditional distribution of paper copies by mail and the preprint mailing list has been substantially reduced, resulting in significant cost savings.

This TRIUMF Annual Report Scientific Activities has been produced totally electronically, extending efforts of the previous two years. It will be available on the WWW at <http://www.triumf.ca/annrep> in a number of formats. The annual report mailing list has also been reduced and the trend is expected to continue

as people become more accustomed to accessing the information over the WWW.

Producing the PAC'97 conference proceedings constituted the major workload for the Publications Office in 1997. The proceedings will be published in three paper volumes and also on a single CD-ROM. In addition, the MENU'97 conference proceedings were published and assistance was given for the publication of the WEEIS workshop proceedings.

### Library

Faced with declining budgets and increasing journal subscription costs, the Library had to cancel several subscriptions and curtail all book purchases. Studies were started to analyze the effects of further journal cancellations in 1998.

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

### Sudbury Neutrino Observatory

(*R. Helmer, TRIUMF*)

During the past year, TRIUMF has continued to provide valuable infrastructure support for SNO. The main contribution has been providing space and technical support for testing two of the major components of the electronics chain. Test stands for both the motherboard and the photomultiplier interface card testing were set up in the Mesa area. The test stands were provided by SNO institutions and the testing was carried out mostly by collaboration members, but some of the testing was done by TRIUMF technical staff, and a great deal of support was provided in the form of power supplies, oscilloscopes, printers, internet access, and so on.

Several other components of the electronics chain were fabricated in the electronics shop. All of the trigger cables, about half of the paddle cards which provide the interface between the PMTs and the rest of the electronics, and half of the backplanes for the electronics crates were put together by shop personnel. Much valuable advice during the electronics testing was also provided free of charge.

About \$23,000 worth of NIM electronics was loaned to the water group to help with setting up a test stand for water assay analysis.

A spooling device for controlling a water sampling tube that can be deployed throughout the SNO detector was designed in the Design Office, and it is being fabricated in a local machine shop under TRIUMF supervision. It will be assembled by beam lines personnel in the near future.

Fabrication of various parts for the universal interface between the acrylic vessel and the glove box, built at TRIUMF last year, was also carried out in a local shop, again under TRIUMF supervision.

Finally, the umbilical storage device, designed and built at TRIUMF last year, was returned for some modifications. It had been found that the device would not wind up the umbilical and at the same time maintain a low enough tension in it. A motor drive was added to the last pulley and this solved the problem. The work was carried out by the Beam Lines group.

### Construction of the BaBar drift chamber

(*C. Hearty, UBC*)

#### Introduction

BaBar is an experiment to study the violation of charge/parity (CP) symmetry in the decay of  $B$  mesons at the PEP-II, the "B factory" currently under construction at the Stanford Linear Accelerator Center. The Canadian hardware contribution to BaBar is the construction of the drift chamber at TRIUMF. The assembly, alignment and stringing of the chamber was successfully completed during 1997 with the help of significant infrastructure support from TRIUMF. The support included the upgrading of a large clean room; engineering, design, technician and machining support; and 50% salary support for the stringing crew.

#### CP violation physics with BaBar

The observation that the universe is composed almost exclusively of matter is the strongest indication that the laws of physics are not symmetric between matter and antimatter. By extension, CP is not a perfect symmetry. The standard model allows for CP violation, and it was first observed in the decays of kaons in 1964. However, there are strong motives for studying CP violation with  $B$  mesons. Not only will new measurements provide better measurements of the underlying parameters of the standard model, the asymmetries – if the standard model is correct – could be as much as 100 times larger than that observed with kaons.

#### The PEP-II collider

The unique features of PEP-II are its asymmetric beam energies, which are necessary to separate the decays of the two  $B$  mesons, and its high luminosity. It will be a two ring  $e^+e^-$  collider operating at the  $\Upsilon(4S)$  resonance, with the low energy ring (3.1 GeV  $e^+$ ) installed in the same tunnel as the high energy ring (9 GeV  $e^-$ ). The centre of mass moves at approximately half the speed of light in the laboratory frame.

The high luminosity is achieved by having 1658 bunches separated by 4.2 ns, for a total current of 2.14 A of  $e^+$  and 0.98 A of  $e^-$ . The peak luminosity of  $3 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ , combined with a nine-month run per year and reasonably high operating efficiency, is expected to produce  $30 \text{ fb}^{-1}/\text{year}$ , or  $15 \times 10^6 B^0\bar{B}^0$ .

The high energy ring started commissioning on May 31, while the low energy ring is scheduled to start commissioning in spring of 1998. The first physics run with the BaBar detector will begin in early 1999.

### The BaBar detector

BaBar must be able to reconstruct  $B$  mesons, particularly decays of interest for CP violation; measure the time between decays of the  $B^0$ 's, which corresponds to a distance of  $235 \mu$  on average; and identify the nature of the other  $B$  in the event ( $B^0$  or  $\bar{B}^0$ ) with good efficiency.

BaBar includes four detector subsystems located within a 1.5 T superconducting solenoid: the silicon vertex tracker (SVT) constructed from doubled sided silicon strips; a low mass drift chamber; a Čerenkov-ring-imaging particle identification system (the DIRC); and a thallium-doped CsI calorimeter. The flux return beyond the solenoid is instrumented with resistive plate chambers to create a muon identification system and a crude hadronic calorimeter, particularly for detecting  $K_L$  interactions (Fig. 90).

The SVT determines not only the decay vertices of the two  $B$  mesons, but also the angles of the charged tracks. The primary functions of the drift chamber (DC) are the measurement of transverse momentum of charged particles, the reconstruction of charged tracks from the decay of neutral hadrons within the DC volume, and the provision – together with the calorimeter – of the event trigger.  $dE/dx$  in the drift chamber is used to identify charged tracks at low momentum and in the forward and backward angular regions not covered by the particle identification system.

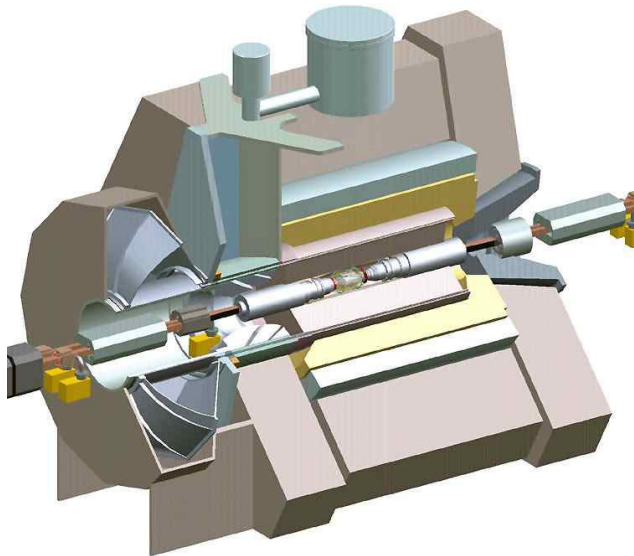


Fig. 90. The BaBar detector, which will measure CP violation in  $B$  mesons at the SLAC PEP-II collider.

The DIRC is designed to distinguish different types of charged hadrons, an important feature in CP violation physics. It is a unique device that relies on the capture of the Čerenkov light by internal reflection in quartz bars. The light cone is reconstructed in a large array of photomultiplier tubes located in a water tank.

The principal function of the CsI (thallium doped) calorimeter is photon resolution and detection, crucial for reconstructing  $B$  decays – there are an average of 11 photons per  $B^0\bar{B}^0$  decay.

### Drift chamber construction

The drift chamber under construction at TRIUMF is essentially cylindrical in appearance, approximately 1.8 m in diameter and 2.8 m long. It is a “small cell” design, where each  $\sim 18 \text{ mm} \times \sim 12 \text{ mm}$  cell consists of an anode wire ( $20 \mu$  gold-coated tungsten) surrounded by a hexagonal array of cathode wires ( $80 \mu$  or  $120 \mu$  gold-coated aluminum). A total of 7104 cells – 28768 wires – are arranged into 40 layers.

In keeping with the goal of minimizing material, the inner cylinder is 1 mm thick beryllium in the acceptance region of the detector and the gas is 80% helium, 20% isobutane. The outer cylinder is a carbon-fibre/nomex sandwich which supports 60% of the wire load and provides protection against impact. The design is somewhat asymmetric: the rear endplate, where the readout electronics are mounted, is 24 mm thick aluminum, while the forward endplate is only 12 mm at angles above 250 mrad.

A resolution per cell of 100–150  $\mu$  was achieved in an earlier prototype. The transverse momentum resolution, which is dominated by multiple scattering, is approximately 0.3%. The  $B^0$  mass resolution depends on the final state, but is  $\sim 22 \text{ MeV}/c^2$  for  $B^0 \rightarrow \pi^+\pi^-$ .

The chamber was strung horizontally, by two crews per shift, two shifts per day. A crew consisted of two stringers plus one robot, supplied by Italian collaborators. The robot reduced the risk of having people work within the detector volume during stringing and improved cleanliness (Fig. 91). Stringing started on August 18 and took 15 weeks to complete.

There were three quality control shifts per day, during which the tensions of wires were measured and the assembly visually inspected. Overall, approximately 0.4% of wires were rejected and restrung. The tension of each wire has been measured twice more to ensure that it has remained within specification.

After the completion of stringing, 19 wires were extracted and replaced by rotating the chamber to the vertical. The outer cylinder was then installed. The chamber was found to be helium-tight (leak rate of approximately 100 cc/min) after very little work.

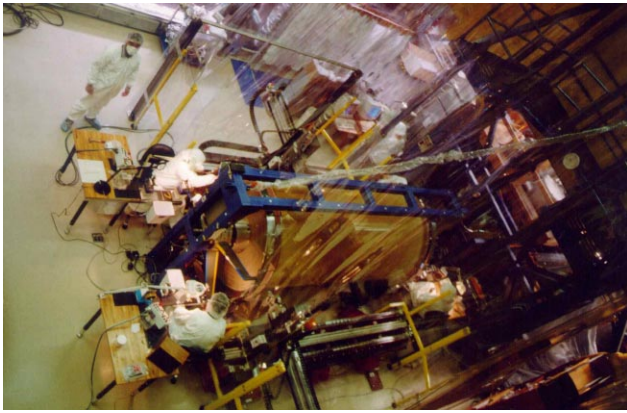


Fig. 91. The BaBar drift chamber being strung with the assistance of robots at TRIUMF.

Upon completion of HV testing, the DC is to be shipped to SLAC in March, 1998, where readout electronics are to be installed and tested, then installed into the detector in August, 1998.

Scientific personnel involved with the construction of the BaBar drift chamber at TRIUMF:

C. Hearty, M. Kelsey, J. McKenna (UBC); K.W. Edwards, D. Karlen (Carleton) P. Bloom, P.M. Patel, J. Trischuk (McGill); A. Hasan, J.-P. Martin, R. Seitz, P. Taras, V. Zacek (Montreal); R. Henderson (TRIUMF); A. DeSilva, R. Kowalewski, M. Roney (Victoria).

### Low temperature nuclear orientation (LTNO) at ISAC

(P.P.J. Delheij, TRIUMF)

A number of discussions took place regarding nuclear orientation studies at ISAC. The result was that several proposals from Oregon State Univ. for nuclear structure studies and from the Univ. of British Columbia for condensed matter experiments were approved by the EEC. In the nuclear structure area (OSU) the determination of the  $E0$  component in the gamma-ray transitions of  $^{182}\text{Pt}$  and  $^{186}\text{Pt}$  for investigation of shape coexistence was encouraged. Furthermore, measurements of ground state moments in the mass 100 region were strongly endorsed to test f.e. shell model calculations. Properties of magnetic multilayers (UBC) will be investigated with  $^{91}\text{Rb}$  and  $^{61}\text{Zn}$ .

In connection with these developments DOE approved the transfer of the UNISOR nuclear orientation set-up from ORNL to TRIUMF. Contacts with Oxford Instruments and ORNL have been established to disassemble and ship the set-up. A location is assigned in the layout plan for the ISAC hall. Figure 92 gives a schematic impression of the set-up. Resources are committed to install and commission the set-up in the ISAC hall in 1998.

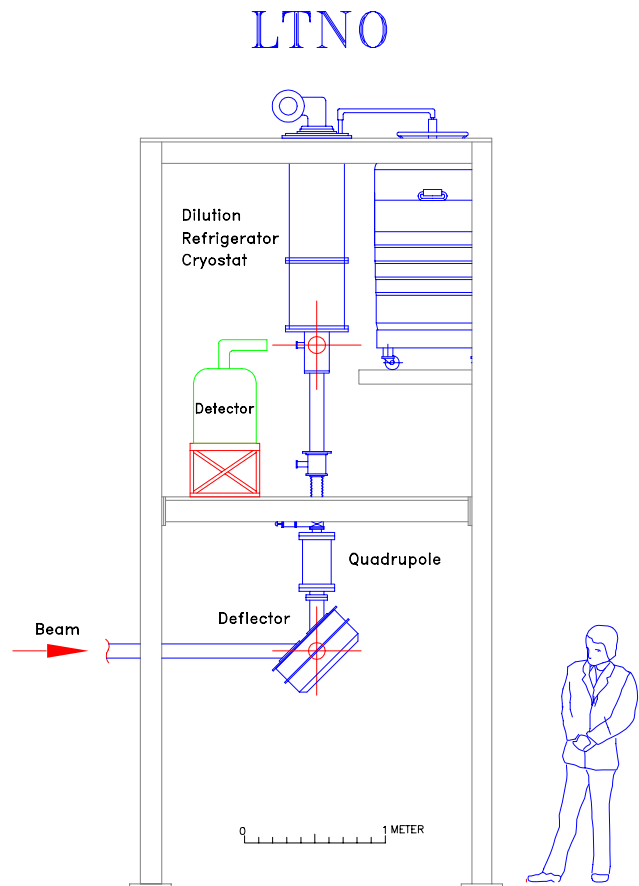


Fig. 92. The LTNO set-up viewed from the side.

### The DRAGON facility

(J. D'Auria, SFU)

#### Introduction

One of the primary areas of research to be pursued at the new ISAC facility is nuclear astrophysics and nucleosynthesis. This unique ISOL based, accelerated radioactive beams facility will provide a wide range of high intensity, low energy (variable from 0.15–1.5 MeV/mass unit) beams with low masses ( $A < 30$ ), ideally suited to study low energy fusion reactions, such as radiative proton and alpha capture, in inverse kinematics. Such reactions involving radioactive reactants play a crucial role in determining the dynamics and consequences of explosive events in the universe which occur under conditions of extreme density and temperature.

#### The science

It is believed that given the relatively higher temperatures occurring in explosive phenomena along with higher hydrogen and helium densities, radiative proton and alpha capture reactions can occur with radioactive species. In order to prove this and indeed to

obtain quantitative confirmation, it is critically important to measure rates of key reactions believed to play a role in the various paths to the production of heavy elements. These new paths generally follow along the  $Z = N$  line of stability, and in its earliest stages involve, in particular, species of masses in the range of  $A < 30$ . Of particular importance is the need to measure the resonance strengths of such reactions at the appropriate energies, which generally lie in the range from 0.15 to 1.5 MeV/u. While details of specific reactions proposed to be performed at ISAC can be found in experimental proposals presented to the TRIUMF EEC in July, one of the most important reactions is the radiative alpha capture on  $^{15}\text{O}$  (Expt. 813). This reaction is believed to be the key which leads to the break out of the so-called hot CNO cycle leading to the rp-process (rapid proton capture). The viability of this proposed new path to heavy element production is critically dependent on whether this reaction does occur to any significant extent. The expected resonance strength of this reaction is believed to be very small and in addition the energy of the key resonance is very low. This combination makes this important study an experimental challenge. At present it is believed that the first study to be pursued will be proton capture on  $^{21}\text{Na}$  (Expt. 824).

### The facility

A necessary component in such studies is a recoil mass separator of high efficiency and high background rejection since the reactions of interest generally have low cross sections. Such facilities are rare in the world and it was decided to design a facility optimized to perform such studies and matched in quality and capability to the new world class ISAC facility. Over the last three years funds were provided by NSERC to develop a conceptual design of the new recoil mass separator detection facility, now called the DRAGON (detector of recoils and gammas of nuclear reactions). The Recoil group was established to implement this charge and in the process selected experts from around the world contributed either on individual visits or in one of several workshops. In 1997 plans were scrutinized by the participants of the TRIUMF WEEIS workshop held at Harrison Hot Springs (described elsewhere in this Annual Report) and as well by a special technical review panel organized by TRIUMF itself. A Major Installation Grant proposal was submitted to NSERC for funding of the DRAGON.

DRAGON consists of an extended gaseous target (presently under construction) to receive the incident radioactive beam. Reaction products and beam particles will both move essentially in the same forward cone into the electromagnetic separator. The purpose of this multi-stage separator is to separate beam

### The DRAGON Facility

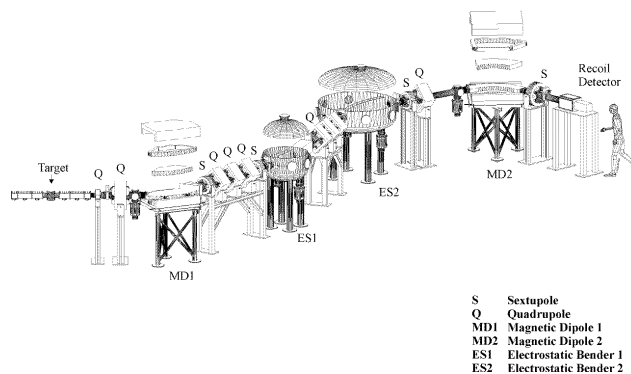


Fig. 93. Proposed DRAGON facility.

particles from the desired recoils with a very high separation factor ( $10^{10}$  to  $10^{15}$ ) and pass the latter efficiently to the recoil heavy ion detection system at the end. This detection station will consist of an initial time-of-flight detector followed by a very thin window, ionization chamber to measure the energy of the recoils. Figure 93 displays an overall perspective representation of the proposed DRAGON facility. In the second phase of the facility, it is planned to surround the gas target with a gamma array to utilize the prompt reaction gamma ray to further reduce effects of background.

It is anticipated that this facility will be available for commissioning in the spring of 2000 assuming that appropriate funding is secured in April, 1998.

### Design of a gamma array for ISAC DRAGON (J.G. Rogers, TRIUMF)

A segmented gamma-ray detector is being developed for use as part of the ISAC DRAGON facility on the high energy beam line [D'Auria *et al.*, Nucl. Phys. **A621**, 599c (1997); Rogers *et al.*, Bull. Am. Phys. Soc. Ser. II, **42**, 1681 (1997)]. The detector will operate in coincidence with the recoil particle detector, which detects the recoiling nucleus from the gas target. The segmentation of the gamma-ray detector permits it to measure three-dimensional gamma-ray interaction position in addition to the usual measurements of energy and time. The detector will be constructed from long fingers of scintillator crystals packed together in a three-dimensional array surrounding the target. One element of the array is shown in Fig. 94. The fingers are coupled on one end through a glass plate to an array of 19 photomultiplier tubes (PMT's). The other ends of the fingers form a pixelated hexagon through which the gamma-rays enter the detector. The PMT array encodes the position of the finger receiving the gamma-ray. The gas target would be at the centre of

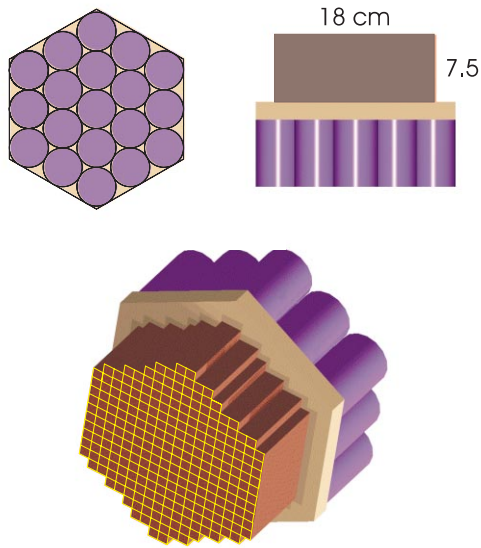


Fig. 94. Schematic representation of one module of proposed gamma array using LSO scintillator.

a regular octahedron formed by 8 hexagonal elements, as shown in Fig. 95.

The encoding of gamma-ray position is useful for several purposes: it provides a measurement of gamma-ray emission angle, which permits correction for the Doppler shift in the energy of the emerging recoil, thus improving the overall energy resolution of the experiment; it permits position-dependent correction of the light collection from the scintillator, thus improving the gamma-ray energy resolution of the large block detectors; and finally, it provides the capability of

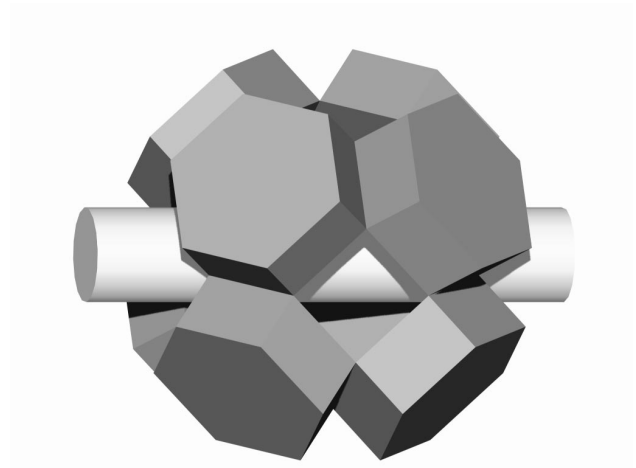


Fig. 95. Schematic representation of one type of gamma array, positioned around the gas target of the DRAGON facility.

rejecting room background gamma-rays based on the spatial pattern of light distribution among the scintillator fingers. This last point may be important for radioactive beam experiments because 0.511 MeV gamma-rays will pile up to masquerade as a capture gamma-ray, and the 0.511's can be largely rejected based on event-by-event position distribution.

An attractive choice being considered for the scintillator material is lutetium oxyorthosilicate (LSO), which has the high density of BGO, but also combined with fast timing and high light output. The present design effort focuses on predicting the detailed performance of one hexagonal element, such as shown in Fig. 94, using GEANT Monte Carlo simulation.