# TRIUMF

# ANNUAL REPORT
# SCIENTIFIC ACTIVITIES
# 2001

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
McMASTER UNIVERSITY
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 2002

*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.*

# SCIENCE DIVISION

## INTRODUCTION AND OVERVIEW

2001 will be remembered at TRIUMF as one of the most successful years in terms of scientific achievements.

The major investments of the last 5 years at ISAC have paid off and both the low energy program and the nuclear astrophysics program with accelerated radioactive beams have produced significant publications. Two other major efforts in particle physics also produced new results; one at TRIUMF with the publication of final results from the parity experiment, the other at the AGS at Brookhaven with the publication of the discovery of a second event from the rare decay $K^+ \to \pi^+ \nu \bar{\nu}$. Finally, one should also acknowledge the major success of the TWIST experiment which took its first data with a complete detector.

Overall, the Science Division reaped the benefits of long years of dedicated effort by TRIUMF staff and collaborators from participating universities.

In ISAC, the low energy part of the program used a large fraction of the beam time in the spring/summer schedule while we were completing and commissioning the facilities using accelerated beams.

The effort connected with our studies of pure Fermi transitions focused this year on determining the contribution of non-analogue transitions to the decay of $^{74}$Rb. The first experiment showed that the superallowed branch was the dominant (>99%) transition. In a second experiment, the transition strength for the non-analogue $O^+ \to O^+$ transition was measured to be less than $3 \times 10^{-4}$. Now that the $8\pi$ spectrometer has been recommissioned at ISAC, further studies of the detailed decay scheme will be undertaken.

The low temperature nuclear orientation (LTNO) set-up was used to study the ground state magnetic dipole moment of heavy odd-$A$ Ga isotopes. In a preliminary run, a 15% $\beta$-asymmetry was observed for $^{75}$Ga.

The TRINAT group has continued the analysis of data taken in late 2000 on the $\beta - \nu$ correlation in the decay of $^{38\mathrm{m}}$K atoms trapped by lasers. A preliminary result was given at several conferences and a ~0.2% final result is expected soon. Also, considerable progress was achieved in establishing methods to polarize trapped potassium atoms (both stable $^{41}$K and $^{37}$K); >99% polarization was achieved for stable $^{41}$K and should be possible for $^{37}$K. Methods for measuring the absolute value of polarization were also developed.

A major success was achieved with the $\beta$-NMR facility. A large polarization for a $^{8}$Li beam was demonstrated (>70%) and maintained during a week-long data-taking run in which a well-focused $^{8}$Li beam was decelerated to less than 1 keV and implanted in pure metallic thin films and in insulator layers in a 3 T magnetic field. The large investment in the polarizer and $\beta$-NMR facility is starting to produce interesting physics results.

Also in the low energy area, considerable progress was made to mount two experiments from Osaka University groups. One will study neutron emitting states populated in the $\beta$-decay of $^{11}\vec{\mathrm{Li}}$ using polarization as a tool to obtain the spin of the decaying states in $^{11}$Be (Expt. 903). The other experiment is studying alignment correlation parameters in $^{20}$Na to extract information on second-class current and meson exchange contributions (Expt. 871).

The beam line to the $8\pi$ spectrometer has been built and partially commissioned, allowing us to start scheduling experiments in the summer of 2002.

By the summer of 2001, the ISAC accelerator system was ready to accelerate radioactive beams. The initial experiment chosen was to look for the $^{8}\vec{\mathrm{Li}}(\alpha, n)$ cross section at energies of 1 MeV/u or less, with intensities on target (after stripping, acceleration) in the range of a few $10^8$/s. The experiment could not be run in "singles" mode (detecting only the neutron) because of the high counting rate in the neutron plastic counters, while the $^{8}\vec{\mathrm{Li}}$ beam intensity proved to be insufficient to run in coincidence mode ($n$, recoil $^{11}$B) either. A new proposal taking the above limitations into consideration will be developed by the RIKEN group.

The fall running period was mainly devoted to $^{21}$Na beams and both the TUDA and DRAGON teams took advantage of the few $10^8$/s intensities available.

TUDA measured the elastic scattering of $^{21}$Na from hydrogen in a $CH_2$ target, establishing the excitation curve between 0.7 and 1.5 MeV (centre of mass energy). Three broad $s$-wave resonances were observed. A rapid communication was approved for publication in Phys. Rev. Lett. while much more data are being analyzed in a Ph.D. thesis.

The DRAGON spectrometer was put into action in mid-October. Within 3 shifts, it was demonstrated that this complex instrument was performing as planned with a beam rejection close to calculated levels. The $^{21}\mathrm{Na}(p, \gamma)$ reaction was then attempted at two resonance energies with beam intensities of $5 \times 10^8$ ions/s. The 212 keV resonance is important for the production of long-lived $^{22}$Na (2.6 years) in nova and X-ray bursts. This is the first such measurement of its $\gamma$ strength. The 822 keV resonance is also measured for its value in nuclear structure modelling of the $^{22}$Mg compound nucleus in these reactions.

The success of these initial runs augurs well for the program of nuclear astrophysics measurements at ISAC, for which the facility has been optimized. Both teams, led by J. D'Auria/D. Hutcheon for DRAGON and our director A. Shotter/L. Buchmann for TUDA, are to be congratulated.

In the base program, centred around our beams of pions and muons, the highlight was the first data-taking of muon decay events in the TWIST spectrometer operating at 2 T. During the year, the superconducting coil was fixed, the 52 high precision wire chambers and their associated gas system, analogue and digital electronics, and mechanical assembly were commissioned, and everything came together on November 23 with nice decay positron tracks spiralling in the 2 T field. This represented the culmination of a very large effort by our detector group, the technical staff assembling the spectrometer, and many summer and co-op students, as well as the TWIST team.

Also in the base program, ten years of effort resulted in the publication of the polarization asymmetry in $p$–$p$ scattering at 221 MeV from which one can extract the value of the weak coupling constant of the $\rho$ meson. This result is important for understanding the weak effective interaction of the nucleon and will also have an impact on the asymmetry measurement in $e - p$ scattering at TJNAF. These experiments are extremely difficult due to the very weak signal ($10^{-7}$ level) and were only possible through the dedication of a large team led by the Manitoba group, which has built up a record of credibility in previous measurements of this type.

TRIUMF is also providing infrastructure support for experiments abroad. During the year, a very significant second rare $K$-decay event was observed in the BNL E787 experiment at the AGS, confirming the 1997 result, still consistent with the standard model prediction and allowing for a more constrained value of the $V_{td}$ quark mixing matrix element. Again, in this case, it is the result of a long (18 year) dedicated effort by the Canadian team led by D. Bryman (UBC).

Preparing for the future program at the LHC, the ATLAS groups at TRIUMF and Victoria are well under way to deliver the two hadronic endcap wheels being assembled at TRIUMF and the associated cryogenic feedthroughs made in Victoria. The focus of activity will now shift to CERN where these devices are going to be fitted into the ATLAS detector.

Focusing also on the future, a Canadian group under A. Konaka's leadership is mounting an effort to join a long baseline neutrino oscillation experiment. So far a collaboration with the JHF-SK program in Japan has been explored, but the option for a similar effort at Fermilab is also contemplated. The very successful Future Opportunities for Neutrino Physics Workshop was held in Victoria in November with 70 attendees, and the most pre-eminent researchers in this exciting field were present.

A proposal to join an effort at the Brookhaven AGS to study $CP$ violation in the $K$ system via the neutral rare decay mode $K^0 \rightarrow \pi^0 \nu \bar{\nu}$ received interim and conditional support from NSERC pending an NSF decision to go ahead with the experiment.

As evident in this Annual Report, the condensed matter community continues to value the superb facilities which have been developed at TRIUMF for $\mu$SR users. Even though our maximum muon fluxes are an order of magnitude smaller than those of our competition in PSI, the new state-of-the-art instruments available here maintain our attractiveness in the whole community.

Our life sciences program got a major boost with the funding, through the Canadian Foundation for Innovation, of two new PET cameras; the recently announced funding for an animal camera will open a wide area of research in the medical sciences. This will put pressure on our local team of radiochemists to develop the required tracers for those studies.

In conclusion, TRIUMF is well positioned to play a major role in internationally competitive science projects at the high energy frontier, at the new frontier in nuclear physics with radioactive beams, in precision experiments, in condensed matter, and in the life sciences. Our reach is only limited by our means, not by our vision or our intellect. Our challenge is now to prepare a new five-year plan and convince our funding agencies that we should expand our world-class program for the benefit of Canada.