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UNDER A CONTRIBUTION FROM THE
NATIONAL RESEARCH COUNCIL OF CANADA

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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

1999 will be remembered as a transitional year. It was the first year of the new ISAC science program with two experiments taking beams for data collection and two engineering runs on the new facilities, while the long-term running programs concluded in the proton hall. In the meson hall, a strong physics program based upon π scattering and $\pi^- p$ reactions continued, with most of the beam time having been devoted to condensed matter research with muons and muonium. New programs have been developed which will take over in a year or so. In its infrastructure role, TRIUMF continued to support a wide range of activities at other laboratories, but the main effort was directed towards the construction of the ATLAS calorimeters for LHC at CERN.

In ISAC, the year was marked by the first scheduled operation. This presented us with the challenge of delivering beam to experiments in the low energy area, while constructing facilities for the accelerator system to produce 1.5 MeV/u beams by Christmas 2000. Two production targets were used. The first, a CaO target made of compressed powder discs, produced ^{38m}K and ^{37}K beams for the TRINAT program and the lifetime measurement group.

TRINAT collected a large data set on $\beta-\nu$ correlations in the β-decay of ^{38m}K using the reconfigured dual trap system. The analysis of the data uncovered a significant discrepancy between the modelled electric field configuration and the value extracted from the data; this led to a systematic error of 0.5% which would dominate the results. As the year ended, a better understanding of the Monte Carlo deficiencies and of the set-up non-uniformities was realized, which should lead to a solid result. A new run with improved conditions will be scheduled next summer.

Using a tape transport system from the TASSC facility, very precise determinations of the lifetimes of ^{38m}K and ^{37}K were made which, in the former case, confirmed that the set-up was reproducing the previous results of the Chalk River group and, in the latter, improved the precision of the lifetime to the point where this will no longer limit the future precision on the correlation coefficient measurements intended at TRINAT.

The CaO target operated with a 1 μA incident proton beam, but showed problems with deposits developing on the extraction electrodes which limit the life of such a target ion source combination. The second production target made use of a stack of niobium foils and operated successfully in two long running periods with 10 μA proton beams. It was used to produce a world record beam of ^{74}Rb ions ($\sim$ 4000/s) and to determine their lifetime precisely. This is part of a more general program of measurement of $0^+ \to 0^+$ β-decay transitions in medium Z nuclei to evaluate nuclear corrections associated with the extraction of the CKM matrix element V_{ud} from such β-decay transitions. The Nb target was also used to generate ^{79}Rb beams to calibrate the performance of the Low Temperature Nuclear Orientation set-up, and to produce a ^{8}Li beam to commission the beam line which will feed the β-NMR set-up for light polarized ion implantation in thin films.

These successes were a good prelude to a scientific symposium in December at which the great scientific potential of radioactive beam facilities like ISAC was reviewed. To conclude the year, a prototype molybdenum target was successfully tested at 100 μA incident proton beam.

ISAC had a good start and we anxiously await the first accelerated beam in 2000.

The prospects were very different in the proton hall, where traditional intermediate energy programs ran their course. 1999 marked the accomplishment of objectives of the parity experiment where a longitudinal polarization asymmetry A_z in $\vec{p}-p$ scattering at 222 MeV was established at the desired precision of $\pm 0.3 \times 10^{-7}$. This in turn uniquely determines the weak meson nucleon coupling h_ρ^{pp}. The future of these kinds of symmetry tests will depend upon further improvements of the polarization and measurements of its moments, as well as better understanding of the theoretical uncertainties associated with the extraction of the weak coupling at higher proton energies.

Another long term investment is about to bear fruit in the proton hall. The charge symmetry breaking experiment searching for the forward/backward asymmetry in $np \to d\pi^0$ completed its data-taking phase in 1999. Considerable progress is reported here on the simulation of the experiment, which is crucial in extracting the asymmetry which is dominated by the contribution from $\eta-\pi$ mixing. With these two high-precision symmetry tests completed, the proton hall program will terminate.

In the meson hall, the nuclear physics program is using the two facilities developed in the last decade: the CHAOS and RMC spectrometers. The CHAOS group has completed its program of low energy polarization asymmetry measurements in πp scattering. The preliminary analysis reported here shows how it supports the recent phase shift analysis of the Virginia group (which discounts the cross-section measurements made before the advent of meson facilities). This seems to close a chapter of confusion in low energy pion scattering. The search for evidence of a d' dibaryon at TRIUMF was negative in three separate experiments reported here. The data taken, both in inclusive and exclusive processes, can be explained via the sequential single charge exchanges and do not require any significant resonant mechanism. The data will have a considerable impact on the other side of the Atlantic where anomalies have been reported in similar data sets. The third plank in the CHAOS program is the study of $\pi-\pi$ scattering lengths in several isospin channels via the $(\pi, 2\pi)$ reactions. These experiments complement similar studies done at Brookhaven and DAΦNE in K_{e4} decays, and provide precision determinations that can be calculated in Chiral perturbation theory; hence of great interest, for example, in establishing the low energy constants of these effective theories. A fourth component of the program is interested in the medium modifications occurring in π production or in nucleon knock-out reactions. It has reported interesting observations obtained with the powerful CHAOS multi-tracking capability.

Pionic hydrogen capture modes were studied with the RMC spectrometer with a view to extracting the pion polarizability. The rare capture mode in 2γ was observed at the 10^{-5} branching ratio level and 1000 events were collected.

The particle physics program at TRIUMF is in a transitional state with, on the one hand, experiments aimed at resolving the puzzle seen in muon radiative capture on hydrogen by remeasuring the ortho-para transition in muonic hydrogen, and on the other, a major development of a new spectrometer to determine the parameters of the muon decay spectrum to a very high precision. This latter program will occupy one of the muon channels for the next half decade and considerable progress has been accomplished in the design and testing of prototype chambers. The final construction phase has started.

The bulk of the activities in the meson hall have been aimed at condensed matter experiments using the μSR method. This report describes the breadth of the program which spans semiconductor and high-T_c superconductor physics, free radicals and catalyst chemistry, spin systems, etc.

In this report, studies of the dynamics of muonium atom impurities (as analogue of hydrogen) have been extended to GaAs samples grown via the liquid phase epitaxy. The very high quality of the samples is key to extracting intrinsic behaviour of hydrogen-like contaminants. GaAs, GaAs:Zn doped, and also GaN crystals have been studied.

For high-T_c superconductors, detailed studies of the London penetration depth in type II YBaCuO were conducted, but unconventional superconductors like UBe and UThBe, and compounds which exhibit none or very few Cu layers, were also examined with the μSR techniques. Another domain of interest focuses on various spin systems, in particular frustrated spin magnets and one-dimensional spin chains.

The chemists were interested in the radical formation in fullerene molecules or zeolite-type materials (of relevance to catalytic processes). A program of chemical reaction rates in the gas phase is continuing for Mu+CO reactions in the presence of a moderator gas over a large range of pressures.

A significant fraction of TRIUMF's resources is used to support scientific programs at other laboratories. This year's report highlights TRIUMF's major contributions to the ATLAS experiment at LHC. Two of Canada's commitments to the ATLAS collaboration are under TRIUMF's responsibility: the hadronic endcap calorimeters and the feedthrough connectors between their liquid argon cryostats and the external world. Another group, $G0$, has entered the construction phase for a magnetic field mapper and trigger scintillators, while previous investments in the HERMES, BaBar, BNL 787 and KEK 246 experiments are producing interesting physics results.

Finally, TRIUMF's contributions to several programs in the life sciences are described herein. The long-term collaboration with UBC's Neurodegenerative Disorders Centre is on a firm footing after the renewal of a 5-year group grant from the Medical Research Council, as well as partial funding for a new high resolution tomograph. TRIUMF has also supplied research isotopes to the Botany and Psychiatry departments at UBC, and to the local hospitals. Pure radioactive metallic ^{7}Be targets have also been produced for an experiment at the University of Washington, aimed at elucidating some of the solar neutrino puzzle by a precise measurement of the low energy cross section of the $^7\text{Be}(p, \gamma)$ reaction.

TRIUMF is also benefitting from a dynamic local theory group which does its own research activities but tries very effectively to support the local experiments.

In conclusion, TRIUMF has had a very productive scientific year and the emergence of a new program based upon ISAC bodes well for the health of our long-term scientific plan. Over the last 5 years, TRIUMF has been meeting the requirements set by the federal government which has recently announced its full support for a further 5 years.