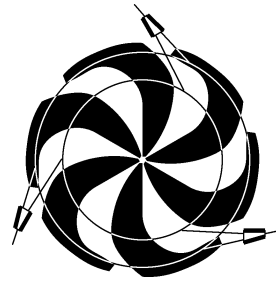


# TRIUMF



## 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.*

# CONTENTS

INTRODUCTION .....	1
SCIENCE DIVISION .....	3
Introduction and Overview .....	3
Particle Physics .....	5
(Expt. 497) Measurement of the flavour conserving hadronic weak interaction .....	5
(Expt. 614) TWIST – the TRIUMF weak interaction symmetry test .....	11
(Expt. 761) Measurement of parity violation in $pp$ scattering at 221 MeV .....	12
(ATLAS) The ATLAS experiment at the LHC .....	14
(BaBar) The BaBar experiment at the Stanford Linear Accelerator Center .....	21
(BNL 787/949/KOPIO) Measurement of $K \rightarrow \pi\nu\bar{\nu}$ and other rare decays .....	22
(HERMES) The HERMES experiment .....	27
(KEK 246/470) Kaon decay studies .....	30
(TJNAF 00-006) Measurement of the flavour singlet form factors of the proton ( $G\emptyset$ ) .....	32
Nuclear and Atomic Physics .....	38
(Expt. 704) Charge symmetry breaking in $np \rightarrow d\pi^0$ close to threshold .....	38
(Expt. 715) Weak interaction symmetries in $\beta^+$ decay of optically trapped $^{37,38\text{m}}\text{K}$ .....	42
(Expt. 744) A kinematically complete study of $\pi^-p \rightarrow e^+e^-n$ .....	45
(Expt. 778) Low energy $\pi^\pm$ differential cross sections in the Coulomb-nuclear interference region with CHAOS .....	45
(Expt. 801) Studies of multi-phonon states via $\beta$ -decay .....	46
(Expt. 823) Pure Fermi decay in medium mass nuclei .....	47
(Expt. 824) Measurement of the astrophysical rate of the $^{21}\text{Na}(p, \gamma)^{22}\text{Mg}$ reaction .....	49
(Expt. 838) Double radiative capture on pionic hydrogen .....	52
(Expt. 862) Analyzing powers in the $\bar{p}(\pi, \pi\pi)$ reactions with CHAOS .....	52
(Expt. 863) Ground state magnetic moments of $^{75,77,79}\text{Ga}$ (LTNO) .....	53
(Expt. 864) Dibaryon search by double radiative capture on pionic deuterium .....	54
(Expt. 875) MuScat: muon scattering in low $Z$ materials for muon cooling studies .....	55
(Expt. 879) $^{21}\text{Na}(p, p)$ resonant elastic scattering .....	58
Chemistry and Solid-State Physics .....	61
(Expt. 758) Effects of quantum impurities in graphite and in one dimensional spin 1/2 chain CPC .....	61
(Expt. 775) Electron transport in insulators, semiconductors and magnetic materials .....	63
(Expt. 776) Rare-earth materials with disordered spin structures .....	65
(Expt. 782) Non-fermi-liquid behaviour and other novel phenomena in heavy-fermion alloys .....	66
(Expt. 783) Knight shifts in unconventional superconductors: $(\text{U,Th})\text{Be}_{13}$ .....	68
(Expt. 784) Spin dynamics in the two dimensional spin system $\text{SrCu}_2(\text{BO}_3)_2$ .....	69
(Expt. 791) Electronic structure and dynamics of charged muonium centres in semiconductors .....	69
(Expt. 804) Muonium in III-V nitrides .....	70
(Expt. 815/816/817) $\beta$ -NMR .....	72
(Expt. 833) Muon spin relaxation studies on MnSi under applied pressure .....	75
(Expt. 834) $\mu\text{SR}$ study of transverse spin freezing in bond-frustrated magnets .....	75
(Expt. 835) $\mu\text{SR}$ studies in doped HfNiCl superconductors .....	77
(Expt. 842) Mu-substituted free radicals in sub- and supercritical water .....	77
(Expt. 846) Complex order parameter symmetry in $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ at low $T$ and high magnetic field ....	79
(Expt. 847) Electron-doped high- $T_c$ superconductors .....	80
(Expt. 848) Vortex state of $d$ -wave superconductors investigated by muon spin rotation .....	81
(Expt. 849) Spin structure and magnetic volume fraction of La214 systems .....	82
(Expt. 852) Magnetic phases in geometrically frustrated rare earth pyrochlores .....	83
(Expt. 876) Disordered magnetism near magnetic instabilities in $f$ -electron materials .....	86
(Expt. 883) Muoniated methyl and associated free radicals .....	87
(Expt. 884) $\mu\text{SR}$ studies on magnetic ground state of $S=1/2$ kagomé spin system $\text{Cu}_3\text{V}_2\text{O}_7(\text{OH})_2 \cdot 2\text{H}_2\text{O}$ .....	89
(Expt. 890) Anisotropic Kondo effect in $\text{Ce}_{0.8}\text{La}_{0.2}\text{Al}_3$ ? .....	89

(Expt. 891)	Superconductivity and magnetism in $Ce_n T_m In_{3n+2m}$ .....	91
(Expt. 894)	Muonium kinetics and free radical formation in solutions of fullerenes .....	92
(Expt. 912)	Formation, structure, and dynamics of muonium in GaAs studied by EF-ALC-RF- $\mu$ SR .....	93
(Expt. 915)	Muonium in semiconductor alloys .....	94
(Expt. 916)	QLCR of diamagnetic muonium states in GaP .....	95
(Expt. 917)	Correlation between magnetism and transport properties of thermoelectric oxides .....	96
Life Sciences .....		98
Introduction .....		98
(Expt. LS0)	PET facilities .....	98
(Expt. LS2)	Synthesis of radiohalogenated carbohydrates for use as imaging agents in PET and SPECT .....	99
(Expt. LS3)	Synthesis of radiopharmaceuticals for positron emission tomography .....	100
(Expt. LS4)	TR13 targets for PET radioisotope production .....	101
(Expt. LS8)	Radiotracers for the physical and biosciences .....	101
(Expt. LS10)	Aptamer imaging agents .....	103
(Expt. LS29)	Production and distribution of FDG (and other tracers) for clinical studies .....	103
(Expt. LS33)	Evaluation and improvement of a dual head coincidence camera .....	103
(Expt. LS35)	Development of $^{18}F$ labelled nitroimidazole PET imaging agents for tissue hypoxia .....	104
(Expt. LS38)	Modelling of the $^{18}F$ -fluorodopa tracer .....	104
(Expt. LS39)	Positron emission profiling (PEP) for pulp and paper fluid dynamic studies .....	106
(Expt. LS42)	Configuration modelling and image reconstruction studies on a depth encoding research tomograph .....	106
(Expt. LS44)	Development of a “formation” (areal density) measurement device for pulp and paper studies .....	107
(Expt. LS46)	Modelling of the dopaminergic system in more severely affected PD patients .....	107
(Expt. LS50)	Antisense imaging nucleic acids for Parkinson’s disease .....	108
(Expt. LS51)	Auger therapy for prostate cancer .....	108
(Expt. LS52)	Comparison of commercial FDG synthesis systems .....	108
(Expt. LS53)	Synthesis of $^{99m}Tc$ and $^{186,188}Re$ sugar derivatives .....	109
Theoretical Program .....		110
Introduction .....		110
The Theory Research Program .....		110
Experimental Facilities .....		118
Proton Irradiation Facility .....		118
Proton Therapy Facility .....		119
$\mu$ SR User Facility .....		119
Beam Lines .....		121
Cryogenic Targets .....		122
Computing Services .....		122
Data Acquisition Systems .....		125
Detector Facility .....		126
GEANT4 .....		127
Scientific Services .....		129
Sudbury Neutrino Observatory .....		131
DRAGON Facility .....		131
$8\pi$ Spectrometer .....		133
Low Temperature Nuclear Orientation at ISAC .....		134
CYCLOTRON OPERATIONS DIVISION .....		136
Introduction .....		136
Beam Production .....		137
Winter Shutdown .....		137
Beam Schedule 99 .....		142
Fall Mini-Shutdown .....		143

Beam Schedule 100 .....	143
Beam Development .....	144
Radio Frequency Systems .....	144
RF Operations .....	144
RF Refurbishing .....	144
RF Support .....	146
Radio Frequency Controls .....	146
Cyclotron .....	146
ISAC .....	146
ISAC-II .....	146
Cyclotron Probes and Diagnostics .....	146
Probes MRO .....	146
Monitor MRO .....	147
Vacuum and Engineering Physics .....	147
Vacuum .....	147
Engineering Physics .....	147
ISIS .....	147
Primary Beam Lines .....	148
BL1A Vault Section .....	148
BL1A West-East Section .....	149
Beam Line 2C Production .....	149
Controls .....	150
CCS Facilities .....	150
Secondary Beam Lines .....	151
Other Systems .....	151
Miscellaneous .....	151
Operational Services .....	151
Remote Handling .....	151
Magnet Power Supplies .....	152
Electrical Engineering Services .....	152
Electrical Systems .....	152
Power Delivery .....	153
Mechanical Systems .....	153
 ISAC PROJECT .....	 155
Introduction .....	155
ISAC Operations .....	155
Safety and Radiation Control .....	161
Licensing .....	161
Access Control and Radiation Monitoring .....	161
Commissioning .....	161
Remote Handling Group .....	161
Target Modules .....	161
Target Hall .....	161
Hot Cell Facility/Targets .....	162
Remote Crane System .....	162
ISAC Targets and Beams .....	162
Ion Sources for ISAC .....	163
Electron Cyclotron Resonance (ECR) Source .....	163
Off-Line Ion Source (OLIS) .....	163
Charge State Booster (CSB) .....	164
ISAC Polarizer .....	164
Beam Dynamics .....	165
Theory .....	165

Software .....	165
Hardware Designed .....	165
ISAC Controls .....	165
Hardware .....	165
Software .....	166
System and Development Support .....	166
Commissioning and Operation .....	166
RF Systems .....	167
RFQ .....	167
MEBT .....	167
DTL .....	168
HEBT .....	169
ISAC Diagnostics .....	169
Target Diagnostics .....	169
MRO .....	170
Beam Commissioning .....	172
MEBT .....	172
Full DTL Beam Tests .....	172
HEBT .....	174
Beam Delivery .....	175
LEBT .....	176
Mass Separator .....	176
East Target Station .....	177
Services .....	178
Faraday Cage and Electrical Room .....	178
Other Systems .....	178
ISAC Planning .....	178
East Target Station .....	178
Target Conditioning Box .....	179
HEBT .....	179
Low Energy Experiments .....	179
High Energy Experiments .....	179
DRAGON .....	179
ISAC-II .....	179
Contract Administration .....	180
Personnel Resources .....	180
Conventional Facilities and Infrastructures .....	182
Mechanical Services .....	182
Electrical Services .....	182
ISAC-II Conventional Construction .....	184
ISAC-II Accelerator .....	184
Linac Lattice .....	184
Stage 1 Installation .....	185
Stage 2 Installation .....	186
SCRF Developments .....	189
 ACCELERATOR TECHNOLOGY DIVISION .....	 191
Introduction .....	191
Beam Dynamics .....	191
Micro-Bunching at Brookhaven AGS .....	191
Muon Acceleration in an FFAG .....	192
Multi-Turn Simulation of Coherent Betatron Resonance with Space-Charge .....	192
Magnets .....	193
Experiment 614 – TWIST .....	194

Magnet Measurements .....	194
Kickers .....	194
Mechanical Engineering .....	195
ISAC East Target Station .....	195
DRAGON .....	196
Engineering – Other .....	198
Engineering - Victoria .....	199
Engineering - Carleton .....	199
Planning .....	200
ISAC .....	200
Shutdown Activities .....	201
TWIST .....	201
KOPIO Preradiator .....	201
Design Office .....	201
Machine Shop .....	202
Building Program .....	202
Electronics Services .....	202
Overview .....	202
Technical Support .....	202
PC Support .....	203
Electronics Repair Shop – Nucleonics .....	203
High Level Software Support .....	203
Site Communications .....	203
Electronics Shop .....	204
Experimental and Target Support .....	204
Electronics Development .....	204
ISAC Support .....	204
CERN .....	204
Safety Systems .....	204
Miscellaneous .....	204
 CERN COLLABORATION .....	 206
Introduction .....	206
Beam Dynamics .....	206
Coherent Beam-Beam Effects in the LHC .....	206
LHC Collimation .....	207
Resonance-Free LHC Optics .....	207
Controls and Instrumentation .....	207
LHC Orbit System Components .....	207
Magnet Development .....	209
Kicker Magnets .....	209
Thyratron Switch Tanks .....	211
 TECHNOLOGY TRANSFER DIVISION .....	 212
Introduction .....	212
Technology Transfer .....	212
Applied Technology Group .....	212
500 MeV Isotope Production Facility .....	212
CP42 Facility .....	212
TR30 Facility .....	212
ATG Development Projects .....	212
Radioisotope Processing (MDS Nordion) .....	212

ADMINISTRATION DIVISION .....	215
Introduction .....	215
Human Resources and Administration .....	215
Operational Safety .....	215
Licensing .....	215
Training .....	215
Occupational Health and Safety .....	215
Interlocks and Monitoring .....	215
Personnel Dosimetry .....	216
Administration Computing and Communications .....	216
Management Information Systems .....	216
Word Processing Systems .....	216
Telephones .....	216
CONFERENCES, WORKSHOPS AND MEETINGS .....	218
ORGANIZATION .....	224
APPENDICES	
A. Publications .....	228
B. Seminars .....	244
C. Users Groups .....	246
D. Experiment Proposals .....	247
E. Life Sciences Project Proposals .....	261