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TRIUMF

The TRIUMF Newsletter

NEWS FROM CANADA'S NATIONAL LABORATORY FOR PARTICLE & NUCLEAR PHYSICS

The new ISAC-II Building
Gordon Campbell, Premier of British Columbia, will open the ISAC-II building June 11, 2003

NEW ISAC-II BUILDING COMPLETED

After a year of construction, parking problems and excited anticipation, TRIUMF has taken possession of the new ISAC-II building.

The new facility was built to house the accelerators and experimental apparatus for the nuclear physics program at ISAC-II. In addition, the building will provide TRIUMF with additional office and laboratory space. ISAC-II is scheduled to provide the first accelerated radioactive beams and begin the ISAC-II experimental program in 2005.

FOR MORE INFORMATION ON ISAC-II CONTACT PAUL SCHMOR AT SCHMOR@TRIUMF.CA

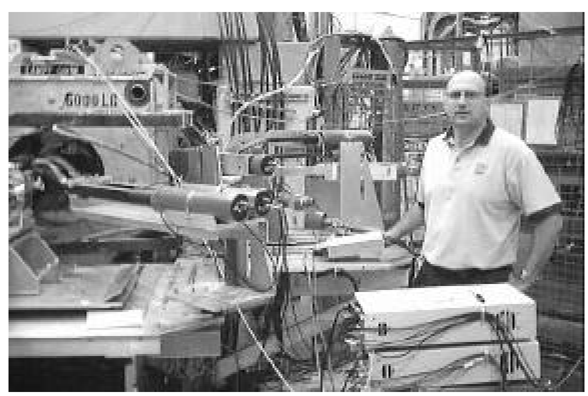
TRIUMF SCIENCE EDUCATION OUTREACH

TRIUMF is building on its successful undergraduate and graduate student programs by launching TOP, the TRIUMF Outreach Project. TOP will introduce the physics laboratory experience to secondary school classrooms in a numb er of ways.

An internship program for secondary school teachers will allow teachers to participate in a running experiment at TRIUMF. Resource materials, including a dedicated website, will assist teachers to show their students how what they learn in the classroom relates to real academic research. TRIUMF will also host the annual Professional Development Day administered by the BC Association of Physics Teachers. One hundred teachers come to TRIUMF for a day long experience that includes lectures, hands-on physics experiment demonstrations and tours.

TOP is also joining the NALTA Cosmic Ray Project where safe, easy-to-use cosmic ray detectors are placed at participating secondary schools. Teachers and students will operate and maintain the detectors as part of their school's career preparation, science programs and information technology programs.

These and other TOP initiatives were made possible by generous grants from The Vancouver Foundation and the TRIUMF Technology Transfer Office.



Penticton school teacher Bruce Gowe shown with experimental apparatus during his internship experience at TRIUMF in August 2002.

FOR MORE INFORMATION ON TOP CONTACT MARCELLO PAVAN AT MARCELLO@TRIUMF.CA

TRIUMF µSR Facility

Jeff Sonier
Assistant Professor
Simon Fraser University

The behaviour of all materials is ultimately determined by their structure and properties at the atomic level, necessitating highly sophisticated experimental techniques to probe materials on a microscopic level. The TRIUMF "Muon Spin Rotation/Relaxation/ Resonance" (µSR) facility is a world leader in materials science, condensed matter physics and chemistry applications of µSR techniques.

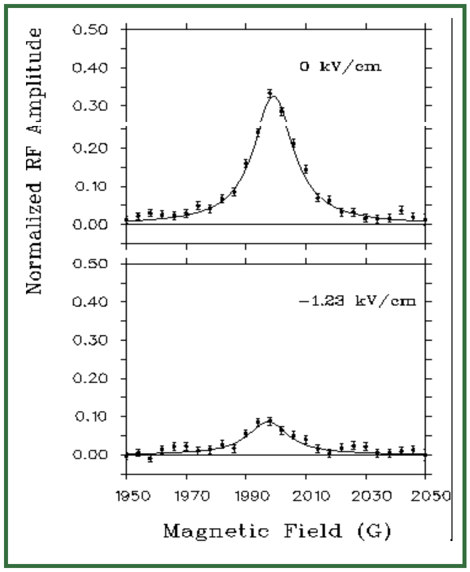


Figure 1 Normalized RF asymmetry signal in semi-insulating GaAs at T = 59 K for different EF values. The amplitude reduction at E = -1.23 kV/cm indicates a dramatic decrease in the population of the Mu^+ final state.

Inside matter, the muon behaves like a tiny bar magnet, where it is extremely sensitive to magnetism fundamentally related to important physical phenomena. As well, the positively charged muon (μ^+) interacts like a normal proton and can provide information on hydrogen defects in semiconductors, and free radicals in molecular gases and liquids. In certain materials, the µ+ can pick up an electron to form an unstable muonium (Mu) atom, which is very similar to the stable hydrogen atom. When this happens, µSR sensitivity is enhanced because the more sensitive electron passes on what it sees to the muon. µSR experiments carried out at TRIUMF are having a major impact on our understanding of superconductivity, semiconductors, chemical reaction kinetics, radical formation, quantum diffusion, novel magnetic systems and charge transport. Some examples of recent applications of the various µSR techniques at TRIUMF are described below.

New Technique developed at TRIUMF

As a trace impurity, atomic hydrogen (H) can have a profound effect on the electronic properties of semiconductors. Most of the experimental information on isolated hydrogen in semiconductors comes from µSR studies of muonium, which can exist in three charges states (Mu^0, Mu^+, Mu^-), analogous to the distinct charge states of isolated hydrogen (H^0, H^+, H^-). Using innovative µSR capabilities, TRIUMF researchers are able to learn more about the transitions that occur between these charge states. A new µSR technique recently developed at TRIUMF combines the effects of an applied electric field (EF) with the signal capabilities of radio frequency (RF) µSR. By applying an EF to a semiconductor, one can modify the concentration of electrons and holes around the implanted μ^+, providing control over the formation of the initial charge state. Simultaneous use of RF-µSR allows for the selective detection of the resulting changes in the final states. The first test (Figure 1) of the EF + RF-µSR technique has been a successful study of the charge states in semi-insulating gallium arsenide (GaAs).

Effects of Impurities Inside Materials

The effect of isolated impurities in magnetic materials is a topic of fundamental interest, but there are few experimental techniques available for confirming the theoretical predictions. For example, interesting magnetic effects are predicted for a non-magnetic impurity placed in special materials called one-dimensional (1D) spin 1/2 antiferrogmagnetic (AF) chains. µSR is an ideal way to test such predictions because the muon acts as both an impurity and a probe of the atomic-level magnetic fields. Jacques Chakhalian and Rob Kiefl have been investigating the magnetic field surrounding a µ+ in the quasi-ID spin 1/2 AF chain compound $CuCl_2{\cdot}2NC_5H_5$. In this system they observed transverse-field µSR signals from three distinct muon stopping sites within the material. The temperature dependence of the average magnetic field at these sites shows striking agreement with theoretical calculations confirming the predicted high sensitivity of 1D chain compounds to a single impurity.

High-Temperature Superconductors

The central issue in the study of high-temperature (high-T_c) cuprate superconductors continues to be the relationship of magnetism and superconductivity. Recent excitement has centered on experiments showing that the presence of magnetic vortices (i.e. swirling tubes of electrical current that form inside a high-T_c superconductor placed in a magnet field) induces AF order of the spins

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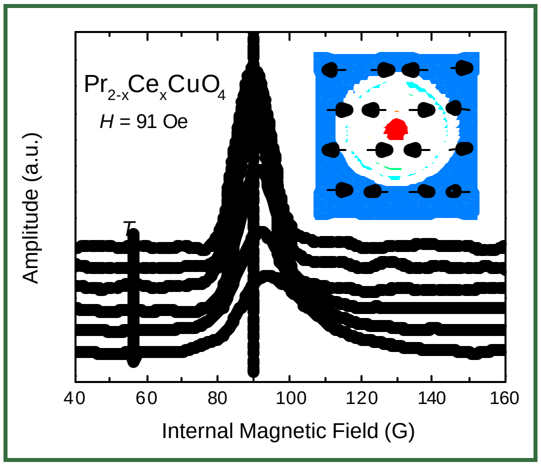

Figure 2 Fourier transforms of the muon-spin precession signal in underdoped $Pr_{2-x}Ce_xCuO_4$ above (dashed) and below (solid) the superconducting transition temperature T_c. The increase in the average internal magnetic field below T_c is attributed to vortex-induced AF order.

(Continued from page 2)

on the nearby copper atoms. In a μSR study led by Roger Miller, measurements of the internal magnetic field distribution have provided strong evidence for AF order in the vortex cores of underdroped ytterbium barium copper oxide. Several theories on the origin of high-T_c superconductivity predict AF order around the vortex cores.

Recently, Jeff Sonier and Graeme Luke have used μSR techniques to show that vortices induce long range AF order in the high-T_c superconductor $Pr_{2-x}Ce_xCuO_4$ (Figure 2). In this compound, the charge carriers are electrons rather than holes. While it is widely believed that the mechanism of superconductivity is the same in both electron-doped and hole-doped cuprates, confirming this experimentally has proven to be quite difficult. μSR has shown for the first time that field-induced AF order in the superconducting state is a common intrinsic property of both types of cuprates. An equally important finding is that the AF order extends well beyond the vortex cores, clearly demonstrating that the vortices stabilize magnetic order.

Environment-Friendly Chemistry

The design of chemical processes that reduce or eliminate the use and production of hazardous substances that are harmful to the earth's environment is a field known as "green chemistry". Supercritical carbon dioxide is an attractive alternative for various organic solvents that are toxic, carcinogenic and damaging to the ozone layer. Khashayer Ghandi and Don Fleming have recently used μSR techniques to show it is possible to modify the reactivity of the simplest free radical (muonium atom) in supercritical carbon dioxide by applying modest pressure (Figure 3). Changing the electronic properties of a free radical by small changes in pressure can have significant impact on the applications of supercritical carbon dioxide as a "green" solvent. Instead of adjusting the reactivity of free radicals by using different environmentally harmful solvents, the same effect can be achieved by a simple change in the pressure of supercritical carbon dioxide.

Studying Chemical Bond Formation

Paul Percival's group at TRIUMF has been studying the exotic chemical species *carbenes*. Carbenes are generally reactive and are postulated to exist only as intermediate steps in a reaction. However, over the past decade the synthesis and isolation of several singlet carbenes has been accomplished. Recently, Percival's group detected a single pair of radical precession frequencies in a carbene by μSR, indicating that only one type of radical is formed. This is a significant result as it represents the first example of radical formation by the direct addition of hydrogen to a carbene. The addition of a hydrogen atom to a dicoordinate carbon is one of the most fundamental addition reactions in chemistry involving the creation of only one new chemical bond. The study of radicals formed from carbenes by μSR may permit the exploration of fundamental questions about chemical bond formations.

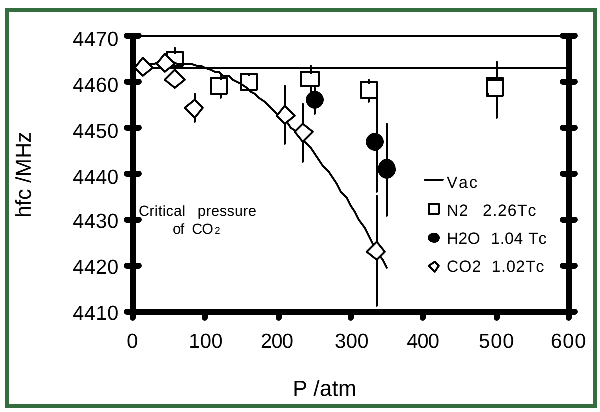

Figure 3 Hyperfine coupling constants of muonium in supercritical carbon dioxide, nitrogen and water compared with the value in vacuum. The decrease in supercritical carbon dioxide above 100 atm is due to molecular interactions of muonium and CO_2 molecules

FOR MORE INFORMATION ON TRIUMF'S μSR FACILITY VISIT HTTP://MUSR.TRIUMF.CA OR CONTACT JEFF SONIER AT JEFF_SONIER@SFU.CA

NEW ION SOURCE COMING ONLINE

Jens Lassen
TRIUMF Laser Ion Source Spectroscopist

The TRIUMF Resonant Ionization Laser Ion Source (TRILIS) is targeted to be operational in the ISAC radioactive beam facility by the fall of 2004. Element selective ionization is achieved by 2 or 3 step resonant laser excitation of the valence electron into an autoionizing atomic state.

TRILIS will augment the capabilities of ISAC's surface and electron-cyclotron resonance (ECR) ion sources by providing access to additional elements. TRILIS will be particularly interesting to experimenters who require beams with low isobaric contamination which can be achieved through the element selectivity of resonant laser ionization.

State-of-the-art laser technology will be used at TRILIS i.e. diode-pumped solid state lasers pumping several narrow line-width high repetition-rate, tunable titanium sapphire lasers. This new generation of lasers operates in the red to infrared wavelength region, differing some to conventional copper vapor laser pumped dye-lasers, but has distinct operational and system maintenance advantages. Efficient resonant laser ionization schemes must be developed for each element individually.

The leading group in resonance ionization mass spectrometry (RIMS) from Mainz University, led by Dr. Klaus Wendt, has entered into a formal collaboration with TRIUMF. Thus the expertise in resonance laser ionization and on-line target sources is combined for the development of new radioactive beams at TRIUMF.

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