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EXOTIC ATOMS
AND
LEPTONIC CONSERVATIONS

By

Raymond Kunselman
University of Wyoming
Laramie, Wyoming 82071

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The major 1989 efforts have been on two aspects of experiments at TRIUMF. One effort was production of muonic hydrogen and muonic deuterium into a vacuum. We study rates relevant to muonic catalyzed fusion, and if there are found an adequate number of muons in the 2s state then we plan to measure precision energies. The second effort was to develop plans for kaonic atoms at the kaon factory. We also completed analyses from the experiments with pionic atoms at LAMPF.

Exotic Atoms: Reactions of Muonic Hydrogen Isotopes.

We have had beam time to test solid hydrogen isotope targets in our cryostat. We have detected μ^- decay from muonic hydrogen and muonic deuterium atoms in vacuum. These systems are produced using the atomic capture technique similar to the muonium conversion search, but now with mu minus being stopped in a hydrogen isotope ice. We are preparing the apparatus for further measurements on these neutral systems in the vacuum. We will pursue measurements of the rates of production as advised and approved by the TRIUMF EEC program advisory committee. As well we are planning measurements of the residual polarization in vacuum, and of the amount of muonic hydrogen and deuterium states in the 2s states. These are all necessary preliminary efforts to utilizing these systems. The fundamental systems of muonic hydrogen, deuterium, and tritium available in a vacuum will lead to studies of the atomic capture process, and of precision energy measurements with the 2s state.

Exotic Atoms: Kaonic Atoms at TRIUMF.

With the high flux of a kaon factory at TRIUMF, we plan to be involved in kaonic atoms experiments. At the workshop at TRIUMF during July, we presented a review of kaonic atoms and emphasized the value of the fundamental kaonic hydrogen measurements of the $2p-1s$ transition. The energy shift and line width are directly related to the fundamental kaon-nucleon scattering lengths. A second priority would be on a range of elements over the periodic table with various isotopes as for pionic atoms. The range of elements would help to clear up discrepancies between the data and theoretical studies. A third priority would be a precision measurement of the sigma-minus magnetic moment.

Exotic Atoms: Pionic Atoms at LAMPF.

The efforts on exotic atoms at LAMPF have ceased. The analysis on pionic atoms from Fe, Co, and Ni isotopes has been completed and published. The energies and the widths of the $3d-2p$ x-ray transitions which were the last observed transitions before the pion was captured by the nucleus have been measured. The energies and widths from the strong interaction of the pion with the nucleus were calculated using a phenomenological pion-nuclear optical potential. The comparison of the calculated values with the measured values allows an interpretation in terms of neutron radii as a free parameter. The neutron distribution relative to the known proton distribution was allowed to vary in the optical model potential calculations.

Exotic Atoms: Kaonic Atoms at BNL.

At BNL several results have come from the measurements on hadronic atoms. The magnetic moment of the sigma-minus hyperon was determined from measurements of the fine structure splittings of x-ray transitions. Precision determination of atomic transition energies were used to extract the masses of the negative kaon and negative sigma hyperon. The strong interaction effects of the sigma-minus nuclear interaction that show up in the data as x-ray energy shifts and line broadenings have been determined.

Leptonic Conservations: Muonium Conversion to Anti-Muonium.

The experiment on leptonic conservations at TRIUMF was called MUBAR (for anti-muonium), an attempt to measure the rate of the muonium to antimuonium conversion process $M^0 \rightarrow \bar{M}^0$ ($\mu^+e^- \rightarrow \mu^-e^+$). The reaction would violate additive lepton flavor conservation. We stopped positive muons in a thin silica powder target where they could capture an electron and produce thermal muonium into a vacuum region. The muonium could then convert to antimuonium in the field-free vacuum region

The potential radioactive target was produced when any antimuonium drifted into tungsten and was captured and produced tantalum. The experiment removed the radioactive target to an off-line counting location. The reaction of a mu-minus on W(184) produced Ta(184) which had an 8.7 hour half-life. The Ta decayed by beta emission to excited states of W. We required a triple coincidence signature of (1) a beta, (2) a gamma of 414 keV (the

cascade produced 91% through this transition), and (3) a second gamma of any of the several other energies which existed in the spectrum of the W daughter. The low background counting area was set up and used for tests of W targets that had been placed in a mu-minus beam to produce the radioactivity for testing the triple coincidence and the chemical procedures. Our data produced a limit of $G \leq 0.28G_F$ (90% C.L.) corresponding to a branching ratio of 2×10^{-6} . At this value of the limit the measurements are of special interest to theorists.

The muonium and antimuonium have the same rest energy. If the difference between muons and electrons is not an additive quantum number, such as charge or strangeness, but a multiplicative quantum number such as parity, then the conversion is a possibility. A model incorporating an additional Higgs triplet would allow conversion as it arises from the direct exchange of a doubly charged Higgs particle. The conversion could also occur if additive lepton quantum numbers are eventually violated at some level because of a boson that exists outside of the present Standard Model. The $M^0, \bar{M}^0$ system is analogous to the $K^0, \bar{K}^0$ system or the $B^0, \bar{B}^0$ system where a flavor violating weak coupling leads to mixing between the two members and a violation of strangeness or beauty.

The results have been analyzed and published in Physical Review, as well as serving as the thesis material for a University of Wyoming student, Tom Huber.

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COO-2197-129 "Leptonic Conservations: An Improved Limit for
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