TECHNICAL PROGRESS REPORT
TO THE
U.S. ATOMIC ENERGY COMMISSION

MASTER

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Covering
Experimental Study of Weak Interactions

Submitted by
The Enrico Fermi Institute
The University of Chicago

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TECHNICAL PROGRESS REPORT

1. LAMBDA BETA DECAY

Introduction

During the past research period, we completed data taking on the lambda beta decay experiment. We had achieved our objective of collecting one thousand beta decays of polarized lambdas. Data analysis is continuing; when the data is fully analyzed we will be able (a) to perform a definitive measurement of the ratio of axial vector to vector form factors (A/V) as a test of the Cabibbo theory and (b) to make a sensitive direct test for time reversal invariance in this fundamental strangeness changing beta decay. This spark chamber and counter experiment, carried out at the Argonne National Laboratory ZGS, is a collaboration with physicists from Argonne National Laboratory, Ohio State University and Washington University.

Principle of the Experiment

The experiment is designed (a) to measure the up-down correlations of e , p and $\bar{\nu}$ with respect to the lambda spin in order to determine A/V and (b) to permit reconstruction of the lambda center of mass in order to perform the T-invariance test. To achieve this, we produce polarized lambdas in hydrogen via the associated-production reaction $\pi^- + p \rightarrow \Lambda + k^0$ near E_K threshold. The direction of lambda polarization normal to the production plane is completely determined by the direction

of the incident pion and the lambda decay vertex. It is important to notice that detection of the kaon is not required. If it were, the event rate would be reduced by an order of magnitude making the experiment unfeasible. The direction of lambda polarization is Lorentz invariant since it is transverse to the lambda velocity. Therefore, the up-down asymmetries can be measured directly in the lab. By measuring the momenta in a magnet spectrometer, we determine for each decay the direction of electron, proton and anti-neutrino with respect to the lambda spin. This enables us to form six up-down correlations for finding A/V. Magnetic analysis also permits reconstructions of the lambda center of mass required for the T-invariance test.

A unique event identification is crucial to this experiment since the branching ratio for lambda beta decay is $\sim 10^{-3}$. This is accomplished as follows: (a) electrons are identified by a threshold gas cerenkov counter. Since electrons of a broad angular range are dispersed over a large area by the magnetic field, this counter requires an unusually large phase-space acceptance and uses a novel method of efficient light collection which we developed for this experiment¹. Without this new light collection technique the cerenkov counter, and hence the experiment, would not have been feasible. (b) protons are identified by their velocity (time-of-flight) which, together with momentum, determines the mass. (c) magnetic analysis removes the small level of background events that

filter through (a) and (b). For example, pairs are identified by their low invariant mass, $\Lambda \rightarrow p\pi$ events are identified by solving the full kinematics (3-constraint fit) of the lambda production and decay. Finally, the experiment is designed to have a mirror plane of symmetry and large solid angles of detection so that practically no bias is introduced into the measured up-down asymmetries.

Data analysis

(a) Procedure

The spark chamber data, in 90° stereo, and the time-of-flight data, displayed on two four-gun oscilloscope tubes, are recorded on film. To illustrate the selectivity of each stage of data analysis, we assume that we start with 10^6 raw data frames; this is in fact close to the actual number.

(i) The film is double scanned for vees with vertices in a fiducial volume about the hydrogen target, yielding 2×10^5 candidate frames.

(ii) For the selected vees, the scope traces are measured and the path length of the positive particle trajectories estimated, enabling us to make a preliminary separation between protons and positrons (or pions). This time-of-flight selection reduces the candidates (mostly electron-positron pairs) by an order of magnitude, leaving us with 2×10^4 data frames to measure.

(iii) The 2×10^4 candidates are measured, reconstructed and kinematically analyzed. Most of these are pairs which filter through stage (ii); these are eliminated by their low invariant mass. There is a low level $\sim 3 \times 10^2$ $\Lambda \rightarrow p\pi$ events which are eliminated by kinematics (3-constraint fit). We believe that

the $\sim 10^3$ lambda beta events are essentially free of background.

(b) Calibration events

In addition to $\sim 10^3$ lambda beta events, we collected

(i) 10^4 $\Lambda \rightarrow p\pi$ events, interspersed through the data. These are needed to determine the lambda polarization in our experiment, the branching ratio $\Lambda \beta / \Lambda p\pi$, and are useful in studying our experimental resolutions. (ii) 10^4 electron-positron pairs useful for calibrating the cerenkov counter (iii) a substantial amount of data with the incident beam energy reduced below Λk^0 threshold. This leaves the dominant source of trigger (pairs from charge exchange) unchanged and is useful for setting an upper limit on background.

(c) Status

At this writing approximately 75% of the film has been double scanned and approximately 10% has been fully analyzed. In addition approximately 10^3 $\Lambda \rightarrow p\pi$ events have been fully analyzed. The $\Lambda \rightarrow p\pi$ events show that our lambdas are $\sim 100\%$ polarized and our experimental resolutions are as good, or better than our estimates in the proposal. For example, our spatial resolution is 0.75mm, our lambda mass resolution $4\text{mev}/c^2$, our missing kaon mass resolution is $10\text{mev}/c^2$ and our transverse neutrino momentum resolution is $10\text{mev}/c$. To extract the physics, i.e. the form factors, we analyze our lambda beta events using a theoretical framework for hyperon beta decay which we developed for this experiment.² We will present our results for vector, axial vector and weak magnetism

form factors based on $\sim 10^2$ events in an invited paper to the January meeting of the American Physical Society.

The film is analyzed at The University of Chicago and at Ohio State University. At Chicago, our group has five measuring machine, six scanning tables and a staff of seven full-time-equivalent scanners and measurers devoted to this experiment.

2. THE CROSS-SECTION FOR LAMBDA PRODUCTION NEAR Σ k THRESHOLD.

Recently, the possibility of a peak (or "cusp") in the lambda production cross-section near Σ k threshold³ was revived by an experiment of O. Van Dyck et al.⁴ The data of Reference 4, while suggestive, is not convincing because the cross-section is measured at widely separated beam energies (only the one point near Σ k threshold lies above a smooth curve) (b) the momentum resolution is 2% (fwhm) which is too coarse for a study of possible cusp phenomena and (c) there was no momentum analysis of the lambda decay products so that a reconstruction of the center of mass of production was not possible. After completing lambda beta decay, we requested and received additional ZGS time to repeat the lambda production experiment in a manner free from the above objections. We collected $\sim 10^3$ $\Lambda \rightarrow p\pi$ events per point at each of twelve different beam energies spaced 5mev/c apart and embracing Σ k threshold. Our beam momentum resolution was 0.5% (fwhm) and with magnetic analysis, we easily reconstruct the production center of mass.

REFERENCES

1. H. Hinterberger, L. Lavoie, B. Nelson, R. L. Sumner, J. M. Watson, R. Winston, D. M. Wolfe, Rev. Sci. Instr., March, 1970.
2. J. M. Watson and R. Winston, Phys. Rev. 181, 1907 (1969).
3. F. Crawford, private communication.
4. S. Frankel, (private communication) and O. Van Dyck et.al., Phys. Rev. Letters 23, 50 (1969).

Bibliography of Published Works

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For the Period April 1, 1969 to March 31, 1970

COO-1701-7

Light Collection within the
Framework of Geometrical Optics,
Roland Winston, Journal of the
Optical Society of America,
February, 1970.

COO-1701-8

The Design and Performance of a
Gas Cerenkov Counter with Large
Phase-Space Acceptance,
H. Hinterberger, L. Lavoie, B. Nelson,
R.L. Sumner, J.M. Watson, R. Winston,
D. M. Wolfe, The Review of Scientific
Instruments, March, 1970.