MASTER

COO-1749-11

Technical Report

for

A Research Program in High Energy Accelerator Physics and Low

Level Counting Elementary Particle Physics

Contract AT(11-1)-1749

1 October 1968 to 30 September 1969

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June, 1969

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Atomic Energy Commission Contract AT(11-1)-1749

Research Program

in

High Energy Accelerator Physics and Low Level Counting

Elementary Particle Physics

by

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Introduction

The counter-spark chamber group at Case Western Reserve has been primarily supported by funds from a National Science Foundation grant which was initially made to Case Institute of Technology in 1965. A two year extension of the grant was made in 1968.

During the fiscal year ending 30 June 1969, the funding of the counter-spark chamber group from the NSF grant will be very close to \$132,400 (\$60,400 for salaries, \$72,000 for equipment). In addition, the A.E.C. contract, AT-(11-1)-1749, will have provided \$70,000 during the period 1 October 1968 to 30 September 1969.

The professional staffing of the group has consisted of four faculty members, Professors Blanpied, Frisken, Jenkins and Sullivan, a Research Associate, Dr. John Todoroff, and six graduate students. The group's activities can be divided into three general categories:

- a) The neutrino and low level counting work. This is a continuation of some of the work in this field which has been performed under A.E.C. support here since 1959.
- b) An accelerator experiment initiated by, and primarily staffed by the CWRU group to study π^-p charge exchange scattering at high momentum transfer.
- c) Collaborations by members of the group (specifically W.A. Blanpied and L.B. Levit) with groups at Harvard and McGill Universities. This year, this has mainly centered on an experiment to search for a charge asymmetry in neutral K decay.

Progress reports for these efforts are given below.

Neutrino and Low Level Counting

We have had two experiments in progress in the underground facility at the Morton Salt Mine in Fairport Harbor, Ohio. One of these, an experiment to set a limit on the lifetime of the proton, is finished. The result of experiment is that the half life of the proton is $\geq 3.7 \times 10^{23}$ years to a confidence level of 90%. The experiment makes much weaker assumptions about the mode of decay than previous experiments of this nature. The same experiment was able to set a limit on the flux of neutrinos from B^8 decay in the sun. The result is $\phi(B^8) \leq 4 \times 10^8 \text{ cm}^{-2} \text{ sec}^{-1}$. This limit is consistent with, and considerably higher than, the result obtained by Davis et al., using a chemical method.¹

The other experiment is designed to improve the experimental limit on the half life for double beta decay of Nd^{150} . The method has been described in a previous proposal.³ The apparatus has been operating during the past year. The present limit on the half life obtained with this equipment is $T_{1/2} \geq 1 \times 10^{18}$ years.

Analysis of the data from the experiment to detect the reaction $\bar{\nu}_e + D \rightarrow e^+ + n + n$ is complete. The reaction was detected and the measured cross section is consistent with theoretical predictions.²

¹R. Davis, D.S. Harmer, K.C. Hoffman, Phys. Rev. Letters 20, 1205 (1968)

²COO-1749-9 "Electron Antineutrino Interaction with Deuterons", T.L. Jenkins, F.E. Kinard, and F. Reines. Submitted to Phys. Rev. for publication.

³"Proposal for A Research Program in High Energy Accelerator Physics and Low Level Counting Elementary Particle Physics", June 1967.

π^-p Charge Exchange Scattering

The experiment has been described elsewhere.^{1,2} Briefly it consists of observing both the π^0 gammas and the neutron in the reaction $\pi^-p \rightarrow \pi^0n$. The particles are detected in large optical spark chamber arrays located on either side of a liquid hydrogen target. The trigger system is such as to suppress events with forward going π^0 's and thus the experiment is sensitive mainly to high momentum transfer events.

The apparatus was installed in the downstream experimental position of the 17° beam of the ZGS during the winter of 1968-69. We first received beam on 11 April, running at a π^- momentum of 3.67 BeV/c. Following the completion of the initially approved 90 shifts, the ZGS Program Committee approved an additional run at higher momentum. We have completed approximately 50 more shifts at 4.83 BeV/c and a few shifts at 5.9 BeV/c to determine the feasibility of additional running at this momentum. Our run ended on 24 June but the apparatus will be kept in position while an experiment runs upstream of us. This would permit additional runs this fall and winter if that seems desirable.

We have pictures of somewhat more than 500,000 events on film. Preliminary hand scanning and measurement indicates that a majority of

¹Proposal P207, "High Momentum Transfer Studies of $\pi^-p \rightarrow \pi^0n$ " submitted to ZGS Program Committee 8 May 1968, C00-1749-2.

²"Technical Report for A Research Program in High Energy Accelerator Physics and Low Level Counting Elementary Particle Physics", June 1968, C00-1749-5

the events at $p_{\pi} = 3.67$ BeV/c showing the correct topology (gamma showers on one side, a neutron conversion on the other) do indeed reconstruct as elastic charge exchange events. We conclude that background is not a serious problem at the lower momentum. The experiment was run with two different trigger systems - a "neutral" trigger (requiring a beam particle in and no charged particle out) and a "gamma" trigger (neutral trigger requirement plus the requirement that a shower occur in the spark chamber array). Comparison of rates obtained with these two trigger systems will permit us to determine certain efficiencies and will provide an overall check on the method. We believe we have sufficient statistics at 3.67 BeV/c to determine the cross section to a precision of 10% in bins of width $0.3 (\text{BeV}/c)^2$ between $1.0 \leq |t| \leq 4.0 (\text{BeV}/c)^2$. Analysis of the film is in progress. Scanning and measuring is being done both manually and using our automatic flying spot scanner.

Search for a CP-Nonconserving Asymmetry in K_L^0 Decay

Recent studies have shown that both uncharged K mesons, K_S^0 and K_L^0 , can decay into 2π . This is evidence against conservation of CP.¹ To date, this is the only evidence for the violation of the CP selection rule. It is important to determine whether or not this is the only decay which demonstrates this violation.

¹J.H. Christenson et al. Phys. Rev. Letters 13, 138 (1964)

The purpose of this effort is to search for a CP asymmetry in the decay $K_L^0 \rightarrow \pi^+ \pi^- \pi^0$. Such an asymmetry would reveal itself in the energy spectra of the π^+ and π^- . Calculation of the size of such an effect involves estimates of the magnitudes of the various 3π decay amplitudes. The estimates lead to results ranging from 10^{-5} to 2.7%.

An experiment was run in a neutral beam of the Brookhaven AGS. It was a counter experiment with a large momentum analyzing magnet. The apparatus was a slight modification of one used for an earlier experiment.¹ Data were recorded on magnetic tape for later analysis.

An initial analysis has been performed using half of the data. Comparison of momentum spectra of the data to Monte-Carlo generated data was used to fit a matrix element of the form

$$\langle M \rangle^2 = 1 + 2\sigma_0(2T_0 - 108.) \frac{M_K}{M_{\pi^2}} + 2\sigma_{\pm}(T_+ - T_-) \frac{M_K}{M_{\pi^2}}$$

Here T_0 , T_+ and T_- are the kinetic energies of the π^0 , π^+ and π^- . This form was suggested by Nefkins et al.² If $\sigma_{\pm}$ is found to be non-zero, this is evidence of CP violation.

¹S. Bennet et al. Phys. Rev. Letters 19, 993 (1967)

²Phys. Rev. 157, 1233 (1967).

Preliminary results yield the values of

$$\sigma_0 = 0.20 \pm 0.05$$

$$\sigma_{\pm} = 0.001 \pm 0.004$$

The large uncertainty in σ_0 is reasonable because this experiment was designed to measure $\sigma_{\pm}$. The value of σ_0 is in agreement with previous values, and the preliminary limit set in $\sigma_{\pm}$ is nearly an order of magnitude below that set by other authors. The complete analysis is being performed at C.W.R.U. and should be completed before October 1969.

Preliminary results of this experiment have been reported.¹

¹Phys. Rev. Letters 21, 1650 (1968) and C00-1749-8.

Bibliography

1. "Muon Pair Production by 12 GeV/c Negative π^- and K-Mesons on Carbon and Iron", A.A. Wehmann, E. Engels Jr., C.M. Hoffman, P.G. Innocenti, Richard Wilson, W.A. Blanpied, D.J. Drickey, L.N. Hand, D.G. Stairs, Phys. Rev. 178, 2095 (1969). COO-1749-6
2. "Experimental Test of Quantum Electrodynamics by Muon Bremsstrahlung", W.A. Blanpied, A.D. Liberman, C.M. Hoffman, E. Engels, Jr., D.C. Imrie, P.G. Innocenti, R. Wilson, C. Zajde, D.G. Stairs, and D.J. Drickey. Phys. Rev. Letters 22, 663 (1969). COO-1749-7.
3. "Search for a CP-Nonconserving Asymmetry in the Decay $K_L^0 \rightarrow \pi^+ \pi^- \pi^0$ " with L.B. Levit, E. Engels, Jr., M. Goitein, T. Kirk, D.G. Ryan and D.G. Stairs, Phys. Rev. Letters, 21, 1650 (1968). COO-1749-8.
4. "Electron Antineutrino Interaction with Deuterons", T.L. Jenkins, F.E. Kinard, and F. Reines. Submitted to Phys. Rev. for publication. COO-1749-9.
5. "High-Energy Muon Inelastic Scattering", W.A. Blanpied, C.M. Hoffman, A.D. Liberman, E. Engels, Jr., D.C. Imrie, P.G. Innocenti, R. Wilson, C. Zajde, D.G. Stairs, and D. Drickey. Phys. Rev. Letters 22, 659 (1969). COO-1749-10.
6. "Technical Report for A Research Program in High Energy Accelerator Physics and Low Level Counting Elementary Particle Physics". W.A. Blanpied, W.R. Frisken, T.L. Jenkins, C.R. Sullivan, J.A. Todoroff, June 1969. COO-1749-11.

Equipment Report
AEC Contract AT(11-1)1749
Case Western Reserve University
for the period 1 October 1968 through 30 June 1969

PURCHASED TO DATE:

<u>ITEM</u>	<u>COST</u>
Type 251-3 Digital plug-in unit	\$ 252.00
Model 431 Bushman modified Gantry crane	881.00
Model E.T. 2000# Elevating tables (2)	504.90
Type RM504 Tektronix Oscilloscope	<u>570.23</u>

\$2208.13

TO BE PURCHASED DURING REMAINING CONTRACT PERIOD:

1 Model 1400/360 Kennedy Incremental Tape Recorder \$3400.00

\$3400.00