MASTER

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 1967 to 30 September 1968

Thomas L. Jenkins

T.L. Jenkins, Principal Investigator,
Associate Professor of Physics

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:
A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.
As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Case Western Reserve University

University Circle
Cleveland 6, Ohio

June, 1968

sep

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

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

Research Program

in

High Energy Accelerator Physics and Low Level Counting

Elementary Particle Physics

by

William A. Blanpied
William R. Frisken
Thomas L. Jenkins
F.F. Liu
Charles R. Sullivan
John A. Todoroff

Associate Professor of Physics
Associate Professor of Physics
Associate Professor of Physics
Assistant Professor of Physics
Postdoctoral Fellow
Postdoctoral Fellow

Introduction

The counter-spark chamber group at Case Western Reserve University has been primarily funded by a National Science Foundation grant to Case Institute which was awarded in 1965. CWRU, created in 1967 by the merger of Case Institute and Western Reserve University, has been awarded a supplemental grant to cover a two year period beginning 1 July 1968. The counter spark chamber work is one of the areas that will be supported in this grant.

In the past year some changes have occurred in the staffing of this group. Professor Liu has resigned, Dr. Charles Sullivan has been promoted to faculty rank and Dr. John Todoroff, formerly at the University of Illinois, has joined us as Postdoctoral Fellow. The electronics technician and computer programmer formerly attached to the group are no longer associated with us. There are six graduate students involved in activities of the group.

The work supported by this contract can be divided into three parts:

- (a) the neutrino and low level counting work which was supported until September of 1967 on a previous contract (AT(11-1)-818). Two experiments are presently in progress: a search for double beta decay in Nd^{150} and an experiment to set a limit on the lifetime of the proton.

- (b) "conventional" elementary particle physics experiments initiated by and chiefly involving the members of the CWRU counter-spark chamber group. These experiments are at present proposed for the ZGS. At present this activity is concentrating on a preparation for a series of experiments studying the charge exchange reaction $\pi^- p \rightarrow \pi^0 n$ at various energies.
- (c) the collaboration at the Brookhaven AGS between part of the CWRU high energy group (W.A. Blanpied and L.B. Levit) and groups from Harvard and McGill Universities. Analysis of the data on one experiment (the production of muon pairs by 12 GeV π^- and K-mesons) was completed, while data were obtained and analysis started on two others (inelastic scattering of 12 GeV muons from carbon and hydrogen, and search for a CP violating contribution in the decay mode $K_2^0 \rightarrow \pi^+ \pi^- \pi^0$).

(a) Neutrino and Low Level Counting

The solar neutrino and baryon stability experiments have been described rather completely in previous reports.^{1,2} The solar neutrino part of this experiment was intended to be complimentary to the chemical detection method used by R. Davis in that it could verify his result and separate the contributions of the pp and CNO cycles to the sun's energy generation. An extremely surprising and unexpected result has been obtained recently by Davis et. al.³, namely that the neutrino flux from B^8 decay in the sun is less than

$2 \times 10^6 \text{ cm}^{-2} \text{ sec}^{-1}$ at the earth. This limit is approximately an order of magnitude less than the theoretically predicted flux⁴.

After a careful consideration of the status of our own experiment and its capabilities, we concluded that, in light of the Davis result, the scientific significance of any result obtained from further operation of the detector as a solar neutrino detector would not be worth the necessary expenditure of effort and money.

The apparatus has operated with the D_2O filling for about a year and data are available to set a model-independent limit on the decay rate of the proton as well as an upper limit on the solar neutrino flux (which will be at least two orders of magnitude greater than that set by Davis et. al.³). Our present, very preliminary, values for these limits are: mean life of proton $> 1.4 \times 10^{23}$ years, flux of solar neutrinos (from B^8) $< 1.2 \times 10^9 \text{ cm}^{-2} \text{ sec}^{-1}$.

The search for the double beta decay of Nd^{150} , described in the previous report, is proceeding well. The double beta ray spectrometer has been installed at the underground location in the Morton salt mine at Fairport Harbor. The vacuum system and solenoid for producing the magnetic field are functioning. The scintillation counters and source holders are presently being installed.

(b) ZGS Experiments

1. K^+ Decay Experiment

An experiment for the study of the decay $K^+ \rightarrow \pi^+ + \pi^0 + \gamma$ was proposed and approved for running at the Zero Gradient Synchrotron (experiment E-164). This experiment is described in our proposal to the ZGS Program Committee⁵. Briefly, it consisted of examining the decay of stopped K^+ 's with an array of spark chambers and an analyzing magnet which would permit complete reconstruction of $\pi^+ \pi^0 \gamma$ final states, providing all final state gamma rays converted in the lead plate chambers. To this end, a beam was designed and spark chamber and counter arrays constructed. In April of 1968 approval of this experiment was, in effect, withdrawn when budgetary considerations forced the Program Committee to the decision that this rather difficult experiment was too high a risk. We were encouraged by the Program Committee to propose a new experiment which we did and which is described below.

2. $\pi^- p$ Charge Exchange Scattering

This experiment is described in detail in our proposal (P-207) to the ZGS Program Committee⁶.

It is an experiment to study the charge exchange reaction $\pi^- p \rightarrow \pi^0 n$ for incident pion momenta from 3 to 5.9 BeV/c and for $|t|$ ranging from 1.5 to 3.5 (BeV/c)² at the lowest incident momentum and 1.5 to 6 (BeV/c)² at the highest incident momentum. This experiment will therefore cover an s and t range in which the charged exit channel ($\pi^- p \rightarrow \pi^- p$) shows some interesting structure^{7,8}.

The instrumentation of the experiment is shown in figure 1. It consists of two spark chamber converter arrays which serve the dual purpose of converting both π^0 gammas and neutron. The system will be triggered on a "neutral" signature, that is, a π^- entering the target and no charged particle leaving it. Shower counters will be disposed around the target, especially in the forward direction, to suppress triggers due to small angle charge exchange events and inelastic events such as $\pi^- p \rightarrow \pi^0 \pi^0 n$.

The experiment should also be capable of measuring cross sections for $\pi^- p \rightarrow \eta^0 n$, $\pi^- p \rightarrow \pi^0 N^*$ as well as obtain information about strange particle production at high momentum transfer.
 $\quad \quad \quad \downarrow \rightarrow \pi^0 n$

The experiment has been approved for running in the 17° beam at 3 BeV/c and, in view of the present schedule at the ZGS, will probably be set up and run starting about December of this year. Professor Bruce Richards of Oberlin College is a collaborator in this experiment and is working with us full time during the summer of 1968 under an NSF research participation grant.

3. Flying Spot Scanner

This device, described in some detail in our original proposal for this contract⁹, was completed by September of 1967. Its performance appears to be as good as anticipated. It is being used in the analysis of the spark chamber film obtained from the inelastic mu scattering experiment described below.

Figure 1 Plan view of the apparatus for studying $\pi^- p \rightarrow \pi^0 n$. B1, B2 are beam counters required in the trigger. CA is an anticoincidence counter to require no charged particle out. NA1 through NA6 are shower counters, also in anticoincidence, to suppress forward $\pi^0 n$ events and inelastic neutral final states. C1 and C2 are arrays consisting of 25 2-gap spark chambers interleaved with lead and steel plates for converting the π^0 gammas and neutron. Not shown are NA7 and NA8, shower counters above and below the target.

(c) AGS Experiments

1. Production of Muon Pairs by 12 GeV π^- and K-Mesons

The latter stages of analysis on this experiment were carried out at CWRU starting during 1967, and have now been completed¹⁰. During the current year the data yielded upper limits on the branching ratios for two rare decay modes of the η^0 meson:

$$\begin{aligned} \text{BR}(\eta^0 \rightarrow \mu^+ \mu^-) &< 2 \times 10^{-5} \\ \text{BR}(\eta^0 \rightarrow \pi^0 \mu^- \mu^+) &< 5 \times 10^{-4}. \end{aligned}$$

The latter mode, if it existed, would proceed via a CP violating electromagnetic interaction. We have also obtained a semi-quantitative result on the leptonic decay mode of the ϕ^0 which is good to within a factor of two:

$$\text{BR}(\phi^0 \rightarrow \mu^+ \mu^-) = 3.5 \times 10^{-4}$$

2. Inelastic Scattering of 12 GeV Muons

Data taking runs for this optical spark chamber experiment began in early August 1967, and continued to November. These data are expected to yield information on: (1) the total cross section for 12 GeV virtual photons, (2) ρ^0 - and single π -meson production by virtual photons, and (3) muon bremsstrahlung production.

The experimental apparatus included three different sets of spark chambers. The task of hand scanning and measuring the film for two of these sets has been divided among the groups at CWRU, Harvard, and McGill, and is well underway. The film from the third set of chambers will be measured on the CWRU flying spot scanner mentioned above. The programming system for measuring the muon experiment film have been written and tested, and it is anticipated that the measurements will be completed in the fall of 1968.

3. Search for a CP Violating Contribution in the Decay Mode

$$\underline{K_2^0 \rightarrow \pi^+ \pi^- \pi^0}$$

Data taking runs for this counter experiment were carried out during March and April, 1968, after the apparatus of the Columbia group (J. Steinberger, et. al.) was modified by adding shower counters to detect γ -rays from the decaying π^0 's. Very preliminary results place an upper limit of $.0025 \pm .0040$ on the CP-violating contribution to the matrix element for the decay. A letter reporting these results should be ready for publication by mid-summer. Since approximately 100,000 examples of the decay mode were obtained during the run, it should be possible to deduce the behavior of the dominant, CP-conserving contribution to the matrix element for the decay as a function of the final state π -meson energies. Analysis of the data with this end in view began at CWRU in June.

References

- ¹COO-818-62 "Request for Loan of D₂O For Use in a Solar Neutrino Experiment" Contract AT(11-1)-818² July 1965.
- ²COO-818-96 "Technical Report for Research Program in Neutrino Physics, Cosmic Rays and Elementary Particles" Contract AT(11-1)-818 October 1965.
- ³R. Davis, D.S. Harmer, K.C. Hoffman, Phys. Rev. Letters 20, 1205 (1968).
- ⁴See, for example, J.N. Bahcall, N.A. Bahcall, W.A. Fowler, G. Shaviv, Physics Letters 26B, 359 (1968).
- ⁵COO-1749-4 "An Experiment for the Study of the Radiative $K_{\pi 2}^+$ Decay Mode", proposal submitted to the ZGS Program Committee, 9 June 1967.
- ⁶COO-1749-2 "High Momentum Transfer Studies of Charge Exchange Pion Scattering", proposal submitted to ZGS Program Committee 8 March 1968.
- ⁷A. Ashmore, C.J.S. Damerell, W.R. Frisken, R. Rubinstein, J. Orear, D.P. Owen, F.C. Peterson, A.L. Read, D.G. Ryan, D.H. White, "High Energy π^-p , K^-p , pp Elastic Scattering", submitted to Phys. Rev. Letters.
- ⁸C.T. Coffin, N. Dikman, L. Ettlinger, D. Meyer, A. Saulys, K. Terwilliger, D. Williams, " π^+p Elastic Scattering", Phys. Rev. Letters 15, 838 (1965) and 17, 458 (1966), and D. Meyer, private communication.
- ⁹Proposal for A Research Program in High Energy Accelerator Physics and Low Level Counting Elementary Particle Physics, June 1967 and COO-818-103 Technical Report for High Energy Machine Physics Contract AT(11-1)818, June 1967.
- ¹⁰"Some Rare Decay Modes in Interactions of π^- and K-Mesons with 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, and D.G. Stairs, Phys. Rev. Letters, 20, 748 (1968).

A final detailed paper on the experiment is in the last stages of preparation; and should be ready for submission to The Physical Review by mid-July.

Bibliography

1. "Momentum Measurement at 100 MCS. of Particles in a High Energy Beam with Large Angular Divergence and Spatial Extent", C. Zajde, E. Engels, C. Hoffman, P.G. Innocenti, A. Liberman, R. Wilson, W.A. Blanpied, D.G. Stairs, D. Drickey, submitted to the Journal of Nuclear Instruments and Methods for publication. COO-1749-1
2. Proposal for: "High Momentum Transfer Studies of $\pi^- p \rightarrow \pi^0 n$ " to be performed at the ZGS, at Argonne National Laboratory, W.A. Blanpied, W.R. Frisken, T.L. Jenkins, F.F. Liu, W.B. Richards, C.R. Sullivan, J.A. Todoroff, W.S. Brockett, A.R. Kirby, 8 May 1968. COO-1749-2.
3. "Some Rare Decays in Interactions of π and K Mesons with Carbon and Iron", A.W. Wehmann, E. Engels, Jr., C.M. Hoffman, P.G. Innocenti, R. Wilson, W.A. Blanpied, D.J. Drickey, L.N. Hand, D.G. Stairs, Phys. Rev. Letters 20, 748 (1968). COO-1749-3
4. Proposal for: "An Experiment for the Study of the Radiative $K_{\pi^2}^+$ Decay Mode", to be performed at the ZGS, at Argonne National Laboratory, W.A. Blanpied, W.R. Frisken, T.L. Jenkins, F.F. Liu, C.R. Sullivan, W.S. Brockett, A.R. Kirby, K.A. Taggart. COO-1749-4
5. 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, F.F. Liu, Charles R. Sullivan, J.A. Todoroff, June 1968. COO-1749-5