COO Contract A(11-1)3230-3

RESEARCH IN ELEMENTARY PARTICLE PHYSICS

Technical Progress Report

Lawrence E. Kirsch and Howard J. Schnitzer

Department of Physics
Brandeis University
Waltham, Massachusetts 02154

September 1, 1973 - May 29, 1974

PREPARED FOR THE U.S. ATOMIC ENERGY COMMISSION
UNDER CONTRACT NO. AT(11-1) 3230

Technical Progress Report: September 1, 1973 to April 30, 1974

Under this contract, research has been performed in both the theoretical and experimental properties of elementary particles. A brief description of work which has either been completed or is in progress is given below:

EXPERIMENT

1. $K^-N \rightarrow \Sigma^-\eta$ Near Threshold

The purpose of this experiment was to clarify the nature of a previously reported[1,2,3] enhancement near threshold in the reaction $K^-n \rightarrow \Sigma^-\eta$. One question to be resolved is whether the enhancement is due to a resonance, which is the case near threshold in the $N\eta$ and $\Lambda\eta$ systems, or can be attributed to an S-wave scattering length. Another question is the conflict between the data of the previous references concerning the angular distribution, with the Cline-Olsson experiment[1] favoring isotropy and the S-wave interpretation and the CERN-Heidelberg-Saclay[2] data favoring the presence of a D_5 wave.

Our data, which come from a 60,000 picture exposure at the BNL 30" bubble chamber, indicate a weak contribution from the A_2 coefficient (2σ), but the combination of our data with that of references 1 and 2 shows no significant deviation from isotropy. From the Fermi momentum of the neutron and two incident beam momenta, we obtained data on the shape of the cross section for this reaction from threshold. This shape was used to attempt to discriminate between the S-wave scattering length hypothesis ($\mathrm{Prob}(\chi^2) = 0.03$) and the S-wave resonance interpretation ($\mathrm{Prob}(\chi^2) = 0.18$).

2. Ξ^* Production

We are in the final stages of analysis of an experiment to search for Ξ^* states produced by 2.87 GeV/c K^- incident on deuterium. With 10^6 pictures taken in the BNL 31" bubble chamber, we have a sensitivity of about 15 eV/μb in K^-n and in K^-p interactions. Of particular interest is the reaction $K^-n \to \Xi^-\pi^-K^+$, where the $\Xi^-\pi^-$ combined mass spectrum shows several peaks which however are not statistically significant enough to be interpreted as exotic Ξ^* states. This reaction, with simple isospin arguments, may also be used to demonstrate conclusively that all Ξ^* states previously observed[4] in $\Xi^-\pi^+K^0$ with a mass less than 2 GeV/c^2 have isospin 1/2 and not 3/2. The other three-body final states $\Xi^{\frac{-}{0}}\pi^{\frac{0}{-}}K^0$ produced in K^-n interactions do not show clear evidence of Ξ^* production other than $\Xi^*(1530)$, although there is a broad peak in the high mass region $1.80 < M(\Xi\pi) < 2.00$ GeV/c^2. There is a possibility of $\Sigma^-(1960) \to \Xi^{\bar{0}}K^0$ decay that needs further evidence for confirmation.

The reaction $K^-n \to \Lambda^0K^-K^0$ can be expected to be important for the analysis of $\Xi^* \to \Lambda\bar{K}$ decay because there is no competing ϕ meson production as in $K^-p \to \Lambda^0(\bar{K}K)^0$. Unfortunately, there is only weak evidence for the production of a $\Xi^-(1820)$. Other final states $\Xi^-\pi^0\pi^-K^+$ and $\Xi^-\pi^+\pi^-K^0$ show strong production of $\Xi(1530)$ and can also be used to set upper limits of $\sim$1 μb for the production of exotic Ξ^{*--}.

The features of the K^-p reactions in deuterium agree with those of the earlier K^-p experiment of the BMST collaboration.[4] The previous claim of a $\Xi^*(1635)$ in the final state $\Xi^-\pi^+K^0$ receives weak support from the $\Xi^-\pi^+K^0_1$ events of the deuterium experiment.

This experiment is a collaboration among Brandeis, Maryland, Syracuse and Tufts Universities.

3. π^+d Interactions

We are analyzing a sample of 27,000 multiprong events from a 3.5×10^5 picture exposure of the SLAC 82 inch bubble chamber to a 15 GeV/c π^+ beam.

The primary goals of the π^+d experiment are: (1) The study of coherent production in the reaction $\pi^+d \rightarrow d(3\pi)$ or $\pi^+d \rightarrow d(5\pi)$. In this channel we see the well-known A_1 and A_3 mesons and no evidence of a $g\pi$ resonance which has been reported at 1.95 GeV. In addition we see some evidence of structure in the U(2400) region (5π data). Further studies of these effects, d* production, and diffraction mechanisms are in progress. (2) We are also investigating the I=0 state in the reaction $\pi d \rightarrow pp_s(n\pi)$ where n = 2, ..., 7. We have seen many of the known resonances and we are searching for evidence of sequential resonance decays. (3) In collaboration with two other high energy deuteron experiments (Caltech-LBL and Seattle-Berkeley), we have observed what may be direct evidence for the existence of a Δ-Δ(1236) component of the deuteron. The experimental technique is to search for spectator-like behavior of one of the Δ's in the reaction $\pi d \rightarrow \Delta\Delta\pi$.

The experiment is a collaboration between Brandeis and Florida State University.

4. Exotic Baryons and Properties of the Deuteron

We are currently analyzing 18,000 events from the reaction $K^-d \rightarrow \Sigma^-\pi^-\pi^+ (P_s)$ from a 10^6 picture exposure of the BNL 31" bubble chamber with a 2.9 GeV/c incident beam. Since normal Y* production cross sections in this energy region are approximately 10 μb, a meaningful search for the production of an exotic baryon in the

$\Sigma^-\pi^-$ system requires a sensitivity in the 1 μb range. The present data sample represents about 15 events/μb.

Another reaction of interest in this final state is $K^-d \rightarrow \Sigma^-\pi^-(\Delta_s^{++})$. It has been suggested[5] that the deuteron dissociation into two isobars rather than two nucleons may account for the discrepancies which exist between nuclear theory and experiment in the values of the magnetic moments of light nuclei, triton beta decay, and double beta decay. This reaction could provide a direct test of this hypothesis.

Technical Development

A major portion of our effort has been devoted to a variety of projects in connection with both the general construction of the Multiparticle Spectrometer facility at Brookhaven and the need of our specific experiments which will use this facility.

These projects include the following:

a) A veto counter for the $\bar{p}p \rightarrow V^\circ V^\circ$ experiment has been designed, constructed and tested. This 24" cylindrical counter with hemispherical endcap fits directly over the vacuum jacket of the liquid hydrogen target. A group of adiabatic light pipes moves the light upstream along the beam line to a region outside of the MPS magnet. The counter has an efficiency in excess of 99%.

b) Construction and testing of a prototype spark chamber with a capacitive readout system to be used in the MPS magnet. A unique feature of this chamber is the use of a "C" frame, with the last edge constructed of a low mass fiberglass girder, so that particles passing through the edge of the chamber will suffer minimal multiple scattering.

c) Testing of a high resolution time of flight system to replace Cerenkov counters in the separated beam. This would reduce multiple scattering and improve the momentum resolution and beam spot size.

d) Testing of the large planar spark chambers which provide the basic tracking of particles through the magnet.

e) Development of software to reconstruct and process events.

f) Experimentation with theoretical and actual properties of the medium energy separated beam.

g) Assistance in mapping and determining parameters of the magnetic field in the MPS magnet.

h) We are in the process of writing a 3-boson partial wave analysis program for use in the meson production experiment described above as well as one at the MPS. This program, which is being developed in collaboration with S.U. Chung and S.D. Protopopescu of BNL, is intended to be equal in scope to the Illinois 3π partial-wave program, however, the code is completely independent of that program and has many distinct features. These include a different parameterization of the density matrix which explicitly guarantees positivity without explicitly calculating eigenvalues, parity conservation, Bose symmetry, and time reversal invariance. This program can be easily adapted to include the angular detection efficiency of the MPS. In addition, this program will provide the only independent check of the Illinois program which is now used in many labs.

THEORY

The theoretical research supported by the present contract covers several areas. During the previous contract year we discovered[6] that Yang-Mills mesons in renormalizable field theories lie on Regge trajectories. This earlier work[6] has subsequently been extended[7] and expanded[8] to give a more complete description of this phenomenon. With the completion of this program, we have more recently concerned ourselves with evolving new methods for field theory appropriate for hadron physics. As a first step, we have developed[9,10] a non-perturbative method for computing $\lambda\phi^4$ in the many-field limit. Other research of our group has dealt with the non-renormalizability of Einstein-Yang-Mills interactions,[11] and the role of scalar mesons in e^+e^- annihilations in asymptotically free field theories.[12] A summary of this research is given below.

1. <u>Reggeization of Yang-Mills Gauge Vector Mesons</u>[6-8]

The question of the Reggeization of all the elementary particles in renormalizable non-Abelian gauge theories with Higgs-Kibble mechanism was examined in great detail.[6-8,13] It was concluded[6,7] that the massive non-Abelian gauge vector mesons and J=1/2 fermions of these theories lie on Regge trajectories in every case in which a counting criterion due to Mandelstam is satisfied. The scalar meson states (J=1) of these theories were also examined.[8] Because of the complexity of the problem, this last study was limited to three typical gauge models, U(1), SU(2), and U(2). It was demonstrated that under special circumstances, the Born approximation for some or all of the J=0 amplitudes can be factorized, the first time the possible Reggeization of elementary scalars has been reported. However, no model is found in which all elementary particles lie on Regge trajectories.

Possible implications of the above work for the bootstrap program were also analyzed.[13] It is argued that bootstraps for spin 1/2 and spin 1 particles may in fact be trivial if hadron dynamics involves non-Abelian gauge mesons, since a calculation correctly carried out will produce bootstraps for <u>any</u> values of mass and coupling constant.

2. <u>Many-Field Limit of Relativistic Field Theory</u>[9,10]

During the last year, motivated by possible connections between dual models and local field theory,[6-8,14,15] as well as a desire to find calculational methods more suitable to hadron physics than the usual perturbation expansions, we began a program whose purpose is to analyze local field theories in the many-field (large N) limit. As a prelude to an analysis of more complicated theories, we studied $\lambda\phi^4$ theory with O(N) symmetry, and developed method[9,15,16] which permits an <u>exact</u> computation of the leading term in a 1/N expansion for the Green's functions of the theory. Among the applications of this result, we studied the stability of the theory.

Our original derivation of the above results was quite lengthy, and perhaps too complicated to be suitable for generalization to a theory as rich as Yang-Mills theory. As an alternative, we also derived the large N limit of $\lambda\phi^4$ theory with O(N) symmetry by functional methods. Since the method does not require the cumbersome analysis of Feynman graphs, it may make possible the study of more complicated theories in the many-field limit.

3. <u>Nonrenormalizability of Einstein-Yang-Mills Interactions</u>[11]

It had been shown by 't Hooft and Veltman[17] that pure gravitation is one-loop finite, but gravitation interacting with massless scalar particles is one-loop non-renormalizable. This program was continued at Brandeis by Deser and van Nieuwenhuizen,[18] who showed that the Einstein-Maxwell and Dirac-Einstein systems were also one-loop nonrenormalizable. Most recently, Dr. Tsao of our group, in collaboration with Deser and van Nieuwenhuizen showed[11] that the Einstein-Yang-Mills system was also one-loop nonrenormalizable. In summary of the above findings, it is thus impossible to construct a perturbatively renormalizable theory for Einstein gravitation interacting with any low spin matter source.

4. <u>Scalar Contribution to the e^+e^- Annihilation</u>[12]

Neutral scalar mesons were incorporated into asymptotically free theories to see if they can explain the experimental approach of the e^+e^- total cross-section to its possible scaling limit. The corresponding fourth order vacuum polarizations were calculated. It was found[12] that the scalar contributions were unable to explain the continued rise of the ratio $R = \frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)}$ in the semi-asymptotic region.

REFERENCES

1. D. Cline, M. Olsson, Phys. Letters 25B, 41 (1967).
2. CERN-Heidelberg-Saclay collaboration. Heidelberg International Conference on Elementary Particles (1967).
3. W. Delaney et al., Lettere Nuovo Cimento 1, 497 (1969).
4. S. Apsell et al., Phys. Rev. Letters 23, 884 (1969). See also BMST collaboration, Duke Conference on Baryon Spectroscopy (1970).
5. For a review see: H. Arenhovel, H. Weber, Springer Tracts in Mod. Phys. V65, 59 (1972).
6. M. Grisaru, H.J. Schnitzer and H.-S. Tsao, Phys. Rev. Letters 30, 811 (1973). H.J. Schnitzer, Annals of the New York Academy of Sciences (to be published).
7. M. Grisaru, H.J. Schnitzer and H.-S. Tsao, Phys. Rev. D8, 4498 (1973).
8. M. Grisaru, H.J. Schnitzer and H.-S. Tsao, to be published in Phys. Rev. D.
9. "Nonperturbative Effective Potential for $\lambda\phi^4$ Theory in the Many-Field Limit," H.J. Schnitzer, submitted to Physics Rev. D.
10. "The Hartree Approximation in Relativistic Field Theory," H.J. Schnitzer, submitted to Phys. Rev. Letters.
11. "Nonrenormalizability of Einstein-Yang-Mills Interactions," S. Deser, P. van Nieuwenhuizen, and H.-S. Tsao, submitted to Physics Letters.
12. "Scalar Contributions to e^+e^- Annihilation in Asymptotically Free Theories," J.S. Kang, submitted to Phys. Rev. D.

13. M. Grisaru and H.-S. Tsao, Phys. Rev. D9, 512 (1974).

14. A. Neveu and J. Scherk, Nucl. Phys. B36, 155 (1972); J.L. Gervais and A. Neveu, ibid. B46, 318 (1972); J. Scherk, ibid. B31, 222 (1971).

15. G. 't Hooft, Nucl. Phys. (to be published); G.P. Canning, Bohr Institute preprint; K. Wilson, Cornell University preprint; D. Amati and M. Testa, CERN preprint; H.B. Nielsen and P. Olesen, Phys. Letters 32B, 207 (1970); A. Casher, J. Kogurt and L. Susskind, Cornell University preprint; and references cited in the above papers.

16. See also K.G. Wilson, Phys. Rev. D7, 2911 (1973); and S. Coleman, H.D. Politzer and R. Jackiw, (in preparation).

17. G. 't Hooft and M. Veltman, CERN preprint.

18. S. Deser and P. van Nieuwenhuizen, Phys. Rev. Letters 32, 245 (1974) and Brandeis preprints.

PUBLICATIONS FROM APRIL 1, 1973 TO APRIL 30, 1974

Experimental

1. $K^-N \rightarrow \Sigma^-\eta$ Near Threshold" (with Tufts University), Il Nuovo Cimento 20, 35 (1974).
2. "Multiparticle Resonances from 15 GeV/c π^+d Interactions" (with Florida State University), Bull. Am. Phys. Soc. 19, 588 (1974).
3. "Study of the η' Produced in K^-p Interactions at 2.885 GeV/c," Phys. Rev. D8, 18 (1973).

Theoretical

Howard J. Schnitzer:

1. Constraints and Anomalies in Finite Quantum Electrodynamics," Phys. Rev. D8, 385 (1973).
2. "Reggeization of Elementary Particles in Renormalizable Gauge Theories: Vectors and Spinors" (with M. Grisaru and H.-S. Tsao), Phys. Rev. D8, 4498 (1973).
3. "Reggeization of Elementary Particles in Renormalizable Gauge Theories: Scalars" (with M. Grisaru and H.-S. Tsao), Phys. Rev. D to be published.
4. "Nonperturbative Effective Potential for $\lambda\phi^4$ Theory in the Many-Field Limit," submitted to Phys. Rev. D.
5. "The Hartree Approximation in Relativistic Field Theory," submitted to Phys. Rev. Letters.

H.-S. Tsao:

6. "Are Bootstraps of Low-Spin Particles Meaningful?" (with M. Grisaru), Phys. Rev. D9, 512 (1974).

7. "Nonrenormalizability of Einstein-Yang-Mills Interactions at the One-Loop Level" (with S. Deser and P. van Nieuwenhuizen), submitted to Physics Letters.

8. "Supergauge Symmetry, Broken Chiral Symmetry, and Renormalization," submitted to Physics Letters.

J.S. Kang:

9. "Scalar Contributions to e^+e^- Annihilation in Asymptotically Free Theories," submitted to Phys. Rev. D.

P. Ford:

10. "Exact Representation of Meson-Meson Scattering Amplitudes Consistent with Current Algebra Constraints," Nuclear Physics B57, 25 (1973).