Report of Technical Progress under
the Current AEC Contract, AT(11-1)-2232B

[on High-Energy Physics]

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The following is a necessarily incomplete review of work done under the present contract. The cut-off date is approximately February 1, 1974. Footnote numbers refer to the list of papers completed, see pages 6-8.

Principal Investigator Dr. A. Pais, and Drs. M.A.B. Beg, N.N. Khuri, and H.R. Pagels have spent at least 1/4 of their time on work related to this contract. This is expected to continue for the remainder of the current term.

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(I) Rigorous results

Under this heading are listed some results which follow from the most generally accepted principles of physical theory only (unitarity, positivity, crossing, etc.), occasionally combined with weak additional conditions:

- a) The derivation of a rigorous representation for the π - π scattering amplitude which exhibits full crossing symmetry⁶.
- b) Application of this representation to improve the Martin bound on the renormalized coupling constant for π - π interaction¹⁷.
- c) Proof that a simple mechanism which limits π -particle production relative to elastic scattering suffices to obtain a unit intercept for the Pomeranchuk singularity¹⁶.
- d) Study of the mathematical analogy between the generating function for particle production and the classical grand partition function reveals that the asymptotic bound on the total cross section follows from the behavior of the zeros of the generating function.²⁴
- e) The derivation of logarithmic energy bounds for average multiplicities and corresponding higher moments under extremely general conditions³⁷.
- f) Constraints on the phases of helicity amplitudes following from positivity³⁶.

(II) Gauge Theories

This area comprises the studies of problems arising in connection with the program of unifying the weak and electromagnetic forces and the harmonization of such attempts with strong interactions.

- (a) Development of a program on which the origins of CP-violation, of the Cabibbo angle and of the non-leptonic decay mechanism appear interlinked^{4,7}.
- (b) Development of a gauge model where the emphasis lies on the three-triplet picture of hadronic structure⁹ and a further analysis of the consequences of this model.²⁰
- (c) Realization of the so-called schizon scheme in terms of a gauge model.¹³
- (d) An attempt to harmonize the three-triplet picture with the considerations under (a).¹⁹
- (e) A study of the properties of electric dipole moments of fermions in gauge models with CP-violation.²¹
- (f) An analysis of some properties of the spontaneous breakdown of symmetry as it appears in gauge models.²²
- (g) A comment on baryon conservation.¹⁸
- (h) A classification of gauge models in regard to weak neutral current properties.^{32a}

(III) Chiral symmetry and its breaking

A systematic investigation was made of the behavior of the S-matrix and Green's functions as one breaks chiral symmetry. The recognition of the failure of conventional perturbation theory serves to eliminate certain paradoxes in several applications of chiral symmetry arguments. Modifications of the so-called non-renormalization theorem were derived⁵. A chiral perturbation theory was developed²⁵. Calculations were performed for pion and kaon electromagnetic masses²⁸. Chiral symmetry realizations of the Nambu-Goldstone type were studied, and the possibility of "dynamical symmetry breaking" was discussed.^{10,32}

(IV) Phenomenology

(A) Weak Interactions

(a) The derivation of simple relations between leptonic weak interactions which should hold for a large class of gauge theories¹⁴.

(b) An investigation into how high energy neutrino experiments may serve to discriminate between various hypotheses concerning the existence of new hadronic quantum numbers²⁹.

(c) A study of questions one may usefully consider if neutral weak currents exist³³.

(d) A study of $n+p \rightarrow d+\gamma$ for the purpose of distinguishing among several proposed models for $\Delta S=0$ non-leptonic decays.²⁶

(B) Electromagnetic properties

(b) A systematic analysis of the lepton-pair production problem in proton-proton collisions^{3,23}.

(c) An inquiry into the origin of the apparently large hadron production cross section in e^+e^- annihilation³⁸.

(C) Strong interactions

(a) A simple s-channel resonance model was proposed to account for the appearance and behavior of "exotic" states.¹

(b) A description of and further predictions for multi-pion production in nucleon-anti nucleon annihilation on the basis of a statistical model⁸.

(c) Application of soft-pion ideas to $N+\bar{N} \rightarrow \pi + \text{anything}$ at rest.¹¹

(d) An analysis of multiparticle production from the point of view of "early" and "late" KNO scaling.²⁷

(e) An inquiry into the role of diffraction dissociation in electroproduction³⁵.

(V) Other topics

- (a) Analysis of the consequences of the conjecture that the π -decay constant sets the scale for hadron dynamics.²
- (b) A study of the $\pi^0 \rightarrow 2\gamma$ decay vertex³.
- (c) A study of the renormalization group for small coupling constants in abelian field theories¹⁵.
- (d) Application of "asymptotic freedom" to e^+e^- annihilation³⁰.
- (e) A study of retarded dispersion forces between conducting spheres³⁴.
- (f) Preparation of a review article on the "two-photon processes" (H. Terazawa, Rev. Mod. Phys., 45, 615, 1973).

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