The previously noted pace and variety of the work under our contract has increased during the past year, and so has the participation of research students in the actual production of paper. The post-Ph.D. manpower remains at seven. Beside having been visited by a significant number of seminar speakers, members of our group continued to maintain close connections with a huge number of colleagues and institutions around the world. The following is the list of institutions and conferences to which members of our group contributed by attendance, talks, and cooperative research: APS meeting, UCLA; Orbis Scientiae meeting, Coral Gables; Workshop in Particle Physics, Pasadena; NATO Advanced Institute in Elementary Particles, Boulder; Second International Symposium on Hadron Structure and Multiparticle Production, Kazimierz; Institute of Theoretical Physics, Warsaw; 19th Summer School in Theoretical Physics, Zakopane; Institute of High Energy Physics, Vienna; Max Planck Institute, Munich; European Physical Society High Energy Physics Conference, Geneva; Rutherford Laboratory, England; Symposium on Lepton-Photon Interactions at High Energy, Fermilab; Department of Physics, Purdue University; Department of Physics, Portland State University; Second International Conference on Energy Storage, Compression, and Switching, Venice; Sixth Vavilov Conference on Coherent and Nonlinear Optics, Novosibirsk; Department of Physics, Moscow State University; DESY, Hamburg; High Energy Physics Laboratory, Orsay; Lebedev Institute, Moscow; Stanford Linear Accelerator Laboratory, Stanford; Third International Symposium on High Energy Physics with Polarized Beams and Polarized Targets, Argonne; Conference on the (p,n) Reaction and the Nucleon-Nucleon Force, Telluride; Physikalisches Institut, Vienna; Department of Physics, Erlangen; Department of Physics, ETH Hönggerberg, Zürich; TRIUMF, Vancouver; Rice University, Houston; University of California, Davis; and Tufts University, Medford. In addition, a member of our group is working, as the chief organizer, on the Ninth International Conference on the Few-Body Problem, which is to take place in Eugene in late August 1980. It is gratifying that many of the above listed contacts and interactions could be financed by funds outside our contract, notably by institutions inviting our members to visit.

The review of our pluralistic research activities is attempted below in terms of eleven sections. The parenthetical numbers refer to the publication list at the end of this report.

A. Dileptonic Processes

a) Hadron-hadron collisions

The process hadron + hadron into two muons + anything has been in the focus of interest since it is thought to probe the quark content of hadrons and hence test QCD. Experimentally this would even be possible with two protons colliding and with at least one of the protons being polarized. The theoretical implications of such experiments have therefore been explored (250, 251), using the parton model. This model predicts the vanishing of some of the generally allowed structure functions. Polarization experiments could verify this prediction, which is not tested in unpolarized differential cross section experiments. The results could also be interpreted, within that model, to yield the polarization of the quarks in a spinning proton. Calculations have been carried out in two cases: First for the experimentally easier case when only one of the two colliding protons are polarized, and, second, for the case with two polarized protons. In both cases definite experimental tests of model predictions were found.
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b) **Photon-photon collisions**

Tests of quark models and of QCD in particular have also been suggested in photon-photon collisions. As it is usually the case in photon-induced reactions, the theoretical interpretation is somewhat cleaner since one believes one understands the interaction of photons. At the same time, cross sections tend to be very much lower than in hadronic processes. Hoping, nevertheless, that experimental techniques continue to improve, calculations have been carried out for lepton pair production in photon-photon collisions. Mass distributions, angular distributions and the asymmetry (in the case of polarization experiments) have been calculated, with only the numerical evaluation remaining.

c) **Leading log approximation**

The inclusive cross section for deep inelastic scattering and lepton-pair production was also investigated in an extended leading log approximation in which gluon emissions are allowed at arbitrary angles. In that way general expressions were obtained for any detected transverse momenta $q_T$ of the lepton pairs. The result is in a non-factorizable form. Upon integration over $q_T$, however, it leads to the unusual parton model interpretation (229).

B. **Ladder Approximations in QCD**

The central question of what the distribution of partons is in the transverse momentum $k_T$ and in the off-shell parameter $k$ has been solved using the improved parton model in the ladder approximation and in the axial gauge. Such a model, originating in QCD, has been used previously with great success, but only integrated over $k$ and $k_T$. Such integrated versions, however, cannot be related to directly observable experimental quantities like the distribution of dimuon $Q_T$ in inclusive dimuon production. The first step in the program was to solve the ladder model for the flavor non-singlet part of the distribution of quarks in a hadron, to a leading order in the relevant asymptotic approximation (252). The second step then was to integrate the result over $k^2$ to produce the distribution of quarks in $k_T$ in the ladder model and to discuss the application to hadronic dimuon production (253).

C. **Quark Models**

a) **Clustering**

A model is suggested to establish a bridge between the bound-state and hard-scattering problems of hadrons. The key concept introduced in this model is the formation of valence quark clusters, called valons, which behave as constituent quarks at low $Q^2$ but possess internal structure when probed at high $Q^2$. Evidence for their existence is found in the nucleon structure function. The valon momentum distribution in a nucleon is extracted from neutrino scattering (231).

b) **The recombination model**

Three aspects and applications of this model were investigated during the past year. First, the inclusive distribution of photo-produced pions was calculated in perturbative QCD. The $q\bar{q}$ distribution can be determined since the EM current operator has no anomalous dimension. Hadronization of quarks is described by recombination. Good agreement with experiment was found (230). Second, the decay function of a quark jet (at high $Q^2$) was calculated using perturbative QCD and renormalization group analysis. The part involving the $Q^2$ degradation of the quark is given reliably
by QCD, and the hadronization part involving recombination is given by the valon model without free parameters. The resulting no-free-parameter fit gives perfect agreement with the data for pion distribution (233). Third, the theory for low \( p_T \) reactions has been reformulated using the valon concept which removes previous elements of arbitrariness in the recombination model. It is then applied to the calculation of inclusive cross sections in the fragmentation region and gives a no-free-parameter agreement with data both in magnitude and shape (232).

D. Weak Interaction Phenomenology

Recently the variety of gauge models have been increasingly constrained by the results of neutrino scattering and polarized electron scattering. Yet, with the atomic parity-non-conservation experiments still in a disarray, models other than the Weinberg-Salam model continue to deserve attention. We therefore explored several of these. One such, \( SU(2) \times U(1) \times U'(1) \), which would be consistent with only a small amount of parity non-conservation in heavy atoms, predicts a rapid \( \gamma \)-dependence in the asymmetry of electron-deuteron deep inelastic scattering (240, 241). Since this prediction turned out to be inconsistent with data, a new model was constructed (245, 248), based on the gauge group \( SU(2)_L \times (T_3)_R \times U_Y(1) \) which is anomaly free and naturally flavor-conserving, and ties in at low energies with grand unified groups based on \( SU(10) \) or \( SU(8) \times SU(8) \) rather than \( SU(5) \). As the mass of the heavier of the two \( Z \) bosons in this theory tends to infinity, the model fuses with the Weinberg-Salam model. Tests for this model have been proposed. Other work on weak interaction phenomenology includes (242) experimental restrictions on the \( SU(2)_L \times SU(2)_R \times U(1) \) model and the observation that the masslessness of the neutrino in the Weinberg-Salam model is related to the quantization of charge (244).

E. Non-leptonic Decays

Due to recent comparison between experiment and theory, the theory of non-leptonic decays of hadrons ran into some trouble. The theory used a QCD-corrected weak Hamiltonian, matrix elements evaluated in the vacuum saturation approximation, and the so-called penguin diagrams in \( K \) and strange-hyperon decays but not in the charmed system. The resulting detailed predictions of the two-body decay in the \( D \) system are in variance with experiments. We undertook work, therefore, to modify the theory using soft gluon corrections (247).

F. Grand Unification

The model proposed here (243, 246) is unique in that it requires the left-handed neutrino to be massless while permitting the right-handed one to acquire a mass. The group is \( SU_L(8) \times SU_R(8) \), emerging naturally from the eight particles in each generation. The model leads to a stable baryon, and there are no CP non-conservation problems due to instanton effects. Tests of the theory include the observation of a right-handed neutrino which is a massive stable Majorana field, and the fact that the low energy group in this model is \( SU(2)_L \times (T_3)_R \times U_Y(1) \) rather than \( SU(2) \times U(1) \) of Weinberg and Salam.

G. Neutrino Pairing

Within spontaneously broken gauge theories, a new dynamical mechanism, namely pairs of right-handed neutrinos condensing into the vacuum, has been developed to obtain parity non-conservation. The mechanism automatically produces all of the observed Weinberg-Salam phenomenology, gives a dynamical basis for the masslessness of neutrinos, and gives rise to the completely chiral group \( SU(4)_L \times SU(4)_R \times U(1)_Y \).
Since the strong interaction is also a SU(4)\textsubscript{L} × SU(4)\textsubscript{R} theory, one can now construct the weak interaction as the local gauge extension of the strong interaction, thus making contact with current algebra. Thus the strong interaction flavor group in this theory is dictated on the strong interaction by the weak interaction leptons (249).

H. Polarization Phenomena

a) General theory

Using the relatively simple and yet practically common example of the reaction with four spin-1/2 (and an arbitrary number of spin-0) particles, the enormous simplifications brought about by "optimal" type formalisms is exhibited. The results are formulated both in terms of entirely polarized and of partially polarized observables. The experiments needed to obtain information of the amplitudes are described, and it is shown that one can define a "distance" between amplitudes so that the complexity of the experiments needed to obtain information about these amplitudes is related to that distance. It is also shown that reactions with arbitrary spins can be decomposed into arrays of structures of the reaction investigated in this paper. The results allow the elimination of intermediary polarization quantities and hence the direct comparison with experiment and the amplitude (235).

b) Polarization studies of the deuteron

Polarization experiments in high energy electron-deuteron scattering have been urged in order to provide information on a variety of problems related to the nature of the deuteron, such as the D-state probability, the small-distance part of the wave functions, meson current exchange effects, the validity of the impulse approximation, the neutron form factor, etc. We have proposed two new tensor polarization quantities and showed that they offer a practical way to distinguish among various proposed deuteron wave functions and to explore the nature of exchange current effects and of the neutron form factor (236, 237).

c) Lambda-polarization

The diffraction excitation model is used to explain the energy independence of the large lambda-polarization in inclusive experiments on proton-proton collisions. The lambda polarization coming from the decay of N\textsuperscript{X}, the diffractive excitation of the initial protons, was calculated. At P\textsubscript{lab} = 24 GeV/c the dominance of a spin-1/2 N\textsuperscript{X} with isotropic decay was assumed, while at P\textsubscript{lab} = 300-400 GeV/c, longitudinal decay distributions for N\textsuperscript{X} with spins greater than 1/2 were also included. The results agree with experiments in the monotonic increase of the polarization with lambda transverse momentum and in the mild Feynman x dependence (234).

I. Deuteron Targets

Reactions utilizing deuterons are prevalently used in nuclear and particle physics: a) in order to learn about the deuteron as a system of two nucleons or of six quarks; b) in order to learn about processes involving the neutron which is not easily available directly as a reaction target. It the past, the various corrections that need to be applied to deuteron data for such interpretations have been calculated only non-relativistically, and even there various controversies arose in connection with the so-called West correction. This controversy was resolved (238) by showing that the West correction is absent in hadronic scattering in the high energy limit, but is very definitely present for lepton scattering in the deep inelastic limit. Subsequently (239) a new relativistic approach to this problem was developed which avoids many of the problems of previous treatments.
J. Electron Beams

High modulation electron beams circulating in storage rings would have spectacular properties in that they would produce radiation in ultra-short burst at very high intensities and brightness. Furthermore, the produced spectrum would deviate from the usual synchrotron radiation spectrum. These effects are due to coherent photon emission by the electrons belonging to one bunch. It was pointed out previously that such beams could be produced by a laser beam interacting with the circulating electron beam passing through a wiggler. The limitation in performance due to the electron energy spread produced by the laser can be reduced by a phase transformation of the beam prior to its entering the device, and by a compensating device applied after the point where the radiation is emitted (256, 257, 258).

Publications, October 1978 - September 1979

The numbering (N) in the first column represents the last number in the code number of publications written under our grant; that is, RLO-2230-T4-N.

229 R.C. Hwa and J. Wosiek
   Inclusive Distributions in Extended Leading Logarithm
   Acta Physical Polonica (to be published)

230 V. Chang and R.C. Hwa
   Inclusive Distribution of Photoproduced Pions in QCD and the Recombination Model

231 R.C. Hwa
   Evidence for Valence Quark Clusters in Nucleon Structure Functions
   Phys. Lett. (to be published)

232 R.C. Hwa
   Some Recent Developments in the Recombination Model
   Proc. of the Kazimierz Symposium (to be published)

233 V. Chang and R.C. Hwa
   A Determination of the Quark Decay Function without Phenomenological Input

234 V. Chang
   Phenomenological Study of Inclusive A Polarization in pp+AX in a Diffraction Excitation Model

235 M.J. Moravcsik
   Polarization Analysis of Reactions with Four Spin-1/2 Particles
   Phys. Rev. D. (to be published)

236 M.A. Kamal and M.J. Moravcsik
   Measurement of Form Factors and Tests of the Deuteron Wave Function through Polarization Experiments
   Phys. Rev. D (to be published)

237 M.A. Kamal and M.J. Moravcsik
   Test of Exchange Currents through Polarization Experiments

238 D. Kusho and M.J. Moravcsik
   Existence of the West β-correction
239 D. Kusno and M.J. Moravcsik  
The Smearing Corrections on Deuterium Targets

240 N.G. Deshpande and D. Iskandar  
Gauge Models and Neutral Current Interactions  

241 N.G. Deshpande and D. Iskandar  
Neutral Current Phenomenology Based on the Gauge Group SU(2) X U(1) X U'(1)

242 N.G. Deshpande  
Restrictions on Neutral Currents in SU(2)_L X SU(2)_R X U(1)

243 N.G. Deshpande and P. Mannheim  
Group Theoretical Restrictions of Anomalies and Grand Unification

244 N.G. Deshpande  
Remark on Charge Quantization and Left-Handed Neutrinos

245 N.G. Deshpande and D. Iskandar  
Neutral Current Interactions Based on the Gauge Group SU(2)_L X (T_3)_R X U'_V(1)  
Phys. Lett. (to be published)

246 N.G. Deshpande and P. Mannheim  
Grand Unification with a Stable Proton and No Axion Problem

247 N.G. Deshpande, M. Gronanand, and D. Sutherland  
Final State Gluon Effects in Charmed Meson Decays  
Fermilab-Pub-79/70 THY

248 N.G. Deshpande and D. Iskandar  
Study of the Gauge Group SU(2)_L X (T_3)_R X U'_V(1)

249 P. Mannheim  
Neutrino Pairing as the Origin of Parity Violation in a Chiral Flavor Theory of Weak Interactions

250 J. Ralston and D. Soper  
Production of Dimuons from High Energy Polarized Proton-Proton Collisions  

251. J. Ralston and D. Soper  

252 D. Soper  
Hadron Structure in the Ladder Model

253 D. Soper  
Partons and their Transverse Momenta in QCD

254 P.L. Csonka  
Communication Mirror Supported by Radiation Pressure  
Microwave Journal (Sept. 1979, in press)

255 P.L. Csonka  
Patent application on a new type of long distance microwave and T.V. communication system without satellites
256  P.L. Csonka
High Modulation Electron Beams in Storage Rings
Particle Accelerators (in press)

257  P.L. Csonka
Ways to Modify the Beam Structure at SPEAR
SSRL 79/04

258  P.L. Csonka
X-ray Laser Pumping with Enhanced Radiation from Electron Storage Rings
Proceed. Venice Conference, Feb. 1979 (to be published)