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PREAMBLE

The High Energy Theory Group at Syracuse has had a very stimulating and productive year. A great deal of progress has been achieved in some long standing projects. Significant contributions have also been made in the area generally called "New Physics", the physics associated with J/ψ particles and the newly discovered charmed particles.

Thus a possible new contribution[1] to $D^{\pm}$-D^{o} mass-difference, a new scheme to classify heavy leptons and the resulting decay patterns were studied.[2] The study of charmed particle decay modes using vector dominance model and current algebra techniques was continued.[3] Masses for the $J^P=\frac{3}{2}^+$ charmed baryons using dispersion theoretic techniques were calculated.[4] The electromagnetic form factors of the new particles were investigated.[5,6] The puzzling aspects of the mass spectrum of the pseudoscalar mesons were clarified within the framework of a new effective strong interaction Lagrangian;[7] extension of this Lagrangian to SU(4) symmetry is currently under investigation. An estimate of the pseudoscalar decay constant using a bound quark model was given.[8] The S-matrix topological approach to strong interaction was shown to give satisfactory results for the intercepts and the slopes of the meson trajectories.[9] A rigorous approach to path integral formulations and the possible elimination of the zero-point mode difficulty in standard formulations was suggested.[10] Semi-classical methods in the case of arbitrary time-dependent Hamiltonian systems were studied.[11] Interesting features in monopole-charge scattering were pointed out.[12] The description of the interaction of classical test particles in non-Abelian gauge theories was given[13] and possible resonances in an SU(2) gauge theory were discussed.[14] The nature of gauge vacua and the role of the conformal group was clarified.[15] Finally, the static finite energy solutions representing monopoles in non-Abelian models were investigated.[16,17]

Besides these research accomplishments which are discussed in more detail in the following pages, members of the group attended topical national and international meetings, visited other institutions to give seminars and colloquia. Theorists from other institutions were invited to give seminars and colloquia concerning their work.

Balachandran has been on sabbatical leave for the past year. He has visited a number of institutions in Europe and India, giving seminars and lectures. Dan Knight completed successfully his Ph.D. requirements last December and George Campbell will be taking his orals this month.

RESEARCH REPORT

It has been a very exciting year for the Syracuse High Energy Group. The 'new physics' which began with the discovery of the J/ψ particles continues to dominate the interests of several members of the group. The experimental confirmation of the existence of charmed particles raises many new problems and provides a testing ground for the standard theories. Our group has contributed significantly to a better understanding of several aspects of the new phenomena. It has also made a great deal of progress in some other long standing projects, providing new insights and opening new lines of investigation. In what follows we shall describe briefly and qualitatively the main results of these research efforts.

I. New Particles

a) $D^{\pm}$-D° Mass Difference

The mass difference between the charged and the neutral D-mesons possessing the new quantum number charm provides a very important ingredient in the understanding of their decay phenomenology. There are several published estimates ranging from 6 to 15 Mev. It is generally assumed that the above mass splitting arises in part from a mass difference between u and d quarks and in part from one photon "Coulomb" contributions. Borchardt, Kandaswamy, Schechter, and Singer (at Wisconsin), have pointed out[1] that there is another contribution which arises because of the asymmetric SU(2) vacuum. This latter asymmetry, is caused by the unified weak-electromagnetic interaction and is expected from Coleman's theorem "Symmetry of the

Vacuum is the Symmetry of the World". Borchardt et al., have shown that the sign of this contribution is such as to reduce the currently estimated mass difference. A one or two Mev mass difference becomes more reasonable according to their arguments.

b) The Heavy Lepton and Unified Weak-EM Gauge Schemes

The probable existence of a new charged heavy lepton (Perl particle) has made it very interesting to look at lepton gauge models with higher symmetry. Kandaswamy and Schechter[2] have investigated the possibility that the Perl particle together with the usual leptons and some new ones constitute a left and a right handed octet representation of an SU(3) group. This leads to a different pattern of interactions for the new particles compared to the one in the standard SU(2)$\otimes$U(1) gauge theory. In particular it turns out that the heavy lepton decays preferentially into muons and neutrinos rather than electrons and neutrinos. This also means that in the e^+e^- annihilation experiments, there should be more $\mu^+\mu^-$ pairs than e^+e^- pairs after an appropriate subtraction of the background. They also discuss in this paper the hadron sector of the theory and neutral current interactions.

c) Decay Modes of Charmed Particles

Borchardt (along with Mathur and Goto of Rochester) has been involved in an extensive program to calculate the decay modes of the charmed particles by generalizing the Vector-Meson-Dominance (VMD) suggested by Sakurai and used successfully in explaining non-leptonic K-meson and hyperon decays. In their analysis[3] they have used VMD and current algebra techniques which have proved very successful in understanding the weak decays of uncharmed hadrons. As such, their results should be very useful not only in understanding the decay modes of the new particles but also they should serve as an important test of the old methods in the high mass region of charm.

d) Masses of Charmed Baryons in Broken SU(4) Symmetry

One of the striking successes of the SU(3) symmetry has been the existence of a decuplet of $J^P=\frac{3}{2}^+$ resonances. In the corresponding SU(4) symmetry scheme, the decuplet becomes a 20-plet of resonances. In addition to the ten strangeness zero resonant states, one has ten additional charmed baryons. Assuming a simple type of symmetry breaking, various authors have predicted masses for these baryons. However, to get a better insight into the symmetry breaking as well as possible decays of these new baryons, one needs dynamics. Towards this end, Campbell has calculated[4] the masses and the total widths of these new states using a dispersion-theoretic N/D method, which, in the past, has proved very successful in explaining the existence of the decuplet starting from meson and baryon octets. His results show that the old methods work quite well when charm is incorporated and should provide a good guide in the experimental search for the new baryons.

e) Electro-magnetic Form Factors of Charmed Mesons; Anomalous Production of D* Mesons

Park (in collaboration with P.Cox and A.Yildiz at Harvard University) has studied[5] the electromagnetic form factors of the newly discovered charmed mesons, which govern their production in e^+e^- colliding beam experiments. They use a light quark exchange model, which simulates the breakdown of the gluon-string between a charmed quark pair and provides a way to incorporate the kinematic (phase space) and dynamic (charmed meson form factor) nature of the process. It gives the DeRujula-Georgi-Glashow ratio $D\bar{D} : D^*\bar{D} + D\bar{D}^* : D^*\bar{D}^* = 1:4:7$ as a kinematic limit with $m_D = m_{D^*}$ and all the moments neglected.

In view of this model, the anomalous production of $D^*\bar{D}^*$ near the threshold energy indicates that D^* either has an anomalously large magnetic dipole moment or an electric quadrupole moment. Subsequently, they also have worked on an alternate explanation[6] of the anomalous production; they assume that the charmed mesons in the final state interact forming a molecular state. They have calculated the possible spectrum of such molecular states in an approximation in which the interaction is a linear potential with an effective mass as a paramter.

II. Symmetry Breaking and the Pseudoscalar Mass Spectrum

An immediate but still not completely solved problem is the calculation or even interrelation of the pseudoscalar masses starting from a dynamical quark model. Even before the charmed particles were discovered the current algebra approach, which provided semi-rigorous constraints on the masses and decay constants had a difficulty. This is the U(1) problem. Based on a) analogy to the SU(3) sigma model which has no U(1) problem because it contains a U(3)xU(3) symmetry breaking term transforming differently from the quark mass terms, b) new work on the dynamical symmetry breaking of the vacuum based on the instanton solutions of SU(2) gauge theories, Mirelli and Schechter have postulated[7] an effective strong interaction quark Lagrangian which avoids the U(1) problem. It leads to a satisfactory solution for pseudoscalar masses and includes the results of the sigma model as a special case. There is the new parameter which is in principle calculable from a fundamental gauge theory.

Kandaswamy, Schechter and Singer (at the University of Wisconsin, Madison) are currently investigating the extension of this to SU(4) (including the charmed quark). In this case the sigma model solutions, though roughly reasonable, give too large a value for m(D), for example. Thus the added freedom to choose decay constants in the current algebra approach based on the new effective Lagrangian is useful. Unfortunately there is too much freedom so they were led to investigate methods of computing some of the decay constants which enter as input. It turns out that, with reasonable assumptions, only the "paracharmonium" decay constant is required. They used a nuclear-physics type model to compute this in terms of the universal Regge slope α' and found an answer about (1.7 to 2)F_π.[8]

It was noted that, despite the method of calculation, there was no a priori incompatibility with PCAC. This raises the possibility that PCAC my be actually realized in a new manner for heavy pseudoscalar bosons.

III. S-Matrix Topological Approach to Strong Interactions

Rosenzweig (along with Chew at LBL, California) has continued his research into various aspects of Dual Unitarity or S-matrix Topological Approaches to Strong Interactions. By incorporating both I=0 and I=1 mesons in their scheme, they have been able to provide an understanding of the complete pattern of exchange degeneracy and its breaking[9]. Their main result is the prediction of reasonable values for the intercepts $\alpha_\rho(0)-\alpha_{A_2}(0)$ and the slopes $\alpha'_\rho(0)-\alpha'_{A_2}(0)$. This implies that starting with a model with perfect exchange degeneracy, the observed discrepancies in the intercept and slope parameters can be calculated. One of the major problems in this approach is that of how to include baryons. Rosenzweig is currently working on this problem and he has some ideas concerning how exotic mesons may relax some of the stringent duality constraints and lead to a more reasonable spectrum for the baryons. He has also worked on the systemactics of Zweig rule violations and the interrelationships between various theoretical approaches.

IV. Path Integral Method; Quantization of Solitons

It is generally believed that the perturbation expansion using naive path integral method fails in the quantization of solitons because of the so-called "zero-mode problem". The problem originates from the degeneracy of the ground state of the system with respect to transformations of some basic symmetries, like the translational invariance. This results in the appearance of a zero frequency eigenfunction of the matrix operator in the second variation, $\delta^2 A=-\frac{1}{2}\tilde{\phi}_\alpha M_{\alpha\beta}\tilde{\phi}_\beta$. Thus, for those variations which are proportional to the zero frequency eigenfunctions, the action does not provide the necessary damping and the path integral for the vacuum-to-vacuum amplitude diverges. Usually the inverse of the matrix M plays the important role of a Feynman propagator in the perturbation expansion. The existence of the zero mode solutions therefore, implies that M is singular and the propagator has an infrared divergence problem.

To deal with the zero mode problem, the collective coordinate method has been proposed by Gervais, Sakita and Jevicki. In their method, the center of mass coordinate is introduced into the path integral expression as a new dynamical variable. The degree of freedom associated with the zero frequency mode is eliminated through a δ-function gauge condition. However, the transformation involved is non-linear and as a consequence a very complicated effective Hamiltonian emerges.

Recently, Chang has initiated a different scheme[10] to deal with the zero mode problem in quantizing solitons. He has observed that the widely accepted procedure of integrating the path integral for field theories is not rigorous and inconsistent with the rigorous definition of the functional integral. Especially, one should not integrate by parts to obtain $-\frac{1}{2}\tilde{\phi}_\alpha M_{\alpha\beta}\tilde{\phi}_\beta$ for the action functional in the path integral. The paths involved in the functional integral are piecewise linear and resemble the trajectories of a particle undergoing Brownian motion. Before taking the functional limit, the Brownian type path cannot be expressed as a linear combination of finite number of eigenfunctions of the operator M. The zero mode problem is actually created by the widely accepted, non-rigorous procedure of handling the path integral. Using a more careful treatment, Chang has found that there is no singularity associated with the zero mode solution in the vacuum-to-vacuum transition amplitude. Without using the collective coordinate method, the propagator Chang has obtained is free of the zero mode singularities and agrees essentially with that proposed by Faddeev and Korepin.

V. Semiclassical Methods

Recently, there has been a great deal of interest in the derivation of semiclassical approximations from the path integral approach to quantum mechanics. A reason for the interest in the semiclassical approach is that it provides a means to quantize about known solutions of classical non-linear equations of motion. The development of this approximation from the path integral is motivated by the fact that the latter lends itself more easily to field theoretic generalizations. The alternative, but equivalent, approach based on the Schrodinger equation seems more awkward to adapt to field theory.

Previous quantum mechanical semiclassical functional methods have dealt almost exclusively with Hamiltonians of the form $\vec{p}^2/2m+V(\vec{\varepsilon})$, that is, with particles moving in a potential. Balachandran, Ramachandran and Rupertsberger have generalized these methods to arbitrary time-independent Hamiltonian systems with no constraints[11].

VI. Charge and Magnetic Monopole Scattering

An outstanding problem in the quantum mechanics of a charged particle in interaction with a Coulomb-like magnetic field is the development of an approximation scheme which is suitable for generalization to a field theoretic context. Perturbation theory is not useful for this system. It violates rotational invariance to any finite order due to the presence of the Dirac string in the Hamiltonian. Further the parameter characterizing the strength of the interaction is large due to the Dirac-Schwinger quantization condition. Previously, K.W.Ford and J.A.Wheeler have applied the JWRB approximation to this system. Their approach relies on the partial-wave expansion of the scattering amplitude and assumes also that the angular momenta which are important are large. Such a technique based on partial-wave expansions does not seem well adapted to field theoretic generalizations, in particular, since the partial-wave expansion for this system is actually divergent. Balachandran, Borchardt, Cahalan, Chang, Ramachandran, Rupertsberger and Stern have developed a JWKB approximation for this system which avoids partial-wave expansion.[12] Its rotational invariance is proved. The following two striking features of the system are pointed out: a) the JWKB cross section approaches the classical cross section rather slowly for a wave range of scattering angles when the Dirac-Schwinger quantization number gets large, or equivalently when $\hbar$ becomes small with the product of the electric and magnetic charges held fixed; b) the regularized helicity amplitude has unusual singularities for scattering in the backward direction. It also exhibits other novel non-analytic features in the scattering angle. The relevance of these features to the Polyakov-'t Hooft monopole solution is pointed out.

VII. Yang-Mills Particles in a Yang-Mills Field

Despite the recent interest in gauge theories, a system which has been poorly studied is that of a Yang-Mills particle in interaction with a Yang-Mills gauge field. This is the non-Abelian analogue of the familiar system composed of a charged particle in interaction with the electromagnetic field. Wong has written down the non-Abelian analogues of the Lorentz force and Maxwell equations. By introducing a new type of classical internal variable, Balachandran, Salomonson, Skagerstam and Winnberg[13] have obtained classical Lagrangians which in general describe a tower of Wong particles. Conventional and supersymmetric particles have been treated, with and without the inclusion of ordinary spin for the particle. The Lagrangians have been quantized following Dirac's procedure. The physical interpretation of the system has been discussed. The decomposition of the tower into irreducible subspaces of the internal symmetry group has been investigated.

VII. Gauge Vacua

Recently there have been many papers which deal with the degeneracy of classical gauge vacua, and the removal of this degeneracy in quantum mechanics due to the tunnelling mechanism. A critical assumption in all these papers is that the space-like hypersurfaces are to be treated as compact. Thus the space-like hypersurfaces in ordinary Minkowski space are compactified in these papers to the three sphere S^3. Such an assumption has not been justified in the literature. Now, it is well known that the "free" Yang-Mills theory and the vacuum sector of the interacting Yang-Mills theory are formally invariant under the conformal group in the absence of the Higgs type mechanisms. However, this group does not act properly on Minkowski space. The latter has to be changed to a new manifold by the addition of "points at infinity" to have such a proper action. Balachandran, Din, Nilsson and Rupertsberger[15] have shown that space-like surfaces on this new manifold do indeed have the topology assumed in the literature. The meaning of a physical observable and of gauge invariance in classical theories has also been studied in this work. It has been shown that the physical observables are required to be invariant only under the component of the identity G_0 of the full gauge group G. Thus, if G/G_0 is non-trivial, it will act much like an internal symmetry group on the physical observables. The relevance of this result to the phenomenon of degeneracy of classical gauge vacua is pointed out.

IX. Monopole Solutions in Non-Abelian Gauge Models

Non-Abelian gauge theories of the Yang-Mills type have created a great deal of interest recently, as possible candidates for unified theory of strong, weak and electromagnetic interactions. While the full quantum field aspects of such theories are still far from being thoroughly understood, classical solutions to the nonlinear field equations have proved to be quite interesting. 't Hooft and Polyakov have found a static, finite energy solution in a non-Abelian model consisting of a triplet of isovector gauge mesons and a triplet of isovector Higgs mesons with interactions invariant under local gauge group SO(3). The solution has the very interesting feature that it can be thought of as corresponding to a magnetic monopole with magnetic charge of strength $(4\pi/e)$ consistent with the famous Dirac quantization condition. Wali (along with Michel and O'Raifeartaigh) has generalized [16,17] this model by considering an arbitrary compact group G. The conditions imposed on the model due to finiteness of energy are fully explored. By making a very plausible hypothesis according to which the radial dependence of the fields is factorized, the above authors have been able to separate the angular equations and the radial equations of the nonlinear system. Further they have been able to solve the angular equations completely and show that the gauge fields vanish outside a fixed SO(3) subgroup of G and that inside the SO(3) they reduce to the 't Hooft-Polyakov solution with unit magnetic charge, the Higgs field in this model can belong to any arbitrary representation. The static Hamiltonian exhibits a mass formula, the lowest mass of the system corresponding to that of the lowest, namely, adjoint representation of SO(3) for both the gauge and the Higgs fields.

X. Concluding Remarks

We have attempted to summarize briefly the main areas of research and some of the results. Various members of the group have been interested from time to time on other areas and through seminars and journal clubs have kept themselves abreast of all the important developments.

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APPENDIX A

ERDA Reports by the Scientific Staff
Under Contract No. EY-76-S-02-3533

C00-3533-73 New Quantization Procedure for Field Theory with Applications to Models of Hadron Binding. S. Blaha, submitted to Phys. Rev. August 1976.

C00-3533-74 The possibility of Asymptotic Boson States Corresponding to Purely Classical Fields and a Time Asymmetric Reformation of Unified Theories of the Electromagnetic and Weak Interactions. S.Blaha, submitted to Phys. Rev. October 1976.

C00-3533-75 Generalization of Weyl's Unified Theory to Encompass a Non-Abelian Internal Symmetry Group. S.Blaha, SLAC preprint, August 1976.

C00-3533-76 Contract 1976-77

C00-3533-77 Leptonic Octets and Heavy Lepton Decays in an SU(3) Gauge Theory. J.Kandaswamy and J.Schechter, Phys.Rev. 15D, 251 (1977).

C00-3533-78 Radially Separated Static, Finite-Energy Yang-Mills-Higgs Fields. L.Michel, L.O'Raifeartaigh and K.C.Wali. (Restricted to SU(2) Gauge Group; unpublished).

C00-3533-79 Semiclassical Functional Methods for Arbitrary Hamiltonian. A.P.Balachandran, R.Ramachandran and H.Rupertsberger, Fack preprint, Goteborg, Sweden.

C00-3533-80 Rotationally Invariant Approximation to Charge Monopole Scattering. A.P.Balachandran, S.Borchardt, R.Cahalan, S.S.Chang, A.Stern, Fack preprint, Goteborg, Sweden.

C00-3533-81 An Effective Strong Interaction Lagrangian. V.Mirelli and J.Schechter, submitted to Phys. Rev. October 1976.

C00-3533-82 G-Parity and the Breaking of Exchange Degeneracy. C.Rosenzweig and G.F.Chew. LBL preprint, December 1976.

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C00-3533-90 Resonances in SU(2) Gauge Theory. Allen Stern, submitted to Physical Review, February 1977.

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48. Eigenvectors for the Partial-Wave "Crossing Matrices"; with W. M. Meggs and P. Ramond; Phys. Rev. 175, 1974, 25 November(1968); SU-160.

49. A Simultaneous Partial-Wave Expansion in the Mandelstam Variables The Group SU(3); with W. J. Meggs, J. Nuyts and P. Ramond; Phys. Rev. 176, 1700-1705(1968); SU-163.

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52. Lecture Notes on Current Algebras, Notes by W. J. Meggs; SU-166.

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54. A Two Variable Expansion of the Scattering Amplitude for any Mass and Spin and Crossing Symmetry for Partial-Waves; with W.Case and M. Modjtehedzadeh; Phys. Rev. D1, 1773-1778, 15 March(1970); SU-209.

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56. The Poincare Group, Lectures by A.P.Balachandran; Notes by D.Goswami and M.Modtehedzadeh; SU-212.

57. Integral Inequalities for the s and p Wave ππ Partial Wave Amplitudes due to Crossing Symmetry and Positivity; with W.L.Blackmon; Physics Letters 31B, 655-657, 11 May (1970); SU-223.

58. No-Go Theorems for Dual Models; A.P.Balachandran, L.N.Chang and P.H.Frampton; Nuovo Cimento, 1A, 545-552, February (1971); SU-232.

59. Inequalities for the s and p Waves ππ Partial Wave Amplitudes; with M.L.Blackmon; Phys. Rev. D3, 3133-3141, 15 June (1971); SU-234.

60. Inequalities for the ππ Partial Waves from the Properties of Class of Orthogonal Polynomials; with M.L.Blackmon; Phys. Rev. D3, 3142-3151, 15 June(1971); SU-240.

61. The Crossing and Positivity Properties of Partial Waves "A Review"; Unpublished; SU-243. [Invited talk presented at the Madras Symposium on High Energy Physics, Madras, January 1971 and at the French-Swedish Conference on High Energy Physics, June 1971].

62. Inequalities for the Pion-Nucleon Partial Waves; with W.Case, A. Della Selva and S.Saito; Nuclear Physics B31, 570 (1971); SU-249.

63. General Considerations on the Derivation of Inequalities for the s- and p-Wave Amplitudes; with M.L.Blackmon; Phys. Rev. D6, 631-639 (1972); SU-252.

64. Physical Region Constraints for π-π Low Energy Parameters; with M.L.Blackmon and C.Sigaud; unpublished; SU-261.

65. Scattering of Particles with Spin: Mackey State Formulation; with J.Nilsson and L.O'Raifeartaigh; Nuclear Physics B49, 221 (1972).

66. Bounds on the Moments of Absorptive Parts of Scattering Amplitudes, with Maurice L. Blackmon and Cassio Sigaud; SU-262, Phys. Rev. D7, 3420(1973).

67. Relativistic Invariance and Discrete Symmetries; SU-10 (Dec. 1972) and Current Science 42, 149 (1973).

68. Dual Models for Four Meson Born Terms; with H.Rupertsberger; SU-18, (March 1973) and Phys. Rev. D8, 4524 (1973).

69. Positivity Conditions for Frampton's Dual Models: with H.Rupertsberger Phys. Rev. D8, 4528 (1973).

70. A New Bound for Total Cross Section; Phys. Rev. D8, 4003 (1973).

71. Monopole Theories with Massless and Massive Gauge Fields; proceedings of the Colloquium on Group Theoretical Methods in Physics, Marseilles, (June, 1974).

72. Monopole Theories with Massless and Massive Gauge Fields; with H.Rupertsberger and J.Schechter; Phys. Rev. D11, 2260 (1975).

73. Monopole Strings and Charmonium; with R.Ramachandran, J.Schechter, Kameshwar C. Wali and H.Rupertsberger; proceedings of the Orbis Scientiae, University of Miami, Coral Gables, Florida, January 1975.

74. Hamiltonian Formulation of Monopole Theories with Strings; with R.Ramachandran, J.Schechter, Kameshwar C. Wali and H.Rupertsberger, Phys. Rev. D13, 354 (1976).

75. Strings, Monopoles and Meson States; with R.Ramachandran, J.Schechter, Kameshwar C.Wali and H.Rupertsberger, Phys. Rev. D13, 361 (1976).

76. Monopole Theories with Strings and their Application to Meson States; Proceedings of the Colloquium on Group Theoretical Methods in Physics, Nijmegen (1975).

77. Semiclassical functional methods for arbitrary Hamiltonians; with R. Ramachandran and H.Rupertsberger. Printed at Inst. for Theore. Physics, Fack, Goteborg, Sweden. (1976) SU-4210-79.

78. Rotationally invariant approximation to charge monopole scattering. with S.S.Chang, S.Borchardt, R.Cahalan, R.Ramachandran, H.Rupertsberger and A.Stern. Printed at Fack, Goteborg, Sweden (1976) SU-80.

79. Gauge Vacua and the conformal group; with A.M.Din, J.S.Nilsson and H.Rupertsberger. Fack, Goteborg, Sweden (1976) SU-4210-86.

80. Classical description of particle interacting with nonabelian gauge field. Fack, Goteborg, Sweden (1976) SU-4210-85. With Per Salomonson, Bo-Sture Skagerstam and Jan-Olof Winnberg.

OTHER ACTIVITIES

Meetings attended:

1. Fourth International Workshop on Weak Interactions with Very High Energy Beams. (International Centre for Theoretical Physics, Trieste, Italy; June 14-23, 1976.)

2. Recent Developments and Trends in Theoretical Physics. (Department of Theoretical Physics, University of Madras, Madras, India. December 21, 1976.)

3. International Symposium on Advanced Mathematical Techniques in Physical Sciences. (University of Calcutta, Calcutta, India, December 27-Jan.1, 1977.)

4. International Conference on Frontiers of Theoretical Physics. (Indian National Science Academy, Delhi, India, Jan.6-12, 1977).

Talks given:

1. Physics Department, Syracuse University

   a) Adler Anomalies, b) Dirac Quantization of Soliton Solutions. May 4, 1976.

   Quark Models. Neutrino physics series of lectures. May 17-24, 1976.

2. Institute of Theoretical Physics, Lund, Sweden

   Monopoles, Gauge Vacua, Yang-Mills Particles. September 17, 1976.

3. Universitat Bielefeld, Bielefeld, W.Germany

   Monopoles, Gauge VAcua, Yang-Mills Particles. September 30, 1976.

4. Istituto di Fisica Teorica, dell' Universita di Napoli, Napoli, Italy

   Topological Quantum Numbers in Classical Field Theories. Nov.3,1976.

   The Structure of Gauge Vacua. November 5, 1976.

5. Universita di Salerno, Salerno, Italy

   Monopoles, Gauge Vacua, Yang-Mills Particles. November 22, 1976

6. dell' Universita di Napoli, Napoli, Italy

   Topological Considerations in Field Theory - A Review. Nov.25, 1976

7. University of Madras, Madras, India

   Topological Considerations in Field Theory, (Invited talk) December 21, 1976

8. University of Madras, Madras, India
   Gauge Vacua. December 22,23 and 24, 1976.

9. University of Calcutta, Calcutta, India
   Topological Considerations in Field Theory - A Review.
   Invited talk in "International Symposium on Advanced Mathematical Techniques in Physical Sciences. December 29, 1976.

10. Indian Institute of Technology, Kanpur, India
    An Introduction to Topological Concepts in Field Theory.
    Colloquium, January 4, 1977.

11. University of Madras, Madras, India
    Fibre Bundles and Gauge Theories. A series of lectures from February 19, 1977 onwards.

Places visited

1. University of Durham, Dept. of Mathematics, Durham, England
   May 31 to June 3, 1976
2. NORDITA guest Professor, Chalmers Technical University. Goteborg, Sweden and Institute of Theoretical Physics, Goteborg, Sweden.
   June 1976 to September 29, 1976.
3. International Centre for Theoretical Physics, Trieste, Italy.
   June 14 to 23, 1976.
4. Institut fur Theoretische Physik der Universitat Wien, Vienna Austria. Sept. 4 to 11, 1976.
5. Institute of Theoretical Physics, University of Lund, Lund, Sweden.
   September 17, 1976.
6. Universitat Bielefeld, Bielefeld, W.Germany. Sept. 29 to Oct.2,'76.
7. International Centre for Theoretical Physics, Trieste, Italy.
   Guest scientist, October 2 to 23, 1976.
8. Instituto di Fisica Teorica dell'Universita di Napoli, Naples, Italy.
   October 23 to December 12, 1976.
9. Universita di Salerno, Salerno, Italy. November 22, 1976.
10. University of Madras, Madras, India. Visiting professor, Dec. 15 to April 15, 1977.

11. University of Calcutta, Department of Applied Mathematics, Calcutta, India. December 1976 to January 1, 1977.

12. Indian Institute of Technology, Kanpur, India. January 1-5, 1977.

13. Indian National Science Academy, Delhi, India. January 6-12, 1977.

14. Center for Theoretical Studies, Indian Institute of Science, Bangalore, India. January 22 to 29, 1977.

Other

Member-American Physical Society
Editorial board of "Fundamenta Scientiae" c/o Dr. M.Paty, Groupe de Chambre a Bulles a Liquide Lourd, Centre de Recherches Nucleaires, Strasbourg, Franc.

Referee- Physical Review
Physical Review Letters

Bibliography of Steven R. Borchardt

1. Renormalizability, Gauge Invariance and $\nu_e \nu_\mu$-Scattering in Weinberg-Salam Model; with K.T.Mahanthappa; Nucl. Phys. B65, 445 (1973).

2. Spectral Function Sum Rules in Asymptotically Free Theories; with V.S.Mathur; Phys. Rev. D9, 2371 (1974).

3. A Possible Explanation of the New Resonance in e^+e^- Annihilation; with V.S.Mathur and S.Okubo; Phys. Rev. Letters 34, 38 (1975).

4. SU(4) Symmetry and the Possible Existence of New Hadrons; with S.Okubo and V.S.Mathur; Phys. Rev. Letters 34, 236 (1975).

5. SU(4) Symmetry and the New Resonances; with V.S.Mathur and S.Okubo; Phys. Rev. D11, 2572 (1975).

6. Weak Decay Modes of Charmed Mesons; with V.S.Mathur (University of Rochester preprint) accepted for publication in Phys. Rev. Letters 36, 1287 (1976).

7. Weak Decays of Charmed Hadrons in Vector Dominance Model; with V.S.Mathur in preparation. (1976)

8. Rotationally invariant approximation to charge monopole scattering. with S.S.Chang, A.P.Balachandran, R.Cahalan, R.Ramachandran, H.Rupertsberger and A.Stern. Fack preprint, Goteborg, Sweden.

9. A new contribution to the $D^{\pm}$-D° mass splitting, with J.Kandaswamy, J.Schechter and M.Singer. Phys. Letters 66B, 95 (1977).

10. Resonant structure in charmed meson decays, with V.S.Mathur; to be published in Physical Review. (1977)

11. Meson mixing and the quark model; with V.S.Mathur; (in preparation).

Meetings Attended:

1. Scottish Universities Summer School in Physics; St. Andrews, Scotland; August 1-21, 1976
2. APS Meeting, Brookhaven, N.Y., October 1976.

Talks Given

1. Brown University, Providence, Rhode Island. "Charmed Meson Decays" (November, 1976).

Bibliography of Sung-Sheng Chang

1. Effective Lagrangian Density in Gauge Symmetry; Phys.Rev. D14, 446 (1976).

2. Current Algebra Evaluation of Pion Pair Production in Two-photon Processes; with R.Arnowitt; submitted to Phys. Rev. D. 1976.

3. Rotationally invariant approximation to charge monopole scattering. with A.P.Balachandran, S.Borchardt, R.Cahalan, R.Ramachandran H.Rupertsberger and A.Stern. Printed in Goteborg, Sweden (Fack).

4. Inconsistency in Feynman and Hibbs' evaluation of path integrals by Fourier Series. (in preparation).

5. Path Integral Quantization of Solitons without using Collective Coordinates. (in preparation)

6. Path Integrals using Non-conjugating Phase Space Variables. (in preparation).

Meetings attended:

Brookhaven Conference on Particles and Fields, October 1976

Bibliography of Soo Yong Park

1. External Field Induced Phase Transition in N-component Thirring Model; with Barry J. Harrington and Asim Yildiz, Phys. Rev. D11, 1472 (1975).

2. Spectrum of Heavy Mesons in e^+e^- Annihilation; with Barry J. Harrington and Asim Yildiz, Phys. Rev. Lett. 34, 168 (1975).

3. Orbital Excitations in Charmonium; with Barry J. Harrington and Asim Yildiz, Phys. Rev. Lett. 54, 706 (1975).

4. Scalar Meson Dominance Model in the Decay $\psi' \to J + 2\pi$; with Barry J. Harrington and Asim Yildz; Phys. Rev. D12, 2765 (1975).

5. Final-Muon Polarization in e^-e^+ Annihilation; with Asim Yildiz, Phys. Rev. Lett. 37, 244 (1976).

6. Heavy Lepton Production in e^-e^+ Annihilation; with Asim Yildiz, Phys. Rev. D14, 2941 (1976).

7. Radiative Decay Modes of Heavy Lepton in e^-e^+ Annihilation; with Asim Yildiz, Phys. Rev. D14, 2945 (1976).

8. Charmed Meson Production in Quark Exchange Model; with Paul Cox, and Asim Yildiz, Harvard Preprint HUTP-76/A177, 1976 (submitted to Phys. Rev. D).

9. Charmonium-Related Four Quark Resonances; with Paul H.Cox and Asim Yildiz, Harvard Preprint, HUTP-76/A182, 1976 (submitted to Phys. Rev. D).

Meetings attended

Brookhaven National Laboratory, Upton, N.Y.
Conference, October 6 to 8

Bibliography of C. Rosenzweig

1. Use of WKB Method for Obtaining Energy Eigenvalues; J.B.Krieger, M.L.Lewis and C.Rosenzweig, J.Chem. Phys. 47, 2942 (1967).

2. Application of a Higher Order WKB Approximation to Radial Problems; J.B.Krieger, and C.Rosenzweig, Phys. Rev. 164, 171 (1967).

3. Exact Quantization Conditions; C.Rosenzweig and J.B.Krieger, J. Math.Phys. 9, 849 (1968).

4. Dual Resonance Amplitude for Spinning Particles; C.Rosenzweig and U.P.Sukhatme, Nuovo Cimento 3A, 511 (1971).

5. Scattering Amplitudes for Physical States in Dual Resonance Models; K.A.Friedman, U.P.Sukhatme, and C.Rosenzweig, Lett. Nuovo Cimento 1, 1109 (1971).

6. Excited Vertices in Model of Neveu-Schwarz; C.Rosenzweig, Lett. Nuovo Cimento 2, 924 (1971).

7. Photon-like particles, Compton Scattering and Sum Rules in Dual Resonance Models, K.Friedman and C.Rosenzweig, Nuovo Cimento 10A, 53 (1972).

8. Unitarity Sum Rules and Soft Pion Amplitudes; C.Rosenzweig and G.Veneziano, Nuovo Cimento 12A, 409 (1972).

9. The $\pi\pi$ Total Cross Section: Its Scale and Massless Pion Limit; M.R.Pennington and C.Rosenzweig, Nucl. Phys. B57, 305 (1973).

10. The Adler Condition and High Energy Bounds on Massless Particle Total Cross Sections; S.P.Auerbach, M.R.Pennington, and C.Rosenzweig, Phys. Lett. B45, 275 (1973).

11. The Dual Model of Neveu and Schwarz: An Introduction and Survey; C.Rosenzweig, Memorie Dell'Accademia Delle Scienze Di Torino Classe di Scienze Fisiche, Mathematiche e Naturali Serie 4^a n.19 (1974).

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13. Regge Couplings and Intercepts from the Planar Dual Bootstrap; C.Rosenzweig and G.Veneziano, Phys. Lett. 52B, 335 (1974).

14. A Systemic Lifting of Exchange Degeneracy that Clarifies the Relationship Between Pomeron Reggeons and SU_3 Symmetry Violation. C.Rosenzweig, G.F.Chew, Phys. Lett. 58B, 93 (1975).

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17. Asymptotic Planarity; An S-Matrix Basis for the Okubo-Zweig-Iizuka Rule; G.F.Chew and C.Rosenzweig, Nucl. Phys. B104, 290 (1976).

18. Have Mesons Composed of Charmed Diquarks Been Discovered? C.Rosenzweig, Phys. Rev. Lett. 36, 697 (1976).

19. Topological Expansions and Decays of New Particles: Phenomenology of Okubo-Zweig-Iizuka Rule Violation. C.Rosenzweig, Phys.Rev. D13, 3080 (1976).

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21. Asymptotic Planarity Prediction of a Pomeron-like Unnatural Parity Trajectory; G.F.Chew and C.Rosenzweig, Phys. Lett 63B, 429 (1976).

22. A statistical Weight Interpretation for the $1/N^2$ Convergence Factors of the Topological Expansion; G.F.Chew and C.Rosenzweig. To be published in Annals of Physics, N.Y.

23. G-Parity and the Breaking of Exchange Degeneracy. G.F.Chew and C.Rosenzweig. To be published in Phys. Rev.D.

Meetings attended:

Coral Gables "Orbis Scientiae", University of Miami, Fla. January 16-20, 1977.

Other

Member APS

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2. Possible Existence of a Boson Isocuplet; Phys. Rev. 135, B219(1964); with B. Lee and S. Okubo.

3. Prediction of a $\pi\eta$ Resonance; Phys. Rev. 135, B1060(1964); with S. Okubo.

4. Permutation Symmetry and a Derivation of Unitary Symmetry; Ann. Phys. 32 424(1965); with Y. Ueda and S. Okubo.

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6. The Strangeness Changing Axial Vector Coupling Constant; Phys. Letters 19, 56(1965); with L. Pandit.

7. Weak Currents in Broken U(3) x U(3); Phys. Rev. 144, 1938(1966); with Y. Ueda.

8. Nonleptonic Decays of Hyperons; Phys. Rev. Letters 16, 380(1966); with Y. Hara and Y. Nambu.

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10. Weak Interaction Universality and Octet Dominance; Phys. Rev. Letters 16, 1022(1966); with Y. Chiu.

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14. Meson-Meson Scattering in the Quark Model and the Adler Sum Rules; N. C. Letters 66, 548(1966); with Y. Chiu.

15. Algebra of Currents and Three Pion Decay Modes of η and K Mesons; Phys. Rev. 151, 1612(1967); with Y. Chiu and Y. Ueda.

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17. Symmetry Restrictions on $K \to 2\pi$ Amplitudes; Phys. Rev. 161, 1660(1967).

18. Asymptotic Chiral Symmetry; Phys. Rev. Letters 19, 276(1967); with G. Venturi.

19. Final State Interaction Effects in the Algebra-of-Currents Approach to the Three-Pion Decay Modes of η and K Mesons; Phys. Rev. 161, 1612(1967); with Y.T.Chiu and Y.Ueda.

20. Phenomenological Chiral Model for Nonleptonic Hyperon Decays; Phys. Rev. 174, 1829(1969); SU-148.

21. K^+-Nucleon Scattering in an Effective Chiral Lagrangian Model; Phys. Rev. 177, 2311(1969); SU-159.

22. Baryon Excitation Form Factors and Asymptotic Chiral Symmetry; Phys. Rev. 177, 2300(1969); SU-162.

23. Note on the Gauge Field Chiral Lagrangian; Phys. Rev. 188, 2184(1969); with Y.Ueda; SU-194.

24. Ω^--Decay; with D.N.Goswami; Phys. Rev. D1, 290(1970); with D.N.Goswami; SU-199.

25. Spontaneous Breakdown of Weak and Electromagnetic Interaction Symmetry; Phys. Rev. D2, 736(1970).

26. Some New Results on Symmetry Breaking in a Chiral Model; (unpublished) with Y.Ueda; SU-228.

27. Electromagnetic Perturbation of the Pseudoscalar Mass Spectrum; Phys. Rev. D3, 176(1971); with Y.Ueda; SU-229.

28. Symmetry Breaking and Spin Zero Mass Spectrum; Phys. Rev. D3, 168 (1971); with Y.Ueda; SU-230.

29. Van Hove Model and Nonleptonic Hyperon Decays; Phys. Rev. D3, 2128 (1971); with D.N.Goswami and Y.Ueda; SU-238.

30. General Treatment of Chiral and Scale Breaking in the SU(3) Sigma Model; Phys. Rev. D3, 2874(1971); with Y.Ueda; SU-241.

31. $\Delta I=I$ Mass Differences and $\eta\rightarrow 3\pi$ Decay; with Y.Ueda; Phys. Rev. D1, 733(1971); SU-245.

32. CP Violation and Chiral Symmetry; with Y.Ueda; Phys. Rev. D5, 2821, (1972); SU-253.

33. Symmetry Breaking and the Pionic Decays of K Mesons; with D.Goswami and Y.Ueda; Phys. Rev. D5, 2276(1972); SU-256.

34. A Possible Origin for Symmetry Breaking; with Y.Ueda; Phys. Rev. D5, 2846(1972), SU-257.

35. Unified Weak-Electromagnetic Gauge Schemes Based on the Three Dimensional Unitary Group; with Y.Ueda; Phys. Rev. D8, 484(1973).

36. High Energy Behaviour of Gauge Theory Tree Graphs; with Y.Ueda, Phys. Rev. D7, 3119(1973).

37. $\eta \to 3\pi$ in a Renormalizable SU(3) Sigma Model; with W.Hudnall; Phys. Rev. D9, 2111(1973).

38. Phenomenological Dynamics for CP Violation; with M.Singer; Phys. Rev. D8, 3866(1973).

39. Higgs Mesons and High Energy Behaviour; with Y.Ueda; Lettere al Nuovo Cimento 8, 991(1973).

40. Spontaneous "Cabibbo" Suppression; with M.Singer; Phys. Rev. D6, 1769(1974).

41. Monopole Theories with Massless and Massive Gauge Fields, with A.P.Balachandran and H.Rupertsberger, Phys. Rev. D11, 2260 (1975).

42. Semi-Leptonic Neutral Current Decays; with M.Singer. Il Nuovo Cimento 26A, 117 (1975).

43. Monopole Strings and Charmonium; with A.P.Balachandran, R.Ramachandran, H.Rupertsberger and Kameshwar C.Wali. Proceedings of the Orbis Scientiae, University of Miami, Coral Gables, Florida, January 1975.

44. Hamiltonian Formulation of Monopole Theories with Strings; with A.P.Balachandran, R.Ramachandran, H.Rupertsberger and K. C. Wali, Phys. Rev. D13, 354 (1976).

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46. SU(4) Sigma Model; with M.Singer, Phys. Rev. D12, 2781 (1975).

47. Possible Enhancement of the Leptonic Decays of Charmed Pseudoscalars; with J.Kandaswamy and M.Singer, Phys. Rev. D13, 3151 (1976).

48. Yang-Mills Particle in 't Hooft's Gauge Field, Phys. Rev. D14, 524 (1976).

49. Leptonic Octets and Heavy-lepton Decays in an SU(3) Gauge Theory. with J.Kandaswamy; Phys. Rev. D15, 251 (1977).

50. An Effective Strong Interaction Lagrangian, with V.Mirelli; COO-81 submitted for publication.

51. A New Contribution to the $D^{\pm}$-D° Mass Splitting. with S.Borchardt, J.Kandaswamy and M.Singer, submitted for publication. COO-84

52. Estimate of the Pseudoscalar Decay Constant; with J.Kandaswamy. C00-87, submitted for publication.

Meetings attended:

International Symposium "Five Decades of Weak Interactions", City College of CUNY, January 20-23, 1977.

Other

Member APS

Bibliography of K. C.Wali

1. Theory of Photoproduction of Pions from Nucleons; J. Enoch, R.G.Sachs and K.C.Wali, Phys. Rev. 108, No.2, 433-455, (October 15, 1957).

2. Electromagnetic Form Factors of the Nucleon; F.J. Ernst, R.G.Sachs, and K.C.Wali, Phys. Rev. 119, No.3, 1105-1114, (August 1, 1960).

3. Pion-Pion Interactions in τ and τ' Decays; R.G.Sawyer and K.C.Wali; Phys. Rev. 119, No.4, 1429-1435, (August 15, 1960).

4. Tests for $\Delta T = 1/2$ in $K^+ \to 3\pi$ and $K_2^0 \to 3\pi$ Decay Modes; R.G.Sawyer and K.C.Wali, Nuovo Cimento, Series X 17, 938-945, (September 16, 1960).

5. Scattering Matrix Approach to the Λ-π Resonances; G.Feldman, T.Fulton and K.C.Wali, Phys. Rev. Letters 6, 664(1961).

6. Some Consequences of the Decay Modes and Production of the New Heavy Bosons; G.Feldman, T.Fulton and K.C.Wali, Nuovo Cimento Series X 24, 278-289(1962).

7. Effect of High Energy Limits on the Nucleon Form Factors; K.C.Wali; Nuovo Cimento, Series X 25, 912-922(1962).

8. $3\pi^0$ to $\pi^+\pi^-\pi^0$ Branching Ratio of a 0^{-+} n Meson; K.C.Wali, Phys. Rev. Letters 9, (August 1, 1962).

9. Coupled Channel Approach to $J = 3^+/2$ Resonances in the Unitary Symmetry Model; A.W.Martin and K.C.Wali, Phys.Rev. 130, 2455-2467 (1962).

10. Meson-Baryon Resonances in the Octet Model; A.W.Martin and K.C.Wali, Nuovo Cimento 31, 1324(1964).

11. Implications of a Possible $J^P = 3+/2$ Octet; E.Johnson, R.F.Sawyer and K.C.Wali, Phys. Rev. Letters 13, 141(1964).

12. A Dynamical Model for a $J^P = 3+/2$ Nonuplet; J.J.Brehm and K.C.Wali, Physics Letters 11, 355(1964).

13. Breaking of SU(3) in the 3+/2 Meson-Baryon Decuplet; K.C.Wali and R.L.Warnock, Phys. Rev. 135, B1358(1965).

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36. Hamiltonian Formulation of Monopole Theories with Strings; with A.P.Balachandran, R.Ramachandran, H.Rupertsberger and J.Schechter; Phys. Rev. D13, 354 (1976).

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38. Current Status of Baryon Spectroscopy; talk published in "New Direction of Hadron Spectroscopy" proceedings of the International Symposium, Argonne, July 1975.

39. Radially separated static, finite-energy Yang Mills Higgs Fields. with L.Michel and L.O'Raifeartaigh. SU-4210-78. (1976)

40. Static Finite-energy solutions of gauge fields with separated radial variable; with L.Michel and L.O'Raifeartaigh. SU-4210-83 (1976)

41. Concerning factorized solutions in a generalized 't Hooft-Polyakov model; with L.Michel and L. O'Raifeartaigh. (in preparation) SU-4210-88 (1977).

Other Activities

Meetings attended:

1. Baryon Conference, Oxford, England. June 24 to July 10, 1976. Chaired the session on "Theory of Resonant States".

2. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Visiting scientist July 20 to August 15, 1976.

3. Argonne Symposium, Argonne National Laboratory, Argonne, Ill. "High Energy Physics with Polarized Beams and Targets", August 23 to 27, 1976.

4. Coral Gables "Orbis Scientiae", University of Miami, Fla. January 16-20, 1977.

5. International Symposium "Five Decades of Weak Interactions" City College of CUNY, January 20-23, 1977.

Talks given:

<u>City College of CUNY</u>

On a Generalized 't Hooft-Polyakov Models.

<u>Other</u>

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