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RESEARCH IN THEORETICAL NUCLEAR PHYSICS

Progress Report

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I. Abstract of Progress Report

The meson-nucleon scattering phase shifts are calculated for the skyrme soliton with spin and isospin projections. The mixing of the $S^6_{1/2}$ and $S^4_{1/2}$ $P^2_{3/2}$ configurations in the MIT bag model is calculated and it shows a large effect. The production of $Q^2\bar{Q}^2$ mesoniums which decay to vector meson pairs are studied in $\gamma\gamma$ reactions, hadronic collisions and J/ψ radiative decays. A possible measurement of the quark gluon plasma temperature in relativistic heavy ion collisions is proposed. The vacuum to glueball transition amplitudes are measured in a lattice guage Monte Carlo calculation. Fusion reactions of the polarized denterons are calculated in DWBA formalisum. An extended Skyrme-Landau effective NN interaction is being developed so that nuclear structure calculations can be carried out.

II. Progress Description

1. Time Dependence of the Skyrme Solition and the NN Interaction

The prion-nucleon scattering phase shifts are calculated in the Skyrme model with spin and isospin projected out from the Skyrme soliton. It is found that the Roper resonance lies only 250 - 300 MeV above the nucleon. This result is reported in Ref. 1 together with J.S. Zhang and G.R.E Black. Further calculations concerning two solition interactions are being undertaken. First we shall consider the static potentials in different spin and isospin channels, then time dependence will be added to calculate the phase shifts in soliton-soliton scattering.

2. Six Quark Configurations in the Bag Model

Mixing of the $S^6_{1/2}$ and $S^4_{1/2}$ $P^2_{3/2}$ configurations are calculated in the MIT bag model. It is found that the mixing is so strong that one should worry about whether the single particle basis in the MIT bag model is appropriate. Work on mixing of $S^3_{1/2}$ and $S_{1/2}$ $P^2_{3/2}$ configurations in nucleon is in progress to check this point. These results will be reported in Ref. 3 with G.R.E. Black.

3. Production of $Q^2\bar{Q}^2$ Mesoniums in $\gamma\gamma$ Reactions, Hadronic Collisions, and the J/ψ Radiative Decays

The structure observed in $\gamma\gamma \to \rho^0\rho^0$ has been interpreted as the 2^{++} $Q^2\bar{Q}^2$ mesonium (Ref. 4) and it is further predicted that it

should be observed in J/ψ radiative decay (Ref. 4 and 5). The latest experimental data has confirmed the finding of the 2^{++} 2^{++} $\rho^{\circ}\rho^{\circ}$ resonance in J/ψ radiative decay. Its branching ratio and the ratios of helicity amplitudes agree with our prediction (Ref. 5). This we consider a strong support for the existance of such $Q^2\bar{Q}^2$ mesoniums. The correlated J/ψ pair production in πp scattering at 150 and 280 GeV/c are interpreted as the $Q^2\bar{Q}^2$ mesonium (Ref. 6). The production cross sections are calculated in a Drell-Yan type of mechanism with gluon fusion via the color vector-dominance model. The calculated cross sections and the longitudinal and transverse monumentum distributions are in good agreement with the experimental data. they are 20-30 times larger than the typical perturbative QCD calculations (Ref. 6).

4. Measurement of Quark Gluon Plasma Temperature in Relativistic Heavy Ion Collisions

A possible measurement of the quark gluon plasma temperature is proposed (Ref. 7). The idea is based on the observation that there are several di-vector-meson resonances produced in hadronic collisions and J/ψ radiative decays. Since the hadronic production cross sections of these objects depend on the gluon distribution function, we may map out the gluon distribution function in the quark gluon plasma by measuring various di-vector-meson resonances, i.e. $\rho\rho$, $\omega\omega$, $\phi\phi$, J/ψ J/ψ etc. at different energies in the relativistic heavy ion collisions. The information on the temperature and the phase transition may be obtained.

5. Glueball Transition Amplitudes in Lattice Guage Calculations

Correlation functions for the pure SU(2) Yang-Mills guage Lagrangian is calculated on a latice with heat-bath Monte Carlo method. Besides the glueball masses for the 0^{++} and 2^{++} states, we will obtain the vacuum to glueball transition amplitudes for the Wilson plaguet operator. Expanding the operator to a^8 (a is the lattice size), we are able to extract the transition amplitudes at the continuum limit with different coupling constants. The amplitudes thus obtained will enable us to calculate the branching ratios of glueball productions in J/ψ radiative decays and check against the existing glueball candidates. Since last year, we have spend about 60 CRAY hours in this calculation. Due to the limitation of the available computer time, this project has not been progressing as fast as we want.

6. Fusion Reactions of Polarized Deuterons

The polarized and unpolarized $d + d \rightarrow n + {}^3He$ fusion reactions in the center of mass energy range 20 - 150 keV are calculated

in DWBA. It is found that the polarized (s = 2) reaction is greatly suppressed due to the angular momentum conservation. The presence of a D-state probability in ^{3}He does not make much difference. Hence the idea of a "neutron free" fusion reactor remains feasible (Ref. 8).

7. Effective NN Interactions, Skyrme-Landau Parametrization

An extended Skyrme-Landau interaction with the T_{13}, t_{23}, t_4, and t_{24} terms included to simulate the finite range density-dependent interaction is under study. We have obtained several sets of parameters which yield a compressions modulus close to 200 MeV and positive G_o and G_o'. We are applying them to calculate various electric and magnetic excitations in a self-consistent RPA scheme. The renormalization of the single particle orbits and optical potential will then be evaluated.

III. Progress Summary

The time dependence of the Skyrme's chiral soliton is derived which, through the small oscillation, yields the pion-nucleon phase shifts. The formalism contains solution for two solitons. We intend to calculate first the static NN potential and then solve the time dependent solution by the scattering of two solitons and obtain the phase shifts in a time-evolution program. The study of the short range NN potential in the MIT bag model has been extended to include the mixing of the $S_{1/2}^6$ and the $S_{1/2}^4 P_{3/2}^2$ configurations. We found that the mixing lowers the 6 quark energy by 600 MeV which casts certain doubt on the validity of the single particle basis in the MIT bag model. We are currently checking this by mixing the $S_{1/2}^3$ and the $S_{1/2}P_{3/2}^2$ configurations in the nucleon sector and see how much change in energy it will bring.

The search for $Q^2\bar{Q}^2$ mesoniums in $\gamma\gamma$ reactions, hadronic collisions and J/ψ radiative decay remains an active research program. With new data from the J/ψ radiative decay confirming the existence of the 2^{++} $\rho^o\rho^o$ resonance seen in $\gamma\gamma$ reaction of the $Q^2\bar{Q}^2$ mesoniums, we believe, are on the verge of being established. Measurement of these vector meson pair resonances is proposed as an effective way of measuring the gluon distribution function in the relativistic heavy ion collisions. It may signal the quark gluon palsma phase transition.

Glueball transition amplitudes are being extracted from an SU(2) lattice guage Monte Carlo calculation. It provides the needed matrix element for calculating the glueball branching ratios in the J/ψ radiative decays and hadronic collisions.

The polarized d = d + n + ^{3}He fusion reaction cross section at low energy is shown to be supressed as compared to the unpolarized cross section. This supports the idea of the "neutron lean" fusion reactor.

Progress is made to parametrize an extended Skyrme-Landau interaction in the Hartree-Fock program. They are being tested in self-consistent RPA calculations.

IV. List of Reprints and Preprints

1. K.F. Liu, J.S. Zhang, and G.R.E. Black, "Time dependence of the Skyrme Soliton", Phys. Rev. D30, 2015 (1984).

2. K.F. Liu and J.S. Zhang, "Time dependence of Skyrmion", Proceedings of the Lewes Workshop on Solitons in Nuclear and Particle Physics (World Schientific, 1984), p. 230.

3. G.R.E. Black and K.F. Liu, "Six quark configurations $S^6_{I/2}$ and $S^4_{I/2}P^2_{3/2}$ in the MIT bag Model", under preparation.

4. B.A. Li and K.F. Liu, "Are $Q^2\bar{Q}^2$ States Observable?", Phys. Rev. D30, 613 (1984).

5. B.A. Li, Q.X. Shen, H. Yu, and K.F. Liu, "In search of $Q^2\bar{Q}^2$ Mesons in J/ψ radiative decays", submitted to Phys. Rev. Lett.

6. B.A. Li and K.F. Liu, "J/ψ pair production in hadronic collisions", Phys. Rev. D29, 426 (1984).

7. K.F. Liu, "A Possible Measurement of Quark Gluon Plasma Temperature in Relativistic Heavy Ion Collision", AIP Conference Proceedings 110, 306 (1984).

8. K.F. Liu, J.S. Zhang, and G.W. Shuy, "Comment on fusion of polarized Deuterons," submitted to Phys. Rev. Lett.

9. K.F. Liu, "NN Deformation Potential in Bag Model and Color Van der Waals Force", Nucleon-Nucleon Interaction and Nuclear Many-Body Problems, ed. S.S Wu and T.T.S. Kuo (World Scientific, 1984), p. 591

10. B.A. Li and K.F. Liu, "J/ψ Pair Production in πp and pp Collisions", Few Body Problems in Physics, ed. B. Zeitnitz (Elsivier Science , 1984), p. 129.

11. B.A Li, and K.F. Liu, "Production of Vector Meson Pairs in Hadronic Collisions", Few Body Problems in Physics, ed. B. Zeitnitz, (Elsevier Science, 1984), p. 131.

12. B.A. Li and K.F. Liu, "Possible Explanation of $\rho^\circ\rho^\circ$ Production in J/ψ Radiative Decays", Few Body Problems in Physics, ed. B. Zeitritz (Elsevier Science, 1984), P. 603.

13. K.F. Liu, "Color Van der Waals Force in the Coupled Channel Approach", Few Body Problems in Physics, ed. B. Zeitritz (Elsevier Science, 1984), p. 675.

V. Attachments: reprints and preprints.