UNUSUAL INITIAL AND FINAL STATE EFFECTS
IN QUANTUM CHROMODYNAMICS

Progress Report
for period July 15, 1990 - December 20, 1990

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Abstract

We have constructed fundamental tests which can be used to probe discrete symmetries, and their possible violations, in the required "new physics" beyond the standard model. In a recent paper for applications at an e^+e^- collider, we have proposed a simple test for "maximal P - maximal C" violation in the $Z^0 \rightarrow \tau_1^- \tau_1^+$ coupling. For $\tau^\mp \rightarrow \pi^\mp \nu$, for example, this test is based on an azimuthal correlation function $I(\phi_e, \phi)$ where the azimuthal angles are defined relative to the final π_1^- . For e^+e^- collisions in the Υ or J/ψ regions, $I(\phi_e, \phi)$ can be used to test for a complex phase in the $\gamma^* \rightarrow \tau\tau^+$ coupling. In other research programs, we are (i) continuing to investigate our proposal that partons be identified with nearly degenerate, coherent quark-gluon "jet" states, and have proven (ii) a completeness relation for the q-analogue of the unusual coherent states.

Text

During the past year most of our research has concentrated on constructing symmetry tests from spin correlation functions in the sequential decay of an integer spin boson into a fermion-antifermion pair such as $\tau^+\tau^-$, followed by 2-body or 3-body decays of the two spin-1/2 particles. This concentration has been necessary in order to produce the results reported in the publications and preprints listed at the end of this "Annual Performance Report". Since both the SLC and the LEP accelerators have begun producing Z^0 's, these proposed electroweak tests can be further developed, and if warranted, soon used to investigate the structure of the τ -W- ν_τ and τ - Z^0 - τ vertices using the $\tau^+\tau^-$ decay mode of the Z^0 . At this time, to us, our decision to concentrate much of our past year's research on this subject appears to have been sound. Some of our research time has been spent on other projects, particularly on QCD programs and on a completeness relation for the q-analogue of the usual coherent states.

A. CONSTRUCTION OF FUNDAMENTAL DISCRETE SYMMETRY TESTS FOR NEW PHYSICS

The $\phi\phi$ parity test proposed by Chang and myself in 1978, as an analogue of C.N. Yang's parity test, was used by the Mark III group at SLAC-SPEAR to experimentally determine the parity of the η_c (2980) meson [Phys. Rev. Lett. 52, 2126 (1984)] and to show

that the $\omega\omega$ mass distribution peak at about 1.8 GeV in $J/\psi \rightarrow \gamma\omega\omega$ is predominantly pseudoscalar [Phys. Rev. Lett. 55, 1723 (1985)].

The technique has been generalized by ourselves and other authors as tool in searching for and establishing the CP eigenvalue of a technipion/Higgs via the W pair or the Z pair decay mode at a large hadron collider such as the SSC.

Construction of Electroweak Symmetry Tests for e^-e^+ Collisions:

We are currently further developing several techniques for measuring electroweak coupling parameters from beam-referenced τ spin correlation functions in e^-e^+ collisions. These methods do not require beam polarization.

At LEP in four high precision experiments, many $\tau\tau^+$ events are being produced by unpolarized e^-e^+ collisions in the Z^0 mass region. Many $\tau\tau^+$ events are also being produced in the Υ region in the ARGUS and CLEO detectors. There is also a strong interest in the physics community in the construction of a high luminosity e^-e^+ collider near the $\tau\tau^+$ threshold to produce a high statistics sample of $\tau\tau^+$ events (the so-called τ /charm factory). Previously we showed [Phys. Rev. Lett. 62, 1347 (1989); Phys. Rev. D40, 123 (1989); D41, 2327(E)] that measurement of the energy correlation function $I(E_A, E_B)$ for $Z^0 \rightarrow \tau_1^- \tau_2^+ \rightarrow A^- B^+ X$ determines independently the fundamental parameters $\sin^2 \theta_W$, the tau Michel parameters, and for hadronic tau decays the analogous "chirality parameter" ξ_A which tests for right-handed currents.

Now By referencing this energy correlation function to the incident e^- beam direction, the associated ideal statistical errors for these parameters for the case of hadronic tau decays are reduced only by about 25%. Using the full BRSC function for 10^7 Z^0 events the ideal statistical error in the determination of $\sin^2 \theta_W$ is 0.8×10^{-3} when the $\{h_1^-, h_2^+\}$ channels are summed over where $h = \pi, K, \rho, K^*, a_1^{ch}$. The best individual mode is $\{(\pi, K)^- \rho^+\}$ for which $\sigma(\sin^2 \theta_W) = 1.2 \times 10^{-3}$. There is a similar, but smaller, reduction in the ideal statistical errors for the chirality parameters ξ_π, ξ_ρ , and ξ_{K^*} when the full BRSC function is used instead of $I(E_1, E_2)$.

Measurement of the $Z^0 \rightarrow \tau^- \tau^+$ decay intensity parameters ($\delta, \alpha, \kappa, \kappa'$) will completely determine the fundamental helicity amplitudes $T(-+)$ and $T(+ -)$.

An azimuthal correlation function $I(\phi_e, \phi)$, where the azimuthal angles are defined relative to the final π_1^- , allows one to simply test for "maximal P - maximal C" violation in the $Z^0 \rightarrow \tau^- \tau^+$ coupling. Such a symmetry would not be present if there were T non-invariance and/or rescattering phase shifts in $Z^0 \rightarrow \tau_1^- \tau_2^+$. For $e^- e^+$ collisions in the Υ or J/ψ regions, $I(\phi_e, \phi)$ can be used to test for a complex phase in the $\gamma^* \rightarrow \tau^- \tau^+$ coupling. The detailed distributions and tests for these latter 2 regions are now being worked out.

This observable $I(\phi_e, \phi)$, can also be used for leptonic tau decay modes. For the $\{\ell_1^-, h_2^+\}$ and $\{\ell_1^-, \ell_2^+\}$ sequential decay channels, an odd ϕ_e component in $I(\phi_e, \phi)$ would indicate a violation of time-reversal invariance if a first-order hermitian Hamiltonian is applicable.

This work has appeared as a SUNY at Binghamton preprint and has been accepted for publication in "Physical Review D". [A masters student, Steve Goozovat, contributed significantly in various phases of this project over the past year and a half. His oral defense of this thesis is scheduled for early January of 1991.]

B. q-Analogue Symmetry Structures

Partially as an outgrowth of our work on the usage of coherent quark-gluon "jet" states in QCD, we have begun an investigation of the properties of the q-analogue of the usual coherent states. These states can be constructed using the q-oscillator realization of quantum groups. In July with a masters student, Bob Gray, we used q-integration to prove a completeness relation for these states. The structure of these states, and of q-analogue symmetries in general, is definitely novel. Our paper on this research has appeared [Lett. to Editor, J. Phys. A: 22, L945 (1990)].

Remarks

During the past year, it has been very helpful to our research to be able to consult with other physicists and visitors at Cornell University, at CERN, in July, and at the 25th International Conference on High Energy Physics in Singapore, in August. We have presented talks on the $e^-e^+ \rightarrow \tau\tau^+$ symmetry tests at CERN in July and at Cornell in November.

Time Committed to Project

The principal investigator committed 100% of his time to the project from July 15, 1990 through August 28, 1990. From August 28, 1990 until May 27, 1991, he will commit about 40% of his time. He expects to contribute 100% of his time from May 27 through July 14, 1991.

Scheduled Conference Presentation

I have accepted an invitation to participate in the "1991 Aspen Winter Physics Conference Elementary Particle Physics," January 6 - 13, 1991, and have requested the committee's approval to present a talk entitled "Electroweak Tests from $e^-e^+ \rightarrow \tau\tau^+$."

Publications to Date: (6 reprints of each submitted with this report)

1. Spin Correlations in Z^0 Decays, in Proceedings of 24th Recontres de Moriond on "Hadronic Interactions," Les Arcs, France (March 1989).
2. CP/P Determination and Other Applications of τ Lepton and t Quark Polarimetry, Phys. Rev. D41, 2805 (1990).
3. A Completeness Relation for the q-Analogue Coherent States by q-Integration, with R.W. Gray, Letter to Editor, J. Phys. A: Math. Gen. 23, L945 (1990).

Preprints to Date:

1. Test for "Maximal P - Maximal C" Violation in e^-e^+ Collisions from Beam-Referenced Spin Correlation Functions, SUNY Bing 7/23/90, Phys. Rev. D (to appear).

Masters Thesis: (oral defense in January of 1991)

1. Stephen Goozovat, "The Forward-Backward Asymmetry of $e^+e^- \rightarrow \tau^- \tau^+$ at the Z^0 ," SUNY at Binghamton Masters Thesis, January 1991.

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