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THEORETICAL PHYSICS

High Energy Physics

Lattice Gauge Theory

The Deconfinement Transition in SU(4) Lattice Gauge Theory

Establishing the order of the deconfinement phase transition for the SU(4) lattice gauge theory at finite temperature is important for understanding of the physics of the phase transition to quark-gluon plasma. Employing a modified action to avoid spurious transitions, the theory was simulated on lattices of different sizes. A first order deconfinement transition with large latent heat was established using finite size scaling. This indicates that current arguments based on large number of colours for quarks are unable to explain the mysterious behaviour of the energy density of quantum chromodynamics at finite temperature. New and better explanations are called for. [R. V. Gavai]

Quark Number Susceptibilities

Quark number susceptibilities, which are the response of the QCD ground state to various chemical potentials, were investigated in detail at temperatures larger than the deconfinement temperature, T_c. In quenched QCD the continuum limit of these quantities were evaluated through lattice simulations. In the continuum, the susceptibilities to baryon and isovector chemical potentials were about 75% of the ideal-gas result for temperature between $2T_c$ and $4T_c$, with the deviations increasing closer to T_c. These deviations are too large to be explained in perturbation theory, even with various resummations, and clearly indicate the presence of non-perturbative contributions. These susceptibilities were also measured with two flavours of light dynamical quarks, and their behaviour was found to be similar to the quenched theory. [Rajiv Gavai, Sourendu Gupta, Pushan Majumdar]

Phase Transition at Finite Isovector Chemical Potential

The phase structure of QCD at zero temperature but finite isovector chemical potential was investigated. A phase transition was found at a chemical potential equal to the pion mass at zero chemical potential. At this critical point the neutral pion and one combination of the charged pions was found to condense and give rise to degenerate massless excitations, showing that the transition is of second order in the O(4) universality class. [Sourendu Gupta]

Chiral Fermions at Finite Temperature

We have investigated chiral (overlap) quarks at finite temperature, above the critical point, T_c, in quenched QCD. We found that zero and near-zero modes of the Dirac operator are localised states, that the density of zero modes decreases rapidly with temperature, and that meson screening masses are closer to ideal than in measurements with staggered quarks. [Rajiv Gavai, Sourendu Gupta and Robert Lacaze (CEA, Saclay, France)]

Beyond Standard Model Physics

Solution to the Solar Neutrino Anomaly

The recent solar neutrino data from the SuperKamiokande and the Sudbury Neutrino Observatory experiments suggest a mild and monotonic energy dependence of the suppression rate. This is shown to disfavour the traditional vacuum oscillation and the matter-enhanced Small Mixing Angle solutions. Instead they favour a large mixing angle between the electron-neutrino and another neutrino flavour. In particular they are shown to be consistent with a practically energy-independent suppression, which is characteristic of maximal mixing. [D.P.Roy with Sandhya Choubey and Srubabati Goswami (SINP, Kolkata)]

Constraints on Radiative Neutrino Mass Models from Oscillation Data

The three neutrino Zee model and its extension including three active and one sterile species are studied in the light of new neutrino oscillation data. We derive analytical relations for the mixing angle in solar oscillations in terms of neutrino mass squared differences. For four neutrinos, we obtain the result $\mathsf{sin}^2 2\theta_\odot \approx 1 - [(\Delta \mathsf{m}^2_{\mathsf{Atm}})^2/(4\Delta \mathsf{m}^2_{\mathsf{LSND}} \Delta \mathsf{m}^2_\odot)]^2$, which can accommodate both the large and small mixing scenarios. We show that within this framework, while both the small and large mixing angle solutions for oscillations of neutrinos in matter can easily be accommodated, it would be difficult to reconcile the other competing solutions. We also comment on the active-sterile admixture within phenomenologically viable textures. [Probir Roy with Sudhir Vempati]

Constraining 4-neutrino Mass Patterns from Neutrinoless Double β Decay

All existing data on neutrino oscillations (including those from the LSND experiment) imply a four neutrino scheme with six different allowed mass patterns. Some of these are shown to be disfavoured by using a conservative upper bound on the neutrinoless nuclear double-beta decay rate, if neutrinos are assumed to be Majorana particles. Comparisons are also made with restrictions from tritium β-decay and cosmology. [Probir Roy with S. Pakvasa of the University of Hawaii]

Anomaly-free Extension of the Standard Model

We construct an anomaly-free extension of the Standard Model gauge group, corresponding to the gauge charge $L_\mu - L_\tau$, i.e. the difference between the muon and tau lepton numbers. The corresponding gauge boson can naturally account for the anomalous magnetic moment of the muon as recently measured at BNL as well as an anomalous muon-neutrino cross-section measured by the NuTev experiment at Fermilab. The model can also account for the Atmospheric and Solar Neutrino Anomalies. [D.P.Roy and Sourov Roy with Ernest Ma (Univ. of California, Riverside)]

Supergravity Phenomenology

In the small m_0 region of supergravity models, the scalar τ lepton becomes relatively light; and the τ lepton coming from its decay provides an important channel for the Supergravity signal. The Supergravity model was shown to predict the polarization of this τ lepton to be $+1$ and ways of testing this prediction at the Fermilab Tevatron suggested. [D.P.Roy with Monoranjan Guchait (CERN, Geneva)]

Phenomenology of Non-minimal Scenarios of Supergravity Type of Models

The recent Brookhaven National Laboratory data for muon $g-2$ strongly favours a positive sign for the Higgsino mixing parameter μ. However, constraints from unification of Yukawa couplings show that $\mu > 0$ is not preferred. It is found that the introduction of gaugino mass non-universalities by considering curved Kahler potential and non-gauge singlet gauge kinetic energy functions can provide the required gaugino masses in specific representations which would allow one to have Yukawa unification ($b-\tau$ in SU(5) and $b-t-\tau$ in SO(10) GUT models). Additionally, this would simultaneously satisfy the strong constraints coming from muon $g-2$ and $Br(b \longrightarrow s+\gamma)$. [Utpal Chattopadhyay]

Implications of Yukawa unifications within non-universal gaugino mass scenario on dark matter is studied for the neutralino relic density and the direct detection rates for neutralinos. The analysis is further extended to include SO(10) based non-universal gaugino mass scenario. [Utpal Chattopadhyay, Achille Corsetti and Pran Nath of Northeastern University]