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THEORETICAL PHYSICS

High Energy Physics

Lattice Gauge Theory

Monopoles, Vortices and the Deconfinement Transition

The effect of Z_2 magnetic monopoles and vortices on the finite temperature deconfinement phase transition in the fundamental-adjoint Villain form of $SU(2)$ lattice gauge theory has been investigated. A complete suppression of the Z_2 monopoles has been shown to lead to an action for the theory which is self-dual under the exchange of the fundamental and adjoint couplings. By further suppressing the Z_2 vortices the theory has been reduced to the usual Wilson action but with a modified coupling. The universality of the $SU(2)$ deconfinement phase transition with the 3-dimensional Ising model should therefore remain intact in the entire plane of the fundamental-adjoint couplings in the continuum limit. Generalizations of these arguments to the $SU(N)$ theory have been outlined. (R. V. Gavai and Manu Mathur, SNBNCBS, Calcutta)

Adding separate chemical potentials λ and γ for Z_2-monopoles and vortices respectively in the Villain form of the mixed action for the SU(2) lattice gauge theory, their role in the interplay between the deconfinement and bulk phase transitions has been studied using Monte Carlo techniques. Setting λ to be nonzero, the line of deconfinement transitions has been shown to shift in the coupling plane but curiously it behaves also like the bulk transition line for large enough adjoint couplings, as for $\lambda = 0$. However, separate deconfinement and bulk phase transition lines have been demonstrated to exist in a narrow range of couplings on the *same* lattice for large λ. This confirms that the two apparently unrelated transition lines do indeed remain coincident for a range of different lattice sizes and couplings. The cause of this coincidence is not yet known. Setting both λ and γ to large values leads to only lines of second order deconfinement phase transitions in the entire coupling plane. This work resolves a long-standing paradox of an apparent lack of universality in these theories. (Saumen Datta and R. V. Gavai)

Beyond Standard Model Physics

Linear Collider Signals

The production of charginos and neutralinos at a 500 GeV e^+e^- collider (NLC) is investigated. Also studied are their decays to the lightest neutralino, which then decays into multi-fermion final states through couplings which do not conserve R-parity. These couplings are assumed to affect only the decay of the lightest neutralino. Detailed analyses of

the possible signals and backgrounds are performed for five selected points in the parameter space. (Dilip Kumar Ghosh, Rohini M. Godbole of C.T.S., Bangalore and Sreerup Raychaudhuri of IIT, Kanpur)

The pair-production of right selectrons has been studied at a 500 GeV e^-e^- Linear Collider followed by their decay into an electron and a lightest neutralino. In the presence of R-parity violating couplings, the lightest neutralino will decay into multifermion final states. Detailed analysis of possible signals, almost free from Standard Model backgrounds, is performed for some important regions of the parameter space. (Dilip Kumar Ghosh and Sourov Roy)

The final states $\tau^+\mu^-\mu^- e(\mu)^+, \tau^-\mu^+\mu^+ e(\mu)^-, \tau^+\mu^- jj$, via the production and cascade decays of a lighter and a heavier chargino in a 1 TeV CM energy e^+e^- Linear Collider, are shown to be unambiguous signals of flavour-mixing between sleptons of the second and third generations. (Probir Roy with M. Guchait of DESY).

Phenomenological Studies of Anomaly Mediated Supersymmetry Breaking

Recently, a class of models has emerged where supersymmetry breaking is communicated to the visible sector through the loop-induced super-Weyl anomaly. The most striking feature of these models is that they possess a neutral Wino lightest supersymmetric particle (LSP), nearly mass-degenerate with the lighter chargino. If produced in the laboratory, the lighter chargino will predominantly decay into the LSP and a soft pion which may be detectable. Pair-produced selectrons (smuons) in a next generation Linear Collider, yielding a fast electron (muon) trigger, a visible heavily ionizing track and/or a resolved soft pion impact parameter and overall $\not{E}_T$ have been shown to provide a smoking gun signature for the minimal Anomaly Mediated Supersymmetry Breaking (AMSB) model where a common m_0^2 has been added to the mass-squared of the sfermions. (Dilip Kumar Ghosh, Probir Roy and Sourov Roy.)

Constraints on chargino and sneutrino masses as well as other parameters in AMSB models have been derived from the current experimental measurement of the muon anomalous magnetic moment $(g-2)_\mu$ at the Brookhaven National Laboratory (BNL). The effects of its accuracy level have also been discussed. (Utpal Chattopadhyay, Dilip Kumar Ghosh and Sourov Roy.)

Effects of Nonuniversality on SUSY Signatures

While canonical SUSY signatures are based on the assumption of universal SUSY breaking parameters, there are theoretically well-motivated models of universality breaking. In particular the GUT scale breaking of SO(10) into the Standard Model gauge group $SU(3) \times SU(2) \times U(1)$ reduces the rank of the gauge group, which is expected to generate nonuniversal D terms in the SUSY breaking scalar mass parameter. The effect of such nonuniversal terms on the SUSY signature has been systematically studied for the Tevatron collider energy. (D. P. Roy with Amitava Datta of Jadavpur University, Aseshkrishna Datta of MRI

and M. Drees of São Paulo University)

Phenomenological Study of Large Extra Dimensions

Recent developments in string theory have suggested the possibility that there could be extra space dimensions which could be as large as a millimetre with effects of quantum gravity being manifest at energies as low as a TeV. The implications of such a large extra dimension and a low quantum gravity scale for deep-inelastic scattering at HERA and jet production at Tevatron have been studied. (K. Sridhar, with Prakash Mathews of IFT, São Paulo and Sreerup Raychaudhuri of IIT, Kanpur)

Future colliders like the Next Linear Collider have a tremendous potential for discovering the new physics of extra spatial dimensions. In this context, the virtual effects of the graviton states in $t\bar{t}$ production in photon-photon collisions have been studied. (K. Sridhar, with Prakash Mathews of IFT, São Paulo and P. Poulose of C.T.S., Bangalore)

Virtual gravitation effects in dijet production in photon-photon collisions have been explored. The production of gravitons in electron-photon collisions at the NLC has also been studied. (K. Sridhar, with Dilip Ghosh, Prakash Mathews of IFT, São Paulo and P. Poulose of C.T.S., Bangalore).

SUSY Higgs at the LHC

The charged Higgs Boson carries a distinct hallmark of the supersymmetric Higgs sector. But extending the charged Higgs Boson search beyond the top quark mass is known to be very difficult due to a large QCD background. The LHC signatures of such a heavy charged Higgs Boson have been analysed along with the backgrounds and viable signatures found over a significant domain of the parameter space. (D. P. Roy with S. Moretti and D. J. Miller of Rutherford Appleton Lab., J. W. Stirling of Durham University, M. Drees of São Paulo University and M. Guchait of DESY).

A critical analysis of the conventional Higgs production mechanism via gluon fusion at the LHC has been made for regions of parameter space with large stop mixing. In this region, it is shown that while the conventional Higgs production mechanism via gluon fusion is strongly suppressed making the Higgs unobservable in this channel, other associated production channels of Higgs production open up, which will rescue the discovery of the Higgs at the LHC. (K. Sridhar, with Fawzi Boudjema and Genevieve Belanger of LAPP, Annecy)

An inverted mass hierarchy, where sfermions of the first two generations are much heavier than those of the third generation with naturalness being preserved, can be helpful to avoid constraints from flavour changing neutral currents (FCNC), CP violating phases and the electric dipole moments of the electron and the neutron. The infra-red fixed point property as well as a focus point scenario of the renormalization group (RG) equations for scalar masses are used within the electroweak symmetry breaking framework to find the mass spectra of supersymmetric particles. Along with collider studies, various relevant phenomenological issues like fermion electric dipole moments, constraints from neutralino dark matter etc. are

studied in heavy scalar domains. (Utpal Chattopadhyay with D.P. Roy)

Quantum Chromodynamics

Polarised Deep Inelastic Scattering

It is shown that the model, which naturally explains the $\bar{u} \neq \bar{d}$ asymmetry in the nucleon and is in quantitative agreement with the Gottfried sum rule data, also predicts that in the proton $\Delta\bar{u} > 0 > \Delta\bar{s} > \Delta\bar{d}$ and $\Delta\bar{u} - \Delta\bar{d} > \bar{d} - \bar{u} > 0$. At the input scale, these results can be derived analytically. Thus the violation of flavor symmetry is more serious in the polarised case than in the unpolarised case. In contrast, many recent analyses of the polarised data have made a simplifying assumption that all the three $\Delta\bar{q}$'s have the same sign and magnitude. There is a need to redo these analyses, allowing for the alternate scenario as described above. Predictions are made for the W^- asymmetry in polarised pp scattering, which can be tested at RHIC. These are quite different from those available in the literature. (R.S. Bhalerao)

Results of a QCD fit to global data on deep-inelastic polarised lepton-hadron scattering are presented. It is found that it is possible to fit the data with strongly broken SU(2) flavour for the polarised sea densities. This can easily be tested in W production at polarised RHIC. The data fails to pin down polarised singlet sea quark and gluon densities. The uncertainties are explored in detail and it is shown that improvement in statistics, achievable at polarised HERA for measurement of A_1 at moderately low values of x, have large payoffs in terms of the improvement in the measurement of gluon and sea quark densities. (Dilip Kumar Ghosh, Sourendu Gupta, and D. Indumathi)

Quark-Gluon Plasma

The Relativistic Heavy Ion Collider (RHIC) in BNL, New York and the Large Hadron Collider (LHC) in CERN, Geneva will look for conclusive evidence of the formation of Quark-Gluon Plasma (QGP), which probably existed in our universe a few microseconds after the Big Bang. A theoretically challenging task is to deduce from first principles, e.g., Lattice QCD, as many properties of the plasma as possible so that clear and unique signals of QGP may be devised. Towards this end, a first determination of a new correlation function of Fermion bilinears has been made in finite temperature QCD with and without dynamical quarks. The Fermion correlator has been found to vanish for $T \geq 3T_c/2$, suggesting the presence of weakly interacting quarks in the plasma. Non-trivial correlations are known to be present for purely gluonic operators in the same quantum number channel, making quarks somewhat special. (R. V. Gavai and Sourendu Gupta)

The production and equilibration of quark-gluon plasma are studied within the color flux-tube model, at the RHIC and LHC energies. Before the chromoelectric field is formed, hard and semihard partons are produced via minijets which provide the initial conditions necessary to solve transport equations. The minijet input significantly alters the evolution of

the deconfined matter, unless the color field is too strong. The model predicts that in spite of the vast difference between the RHIC and LHC incident energies, once the local equilibrium is reached, the energy densities, the number densities and the temperatures at the two machines may not be very different from each other. The temperature at equilibration is found to be ~ 250 MeV at RHIC and ~ 300 MeV at LHC. The equilibration time is estimated to be ~ 1 fm at RHIC and ~ 0.5 fm at LHC, measured from the instant when the two colliding nuclei have just passed through each other. (R.S. Bhalerao and G.C. Nayak)

Strangeness Production by Parametric Resonance

Classical field equations have been used to probe the dynamics of approach to thermal equilibrium for a long time. This approach has been used recently to understand the dynamics after a quench in heavy-ion collisions and of electro-weak baryogenesis. This technique is used to study off-equilibrium dynamics after a heavy-ion collision event in the $SU(3) \times SU(3)$ linear sigma model with explicit symmetry breaking appropriate to the known spectrum of hadrons. In this model, a parametric resonance leads to copious production of strangeness. (Sourendu Gupta and Krishnendu Mukherjee)

Structure of Finite Temperature QCD

When normal matter is heated to a temperature comparable to that existing in the universe in the first second of its existence, there occurs a phase transition to chiral symmetric and deconfined quark matter. It has been shown that, if such matter is described by a pure gauge theory, it undergoes dimensional reduction. The group theory of fermion operators in such a theory has been studied and it has further been shown that all components of the vector meson behave as if the theory were weakly coupled at such high temperatures. (Sourendu Gupta)

Production of Thermal Jets in e^+e^- Collisions

It has been shown that at zero temperature the cross-section of jets produced in e^+e^- collisions is infrared finite. However, the infrared divergences are considerably worse at non-zero temperatures because the usual infrared logarithms are enhanced by the Bose-Einstein distribution function. Therefore it would be interesting to study the infrared finiteness of the production rates of thermal jets that are produced in hard e^+e^- collisions. (Sourendu Gupta and Krishnendu Mukherjee.)