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THEORETICAL PHYSICS

High Energy Physics

Lattice Gauge Theory

Continuum Limit of Quark Number Susceptibilities

The continuum limit of quark number susceptibilities was investigated in quenched quantum chromodynamics (QCD) for $1.5 \leq T/T_c \leq 3$, using two different lattice discretisations of quark action and extrapolating from lattice spacings between $1/4T$ and $1/14T$. The light quark (u, d)-susceptibilities were found to be about 10% less than the ideal gas results even at the highest T, in agreement with hard thermal loop predictions but marginally below a resummed perturbative computation. For the mass range appropriate to the strange quark, the flavour diagonal susceptibility was significantly smaller. Our estimate of the Wroblewski parameter, which is a measure of the produced strange particles, is compatible with observations at RHIC and SPS. The continuum limit of screening masses in all (local) quark-bilinears is very close to the ideal gas results in contrast with earlier results on coarser lattices which reported a much lower pion screening mass. The flavour off-diagonal susceptibility was found to be compatible with zero at each lattice spacing, and hence also in the continuum limit, at each temperature. This result can not be understood in any perturbation theoretic framework. [Rajiv V. Gavai and Sourendu Gupta]

The Phase Transition in QCD with Broken $SU(2)$ Flavour Symmetry

A first investigation of the QCD transition temperature, T_c, was carried out for two flavours of staggered quarks with unequal masses at lattice spacings of $1/4T$. On changing the u/d quark mass ratio in such a way that $m^2_{\pi_0}/m^2_{\pi^\pm}$ changes from 1 to 0.78, thus bracketing the physical value of this ratio, T_c was found to remain unchanged in units of both ρ-mass and the QCD Λ-parameter. [Rajiv V. Gavai and Sourendu Gupta]

Pressure in QCD at Finite Chemical Potentials and Non-Linear Susceptibilities

When the free energy density of QCD is expanded in a series in the chemical potential, μ, the Taylor coefficients are the non-linear quark number susceptibilities. It was shown that these depend on the prescription for putting chemical potential on the lattice, making all extrapolations in chemical potential prescription dependent at finite lattice spacing. To put bounds on the prescription dependence, the magnitude of the non-linear susceptibilities was investigated over a range of temperature, T, in QCD with two degenerate flavours of light dynamical quarks at lattice spacing $1/4T$. The prescription dependence was removed in quenched QCD through a continuum extrapolation, and the dependence of the pressure, P, on μ was obtained. [Rajiv V. Gavai and Sourendu Gupta]

Improving the Quark Number Susceptibilities for Staggered Fermions

Quark number susceptibilities approach their ideal gas limit at sufficiently high temperatures. As in the case of other thermodynamic quantities, this limit itself is altered substantially on lattices with small temporal extent, making it thus difficult to check the validity of perturbation theory. Unlike other observables, improving susceptibilities or number densities is subject to constraints of current conservation and absence of chemical potential dependent divergences. Such an improved number density and susceptibility for staggered fermions was constructed and shown to approximate the continuum ideal gas limit better on small temporal lattices. [Rajiv V. Gavai]

The Electrical Conductivity and Soft Photon Emissivity of the QCD Plasma

The electrical conductivity in the hot phase of the QCD plasma is extracted from a quenched lattice measurement of the Euclidean time vector correlator for $1.5 < T/T_c < 3$. The spectral density in the vicinity of the origin is analysed using a method specially adapted to this region, and a peak at small energies is seen. The vector susceptibility is then used to extract the electrical conductivity and make a continuum extrapolation. This allows us to predict the soft photon emissivity of the QCD plasma. [Sourendu Gupta]

Beyond Standard Model Physics

Solar Neutrino Oscillations

There is a great deal of current interest in the atmospheric and solar neutrino oscillations as the first experimental indications of physics beyond the Standard Model. Unlike the atmospheric case however the solar neutrino oscillation data used to suffer from the ambiguity of multiple solutions with no clear winner. The first neutral current data from the Solar Neutrino Observatory experiment has been used in a global analysis of the solar neutrino data to show for the first time the emergence of a clearly favoured solution. This corresponds to a Large Mixing Angle (LMA) oscillation of the solar neutrino into another neutrino species and its resonant enhancement through the solar matter effect — the so called MSW effect. Subsequently this conclusion has been confirmed by analysing the first atomic reactor neutrino data from the KAMLAND experiment, which practically rules out all the alternatives to the LMA solution. Both the results have been simultaneously obtained by several other groups. [D.P. Roy with A. Bandyopadhyay of SINP, Kolkata, S. Choubey of SISSA, Trieste, R. Gandhi and S. Goswami of HRI, Allahabad]

Extensions of the Standard Model

The extensions of the Standard Model gauge group are being widely studied as the most promising source of neutrino mass and mixing, as implied by the neutrino oscillation data. They predict additional gauge bosons as well as matter fermions. Two such models have been constructed and the phenomenological implications of the predicted gauge bosons and fermions investigated with the help of both low and high energy data. [D.P. Roy with E. Ma of Univ. of California, Riverside]

Using Tau Polarization in SUSY and Higgs Particle Searches

The Supersymmetric (SUSY) extension of the Standard Model predicts SUSY partners of the SM particles along with an expanded Higgs sector containing at least three neutral and a pair of charged Higgs bosons. A promising channel for the search of these particles at the high energy colliders is a channel containing one or more tau leptons. Earlier publications from this group had showed how the tau polarization can be utilised to enhance the charged Higgs boson signal at the Tevatron and the Large Hadron Collider, which is being used now by the concerned experimental collaborations. A similar technique has been shown now to enhance the SUSY signal in the tau channel. Moreover an extension of the technique has shown how the neutral Higgs boson signal can be enhanced in their decay channel into a pair of tau leptons by looking at the correlation between their polarizations. [D.P. Roy with M. Guchait of DHEP, TIFR, and S. Moretti of CERN, Geneva]

Matter Effect on Muon Neutrinos Propagating over Long Baselines

The perturbative treatment of subdominant oscillation and the matter effect in neutrino beams/superbeams, propagating over long distances (and being used to look for CP violation), is studied for a general matter density function varying with distance. New lowest order analytic expressions are given for different flavour transition and survival probabilities in a general neutrino mixing basis and a variable earth-density profile. It is demonstrated that the matter effect in the muon neutrino (antineutrino) flavour survival probability vanishes to this order, provided the depletion, observed for atmospheric neutrinos and antineutrinos at super-Kamiokande, is strictly maximal. This result is independent of the earth's density profile and the distance between the source and the detector. The asymmetry generated by the earth-matter effect is estimated with particular density profiles and some chosen parameters for very long-baseline neutrino oscillation experiments. [Probir Roy with B. Brahmachari of SINP, Kolkata and S. Choubey of SISSA, Italy]

Higher Dimensional Models of Majorana Neutrino Mixing

There exist proposed models in which flavour diagonal light Majorana neutrinos on the 3-brane develop mixing among themselves and a light sterile species (from the zero mode) by combining with a tower of Kaluza- Klein states derived from a bulk neutrino propagating in compactified higher dimensions. Their predictions are compared with what is now known about light neutrino masses and oscillations from super-K, SNO, KamLAND and WMAP data. It is shown that such models are untenable. [Probir Roy with S. Roy of Technion, Israel and J.L. Hewett of SLAC, U.S.A]

R-Parity Violating Supersymmetry and Ultralight Gravitino Model

A model of supersymmetry with an ultralight gravitino of mass in the range of 10^{-3} eV has been investigated to explain anomalous muon- photon-missing transverse energy events observed by the CDF experiment at the Tevatron. Kinematic distributions of these events have been fitted and the consistency of these fits with data from the D0 experiment has been demonstrated. Predictions for other channels especially at RunII of the Tevatron experiment have been made. [K. Sridhar with B.C. Allanach of LAPP, Annecy and S. Lola of CERN, Geneva]

Quantum Chromodynamics

Collective Flow in Relativistic Heavy-Ion Collisions

A new method is presented, to extract anisotropic flow in heavy-ion collisions, from genuine correlations among a large number of particles. Anisotropic flow is obtained from the zeroes of a generating function of azimuthal correlations, in the complex plane, in close analogy with the theory of phase transitions by Lee and Yang. Flow is first estimated globally, i.e., integrated over the phase space covered by the detector, and then differentially, as a function of transverse momentum and rapidity for identified particles. The corresponding estimates are less biased by nonflow correlations than with any other method. The practical implementation of the method is rather straightforward. It is not necessary to construct subevents, or to subtract autocorrelations. Furthermore, it automatically takes into account most corrections due to azimuthal anisotropies in the detector acceptance. We expect this to be the most accurate method to analyze directed and elliptic flows in heavy-ion collisions. [R.S. Bhalerao with N. Borghini and J.-Y. Ollitrault of CEA, Saclay, France]