Selected Abstracts from Other Physical Review Journals

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Concepts in computation of preequilibrium neutron emission from heavy ion reactions. P. K. Sarkar, *HP Unit, Variable Energy Cyclotron Centre, 1/AF, Bidhannagar, Calcutta 700064, India;* Maitreyee Nandy *Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Calcutta 700064, India.* (Received 30 November 1999)

Integral forms of the Boltzmann-like transport equations are derived to treat neutron emissions from heavy ion collisions. The derivations are based on the probability of contribution (score) from nucleon occupied phase space bins to the double differential emission spectra. Two-body interactions among the nucleons in ''hot spot'' and ''cold spot'' regions of the composite system resulting in creation, annihilation, or energy redistribution of the colliding particles are considered. The resulting equations are solved numerically in energy-angle bins to study thermal and kinematic equilibrium of the target + projectile (^{165}Ho+^{20}Ne) excited system at different projectile energies (10 MeV/A to 30 MeV/A). [Phys. Rev. E **61**, 7161 (2000)]

Approximate mass and radius formulas for static and rotating strange stars. K. S. Cheng and T. Harko, *Department of Physics, University of Hong Kong, Pokfulam Road, Hong Kong, China.* (Received 27 March 2000; published 26 September 2000)

Using the general relativistic conditions of thermodynamic equilibrium and fitting with values obtained from numerical integration of structure equations we derive approximate mass and radius formulas for static and uniformly rotating strange stars obeying the bag model equation of state. In the static case our formulas can reproduce the values of the mass and radius of the quark star with an error smaller than 1%. The maximum mass and radius of the strange stars can be predicted by fitting only one set of static configuration data. With the use of results obtained for the static configuration and with some supplementary assumptions about the behavior of the metric tensor at the center of the star, we can predict the rotational properties of maximally rotating strange stars within an error of 3%. From the approximate formulas we can derive the ''empirical'' formula relating the maximum rotation frequency of the uniformly rotating strange stars to the mass and radius of the maximum allowable static configuration. [Phys. Rev. D **62**, 083001 (2000)]

Coherent neutrino radiation in supernovae at two loops. A. Sedrakian and A. E. L. Dieperink, *Kernfysisch Versneller Instituut, NL-9747 AA Groningen, The Netherlands.* (Received 14 February 2000; published 26 September 2000)

We develop a neutrino transport theory, in terms of the real-time nonequilibrium Green's functions, which is applicable to physical conditions arbitrary far from thermal equilibrium. We compute the coherent neutrino radiation in cores of supernovae by evaluating the two-particle–two-hole ($2p$-$2h$) polarization function with dressed propagators. The propagator dressing is carried out in the particle-particle channel to all orders in the interaction. We show that at two loops there are two distinct sources of coherence effects in the bremsstrahlung. One is the generically off-shell intermediate state propagation, which leads to the Landau-Pomeranchuk-Migdal type suppression of radiation. We extend previous perturbative results, obtained in the leading order in quasiparticle width, by deriving the exact nonperturbative expression. A new contribution due to off-shell final or initial baryon states is treated in the leading order in the quasiparticle width. The latter contribution corresponds to processes of higher order than second order in the virial expansion in the number of quasiparticles. At the $2p$-$2h$ level, the time component of the polarization tensor for the vector transitions vanishes identically in the soft neutrino approximation. Vector current thereby is conserved. The contraction of the neutral axial vector current with the tensor interaction among the baryons leads to a nonvanishing contribution to the bremsstrahlung rate. These rates are evaluated numerically for finite temperature pure neutron matter at and above the nuclear saturation density. [Phys. Rev. D **62**, 083002 (2000)]

Frame independence of exclusive amplitudes in light-front quantization. Chueng-Ryong Ji and Chad Mitchell, *Department of Physics, North Carolina State University, Raleigh, North Carolina 27695-8202.* (Received 13 March 2000; published 27 September 2000)

While the particle-number-conserving convolution formalism established in the Drell-Yan-West reference frame is frequently used to compute exclusive amplitudes in the light-front quantization, this formalism is limited to only those frames where the light-front helicities are not changed and the good (plus) component of the current remains unmixed. For an explicit demonstration of such criteria, we present the relations between the current matrix elements in the two typical reference frames used for calculations of the exclusive amplitudes, i.e., the Drell-Yan-West and Breit frames, and investigate both pseudoscalar and vector electromagnetic currents in detail. We find that the light-front helicities are unchanged and the good component of the current does not mix with the other components of the current under the transformation between these two frames. Thus, the pseudoscalar and vector form factors obtained by the diagonal convolution formalism in both frames must indeed be identical. However, such coincidence between the Drell-Yan-West and Breit frames does not hold in general. We give an explicit example in which the light-front helicities are changed and the plus component of the current is mixed with other components under the change of reference frame. In such a case, the relationship between the frames should be carefully analyzed before the established con-

volution formalism in the Drell-Yan-West frame is used. [Phys. Rev. D **62**, 085020 (2000)]

Diquarks in cold dense QCD with two flavors. V. A. Miransky, *Bogolyubov Institute for Theoretical Physics, 252143, Kiev, Ukraine and Department of Physics, Nagoya University, Nagoya 464-8602, Japan;* I. A. Shovkovy and L. C. R. Wijewardhana, *Physics Department, University of Cincinnati, Cincinnati, Ohio 45221-0011.* (Received 25 May 2000; published 28 September 2000)

We derive and analyze the Bethe-Salpeter equations for spin zero diquarks in the color superconducting phase of cold dense QCD with two massless flavors. The spectrum of diquarks contains an infinite number of massive excitations and five (nearly) massless pseudoscalars. The former are singlets while the latter include a doublet, an antidoublet and a singlet with respect to the unbroken $SU(2)_c$. Because of approximate parity doubling at a large chemical potential, all massive states come in pairs. The decay constants, as well as the velocities of the (nearly) massless pseudoscalars, are derived. The different role of the Meissner effect for tightly bound states and quasiclassical bound states is revealed. [Phys. Rev. D **62**, 085025 (2000)]

Increase in the primordial ^{4}He yield in the two-doublet four-neutrino mixing scheme. Kevork Abazajian, George M. Fuller, and Xiangdong Shi, *Department of Physics, University of California, San Diego, La Jolla, California 92093-0319.* (Received 6 August 1999; revised manuscript received 21 June 2000; published 25 September 2000)

We assess the effects on big bang nucleosynthesis (BBN) of lepton number generation in the early universe resulting from the two-doublet four-neutrino mass-mixing scheme. It has been argued that this neutrino mass-mixing arrangement gives the most viable fit to the existing data. We study full 4×4 mixing matrices and show how possible symmetries in these can affect the BBN ^{4}He abundance yields. Though there is as yet no consensus on the reliability of BBN calculations with neutrino flavor mixing, we show that, in the case where the sign of the lepton number asymmetry is unpredictable, BBN considerations may pick out specific relationships between mixing angles. In particular, reconciling the observed light element abundances with a $\overline{\nu}_\mu \rightleftharpoons \overline{\nu}_e$ oscillation interpretation of LSND would allow unique new constraints on the neutrino mixing angles in this model. [Phys. Rev. D **62**, 093003 (2000)]

SNO: Predictions for ten measurable quantities. John N. Bahcall, *School of Natural Sciences, Institute for Advanced Study, Princeton, New Jersey 08540;* Plamen I. Krastev, *Department of Physics, University of Wisconsin, Madison, Wisconsin 53706;* Alexei Yu. Smirnov, *International Center for Theoretical Physics, 34100 Trieste, Italy.* (Received 6 March 2000; published 28 September 2000)

We calculate the range of predicted values for 10 quantities that will be measured by the Sudbury Neutrino Observatory (SNO). We use neutrino oscillation solutions (vacuum and MSW; active and sterile neutrinos) that are globally consistent with all available neutrino data and estimate realistic theoretical and experimental uncertainties. The neutral current to charged current double ratio is predicted to be more than 9σ from the no-oscillation solution for all of the currently favored neutrino oscillation solutions. The best-fit oscillation solutions predict a CC day-night rate difference between -0.1% and $+12.5\%$ and a NC day-night difference $<0.01\%$. We present also the predicted range for the first and the second moments of the charged current electron recoil energy spectrum, the charged current, the neutral current, and the ν-e scattering rates, the seasonal dependence of the charged current rate, and the double ratio of neutrino-electron scattering rate to charged current rate. [Phys. Rev. D **62**, 093004 (2000)]

Day-night effect predictions for the SNO detector. M. Maris, *Osservatorio Astronomico di Trieste, I-34131 Trieste, Italy;* S. T. Petcov, *Scuola Internazionale Superiore di Studi Avanzati, I-34014 Trieste, Italyand Istituto Nazionale di Fizica Nucleare, Sezione di Trieste, I-34014 Trieste, Italy.* (Received 27 March 2000; published 3 October 2000)

Detailed predictions for the day-night (D-N) asymmetry in the energy-integrated one year signals in the Sudbury Neutrino Observatory (SNO) detector in the case of the Mikheyev-Smirnov-Wolfenstein (MSW) $\nu_e \rightarrow \nu_{\mu(\tau)}$ and/or $\nu_e \rightarrow \nu_s$ transition solutions of the solar neutrino problem are presented. The asymmetries in the charged current (CC) and $\nu - e^-$ elastic-scattering (ES) event rates are calculated for both MSW solutions; in the case of the $\nu_e \rightarrow \nu_s$ transition solution the D-N asymmetry in the neutral current (NC) event rate are derived as well. The asymmetries are calculated for three night samples of events which are produced by the solar neutrinos crossing (i) the Earth's mantle only (*Mantle*), (ii) the Earth's core (*Core*) and (iii) the Earth's core and/or the mantle (*Night*). The effects of the uncertainties (i) in the values of the cross sections of the CC and NC neutrino-induced reactions on deuterium, and (ii) in the value of the bulk matter density and/or the chemical composition of the Earth's core, on the corresponding D-N asymmetry predictions are analyzed. It is shown, in particular, that due to the strong enhancement of the transitions of the solar neutrinos crossing the Earth's core, at $\sin^2 2\theta_V \leqslant 0.01$, the corresponding one year average D-N asymmetry in the *Core* sample of CC events in the case of the $\nu_e \rightarrow \nu_{\mu(\tau)}$ solution can be larger by a factor of up to ~ 8 than the asymmetry in the *Night* sample. In certain subregions of the MSW solution regions at small $\sin^2 2\theta_V$, the predicted magnitude of the *Core* D-N asymmetry in the CC sample is very sensitive to the value of the electron fraction number in the Earth's core. Iso-(D-N) asymmetry contours in the $\Delta m^2 - \sin^2 2\theta_V$ plane for the SNO detector are derived in the region $\sin^2 2\theta_V \gtrsim 10^{-4}$ for the *Core* and *Night* samples of the CC, ES, and NC events. The dependence of the D-N asymmetries considered on the final-state e^- threshold energy in the CC and ES reactions is also investigated. Our results show, in particular, that the SNO experiment will be able to probe a substantial part of the small mixing angle and most of the large mixing angle MSW $\nu_e \rightarrow \nu_{\mu(\tau)}$ solution regions by performing *Night* and *Core* D-N asymmetry measurements. [Phys. Rev. D **62**, 093006 (2000)]

Tritium beta decay, neutrino mass matrices, and interactions beyond the standard model. G. J. Stephenson, Jr., *University of New Mexico, Albuquerque, New Mexico 87131;* T. Goldman, *Los Alamos National Laboratory, Los Alamos, New Mexico 87545;* B. H. J. McKellar, *University of Melbourne, Parkville, Victoria 3052, Australia.* (Received 27 June 2000; published 5 October 2000)

The interference of charge changing interactions, weaker than the $V-A$ standard model (SM) interaction and having a different Lorentz structure, with that SM interaction, can, in principle, produce effects near the end point of the tritium beta decay spectrum which are of a different character from those produced by the purely kinematic effect of neutrino mass expected in the simplest extension of the SM. We show that the existence of more than one mass eigenstate can lead to interference effects at the end point that are stronger than those occurring over the entire spectrum. We discuss these effects both for the special case of Dirac neutrinos and the more general case of Majorana neutrinos and show that, for the present precision of the experiments, one formula should suffice to express the interference effects in all cases. Implications for ''sterile'' neutrinos are noted. [Phys. Rev. D **62**, 093013 (2000)]

Neutrinos from stellar collapse: Comparison of the effects of three and four flavor mixings. Gautam Dutta, D. Indumathi, M. V. N. Murthy, and G. Rajasekaran, *The Institute of Mathematical Sciences, Chennai 600 113, India.* (Received 19 June 2000; published 6 October 2000)

We study the effect of non-vanishing masses and mixings among neutrino flavors on the detection of neutrinos from stellar collapse by a water Cherenkov detector. We consider a framework in which there are four neutrino flavors, including a sterile neutrino, whose mass squared differences and mixings are constrained by the present understanding of solar, atmospheric and laboratory neutrino detection. We also include the effects of high density matter within the supernova core. Unlike in the three flavor scenario, we find that the number of events due to the dominant process involving electron-antineutrinos changes dramatically for some allowed mixing parameters. Furthermore, contributions from charged-current scattering off oxygen nuclei in the detector can be considerably enhanced due to flavor mixing. We also present a comparison between the two possible scenarios, namely, when only three active neutrino flavors are present and when they are accompanied by a fourth sterile neutrino. [Phys. Rev. D **62**, 093014 (2000)]

High energy neutrinos from gamma ray bursts: Event rates in neutrino telescopes. J. Alvarez-Muñiz, F. Halzen, and D. W. Hooper, *Department of Physics, University of Wisconsin, Madison, Wisconsin 53706.* (Received 2 June 2000; published 10 October 2000)

Following Waxman and Bahcall we calculate the event rate, energy and zenith angle dependence of neutrinos produced in the fireball model of gamma ray bursts (GRB). We emphasize the primary importance of (i) burst-to-burst fluctuations and (ii) absorption of the neutrinos in the Earth. From the astronomical point of view, we draw attention to the sensitivity of neutrino measurements to the boost Lorentz factor of the fireball Γ, which is central to the fireball model, and only indirectly determined by follow-up observations. Fluctuations result in single bursts emitting multiple neutrinos, making it possible to determine the flavor composition of a beam observed after a baseline of thousands of megaparsecs. [Phys. Rev. D **62**, 093015 (2000)]

Boltzmann equations for neutrinos with flavor mixings. Shoichi Yamada, *Research Center for the Early Universe (RESCEU), School of Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan.* (Received 27 December 1999; published 12 October 2000)

With a view of applications to the simulations of supernova explosions and protoneutron star cooling, we derive the Boltzmann equations for the neutrino transport with flavor mixing based on the real time formalism of the nonequilibrium field theory and the gradient expansion of the Green function. The relativistic kinematics is properly taken into account. The advection terms are derived in the mean field approximation for the neutrino self-energy while the collision terms are obtained in the Born approximation. The resulting equations take the familiar form of the Boltzmann equation with corrections due to mixing both in the advection part and in the collision part. These corrections are essentially the same as those derived by Sirera *et al.* for the advection terms and those by Raffelt *et al.* for the collision terms, respectively, though the formalism employed here is different from theirs. The derived equations will be easily implemented in numerical codes employed in the simulations of supernova explosions and protoneutron star cooling. [Phys. Rev. D **62**, 093026 (2000)]

Polarization of prompt J/ψ at the Fermilab Tevatron. Eric Braaten, *Physics Department, Ohio State University, Columbus, Ohio 43210;* Bernd A. Kniehl and Jungil Lee, *II. Institut für Theoretische Physik, Universität Hamburg, 22761 Hamburg, Germany.* (Received 22 November 1999; published 25 September 2000)

The polarization of prompt J/ψ at the Fermilab Tevatron is calculated within the nonrelativistic QCD factorization framework. The contribution from radiative decays of P-wave charmonium states decreases, but does not eliminate, the transverse polarization at large transverse momentum. The angular distribution parameter α for leptonic decays of the J/ψ is predicted to increase from near 0 at $p_T=5$ GeV to about 0.5 at $p_T=20$ GeV. The prediction is consistent with measurements by the CDF Collaboration at intermediate values of p_T, but disagrees by about 3 standard deviations at the largest values of p_T measured. [Phys. Rev. D **62**, 094005 (2000)]

Quark hadron continuity in QCD with one flavor. Thomas Schäfer, *Department of Physics, SUNY Stony Brook, Stony Brook, New York 11794 and Riken-BNL Research Center, Brookhaven National Laboratory, Upton, New York 11973.* (Received 12 June 2000; published 28 September 2000)

We study QCD with one flavor at finite baryon density. In the limit of very high baryon density the system is expected to be a color superconductor. In the case of one flavor, the order parameter is in a $\bar{3}$ of color and has a total angular momentum of 1. We show that, in weak coupling perturbation theory, the energetically preferred phase exhibits ''color-spin locking''; i.e., the color and spin direction of the condensate are aligned. We discuss the properties of this phase and argue that it shares important features of the hadronic phase at low density. In particular, we find an unbroken rotational symmetry, spin-3/2 quasiparticles, and an unusual mechanism for quark-antiquark condensation. Our results are relevant to three flavor QCD in the regime where the strange quark mass is bigger than the critical value for color-flavor locking. We find that the gaps in this case are on the order of 1 MeV. [Phys. Rev. D **62**, 094007 (2000)]

Critical coupling for chiral symmetry breaking in QCD motivated models. A. C. Aguilar, A. A. Natale, and R. Rosenfeld, *Instituto de Física Teórica, Universidade Estadual Paulista, Rua Pamplona 145, 01405-900, São Paulo, SP, Brazil.* (Received 21 January 2000; revised manuscript received 8 June 2000; published 3 October 2000)

We determine the critical coupling constant above which dynamical chiral symmetry breaking occurs in a class of QCD motivated models where the gluon propagator has an enhanced infrared behavior. Using methods of bifurcation theory we find that the critical value of the coupling constant is always smaller than the one obtained for QCD. [Phys. Rev. D **62**, 094014 (2000)]

Quark-antiquark potential in the analytic approach to QCD. A. V. Nesterenko, *Physical Department, Moscow State University, Moscow, 119899, Russia.* (Received 16 December 1999; published 12 October 2000)

The quark-antiquark potential is constructed by making use of a new analytic running coupling in QCD. This running coupling arises under ''analytization'' of the renormalization group equation. The rising behavior of the quark-antiquark potential at large distances, which provides the quark confinement, is shown explicitly. At small distances, the standard behavior of this potential originating in the QCD asymptotic freedom is revealed. The higher loop corrections and the scheme dependence of the approach are briefly discussed. [Phys. Rev. D **62**, 094028 (2000)]

Temperature dependence of instantons in QCD. M.-C. Chu,[1] S. M. Ouellette,[2] S. Schramm,[3] and R. Seki,[4,5] [1]*Department of Physics and the Institute of Mathematical Sciences, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong* [2]*Lauritsen Laboratory, Caltech 452-48, Pasadena, California 91125* [3]*GSI, Darmstadt, Germany* [4]*W. K. Kellogg Radiation Laboratory, Caltech 106-38, Pasadena, California 91125* [5]*Department of Physics California State University, Northbridge, California 91330.* (Received 15 June 1999; published 12 October 2000)

We investigate the temperature dependence of the instanton content of gluon fields, using unquenched lattice QCD and the cooling method. The topological susceptibility arising from instantons decreases rapidly below the phase-transition temperature T_c ($\approx$150 MeV), becoming practically zero at $T \approx T_c$. The dominant caloron size parameter deduced from the correlation function decreases from about 0.9 fm below T_c to 0.4 fm at $1.3T_c$. The instanton charge distribution is Poissonian above T_c with deviations at low temperature. [Phys. Rev. D **62**, 094508 (2000)]

Neutrino propagation in color superconducting quark matter. Gregory W. Carter, *Department of Physics and Astronomy, SUNY Stony Brook, Stony Brook, New York 11794-3800;* Sanjay Reddy, *Institute For Nuclear Theory, University of Washington, Seattle, Washington 98195.* (Received 24 May 2000; published 6 October 2000)

We calculate the neutrino mean free path in color superconducting quark matter, and employ it to study the cooling of matter via neutrino diffusion in the superconducting phase as compared to a free quark phase. The cooling process slows when quark matter undergoes a second order phase transition to a superconducting phase at the critical temperature T_c. Cooling subsequently accelerates as the temperature decreases below T_c. This will directly impact the early evolution of a newly born neutron star, should its core contain quark matter. Consequently, there may be observable changes in the early neutrino emission which would provide evidence for superconductivity in hot and dense matter. [Phys. Rev. D **62**, 103002 (2000)]