Selected Abstracts from Physical Review D

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Chaotic amplification of neutrino chemical potentials by neutrino oscillations in big bang nucleosynthesis. Xiangdong Shi, *Department of Physics, Queen's University, Kingston, Ontario, Canada K7L 3N6.* (Received 1 March 1996)

We investigate in detail the parameter space of active-sterile neutrino oscillations that amplifies neutrino chemical potentials at the epoch of big bang nucleosynthesis. We calculate the magnitude of the amplification and show evidence of chaos in the amplification process. We also discuss the implications of the neutrino chemical potential amplification in big bang nucleosynthesis. It is shown that with a ~ 1 eV ν_e, the amplification of its chemical potential by active-sterile neutrino oscillations can lower the effective number of neutrino species at big bang nucleosynthesis to significantly below three. [S0556-2821(96)05616-0] [Phys. Rev. D **54**, 2753 (1996)]

Three-flavor gravitationally induced neutrino oscillations and the solar neutrino problem. J. R. Mureika and R. B. Mann, *Department of Physics, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1.* (Received 20 March 1996)

Some implications of the proposal that flavor nondiagonal couplings of neutrinos to gravity might resolve the solar neutrino problem are considered in the context of three neutrino flavors. The two-flavor model is discussed as a limiting case of the full three-generation mechanism, and the behavior of the ν_e survival probability for various values of the three-flavor parameters is studied. Overlapping allowed SNU regions are obtained for the neutrinos which most likely contribute to the observed solar neutrino deficiency, and the effects of the addition of a third flavor are discussed. The extension to a three-generation framework is found to yield a greater allowed region of parameter space, suggesting that gravitationally induced neutrino oscillations remain a viable explanation of the solar neutrino problem. [S0556-2821(96)02916-5] [Phys. Rev. D **54**, 2761 (1996)]

Supernova neutrino scattering rates reduced by nucleon spin fluctuations: Perturbative limit. Georg Raffelt, *Max-Planck-Institut für Physik, Föhringer Ring 6, 80805 München, Germany* David Seckel *Bartol Research Institute, University of Delaware, Newark, Delaware 19716* Günter Sigl *Department of Astronomy and Astrophysics, The University of Chicago, Chicago, Illinois 60637-1433 and NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500.* (Received 4 December 1995; revised manuscript received 5 March 1996)

In a nuclear medium, spin-dependent forces cause the nucleon spins to fluctuate with a rate Γ_σ. We have previously shown that as a consequence the effective axial-vector current neutrino-nucleon scattering cross section is reduced. Here, we calculate this reduction explicitly in the perturbative limit $\Gamma_\sigma \ll T$. By virtue of an exact sum rule of the spin-density structure function, we express the modified cross section in terms of the matrix element for neutrino-nucleon scattering in the presence of a spin-dependent nuclear potential. This representation allows for a direct comparison with, and confirmation of, Sawyer's related perturbative result. In a supernova core with a typical temperature $T = 10$ MeV, the perturbative limit is relevant for densities $\rho \lesssim 10^{13}$ g cm^{-3} and thus applies around the neutrino sphere. There, the cross-section reduction is of order a few percent and thus not large; however, a new mode of energy transfer between neutrinos and nucleons is enabled which may be important for neutrino spectra formation. We derive an analytic perturbative expression for the rate of energy transfer. [S0556-2821(96)00216-0] [Phys. Rev. D **54**, 2784 (1996)]

Proton and deuteron structure functions in muon scattering at 470 GeV. M. R. Adams,[6] S. Aïd,[10] P. L. Anthony,[9] D. A. Averill,[6] M. D. Baker,[11] B. R. Baller,[4] A. Banerjee,[15] A. A. Bhatti,[16] U. Bratzler,[16] H. M. Braun,[17] T. J. Carroll,[12] H. L. Clark,[14] J. M. Conrad,[5] R. Davisson,[16] I. Derado,[12] F. S. Dietrich,[9] W. Dougherty,[16] T. Dreyer,[1] V. Eckardt,[12] U. Ecker,[17] M. Erdmann,[1] G. Y. Fang,[5] J. Figiel,[8] R. W. Finlay,[14] H. J. Gebauer,[12] D. F. Geesaman,[2] K. A. Griffioen,[15] R. S. Guo,[6] J. Haas,[1] C. Halliwell,[6] D. Hantke,[12] K. H. Hicks,[14] H. E. Jackson,[2] D. E. Jaffe,[6] G. Jancso,[7] D.M. Jansen,[16] Z. Jin,[16] S. Kaufman,[2] R. D. Kennedy,[3] E. R. Kinney,[2] H. G. E. Kobrak,[3] A. V. Kotwal,[5] S. Kunori,[10] J. J. Lord,[16] H. J. Lubatti,[16] D. McLeod,[6] P. Madden,[3] S. Magill,[6] A. Manz,[12] H. Melanson,[4] D. G. Michael,[5] H. E. Montgomery,[4] J. G. Morfin,[4] R. B. Nickerson,[5] J. Novak,[13] S. O'Day,[10] K. Olkiewicz,[8] L. Osborne,[11] R. Otten,[17] V. Papavassiliou,[2] B. Pawlik,[8] F. M. Pipkin,[5] D. H. Potterveld,[2] E. J. Ramberg,[10] A. Röser,[17] J. J. Ryan,[11] C. W. Salgado,[4] A. Salvarani,[3] H. Schellman,[13] M. Schmitt,[5] N. Schmitz,[12] G. Siegert,[1] A. Skuja,[10] G. A. Snow,[10] S. Söldner-Rembold,[12] P. Spentzouris,[13] H. E. Stier,[1] P. Stopa,[8] R. A. Swanson,[3] H. Venkataramania,[13] M. Wilhelm,[1] Richard Wilson,[5] W. Wittek,[12] S. A. Wolbers,[4] A. Zghiche,[2] and T. Zhao[16] (Fermilab E665 Collaboration), [1]*Albert-Ludwigs-Universität Freiburg, D-79104, Freiburg, Germany* [2]*Argonne National Laboratory, Argonne, Illinois 60439* [3]*University of California, San Diego, California 92093* [4]*Fermi National Accelerator Laboratory, Batavia, Illinois 60510* [5]*Harvard University, Cambridge, Massachusetts 02138* [6]*University of Illinois, Chicago, Illinois 60680* [7]*KFKI Research Institute for Particle and Nuclear Physics of the Hungarian*

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The proton and deuteron structure functions F_2^p and F_2^d are measured in inelastic muon scattering with an average beam energy of 470 GeV. The data were taken at Fermilab experiment E665 during 1991 and 1992 using liquid hydrogen and deuterium targets. The F_2 measurements are reported in the range $0.0008<x<0.6$ and $0.2<Q^2<75$ GeV^2. These are the first precise measurements of F_2 in the low x and Q^2 range of the data. In the high x range of the data where they overlap in x and Q^2 with the measurements from NMC, the two measurements are in agreement. The E665 data also overlap in x with the DESY HERA data, and there is a smooth connection in Q^2 between the two data sets. At high Q^2 the E665 measurements are consistent with QCD-evolved leading twist structure function models. The data are qualitatively described by structure function models incorporating the hadronic nature of the photon at low Q^2. The Q^2 and the W dependence of the data measure the transition in the nature of the photon between a pointlike probe at high Q^2 and a hadronic object at low Q^2. [S0556-2821(96)05517-8] [Phys. Rev. D **54**, 3006 (1996)]

Cut diagrams for high energy scatterings. Y. J. Feng, O. Hamidi-Ravari, and C. S. Lam, *Department of Physics, McGill University, 3600 University St., Montreal, P.Q., Canada H3A 2T8.* (Received 26 April 1996)

A new approach is introduced to study QCD amplitudes at high energy and comparatively small momentum transfer. Novel cut diagrams, representing the resummation of Feynman diagrams, are used to simplify the calculation and to avoid delicate cancellations encountered in the usual approach. An explicit calculation to the sixth order is carried out to demonstrate the advantage of cut diagrams over Feynman diagrams. [S0556-2821(96)02417-4] [Phys. Rev. D **54**, 3114 (1996)]

Photon production from a quark-gluon plasma. E. Quack, *Theory Group, Stanford Linear Accelerator Center, Stanford University, P.O. Box 4349, Stanford, California 94309;* P. A. Henning, *Theoretical Physics, Gesellschaft für Schwerionenforschung (GSI), P.O. Box 110552, D-64220 Darmstadt, Germany.* (Received 1 August 1995)

In-medium interactions of a particle in a hot plasma are considered in the framework of thermal field theory. The formalism to calculate gauge-invariant rates for photon and dilepton production from the medium is given. In the application to a QED plasma, astrophysical consequences are pointed out. The photon production rate from strongly interacting quarks in the quark-gluon plasma, which might be formed in ultrarelativistic heavy ion collisions, is calculated in the previously unaccessible regime of photon energies of the order of the plasma temperature. For temperatures below the chiral phase transition, an effective field theory incorporating dynamical chiral symmetry breaking is employed, and perturbative QCD at higher temperatures. A smooth transition between both regions is obtained. The relevance to the soft photon problem and to high energy heavy ion experiments is discussed. [S0556-2821(96)06017-1] [Phys. Rev. D **54**, 3125 (1996)]

Probing charge-symmetry-violating quark distributions in semi-inclusive leptoproduction of hadrons. J. T. Londergan and Alex Pang, *Department of Physics and Nuclear Theory Center, Indiana University, Bloomington, Indiana 47404;* A. W. Thomas, *Department of Physics and Mathematical Physics and Institute for Theoretical Physics, University of Adelaide, Adelaide, South Australia, 5005, Australia.* (Received 3 May 1996)

Recent experiments by the HERMES group at DESY HERA are measuring semi-inclusive electroproduction of pions from deuterium. We point out that by comparing the production of π^+ and π^- from an isoscalar target, it is possible, in principle, to measure charge symmetry violation in the valence quark distributions of the nucleons. It is also possible in the same experiments to obtain an independent measurement of the quark fragmentation functions. We review the information which can be deduced from such experiments and show the ''signature'' for charge symmetry violation in such experiments. Finally, we predict the magnitude of the charge symmetry violation, from both the valence quark distributions and the pion fragmentation function, which might be expected in these experiments. [S0556-2821(96)05917-6] [Phys. Rev. D **54**, 3154 (1996)]

Hard diffractive electroproduction of vector mesons in QCD. Leonid Frankfurt and Werner Koepf, *School of Physics and Astronomy, Raymond and Beverly Sackler Faculty of Exact Sciences, Tel Aviv University, Tel Aviv, Israel;* Mark Strikman, *Pennsylvania State University, University Park, Pennsylvania.* (Received 25 September 1995; revised manuscript received 9 February 1996)

Hard diffractive electroproduction of longitudinally polarized vector mesons is calculated within the leading $\alpha_s \ln(Q^2/\Lambda^2_{\rm QCD})$ approximation of QCD using the leading order parton densities within the nucleon. Novel QCD features of the production of excited states and of the restoration of flavor symmetry are analyzed. At the onset of the asymptotic regime, our analysis finds an important role of quark Fermi motion within the diffractively produced vector mesons, and we suggest to use this effect to measure the high momentum tail of the wave function of the vector mesons. We deduce a kinematical boundary for the region of applicability of the decomposition of the hard amplitudes over powers of Q^2 and/or a limit on the increase of the cross sections of hard processes at small x, and briefly analyze its consequences. We also estimate the nuclear attenuation of the diffractive electroproduction of vector mesons and compare with estimates of the shadowing of the longitudinal structure function. [S0556-2821(96)04513-4] [Phys. Rev. D **54**, 3194 (1996)]

Finite-size effects in multiquark droplets: An anatomical study. V. S. Uma Maheswari, *Variable Energy Cyclotron Centre, 1/AF Bidhan Nagar, Calcutta 700 064, India.* (Received 24 January 1996)

Strutinsky's averaging (SA) method is applied to multiquark droplets to systematically extract the smooth part of the exact quantal energy and thereby the shell correction energies. It is shown within the bag model that the semiphenomenological density of states expression given up to curvature order is almost equivalent to the SA method. A comparative study of the bag model and the relativistic harmonic oscillator potential for quarks is done to investigate the quark mass dependence of the finite-size effects. It is found that there is an important difference between these two cases, which may be related to the presence or nonpresence of the net spin-orbit effect. [S0556-2821(96)00115-4] [Phys. Rev. D **54**, 3389 (1996)]

Effects of symmetry breaking on the strong and electroweak interactions of the vector nonet. Masayasu Harada and Joseph Schechter, *Department of Physics, Syracuse University, Syracuse, New York 13244-1130.* (Received 30 June 1995)

Starting from a chiral-invariant and quark-line-rule-conserving Lagrangian of pseudoscalar and vector nonets we introduce first- and second-order symmetry breaking as well as quark-line-rule-violating terms and fit the parameters, at the tree level, to many strong and electroweak processes. A number of predictions are made. The electroweak interactions are included in a manifestly gauge-invariant manner. The resulting symmetry-breaking pattern is discussed in detail. Specifically, for the ''strong'' interactions, we study all the vector meson masses and $V\rightarrow\phi\phi$ decays, including isotopic spin violations. In the electroweak sector we study the $\{\rho^0,\omega,\phi\}\rightarrow e^+e^-$ decays, $\{\pi^+,K^+,K^0\}$ ''charge radii,'' K_{l3} ''slope factor,'' and the overall $e^+e^-\rightarrow\pi^+\pi^-$ process. It is hoped that the resulting model may be useful as a reasonable description of low energy physics in the range up to about 1 GeV. [S0556-2821(96)02117-0] [Phys. Rev. D **54**, 3394 (1996)]

Real oscillations of virtual neutrinos. W. Grimus and P. Stockinger, *Institut für Theoretische Physik, Universität Wien, Boltzmanngasse 5, A-1090 Vienna, Austria.* (Received 26 March 1996)

We study the conditions for neutrino oscillations in a field-theoretical approach by taking into account that only the neutrino production and detection processes, which are localized in space around the coordinates $\vec{x}_P$ and $\vec{x}_D$, respectively, can be manipulated. In this sense the neutrinos whose oscillations are investigated appear as virtual lines connecting production with detection in the total Feynman graph and all neutrino fields or states to be found in the discussion are mass eigenfields or eigenstates. We perform a thorough examination of the integral over the spatial components of the inner neutrino momentum and show that in the asymptotic limit $L=|\vec{x}_D-\vec{x}_P|\rightarrow\infty$ the virtual neutrinos become ''real'' and under certain conditions the usual picture of neutrino oscillations emerges without ambiguities. [S0556-2821(96)02517-9] [Phys. Rev. D **54**, 3414 (1996)]

Temperature and baryon-chemical-potential-dependent bag pressure for a deconfining phase transition. B. K. Patra and C. P. Singh, *Department of Physics, Banaras Hindu University, Varanasi-221005, India.* (Received 24 October 1995; revised manuscript received 6 May 1996)

We explore the consequences of a bag model developed by Leonidov *et al.* for the deconfining phase transition in which the bag pressure is made to depend on the temperature and baryon chemical potential in order to ensure the entropy and baryon number conservation at the phase boundary together with the Gibbs construction for an equilibrium phase transition. We show that the bag pressure thus obtained yields an anomalous increasing behavior with the increasing baryon chemical potential at a fixed temperature which defies a physical interpretation. We demonstrate that the inclusion of the perturbative interactions in the QGP phase removes this difficulty. Further consequences of the modified bag pressure are discussed. [S0556-2821(96)04917-X] [Phys. Rev. D **54**, 3551 (1996)]

Analytic study of disoriented chiral condensates. Mahiko Suzuki, *Department of Physics and Lawrence Berkeley National Laboratory, University of California, Berkeley, California 94720.* (Received 2 April 1996)

By introducing a quark source in the nonlinear σ model, we obtain an analytic boost-invariant solution as a candidate for the disoriented chiral condensate (DCC) in $3+1$ dimensions. In order to trigger formation of the DCC, a strong transfer of axial isospin charge must occur between the expanding source and the interior in the baked Alaska scenario. An explicit chiral symmetry breaking is incorporated in the solution by connecting the decay period to the formation period. Quantitative estimates are presented with our simple solution. At least in this class of solutions, the explicit symmetry breaking masks almost completely the disorientation which would be reached asymptotically in the symmetric limit. [S0556-2821(96)05117-X] [Phys. Rev. D **54**, 3556 (1996)]

Bounds on new Majoron models from the Heidelberg-Moscow experiment. M. Günther, J. Hellmig, G. Heusser, M. Hirsch, H. V. Klapdor-Kleingrothaus, B. Maier, H. Päs, F. Petry, Y. Ramachers, H. Strecker, and M. Völlinger, *Max-Planck-Institut für Kernphysik, P.O. Box 10 39 80, D-69029 Heidelberg, Germany;* A. Balysh, S. T. Belyaev, A. Demehin, A. Gurov, I. Kondratenko, D. Kotel'nikov, and V. I. Lebedev, *Russian Science Center Kurchatov Institute, 123 182 Moscow, Russia;* A. Müller, *Istituto Nazionale di Fisica Nucleare, I-67010 Assergi, Italy.* (Received 13 November 1995)

In recent years several new Majoron models were invented to avoid the shortcomings of the ordinary models while leading to observable decay rates in double β experiments. We give the first experimental half-life bounds on double β decays with new Majoron emission and derive bounds on the effective neutrino-Majoron couplings from the data of the ^{76}Ge Heidelberg-Moscow experiment. While stringent half-life limits for all decay modes and the coupling constants of the ordinary models were obtained, small matrix elements and phase space integrals result in much weaker limits on the effective coupling constants of the new Majoron models. [S0556-2821(96)05217-4] [Phys. Rev. D **54**, 3641 (1996)]

Rapidity gaps and scaling in high energy interactions. Sudhir Malik, *Department of Physics and Astrophysics, University of Delhi, Delhi-110007, India.* (Received 10 January 1996)

The rapidity gap probability is investigated in varying symmetric bin sizes in proton-nucleus interactions at 800 GeV. It shows a scaling behavior and confirms the linked pair approximation for the n-particle cumulant correlation functions to high order. A comparison of the scaled rapidity gap probability is made with the negative binomial distribution. We also interpret the rapidity gap probability in the clan production model of hadronization and reanalyze the clan parameters in its light. [S0556-2821(96)03717-4] [Phys. Rev. D **54**, 3655 (1996)]