

Selected Abstracts from Physical Review D

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Resonant neutrino spin-flavor precession and supernova nucleosynthesis and dynamics. H. Nunokawa, Y.-Z. Qian, and G. M. Fuller, *Institute for Nuclear Theory, University of Washington, Box 351550, Seattle, Washington 98195*. (Received 10 October 1996)

We discuss the effects of resonant spin-flavor precession (RSFP) of Majorana neutrinos on heavy element nucleosynthesis in neutrino-heated supernova ejecta and the dynamics of supernovae. In assessing the effects of RSFP, we explicitly include matter-enhanced (MSW) resonant neutrino flavor conversion effects where appropriate. We point out that for plausible ranges of neutrino magnetic moments and protoneutron star magnetic fields, spin-flavor conversion of ν_τ (or ν_μ) with a cosmologically significant mass (1–100 eV) into a light ν_e could lead to an enhanced neutron excess in neutrino-heated supernova ejecta. This could be beneficial for models of r -process nucleosynthesis associated with late-time neutrino-heated ejecta from supernovae. Similar spin-flavor conversion of neutrinos at earlier epochs could lead to an increased shock reheating rate and, concomitantly, a larger supernova explosion energy. We show, however, that such increased neutrino heating likely will be accompanied by an enhanced neutron excess which could exacerbate the problem of the overproduction of the neutron number $N=50$ nuclei in the supernova ejecta from this stage. In all of these scenarios, the average $\bar{\nu}_e$ energy will be increased over those predicted by supernova models with no neutrino mixings. This may allow the SN 1987A data to constrain RSFP-based schemes. [S0556-2821(97)04406-8] [Phys. Rev. D 55, 3265 (1997)]

Big-bang nucleosynthesis limit to the number of neutrino species. Craig J. Copi, *Department of Physics, Enrico Fermi Institute, The University of Chicago, Chicago, Illinois 60637-1433 and NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500*; David N. Schramm and Michael S. Turner, *Department of Physics, Enrico Fermi Institute, The University of Chicago, Chicago, Illinois 60637-1433; NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500; and Department of Astronomy & Astrophysics, The University of Chicago, Chicago, Illinois 60637-1433*. (Received 10 June 1996)

Concern about the systematic uncertainty in the ^4He abundance as well as the chemical evolution of ^3He leads us to reexamine this important limit. It is shown that with conservative assumptions no more than the equivalent four massless neutrino species are allowed. Even with the most extreme estimates of the astrophysical uncertainties a meaningful limit still exists, less than five massless neutrino species, and illustrates the robustness of this argument. We show that a definitive measurement of the deuterium abundance in high-redshift hydrogen clouds can sharpen the limit. [S0556-2821(97)07604-2] [Phys. Rev. D 55, 3389 (1997)]

New QCD sum rules for nucleon axial-vector coupling constants. Frank X. Lee, *TRIUMF, 4004 Wesbrook Mall Vancouver, British Columbia, Canada V6T 2A3 and Nuclear Physics Laboratory, Department of Physics, University of Colorado, Boulder, Colorado 80309-0446*; Derek B. Leinweber, *Department of Physics, University of Washington, Seattle, Washington 98195*; Xuemin Jin, *TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia, Canada V6T 2A3 and Center for Theoretical Physics, Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139*. (Received 4 November 1996)

Two new sets of QCD sum rules for the nucleon axial-vector coupling constants are derived using the external-field technique and generalized interpolating fields. An in-depth study of the predictive ability of these sum rules is carried out using a Monte Carlo-based uncertainty analysis. The results show that the standard implementation of the QCD sum rule method has only marginal predictive power for the nucleon axial-vector coupling constants, as the relative errors are large. The errors range from approximately 50% to 100% compared to the nucleon mass obtained from the same method, which has only a 10%–25% error. The origin of the large errors is examined. Previous analyses of these coupling constants are based on sum rules that have poor operator product expansion convergence and large continuum contributions. Preferred sum rules are identified and their predictions are obtained. We also investigate the new sum rules with an alternative treatment of the problematic transitions which are not exponentially suppressed in the standard treatment. The alternative treatment provides exponential suppression of their contributions relative to the ground state. Implications for other nucleon current matrix elements are also discussed. [S0556-2821(97)04207-0] [Phys. Rev. D 55, 4066 (1997)]

Strong $U_A(1)$ breaking in radiative η decays and baryon systems. M. Takizawa, *Institute for Nuclear Study, University of Tokyo, Tanashi, Tokyo 188, Japan*; Y. Nemoto and M. Oka, *Department of Physics, Tokyo Institute of Technology, Meguro, Tokyo 152, Japan*. (Received 20 August 1996; revised manuscript received 15 November 1996)

We study the $\eta \rightarrow \gamma\gamma$, $\eta \rightarrow \gamma\mu^-\mu^+$, and $\eta \rightarrow \pi^0\gamma\gamma$ decays using an extended three-flavor Nambu–Jona-Lasinio model that includes the 't Hooft instanton induced interaction. We find that the η -meson mass, the $\eta \rightarrow \gamma\gamma$, $\eta \rightarrow \gamma\mu^-\mu^+$, and $\eta \rightarrow \pi^0\gamma\gamma$ decay widths are in good agreement with the experimental values when the $U_A(1)$ breaking is strong and the flavor SU(3) singlet-octet mixing angle θ is about zero. The calculated $\eta\gamma\gamma^*$ transition form factor has a somewhat weaker dependence on the squared four-momentum of the virtual photon. The effects of the $U_A(1)$ anomaly on the scalar quark contents in the nucleon, the $\Sigma_{\pi N}$ and Σ_{KN} terms, and the

baryon number one and two systems are also studied. [S0556-2821(97)02607-6] [Phys. Rev. D 55, 4083 (1997)]

Relativistic corrections to the polarized structure functions in the resonance region. Dong Yu-bing, *Faculty of Human Development, Kobe University, Kobe 657, Japan and Institute of High Energy Physics, Academia Sinica, Beijing 100039, People's Republic of China*; T. Morii, *Faculty of Human Development, Kobe University, Kobe 657, Japan*; T. Yamanishi, *Research Center for Nuclear Physics, Osaka University, Ibaraki, Osaka 567, Japan*. (Received 13 August 1996; revised manuscript received 2 December 1996)

Based on the relativistic harmonic oscillator model, the polarized structure functions of $\Gamma_1(Q^2)$ and $\Gamma_2(Q^2)$ are calculated in the resonance region. The relativistic effects on the transition amplitudes and the structure functions are addressed. [S0556-2821(97)04107-6] [Phys. Rev. D 55, 4141 (1997)]

Decay constants of pseudoscalar mesons in a relativistic quark model. L. Micu, *Department of Theoretical Physics, Institute of Physics and Nuclear Engineering, Institute of Atomic Physics, P.O. Box MG-6, 76900 Romania*. (Received 19 August 1996)

The decay constants of pseudoscalar mesons are calculated in a relativistic quark model which assumes that mesons are made of a valence quark-antiquark pair and of an effective vacuumlike component. The results are given as functions of quark masses and of some free parameters entering the expression of the internal wave functions of the mesons. Using $F_{\pi^+} = 130.7$ MeV, $F_{K^+} = 159.8$ MeV to fix the parameters of the model, we predict $60 \text{ MeV} \leq F_{D^+} \leq 185 \text{ MeV}$, $95 \text{ MeV} \leq F_{D_s} \leq 230 \text{ MeV}$, $80 \text{ MeV} \leq F_{B^+} \leq 205 \text{ MeV}$, $90 \text{ MeV} \leq F_{B_s} \leq 235 \text{ MeV}$ for the light quark masses $m_u = 5.1$ MeV, $m_d = 9.3$ MeV, $m_s = 175$ MeV and the heavy quark masses in the range $1 \text{ GeV} \leq m_c \leq 1.6 \text{ GeV}$, $4.1 \text{ GeV} \leq m_b \leq 4.5 \text{ GeV}$. In the case of light neutral mesons one obtains with the same set of parameters $F_{\pi^0} \approx 138$ MeV, $F_\eta \approx 130$ MeV, $F_{\eta'} \approx 78$ MeV. The values are in agreement with the experimental data and other theoretical results. [S0556-2821(97)07005-7] [Phys. Rev. D 55, 4151 (1997)]

0^{++} glueball mass. Stuart Samuel, *Department of Physics, City College of New York, New York, New York 10031*. (Received 7 October 1996)

An approximate vacuum wave functional Ψ_0 is proposed for (2 + 1)-dimensional Yang-Mills theories. Using Ψ_0 , one can compute the 0^{++} glueball mass M_G in terms of the string tension. By using the idea of dimensional reduction, a prediction for M_G can be made in 3+1 dimensions. One finds $M_G \approx 1.5 \text{ GeV}$. [S0556-2821(97)02107-3] [Phys. Rev. D 55, 4189 (1997)]

QCD description of diffractive ρ meson electroproduction. A. D. Martin, M. G. Ryskin, and T. Teubner, *Department of Physics, University of Durham, Durham, DH1 3LE, United Kingdom*. (Received 24 September 1996)

We critically review the QCD predictions for the cross sections σ_L and σ_T for diffractive ρ meson electroproduction in longitudinally and transversely polarized states in the DESY HERA energy region. We show that both perturbative and nonperturbative approaches, which involve convolution with the ρ meson wave function, predict values of σ_T which fall off too quickly with increasing Q^2 , in comparison with the data. We present a perturbative QCD model based on the open production of light $q\bar{q}$ pairs and parton-hadron duality, which describes all features of the data for ρ electroproduction at high Q^2 and, in particular, predicts a satisfactory Q^2 behavior of σ_L/σ_T . We find that precise measurements of the latter can give valuable information on the Q^2 behavior of the gluon distribution at small x . [S0556-2821(97)00807-2] [Phys. Rev. D 55, 4329 (1997)]

Thermal dileptons from π - ρ interactions in a hot pion gas. R. Baier and M. Dirks, *Fakultät für Physik, Universität Bielefeld, D-33501 Bielefeld, Germany*; K. Redlich, *Institute for Theoretical Physics, University of Wrocław, PL-50204 Wrocław, Poland and GSI, PF 110552, D-64220 Darmstadt, Germany*. (Received 2 October 1996)

The production of low mass dileptons from π - ρ interactions in a hot medium is studied. Applying finite temperature perturbation theory the dilepton rate is computed up to order g_ρ^2 . For dilepton masses below the ρ the two-body reactions $\pi\pi \rightarrow \rho\gamma^*$, $\pi\rho \rightarrow \pi\gamma^*$, and the decay process $\rho \rightarrow \pi\pi\gamma^*$ give significant contributions. Nonequilibrium contributions to the thermal rate are estimated, including the modification of the particle distribution function with a nonzero pion chemical potential. A comparison of the dilepton rate with the recent data measured in nucleus-nucleus collisions at CERN SPS energy by the CERES Collaboration is also performed. It is shown that the additional thermal dileptons from π - ρ interactions can partially account for the excess of the soft dilepton yield seen experimentally. [S0556-2821(97)03107-X] [Phys. Rev. D 55, 4344 (1997)]

Relevance of nucleon spin in an amplitude analysis of reactions $\pi^- p \rightarrow \pi^0 \pi^0 n$ and $\pi^- p \rightarrow \eta \eta n$. M. Svec, *Physics Department, Dawson College, Montreal, Quebec, Canada H3Z 1A 4 and McGill University, Montreal, Quebec, Canada H3A 2T8*. (Received 15 August 1996)

The measurements of reactions $\pi^- p \rightarrow \pi^- \pi^+ n$ and $\pi^+ n \rightarrow \pi^+ \pi^- p$ on polarized targets at CERN found a strong dependence of pion production amplitudes on nucleon spin. Analyses of recent measurements of the $\pi^- p \rightarrow \pi^0 \pi^0 n$ reaction on unpolarized targets by the GAMS Collaboration at 38 GeV/c and the BNL E852 Collaboration at 18 GeV/c use the assumption that pion production amplitudes do not depend on nucleon spin, in conflict with the CERN results on polarized targets. We show that measurements of $\pi^- p \rightarrow \pi^0 \pi^0 n$ and $\pi^- p \rightarrow \eta \eta n$ on unpolarized targets can be analyzed in a model-independent way in terms of four partial-wave intensities and three independent interference phases in the mass region where S and D waves dominate. We also describe model-independent amplitude analysis of the $\pi^- p \rightarrow \pi^0 \pi^0 n$ reaction measured on a polarized target, both in the absence and in the presence of G -wave amplitudes. We suggest that high statistics measurements of reactions $\pi^- p \rightarrow \pi^0 \pi^0 n$ and $\pi^- p \rightarrow \eta \eta n$ be made on

polarized targets at Protvino IHEP and at BNL, and that model-independent amplitude analyses of this polarized data be performed to advance hadron spectroscopy on the level of spin-dependent production amplitudes. [S0556-2821(97)01207-1] [Phys. Rev. D **55**, 4355 (1997)]

Unified description of kaon electroweak form factors. Andrei Afanasev, *Thomas Jefferson National Accelerator Facility, 12000 Jefferson Ave., Newport News, Virginia 23606 and The NuHEP Research Center, Department of Physics, Hampton University, Hampton, Virginia 23668*; W. W. Buck, *Thomas Jefferson National Accelerator Facility, 12000 Jefferson Ave., Newport News, Virginia 23606 and Institut für Kernphysik, Universität Mainz, Germany.* (Received 13 June 1996)

A calculation of the semileptonic decays of the kaon (K_{l3}) is presented. The results are direct predictions of a covariant model of the pion and kaon introduced earlier by Ito, Buck, and Gross. The weak form factors for K_{l3} are predicted with absolutely no parameter adjustments of the model. We obtained, for the form factor parameters, $f_-(q^2=m_l^2)/f_+(q^2=m_l^2) = -0.28$ and $\lambda_+ = 0.028$, both within experimental error bars. The connections of this approach to heavy quark symmetry are discussed. [S0556-2821(97)03007-5] [Phys. Rev. D **55**, 4380 (1997)]

Three-flavor atmospheric neutrino anomaly. G. L. Fogli,² E. Lisi,^{1,2} D. Montanino,² and G. Scioscia² ¹*Institute for Advanced Study, Princeton, New Jersey 08540* ²*Dipartimento di Fisica dell'Università and Sezione INFN di Bari, 70126 Bari, Italy.* (Received 8 July 1996)

We investigate the indications of flavor oscillations that come from the anomalous flavor composition of the atmospheric neutrino flux observed in some underground experiments. We study the information coming from the neutrino-induced μ -like and e -like events both in the sub-GeV energy range (Kamiokande, IMB, Fréjus, and NUSEX experiments) and in the multi-GeV energy range (Kamiokande experiment). First we analyze all the data in the limits of pure $\nu_\mu \leftrightarrow \nu_\tau$ and $\nu_\mu \leftrightarrow \nu_e$ oscillations. We obtain that $\nu_\mu \leftrightarrow \nu_e$ oscillations provide a better fit, in particular, to the multi-GeV data. Then we perform a three-flavor analysis in the hypothesis of dominance of one neutrino square mass difference m^2 implying that the neutrino mixing is parametrized by two angles $(\psi, \phi) \in [0, \pi/2]$. We explore the space (m^2, ψ, ϕ) exhaustively, and find the regions favored by the oscillation hypothesis. The results are displayed in a form suited to the comparison with other flavor oscillation searches at accelerator, reactor, and solar ν experiments. In the analysis, we pay particular attention to the Earth matter effects, to the correlation of the uncertainties, and to the symmetry

properties of the oscillation probability. [S0556-2821(97)00407-4] [Phys. Rev. D **55**, 4385 (1997)]

How large is the ${}^7\text{Be}$ neutrino flux from the Sun? L. Wolfenstein, *Carnegie Mellon University, Pittsburgh, Pennsylvania 15213*; P. I. Krastev, *Institute for Advanced Study, Princeton, New Jersey 08540.* (Received 18 October 1996)

On the basis of present solar neutrino observations and relaxing the constraints from solar models it is possible that most (or nearly all) of the flux of electron neutrinos detected comes from electron capture in ${}^7\text{Be}$. These solutions arise from neutrino oscillations in which ν_e - ν_τ mixing suppresses high energy ν_e and ν_e - ν_μ mixing suppresses low energy ν_e as qualitatively suggested from some SO(10) grand unified models. The importance of future observations is emphasized. [S0556-2821(97)01007-2] [Phys. Rev. D **55**, 4405 (1997)]

What thermodynamics tells us about the QCD plasma. M. Asakawa, *Department of Physics, Columbia University, New York, New York 10027*; T. Hatsuda, *Institute of Physics, University of Tsukuba, Tsukuba, Ibaraki 305, Japan.* (Received 31 January 1996)

As long as a rapid change of the entropy density $s(T)$ takes place across the critical temperature T_c of the QCD phase transition, the pressure $P(T)$, and the energy density $e(T)$ normalized by their Stefan-Boltzmann values generally deviate from unity for $T \gg T_c$, even if there are no interactions among quarks and gluons at $T > T_c$. We shall demonstrate this both analytically and numerically for a general class of $s(T)$ consistent with thermodynamical constraints and make a qualitative comparison of the result with the lattice QCD data. Quantities related to $ds(T)/dT$ such as the specific heat and sound velocity are also discussed. [S0556-2821(97)02807-5] [Phys. Rev. D **55**, 4488 (1997)]

Boost-invariant quantum evolution of a meson field at large proper times. D. Vautherin, *Division de Physique Théorique, Institut de Physique Nucléaire, F-91406 Orsay Cedex, France*; T. Matsui, *Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto 606, Japan.* (Received 10 September 1996)

We construct asymptotic solutions of the functional Schrödinger equation for a scalar field in the Gaussian approximation at large proper times. These solutions describe the late proper time stages of the expansion of a meson gas with boost-invariant boundary conditions. The relevance of these solutions for the formation of a disoriented chiral condensate in ultrarelativistic collisions is discussed. [S0556-2821(97)00907-7] [Phys. Rev. D **55**, 4492 (1997)]