

Selected Abstracts from Physical Review D

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Effect of the 3 K background radiation on ultrahigh energy cosmic rays. L. A. Anchordoqui, M. T. Dova, and L. N. Epele, *Departamento de Física, Universidad Nacional de La Plata, C.C. 67, (1900) La Plata, Argentina*; J. D. Swain, *Department of Physics, Northeastern University, Boston, Massachusetts 02115*. (Received 26 November 1996)

In this work we reexamine the opacity of the cosmic background radiation to the propagation of extremely high-energy cosmic rays. We use the continuous energy loss approximation to provide spectral modification factors for several hypothesized cosmic ray sources. Earlier problems with this approximation are resolved including the effects of resonances other than the Δ . [S0556-2821(97)01012-6] [Phys. Rev. D **55**, 7356 (1997)]

Limits to radiative neutrino decay from SN 1987A. Andrew H. Jaffe, *Center for Particle Astrophysics, 301 LeConte Hall, University of California, Berkeley, California 94720*; Michael S. Turner, *Departments of Physics and of Astronomy and Astrophysics, Enrico Fermi Institute, The University of Chicago, Chicago, Illinois 60637-1433 and NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500*. (Received 12 December 1995; revised manuscript received 24 January 1997)

We calculate limits to the properties of massive, unstable neutrinos using data from γ -ray detectors on the Pioneer Venus Orbiter (PVO) spacecraft. The absence of a γ -ray signal in the PVO detector constrains the branching ratio to photons (B_γ), mass (m_ν), and radiative lifetime ($\tau_\gamma = \tau/B_\gamma$). For low-mass ($m \lesssim T \sim 8$ MeV) neutrinos decaying $\nu \rightarrow \nu' \gamma$, $B_\gamma < 3 \times 10^{-7}$ for $m_\nu \tau \lesssim 10^6$ keVsec, and $B_\gamma < 2 \times 10^{-13} m_\nu \tau$ /keV sec for $m_\nu \tau \gtrsim 10^6$ keVsec; limits for high-mass neutrinos are somewhat weaker due to Boltzmann suppression. We also calculate limits for decays that produce γ rays through the bremsstrahlung channel, $\nu \rightarrow \nu' e^+ e^- \gamma$. With one exception, the PVO limits are roughly comparable to those from an analysis of data from the Solar Max Mission (SMM) Satellite (which observed at higher γ -ray energies but for a much shorter time). For neutrino mass states that are nearly degenerate, $\delta m^2/m^2 \sim 0.1 \ll 1$, our limits for the mode $\nu \rightarrow \nu' \gamma$ become more stringent by a factor as large as $m^2/\delta m^2$, because more decay photons are shifted into the PVO energy window. For this same reason, SMM cannot constrain this case. [S0556-2821(97)05912-2] [Phys. Rev. D **55**, 7951 (1997)]

Neutrino oscillations in curved spacetime: A heuristic treatment. Christian Y. Cardall and George M. Fuller, *Department of Physics, University of California, San Diego, La Jolla, California 92093-0319*. (Received 28 October 1996)

We discuss neutrino oscillations in curved spacetime. Our heuristic approach can accommodate matter effects and gravitational contributions to neutrino spin precession in the presence of a magnetic field. By way of illustration, we perform explicit calculations in the Schwarzschild geometry. In this case, gravitational effects on neutrino oscillations are intimately related to the redshift. We discuss how spacetime curvature could affect the resonance position and adiabaticity of matter-enhanced neutrino flavor conversion. [S0556-2821(97)04912-6] [Phys. Rev. D **55**, 7960 (1997)]

Spin-dependent twist-four matrix elements from g_1 data in the resonance region. Xiangdong Ji and W. Melnitchouk, *Department of Physics, University of Maryland, College Park, Maryland 20742* (Received 8 April 1997)

Matrix elements of spin-dependent twist-four operators are extracted from recent data on the spin-dependent g_1 structure function of the proton and deuteron in the resonance region. We emphasize the need to include the elastic contributions to the first moments of the structure functions at $Q^2 < 2$ GeV². The coefficients of the $1/Q^2$ corrections to the Ellis-Jaffe sum rules are found to be 0.04 ± 0.02 and 0.03 ± 0.04 GeV² for the proton and neutron, respectively. [S0556-2821(97)50113-5] [Phys. Rev. D **56**, 1 (1997)]

Time-reversal violation in β decay in the standard model. P. Herczeg, *Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545*; I. B. Khriplovich, *Budker Institute of Nuclear Physics, 630090 Novosibirsk, Russia*. (Received 21 January 1997)

We estimate the size of time-reversal violation in β decay due to the Kobayashi-Maskawa phase δ , and the θ term $\mathcal{L}_\theta$. We find that the contribution of δ to the D and R correlations is not likely to be larger than of the order of $10^{-12} |a| (|s_2 s_3 s_\delta|/10^{-3})$ and $10^{-14} |a| (|s_2 s_3 s_\delta|/10^{-3})$, respectively, where $|a| \approx 1$ for neutron and ^{19}Ne decay. For the contribution of $\mathcal{L}_\theta$ to D and R we conclude that it is not likely to be larger than of the order of $10^{-14} |a| (|\theta|/3 \times 10^{-10}) Q/(m_n - m_p)$ and $10^{-12} |a| (|\theta|/3 \times 10^{-10})$, respectively (the present experimental limits on $s_2 s_3 s_\delta$ and θ are $|s_2 s_3 s_\delta| \lesssim 10^{-3}$ and $|\theta| \lesssim 3 \times 10^{-10}$), where Q is the energy release in the decay. For both δ and $\mathcal{L}_\theta$ the D and R coefficients are dominated by long-distance contributions. The small values of D and R in the standard model compared to the best experimental limit on T -odd correlations (10^{-3} for D in ^{19}Ne decay) give potentially a wide window in which T -violating interactions beyond the standard model can be searched for. However, the range in this window that one will be able to exploit depends on the level at which the contributions of the final-state interactions can be kept under control. [S0556-2821(97)03513-3] [Phys. Rev. D **56**, 80 (1997)]

Production of energetic dileptons with small invariant masses from the quark-gluon plasma. Markus H. Thoma and Christoph T. Traxler, *Institut für Theoretische Physik, Universität Giessen, D-35392 Giessen, Germany.* (Received 23 January 1997)

The resummation technique of Braaten and Pisarski is used for a complete calculation of the $\alpha^2\alpha_s$ contribution to the production rate of dileptons with energy $E \gg T$ and invariant mass $M \lesssim T$ from a quark-gluon plasma. In particular the cancellation of the infrared singularity by medium effects is discussed in detail. [S0556-2821(97)02413-2] [Phys. Rev. D **56**, 198 (1997)]

Chiral Lagrangian for excited pions. M. K. Volkov, *Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna Head Post Office, P.O. Box 79, 101000 Moscow, Russia*; C. Weiss, *Institut für Theoretische Physik II, Ruhr-Universität Bochum, D-44780 Bochum, Germany.* (Received 8 August 1996)

We construct a chiral Lagrangian containing, in addition to the usual pion field (π), also its first radial excitation (π'). The Lagrangian is derived in the large- N_c limit from a Nambu–Jona-Lasinio (NJL) quark model with separable nonlocal interactions, with form factors corresponding to three-dimensional ground- and excited-state wave functions. Chiral symmetry breaking is governed by the NJL gap equation. The effective Lagrangian for π and π' mesons shows the decoupling of the Goldstone pion and the vanishing of the π' leptonic decay constant $f_{\pi'}$ in the chiral limit, as required by axial-vector current conservation. We derive the excited-state contribution to the axial-vector current of the model using Noether's theorem. For a finite pion mass and π' masses in the range of 750–1300 MeV, $f_{\pi'}/f_\pi$ is found to be of the order of 1%. [S0556-2821(97)01811-0] [Phys. Rev. D **56**, 221 (1997)]

Effective quark operator models of $U_A(1)$ symmetry breaking. V. Dmitrašinović, *Department of Physics and Astronomy, University of South Carolina, Columbia, South Carolina 29208.* (Received 15 January 1997)

We undertake a systematic investigation of $U_A(1)$ symmetry-breaking, C -, P -, T -, and $SU_L(N_f) \times SU_R(N_f)$ -invariant effective fermion operators and their consequences for pseudoscalar and scalar mesons. We construct four types of such operators that exist for any number of flavors $N_f \geq 2$, two of which can be identified with 't Hooft's interaction and the quark self-interaction leading to the Veneziano-Witten meson-interaction term. We isolate the $U_A(1)$ symmetry-breaking effect from the quark mass- and electromagnetic interaction-induced chiral symmetry-breaking effects and quantify it as the deviation from zero of $f_0^2 m_{U(1)}^2 = f_\eta^2 m_\eta^2 + f_{\eta'}^2 m_{\eta'}^2 - f_K^2 (m_{K^+}^2 + m_{K^0}^2) + f_\pi^2 (m_{\pi^+}^2 - m_{\pi^0}^2)$, where m_ϕ, f_ϕ are the pseudoscalar ϕ meson mass and weak decay constant, respectively. Then we use Dashen's general formula to evaluate the masses and the mixing angle of isoscalar pseudoscalar mesons in the presence of the current quark masses and each one of these four types of $U_A(1)$ symmetry-breaking interactions. We find that both the 't Hooft and the Veneziano-Witten interaction push the sum of the η' and η masses squared upward and the mixing angle to negative values, in accord with empirical evidence. The other two types of $U_A(1)$ symmetry-breaking operators do not influence the pseudoscalar meson spectrum to leading order in N_c , so long as no new higher-order quark condensates are assumed. In an attempt to determine which linear combination of the 't Hooft and the

Veneziano-Witten operators is responsible for the observed $U_A(1)$ symmetry breaking, we calculate the scalar meson masses in the three-flavor Nambu–Jona-Lasino model in the presence of either of these two interactions. Presently available data do not allow a definitive answer to that question, though they can be interpreted as favoring the 't Hooft interaction. [S0556-2821(97)04113-1] [Phys. Rev. D **56**, 247 (1997)]

Production and polarization of the Λ_c^+ and the charm content of the proton. J. C. Anjos, G. Herrera, J. Magnin, and F. R. A. Simão, *Centro Brasileiro de Pesquisas Físicas, Rua Dr. Xavier Sigaud 150, 22290-180, Rio de Janeiro, Brazil.* (Received 3 February 1997)

We propose a two-component model involving the parton fusion mechanism and recombination of a ud valence diquark with a sea c quark of the incident proton to describe Λ_c^+ inclusive production in pp collisions. We also study the polarization of the produced Λ_c^+ in the framework of the Thomas precession model for polarization. We show that a measurement of the Λ_c polarization is a sensitive test of its production mechanism. In particular, the intrinsic charm model predicts a positive polarization for the Λ_c within the framework of the Thomas precession model, while according to the model presented here the Λ_c polarization should be negative. The measurement of the Λ_c polarization provides a close examination of intrinsic charm Fock states in the proton and gives interesting information about the hadroproduction of the charm quark. [S0556-2821(97)04513-X] [Phys. Rev. D **56**, 394 (1997)]

Tensor charge of the nucleon in lattice QCD. S. Aoki, M. Doui, and T. Hatsuda, *Institute of Physics, University of Tsukuba, Tsukuba, Ibaraki 305, Japan*; Y. Kuramashi, *National Laboratory for High Energy Physics (KEK), Tsukuba, Ibaraki 305, Japan.* (Received 22 August 1996)

The first results of lattice QCD simulations on the nucleon tensor charge δq are presented. From the quenched QCD simulations with the Wilson quark action at $\beta=5.7$ (the lattice spacing $a \approx 0.14$ fm) on a $16^3 \times 20$ lattice and on a $12^3 \times 20$ lattice, we find (i) the connected part δq_{con} is determined with small statistical error, (ii) the disconnected part δq_{dis} , which violates the OZI rule, is consistent with zero, and (iii) the flavor-singlet tensor charge $\delta \Sigma (\mu^2 = 2 \text{ GeV}^2) = \delta u + \delta d + \delta s$ takes 0.562(88) in the quenched simulation at $\beta=5.7$ on a $16^3 \times 20$ lattice. [S0556-2821(97)01713-X] [Phys. Rev. D **56**, 433 (1997)]

Atmospheric neutrinos with three flavor mixing. Mohan Narayan and G. Rajasekaran, *Institute of Mathematical Sciences, Madras 600 113, India*; S. Uma Sankar, *Department of Physics, I.I.T., Powai, Bombay 400 076, India.* (Received 12 July 1996; revised manuscript received 3 February 1997)

We analyze the atmospheric neutrino data in the context of three flavor neutrino oscillations taking account of the matter effects in the Earth. With the hierarchy among the vacuum mass eigenvalues $\mu_3^2 \gg \mu_2^2 \gg \mu_1^2$, the solution of the atmospheric neutrino problem depends on $\delta_{31} = \mu_3^2 - \mu_1^2$ and the 13 and 23 mixing angles ϕ and

ψ . Whereas the sub-GeV atmospheric neutrino data imposes only a lower limit on $\delta_{31} > 10^{-3} \text{eV}^2$, the zenith-angle-dependent suppression observed in the multi-GeV data limits δ_{31} from above also. The allowed regions of the parameter space are strongly constrained by the multi-GeV data. Combined with our earlier solution to the solar neutrino problem which depends on $\delta_{21} = \mu_2^2 - \mu_1^2$ and the 12 and 13 mixing angles ω and ϕ , we have obtained the ranges of values of the five neutrino parameters which solve both the solar and the atmospheric neutrino problems simultaneously. [S0556-2821(97)05411-8] [Phys. Rev. D **56**, 437 (1997)]

ω - ϕ mixing at finite temperature. Charles Gale and David Seibert, *Physics Department, McGill University, Montréal, Québec, Canada H3A 2T8*; Joseph Kapusta, *School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455*. (Received 3 February 1997)

We compute the mass shifts and mixing of the ω and ϕ mesons at finite temperature due to scattering from thermal pions. The ρ and b_1 mesons are important intermediate states. Up to a temperature of 140 MeV the ω mass increases by 12 MeV and the ϕ mass decreases by 0.6 MeV. The change in mixing angles is negligible. [S0556-2821(97)05213-2] [Phys. Rev. D **56**, 508 (1997)]

Chirality and reliability of baryon QCD sum rules. Xuemin Jin and Jian Tang, *Center for Theoretical Physics, Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139*. (Received 6 January 1997)

The QCD sum-rule method has been widely used in studying various baryon properties. For a given problem, there is usually

more than one sum rule and they all do not work equally well. In this paper, we point out that chirality plays an important role in determining the reliability of a baryon sum rule. The contributions of positive- and negative-parity excited baryon states partially cancel each other in the chiral-odd sum rules, but add up in the chiral-even sum rules. As such, the chiral-odd sum rules are generally more reliable than the chiral-even sum rules. This allows one to identify the more reliable sum rules and use them in extracting the ground-state baryon property of interest. This is illustrated in an explicit example. [S0556-2821(97)00613-9] [Phys. Rev. D **56**, 515 (1997)]

Double-spin transverse asymmetries in Drell-Yan processes. V. Barone, *Dipartimento di Fisica Teorica, Università di Torino and INFN, Sezione di Torino, 10125 Torino, Italy and II Facoltà di Scienze MFN, 15100 Alessandria, Italy*; T. Calarco and A. Drago, *Dipartimento di Fisica, Università di Ferrara and INFN, Sezione di Ferrara, 44100 Ferrara, Italy*. (Received 3 February 1997)

We calculate the double-spin transverse asymmetries for the Drell-Yan lepton pair production in pp and $\bar{p}p$ collisions. We assume the transverse and the longitudinal polarization densities to be equal at a very small scale, as is suggested by confinement model results. Using a global fit for the longitudinal distributions, we find transverse asymmetries of order of 10^{-2} at most, in the accessible kinematic regions. [S0556-2821(97)03511-X] [Phys. Rev. D **56**, 527 (1997)]