

Selected Abstracts from Physical Review D

Abstracts of papers published in Physical Review D which may be of interest to our readers are printed here.

Neutrino trapping in a supernova and the screening of weak neutral currents. C. J. Horowitz, *Nuclear Theory Center and Department of Physics, Indiana University, Bloomington, Indiana 47405.* (Received 9 December 1996)

Neutrino-nucleus elastic scattering is reduced in dense matter because of correlations. The static structure factor for a plasma of electrons and ions is calculated from Monte Carlo simulations and parametrized with a least squares fit. Our results imply a large increase in the neutrino mean-free path. This impacts the trapping of neutrinos in a supernova by coherent neutral current interactions. [S0556-2821(97)03508-X] [Phys. Rev. D **55**, 4577 (1997)]

Self-consistent determination of hard modes in hot QCD. A. Niegawa, *Department of Physics, Osaka City University, Sumiyoshi-ku, Osaka 558, Japan* (Received 1 October 1996)

We determine self-consistently the hard-quark and hard-gluon modes in hot QCD. The damping-rate part in resummed hard-quark or hard-gluon propagators, rather than the thermal-mass part, plays the dominant role. [S0556-2821(97)01708-6] [Phys. Rev. D **55**, 4997 (1997)]

Studies of neutrino asymmetries generated by ordinary-sterile neutrino oscillations in the early Universe and implications for big bang nucleosynthesis bounds. R. Foot and R. R. Volkas, *Research Centre for High Energy Physics, School of Physics, University of Melbourne, Parkville, 3052 Australia.* (Received 3 October 1996)

Ordinary-sterile neutrino oscillations can generate a significant lepton number asymmetry in the early Universe. We study this phenomenon in detail. We show that the dynamics of ordinary-sterile neutrino oscillations in the early Universe can be approximately described by a single integrodifferential equation which we derive from both the density matrix and Hamiltonian formalisms. This equation reduces to a relatively simple ordinary first-order differential equation if the system is sufficiently smooth (static limit). We study the conditions for which the static limit is an acceptable approximation. We also study the effect of the thermal distribution of neutrino momenta on the generation of lepton number. We apply these results to show that it is possible to evade (by many orders of magnitude) the big bang nucleosynthesis (BBN) bounds on the mixing parameters δm^2 and $\sin^2 2\theta_0$ describing ordinary-sterile neutrino oscillations. We show that the large angle or maximal vacuum oscillation solution to the solar neutrino problem does not significantly modify BBN for most of the parameter space of interest, provided that the τ and/or μ neutrinos have masses greater than about 1 eV. We also show that the large angle or maximal ordinary-sterile neutrino oscillation solution to the atmospheric neutrino

anomaly does not significantly modify BBN for a range of parameters. [S0556-2821(97)05908-0] [Phys. Rev. D **55**, 5147 (1997)]

Kaon zero-point fluctuations in neutron star matter. Vestein Thorsson, *Department of Physics, University of Washington, Box 351560, Seattle, Washington 98195-1560 and NORDITA, Blegdamsvej 17, DK-2100 Copenhagen Ø, Denmark;* Paul J. Ellis, *School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455-0112.* (Received 13 November 1996)

We investigate the contribution of zero-point motion, arising from fluctuations in kaon modes, to the ground state properties of neutron star matter containing a Bose condensate of kaons. The zero-point energy is derived via the thermodynamic partition function, by integrating out fluctuations for an arbitrary value of the condensate field. It is shown that the vacuum counterterms of the chiral Lagrangian ensure the cancellation of divergences dependent on μ , the charge chemical potential, which may be regarded as an external vector potential. The total grand potential, consisting of the tree-level potential, the zero-point contribution, and the counterterm potential, is extremized to yield a locally charge neutral, β -equilibrated and minimum energy ground state. In some regions of parameter space we encounter the well-known problem of a complex effective potential. Where the potential is real and solutions can be obtained, the contributions from fluctuations are found to be small in comparison with tree-level contributions. [S0556-2821(97)00608-5] [Phys. Rev. D **55**, 5177 (1997)]

Study of cosmic ray composition in the knee region using multiple muon events in the Soudan 2 detector. S. M. Kasahara,² W. W. M. Allison,³ G. J. Alner,⁴ D. S. Ayres,¹ W. L. Barrett,⁶ C. R. Bode,² P. M. Border,² C. B. Brooks,³ J. H. Cobb,³ D. J. A. Cocke,⁴ R. J. Cotton,⁴ H. Courant,² D. M. DeMuth,² B. Ewen,⁵ T. H. Fields,¹ H. R. Gallagher,³ M. C. Goodman,¹ R. W. Gran,² R. N. Gray,² K. Johns,² T. Kafka,⁵ W. Leeson,⁵ P. J. Litchfield,⁴ N. P. Longley,² M. J. Lowe,² W. A. Mann,⁵ M. L. Marshak,² E. N. May,¹ R. H. Milburn,⁵ W. H. Miller,² L. Muallem,² A. Napier,⁵ W. Oliver,⁵ G. F. Pearce,⁴ E. A. Peterson,² L. E. Price,¹ D. M. Roback,² K. Ruddick,² D. J. Schmid,² J. Schneps,⁵ M. H. Schub,² R. V. Seidlein,¹ M. A. Shupe,² N. Sundaralingam,⁵ J. L. Thron,¹ H. J. Trost,¹ J. L. Uretsky,¹ V. Vassiliev,² G. Villaume,² S. P. Wakely,² D. Wall,⁵ S. J. Werkema,² and N. West,³ ¹Argonne National Laboratory, Argonne, Illinois 60439 ²University of Minnesota, Minneapolis, Minnesota 55455 ³Department of Physics, University of Oxford, Oxford OX1 3RH, United Kingdom ⁴Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX, United Kingdom ⁵Tufts University, Medford, Massachusetts 02155 ⁶Western Washington University, Bellingham, Washington 98225. (Received 4 December 1996)

Deep underground muon events recorded by the Soudan 2 detector, located at a depth of 2100 m of water equivalent, have been used to infer the nuclear composition of cosmic rays in the “knee” region of the cosmic ray energy spectrum. The observed muon multiplicity distribution favors a composition model with a substantial proton content in the energy region $8 \times 10^5 - 1.3 \times 10^7$ GeV/nucleus. [S0556-2821(97)00409-8] [Phys. Rev. D **55**, 5282 (1997)]

Unified effective theory for light mesons and heavy mesons. Lai-Him Chan, *Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803-4001.* (Received 24 September 1996)

We present a unified effective field theory for the light mesons and heavy mesons which integrates many features from the quark model, vector dominance, chiral dynamics, Skyrmin physics, and the heavy quark effective theory into a single universal theory. By identifying the meson fields as the Bargmann-Wigner superfields with the direct product representation of a quark and antiquark and using the Bargmann-Wigner equation and Lagrangian, we can readily match the meson Lagrangian with the quark Lagrangian. Thus we not only incorporate various aspects of the quark contents into the meson fields but we can also transcribe the implementation of the chiral symmetry and spontaneous symmetry breakings from the quark Lagrangian to the meson Lagrangian. The physical light meson fields can be constructed nonlinearly from the quark and antiquark direct product representation, with the 0^- pseudoscalar mesons as the Goldstone mesons and the 1^- vector mesons as the non-Abelian gauge fields of the hidden local SU(3) symmetry. Phenomenological consequences and theoretical implications of this theory will be discussed. Various aspects of the heavy quark effective theory are automatically integrated into this formulation. [S0556-2821(97)02009-2] [Phys. Rev. D **55**, 5362 (1997)]

SU(3) breaking in neutral current axial matrix elements and the spin content of the nucleon. Martin J. Savage and James Walden, *Department of Physics, University of Washington, Seattle, Washington 98195.* (Received 21 November 1996)

We examine the effects of SU(3) breaking in the matrix elements of the flavor-diagonal axial-vector currents between octet baryon states. Our calculations of K , η , and π loops indicate that the SU(3) breaking may be substantial for some matrix elements and at the very least indicate large uncertainties. In particular, the strange axial matrix element in the proton determined from the measurements of $g_1(x)$ is found to have large uncertainties and might yet be zero. We estimate the strange axial matrix element in the proton to be $-0.35 \leq \Delta s \leq 0$ and the matrix element of the flavor-singlet current in the proton to be $-0.1 \leq \Sigma \leq +0.3$ from the E143 measurement of $\int dx g_1(x) = 0.127 \pm 0.004 \pm 0.010$. The up-quark content of the Ξ^- is discussed and its implications for nonleptonic weak processes discussed. We also estimate the matrix element of the axial-vector current coupling to the Z^0 between all octet baryon states. This may be important for neutrino interactions in dense nuclear environments, where hyperons may play an important role. [S0556-2821(97)00709-1] [Phys. Rev. D **55**, 5376 (1997)]

Some implications of meson dominance in weak interactions.

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The hypothesis is scrutinized that the weak interaction of hadronic systems at low energies is dominated by the coupling of the pseudoscalar, vector, and axial-vector mesons to the weak gauge bosons. The strength of the weak coupling of the $\rho(770)$ meson is uniquely determined by vector-meson dominance in electromagnetic interactions; flavor and chiral symmetry-breaking effects modify the coupling of other vector mesons and axial-vector mesons. Many decay rates are calculated and compared to experimental data and partly to predictions of other models. A parameter-free description of the decay $K^+ \rightarrow \pi^+ \ell^+ \ell^-$ is obtained. Predictions for several not yet observed decay rates and reaction cross sections are presented. The relation between the conserved vector current hypothesis and meson dominance is clarified. Phenomenological success of the meson dominance suggests that in some calculations based on the standard model the weak quark-antiquark annihilation and creation diagrams may be more important than anticipated so far. The processes are identified where the meson dominance fails, implying that they are governed, on the quark level, by some other standard model diagrams. [S0556-2821(97)01709-8] [Phys. Rev. D **55**, 5385 (1997)]

Intrinsic glue distribution at very small x . Jamal Jalilian-Marian, Alex Kovner, Larry McLerran, and Heribert Weigert, *Physics Department, University of Minnesota, 116 Church Street S.E., Minneapolis, Minnesota 55455.* (Received 6 August 1996)

We compute the distribution functions for gluons at very small x and not too large values of transverse momenta. We extend the McLerran-Venugopalan model by using renormalization group methods to integrate out effects due to those gluons which generate an effective classical charge density for Weizsäcker-Williams fields. We argue that this model can be extended from the description of nuclei at small x to the description of hadrons at yet smaller values of x . This generates a Lipatov-like enhancement for the intrinsic gluon distribution function and a nontrivial transverse momentum dependence as well. We estimate the transverse momentum dependence for the distribution functions, and show how the issue of unitarity is resolved in lepton-nucleus interactions. [S0556-2821(97)05407-6] [Phys. Rev. D **55**, 5414 (1997)]

Quantum structure of the non-Abelian Weizsäcker-Williams field for a very large nucleus. Yuri V. Kovchegov *Department of Physics, Columbia University, New York, New York 10027.* (Received 6 January 1997)

We consider the McLerran-Venugopalan model for calculation of the small- x part of the gluon distribution function for a very large ultrarelativistic nucleus at weak coupling. We construct the Feynman diagrams which correspond to the classical Weizsäcker-Williams field found previously [Yu. V. Kovchegov, Phys. Rev. D **54**, 5463 (1996)] as a solution of the classical equations of motion for the gluon field in the light-cone gauge. Analyzing these diagrams we obtain a limit for the McLerran-Venugopalan model.

We show that as long as this limit is not violated a classical field can be used for the calculation of scattering amplitudes. [S0556-2821(97)03009-9] [Phys. Rev. D **55**, 5445 (1997)]

$\Delta(1232)$ and the polarizabilities of the nucleon. Thomas R. Hemmert, *Theory Division, TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia, Canada V6T 2A3*; Barry R. Holstein, *Department of Physics and Astronomy, University of Massachusetts, Amherst, Massachusetts 01003*; Joachim Kambor, *Theoretische Physik, Universität Zürich, CH-8057 Zürich, Switzerland*. (Received 17 December 1996)

Previous calculations of the polarizabilities of the nucleon within the framework of heavy baryon chiral perturbation theory have included the contribution of the $\Delta(1232)$ only in its effects on various contact terms or have been performed in chiral SU(3) where systematic errors are difficult to control. Herein, we perform a corresponding calculation in chiral SU(2) wherein $\Delta(1232)$ is treated as an explicit degree of freedom and the expansion is taken to third order in soft momenta, the pion mass, and the quantity $M_\Delta - M_N$, collectively denoted ϵ . We present the results of a systematic $O(\epsilon^3)$ calculation of forward Compton scattering off the nucleon, extract the electric polarizability α_E , the magnetic polarizability β_M , and the spin polarizability γ , and compare with available information from experiments and from previous calculations. Concluding with a critical discussion of our results, we point out the necessity of a future $O(\epsilon^4)$ calculation. [S0556-2821(97)04909-6]

Inverse amplitude method and chiral perturbation theory to two loops. Torben Hannah, *Institute of Physics and Astronomy, Aarhus University, DK-8000 Aarhus C, Denmark*. (Received 4 November 1996)

The inverse amplitude method is analyzed to two-loop order in the chiral expansion in the case of $\pi\pi$ scattering and the pion form factors. The analysis is mainly restricted to the elastic approximation but the possible extension to the inelastic case is also discussed in some detail. It is shown how the two-loop approach improves the inverse amplitude method applied to one-loop order in the chiral expansion. For both $\pi\pi$ scattering and the pion form factors, it is in fact found that the inverse amplitude method to two-loop order agrees remarkably well with the experimental data up to energies where inelasticities become essential. At somewhat lower energies, the two-loop approach compares well with the one-loop approximation, and in the threshold region they both agree with chiral perturbation theory. This suggests that the inverse amplitude method is indeed a rather systematic way of improving chiral perturbation theory order by order in the chiral expansion. [S0556-2821(97)00609-7] [Phys. Rev. D **55**, 5613 (1997)]

Weak hyperon production in ep scattering. Xuemin Jin and R. L. Jaffe, *Center for Theoretical Physics, Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Tech-*

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We study the kinematics and cross section of the scattering process $ep \rightarrow e\Sigma^+$. The cross section is expressed in terms of complex form factors characterizing the hadron vertices. We estimate the cross section for small momentum transfer using known experimental information. To first order in the momentum transfer, we obtain a model-independent result for the photon-exchange part of the cross section, which is completely determined by the decay width $\Gamma(\Sigma^+ \rightarrow p\gamma)$. For the kinematics of the parity violation experiment at MAMI, this first-order result gives rise to a ratio of $(d\sigma/d\Omega)_{ep \rightarrow e\Sigma^+} / (d\sigma/d\Omega)_{ep \rightarrow ep} \simeq 4.0 \times 10^{-15}$. The Z^0 -exchange and interference parts give much smaller contributions due to the suppression of the flavor-changing weak neutral current in the standard model. The feasibility of the experimental measurement is briefly discussed. [S0556-2821(97)02909-3] [Phys. Rev. D **55**, 5636 (1997)]

Fractal structure of multiparticles produced in p - p collisions at 400 GeV/c. Yunxiu Ye, Shaoshun Wang, Yu Zhong, Chenguo Xiao, Xing Zhou, and Je Zhang, *University of Science and Technology of China, Hefei, Anhui 230026, China*. (Received 3 June 1996)

Different fractal methods have been used for the analysis of distributions of charged particles in pseudorapidity η , azimuthal angle ϕ , and η - ϕ phase spaces of final states in p - p collisions at 400 GeV/c, by measuring the LEBC films offered by the CERN NA27 Collaboration. Monte Carlo events with pure statistical fluctuations are generated and the corresponding results are compared with the experimental ones. The experimental results indicate that the distribution of charged particles in pseudorapidity and azimuthal angles show a fractal behavior and dynamical fluctuations and that the mechanism of multiparticle production may be a self-similar cascade process. [S0556-2821(97)04007-1] [Phys. Rev. D **55**, 5641 (1997)]

Weak electricity of the nucleon in the chiral quark-soliton model. Hyun-Chul Kim, Maxim V. Polyakov, and Klaus Goeke, *Institute for Theoretical Physics II, Ruhr-University Bochum, D-44780 Bochum, Germany*. (Received 3 September 1996)

The induced pseudotensor constant (weak electricity) of the nucleon is calculated in the framework of the chiral quark-soliton model. This quantity originates from G -parity violation and, hence, is proportional to $m_u - m_d$. We obtain for $m_u - m_d = -5$ MeV a value of $g_T/g_A = -0.0038$. [S0556-2821(97)00209-9] [Phys. Rev. D **55**, 5698 (1997)]

Neutrino oscillations from Dirac and Majorana masses. D. Ring, *Center for Theoretical Physics, Department of Physics, Texas A&M University, College Station, Texas 77843-4242*. (Received 22 October 1996)

We present a scenario of neutrino masses and mixing angles. Each generation includes a sterile right-handed neutrino in addition

to the usual left-handed one. We assume a hierarchy in their Dirac masses similar to, but much larger than, the hierarchies in the quarks and charged leptons. In addition, we include a Majorana mass term for the sterile neutrinos only. These assumptions prove sufficient to accommodate scales of mass differences and mixing angles consistent with all existing neutrino oscillation data. [S0556-2821(97)03509-1] [Phys. Rev. D **55**, 5767 (1997)]

γ -hadron families sensitivity to disoriented chiral condensates.

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Presented in this study is a possible coherent emission of pions from a large domain of disoriented chiral condensate (DCC) in the leading particle region, through their influence on the development of the γ -hadron families, initiated by cosmic ray particles in the atmosphere. The production rate of DCC's is obtained by using a phenomenological framework in the quenching approximation and is included in a Monte Carlo code. In this context, we have found, under the assumption of a "normal" proton dominant composition in the primary flux, that the anomalous hadron-rich families, observed in the experimental data, can be reproduced. However, the production rate of DCC's obtained here is not enough to describe the global characteristics, such as the family flux, observed at mountain altitudes. The implications of these results are here discussed.

[S0556-2821(97)04407-X] [Phys. Rev. D **55**, 5834 (1997)]