

Selected Abstracts from Other Physical Review Journals

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Do solar neutrinos decay? John F. Beacom and Nicole F. Bell, *NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500*. (Received 9 April 2002; published 24 June 2002)

Despite the fact that the solar neutrino flux is now well understood in the context of matter-affected neutrino mixing, we find that it is not yet possible to set a strong and model-independent bound on solar neutrino decays. If neutrinos decay into truly invisible particles, the Earth-Sun baseline defines a lifetime limit of $\tau/m \gtrsim 10^{-4}$ s/eV. However, there are many possibilities which must be excluded before such a bound can be established. There is an obvious degeneracy between the neutrino lifetime and the mixing parameters. More generally, one must also allow the possibility of active daughter neutrinos and/or antineutrinos, which may partially conceal the characteristic features of decay. Many of the most exotic possibilities that presently complicate the extraction of a decay bound will be removed if the KamLAND reactor antineutrino experiment confirms the large-mixing angle solution to the solar neutrino problem and measures the mixing parameters precisely. Better experimental and theoretical constraints on the ^8B neutrino flux will also play a key role, as will tighter bounds on absolute neutrino masses. Though the lifetime limit set by the solar flux is weak, it is still the strongest direct limit on nonradiative neutrino decay. Even so, there is no guarantee (by about eight orders of magnitude) that neutrinos from astrophysical sources such as a Galactic supernova or distant active galactic nuclei will not decay. [Phys. Rev. D **65**, 113009 (2002)]

Solar neutrino zenith angle distribution and uncertainty in Earth's matter density. Lian-You Shan and Xin-Min Zhang, *Institute of High Energy Physics, Chinese Academy of Science, P.O. Box 918, Beijing 100039, People's Republic of China*. (Received 6 January 2002; published 24 June 2002)

We estimate in this paper the errors in the zenith angle distribution for the charged current events of the solar neutrinos caused by the uncertainty of Earth's electron density. In the model of the Preliminary Reference Earth Model with a 5% uncertainty in the Earth's electron density we numerically calculate the corrections to the correlation between $[N]_5/[N]_2$ and $[N]_2/[N]_3$, and find the errors notable. [Phys. Rev. D **65**, 113011 (2002)]

Role of the 't Hooft interaction in the calculation of the properties of scalar mesons. C. M. Shakin, *Department of Physics and Center for Nuclear Theory, Brooklyn College of the City University of New York, Brooklyn, New York 11210*. (Received 28 January 2002; published 19 June 2002)

A survey of the literature dealing with the quark-model configurations of the scalar-isoscalar light mesons suggests that a theoret-

ical model is needed to deal with these characterizations, since various researchers have come to widely different conclusions concerning the nature of the $\sigma(500-600)$ or the $f_0(980)$, basing their analysis on an attempt to fit experimental data with models for the wave functions of these states. In an earlier work we demonstrated that our generalized Nambu–Jona-Lasinio model may be used to provide a very good fit to the mixing angles and decay constants of the $\eta(547)$ and $\eta'(958)$ mesons. It was found that the $\eta(547)$ was mainly a flavor octet state. On the other hand, when we use our model to describe the scalar-isoscalar $f_0(980)$ meson, we find that it is mainly a singlet state, in agreement with the recent suggestion of Ochs. We stress that these results for the properties of the pseudoscalar and scalar mesons arise from the different behavior of the 't Hooft interaction in the two cases. In this work we demonstrate that the singlet-octet flavor representation largely brings the interaction matrix to diagonal form, with some residual singlet-octet mixing due, in part, to the 't Hooft interaction and to the difference of the up (or down) and the strange quark constituent mass values. We find that, if we neglect the coupling to the two-meson continuum and use the same interaction that was used in our study of the η mesons, the $f_0(980)$ has a mass of 981 MeV and is the $q\bar{q}$ state of lowest energy. That result implies that the $\sigma(500-600)$ is not a $q\bar{q}$ state, but is generated dynamically in $\pi\pi$ scattering, as we have discussed in an earlier work. We suggest that the proper treatment of the 't Hooft interaction leads to a unified interpretation of the pseudoscalar and scalar meson characteristics. [Phys. Rev. D **65**, 114011 (2002)]

Charm antiquark and charm quark in the nucleon. Xiaotong Song, *Institute of Nuclear and Particle Physics, Jesse W. Beams Laboratory of Physics, Department of Physics, University of Virginia, Charlottesville, Virginia 22904*. (Received 14 November 2001; published 25 June 2002)

We estimate the intrinsic charm contributions to the quark flavor and spin observables of the nucleon in the SU(4) quark meson fluctuation model. In this model, the charm or anticharm resides in the charmed mesons created by the nonperturbative quantum quark-meson fluctuations. The intrinsic charm content in the proton, $2c/\Sigma(q+\bar{q}) \approx 0.011 \pm 0.008$, is almost one order of magnitude smaller than the intrinsic strange content. The intrinsic charm helicity is also small and negative, $\Delta c \approx -(0.009 \pm 0.006)$. The fraction of the total quark helicity carried by the charm is $|\Delta c/\Delta\Sigma| \approx 0.021 \pm 0.014$. The ratio of the charm with positive helicity to that with negative helicity is $c_+/c_- = 35/67$. For the intrinsic strange component, one has $s_+/s_- \approx 7/13$. A detailed comparison of our predictions with data and other models or analyses is given. The intrinsic charm contribution to the Ellis-Jaffe sum rule is also discussed. [Phys. Rev. D **65**, 114022 (2002)]

Quasiquarks in two stream system. Stanisław Mrówczyński, *Sołtan Institute for Nuclear Studies, ul. Hoża 69, PL-00-681 Warsaw, Poland, and Institute of Physics, Świętokrzyska Academy, ul.*

Konopnickiej 15, PL-25-406 Kielce, Poland. (Received 26 March 2002; published 20 June 2002)

We study the collective quark excitations in an extremely anisotropic system of two interpenetrating streams of the quark-gluon plasma. In contrast with the gluon modes, all quark ones appear to be stable in such a system. Even more, the quark modes in the two-stream system are very similar to those in the isotropic plasma. [Phys. Rev. D **65**, 117501 (2002)]

Charm antiquark and charm quark in the nucleon. Xiaotong Song, *Institute of Nuclear and Particle Physics, Jesse W. Beams Laboratory of Physics, Department of Physics, University of Virginia, Charlottesville, Virginia 22904.* (Received 14 November 2001; published 25 June 2002)

We estimate the intrinsic charm contributions to the quark flavor and spin observables of the nucleon in the SU(4) quark meson fluctuation model. In this model, the charm or anticharm resides in the charmed mesons created by the nonperturbative quantum quark-meson fluctuations. The intrinsic charm content in the proton, $2c/\Sigma(q+q) \approx 0.011 \pm 0.008$, is almost one order of magnitude smaller than the intrinsic strange content. The intrinsic charm helicity is also small and negative, $\Delta c \approx -(0.009 \pm 0.006)$. The fraction of the total quark helicity carried by the charm is $|\Delta c/\Delta \Sigma| \approx 0.021 \pm 0.014$. The ratio of the charm with positive helicity to that with negative helicity is $c_+/c_- = 35/67$. For the intrinsic strange component, one has $s_+/s_- \approx 7/13$. A detailed comparison of our predictions with data and other models or analyses is given. The intrinsic charm contribution to the Ellis-Jaffe sum rule is also discussed. [Phys. Rev. D **65**, 114022 (2002)]

Stability of the lattice formed in first-order phase transitions to matter containing strangeness in protoneutron stars. J. J. Zach, *Department of Physics, The Ohio State University, 174 W. 18th Ave, Columbus, Ohio 43210.* (Received 16 February 2002; published 30 May 2002)

Well into the deleptonization phase of a core collapse supernova, a first-order phase transition to matter with macroscopic strangeness content is assumed to occur and lead to a structured lattice defined by negatively charged strange droplets. The lattice is shown to crystallize for expected droplet charges and separations at temperatures typically obtained during the protoneutron star evolution. The melting curve of the lattice for small spherical droplets is presented. The one-component plasma model proves to be an adequate description for the lattice in its solid phase with deformation modes freezing out around the melting temperature. The mechanical stability against shear stresses is such that velocities predicted for convective phenomena and differential rotation during the Kelvin-Helmholtz cooling phase might prevent the crystallization of the phase transition lattice. A solid lattice might be fractured by transient convection, which could result in anisotropic neutrino transport. The melting curve of the lattice is relevant for the mechanical evolution of the protoneutron star and therefore should be included in future hydrodynamics simulations. [Phys. Rev. D **65**, 123002 (2002)]

Aspects of higher order gravity and holography. Elcio Abdalla and L. Alejandro Correa-Borbonet, *Instituto de Física, Universidade de São Paulo, C.P.66.318, CEP 05315-970, São Paulo, Brazil.* (Received 17 September 2001; published 4 June 2002)

Some thermodynamical properties of Lovelock gravity in the vanishing cosmological constant limit are discussed in several space-time dimensions, the holographic principle being one of the ingredients of the discussion. As it turns out, the area law and the brickwall method, though correct for the Einstein-Hilbert theory, may fail to work in general. [Phys. Rev. D **65**, 124011 (2002)]

Chiral condensate and short-time evolution of (1+1)-dimensional QCD on the light cone. Matthias Burkardt, *Department of Physics, New Mexico State University, Las Cruces, New Mexico 88003-0001;* Frieder Lenz and Michael Thies, *Institut für Theoretische Physik III, Universität Erlangen-Nürnberg, Staudtstraße 7, D-91058 Erlangen, Germany.* (Received 31 January 2002; published 23 May 2002)

Chiral condensates in the trivial light-cone vacuum emerge if defined as short-time limits of fermion propagators. In gauge theories, the necessary inclusion of a gauge string in combination with the characteristic light-cone infrared singularities contain the relevant nonperturbative ingredients responsible for the formation of the condensate, as demonstrated for the 't Hooft model. [Phys. Rev. D **65**, 125002 (2002)]

$\mathcal{N}=3$ warped compactifications. Andrew R. Frey, *Department of Physics, University of California, Santa Barbara, California 93106;* Joseph Polchinski, *Institute for Theoretical Physics, University of California, Santa Barbara, California 93106-4030.* (Received 9 April 2002; published 19 June 2002)

Orientifolds with three-form flux provide some of the simplest string examples of warped compactification. In this paper we show that some models of this type have the unusual feature of $D=4$, $\mathcal{N}=3$ spacetime supersymmetry. We discuss their construction and low energy physics. Although the local form of the moduli space is fully determined by supersymmetry, to find its global form requires a careful study of the Bogomol'nyi-Prasad-Sommerfield spectrum. [Phys. Rev. D **65**, 126009 (2002)]

$B=3$ tetrahedrally symmetric solitons in the chiral quark soliton model. Nobuyuki Sawado and Noriko Shiiki, *Department of Physics, Tokyo University of Science, Noda, Chiba 278-8510, Japan.* (Received 4 February 2002; published 8 July 2002)

In this paper, $B=3$ soliton solutions with tetrahedral symmetry are obtained numerically in the chiral quark soliton model using the rational map ansatz. The solution exhibits a triply degenerate bound spectrum of the quark orbits in the background of tetrahedrally symmetric pion field configuration. The corresponding baryon density is tetrahedral in shape. Our numerical technique is independent of the baryon number and its application to $B \geq 4$ is straightforward. [Phys. Rev. D **66**, 011501 (2002)]

Bounds on neutrino magnetic moment tensor from solar neutrinos. Anjan S. Joshipura and Subhendra Mohanty, *Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India.* (Received 26 April 2002; published 24 July 2002)

Solar neutrinos with nonzero magnetic moments will contribute to the electron scattering rates in the Super-Kamiokande experiment. The magnetic moment scattering events in Super-K can be accommodated in the standard vacuum oscillation or Mikheyev-Smirnov-Wolfenstein solutions by a change of the parameter space of mass square difference and mixing angle, but the shifted neutrino parameters obtained from Super-K will (for some values of neutrino magnetic moments) become incompatible with the fits from SNO, gallium, and chlorine experiments. We compute the upper bounds on the Dirac and Majorana magnetic moments of solar neutrinos by simultaneously fitting all the observed solar neutrino rates. The bounds of the magnetic moment matrix elements are of the order of $10^{-10} \mu_B$. [Phys. Rev. D **66**, 012003 (2002)]

Observation of high energy atmospheric neutrinos with the Antarctic muon and neutrino detector array. J. Ahrens,⁹ E. Andrés,¹⁴

X. Bai,¹ G. Barouch,¹¹ S. W. Barwick,⁸ R. C. Bay,⁷ T. Becker,⁹ K.-H. Becker,² D. Bertrand,³ F. Binon,³ A. Biron,⁴ J. Booth,⁸ O. Botner,¹³ A. Bouchta,⁴ O. Bouhali,³ M. M. Boyce,¹¹ S. Carius,⁵ A. Chen,¹¹ D. Chirkin,⁷ J. Conrad,¹³ J. Cooley,¹¹ C. G. S. Costa,³ D. F. Cowen,¹⁰ E. Dalberg,¹⁴ C. De Clercq,¹⁵ T. DeYoung,¹¹ P. Desiati,¹¹ J.-P. Dewulf,³ P. Doksus,¹¹ J. Edsjö,¹⁴ P. Ekström,¹⁴ T. Feser,⁹ J.-M. Frère,³ T. K. Gaisser,¹ M. Gaug,⁴ A. Goldschmidt,⁶ A. Hallgren,¹³ F. Halzen,¹¹ K. Hanson,¹⁰ R. Hardtke,¹¹ T. Hauschildt,⁴ M. Hellwig,⁹ H. Heukenkamp,⁴ G. C. Hill,¹¹ P. O. Hulth,¹⁴ S. Hundertmark,⁸ J. Jacobsen,⁶ A. Karle,¹¹ J. Kim,⁸ B. Koci,¹¹ L. Köpke,⁹ M. Kowalski,⁴ J. I. Lamoureux,⁶ H. Leich,⁴ M. Leuthold,⁴ P. Lindahl,⁵ I. Liubarsky,¹¹ P. Loaiza,¹³ D. M. Lowder,⁷ J. Madsen,¹² P. Marciniwski,¹³ H. S. Matis,⁶ C. P. McParland,⁶ T. C. Miller,¹ Y. Minaeva,¹⁴ P. Miočinić,⁷ P. C. Mock,⁸ R. Morse,¹¹ T. Neunhöffer,⁹ P. Niessen,^{4,15} D. R. Nygren,⁶ H. Ögelman,¹¹ Ph. Olbrechts,¹⁵ C. Pérez de los Heros,¹³ A. C. Pohl,⁵ R. Porrata,⁸ P. B. Price,⁷ G. T. Przybylski,⁶ K. Rawlins,¹¹ C. Reed,⁸ W. Rhode,² M. Ribordy,⁴ S. Richter,¹¹ J. Rodríguez Martino,¹⁴ P. Romenesko,¹¹ D. Ross,⁸ H.-G. Sander,⁹ T. Schmidt,⁴ D. Schneider,¹¹ R. Schwarz,¹¹ A. Silvestri,^{2,4} M. Solarz,⁷ G. M. Spiczak,¹² C. Spiering,⁴ N. Starinsky,¹¹ D. Steele,¹¹ P. Steffen,⁴ R. G. Stokstad,⁶ O. Streicher,⁴ P. Sudhoff,⁴ K.-H. Sulanke,⁴ I. Taboada,¹⁰ L. Thollander,¹⁴ T. Thon,⁴ S. Tilav,¹ M. Vander Donckt,³ C. Walck,¹⁴ C. Weinheimer,⁹ C. H. Wiebusch,^{4*} C. Wiedeman,¹⁴ R. Wischniewski,⁴ H. Wissing,⁴ K. Woschnagg,⁷ W. Wu,⁸ G. Yodh,⁸ and S. Young⁸ (AMANDA Collaboration), ¹Bartol Research Institute, University of Delaware, Newark, Delaware 19716, ²Fachbereich 8 Physik, BUGH Wuppertal, D-42097 Wuppertal, Germany, ³Université Libre de Bruxelles, Science Faculty CP230, Boulevard du Triomphe, B-1050 Brussels, Belgium, ⁴DESY-Zeuthen, D-15735 Zeuthen, Germany, ⁵Department of Technology, Kalmar University, S-39182 Kalmar, Sweden, ⁶Lawrence Berkeley National Laboratory, Berkeley, California 94720, ⁷Department of Physics, University of California, Berkeley, California 94720, ⁸Department of Physics and Astronomy, University of California, Irvine, California 92697, ⁹Institute of Physics, University of Mainz, Staudinger Weg 7, D-55099 Mainz, Germany, ¹⁰Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, Pennsylvania 19104, ¹¹Department of Physics, University of Wisconsin, Madison, Wisconsin 53706, ¹²Physics Department, University of Wisconsin, River Falls, Wisconsin 54022, ¹³Division of High Energy Physics, Uppsala University, S-75121 Uppsala, Sweden, ¹⁴Department of Physics, Stockholm University, SCFAB, SE-10691 Stockholm, Sweden, ¹⁵Vrije Universiteit Brussel, Dienst ELEM, B-1050 Brussel, Belgium. (Received 1 February 2002; published 31 July 2002)

The Antarctic muon and neutrino detector array (AMANDA) began collecting data with ten strings in 1997. Results from the first year of operation are presented. Neutrinos coming through the Earth from the Northern Hemisphere are identified by secondary muons moving upward through the array. Cosmic rays in the atmosphere generate a background of downward moving muons, which are about 10^6 times more abundant than the upward moving muons. Over 130 days of exposure, we observed a total of about 300 neutrino events. In the same period, a background of 1.05×10^9 cosmic ray muon events was recorded. The observed neutrino flux is consistent with atmospheric neutrino predictions. Monte Carlo simulations indicate that 90% of these events lie in the energy range 66 GeV to 3.4 TeV. The observation of atmospheric neutrinos consistent with expectations establishes AMANDA-B10 as a working neutrino telescope. [Phys. Rev. D **66**, 012005 (2002)]

Statistical analysis of different $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ searches. E. D. Church,¹ K. Eitel,² G. B. Mills,³ and M. Steidl,² ¹University of California, Riverside, California 92521, ²Forschungszentrum Karlsruhe, Institut für Kernphysik, 76021 Karlsruhe, Germany, ³Los Alamos National Laboratory, Los Alamos, New Mexico 87545. (Received 14 March 2002; published 28 June 2002)

A combined statistical analysis of the experimental results of the LSND and KARMEN $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillation search is presented. LSND has evidence for neutrino oscillations that is not confirmed by the KARMEN experiment. This joint analysis is based on the final likelihood results for both data sets. A frequentist approach is applied to deduce confidence regions. At a combined confidence level of 36%, there is no area of oscillation parameters compatible with both experiments. For the complementary confidence of $1 - 0.36 = 64\%$, there are two well defined regions of oscillation parameters ($\sin^2(2\Theta), \Delta m^2$) compatible with both experiments. [Phys. Rev. D **66**, 013001 (2002)]

Towards a unique formula for neutrino oscillations in vacuum. M. Beuthe, *Institut de Physique Théorique, Université Catholique de Louvain, B-1348 Louvain-la-Neuve, Belgium.* (Received 9 February 2002; published 8 July 2002)

We show that all correct results obtained by applying quantum field theory to neutrino oscillations can be understood in terms of a single oscillation formula. In particular, the model proposed by Grimus and Stockinger is shown to be a subcase of the model proposed by Giunti, Kim and Lee, while the new oscillation formulas proposed by Ioannisian and Pilaftsis and by Shtanov are disproved. We derive an oscillation formula without making any relativistic assumption and taking into account the dispersion, so that the result is valid for both neutrinos and mesons. This unification gives a stronger phenomenological basis to the neutrino oscillation formula. We also prove that the coherence length can be increased without bound by more accurate energy measurements. Finally, we insist on the wave packet interpretation of the quantum field treatment of oscillations. [Phys. Rev. D **66**, 013003 (2002)]

Manifestations of extra dimensions in a neutrino telescope. A. Nicolaidis and D. T. Papadamou, *Department of Theoretical Physics, University of Thessaloniki, GR-54006 Thessaloniki, Greece.* (Received 29 March 2002; published 12 July 2002)

Theories with large extra dimensions provide the possibility that a flavor neutrino, localized in a $3+1$ brane, can mix with a singlet neutrino living in the bulk. This mixing leads to unconventional patterns of neutrino matter oscillations and we examine in detail how these oscillations depend upon two parameters: the brane-bulk coupling ξ and the effective mass μ of the flavor neutrino inside matter. We find that high energy ($E \geq 50$ GeV) ν_μ neutrinos, to be detected by neutrino telescopes, can give signals of extra dimensions. With a 1 km^3 neutrino telescope extra dimensions with a radius down to $1 \text{ } \mu\text{m}$ can be tested directly, while for a smaller radius indirect evidence can be established. [Phys. Rev. D **66**, 013005 (2002)]

Confusing nonstandard neutrino interactions with oscillations at a neutrino factory. P. Huber, *Theoretische Physik, Physik Department, Technische Universität München, James-Frank-Strasse, D-85748 Garching, Germany, and Max-Planck-Institut für Physik, Postfach 401212, D-80805 München, Germany*; T. Schwetz and J. W. F. Valle, *Instituto de Física Corpuscular-C.S.I.C., Universitat de València, Edificio Institutos, Aptdo. 22085, E-46071 València, Spain*. (Received 15 February 2002; published 24 July 2002)

Most neutrino mass theories contain nonstandard interactions (NSI) of neutrinos which can be either nonuniversal (NU) or flavor changing (FC). We study the impact of such interactions on the determination of neutrino mixing parameters at a neutrino factory using the so-called “golden channels” $\nu_e \rightarrow \nu_\mu$ for the measurement of θ_{13} . We show that a certain combination of FC interactions in neutrino source and earth matter can give exactly the same signal as oscillations arising due to θ_{13} . This implies that information about θ_{13} can only be obtained if bounds on NSI are available. Taking into account the existing bounds on FC interactions, this leads to a drastic loss in sensitivity in θ_{13} , at least two orders of magnitude. A near detector at a neutrino factory offers the possibility to obtain stringent bounds on some NSI parameters. Such a near site detector constitutes an essential ingredient of a neutrino factory and a necessary step towards the determination of θ_{13} and subsequent study of leptonic CP violation. [Phys. Rev. D **66**, 013006 (2002)]

Estimates of weak and electromagnetic nuclear decay signatures for neutrino reactions in Super-Kamiokande. E. Kolbe, *Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6373*; K. Langanke, *Institut for Fysik og Astronomi, Århus Universitet, DK-8000 Århus C, Denmark*; P. Vogel, *Department of Physics, California Institute of Technology, Pasadena, California 91125*. (Received 2 October 2001; revised manuscript received 26 April 2002; published 24 July 2002)

We estimate possible delayed β decay signatures of the neutrino induced reactions on ^{16}O in a two-step model: the primary neutrino (ν, l) process, where l is the lepton in the final state, is described within the random phase approximation, while the subsequent decay of the excited nuclear state in the final channel is treated within the statistical model. We calculate partial reaction cross sections leading to β unstable nuclei. We consider neutrino energies up to 500 MeV, relevant for atmospheric neutrino detection in Super-Kamiokande, and supernova neutrino spectra. [Phys. Rev. D **66**, 013007 (2002)]

Stringent constraints on cosmological neutrino-antineutrino asymmetries from synchronized flavor transformation. Kevork N. Abazajian, John F. Beacom, and Nicole F. Bell, *NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500*. (Received 25 March 2002; published 29 July 2002)

We assess a mechanism which can transform neutrino-antineutrino asymmetries between flavors in the early universe, and confirm that such transformation is unavoidable in the near bimaximal framework emerging for the neutrino mixing matrix. We show that the process is a standard Mikheyev-Smirnov-Wolfenstein flavor transformation dictated by a synchronization of momentum states. We also show that flavor “equilibration” is a special feature of maximal mixing, and carefully examine new constraints placed on neutrino asymmetries. In particular, the big bang nucleosynthesis limit on electron neutrino degeneracy $|\xi_e| \leq 0.04$ does not apply directly to all flavors, yet confirmation of the large-mixing-angle solution to the solar neutrino problem will eliminate the possibility of degenerate big bang nucleosynthesis. [Phys. Rev. D **66**, 013008 (2002)]

Modification of the saturation model: Dokshitzer-Gribov-Lipatov-Altarelli-Parisi evolution. J. Bartels, *II. Institut für Theoretische Physik, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany*; K. Golec-Biernat, *II. Institut für Theoretische Physik, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany, and H. Niewodniczański Institute of Nuclear Physics, Kraków, Poland*; H. Kowalski, *Deutsches Elektronen Synchrotron DESY, Hamburg, Germany*. (Received 10 May 2002; published 28 June 2002)

We propose to modify the saturation model of Golec-Biernat and Wüsthoff by including Dokshitzer-Gribov-Lipatov-Altarelli-Parisi evolution. We find considerable improvement for the total deep inelastic cross section, in particular in the large Q^2 region. The successful description of deep inelastic scattering diffraction is preserved. [Phys. Rev. D **66**, 014001 (2002)]

Reaction operator approach to multiple elastic scatterings. M. Gyulassy, *Department of Physics, Columbia University, 538 West 120th Street, New York, New York 10027*; P. Levai, *KFKI Research Institute for Particle and Nuclear Physics, P.O. Box 49, Budapest 1525, Hungary*; I. Vitev, *Department of Physics, Columbia University, 538 West 120th Street, New York, New York 10027*. (Received 28 January 2002; published 10 July 2002)

We apply the Gyulassy-Levai-Vitev reaction operator formalism to compute the effects of multiple elastic scatterings of on-shell partons propagating through dense matter. We derive the elastic reaction operator and demonstrate that the recursion relations have a closed form solution that reduces to the familiar Glauber form. We also investigate the accuracy of the Gaussian dipole approximation for the parton transverse momentum broadening. [Phys. Rev. D **66**, 014005 (2002)]

Predictive ability of QCD sum rules for excited baryons. Frank X. Lee, *Center for Nuclear Studies, Department of Physics, The George Washington University, Washington, D.C. 20052, and Jef-*

person Laboratory, 12000 Jefferson Avenue, Newport News, Virginia 23606; Xinyu Liu, Center for Nuclear Studies, Department of Physics, The George Washington University, Washington, D.C. 20052. (Received 22 March 2002; published 30 July 2002)

The masses of octet baryons are calculated by the method of QCD sum rules. Using generalized interpolating fields, three independent sets of QCD sum rules are derived which allow the extraction of low-lying N^* states with spin-parity $1/2^+$, $1/2^-$ and $3/2^-$ in both the non-strange and strange channels. The predictive ability of the sum rules is examined by a Monte Carlo based analysis procedure in which the three phenomenological parameters (mass, coupling, threshold) are treated as free parameters simultaneously. Realistic uncertainties in these parameters are obtained by simultaneously exploring all uncertainties in the QCD input parameters. Those sum rules with good predictive power are identified and their predictions are compared with experiment where available. [Phys. Rev. D **66**, 014014 (2002)]

Superfluid phases of quark matter. III. Supercurrents and vortices. Kei Iida, Department of Physics, University of Illinois at Urbana-Champaign, 1110 West Green Street, Urbana, Illinois 61801-3080, Department of Physics, University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan, and The Institute of Physical and Chemical Research (RIKEN), 2-1 Hirosawa, Wako, Saitama 351-0198, Japan; Gordon Baym, Department of Physics, University of Illinois at Urbana-Champaign, 1110 West Green Street, Urbana, Illinois 61801-3080, and Department of Physics, University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan. (Received 11 April 2002; published 30 July 2002)

We study, within Ginzburg-Landau theory, the responses of three-flavor superfluid quark-gluon plasmas to external magnetic fields and rotation, in both the color-flavor locked and isoscalar color-antitriplet diquark phases near the critical temperature. Fields are incorporated in the gradient energy arising from long wavelength distortions of the condensate, via covariant derivatives to satisfy local gauge symmetries associated with color and electric charge. Magnetic vortex formation, in response to external magnetic fields, is possible only in the isoscalar phase; in the color-flavor locked phase, external magnetic fields are incompletely screened by the Meissner effect. On the other hand, rotation of the superfluid produces vortices in the color-flavor locked phase; in the isoscalar phase, it produces a London gluon-photon mixed field. We estimate the coherence and Meissner lengths and critical magnetic fields for the two phases. [Phys. Rev. D **66**, 014015 (2002)]

Photon production in high energy proton-nucleus collisions. François Gelis, Laboratoire de Physique Théorique, Bâtiment 210, Université Paris XI, 91405 Orsay Cedex, France; Jamal Jalilian-Marian, Physics Department, Brookhaven National Laboratory, Upton, New York 11973. (Received 8 May 2002; published 31 July 2002)

We calculate the photon production cross section in pA collisions under the assumption that the nucleus has reached the saturation regime, while the proton can be described by the standard parton distribution functions. We show that, due to the strong classical field $O(1/g)$ of the nucleus, bremsstrahlung diagrams become dominant over the direct photon diagrams. In particular, we show that γ -jet

transverse momentum spectrum and correlations are very sensitive to gluon saturation effects in the nucleus. [Phys. Rev. D **66**, 014021 (2002)]

Enhanced signal of astrophysical tau neutrinos propagating through Earth. John F. Beacom, NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500; Patrick Crotty, Department of Physics, University of Chicago, Chicago, Illinois 60637; Edward W. Kolb, NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500, Department of Astronomy and Astrophysics, University of Chicago, Chicago, Illinois 60637, and TH Division, CERN, CH-1211 Geneva 23, Switzerland. (Received 26 November 2001; published 9 July 2002)

Earth absorbs ν_e and ν_μ of energies above about 100 TeV. As is well known, although ν_τ will also disappear through charged-current interactions, the ν_τ flux will be regenerated by prompt tau decays. We show that this process also produces relatively large fluxes of secondary $\bar{\nu}_e$ and $\bar{\nu}_\mu$, greatly enhancing the detectability of the initial ν_τ . This is particularly important because at these energies ν_τ is a significant fraction of the expected astrophysical neutrino flux, and only a tiny portion of the atmospheric neutrino flux. [Phys. Rev. D **66**, 021302 (2002)]

Bulk QCD thermodynamics and sterile neutrino dark matter. Kevork N. Abazajian, NASA/Fermilab Astrophysics Group, Fermi National Accelerator Laboratory, Box 500, Batavia, Illinois 60510-0500; George M. Fuller, Department of Physics, University of California, San Diego, La Jolla, California 92093-0319. (Received 18 April 2002; published 31 July 2002)

We point out that the relic densities of singlet (sterile) neutrinos of interest in viable warm and cold dark matter scenarios depend on the characteristics of the QCD transition in the early universe. In the most promising of these dark matter scenarios, the production of the singlets occurs at or near the QCD transition. Since production of the singlets, their dilution, and the disappearance of weak scatterers occur simultaneously, we calculate these processes contemporaneously to obtain accurate predictions of relic sterile neutrino mass density. Therefore, a determination of the mass and superweak mixing of the singlet neutrino through, for example, its radiative decay, along with a determination of its contribution to the critical density, can provide insight into the finite-temperature QCD transition. [Phys. Rev. D **66**, 023526 (2002)]

Analytical treatment of neutrino asymmetry equilibration from flavor oscillations in the early universe. Yvonne Y. Y. Wong, Department of Physics and Astronomy, University of Delaware, Newark, Delaware 19716. (Received 19 March 2002; published 18 July 2002)

A recent numerical study by A. D. Dolgov, S. H. Hansen, S. Pastor, S. T. Petcov, G. G. Raffelt, and D. V. Semikoz (DHPPRS) [Nucl. Phys. **B632**, 363 (2002)] found that complete or partial equilibrium between all active neutrino flavors can be achieved before the big bang nucleosynthesis epoch via flavor oscillations, if the oscillation parameters are those inferred from the atmospheric and solar neutrino data, and, in some cases, if θ_{13} is also sizable. As

such, cosmological constraints on the electron neutrino-antineutrino asymmetry are now applicable in all three neutrino sectors. In the present work, we provide an analytical treatment of the scenarios considered in DHPPRS, and demonstrate that their results are stable even for very large initial asymmetries. The equilibration mechanism can be understood in terms of a Mikheyev-Smirnov-Wolfenstein-like effect for a maximally mixed and effectively monochromatic system. We also comment on the DHPPRS's choices of mixing parameters, and their handling of collisional effects, both of which could impinge on the extent of flavor equilibrium. [Phys. Rev. D **66**, 025015 (2002)]

Two-gluon form factor of the nucleon and J/ψ photoproduction. L. Frankfurt, *School of Physics and Astronomy, Raymond and Beverly Sackler Faculty of Exact Science, Tel Aviv University, Ramat Aviv 69978, Tel Aviv, Israel*; M. Strikman, *Pennsylvania State University, University Park, Pennsylvania 16802*. (Received 23 May 2002; published 26 August 2002)

We argue that the t dependence of the two-gluon form factor of the nucleon should be given by $\Gamma(t) = (1 - t/m_{2g}^2)^{-2}$ with $m_{2g}^2 \approx 1 \text{ GeV}^2$. We demonstrate that this form provides a good description of the t dependence of the cross section of the elastic photo-production of J/ψ mesons between the threshold region of $E_\gamma = 11 \text{ GeV}$ (Cornell), $E_\gamma = 19 \text{ GeV}$ (SLAC) and $E_\gamma = 100 \text{ GeV}$ (Fermilab), including the strong energy dependence of the t slope. It is also well matched with the recent DESY HERA data. The same assumption explains also the t dependence of ϕ -meson electroproduction near threshold at $W = 2.3 \text{ GeV}$, $Q^2 = 1.0 \text{ GeV}^2$. [Phys. Rev. D **66**, 031502 (2002)]

Search for neutron-antineutron oscillations using multiprong events in Soudan 2. J. Chung,⁵ W. W. M. Allison,³ G. J. Alner,⁴ D. S. Ayres,¹ W. L. Barrett,⁶ P. M. Border,² J. H. Cobb,³ H. Courant,² D. M. Demuth,² T. H. Fields,¹ H. R. Gallagher,⁵ M. C. Goodman,¹ R. Gran,² T. Joffe-Minor,¹ T. Kafka,⁵ S. M. S. Kasahara,² P. J. Litchfield,⁴ W. A. Mann,⁵ M. L. Marshak,² R. H. Milburn,⁵ W. H. Miller,² L. Mualem,² A. Napier,⁵ W. P. Oliver,⁵ G. F. Pearce,⁴ E. A. Peterson,² D. A. Petyt,⁴ K. Ruddick,² M. Sanchez,⁵ J. Schneps,⁵ A. Sousa,⁵ B. Speakman,² J. L. Thron,¹ S. P. Wakely,² and N. West³
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 29 May 2002; published 15 August 2002)

We have searched for neutron-antineutron oscillations using the 5.56 fiducial kiloton-year exposure of the Soudan 2 iron tracking calorimeter. We require candidate $n\bar{n}$ occurrences to have ≥ 4 prongs (tracks and showers) and to have kinematics compatible with $n\bar{n}$ annihilation within a nucleus. We observe five candidate events, with an estimated background from atmospheric neutrino and cosmic ray induced events of 4.5 ± 1.2 events. Previous experiments with smaller exposures observed no candidates, with estimated background rates similar to this experiment. We set a lifetime lower limit at 90% C.L. for the $n\bar{n}$ oscillation time in iron:

$T_A(\text{Fe}) > 7.2 \times 10^{31} \text{ yr}$. The corresponding lower limit for oscillation of free neutrons is $\tau_{n\bar{n}} > 1.3 \times 10^8 \text{ sec}$. [Phys. Rev. D **66**, 032004 (2002)]

Detection of supernova neutrinos by neutrino-proton elastic scattering. John F. Beacom, *NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500*; Will M. Farr and Petr Vogel, *Physics Department 161-33, Caltech, Pasadena, California 91125*. (Received 20 May 2002; published 1 August 2002)

We propose that neutrino-proton elastic scattering, $\nu + p \rightarrow \nu + p$, can be used for the detection of supernova neutrinos in scintillator detectors. Though the proton recoil kinetic energy spectrum is soft, with $T_p \approx 2E_\nu^2/M_p$, and the scintillation light output from slow, heavily ionizing protons is quenched, the yield above a realistic threshold is nearly as large as that from $\bar{\nu}_e + p \rightarrow e^+ + n$. In addition, the measured proton spectrum is related to the incident neutrino spectrum, which solves a long-standing problem of how to separately measure the total energy and temperature of ν_μ , ν_τ , $\bar{\nu}_\mu$, and $\bar{\nu}_\tau$. The ability to detect this signal would give detectors like KamLAND and Borexino a crucial and unique role in the quest to detect supernova neutrinos. [Phys. Rev. D **66**, 033001 (2002)]

(μ^-, μ^+) conversion in nuclei as a probe of new physics. Fedor Simkovic and Amand Faessler, *Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany*; Sergey Kovalenko and Ivan Schmidt, *Departamento de Física, Universidad Técnica Federico Santa María, Casilla 110-V, Valparaíso, Chile*. (Received 20 December 2001; published 14 August 2002)

We present a detailed analysis of the muonic analogue of neutrinoless double beta decay (μ^-, μ^+) conversion. We study several lepton number violating (LNV) mechanisms potentially triggering this process: exchange by light and heavy Majorana neutrinos as well as exchange by supersymmetric particles participating in R -parity violating interactions. The nuclear structure is taken into account within the renormalized quasiparticle random phase approximation method. This is the first realistic treatment of nuclear structure aspects of the (μ^-, μ^+) conversion. We estimate the rate of this process utilizing the existing experimental constraints on the parameters of the underlying LNV interactions and conclude that the (μ^-, μ^+) conversion will hardly be detectable in the near future experiments. [Phys. Rev. D **66**, 033005 (2002)]

Earth effects on supernova neutrinos and their implications for neutrino parameters. Keitaro Takahashi, *Department of Physics, University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan*; Katsuhiko Sato, *Department of Physics, University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan*, and Research Center for the Early Universe, *University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan*. (Received 9 October 2001; published 19 August 2002)

We perform a detailed study of the Earth matter effects on supernova neutrinos with neutrino oscillation parameter LMA and small θ_{13} . The Earth effects show significant dependences on the neutrino

path length inside the Earth and the value of Δm_{12}^2 . We investigate rather optimistically the possibility that we can probe the value of Δm_{12}^2 by the Earth effects. We assume that θ_{12} and the direction of the supernova are known with enough accuracy and that the resonance that occurs at higher density in supernova envelope is completely nonadiabatic. Further the neutrino spectra before neutrinos go through the Earth are assumed to be known. Then we show that, making use of these dependences, we can obtain an implication for the value of Δm_{12}^2 by comparing the observed energy spectrum to the predicted one. When SK detects neutrinos from supernova at 10 kpc which traveled through Earth (nadir angle $< 80^\circ$), Δm_{12}^2 can be determined with an accuracy of $\sim 10\%$. In much of the neutrino-detection-time- Δm_{12}^2 plane, Δm_{12}^2 might be determined with an accuracy equal to or better than $\pm 0.5 \times 10^{-5} \text{eV}^2$. [Phys. Rev. D **66**, 033006 (2002)]

Polyakov loops versus hadronic states. Francesco Sannino, *NORDITA, Blegdamsvej 17, DK-2100 Copenhagen Ø, Denmark*. (Received 19 April 2002; published 15 August 2002)

The order parameter for the pure Yang-Mills phase transition is the Polyakov loop which encodes the symmetries of the Z_N center of the $SU(N)$ gauge group. On the other side the physical degrees of freedom of any asymptotically free gauge theory are hadronic states. Using the Yang-Mills trace anomaly and the exact Z_N symmetry we construct a model able to communicate to the hadrons the information carried by the order parameter. [Phys. Rev. D **66**, 034013 (2002)]

Closed-time path integral formalism and medium effects of nonequilibrium QCD matter. Chung-Wen Kao, Gouranga C. Nayak, and Walter Greiner, *Institut für Theoretische Physik, J. W. Goethe-Universität, 60054 Frankfurt am Main, Germany*. (Received 13 February 2001; revised manuscript received 19 April 2002; published 20 August 2002)

We apply the closed-time path integral formalism to study the medium effects of nonequilibrium gluon matter. We derive the medium modified resummed gluon propagator to the one loop level in nonequilibrium in the covariant gauge. The gluon propagator we derive can be used to remove the infrared divergences in the secondary parton collisions to study the thermalization of minijet parton plasma at BNL RHIC and CERN LHC. [Phys. Rev. D **66**, 034017 (2002)]

Critical correlations of Wilson lines in $SU(3)$ and the high energy γ^*p cross section. Hans J. Pirner^{1,2} and Feng Yuan¹ *¹Institut für Theoretische Physik der Universität Heidelberg, Heidelberg, Germany, ²Max-Planck-Institut für Kernphysik, Heidelberg, Germany*. (Received 21 March 2002; published 20 August 2002)

We discuss deep inelastic scattering at high energies as a critical phenomenon in $2+1$ space-time dimensions. In the limit of Bjorken $x \rightarrow 0$, QCD $SU(3)$ with quark fields becomes a critical theory with a diverging correlation length $\xi(x) \propto x^{-1/2\lambda_2}$ where the exponent $\lambda_2 = 2.52$ is obtained from the center group $Z(3)$ of $SU(3)$. We conjecture that the dipole wave function of the virtual photon for transverse sizes $1/Q < x_\perp < \xi$ obeys a correlation scaling $\Psi \propto (x_\perp)^{-(1+n)}$ before exponentially decaying for distances larger

than the correlation length. Using this behavior combined with different x -independent dipole proton cross sections we calculate the proton structure function and compare it with the experimental data. We take the good agreement with the measured proton structure function $F_2(x, Q^2)$ as an indication that at high energies dimensional reduction to an effective three dimensional theory with a critical point occurs. [Phys. Rev. D **66**, 034020 (2002)]

Recoil order chiral corrections to baryon octet axial vector currents and large N_c QCD. Shi-Lin Zhu, *Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California 91125*; G. Sacco and M. J. Ramsey-Musolf, *Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California 91125, and Department of Physics, University of Connecticut, Storrs, Connecticut 06269*. (Received 22 January 2002; published 20 August 2002)

We compute the chiral corrections to octet baryon axial vector currents through $\mathcal{O}(p^3)$ in heavy baryon chiral perturbation theory, including both octet and decuplet baryon intermediate states. We include the latter in a consistent way by using the small scale expansion. We find that, in contrast to the situation at $\mathcal{O}(p^2)$, there exist no cancellations between octet and decuplet contributions at $\mathcal{O}(p^3)$. Consequently, the $\mathcal{O}(p^3)$ corrections spoil the expected scaling behavior of the chiral expansion. We discuss this result in terms of the $1/N_c$ expansion. We also consider the implications for the determination of the strange quark contribution to the nucleon spin from polarized deep inelastic scattering data. [Phys. Rev. D **66**, 034021 (2002)]

Investigations of the πN total cross sections at high energies using a new finite-energy sum rule: $\log \nu$ or $(\log \nu)^2$. Keiji Igi, *Department of Information Science, Kanagawa University, Hiratsuka, Kanagawa 259-1293, Japan*; Muneyuki Ishida, *Department of Physics, Tokyo Institute of Technology, Tokyo 152-8551, Japan*. (Received 27 April 2002; published 22 August 2002)

We propose to use rich information on πp total cross sections below $N(\sim 10 \text{ GeV})$ in addition to high-energy data in order to discern whether these cross sections increase like $\log \nu$ or $(\log \nu)^2$ at high energies, since it is difficult to discriminate between asymptotic $\log \nu$ and $(\log \nu)^2$ fits from high-energy data alone. A finite-energy sum rule (FESR) which is derived in the spirit of the P' sum rule as well as the $n=1$ moment FESR is required to constrain the high-energy parameters. We then search for the best fit of $\sigma_{\text{tot}}^{(+)}$ above 70 GeV in terms of high-energy parameters constrained by these two FESR's. We can show from this analysis that the $(\log \nu)^2$ behavior is preferred to the $\log \nu$ behavior. [Phys. Rev. D **66**, 034023 (2002)]

Parton model versus color dipole formulation of the Drell-Yan process. Jörg Raufeisen, *Los Alamos National Laboratory, Los Alamos, New Mexico 87545*; Jen-Chieh Peng, *Los Alamos National Laboratory, Los Alamos, New Mexico 87545, and Department of Physics, University of Illinois, Urbana, Illinois 61801*; Gouranga C. Nayak, *Los Alamos National Laboratory, Los Alamos, New Mexico 87545*. (Received 10 April 2002; published 22 August 2002)

In the kinematical region where the center of mass energy is much larger than all other scales, the Drell-Yan process can be formulated in the target rest frame in terms of the same color dipole cross section as low Bjorken- x deep inelastic scattering. Since the mechanisms for heavy dilepton production appear very different in the dipole approach and in the conventional parton model, one may wonder whether these two formulations really represent the same physics. We perform a comparison of numerical calculations in the color dipole approach with calculations in the next-to-leading order parton model. For proton-proton scattering, the results are very similar at low x_2 from fixed target to Relativistic Heavy Ion Collider (RHIC) energies, confirming the close connection between these two very different approaches. We also compare the transverse momentum distributions of Drell-Yan dileptons predicted in both formulations. The range of applicability of the dipole formulation and the impact of future Drell-Yan data from RHIC for determining the color dipole cross section are discussed. A detailed derivation of the dipole formulation of the Drell-Yan process is also included. [Phys. Rev. D **66**, 034024 (2002)]

Hard production in multiple parton scattering. Giorgio Calucci and Enrico Cattaruzza, *Dipartimento di Fisica Teorica dell'Università di Trieste, Trieste I 34014, Italy, and INFN, Sezione di Trieste, Italy*. (Received 22 May 2002; published 28 August 2002)

In some previous treatments of multiple scattering in hadron-hadron collisions a sharp distinction was introduced between a soft part of the interaction, which generates the parton population and the hard part which produces the scattering between forward and backward partons, this last being followed by other soft processes that give rise to the hadronization. So at the elementary partonic level the interaction is elastic. An attempt to complete this description is now presented; it introduces into the dynamics the possibility of hard production. The topic is developed at the level in which in an elementary partonic collision at most one secondary particle is produced but this production can happen any number of times and may be followed by the reabsorption of the produced partons and by their elastic scattering. Some possible consequences of these basically inelastic processes are outlined. [Phys. Rev. D **66**, 034028 (2002)]

Diffraction effects in spin-flip pp amplitudes and predictions for relativistic energies. A. F. Martini, *Instituto de Física Gleb Wataghin, Universidade Estadual de Campinas, Unicamp, 13083-970 Campinas, São Paulo, Brazil*; E. Predazzi, *Università di Torino and INFN, Sezione di Torino, Via Pietro Giuria, 1, 10125 Torino, Italy*. (Received 13 June 2002; published 28 August 2002)

We analyze the diffractive (Pomeron) contribution to the pp spin-flip amplitude and discuss the possible scenarios for energies available at the Relativistic Heavy-Ion Collider (RHIC). In particular, we show that RHIC data will be instrumental in assessing the real contribution of diffraction to spin amplitudes. [Phys. Rev. D **66**, 034029 (2002)]

Moments of nucleon light cone quark distributions calculated in full lattice QCD. D. Dolgov, R. Brower, S. Capitani, P. Dreher, J. W. Negele, A. Pochinsky, and D. B. Renner, *Center for Theoretical Physics, Laboratory for Nuclear Science, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139*; N. Eicker, Th. Lippert, and K. Schilling, *Department of Physics, University of Wuppertal, D-42097 Wuppertal, Germany*; R. G. Edwards, *Jefferson Lab, 12000 Jefferson Avenue, MS 12H2, Newport News, Virginia 23606*; U. M. Heller, *CSIT, Florida State University, Tallahassee, Florida 32306* (LHPC and SESAM Collaborations). (Received 5 February 2002; published 26 August 2002)

Moments of the quark density, helicity, and transversity distributions are calculated in unquenched lattice QCD. Calculations of proton matrix elements of operators corresponding to these moments through operator product expansion have been performed on $16^3 \times 32$ lattices for Wilson fermions at $\beta=5.6$ using configurations from the SESAM Collaboration and at $\beta=5.5$ using configurations from SCRI. One-loop perturbative renormalization corrections are included. At quark masses accessible in present calculations, there is no statistically significant difference between quenched and full QCD results, indicating that the contributions of quark-antiquark excitations from the Dirac sea are small. The close agreement between calculations with cooled configurations containing essentially only instantons and the full gluon configurations indicates that quark zero modes associated with instantons play a dominant role. A naive linear extrapolation of the full QCD calculation to the physical pion mass yields results inconsistent with experiment. An extrapolation to the chiral limit including the physics of the pion cloud can resolve this discrepancy and the requirements for a definitive chiral extrapolation are described. [Phys. Rev. D **66**, 034506 (2002)]

Forced tunneling and turning state explosion in pure Yang-Mills theory. D. M. Ostrovsky, *Department of Physics and Astronomy, State University of New York, Stony Brook, New York 11794-3800*; G. W. Carter, *Department of Physics, Box 351560, University of Washington, Seattle, Washington 98195-1560*; E. V. Shuryak, *Department of Physics and Astronomy, State University of New York, Stony Brook, New York 11794-3800*. (Received 25 April 2002; published 20 August 2002)

We consider forced tunneling in QCD, described semiclassically by instanton-anti-instanton field configurations. By separating topologically different minima we obtain details of the effective potential and study the turning states, which are similar to the sphaleron solution in electroweak theory. These states are alternatively derived as minima of the energy under the constraints of fixed size and Chern-Simons number. We study, both analytically and numerically, the subsequent evolution of such states by solving the classical Yang-Mills equations in real time, and find that the gauge field strength is quickly localized into an expanding shell of radiating gluons. The relevance to high-energy collisions of hadrons and nuclei is briefly discussed. [Phys. Rev. D **66**, 036004 (2002)]