

## 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.*

**Study of the reaction  $\bar{p}p \rightarrow \phi\phi$  from 1.1 to 2.0 GeV/c.** C. Evangelista and A. Palano, *University of Bari and INFN, I-70126 Bari, Italy*; D. Drijard, N. H. Hamann, R. T. Jones, B. Mouëllic, S. Ohlsson, and J.-M. Perreau, *CERN, CH-1211 Geneva, Switzerland*; W. Eylich, M. Moosburger, S. Pomp, and F. Stinzinger, *University of Erlangen-Nürnberg, W-8520 Erlangen, Germany*; H. Fischer, J. Franz, E. Rösle, H. Schmitt, and H. Wirth, *University of Freiburg, W-7800 Freiburg, Germany*; A. Buzzo, K. Kirsebom, M. Lo Vetere, M. Macrì, M. Marinelli, S. Passaggio, M. G. Pia, A. Pozzo, E. Robutti, and A. Santroni, *University of Genova and INFN, I-16132 Genova, Italy*; P. T. Debevec, R. A. Eisenstein, P. G. Harris, D. W. Hertzog, S. A. Hughes, P. E. Reimer, J. Ritter, *University of Illinois, Urbana, Illinois 61801*; R. Geyer, K. Kilian, W. Oelert, K. Röhlich, M. Rook, and O. Steinkamp, *Institut für Kernphysik, Forschungszentrum Jülich, D-5170 Jülich, Germany*; H. Korsmo and B. Stugu, *University of Oslo, N-0316 Oslo, Norway*; T. Johansson, *Uppsala University, S-75121 Uppsala, Sweden*. (Received 13 January 1998; published 7 April 1998)

A study has been performed of the reaction  $\bar{p}p \rightarrow 4K^\pm$  using in-flight antiprotons from 1.1 to 2.0 GeV/c incident momentum interacting with a hydrogen jet target. The reaction is dominated by the production of a pair of  $\phi$  mesons. The  $\bar{p}p \rightarrow \phi\phi$  cross section rises sharply above threshold and then falls continuously as a function of increasing antiproton momentum. The overall magnitude of the cross section exceeds expectations from a simple application of the Okubo-Zweig-Iizuka rule by two orders of magnitude. In a fine scan around the  $\xi/f_J(2230)$  resonance, no structure is observed. A limit is set for the double branching ratio  $B(\xi \rightarrow \bar{p}p) \times B(\xi \rightarrow \phi\phi) < 6 \times 10^{-5}$  for a spin 2 resonance of  $M=2.235$  GeV and  $\Gamma=15$  MeV. [S0556-2821(98)02511-9] [Phys. Rev. D **57**, 5370 (1998)]

**Different low- $x$  behavior of the spin structure functions  $g_1(x)$  and  $h_1(x)$ .** S. M. Troshin and N. E. Tyurin, *Institute for High Energy Physics, Protvino, Moscow Region, 142284 Russia*. (Received 14 October 1997; revised manuscript received 5 January 1998; published 3 April 1998)

We consider the low- $x$  behavior of the spin structure functions  $g_1(x)$  and  $h_1(x)$  in the unitarized chiral quark model that combines the ideas on constituent quark structure of hadrons with a geometrical scattering picture and unitarity. A nondiffractive singular low- $x$  dependence of  $g_1^p(x)$  and  $g_1^n(x)$  is obtained and a diffractive type smooth behavior of  $h_1(x)$  is predicted at small  $x$ . A comparison with the experimental data is given. The estimations for the double-spin asymmetries in the low-mass Drell-Yan production at BNL RHIC in the central region are presented also. [S0556-2821(98)01711-1] [Phys. Rev. D **57**, 5473 (1998)]

**Hadronic molecules in lattice QCD.** Chris Stewart and Roman Koniuk, *Department of Physics and Astronomy, York University, 4700 Keele Street, Toronto, Ontario, Canada M3J 1P3*. (Received 17 November 1997; published 7 April 1998)

An adiabatic approximation is used to derive the binding potential between two heavy-light mesons in quenched SU(2)-color lattice QCD. Analysis of the meson-meson system shows that the potential is attractive at short and medium range. The numerical data is consistent with the Yukawa model of pion exchange. [S0556-2821(98)02911-7] [Phys. Rev. D **57**, 5581 (1998)]

**Matching of matrix elements and parton showers.** J. André and T. Sjöstrand, *Department of Theoretical Physics, Lund University, Sölvegatan 14A, S-223 62 Lund, Sweden*. (Received 18 August 1997; published 3 April 1998)

We propose a simple scheme to start a parton-shower evolution description from a given jet configuration in  $e^+e^-$  annihilation events. This allows a convenient combination of the full angular information content of matrix elements with the detailed sub-jet structure of parton showers, and should give a realistic overall description of event properties. Explicit studies with this hybrid approach are presented for the four-jet case, as a simple testing ground of the ideas. [S0556-2821(98)02711-8] [Phys. Rev. D **57**, 5767 (1998)]

**Upward-going muons and neutrino oscillations.** G. L. Fogli, E. Lisi, and A. Marrone, *Dipartimento di Fisica and Sezione INFN di Bari, Via Amendola 173, I-70126 Bari, Italy*. (Received 31 July 1997; published 7 April 1998)

The available upward-going muon data from the Kamiokande, Baksan, MACRO, IMB, and SuperKamiokande experiments are reviewed and combined. Bounds on the neutrino mass and mixing parameters are derived for oscillations in two and three flavors. These bounds are not in significant conflict with the oscillation solution to the atmospheric neutrino flavor anomaly observed in the sub-GeV and multi-GeV energy range. The combination of all the available atmospheric data tends to favor the  $\nu_\mu \leftrightarrow \nu_e$  channel with respect to the  $\nu_\mu \leftrightarrow \nu_\tau$  channel, and to disfavor the threefold maximal mixing scenario. [S0556-2821(98)00311-7] [Phys. Rev. D **57**, 5893 (1998)]

**Cooling modes of neutron stars.** Chueng-Ryong Ji, *Department of Physics, North Carolina State University, Raleigh, North Carolina 27695-8202*; Dong-Pil Min, *Department of Physics, North Carolina State University, Raleigh, North Carolina 27695-8202 and Department of Physics, Seoul National University, Seoul, Korea*. (Received 10 March 1997; published 28 April 1998)

The direct Urca process is studied in the presence of kaon condensation. We consider the contributions from both strange and nonstrange hadrons. Our calculations indicate that the role of hyperons is as important as the role of nonstrange nucleons in the cooling mechanism of neutron stars. We also find that the temperature dependence of the weak neutral current contribution is given by  $T^7$ , which intermediates between the direct Urca process of  $T^6$  and the modified Urca process of  $T^8$ . [S0556-2821(98)01910-9] [Phys. Rev. D **57**, 5963 (1998)]

**Proton spin content and QCD topological susceptibility.** B. L. Ioffe and A. G. Oganesian, *Institute of Theoretical and Experimental Physics, B. Cheremushkinskaya 25, Moscow 117218, Russia*. (Received 20 January 1998; published 8 May 1998)

The part of the proton spin  $\Sigma$  carried by  $u, d, s$  quarks is calculated in the framework of the QCD sum rules in the external fields. The operators up to dimension 9 are accounted for. An important contribution comes from the operator of dimension 3, which in the limit of massless  $u, d, s$  quarks is equal to the derivative of the QCD topological susceptibility  $\chi'(0)$ . The comparison with the experimental data on  $\Sigma$  gives  $\chi'(0) = (2.3 \pm 0.6) \times 10^{-3} \text{ GeV}^2$ . The limits on  $\Sigma$  and  $\chi'(0)$  are found from self-consistency of the sum rule,  $\Sigma \geq 0.05$ ,  $\chi'(0) \geq 1.6 \times 10^{-3} \text{ GeV}^2$ . The values of  $g_A = 1.37 \pm 0.10$  and  $g_A^8 = 0.65 \pm 0.15$  are also determined. [S0556-2821(98)50211-1] [Phys. Rev. D **57**, 6590 (1998)]

**Examination of neutrino oscillations using high-energy atmospheric neutrino data from Kamiokande.** Yuichi Oyama, *High Energy Accelerator Research Organization (KEK), Ibaraki 305, Japan*. (Received 17 December 1997; published 7 May 1998)

The possibility of neutrino oscillations using high-energy atmospheric neutrinos are reconsidered. High-energy ( $> 10 \text{ GeV}$ ) electron events from atmospheric electron neutrinos are drastically enhanced in the case of  $\nu_e \leftrightarrow \nu_\mu$  oscillation. This should be compared to the conventional neutrino oscillation analysis, in which only disappearance of upward-going muons was examined. Constraints for  $\nu_e \leftrightarrow \nu_\mu$  oscillation are calculated, using data of the Kamiokande experiment. The resulting 90% C.L. upper limits on the neutrino oscillation parameters,  $\Delta m^2$  and  $\sin^2 2\theta$ , are  $\Delta m^2 < 5.6 \times 10^{-3} \text{ eV}^2$  for  $\sin^2 2\theta = 1$  and  $\sin^2 2\theta < 0.60$  for large  $\Delta m^2$ , respectively. This result excludes most of the allowed region for the  $\nu_e \leftrightarrow \nu_\mu$  oscillation, which was obtained from a recent sub-GeV and multi-GeV atmospheric neutrino analysis. [S0556-2821(98)50411-0] [Phys. Rev. D **57**, 6594 (1998)]

**Measuring the antihydrogen Lamb shift with a relativistic antihydrogen beam.** G. Blanford, K. Gollwitzer, M. Mandelkern, J. Schultz, G. Takei, and G. Zioulas, *University of California at Irvine, Irvine, California 92717*; D. C. Christian, *Fermilab, Batavia, Illinois 60510*; C. T. Munger, *Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309*. (Received 18 December 1997; published 4 May 1998)

We propose an experiment to measure the Lamb shift and fine structure (the intervals  $2s_{1/2} - 2p_{1/2}$  and  $2p_{1/2} - 2p_{3/2}$ ) in antihydro-

gen. A sample of 10 000 antihydrogen atoms at a momentum of  $8.85 \text{ GeV}/c$  suffices to measure the Lamb shift to 5% and the fine structure to 1%. Atomic collisions excite antihydrogen atoms to states with  $n=2$ ; field ionization in a Lorentz-transformed laboratory magnetic field then prepares a particular  $n=2$  state, and is used again to analyze that state after it is allowed to oscillate in a region of zero field. This experiment is feasible at Fermilab. [S0556-2821(98)04711-0] [Phys. Rev. D **57**, 6649 (1998)]

**Effect of off-diagonal parton distributions in diffractive vector meson electroproduction.** A. D. Martin and M. G. Ryskin, *Department of Physics, University of Durham, DH1 3LE, United Kingdom*. (Received 18 November 1997; published 16 April 1998)

We present a simple physical description of the off-diagonal gluon distribution  $g(x, x', Q^2)$  and splitting function  $P_{gg}(x, x')$  which enter the amplitude for diffractive vector meson production. We study the off-diagonal effects both on the evolution in  $Q^2$  and on the input distribution. We predict the ratio  $R$  of the off-diagonal to the diagonal gluon density,  $x'g(x, x', Q^2)/xg(x, Q^2)$ , as a function of the kinematic variables. [S0556-2821(98)04511-1] [Phys. Rev. D **57**, 6692 (1998)]

**Mass spectrum of light and heavy hadrons from improved lattice actions.** J. P. Ma and B. H. J. McKellar, *School of Physics, University of Melbourne, Parkville, Victoria 3052, Australia*. (Received 30 June 1997; published 13 May 1998)

We use improved lattice actions for glue, light quarks, and heavy quarks for which we use lattice NRQCD to compute hadron masses. Our results are in good agreement with experiment, except for charmed hadrons. It seems that charmed quarks are not well approximated as heavy quarks nor as light quarks. [S0556-2821(98)03311-6] [Phys. Rev. D **57**, 6723 (1998)]

**Photoproduction and electroproduction of  $J^{PC} = 1^{-+}$  exotics.** Andrei Afanasev and Philip R. Page, *Theory Group, Thomas Jefferson National Accelerator Facility, 12000 Jefferson Avenue, Newport News, Virginia 23606*. (Received 15 January 1998; published 13 May 1998)

We estimate the kinematic dependence of the exclusive photo- and electro-production of  $J^{PC} = 1^{-+}$  exotic mesons due to  $\pi$  exchange. We show that the kinematic dependence is largely independent of the exotic meson form factor, which is explicitly derived for a  $1^{-+}$  isovector hybrid meson in the flux-tube model of Isgur and Paton. The relevance to experiments currently planned at Jefferson Lab is indicated. [S0556-2821(98)05411-3] [Phys. Rev. D **57**, 6771 (1998)]

**Tetraquarks with heavy flavors.** D. M. Brink, *Dipartimento di Fisica, Università degli Studi di Trento, I-38050 Povo (Trento), Italy*; Fl. Stancu, *Université de Liège, Institut de Physique B5, Sart Tilman, B-4000 Liège 1, Belgium*. (Received 4 November 1997; published 12 May 1998)

In the framework of a simple nonrelativistic potential model, we have previously studied the stability of a system of two quarks and two antiquarks of identical light flavor. Here, we extend our analysis to quarks (antiquarks) of different masses and discuss the role of heavy flavors on the stability of the system. This analysis is performed by using a simple variational method which proved powerful in the treatment of other few-body systems. We compare our results with other results from the literature and single out a few characteristics of the spectrum of the tetraquarks. [S0556-2821(98)05811-1] [Phys. Rev. D **57**, 6778 (1998)]

**Towards a unified description of total and diffractive structure functions at DESY HERA in the QCD dipole picture.** A. Bialas, *Institute of Physics, Jagellonian University, Reymonta 4, 30-059 Cracow, Poland*; R. Peschanski, *Commissariat à l'Energie Atomique, Service de Physique Théorique, CE-Saclay, F-91191 Gif-sur-Yvette Cedex, France*; Ch. Royn, *Commissariat à l'Energie Atomique, DAPNIA, Service de Physique des Particules, CE-Saclay, F-91191 Gif-sur-Yvette, France*. (Received 1 December 1997; published 4 May 1998)

It is argued that the QCD dipole picture allows us to build a unified theoretical description, based on Balitskii-Fadin-Kuraev-Lipatov dynamics, of the total and diffractive nucleon structure functions. This description is in qualitative agreement with the present collection of data obtained by the H1 Collaboration. More precise theoretical estimates, in particular the determination of the normalizations and proton transverse momentum behavior of the diffractive components, are shown to be required in order to reach definite conclusions. [S0556-2821(98)03011-2] [Phys. Rev. D **57**, 6899 (1998)]

**Double-scattering contribution to  $b_1(x, Q^2)$  in the deuteron.** K. Bora, *Center for Theoretical Physics, Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139*; R. L. Jaffe, *Center for Theoretical Physics, Laboratory for Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139 and RIKEN BNL Research Center, Brookhaven National Laboratory, Upton, New York 11973*. (Received 30 December 1997; published 8 May 1998)

We study the tensor structure function  $b_1(x, Q^2)$  in deep inelastic scattering of an electron from a polarized deuteron target. We model the electron-nucleon cross section at the starting point for  $Q^2$  evolution by vector-meson dominance. Shadowing due to the double scattering of vector mesons, along with the presence of a  $d$ -state admixture in a ground-state deuteron wave function gives rise to a nonvanishing contribution to  $b_1(x, Q^2)$ . We find a large enhancement at low  $x$  in qualitative agreement with other recent estimates of double-scattering contributions to  $b_1(x, Q^2)$ . If the model is valid, it should apply within the range of present fixed-target experiments. [S0556-2821(98)06111-6] [Phys. Rev. D **57**, 6906 (1998)]

**Neutrino oscillation constraints on neutrinoless double-beta decay.** S. M. Bilenky, *Joint Institute for Nuclear Research, Dubna, Russia and Institute for Advanced Study, Princeton, New Jersey 08540*; C. Giunti, *INFN, Sezione di Torino, and Dipartimento di Fisica Teorica, Università di Torino, Via P. Giuria 1, I-10125 Torino, Italy*; C. W. Kim, *Department of Physics and Astronomy, The Johns Hopkins University, Baltimore, Maryland 21218 and School of Physics, Korea Institute for Advanced Study, Seoul 130-012, Korea*; M. Monteno, *INFN, Sezione di Torino, and Dipartimento di Fisica Sperimentale, Università di Torino, Via P. Giuria 1, I-10125 Torino, Italy*. (Received 21 November 1997; published 7 May 1998)

We have studied the constraints imposed by the results of neutrino oscillation experiments on the effective Majorana mass  $|\langle m \rangle|$  that characterizes the contribution of Majorana neutrino masses to the matrix element of neutrinoless double-beta decay. We have shown that in a general scheme with three Majorana neutrinos and a hierarchy of neutrino masses (which corresponds to the standard seesaw mechanism) the results of neutrino oscillation experiments imply rather strong constraints on the parameter  $|\langle m \rangle|$ . From the results of the first reactor long-baseline experiment CHOOZ and the Bugey experiment it follows that  $|\langle m \rangle| \lesssim 3 \times 10^{-2}$  eV if  $\Delta m^2 \lesssim 2$  eV<sup>2</sup> ( $\Delta m^2$  is the largest mass-squared difference). Hence, we conclude that the observation of neutrinoless double-beta decay with a probability that corresponds to  $|\langle m \rangle| \gtrsim 10^{-1}$  eV would be a signal for a nonhierarchical neutrino mass spectrum and/or nonstandard mechanisms of lepton number violation. [S0556-2821(98)04811-5] [Phys. Rev. D **57**, 6981 (1998)]