

Selected Abstracts from Physical Review D

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Temperature dependence of solar neutrino fluxes. John N. Bahcall, *Institute for Advanced Study, Princeton, New Jersey 08540*; Andrew Ulmer, *Princeton University Observatory, Princeton, New Jersey 08544*. (Received 4 August 1995)

By comparing neutrino fluxes and central temperatures calculated from 1000 detailed numerical solar models, we derive improved scaling laws which show how each of the neutrino fluxes depends upon the central temperature (flux $\propto T^m$); we also estimate uncertainties for the temperature exponents. With the aid of a one-zone model of the Sun, we derive expressions for the temperature exponents of the neutrino fluxes. For the most important neutrino fluxes, the exponents calculated with the one-zone model agree to within 20% or better with the exponents extracted from the detailed numerical models. The one-zone model provides a physical understanding of the temperature dependence of the neutrino fluxes. For the pp neutrino flux, the one-zone model explains the (initially surprising) dependence of the flux upon a negative power of the temperature and suggests a new functional dependence. This new function makes explicit the strong anticorrelation between the ${}^7\text{Be}$ and pp neutrino fluxes. The one-zone model also predicts successfully the average linear relations between neutrino fluxes, but cannot predict the appreciable scatter in a $\Delta\phi_i/\phi_i$ versus $\Delta\phi_j/\phi_j$ diagram. [Phys. Rev. D **53**, 4202 (1996)]

How well do we (and will we) know solar neutrino fluxes and oscillation parameters? J. N. Bahcall and P. I. Krastev, *School of Natural Sciences, Institute for Advanced Study, Princeton, New Jersey 08540*. (Received 12 December 1995)

Individual neutrino fluxes are not well determined by the four operating solar neutrino experiments. Assuming neutrino oscillations occur, the pp electron neutrino flux is uncertain by a factor of 2, the ${}^8\text{B}$ flux by a factor of 5, and the ${}^7\text{Be}$ flux by a factor of 45. For matter-enhanced oscillation (MSW) solutions, the range of allowed differences of squared neutrino masses, Δm^2 , varies between $4 \times 10^{-6} \text{ eV}^2$ and $1 \times 10^{-4} \text{ eV}^2$, while $4 \times 10^{-3} \leq \sin^2 2\theta \leq 1.5 \times 10^{-2}$ or $0.5 \leq \sin^2 2\theta \leq 0.9$. For vacuum oscillations, Δm^2 varies between $5 \times 10^{-11} \text{ eV}^2$ and $1 \times 10^{-10} \text{ eV}^2$, while $0.7 \leq \sin^2 2\theta \leq 1.0$. The inferred ranges of neutrino parameters depend only weakly on which standard solar model is used. Calculations of the expected results of future solar neutrino experiments (SuperKamiokande, SNO, BOREXINO, ICARUS, HELLAZ, and HERON) are used to illustrate the extent to which these experiments will restrict the range of the allowed neutrino mixing parameters. For example, the double ratio (observed ratio divided by standard model ratio) of neutral current to charged current event rates to be measured in the SNO experiment varies, at 95% confidence limit, over the range 1.0 (no oscillations into active neutrinos), $3.1^{+1.8}_{-1.3}$ (small mixing angle MSW), $4.4^{+2.0}_{-1.4}$ (large mixing angle

MSW), and $5.2^{+5.6}_{-2.9}$ (vacuum oscillations). We present an improved formulation of the "luminosity constraint" and show that at 95% confidence limit, this constraint establishes the best available limits on the rate of creation of pp neutrinos in the solar interior and provides the best upper limit to the ${}^7\text{Be}$ neutrino flux. The actual rate of creation of solar neutrinos in the solar interior to the rate predicted by the standard solar model can vary (while holding the CNO neutrino flux constant) between 0.55 and 1.08 for pp neutrinos and between 0.0 and 6.35 for ${}^7\text{Be}$ neutrinos. [Phys. Rev. D **53**, 4211 (1996)]

Nucleon tensor charges in the SU(2) chiral quark-soliton model. Hyun-Chul Kim, *Institute for Theoretical Physics II, P.O. Box 102148, Ruhr-University Bochum, D-44780 Bochum, Germany*; Maxim V. Polyakov, *Petersburg Nuclear Physics Institute, Gatchina, St. Petersburg 188350, Russia*; Klaus Goeke, *Institute for Theoretical Physics II, P.O. Box 102148, Ruhr-University Bochum, D-44780 Bochum, Germany*. (Received 27 November 1995)

We investigate the singlet $g_T^{(0)}$ and isovector $g_T^{(3)}$ tensor charges of the nucleon, which are deeply related to the first moment of the leading twist transversity quark distribution $h_1(x)$, in the SU(2) chiral quark-soliton model. With rotational $O(1/N_c)$ corrections taken into account, we obtain $g_T^{(0)} = 0.69$ and $g_T^{(3)} = 1.45$ at a low normalization point of several hundreds MeV. Within the same approximation and parameters the model yields $g_A^{(0)} = 0.36$, $g_A^{(3)} = 1.21$ for axial charges and a correct octet-decuplet mass splitting. We show how the chiral quark-soliton model interpolates between the nonrelativistic quark model and the Skyrme model. [S0556-2821(96)50309-7] [Phys. Rev. D **53**, 4715 (1996)]

Strangelets with finite entropy. Dan M. Jensen, *Physics Department, Brookhaven National Laboratory, Upton, New York 11973 and Institute of Physics and Astronomy, University of Aarhus, DK-8000 Århus C, Denmark*; Jes Madsen, *Institute of Physics and Astronomy, University of Aarhus, DK-8000 Århus C, Denmark*. (Received 12 July 1995; revised manuscript received 22 December 1995)

Strangelets with nonzero entropy are studied within the MIT bag model. Explicit account is taken of the constraints that strangelets must be color neutral and have a fixed total momentum. In general, masses increase with increasing entropy per baryon, and the constraints work so as to increase masses further. This has an important destabilizing effect on strangelets produced in ultrarelativistic heavy ion collisions. [S0556-2821(96)50209-2] [Phys. Rev. D **53**, 4719 (1996)]

Production of J/ψ and $\psi(2S)$ mesons in π^- Be collisions at 515 GeV/c. A. Gribushin,⁴ V. Abramov,² Yu. Antipov,² B. Baldin,² R. Crittenden,⁴ C. Davis,⁵ L. Dauwe,⁶ S. Denisov,² A. Dyshkant,² A. Dzierba,⁴ V. Glebov,² H. Goldberg,³ R. Jesik,³ V. Koreshev,² J. Krider,¹ A. Krinitsyn,² R. Li,⁴ S. Margulies,³ T. Marshall,⁴ J. Martin,⁴ H. Mendez,³ A. Petrukhin,² J. Solomon,³ V. Sirotenko,² P. Smith,⁴ T. Sulanke,⁴ R. Sulyaev,² F. Vaca,³ and A. Ziemiński⁴ (E672 Collaboration), S. Blusk,¹² C. Bromberg,⁹ P. Chang,¹⁰ B. Choudhary,⁸ W. H. Chung,¹² L. de Barbaro,¹³ W. Długosz,¹⁰ J. Dunlea,¹³ E. Engels, Jr.,¹² G. Fanourakis,¹³ G. Ginther,¹³ K. Hartman,¹¹ J. Huston,⁹ V. Kapoor,⁸ C. Lirakis,¹⁰ S. Mani,⁷ J. Mansour,¹³ A. Maul,⁹ R. Miller,⁹ B. Y. Oh,¹¹ E. Pothier,¹⁰ R. Roser,¹³ P. Shepard,¹² D. Skow,¹ P. Slattery,¹³ L. Sorrell,⁹ W. Toothacker,¹¹ N. Varelas,¹³ D. Weerasundara,¹² J. Whitmore,¹¹ C. Yosef,⁹ and M. Zieliński¹³ (E706 Collaboration), ¹Fermi National Accelerator Laboratory, Batavia, Illinois 60510 ²Institute for High Energy Physics, Serpukhov, Russia ³University of Illinois at Chicago, Chicago, Illinois 60607 ⁴Indiana University, Bloomington, Indiana 47405 ⁵University of Louisville, Louisville, Kentucky 40292 ⁶University of Michigan at Flint, Flint, Michigan 48502 ⁷University of California-Davis, Davis, California 95616 ⁸University of Delhi, Delhi, India 110007 ⁹Michigan State University, East Lansing, Michigan 48824 ¹⁰Northeastern University, Boston, Massachusetts 02115 ¹¹Pennsylvania State University, University Park, Pennsylvania 16802 ¹²University of Pittsburgh, Pittsburgh, Pennsylvania 15260 ¹³University of Rochester, Rochester, New York 14627. (Received 11 September 1995)

We have studied the production of J/ψ and $\psi(2S)$ charmonium mesons in 515 GeV/c π^- Be collisions in the Feynman- x range $0.1 < x_F < 0.8$. J/ψ mesons were detected via their decay into $\mu^+\mu^-$, and $\psi(2S)$ mesons were studied in both the $\mu^+\mu^-$ and $J/\psi\pi^+\pi^-$ decay modes. J/ψ differential cross sections have been measured as functions of x_F , p_T^2 , and the cosine of the Gottfried-Jackson decay angle. We measure an inclusive J/ψ cross section of $B(J/\psi \rightarrow \mu^+\mu^-)\sigma(\pi^- \text{Be} \rightarrow J/\psi + X)/A = [9.3 \pm 0.1(\text{stat}) \pm 1.1(\text{syst})]$ nb/nucleon for J/ψ $x_F > 0.1$. Our results are compared with those from other experiments performed at lower beam energies. We also measure the differential $\psi(2S)$ cross section as a function of both x_F and p_T^2 , and a $\psi(2S)$ inclusive cross section of $B(\psi(2S) \rightarrow J/\psi\pi^+\pi^-)\sigma(\pi^- \text{Be} \rightarrow \psi(2S) + X)/A = [7.4 \pm 1.5(\text{stat}) \pm 1.2(\text{syst})]$ nb/nucleon for $\psi(2S)$ $x_F > 0.1$. The fraction of the inclusive J/ψ yield due to $\psi(2S)$ meson decays is $0.083 \pm 0.017(\text{stat}) \pm 0.013(\text{syst})$, and the observed ratio of $\psi(2S)$ decay rates is $B(\psi(2S) \rightarrow J/\psi\pi^+\pi^-)/B(\psi(2S) \rightarrow \mu^+\mu^-) = 30.2 \pm 7.2(\text{stat}) \pm 6.8(\text{syst})$. We have searched for production of “hidden” charm resonances decaying into either $J/\psi\pi^\pm$, $\psi(2S)\pi^\pm$, or $J/\psi\pi^+\pi^-$ systems, and report an upper limit of 3.1 nb/nucleon for the product of branching ratio and cross section for the recently reported enhancement at a $J/\psi\pi^+\pi^-$ mass of 3.836 GeV/c². [Phys. Rev. D 53, 4723 (1996)]

$\alpha_1(1260)$ contribution to photon and dilepton productions from hot hadronic matter reexamined. Jae Kwan Kim,¹ Pyungwon Ko,² Kang Young Lee,¹ and Serge Rudaz,³ ¹Department of Physics, KAIST, Taejeon, 305-701, Korea ²Department of Physics, Hong-Ik University, Seoul 121-791, Korea ³School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455. (Received 15 June 1995)

We consider the $\alpha_1(1260)$ contribution to photon and dilepton productions from hot hadronic matter. The effective Lagrangian

with π , ρ , and a_1 discussed by Ko and Rudaz is employed, which successfully reproduces the $\Gamma(a_1 \rightarrow \pi\gamma) = 670$ keV. Our results for the photon production rate are comparable to those obtained by Xiong, Shuryak, and Brown, while the dilepton production rates come out smaller than those obtained by Song, Ko, and Gale by an order of magnitude. [Phys. Rev. D 53, 4787 (1996)]

Dilepton bremsstrahlung from pion-pion scattering in a relativistic one boson exchange model. H. C. Eggers, *Department of Physics, McGill University, Montréal, Québec, Canada H3A 2T8* and *Institut für Hochenergiephysik der Österreichischen Akademie der Wissenschaften, Nikolsdorfergasse 18, A-1050 Vienna, Austria*; R. Tabti and C. Gale, *Department of Physics, McGill University, Montréal, Québec, Canada H3A 2T8*; K. Haglin, *National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, Michigan 48824-1321*. (Received 26 October 1995)

We have made a detailed and quantitative study of dilepton production via bremsstrahlung of a virtual photon during collisions of two free pions. Most calculations of electromagnetic radiation from strong interaction processes rely on the soft photon approximation (SPA). The conditions underlying this approximation are generally violated when dilepton spectra are calculated in terms of their invariant mass, so that an approach going beyond the SPA becomes necessary. Superseding previous derivations, we derive an exact formula for the bremsstrahlung cross section. The resulting formulation is compared to various forms based on the SPA, the two-particle phase space approximation, and Rückl's formula using a relativistic one boson exchange (OBE) model. Within the OBE approach, we show that approximations to the bremsstrahlung dilepton cross sections often differ greatly from the exact result; discrepancies become greater both with rising temperature and with invariant mass. Integrated dilepton production rates are overestimated by Rückl-based approximations by factors 1.5–8.0. The largest discrepancies occur for the reaction $\pi^+\pi^+ \rightarrow \pi^+\pi^+\ell^+\ell^-$, where such approximations overestimate the exact rate by factors ranging from 2 to 30 for invariant masses between 10 and 500 MeV. Our findings, combined with recent estimates of the Landau-Pomeranchuk effect, indicate that bremsstrahlung dilepton rates in ultrarelativistic heavy ion collisions should be even more suppressed than had been thought before. [Phys. Rev. D 53, 4822 (1996)]

Return of the prodigal Goldstone boson. J. Kapusta, *School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455*; D. Kharzeev, *Theory Division, CERN, Geneva, Switzerland* and *Fakultät für Physik, Universität Bielefeld, Bielefeld, Germany*; L. McLerran, *School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455*. (Received 14 July 1995)

We propose that the mass of the η' meson is a particularly sensitive probe of the properties of finite energy density hadronic matter and quark-gluon plasma. We argue that the mass of the η' excitation in hot and dense matter should be small, and, therefore, that the η' production cross section should be much increased rela-

tive to that for pp collisions. This may have observable consequences in dilepton and diphoton experiments. [Phys. Rev. D **53**, 5028 (1996)]

Effective Lagrangians and parity-conserving time-reversal violation at low energies. Jonathan Engel and Paul H. Frampton, *Department of Physics and Astronomy, University of North Carolina, Chapel Hill, North Carolina 27599-3255*; Roxanne P. Springer, *Department of Physics, Duke University, Durham, North Carolina 27708*. (Received 18 May 1995)

Using effective Lagrangians, we argue that any time-reversal-violating but parity-conserving effects are too small to be observed in flavor-conserving nuclear processes without dramatic improvement in experimental accuracy. In the process we discuss other arguments that have appeared in the literature. [S0556-2821(96)06509-5] [Phys. Rev. D **53**, 5112 (1996)]

Strangelets at finite temperature. M. G. Mustafa and A. Ansari, *Institute of Physics, Bhubaneswar-751005, India*. (Received 26 May 1995; revised manuscript received 23 October 1995)

Within the MIT bag model picture of QCD with a bag pressure constant $B^{1/4}=145$ MeV we study the stability of finite-size strangelets at finite temperature (T) with baryon number $A \leq 100$. The light quarks u and d are considered massless while the mass of the s quark is taken as 150 MeV. Using discrete eigenenergies of the noninteracting quarks in the bag, a grand canonical partition function is constructed and then the free energy is minimized with respect to the bag radius. In the $T \rightarrow 0$ limit clear shell structures are found which persist up to about $T=10$ MeV. In fact for $A=6$ the shell structure melts away only at $T > 20$ MeV. [Phys. Rev. D **53**, 5136 (1996)]