

Selected Abstracts from Other Physical Review Journals

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Effect of hyperon bulk viscosity on neutron-star r -modes. Lee Lindblom, *Theoretical Astrophysics 130-33, California Institute of Technology, Pasadena, California 91125*; Benjamin J. Owen, *Department of Physics, University of Wisconsin–Milwaukee, P.O. Box 413, Milwaukee, Wisconsin 53201*, and Albert Einstein Institut (Max Planck Institut für Gravitationsphysik), Am Mühlenberg 1, 14476 Golm, Germany. (Received 25 October 2001; published 4 March 2002)

Neutron stars are expected to contain a significant number of hyperons in addition to protons and neutrons in the highest density portions of their cores. Following the work of Jones, we calculate the coefficient of bulk viscosity due to nonleptonic weak interactions involving hyperons in neutron-star cores, including new relativistic and superfluid effects. We evaluate the influence of this new bulk viscosity on the gravitational radiation driven instability in the r -modes. We find that the instability is completely suppressed in stars with cores cooler than a few times 10^9 K, but that stars rotating more rapidly than 10–30% of maximum are unstable for temperatures around 10^{10} K. Since neutron-star cores are expected to cool to a few times 10^9 K within seconds (much shorter than the r -mode instability growth time) due to direct Urca processes, we conclude that the gravitational radiation instability will be suppressed in young neutron stars before it can significantly change the angular momentum of the star. [Phys. Rev. D **65**, 063006 (2002)]

High temperature matter and gamma ray spectra from microscopic black holes. Ramin Daghigh and Joseph Kapusta, *School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455*. (Received 8 October 2001; published 28 February 2002)

The relativistic viscous fluid equations describing the outflow of high temperature matter created via Hawking radiation from microscopic black holes are solved numerically for a realistic equation of state. We focus on black holes with initial temperatures greater than 100 GeV and lifetimes less than 6 days. The spectra of direct photons and photons from π^0 decay are calculated for energies greater than 1 GeV. We calculate the diffuse gamma ray spectrum from black holes distributed in our galactic halo. However, the most promising route for their observation is to search for point sources emitting gamma rays of ever-increasing energy. [Phys. Rev. D **65**, 064028 (2002)]

Continuum versus periodic lattice Monte Carlo approach to classical field theory. Bogdan Mihaila, *Physics Division, Argonne National Laboratory, Argonne, Illinois 60439*; John F. Dawson, *Department of Physics, University of New Hampshire, Durham, New Hampshire 03824*. (Received 4 October 2001/Published 8 March 2002)

We compare the momentum space with the standard periodic lattice approach to Monte Carlo calculations in classical ϕ^4 field theory. We show that the mismatch in the initial value of $\phi_c^2(t)$ results in a shift in the “thermalized” value, at large times. The two approaches converge to the same result in the continuum limit. [Phys. Rev. D **65**, 071501 (2002)]

Search for anomalously heavy nuclei in gold and iron. D. Javorksek II,¹ D. Elmore,¹ E. Fischbach,¹ D. Granger,² T. Miller,¹ D. Oliver,³ and V. Teplitz⁴ ¹*Department of Physics, Purdue University, West Lafayette, Indiana 47907*, ²*Department of Earth and Atmospheric Sciences, Purdue University, West Lafayette, Indiana 47907*, ³*Department of Geological Sciences, Southern Methodist University, Dallas, Texas 75275*, ⁴*Department of Physics, Southern Methodist University, Dallas, Texas 75275*. (Received 4 November 2001; published 1 April 2002)

There are a number of theoretical motivations for searching for anomalously heavy isotopes ${}_ZX$ of known elements, where Z is the nuclear charge of the anomalous nucleus X . Such nuclei could arise from the binding of a new strongly interacting massive particle (SIMP) to the nucleus of a known element, and could thus be detected as an anomalously heavy isotope of that element. SIMPs have been proposed as candidates for dark matter, and for the lightest supersymmetric particle, as well as a possible explanation for ultra high-energy cosmic rays. A search for anomalous nuclei X has been performed by analyzing several unique samples including gold nuggets collected in Australia, Arizona and North Carolina, gold foils flown on NASA’s LDEF satellite, and an Fe meteorite. In each gold sample we scanned for Au isotopes with masses up to $1.67 \text{ TeV}/c^2$ using PRIME Lab, the Purdue accelerator mass spectrometer facility. We have also searched for anomalous Fe isotopes with masses up to $0.65 \text{ TeV}/c^2$ in the iron meteorite sample. We find no evidence for SIMPs in any of our samples, and our results set stringent limits on the abundance of anomalous isotopes of ordinary matter as a function of X mass. [Phys. Rev. D **65**, 072003 (2002)]

Energy independent solution to the solar neutrino anomaly including the SNO data. Sandhya Choubey and Srubabati Goswami, *Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Kolkata 700 064, India*; D. P. Roy, *Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India*. (Received 14 September 2001; published 27 February 2002)

The global data on solar neutrino rates and spectrum, including the SNO charged current rate, can be explained by LMA, LOW or the energy independent solution—corresponding to near-maximal mixing. All three favor a mild upward renormalization of the Cl rate. A mild downward shift of the B neutrino flux is favored by the energy independent and to a lesser extent the LOW solution, but not

by LMA. A comparison with the ratio of SK elastic and SNO charged current scattering rates favors the LMA over the other two solutions, but by no more than 1.5σ . [Phys. Rev. D **65**, 073001 (2002)]

Grand unified model predictions for neutrino oscillation parameters compatible with the large mixing angle solution. Carl H. Albright, *Department of Physics, Northern Illinois University, DeKalb, Illinois 60115, and Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, Illinois 60510*; S. Geer, *Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, Illinois 60510*. (Received 8 August 2001; revised manuscript received 16 October 2001; published 8 March 2002)

Within the framework of an SO(10) GUT model that can accommodate both the atmospheric and the LMA solar neutrino mixing solutions, we present explicit predictions for the neutrino oscillation parameters $\sin^2 2\theta_{13}$, $\sin^2 2\theta_{12}$, $\sin^2 2\theta_{23}$, and Δm_{21}^2 . Precise measurements of $\sin^2 2\theta_{12}$ and Δm_{21}^2 by KamLAND can be used to precisely determine the GUT model parameters. We find that the model can then be tested at neutrino superbeams and neutrino factories with precision neutrino oscillation measurements of $\sin^2 2\theta_{23}$, $\sin^2 2\theta_{13}$, and the leptonic CP phase δ_{CP} .
12.15.Ff, 12.10.Dm, 12.60.Jv, 14.60.Pq

Optimum long baseline for the next generation neutrino oscillation experiments. Yifang Wang, *Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100039, China*; Kerry Whisnant and Bing-Lin Young, *Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011*. (Received 6 September 2001; published 11 March 2002)

For high-energy long baseline neutrino oscillation experiments, we propose a figure of merit criterion to compare the statistical quality of experiments at various baseline lengths under the condition of identical detectors and a given neutrino beam. We take into account all possible experimental errors under general consideration. In this way, the figure of merit is closely related to the usual statistical criterion of number of sigmas. We use a realistic neutrino beam for an entry-level neutrino factory and a possible superbeam from a meson source and a 100 kt detector for the calculation. We consider in detail four baseline lengths—300 km, 700 km, 2100 km, and 3000 km in the neutrino energy range of 0.5–20 GeV for a 20 GeV entry-level neutrino factory and a 50 GeV superbeam. We find that the very long baselines of 2100 km and 3000 km are preferred for the neutrino factory according to the figure of merit criterion. Our results also show that, for a neutrino factory, lower primary muon energies such as 20 GeV are preferred rather than higher ones such as 30 or 50 GeV. For the superbeam, the combination of a long baseline such as 300 km and a very long baseline such as 2100 km will form a complete measurement of the oscillation parameters in addition to the CP phase. To measure the CP phase in a superbeam, a larger detector (a factor 3 beyond what is considered in this paper) and/or a higher intensity beam will be needed to put some significant constraints on the size of the CP angle. [Phys. Rev. D **65**, 073006 (2002)]

Supernova neutrino oscillations: A simple analytical approach. G. L. Fogli,¹ E. Lisi,¹ D. Montanino,² and A. Palazzo¹
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Analyses of observable supernova neutrino oscillation effects require the calculation of the electron (anti)neutrino survival probability P_{ee} along a given supernova matter density profile. We propose a simple analytical prescription for P_{ee} , based on a double-exponential form for the crossing probability and on the concept of maximum violation of adiabaticity. In the case of two-flavor transitions, the prescription is shown to reproduce accurately, in the whole neutrino oscillation parameter space, the results of exact numerical calculations for generic (realistic or power-law) profiles. The analytical approach is then generalized to cover three-flavor transitions with (direct or inverse) mass spectrum hierarchy, and to incorporate Earth matter effects. Compact analytical expressions, explicitly showing the symmetry properties of P_{ee} , are provided for practical calculations. [Phys. Rev. D **65**, 073008 (2002)]

Global analysis of the post-SNO solar neutrino data for standard and nonstandard oscillation mechanisms. A. M. Gago,^{1,2,3} M. M. Guzzo,⁴ P. C. de Holanda,⁵ H. Nunokawa,^{4,6} O. L. G. Peres,⁴ V. Pleitez,⁶ and R. Zukanovich Funchal³ ¹*Sección Física, Departamento de Ciencias, Pontificia Universidad Católica del Perú, Apartado 1761, Lima, Peru*, ²*Department of Physics, California State University, Dominguez Hills, Carson, California 90747*, ³*Instituto de Física, Universidade de São Paulo, Caixa Postal 66.318, 05315-970 São Paulo SP, Brazil*, ⁴*Instituto de Física Gleb Wataghin, Universidade Estadual de Campinas—UNICAMP, 13083-970 Campinas SP, Brazil*, ⁵*The Abdus Salam International Center for Theoretical Physics, I-34100 Trieste, Italy*, ⁶*Instituto de Física Teórica, Universidade Estadual Paulista, Rua Pamplona 145, 01405-900 São Paulo SP, Brazil*. (Received 7 December 2001; published 19 March 2002)

What can we learn from solar neutrino observations? Is there any solution to the solar neutrino anomaly which is favored by the present experimental panorama? After SNO results, is it possible to affirm that neutrinos have mass? In order to answer such questions we analyze the current available data from the solar neutrino experiments, including the recent SNO result, in view of many acceptable solutions to the solar neutrino problem based on different conversion mechanisms, for the first time using the same statistical procedure. This allows us to do a direct comparison of the goodness of the fit among different solutions, from which we can discuss and conclude on the current status of each proposed dynamical mechanism. These solutions are based on different assumptions: (a) neutrino mass and mixing, (b) a nonvanishing neutrino magnetic moment, (c) the existence of nonstandard flavor-changing and nonuniversal neutrino interactions, and (d) a tiny violation of the equivalence principle. We investigate the quality of the fit provided by each one of these solutions not only to the total rate measured by all the solar neutrino experiments but also to the recoil electron energy spectrum measured at different zenith angles by the Super-Kamiokande Collaboration. We conclude that several nonstandard neutrino flavor conversion mechanisms provide a very good fit to the experimental data which is comparable with (or even slightly better than) the most famous solution to the solar neutrino anomaly based on the neutrino oscillation induced by mass. [Phys. Rev. D **65**, 073012 (2002)]

Zee model confronts SNO data. Paul H. Frampton, Myoung C. Oh, and Tadashi Yoshikawa, *Institute of Field Physics, Department of Physics and Astronomy, University of North Carolina, Chapel Hill, North Carolina 27599-3255.* (Received 26 October 2001; published 19 March 2002)

We reexamine the solution of the minimal Zee model by comparing with the data of the SNO experiment, and conclude that the model is strongly disfavored but not yet excluded by the observations. Two extensions of the Zee model are briefly discussed both of which introduce additional freedom and can accommodate the data. [Phys. Rev. D **65**, 073014 (2002)]

SN 1987A and the status of oscillation solutions to the solar neutrino problem. M. Kachelrieß,¹ A. Strumia,¹ R. Tomàs,² and J. W. F. Valle² ¹*TH Division, CERN, CH-1211 Geneva 23, Switzerland,* ²*Instituto de Fisica Corpuscular, C.S.I.C., Universitat de València, Edificio de Institutos, Apartado de Correos 22085, 46071 València, Spain.* (Received 22 August 2001; published 21 March 2002)

We study neutrino oscillations and the level-crossing probability P_{LSZ} in power-law potential profiles $A(r) \propto r^n$. We give local and global adiabaticity conditions valid for all mixing angles ϑ and discuss different representations for P_{LSZ} . For the $1/r^3$ profile typical of supernova envelopes we compare our analytical to numerical results and to earlier approximations used in the literature. We then perform a combined likelihood analysis of the observed SN 1987A neutrino signal and of the latest solar neutrino data, including the recent SNO CC measurement. We find that, unless all relevant supernova parameters (released binding energy, $\bar{\nu}_e$ and $\bar{\nu}_{\mu,\tau}$ temperatures) are near their lowest values found in simulations, the status of large mixing type solutions deteriorates considerably compared to fits using only solar data. This is sufficient to rule out the vacuum-type solutions for most reasonable choices of astrophysics parameters. The LOW solution may still be acceptable, but becomes worse than the SMA-MSW solution which may, in some cases, be the best combined solution. On the other hand the LMA-MSW solution can easily survive as the best overall solution, although its size is generally reduced when compared to fits to the solar data only. [Phys. Rev. D **65**, 073016 (2002)]

Quasi-energy-independent solar neutrino transitions. G. L. Fogli, E. Lisi, and A. Palazzo, *Dipartimento di Fisica and Sezione INFN di Bari, Via Amendola 173, I-70126 Bari, Italy.* (Received 14 May 2001; published 25 March 2002)

Current solar, atmospheric, and reactor neutrino data still allow oscillation scenarios where the squared mass differences are all close to 10^{-3} eV², rather than being hierarchically separated. For solar neutrinos, this situation (realized in the upper part of the so-called large-mixing angle solution) implies adiabatic transitions which depend weakly on the neutrino energy and on the matter density, as well as on the “atmospheric” squared mass difference. In such a regime of “quasi-energy-independent” (QEI) transitions, intermediate between the more familiar “Mikheyev-Smirnov-Wolfenstein” (MSW) and energy independent (EI) regimes, we first perform analytical calculations of the solar ν_e survival probability at first order in the matter density, beyond the usual hierarchical approximations. We then provide accurate, generalized expressions

for the solar neutrino mixing angles in matter, which reduce to those valid in the MSW, QEI and EI regimes in appropriate limits. Finally, a representative QEI scenario is discussed in some detail. [Phys. Rev. D **65**, 073019 (2002)]

Rephasing invariants of CP and T violation in the four-neutrino mixing models. Wan-lei Guo, *Institute of High Energy Physics, P.O. Box 918 (4), Beijing 100039, China;* Zhi-zhong Xing, *CCAST (World Laboratory), P.O. Box 8730, Beijing 100080, China, and Institute of High Energy Physics, P.O. Box 918 (4), Beijing 100039, China.* (Received 7 December 2001; published 27 March 2002)

We calculate the rephasing invariants of CP and T violation in a favorable parametrization of the 4×4 lepton flavor mixing matrix. Their relations with the CP- and T-violating asymmetries in neutrino oscillations are derived, and the matter effects are briefly discussed. [Phys. Rev. D **65**, 073020 (2002)]

Probing neutrino oscillations jointly in long and very long baseline experiments. Y. F. Wang,¹ K. Whisnant,² Zhaohua Xiong,³ Jin Min Yang,³ and Bing-Lin Young² ¹*Institute of High Energy Physics, Academia Sinica, Beijing 100039, China,* ²*Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011,* ³*Institute of Theoretical Physics, Academia Sinica, Beijing 100080, China.* (Received 27 November 2001; published 29 March 2002)

We examine the prospects of making a joint analysis of neutrino oscillations at two baselines with neutrino superbeams. Assuming narrow band superbeams and a 100 kiloton water Cherenkov calorimeter, we calculate the event rates and sensitivities to the matter effect, the signs of the neutrino mass differences, the CP phase, and the mixing angle θ_{13} . Taking into account all possible experimental errors under general consideration, we explore the optimum cases of a narrow band beam to measure the matter effect and the CP violation effect at all baselines up to 3000 km. We then focus on two specific baselines, a long baseline of 300 km and a very long baseline of 2100 km, and analyze their joint capabilities. We find that the joint analysis can offer extra leverage to resolve some of the ambiguities that are associated with the measurement at a single baseline. [Phys. Rev. D **65**, 073021 (2002)]

Global analysis with SNO: Toward the solution of the solar neutrino problem. P. I. Krastev, *Philips Analytical, Natick, Massachusetts 01760;* A. Yu. Smirnov, *The Abdus Salam International Centre for Theoretical Physics, I-34100 Trieste, Italy, and Institute for Nuclear Research of Russian Academy of Sciences, Moscow 117312, Russia.* (Received 15 November 2001; published 29 March 2002)

We perform a global analysis of the latest solar neutrino data including the Solar Neutrino Observatory (SNO) result on the charged current (CC) event rate. This result further favors the large mixing angle (LMA) Mikheyev-Smirnov-Wolfenstein (MSW) solution of the solar neutrino problem. The best fit values of parameters we find are $\Delta m^2 = (4.8-5.0) \times 10^{-5}$ eV², $\tan^2 \theta = 0.35-0.38$, $f_B = 1.08-1.12$, and $f_{\text{hep}} = 1-4$, where f_B and f_{hep} are the boron and ³He + p (hep) neutrino fluxes in units of the corresponding fluxes in the standard solar model (SSM). With respect to this best fit point the low Δm^2 (LOW) MSW solution is accepted at 90% C.L. The

vacuum oscillation solution (VAC) with $\Delta m^2 = 1.4 \times 10^{-10} \text{ eV}^2$, gives a good fit to the data provided that the boron neutrino flux is substantially smaller than the SSM flux ($f_B \sim 0.5$). The small mixing angle (SMA) solution is accepted at about the 3σ level. We find that vacuum oscillations to a sterile neutrino, VAC(sterile), with $f_B \sim 0.5$ also give a rather good global fit to the data. All other sterile neutrino solutions are strongly disfavored. We check the quality of the fit by constructing the pull-off diagrams of observables for the global solutions. Maximal mixing is allowed at the 3σ level in the LMA region and at 95% C.L. in the LOW region. Predictions for the day-night asymmetry, spectrum distortion, and ratio of the neutral to charged current event rates $[NC]/[CC]$ at SNO are calculated. In the best fit points of the global solutions we find $A_{DN}^{CC} \approx 7-8\%$ for the LMA, $\sim 3\%$ for the LOW, and $2-3\%$ for the SMA regions. In the LMA region the asymmetry can be as large as $15-20\%$. Observation of $A_{DN}^{CC} > 5\%$ will further favor the LMA solution. It will be difficult to see the distortion of the spectrum expected for LMA as well as LOW solutions. However, future SNO spectral data can significantly affect the VAC and SMA solutions. We present the expected values of the BOREXINO event rate for global solutions. [Phys. Rev. D **65**, 073022 (2002)]

Breaking eightfold degeneracies in neutrino CP violation, mixing, and mass hierarchy. V. Barger, *Department of Physics, University of Wisconsin, Madison, Wisconsin 53706*; D. Marfatia, *Department of Physics, Boston University, Boston, Massachusetts 02215*; K. Whisnant, *Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011*. (Received 10 December 2001; published 29 March 2002)

We identify three independent twofold parameter degeneracies (δ, θ_{13}) , $\text{sgn}(\delta m_{31}^2)$ and $(\theta_{23}, \pi/2 - \theta_{23})$ inherent in the usual three-neutrino analysis of long-baseline neutrino experiments, which can lead to as much as an eightfold degeneracy in the determination of the oscillation parameters. We discuss the implications these degeneracies have for detecting CP violation and present criteria for breaking them. A superbeam facility with a baseline at least as long as the distance between Fermilab and Homestake (1290 km) and a narrow band beam with energy tuned so that the measurements are performed at the first oscillation peak can resolve all the ambiguities other than the $(\theta_{23}, \pi/2 - \theta_{23})$ ambiguity (which can be resolved at a neutrino factory) and a residual $(\delta, \pi - \delta)$ ambiguity. However, whether or not CP violation occurs in the neutrino sector can be ascertained independently of the latter two ambiguities. The $(\delta, \pi - \delta)$ ambiguity can be eliminated by performing a second measurement to which only the $\cos \delta$ terms contribute. The hierarchy of mass eigenstates can be determined at other oscillation peaks only in the most optimistic conditions, making it necessary to use the first oscillation maximum. We show that the degeneracies may severely compromise the ability of the proposed SuperJHF-HyperKamiokande experiment to establish CP violation. In our calculations we use approximate analytic expressions for oscillation probabilities that agree with numerical solutions with a realistic Earth density profile. [Phys. Rev. D **65**, 073023 (2002)]

Neutrino anomalies and quasi Dirac neutrinos. Srubabati Goswami, *Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Calcutta, 700 064, India*; Anjan S. Joshipura, *Theoretical Physics Group, Physical Research Laboratory, Navarangpura, Ahmedabad,*

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We discuss the possibility of describing solar, atmospheric and LSND results with four neutrinos forming two quasidegenerate pairs. The simplest versions of this $2+2$ scheme with either ν_e or ν_μ mixing exclusively with sterile neutrino are disfavored by the SNO and atmospheric neutrino results, respectively. A generalized scheme with sterile state participating in both the solar and atmospheric oscillations is still allowed. We show that the complex pattern of mixing needed for this purpose follows from a simple $L_e + L_\mu - L_\tau - L_s$ symmetry. The specific form of the $L_e + L_\mu - L_\tau - L_s$ symmetric mass matrix is determined from experimental results. Two theoretical schemes which lead to this form and a proper breaking of $L_e + L_\mu - L_\tau - L_s$ symmetry are discussed. [Phys. Rev. D **65**, 073025 (2002)]

Indications on neutrino oscillation parameters from initial KEK-to-Kamioka and current SK data. G. L. Fogli, E. Lisi, and A. Marrone, *Dipartimento di Fisica and Sezione INFN di Bari, Via Amendola 173, 70126 Bari, Italy*. (Received 11 October 2001; published 1 April 2002)

We briefly discuss the impact of initial data from the KEK-to-Kamioka (K2K) neutrino experiment on the $\nu_\mu \rightarrow \nu_\tau$ oscillation parameters ($m^2, \tan^2 \psi$) currently indicated by the Super-Kamiokande (SK) atmospheric neutrino experiment. After showing the very good agreement between K2K and SK, we combine the two separate pieces of information. We find that the 99% C.L. range for the squared neutrino mass difference m^2 allowed by SK only, $m^2 \in [1.3, 5.6] \times 10^{-3} \text{ eV}^2$, is reduced to $[1.5, 4.8] \times 10^{-3} \text{ eV}^2$ by including K2K data. By halving the uncertainties of the K2K total rate (with central value unchanged), the m^2 range would be further reduced to $[1.8, 4.0] \times 10^{-3} \text{ eV}^2$. Such information appears to be already useful in planning (very) long baseline neutrino oscillation experiments. [Phys. Rev. D **65**, 073028 (2002)]

Three generation neutrino oscillation parameters after SNO. Abhijit Bandyopadhyay, Sandhya Choubey, Srubabati Goswami, and Kamales Kar, *Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Kolkata 700 064, India*. (Received 10 November 2001; published 3 April 2002)

We examine the solar neutrino problem in the context of the realistic three neutrino mixing scenario including the SNO charged current (CC) rate. The two independent mass squared differences Δm_{21}^2 and $\Delta m_{31}^2 \approx \Delta m_{32}^2$ are taken to be in the solar and atmospheric ranges, respectively. We incorporate the constraints on Δm_{31}^2 as obtained by the SuperKamiokande atmospheric neutrino data and determine the allowed values of Δm_{21}^2 , θ_{12} and θ_{13} from a combined analysis of solar and CHOOZ data. Our aim is to probe the changes in the values of the mass and mixing parameters with the inclusion of the SNO data as well as the changes in the two-generation parameter region obtained from the solar neutrino analysis with the inclusion of the third generation. We find that the inclusion of the SNO CC rate in the combined solar+CHOOZ analysis puts a more restrictive bound on θ_{13} . Since the allowed values of θ_{13} are constrained to very small values by the CHOOZ experiment there is no qualitative change over the two generation allowed regions in the $\Delta m_{21}^2 - \tan^2 \theta_{12}$ plane. The best fit comes in

the LMA region and no allowed area is obtained in the SMA region at the 3σ level from combined solar and CHOOZ analysis. 14.60.Pq, 12.15.Ff, 26.65.+t

Violation of the equivalence principle in the light of the SNO and SK solar neutrino results. Amitava Raychaudhuri and Arunansu Sil, *Department of Physics, University of Calcutta, 92 Acharya Prafulla Chandra Road, Kolkata 700009, India.* (Received 10 October 2001; published 5 April 2002)

The Sudbury Neutrino Observatory (SNO) result on charged current deuteron disintegration, the Super Kamiokande 1258-day data on electron scattering, and other solar neutrino results are used to reexamine the model of neutrino oscillations driven by a violation of the equivalence principle. We use a χ^2 minimization technique to examine oscillations between the ν_e and another active neutrino, both massless, and find that within the standard solar model the fit to the SNO and Super-Kamiokande spectra is moderately good while a very good fit is obtained when the absolute normalizations of the ^8B and $^3\text{He}+p$ (hep) neutrino fluxes are allowed to vary. The fit to the total rates from the different experiments is not encouraging but when the rates and spectra are considered together the situation is much improved. The best fit prefers maximal mixing, essentially no hep neutrinos, and a 23% reduction in the ^8B neutrino flux. We remark on the expectations of the violation of the equivalence principle model for the neutral current measurements at SNO. [Phys. Rev. D **65**, 073035 (2002)]

Color superconductivity in finite systems. Paolo Amore,^{1,2} Michael C. Birse,¹ Judith A. McGovern,¹ and Niels R. Walet²
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In this paper we study the effect of finite size on the two-flavor color superconducting state. As well as restricting the quarks to a box, we project onto states of good baryon number and onto color singlets, these being necessary restrictions on any observable “quark nuggets.” We find that whereas finite size alone has a significant effect for very small boxes, with the superconducting state often being destroyed, the effect of projection is to restore it again. The infinite-volume limit is a good approximation even for quite small systems. [Phys. Rev. D **65**, 074005 (2002)]

Mass terms in effective theories of high density quark matter. T. Schäfer, *Department of Physics, SUNY Stony Brook, Stony Brook, New York 11794, and Riken-BNL Research Center, Brookhaven National Laboratory, Upton, New York 11973.* (Received 14 September 2001; published 8 March 2002)

We study the structure of mass terms in the effective theory for quasiparticles in QCD at high baryon density. To next-to-leading order in the $1/p_F$ expansion we find two types of mass terms: chirality conserving two-fermion operators and chirality violating four-

fermion operators. In the effective chiral theory for Goldstone modes in the color-flavor-locked (CFL) phase the former terms correspond to effective chemical potentials, while the latter lead to Lorentz invariant mass terms. We compute the masses of Goldstone bosons in the CFL phase, confirming earlier results by Son and Stephanov as well as Bedaque and Schäfer. We show that to leading order in the coupling constant g there is no antiparticle gap contribution to the mass of Goldstone modes, and that our results are independent of the choice of gauge. [Phys. Rev. D **65**, 074006 (2002)]

Next-to-leading order QCD analysis of deeply virtual Compton scattering amplitudes. Andreas Freund, *Institut für Theoretische Physik, University of Regensburg, Universitätstrasse 31, 93053 Regensburg, Germany;* Martin McDermott, *Division of Theoretical Physics, Department of Mathematical Sciences, University of Liverpool, Liverpool, L69 3BX, United Kingdom.* (Received 3 July 2001; published 11 March 2002)

We present a next-to-leading order (NLO) QCD analysis of unpolarized and polarized deeply virtual Compton scattering (DVCS) amplitudes, for two different input scenarios, in the $\overline{\text{MS}}$ scheme. We illustrate and discuss the size of the NLO effects and the behavior of the amplitudes in skewedness, ζ , and photon virtuality, Q^2 . In the unpolarized case, at fixed Q^2 , we find a remarkable effective power-law behavior in ζ , akin to Regge factorization, over several orders of magnitude in ζ . We also quantify the ratio of real to imaginary parts of the DVCS amplitudes and their sensitivity to changes of the factorization scale. [Phys. Rev. D **65**, 074008 (2002)]

Exploring skewed parton distributions with two-body models on the light front. II. Covariant Bethe-Salpeter approach. B. C. Tiburzi and G. A. Miller, *Department of Physics, University of Washington, Box 351560, Seattle, Washington 98195-1560.* (Received 26 September 2001; revised manuscript received 30 November 2001; published 11 March 2002)

We explore skewed parton distributions for two-body, light-front wave functions. In order to access all kinematical régimes, we adopt a covariant Bethe-Salpeter approach, which makes use of the underlying equation of motion (here the Weinberg equation) and its Green’s function. Such an approach allows for the consistent treatment of the non-wave-function vertex (but rules out the case of phenomenological wave functions derived from *ad hoc* potentials). Our investigation centers around checking internal consistency by demonstrating time-reversal invariance and continuity between valence and nonvalence régimes. We derive our expressions by assuming the effective qq potential is independent of the mass squared, and verify the sum rule in a nonrelativistic approximation in which the potential is energy independent. We consider bare-coupling as well as interacting skewed parton distributions and develop approximations for the Green’s function which preserve the general properties of these distributions. Lastly, we apply our approach to timelike form factors and find similar expressions for the related generalized distribution amplitudes. [Phys. Rev. D **65**, 074009 (2002)]

Differential distributions for next-leading-order analyses of charged current neutrino production of charm quarks. S. Kretzer, *Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan 48824*; D. Mason, *Department of Physics, University of Oregon, Eugene, Oregon 97403*; F. Olness, *Department of Physics, Southern Methodist University, Dallas, Texas 75275-0175*. (Received 17 December 2001; published 12 March 2002)

Experimental analyses of charged current deep inelastic charm production—as observed through dimuon events in neutrino-iron scattering—measure the strangeness component of the nucleon sea. A complete analysis requires a Monte Carlo simulation to account for experimental detector acceptance effects; therefore, a fully differential theoretical calculation is necessary to provide complete kinematic information. We investigate the theoretical issues involved in calculating these differential distributions at next-leading order (NLO). Numerical results are presented for typical fixed-target kinematics. We present a corresponding FORTRAN code suitable for experimental NLO analysis. [Phys. Rev. D **65**, 074010 (2002)]

Light-cone sum rules for the nucleon form factors. V. M. Braun,¹ A. Lenz,¹ N. Mahnke,¹ and E. Stein^{1,2} ¹*Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany*, ²*Physics Department, Maharishi University of Management, NL-6063 NP Vlodrop, The Netherlands*. (Received 6 December 2001; published 12 March 2002)

We argue that soft nonfactorizable terms give a significant contribution to the baryon form factors at intermediate momentum transfers and set up a framework for the calculation of such terms in the light-cone sum rule approach. Among them, contributions of three-quark states with different helicity structure compared to the leading twist prove to be the most important. The leading-order sum rules are derived and confronted with the experimental data. [Phys. Rev. D **65**, 074011 (2002)]

Decay constants, light quark masses, and quark mass bounds from light quark pseudoscalar sum rules. Kim Maltman, *CSSM, University of Adelaide, 5005, Australia, and Theory Group, TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia, Canada V6T 2A3*; Joachim Kambor, *Institut für Theoretische Physik, Universität Zürich, CH-8057 Zürich, Switzerland*. (Received 1 September 2001; published 15 March 2002)

The flavor ud and us pseudoscalar correlators are investigated using families of finite energy sum rules (FESR's) known to be very accurately satisfied in the isovector vector channel. It is shown that the combination of constraints provided by the full set of these sum rules is sufficiently strong to allow determination of both the light quark mass combinations $m_u + m_d$, $m_s + m_u$ and the decay constants of the first excited pseudoscalar mesons in these channels. The resulting masses and decay constants are also shown to produce well-satisfied Borel transformed sum rules, thus providing non-trivial constraints on the treatment of direct instanton effects in the FESR analysis. The values of $m_u + m_d$ and $m_s + m_u$ obtained are in good agreement with the values implied by recent hadronic τ decay analyses and the ratios obtained from ChPT. New light quark mass bounds based on FESR's involving weight functions which strongly

suppress spectral contributions from the excited resonance region are also presented. [Phys. Rev. D **65**, 074013 (2002)]

Structural change of Cooper pairs and momentum-dependent gap in color superconductivity. Hiroaki Abuki and Tetsuo Hatsuda, *Department of Physics, University of Tokyo, Tokyo 113-0033, Japan*; Kazunori Itakura, *RIKEN BNL Research Center, Brookhaven National Laboratory, Upton, New York 11973*. (Received 2 September 2001; published 19 March 2002)

The two-flavor color superconductivity is studied over a wide range of baryon density with a single model. We pay special attention to the *spatial*-momentum dependence of the gap and to the *spatial* structure of Cooper pairs. At an extremely high baryon density [$\sim \mathcal{O}(10^{10}\rho_0)$ with ρ_0 being the normal nuclear matter density], our model becomes equivalent to the usual perturbative QCD treatment and the gap is shown to have a sharp peak near the Fermi surface due to the weak-coupling nature of QCD. On the other hand, the gap is a smooth function of momentum at lower densities [$\sim \mathcal{O}(10\rho_0)$] due to strong color magnetic and electric interactions. To study the structural change of Cooper pairs from high density to lower density, the quark correlation in the color superconductor is studied both in momentum space and in coordinate space. The size of the Cooper pair is shown to become comparable to the averaged interquark distance at low densities. Also, the effects of the momentum-dependent running coupling and the antiquark pairing, which are both small at high density, are shown to be non-negligible at low densities. These features are highly contrasted to the standard BCS superconductivity in metals. [Phys. Rev. D **65**, 074014 (2002)]

Expectation values of four-quark operators in pions. E. G. Drukarev, M. G. Ryskin, and V. A. Sadovnikova, *Petersburg Nuclear Physics Institute, Gatchina, 188300 St. Petersburg, Russia*; Amand Faessler, *Institute of Theoretical Physics, University of Tübingen, Morgenstelle 14, D-72076, Tübingen, Germany*. (Received 20 November 2001; published 19 March 2002)

The values of four-quark operators averaged over pions are expressed through those averaged over vacuum. The specific values are obtained in the framework of the factorization assumption. For the condensates of the light quarks of the same flavor $\bar{q}\Gamma q\bar{q}\Gamma q$ the scalar condensate is shown to be an order of magnitude larger than the other ones. The condensates containing the strange quarks $\bar{q}q\bar{s}s$ appear to be only about twice as small as those of the light quarks. The degeneracy of the ground state in the Nambu–Jona-Lasinio model is shown explicitly. [Phys. Rev. D **65**, 074015 (2002)]

Applicability of perturbative QCD and NLO power corrections for the pion form factor. Tsung-Wen Yeh, *Institute of Physics, National Chiao-Tung University, Hsinchu, Taiwan 300, Republic of China*. (Received 4 September 2001; revised manuscript received 7 January 2002; published 19 March 2002)

As is well recognized, the asymptotic of the perturbative QCD prediction for the pion form factor is much smaller than the upper end of the data. We investigate this problem. We first evaluate the next-to-leading-order (NLO) power correction for the pion form factor. The corrected form factor contains nonperturbative parameters which are determined from a χ^2 fit to the data. Interpreting

these parameters leads to the fact that the involved strong interaction coupling constant should be identified as an effective coupling constant under a nonperturbative QCD vacuum. If the scale associated with the effective coupling constant is identified as $\langle x \rangle^2 Q^2$, then Q^2 , the momentum transfer square for the pion form factor to be measured, can have a value about 1 GeV², and $\langle x \rangle$, the averaged momentum fraction variable, can locate around 0.5. This circumstance is consistent with the asymptotic model for the pion wave function. [Phys. Rev. D **65**, 074016 (2002)]

Chiral extrapolation of lattice data for the hyperfine splittings of heavy mesons. X.-H. Guo and A. W. Thomas, *Department of Physics and Mathematical Physics and Special Research Center for the Subatomic Structure of Matter, Adelaide University, Adelaide, SA 5005, Australia.* (Received 4 December 2001; published 21 March 2002)

Hyperfine splittings between the heavy vector (D^*, B^*) and pseudoscalar mesons have been calculated numerically in lattice QCD, where the pion mass (which is related to the light quark mass) is much larger than its physical value. Naive linear chiral extrapolations of the lattice data to the physical mass of the pion lead to hyperfine splittings which are smaller than experimental data. In order to extrapolate these lattice data to the physical mass of the pion more reasonably, we apply the effective chiral perturbation theory for heavy mesons, which is invariant under chiral symmetry when the light quark masses go to zero and heavy quark symmetry when the heavy quark masses go to infinity. This leads to a phenomenological functional form with three parameters to extrapolate the lattice data. It is found that the extrapolated hyperfine splittings are even smaller than those obtained using linear extrapolation. We conclude that the source of the discrepancy between lattice data for hyperfine splittings and experiment must lie in non-chiral physics. [Phys. Rev. D **65**, 074019 (2002)]

Compton scattering, vector-meson photoproduction, and the partonic structure of the nucleon. F. Cano and J. M. Laget, *CEA Saclay, DAPNIA-SPhN, F91191 Gif-sur-Yvette Cedex, France.* (Received 13 November 2001; published 25 March 2002)

At moderate and large momentum transfer, high energy vector-meson photoproduction and Compton scattering can be consistently explained by mechanisms based on interactions and exchanges of constituent quarks and gluons. This opens an original window to the partonic structure of hadronic matter by emphasizing the role of quark correlations, quark exchange as implemented through saturating Regge trajectories, and nonperturbative effects in the gluon propagator, which provides us with a bridge to lattice calculations. Compton scattering is directly related to vector-meson photoproduction and enlarges the data set. [Phys. Rev. D **65**, 074022 (2002)]

Hadronic scattering amplitudes: Medium-energy constraints on asymptotic behavior. J. R. Cudell,¹ V. V. Ezhela,² P. Gauron,³ K. Kang,⁴ Yu. V. Kuyanov,² S. B. Lugovsky,² B. Nicolescu,³ and N. P. Tkachenko² (COMPETE Collaboration), ¹*Institut de Physique, Bât. B5, Université de Liège, Sart Tilman, B4000 Liège, Belgium*, ²*COMPAS group, IHEP, Protvino, Russia*, ³*LPNHE-LPTPE, Université Pierre et Marie Curie, Tour 12 E3, 4 Place Jussieu, 75252 Paris Cedex 05, France*, ⁴*Physics Department, Brown University,*

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We consider several classes of analytic parametrizations of hadronic scattering amplitudes, and compare their predictions to all available forward data (pp , $\bar{p}p$, πp , Kp , γp , $\gamma\gamma$, Σp). Although these parametrizations are very close for $\sqrt{s} \geq 9$ GeV, it turns out that they differ markedly at low energy, where a universal Pomeron term $\sim \ln^2 s$ enables one to extend the fit down to $\sqrt{s} = 4$ GeV. [Phys. Rev. D **65**, 074024 (2002)]

Inclusive gluon production in deep inelastic scattering at high parton density. Yuri V. Kovchegov, *Department of Physics, University of Washington, Box 351560, Seattle, Washington 98195*; Kirill Tuchin, *Institute for Nuclear Theory, University of Washington, Box 351550, Seattle, Washington 98195.* (Received 4 December 2001; published 29 March 2002)

We calculate the cross section of single inclusive gluon production in deep inelastic scattering at very high energies in the saturation regime, where the parton densities inside hadrons and nuclei are large and the evolution of structure functions with energy is nonlinear. The expression we obtain for the inclusive gluon production cross section is generated by this nonlinear evolution. We analyze the rapidity distribution of the produced gluons as well as their transverse momentum spectrum given by the derived expression for the inclusive cross section. We propose an ansatz for the multiplicity distribution of gluons produced in nuclear collisions which includes the effects of nonlinear evolution in both colliding nuclei. [Phys. Rev. D **65**, 074026 (2002)]

Spin force dependence of the parton distributions: The ratio $F_2^n(x, Q^2)/F_2^p(x, Q^2)$. Barbara Pasquini, *ECT*, Strada delle Tabarelle 286, I-38050 Villazzano, Trento, Italy*, and INFN, Trento, Italy; Marco Traini, *Dipartimento di Fisica, Università degli Studi di Trento, I-38050 Povo (Trento), Italy*, and INFN, Trento, Italy; Sigfrido Boffi, *Dipartimento di Fisica Nucleare e Teorica, Università degli Studi di Pavia, I-27100 Pavia, Italy*, and INFN, Pavia, Italy. (Received 4 January 2002; published 29 March 2002)

Light-front Hamiltonian dynamics is used to relate low-energy constituent quark models to deep inelastic unpolarized structure functions of the nucleon. The approach incorporates the correct Pauli principle prescription consistently and it allows a transparent investigation of the effects due to the spin-dependent $SU(6)$ -breaking terms in the quark model Hamiltonian. Both the Goldstone-boson-exchange interaction and hyperfine-potential models are discussed in a unified scheme and a detailed comparison between the two (apparently) different potential prescriptions is presented. [Phys. Rev. D **65**, 074028 (2002)]

Instanton-induced semihard parton interactions and phenomenology of high energy hadron collisions. G. W. Carter, *Department of Physics, University of Washington, Seattle, Washington 98195-1560*; D. M. Ostrovsky and E. V. Shuryak, *Department of Physics and Astronomy, State University of New York, Stony Brook, New York 11794-3800.* (Received 4 December 2001; published 1 April 2002)

We study phenomenologically whether partonic collisions responsible for the growth of hadron-hadron cross sections at high energy can be ascribed to instanton-induced processes. Although nonperturbative in nature, these interactions occur at the semihard scale $Q \sim 1-2$ GeV, and should therefore be described using information from deep inelastic leptonic scattering on the partonic constituents in nucleons, pions, and photons. After considering shadowing corrections in nucleon-nucleon scattering, we fix a free instanton tail suppression parameter and determine the effective quark-quark cross section. The resulting contributions to NN , πN , γN , and $\gamma\gamma$ cross sections all *increase* with energy differently, but in reasonable agreement with experimental data. We then proceed to an estimate of the number of such processes present in high energy Au-Au collisions at BNL RHIC, finding that the amount of entropy produced by instanton or sphaleron events matches the observed amount. [Phys. Rev. D **65**, 074034 (2002)]

Lattice study of the nucleon excited states with domain wall fermions. Shoichi Sasaki, *RIKEN-BNL Research Center, Brookhaven National Laboratory, Upton, New York 11973-5000, and Department of Physics, University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-0033, Japan*; Tom Blum, *RIKEN-BNL Research Center, Brookhaven National Laboratory, Upton, New York 11973-5000*; Shigemi Ohta, *Institute for Particle and Nuclear Studies, KEK, Tsukuba, Ibaraki 305-0801, Japan, and RIKEN-BNL Research Center, Brookhaven National Laboratory, Upton, New York 11973-5000*. (Received 26 February 2001; published 11 March 2002)

We present results of our numerical calculation of the mass spectrum for isospin one-half and spin one-half nonstrange baryons, i.e., the ground and excited states of the nucleon, in quenched lattice QCD. We use a new lattice discretization scheme for fermions, domain wall fermions, which possess almost exact chiral symmetry at nonzero lattice spacing. We make a systematic investigation of the negative-parity N^* spectrum by using two distinct interpolating operators at $\beta = 6/g^2 = 6.0$ on a $16^3 \times 32 \times 16$ lattice. The mass estimates extracted from the two operators are consistent with each other. The observed large mass splitting between this state, $N^*(1535)$, and the positive-parity ground state, the nucleon $N(939)$, is well reproduced by our calculations. We have also calculated the mass of the first positive-parity excited state and find that it is heavier than the negative-parity excited state for the quark masses studied. [Phys. Rev. D **65**, 074503 (2002)]

$g_{\rho\sigma\gamma}$ coupling constant in light cone QCD. T. M. Aliev, A. Özpıneci, and M. Savcı, *Physics Department, Middle East Technical University, 06531 Ankara, Turkey*. (Received 6 September 2001; published 8 March 2002)

The coupling constant $g_{\rho\sigma\gamma}$ is determined from light cone QCD sum rules. A comparison of our result with the ones existing in the literature is presented. [Phys. Rev. D **65**, 076004 (2002)]

Explicit proof that electroproduction of transversely polarized mesons vanishes in perturbative QCD. Pervez Hoodbhoy, *Department of Physics, University of Maryland, College Park, Maryland 20742*. (Received 28 August 2001; published 11 March 2002)

By means of an explicit one-loop calculation, it is shown that the leading twist contribution to the exclusive electroproduction of transversely polarized vector mesons from the nucleon vanishes. This confirms the all-orders proof by Collins and Diehl [Phys. Rev. D **61**, 114015 (2000)]. [Phys. Rev. D **65**, 077501 (2002)]

Chiral perturbation theory and the $f_2(1270)$ resonance. A. Dobado and J. R. Peláez, *Departamento de Física Teórica I and II, Universidad Complutense de Madrid, 28040 Madrid, Spain*. (Received 12 November 2001; published 14 March 2002)

Within chiral perturbation theory, we study elastic pion scattering in the $I=0, J=2$, channel, whose main features are the $f(1270)$ resonance and the vanishing of the lowest order. By means of a chiral model that includes an explicit resonance coupled to pions, we describe the data and calculate the resonance contribution to the $O(p^4)$ and $O(p^6)$ chiral parameters. We also generalize the inverse amplitude method to higher orders, which allows us to study channels with vanishing lowest order. In particular, we apply it to the $I=0, J=2$ case, finding a good description of the $f_2(1270)$ resonance, as a pole in the second Riemann sheet. [Phys. Rev. D **65**, 077502 (2002)]

Baryons in partially quenched chiral perturbation theory. Jiunn-Wei Chen, *Department of Physics, University of Maryland, College Park, Maryland 20742-4111*; Martin J. Savage, *Department of Physics, University of Washington, Seattle, Washington 98195*. (Received 10 December 2001; published 9 April 2002)

We include the lowest-lying octet and decuplet baryons into partially quenched chiral perturbation theory. Perturbing about the chiral limit of the graded $SU(6|3)_L \otimes SU(6|3)_R$ flavor group of partially quenched QCD, we compute the leading one-loop contributions to the octet-baryon masses, magnetic moments and matrix elements of isovector twist-2 operators. We work in the isospin limit and keep two of the three sea quarks degenerate. The usefulness of the non-unique extension of the electric charge matrix and the isovector twist-2 operators from QCD to partially quenched QCD is discussed. [Phys. Rev. D **65**, 094001 (2002)]