Selected Abstracts from Other Physical Review Journals

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Pairing of fermions in atomic traps and nuclei. H. Heiselberg, *University of Southern Denmark, Campusvej 55, DK-5230 Odense M, Denmark.* (Received 2 April 2003; published 24 November 2003)

Pairing gaps for fermionic atoms in harmonic-oscillator traps are calculated for a wide range of interaction strengths and particle numbers, and compared to pairing in nuclei. Especially systems where the pairing gap exceeds the single-level spacing but is smaller than the shell splitting $\hbar\omega$ are studied, which applies to most trapped Fermi atomic systems as well as to finite nuclei. When solving the gap equation for a large trap with such multilevel pairing, one finds that the matrix elements between nearby harmonic-oscillator levels and the quasi particle energies lead to a double logarithm of the gap, and a pronounced shell structure at magic numbers. It is argued that neutron and proton pairing in nuclei belongs to the class of multilevel pairing, that their shell structure follows naturally, and that the gaps scale as $\sim A^{-1/3}$—all in qualitative agreement with odd-even staggering of nuclear binding energies. Pairing in large systems is related to that in the bulk limit. For large nuclei the neutron and proton superfluid gaps approach the asymptotic value in infinite nuclear matter: $\Delta \simeq 1.1$ MeV. [Phys. Rev. A **68**, 053616 (2003)]

Big bang nucleosynthesis and $\Lambda_{\mathbf{QCD}}$. James P. Kneller and Gail C. McLaughlin, *Department of Physics, North Carolina State University, Raleigh, North Carolina 27695-8202, USA.* (Received 3 June 2003; revised manuscript received 7 July 2003; published 19 November 2003)

Big bang nucleosynthesis (BBN) has increasingly become the tool of choice for investigating the permitted variation of fundamental constants during the earliest epochs of the Universe. Here we present a BBN calculation that has been modified to permit changes in the QCD scale, Λ_{QCD}. The primary effects of changing the QCD scale upon BBN are through the deuteron binding energy B_{D} and the neutron-proton mass difference δm_{np}, which both play crucial roles in determining the primordial abundances. In this paper we show how a simplified BBN calculation allows us to restrict the nuclear data we need to just B_{D} and δm_{np} yet still gives useful results so that any variation in Λ_{QCD} may be constrained via the corresponding shifts in B_{D} and δm_{np} by using the current estimates of the primordial deuterium abundance and helium mass fraction. The simplification predicts the helium-4 and deuterium abundances to within 1% and 50%, respectively, when compared with the results of a standard BBN code. But Λ_{QCD} also affects much of the remaining required nuclear input so this method introduces a systematic error into the calculation and we find a degeneracy between B_{D} and δm_{np}. We show how increased understanding of the relationship of the pion mass and/or B_{D} to other nuclear parameters, such as the binding energy of tritium and the cross section of $\mathrm{T}+\mathrm{D}\rightarrow{}^4\mathrm{He}+n$, would yield constraints upon any change in B_{D} and δm_{np} at the 10% level. [Phys. Rev. D **68**, 103508 (2003)]

Effect of the pion thermal width on the sigma spectrum. Yoshimasa Hidaka, Osamu Morimatsu, Tetsuo Nishikawa, and Munehisa Ohtani, *Institute of Particle and Nuclear Studies, High Energy Accelerator Research Organization, 1-1, Ooho, Tsukuba, Ibaraki, 305-0801, Japan.* (Received 25 April 2003; published 29 December 2003)

We study the effect of the thermal width of π on the spectral function of σ applying a resummation technique called the optimized perturbation theory at finite temperature (T) to the $O(4)$ linear sigma model. In order to take into account a finite thermal width of π, we replace the internal pion mass in the self-energy of σ with that of the complex pole found in a previous paper. The obtained spectral function for $T \gtrsim 100$ MeV turns out to possess two broad peaks. Although a sharp peak at $\sigma \rightarrow \pi\pi$ threshold was observed in the one-loop calculation without the pion thermal width, the peak is shown to be smeared out. We also search for the poles of the σ propagator and analyze the behavior of the spectral function with these poles. [Phys. Rev. D **68**, 111901 (2003)]

Constraints on neutrino parameters from neutral-current solar neutrino measurements. A. B. Balantekin and H. Yüksel, *Department of Physics, University of Wisconsin, Madison, Wisconsin 53706, USA.* (Received 10 September 2003; published 5 December 2003)

We generalize the pull approach to define the χ^2 function to the analysis of the data with correlated statistical errors. We apply this method to the analysis of the Sudbury Neutrino Collaboration data obtained in the salt phase. In the global analysis of all the solar neutrino and KamLAND data we find the best fit (minimum χ^2) values of neutrino parameters to be $\tan^2\theta_{12} \sim 0.42$ and $\delta m^2_{12} \sim 7.1 \times 10^{-5}$ eV^2. We confirm that the maximal mixing is strongly disfavored while the bounds on δm^2_{12} are significantly strengthened. [Phys. Rev. D **68**, 113002 (2003)]

Measurement of the L/E distributions of atmospheric ν in Soudan 2 and their interpretation as neutrino oscillations. M. Sanchez,[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] D. J. A. Cockerill,[4] H. Courant,[2] D. M. Demuth,[2] T. H. Fields,[1] H. R. Gallagher,[5] M. C. Goodman,[1] T. Joffe-Minor,[1] T. Kafka,[5] S. M. S. Kasahara,[2] P. J. Litchfield,[2] W. A. Mann,[5] M. L. Marshak,[2] R. H. Milburn,[5] W. H. Miller,[2] L. Mualem,[2] J. K. Nelson,[2] A. Napier,[5] W. P. Oliver,[5] G. F. Pearce,[4] E. A. Peterson,[2] D. A. Petyt,[2] K. Ruddick,[2] J. Schneps,[5] A. Sousa,[5] B. Speakman,[2] J. L. Thron,[1] and N. West[3] [1]*Argonne National Laboratory, Argonne, Illinois 60439, USA,* [2]*University of Minnesota, Minneapolis, Minnesota 55455, USA,* [3]*Department of Physics, University of Oxford, Oxford OX1 3RH, United Kingdom,* [4]*Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire*

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A deficit of atmospheric ν_μ events, consistent with the hypothesis of neutrino oscillations, is observed in the 5.90 kiloton-year fiducial exposure of the Soudan 2 detector. An unbinned maximum likelihood analysis of the neutrino L/E distribution has been carried out using the Feldman-Cousins prescription. The probability of the no oscillation hypothesis is 5.8×10^{-4}. The 90% confidence allowed region in the $\sin^2 2\theta, \Delta m^2$ plane is presented. The region includes the 90% confidence allowed region of the Super-K experiment. [Phys. Rev. D **68**, 113004 (2003)]

Precision neutrino oscillation physics with an intermediate baseline reactor neutrino experiment. Sandhya Choubey, *INFN, Sezione di Trieste, Trieste, Italyand Scuola Internazionale Superiore di Studi Avanzati, I-34014 Trieste, Italy;* S. T. Petcov, *Scuola Internazionale Superiore di Studi Avanzati, I-34014 Trieste, Italy, INFN, Sezione di Trieste, Trieste, Italy, and Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, 1784 Sofia, Bulgaria;* M. Piai, *Department of Physics, Yale University, New Haven, Connecticut 06520, USA.* (Received 16 June 2003; published 30 December 2003)

We discuss the physics potential of intermediate $L\sim20$–30 km baseline experiments at reactor facilities. Assuming that the solar neutrino oscillation parameters $\Delta m^2_\odot$ and $\theta_\odot$ lie in the high LMA solution region, we show that such an intermediate baseline reactor experiment can determine both $\Delta m^2_\odot$ and $\theta_\odot$ with a remarkably high precision. We perform also a detailed study of the sensitivity of the indicated experiment to $\Delta m^2_{\rm atm}$, which drives the dominant atmospheric ν_μ ($\overline{\nu}_\mu$) oscillations, and to θ—the neutrino mixing angle limited by the data from the CHOOZ and Palo Verde experiments. Irrespective of the actual values of $\Delta m^2_\odot$, we find that this experiment can improve the bounds on $\sin^2\theta$, and, if the value of $\sin^2\theta$ is large enough, $\sin^2\theta\gtrsim0.02$, the energy resolution of the detector is sufficiently good and if the statistics is relatively high, it can determine with extremely high precision the value of $\Delta m^2_{\rm atm}$. We also explore the potential of the intermediate baseline reactor neutrino experiment for determining the type of the neutrino mass spectrum, which can be with normal or inverted hierarchy, assuming $\Delta m^2_\odot$ to lie in the high LMA solution region. We show that the conditions under which the type of neutrino mass hierarchy can be determined are quite challenging, but are within the reach of the experiment under discussion. [Phys. Rev. D **68**, 113006 (2003)]

Supernova neutrinos, neutrino oscillations, and the mass of the progenitor star. Keitaro Takahashi,[1] Katsuhiko Sato,[1,2] Adam Burrows,[3] and Todd A. Thompson[4] [1]*Department of Physics, University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan,* [2]*Research Center for the Early Universe, University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan,* [3]*Steward Observatory, The University of Arizona, Tucson, Arizona 85721, USA,* [4]*Astronomy Department and Theoretical Astrophysics Center, 601 Campbell Hall, The University of California, Berkeley, California 94720, USA.* (Received 9 June 2003; published 30 December 2003)

We investigate the initial progenitor mass dependence of the early-phase neutrino signal from supernovae taking neutrino oscillations into account. The early-phase analysis has advantages in that it is not affected by the time evolution of the density structure of the star due to shock propagation or whether the remnant is a neutron star or a black hole. The initial mass affects the evolution of the massive star and its presupernova structure, which is important for two reasons when considering the neutrino signal. First, the density profile of the mantle affects the dynamics of neutrino oscillation in supernova. Second, the final iron core structure determines the features of the neutrino burst, i.e., the luminosity and the average energy. We find that both effects are rather small. This is desirable when we try to extract information on neutrino parameters from future supernova-neutrino observations. Although the uncertainty due to the progenitor mass is not small for intermediate θ_{13} ($10^{-5}\lesssim\sin^2 2\theta_{13}\lesssim10^{-3}$), we can, nevertheless, extract information on the character of the mass hierarchy and whether θ_{13} is very large or very small. [Phys. Rev. D **68**, 113009 (2003)]

Status of three-neutrino oscillations after the SNO-salt data. M. Maltoni,[1] T. Schwetz,[2] M. A. Tórtola,[1] and J. W. F. Valle[1] [1]*Instituto de Física Corpuscular-CSIC/Universitat de València, Edificio Institutos de Paterna, Apartado 22085, E-46071 Valencia, Spain,* [2]*Theoretische Physik, Physik Department, Technische Universität München, James-Franck-Strasse D-85748 Garching, Germany.* (Received 19 September 2003; published 30 December 2003)

We perform a global analysis of neutrino oscillation data in the framework of three neutrinos, including the recent improved measurement of the neutral current events at the Sudbury Neutrino Observatory. In addition to all current solar neutrino data, we take into account the reactor neutrino data from KamLAND and CHOOZ, the atmospheric neutrino data from Super-Kamiokande and MACRO, as well as the first spectral data from the K2K long baseline accelerator experiment. The up-to-date best-fit values and allowed ranges of the three-flavor oscillation parameters are determined from these data. Furthermore, we discuss in detail the status of the small parameters $\alpha\equiv\Delta m^2_{\rm sol}/\Delta m^2_{\rm atm}$ and $\sin^2\theta_{13}$, which fix the possible strength of *CP*-violating effects in neutrino oscillations. [Phys. Rev. D **68**, 113010 (2003)]

Impact parameter dipole saturation model. Henri Kowalski, *Physics Department, Brookhaven National Laboratory, Upton, New York 11973, USA, Department of Physics, Columbia University, New York, New York 10027, USA, and Deutsches Elektronen Synchrotron DESY, Hamburg, Germany;* Derek Teaney, *Physics Department, Brookhaven National Laboratory, Upton, New York 11973, USA.* (Received 3 June 2003; published 15 December 2003)

We develop a dipole model for DESY HERA deep inelastic scattering data which incorporates the impact parameter distribution of the proton. The model describes the inclusive total $\gamma^* p$ cross sections as well as the diffractive J/ψ differential cross sections. We compare the model with previous approaches and show that the t distributions are sensitive to saturation phenomena. We estimate the

boundary of the saturation region and show that it dominates the data in the low-Q^2 region where the total $\gamma^* p$ cross section exhibits the same universal rise as hadronic cross sections. The model is then extended to nuclei and shows good agreement with the nuclear shadowing data at small x. Finally, we estimate the saturation scale in nuclei. [Phys. Rev. D **68**, 114005 (2003)]

Deep inelastic scattering as $x \to 1$ using soft-collinear effective theory. Aneesh V. Manohar, *Department of Physics, University of California at San Diego, La Jolla, California 92093, USA.* (Received 17 September 2003; published 30 December 2003)

Soft-collinear effective theory (SCET) is used to sum Sudakov double logarithms in the $x \to 1$ end point region for the deep inelastic scattering structure function. The calculations are done in both the target rest frame and the Breit frame. The separation of scales in the effective theory implies that the anomalous dimension of the SCET current is linear in $\ln \mu$, and the anomalous dimension for the Nth moment of the structure function is linear in $\ln N$, to all orders in perturbation theory. The SCET formulation is shown to be free of Landau pole singularities. Some important differences between the deep inelastic structure function and the shape function in B decay are discussed. [Phys. Rev. D **68**, 114019 (2003)]

Nucleon properties at finite lattice spacing in chiral perturbation theory. Silas R. Beane, *Institute for Nuclear Theory, University of Washington, Seattle, Washington 98195, USA,* Martin J. Savage *Department of Physics, University of Washington, Seattle, Washington 98195, USA.* (Received 8 July 2003; published 4 December 2003)

Properties of the proton and neutron are studied in partially quenched chiral perturbation theory at finite lattice spacing. Masses, magnetic moments, the matrix elements of isovector twist-2 operators and axial-vector currents are examined at the one-loop level in a double expansion in the light-quark masses and the lattice spacing. This work will be useful in extrapolating the results of simulations using Wilson valence and sea quarks, as well as simulations using Wilson sea quarks and Ginsparg-Wilson valence quarks, to the continuum. [Phys. Rev. D **68**, 114502 (2003)]

Self-energy-part resummed quark and gluon propagators in a spin-polarized quark matter and generalized Boltzmann equations. A. Niégawa, *Graduate School of Science, Osaka City University, Sumiyoshi-ku, Osaka 558-8585, Japan.* (Received 29 July 2003; published 29 December 2003)

We construct perturbative frameworks for studying nonequilibrium spin-polarized quark matter. We employ the closed-time-path formalism and use the gradient approximation in derivative expansion. After constructing self-energy-part resummed quark and gluon propagators, we formulate two kinds of mutually equivalent perturbative frameworks: The first one is formulated on the basis of the initial-particle distribution function, and the second one is formulated on the basis of a ''physical'' particle distribution function. In the course of the construction of the second framework, the generalized Boltzmann equations and their relatives *directly* come out, which describe the evolution of the system. The frameworks are relevant to the study of a magnetic character of quark matter, e.g., possible quark stars. [Phys. Rev. D **68**, 116007 (2003)]