

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.

Superlight neutralino as a dark matter particle candidate. V. A. Bednyakov, *Max-Planck-Institut für Kernphysik, Postfach 103980, D-69029, Heidelberg, Germany and Laboratory of Nuclear Problems, Joint Institute for Nuclear Research, Moscow region, 141980 Dubna, Russia*; H. V. Klapdor-Kleingrothaus, *Max-Planck-Institut für Kernphysik, Postfach 103980, D-69029, Heidelberg, Germany*; S. G. Kovalenko, *Max-Planck-Institut für Kernphysik, Postfach 103980, D-69029, Heidelberg, Germany and Laboratory of Nuclear Problems, Joint Institute for Nuclear Research, Moscow region, 141980 Dubna, Russia.* (Received 2 August 1996)

We address the question of how light the lightest supersymmetric particle neutralino can be to be a reliable cold dark matter (CDM) particle candidate. To this end we perform a combined analysis of the parameter space of the minimal supersymmetric standard model (MSSM) taking into account cosmological and accelerator constraints including those from the radiative $b \rightarrow s \gamma$ decay. Appropriate grand unification (GUT) scenarios are considered. We find that the relaxation of gaugino mass unification is sufficient to obtain a phenomenologically and cosmologically viable solution of the MSSM with a neutralino as light as 3 GeV. We find good prospects for the direct detection of these superlight CDM neutralinos via elastic scattering off various nuclei in the forthcoming experiments with low-threshold DM detectors. In a certain sense, these experiments can probe the gaugino mass unification giving constraints on the possible GUT scenarios within the MSSM.

[S0556-2821(97)05102-3] [Phys. Rev. D **55**, 503 (1997)]

Reduction of weak interaction rates in neutron stars by nucleon spin fluctuations: Degenerate case. Georg Raffelt and Thomas Strobel, *Max-Planck-Institut für Physik, Föhringer Ring 6, 80805 München, Germany.* (Received 8 April 1996)

Nucleon spin fluctuations in a dense medium reduce the “naive” values of weak interaction rates (neutrino opacities, neutrino emissivities). We extend previous studies of this effect to the degenerate case which is appropriate for neutron stars a few ten seconds after formation. If neutron-neutron interactions by a one-pion exchange potential are the dominant cause of neutron spin fluctuations, a perturbative calculation of weak interaction rates is justified for $T \lesssim 3m/(4\pi\alpha_\pi^2) \approx 1$ MeV, where m is the neutron mass and $\alpha_\pi \approx 15$ the pion fine-structure constant. At higher temperatures, the application of Landau’s theory of Fermi liquids is no longer justified; i.e., the neutrons cannot be viewed as simple quasiparticles in any obvious sense. [S0556-2821(97)00402-5] [Phys. Rev. D **55**, 523 (1997)]

Cosmological implications of two conflicting deuterium abundances. Naoya Hata and Gary Steigman, *Department of Physics, The Ohio State University, Columbus, Ohio 43210*; Sidney Bludman and Paul Langacker, *Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania 19104.* (Received 5 April 1996)

Constraints on big bang nucleosynthesis (BBN) and on cosmological parameters from conflicting deuterium observations in different high redshift QSO systems are discussed. The high deuterium observations by Carswell *et al.*, Songaila *et al.*, and Rugers and Hogan are consistent with ^4He and ^7Li observations and standard BBN ($N_\nu = 3$) and allows $N_\nu \leq 3.6$ at 95% C.L., but are inconsistent with local observations of D and ^3He in the context of conventional theories of stellar and galactic evolution. In contrast, the low deuterium observations by Tytler, Fan, and Burles and Burles and Tytler are consistent with the constraints from local galactic observations, but require $N_\nu = 1.9 \pm 0.3$ at 68% C.L., excluding standard BBN at 99.9% C.L., unless the systematic uncertainties in the ^4He observations have been underestimated by a large amount. The high and low primordial deuterium abundances imply, respectively, $\Omega_B h^2 = 0.005 - 0.01$ and $\Omega_B h^2 = 0.02 - 0.03$ at 95% C.L. When combined with the high baryon fraction inferred from x-ray observations of rich clusters, the corresponding total mass densities (for $50 \leq H_0 \leq 90$) are $\Omega_M = 0.05 - 0.20$ and $\Omega_M = 0.2 - 0.7$, respectively (95% C.L.). The range of Ω_M corresponding to high D is in conflict with dynamical constraints ($\Omega_m \geq 0.2 - 0.3$) and with the shape parameter constraint ($\Gamma = \Omega_M h = 0.25 \pm 0.05$) from large scale structure formation in CDM and Λ CDM models. [S0556-2821(96)00118-X] [Phys. Rev. D **55**, 540 (1996)]

Statistical properties of the linear σ model used in dynamical simulations of DCC formation. Jørgen Randrup, *Nuclear Science Division, Lawrence Berkeley National Laboratory, University of California, Berkeley, California 94720.* (Received 15 January 1996)

The present work develops a simple approximate framework for initializing and interpreting dynamical simulations with the linear σ model exploring the formation of disoriented chiral condensates in high-energy collisions. By enclosing the system in a rectangular box with periodic boundary conditions, it is possible to decompose uniquely the chiral field into its spatial average (the order parameter) and its fluctuations (the quasiparticles) which can be treated in the Hartree approximation. The quasiparticle modes are then described approximately by Klein-Gordon dispersion relations containing an effective mass depending on both the temperature and the magnitude of the order parameter; their fluctuations are instrumental in shaping the effective potential governing the order parameter, and the emerging statistical description is thermodynamically consistent. The temperature dependence of the statistical distribution of the order parameter is discussed, as is the behavior of the associated effective masses; as the system is cooled, the field fluctuations subside, causing a smooth change from the high-temperature phase in which chiral symmetry is approximately restored towards the normal phase. Of practical interest is the fact that the equilibrium field configurations can be sampled in a simple manner, thus providing a convenient means for specifying the initial conditions in dynamical simulations of the nonequilibrium relaxation of the chiral field; in particular, the correlation function is much more realistic than those emerging in previous initialization methods. It is illustrated how

such samples remain approximately invariant under propagation by the unapproximated equation of motion over times that are long on the scale of interest, thereby suggesting that the treatment is sufficiently accurate to be of practical utility. [S0556-2821(97)05803-7] [Phys. Rev. D **55**, 1188 (1997)]

Muon bremsstrahlung on heavy atoms. Yu. M. Andreev and E. V. Bugaev, *Institute for Nuclear Research, Russian Academy of Sciences, 60-letiya Oktyabrya Ave., 117312 Moscow, Russia.* (Received 25 July 1996)

The cross section for high energy muon bremsstrahlung on heavy atoms is calculated without the use of the Born approximation. It is shown that the correction to the Born approximation in the region of momentum transfers q of the order of μc has the same order of magnitude as the well-known correction of Davies, Bethe, and Maximon. It is shown also that these corrections have different signs and nearly compensate each other. [S0556-2821(97)06403-5] [Phys. Rev. D **55**, 1233 (1997)]

What we can learn about nucleon spin structure from recent data. M. Goshtasbpour, *Center for Theoretical Physics and Mathematics, AEOL, Tehran, Iran and Department of Physics, Shahid Beheshti University, Tehran, Iran;* Gordon P. Ramsey, *Physics Department, Loyola University, Chicago, Illinois 60626 and High Energy Physics Division, Argonne National Laboratory, Argonne, Illinois 60439.* (Received 11 December 1995)

We have used recent data from the CERN and SLAC to extract information about nucleon spin structure. We find that the SMC proton data on $\int_0^1 g_1^p dx$, the E142 neutron data on $\int_0^1 g_1^n dx$, and the deuteron data from the SMC and E143 give different results for fractions of the spin carried by each of the constituents. These appear to lead to two different and incompatible models for the polarized strange sea. The polarized gluon distribution occurring in the gluon anomaly does not have to be large in order to be consistent with either set of experimental data. However, it appears that the discrepancies in the implications of these data cannot be resolved with any simple theoretical arguments. We conclude that more experiments must be performed in order to adequately determine the fraction of spin carried by each of the nucleon constituents. [S0556-2821(97)02003-1] [Phys. Rev. D **55**, 1244 (1997)]

Applying factorial moments of continuous order to experimental data of 400 GeV/c pp collisions. Zhang Jie and Wang Shaoshun, *Department of Modern Physics, University of Science and Technology of China, Hefei, 230027, China.* (Received 21 February 1996)

Factorial moments of continuous order are studied by using Monte Carlo events and experimental data. A maximum likelihood method is proposed and dynamical fluctuations are studied in normalized pseudorapidity space for 400 GeV/c pp collisions. Multifractal dimensions $D(q)$ and multifractal spectrum $f(\alpha)$ are presented. Monte Carlo simulation indicates that the statistical fluctuations are filtered out. The values of $D(q)$ are consistent with the previous ones obtained by the ordinary method of scaled facto-

rial moment. The observed hierarchy $D(0) > D(1) > D(2)$ provides evidence of multifractal behavior for multiparticle production of 400 GeV/c pp collisions. The multifractal spectrum $f(\alpha)$ can be well reproduced by the random cascade α model. [S0556-2821(97)05403-9] [Phys. Rev. D **55**, 1257 (1997)]

Hyperon polarization in the constituent quark model. S. M. Troshin and N. E. Tyurin, *Institute for High Energy Physics, Protvino, Moscow Region, 142284 Russia.* (Received 28 May 1996)

We consider a nonperturbative mechanism for hyperon polarization in inclusive production at moderate transverse momenta. The main role belongs to the orbital angular momentum and the polarization of the strange quark-antiquark pairs in the internal structure of the constituent quarks. We consider a nucleon as a core consisting of the constituent quarks embedded into a quark condensate. The nonperturbative hadron structure is inspired by the results of the chiral quark models. [S0556-2821(97)02303-5] [Phys. Rev. D **55**, 1265 (1997)]

Prompt ν_τ fluxes in present and future τ neutrino experiments. M. C. Gonzalez-Garcia, *Theory Division, CERN, CH-1211 Geneva 23, Switzerland;* J. J. Gomez-Cadenas, *PPE Division, NOMAD experiment, CERN, CH-1211 Geneva 23, Switzerland.* (Received 13 August 1996)

We use a nonperturbative QCD approach, the quark-gluon string model, to compute the τ -neutrino fluxes produced by fixed target pA collisions (where A is a target material) for incident protons of energies ranging from 120 to 800 GeV. The purpose of this calculation is to estimate in a consistent way the prompt background for the $\nu_\mu(\nu_e) \leftrightarrow \nu_\tau$ oscillation search in the on-going $\nu_\mu(\nu_e) \leftrightarrow \nu_\tau$ oscillation search experiments CHORUS and NOMAD, as well as the expected prompt background in future experiments, such as COSMOS at Fermilab and a possible second-generation $\nu_\mu(\nu_e) \leftrightarrow \nu_\tau$ search experiment at the CERN SPS. In addition, we compute the number of ν_τ interactions expected by the experiment E872 at Fermilab. [S0556-2821(97)04703-6] [Phys. Rev. D **55**, 1297 (1997)]

Solar neutrinos: Near-far asymmetry and just-so oscillations. B. Faïd,¹ G. L. Fogli,² E. Lisi,^{2,3} and D. Montanino,² ¹*Institut de Physique, Université des Sciences et de la Technologie, DZ-16111 Algiers, Algeria* ²*Dipartimento di Fisica dell'Università and Sezione INFN, I-70126 Bari, Italy* ³*Institute for Advanced Study, Princeton, New Jersey 08540.* (Received 12 August 1996)

We propose to study possible signals of just-so oscillations in new-generation solar neutrino experiments by separating the events detected when the Earth is nearest to the Sun (perihelion ± 3 months) from those detected when the Earth is farthest from the Sun (aphelion ± 3 months). We introduce a solar-model-independent near-far asymmetry, which is nonzero if just-so oscillations occur. We apply our calculations to the kinetic energy spectra of electrons induced by ^8B solar neutrino interactions in the SuperKamiokande and Sudbury Neutrino Observatory experiments. We show that the sensitivity to the neutrino oscillation parameters can be increased by probing the near-far asymmetry in selected

parts of the electron energy spectra. [S0556-2821(97)00403-7] [Phys. Rev. D **55**, 1353 (1997)]

Nature of the highest energy cosmic rays. Todor Stanev, *Bartol Research Institute, University of Delaware, Newark, Delaware 19716*; H. P. Vankov, *Institute for Nuclear Research and Nuclear Energy, Sofia 1184, Bulgaria*. (Received 24 June 1996)

Ultrahigh energy γ rays produce electron-positron pairs in interactions on the geomagnetic field. The pair electrons suffer magnetic bremsstrahlung and the energy of the primary γ ray is shared by a bunch of lower energy secondaries. These processes reflect the structure of the geomagnetic field and cause experimentally observable effects. The study of these effects with future giant air shower arrays can identify the nature of the highest energy cosmic rays as either γ rays or nuclei. [S0556-2821(97)05003-0] [Phys. Rev. D **55**, 1365 (1997)]

Isospin breaking and instantons in QCD nucleon sum rules. Hilmar Forkel, *European Centre for Theoretical Studies in Nuclear Physics and Related Areas, Villa Tambosi, Strada delle Tabarelle 286, I-38050 Villazzano, Italy*; Marina Nielsen, *Instituto de Física, Universidade de São Paulo, Caixa Postal 66318, 05389-970 São Paulo, SP, Brazil*. (Received 7 June 1995)

We study isospin-breaking instanton corrections to the operator product expansion of the nucleon correlation functions. After a comparison with quark model calculations based on the 't Hooft interaction, we examine the role of instantons in the corresponding QCD sum rules. Instanton contributions are found to be absent in the chirally even sum rule, but significant in the chirally odd one. They improve the consistency of both sum rules and favor a value of the isovector quark condensate close to the chiral estimate. [S0556-2821(97)01003-5] [Phys. Rev. D **55**, 1471 (1997)]

Neutron electric dipole moment from supersymmetric anomalous W -boson coupling. Tomoko Kadoyoshi and Noriyuki Oshimo, *Department of Physics, Ochanomizu University, Otsuka 2-1-1, Bunkyo-ku, Tokyo 112, Japan*. (Received 10 July 1996)

In the supersymmetric standard model (SSM) the W boson could have a nonvanishing electric dipole moment (EDM) through a one-loop diagram mediated by the charginos and neutralinos. Then the W -boson EDM induces the EDMs of the neutron and the electron. We discuss these EDMs, taking into consideration the constraints from the neutron and electron EDMs at the one-loop level induced by the charginos and squarks or sleptons. It is shown that the neutron and the electron could, respectively, have EDMs of the order of $10^{-26}e$ cm and $10^{-27}e$ cm, solely owing to the W -boson EDM. Since these EDMs do not depend on the values of the SSM parameters for the squark or slepton sector, they provide less ambiguous predictions for CP violation in the SSM. [S0556-2821(97)04003-4] [Phys. Rev. D **55**, 1481 (1997)]

CP and T violation tests in neutrino oscillation. Jiro Arafune and Joe Sato, *Institute for Cosmic Ray Research, University of Tokyo, Midori-cho, Tanashi, Tokyo 188, Japan*. (Received 25 July 1996; revised manuscript received 16 September 1996)

We examine how large violation effects of CP and T are allowed in long baseline neutrino experiments. When we attribute only the atmospheric neutrino anomaly to neutrino oscillation we may have large CP -violation effects. When we attribute both the atmospheric neutrino anomaly and the solar neutrino deficit to neutrino oscillation we may have sizable T violation effects proportional to the ratio of the two mass differences; it is difficult to see CP violation since we cannot ignore the matter effect. We give a simple expression for T violation in the presence of matter. [S0556-2821(97)00903-X] [Phys. Rev. D **55**, 1653 (1997)]

Predictive models of large neutrino mixing angles. S. M. Barr, *Bartol Research Institute, University of Delaware, Newark, Delaware 19716*. (Received 5 August 1996)

Several experimental results could be interpreted as evidence that certain neutrino mixing angles are large, of order unity. However, in the context of grand unified models the neutrino angles come out characteristically to be small, like the KM angles. It is shown how to construct simple grand-unified models in which neutrino angles are not only large but completely predicted with some precision. Six models are presented for illustration. [S0556-2821(97)03303-1] [Phys. Rev. D **55**, 1659 (1997)]

Is the Zee model the model of neutrino masses? Alexei Yu. Smirnov, *International Center for Theoretical Physics, I-34100 Trieste, Italy*; Morimitsu Tanimoto, *Science Education Laboratory, Ehime University, Matsuyama 790, Japan*. (Received 26 April 1996)

The Zee model predicts naturally two heavy, strongly degenerate and almost maximally mixed neutrinos and one light neutrino with small mixing. This pattern coincides with the one needed for a solution of the atmospheric neutrino problem by $\nu_\mu \rightarrow \nu_\tau$ oscillations and for existence of the two component hot dark matter in the Universe. Furthermore, the oscillations $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ can be in the range of sensitivity of KARMEN, LSND experiments. The phenomenology of this scenario is considered and the possibility to check it in the forthcoming experiments is discussed. The scenario implies large values and inverse flavor hierarchy of couplings of the Zee boson with fermions: $f_{e\tau} \ll f_{\mu\tau} \ll f_{e\mu} \sim 0.1$. The main signatures of the scenario are a strongly suppressed signal of $\nu_\mu \rightarrow \nu_\tau$ oscillation in CHORUS and NOMAD experiments, so that a positive result from these experiments will rule out the scenario, the possibility of the observation of $\nu_e \rightarrow \nu_\tau$ oscillations by CHORUS and NOMAD, the corrections to the muon decay and neutrino-electron scattering at the level of experimental errors, and a branching ratio $B(\mu \rightarrow e \gamma)$ bigger than 10^{-13} . The solar neutrino problem can be solved by the introduction of an additional very light singlet fermion without appreciable modification of the active neutrino pattern. [S0556-2821(97)04903-5] [Phys. Rev. D **55**, 1665 (1997)]

Remark on the external-field method in QCD sum rules.

Xuemin Jin, *TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia, Canada V6T 2A3 and Institute for Nuclear Theory, University of Washington, Seattle, Washington 98195*. (Received 18 September 1996)

The external-field method has been used extensively in the QCD sum-rule approach to explore various hadron static properties. In the traditional formalism of this method, the transitions from the ground state hadron to excited states are not exponentially sup-

pressed relative to the ground state term and thus contaminate the ground state hadron property to be extracted. In this paper, we suggest a modified formalism, in which the transition terms are exponentially suppressed relative to the ground state term. As such, the pole plus continuum spectral model, traditionally invoked in the QCD sum-rule approach, can be adopted. Thus, this modified formalism has the potential to improve the predictability and reliability of external-field sum-rule calculations, which is illustrated in an explicit example. [S0556-2821(97)01403-3] [Phys. Rev. D **55**, 1693 (1997)]