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.*

Screening of mass singularities and finite soft-photon production rate in hot QCD. A. Niégawa, *Department of Physics, Osaka City University, Sumiyoshi-ku, Osaka 558, Japan.* (Received 8 July 1996; revised manuscript received 19 February 1997)

The production rate of a soft photon from a hot quark-gluon plasma is computed to leading order at logarithmic accuracy. The canonical hard-thermal-loop resummation scheme leads to a logarithmically divergent production rate due to mass singularities. We show that these mass singularities are screened by employing the effective hard-quark propagator, which is obtained through resummation of the one-loop self-energy part in a self-consistent manner. The damping-rate part of the effective hard-quark propagator, rather than the thermal-mass part, plays the dominant role of screening mass singularities. Diagrams including photon–(hard-)quark vertex corrections also yield the leading contribution to the production rate. [S0556-2821(97)06014-1] [Phys. Rev. D **56**, 1073 (1997)]

Gluon polarization in transversely polarized nucleons and jet spin asymmetries at BNL RHIC. J. Soffer, *Centre de Physique Théorique - CNRS - Luminy, Case 907 F-13288 Marseille Cedex 9, France;* O. V. Teryaev, *Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, 141980, Russia.* (Received 12 February 1997)

We derive the analogue of the Wandzura-Wilczek relation for the light-cone distributions of polarized gluons in a transversely polarized nucleon. The short distance cross section is entirely due to the intrinsic transverse momenta of gluon in the nucleon, in complete analogy with the quark case. We provide numerical estimates for the double transverse spin asymmetries A_{TT} at BNL RHIC energy, which come out to be small, since we find that the gluon contribution is of the same order as for the quark contributions. [S0556-2821(97)50315-8] [Phys. Rev. D **56**, 1353 (1997)]

High energy cosmic ray physics with underground muons in MACRO. I. Analysis methods and experimental results. M. Ambrosio,[12] R. Antolini,[7] G. Auriemma,[14] R. Baker,[11] A. Baldini,[13] G. C. Barbarino,[12] B. C. Barish,[4] G. Battistoni,[6] R. Bellotti,[1] C. Bemporad,[13] P. Bernardini,[10] H. Bilokon,[6] V. Bisi,[16] C. Bloise,[6] T. Bosio,[7] C. Bower,[8] S. Bussino,[14] F. Cafagna,[1] M. Calicchio,[1] D. Campana,[12] M. Carboni,[6] M. Castellano,[1] S. Cecchini,[2] F. Cei,[13] V. Chiarella,[6] A. Corona,[14] S. Coutu,[11] G. De Cataldo,[1] H. Dekhissi,[2] C. De Marzo,[1] I. De Mitri,[9] M. De Vincenzi,[14] A. Di Credico,[7] O. Erriquez,[1] R. Fantini,[2] C. Favuzzi,[1] C. Forti,[6] P. Fusco,[1] G. Giacomelli,[2] G. Giannini,[13] N. Giglietto,[1] M. Goretti,[4,14] M. Grassi,[13] A. Grillo,[7] F. Guarino,[12] P. Guarnaccia,[1] C. Gustavino,[7] A. Habig,[8] K. Hanson,[11] A. Hawthorne,[8] R. Heinz,[8] J. T. Hong,[3] E. Iarocci,[6] E. Katsavounidis,[4] E. Kearns,[3] S. Kyriazopoulou,[4] E. Lamanna,[14] C. Lane,[5] D. S. Levin,[11] P. Lipari,[14] N. P. Longley,[17] M. J. Longo,[11] G. Mancarella,[10] G. Mandrioli,[2] A. Margiotta-Neri,[2] A. Marini,[6] D. Martello,[10] A. Marzari-Chiesa,[16] M. N. Mazziotta,[1] D. G. Michael,[4] S. Mikheyev,[7] L. Miller,[8] P. Monacelli,[9] T. Montaruli,[1] M. Monteno,[16] S. Mufson,[8] J. Musser,[8] D. Nicoló,[13] R. Nolty,[4] C. Okada,[3] C. Orth,[3] G. Osteria,[12] O. Palamara,[10] S. Parlati,[7] V. Patera,[6] L. Patrizii,[2] R. Pazzi,[13] C. W. Peck,[4] S. Petrera,[10] P. Pistilli,[10] V. Popa,[2] A. Rainó,[1] J. Reynoldson,[7] M. Ricciardi,[10] F. Ronga,[6] U. Rubizzo,[12] A. Sanzgiri,[15] F. Sartogo,[14] C. Satriano,[14] L. Satta,[6] E. Scapparone,[7] K. Scholberg,[4] A. Sciubba,[6] P. Serra-Lugaresi,[2] M. Severi,[14] M. Sitta,[16] P. Spinelli,[1] M. Spinetti,[6] M. Spurio,[2] R. Steinberg,[5] J. L. Stone,[3] L. R. Sulak,[3] A. Surdo,[10] G. Tarlé,[11] V. Togo,[2] V. Valente,[6] C. W. Walter,[4] and R. Webb[15] (MACRO Collaboration) [1]*Dipartimento di Fisica dell'Università di Bari and INFN, 70126 Bari, Italy* [2]*Dipartimento di Fisica dell'Università di Bologna and INFN, 40126 Bologna, Italy* [3]*Physics Department, Boston University, Boston, Massachusetts 02215* [4]*California Institute of Technology, Pasadena, California 91125* [5]*Department of Physics, Drexel University, Philadelphia, Pennsylvania 19104* [6]*Laboratori Nazionali di Frascati dell'INFN, 00044 Frascati (Roma), Italy* [7]*Laboratori Nazionali del Gran Sasso dell'INFN, 67010 Assergi (L'Aquila), Italy* [8]*Departments of Physics and of Astronomy, Indiana University, Bloomington, Indiana 47405* [9]*Dipartimento di Fisica dell'Università dell'Aquila and INFN, 67100 L'Aquila, Italy* [10]*Dipartimento di Fisica dell'Università di Lecce and INFN, 73100 Lecce, Italy* [11]*Department of Physics, University of Michigan, Ann Arbor, Michigan 48109* [12]*Dipartimento di Fisica dell'Università di Napoli and INFN, 80125 Napoli, Italy* [13]*Dipartimento di Fisica dell'Università di Pisa and INFN, 56010 Pisa, Italy* [14]*Dipartimento di Fisica dell'Università di Roma ''La Sapienza'' and INFN, 00185 Roma, Italy* [15]*Physics Department, Texas A&M University, College Station, Texas 77843* [16]*Dipartimento di Fisica Sperimentale dell'Università di Torino and INFN, 10125 Torino, Italy* [17]*Swarthmore College, Swarthmore, Pennsylvania 19081* (Received 3 September 1996; revised manuscript received 5 February 1997)

In this paper, the first of a two-part work, we present the reconstruction and measurement of muon events detected underground by the MACRO experiment at Gran Sasso ($E_\mu \geq 1.3$ TeV in atmosphere). The main aim of this work is to discuss the muon multiplicity distribution as measured in the detector. The data sample analyzed consists of 4.4×10^6 muon events, of which $\sim$ 263 000 are multiple muons, corresponding to a total live time of 5850 h. In this sample, the observed multiplicities extend above $N_\mu=35$, with intermuon separations up to 50 m and beyond. Additional complementing measurements, such as the inclusive muon flux, the angular distribution, and the muon separation distribution (decoherence), are also included. The physical interpretation of the results presented here is reported in the following companion paper. [S0556-2821(97)00615-2] [Phys. Rev. D **56**, 1407 (1997)]

High energy cosmic ray physics with underground muons in

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MACRO. II. Primary spectra and composition. M. Ambrosio,[12] R. Antolini,[7] G. Auriemma,[14] R. Baker,[11] A. Baldini,[13] G. C. Barbarino,[12] B. C. Barish,[4] G. Battistoni,[6] R. Bellotti,[1] C. Bemporad,[13] P. Bernardini,[10] H. Bilokon,[6] V. Bisi,[16] C. Bloise,[6] T. Bosio,[7] C. Bower,[8] S. Bussino,[14] F. Cafagna,[1] M. Calicchio,[1] D. Campana,[12] M. Carboni,[6] M. Castellano,[1] S. Cecchini,[2] F. Cei,[13] V. Chiarella,[6] A. Corona,[14] S. Coutu,[11] G. De Cataldo,[1] H. Dekhissi,[2] C. De Marzo,[1] I. De Mitri,[9] M. De Vincenzi,[14] A. Di Credico,[7] O. Erriquez,[1] R. Fantini,[2] C. Favuzzi,[1] C. Forti,[6] P. Fusco,[1] G. Giacomelli,[2] G. Giannini,[13] N. Giglietto,[1] M. Goretti,[14,4] M. Grassi,[13] A. Grillo,[7] F. Guarino,[12] P. Guarnaccia,[1] C. Gustavino,[7] A. Habig,[8] K. Hanson,[11] A. Hawthorne,[8] R. Heinz,[8] J. T. Hong,[3] E. Iarocci,[6] E. Katsavounidis,[4] E. Kearns,[3] S. Kyriazopoulou,[4] E. Lamanna,[14] C. Lane,[5] D. S. Levin,[11] P. Lipari,[14] N. P. Longley,[17] M. J. Longo,[11] G. Mancarella,[10] G. Mandrioli,[2] A. Margiotta-Neri,[2] A. Marini,[6] D. Martello,[10] A. Marzari-Chiesa,[16] M. N. Mazziotta,[1] D. G. Michael,[4] S. Mikheyev,[7] L. Miller,[8] P. Monacelli,[9] T. Montaruli,[1] M. Monteno,[16] S. Mufson,[8] J. Musser,[8] D. Nicoló,[13] R. Nolty,[4] C. Okada,[3] C. Orth,[3] G. Osteria,[12] O. Palamara,[10] S. Parlati,[7] V. Patera,[6] L. Patrizii,[2] R. Pazzi,[13] C. W. Peck,[4] S. Petrera,[10] P. Pistilli,[10] V. Popa,[2] A. Rainó,[1] J. Reynoldson,[7] M. Ricciardi,[10] F. Ronga,[6] U. Rubizzo,[12] A. Sanzgiri,[15] F. Sartogo,[14] C. Satriano,[14] L. Satta,[6] E. Scapparone,[7] K. Scholberg,[4] A. Sciubba,[6] P. Serra-Lugaresi,[2] M. Severi,[14] M. Sitta,[16] P. Spinelli,[1] M. Spinetti,[6] M. Spurio,[2] R. Steinberg,[5] J. L. Stone,[3] L. R. Sulak,[3] A. Surdo,[10] G. Tarlé,[11] V. Togo,[2] V. Valente,[6] C. W. Walter,[4] and R. Webb[15] (MACRO Collaboration) [1]*Dipartimento di Fisica dell'Università di Bari and INFN, 70126 Bari, Italy* [2]*Dipartimento di Fisica dell'Università di Bologna and INFN, 40126 Bologna, Italy* [3]*Physics Department, Boston University, Boston, Massachusetts 02215* [4]*California Institute of Technology, Pasadena, California 91125* [5]*Department of Physics, Drexel University, Philadelphia, Pennsylvania 19104* [6]*Laboratori Nazionali di Frascati dell'INFN, 00044 Frascati (Roma), Italy* [7]*Laboratori Nazionali del Gran Sasso dell'INFN, 67010 Assergi (L'Aquila), Italy* [8]*Departments of Physics and Astronomy, Indiana University, Bloomington, Indiana 47405* [9]*Dipartimento di Fisica dell'Università dell'Aquila and INFN, 67100 L'Aquila, Italy* [10]*Dipartimento di Fisica dell'Università di Lecce and INFN, 73100 Lecce, Italy* [11]*Department of Physics, University of Michigan, Ann Arbor, Michigan 48109* [12]*Dipartimento di Fisica dell'Università di Napoli and INFN, 80125 Napoli, Italy* [13]*Dipartimento di Fisica dell'Università di Pisa and INFN, 56010 Pisa, Italy* [14]*Dipartimento di Fisica dell'Università di Roma ''La Sapienza'' and INFN, 00185 Roma, Italy* [15]*Physics Department, Texas A&M University, College Station, Texas 77843* [16]*Dipartimento di Fisica Sperimentale dell'Università di Torino and INFN, 10125 Torino, Italy* [17]*Swarthmore College, Swarthmore, Pennsylvania 19081* (Received 3 September 1996; revised manuscript received 5 February 1997)

Multimuon data from the MACRO experiment at Gran Sasso have been analyzed using a new method, which allows one to estimate the primary cosmic ray fluxes. The estimated all-particle spectrum is higher and flatter than the one obtained from direct measurements but is consistent with EAS array measurements. The spectral indexes of the fitted energy spectrum are 2.56 ± 0.05 for $E<500$ TeV and 2.9 ± 0.3 for $E>5000$ TeV with a gradual change at intermediate energies. The average mass number shows little dependence on the primary energy below 1000 TeV, with a value of 10.1 ± 2.5 at 100 TeV. At higher energies the best fit average mass shows a mild increase with energy, even though no definite conclusion can be reached taking into account errors. The fitted spectra cover a range from $\sim$ 50 TeV up to several thousand TeV. [S0556-2821(97)00915-6] [Phys. Rev. D **56**, 1418 (1997)]

Distribution of valence quarks and light-cone QCD sum rules. V. M. Belyaev, *SPhT, CEA-Saclay, 91191 Gif-sur-Yvette, Cedex, France;* Mikkel B. Johnson, *Los Alamos National Laboratory, Los Alamos, New Mexico 87545.* (Received 6 March 1997)

A method for calculating the pion structure function directly in terms of light-cone wave functions is suggested. Taking twist-two and twist-four pion light-cone wave functions into account, it is shown that the QCD sum rule prediction is in agreement with the quark distribution obtained from an analysis of the Drell-Yan process. Twist-four quark-gluon light-cone wave functions give a large positive contribution to the pion structure function for $x_B<0.2$. A new constraint on the twist-two pion light-cone wave function is obtained. We argue that the leading twist pion wave function $\varphi_\pi(u)\simeq1$ for $u=0.3$ with an accuracy of about 20–30 %. [S0556-2821(97)00815-1] [Phys. Rev. D **56**, 1481 (1997)]

Neutron spin-dependent structure function, Bjorken sum rule, and first evidence for singlet contribution at low x. J. Soffer, *Centre de Physique Théorique - CNRS - Luminy, Case 907 F-13288 Marseille Cedex 9, France;* O. V. Teryaev, *Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, 141980, Russia.* (Received 27 August 1996)

We perform the isospin decomposition of proton and neutron SLAC data for moderately low x in the region $0.01\leqslant x\leqslant0.1$. The isovector part is well described by a power behavior x^α, where α does not correspond to the intercept of a single a_1 Regge trajectory, as expected. However, the observed power leads to the validity of the Bjorken sum rule and it is consistent with the power extracted from all previous data using next-to-leading order evolution. At the same time, the isoscalar behavior may be interpreted as a partial cancellation between a positive nonsinglet contribution and a strongly negative singlet one. Further experimental consequences are mentioned. [S0556-2821(97)01413-6] [Phys. Rev. D **56**, 1549 (1997)]

Exclusive diffractive processes and the quark substructure of mesons. M. A. Pichowsky, *Physics Division, Argonne National Laboratory, Argonne, Illinois 60439-4843 and Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, Pennsylvania 15260;* T.-S. H. Lee, *Physics Division, Argonne National Laboratory, Argonne, Illinois 60439-4843.* (Received 18 December 1996)

Exclusive diffractive processes on the nucleon are investigated within a model in which the quark-nucleon interaction is mediated by Pomeron exchange and the quark substructure of mesons is described within a framework based on the Dyson-Schwinger equations of QCD. The model quark-nucleon interaction has four parameters which are completely determined by high-energy πN and KN elastic scattering data. The model is then used to predict vector-meson electroproduction observables. The obtained ρ- and ϕ-meson electroproduction cross sections are in excellent agree-

ment with experimental data. The predicted q^2 dependence of J/ψ-meson electroproduction also agrees with experimental data. It is shown that confined-quark dynamics plays a central role in determining the behavior of the diffractive, vector-meson electroproduction cross section. In particular, the onset of the asymptotic $1/q^4$ behavior of the cross section is determined by a momentum scale that is set by the current-quark masses of the quark and antiquark inside the vector meson. This is the origin of the striking differences between the q^2 dependence of ρ-, ϕ-, and J/ψ-meson electroproduction cross sections observed in recent experiments. [S0556-2821(97)01415-X] [Phys. Rev. D **56**, 1644 (1997)]

Estimate of H dibaryon production through $\Lambda\Lambda$ coalescence in $p+A$ collisions. Robert D. Cousins, *Department of Physics and Astronomy, University of California, Los Angeles, California 90095-1547;* Joshua R. Klein, *Department of Physics, Princeton University, Princeton, New Jersey 08544-0708.* (Received 20 December 1996)

We estimate the production cross section of H dibaryons in proton-nucleus collisions, modeling the H formation as the coalescence of two Λ particles. We survey coalescence calculations made in this and other contexts, and comment on the assumptions inherent in estimates such as ours. The results depend on the unknown H wave function, which we attempt to incorporate via a parametrization of its momentum scale. [S0556-2821(97)05315-0] [Phys. Rev. D **56**, 1673 (1997)]

Constraining almost degenerate three-flavor neutrinos. Hisakazu Minakata, *Department of Physics, Tokyo Metropolitan University, Minami-Osawa, Hachioji, Tokyo 192-03, Japan and Institute for Nuclear Theory, University of Washington, Seattle, Washington 98195-1550;* Osamu Yasuda, *Department of Physics, Tokyo Metropolitan University, Minami-Osawa, Hachioji, Tokyo 192-03, Japan.* (Received 5 December 1996)

We discuss constraints on a scenario of almost degenerate three-flavor neutrinos imposed by the solar and the atmospheric neutrino anomalies, hot dark matter, and in particular by the neutrinoless double β decay experiments. It is found that in the Majorana version of the model the region with relatively large θ_{13} is favored and the model is not compatible with the popular small-θ_{12} Mikheyev-Smirnov-Wolfenstein solution of the solar neutrino problem. A constraint on the CP-violating phases including the one characteristic to Majorana neutrinos is also obtained. The stability of our conclusion against the uncertainty of the nuclear matrix elements of double β decay is briefly addressed. [S0556-2821(97)02015-8] [Phys. Rev. D **56**, 1692 (1997)]

Interplay of nonrelativistic and relativistic effects in neutrino oscillations. D. V. Ahluwalia and T. Goldman, *Los Alamos National Laboratory, Los Alamos, New Mexico 87545.* (Received 12 February 1997)

A theoretical structure that involves neutrino mass eigenstates at nonrelativistic as well as relativistic energies is presented. Using this framework, we find that if the particle X, with a mass 33.9 MeV, of the KARMEN Collaboration anomaly is identified with the third neutrino mass eigenstate, then the present limit of 23 MeV upper bound on the τ neutrino mass implies $|U_{\tau 3}|<0.82$. [S0556-2821(97)03715-6] [Phys. Rev. D **56**, 1698 (1997)]

Supernova bounds on resonant active-sterile neutrino conversions. H. Nunokawa,[1] J. T. Peltoniemi,[2] A. Rossi,[1] and J. W. F. Valle[1] [1]*Instituto de Física Corpuscular–C.S.I.C., Departament de Física Teòrica, Universitat de València, 46100 Burjassot, València, Spain* [2]*Department of Physics, Box 9, 00014, University of Helsinki, Finland.* (Received 20 February 1997)

We discuss the effects of resonant $\nu_e \to \nu_s$ and $\overline{\nu_e} \to \overline{\nu_s}$ (ν_s is a *sterile* neutrino) conversions in the dense medium of a supernova. In particular, we assume the sterile neutrino ν_s to be in the hot dark matter few eV mass range. The implications of such a scenario for the supernova shock reheating, the detected $\overline{\nu_e}$ signal from SN 1987A, and for the r-process nucleosynthesis hypothesis are analyzed in some detail. The resulting constraints on the mixing and mass difference for the ν_e-ν_s system are derived. There is also an allowed region in the neutrino parameter space for which the r-process nucleosynthesis can be enhanced.
[S0556-2821(97)04115-5] [Phys. Rev. D **56**, 1704 (1997)]

Muon capture by a proton in heavy baryon chiral perturbation theory. Harold W. Fearing and Randy Lewis, *TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia, Canada V6T 2A3;* Nader Mobed, *Department of Physics, University of Regina, Regina, Saskatchewan, Canada S4S 0A2;* Stefan Scherer, *Institut für Kernphysik, Johannes Gutenberg-Universität, J. J. Becher-Weg 45, D-55099 Mainz, Germany.* (Received 24 February 1997)

The matrix element for muon capture by a proton is calculated to $O(p^3)$ within heavy baryon chiral perturbation theory using the new $O(p^3)$ Lagrangian of Ecker and Mojžiš. External nucleon fields are renormalized using the appropriate definition of the wave function renormalization factor Z_N. Our expression for Z_N differs somewhat from that found in the existing literature, but is the one which is consistent with the Lagrangian we use and the one which ensures, within our approach, the nonrenormalization of the vector coupling as required by the conserved vector current. Expressions for the standard muon capture form factors are derived and compared to experimental data and we determine three of the coefficients of the Ecker-Mojžiš Lagrangian, namely, b_7, b_{19}, and b_{23}. [S0556-2821(97)00715-7] [Phys. Rev. D **56**, 1783 (1997)]

Earth regeneration effect in solar neutrino oscillations: An analytic approach. Eligio Lisi and Daniele Montanino, *Dipartimento di Fisica and Sezione INFN di Bari, Via Amendola 173, I-70126 Bari, Italy.* (Received 18 February 1997)

We present a simple and accurate method for computing analytically the regeneration probability of solar neutrinos in the Earth. We apply this method to the calculation of several solar-model-independent quantities that can be measured by the SuperKamio-

kande and Sudbury Neutrino Observatory experiments. [S0556-2821(97)01015-1] [Phys. Rev. D **56**, 1792 (1997)]

Composite Skyrme model with vector mesons. Kwanghoon Hahm, KyoungHo Han, and H. J. Shin, *Department of Physics and Research Institute of Basic Sciences, Kyunghee University, Seoul, 130-701, Korea.* (Received 13 January 1997)

We study the composite Skyrme model, proposed by Cheung and Gürsey, introducing vector mesons in a chiral Lagrangian. We calculate the static properties of baryons and compare them with results obtained from models without vector mesons. [S0556-2821(97)01215-0] [Phys. Rev. D **56**, 1812 (1997)]

MeV neutrinos in double β decay. K. Zuber, *Lehrstuhl für Experimentelle Physik IV, Universität Dortmund, Otto-Hahn-Strasse 4, D-44221 Dortmund, Germany.* (Received 11 September 1996)

The effect of Majorana neutrinos in the MeV mass range on the double β decay of various isotopes is studied on pure phenomenological arguments. By using only experimental half-life data, limits on the mixing parameter U_{eh}^2 of the order 10^{-7} can be derived. Also the possible achievements of upcoming experiments and some consequences are outlined. [S0556-2821(97)02215-7] [Phys. Rev. D **56**, 1816 (1997)]