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Measurement of beam-spin asymmetries for π^+ electroproduction above the baryon resonance region. H. Avakian,[1,2] V.D. Burkert,[1] L. Elouadrhiri,[1] N. Bianchi,[2] G. Adams,[30] A. Afanasev,[1] P. Ambrozewicz,[12] E. Anciant,[4] M. Anghinolfi,[16] D.S. Armstrong,[37] B. Asavapibhop,[23] G. Audit,[4] T. Auger,[4] H. Bagdasaryan,[38] J.P. Ball,[3] S. Barrow,[13] M. Battaglieri,[16] K. Beard,[20] M. Bektasoglu,[26,21] M. Bellis,[30] N. Benmouna,[14] A.S. Biselli,[6,30] S. Boiarinov,[19,1] B.E. Bonner,[31] S. Bouchigny,[17,1] R. Bradford,[6] D. Branford,[11] W.K. Brooks,[1] C. Butuceanu,[37] J.R. Calarco,[24] D.S. Carman,[26] B. Carnahan,[7] C. Cetina,[14] L. Ciciani,[27] P.L. Cole,[34,1] A. Coleman,[37] D. Cords,[1] P. Corvisiero,[16] D. Crabb,[36] H. Crannell,[7] J.P. Cummings,[30] E. DeSanctis,[2] R. DeVita,[16] P.V. Degtyarenko,[1] H. Denizli,[28] L. Dennis,[13] K.V. Dharmawardane,[27] C. Djalali,[33] G.E. Dodge,[27] D. Doughty,[8,1] P. Dragovitsch,[13] M. Dugger,[3] S. 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We report the first evidence for a nonzero beam-spin azimuthal asymmetry in the electroproduction of positive pions in the deep-inelastic kinematic region. Data for the reaction $ep \rightarrow e' \pi^+ X$ have been obtained using a polarized electron beam of 4.3 GeV with the CEBAF Large Acceptance Spectrometer at the Thomas Jefferson National Accelerator Facility. The amplitude of the $\sin \phi$ modulation increases with the momentum of the pion relative to the virtual photon, z. In the range $z = 0.5$–0.8 the average amplitude is $0.038 \pm 0.005 \pm 0.003$ for a missing mass $M_X > 1.1$ GeV and $0.037 \pm 0.007 \pm 0.004$ for $M_X > 1.4$ GeV. [Phys. Rev. D **69**, 112004 (2004)]

Neutrino processes in strong magnetic fields and implications for supernova dynamics. Huaiyu Duan and Yong-Zhong Qian, *School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455, USA.* (Received 30 January 2004; published 18 June 2004)

The processes $\nu_e + n \rightleftharpoons p + e^-$ and $\bar{\nu}_e + p \rightleftharpoons n + e^+$ provide the dominant mechanisms for heating and cooling the material between the protoneutron star and the stalled shock in a core-collapse supernova. Observations suggest that some neutron stars are born with magnetic fields of at least $\sim 10^{15}$ G while theoretical considerations give an upper limit of $\sim 10^{18}$ G for the protoneutron star magnetic fields. We calculate the rates for the above neutrino processes in strong magnetic fields of $\sim 10^{16}$ G. We find that the main effect of such magnetic fields is to change the equations of state through the phase space of e^- and e^+, which differs from the classical case due to quantization of the motion of e^- and e^+ perpendicular to the magnetic field. As a result, the cooling rate can be greatly reduced by magnetic fields of $\sim 10^{16}$ G for typical conditions below the stalled shock and a nonuniform protoneutron star magnetic field (e.g., a dipole field) can introduce a large angular dependence of the cooling rate. In addition, strong magnetic fields always lead to an angle-dependent heating rate by polarizing the spin of n and p. The implications of our results for the neutrino-driven supernova mechanism are discussed. [Phys. Rev. D **69**, 123004 (2004)]

Solar neutrino constraints on the BBN production of Li. Richard H. Cyburt, *TRIUMF, Vancouver, British Columbia, Canada V6T 2A3, and Department of Physics, University of Illinois, Urbana, Illinois 61801, USA;* Brian D. Fields, *Center for Theoretical Astrophysics, Department of Astronomy, University of Illinois, Urbana, Illinois 61801, USA;* Keith A. Olive, *William I. Fine Theoretical Physics Institute, University of Minnesota, Minneapolis, Minnesota 55455, USA.* (Received 5 January 2004; published 28 June 2004)

Using the recent WMAP determination of the baryon-to-photon ratio, $10^{10}\eta = 6.14$ to within a few percent, big bang nucleosynthesis (BBN) calculations can make relatively accurate predictions of the abundances of the light element isotopes which can be tested against observational abundance determinations. At this value of η, the ^{7}Li abundance is predicted to be significantly higher than that observed in low metallicity halo dwarf stars. Among the possible resolutions to this discrepancy are (1) ^{7}Li depletion in the atmosphere of stars, (2) systematic errors originating from the choice of stellar parameters—most notably the surface temperature, and (3) systematic errors in the nuclear cross sections used in the nucleosynthesis calculations. Here, we explore the last possibility, and focus on possible systematic errors in the $^3\mathrm{He}(\alpha,\gamma)^7\mathrm{Be}$ reaction, which is the only important ^{7}Li production channel in BBN. The absolute value of the cross section for this key reaction is known relatively poorly both experimentally and theoretically. The agreement between the standard solar model and solar neutrino data thus provides additional constraints on variations in the cross section (S_{34}). Using the standard solar model of Bahcall, and recent solar neutrino data, we can exclude systematic S_{34} variations of the magnitude needed to resolve the BBN ^{7}Li problem at the $\gtrsim 95\%$ C.L., or more strongly, depending on the Li observations used. Additional laboratory data on $^3\mathrm{He}(\alpha,\gamma)^7\mathrm{Be}$ will sharpen our understanding of both BBN and solar neutrinos, particularly if care is taken in determining the absolute cross section and its uncertainties. Nevertheless, it is already clear that this ''nuclear fix'' to the ^{7}Li BBN problem is unlikely; other possible solutions are briefly discussed. [Phys. Rev. D **69**, 123519 (2004)]

Deep electroproduction of exotic hybrid mesons. I. V. Anikin,[1,2] B. Pire,[1] L. Szymanowski,[3] O. V. Teryaev,[2,4] and S. Wallon[5] [1]*Unité Mixte de Recherche du CNRS (UMR 7644), CPHT de l'École Polytechnique, 91128 Palaiseau Cedex, France,* [2]*Bogoliubov Laboratory of Theoretical Physics, JINR, 141980 Dubna, Russia,* [3]*Soltan Institute for Nuclear Studies, Warsaw, Poland,* [4]*Unité Propre de Recherche du CNRS (UPR 7061), CPT-CNRS F-13288 Marseille Cedex 9, France,* [5]*Unité Mixte de Recherche du CNRS (UMR 8627), LPT, Université Paris-Sud, 91405, Orsay, France.* (Received 22 January 2004; published 19 July 2004)

We evaluate the leading order amplitude for the deep exclusive electroproduction of an exotic hybrid meson in the Bjorken regime. We show that, contrarily to naive expectation, this amplitude factorizes at the twist 2 level and thus scales like usual meson electroproduction when the virtual photon and the hybrid meson are longitudinally polarized. Exotic hybrid mesons may thus be studied in electroproduction experiments at JLAB, HERA (HERMES) or CERN (Compass). [Phys. Rev. D **70**, 011501 (2004)]

Spin asymmetries for events with high p_T hadrons in DIS and an evaluationof the gluon polarization. B. Adeva,[20] E. Arik,[2] A. Arvidson,[23] B. Badełek,[23,25] G. Baum,[1] P. Berglund,[8] L. Betev,[13] R. Birsa,[22] N. de Botton,[19] F. Bradamante,[22] A. Bravar,[11] A. Bressan,[22] S. Bültmann,[1] E. Burtin,[19] D. Crabb,[24] J. Cranshaw,[18] T. Çuhadar,[2,15] S. Dalla Torre,[22] R. van Dantzig,[15] B. Derro,[4] A. Deshpande,[26] S. Dhawan,[26] C. Dulya,[4,15] S. Eichblatt,[18] D. Fasching,[17] F. Feinstein,[19] C. Fernandez,[20,9] B. Frois,[19] A. Gallas,[20] J. A. Garzon,[20,9] H. Gilly,[6] M. Giorgi,[22] E. von Goeler,[16] S. Goertz,[3] G. Gracia,[20] N. de Groot,[15] M. Grosse Perdekamp,[26] K. Haft,[13] D. von Harrach,[11] T. Hasegawa,[14] P. Hautle,[5] N. Hayashi,[14] C. A. Heusch,[5] N. Horikawa,[14] V. W. Hughes,[26] G. Igo,[4] S. Ishimoto,[14] T. Iwata,[14] E. M. Kabuß,[11] A. Karev,[10] H. J. Kessler,[6] T. J. Ketel,[15] J. Kiryluk,[25] Yu. Kisselev,[10] L. Klostermann,[15] K. Kowalik,[25] A. Kotzinian,[10] W. Kröger,[5] F. Kunne,[19] K. Kurek,[25] J. Kyynäräinen,[1,8] M. Lamanna,[22] U. Landgraf,[6] J. M. Le Goff,[19] F. Lehar,[19] A. de Lesquen,[19] J. Lichtenstadt,[21] M. Litmaath,[15] A. Magnon,[19] G. K. Mallot,[11] F. Marie,[19] A. Martin,[22] J. Martino,[19] T. Matsuda,[14] B. Mayes,[9] J. S. McCarthy,[24] K. Medved,[10] W. Meyer,[3] D. Miller,[17] Y. Miyachi,[14] K. Mori,[14] J. Moromisato,[16] J. Nassalski,[25] T. O. Niinikoski,[5] J. E. J. Oberski,[15] A. Ogawa,[14] C. Ozben,[2] H. Pereira,[19] D. Peshekhonov,[10] R. Piegaia,[26] L. Pinsky,[9] S. Platchkov,[19] M. Plo,[20] D. Pose,[10] H. Postma,[15] J. Pretz,[11] G. Rädel,[5] G. Reicherz,[3] J. Roberts, M. Rodriguez,[23] E. Rondio,[25] I. Sabo,[21] J. Saborido,[20] A. Sandacz,[25] I. Savin,[10] P. Schiavon,[22] E. P. Sichtermann,[15,26] F. Simeoni,[22] G. I. Smirnov,[10] A. Staude,[13] A. Steinmetz,[11] U. Stiegler,[5] H. Stuhrmann,[7] R. Sulej,[25] F. Tessarotto,[22] D. Thers,[19] W. Tłaczała,[25] A. Tripet,[1] G. Unel,[2] M. Velasco,[17] J. Vogt,[13] R. Voss,[5] C. Whitten,[4] R. Windmolders,[12] R. Willumeit,[7] W. Wiślicki,[25] A. Witzmann,[6] A. M. Zanetti,[22] K. Zaremba,[25] and J. Zhao[7] (Spin Muon Collaboration) [1]*Physics Department, University of Bielefeld, 33501 Bielefeld, Germany,* [2]*Bogaziçi University and Istanbul Technical University, Istanbul, Turkey,* [3]*Physics Department, University of Bochum, 44780 Bochum, Germany,* [4]*Department of Physics, University of California, Los Angeles, California 90024, USA,* [5]*CERN,*

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We present a measurement of the longitudinal spin cross section asymmetry for deep-inelastic muon-nucleon interactions with two high transverse momentum hadrons in the final state. Two methods of event classification are used to increase the contribution of the photon-gluon fusion process to above 30%. The most effective one, based on a neural network approach, provides the asymmetries $A_p^{\ell N\to\ell hhX}=0.030\pm0.057(\text{stat})\pm0.010(\text{syst})$ and $A_d^{\ell N\to\ell hhX}=0.070\pm0.076(\text{stat})\pm0.010(\text{syst})$. From these values we derive an averaged gluon polarization $\Delta G/G=-0.20\pm0.28(\text{stat})\pm0.10(\text{syst})$ at an average fraction of nucleon momentum carried by gluons $\langle\eta\rangle=0.07$. [Phys. Rev. D **70**, 012002 (2004)]

Three-generation flavor transitions and decays of supernova relic neutrinos. G. L. Fogli,[1] E. Lisi,[1] A. Mirizzi,[1] and D. Montanino[2] [1]*Dipartimento di Fisica and Sezione INFN di Bari, Via Amendola 173, 70126 Bari, Italy,* [2]*Dipartimento di Scienza dei Materiali and Sezione INFN di Lecce, Via Arnesano, 73100 Lecce, Italy.* (Received 5 February 2004; published 20 July 2004)

If neutrinos have mass, they can also decay. Decay lifetimes of cosmological interest can be probed, in principle, through the detection of the redshifted, diffuse neutrino flux produced by all past supernovae—the so-called supernova relic neutrino (SRN) flux. In this work, we solve the SRN kinetic equations in the general case of three-generation flavor transitions followed by invisible (nonradiative) two-body decays. We then use the general solution to calculate observable SRN spectra in some representative decay scenarios. It is shown that, in the presence of decay, the SRN event rate can basically span the whole range below the current experimental upper bound—a range accessible to future experimental projects. Radiative SRN decays are also briefly discussed. [Phys. Rev. D **70**, 013001 (2004)]

Charged lepton contributions to the solar neutrino mixing and θ_{13}. Andrea Romanino, *CERN, Department of Physics, Theory Division, CH–1211 Geneva 23, Switzerland.* (Received 3 March 2004; published 27 July 2004)

A charged lepton contribution to the solar neutrino mixing induces a contribution to θ_{13}, barring cancellations or correlations, which is independent of the model building options in the neutrino sector. We illustrate two robust arguments for that contribution to be within the expected sensitivity of high intensity neutrino beam experiments. We find that the case in which the neutrino sector gives rise to a maximal solar angle (the natural situation if the hierarchy is inverse) leads to a θ_{13} close to or exceeding the experimental bound depending on the precise values of θ_{12}, θ_{23}, an unknown phase and possible additional contributions. We finally discuss the possibility that the solar angle originates predominantly in the charged lepton sector. We find that the construction of a model of this sort is more complicated. We comment on a recent example of natural model of this type. [Phys. Rev. D **70**, 013003 (2004)]

Dihadron fragmentation function and its evolution. A. Majumder and Xin-Nian Wang, *Nuclear Science Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, California 94720, USA.* (Received 5 March 2004; published 27 July 2004)

Dihadron fragmentation functions and their evolution are studied in the process of e^+e^- annihilation. Under the collinear factorization approximation and facilitated by the cut-vertex technique, the two hadron inclusive cross section at leading order is shown to factorize into a short distance parton cross section and a long distance dihadron fragmentation function. We provide the definition of such a dihadron fragmentation function in terms of parton matrix elements and derive its Dokshitzer-Gribov-Lipatov-Altarelli-Parisi evolution equation at leading log. The evolution equation for the nonsinglet quark fragmentation function is solved numerically with a simple ansatz for the initial condition and results are presented for cases of physical interest. [Phys. Rev. D **70**, 014007 (2004)]

Nuclear and nucleon transitions of the H dibaryon. Glennys R. Farrar[1,2] and Gabrijela Zaharijas[1] [1]*Center for Cosmology and Particle Physics, New York University, New York, New York 10003, USA,* [2]*Departments of Physics and Astronomy, Princeton University, Princeton, New Jersey 08540, USA.* (Received 23 July 2003; published 27 July 2004)

We consider 3 types of processes pertinent to the phenomenology of an H dibaryon: conversion of two Λ's in a doubly strange hypernucleus to an H, decay of the H to two baryons, and—if the H is light enough—conversion of two nucleons in a nucleus to an H. We compute the spatial wave function overlap using the Isgur-Karl, Miller-Spencer and Bethe-Goldstone wave functions, and treat the weak interactions phenomenologically. The observation of Λ de-

cays from doubly strange hypernuclei puts a constraint on the H wave function which is plausibly satisfied. Imposing this constraint, we obtain model-independent lower limits on the H lifetime; if $m_H < m_N + m_\Lambda$, the H lifetime can be of the order of or longer than the age of the Universe. We discuss limits on a long-lived or stable H, and point out how experiments can improve the constraints. [Phys. Rev. D **70**, 014008 (2004)]

All-charm tetraquarks. Richard J. Lloyd and James P. Vary, *Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA.* (Received 5 November 2003; published 27 July 2004)

We investigate four-body states with only charm quarks. Working in a large but finite oscillator basis, we present a net binding analysis to determine if the resulting states are stable against breakup into a pair of $c\bar{c}$ mesons. We find several close-lying bound states in the two models we examine. [Phys. Rev. D **70**, 014009 (2004)]

θ^+ baryon in soliton models: Large N_c QCD and the validity of rigid-rotor quantization. Thomas D. Cohen, *Department of Physics, University of Maryland, College Park, Maryland 20742-4111, USA.* (Received 19 December 2003; published 29 July 2004)

A light collective θ^+ baryon state (with strangeness $+1$) was predicted via rigid-rotor collective quantization of SU(3) chiral soliton models. This paper explores the validity of this treatment. A number of rather general analyses suggest that predictions of exotic baryon properties based on this approximation do not follow from large N_c QCD. These include an analysis of the baryon's width, a comparison of the predictions with general large N_c consistency conditions of the Gervais-Sakita-Dashen-Manohar type; an application of the technique to QCD in the limit where the quarks are heavy; a comparison of this method with the vibration approach of Callan and Klebanov; and the $1/N_c$ scaling of the excitation energy. It is suggested that the origin of the problem lies in an implicit assumption in the that the collective motion is orthogonal to vibrational motion. While true for non-exotic motion, the Wess-Zumino term induces mixing at leading order between collective and vibrational motion with exotic quantum numbers. This suggests that successful phenomenological predictions of θ^+ properties based on rigid-rotor quantization were accidental. [Phys. Rev. D **70**, 014011 (2004)]

Sigma and hydrodynamic modes along the critical line. H. Fujii[1] and M. Ohtani[2] [1]*Institute of Physics, University of Tokyo, Tokyo 153-8902, Japan,* [2]*Radiation Laboratory, RIKEN, Wako, Saitama 351-0198, Japan.* (Received 26 February 2004; published 30 July 2004)

Assuming a tricritical point of two-flavor QCD in the space of temperature, baryon number chemical potential, and quark mass, we study the change of the associated soft mode along the critical line within the Ginzburg-Landau approach and the Nambu–Jona-Lasinio model. The ordering density along the chiral critical line is the scalar density whereas a linear combination of the scalar, baryon number, and energy densities becomes the proper ordering density along the critical line with finite quark masses. It is shown that the critical eigenmode shifts from the sigma-like fluctuation of the scalar density to a hydrodynamic mode at the tricritical point, where we have two ordering densities, the scalar density and a linear combination of the baryon number and energy densities. We argue that the appearance of the critical eigenmode with hydrodynamic character is a logical consequence of divergent susceptibilities of the conserved densities. [Phys. Rev. D **70**, 014016 (2004)]