

Selected Abstracts from Other Physical Review Journals

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More straightforward extraction of the fundamental lepton mixing parameters from long-baseline neutrino oscillations.

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We point out the simple reversibility between the fundamental neutrino mixing parameters in vacuum and their effective counterparts in matter. The former can therefore be expressed in terms of the latter, allowing more straightforward extraction of the genuine lepton mixing quantities from a variety of long-baseline neutrino oscillation experiments. In addition to the parametrization-independent results, we present the formulas based on the standard parametrization of the lepton flavor mixing matrix and give a typical numerical illustration. [*Phys. Rev. D* **64**, 073014 (2001)]

Massless neutrino oscillations. F. Benatti, *Dipartimento di Fisica Teorica, Università di Trieste, Strada Costiera 11, 34014 Trieste, Italy and Istituto Nazionale di Fisica Nucleare, Sezione di Trieste, Strada Costiera 11, 34014 Trieste, Italy*; R. Floreanini, *Istituto Nazionale di Fisica Nucleare, Sezione di Trieste, Strada Costiera 11, 34014 Trieste, Italy and Dipartimento di Fisica Teorica, Università di Trieste, Strada Costiera 11, 34014 Trieste, Italy.* (Received 23 May 2001; published 26 September 2001)

Quantum dynamical semigroups provide a general framework for studying the evolution of open systems. Neutrino propagation both in vacuum and in matter can be analyzed using these techniques: They allow a consistent treatment of nonstandard, dissipative effects that can alter the pattern of neutrino oscillations. In particular, initially massless neutrinos can give rise to a nonvanishing flavor transition probability, involving in addition the Majorana *CP*-violating mixing phase. [*Phys. Rev. D* **64**, 085015 (2001)]

High energy neutrinos from superheavy dark matter annihilation.

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Superheavy ($M > 10^{10}$ GeV) particles produced during inflation may be the dark matter, independent of their interaction strength. Strongly interacting superheavy particles will be captured by the

Sun, and their annihilation in the center of the Sun will produce a flux of energetic neutrinos that should be detectable by neutrino telescopes. Depending on the particle mass, event rates in a cubic-kilometer detector range from several per hour to several per year. The signature of the process is a predominance of tau neutrinos, with a relatively flat energy spectrum of events ranging from 50 GeV to many TeV, and with the mean energy of detected tau neutrinos about 3 TeV. [*Phys. Rev. D* **64**, 083504 (2001)]

Normalization of the neutrino-deuteron cross section.

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As is well known, the comparison of the solar neutrino fluxes measured in SuperKamiokande (SK) by $\nu + e^- \rightarrow \nu + e^-$ and in the Sudbury Neutrino Observatory (SNO) by $\nu_e + d \rightarrow e^- + p + p$ can provide a “smoking gun” signature for neutrino oscillations as the solution to the solar neutrino puzzle. This occurs because SK has some sensitivity to all active neutrino flavors whereas SNO can isolate electron neutrinos. This comparison depends crucially on the normalization and uncertainty of the theoretical charged-current neutrino-deuteron cross section. We address a number of effects which are significant enough to change the interpretation of the SK-SNO comparison. [*Phys. Rev. D* **64**, 091302 (2001)]

Solar and atmospheric four-neutrino oscillations.

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We present an analysis of the neutrino oscillation solutions of the solar and atmospheric neutrino problems in the framework of four-neutrino mixing where a sterile neutrino is added to the three standard ones and the mass spectra present two separated doublets. Such scenarios allow for simultaneous transitions of solar ν_e , as well as atmospheric ν_μ , into active and sterile neutrinos controlled by the additional mixing angles ϑ_{23} and ϑ_{24} , and they contain as limiting cases the pure solar ν_e -active and ν_e -sterile neutrino oscil-

lations, and the pure atmospheric $\nu_\mu \rightarrow \nu_s$ and $\nu_\mu \rightarrow \nu_\tau$ oscillations, respectively. We evaluate the allowed active-sterile admixture in both solar and atmospheric oscillations from the combined analysis. Our results show that, although the Super-Kamiokande data disfavor both the pure $\nu_\mu \rightarrow \nu_s$ atmospheric channel and the pure $\nu_e \rightarrow \nu_s$ solar channel, the result from the combined analysis still favors close-to-pure active and sterile oscillations and disfavors oscillations into a near-maximal active-sterile admixture. [Phys. Rev. D **64**, 093001 (2001)]

Effects of neutrino oscillation on the supernova neutrino spectrum. Keitaro Takahashi,¹ Mariko Watanabe,¹ and Katsuhiko Sato^{1,2} ¹*Department of Physics, School of Science, the University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-0033, Japan* ²*Research Center for the Early Universe, School of Science, the University of Tokyo, Hongo 7-3-1, Bunkyo-Ku, Tokyo 113-0033, Japan; Tomonori Totani, Theory Division, National Astronomical Observatory, Mitaka, Tokyo 181-8588, Japan.* (Received 22 May 2001; published 3 October 2001)

The effects of three-flavor neutrino oscillation on the supernova neutrino spectrum are studied. We calculate the expected event rate and energy spectra, and their time evolution at SuperKamiokande (SK) and the Sudbury Neutrino Observatory (SNO) by using a realistic neutrino burst model based on numerical simulations of supernova explosions. We also employ a realistic density profile based on a presupernova model for the calculation of neutrino conversion probability in supernova envelopes. These realistic models and numerical calculations allow us to quantitatively estimate the effects of neutrino oscillation in a more realistic way than previous studies. We then find that the degeneracy of the solutions of the solar neutrino problem can be broken by the combination of the SK and SNO detections of a future Galactic supernova. [Phys. Rev. D **64**, 093004 (2001)]

Super-Kamiokande atmospheric neutrinos: Status of subdominant oscillations. G. L. Fogli, E. Lisi, and A. Marrone, *Dipartimento di Fisica and Sezione INFN di Bari, Via Amendola 173, I-70126 Bari, Italy.* (Received 17 May 2001; published 3 October 2001)

In the context of the recent (79.5 kTy) Super-Kamiokande atmospheric neutrino data, we concisely review the status of muonic-tauonic flavor oscillations and of the subdominant electron or sterile neutrino mixing, in schemes with three or four families and one dominant mass scale. In the three-family case, where we include the full CHOOZ spectral data, we also show, through a specific example, that “maximal” violations of the one-dominant mass scale approximation are not ruled out yet. [Phys. Rev. D **64**, 093005 (2001)]

Model-dependent and -independent implications of the first Sudbury Neutrino Observatory results. G. L. Fogli,¹ E. Lisi,¹ D. Montanino,² and A. Palazzo¹ 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 21 June 2001; published 4 October 2001)

We briefly discuss some implications of the first solar ν results from the Sudbury Neutrino Observatory (SNO) experiment in the charged-current channel. We first show that the present SNO response function is very similar to the Super-Kamiokande (SK) one above 8.6 MeV in kinetic electron energy. On the basis of such equivalence we confirm, in a completely model-independent way, the SNO evidence for an active, nonelectron neutrino component in the SK event sample, with a significance greater than 3σ . Then, by assuming no oscillations into sterile neutrinos, we combine the SK + SNO data to derive allowed regions for two free parameters: (i) the ratio f_B of the true ${}^8\text{B}$ ν flux from the Sun to the corresponding value predicted by the standard solar model (SSM), and (ii) the ν_e survival probability $\langle P_{ee} \rangle$, averaged over the common SK and SNO response function. We obtain the separate 3σ ranges: $f_B = 1.03^{+0.50}_{-0.58}$ (in agreement with the SSM central value, $f_B = 1$) and $\langle P_{ee} \rangle = 0.34^{+0.61}_{-0.18}$ (in $>3\sigma$ disagreement with the standard electroweak model prediction, $\langle P_{ee} \rangle = 1$), with strong anticorrelation between the two parameters. Finally, by taking f_B and its uncertainties as predicted by the SSM, we perform an updated analysis of the 2ν active neutrino oscillation parameters ($\delta m^2, \tan^2 \omega$) including all the solar ν data, as well as the spectral data from the CHOOZ reactor experiment. We find that only the solutions at $\tan^2 \omega \sim O(1)$ survive at the 3σ level in the global fit, with a preference for the one at high δm^2 —the so-called large mixing angle solution. [Phys. Rev. D **64**, 093007 (2001)]

Correlations of errors in measurements of CP violation at neutrino factories. John Pinney, *The Daiwa Anglo-Japanese Foundation, Daiwa Securities Kabuto-cho Bldg 9F, 1-1-9 Nihonbashi Kayabacho, Chuo-ku, Tokyo 103-0025, Japan; Osamu Yasuda, Department of Physics, Tokyo Metropolitan University, Minami-Osawa, Hachioji, Tokyo 192-0397, Japan.* (Received 10 May 2001; published 5 October 2001)

Using $\Delta\chi^2$ which is defined by the difference of the number of events with the CP phase δ and the hypothetical one with $\delta=0$, we discuss correlations of errors of the CP phase and other oscillation parameters as well as the matter effect in measurements at neutrino factories. By varying the oscillation parameters and the normalization of the matter effect, we evaluated the data size required to reject a hypothesis with $\delta=0$ at 3σ C.L. The optimum muon energy and the baseline depend on the magnitude of θ_{13} , the background fraction, and the uncertainty of the normalization of the matter effect, but in general lie in the range $20 \text{ GeV} \leq E_\mu \leq 50 \text{ GeV}$, $1000 \text{ km} \leq L \leq 3000 \text{ km}$. If we assume that the uncertainty of the matter effect is as large as 20% then the optimum values may be modified to $E_\mu \leq 10 \text{ GeV}$, $L \leq 1000 \text{ km}$ due to the strong correlation of δ and the matter effect. We show analytically that sensitivity to CP violation is lost for $E_\mu \ll 10 \text{ GeV}$ or for $E_\mu \gg 50 \text{ GeV}$. We also discuss the possibility of measuring CP violation at the upgraded JHF experiment by taking all the error correlations into account, and show that it is possible to demonstrate $\delta \neq 0$ at 3σ C.L. for $\theta_{13} \gtrsim 3^\circ$. [Phys. Rev. D **64**, 093008 (2001)]

Neutrinos from propagation of ultrahigh energy protons. Ralph Engel, David Seckel, and Todor Stanev, *Bartol Research Institute, University of Delaware, Newark, Delaware 19716.* (Received 19 January 2001; revised manuscript received 12 June 2001; published 8 October 2001)

We present a calculation of the production of neutrinos during propagation of ultrahigh energy cosmic rays, as may be produced in astrophysical sources. Photoproduction interactions are modeled with the event generator SOPHIA that represents very well the experimentally measured particle production cross sections at accelerator energies. We give the fluxes expected from different assumptions on cosmic ray source distributions, cosmic ray injection spectra, cosmological evolution of the sources and different cosmologies, and compare them to the Waxman-Bahcall limit on source neutrinos. We estimate rates for detection of neutrino induced showers in a km^3 water detector. The ratio of the local high energy neutrino flux to the ultrahigh energy cosmic ray flux is a crucial parameter in distinguishing between astrophysical and cosmological (top-down) scenarios of the ultrahigh energy cosmic ray origin. [Phys. Rev. D **64**, 093010 (2001)]

Almost maximal lepton mixing with large T violation in neutrino oscillations and neutrinoless double beta decay. Zhi-zhong Xing, *CCAST (World Laboratory), P.O. Box 8730, Beijing 100080, China and Institute of High Energy Physics, P.O. Box 918, Beijing 100039, China.* (Received 2 July 2001; published 10 October 2001)

We point out two simple but instructive possibilities to construct the charged lepton and neutrino mass matrices, from which the nearly bimaximal neutrino mixing with large T violation can naturally emerge. The two lepton mixing scenarios are very compatible with current experimental data on solar and atmospheric neutrino oscillations, and one of them may lead to an observable T -violating asymmetry between $\nu_\mu \rightarrow \nu_e$ and $\nu_e \rightarrow \nu_\mu$ transitions in the long-baseline neutrino oscillation experiments. Their implications for the neutrinoless double beta decay are also discussed. [Phys. Rev. D **64**, 093013 (2001)]

Single-spin asymmetry in deeply virtual Compton scattering: Fragmentation region of polarized lepton. I. Akushevich, *North Carolina Central University, Durham, North Carolina 27707 and TJNAF, Newport News, Virginia 23606*; E. A. Kuraev and B. G. Shaikhatdenov, *JINR, 141980 Dubna, Russia.* (Received 12 March 2001; published 4 October 2001)

For the kinematical region when a hard photon is emitted predominantly close to the direction of motion of a longitudinally polarized initial electron and relatively small momentum is transferred to a proton we calculate the azimuthal asymmetry of photon emission. It arises from the interference of the Bethe-Heitler amplitude and amplitudes described by a heavy photon impact factor. Azimuthal asymmetry does not decrease in the limit of infinite c.m.s. energy. The lowest order expression for the impact factor of a heavy photon is presented. [Phys. Rev. D **64**, 094010 (2001)]

Photon self-energy in a color superconductor. Daniel F. Litim and Cristina Manuel, *Theory Division, CERN, CH-1211 Geneva 23, Switzerland.* (Received 30 May 2001; published 5 October 2001)

In a color superconductor the diquark condensates break spontaneously both the color and ordinary electromagnetism, leaving a remaining rotated $U(1)$ symmetry unbroken. The gauge interactions associated with this rotated symmetry may be considered as

the in-medium electromagnetism. We compute the in-medium photon self-energy in the presence of diquark condensates at high baryonic density and weak coupling. This is done to one-loop order for the cases of two and three quark flavors. For vanishing temperature, a detailed discussion is given of the low momentum behavior of the photon polarization tensor. A simple physical picture for the propagation of light in color superconducting media is obtained. The main new effect is due to the diquark condensates, which lead to a strong dielectric constant of the medium. The magnetic permeability remains unchanged, because the primary condensates have vanishing spin and angular momentum. In the two flavor case, an additional contribution arises due to gapless quarks and electrons, which is responsible for Debye screening effects. We also discuss the low energy effective theory for the three flavor case in the presence of electromagnetic interactions. [Phys. Rev. D **64**, 094013 (2001)]

CP violation in the kaon system in a supersymmetric $SU(5)$ model with seesaw-induced neutrino masses. Naoyuki Akama, Yuichiro Kiyo, Shinji Komine, and Takeo Moroi, *Department of Physics, Tohoku University, Sendai 980-8578, Japan.* (Received 10 May 2001; published 9 October 2001)

CP violations in the kaon system are studied in the supersymmetric $SU(5)$ model with right-handed neutrinos. We pay special attention to the renormalization group effect on the off-diagonal elements of the squark mass matrices. In particular, if the Yukawa couplings and mixings in the neutrino sector are sizable, off-diagonal elements of the right-handed down-type squark mass matrix are generated, which affect CP and flavor violations in decay processes of the kaon. We calculate supersymmetric contributions to ϵ (as well as Δm_K), $Br(K_L \rightarrow \pi^0 \nu \bar{\nu})$, and ϵ'/ϵ in this framework. We will see that the supersymmetric contribution to the ϵ parameter can be as large as (and in some cases, larger than) the experimentally measured value. We also discuss its implication to future tests of the unitarity triangle of the Kobayashi-Maskawa matrix. [Phys. Rev. D **64**, 095012 (2001)]

Masses of the pseudo Nambu-Goldstone bosons in the two flavor color superconducting phase. V. A. Miransky, *Department of Applied Mathematics, University of Western Ontario, London, Ontario N6A 5B7, Canada*; I. A. Shovkovy, *School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455*; L. C. R. Wijewardhana, *Physics Department, University of Cincinnati, Cincinnati, Ohio 45221-0011.* (Received 19 April 2001; published 3 October 2001)

The masses of the pseudo Nambu-Goldstone bosons in the color superconducting phase of dense QCD with two light flavors are estimated by making use of the Cornwall-Jackiw-Tomboulis effective action. Parametrically, the masses of the doublet and antidoublet bosons are suppressed by a power of the coupling constant as compared to the value of the superconducting gap. This is qualitatively different from the mass expression for the singlet pseudo Nambu-Goldstone boson, resulting from nonperturbative effects. It is argued that the (anti) doublet pseudo Nambu-Goldstone bosons form colorless [with respect to the unbroken $SU(2)_c$] charmonium-

like bound states. The corresponding binding energy is also estimated. [Phys. Rev. D **64**, 096002 (2001)]

New CP violation in neutrino oscillations. M. C. Gonzalez-Garcia,^{1,2,3} Y. Grossman,⁴ A. Gusso,^{1,5} and Y. Nir⁶
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Measurements of CP-violating observables in neutrino oscillation experiments have been studied in the literature as a way to determine the CP-violating phase in the mixing matrix for leptons. Here we show that such observables also probe new neutrino interactions in the production or detection processes. Genuine CP violation and fake CP violation due to matter effects are sensitive to the imaginary and real parts of new couplings. The dependence of the CP asymmetry on the source-detector distance is different from the standard one and, in particular, enhanced at short distances. We estimate that future neutrino factories will be able to probe in this way new interactions that are up to four orders of magnitude weaker than the weak interactions. We discuss the possible implications for models of new physics. [Phys. Rev. D **64**, 096006 (2001)]

Single-spin azimuthal asymmetries in electroproduction of neutral pions in semi-inclusive deep-inelastic scattering. A. Airapetian,³¹ N. Akopov,³¹ Z. Akopov,³¹ M. Amarian,^{26,31} E. C. Aschenauer,⁷ H. Avakian,¹¹ R. Avakian,³¹ A. Avetissian,³¹ E. Avetissian,³¹ P. Bailey,¹⁵ B. Bains,¹⁵ V. Baturin,²⁴ C. Baumgarten,²¹ M. Beckmann,^{6,12} S. Belostotski,²⁴ S. Bernreuther,²⁹ N. Bianchi,¹¹ H. Böttcher,⁷ A. Borissov,^{6,19} O. Bouhali,²³ M. Bouwhuis,¹⁵ J. Brack,⁵ S. Brauksiepe,¹² W. Brückner,¹⁴ A. Brüll,¹⁸ I. Brunn,⁹ H. J. Bulten,^{23,30} G. P. Capitani,¹¹ P. Chumney,²² E. Cissani,²⁶ G. Ciullo,¹⁰ G. R. Court,¹⁶ P. F. Dalpiaz,¹⁰ R. De Leo,³ L. De Nardo,¹ E. De Sanctis,¹¹ D. De Schepper,² E. Devitsin,²⁰ P. K. A. de Witt Huberts,²³ P. Di Nezza,¹¹ V. Djordjadze,⁷ M. Düren,⁹ M. Ehrenfried,⁷ G. Elbakian,³¹ F. Ellinghaus,⁷ J. Ely,⁵ A. Fantoni,¹¹ A. Fechtchenko,⁸ L. Felawka,²⁸ B. W. Filippone,⁴ H. Fischer,¹² B. Fox,⁵ J. Franz,¹² S. Frullani,²⁶ Y. Gärber,^{7,9} F. Garibaldi,²⁶ E. Garutti,²³ G. Gavrilo, ²⁴ V. Gharibyan,³¹ A. Golendukhin,^{6,21,31} G. Graw,²¹ O. Grebenioun, ²⁴ P. W. Green,^{1,28} L. G. Greeniaus,^{1,28} A. Gute,⁹ W. Haeberli,¹⁷ K. Hafidi,² M. Hartig,²⁸ D. Hasch,^{9,11} D. Heesbeen,²³ F. H. Heinsius,¹² M. Henoch,⁹ R. Hertenberger,²¹ W. H. A. Hesselink,^{23,30} G. Hofman,⁵ Y. Holler,⁶ R. J. Holt,^{2,15} B. Hommez,¹³ G. Iarygin,⁸ A. Izotov,²⁴ H. E. Jackson,² A. Jgoun,²⁴ P. Jung,⁷ R. Kaiser,⁷ J. Kanesaka,²⁹ E. Kinney,⁵ A. Kisselev,^{2,24} P. Kitching,¹ H. Kobayashi,²⁹ N. Koch,⁹ K. Königsmann,¹² H. Kolster,^{18,23} V. Korotkov,⁷ E. Kotik,¹ V. Kozlov,²⁰ B. Krauss,⁹ V. G. Krivokhijine,⁸ G. Kyle,²² L. Lagamba,³ A. Laziev,^{23,30} P. Lenisa,¹⁰ P. Liebing,⁷ T. Lindemann,⁶ W. Lorenzon,¹⁹ A. Maas,⁷ N. C. R. Makins,¹⁵ H. Marukyan,³¹ F. Masoli,¹⁰ M. McAndrew,¹⁶ K.

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A single-spin asymmetry in the azimuthal distribution of neutral pions relative to the lepton scattering plane has been measured for the first time in deep-inelastic scattering of positrons off longitudinally polarized protons. The analyzing power in the $\sin \phi$ moment of the cross section is $0.019 \pm 0.007(\text{stat}) \pm 0.003(\text{syst})$. This result is compared to single-spin asymmetries for charged pion production measured in the same kinematic range. The π^0 asymmetry is of the same size as the π^+ asymmetry and shows a similar dependence on the relevant kinematic variables. The asymmetry is described by a phenomenological calculation based on a fragmentation function that represents sensitivity to the transverse polarization of the struck quark. [Phys. Rev. D **64**, 097101 (2001)]

Massless “just-so” solution to the solar neutrino problem. M. M. Guzzo,¹ H. Nunokawa,¹ P. C. de Holanda,¹ and O. L. G. Peres^{1,2}
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We study the effect of the nonresonant, vacuum oscillationlike neutrino flavor conversion induced by nonstandard flavor changing and nonuniversal flavor diagonal neutrino interactions with electrons in the Sun. We have found an acceptable fit for the combined analysis for the solar experiments total rates, the Super-Kamiokande energy spectrum and zenith angle dependence. Phenomenological constraints on nonstandard flavor changing and nonuniversal flavor diagonal neutrino interactions are considered. [Phys. Rev. D **64**, 097301 (2001)]

Nonlinear Landau damping of a plasmino in the quark-gluon plasma. Yu. A. Markov and M. A. Markova, *Institute of System Dynamics and Control Theory, Siberian Branch of Academy of Sciences of Russia, P.O. Box 1233, 664033 Irkutsk, Russia.* (Received 6 February 2001; revised manuscript received 15 May 2001; published 17 October 2001)

On the basis of the Blaizot-Iancu equations, which are a local

formulation of the hard thermal loop (HTL) equations of motion for soft fluctuating quark and gluon fields and their induced sources, the coupled kinetic equations for plasminos and plasmons are obtained. The equality of matrix elements for nonlinear scattering of a plasmino by hard particles in covariant and temporal gauges is established by using effective Ward identities. The model problem of the interaction of two infinitely narrow packets with fermion and boson quantum numbers is considered. The kinematical relations between wave vectors of the plasmino and plasmon are derived, when the effective pumping over of the plasma excitation energy from the fermion branch of plasma excitations to the boson branch and vice versa occur. The expression for the nonlinear Landau damping rate of a plasmino at rest is found, and a comparison with a plasmino damping constant obtained within the framework of the hard thermal loop approximation is made. The nonlinear Landau damping rate for normal quark excitations is shown to diverge like $1/\sqrt{q^2}$ near the light cone where q is a four-momentum of excitations, and the improved Blaizot-Iancu equations removing this divergence are proposed. [Phys. Rev. D **64**, 105009 (2001)]

Eikonal evolution and gluon radiation. Alex Kovner, *Theory Division, CERN, CH-1211 Geneva 23, Switzerland and Department of Mathematics and Statistics, University of Plymouth, Plymouth PL4 8AA, United Kingdom*; Urs Achim Wiedemann, *Theory Division, CERN, CH-1211 Geneva 23, Switzerland.* (Received 27 June 2001; published 19 October 2001)

We give a simple quantum mechanical formulation of the eikonal propagation approximation, which has been heavily used in recent years in problems involving hadronic interactions at high energy. This provides a unified framework for several approaches existing in the literature. We illustrate this scheme by calculating the total, elastic, inelastic and diffractive DIS cross sections, as well as gluon production in high energy hadronic collisions. From the $q\bar{q}g$ component of the DIS cross sections, we straightforwardly derive low x evolution equations for inelastic and diffractive DIS distribution functions. In all calculations, we provide all order $1/N$ corrections to the results existing in the literature. [Phys. Rev. D **64**, 114002 (2001)]