TIFR Annual Report 2004-05
THEORETICAL PHYSICS

High Energy Physics

Highlights

It was demonstrated how the propagation of the shock wave inside a supernova can be tracked using the spectra of neutrinos emanating from it.

(a) A new direction in lattice QCD was opened up with the development of a new technique and the determination of a transport coefficient in QCD. (b) A new method was found to avoid the fermion sign problem. This was applied to finding the critical end point of QCD at finite chemical potential. (c) The first determination of the specific heat of QCD was made.

The recent KamLAND reactor neutrino data was used in a global analysis to provide finally a unique oscillation solution to the solar neutrino puzzle with precise mass and mixing angle.

The top Yukawa infrared fixed point scenario was investigated and was shown to be disfavoured within the split supersymmetry scheme.

(a) The computation of next-to-leading order QCD corrections to virtual graviton exchange processes in TeV-scale gravity models was completed. (b) The implications of the existence of a minimal length scale for TeV-scale gravity models were studied.

High Energy Physics

Research in High Energy Physics was carried out in the broad areas of Beyond Standard Model Physics, Lattice Gauge Theory and Quantum Chromodynamics.

Beyond Standard Model Physics

Tracking the Supernova Shock Wave in Neutrinos

A few seconds after bounce in a core-collapse supernova, the shock wave passes the density region corresponding to resonant neutrino oscillations with the "atmospheric" neutrino mass difference. The resulting transient violation of adiabaticity would give rise to an observable modulation of the neutrino signal from a future galactic supernova. When the supersonically expanding neutrino-driven wind collides with the slower in-falling matter, a reverse shock wave is generated, which manifests itself in a "double dip" feature in the average neutrino energy as a function of time. This effect was studied both analytically and numerically and it was demonstrated how it allows one to trace the positions of the forward and reverse shocks. These features are observable in the antineutrino signal for an inverted and in the neutrino signal for a normal neutrino mass hierarchy, provided the 13-mixing angle is "large" ($\sin^2\theta_{13} \gg 10^{-5}$). [A. Dighe with M. Kachelriess, G. Raffelt and R. Tomas of MPP, Munich, and H.-T. Janka and L. Scheck of MPA, Munich]

Higgsino LSP

It can be seen that a large part of the MSUGRA parameter space satisfying the WMAP constraint on the dark matter relic density corresponds to a Higgsino LSP of mass $\simeq 1$ TeV. Detection possibility of this 1 TeV Higgsino LSP in future Linear Collider like CLIC was investigated. Dark matter experiments were also investigated by looking at monochromatic γ-ray signal from LSP pair annihilation at the galactic centre. [Partha Konar and D.P. Roy with Utpal Chattopadhyay of IACS, Kolkata and Manuel Drees of Bonn U.]

Solar Neutrino Oscillation

The latest KamLAND reactor neutrino data was used in a global analysis to remove the two-fold ambiguity in the mass parameter and give a unique oscillation solution to the long-standing solar neutrino puzzle with precise mass and mixing angle. With this the solar neutrino oscillation has finally entered the era of precision physics (see figure). [D.P. Roy with A. Bandyopadhyay of SINP, Kolkata, S. Goswami of HRI, Allahabad, S. Choubey and S.T. Petcov of SISSA, Trieste].

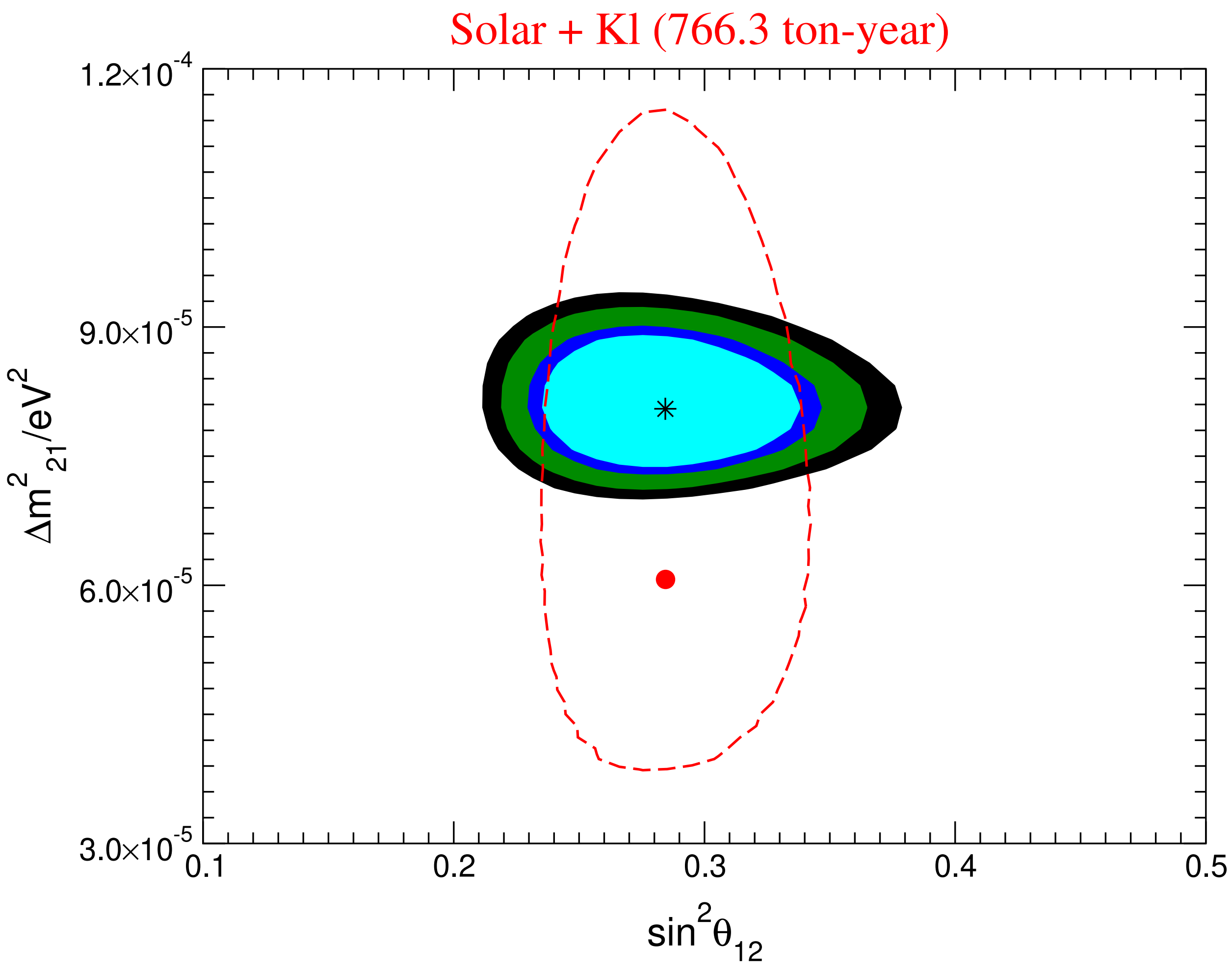

Figure 1: The allowed ranges of neutrino mass and mixing angle from oscillation fit to global solar and KamLAND reactor neutrino data at 90,95,99 and 99.73% C.L. (shaded areas), shown alongwith the 90% C.L. contour of the global solar fit.

Charged Higgs Boson Signatures

The charged Higgs boson $H^{\pm}$ carries a distinctive hallmark of the Minimal Supersymmetric Standard Model (MSSM), since it does not have a Standard Model analogue. The viable signatures for the $H^{\pm}$ search were investigated for the forthcoming Large Hadron Collider [D.P. Roy]

A novel decay channel of $H^{\pm}$ to a relatively light neutral Higgs h^0 and a $W^{\pm}$ boson was shown to provide a unique signature for discovering the $H^{\pm}$ along with the light neutral Higgs boson h^0, which might have escaped detection at LEP in the CP violating MSSM [D.P. Roy with D. Ghosh of Urzburg U., Germany and R.M. Godbole of IISc, Bangalore]

Using Tau Polarization for SUSY Studies at the ILC

The most promising SUSY signal at the proposed International Linear Collider is expected to occur in the tau lepton channel. A simple method of measuring tau polarization in its inclusive hadronic decay was used to show how this polarization can be used to discriminate between SUSY models and also to measure SUSY parameters in a model independent way [D.P. Roy with M. Guchait of DHEP, TIFR and R.M. Godbole of IISc, Bangalore]

Infrared Fixed Point of the Top Yukawa Coupling in Split Supersymmetry

The severe constraints imposed on the parameter space of the minimal split supersymmetry model by the infrared fixed point solution of the top Yukawa coupling Y_t were studied in detail in terms of the value of the top quark mass measured at the Tevatron together with the lower bound on the lightest Higgs mass established by LEP. The sensitive dependence of the higgsino mass parameter μ and of the gaugino coupling strengths $\tilde{g}_{u,d}$, $\tilde{g}_{u,d}^{primed}$ on the value of Y_t in the vicinity of the Landau pole is a remarkable consequence. A few other interesting features emerge, though the model is found to be disfavoured within the infrared fixed point scenario because of the need to have several fine tunings at work on account of the requirement of a low upper bound on $\tan\beta$. [Probir Roy with K. Huitu, J. Laamanen and S. Roy of the Helsinki Institute of Physics]

Deviation from Maximal Mixing of Atmospheric Muon Neutrinos via Matter Effects

The difference $\Delta P^A_{\mu\mu}$ between atmospheric muon neutrino and antineutrino survival probabilities was considered, for a nonzero $|U_{e3}|$, as a probe into the deviation $D = 1/2$ - $|U_{\mu 3}|^2$ of the flavour mixing of ν_μ, $\bar{\nu}_\mu$ from its maximal value. The feasibility of measuring D from 1000 kton-years of exposure with a magnetized iron calorimeter such as the proposed INO detector for various values of $|U_{e3}|$ was quantitatively investigated. [Probir Roy with S. Choubey of Oxford U.]

TeV-Scale Gravity

Next-to-leading order QCD corrections to hadron production in electron-positron collisions with virtual graviton exchange in the context of TeV-scale gravity models have been computed. The implications of these corrections for electron-positron collisions at a Linear

Collider have been studied. [K. Sridhar with Prakash Mathews of SINP, Kolkata and V. Ravindran of HRI, Allahabad]

Models of gravity suggest the existence of a minimal length scale. The existence of such a scale in TeV-scale gravity models has two important implications: i) the weakening of the bounds on the low-energy quantum gravity scale and ii) the taming of the ultraviolet divergence which results from the summation of the Kaluza-Klein tower of gravitons. These effects have been studied in the context of dilepton production at hadron colliders. [K. Sridhar and Kumar Rao, with Gautam Bhattacharyya and Prakash Mathews of SINP, Kolkata]

Next-to-leading order QCD corrections to dilepton production in hadron collisions with virtual graviton exchange in the context of TeV-scale gravity models have been computed. Numerical studies of the magnitude of these corrections at hadron colliders like the Tevatron and the LHC have been studied. [K. Sridhar with Prakash Mathews of SINP, Kolkata, V. Ravindran of HRI, Allahabad and W.L. van Neerven of Leiden U.]

Lattice Gauge Theory

On the Critical End Point of QCD

The critical end point of QCD was investigated with two flavours of light dynamical quarks at finite lattice cutoff $a = 1/4T$ using a Taylor expansion of the baryon number susceptibility. A strong volume dependence of its radius of convergence was found. In the large-volume limit, $\mu_B/T \approx 1.1$ was obtained as the radius of convergence at $T/T_c \approx 0.95$ where T_c is the crossover temperature at zero chemical potential. Since this estimate is a lower bound on the critical end point of QCD, the above small value of μ may place it in the range of observability in energy scans at the RHIC. [R.V. Gavai and Sourendu Gupta]

Hydrodynamics, Fluctuations and Conformal Symmetry

The continuum limits of the equation of state, speed of sound and the specific heat at constant volume were obtained in the high-temperature phase of quenched lattice QCD. At temperatures of 2–3 T_c, the speed of sound was compatible with the ideal gas, whereas the remaining quantities were not. However, both were compatible with approximate conformal symmetry. Effective measures of conformal symmetry in the high-temperature phase of QCD were investigated. [R.V. Gavai, Sourendu Gupta and Swagato Mukherjee]

Transport Coefficients in the Quark-Gluon Plasma

A lattice determination of the electrical conductivity of the quark-gluon plasma was made. This was used to make estimates of other transport-related quantities using kinetic theory formulæ. The resulting estimates were applied to fluctuations, ultra-soft photon spectra and the viscosity. Dimming of ultra-soft photons was found to be exponential in the mean free path, and hence a very sensitive probe of transport. [Sourendu Gupta]