Dr Chris Allton (Dept. of Physics, Swansea University)
The scale of SU(N) gauge theories

There is a well-known discrepancy between the running of the energy scale from lattice simulations and the asymptotic freedom formula when the latter is expressed in terms of the bare (lattice) coupling, $g_0$. The conventional explanation of this discrepancy, due to Parisi, Lepage and Mackenzie, is that $g_0$ is a poor expansion parameter, and that a ”renormalised” coupling is required.

There is however, an alternative point of view in which lattice spacing artefacts which contaminate the lattice data causing the discrepancy. This idea has been tested successfully in the past on SU(3) data. This talk applies this approach to SU(N) data for several values of N, and shows that this alternative point of view is also valid in these cases too. Using this approach we estimate $\Lambda_{\overline{MS}}/\sqrt{\sigma} = 0.503(2)(40) + 0.33(3)(3)/N^2$ for $N \geq 3$, where the first error is statistical and the second is our estimate of the systematic error from all sources.

Dr Francois Bissey (Institute of Fundamental Sciences, Massey University)
Quarks at the hadron source?

In our work on the distribution of the gluon field in baryon we studied various way of connecting the quarks to the baryonic source (hep-lat/0606016). The particular configuration we dubbed ”L” shape displays a different pattern that we attributed to the fact that the quarks were far away from an ideal equilateral triangle. I will show that in fact this odd behavior is caused by putting a ”quark” at the hadron source. The nature of the resulting object will be briefly discussed.

Prof. Stanley J. Brodsky (Stanford Linear Accelerator Center, Stanford University)
New Perspectives for QCD from AdS/CFT

One of the most interesting recent advances in hadron physics has been the application of the AdS/CFT correspondence to quantum chromodynamics. Although QCD is not a conformally invariant field theory, one can nevertheless use the mathematical representation of the conformal group in five-dimensional anti-de Sitter space to construct an analytic first approximation to the theory. The resulting AdS/QCD model gives accurate predictions for hadron spectroscopy and a description of the quark structure of mesons and baryons which has scale invariance and dimensional counting at short distances, together with color confinement at large distances. In addition, one can compute the form of the frame-independent light-front bound-state wavefunctions, the fundamental nonperturbative entities which encode hadron properties and which allow the computation of hadronic scattering amplitudes and decays. A number of novel applications of light-front wavefunctions to QCD phenomenology will also be discussed, such as color transparency,
hidden color, intrinsic charm, sea-quark asymmetries, dijet diffraction, direct hard processes, and hadronic spin dynamics.

Dr Fu-Guang Cao (Institute of Fundamental Sciences, Massey University)
Strangeness of the Nucleon

We review current experimental information and various theoretical calculations on the strangeness in the nucleon.

Prof. Robert Delbourgo (School of Mathematics and Physics, University of Tasmania)
Chromicity

Chromicity refers to the U(3) property possessed by quarks, in contrast to the SU(3) colour property. Leptonicity are two further properties possessed by the elementary particles. By associating these properties with SCALAR anticommuting coordinates in various combinations, one obtains a limited set of fundamental particles in their various generations. I shall describe such a scheme and where it leads to.

Prof. Victor Flambaum (New Zealand Insitute of Advanced Study, Massey University and School of Physics, UNSW)
1. Variation of fundamental constants from Big Bang to atomic clocks and QCD calculations

Rapidly developing field of search for temporal and spatial variation of the fundamental constants now includes a very large number of laboratory, astronomical and geochemical measurements. Interpretation of these measurements and search for new research directions require nuclear and QCD calculations of dependence of nuclear parameters on quark masses. We need to calculate this dependence for deuteron binding energy, positions of nuclear resonances, nuclear magnetic moments, strong interaction between nucleons and nuclear potentials.

Theories unifying gravity with other interactions suggest temporal and spatial variation of the fundamental ”constants” in expanding Universe. I discuss effects of variation of the fine structure constant $\alpha = e^2/\hbar c$, strong interaction and quark mass. The measurements of these variations cover lifespan of the Universe from few minutes after Big Bang to the present time and give controversial results. There are some hints for the variation in Big Bang nucleosynthesis, quasar absorption spectra and Oklo natural nuclear reactor data.

A very promising method to search for the variation of the fundamental constants consists in comparison of different atomic clocks. A billion times enhancement of the variation effects happens in transition between accidentally degenerate nuclear, atomic and molecular energy levels.
2. Coulomb problem for vector particles in gauge theories: when renormalizability may be not enough

We argue that the renormalizability of a theory does not necessarily guarantee a reasonable behaviour at small distances for a non-perturbative problem, such as a bound state problem. As an example we consider the Coulomb problem for W-bosons (spin S=1) which incorporates a well known difficulty; the charge of the boson localized in a close vicinity of the attractive Coulomb center proves to be infinite. The vector boson falls on the Coulomb center. The phenomenon was discovered in the works of Tamm, Schwinger, Oppenheimer and others 66 years ago, and since then was a nuisance for the theory.

We show that in pure QED the paradox is resolved by the polarization of the fermion vacuum, which brings in a strong effective repulsion at very small distances that eradicates the infinite charge of the boson on the Coulomb center. This property allows one to define the Coulomb problem for vector bosons properly. It is interesting that the vacuum polarization for scalar and spinor particles produces only a weak effect while for vector bosons the situation is completely different, it produces the impenetrable potential barrier $\sim 1/r^4$.

In a renormalizable SU(2) theory containing vector triplet (W+,W-, photon) and fermion doublet (F1/2+,F1/2-) with large mass M (Coulomb centers) the vacuum polarization does not help; W boson falls to the Coulomb center to distances $r \sim 1/M$, where M can be made arbitrary large. Thus, the renormalizability itself does not prevent the theory from exhibiting poor behaviour at small distances. To save the situation, the theory needs additional fermions or scalars, which switch the ultraviolet behavior from the asymptotic freedom to the Landau pole.

Another interesting feature of vector bosons: charge density of a positively charged particle may be negative.


Dr Noriyoshi Ishii (Center for Computational Sciences, University of Tsukuba)
Lattice QCD approach to NN potentials

We report our recent results of nucleon-nucleon potentials in quenched lattice QCD. By identifying the Bethe-Salpeter wave function for NN with the quantum mechanical wave function, we construct the NN potential demanding that the wave function should satisfy the Schrodinger equation. Resulting NN potential has all the qualitative features, which phenomenological NN potentials commonly have, i.e., the repulsive core of 500-600 MeV at short distance and the attractive pocket of about 30 MeV at medium distance. The quark mass dependence of the NN potential suggests that both the repulsive core and the attractive pocket are enhanced in the light quark mass region. We also present our recent preliminary result on the tensor force. We finally make a comment on subtleties of our potential arising from a particular choice of interpolating field of nucleon, and a brief idea how to solve it by using scattering theory.
Dr David Krofcheck (Dept. of Physics, University of Auckland)
Experimental Signatures for AdS/CFT at the RHIC and the LHC

Recent observations of jet suppression via heavy ion collisions at the RHIC suggest that the produced, high temperature nuclear matter is “colour opaque”. Furthermore, observation of large collective motions, known as elliptic flow, in this strongly interacting nuclear matter led to the suggestion that ideal hydrodynamic behavior was observed. We will have a look at what is measured in these experiments, and how the higher centre-of-mass energy that will be available at the LHC will permit access to new observables and laboratory tests of AdS/CFT versus pQCD.

Prof. Derek Leinweber (CSSM and Dept. of Physics, University of Adelaide)
Aspects of QCD Vacuum Structure

We are comparing the topological-charge densities obtained from the Overlap-Dirac operator, three-loop $\mathcal{O}(a^4)$-improved cooling, and a new over-improved Stout-link smearing algorithm designed to preserve instantons. Of particular interest is the nature of the topological charge correlator, $\langle q(x)q(0) \rangle$. We are examining the extent to which the various smoothing methods reveal negative values for $\langle q(x)q(0) \rangle$ at small but finite $x$, suggesting a sign-alternating layered structure to the topological-charge density of the QCD vacuum. We are also exploring the extent to which such layers are “featureless.” We apply our proven methodology to explore the topological charge distribution in large-volume quenched and light 2+1 flavour dynamical-fermion configurations from the MILC Collaboration. We find the topological structures revealed on the lattice to be rather un-instanton like. We also observe substantial differences in the distribution of topological charge between quenched and dynamical-fermion configurations. Finally, we examine correlations between low-lying eigenmodes of the Overlap-Dirac operator and the topological structures revealed using gluonic operators. We report that it is possible to draw strong parallels with conventional smoothing methods and the more recent eigenmode-based filtering techniques.

Prof. Kim Maltman (Dept. of Mathematics and Statistics, York University)
Status of the hadronic tau decay determination of $V_{us}$

Flavor-breaking combinations of hadronic tau decay data allow one to make a determination of $V_{us}$ with uncertainties entirely independent of those associated with alternate approaches based on either $K_{\ell 3}$ decays or the ratio $\Gamma[K_{\mu 2}]/\Gamma[\pi_{\mu 2}]$. Recent improvements in the determinations of the branching fractions of a number of key strange decay modes by BaBar and Belle have significantly altered the situation, producing results for $V_{us} \sim 3\sigma$ lower than expectations based on 3-family unitarity. I discuss the current status of the hadronic tau decay determination, as well as important outstanding questions and directions for future study.
Dr Hidekatsu Nemura (Advanced Meson Science Laboratory, RIKEN)

Hyperon-nucleon potential calculated from lattice QCD simulation

We calculate proton-\(\Xi^0\) potential from the Bethe-Salpeter amplitude measured in the quenched QCD simulation with the spatial lattice volume, \((4.4 \text{ fm})^3\). This is a first attempt to describe baryon-baryon potentials including strangeness from lattice QCD. The strange degrees of freedom should play a characteristic role in various nuclear systems from light hypernuclei to high density systems such as neutron stars. So far, the phenomenological description of hyperon-nucleon (YN) and hyperon-hyperon (YY) interactions has large uncertainties, which is in sharp contrast to the nice description of phenomenological NN potential. One of the reasons is that the YN and YY scattering experiments are either difficult or impossible due to the short life-time of the hyperons. Therefore, the present approach can be a new ”experiment” to study the hyperon interactions from ab initio numerical simulations.

Mr Vaibav Prakash (Institute of Fundamental Sciences, Massey University)

Transversity in Meson Cloud Model

The mesonic corrections to the Deep-Inelastic Scattering processes were recognized in the early 1970s where it was shown that the pion cloud affects the scattering cross-section. This means that the parton distributions of the meson and the momentum distribution of the meson cloud itself affect the parton distributions of the nucleon. Several efforts have been made to calculate valence as well as sea quark distributions in the proton via the “Meson Cloud Model” (MCM). MCM treats the physical nucleon as the sum of bare nucleon and Meson-Baryon Fock states. The parton distributions are then modified via a series of relevant convolutions of momentum and parton distributions for each of the MB state. MCM has been quite succesful in explaining the HERMES data on sea quark distributions. In this talk I try to show the influence of the meson cloud on transverse spin structure for valence u and d quarks. I will be calculating the fluctuation function for transverse spin. In the near future I along with my group will be using the MIT bag model transversity calculations as the initial parton distributions and look at the effect of adding the Meson-Baryon Fock state.

Prof. Peter Schwerdtfeger (New Zealand Institute for Advanced Study and CTCP, Massey University)

Small Effects, Large Consequences: From Relativity to Electroweak Interactions

Relativistic effects scale approximately with \(Z^2\) (\(Z = \text{nuclear charge}\)); hence one expects relativistic effects to become important to inner shell electrons of heavy elements only. Only in the last two decades has it become clear that relativistic effects are not small and are responsible for a number of anomalies now observed in molecules or in the solid state. For example, the chemistry of gold cannot be understood without including relativity. To include such effects, however, one has to go beyond the Schrödinger equation to its relativistic extension, the Dirac equation.
The question one may now ask: are other effects regarded as too small (like quantum electrodynamic or weak interactions) to be important for chemistry? For example, weak interactions (Z-boson exchange between electrons and nucleons) leads to symmetry breaking (parity violation or break-down of mirror image symmetry) in chiral molecules. Such tiny effects (estimated to be in the mHz region) scale like $Z^5$, and the search parity violation in chiral molecules including heavy elements is currently underway using NMR, vibrational or Mössbauer spectroscopy. The talk will give an overview how important relativistic, QED and electroweak effects are in molecular properties.

Prof. Tony Signal (Institute of Fundamental Sciences, Massey University)

Diquarks and Triquarks on the Lattice

The distribution of gluon fields in hadrons is of fundamental interest in QCD. Using lattice QCD we have observed the formation of gluon flux tubes within three quark (baryon) and quark plus anti-quark (meson) systems for a wide variety of spatial distributions of the color sources. In particular we have investigated three quark configurations where two of the quarks are close together and the third quark is some distance away, which approximates a quark plus diquark string. We find that the string tension of the quark - diquark string is the same as that of the quark - anti-quark string on the same lattice. We also compare the longitudinal and transverse profiles of the gluon flux tubes for both sets of strings, and find them to be of similar radii and to have similar vacuum suppression.

Adam Szczepaniak (Nuclear Theory Center, Indiana University)

From gluons to hybrids: gluon dynamics from the Coulomb gauge perspective

Gluon dynamics in vacuum and presence of external sources is discussed in the Coulomb gauge. We show how confinement eliminates color excitations from the spectrum and how the non-ableian Coulomb interaction is responsible for yielding the correct spin-parity splitting between gluelumps. Finally spectrum of quarkonium hybrids will be discussed.

Prof. Terry Tomboulis (Dept. of Physics and Astronomy, UCLA)

From short to long scales and confinement via RG blockings in 4-dim non-Abelian gauge theory

We present a method in which approximate but explicitly computable RG decimations are shown to bound the partition function and some order parameters in SU(2) LGT from above and below. By interpolating between the bounds, the RG flow from the short to long scales in the exact theory can thus be followed. It is seen to proceed from the weak to the strong coupling confining regime without encountering a fixed point for all values of the gauge coupling and space-time dimension equal or less than four.
Prof. Frank Wilczek (MIT)
QCD Meets BCS Meets QQ

The behavior of hadronic matter at asymptotically high density can be treated analytically by adapting methods from condensed matter physics – specifically, the BCS theory of superconductivity. Confinement and chiral symmetry breaking are calculable consequences. In these considerations, condensation of diquarks plays a central role. I will discuss the phenomenological evidence for significant diquark correlation energy (even at zero density), and use this concept to predict some new phenomena.

Dr György Wolf (KFKI RMKI)
Vector Mesons in Matter

Chiral symmetry and its spontaneous breaking is one of the most important phenomena in strong interaction physics. One consequence of the chiral symmetry restoration is the mixing of parity partners. We look for a possible signature of the mixing of vector and axialvector mesons in heavy-ion collisions. We suggest an experimental method for its observation. The dynamical evolution of the heavy ion collision is described by a transport equation of QMD type evolving nucleons, N* and Δ resonances, Λ’s and Σ baryons, furthermore, π’s, η’s ρ’s σ’s ω’s and kaons with their isospin degrees of freedom. The input cross sections and resonance parameters of the model are fitted to the available nucleon-nucleon and pion-nucleon cross sections.

Dr Ross Young (Physics Division, Argonne National Laboratory)
Strange Quark Contributions to Nucleon Form Factors

We present our theoretical determination of the strange quark component of the electromagnetic form factors of the nucleon. This work is based upon lattice-QCD simulations and advanced chiral extrapolation techniques, supplemented with experimental form factors and charge symmetry constraints. The results of this theoretical prediction are compared with the latest experimental results on strangeness, as seen in parity-violating electron–nucleon scattering.