

MEETING Lattice 88

The forty-year dream of understanding the properties of the strongly interacting particles from first principles is now approaching reality. Quantum chromodynamics (QCD – the field theory of the quark and gluon constituents of strongly interacting particles) was initially handicapped by the severe limitations of the conventional (perturbation) approach in this picture, but Ken Wilson's inventions of lattice gauge theory and renormalization group methods opened new doors, making calculations of masses and other particle properties possible.

Lattice gauge theory became a major industry around 1980, when Monte Carlo methods were introduced, and the first prototype calculations yielded qualitatively reasonable results. The promising developments over the past year were highlighted at the 1988 Symposium on Lattice Field Theory – Lattice 88 – held at Fermilab.

Peter Hasenfratz of Bern summarized recent lattice work on the mass limits of the so-far unseen Higgs particle (responsible for mass in the standard electroweak model). It has long been known that simple Higgs theory breaks down if the Higgs is heavier than about 1 TeV. Recent lattice work has even brought the limit down to about 600 – 700 GeV and made it more general. According to these calculations, no Higgs below this level means some new physics beyond the standard model.

Julius Kuti of San Diego outlined further lattice applications in the electroweak sector, including bounds on the mass of the missing sixth

('top') quark. Ideas of a new strongly coupled phase of quantum electrodynamics were aired by John Kogut of Illinois.

The calculation of particle masses is one of the main lattice theory goals, the contribution of itinerant 'sea' quarks being the most difficult to include. A 'quenched' approximation with valence quarks only, ignoring sea effects, is not expected to give the right answer, but it is still important to see what happens before embarking on the full calculation.

Progress with the quenched approximation was covered by Enzo Marinari of Rome. High statistics calculations by a special-purpose computer using improved calculational methods say the proton is about 1.4 times heavier than the rho meson, compared to the actual value of 1.22.

New improved algorithms were reviewed by Don Weingarten of IBM, Yorktown Heights, and Stephen Adler of the Institute for Advanced Study, Princeton. Progress has been most spectacular in gauging the effects of sea quarks, with new Monte Carlo algorithms being about 10,000 times faster than their predecessors.

Hardware too has seen comparable improvements. The special purpose machines under construction at various institutions around the world are roughly 10,000 times more powerful than the VAXes used for the original calculations seven years ago. Norman Christ of Columbia described machines existing or under construction at Columbia, IBM, Rome, Fermilab, Caltech, and Tsukuba, and in industry. Some of these borrow ideas from the approach pioneered by the Columbia group and now in widespread use for lattice calculations – fast floating point chips on a mas-

Peter Hasenfratz – mass limits for the long-awaited but still unseen Higgs particle.

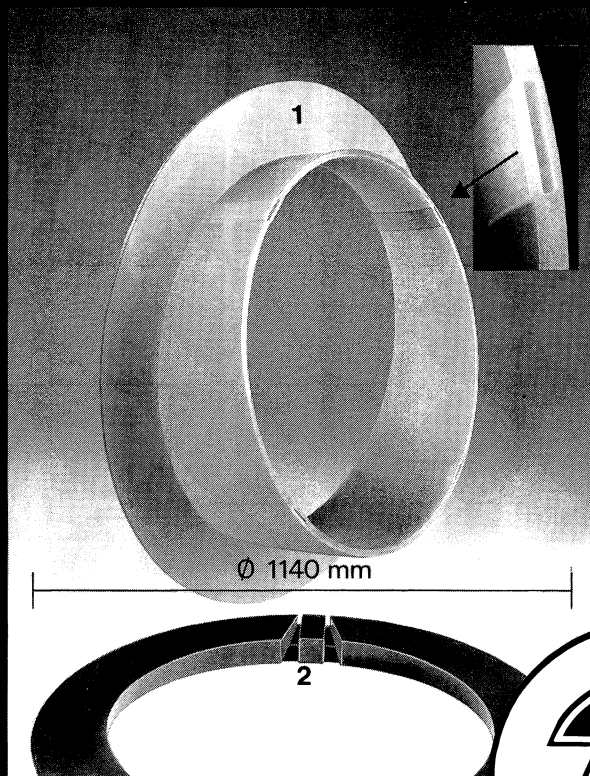


sive parallel array of nodes.

The better understanding of glueballs (particles containing gluons rather than quarks) was pointed out by Andreas Kronfeld of Fermilab. Two years ago, confusion reigned in this area and there was no unanimity even on basic questions. Improved methods of calculating glueball masses have helped to clarify the situation, the consensus being that the spin 2, positive parity glueball is about 1.5 times heavier than its spin zero counterpart.

Pierre van Baal of CERN summarized recent analytic work on the spectrum of a pure glue theory. In addition to being very beautiful, this work has been accurately verified by Monte Carlo methods, so increasing confidence in the numerical approach.

The physics of QCD at high temperatures and densities – interesting for heavy ion physics, astrophysics, and cosmology – has provided the first accurate, reliable simulation result – the transition temperature at which quarks are unlocked from their conventional



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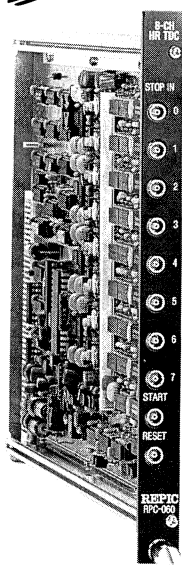
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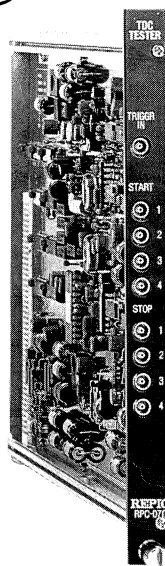
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A.A. Migdal – putting strings on the lattice.



nucleon imprisonment. Masataka Fukagita of Kyoto concluded that this calculation is still in good shape. The phase transition seems to be much weaker than originally thought, and there is some controversy as to its type (weak first order or second order). Preliminary calculations in full QCD hint that the transition temperature may be around 150 MeV (about 10^{12} degrees!). Frithjof Karsch of CERN claimed that the simple picture of the hot QCD plasma as an ideal gas of quarks and gluons interacting through small perturbations looks good so far, though much room remains for nonperturbative effects.

Input from lattice calculations provides a useful complement to new data, giving theorists additional room to manoeuvre. These difficult calculations were described by Claude Bernard of Santa Barbara. The kinematic behaviour of quark content (structure functions) and of particle form factors was one of the earliest successes of perturba-

tive QCD, but prediction of the quantities themselves requires lattice calculations, reviewed by Guido Martinelli of CERN. Chris Sachrajda of Southampton described the painstaking analytic work behind the lattice treatment of the standard model.

The powerful simulation methods of lattice theory are useful in other areas of physics. Jorge Hirsch of San Diego ('What should a lattice gauge theorist be doing in his/her spare time?') reviewed current theoretical ideas on high temperature superconductivity. Sasha Migdal of the Cybernetics Council in Moscow described progress towards a lattice formulation of bosonic string theory, complementing analytic work based on Polyakov's conformal field theory approach. The agreement between analytic and numerical calculations is as important in this field as for QCD.

The past year has been the most active ever for lattice gauge theory, but the vast increase in algorithmic and hardware computing power of the past seven years is not the end of the line. Approximation schemes show promising results, and full calculations will not be far behind. With unrestricted predictive power, a full exploration of the wide open physics territory both in and beyond the standard model will then begin in earnest.

From Paul Mackenzie

DESY Theory with flavour

Last year, the annual Theory Workshop at the German DESY Laboratory in Hamburg had 'Flavour Physics' as its main theme. The sighting by the UA1 experiment at

CERN's proton-antiproton collider and by the ARGUS team at DESY of 'oscillations' in the electrically neutral B mesons carrying the beauty quantum number, and the measurement at CERN of a new parameter in the delicate violation of combined particle-antiparticle and left-right symmetry (CP) in the decays of neutral kaons (July/August 1988, page 7) have made this subject particularly topical.

Setting the tone for the meeting, W. Schmidt-Parzefall (DESY) described the current evidence for neutral B mixing, looking also at the possibilities for a B meson 'factory' at DESY to search for additional signs of CP violation.

In the production, spectroscopy and decay of charm particles (R.J. Morrison – Santa Barbara), significant advances have been made by new high-statistics experiments. B. Stech (Heidelberg) showed how B and charm decay theory was in line with the data. Less conventionally, his explanation of isospin selection rules for weak kaon and hyperon decays based on 'diquarks' provoked some lively discussion.

Mass limits for the so-far unseen sixth ('top') and other heavy quarks (J. Kuehn, MPI Munich) turned the discussion towards an outlook for the future. Kuehn assessed the chances of finding the top up to 80 GeV at the CERN proton-antiproton collider and up to 100 GeV at the Fermilab Tevatron, going on to look at the implications of top physics for the new electron-positron colliders – LEP at CERN and SLC at Stanford.

A. Ali (DESY) examined the physics of heavy quarks at the HERA electron-proton collider being built at DESY and underlined the potential of HERA in the search for top and for a detailed study of B meson oscillations. Open questions