Eur. Phys. J. A **18**, 567–569 (2003)
DOI 10.1140/epja/i2002-10285-3

The European Physical Journal A

Summary talk

R.G. Milner[a]

MIT-Bates Linear Accelerator Center, 21 Manning Avenue, Middleton, MA, 01949 USA

Received: 30 September 2002 /
Published online: 22 October 2003 –

Abstract. An overview of some of major physics themes covered at this conference is presented.

PACS. 12.38.-t Quantum chromodynamics – 12.39.-x Phenomenological quark models – 11.15.-q Gauge field theories – 24.85.+p Quarks, gluons, and QCD in nuclei and nuclear processes – 12.38.Mh Quark-gluon plasma – 25.20.-x Photonuclear reactions – 25.30.-c Lepton-induced reactions – 21.80.+a Hypernuclei – 25.40.-h Nucleon-induced reactions – 25.75.-q Relativistic heavy-ion collisions

1 Introduction

It is a pleasure to be asked to summarize what has been an outstanding Quark Nuclear Physics 2002 meeting here at Jülich. The focus of this meeting is the study of strongly interacting matter in terms of the fundamental constituents of Quantum Chromodynamics (QCD). Approximately 99.9% of the mass of the physical world around us is due to atomic nuclei. Approximately 98% of this mass is due to QCD. Thus, Quark Nuclear Physics is the study of the fundamental structure of matter and remains one of the core problems in Physics at the dawn of the 21st century.

The Jülich conference has continued the excellent series of QNP international meetings and has demonstrated the vigorous intellectual vitality and tremendous excitement in this field of physics. This past week we have heard of significant new advances in theoretical understanding of this complex, non-linear problem. We have also seen impressive new data in all experimental areas of investigation. Further, we have glimpsed into the future with presentations on exciting new initiatives underway worldwide. Here I will present a selection of QNP2002 highlights from the conference plenary sessions. My summary is influenced by available time and personal taste.

2 Theoretical highlights

The ability to carry out *ab initio* calculations in QCD is a much prized goal among physicists working in strong-interaction physics. This would allow definitive tests of QCD —an essential requirement to establish whether this is the corrrect theory of the strong interaction. Calculations using the world's most powerful computers and a discretization of space-time, lattice calculations, are the present technique which come closest to exact calculations.

A. Thomas presented a summary of recent developments in the field of lattice QCD. A major area of current activity is the use of extrapolations to low quark mass based on chiral-symmetry arguments. For a number of observables these new extrapolations provide a determination of the observable which is much closer to the experimental value. For example, lattice calculation of the moments of parton distributions provide determination of the Bjorken-x dependence which is in good agreement with experiment. This success demonstrates that chiral-symmetry considerations play a fundamental role in understanding hadron structure. Further, it demonstrates that present lattice QCD calculations, while still being far from exact, can provide important insight into hadron structure.

B. Holstein provided an overview of effective field theory (EFT), which provides a theoretical framework consistent with QCD for processes below the chiral-symmetry-breaking scale, a scale comparable with the nucleon mass. EFT organizes quantum field theories according to hierarchies of physical scale. The Standard Model of electroweak interactions is a beautuful example of an EFT, which describes observables at energies below the scale of electroweak symmetry breaking. To describe hadronic interactions, a dual expansion in the up- and down-quark masses, m_u and m_d, and in the momentum of external probes is required. This framework, known as chiral perturbation theory (χPT), provides a cornerstone in our understanding of QCD and is the only rigorous way in which to encode the entire body of QCD predictions at low energy. χPT has developed a very successful calculational scheme for pseudoscalar meson interactions. At present, a major focus is to extend this scheme to the baryonic realm and to multinucleon systems. A consistent and convergent power

[a] e-mail: milner@MITLNS.mit.edu

counting remains to be established for systems of pions and nucleons below the chiral-symmetry-breaking scale.

D. Riska presented a derivation of the major aspects of the phenomenological nucleon-nucleon interaction in terms of the $1/N_c$ expansion, in the large-N_c limit.The numerically significant components of a number of different modern realistic phenomenological interaction models are shown to admit very similar meson exchange interpretations in the large-N_c limit. The conclusion is that the ordering of nuclear inteactions and interaction current operators by their dependence on $1/N_c$ corresponds well with their significance ordering based on empirical evidence and phenomenological analysis.

A. Mueller described the current understanding of low-x parton distributions and diffractive processes in terms of some phenomenological models. Unitarity tells us that the rising gluon distribution at low-x must saturate. HERA data do not provide definitive evidence for saturation. Using nuclear targets, it should be possible to probe substantially lower-x values, because the Lorentz contraction boosts the gluon density by $A^{\frac{1}{3}}$. Such a search for saturation could be carried out at an electron-nuclear collider.

3 Cold QCD: hadronic physics

QNP2002 contained a number of excellent review talks which spanned the essential aspects of the worldwide program to understand and study the structure and properties of hadrons. I divide my summary into separate highlights from studies which use electromagnetic and hadronic probes, respectively.

3.1 Electromagnetic probe

K. Kumar presented a comprehensive review of the worldwide program in the study of hadron structure using parity-violating electron scattering. By measuring the interference between Z^0 and single-photon exchange, experiments can determine the strange-quark contribution to the charge and magnetism of the nucleon, the neutron matter distribution in ^{208}Pb and can test the Standard Model with a precise measurement of $\sin^2\theta_W$. Experiments are in progress at MIT-Bates, Mainz, Jefferson Laboratory and SLAC and the demonstrated experimental capabilities are truly impressive.

C. Papanicolas presented the latest information on a determination of the shape of the proton. This shape has been called the most fundamental in our universe as QCD tells us that the proton is constructed completely from the binding of pointlike constituents. By studying deformation in the transition of the proton to its first excited state, the $\Delta(1232)$, it is concluded (within model uncertainties) that the proton is cigar-shaped at the level of a few percent.

R. Schumacher presented new data from the CLAS detector at Jefferson Lab. Measurement of photoproduction of strangeness from the nucleon substantially extends in kinematic range and precision the data from previous experiments. Further, CLAS data show hints of strength at locations where missing resonances are sought. However, no definite conclusions are yet available. M. Garçon presented new data from CLAS on deeply virtual Compton scattering (DVCS) which can open up an entirely new vista into hadronic physics using generalized parton distributions (GPSDs).

G. van der Steenhoven presented the latest results from the HERMES experiment at DESY. These included the latest polarized quark distribution results. The u-quark polarization is measured to be positive; the d-quark polarization is found to be negative; and the sea polarization is consistent with zero. HERMES has also measured deeply virtual Compton scattering for the first time and the results are consistent with theoretical expectation. CLAS and HERMES should produce new data on GPDs over the next several years. In addition, the HERMES determination of parton energy loss in nuclei is used to constrain a successful theoretical caluclation which describes measured high-p_T meson production by PHENIX at RHIC.

3.2 Hadronic probe

T. Nagae presented an overview of some recent exciting work in hypernuclear physics. A bubble chamber sighting of a very rare $^{6}_{\Lambda\Lambda}$He was shown and the binding energy $\Delta B_{\Lambda\Lambda}$=1.01±0.20$^{+0.18}_{-0.11}$ determined. In addition, the Hyperball was cleverly used to study the spectroscopy of $^{7}_{\Lambda}$Li. The structure of ^{6}Li can be approximated by an α-particle orbited by a loosely bound proton and neutron. The addition of a Λ-particle to this system causes the $^{7}_{\Lambda}$Li to be significantly smaller in size than the ^{6}Li. Consequently, the spectroscopy of $^{7}_{\Lambda}$Li can be well described by a calculation using the ΛN interaction.

J.-C. Peng discussed the present understanding of the flavor structure of the quark sea of the nucleon. Drell-Yan data show that $\overline{d}>\overline{u}$, which can be understood in terms of a model based on the meson cloud picture of the nucleon. Upcoming experiments planned for RHIC using polarized protons should provide accurate determination of any flavor asymmetry in the polarized sea.

H. Ströher gave an overview of status and plans at the local COSY facility in Jülich. A central focus of the program is the study of strangeness production above 2 GeV/c using polarized beams and targets. First results include the ratio of Λ to Σ production as a function of incident proton energy and Λ polarization measurements. This promises to be a productive area of research in an almost virgin territory before COSY.

4 Hot QCD: the search for the quark gluon plasma

B. Jacak gave a comprehensive overview of one of the most important new areas of research, namely the search for the quark gluon plasma using the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National

Laboratory. This machine has turned on and the four detectors have acquired and analyzed initial data in a most impressive fashion. The energy density at RHIC has been determined to be greater than 4.6 GeV/fm^3, which exceeds the calculated value of 3 GeV/fm^3 at which the phase transition occurs. The freeze-out temperature at RHIC has been determined to be about 175 MeV which is close to the phase transition temperature predicted by lattice QCD. Significant elliptic flow is observed for central collisions which supports the conclusion of early equilibrium and pressure buildup. Significant quenching of jets is observed in central collisions. While the general parameters observed at RHIC are consistent with formation of a quark gluon plasma, it is too early for a definitive conclusion. It is clear that RHIC data will be of great interest in the next several years as a detailed understanding of what is happening in these tremendously violent and energetic collisions becomes possible.

5 Summary

In closing, I would like to thank Prof. Speth for his leadership in the successful organization of QNP2002. I would like to acknowledge the hospitality of his Jülich colleagues for the very pleasant nature of the meeting, particularly the excellent banquet and social activities. Jülich has set a high standard for the next meeting of QNP in 2004 at Bloomington, Indiana, USA.