Appendix G

Summary of the PAC17 Workshop on the Physics of Strange Quarks at JLab (Duck, NC, January 29, 2000)

Introduction

This was the fourth workshop to provide an opportunity for the Program Advisory Committee to focus on one of the five broad scientific areas that comprise the Jefferson Lab physics program. The goals of these workshops are to review the approved program in the context of recent developments, to identify the key scientific questions in the area of concentration and to suggest opportunities for future experimental work.

Mike Ramsey-Musolf presented an overview of the theoretical status and prospects for parity violating electron scattering experiments. This experimental technique offers a unique flavor decomposition of the nucleon elastic form factors and can isolate the contributions of strange quarks. Such experiments also can search for physics beyond the standard model. Doug Beck reviewed the framework of neutral weak currents and the experimental situation worldwide, including the SAMPLE experiment at M.I.T. Bates, the PVA4 experiment at Mainz, and the HAPPEX results from JLab. The preliminary SAMPLE results on deuterium may indicate a significant nucleon anapole moment and suggest that the nucleon structure implications are even richer than previously thought. Overviews of all the approved experimental programs in the physics of strange quarks category were then presented by the three Hall leaders. In a round-table discussion, each PAC member summarized the areas of interest and possible experiments for the laboratory.

Scientific Areas and Experiments

Historically this subprogram of JLAB physics includes measurements of strange contributions of nucleon form factors, strange meson and baryon electroproduction experiments and hypernuclear measurements. The latter measurements were included in the physics of nuclei discussions at the PAC16 workshop and so were not discussed in detail here.

The heart of the strange quark program is firmly rooted in our goal to understand the structure of hadrons in quantum chromodynamics. In particular, strangeness gives us a special window on the nature of the sea of quark-antiquark pairs in the nucleon. While many of the same scientific questions apply to the light up and down quarks and antiquarks, these quarks are also involved in the special role of the pion as a Goldstone boson of chiral symmetry in the theory. Studies of strange quarks in, for example, the proton look directly at the sea of the nucleon. Thus the physics of the strange quarks in the strange form factors of the proton is closely linked to other properties which have small valence contributions such as the electric form factor of the neutron.

Quark flavor only enters into QCD in quark mass terms. With heavier quark flavors, the heavy quark symmetry of QCD provides a valuable expansion to examine the physics. As the energy of Jefferson Lab is upgraded to charm threshold, this will be exploited much more extensively, but the strange quarks are in an interesting transition region where quark mass effects and other dynamics are on comparable footing.

The weak interaction as employed in parity violating electron scattering offers a precise tool to separate the flavor contributions of nucleon form factors and isolate the strange quark matrix elements. The progress of the laboratory and the experimenters in these measurements is outstanding. The exquisite quality of the polarized beam at JLab is the best in the world for these kinds of measurements. An extensive program of parity violating elastic electron scattering from the proton in HAPPEX and G^0 will provide separated electric and magnetic strange quark matrix elements over a broad range of Q^2. A simplification is provided by ^{4}He with only one form factor and the opportunity exists either to examine changes of the strangeness content in nuclei or to focus specifically on the strangeness radius. Future G^0 measurements on the deuteron will determine the axial contribution to the proton measurements.

More precise measurements of the nucleon electromagnetic form factors are necessary to garner the maximum information from the parity violating measurements. Programs to improve the electromagnetic form factors measurements to the required precision are part of the JLab experimental program and must be carried out effectively in a timely manner. At the same time, theoretical progress is essential for interpreting the new results. Lattice QCD offers considerable promise in the long run to place these measurements in a firm theoretical context and we believe that the new collaborative initiative of the JLab theory group in this area could have a real impact.

It is the opinion of the PAC that the program described above will provide us with a comprehensive look at the strange quark effects in nucleon form factors. We believe now is the time to run these experiments efficiently and then it is appropriate to digest the experimental results before undertaking significant further effort along these lines. However we do believe that parity violation in deep inelastic scattering could become a valuable new tool for flavor decomposition. With the 12-GeV upgrade this should be even more important to the JLab program.

While not directly involving strange quarks, the flavor decomposition made possible with parity violating electron scattering also permits measurements of neutron distributions in heavy nuclei, and possibly even the charge distribution of the neutron itself. The PAC conditionally approved one such experiment at this meeting and looks forward to new ideas for this type of measurement.

While the strange form factors directly measure the contributions of the current quarks, looking directly at hadronic production channels may give us special insight into the low energy degrees of freedom of QCD that dominate the strange quark physics and identify the essential physics elements that model builders need to interpret the strange quark distributions. If the strange form factors prove to be small, it may be due to delicate cancelations rather than an inert strange sea. For example in the isocalar charge distribution of the nucleon, the s-sbar contribution of the ϕ meson plays an important role in the spectral function decomposition. We have received interesting proposals to use ϕ production to examine the strange quark content of the proton. In our opinion the reaction mechanisms are not well enough understood for a definitive measurement at this time, but the CLAS will provide much valuable data on the reaction mechanism. If this proves to be under control, such experiments will become more attractive. Similarly, kaon electroproduction experiments may under carefully controlled circumstances provide new insight. Complementary data at the hadronic and quark level could provide a compelling case that we have gotten the essential physics right.

There is certainly much still to learn about the reaction mechanism in other strangeness production reactions. However, the PAC is not enthusiastic about new proposals where these studies are the primary focus. We expect much will be learned in the approved CLAS program.

While in the nucleon, the strange quarks isolate sea effects; in hyperons, the strange quarks contribute to the valence distributions. Again considerable insight can be obtained in replacing a light quark with a strange quark, but now at the constituent quark level. Indeed it was the SU(3) symmetry of the hadron states which led to the constituent quark model. The physics is well addressed by the CLAS baryon resonance program and will be discussed at a later workshop. We would certainly like to see measurements of the electromagnetic properties of hyperons, such as the electric form factor of the Λ, but such measurements are difficult and we are not convinced a decisive experiment is possible.

Several other physics ideas surfaced in the strange quark program. At the PAC16 physics of nuclei workshop, the importance of addressing possible medium modifications of hadron masses in nuclei with electromagnetic probes was highlighted. Di-lepton decay modes of vector mesons were identified as the most promising avenue. The relative effect on the ω and ϕ channels will be a revealing measurement. Heavy ion experiments have been interpreted to indicate a significant change in kaon masses in the medium. A definitive experiment with electromagnetic probes in the entrance channel would be welcomed.

Stan Brodsky has pointed out that the energy dependence of polarization observables in p-p scattering seems to change dramatically as the strangeness and charm production thresholds are crossed. He suggests that there may be very interesting meson-nucleon dynamical effects near these thresholds with a mixture of hard and soft scales at work. Several ideas for charm physics at threshold are being discussed for the 12-GeV upgrade. Pursuing this now at the strangeness threshold may address the same physics.

Finally a precision measurement of the weak charge of the proton offers a precise test of physics beyond the standard model at mass scales beyond the reach of present colliders. We heard about ideas to perform such a measurement using the G^0 spectrometer. Such an experiment in the leptonic sector in Moeller scattering is underway at SLAC, but the hints of such effects in atomic parity violation and Fermi beta decays are only seen in semi-leptonic experiments. A sufficiently precise experiment would be of great interest to the particle and nuclear communities.