WORKSHOP SUMMARY

Franz Gross

Continuous Electron Beam Accelerator Facility
12070 Jefferson Avenue
Newport News, Virginia 23606

I have been asked by the conference organizers to close this workshop with a few remarks. I am very pleased to do this for this has been an excellent workshop; I have enjoyed it very much. I won't attempt to give a comprehensive summary; this is always an impossible thing to do and would be even more difficult in this situation since I did not know until yesterday morning that I was to make these remarks! What I have decided to do is to mention some of the things which I will remember from this conference, and to make a few personal remarks about my own view of the state in which nuclear physics finds itself today.

In my opinion, nuclear physics is entering one of its most challenging and exciting eras. On the one hand, a number of beautiful experiments have recently been performed which measure important physical quantities. On the other hand, the contrast between the new generation of precise calculations based on meson theory, and the new ideas about nuclear structure which are stimulated by quarks and QCD makes modern nuclear theory a very exciting undertaking.

A number of beautiful new experimental results have been reported at this workshop. Some which struck me particularly are:

- ^{3}H (and ^{3}He) form factors recently measured at Saclay - reported by Cavedon. These measurements of the fundamental 3-body system have long been awaited. I also look forward to new measurements from Bates expected this fall.

- High resolution measurements of shell structure at NIKHEF - presented by DeWitt-Huberts. These new measurements, together with measurements previously done at Bates, are giving more precise knowledge about the structure of complex nuclei than ever before obtained.

- Separation of transverse and longitudinal structure functions at Saclay - presented by Morgenstern. The decomposition of the scattering from individual shells into longitudinal and transverse parts should give us important new insights.

- Deuteron photo-disintegration at Frascati - presented by Ricco. New precise measurements of this classic reaction will be important for our understanding of photo-disintegration.

- Coincidence measurements planned at Mainz - discussed by Schoch. While these experiments have not yet been completed, the program planned at Mainz promises to be very exciting.

In this context I also want to mention a number of calculations of electromagnetic structure functions reported by Krewald, Orlandini, Pacati, Salmé, and Saruis. While these are not experimental measurements, I mention them in connection with the experimental program because I believe it is very important that theorists work hard to give us a good idea, in advance, of what the new structure functions to be measured by the next generation of accelerators will look like. We need this knowledge in order to plan the next generation of facilities wisely. It is particularly important to estimate the size of the five structure functions which occur in the (e, e'N) reaction, especially the famous fifth structure function which can only be measured out of plane with polarized electrons.

Next I want to mention some of the precise calculations, based on meson theory, which I find very impressive. In particular, I recall:

- Calculations of the 3-body system carried out by Sauer and his group. Not only have precise numerical solutions of the Faddeev equation been obtained, but the effect of Δ's and 3-body forces have been carefully studied.

- Fits to the nucleon-nucleon force and study of the binding energy and density of nuclear matter reported by Machleidt. These latest Bonn calculations are very impressive; in the context of meson theory, they include practically everything, and Machleidt's recent results for nuclear matter, including relativistic effects, are very impressive.

- Systematic studies of electromagnetic processes carried out by Laget. Laget's calculations give us a good idea of the important physical processes which contribute to a wide range of electromagnetic interactions.

- Recent results from the Δ-hole model reported by Koch. The Δ-hole model has achieved considerable success explaining photo-pion and pion-scattering processes.

In contrast to these precise calculations are the new ideas based on the quark model and QCD. Some of the new ideas are:

- Use of 6-quark states to describe the NN system for inter-nucleon separations less than one Fermi - described by Kisslinger. A variety of phenomena are well described by this new approach.

- Skyrmions and the "mesonization" of baryons - described by Vento. The idea that baryons can be constructed completely from mesons seems like a strange idea, but might very well play a role in our final understanding of matter.

- The quark shell model - described by Petry. This bold attempt to describe nuclei directly from quarks is very interesting.

- Static quarks on a lattice - described by Faber. This simplification of lattice QCD makes complicated systems calculable.

- Treatment of the quark pair term - by Giannini. The relationship between the quark pair-term and the nucleon pair-term remains a question of great interest, in view of the size of nucleon-pair contributions.

- Hedgehogs and bags - discussed by Fiolhais. New results which give insight into bag models and hedgehog solutions are always of interest.

- Many-body techniques applied to QCD - described by Schütte. Calculations of the gluball spectrum are of fundamental importance, and I await Schütte's further results with interest.

There has been considerable discussion at this workshop about these two different approaches to nuclear theory, meson theory on the one hand, and quarks and QCD on the other. Are these two approaches really in conflict with one another, as many physicists seem to believe and as is suggested in Fig. 1?

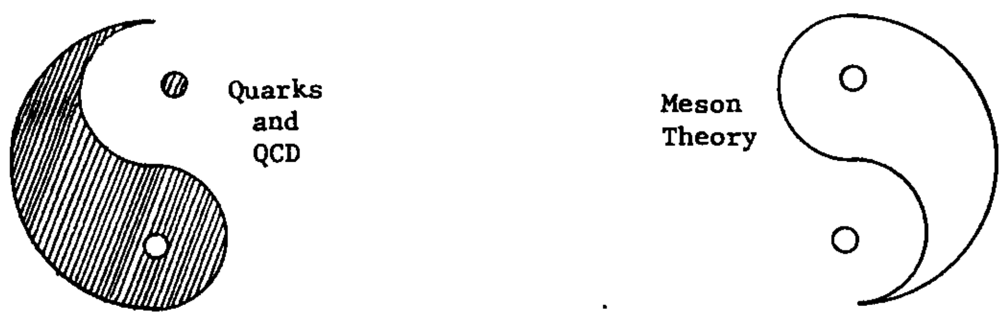

Fig. 1

Or, is there some sort of duality in which both approaches can exist simultaneously as suggested by Fig. 2? If we try to combine these approaches, as suggested by Fig. 2, it is possible that one could devour the other: it could be true that quarks and QCD will provide the only explanation of nuclear physics; nothing remaining of meson theory. However, this seems unlikely because we know that the pion is very difficult to describe using quark models, and that the one-pion exchange force has a relatively long range. It seems

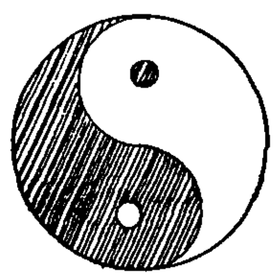

Fig. 2

likely that at least the one-pion exchange force will survive the unification and remain a component in the fundamental description of nuclear matter. Alternatively, it could turn out that it is a good approximation to regard baryons as made up entirely of mesons, or that quarks are confined in a truly tiny volume, so that meson exchange remains a basic description even down to very short distances. However, recent successes with quark model descriptions of the short range nucleon-nucleon interaction suggest that the repulsive core may well be described by the explicit treatment of 6-quark states, putting the role of the ω as a fundamental mediator of nuclear forces in question.

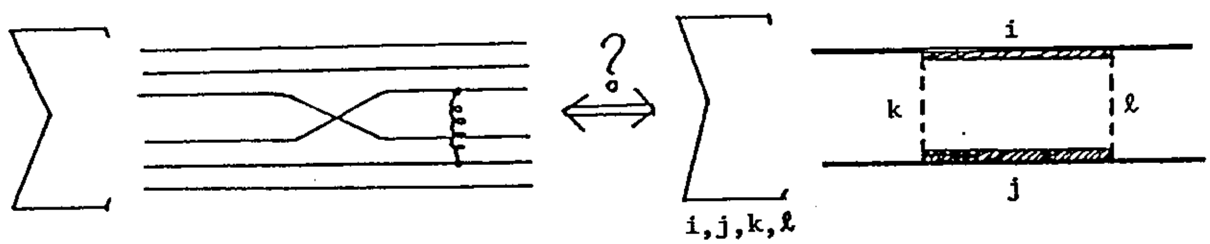

Fig. 3

Perhaps, as the symbol in Fig. 2 suggests, there may be a duality between QCD and meson theory, as suggested in Fig. 3. This figure is meant to suggest that a sum over a sufficiently large number of 6-quark states with gluon interactions may be equivalent to a sum over a large number of two-baryon channels, in which the basis of baryons is expanded to include a number of excited states, and the mesons exchanged between them may be large in number. If such a duality does exist, over what region of configuration space does this duality hold? What excited states of mesons and baryons must be included in the meson theory which effectively describes the important degrees of freedom in the nucleon-nucleon interaction? I leave the answers to these questions for the next workshop!

The success of a conference or workshop is measured not only by the quality of its formal program, but also by the quality of the informal interactions and discussions which take place. I enjoyed the informal interactions during this workshop very much; I will always remember stimulating discussions over excellent Italian coffee, convenient lunches at the Center, and superb Italian dinners. And the setting of this workshop was very beautiful. We were fortunate with the weather; although it rained a little, several of the days were beautiful. In closing, I want to thank the International Center for Theoretical Physics for hosting this conference and I want to thank the conference organizers, Professors Boffi, Ciofi degli Atti, and Giannini for an excellent workshop. I look forward very much to the next conference!