

CONCLUDING REMARKS*

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It is my honorable and dangerous task to try to identify among the many exciting ideas I have learned at this Conference a few which could point the way in which our field might go. What struck me forcefully was that once again nuclear and particle physics are finding a common ground. I believe that significant progress will come from strengthening this intimate relationship. In the area of nuclear and pionic phenomena I found again and again that both experiment and theory have been forced to the point where existing phenomenological methods of verification are inadequate. I will illustrate this shortly by several instances where only by including the pionic degrees of freedom in the systems which many of us are accustomed to think only contain nucleons can we hope to avoid triviality and frustration in our endeavors. At the same time we have learned many experimental and theoretical techniques which when joined might help us to meet this challenge. Thus we might be on the verge of an explosive development of new physics if we have the courage to seize the time.

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It has not been easy to reach this point. Much phenomenological work had to be done over the years when nuclear and particle physics appeared to be drifting apart. Experimental techniques such as polarization and complete kinematic experiments had to mature accompanied by sophisticated analyses and advanced computer programs. It is also clear that one catalyzing agent that has brought us together is the meson factories which soon will be flooding us with data.

This raises a question which, if I correctly interpret the duty held up to us by the Secretary General of the International Union of Pure and Applied Physics, I cannot ignore. As one organ of the conscience of the scientific community for our field, we must look beyond surface phenomena and our immediate interests to the various reasons why our work is supported. For instance, in describing some of the new laboratories, medical research facilities were mentioned. Significant by its omission is the fact that at least one of these accelerator installations envisages as well a weapons neutron test facility. I do not wish my words to be misinterpreted. This is just a dramatic instance of a fact known to practically all of us. Circumstances differ from individual to individual and country to country but all of us, myself included, draw support from our societies for reasons other than subjects which have been discussed at this conference. In particular we all represent a privileged class whose training separates us from the people and whose support disappears if we move too directly to aid the people against the interests of our ruling national elites. Some of us believe that we should welcome this fact, others accept it as an unpleasant necessity, and still others abhor it. But too many simply ignore it. This can only make trouble for us in the future as it has in the past, unless we face this issue openly in meetings such as this to discuss how it affects our work. In raising this issue I

follow a precedent set by the banquet speaker at UCLA in 1972.

Having followed a much older tradition by drawing back the curtain so that the skeleton who shares our feast can join us, I turn to the exciting scientific challenges which lie before us. I trust I have not spoiled your appetite for them.

One unfortunate phrase which I have heard used at this conference is "theorems of ignorance". In each instance where that phrase has been used, so far as I can see, all this means is that older phenomenological methods cannot resolve critical physical problems. But in each instance we also have in hand or can readily develop methods to turn this situation into a new and challenging opportunity. For example, the fact that many three body experiments are insensitive in some kinematic regions to pionic degrees of freedom, which some people call off-shell effects, has the immediate corollary that experiments in these regions can be used to measure two nucleon phase shifts which are still inaccessible to direct attack using conventional two nucleon experiments. Conversely, we have also seen that when the phase shifts are fixed there are other regions that are sensitive to the pionic degrees of freedom. This information will be difficult to extract but precious when obtained. The combined theoretical and experimental attack can clearly take us here into a new and exciting region. I wish to stress particularly that coulomb corrections can now be included so that p-d data can be analyzed unambiguously. It is time to start the code development - or in fact past time I would say - needed for this.

Of course some of us have believed for two years or more that the 1-2 MeV by which the so-called "realistic" potentials fail to bind the triton, and the structure observed at high momentum transfer in the electric form factor of He^3 , can only be understood by including mesons explicitly. Work presented at this conference should convince most of the rest that no physically acceptable

modification of physically acceptable two nucleon interactions could resolve these discrepancies. We have long known that this must be true of magnetic effects in the two and three nucleon systems. If we can incorporate mesons directly into our picture of nuclei, we might be able to meet both problems simultaneously. This could also lead to a breakthrough in the old problem of how to connect the quadrupole moment, S-D asymptotic ratio, percentage D state, and magnetic moment of the deuteron so intimately that we can account for the many different phenomena which depend on these quantities.

This will not be easy. We have heard that the effective pion-nucleon scattering length changes in nuclear matter and the same will obviously be true of the charge and current distributions in the vicinity of the nucleon. This might explain the discrepancy between predicted coulomb energies of nuclei and experiment which increases systematically with A. We have also heard that pion capture leads to emerging clusters which seem to contain pions as well as nucleons. Two-nucleon interactions seem incapable of explaining simultaneously the density and binding energy of nuclear matter, though inclusion of the dominant π - π resonance seems to move the prediction in the right direction. The key to a successful attack on all these problems is obviously the same.

At a deeper level we have learned that it is now possible to use the whole range of two nucleon phase shifts to extrapolate to the coupling constants of the π -nucleon-nucleon system including coulombic effects. The same is true of the charged and neutral pion-nucleon coupling constants. It is to be emphasized that the constants so obtained have a unique theoretical and experimental significance, in contrast to the model-dependent scattering lengths which have so long been a source of frustration. Splittings among these constants will describe the breaking of the isospin symmetry in an unambiguous way and present elementary

particle theorists with a quantitative challenge they cannot ignore. Here again two-nucleon parameters from p-d and n-d experiments will play a critical role in achieving the required precision.

On the experimental side these precise extrapolation techniques provide a new and powerful way of parametrizing nucleon-nucleon phase shifts in the physical region. They can thus be used to point out those systematic discrepancies which undoubtedly still exist, but which still are hidden, in data from different laboratories. They can also help resolve questions at low energy about vacuum polarization and the 3P waves in pp scattering. In particular they will be critical in isolating the $1/r^3$ interaction between the magnetic moments of the two protons from nuclear effects - a phenomenon which now appears to be capable of experimental test below 10 MeV.

At a still deeper level we are told that the parity violation evidenced by the circular polarized gamma-rays from n-p capture might serve as a probe of the nucleon distribution at short distances in the two nucleon system. The experiment needs repeating, and much work will have to be done before the theory is sufficiently well understood for unambiguous conclusions to be drawn, but the challenge has a rich reward if it can be met.

Until we can go below the hadrons to the quarks, or whatever underlies the hadronic physics we have been discussing, we are still dealing with phenomenology. We have heard at this conference that very energetic electrons and neutrinos "see" these massless quarks in much the same way that alpha particles enabled Rutherford to "see" the massive nucleus. On the other hand, when two systems of quarks collide at ultra-high energies we are told that only some of them appear to be "active" in the collision. Here we might offer a suggestion coming from our own experience to our high energy brethren. Wick pointed out

long ago that when two nuclear particles come close enough together for the active fluctuation to materialize what we now call the pion, they scatter independent of any specific interaction mechanism. If this is all that is available to quarks in the collisions between two quark systems, their "activity" might be explained by the creation of the clusters with which we are already familiar. This idea might unify our fields in still another way.

I conclude that, for those with courage to abandon old thought and a determination to carry through the difficult integrated theoretical and experimental programs successful attack on these problems will require, this conference has helped to open up a host of exciting new directions for research in the few body problems in nuclear and particle physics.