

the HERA electron-proton Collider now under construction at the German DESY Laboratory in Hamburg will attain energies far beyond those currently used to probe nuclei with lepton beams.

Thus the Topical Conference on the Quark Structure of Matter held in Strasbourg and Karlsruhe from 26 September to 1 October was especially interesting. The first meeting to be jointly organized by the Société Française de Physique

(SFP) and the Deutsche Physikalische Gesellschaft (DPG) and bringing together 160 participants, it emphasized the interfaces between particle physics, medium energy physics and nuclear physics. These are being strengthened because of the growing interest in the quark structure of matter, and it was interesting to see that the researchers from different fields were not in any way isolated.

Host institutions were the Parlia-

mentary Assembly of the Council of Europe and the local Centre de Recherches Nucléaires in Strasbourg and the University in Karlsruhe. Co-chairmen of the Organizing Committee were H. Meyer from Wuppertal, president of the particle physics division of the DPG, and Maurice Jacob from CERN, currently president of the SFP.

By Maurice Jacob

Nuclear truth

There is no single 'true' picture of the nucleus. Instead, there are many alternative pictures, all equally 'true' within their own regions of validity. A relative newcomer on the scene, but no less 'true' than the others, is the description in terms of the quarks and gluons which are the constituents of the nucleons and other particles inside nuclei. Summing up at the Conference on Nuclear Physics with Electromagnetic Probes, held in Paris earlier this year, Torleif Ericson of CERN showed just how many facets there are to the nuclear 'truth'.



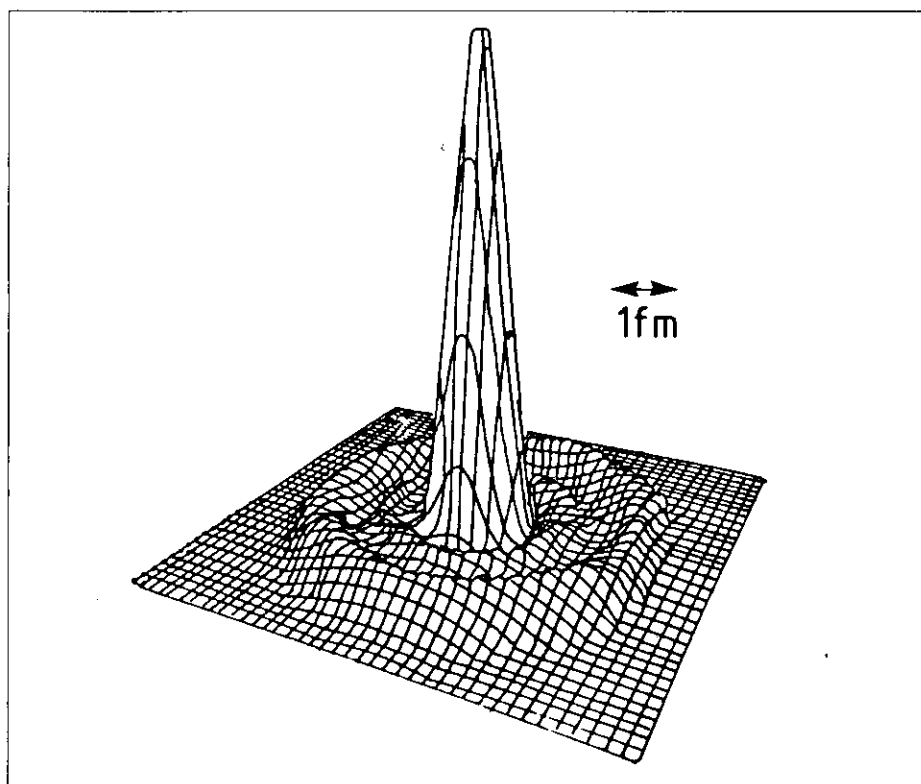
Torleif Ericson – the many truths of nuclear physics

What is the 'correct' way to view the nucleus? Should we view it as a system of interacting nucleons or as a system of interacting quasi-particles? Is it more valid to discuss it in terms of particle degrees of freedom? Is it not more 'fundamental' to assume that the nucleus is a system of quarks? What is right? What is the 'truth'?

In many areas of physics, there are alternative pictures, corresponding to a whole spectrum of viewpoints which depend on the framework and the scale. It all depends on how one looks at the problems and on what is emphasized. Nuclear physics is especially well-endowed with alternative descriptions.

Nearly classical modes of collective nuclear excitations have been investigated for a long time, but even in this well explored field there are still new features. A prediction made a few years ago that in a deformed nucleus protons

Electron scattering experiments give this striking distribution for a single nucleon in a high density nuclear region.



and neutrons could beat against each other in a scissor-like mode corresponding to a magnetic dipole excitation has now been seen. At this level, nuclei appear like chunks of proton-neutron matter.

However electron scattering experiments have in recent years clearly demonstrated how individual nucleons contribute to nuclear structure (see March 1984 issue, page 64). Thus it is also true that nuclei consist of nucleons even in their densest regions, enabling many features to be explained in terms of two-nucleon interactions caused by the exchange of single bosons.

More than eighty years after its discovery by Rutherford, the humble alpha particle is still an invaluable source of nuclear information. Conventionally thought of as the most spherical and symmetrical of

all nuclei, the alpha has now been found instead to be a deformed nucleus!

Other discoveries show the limitations of explanations in terms of two nucleon interaction, demanding three-body forces, while further clues show clearly that a picture of nuclei as inert nucleons has definite limitations.

For a long time it was tacitly assumed that the nucleus is a system of non-relativistic nucleons. However in the past few years there has been increasing speculation that the component nucleons are instead relativistic (see June issue, page 183), and now one clear case of relativity has been seen in low energy nuclear physics (photodisintegration of the deuteron).

Another well established nuclear physics picture involves explaining everything in terms of the physics

of pions, nucleons and nucleon isobar (delta) resonances. Accumulated evidence shows that the nucleon resonance is a 'true' nuclear component. There is in addition clear-cut evidence for meson exchange currents.

These various ways of looking at nuclear physics in terms of nucleons and resonances interacting via mesons are quite successful and are underlined by many experiments without any recourse to the quarks and gluons which are the constituents of nucleons, pions, etc. Particle physics shows that field theory with quarks and gluons works very well: for nucleons it has even been possible to map the distribution of the different quarks. The central question is: how do quarks and gluons manifest themselves and what criteria for acceptable evidence should we use? What are the 'smoking gun' experiments for nuclear quarks?

We must obviously aim for 'clean' situations where alternative explanations are unlikely or, better, suppressed. Unless other explanations can be ruled out, we do not want to have 10 per cent effects as evidence. Sir Denys Wilkinson has defined the problem in the following terms: 'We must not be tempted into mistaking a demonstration of consistency between nuclear behaviour and expectation based on an explicit involvement of quarks for a proof of that involvement. We gain nothing unless those descriptions bring us an enhanced understanding of nuclear structure and transitions.'

The now-famous EMC Effect (variation of nucleon quark structure with the surrounding nuclear environment) provides the most specific example of a quark effect

in nuclei. In a quark description of deep inelastic muon scattering, the quark distribution for a nucleon inside a nucleus differs from that for a free nucleon. Is this changed distribution produced by quark-anti-quark pairs showing up as pions, or by the nucleon binding, or is it a genuine new effect on the quark level linked to incipient quark deconfinement from the nucleons as the quark 'bag' gets bigger?

It is important to restrict such possibilities by exploiting all the new information we can find. Two novel points came up during this conference: first A. W. Thomas of Adelaide drew attention to the importance of nucleon binding in the EMC Effect and advocated that this be further explored. Second, there was a considerable discussion on the experimental restrictions on nucleon swelling inside nuclei.

New data from wide angle electron scattering on aluminium 27 suggests that the nucleon swells by less than about five per cent, since the assumption of a normal nucleon size works very well. However the detailed analysis was questioned so any firm conclusion is premature; we eagerly await the final analysis. Electron scattering specialists consider five per cent swelling a generous upper limit, but this strong restriction comes from light elements.

Finally, magnetic moments in nuclei scale with the quark bag radius and are therefore sensitive to nucleon swelling in nuclei. While the detailed relation is less transparent, specialists insist that modifications of magnetic moments on the 5-10 per cent level will cause havoc. All of these point to a small nucleon swelling, while the EMC Effect explanation needs about 15 per cent or even more. The situa-

tion is further confused by the analysis of quasielastic electron scattering on carbon 12. At low energy release there seems to be evidence for an increased nucleon size.

Although there is no answer to the question of nucleon swelling at present, the issue is now approached in a variety of ways, independent of the EMC Effect. In the future we expect therefore reliable limits from different approaches restricting the theoretical explanations of the EMC Effect.

The issue of how to find evidence for quarks in nuclei was examined by an expert panel, but with inconclusive results. The big Stanford linac now probes the deuteron down to distances of about 0.2 fm, a factor two better than before. At this level, the experiment clearly is sensitive to detailed features well on the level of the structure in any quark description. Most likely, the deuteron electrodisintegration and the three-nucleon form factor at this level are even better systems to study such effects, and we can now expect them.

Second, the system of hypernuclei and nuclear physics with strange particles should provide a happy hunting ground. Since lambda and sigma hypernuclei can be regarded as nuclear systems with controlled and tagged impurities, they are a rich source of physics. In particular, the strange quark can be directly 'observed'.

A third approach to quark physics uses relativistic heavy ions. The idea is to squeeze so much energy density into an interaction volume that a phase transition to a quark-gluon plasma develops. There are good theoretical reasons to believe that such an effect

should occur, although the accompanying background might obscure the otherwise spectacular signal. This means that low energy exploration of quark physics will be a very important complement to the high energy relativistic approach.

The characteristic feature of electron machines is their ability to isolate exact features. For this reason the heavy ion approach and the electron approach are not rival ones but complementary. It is by a common attack by these means that we hope to establish quark field theory as a nuclear 'truth' as well.

In conclusion, as we examine the physics of nuclei on various levels we find many 'truthful' descriptions. These are not contradictory to each other; each of them is invaluable for our understanding of nuclei inside its own region of validity. It is characteristic that each of the approaches uses a wealth of detailed knowledge, for instance from particle interactions, which is quantitatively incorporated in the appropriate 'truth'. The many new developments presented at this conference bear ample witness to the many 'truths' in nuclear physics.