Program of the Workshop

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Abstract

This is a summary of the opening speech.

Welcome to Poland. Welcome to the Tatra Mountains. Welcome to Zgorzelisko. It is great that you are here!

This workshop is organized by the Institute of Theoretical Physics of Warsaw University under patronage of the Polish Physical Society. It is sponsored by the Polish Committee for Scientific Research, Komitet Badań Naukowych, which is the major state institution that funds science in Poland; by the Polish-American Maria Skłodowska-Curie Joint Fund II, with the National Science Foundation on the American side and the Ministry of National Education on the Polish side; and by the Stefan Batory Foundation, Polish branch of the Soros Foundation. I thank these institutions for their support. I also thank all people that I cannot name here now who helped in making it happen. Mostly, I would like to thank Professor Kenneth G. Wilson whose help and commitment to come were crucial.

Part of the program of the Workshop is stimulated by recent progress in formulating the light-front Hamiltonian approach to QCD (LFQCD).[1] The theory is far from being complete. Especially, calculations required to make meaningful comparison of LFQCD with experiment are not yet completed. We are at the stage of establishing details of a picture of a single hadron in LFQCD, starting from the assumption that it should resemble the Constituent Quark Model (CQM) picture. Then, we will calculate corrections and see how large they are. High energy processes involving hadrons will be considered later. My belief is that we have found a way to begin a long and tedious procedure of constructing a numerical description of hadrons in QCD. It is linked to an exact representation of QCD and we shall explain the link during the workshop. My complaint that the numerical results are not yet available is, in practice, an expression of an urgent desire to get them.

Let me show you the following schematic figure that I have copied from Europhysics News for the purpose of explaining how the program was created. The figure shows basic processes contributing to deep-inelastic scattering (DIS) and displays the kinematic region in $1/x$ and Q^2 that is accessible at HERA and with a 600 GeV muon beam incident on protons at rest. It is reproduced from Ref. 2.

I want to bring your attention to four features of the picture of hadrons in the figure.

1. The incoming proton is represented as three quarks. This is the CQM picture - a precursor of QCD. The presence of gluons or quark-antiquark pairs in the proton is not indicated because the figure would become complicated.

2. The final state masses in the deep inelastic experiments, $W^2 = (p+q)^2$, where p is the initial proton momentum and q is the momentum transfer carried by the photon or other intermediate bosons, is

$$W^2 = m^2_{proton} + \frac{1-x}{x} Q^2,$$

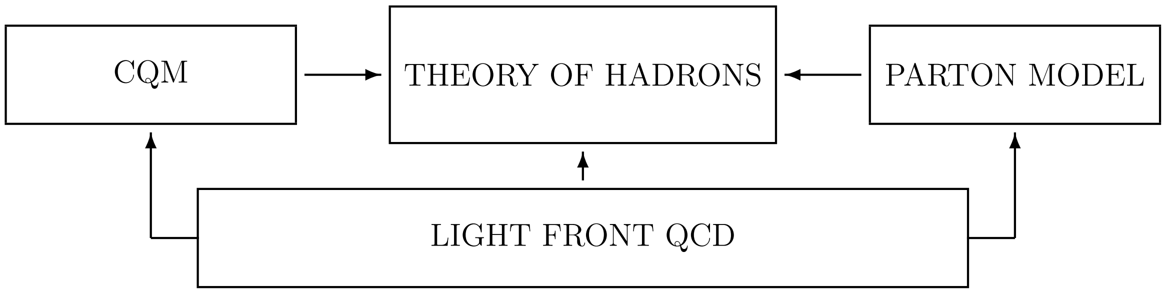
with $Q^2 = -q^2$ and $x = Q^2/2pq$. One can estimate from the figure that the typical values of W at HERA are of the order of up to 100 GeV with maximal values on the order of 300 GeV.

3. The constituent quark masses for up and down quarks are of the order of 300 MeV. Therefore, a theory that can explain in detail results of measurements at HERA has to span at least 2 to 3 orders of magnitude in energy, counting in units of the constituent quark mass. If one makes a connection between the constituent quarks and the current quarks, another two orders of magnitude need to be covered.

4. The figure does not include the QCD vacuum background, which is a theoretical notion supported by many arguments.

We would like to understand the CQM and DIS (and also hadronic collisions) in one theory. We shall argue during this meeting about how LFQCD may help us achieve this goal. The four points above illustrate issues that we will focus on. We shall discuss the connection between the CQM and QCD and the parton model. Static properties, form factors, structure functions and various other hadronic matrix elements and the Regge limit will be discussed. Low-x physics, wee-parton dynamics and the vacuum problem in LFQCD are intimately related and we have a chance to discuss the relations here. We shall consider LFQCD as a candidate that may provide a unified point of view, in analogy to QED. In QED, one can deal with processes involving high energy electrons and at the same time one can calculate the hydrogen atom binding energy, $\simeq \alpha^2 m_e/4$, that is almost 5 orders of magnitude smaller than the electron mass. And one can also calculate small corrections that are still two orders of magnitude smaller. But important differences and problems will have to be considered. The chief ones are confinement, strong coupling and chiral symmetry breaking, and the path that LFQCD is following towards the solution is highly nontrivial and has many branches that relate to different aspects of hadronic physics. The vacuum structure in light-front dynamics with its wee-parton content and whole condensates hidden in it in a new way will be an important issue. If the light-front vacuum of QCD is nontrivial we have to understand it. Unfortunately, the ideas from equal-time or Euclidean formulations of QCD are of little help and the light-front approach to QCD is largely on its own with its completely different setup of the vacuum problem. We shall discuss the light-cone zero-mode issues that are related to the vacuum problem and are of primary interest to many participants. Another important difference between the QED picture of atoms and the QCD picture of hadrons is that electrons in atoms are nonrelativistic while quarks in nucleons and mesons, especially pions, are relativistic. LFQCD faces the challenge of solving the relativistic bound state problem and this is a major challenge.

When I was thinking about the program, initially, I had the following picture in my mind,



with a number of satellite boxes with titles: χSB, lattice QCD, Dyson-Schwinger equations, Regge limit, "evolution" equations, light-front model studies, and relativistic nuclear physics to be linked to the central box. In fact, there would be virtually no theory of hadrons yet if those satellite boxes would not exist. However, we must admit, that a theoretical scheme that can handle hadrons with the required precision and in the whole range of phenomena that we face now in strong interactions, is missing. The program was driven by the desire to discuss the most important theoretical problems that need solution in order to fill in the central box with a machinery that will be able to crank numbers for hadronic bound states and let them move and scatter with energies large in comparison to their masses. One possibility I have in mind is to clarify the connection between QCD and the constituent quark model in light-front Hamiltonian dynamics. The light-front QCD box is drawn as underlying the central and the side boxes in order to stress that the theory has an additional, 7-th, kinematical symmetry - it is invariant under boosts along one spatial axis, conventionally denoted as the z-axis. Thus, the theory is suitable to make the required bridges between the different areas of hadronic physics by boosting solutions from one frame of reference to another. Unfortunately, divergences and corresponding cutoffs violate the boost invariance and interfere with the ground state formation in QCD. Therefore, one needs to understand renormalization theory for Hamiltonians in order to proceed. Recent progress in this direction will be extensively discussed during this Workshop.

The Workshop program evolved in discussions in the organizing committee. Ken Wilson proposed the format of facilitated discussions for many topics that we want to cover. During the first week we shall have lectures on the basic issues of hadronic physics and a number of discussions about how LFQCD may deal with them. During the second week we shall have a series of shorter talks about recent results and we will continue discussions.

I should also mention an important fact that was stressed during discussions at the meetings of the International Advisory Committee and which I consider to be important too. The Workshop in Poland provides an opportunity for new and inspiring international contacts.

Let me also mention two additional events in the program. Yuri Orlov from Cornell will be here with us on Thursday and he will give a talk on Friday afternoon. The same Friday, in the evening, there will be a meeting on education where a group of people working in education in Poland will meet with Ken Wilson and take the opportunity of his being here to learn about the project "Discovery" and other educational efforts that Ken is undertaking. You are welcome to participate in this meeting.

I wish you a fruitful workshop. The weekend is essentially free from scheduled activities and the mountains are yours. I hope the weather will provide opportunities to enjoy Nature, think about it, and talk about it.

References

1. K. G. Wilson et al, Phys. Rev. D **49**, 6720 (1994).
2. J.R. Schneider, P. Söding, G.-A. Voss, A. Wagner, B.H. Wiik, *"The Deutsches Elektronen-Synchrotron"* Europhysics News **25**, 91 (1994).