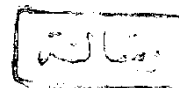


HIGH-ENERGY HADRON-NUCLEUS SCATTERING AND THE COMPOSITE STRUCTURE OF NUCLEONS

Thesis

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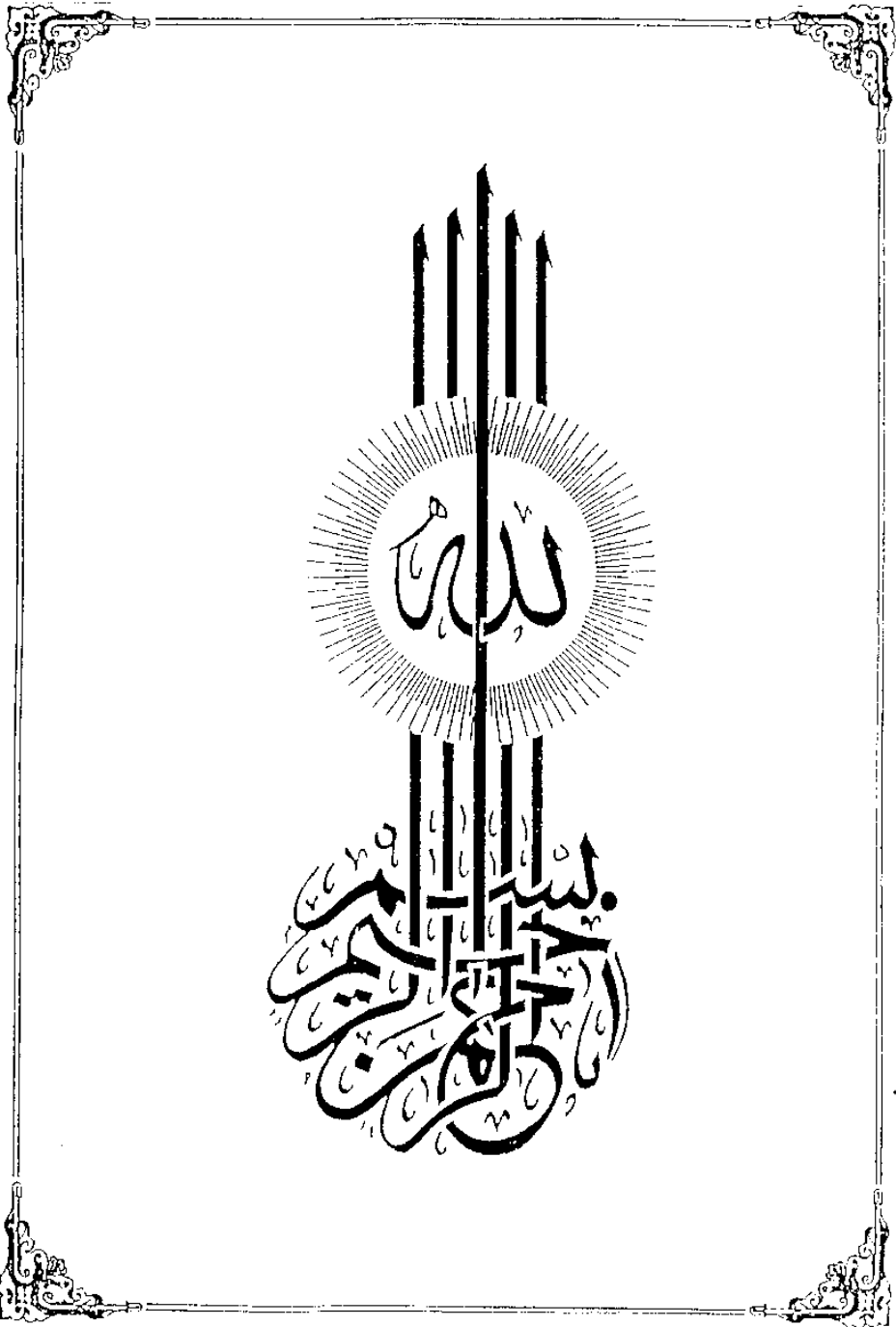
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ABSTRACT

ABSTRACT

This thesis is concerned with study of the short-range correlation between quarks constituting the nucleon and its effect on proton-proton and proton-nucleus collisions, taking proton- ^3He as a special case. The study is investigated at very high energies (ISR) where the center-of-mass energy ($\sqrt{s}$) lies between 20-60 GeV ($P_L \approx 290\text{--}2000$ GeV/c) where at this energy range the cross section is more sensitive to the internal structure of the nucleon. The Glauber high energy approximation is used to calculate the scattering cross sections.

The thesis consists of an introductory chapter, four main chapters materializing our obtained results and an appendix.

Chapter I introduces the Gell-Mann quark-model and its development where the nucleon consists of three quarks concentrated in the core of the nucleon surrounded by a mesonic cloud. Also we presented the works that used the Glauber approximation in study proton-proton and proton-nucleus collisions at high energy taking the quark model into account. From this study, an investigation about the structure of the nucleon and the size of quarks is illustrated. At the end of this chapter we presented briefly the Glauber formalism with the quark structure of colliding particles taking the geometrical scaling into account.

Chapter II is devoted to solve an essential problem, that is the determination of the parameters (A , a and α) which describe the

interaction between quarks at the used energies. / It is well known that there is no experimental data for these parameters, but they can be extracted from the fitting of the theoretical calculations of proton-proton collision with the experimental data for the cross sections. To determine these parameters we used a Gaussian wave function to describe the distribution of quarks in the proton.

In chapter III, we studied how the quarks can behave at very small distance i.e. quark-quark short range correlation. Therefore, a proton's wave function with some kind of short range correlation is proposed. / Our results for proton-proton elastic scattering differential cross section at laboratory momenta 290, 500, 1070, and 1500 GeV/c respectively led to that the above representation of quark distribution can be accepted. Also our results predicted that the core radius of the proton is ~ 0.34 fm and the quark radius is ~ 0.17 fm which agree with some previous calculations and do not contradict with the assumption that the quark can be regarded as a geometrical point.

Since our results in chapter III considered the quark as elementary particle with finite size, this prevents their centers of masses approach to a certain distance. To ensure that, we suggested in chapter IV another form for proton's wave function taking into consideration the short range correlation, where the quarks can approach and coincide on each other. / Using this form of short range correlation, we obtained unacceptable results for proton-proton elastic scattering differential cross section.

Therefore the consideration of short range correlation between quarks as introduced in chapter III is more realistic.

Chapter V contains the calculation of the elastic scattering differential cross section for proton- ^3He at 1500 GeV/c where the nucleon structure and short range correlation are introduced. Our results indicated the importance of short range correlation between quarks in the nucleon on the diffractive structure of the cross section at all values of q^2 .

The appendix contains all quantities of proton- ^3He elastic scattering amplitude with correlation effect.

CHAPTER I

INTRODUCTION

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1.1 Introduction:

Dramatic progress has been made in particle physics during the past three decades. The protons and neutrons (collectively labeled nucleons), which glued together with a strong (nuclear) force to form the nuclei, are no longer regarded as elementary particles. The proton and neutron were not alone, they turned out to be just the lightest particles in a spectrum of strongly interacting fermion states called baryons. A corresponding sequence of strongly interacting bosons, called mesons, has also been discovered, the pion being the lightest. Fermions (bosons) refer to particles states with spin $J = n\hbar/2$, where n is an odd (even) integer. All the particles which undergo strong interaction, baryons and mesons, are collectively called hadrons.

At the most interesting and promising model "quark model", proposed by [Gell-Mann, 1964]¹, the proton and the other elementary particles known at that time were in fact built from more basic entities named quarks. It is well known that the experimental evidence of the existence of many hadronic resonant states necessitates a composite model of hadrons [Takada, 1968]². In 1968, electron scattering experiments at Stanford California, at the Stanford Linear Accelerator Center (SLAC), gave the first clear

hints that point-like particles existed inside the proton. The reference to the constituents of the proton as point-like means that they have no internal structure or, more probably, we have not yet resolved any that they have, these constituents were named quarks.

Kuroda and Miyazawa, [1973; 1974]^{3,4} concluded that the proton is made of structureless quarks, which are distributed over an extension with the root mean square radius of 0.8 fm, while in the pion which made of quark and antiquark, are confined in a smaller radius $r_h \simeq 0.5$ fm. The difference between the quark and antiquark is the sign of their baryon, lepton, and charge numbers. They concluded that a proton is a loosely bound system, while a pion is a more tightly bound one.

The determination of the size of hadron and quark is an interesting problem, since it may teach us how closely the quarks are packed in a hadron. Wakaizumi [1969]⁵ showed that the size of quark is small compared to the size of the hadron.

Tanimoto and Wakaizumi [1974]⁶ and Wakaizumi [1975]⁷ showed that the size of quark is much smaller than that of proton, and that quarks are distributed at a fixed distance of 0.6 fm from the center of proton.

Bogolyuskii [1982]⁸ found that the hadronic radii of the proton and the K^- meson are 0.72-0.74 fm and 0.70-0.73 fm respectively, while the radius of a quark is less by a factor 1.8-2.4. These results agree with the ideas of [Levin and Shekhter,

1974; Anisovich, 1979]⁹ on the structure of a hadron as a spatial distribution of dressed constituents quarks, and on two characteristic radii in the strong interactions, the large one giving the size of the hadron and the small one the size of the dressed quark.

It is known that, from the present's point of view quark-parton models, part of the hadronic matter, and in particular gluons, which play an important role in the dynamics of the strong interactions, are neutral particles and their distributions are therefore not directly measured in electromagnetic interactions. Therefore, hadronic matter may not everywhere be distributed like electromagnetic matter, i.e., the hadronic and electromagnetic form factors may not be identical. A certain approach to the problem of determining hadronic form factors has been developed in the paper by [Chau and Yang, 1968]¹⁰ and Savrin et al. [1976]¹¹ by describing collisions in the impact picture. In these works hadrons are considered as extended objects which in the center-of-mass system are strongly compressed in the longitudinal direction because of their high velocity. In the paper of Chou and Yang the hadronic matter in the proton is concentrated somewhat closer to the center of the proton than the electromagnetic matter. At the same time the analysis in the paper of Savrin et al. leads to another conclusion: part of the strongly interacting matter is spread out to larger distances from the center of the hadron than the electromagnetic matter. It appears that this part of the hadronic matter may be

identical to the neutral gluons. Thus, the final conclusions depend mainly on the model adopted.

The final picture of the baryon structure from point of view of non-relativistic quantum chromodynamics (QCD) describes the strong interactions of quarks and gluons is that, there are three valence coloured quarks constituting the core, in addition to a sea consisting of quark-antiquark pairs and gluons (meson cloud). The gluons are the quanta of the color field that bind quarks in nucleons and also nucleons into nuclei.

The non-relativistic quark model assumes that [Isgur and Karl, 1978, 1979, 1980; Oka and Yazaki, 1980, 1983; Faessler et al., 1983; Lipkin, 1985; Silvestre-Brac and Cignoux, 1985; Yamauchi et al., 1985]^{66,67,68,69,70,71}, baryons are antisymmetrized clusters of three quarks, each of them carrying color, spin and isospin degrees of freedom. Quarks interact via a potential whose main terms are a confining and a hyperfine term. The former is responsible for the confinement of the quarks within the baryons, while the latter simulates the exchange of one gluon between quarks.

The presence of quarks in nuclei as constituents is universally accepted. Kizukuri et al. [1979, 1980]^{72,73} presented a multiquark theoretical approach to the deuteron form factor based on the relativistic harmonic oscillator quark model (RHOM) [Fujimura et al., 1970]⁷⁴. Namiki et al. [1982]⁷⁵ analyzed the ^3He and ^4He form factors using a neutral extension of the deuteron case. They