where C_a is some conserved quantum number of a -th parton and c_N - that of a nucleon.

Now we can invert the moments and obtain hard scattering formula

$$W = \int_{1/\omega}^{1} \frac{dx}{x}\Big\{E^{NS}(q^2/\mu^2,\omega x)\times \sum_{p=a,\bar a}(Q_p^2-\langle Q^2\rangle)\, f_p(x,\mu^2) + E^{S}(q^2/\mu^2,\omega x)\cdot \sum_{p=a,\bar a}\langle Q^2\rangle f_p(x,\mu^2) + E^{g}(q^2/\mu^2,\omega x)\langle Q^2\rangle f_g(x,\mu^2)\Big\}$$

From these formulae it is evident that f_p plays the same role as parton distribution functions do and the functions E describe the small distance interactions. Born's approximation of hard scattering formula gives the standard quark-parton model. In the first order in effective coupling constant multiplied by $\ln(-q^2/\mu^2)$ the scaling is violated. This violation has the following form (for the sake of simplicity γ_5-theory is considered):

$$W(q^2,\omega) = W_0(\omega)\times\Big\{1+\bar g^2(\mu^2)\ln(-q^2/\mu^2)\Big(\Big[\int_1^{\omega} W_0(\xi)/\xi W^0(\omega)\,d\xi - \frac{1}{\omega}\int_1^{\omega}\frac{W_0(\xi)}{W_0(\omega)}d\xi-\frac{1}{2}\Big] + 2\sum_{p=a,\bar a}Q_p^2\times \int_1^{\omega} f_g(1/\xi)\,d\xi/\xi W^0(\omega)\Big)\Big\}$$

where W_0 is the Born term. The term in [ ] is the function of ω monotonically approaching zero from below. When this term cancels the remaining term in ( ) the character of scaling violation is changed. The situation is the same in vector theory, i.e., the change in the character of scaling violation is due to the gluon contribution (when only first-order corrections are considered).

Finally, we summarize: parton distribution functions a) can exist in renormalizable QFT; b) they do not depend on transverse momentum, c) but do depend on the choice of the renormalization point μ^2, d) they obey Feynman sum rules for arbitrary μ^2 , e) and are directly connected with light-cone expansions.

References

1. K.Wilson. Phys.Rev., 179, 1499 (1969).
2. A.V.Efremov, A.V.Radyushkin. JINR, P2-9821, Dubna, 1976, paper 1080/B2, and JINR P2-9906, Dubna, 1976.
3. G.Parisi, R.Petronzio. Roma University preprint, Nota interna, 617 (1975).
4. H.Georgi, H.D.Politzer. Phys.Rev.Lett., 36, 1281 (1976) and "Freedom at Moderate Energies etc.", Harvard preprint, 1976.

PLENARY REPORT

DEEP INELASTIC SCATTERING

V.I.Zakharov
ITEP, Moscow, USSR

Introduction

The basic motivation to study Deep Inelastic is to learn

a) structure of nucleon and

b) structure of the underlying field theory.

The landmarks here are the discoveries of the Bjorken scaling and of the asymptotically free field theories which dominate our way of thinking in the past several years.

Before the problems a) and b) were completely solved there came the era of new particles and in the most recent time the theory of deep inelastic scattering is not so much developing on its own right as in connection with

c) production of heavy particles.

May be not so impressive but still very promising, to my mind, is the application of the theory to

d) lepton-nuclear scattering.

The problems a)-d) above are dealt with in three parts of the Talk:

I) Valence quark approximation;

II) Gluon corrections to the parton model;

III) Applications (Nuclei; Heavy Particles).

The general framework of the Talk is mostly theoretical and is confined to the status of the quark-parton-gluon picture of the deep inelastic scattering [x]) . The experimental

---

x) For a review of this and other approaches see Refs. /1/ .

data are presented in an illustrative way.

I. Valence quark approximation

There exist basicly two different pictures of deep inelastic. One views nucleon as a collection of a large-or even infinite- number of partons. The other starts from three valence quarks.

The foundation of the former approach lies in the strong interactions physics. Indeed, as a result of a rather mild collision at high energy the incident hadron goes into many particles. The other approach links deep inelastic to the hadron spectroscopy in the most straightforward way.

Since the first measurements of the total cross sections of νN and $\bar{\nu} N$ interactions [2] we know that admixture of antiquarks in nucleon is small. Thus, the valence quark approximation is a meaningful one.

Therefore, we will start from the model which considers nucleon as a system of three partons. The momentum distribution of the partons is to be extracted from the data (for a review of the model see, e.g., Ref. [3]) .

1.1. Experimental status of the parton model

Let me list first some well-known predictions of the parton model and confront them with the data available.

1) Quark counting rule [4] . According to the rule

$$F(Q^2) \sim (Q^2)^{-n+1} \qquad (1)$$

where $F(Q^2)$ is the electromagnetic form factor and n is the number of constituents which is equal to 3 in the case of nucleon and to 2 in the case of pion. In both cases the agreement with the data is excellent, the nucleon form factor being studied up to $Q^2 = 33$ GeV^2 (see, e.g., the Proceedings of the Stanford Conference, [5]).

2) Drell-Yan-West relation [6]

It links the number of constituents to the behaviour of the structure function at $x \to 1$:

$$F_1(x),\ F_2(x) \underset{x \to 1}{\longrightarrow} (1-x)^{2n-3}$$

where

$$x = Q^2/2m_N\nu$$

and Q^2 and ν are the momentum transfer squared and the energy transfer, respectively.

The validity of the relation which had been thought to be safe is being questioned now by experimentalists who give [7]

$$m_N W_1^{ep} \sim (1-x_s^p)^4, \quad m_N W_1^{en} \sim (1-x_s^n)^4 \qquad (2)$$

where

$$x_s^p = Q^2/(2m_N\nu + 1.5\,\mathrm{GeV}^2); \quad x_s^n = Q^2/(2m_N\nu + 0.6\,\mathrm{GeV}^2)$$

(For discussion see Section 2.7).

3) Spin 1/2 constituents.

Smallness of the ratio of the cross sections of the longitudinally and transversely polarized photons

$$R = \sigma_L/\sigma_T \underset{Q^2 \to \infty}{\longrightarrow} 0 \qquad (3)$$

is expected in this case ($R = \infty$ for spin 0 constituents).

To this Conference the new data by the CHIO collaboration are presented according to which [8]

$$R = -0.10 \pm 0.27 \quad (1 < Q^2 < 2\,\mathrm{GeV}^2)$$
$$R = 0.02 \pm 0.30 \quad (2 < Q^2 < 6\,\mathrm{GeV}^2) \qquad (4)$$

The importance of the measurement lies in the fact that it refers to large ω ($\langle\omega\rangle$ = 80 and 40, respectively), so that there is no effect of the leading particle.

4) Smallness of the antiquark admixture

The prediction is checked in the neutrino experiments and works well at least if the initial energy is not too high (otherwise the new particles production makes the interpretation dubious). In particular

$$\frac{\int \bar{q}(x)dx}{\int[\bar{q}(x)+q(x)]dx} = \begin{cases} 0.05 \pm 0.02 & \text{(Gargamelle Coll.) [9]} \\ 0.05 \pm 0.05 & \text{(HPWF group [10])} \end{cases}$$

where $\int q(x)dx$ and $\int \bar{q}(x)dx$ refer to the momentum carried by partons and antipartons, respectively.

5) Limited $p_\perp$ distribution of the final hadrons.

There are new and very interesting data/11/ both from neutrino reactions and electroproduction which confirm the prediction. In the former case the data extend to $Q^2 = 60$ GeV^2 (see Fig.1) and the mean value of $p_\perp$ is independent on Q^2.

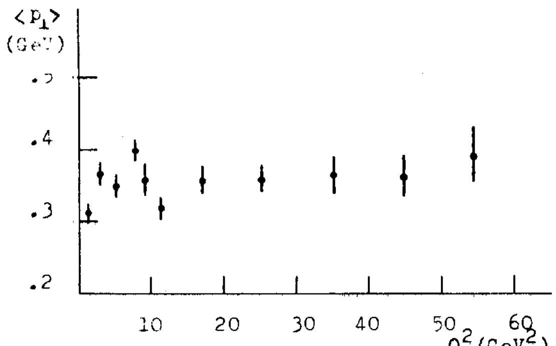


Fig.1 The average value of $p_\perp$ of the final hadron in reaction $\nu N \to \mu^- h X$ as a function of Q^2. The data are from Ref.[11] (J.W. Chapman et al.)

One of the most striking pieces of data is the confirmation of the simple vector dominance model in the diffractive ρ°-electroproduction

$$\gamma_V p \to \rho^\circ p \qquad (6)$$

up to $Q^2 \simeq 2.5$ GeV^2. The data are presented to this Conference by the CHIO and DESY groups. The cross section follows well the VMD model (see Fig.2). Moreover, the data show no shrinkage of the virtual photon, i.e., if the differential cross section is fitted to

$$\frac{d\sigma}{dt} \sim e^{At}$$

then coefficient A is independent on Q^2 (see Fig.3 /13/).

The agreement with VMD seems even more puzzling since the model has nothing to do with the total cross section (predicts an

6) The yield of hadrons is given by the quarks fragmentation functions.

The data do show striking similarity of the final state in e^+e^-, eN, νN and even NN interactions. The point was amply substantiated at this Conference by B.Roe (B3 Section) and by A.Sessoms (Section B2).

Conclusion: naive parton model works well in most cases.

1.2. Diffractive production of ρ° mesons

Thus far, we considered inclusive processes. A lot of data is accumulated on the exclusive channels as well (see, e.g., the Weber's and M.Duong-Van's Talks at Section B2) and there is a challenge to theorists to interprete the data.

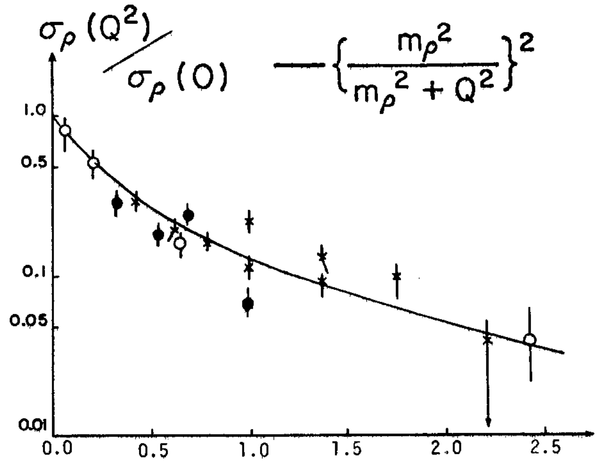


Fig.2 Cross section of diffractive electroproduction of ρ-mesons as a function of Q^2. Crosses are the Cornell data (Phys.Rev.Lett.,31,131,(1973)), bald-faced points are from Ref.[13] and open circles are from Ref.[12] The solid curve is the prediction of the VDM .

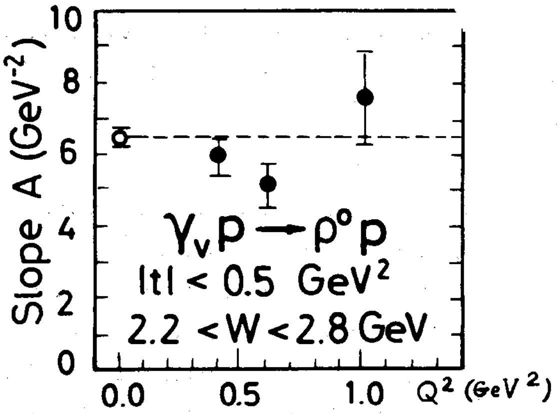


Fig.3 Slope of $d\sigma/dt$ as function of Q^2, Ref.[13]

extra power of Q^2 down). It is worth trying, therefore, the parton model to describe the data.

1.3. Diffraction and the parton model

Diffractive deep inelastic scattering can be described as a fluctuation of virtual photon into a quark-antiquark pair with a subsequent scattering of a parton on the target (for an analysis based on the space-time picture of the parton model /14/ see Ref. /15/) .

Only soft partons have large cross section. Therefore, the scattering occurs only if the partons are separated by a large distance and long-range forces between the color quarks produce partons from the vacuum. It follows from the kinematical consideration alone that the quark separation is large if one of the partons is much more energetic than the other:

$$E_1 \sim \nu \ , \quad E_2 \sim æ/x \tag{7}$$

where æ is some intrinsic hadronic mass. The other parton penetrate the target almost without interaction[*] .

[*] It would be interesting to learn the fate of these partons as well. They have a small cross section (of the order Q^{-2}, ?) but occupy large phase space, of the order Q^2 . Thus, we could expect a halo of large $p_\perp$ particles, the corresponding cross section being a permanent fraction of the total.

If diffraction were large, then the contribution from the sea of the quark-antiquark pairs would have been large. In other words, the valence quark dominance implies smallness of diffraction in deep inelastic.

Qualitatively, this means, in turn, that vacuum is unstable only if the distance between the quarks is rather large. Quantitatively, the distance of the order $\langle p_\perp \rangle^{-1}$ can be O.K. Indeed, a relation of the type

$$x_{diff} \lesssim \frac{\langle p_\perp^2 \rangle}{2m_N (\text{several GeV})} \lesssim 0.05 \tag{8}$$

seems to be reasonable in this case and is in accordance with the data (here, factor $\langle p_\perp^2 \rangle / 2m_N$ is purely kinematical, while "Several GeV" stand for the quark energy at which diffraction is possible).

Thus, inclusive diffraction in deep inelastic gives a small but a Q^2-independent part of the total cross section.

Let us turn now to the consideration of an exclussive channel (6). The crucial point here is that the two quarks emerging from the scattering off the target (see the discussion above) do not look like ρ-meson. Indeed, quarks within the ρ-meson share the energy on equal, roughly speaking, while here we have one much more energetic parton than the other.

The situation is form factor-like, and the overlap of the wave functions is small. As a result we get an extra factor Q^{-2} in the cross section.

To summarise, the observed Q^2 dependence of the cross section of reaction (6) as well as absence of the virtual photon shrinkage are well understood within the parton model. However, one would expect that the diffraction in deep inelastic is numerically small. In the other words, ρ-production is expected to fall off as function of x at, say, $x \sim 0.05$. This does not seem to be confirmed by the DESY data /13/ .

1.4. Nonrelativistic vs.Relativistic quarks

Let me discuss in brief another theoretical problem arising in the context of the valence quark approximation. Even if it is granted that nucleon consists of three quarks, then there exists a question whether the quarks are nonrelativistic or ultrarelativistic (or something in between).

In the ultrarelativistic case the quark struck by the virtual photon is almost on-mass-shell, while in the nonrelativistic case it is well off-mass-shell if x is close to 1:[16]

$$p^2 \sim \frac{\ae^2}{1-x} \qquad (9)$$

In the latter case the simplest realization of the quark model predictions come from the graphs [4b] represented in Fig.4. In particular, the smallness of the cross section at $x\sim 1$ is due to the propagators (see Eq. (9)).

An alternative possibility of ultrarelativistic quarks was considered by Berestetsky and Terentjev [17] . The result is that the form factor is unchanged (see Eq. (1)) but

$$F_2^N(x) \xrightarrow[x\to 1]{} (1-x) \;;\; F_2^\pi \xrightarrow[x\to 1]{} \text{const} \qquad (10)$$

Indeed, in the case of pion, e.g., the S-wave nature of the quark wave function implies independence on the angle in the quark c.m. system. Reexpressed in terms of the scaling variable this prediction means independence on x as well ($d\cos\theta_{cM} \sim dx$).

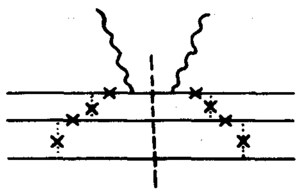


Fig.4 Brodsky-Farrar graph for deep inelastic scattering (or for form factor). Crosses mark the lines with large virtual momenta.

Since eq. (10) is in contradiction with the data the authors conclude that the ultrarelativistic quarks are ruled out.

Conclusions to part I

The parton model is healthy and explains a lot of data.There is room for further checks as well.

But it cannot be all the truth since quarks in deep inelastic carry about 0.5 of the total momentum - blame gluons.

Moreover, large admixture of gluons is difficult to reccincile with success of the quark counting rule which just assumes that there is nothing else in the nucleon except for three quarks.

Thus, we come to consideration of gluons in deep inelastic.

II. GLUON CORRECTIONS

2.1. Cooking of nucleon in deep inelastic

Since the valence quark approximation proved to be successful let us try to stick to the idea as long as possible. Then one can imagine that the following simple model for the structure function in deep inelastic makes sense.

A) Start with nonrelativistic quarks. The corresponding structure function is $F_2(x) \sim \delta(x-1/3)$ and has little to do with the observed one. But

B) Gluon exchanges smear the quark distribution. In particular, the graphs of Fig.4 produce a tail in the parton distribution at $x\to 1$, $F_2(x) \sim (1-x)^3$.

The effect of the gluon exchanges between the quarks is schematically represented in Fig.5. Moreover,

C) Gluon bremsstrahlung and inner conversion (see Fig.6) make further change in the structure function. In particular,

1) Part of the quark momentum goes into gluons;

2) $F_2(x)$ is shifted to smaller x ;

3) Antiquarks appear.

Schematically, the change is represented in Fig.7 and, hopefully, the net result of gluon corrections to valence quarks is the observed $F_2(x)$.

Conclusion: gluons mask the structure of nucleon and reveal the structure of strong interactions. It is important, therefore, to check the reality of both steps (gluon exchanges and bremsstrahlung) experimentally.

2.2. Experimental consequences of the gluon exchanges

Analysis of the graphs of the type represented in Fig.4 allows to make certain predictions concerning both deep inelastic structure functions and form factors. Let me

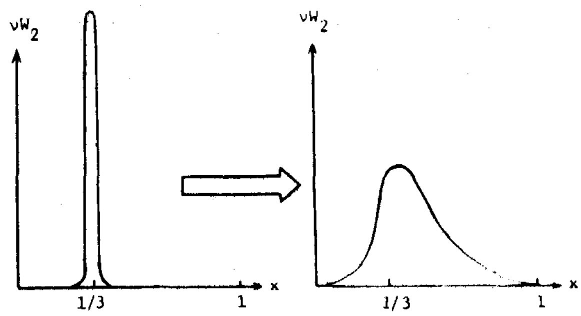


Fig.5 Change in the structure function as a result of gluon exchanges (schematical)

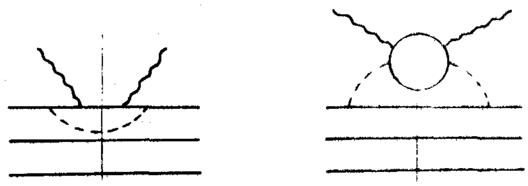


Fig.6 Examples of gluon bremsstrahlung and internal gluon conversion in the forward Compton scattering of a virtual photon on nucleon.

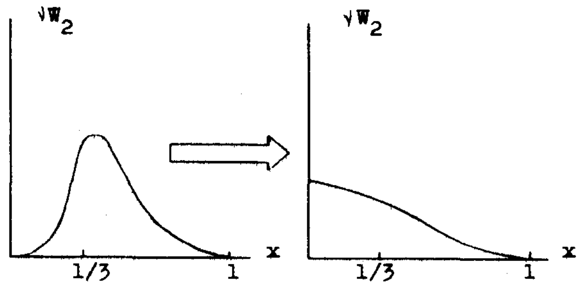


Fig. 7. Change in the structure function as a result of gluon bremsstrahlung. (schematically).

list some of them.

1) Leading parton has the same polarisation as nucleon:/18/

$$\frac{g_-(x)}{g_+(x)} \sim (1-x) \quad \text{when } x \to 1 \qquad (11)$$

where $g_+(g_-)$ is the density of quarks with the same (opposite) helicity as nucleon.

2) If prediction (11) is combined with SU(6) symmetry for the wave function, then /18/

$$\frac{\nu W_2^{en}}{\nu W_2^{ep}} \xrightarrow[x \to 1]{} \frac{3}{7} \qquad (12)$$

which is a remarkable step towards experimental data as compared to the previously believed prediction of 2/3 for the r.h.s. of Eq. (12).

3) As is noticed by many people, the transversal form factor of nucleon is predicted to dominate over the longitudinal one at large Q^2 :

$$F_T^N(Q^2)/F_L^N(Q^2) \gg 1 \quad (Q^2 \to \infty) \qquad (13)$$

The prediction is in good agreement with the data.

4) As is shown by Ioffe in a contributed paper /19/ the electric- and magnetic-dipole form factors in the nucleon-isobar transition are expected to be of the same order at large Q^2

$$G_E^{N\Delta}(Q^2) \approx -G_M^{N\Delta}(Q^2) \quad (Q^2 \to \infty) \qquad (13)$$

This is even more interesting since at low Q^2 the trend is reversed and $G_M \gg G_E$.

5) As is noticed by Vainshtein and Zakharov in the case of the deuteron form factor the longitudinal component dominates at large Q^2 (i.e., in the six-quark limit, see Section 3.1):

$$F_L^D(Q^2)/F_T^D(Q^2) \gg 1 \qquad (14)$$

This prediction implies vanishing of the magnetic form factor and can be checked by studying the angular distribution alone.

It is worth making a warning that all the predictions (11)-(14) are derived in the lowest order in the gluon coupling constant. However, it is reasonable to expect them to be valid with some accuracy after the summation of all the orders as well. To substanciate the point let me give a simple example.

According to the parton model one has

$$\sigma_L/\sigma_T \sim 1/Q^2 \quad (Q^2 \to \infty) \qquad (15)$$

If the gluon corrections are taken into account, then the power is changed but the smallness of the ration persists and /20/ :

$$\sigma_L/\sigma_T \sim \frac{g^2(Q^2)}{16\pi^2}(1-x) \qquad (16)$$

where $g^2(Q^2)$ is the effective coupling constant of strong interactions ($g^2 \sim 1/\ln Q^2$).

Therefore, all the predictions mentioned above are worth checking experimentally.

2.3. Consequences of the gluon bremsstrahlung

A refined way of calculating the effect of the gluon bremsstrahlung is provided by the well-known technique of the moments from the structure functions /21/ . The assumption that there are only three quarks in the initial state implies vanishing of the reduced matrix elements from all the operators except for those constructed from the u- and d- quarks alone /22/ . This conditions fixes the moments to a large extent.

The effect of the gluon bremsstrahlung still naturally depends on the effective coupling constant of strong interactions (as well as on the nonabelian nature of the quantum chromodynamics).

An explicit calculation /22a/ shows that if $\frac{g^2(2\,GeV^2)}{4\pi} \simeq 1/4$ then

1) Momentum carried by quarks goes down from 1 to $\sim$ 0.55 (in the units of the nucleon's momentum);

2) Momentum carried by antiquarks goes up from 0 to $\sim$ 0.03;

3) The mean value of the parton's momentum goes down from 0.33 to $\sim$ 0.22.

4) The difference between proton and neutron structure functions is about 0.06 ($\int_0^1 (F_2^{ep} - F_2^{en})dx \approx 0.06$)

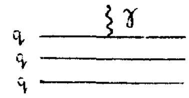
All the predictions are in rough (10-20%) agreement with the data. Thus, $F_2(x)$ as is seen experimentally could arise as a result of the gluon bremsstrahlung. To be sure, however, an independent determination of the effective coupling constant is needed.

It may turn necessary to include gluons in the initial state to improve the fit. The admixture cannot be too large, however, not to spoil the quark counting rules.

It is interesting that if the picture with gluon bremsstrahlung is relevant to the data, then the variation in the lowest moments from the structure functions is very slow up to very high Q^2 . For example, the momentum carried by antiquarks at $Q^2 =$ 1000 GeV^2 is three times as small as in the limit of $Q^2 \to \infty$ /22a,45/ .

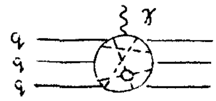
To summarize, there exist two extreme pictures of deep inelastic scattering:

Valence quarks



= strong interactions switched off

Deep Asymptopia



= so many virtual lines that there is no dependence on the initial state (target "switched off"). New equilibrium of quarks and gluons.

We are in between (closer to the left):

Preasymptopia, when both target and interaction count (extends to $Q^2 \geq 10000$ GeV^2) .

2.4. Scaling violations

The next logical step is to confront with the predictions from the asymptotic freedom with the parton model and to look which works better.

Let us start with the most widely discussed predictions of the quantum chromodynamics on the scaling violations /21b/ .

One would expect that as a result of the gluon bremsstrahlung $F_2(x)$ sharpens with increasing Q^2 . Such an effect seems to have been observed both in electroproduction /23/ and in neutrino reactions (for a summary see Ref. /24/). To this Conference the data of the CHIO group are presented which show in the same direction (see Fig.8) /25/ .

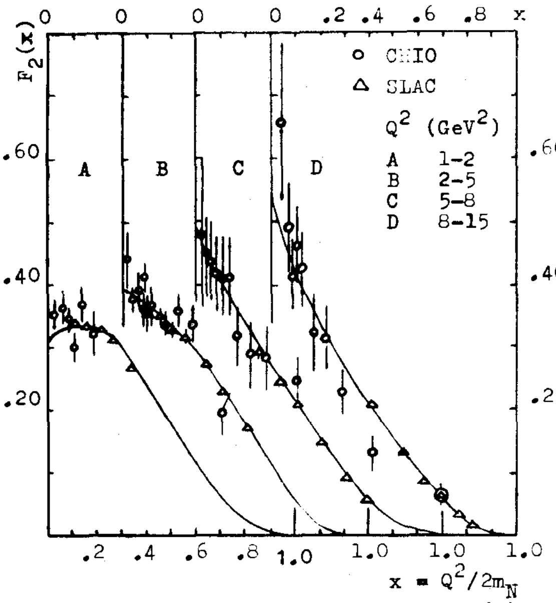


Fig. 8 Proton structure function $F_2(x)$ versus Q^2. The x scales of the subsequent graphs are shifted by 0.3. The curves are the fits $F_2(x) = \sum_{i=3}^{i=5} a_i(1-x)^i$.

The conclusions seem to be:

- scaling violations are seen,
- $\int F_2(x)dx$ remains a constant (see Fig.9 /25/) (qualified to the validity of the extrapolation procedure from small (and measured) x to large x).

2.5. Implications of the scaling violation

If the effect is seen experimentally, then there arises a number of theoretical questions. The most urgent are:

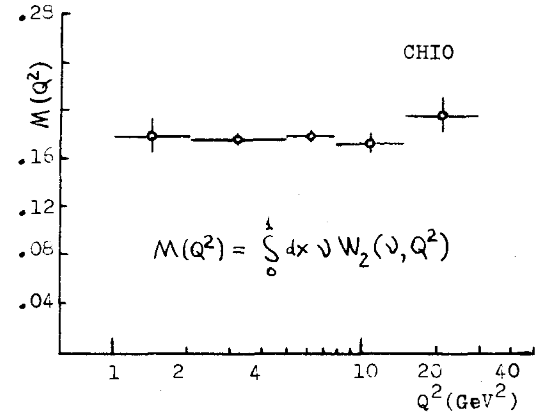


Fig.9. The dependence on Q^2 of the first moment $M(Q^2)$ computed from the CHIO data Ref. 25.

1) Is observed scaling violation compatible with quantum chromodynamics?

2) Is it the sea of $q\bar{q}$ pairs that shows up at small x or is it just charpening of valence quarks?

3) What is the contribution to the scaling violation from the pair production of charmed particles?

No agreed answers to these questions exist at the moment. My own prejudices are as follows:

1) In general, yes, but the rise looks too fast if one judges from the fitted curves (Fig.8) .

2) Sharpening of the valence partons.

3) Pair production of charmed particles is negligible.

Since the situation is far from being clear some further short comments can be helpful:

1) Sharp rise in $F_2(x)$ with Q^2 would encourage speculations on the non-field-theoretical pattern of scaling violation:

$$\delta F \sim R^2 Q^2$$

where R is some new intrinsic dimension. The simplest model of this kind is the introduction of the parton's form factor by Drell and Chanowitz /26/ . There are also some other elaborated versions which utilize the models of strong interactions and relate R to the parameters of the Regge pole fit. These are discussed by Levin and Ryskin /27/ , Anisovich, Gershtein and Folomeshkin /28/ .

2) Increase at small x does not necessarily implies rise in the sea contribution. There is a competition between gluon bremsstrahlung and gluon splitting which sharpen the valence quarks and pair production which increases the sea. The balance depends on the coupling constant of strong interactions and on the input assumptions on the nucleon structure. If the gluons and antiquarks are not initially present (see Section 2.3) then the effect is mostly the change in the distribution of the valence partons. An alternative conclusion can also be reached if one changes the assumptions /28,45/ .

3) The relative contribution of charmed particles production to the total cross section does grow with Q^2 (as $Q^2/(Q^2+m_\psi^2)$ /29/) and is concentrated at small x , as is observed experimentally. However, the estimates based on quantum chromodynamics give too small an effect numerically /30/ . The conclusion is contested by the generalized vector dominance which gives more (see Close's Talk at Session B2) . Moreover, there are some independent experimental indications to the same effect (see Section 3.3 of the present Talk).

Conclusion on scaling violations: we are at the beginning of the story.

2.6. Asymptotic freedom vs. partons

Let us continue with comparing predictions of the field theory and the parton model.

In particular, the effect of gluon corrections on the $p_\perp$ distribution turns out to be drastic at $Q^2 \to \infty$. According to field theory /31/

$$\langle p_\perp^2 \rangle \sim Q^2/\ln Q^2 \qquad (17)$$

while in the parton model $\langle p_\perp^2 \rangle \sim const.$

Eq. (17) is a manifestation of the simple fact that all the integrations over virtual momenta extend up to Q^2 . Indeed, there is just no other parameter in the quantum chromodynamics and at large Q^2 the interaction becomes only logarithmically weak. On the other hand, the study of the $p_\perp$ distribution reveals the virtuality of the parton.

As was already mentioned in Section 1.1 there is no sign of growth in $\langle p_\perp \rangle$ with Q^2 up to $Q^2 = 60\ GeV^2$. Thus, there is no indication to the asymptotic freedom so far.

The argument is not too strong, however, for at least two reasons:

a) From the theoretical point of view it is necessary to use the Breit system. In this frame $Q = 60\ GeV^2$ corresponds to a fragmentation of parton with energy 4 GeV. If it decays, say, into three hadrons and $\langle p_\perp \rangle \sim 500$ MeV for each of them, then the longitudinal momentum of hadrons is not too much larger than the transverse one. Anyhow, 60 GeV^2 in deep inelastic correspond to 4+4 GeV e^+e^- collisions. Jets can hardly be seen at this energy (see also Kheze's Talk).

b) Large $p_\perp$ events are populated mostly by gluons (the contribution of the quark - antiquark pairs is relatively small). Therefore it is a good place to look for glue-balls. On the other hand, if the glue-balls are heavy and introduce some new mass scale m_g , then the whole picture can change in favour of the configurations when the quarks and gluons are aligned. In the other words, the confinement mechanism can be important.

But, anyhow, it seems fair to conclude that - the $\langle p_\perp^2 \rangle$ business is serious. There is a lack of detailed calculations to evaluate the situation better.

2.7. Breaking of duality?

It is worth mentioning that the gluon corrections provide a natural mechanism for the breaking of the Drell-Yan-West type relations.

Indeed, at fixed (1-x) and Q^2 tending to infinity the gluon corrections always come from the graphs of the bremsstrahlung type. (Fig.6). In the field theoretical language it means that the bilinear in the quark fields operators dominate and the usual technique of the moments from the structure functions is applicable.

On the other hand, if $(1-x) \sim æ^2 Q^{-2}$ and we are considering form factor, then the graphs of the type represented in Fig.4 are essential. Effectively, we get a six-quark operator here. The gluon corrections to these operators have never been calculated.

One is free to speculate, therefere, that the gluon corrections to the form factor are smaller than to the structure functions. It is worth emphasizing that for the relativistic quarks just the opposite is true and the gluon corrections to form factor are the largest (this case was considered, in fact, in Refs. /32/).

To summarize, one may hope to explain the observed derivations from the Drell-Yan-West relation by gluon corrections. The calculation of the gluon correction to the form factor is needed to verify this hypothesis.

2.8. Precocious scaling

As is known for quite a long time, scaling is observed better in terms of some new variables. In particular the Bloom-Gilman variable x'

$$x' = Q^2/(2m_N\nu + m_N^2) \tag{18}$$

coincides with standard definition of the scaling variable at ν tending to infinity but makes much better at moderate values of Q^2 and $x \sim 1$.

To understand the meaning of such a variable we need a theory of approach to scaling. Some efforts in this direction have been made recently.

As was first noticed by Nachtmann /33/ it is possible to account for the kinematical effect of the nucleon mass within the Wilson operator expansion technique. Namely, one can keep terms of the order m_N^2/Q^2 explicitly.

Georgi and Politzer /34/ and Baluni and Eichten in a contributed paper /35/ pursued the idea firther and assumed that the kinematical factor is the only important one as far as corrections of the order Q^{-2} are concerned.

In this approximation scaling in variable ξ arises /33-35/

$$\xi = x\,\frac{2}{1+\sqrt{1+Q^2/\nu^2}} \tag{19}$$

and at x close to unity ξ coincides with x' if the expansion in Q^2/ν^2 is made.

The derivation is based on the assumptions that the effective coupling constant is relatively weak at $Q^2 \simeq 2$ GeV^2 and that $m_N^2 \gg æ^2$ where $æ$ is some internal mass. Both seem reasonable (except for x too close to 1 where the latter assumption becomes dangerous, see Eq. (9)). Thus, in the two-dimensional models /36/ $æ$ stands for the quarks mass.

Although it seems gratifying to derive the precocious scaling in the field theory, the phenomenological basis for it is not clear to me at the moment in view of the data presented to this Conference. The point is that the CHIO group has found that the lowest moment from the structure function remains constant if x not x' is used as the scaling variable. The higher moments vary rather strongly (see Fig.10). If x is changed into x' then the first moment varies with Q^2 .

On the other hand, the higher moments become Q^2 independent for, say, $Q^2 \approx 5$ GeV^2 if calculated in terms of x' . The corresponding

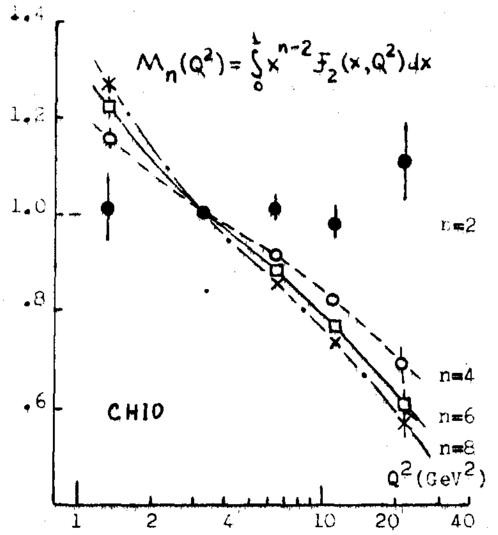


Fig. 10 Higher moments from the proton structure function as calculated by Anderson et.al.[25] The moments are normalized to unity at some arbitrary point.

calculations are examplified in Fig.11 which is borrowed from the Bloom's report /37/ .

To summarize, the hopes are high now that the leading corrections to the scaling behaviour of the order Q^{-2} reduce to the kinematical effect of the nucleon mass.

Conclusion to part II

Asymptotic freedom is very attractive and provides qualitative explanation to some experimental observations.

It is far from being proved, however.

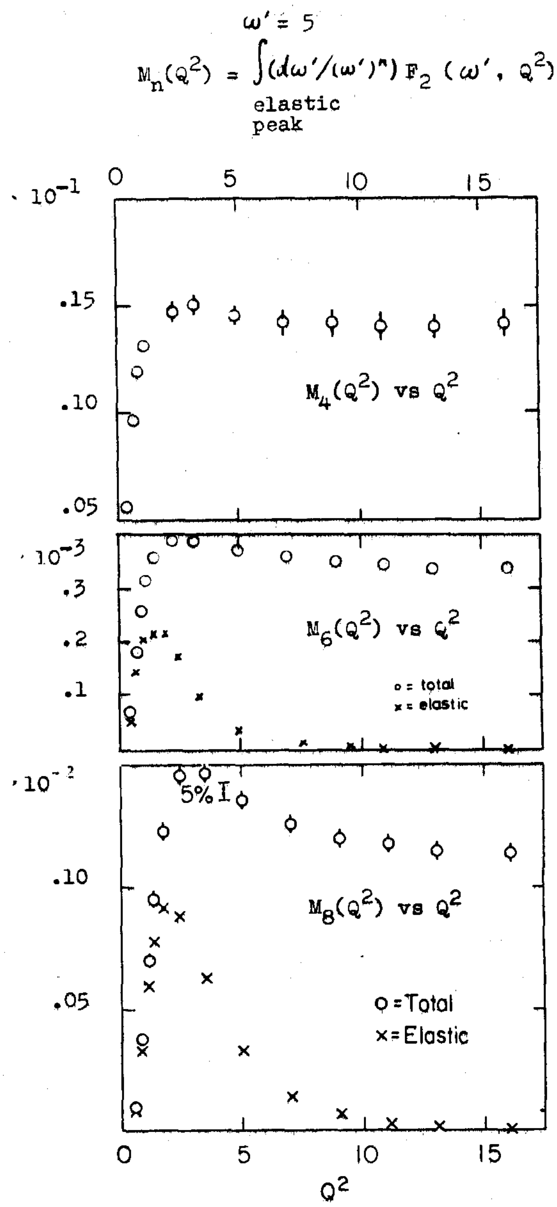


Fig. 11. The moments from the structure function. Ref. 37

III. APPLICATIONS (NUCLEI: NEW PARTICLES)

First data on eD scattering at rather high Q^2 (up to 6 GeV^2) are presented to this Conference by the Chertok's group. I think, therefore, that this is a good time to review some ideas on deep inelastic scattering on nuclei.

3.1. Multi-quark nuclei

There is an exciting possibility to observe at short distances in nuclei multi-quark states. Thus, deuteron can be considered as a six-quark state and so on (see the Chertok's and Brodsky Talks at this Conference).

In strong interactions physics there existed for some time indications to the clustering in nuclei at short distances. The hint comes from the so called cumulative effect and nuclear scaling (see Baldin's and Leksin's Talks at Session A6). The origin of these phenomena could be clarified by studying deep inelastic scattering which is a true short distance process.

In particular, the deuteron from factor is predicted by the quark counting rule to fall off as

$$F_D(Q^2) \sim F_N^2(Q^2)(Q^2+\varkappa^2)^{-1} \qquad (20)$$

The data fit the extrapelation curve very well starting from $Q^2 \sim m_\rho^2$ (see Fig.12).

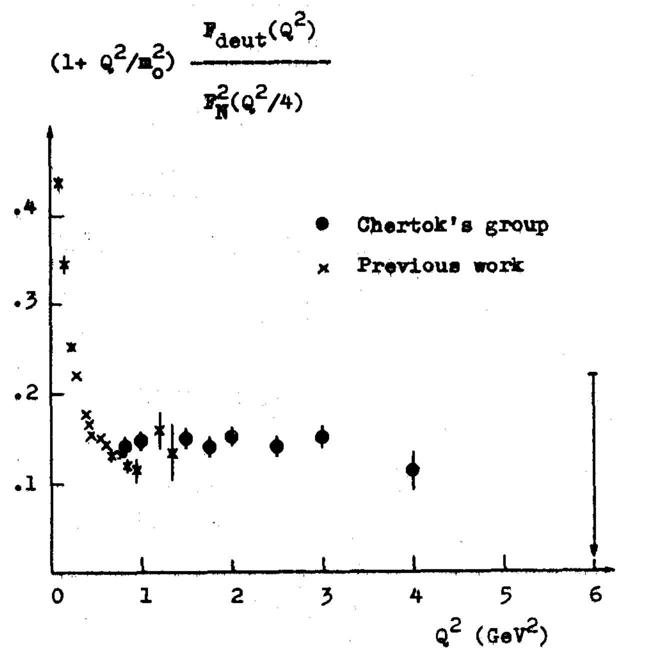


Fig. 12 (taken from S. Brodsky and B. Chertok contributed paper A7/41). The behavior of the deuteron form factor. The points marked with circle are from R. Arnold et al. Phys. Rev. Lett. 35, 776 (1975), and those with crosses are from J. Elias et al. Phys. Rev. 177, 2075 (1969)

To be fair, I must say that at present energies the usual description of deuteron as consisting of neutron + proton may work too. In particular, a successful calculation of the deuteron form factor within this framework was performed by Karmanov and Shapiro.

Moreover, Frankfurt and Strickman /38/ calculated the cross section of deep inelastic scattering on deuteron and the data agree with the calculation (see Fig.13).

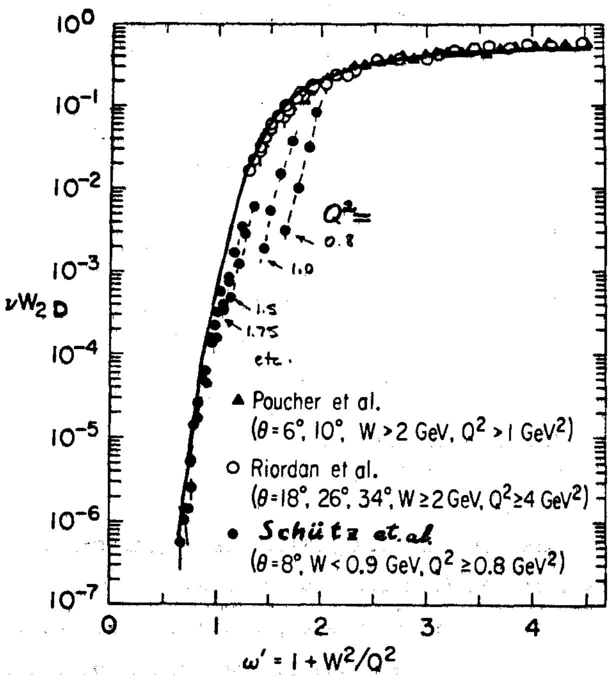


Fig. 13. The data on eD inelastic scattering (See Chertok's Talk at Section A7). The solid line is the theoretical calculation by Frankfurt and Strikman (Ref. 38).

What is indeed remarkable is that experimentally only "shallow" inelastic scattering was observed. Namely, the final mass is relatively low so that one pion can hardly be produced. Nevertheless, the data approach some scaling limit with increasing Q^2 .

I do not feel that there exists a real contradiction between the quark-like and conventional picture of eD scattering at present energies. The description could be dual.

Let me mention also some other related suggestions concerning lepton-nuclear scattering:

a) By studying scattering off nuclei with atomic number $A \geqslant 5$ one can check the quark statistics. Indeed, there can be no more then

12 quarks in S-state in the three-colour scheme. Therefore, the usual quark counting rule breaks down for $A \geq 5$ /39/ .

b) By studying the νN ($\bar{\nu} N$) scattering in the region which is kinematically forbidden for an interaction with a free nucleon one can probe the nature of nuclear forces /40/ at short distances. If the conventional models with vector meson exchanges are correct, then it is natural to expect large increase in the sea content. If the "core" in NN interaction is due to the quark repulsion, then there is no such effect, generally speaking. Numerically, the difference between the two cases is about 50% /40/ .

3.2. Nuclear shadowing and partons

By studying deep inelastic scattering on nuclei we can learn more on the time development of the parton system. In particular, the parton model leads to the following specific predictions for the structure function of scattering:/15/

a) Shadowing is absent in deep inelastic up to high ω ,

b) Just before the shadowing antishadowing is predicted so that the expected form of the ratio $F^{eA}(x)/F^{eN}(x)$ looks as is represented in Fig.14.

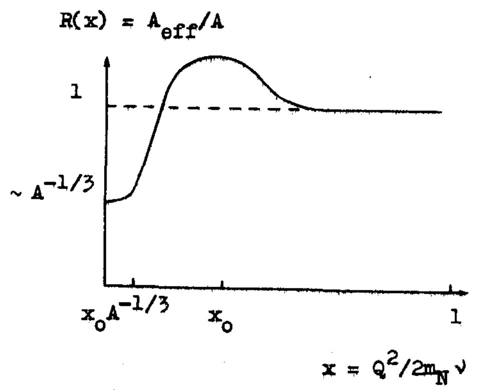


Fig. 14. The expected dependence on x of the shadowing parameter.

The first point is easy to substanciate since valence quark dominance means exactly absence of any diffraction, and shadowing is a pure diffractive process. The second point is not so easy to explain and I refer the reader to the original paper /15/ for details. Let me mention here that the prediction is intimately connected to the fusion of partons as a result of their interaction and, in this way, to the nature of the Pomeranchuk singularity.

The experimental data are represented in Fig.15 (there is a new measirement in cosmic rays at very high energy, $\nu \sim 200$ GeV and $Q^2 \sim 0.1$ GeV^2 /41/). One may conclude that

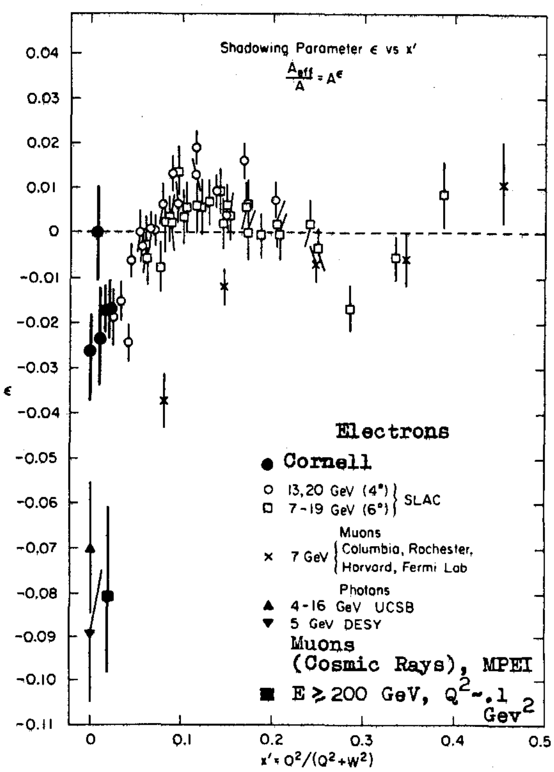


Fig. 15. Shadowing parameter ε as a function of x' as compiled by R.E. Taylor, Ref. 5. Cosmic ray muon point is from Ref. 41 .

a) Expectations of the shadowing evasion are more than satisfied. There is some effect even if Q^2 is changed from 0 to 0.1 GeV^2 *).

b) There is some hint on antishadowing but the systematic errors are too large. Wait for higher Q^2.

Further information can be extracted from the study of the final state in deep inelastic scattering on nuclei. In particular, absence of shadowing implies that the volume term dominates in the cross section. It means, in turn, that there is less time available for a development of internuclear cascade. As a result, the multiplicity in electroproduction on nuclei is expected to be lower than that in photoproduction.

The effect is suggested and discussed in detail by Nikolaev and Davidenko /42/. It turns to be quite significant numerically (see Fig.16).

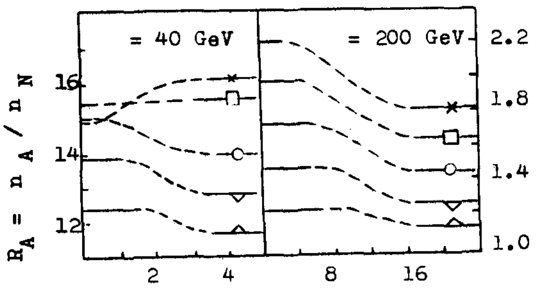


Fig. 16. The total multiplicities in the electroproduction on nuclei as a function of Q^2. The curves marked by △, ▽, ○, □ and by ✱ are for $A^{1/3}$ = 2,3,4,5 and 6 respectively (Ref./42/).

I hope that even the examples given above allow to conclude that deep inelastic scattering of leptons on nuclei can bring a lot.

3.3. Events $\mu N \to \mu\mu X$ (experiment)

My next task is to estimate the cross sections of charmed particles production. But let me present first the data on the events of the type

$$\mu N \to \mu\mu X, \ \mu\mu\mu X \qquad (21)$$

which are submitted to this Conference /43/ (although none of the experimental group is present to answer possible questions).

The events are above the expected background from the π- and K-decays (see Fig.17). The cross section is estimated as

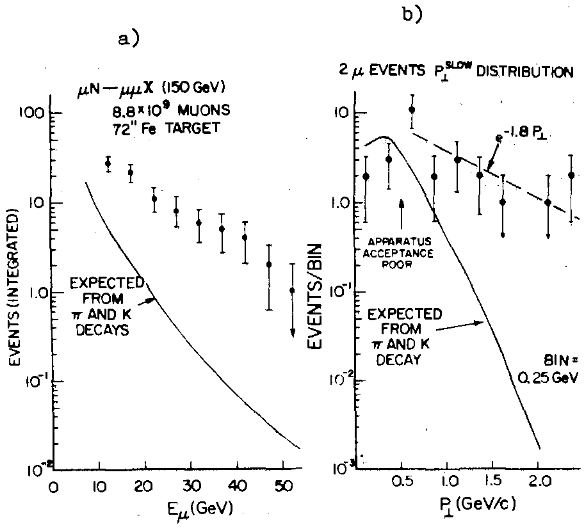


Fig. 17

a). The dimuon events with extra muon energy $E_2 > E_\mu$ in muon interactions. Expected number of muons from π- or K-decays in hadron cascade is shown in solid curve (Ref. 43)

b). Transverse momentum distributions for the extra muon in dimuon sample. The distribution expected from π- and K-decays is shown in solid curve. (Ref. 43)

---

*) See, however, the Wagener's Talk at Session A7 for a warning concerning radiative corrections.

$$\frac{\sigma(\mu N \to \mu\mu X)}{\sigma(\mu N \to \mu X)} \sim 10^{-3} \qquad (22)$$

and has threshold behaviour (W > 7–8 GeV). The events lie at high Q^2 and large ω, $\langle\omega\rangle = 20$.

Conclusions (by Chen [43]):

- signal for charmed production is observed,
- this is responsible for a sizeable part of scaling violations at small x (see Section 2.1).

3.4. Production of a charmed quark off a light quark

I would like to discuss now the problems encountered in a calculation of the cross section of charmed particle production. I do not intend to compare the results obtained within some specific model with experimental data since this problem is dealt with by some other rapporteurs at this Conference.

From theoretical point of view all the processes of new particle production naturally fall into two categories. These are production off a light and off a heavy quark. The examples are

$$\nu d \to \mu^- c \qquad (23)$$

and

$$\nu \bar{c} \to \bar{d}\mu \qquad (24)$$

respectively, where d and c are the down and charmed quarks.

The first case can be adequately described within the parton model and reduces in fact to some kinematics. The point is that the density of light quarks can be extracted in an independent way. The only difference as compared to the standard case is the account for a heavy quark mass.

Thus, if the initial quark carries z-th fraction of the nucleon momentum, then from the energy-momentum conservation we get [44]

$$z = (Q^2 + m_c^2)/2m_N\nu \qquad (25)$$

and this is a true scaling variable now. (It can be corrected for the target mass in the same way as x , see Eq. (19) [34]).

Moreover, the heavy quark mass m_c must be kept in the matrix element squared as well. In this way we get, e.g., for the cross section of reaction (23)

$$\frac{d^2\sigma}{dz\,dy} = \frac{G^2 s}{\pi} \sin^2\theta_c \left(z\,d(z)\right)\left(1 - \frac{m_c^2}{sz}\right); \qquad (26)$$
$$\frac{m_c^2}{sz} \leq y \leq 1 \;;\quad \frac{m_c^2}{s} \leq z \leq 1$$

if the interaction is of the usual (V–A) form, $d(z)$ is the quark density).

In spite of the triviality of the substitution (25) there is an important message in it. Namely, m_c^2 enters along with Q^2 , not the total energy. Since Q^2 is only a small fraction of s (in the antineutrino interaction $Q^2 \sim (1/20)s$) this implies "slow" rescaling. In the other words, the initial energy must be very large to make the threshold effect of heavy quark production negligible.

Detailed numerical estimates of the new particle production cross section can be found in Refs.[44] .

If we turn now to quantum chromodynamics, then there arise some extra log factors. To account for these factors one must, as usual, consider the moments from the structure functions. The difference due to high quark mass reduces to the substitution of $\ln Q^2$ in all the standard expressions by $\ln(Q^2 + m_c^2)$. We have, e.g., [30,34]

$$\int_0^1 F^{(d\to c)}(Q^2, z)\,dz = \int_0^1 F^{(d\to u)}(Q^2 + m_c^2, x)\,dx \qquad (27)$$

where $F^{(d\to u)}$ and $F^{(d\to c)}$ are the structure functions induced by the $d \to u$ and $d \to c$ transitions, respectively.

The effects due to the log factors are not large, however, and one may rely on the simple parton model for rough estimates.

Moreover, there is an additional problem as to how relate the moments to the cross sections which are measurable in the most direct way. The simplest and rather reliable way /22a,45/ is just to replace Q^2 by its mean value $\langle Q^2 \rangle$ ($\langle Q^2 \rangle \simeq s\langle xy \rangle$ and $\langle x \rangle$ depends on whether we deal with valence quarks or the sea).

Therefore, there are no much problems as far as theory is concerned. The real problem arises if the result is sensitive to the sea contribution. There is no reliable measurements of the sea component at sufficiently large Q^2 (i.e., in the scaling region). (Asymptotic freedom gives an additional variation of the sea with Q^2 but this seems to lie within a factor of two and does not exceed the existing uncertainty in the experimental numbers).

Measurements of sea at, say, $Q^2 = 50\,\mathrm{eV}^2$, would be very helpful in this respect. Nowadays, one has to rely more on intuition or some theoretical models.

3.6. Photoproduction of charmed particles

If the heavy quark is in the initial state, then there is no much help in the parton model since it gives no idea on the mass dependence of the quark density. Quantum chromodynamics as an interaction theory makes much better in this case.

First of all, it is rather clear that the relative contribution of charmed particles production into the total cross section grows with Q^2. This can be seen from the uncertainty principle.

Let us consider electroproduction of charmed particles. It can be viewed as a fluctuation of the photon into a pair of charmed quarks with subsequent scattering of one of them on the target. The time of fluctuation is of the order

$$\tau \sim \nu/(4m_c^2 + Q^2) \tag{28}$$

and is much smaller than the time relevant to the usual electroproduction

$$\tau' \sim \nu/(\varkappa^2 + Q^2) \tag{29}$$

if $Q^2 \ll 4m_c^2$. The smallness of the time available results in the smallness of the cross section. With growing Q^2 this factor dies away.

Thus, even for a real photon ($Q^2 = 0$) the space-time picture of the charmed particles production is similar to that of electroproduction with $Q^2 \sim m_c^2$. This allows to apply the theory of deep inelastic scattering to charmed particles photoproduction.

The absence of the charmed quarks in the initial state implies that only the loop graphs with c-quarks in the intermediate state must be kept. Moreover, as far as charmed quarks are considered to be heavy the loop graph reduces to some local operator constructed from the fields of the light quarks and gluons. The matrix elements from these operators are to be extracted from the experimental data on deep inelastic.

Proceeding in this way one gets /46/

$$\int_{\text{threshold}}^{\infty} \frac{d\nu}{\nu^2}\sigma_c^\gamma = \frac{22\pi}{405}\rho\frac{\alpha\alpha_s(m_c^2)}{m_c^4}m_N \tag{30}$$

where ρ is the fraction of the nucleon's momentum carried by gluons as is measured in deep inelastic scattering at $Q^2 \sim m_c^2$ ($\rho \approx 0.5$), σ_c^γ is the cross section of charmed particles photoproduction, m_c is the charmed quark mass, $\alpha_s(m_c^2)$ is the effective coupling constant of strong interactions, $\alpha_s \equiv g^2/4\pi$ and $\alpha = 1/137$.

Substituting $m_c = 1.6$ GeV, $\alpha_s(m_c^2) = 0.3$ and using experimental data on the Ψ-meson photoproduction we find that the latter contribution is about 1/20 from the total photoproduction of charm. The prediction seems quite reasonable. It is worth emphasizing that the prediction does not use as an input any information on the cross section of the ΨN interaction which is crucial for conventional models of Ψ- meson photoproduction.

Other processes of the charmed particles production can be treated in a similar way . (It might worth mentioning that the result does not reduce to introducing any new scaling variable).

Conclusions to the Talk

- parton model works not bad indeed,
- asymptotic freedom may show up,
- the overall picture has not yet settled in but it may be simple (rather small effective coupling constant at (1-2) GeV^2 + precocious scaling + preasymptopia).

As to the applications:

- lepton-nuclear scattering can be used to probe the nature of nuclear forces and to study the space-time picture of the parton model,
- if partons + quantum chromodynamics are reliable, then there are no major theoretical problems with describing charmed particles production.

Acknoledgements

I am grateful to G.Altarelli, J.D.Bjorken, S.Brodsky, F.Close, S.S.Gerstein, N.N.Nikolaev, V.A.Novikov, L.B.Okun, M.A.Shifman, Yu.A.Simonov, M.I.Strikman, V.A.Khoze, M.V. Terentjev, A.I.Vainshtein for valuable discussions of the problems considered in the Talk. I am also thankful to H.L.Anderson, D.O.Caldwell, K.W.Chen, M.Duong Van, V.S.Kaftanov, V.D.Khovanskij, A.K.Mann, T.Quirk, B.Roe, A.Sessoms, G.Weber for explaining to me the experimental situation and to the Scientific Secretaries N.N.Nikolaev and M.A.Shifman for generous help in preparing the Talk. I am grateful to A.I.Vainshtein for numerous discussions and hospitality during my stay at Novosibirsk where part of this Talk was prepared.

References

1. R.P.Feynman, Photon-Hadron Interactions, Benjamin, N.Y. (1972).
J.D.Bjorken, Proc.of the 1971 Int.Symp. on Electron and Photon Interactions, Cornell Univ.press (1972), p.282.
H.D.Politzer, Phys.Repts., 14, 130 (1974).
J.Kogut, Particles and Fields, 1974 Meeting of APS, N.Y., (1975) p.450.
F.J.Gilman, Proc.XVIII Intern.Conf. on High Energy Physics, Rutherford Laboratory, London, (1974), IV-149.
C.H.Llewellyn-Smith, Proc. 1975 Int.Symp. on Lepton and Photon Interactions, Stanford, 1975, p.709.
P.V.Landshoff, H.Osborn, CERN preprint, TH-2157 (1976).
2. Ph.Heusse, Proc. of the XVI Int.Conf. on High Energy Physics, Batavia-Chicago (1972), v.II, p.206.
3. E.A.Paschoz, preprint NAL-Conf-73/27 (1973), Batavia.
V.I.Zakharov, in "Elementary Particles", Atomizdat, Moscow (1973), v.1, p.82 (In Russian).
4. a) V.Matveev, R.Muradyan, A.Tavkhelidze,Lett. Nuovo Cim., 7, 719 (1973).
b) S.Brodsky, G.Farrar, Phys.Rev.Lett., 31, 1153 (1973), Phys.Rev., D11, 1309 (1975).
5. R.E.Taylor, Proc. 1975 Int.Symp. on Lepton and Photon Interactions, Stanford (1975), p.679, See also Ref. /7/ .
6. S.D.Drell, T.M.Yan, Phys.Rev.Lett., 24, 181 (1970),
G.B.West, Phys.Rev.Lett., 24, 1206 (1970).
7. W.B.Atwood, Ph.D.Thesis, SLAC Report 185 (1975).
8. H.L.Anderson et al. (CHIO Collaboration) contributed paper B2 (24).
9. W.Krenz, Talk at 1976 Int.Conf. on Neutrino Physics, Aachen, June 1976.
10. A.Benvenuti et al. Phys.Rev.Lett., 36, 1478 (1976).
11. J.W.Chapman et al., Neutrino-Proton Interactions at Fermilab Energies, contributed paper.
CHIO Collaboration "Some Data on Muon--Hydrogen Scattering from 1974 and 1975 Runs", contribute paper.
T.P.McPharlin et al., contributed paper B2 (22).

12. H.L.Andersen et al., Diffractive Production of Rho Mesons by 150 GeV Muons", contributed paper.
13. P.Joos et al., preprint DESY 76/17 (1976).
14. V.N.Gribov, in "Elementary Particles", Atomizdat, Moscow (1973), vol.1, p.65. (in Russian).
15. N.N.Nikolaev, V.I.Zakharov, Yad.Fiz., 21, 434 (1975); Review Talk at Int.Seminar "Quarks and Partons", Moscow, 1974 (Chernogolovka preprint (1975)).
16. P.V.Landshoff, J.C.Polkinhorne, R.D.Short, Nucl.Phys., B28, 225 (1971).
17. V.B.Berestetskij, M.V.Terentjev, contributed paper C4 (28) .
18. G.Farrar, D.R.Jackson, Phys.Rev.Lett., 35, 1416 (1975).
19. B.L.Ioffe, preprint ITEP-50, Moscow (1976).
20. A.Zee, F.Wilczek, S.B.Treiman, Phys.Rev., D10, 2881 (1974).
21. a) A.M.Polyakov, Proc. XV Int.Conf. on High Energy Physics, 1970, Kiev Naukova Dumka (1972), p.509.
G.Mack, Phys.Rev.Lett., 25, 400 (1970).
N.Christ, B.Hasslacher, A.Mueller, Phys.Rev., D6, 3543 (1972).
b) D.J.Gross, F.Wilczek, Phys.Rev., D8, 3633 (1973); D9, 980 (1974).
H.Georgi, H.D.Politzer, Phys.Rev., D9, 416 (1974).
D.Bailin, A.Love, Nucl.Phys., B75, 519 (1974).
22. a) V.A.Novikov, M.A.Shifman, A.I.Vainshtein, V.I.Zakharov, preprint ITEP-112, Moscow (1976).
b) G.Parisi, R.Petronzio, Phys.Lett., 62B, 331 (1976).
23. D.J.Fox et al., Phys.Rev.Lett., 33, 1504 (1974), Y.Watanabe et al., Phys.Rev.Lett., 35, 901 (1975),
C.Chang et al., Phys.Rev.Lett., 35, 898 (1975).
24. D.H.Perkins, Proc.of 1975 Int.Symp. on Lepton and Photon Interactions, Stanford, (1975), p.571.
25. H.L.Anderson, T.Quirk, private communication and Ref./8/ .
26. M.Chanowitz, S.D.Drell, Phys.Rev.Lett., 30, 807 (1973), Phys.Rev., D9, 2078 (1974).
27. E.M.Levin, M.G.Ryskin, Zh.Exp. i Teor.Fiz., 69, 1537 (1975).
28. V.V.Anisovich et al., Zh.Exp. i Teor.Fiz., 70, 1613 (1976).
S.S.Gershtein, V.N.Folomeshkin, preprint IHEP, Serpukhov (1976).
29. V.I.Zakharov, B.L.Ioffe, L.B.Okun, Zh. Exp. i Teor.Fiz., 68 , 1635 (1975).
30. E.Witten, Nucl.Phys., B104, 445 (1976).
31. A.M.Polyakov, Zh.Exp. i Teor.Fiz., 59, 542 (1970); 60, 1572 (1971).
V.N.Gribov, L.N.Lipatov, Yad.Fiz., 15 , 781 (1972).
J.Kogut, L.Susskind, Phys.Rev., D9, 697, 3391 (1974).
32. A.DeRujula, Phys.Rev.Lett., 32, 1143 (1974).
D.Gross, S.Treiman, Phys.Rev.Lett., 32, 1145 (1974).
33. O.Nachtman, Nucl.Phys., B63, 237 (1973).
34. H.Georgi, H.Politzer, Phys.Rev.Lett., 36, 1281 (1976); 37, 68 (1976).
35. V.Baluni, E.Eichten, contributed paper B2 (21) .
36. C.G.Callan, Jr., N.Coote, D.J.Gross, Phys. Rev., D13, 1649 (1976);
M.B.Einhorn, contributed paper, B2(1).
37. E.Bloom, Proc. of 1975 SLAC Summer School, SLAC Report No.191, Stanford, 1975, p.25.
38. L.L.Frankfurt, M.I.Strikman, preprint LNPI-238, Leningrad (1976).
39. G.DeFranceschi, F.Palumbo, Yu.A.Simonov, preprint LNF-76 (P), Rome (1976).
40. L.L.Frankfurt, M.I.Strikman, preprint LNPI-227, Leningrad (1976).
41. V.V.Borog, V.G.Kirillov-Ugryumov, A.A.Petrukhin, contributed paper B2 (27) .
42. G.V.Davidenko, N.N.Nikolaev, contributed paper B2(10), N.N.Nikolaev, Pis'ma v Redakziu ZhETF, 22, 419 (1975).
43. K.W.Chen, Invited Talk at the Int.Conf. on New Particles, Madison, Wisc., 1976, preprint MSU-CSL, Michigan (1976).
44. V.I.Zakharov, Proc. of the Int.Conf. "Neutrino-75", Balatonfured(1975),v.II, p.151; preprint ITEP-91, Moscow (1975).
R.M.Barnett, Phys.Rev.Lett., 36, 1163 (1976).
45. G.Altarelli, G.Parisi, R.Petronzio, contributed paper, B3 (25).
46. M.A.Shifman, A.I.Vainshtein, V.I.Zakharov, preprint ITEP-114, Moscow (1976).