CBPF-NF-006/81
IFT-P.01/81

HEAVY QUARK FUSION AND RECENT DATA ON CHARM MUON-PRODUCTION

by

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ABSTRACT - The heavy quark fusion mechanism for the hadronic production of $Q\overline{Q}$ bound states is considered in view of the recent results on charm muon-production. We present arguments against a contribution of $C\overline{C}$ fusion to the production of hidden charm.

Among the earliest theoretical attempts to explain the hadronic production of heavy $Q\overline{Q}$ bound states[1], is the mechanism involving the fusion of heavy quarks Q, coming from the sea component of the colliding hadrons[2-6]. The main ingredients in this kind of model are: 1)the sea distribution of heavy flavours, 2)the coupling constant of the bound state to its heavy quarks constituents, 3) a light quark-anti-quark fusion component to build up the cross-section at low energies.

For a $Q\overline{Q}$ fusion model to be compatible with both the energy dependence of the total cross-section and the x_F- distribution, $\frac{d\sigma}{dx_F}$, it is necessary to assume a rather broad sea distribution, behaving as $(1-x)^5$ for nucleons and $(1-x)^2$ for pions[4], at a mass scale $Q^2=M_\psi^2$ and $(1-x)^7$ for nucleons and $(1-x)^{3.5}$ for pions[6] at the mass scale of the Υ. If the above sea distributions were instead chosen to be compatible with deep inelastic lepton-scattering data[7] and the Drell-Yan continuum[8], the total cross-section so obtained would rise too steeply with the energy and the x_F-distribution would be narrower than the experimental one[1]. On the other hand, when considering the heavy quark distribution in this model, no attempt is made at including threshold effects and a proper kinematics for dealing with the massive quark. As a consequence it is assumed that the heavy quark distribution covers the whole kinematical range $0\leq x\leq 1$.Even if we adopt the procedure of Buras and Gaemers[9], who take $C(x)= 0$ at a certain value of $Q^2(Q_0^2 = 1.8\text{Gev}^2)$,the charmed quark distribution builds up significantly at higher values of Q^2 and still does not include threshold effects.

The overall normalization of this model depends on the coupling constant of the bound state to the heavy quarks. If $\frac{g^2_{\psi c\bar{c}}}{4\pi} \simeq 0.5$, as appropriate for a strong coupling, the cross-sections so obtained are above the data by a factor of about twenty[4]. This discrepancy is resolved in an "ad hoc" manner by assuming that the sea is not SU(4) symmetric, therefore there must be a suppresion factor[4], called σ_c, whose origin is not well understood, which lowers the charm distribution with respect to the up, down and strange seas. Since the coupling constant and the supression factor come together in the combination $g^2/4\pi\ r^2_c$, it is not possible to separate them[10].

In our opinion there is a serious objection to the use of a Drell-Yan type process employing heavy quarks, to form a bound state. The heavy quarkonia are non-relativistic bound states, wherein the constituents move slowly[11]. It is not possible to achieve this condition in the Drell-Yan picture, where the constituents are moving relativistically, carrying a finite fraction of the parent hadron's momentum. At $x_F = 0$, the average longitudinal fraction of the heavy quarks is $<x> = M_{Q\bar{Q}}/\sqrt{s}$, which implies that the momentum of each quark is $<p> = \frac{M_{Q\bar{Q}}}{2}$ (or $<v^2> \simeq 0.5$)[11]. For this reason, direct fusion of a heavy $Q\bar{Q}$ pair must be supressed and quarkonium production proceeds mainly by a perturbative mechanism[1].

Another aspect which is worth stressing, is the fact that heavy quark fusion alone cannot reproduce the data at all energies; a light quark component is often added[4-6] and plays an important role at low energies[12]. A remarkable thing in this two-component fit is that we could use $q\bar{q}$ plus $Q\bar{Q}$ or instead $q\bar{q}$ plus gluon-gluon, with a gluon distribution behaving as

$(1-x)^5$ and, as expected, the amount of light quark fusion which is needed in each of the two fits is exactly the same[13]. We are thus led to conclude that what some authors call charmed quark fusion, is nothing else but gluon-gluon fusion ! We compare in Fig.1 the charmed quark distribution of Donnachie and Landshoff[4], with the usual gluon distribution, behaving as $(1-x)^5$. As can be seen from this figure, there is only a small departure between the two distributions for $x<0.2$, they being identical for $x>0.2$.

Another evidence against a significant charm component inside hadrons, which could be excited in hard scattering process[14], is provided by the recent data from the European Muon Collaboration (EMC)[15]and the Berkeley-FNAL-Princeton Collaboration (BFP)[16] on dimuon events in muon-nucleon scattering. Both experiments have clear signals for charm production,which are in good agreement with a photon-gluon fusion model[17]. This model is pictured in Fig.2. The charmed quark so produced fragments into a charmed meson which in turn decays into a muon plus other particles. A nice feature of the photon-gluon fusion model is that it incorporates the threshold effects for heavy quark production. It is well known that the charmed quark distribution so obtained is very small for $x>0.1$[17,18], indeed, it is only appreciable for $x<0.01$ (see Fig.3, of Glück and Reya , ref.17). This would imply that heavy quark fusion becomes important only at very high energies, for example, in the case of the ψ, $<x> \simeq 0.01$ implies that $\sqrt{s} \simeq 300$ GeV.

If one tries to interpret the dimuon data in terms of an intrinsic charm component inside the nucleon (Fig.3) and use for the charm distribution the Buras-Gaemers[9] fit, the resulting cross-section for dimuon events would be larger, by one order of magnitude than the experimental data[15] (Fig.4). Using instead the charmed quark distribution of Donnachie and Landshoff[4,5] in such calculation, results in an equally large cross-section, as is also shown in Fig.4.

We have thus gathered evidence against significant contribution of heavy quark fusion for the hadronic production of $Q\bar{Q}$ bound states. We call attention, however, that the absence of constraining principles in the choice of the structure functions other than fitting the data, obeying the momentum sum rule and agreeing with the Q^2 evolution predicted by QCD, is what allows the present uncertainty regarding the controversial heavy sea distribution.

ACKNOWLEDGMENTS

We acknowledge the partial support received from FAPESP.

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[10] The authors of references 4 and 5 have argued, on the basis of deep inelastic scattering data, that σ_C should be less than 0.2.

[11] The charmonium model result, for the mean square velocity of the charmed quark in the ψ is, $\langle v^2 \rangle \simeq 0.14-0.17$, see E.Eichten, K.Gottfried, T.Kinoshita, K.D. Lane and T.M.Yan, Phys.Rev.D17, 3090(1978).

[12] At $\sqrt{s} = 8.2$ GeV, the ratio $\sigma(P)/\sigma(\overline{P}) = 0.19\pm0.03$, strongly suggests a light valence quark component, see M.J.Corden et al., Phys. Lett. 96B, 411(1980).

[13] The coupling constant of the ψ to the light quarks, which fixes the normalization of the $q\overline{q}$ component, turns out to be the same, if one uses either of the two possibilities ($q\overline{q}+c\overline{c}$ or $q\overline{q}+gg$), see A.Romana, ref.1.

[14] In a recent paper by S.J.Brodsky, P.Hoyer, C.Peterson and N. Sakai(Phys. Lett. 93B, 451(1980)), it is argued that there is a significant intrinsic charm component in the hadrons, which is responsible for the hadronic production of naked charm. As stressed by these authors, the main test of their proposal would be charmed muonproduction, which as we show in this paper, does not support the existence of such an intrinsic charm component.

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FIGURE CAPTIONS

Fig.1 - Comparison between the charmed quark distribution xC(x) of Donnachie and Landshoff[4] and a counting-rule gluon distribution xG(x). The curves are normalized such as to coincide at the point x=0.2.

Fig.2 - The photon-gluon mechanism for charm production.

Fig.3 - Charm production from an intrinsic charmed sea.

Fig.4 - Differential cross-section $d\sigma/dQ^2$ for dimuon events. The data in this figure are from Ref.15, with the experimental cuts and background corrections as indicated therein. The curves are the results of the calculation outlined in the text, respecting the experimental cuts and assuming a flat fragmentation function for the c quark to a D meson and 10% branching ratio for the decay of the D to a muon. The solid line is for Buras-Gaemers[9] charm distribution, while the dashed line is for the Donnachie-Landshoff[4] corresponding distribution.

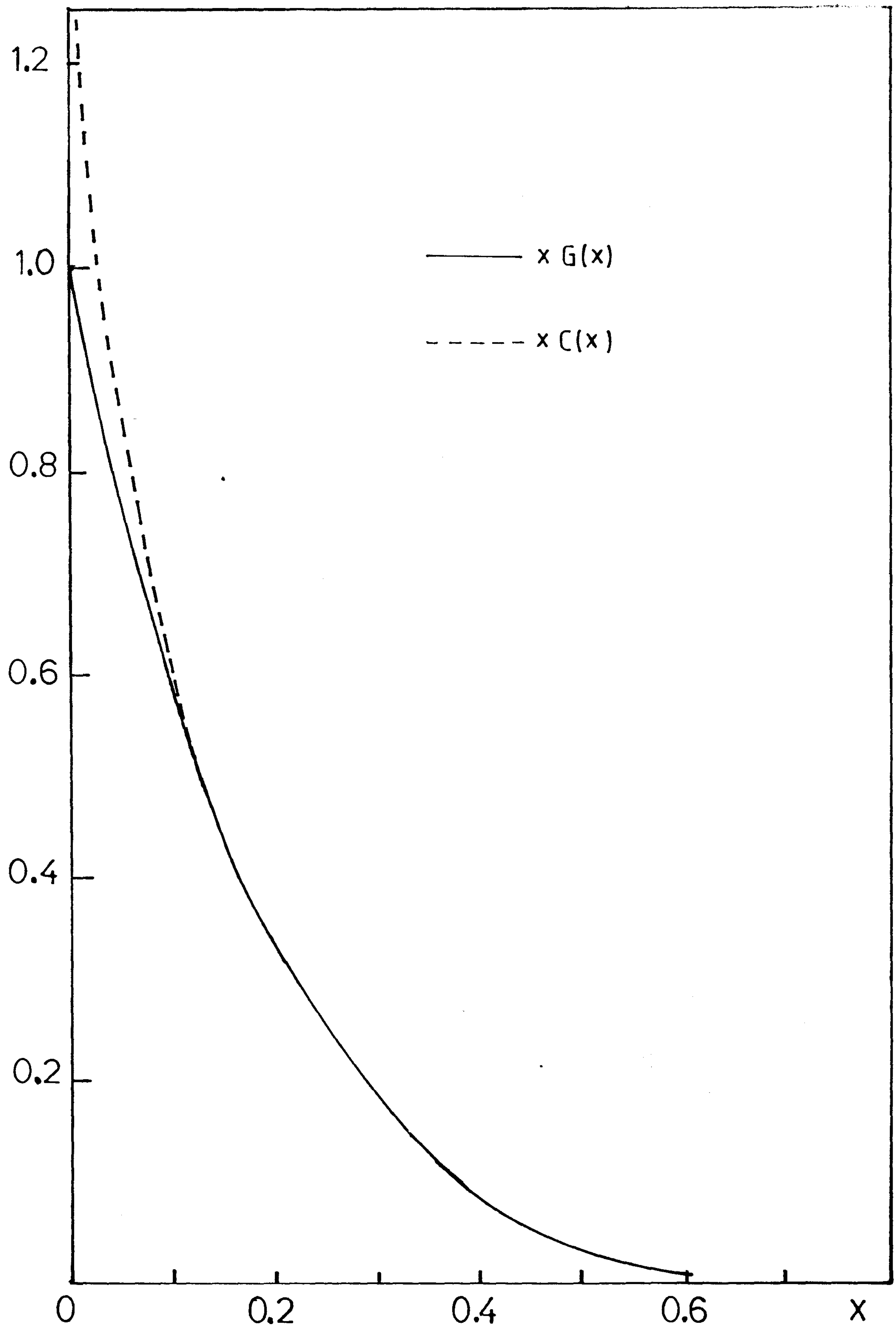

Fig. 1

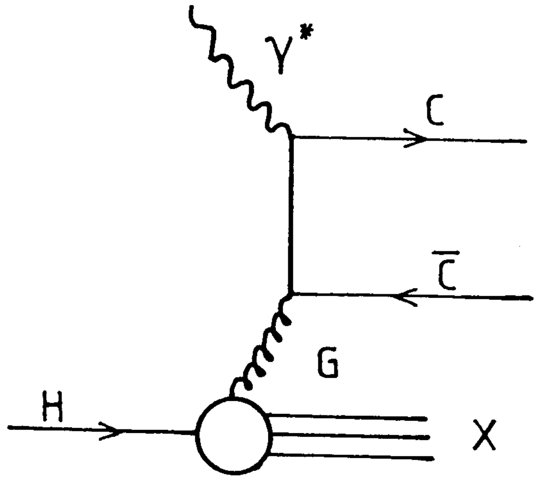

Fig. 2

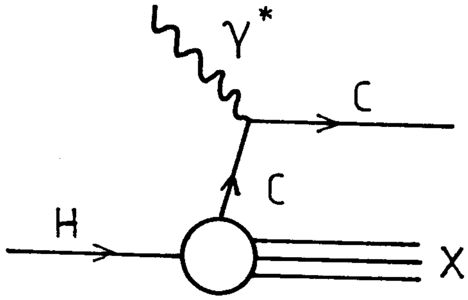

Fig. 3

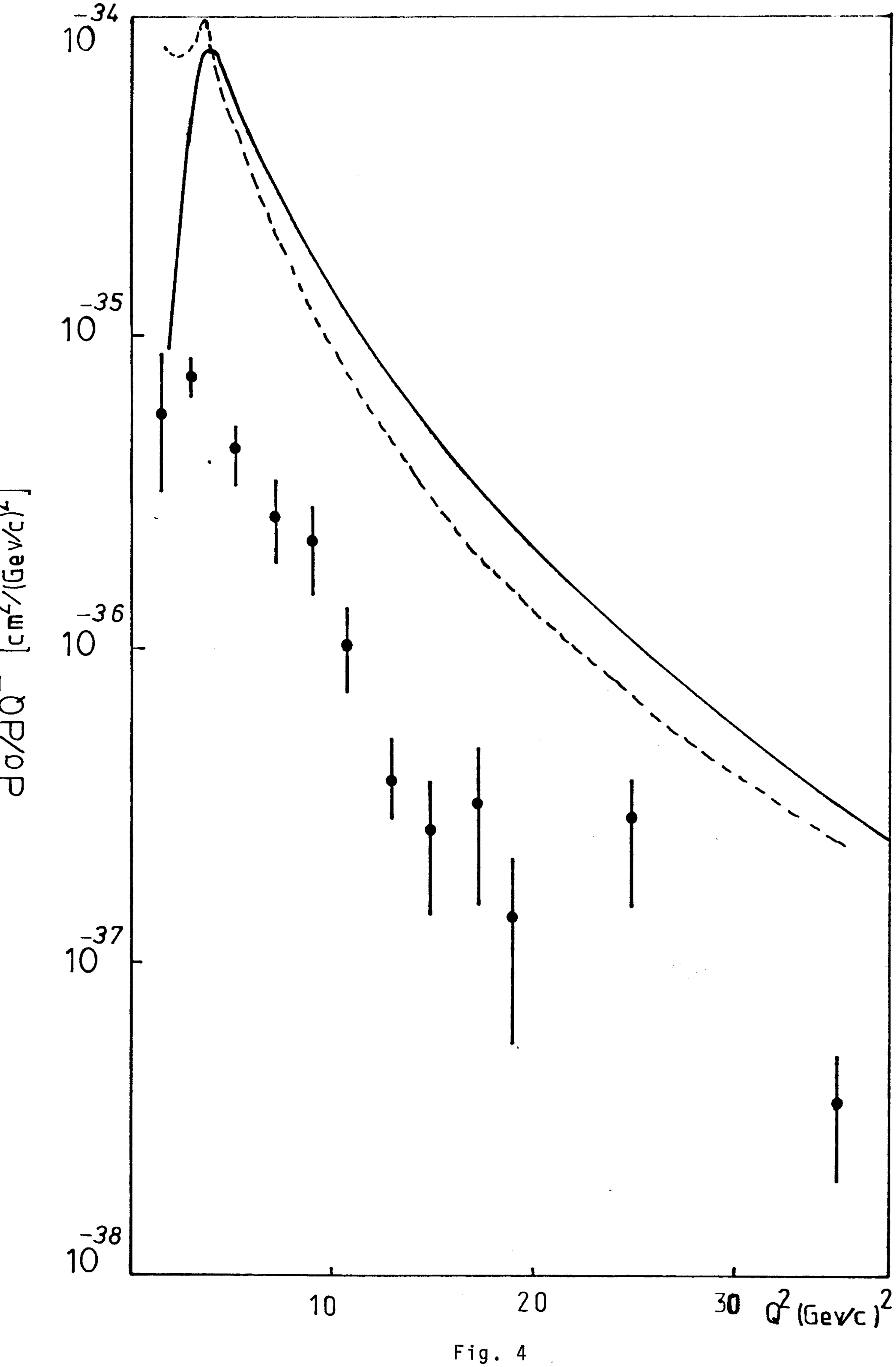
10^{-34}
10^{-35}
10^{-36}
10^{-37}
10^{-38}
$d\sigma/dQ^2$ $[cm^2/(GeV/c)^2]$
10
20
30
Q^2 $(GeV/c)^2$

Fig. 4