THE DEEP COMPTON EFFECT

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Abstract :

The various contributions to the deep Compton effect are discussed. In order to separate them, we propose to select 3-jet events and measure differences of double inclusive cross-sections. In particular this should allow extracting the box-diagram $\gamma g \to \gamma g$ contribution.

Résumé :

On passe en revue les différentes contributions à l'effet Compton inélastique. En vue de les séparer, nous proposons de sélectionner les événements à 3 jets et de mesurer des différences de sections efficaces inclusives doubles. En particulier, cela devrait permettre d'extraire la contribution du graphe carré $\gamma g \to \gamma g$.

I. Introduction

The interest of measuring the deep Compton effect $\gamma p \to \gamma X$ has been emphasized several times [1,4]. The NA 14 photon beam experiment at CERN is already collecting high p_T data in the range $100 < E_\gamma < 200$ GeV for the initial photon beam [5]. This stimulates the interest in revisiting the deep Compton effect, discussing the various contributions and the way to extract them from the data [6].

Let us list the terms to be considered :

i) The QED Compton effet $\gamma q \to \gamma q$ (Fig. 1a) where the photon couples directly to quarks.

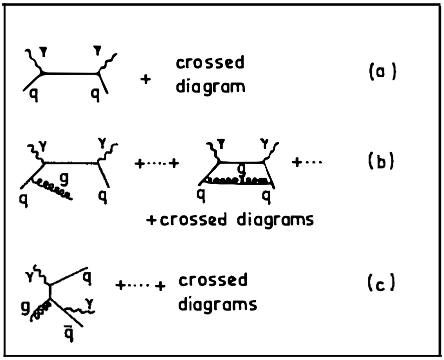

Fig. 1

Diagrams illustrating the QED Compton effect (a) and higher order corrections (b) and (c).

ii) Leading logarithm corrections (LL) involving the photon structure function and the fragmentation function describing the photon bremmstrahlung off a quark [7] (Figs. 2 and 3). As usual, these functions involve two components : the anomalous term exactly calculable in QCD and the hadronic term which may be estimated using the vector dominance model (VDM).

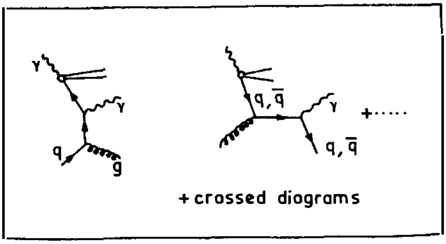

Fig. 2 : The photon structure function contribution

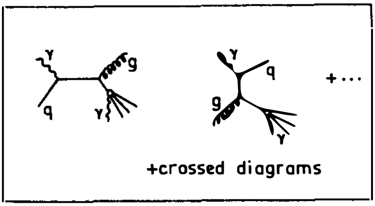

Fig. 3 : The quark into photon fragmentation function.

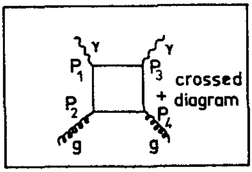

Fig. 4

iii) The box-diagram (Fig. 4)

iv) Beyond leading logarithm corrections coming from graphs of Figs. 1b and 1c. The LL corrections of these graphs are already included in ii).

We shall first study the single inclusive cross-section. In the energy and p_T range, appropriate to present experiments : $E_\gamma \sim 150$ GeV and $p_T \sim 3$ GeV/c, it turns out that the corrections due to the photon structure function and in particular to its not well-known hadronic part are large. Restricting to 3-jet events allows separating the direct coupling contributions. The next step is to isolate the QED Compton effect by measuring the difference : $\sigma(\gamma p \to \gamma\pi^+ X) - \sigma(\gamma p \to \gamma\pi^- X)$. It may be then possible to extract the box-diagram contribution by difference from the single inclusive cross-section.

II. The single inclusive cross-section

1) Direct coupling $2 \to 2$ subprocess

In this case ($\gamma q \to \gamma q$ (Fig. 1a) and $\gamma g \to \gamma g$ (Fig. 4)), the kinematics is particularly simple. Given the initial photon energy-momentum ($\frac{\sqrt{s}}{2}$ in the CM frame), the final photon momentum $(y, \vec{p}_T)$ determines the subprocess kinematics completely. Notice that the initial and final state direct coupling terms correspond to 3-jet events where the momentum of the 3rd jet recoiling against the large p_T photon is completely determined : $\vec{p}\,'_T = -\vec{p}_T$ and $y' = \mathrm{Log}\,(\sqrt{s}/p_T - e^y)$. Denoting by x the fraction of the proton momentum taken by the constituent c (quark or gluon), $\hat{s},\hat{t},\hat{u}$ the Mandelstam invariants for the subprocess $\gamma c \to \gamma c$, the single photon cross section is straightforwardly written :

$$\frac{d\sigma}{dy\, d\vec{p}_T} = \frac{1}{\pi} \frac{\sqrt{s}}{\sqrt{s} - p_T e^y} \sum_c x\, G_{c/p}(x,Q^2)\, \frac{d\sigma}{d\hat{t}}\,(\gamma c \to \gamma c) \qquad (1)$$

$G_{c/p}(x,Q^2)$ is the quark or gluon structure function in the proton. The quark structur• functions are taken from Buras and Gaemers [8] as modified by Owens and Reya [9] for the sea. The gluon content of the proton may also be taken from Owens and Reya i.e. behaving like $(1-x)^5$ at $Q_o^{\;2} = 1.8$ GeV^2 when $x \to 1$. The recent deep inelastic scattering experimental results [10], however, suggest a harder behavior : like $(1-x)^5$ for large $Q^2 \sim 10$ GeV^2 [11]. In order to describe the function, we shall perform the calculation with two extreme choices :

a) parametrization given by Owens and Reya [9]

b) $G_{g/p}(x) = 3(1-x)^5/x$

(we shall use the usual definition of Q^2 : $Q^2 = 2\hat{s}\hat{t}\hat{u}/(\hat{s}^2 + \hat{t}^2 + \hat{u}^2)$ which implies, for values of $p_T \sim 3$ GeV/c, Q^2 values close to $Q^2 \sim 10$ GeV^2 for which the experimental data favor parametrization b)).

We neglect the initial parton transverse momentum. In direct coupling terms, the smearing effects are expected to be small. The results of a detailed study are given in [12] :
for $s = 200$ GeV^2 and $p_T = 2$ GeV/c, the effect is less than 30 %.

In the case of $\gamma g \to \gamma g$, we use formulae given in ref. 4). As emphasized there, for sufficiently small values of $-\hat{t}/\hat{s}$ ($\frac{d\sigma^{box}}{d\hat{t}}$ increases when $-\hat{t}/\hat{s}$ decreases whereas $\frac{d\sigma^{Compton}}{d\hat{t}}$ decreases in the forward direction) and x (more gluons) the box diagram may contribute a substantial amount to (1).

Let us discuss numerical results. Calculations have been performed for E_γ = 150 GeV and 400 GeV (Tevatron energy) and p_T = 3 GeV/c. As seen on Fig. 5 the box-diagram becomes appreciable compared to the QED Compton graph in the forward direction : when E_γ = 150 GeV and y $\simeq$ 1.5 the ratio box/Compton

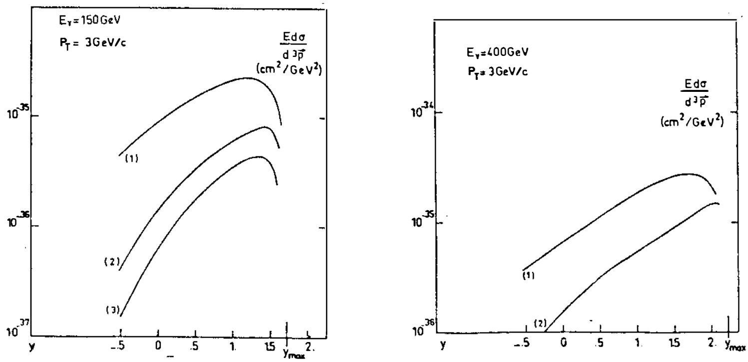

Fig. 5

The single inclusive cross-section plotted as a function of y. The curve (1) is the Born term $\gamma q \to \gamma q$. Curves (2) and (3) represent the $\gamma g \to \gamma g$ contribution with the gluon structure function taken from parametrizations b) and a) respectively.

$\sim$ 0.2 or 0.45 with parametrizations a) and b) for the gluon structure function. For E_γ = 400 GeV, this ratio is higher, about .6 when y $\simeq$ 2. (These calculations are performed with Λ = 0.3 GeV).

2) Leading Log corrections

A discussion of the results of ref. 2) leads to an estimate of these corrections [6]. It turns out that the photon-structure function contribution is large, in particular its hadronic part which may be calculated in an approximate way from VDM. In order to get rid of such a large source of uncertainty, we propose to select 3-jet events as a way of measuring the direct coupling terms only. The selection efficiency may be improved by imposing a trigger on the rapidity of the jet which recoils against the photon ($y' = \mathrm{Log}(\sqrt{s}/p_T - e^y)$.

3) QCD soft gluon corrections

A simple method has recently been proposed [13] to calculate the large constant factors due to soft gluon loops. In our case, it is easy to derive that the $0(\alpha_s)$ diagrams to be considered do not contribute any such large π^2 factor. Beyond leading log corrections are thus expected to be small [6].

Many uncertainties remain, however, which forbid a definite determination of the subprocesses at work when measuring single inclusive cross-section in the 3-jet sample : gluon structure function, primordial transverse momentum ... Therefore it will be difficult in particular to prove or disprove the presence of the box contribution in the data. We propose to adopt the following strategy.

II. The double inclusive cross-sections

The additional observation of charged hadrons in the jet opposite to the large p_T photon provides a clear way to isolate the Compton subprocess. Let us define the quantity $\Delta^{\pi^+ - \pi^-} = (d\sigma(\gamma p \to \gamma\pi^+ X) - d\sigma(\gamma p \to \gamma\pi^- X))/d\vec{p}_T\, dy\, dp_{2x}$ where p_{2x} is the $\pi^\pm$ hadron momentum component $\perp$ to the collision axis in the scattering plane. $\Delta^{\pi^+ - \pi^-}$ receives no contribution from $\gamma g \to \gamma g$ nor from $\gamma g \to \gamma q\bar{q}$ and from previous experience [14] we may expect that the 4-jet event contribution is considerably depressed. The main contribution to $\Delta^{\pi^+ - \pi^-}$ thus comes from the QED Compton effect. As previously [6], we expect next-to-leading log corrections to be small. The integrated quantity

$$\Delta^{\pi^+ - \pi^-}(\vec{p}_T, y) = \int_{p_{2x}^{min}}^{p_{2x}^{max}} dp_{2x}\, \Delta^{\pi^+ - \pi^-}(\vec{p}_T, y, p_{2x})$$ is plotted as a

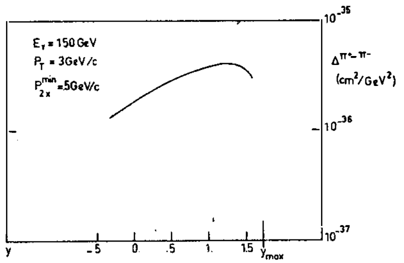

Fig. 6
The double inclusive cross-section difference $\Delta^{\pi^+-\pi^-}(\vec{p}_T, y)$

function of y on Fig. 6. The cross-section although smaller than the single inclusive one is still sizable.

If the data were precise enough and the fragmentation functions well known, it could be possible to go back from $\Delta(\vec{p}_T, y)$ to the single inclusive Compton cross-section and to subtract this latter from the data in order to isolate the box contribution.

IV. Conclusion

We propose a way to interpret the deep Compton effect data by isolating the calculable terms : the QED Compton effect and the box-diagram. Selecting 3-jet events and measuring differences of double inclusive cross-sections may allow extracting separately both subprocesses (at 400 GeV, the situation will be more favorable in that in the forward direction, they are of the same order of magnitude).

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