LAL 90-37
May 1990

Laboratoire de l'Accélérateur Linéaire

POINT-LIKE INTERACTIONS OF PHOTONS IN HIGH P_T PHOTOPRODUCTION

Guy Wormser

Talk given at the Workshop on Vector Dominance Phenomena
20 – 21 February 1990, Göttingen, Germany

U.E.R
de
l'Université Paris-Sud

Institut National
de Physique Nucléaire
et
de Physique des Particules

Bâtiment 200 - 91405 ORSAY Cedex

LAL 90-37
May 1990

POINT-LIKE INTERACTIONS OF PHOTONS IN HIGH P_T PHOTOPRODUCTION

Guy WORMSER
Laboratoire de l'Accélérateur Linéaire, IN2P3-CNRS
et Université de Paris-Sud, F-91405 Orsay Cedex, France

ABSTRACT

High p_T photoproduction offers a unique opportunity to observe the interplay between VDM-like and point-like interactions of the photon. The relative strength of these two phenomena strongly depends of the selected final state: high p_T photon, high p_T hadron or J/ψ . The results obtained by the NA14 experiment at the CERN-SPS concerning the inclusive cross-section for such reactions as well as detailed properties of the associated final state are reported here.

INTRODUCTION

It is well known that low p_T photoproduction processes can be well described by the VDM formalism, that is the assumption that the incoming photon is equivalent to the superposition of ρ, ω and ϕ vector mesons. However, at higher p_T , the point-like interaction, that is the direct coupling between the photons and the constituent quarks, will become dominant. It is therefore very interesting to study the transition between these two regimes.

This experimental program was carried out by the NA14 collaboration, at the CERN SPS, between 1980 and 1984. The photon beam was an intense (10^7 γ per burst) tagged wide band photon beam, with a mean energy of 90 GeV. The large acceptance spectrometer[1] allowed the study of a variety of final states in great detail. The experimental setup is displayed in figure 1, where can be seen the three electromagnetic calorimeters used for γ and π° reconstruction and the two magnets and the set of MWPCs used for charged tracks analysis.

1. High p_T prompt photon photoproduction

This reaction, the elastic photon-quark scattering, was suggested 20 years ago by Bjorken and Paschos to measure the quark charges[2]. It is an excellent way to exhibit point-like interactions of the photon. since important features are indeed met :

- The VDM contribution in the p_T range between 2 and 3 GeV/c is quite small, of the order of 1 %, as inferred from the prompt photon hadroproduction results in that kinematical domain[3].

- The Born term, the γ -quark elastic scattering or QED Compton graph, is readily calculable and it only involves the nucleon structure function. The leading logarithm QCD corrections to this term have been calculated and are found to be large at low p_T and decreasing with p_T [4].

- The next-to-leading order terms have also been calculated and turned out to be small, giving a good confidence in the convergence of the pertubative computation.

On the experimental side, the extraction of a prompt photon signal is a difficult task because of the large background of non-prompt photons coming from π° and η decays. In NA14, this contamination was measured in two ways: firstly by a MonteCarlo program based upon a careful simulation of the electromagnetic calorimeters, and secondly by an experimental measure fo the yield of prompt photon candidates obtained in a π^- beam where as mentioned above, no prompt photons are expected.

The results obtained[1] are summarized in figure 2, where the measured prompt photon cross-section, expressed in units of the QED Compton cross-section, is plotted against p_T . In the absence of the QCD corrections, the measured value should be 1, regardless of p_T . Were the quark charge integers, the result should be at least 2.65. The solid line is the QCD prediction computed beyond the leading order terms. The data exclude the interger charge model and are in good agreement with the QCD prediction.

We have also been able to perform a topological isolation of the QED Compton term, thanks to its specific γ -jet topology[5]. Figure 3 represents the distance between the high p_T photon and all the other tracks in the event. The distance is defined as $d^2=(\Delta\phi)^2 + (\Delta\eta)^2$, where ϕ and η are the azimuth angle and the pseudorapidity. The dotted line represents the distance distribution for events containing a reconstructed high p_T π° , which is, to a very good approximation, the distribution for non prompt photons. A clear difference is observed, showing the presence of isolated prompt photons, with all other tracks at large distance from it, that is the expected topology from QED Compton scattering. The solid line represents the fit to the data of the sum of a QED Compton term , simulated by Monte-Carlo, and the non prompt photon term. The fraction of events produced by the QED Compton term was thus measured to be 0.34 ± 0.06 for p_T above 2.5 GeV/c and 0.05 ± 0.02 below, in good agreement with inclusive measurements.

The predicted charge asymmetry in the final state of QED Compton events, due to the electromagnetic coupling favoring u quarks over d quarks by a factor 16, is also observed. Figure 4 shows the charge asymmetry as a function of the distance defined above. At large distance, i.e inside the hadronic jet recoiling against the photon, the measured positive charge asymmetry is in good agreement with the QED Compton fraction mentioned above, since u quarks lead to an asymmetry of 33 % after hadronisation.

In summary, the measurement of the prompt photon signal shows unambiguously the point-like interaction of the photon beam. All the observed properties of the events (rate, topology, charge asymmetry) have been found compatible with the expectations from the QED Compton scattering, once pertubative QCD corrections have been applied.

2. High p_T π° photoproduction[6]

In this reaction, the VDM contribution to the total cross-section is large and should be dominant at low p_T . It has been estimated using the experimental measurements of π° *hadroproduction* with the assumption that ρ-production is well described by the mean of π^+ and π^- production. The systematic uncertainty on the VDM component is estimated to be of 10 %. The point-like interaction proceeds at the Born term level, through QCD Compton scattering (γ q$\rightarrow$ qg) and γ -gluon fusion (γ g$\rightarrow$ $q\bar{q}$). These terms are directly proportional to α_s and therefore this reaction constitutes a good laboratory to test pertubative QCD. Higher order terms are predicted beyond leading logarithm approximation[7].

Figure 5 displays the π° cross section as a function of p_T . The dotted curve repre sents the VDM prediction which fails to explain the data by a factor 2. The solid line is the sum of the VDM and point-like contributions and reproduces well the data. This good agreement is achieved when :

- the VDM and QCD contributions are simply added
- the next-to-leading log terms are taken into account
- the gluon fragmentation is as hard as a quark's one

The QCD cross-section is of the same order of magnitude as the VDM term on the whole kinematical domain except in the low p_T , low p_l region (Fig. 6). Similar results have been obtained with charged pions in the final state[8].

With such an high signal to background ratio,topological differences between γ and π^- beam can be looked for. Striking difference are observed on figure 8, where the distance is defined as in the previous paragraph. Clearly,γ data look more jet-like and this is a good signature of QCD terms. This topological difference explains the absence of double counting between the VDM and QCD terms observed in the inclusive measurements.

The observed charge asymmetry (Fig. 8) can only be produced by the QCD Compton term, when the high p_T triggering particle comes from the gluon jet,hence confirming the hard fragmentation of the gluon in this Q^2 range.

3. J/ψ photoproduction[9]

This reaction is interesting because it can be interpreted using two different approaches : a VDM approach, where the photon couples to the J/ψ before interacting with the nucleus and the J/ψ is then scattered through the nuclear matter[10], or a QCD approach where the J/ψ is produced by the recombination of a $c\bar{c}$ pair produced by γ -gluon fusion. The p_T dependance of the cross section is shown in figure 9, where the three components : coherent elastic, incoherent elastic and inelastic can be easily distinguished.

For incoherent elastic J/ψ scattering, both approaches are in fact equivalent and predict the same cross-section, in good agreement with the experimental measurement. The A dependance of the cross section will bring information upon the real mechanism at work[11].

For the inelastic scattering, the pertubative QCD computaion predicts the correct shape for the z and p_T distribution but is off in rate by a large factor. It is interesting to note that a pure gluon jet sample can be obtained in inelastic J/ψ photoproduction and could therfore be used for detailed quark-gluon fragmentation comparison.

4. Conclusion

High p_T photoproduction offers a unique opportunity to observe the interplay between the point-like and VDM-like interactions of the photon. The relative strength of these two phenomena strongly depends of the selected final state.

In high p_T γ photoproduction, the VDM contribution is negligible and the elastic photon-quark scattering (QED Compton scattering) has been observed. Its cross-section is in good agreement with prediction once the pertubative QCD corrections have been applied. In high p_T π° production, VDM and point-like terms have the same order of magnitude but the final state topology is very different in the two cases. Finally, in elastic incoherent J/ψ photoproduction, both VDM and point-like approaches can be used to interpret the data in a satisfactory manner.

References

1. P. Astbury et al., Phys. Lett. 152B, 5, 6 (1985) 419.
2. Bjorken and Paschos, Phys. Rev. 185 (1969) 1975.
3. High momentum transfer reactions, Session 8, in the Proceedings of the XXIV International Conference on High Energy Physics, pp. 713, Munich, 1988, Springer-Verlag (Kotthaus and Kuhn editors)
4. Aurenche et al., Z. Phys. C24 (1984) 309.
5. Augé et al., Phys. Lett. 182B (1986) 409.
6. Aurenche et al., Phys. Lett. 135B (1984) 164.
7. Augé et al., Phys. Lett. 168B (1986) 163.
8. Augé et al., Phys. Lett. 174B (1986) 458.
9. Barate et al., Z. Phys. C33 (1987) 505.
10. Sakurai and Schildknecht, Phys. Lett. B40 (1972) 121.
    Margolis, Phys. Rev. D17 (1978) 1310.
11. Sokoloff et al., Phys. Rev. Lett. 57 (1986) 3003.

Figure captions

Fig. 1. The NA14 set-up.

Fig. 2. Ratio of the experimental cross section by the QED Compton one. The solid curve is the the QCD prediction.

Fig. 3. Track-high p_T γ distance distribution. The histogram represents the data for p_T >2.5 GeV/c. The dotted curve is the distribution obtained for high p_T π° . The solid line is the fit to the data using the π° data and the QED Compton Monte Carlo.

Fig. 4. Charge asymmetry in the final state associated with a prompt photon candidate as a function of the distance between the track and the photon.

Fig. 5. p_T distribution of reconstructed π° . The solid curve is the sum of the QCD prediction and the VDM contribution (dotted curve).

Fig. 6. Cross section for π° photoproduction versus longitudinal momentum for three p_T bins. The dotted curves are the VDM prediction, the solid curves are the sum of VDM and QCD predictions.

Fig. 7. Track-high p_T π° distance for p_T >1.7 GeV/c, produced by γ beam (solid line) and π^- beam (dotted line).

Fig. 8. Charge asymmetry with a high p_T π° in the final state measured using identified kaons and protons, as a function of the track-π° distance.

Fig. 9. p_T dependance of the J/ψ photoproduction cross section.

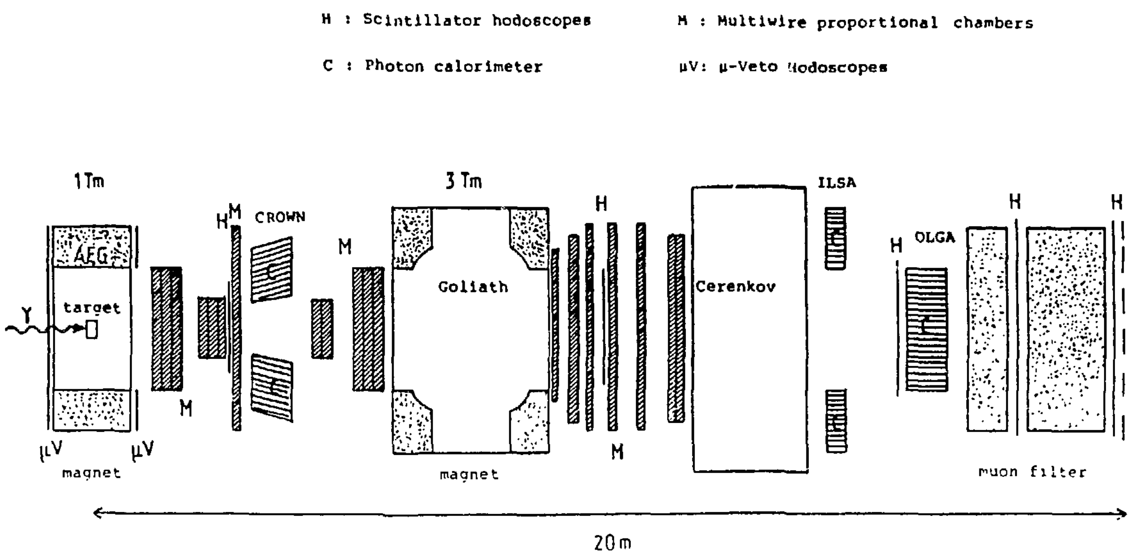

Figure 1

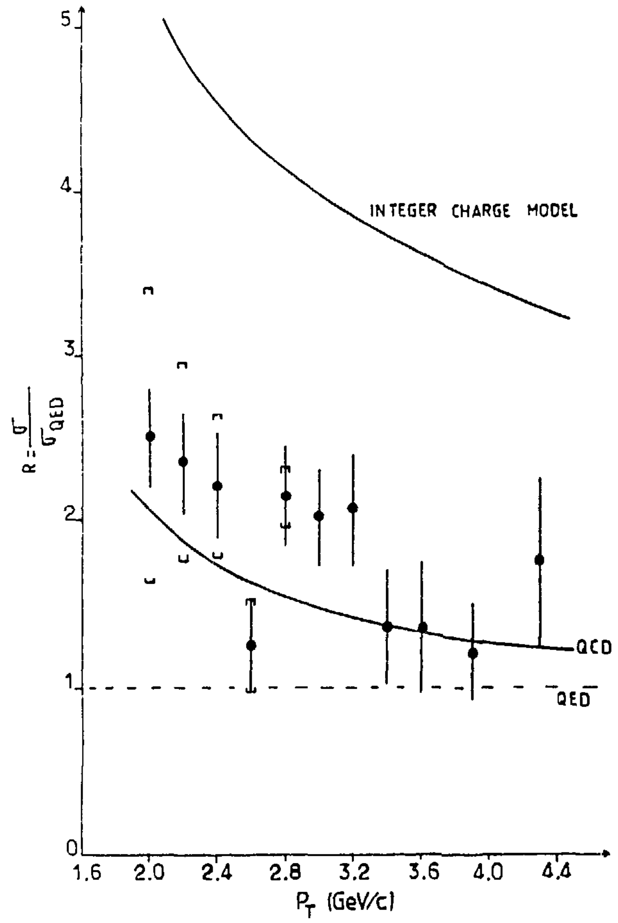

Figure 2

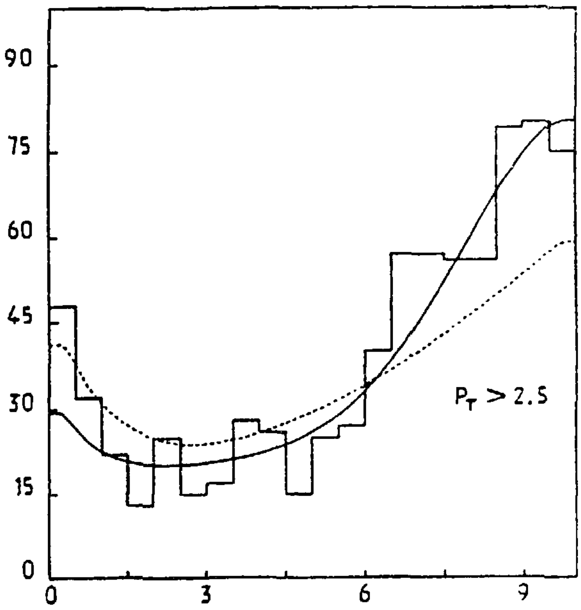

Figure 3

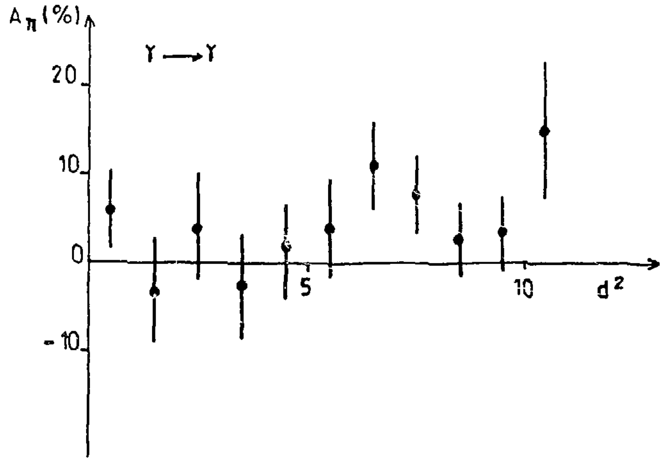

Figure 4

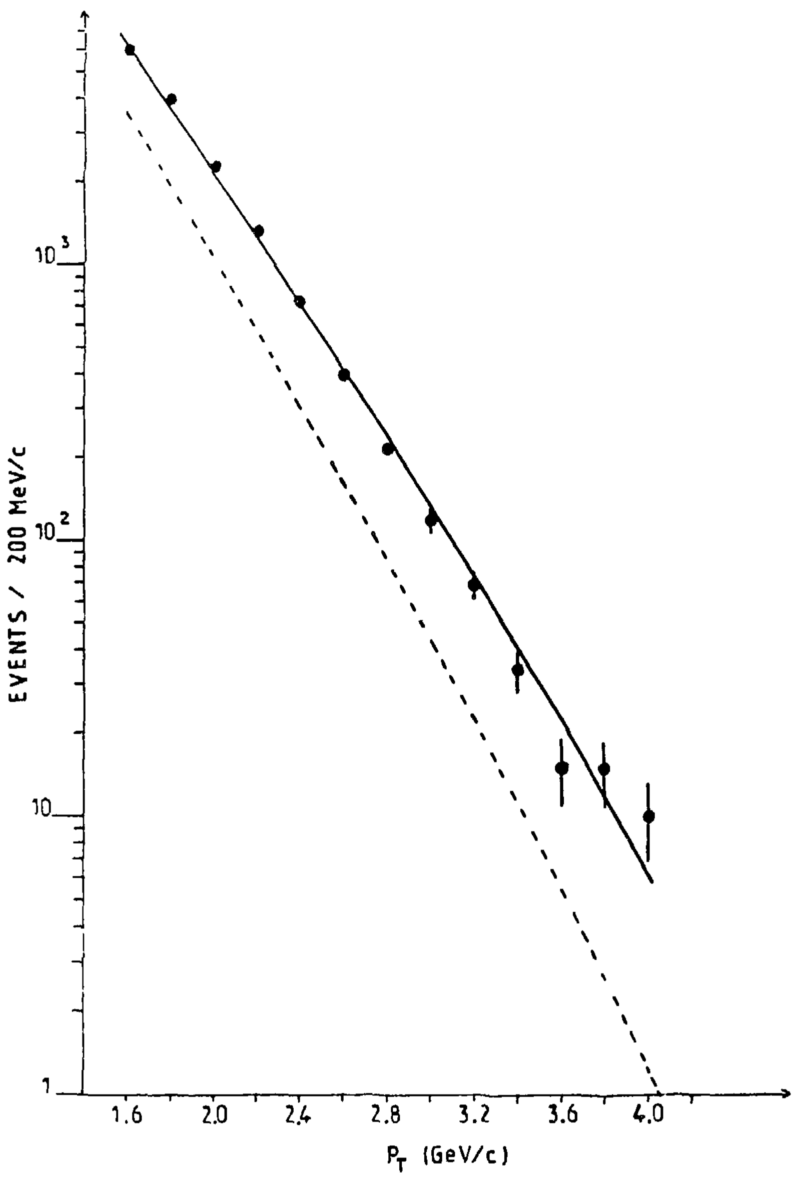

Figure 5

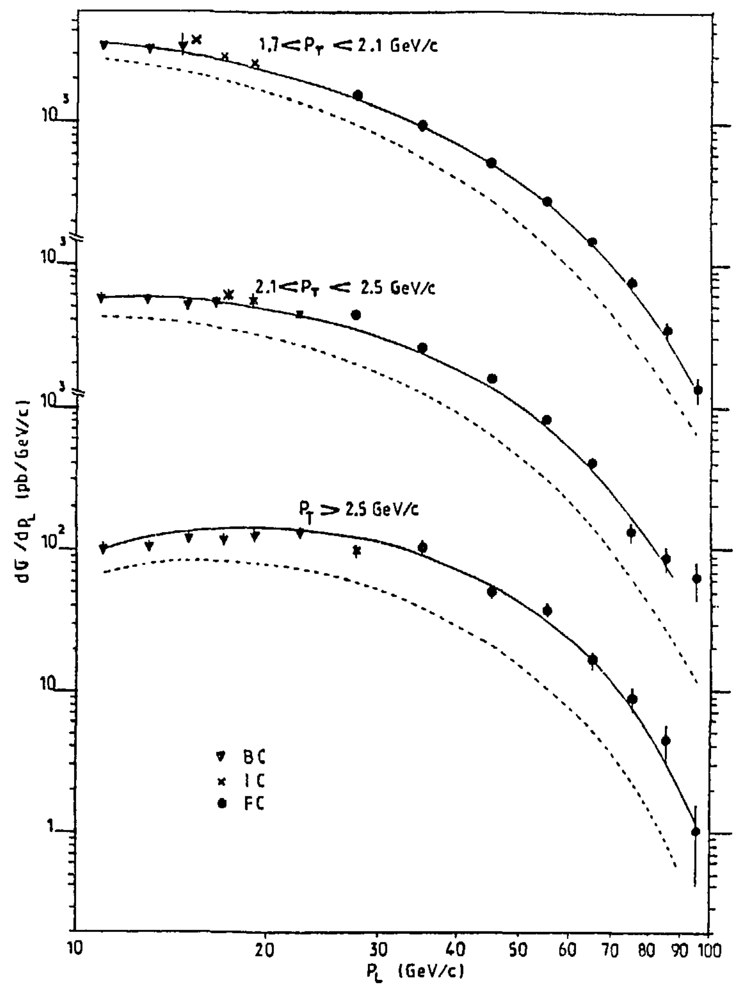

Figure 6

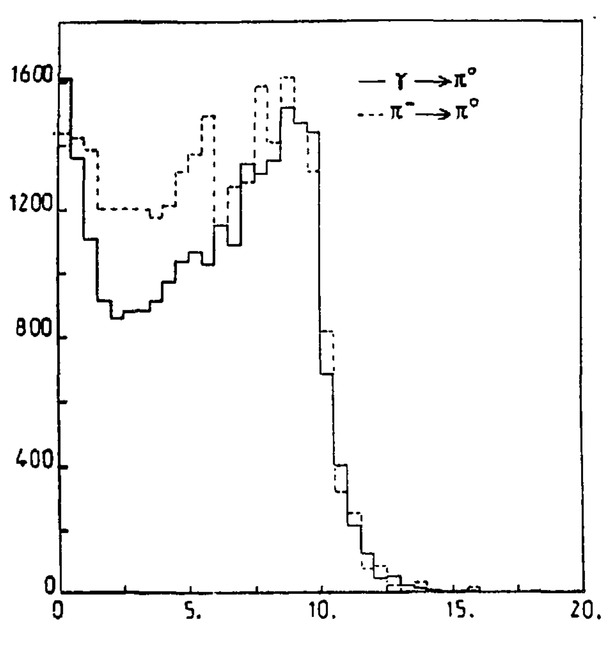

Figure 7

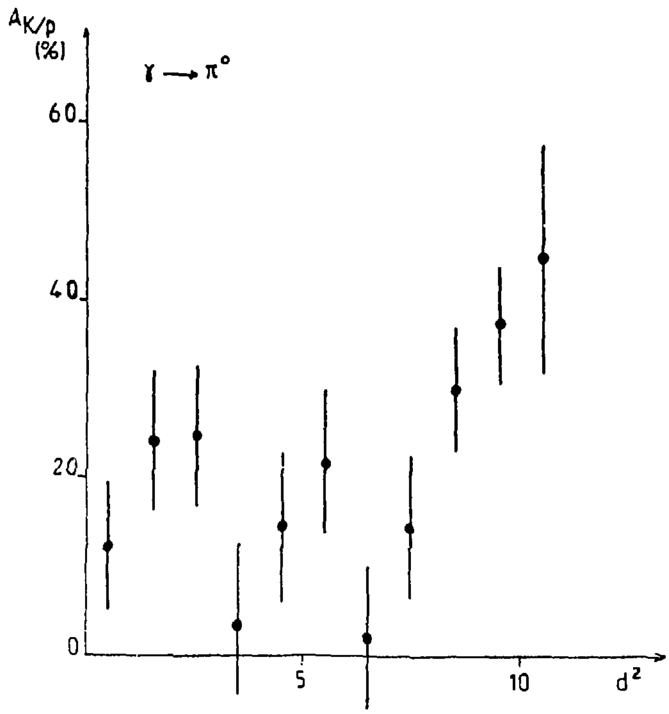

Figure 8

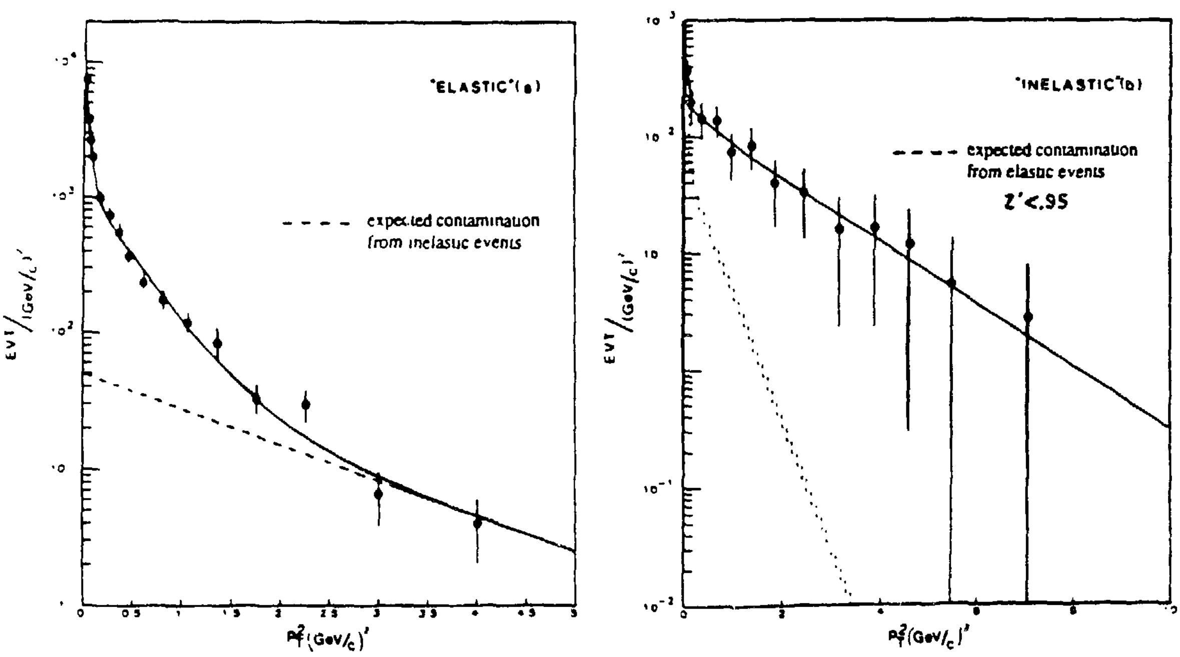

Figure 9