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**TOPOLOGICAL ISOLATION OF
THE DEEP INELASTIC QED COMPTON SCATTERING**

NA14 Collaboration

National Technical University (Athens)¹ – CERN² – Imperial College (London)³ – LAL (Orsay)⁴ –
LPNHE Ecole Polytechnique (Palaiseau)⁵ – Collège de France (Paris)⁶ – DPhPE (Saclay)⁷ –
Southampton University⁸ – CRN and Université Louis Pasteur (Strasbourg)⁹ –
Institute of Experimental Physics (Warsaw)¹⁰

E. Auge⁴, R. Barate², D. Bloch⁹, P. Bonamy⁷, P. Borgeaud⁷, G. De Bouard⁴, B. Bouquet⁴,
J.M. Brunet⁶, H. Burmeister², M. Burchell³, M. Cattaneo³, S. Costa Ramos⁵, B. D'Almagne⁴,
M. David⁷, A. de Bellefon⁶, A. de Lesquen⁷, P. Dello Russo^{9a}, J. Dixon^{3b}, A. Duane³, J.P. Engel⁹,
J. Engelen^{2c}, A. Ferrer⁴, T.A. Filippas¹, E. Fokitis¹, E.N. Gazis¹, Y. Giomataris^{1,*}, J.L. Guyonnet⁹,
T. Hofmohl¹⁰, E.C. Katsoufis¹, J. Kent^{6d}, B. Lefievre⁶, R. Legendre⁷, Y. Lemoigne⁷,
K. Maeshima^{2e}, J.G. McEwen⁸, P. Noon^{3b}, S. Orenstein^{5f}, T. Papadopoulou¹, J.B.M. Pattison²,
P. Petroff⁴, F. Richard⁴, P. Roudeau⁴, A. Rouge⁵, M. Schaeffer⁹, C. Seez³, H. Shoostari^{8g},
I. Siotis³, J. Six⁴, D. Treille², G. Tristram⁶, G. Villet⁷, T.S. Virdee³, A. Volte⁶, D.M. Websdale³,
G. Wormser⁴, J.P. Wuthrick⁵ and Y. Zolnierowski⁷

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- a) Università di Bari, Bari, Italy.
b) Logica Ltd., London, UK.
c) NIKHEF, Amsterdam, Netherlands.
d) University of California, Santa Cruz, USA.
e) University of California, Davis, USA.
f) City College, New York, USA.
g) Max-Planck Institute, Munich, Fed. Rep. Germany.
*) Now at CERN.

ABSTRACT

The NA14 photoproduction experiment, carried out at the CERN SPS, has measured the inclusive cross-section of events with a prompt photon at high p_T in the final state.

Here we present a study of the topology of the final state of these events. The topology differs from that observed for events with an identified π^0 in the same kinematical domain.

Using these differences we have extracted the contribution from the Born term to the inclusive prompt photon cross-section. The result is in good agreement with theoretical predictions and supports the assignment of a fractional electric charge to the quarks.

1. INTRODUCTION

The prompt photon photoproduction cross-section has recently been measured by the NA14 experiment in the E12 γ beam, at the CERN Super Proton Synchrotron (SPS) [1]. The observed yield of prompt photons has been found to be in quantitative agreement with the quantum electrodynamic (QED) Compton term (or Born term)—the elastic scattering of photons upon quarks—corrected by the quantum chromodynamic (QCD) predictions computed beyond the leading-logarithm approximation [2] (fig. 1). The presence of these correction terms is necessary to reproduce correctly the experimental data. This measurement is thus a good quantitative test of QCD.

The QED Compton term has a specific 1 photon-1 jet topology, which differs from both non-prompt γ events—where the photon is accompanied—and from the higher order terms—where a second jet is present. It is therefore possible to separate the QED Compton component, by the study of the topology of prompt photon candidates.

2. EXPERIMENTAL APPARATUS

The main features of the NA14 spectrometer, which is described in greater detail elsewhere [3], are:

- i) the high-energy ($\langle E \rangle = 90$ GeV) and high-flux ($10^7/s$) broad-band tagged γ beam;
- ii) its large acceptance, up to 300 mrad for both charged and neutral particles.

The charged particles are measured by a set of 70 multiwire proportional chamber (MWPC) planes and analysed through two magnets of total bending power 4 T·m. The photons are measured in three calorimeters, which were used to select events with a high- p_T local energy deposit. The forward calorimeter (FC) and the backward one (BC) are lead-glass arrays, the intermediate one (IC) is a lead/scintillator sandwich.

3. RESULTS

The prompt γ candidates sample is compared with that from reconstructed π^0 's, which has, to a very good approximation, the same exclusive characteristics as the one from non-prompt photons.

Some events showing very clearly the QED Compton topology are displayed in fig. 2. In the polar representation of (θ, ϕ) used here, all the particles except the triggering γ form a jet-like cluster.

All events with trigger $p_T > 3$ GeV were examined to measure the fraction of isolated triggers and of topologies compatible with the QED Compton process. The trigger was said to be isolated if the smallest distance between the trigger and all other tracks was greater than 80 mrad. The event was said to be QED Compton compatible if most of the energy was concentrated in a cluster opposite in azimuth to the trigger. The results are given in table 1.

The high- p_T prompt γ candidates appear more often isolated than the π^0 's. This means that the true prompt photons are indeed produced mostly isolated. One can see that, despite the trigger bias, 2/3 of the π^0 's are accompanied.

More detailed information on the jet structure can be gathered from the tracks-to-trigger distance. The distance is now defined in a Lorentz invariant way:

$$d^2 = (\Delta\phi)^2 + (\Delta\eta)^2,$$

where $\Delta\phi(\Delta\eta)$ is the difference in azimuth (pseudorapidity) between any track and the trigger. At low p_T (fig. 3a) the distributions obtained on the γ and π^0 samples are very similar, while at high p_T (fig. 3b, c, d) a clear difference can be seen: in the γ sample, a smaller fraction of energy is carried along the trigger while a narrower structure is observed on the away side.

Such an effect is indeed expected if prompt γ production at high p_T is dominated by the QED Compton mechanism, leading to a single jet opposite to an isolated γ in the final state. To disentangle the contribution of the kinematical bias induced by p_T conservation, data taken with a 90 GeV π^- beam and with the same experimental conditions were used. With this sample, the distance distributions are almost flat (fig. 3). Therefore, the peaks observed at high distance in the γ -beam data are not the reflection of a trigger bias but are really indicating a jet-like structure. Though not germane to the argument of this paper we note the striking differences observed with π^- and γ produced π^0 samples which show that, in addition to the vector-meson dominance (VMD) terms, described to a very good approximation by the π^- data, QCD processes with jet-like topologies are needed to describe the π^0 photoproduction mechanism. This result is in full agreement with the conclusions of our inclusive analysis [4].

4. INTERPRETATION OF THE TOPOLOGICAL ANALYSIS

Quantum electrodynamic Compton events were generated by a Monte Carlo program, using the Lund model for quark fragmentation, and processed by the same analysis chain as real data.

The distance distributions obtained for the Monte Carlo and for the π^0 samples are fitted by polynomials respectively labelled f_{QED} and f_{π^0} . The distance distribution for the γ sample is then fitted by the function $(1 - \epsilon) f_{\pi^0} + \epsilon f_{\text{QED}}$, where ϵ is thus the fraction of QED Compton events found in the prompt γ candidates sample. The results of these fits are given in table 2 for the three calorimeters.

The prompt γ properties are found to be well described by such a combination (see fig. 3). Furthermore, the measured QED Compton yield is in good agreement with the expected one, in the standard fractional charge model, in the whole kinematical domain.

At high p_T , in the FC, the fraction ($\sim 35\%$) which corresponds with the QED term is lower than the prompt γ level measured in the inclusive analysis [1], which was found to be equal to $58 \pm 5\%$. This difference can only come from prompt photon events with a π^0 -like topology. Such events are expected, since the QCD corrections to the Born term represent 40% of the total prompt photon cross-section for $p_T > 2.5$ GeV [2]. They involve parton graphs, for example anomalous structure function graphs which are very similar to those leading to a triggering π^0 . This observation of events corresponding to the correction terms is incompatible with an interpretation of our data based on integer charged quark models. If only the Born term of the QED Compton process is multiplied directly by 2.65 to give the integer charged quark prediction (see ref. [1]) then although it cannot be completely excluded by the inclusive prompt photon data, it would leave no room for the correction terms which we claim are present in our data.

An independent effect of the presence of the QED Compton term can be found in the charge asymmetry of the final state. The QED Compton term leads to a large positive-charge asymmetry, of the order of 30%. Such an effect has been looked for, using the sign of the most energetic particle. (Events where this particle was neutral have been removed from the analysis.) The highest statistical significance in the measurement of this asymmetry is expected from the total data sample, where a moderate p_T cut of 1.7 GeV/c is applied. The QED Compton term contributes 10% to this sample so a charge asymmetry of 3% is expected. This effect is seen in table 3, where the asymmetry in the γ sample is compared with that in the π^0 sample, and an excess asymmetry compatible with the expected 3% is observed.

5. CONCLUSION

A clear difference is observed between topologies of the γ and π^0 samples at high p_T . Using this difference, the QED Compton yield has been directly measured and found to be in agreement with the standard fractional charge model.

Evidence has been found of an important yield from higher order terms, with a similar topology to the one observed in a reconstructed π^0 sample. This yield is in good agreement with the perturbative QCD computations of ref. [2].

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Table 1

Fraction of events having an isolated trigger and a QED Compton-like topology for $p_T > 3$ GeV/c, for both γ and π^0 samples in the FC

	Trigger	
	γ (%)	π^0 (%)
Isolated	53 ± 5	36 ± 4
QED compatible	43 ± 6	27 ± 5

Table 2

Relative yield of the QED Compton term ϵ in the prompt γ candidates samples of the three calorimeters at low and high p_T . ϵ_{fit} is determined by the topological analysis (see text) and $\epsilon_{\text{predicted}}$ is known from the inclusive analysis of ref. [1].

		ϵ_{fit}	$\epsilon_{\text{predicted}}$
FC	$1.7 < p_T < 2.5$	0.05 ± 0.02	0.13 ± 0.03
	$p_T > 2.5$	0.34 ± 0.06	0.35 ± 0.09
IC	$1.7 < p_T < 2.5$	0.04 ± 0.02	0.07 ± 0.02
	$p_T > 2.5$	0.38 ± 0.10	0.38 ± 0.10
BC	$1.7 < p_T < 2.5$	0.03 ± 0.03	0.06 ± 0.09
	$p_T > 2.5$	0.22 ± 0.06	0.25 ± 0.08

Table 3

Charge asymmetry observed in the final state for the three calorimeters for $p_T > 1.7$ GeV/c, in both γ and π^0 samples

	γ	π^0
FC	$+ 0.10 \pm 0.02$	$+ 0.06 \pm 0.01$
IC	$+ 0.10 \pm 0.01$	$+ 0.08 \pm 0.02$
BC	$+ 0.12 \pm 0.03$	$+ 0.08 \pm 0.01$

Figure captions

- Fig. 1** The inclusive cross-section of photoproduced prompt γ . The background has been subtracted. The dashed-dotted and solid curves correspond to the QED C Born term and the Born + QCD correction terms, respectively. The dashed curve is 2.65 times the solid curve. Also shown are systematic errors on the subtraction of background. The statistical errors dominate for $p_T > 2.6 \text{ GeV}/c$.
- Fig. 2** QED Compton-like events, represented in the transverse plane. The vertical axis is proportional to the energy of each track. The azimuth ϕ is defined relative to the γ . At a given azimuth the distance to the origin O is equal to the polar angle θ .
- Fig. 3** Tracks-to-trigger distance distribution. The distance d^2 is defined by $d^2 = (\Delta\phi)^2 + (\Delta\eta)^2$, where ϕ and η are the azimuth angle and the pseudorapidity. The histogram represents γ data in the three calorimeters; the dotted curve is the best fit to these data using the π^0 distribution; the solid curve is the fit using $(1 - \epsilon) f_{\pi^0} + \epsilon f_{\text{QED}}$ (see text); the dashed line is the distribution obtained with the π^- beam (arbitrary normalization).

Fig. 1

Fig. 2

Fig. 3