УДК 539.12...164

STUDY OF THE PHOTON STRUCTURE FUNCTION F_2^γ IN THE REACTION $e^+e^- \to e^+e^-$ + hadrons AT LEP1 AND LEP2

***F.Kapusta*[1], *I.Tyapkin*[2], *N.Zimin*[2,3], *A.Zinchenko*[2]**

The photon structure function F_2^γ is studied in the Q^2 range from 3 to 150 $(\mathrm{GeV/c^2})^2$. The data correspond to an integrated luminosity of 70 $\mathrm{pb^{-1}}$, collected by the DELPHI detector during the 1994—1995 LEP runs at centre-of-mass energies around the Z^0 mass, and the 15 $\mathrm{pb^{-1}}$ during 1996 run at centre-of-mass energies from 161 GeV to 172 GeV. Experimental distributions, including variables from a jet and energy flow analysis, are compared with Monte Carlo predictions. The data are found to be in good agreement with model predictions. The photon structure function is extracted for 6 Q^2 bins. The Q^2 evolution of the photon structure function is estimated.

The investigation has been performed at the Laboratory of High Energies, JINR.

Изучение структурной функции фотона F_2^γ в реакции $e^+e^- \to e^+e^-$ + адроны на ЛЭП1 и ЛЭП2

Ф.Капуста, И.Тяпкин, Н.Зимин, А.Зинченко

Представлены результаты работ по изучению структурной функции фотона F_2^γ в интервале значений Q^2 от 3 до 150 $(\text{ГэВ/c}^2)^2$. Проанализированы данные, полученные установкой ДЕЛФИ на коллайдере ЛЭП в 1994—1995 гг. при энергиях около массы Z^0 (накопленная светимость 70 пб$^{-1}$) и в 1996 г. при энергиях от 161 ГэВ до 172 ГэВ (15 пб$^{-1}$). Проведено сравнение экспериментальных распределений, в том числе полученных при анализе струй и потока энергии, с распределениями, полученными при математическом моделировании. Показано хорошее согласие экспериментальных и моделированных результатов. Структурная функция фотона восстановлена для 6 интервалов Q^2. Приведена оценка Q^2-эволюции структурной функции.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

[1]LPNHE, IN2P3-CNRS, Universités Paris VI et VII, France.
[2]JINR, Dubna.
[3]Department of Physics, University of Lund, Sweden.

1. Introduction

Recent photon structure function measurements have been done at LEP [1] in the reaction $e^+e^- \rightarrow e^+e^-X$, where X is a multihadronic system and one of the scattered leptons is observed at a large scattering angle (tagging condition) while the other, remaining at a small angle, is undetected (antitagging condition). This reaction can be described as a deep inelastic $e\gamma$ scattering (DIS), where γ is almost a real photon. The study of photon structure function is heavily based on the procedure, where F_2^γ is reconstructed from $x_{\rm visible}$, the so-called unfolding procedure, which strongly depends on the models used in it. Most of the previous studies were done with generators based on two models, the one that is QPM-like, describing a perturbative part, and the other, which is VDM-like, for the hadron-like part. It is shown by the DELPHI collaboration that an added resolved photon contribution (RPC) significantly improves agreement with experimental data, especially a description of the final state topology of the hadronic system, which is very important for the interpretation of the results. The present study is extended to a wider Q^2 region.

2. Model

The TWOGAM event generator is based on an exact decomposition of the matrix element of the process. The total cross section is described by the sum of three parts: point-like (QPM), resolved photon contribution (RPC), and soft hadronic (VDM). The QPM and VDM models can be used at any Q^2. The RPC can be partially extended to the high Q^2 region by its $\gamma q(g)$ component. For the point-like part exact differential cross sections are used. The quark masses are taken to be 0.3 GeV/c^2 for u and d quarks, 0.5 GeV/c^2 for s, and 1.6 GeV/c^2 for c quarks. The produced $q\bar{q}$ pair is fragmented as a LUND string by JETSET 7.3 [2]. For the single or double resolved perturbative part the lowest order cross sections are used. Only the transverse-transverse part of the luminosity function is used in this case. There is no initial or final state parton showering. Strings are formed following the colour flow of the subprocesses and are fragmented according to the LUND model by JETSET. The remnant of a quark is an antiquark (and vice versa), and the remnant of a gluon is a $q\bar{q}$ pair. TWOGAM treats exactly the kinematics of the scattered electron and positron, and uses exact (unfactorized) expressions for the two-photon luminosity functions. All the parameters in the TWOGAM generators were fixed in 1993 and no tuning was performed since then.

3. Event Selection

The tagged particle was detected by the DELPHI luminometer STIC. The main criteria used to select two-photon events with tagging are:

1. $E_{\rm tag} > 0.5 * E_{\rm beam}$ (0.25 for LEP2);
2. No additional clusters with energy exceeding $0.3 * E_{\rm beam}$;
3. Ntrk > 2;

4. $W > 3$ GeV;

5. Longitudinal and transverse momentum balance.

Jets were reconstructed by the LUCLUS algorithm with $d_{join} = 1.6$ GeV. None of the conclusions drawn below is sensitive to the variation of d_{join} across a fairly wide region. All calorimeters (including forward luminometer) are used in this analysis to reconstruct invariant mass.

The main source of background was $\gamma\gamma \to \tau\tau$ interactions and their contribution was estimated from a simulation as 0.8 pb (0.13 pb LEP2). The Z^0 hadronic decays contributed 0.2 pb (negligible for LEP2) to the background. Contamination from other background sources was found to be much lower. After subtracting this background the visible cross section of the investigated process was estimated as being 30.4 pb (39.3 pb for LEP2).

The trigger efficiency was studied and found to be of the order of (98 ± 1%).

4. Comparison of Experimental and Simulated Data

Many observables were studied, with special attention to those that are not strongly correlated with x_{true}. Most of such observables are defined by the hadronic final state topology. All variables were found to be in good agreement with TWOGAM prediction.

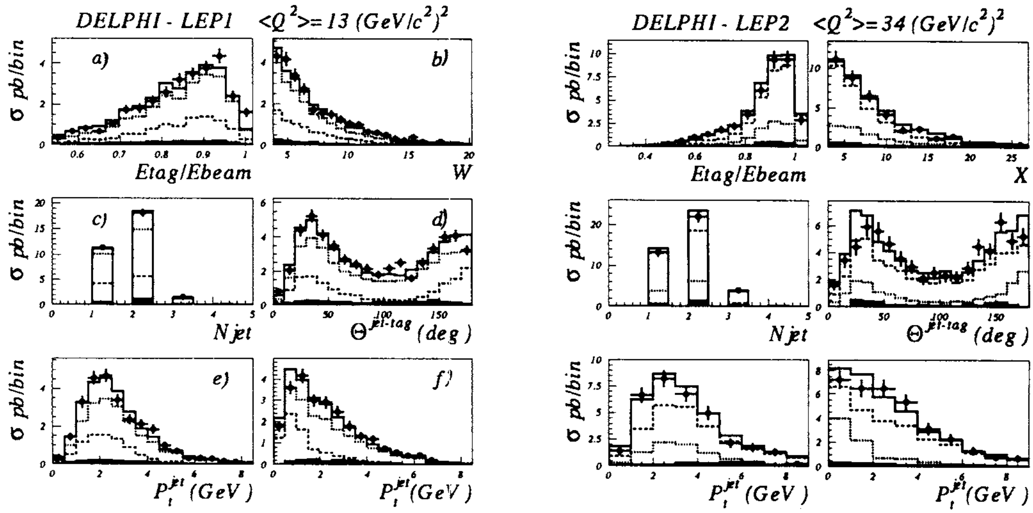

Fig. 1. Comparison between data and Monte Carlo prediction for a sample with $\langle Q^2 \rangle = 13$ (GeV/c^2)^2 and $\langle Q^2 \rangle = 34$ (GeV/c^2)^2. a) Energy of tagged particle, b) Invariant mass; c) Number of jets; d) Jet angle with respect to the tagged particle; e) Transverse momentum of reconstructed jets for jets in the same hemisphere as the tagged particle; f) Transverse momentum of reconstructed jets for jets in the opposite hemisphere to the tagged particle. Points are data and lines show the Monte Carlo predictions. QPM + GVDM + RPC — solid line, GVDM + QPM — dotted line, GVDM — dashed line, hatched area is the background estimate

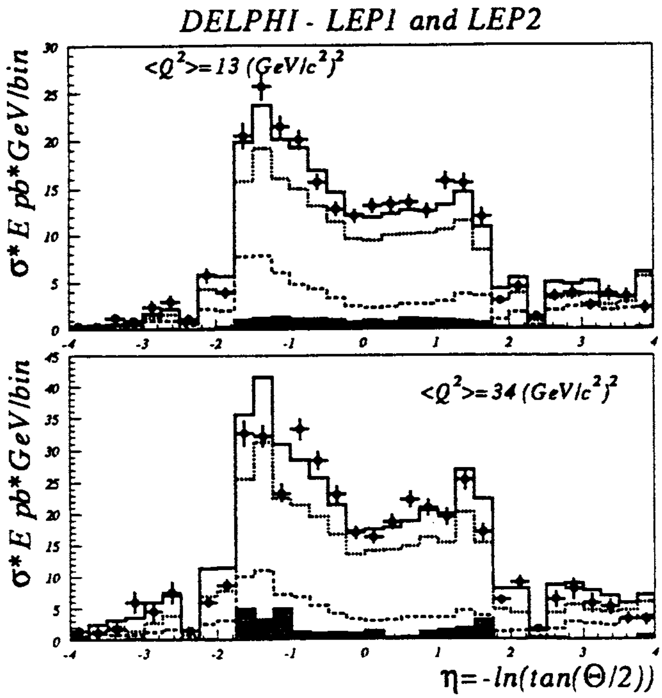

Fig.2. Event energy flow normalized to the visible cross section. Rapidity is measured from the detection of the tagged particles, i.e., the tagged particle is always in the range from – 4.0 to – 2.5 units of rapidity. Notations as in Fig.1

Some of them are presented in Fig.1 for the LEP1 and LEP2 data. The event from a 3 jet domain, mostly described by the RPC, were selected and many of distributions studied. All of them were found to be in good agreement with the model. The event energy flow, which strongly depends on the event topology, was studied and found to be in reasonable agreement with the TWOGAM prediction (Fig.2).

5. Photon Structure Function

Since the TWOGAM describes data quite well, it can be used to estimate F_2^γ. First of all both (LEP1 and LEP2) samples were separated into two statistically equivalent ones by Q^2. This yields three Q^2 bins for both LEP1 and LEP2 samples. The x distributions for these samples are shown in Fig.3. Even from these plots it can be concluded that F_2^γ unfolding results should be very close to the structure function used in the TWOGAM. There is some indication of deviations of TWOGAM predictions for the data in the high

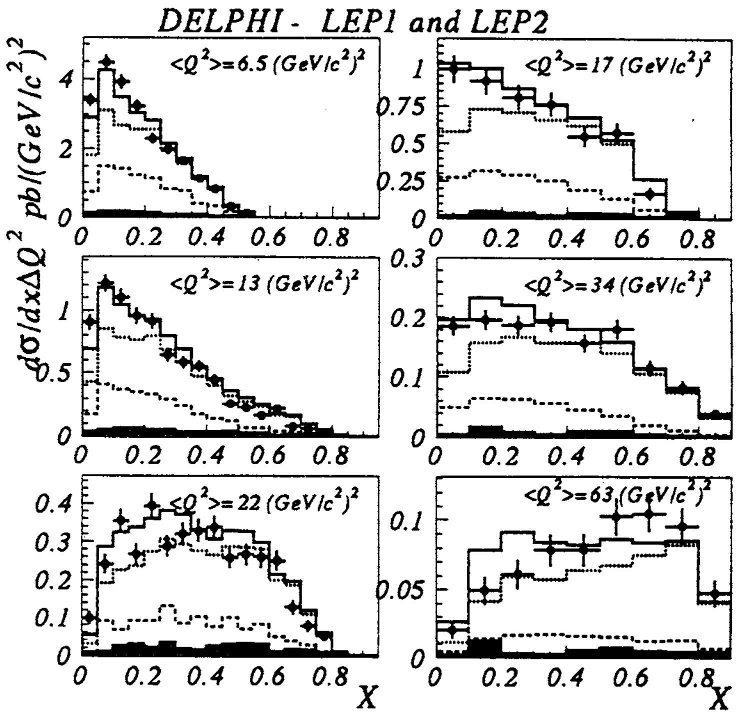

Fig.3. Distributions of x visible for three Q^2 bins for LEP1 and LEP2 measurements. Notations as in Fig.1

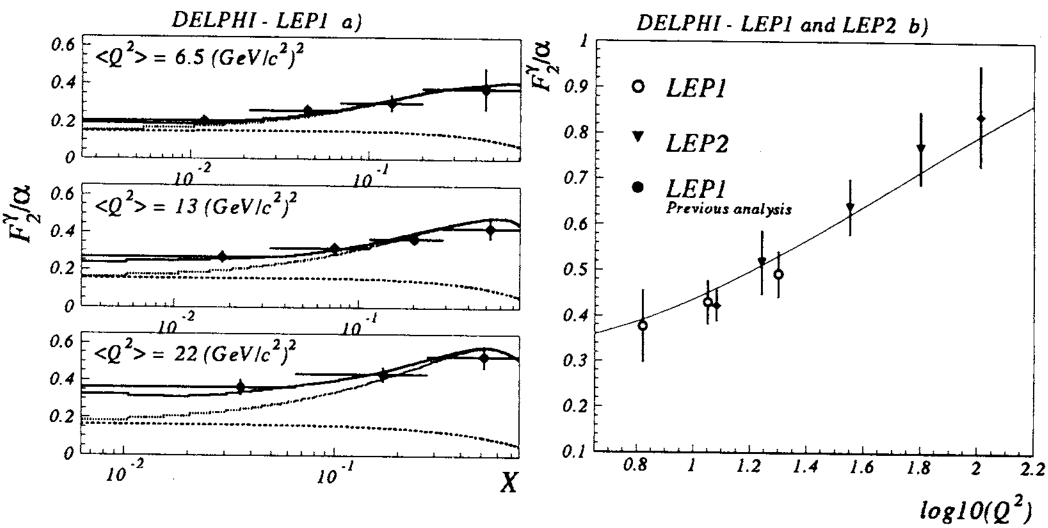

Fig.4. a) Unfolding results for LEP1. b) Q^2 evolution of the structure function for the x region between 0.3 and 0.8

Q^2 region. Unfolding is performed by the Blobel program. Some examples of the unfolding results are shown in Fig.4 and confirm the conclusions drawn on the basis of Fig.3. The systematics included in the total error on the plot consists of the cut variation effect, uncertainty from virtuality suppression in RPC, and background uncertainty. Figure 4b shows the average value extracted from the data of F_2^γ for $0.3 < x < 0.8$ as a function of Q^2 for the DELPHI measurements.

6. Conclusions

The model, including RPC was tested in the wider Q^2 region. It is demonstrated that TWOGAM describes data quite well up to Q^2 close to 100 $(\mathrm{GeV}/c^2)^2$ without any tuning. The main advantage of this generator is that it describes observables that are not very closely correlated with x_{true} and are determined by the event topology. All this means that F_2^γ can be estimated with small extra systematics, determined by the description of the event shape.

References

1. DELPHI Coll., Warsaw, pa02-021; OPAL Coll., Warsaw, pa03-007, OPAL Coll., CERN-PPE/96-155.
2. Sjöstrand T. — Comp. Phys. Comm., 1994, v.82, p.74.

Received on October 6, 1997.