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A STUDY OF SINGLE TAGGED MULTIHADRONIC $\gamma\gamma^*$ EVENTS AT A $\langle Q^2 \rangle \cong 90$ GeV^2

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Изучение тагируемых мультиадронных $\gamma\gamma^*$-событий при $\langle Q^2 \rangle \cong 90$ ГэВ^2

Отбор двухфотонных мультиадронных событий с тагированием электрона или позитрона проводился с помощью переднего электромагнитного калориметра. Данные, соответствующие интегральной светимости 60,6 пб$^{-1}$, сравнивались с предсказанием двухкомпонентной модели: кварк-партонной модели (КПМ), описывающей точечную фотон-кварковую связь и обобщенной модели векторной доминантности (ОВДМ) для описания адронной части. Удовлетворительное согласие экспериментальных и моделированных данных позволяет измерить структурную функцию $F_2^\gamma(x, Q^2)$ фотона в рамках предсказаний КХД.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

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A Study of Single Tagged Multihadronic $\gamma\gamma^*$ Events at a $\langle Q^2 \rangle \cong 90$ GeV^2

A selection of multihadronic two photon events has been performed in the single tagged mode using the Forward ElectroMagnetic Calorimeter (FEMC). The 60.6 pb^{-1} integrated luminosity data was compared to a two-component model prediction: a Quark Parton Model (QPM) describing the point-like photon-quark coupling and a Generalized Vector meson Dominance Model (GVDM) for the hadron-like part. The agreement between data and Monte Carlo simulation is satisfactory to measure the photon structure function $F_2^\gamma(x, Q^2)$ and to chek a QCD prediction on the evolution of the photon structure function.

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

Communication of the Joint Institute for Nuclear Research. Dubna, 1994

1 Introduction

In the reaction $e^+e^- \to e^+e^-X$, where X is a multihadronic system produced by the collision of two virtual photons coming from the beam particles, one of the scattered leptons can be detected. Its energy E_{tag} and scattering angle θ_{tag} can be measured (Fig.1), thus giving the virtual photon squared mass through $-Q^2 = -4E_{tag}E_b\sin^2(\theta_{tag}/2)$, where E_b is the beam energy. In these "single tag" events the other photon can be required to be almost on-shell, and the whole process is viewed as deep inelastic scattering of an electron off a quasi-real photon with a squared mass $-P^2 \simeq 0$.

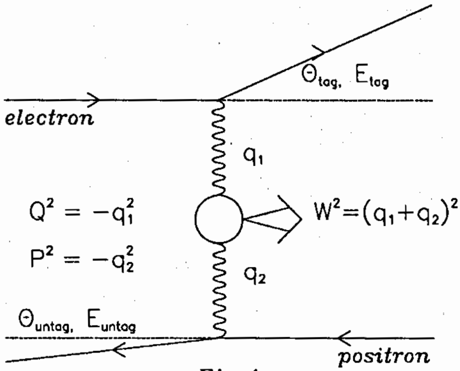


Fig.1

The corresponding cross section reads :

$$\frac{d\sigma}{dE_{tag}dcos(\theta_{tag})} = \frac{4\pi\alpha^2 E_{tag}}{Q^4 y}\left[(1+(1-y)^2)F_2^\gamma(x,Q^2) - y^2 F_L(x,Q^2)\right] \tag{1}$$

with

$$y = 1 - E_{tag}/E_b\cos^2(\theta/2),$$
$$x = \frac{Q^2}{Q^2+W^2}.$$

$F_2(x,Q^2)$ and $F_L(x,Q^2)$ structure functions are defined in terms of cross sections for photons with different helicities (for details see [1]). W is the invariant mass of produced hadron system.

Only a few previous experiments have studied the photon structure function F_2^γ at Q^2 greater than 50 GeV^2 [2, 3, 4] . Using the DELPHI detector a new measurement of F_2^γ can be obtained. The description of the detector in detailes can be found elsewhere [5]. Experimentally, a scattered lepton can be tagged in the Forward ElectroMagnetic Calorimeter (FEMC) at relatively large angles ($10° \leq \theta_{tag} \leq 36.5°$). Using estimates for F_2^γ and F_L in the Quark Parton Model (QPM) [1], and taking into account that $< y > \simeq 0.15$ under experimental conditions, it was found that the cross-section of the process is saturated by the structure function F_2^γ only.

The theoretical background of the photon structure function can be found elsewhere [6, 7].

Section 2 describes the data selection, while the two-component model used here is described in section 3. The background subtraction is discussed in section 4. Finally, in section 5 are the results and a comparison with a two-component model presented.

2 Event selection

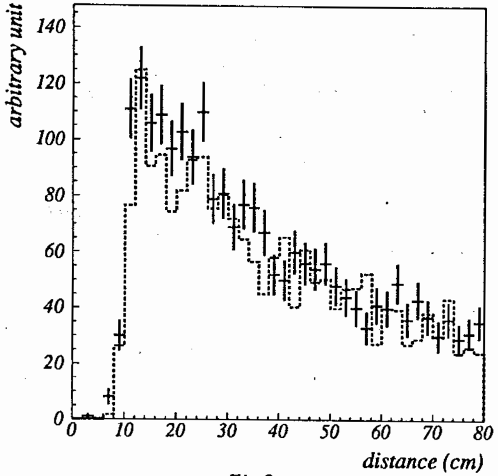


Fig.2

Since there is about two radiation lengths of materia in front of the FEMC a specific algorithm was used to determine the tagged particle energy. The largest cluster in each FEMC arm was found. Smaller clusters, but with energies greater than 0.5 GeV, were then added if their distances to the largest cluster were smaller than 30 *cm* in the $R\phi$ plane. The values were found based on e^+e^- events detected in the FEMC. We will call this final cluster a "summed cluster". The kinematic characteristics of the summed cluster are thus determined by the summed clusters barycenter, where a weight of each cluster component was proportional to its energy. The comparison of the distribution for the distance for the data and Monte Carlo described below is shown on fig.2.

Events were accepted if there was a summed cluster (tagged cluster) with energy greater than 30 GeV in one FEMC arm and no summed cluster with energy greater than 15 GeV in the other arm.

The following selection criteria were used:

- At least 3 charged tracks having momentum greater than 0.4 GeV and polar angles θ between 20^0 and 160^0 were required. The error on the momentum had to be less than 100%, while the impact parameter had to be smaller than 4 *cm* in $R\phi$ and 10 *cm* in z;
- Neutral particles were required to deposit at least 1.0 GeV in the barrel electromagnetic calorimeter High-density Projection Chamber (HPC) or 0.5 GeV in the FEMC;
- To avoid the resonance regions and problems with the Monte Carlo fragmentation reliability, the invariant mass of the system (excluding tagged cluster) had to be greater than 2.0 GeV;
- The thrust (excluding the tagged cluster) was required to be smaller than 0.99 in order to reject photon conversion events as well as contaminations from $\tau^+\tau^-$ pairs.

After the preselection there are 367, 1166 and 1087 events for the 1991, 1992 and 1993 runs respectively. It was checked that there was no essential disagreement between the different year data. The data was united into one sample.

Since the threshold for the trigger in the FEMC is 25 GeV, the requirement of the large energy cluster in the FEMC makes us sure that the efficiency to trigger $\gamma\gamma$ events is close to 100%.

3 Monte Carlo simulation

A two-component model was used for the $\gamma\gamma$ event simulation. QPM describes a perturbative term of the process where a photon splits into a quark pair (the point-like term). The non-perturbative part describing a bound state in the photon quark coupling (the hadron-like term) was introduced through GVDM [8]. The GVDM multihadronic final system was generated as a $q\bar{q}$ system according to a quark $d\sigma/dp_T^2 \simeq \exp(-5p_T^2)$ distribution in the $\gamma\gamma$ center-of-mass system. The TWOGAM $\gamma\gamma$ event generator [9] was used with default parameters, while the JETSET7.3 string fragmentation scheme was used for the fragmentation of the produced quarks.

Measurements at PEP and PETRA have shown that for Q^2 values greater than 20 GeV^2 the point-like coupling part dominates the cross section of the $\gamma\gamma^*$ process. The following table gives the cross section σ_{tot} when one of the scattered leptons is within the angular range of the FEMC. The cross section σ_{expect} is after detector simulation and selection procedure introduced above. The large decrease of the cross section is due to the cuts applied to the hadron system.

cross section in pb	GVDM	QPM
σ_{tot}	9.4	12.6
σ_{expect}	0.5	1.5

4 Background rejection

The expected number of two-photon events (around 100) is small compared with powerful Z^0 background. To determine criteria in order to extract $\gamma\gamma$ events, one needs to make sure that the data and Z^0 Monte Carlo simulation are in agreement. Around 900000 Z^0 simulated hadronic events ($\simeq 30pb^{-1}$) were processed taking into account the selection criteria. Also Monte Carlo simulation of other sources of a background was considered. The contribution of e^+e^- events in the sample was evaluated to be around 11 ± 5.5 events, $Z^0 \to \tau^+\tau^-$ gives 6.3 ± 1.8 events, $\gamma\gamma^* \to \tau^+\tau^-$ gives 8 ± 3 events. Fig.3(a,b) show energy and polar angle distributions for the tagged cluster. A charged multiplicity and invariant mass calculated using charged and neutral component distributions of hadron system are shown in fig.3(c,d) respectively. All distributions are compared to the Z^0 simulated events together with $\gamma\gamma$ simulation. The agreement is reasonable to choose for criteria to extract two-photon events based on Monte Carlo.

Let us introduce two dimensionless variables : Normalized Longitudinal Momentum Balance

$$NLMB = sign(p_z^{tag})\frac{p_z^{tag} + \sum_i p_z^{i,hadron}}{E_{beam}}, \quad (2)$$

and Normalized Transverse Momentum Balance

$$NTMB = \frac{\| \vec{p}_{T,tag} + \sum_i \vec{p}_{i,hadron} \|}{E_{beam}} \quad (3)$$

For the events with a few lost particles both the first variable and the second one express the fact that the longitudinal and transverse momentum are balanced.

Besides from that at least one scattered lepton (most probable with a small transverse momentum) is undetected in two-photon single tagged mode. The main consequence is an expected unbalance in longitudinal direction for two-photon events.

Fig.4(a-c) show the NLMB *vs* NTMB for the data, Z^0 and two-photon Monte Carlo respectively. It is seen that the main part of Z^0 background is concentrated below 0.6 NLMB. The two-dimensional cut was used:

- NTMB $\leq$ 0.2 and the domain above the line connecting the point (0.6,0.0) and (0.85,0.2) was rejected (solid line in figures 4).

To suppress the remaining background the following cuts were added:

- the sum of charged particle momentum in the event was lower than 20 GeV;
- the polar angle of the tagged cluster was below 17 degree. Fig.3b shows that the polar angle distribution for a tagged cluster for Z^0 events has an uniform behaviour. Besides from that two-photon events are peaked at the small polar angle domain. The upper limit of the polar angle domain for the tagged cluster allows to remove many Z^0 events saving most part of $\gamma\gamma$ events;
- there is no particle detected in the luminosity monitor [5] with the energy greater than 20 GeV (" antitagging condition").

After applying the cuts above we are left with 123 events with the background from Z^0 of 9.4 $\pm$ 3.9 events. The other sources of a background like τ pair production (both in two-photon and annihilation reactions), Bhabha events and beam-gas interactions were estimated as negligible.

5 Result and conclusion

Two photon single events tagged in the FEMC can be selected with less than 10% background. They are in qualitative agreement with the sum of two models: QPM and GVDM describing the point-like and bound state behaviours of the photon to quark coupling. Fig.5(a-d) show the charged multiplicity, invariant mass, Q^2 and x distributions respectively for the data compared to QPM plus GVDM Monte Carlo predictions.

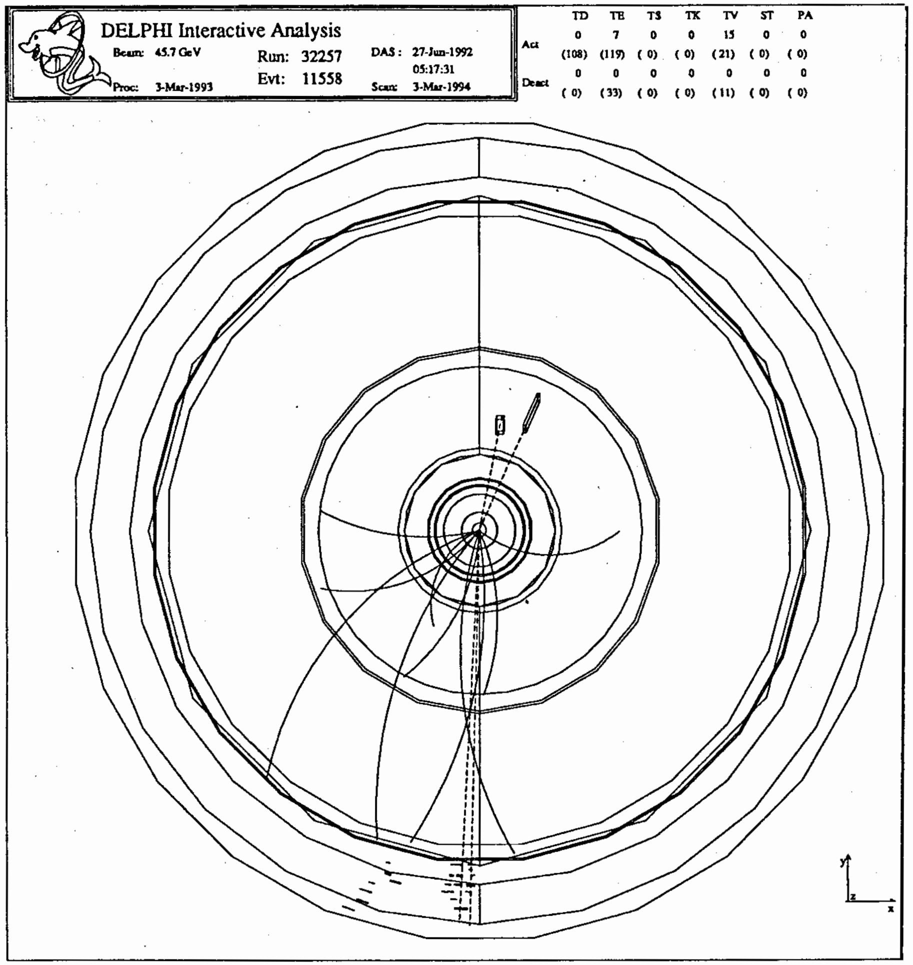
Mean value for the Q^2 is around 90 GeV^2.

QCD prediction testing should proceed through F_2^γ unfolding [10] to take into account the effect of limited acceptance and finite resolution of the detector.

The main features of a single tagged event can be seen on the $R\phi$ and Rz projections for one selected event. The track detectors and electromagnetic calorimeters are drawn. The showers in calorimeters are drawn by boxes. The solid lines show reconstructed charged particles, the dashed show neutrals. It is seen a separate cluster in the FEMC produced due to a shower before the FEMC.

The features described below are an consequence of the fact that both an energy and a polar angle of emitted photons are peaked at small values. Thus the most probable that produced quarks (hadrons) are boosted in z direction of a tagged particle if its energy is small compared to the beam energy (the normalized longitudinal momentum balance NLMB introduced above is the quantative description of such feature). The reconstructed energy of the tagged electron was 37.4 GeV for the selected event. It is seen on the Rz projection that the main part of produced hadrons move in positive z direction as the tagged electron.

On the $R\phi$ projection one can see that the produced hadrons move in the direction opposite to the tagged particle, because a target photon polar angle is peaked at small values.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Act 0 7 0 0 15 0 0
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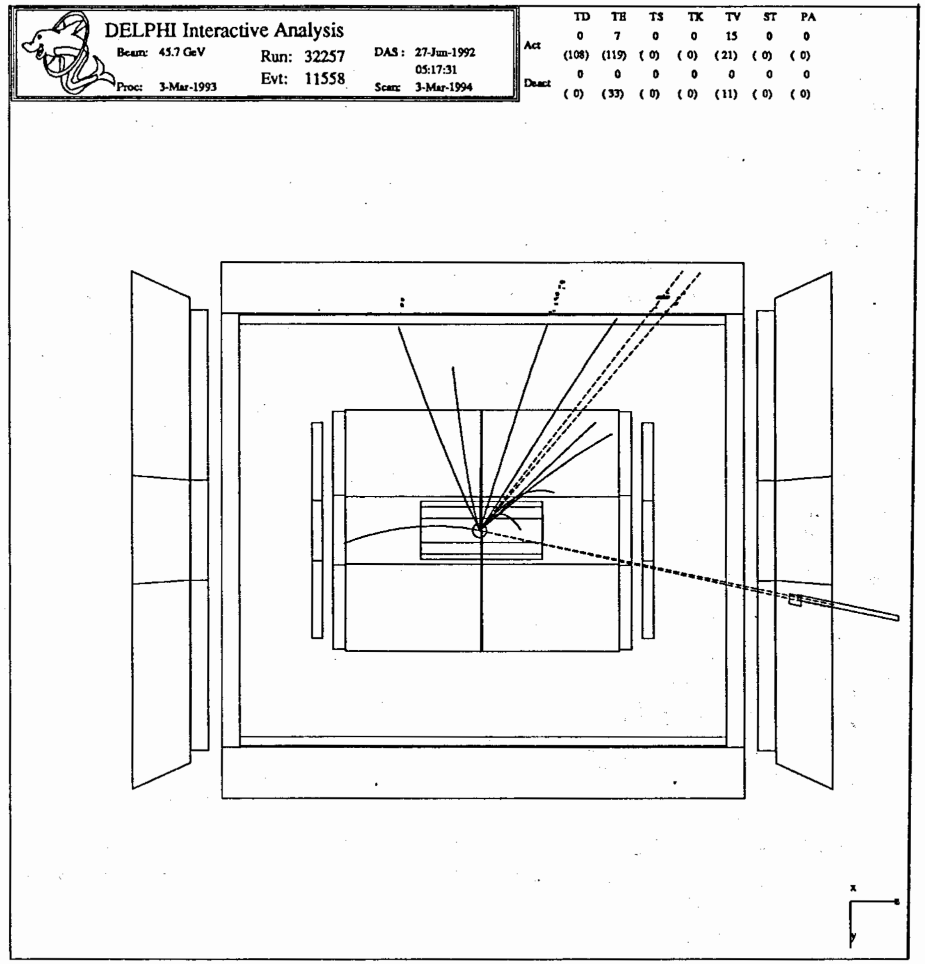
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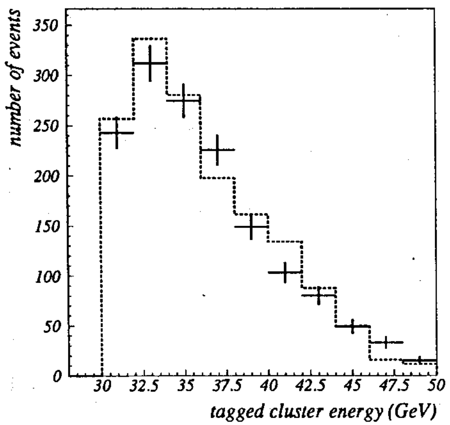


Fig.3a

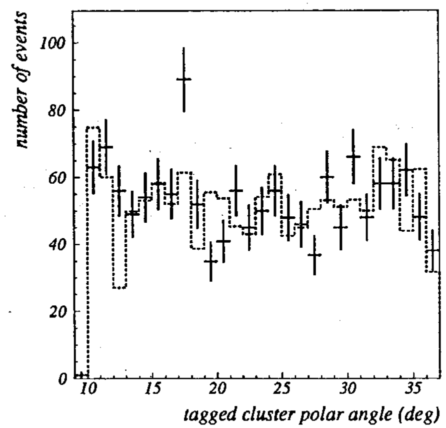


Fig.3b

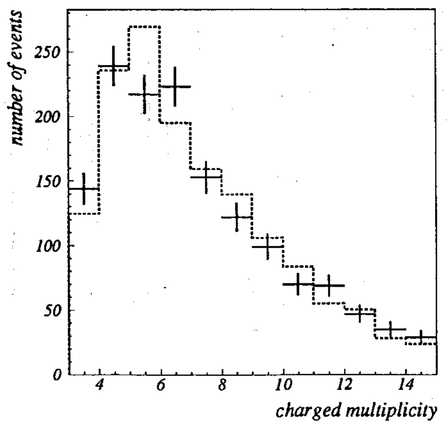


Fig.3c

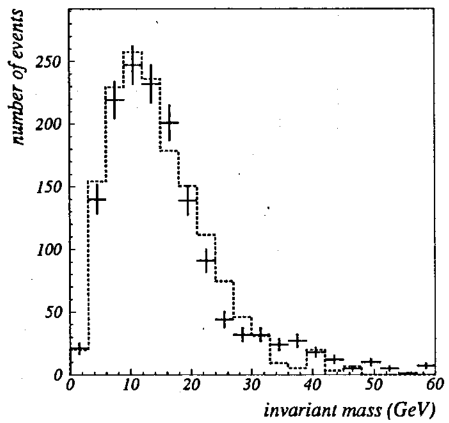


Fig.3d

- **Fig.3** The comparison of the distributions for the data (bars) and Monte Carlo simulation (histograms) : tagged cluster energy (a); tagged cluster polar angle (b); charged multiplicity in the event (c); invariant mass of the hadron system calculated using charged particles and neutrals measured in the electromagnetic calorimeters (d).

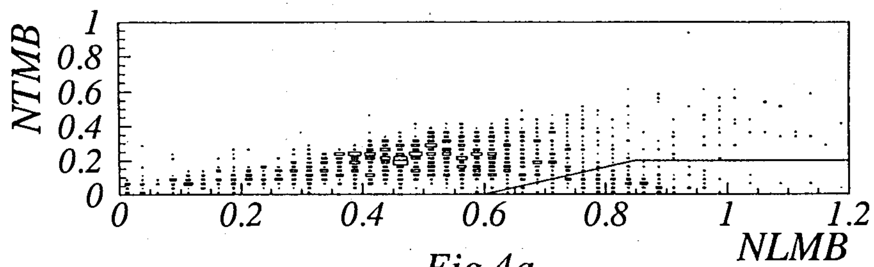


Fig.4a

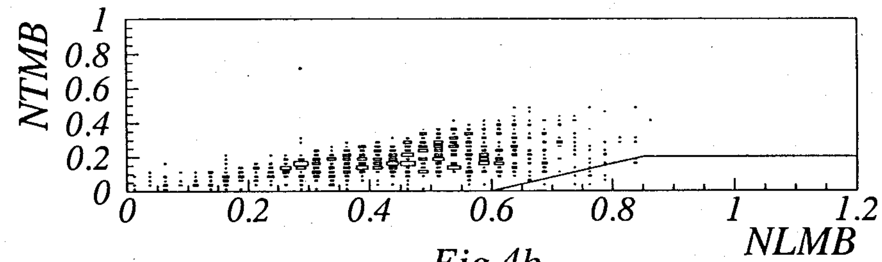
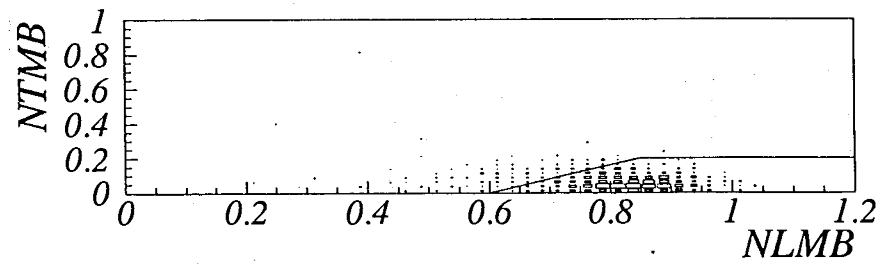
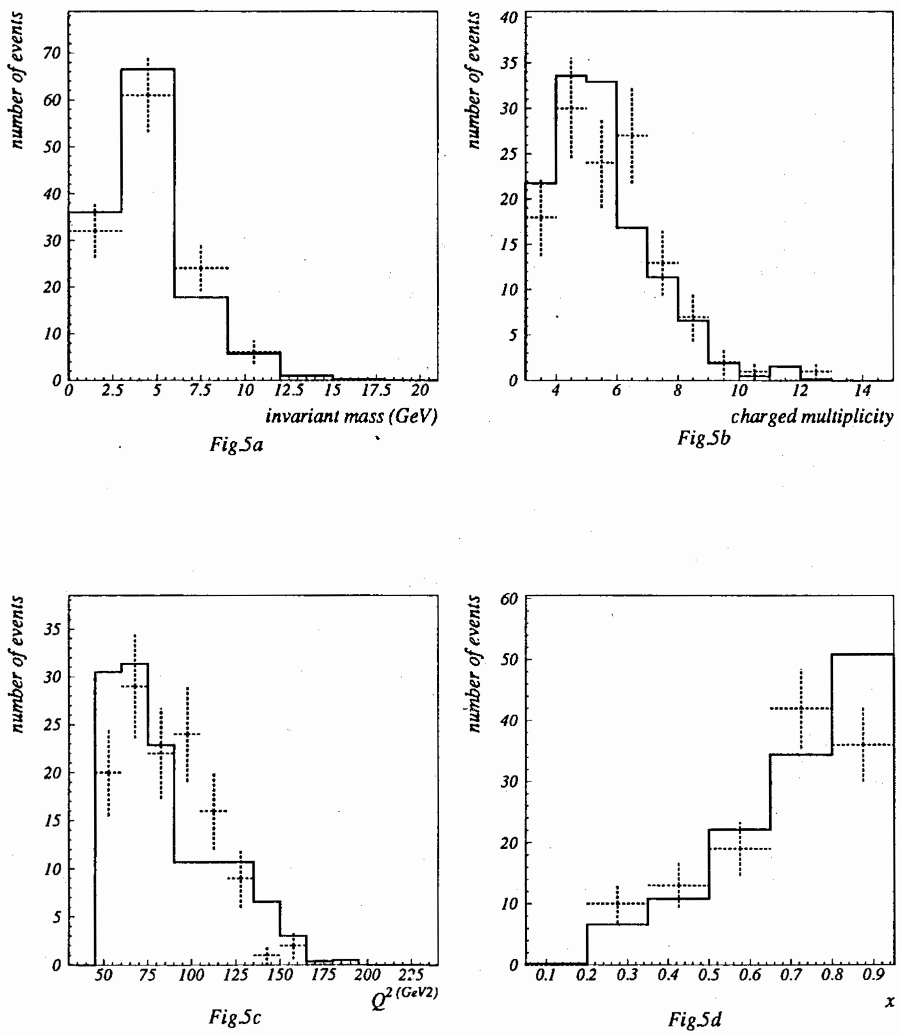


Fig.4b



- **Fig.4** The correlation plots between NLMB and NTMB for the data (a) and Z^0 (b) and $\gamma\gamma$ (c) Monte Carlo simulation.



• **Fig.5** The comparison of the distributions for the finally selected data (bars) and the simulation (histograms) : invariant mass of the hadron system (a); charged multiplicity in the event (b); Q^2 (c) and x (d).

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