Disclaimer

Diphoton + Jet Event Structure in $p\bar{p}$ Collisions at $\sqrt{s} = 1.8\,\mathrm{TeV}$

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We present results on the structure of $\gamma\gamma$ events where the diphoton pair has large transverse momentum, indicating the presence of a recoil jet. The fractions of events where the jet is leading in p_T, intermediate between the two photons, and lowest in p_T, and the separation between the two photons for each of these classes, are all in agreement with expectations. With present statistics, however, it is not possible to distinguish the predictions of next to leading order (NLO) QCD from simple phase space effects.

I. INTRODUCTION

New results on the diphoton cross section and k_T distribution have recently been presented by DØ [1], [2]. This analysis uses the same data sample to explore a suggestion due to Bailey [3] and Huston and Owens [4] that one may test next-to-leading-order (NLO) QCD by studying the structure of diphoton events with an additional jet. The data may be divided into three classes: those where the jet is leading in p_T, where its p_T is intermediate between the two photons, and where it is lowest in p_T. The fraction of events in each class, and the distribution of the photons in each case, are predicted at NLO.

Compared with the case of photon + dijet events, where similar tests [5] are possible[2], the diphoton + jet final state has the great advantage that (to the level at which k_T effects may be ignored) the diphoton momentum will balance that of the recoil jet. One may then infer the presence of the jet and accurately measure its transverse momentum from that of the two photons. This avoids the need to understand the reconstruction efficiency and energy resolution for low-p_T jets, which we know to be a complex issue. On the other hand, one suffers from much reduced statistics compared with the photon + dijet analysis.

This study uses $60\,\mathrm{pb}^{-1}$ of data taken during Run IB with the EM2_GIS_GAM filter, which required 2 EM objects with $E_T > 12\,\mathrm{GeV}$ at Level 2.

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II. DATA SELECTION

Events were required to have two photon candidates satisfying the following cuts:

- $E_T^1 > 20\,\text{GeV}$, $E_T^2 > 18\,\text{GeV}$;
- Isolation with $E_T^{R=0.4} - E_T^{R=0.2} < 2\,\text{GeV}$;
- EM fraction > 0.96;
- $|\eta| < 0.9$ and detector IETA ≤ 9;
- H-matrix $\chi^2 < 100$;
- CCEM crack cut (10% of 2π excluded);
- No track found in the road in front of the EM cluster.

The combined acceptance and efficiency of these cuts is estimated to be 0.28 ± 0.03 from plate level Monte Carlo simulations including noise and pileup effects [1].

In addition to the cuts outlined above, it was found necessary to impose an invariant mass requirement to remove $Z \rightarrow ee$ events where both electron tracks were lost because of tracking inefficiencies. Events with $80 < m_{\gamma\gamma} < 110\,\text{GeV}$ were therefore excluded.

217 events remain after these selections, forming the inclusive $\gamma\gamma$ sample used in [1], [2]. The estimated purity is 0.27 [1].

Two additional cuts are then made for the diphoton + jet analysis:

- To increase the purity of the sample, one or both photons is required to have an energy in the EM1 layer less than 1% of the cluster energy;
- The combined transverse momentum of the photon pair is required to be greater than $10\,\text{GeV}/c$.

This yields a sample of 26 events with a purity of 0.41.

A complementary sample of highly electromagnetic jets was selected from the same diphoton trigger and dataset. The EM jets were selected as in [1], [2] by requiring the same kinematic and invariant mass cuts as above, but:

- Anti-isolation with $E_T^{R=0.4} - E_T^{R=0.2} \geq 2\,\text{GeV}$,
- EM fraction > 0.90;
- $EM1/E \geq 0.01$;
- One or more of: EM fraction < 0.96, H-matrix $\chi^2 \geq 150$, or ≥ 2 tracks found in the road in front of the EM cluster.

These selections yield 39 events. This sample is expected to be composed almost entirely of dijet events where both jets have fragmented into electromagnetically-decaying particles. No real isolated photons are expected to remain in this sample.

III. DOES THE DIPHOTON P_T BALANCE THE JET P_T?

In this analysis we shall assume that $\mathbf{p}_T^{jet} = -\mathbf{p}_T^{\gamma\gamma}$, i.e. that the 'jet' transverse momentum may be estimated from the diphoton transverse momentum, even in cases where no jet is seen (due to reconstruction inefficiencies). In order to test this assumption, the jet p_T and ϕ have been compared with the diphoton p_T and ϕ, for those events where a jet is found. (In order to obtain sufficient statistics no cut on EM1 energy was imposed on either photon for these plots). Figure 1 shows the results of this comparison. It will be seen that the jet energy does not match the diphoton energy very well, which is not surprising given the very poor resolution for low-p_T jets, but that the reconstructed jet direction is strongly peaked back-to-back in ϕ from the diphoton system. This supports the assumption that the diphoton recoils against the jet and may thus be used to measure its transverse momentum.

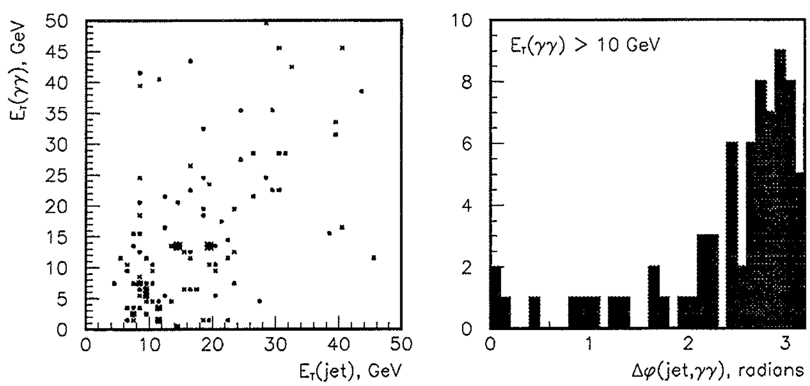

FIG. 1. (a) Diphoton p_T compared with jet p_T, for events with a reconstructed jet; (b) Difference in azimuthal angle between the diphoton system and the reconstructed jet.

IV. DIPHOTON + JET EVENT STRUCTURE

Class	NLO QCD	Phase space	$\gamma\gamma$ data	EM jet data
$p_T^{jet} > p_T^{\gamma_1} > p_T^{\gamma_2}$	0.17	0.28	0.27±0.09	0.18±0.06
$p_T^{\gamma_1} > p_T^{jet} > p_T^{\gamma_2}$	0.23	0.24	0.27±0.09	0.15±0.06
$p_T^{\gamma_1} > p_T^{\gamma_2} > p_T^{jet}$	0.60	0.48	0.46±0.10	0.67±0.08

TABLE I. Fraction of events in each of the three classes.

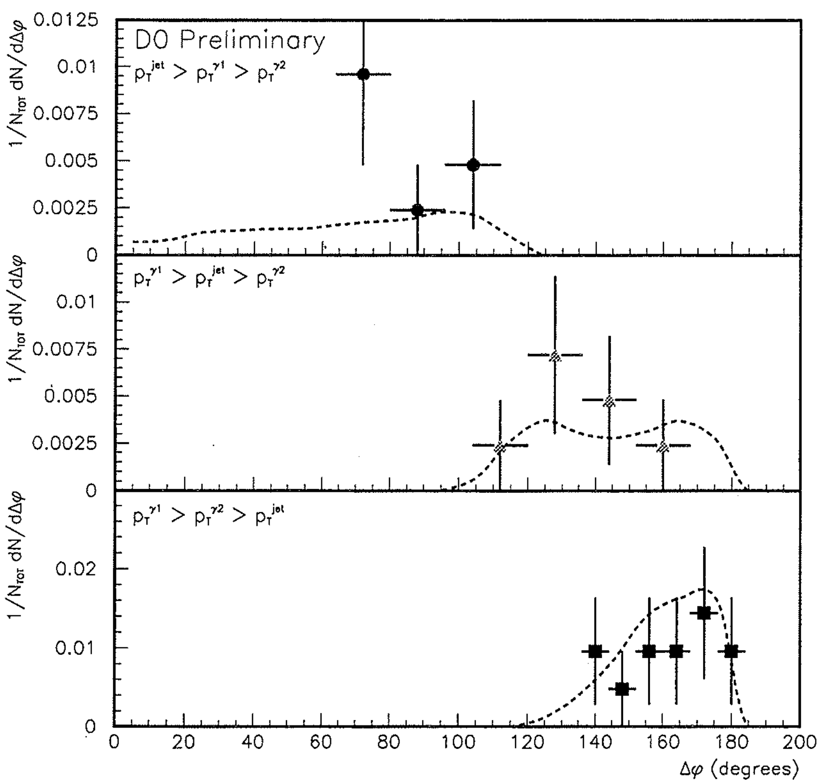

FIG. 2. Separation in ϕ between the two photons, for events in each of the three classes shown. The dashed line is the NLO QCD prediction, normalized to the total number of events in the three classes combined.

Table 1 shows the fraction of events falling into each of the three classes, for the NLO QCD calculation of Ref. [3] (evaluated with our kinematic cuts [6]), phase space only [6], the $\gamma\gamma$ data sample, and the EM jet background sample. It will be seen that with the present statistics, it is not possible to distinguish the data from the EM jet background, or to distinguish between the NLO QCD prediction and pure phase space.

Figures 2 and 3 show the separation in ϕ and $R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$ between the two photons, for each of the three classes of events. The data are in line with the NLO QCD prediction, but the statistics are extremely limited.

V. CONCLUSIONS

We have investigated the structure of $\gamma\gamma$ events where the diphoton pair has large transverse momentum, indicating the presence of a recoil jet. The fractions of events where the jet is leading in p_T, intermediate between the two photons, and lowest in p_T, and the separation between the two photons for each of these classes, are all in agreement with expectations. With present statistics, however, it is not possible to distinguish the predictions of next to leading order (NLO) QCD from simple phase space effects. Nonetheless, this study may become interesting with increased statistics due to its avoidance of any dependence on jet reconstruction or energy measurement.

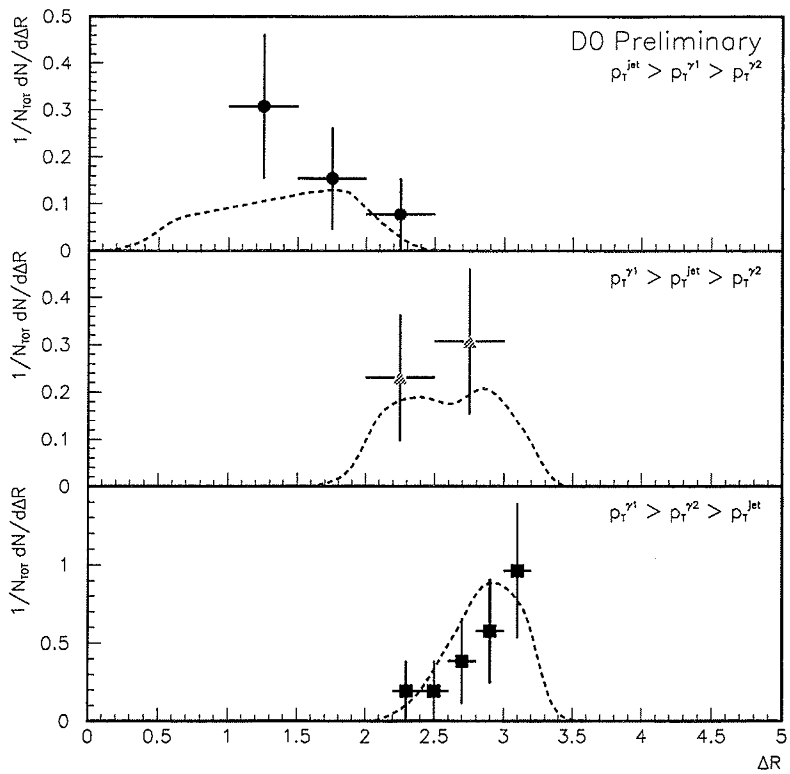

FIG. 3. Separation in R between the two photons, for events in each of the three classes shown. The dashed line is the NLO QCD prediction, normalized to the total number of events in the three classes combined.

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