Fermi National Accelerator Laboratory

FERMILAB-Conf-92/317-E

Isolated Double Prompt Photon Production at CDF

presented by Robert M. Harris
The CDF Collaboration

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P.O. Box 500, Batavia, Illinois 60510

November 1992

Presented at the *1992 Division of Particles and Fields*,
Fermi National Accelerator Laboratory, Batavia, Illinois, November 10-14, 1992

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

CDF/PUB/JET/PUBLIC/1877
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November 4, 1992

ISOLATED DOUBLE PROMPT PHOTON PRODUCTION AT CDF

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ABSTRACT

We present a measurement of the cross section for production of two isolated prompt photons in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV. The cross section, measured as a function of transverse momentum (P_T) of each photon, is roughly three times what full QCD calculations predict. Calculations that only include the Born and box diagrams, which are commonly used to estimate the prompt diphoton background to Higgs decay at future hadron colliders, are lower than our measurement by roughly a factor of five. We also study variables sensitive to K_T: the transverse momentum of initial state partons. The vector sum of the transverse momenta of both photons, $K_T = |\vec{P}_{T1} + \vec{P}_{T2}|$, is compared to previous measurements at lower collision energies, and we find a roughly logarithmic increase with $\sqrt{s}$. The measured mean value is $< K_T >= 5.1 \pm 1.1$ GeV at $\sqrt{s} = 1.8$ TeV.

1. Introduction

According to Quantum Chromodynamics (QCD), there are three types of processes that contribute significantly to diphoton production: the Born process ($q\bar{q} \to \gamma\gamma$), the box process ($gg \to \gamma\gamma$), and *bremsstrahlung* processes (e.g. $qg \to \gamma\gamma q$) shown in Fig. 1a. Diphotons, generally used to study QCD and measure K_T, are also a background to a Higgs signal ($H \to \gamma\gamma$) at future hadron colliders.

2. Event Selection and Background Subtraction

To identify diphotons we use the CDF central electromagnetic (EM) and hadronic (HAD) calorimeters and the central EM strip chambers (CES) embedded inside the EM calorimeter near shower maximum. In 1989 an integrated luminosity of 4.3 pb^{-1} was accumulated with a trigger that required two clusters with EM transverse energy greater than 10 GeV each. For each photon candidate, we required the lateral and longitudinal energy deposition in the calorimeter be consistent with a photon. Identical to the single photon analysis,[1] we required there be no track pointing at at each photon candidate, and within the boundaries of each EM cluster, associated the highest energy CES cluster with the photon and required there be no other CES clusters with greater than 1 GeV. Also, each photon had to be within the CES fiducial area and in the pseudorapidity interval $|\eta| < 0.9$ and have P_T in the range $10 < P_T < 35$ GeV. An isolation cut required the total transverse energy

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† Supported by the U.S. Department of Energy, contract number DE-AC02-76CH03000.

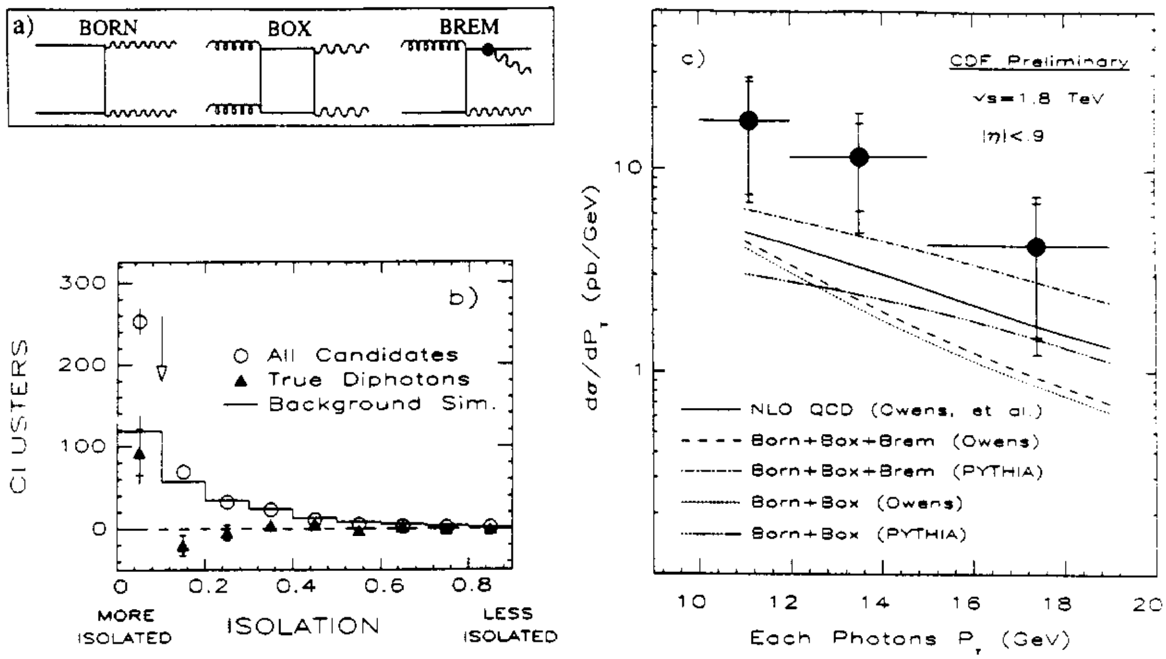

Figure 1: **a)** Leading diagrams for isolated $\gamma\gamma$ production. **b)** Neutral EM clusters in diphoton candidate events (open circles) are less isolated than true diphotons after background subtraction (triangles) but show an excess of isolated events when compared to a background simulation (solid histogram) normalized to the data to the right of the arrow. **c)** The cross section for producing a photon in a bin of P_T in a diphoton event is compared to QCD predictions. Each photon is counted once. Inner error bars are statistical; outer error bars include systematic uncertainties also.

in towers bordering the EM cluster be less than 10% of the EM cluster transverse energy. The isolation of each photon candidate, shown in Fig. 1b, displays this cut and suggests the presence of diphotons above the background. To subtract the background, predominantly from π^0 and η mesons, we use the CES profile method employed by the single photon analysis. The difference between the narrow transverse profile of photon induced EM showers, and the broader transverse profile of the background, is used to measure the fraction of diphoton candidates that are signal (37% for photons in the range $10 < P_t < 19$ GeV).

3. Diphoton Production Cross Section

In Fig. 1c the diphoton cross section is compared to a full QCD calculation[2] to order $\alpha^2\alpha_s$, which includes lowest order Born, box and *bremsstrahlung* processes and most next to lowest order (NLO) processes. The CDF diphoton cross section is roughly three times what the full QCD calculation predicts. Also shown is an analytic leading log calculation (which includes the Born, box and *bremsstrahlung* processes) and an analytic calculation of the Born plus box processes alone,[2] and for comparison both these calculations are repeated using the Monte Carlo program PYTHIA.[3] Calculations that only include the Born and box diagrams, which are commonly used to estimate the prompt diphoton background to Higgs decay at

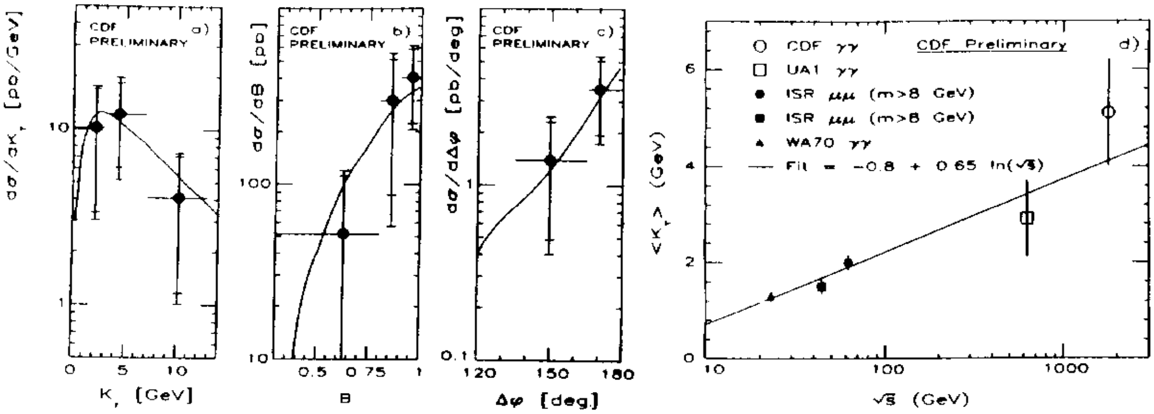

Figure 2: The correlation of the two photons is shown by the cross section versus **a)** the vector sum of the transverse momenta $K_T = |\vec{P}_{T1} + \vec{P}_{T2}|$, **b)** the P_T balance $B = P_{T2}/P_{T1}$, and **c)** the azimuthal angular separation $\Delta\phi = \phi_2 - \phi_1$. The solid curve is PYTHIA normalized to the data. **d)** The mean value of K_T versus collision energy measured in diphoton events at CDF, UA1[5] and WA70,[6] and in high mass dimuon events at the ISR.[7] The data is fit with $< K_T >= a + b \ln \sqrt{s}$.

future hadron colliders, are too low by roughly a factor of five. All calculations include the isolation cut and use HMRSB parton distributions.[4] Fig. 1c shows there is some uncertainty in the size of the lowest order *bremsstrahlung* process, which is smaller in the analytic calculation than in PYTHIA. The differences between the Born + box analytic calculation and PYTHIA are primarily due to K_T effects.

4. Study of Initial State K_T

According to QCD the transverse momentum of initial state partons, K_T, comes predominantly from emission of soft gluons prior to the hard collision. In Fig. 2 we present measurements of three distributions sensitive to initial state K_T. All of the measurements agree with PYTHIA, using the Born and box diagrams only, which effectively sums up the initial state gluon *bremsstrahlung* via backwards shower evolution. Full QCD calculations to order $\alpha^2\alpha_s$, according to reference,[2] are not expected to agree with the measurements because they do not resum all the soft gluon radiation. However, the mean value of K_T is quite large, $< K_T >= 5.1 \pm 1.1$ GeV is the mean of the data in Fig.2a, and $< K_T >$ increases roughly logarithmically with collision energy as shown in Fig. 2d. This K_T, which is often not adequately included in QCD calculations, can affect P_T distributions in hadronic collisions.

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