Photon measurements with the full CDF data set

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We present results of the cross section measurement of photon production associated with bottom- and charm-quark production and of the cross section measurement for diphoton production. The measurements involve the full CDF data sample and they are compared with state-of-the-art calculations. The comparisons show only partial agreement between data and calculations.

1 Introduction

CDF has an extensive active program of prompt photon measurements using of the full data set. The measurements benefit from the clean identification and precise measurement of the energy and direction of photons with the CDF detector. For the reported measurements the candidate prompt photons are selected offline from tower clusters of the electromagnetic calorimeter and reconstructed in a cone of radius R=0.4 in the $\eta-\phi$ plane. The photons are required to be central $|\eta| < 1$, and to have a transverse energy $E_T = E \sin\theta > 30$ GeV for the photon+heavy flavor measurements and $E_T > 17, 15$ GeV (for the 1st and 2nd photon in the event, respectively) in the diphoton measurements, where E is the total energy of the photon. For the photon+heavy flavor measurements a secondary vertex algorithm is also used to select heavy flavor jets. This is done by fitting the invariant mass of the selected jet to derive the light flavor, charm, and bottom fractions.

2 Photon+heavy flavor production

	$\sigma_{total}(\gamma$+b) (pb)	$\sigma_{total}(\gamma$+c) (pb)
Data	19.7±0.7$_{\rm stat}$ (+5.0−4.2)$_{\rm syst}$	132.2±4.6$_{\rm stat}$ (+13.2−19.2)$_{\rm syst}$
PYTHIA	17.0	101.4
PYTHIA (×2 g→ Q$\bar{\rm Q}$)	19.5	106.0

Table 1: Total cross sections for photon+b/c production.

The measurements are compared with LO calculations from the PYTHIA [1] parton shower Monte Carlo and with a NLO calculation from [2]. The latter calculation includes pointlike photon subprocesses through O($\alpha\alpha_s^2$) and fragmentation subprocesses through O (α_s^3). Predictions from PYTHIA are obtained for two cases: One with the default gluon splitting rate into heavy flavor quark pairs and one with the gluon splitting rate increased by a factor of 2. The kinematic cuts applied on both the data and the calculations are $|y| < 1$, $30 < p_T < 300$ GeV/c for the photon and $|y| < 1.5$, $p_T > 20$ GeV/c for the b or c quark, where y is the rapidity and p_T the transverse momentum. The photons are required to be isolated in a cone of radius R=0.4, with an isolation energy <2 GeV, and the angular distance between the photon and the b or c quark is required to be ΔR>0.4.

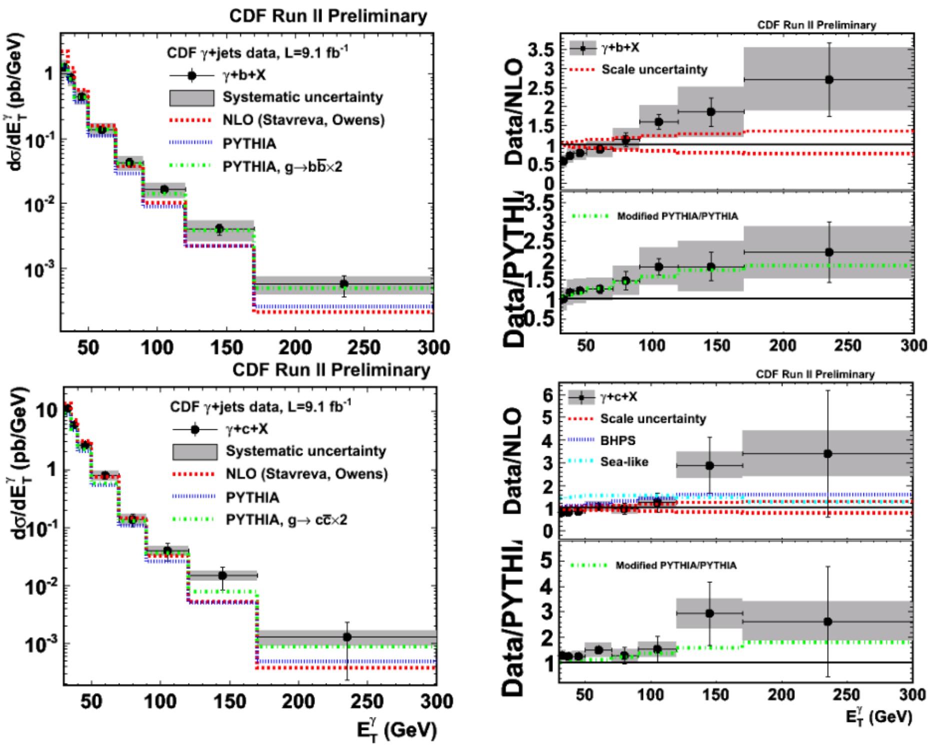

Figure 1: Differential cross sections and data/theory ratios for photon+heavy flavor production. The shaded band depicts the total systematic uncertainty of the measurement.

Table 1 shows the total cross sections from the data and from the two PYTHIA calculations. The γ+b calculation is in relatively good agreement with the data, especially when the gluon splitting rate is increased. The γ+c calculation underestimates the data. Figure 1 shows the measured and predicted cross sections and the data/theory ratios differential in the photon transverse energy. A scale uncertainty is estimated for the NLO calculations. The ratio of data to PYTHIA is taken with respect to the default calculation and then the ratio of the modified to the default PYTHIA calculation is also plotted. In the case of γ+c production two variations of the NLO calculation using intrinsic charm hadron models are also compared with the data. The NLO calculations do not reproduce the shapes of the data. The PYTHIA predictions are in better agreement with the shapes of the data when the gluon splitting rate is increased.

3 Diphoton production

The measurements are compared with five calculations: (i) Predictions from the LO parton shower program PYTHIA [1]. (ii) Predictions from the LO parton shower program SHERPA [3]. (iii) Fixed-order NLO predictions including non-perturbative fragmentation processes at LO from the program MCFM [4]. (iv) Fixed-order NLO predictions including non-perturbative fragmentation processes at NLO from the program DIPHOX [5]. (v) Predictions from the program RESBOS [6] performing a low-p_T analytically resummed calculation which is then matched to the high-p_T NLO matrix element calculation. The RESBOS calculation is constrained by a cut on the diphoton invariant mass $M_{\gamma\gamma} < 350$ GeV$/c^2$. PYTHIA is run in a mode that combines $\gamma\gamma$ and γ+jet production from which events with at least two prompt photons are selected during the simulation, thus including in part real NLO contributions from initial and final state radiation. Table 2 shows the total cross sections from the data and from calculations. Theoretical uncertainties from the choice of scale and the parton distribution functions (PDF) are included for NLO parton-level calculations, where such uncertainties are better defined. All predictions are consistent with the data. Figure 2 shows the relative deviations, in the form of (data−theory)/theory, between measured and predicted cross sections differential in the diphoton transverse momentum p_T and in the azimuthal distance $\Delta\phi$ between the two photons in the event. The fixed-order NLO calculations fail to describe the data in the limit $p_T \to 0$. The RESBOS calculation provides the best description of the data in the limit of low diphoton p_T, where resummation is most important. The best overall agreement is achieved by the SHERPA prediction, although this one too underestimates the data in the region of $\Delta\phi < 1.5$ rad.

	$\sigma_{total}(\gamma\gamma)$ (pb)
Data	$12.3 \pm 0.2_{\mathrm{stat}} \pm 3.5_{\mathrm{syst}}$
RESBOS	11.3±2.4
DIPHOX	10.6±0.6
MCFM	11.6±0.3
SHERPA	10.9
PYTHIA	9.2

Table 2: Total cross sections for diphoton production.

4 Summary

We reported high precision measurements of the cross sections for prompt photon production associated with heavy quark flavor and for prompt diphoton production, both using the full CDF data sample. The measurements are compared with state-of-the-art calculations. The comparisons show only partial agreement between data and calculations.

5 Bibliography

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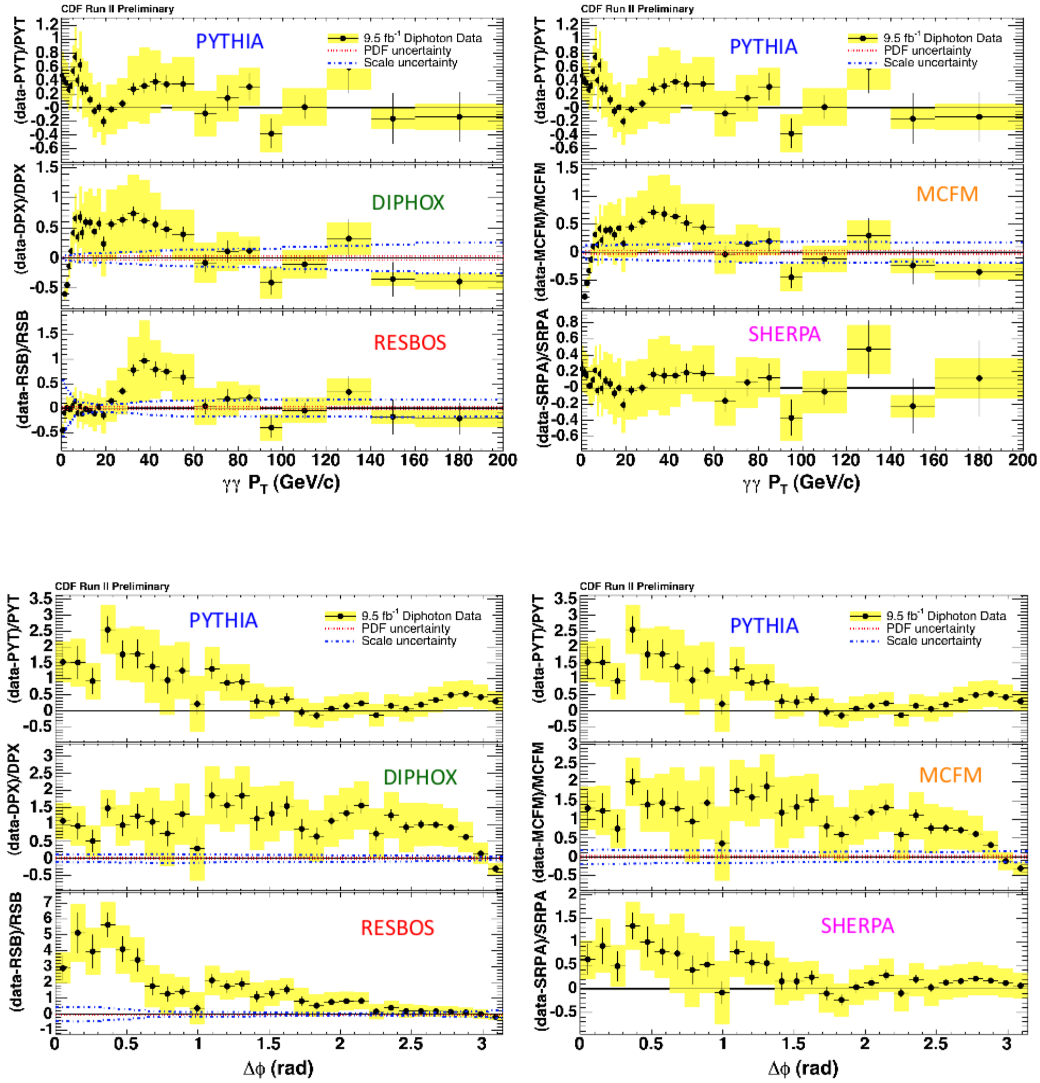

Figure 2: (Data−theory)/theory differential cross section ratios for diphoton production. The shaded band depicts the total systematic uncertainty of the measurement.