Photons and Diphotons from the Tevatron

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Abstract. Photon measurements from the CDF and DØ collaboration are described. The subjects touched on are loosely organized around the fact that they all have some bearing on the structure functions and pQCD. The methodology of collider measurements is briefly reviewed, and the results for single photons, photons plus jets, photons plus charm and diphotons are discussed. Finally there is a very brief indication of what is expected from the Tevatron based experiments in the future.

INTRODUCTION

Measurements of photon production at a hadron collider invariably require a certain amount of *art* to accomplish [1] [2]. Both the CDF and DØ measurements start out by looking for neutral electromagnetic rich *jets* and then require that the energy surrounding that jet is small. In the CDF case this is 2 GeV in a cone of $R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$ of radius 0.7, this cut is raised to 4 GeV for the later high luminosity running. In the DØ case the cut is 2 GeV in an annulus from 0.2 to 0.4 in R. Still the number of events coming from jets and decays of single hadrons is comparable to the number that are true single photon events. Each experiment has different tools to sort out the background level. For CDF the fraction of events that have an observed conversion in the material just in front of the calorimeter plus the lateral shape measured in a proportional chamber at shower maximum in the calorimeter are each used. The later is the preferred method for low energy photons (less than 35 GeV) and the former for high energy photons. In the end one of the two methods is used to evaluate point by point (depending on what quantity is being plotted) the fraction of photons in the sample. For DØ the fraction of energy observed in the first two radiation lengths of the calorimeter is used . The photon fraction is then fit to a smooth function versus E_T and this smooth curve is used to evaluate the purity.

[1] Results reported here are from the CDF and DØ collaborations.

THE INCLUSIVE PHOTON CROSS SECTION

The inclusive photon cross section was initially considered as a good way to evaluate the proton gluon distribution. Both the E_T and η distributions are sensitive to structure functions. Comparisons of NLO pQCD calculations with the measured results are helpful in checking the structure functions (see figure 1) [3].

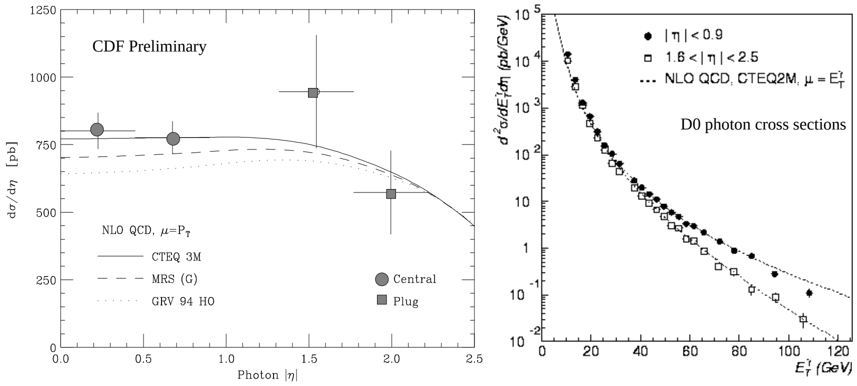

FIGURE 1. The inclusive photon cross section plotted versus the η of the photon measured by CDF(left) showing the expected shape for several different choices of structure functions.The inclusive photon cross section for two different regions of η versus photon E_T measured by DØ (right).

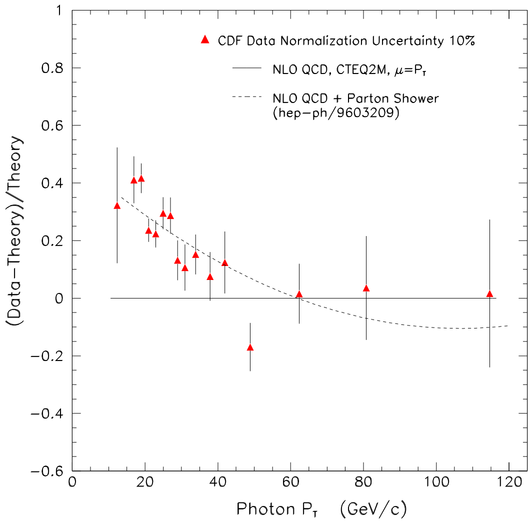

FIGURE 2. The effect of multiple gluon emission is illustrated by comparing the NLO calculation to the measured cross section (points) and to the same calculation with the addition of gluon emissions using a shower monte-carlo (smooth curve).

One conclusion that has emerged from the study of the inclusive cross section is that at low E_T the effect of soft multiple gluon emission which smears the measured E_T is an important effect. A number of experiments have observed deviations from NLO predictions at low E_T and these deviations can be explained by grafting a NLO calculation onto a shower monte-carlo as can be seen in figure 2 [4].

PHOTON PLUS JETS

The jets in single photon events can be used to shed further light on the agreement of theory and experiment. Figure 3 compares leading jet rapidity distribution for events with a central photon ($|\eta| < 0.9$) to the NLO prediction using several different structure functions. Since a scatter with both the jet and the photon central will have a better match between the two constituent x's than one in which the jet is forward, this measurement is very sensitive to the x distributions of the scattering constituents.

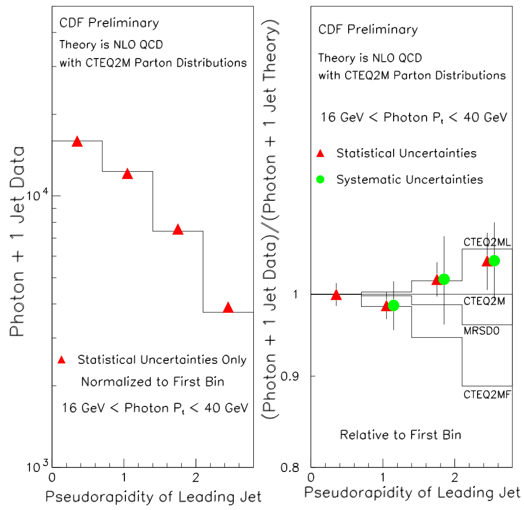

FIGURE 3. The leading jet rapidity in photon events is compared to the expected distribution for several different structure function choices.

Events with two jets are observed and the inclusive NLO prediction is a LO calculation for this subclass of events [5]. There is reasonable agreement between this prediction and the observed rate. One surprising source of background to this class of events is double interactions. A clear indication of the presence of such events appears in the distribution in angle between the second jet and the photon plus lead jet system (see figure 4). A flat contribution comes from events in which the lead jet and the photon come from a different hard scatter than the second jet. The study of events where there are two hard scatters in the same $p\overline{p}$ collision opens up the possibility of exploring the

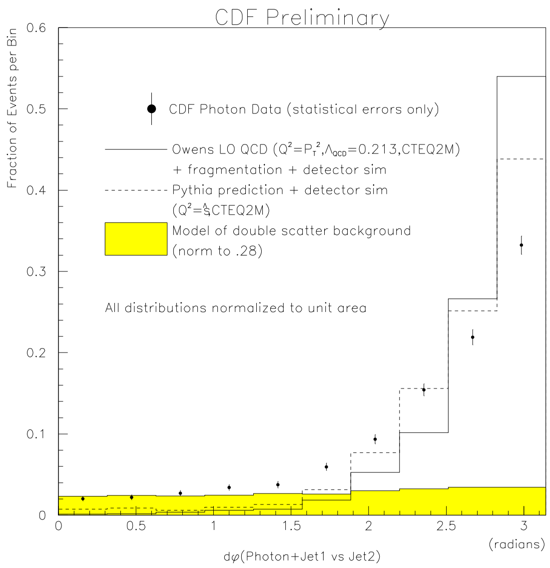

FIGURE 4. The difference between the net angle of the photon and lead jet pair and the second jet in photon plus two jet events. A flat contribution (indicated) is expected from pairs of hard scatters.

x distributions of more than one constituent in a nucleon.

PHOTONS PLUS CHARM

An area that is still quite statistics limited is the measurement of photon production in association with a final state charmed particle. CDF has measured photon production in association with muons, electrons and $D^{*\pm}$ mesons. This yields constraints on the charm content of the proton. The current CDF measurements rely on the first $20pb^{-1}$ of data (see figure 5). Photon plus muon events from later running with lower trigger thresholds and four times the luminosity are currently being analyzed.

DIPHOTONS

The production of two photons in $p\overline{p}$ collisions is a process that benefits from the accuracy with which the energy and location of photons can be determined. The net P_T of the two photon system is a direct measure of the soft gluon emission phenomenon described above. Recent calculations have been done to evaluate this effect [6] [7] [8]. The $\Delta\phi$ distribution and the net P_T distribution are compared to the resummed calculations in figure 6 [9].

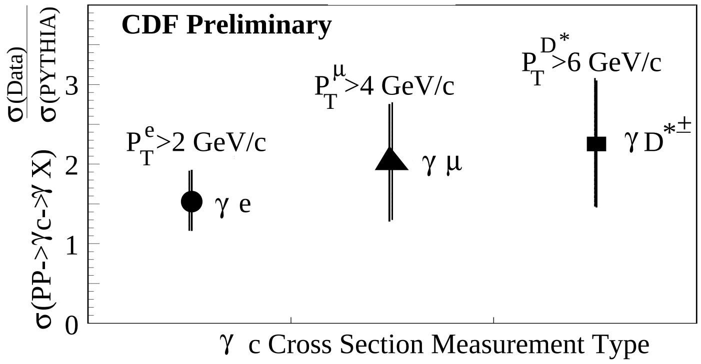

FIGURE 5. The ratio of measured over expected charm production for several different photon-charm channels.

CONCLUSIONS

A number of photon measurements at the Tevatron collider have helped to constrain both the structure functions and the underlying assumptions used to interpret these measurements. In some cases (photons plus muons in particular) there is a significant amount of data that remains to be analyzed from the last collider run.

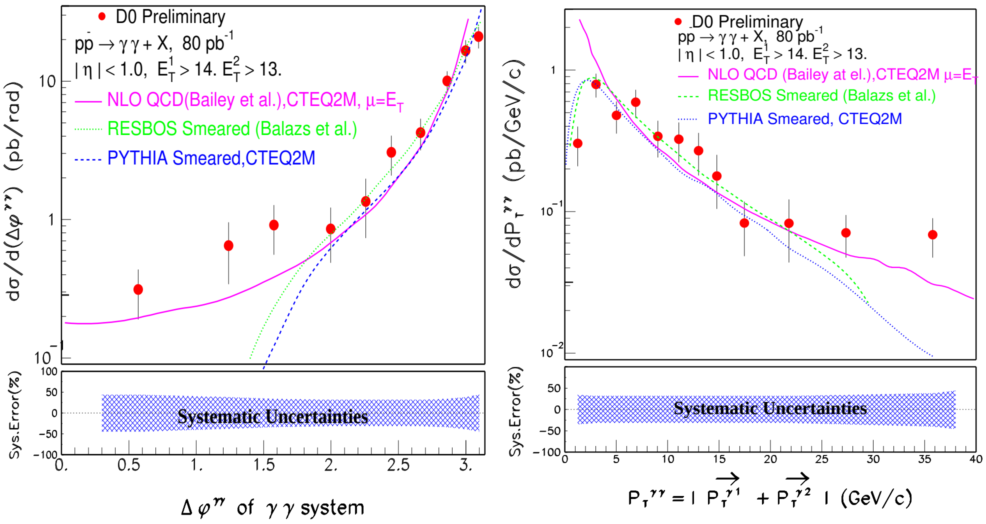

FIGURE 6. The distribution (left plot) in azimuthal angle difference for the two photons in diphoton events. The expected distribution is shown with and without the effect of multiple soft gluon emission. The right plot shows the net P_T of the two photon system with the same theory predictions as the azimuthal angle.

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