

Inclusive Prompt γ Production at CDF

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On behalf of the CDF Collaboration

DIS 2009, Madrid



Introduction and Motivation

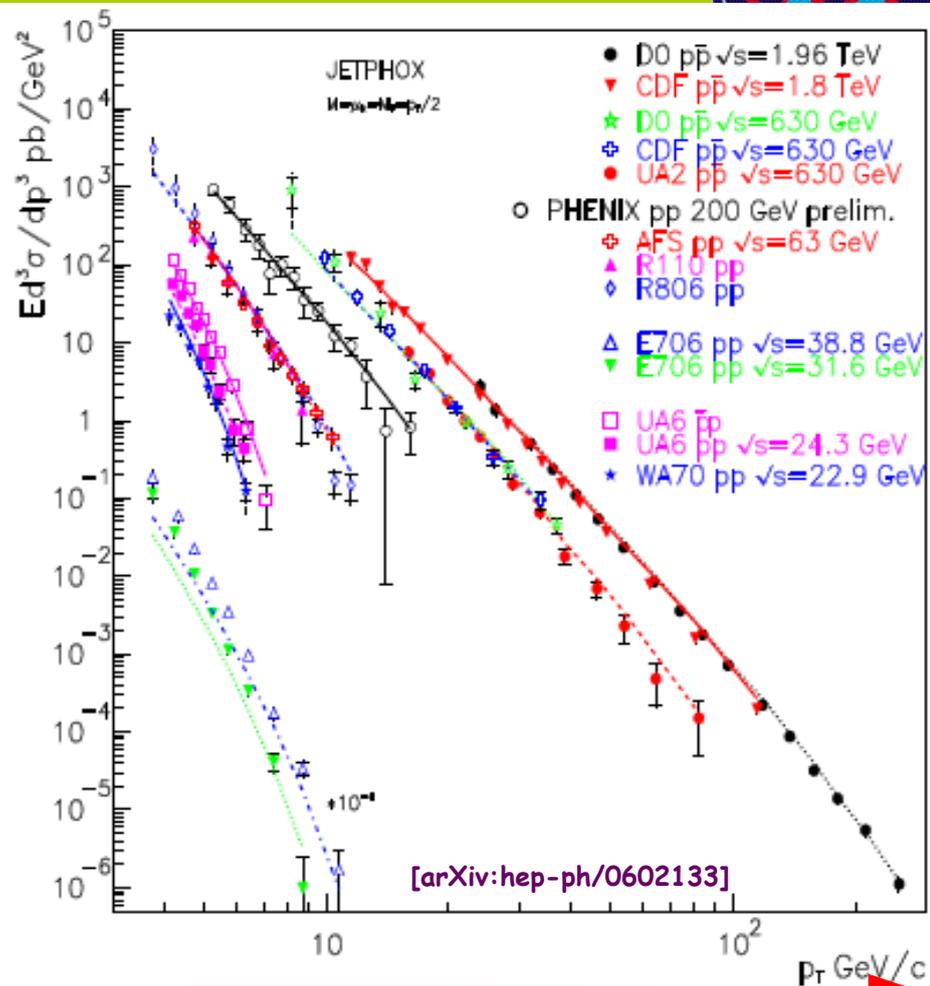


- **Test pQCD predictions over several orders of magnitude**
- The gluon-mediated production dominates up to 150 GeV → the high statistics Tevatron datasets can further constrain the **gluon PDF**

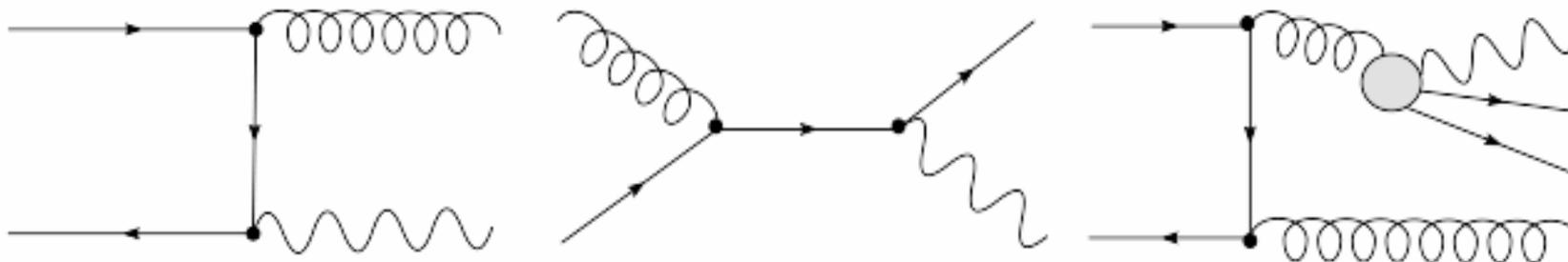
Advantages over pure QCD

- ★ **Point-like coupling** of quarks and photons
- ★ **No need of algorithms** to define photons
- ★ **Better energy resolution** (EM calorimeters)

- Probe **photon techniques** over a wide energy range
- **Irreducible background** for important searches (f.ex. light Higgs)



Extend E_T coverage

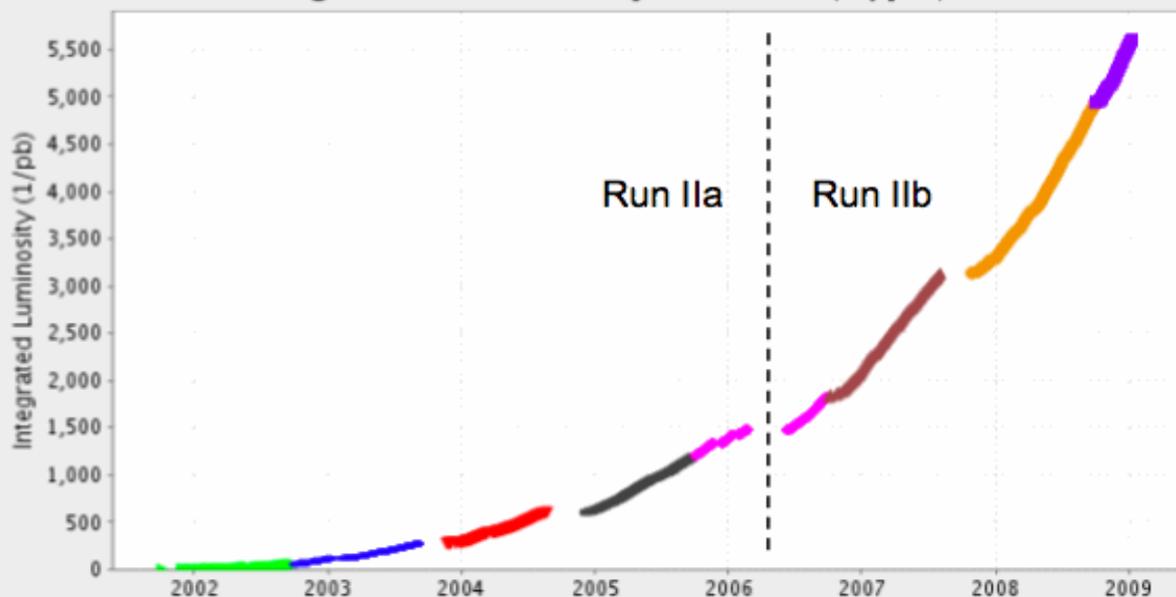


Tevatron Collider

- The Tevatron is a **p-pbar collider at $\sqrt{s}=1.96$ TeV** located Fermilab (Illinois, USA)
- In Run II (2001) it has **already delivered more than 6 fb^{-1}** of data
- Current previsions **expect a total dataset of more than 8 fb^{-1}**



Integrated Luminosity 5613.92 (1/pb)



- **Excellent performance:**
 - Typical inst. luminosity $> 3.0 \times 10^{32} \text{ cm}^2 \text{ s}^{-1}$
 - Record inst. lum. $3.6 \times 10^{32} \text{ cm}^2 \text{ s}^{-1}$
 - Delivered $> 6 \text{ fb}^{-1}$

CDF Detector



CDF is a multipurpose particle detector

Silicon Vertex detector
(L00, SVXII, ISL)

Central Drift Chamber (COT)

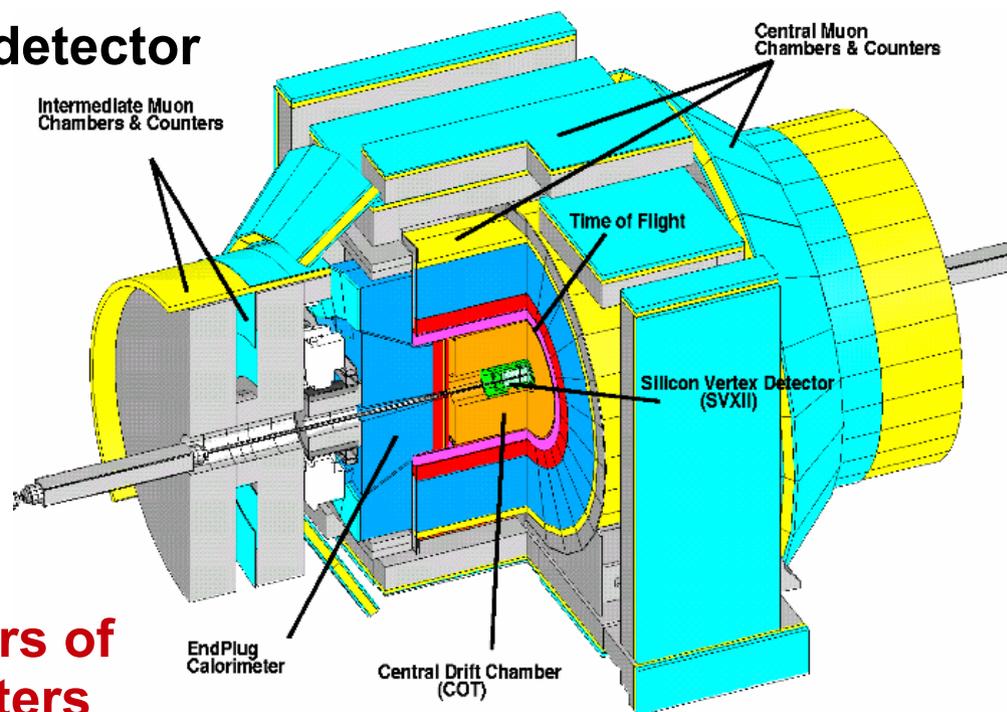
SC solenoid (B=1.4T)

Calorimeters

(central: CEM, CHA, WHA)

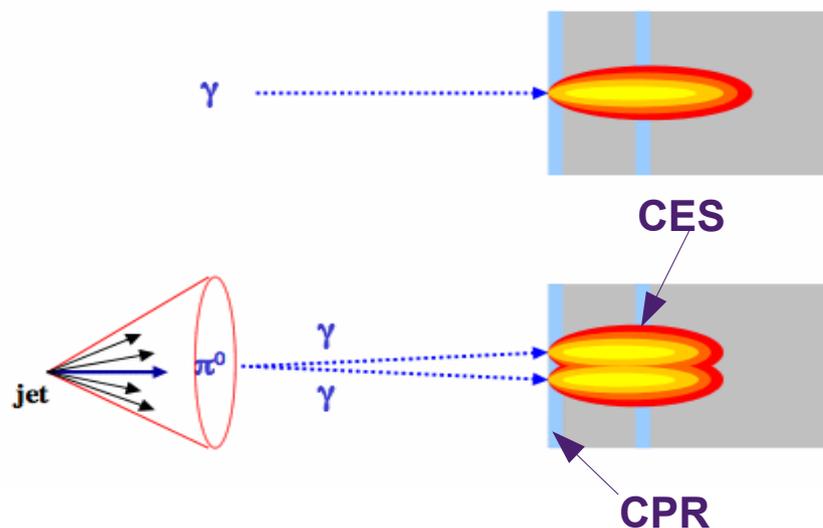
(forward: PEM, PHA)

Muon chambers



Photons are detected as clusters of 2-3 towers in the CDF calorimeters

CEM calorimeter

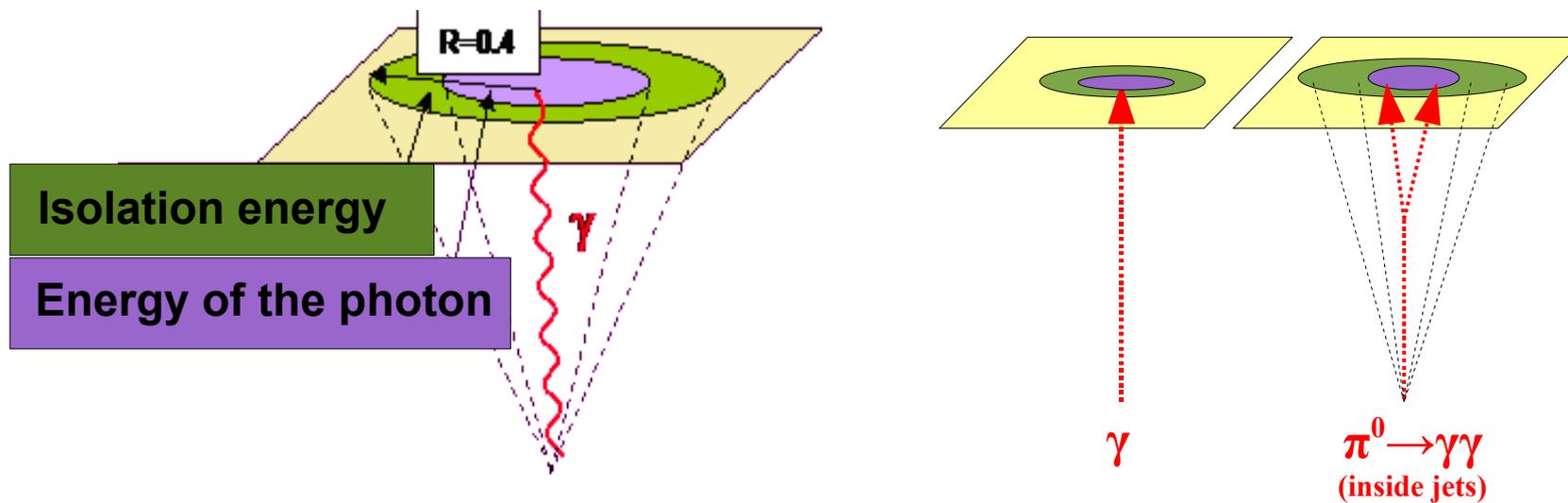


- γ and π^0 separation in the CEM:
 - **CES**: strip-wire chamber situated at the shower maximum position measures photon candidate position and shower shape (2mm resolution in each direction for 50 GeV electrons)
 - **CPR**: pre-radiator detector located before the calorimeter

Photon detection



- **Main background:** photons from light meson decays
 - ★ Suppressed by requiring **isolated photons**
 - ★ **isolation E_T** : Iso = energy in a cone of radius ~ 0.4 around the photon



- **Background** surviving the isolation cuts must be subtracted using **statistical techniques**:

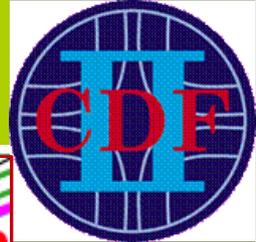
- **CES/CPR:**

Use information from the CES and CPR detectors

- **Isolation-shape templates:**

Fit the calorimeter isolation in the data to signal and background templates

Inclusive photon cross section

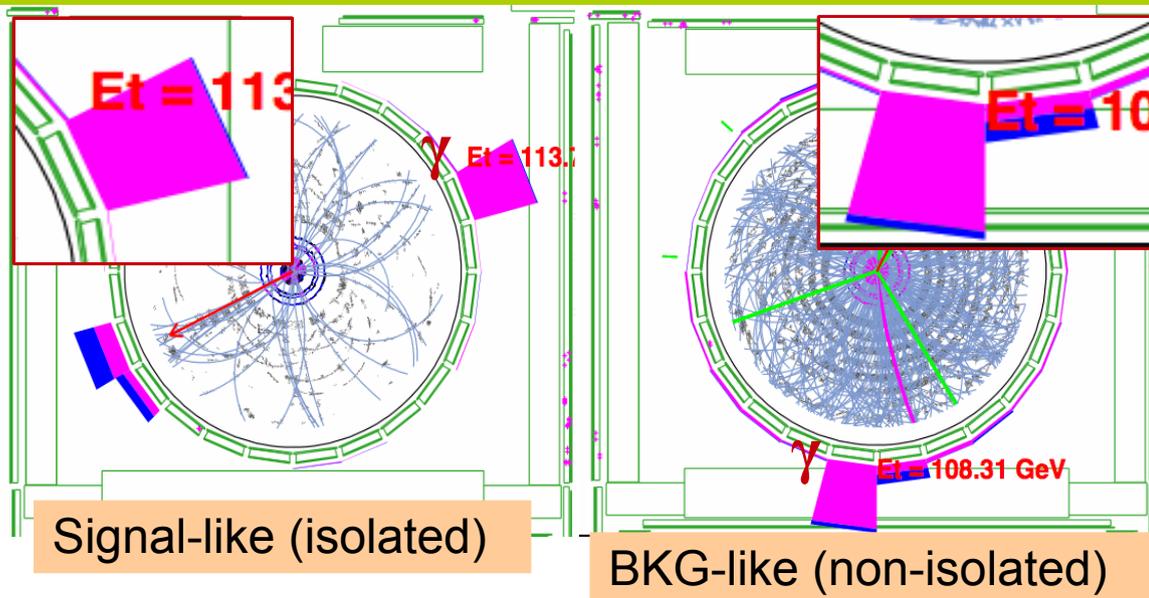


Photons

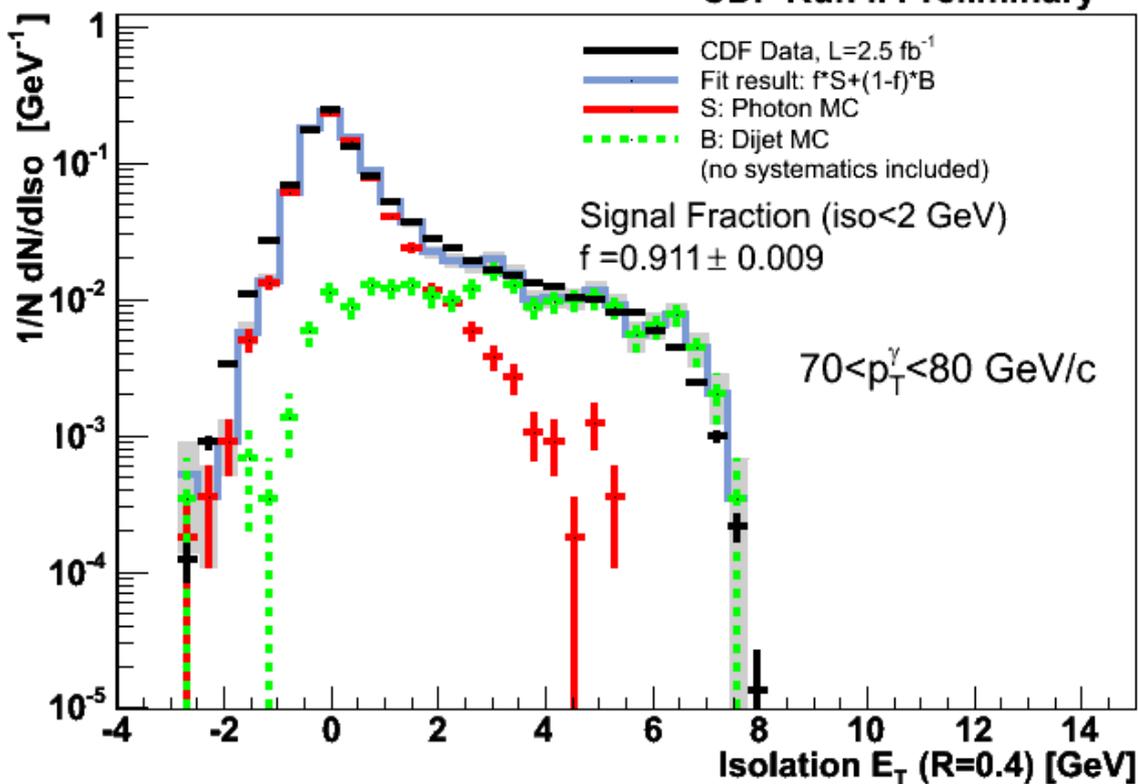
Central: $|\eta| < 1.0$
 $E_T > 30$ GeV

Isolated: $\text{Iso} < 2.0$ GeV
 Missing $E_T < 0.8 E_T$

Luminosity: $L = 2.5 \text{ fb}^{-1}$



CDF Run II Preliminary



Data

Fit Result:

χ^2 fit that takes into account the statistical uncertainties in the templates and in the data

Signal:

inclusive photon MC

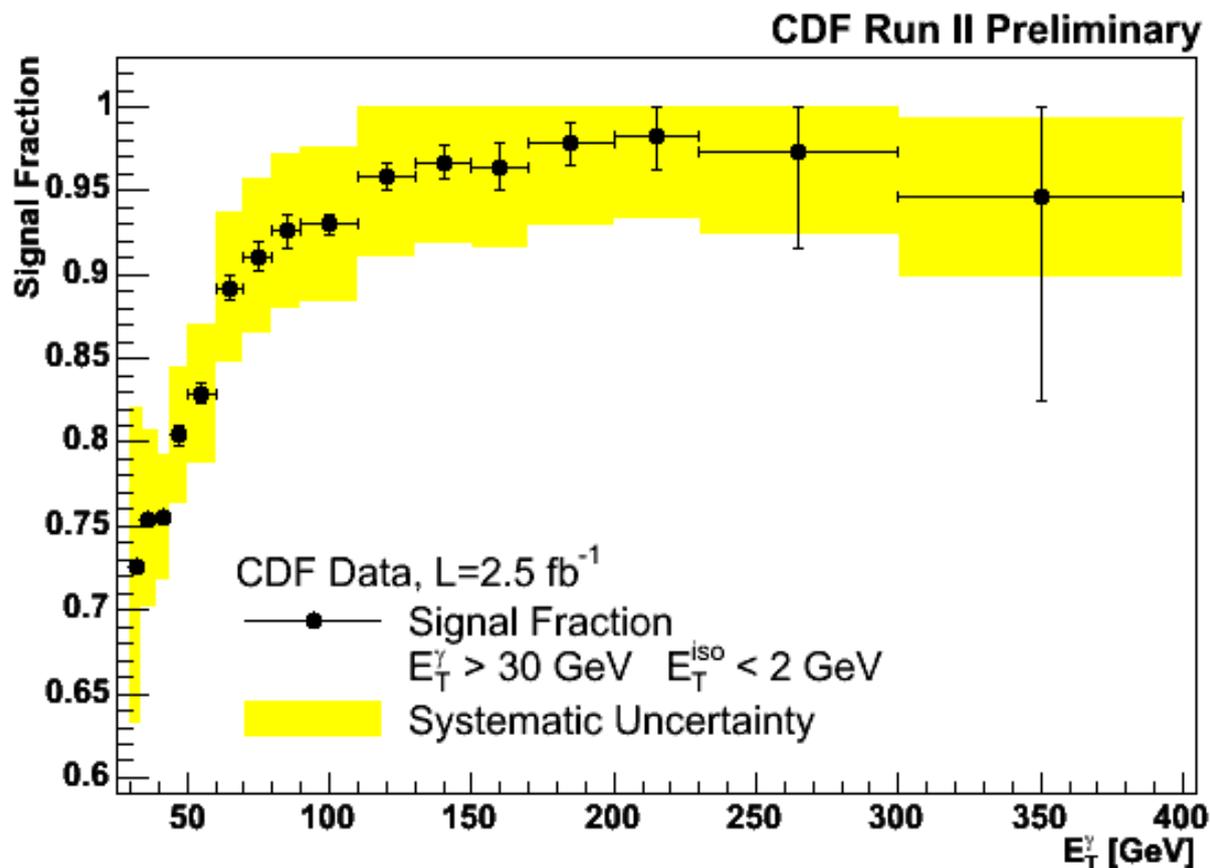
Bkg:

photons from meson decays in dijet MC

Photon purity



The signal fraction goes from ~70% to ~98% as the photon E_T increases

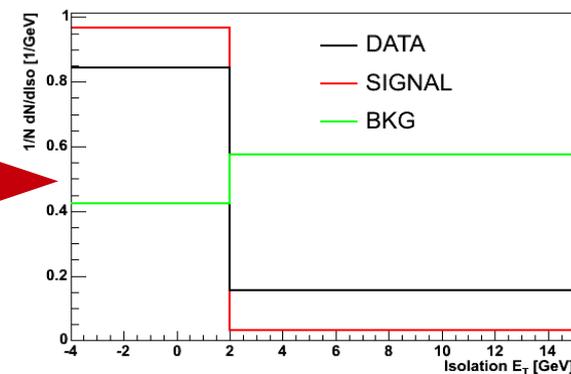
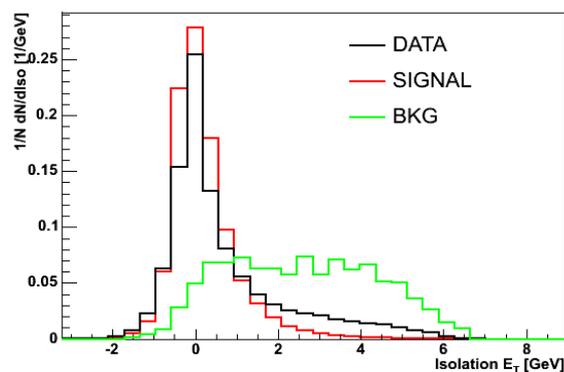


Systematic uncertainty in the signal fraction:

13% at low E_T to 5% at high E_T

Estimated using

- Templates from electrons in Z decays in DATA samples
- The CES/CPR methods
- 2-bin templates (removes details in the shape)

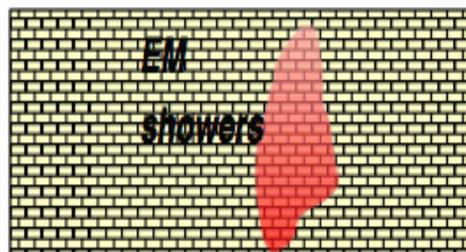


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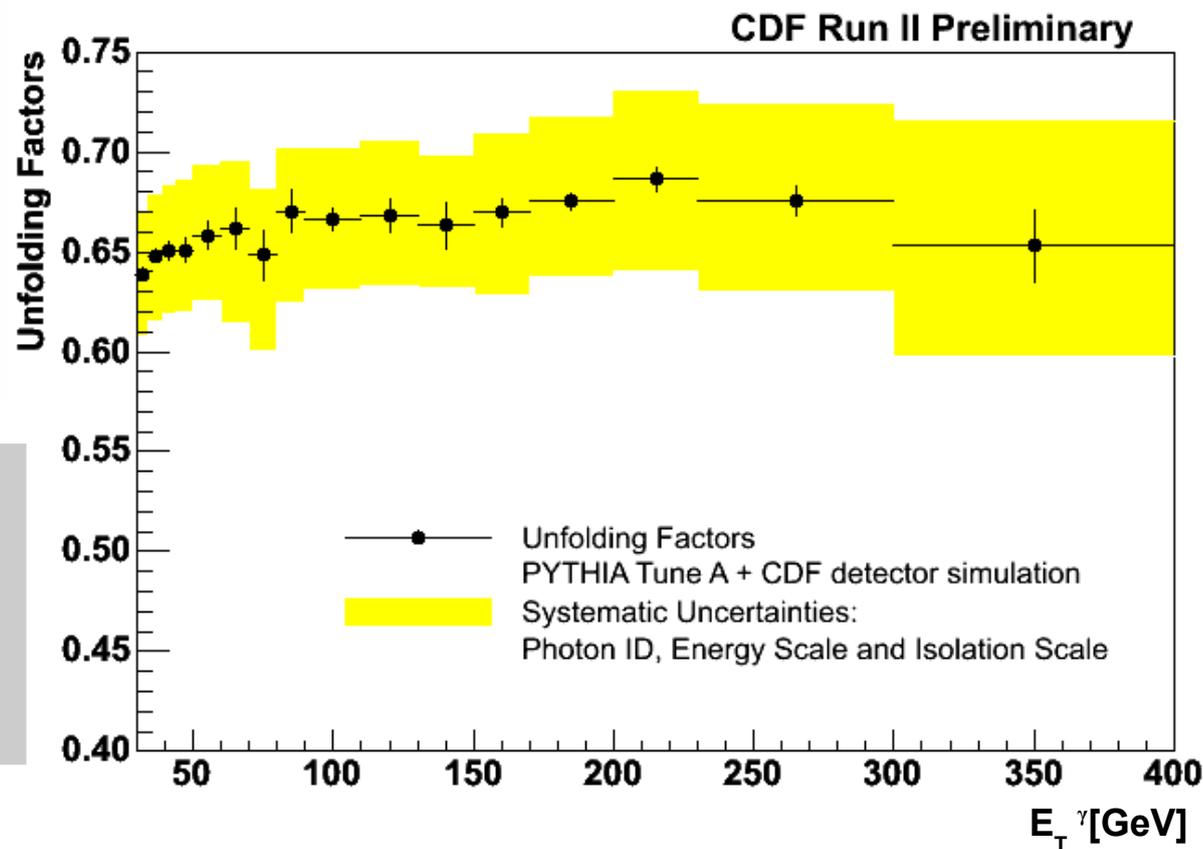
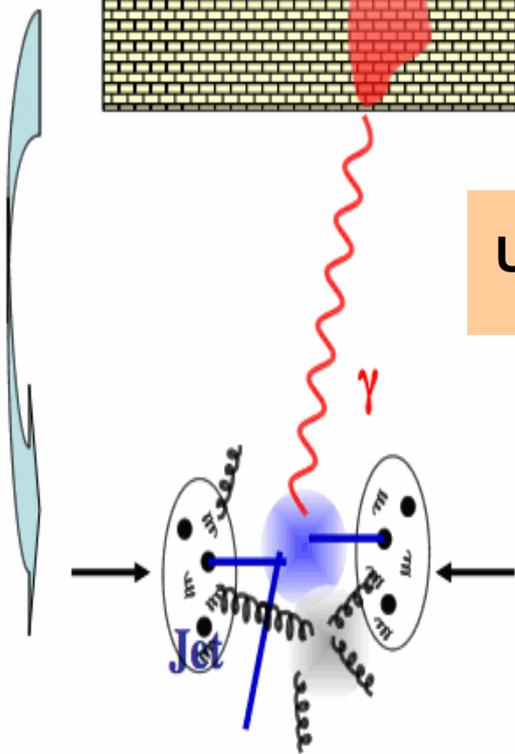
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The cross section unfolding

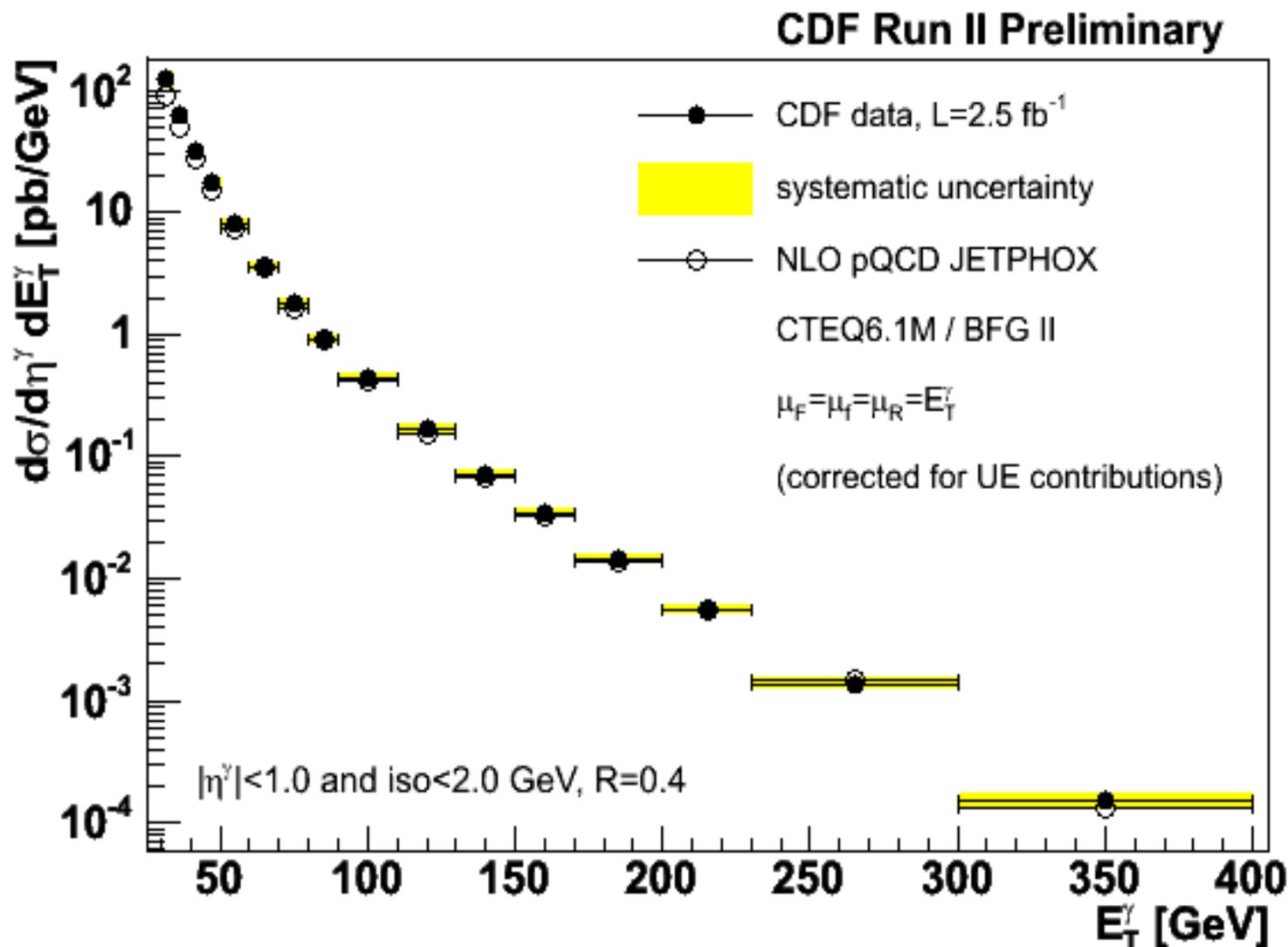


Correct the cross section for acceptance, efficiency and resolution effects back to hadron level

$$U = \frac{\text{Reconstructed photons passing offline cuts}}{\text{Generated photons with } E_T > 30 \text{ GeV, } |\eta| < 1.0 \text{ and iso} < 2 \text{ GeV}}$$



Vary between 64% and 69% as the photon E_T increases and do not present strong E_T dependence



- **Total systematic uncertainty is ~10-15%**
 - signal fraction (dominant at low E_T)
 - photon energy scale (dominant at high E_T)

Uses **~6 times more statistics** than previous results
Extends the E_T coverage up to 400 GeV
Tests the pQCD predictions over **6 orders of magnitude**

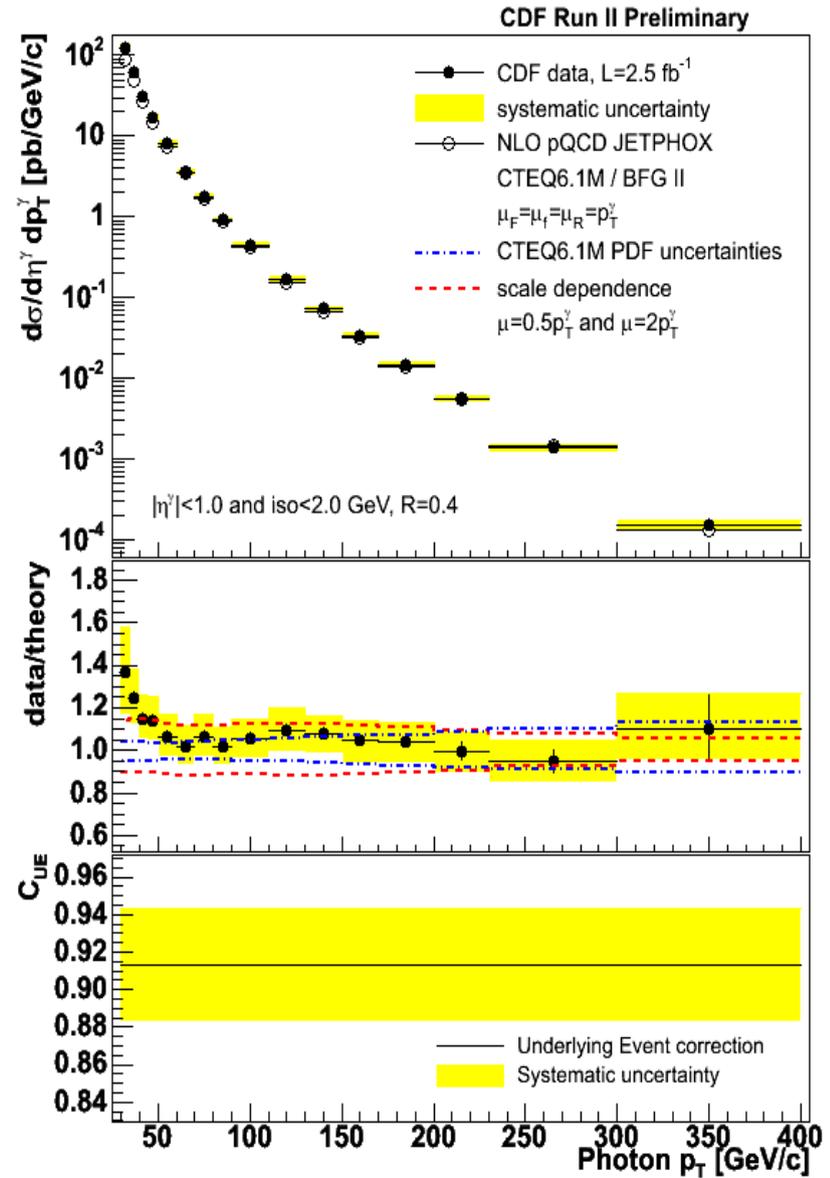
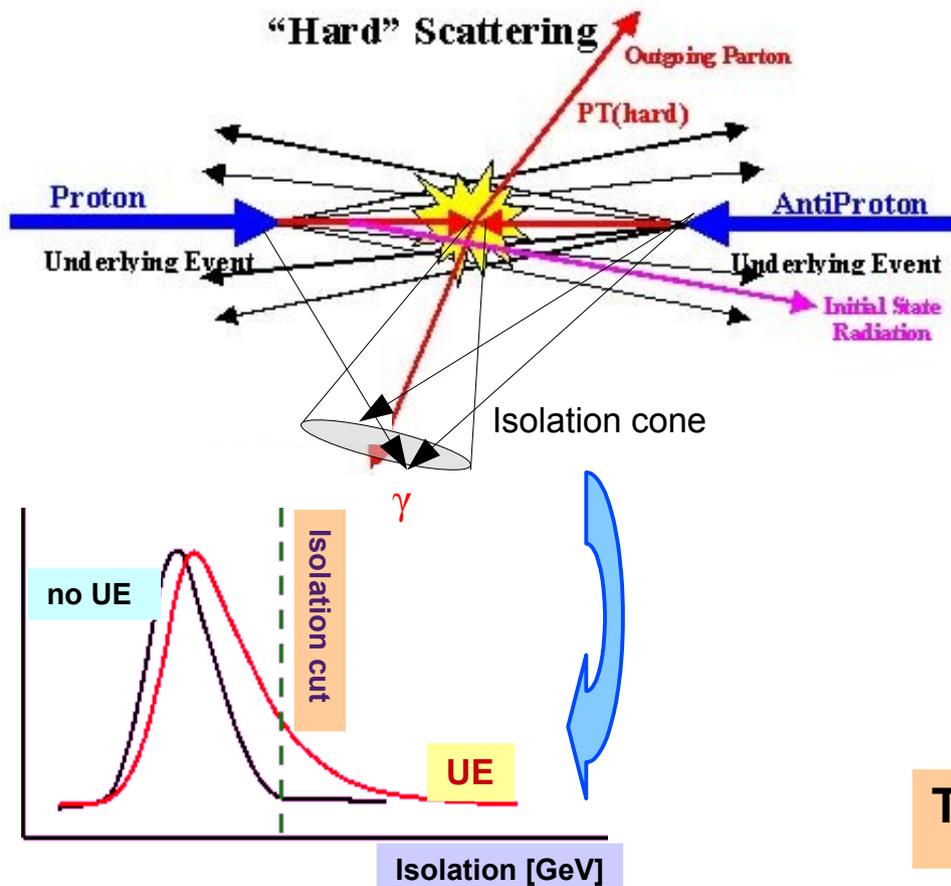
Non-pQCD correction



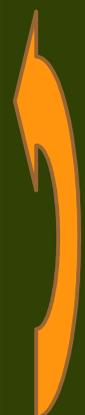
Predictions are **corrected** for the **non-pQCD contributions** of the **UNDERLYING EVENT**

The UE tends to decrease the cross section due to its contribution to the energy in the isolation cone

Estimated using two different UE Tunes in PYTHIA MC



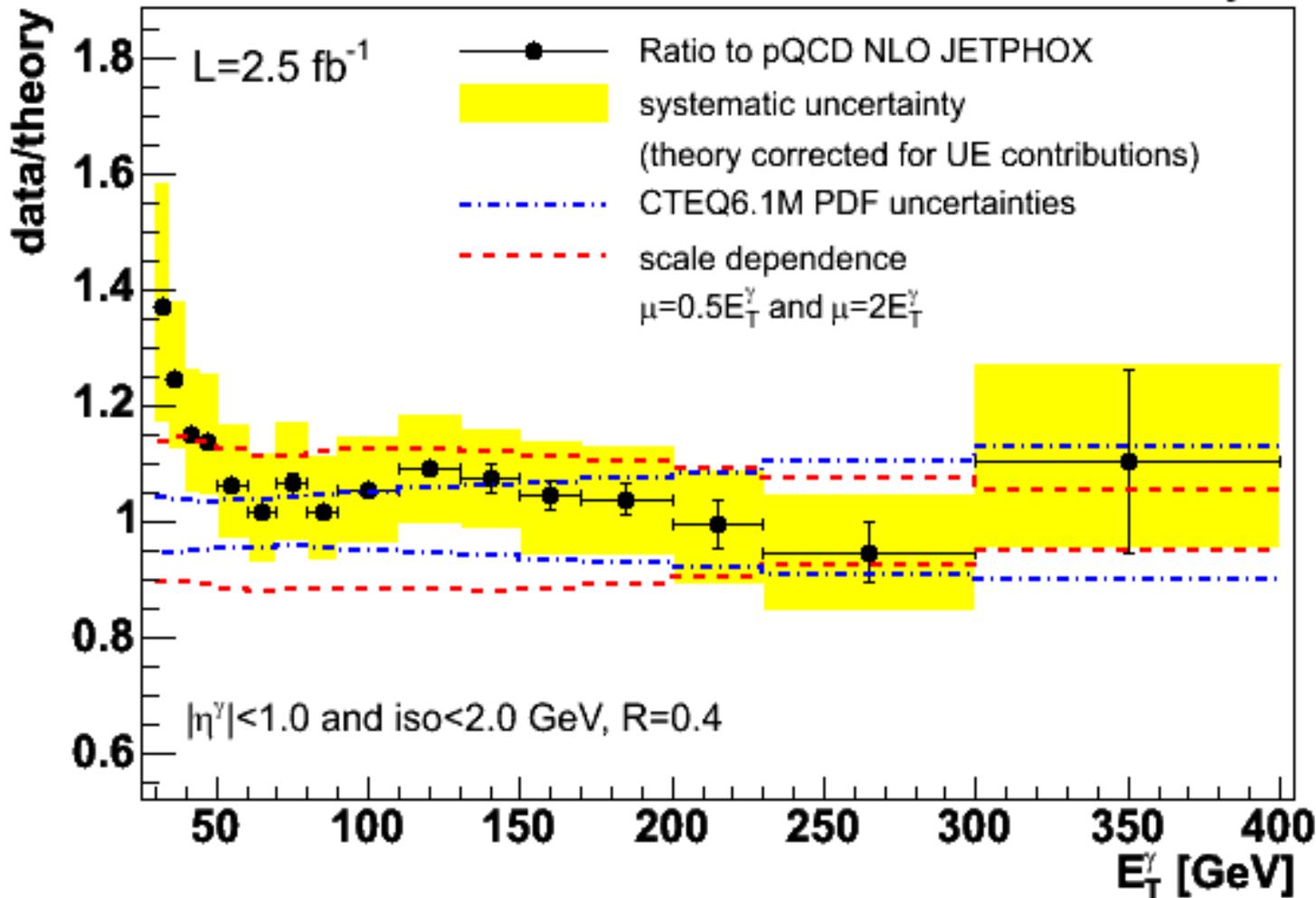
The correction is of ~9% and flat in E_T



Comparison to theory



CDF Run II Preliminary



UNCERTAINTIES

PDF uncertainty

~5% at low E_T

~15% at high E_T

Scale dependence

~15% at low E_T

~8% at high E_T

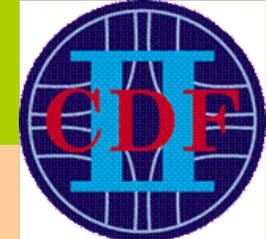
In the measurement

~10 to 15%

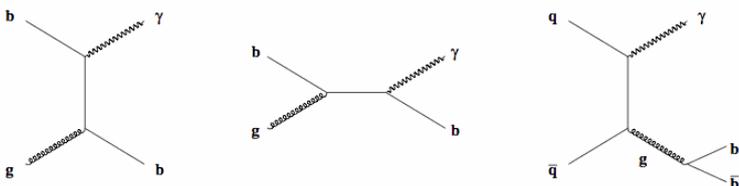
- Agreement between data and theory
- But different shape at low E_T
 - Not covered by theoretical or experimental uncertainties
 - Already observed by DØ Run II, Tevatron Run I and UA2

Photon+bjet

340 pb⁻¹



Sensitive to the b content of the proton



Combination of two results with 208 and 340 pb⁻¹

208 pb⁻¹: dedicated secondary vertex trigger

PHOTONS: $|\eta| < 1.1$

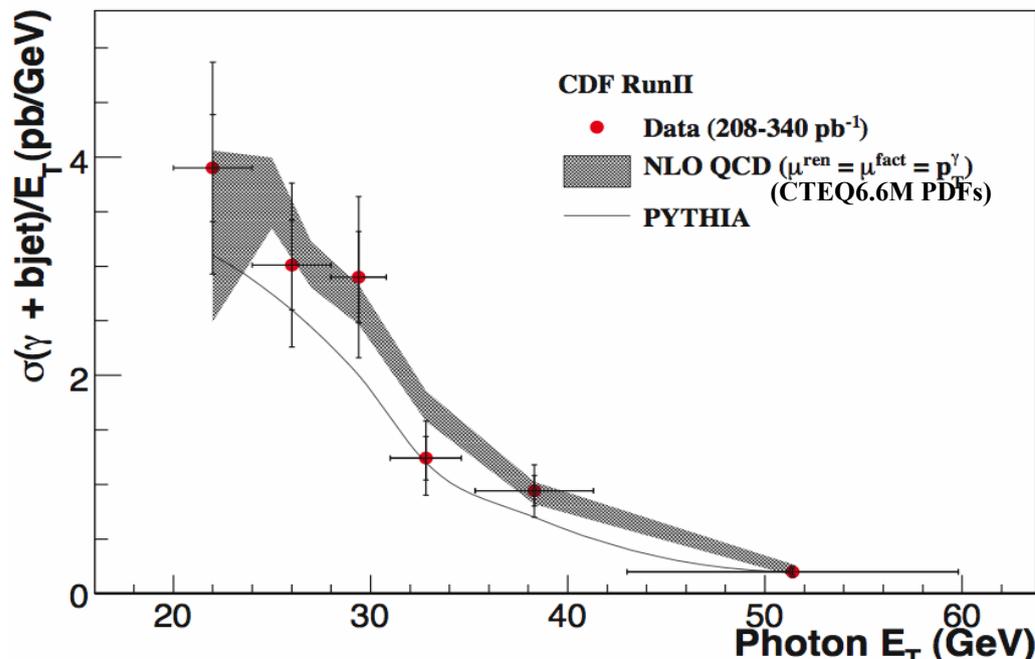
$E_T > 20$ GeV

Iso < 1.0 GeV

JETS: $|\eta| < 1.5$

$E_T > 20$ GeV

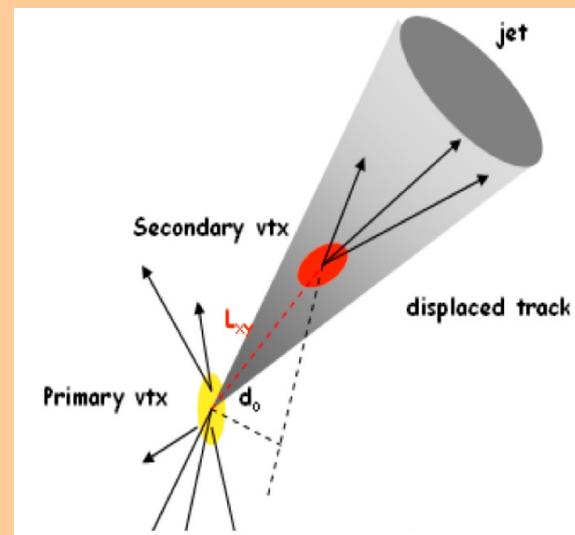
$\Delta R(\gamma, j) > 0.7$



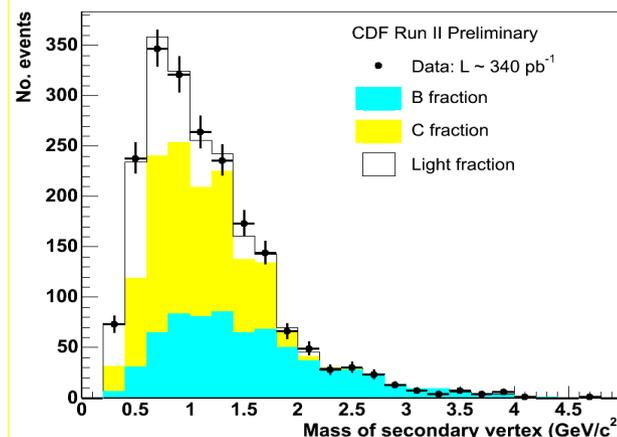
Agreement between data and theory
Limited statistics

B-tagging:

Presence of a displaced secondary vertex



b-contribution extracted using the secondary vertex invariant mass



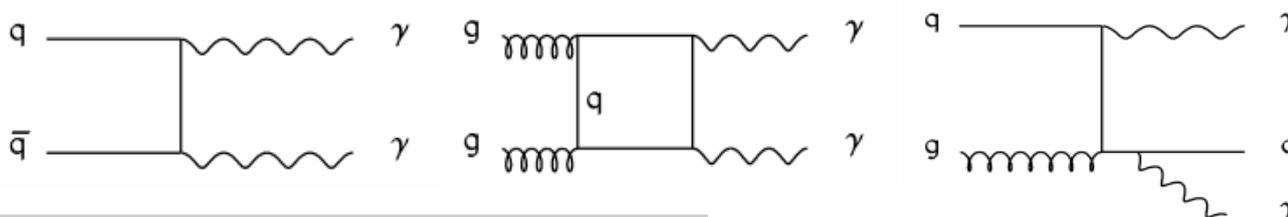
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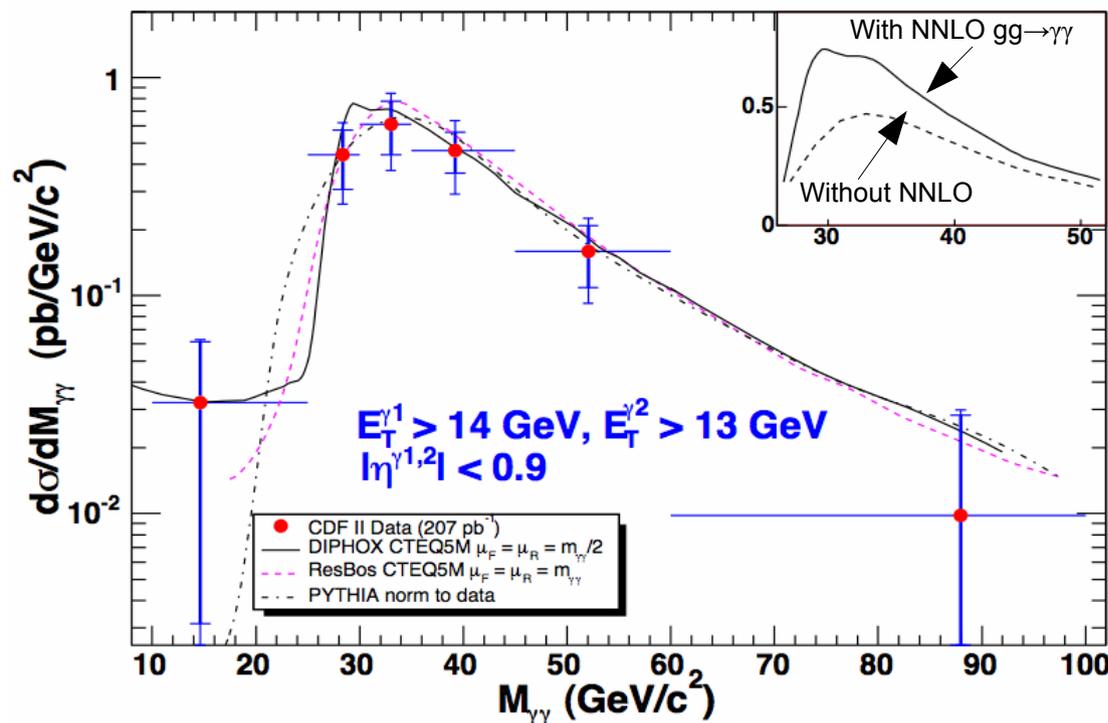
Irreducible background to
 SM Higgs searches ($H \rightarrow \gamma\gamma$)
 BSM searches (SUSY with light gravitino, extra-dimensions)



Photons: $|\eta^{1,2}| < 0.9$
 $E_T^{\gamma^1} > 14 \text{ GeV}, E_T^{\gamma^2} > 13 \text{ GeV}$
 $Iso^{1,2} < 1.0 \text{ GeV}$

- **DIPHOX:**
 - NLO prompt diphotons
 - NLO fragmentation (1 or 2 γ)
 - High $q_T^{\gamma\gamma}$, small $\Delta\Phi$ and low mass
 - NNLO $gg \rightarrow \gamma\gamma$
- **ResBos:**
 - NLO prompt diphotons
 - LO fragmentation with resummed initial state gluon radiation (low $q_T^{\gamma\gamma}$)

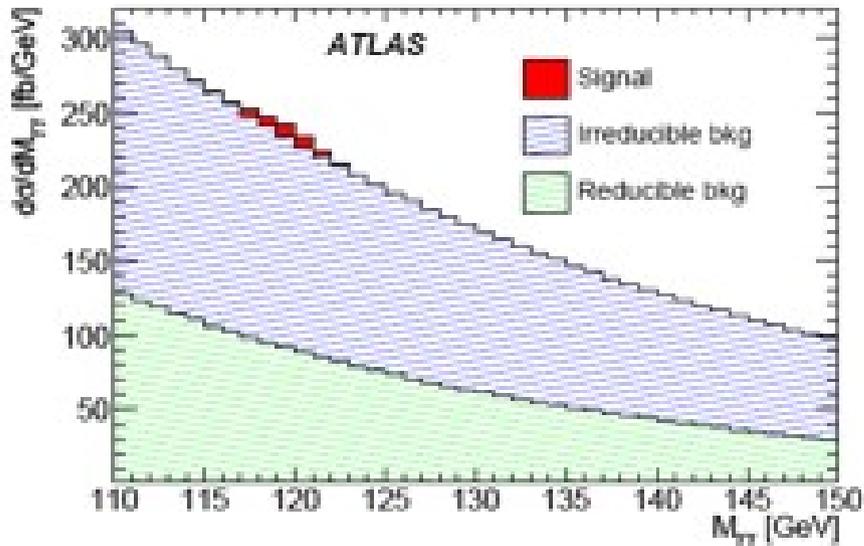
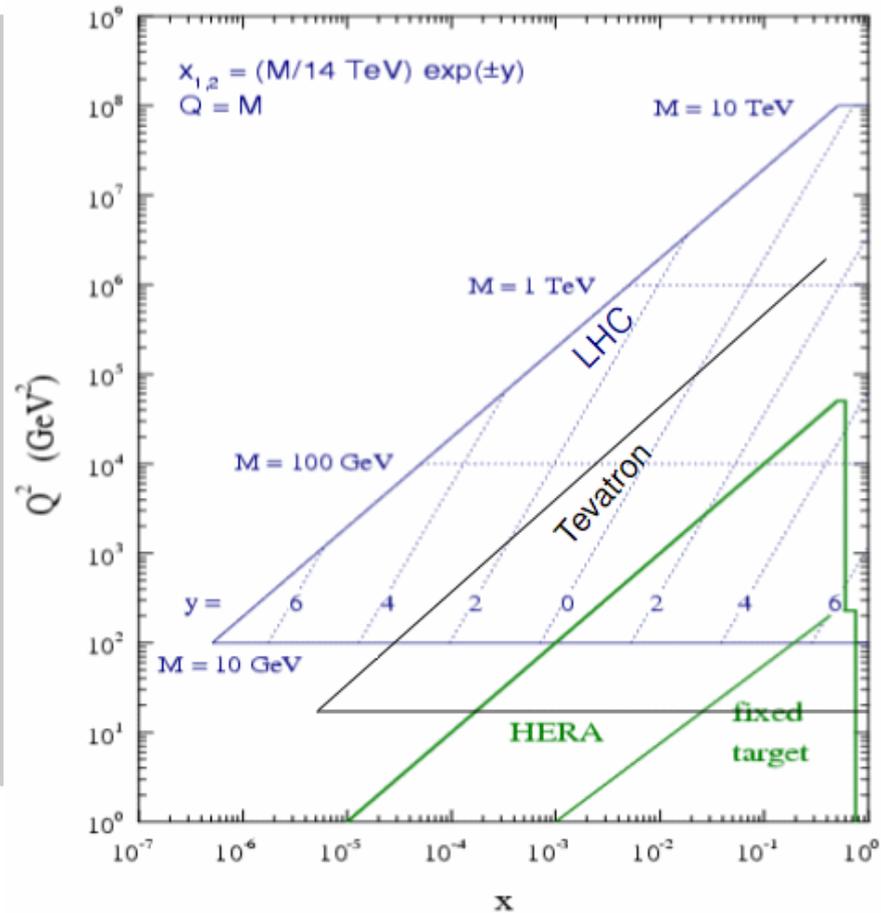
Well described by **DIPHOX** and **ResBos** in the different regions
PYTHIA also describes the shape (underestimates x-section by a factor 2)



Summary



- Latest CDF results with luminosities up to 2.5 fb^{-1}
- **Inclusive photon**
 - Agreement with theory
 - But different shape at low E_T
- **Photon+bjet**
 - Agreement with theory
 - Limited statistics
- **Diphoton**
 - Old (but very important) measurement
 - Update with more statistics?

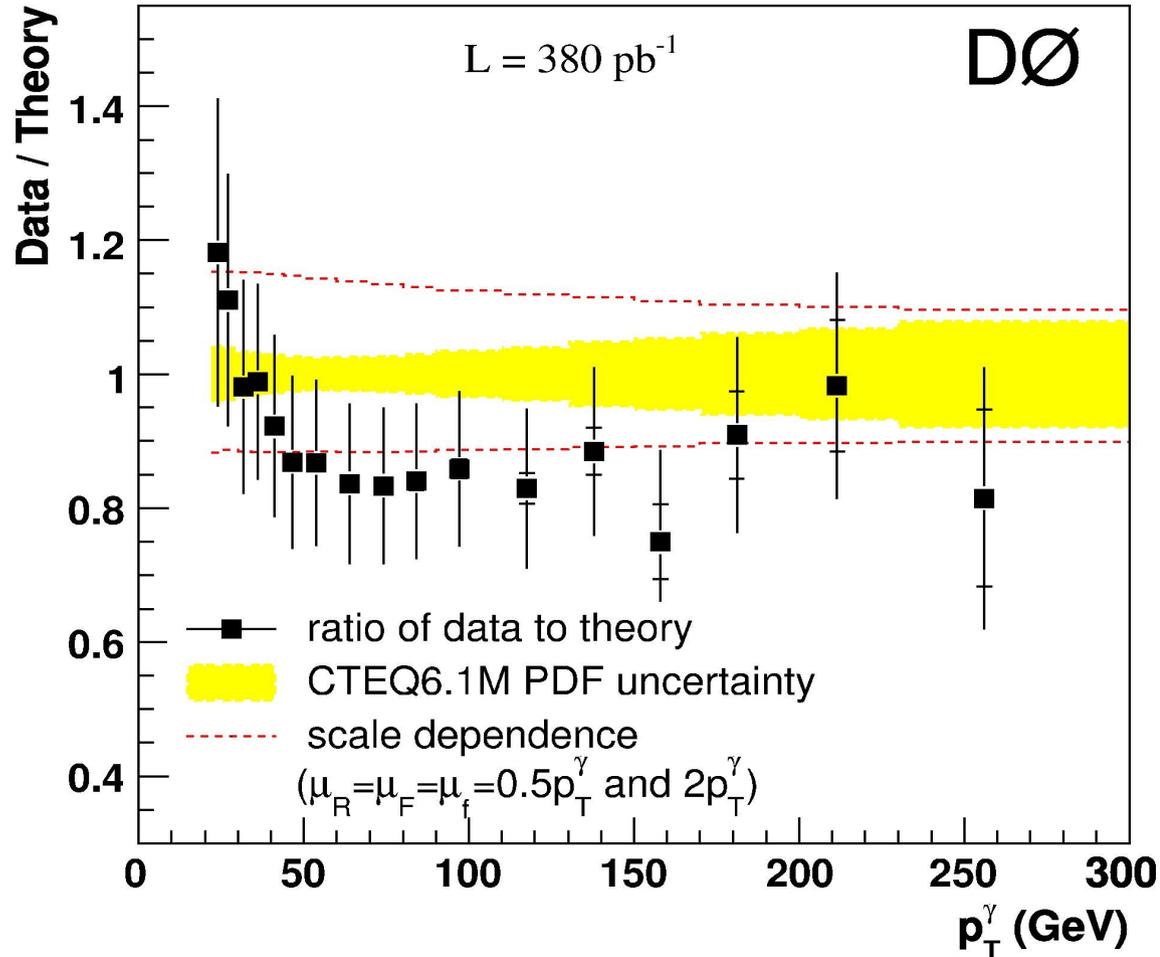


Still more to come at the Tevatron and at the LHC!



Backup slides

Inclusive Photon $D\bar{O}$ result



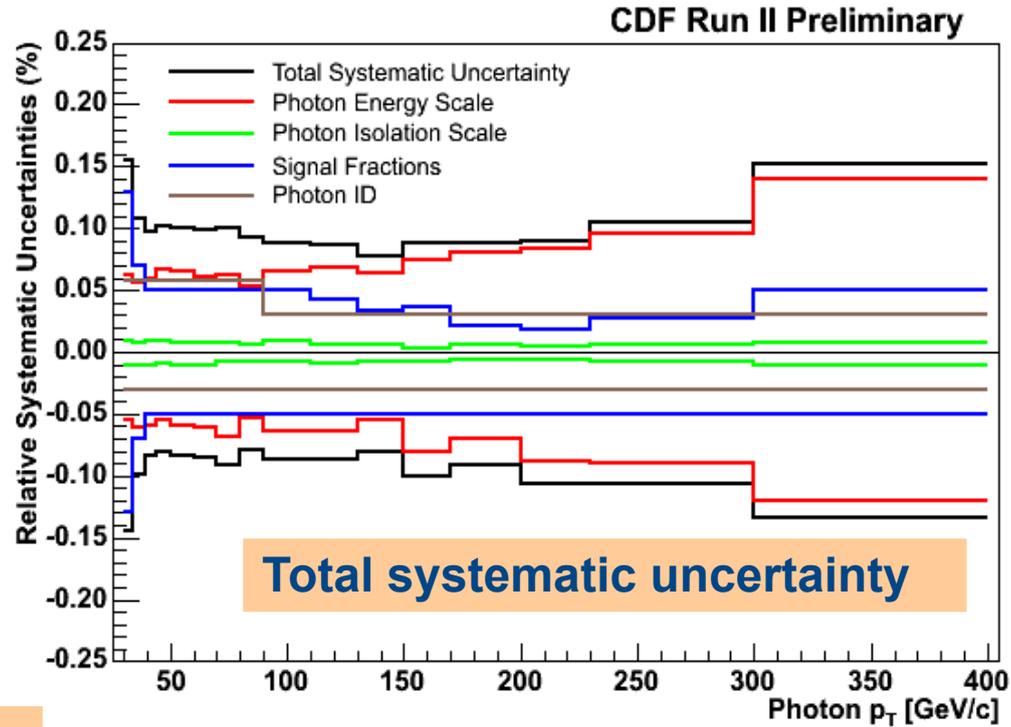
Same shape as measured by CDF, especially at low p_T

Systematic uncertainties (inc γ cross section)

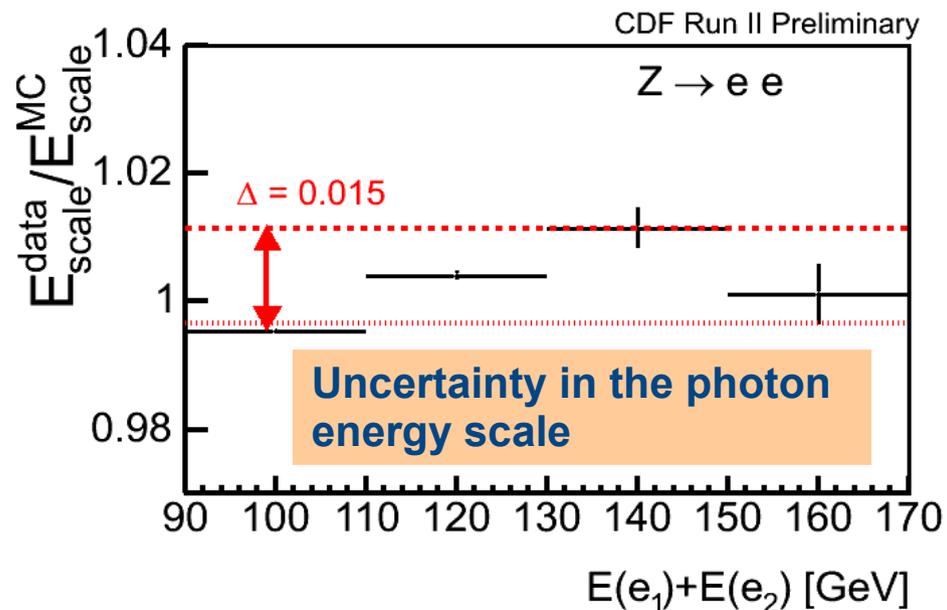
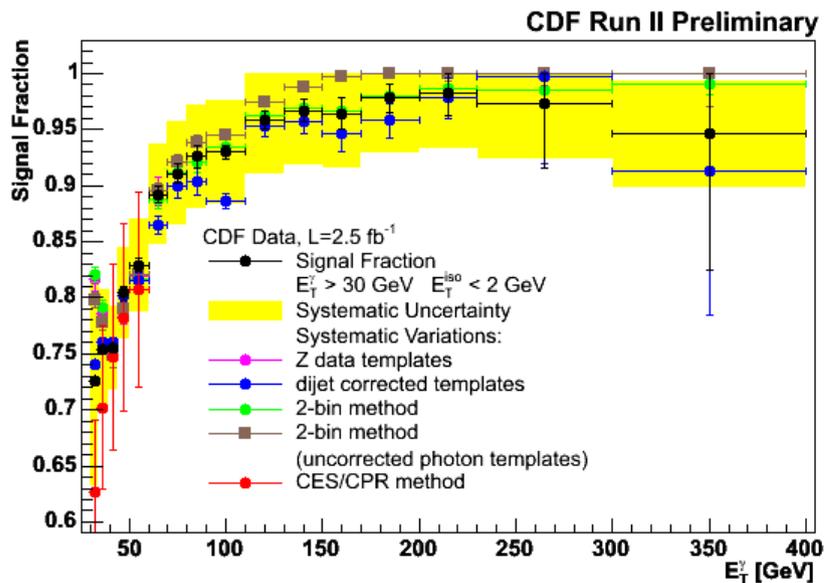


Total systematic uncertainty in the inclusive photon cross section goes from 10 to 15% depending on the photon E_T

The major contributions are due to the signal fractions at low E_T and the photon energy scale at high E_T



Uncertainty in the photon purity



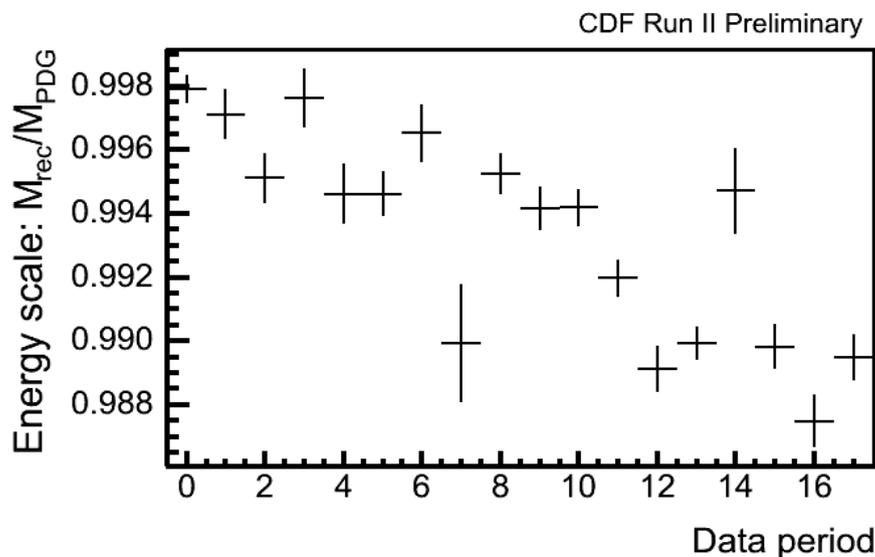
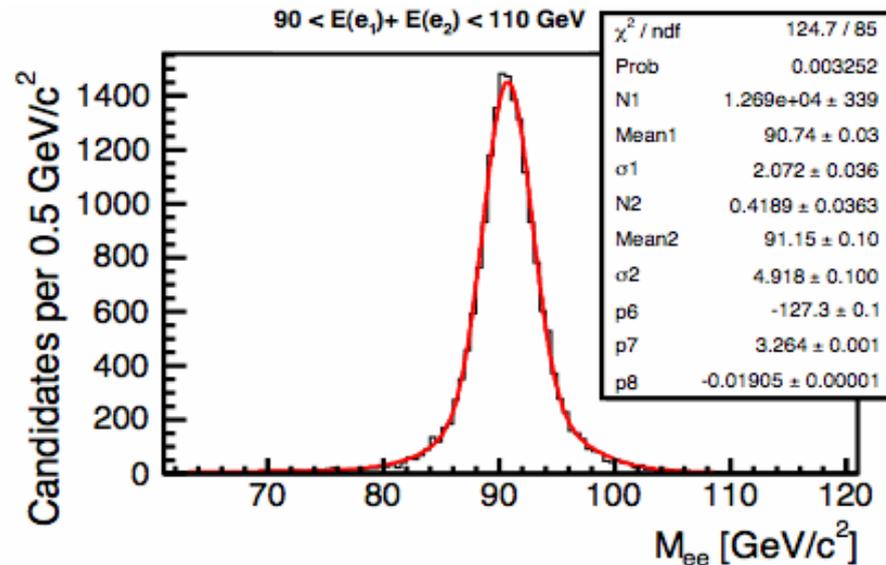
The photon energy scale

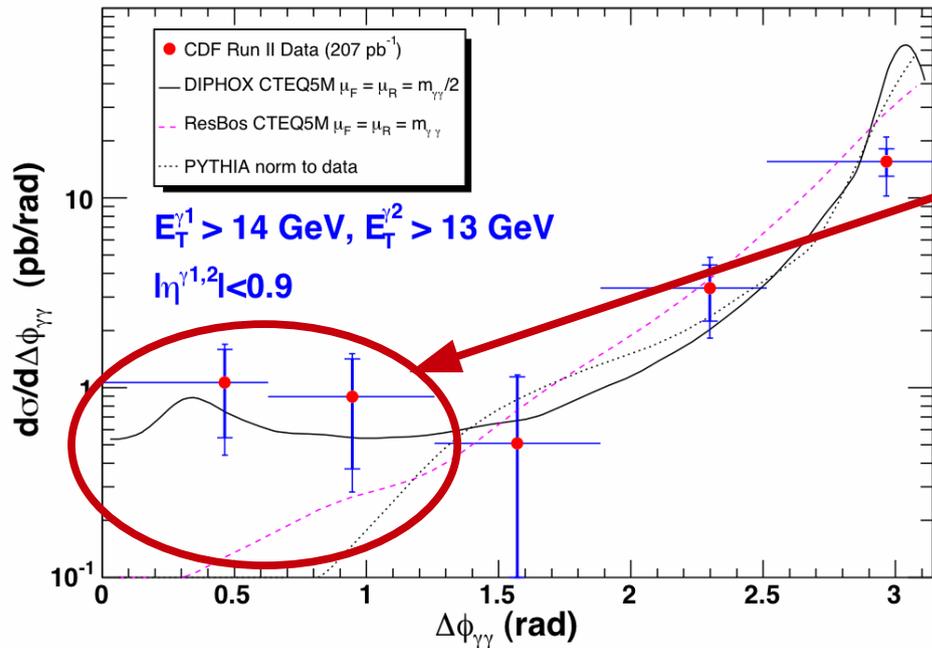


- Photon energy scale corrected back to generator level with the **Z mass scale in both data and MC**
- Z mass from electrons in $Z \rightarrow ee$ decays in data and run-dependent MC

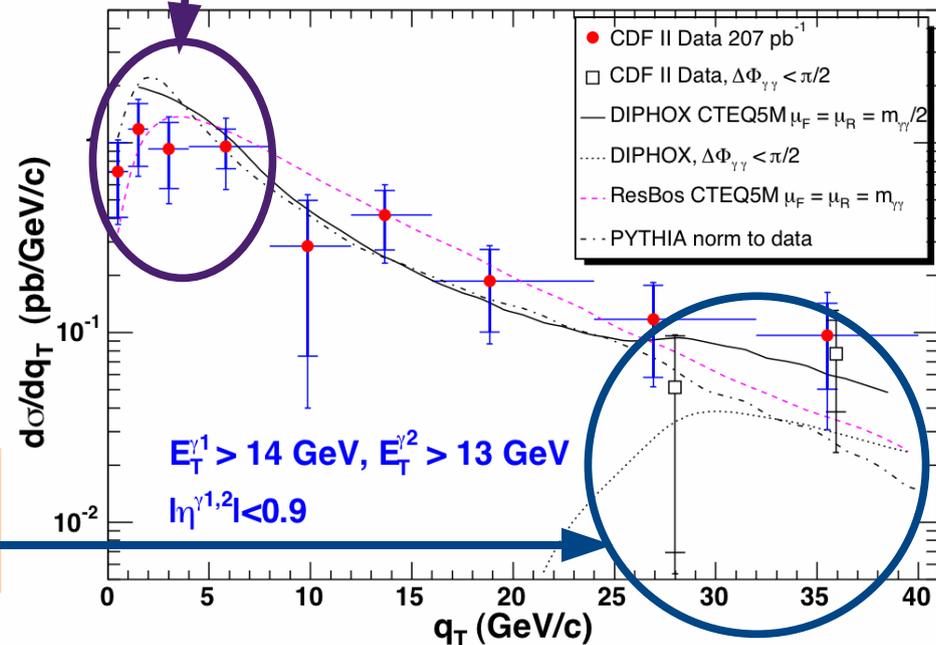
$$E_{\text{scale}} = M_Z^{\text{rec}} / M_Z^{\text{PDG}}$$

- Correction in the data is run-dependent and increases with luminosity (mean ~ 0.994)
- In MC, constant at ~ 1.0035





- **NLO fragmentation contribution**
 - High $q_T^{\gamma\gamma}$, small $\Delta\Phi$ and low mass
- **Resummed initial state gluon radiation**
 - Low $q_T^{\gamma\gamma}$



Measurement with $\Delta\phi(\gamma,\gamma) > \pi/2$ further tests fragmentation part