Diphoton and Photon+b/c Production Cross Section at E_{cm}=1.96 TeV

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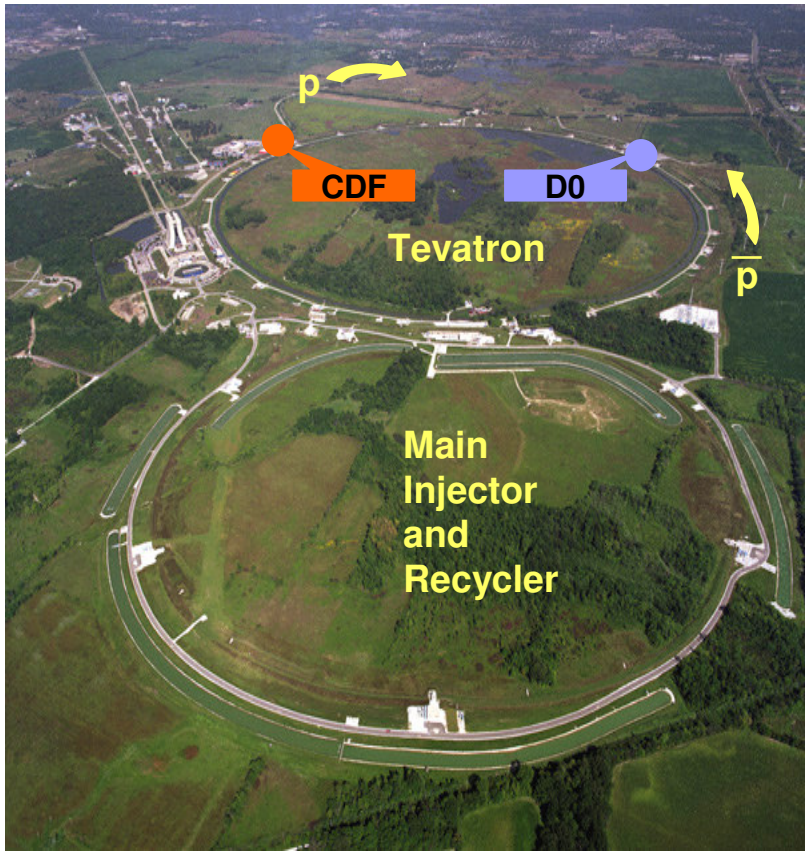
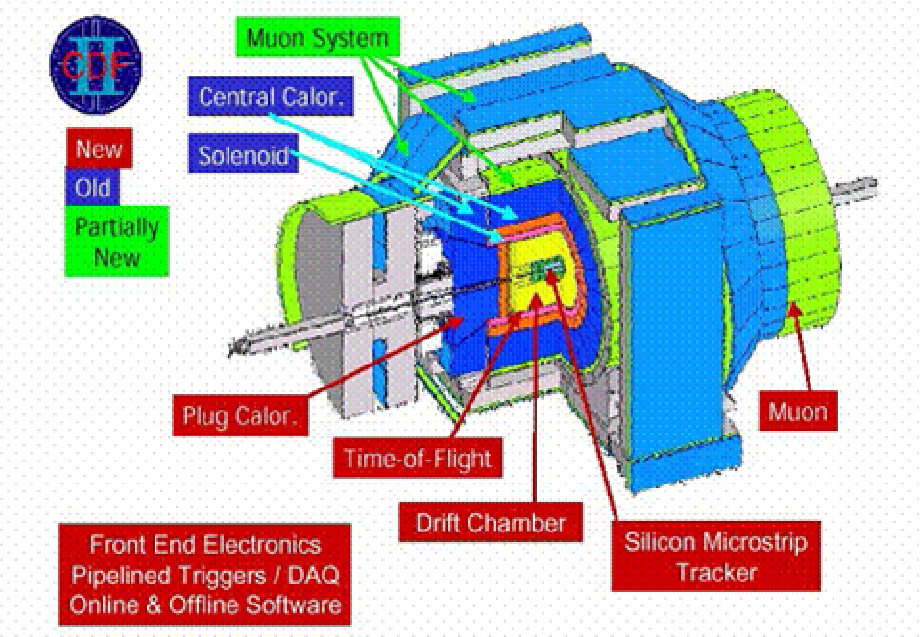
Outline

- The Tevatron and CDF
- Production Mechanisms and Motivation
- Identifying Photons and Determining Background
- Diphoton Analysis
  - Submitted to Phys. Rev. Lett. December 14, 2004
  - hep-ex/0412050
- Photon +b/c Analysis
- Conclusions

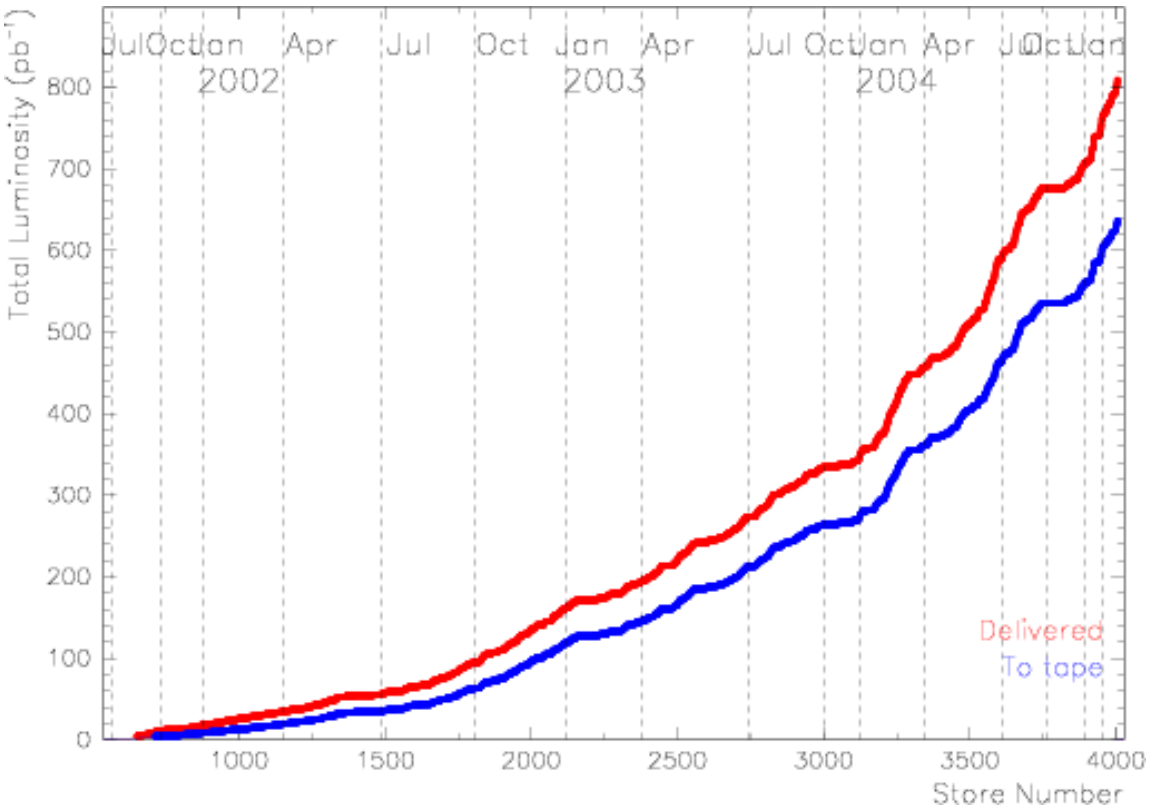
The Tevatron and CDF



Proton – Antiproton collisions at E_{cm} = 1.96TeV



The Tevatron and CDF - Luminosity



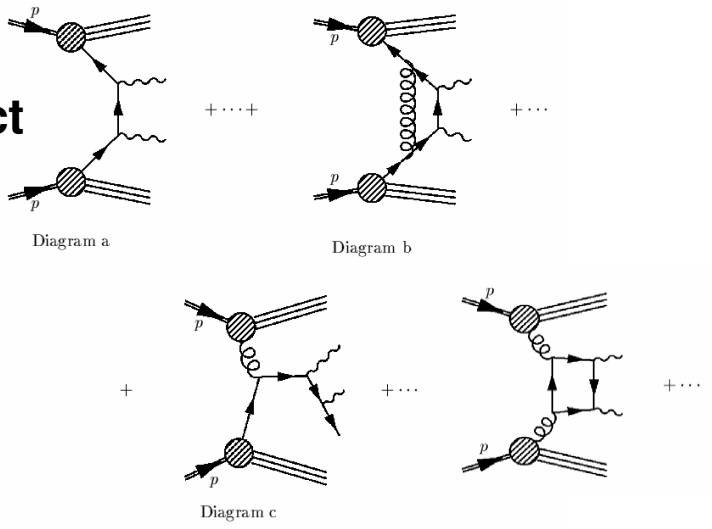
Record Instantaneous Luminosity:

1.1*10^32

Analyses Presented Use 67 – 207pb^{-1}

Diphoton Production Mechanisms

Direct



PYTHIA – T. Sjostrand, P. Eden, C. Friberg, L. Lonnblad, G. Miu, S. Mrenna and E. Norrbin (Computer Physics Commun. 135 (2001) 238

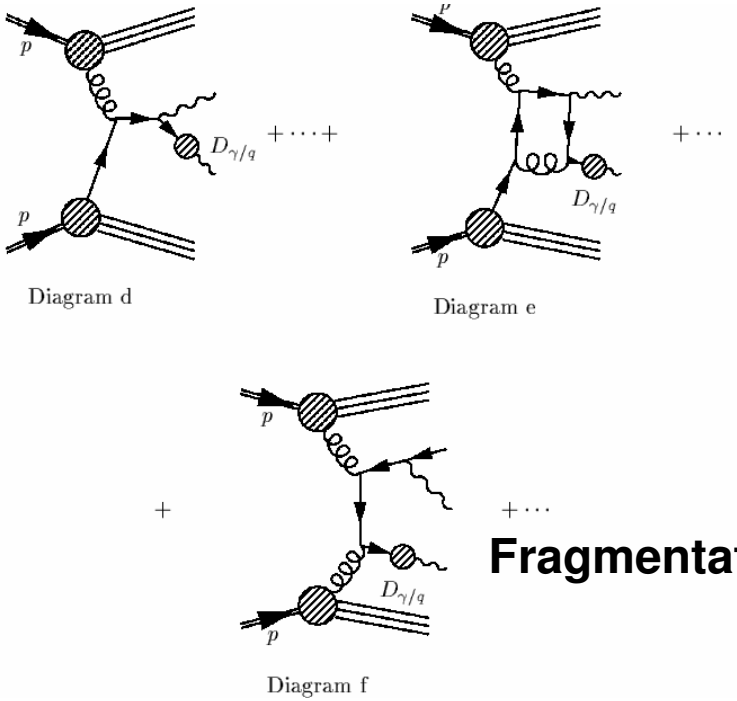
- Includes all processes at LO

DIPHOX – T.Binoth, J. Ph. Guillet, E. Pilon and M. Werlon (Eur. Phys. J. C 16, 311(2000)

- Includes all diagrams at NLO

RESBOS – C. Balazs, E. L. Berger, S. Mrenna and C. –P. Yuan (Phys.Rev. D 57, 6934(1998))

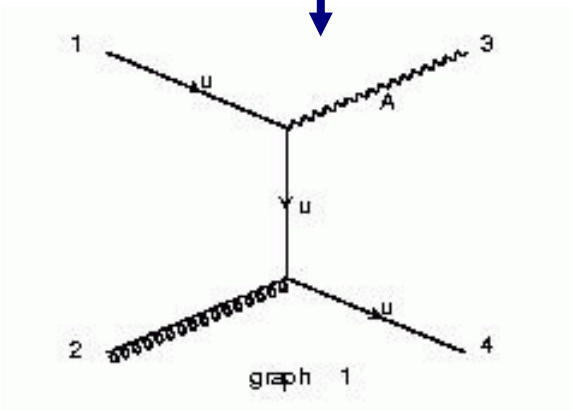
- Direct Processes at NLO, fragmentation processes at LO
- Initial state soft gluon resummation

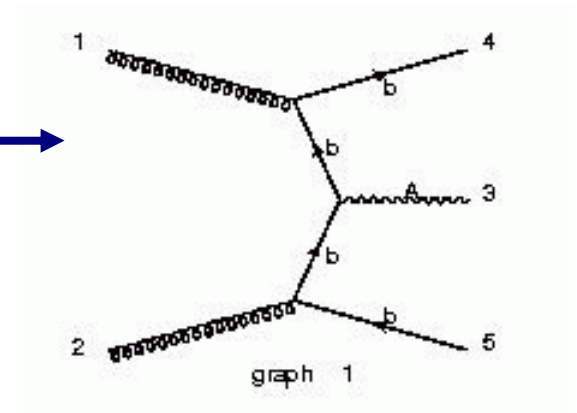


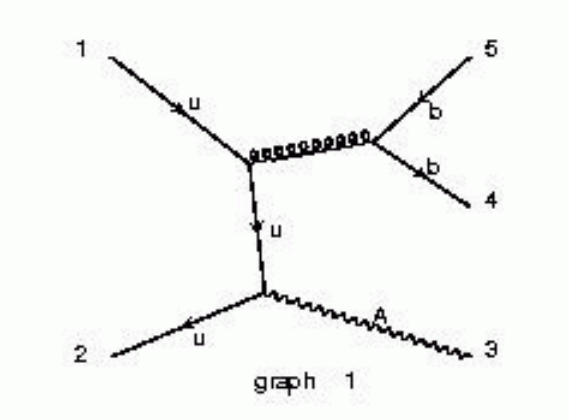
Fragmentation

Photon +b/c Production Mechanisms

Dominates for γ+c







All Diagrams equal for γ+b

Pythia used for theoretical predictions

Motivation

Diphoton Cross Section

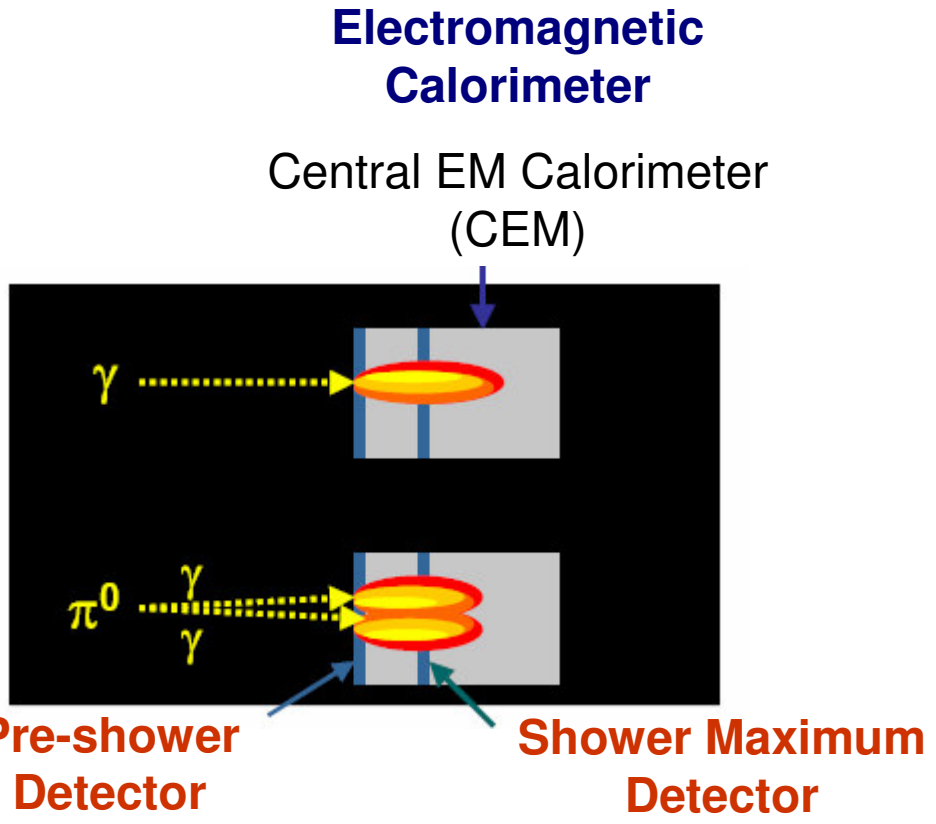
Photon +b/c Cross Section

- Provide an understanding of QCD production mechanisms
- Possible Signatures of New Physics

- Sensitive to initial state soft gluon radiation
- Gluon PDF Measurements
- Background for $H \rightarrow \gamma\gamma$ (LHC)

- Ratio of γ+c to γ+b sensitive to charm content of proton

Identifying Photons



Electromagnetic showers in the calorimeter

- Isolated – $E_T(R < 0.4) < 1GeV$
- No associated track
- Very low energy in hadronic calorimeter
- These analyses use central calorimetry only
  - Extend to forward regions

Photon Background Estimation

Background comes from neutral mesons decaying to multiple photons (π^0, η)

Using CES

- Different shower profiles for single photon compared to multiple photons
- Only valid for $E_T < 35GeV$

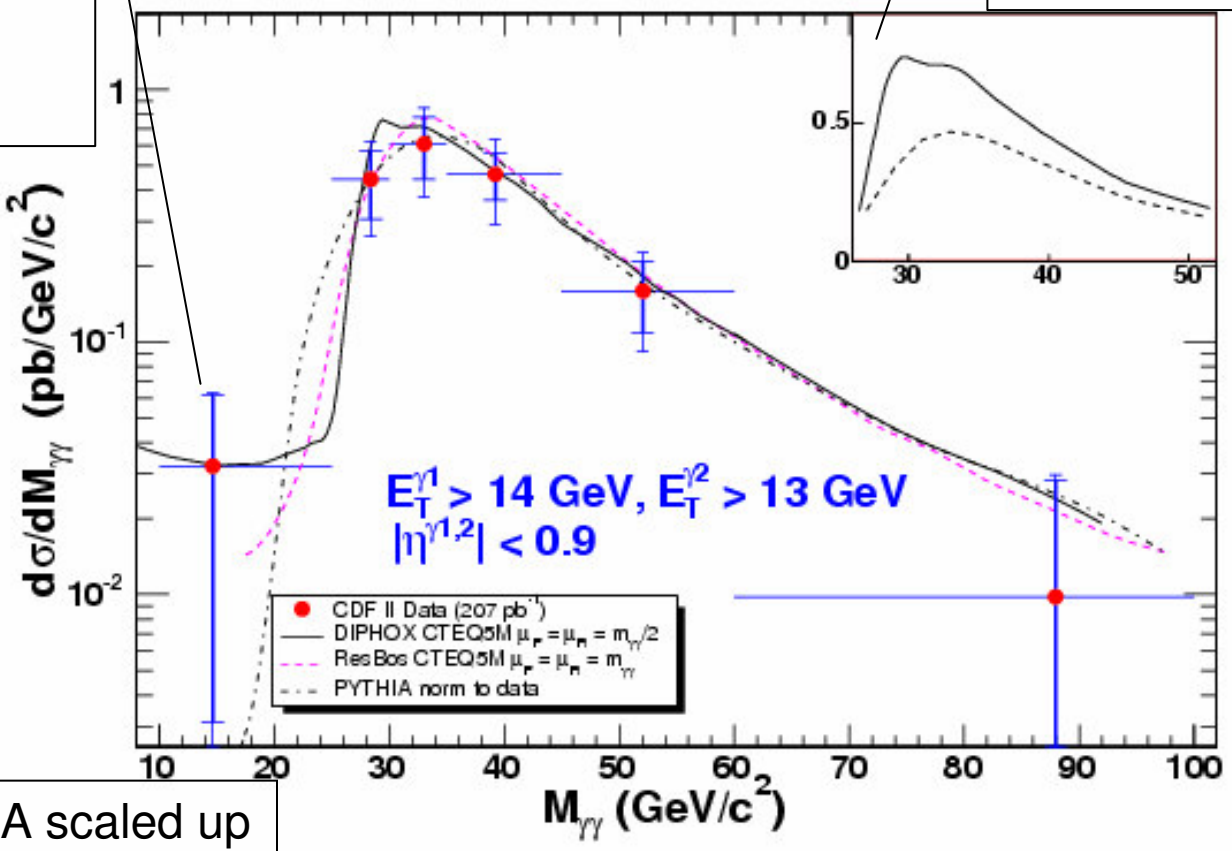
Using CPR

- Probability of conversion higher for multiple photons
- Multiple photons more likely to generate a hit in the CPR

Diphoton Results

All NLO contributions included in DIPHOX

DIPHOX Prediction with (solid)/ without (dashed) gg contribution (Linear Scale)



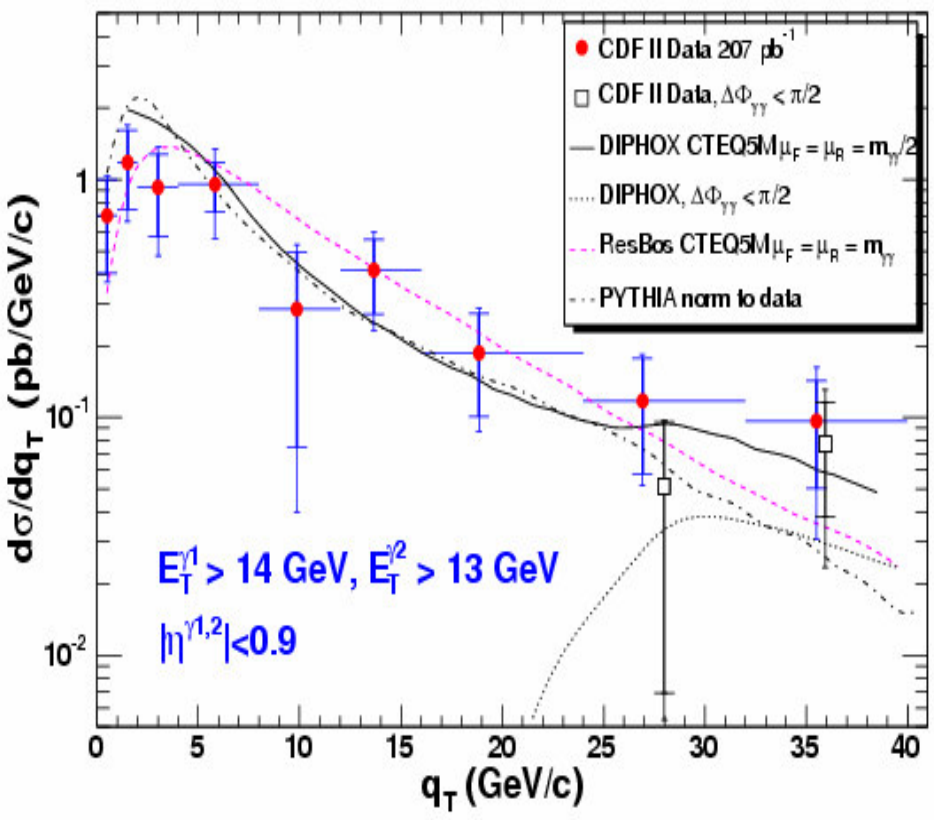
PYTHIA scaled up by a factor of 2

Diphoton Results

Low q_T Region

DIPHOX Unstable – NLO calculation divergent

RESBOS includes soft gluon resummation – describes data



High q_T Region

Fragmentation processes included at NLO for DIPHOX and LO for RESBOS

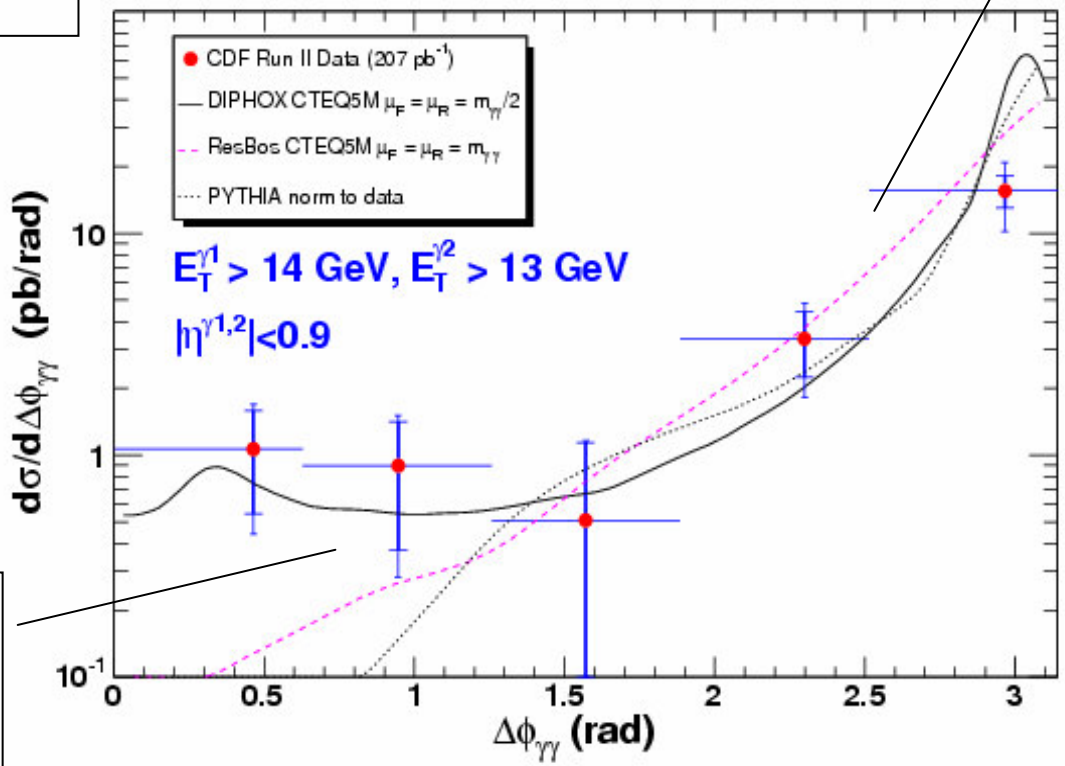
Extra phase space accessible at NLO results in DIPHOX "shoulder"

PYTHIA scaled up by a factor of 2

Transverse Momentum of $\gamma\gamma$ System

Diphoton Results

PYTHIA scaled up by a factor of 2

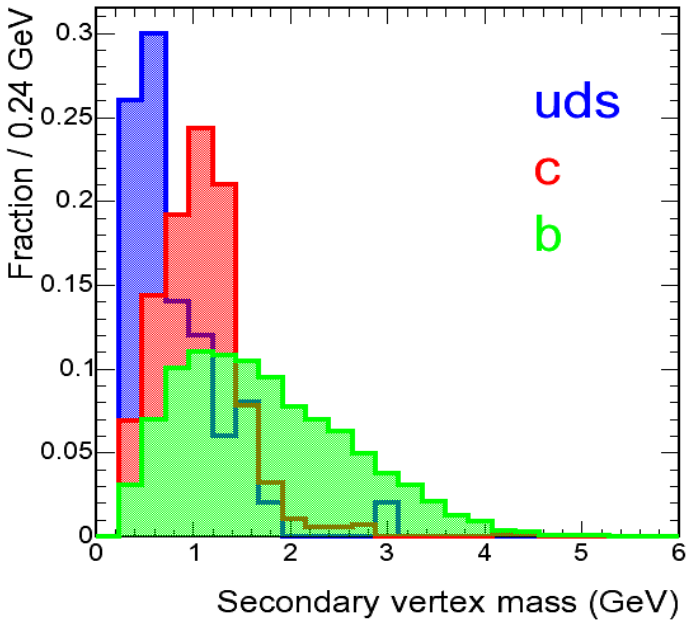


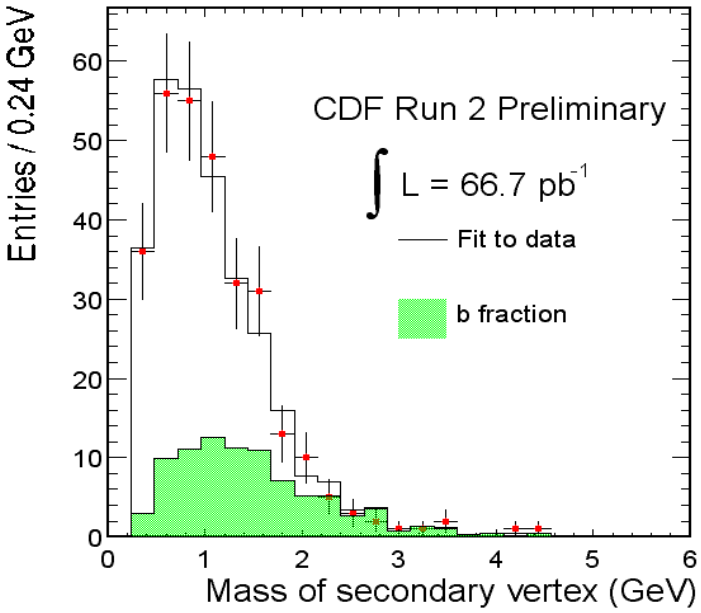
Gluon Resummation Contributions – Better agreement wit RESBOS

NLO Contributions – Better agreement with DIPHOX

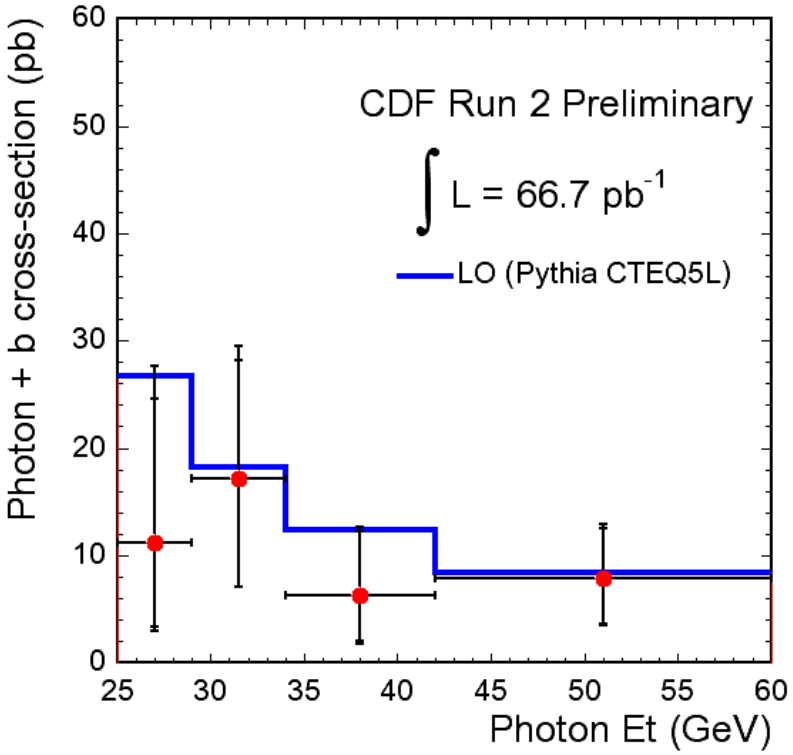
Photon + b/c Analysis

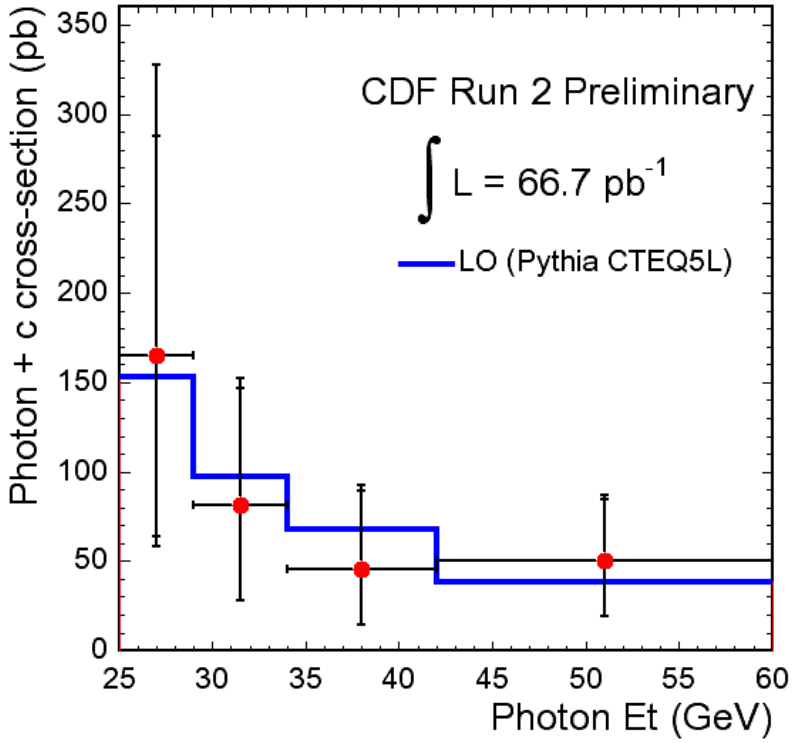
- γ Et > 25 GeV and $|\eta|<1.0$
- jet with secondary vertex
- Determine b, c, uds contributions
- Subtract background
- Find cross section as a function of Et





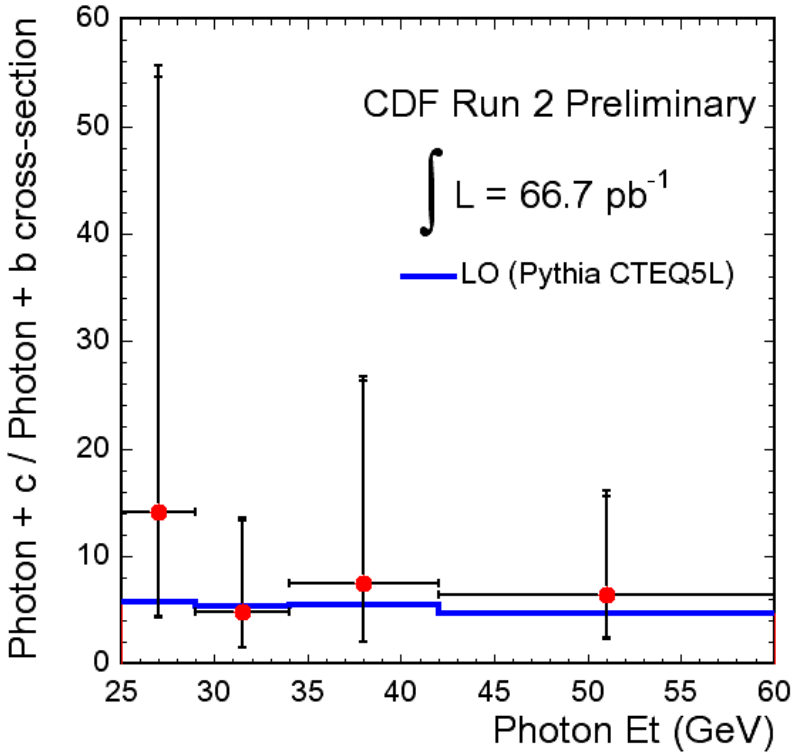
Photon+b, Photon+c results





- Good agreement with LO

Ratio of Photon+c to Photon+b



- Consistent with LO prediction

Conclusions and Outlook

- Diphoton production rate measured at CDF
  - Agreement with NLO and resummed predictions in different regions of phase space
  - Require resummed full NLO calculations
  - Extend measurements to forward region
  - Move towards gluon PDFs

- Photon+c and photon+b cross sections and ratio have been measured at CDF
  - Good agreement seen between data and Leading Order predictions
  - Compare to NLO predictions
  - Results shown dominated by statistical uncertainty – include extra data
  - Updated results and exotic limits coming soon

Back Up Slides

Diphoton Systematic Error Contributions

- Selection Efficiencies (11%)
- Background Subtraction (20-30%)
- Luminosity Determination (6%)

Photon + b Systematics

Systematic error (pb)	25 – 29 GeV	29 – 34 GeV	34 – 42 GeV	42 – 60 GeV
Tag efficiency	+1.7 –1.3	+2.6 –2.0	+0.9 –0.7	+1.1 –0.9
Photon id	± 0.2	± 0.1	< 0.1	± 0.1
Jet correction	± 0.5	± 0.5	± 0.1	± 0.1
Jet energy scale	+3.3 –1.4	+2.2 –2.1	+0.5 –0.3	+0.5 –0.4
B jet correction	± 0.2	± 0.3	± 0.1	± 0.1
CPR fake estimate	- 0.1	< 0.1	< 0.1	< 0.1
trigger	+2.5 –1.7	< 0.1	< 0.1	< 0.1
PDF	± 0.3	± 0.5	± 0.2	± 0.2
luminosity	+0.7 –0.6	+1.1 –1.0	+0.4 – 0.3	+0.5 –0.4
Final value* of σ(bγ)	**11.2 $^{+16.4}_{-8.2}$**	**17.2 $^{+12.3}_{-10.1}$**	**6.2 $^{+6.4}_{-4.4}$**	**7.9 $^{+5.0}_{-4.1}$**

** The errors quoted are the total error, consisting of both statistical and systematic contributions*

Photon + c Sytematics

Systematic error (pb)	25 – 29 GeV	29 – 34 GeV	34 – 42 GeV	42 – 60 GeV
Tag efficiency	+26.5 –19.8	+13.1 –9.9	+7.4 – 5.6	+8.7 –6.4
Photon id	± 2.2	± 0.4	± 0.3	± 0.4
Jet correction	+7.9 –7.2	+2.5 –2.4	0.8	0.4
Jet energy scale	+48.0 –21.0	+10.4 –9.6	+3.5 –2.4	+2.9 –2.3
CPR fake estimate	- 0.6	- 0.1	- 0.2	+ 0.2
trigger	+37.3 –25.3	< 0.1	< 0.1	< 0.1
PDF	± 2.2	± 0.7	± 0.3	± 0.2
luminosity	+9.6 – 8.6	+5.0 –4.4	+2.8 –2.5	+3.0 –2.7
Final value* of σ(cγ)	**164.7 +163.2 -106.5**	**81.1 +71.0 -53.0**	**45.4 +46.8 -31.3**	**50.0 +37.3 -30.9**

** The errors quoted are the total error, consisting of both statistical and systematic contributions*

Photon +c / Photon +b Sytematics

Systematic error (pb)	25 – 29 GeV	29 – 34 GeV	34 – 42 GeV	42 – 60 GeV
B tag efficiency	- 1.2	- 0.6	- 1.0	- 0.8
C tag efficiency	+2.4 –1.8	+0.8 –0.6	+1.3 –0.9	+1.1 –0.8
B jet correction	± 0.2	± 0.1	± 0.1	± 0.1
CPR fake estimate	+ 0.1	< 0.1	- 0.1	< 0.1
Final value* of $\sigma(c\gamma)/\sigma(b\gamma)$	**14.1 $^{+41.5}_{-9.8}$**	**4.8 $^{+8.7}_{-3.3}$**	**7.4 $^{+19.3}_{-5.4}$**	**6.4 $^{+9.7}_{-4.1}$**

** The errors quoted are the total error, consisting of both statistical and systematic contributions*

Origin of q_T Shoulder

T. Binoth, J. Ph. Guillet, E. Pilon, M. Werlen

Phys.Rev. D63 (2001) 114016

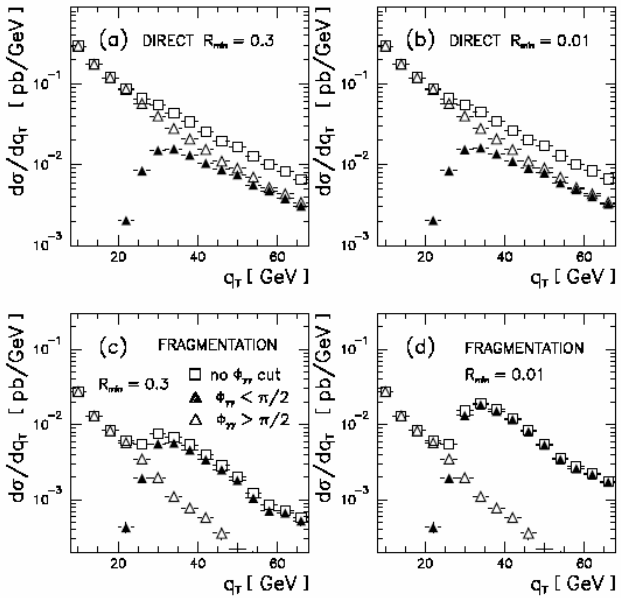


Figure 2: *Origin of the q_T shoulder in the theoretical calculation. Plot (a) shows the direct component (open squares) split into the phase space regions $\phi_{\gamma\gamma} < \pi/2$ (full triangles) and $\phi_{\gamma\gamma} > \pi/2$ (open triangles) for the experimentally used value $R_{min} = 0.3$. Plot (b) is the same as (a) but for $R_{min} = 0.01$ to show the sensitivity of the effect to this collinear cut. Plots (c) and (d) show the corresponding histograms for the fragmentation component where the enhancement due to photon collinearity is clearly visible.*