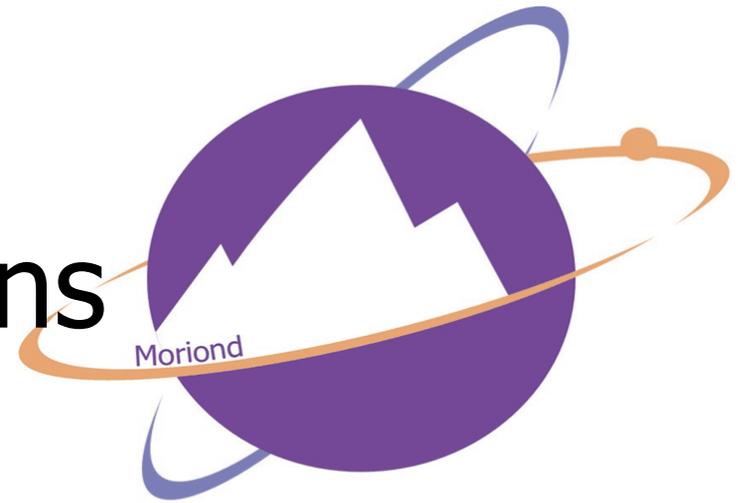
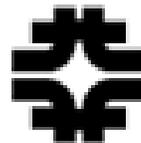


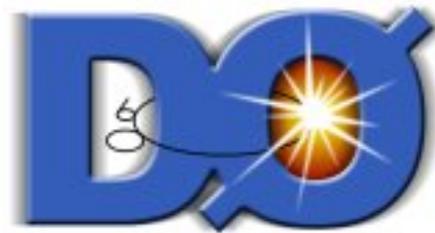
Photon Cross Sections at $E_{\text{cm}} = 2\text{TeV}$



Markus Wobisch, Fermilab



for the CDF and DØ Collaborations



40th anniversary

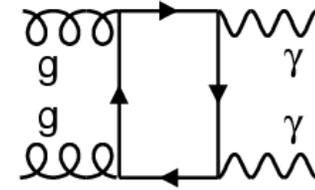
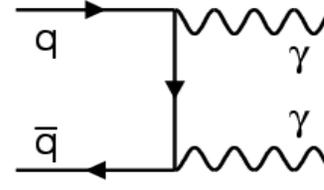
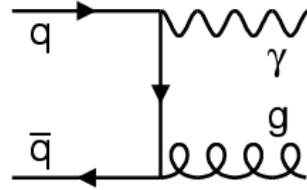
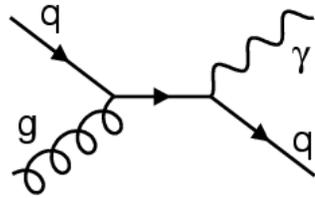
rencontres de
Moriond

QCD and High Energy
Hadronic Interactions

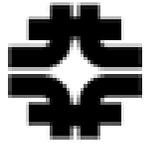
March 18-25, 2006
La Thuile, Vallee d'Aoste, Italy



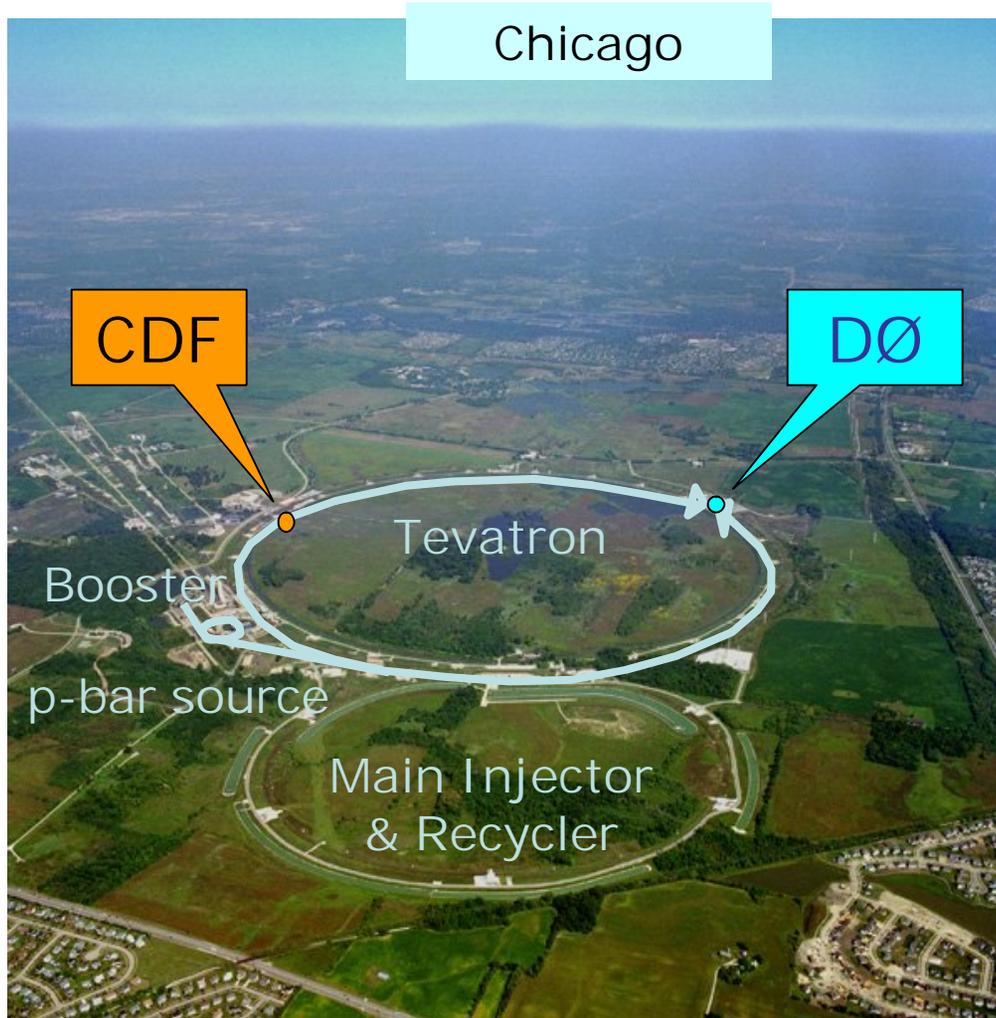
Motivation



- Direct photons come unaltered from the hard subprocess
→ direct probe of the hard scattering dynamics
- Calibration of electromagnetic energies well-understood
(in contrast to energies of hadronic jets)
- Large statistics
- Direct photons are substantial background
to many physics processes
- QCD production dominates:
Understanding the QCD production mechanism is
a prerequisite to searches for new physics & Higgs

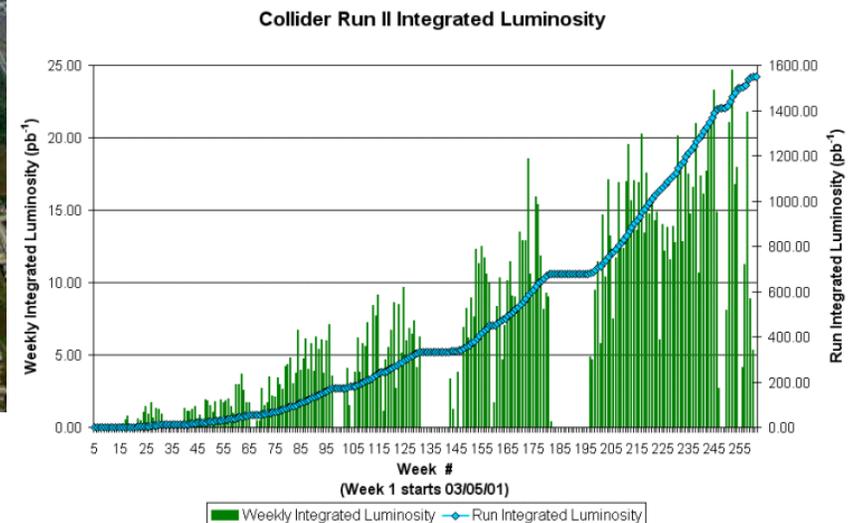


Fermilab Tevatron – Run II

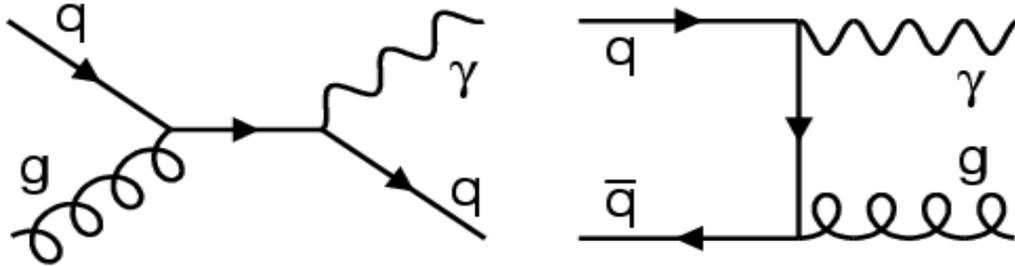


- Ecm: 1.8 → 1.96 TeV
- more Bunches 6 → 36
- Bunch Crossing 3500 → 396ns

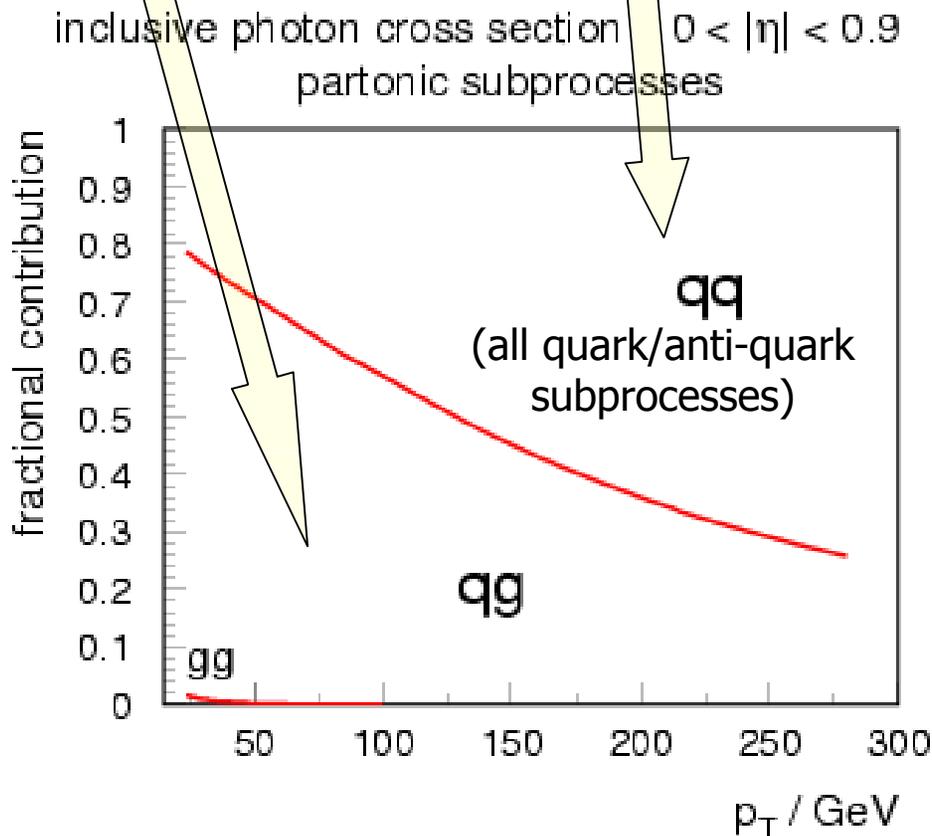
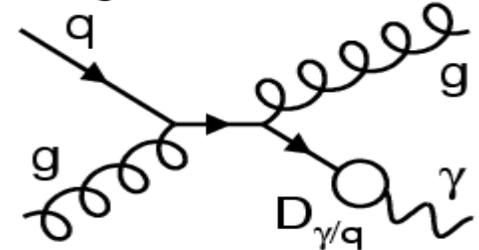
- Run II started in March 2001
- Peak Luminosity:
 $1.7E32 \text{ cm}^{-2} \text{ sec}^{-1}$
- Delivered: $>1.5 \text{ fb}^{-1}$
(Run I : 0.26 fb^{-1})
- Goal: 8 fb^{-1} before 2009



Prompt Photon Production



also fragmentation:



- Dominant production at $p_T < 120 \text{ GeV}$ through Compton scattering: $q+g \rightarrow q+\text{photon}$
- Probe the PDFs at $0.005 < x < 0.3$
 \rightarrow where quarks are constrained from HERA data
 \rightarrow sensitive to gluon density
- Test of NLO pQCD, soft gluon resummation, models of gluon radiation

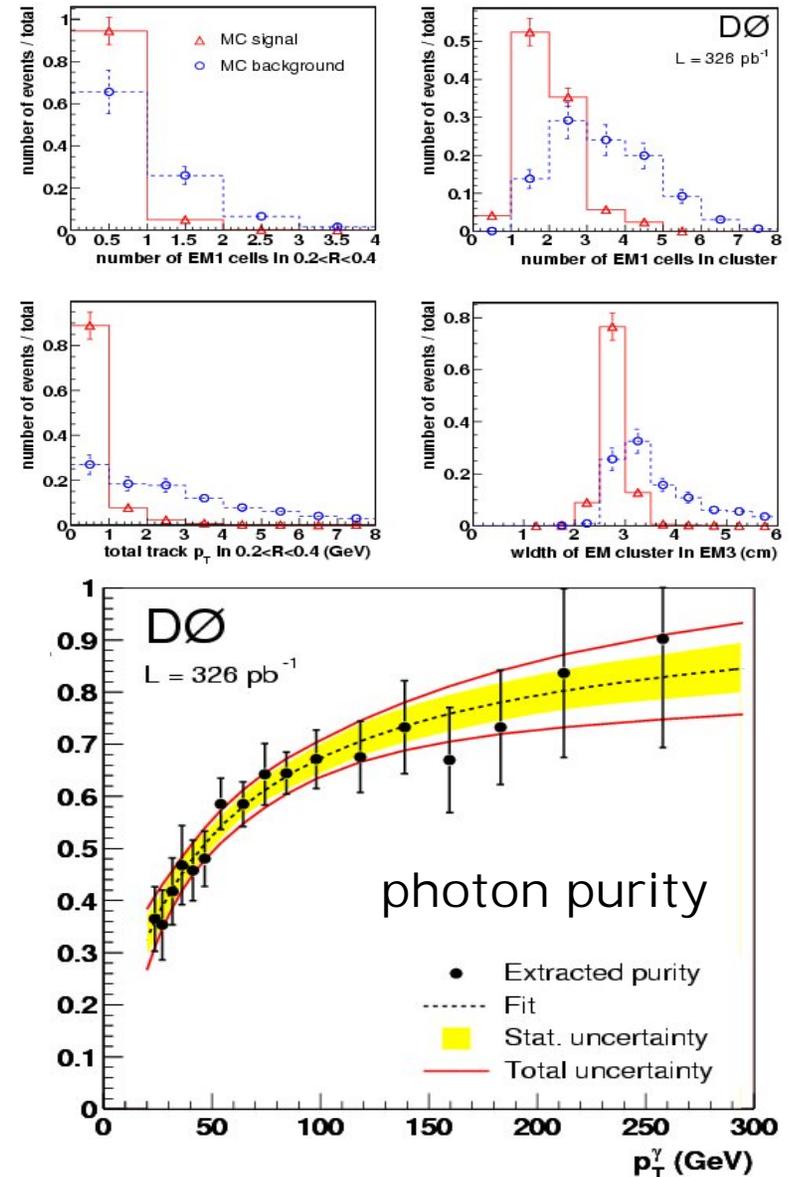


Isolated Photon Production

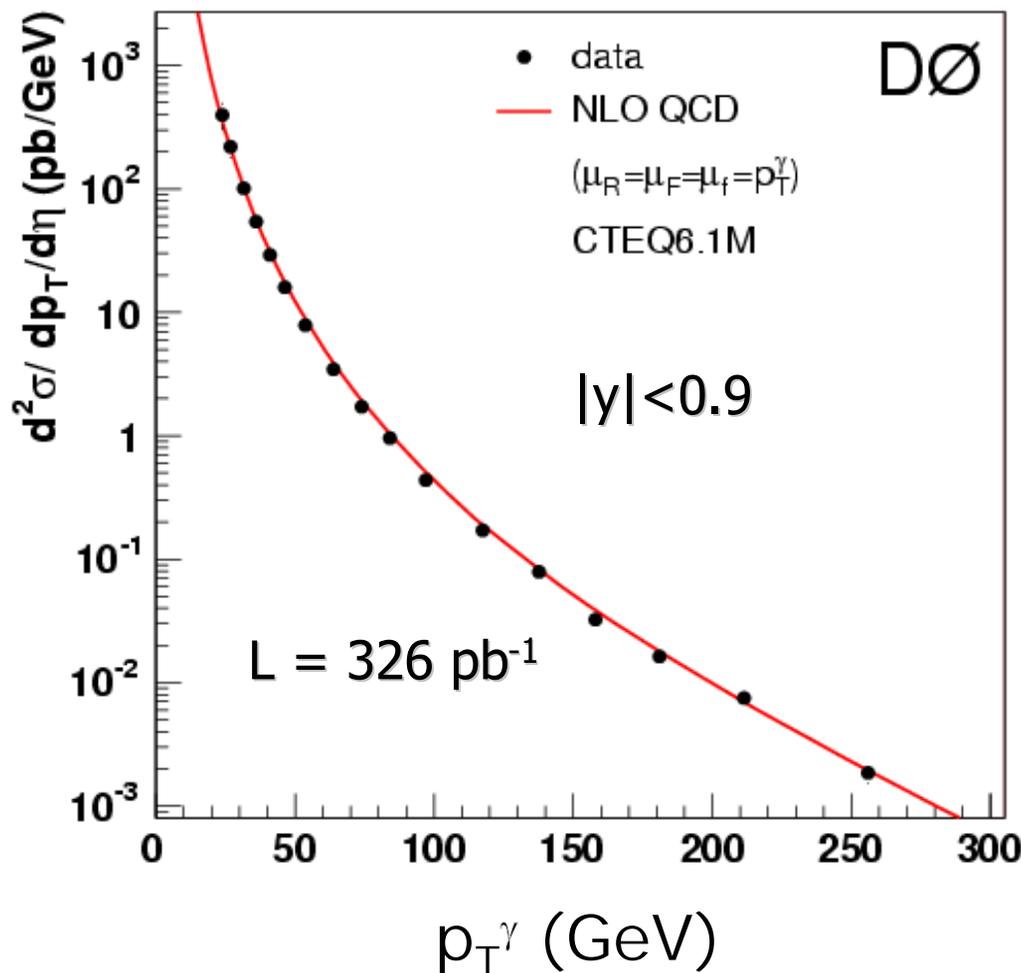
new DØ result: hep-ex/0511045 - submitted to Phys. Lett. B.

- At least one isolated shower in the electromagnetic (EM) calorimeter
 - no associated track
 - pseudorapidity < 0.9
 - $p_T > 23$ GeV
- Small missing transverse energy:
 $MET/p_T < 0.7$
to reject cosmics and electrons from Ws
- Main background:
jets with large EM fraction
 - can be reduced but not entirely removed

- Neural Net is trained to discriminate between photons and EM jets and tested on $Z \rightarrow ee$
- Photon purity: from fit of NN output for MC signal and EM jets to data



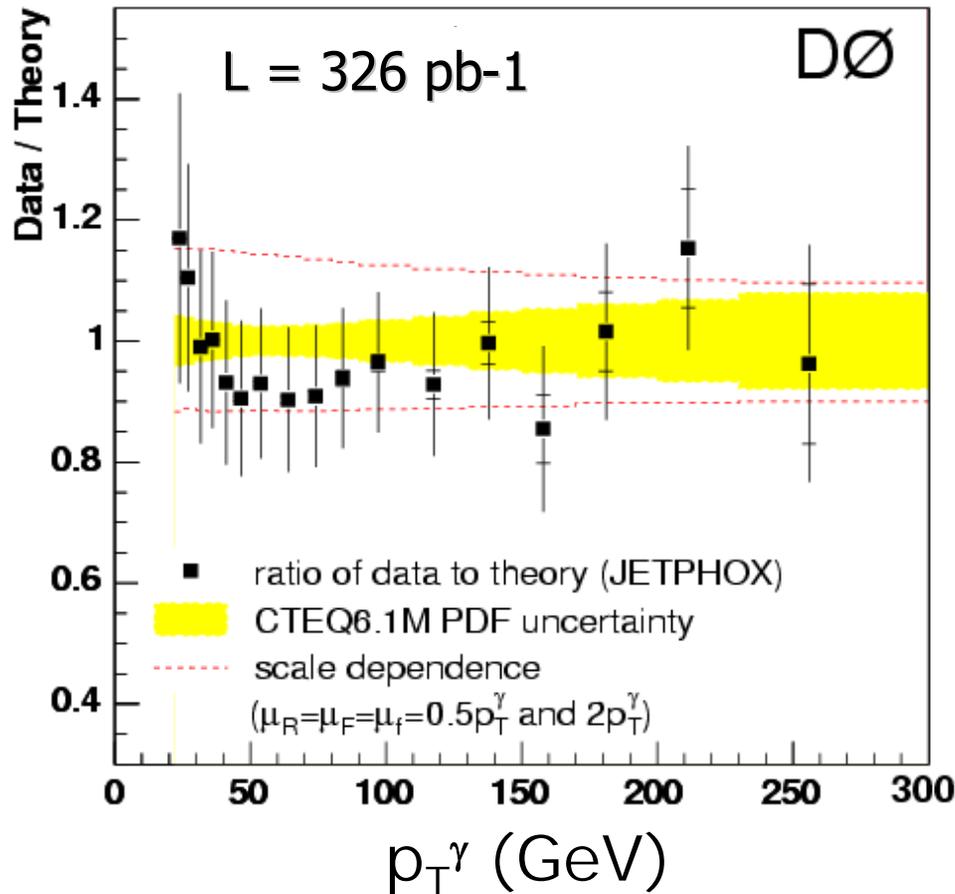
Isolated Photon Cross Section



- Integrated Luminosity: 326 pb^{-1}
- 2.7 million photon candidates
- Analytical unfolding for detector resolution
- Inclusive Isolated Photon Cross Section Results shown with stat. + syst. Uncertainties
- Theory: NLO pQCD from JETPHOX with CTEQ6.1 PDFs and $\mu_r = \mu_f = \mu_F = p_T^\gamma$



Isolated Photon Cross Section



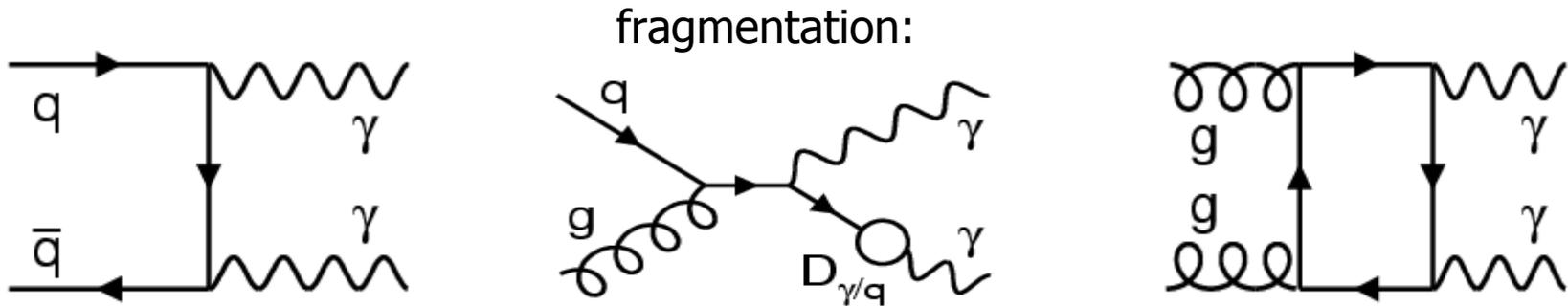
- Ratio: data/theory (JETPHOX) good agreement over the whole range $23 < p_T < 300 \text{ GeV}$
- A NLO pQCD calculation by Gordon and Vogelsang agrees within 7%
- Interpretation is limited by
 - theoretical scale uncertainty
 - experimental syst. uncertainty

→ PDF sensitivity requires:

- Reduced exp. uncertainties – dominated by purity uncertainty
- Improved theory (resummation / NNLO)

Di-Photon Production

- Di-Photon final state: one of main discovery channels for Higgs at the LHC
- Possible signatures of new physics, such as large Extra Dimensions



Leading Order Diagram:
dominant at
high Di-Photon mass
(Higgs background at LHC)

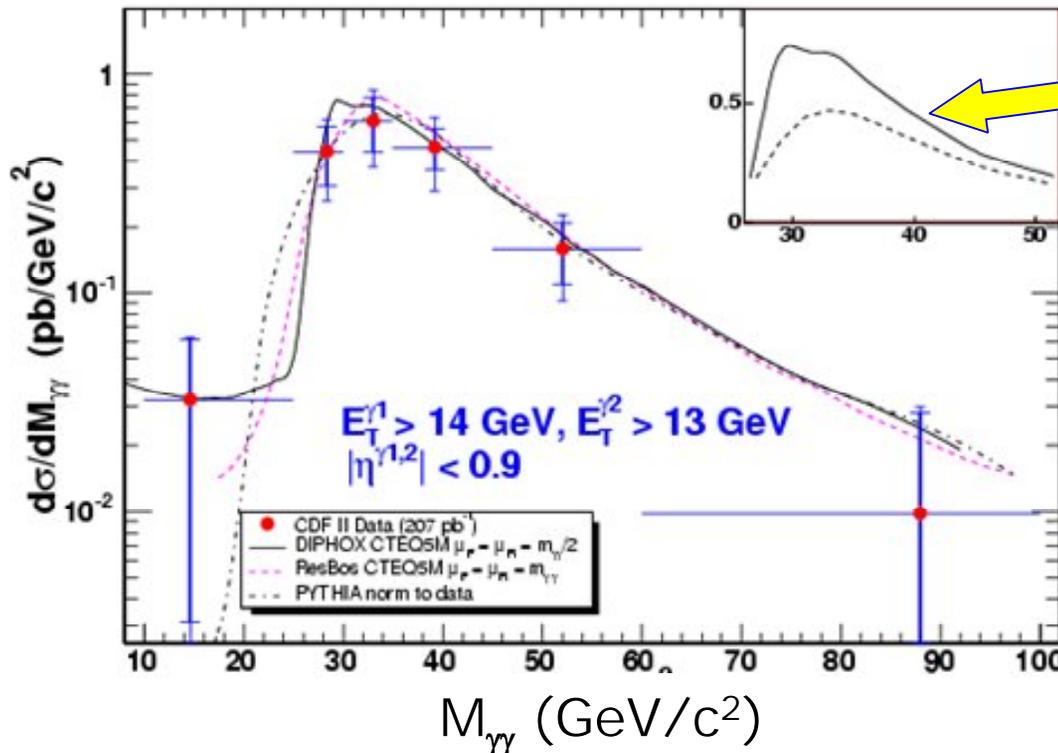
Next-to-next-to leading
order contribution
→ suppressed by
factor α^2
But important at low mass
→ large gluon density



Di-Photon Cross Section

CDF Collab., Phys. Rev. Lett. 95, 022003, 2005.

- Integrated luminosity about 207pb^{-1}
- Two isolated showers in the EM calorimeter w/o associated track
- Pseudorapidity < 0.9
- Photon $p_T > 13$ & 14 GeV (avoid IR-sensitive regions in pQCD)
- 889 Di-photon candidate events - tot. eff: 15.2% - purity about 50%

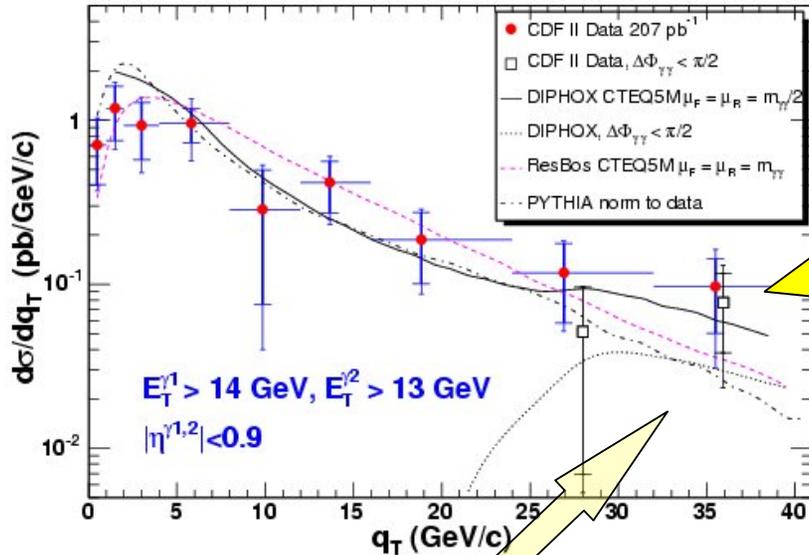


DIPHOX: with and w/o NNLO gg-diagram

- DIPHOX:
 - NLO prompt di-photons
 - NLO fragmentation (1 or 2 γ)
 - NNLO $gg \rightarrow \gamma\gamma$ diagram
- ResBos:
 - NLO prompt di-photons
 - LO fragmentation contribution
 - Resummed initial state gluon radiation (important for q_T)
- PYTHIA (increased by factor 2)

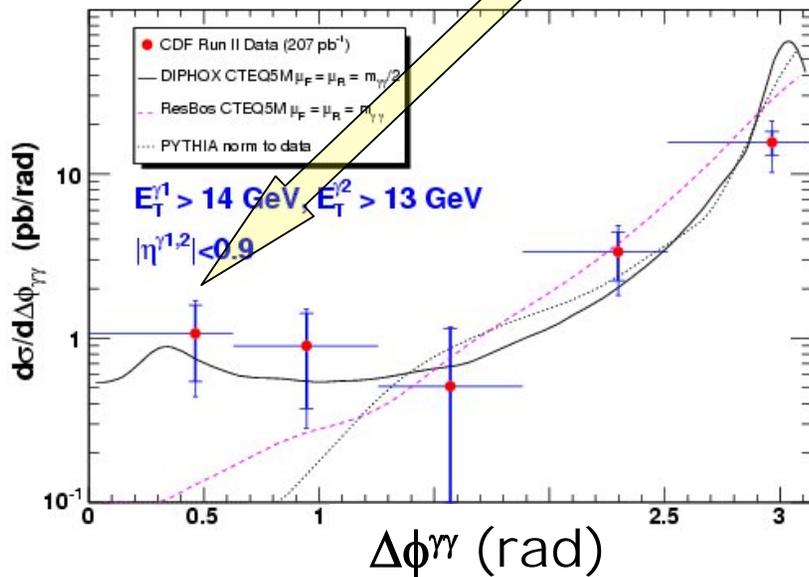


Di-Photon Cross Section



Additional measurement for $\Delta\phi$ (gamma-gamma) $< \pi/2$ (open markers) compared to DIPHOX

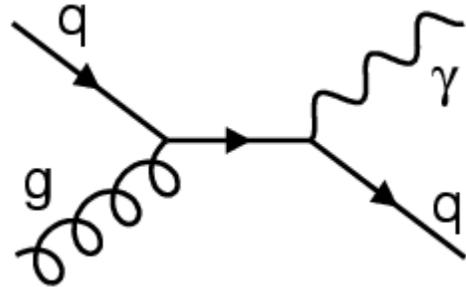
- NLO fragmentation contribution - only in DIPHOX → at high q_T , low $\Delta\phi$, low mass
- Resummed initial-state gluon radiation - only in ResBos → at low q_T



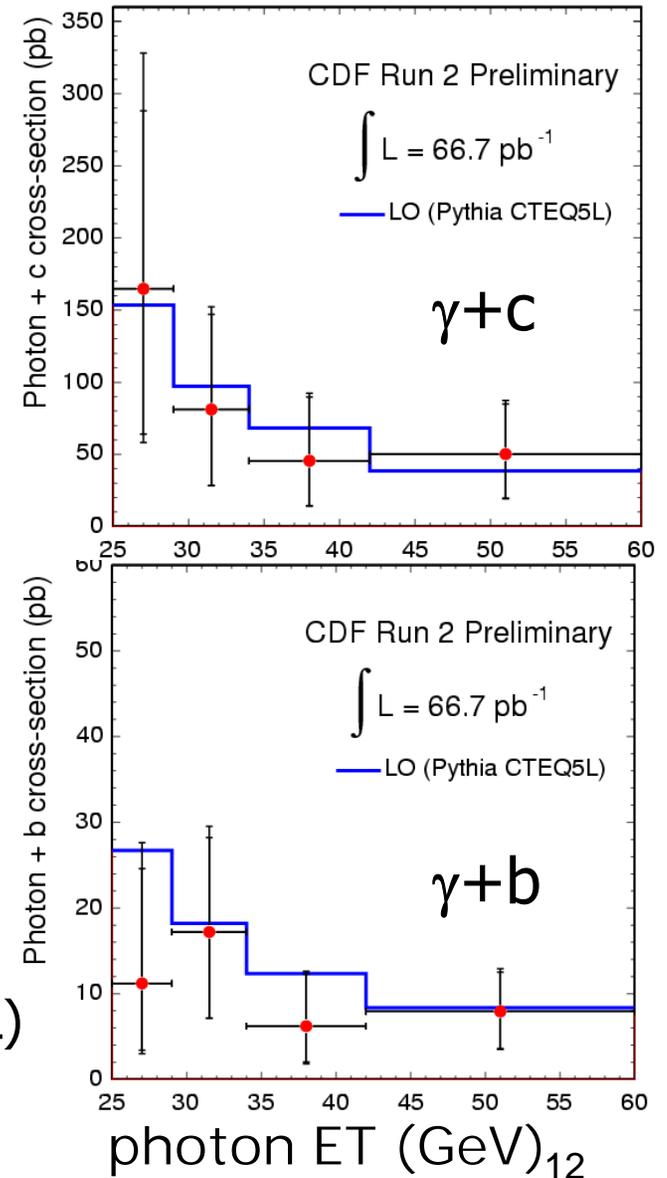
- Systematic uncertainties
- Selection efficiencies (11%)
 - Background subtraction (20-30%)
 - Luminosity (6.5%)



Outlook: Photon plus HF Jets

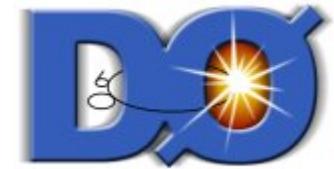


- outgoing quark flavor = incoming quark
 - dominated by: HF + g \rightarrow photon + HF
 - constrain heavy flavor PDFs
(so far in CTEQ/MRST PDF fits:
generated from gluon-splitting /
no experimental constraints)
 - early Run II CDF preliminary results
 - integrated Lumi = 67pb-1
 - good description of data by PYTHIA(CTEQ5L)
- new Tevatron analyses are in progress



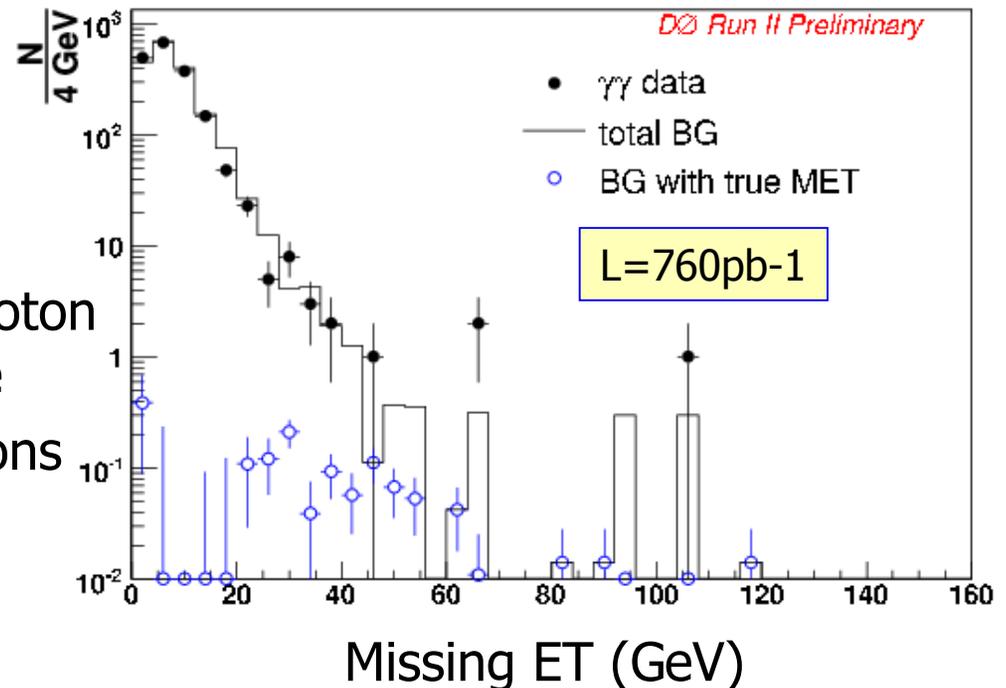


Summary and Outlook



- Photon Production is an ideal testing ground for QCD predictions & add. source for constraining PDFs
- Discovery Channel for Higgs and Large Extra Dimensions, ...
- CDF and DØ data for Isolated Photon and Di-Photon Cross Sections are well-described by pQCD calculations
- Current work in progress:
Di-Photon, Photon + Jet,
Photon + heavy flavor jet

New preliminary DØ result:
Missing ET in Di-Photon events
→ limits for GMSB SUSY particles



Limits (95% CL):
lightest neutralino > 120 GeV
lightest chargino > 220 GeV