Paper Seminar: Measurement of the Cross Section for Production of Two Isolated Prompt Photons

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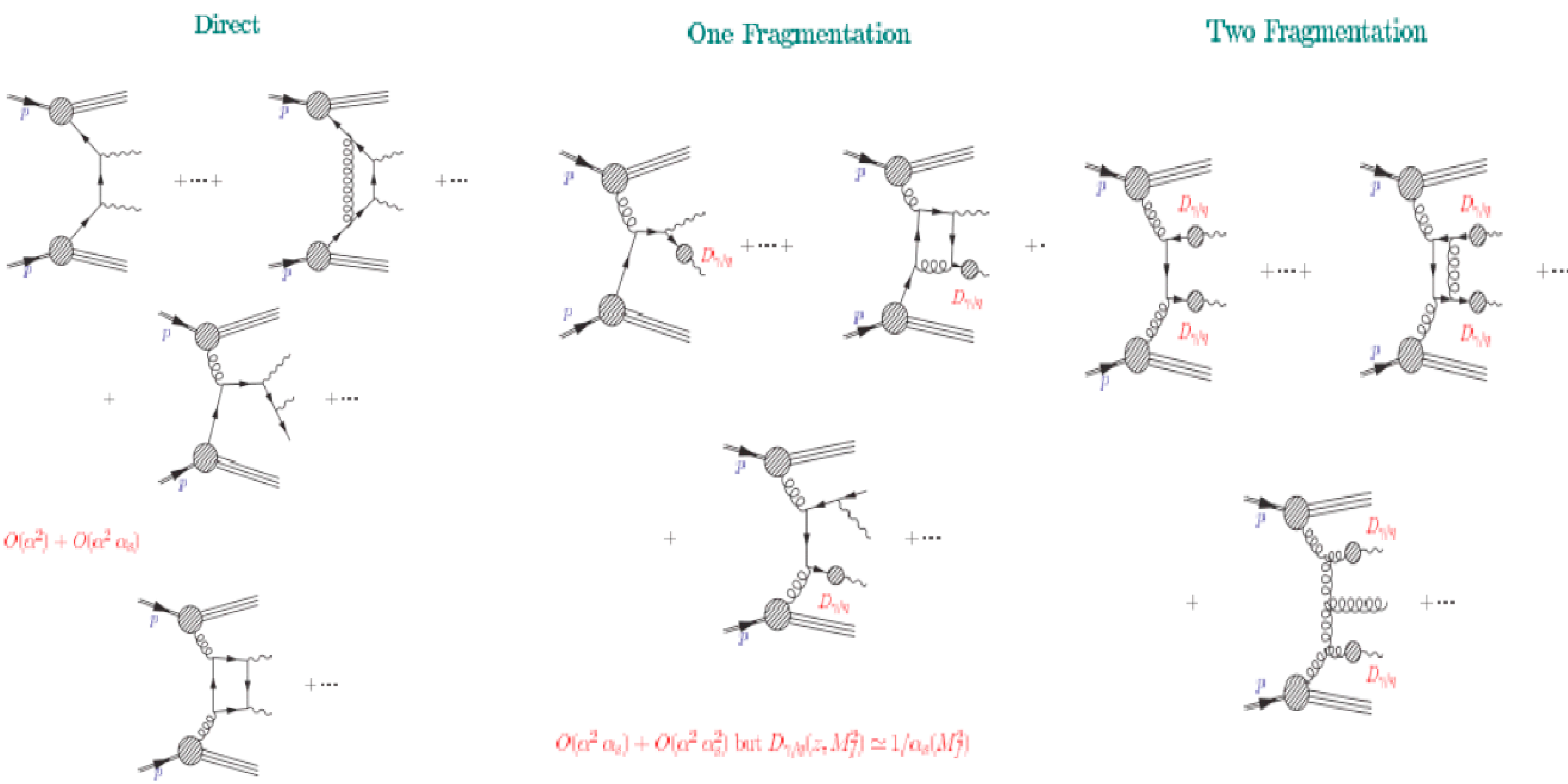
Interested parties

- Authors
  - (Dr.) Yanwen Liu
    - thesis: CDF7366
    - currently on way from Geneva to Belgium for post-doc
  - R. Blair
  - R. Culbertson
  - J. Huston
  - S. Kuhlmann
  - X. Wu
- Paper is available as CDF note 7204
  - still have a few minor edits
- See also CDF note 6312 for analysis details
- Godparents
  - Peter Wilson (head honcho)
  - Gary Barker
  - Songwon Lee
  - actually made the godparenting process a pleasant experience
  - webpage: fcdfwww.fnal.gov/internal/physics/DiPhotonXsec/

Motivation

- Diphoton final states are a signature of many interesting physics processes
  - H->$\gamma\gamma$ at the LHC
  - LED
  - SUSY
- Understanding of the QCD production mechanism is prerequisite to searches for new physics
- 4-momenta of two photons can be measured very precisely, allowing for some precision comparisons to theory
  - diphoton q_T, sensitive to initial state soft gluon radiation
- There are potentially large backgrounds, though, from quarks and gluons fragmenting into neutral mesons which carry most of parent parton's momentum
  - analysis strategy has to reduce this background

Diphoton subprocesses

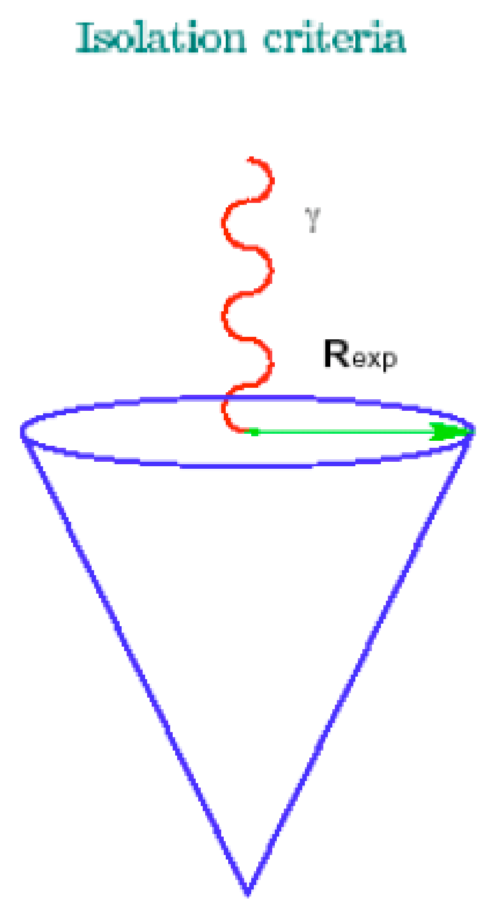


Theory comparisons

- We have compared our experimental results to 3 predictions
  - DIPHOX
    - fixed order calculation that contains all of the subprocesses listed on previous slide at NLO except for gg->$\gamma\gamma$
    - with Carl Schmidt, we have calculated and incorporated the NLO corrections for gg->$\gamma\gamma$ in DIPHOX for comparison with our data
  - ResBos
    - direct contributions at NLO; fragmentation at LO
    - …but also resums effects of soft gluon radiation
  - Pythia
    - LO parton shower program

Isolation

- To reduce background from π^o's and η's, we have imposed an isolation requirement on the photon candidate
  - E_T in cone of radius 0.4 has to be less than 1 GeV/c
- Dramatically reduces jet backgrounds, but also has effect of significantly reducing fragmentation contributions



Analysis

- Trigger requires 2 photon candidates with E_T>12 GeV
  - Requirement in offline that E_T>14 (13) GeV for harder (softer) candidate
- Cuts
  - $|\eta|<0.9$; fiducial cuts
  - $|z_{vertex}|<60$ cm
  - HAD/EM < 0.055+0.00045xE
  - no track pointing to EM cluster
  - no extra CES cluster above 1 GeV
  - CES $\chi^2<20$

Table 1: The efficiencies per diphoton event for the cuts.

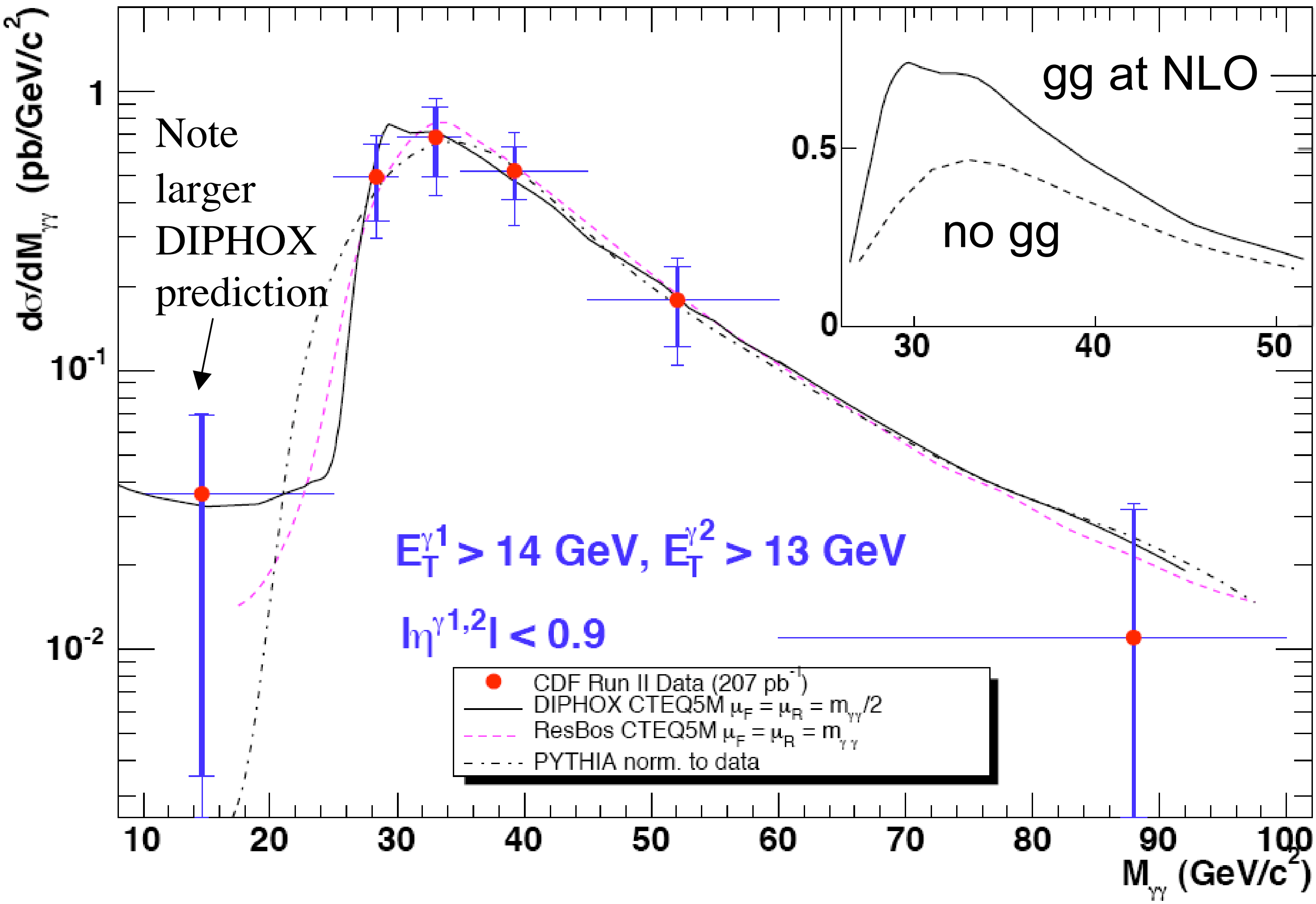
Trigger efficiency	0.951
Reconstruction efficiency and fiducial cuts	0.423
Isolation energy in 0.4 cone < 1 GeV	0.727
No track pointing to the EM cluster	0.699
No extra CES cluster above 1 GeV	0.899
CES χ^2 < 20	0.970
Had/EM <0.055 + 0.00045× E	0.976
|z-vertex| < 60 cm	0.877
Combined	0.152

CES χ2 test (<4) used for photon candidates below 35 GeV; CPR test used above 35 GeV

207 pb^{-1} of data used; of 889 candidates, 427+/-59 (stat) are real photons

background determined on bin-by-bin basis

Diphoton mass distribution



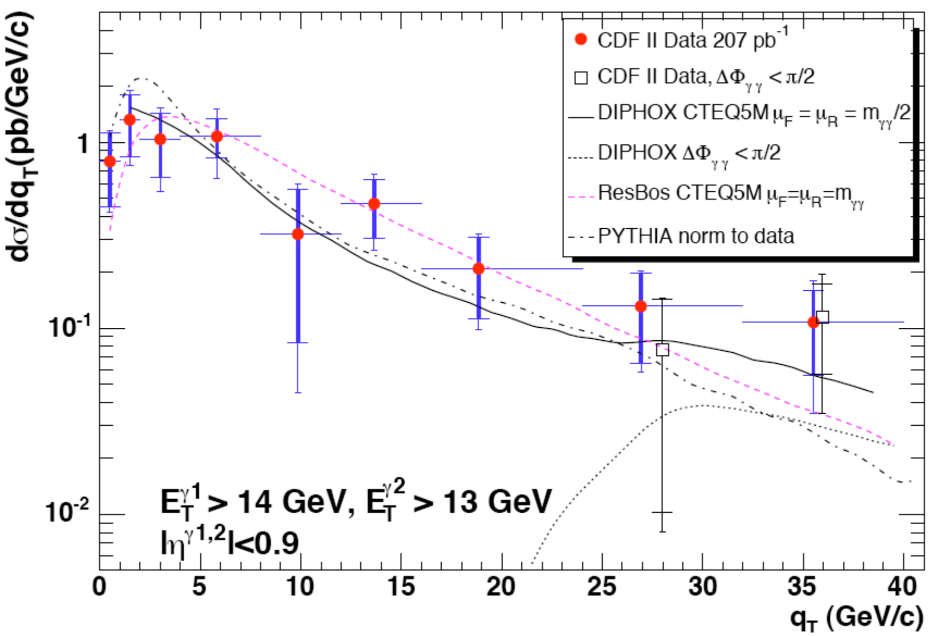
K-factor for gg is large (100%)

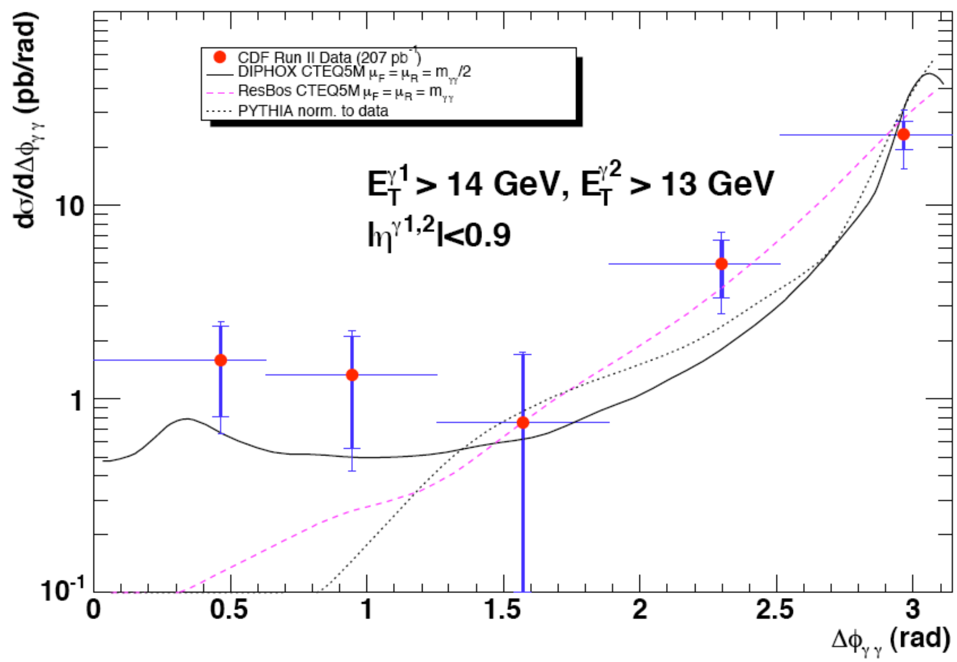
low mass diphoton production useful for testing gg resummation

Pythia needs to be scaled by factor of 2

Other diphoton variables

small q_T, large $\Delta\phi$: effects of gluon resummation evident
large q_T, small $\Delta\phi$: NLO fragmentation important





DIPHOX breaks down at low q_T due to singularity; need to resum a la ResBos
ResBos does a better job in general at low qT due to gluon resummation
DIPHOX shows additional source of production at low $m_{\gamma\gamma}$, small $\Delta\phi$ and large q_T
->NLO fragmentation

We need a full NLO resummed calculation.

Cross sections

- Systematic errors from
  - selection cuts
  - background subtraction
  - luminosity determination

Table 3: A comparison of the cross section as a function of the $\gamma\gamma$ q_T for the data and predictions from DIPHOX, ResBos and PYTHIA.

q_T (GeV)	CDF Data (pb/GeV)	DIPHOX (pb/GeV)	ResBos (pb/GeV)	PYTHIA (pb/GeV)
0-1	0.70 ± 0.30 ± 0.14	-2.45	0.34	0.53
1-2	1.18 ± 0.43 ± 0.28	5.59	0.95	1.15
2-4	0.92 ± 0.35 ± 0.28	2.06	1.03	0.94
4-8	0.96 ± 0.23 ± 0.32	1.17	0.94	0.46
8-12	0.29 ± 0.21 ± 0.13	0.44	0.59	0.21
12-16	0.42 ± 0.14 ± 0.12	0.24	0.36	0.12
16-24	0.19 ± 0.09 ± 0.05	0.13	0.19	0.07
24-32	0.12 ± 0.06 ± 0.03	0.09	0.07	0.03
32-40	0.10 ± 0.05 ± 0.05	0.06	0.03	0.01

Table 4: A comparison of the cross section as a function of the $\gamma\gamma$ $\Delta\phi$ for the data and predictions from DIPHOX, ResBos and PYTHIA.

$\Delta\phi_{\gamma\gamma}$ (π rad)	CDF Data (pb/rad)	DIPHOX (pb/rad)	ResBos (pb/rad)	PYTHIA (pb/rad)
0.0-0.2	1.06 ± 0.52 ± 0.34	0.69	0.01	0.02
0.2-0.4	0.89 ± 0.52 ± 0.32	0.56	0.23	0.09
0.4-0.6	0.51 ± 0.63 ± 0.19	0.71	0.73	0.44
0.6-0.8	3.34 ± 1.10 ± 1.04	1.83	3.08	1.09
0.8-1.0	15.56 ± 2.59 ± 4.70	23.37	17.52	10.68

Table 2: A comparison of the cross section as a function of the $\gamma\gamma$ mass for the data and predictions from DIPHOX, ResBos and PYTHIA.

$M_{\gamma\gamma}$ (GeV)	CDF Data (pb/GeV)	DIPHOX (pb/GeV)	ResBos (pb/GeV)	PYTHIA (pb/GeV)
10-25	0.03 ± 0.03 ± 0.01	0.04	0.01	0.01
25-30	0.44 ± 0.13 ± 0.12	0.41	0.31	0.18
30-35	0.61 ± 0.17 ± 0.16	0.70	0.65	0.38
35-45	0.46 ± 0.10 ± 0.14	0.46	0.43	0.24
45-60	0.16 ± 0.05 ± 0.04	0.19	0.16	0.09
60-100	0.01 ± 0.02 ± 0.01	0.04	0.04	0.02

Summary

- We have measured diphoton production in Run 2 with 207 pb^{-1} of data
  - best measurement of diphoton production to date
- Comparisons with theory indicate interesting features which further data will help to pin down
  - a full NLO resummed theory is necessary for agreement with data in all kinematic regions
- Paper will have minor revisions and then be (re)posted
  - then Los Alamos
  - then PRL
- Meanwhile more data will be incorporated into the diphoton analysis