# Di-photon cross section measurement at CDF II

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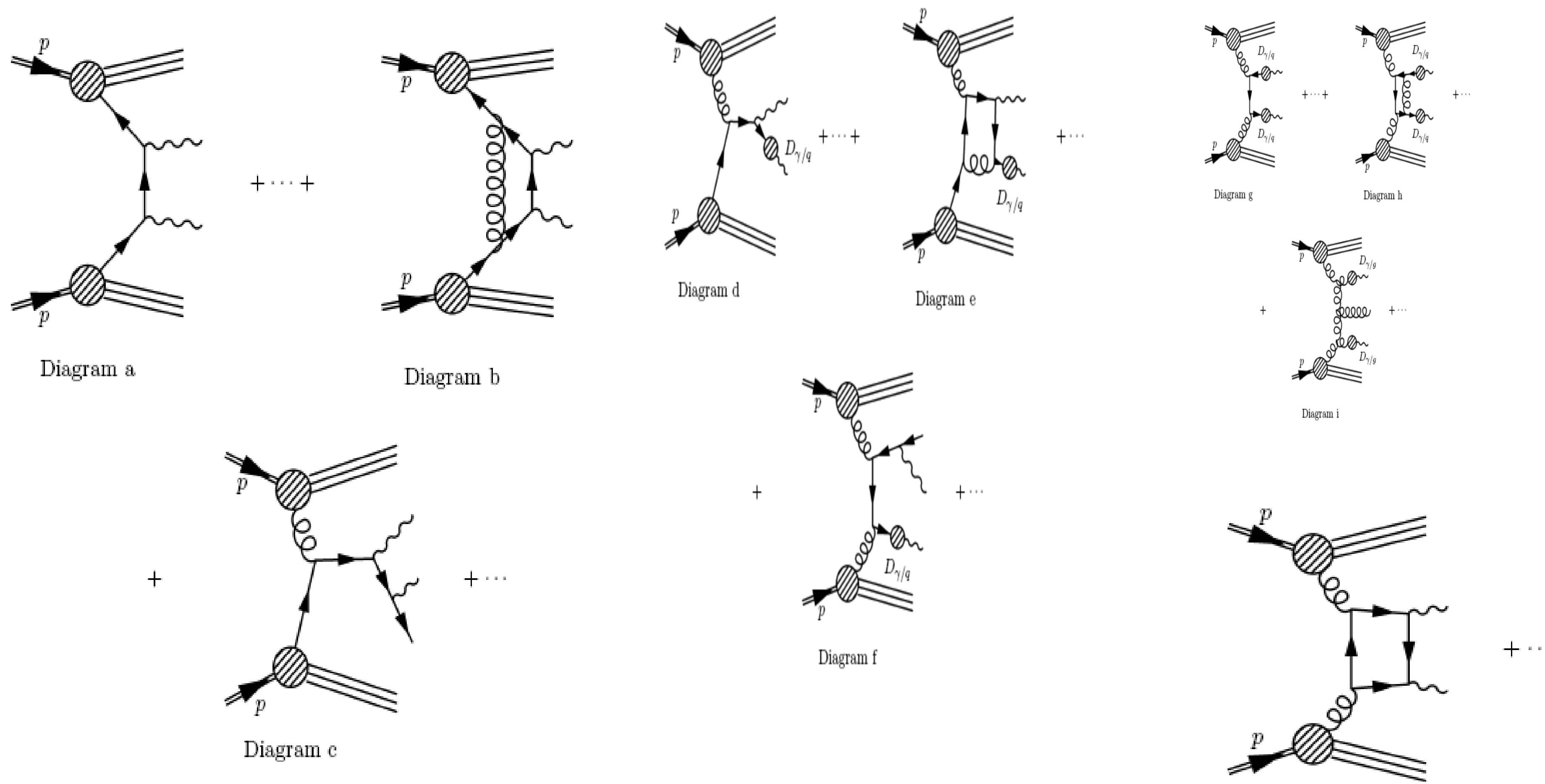
# Motivation

- A signature of many interesting physics processes, e.g. Higgs-> γγ.
- QCD production – important background.
- A good tool for studying QCD : e.g. final state can be measured with good precision, the imbalance of the photon momenta is sensible to initial state soft gluon emission.

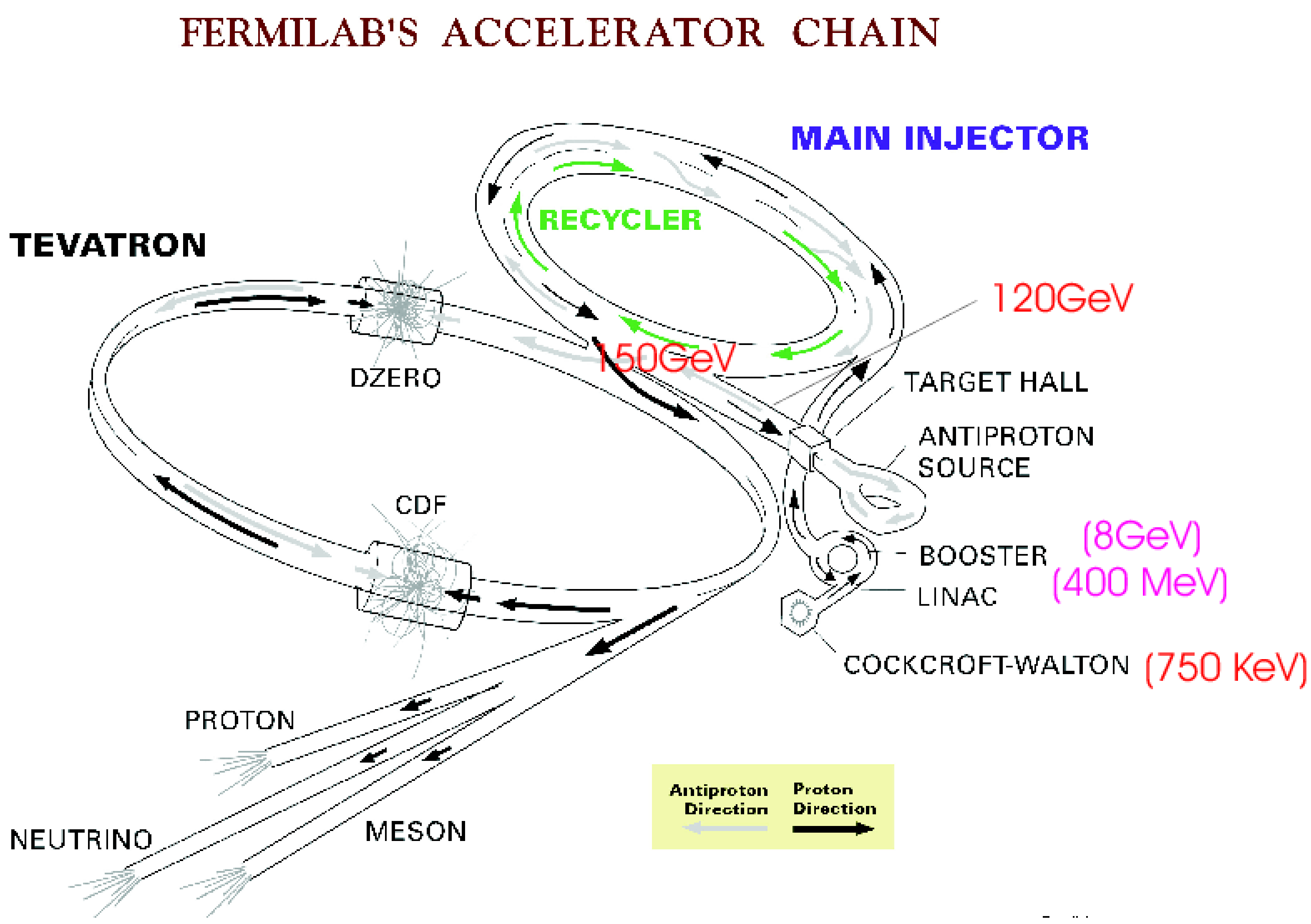
# Prompt isolated photons

- "prompt photons": photons produced from the hard scattering, not from neutral meson decay.
- Essentially every jet contains one or more neutral pions that decay to photons->background.
- Isolation (e.g. additional energy in 0.4 cone below 1 GeV) typically used to reduce the background.
- This rejects most of the jet background, but leaves those (10^-3) cases where a single meson carries most of the jet energy. But since the jet cross section is 10^3 times larger than prompt photon cross section, s/b is still at the order of 1:1.

# Main contributions from pQCD

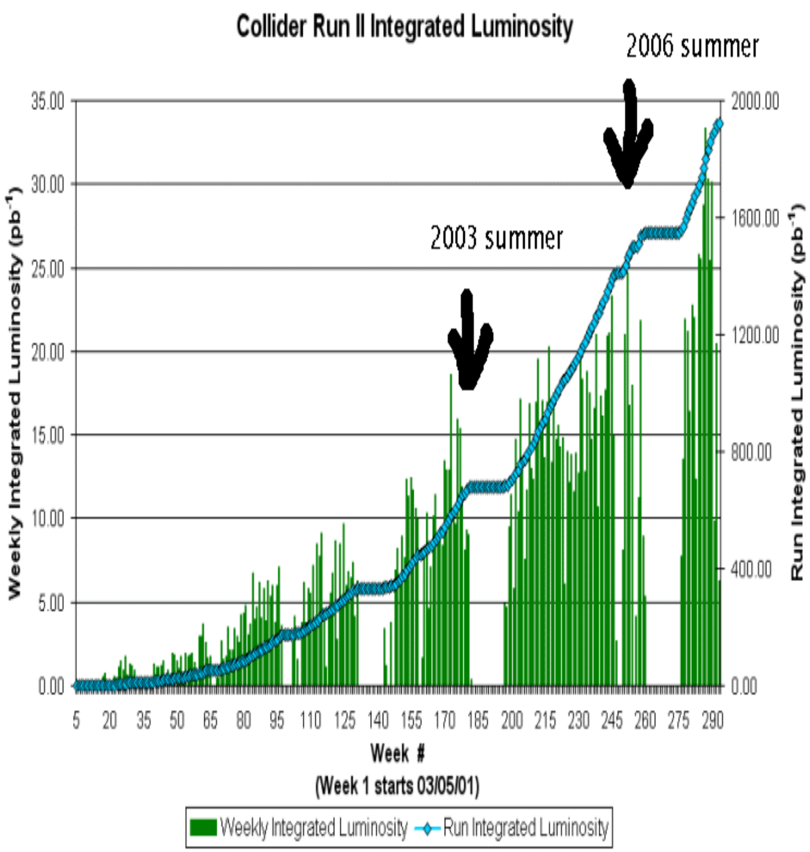


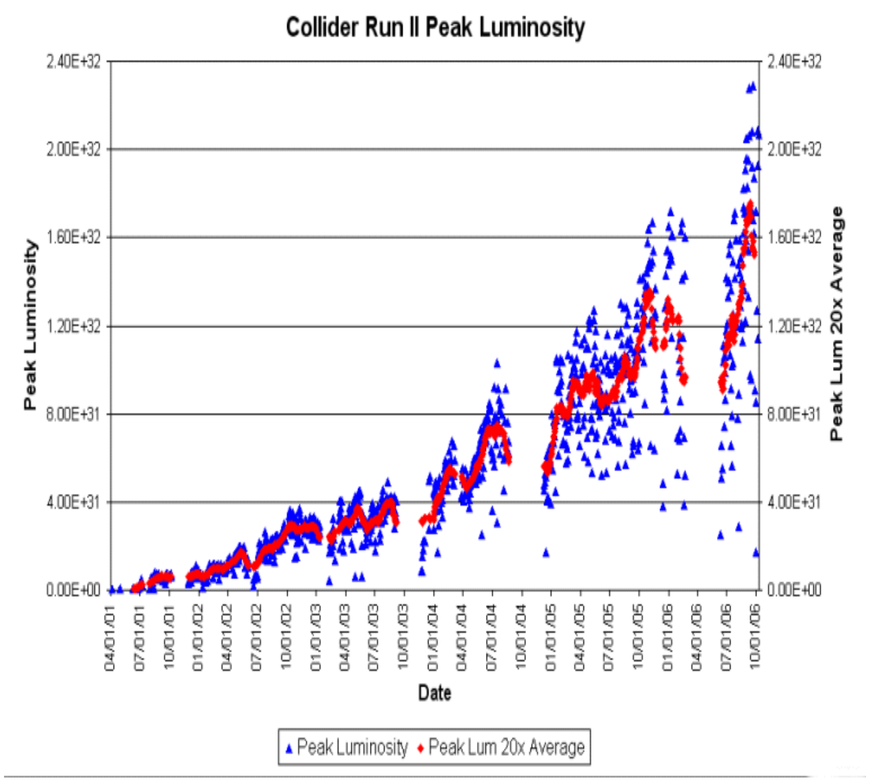
# Tevatron



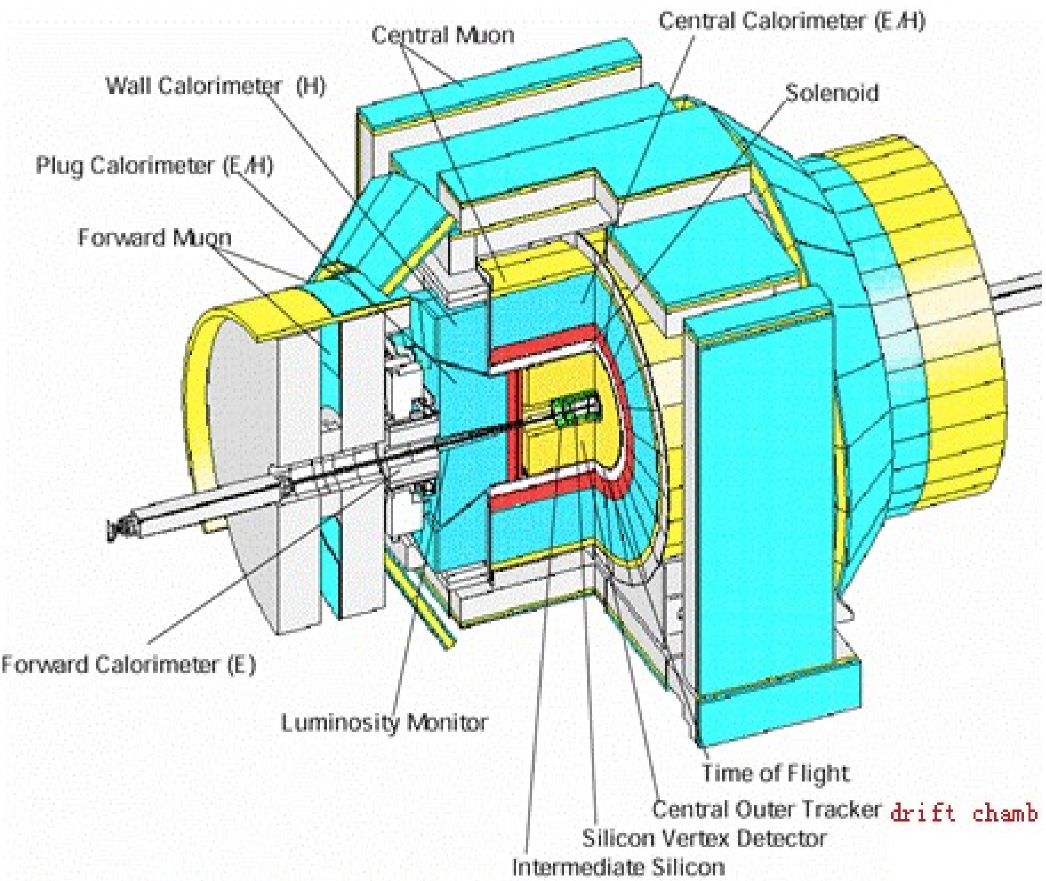
FERMILAB'S ACCELERATOR CHAIN
MAIN INJECTOR
RECYCLER
TEVATRON
120GeV
150GeV
DZERO
TARGET HALL
ANTIPROTON
SOURCE
CDF
BOOSTER
(8GeV)
(400 MeV)
LINAC
COCKCROFT-WALTON
(750 KeV)
PROTON
NEUTRINO
MESON
Antiproton Direction
Proton Direction

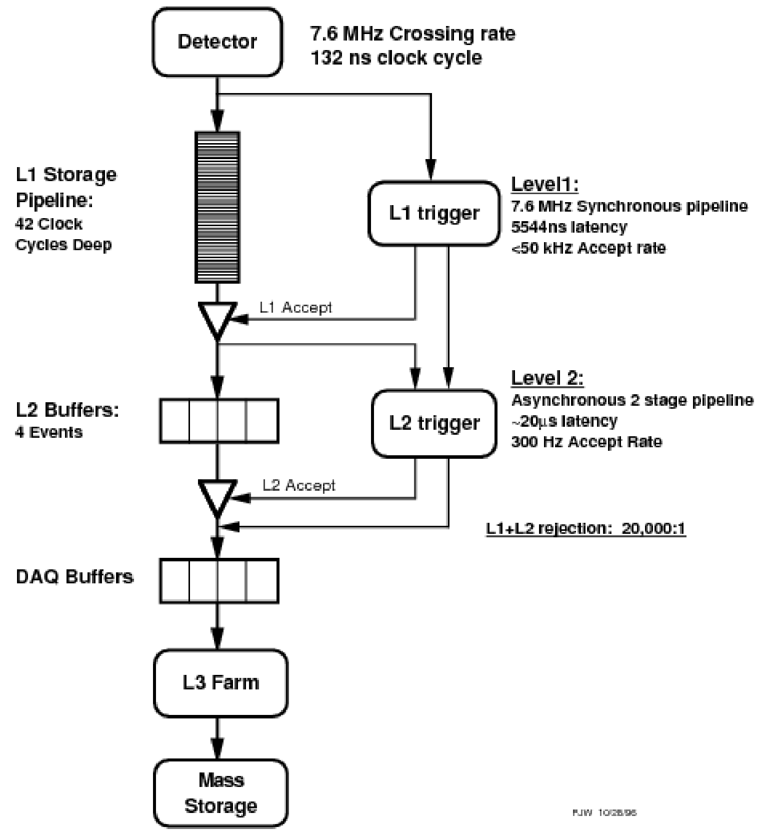
# Accelerator performance



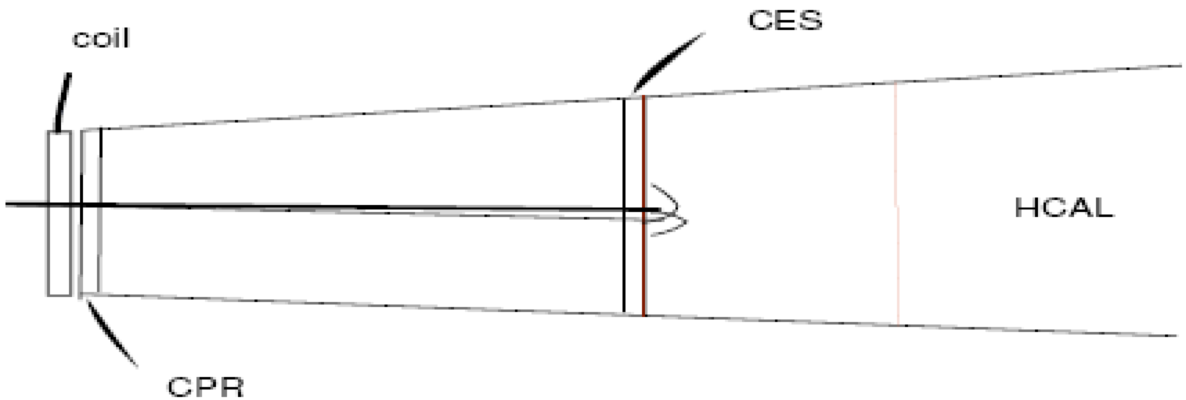



# CDF II detector and TDAQ



# Photon identification at CDF

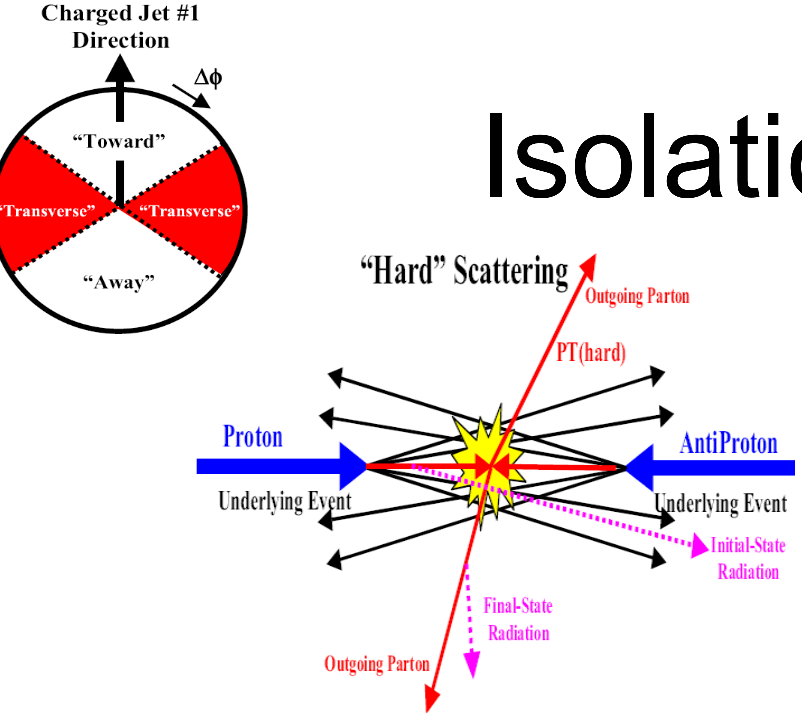



-Shower shape measured by the CES, consistent with photon.

- Isolated : no other CES cluster,

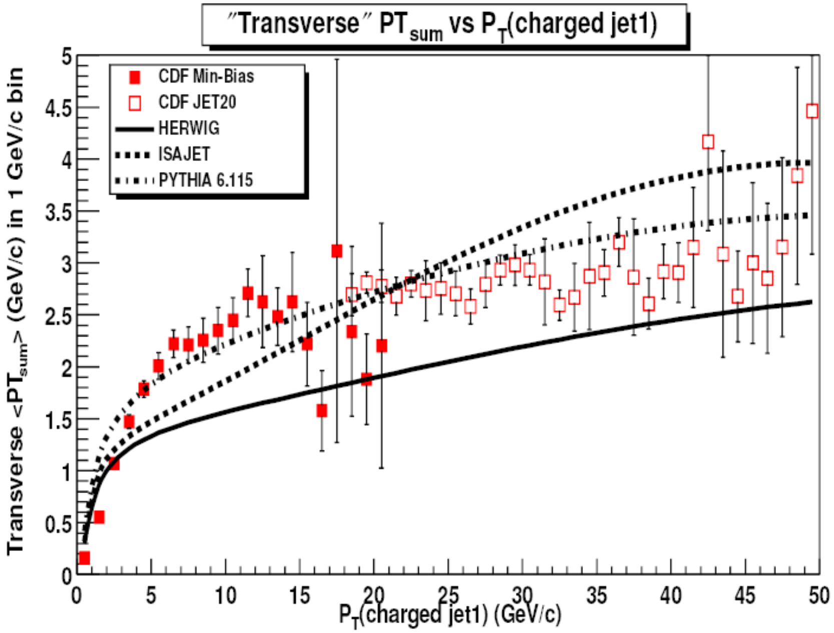
- additional energy in 0.4 cone neighborhood < 1GeV.

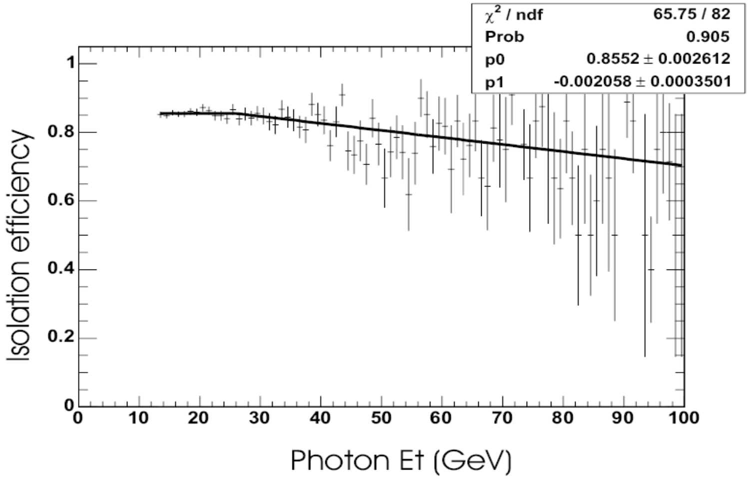
- Had/EM small.




# Isolation efficiency

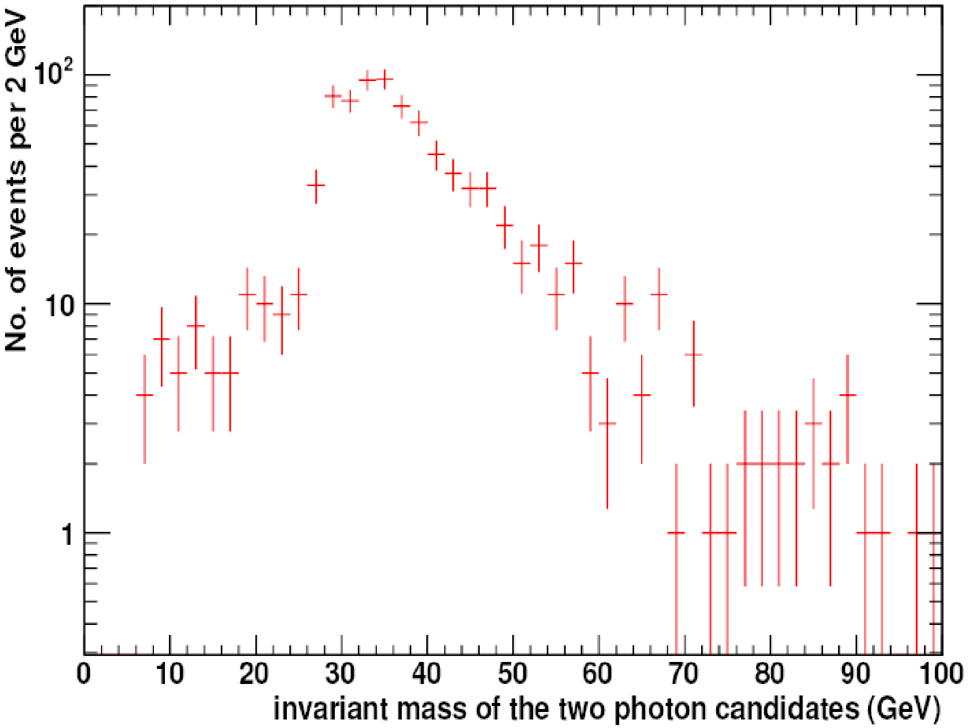
- Inefficiency from underlying energy.
- PYTHIA MC : efficiency flat up to $E_T$ = 26 GeV, followed by a slight slope.
- The isolation from PYTHIA MC conistent with Min-Bias data.
- CDF 2 default PYTHIA underlying event modeling : R. Field's Tune A [PRD65,092002(2002)]



# Di-photon candidates

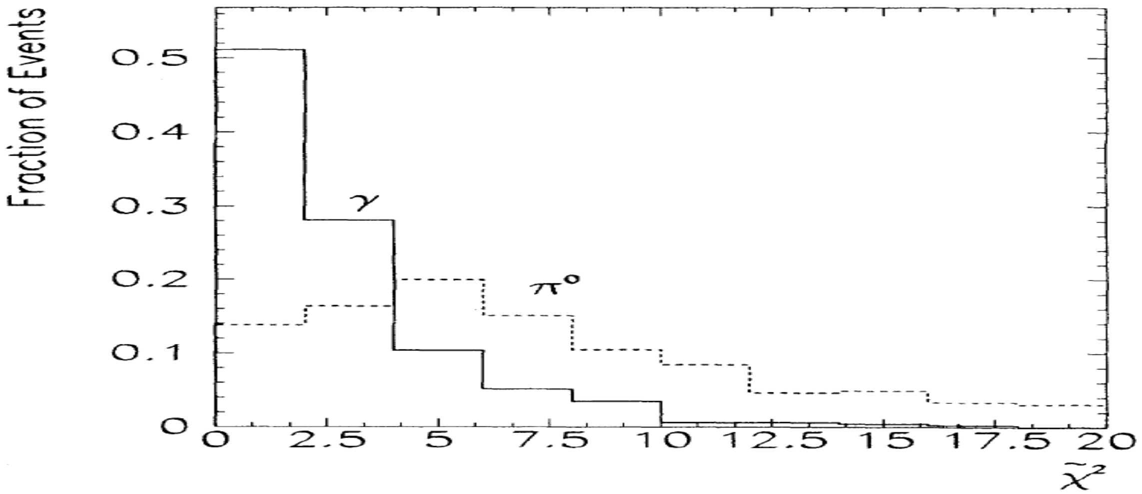
- Dataset collected during Feb 2002 - Sep 2003. 207 pb-1 after data quality cut :889 candidates
- Expect about ½ of background.




$$E_T^{\gamma_1} > 14, E_T^{\gamma_2} > 13 \text{ GeV}$$

$$|\eta^{\gamma 1}|, |\eta^{\gamma 2}| < 0.9$$

# Background subtraction




- Suppose : $\varepsilon_s$ of signal objects pass some cuts of X, e.g. X $<$ Xo cut.
- $\varepsilon_b$ of the background objects pass the X<Xo cut.
- In the data sample : $N_p$ candidates pass the cut; $N_f$ of them fail. $(\varepsilon \equiv \frac{N_p}{N_{total}}; N_{total} \equiv N_p + N_f)$.
- $N_s, N_b$?
- $$\begin{cases} (1-\varepsilon_s) \times N_s + (1-\varepsilon_b) \times N_b = N_f \\ \varepsilon_s \times N_s + \varepsilon_b \times N_b = N_p \end{cases}$$
- $N_s = \frac{\varepsilon - \varepsilon_b}{\varepsilon_s - \varepsilon_b} \times \mathrm{N}_{total}$.

# Background subtraction (γγ)

- For the two-photon case : two cuts, one per photon.
- Four categories from the two cuts : $N_{ff}, N_{fp}, N_{pf}, N_{pp}$.
- $N_{bb}, N_{bs}, N_{sb}, N_{ss}$ ?
- The two 4-vectors related by a 4x4 matrix.

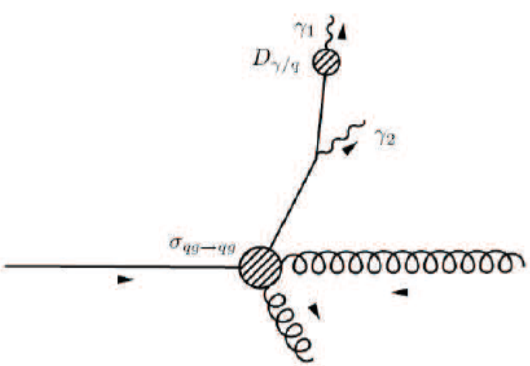
$$\begin{bmatrix} N_{ff} \\ N_{fp} \\ N_{pf} \\ N_{pp} \end{bmatrix} = E \times \begin{bmatrix} N_{bb} \\ N_{bs} \\ N_{sb} \\ N_{ss} \end{bmatrix}$$

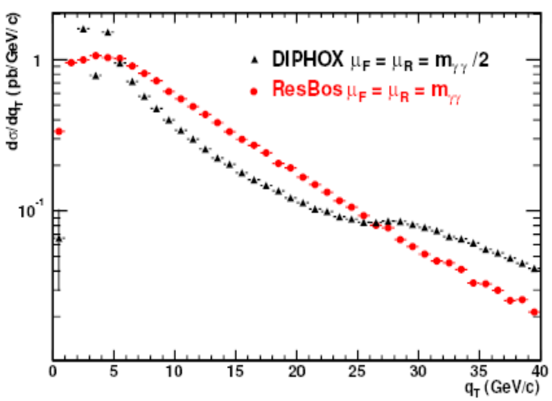
- The matrix $E$ :

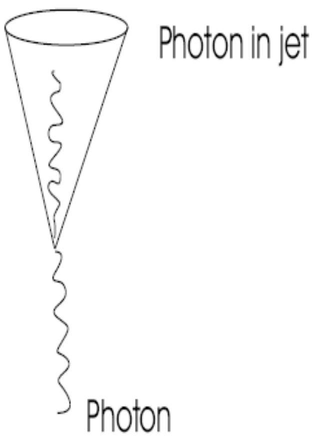
$$\begin{bmatrix} (1-\varepsilon_{b1})(1-\varepsilon_{b2}) & (1-\varepsilon_{b1})(1-\varepsilon_{s2}) & (1-\varepsilon_{s1})(1-\varepsilon_{b2}) & (1-\varepsilon_{s1})(1-\varepsilon_{s2}) \\ (1-\varepsilon_{b1})\varepsilon_{b2} & (1-\varepsilon_{b1})\varepsilon_{s2} & (1-\varepsilon_{s1})\varepsilon_{b2} & (1-\varepsilon_{s1})\varepsilon_{s2} \\ \varepsilon_{b1}(1-\varepsilon_{b2}) & \epsilon_{b1}(1-\varepsilon_{s2}) & \varepsilon_{s1}(1-\varepsilon_{b2}) & \varepsilon_{s1}(1-\varepsilon_{s2}) \\ \varepsilon_{b1}\varepsilon_{b2} & \varepsilon_{b1}\varepsilon_{s2} & \varepsilon_{s1}\varepsilon_{b2} & \varepsilon_{s1}\varepsilon_{s2} \end{bmatrix}$$

# Theoretic predictions (~2005)

- DIPHOX, NLO calculation [Eur.Phys.J.C16,311(2000)]; ResBos resums effect of multiple gluon radiations at initial state to all orders[PRD57,6934(1998)]. NLL accuracy
- DIPHOX includes contributions involving photons produced at hadronization effectively to the order of $\alpha_{em}^2\alpha_s$, while ResBos is at $\alpha_{em}^2$.
- Experimental isolation criteria implemented to parton level in DIPHOX, causing divergence at low $q_T$.[JHEP 9710,005(1997)]
- The cut value is set to 4 GeV, compared to the 1 GeV used in the experimental analysis. The larger theoretical isolation cut improves the stability of the theory without having a significant impact on the numerical prediction.



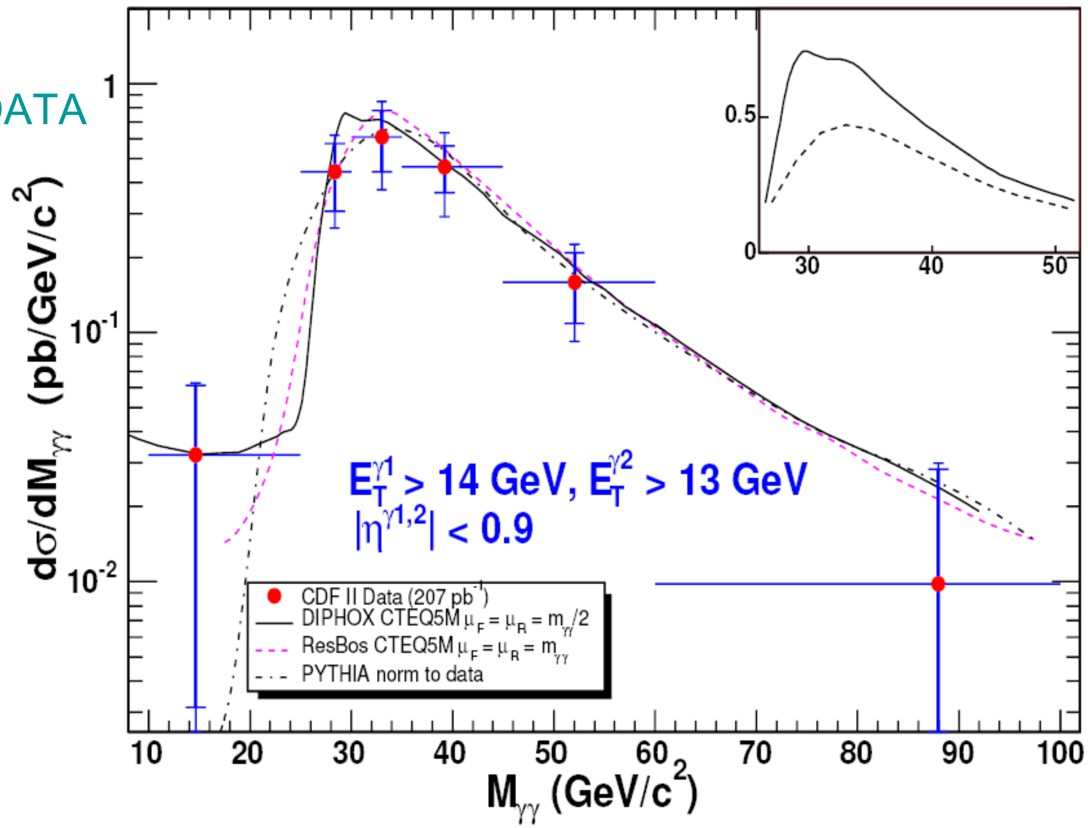



# Comparisons (mass)

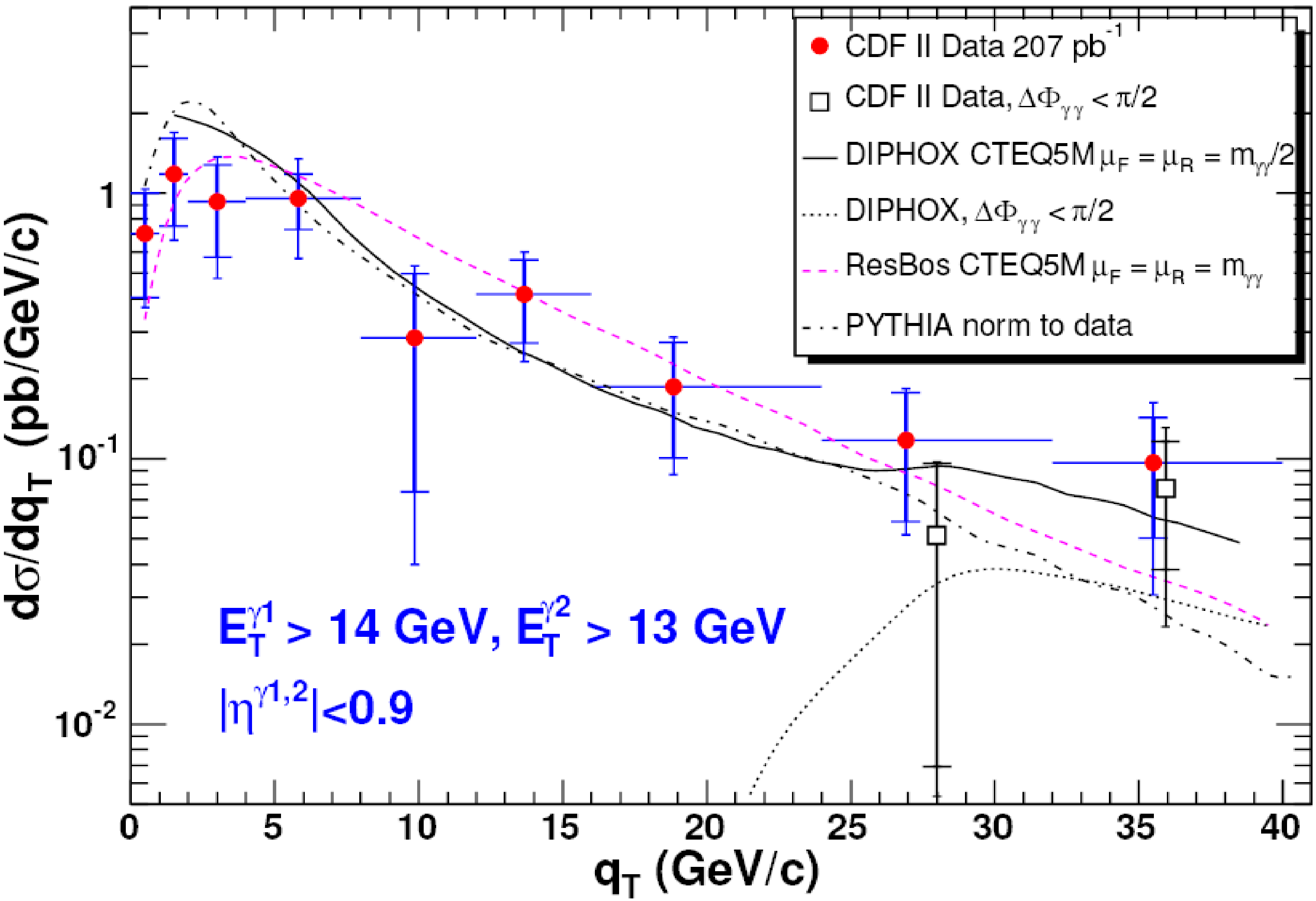
Low x gluon more important at LHC

Results collected in durpdg.dur.ac.uk/HEPDATA

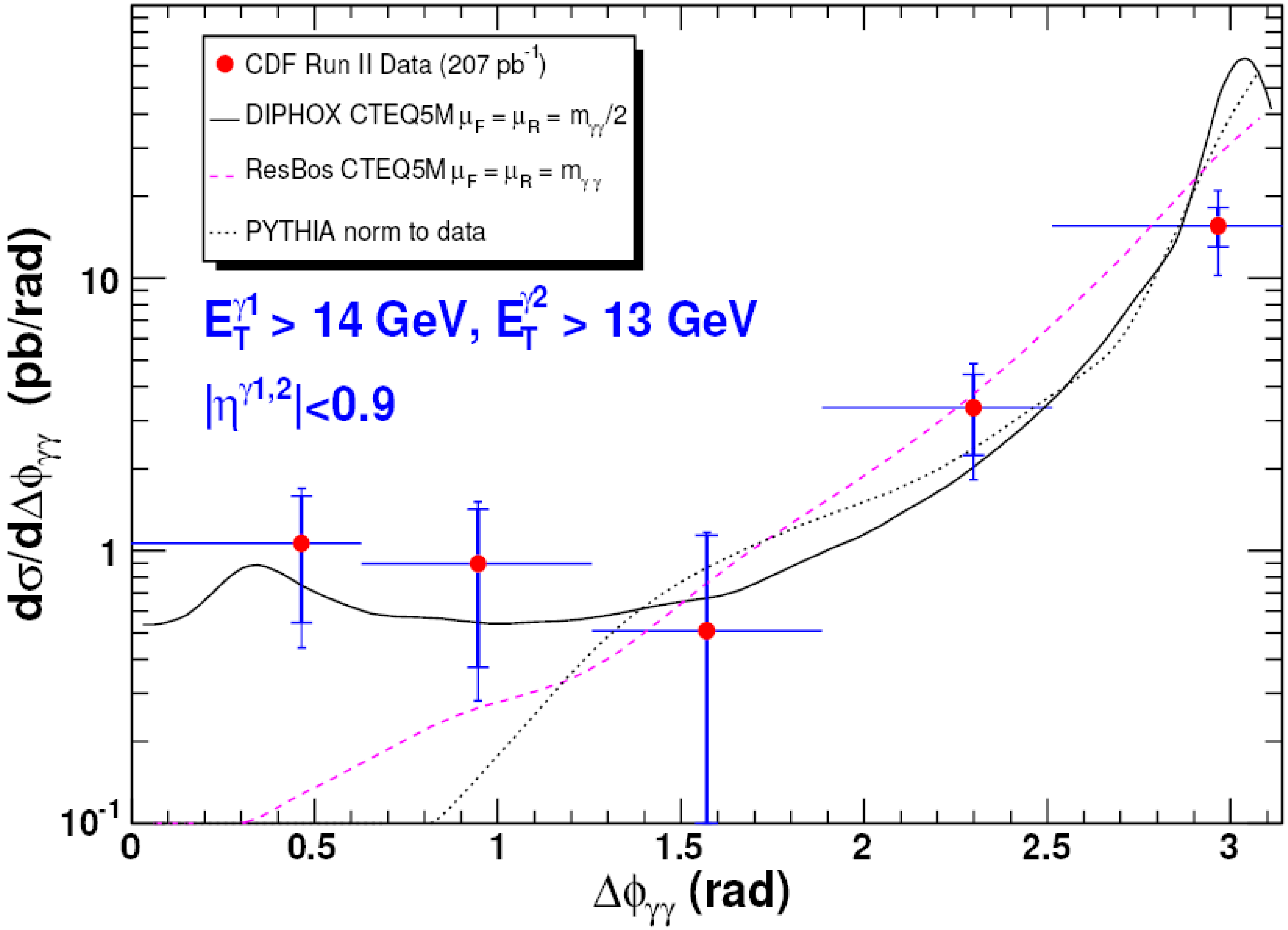



DIPHOX prediction in linear scale (solid), and DIPHOX without gg contribution (dashed).

# Comparisons (diphoton system pT)



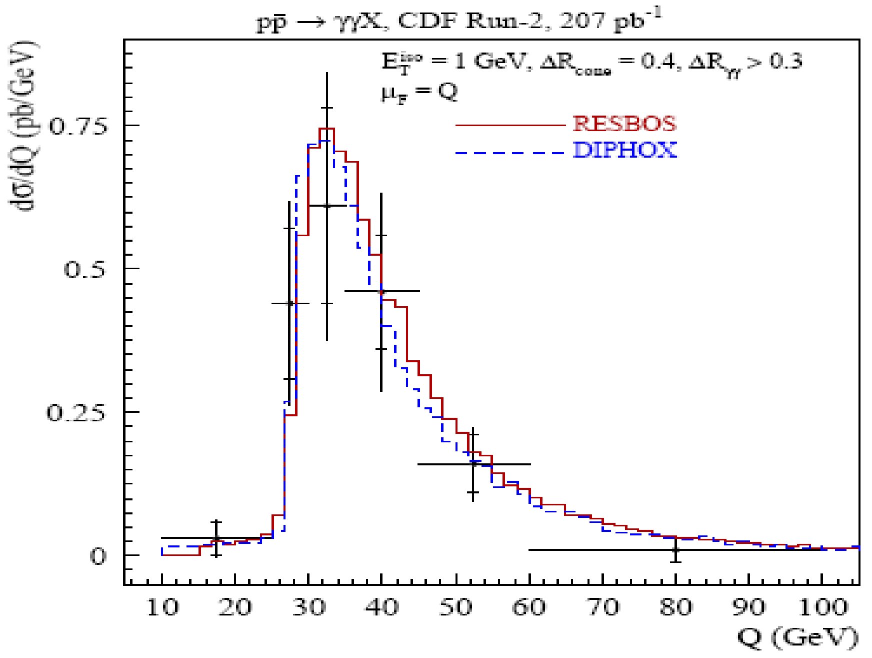
# Comparison (dφ)

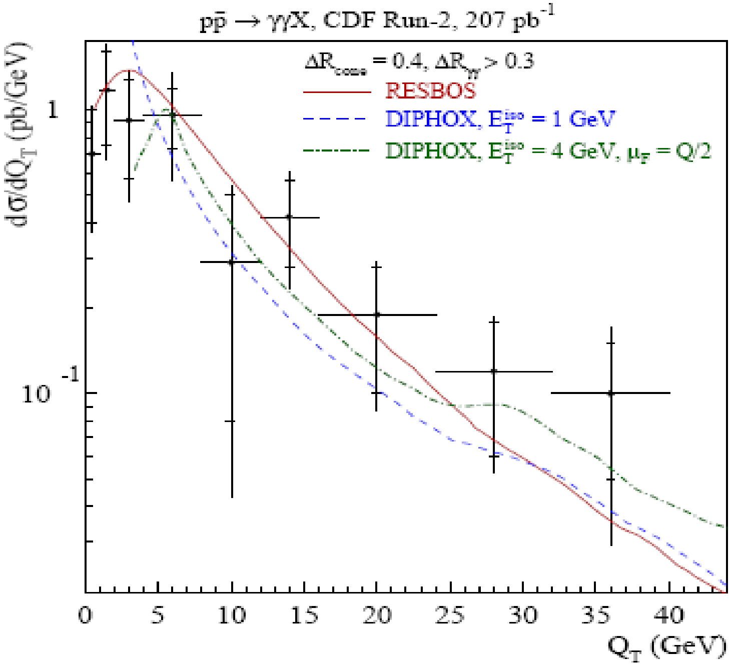


# ResBos 2006

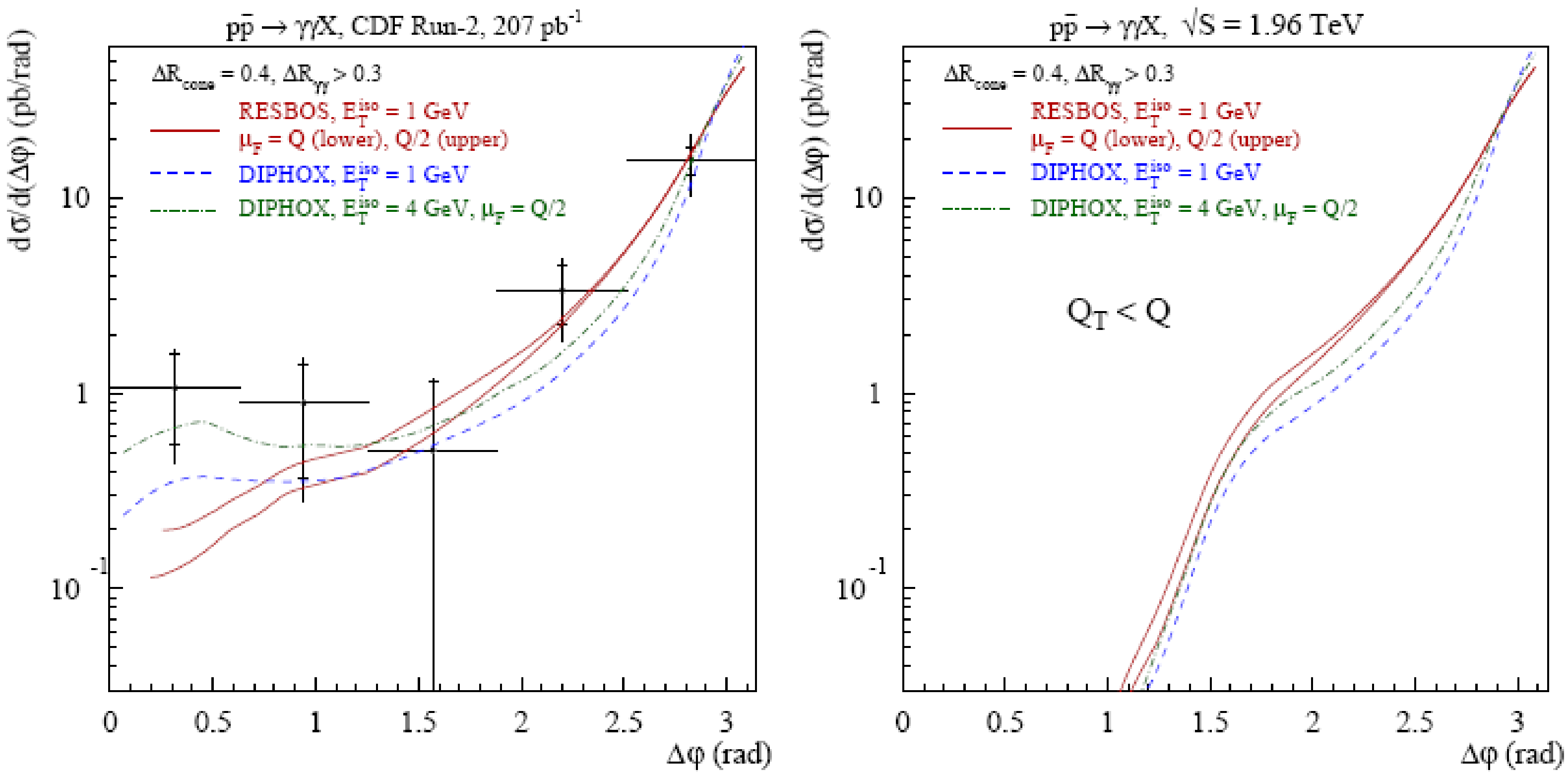
ResBos, now resums to NNLL accuracy and describes the data better. Authors argue the fragmentation contribution is not the unique explanation.

Phys.Lett. B637 (2006) 235-240



# ResBos reliable at qT<Mass




For qT > mass phase space, fragmentation or initial state gluon emission? need to shrink the error bars on data points.

# Conclusion

- Measured 2γ+X production cross section with 207 pb-1 of Tevatron  Run IIa data. Results compared with available theoretic predictions.
- More statistics needed to clear the ambiguity at qT > M.
- Outlook: I'm now at the D0 - expect to shrink the error bars with D0 Run II data.

Those will be  8-9 fb-1 of data!