Di-Photon and Photon+b/c Production Cross Sections at CDF II

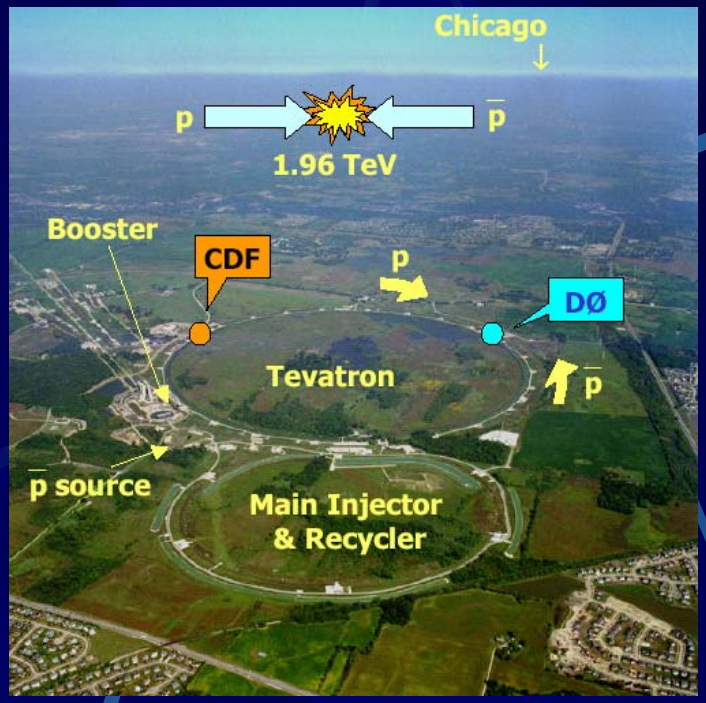
Andrea Bocci

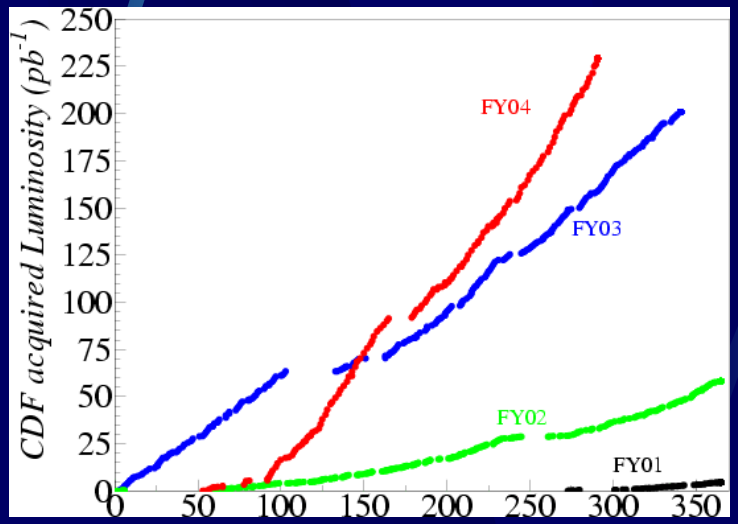
The Rockefeller University, New York, NY

On behalf of the

CDF Collaboration

Hanoi *, August 6 – August 12, 2004*





Tevatron is proton-antiproton collider with

$$\sqrt{s} = 1.96\text{TeV} \quad \text{RunII (1.8TeV RunI)}$$

36 bunches ⇒ 396 ns bunch crossing

Record Luminosity: **1.01×10^{32}**

Number of interactions (@ $L=10^{32}$) ~ 2

Extensive detector and hardware Upgrade for Run II

Total Lum @CDF (2004): **~400/450 pb^{-1}**

Run I (1992-96) ~ 110 pb^{-1}

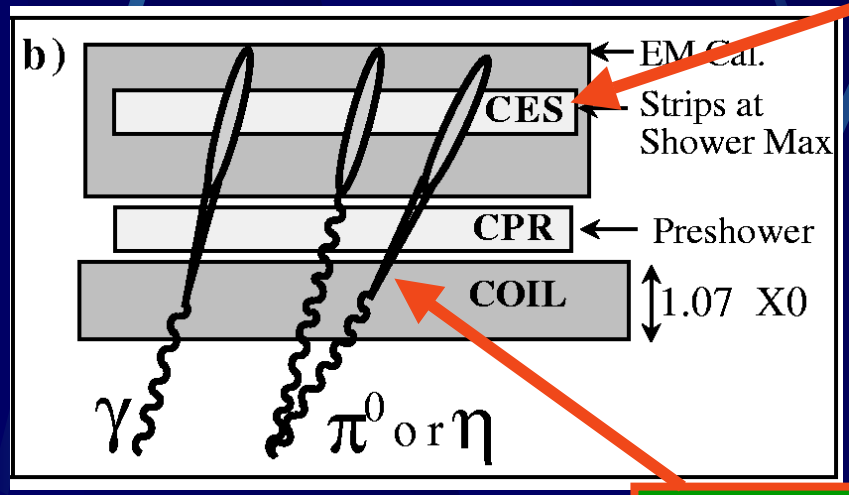
Long term goal (2009): 4-8 fb^{-1}

Diphoton Cross Section Measurement

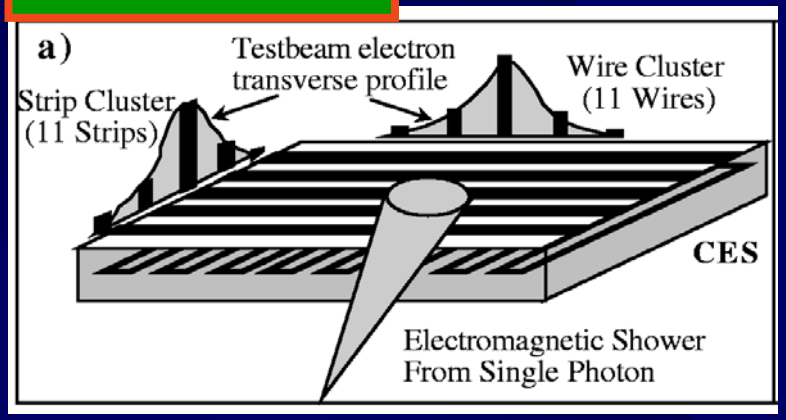
Photon ID

Def: Collimated cluster in the EM calorimeter, no tracks, Very low HAD energy and **isolated** (E_T (0.4) < 1 GeV)

Bkg: Multiple photon decays of mesons ($\pi^0/\eta/K_S$ ...)



Shower Profile

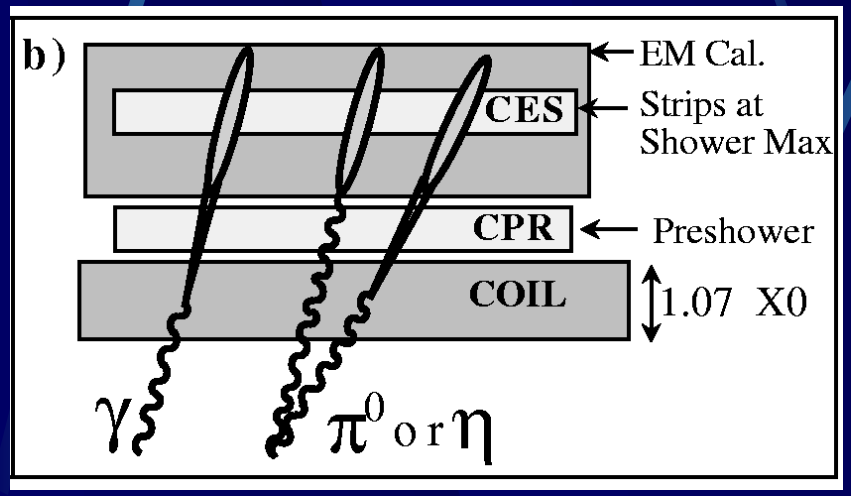


Conversion

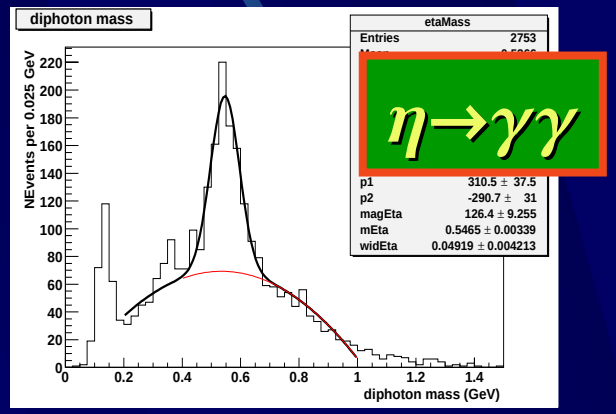
Photon ID

Def: Collimated cluster in the EM calorimeter, no tracks, Very low HAD energy and **isolated** (E_T (0.4) < 1 GeV)

Bkg: Multiple photon decays of mesons ($\pi^0/\eta/K_S$ ...)



Calibration using data



Motivation

Experimentally:

- ✓ Very clean signature
- ✓ Excellent Resolution

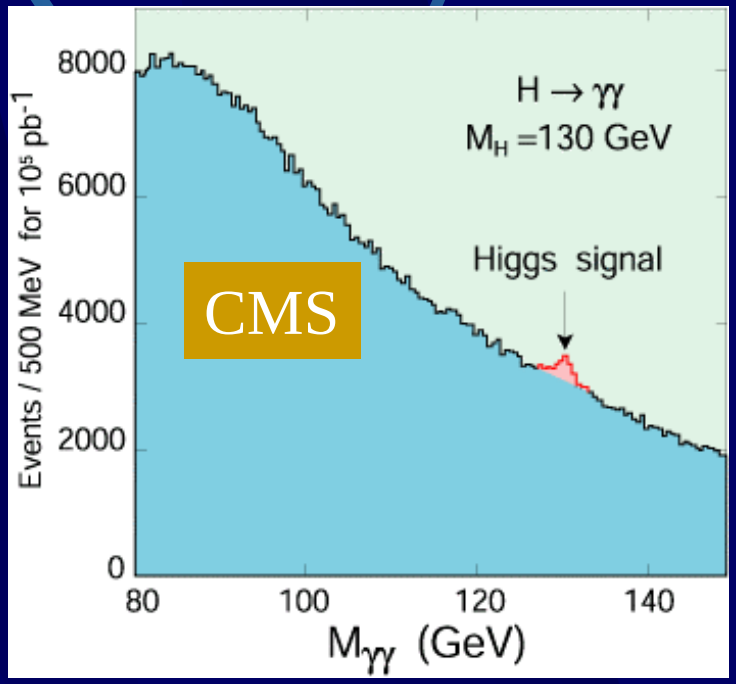
(precision measurement of photons 4-vector)

Theoretically:

- ✓ May infer presence of extra dimension
- ✓ Signature for SUSY particles
- ✓ Sensitive to many aspects of pQCD

(ISR, resummation,…)

Background for $H \rightarrow \gamma\gamma$



Motivation

Experimentally:

- ✓ Very clean signature
- ✓ Excellent Resolution

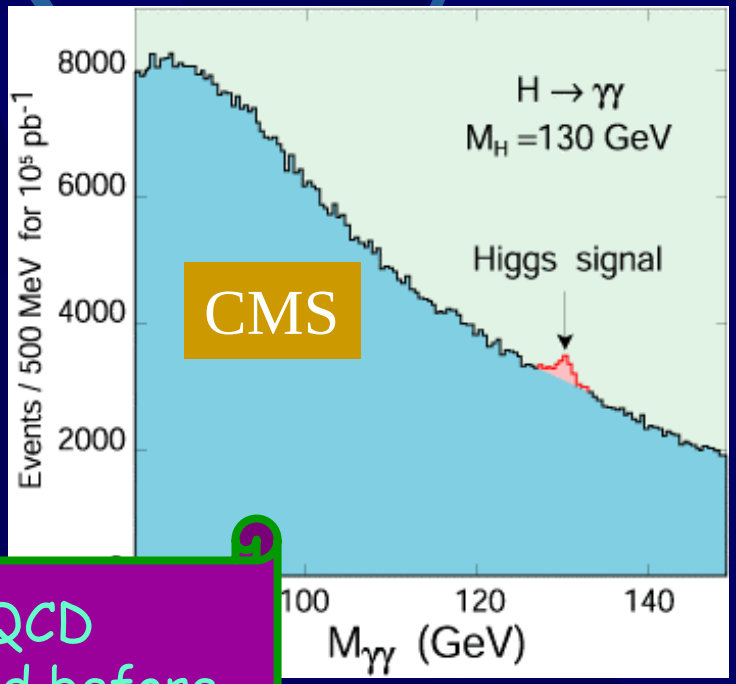
(precision measurement of photons 4-vector)

Theoretically:

- ✓ May infer presence of extra dimension
- ✓ Signature for SUSY particles
- ✓ Sensitive to many aspects of pQCD

(ISR, resummation)

Background for $H \rightarrow \gamma\gamma$



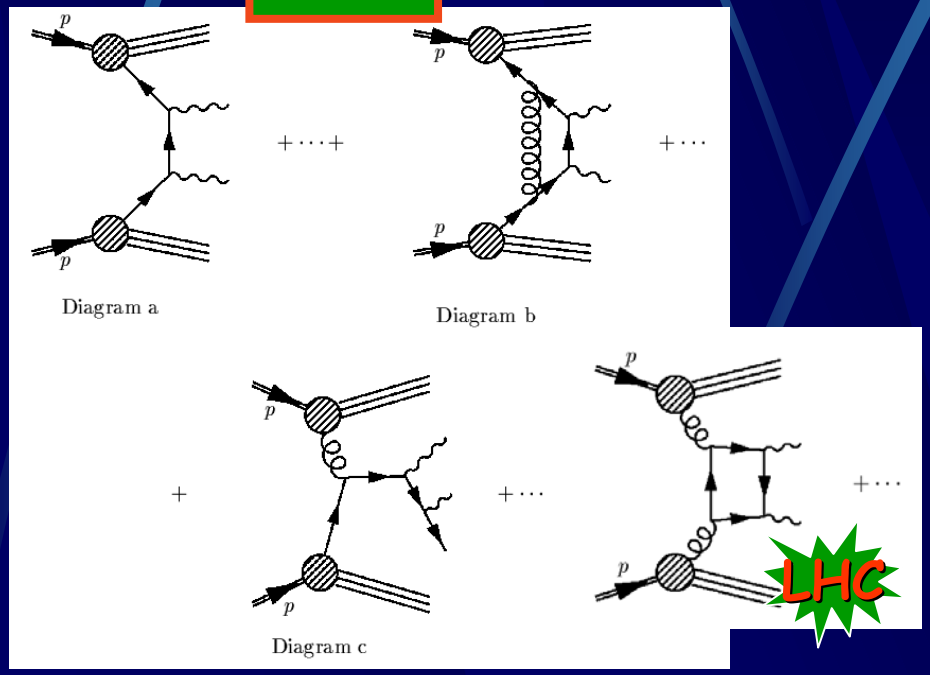
Understand the QCD
$\gamma\gamma$ production is needed before
Any other possible search

Production Mechanism

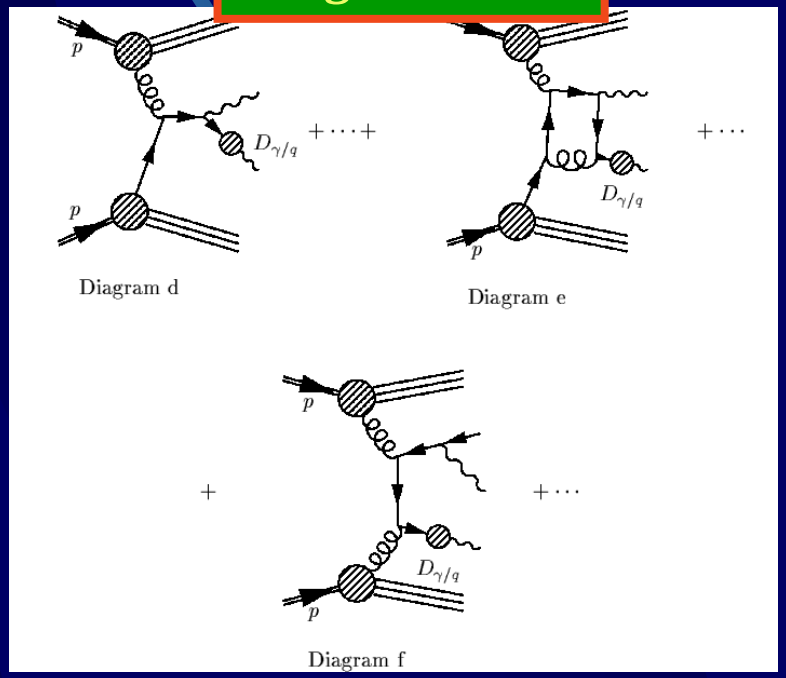
"*Prompt Photon*": <u>not</u> from hadrons decays ($\pi^0/\eta/K_S$ ...)

- **Direct:** Directly from the hard subprocess
- **Fragmentation:** from a collinear fragmentation of a hard parton

Direct



Fragmentation



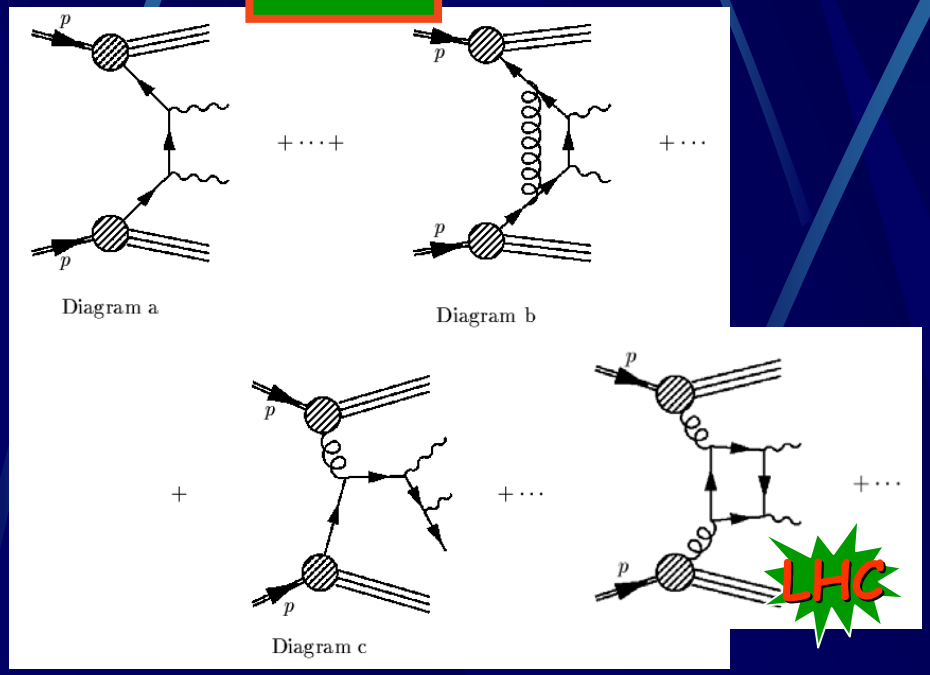
Product… m

"*Prompt Photon*": not … g …)

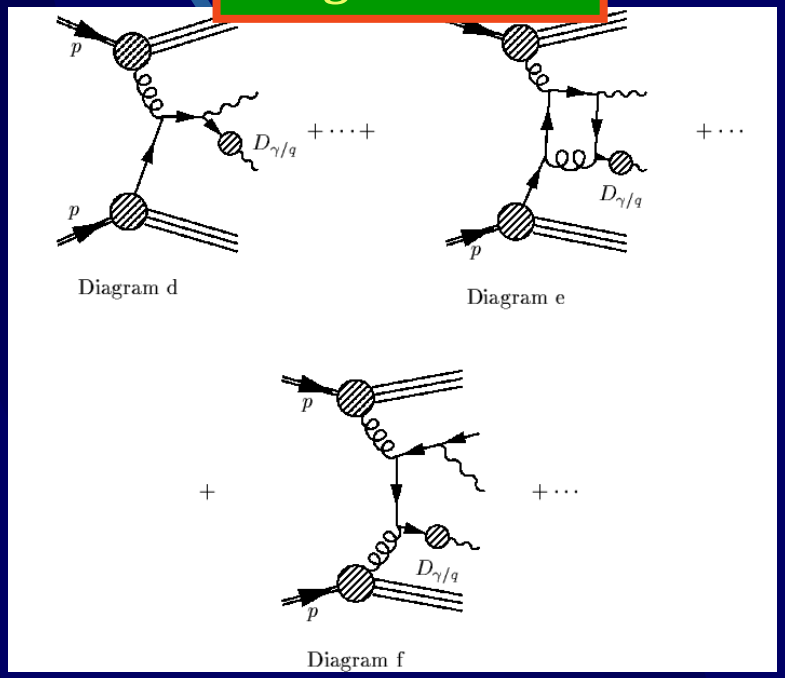
Contributions are absorbed in a $D_{\gamma/q}(z,M_f^{\,2})$ ⇒ ambiguous distinction. Only the sum is meaningful (not depending on M_f)

- **Direct:** Directly from the hard subprocess
- **Fragmentation:** from a collinear fragmentation of a hard parton

Direct



Fragmentation



Production Mechanism

"*Prompt Photon*": not from hadrons decays ($\pi^0/\eta/K_S$ ...)

- **Direct:** Directly from the hard subprocess
- **Fragmentation:** from a collinear fragmentation of a hard parton

DIPHOX	ResBos
✓ Fixed QCD NLO calculation for both Direct and Fragmentation mechanism ✓ No Resummation for initial and final gluon radiation	✓ QCD NLO calculation for direct and LO for the other subprocess ✓ Resummation of soft gluon emissions to all orders

Outline of the Analysis

Trigger: 2 EM Cluster with E_T>12 GeV

Data: 207 pb^{-1} (Feb 2002 – Sep 2003)

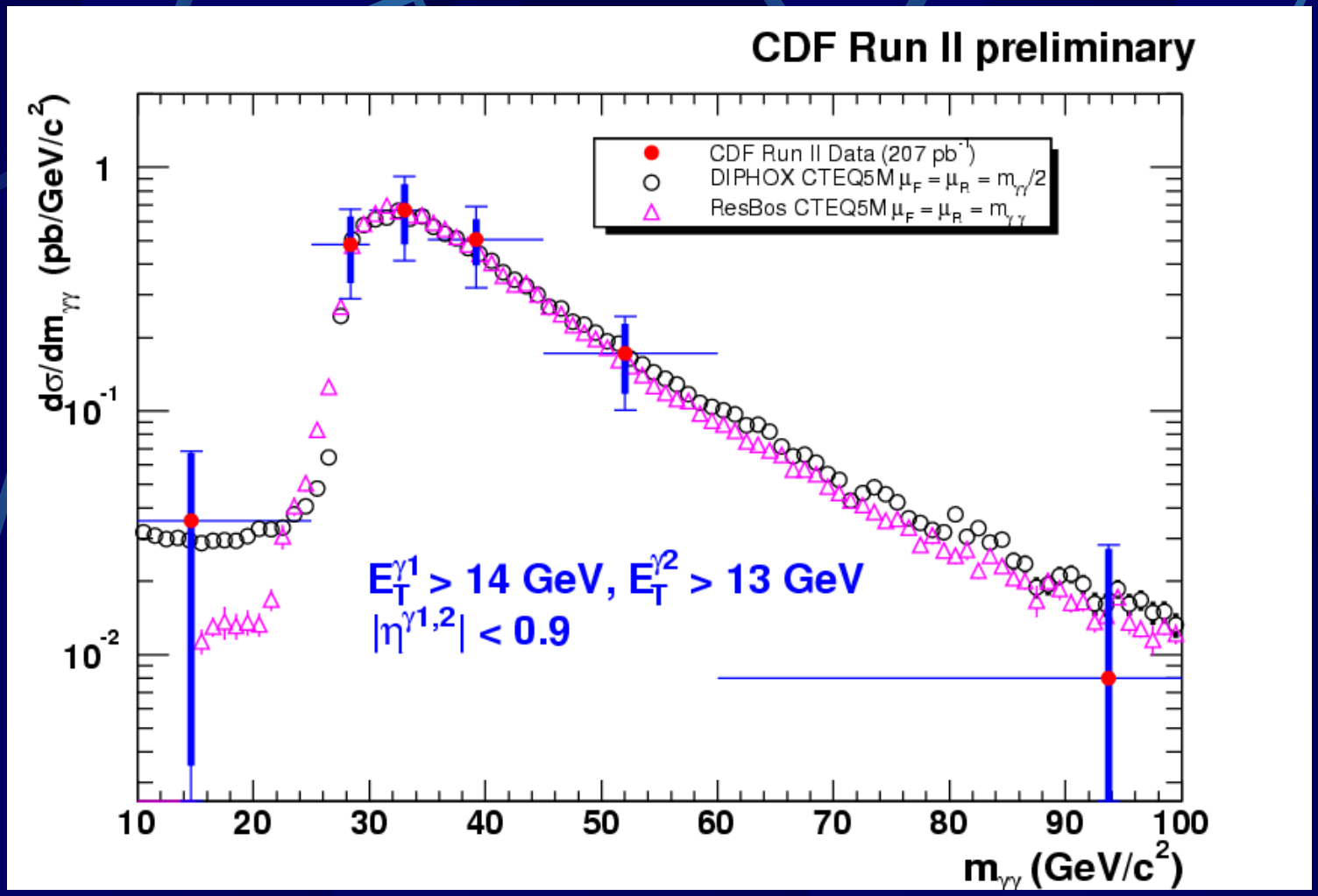
Offline Cuts:

- ✓ Photon ID
- ✓ Isolation : E_T (cone 0.4) < 1 GeV
- ✓ $E^{\gamma 1}_T$>14 GeV and $E^{\gamma 2}_T$>13 GeV
- ✓ $|\eta^{\gamma}|$ < 0.9 (Central Calorimeter)

Outcome:

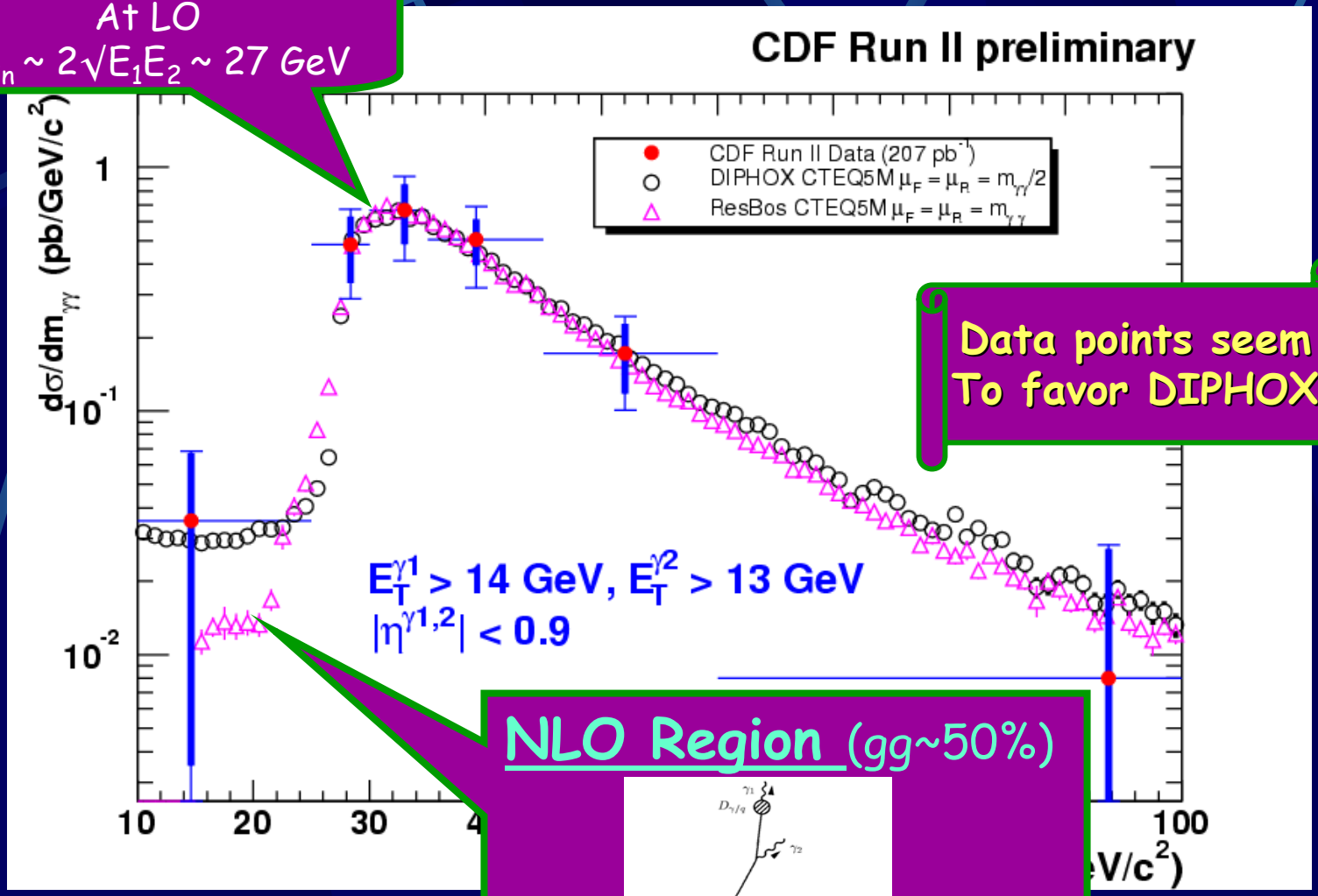
- ❑ Total Efficiency: 14% (Most due to fiducial cuts)
- ❑ Number of Candidates: **893**
- ❑ Number of "prompt" photons: **426 ± 58**

Mass Distribution



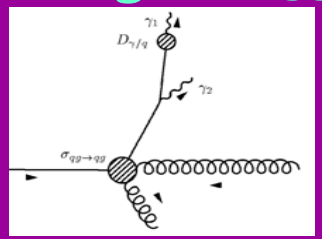
Mass Distribution

At LO
$m_{min} \sim 2\sqrt{E_1 E_2} \sim 27$ GeV

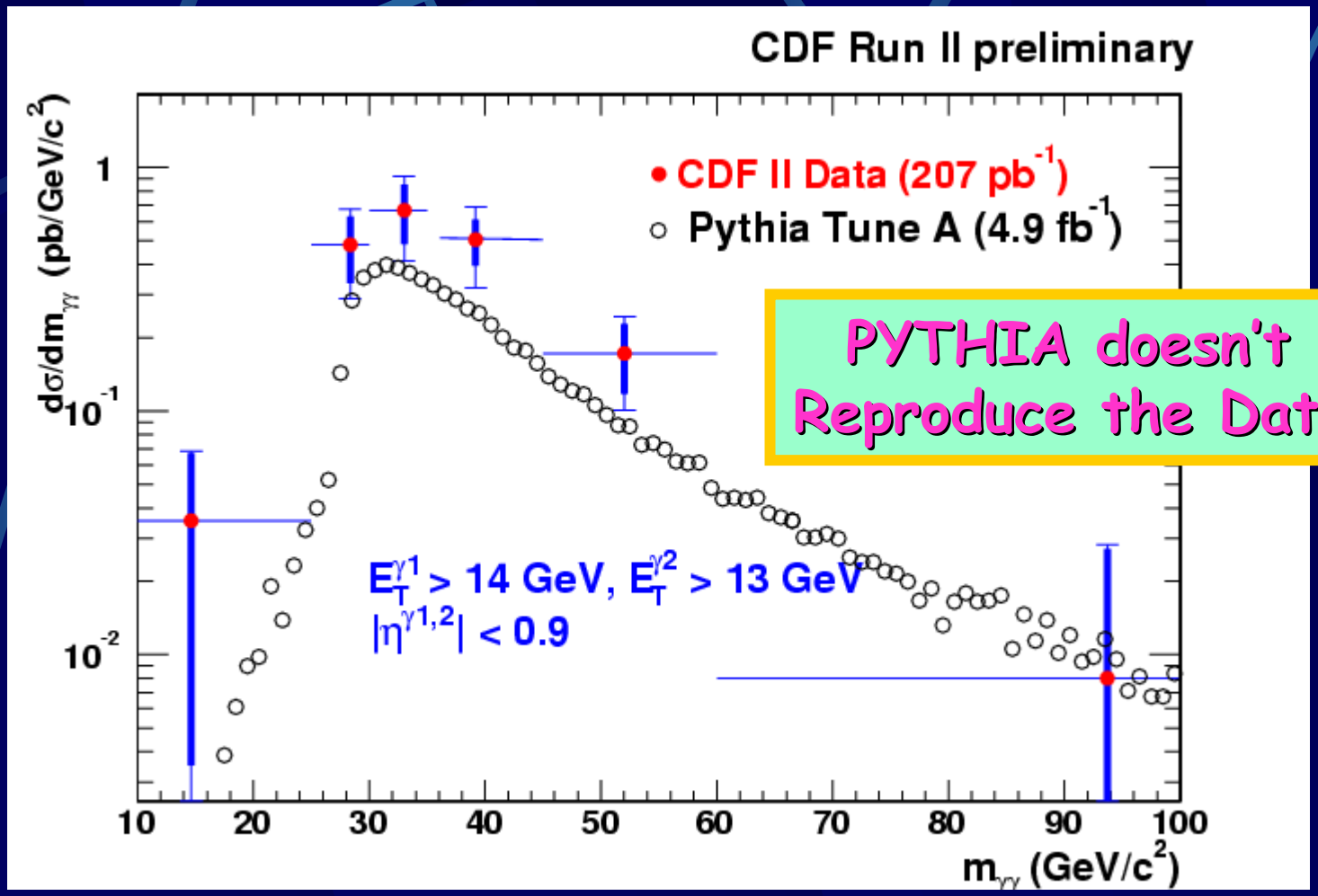


Data points seem
To favor DIPHOX

NLO Region (gg~50%)



Mass Distribution

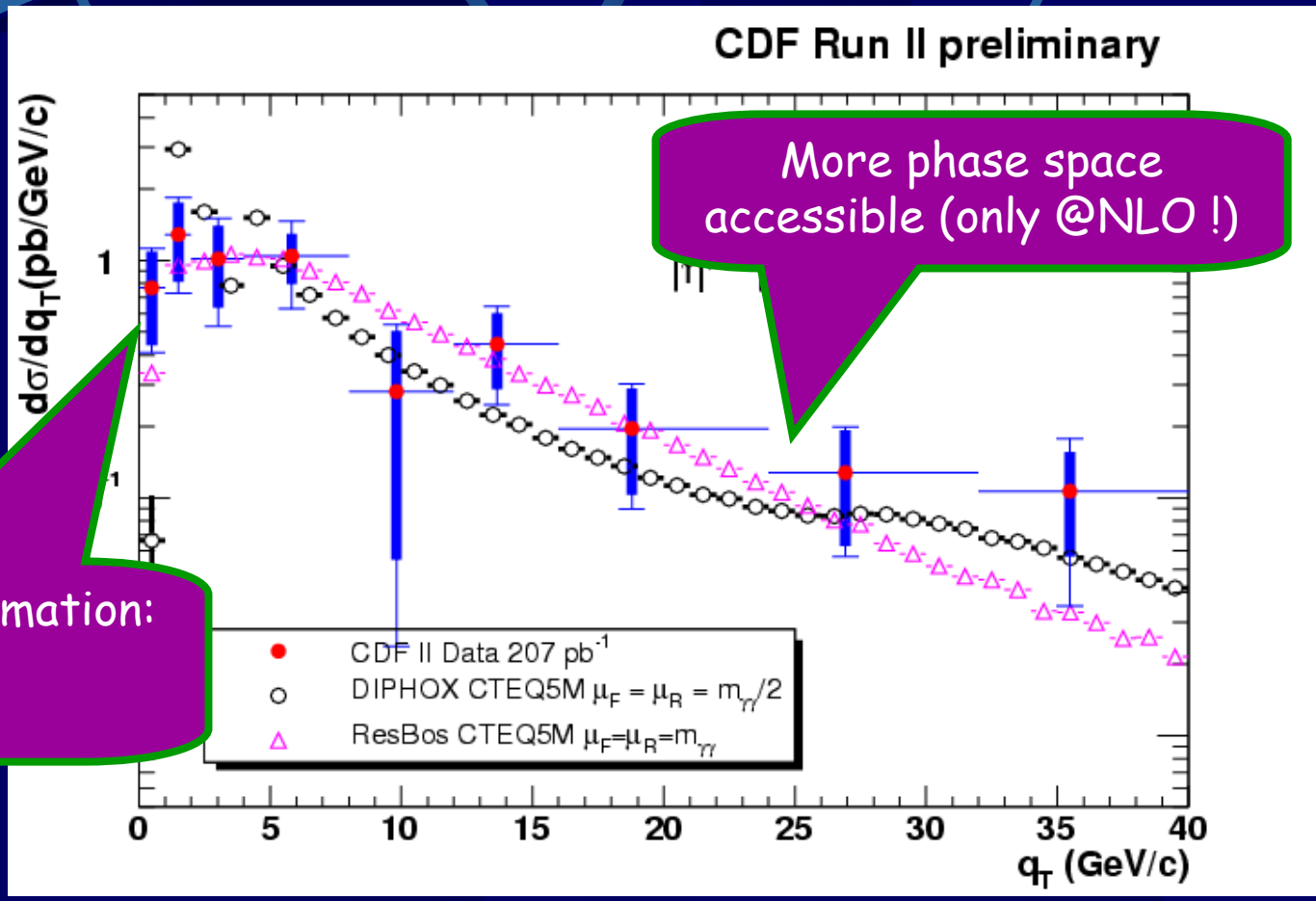


PYTHIA doesn't Reproduce the Data

q_T Distribution

$$\vec{q}_T = \vec{P}_T^{\gamma 1} + \vec{P}_T^{\gamma 2}$$

$$\vec{q}_T = -\sum_{rest} \vec{P}_T$$

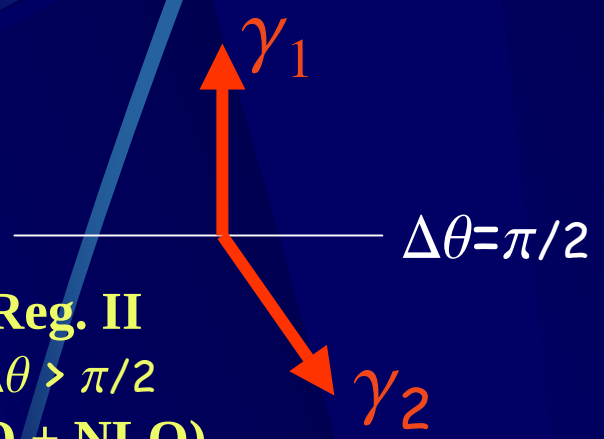


More phase space accessible (only @NLO !)

Effect of gluon Resummation:
⇒ DIPHOX unstable
⇒ ResBos smooth

q_T Distribution

$$\vec{q}_T = \vec{P}_T^{\gamma_1} + \vec{P}_T^{\gamma_2}$$

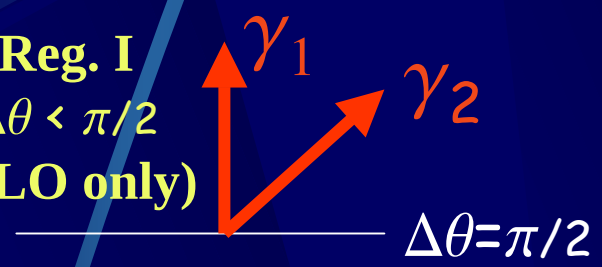


Reg. II
$\Delta\theta > \pi/2$
(LO + NLO)

q_T Distribution

$$\vec{q}_T = \vec{P}_T^{\gamma_1} + \vec{P}_T^{\gamma_2}$$

Reg. I
$\Delta\theta < \pi/2$
(NLO only)



Reg. II
$\Delta\theta > \pi/2$
(LO + NLO)

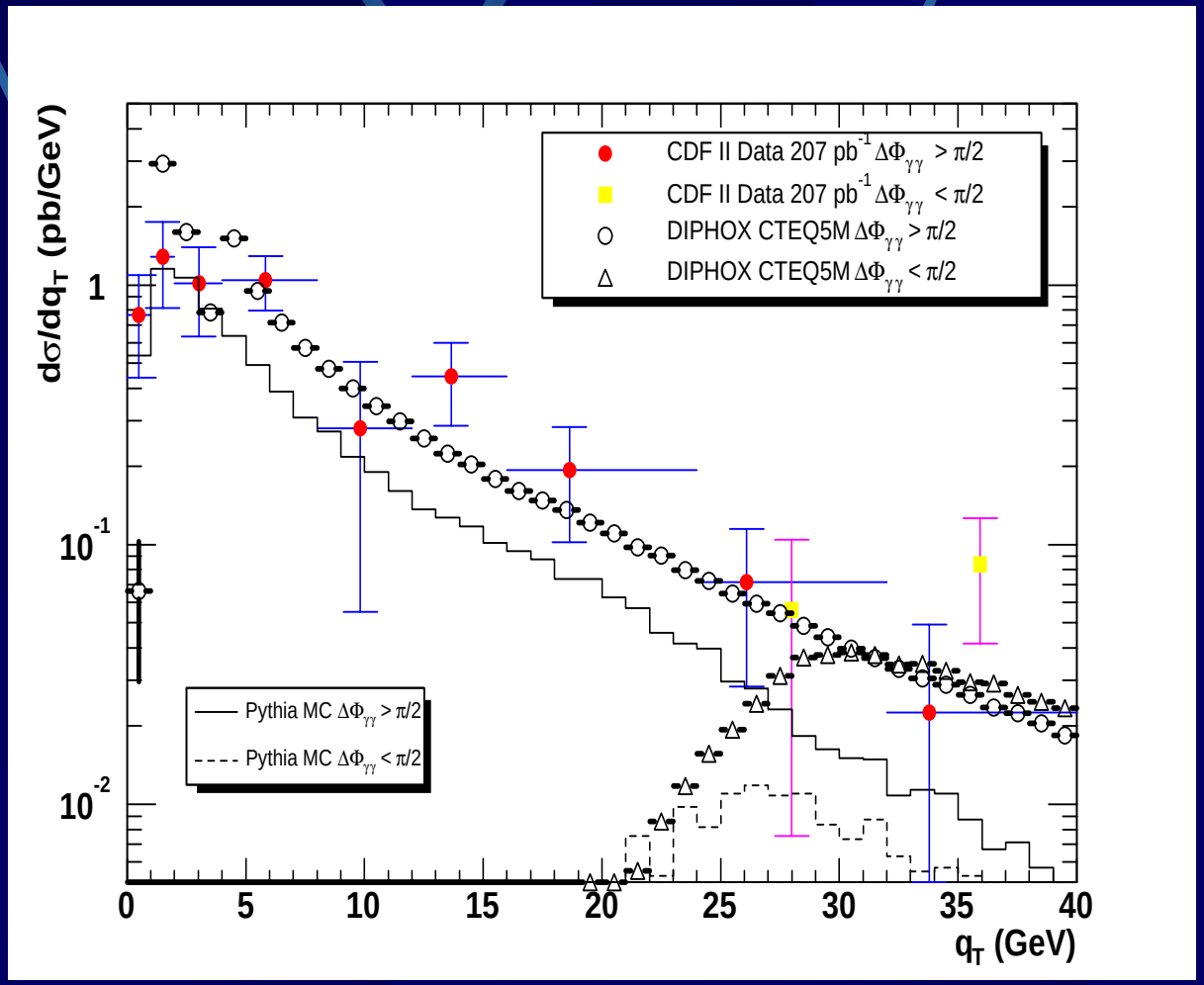
q_T Distribution

$$\vec{q}_T = \vec{P}_T^{\gamma 1} + \vec{P}_T^{\gamma 2}$$

Reg. I
$\Delta\theta < \pi/2$
(NLO only)

$\Delta\theta = \pi/2$

Reg. II
$\Delta\theta > \pi/2$
(LO + NLO)



q_T Distribution

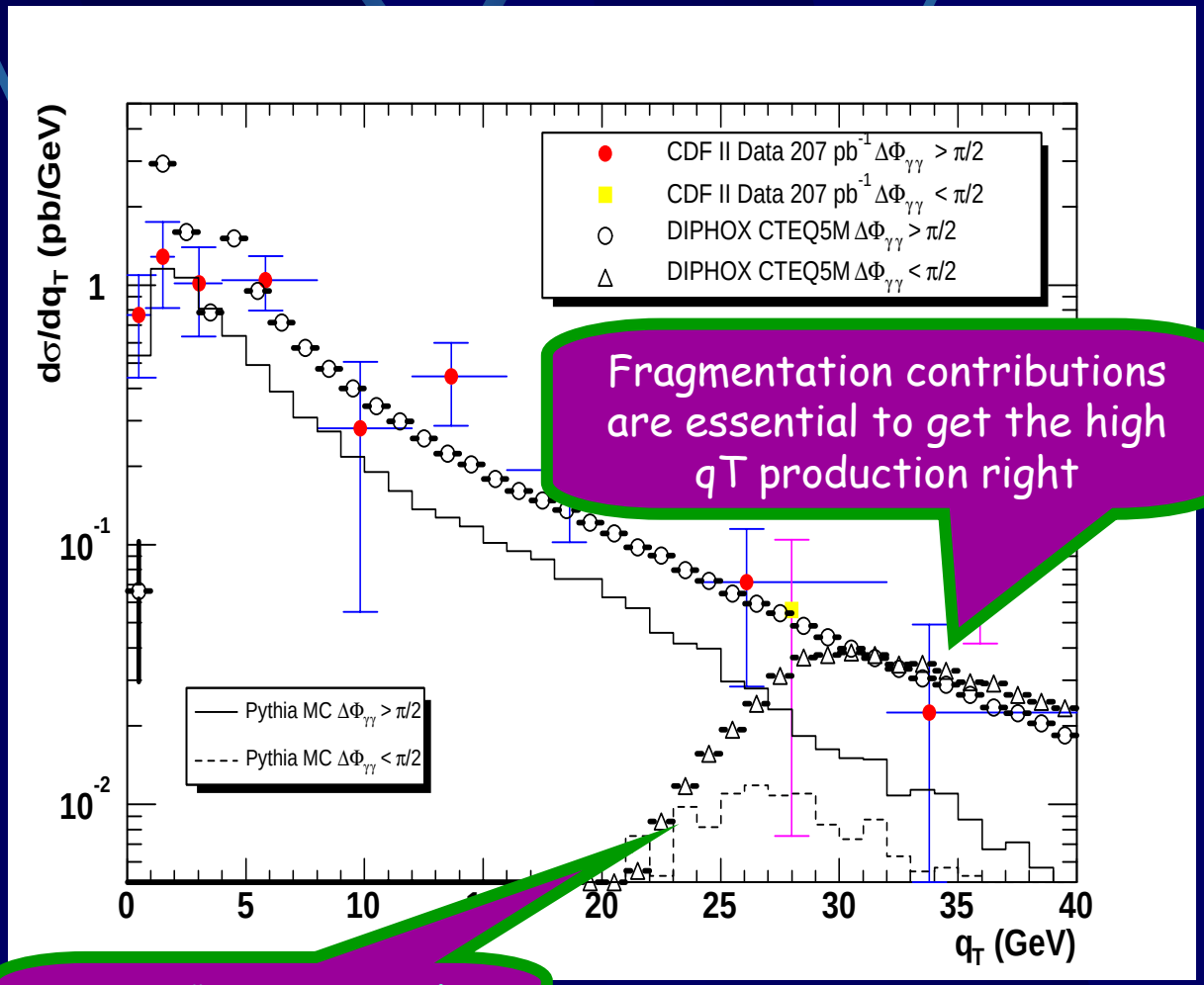
$$\vec{q}_T = \vec{P}_T^{\gamma 1} + \vec{P}_T^{\gamma 2}$$

Reg. I
$\Delta\theta < \pi/2$
(NLO only)

$\Delta\theta = \pi/2$

Reg. II
$\Delta\theta > \pi/2$
(LO + NLO)

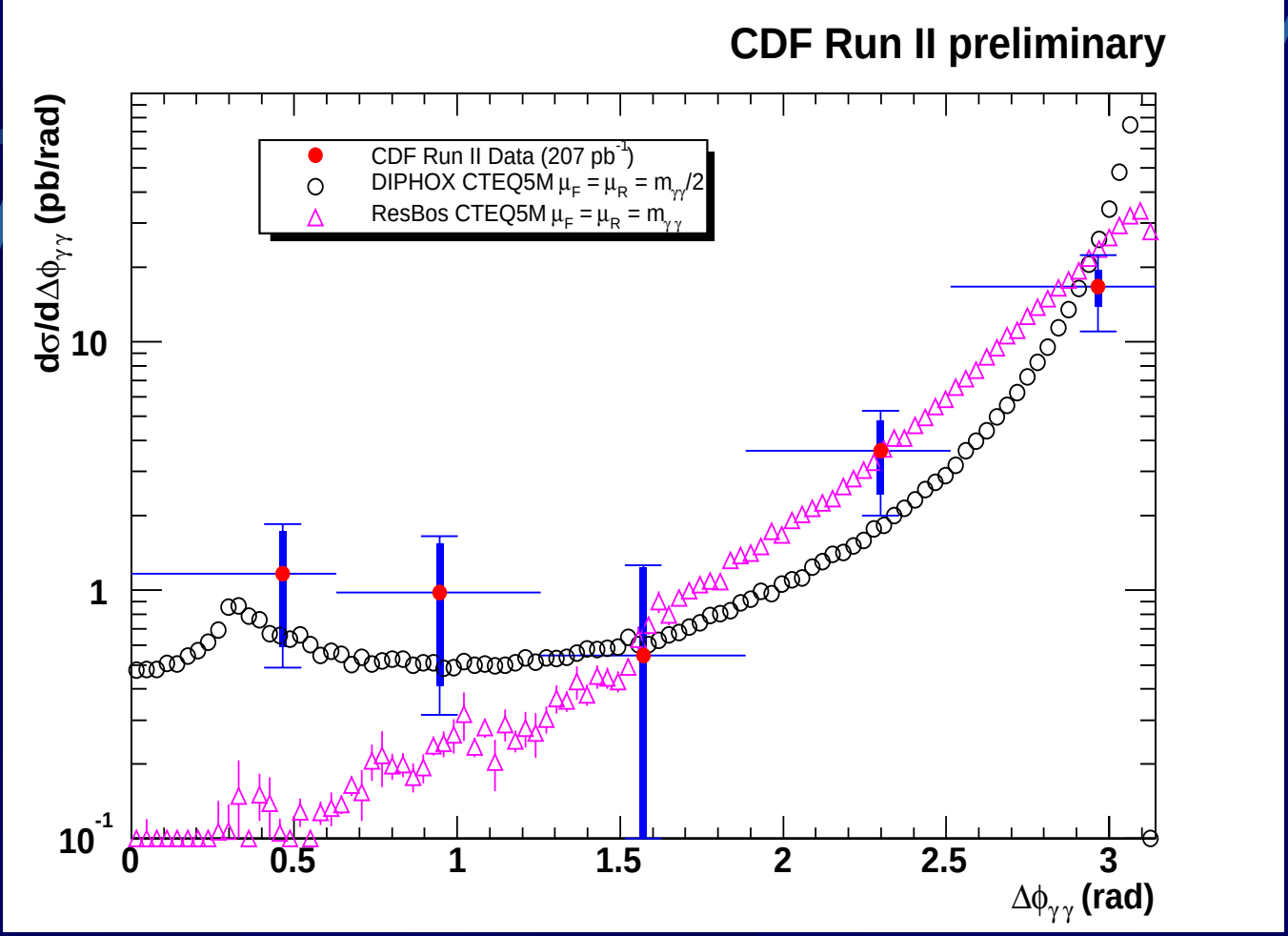
Note: Fragmentation Contribution sensitive to the isolation cut.



Fragmentation contributions are essential to get the high qT production right

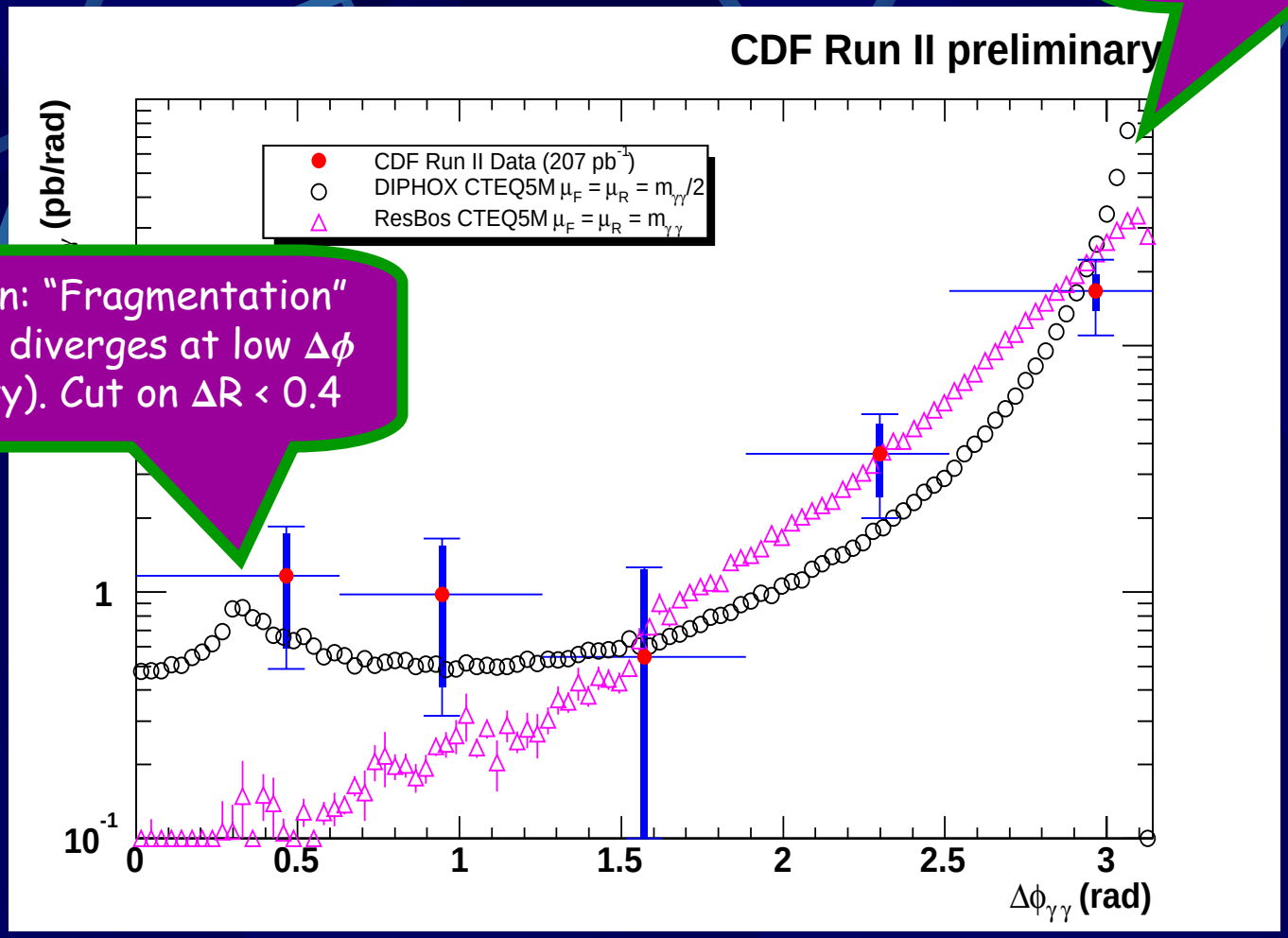
Reg I "*turn on*" only
For $q_T > q_{Tmin}$~20 GeV

$\Delta\phi$ Distribution



$\Delta\phi$ Distribution

Soft Gluon resummation effect

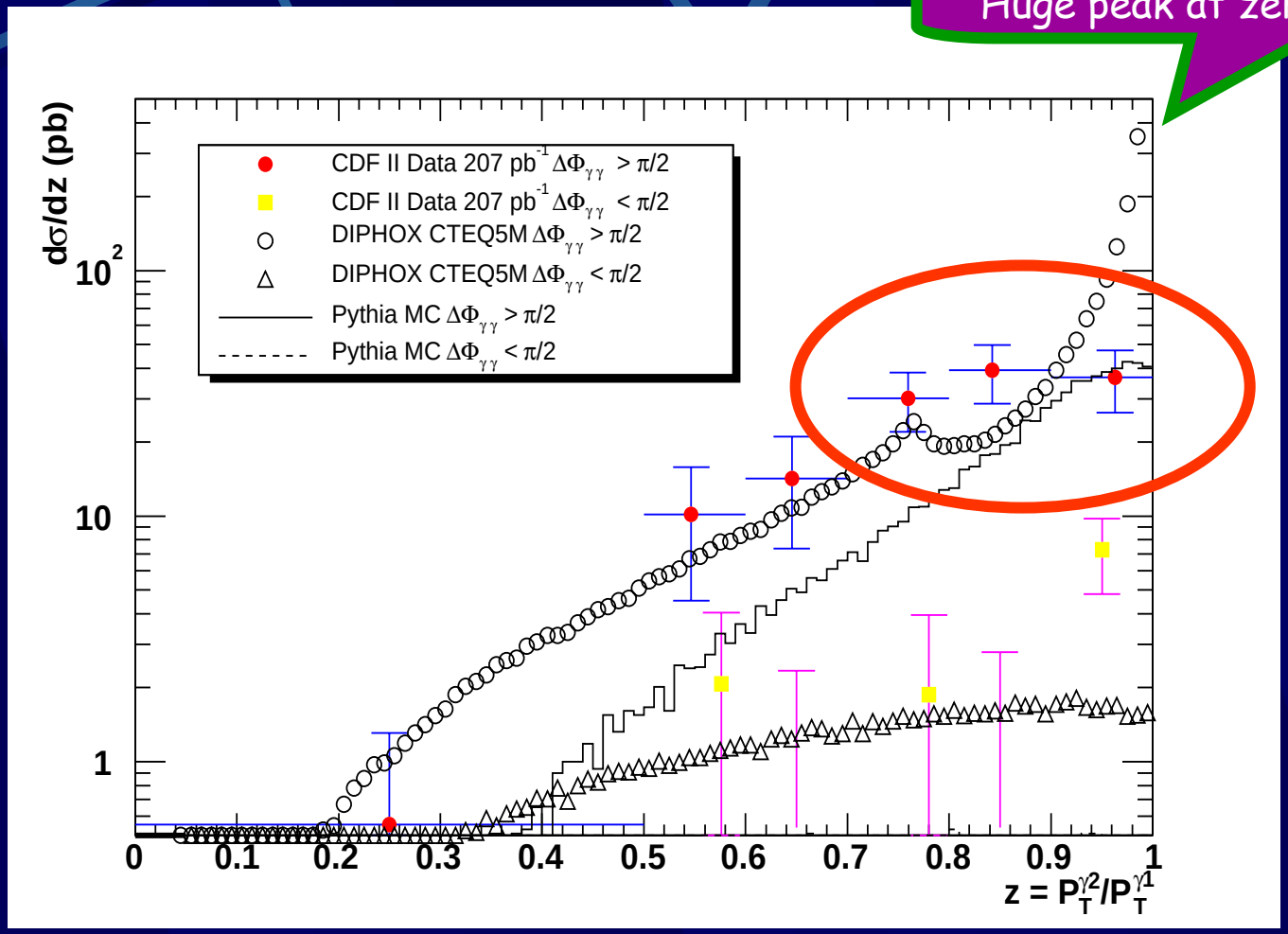


NLO Region: "Fragmentation" component diverges at low $\Delta\phi$ (collinearity). Cut on $\Delta R < 0.4$

Z Distribution

$$z = \frac{\vec{P}_T^{\gamma 1}}{\vec{P}_T^{\gamma 2}}$$

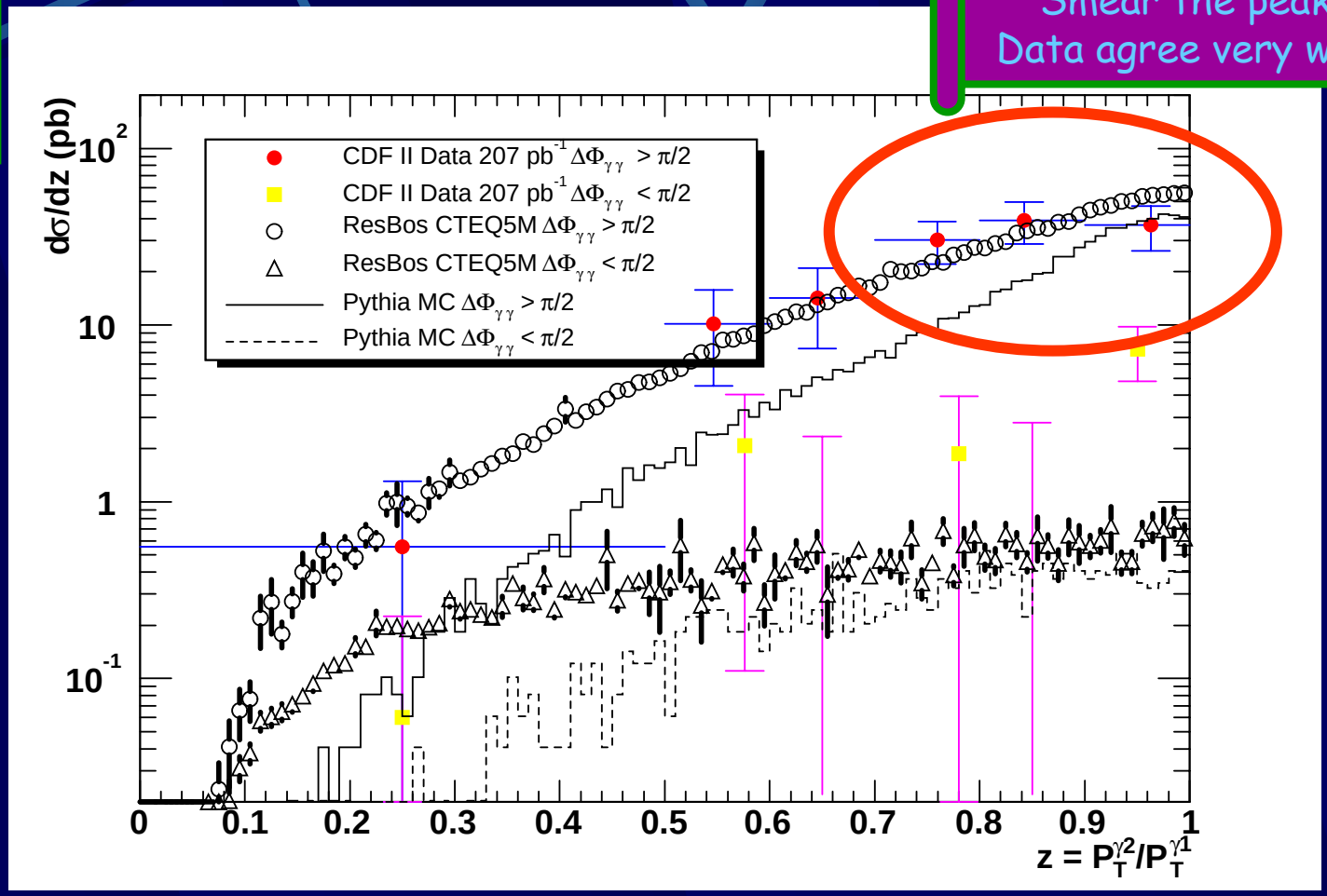
Huge peak at zero



Z Distribution

$$z = \frac{\vec{P}_T^{\gamma 1}}{\vec{P}_T^{\gamma 2}}$$

Including resummation
Smear the peak
Data agree very well



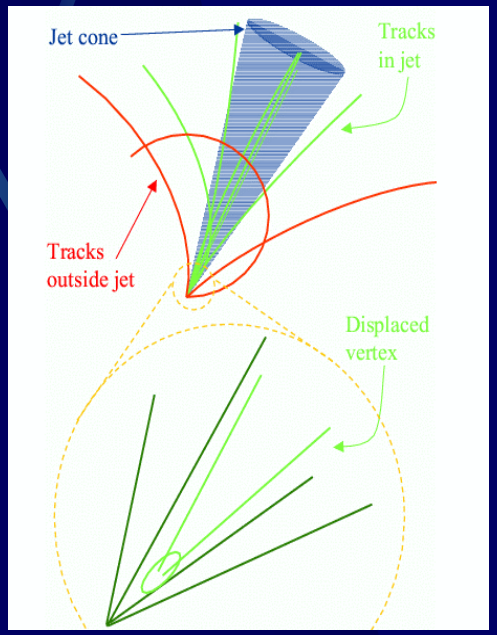
γ + b/c Cross Section Measurement

Motivation

Signature: "Prompt Photon" + heavy flavor jet

- Test of QCD flavor production
- New physics (light stop, techniomega)

Heavy flavor jet identified with The Silicon Vertex Detector (b-tagging)



Search for a secondary vertex
Inside the jet

Outline of the Analysis

Trigger: High P_T photon (E_T > 25 GeV)

Data: 66.7 pb^{-1} (Feb 2002 – Jan 2003)

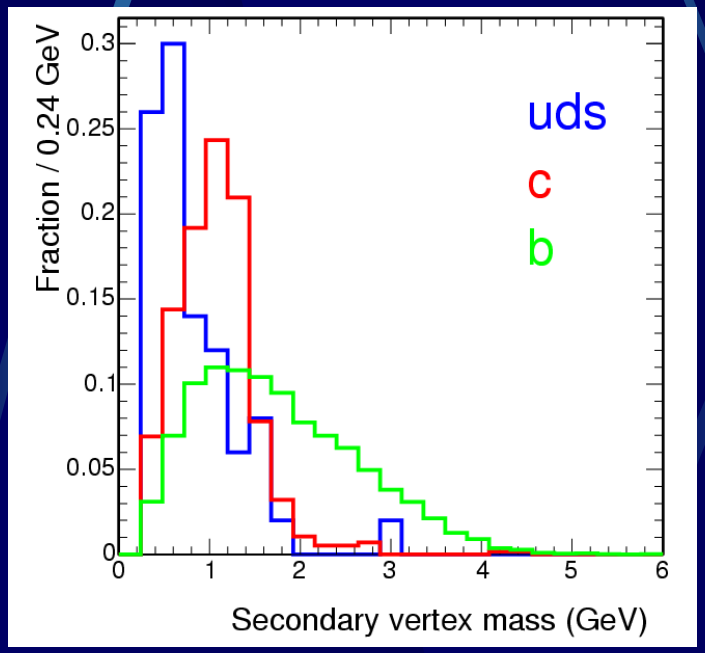
- Photon ID cuts
- At least 1 jet with >1 tracks
- "*b-tagged*" jet only

B/c separation using secondary vertex mass method

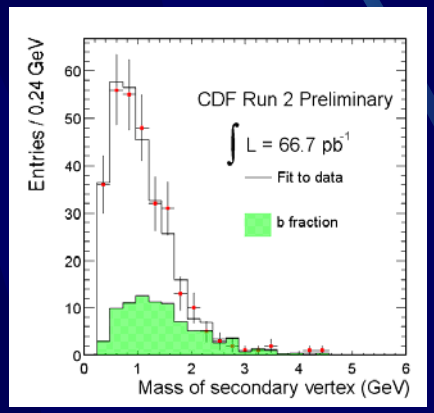
Outline of the Analysis

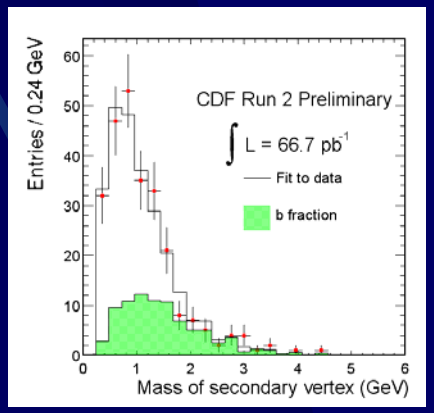
B/c separation using secondary vertex mass method

Invariant mass of tracks associated with secondary vertex from MC

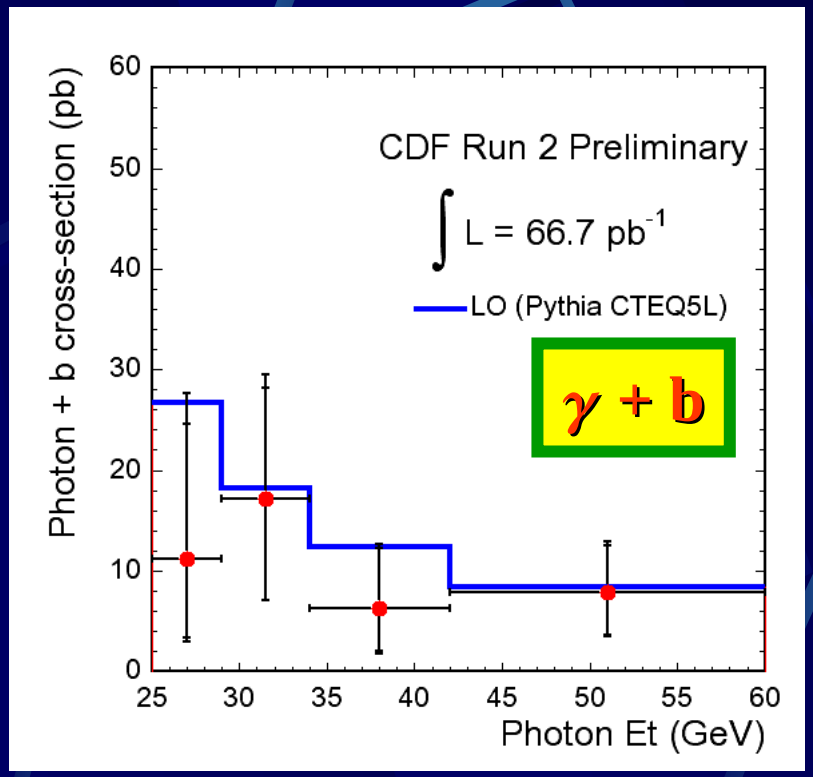


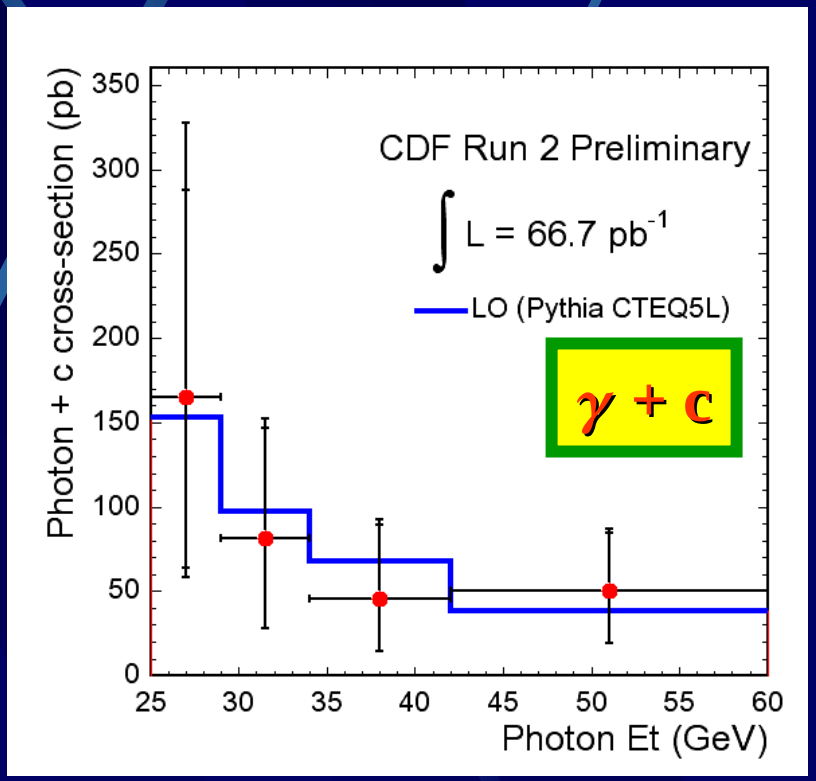
Fit the mass distribution for Different bin in photon E_T





γ + b/c Production

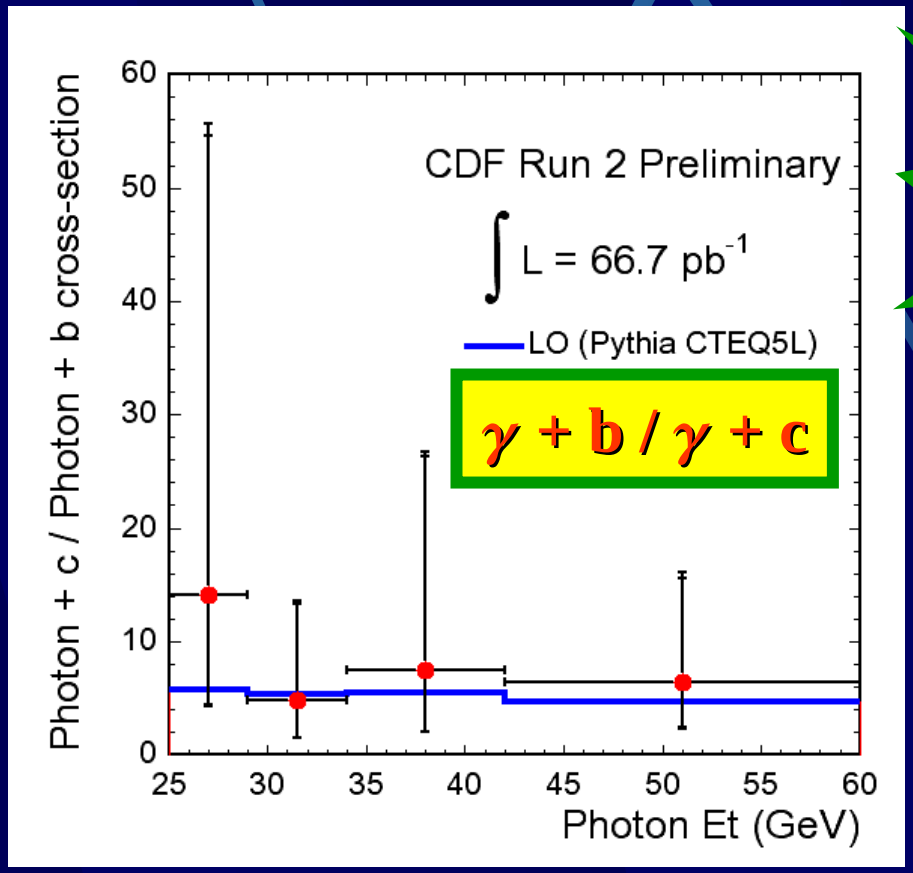




Main sources of systematic: b/c-tag, jet scale, trigger eff.

γ + b/c Production

In the ratio $\sigma(\gamma+b)/\sigma(\gamma+c)$ only tagging systematic counts



Statistical Errors Dominate

Summary

Photon physics program at CDF in very good shape !

Diphoton Production:

- Data agree with NLO QCD calculation
- Feedback with theorists to tune the MC generators
- **Both soft gluon resummation and fragmentation production Needed to reproduce the data distributions**

Photon+heavy flavor Production:

- Exploit the excellent CDF capability for photon ID and heavy flavor tag
- Measurement still statistical dominated (x2.5 at the end of August)
- **New updated analysis and exotics limits very soon**