QCD Physics With Photons

Quark-to-Photon Fragmentation at LEP

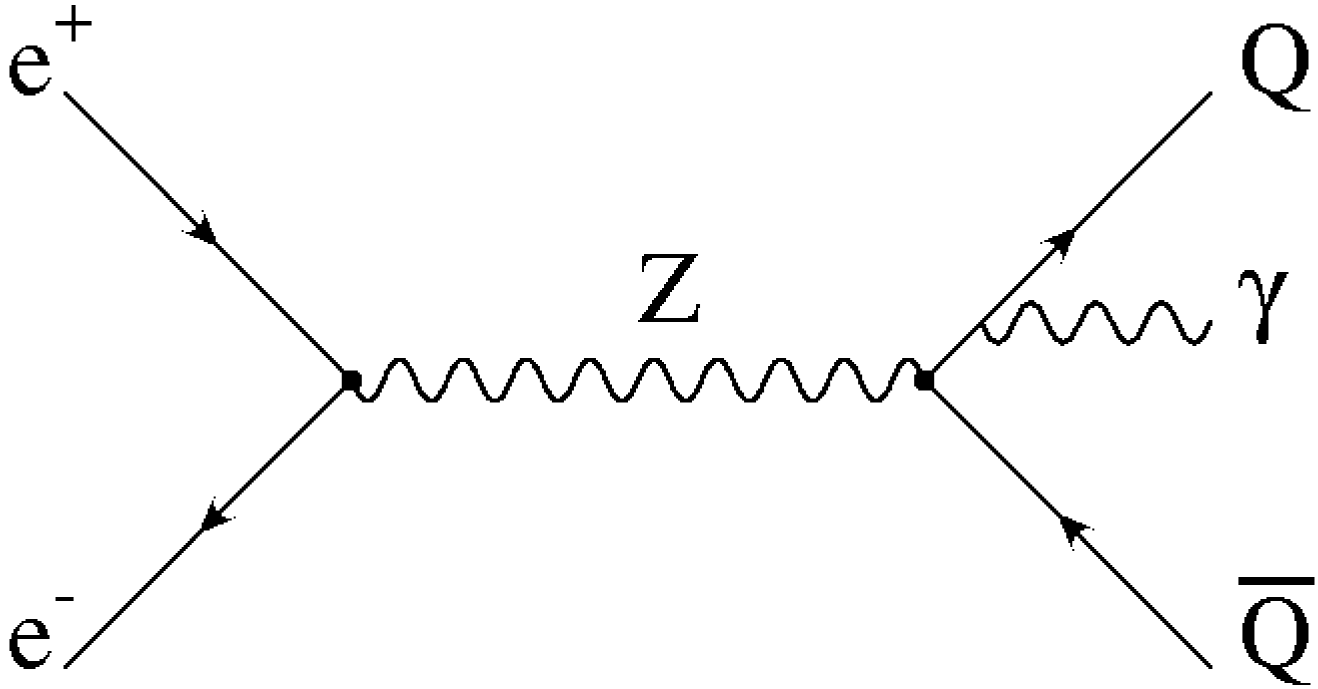
Photon+Jet Angles in Hadronic Production

Photon Vertex sensitive to Electric Charge

Photon Production at HERA

Cross Sections in Hadron Collisions

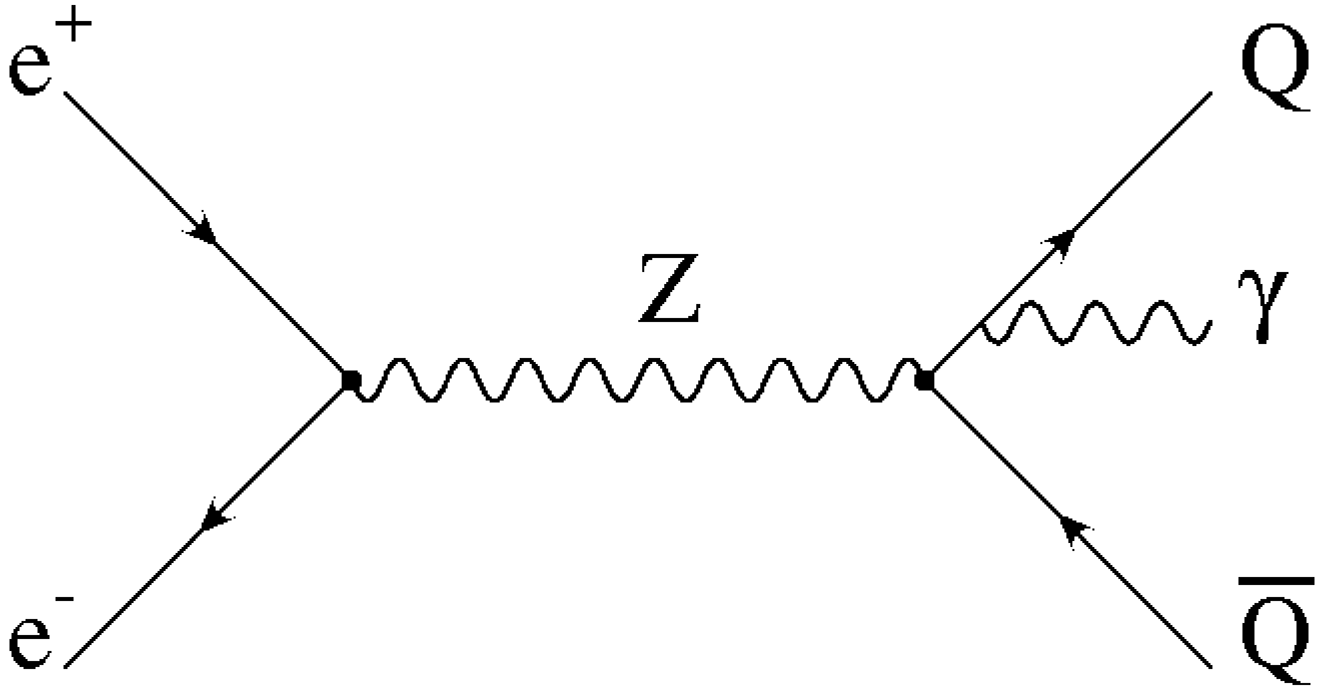
Quark-to-Photon Fragmentation at LEP



<u>Semantics:</u>

This diagram generally called
"Hard *Bremsstrahlung*" or
"Hard Photon Radiation" or
"Large-Angle Photon Radiation"

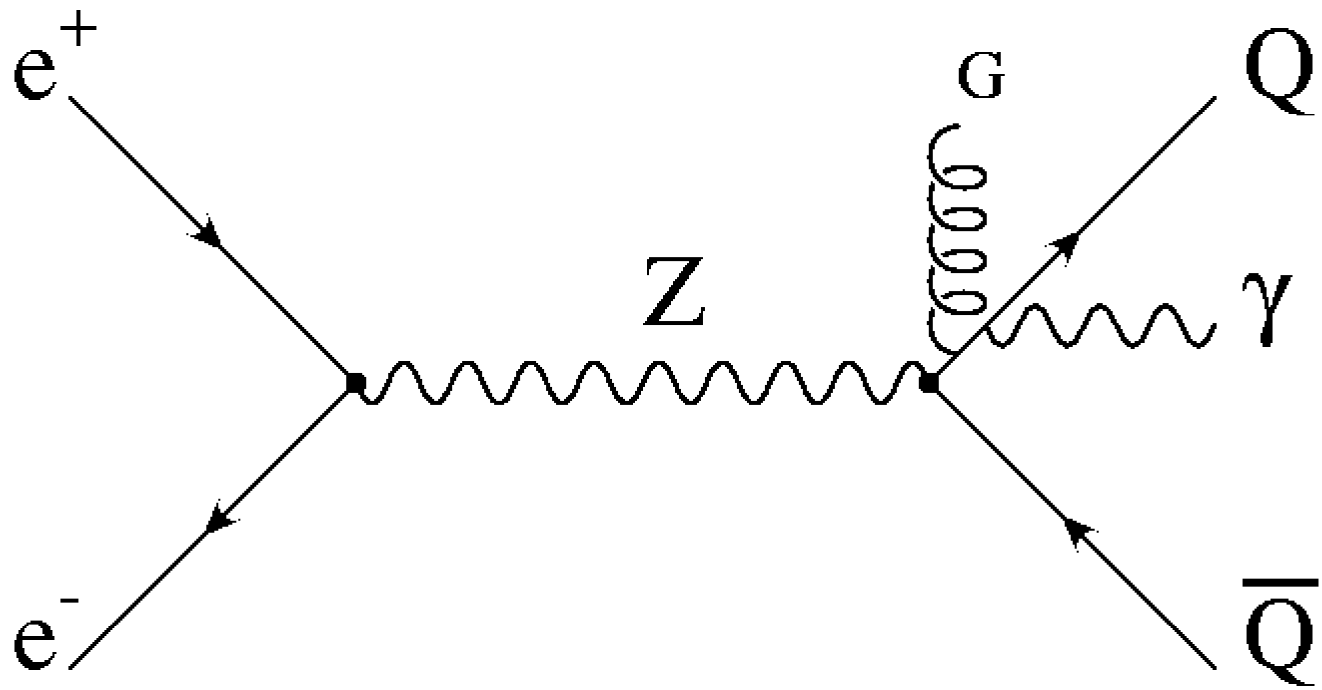
Quark-to-Photon Fragmentation at LEP



These photons are generally isolated and relatively easy to measure.

Only problem, there is no QCD in this photon production so far...

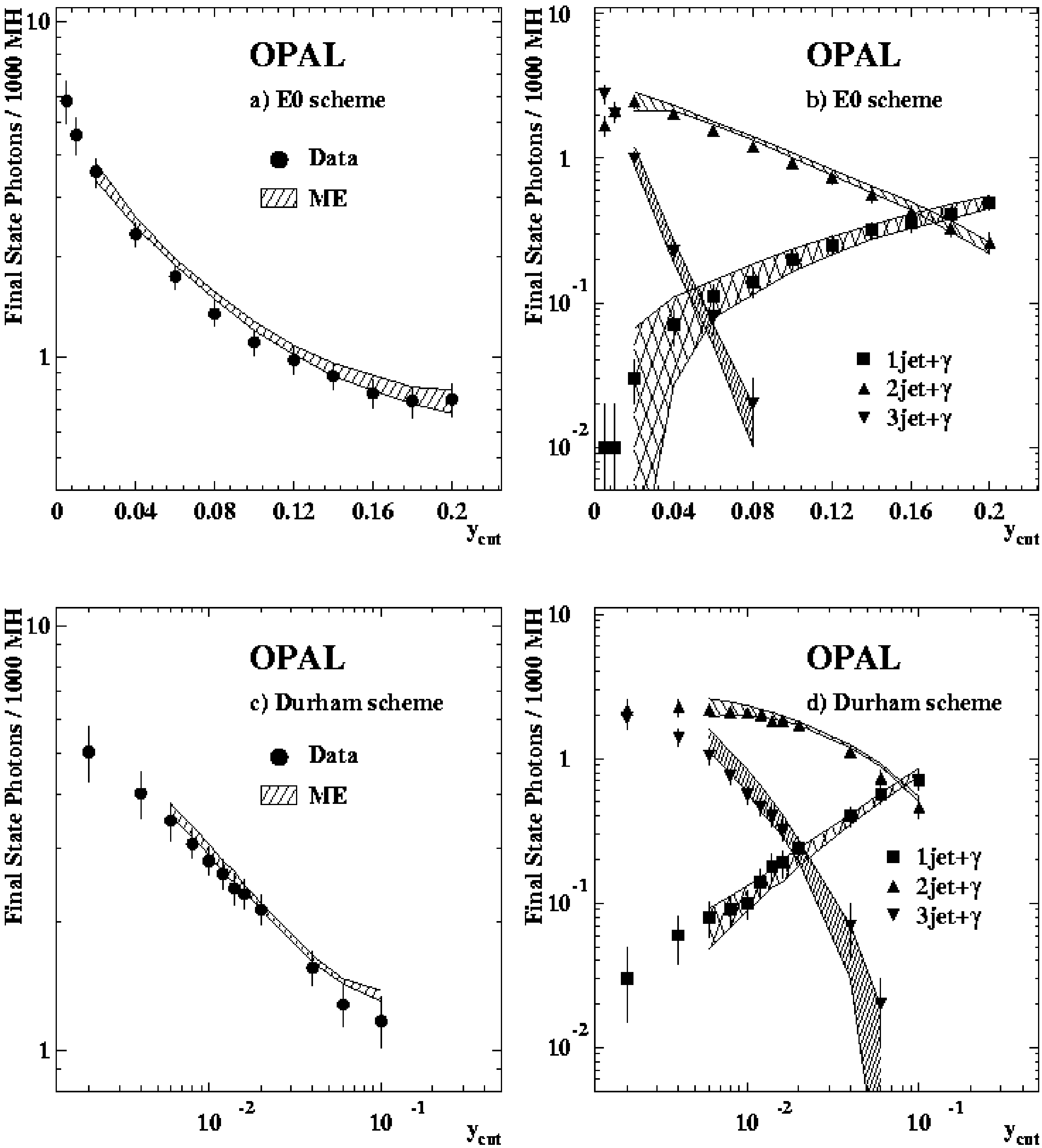
Quark-to-Photon Fragmentation at LEP



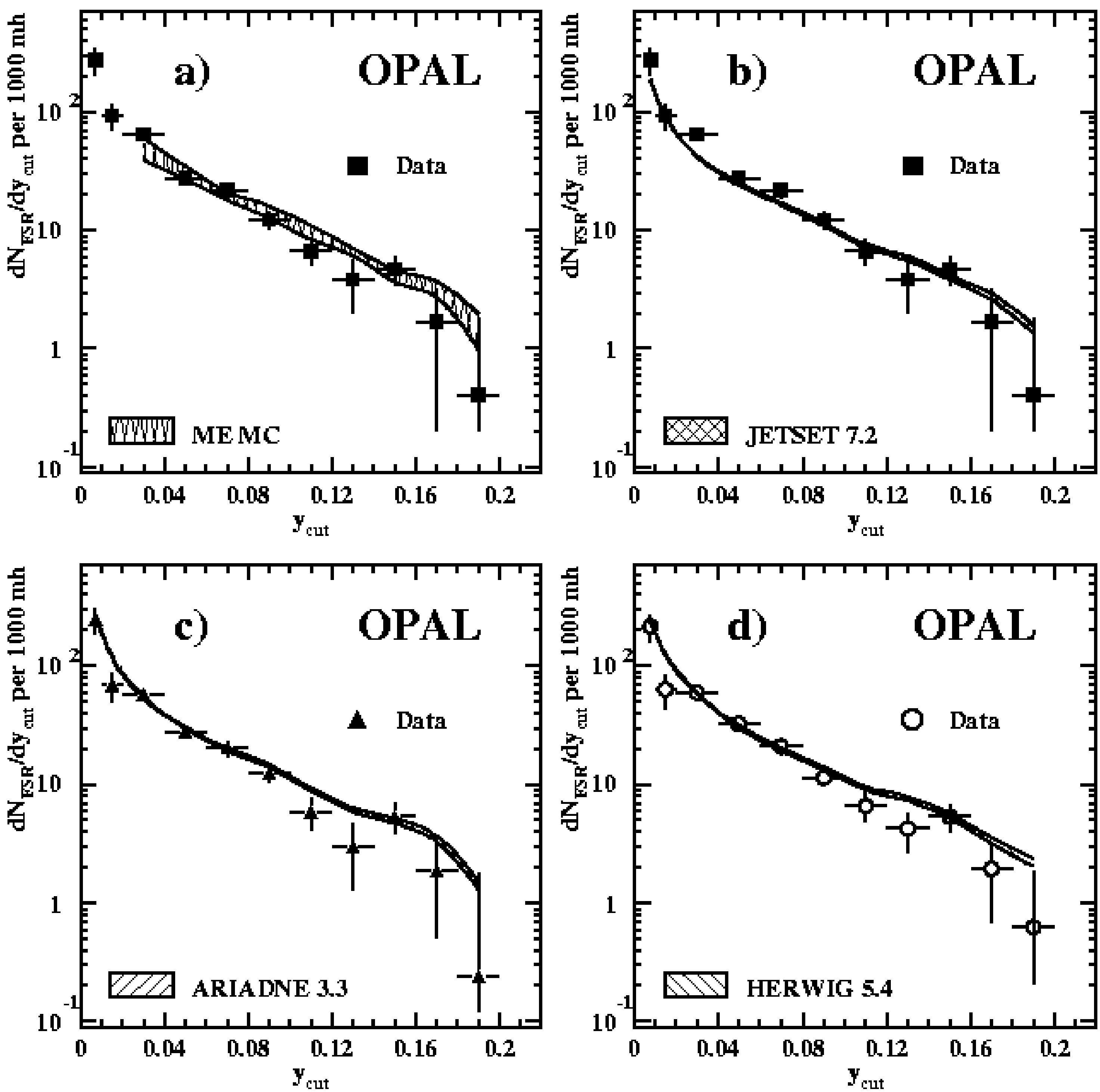
QCD enters into this process by gluon radiation before the photon emission.

Generates all the normal QCD issues such as Q^2 dependence, higher orders, etc.

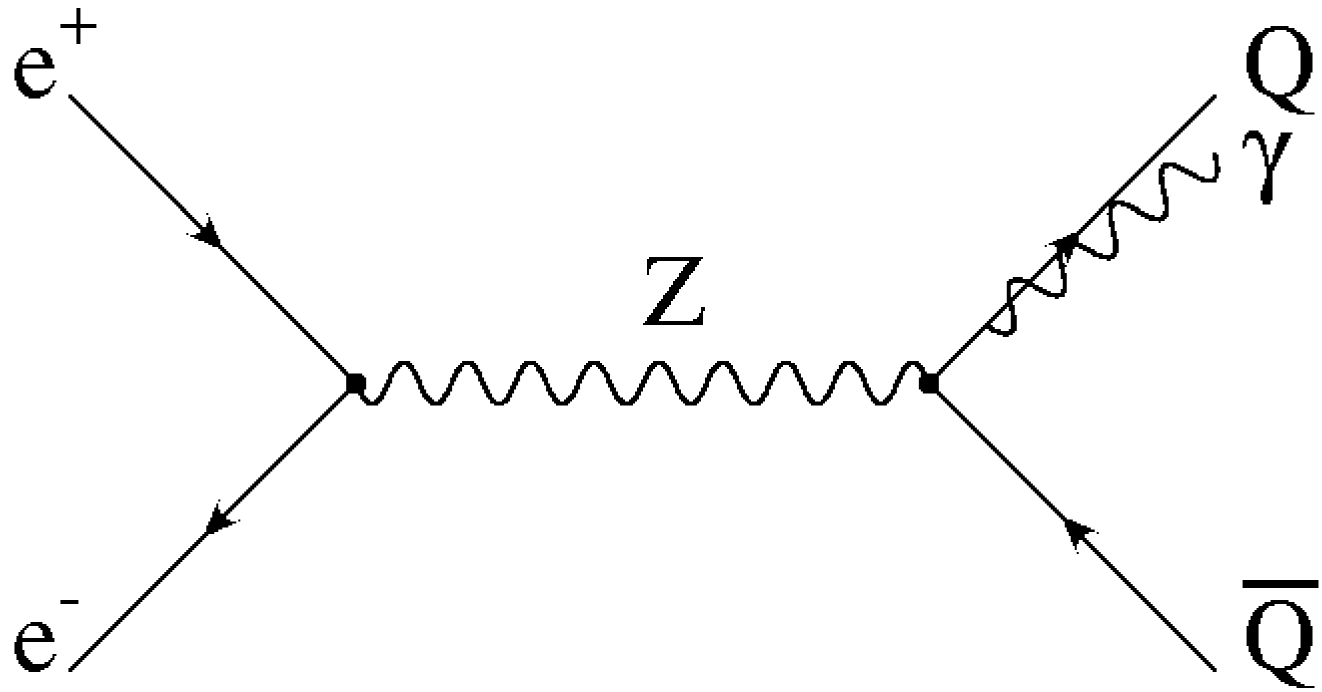
Quark-to-Photon Fragmentation at LEP



Quark-to-Photon Fragmentation at LEP



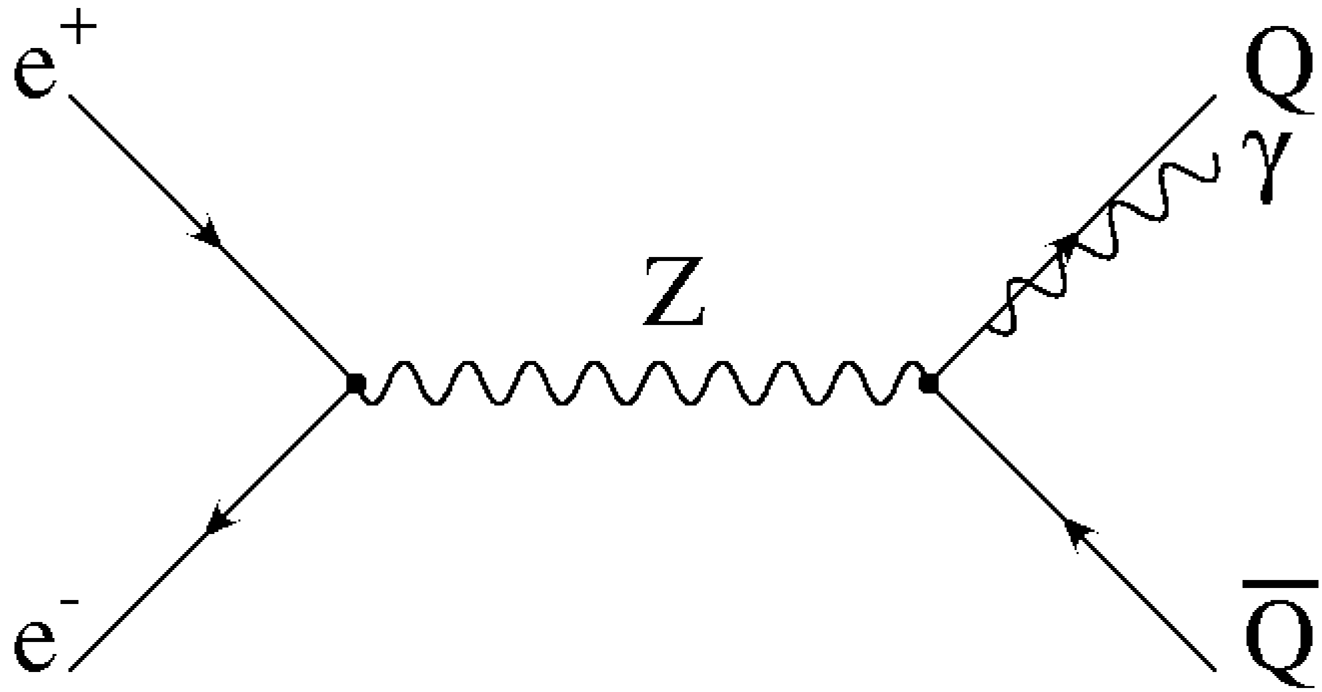
Quark-to-Photon Fragmentation at LEP



<u>Semantics:</u>

This diagram is the collinear limit of the previous one and generally called "Photon Fragmentation"

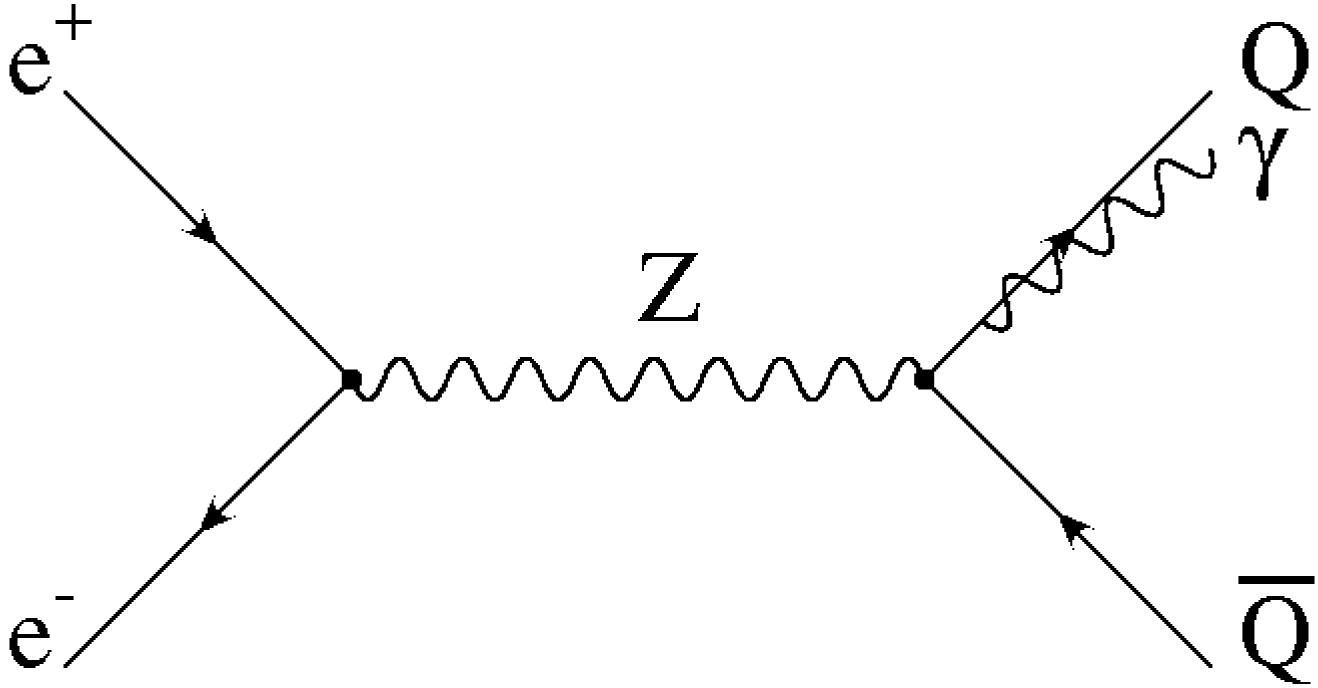
Quark-to-Photon Fragmentation at LEP



A non-pertubative fragmentation function must be inserted at Q_0, then evolved to higher Q^2 due to multiple gluon radiation.

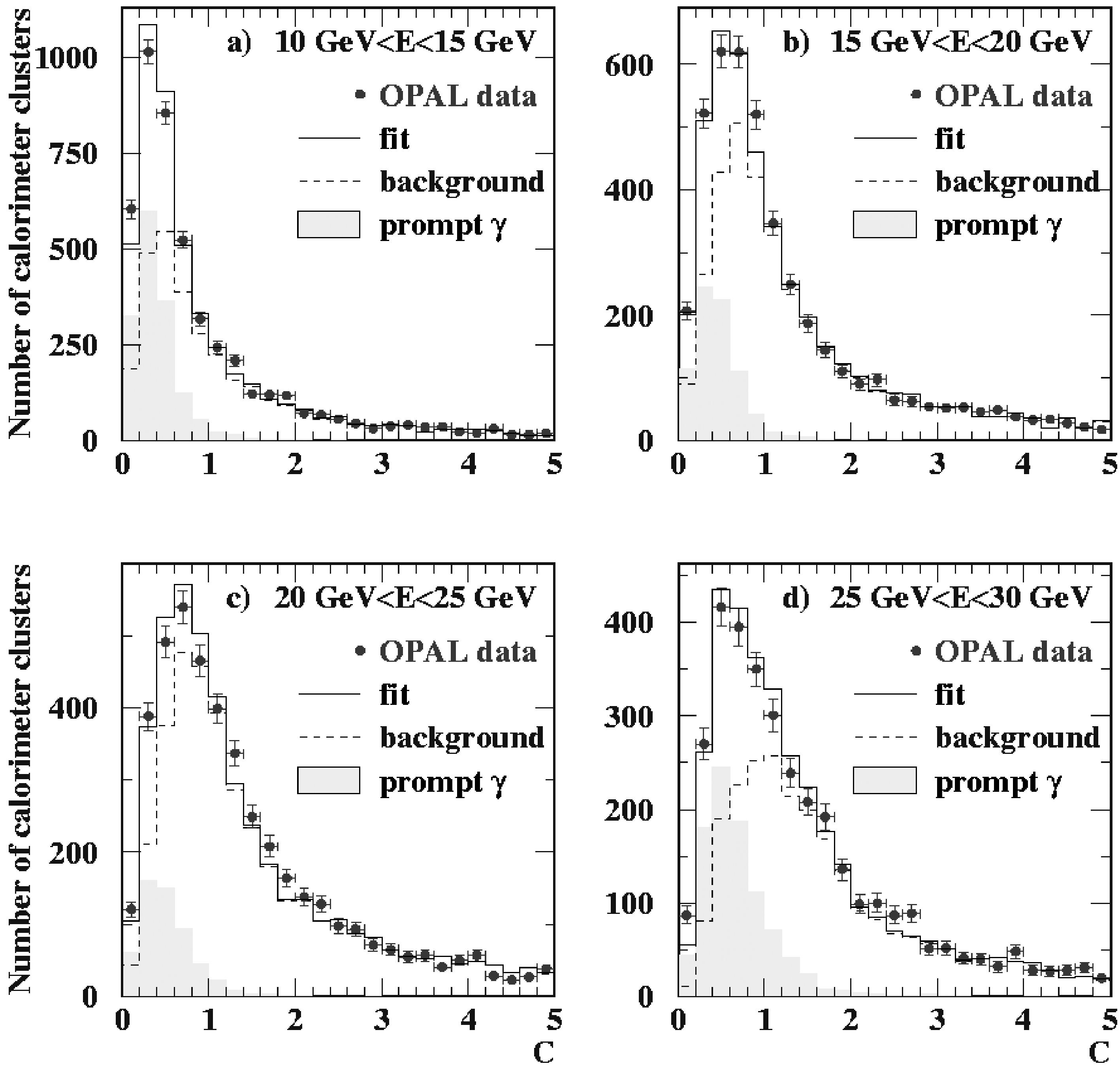
This leads to various models to test...

Quark-to-Photon Fragmentation at LEP

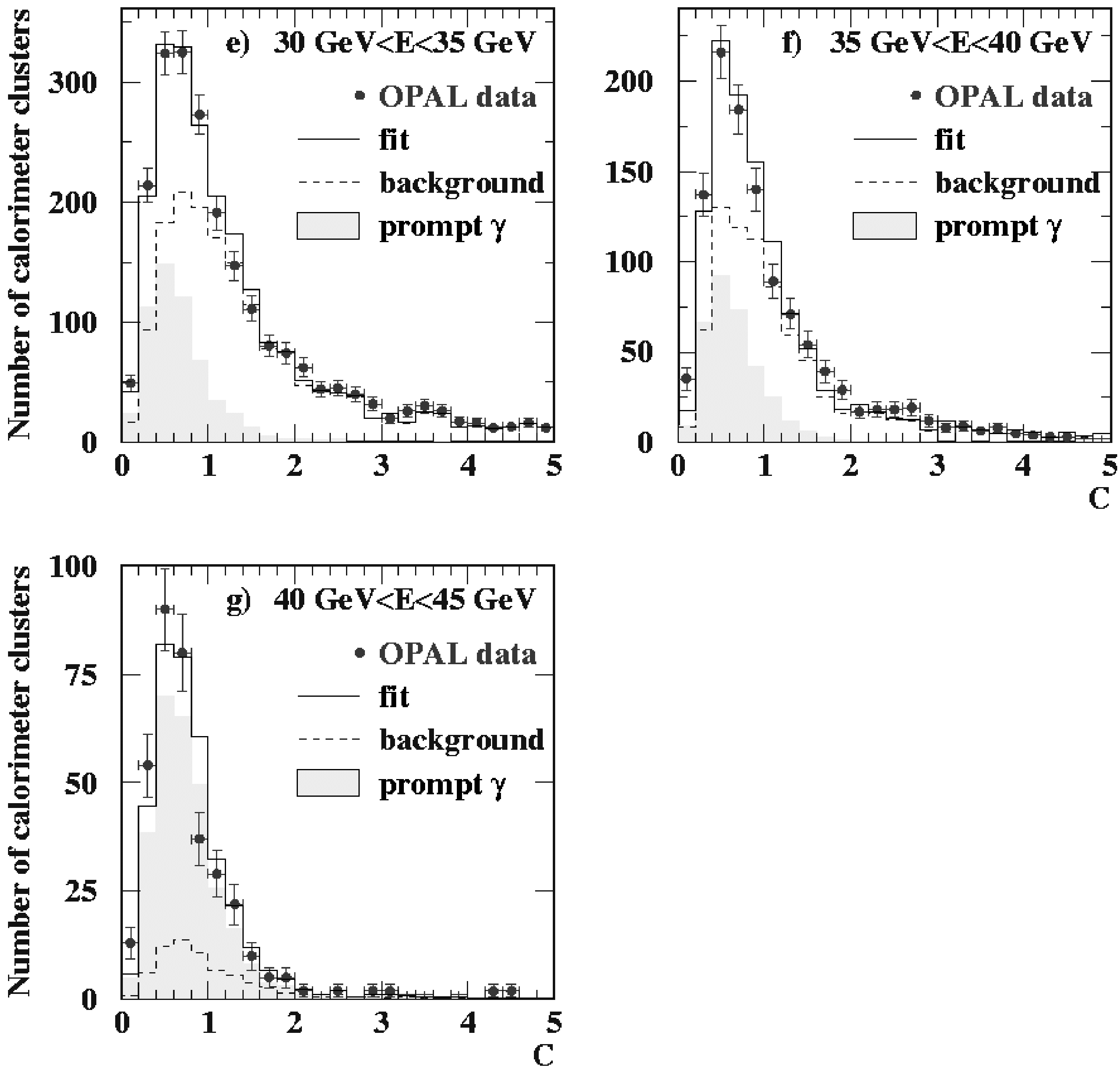


The more challenging measurement of the fragmentation involves nonisolated photons

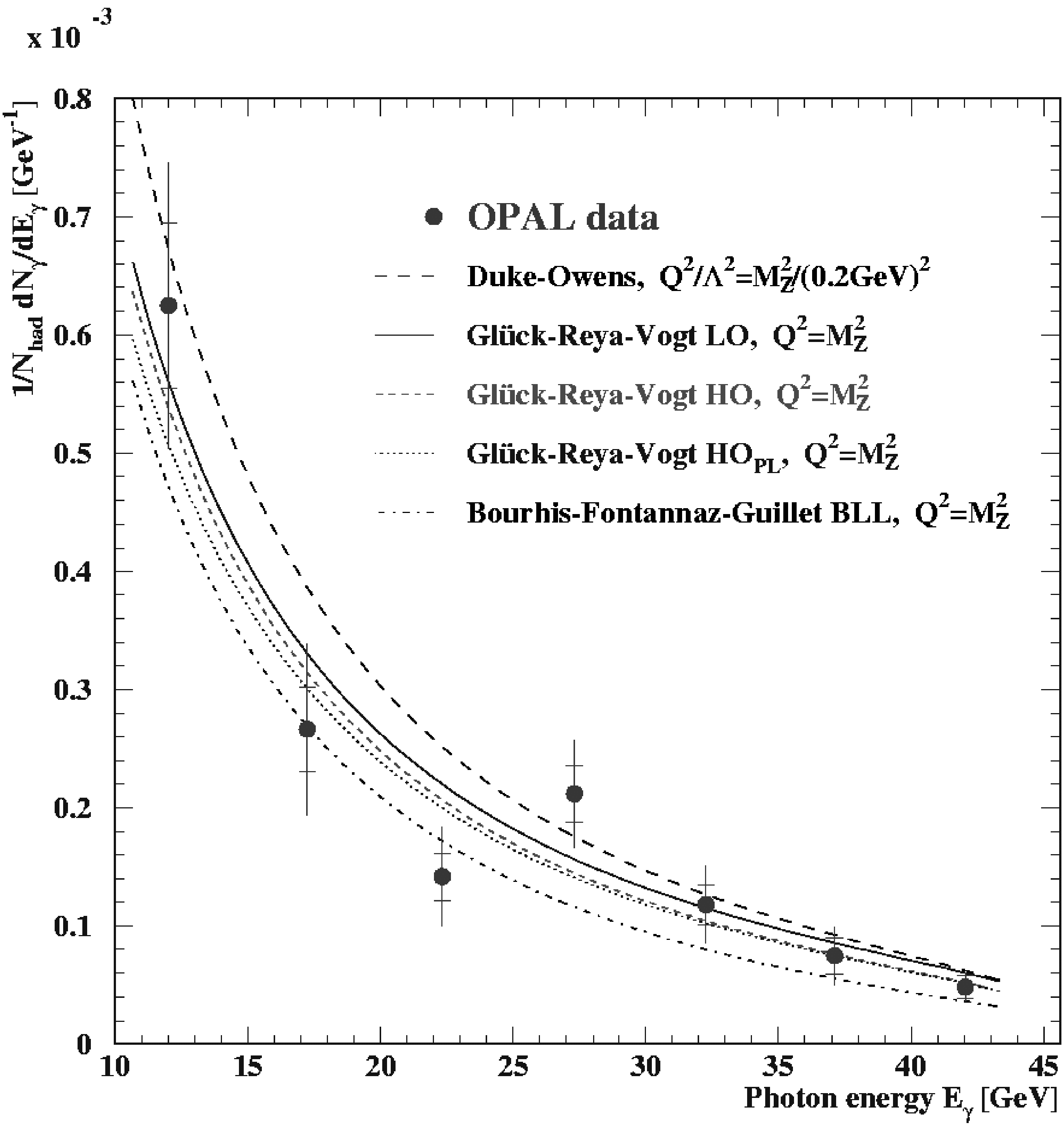
Quark-to-Photon Fragmentation at LEP



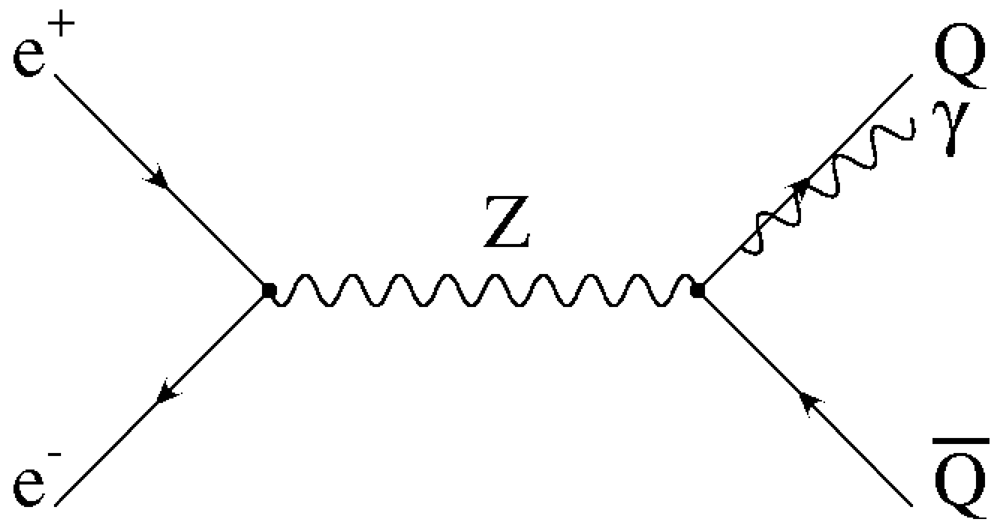
Quark-to-Photon Fragmentation at LEP



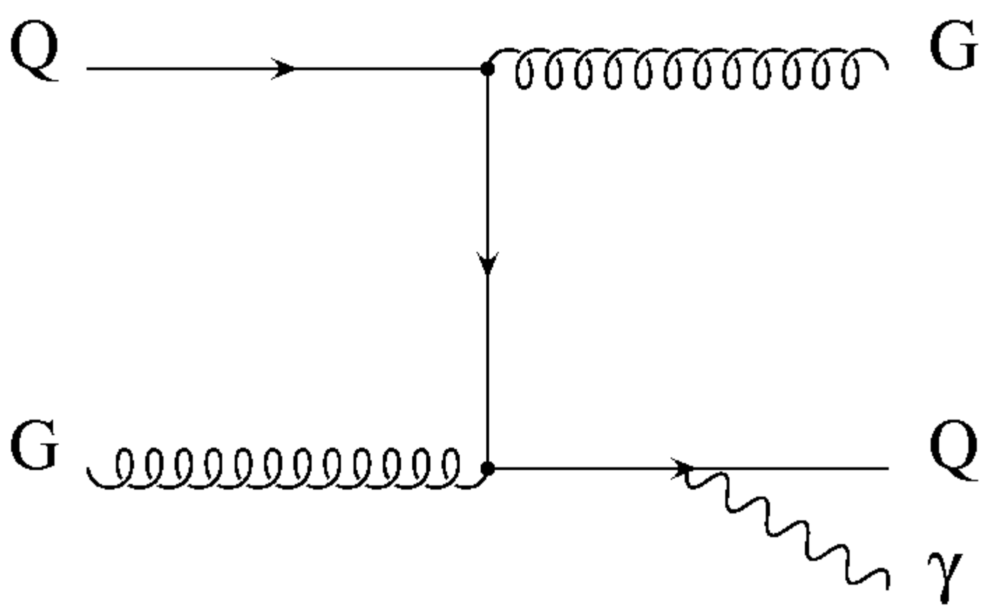
Quark-to-Photon Fragmentation at LEP



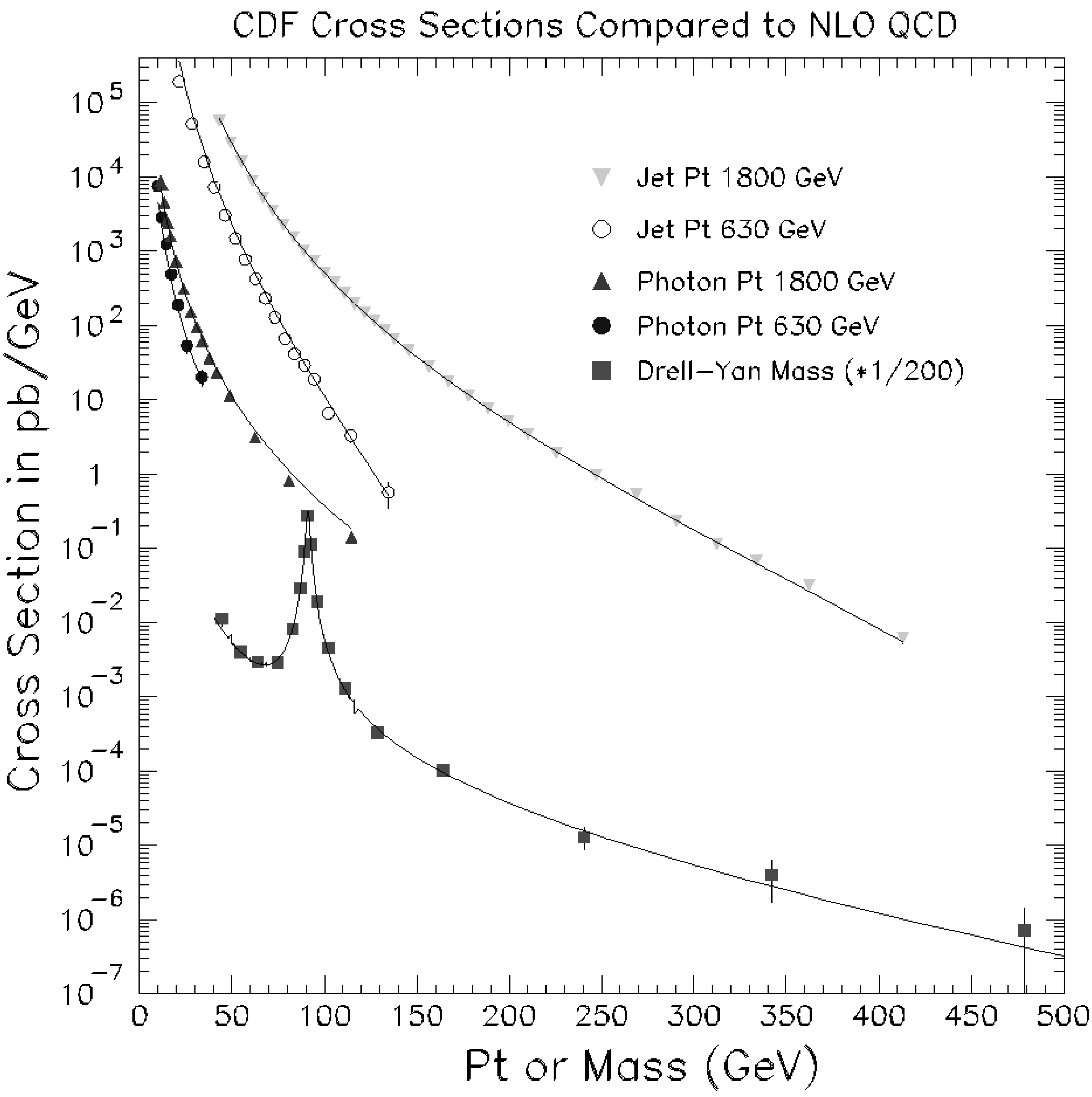
Quark-to-Photon Fragmentation at LEP



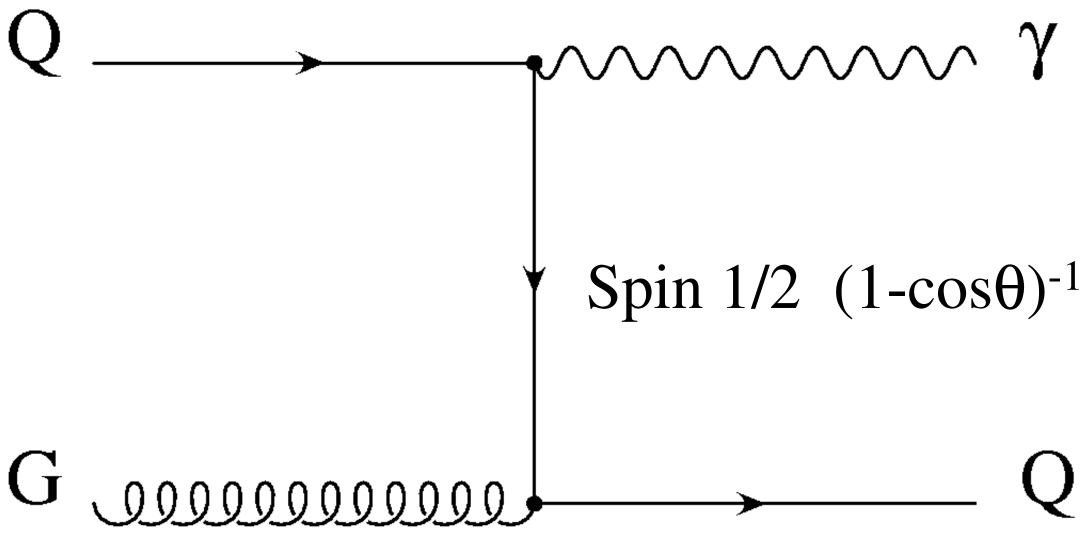
What is learned at LEP provides important input to a part of Hadronic Production of Direct Photons



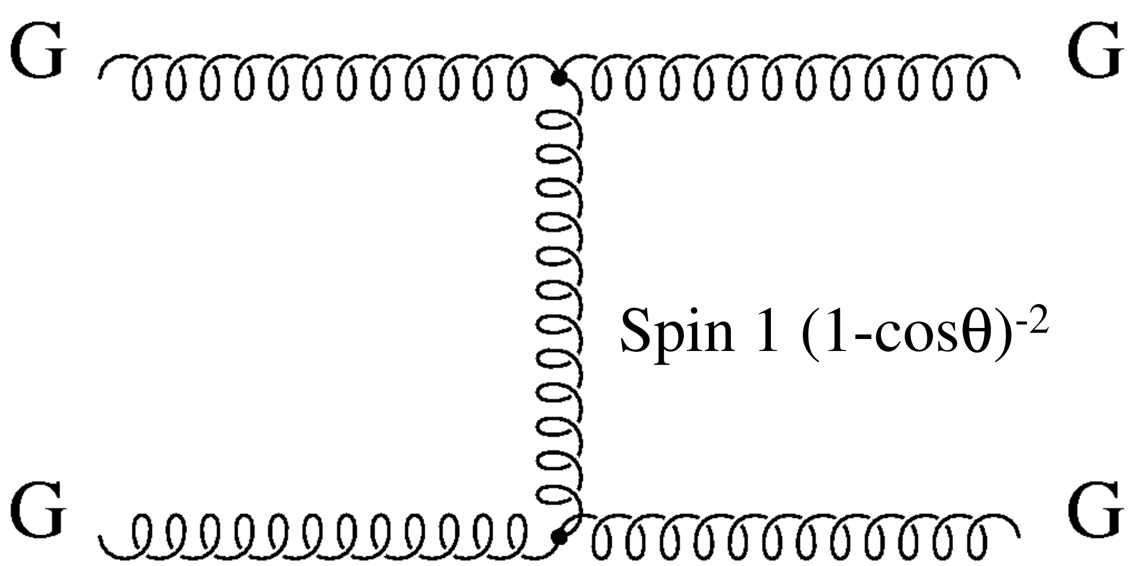
Perturbative QCD Works Well in Hadron Collisions!



Photon+Jet Angles in Hadronic Collisions



The main process producing photons is quite different than generic dijet events...



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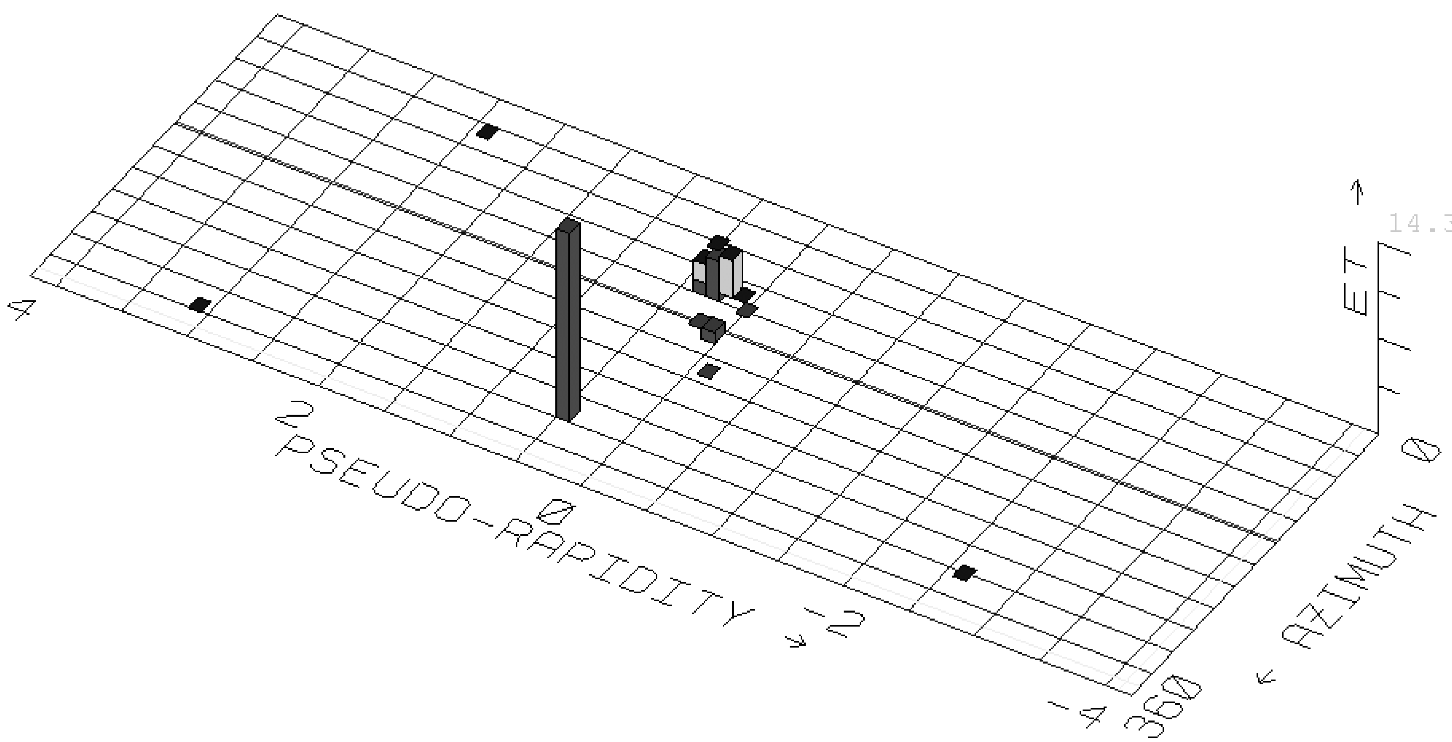

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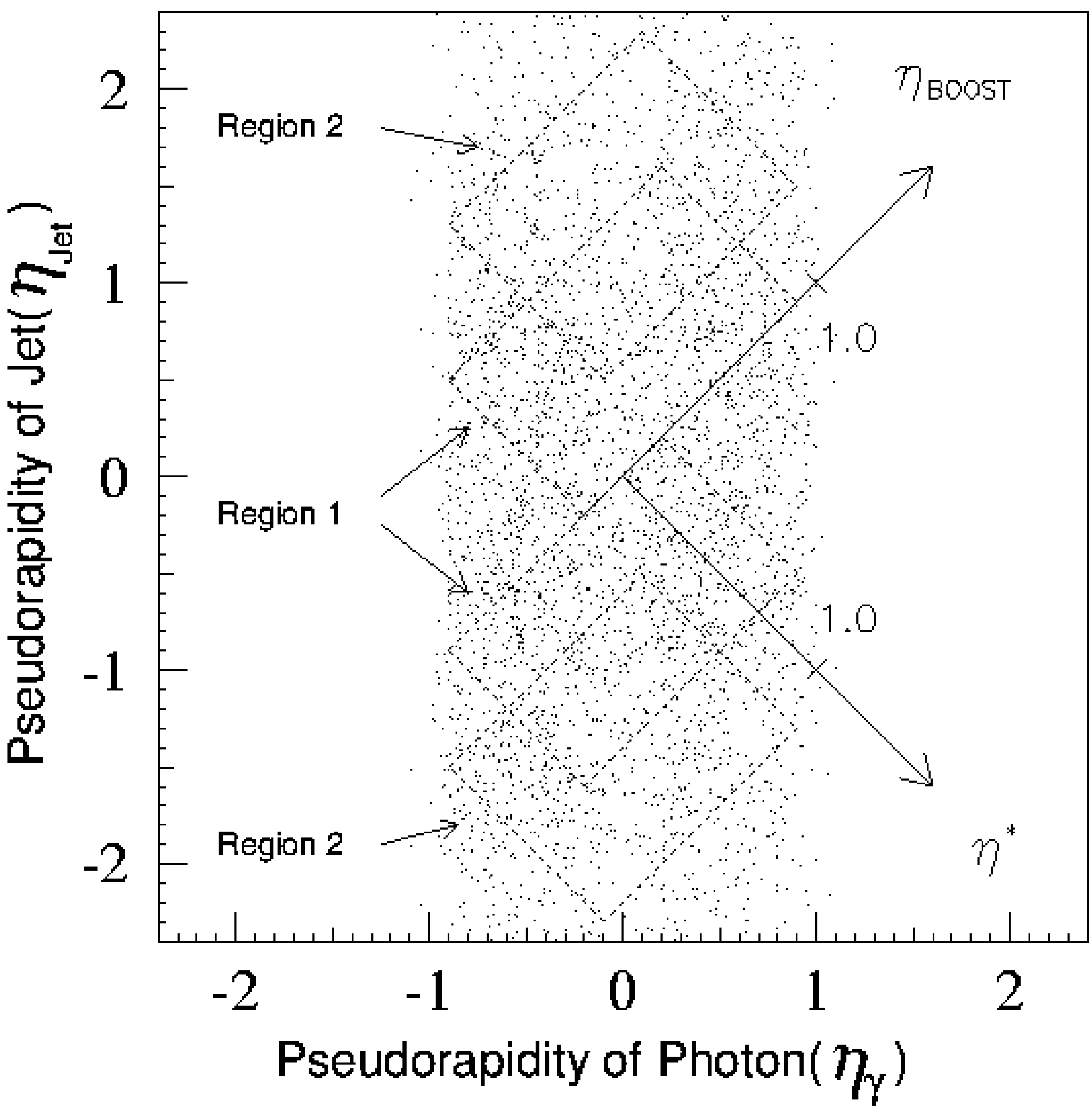
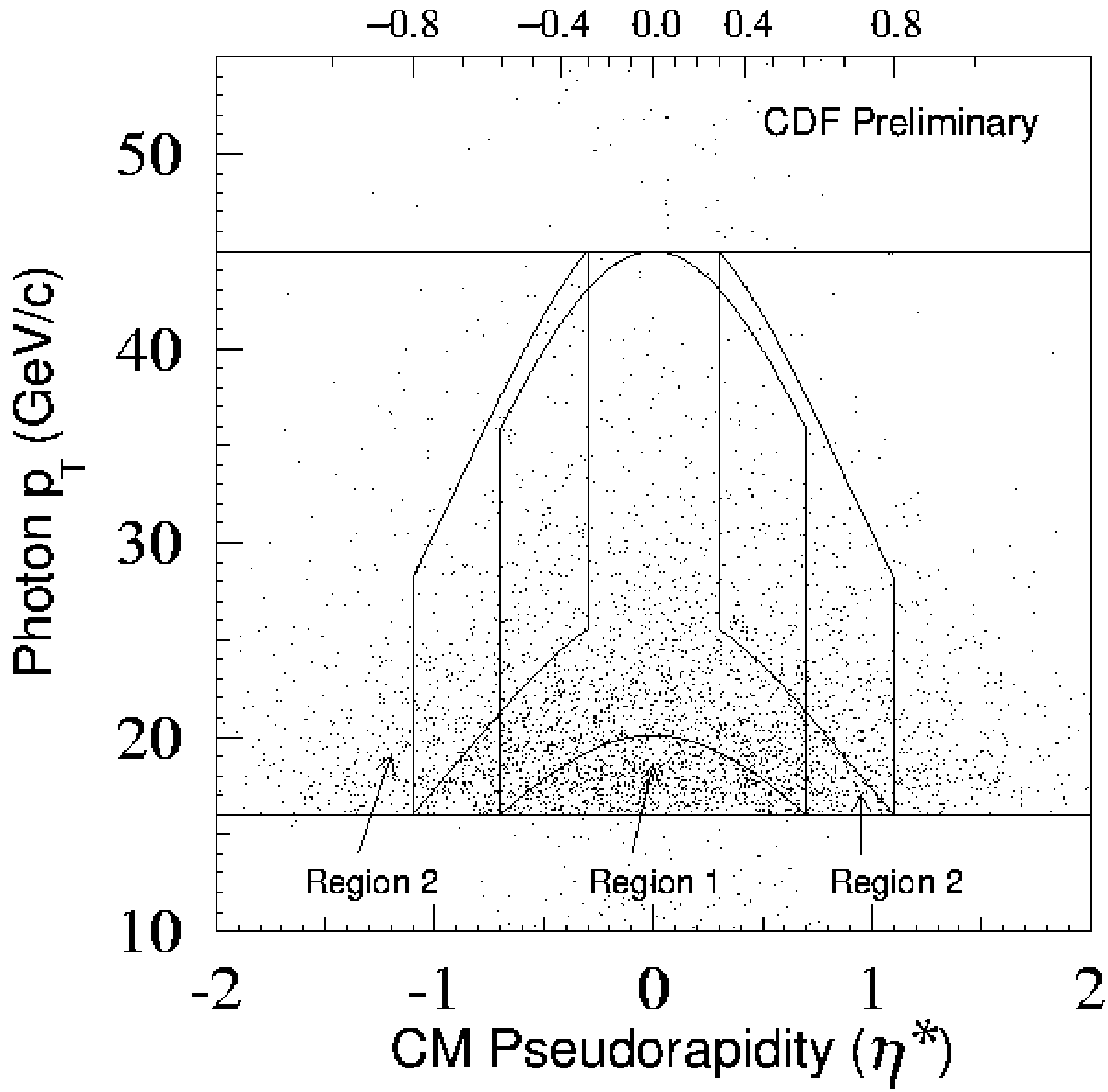
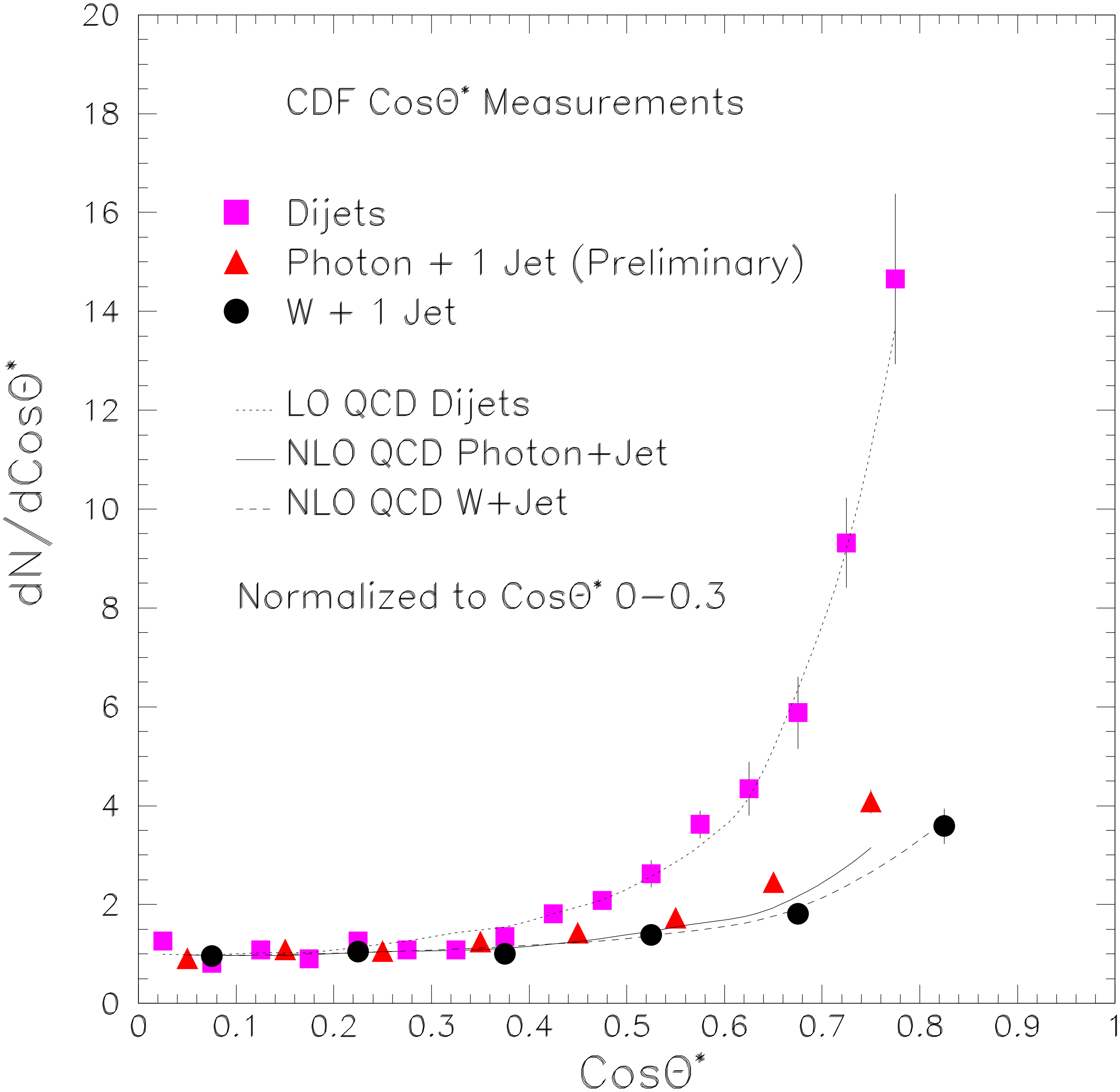


Photon+Jet Angles in Hadronic Collisions

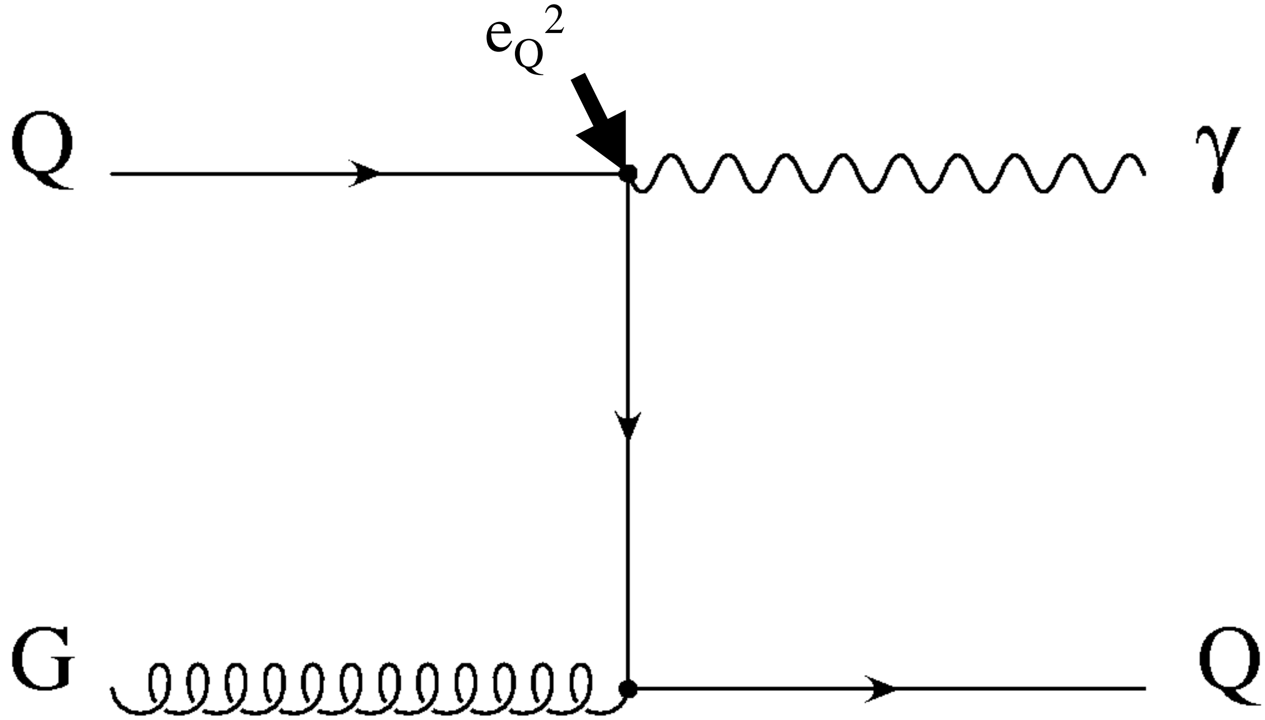
$\cos\theta^* = \tanh(\eta^*)$



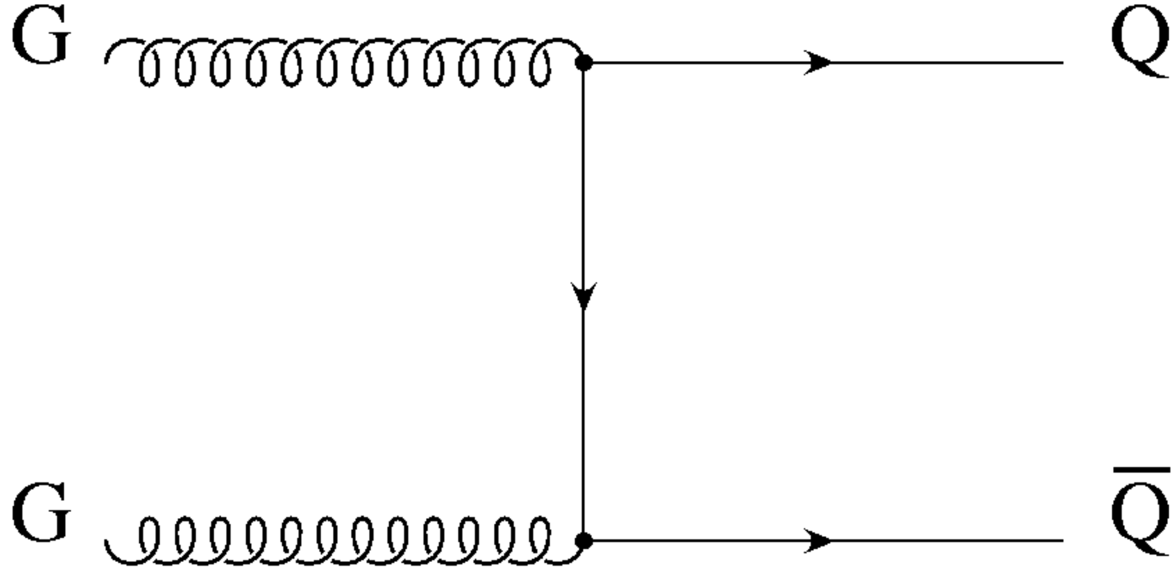
Photon+Jet Angles in Hadronic Collisions



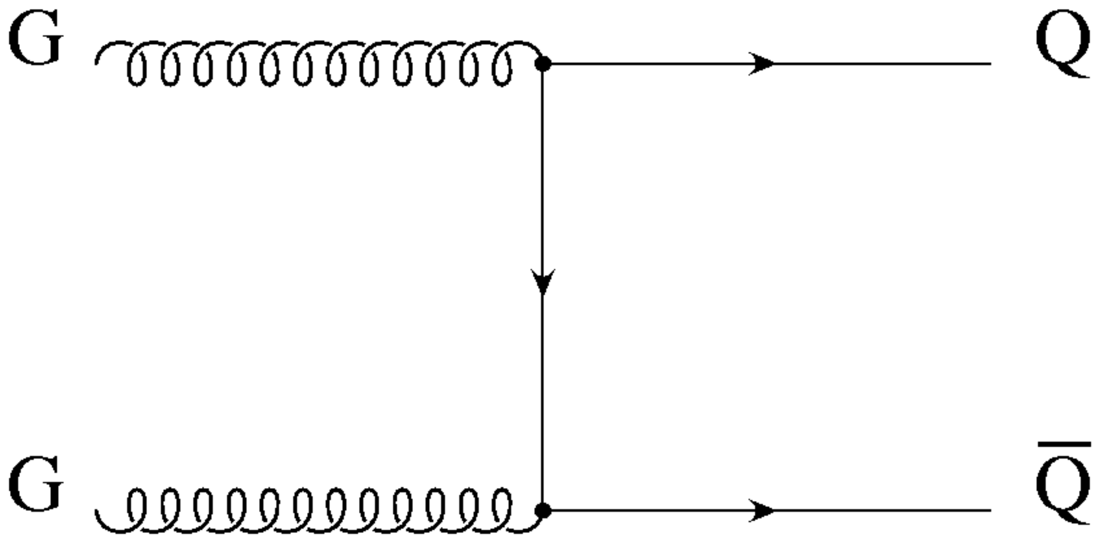
Photon vertex sensitive to electric charge



Photon+Charm Production is enhanced compared to Gluon-Gluon Production



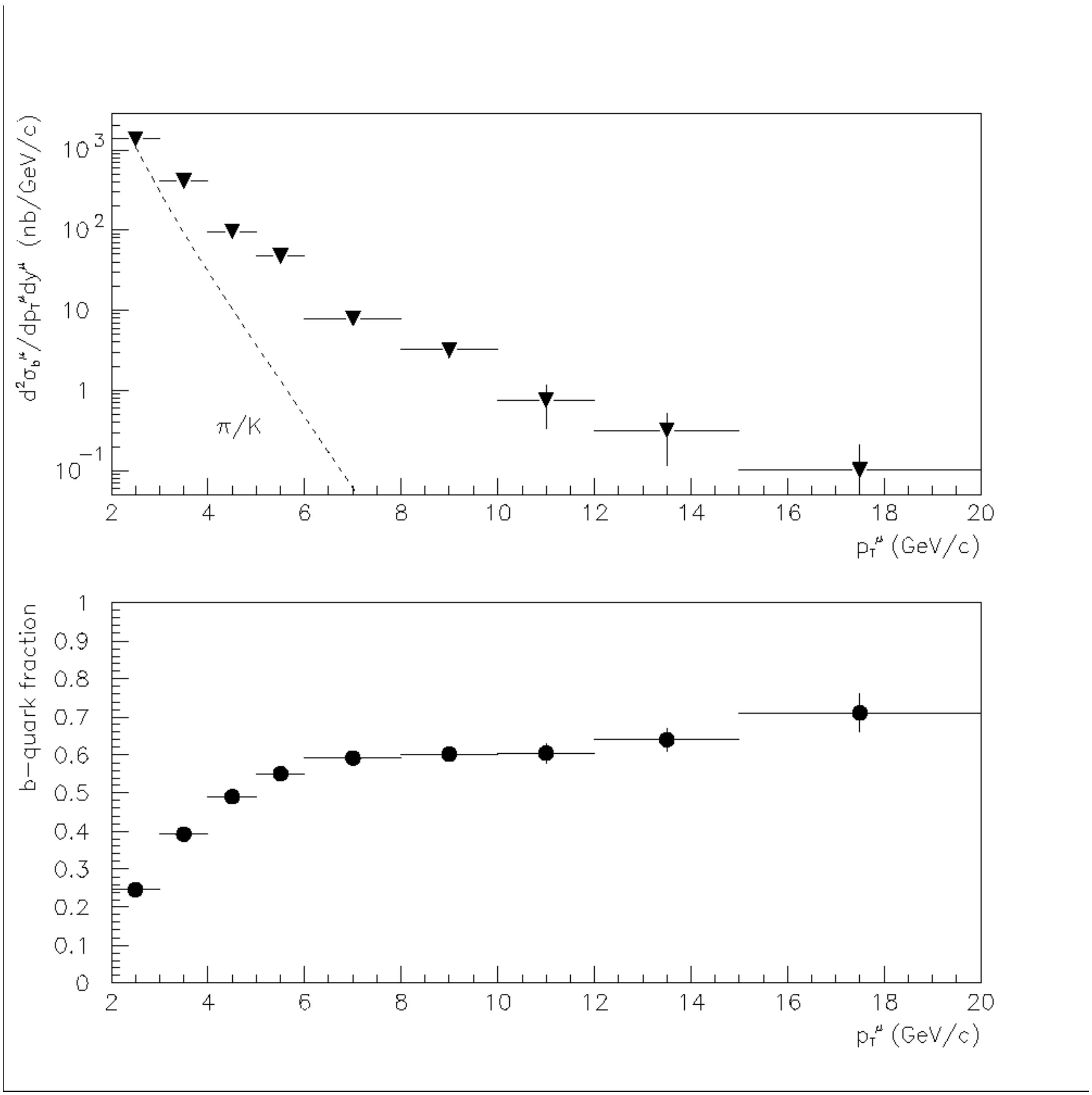
Photon vertex sensitive to electric charge



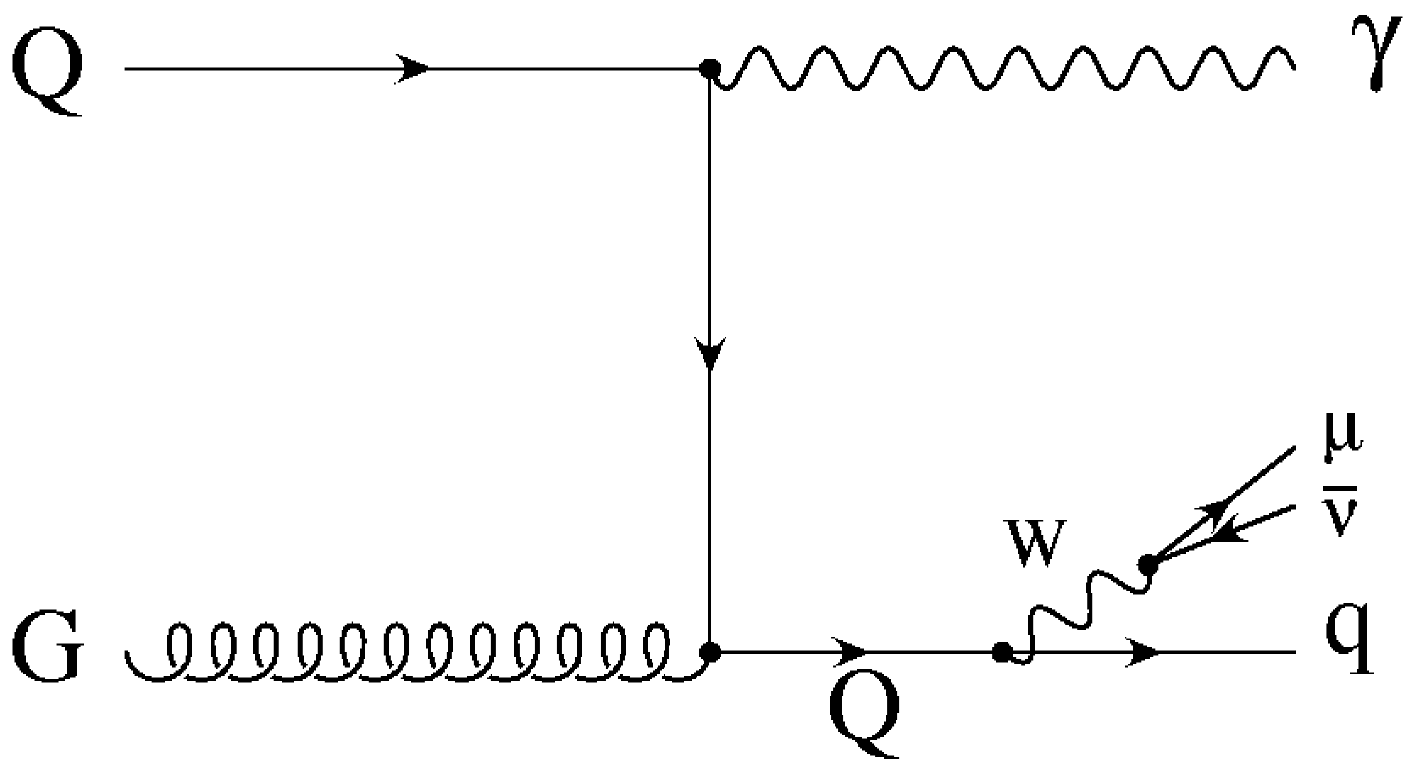
In semileptonic decays of heavy quarks, bottom quark fraction is enhanced by harder fragmentation and sequential decays of the charm.

Photon vertex sensitive to electric charge

D0 Inclusive Muons



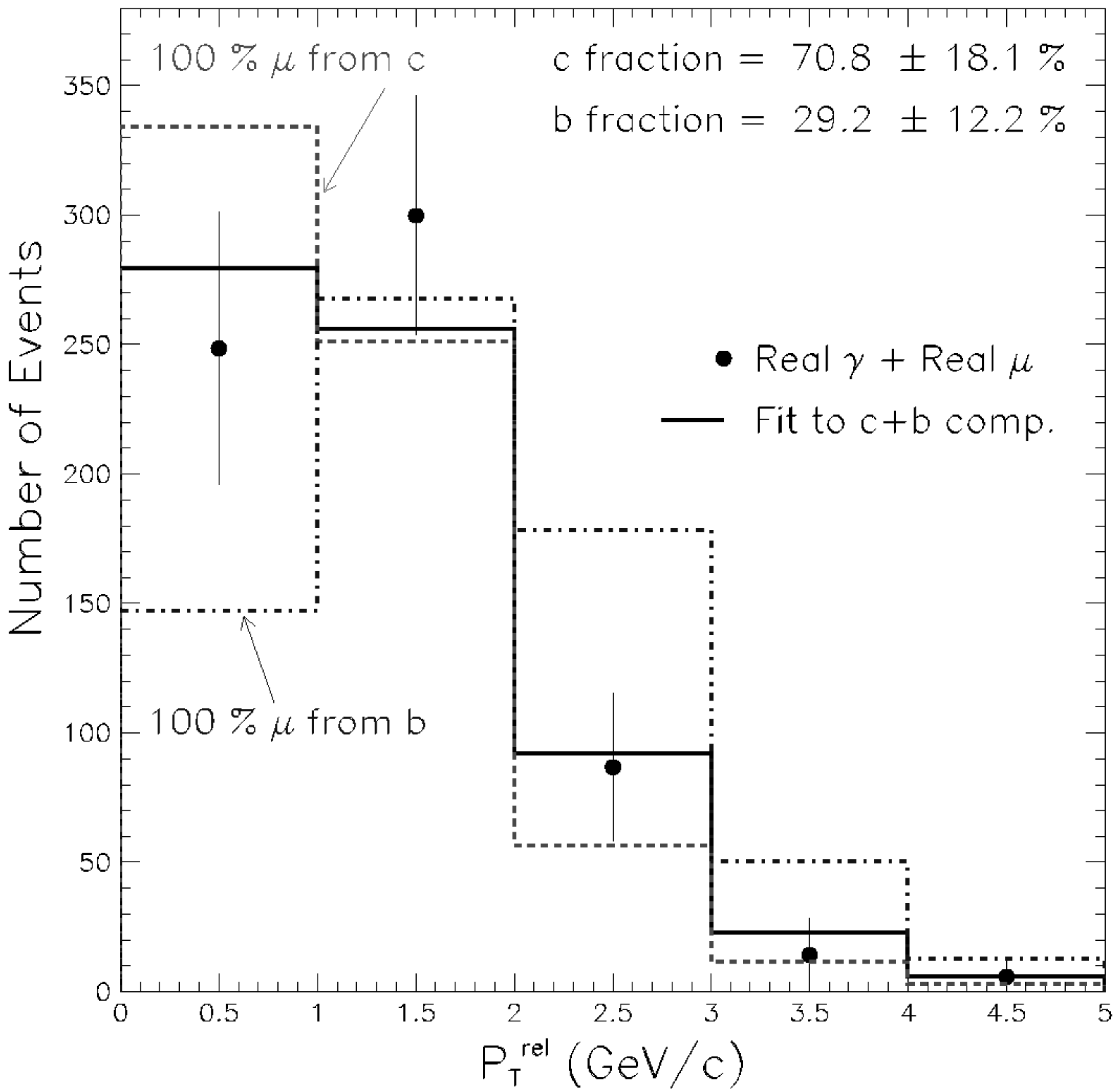
Photon vertex sensitive to electric charge



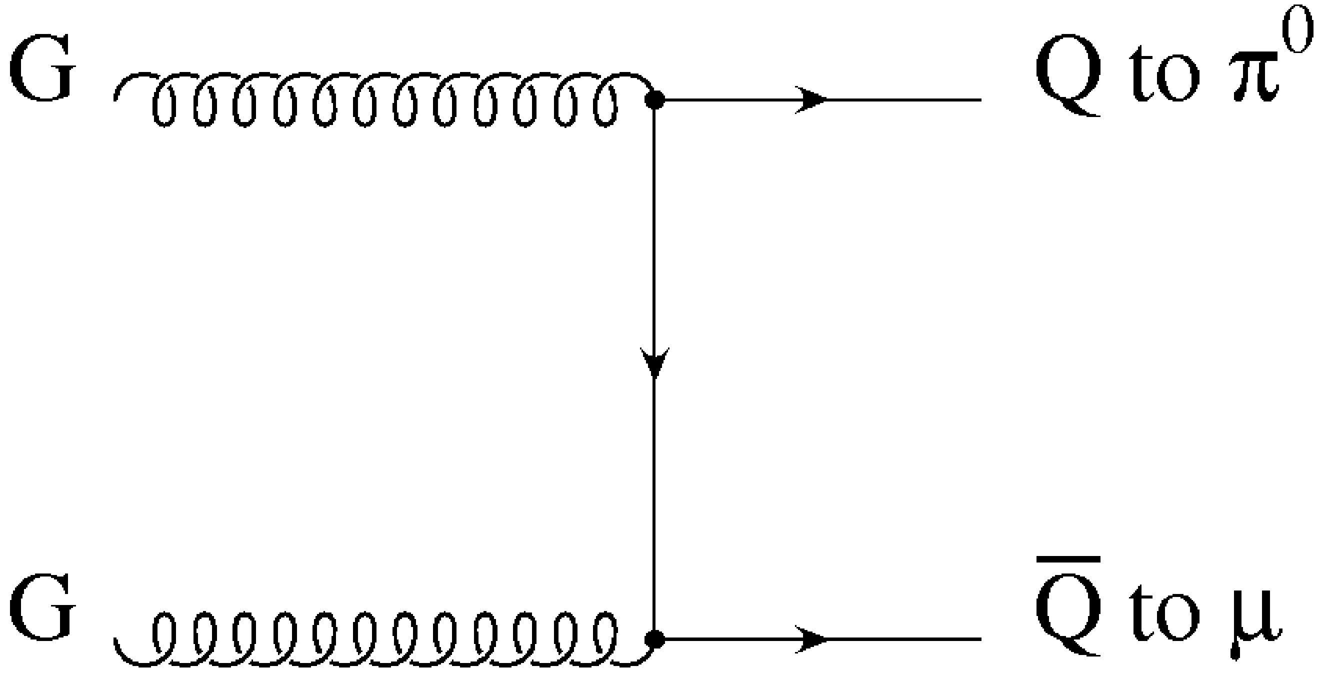
Back to a photon sample, use the classic “Pt_relative” Technique to separate final state charm and bottom.

Photon vertex sensitive to electric charge

New CDF Result on Photon+HQ



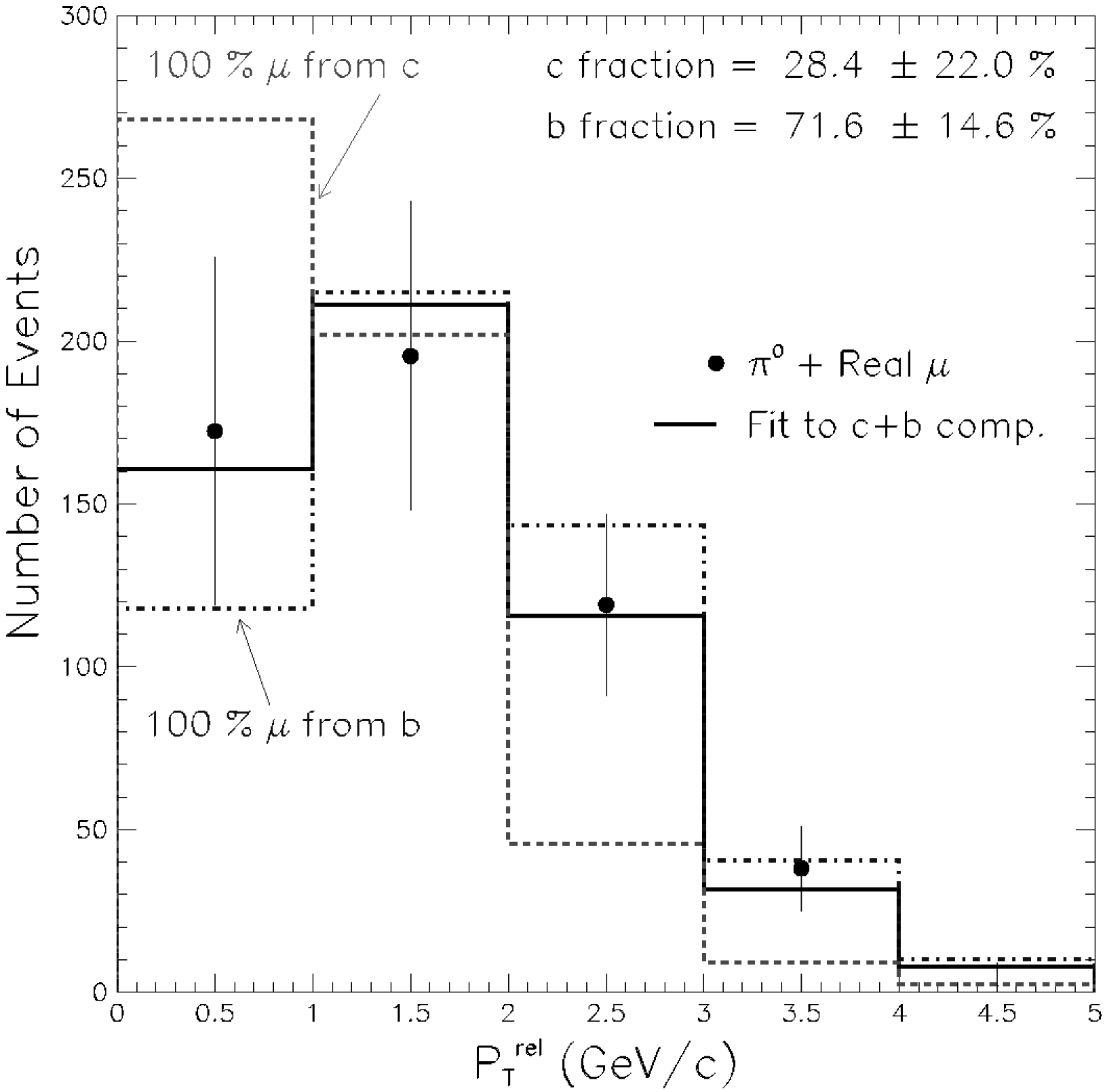
Photon vertex sensitive to electric charge



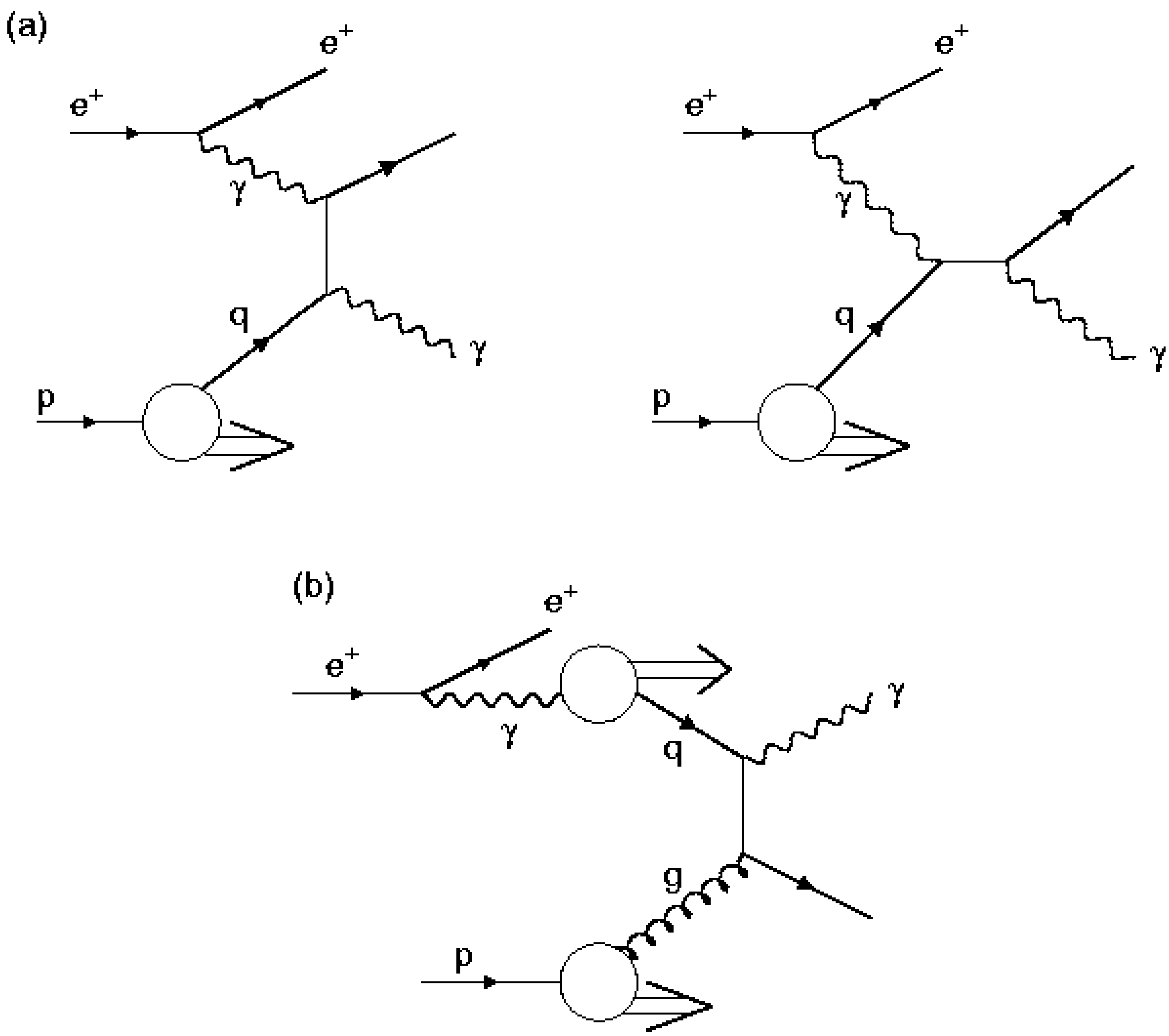
<u>Analysis Check:</u>

Same data sample as Direct Photons, but look at π^0s in the sample...

Photon vertex sensitive to electric charge



Prompt Photons at HERA



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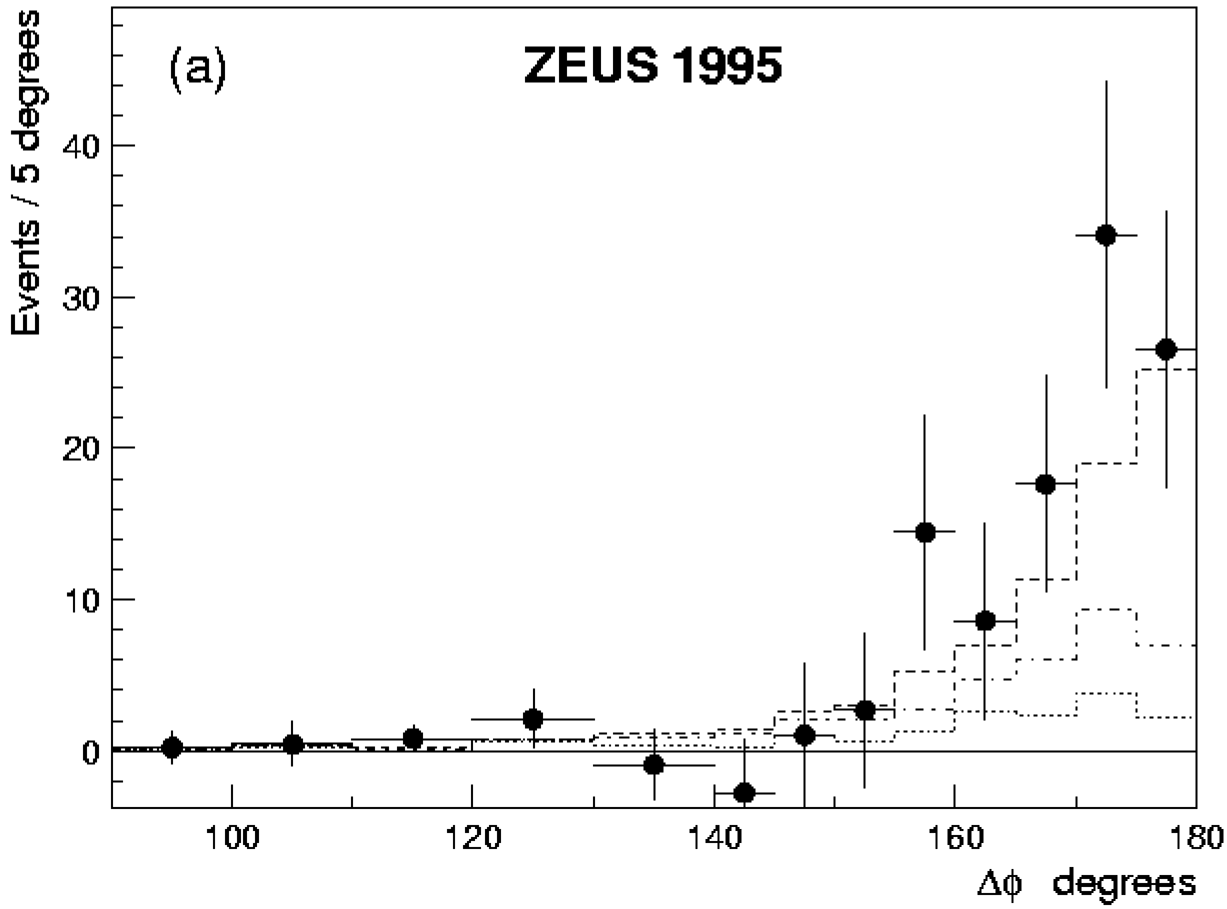

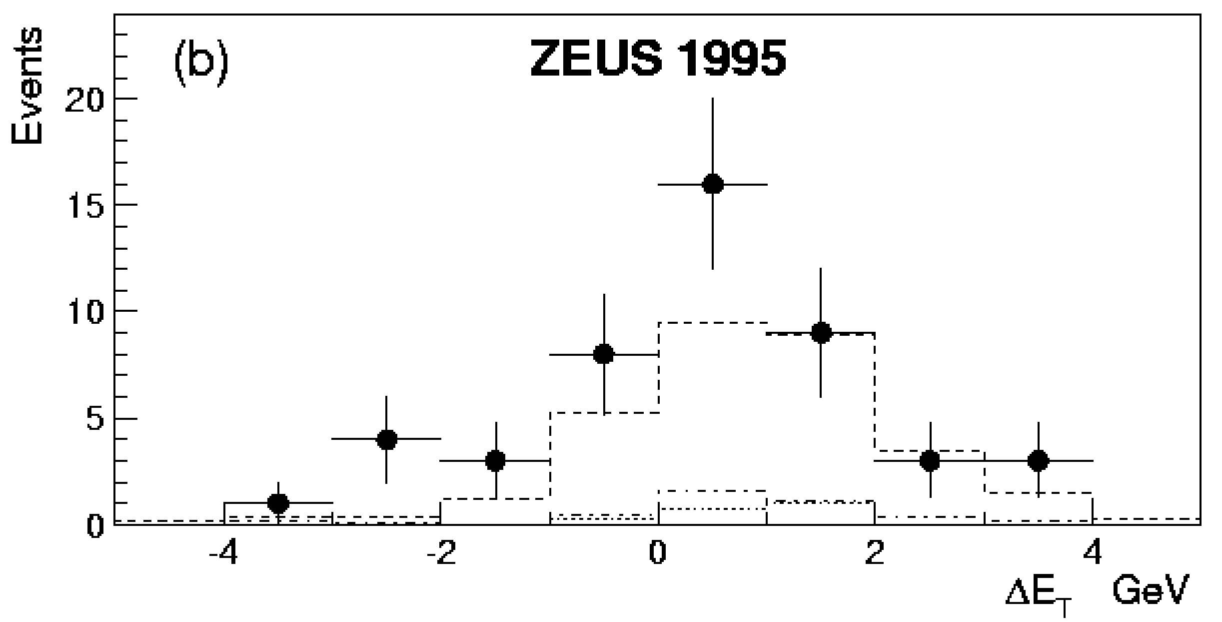

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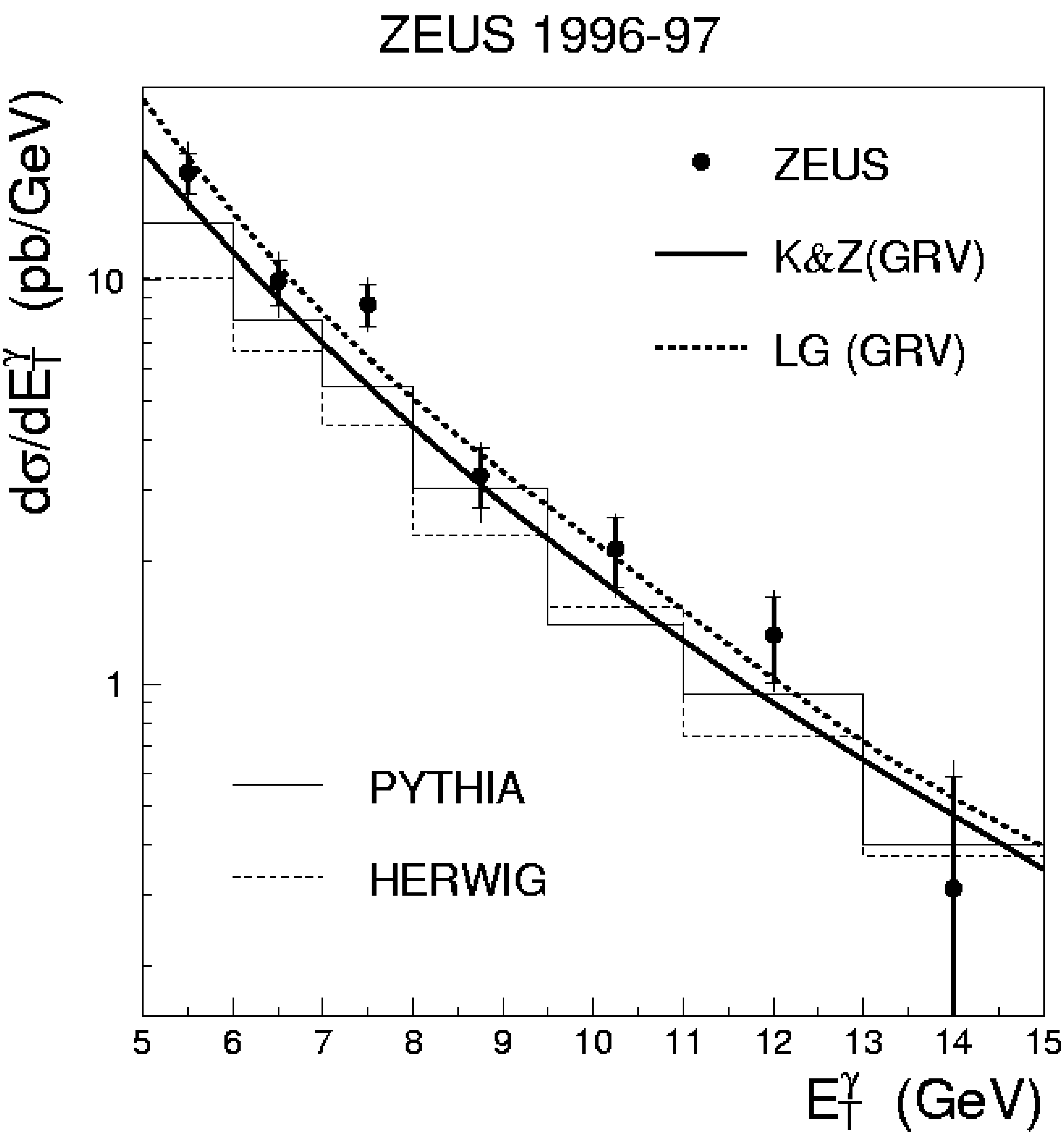

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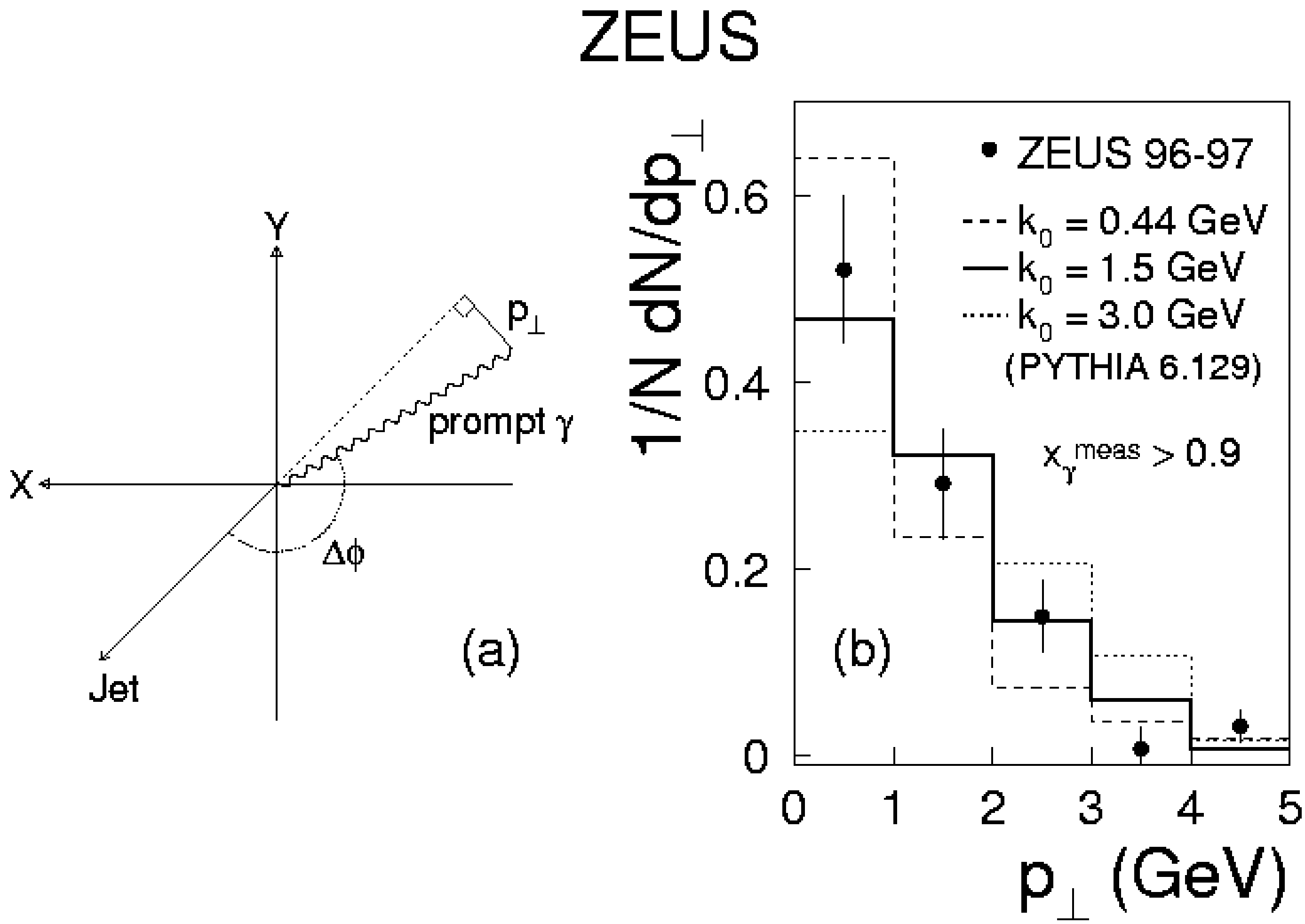
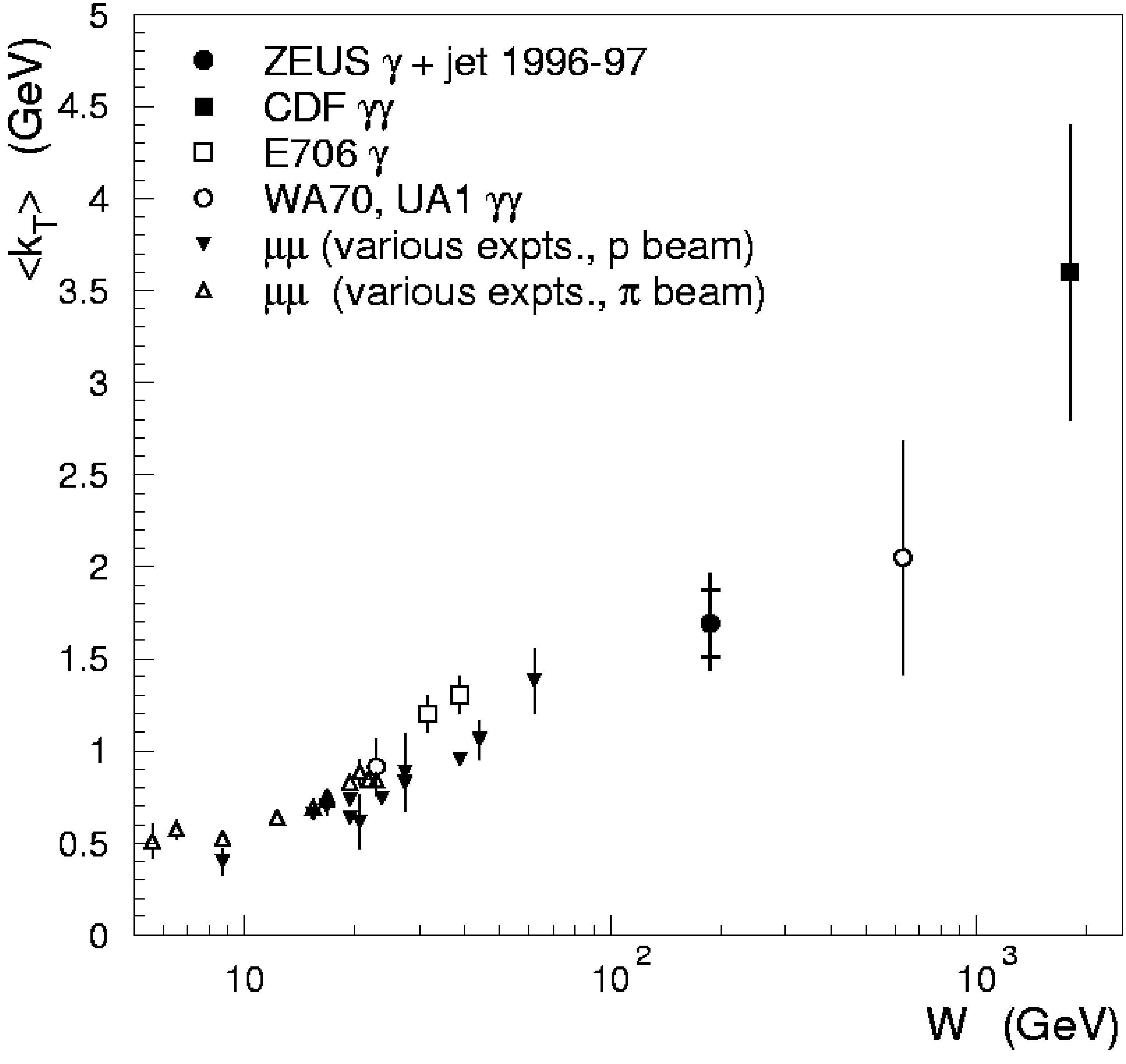


Most recent study investigated the Pt Recoil of the Photon+Jet System Caused by Initial State Gluons

("Kt")

Prompt Photons at HERA



Cross Sections in Hadron Collisions

Pt Recoil values of 2-4 GeV may Cause Smearing of the Measured Direct Photon Falling Pt Spectrum

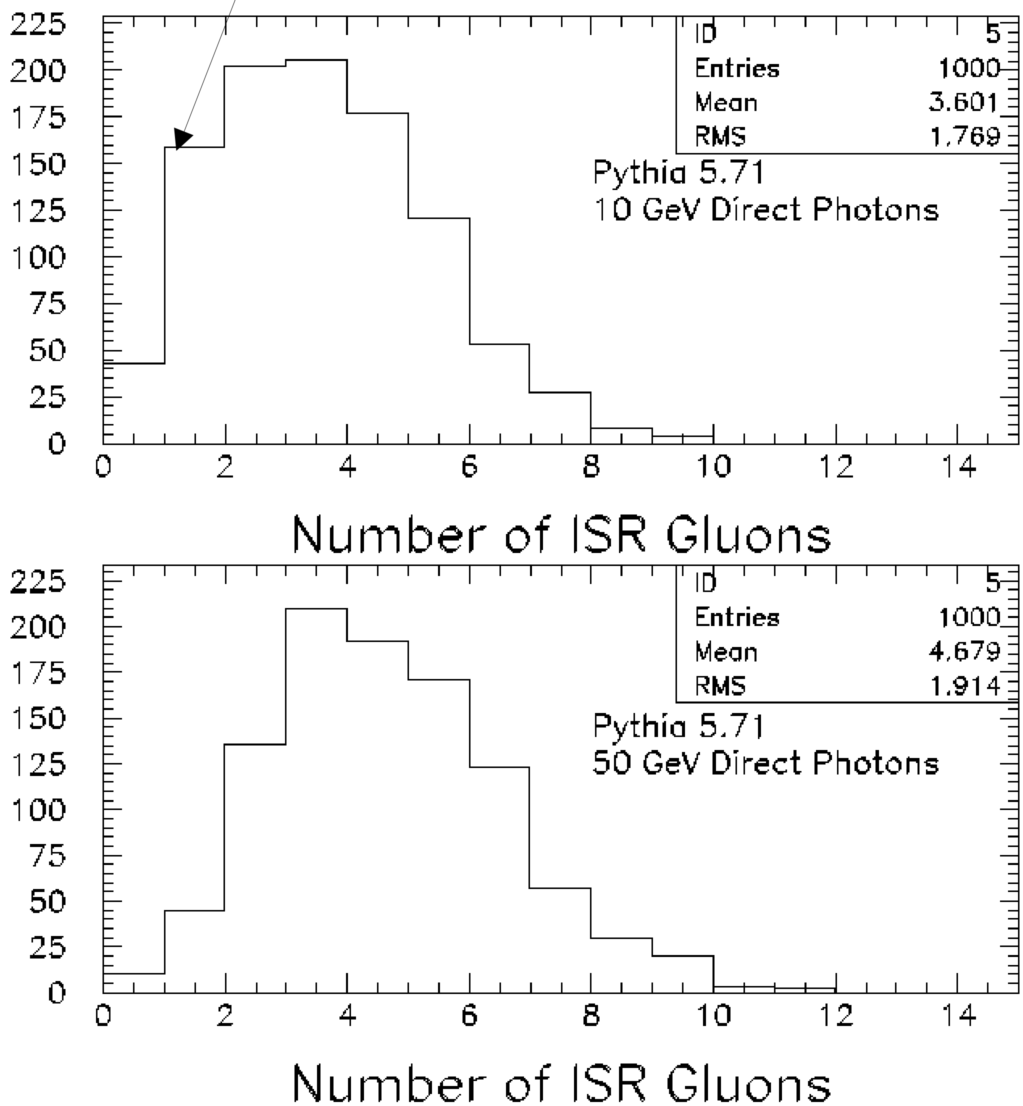
But only matters if the effect is not completely included in the model considered, typically NLO QCD

Study the Number and Pt of Initial State Gluons with PYTHIA Monte Carlo

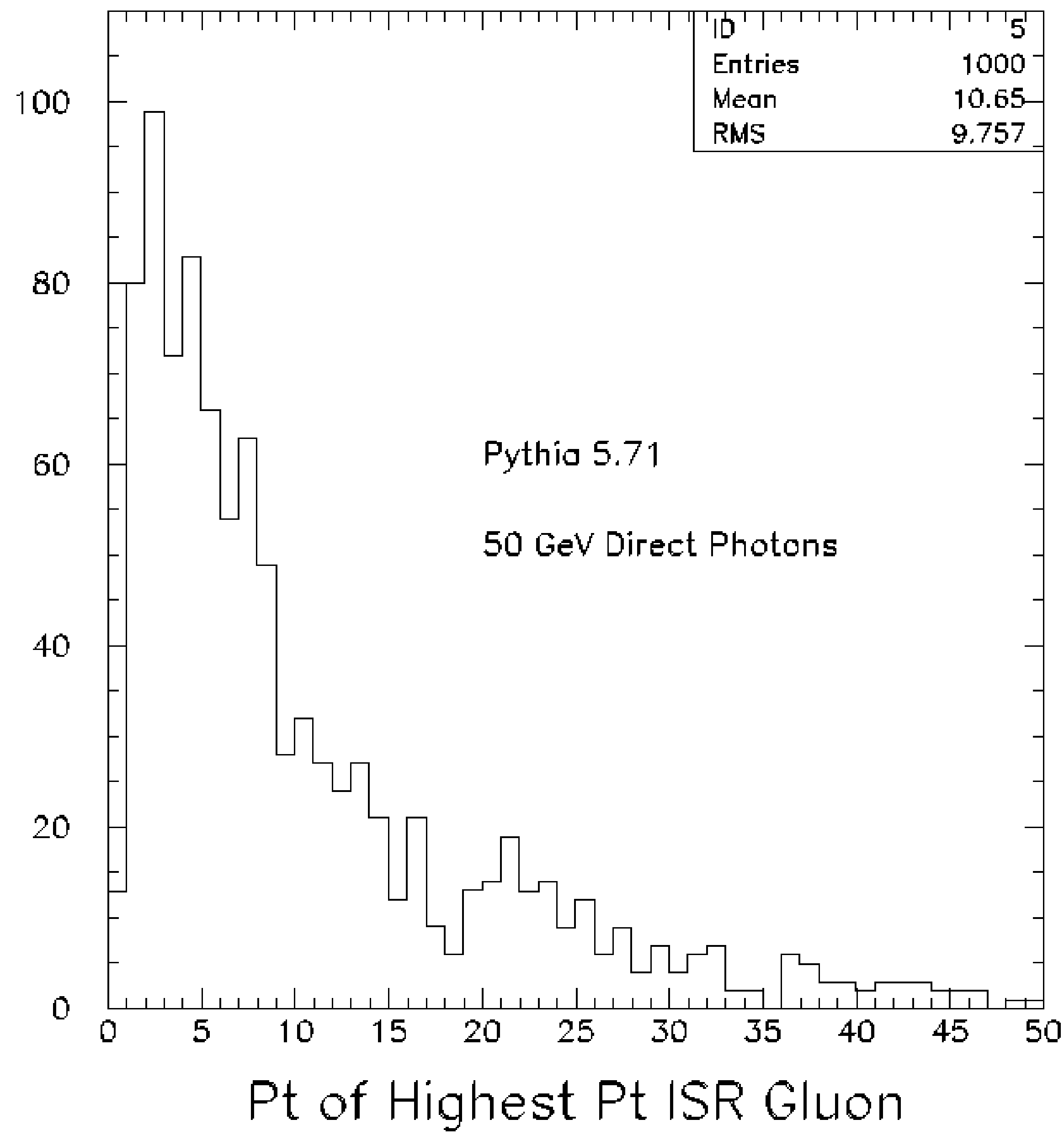
Cross Sections in Hadron Collisions

PYTHIA 1.8 TeV Direct Photons

NLO QCD Has Zero or One

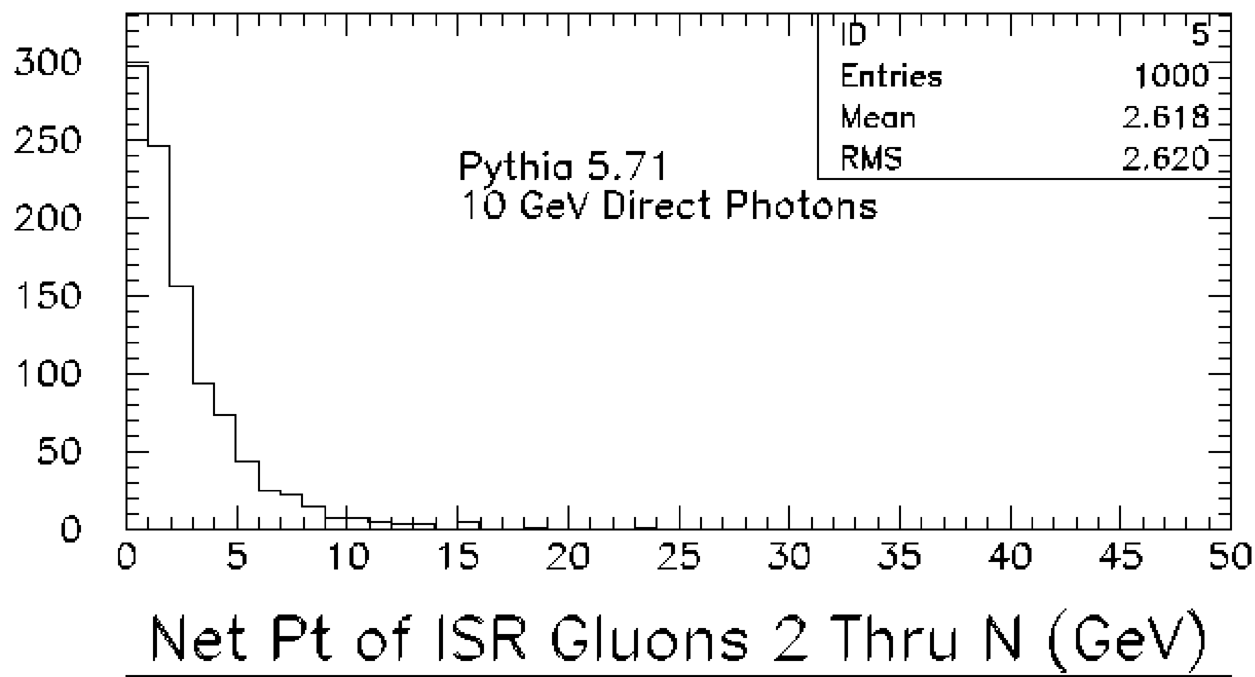


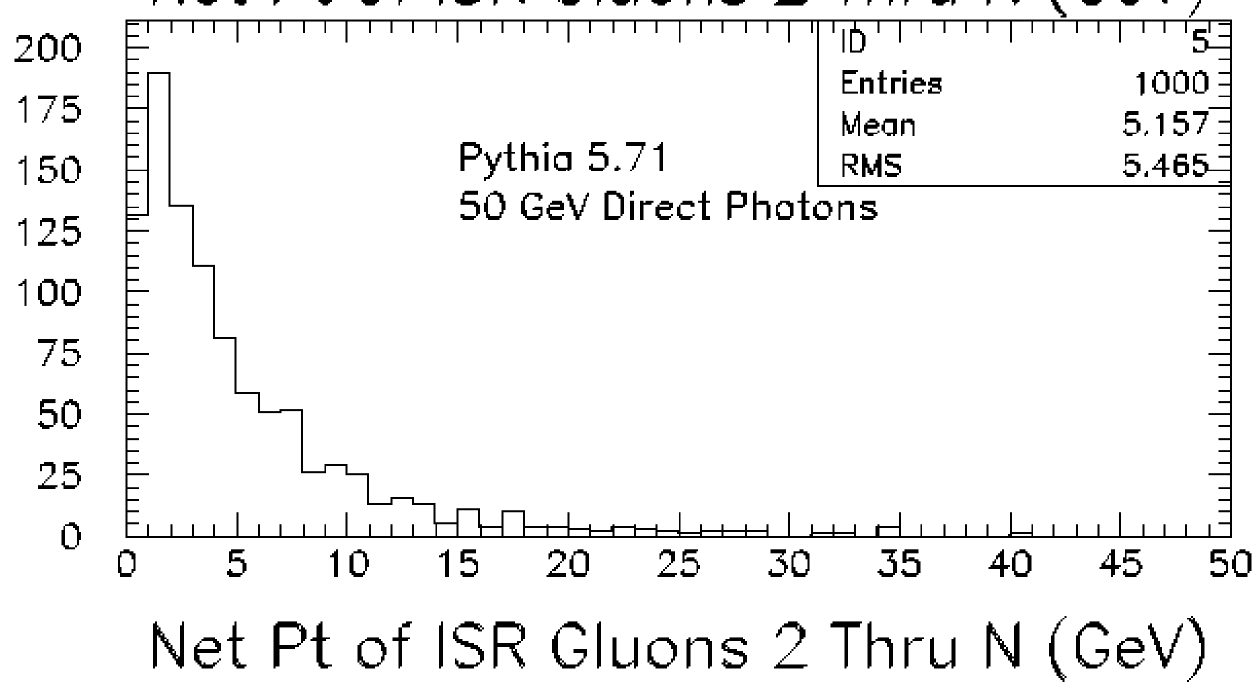
Cross Sections in Hadron Collisions



Cross Sections in Hadron Collisions

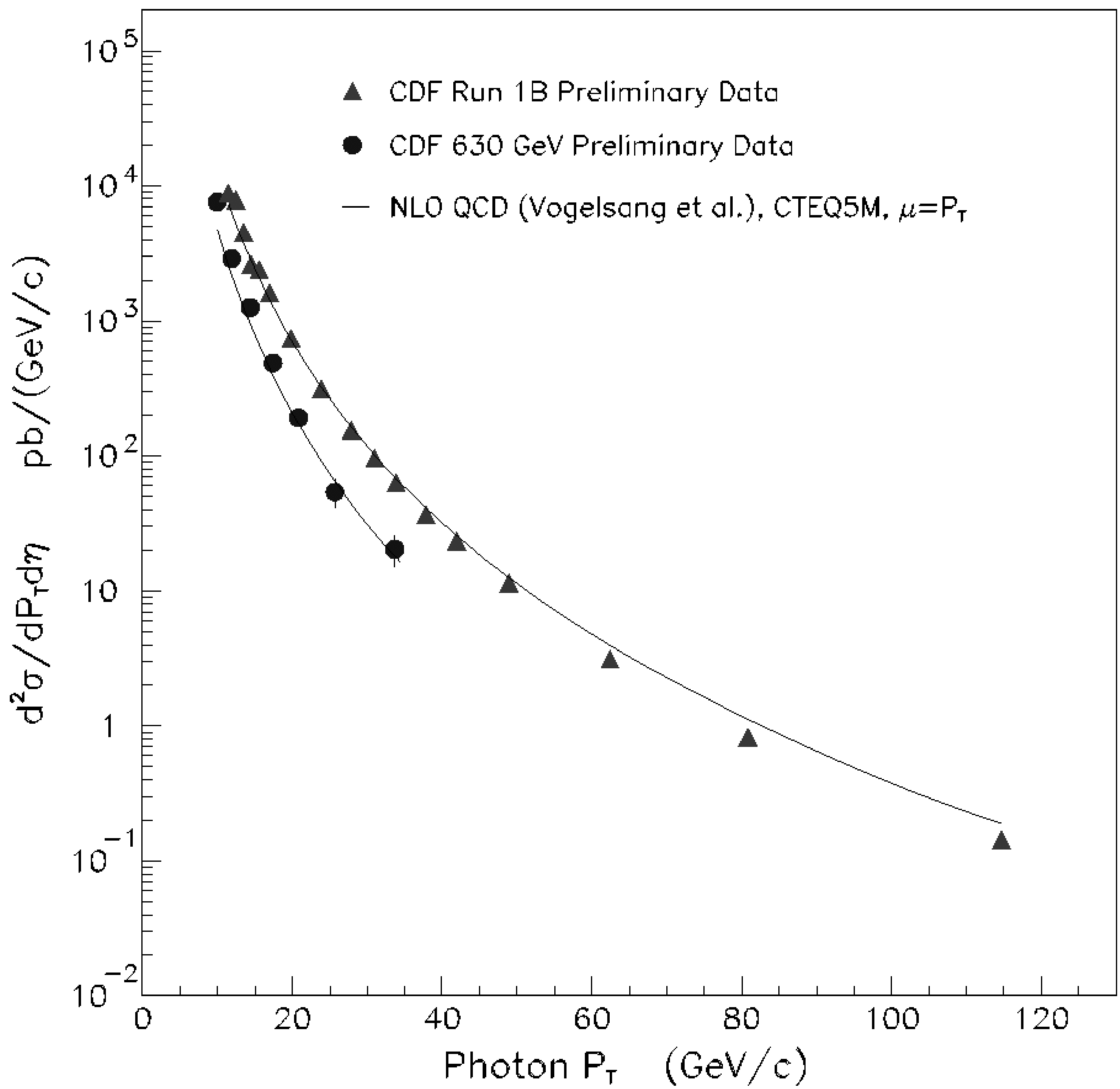
Net Pt of Initial State Gluons beyond NLO is 2.5-5 GeV at 1.8 TeV, 2-3 GeV at 630 GeV (not shown)



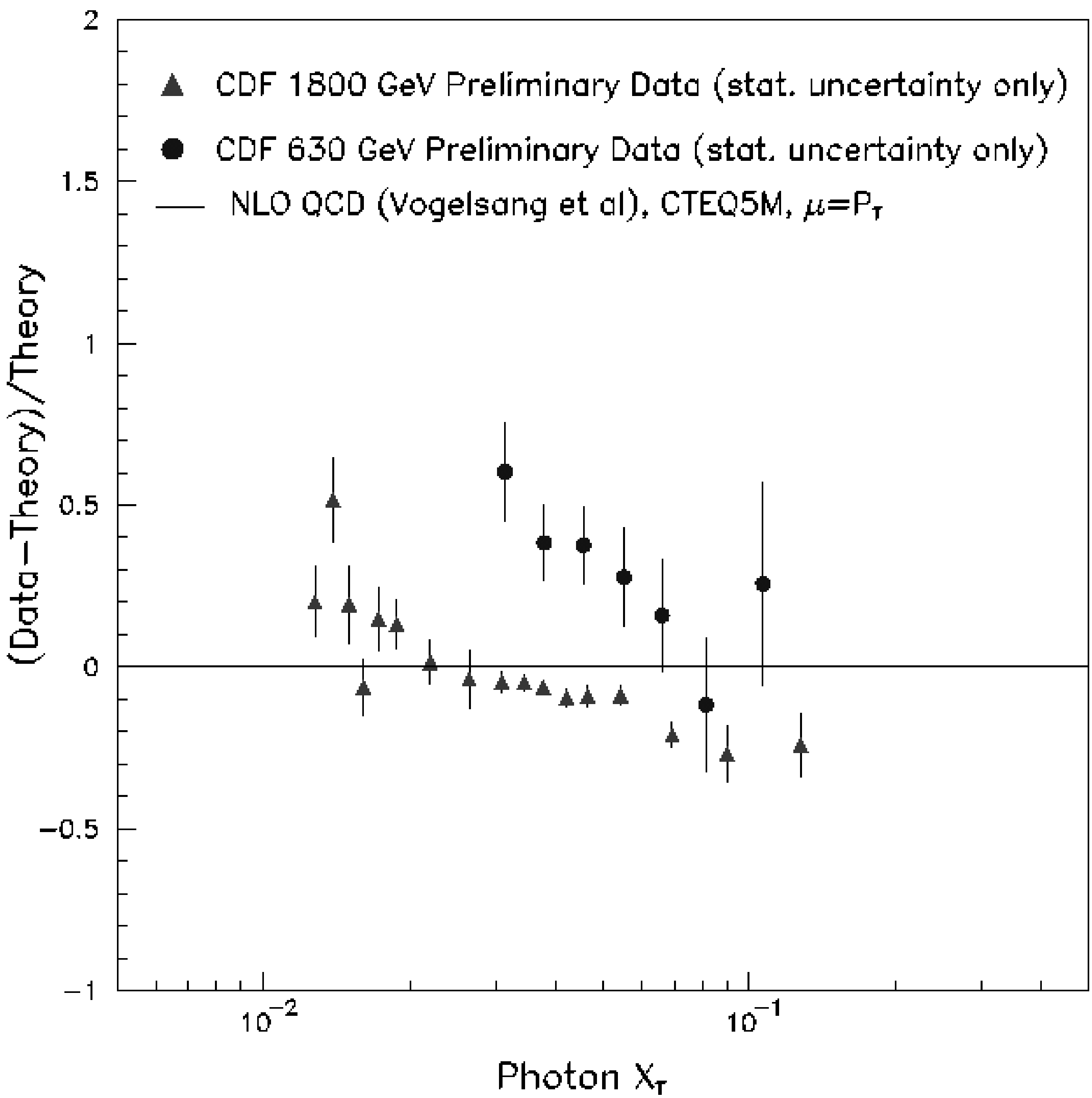


Cross Sections in Hadron Collisions

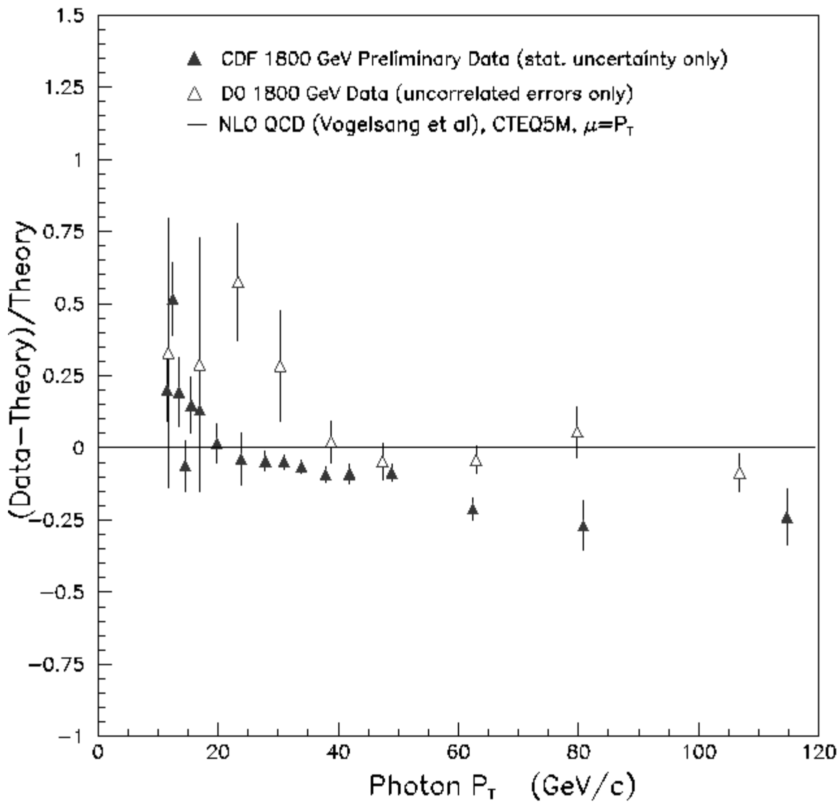
Check CDF Measurements at 1.8 TeV and 630 GeV

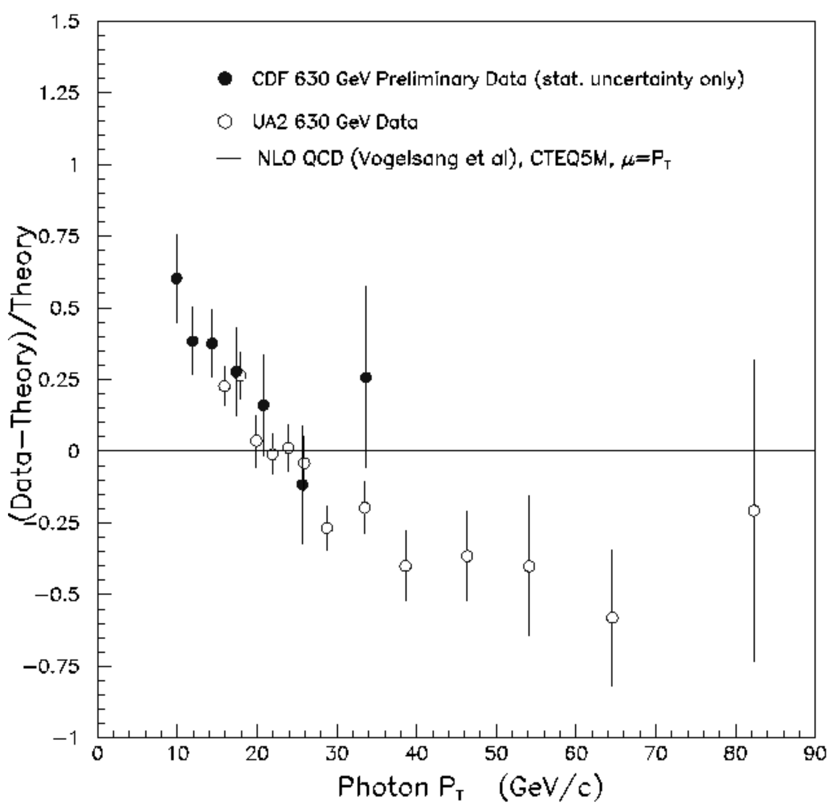


Cross Sections in Hadron Collisions



Cross Sections in Hadron Collisions





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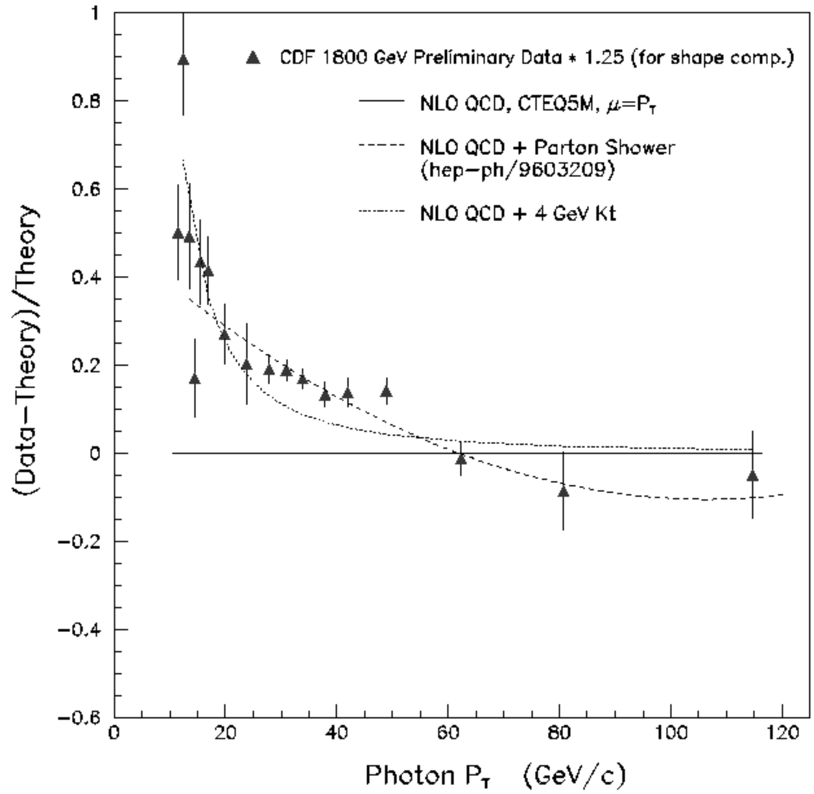
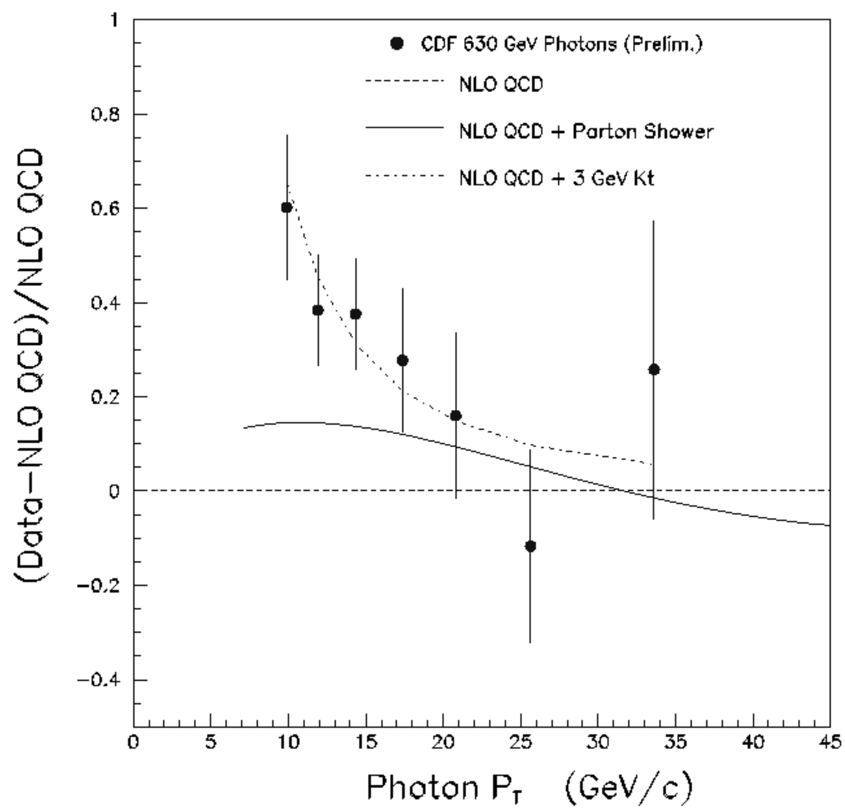
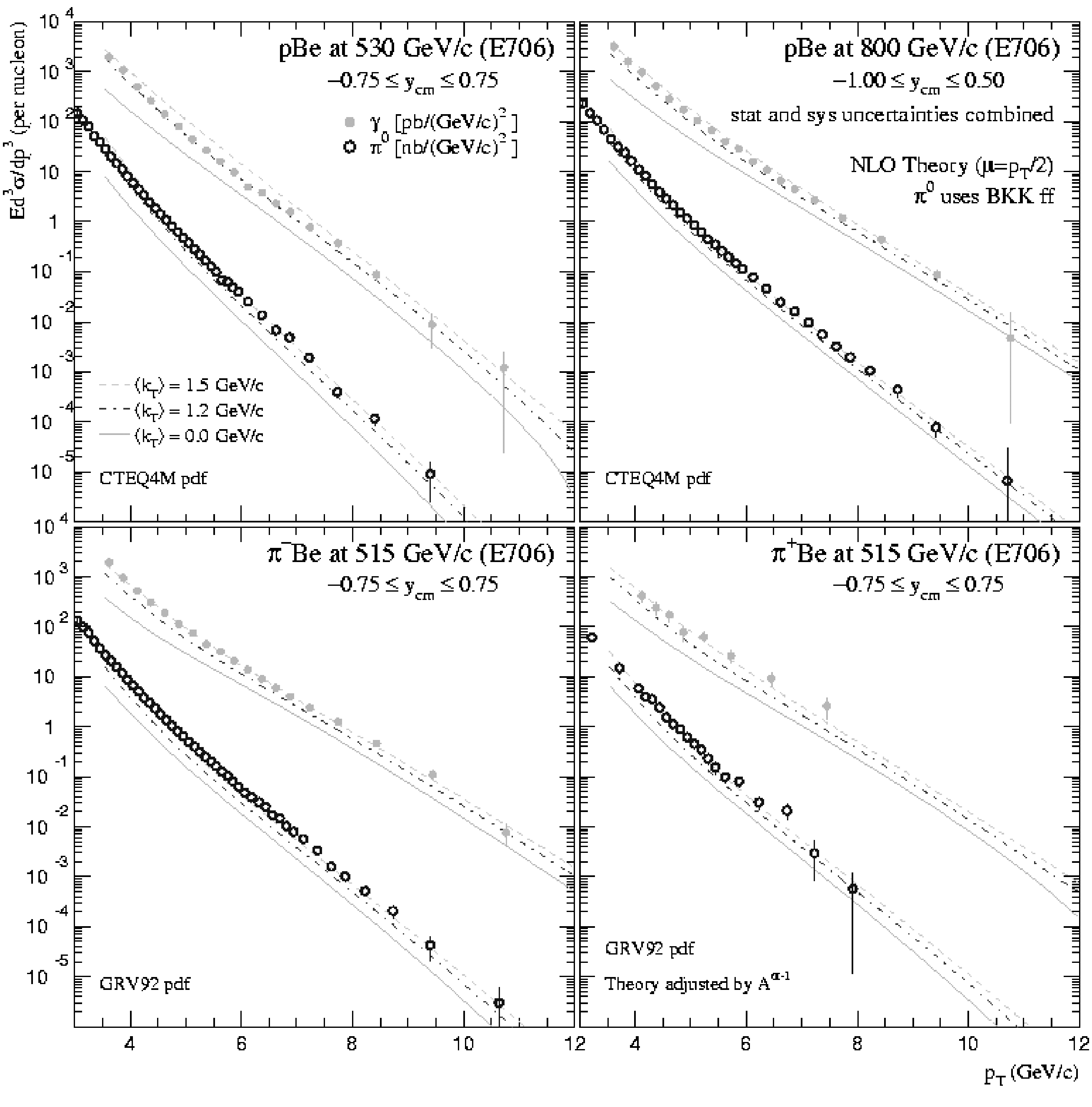


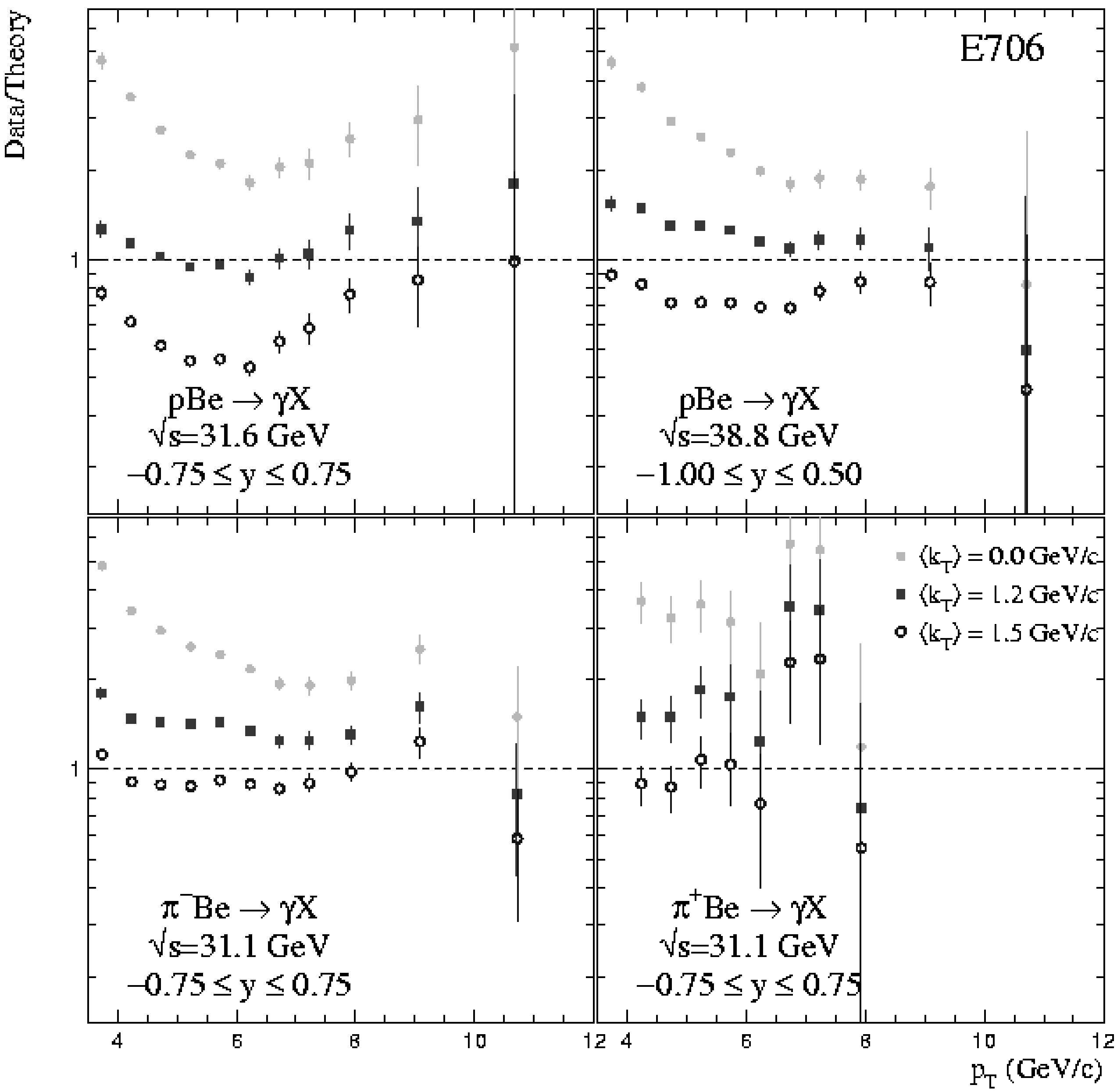


Cross Sections in Hadron Collisions

Fixed Target experiment E706 sees the largest disagreement with NLO QCD

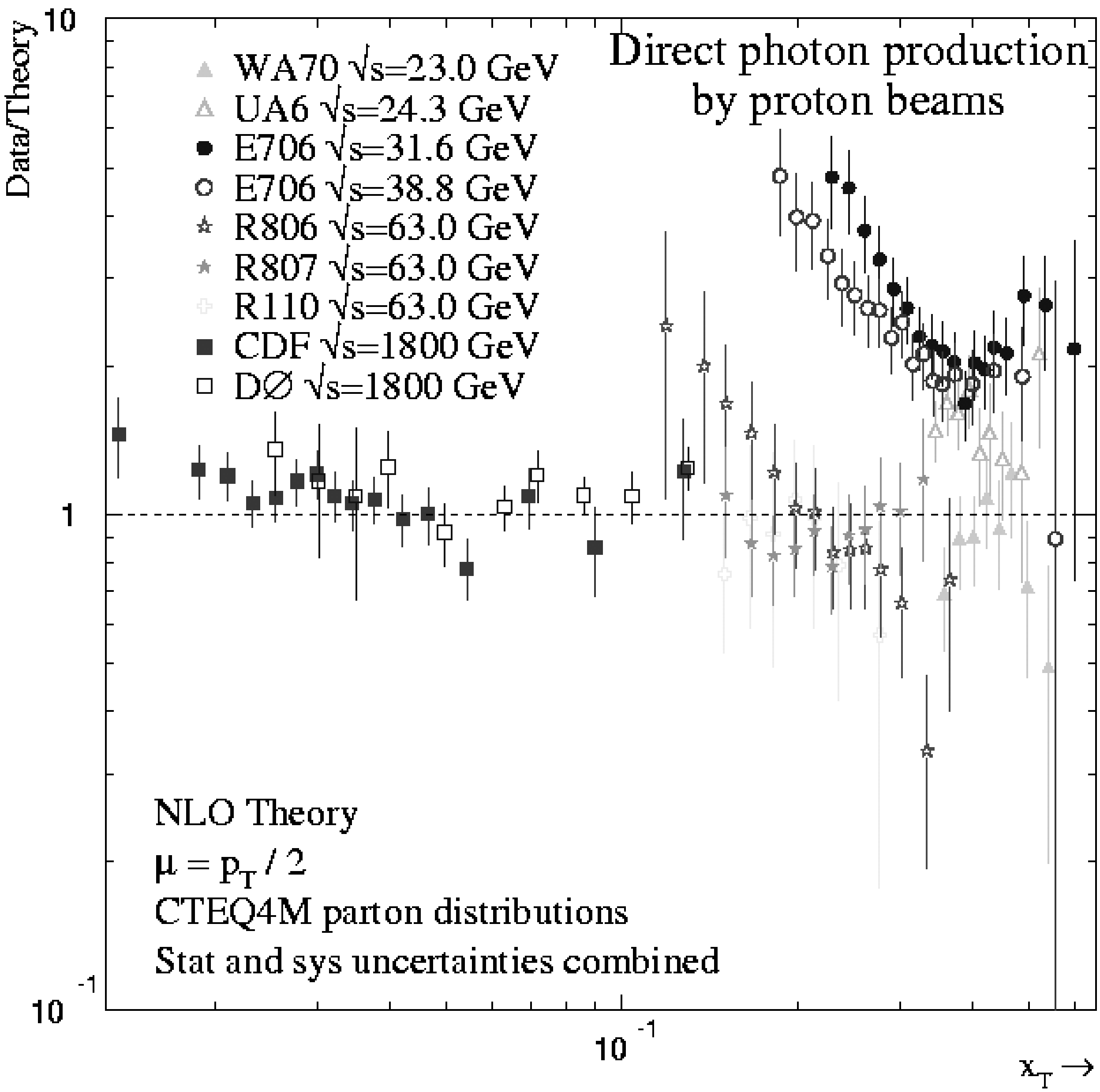


Cross Sections in Hadron Collisions



Cross Sections in Hadron Collisions

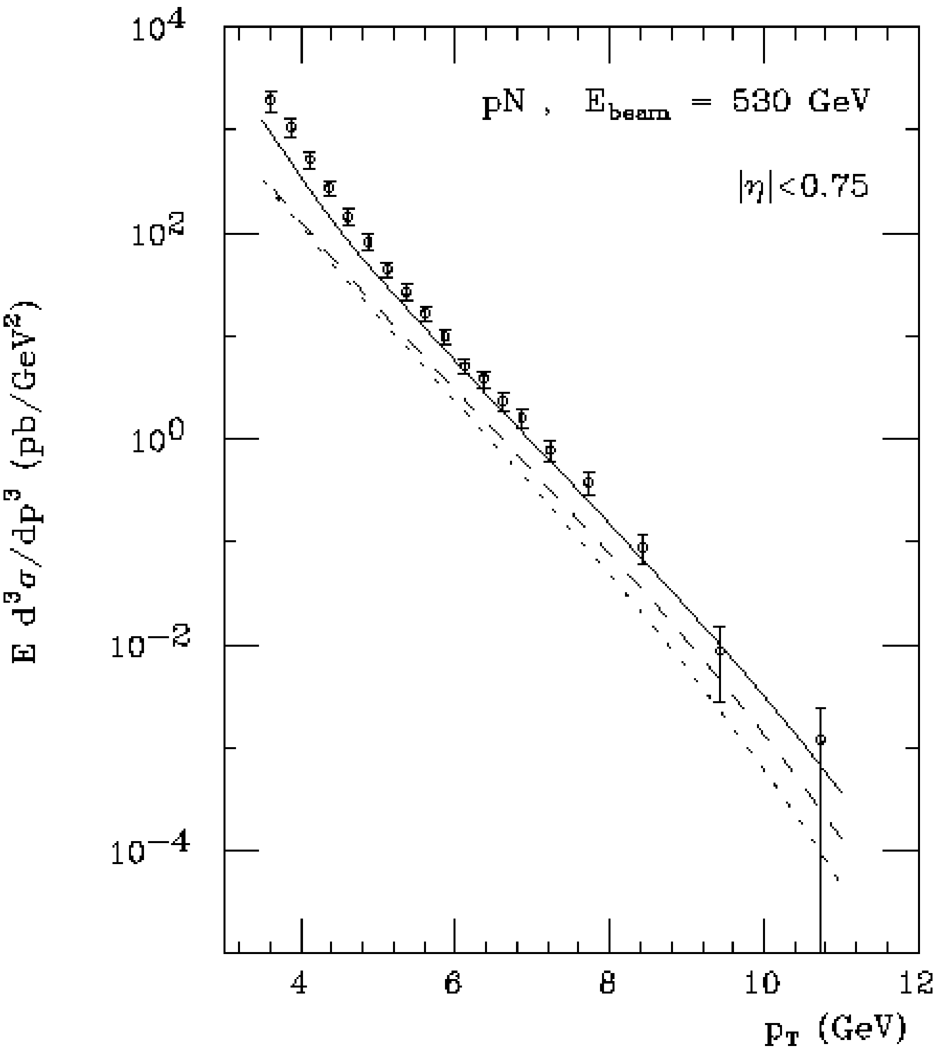
A summary plot of various fixed target and collider experiments, not all data agree!



Cross Sections in Hadron Collisions

Calculations using Pt Resummation of Initial State Gluons are on the Horizon

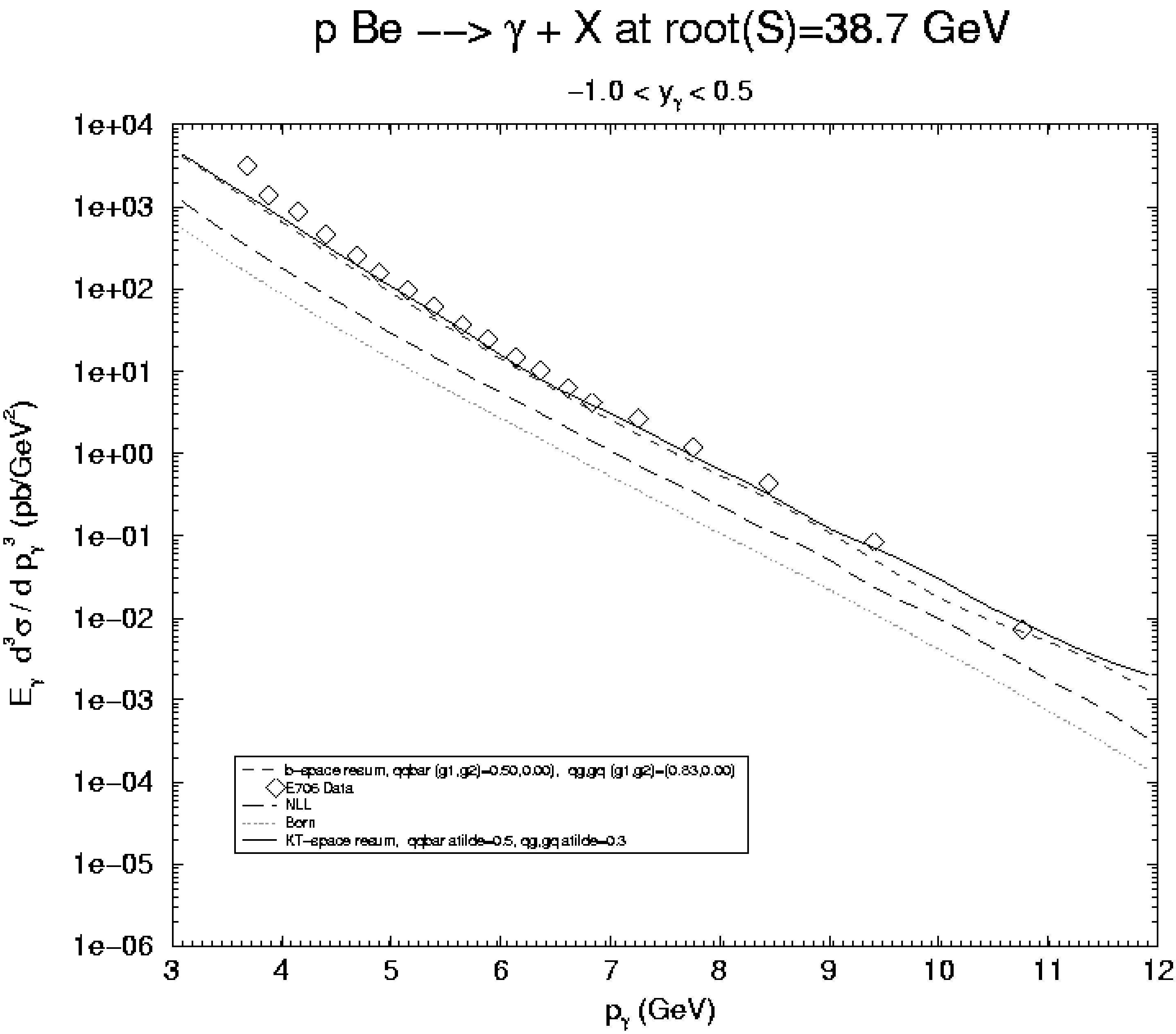
Laenen, Sterman, Vogelsang



Cross Sections in Hadron Collisions

Calculations using Pt Resummation of Initial State Gluons are on the Horizon

Fink and Owens



Cross Sections in Hadron Collisions

In addition, Considerable Effort in Merging Parton Showers and NLO QCD for many processes.

Likely to impact Direct Photons

Conclusions

Photon Production in e+e-, ep, and pp provides many unique tests of Perturbative QCD

Overall there is excellent agreement between QCD models and data.

Where discrepancies appear, theory is being pushed to higher orders