PROMPT PHOTONS in PHOTOPRODUCTION at HERA.

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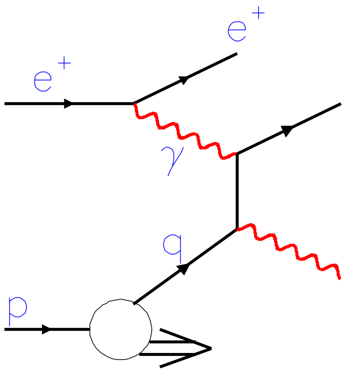
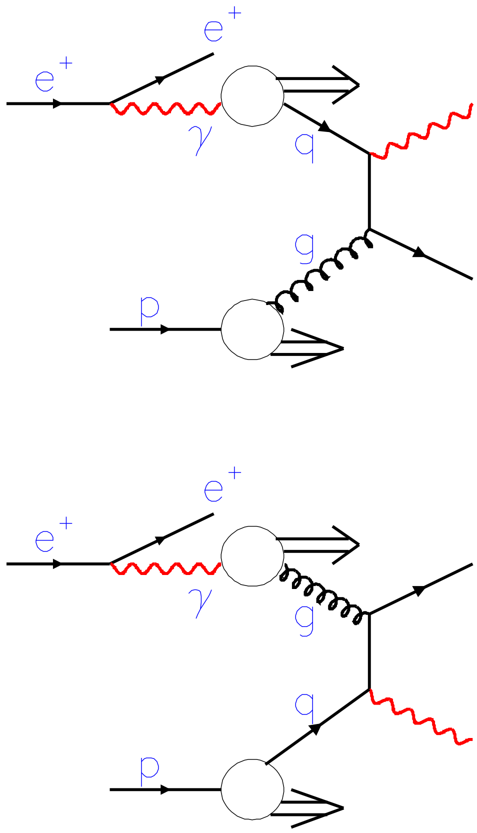
Contents

- Inclusive prompt photon production
- Prompt photon + jet
- Determine $<k_T>$ for partons in proton.

Prompt photon processes.

At LO the diagrams are of the following kinds:





Direct **Resolved (examples)**

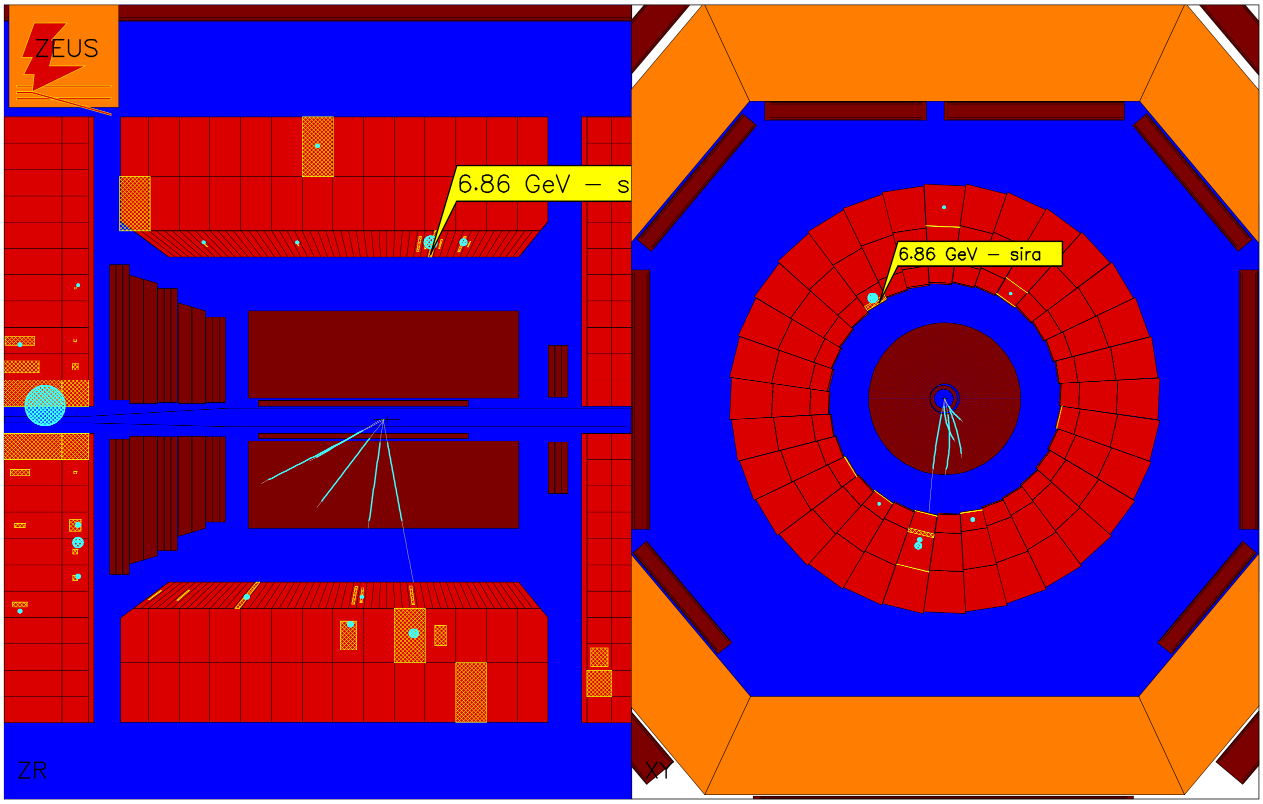
One LO direct process: Direct Compton process.

In the resolved process, HERA kinematics favour: g from proton, q from incoming γ.

ALL measurements here are photoproduction.

($Q^2 <\approx 1\text{GeV}^2$)

Measurement at HERA:



ZEUS barrel calorimeter $(-0.7 < \eta < 0.9)$
has good granularity to separate high E_T γs from π^0, η backgrounds.
(mainly from $\gamma p \to$ dijets.)

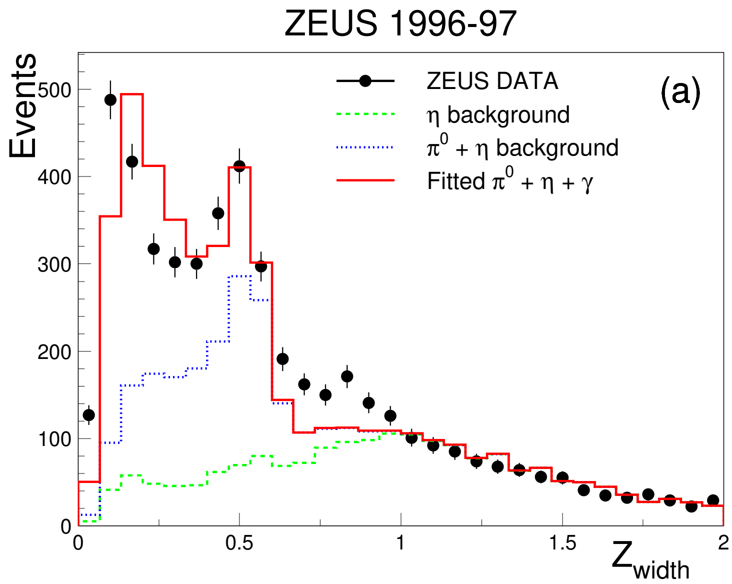
Isolation Criterion:

within cone in η, ϕ of radius 1 around γ demand

$$\sum E_T \; < \; 0.1 \, E_T(\gamma)$$

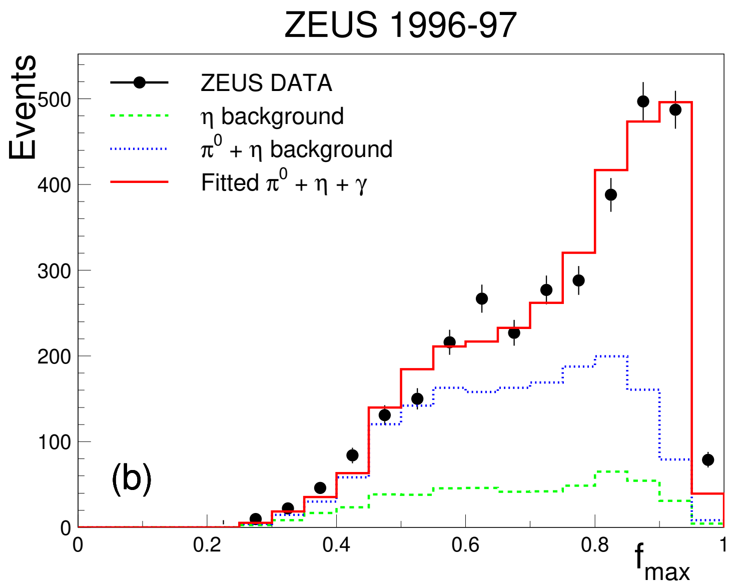
Removes most π^0, η and γs radiated from final state quarks in dijet events.

Width of photon candidate in Z



Structure indicating photons and π^0, and a multi-pion tail modelled as η mesons.

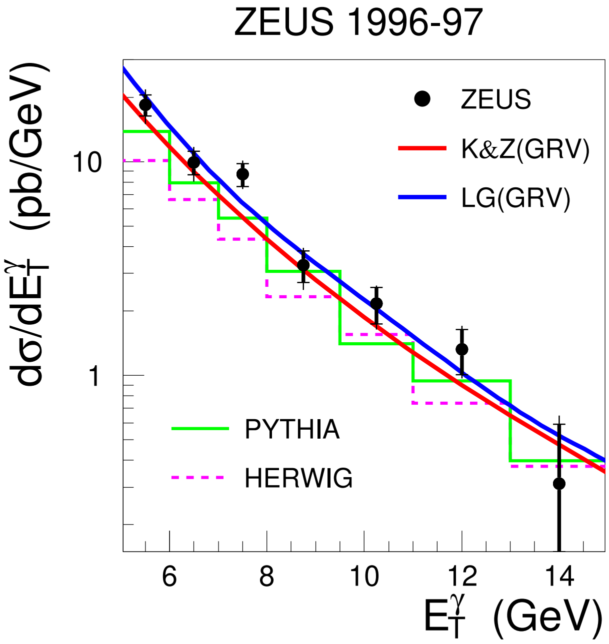
Remove broad clusters. Then look at fraction of cluster energy in highest energy cell:

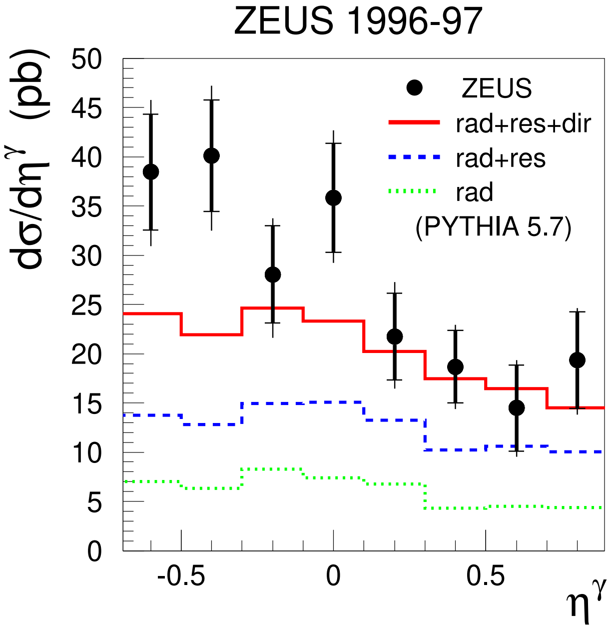


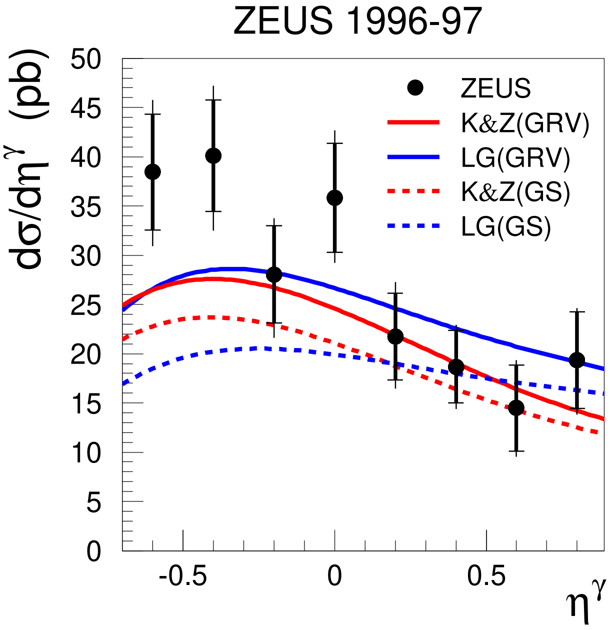
γ signal can be extracted by comparing numbers of events with $f_{max} > 0.75$ and < 0.75

INCLUSIVE PROMPT PHOTONS

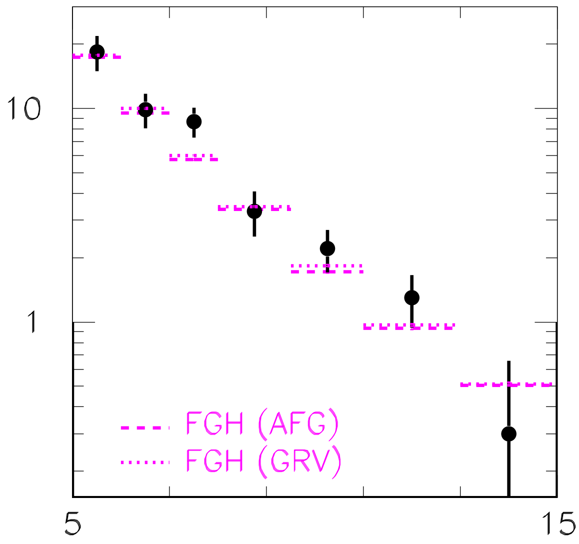
$E_T > 5$ **GeV,** $134 < W < 285$ **GeV** **PLB 472 (2000) 175**



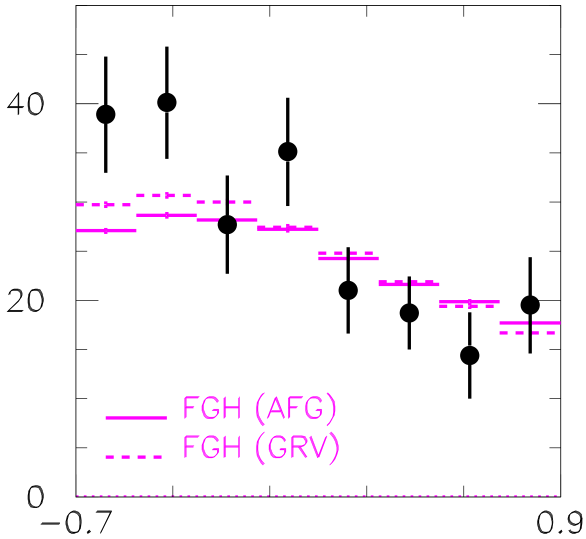




PYTHIA does only fairly well (HERWIG is lower).
NLO calculations an improvement.
GRV photon structure apparently favoured.
Signs of a discrepancy?

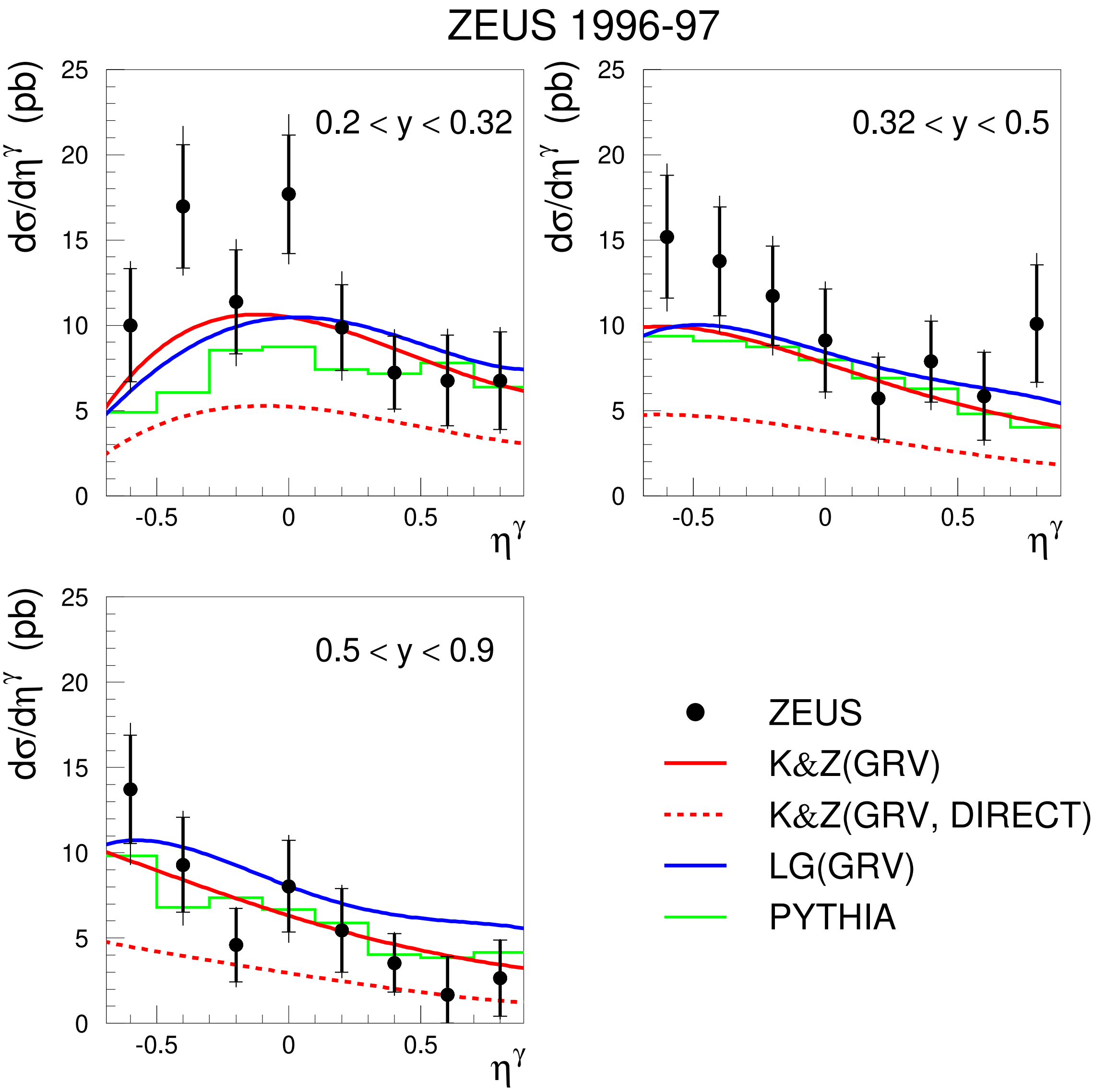


Now we have new NLO calculations from FGH = Fontannaz, Guillet, Heinrich

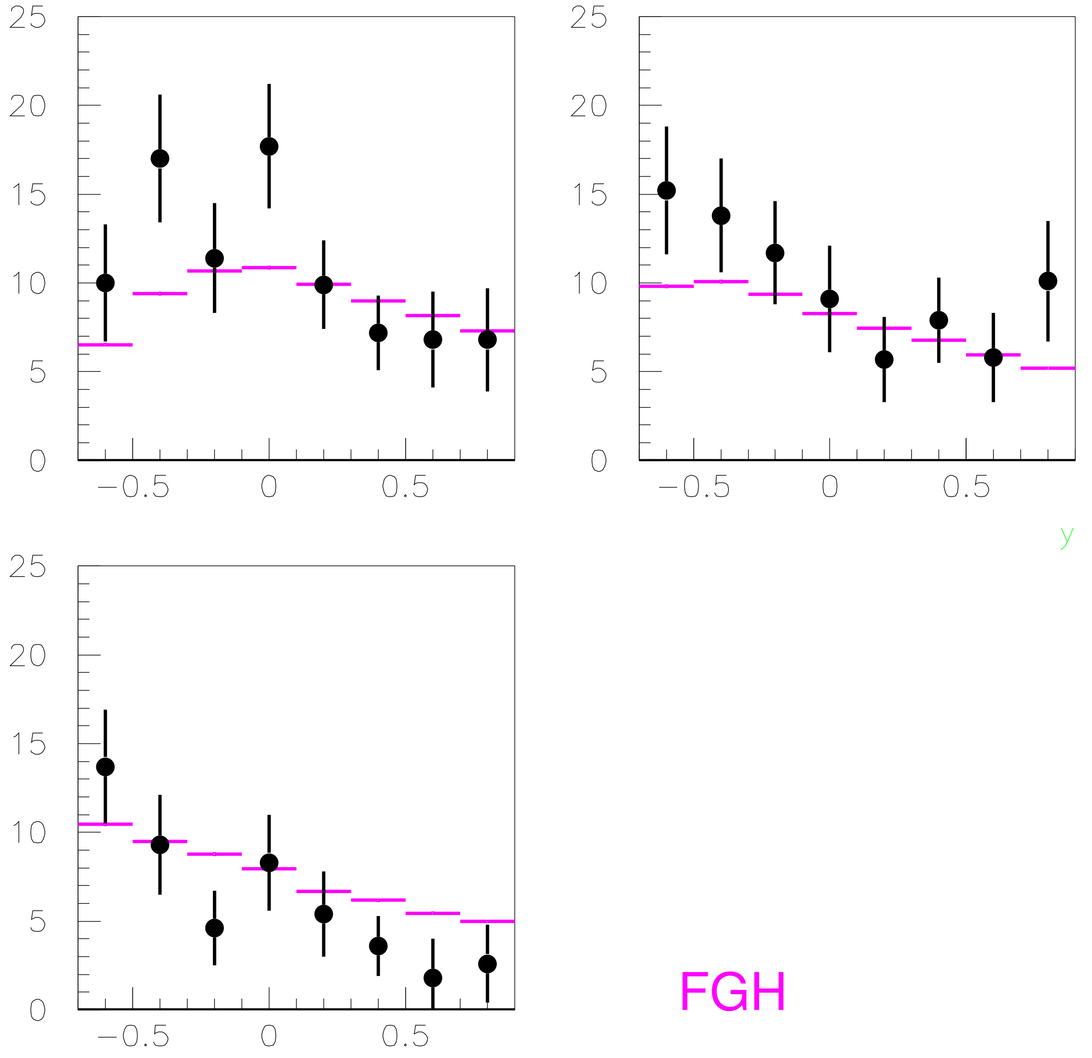


FGH an improvement?

Divide incident E_γ range into 3 bands:



As $E_\gamma = yE_e$ increases, peak moves to –ve η.
Suggestion of possible discrepancy at high x_γ.

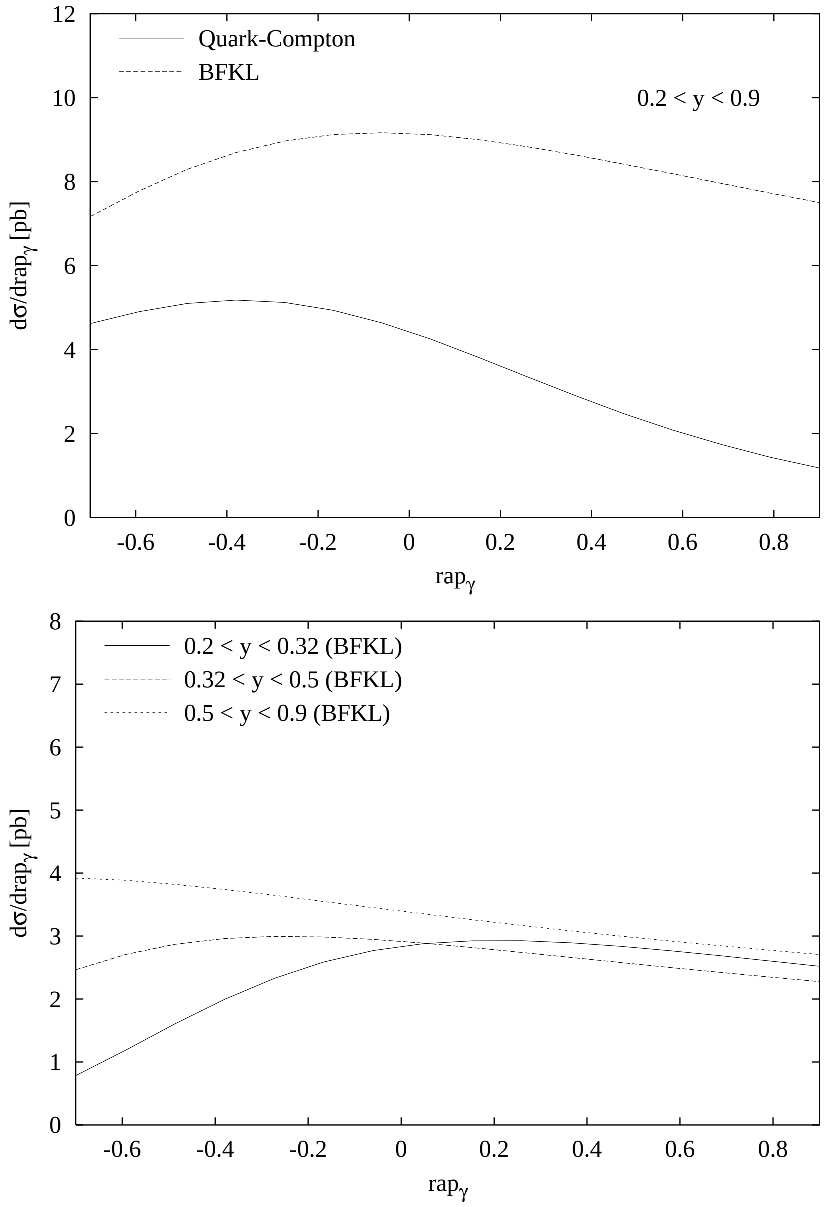


The problem remains!

FGH resembles LG + box diagram

BFKL Calculation from Hoyer, Maul, Metz

hep-ph/0003257, Eur.J.P. C17 (2000) 113



(A. Metz)

The contribution seems rather large and is not the right shape to solve the present problem!

PROMPT PHOTON + JET

Can use photon + jet events to evaluate x_γ.

$$x_\gamma^{meas} = \sum_{\gamma+jets}(E-p_z) / \sum_{all\ event}(E-p_z)$$

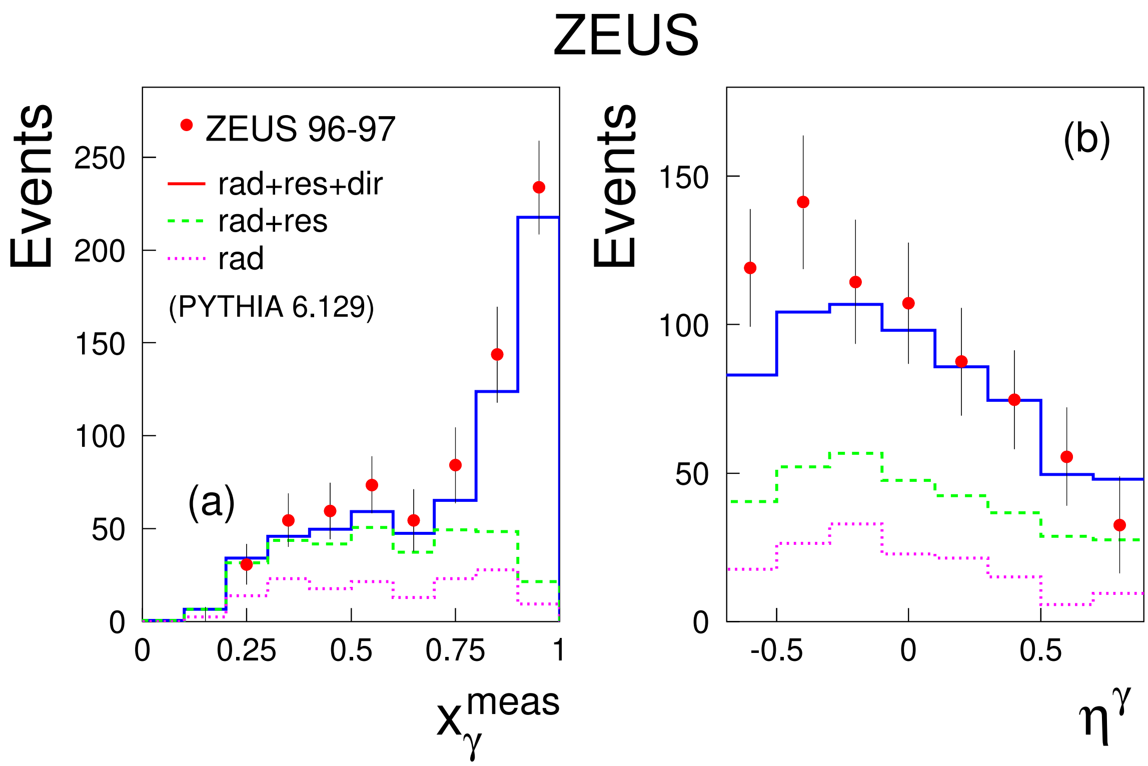
Select: photon: $E_T > 5$ GeV, $-0.7 < \eta < 0.9$

jet: $E_T > 5$ GeV, $-1.5 < \eta < 1.8$

$0.2 < y_{JB} < 0.7$

$\equiv$ γp c.m. energy $134 < W < 251$ GeV

Jet finder: KTCLUS



Prominent peak near $x_\gamma = 1$ corresponding to **Direct Compton process** $\gamma q \to \gamma q$.

PYTHIA gives a good description of x_γ and now a reasonable distribution of η.

We do not yet have a suitable NLO calculation.
– differences are compatible with LO→NLO.
Note the different contributions.

Select a highly direct-enhanced sample
by requiring $x_\gamma^{meas} > 0.9$
to minimise effects of photon structure.

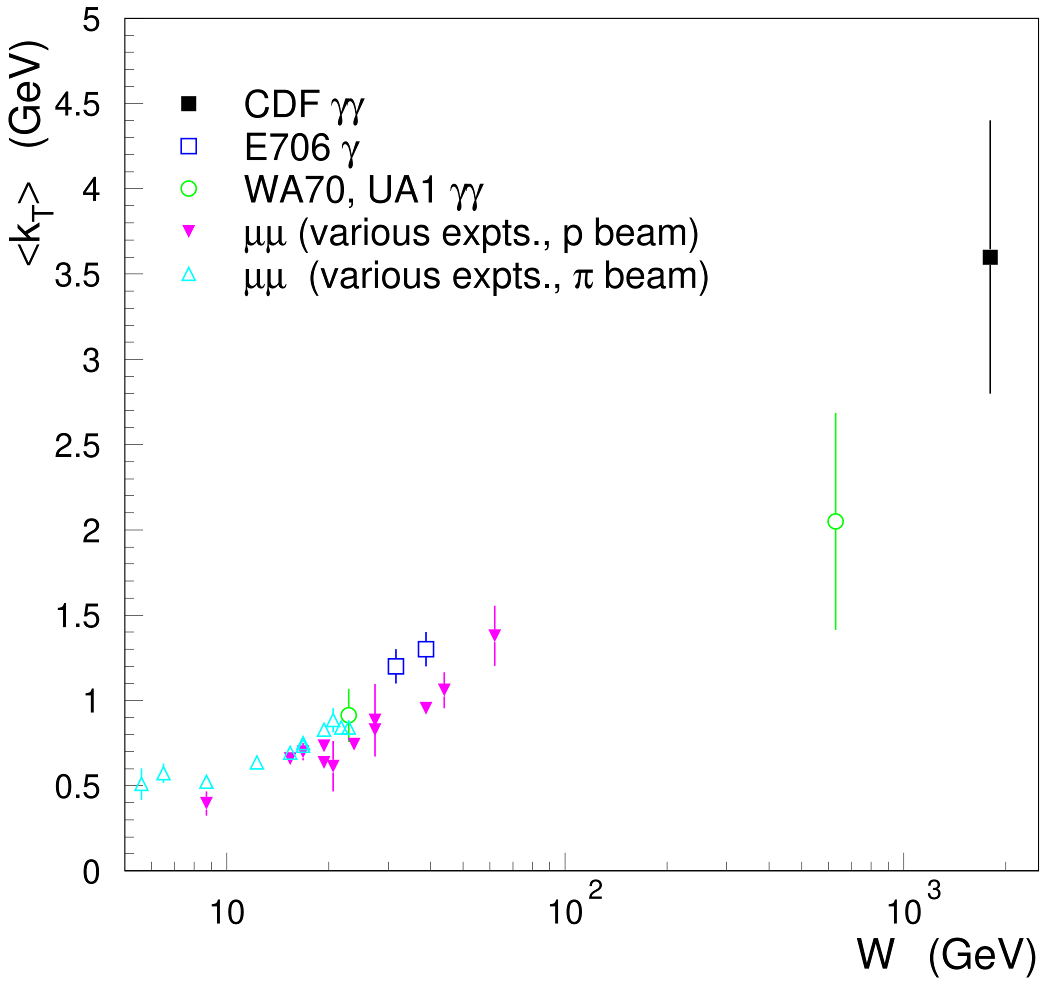
$<k_T>$ OF PARTONS IN PROTON

Background:

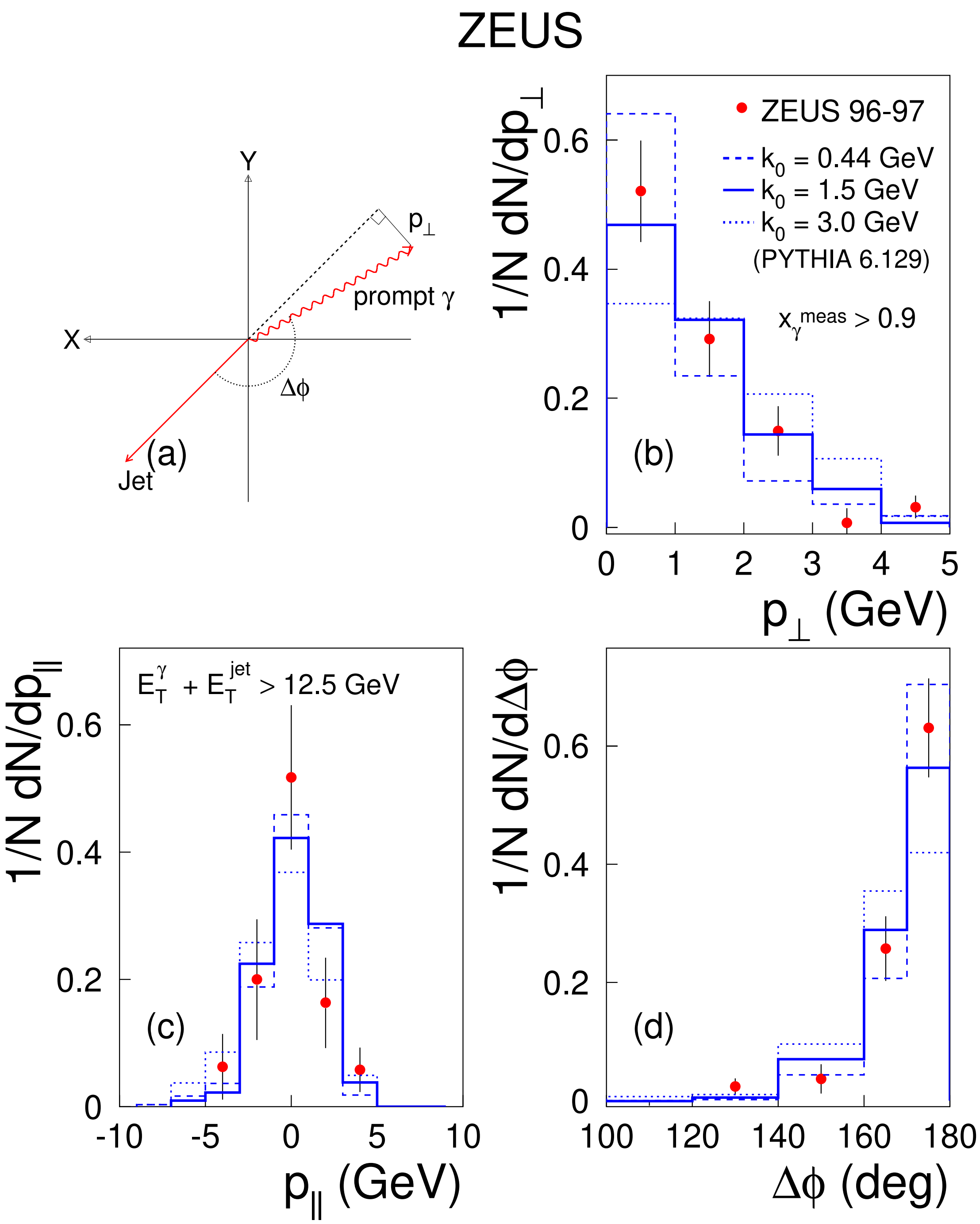
Many experiments have made measurements of effective $<k_T>$ of partons in proton:
Drell-Yan muon pairs
Prompt photons in hadron collisions.

Low energies: expect a value ≈ 0.5 GeV corresponding to size of proton

Higher energies: higher values obtained – initial state parton showers?

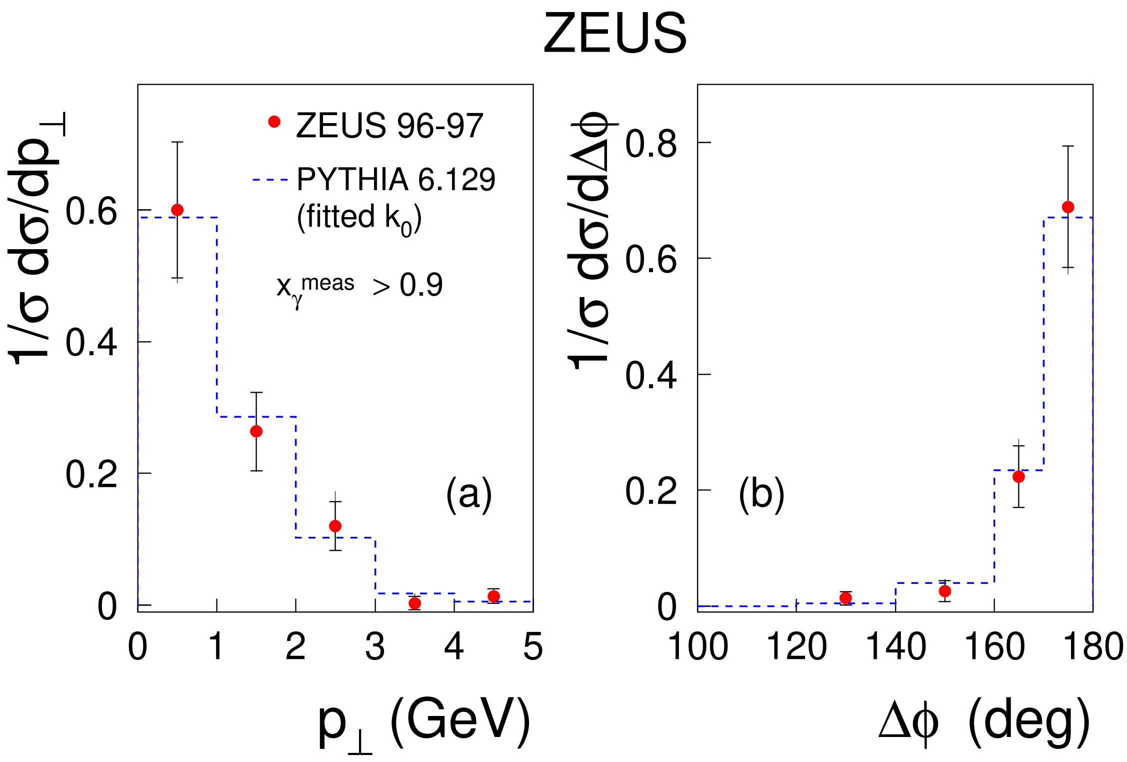


Use direct γ + jet kinematics to determine $<k_T>$



$p_\perp$ is best. No sensitivity in $p_{||}$

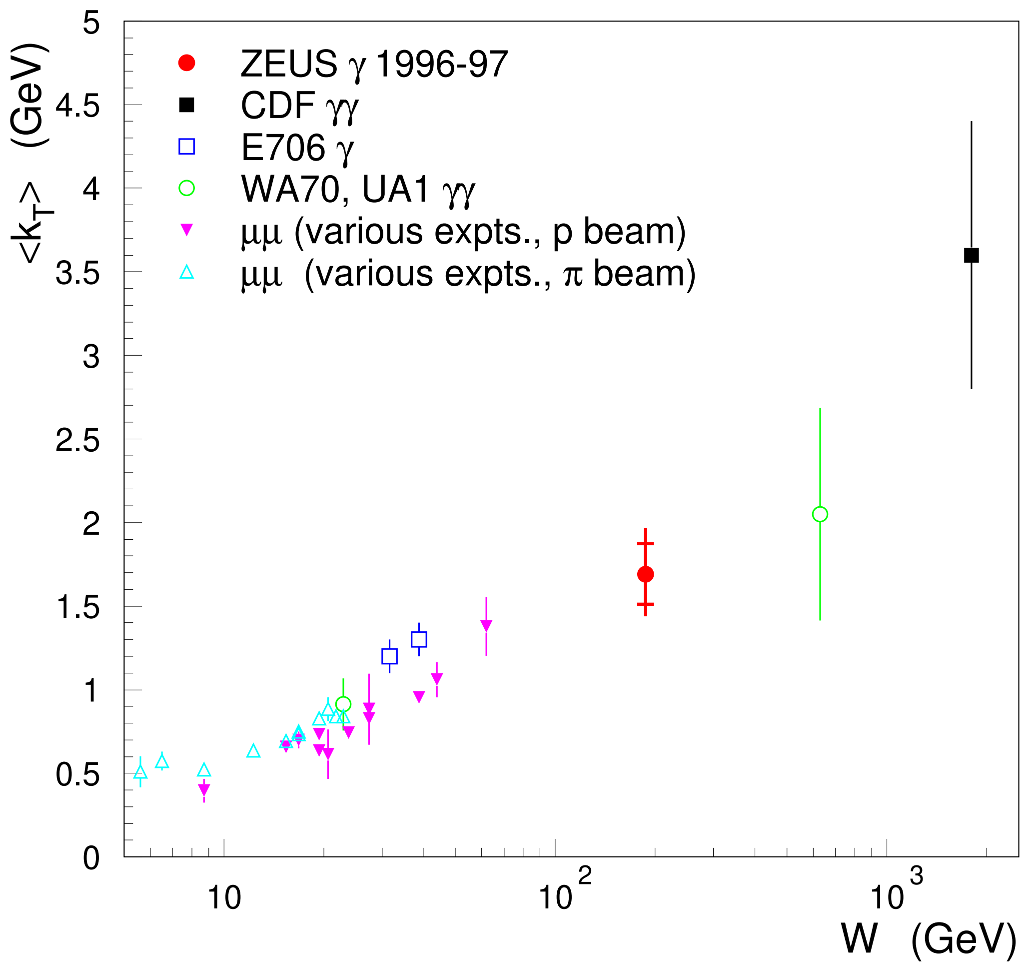
Normalised hadron-level Cross Sections.



Procedure to evaluate $<k_T>$:

– Use direct-enhanced sample to minimise sensitivity to resolved photon
– Vary 'intrinsic' contribution k_0 in PYTHIA.
– Fit $p_\perp$ distribution using series of k_0 values
– Use PYTHIA at parton level to incorporate parton shower effects
– Check with HERWIG: result $\approx 10\%$ higher

$$< k_T >= 1.69 \pm 0.18\ ^{+0.18}_{-0.20}\ \text{GeV}$$



Comments:

Factor $\sqrt{2}$ removed: 2 hadrons $\rightarrow$ only 1 in γp.

Different experiments use different methods, but the trend is evident.

ZEUS consistent with this trend.

(However increasing $<k_T>$ does not help the situation with ZEUS inclusive prompt photons.)

CONCLUSIONS

- **Inclusive prompt photons** measured by ZEUS. ($E_T > 5$ GeV, $134 < W < 285$ GeV) Good agreement with models over forward rapidities and in E_T
- Suggestion of low-η enhancement needs further study. Appears to be in events without an observed jet.

- **Photon + jet distributions have been measured.**
- Strong Direct Compton signal. Good PYTHIA description.
- Use direct γp events to determine $<k_T>$ for partons in proton.

$$< k_T >= 1.69 \pm 0.18\ ^{+0.18}_{-0.20}\ \text{GeV}$$

- Results consistent with rising trend in W seen in other experiments.

ZEUS: PROMPT PHOTON + JET in γp

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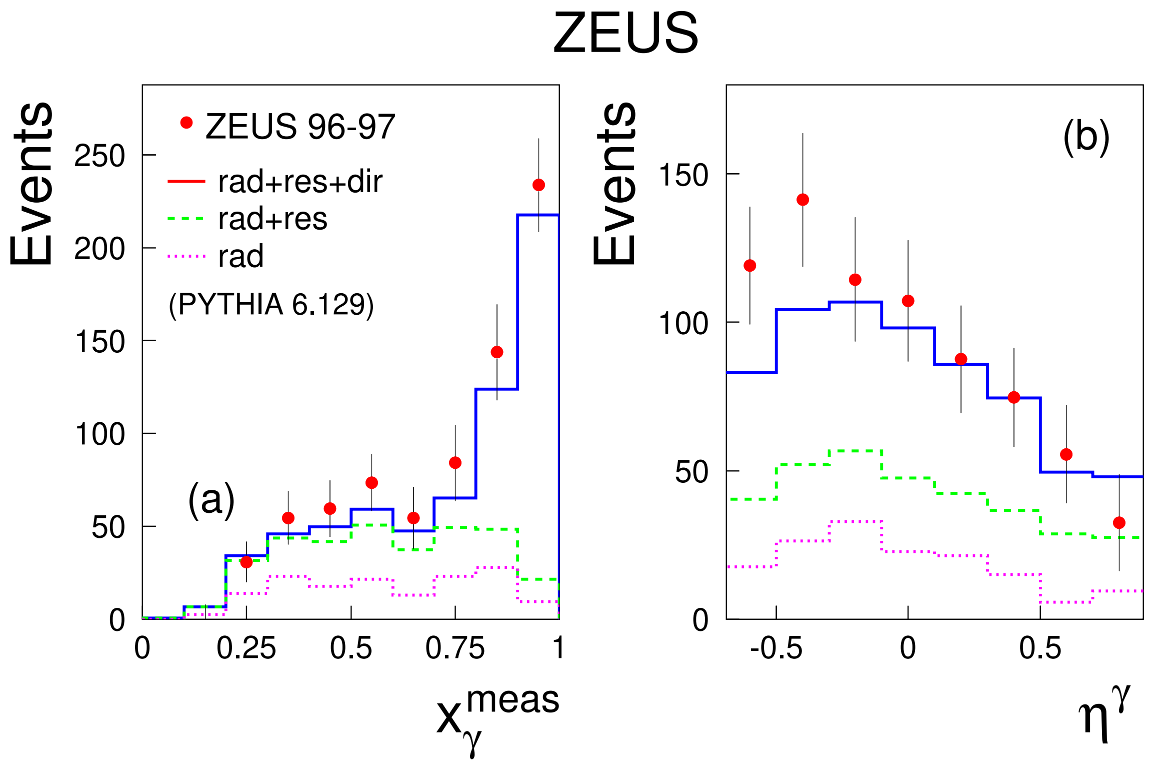


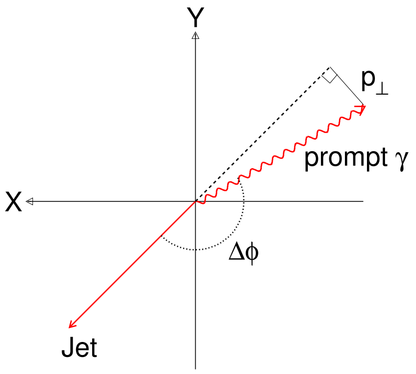
Prominent peak near $x_\gamma = 1$ corresponding to Direct Compton process $\gamma q \to \gamma q$.

PYTHIA OK! – differences are compatible with LO$\to$NLO.

Select a highly direct-enhanced sample by requiring $x_\gamma^{meas} > 0.9$ to minimise effects of photon structure.

$<k_T>$ OF PARTONS IN PROTON

Use direct γ + jet kinematics to determine $<k_T>$



– Use direct-enhanced sample to minimise sensitivity to resolved photon

– Vary ‘intrinsic’ contribution k_0 in PYTHIA.

– Fit $p_\perp$ distribution using series of k_0 values

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$< k_T >= 1.69 \pm 0.18 \; {}^{+0.18}_{-0.20}$ GeV