VIRTUAL PHOTON STRUCTURE AT HERA.

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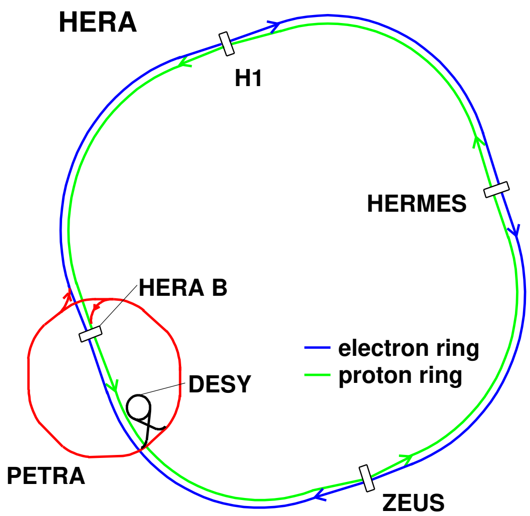
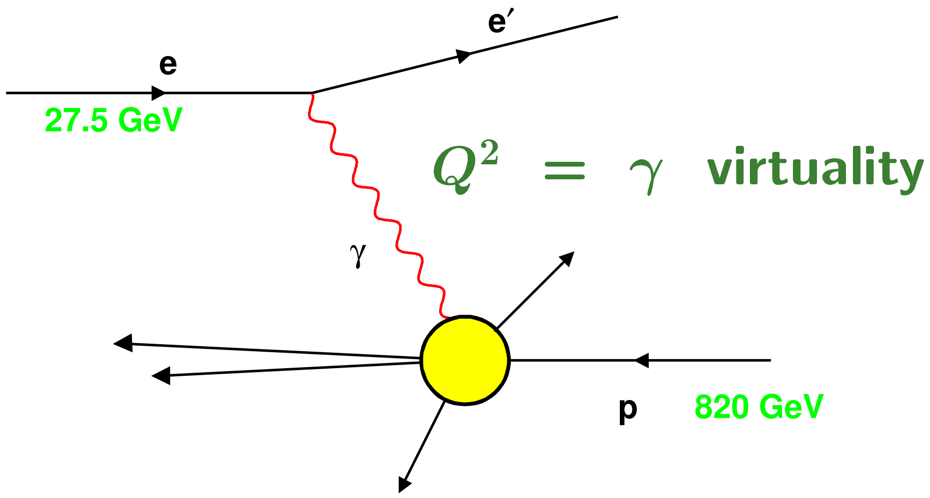
THE HERA COLLIDER



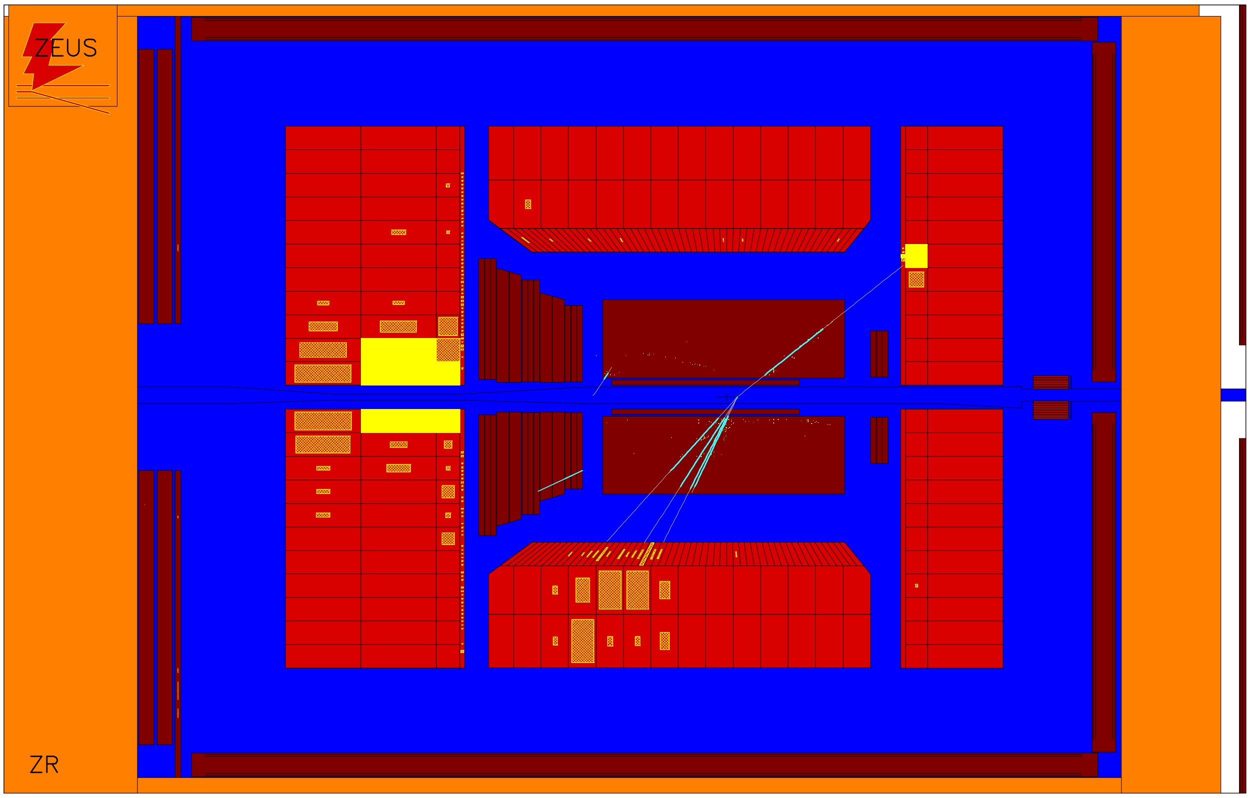


$Q^2 \approx 0$ — photoproduction γp
$Q^2 = O(1 \text{ GeV}^2)$ — 'Low Q^2' transition region
$Q^2 \gg 1 \text{ GeV}^2$ — Deep Inelastic Scattering (DIS)

Wish to study photon structure over these regions with special regard to transition region and DIS.

DIS AT HERA

A typical DIS event



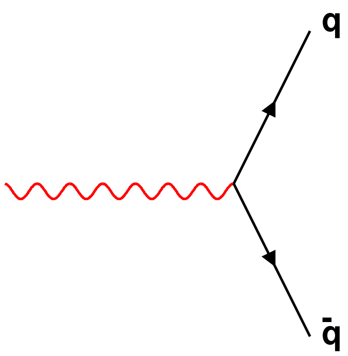
At lowest order (quark parton model) the virtual photon ejects a single quark from the proton: $\rightarrow$ one jet

No equivalent in photoproduction ($Q^2 \approx 0$)

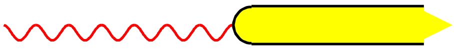
Can tag with e' for $Q^2 \gtrsim 0.2$ GeV ^{2} using low-angle 'beam-pipe' + rear calorimeters $\rightarrow$ measure dijet events through transition region from photoproduction.

Use tag to reconstruct $\gamma^* p$ c.m. frame.

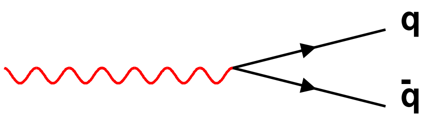
TYPES OF PHOTON COUPLING



point-like (perturbative)



hadronic (non-perturbative)



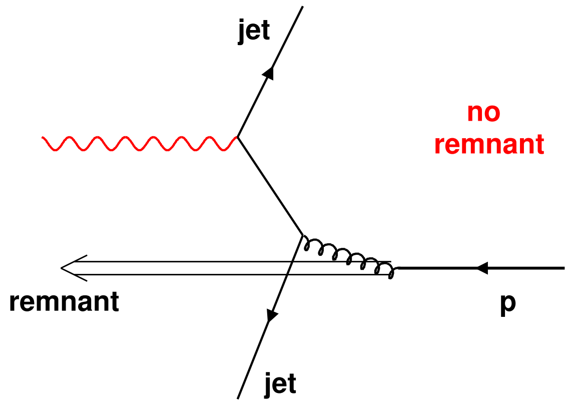
anomalous (perturbative)

These couplings can in principle be studied at all Q^2 .

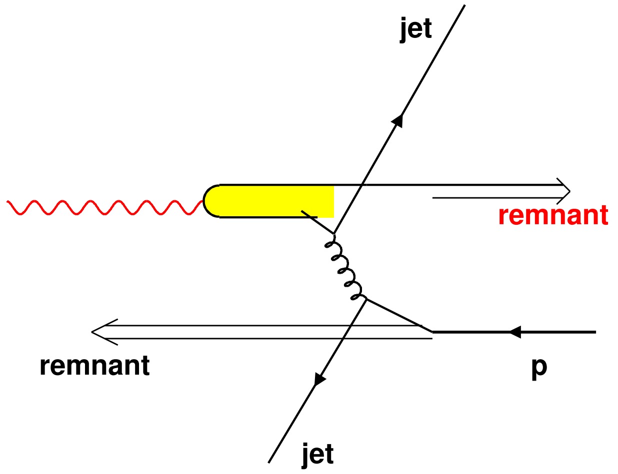
$\rightarrow$ sensitivity to photon structure

TYPES OF PHOTON PROCESS

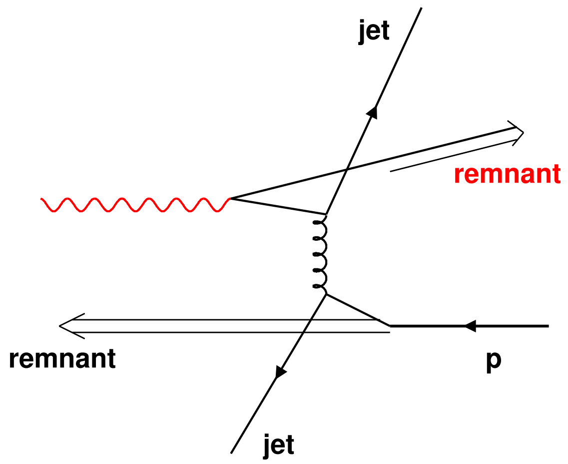
Examples of dijet processes.



DIRECT



RESOLVED



looks resolved.

NLO since 3 perturbative vertices

Direct / resolved fully distinct only at LO.

THEORETICAL FRAMEWORK

Aim: to study effective structure of virtual photon as function of Q^2 , with special reference to 'transition region' $Q^2 = O(1)$ GeV ^{2}

In perturbative QCD, assuming factorisation (OK at NLO):

$$d\sigma_{ep\to e+2\mathrm{jets}} = \sum_{a,b} \int_0^1 dy\, f_{\gamma^*/e}(y, Q^2) \int_0^1 dx_{\gamma^*}\, f_{a/\gamma^*}(x_{\gamma^*}, Q^2, \mu^2_{F\gamma^*}) \times \int_0^1 dx_p\, f_{b/p}(x_p, \mu^2_{Fp})\, d\sigma_{ab\to 2\mathrm{jets}}(\mu_R)$$

where there are two contributions to the $\gamma*$ PDFs:

$$f_{a/\gamma^*} = f^{\mathrm{had}}_{a/\gamma^*} + f^{\mathrm{pert}}_{a/\gamma^*}$$

Boundary is factorisation-scale (μ_F) dependent.

DISASTER++ (D. Graudenz) used as NLO parton-level Monte Carlo.

PYTHIA and ARIADNE used to convert data and NLO partons to the hadron level.

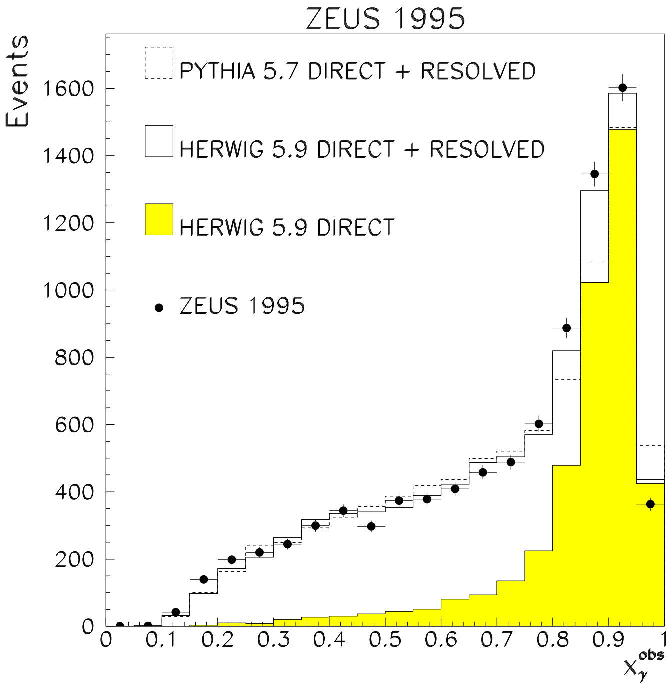
DIJET EVENTS

Dijet events identified in $\gamma^* p$ c.m. frame
$E_T^1, E_T^2 > 7.5, 6.5$ **GeV**, $-3 < \eta < 0$

A measure of the fraction of the photon energy given to the dijet final state is:

$$x_\gamma^{\rm obs} = \left(E_T^{\,1} e^{-\eta_1} + E_T^{\,2} e^{-\eta_2}\right)/2E_\gamma$$

$x_\gamma^{\rm obs}$ **in photoproduction (typical)**



$x_\gamma^{\rm obs} < 0.75$ **Resolved-dominated**
$x_\gamma^{\rm obs} > 0.75$ **Direct-dominated**

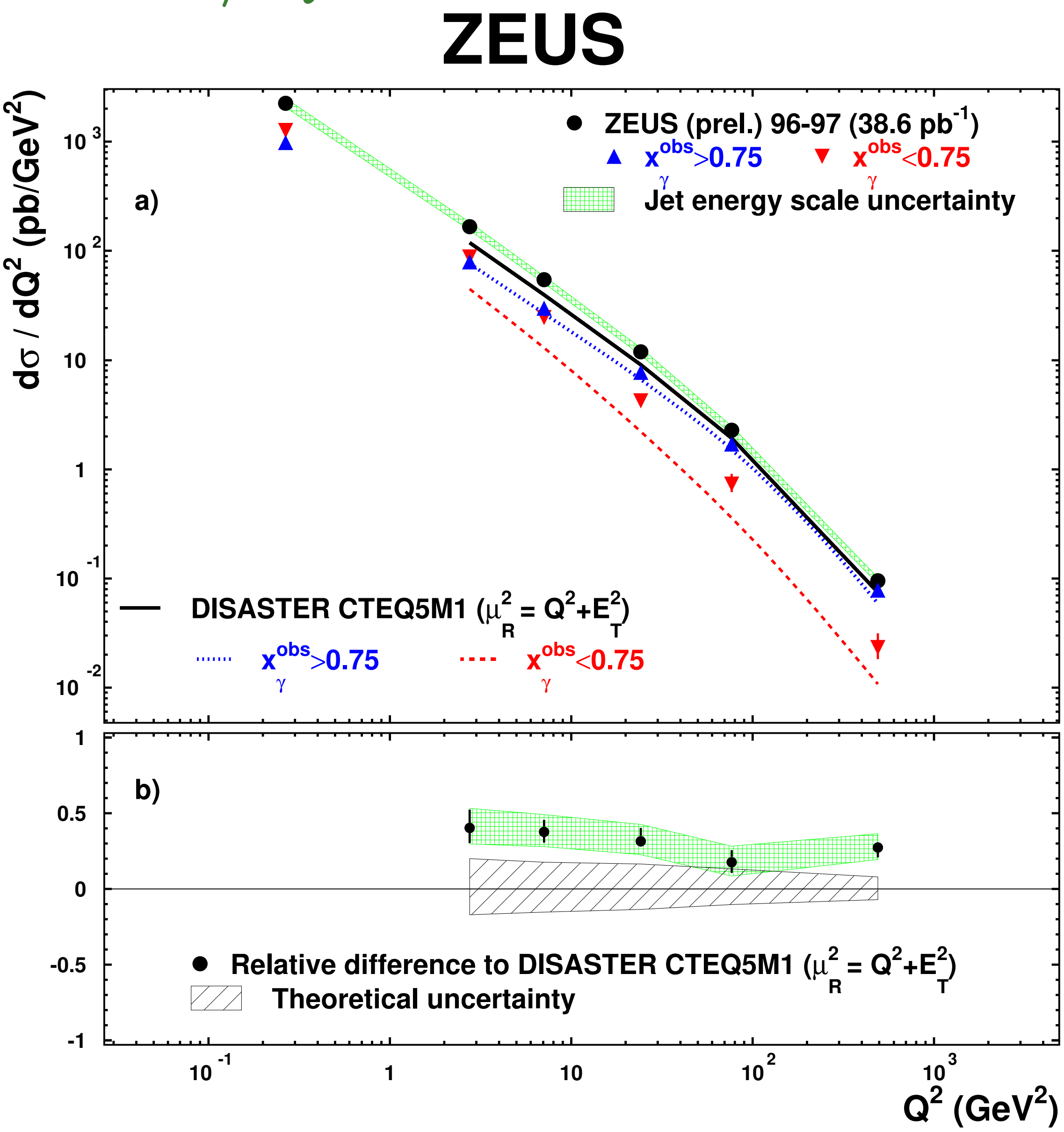
The ratio

$$R = \frac{d\sigma}{dQ^2}(x_\gamma^{\rm obs} < 0.75)/\frac{d\sigma}{dQ^2}(x_\gamma^{\rm obs} > 0.75)$$

is a measure of the resolved fraction of the virtual photon events within the acceptance. Various experimental and theoretical uncertainties cancel in R .

RESULTS

Results for $d\sigma/dQ^2$



Using QCD renormalisation scale $\mu_R^2 = Q^2 + E_T^2$:

— Data tend to lie above DISASTER NLO

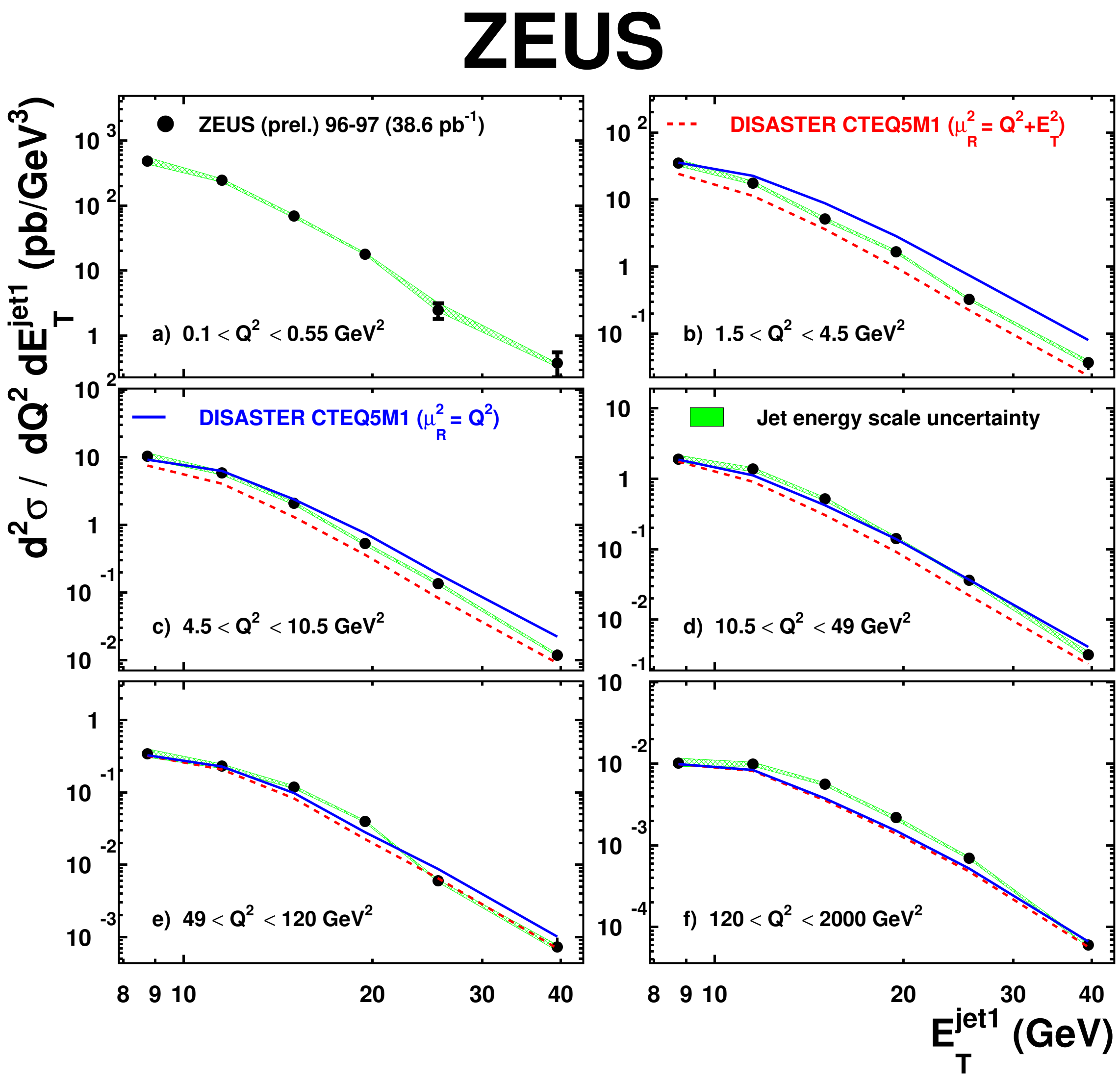
— But good agreement with $x_\gamma^{\mathrm{obs}} > 0.75$ component

— Discrepancy mainly with the $x_\gamma^{\mathrm{obs}} < 0.75$ component

DISASTER contains only perturbative processes, no hadronic component to photon.

RESULTS

Plot against higher E_T^2 for varying Q^2 ranges:



Comparison with NLO is not strongly $E_T^{\rm jet}$ dependent.

Note presence of two hard QCD scales, Q^2 and $E_T^{\rm jet}$.

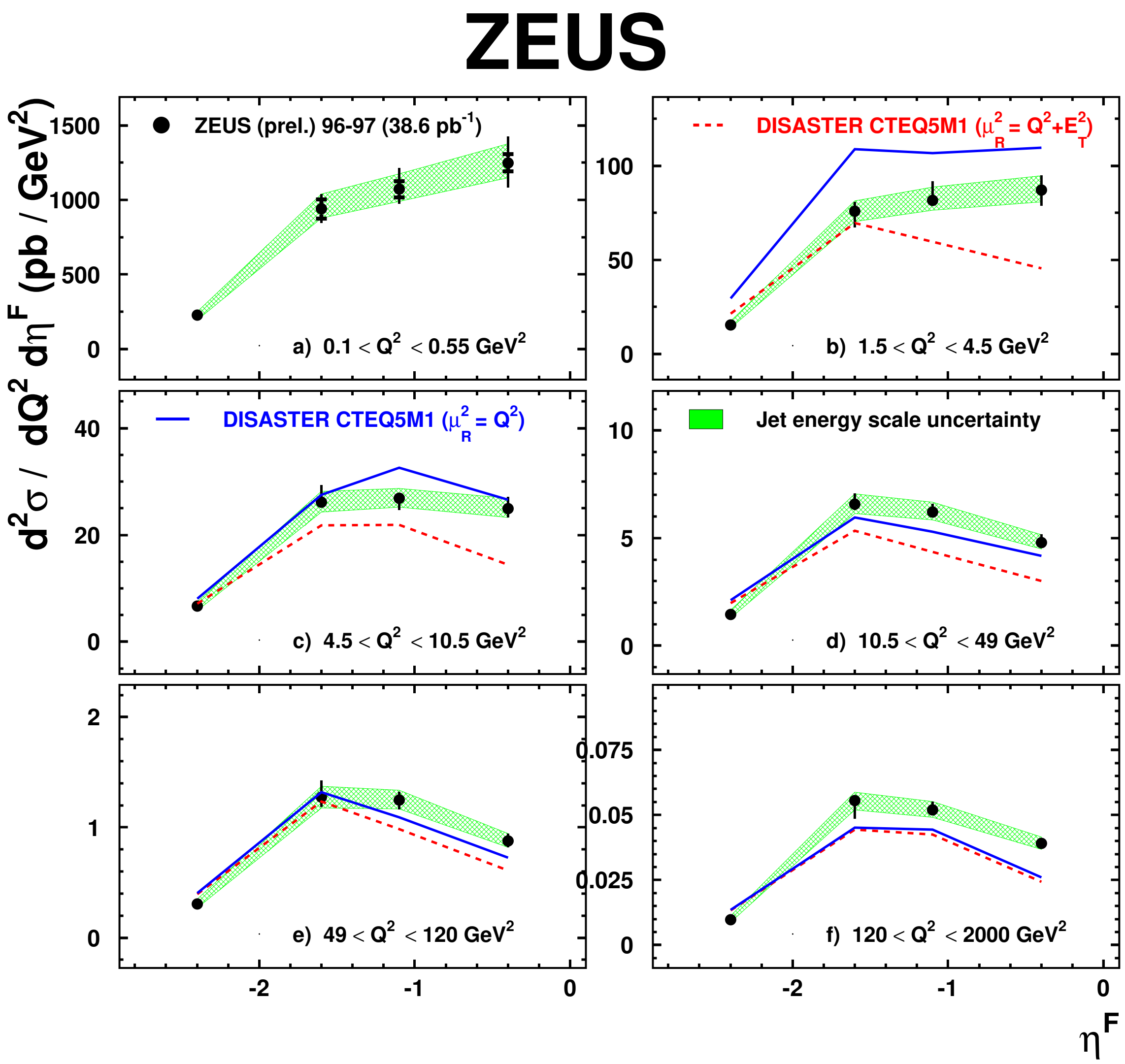
More natural to use $\mu_R^2 = Q^2 + E_T^2$.

Using $\mu_R^2 = Q^2$ raises the prediction.

Is this a better procedure?

RESULTS

$d\sigma/dQ^2$ vs forward jet pseudorapidity enhances resolved contribution



At low Q^2, big sensitivity to μ_R^2

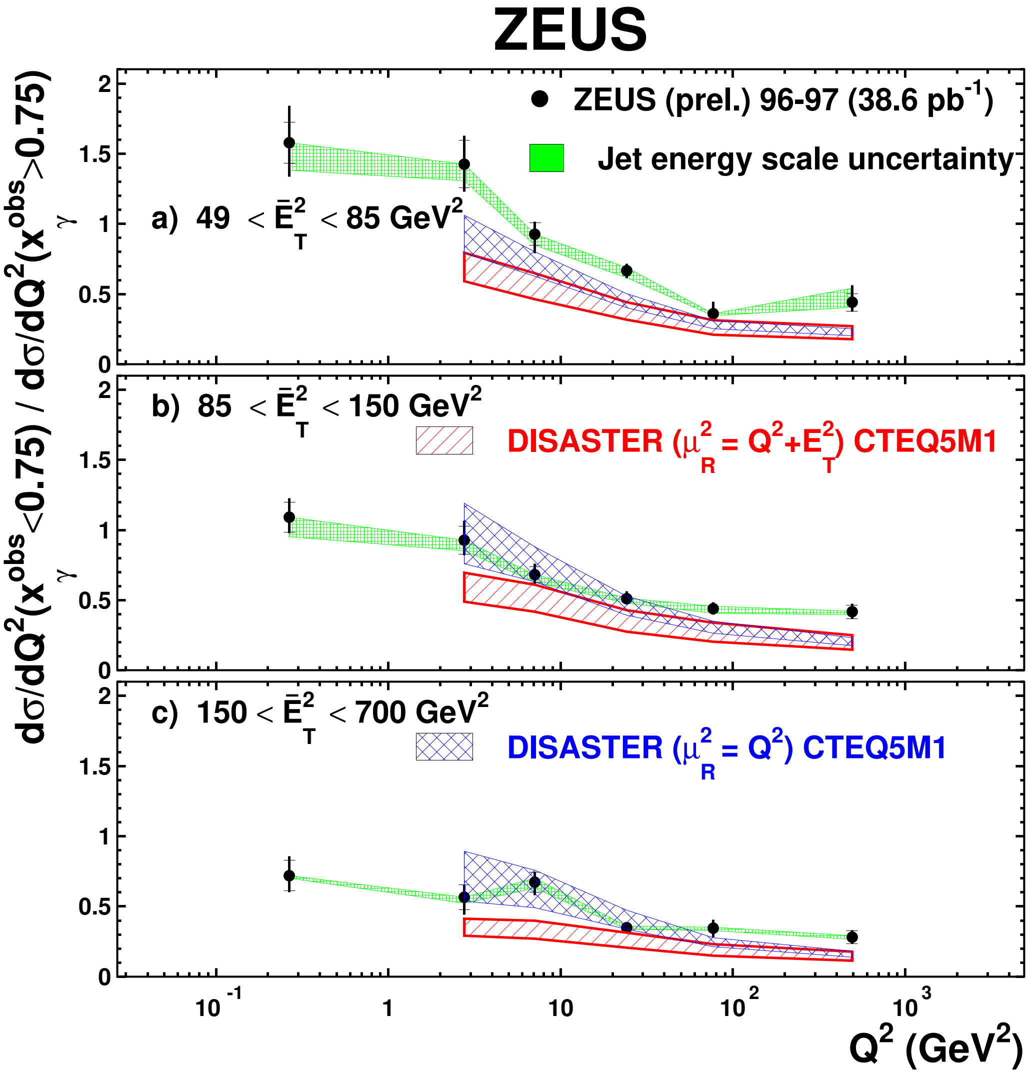
At high Q^2, low sensitivity; data tend to be above theory in both cases.

So decreasing μ_R^2 is not a successful solution.

RESULTS

$$R = \frac{d\sigma}{dQ^2}(x_\gamma^{\rm obs} < 0.75) / \frac{d\sigma}{dQ^2}(x_\gamma^{\rm obs} > 0.75)$$

vs Q^2 in ranges of $E_T^{\rm jet}$



$\rightarrow$ all resolved effects fall with Q^2 and $E_T^{\rm jet}$

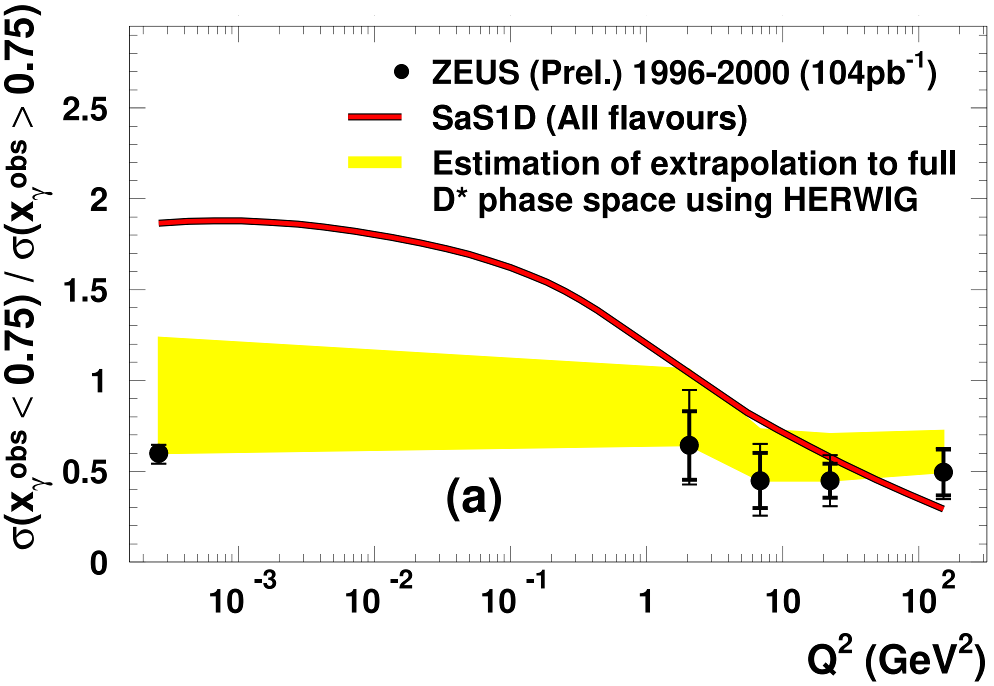
(R at $Q^2 \approx 0$ estimated similar to $Q^2 \approx 0.3$)

Comparison with DISASTER NLO $(\mu_R^2 = Q^2 + E_T^2)$ is insensitive to either hard scale. Data lie above theory.

$\rightarrow$ consistent need for higher-order resolved contribn. (hadronic!) to photon even at high Q^2

COMPARISONS

Compare with prelim. ZEUS data with identified charm (D meson) required in event.
Jet selections similar to present analysis.



Presence of c quark forces hard scale on process.

Flat in Q^2

Should all be perturbatively calculable.

CONCLUSIONS

— Have measured dijet cross sections in ZEUS over a range of Q^2 values crossing the transition between photoproduction and DIS.

— There is a component to the cross sections which is not modelled in NLO QCD, and is associated with resolved processes.

— Decreasing the renormalisation scale does not satisfactorily account for the discrepancy.

— Suggests presence of a hadronic part of the photon even at high Q^2 values.

— The effect appears absent in dijets with heavy quarks

— Need a NLO MC which includes general photon PDFs to test these ideas further.