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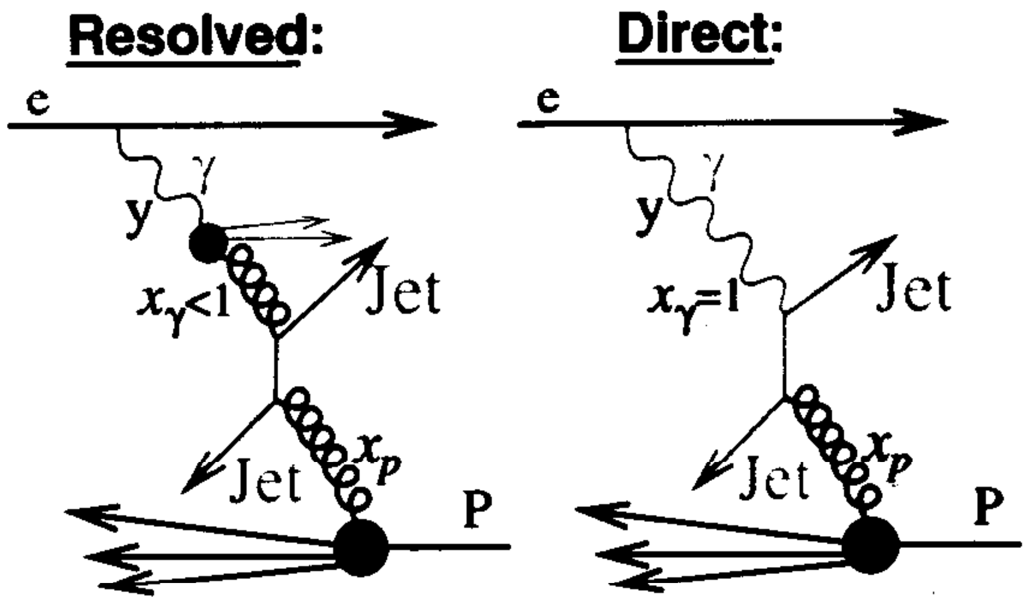
Recent Photoproduction Results From ZEUS

- Hard Photoproduction processes at HERA
- Jet cross sections
  - Inclusive jet cross sections
  - Dijet angular distributions
  - Dijet cross sections
- Observation of isolated High-P_t photons (prompt photon)

Hard Photoproduction at HERA



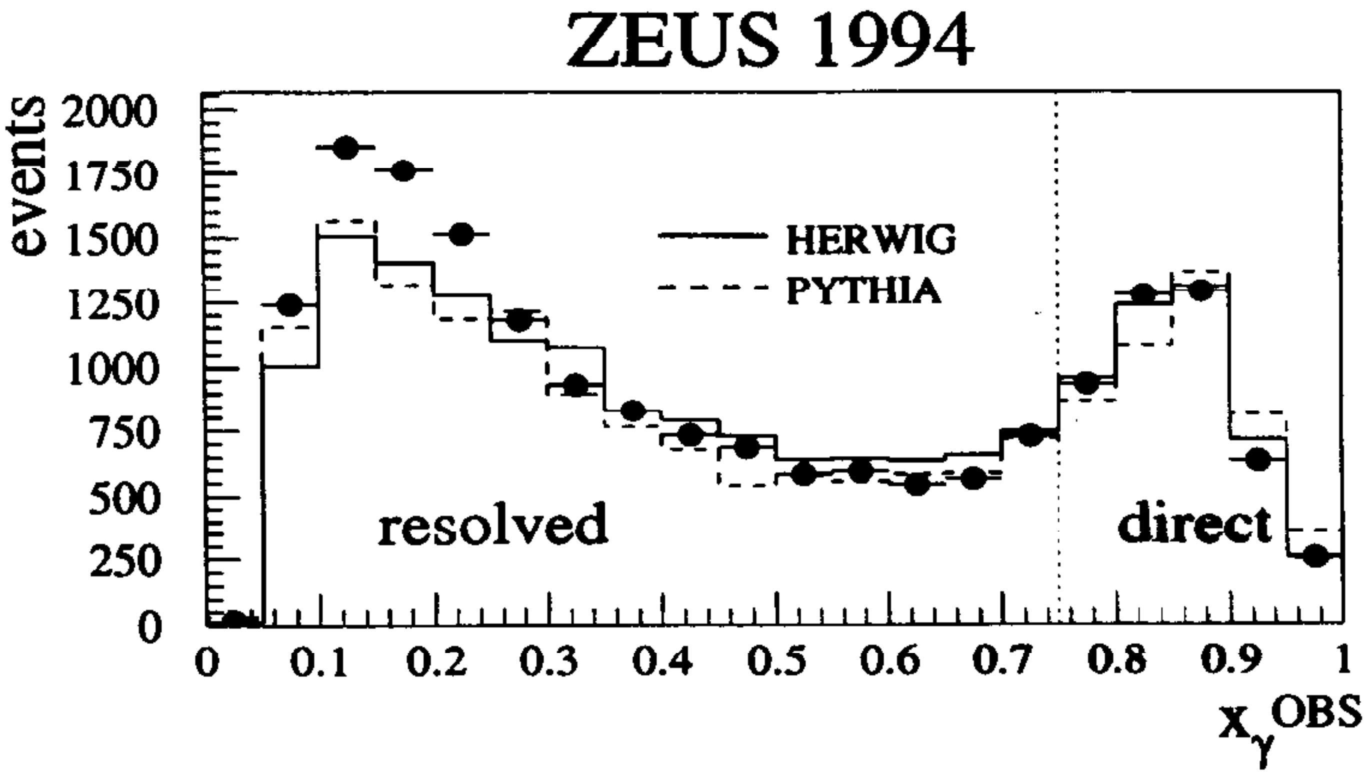
Scattered positron doesn't enter detector

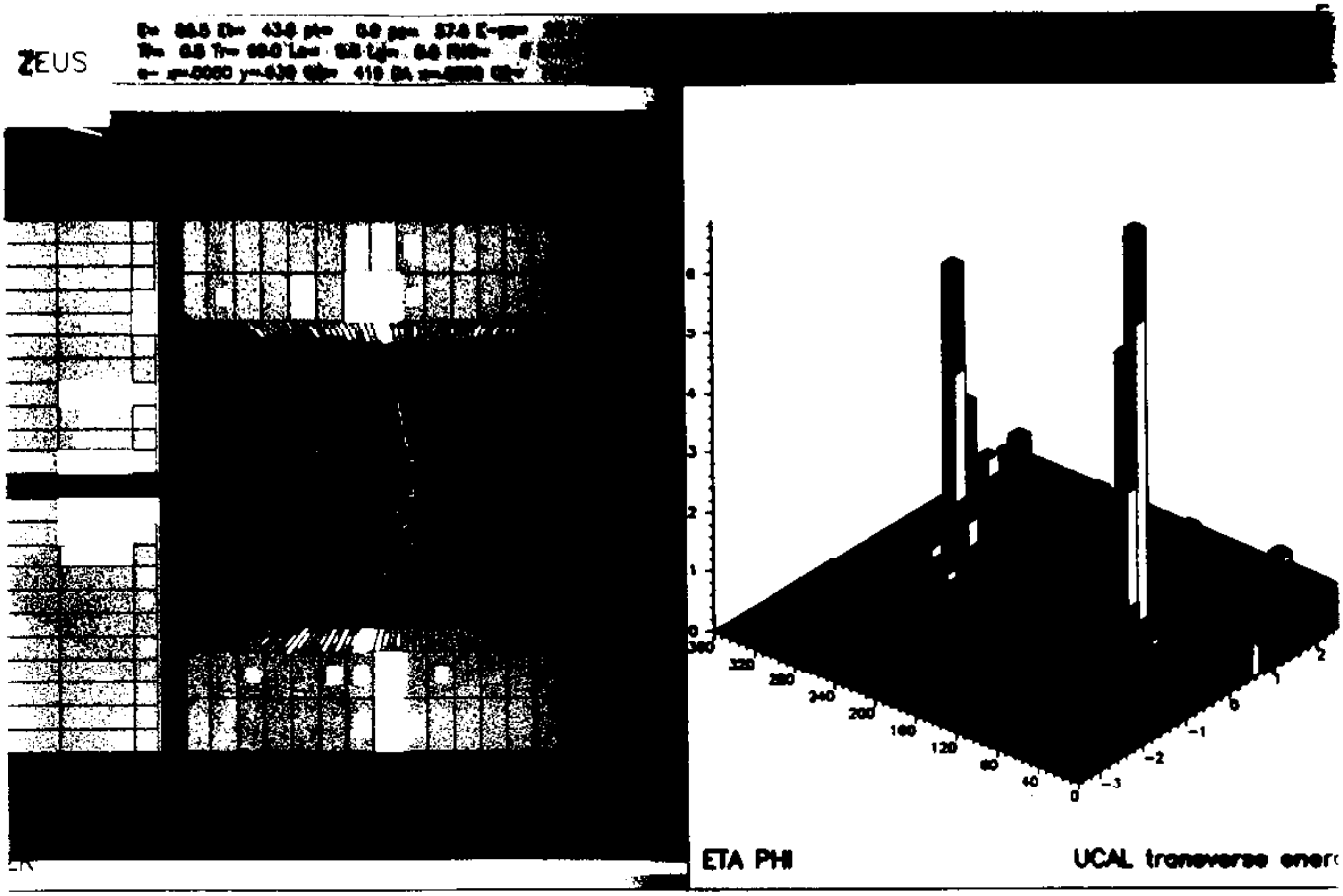
$\longrightarrow \quad P_\gamma^2 \approx 10^{-3} GeV^2 \qquad y \approx \frac{E_\gamma}{E_e}$

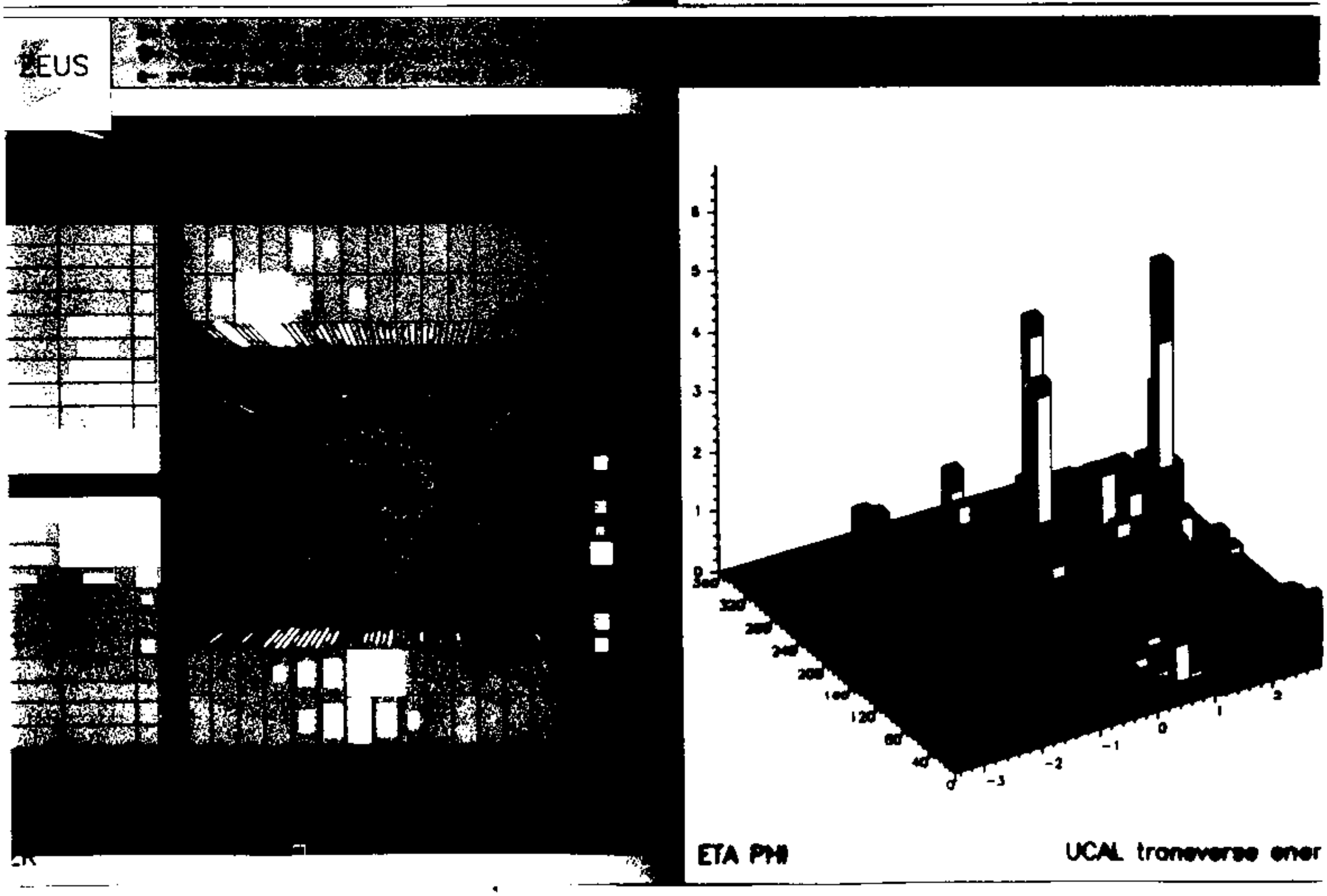
pseudorapidity $\eta =$

$$x_\gamma^{OBS} = \frac{1}{2yE_e}\left(E_t^{jet1} e^{-\eta^{jet1}} + E_t^{jet2} e^{-\eta^{jet2}}\right)$$

Measured x_γ^{OBS} for E_t^{jet} >6 GeV:




ZEUS
ETA PHI


ZEUS
ETA PHI

Jet Cross Sections

The jet cross section at LO is:

$$\frac{d\sigma(\gamma p \to j_1 j_2 X)}{dp_t^2 d\eta_1 d\eta_2} = \sum_a \sum_b x_p x_\gamma f_{a/p}(x_p, Q^2) \times f_{b/\gamma}(x_\gamma, Q^2) \frac{d\hat{\sigma}(ab \to j_1 j_2 X)}{d\hat{t}}$$

→ measuring jet cross sections can test QCD, and constrain the parton distributions in the proton and photon.

Presented here are $\frac{d\sigma}{d\eta^{jet}}$ for:

Cone Jets with a radius of 1 in η - ϕ space.

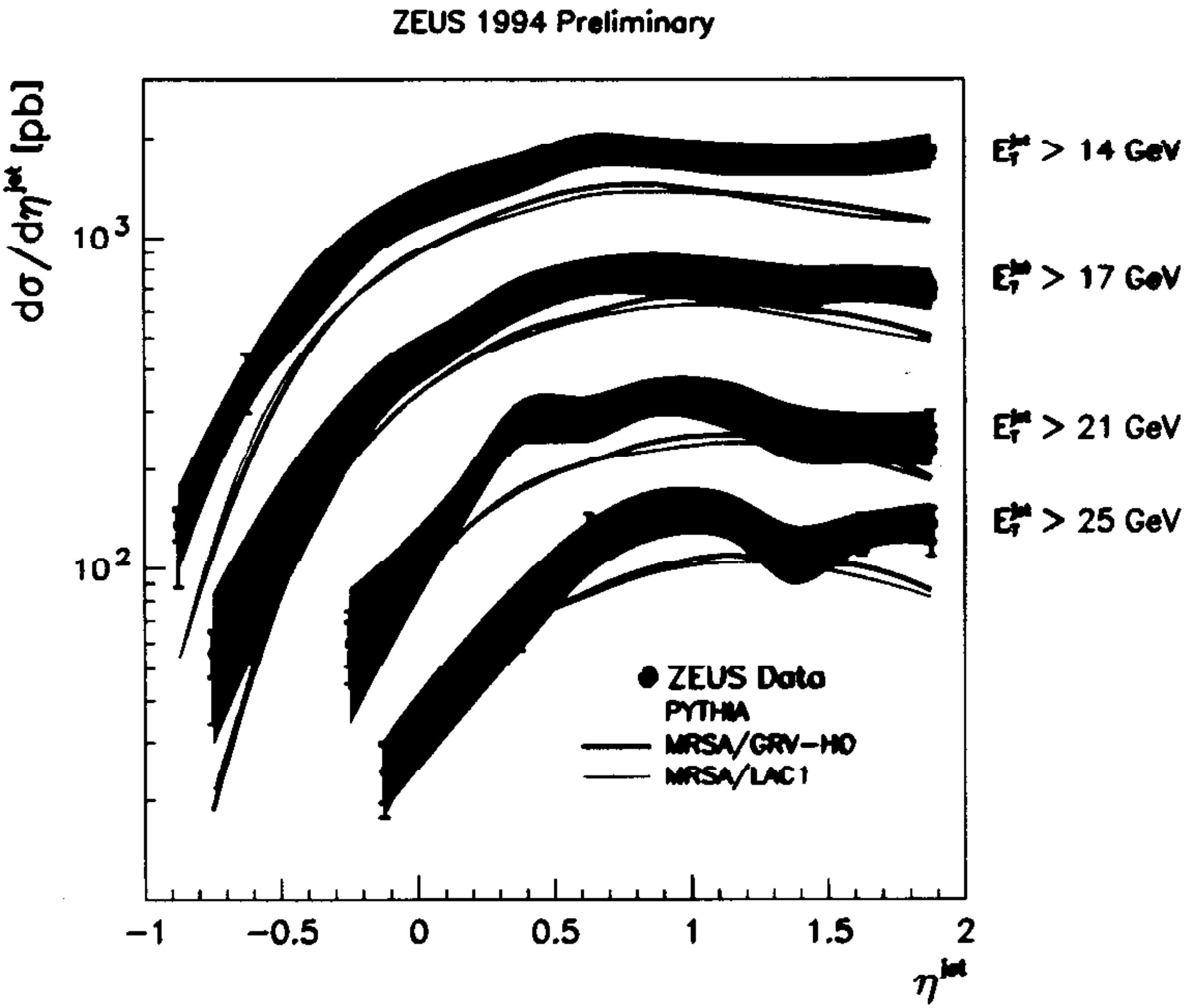
E_t^{jet} >14,17,21, and 25 GeV

-1< η^{jet} <2

For 134< $W = \sqrt{yE_eE_p}$ <277 GeV

Cross sections are corrected back to final state hadron level using Monte Carlo.

Comparison with Monte Carlo



The Monte Carlo prediction describes the measured shape well, but is lower in magnitude

Comparison with NLO Calculations

(Klasen,Kramer,Salesch)

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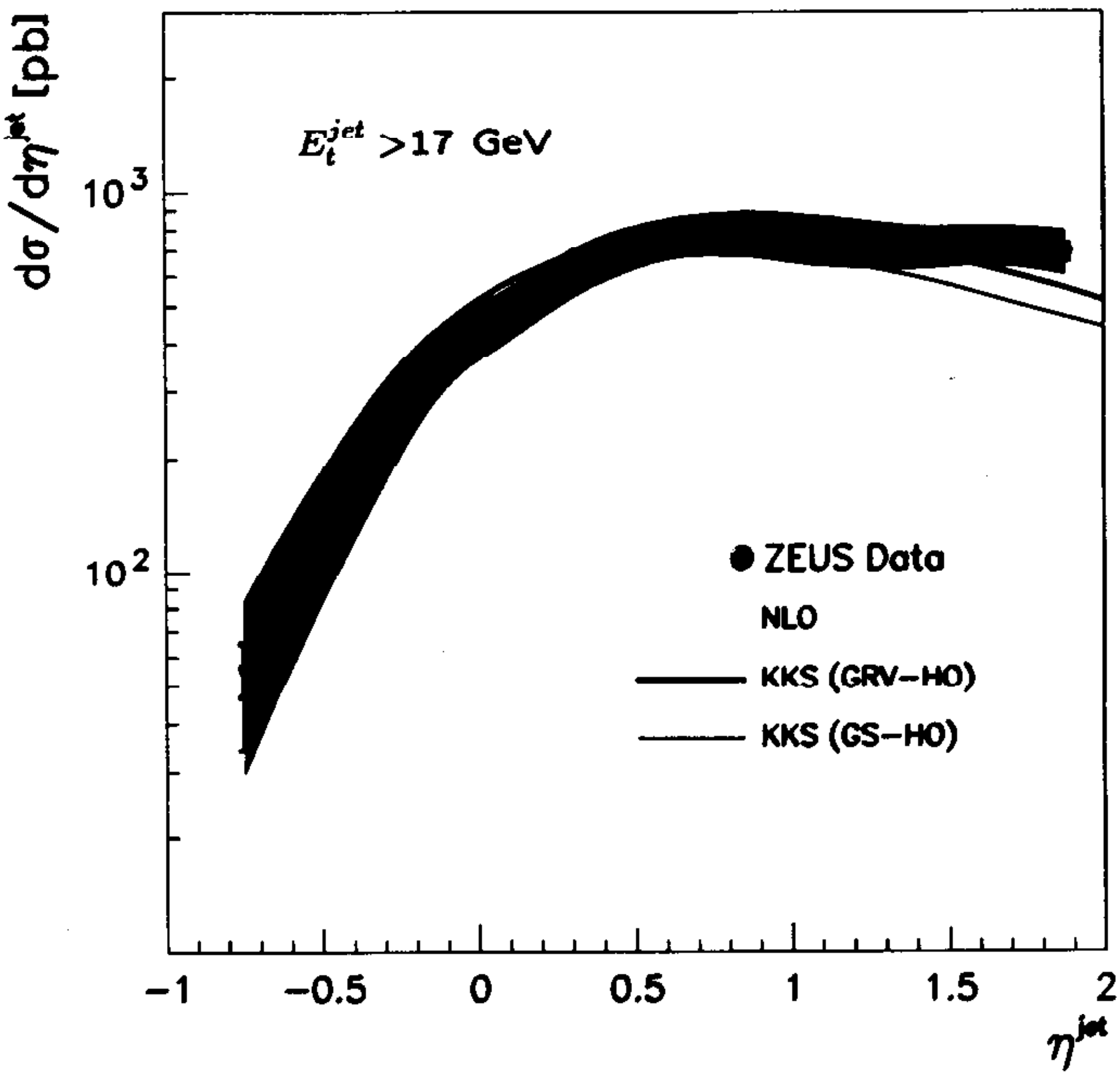

The Calculated cross sections are close in magnitude to the measured, but agree less well in shape

Difference Between Data and Predictions

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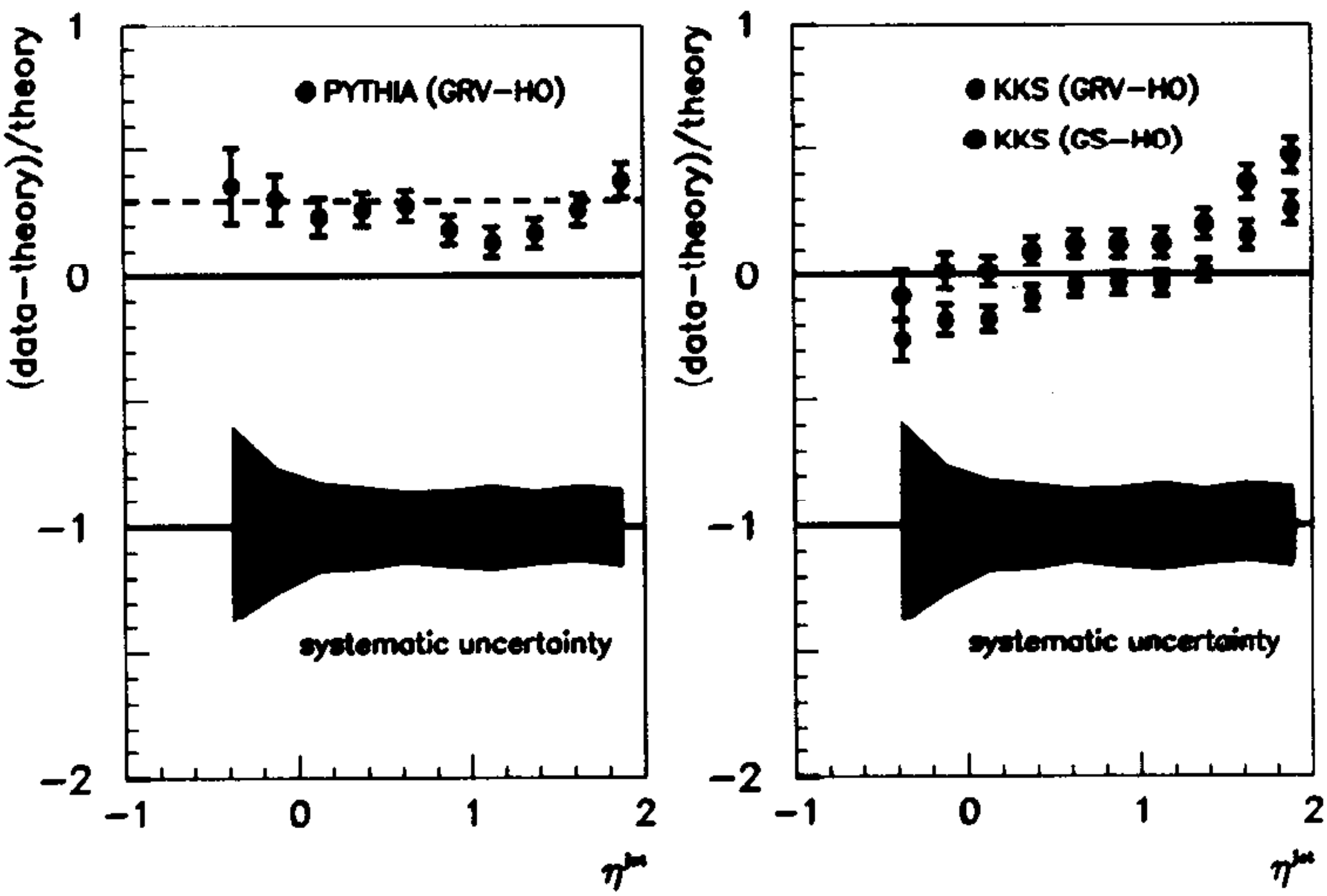
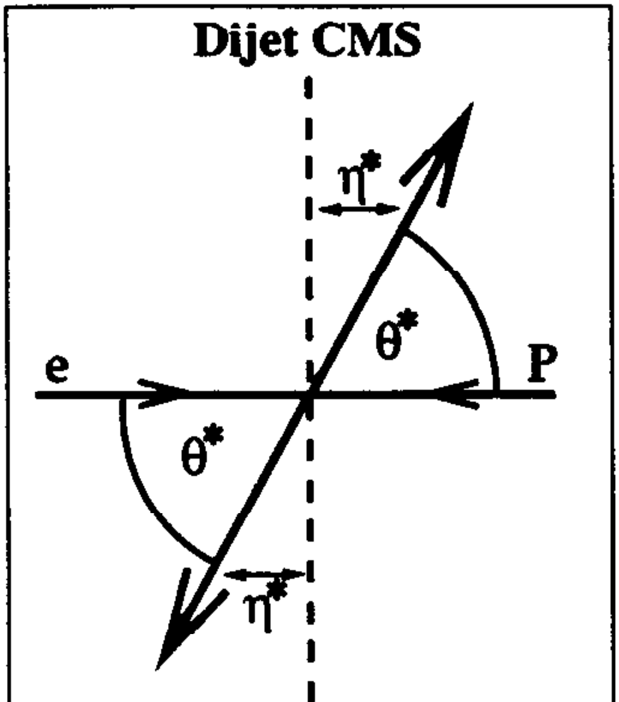
$E_t^{jet} > 17$ GeV



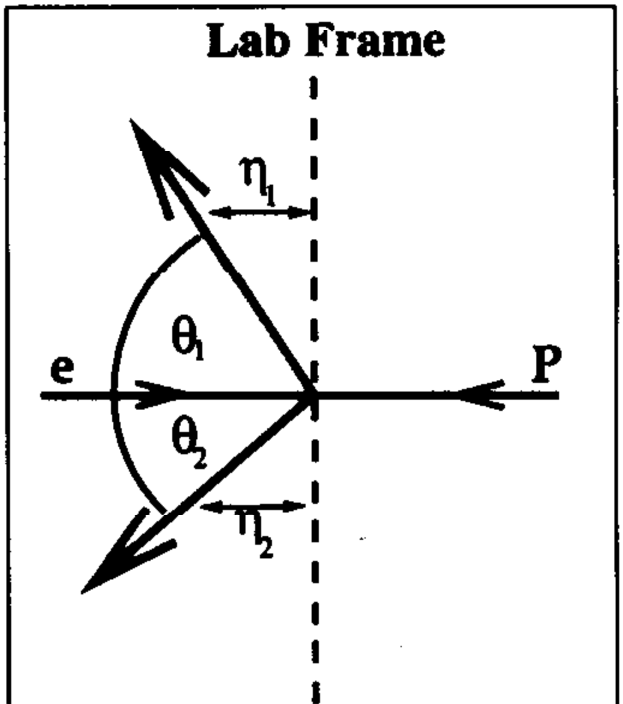
The difference between the measurement and NLO Calculations is mostly small, but rises in the forward region

The difference between the measurement and Monte Carlo predictions is around 30%

Dijet Kinematics



$$\eta^* = \frac{1}{2}(\eta_2 - \eta_1)$$
$$\bar{\eta} = \frac{1}{2}(\eta_2 + \eta_1)$$



$$\eta_1 = \bar{\eta} - \eta^*$$
$$\eta_2 = \bar{\eta} + \eta^*$$

$\eta = -\ln(\tan \theta/2)$

Parton Momenta:

$\bar{\eta} = \frac{1}{2}(\eta_2 + \eta_1) = \frac{1}{2} ln \frac{x_p E_p}{y x_\gamma E_e}$

$\Longrightarrow$ Information about the structure functions.

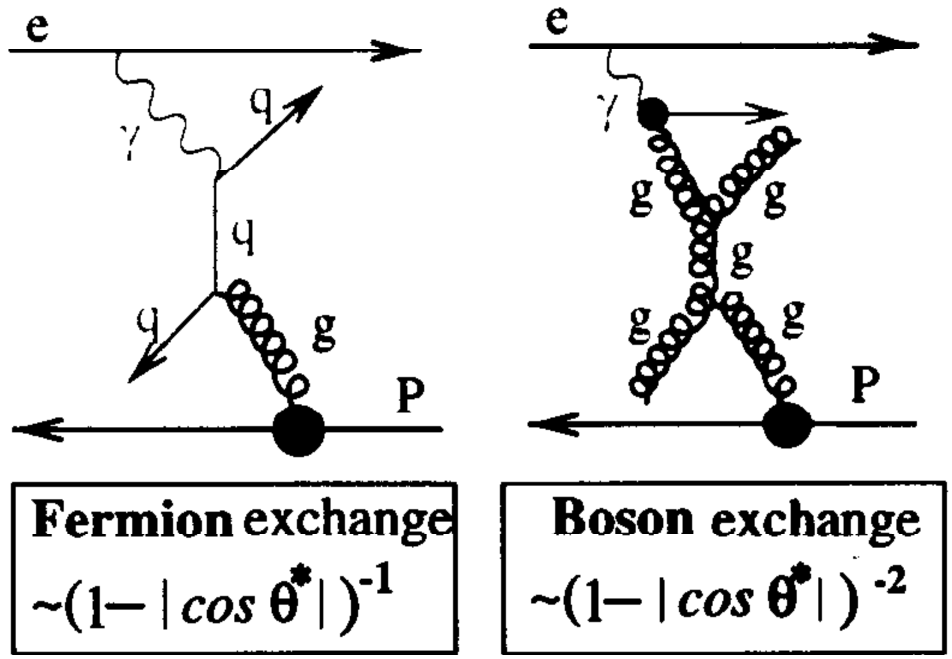
Angular Distribution:

$tanh(\eta^*) = tanh\left(\frac{1}{2}(\eta_2 - \eta_1)\right) = cos(\theta^*)$

θ^* is the angle between the jet-jet-axis and the beam beam direction in the dijet CMS)

$\Longrightarrow$ Information about the spin of the exchanged particle.

Dijet Angular Distribution Measurement



→ Expect different angular distributions for direct and resolved processes

→ measure $\frac{d\sigma}{d|cos\theta^*|}$ for $x_\gamma^{OBS} > 0.75$ and $x_\gamma^{OBS} < 0.75$.

$\frac{d\sigma}{d|cos\theta^*|}$ is measured for events with:

at least 2 jets with $E_T^{jet} > 6 GeV$ and $|\eta^{jet}| < 2.5$

(if there are more than 2 jets the two with highest E_T^{jet} are taken)

$\frac{1}{2}(\eta^{jet1} + \eta^{jet2}) < 0.5$ → LAB ≈ CMS

dijet invariant mass $M_{JJ} > 23 GeV$

$0.2 < y < 0.8$

Results of Dijet Angular Distribution Measurement

Compared to QCD calculations (Owens et al.)

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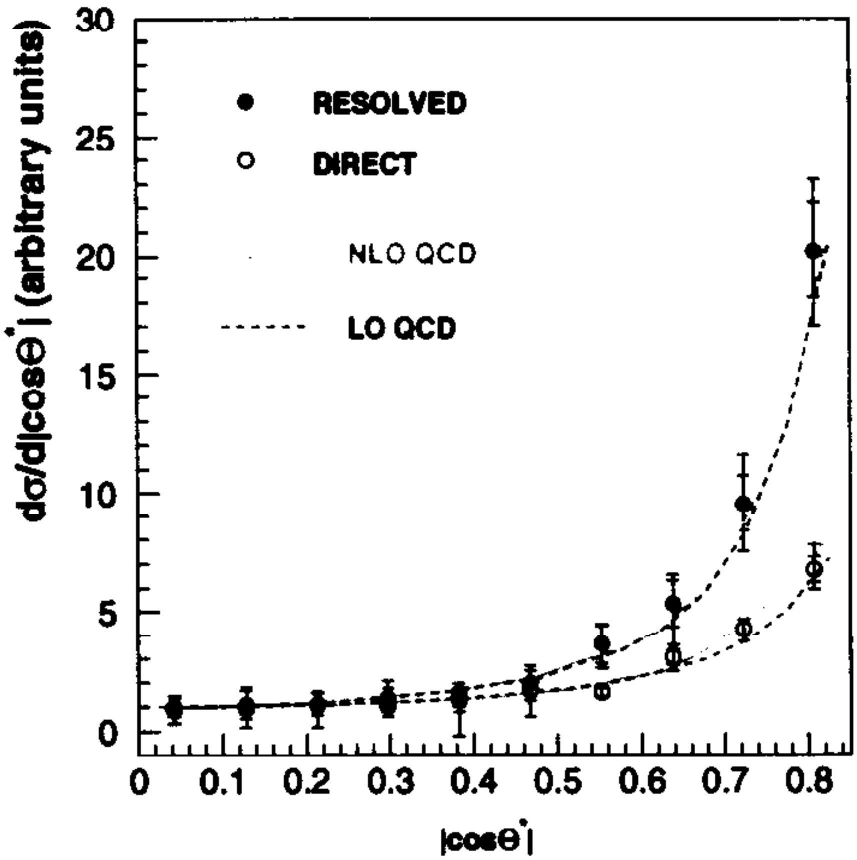


Different angular distributions are seen for jets from resolved and direct photon interactions.

This is consistent with the resolved process being dominated by gluon (spin $1\hbar$) exchange, and the direct process being dominated by quark (spin$\frac{1}{2}\hbar$) exchange.

Dijet Cross sections

$\bar{\eta} = \frac{1}{2}(\eta_2 + \eta_1) = \frac{1}{2} ln \frac{x_p E_p}{y x_\gamma E_e}$
$\Longrightarrow$ Information about the structure functions.

$x_\gamma^{OBS} \approx \frac{cosh\ \eta^*}{y E_e} E_t^{Jet} e^{-\bar{\eta}}$
$\rightarrow$ **measuring $\frac{d\sigma}{d\bar{\eta}}$ for small η^* means that the smallest x_γ values are probed for a given $\bar{\eta}$, and that scanning across $\bar{\eta}$ $\equiv$ scanning across x_γ**

$\frac{d\sigma}{d\bar{\eta}}$ is measured in the x_γ^{OBS} ranges:

All x_γ^{OBS}, $x_\gamma^{OBS} > 0.75$, and $0.3 < x_\gamma^{OBS} < 0.75$

for events with:

$\geq$2 jets with $E_t^{jet} > \mathbf{6}, 8, 11, 15\ GeV$, $-1.375 < \eta^{jet} < 1.875$

(if there are more than two jets the two with highest E_t are used)

$\eta^* = \frac{1}{2}|\eta^{jet1} - \eta^{jet2}| < 0.25$

$0.2 < y < 0.8$

Jet Definitions

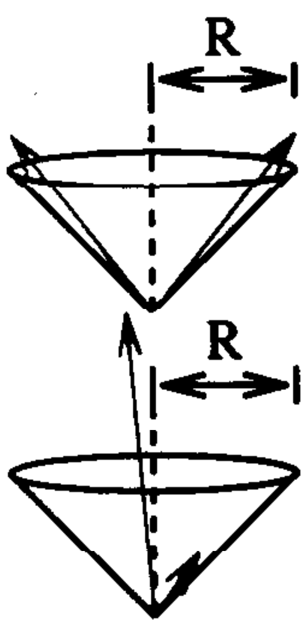
Standard in Hadron Physics: 'Snowmass' cone algorithms

We compare two algorithms using a cone radius $R = 1$:
PUCELL CDF type cone algorithm
EUCELL another cone algorithm used by ZEUS
Differences: seed finding and cone merging
(but both are in agreement with the Snowmass convention)

A new approach for Hadron Physics: cluster algorithm

KTCLUS (by M. Seymour)
using distance $d_{ij} = min({E_{ti}}^2, {E_{tj}}^2)[\Delta\eta_{ij}^2 + \Delta\phi_{ij}^2]$
There are no ambiguities in seed finding and merging.

Comparison with NLO Theory



→two or three parton final state
(no overlapping jets)

two partons are combined if

$$\Delta \equiv \sqrt{\Delta\eta_{ij}^2 + \Delta\phi_{ij}^2} < \frac{E_t^1 + E_t^2}{max\{E_t^1, E_t^2\}} R$$

with R_{sep} parameter (Ellis,Kunszt,Soper)

$$\Delta < min\left\{\frac{E_t^1 + E_t^2}{max\{E_t^1, E_t^2\}} R, R_{sep}\right\}$$

PUCELL $\longleftrightarrow R_{sep} = 1\ R$
EUCELL $\longleftrightarrow R_{sep} \approx 1.5 \ldots 2.0\ R$
KTCLUS $\longleftrightarrow R_{sep} = 1.$

Comparison of Different Jet Algorithms With NLO Calculations

(Klasen, Kramer)

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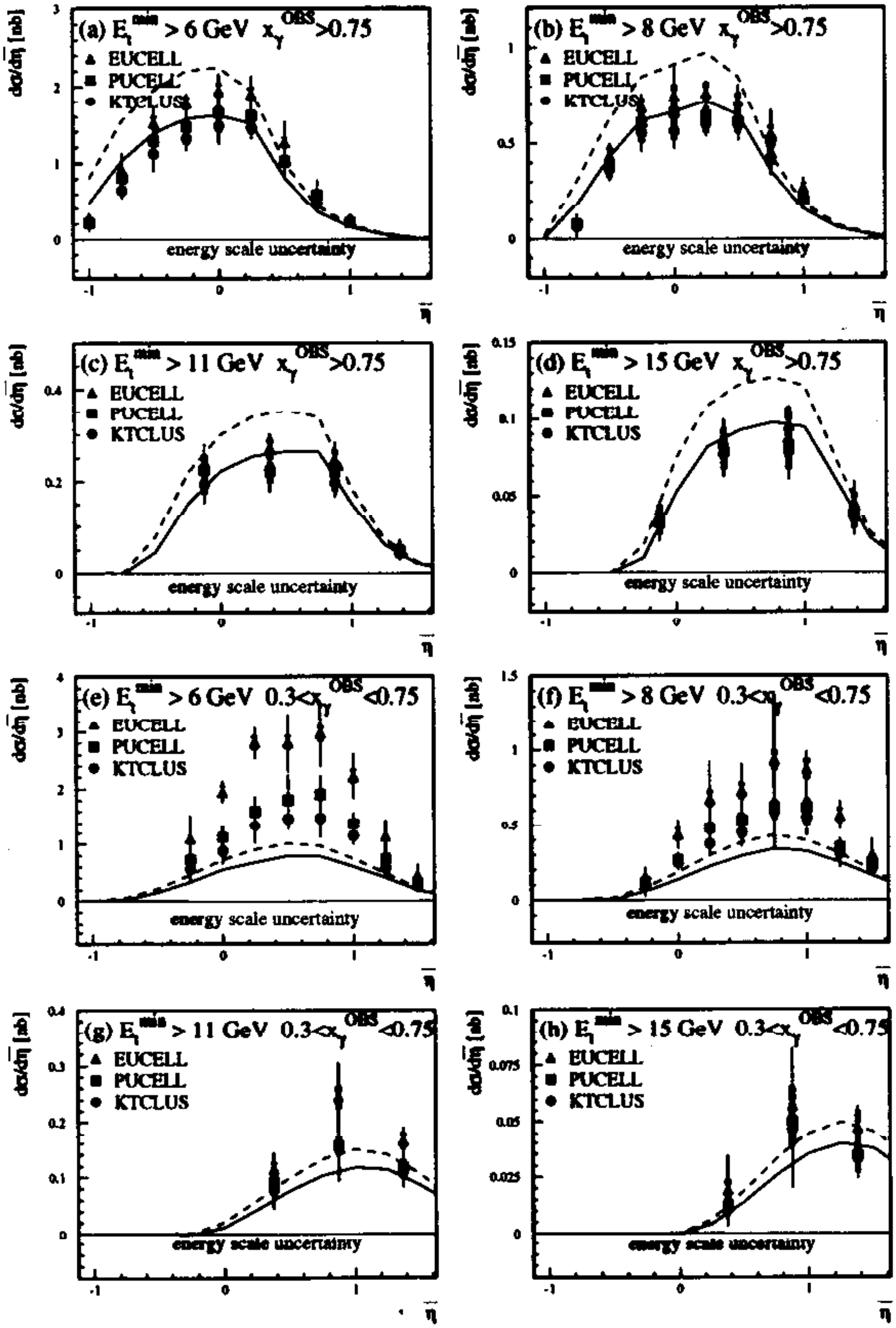
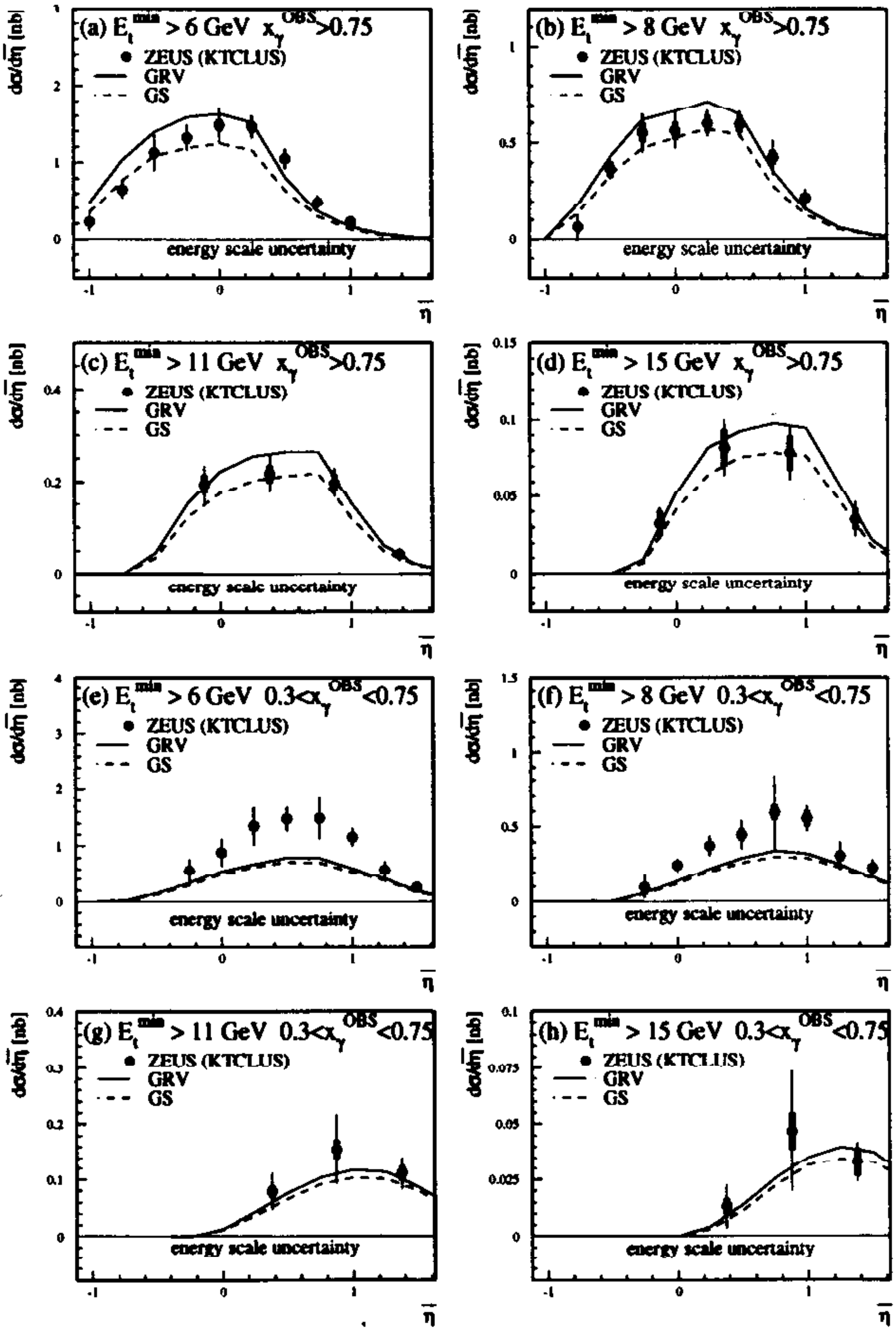
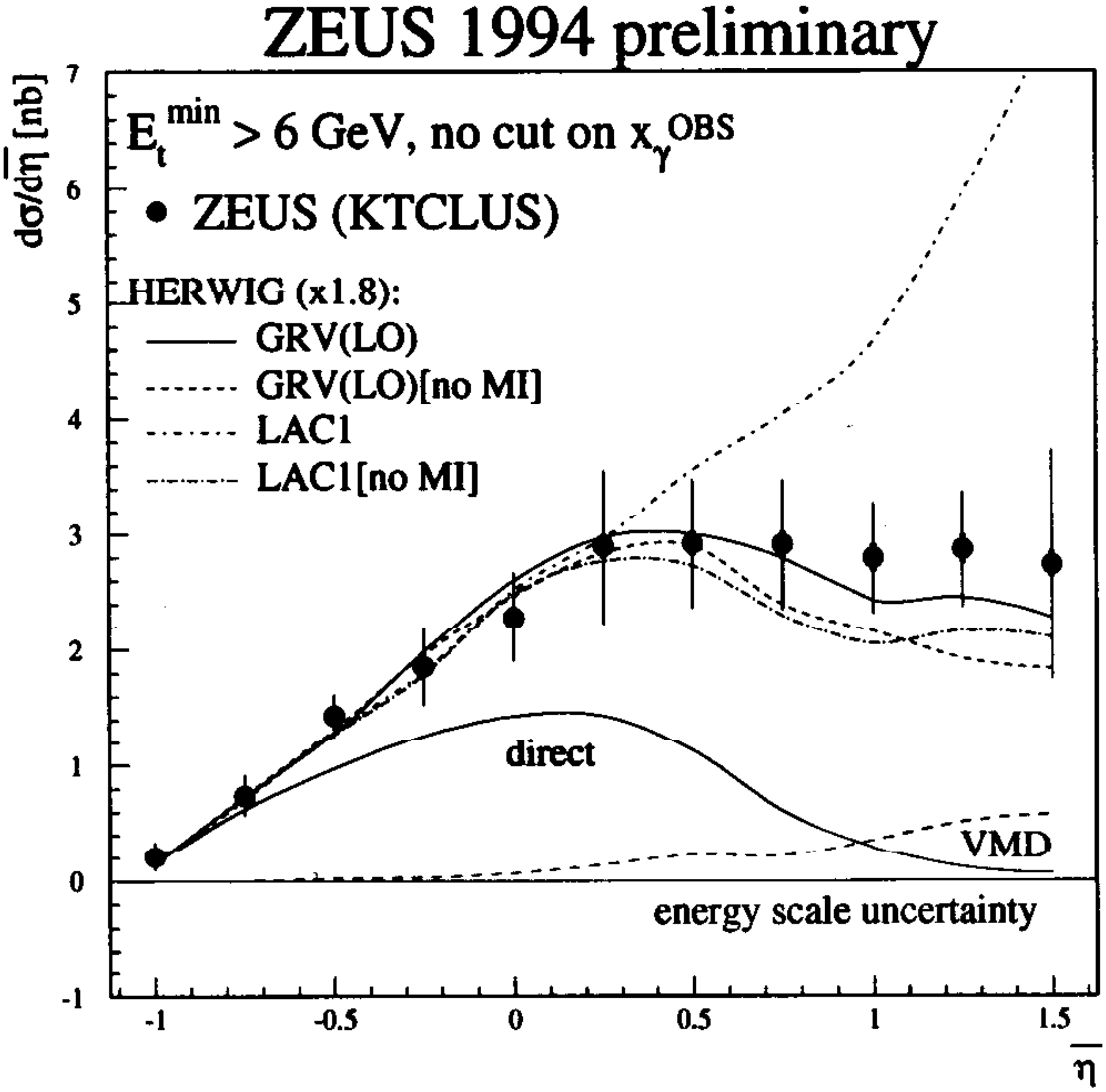


Comparison with NLO calculations
(Klasen, Kramer)

ZEUS 1994 preliminary



Comparison with Monte Carlo predictions

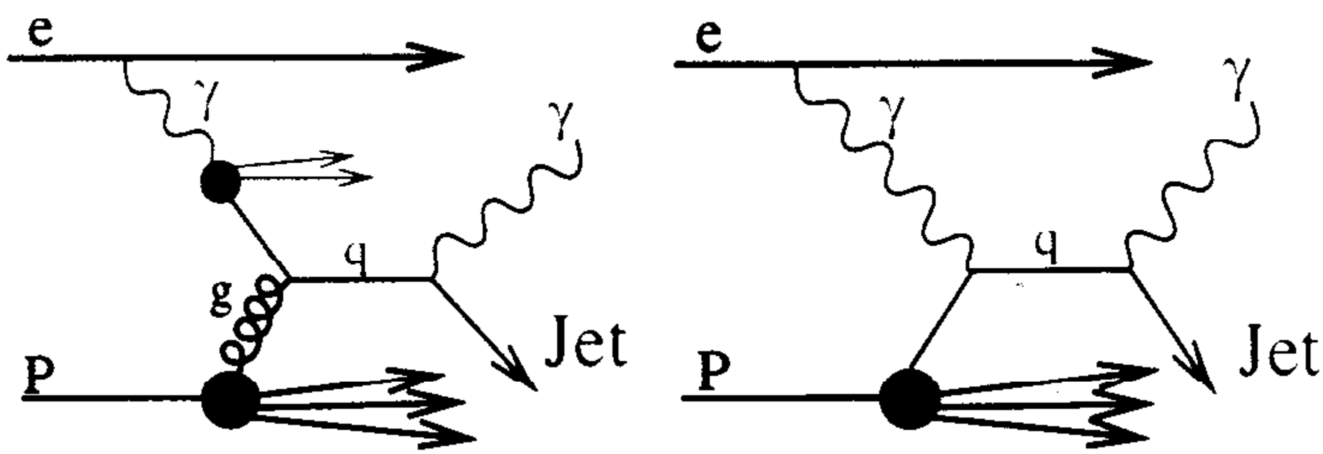


It is necessary to scale all the Monte Carlo predictions by a factor of 1.8 to bring them close to the data.

After renormalizing GRV with Multiple interactions is slightly favoured

Prompt Photons

Resolved: **Direct:**



→ Particularly sensitive to quark distributions

Momentum of final state photon not subject to hadronization effects.

Select Events with:

One jet with E_t^{jet} >4 GeV

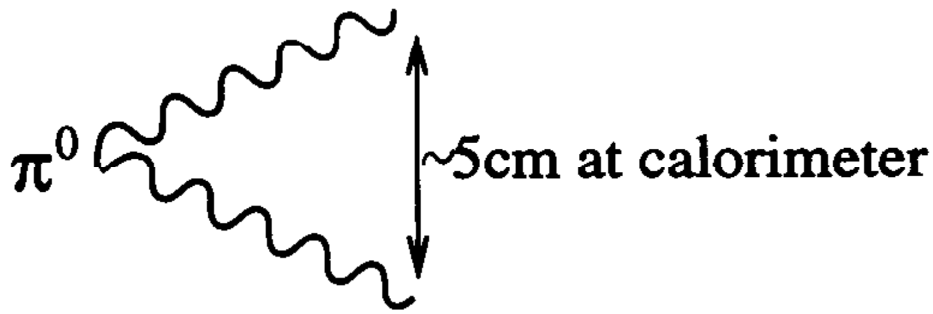
One Photon:-

Electromagnetic deposit with 5 GeV< E_t < 10 GeV.

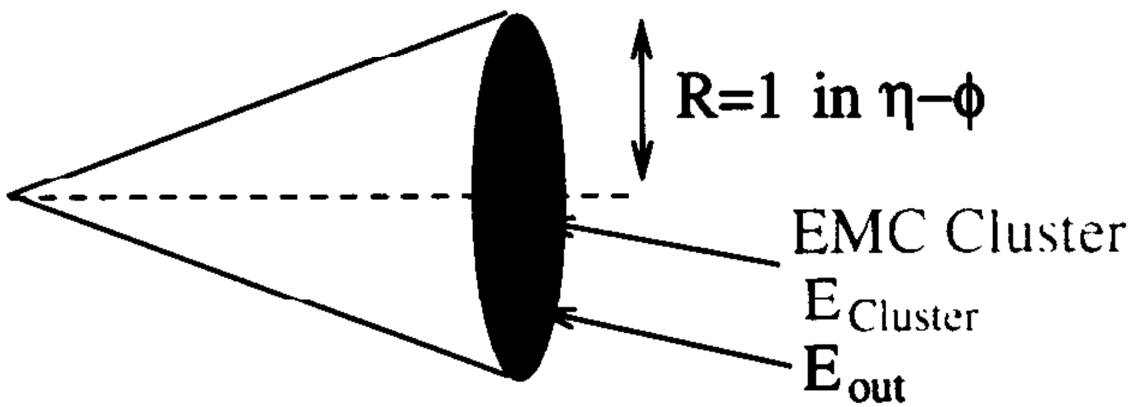
No track within a radius of 0.3 in η-ϕ.

γ- Neutral Meson Separation

For ~10 Gev $\pi^0 \rightarrow 2\gamma$

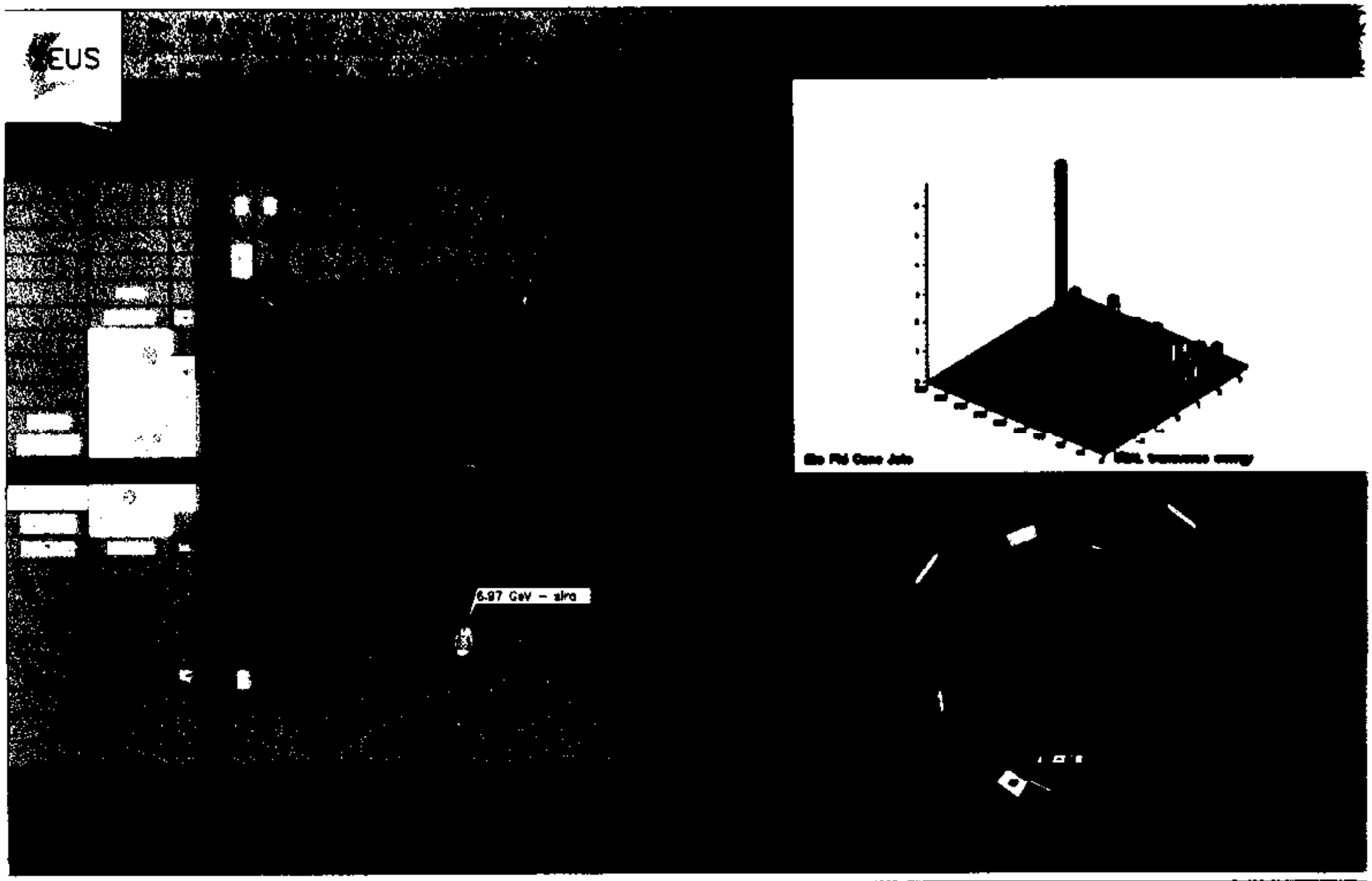


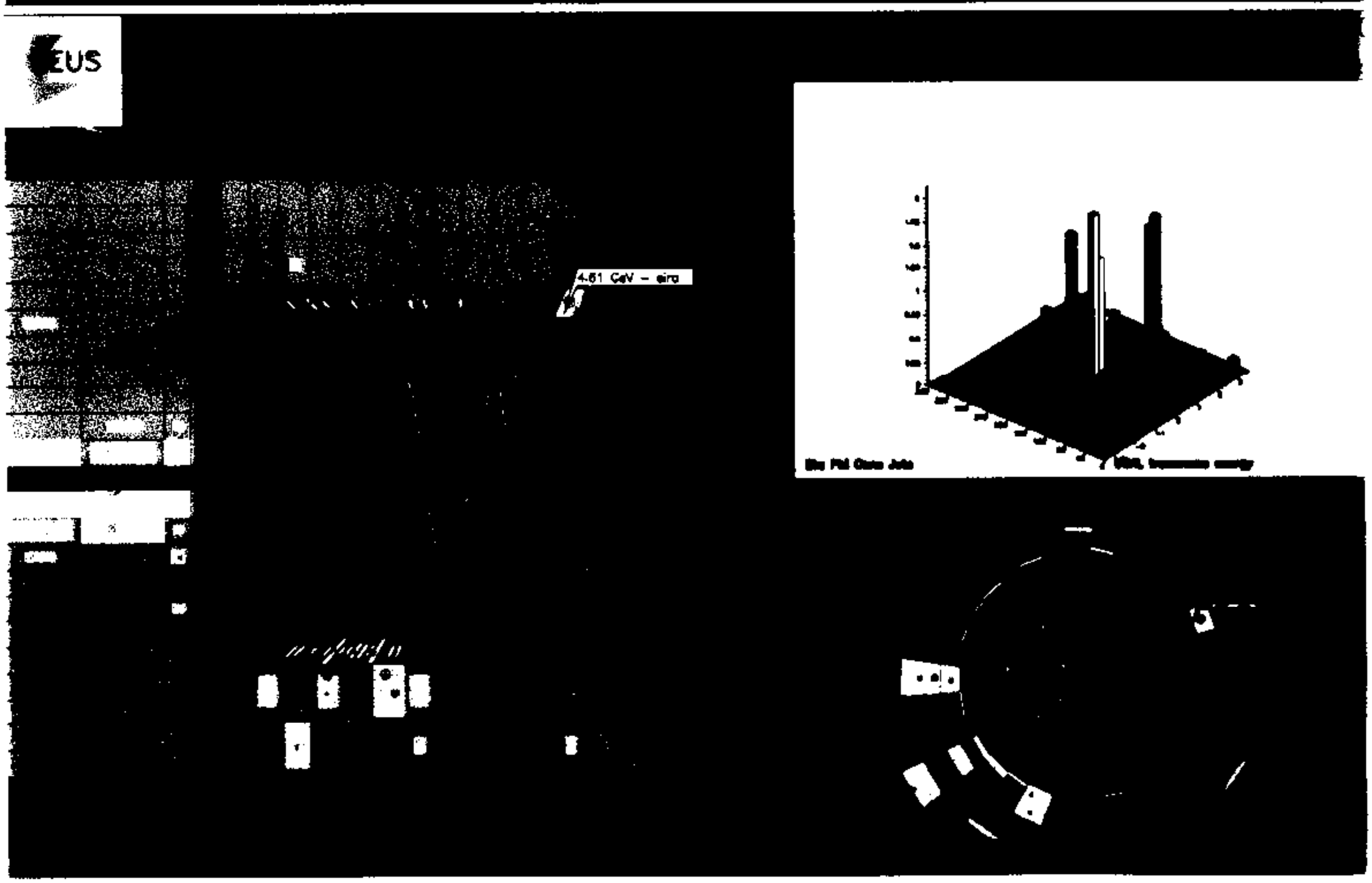
≈ Dimensions of calorimeter cell
→ π^0 decay gives a wider energy deposit.



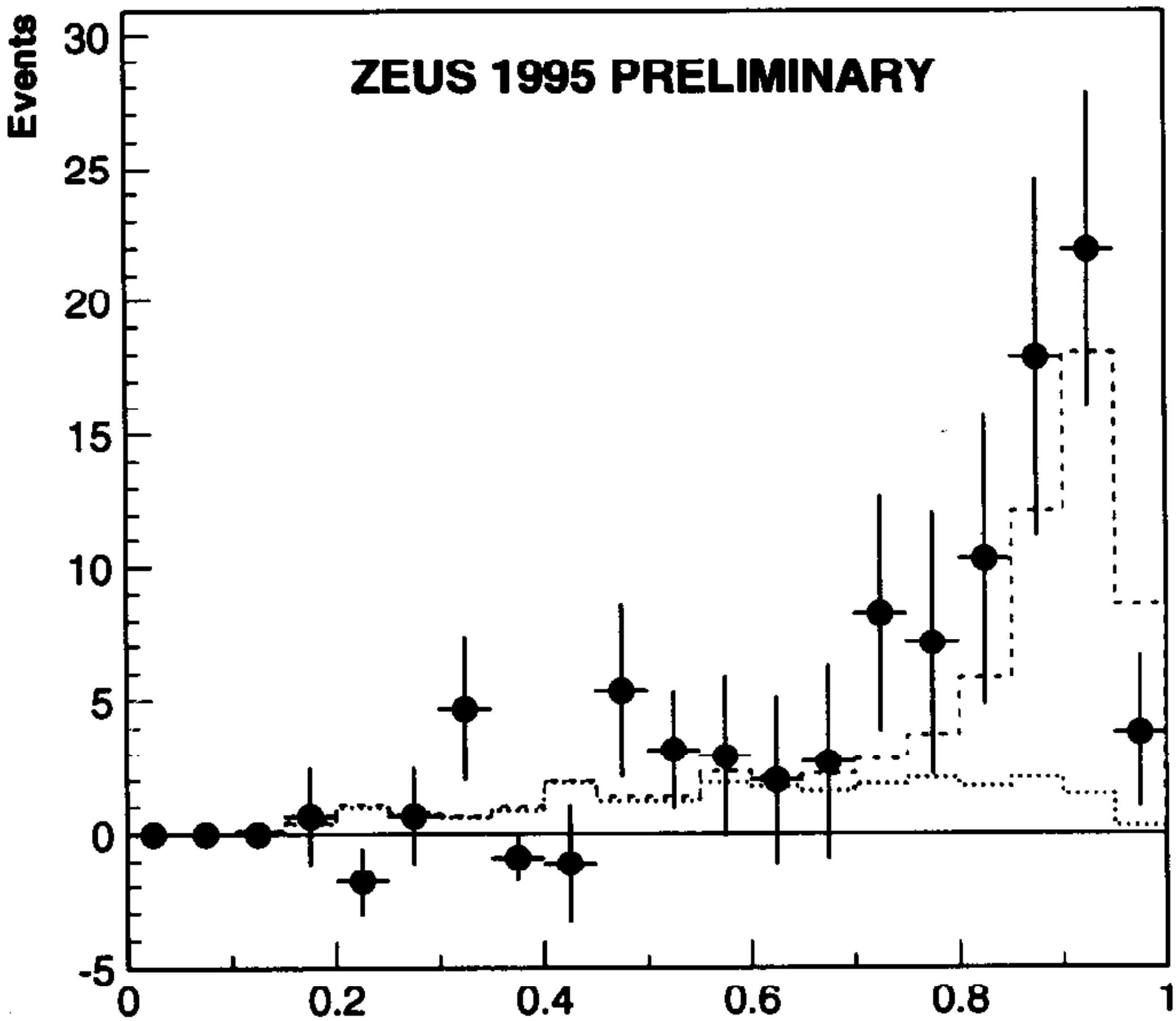
Reject if $E_{out} > 10\% \; E_{Cluster}$

Remaining contributions from π^0 and η decay evaluated by fitting f_{max}, the fraction of the cluster energy in the highest energy calorimeter cell, using Monte Carlo distributions.


ZEUS
6.97 GeV


ZEUS
4.61 GeV

X_γ^{OBS} for Prompt Photon Events



x_γ photon signal

MC resolved + direct

MC resolved

As expected direct processes dominate

Conclusions

[illegible] production offers the opportunity to study [illegible] and parton distributions f[illegible] [illegible] With the unique property [illegible] interact with point-like [illegible]

Inclusive Jet cross sections

- Cross sections in η have been measured for several minimum E_t^{jet}
- Monte Carlo predictions are of the same shape as the data, but ~30% lower
- Data and NLO calculations are in better agreement in magnitude but not shape

Dijet angular distributions

- The measured dijet $|cos\theta^*|$ distribution agrees with the angular dependence predicted by pQCD, arising from the different spins of the exchanged particles in direct and resolved processes.

Dijet cross sections

- Cross sections in $\bar{\eta}$ have been measured for different E_t cuts and in different x_γ^{OBS} regions, with 3 different jet algorithms.
- The differences between the jet algorithms become less significant as E_t^{jet} increases.

Monte Carlo predictions with and without multi-parton interactions can describe the shape of the cross section for the complete x_γ region, although models with multiple interactions are slightly favoured.

Comparison of the direct cross section with NLO QCD calculations shows good agreement in both shape and magnitude.

Comparison of resolved photon cross section in the region 0.3< x_γ^{OBS} <0.75 with NLO QCD calculations shows a good agreement in shape and magnitude for E_T^{jet} >11 GeV. The data lies above the calculations when lower E_t jets are included.

Prompt Photon

Isolated high E_t photon events are seen.

The x_γ^{OBS} has been measured and shows that the dominant process is from direct photons

Jet Shapes

Jet shapes from γ - P have been studied. See presentation by M. Martinez