# Summary of jets and inclusive hadron production session

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- Hadron production
- Photon and $Z^0$ production
- Jet production
- Outlook
- Summary and conclusions

# Universality of quark fragmentation I (D. Traynor)

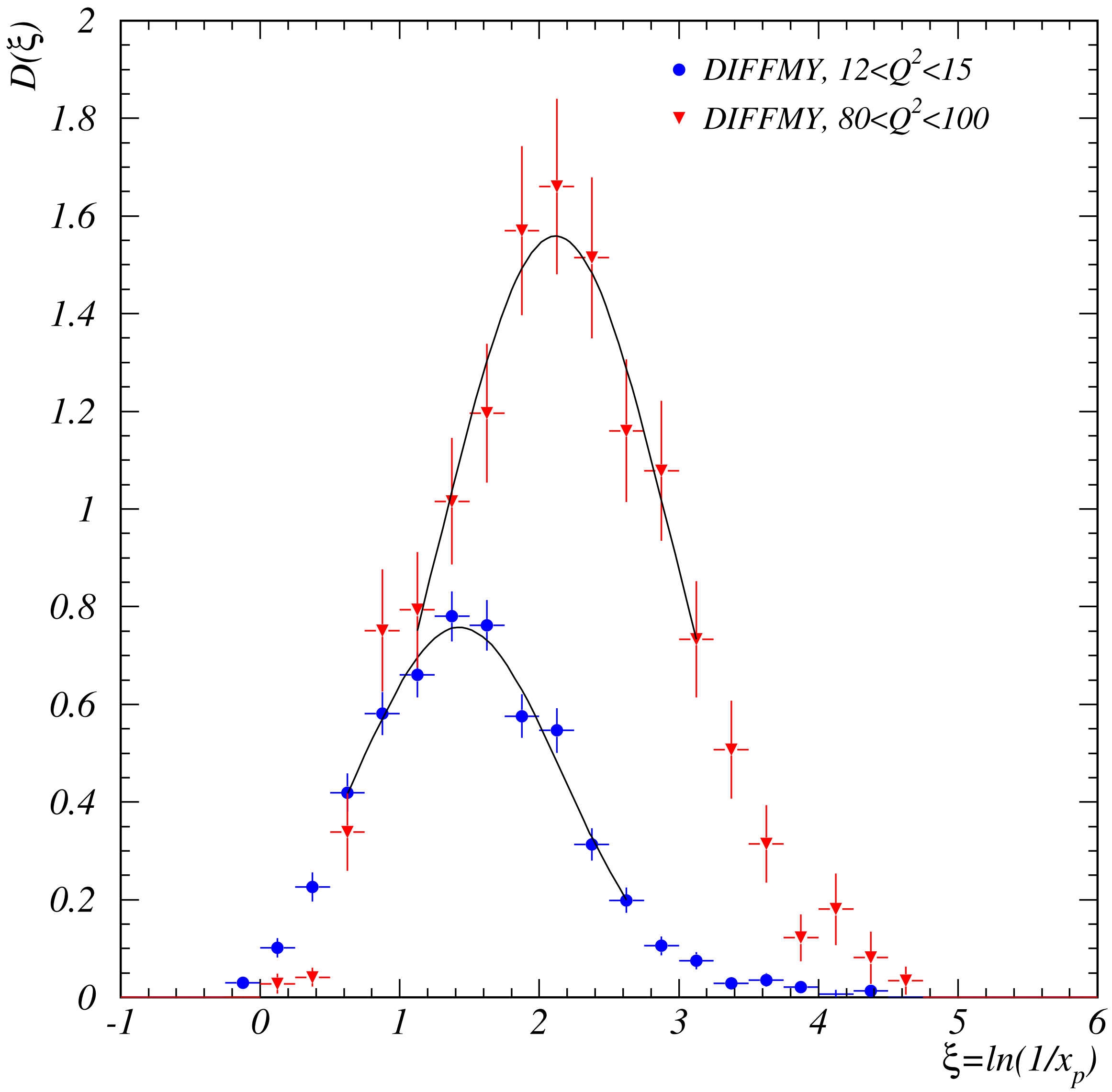
**Is quark fragmentation universal?**

**Consider,**

$$\xi = \ln\left(\frac{1}{x_p}\right), \quad D^{\pm}(\xi) = \frac{1}{N}\left(\frac{dn^{\pm}}{d\xi}\right)$$

**Example regions show:**

- approximate Gaussian shape seen in peak region,
- predicted by MLLA,
- MLLA also predicts evolution with $Q$.

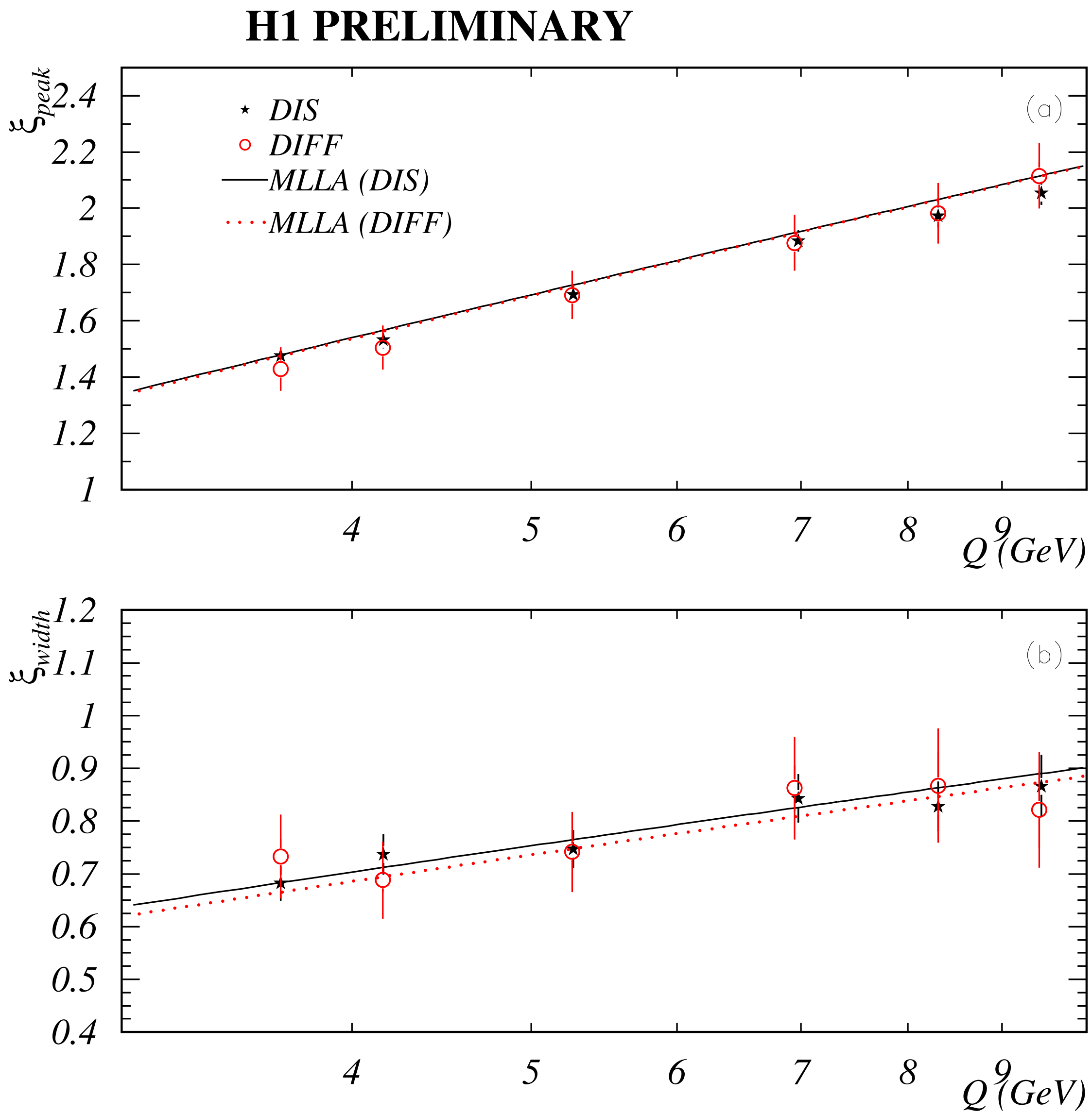


# Universality of quark fragmentation II

Peak position and width measured as a function of $Q$.

Evolution with $Q$

- is similar between inclusive and diffraction,
- is described by MLLA fits,




Supports concept of universal quark fragmentation

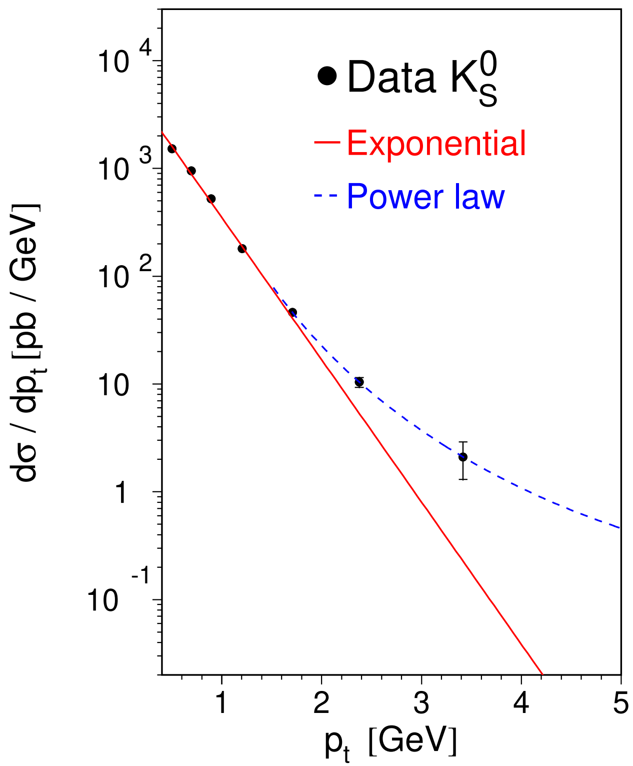
# Inclusive hadron production at LEP I (P. Achard)

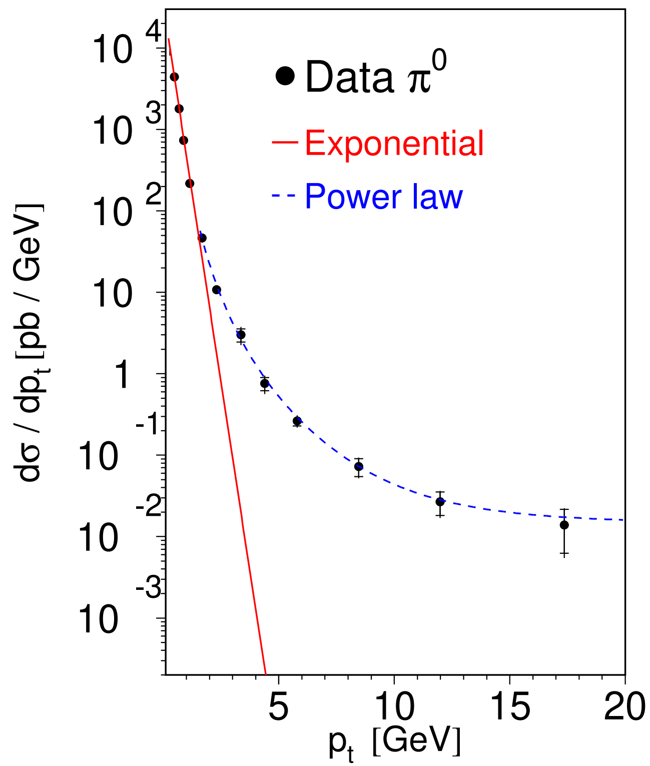
**Large data sample being exploited.**

**Exponential fall off of cross section poor at $p_T >$ few GeV.**

**Power law describes the data very well.**

- **normally associated with soft physics processes,**
- **can be measured at other colliders to higher $p_T$?**



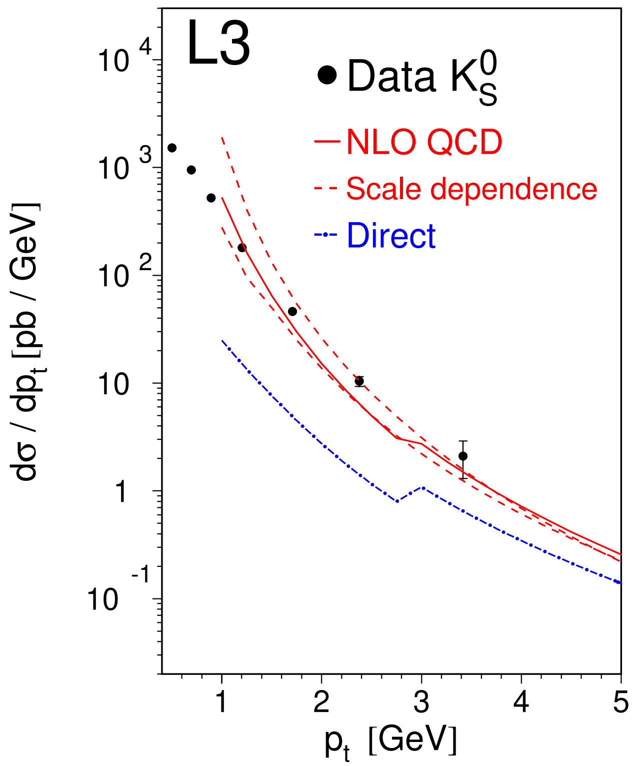

**Comparison the theory; MC and NLO? $\rightarrow$**

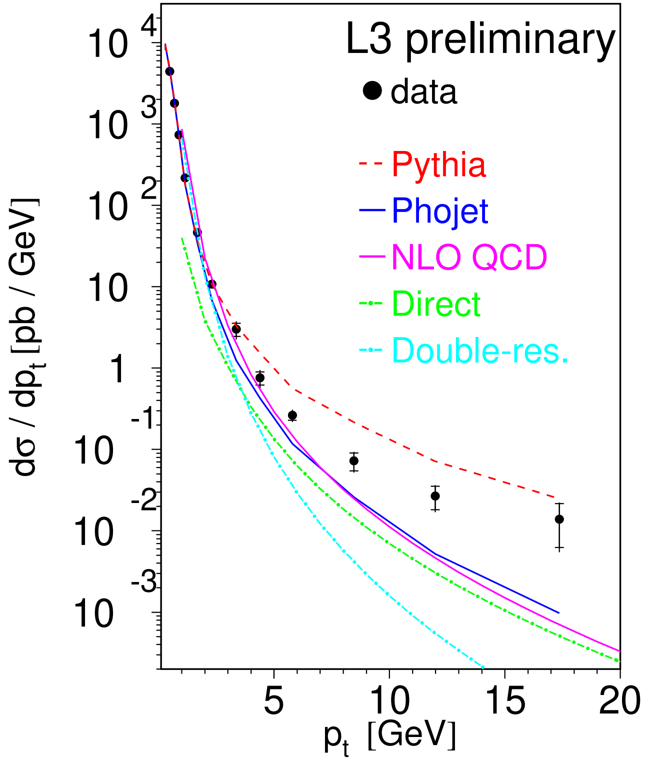
# Inclusive hadron production at LEP II

**QCD predictions (NLO,** Phojet **and** Pythia**) work well at low** $p_T$.

**For high** $p_T$**:**

- **NLO and** Phojet **underestimate the data,**
- Pythia **overestimates the data,**
- **data/MC and MC/MC differences are over factor of 10!**




Clear need for improvement in the models/predictions.

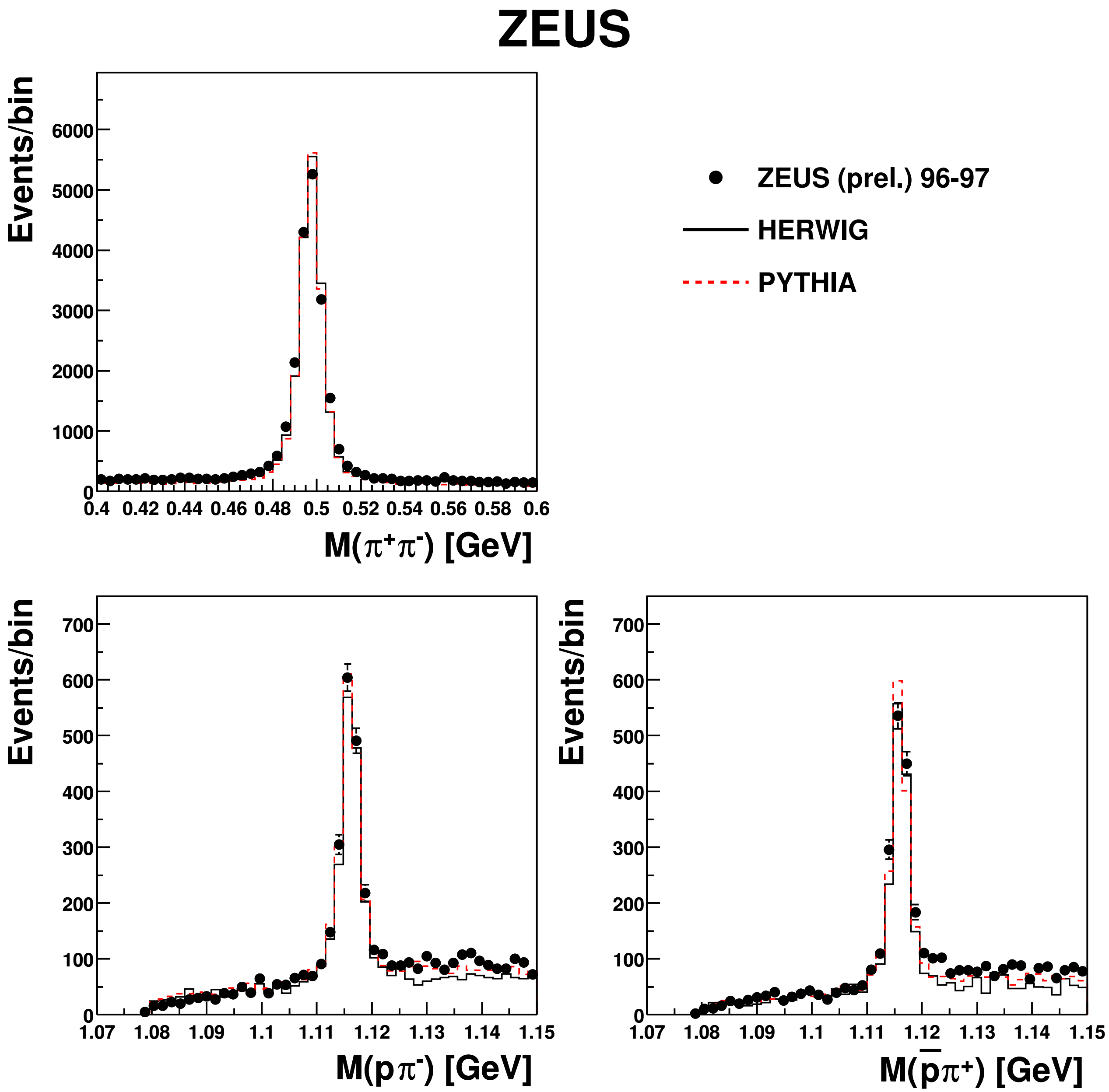
# Strange hadron production at HERA I (S. Boogert)

Hadron production being studied again at HERA.

Sample of $K_s^0$ (in dijet photoproduction) is particularly large and clean.

Can be used:

- to investigate fragmentation at HERA,
- compliment LEP results,
- reveal information on the proton and photon structure.



# Strange hadron production at HERA II

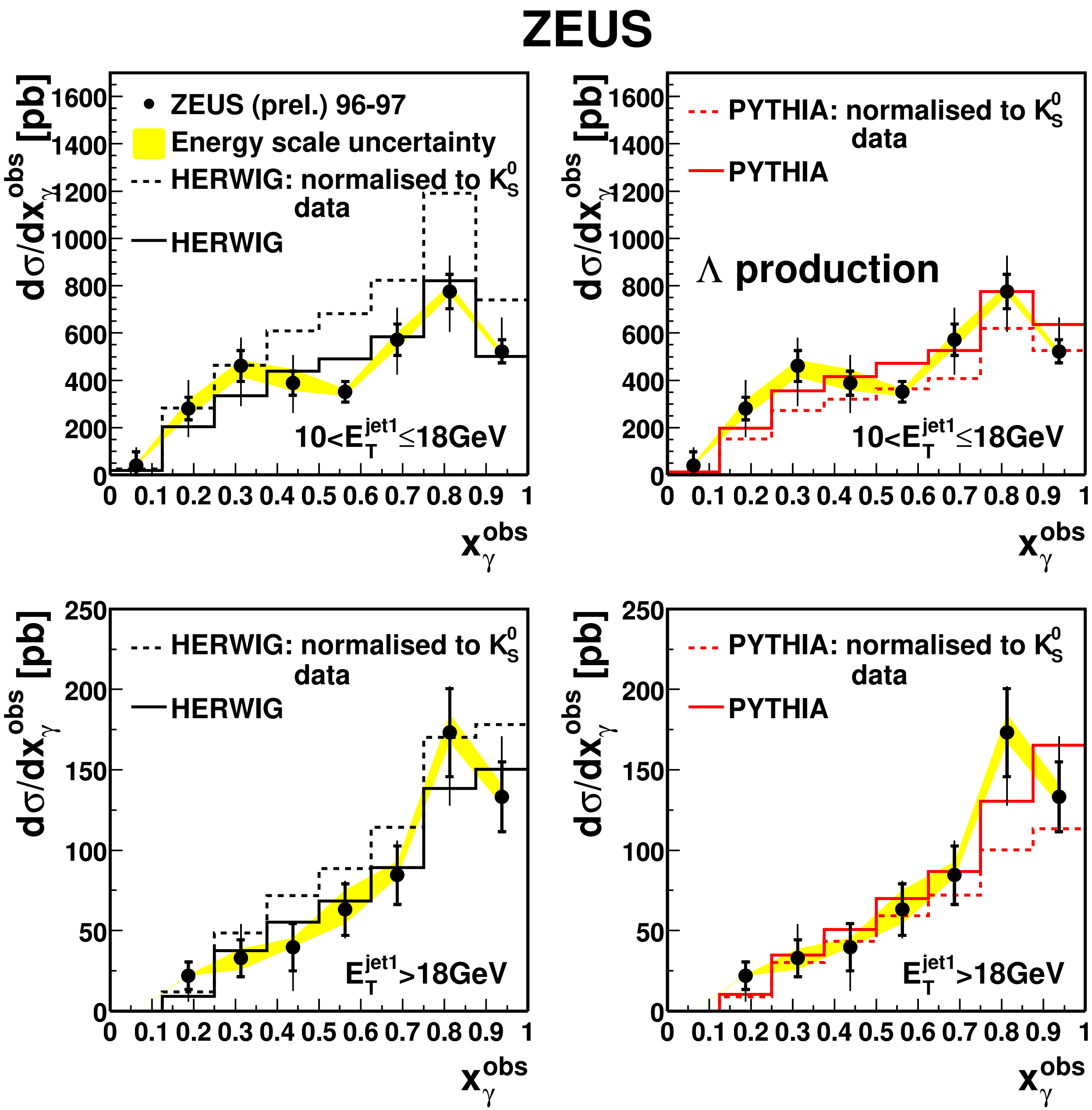
**Monte Carlo generally describes shapes of data distributions.**

**Normalising MC to production of $K_s^0$, $\Lambda$ (and $\bar{\Lambda}$) cross sections are:**

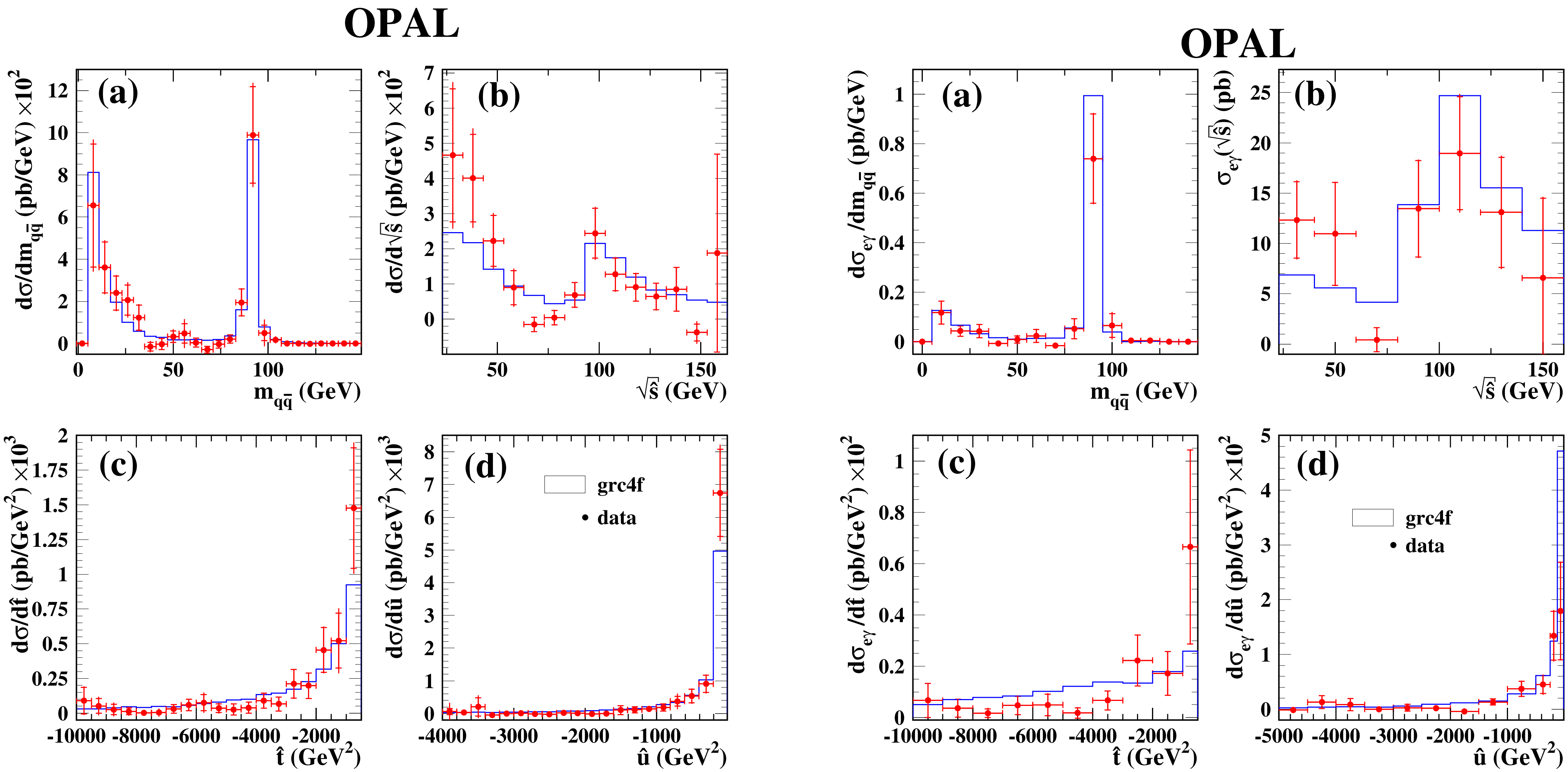
- **too high in** Herwig**,**
- **too low in** Pythia**.**

**Future:**

- **rates relative to inclusive dijet cross section?**
- **comparison to NLO?**
- **behaviour at high $p_T(K_s^0)$?**



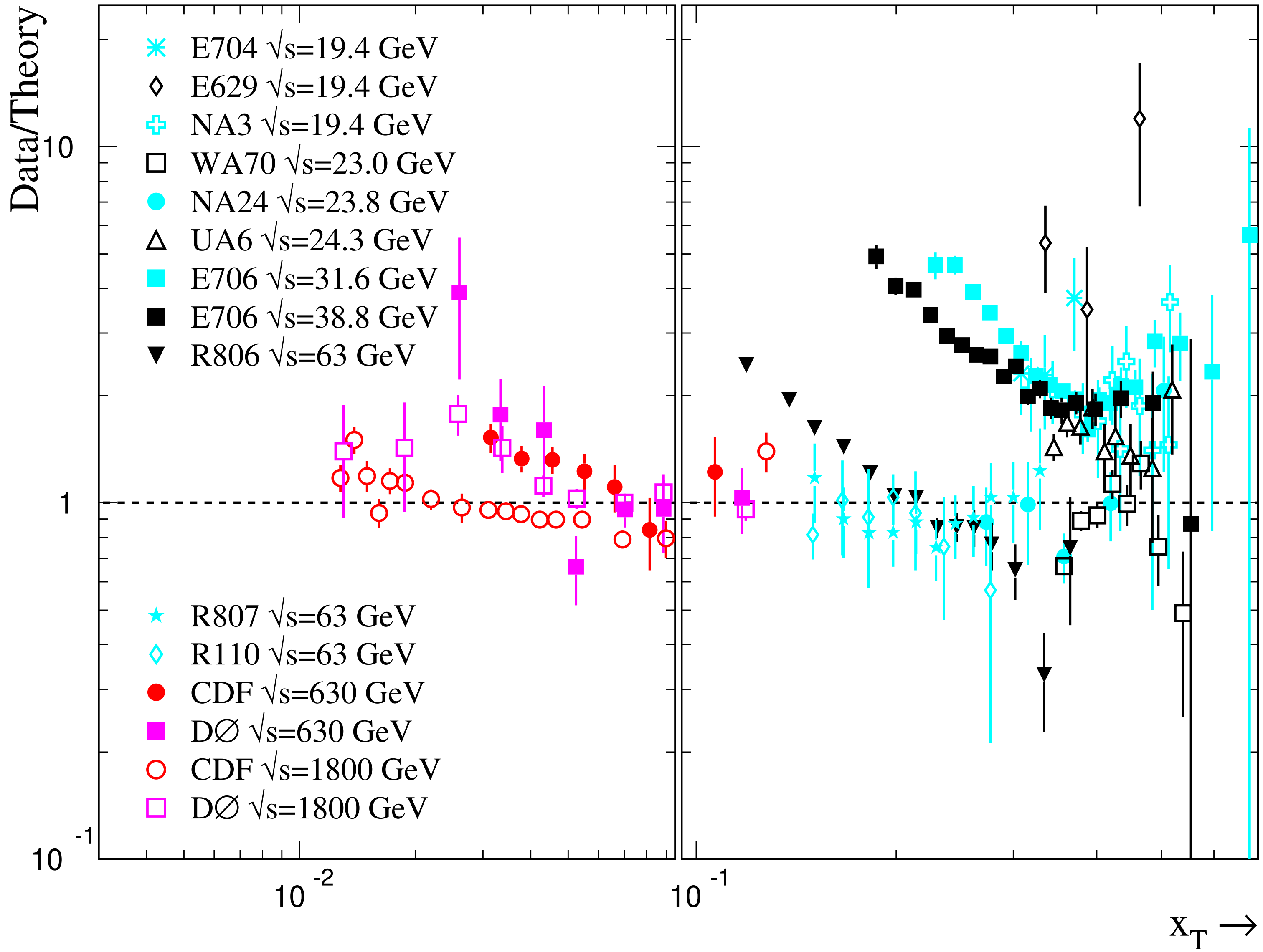
# Measurement of $Z/\gamma^*$ production (I. Fleck)




**MC generators describe the processes, $e^+e^- \to e^+e^- Z\gamma^*$ and $e\gamma \to eZ\gamma^*$**

# Prompt photon production (M.Begel, U. Jezuita-Dabrowska, J. Lillich)

## Summary of hadron-hadron collisions



# Photons at the TeVatron and HERA and $k_T$

**Predictions generally agree with D0 measurements but not so well with CDF.**

**Influence of $k_T$ effects in data?**

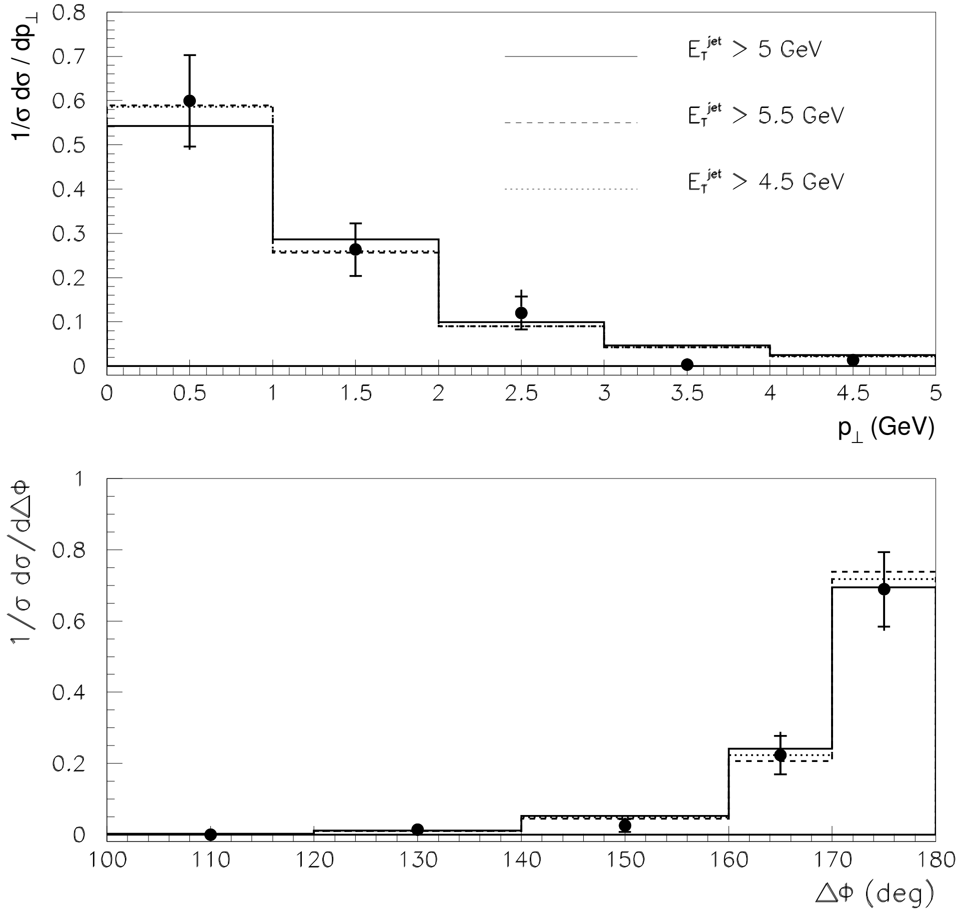
**ZEUS recently measured $k_T$-sensitive variables.**

**Extracted value followed trend of hadron-hadron measurements**

**$\rightarrow$ increasing with increasing $\sqrt{s}$.**

**New calculation (Fontannaz et al, `hep-ph/0107262`) describes data well.**

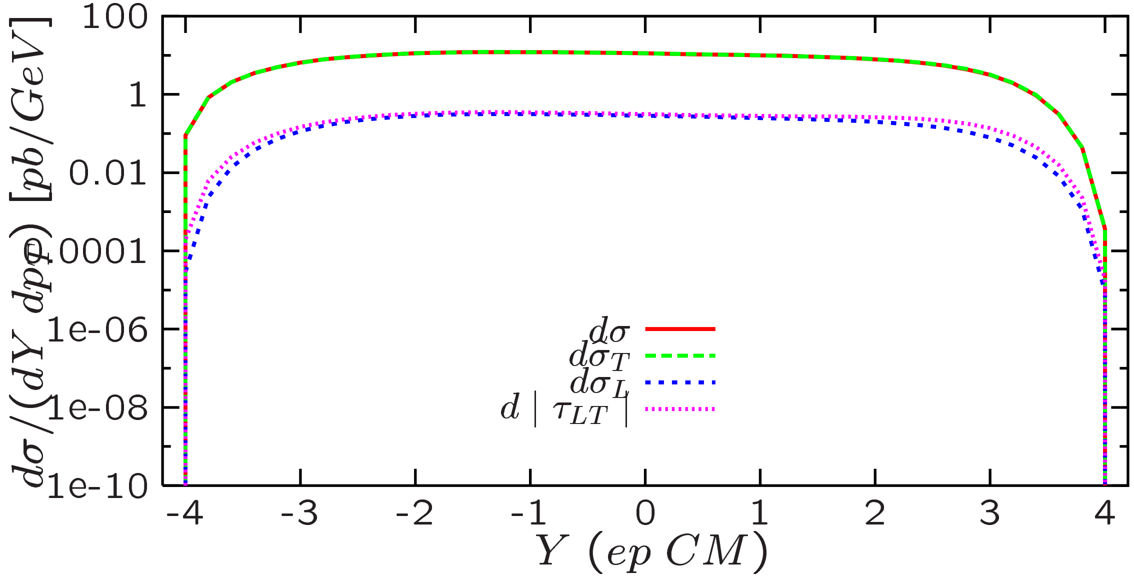
**No need for "additional" $k_T$.**



# Interference and longitudinal $\gamma^*$ terms in $ep$ collisions

**Have seen a study of potential importance of $\gamma_L^*$ in dijet production (K. Sedlak)**

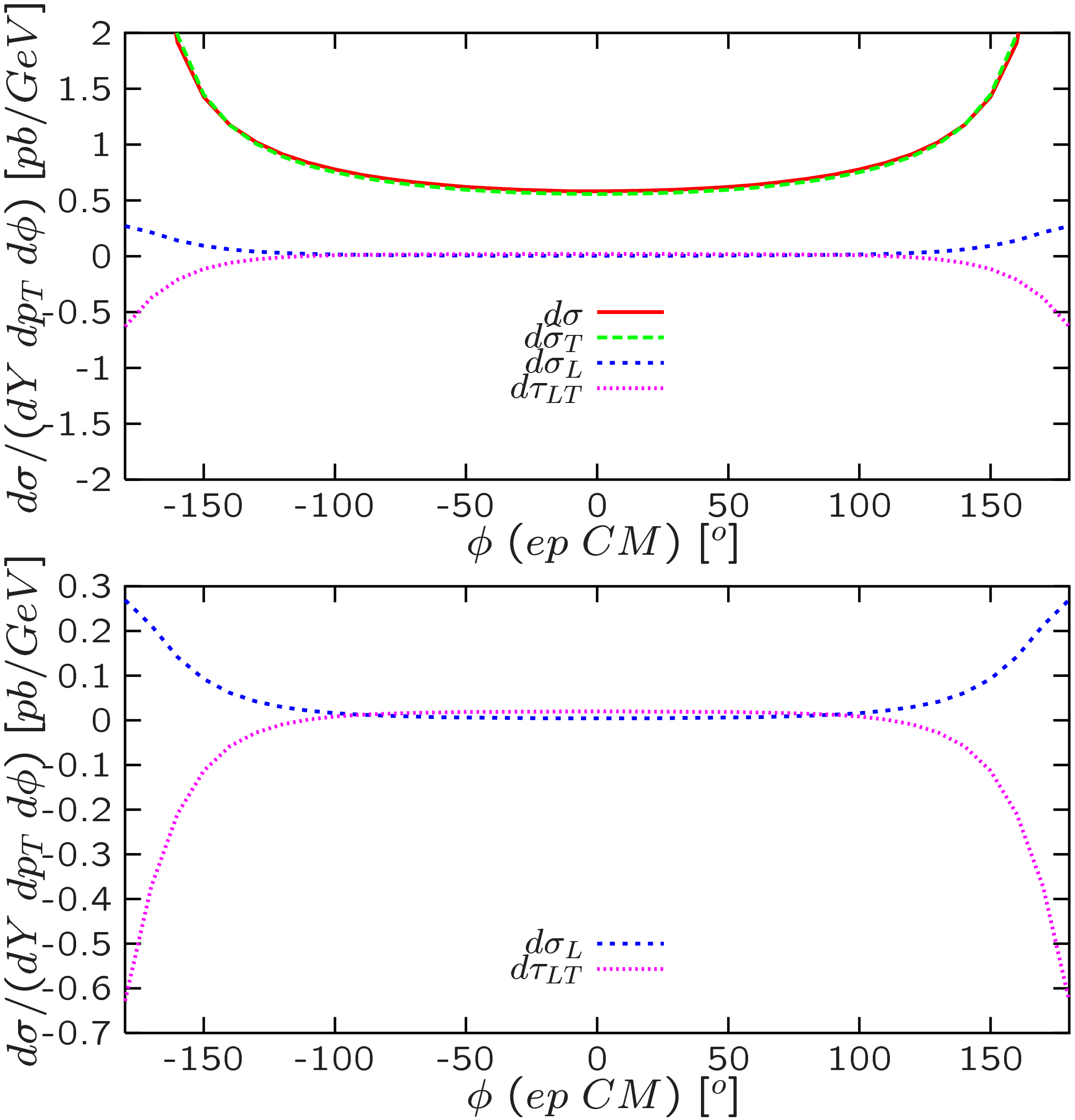
**Consider now Compton process $ep \to e\gamma X$.**




**Longitudinal and interference terms almost cancel - should be included on the same footing**

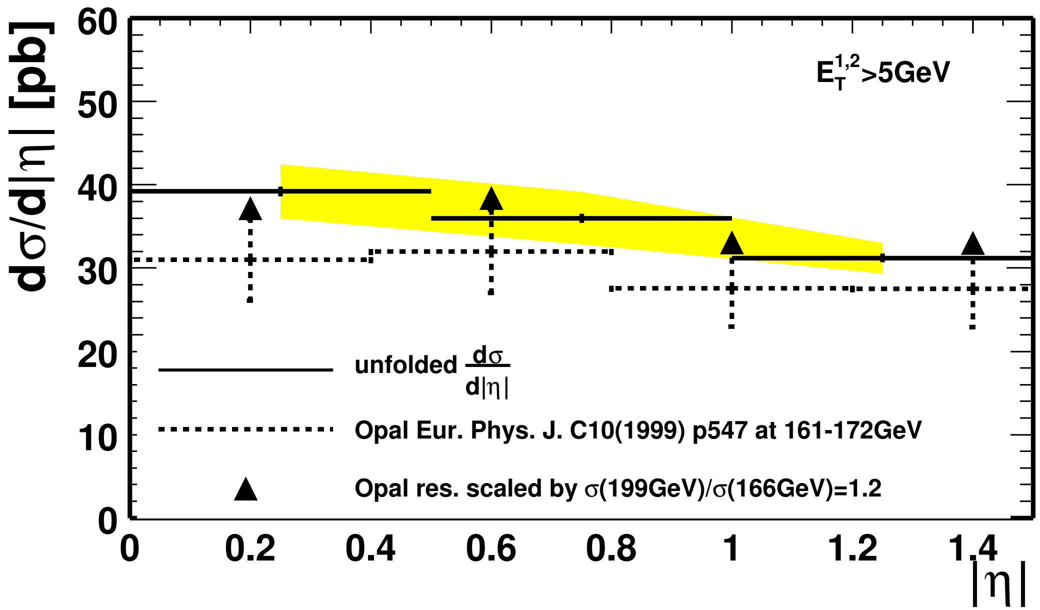
# Interference and longitudinal $\gamma^*$ terms in $ep$ collisions

**Azimuthal angle useful for studying effects**




**How important is $\gamma_L^*$?**

# Dijet production in $\gamma\gamma$ I (J. Masik, T. Wengler)

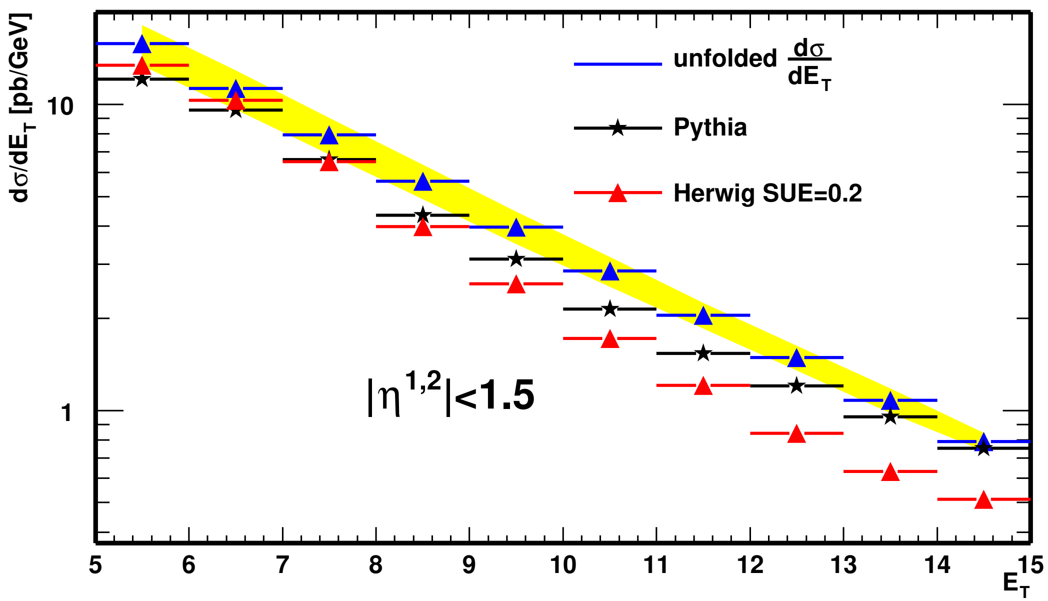



First results from DELPHI on dijet cross sections.

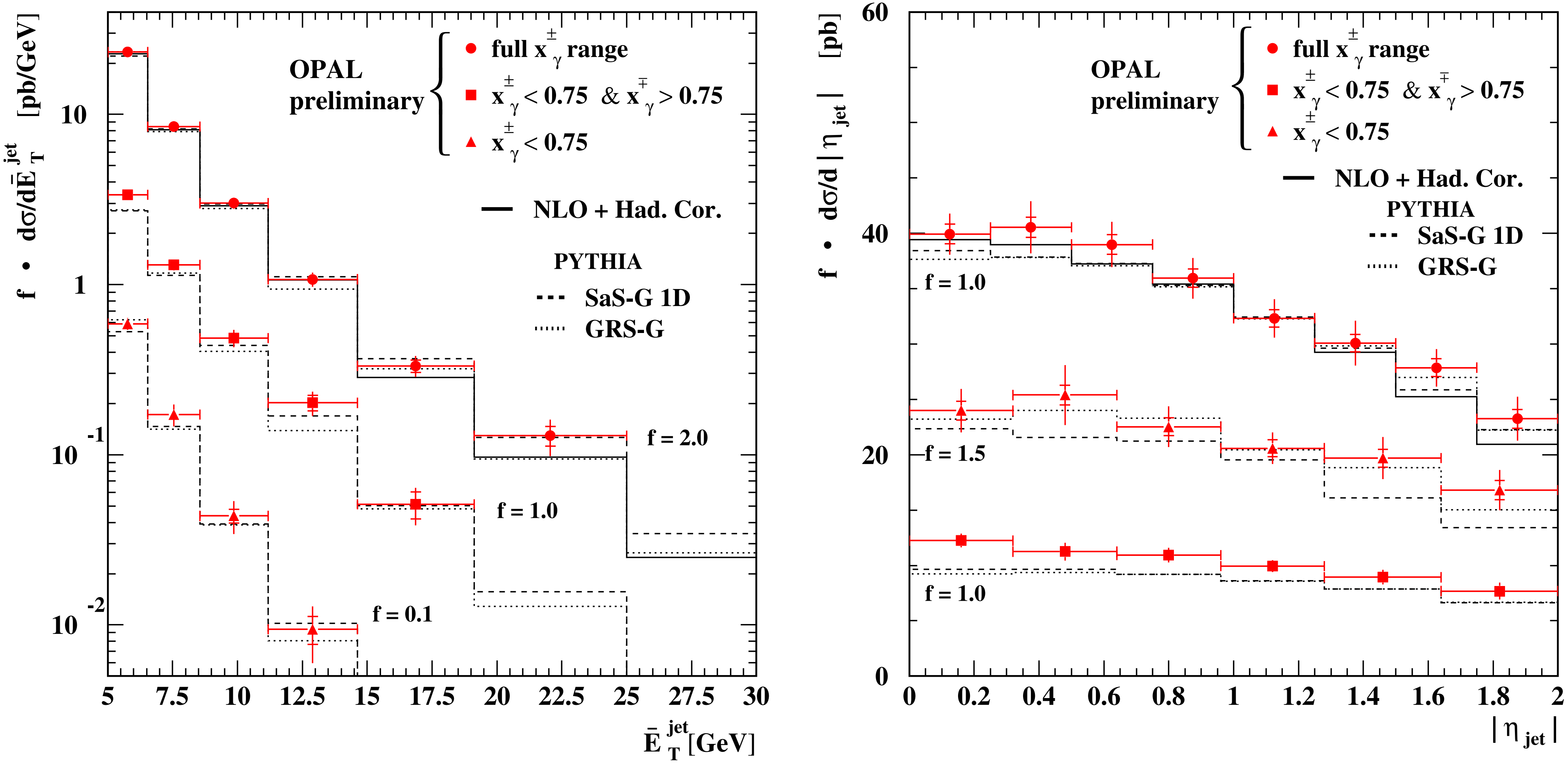
Very good agreement with OPAL.

Comparisons with LO MC generally okay in shape.

Comparisons with NLO? $\rightarrow$



# Dijet production in $\gamma\gamma$ II




**Huge data sample: $\mathcal{L} \sim 600$ pb$^{-1}$.**

**Reasonable agreement between data and NLO in all-$x_\gamma^\pm$ region.**

**Cross section in $x_\gamma$ very sensitive to hadronisation effects - to be studied further.**

# Dijets in DIS - jet cuts (T. Schoerner)

Dijet measurements pose more problems than inclusive jets.

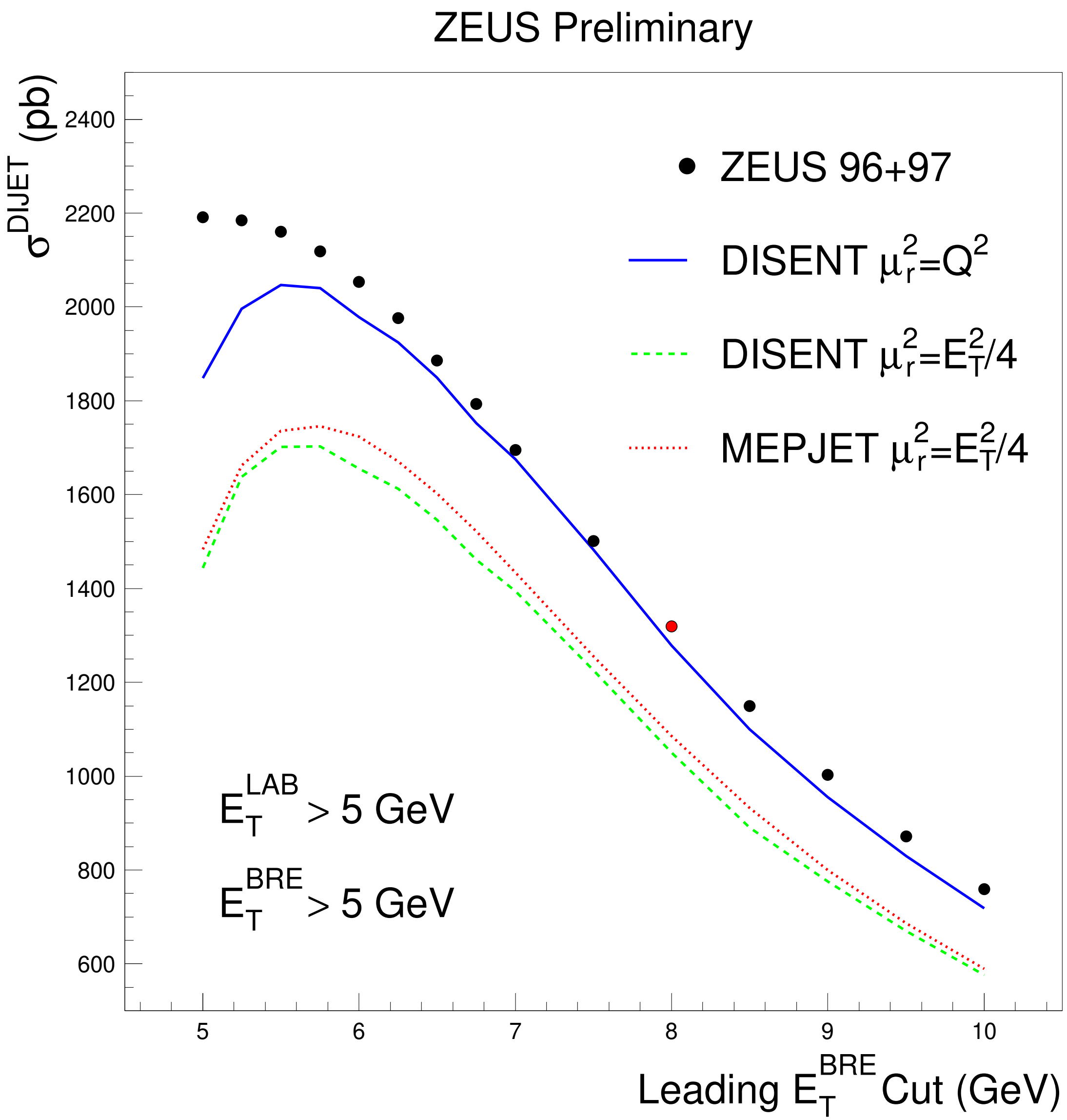
Choice of cuts important.

Cross sections should not be infra-red sensitive.

Need to have:

- "asymmetric" cuts; $E_{T,1}^{\rm jet} > E_T^{\rm cut}$, $E_{T,2}^{\rm jet} > E_T^{\rm cut} - \Delta$
- "sum" cuts; $E_{T,1}^{\rm jet}, E_{T,2}^{\rm jet} > E_T^{\rm cut}$, $E_{T,1}^{\rm jet} + E_{T,2}^{\rm jet} > 2E_T^{\rm cut} + \Delta'$

How relevant in photoproduction?



# Dijet photoproduction at HERA

Dijet cuts have significant impact on the results.

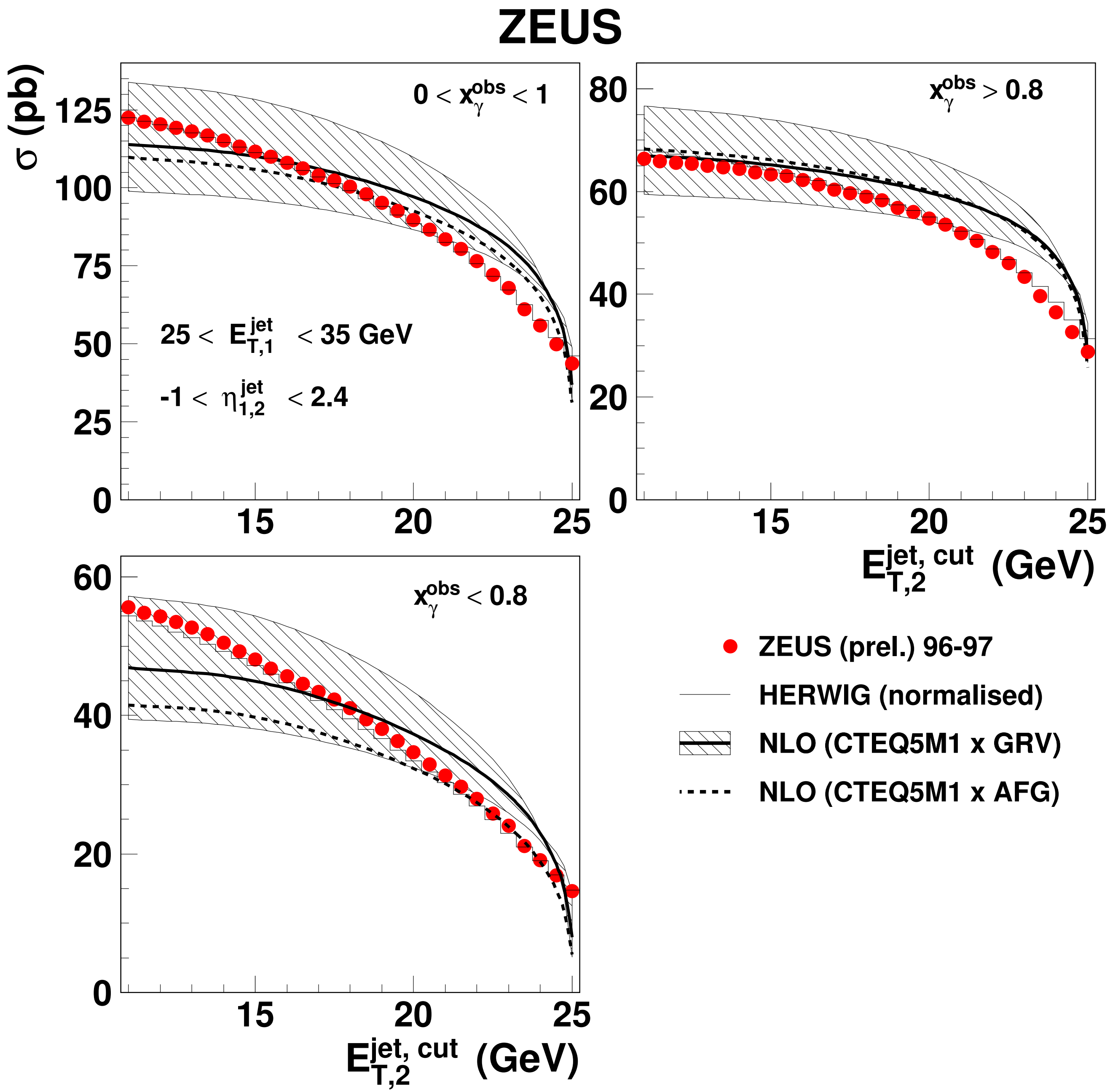
Familiar problem when cuts too close.

Significant difference in shape between high- and low-$x_\gamma^{\rm obs}$.

Definite shape differences between data and NLO - Herwig is perfect!

Choosing lower $E_{T,2}^{\rm jet,cut}$ seems more reasonable - flat dependence.

Explains some differences between H1 and ZEUS!




In the low-$E_{T,2}^{\rm jet,cut}$ region, data significantly above AFG!

# HERA $\alpha_s$ measurements

Need more theoretical input to jet production!

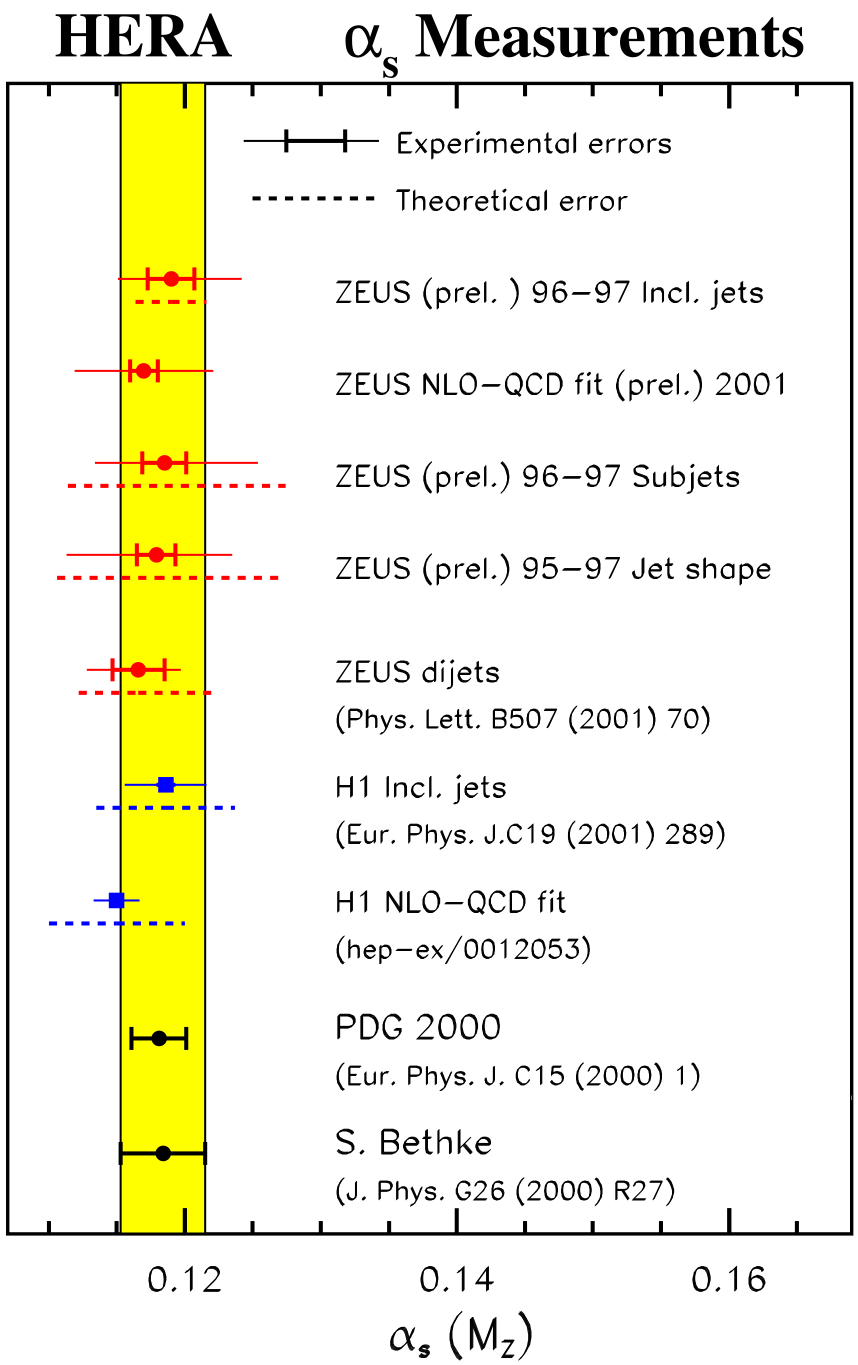
Here is demonstration of power of jet measurements.

HERA producing many competitive measurements of strong coupling constant

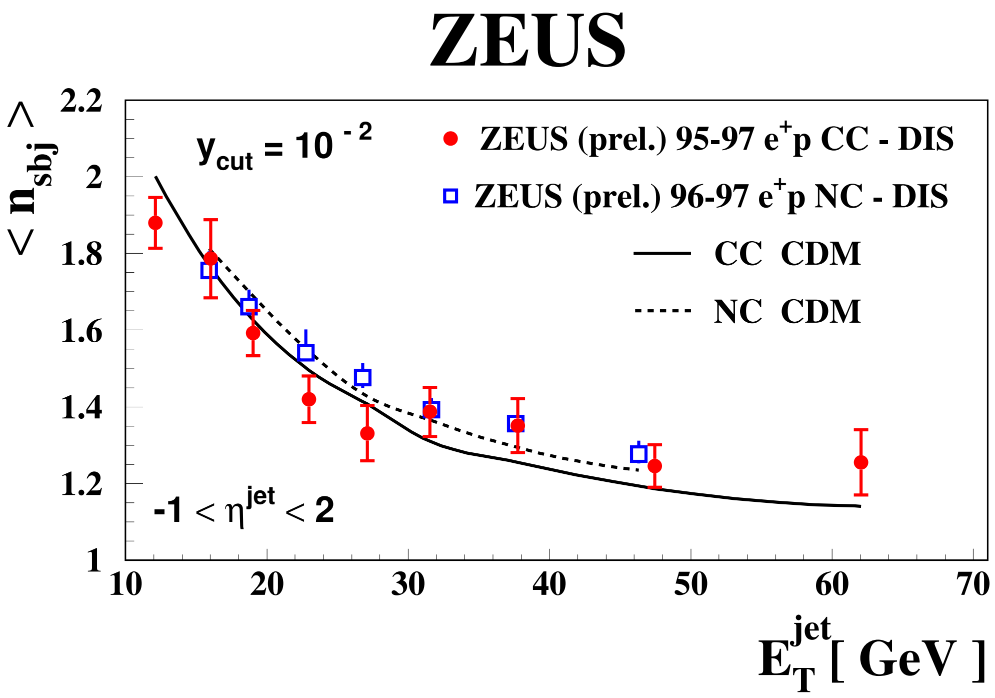
Important in many facets of the processes we study.

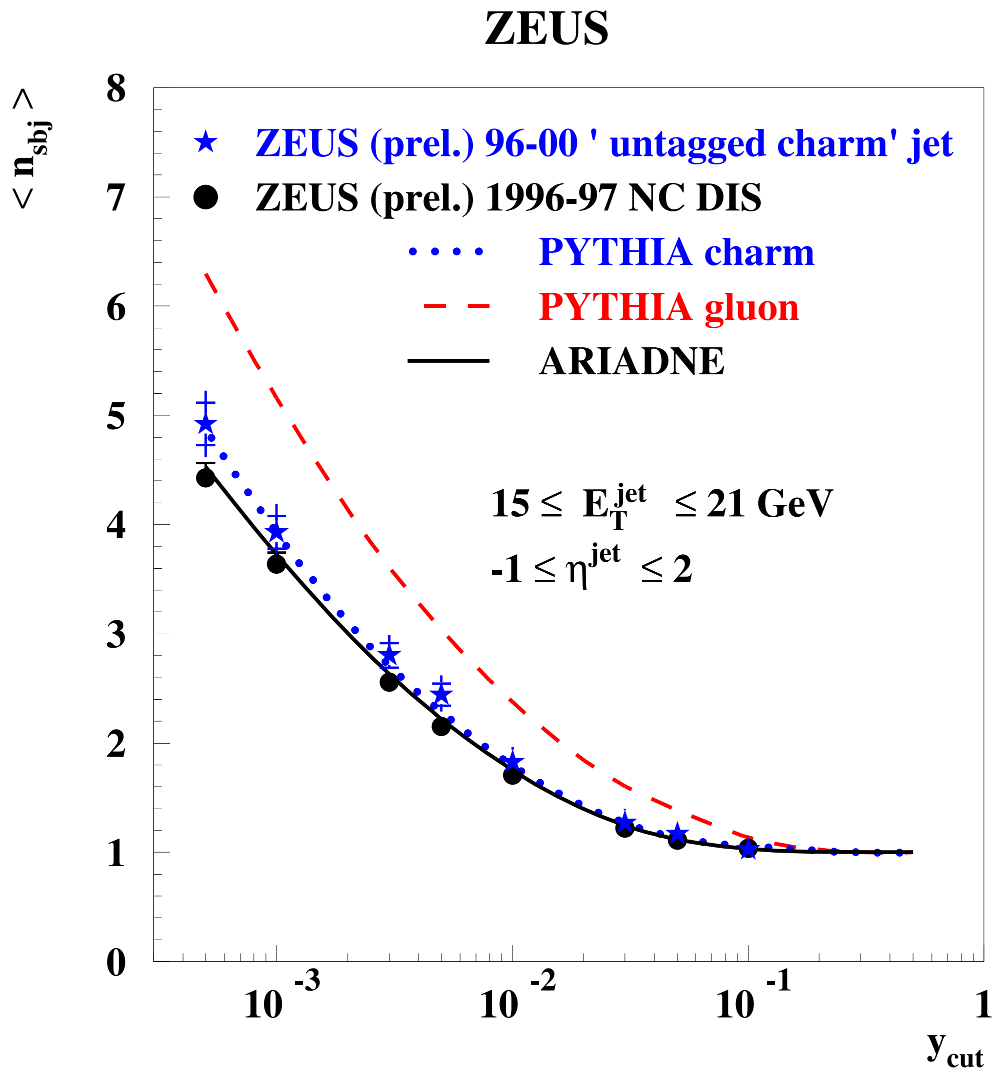
Combination of HERA results?

How will this improve the world average?



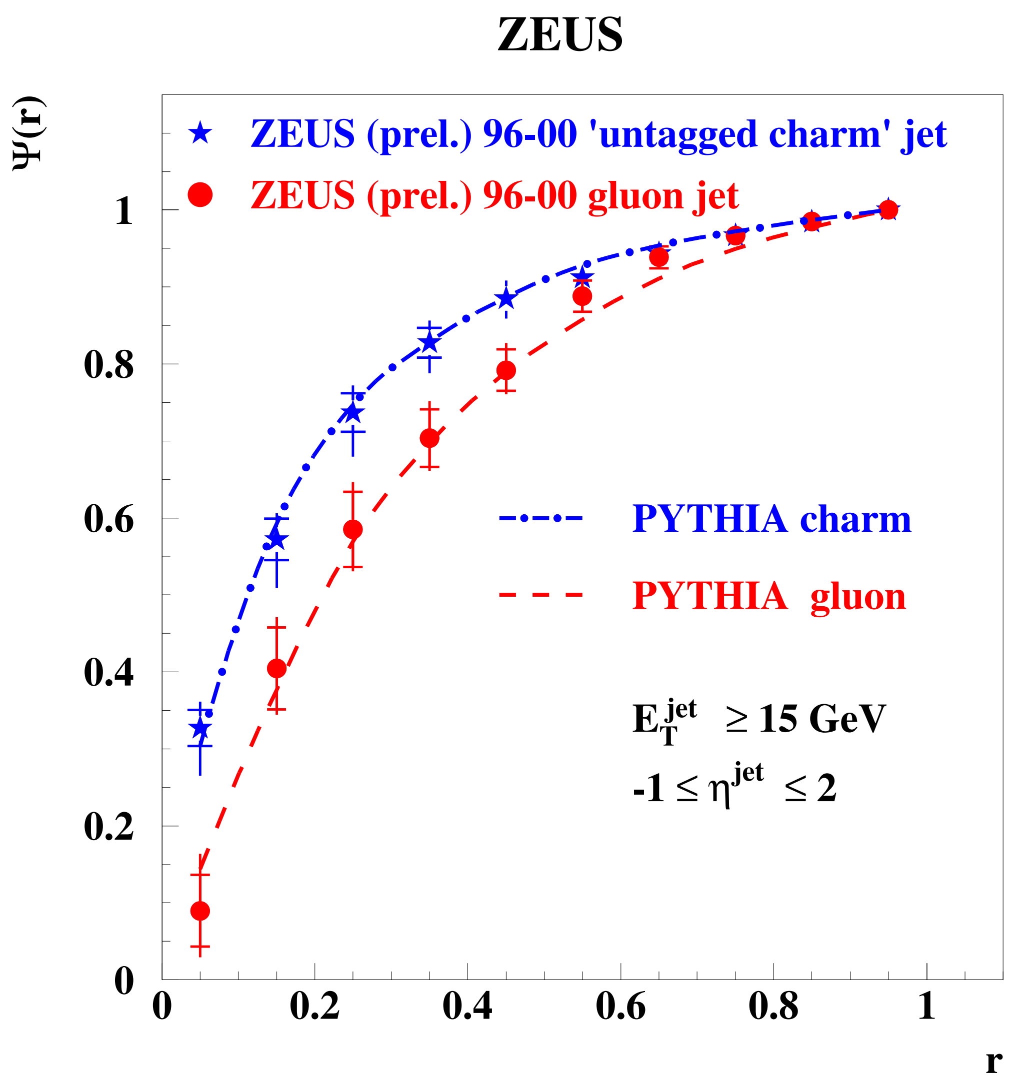
# Jet substructure at HERA I (M. Vazquez)

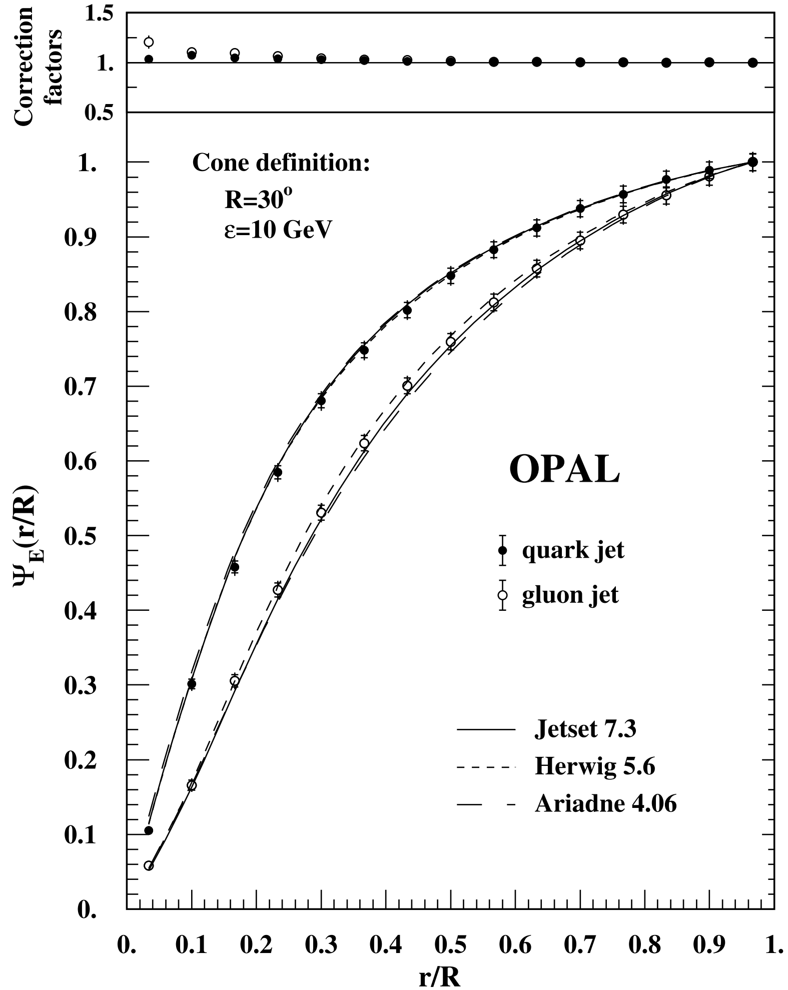



- Charm jets look like quark jets.
- Jets in CC- and NC-DIS are predominantly quark-like.
- Clear tagging of quark jets in many types of process.

# Jet substructure at HERA II



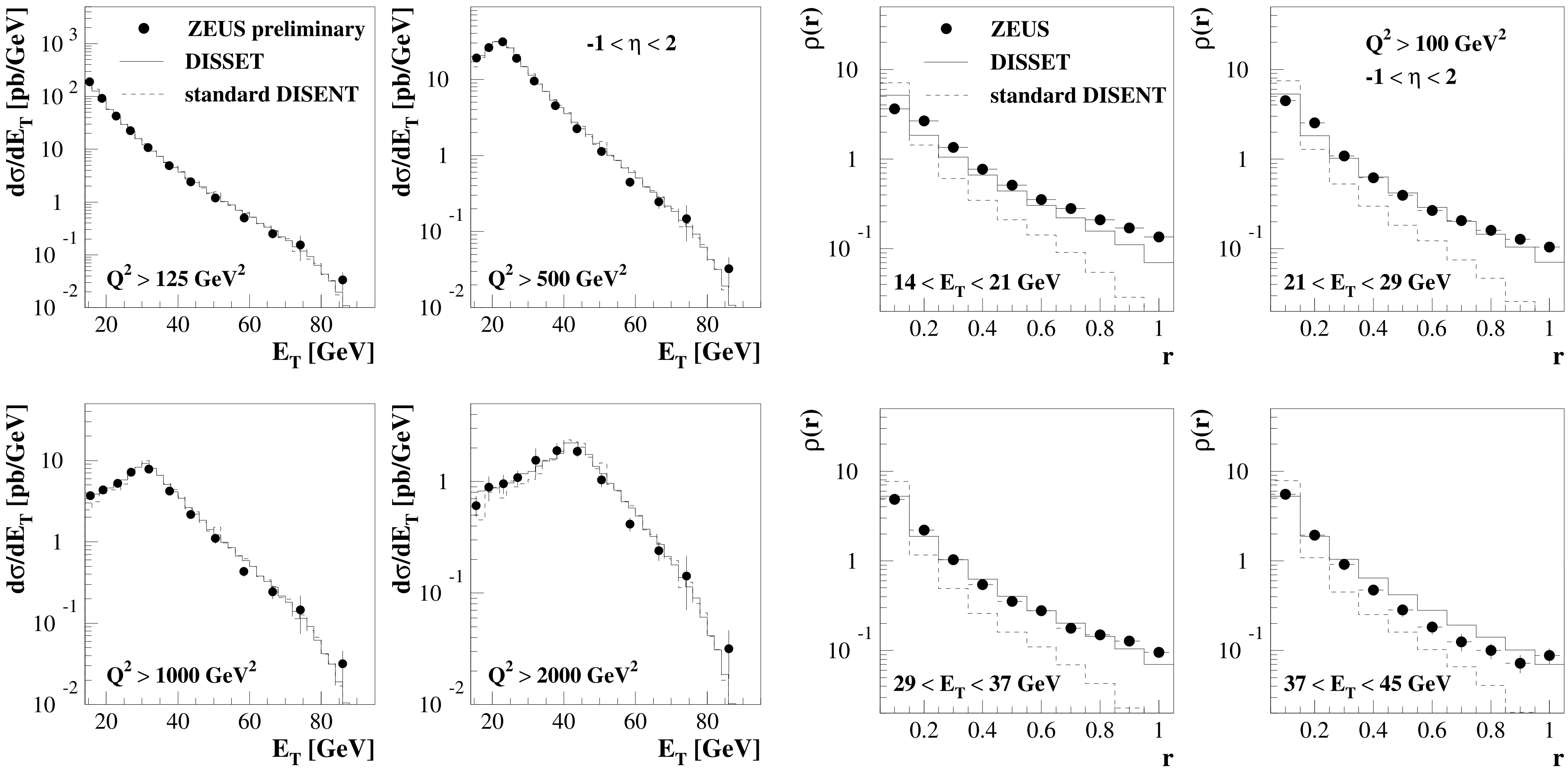




Gluon jet extracted for the first time at HERA (*cf* LEP).

Possibilities for measurements of colour factors, "tagging" the sub-process?

# NLO+PS I (B. Poetter)

## Combining NLO+PS in first step towards NLO MC




**Normalisation for inclusive jet production has been achieved**

**Marked improvement over "standard NLO" in description of jet substructure**

# NLO+PS II

Extend inclusive jet case to dijet events

Still some work to do; initial state parton showers, hadronisation

Can and should be extended to even more event classes

VERY important work which is lacking people

Such improved calculations are absolutely essential for confrontation with ever increasingly accurate data.

# Summary and conclusions

Knowledge of jet and hadron production being tested in more and more detail.

Still advances in theory would be most welcome.

Who is going to do these advances?

Jet and hadron production can then be used more thoroughly in e.g. extracting photon/proton structure.