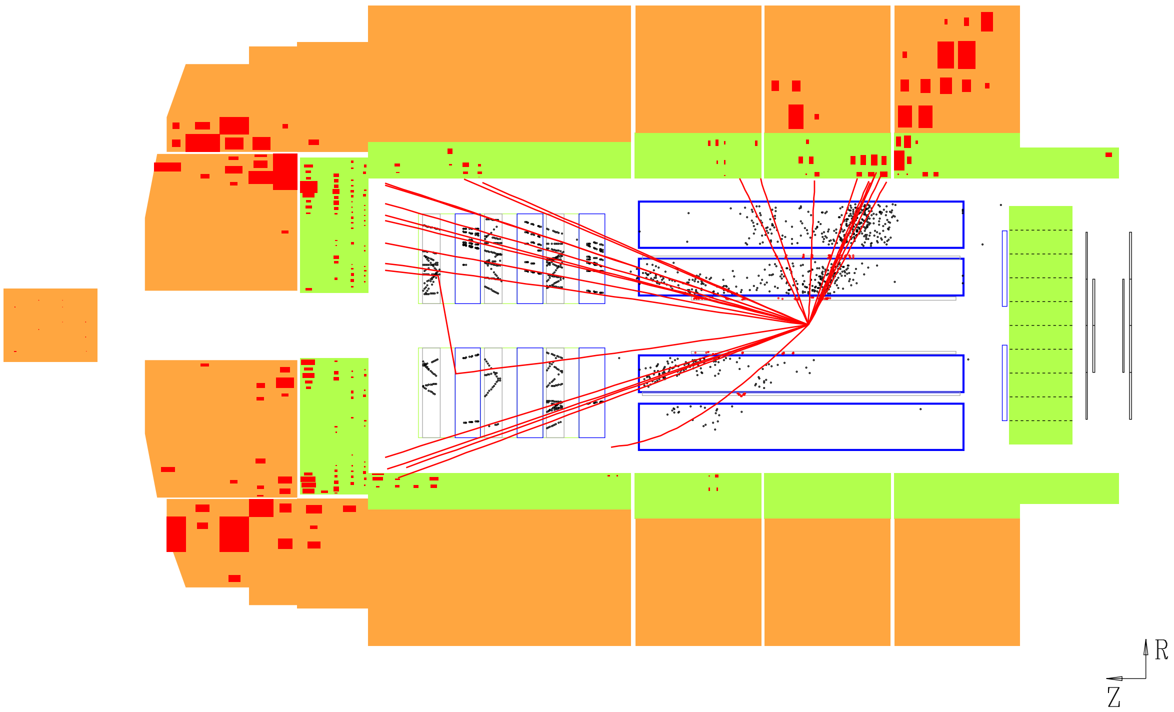
Lake Louise Winter Institute
Alberta, Canada
20-26 Feb. 2000

pQCD at HERA



Ricardo Graciani Díaz

Deutsches Elektronen-Synchrotron

Jets Studies at HERA

$$ep \to e + jet(s) + X$$

"jets provide a view of the underlying hard quark and gluon interactions that occur at very small distance scale"

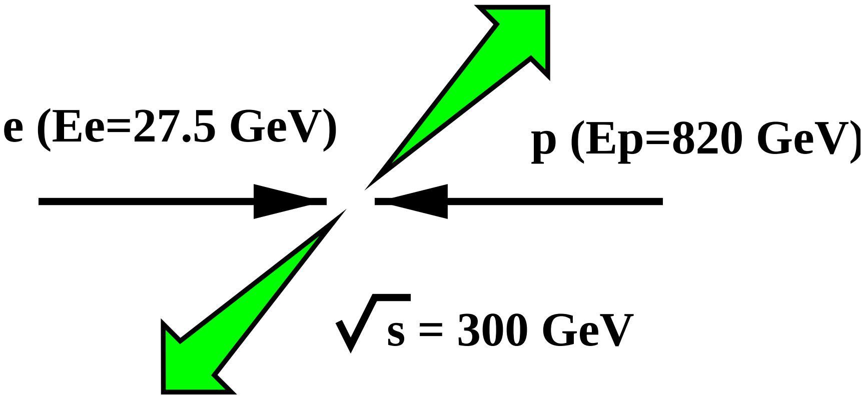
S.D.Ellis and D.E.Soper, Phys. Rev. D48 (1993) 3160.

"the structure of hadronic final states in high energy physics may be described in a simple way in terms of jets characteristics"

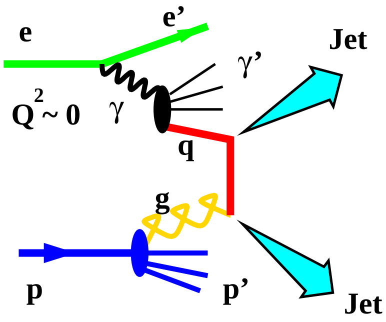
S.Catani *et al.*, Nucl. Phys. B406 (1993) 187.

$$\sigma^{ep\to jet(s)} = \int d\Omega f_{\gamma/e} \times f_{i(\gamma)/\gamma} \times f_{j/p} \times d\sigma_{QCD}^{i(\gamma)j\to jet(s)}$$

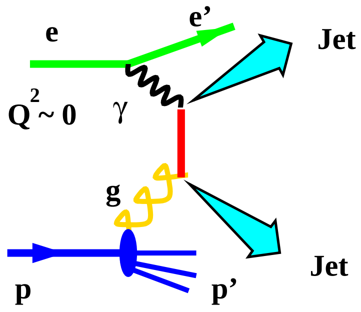
- $f_{\gamma/e}(y, Q^2)$: photon flux (WW,EPA,QED,...).
- $f_{i(\gamma)/\gamma}(x_\gamma, \mu_F^2, Q^2)$: parton $i(\gamma)$ density in γ (F_2^γ).
- $f_{j/p}(x_p, \mu_F^2)$: parton j density in p (F_2^p).
- $d\sigma_{QCD}^{i(\gamma)j\to jet(s)}(Q^2, \alpha_S, \mu_R^2, \mu_F^2)$: partonic subprocess cross section (pQDC).



Photoproduction (γp)

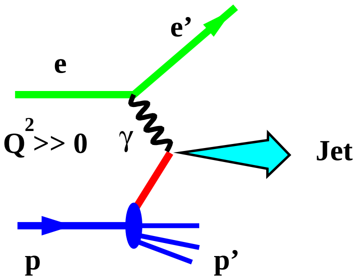


RESOLVED

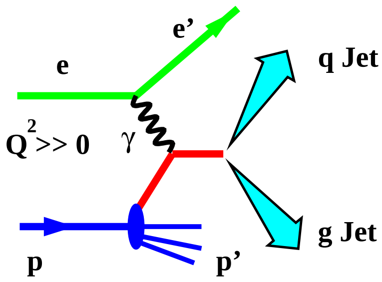


DIRECT

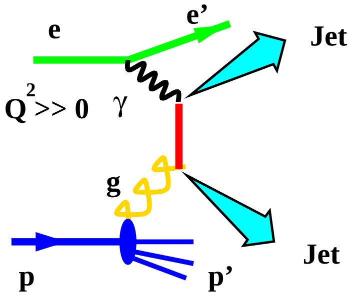
Deep Inelastic Scattering (DIS)



LO



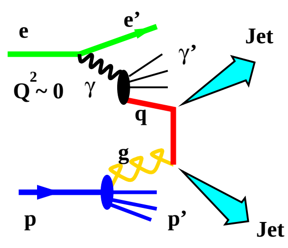
QCD-COMPTON



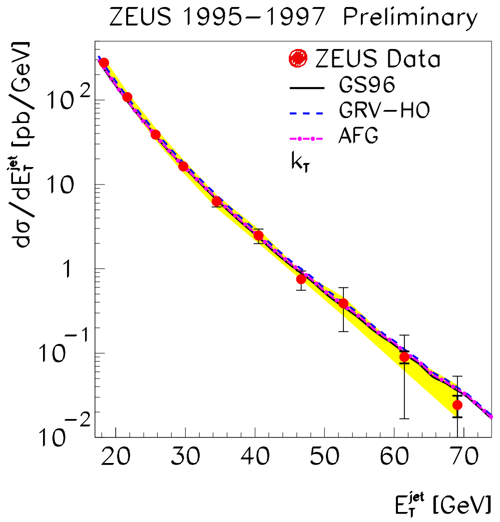
BGF

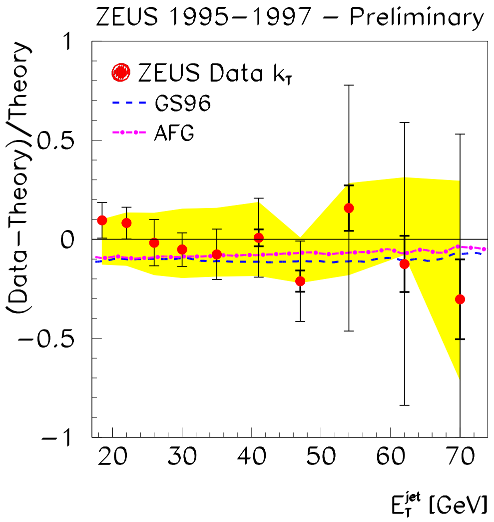
Inclusive Jet Cross Sections, $d\sigma_{QCD}^{i(\gamma)j\to jet}$

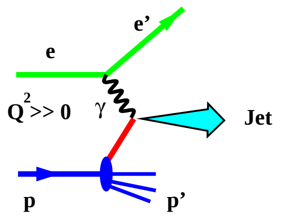
- High $E_\perp^{jet}$ jets in the Lab frame with the $k_\perp$ algorithm.
- pQCD calculations are tested over a large range of $E_\perp^{jet}$:
  - $\to$ Negligible effect from underlying event.
  - $\to$ Small hadronization corrections (not applied).
  - $\to$ Small QCD uncertainties.



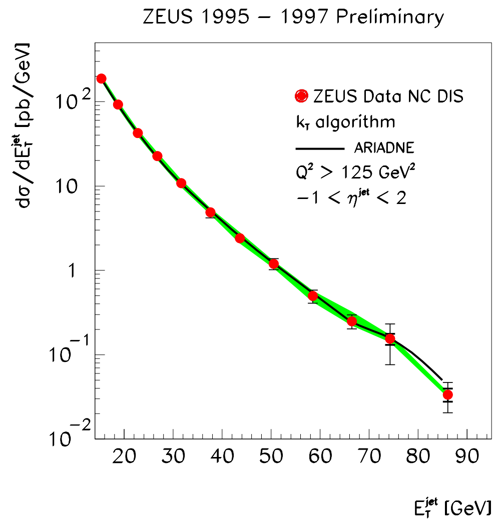
$E_\perp^{jet} > 17$ GeV
$Q^2 < 4$ GeV^2

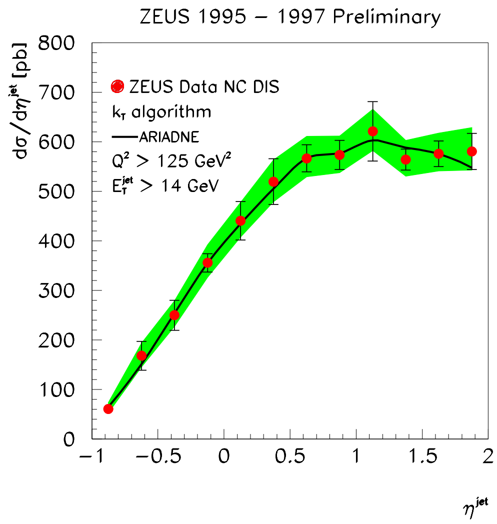






$E_\perp^{jet} > 17$ GeV
$Q^2 > 125$ GeV^2



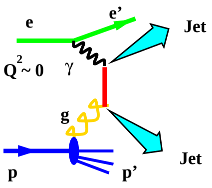


Good agreement over 4 orders of magnitude.

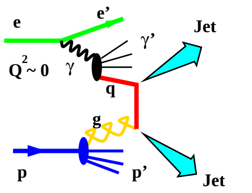
The Photon Structure, $f_{i/\gamma}$

- High $E_{\perp}^{jet}$ di-jets in the Lab frame with the $k_{\perp}$ algorithm.
- pQCD calculations are well known:

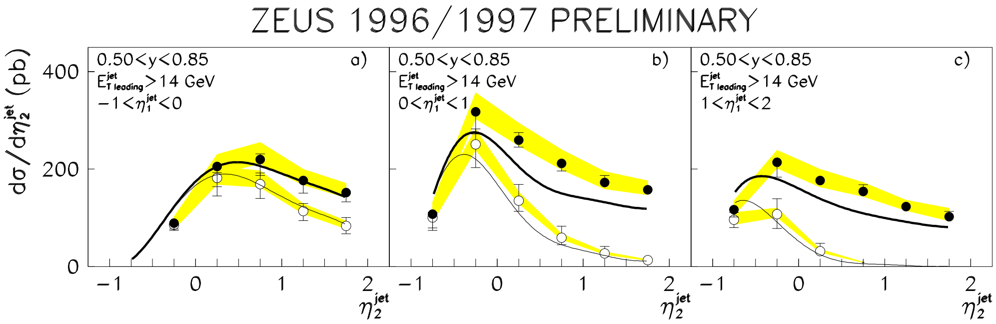
  $\rightarrow$ Strong sensitivity to $f_{i/\gamma}$.
  $\rightarrow$ Quarks and Gluons in the photon are both tested.
  $\rightarrow$ Complementary to LEP F_2^{γ}.



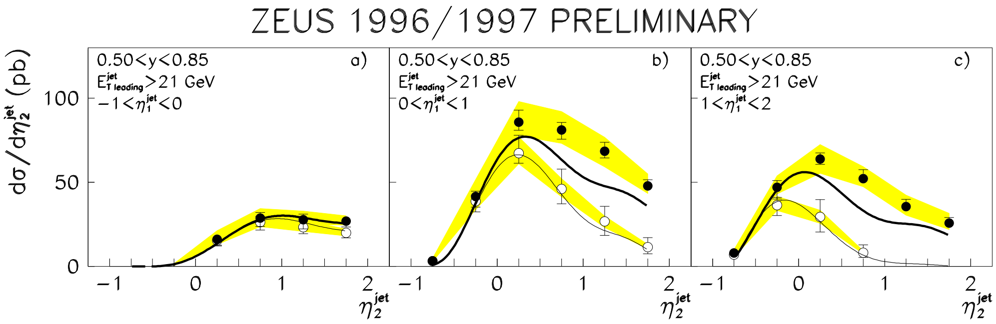
$$x_{\gamma}^{jets} = \frac{E_{\perp 1}^{jet} e^{-\eta_1^{jet}} + E_{\perp 2}^{jet} e^{-\eta_2^{jet}}}{2yE_e}$$



○ $x_{\gamma}^{jets} > 0.75$
$E_{\perp}^{jet} > 14$ GeV
$Q^2 < 1$ GeV^2
$0.5 < y < 0.85$



○ $x_{\gamma}^{jets} > 0.75$
$E_{\perp}^{jet} > 21$ GeV
$Q^2 < 1$ GeV^2
$0.5 < y < 0.85$



Clear excess at forward η^{jet} (small x_{γ}).

- Di-jets in Lab frame with cone, R = 0.7.

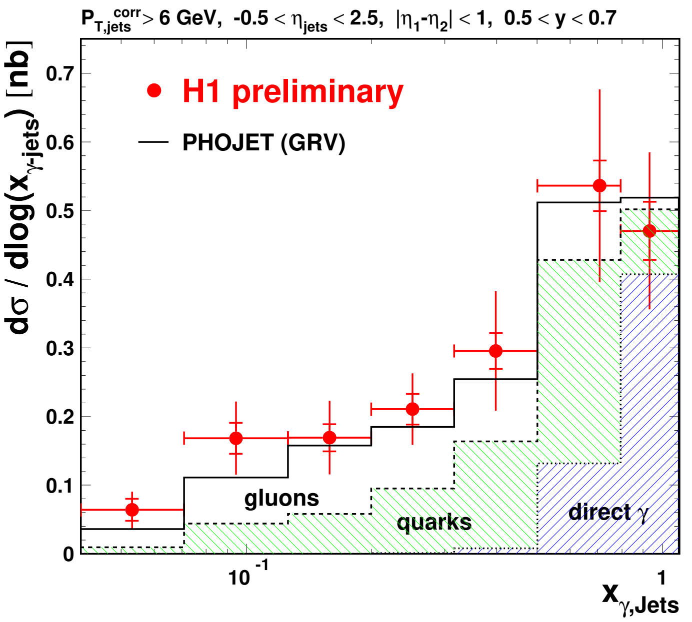
- Use MC models to unfold $d\sigma/dx_\gamma$ and extract an Effective Parton Distribution of the photon:

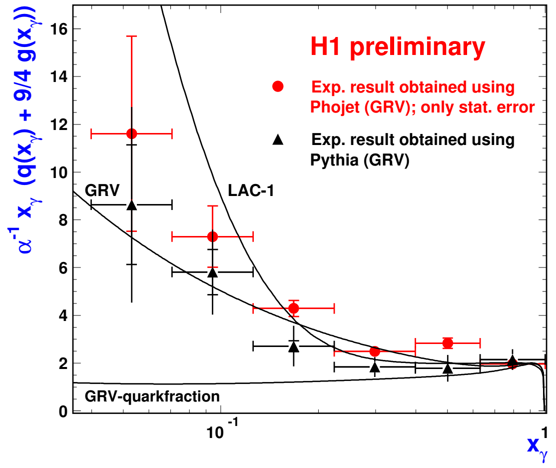
$$\rightarrow \; f^{SES}_{\gamma,p} = \sum_{n_f}(f_{q/\gamma,p} + f_{\bar{q}/\gamma,p}) + \frac{9}{4} f_{g/\gamma,p}$$

$E^{jet}_{\perp} > 6$ GeV
$Q^2 < 0.01$ GeV^2
$0.5 < y < 0.7$

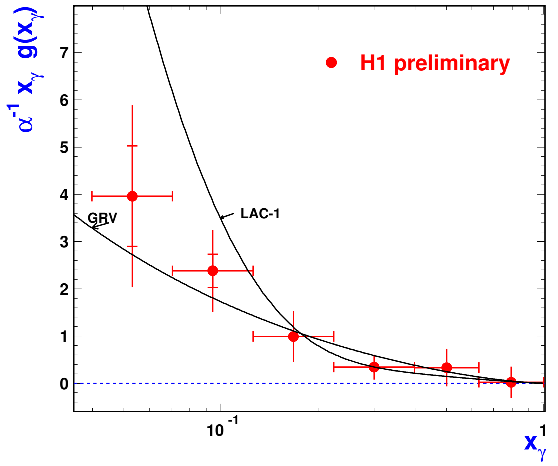
$$f^{DATA}_{\gamma} = f^{MC}_{\gamma} \frac{\sigma^{DATA}}{\sigma^{MC}}$$

Subtract GRV quark content.



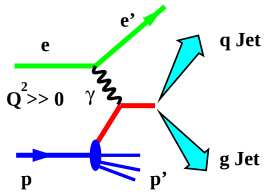


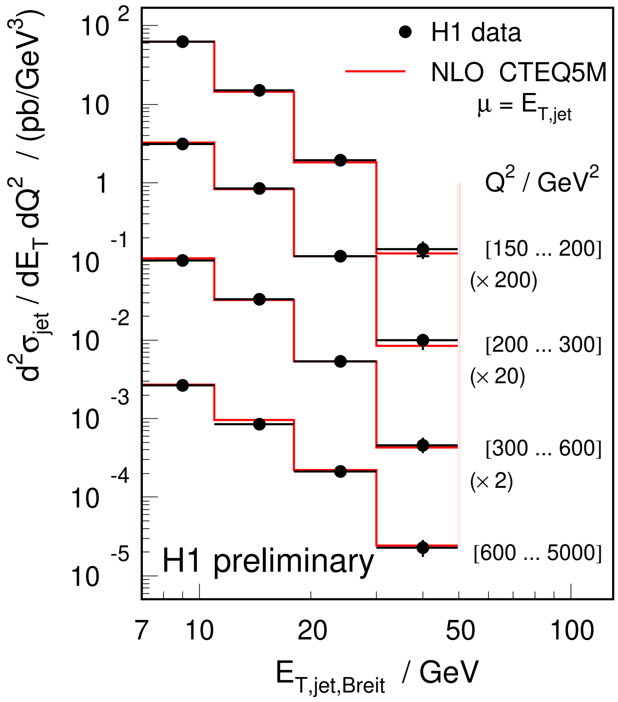
$\Rightarrow$



Extraction of Gluon content in the photon.

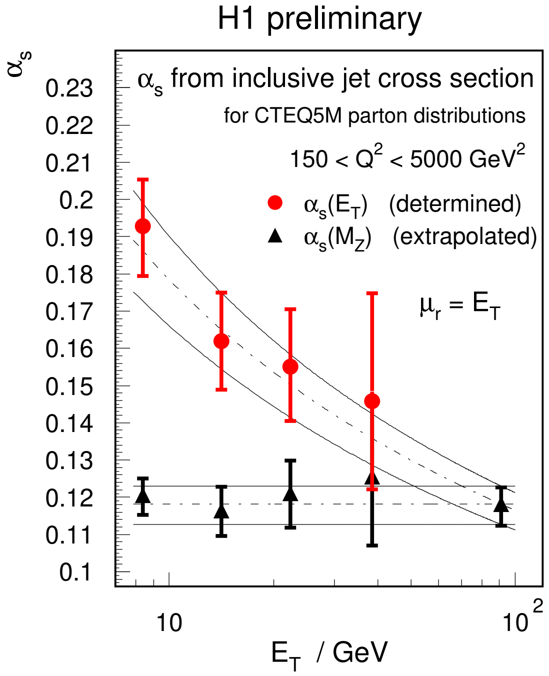
Determination of α_S

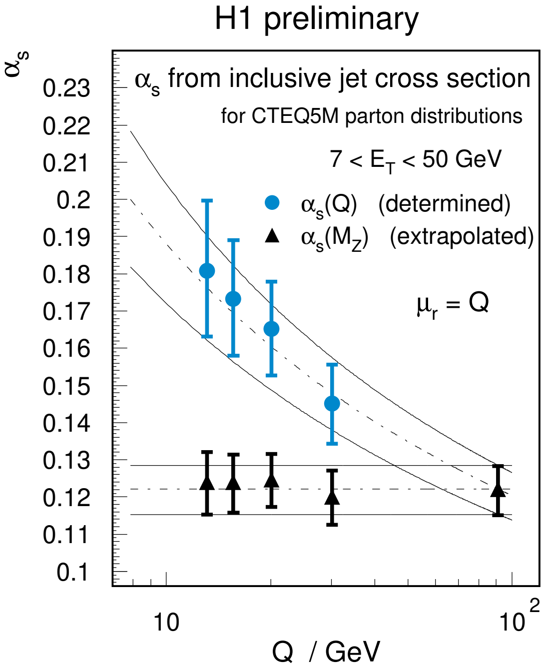




- From inclusive, $k_\perp$, jet cross section in Breit frame at high Q^2:

  $E_\perp^{jet} > 7$ GeV
  $Q^2 > 150$ GeV^2

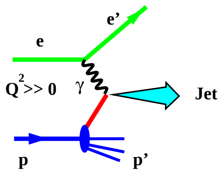




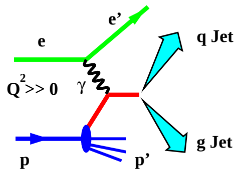
$$E_\perp\!: \ \alpha_S(M_Z) = 0.118 \pm 0.003(exp)^{+0.004}_{-0.005}(th)^{+0.004}_{-0.002}(pdf)$$

$$Q^2\!: \ \alpha_S(M_Z) = 0.122 \pm 0.003(exp)^{+0.005}_{-0.006}(th)^{+0.003}_{-0.002}(pdf)$$

- From exclusive, $k_\perp$, 2+1 jet ratio, $R_{2+1}(Q^2)$, in Breit frame at high Q^2.



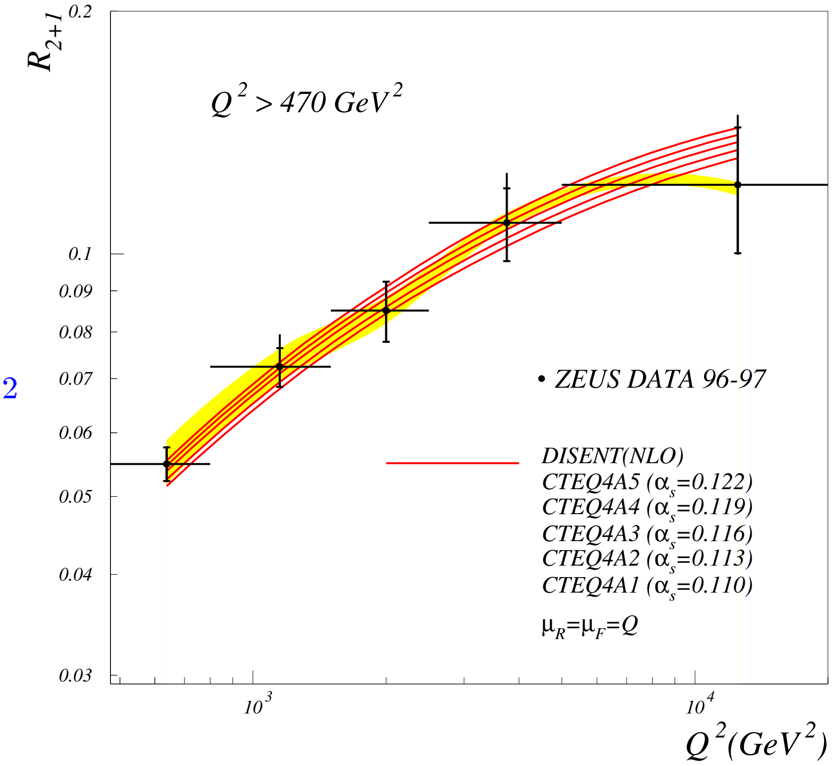
$$\boxed{R_{2+1}(Q^2) = \frac{\sigma_{2+1}(Q^2)}{\sigma_{tot}(Q^2)}}$$



- QCD fit to $R_{2+1}(Q^2)$ using the CTEQ4-A- and MRST($\alpha_S \uparrow\uparrow$,$\alpha_S$, $\alpha_S \downarrow\downarrow$)-series.

$E_\perp^{jet} > 5$ GeV
$E_{\perp\,1}^{jet} + E_{\perp\,2}^{jet} > 12$ GeV
$470 < Q^2 < 20000$ GeV^2

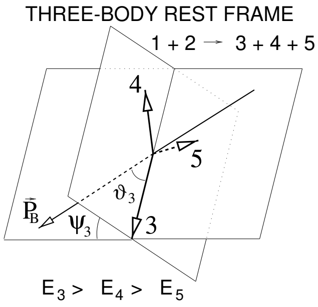
ZEUS 96-97 PRELIMINARY



$$\boxed{Q^2\!:\ \alpha_S(M_Z) = 0.120 \pm 0.003(stat)^{+0.005}_{-0.006}(exp)^{+0.003}_{-0.002}(th)}$$

Three-Jet Distributions, $d\sigma_{QCD}^{i(\gamma)j\to jets}$

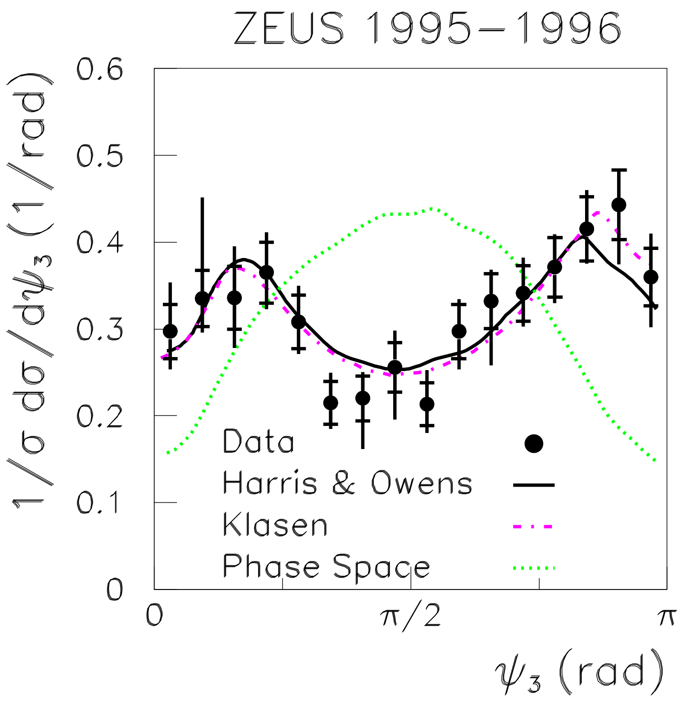
- Three-jet angular distributions, $k_\perp$ in Lab frame.

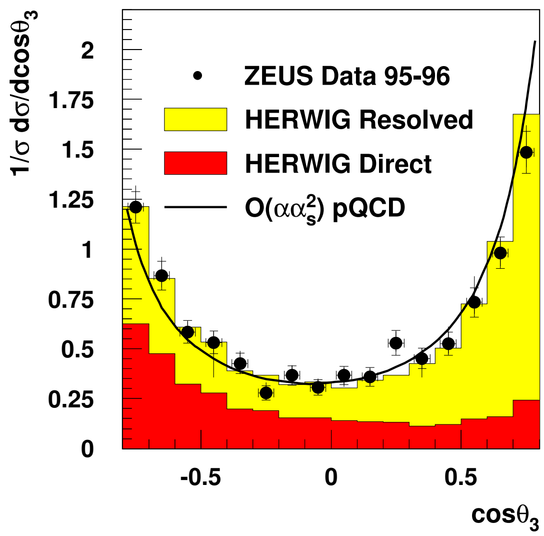


$$X_i \equiv \frac{2E_i}{M_{3J}},$$
$$\cos\theta_3 \equiv \frac{\vec{p}_B\cdot\vec{p}_3}{|\vec{p}_B||\vec{p}_3|}$$
$$\cos\Psi_3 \equiv \frac{(\vec{p}_3\times\vec{p}_B)\cdot(\vec{p}_4\times\vec{p}_5)}{|\vec{p}_3\times\vec{p}_B||\vec{p}_4\times\vec{p}_5|}$$

$E^{jet}_{\perp 3,4} > 6$ GeV,
$E^{jet}_{\perp 5} > 5$ GeV.
$|\eta^{jet}| < 2.4$.
$M_{3J} > 50$ GeV.

$Q^2 \leq 1$ GeV^2.

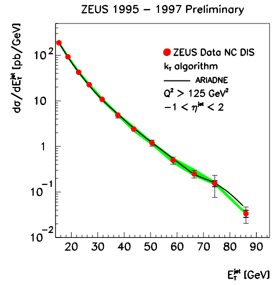




Only LO available.
Ψ_3 and $cos\theta_3$ well described by pQCD.
MC parton shower model give also good description.

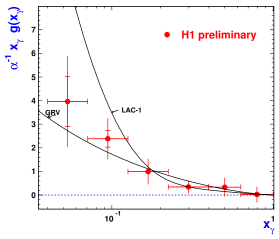
Summary and Outlook

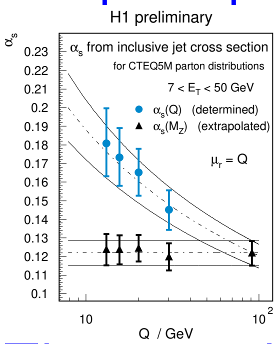
Preliminary results from HERA 96-97 data samples have been shown. They correspond to 30-40 pb^{-1}



Inclusive Jet cross sections expand now over 4 decades up to 70-80 GeV of $E_{\perp}^{jet}$. They are well described by existing NLO calculations.

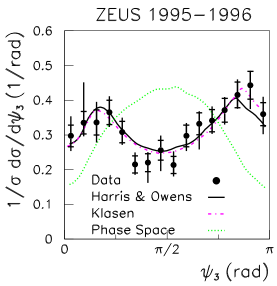
Di-jet cross sections in γp give access to the photon parton distributions, being sensitive to both the quarks and the gluons, complementing existing LEP data. A combined fit with F_2^{γ} data will provide a more complete picture of the photon structure.





Di-jet cross sections in DIS are a powerful tool for the measurement of α_S, where the running can be tested over a large range of μ_R in a single experiment.

Three-jet distributions show the expected behaviour from QCD dynamics, not compatible with pure phase space. pQCD calculations are LO for this process and NLO calculations will be welcome.



Thanks to all colleges from ZEUS and H1 who made possible all these results.