Measurement of Event Shapes and Jet Shapes at HERA

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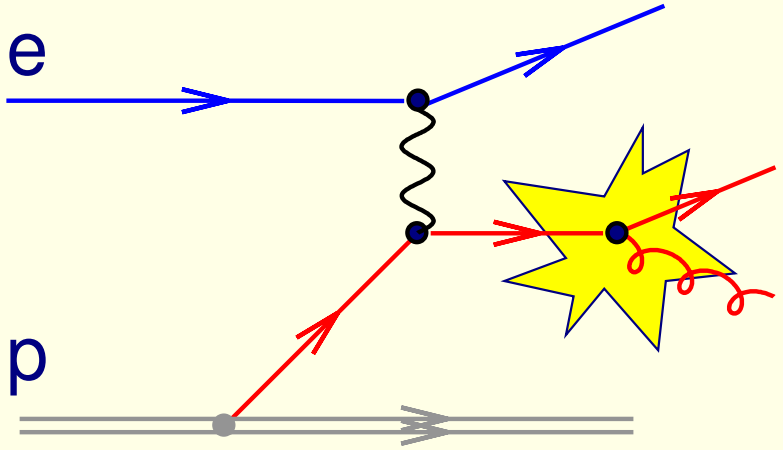
on behalf of the H1 and ZEUS collaborations

EPS 2003 — July, 17-23 2003, Aachen

- Subjet Multiplicities
- Jet Substructure
- Event Shapes



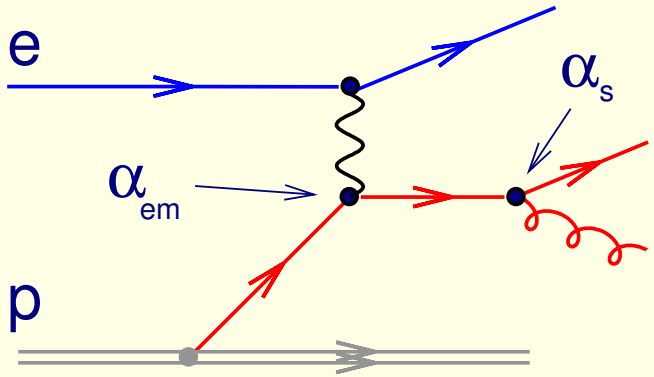
Introduction

measure energy-momentum flow $\longrightarrow$ study gluon radiation of QCD

shape variables are independent of total cross section

HERA: large E_T and Q range of $10..100\ \mathrm{GeV}$ for a single experiment

how far can one push QCD to the soft limit?



Jet Shapes

apply k_T jet cluster algorithm, require min. E_T

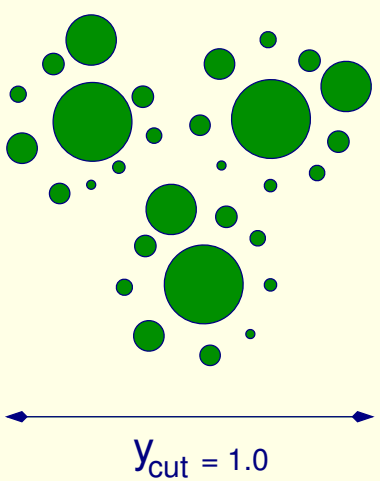
relevant scale $E_T = 10..60$ GeV

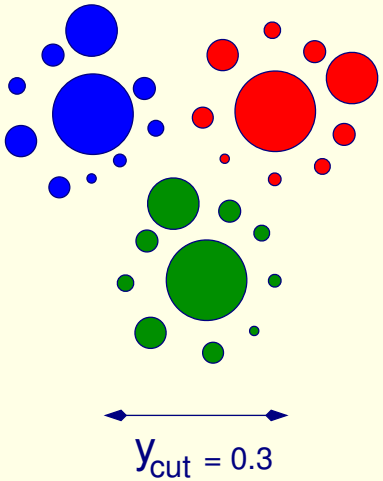
high $E_T \rightarrow$ fragmentation weak $\rightarrow$ pQCD

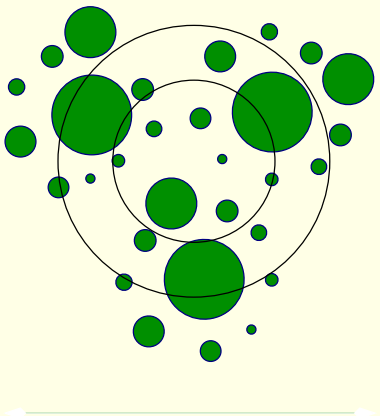
study jet structure:

higher resolution y_{cut}: more subjets are resolved

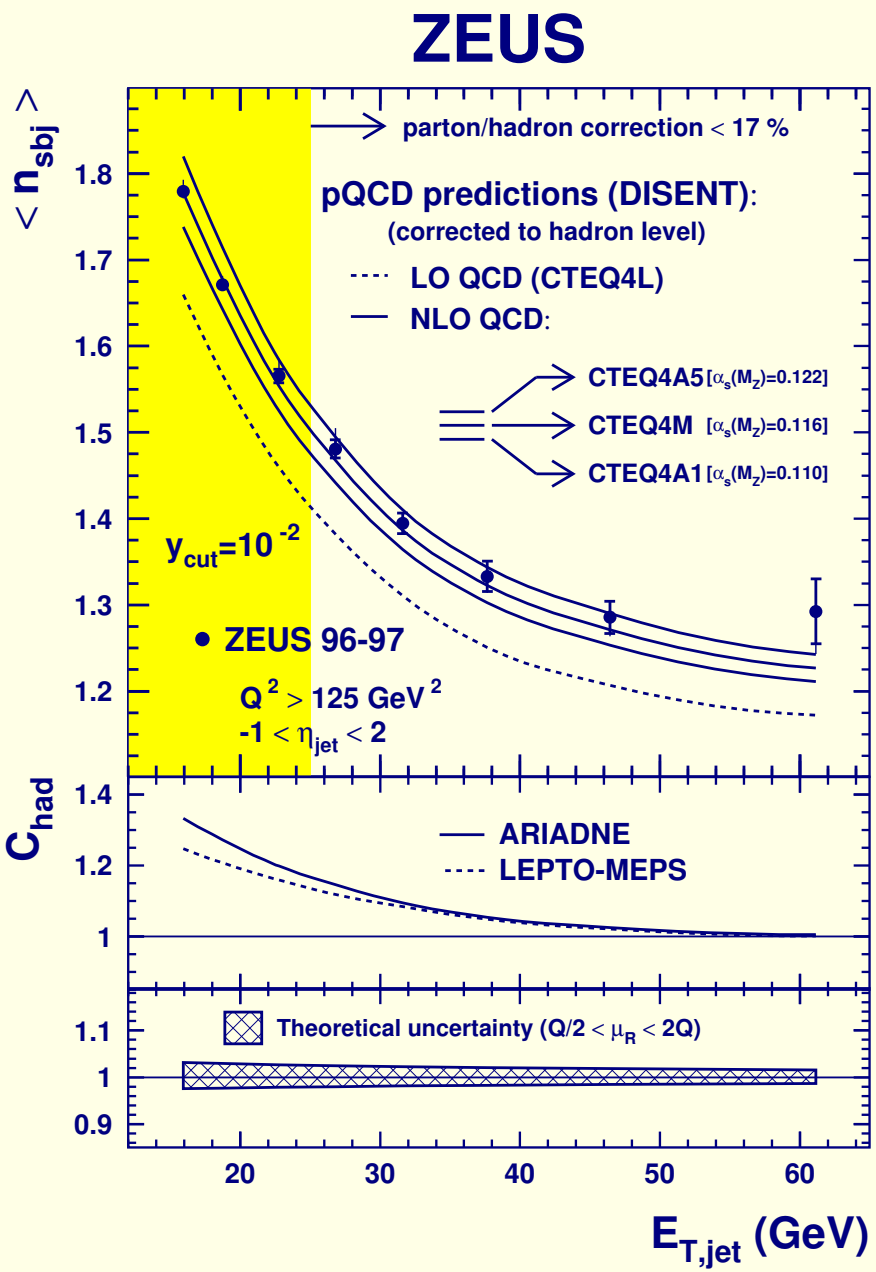
ψ measures the E_T within a cone of the jet







Subjet Multiplicity



$38.6\ \mathrm{pb}^{-1}$ NC DIS, $Q^2 > 125\ \mathrm{GeV}^2$

jets build in the lab frame

fixed value of $y_{\mathrm{cut}} = 10^{-2}$:
the jets become narrower with increasing E_T

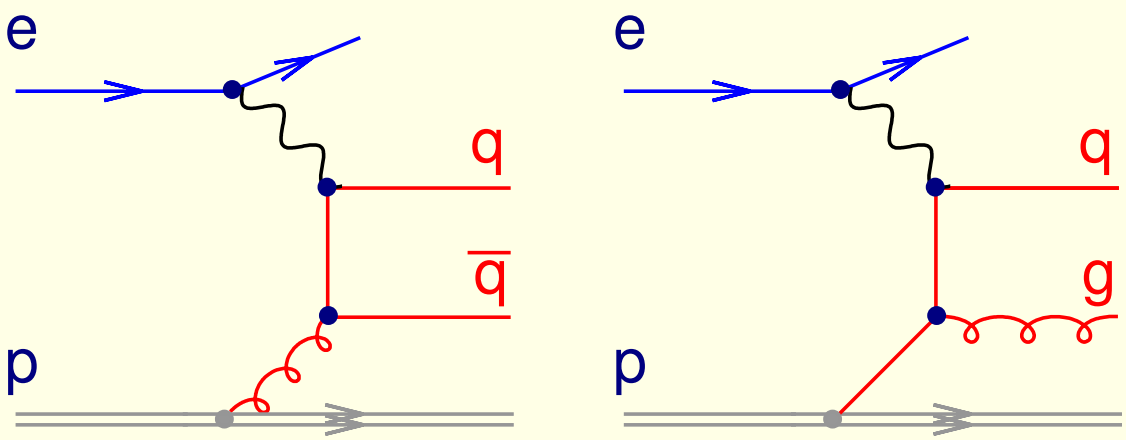
comparison with fixed-order QCD calculations with parton-to-hadron corrections applied

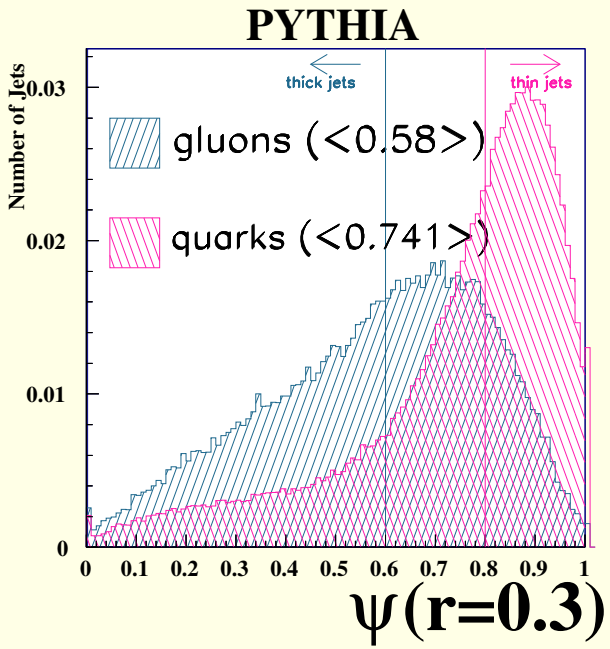
NLO calculations describe the data well $\rightarrow$ determination of α_s

$$0.1187 \pm 0.0017(\mathrm{stat.})^{+0.0024}_{-0.0009}(\mathrm{syst.})^{+0.0093}_{-0.0076}(\mathrm{th.})$$

Jet Shapes

jets can stem from quarks or gluons





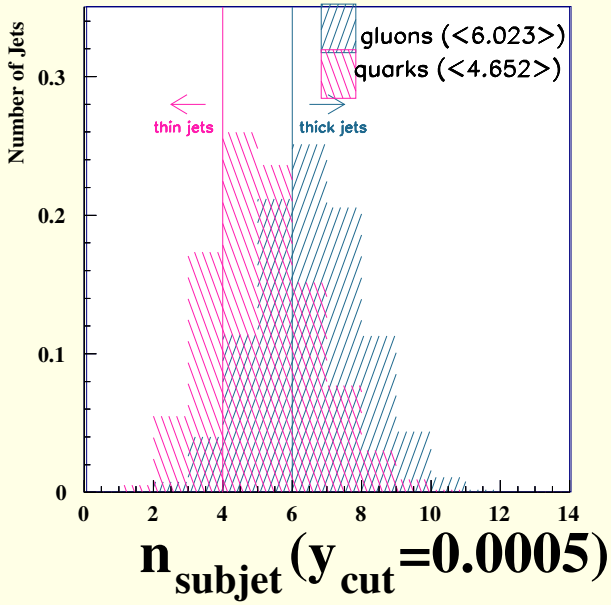
Selection with ψ and n_{sbj}

"thick" jets := $\psi < 0.6$, $n_{\mathrm{sbj}} \geq 6$

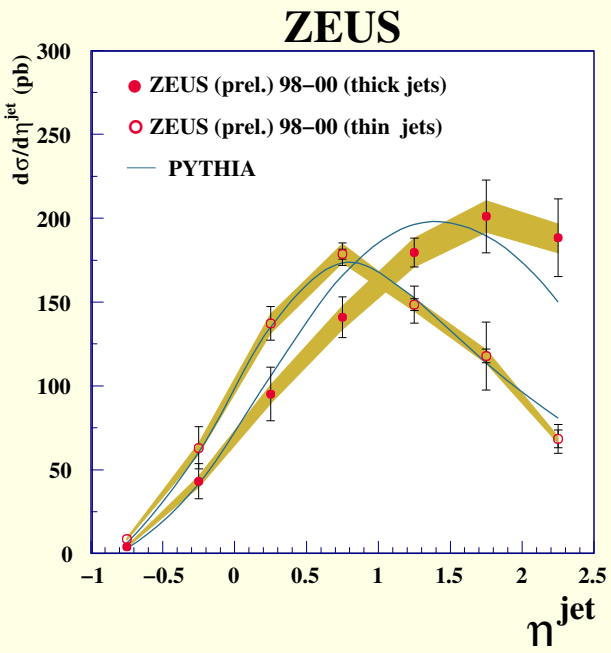
$\rightarrow$ purity of gluons 67% (MC)

"thin" jets := $\psi > 0.8$, $n_{\mathrm{sbj}} \leq 4$

$\rightarrow$ purity of quarks 98% (MC)



Differential Jet Cross Sections

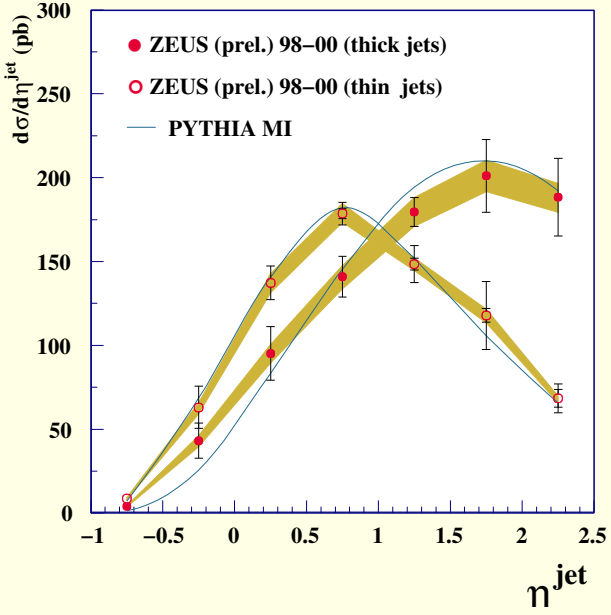


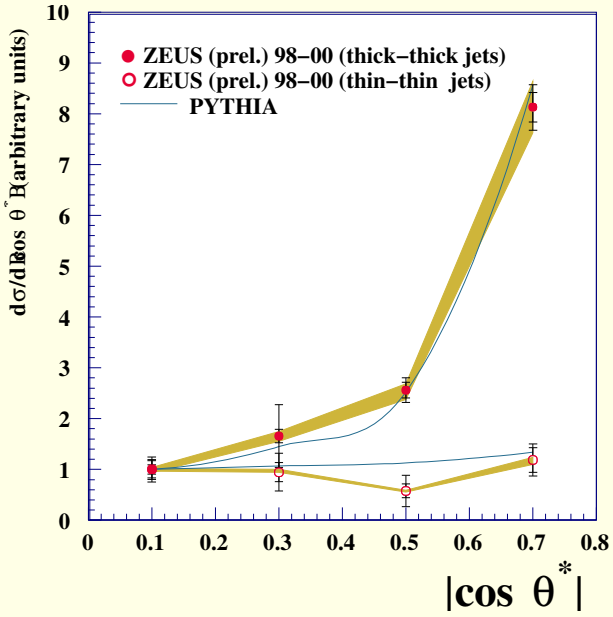
$82.2\ \mathrm{pb}^{-1}$ photoproduction, $(Q^2 < 1\ \mathrm{GeV}^2)$

gluon jets are more forward than quark jets

improved description by PYTHIA with multiparton interactions(MI) at high η^{jet}

results are consistent with expectations for quark/gluon jets





Event Shapes

study whole hadronic final state without proton remnant

Breit frame to seperate proton remnant

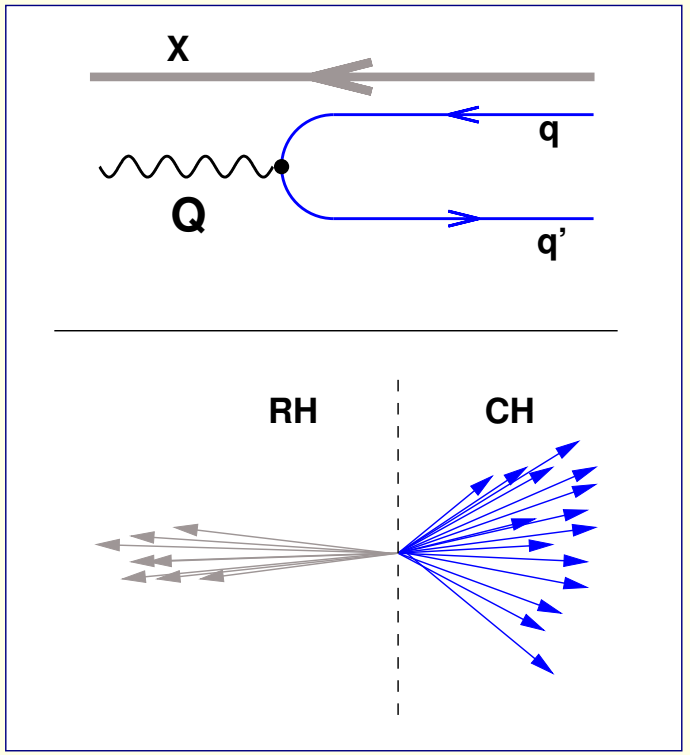
Current hemisphere (CH):
similar to $1/2$ e^+e^- event

Observables defined in the CH:
thrust τ, τ_c, jet broadening B, C-parameter and jet mass ρ_0

$\eta_{\mathrm{breit}} < 3$:
out-of-event-plane momentum K_{out} and azimuthal correlation χ

use k_t jet algorithm (no E_T cut!):
jet rates y_2, y_3 and y_4

relevant scale $Q = 10..100$ GeV



Event Shapes

mean value:

$$\begin{aligned} \langle F \rangle &= \langle F \rangle_{\mathrm{pQCD}} + a_F \mathcal{P} \\ \langle F \rangle_{\mathrm{pQCD}} &= c_{1,F}\alpha_s(Q) + c_{2,F}\alpha_s^2(Q) \end{aligned}$$

distribution:

$$\frac{1}{\sigma_{\mathrm{tot}}}\frac{d\sigma(F)}{dF} = \frac{1}{\sigma_{\mathrm{tot}}}\frac{d\sigma^{\mathrm{pQCD}}(F - a_F\mathcal{P})}{dF}$$

power correction:

$$\mathcal{P} = \frac{16}{3\pi}\mathcal{M}'\frac{\mu_I}{Q}[\bar{\alpha}_0(\mu_I) - \alpha_s(Q) - \frac{\beta_0}{2\pi}\left(\ln\frac{Q}{\mu_I} + \frac{K}{\beta_0} + 1\right)\alpha_s^2(Q)]$$

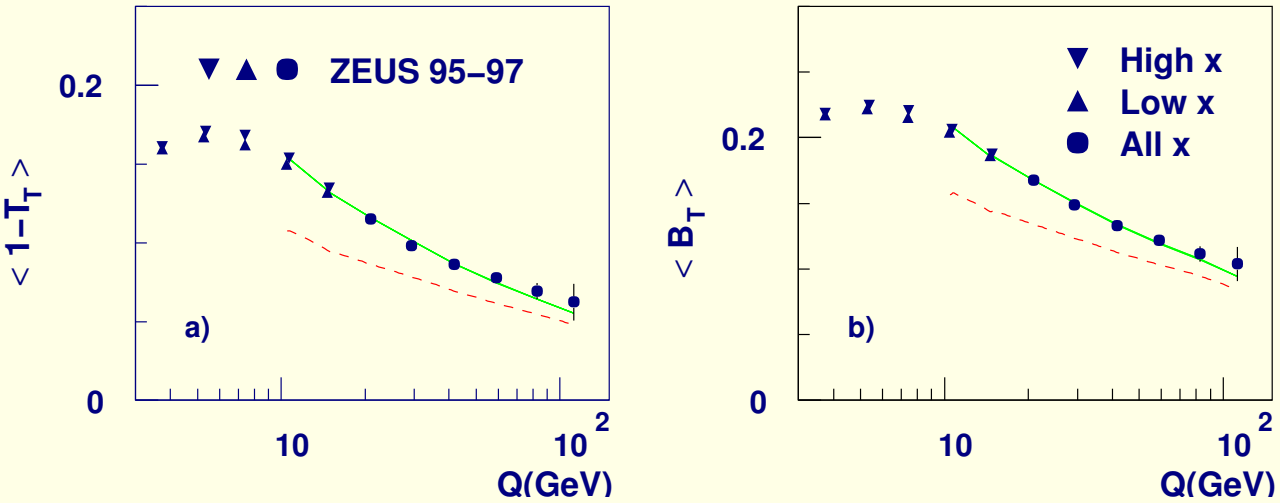
power corrections take care of hadronization
→shift of distributions

2 free parameters: α_s and $\bar{\alpha}_0$

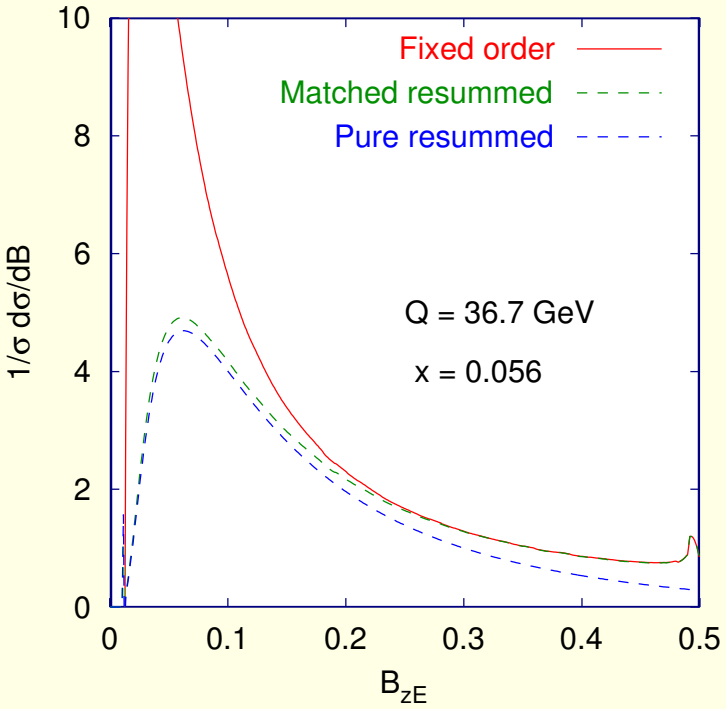
data fitted well by pQCD and power correction

common $\bar{\alpha}_0$ for means and distributions?

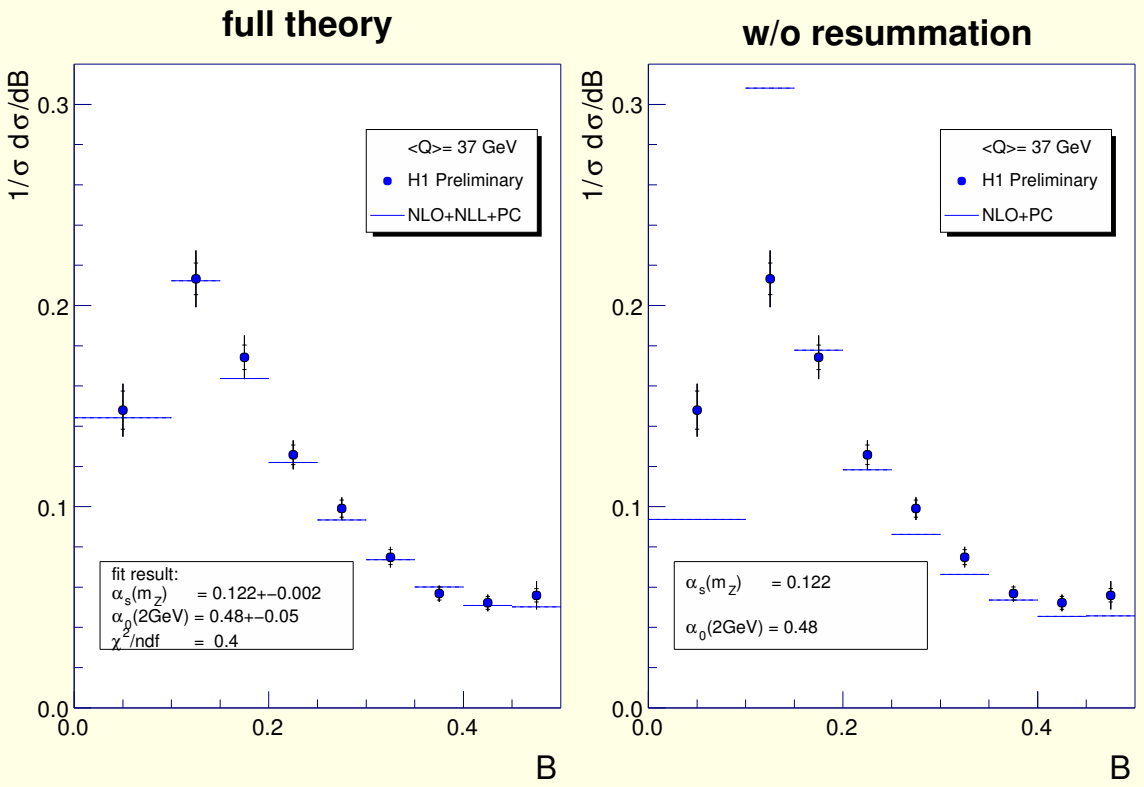
ZEUS



Resummed Event Shapes Distributions



M. Dasgupta G.P. Salam

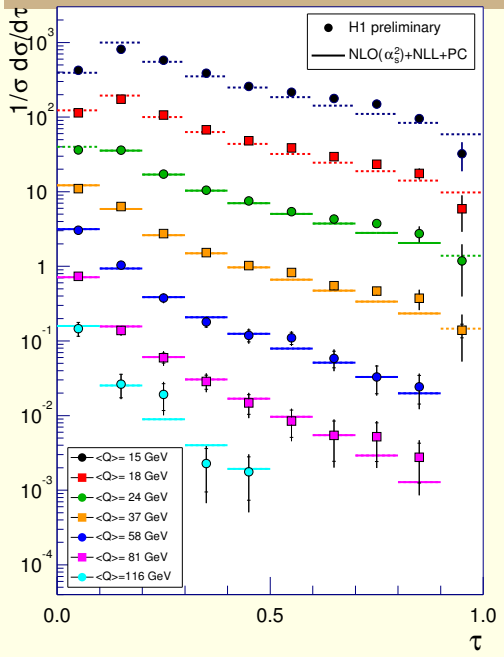


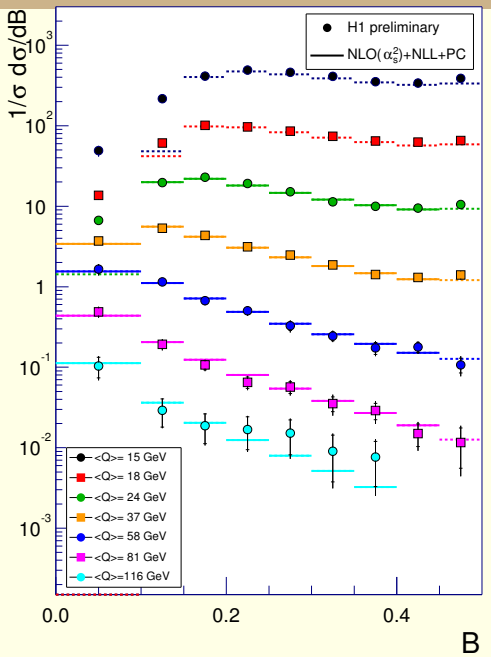
resum terms $(\alpha_s \log^2 1/F)^n$ to all orders, log-R matching to fixed order

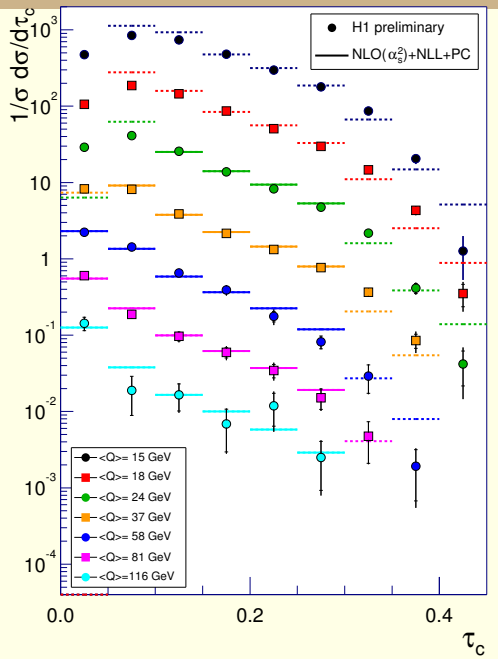
important at low values$\longrightarrow$ QPM limit

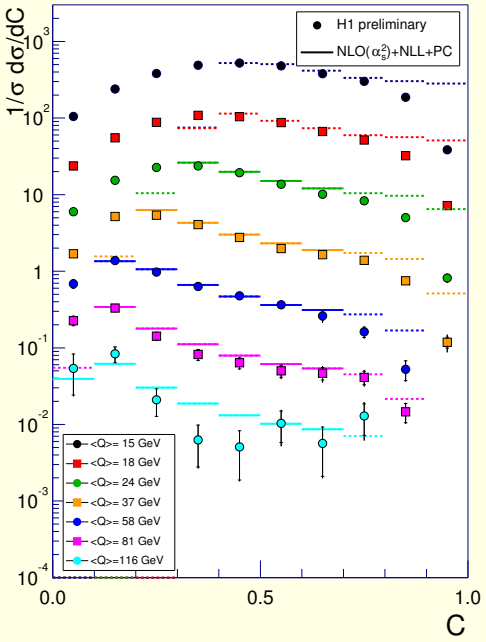
larger interval described

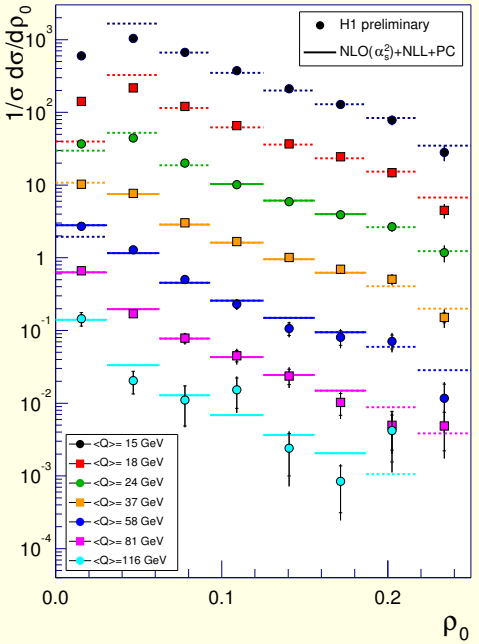
Event Shapes Distributions









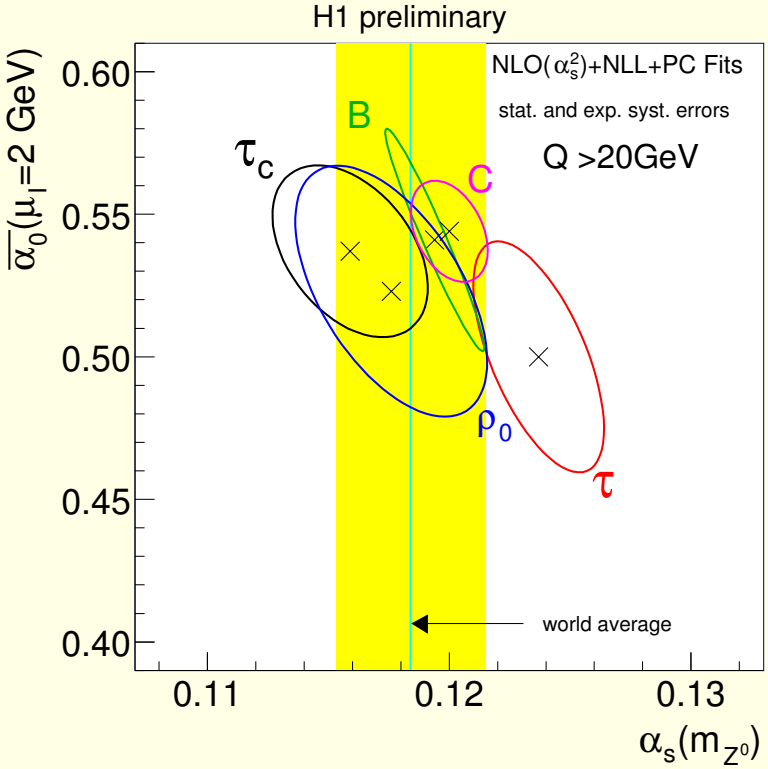


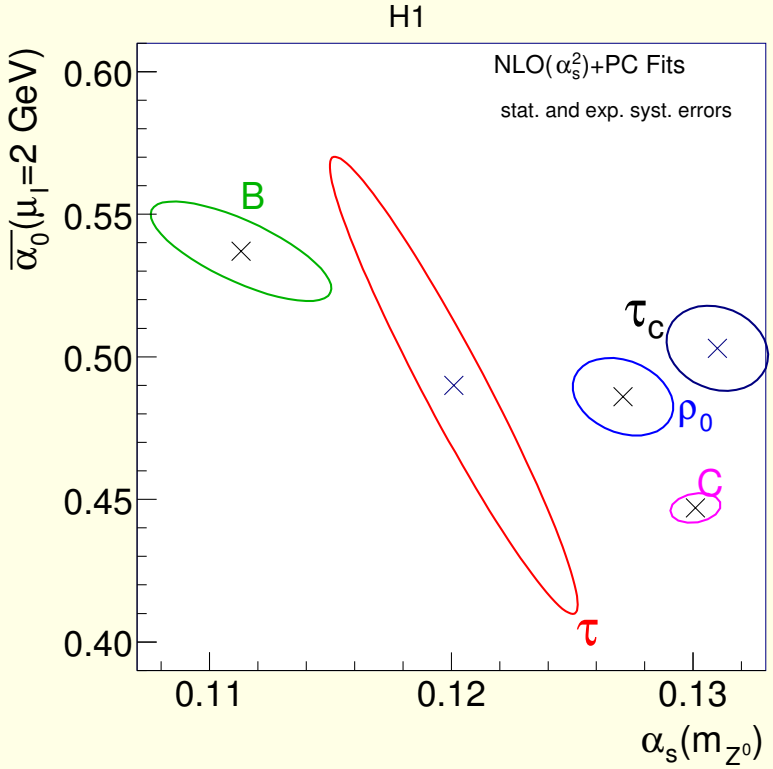
$112\ \mathrm{pb}^{-1}$ NC DIS, $Q^2 > 196\ \mathrm{GeV}^2$

new analysis of distributions τ, τ_c, B, C and ρ_0

data fitted well by resummed pQCD and power correction

Event Shapes



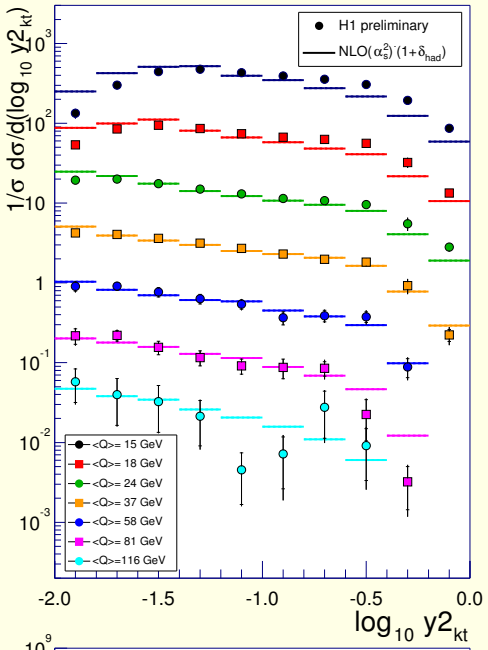


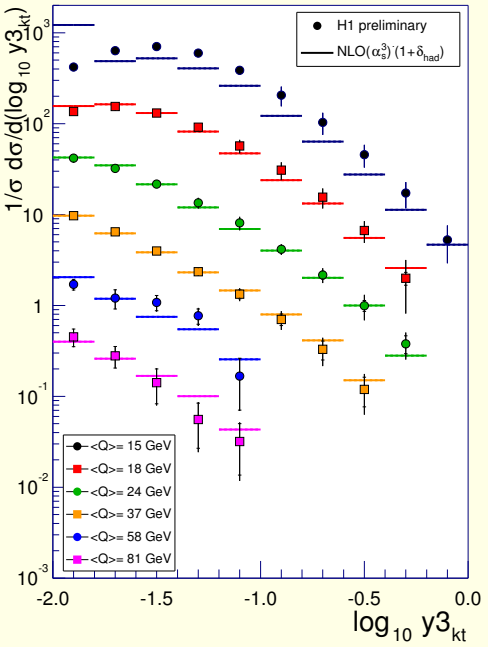
results are consistent with $\bar{\alpha}_0 = 0.5$, within 10%

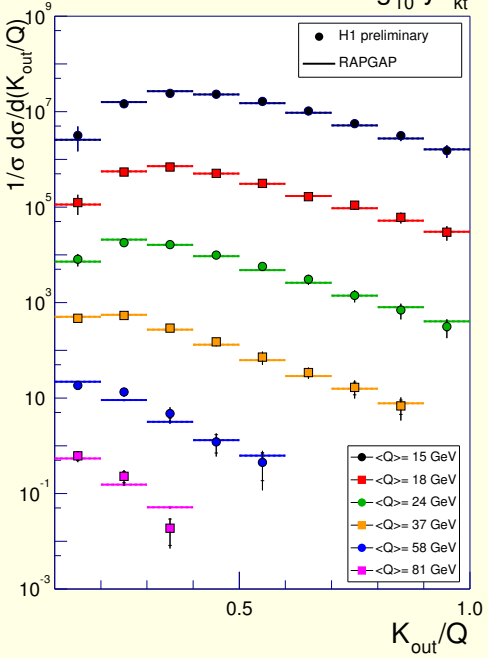
distributions give more consistent values for α_s, also with world average

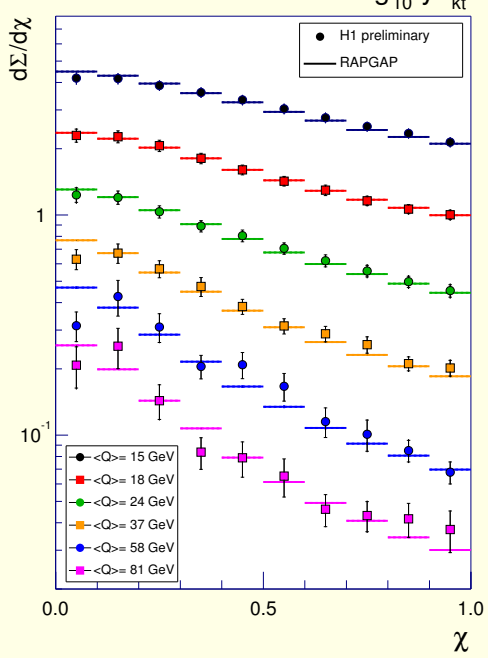
theoretical uncertainty $\approx 5 - 10\%$

Event Shapes Distributions









measurements of jet rates y_2 and y_3 plus 3-jet event shapes $K_{\rm out}$ and χ are performed

theory calculation for this observables:
generalized resummation program near completion, A. Banfi et al.

Summary

jet and event shapes offer a rich field for testing QCD

the scale dependence of α_s is studied over a large range of Q resp. E_T

a determination of α_s in an alternative way with subjet multiplicities

quark and gluon enriched jet samples show consistent behaviour

the universality of power corrections for event shape variables has been shown for mean values and distributions