# High Pt Jet Production and $\alpha_s$ measurements in ep collisions

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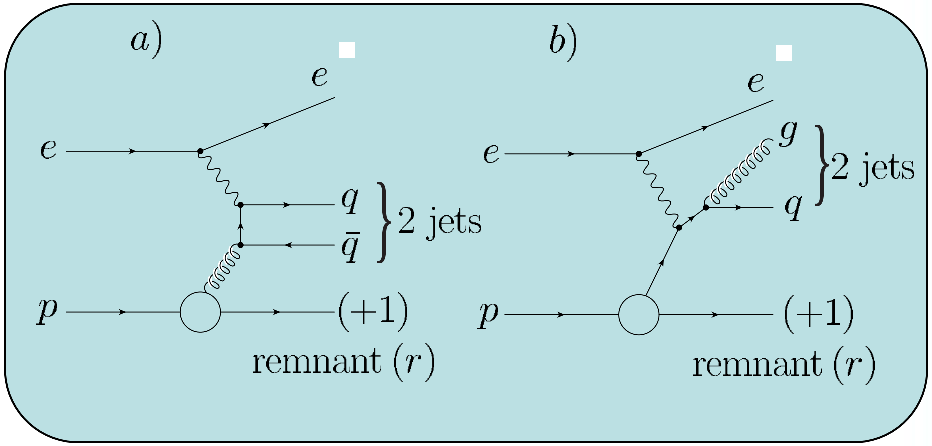
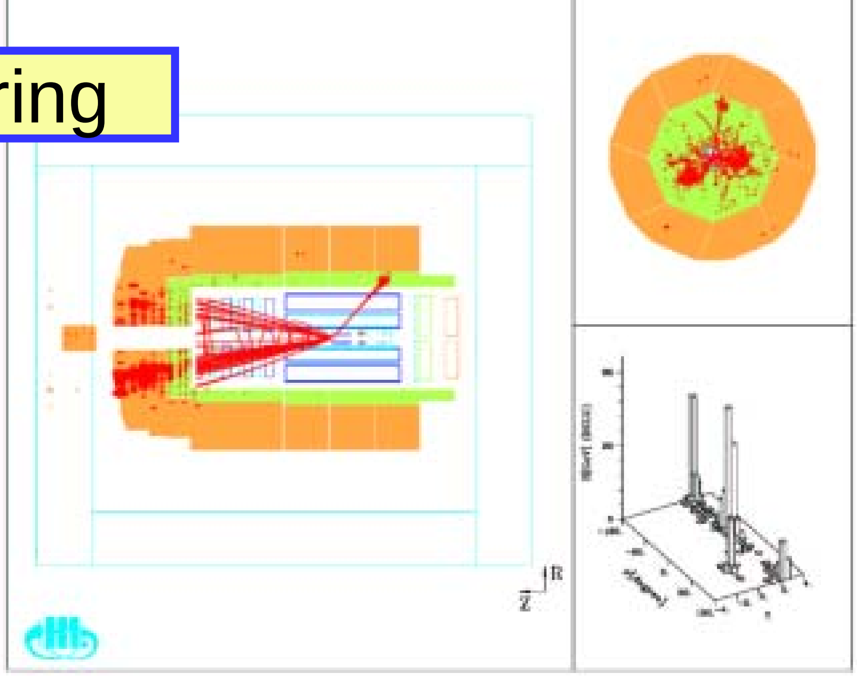
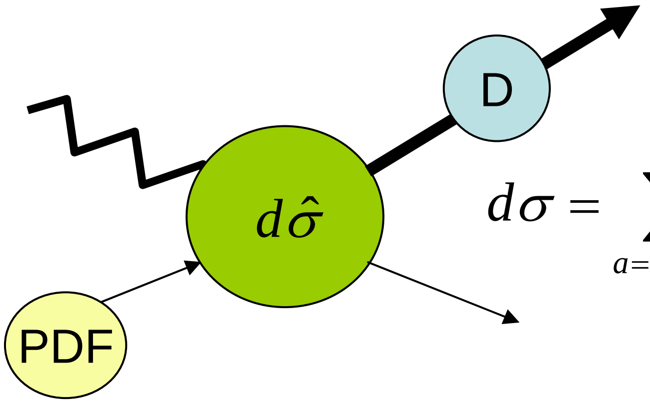
on behalf of H1 and ZEUS Collaborations

# Jet Production in ep scattering






$$d\sigma = \sum_{a=q,\bar{q},g} \int dx f_a(x, \mu_F; \alpha_s)\, d\hat{\sigma}(xP, \mu_F; \mu_R; \alpha_s(\mu_R)_s)\, D(z, \mu_{F'}; \alpha_s)$$

source parton distribution | Hard scattering cross section | Fragmentation Function

Many part depends on as: <-- several way to extract

In the jet study, Fragmentation part is regarded as "hadronisation correction"

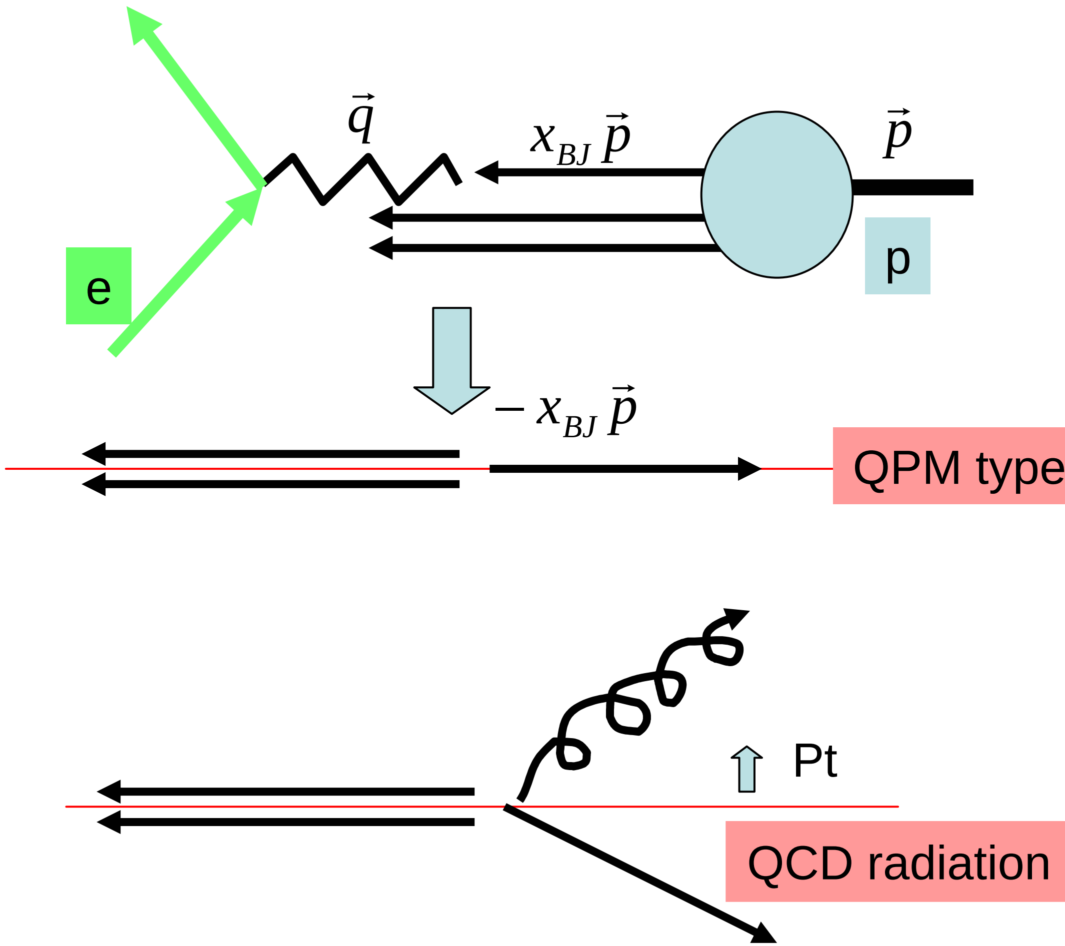
$$d\sigma = \sum_{a=q,\bar{q},g} \int dx f_a(x, \mu_F; \alpha_s)\, d\hat{\sigma}(xP, \mu_F; \mu_R; \alpha_s(\mu_R)_s)(1+\delta_{had})$$

# Jet Production in DIS

In DIS, it is better to observe jets in the Breit frame, defined as $2x_{BJ} + \vec{p} = 0$

In this frame, photon is purely space-like.

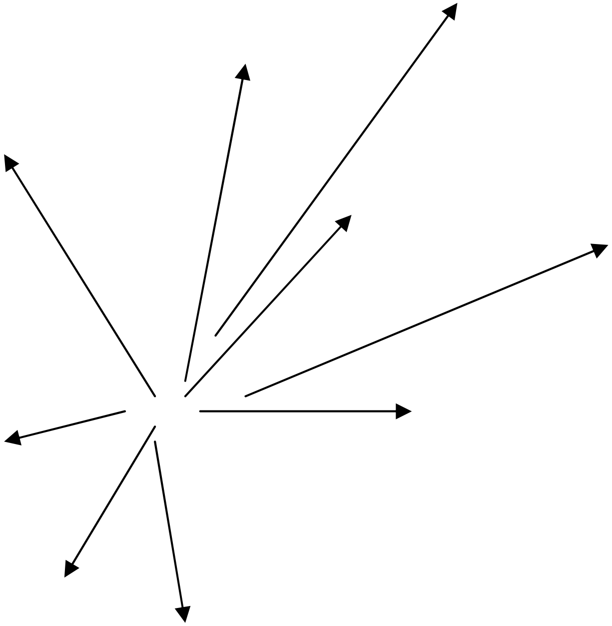
$\vec{q} = (0,0,0,-2x_{BJ}P)$




In the Breit frame, the current quark and the remnants are well separated.
In QPM, the scattered quark has no pt. High Pt jets emerges from QCD effect.

# Jet Algorithm

There are many algorithm to define jets.
Typically cone-type and cluster-type algorithm
: Most of recent HERA results are with cluster-type algorithm
because it's no ambiguous and theoretically safe.



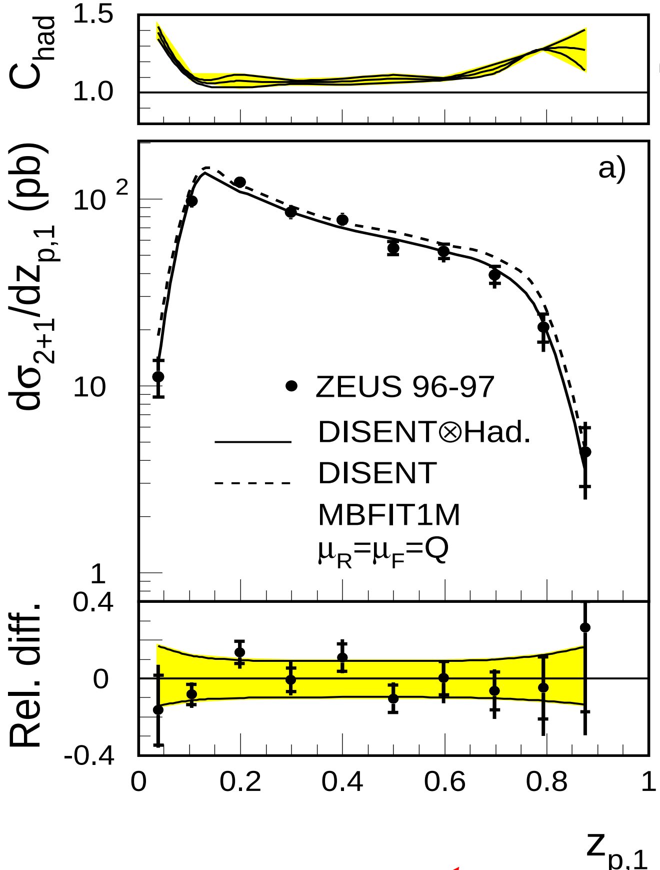
•Calculate a norm ($y_{ij}$) between each object i,j in kt-algorithm:

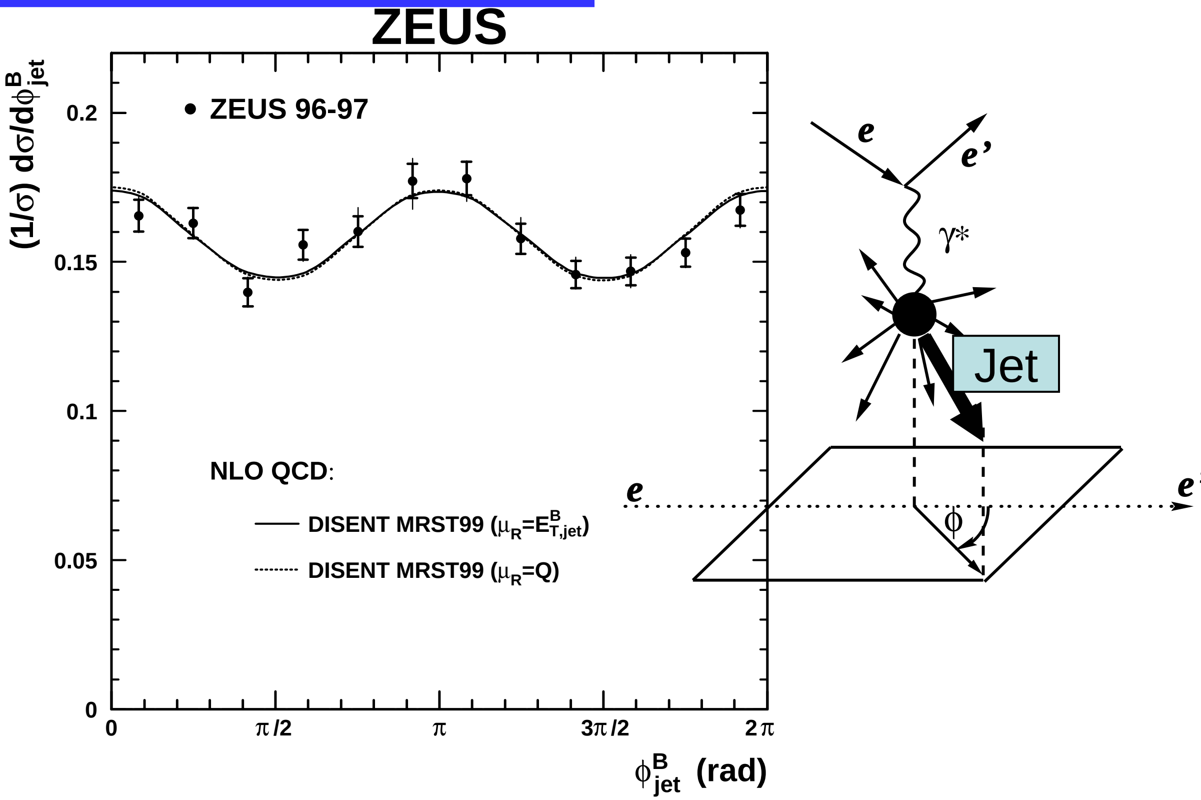
$$y_{ij} = 2\min(E_i^2, E_j^2)(1-\cos\theta_{ij})/s$$

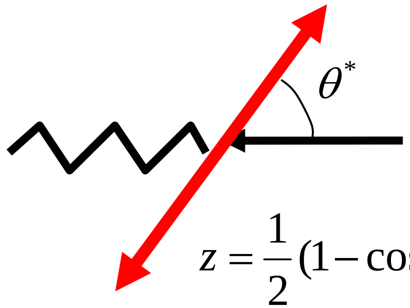
•Merge two objects with smallest $y_{ij}$ (number of object N -> N-1)

•Continue until some stopping condition for example, (the smallest $y_{ij}$ ) > $y_{cut}$

# Jet Production in DIS



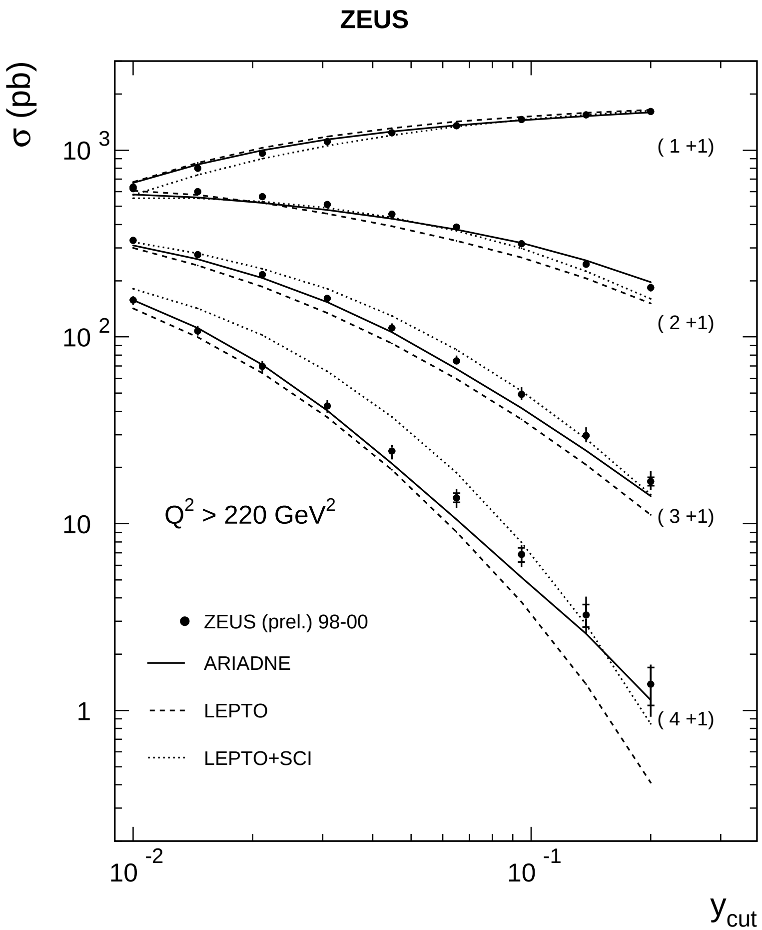



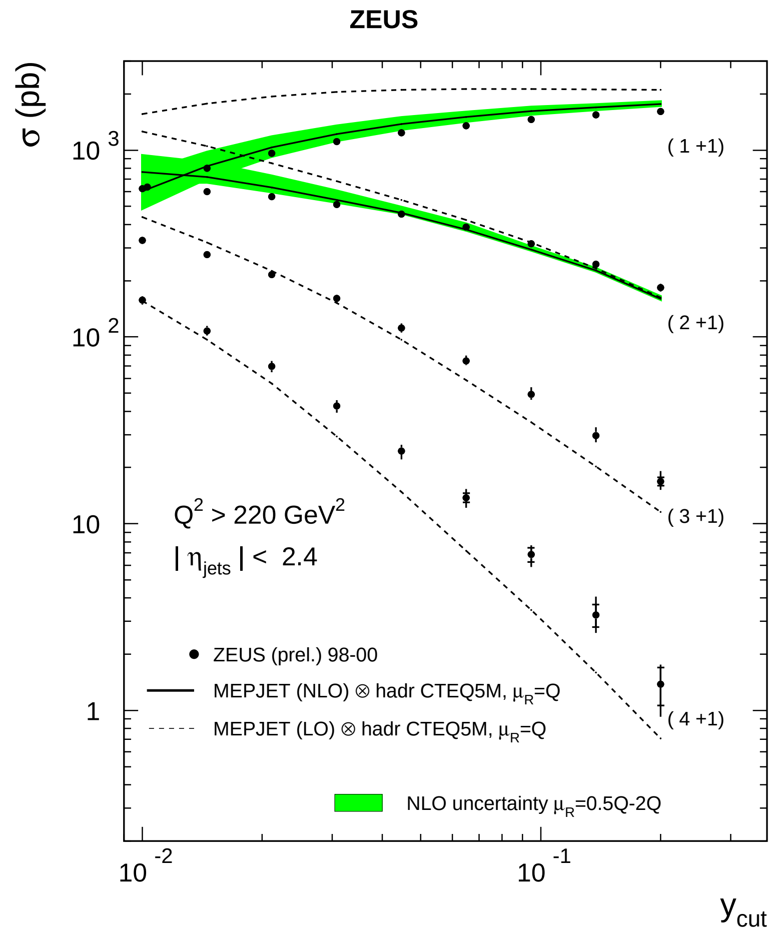




$$z = \frac{1}{2}(1 - \cos\theta^*)$$

Angular distribution is well described by the NLO calculations

# Jet Multiplicity

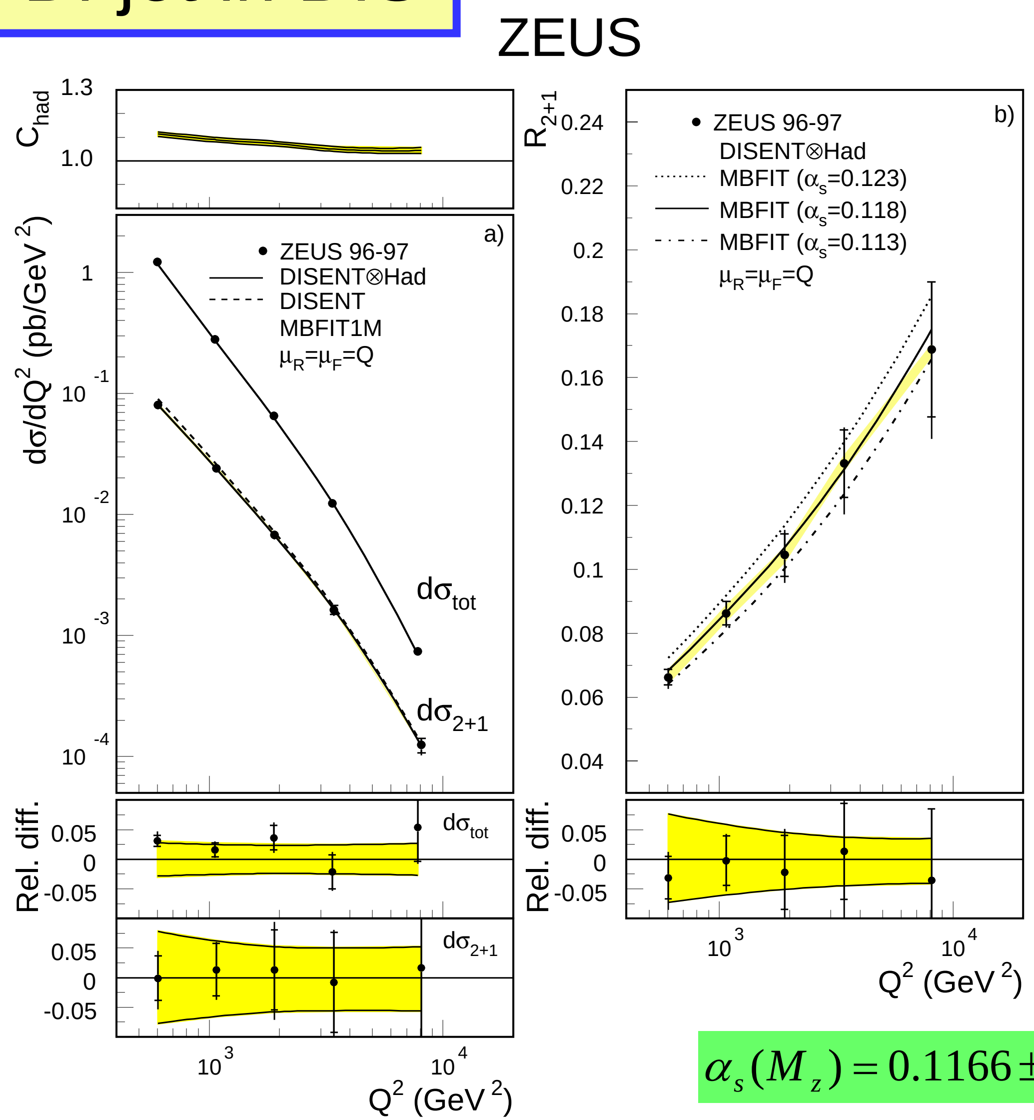


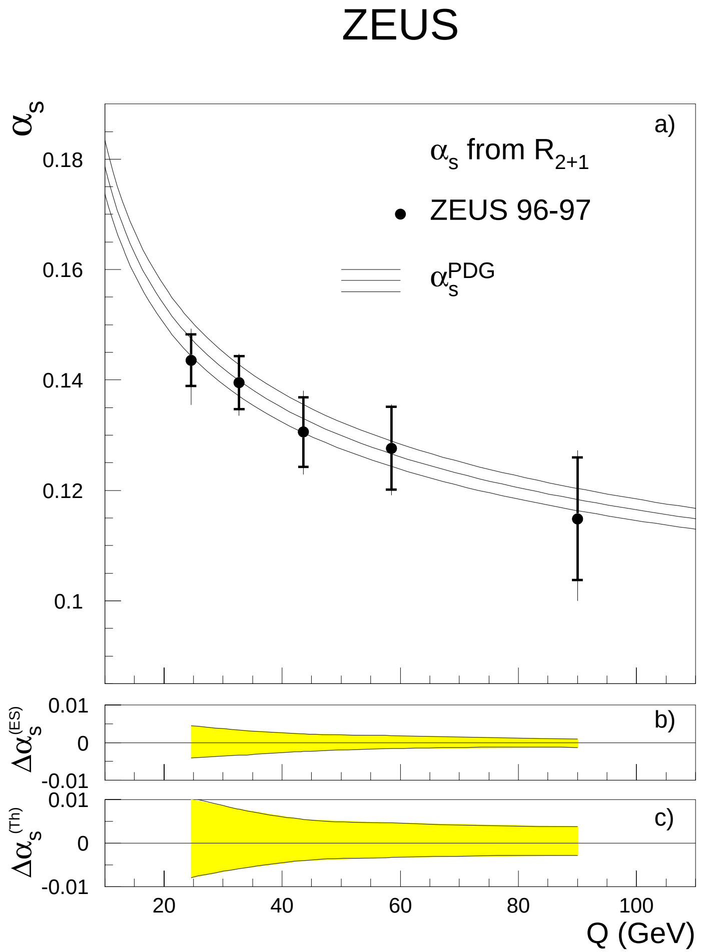




MC model including parton shower reasonably describe the Jet multiplicity.

NLO-QCD gives good description for 2+1 jets. --> classical $\alpha_s$ measurement

# Di-jet in DIS



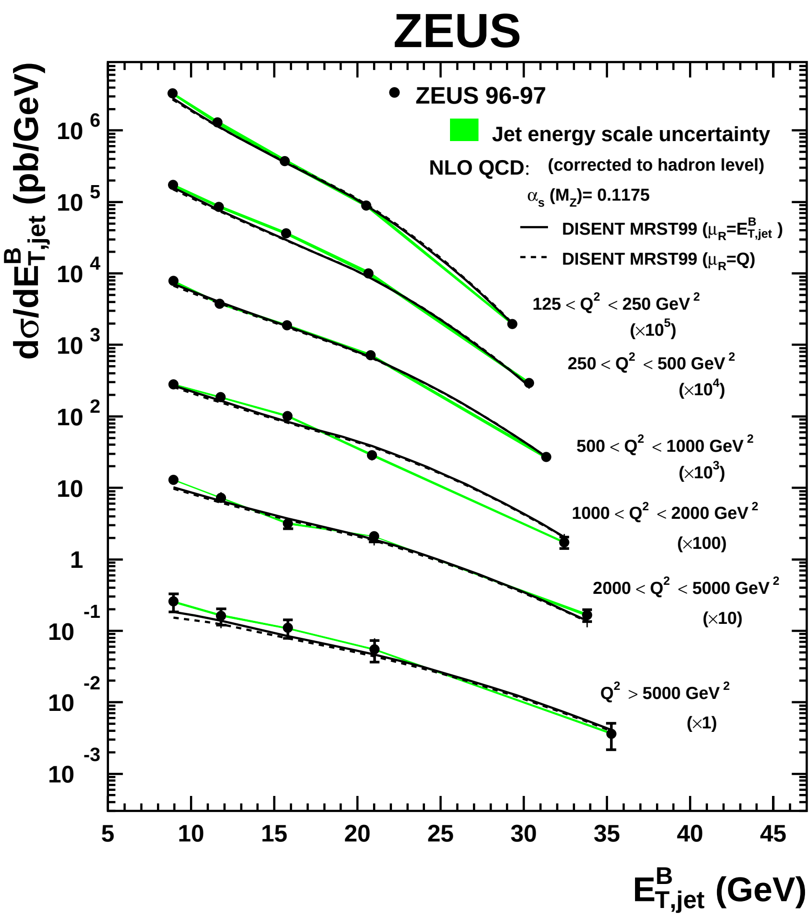




$$\alpha_s(M_z) = 0.1166 \pm 0.0019(stat.)^{+0.0024}_{-0.0033}(\text{exp.})^{+0.0057}_{-0.0044}(th.)$$

PLB 507 (2001) 70-88

# Inclusive jet cross section in Breit frame

$$d\sigma = \sum_{a=q,\bar{q},g} \int dx f_a(x, \mu_F; \alpha_s) d\hat{\sigma}(xP, \mu_F; \mu_R; \alpha_s(\mu_R)_s)(1+\delta_{had})$$




Etjet cross section in Breit frame.

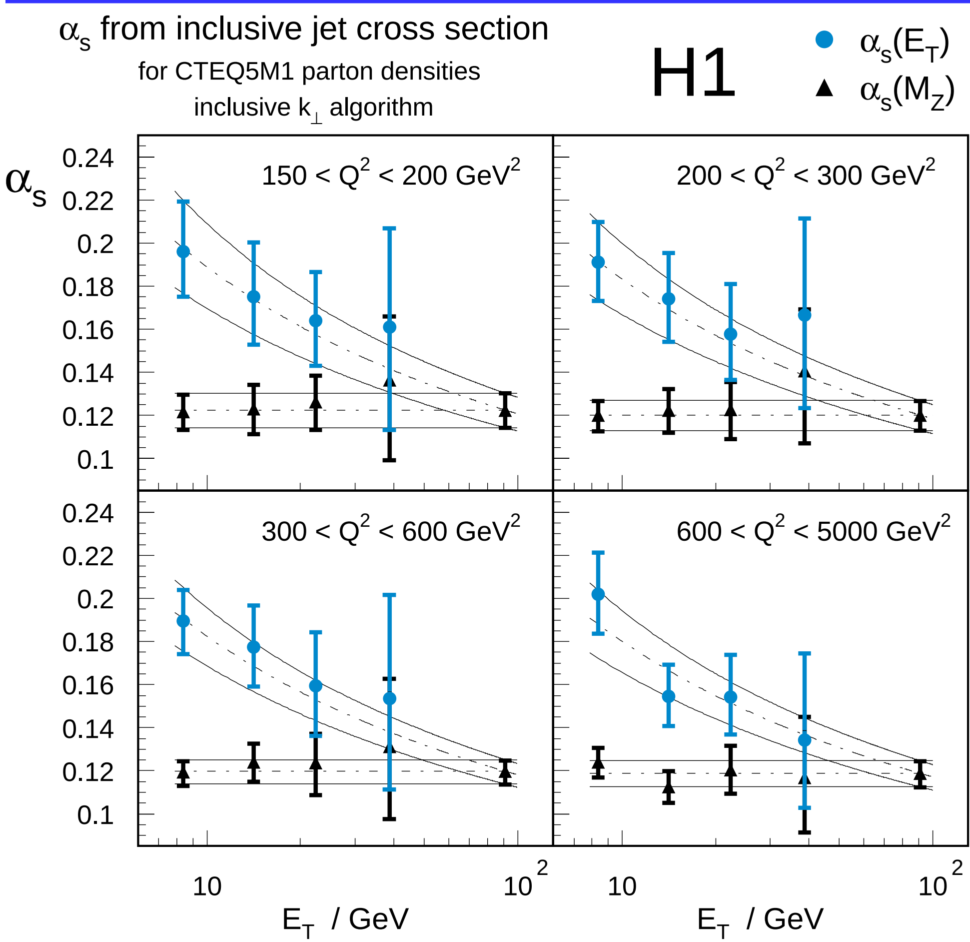
NLO calculation available

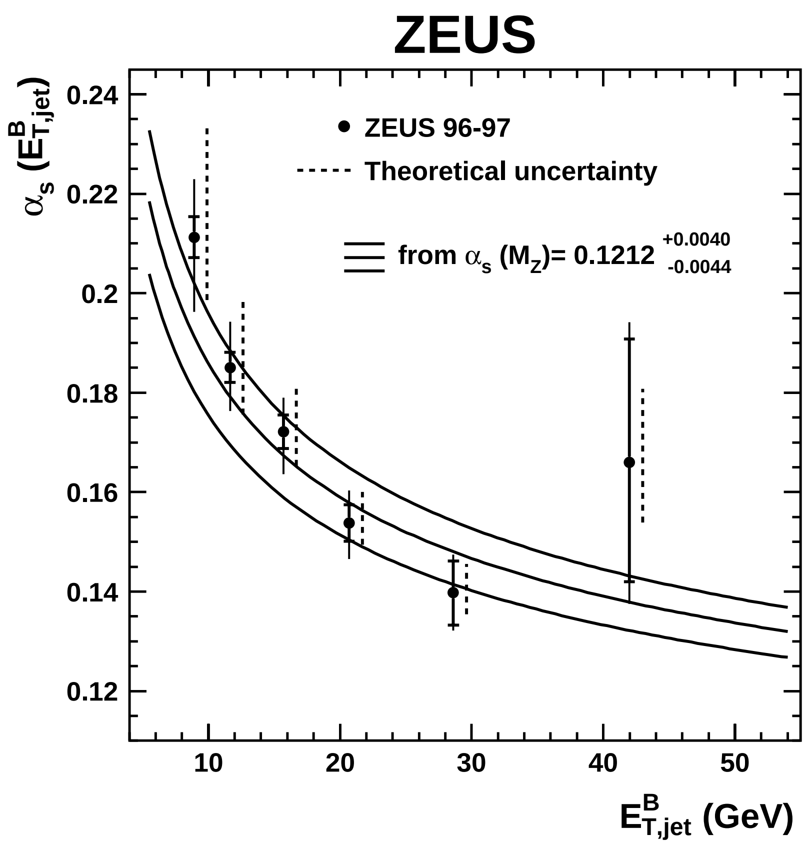
Now, well-known from the global PDF fitting. PDF-sets with several different $\alpha_s$ values exist.

All known parameters -->
$\alpha_s$ can be extracted from the measured cross section.

# Jet Production in DIS

running $\alpha_s$



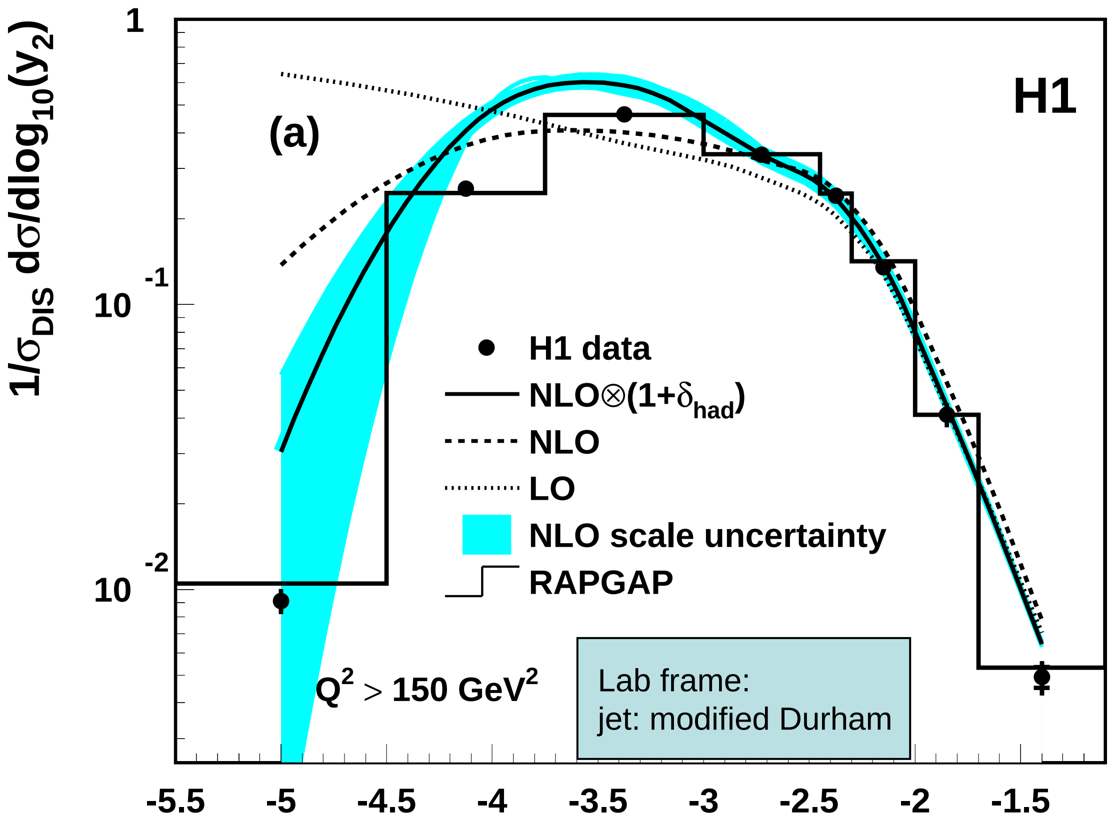

$$\alpha_s(M_z) = 0.1186 \pm 0.0030(\exp.)^{+0.0039}_{-0.0045}(th.)^{+0.0033}_{-0.0023}(PDF)$$

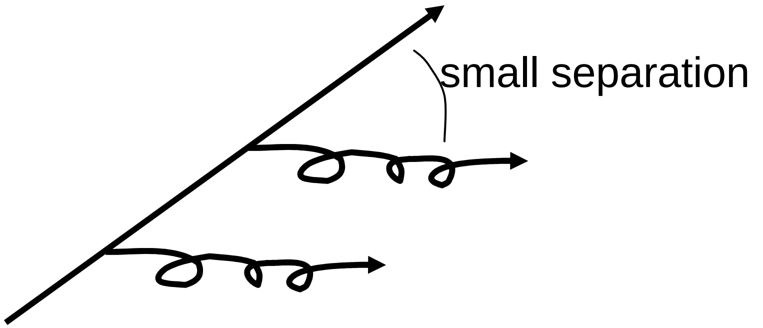
H1: E.P.J.C19 (2001) 289

$$\alpha_s(M_z) = 0.1212 \pm 0.0017(stat.)^{+0.0023}_{-0.0031}(\exp.)^{+0.0028}_{-0.0027}(th.)$$

DESY02-112

# Jet Production in DIS (sub-jet)

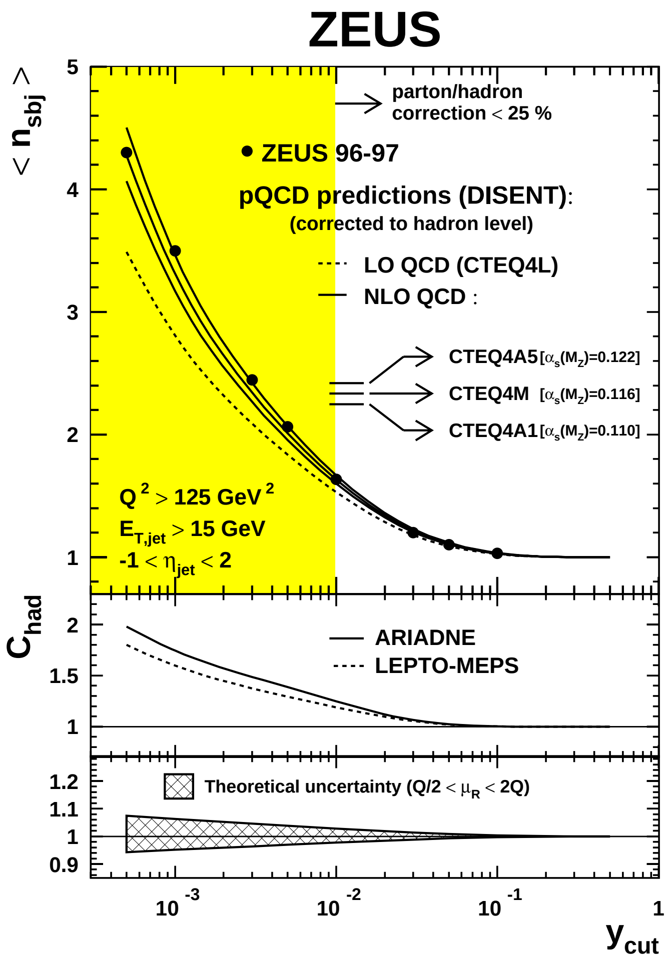



NLO QCD can describe the jets with smaller separation, down to $y_{cut}$ ~$10^{-3}$

Large sample of dijet events can be studied with lower $y_{cut}$.
This also demonstrates the validity of NLO study for jets inside a jet --> next page

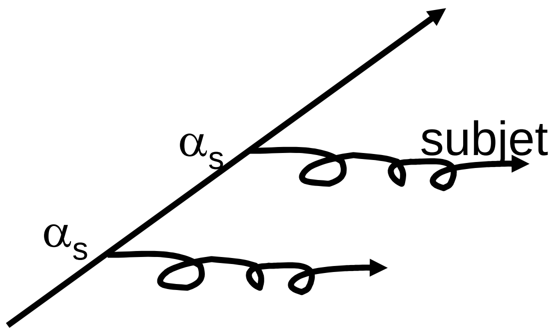
# Jet Production in DIS (sub-jet multiplicity)




Lab frame:
jet: Kt inside jet

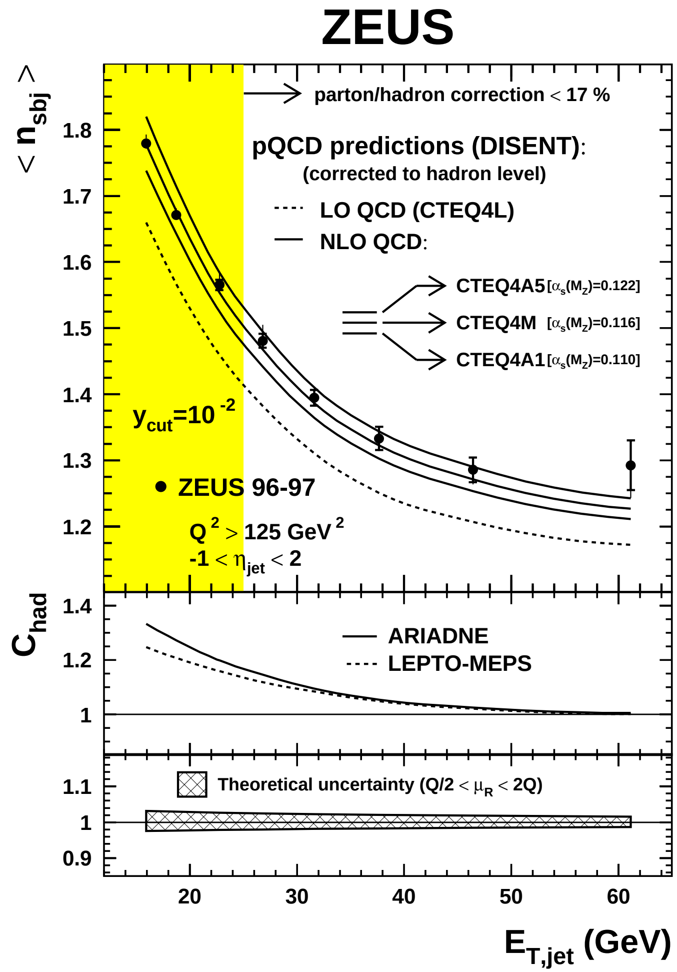
If $\alpha_s$ is larger, more hard parton are emitted.
By studying the internal structure of jet,
$\alpha_s$ can be extracted.

-> Jet shape analysis
-> sub-jet: (re-apply jet algorithm inside a jet, using smaller $y_{cut}$.




NLO calculation gives up to 3 jets in lab frame.
To keep meaningful comparison, $y_{cut}$ >0.01 region is used.

# Jet Production in DIS (sub-jet multiplicity)



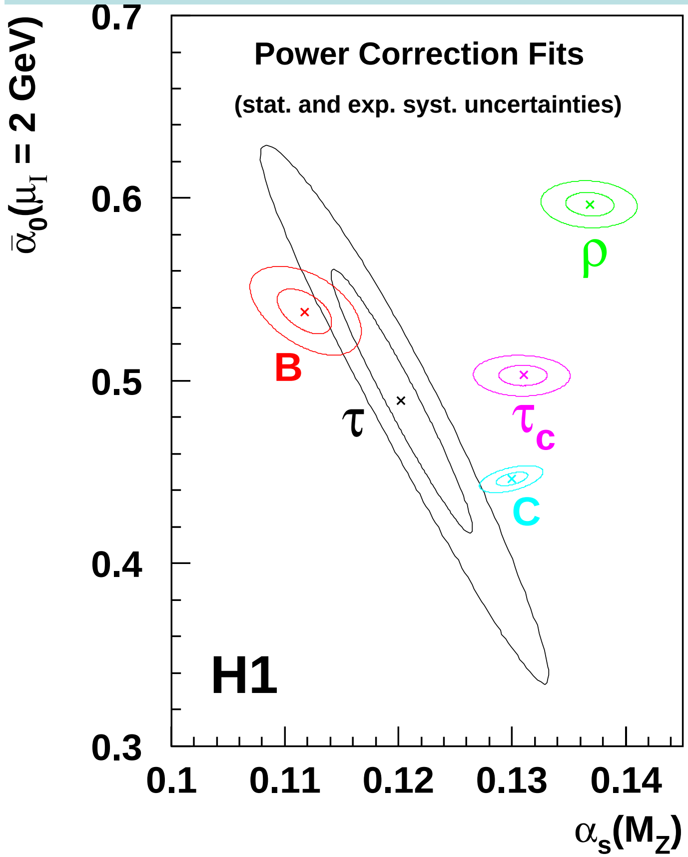

Subjet multiplicity decreases as $Et_{jet}$ increase. --> running coupling.

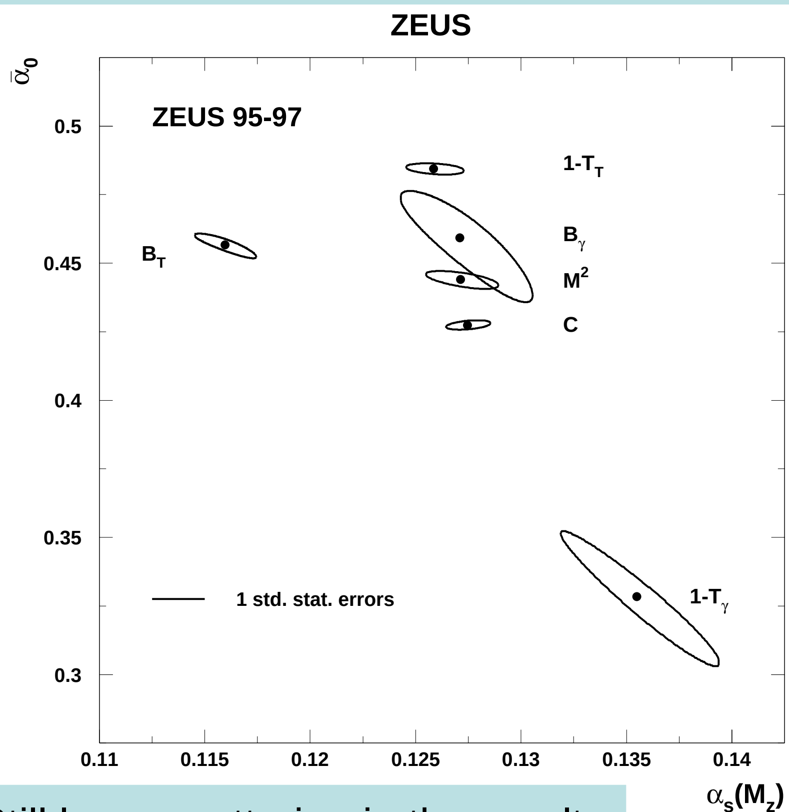
$$\alpha_s(M_z) = 0.1187 \pm 0.0017(stat.)^{+0.0024}_{-0.0009}(\exp.)^{+0.0093}_{-0.0076}(th.)$$

DESY02-217

# $\alpha_s$ from Event Shape

Event-shape variables (Thrust, Jet mass, Jet broadening,... ) are other places to determine $\alpha_s$.
Recent theoretical progress on the treatment of non-perturbative part (power correction) suggests that the shape distribution can be described by two parameters ($\alpha_s$ and $\overline{\alpha_0}$).

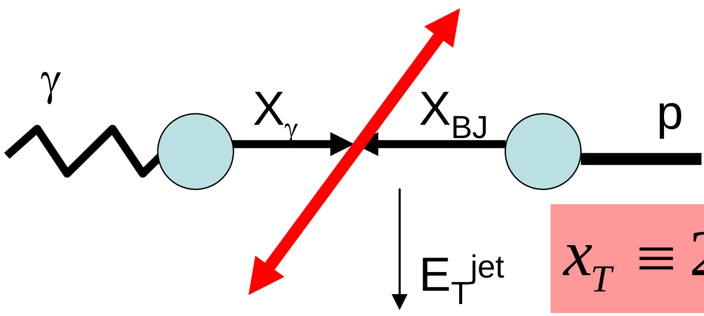



Still large scattering in the results

# Jet Production in photoproduction

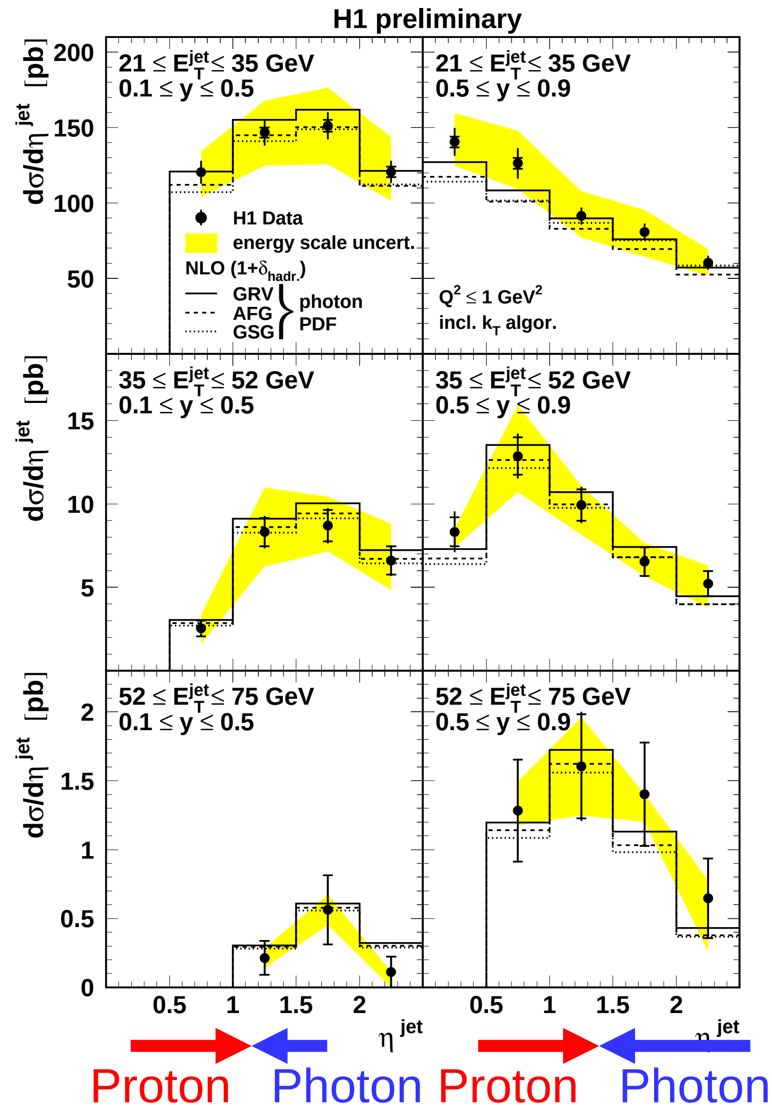
Jet production in γp reaction is regarded as the scattering between
a parton in the proton
and
a parton in the photon (or photon itself)




$$x_T \equiv 2E_T^{jet} / W_{\gamma p}$$

Jet production in two different γp CM energy. In naive QPM, the cross section scales with $x_T$.
<-- In QCD, PDF and ME changes as the probing scale changes.

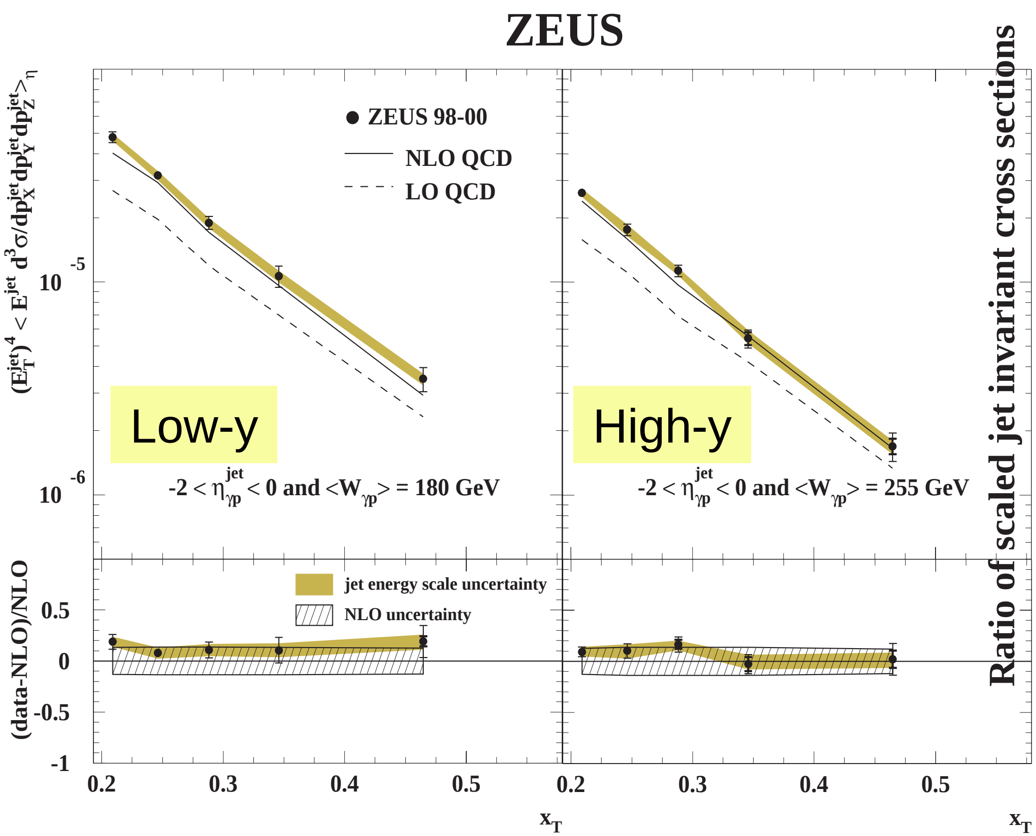
In $p\bar{p}$ (D0,CDF), the scaling violation is observed. NLO QCD describe the shape well but magnitude significantly higher.

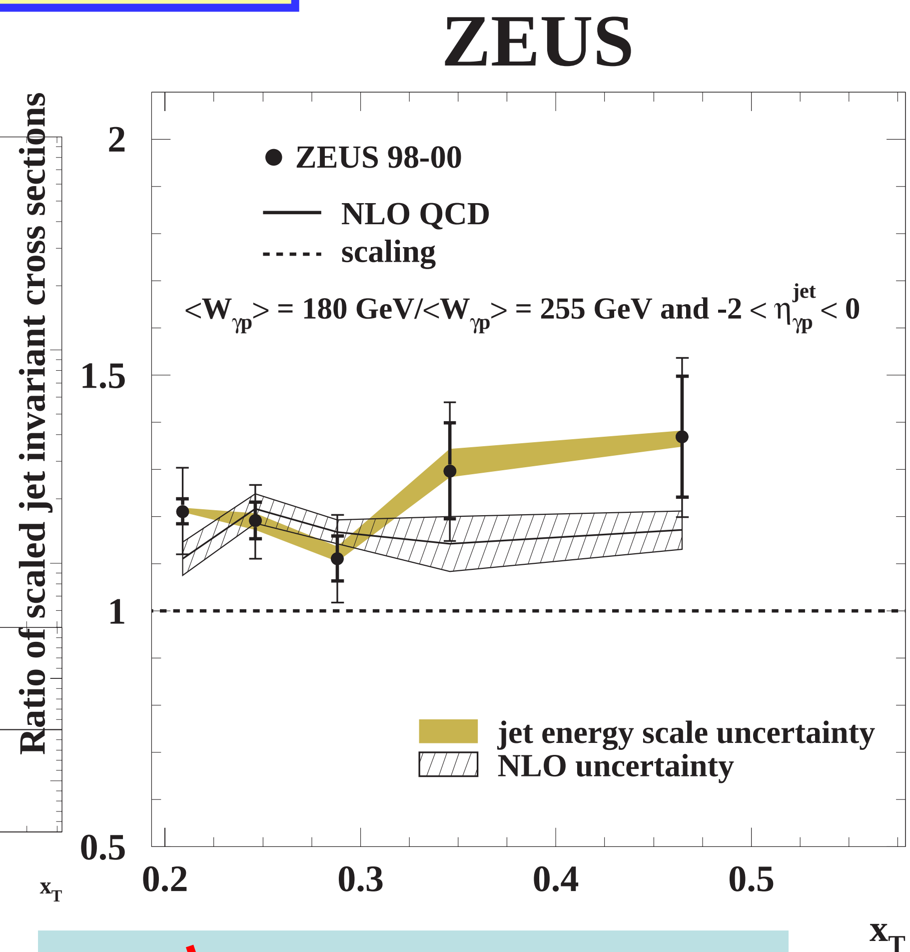



Low-y

High-y

# Jet Production in photoproduction

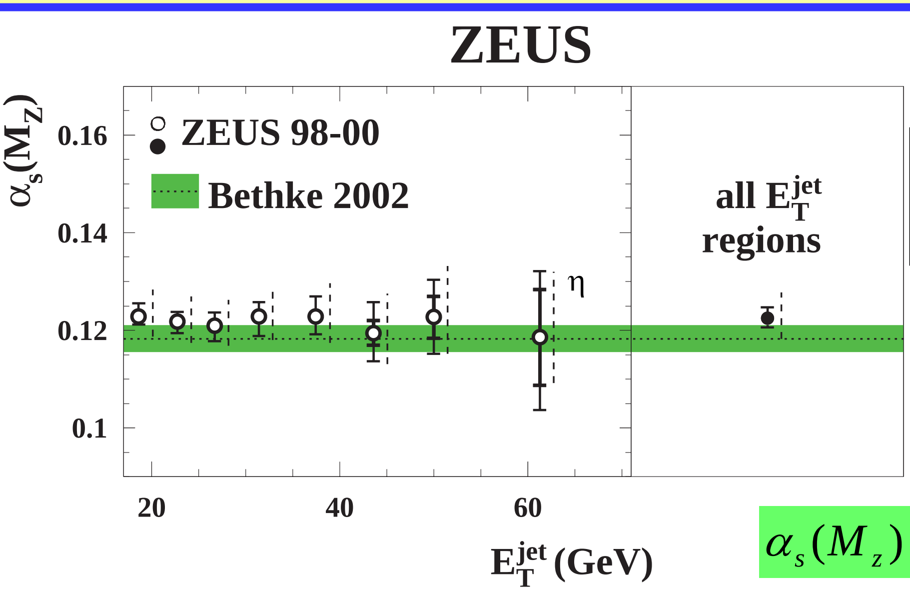



Ratio ≠ 1 <-- Scaling violation
: First time observed in $\gamma p$ jet.

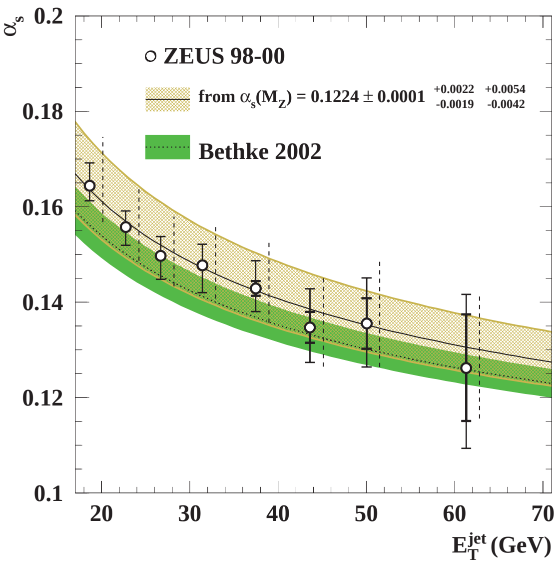
NLO-QCD describe the data well.

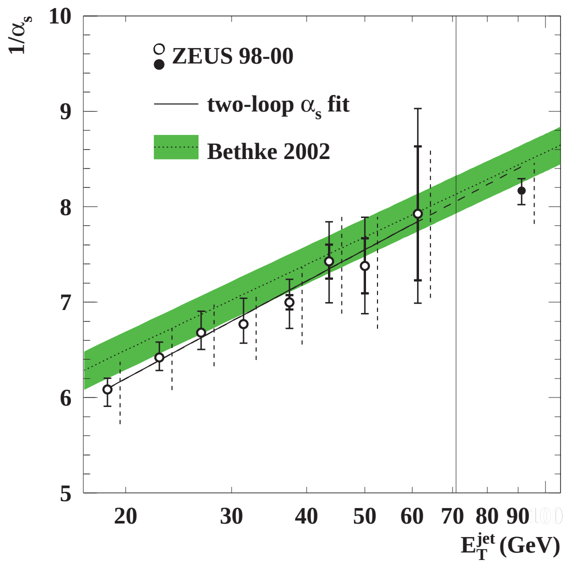
# Jet Production in photoproduction



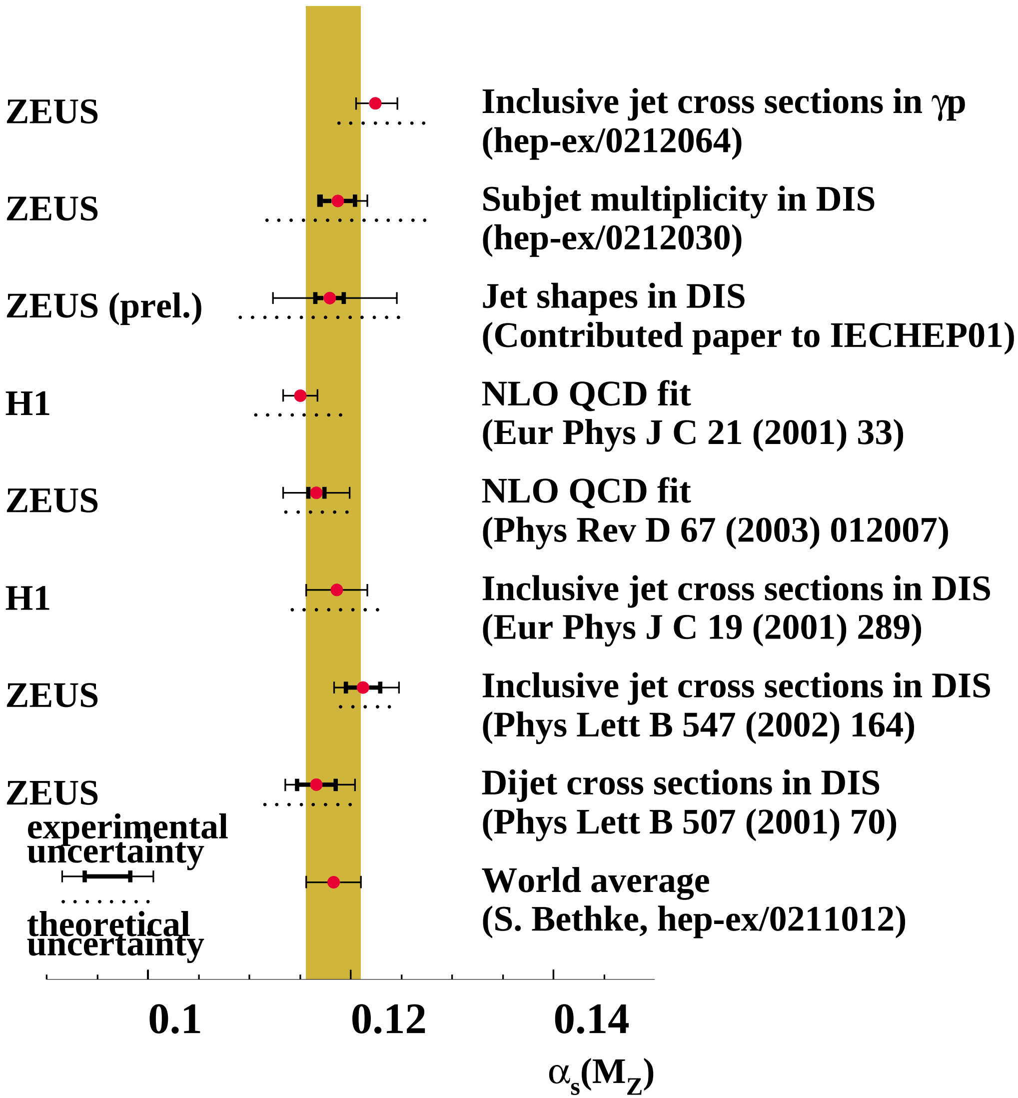

$\alpha_s$ determination using MRST99 PDFs
(similar method as DIS inclusive jet

$$\alpha_s(M_z) = 0.1224 \pm 0.0001(stat.)^{+0.0022}_{-0.0019}(\exp.)^{+0.0054}_{-0.0042}(th.)$$



# Summary




- $X_T$ scaling violation in jet production is, for the first time, observed in photoprodution. The NLO QCD calculations give a good description of both the shape and magnitude.

- The coupling constant of the strong interaction ($\alpha_s$) is measured through the various measurements of high Pt jets in ep collisions, with help of recent developments in NLO pQCD calculations and the PDF analyses.

- Each measurement is well precise. Obtained values are consistent with each other and with the world average.

- After HERA-1, statistical errors are already very small. Systematical uncertainty can be reduced from the precise measurement with a large data set in HERA-II but more helps from the theory side are highly welcome.