

Hadronic Final States and QCD

JET CROSS SECTIONS AND a_s IN NC DIS AT ZEUS

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MOTIVATION + OUTLINE

¶ Jets in NC DIS (at high $Q^2 > 125 \text{ GeV}^2$)

- General **tests of pQCD** (factorisation, perturbative expansion, PDF universality).
- **High-precision measurements** of strong coupling α_S .
- Valuable **input to NLO QCD fits** of the parton distributions.

$$\sigma = \sum_n \alpha_S^n \cdot \sum_{a=q,\bar{q},g} f_{a/p} \otimes \hat{\sigma}_a^{(n)}$$

¶ News since DIS06 in Tsukuba

- **New data:** First HERA-2 jet measurements available
→ dijets measurement in combined HERA-1+2 data set (210 pb^{-1}).
- **New measurements** in old data
→ dependence of inclusive jet cross section on jet radius, α_S extraction.
- **HERA has finished high-energy running**
→ Working on combined analyses of all data sets.

¶ Outline

- Data and MC samples, selections, theory predictions, uncertainties
- Inclusive-jet measurements and dependence on the jet radius,
- Dijet measurements,
- Measurements of α_S at ZEUS.

SAMPLES AND SELECTIONS

¶ Samples and Theory

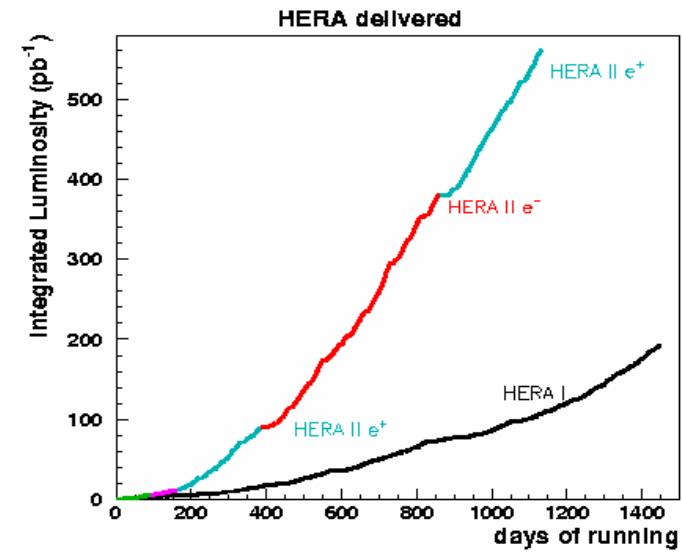
- inclusive jets: 1998-2000 $e\pm$ (81.7 pb^{-1}).
- dijets: plus 2004/05 $e-$ ($+127.6 \text{ pb}^{-1} = 209.3 \text{ pb}^{-1}$).
- ARIADNE and LEPTO MC samples
- Theory: NLO QCD (DISENT), CTEQ6M PDFs.

¶ Typical event selection

- $|cos\gamma_{had}| < 0.65$
- $Q^2 > 125 \text{ GeV}^2$ dijets: $Q^2 < 5000 \text{ GeV}^2 \rightarrow \text{no } Z^0$.
- long.-inv. k_T cluster algo (inclusive mode) in Breit frame.
- $E_{T,\text{jet}} > 8 \text{ GeV}$ dijets: $E_{T,\text{jet}1(2)} > 12(8) \text{ GeV}$.
- $-2 < \eta_{\text{jet,Breit}} < 1.5$

¶ Uncertainties

- **statistical**: HERA-1: at most $\sim 8\%$ for highest E_T , Q^2 bins, HERA-2: 1-5%.
- **systematics** dominated by jet energy scale ($\pm 1\text{-}3\%$) \rightarrow typically 5-10%.
Next important: model uncertainty in acceptance correction.
- **theoretical**: scale variations (higher order effects): typically 5-20%; other sources (α_S , PDFs, factorisation scale, hadronisation) mostly negligible.

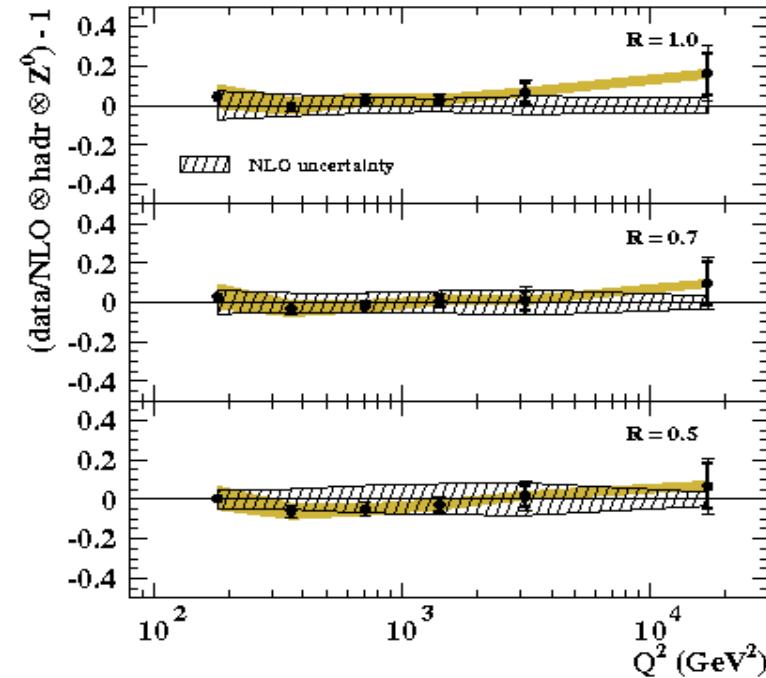
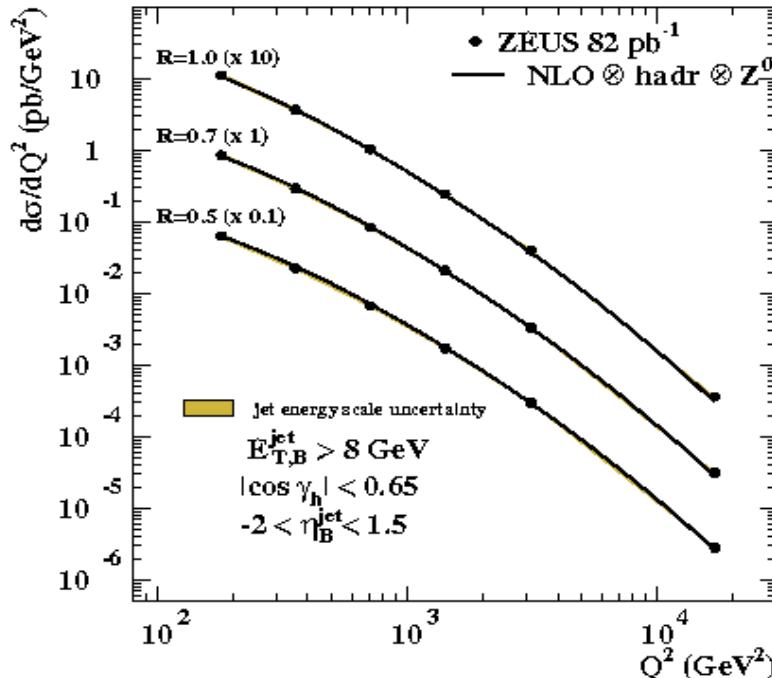


INCLUSIVE JETS AND JET RADIUS (HERA-1)

¶ Inclusive jet cross-section for $E_T > 8 \text{ GeV}$

- ~20k events in HERA-1 sample. Here: $d\sigma/dQ^2$
- for various ‘jet radii’: $R_0=0.5, 0.7, 1.0$ (def.)
→ reliability of theory? Heavy flavour decays?

$$d_i = E_{T,i}^2 \cdot R_0^2 \quad d_{ij} = \min(E_{T,i}^2, E_{T,j}^2) \cdot R_{ij}^2$$



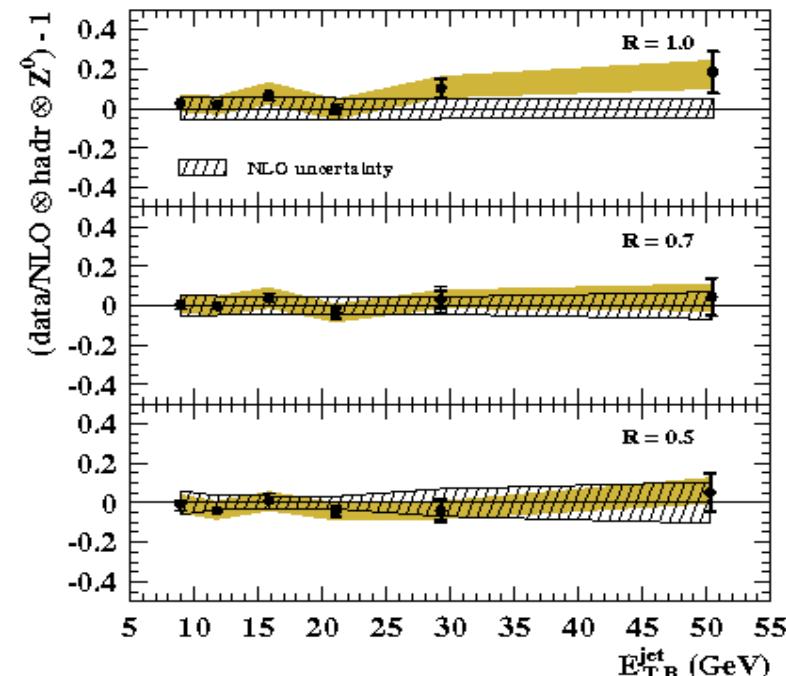
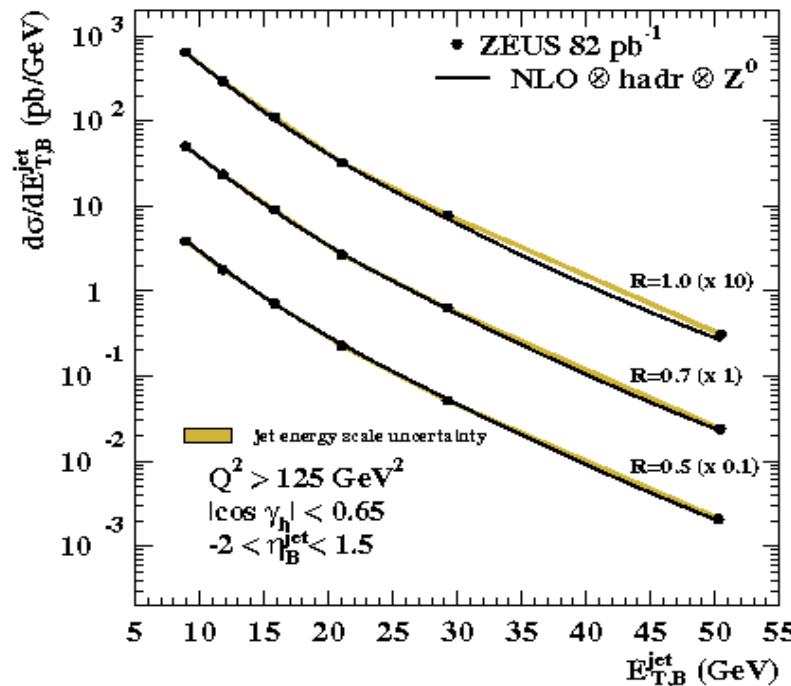
¶ Conclusion:

- Good description of all data by NLO QCD (for both $\mu_R = E_T$ and Q^2).
- $R=1$, $Q^2 > 500 \text{ GeV}^2$: Used for extraction of $\alpha_S(M_Z)$ (later).

INCLUSIVE JETS AND JET RADIUS (HERA-1)

¶ Inclusive jet cross-section for $E_T > 8 \text{ GeV}$

- Here: $d\sigma/dE_T$ for $R=0.5, 0.7, 1.0$.



¶ Conclusion

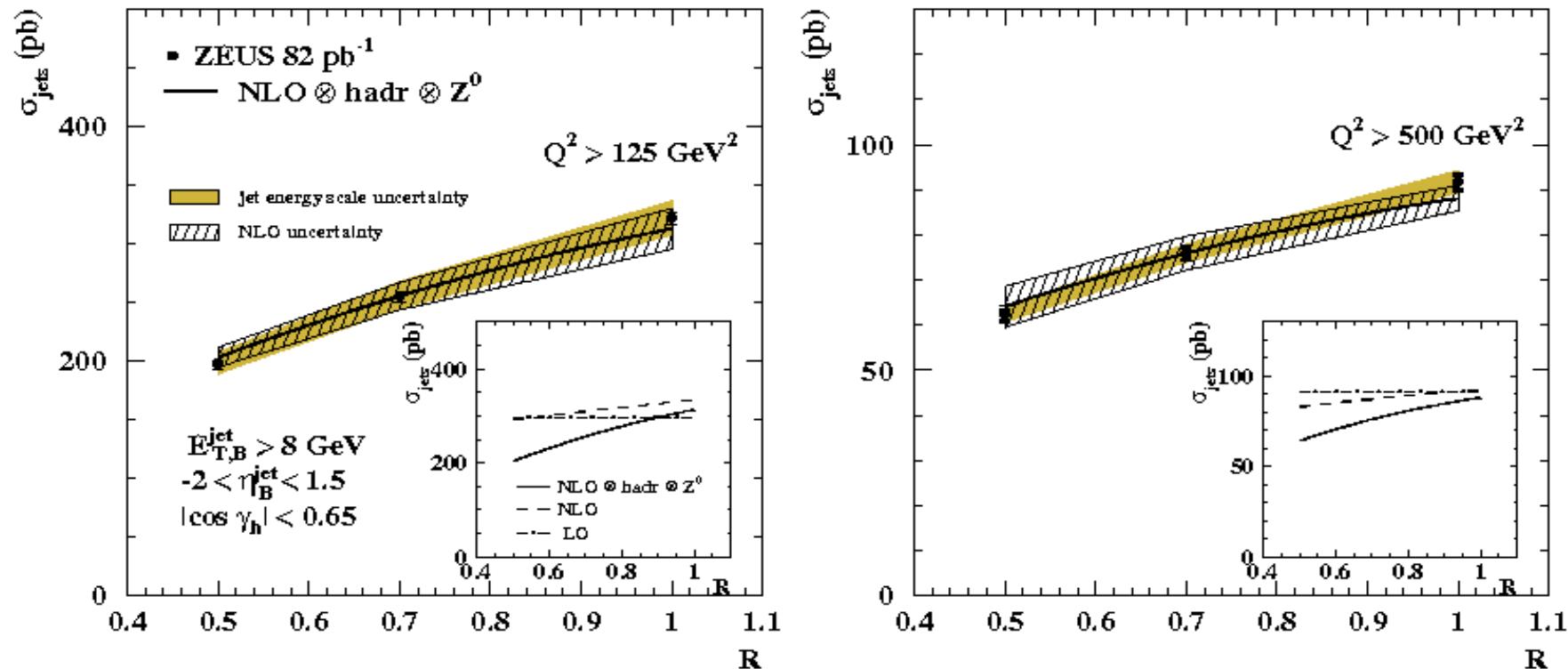
- good description by NLO QCD
- R=1: data used for demonstration of running of α_S (later).
- For lower (higher) R: larger hadronisation (NLO) errors

INCLUSIVE JETS AND JET RADIUS (HERA-1)



¶ Integrated incl. jet cross section as function of parameter R

- For $R=0.5, 0.7, 1.0$ (default) and two lower Q^2 boundaries: $125 / 500 \text{ GeV}^2$.



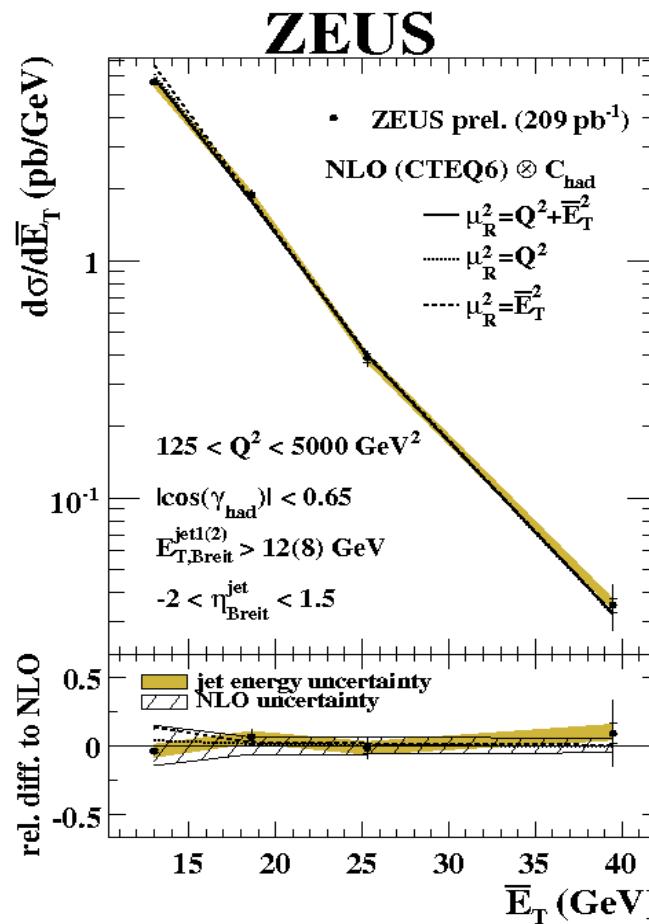
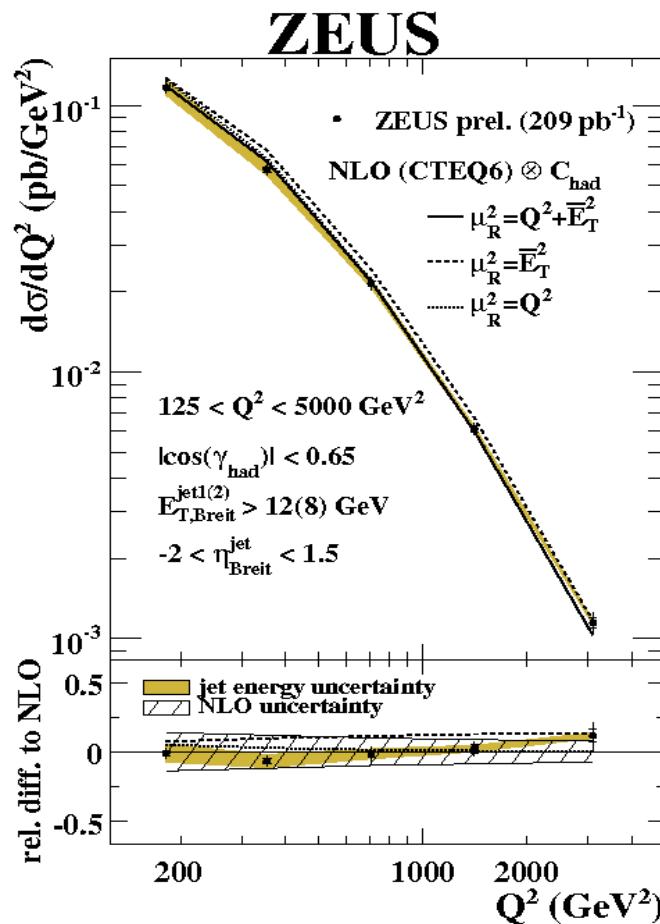
¶ Conclusion

- at LO σ_{jet} flat in R (1 parton!), ‘NLO’ $O(\alpha_S^2)$ is lowest-order for R -dependence.
- linear increase of σ_{jet} with R (more energy \rightarrow more easily above threshold).

DIJETS IN HERA-1 + HERA-2

¶ Update wrt DIS06: 128 pb⁻¹ from 04/05 (factor 2.5 increase)

- comparison to NLO QCD with various scale choices μ_R .
- First ZEUS jets analysis in HERA-2 data. Here: $d\sigma/dQ^2$ and $d\sigma/d\bar{E}_T$,mean



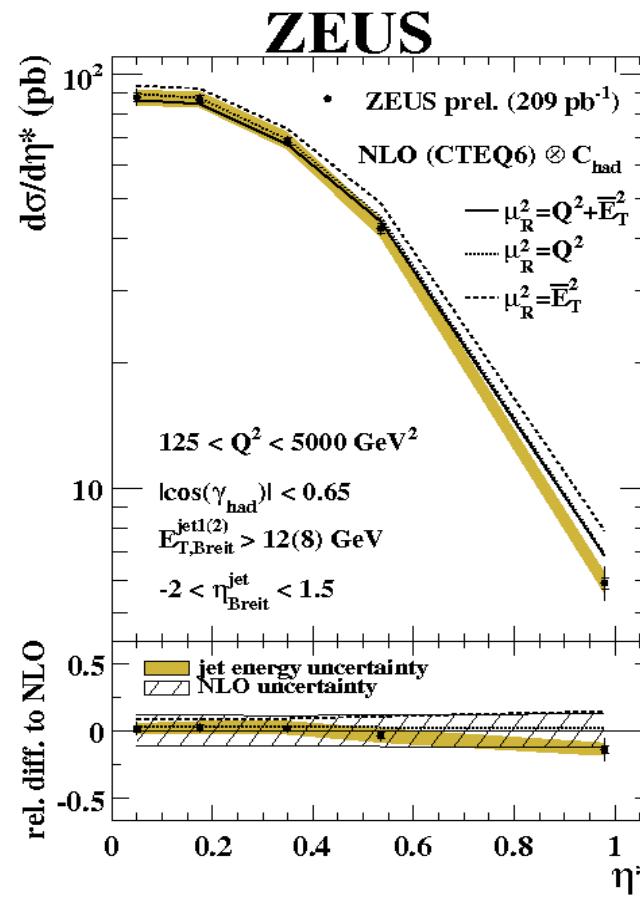
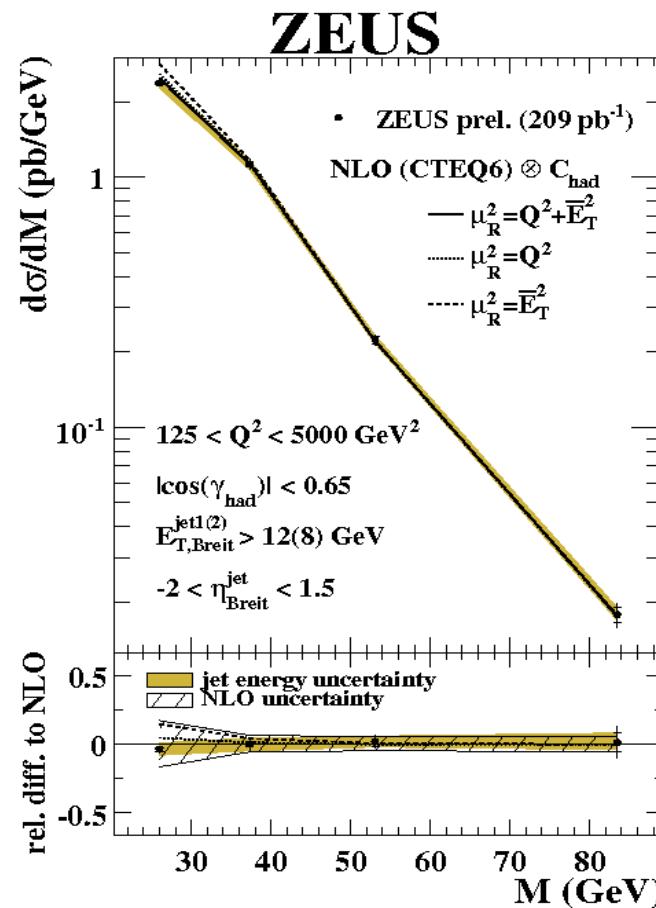
¶ Conclusion

- Good description of data by NLO.
- Data dominated by theo. errors.
- syst. errors: jet scale and model.

DIJETS IN HERA-1 + HERA-2

¶ $d\sigma/dM_{jj}$ and $d\sigma/d\eta^*$.

– $\eta^* = 0.5 \cdot (\eta_1 + \eta_2)$: sensitive to matrix element



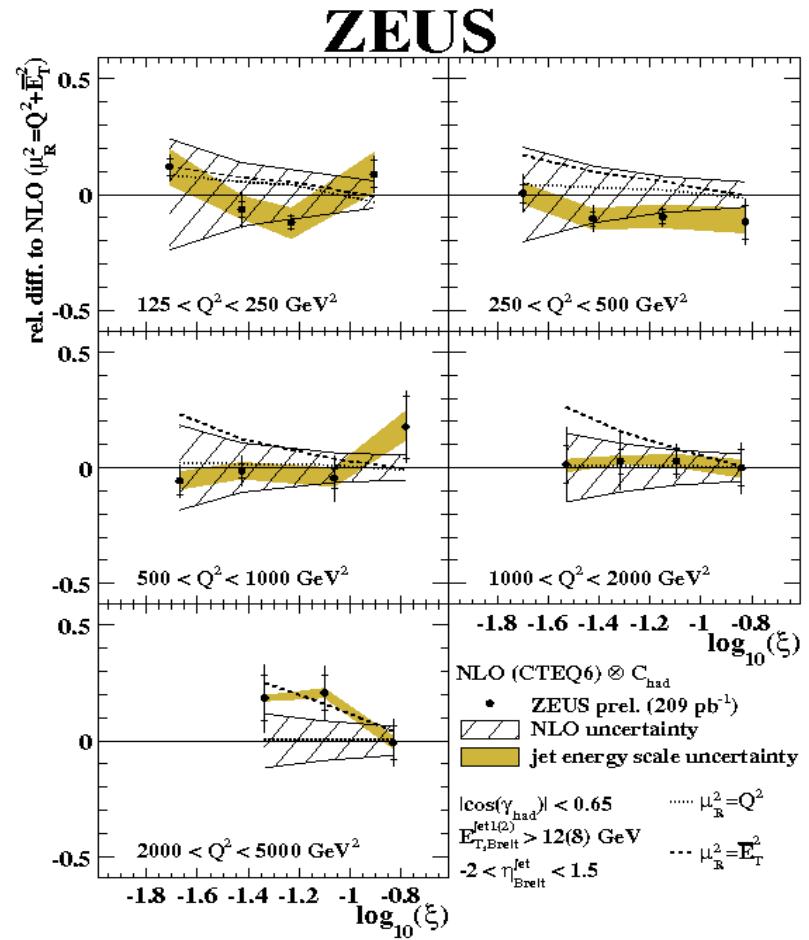
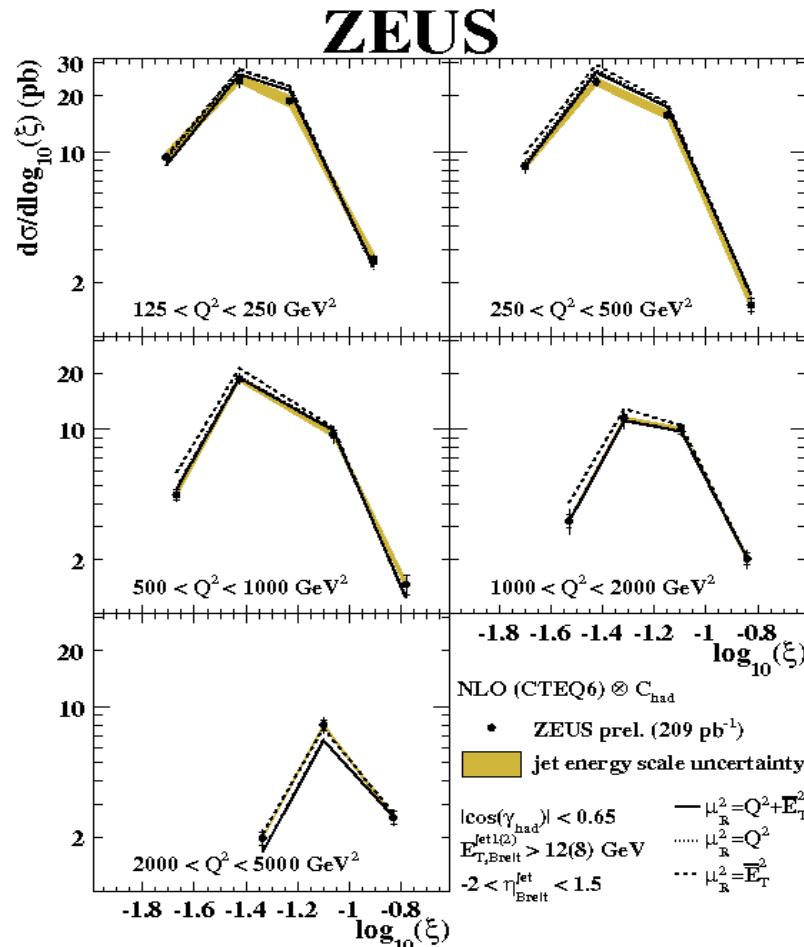
¶ Conclusion

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DIJETS IN HERA-1 + HERA-2

¶ Double-differential: $d\sigma/d\log_{10}\xi$ in different Q^2 bins.

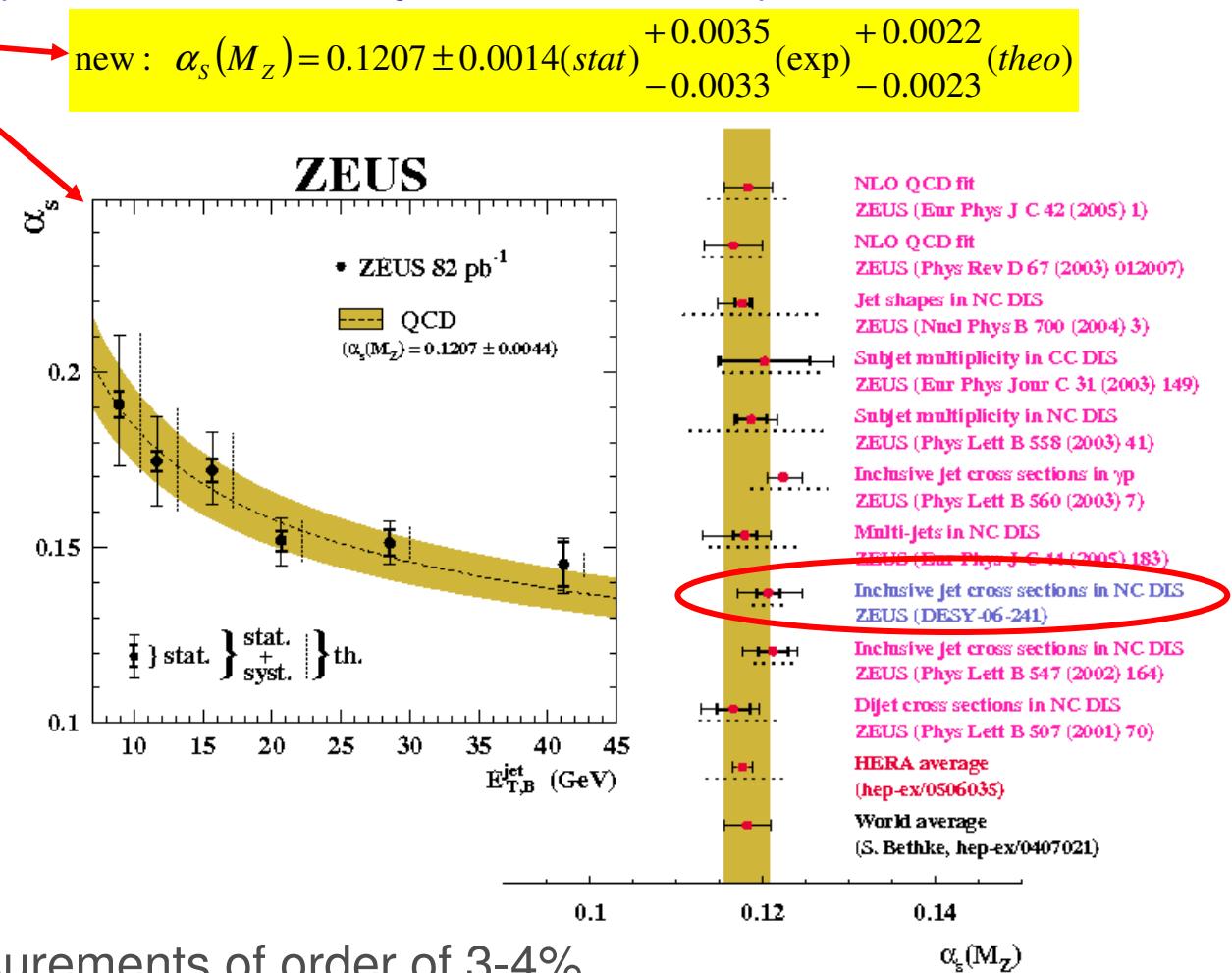
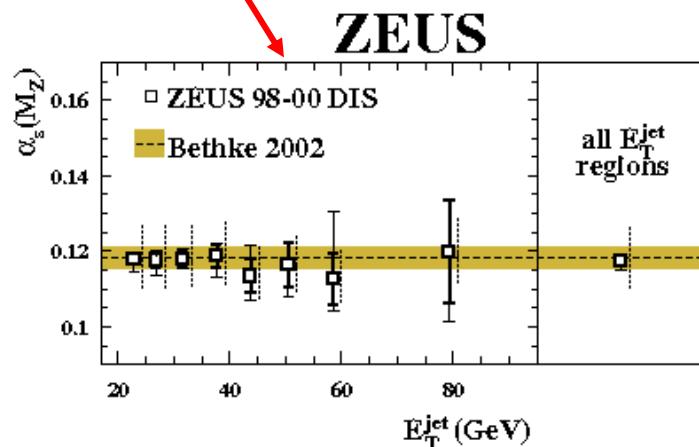
- sensitivity to proton PDFs: scale and momentum fraction!
- Reasonable description by NLO QCD (note various scales μ_R).



MEASUREMENTS OF α_s AT ZEUS

¶ From various input data (see also talk by C. Glasman)

- Inclusive jets in NC DIS
- NC DIS di- and multi-jets
- Photoproduction (di)jets
- NLO QCD fits.
- Jet shapes



¶ Conclusion:

- Uncertainties of single measurements of order of 3-4%.
- Good agreement between measurements, clear demonstration of running α_s .

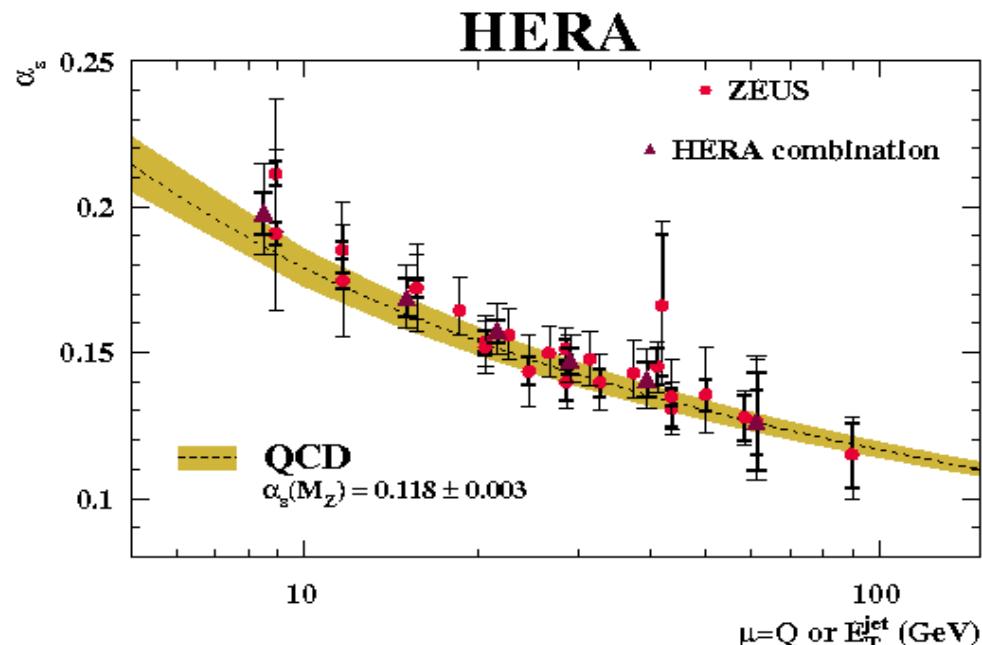
DIS MEASUREMENTS OF α_s AT ZEUS

¶ Combination of ZEUS and H1 data.

- excellent level of agreement between experiments
- large number of data points over large scale range.
- Combined HERA value (C. Glasman, hep-ex/0506035):

$$\alpha_s(M_Z) = 0.1186 \pm 0.0011(\text{exp}) \pm 0.0050(\text{theo})$$

¶ Summary: Running of α_s (including new inclusive-jet measurement)



- ## ¶ Data sets in HERA average
- ZEUS inclusive jets in PHP
→ PLB 560 (2003) 7
 - ZEUS inclusive jets in DIS
→ PLB 547 (2002) 164
 - H1 inclusive jets in DIS
→ EPJ C19 (2001) 289

SUMMARY AND OUTLOOK

¶ Jets in NC DIS (at high $Q^2 > 125 \text{ GeV}^2$)

- NLO QCD gives good description of jet cross sections.
- Measurements are dominated by their theoretical uncertainties (variation of scale μ_R by factors of 2 or use of different scale choices).

¶ News since DIS06 in Tsukuba

- First HERA-2 jet measurements (dijets), combined with HERA-1 (210 pb^{-1})
- jet-radius-dependent measurement of inclusive jet cross sections
- strong coupling from inclusive jets $d\sigma/dQ^2$ with $R=1$ and $Q^2 > 500 \text{ GeV}^2$:

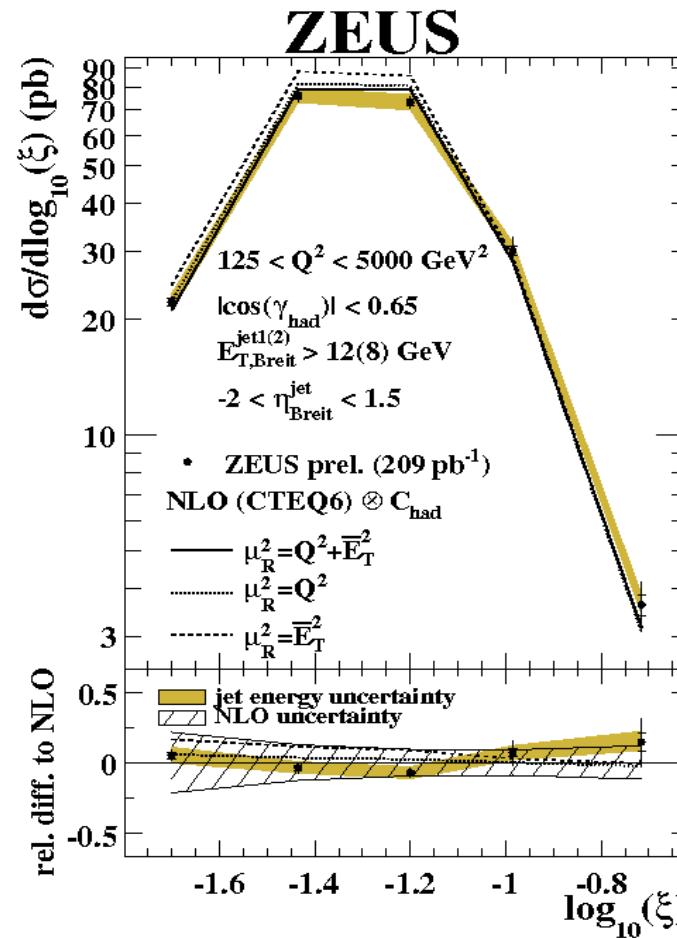
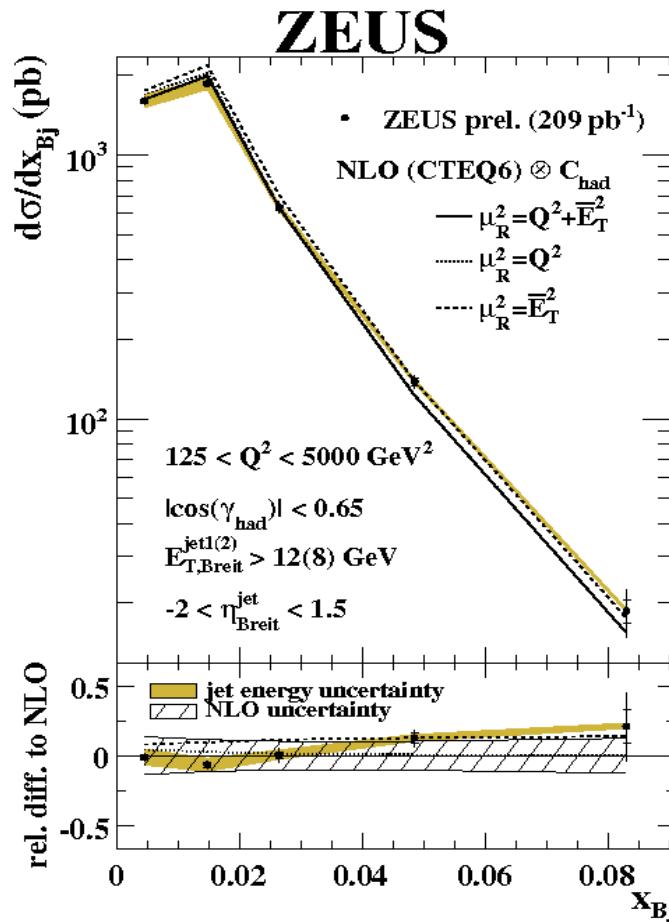
$$\alpha_s(M_Z) = 0.1207 \pm 0.0014 \text{ (stat)} \quad {}^{+ 0.0035}_{- 0.0033} \text{ (exp)} \quad {}^{+ 0.0022}_{- 0.0023} \text{ (theo)}$$

¶ Future

- Make use of full HERA-1+2 statistics (500 pb^{-1})
- Produce final HERA answer: strong coupling from jets in DIS!
- Refine jet input to QCD fits → improvement of PDFs?

DIJETS IN HERA-1 + HERA-2

¶ $d\sigma/dx_{Bj}$ and $d\sigma/d\log_{10}\xi$.
 $\xi = x_{Bj} \cdot (1 + M^2/Q^2)$



¶ Conclusion

- Good description of data by NLO.
- Data dominated by theo. errors.