European Physical Society
HEP 2007

Inclusive Jet & Dijet Production at HERA

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On behalf of H1 and ZEUS collaborations

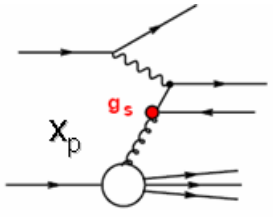
DIS and Photoproduction Physical sensitivity

$e + p \rightarrow X + e$

Q^2 : momentum transfer

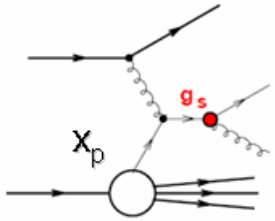
x_p (x_γ) : proton (photon) momentum fraction carried by interacting parton

Boson Gluon Fusion



$x_p < 0.1$

QCD Compton

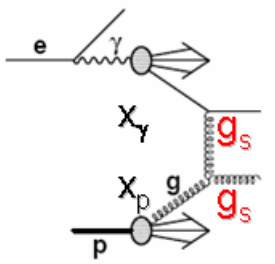


$x_p > 0.1$

DIS

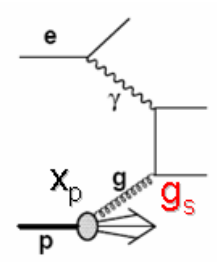
$Q^2 > 1 GeV^2$

RESOLVED



$x_\gamma < 0.8$

DIRECT



$x_\gamma > 0.8$

γp

$Q^2 \sim 0$

Theoretical description

- Proton PDF
- Photon PDF
- pQCD with $\alpha_s(M_z)$

QCD param.	Observables
Photon PDF	2-jets **γp**
Proton PDF α_s	2-jets **γp** 2-jets **DIS** Inclusive jets **DIS**

Jet reconstruction

Longitudinally invariant kT algorithm

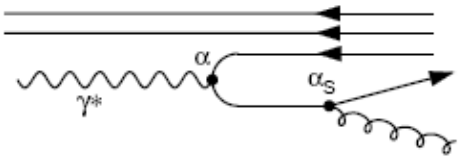
- Iterative clustering:

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

$$R_{ij} = (\eta_i - \eta_j)^2 + (\varphi_i - \varphi_j)^2$$

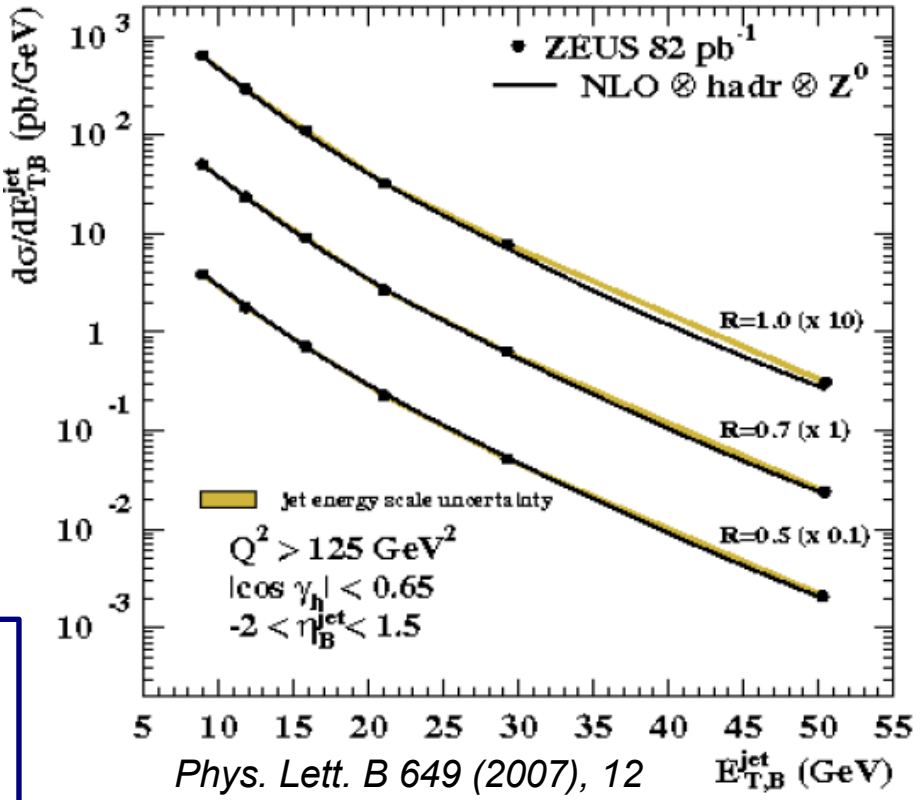
- p_T-weighted recomb. Scheme
- Resulting jets: n jets with $R_{ij} > R$
- **Collinear and infrared safe**

Applied in photon-proton collinear frame



Photoproduction – laboratory frame

DIS – Breit frame



Phys. Lett. B 649 (2007), 12

Usually R = 1, but Inclusive jets data are well described for R = 0.5; 0.7; 1

Probing the structure of the photon

2-jet photoproduction cross section (H1-ZEUS)

$Q^2 \sim 0$

Jet phase space:

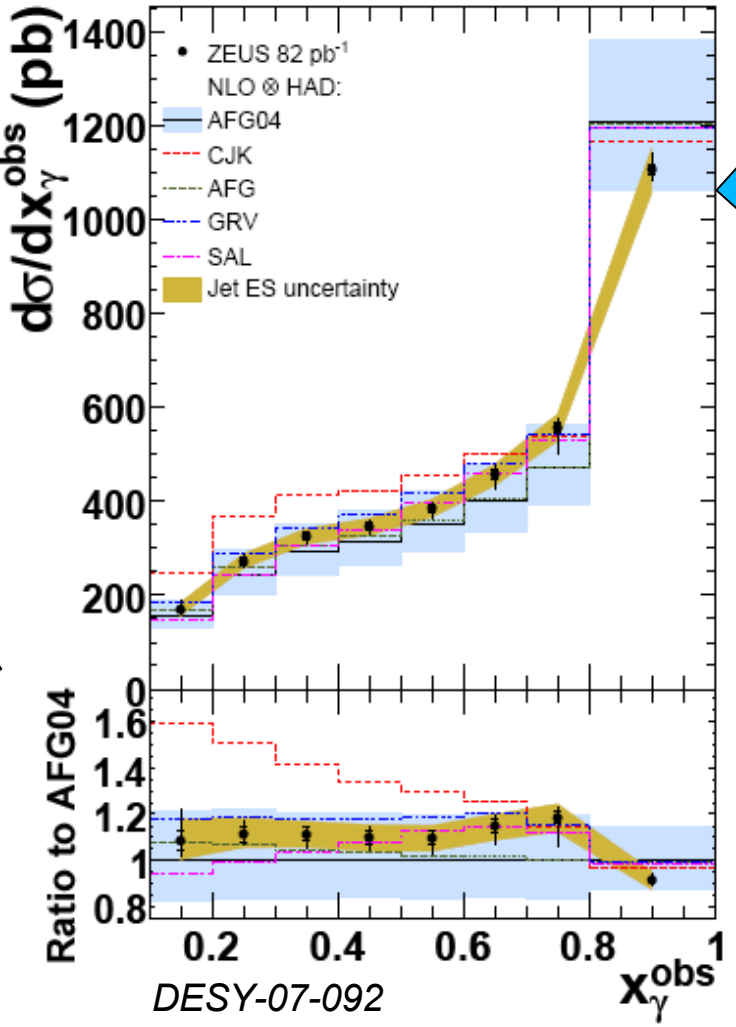
$E_T^{jet1} > 25$ GeV

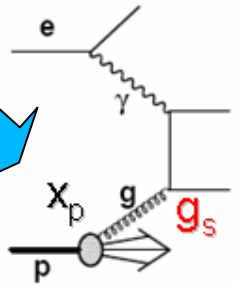
$E_T^{jet2} > 15$ GeV

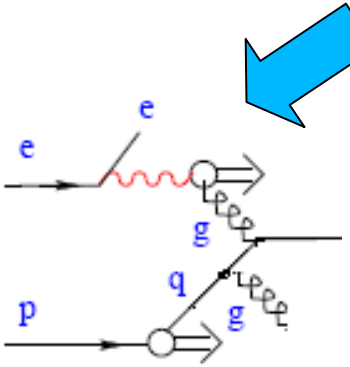
$-1 < \eta_{jet} < 3.0$ (ZEUS)

$$x_\gamma = f(\eta_{jet1}, \eta_{jet2}, E_{T,jet1}, E_{T,jet2})$$

$$x_p = g(\eta_{jet1}, \eta_{jet2}, E_{T,jet1}, E_{T,jet2})$$





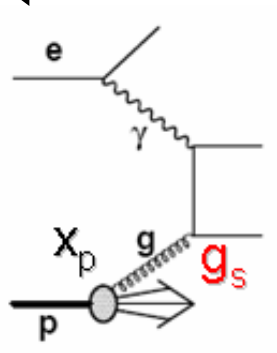


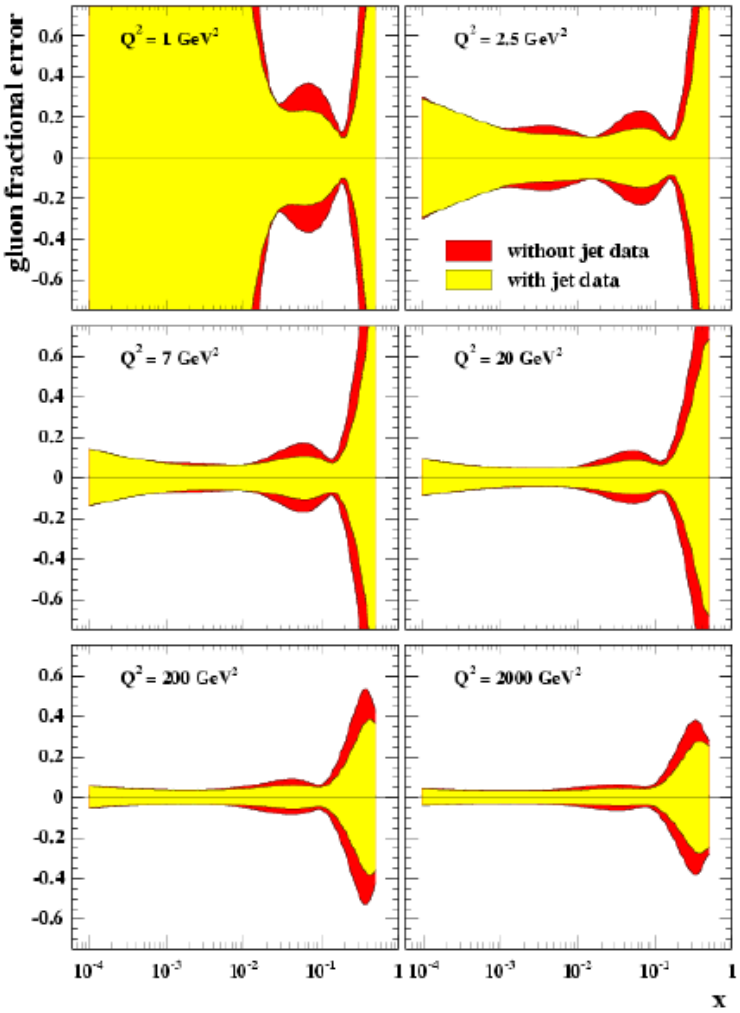
Sensitive region to gluons in the resolved photon

High precision data helps to discriminate between photon PDF parameterisations

Jets help constraining the gluon content of the proton

Jet data used for the fits by ZEUS collaboration:
- Incl. jets in DIS (96/97)
- “resolved” 2-jet in γp (96/97)





From Eur.Phys.J. C42 (2005)

Jets help constraining the gluon content of the proton

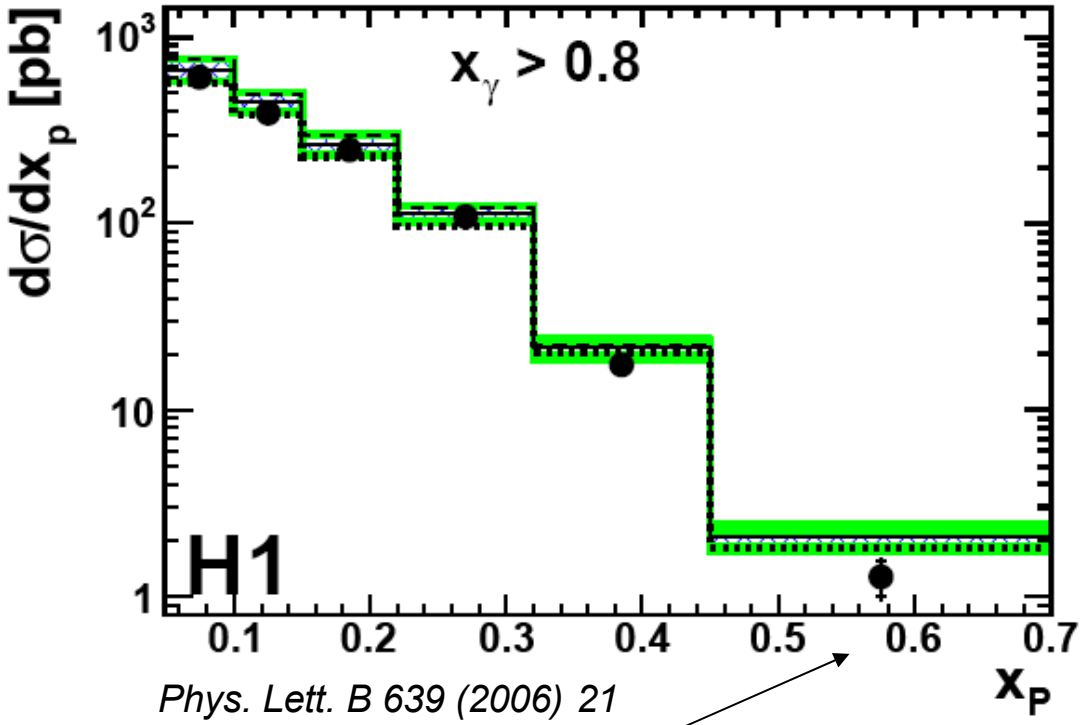
2-jet "**direct**" photoproduction cross section (H1)

Jet phase space:

$E_T^{jet1} > 25$ GeV

$E_T^{jet2} > 15$ GeV

$-0.5 < \eta_{jet} < 2.75$ (H1)



Phys. Lett. B 639 (2006) 21

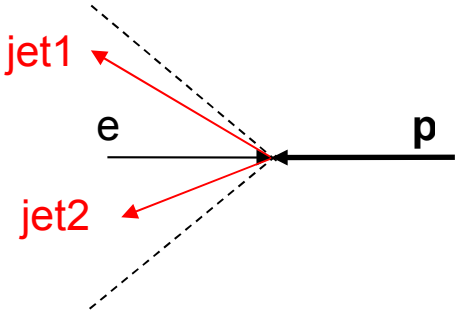
Can constrain gluon density up to high proton momentum fractions

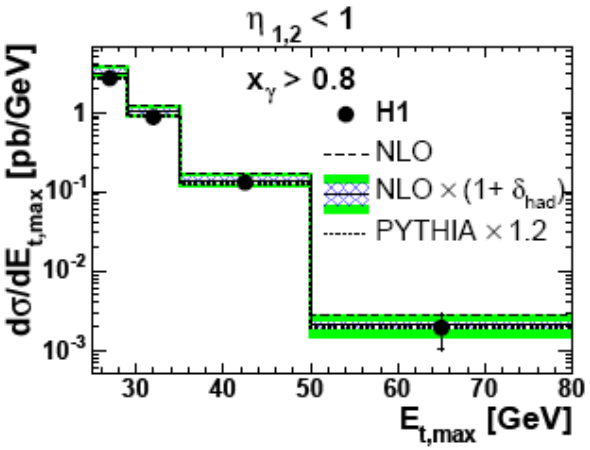
Probing the gluon content of the proton

2-jet "**direct**" photoproduction cross section (H1)

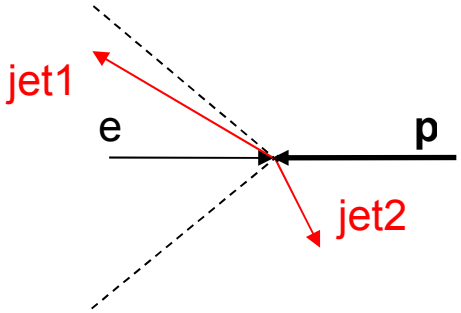
ÉCOLE POLYTECHNIQUE

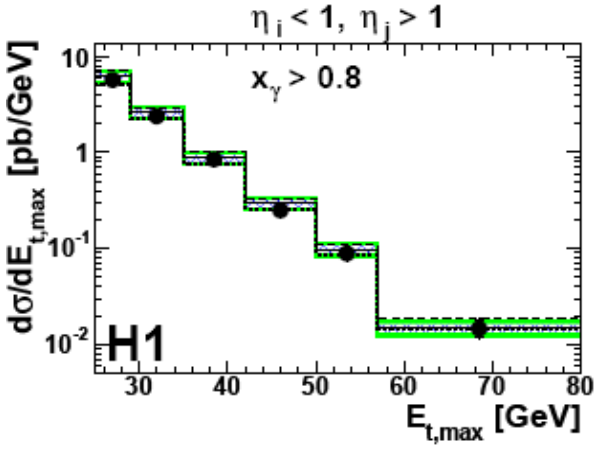
Forward topology



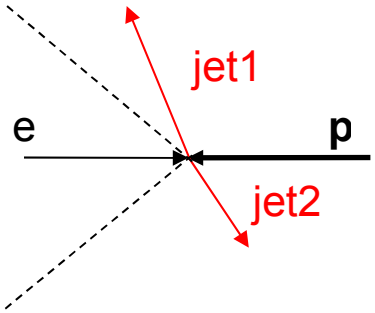


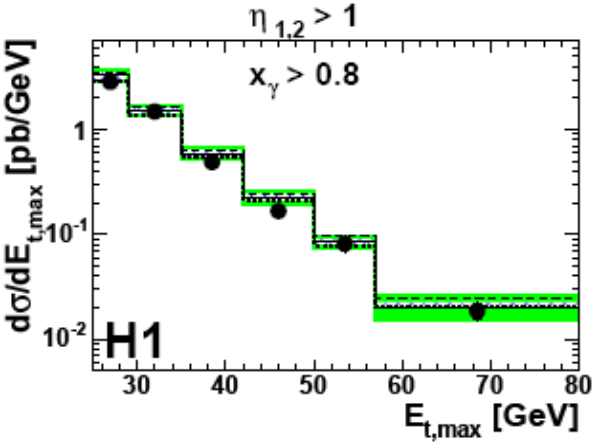
Forward-Central topology





Central topology





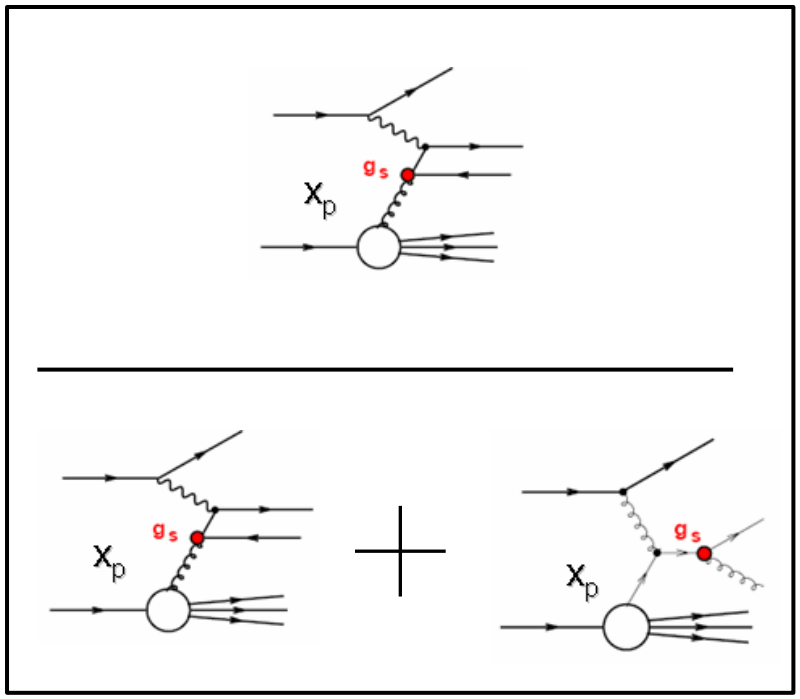
Similar studies done by ZEUS collaboration

High precision measurement in "optimised" exclusive topologies leads to an important constraint to the gluon structure function

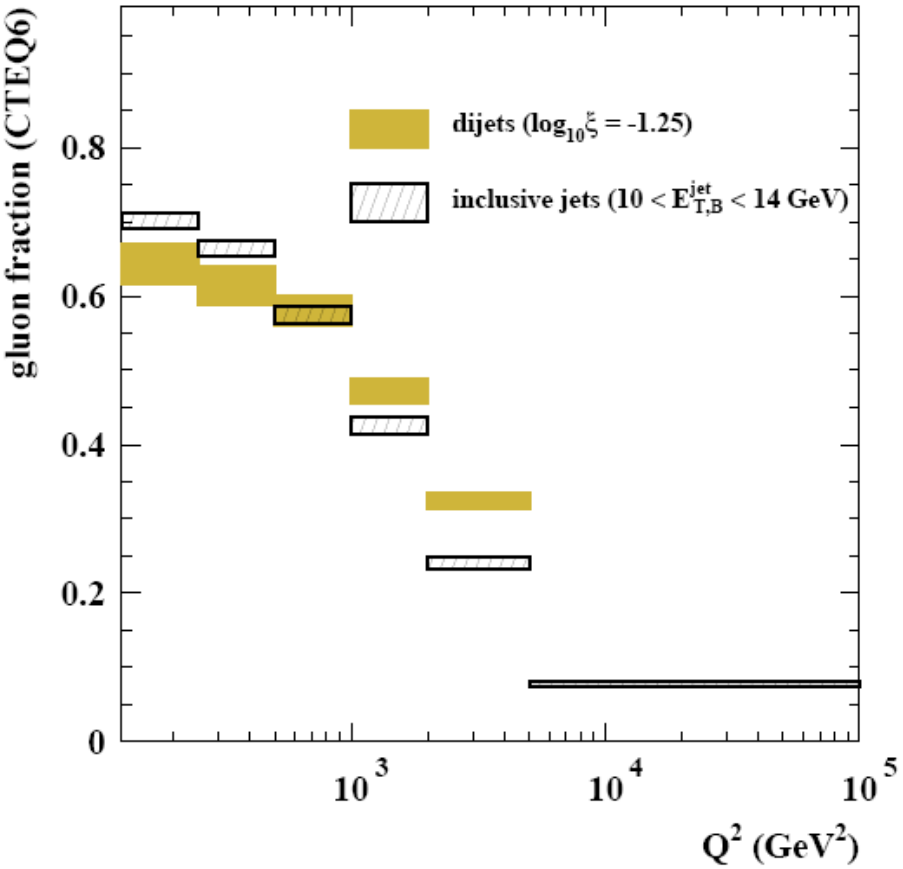
Jets help constraining the gluon content of the proton

DIS

Q^2>~100 GeV2

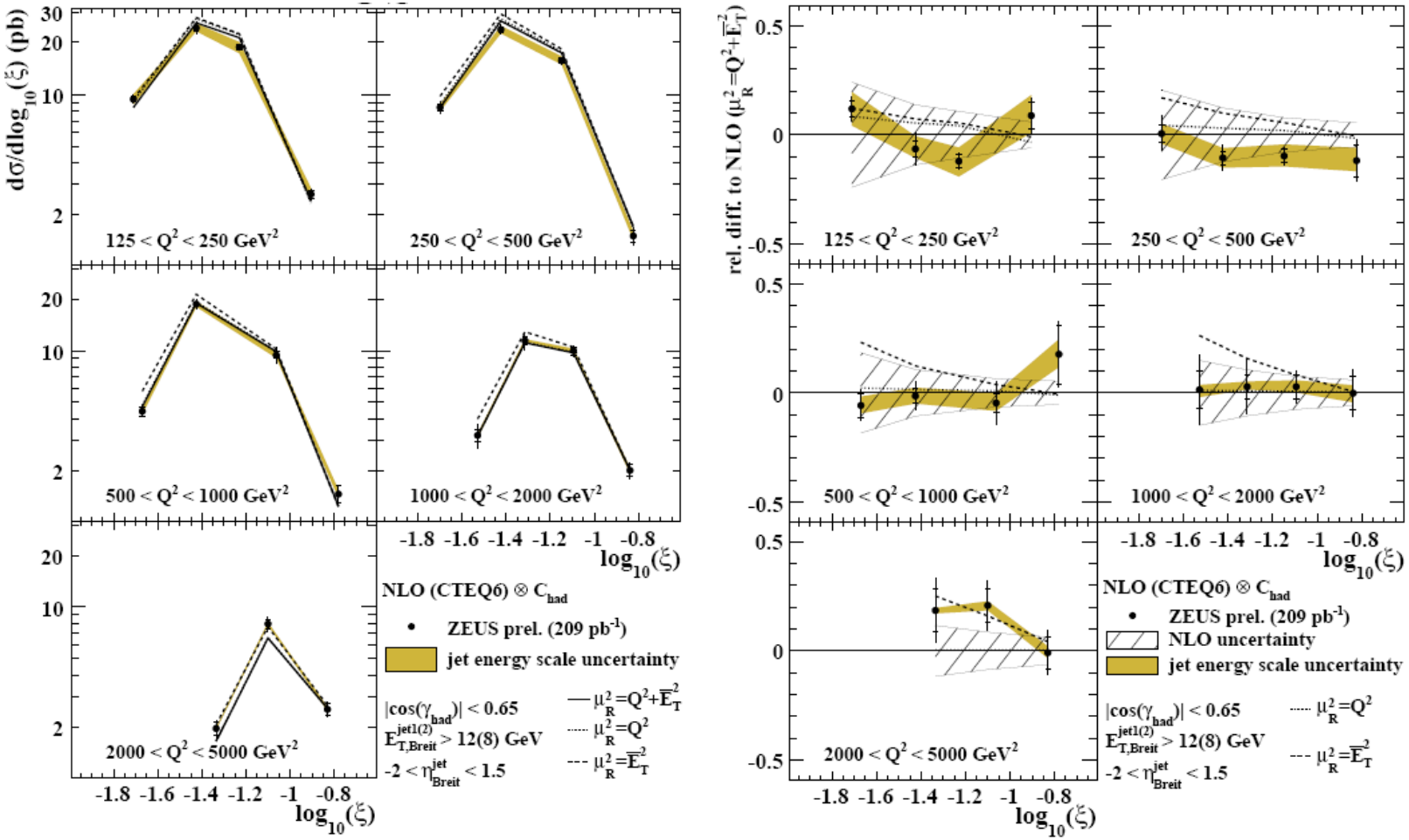


Incl. jet and di-jet in DIS
sensitivity to gluon in proton PDF



Probing the gluon content of the proton

2-jet cross section in DIS (ZEUS)

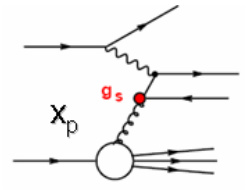


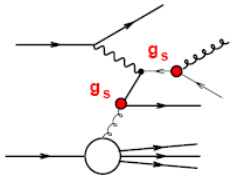
HERA I + part of HERA II data : 209 pb^{-1} (previous measurement 82 pb^{-1})

Probing gluon density up to high proton momentum fraction

High p_T inclusive jets sensitive to the proton PDF

Jets are counted instead of the events:

2 x 

3 x 

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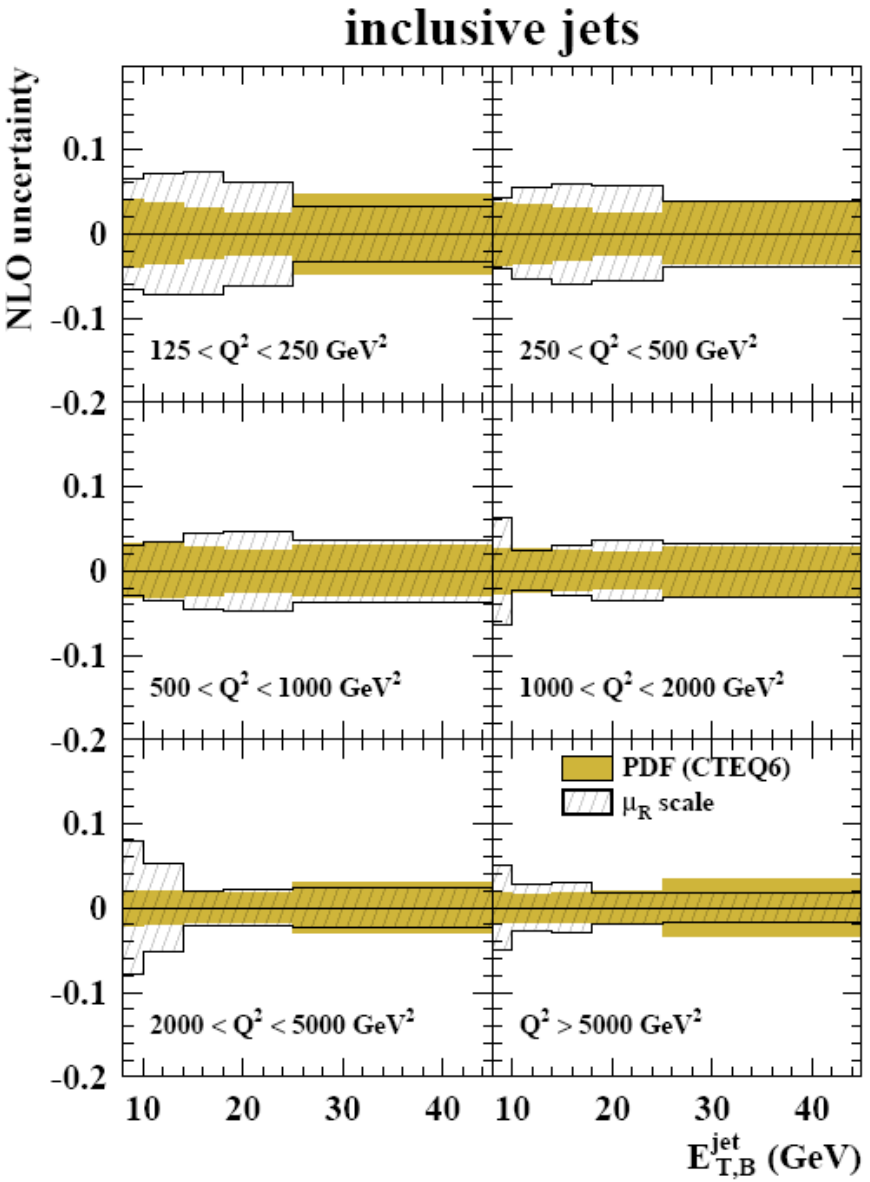
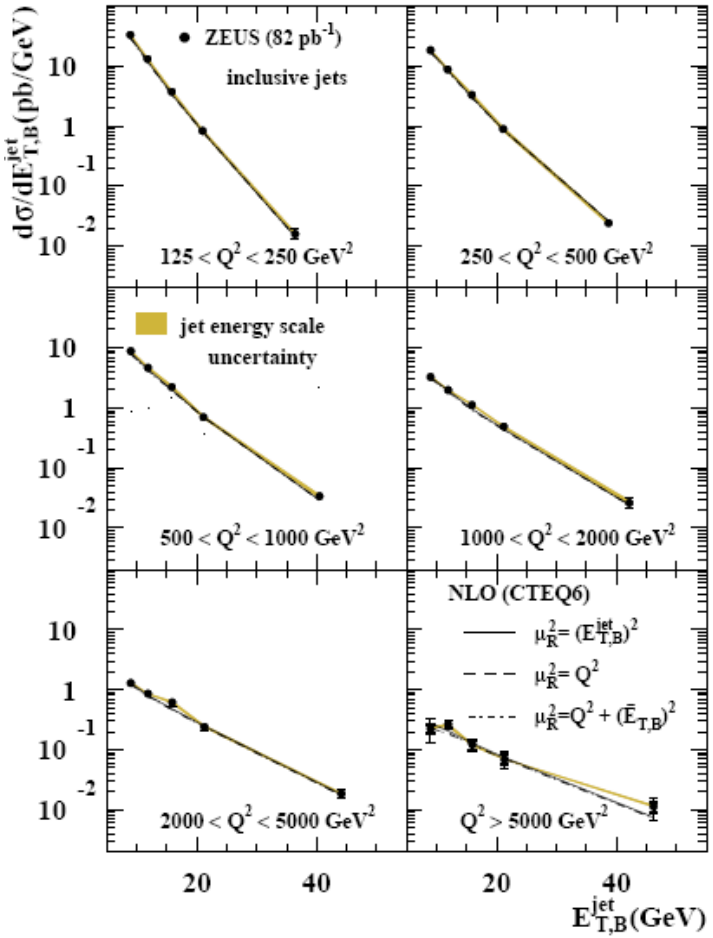
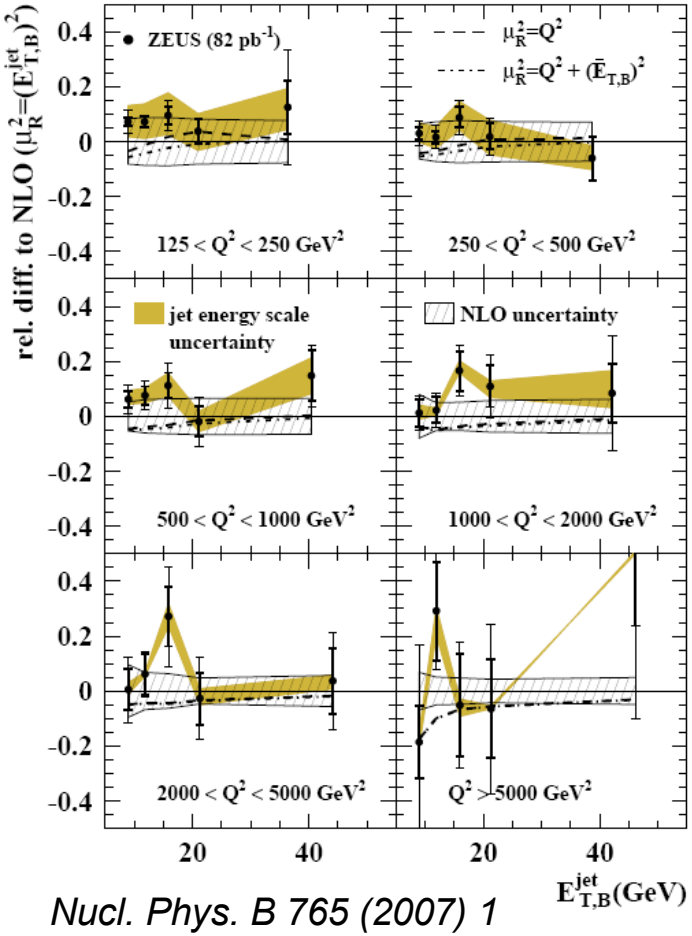
- Designed to have a direct sensitivity to α_S
- At high p_T pQCD prediction uncertainty dominated by PDF (constraining power)



High precision QCD measurement tool (proton PDF - α_s)

Inclusive jet cross section in DIS (ZEUS)





Nucl. Phys. B 765 (2007) 1

Jet phase space : $E_T > 8$ GeV; $-2 < \eta^{jet}_{Breit} < 1.5$

NLO pQCD (DISENT): $\mu_F = Q$; $\mu_R = E_T$; Q; $\sqrt{E_T^2 + Q^2}$; PDF: CTEQ6

High Q^2 jet multiplicity
Incl. jet normalized to DIS NC cross section (H1)

HERA I - 65.4 pb^{-1}

HERA II - 320 pb^{-1}

reduced jet phase space:

$-0.8 < \eta^{jet}_{lab} < 2$

NLO pQCD (FastNLO):

$\mu_F = Q; \quad \mu_R = E_T;$

experimental uncertainties *(~6%)*:

- jet energy scale (calibration) *~4%*

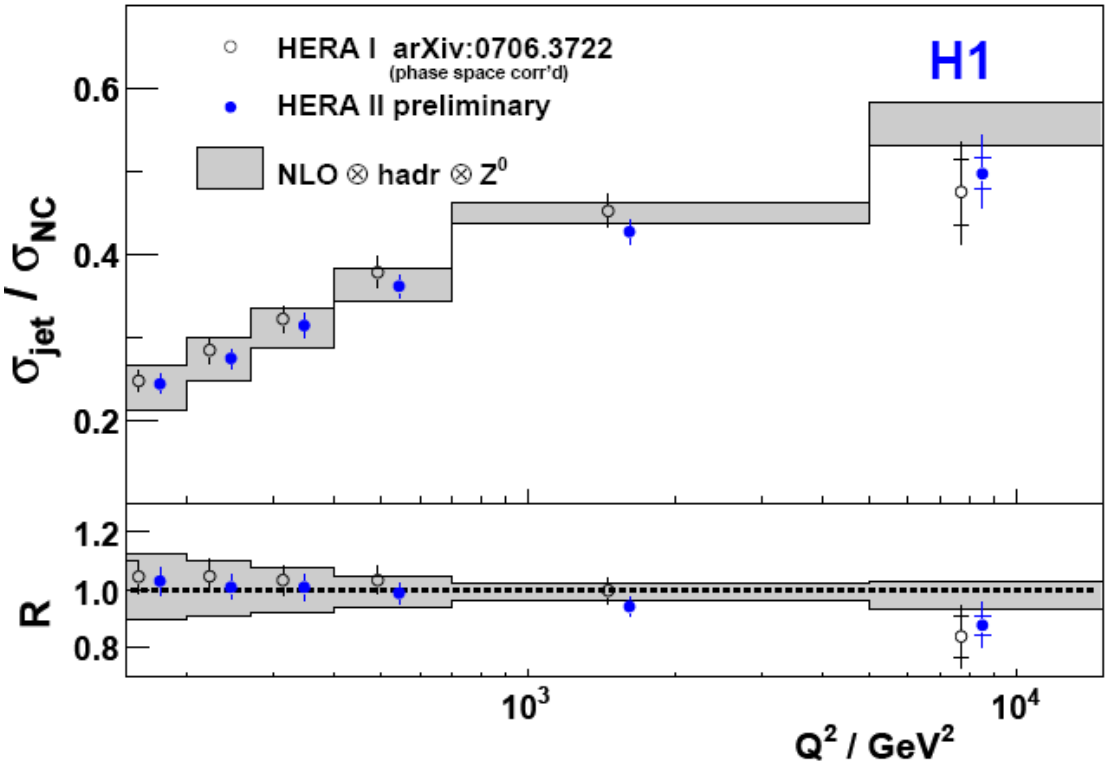
- data correction model dependence *~2-3%*

theory uncertainties *(~5-10%)*:

- renormalization scale dependence (missing higher orders)

- PDF dependence

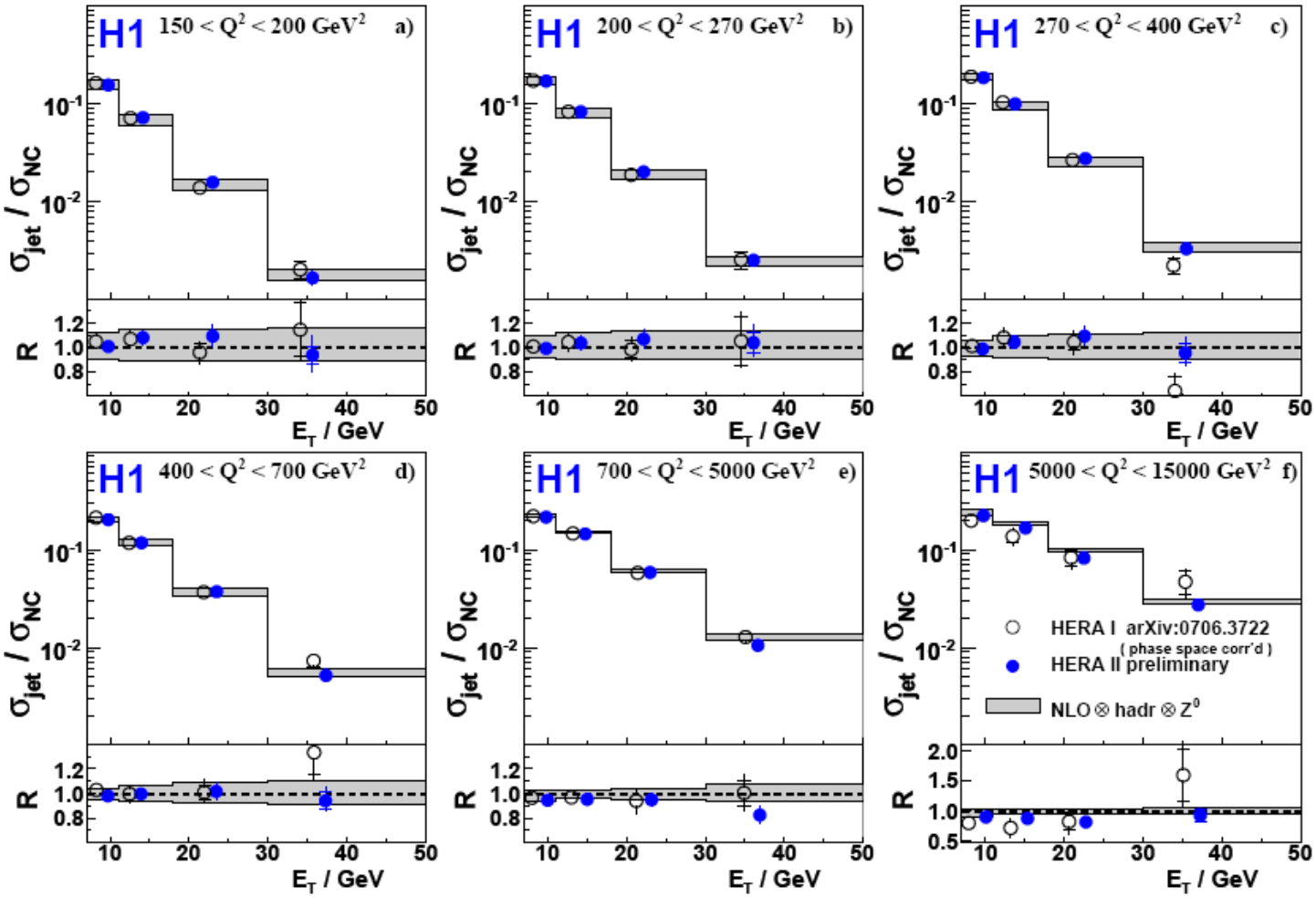
Partial cancellation of exp. syst. uncertainties:
~7% → 6% on multiplicities
=> ~ 40% reduction of experimental uncertainties on α_s



Good agreement with NLO QCD prediction

High Q2 jet multiplicity

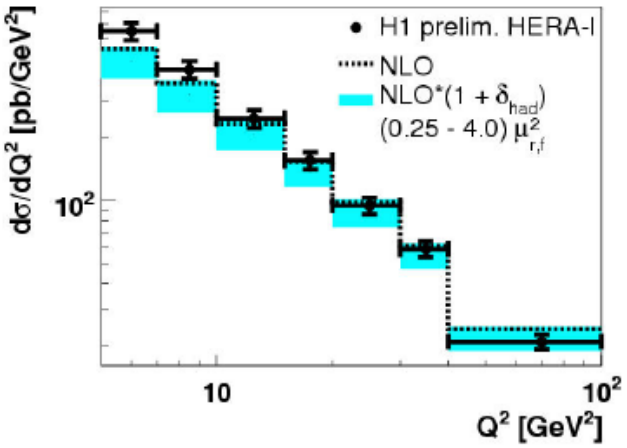
Incl. jet normalized to DIS NC cross section (H1)

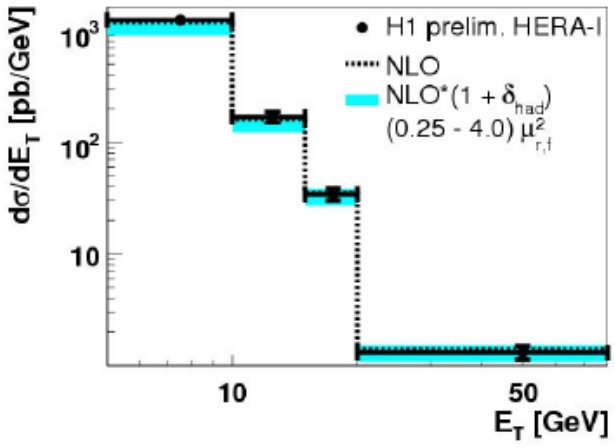


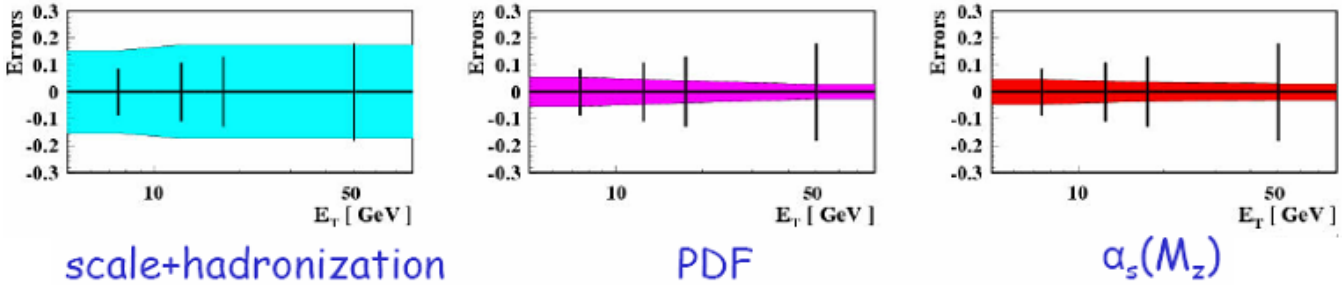
Significant errors improvement at high Q2 and E_T in HERA II compared to HERA I

Low Q2 jets are promising QCD testing field

Inclusive jet cross section in DIS (H1)







DIS phase space:

$5 < Q^2 < 100\ \mathrm{GeV}^2$

$0.2 < y < 0.7$

Jet phase space :

$E_T > 5$ GeV;

$-1 < \eta_{lab}^{jet} < 2.5$

NLO pQCD (NLOJET++) :

$\mu_R = E_T$

$\mu_F = Q$;

PDF : CTEQ6.1M

Experimental errors improvement compared to previous publications
Good agreement with NLO for $Q^2 > 10$GeV and $E_T > 10$ GeV (also in double differential)
Rather large NLO uncertainty (Interesting phase space region if NNLO calculations available)

CONCLUSION

1) High p_T Jet production at HERA provides direct handle to structure of resolved photon and gluon density in proton
2) Wealth of new results in photoproduction and DIS (Inclusive and 2-jets):
    1) Higher statistics (first time HERA II data)
    2) Improved jet calibrations
3) Data are reasonably well described by NLO, theory uncertainties often larger than experimental errors
4) In specific kinematic regions new data will improve considerably the PDFs
5) Inclusive jet in DIS HERA I data was used by ZEUS and H1 collaborations for a high precision α_S common fit (*ZEUS - Phys. Lett. B 649 (2007), 12; H1- arXiv:0706.3722; "Alpha_S results fro HERA" by Claudia Glasman)*

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