Jet Production at HERA and Determination of α_s with H1

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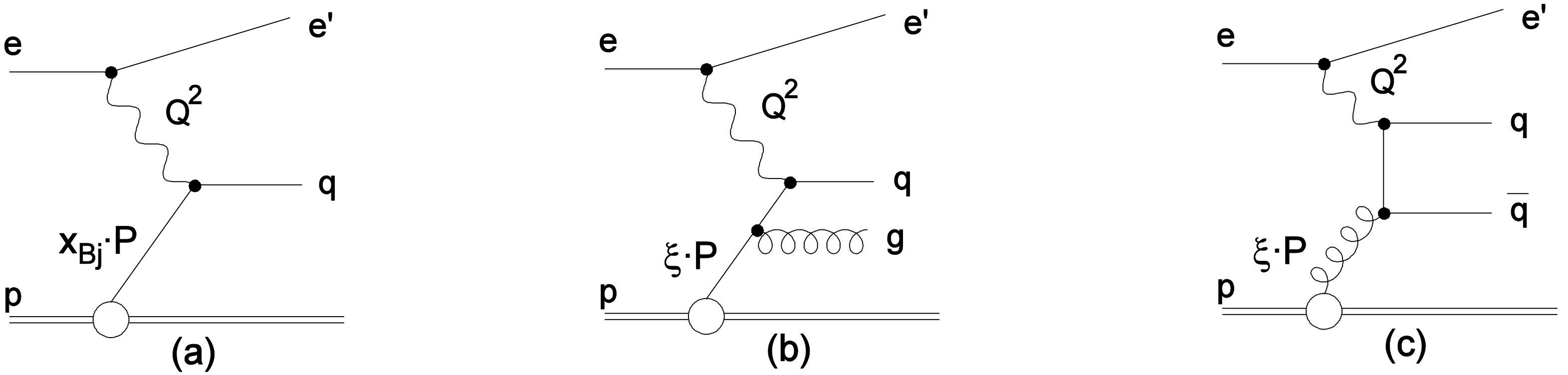
EPS, Grenoble 2011

Jet Production

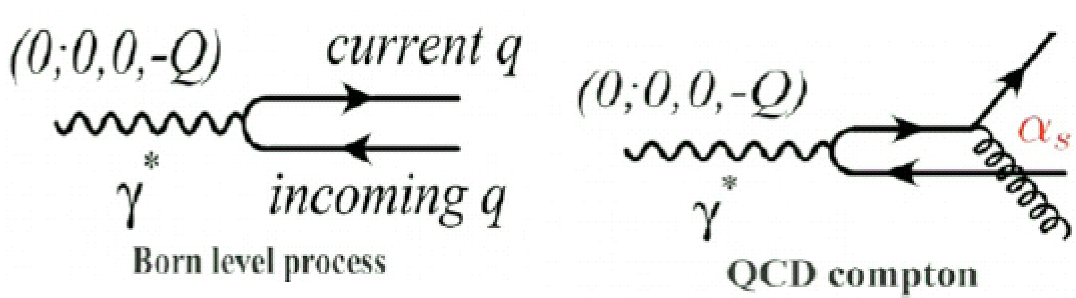


Born Level **QCD Compton** **Boson Gluon Fusion**

$\xi = x_{Bj}(1 + M^2_{12}/Q^2)$ - momentum fraction of struck parton (in LO)

Breit frame ($2xP + q = 0$) is ideal for studying QCD with large P_T.

In Breit frame processes with low P_T (Born level contribution, jet contribution from proton remnant, etc) are suppressed



Jet Measurement at H1

Neutral Current Phase Space	
Low Q^2 (HERA1 (99-00), L=43.6/ pb)	High Q^2 (full HERA2, L=351.6/ pb)
$5 < Q^2 < 100$ GeV^2	$150 < Q^2 < 15\,000$ GeV^2
$0.2 < y < 0.7$	
Jet Finder: longitudinally invariant infrared &collinear safe k_T algorithm with merging parameter $R_0 = 1$ and jet minimal transvers momentum in Breit frame $P_{TBreit} = 5$ GeV	
Jet Phase Space	
$5 < P_{TBreit} < 80$ GeV	$5 < P_{TBreit} < 50$ GeV
$-1.0 < \eta_{(lab)} < 2.5$	
For avoiding problem with singularities additional cut implied on 2- & 3-jet level: $M_{12} > 18$ GeV (Low Q^2)	$M_{12} > 16$ GeV (High Q^2)

Notation:

Q^2 – exchanged boson virtuality
y - inelasticity
$\eta_{(lab)}$ - jet pseudorapidity (laboratory frame)
M_{12} – invariant mass of two leading jets

NLO Calculations

- NLOJet++ with MSbar scheme for five massless quark flavors
- PDF: CTEQ6.5M (low Q^2) and HERAPDF1.5 (high Q^2) with $\alpha_S(M_z) = 0.118$
- NLO corrected for hadronization and Z_0 exchange effects
  - The hadronization correction factor differ from unity
    - less the 10% for inclusive and dijet cross sections
    - less then 20% for trijet and trijet to dijet cross sections ratio
- Scales: $\mu_f^2 = \mu_r^2 = (Q^2 + P_T^2)/2$
- Theoretical uncertainties $\Delta\mu_f$ and $\Delta\mu_r$ estimated by variation of μ_f and μ_r by a factor 2
- Total scale uncertainty = $\sqrt{(\Delta\mu_f^2 + \Delta\mu_r^2)}$

Cross Sections as function of Q^2 and ξ (Low Q^2)

First double differential cross section measurements
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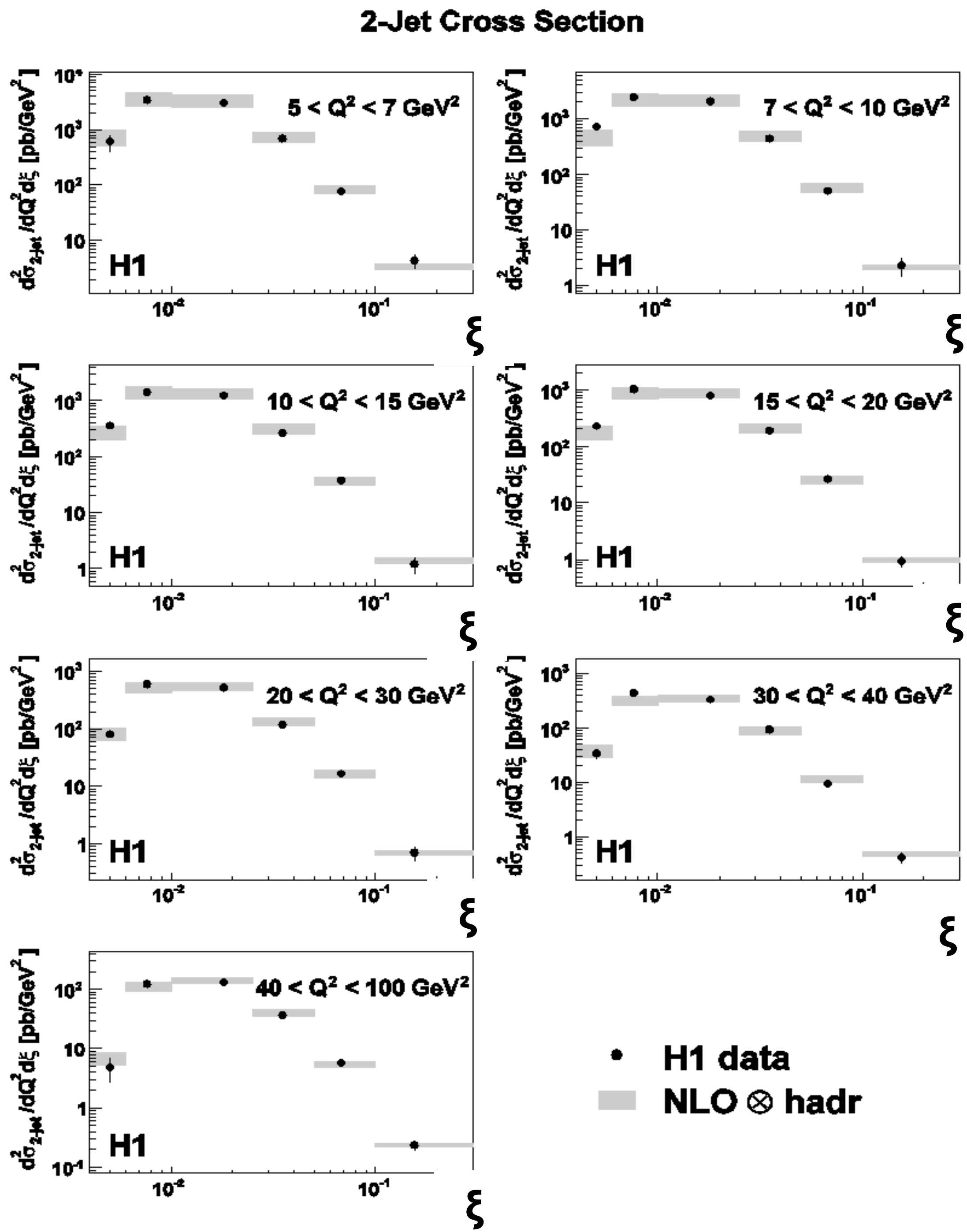
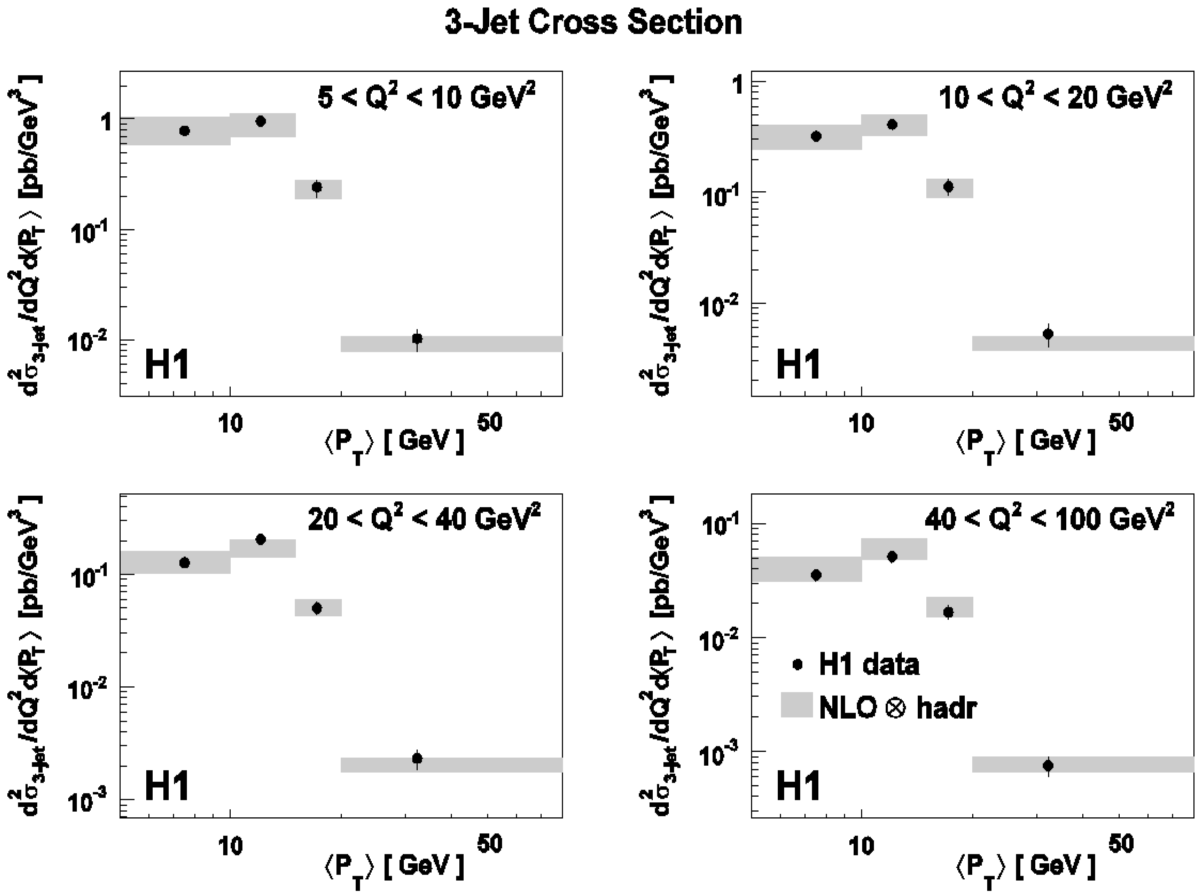
Experimental uncertainties (<~10%) dominate by HFS and model uncertainties and are essentially smaller then theoretical ones.

Theoretical uncertainties (up to 30%) dominated by renormalization scale.

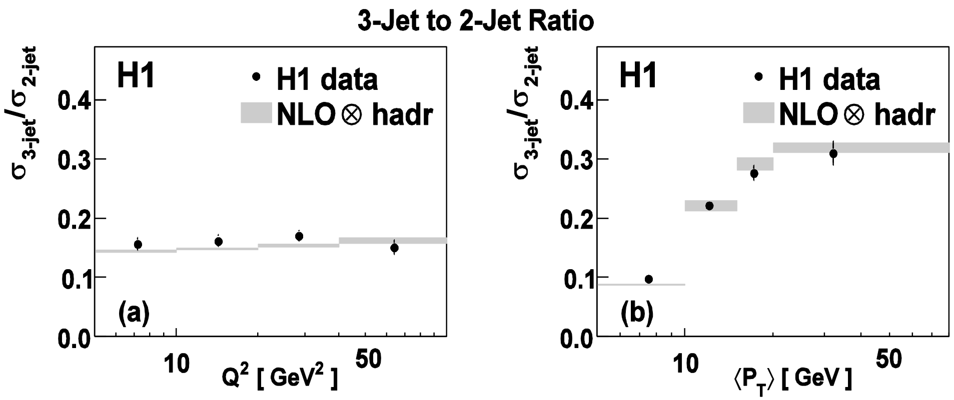


Trijet Double Differential Cross Sections (Low Q^2)



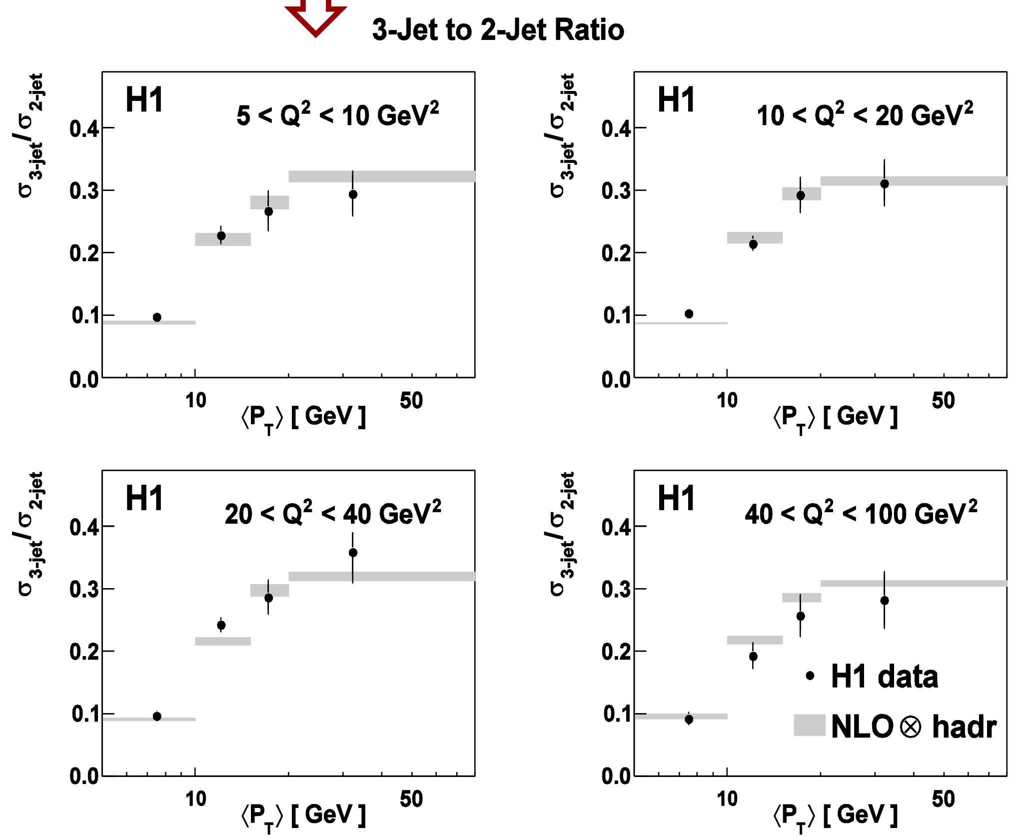
The 3-jet cross section in four Q^2 bins as a function of P_T. The NLO QCD calculation provides an overall good description of the measured distributions within the quoted theoretical and experimental uncertainties.

Trijet/Dijet Cross Sections Ratio (Low Q^2)



The 3-jet cross section normalised to the 2-jet cross section is presented for single differential (on the left)

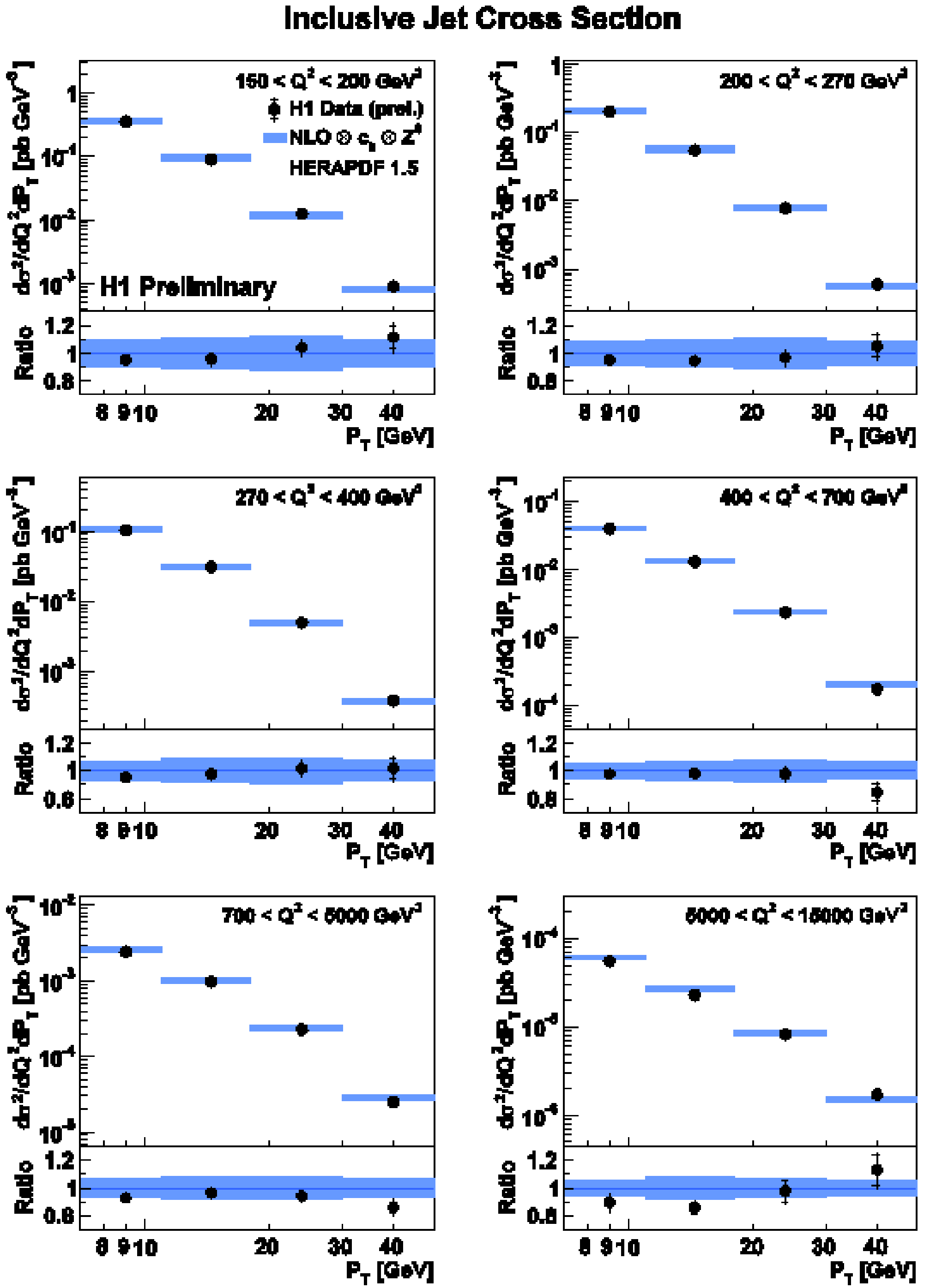
and for double differential distributions (below).



This observable benefits from cancellation of the normalisation uncertainties and reduction of the other systematic uncertainties by about 50%.

It is described by the NLO cross section except for the lowest P_T bin, and shows a reduced sensitivity to the renormalisation scale variation which is done simultaneously for 2-jet and 3-jet cross sections.

Double differential Inclusive Jet Cross Sections (High Q^2)



Jet energy scale uncertainty ~ 1%

Experimental uncertainty of 4-8% about half of the theoretical one.

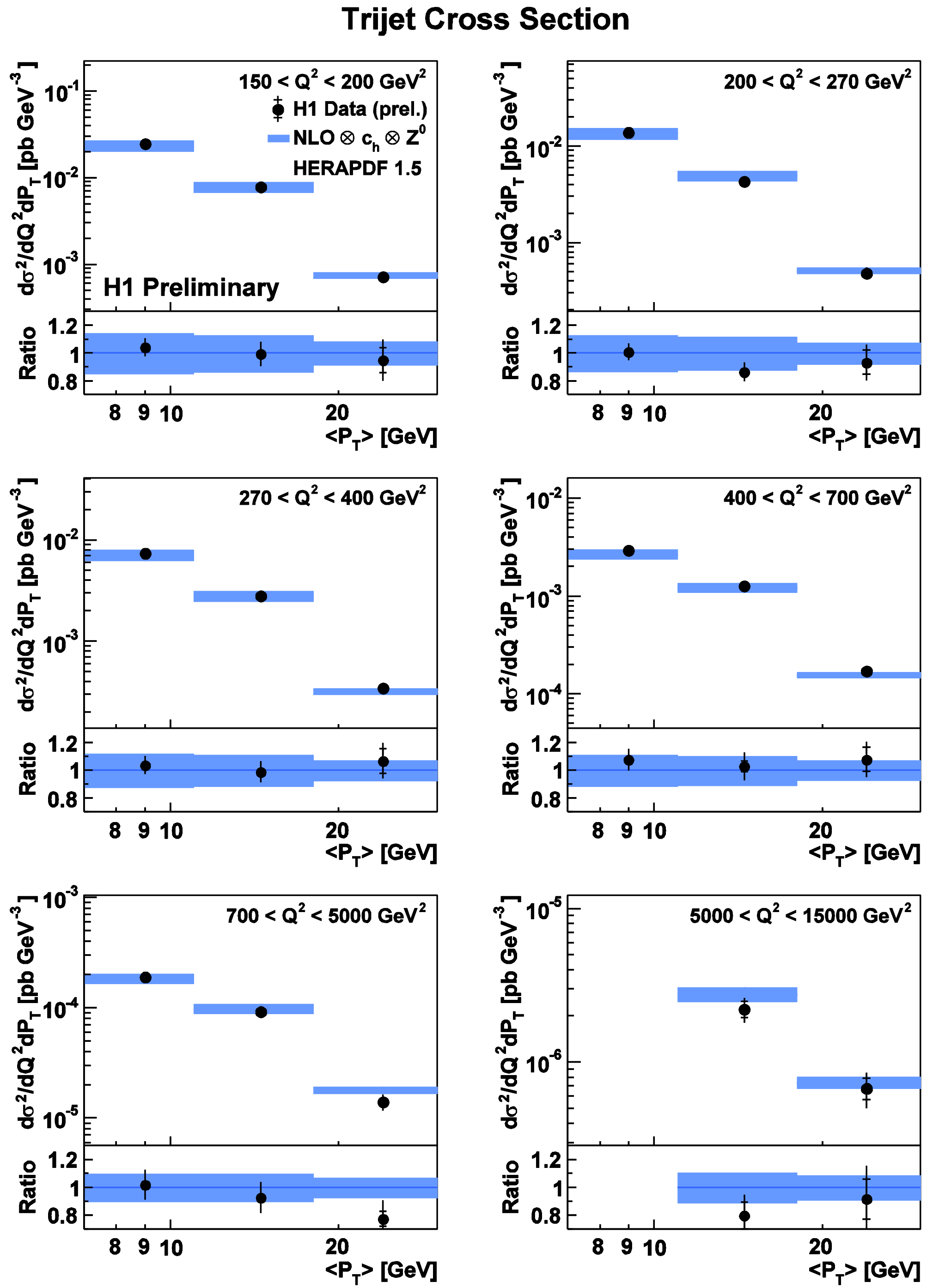
Data are well described by NLO.

Double differential Trijet Cross Section (High Q^2)

First double differential trijet cross section measurements at high Q^2.

Experimental uncertainties dominated by model and HFS uncertainties.

Data are well described by NLO.



$\alpha_S(M_Z)$ Measurements

Extracted **$\alpha_S(M_Z)$** with correlated and uncorrelated errors taken into account

Inclusive+ Dijet + Trijet without points with k = σ_{NLO}/σ_{LO} > 2.5):

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$$\alpha_s(M_Z) = 0.1160 \pm 0.0014(\text{exp.}) \pm 0.0016(\text{pdf})\,^{+0.0093}_{-0.0077}(\text{th.})$$

H1 preliminary 11-032

Inclusive jet:

$$\alpha_s(M_Z) = 0.1190 \pm 0.0021\ (\text{exp.}) \pm 0.0020\ (\text{pdf})\ ^{+0.0050}_{-0.0056}\ (\text{th.})$$

Dijet:

$$\alpha_s(M_Z) = 0.1146 \pm 0.0022\ (\text{exp.}) \pm 0.0021\ (\text{pdf})\ ^{+0.0044}_{-0.0045}\ (\text{th.})$$

Trijet:

$$\alpha_s(M_Z) = 0.1196 \pm 0.0016\ (\text{exp.}) \pm 0.0010\ (\text{pdf})\ ^{+0.0055}_{-0.0039}\ (\text{th.})$$

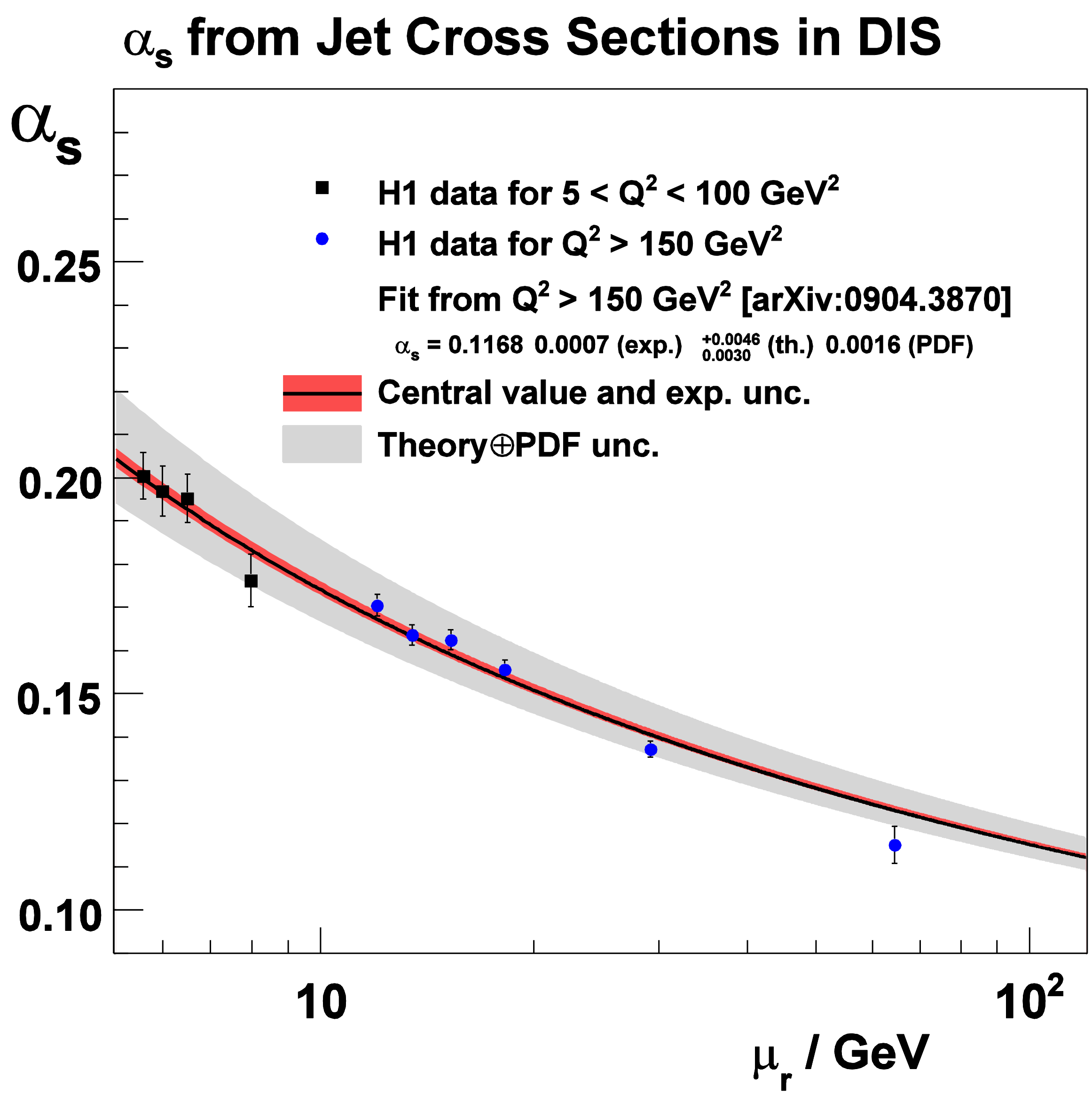
Main uncertainties come from theory uncertainties (~4-8%)
-> theory improvement is desirable

Running of $\alpha_s(\mu_r)$

Theoretical and experimental uncertainties for high Q^2 $\boldsymbol{\alpha_s}$ **(Eur.Phys.J.C65(2010)363)** extrapolated down to low Q^2.

Remarkable agreement between extraction of $\boldsymbol{\alpha_s(\mu_r)}$ at low and high Q^2.

Nice running of strong coupling between 6 – 70 GeV in single experiment.



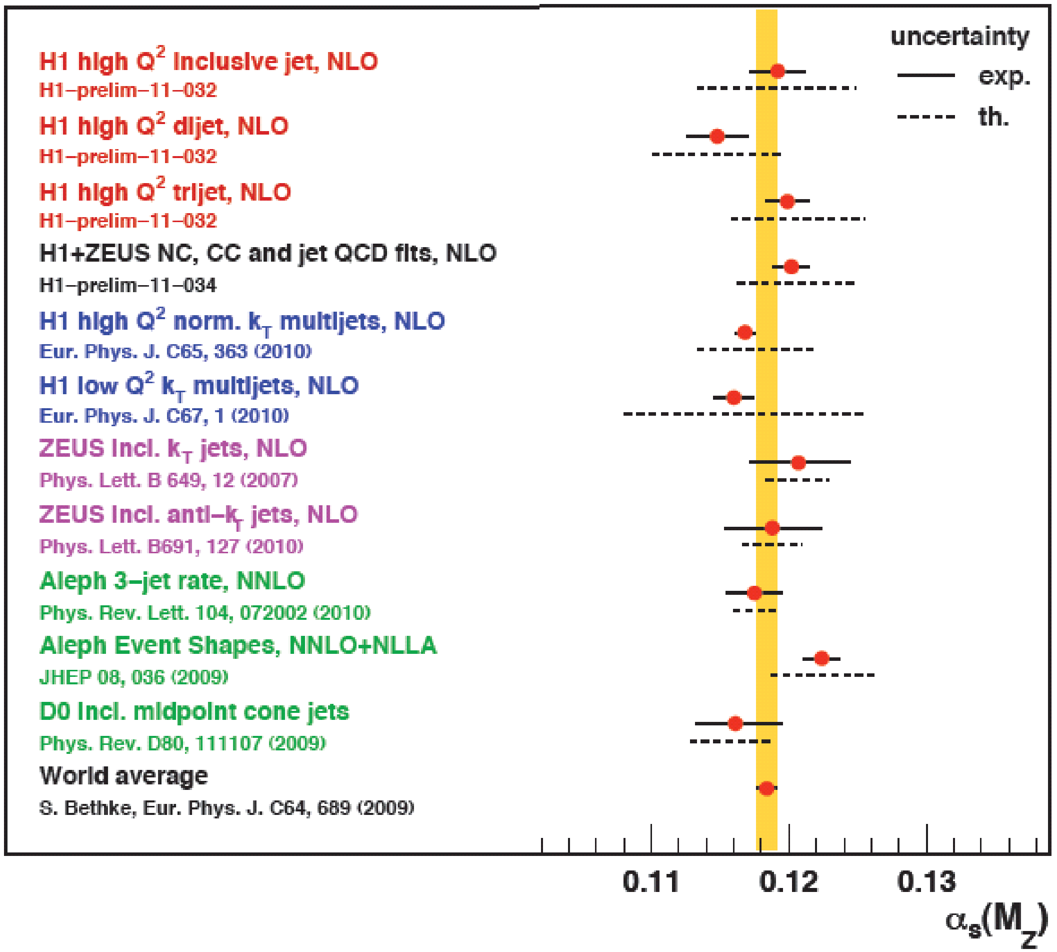
Summary

High precision measurement of inclusive, dijet, trijet cross sections at low and high Q^2 as well as 3J to 2J cross sections ratio for low Q^2 presented.

All measurements are in good agreement with NLO.

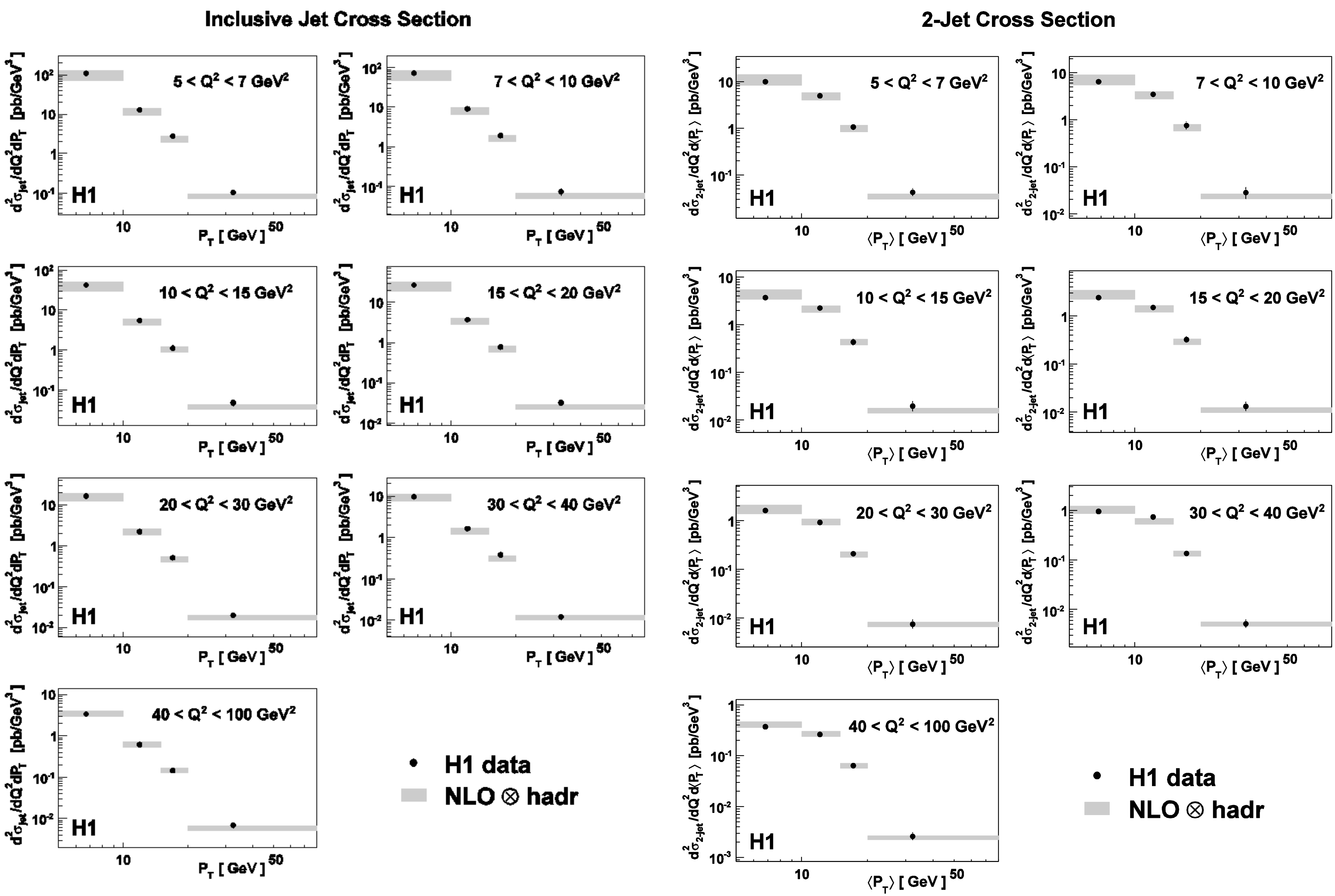
To reduce large theoretical uncertainties calculation of terms beyond NLO necessary.

$\alpha_s(M_Z)$ from jet measurements at HERA are in good agreement between each other and with world average.

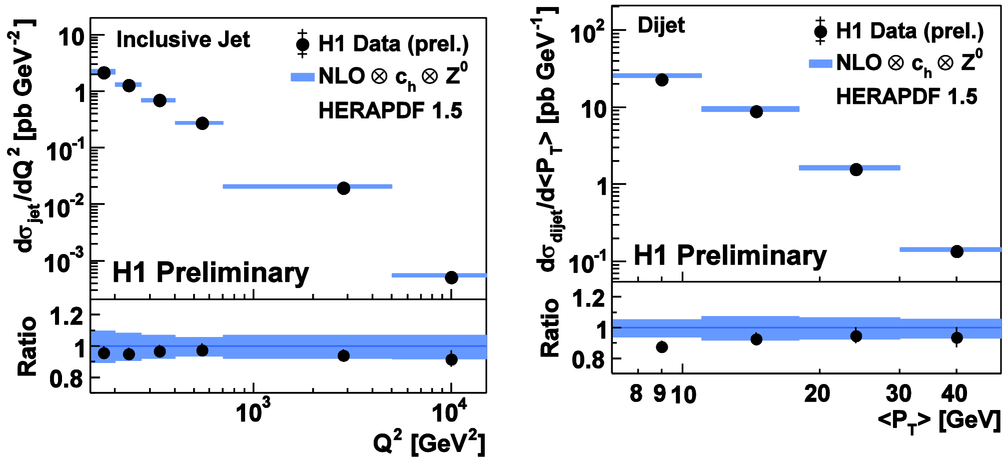


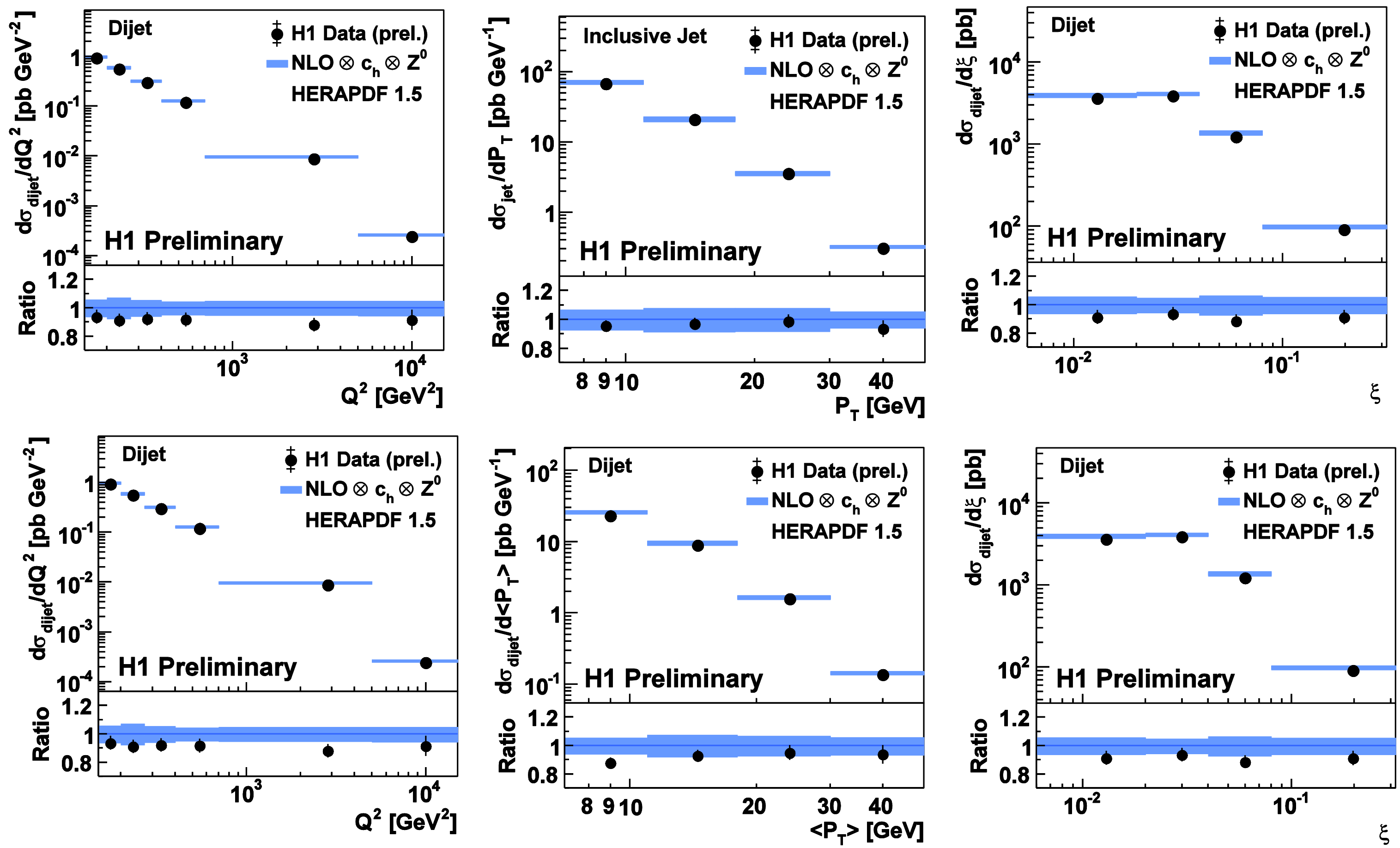
BACKUP

Double differential Dijet Cross Sections Low Q^2

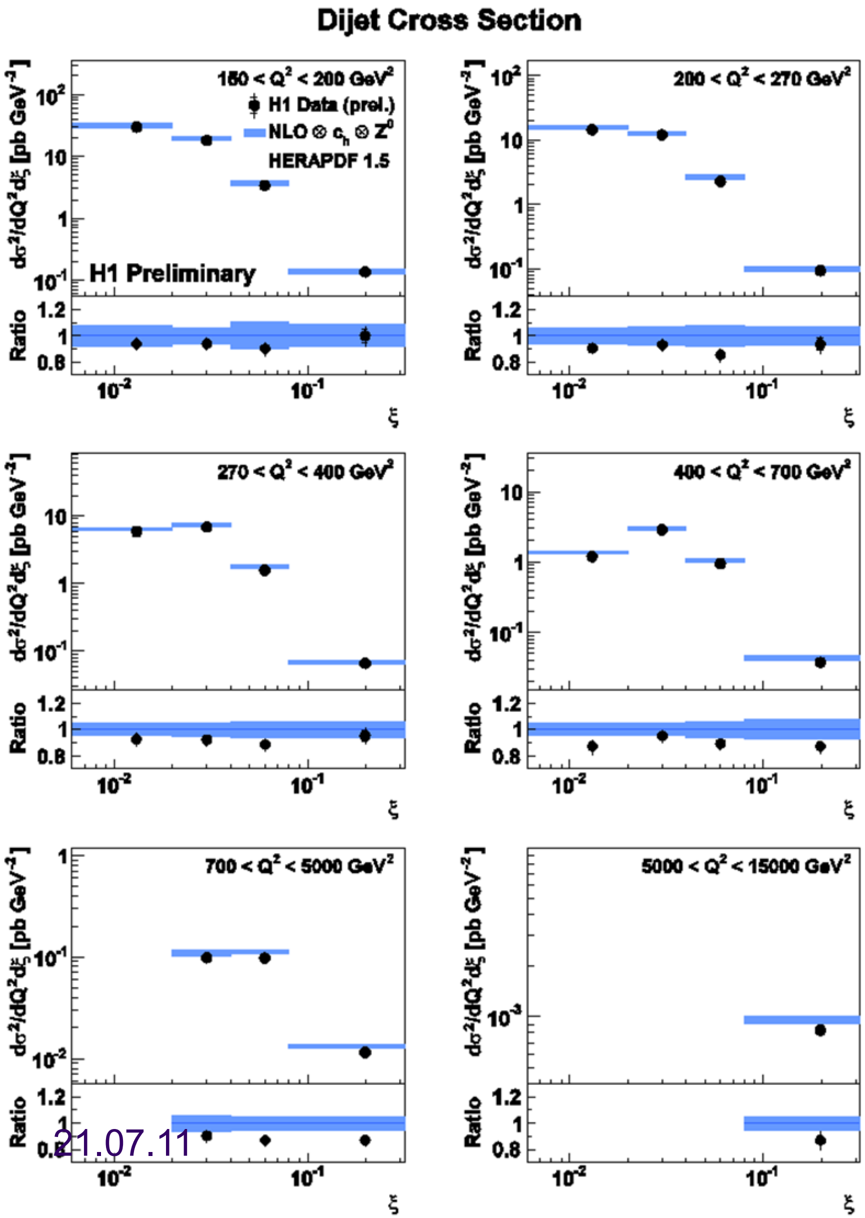


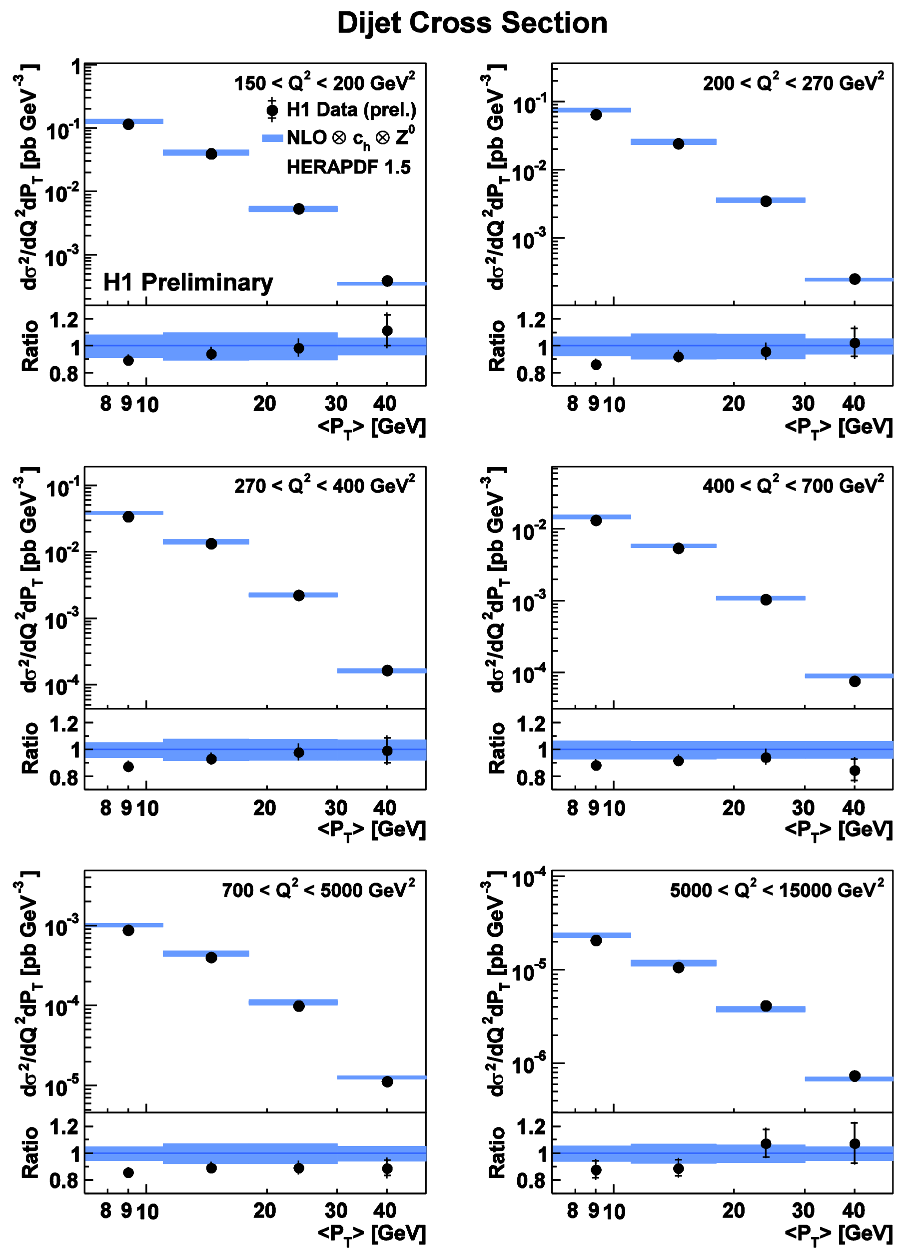
Single differential Jet Cross Sections (High Q2)



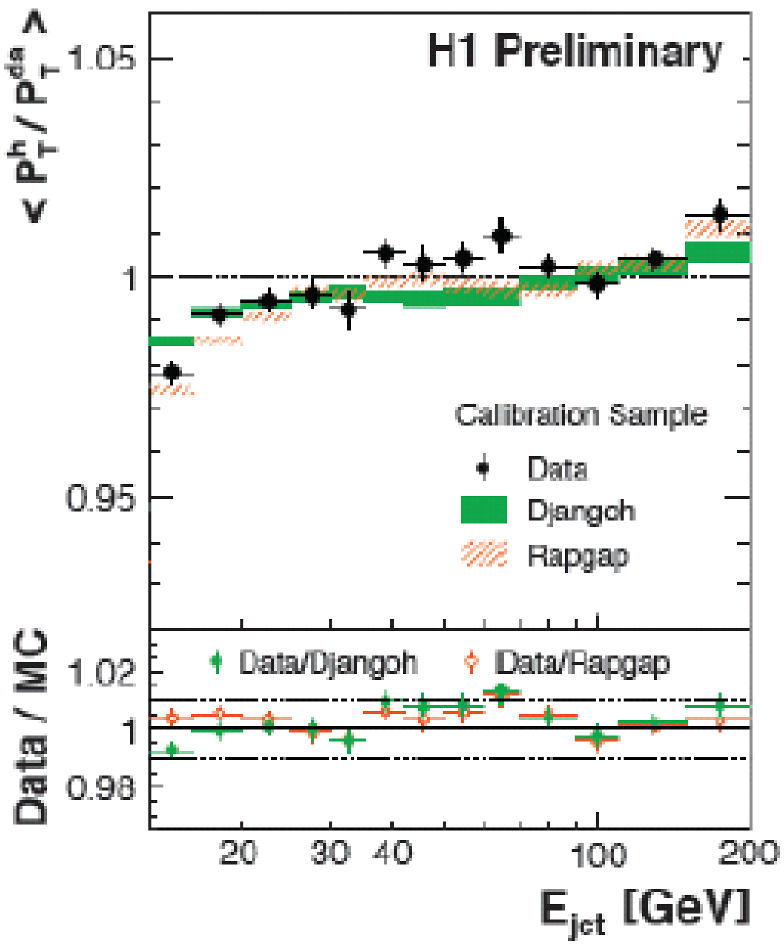


Double differential Dijet Cross Section (High Q2)

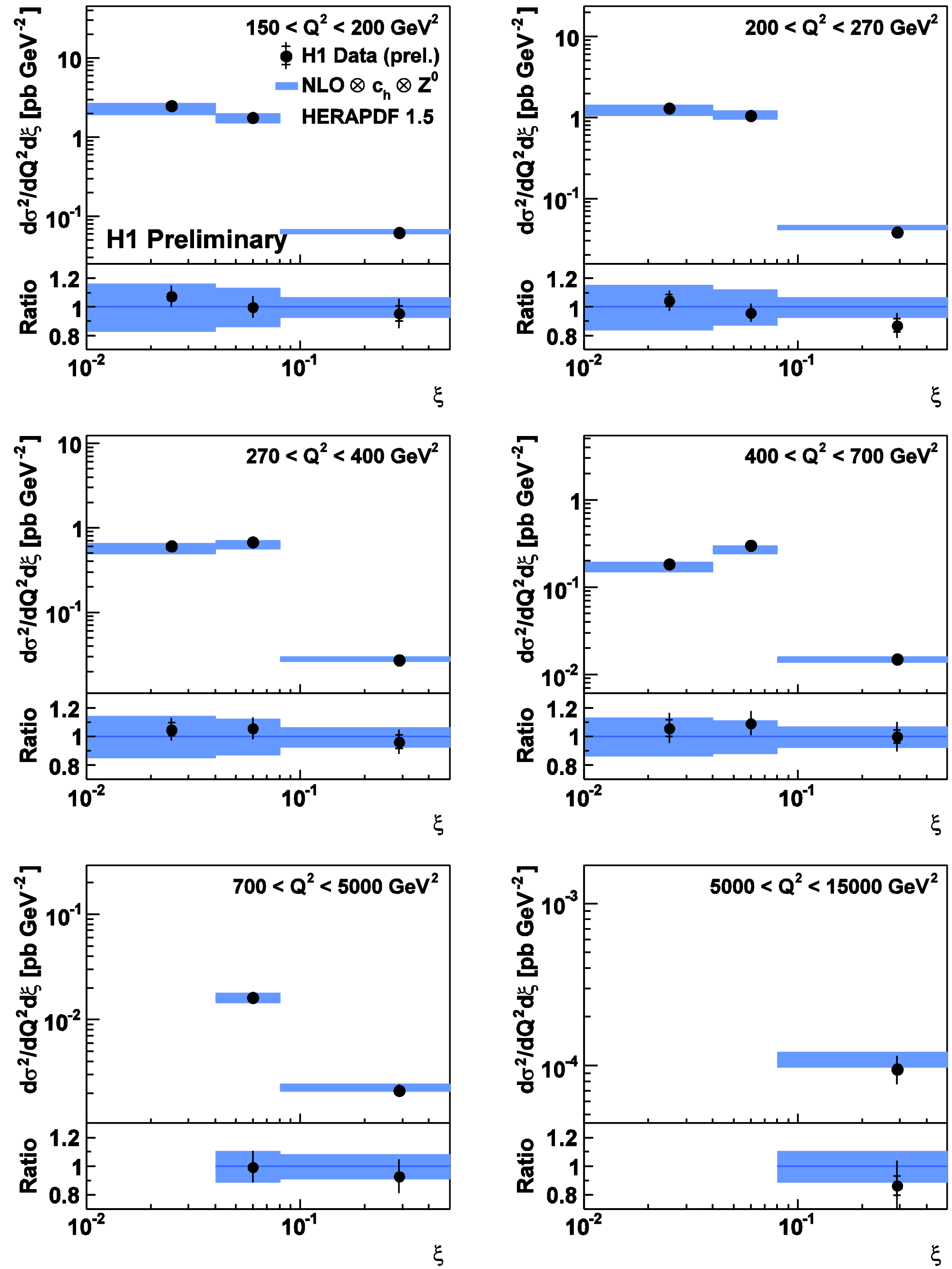




Double Differential Trijet Cross Sections



Trijet Cross Section



$\alpha_S(M_Z)$ Fit

Minimise $\chi^2(\alpha_s(M_Z))$ defined as:

$$\chi^2 = \vec{V}^T \cdot M^{-1} \cdot \vec{V} + \sum_k \varepsilon_k^2$$

correlated version of $\sum$(difference/error)²

penalty term for fitted systematics
"Hessian" method

$$M = M^{\mathrm{stat.}} + M^{\mathrm{uncor.}}$$

correlated for some bins

uncorrelated systematics

$$V_i = \sigma_i^{\mathrm{exp.}} - \sigma_i^{\mathrm{theo.}}\left(1 - \sum_k \Delta_{ik}\varepsilon_k\right)$$

bin #

correlated systematical error #k

parameter in fit, pull
"Hessian" method

Exp. uncertainty of fit defined as α_s interval upto minimum χ^2+1