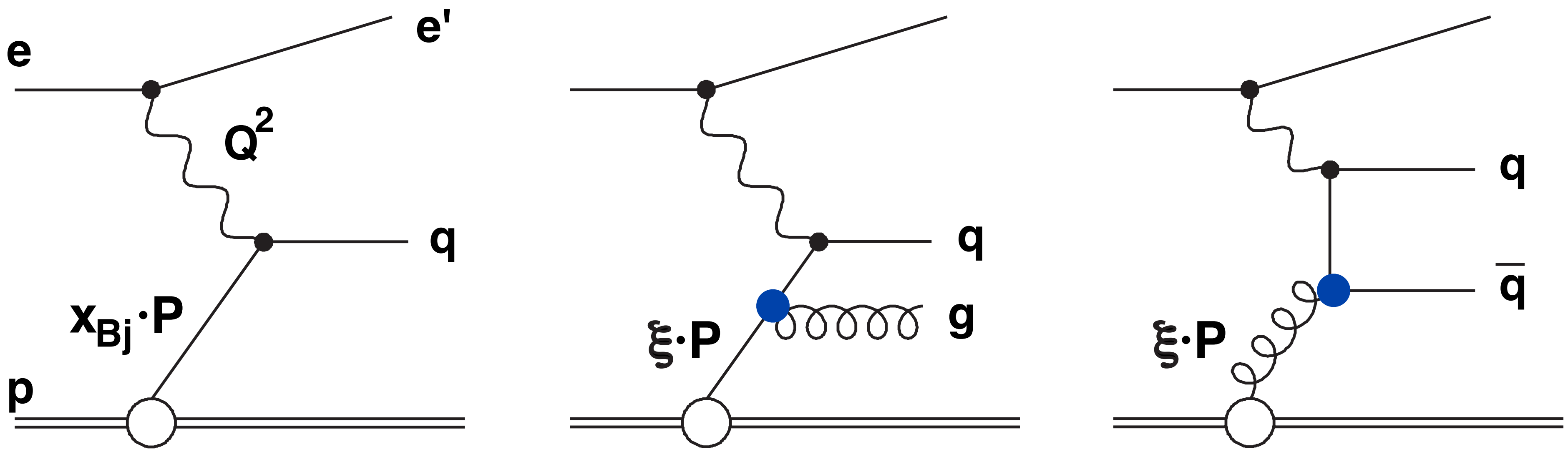
Multijet Production In Neutral Current DIS And The Determination Of α_s

Roman Kogler
on behalf of the H1 collaboration

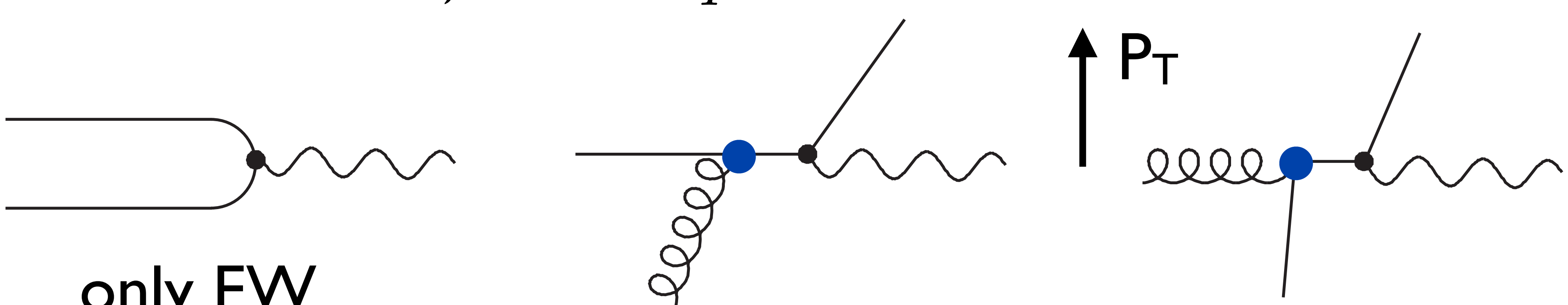
DIS2011 Newport News, April 12, 2011

Jet Production in Leading Order



Momentum fraction of struck parton (in LO): $\xi = x\left(1 + \frac{M_{12}^2}{Q^2}\right)$

Boost to Breit frame, $2xP + q = 0$



only EW coupling

$\propto \alpha_s$

$\propto \alpha_s$

Only hard QCD processes generate considerable P_T in the Breit frame
n-jet production in LO $\propto \alpha_s^{n-1}$

Multijet Measurement

Neutral current phase space:

$150 < Q^2 < 15\,000$ GeV^2
$0.2 < y < 0.7$

Common Jet Phase Space:

$-1.0 < \eta_{lab} < 2.5$

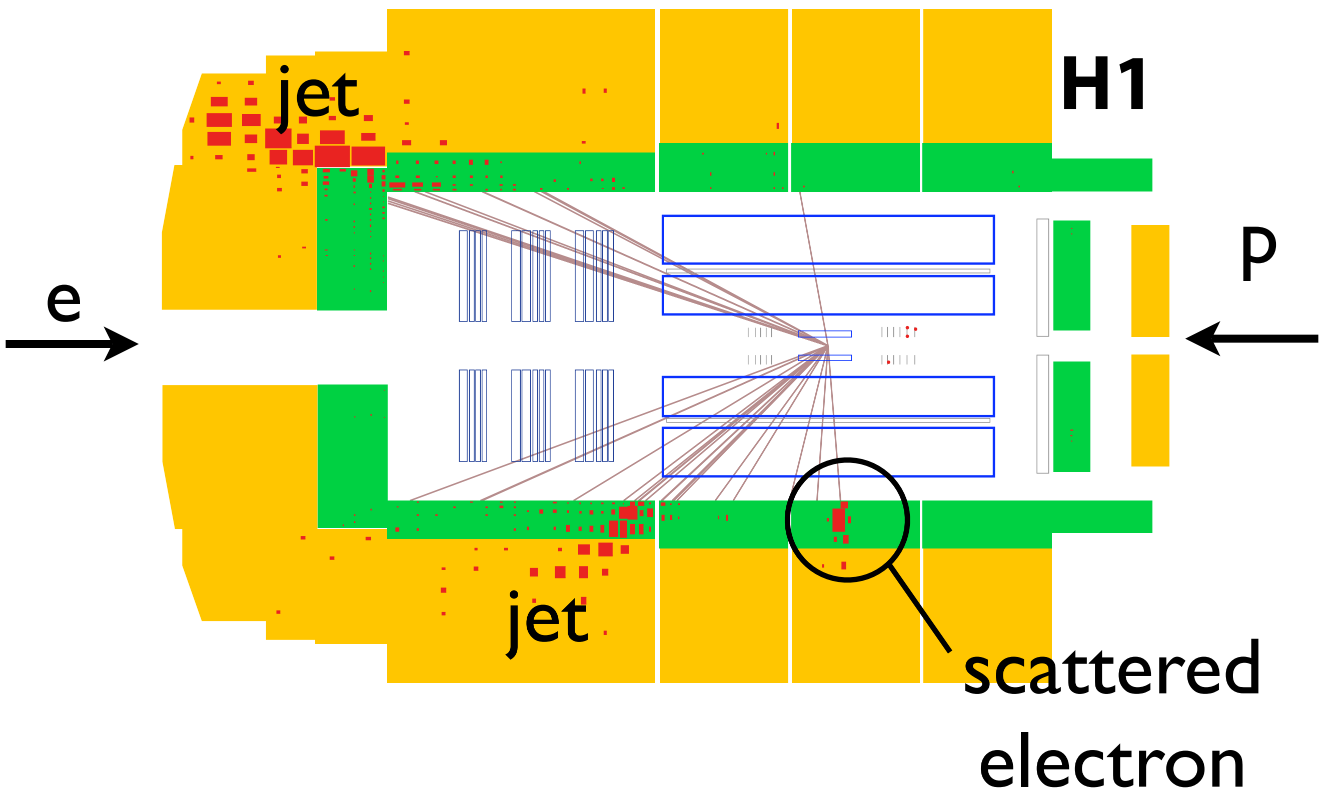
Inclusive Jets:

$7 < P_T < 50$ GeV

Dijets and Trijets:

$5 < P_T < 50$ GeV
$M_{12} > 16$ GeV

inclusive k_T algorithm with $R_0 = 1$



Q^2 ... virtuality of exchanged boson
y ... inelasticity
η_{lab} ... jet pseudorapidity in lab frame
P_T ... jet transverse momentum in Breit frame
M_{12} ... invariant mass of two leading jets

Jet and Event Reconstruction

Final reconstruction and analysis software

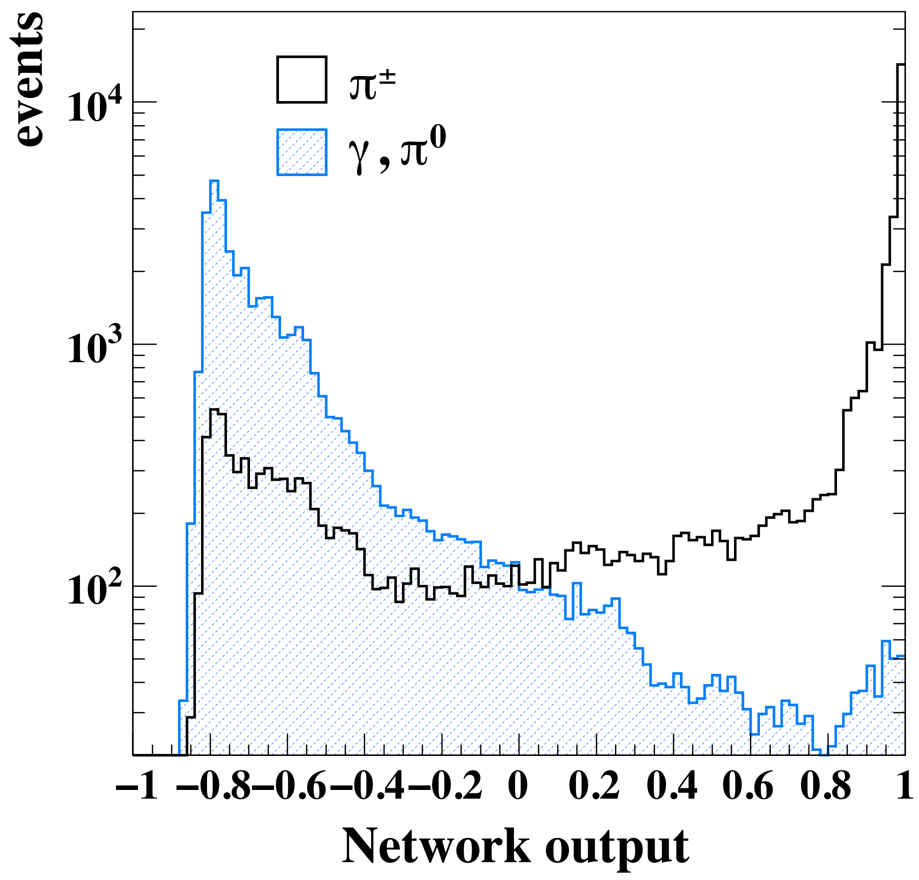
Improvements in many aspects:

- Track and vertex finding
- Scattered electron: energy and polar angle measurement
- Reconstruction of the hadronic final state

The Hadronic Final State (HFS):

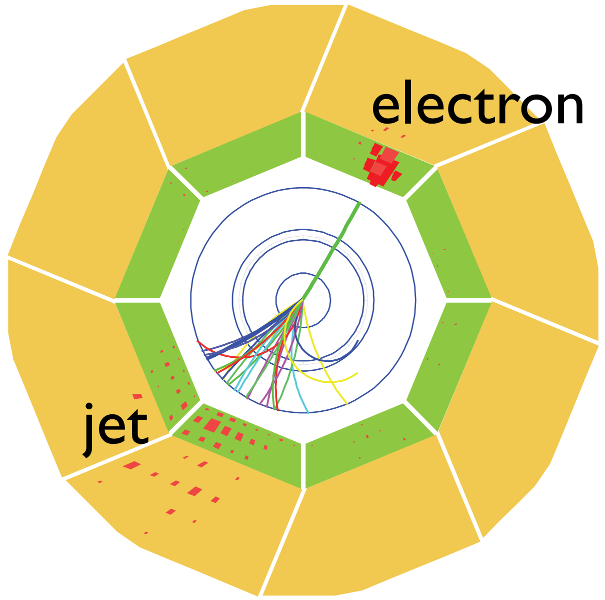
Neural networks employed to separate electromagnetic from hadronic showers in the LAr calorimeter

Electromagnetic probability derived from neural network output

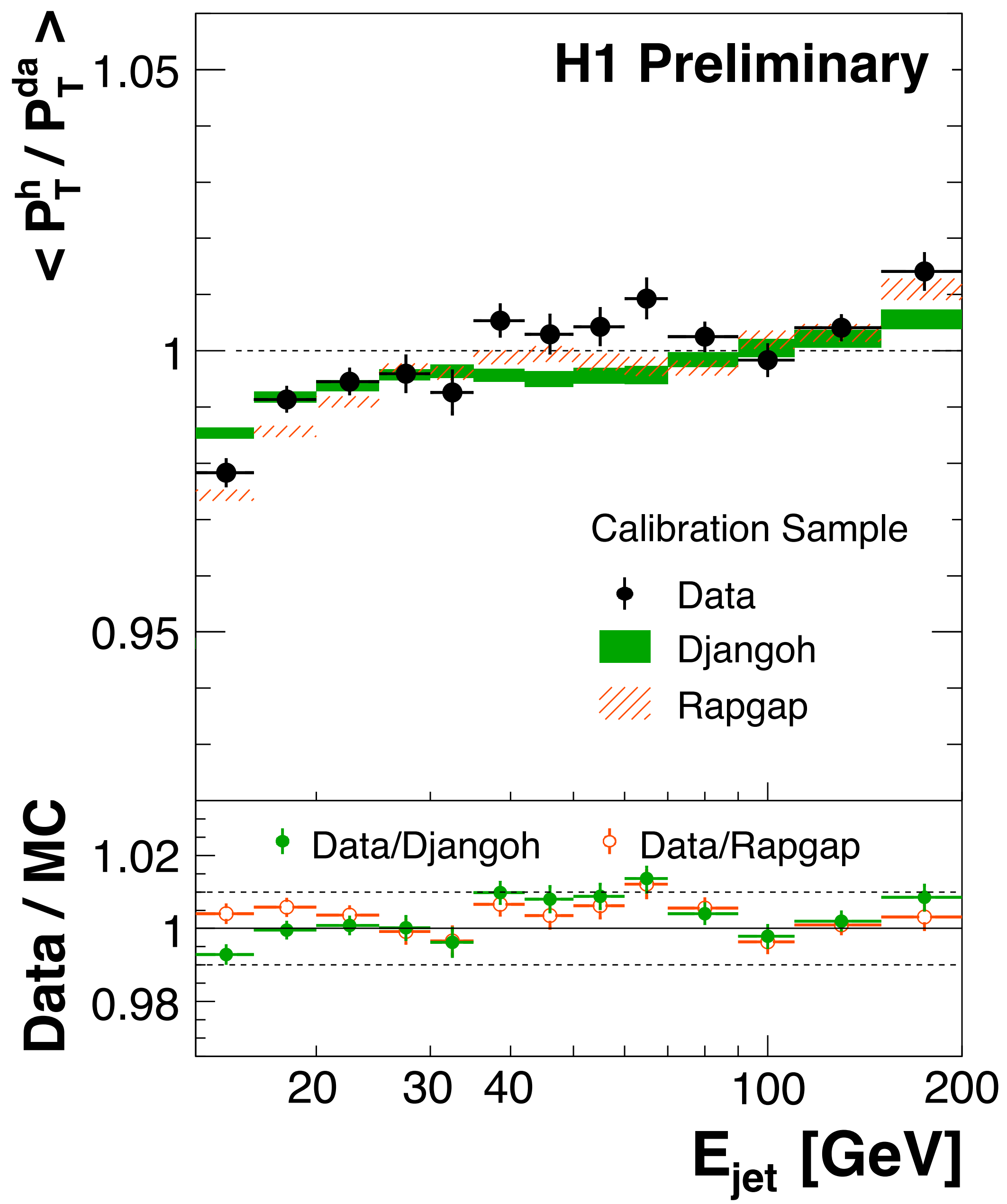


Energy flow algorithm:
combines information from tracks and calorimeter clusters

Jet Energy Scale Uncertainty



Overconstrained kinematics allow calibration of jets in dedicated sample



Calibration takes the probability of clusters to originate from electromagnetic showers into account

Improved resolutions

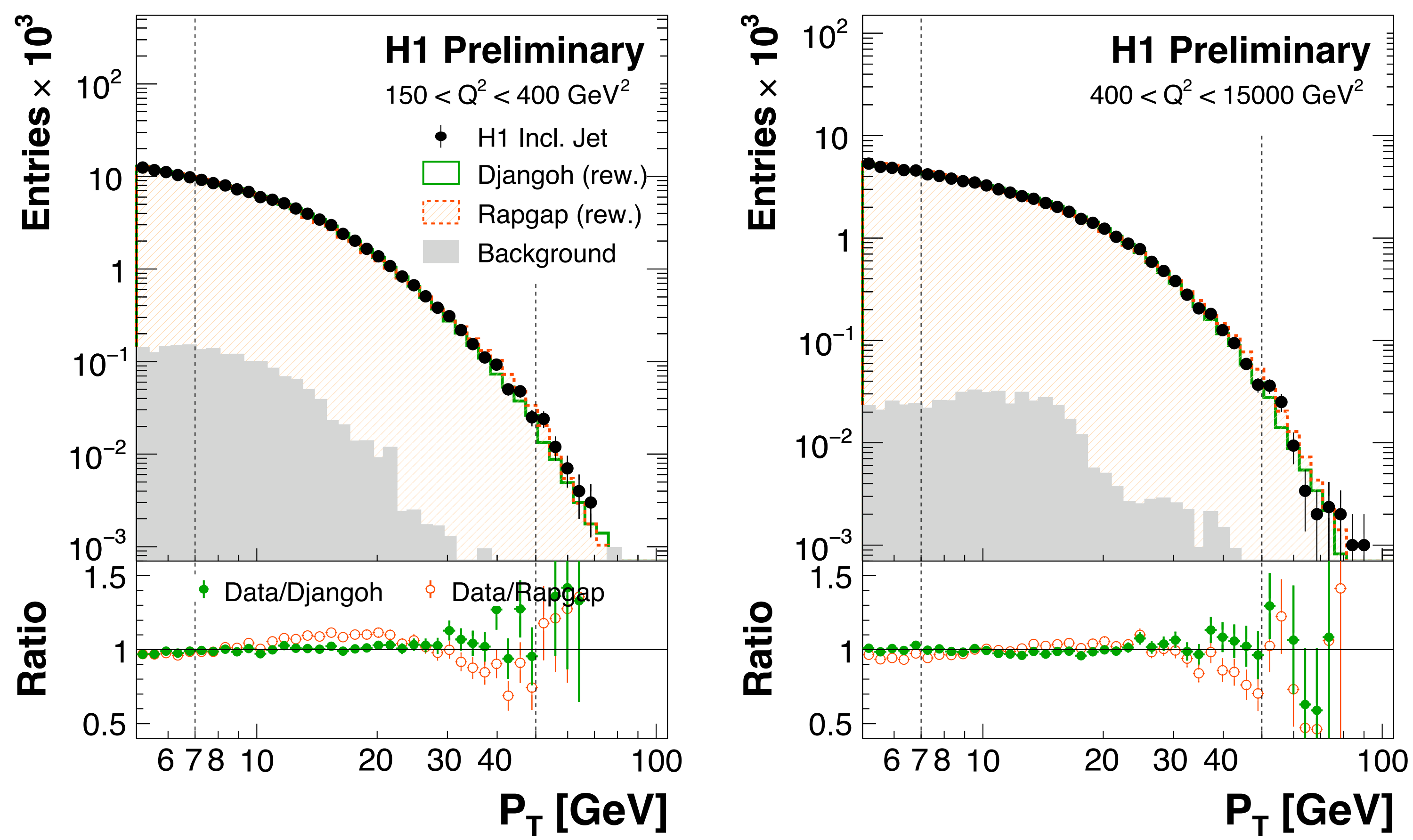
Jet Energy Scale uncertainty of 1% over a large range in pseudorapidity

Jet Measurement

Full Hera-2 dataset with $L \approx 350\ pb^{-1}$

Background between 1.1 and 0.4%

MCs were reweighted to improve the description of the data → reliable detector correction



Main experimental uncertainties:

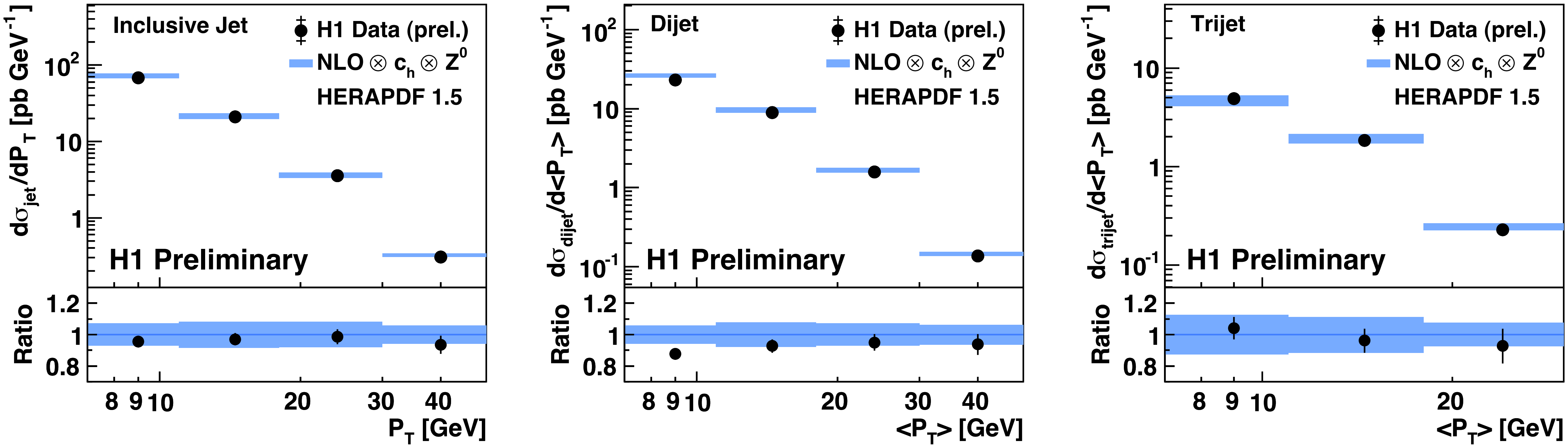
acceptance correction → $\Delta\sigma/\sigma$ = 1.5-8%

jet energy scale 1% → $\Delta\sigma/\sigma$ = 2-5%

luminosity measurement → $\Delta\sigma/\sigma$ = 2.5%

Measurement of single and double-differential cross sections as function of Q^2, P_T and ξ

Multijet Cross Sections



Data: corrected for detector effects and QED radiation

NLO calculations: NLOJet++ using HERAPDF1.5

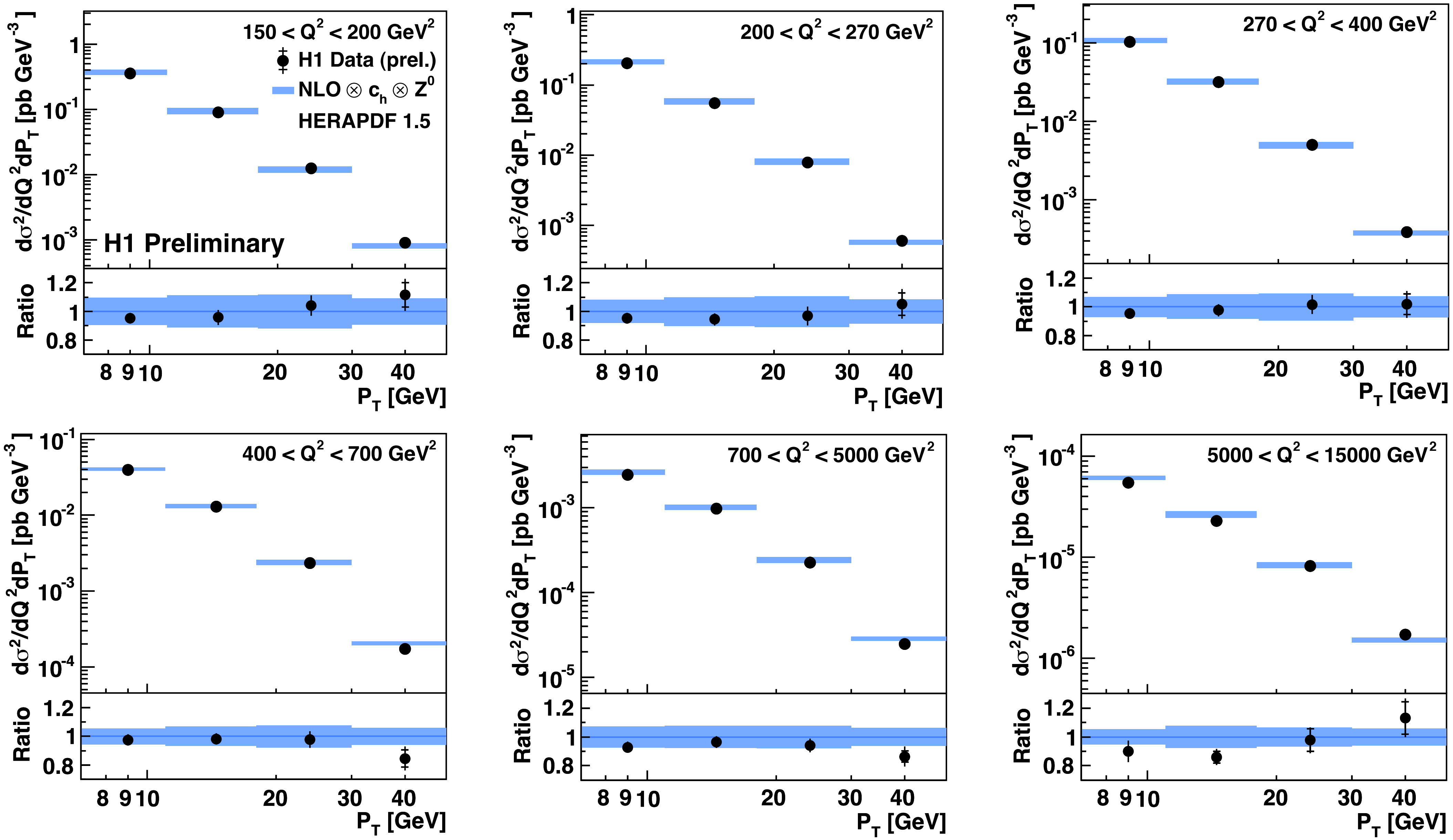
$$\alpha_s(M_Z)=0.118, \quad \mu_r = \mu_f = \sqrt{\left(Q^2 + P_T^2\right)/2}$$

NLO corrected for hadronisation and effects from Z^0 exchange

Hadronisation correction 0.94-0.98 (0.8-0.9 for trijet)

Theoretical uncertainty estimated by variation of μ_r and μ_f by a factor of 2

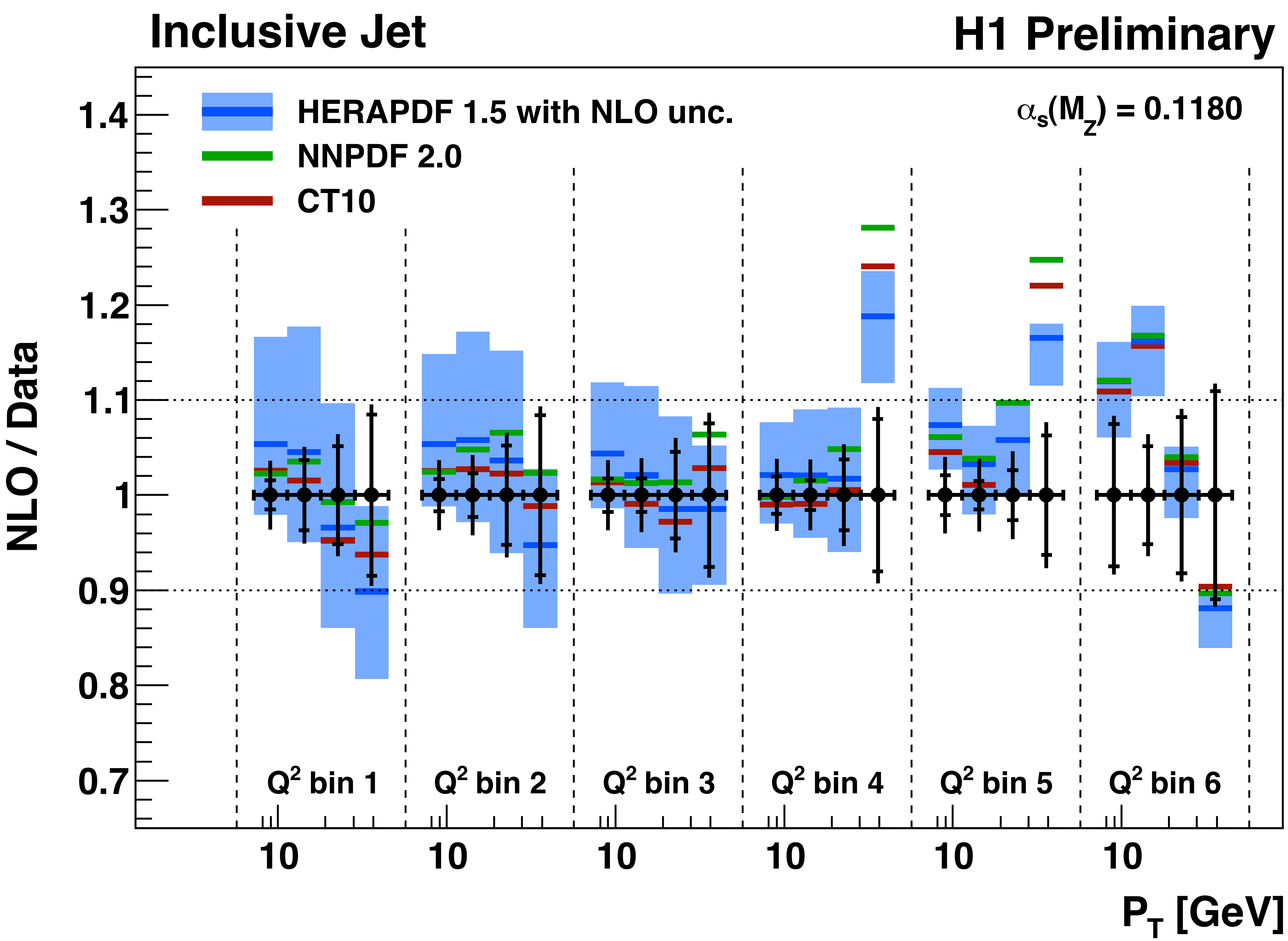
Inclusive Jet Cross Sections



Data are well described by NLO calculations over large range in Q^2 and P_T

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

Comparison With Different PDFs

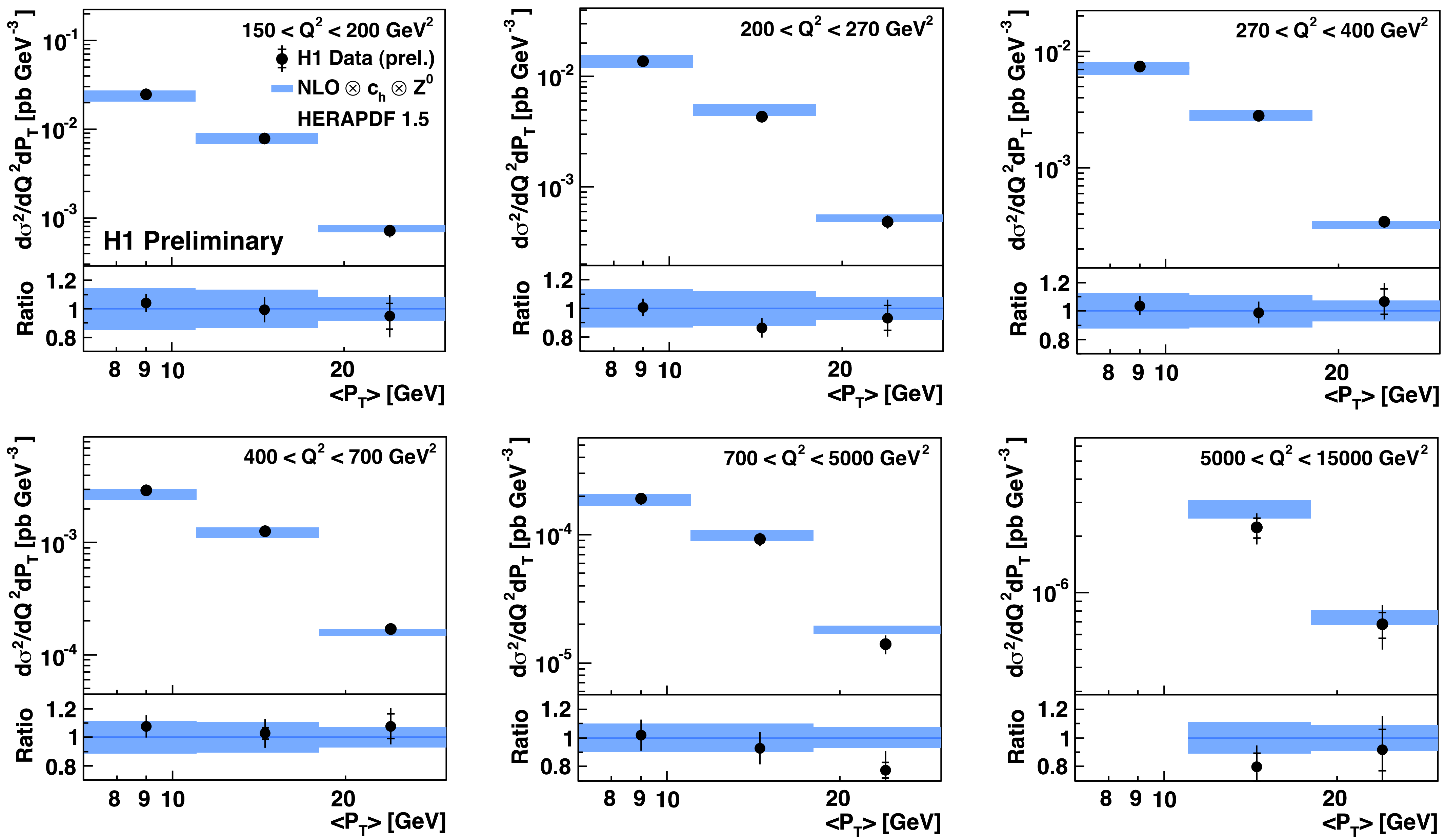


Central predictions for different PDFs shown

Different x regions of gluon and valence distributions probed in different regions of Q^2 and P_T

Differences small in most regions of phase space, visible differences at high P_T

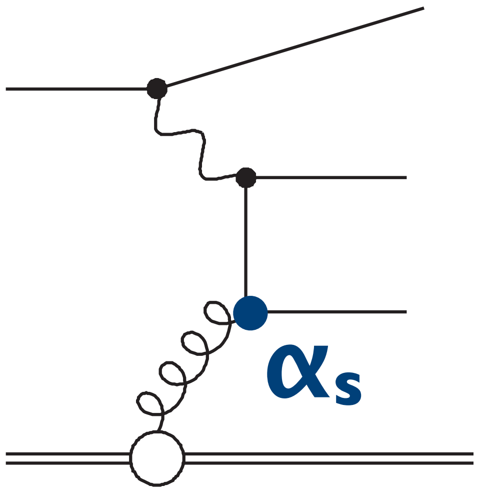
Trijet Cross Sections



First double-differential trijet cross section measurement at high Q^2

Experimental uncertainty of 6% (low $\langle P_T \rangle$) and 15% (high $\langle P_T \rangle$)

Determination of $\alpha_s(M_Z)$



NLO calculation depends on PDF and $\alpha_s(M_Z)$

⇒ Keep PDF (CT10) fixed and fit $\alpha_s(M_Z)$

⇒ Assign an error due to PDF uncertainty

Hessian method: Minimise $\chi^2(\alpha_s)$

$$\chi^2 = \sum_{i=1}^{N} \frac{[d_i - t_i(1 - \sum_k \epsilon_k \Delta_{ik})]^2}{\sigma_{i,\mathrm{stat}}^2 + \sigma_{i,\mathrm{uncorr}}^2} + \sum_k \epsilon_k^2$$

d_i ... measured cross section in bin i

t_i ... theoretical prediction for bin i obtained with FastNLO (based on NLOJet++)

$\sigma_{i,\mathrm{stat}}$ ... statistical uncertainty in bin i

$\sigma_{i,\mathrm{uncorr}}$ ... uncorrelated systematic uncertainty in bin i

Δ_{ik} ... effect of correlated systematic uncertainty k in bin i

ε_k ... free variables of the fit, one for each correlated uncertainty

Statistical correlations taken into account in case of inclusive jet cross sections

$\alpha_s(M_Z)$ From Multijet Cross Sections

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:

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

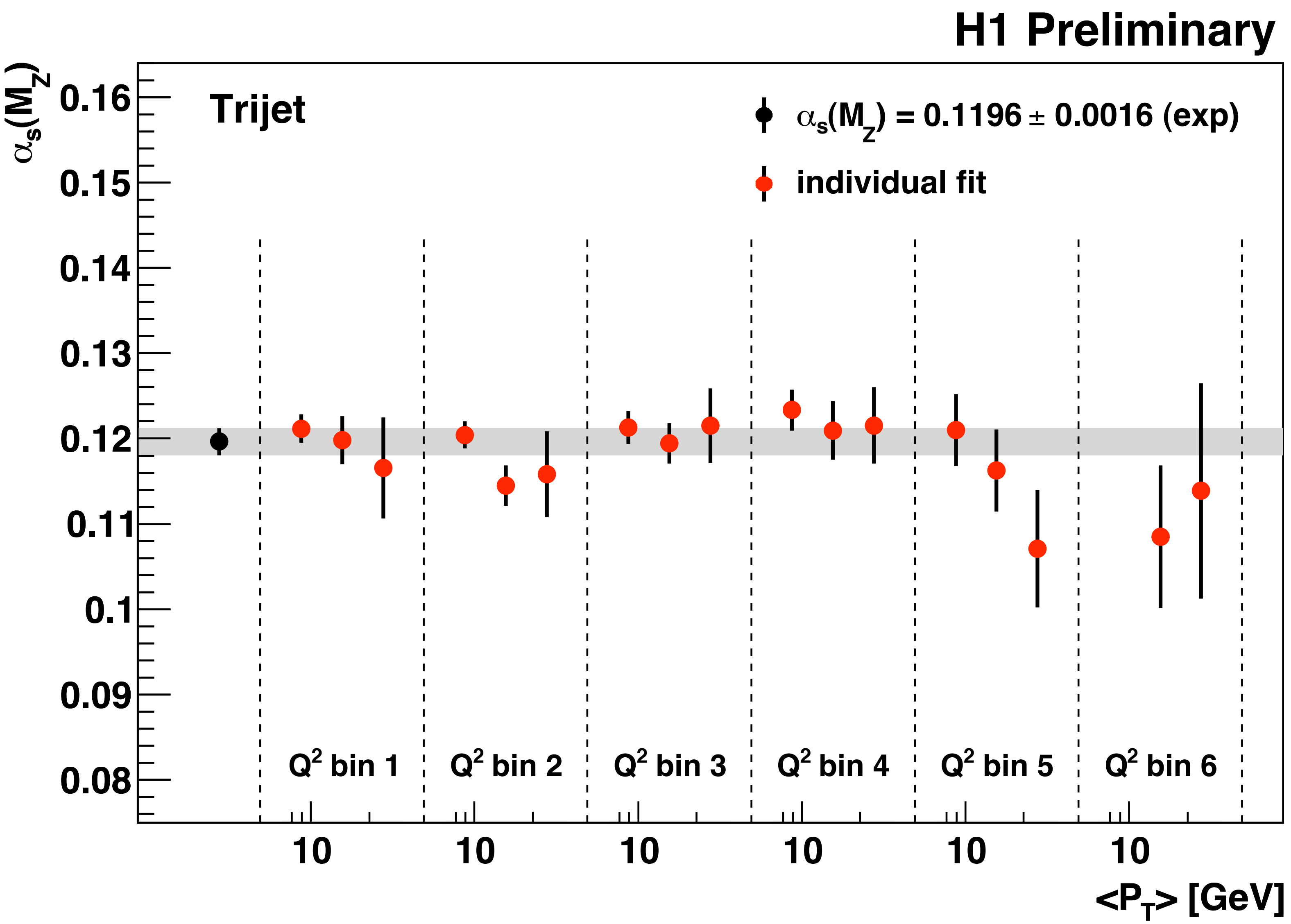
Trijet:

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

Theoretical uncertainty dominates for all observables, determined from scale variations: μ_r and μ_f varied by a factor of 2

α_s from trijet cross sections: most precise experimental result, smallest PDF uncertainty

$\alpha_s(M_Z)$ From Trijet Cross Sections



Individual fits performed to all data points

Grey band shows the experimental uncertainty of the simultaneous fit

Error bars of individual fit from uncorrelated uncertainties only

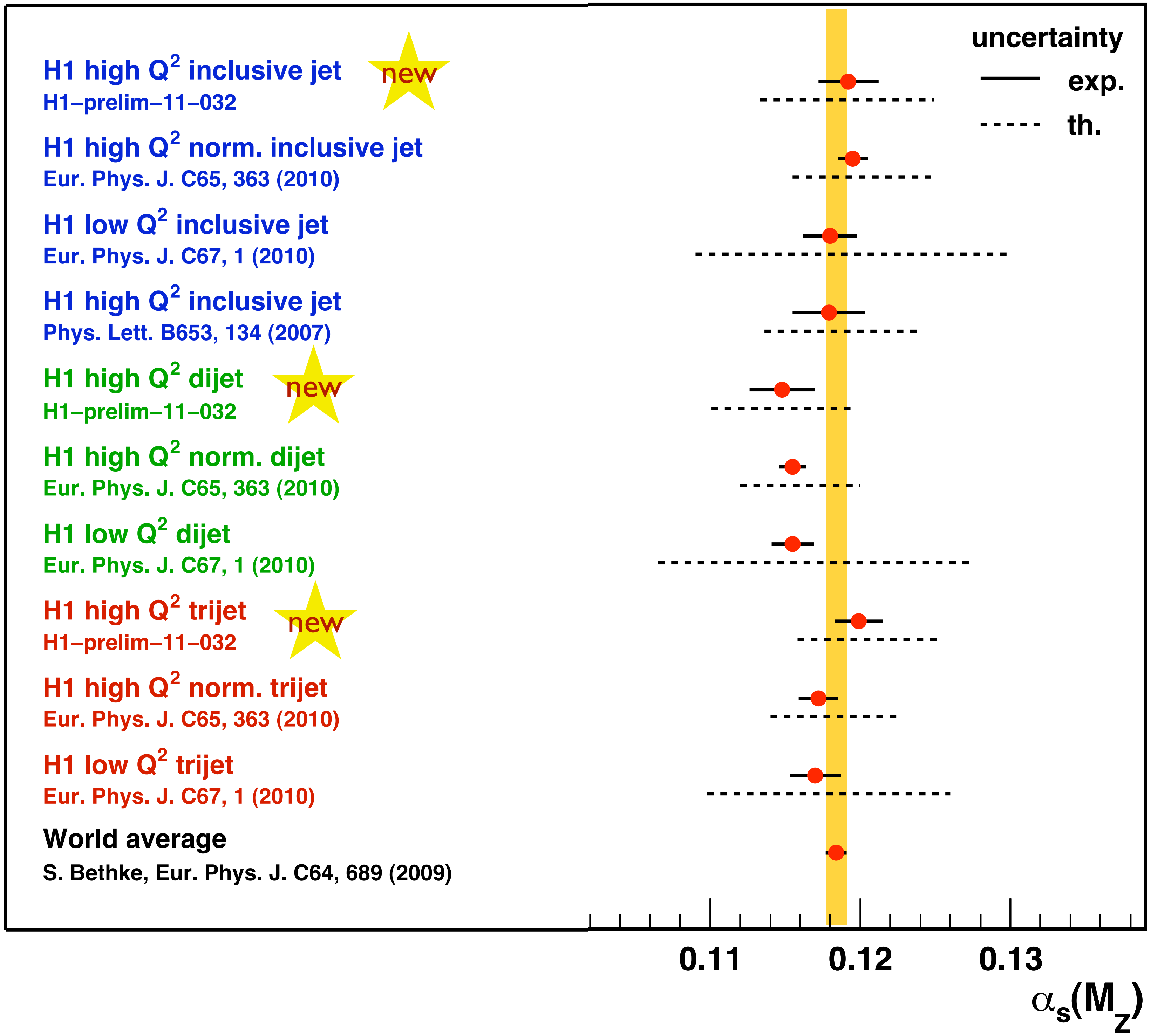
PDF, hadronisation uncertainty and uncertainty from terms beyond NLO not shown

$\alpha_s(M_Z)$ From Different Jet Multiplicities

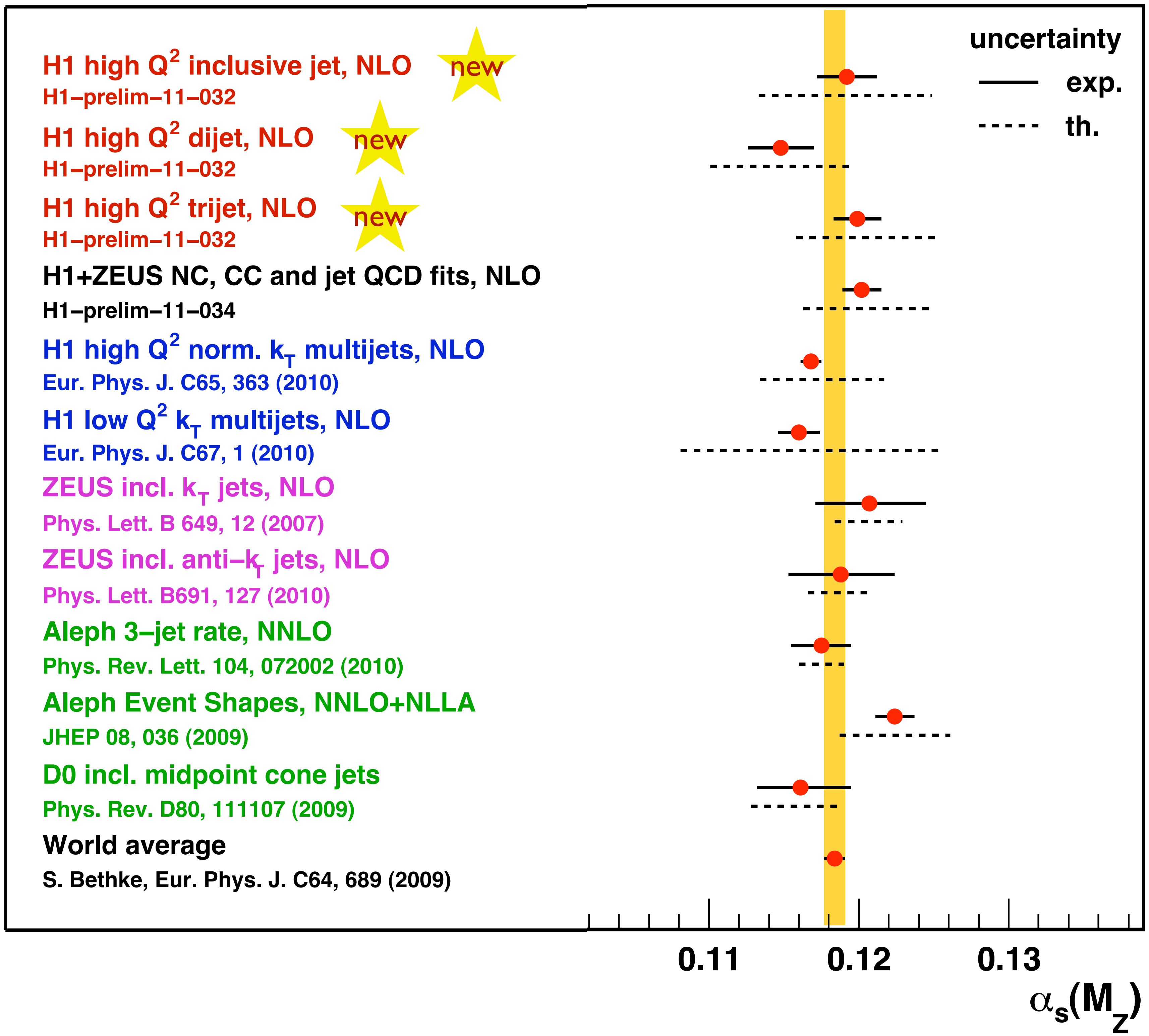
$\alpha_s(M_Z)$ values from inclusive jet, dijet and trijet measurements by H1

Experimental uncertainties always smaller than uncertainties due to terms beyond NLO

Dijet data give smaller values of $\alpha_s(M_Z)$, within theoretical uncertainty



Comparison With Recent Results



Summary

Most precise measurement of jet cross sections at e^+e^-, ep and hadron colliders (together with ZEUS dijets at high Q^2)

Inclusive jet, dijet and trijet cross sections at high Q^2 measured single and double differentially

- Stringent test of pQCD
- Tests of available PDFs
- Important for future combined PDF and α_s determinations

Extracted values of $\alpha_s(M_Z)$ competitive with other measurements, dominated by theoretical uncertainties

Trijet cross sections give smallest PDF and experimental uncertainties on $\alpha_s(M_Z)$

Looking forward to eventual NNLO calculations or resummation corrections as calculated for the Tevatron

$\alpha_s(M_Z)$ From Multijet Cross Sections

Inclusive Jet:

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

Norm. Inclusive Jet (Eur. Phys. J C65, 363):

$$\alpha_s(M_Z) = 0.1195 \pm 0.0010\ (\text{exp.}) \pm 0.0018\ (\text{pdf})\ ^{+0.0049}_{-0.0036}\ (\text{th.})$$

Dijet:

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

Norm. Dijet (Eur. Phys. J C65, 363):

$$\alpha_s(M_Z) = 0.1155 \pm 0.0009\ (\text{exp.}) \pm 0.0017\ (\text{pdf})\ ^{+0.0042}_{-0.0031}\ (\text{th.})$$

Trijet:

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

Norm. Trijet (Eur. Phys. J C65, 363):

$$\alpha_s(M_Z) = 0.1172 \pm 0.0013\ (\text{exp.}) \pm 0.0009\ (\text{pdf})\ ^{+0.0052}_{-0.0031}\ (\text{th.})$$