α_s measurements

- α_s measurements
- Deep Inelastic Scattering:
  - Sum rules
  - **Scaling violation**
  - Jets in DIS
- **τ lepton decay**
- Quarkonium
- e+e- annihilation
  - hadronic cross sections
  - Z decay
  - Event shapes
  - Scaling violation in fragmentation
- **Hadron-Hadron scattering**

α_s measurements

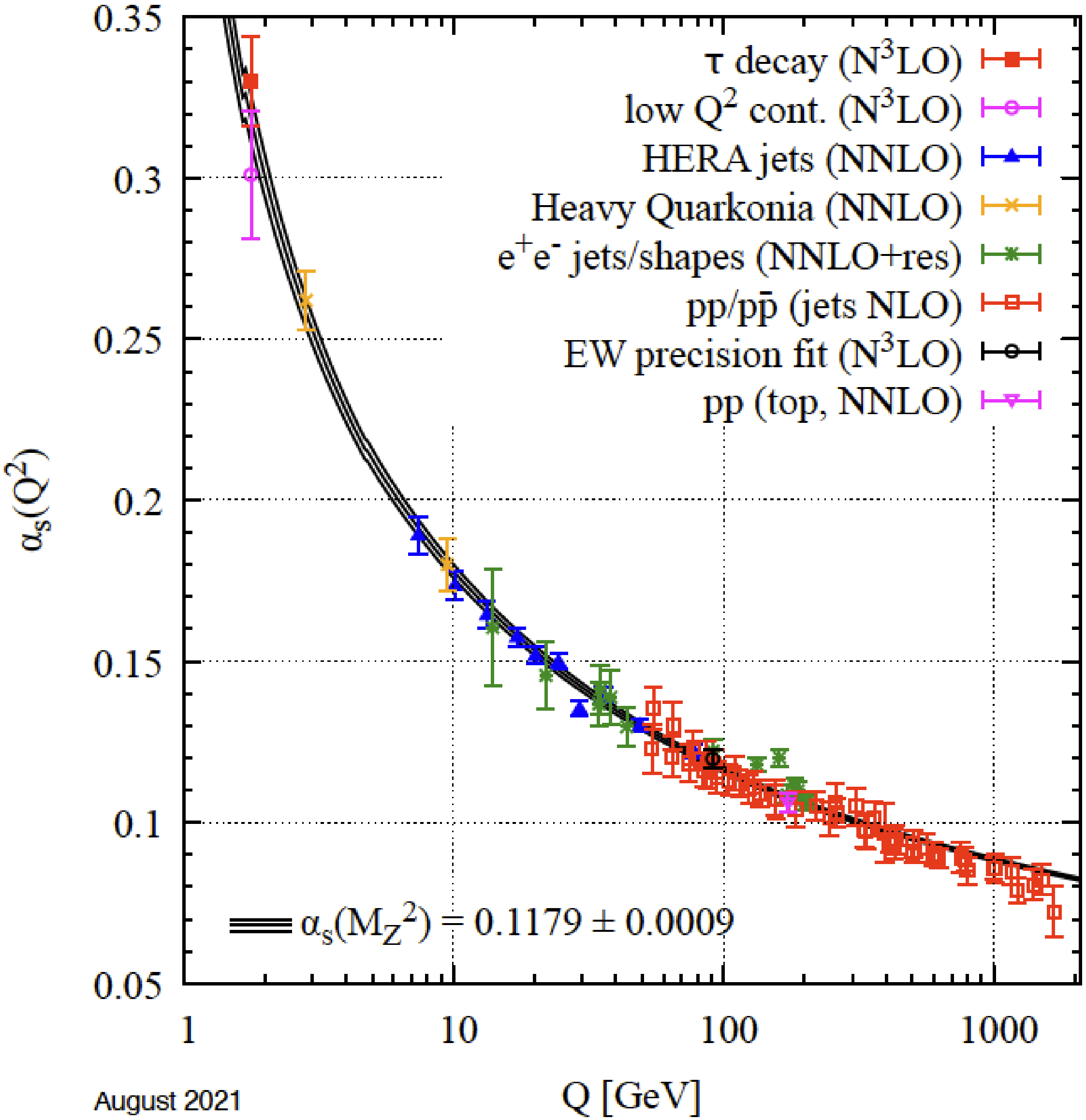


Figure 9.4: Summary of measurements of α_s as a function of the energy scale Q. The respective degree of QCD perturbation theory used in the extraction of α_s is indicated in brackets (NLO: next-to-leading order; NNLO: next-to-next-to-leading order; NNLO+res.: NNLO matched to a resummed calculation; N^{3}LO: next-to-NNLO).

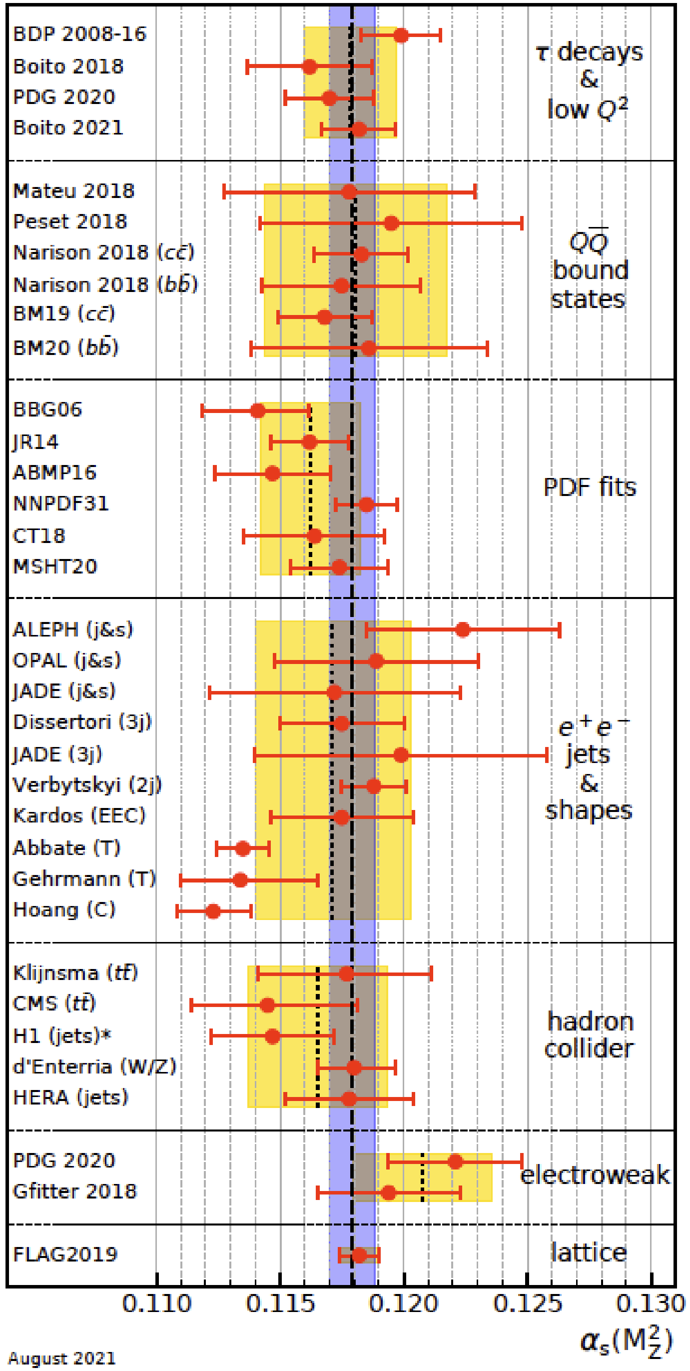


Figure 9.2: Summary of determinations of $\alpha_s(M_Z^2)$ from the seven sub-fields discussed in the text. The yellow (light shaded) bands and dotted lines indicate the pre-average values of each sub-field. The dashed line and blue (dark shaded) band represent the final world average value of $\alpha_s(M_Z^2)$. The "*" symbol within the "hadron colliders" sub-field indicates a determination including a simultaneous fit of PDFs.

α_s measurement: Scaling Violation in DIS

- In the evolution of F_2 at intermediate value of x ($0.01 < x < 0.3$), $\alpha_s(M_Z)$ and the $xg(x)$ are strongly correlated through the DGLAP. An increase of $\alpha_s(M_Z)$ can be compensated by a harder $xg(x)$. This has limited, in the past, the precision of the $\alpha_s(M_Z)$ measurements from NLO DGLAP fits using DIS data.
- At small x, ($x < 0.01$) this correlation becomes weaker $\Rightarrow$ $xg(x)$ drives the behaviour of F_2 (not only of $dF_2/dlnQ^2$).
- The jets data help a lot: **BGF** directly sensible to *xg(x)*, **QCDC to** $\alpha_s(M_Z)$
- A simultaneous fit of $\alpha_s(M_Z)$ and of the parameters of the p.d.f. gives:

$$\alpha_s(M_Z) = 0.1156 \pm 0.0011\,(exp.)^{+0.0001}_{-0.0002}\,(model+parameterization) \pm 0.0029\,(scale)$$

to compare with $\alpha_s(M_Z) = 0.1179 \pm 0.0009$ (PDG).

α_s measurement: τ lepton decay

- $$R_\tau^{th} = \frac{\Gamma(\tau \to \nu_\tau + hadrons)}{\Gamma(\tau \to \nu_\tau + \bar{\nu}_e + e)} = 3 S_{EW} (1 + \delta_{pQCD} + \delta_{NPQCD})$$

- $S_{EW} = 1.0194$ from the electroweak theory

- $$\delta_{pQCD} = \frac{\alpha_s(m_\tau^2)}{\pi} + 5.2\left(\frac{\alpha_s(m_\tau^2)}{\pi}\right)^2 + 26.4\left(\frac{\alpha_s(m_\tau^2)}{\pi}\right)^3 \left(\pm 130\left(\frac{\alpha_s(m_\tau^2)}{\pi}\right)^4\right)$$

- $\delta_{NPQCD} = -0.007 \pm 0.004$

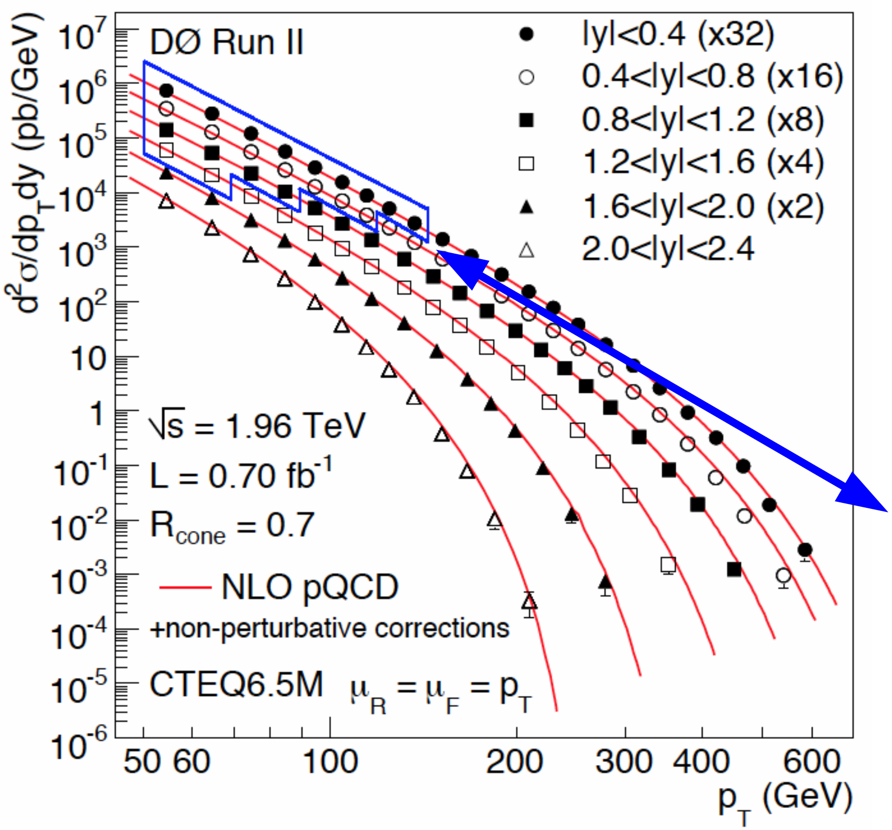
- $R_\tau^{exp} = \frac{1 - B_e - B_\mu}{B_l} = \frac{1}{B_l} - 1 - f_\mu$ with $f_\mu = 0.9726$ phase space correction

  B_l can be measured in 3 different manners: from the leptonic branching ratio of e, μ, $B_e = B_l$ e $B_\mu = f_\mu B_l$, and from the life time $\tau_\tau = B_l \, \tau_\mu (m_\mu / m_\tau)^5$

- $\alpha_s(M_\tau^2) = 0.312 \pm 0.015$ ➔ $\alpha_s(M_Z^2) = 0.1178 \pm 0.0019$

α_s measurement: hadron collider jets

- D0, the other experiment at the TEVATRON collider, has measured α_s with the Run II data
- The coupling is obtained by the single-jet inclusive cross section at a CM energy of $\sqrt{s}$ =1.96 TeV
- The $d^2\sigma_{jet}/dp_T dy$ is measured (y is the rapidity)
- The jets are recognized by a cone-algorithm with radius R = 0.7



D0 uses only these events with central jets, where the detector is well calibrated $|y| < 1.6$, and at an energy not very high ($50 < p_T < 145$ GeV) to avoid a region where the cross section for jet production is used to constrain the PDF.

α_s measurement: hadron collider jets

- From the theoretical point of view:

$$\sigma(\alpha_s(M_Z)) = \sigma_{pert}(\alpha_s(M_Z))\cdot c_{nonpert} = \left(\left(\sum_n \alpha_s^n c_n\right)\otimes f_1(\alpha_s)\otimes f_2(\alpha_s)\right)\cdot c_{nonpert}$$

- f_1, f_2 are the structure functions of the proton and of the antiproton
- $\otimes$ convolution,
- $c_{nonpert}$ contains the corrections due to the hadronization and underlying event
- The α_s value is obtained through a minimization procedure between experimental data and the theoretical formula.

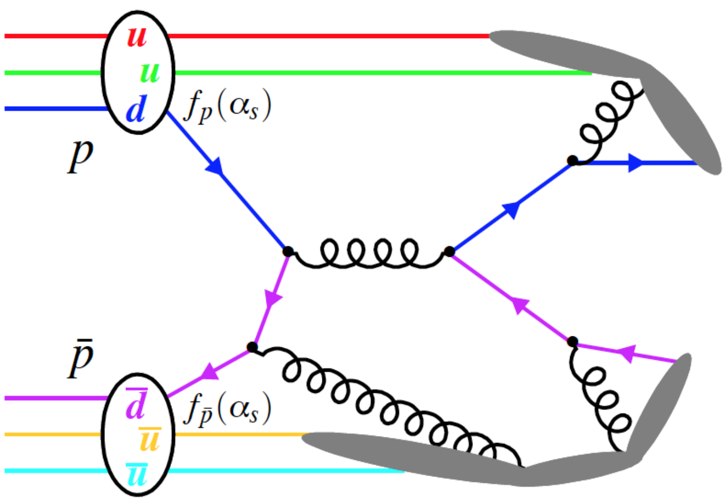
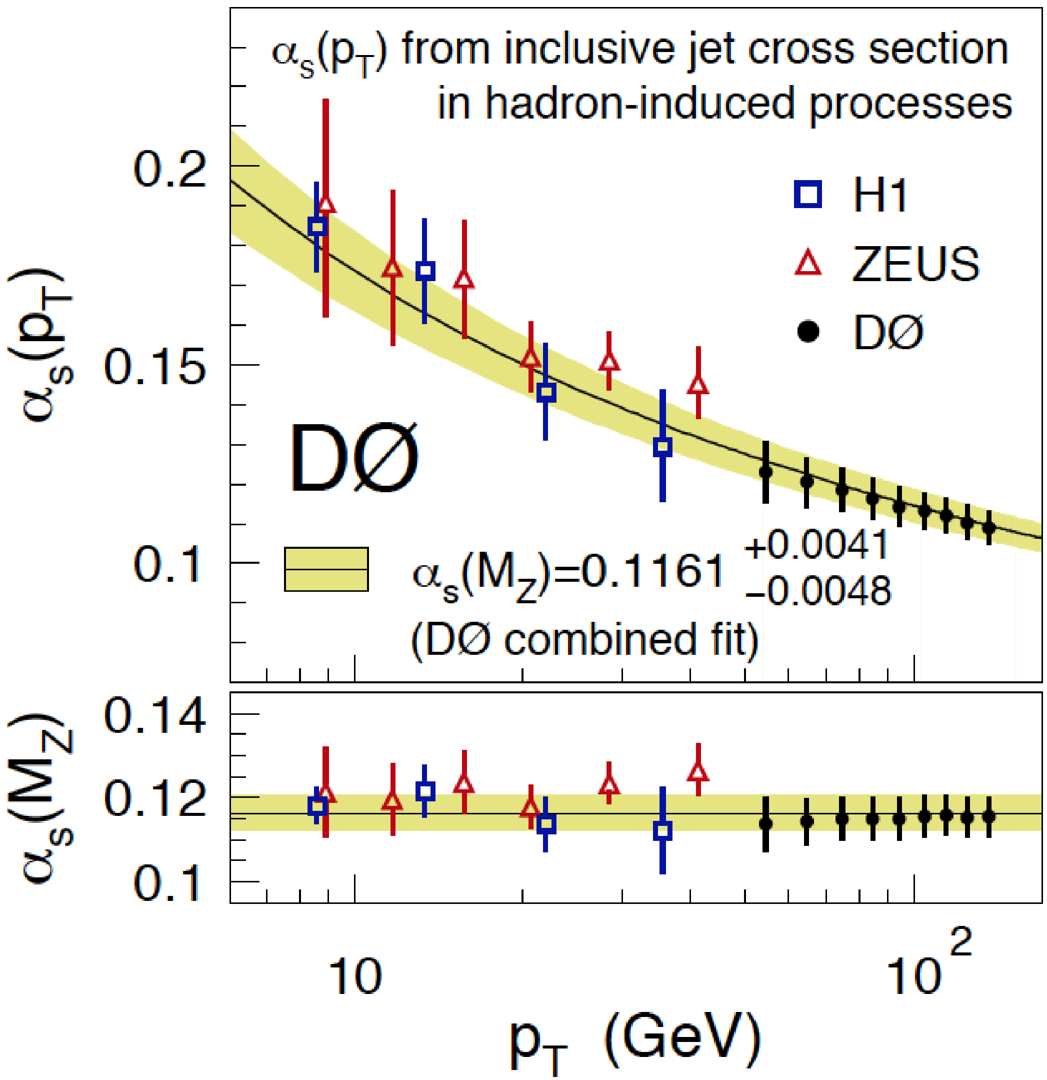


Figure 1: A drawing, illustrating jet production in a proton anti-proton collision with the hard scattering process, initial state, final state radiation and hadronisation (jet fragmentation) including the underlying event.

α_s measurement: hadron collider jets



$$\alpha_s(M_Z) = 0.1161^{\pm 0.0041}_{-0.0048}$$

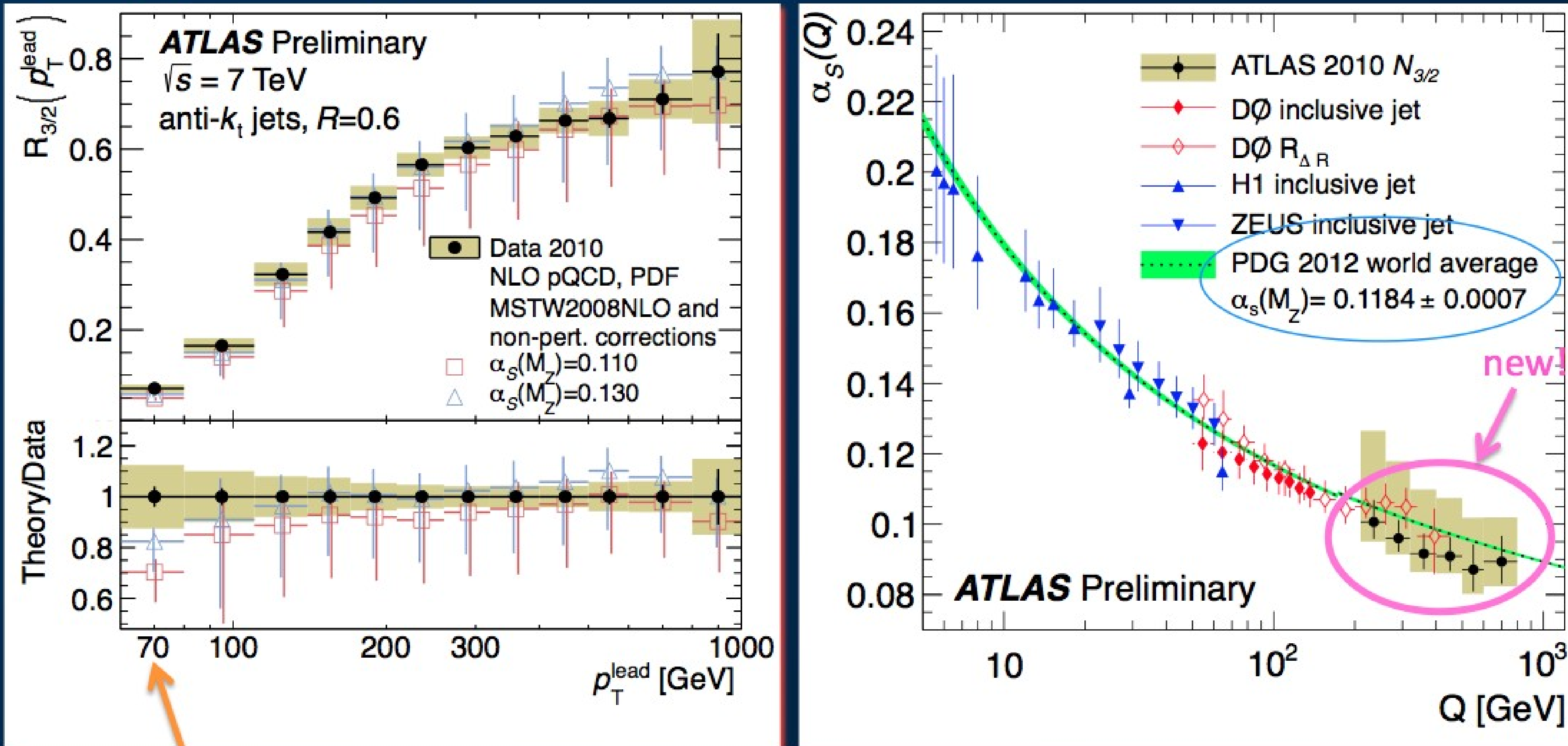
Inclusive Jet Ratios

Inclusive 3-Jet / Inclusive 2-Jet Ratio ($R_{3/2}$, $N_{3/2}$) ($\sqrt{s}$ = 7 TeV)

$$R_{3/2} = \frac{\sigma_{3\text{-jet}}}{\sigma_{2\text{-jet}}} \quad \text{(lead jet)} \qquad N_{3/2} = \frac{\sigma_{3\text{-jet}}}{\sigma_{2\text{-jet}}} \quad \text{(all jets)} \quad \Rightarrow \alpha_s$$

- Extract α_s:

$\alpha_s(M_Z) = 0.111 \pm 0.006 \text{ (exp.)} ^{+0.016}_{-0.003} \text{ (theory)}$



- Good agreement overall, except here for $p_T^{lead} < 140$ GeV

ATLAS: ATLAS-CONF-2013-041

Inclusive Jet Ratios

Inclusive 3-Jet / Inclusive 2-Jet Ratio ($R_{3/2}$) ($\sqrt{s}$ = 7 TeV)

Measure $R_{3/2}$ vs. $\langle p_{T1,2} \rangle$, the average p_T of the two leading jets in the event

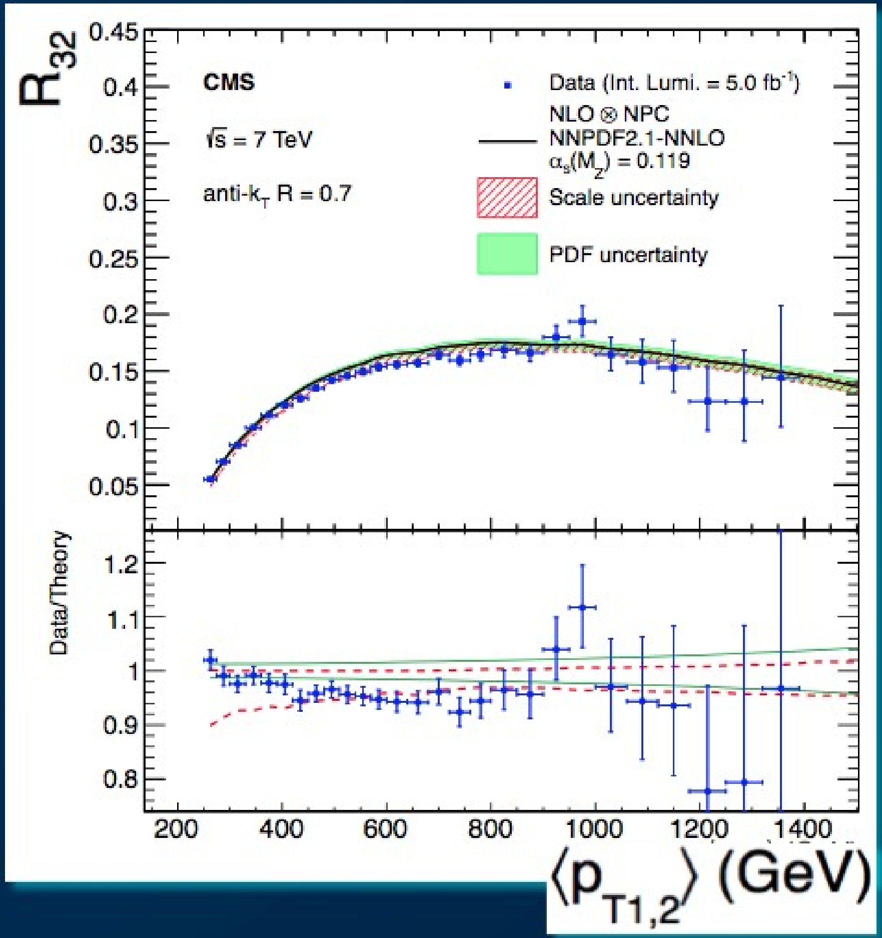
$250 < \langle p_{T1,2} \rangle < 1390$ GeV

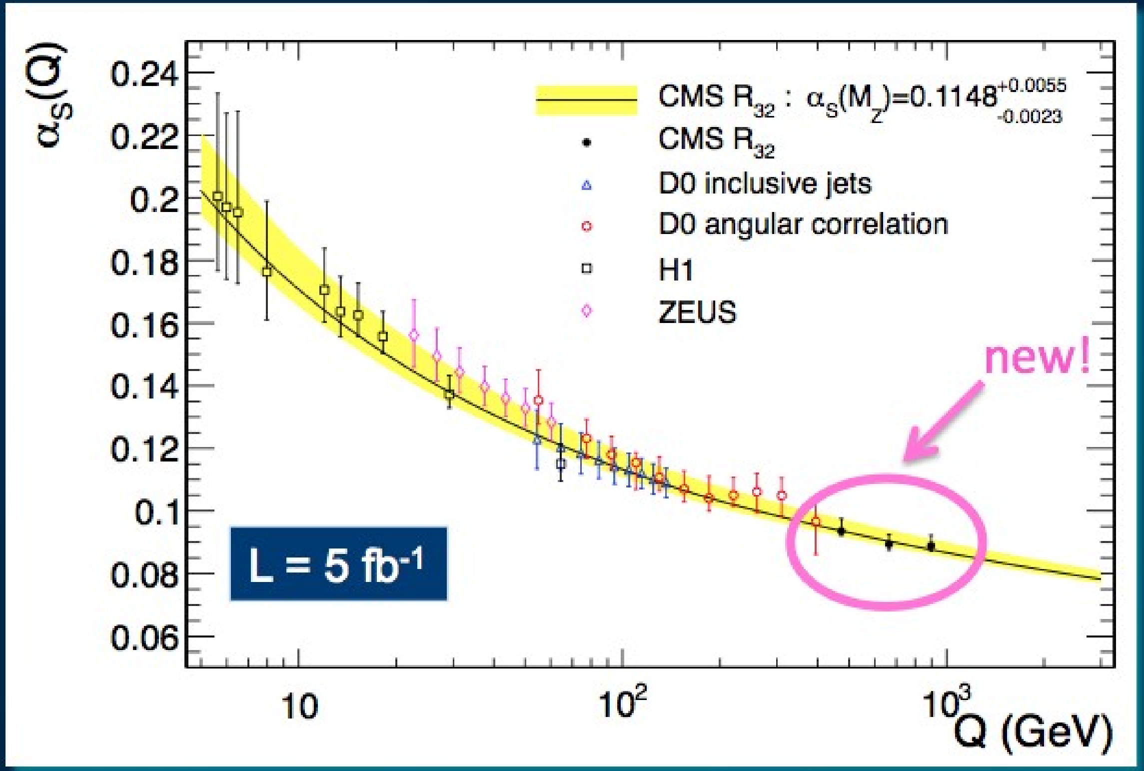
Compare data to NLO QCD → Good agreement!

Extract

$\alpha_s(M_Z) = 0.1148 \pm 0.0014$ (exp.) ± 0.0018 (PDF) $^{+0.0050}_{-0.0000}$ (scale)

- First determination of α_s from measurements at Q scales up to 1 TeV





CMS: arXiv:1304.7498, submitted to Eur. Phys. J. C