QCD analysis of 7 TeV Inclusive Jet Data

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on behalf of CMS collaboration

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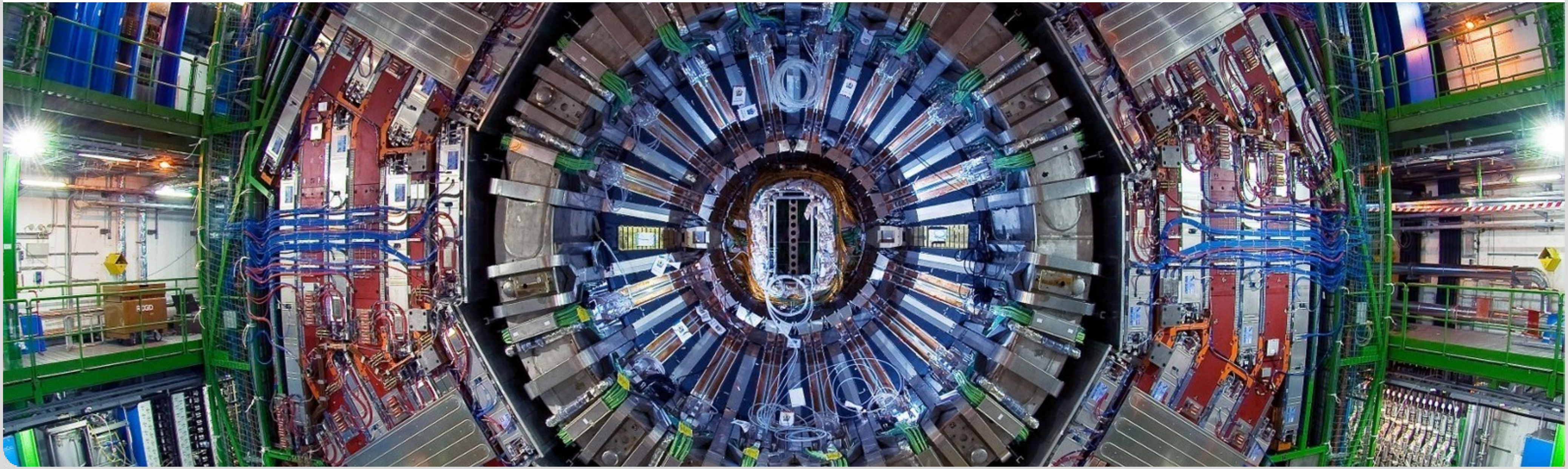

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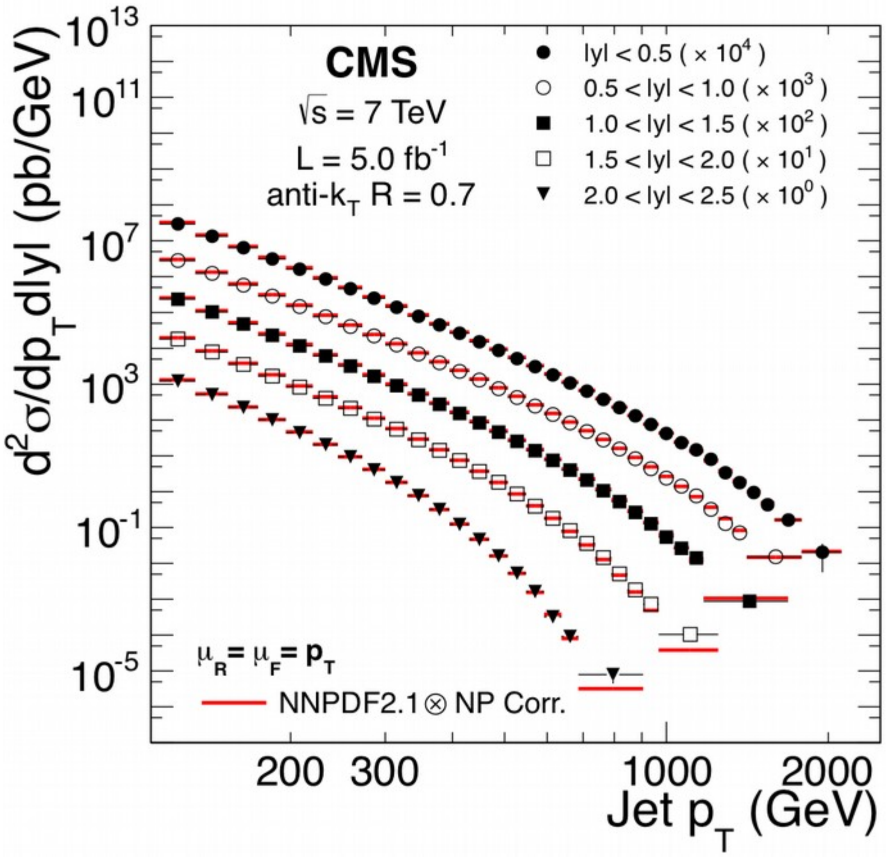
CMS inclusive jet measurement

- Double differential inclusive jet cross section
- Inclusive jet cross section can be precisely calculated in perturbative QCD
- Performing detailed fits, the PDFs, in particular the gluon PDF at high x, can be constrained and the strong coupling constant can be determined
- Demonstrated by means of published CMS data of inclusive jet production (Phys. Rev. D 87 (2013) 112002)
- Electroweak corrections to hard scattering cross sections are applied (JHEP 1211 (2012) 095)
  - We thank S. Dittmaier and A. Huss for providing us the exact factors for our kinematic phase space



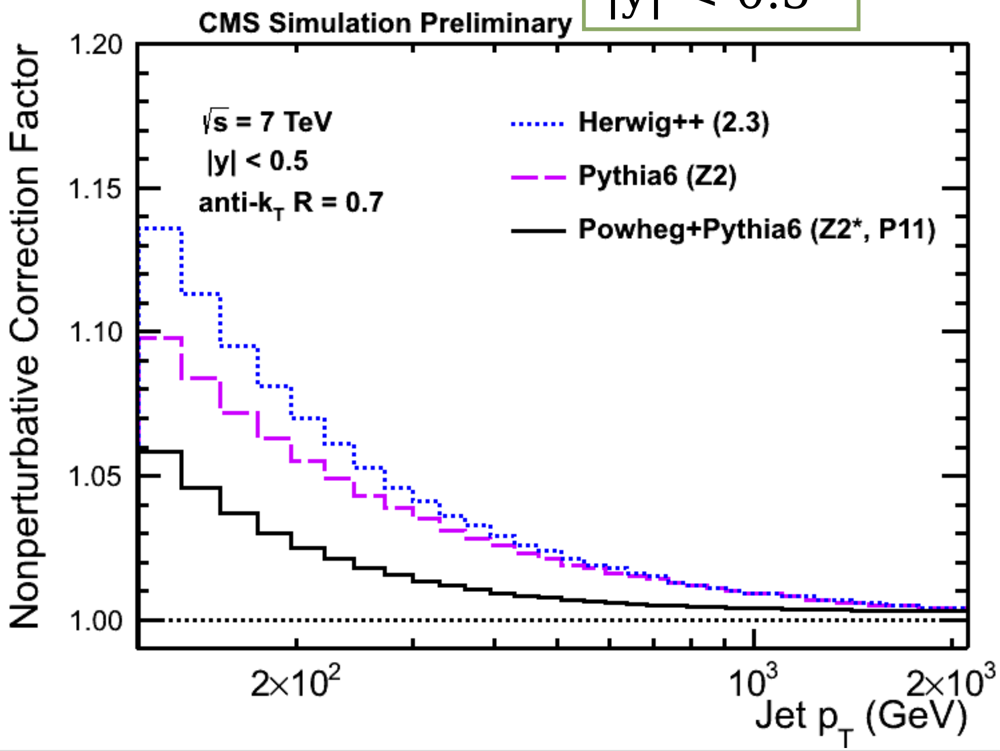
$$\frac{d^2\sigma}{dp_T\,dy} = \frac{1}{\epsilon \cdot \mathcal{L}_{int}} \frac{N_{jets}}{\Delta p_T\ (2 \cdot \Delta|y|)}$$

Nonperturbative Corrections

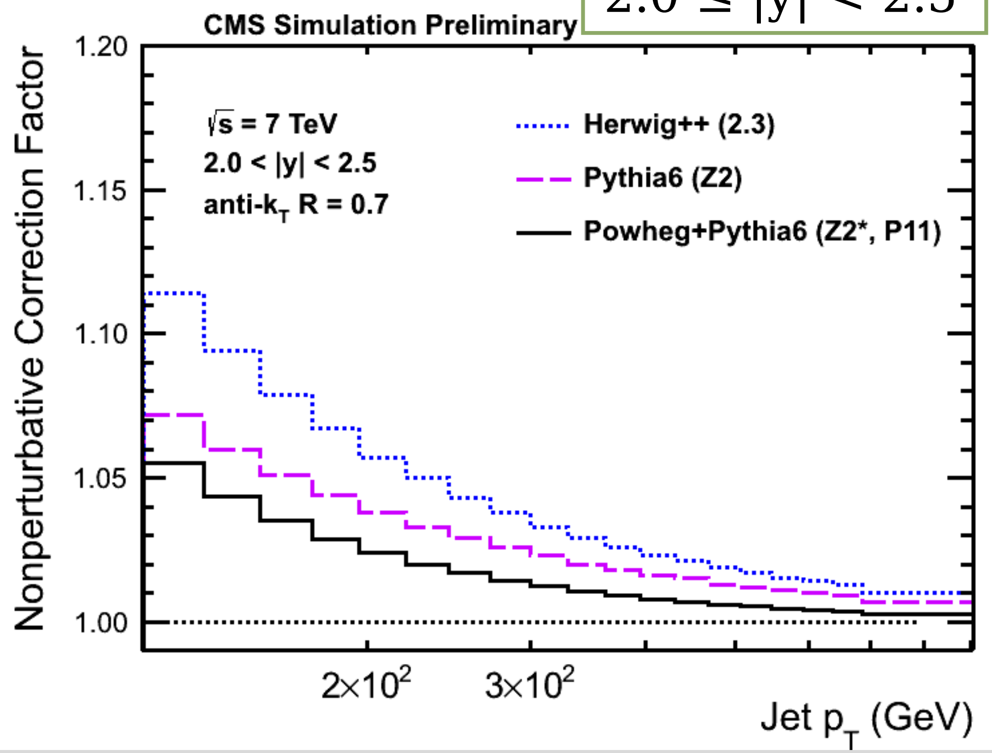
- For the first time NP correction from matched-NLO MC generator compared to NP predictions from Pythia6 and Herwig++
- Similar results from NLO and LO ME calculation but corrections from Powheg are smaller
- Central results on NP correction and uncertainty defined by the envelope given by the three predictions

$$C^{\mathrm{NP}} = \frac{\sigma_{\mathrm{(N)LO+PS+HAD+MPI}}}{\sigma_{\mathrm{(N)LO+PS}}}$$

$|y| < 0.5$

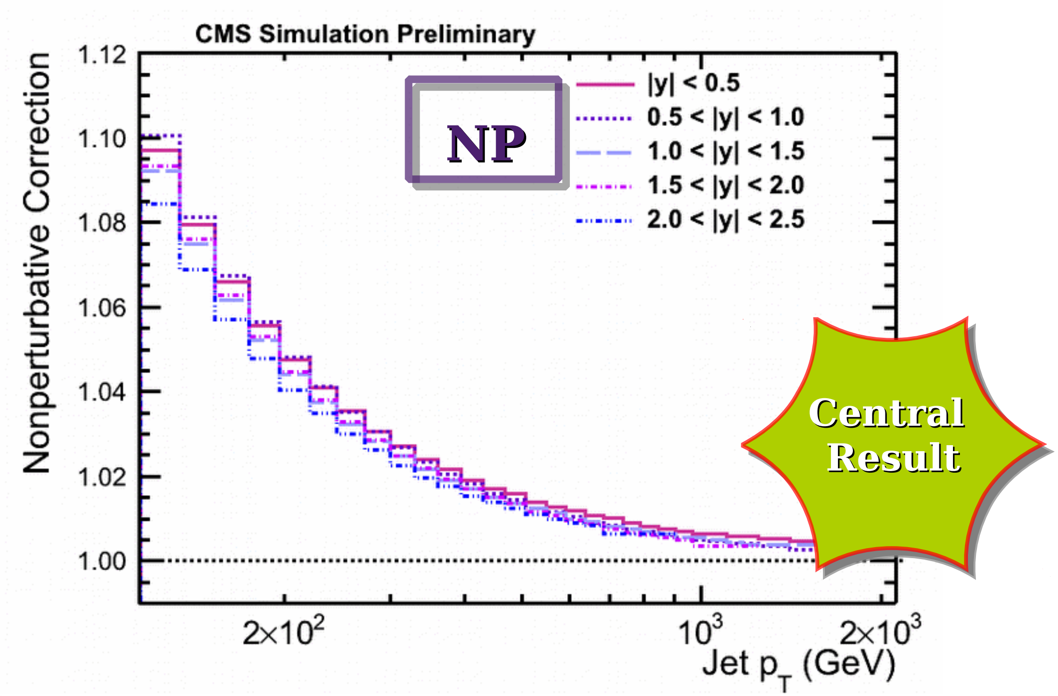


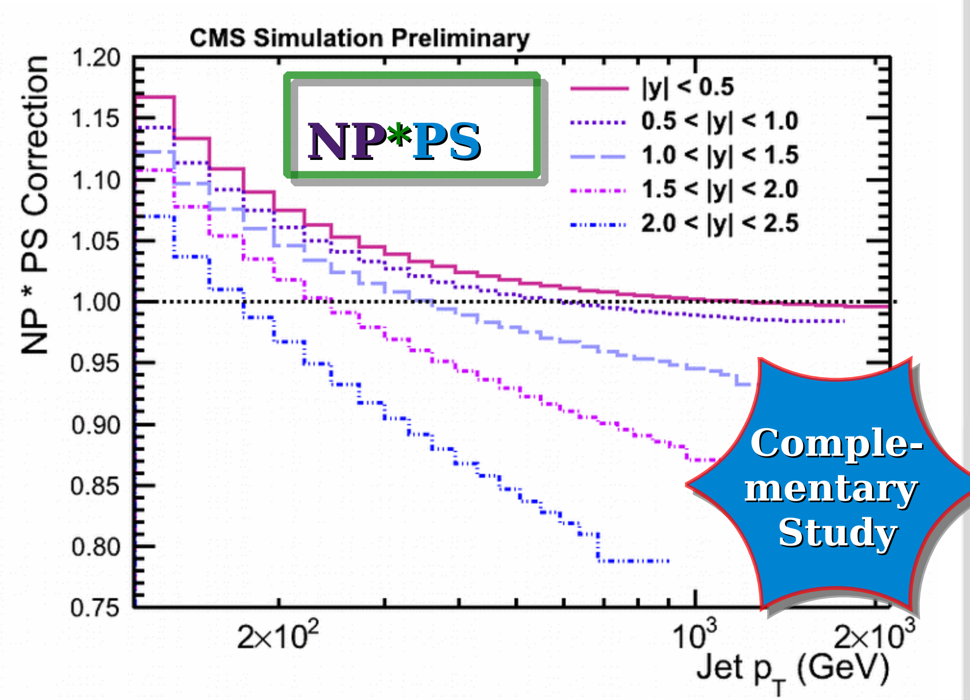
$2.0 \leq |y| < 2.5$



NP & PS Correction

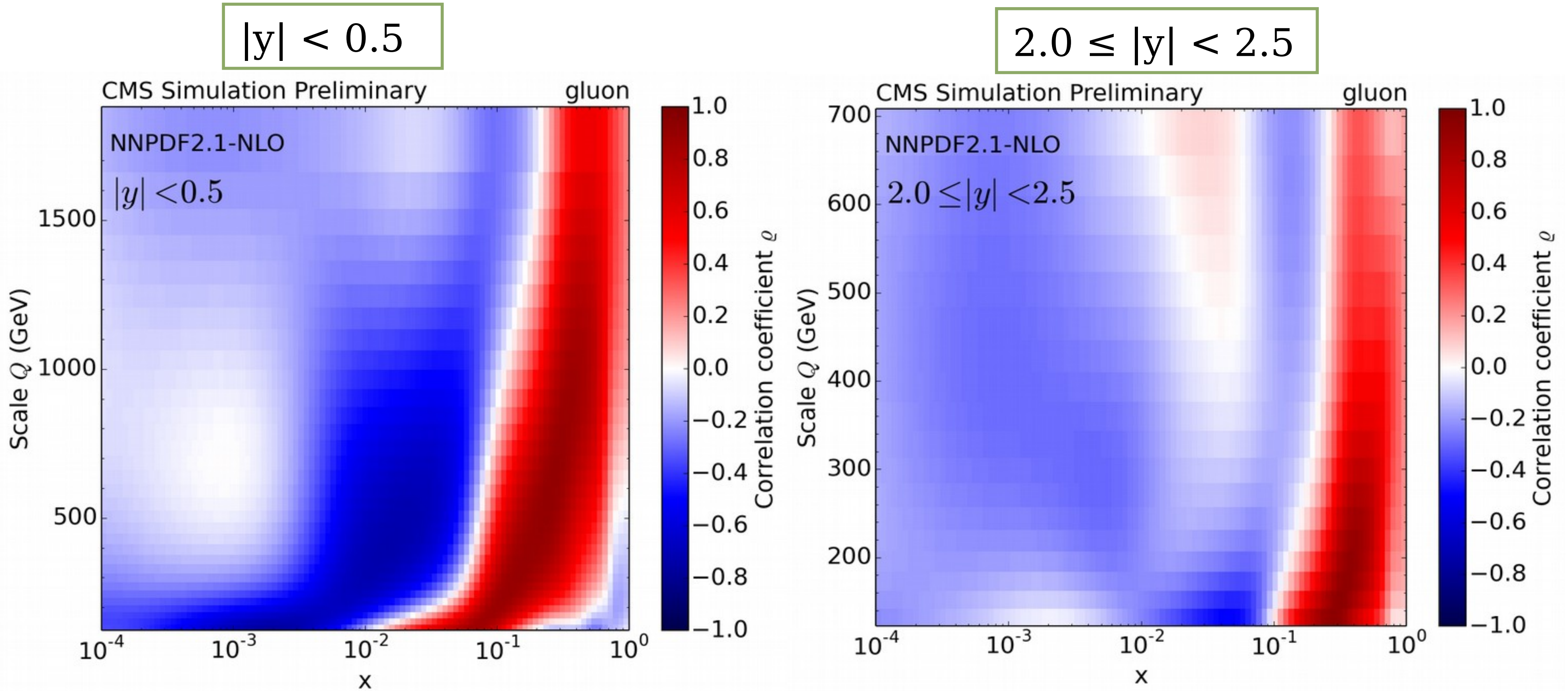
- NP defined as the center of the envelope given by the three predictions $C^{\mathrm{NP}} = \frac{\sigma_{\mathrm{(N)LO+PS+HAD+MPI}}}{\sigma_{\mathrm{(N)LO+PS}}}$
- PS correction determined as the average of the predictions from the two extreme scale limits $C^{\mathrm{PS}} = \frac{\sigma_{\mathrm{NLO+PS}}}{\sigma_{\mathrm{NLO}}}$
- NP * PS correction investigated in a complementary study





Correlation of gluon PDF and σ_{jet}

- Central region: High correlation at $0.05 < x < 0.7$ and $Q < 1500$ GeV
- Forward region: High correlation at $0.1 < x < 0.7$ and $Q < 300$ GeV
- **Constraints on PDFs expected at high-*x***



PDF fit settings

- Fits performed with HERAFitter
- Standard 13p-HERAPDF parameterization is used
- A: normalization, B: low-x behaviour, C: high-x shape

$$xg(x) = A_g x^{B_g}(1-x)^{C_g} - A'_g x^{B'_g}(1-x)^{C'_g}$$
$$xu_v(x) = A_{u_v} x^{B_{u_v}}(1-x)^{C_{u_v}}(1+E_{u_v}x^2)$$
$$xd_v(x) = A_{d_v} x^{B_{d_v}}(1-x)^{C_{d_v}}$$
$$x\bar{U}(x) = A_{\bar{U}} x^{B_{\bar{U}}}(1-x)^{C_{\bar{U}}}$$
$$x\bar{D}(x) = A_{\bar{D}} x^{B_{\bar{D}}}(1-x)^{C_{\bar{D}}}$$

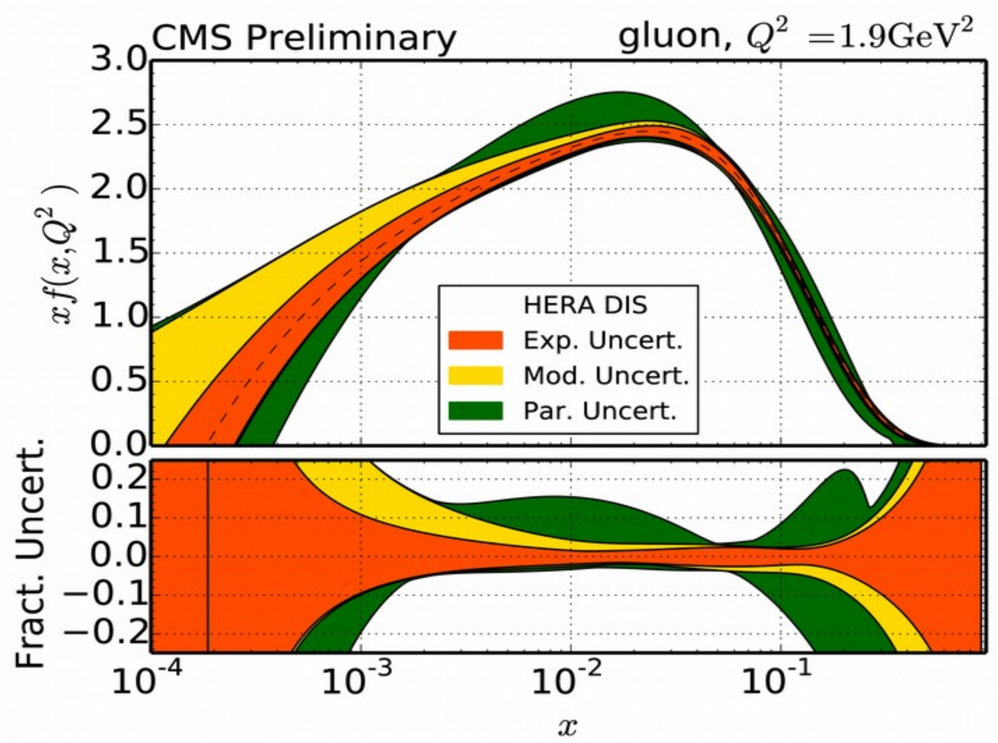
- Evolution at NLO
- Normalization parameters A_i determined by QCD sum rules
- Additional constraints for small-x behaviour

$$B_{\bar{U}} = B_{\bar{D}} \qquad A_{\bar{U}} = A_{\bar{D}}(1-f_S)$$

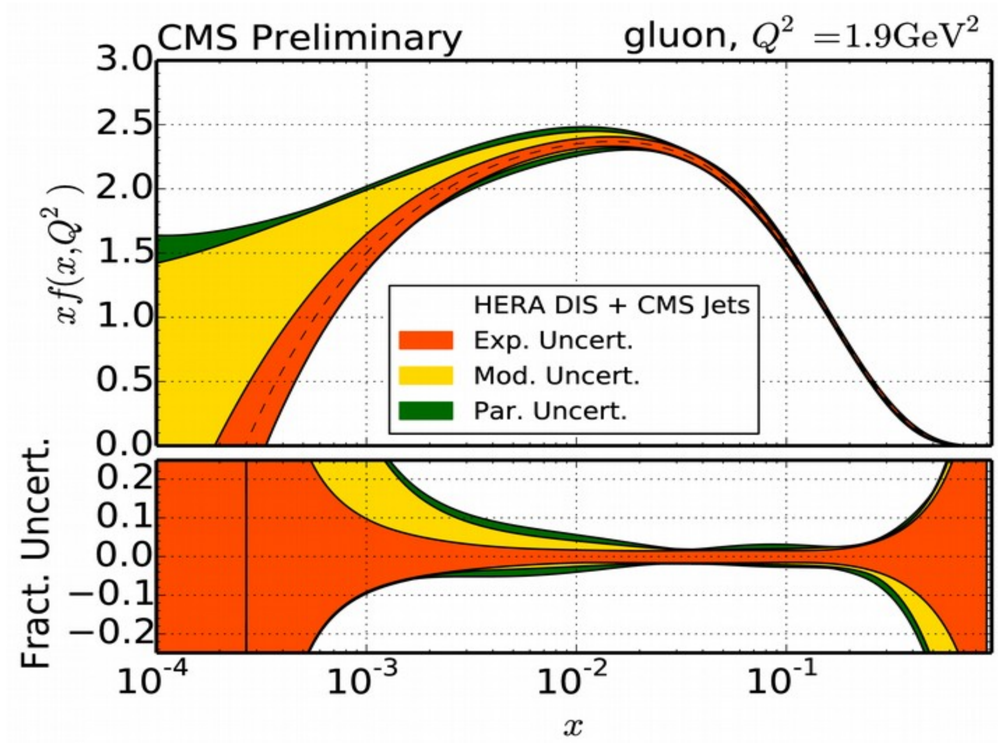
Constraints on the gluon, Q^2=1.9 GeV^2

- Strong impact on gluon PDF
- Uncertainty reduced in high-x region
- PDF at starting scale Q_0^2=1.9 GeV^2

HERA DIS



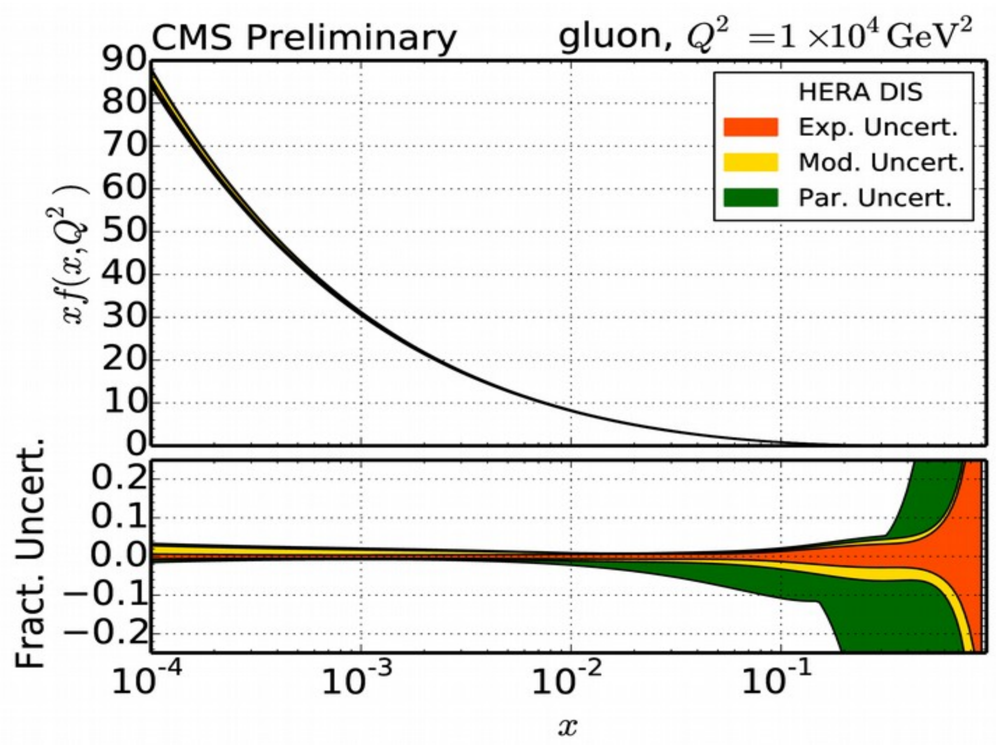
HERA DIS+CMS Jets



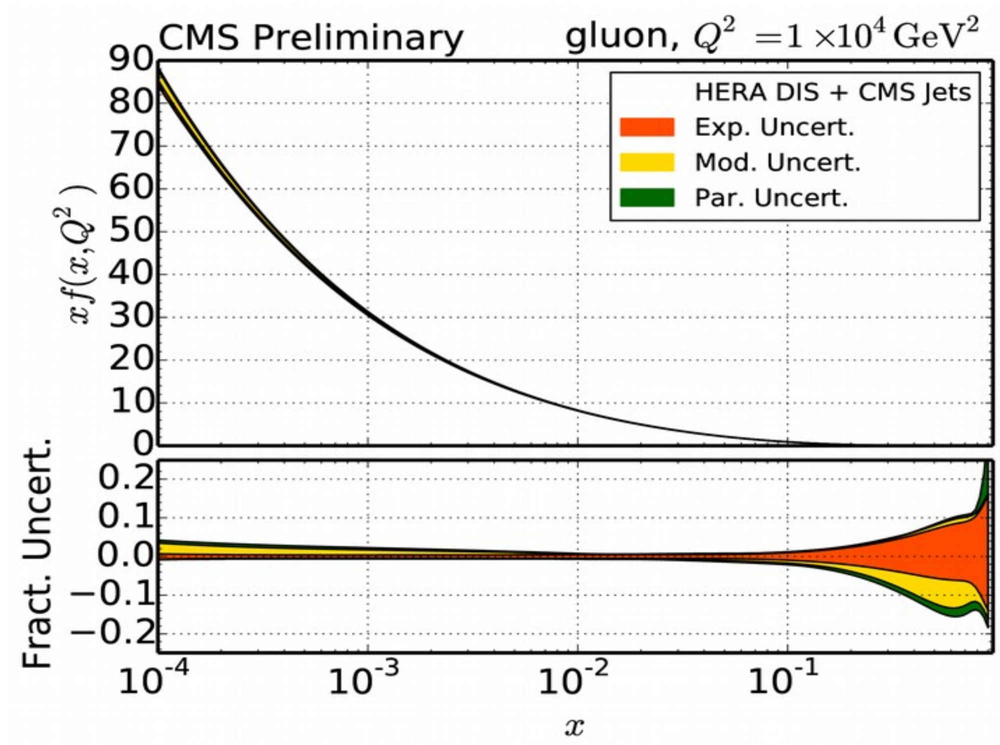
Constraints on the gluon, $Q^2=10^4$ GeV^2

- Strong impact on gluon PDF
- Uncertainty reduced in high-x region
- PDF at scale $Q^2=10^4$ GeV^2

HERA DIS

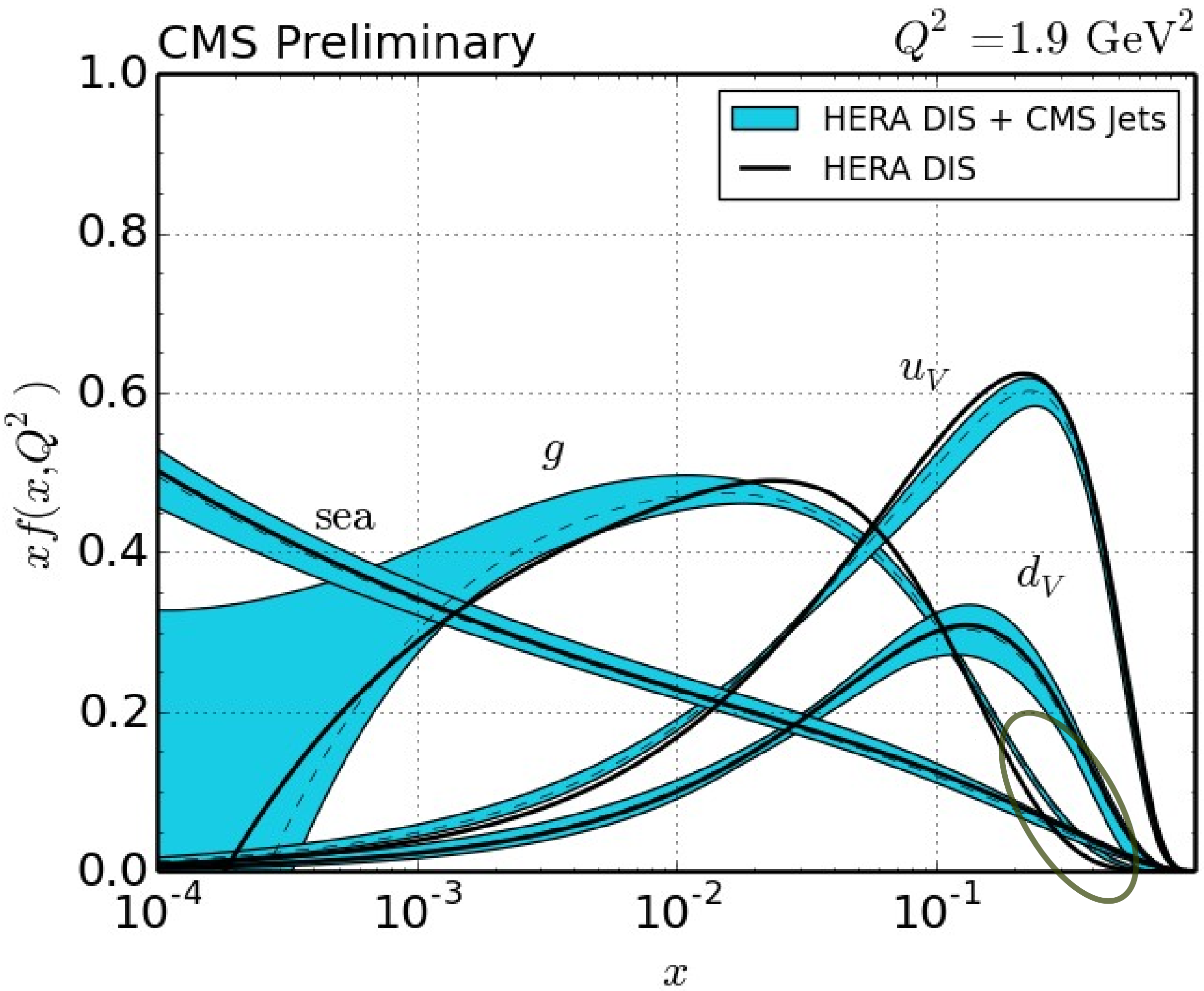


HERA DIS+CMS Jets



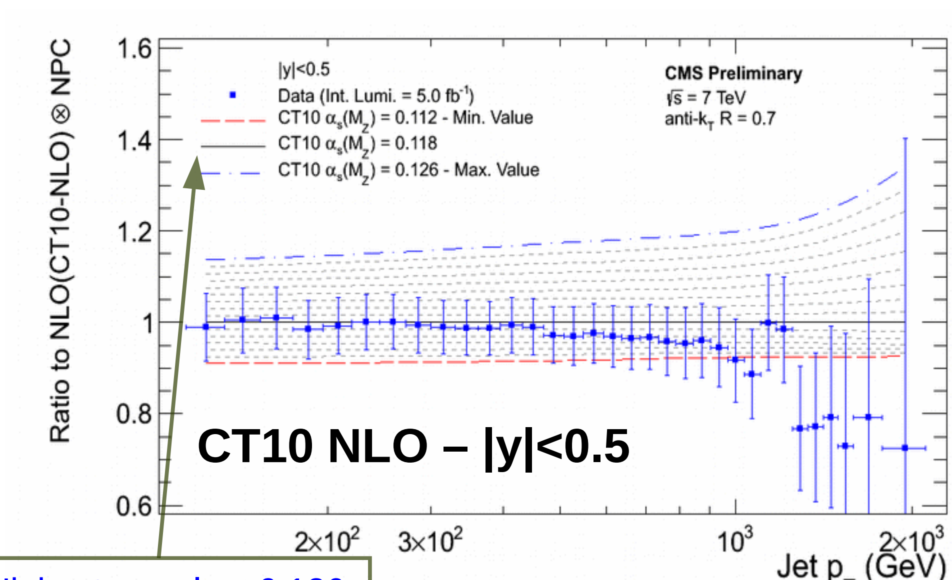
Overview on PDF fits

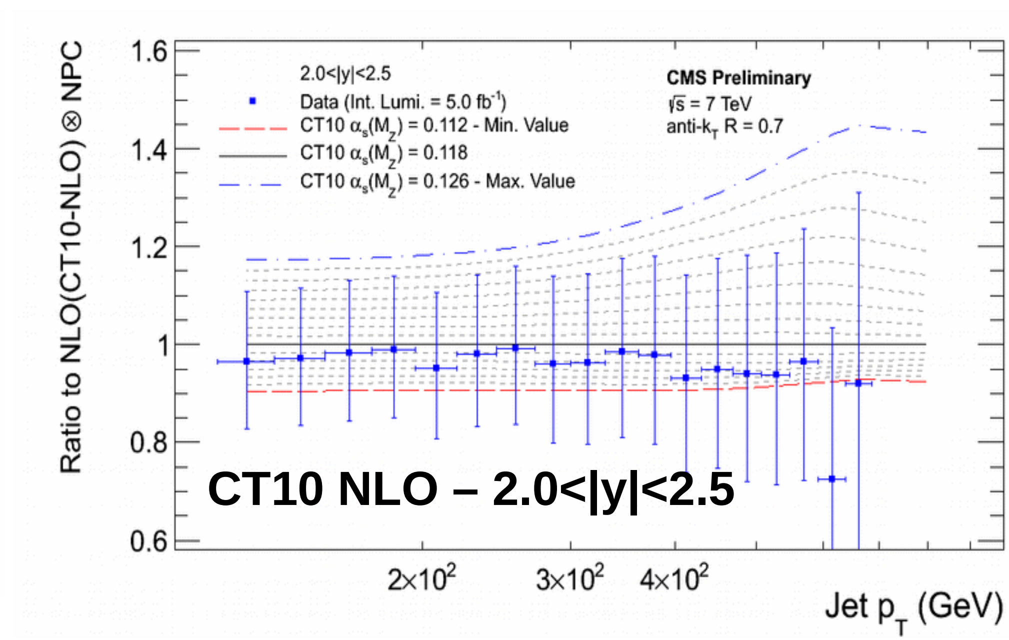
- Harder gluon observed with reduced uncertainties
- Some impact on u-valence distribution as well



Sensitivity of $\alpha_S(m_Z)$: CT10-NLO

- Sensitivity plots show the ratio of predictions with different values of $\alpha_S(m_Z)$ to the central PDF predictions
- Data with total uncertainty is shown
- Ratio is flat over wide range of p_T and well described within a small $\alpha_S \rightarrow$ **suitable** for α_S extraction

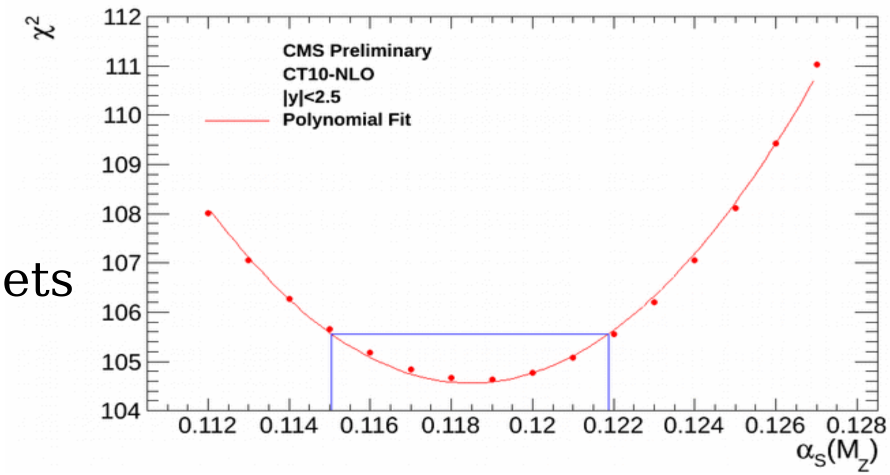




Highest α_S value: 0.126
Central α_S value: 0.118
Lowest α_S value: 0.112

Extraction of $\alpha_s(m_Z)$

- Central result with CT10-NLO
- PDF and scale uncertainties dominant
- Perfectly compatible with world average
- Consistent with results using other PDF sets within uncertainties



PDF set	$\alpha_S(M_Z)$	χ^2/n_{dof}
CT10-NLO	$0.1185 \pm 0.0019(\text{exp}) \pm 0.0028(\text{PDF}) \pm 0.0004(\text{NP})^{+0.0055}_{-0.0022}(\text{scale})$	104.6/132
MSTW2008-NLO	$0.1157 \pm 0.0012(\text{exp}) \pm 0.0013(\text{PDF}) \pm 0.0001(\text{NP})^{+0.0029}_{-0.0028}(\text{scale})$	108.3/132
CT10-NNLO	$0.1170 \pm 0.0012(\text{exp}) \pm 0.0024(\text{PDF}) \pm 0.0004(\text{NP})^{+0.0046}_{-0.0027}(\text{scale})$	106.1/132
NNPDF2.1-NNLO	$0.1173 \pm 0.0012(\text{exp}) \pm 0.0018(\text{PDF}) \pm 0.0001(\text{NP})^{+0.0020}_{-0.0018}(\text{scale})$	104.1/132
MSTW2008-NNLO	$0.1133 \pm 0.0010(\text{exp}) \pm 0.0011(\text{PDF}) \pm 0.0001(\text{NP})^{+0.0020}_{-0.0021}(\text{scale})$	107.6/132

Complementary studies

- Result using **NP+PS corrections** from POWHEG also in agreement with our central result :

$$\alpha_s(M_Z) = 0.1205 \pm 0.0018\,(exp.) \pm 0.0031\,(PDF) \pm 0.0264\,(NP+PS)\,^{+0.0053}_{-0.0029}\,(scale)$$
$$= 0.1205\,^{+0.0272}_{-0.0268}$$

- NP+PS are the dominant uncertainties because of lacking knowledge of and experience with PS effects.

- **Simultaneous fit** of PDFs & $\alpha_S(m_Z)$

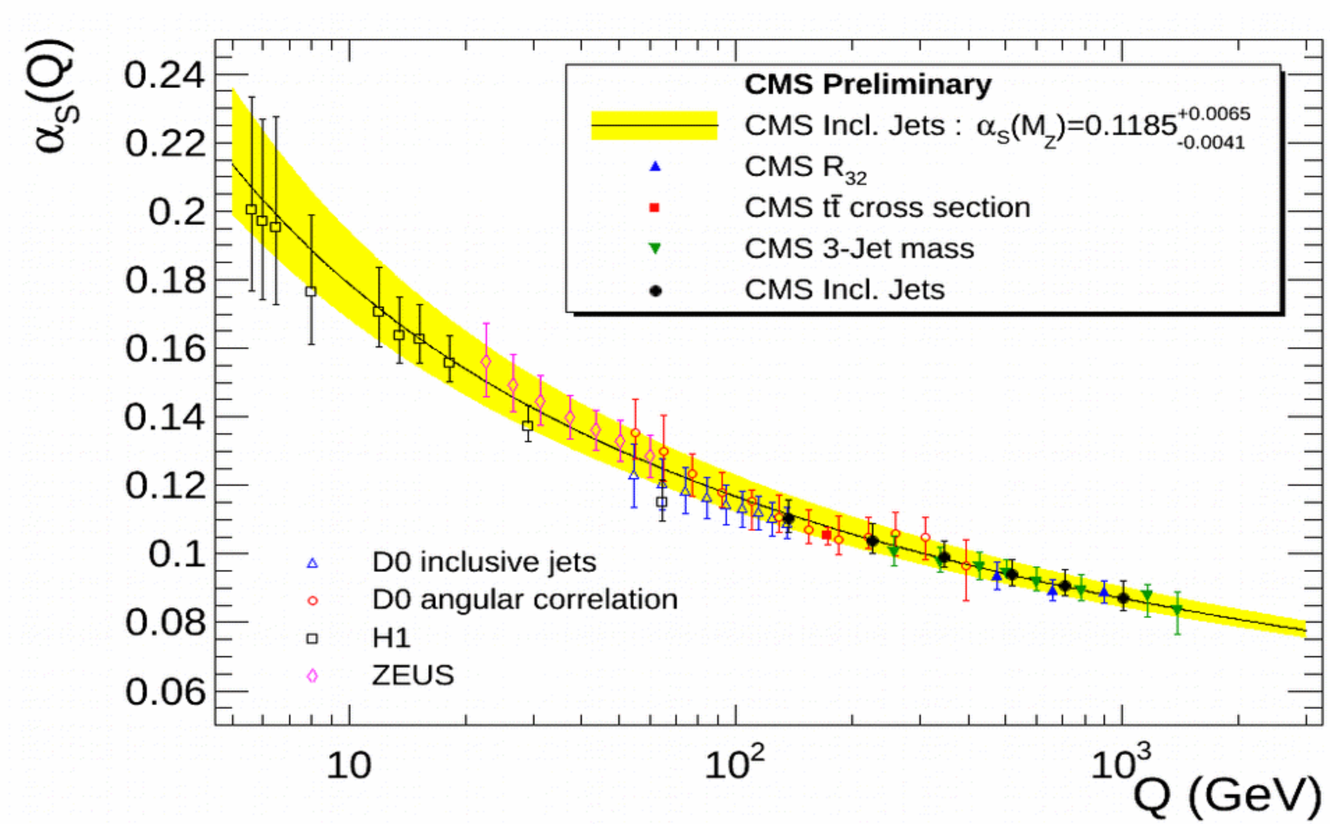
$$\alpha_S(M_Z) = 0.1192^{+0.0017}_{-0.0015}(\mathrm{exp., NP})$$

- Uncertainty accounts for experimental HERA DIS and CMS inclusive jet uncertainty and NP uncertainty, but not for model/parametrization and scale uncertainties
- Both results are in agreement with the “central” result derived using CT10-NLO

Running of $\alpha_s(Q)$

- Fitted region is split into six regions as shown in table and αs(MZ) derived for each region.
- Using the 2-loop RGE these values evolved back to the corresponding αs(Q).
- The new CMS results on αs are consistent with the energ dependence predicted by the RGE.

p_T range (GeV)	Q (GeV)	$\alpha_S(M_Z)$	$\alpha_S(Q)$	No. of data points	χ^2/n_{dof}
114–196	136	$0.1170^{+0.0062}_{-0.0045}$	$0.1103^{+0.0054}_{-0.0039}$	20	6.2/19
196–300	226	$0.1179^{+0.0067}_{-0.0049}$	$0.1037^{+0.0052}_{-0.0037}$	20	7.6/19
300–468	345	$0.1194^{+0.0067}_{-0.0049}$	$0.0993^{+0.0045}_{-0.0033}$	25	8.2/24
468–638	521	$0.1188^{+0.0072}_{-0.0051}$	$0.0940^{+0.0044}_{-0.0032}$	20	10.6/19
638–905	711	$0.1193^{+0.0080}_{-0.0056}$	$0.0910^{+0.0044}_{-0.0033}$	22	11.4/21
905–2116	1007	$0.1180^{+0.0104}_{-0.0061}$	$0.0868^{+0.0054}_{-0.0033}$	26	39.4/25



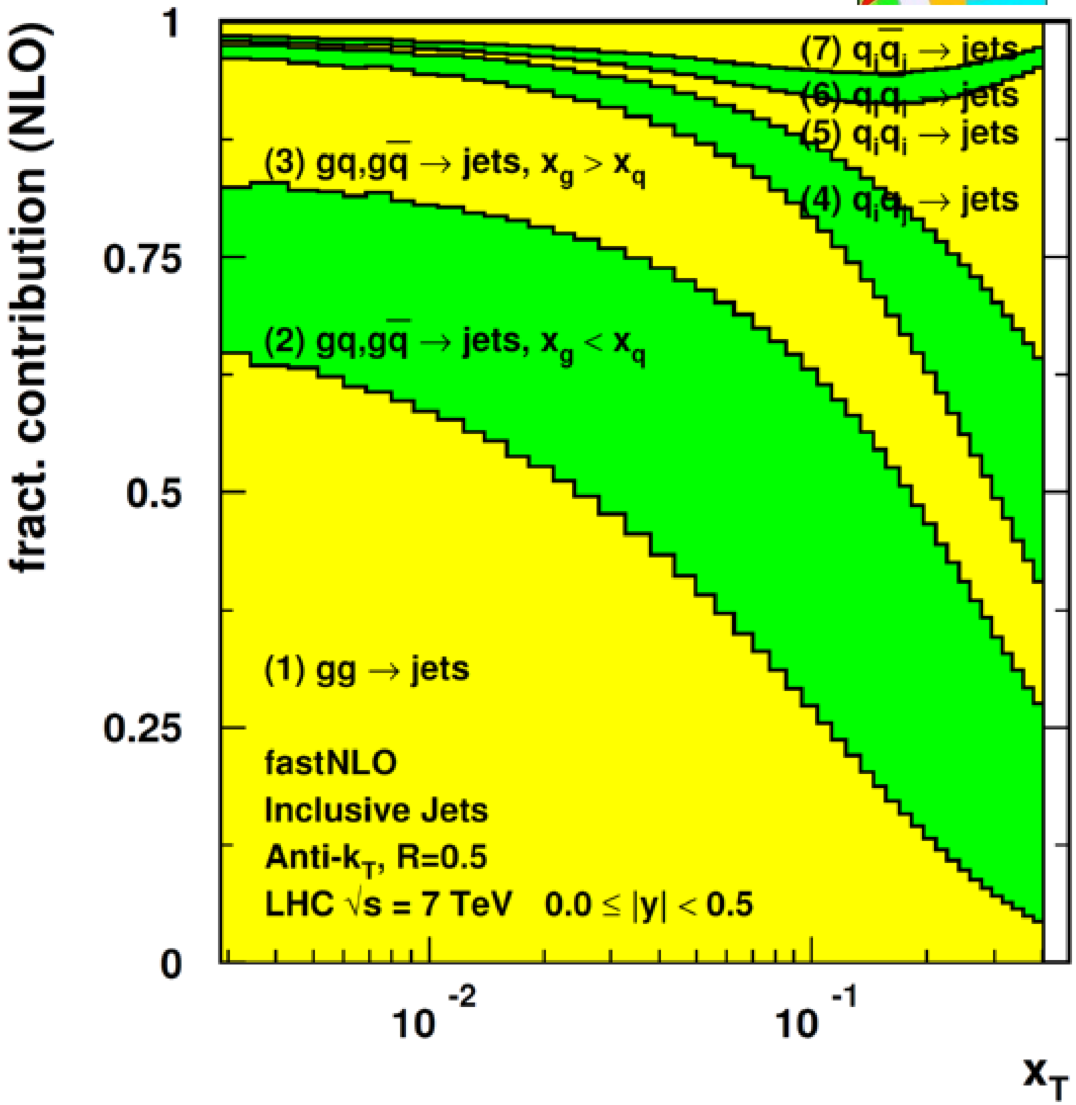
Summary

- For the first time include electroweak and matched NLO+parton showers in PDF+α_s fits
- PDF fits including CMS inclusive jet data demonstrate significant impact on the PDFS, particularly the gluon PDF
- New determination of $\alpha_s(M_Z)$ from inclusive jet cross section
- Results consistent with previous CMS results and the world average
- Running of $\alpha_s(Q)$ consistent with RGE of QCD

Additional material

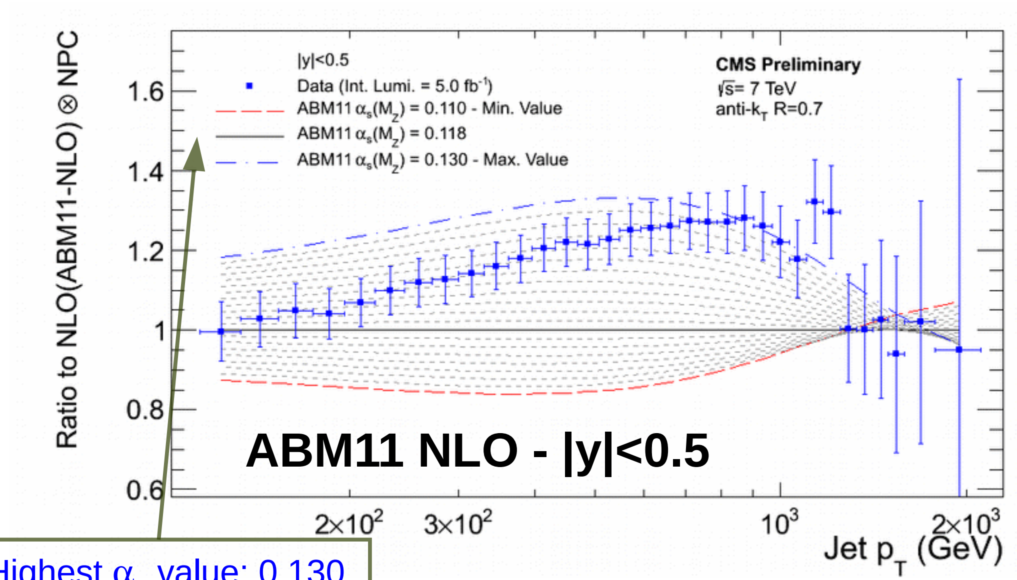
Subprocesses in dijet production

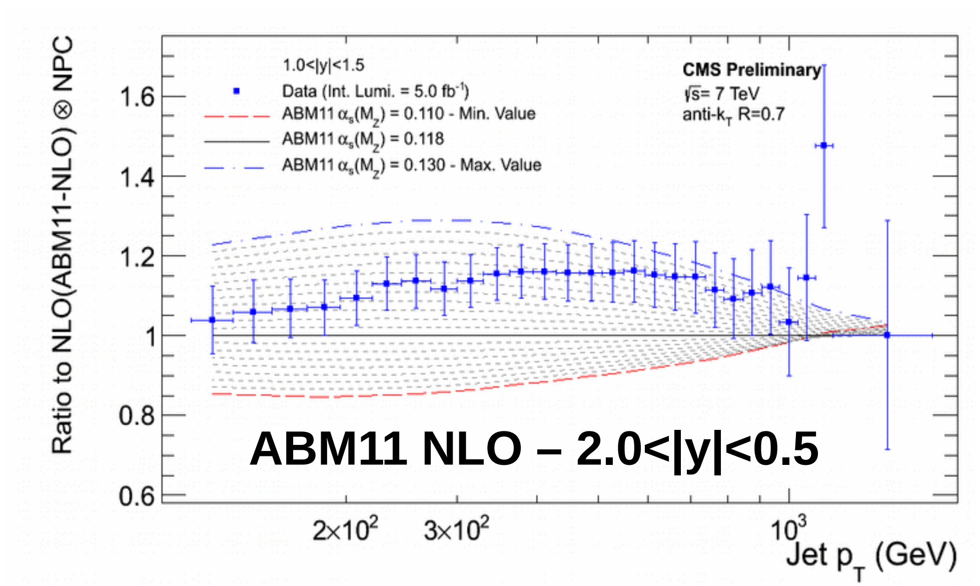
- subprocess fraction as a funct
- **qg and gg processes**
  - dominant below 800 GeV
    → Sensitive to gluon PDF
- **qq processes**
  - prevail above 800 GeV
    → Sensitive to quark PDFs
- **$q\bar{q}$ processes**
  - Suppressed
  - → No sensitivity to antiquark PDFs



Sensitivity of $\alpha_S(m_Z)$: ABM11-NLO

- Sensitivity plots show the ratio of predictions with different values of $\alpha_S(m_Z)$ to the central PDF predictions
- Data with total uncertainty is shown
- Inclusive jet data are not well described using ABM PDFs
  - omitted from further study

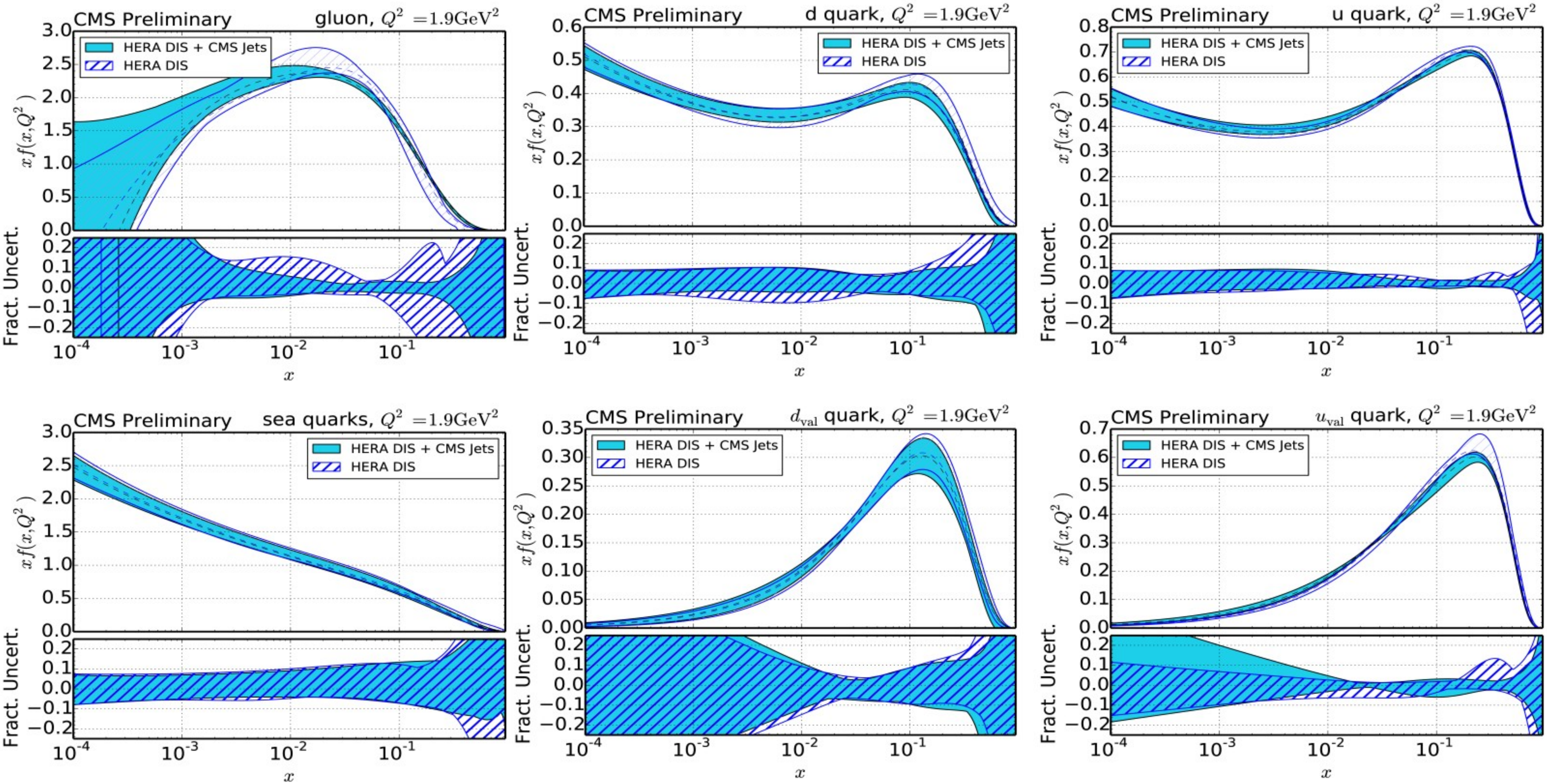




Highest α_S value: 0.130
Central α_S value: 0.118
Lowest α_S value: 0.110

PDF Constraints: Q^2=1.9 GeV^2

- Direct comparison of fitted PDFs at starting scale Q^2 = 1.9 GeV^2
- Overall PDF uncertainty reduced, only increase in low-x u-valence
- Low-x u valence uncertainty previously underestimated



Combined Fits: Constraints

- Direct comparison of all PDFs
- Q^2 = 1E4 GeV^2
- Overall PDF uncertainty reduced, only increase in low-x u-valence