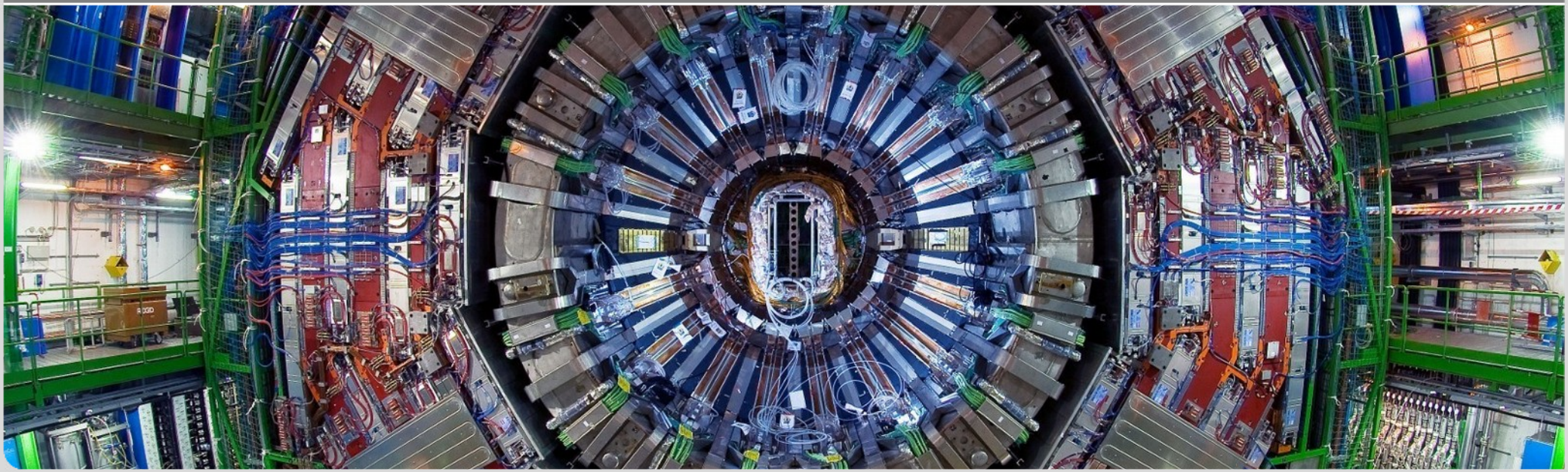
α_s-Extraction and PDF Constraints from Jet Measurements at CMS

G. Sieber on behalf of the CMS collaboration

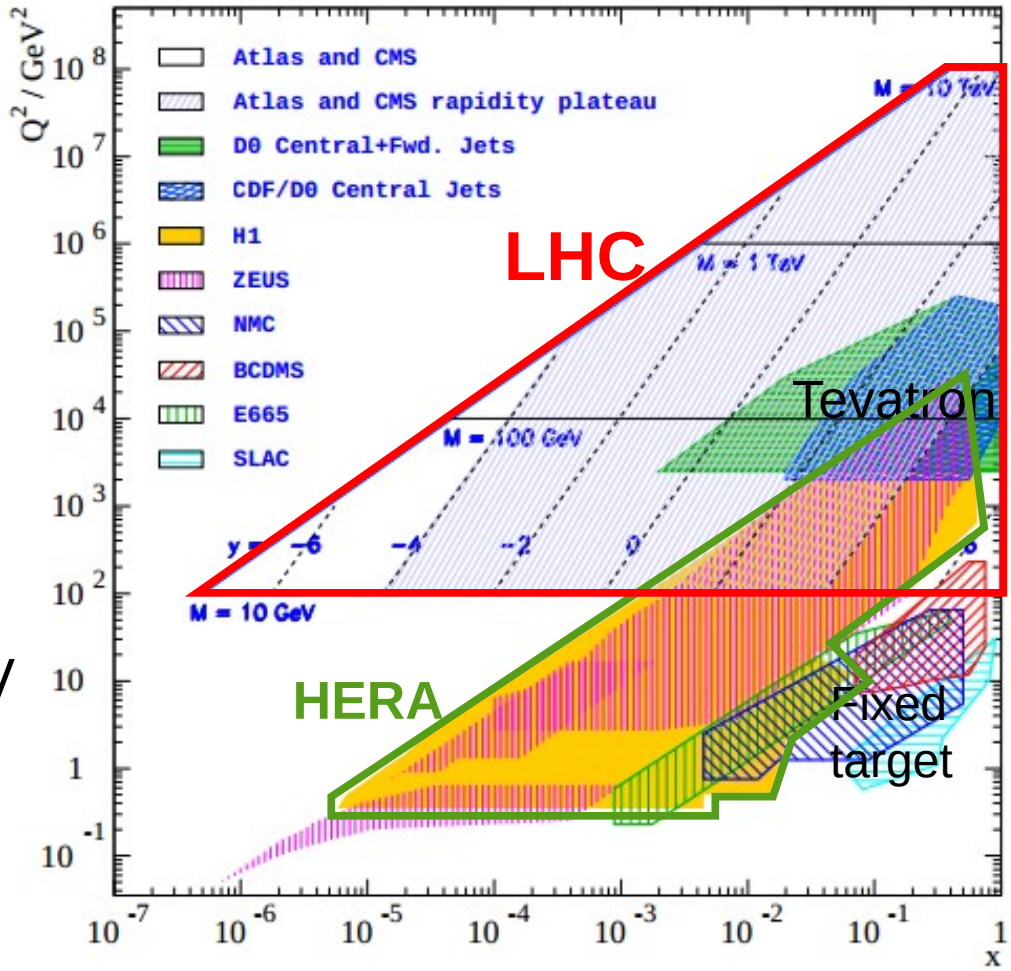
Institut für Experimentelle Kernphysik (IEKP) - KIT



KIT – University of the State of Baden-Wuerttemberg and
National Research Center of the Helmholtz Association

Introduction

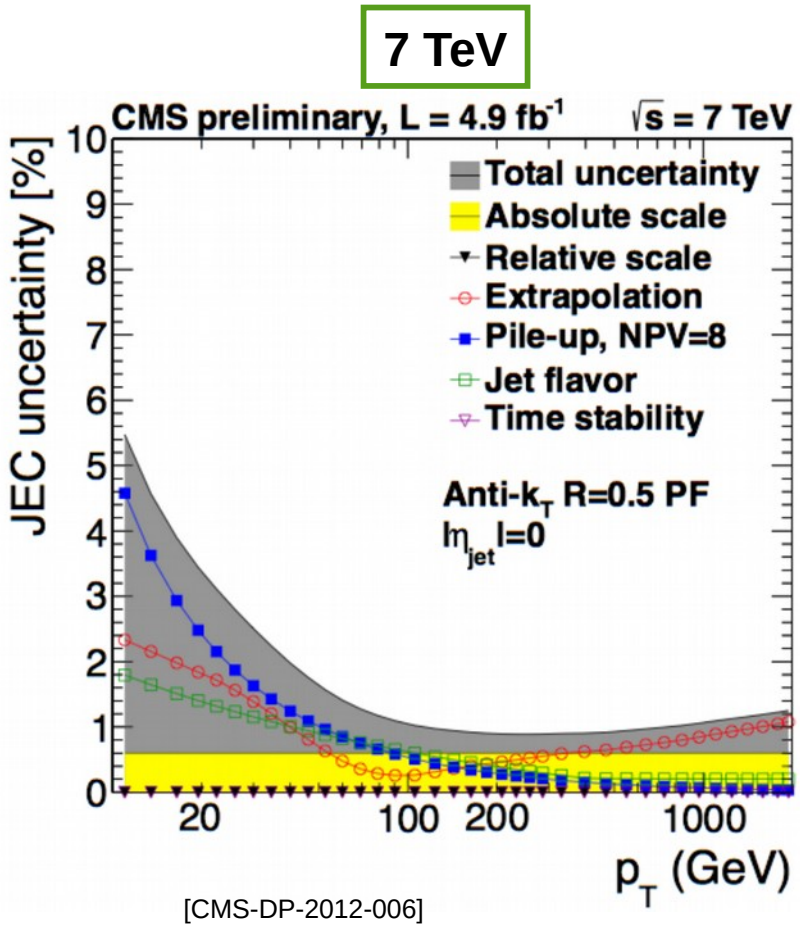
- PDFs and Strong Coupling are a key ingredient for precision measurements
- PDFs up to now mainly constrained by DIS and fixed-target measurements
- LHC measurements provide additional information for PDFs in unexplored phase space regions
- Determination of the Strong Coupling at energies beyond 1 TeV



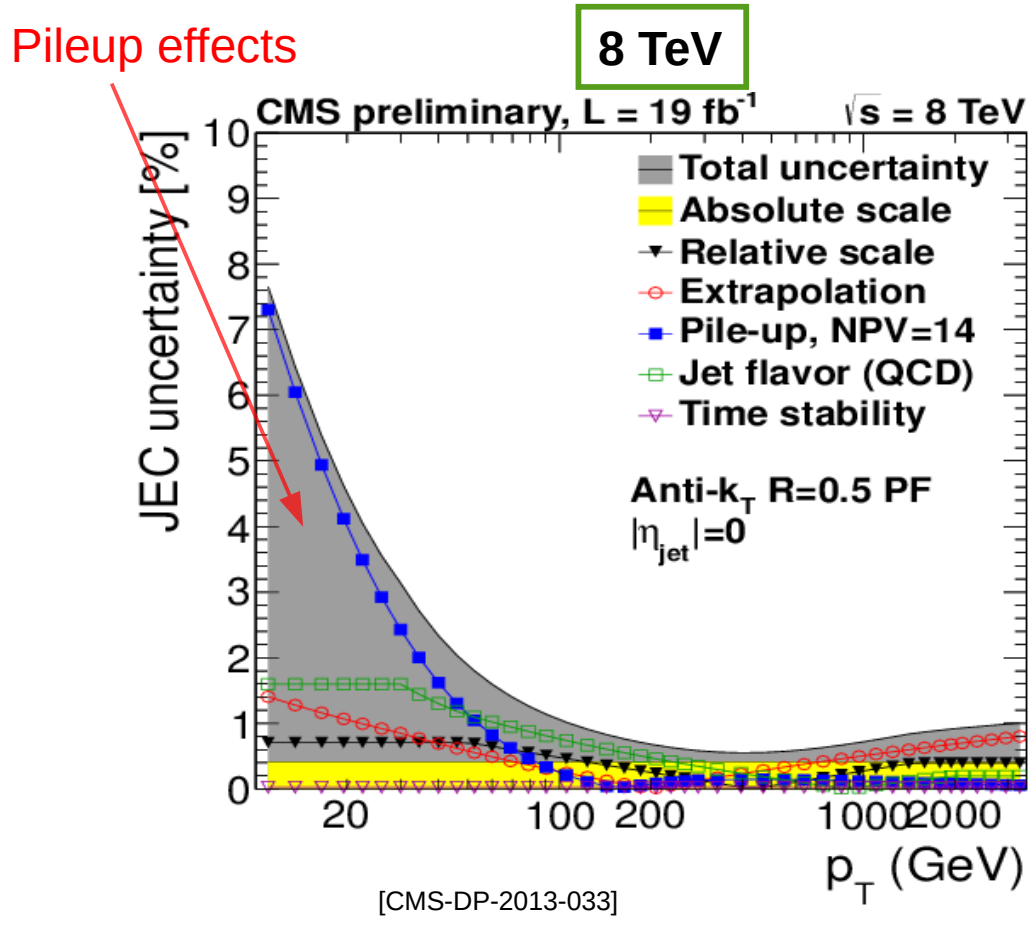
[Braz.J.Phys. 37 (2007) 793-797]

Jet Energy Scale

- Dominant experimental uncertainty for jets
- CMS achieved excellent jet energy scale uncertainties within short time



[CMS-DP-2012-006]



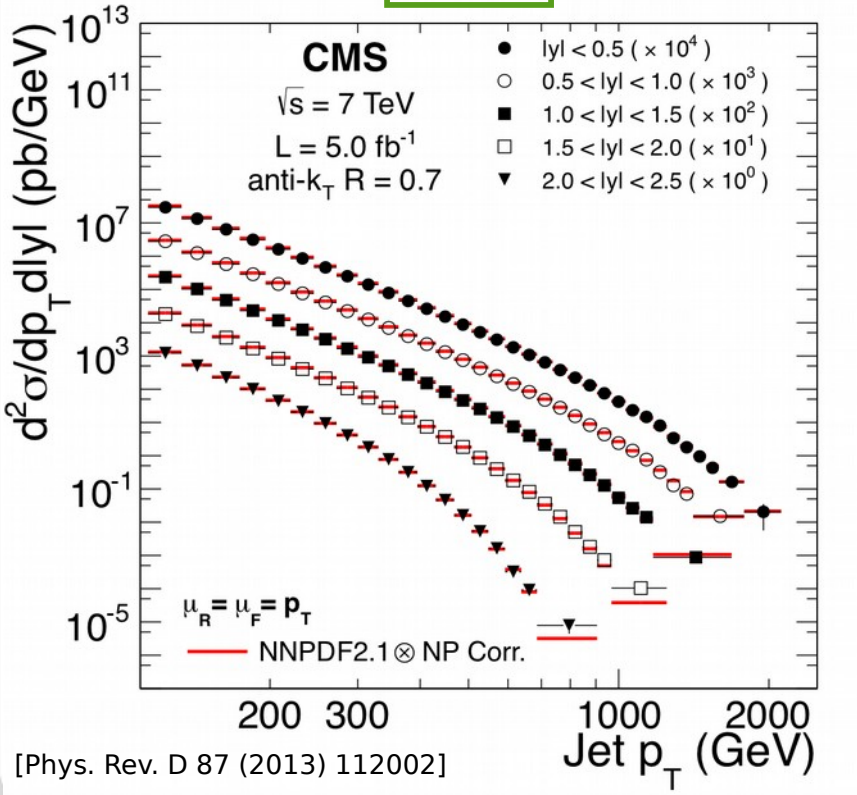
[CMS-DP-2013-033]

Inclusive Jet Production

- Fundamental test of QCD
- Inclusive jet cross section measured by CMS at 7 TeV and 8 TeV
- **Agreement** with NLO+NP calculations over **many orders of magnitude**

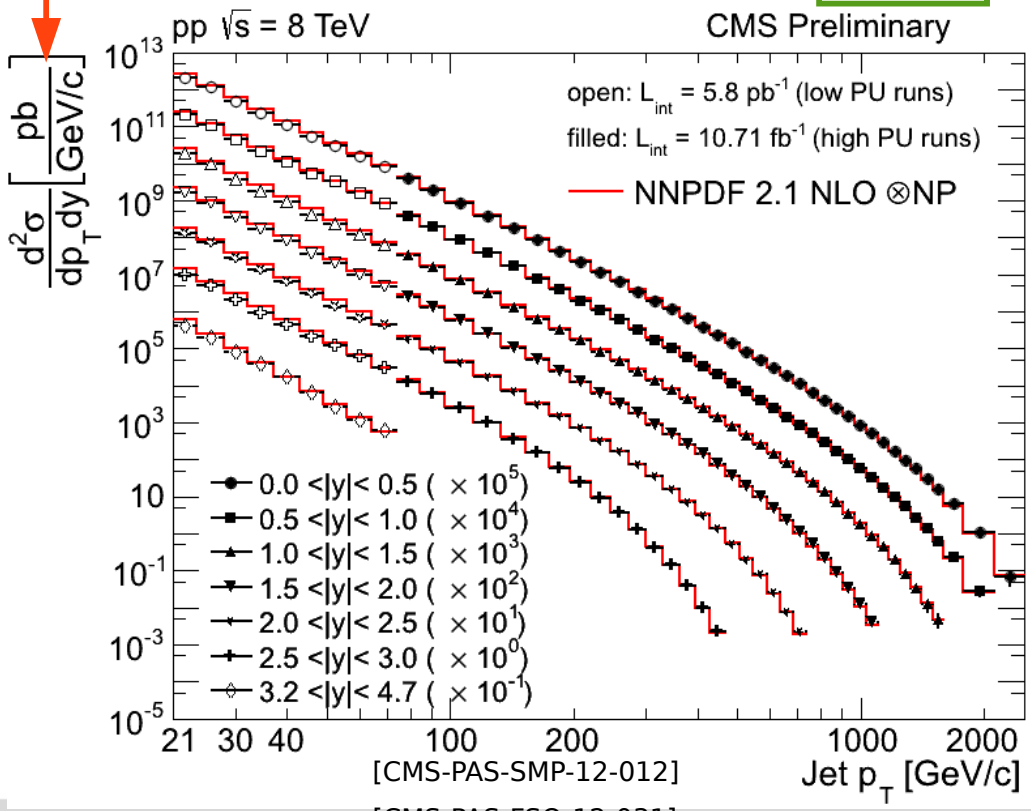
$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}p_\mathrm{T}\,\mathrm{d}y} = \frac{1}{\epsilon \cdot \mathcal{L}_\mathrm{int}} \frac{N_\mathrm{jets}}{\Delta p_\mathrm{T}\ (2 \cdot \Delta|y|)}$$

7 TeV



[Phys. Rev. D 87 (2013) 112002]

8 TeV



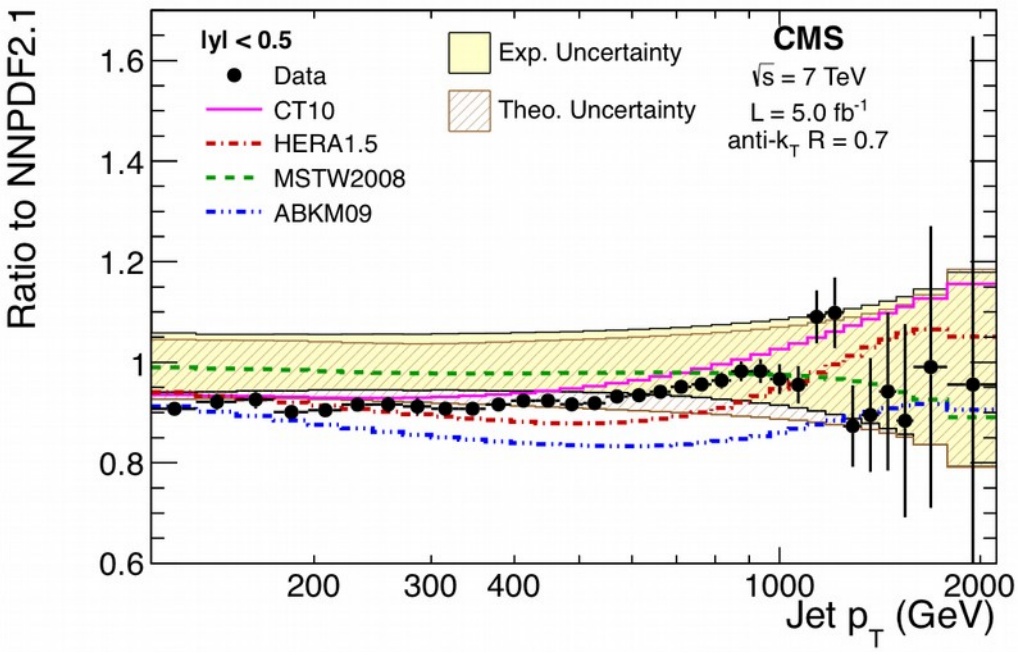
[CMS-PAS-SMP-12-012]

[CMS-PAS-FSQ-12-031]

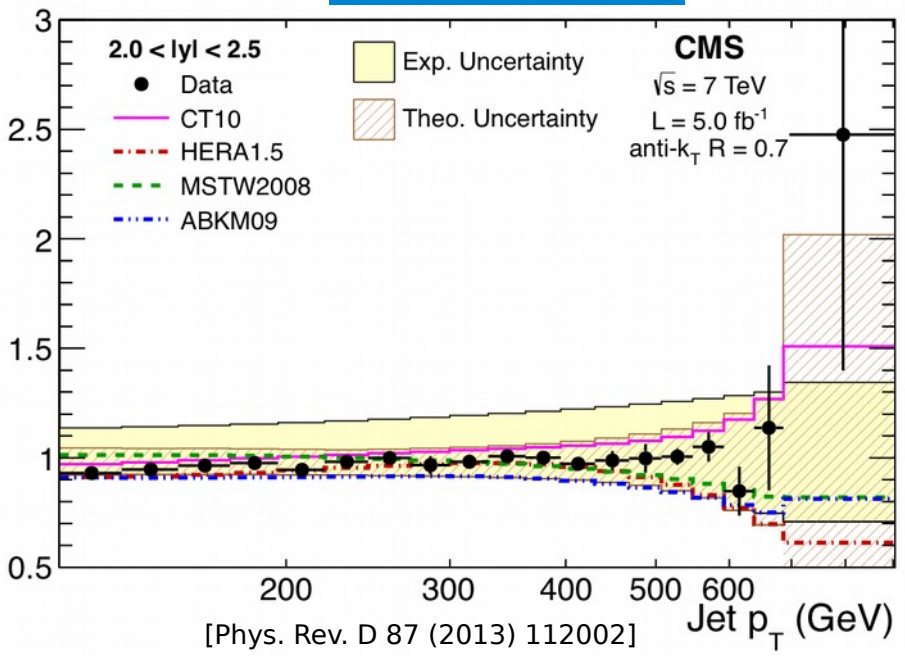
QCD Analysis of 7 TeV Inclusive Jet Data

- Discrimates between PDFs to some extent
- Performing PDF fits, in particular the gluon PDF at high-*x*, can be constrained
- The Strong coupling can be extracted at high jet-p_T

|y| < 0.5



2.0 < |y| < 2.5

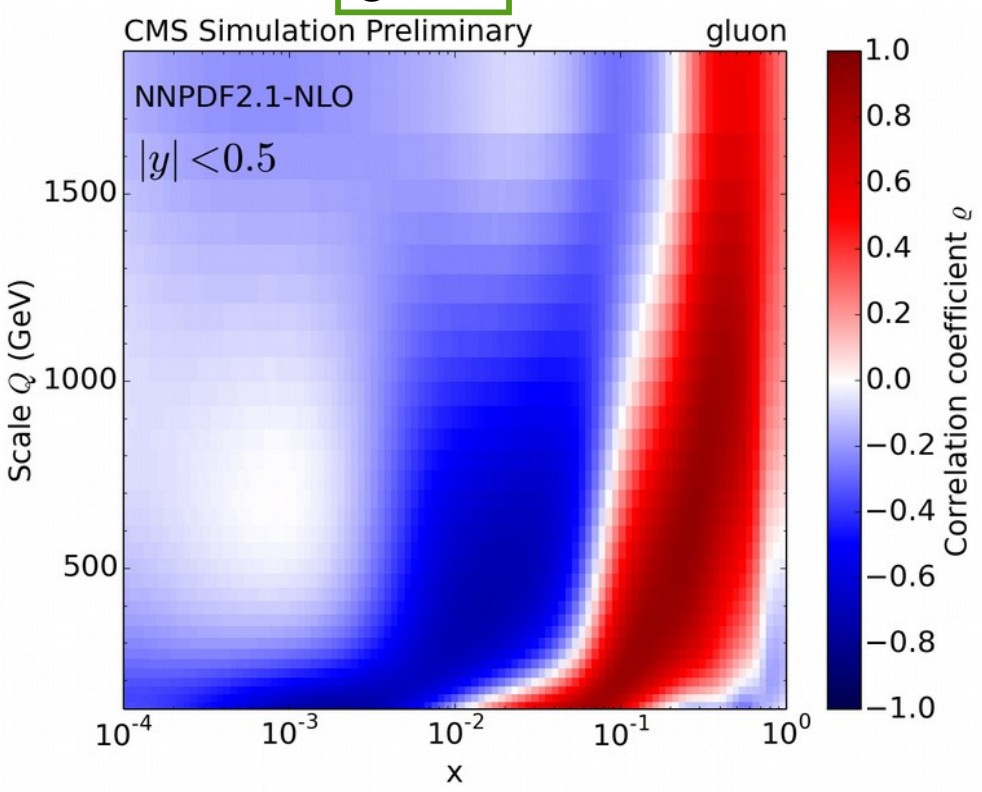


[Phys. Rev. D 87 (2013) 112002]

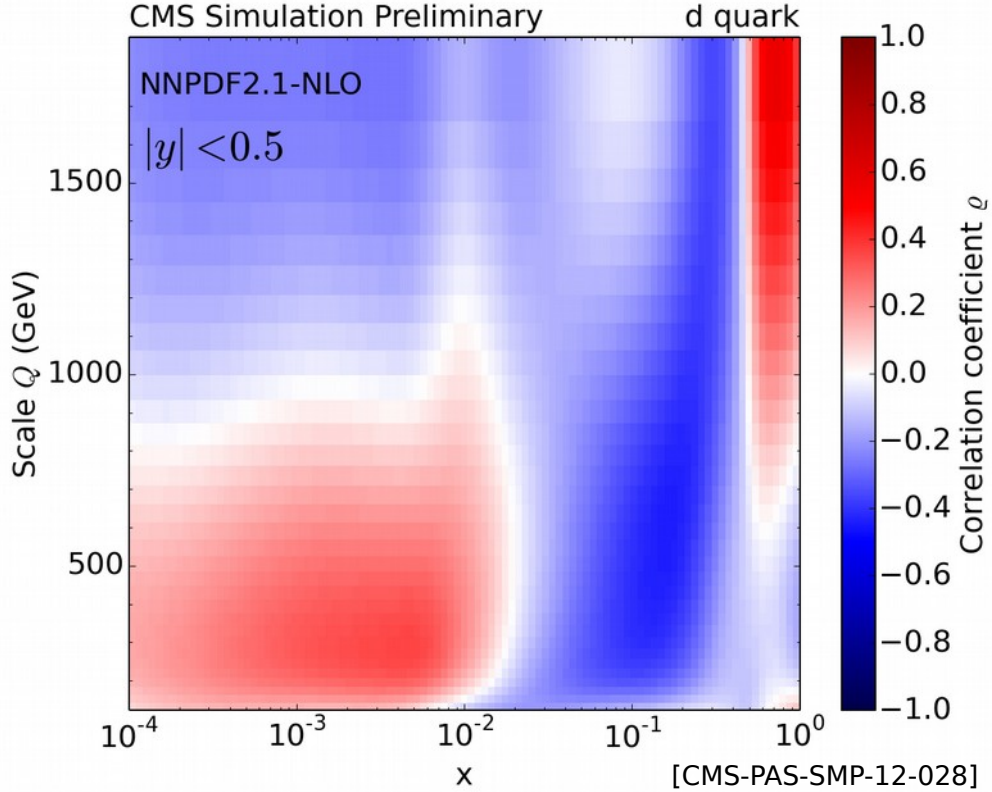
Correlation of Gluon PDF and σ_{jet}

- Gluon PDF: High correlation at 0.05 < x < 0.7 and Q < 1500 GeV
- Quark PDF: High correlation at 0.4 < x < 0.7 and Q > 1000 GeV
- **Constraints on PDFs expected at high-*x***

gluon



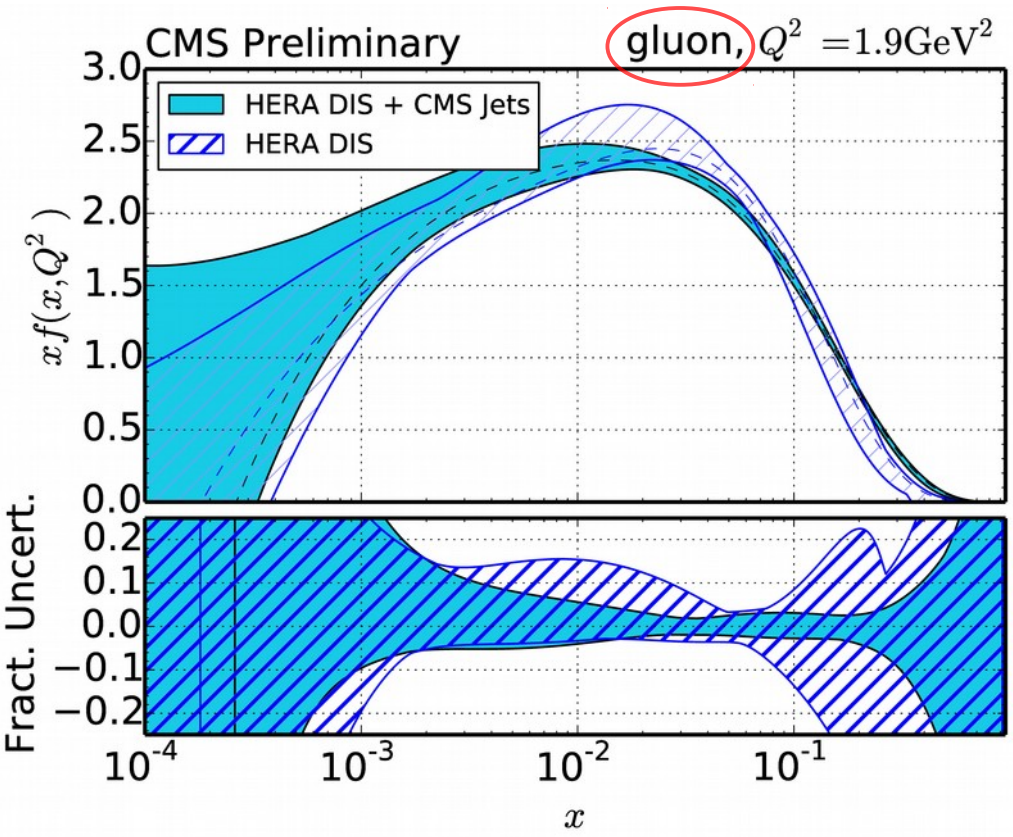
d-quark

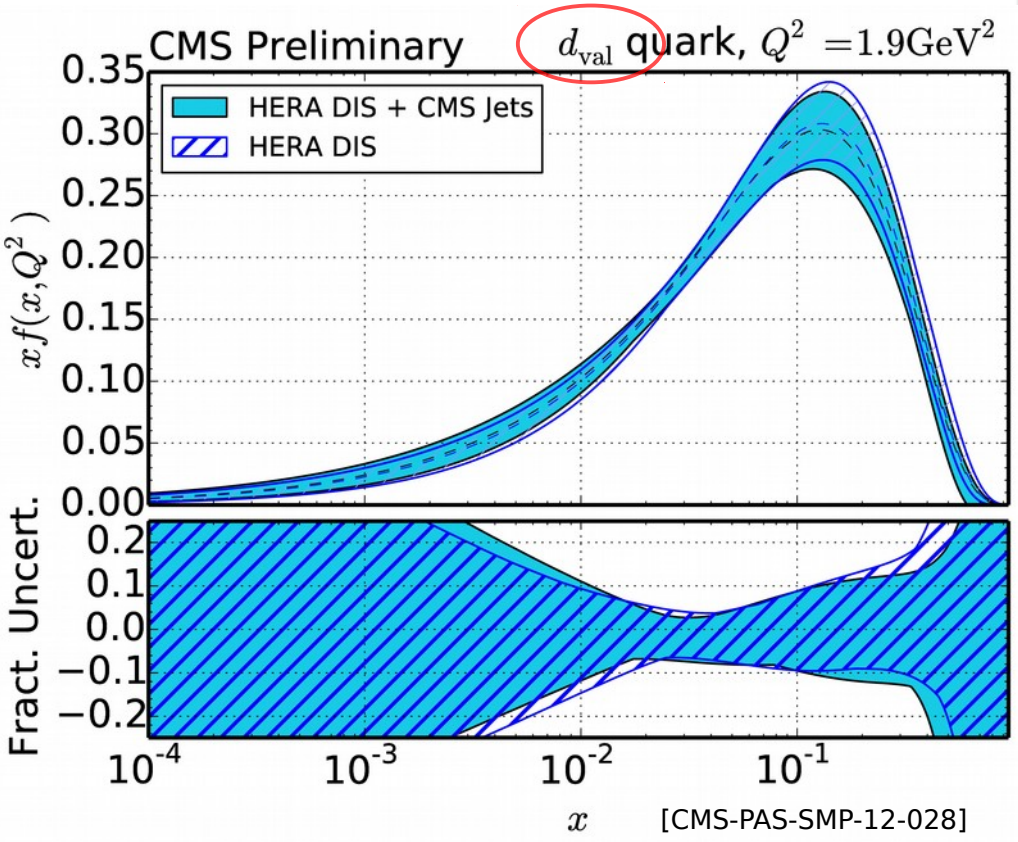


[CMS-PAS-SMP-12-028]

Inclusive Jet Production: PDF Constraints

- Impact of CMS inclusive jet data demonstrated by adding data to PDF fit using HERA-I DIS data
- **Significant improvement** of **gluon** at high-*x*
- Slight changes of d_{val} quark distribution

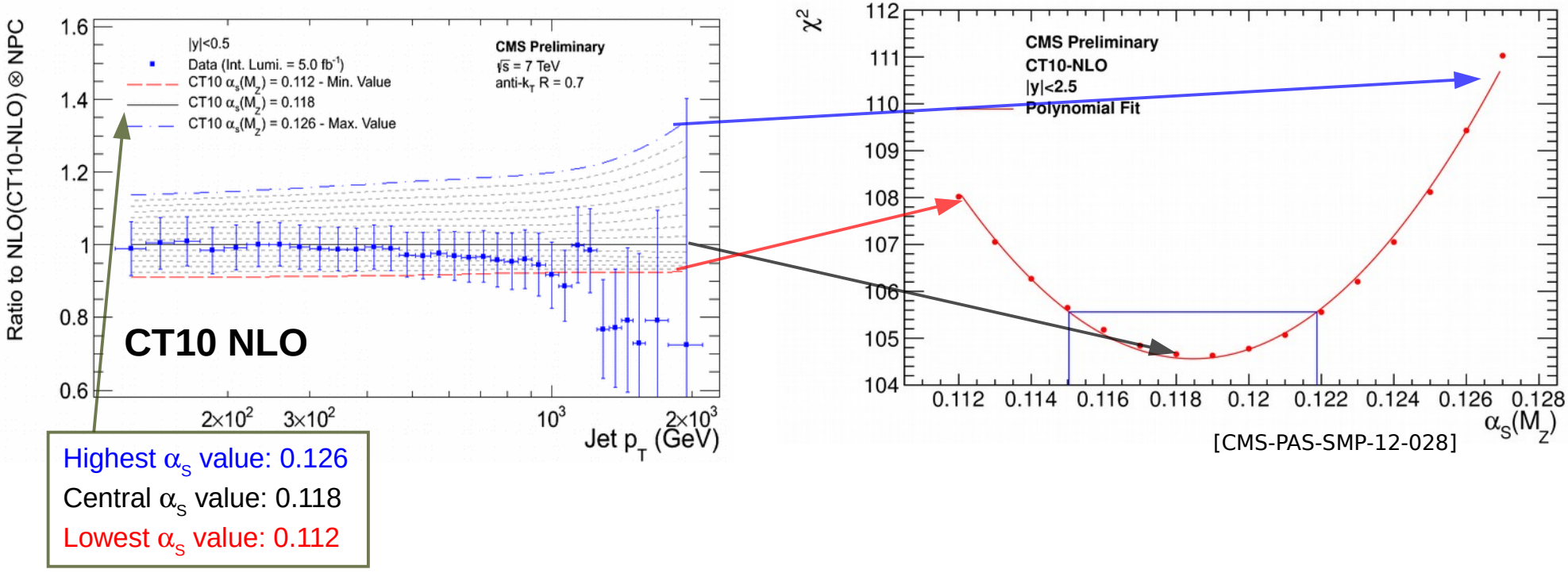




[CMS-PAS-SMP-12-028]

Sensitivity of $\alpha_s(m_z)$: CT10-NLO

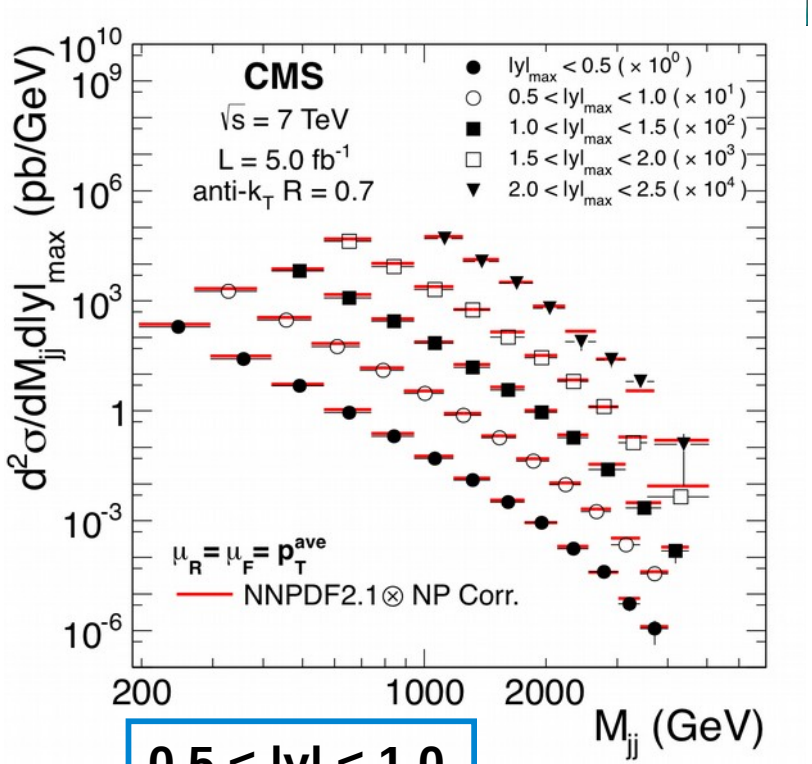
- Sensitivity plots show the ratio of predictions with different values of $\alpha_S(m_Z)$ to the central PDF predictions
- NLO+NP theory prediction using the $a_s(m_Z)$ series of the PDF groups compared to data using χ^2-test



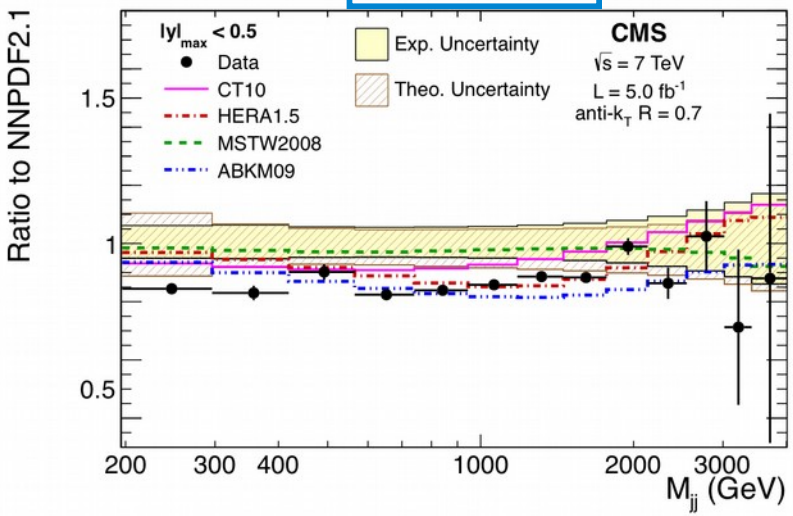
$$\alpha_S(m_Z) = 0.1185 \pm 0.0019(\text{exp.}) \pm 0.0028(\text{PDF}) \pm 0.0004(\text{NP})^{+0.0055}_{-0.0022}(\text{scale})$$

Dijet Mass Cross Section

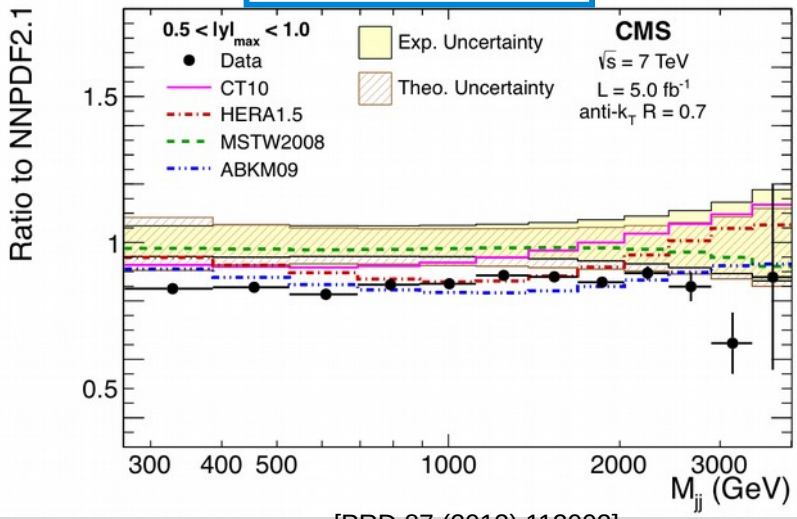
- Study of invariant mass of dijet events
  - $p_{T1} > 60$ GeV
  - $p_{T2} > 30$ GeV
- Double differential measurent in
  - invariant mass m_{12}
  - rapidity separation y_{max}
- Comparison with NLO+NP calculations



|y| < 0.5



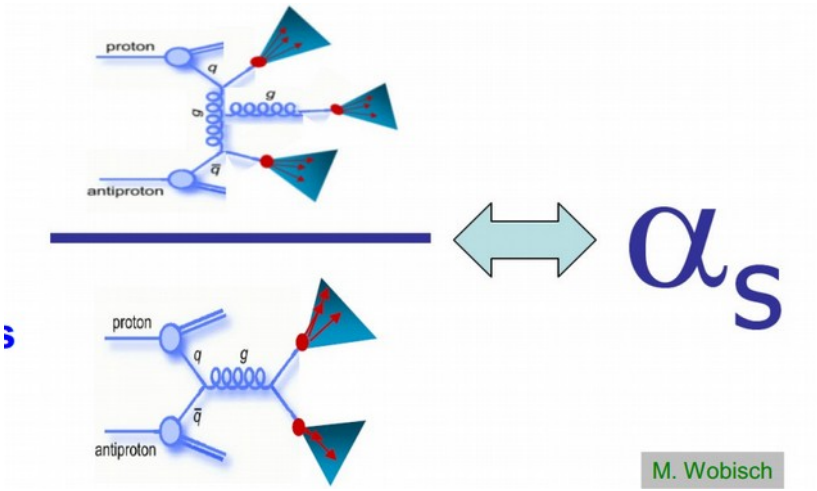
0.5 < |y| < 1.0

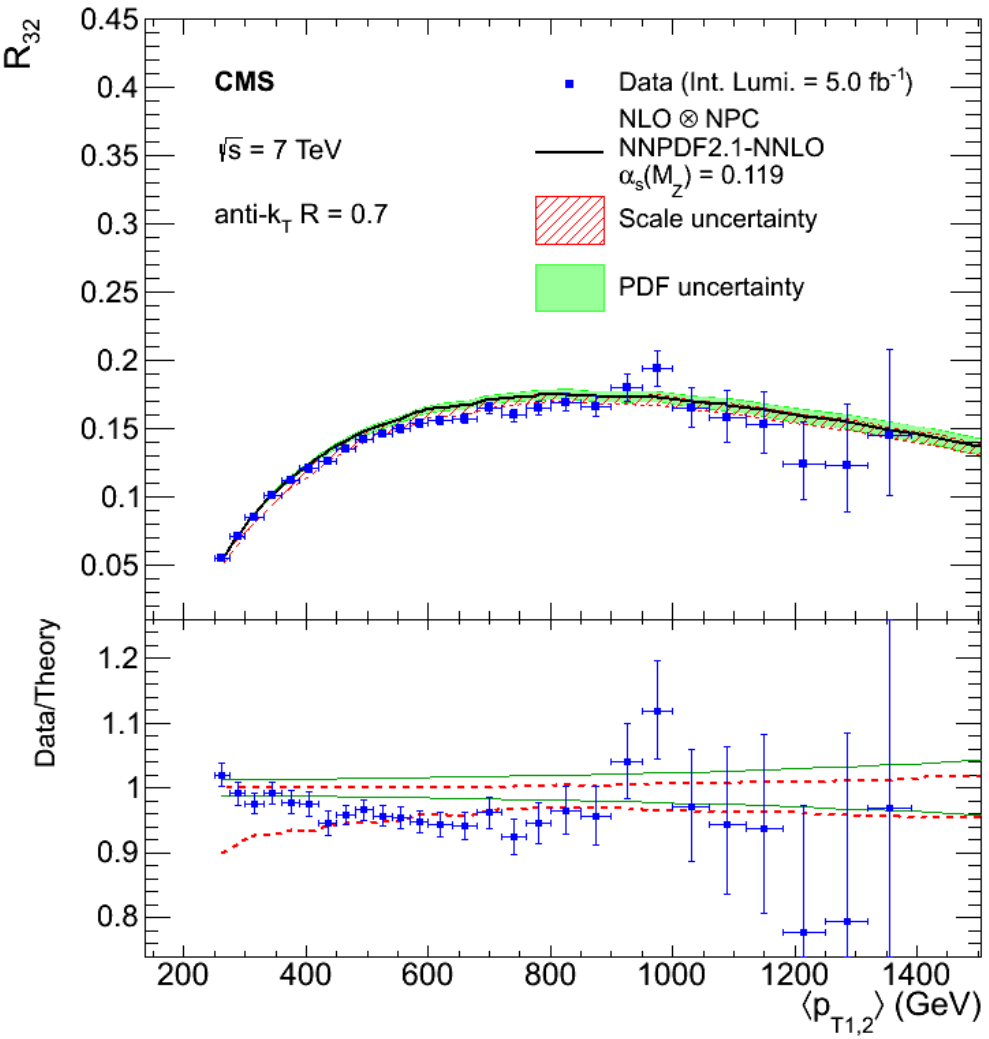


[PRD 87 (2013) 112002]

3-jet to 2-jet cross section ratio

- Ratio of 3-jet and 2-jet production as function of the average p_T
- Cancellation of luminosity uncertainty and reduction of systematic uncertainties
- Avoids direct dependence on PDFs and RGE of QCD



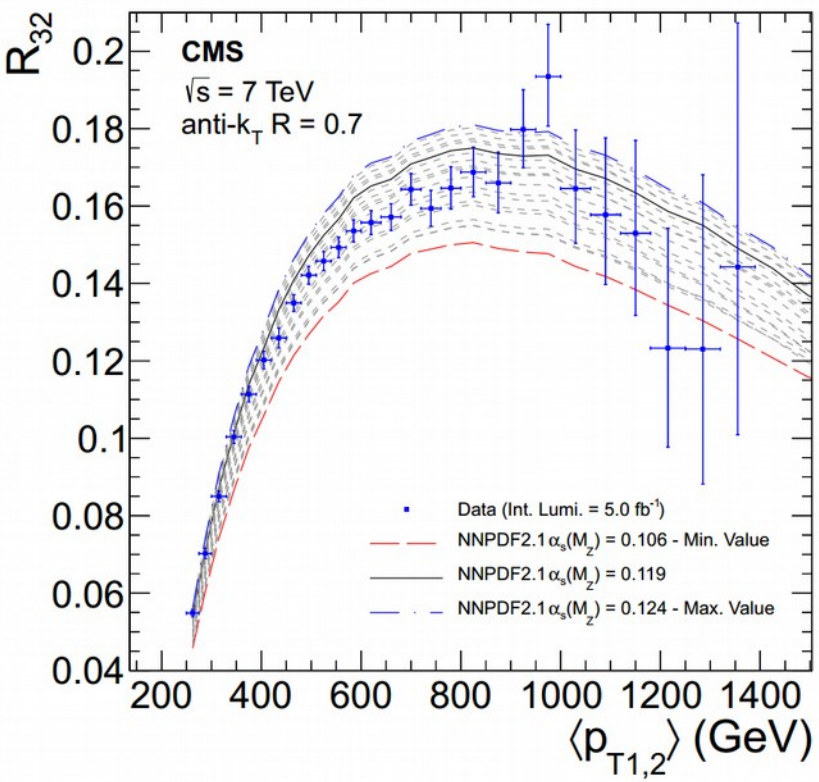


[EPJ C 73 (2013) 2604]

3-jet to 2-jet cross section ratio

- To avoid threshold effects, only region > 400 GeV fitted
- Fit result:

$$\alpha_S(m_Z) = 0.1148 \pm 0.0014(\text{exp.}) \pm 0.0018(\text{PDF}) \pm 0.0050(\text{theory})$$



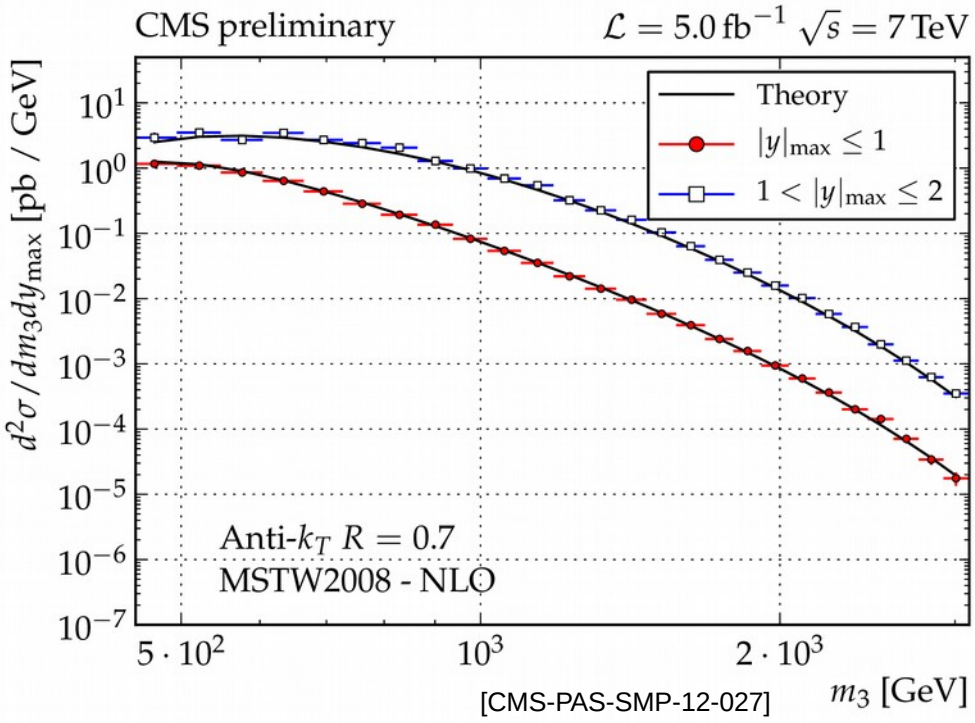
- Running can be tested by splitting measurement in Q-dependent regions

$\langle p_{T1,2} \rangle$ range (GeV)	Q (GeV)	$\alpha_S(M_Z)$	exp.	PDF	theory
420–600	474	0.1147	±0.0015	±0.0015	±0.0057
600–800	664	0.1132	±0.0018	±0.0025	±0.0039
800–1390	896	0.1170	±0.0024	±0.0021	±0.0048

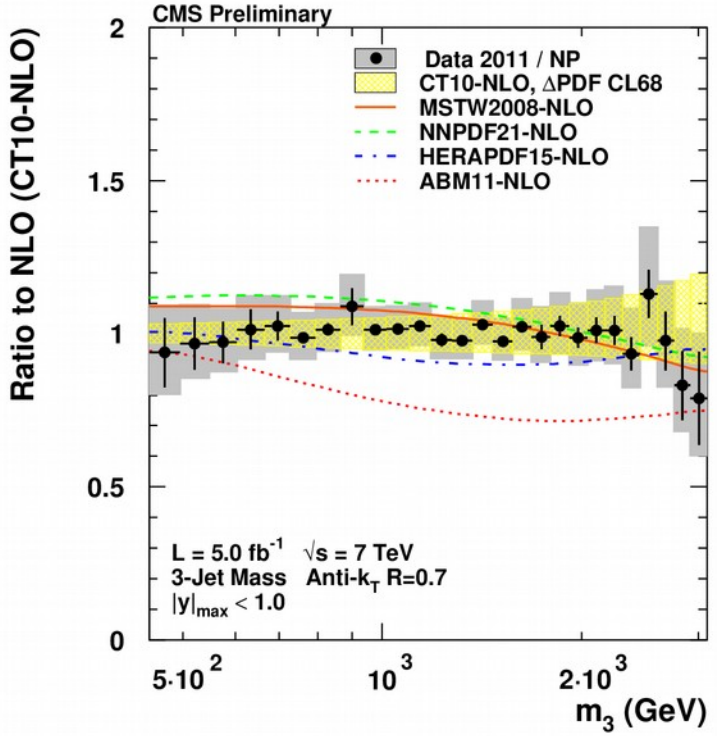
[EPJ C 73 (2013) 2604]

3-Jet Mass Cross Section

- 3-jet system defined using invariant mass and max. rapidity
- Double differential 3-jet cross section measured $\dfrac{d^2\sigma}{dm_3 dy_{\max}}$
- Compared to NLO+NP calculations
  - Sensitive to PDFs and α_s



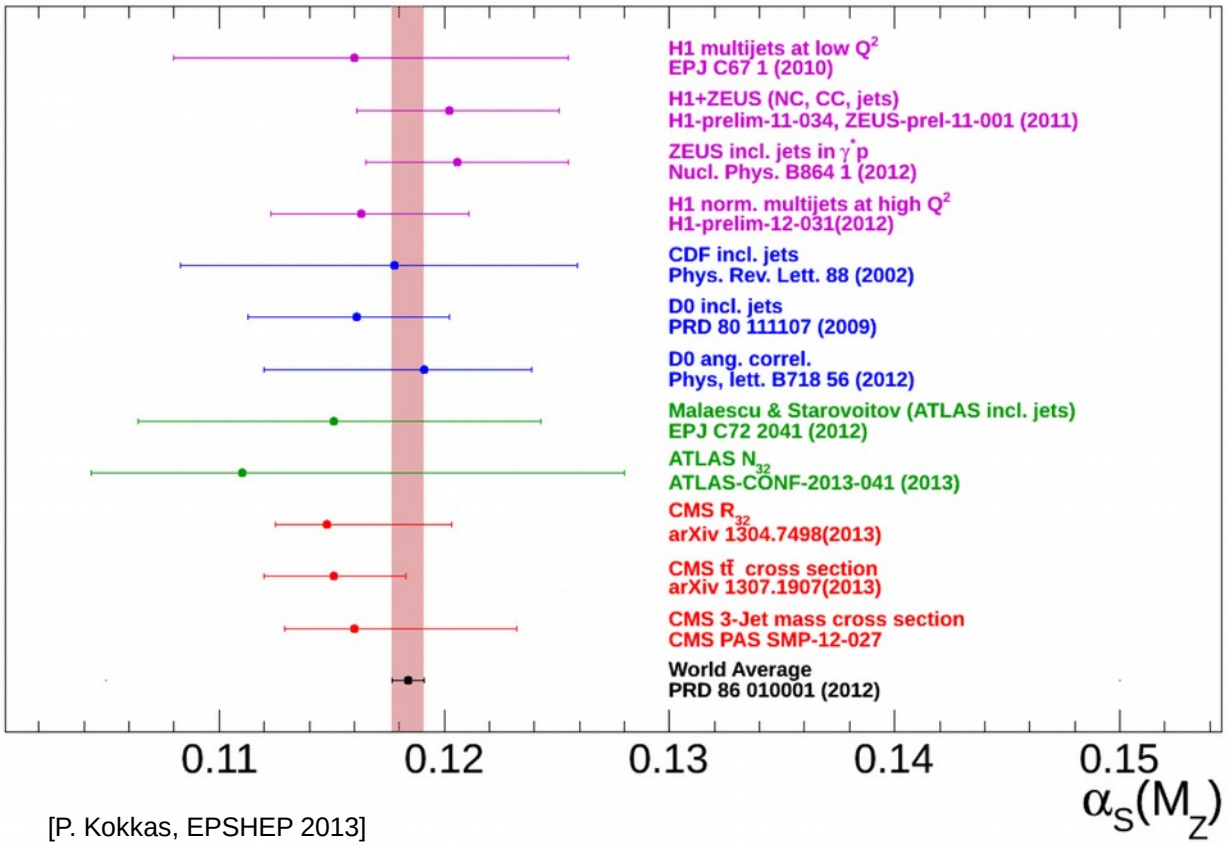
[CMS-PAS-SMP-12-027]



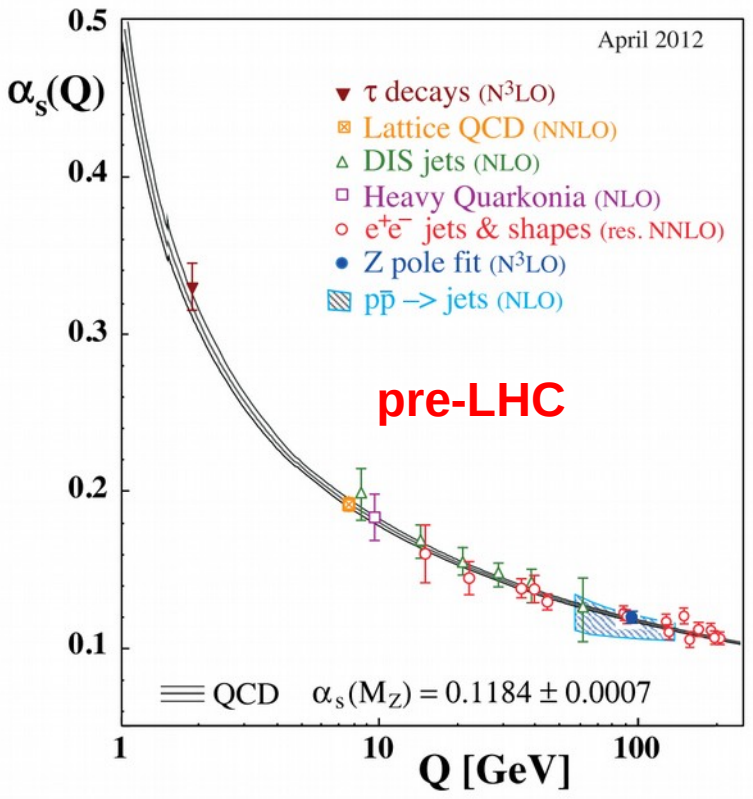
$$\alpha_S(m_Z) = 0.1160^{+0.0025}_{-0.0023}(\mathrm{exp,PDF,NP})^{+0.0068}_{-0.0021}(\mathrm{scale})$$

Comparison of Results

- All extracted values of $\alpha_S(m_Z)$ from CMS measurements are in good agreement with each other and the world average
- Measurements can be used to test running of the Strong Coupling

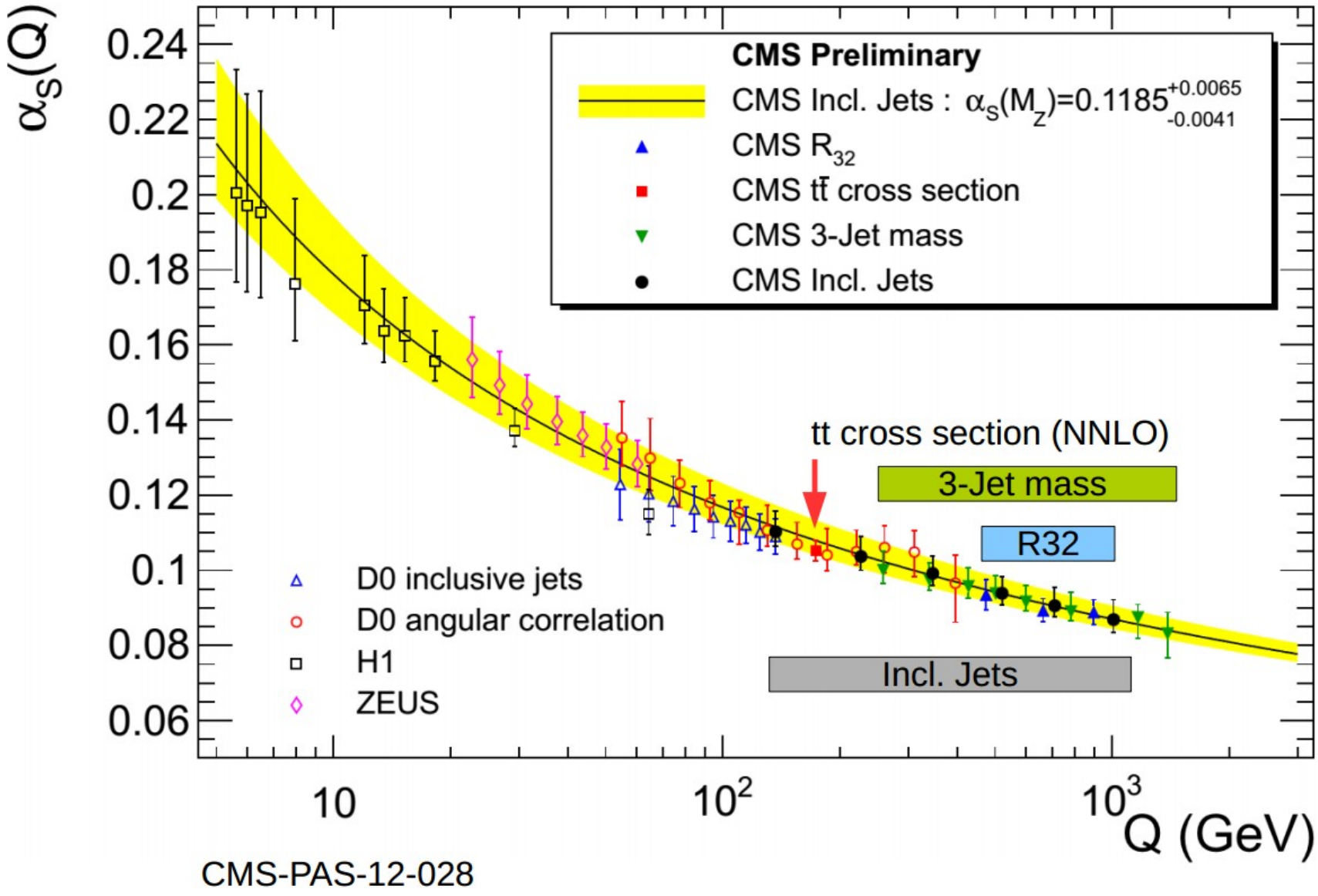


[P. Kokkas, EPSHEP 2013]



[PDG 2012]

Running of the Strong Coupling



Summary

- Many Jet observables analyzed with **7** and **8 TeV** data
- Measurements **well described** by NLO+NP theory predictions
- Precision of **gluon PDF** can be significantly improved at high-*x*
- The Strong Coupling has been extracted **beyond 1 TeV**
  - **Running confirmed** at high energies

- Scale uncertainties dominant uncertainty contribution when extracting the Strong Coupling
  - NNLO calculations needed to improve precision on a_S

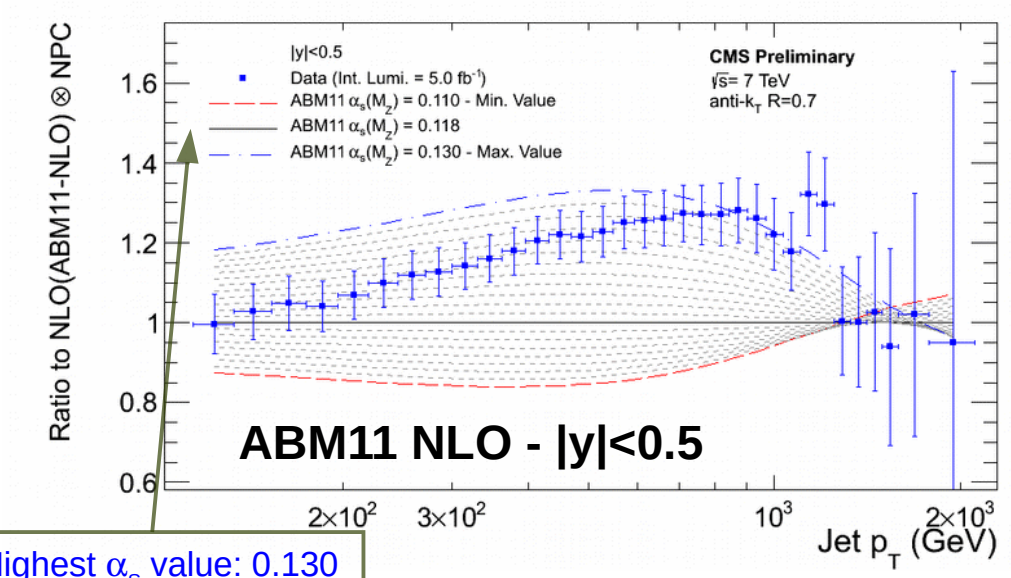
See also talks by
P. Kokkas: Jet Production measurements at CMS
R. Placakyte: Strange quark PDF from CMS W measurements

More interesting results by CMS:
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsFSQ

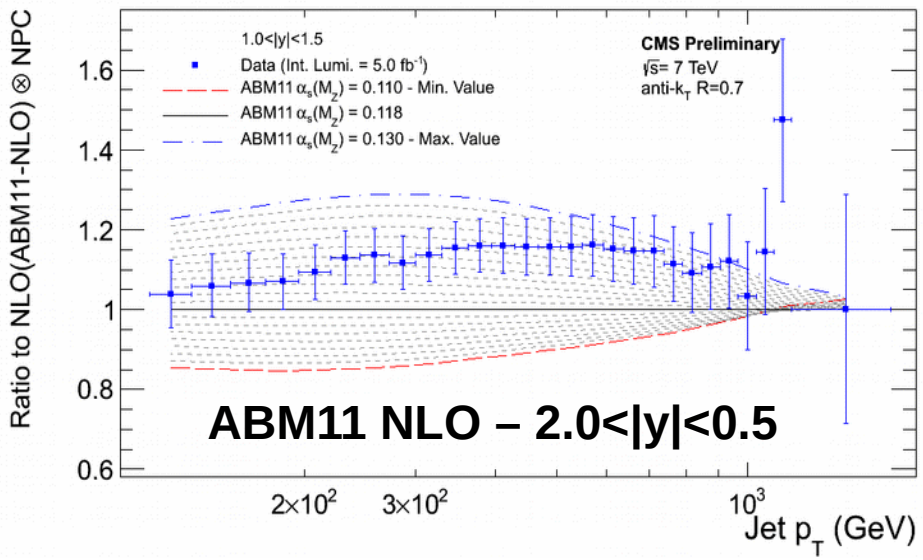
Additional material

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



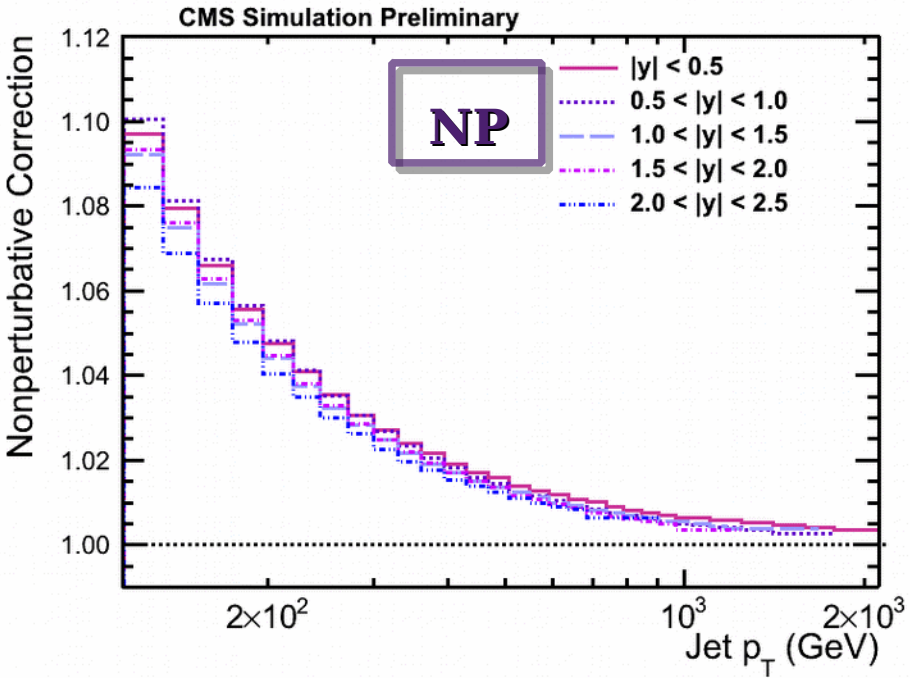
Highest α_s value: 0.130
Central α_s value: 0.118
Lowest α_s value: 0.110

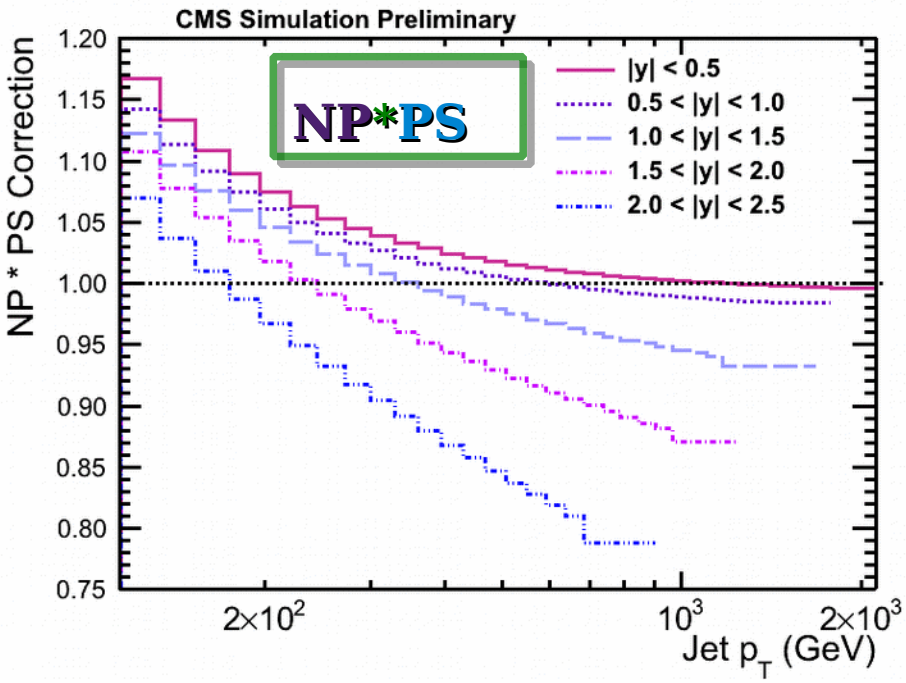


[CMS-PAS-SMP-12-028]

NP & PS Correction

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

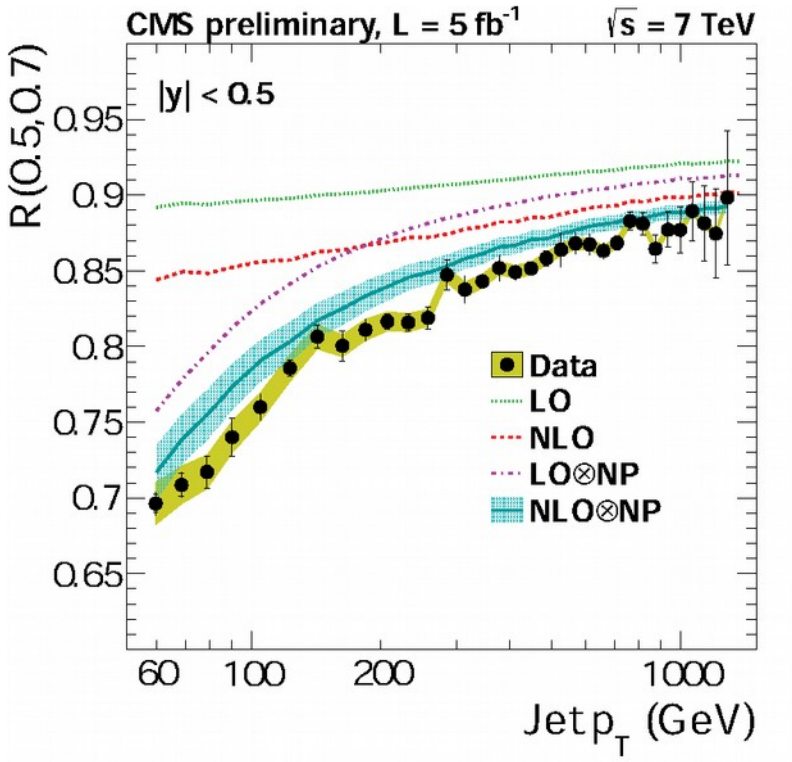


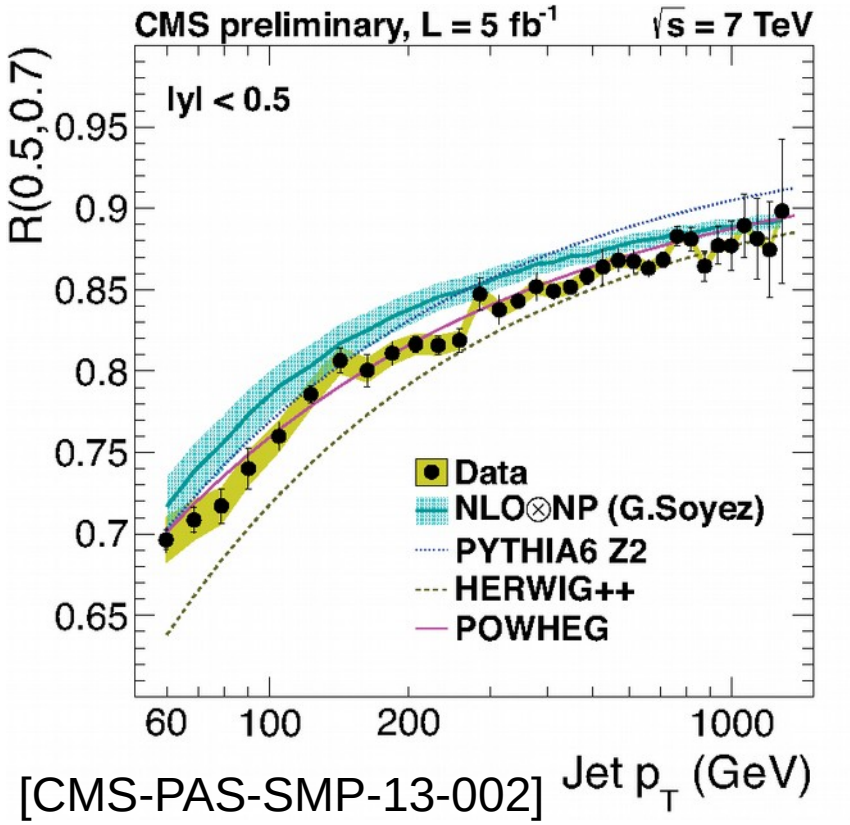


[CMS-PAS-SMP-12-028]

Inclusive Jets – Ratio of R=0.5 and 0.7

- Ratio of different jet clustering sizes
- Large discrepancies when comparing to LO simulations and also to fixed order calculation at NLO+NP
- NLO calculation with matched parton showers describe data well





[CMS-PAS-SMP-13-002]