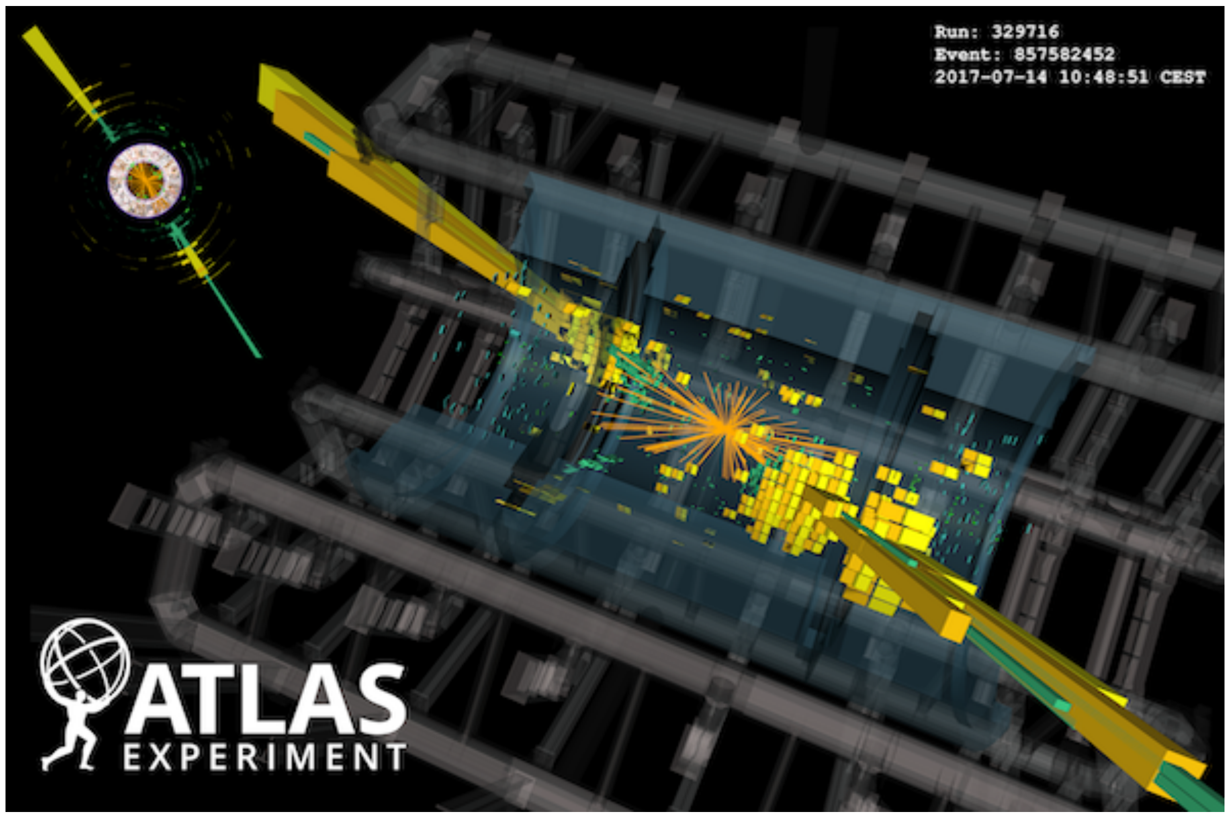
Measurement of Dijet Azimuthal Decorrelations and Extraction of α_S



- Motivation – QCD, α_S and the RGE
- Dijet azimuthal decorrelation observable
- Measurement of azimuthal decorrelations
  Phys. Rev. D 98 (2018) 092004
- Extraction of the strong coupling constant α_S

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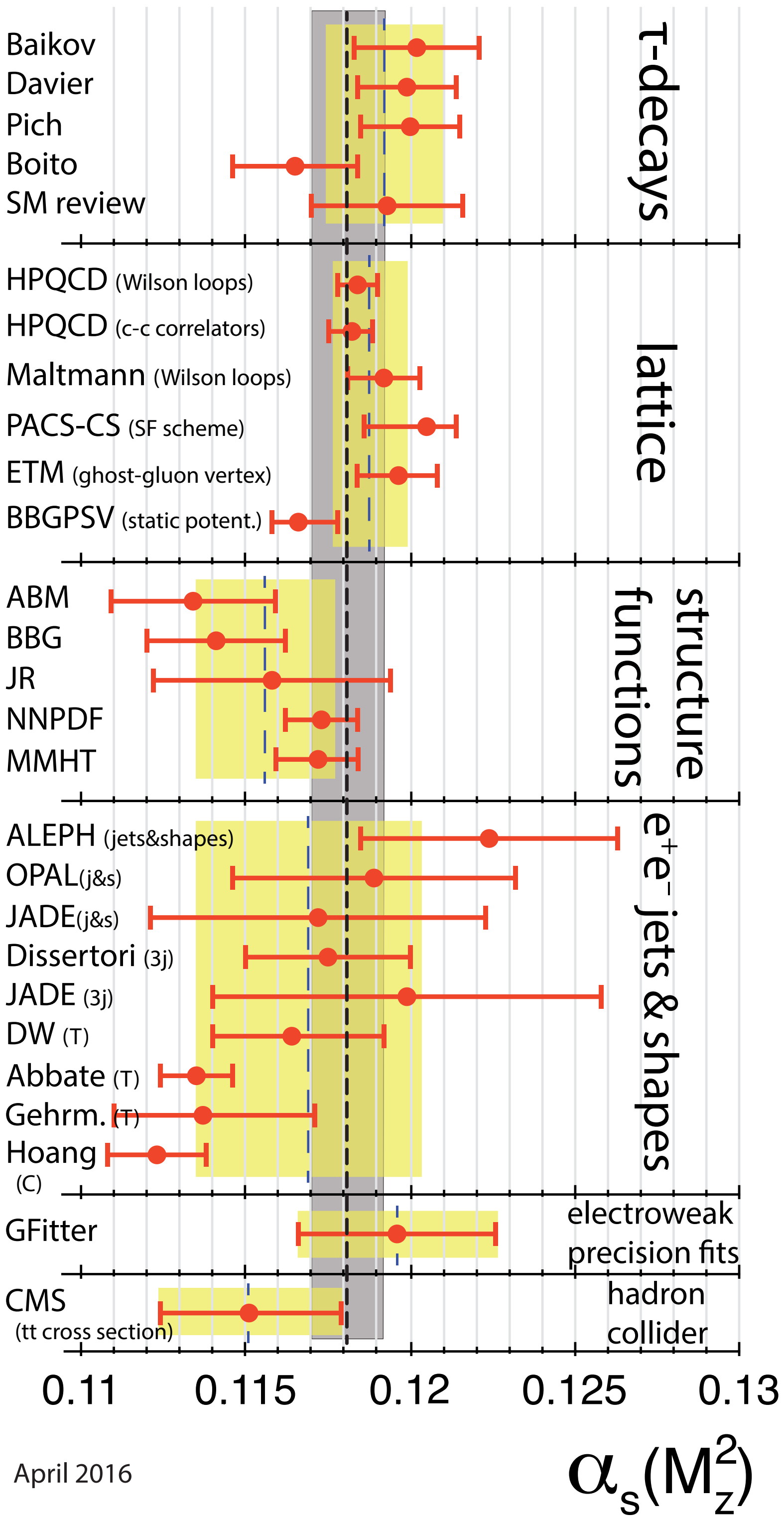
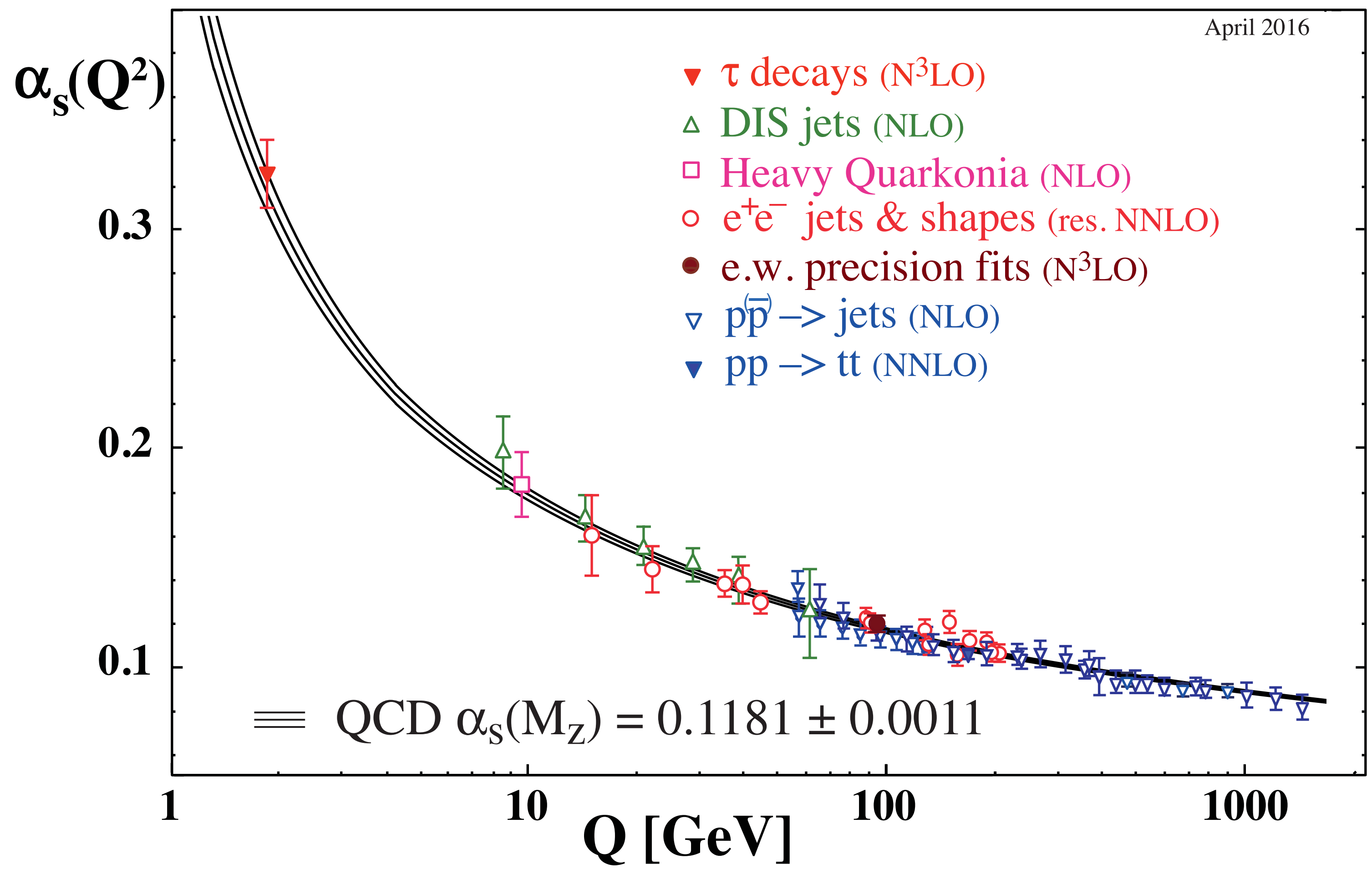
QCD, α_S and the RGE



- Quantum Chromodynamics (QCD) is the theory of the strong interaction
- Renormalization group equation (RGE) encodes the dependence of the coupling parameter on the energy scale μ (=running)
- Values of $\alpha_S(\mu)$ are not predicted



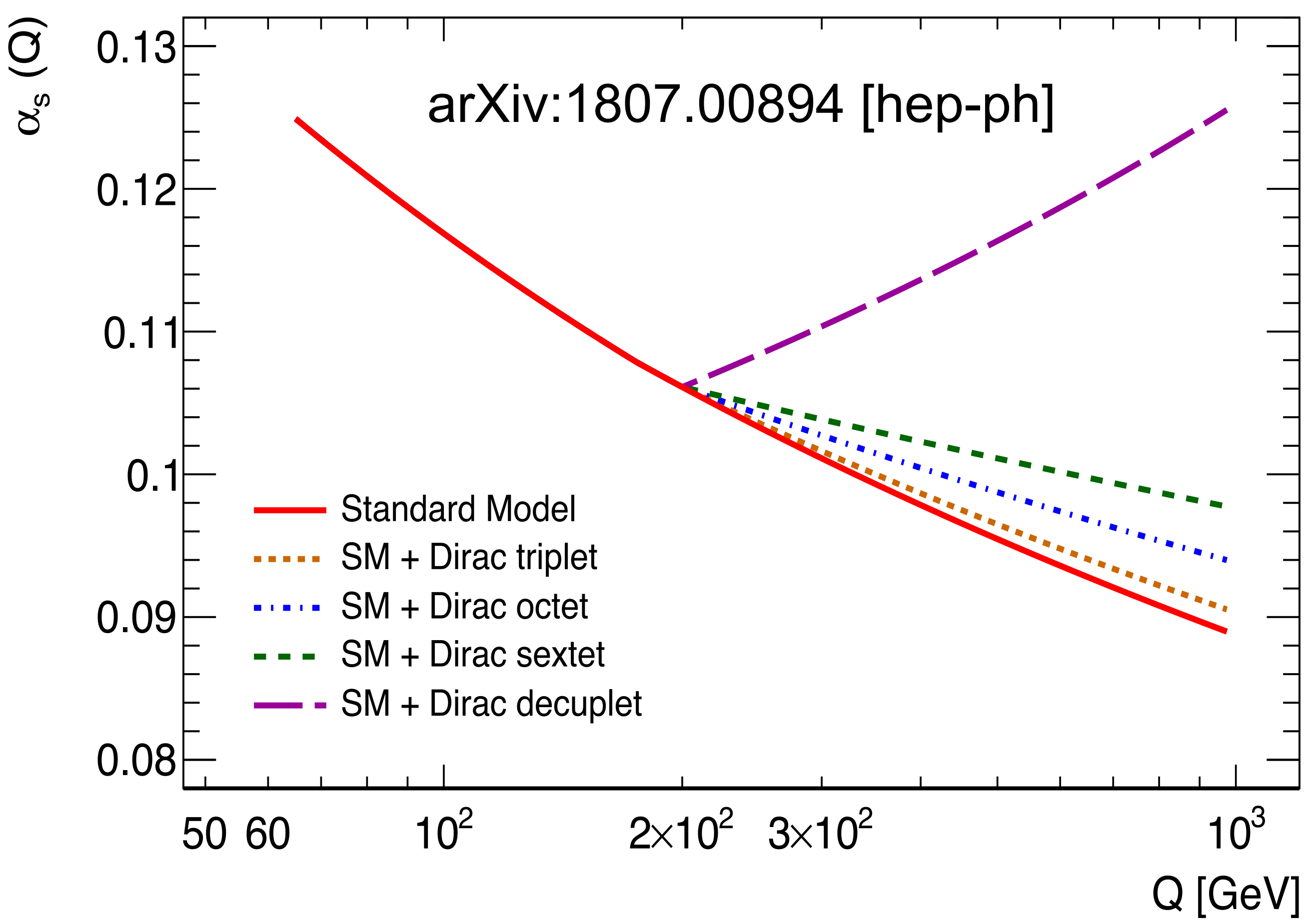
M. Tanabashi et al. (Particle Data Group), Phys. Rev. D **98**, 030001 (2018)

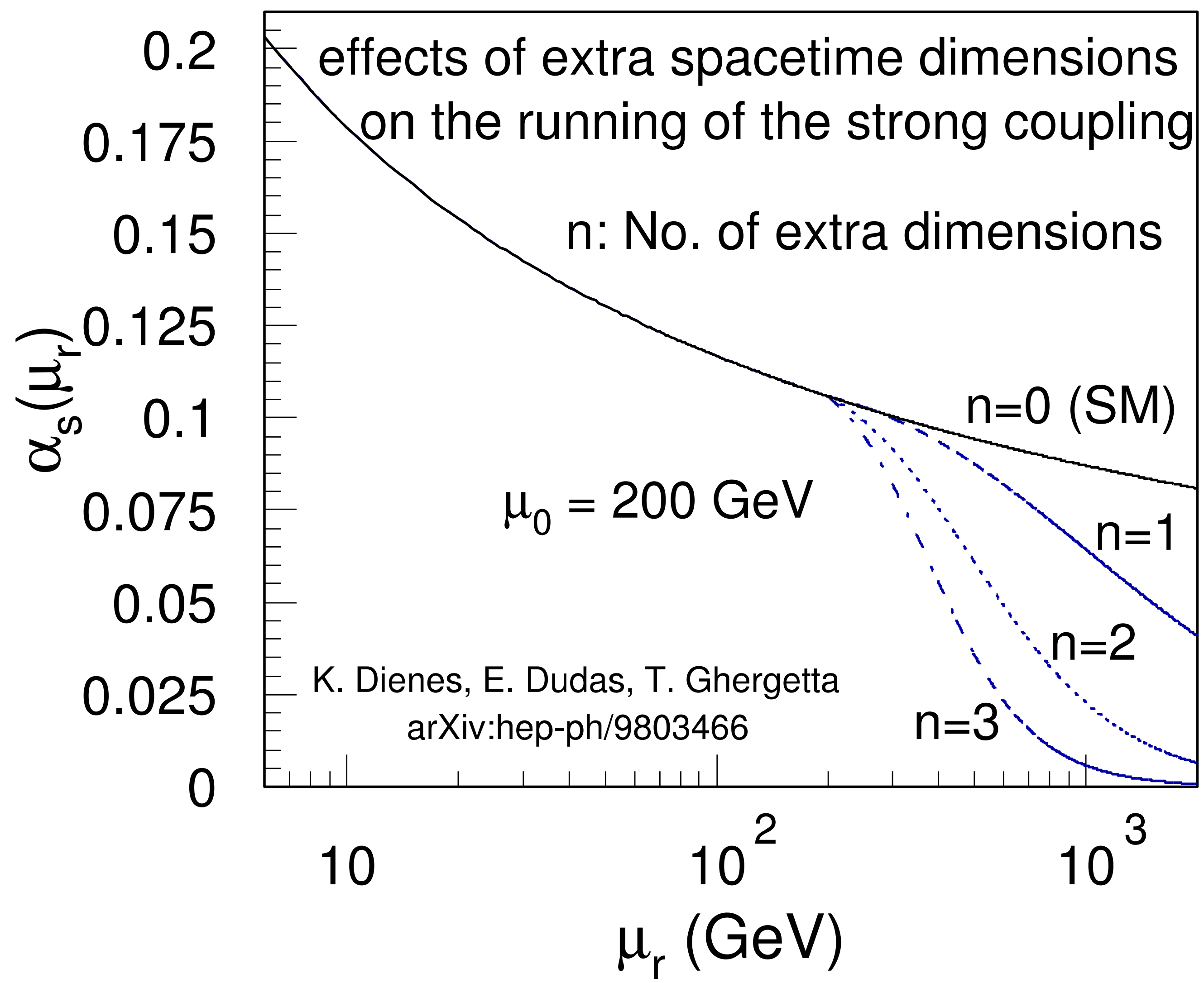
QCD Tests probe two aspects:

- determination of the value at some fixed scale $\alpha_S(\mu = M_Z)$
- scale dependence of $\alpha_S(\mu)$

Renormalization group equation is affected by new physics

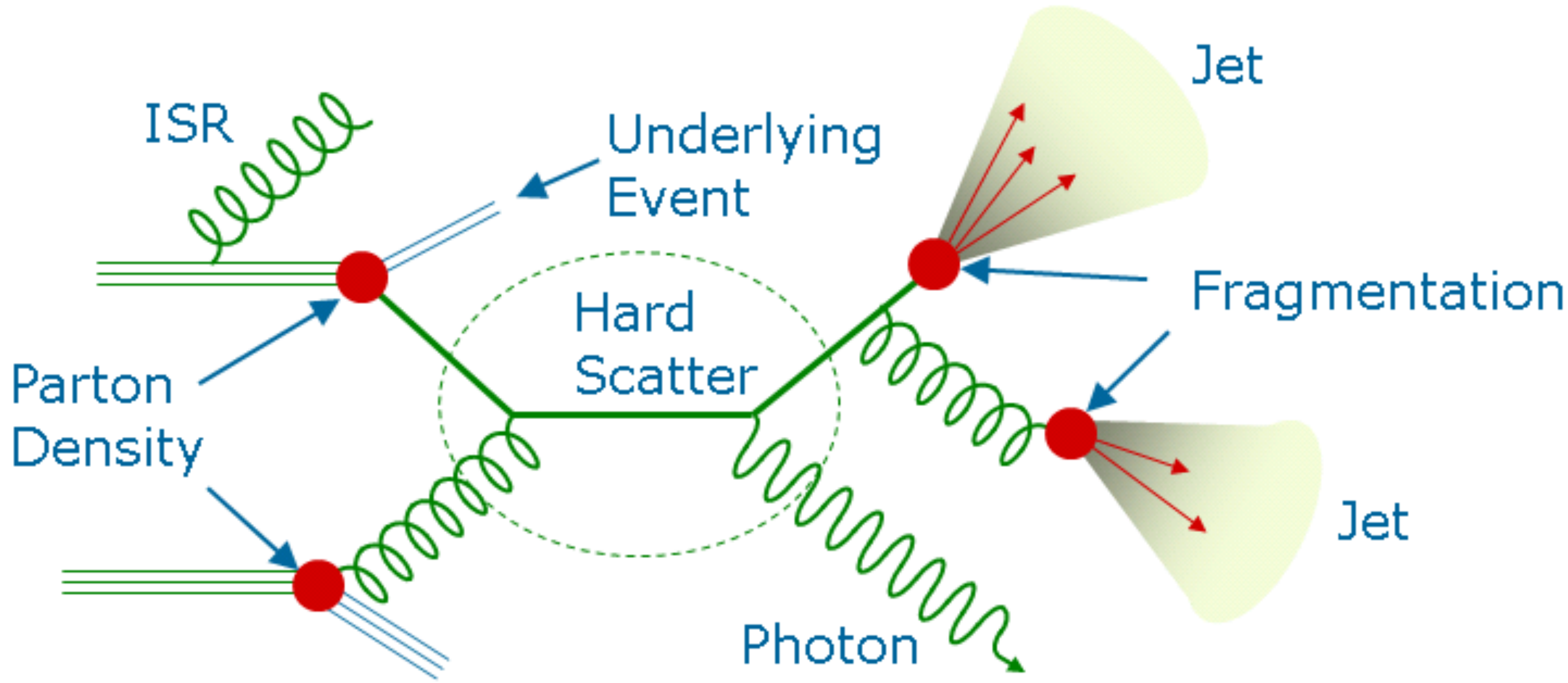
At LHC we test running at highest scales





Jet Production at Hadron Colliders

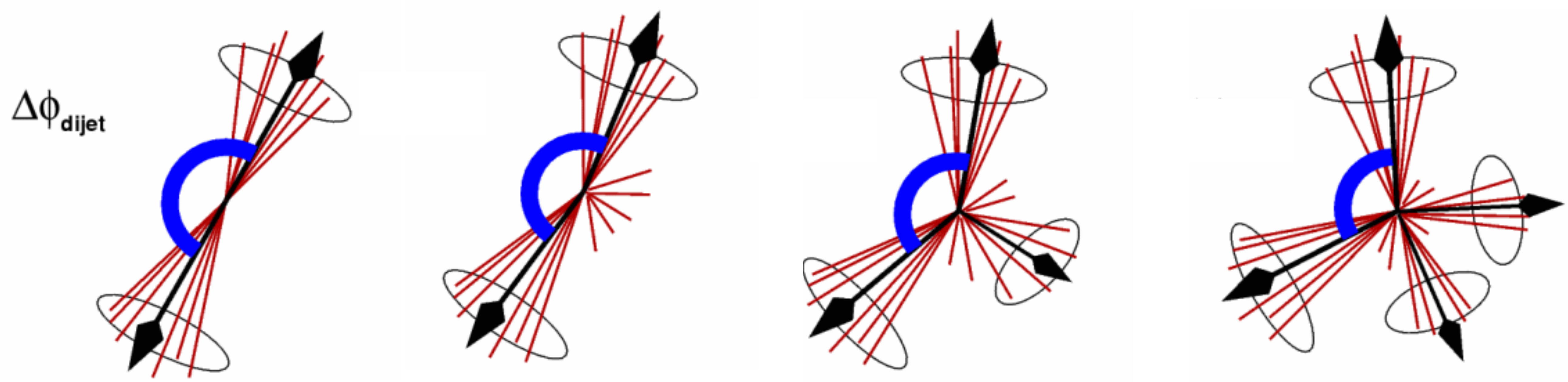
- all LHC pp collisions involves QCD (PDFs, α_S at the vertices)
- Jets are copiously produced in the final states
  → great for measuring and testing the properties of the coupling
- New Physics could enter in the hard scatter



- Every additional QCD branching will involve an additional power of the α_S
- Ratios of cross sections (e.g. R3/2) directly sensitive to α_S (3-jet cross section $\propto \alpha_S^3$ vs 2-jet cross section $\propto \alpha_S^2$)
- Ratios of observables less sensitive to both experimental and PDF uncertainties due to cancellations

Dijet Azimuthal Decorrelations

- Another way to study the strong coupling
- At leading order (LO), 2 jets are produced back-to-back in the azimuthal angle
- Any additional radiation will cause the decorrelation
- 3rd jet production (2→ 3 process) restricts the phase space to $\Delta\phi > \frac{2\pi}{3}$
- Lower values accessible only in 2→ 4 processes
  ⇒by measuring $\Delta\phi$, higher order predictions can be tested



Define $\Delta\phi$ as azimuthal separation of 2 highest p_T jets

Dijet azimuthal decorrelation observable

- Dijet azimuthal decorrelations have been measured before (D0, CMS, ATLAS)
- New ATLAS measurement presents a new observable based on ratios of cross sections
- Studies energy and rapidity dependence

$$R_{\Delta\phi}(H_T, y^*, \Delta\phi_{max}) = \frac{\dfrac{d^2\sigma_{dijet}(\Delta\phi < \Delta\phi_{max})}{dH_T dy^*}}{\dfrac{d^2\sigma_{dijet}(inclusive)}{dH_T dy^*}}$$

M. Wobisch and K. Rabbertz, JHEP 12 (2015) 024

$y^* = \frac{|y_1 - y_2|}{2}$ dijet rapidity separation

H_T = scalar sum of all jets with $p_T > p_{T,min}$

Fraction of dijet events where $\Delta\phi$ between the two leading jets is smaller than some value $\Delta\phi_{max}$ w.r.t. to the inclusive dijet cross section

- Analysis of 2012 dataset, $\sqrt{s}$=8TeV, $\mathscr{L}$ = 20.2 fb^{-1}
- anti-k_T jets with R=0.6
- y* : study rapidity dependence
- H_T : one possible scal … lated to the scale at which α_S is probed
- Phase space cuts:

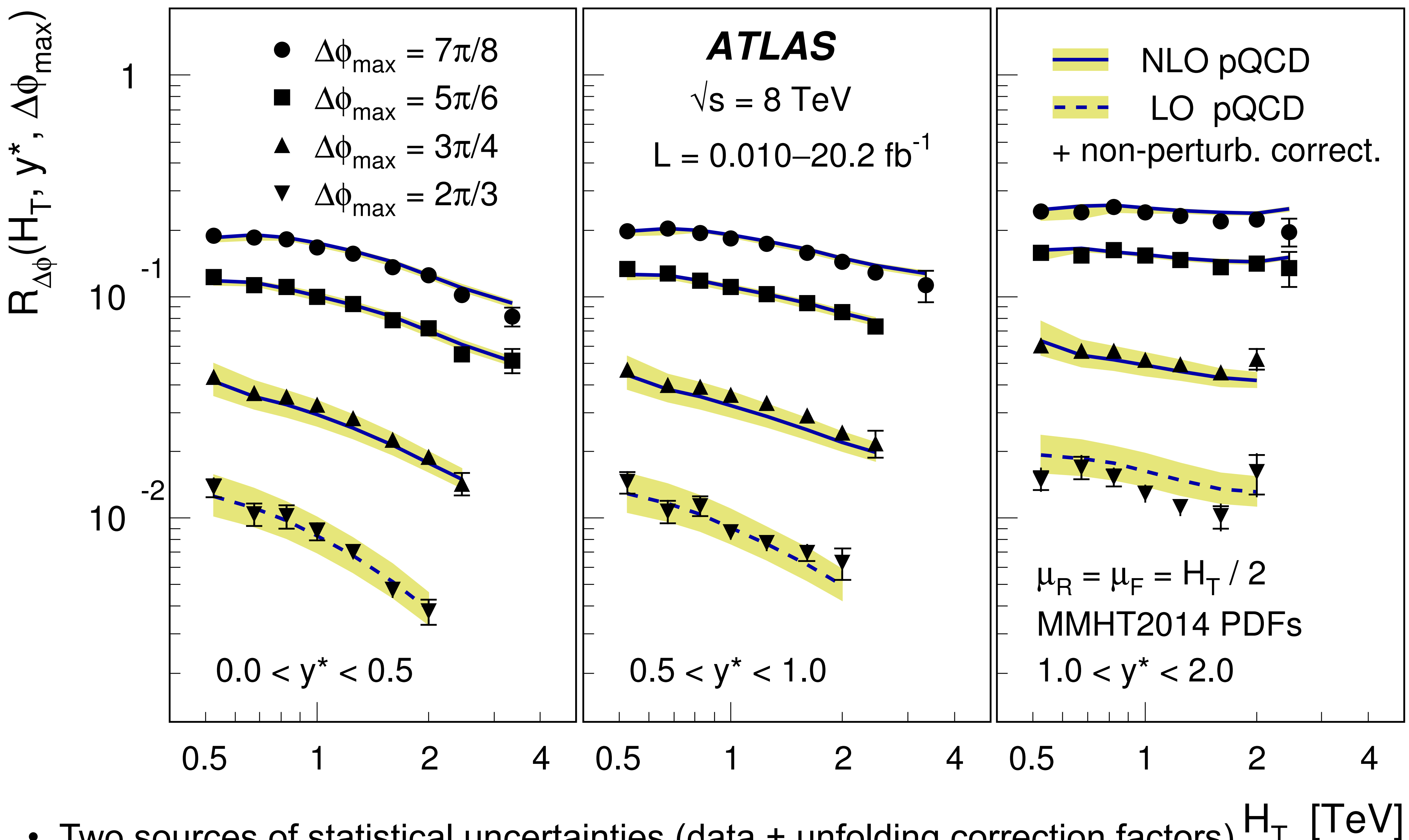
Variable	Value
p_{Tmin}	100 GeV
$y_{\mathrm{boost}}^{\mathrm{max}}$	0.5
y_{max}^*	2.0
$p_{\mathrm{T1}}/H_{\mathrm{T}}$	$> 1/3$

Quantity	Value
H_{T} bin boundaries (in TeV)	0.45, 0.6, 0.75, 0.9, 1.1, 1.4, 1.8, 2.2, 2.7, 4.0
y^* regions	0.0–0.5, 0.5–1.0, 1.0–2.0
$\Delta\phi_{\mathrm{max}}$ values	$7\pi/8$, $5\pi/6$, $3\pi/4$, $2\pi/3$

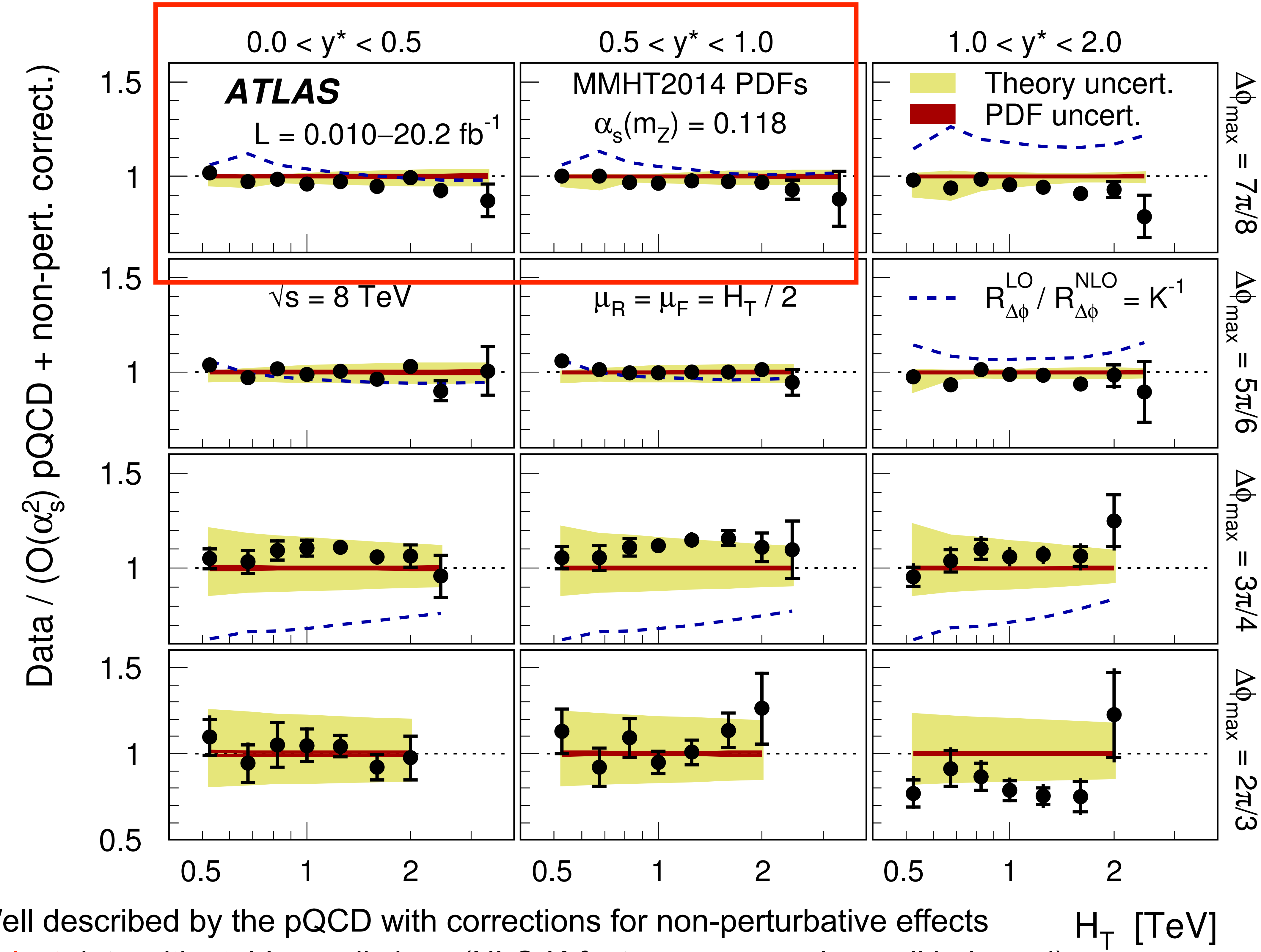
Theoretical Predictions

- pQCD predictions from NLOJET++ interfaced to FASTNLO
- Non-perturbative effects corrected using PYTHIA6 and HERWIG6 MC generators
- NLO (LO) predictions for 3 (4) jet quantities depending on $\Delta\phi_{max}$
- Scale choice: μ_R = μ_R = $H_T/2$
- PDFs tested: MMHT2014, CT14, NNPDF2.3, ABMP16 (NNLO), HERAPDF2.0
  These sets provide range of α_S values
- Best fit obtained through χ^2 minimization

ATLAS Measurement



- Two sources of statistical uncertainties (data + unfolding correction factors)
- 62 sources of systematic uncertainties
- Dominant experimental correlated uncertainty is the jet energy calibration
- In two highest $\Delta\phi_{max}$ intervals, uncertainties are typically 1.0 — 1.5%, always less than 3.1%
- At lower $\Delta\phi_{max}$ they can be up to 4% — 9%



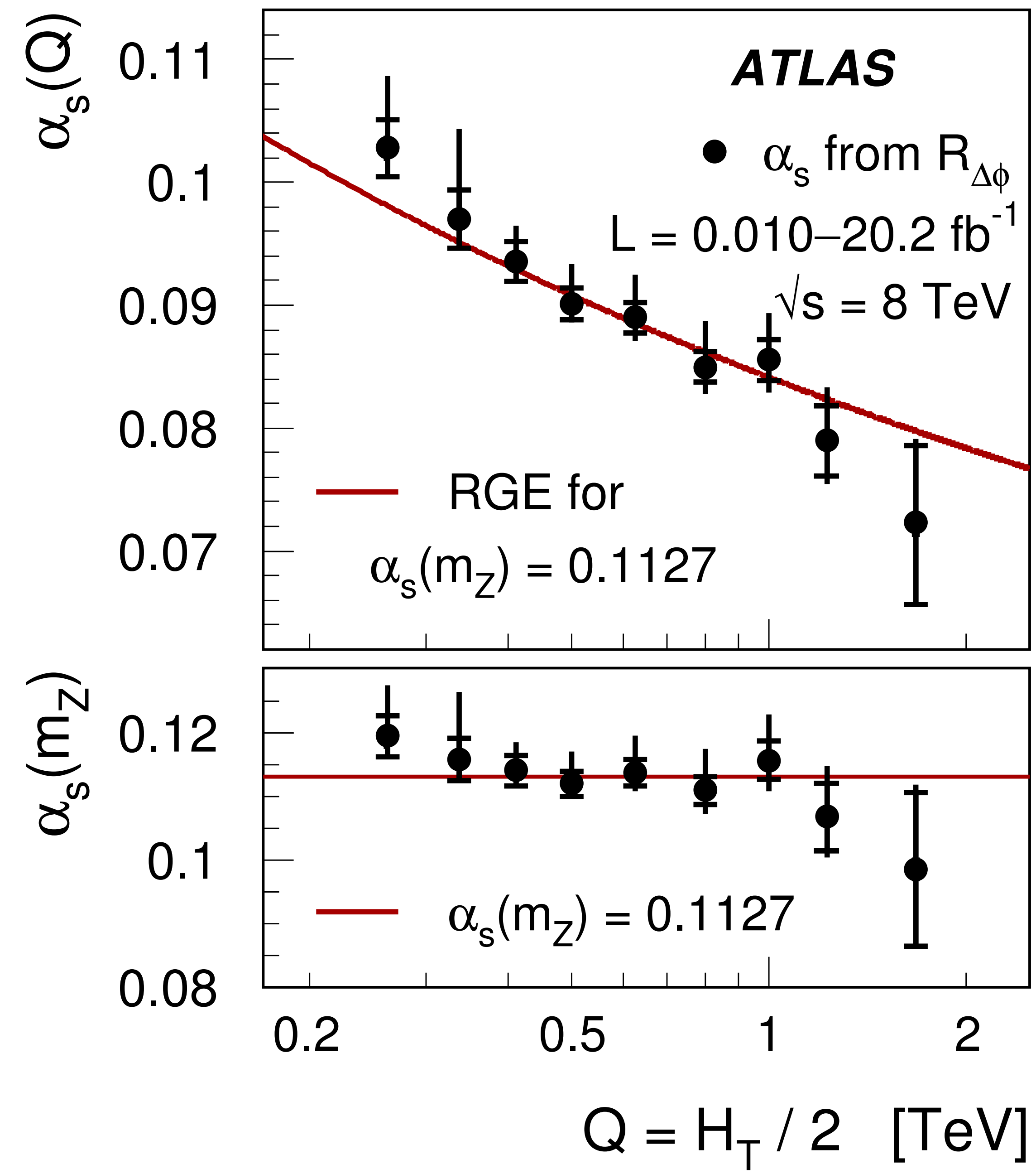
Well described by the pQCD with corrections for non-perturbative effects

Select data with stable predictions (NLO K-factor, μ_F, μ_R scales well behaved)

PDF uncertainty cancellations best for similar $\Delta\phi_{max}$ in numerator & denominator

α_S Extraction

- Use bins [0<y*<0.5] and [0.5<y*<1.0] for $\Delta\phi_{max}$< 7**π**/8
- $\alpha_s(H_T/2)$ extracted with χ^2 minimization
- 9 intervals in the range 262 < Q=H_T < 1675 GeV
- Single minimization for statistical, experimental, non-perturbative and MMHT uncertainty
- Additional minimization for PDF set & scale uncertainty



Extra fit to all nine data points yields combined result
χ^2/ndf = 21.7 / 17

x 10^{-3}

$\alpha_S(m_Z)$	Total uncert.	Statistical	Experimental correlated	Non-perturb. corrections	MMHT2014 uncertainty	PDF set	$\mu_{R,F}$ variation
0.1127	$^{+6.3}_{-2.7}$	±0.5	$^{+1.8}_{-1.7}$	$^{+0.3}_{-0.1}$	$^{+0.6}_{-0.6}$	$^{+2.9}_{-0.0}$	$^{+5.2}_{-1.9}$

Comparison with other extractions

Previous ATLAS results:
Transverse energy-energy correlations √s= 7 TeV
Physics Letters B 750 (2015) 427-447

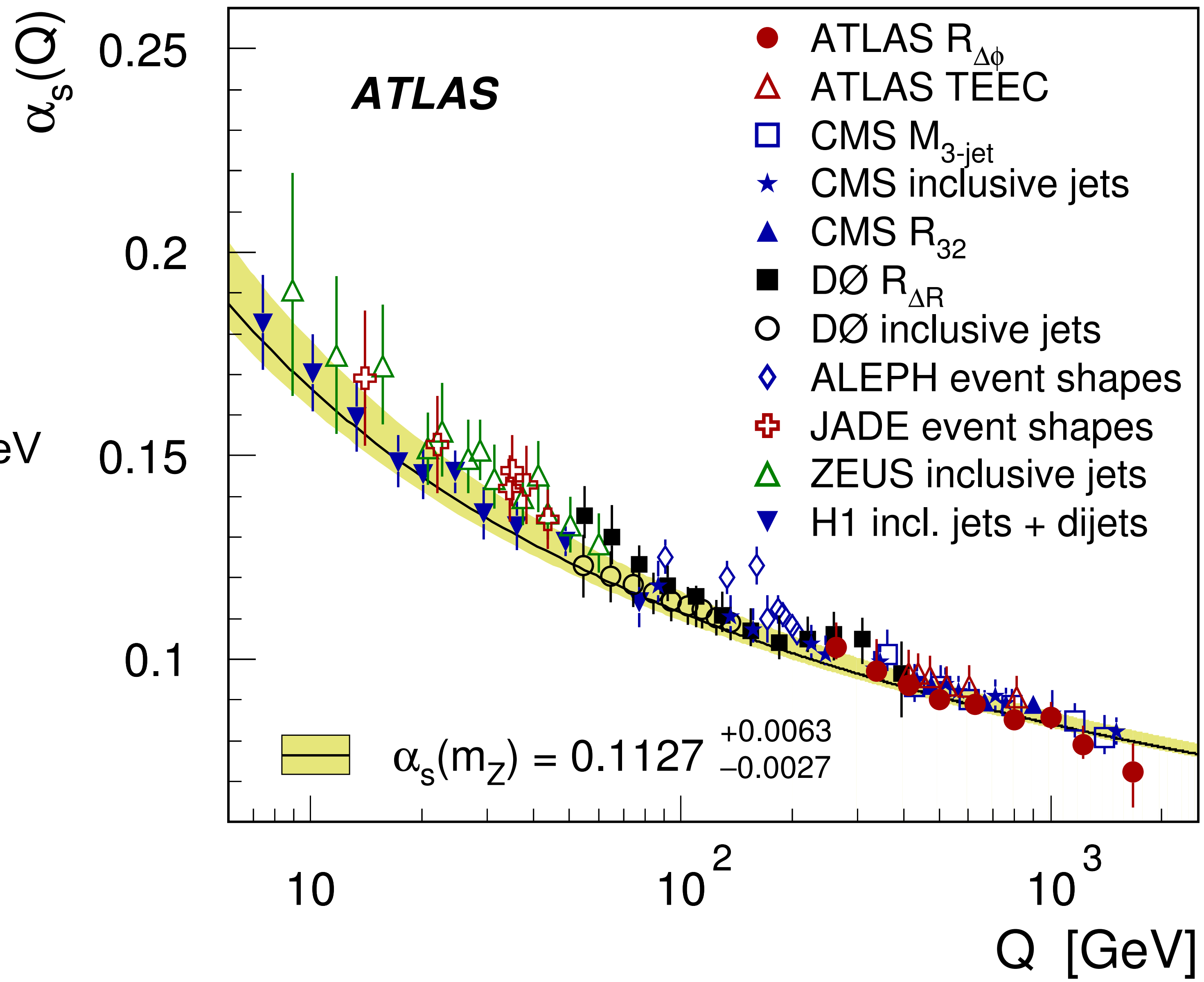
$$\alpha_s(m_Z) = 0.1173 \pm 0.0010\,(\text{exp.})\,^{+0.0065}_{-0.0026}\,(\text{theo.})$$

$$\alpha_s(m_Z) = 0.1195 \pm 0.0018(\text{exp.})^{+0.0062}_{-0.0022}(\text{theo.})$$

Transverse energy-energy correlations √s= 8 TeV
Eur. Phys. J. 77 (2017) 872

$$\alpha_s(m_Z) = 0.1162 \pm 0.0011\,(\text{exp.})^{+0.0084}_{-0.0070}\,(\text{theo.})$$

$$\alpha_s(m_Z) = 0.1196 \pm 0.0013\,(\text{exp.})^{+0.0075}_{-0.0045}\,(\text{theo.})$$



Summary

- Multijet cross section ratio $R_{\Delta\phi}$ measured by the ATLAS Collaboration at $\sqrt{s}$ = 8 TeV
- H_T and y* dependence well described by the pQCD with corrections for non-perturbative effects
- $\alpha_S(H_T/2)$ extracted over the range 262 < Q <1675 GeV
- Combined analysis results in $\alpha_S(m_Z) = 0.1127^{+0.0063}_{-0.0027}$
- Result dominated by the scale dependence of the NLO pQCD predictions
- Consistent with world average

Extracted α_S values

Q [GeV]	$\alpha_S(Q)$	Total uncert.	Stat.	Exp. correlated	Non-perturb. corrections	MMHT2014 uncertainty	PDF set	$\mu_{R,F}$ variation
262.5	0.1029	$^{+6.0}_{-2.8}$	±1.6	$^{+1.6}_{-1.7}$	$^{+0.4}_{-0.4}$	$^{+0.4}_{-0.4}$	$^{+1.4}_{-0.9}$	$^{+5.3}_{-0.2}$
337.5	0.0970	$^{+8.0}_{-2.6}$	±1.8	$^{+1.5}_{-1.5}$	$^{+0.4}_{-0.4}$	$^{+0.3}_{-0.3}$	$^{+3.0}_{-0.5}$	$^{+7.0}_{-0.7}$
412.5	0.0936	$^{+4.0}_{-2.2}$	±0.9	$^{+1.3}_{-1.3}$	$^{+0.3}_{-0.3}$	$^{+0.3}_{-0.3}$	$^{+2.6}_{-1.4}$	$^{+2.5}_{-0.2}$
500.0	0.0901	$^{+3.7}_{-1.5}$	±0.6	$^{+1.2}_{-1.2}$	$^{+0.2}_{-0.2}$	$^{+0.3}_{-0.3}$	$^{+1.9}_{-0.3}$	$^{+2.9}_{-0.6}$
625.0	0.0890	$^{+3.9}_{-1.8}$	±0.5	$^{+1.1}_{-1.1}$	$^{+0.1}_{-0.1}$	$^{+0.3}_{-0.4}$	$^{+1.7}_{-0.3}$	$^{+3.3}_{-1.3}$
800.0	0.0850	$^{+5.9}_{-2.2}$	±0.6	$^{+1.0}_{-1.1}$	$^{+0.1}_{-0.1}$	$^{+0.4}_{-0.4}$	$^{+4.6}_{-0.2}$	$^{+3.5}_{-1.8}$
1000	0.0856	$^{+4.0}_{-2.7}$	±1.2	$^{+1.1}_{-1.1}$	$^{+0.1}_{-0.1}$	$^{+0.4}_{-0.4}$	$^{+1.4}_{-0.4}$	$^{+3.4}_{-2.0}$
1225	0.0790	$^{+4.6}_{-3.5}$	±2.5	$^{+1.2}_{-1.2}$	$^{+0.1}_{-0.1}$	$^{+0.5}_{-0.5}$	$^{+1.6}_{-0.4}$	$^{+3.2}_{-1.9}$
1675	0.0723	$^{+7.0}_{-8.6}$	±6.1	$^{+1.3}_{-1.2}$	$< \pm0.1$	$^{+0.5}_{-0.5}$	$^{+1.7}_{-5.1}$	$^{+2.8}_{-1.6}$