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Multi-jet cross section ratios and determination of α_s in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV

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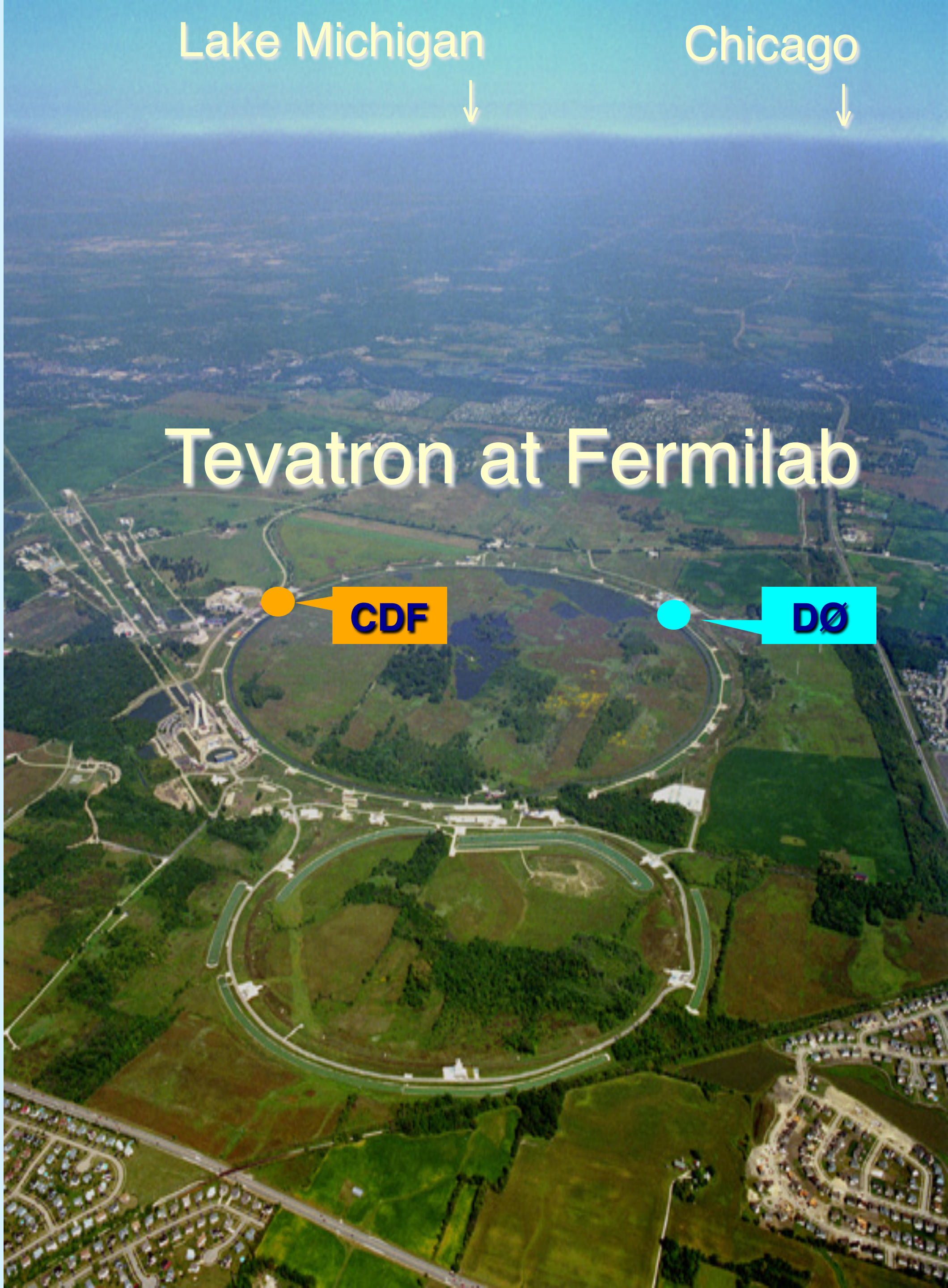
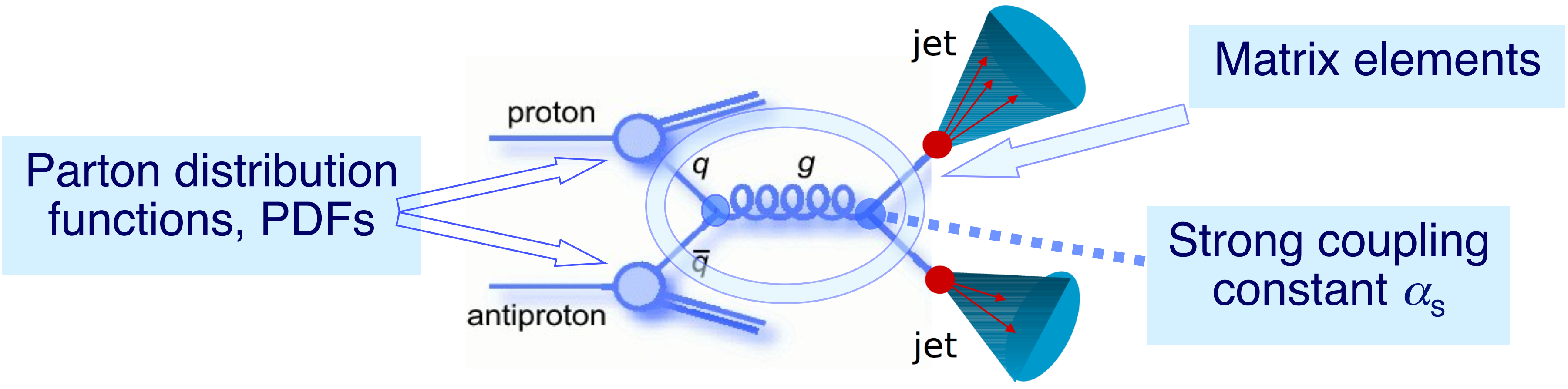
Outline

- Introduction
- Measurement of multi-jet cross section ratios: $R_{3/2}$, $R_{\Delta\phi}$, $R_{\Delta R}$
- Determination of α_s
- Summary

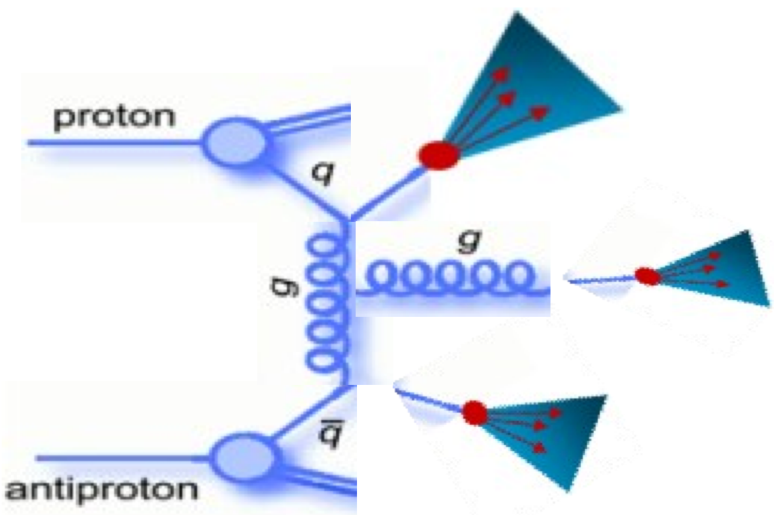


Introduction

- Studies of multi-jet production in hadron collisions provide important tests of pQCD calculations



- Measurement of ratios allow for improved precisions



- For instance, measurements of 3-jet ($\sim\alpha_s^3$) over 2-jet ($\sim\alpha_s^2$) cross section ratios are sensitive to α_s
- Sensitivity to uncertainties in PDF are significantly reduced

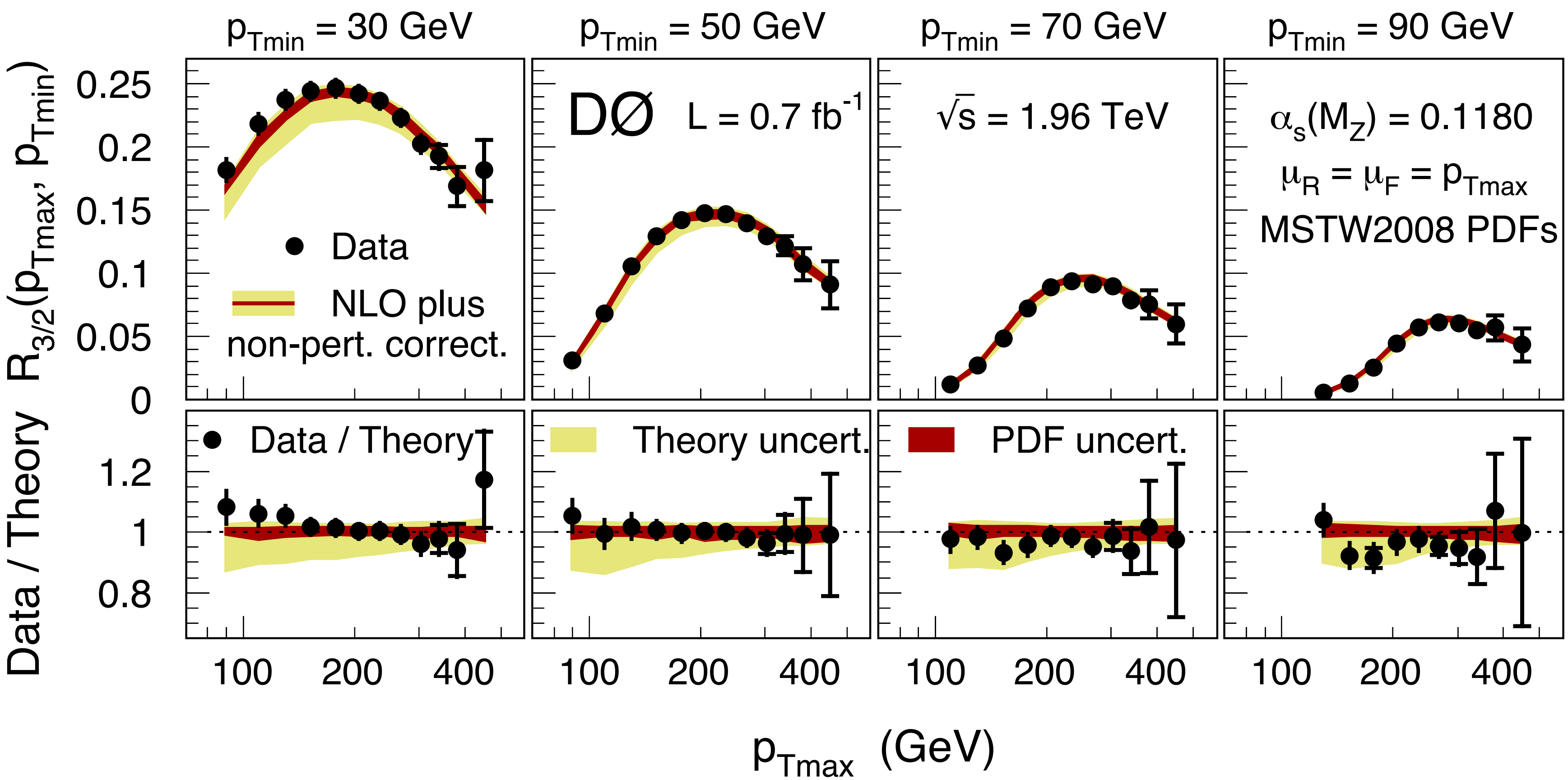
Data, jet definition, comparison to theory

- All three analyses are based on 0.7 fb^{-1} of Run II data
- Jets are identified with the DØ Run II midpoint cone algorithm
  - $R_{cone} = 0.7$, $p_T > p_{Tmin}$, $|y| < 2.4$, $R_{jj} > 2R_{cone}$
- Jets are corrected for the calorimeter response, instrumental out-of-cone showering and pile-up effects
- These jet energy scale corrections are determined in-situ using γ+jet, $Z \rightarrow e^+e^-$, di-jet and minimum bias collider data
  - Energy calibration is known to 1.2 – 2.5% in $50 < p_T < 500$ GeV
- Resulting calorimeter jets are corrected to the particle level jets using detailed simulations of the DØ detector
- Theoretical predictions from NLOJET++ (Z. Nagy, Phys. Rev. D 68 (2003) 094002) are corrected for non-perturbative effects derived from Pythia (various tunes) and Herwig simulations

Multi-jet cross section ratio $R_{3/2}$

Phys. Lett. B 720, 6 (2013)

- Calculate the ratio $R_{3/2}=\sigma(\text{3-jet})/\sigma(\text{2-jet})$
- Measure $R_{3/2}(p_{Tmax}, p_{Tmin})$
  - Probes α_s at the p_{Tmax} scale. p_{Tmin} sets a "hardness" criterion for the 3rd jet



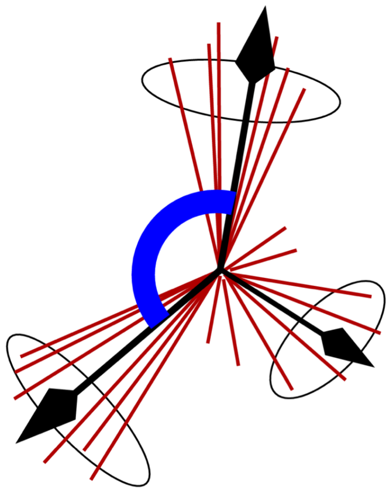
Data well described by theory for p_{Tmin} = 50, 70, 90 GeV

Dijet azimuthal decorrelations $R_{\Delta\phi}$

$R_{\Delta\phi}$: Fraction of all dijet events with $\Delta\phi < \Delta\phi_{max}$

M. Wobisch *et al.*, JHEP 1301 (2013) 172

$$R_{\Delta\phi} = \frac{\sigma_{dijet}(\Delta\phi < \Delta\phi_{max})}{\sigma_{dijet}(inclusive)}$$



Numerator is effectively a 3-jet quantity, due to $\Delta\phi_{max}$ requirement, but the 3rd jet is not explicitly required → more inclusive quantity than $R_{3/2}$

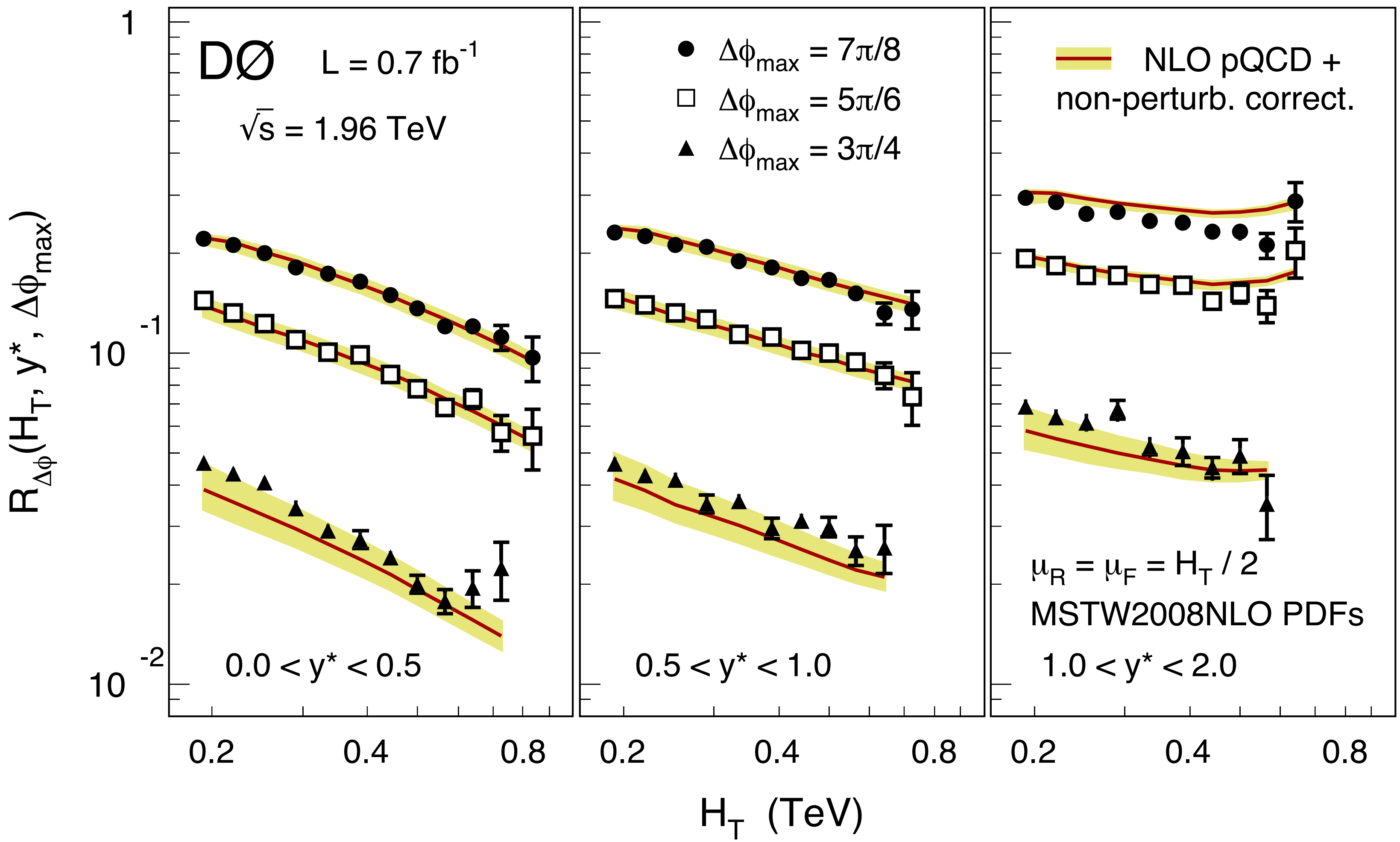
- Measure $R_{\Delta\phi}(H_T, y^*, \Delta\phi_{max})$ in kinematic regions of y^* and $\Delta\phi_{max}$

  $y^* = ½\,|y_1 - y_2|$

  H_T is the total transverse momentum in the event
- Scale for α_s is set at $H_T/2$

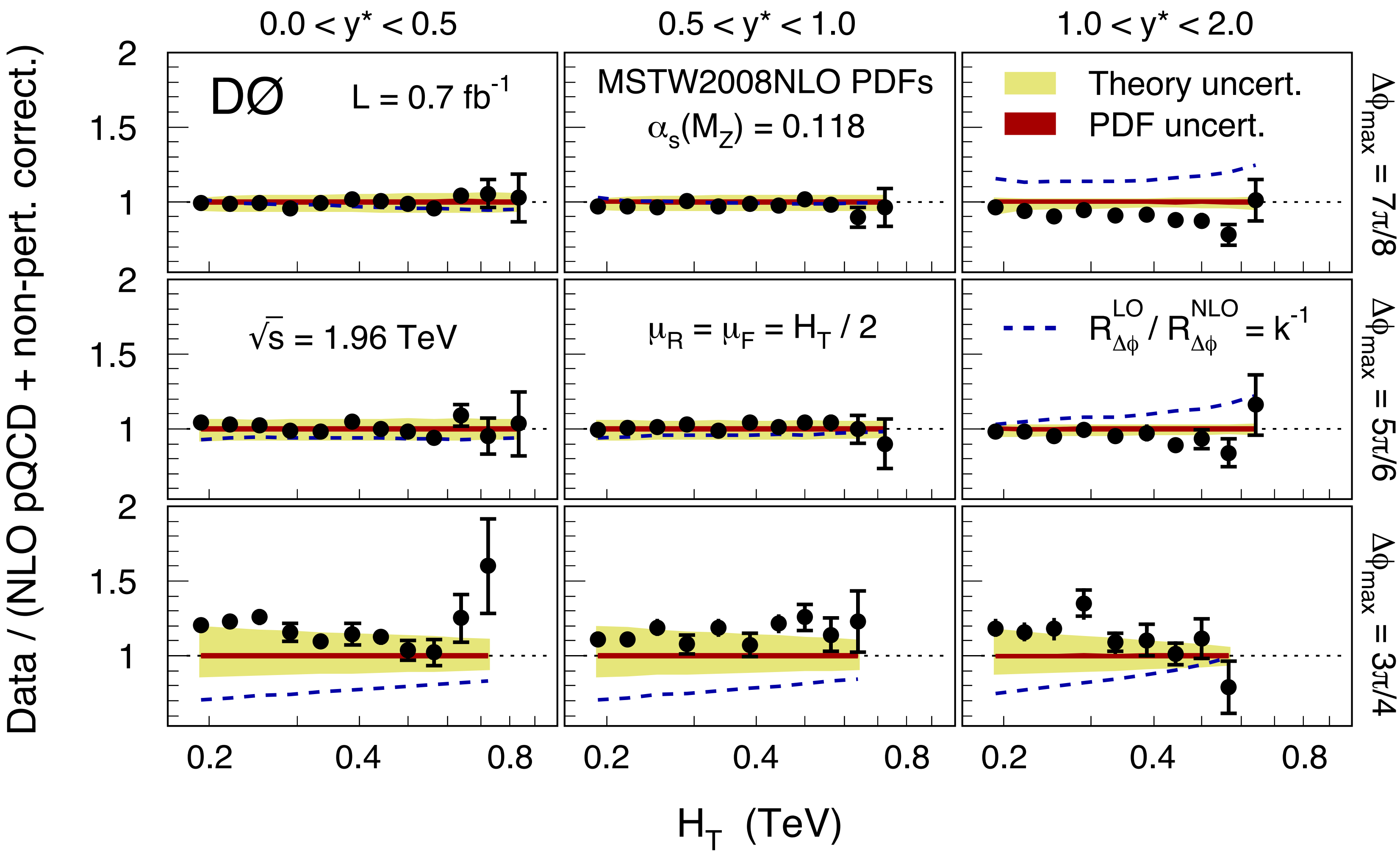
Dijet azimuthal decorrelations $R_{\Delta\phi}$

Phys. Lett. B 721, 212 (2013)



Weaker H_T dependence at larger rapidity y^*

Dijet azimuthal decorrelations $R_{\Delta\phi}$



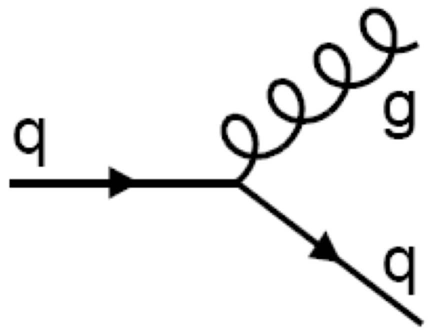
- Well described by theory for $\Delta\phi_{max} = 7\pi/8, 5\pi/6$
- Large scale dependence for smaller $\Delta\phi_{max} = 3\pi/4$
  - Since larger 4-jet contribution

A new quantity $R_{\Delta R}$: angular correlations of jets

- Average number of neighboring jets for an inclusive jets sample

$$R_{\Delta R}\left(p_T, \Delta R, p_{T\,\mathrm{min}}^{\mathrm{nbr}}\right) = \frac{\sum_{i=1}^{N_{\mathrm{jet}}(p_T)} N_{\mathrm{nbr}}^{(i)}(\Delta R, p_{T\,\mathrm{min}}^{\mathrm{nbr}})}{N_{\mathrm{jet}}(p_T)}$$

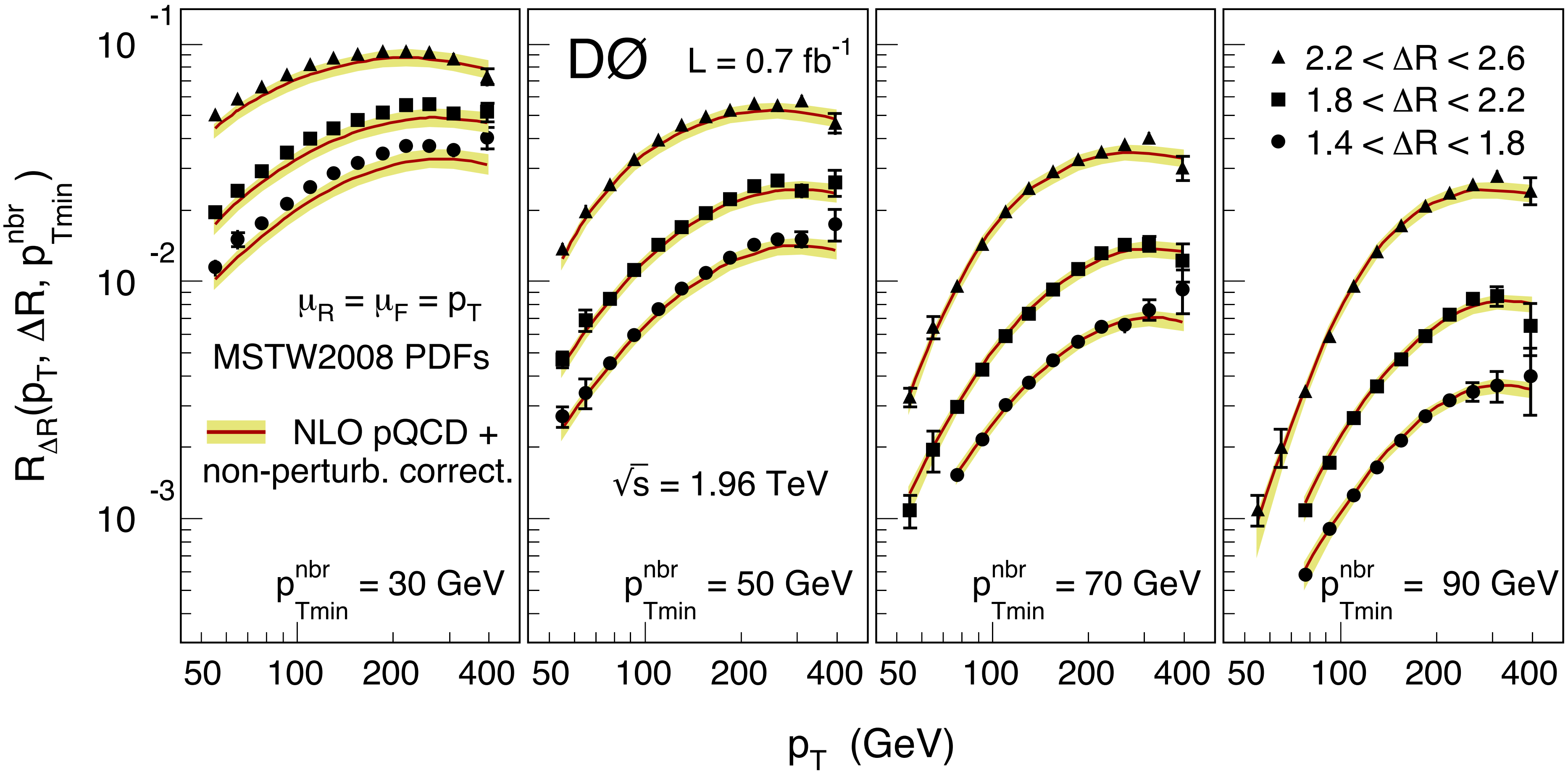
- Require at least one nearby jet →



- Depends on 3 variables
  - Inclusive jet p_T → sets scale for α_s
  - Distance ΔR to neighboring jet in the (y, ϕ) space
  - Neighbor jet p_T-nbr-min requirement

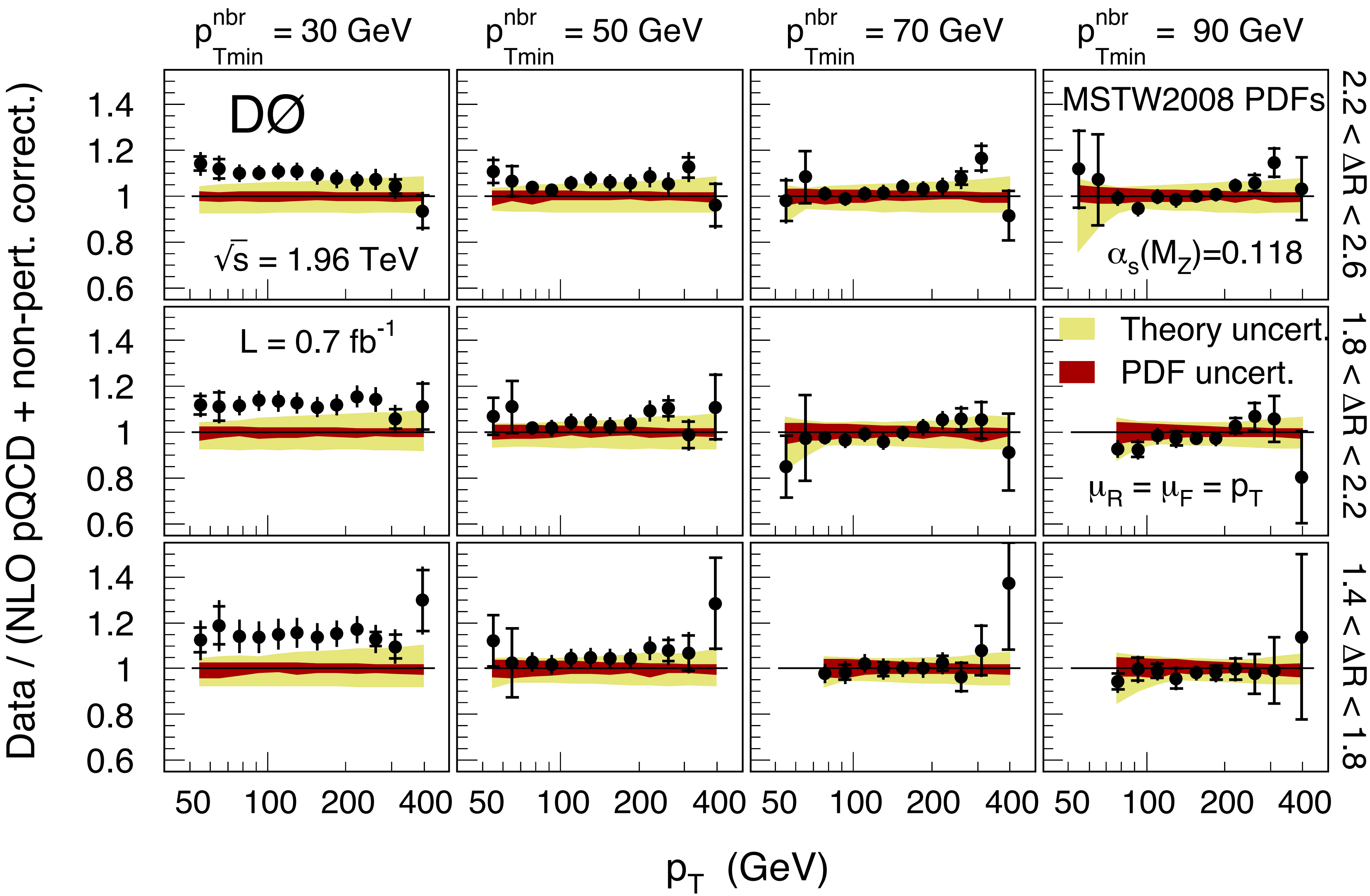
Angular correlations of jets $R_{\Delta R}$

Phys. Lett. B 718, 56 (2012)



$R_{\Delta R}(p_T, \Delta R, p_{T\text{-nbr-min}})$ increases with p_T and with ΔR

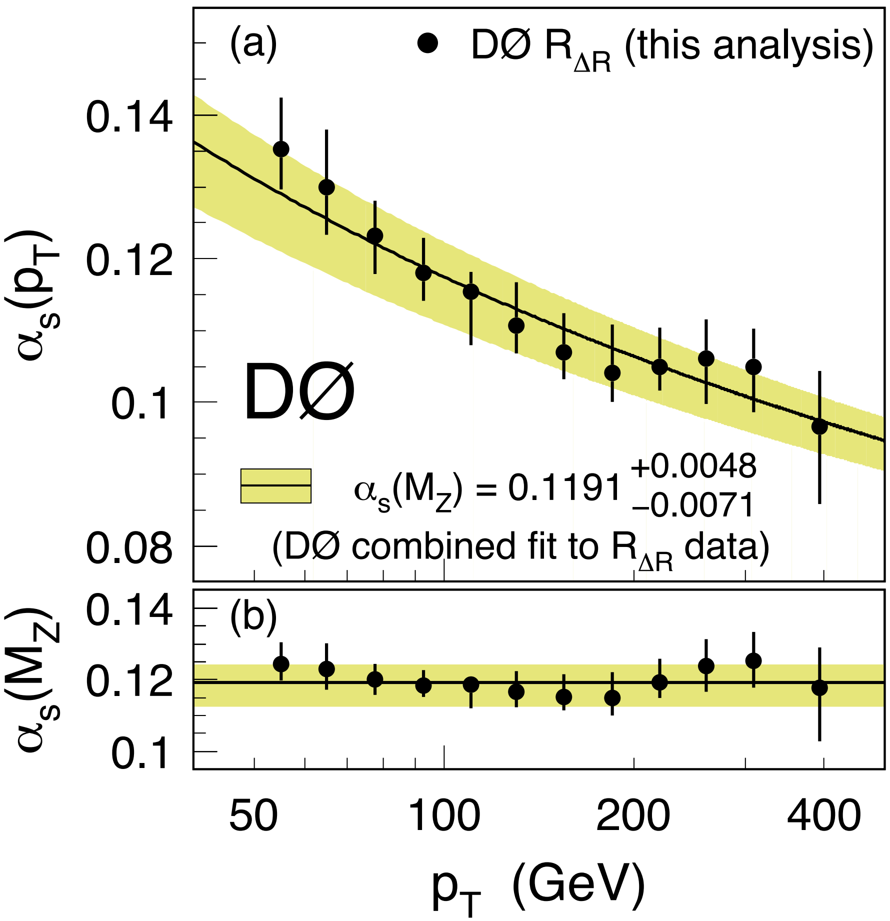
Angular correlations of jets $R_{\Delta R}$



Theory describes data for $p_{T\text{-nbr-min}}$ = 50, 70, 90 GeV

$\alpha_s(p_T)$ and $\alpha_s(M_Z)$ from $R_{\Delta R}$ data

Combine all data points with $p_{T\text{nbr-min}} \geq$ 50, 70, 70 GeV (all ΔR, all p_T)



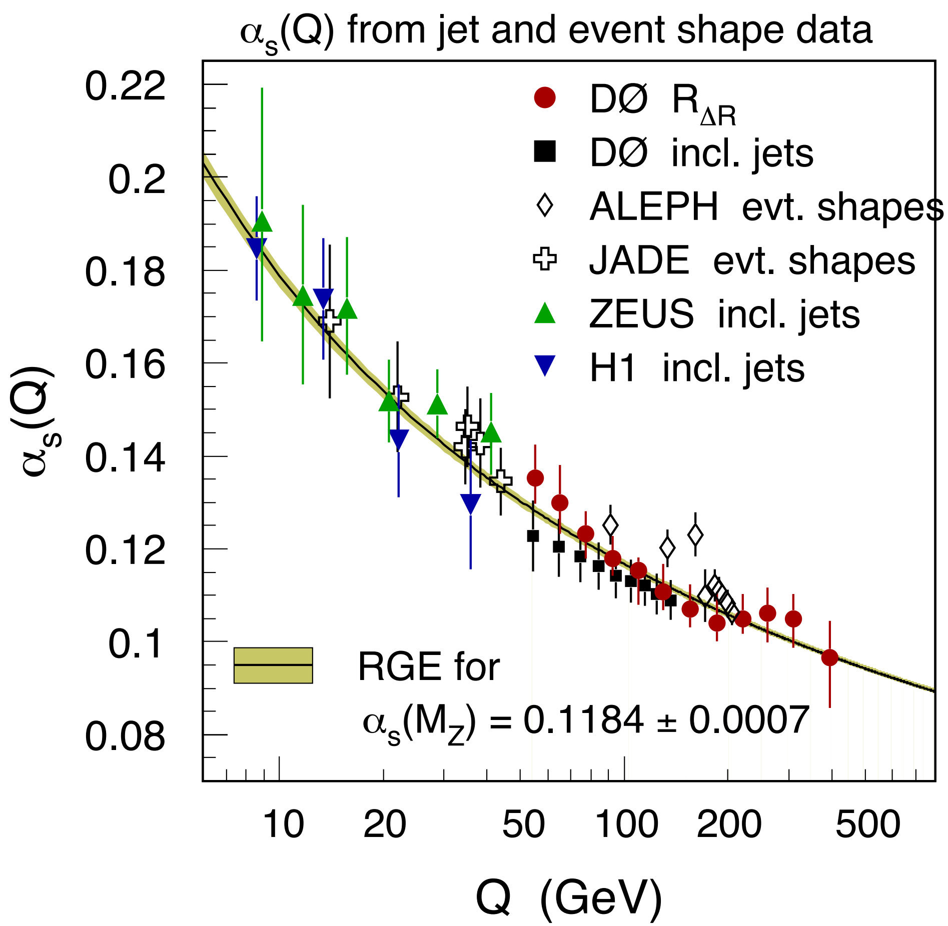
$$\alpha_s(M_Z) = 0.1191^{+0.0048}_{-0.0071}$$

Sources of uncertainties	
Statistical	±0.0003
Experimental correlated	+0.0007 -0.0009
Non-perturb. corrections	+0.0002 -0.0001
MSTW2008NLO	+0.001 -0.0005
PDF set	+0.0 -0.0024
$\mu_{R,F}$ variation	+0.0046 -0.0066

- $\alpha_s(p_T)$ follows RGE predictions
- For higher precision, need 2- and 3-jet calculations at NNLO

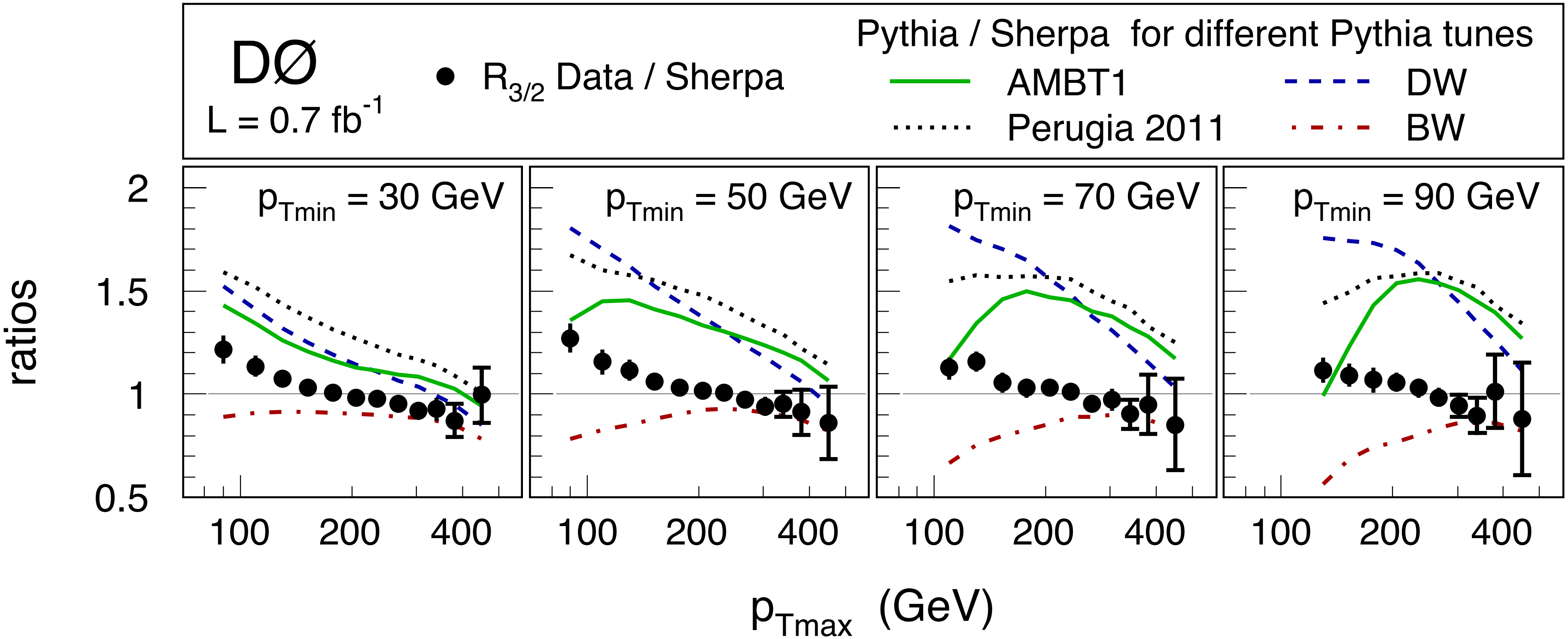
Summary

- Detailed tests of pQCD carried out in DØ by measuring multi-jet cross section ratios using $R_{3/2}$, $R_{\Delta\phi}$ and $R_{\Delta R}$ quantities
- α_s has been precisely measured with reduced sensitivity to PDF
- Precisions are limited by pQCD calculations at higher orders



Backup

Multi-jet cross section ratio $R_{3/2}$

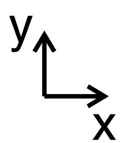


Examples of $R_{\Delta R}$ variable

$R_{\Delta R}$ = average number of neighboring jets per jet

here: for $\Delta R < \pi/2$

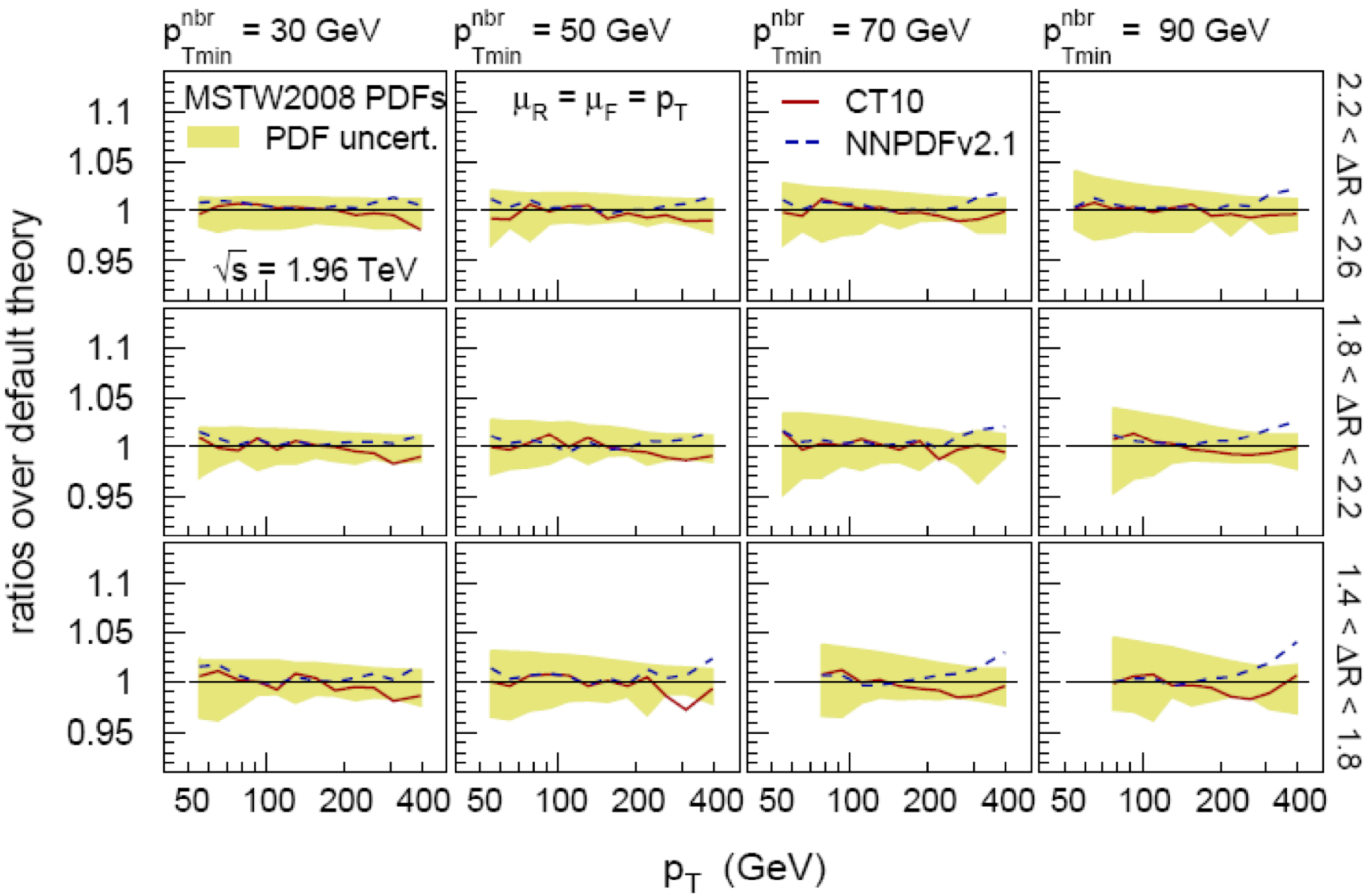
in this example all jets have same (p_T, y)



2 jets	3 jets	4 jets
no neighbors within ΔR:	two jets have one neighbor each:	each of the four jets has one neighbor:
0 neighbors	2 neighbors	4 neighbors

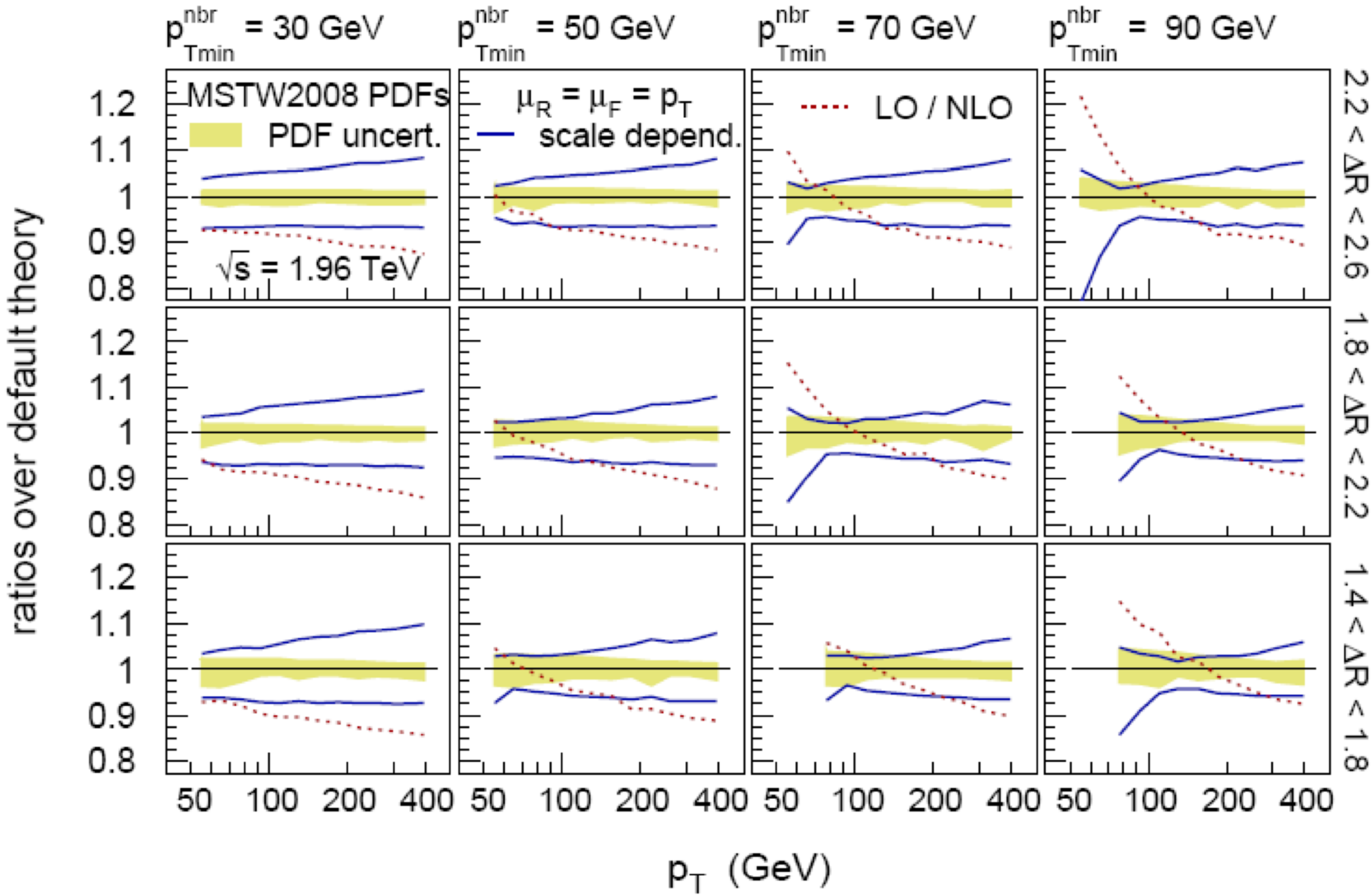
if all events were like this	$R_{\Delta R} = 0$	$R_{\Delta R} = 2/3$	$R_{\Delta R} = 1$

$R_{\Delta R}$ PDF sensitivity



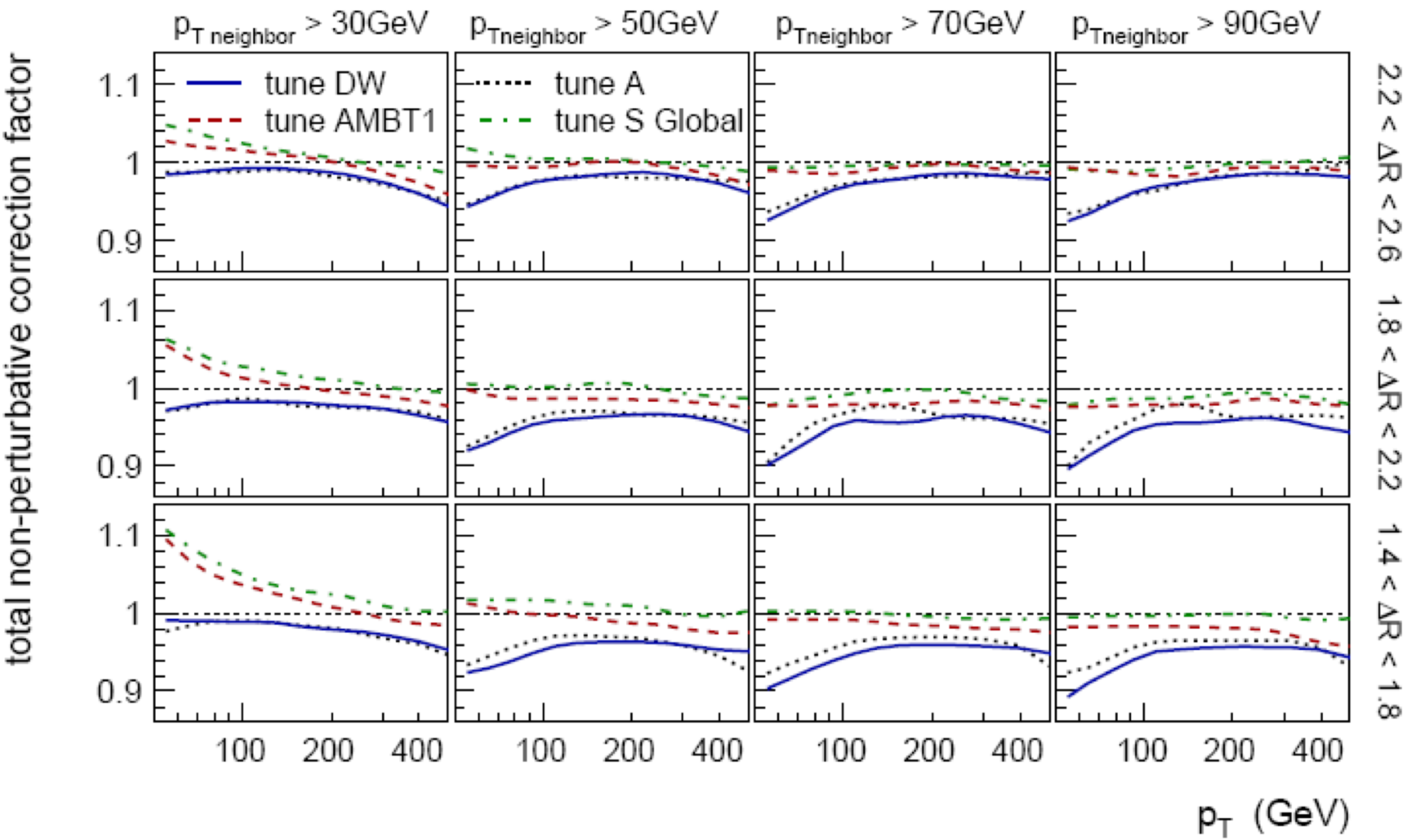
MSTW2008, CT10, NNPDFv2.1 all agree within 3%

$R_{\Delta R}$ scale dependence



Small, 5 – 10%, scale dependence

$R_{\Delta R}$ non-perturbative corrections



Typically small corrections, ~3–5% at higher p_T