ttbar @ LHCb

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- Theoretical uncertainties
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- Constraining the gluon PDF
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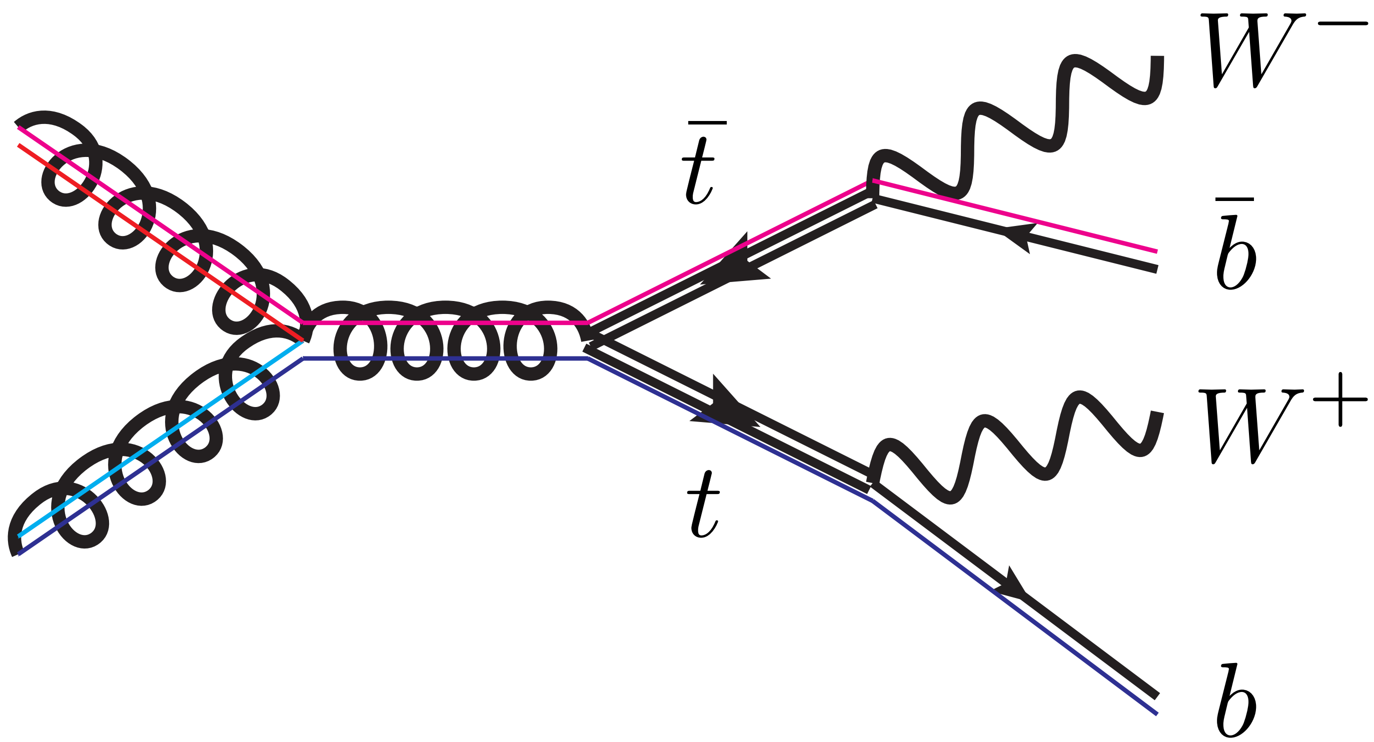
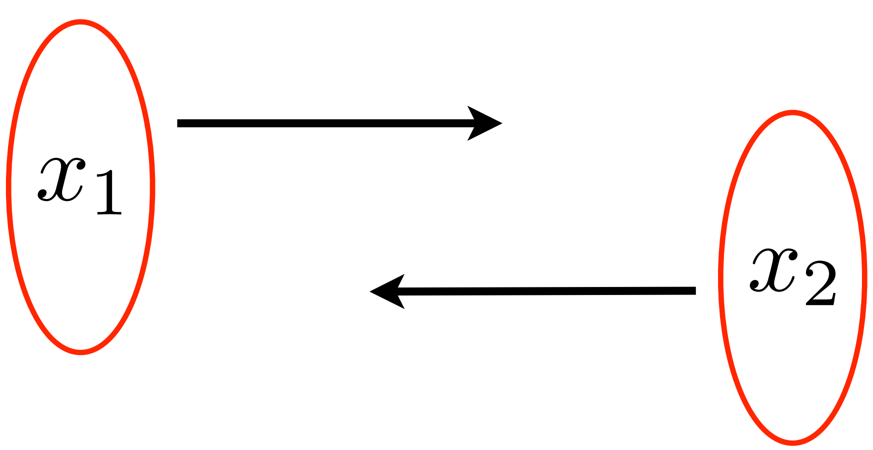
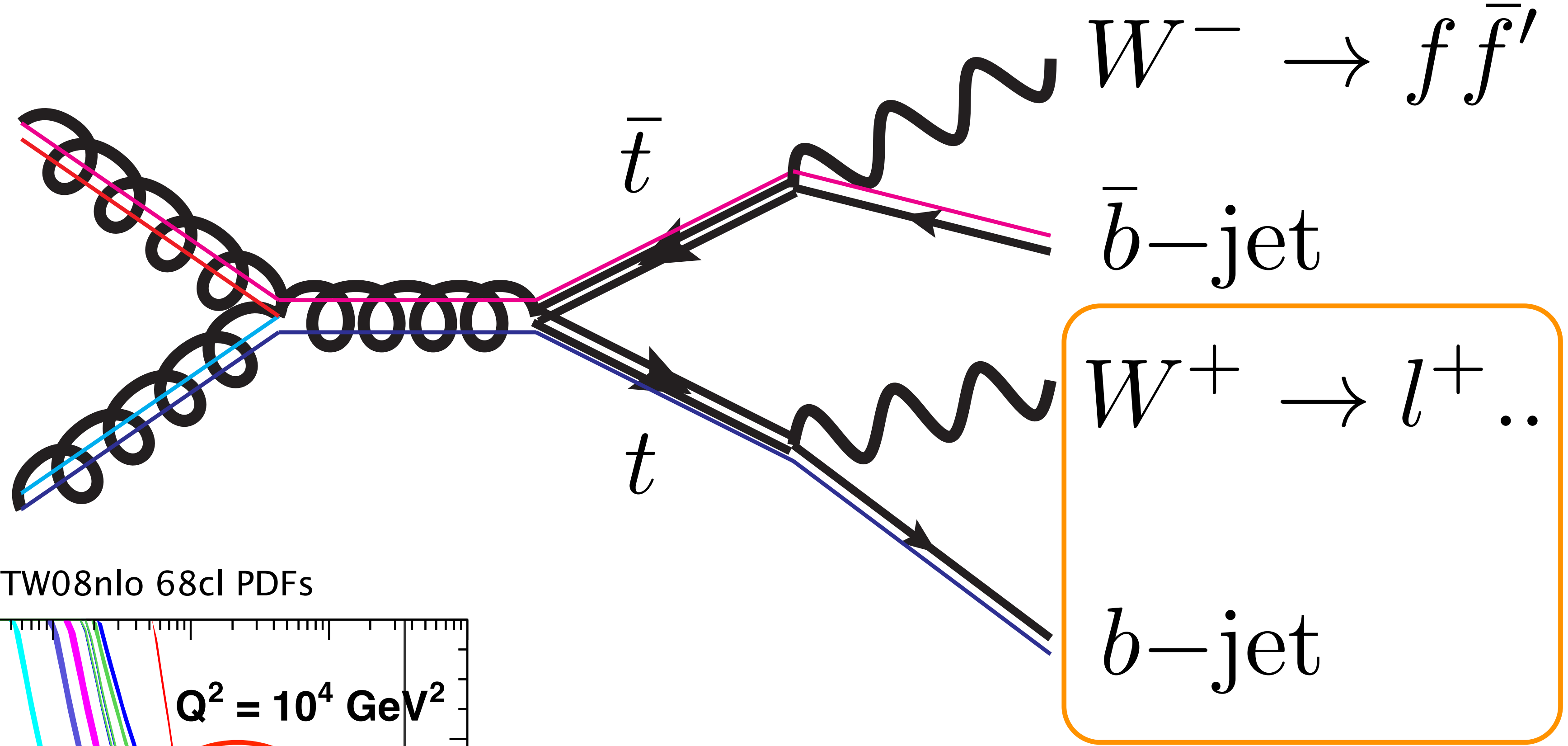
ttbar production

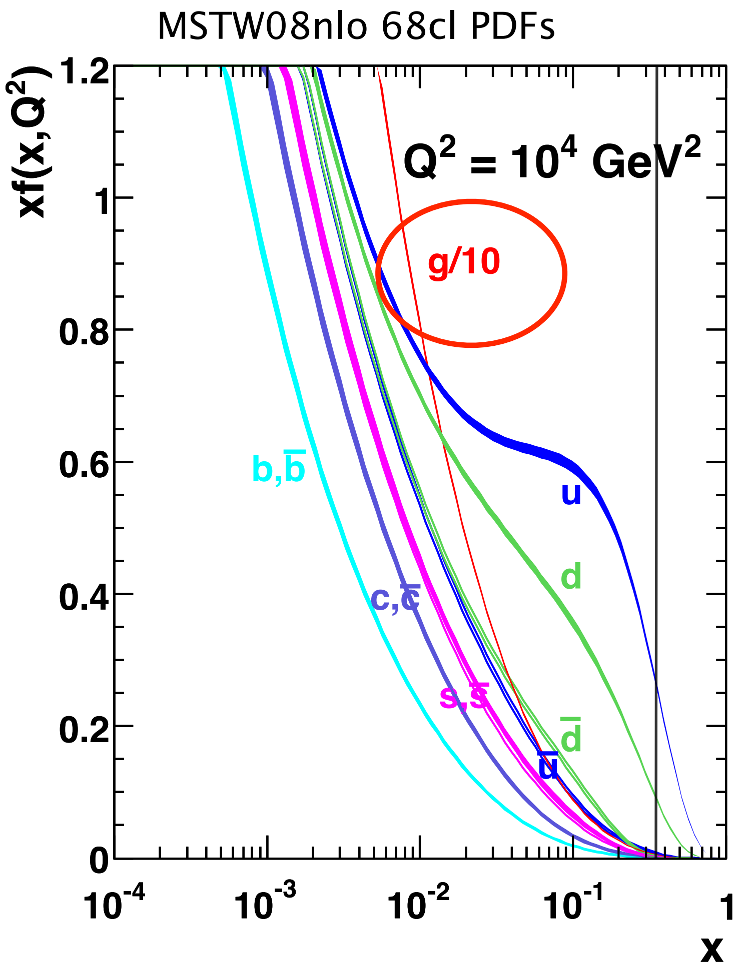


$$x_{1,(2)} = \frac{m_T}{\sqrt{\hat{s}}}\left(e^{(-)y_3} + e^{(-)y_4}\right)$$



ttbar production

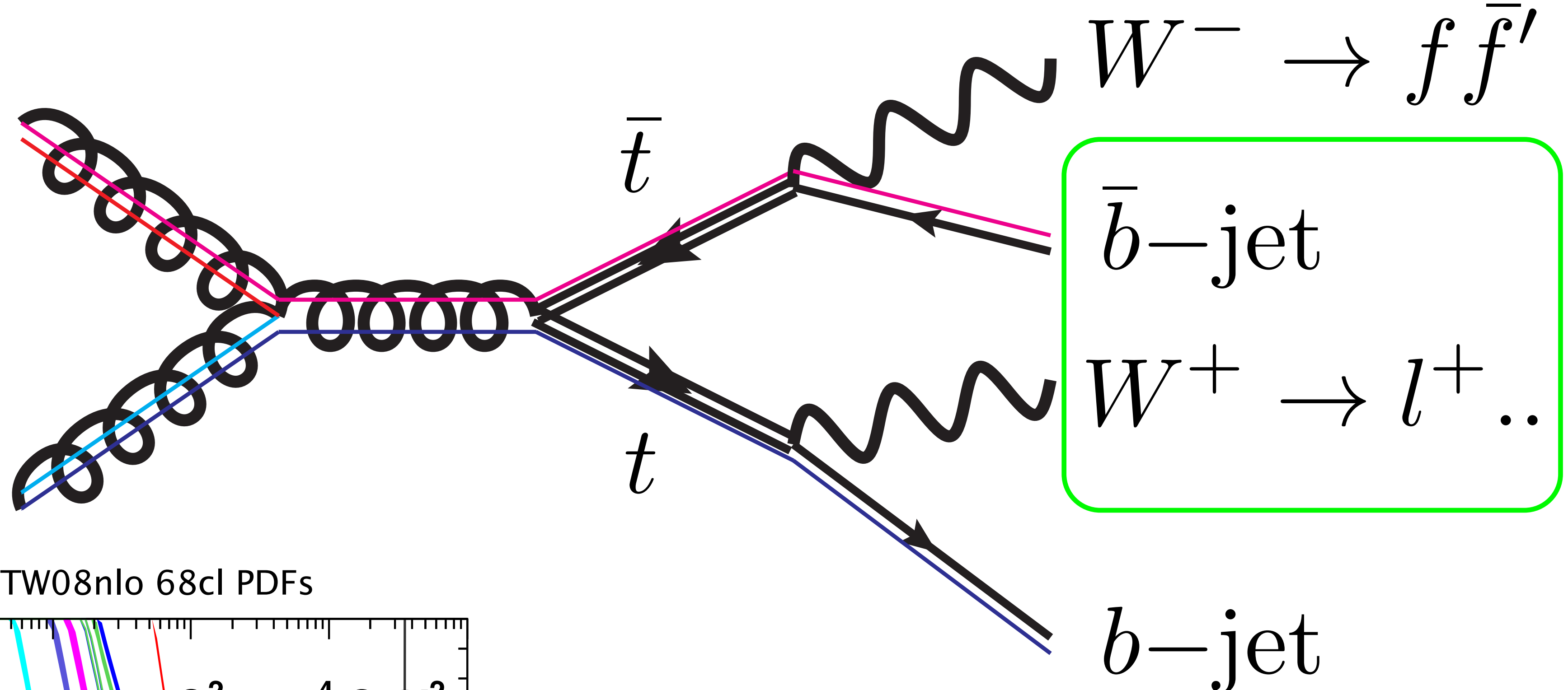


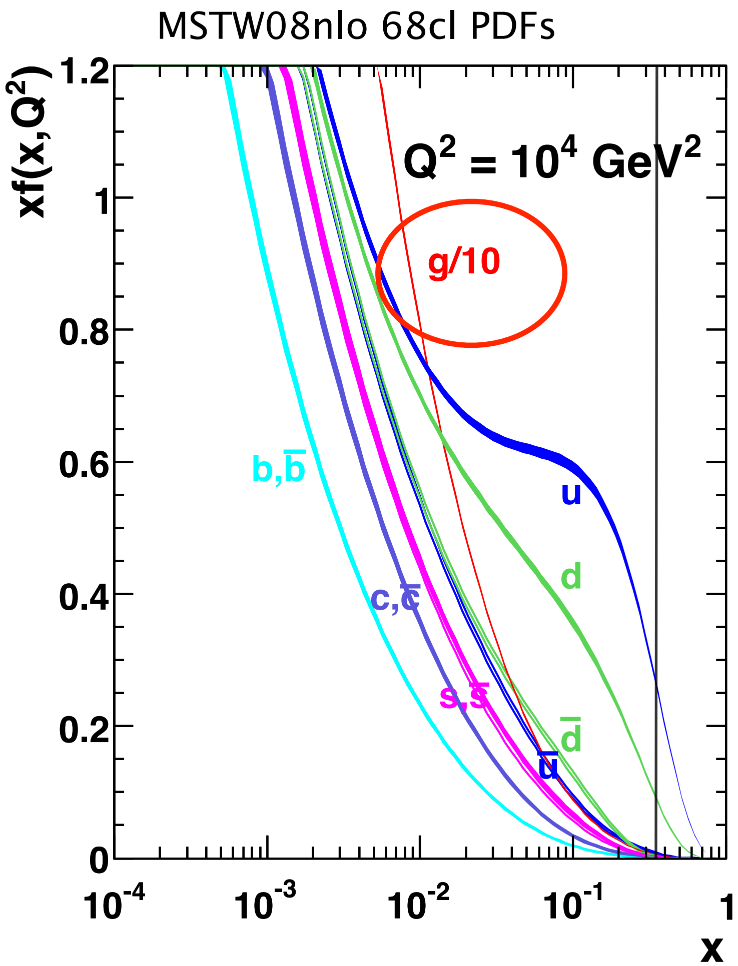


tops at LHCb = high x_1 partons

e.g. **arXiv:1103.3747** A. Kagan, J. Kamenik, G. Perez, S. Stone

ttbar production





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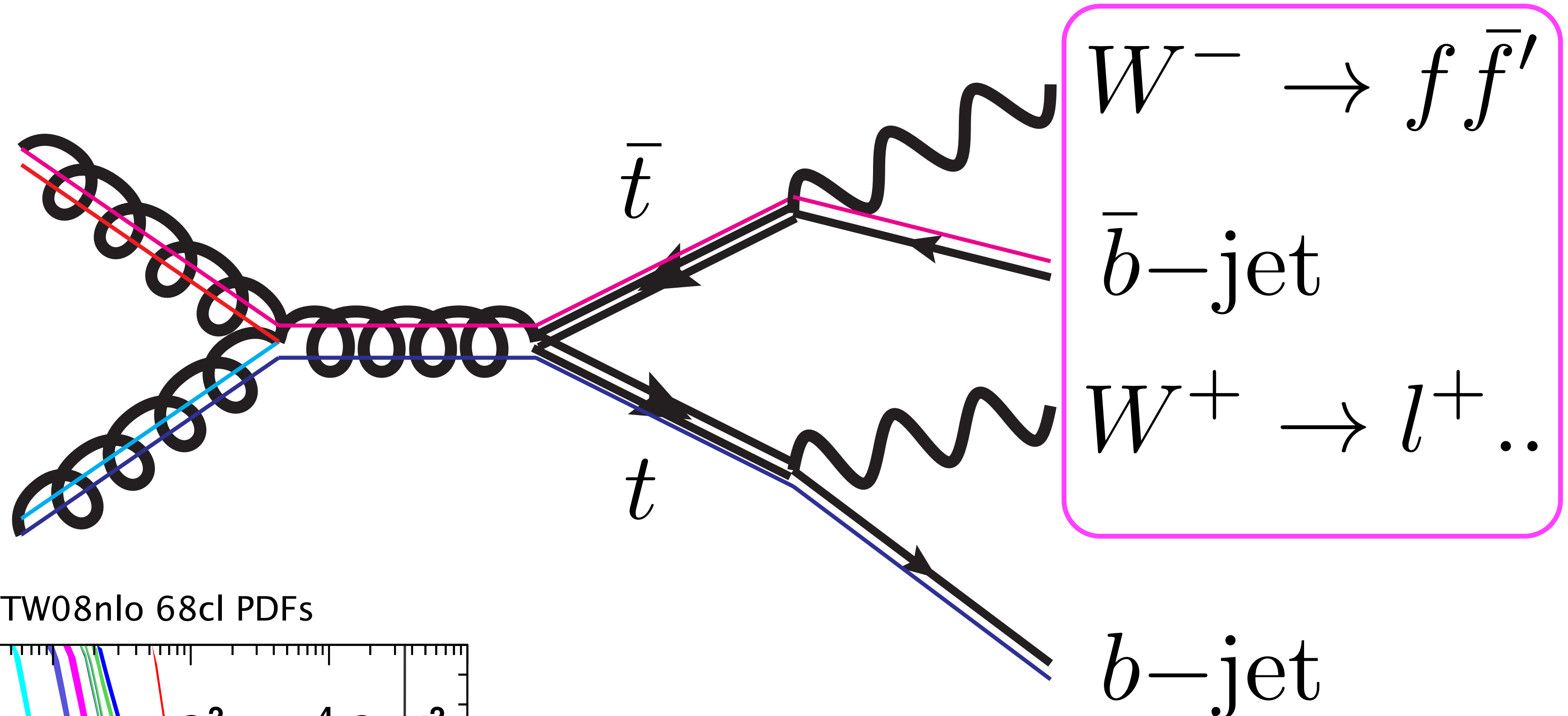
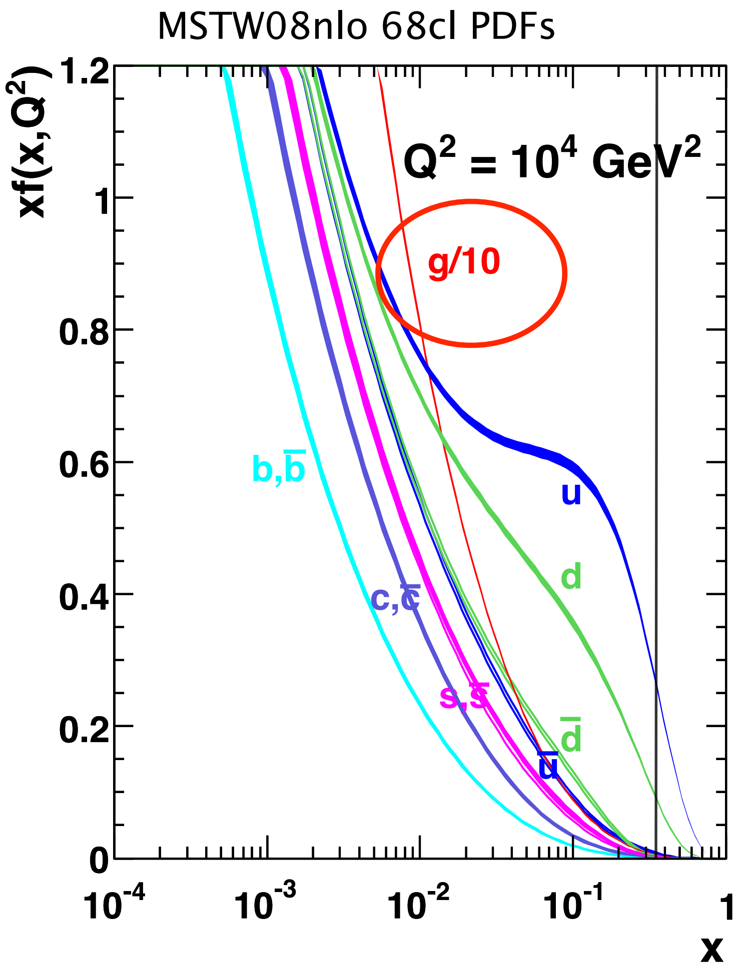




tag top charge by lepton charge!

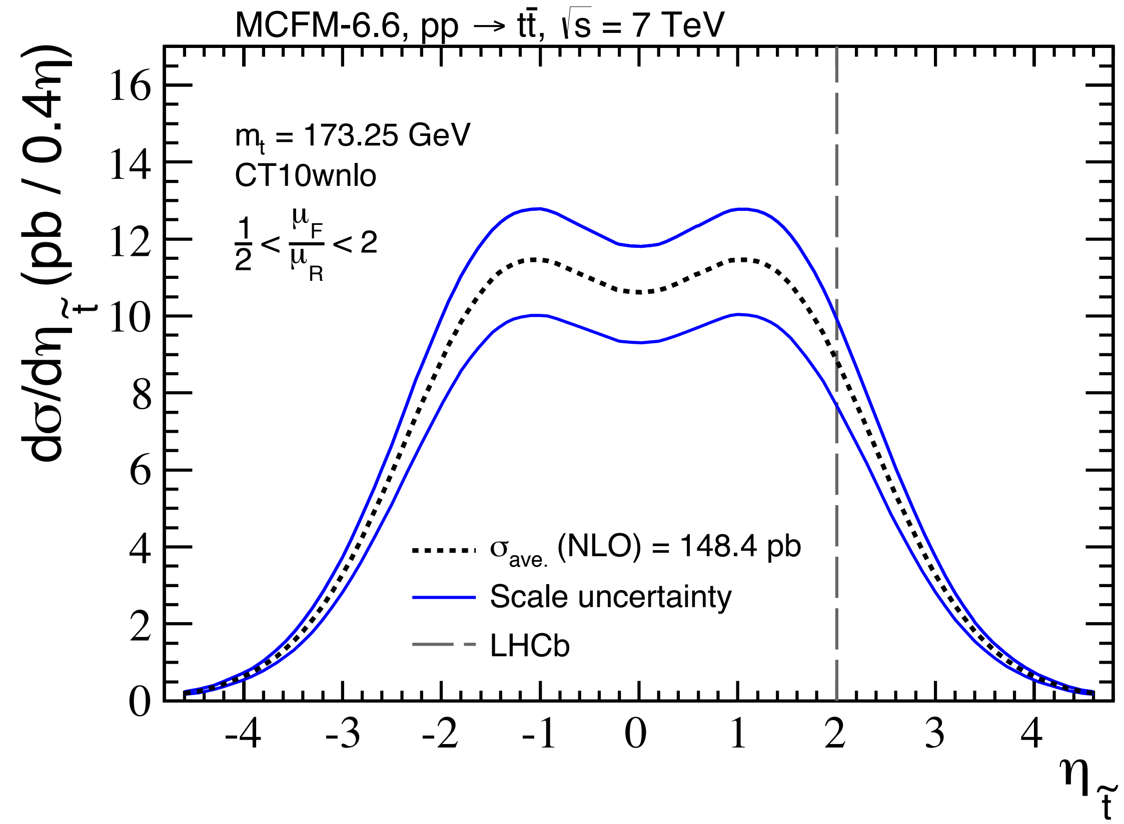
tops at LHCb = high x_1 partons

e.g. **arXiv:1103.3747** A. Kagan et al.
see back-ups for various cross-sections

ttbar production II

$$\frac{\partial\sigma}{\partial X_{\tilde{t}}} = \frac{1}{2}\left(\frac{\partial\sigma}{\partial X_t} + \frac{\partial\sigma}{\partial X_{\bar{t}}}\right)$$

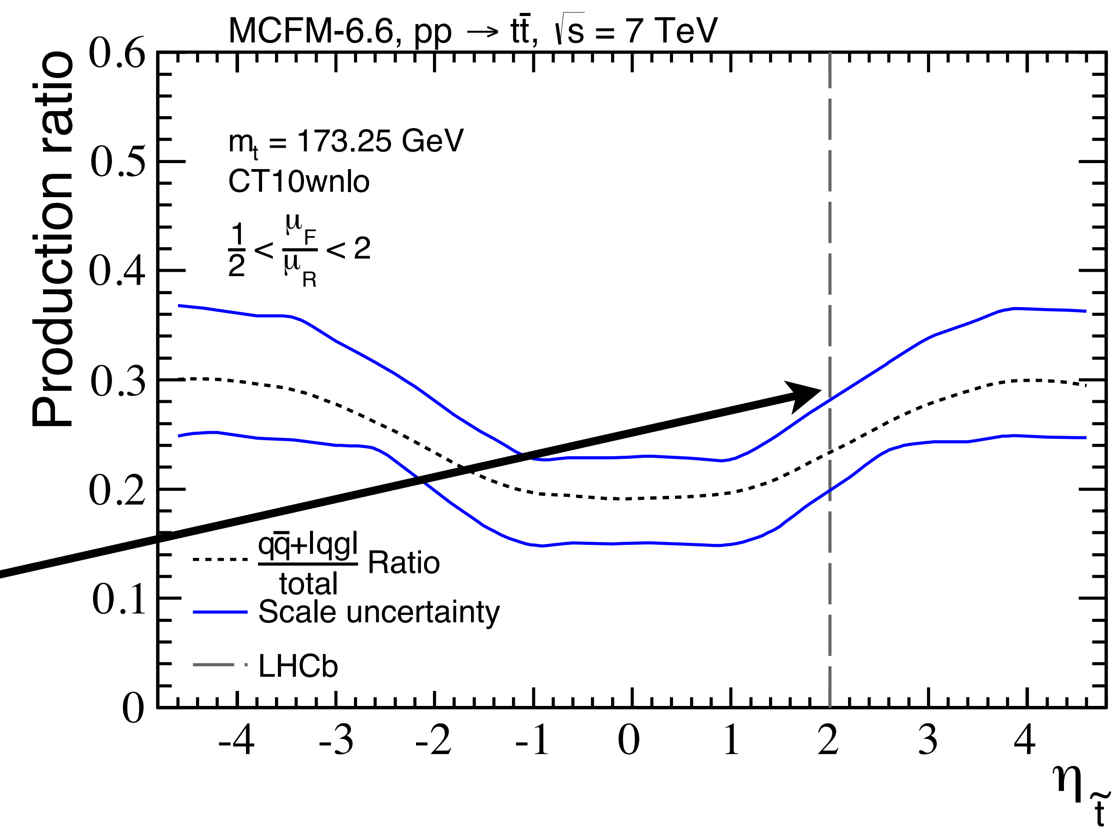
$$\sigma^{LHCb} = \int_{\eta=2} \frac{\partial\sigma}{\partial\eta_{\tilde{t}}}$$



Production mechanism ratio:

$$\frac{q\bar{q} + |qg|}{total}$$

LHCb probes unique region



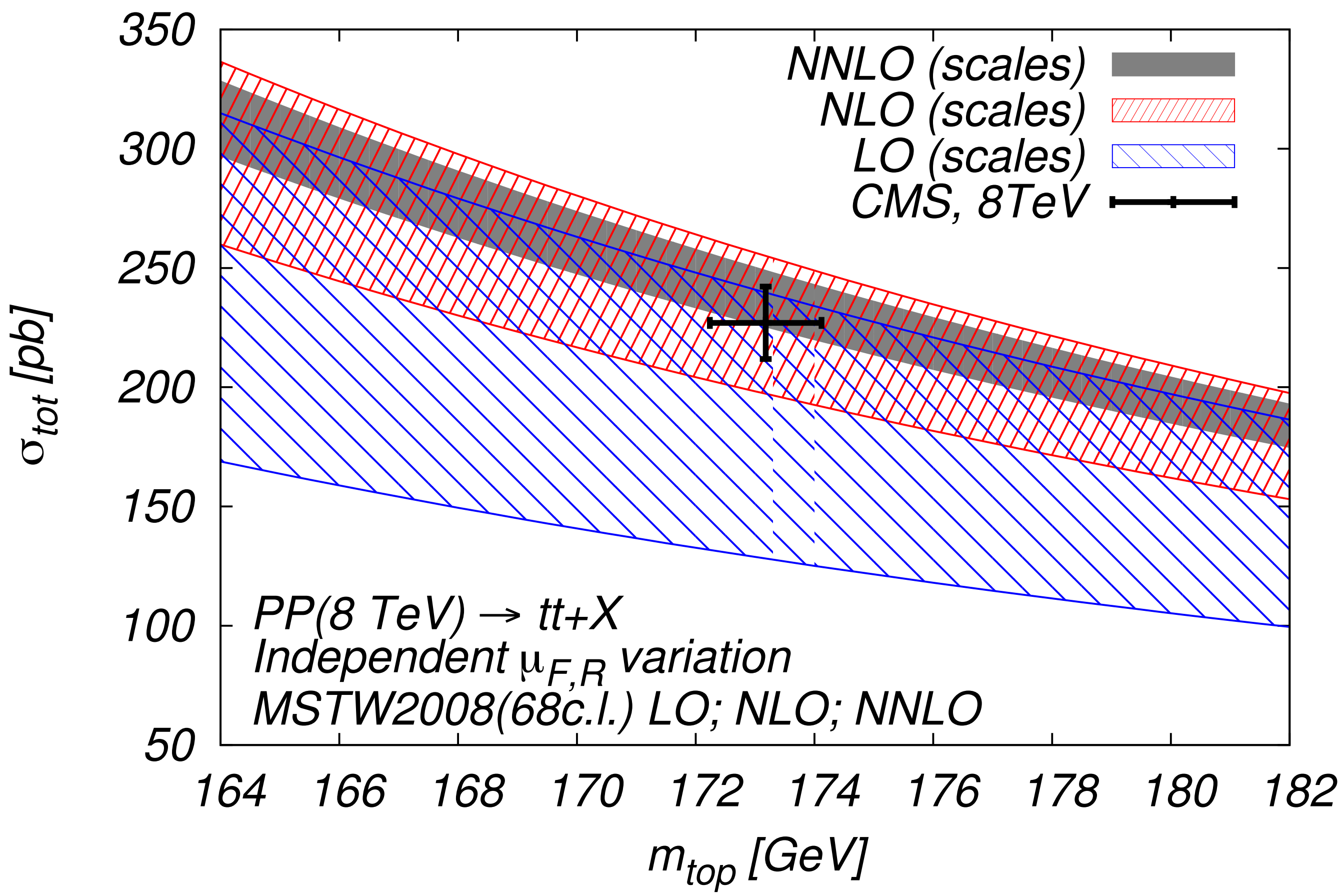
top mass

$$\hat{\sigma}(\beta) = \frac{\alpha_s^2}{m^2}\left(\sigma_{ij}^{(0)} + \alpha_s \sigma_{ij}^{(1)} + \alpha_s^2 \sigma_{ij}^{(2)} + \mathcal{O}(\alpha_s^3)\right)$$

TeVatron combination $8.7 fb^{-1}$

$173.20 \pm 0.51(stat) \pm 0.71(sys) GeV/c^2$

arXiv:1305.3929



arXiv:1305.3892 M. Czakon et al.

$$\delta m_t = 1 GeV \rightarrow \delta\sigma^{LHCb} = 3\%$$

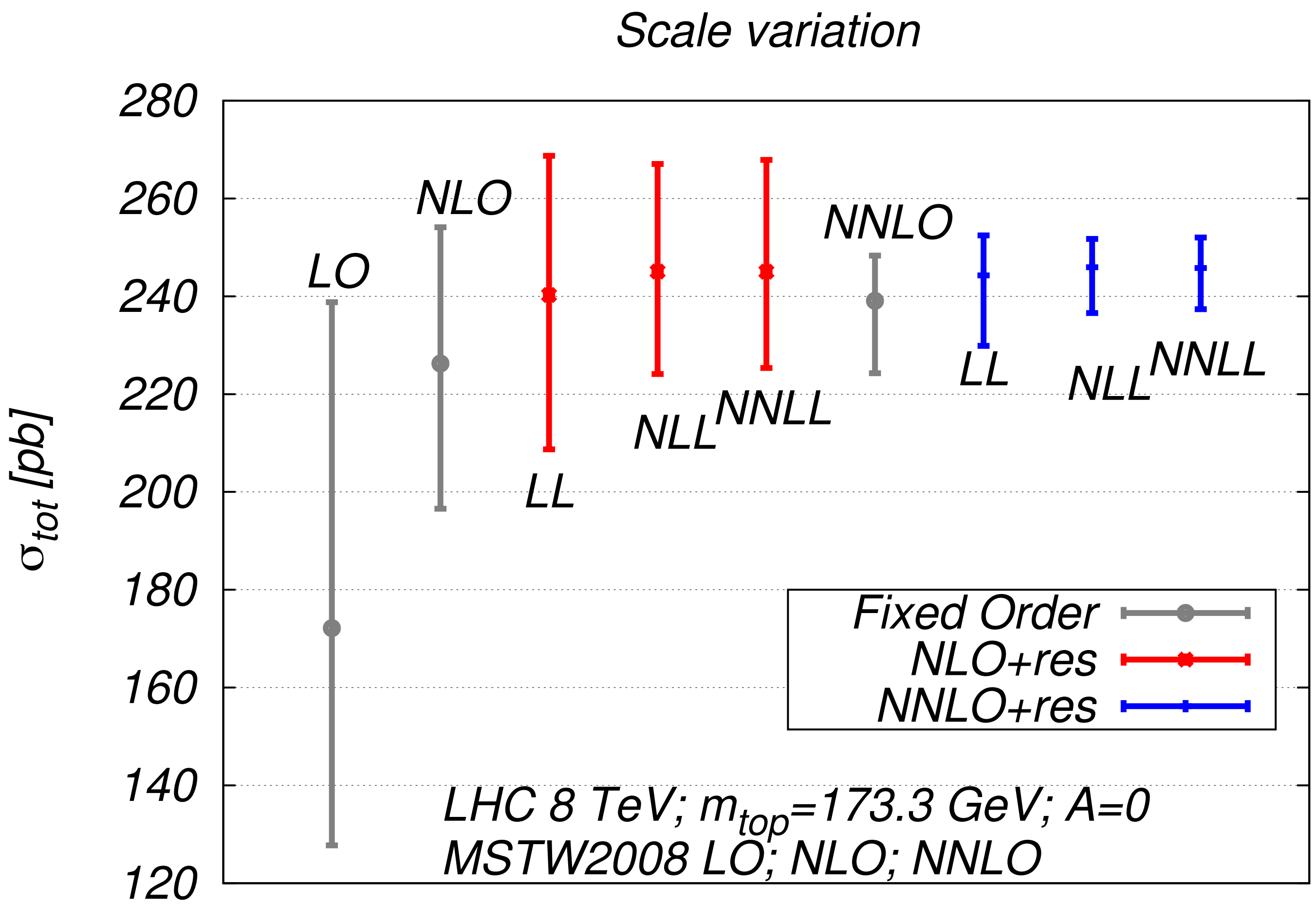
scale

Completion of inclusive NNLO calculation arXiv:1303.6254

M. Czakon, P. Fielder, A. Mitov

Vary ren./factorisation

$$\frac{1}{2} < \frac{\mu_F \cdot m_t}{\mu_t \cdot m_t} < 2$$

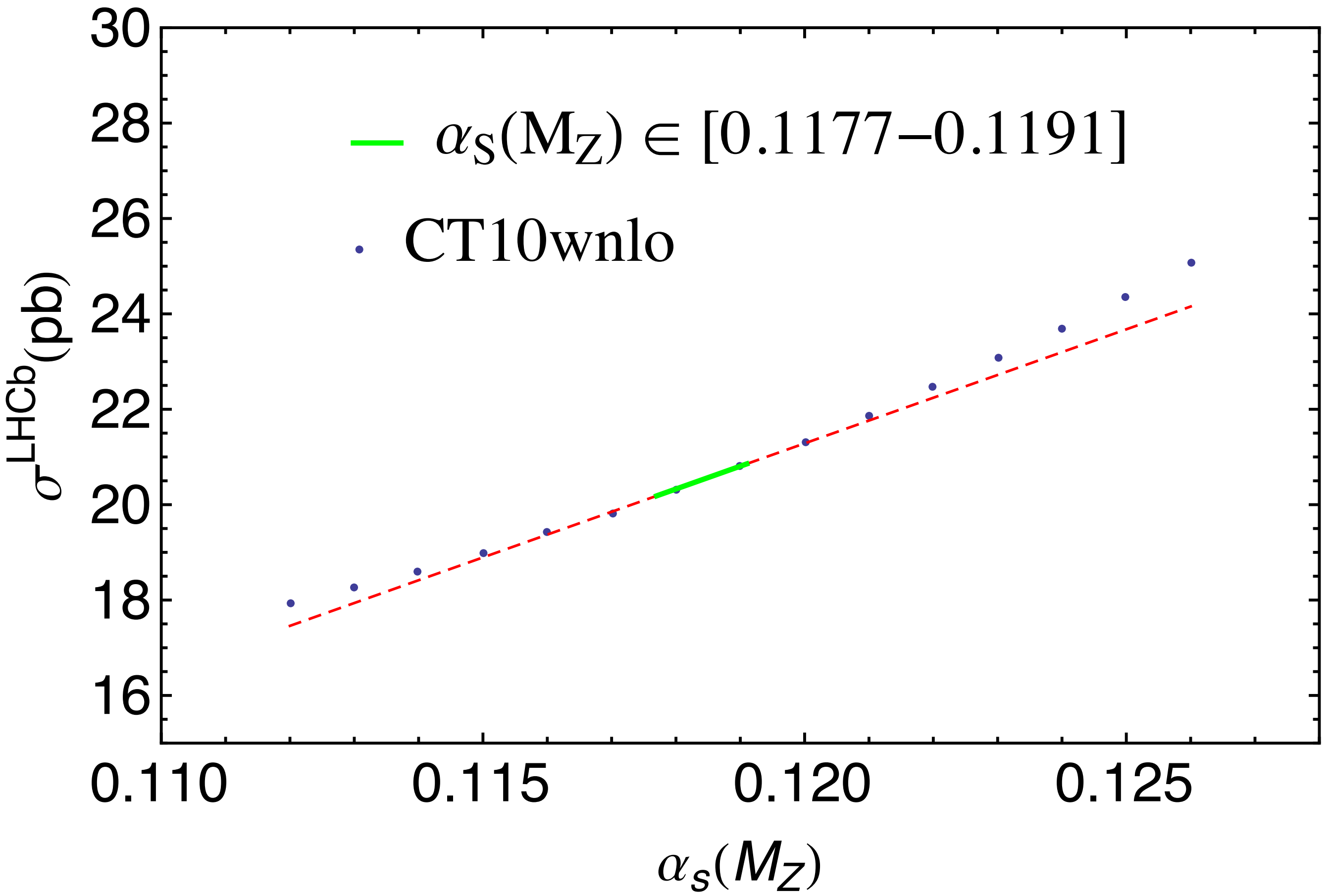


arXiv:1305.3892 M. Czakon et al.

$\delta\sigma^{LHCb}(\mathrm{NLO})$	$^{+13.9\%}_{-14.2\%}$
NNLO	$^{+4.0\%}_{-6.4\%}$
NNLO+NNLL	$^{+2.6\%}_{-3.4\%}$

strong coupling

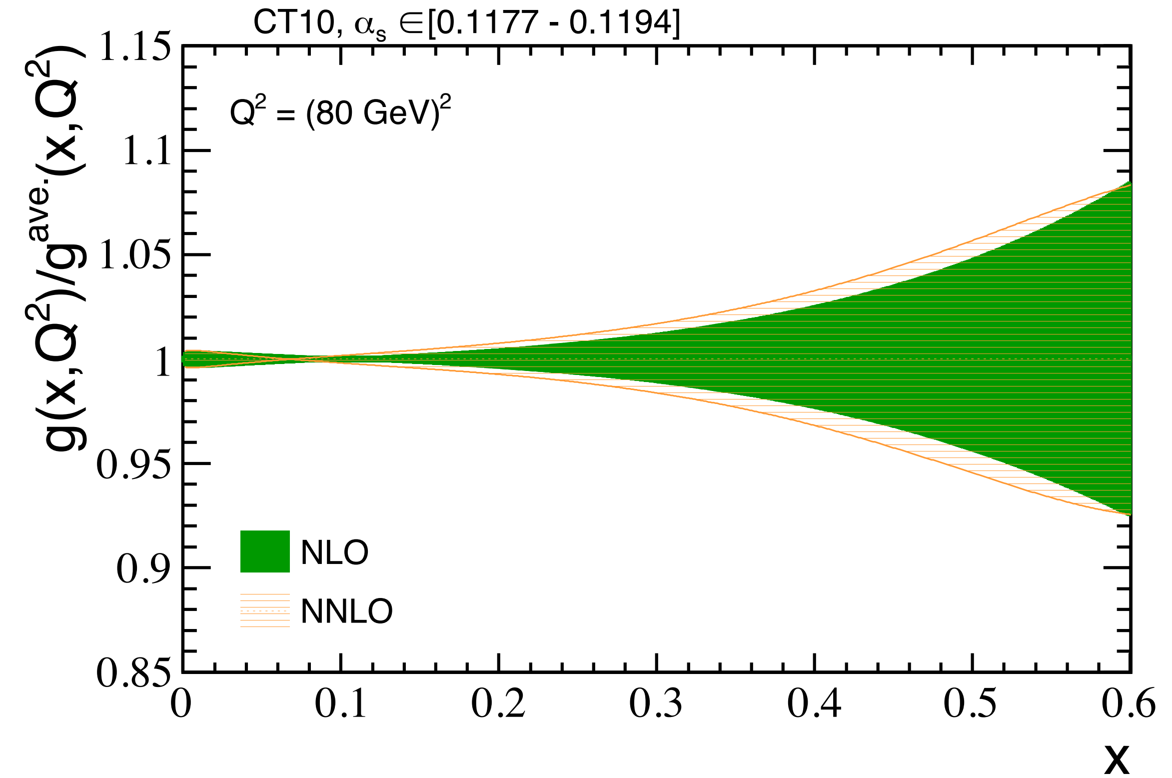
σ^{LHCb} vs. $\alpha_s(M_Z)$



Current PDG value

$$\alpha_s(M_Z) = 0.1184 \pm 0.0007$$

gluon PDF uncertainty for $\delta\alpha_s$

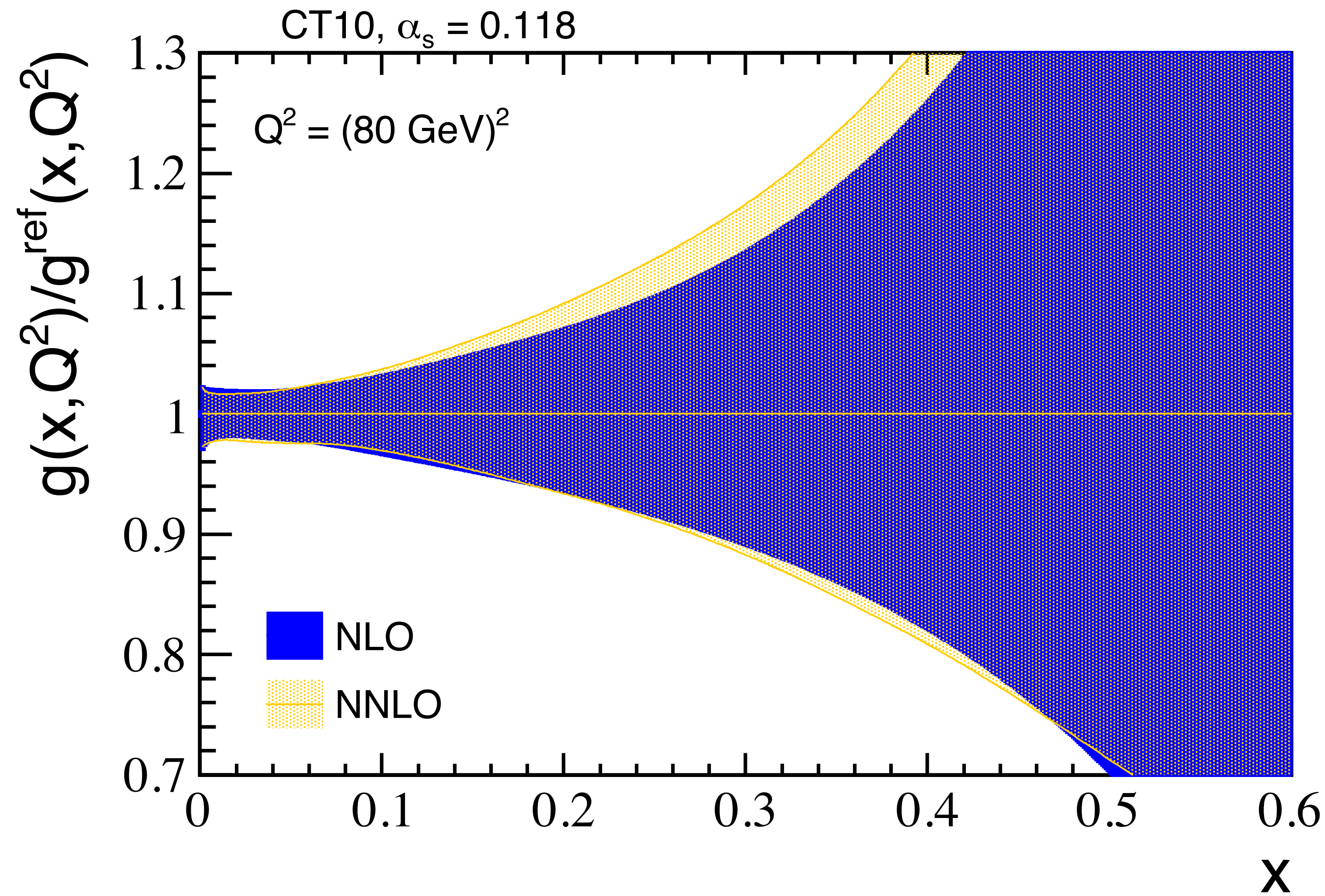


$$\delta\alpha_s \rightarrow \delta\sigma^{LHCb} \approx 1.5\%$$

PDF uncertainties

high-x gluon PDF un-constrained

uncertainty generally grows with increasing x



Remark:ttbar at LHCb still dominated by gg-scattering (slide 7)

Compare PDF uncertainty: inclusive vs LHCb cross-section

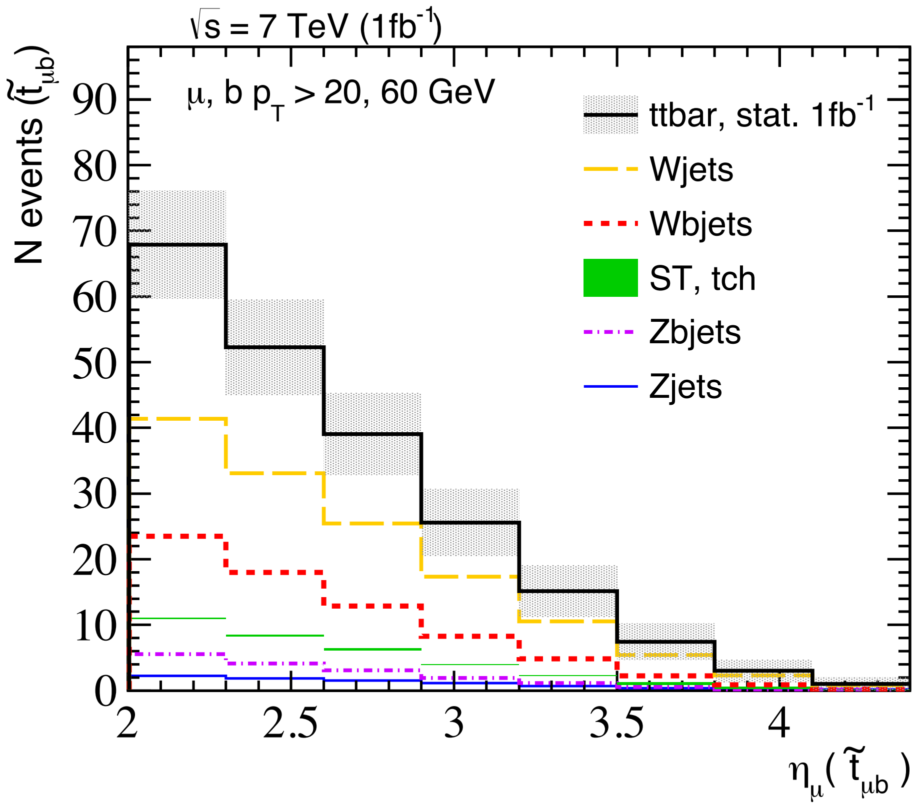
$$\delta PDF \rightarrow \delta\sigma^{NLO} =^{+4.4\%}_{-4.2\%}$$

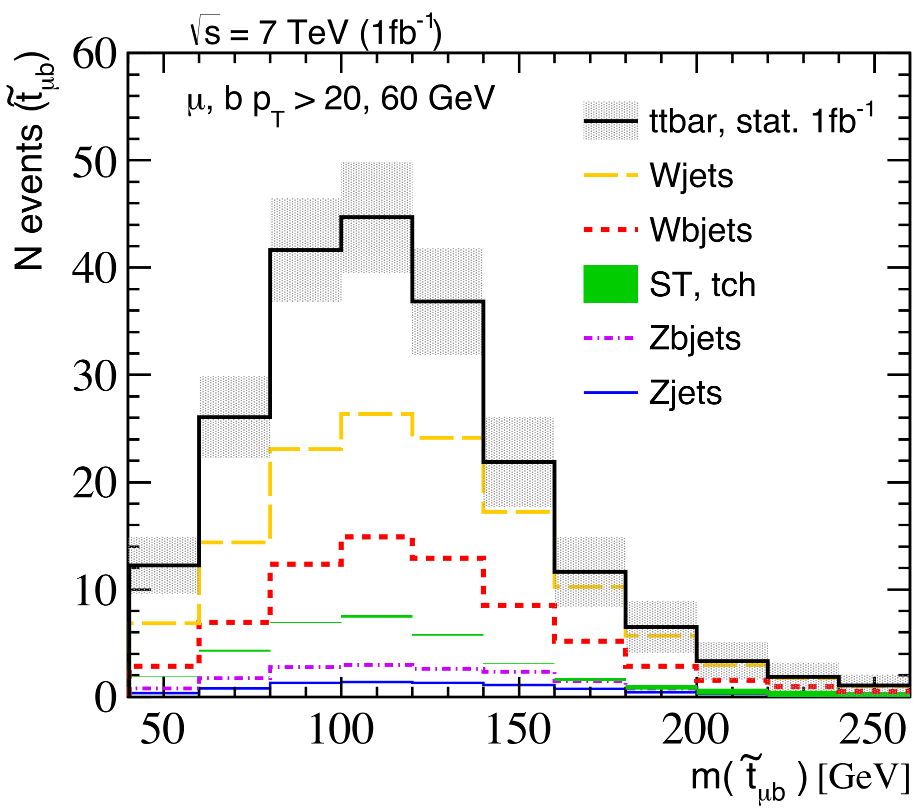
$$\delta PDF \rightarrow \delta\sigma^{LHCb} =^{+6.9\%}_{-5.5\%}$$

summary of uncertainties

Order	PDF	σ(pb)	δ_{scale} (pb)	δ_{PDF} (pb)	δ_{α_s} (pb)	δ_{m_t} (pb)	δ_{total} (pb)
NNL(O/L)		172.5	$^{+4.6}_{-6.0}$ $(^{+2.7\%}_{-3.5\%})$	$^{+8.0}_{-6.5}$ $(^{+4.6\%}_{-3.8\%})$	$^{+3.7}_{-3.7}$ $(^{+2.2\%}_{-2.2\%})$	$^{+8.0}_{-7.7}$ $(^{+4.6\%}_{-4.4\%})$	$^{+16.5}_{-16.7}$ $(^{+9.5\%}_{-9.7\%})$
NLO	CT10	148.3	$^{+17.7}_{-19.2}$ $(^{+11.9\%}_{-12.9\%})$	$^{+6.6}_{-6.1}$ $(^{+4.4\%}_{-4.2\%})$	$^{+1.9}_{-1.9}$ $(^{+1.3\%}_{-1.3\%})$	$^{+6.6}_{-6.4}$ $(^{+4.6\%}_{-4.4\%})$	$^{+27.2}_{-28.2}$ $(^{+18.4\%}_{-19.0\%})$
LHCb		19.9	$^{+2.6}_{-2.7}$ $(^{+13.3\%}_{-13.7\%})$	$^{+1.4}_{-1.1}$ $(^{+6.9\%}_{-5.5\%})$	$^{+0.3}_{-0.3}$ $(^{+1.7\%}_{-1.7\%})$	$^{+0.9}_{-0.9}$ $(^{+4.8\%}_{-4.8\%})$	$^{+4.4}_{-4.2}$ $(^{+21.9\%}_{-21.2\%})$
NNL(O/L)		177.2	$^{+4.8}_{-4.2}$ $(^{+2.7\%}_{-2.3\%})$	$^{+4.0}_{-6.4}$ $(^{+2.3\%}_{-3.6\%})$	$^{+3.0}_{-3.0}$ $(^{+1.7\%}_{-1.7\%})$	$^{+8.1}_{-7.8}$ $(^{+4.6\%}_{-4.4\%})$	$^{+14.3}_{-14.7}$ $(^{+8.1\%}_{-8.3\%})$
NLO	HERA	136.1	$^{+15.6}_{-16.3}$ $(^{+11.5\%}_{-12.0\%})$	$^{+3.9}_{-3.4}$ $(^{+2.9\%}_{-2.5\%})$	$^{+1.4}_{-1.4}$ $(^{+1.0\%}_{-1.0\%})$	$^{+6.3}_{-6.1}$ $(^{+4.6\%}_{-4.5\%})$	$^{+23.1}_{-23.4}$ $(^{+17.0\%}_{-17.2\%})$
LHCb		16.9	$^{+2.1}_{-2.0}$ $(^{+12.3\%}_{-12.0\%})$	$^{+0.5}_{-0.3}$ $(^{+2.9\%}_{-1.6\%})$	$^{+0.2}_{-0.2}$ $(^{+1.2\%}_{-1.2\%})$	$^{+0.8}_{-0.8}$ $(^{+4.9\%}_{-4.8\%})$	$^{+3.1}_{-2.9}$ $(^{+18.1\%}_{-17.2\%})$
NNL(O/L)		172.0	$^{+4.4}_{-5.8}$ $(^{+2.6\%}_{-3.4\%})$	$^{+4.7}_{-4.7}$ $(^{+2.7\%}_{-2.7\%})$	$^{+2.9}_{-2.9}$ $(^{+1.7\%}_{-1.7\%})$	$^{+8.0}_{-7.7}$ $(^{+4.6\%}_{-4.4\%})$	$^{+14.1}_{-15.2}$ $(^{+8.2\%}_{-8.9\%})$
NLO	MSTW	158.4	$^{+19.6}_{-21.2}$ $(^{+12.4\%}_{-13.4\%})$	$^{+4.0}_{-5.5}$ $(^{+2.6\%}_{-3.5\%})$	$^{+2.1}_{-2.1}$ $(^{+1.3\%}_{-1.3\%})$	$^{+7.0}_{-6.9}$ $(^{+4.6\%}_{-4.4\%})$	$^{+27.9}_{-30.3}$ $(^{+17.6\%}_{-19.1\%})$
LHCb		20.8	$^{+2.9}_{-2.9}$ $(^{+13.9\%}_{-14.2\%})$	$^{+0.7}_{-0.9}$ $(^{+3.2\%}_{-4.2\%})$	$^{+0.3}_{-0.3}$ $(^{+1.5\%}_{-1.5\%})$	$^{+1.0}_{-1.0}$ $(^{+4.8\%}_{-4.8\%})$	$^{+4.1}_{-4.3}$ $(^{+19.9\%}_{-20.8\%})$
NNL(O/L)		172.7	$^{+4.6}_{-6.0}$ $(^{+2.7\%}_{-3.5\%})$	$^{+5.2}_{-5.2}$ $(^{+3.0\%}_{-3.0\%})$	$^{+2.7}_{-2.7}$ $(^{+1.6\%}_{-1.6\%})$	$^{+8.0}_{-7.8}$ $(^{+4.6\%}_{-4.5\%})$	$^{+14.5}_{-15.8}$ $(^{+8.4\%}_{-9.1\%})$
NLO	NNPDF	158.6	$^{+19.3}_{-20.5}$ $(^{+12.2\%}_{-12.9\%})$	$^{+4.0}_{-4.0}$ $(^{+2.5\%}_{-2.5\%})$	$^{+2.4}_{-2.4}$ $(^{+1.5\%}_{-1.5\%})$	$^{+7.1}_{-7.0}$ $(^{+4.6\%}_{-4.5\%})$	$^{+27.8}_{-28.9}$ $(^{+17.5\%}_{-18.2\%})$
LHCb		20.2	$^{+2.8}_{-2.7}$ $(^{+14.0\%}_{-13.3\%})$	$^{+0.7}_{-0.7}$ $(^{+3.3\%}_{-3.3\%})$	$^{+0.4}_{-0.4}$ $(^{+1.8\%}_{-1.8\%})$	$^{+1.0}_{-0.9}$ $(^{+4.9\%}_{-4.8\%})$	$^{+4.1}_{-3.9}$ $(^{+20.2\%}_{-19.4\%})$

potential precision 7 TeV





Expected number of events?

Consider muon + b-jet final state

POWHEG(NLO)->pythia8
anti-kt R = 0.5 jets
ST, tch = t-channel single top

Kinematic cuts:

$$\mu\ p_T > 20\ GeV$$
$$b\text{−jet}\ p_T > 60\ GeV$$
$$\mu, b\text{−jet}\ \eta \in [2.0 - 4.5]$$

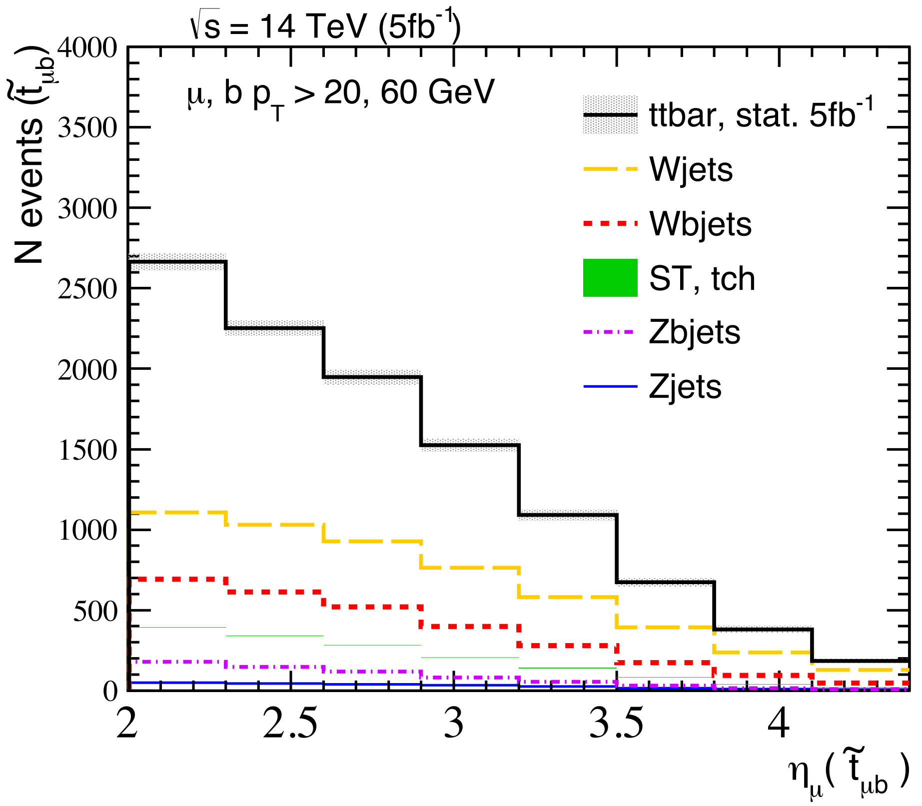
Isolation:

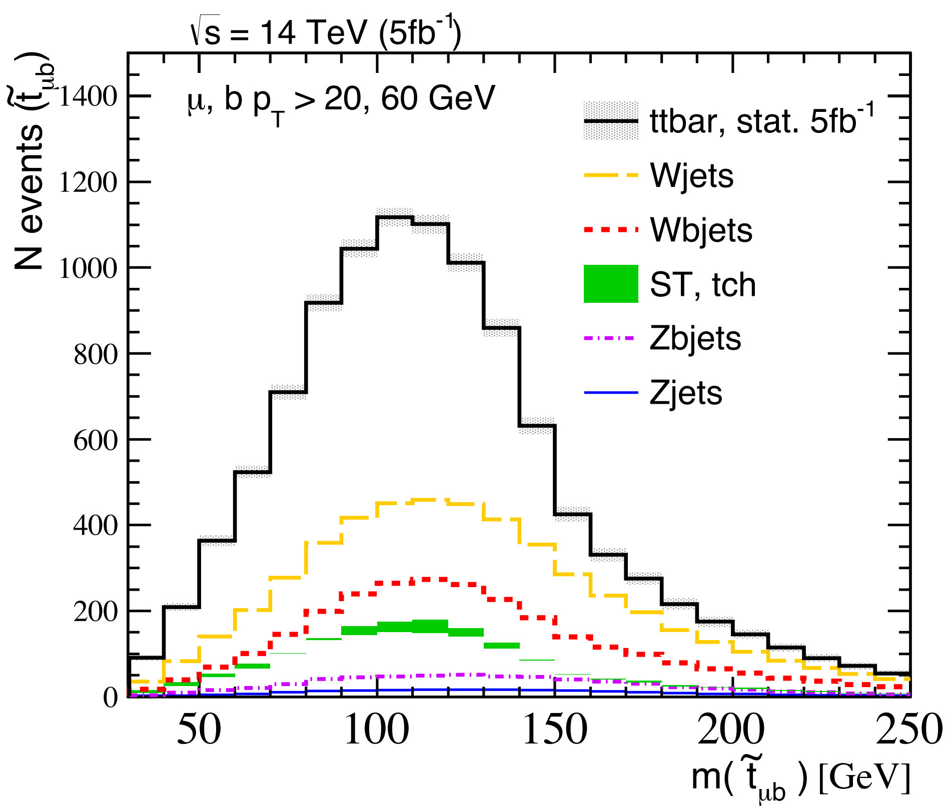
$$\Delta R(\mu, \text{jet}) > 0.5$$

Efficiencies:

b mis-tag = 1%
b efficiency = 70%
muon efficiency = 75%

potential precision 14 TeV





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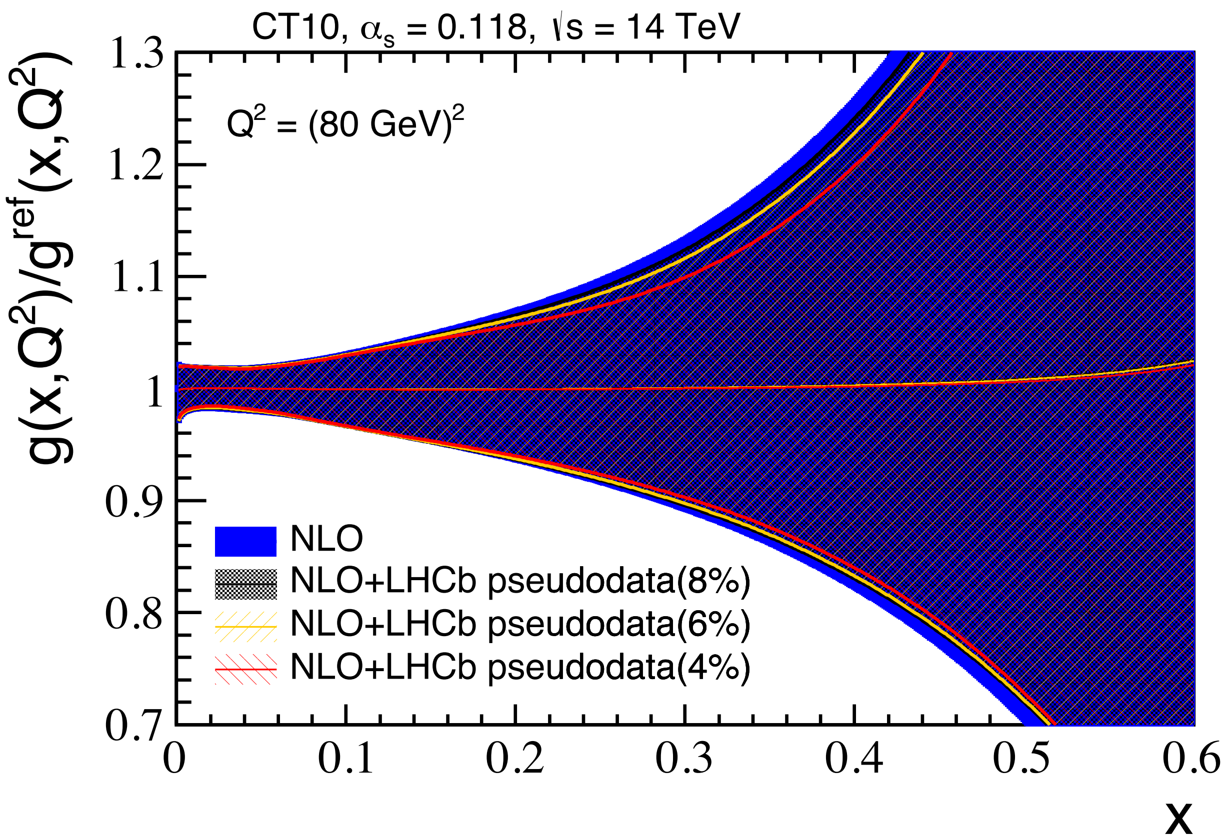
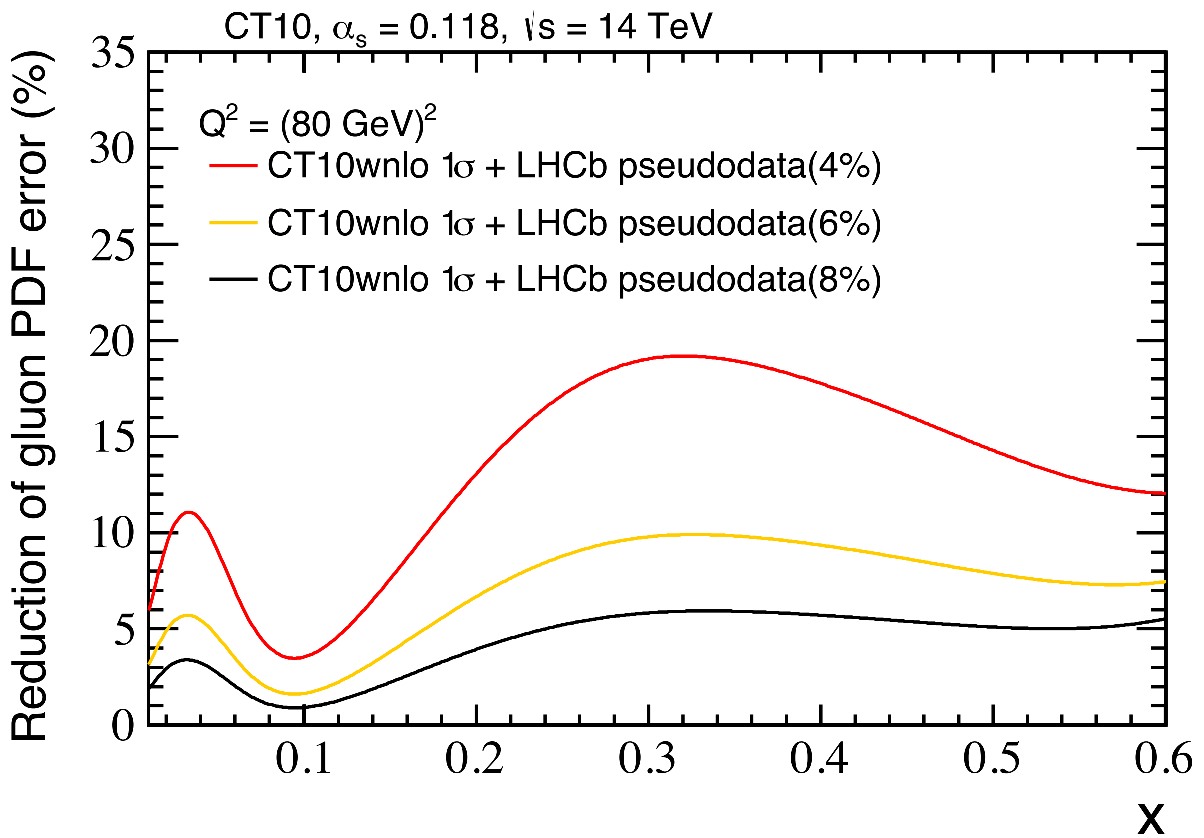
what can LHCb provide?

perform a PDF re-weighting based on LHCb cross-section measurement at 14TeV with 4, 6, 8% exp. uncertainty

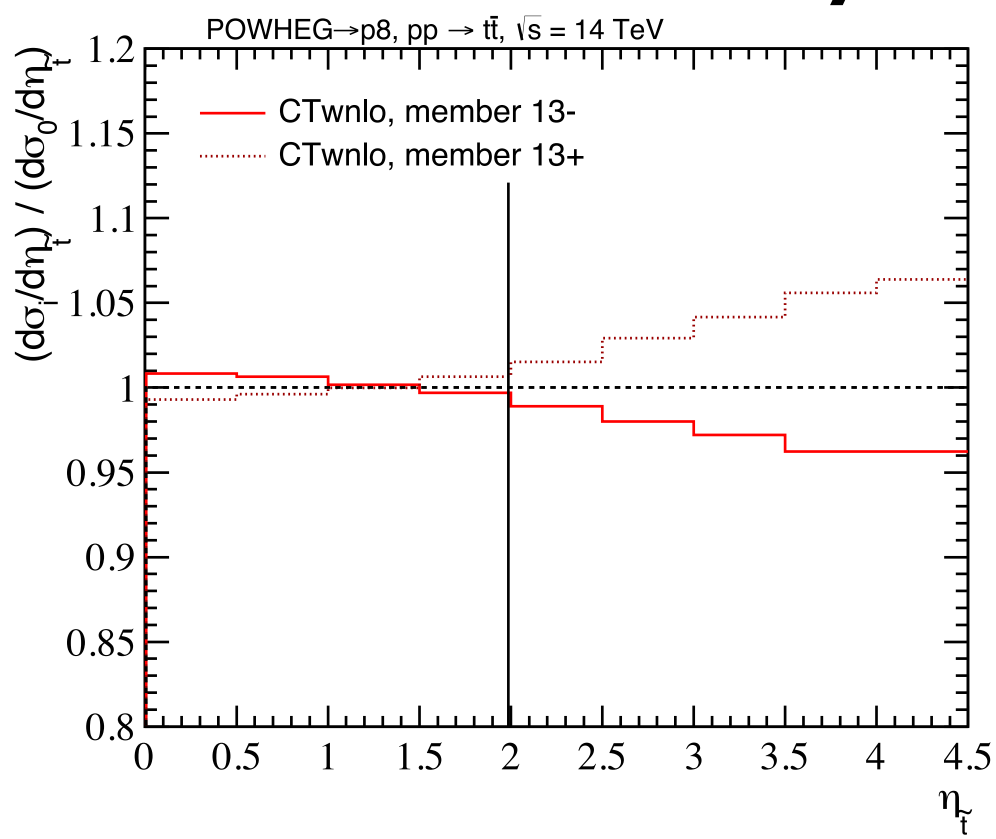
$$W_k(\chi^2_k) = (\chi^2_k)^{\frac{1}{2}(N_{pts.}-1)} \exp(-\frac{1}{2}\chi^2_k)$$

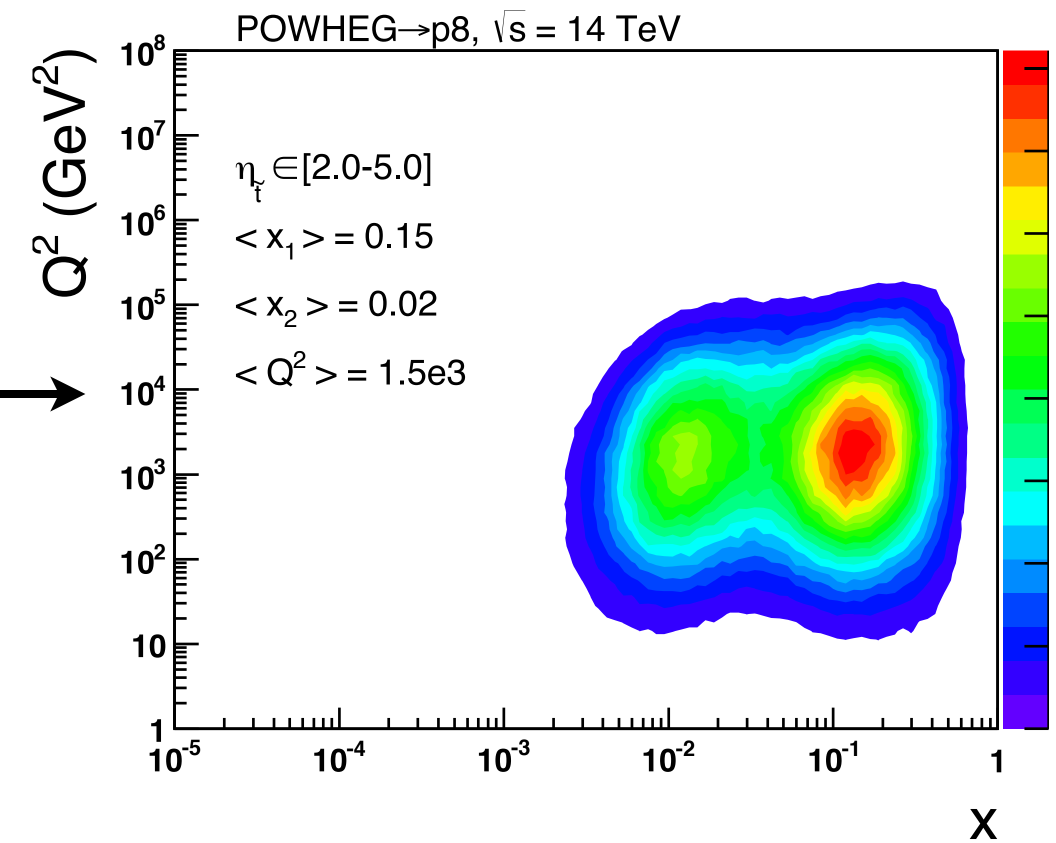
$$\langle X \rangle_{new} = \mathcal{N} \sum_{k=1}^{N_{PDF}} W_k(\chi^2_k) X_k$$

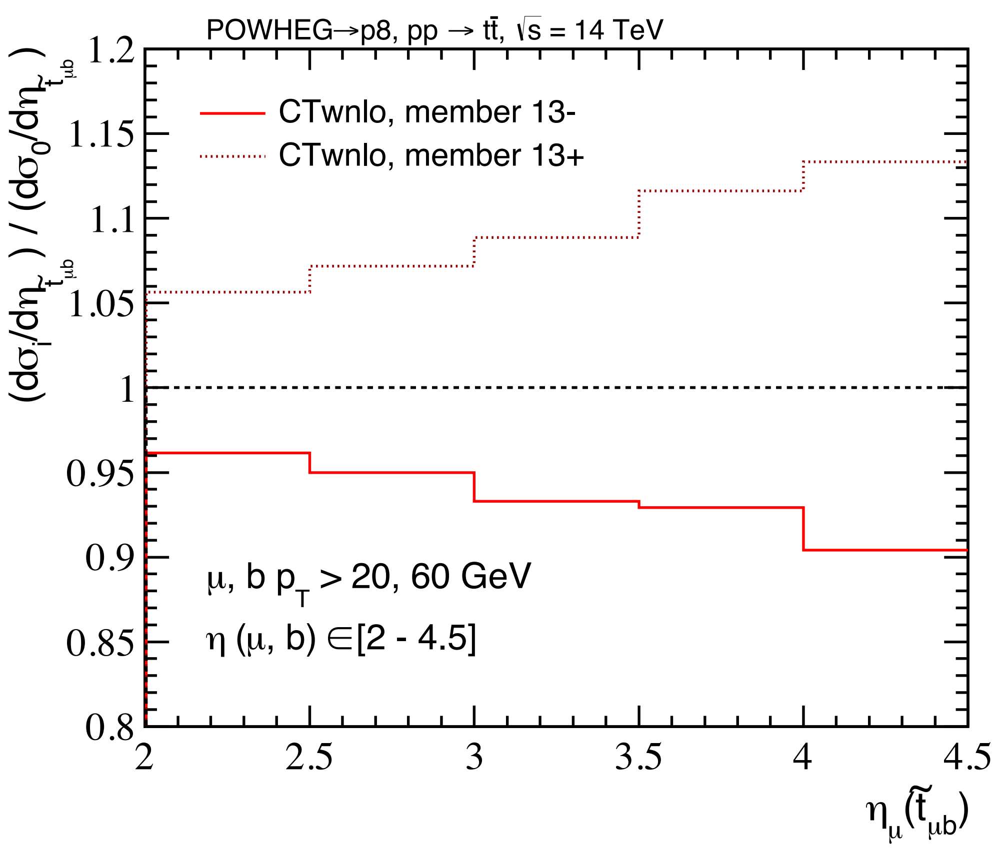


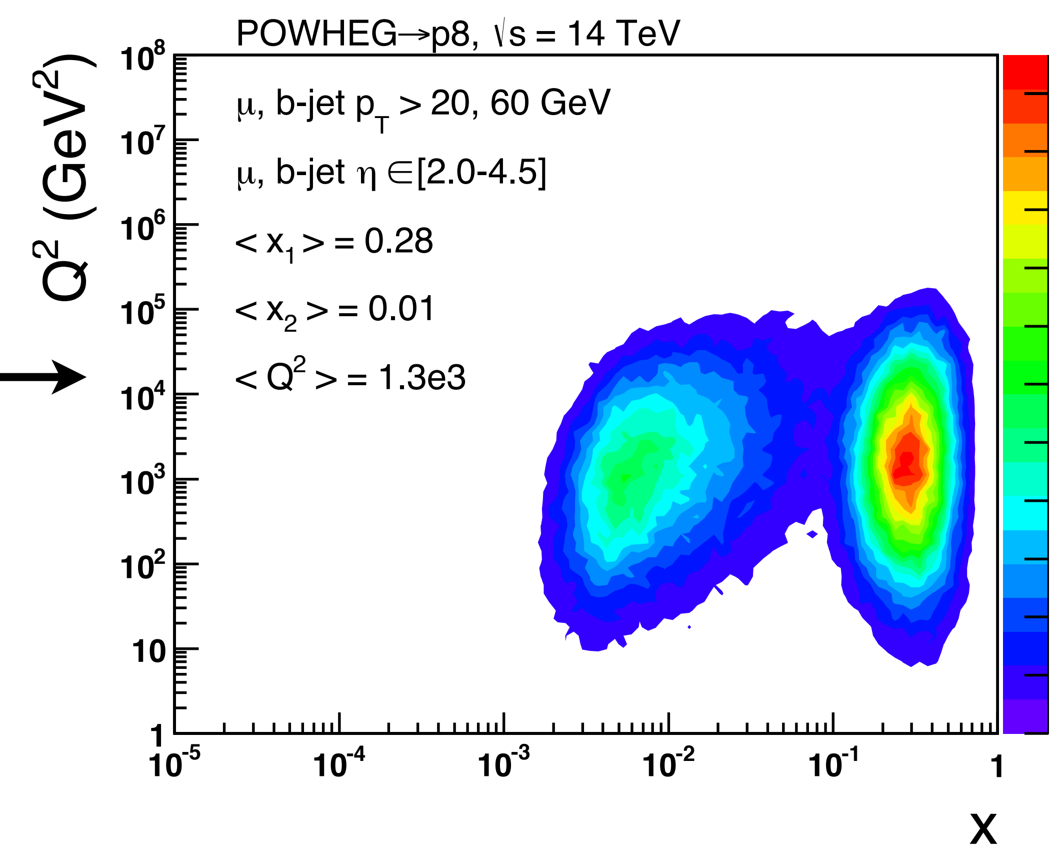


Actually an under-estimate!!









Conclusions

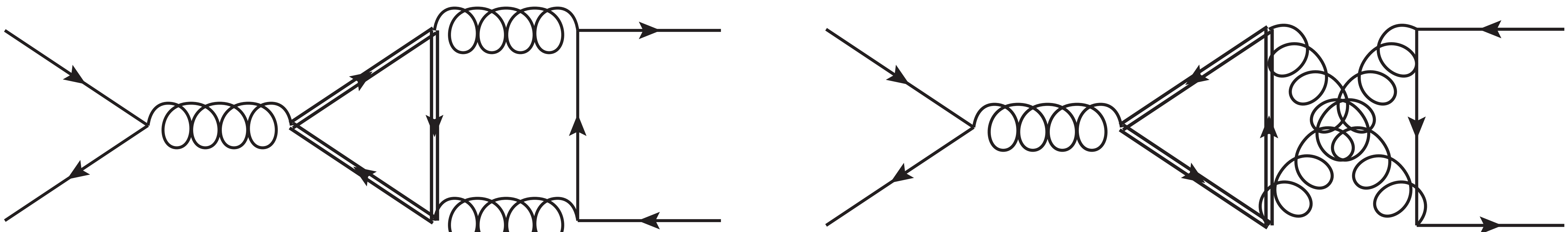
- 1 year of 13/14 TeV - no longer stat. limited
- A cross-section measurement can strongly constrain the high-x gluon PDF
- Necessary ingredients:
    - Wjets measurement
    - high pT b-jet tagger trained vs light jets
    - all background modelling NLO+
    - differential NNLO ttbar

Backups - truth b-tag matching

ttbar cross-sections for various final states.
uncertainty is combined scale, PDF and showering contributions
Same cuts as slide 13, sub-leading/non b-jets pT > 20 GeV

$d\sigma$(fb)	7 TeV	8 TeV	14 TeV
lb	285 ± 52	504 ± 94	4366 ± 663
lbj	97 ± 21	198 ± 35	2335 ± 323
lbb	32 ± 6	65 ± 12	870 ± 116
$lbbj$	10 ± 2	26 ± 4	487 ± 76
l^+l^-	44 ± 9	79 ± 15	635 ± 109
l^+l^-b	19 ± 4	39 ± 8	417 ± 79

Backups - asymmetry source



$$C_{planar} = \frac{1}{16N_c^2}(f_{abc}^2 + d_{abc}^2) \qquad C_{crossed} = \frac{1}{16N_c^2}(-f_{abc}^2 + d_{abc}^2)$$

where I used,

$$d_{abc}^2 = Tr[\{T^a, T^b\}T^c]^2$$

$$d_{abc}^2 = (N_c^2 - 1)(N_c^2 - 4)/N_c$$

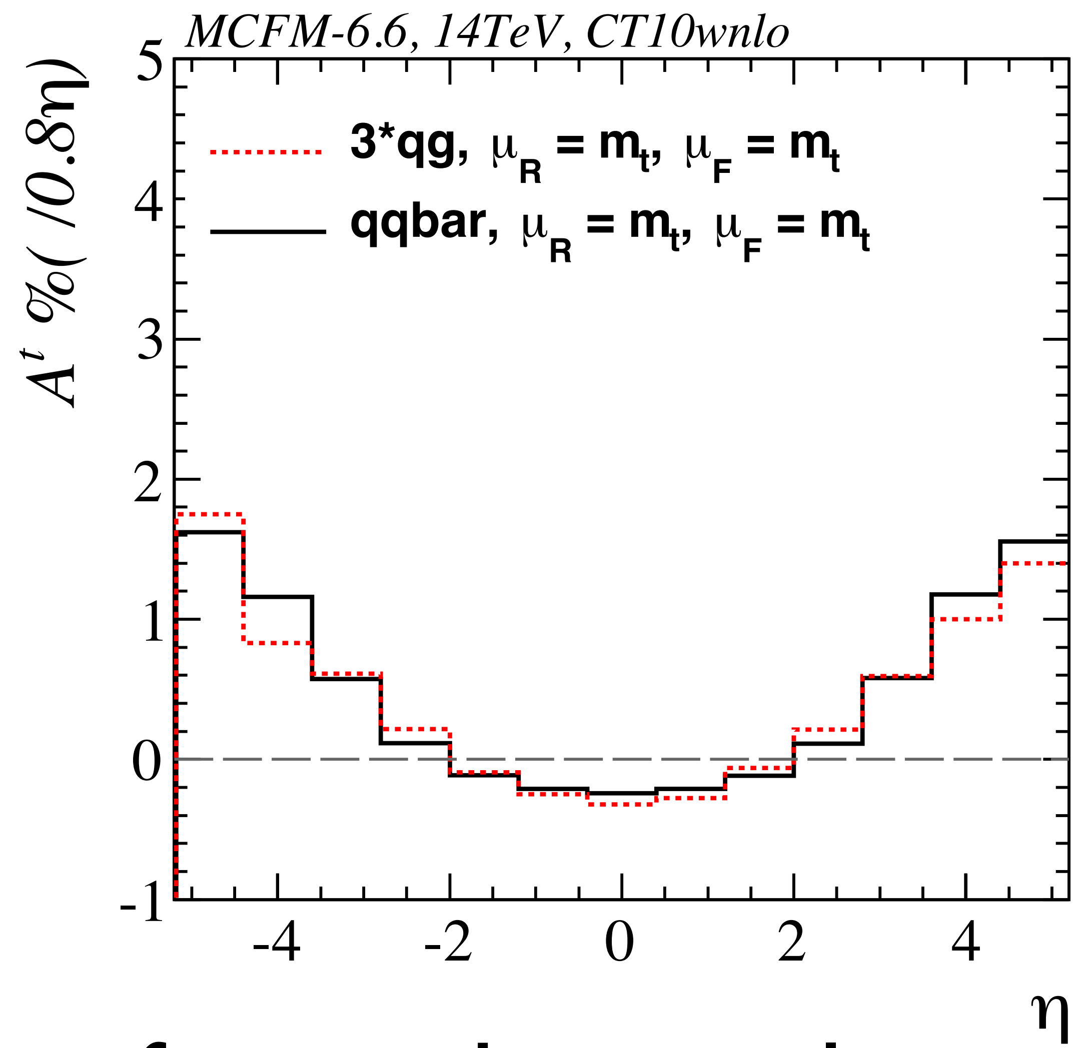
$$f_{abc}^2 = (N_c^2 - 1)N_c$$

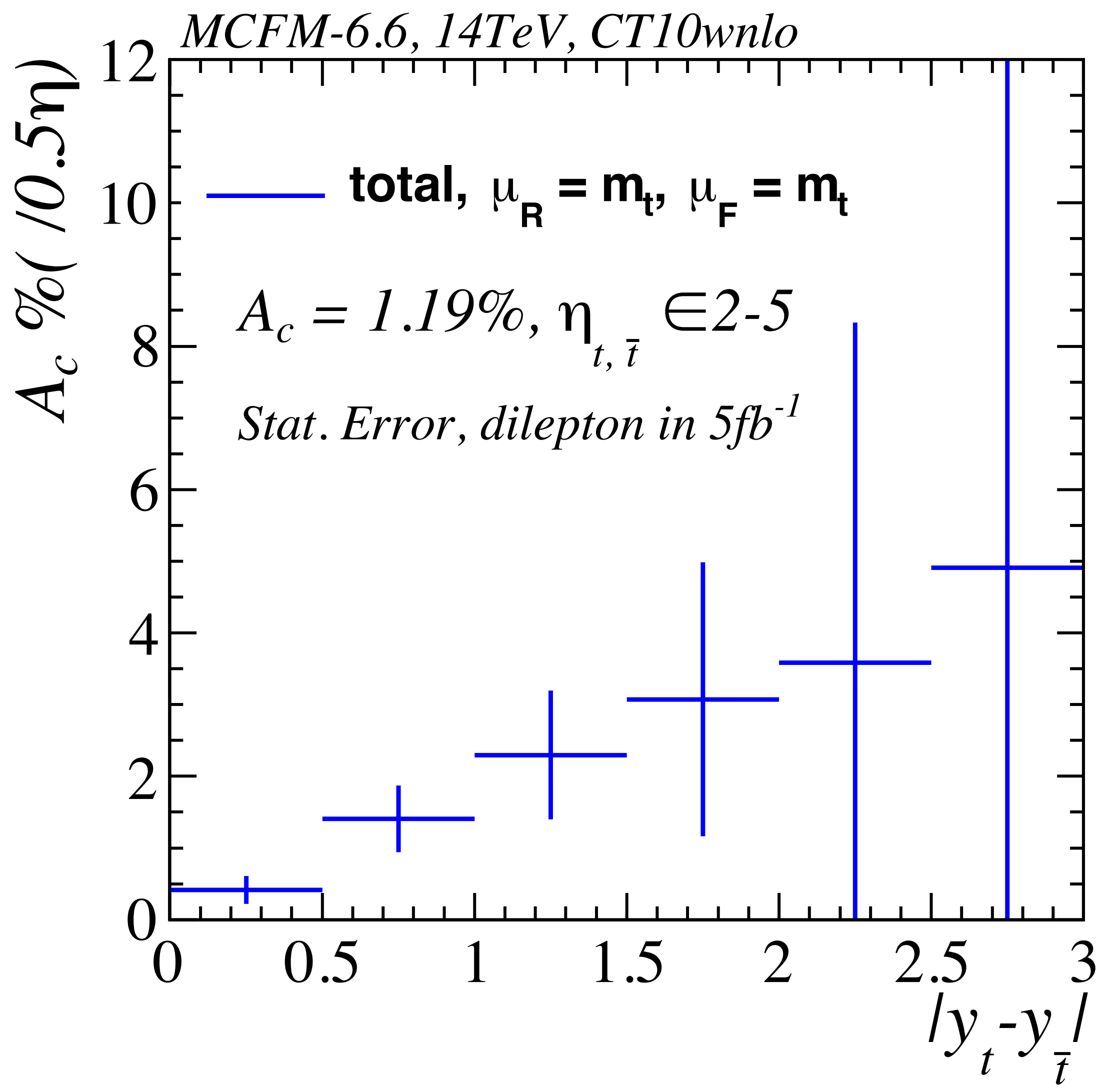
- comes from colour!
- effect is $\mathcal{O}(\alpha_s^3)$
- diluted by symmetric gg

1. J.H.Kuhn, G. Rodrigo, arXiv:hep-ph/9807420 [hep-ph]

Backups - asymmetry at 7/8 TeV?

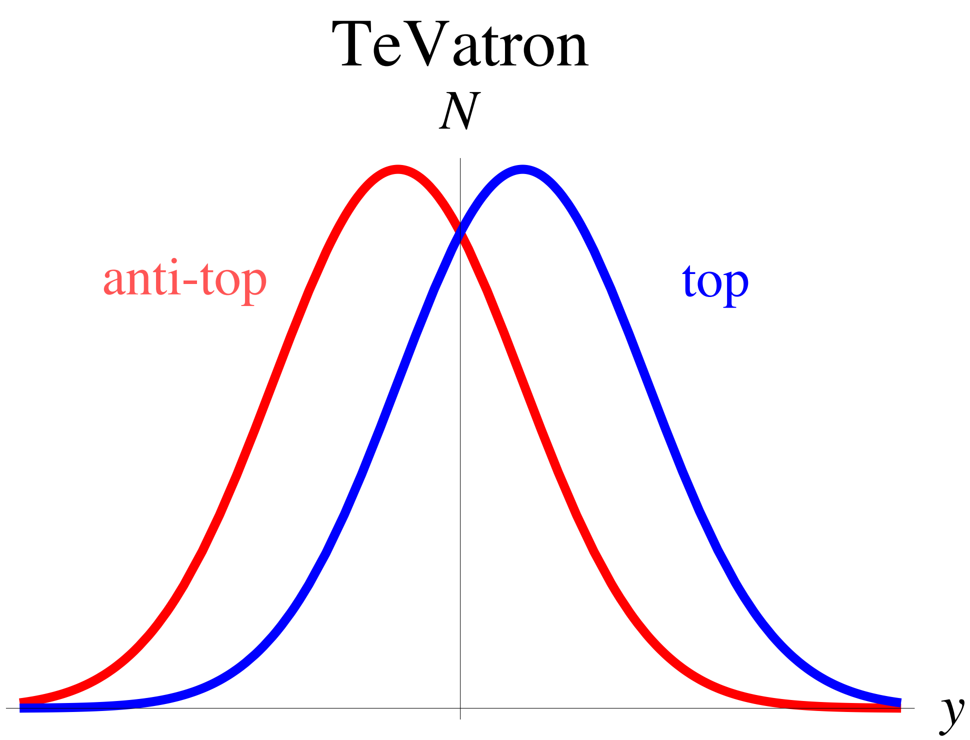
Single particle asym.

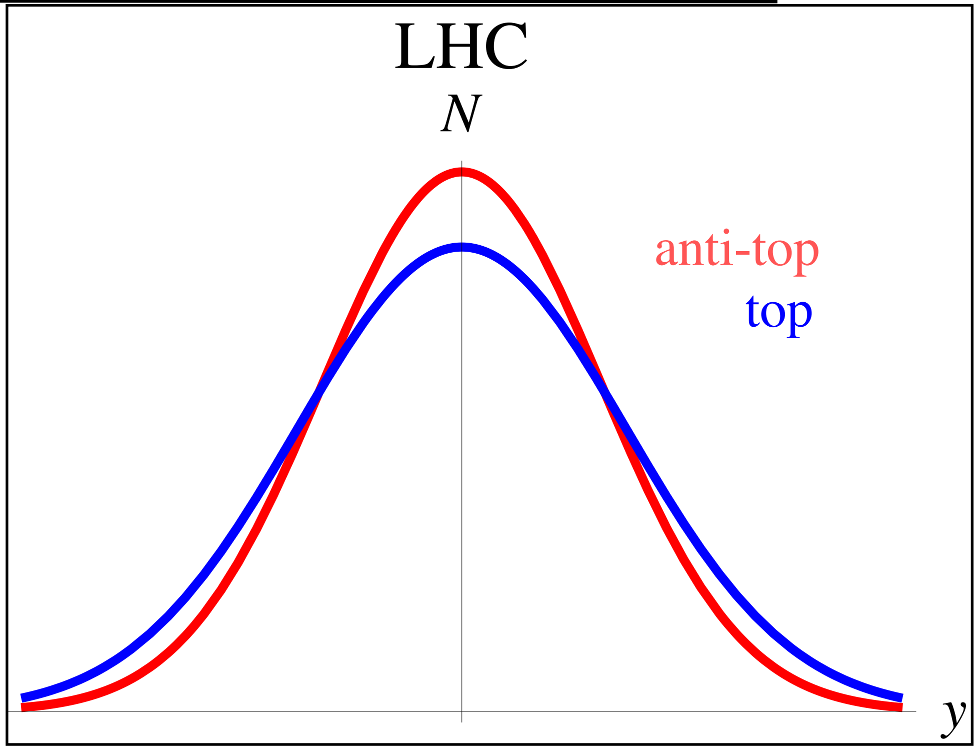




forward-central asymmetry, assuming stat. error of dilepton signal at 14 TeV

Backups - published ttbar asymmetry results





$$A_{fb} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

$$A_{fb}^{SM} = 8.7\%$$

$$A_{fb}^{CDF}(9.4 fb^{-1}) = 16.4 \pm 4.7\%$$

$$A_{fb}^{D0}(5.4 fb^{-1}) = 19.6 \pm 6.5\%$$

$$\Delta y = y_t - y_{\bar{t}}$$

$$A_c = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$

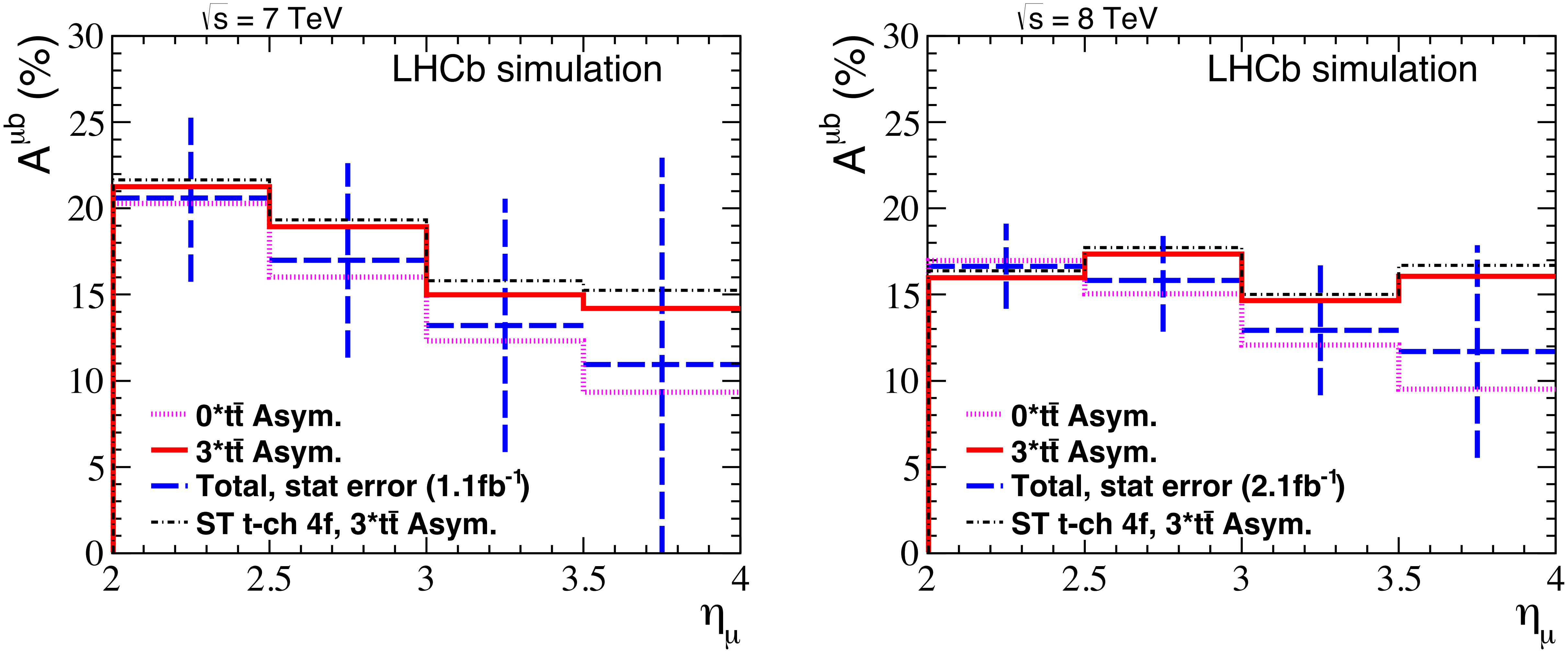
$$A_c^{SM} = 1.15\%$$ 7TeV

$$A_c^{ATLAS}(4.71 fb^{-1}) = 2.9 \pm 1.8 \pm 1.4\%$$

$$A_c^{CMS}(5.0 fb^{-1}) = 0.4 \pm 1.0 \pm 1.1\%$$

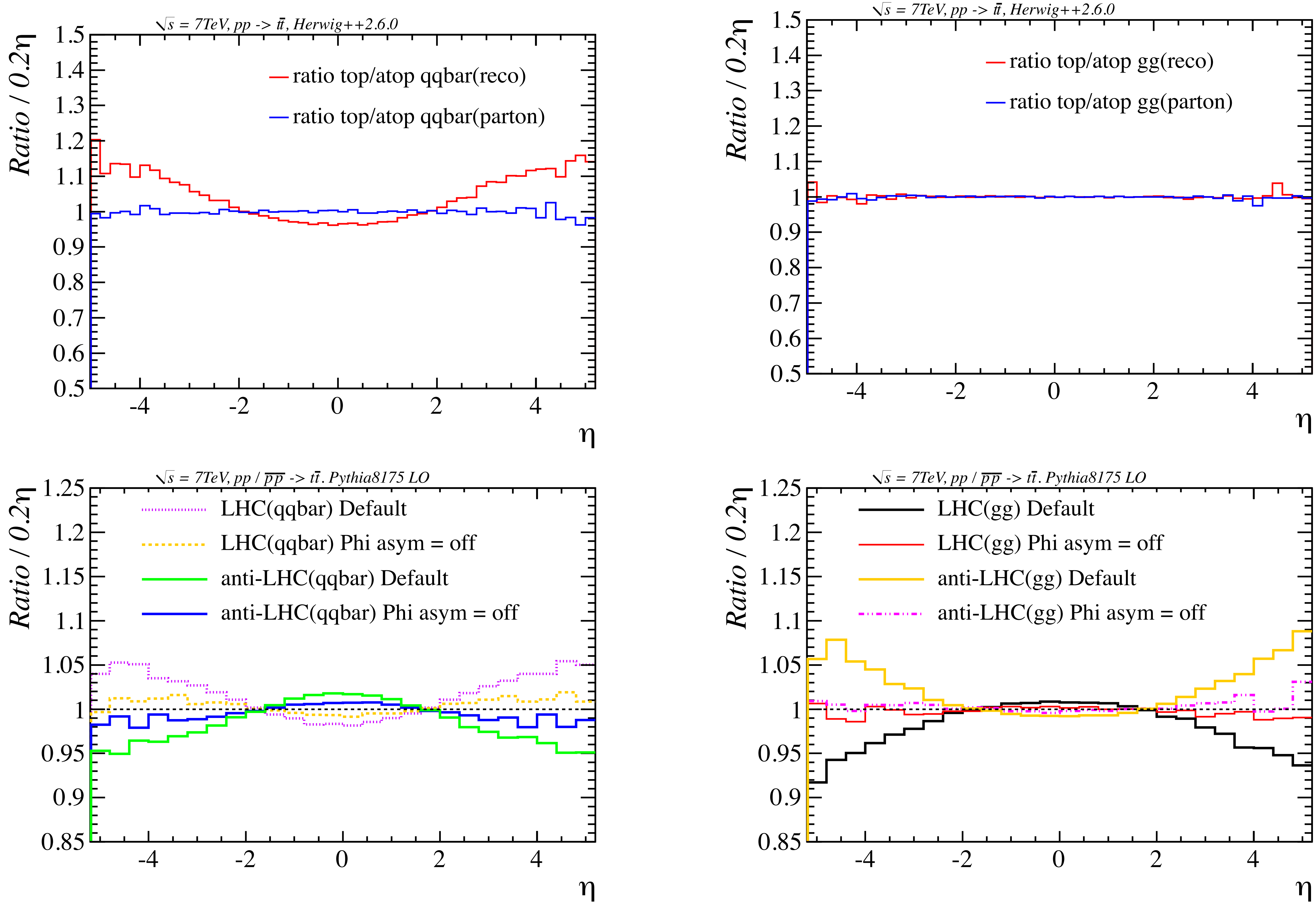
$$\Delta|y| = |y_t| - |y_{\bar{t}}|$$

Backups - asymmetry at 7/8 TeV?



$$A^{\mu b} = \frac{N^{\mu^+ b} - N^{\mu^- b}}{N^{\mu^+ b} + N^{\mu^- b}}$$

Backups - controlling shower effects



Backups - truth b-tag matching

R - parameter tests for truth bjet matching to partons

Energy (right), Efficiency(lower-left)