Measuring top asymmetries at LHCb

Rhorry Gauld, on behalf of the LHCb collaboration

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This talk - CERN-LHCb-PUB-2013-009 https://cds.cern.ch/record/1557385/

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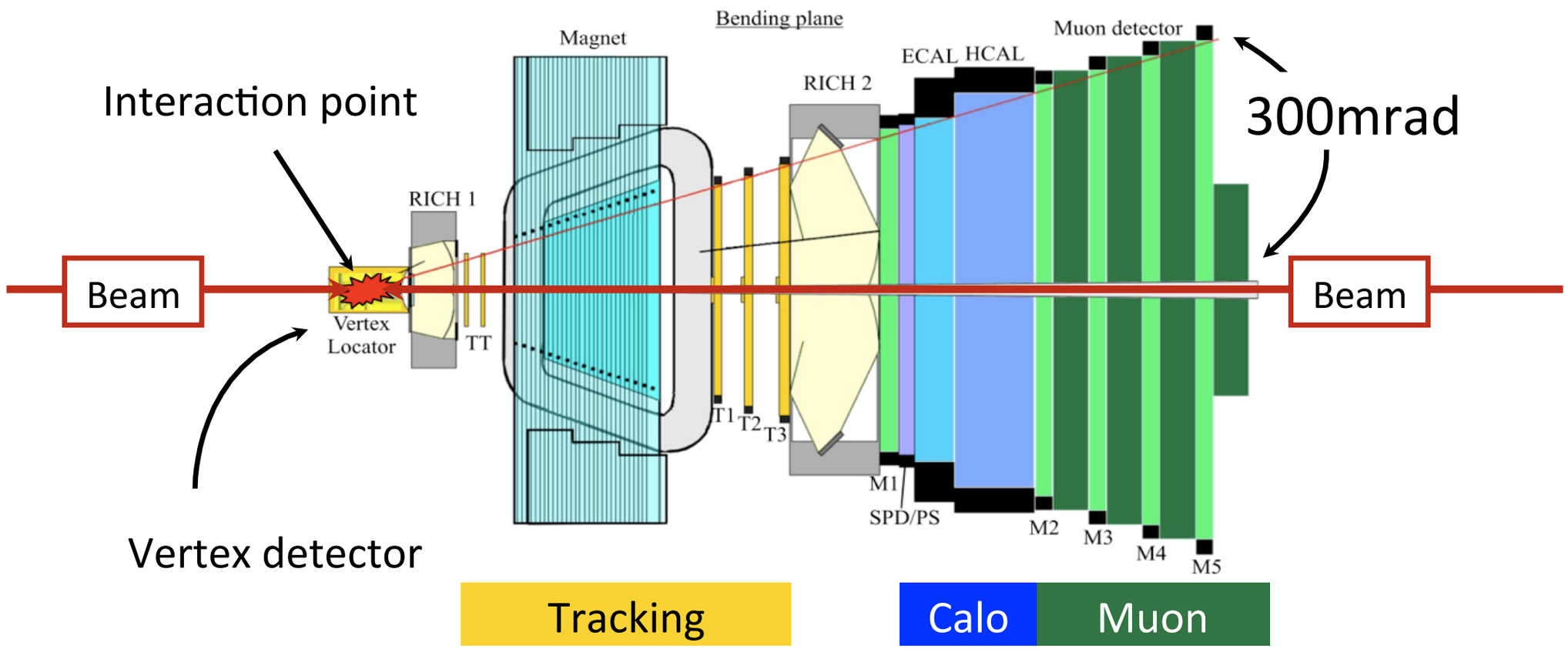
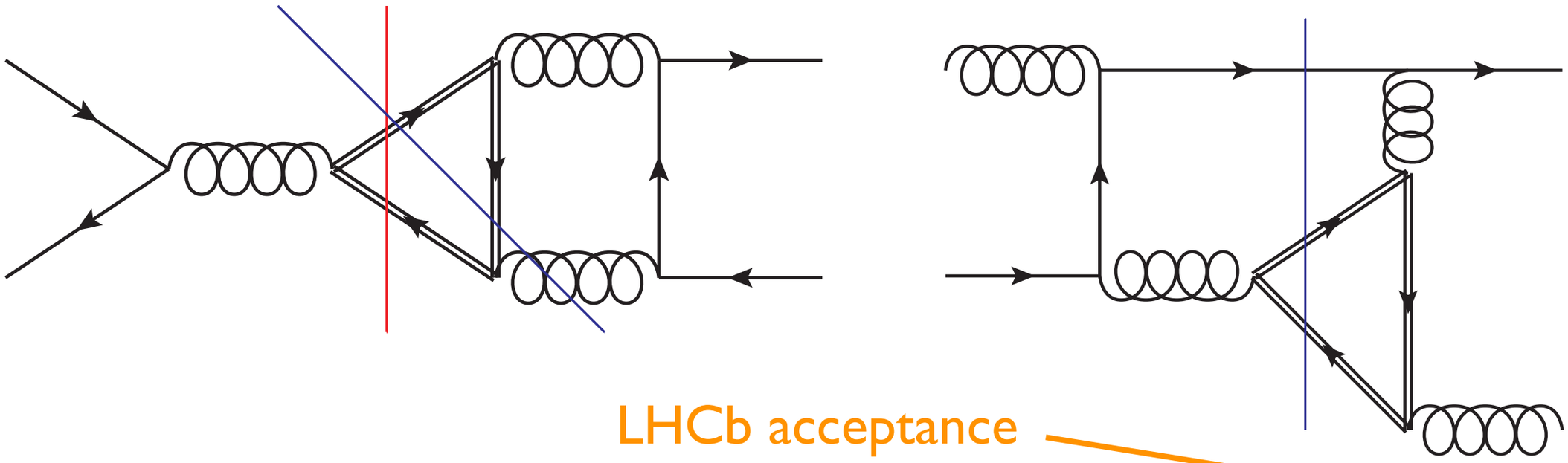
Introduction



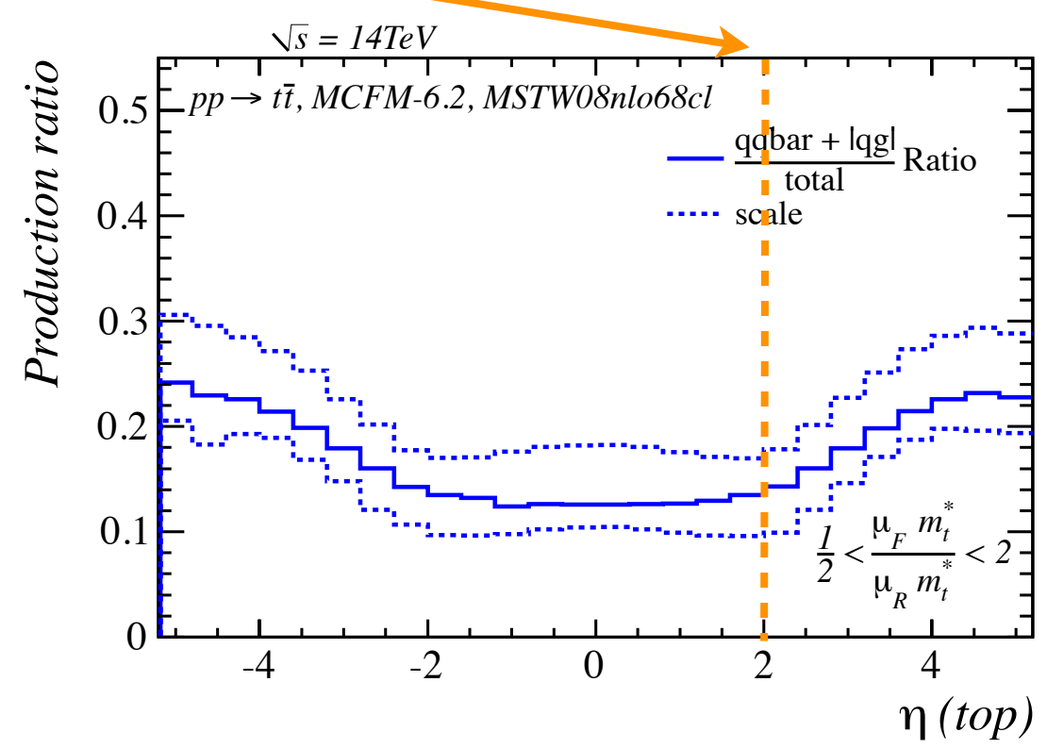
- LHCb: a general purpose detector instrumented within $2 \leq \eta \leq 5$
  Recorded/Potential luminosity:
  - (2011): 1.1 fb^{-1} $\sqrt{s} = 7\ \mathrm{TeV}$
  - (2012): 2.1 fb^{-1} $\sqrt{s} = 8\ \mathrm{TeV}$
  - (2015-2017): ~5 fb^{-1} $\sqrt{s} = 13\ \mathrm{TeV}$
  - (2020-2030): ~50 fb^{-1} $\sqrt{s} = 14\ \mathrm{TeV}$

Motivations - Charge asymmetry at NLO

- Illustrative contributions to $|\mathcal{M}_{fi}|^2$ (NLO) with real and virtual cuts



LHCb acceptance

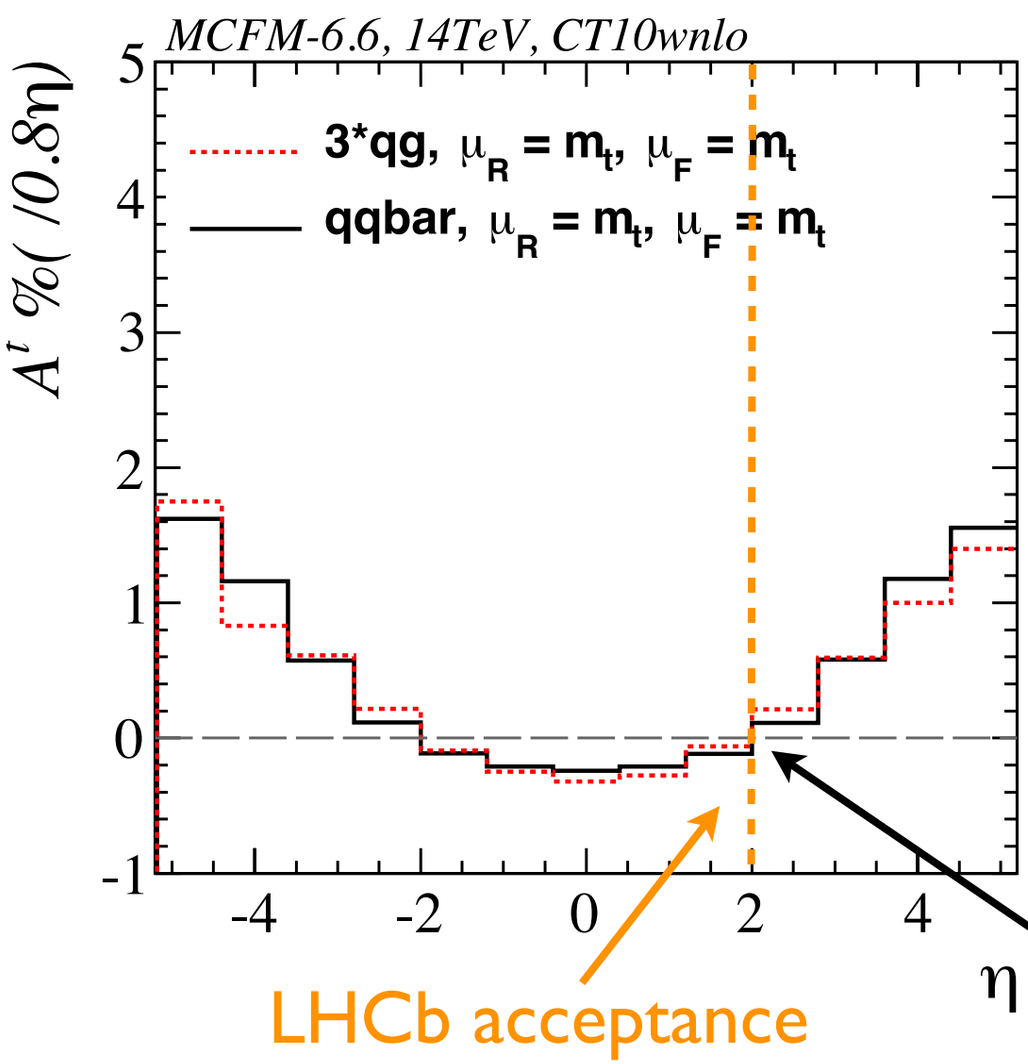


- quark in initial state
- quark initiated processes less diluted by gg-fusion at high rapidity
- (cross section falls with rapidity)

What asymmetry to measure?

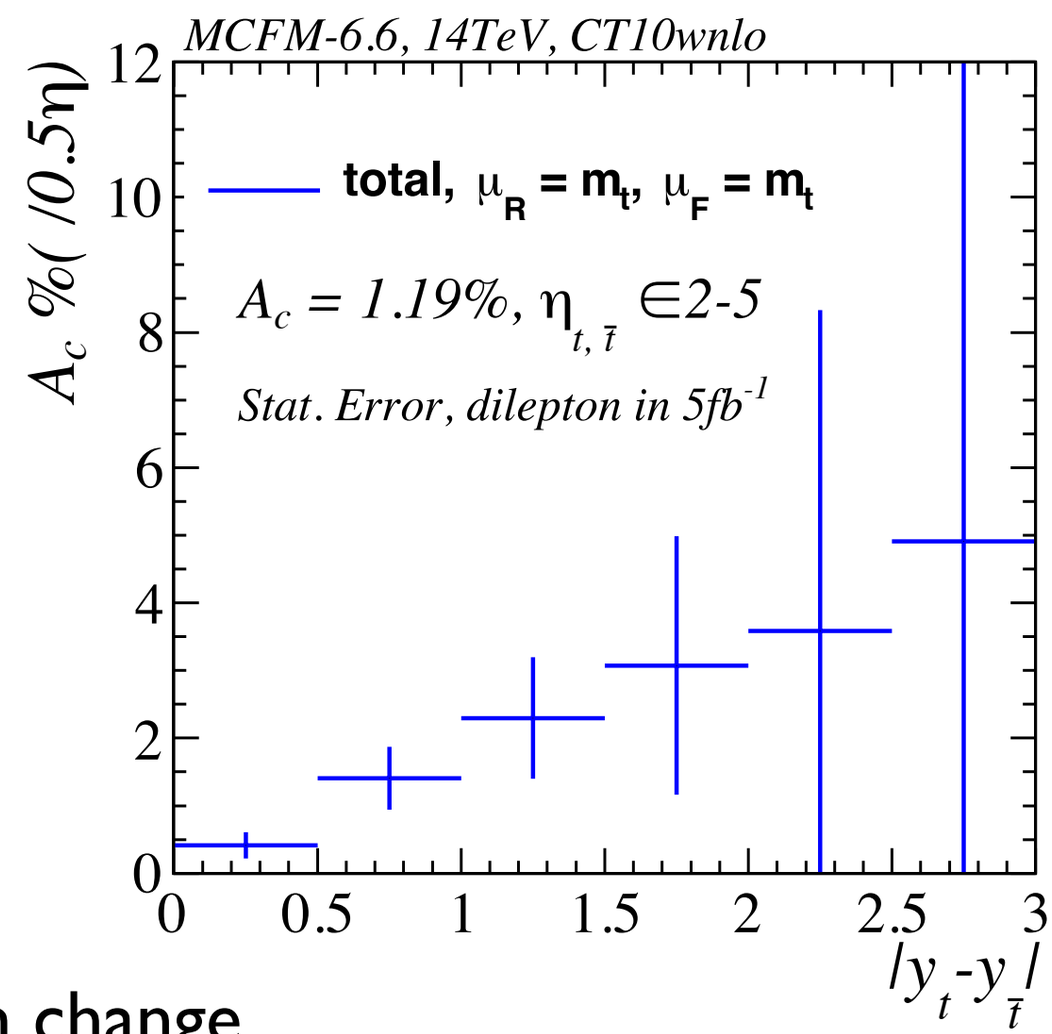
Single particle asymmetry

$$A^t = \frac{N^t - N^{\bar{t}}}{N^t + N^{\bar{t}}}$$



Forward-Central asymmetry

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



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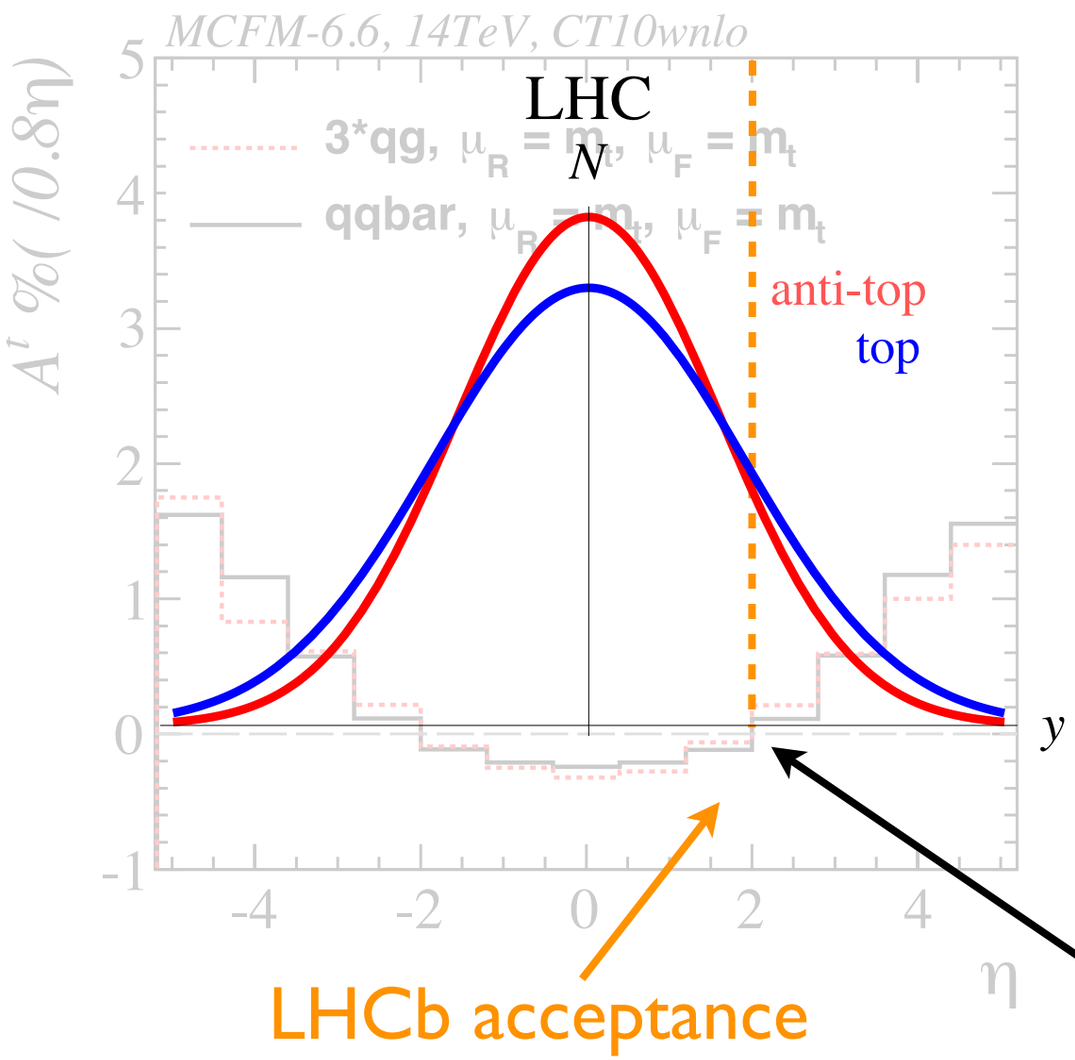
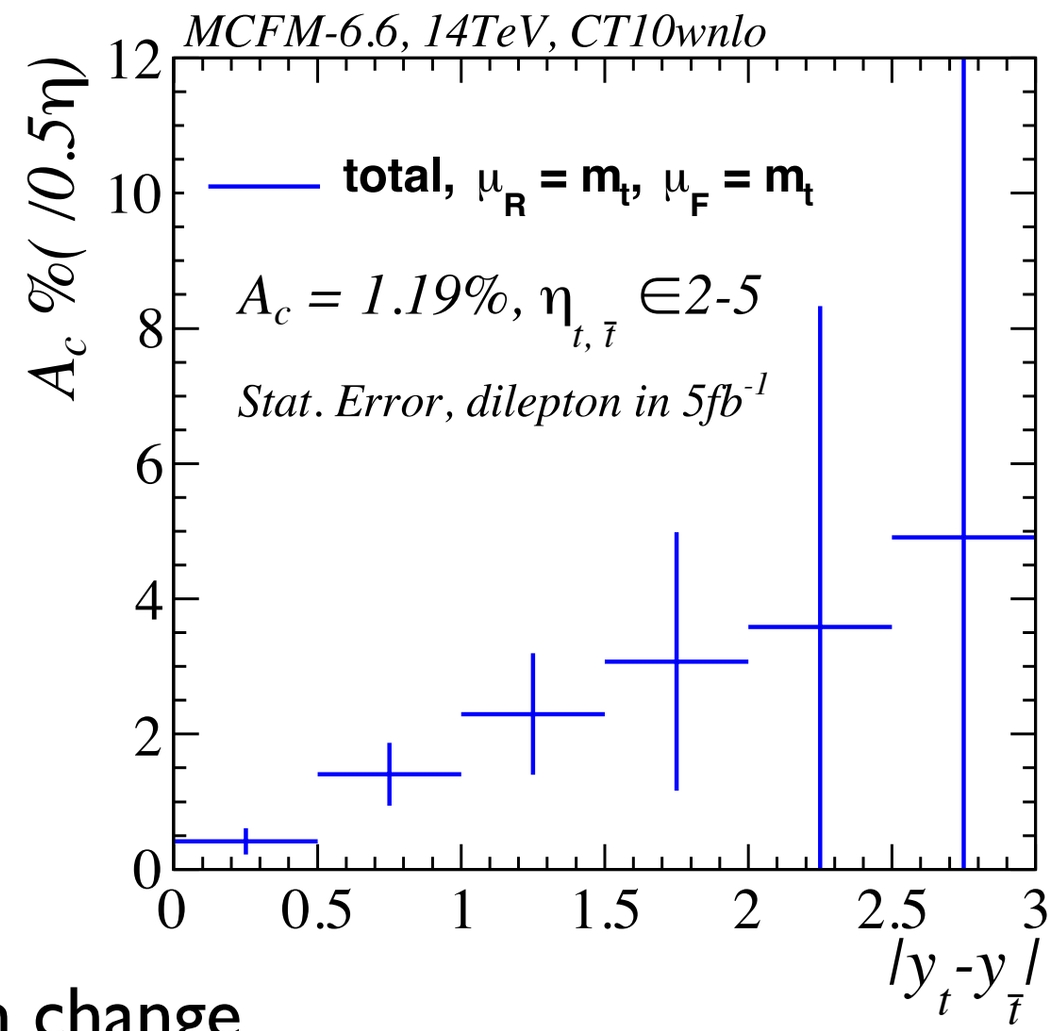
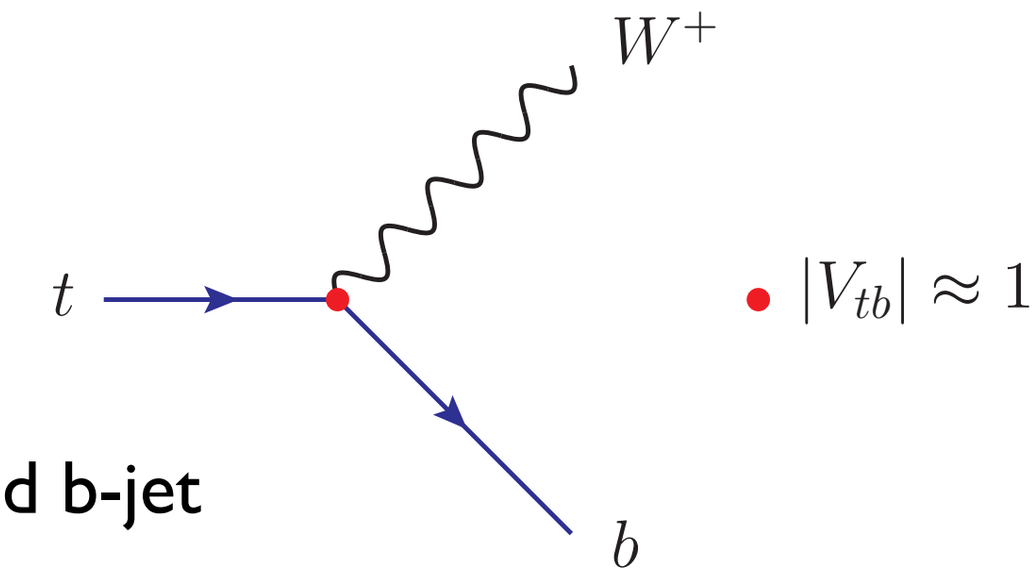




sign change

LHCb event yield

- Partially reconstruct ttbar
- At least 1 leptonic W decay
- Use (b)-jets to suppress background



Objects: R = 0.5, anti-kt jets, truth matched b-jet

Cuts: **b-jet pT > 60** GeV , **lepton pT > 20** GeV

All simulation POWHEG(NLO) matched to Pythia8 parton shower
Errors: scale variation, central PDF sets, shower effects

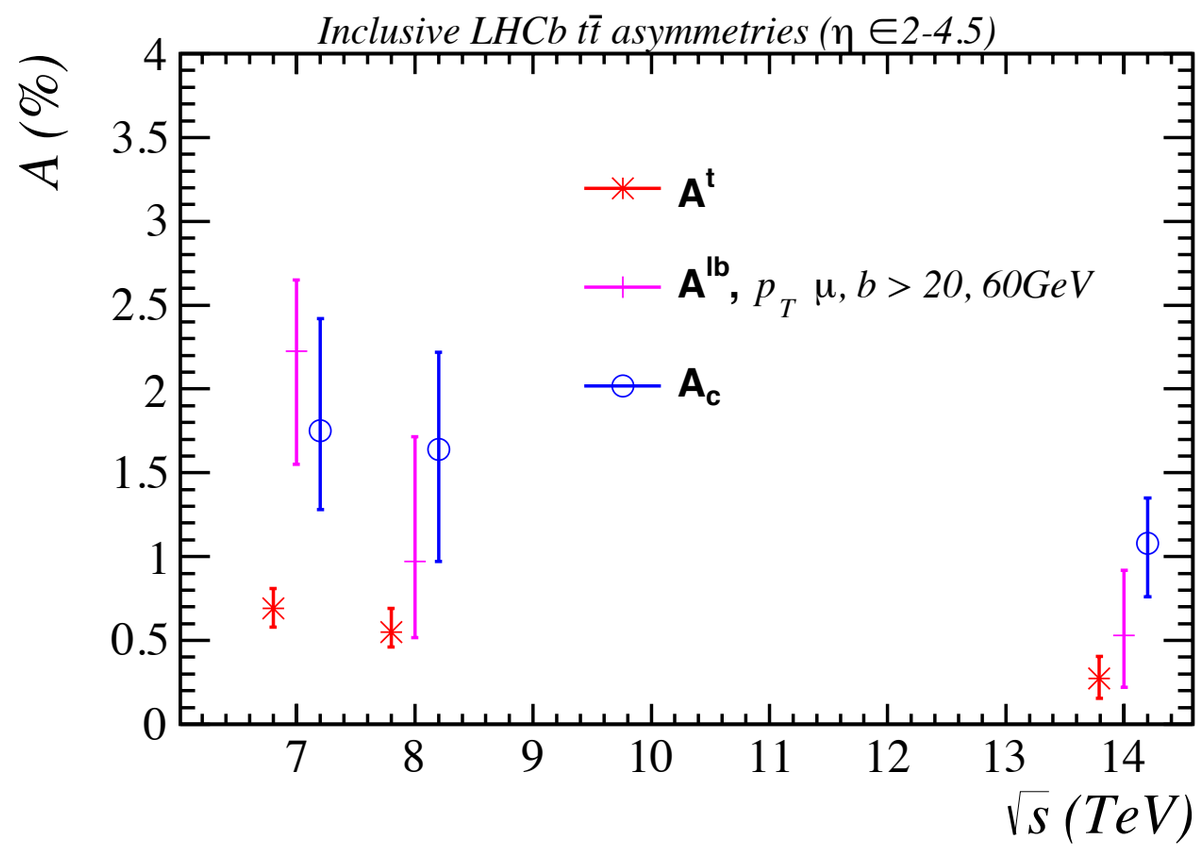
$\int \mathcal{L}dt(\mathrm{fb}^{-1})$	1	2	5*+50
$d\sigma(\mathrm{fb})$	7 TeV	8 TeV	14 TeV
lb	285 ± 52	504 ± 94	4366 ± 663
lbj	97 ± 21	198 ± 35	2335 ± 323
lbb	32 ± 6	65 ± 12	870 ± 116
$lbbj$	10 ± 2	26 ± 4	487 ± 76
l^+l^-	44 ± 9	79 ± 15	635 ± 109
l^+l^-b	19 ± 4	39 ± 8	417 ± 79

*13 TeV

Asymmetry expectations

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

Channel	7TeV	8TeV	14TeV
$A^t(\%)$	$0.69^{+0.12}_{-0.11}$	$0.55^{+0.1}_{-0.09}$	$0.27^{+0.13}_{-0.12}$
$A^{lb}(\%)$	$2.23^{+0.43}_{-0.68}$	$0.97^{+0.74}_{-0.45}$	$0.54^{+0.39}_{-0.31}$
$A_c(\%)$	$1.75^{+0.67}_{-0.47}$	$1.64^{+0.58}_{-0.67}$	$1.08^{+0.27}_{-0.32}$

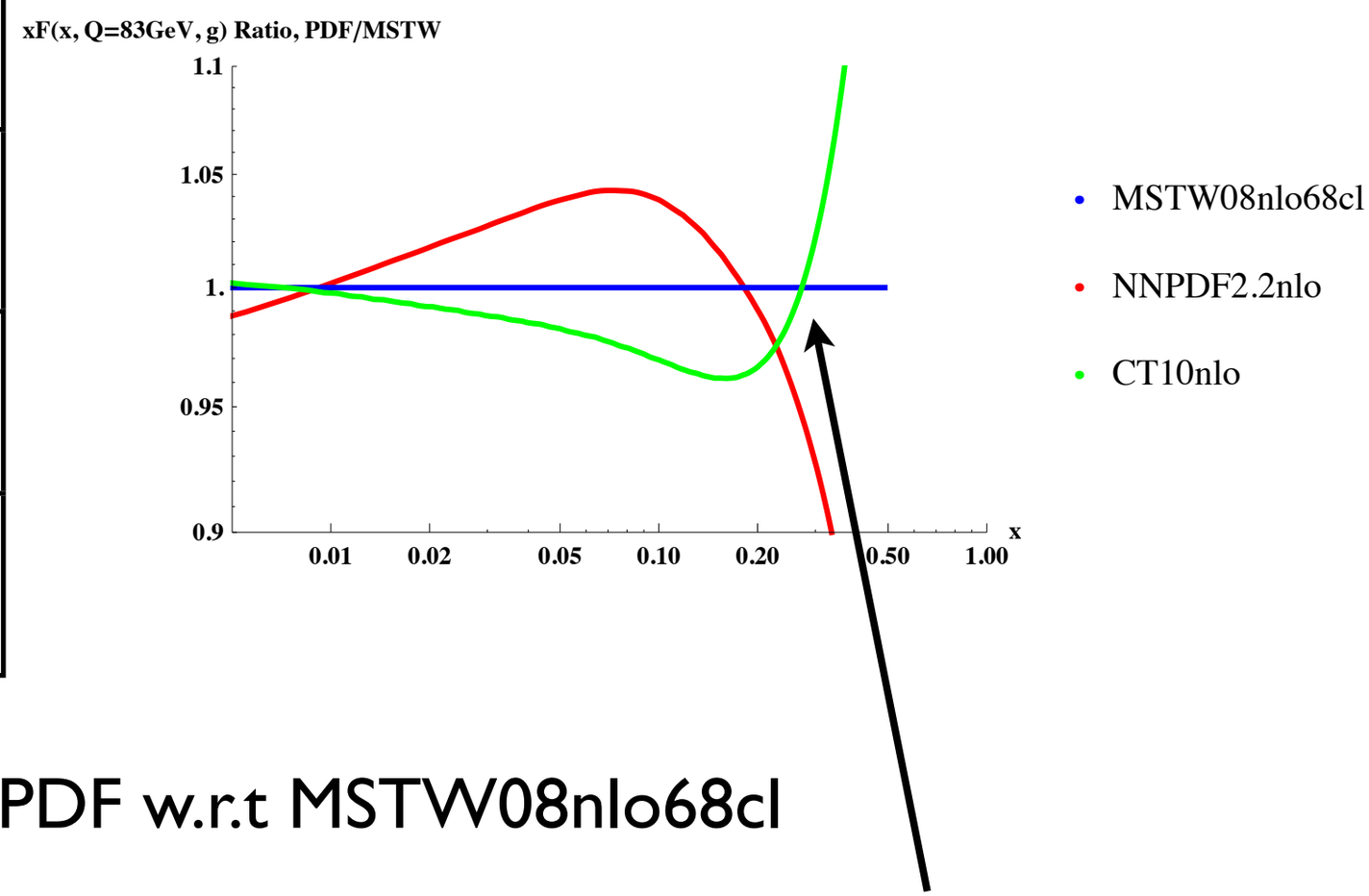


A few comments on asymmetries/errors,

- Asymmetries decrease with increasing energy (gluon dilution)
- $A^{lb} > A^t$, cuts applied to reconstructed top remove gluon dilution
- Errors are total envelope of scale + central PDF set (next slide)

Comment on PDF errors

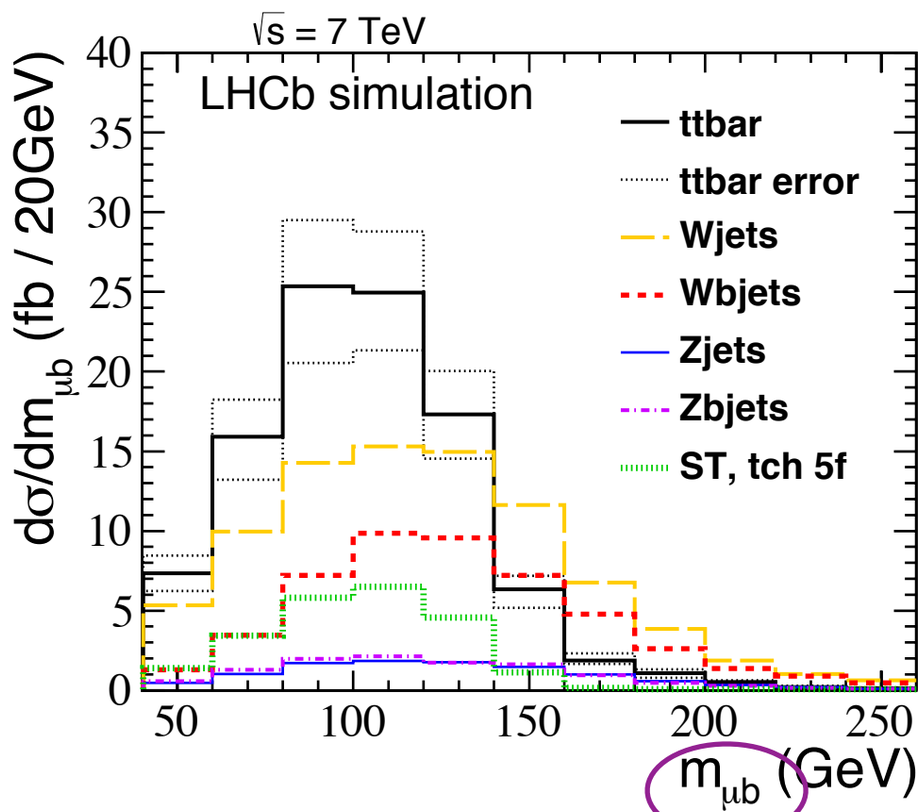
$\sigma(t\bar{t}\ )$ @14 TeV	PDF(NLO)
865	CT10
918	MSTW08
930	NNPDF2.2

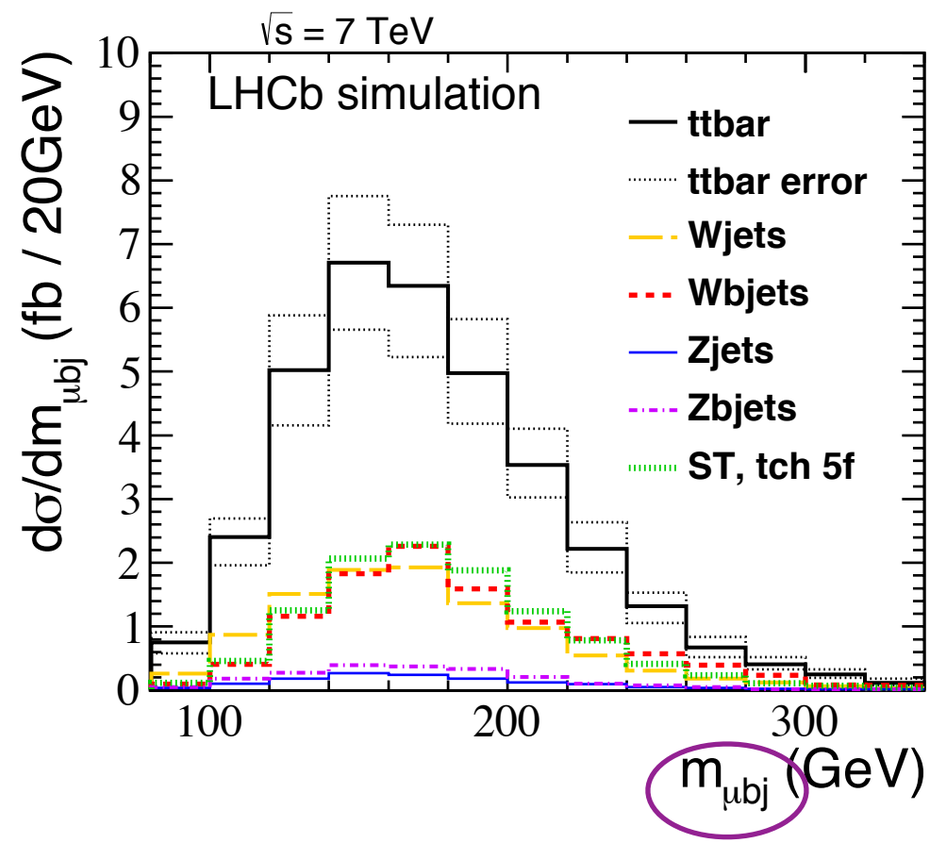


- Have plotted central gluon PDF w.r.t MSTW08nlo68cl
- However, in LHCb acceptance largest cross section from CT10
- Probing higher-x of proton 1 (travelling in LHCb direction)
- Translates into dilution on charge asymmetry prediction

Including Signal/Background

- Study the high statistics lb-jet channel for asymmetry
- muons; trigger efficiency ~75%, id/tracking ~ 95% (from data [1])
- b-tagging; mis-tag 1%, efficiency 70% (estimates from MC)
- for jet reconstruction: LHCb-CONF-2012-016 Zjets@ 7TeV
- b-jet reconstruction: LHCb-CONF-2013-001 b bbar Ac@ 7TeV



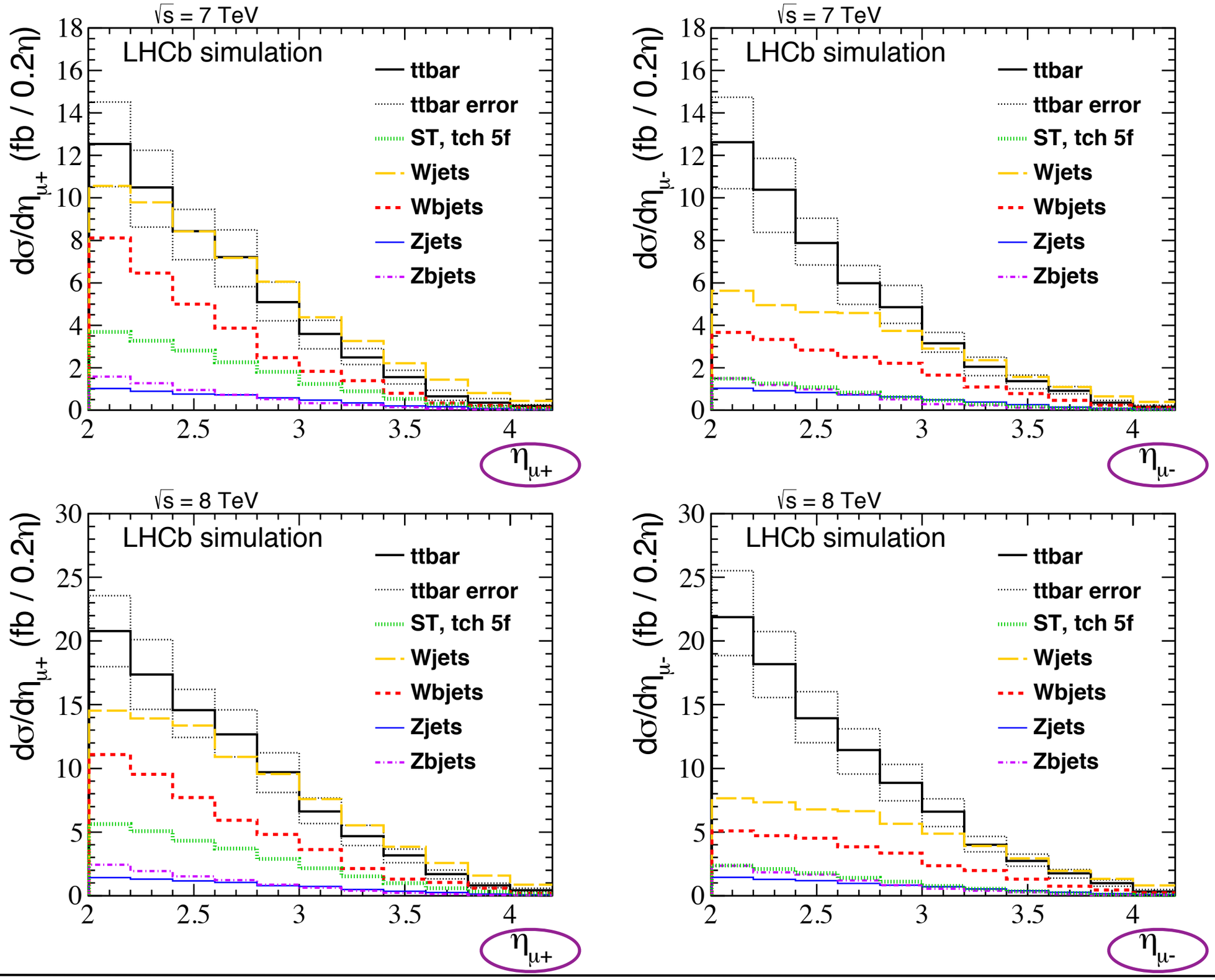


[1] - arXiv:1204.1620, DOI:10.1007/JHEP06(2012)

lepton distributions 7 and 8 TeV

7 TeV

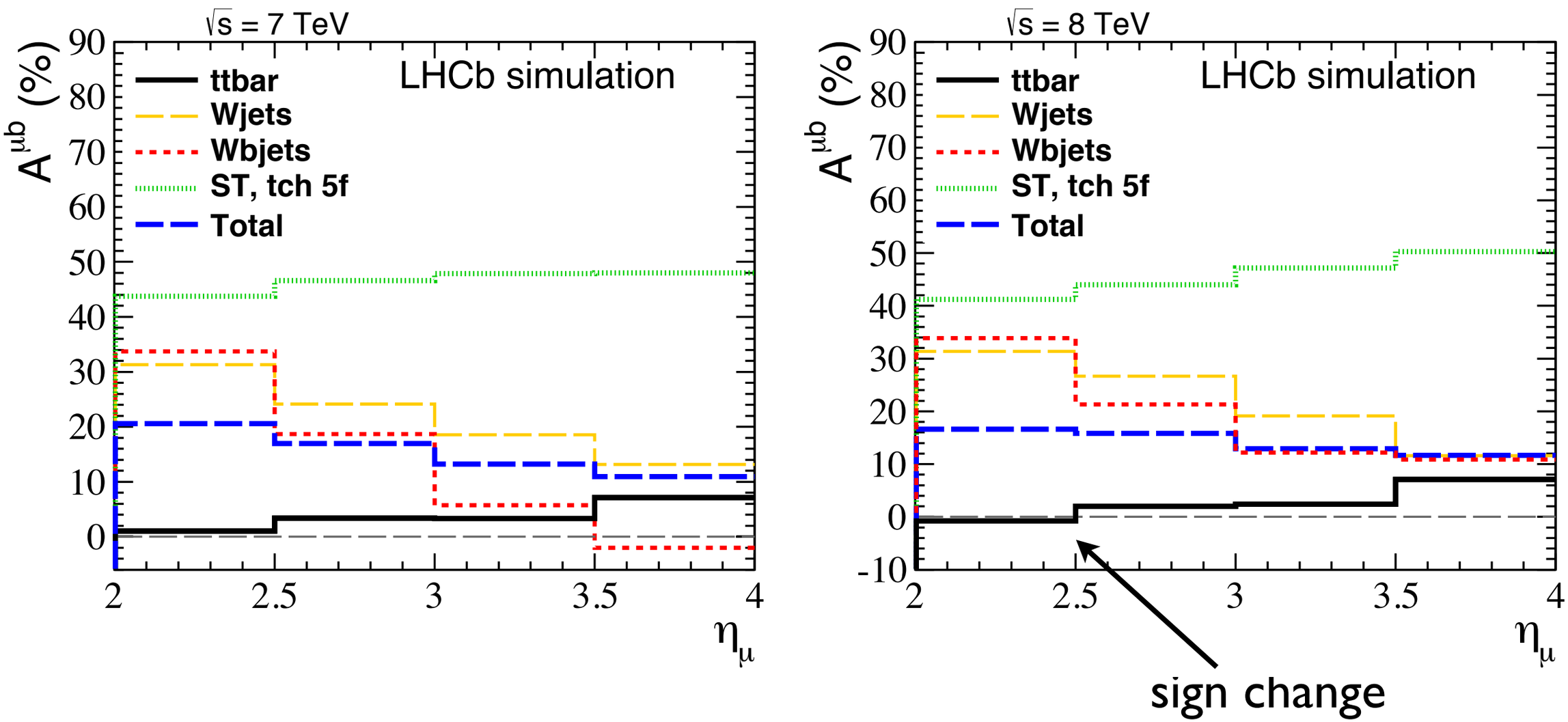
8 TeV



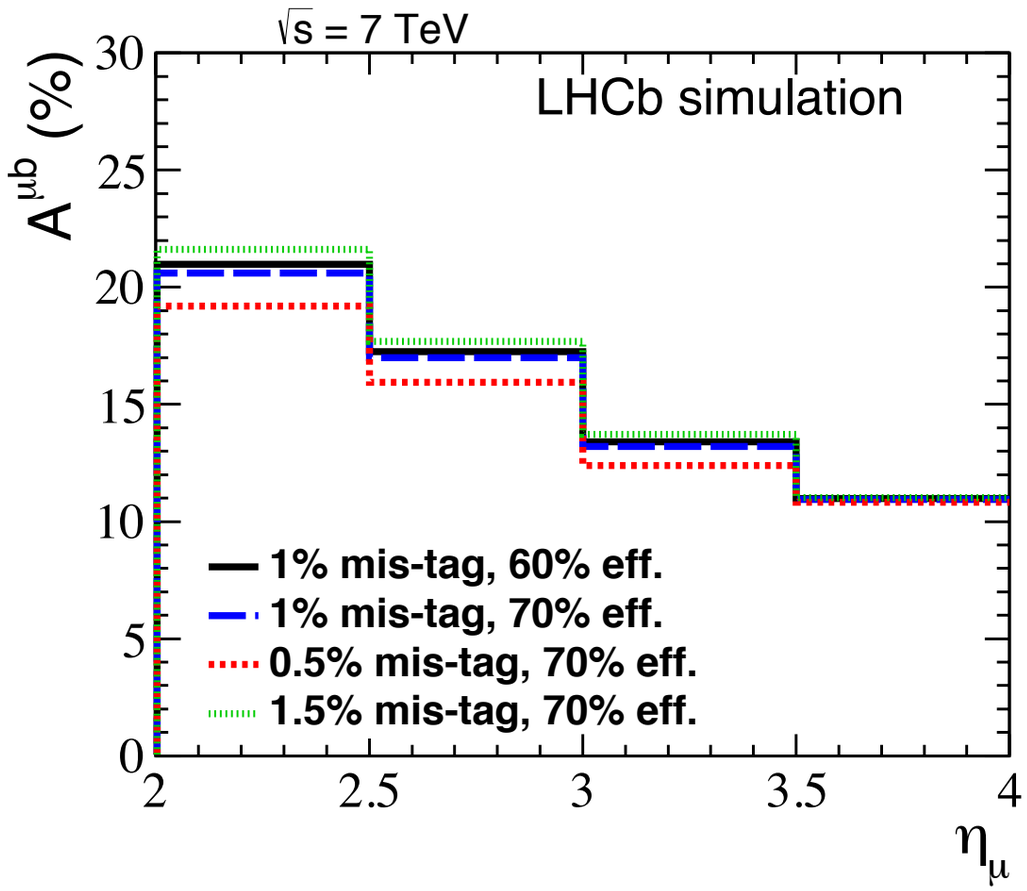
Differential Alb asymmetry

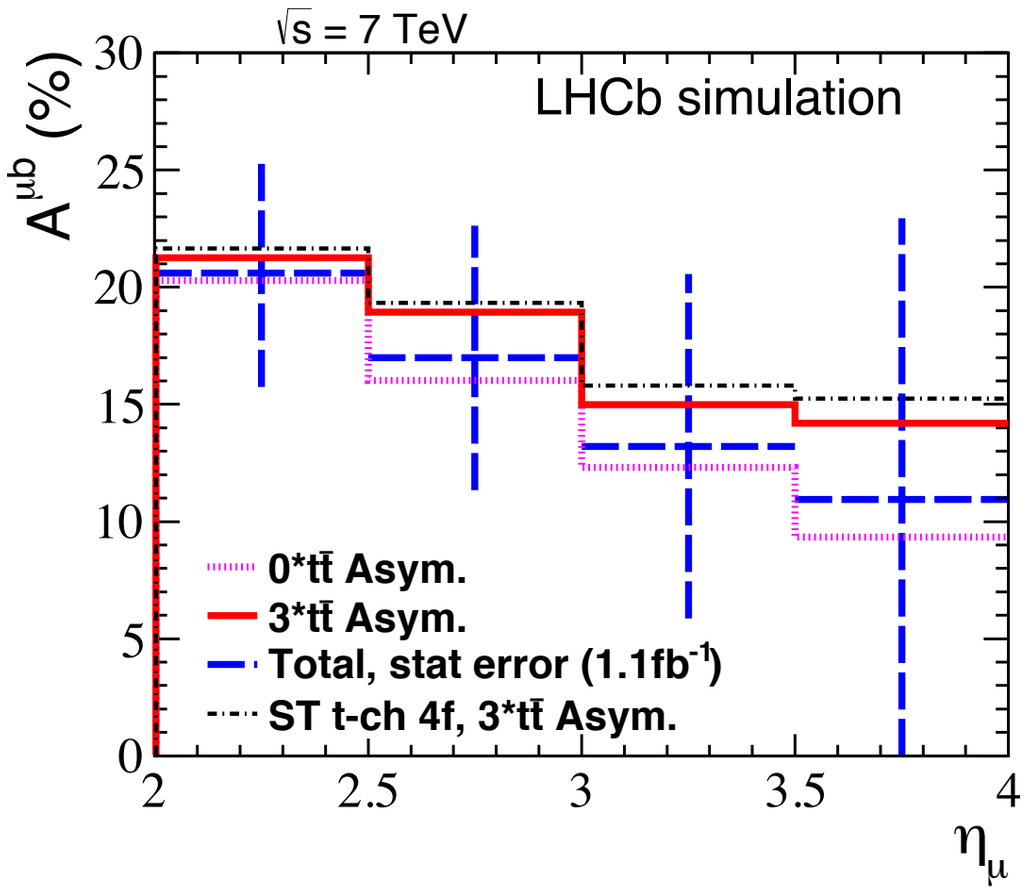
- Alb as a function of muon eta
- Highly asymmetric backgrounds from PDF
- Total: all backgrounds and signal (ttbar)

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



Sensitivity

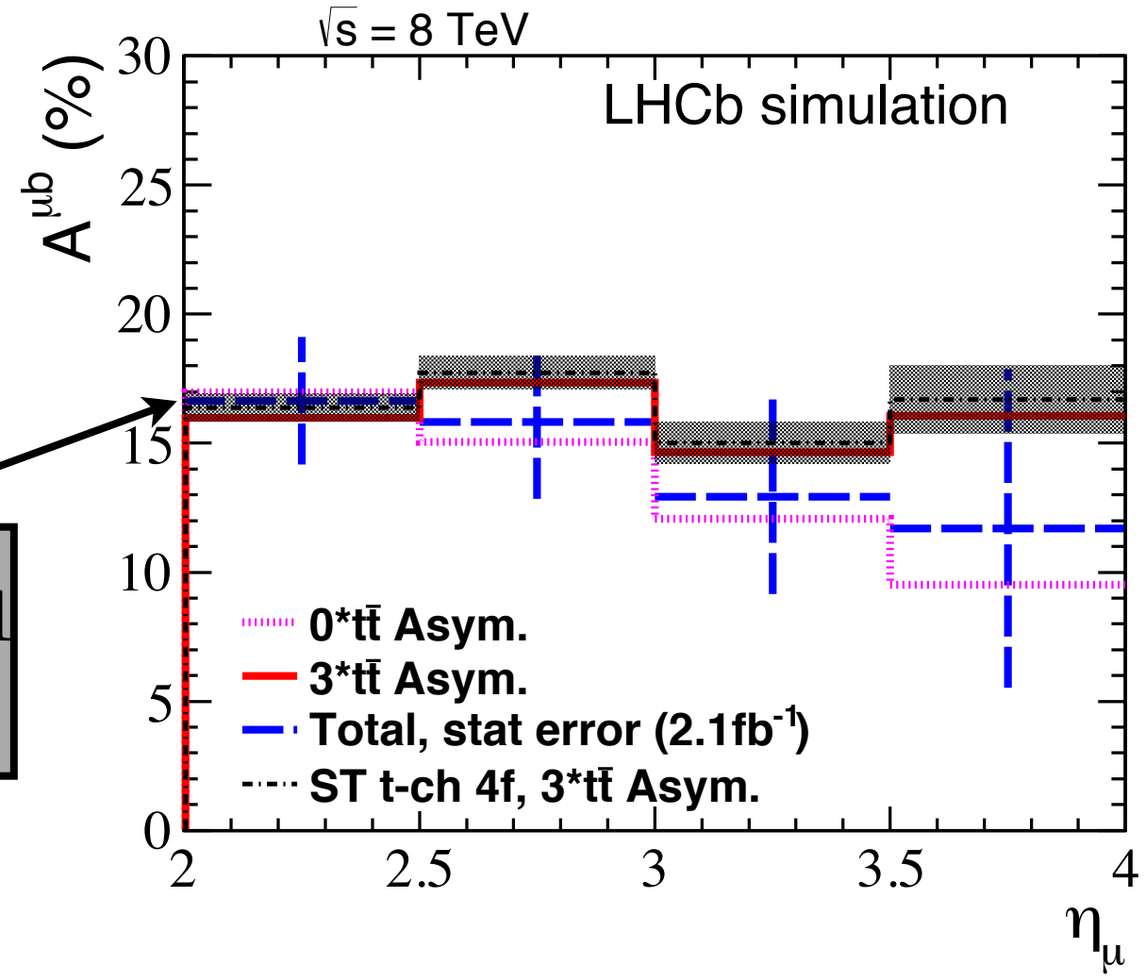




- Vary mis-tagging and efficiency of b-tagging (left plot)
- Alter ttbar asymmetry contribution to total (fixed normalization)
- Also include 4-flavour t-channel single top prediction
- At high eta (lowest stats) hard to reproduce positive asymmetry!

Conclusions

- Differential measurement of Alb necessary
- More data required for statistical precision at high eta



~14TeV stat. error for $5\mathrm{fb}^{-1}$

- Relative increase of ttbar/Wjets: factor of 2 as Ecm 7 -> 14 TeV
  - no large pile-up changes expected
- At Ecm 14TeV, Ac measurement possible in dilepton channel
- Large efforts to improve jet tagging and reconstruction at LHCb

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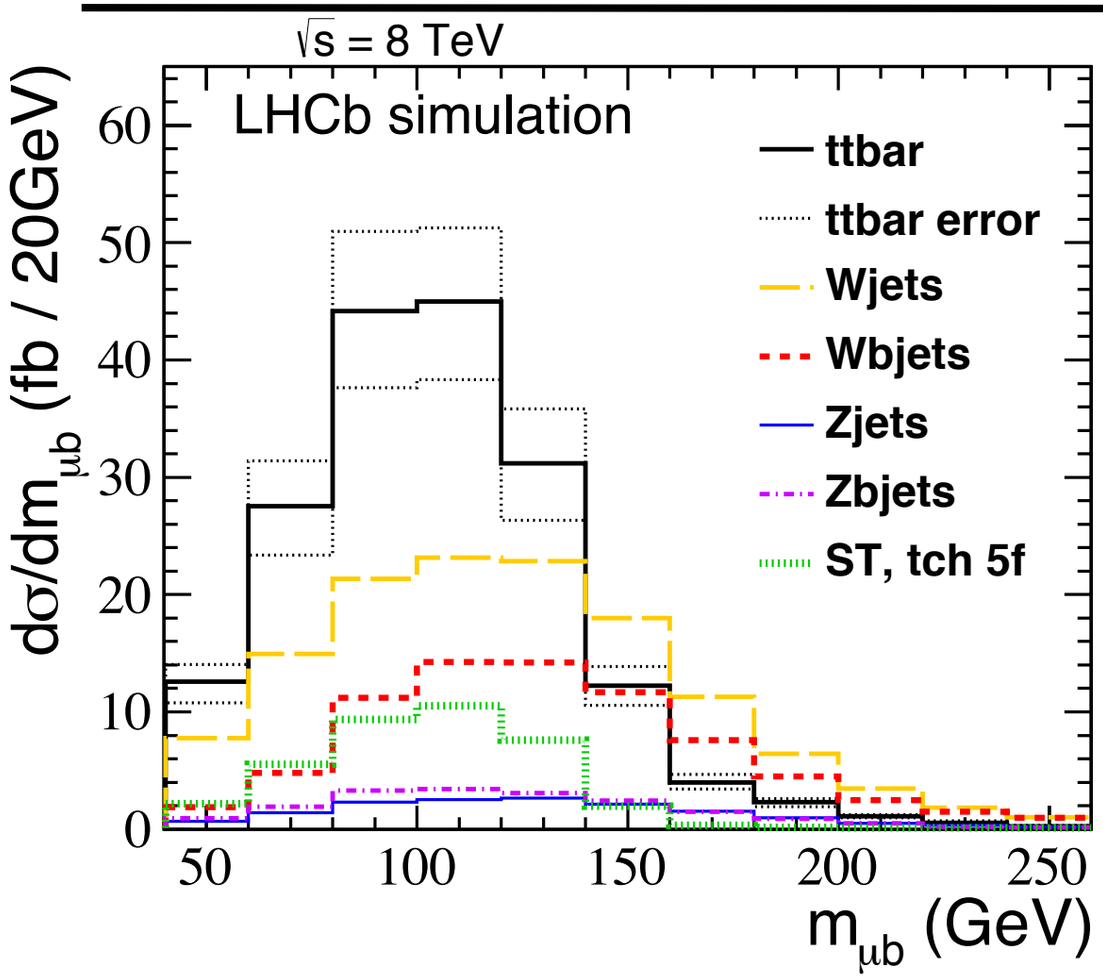
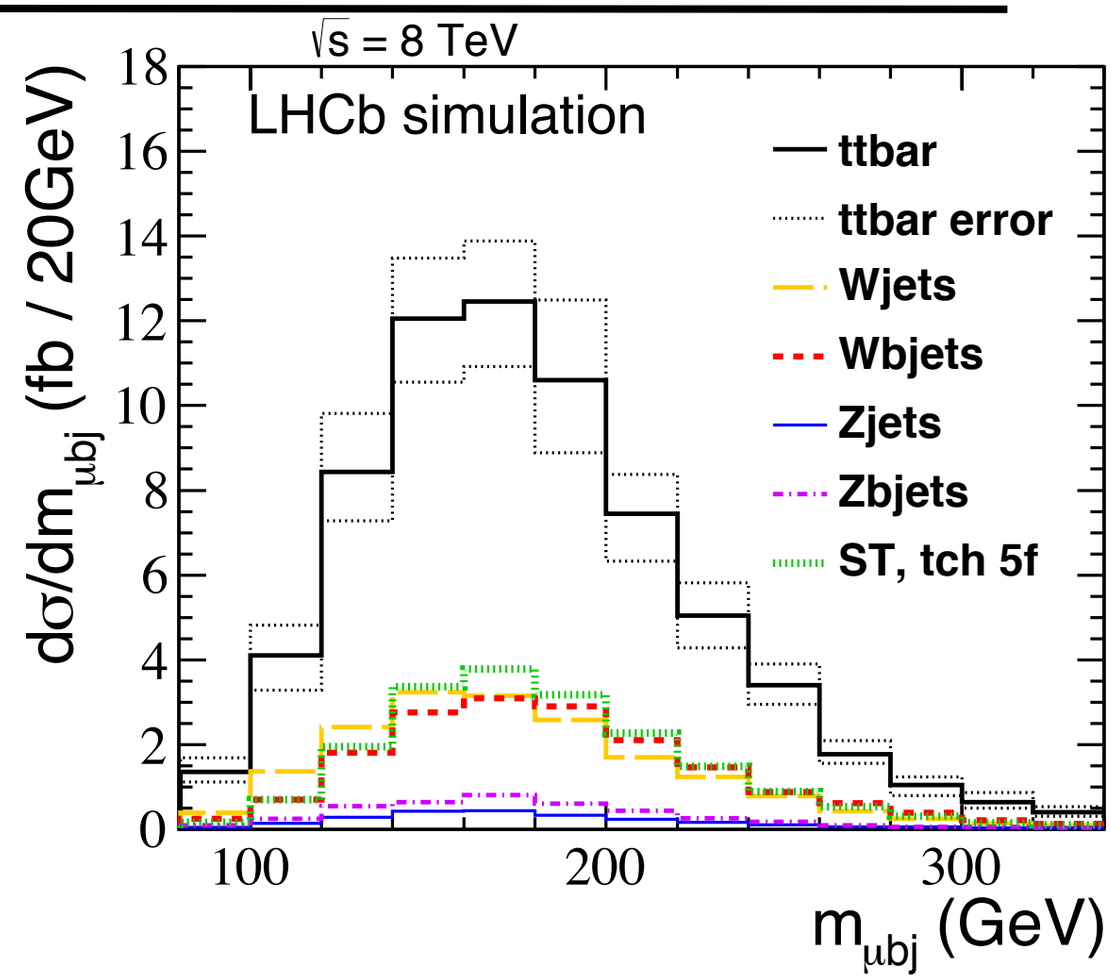
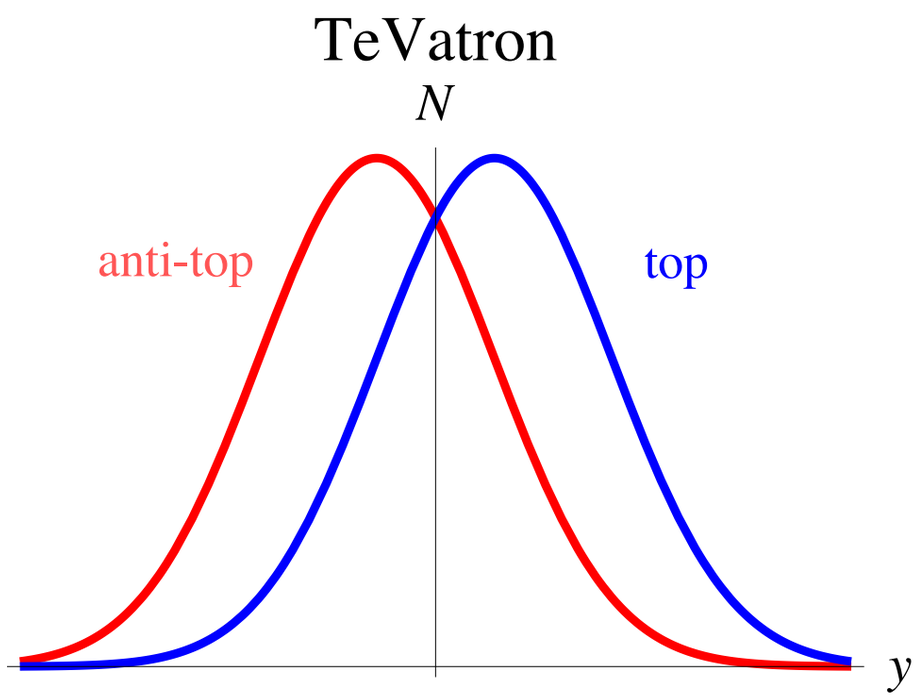
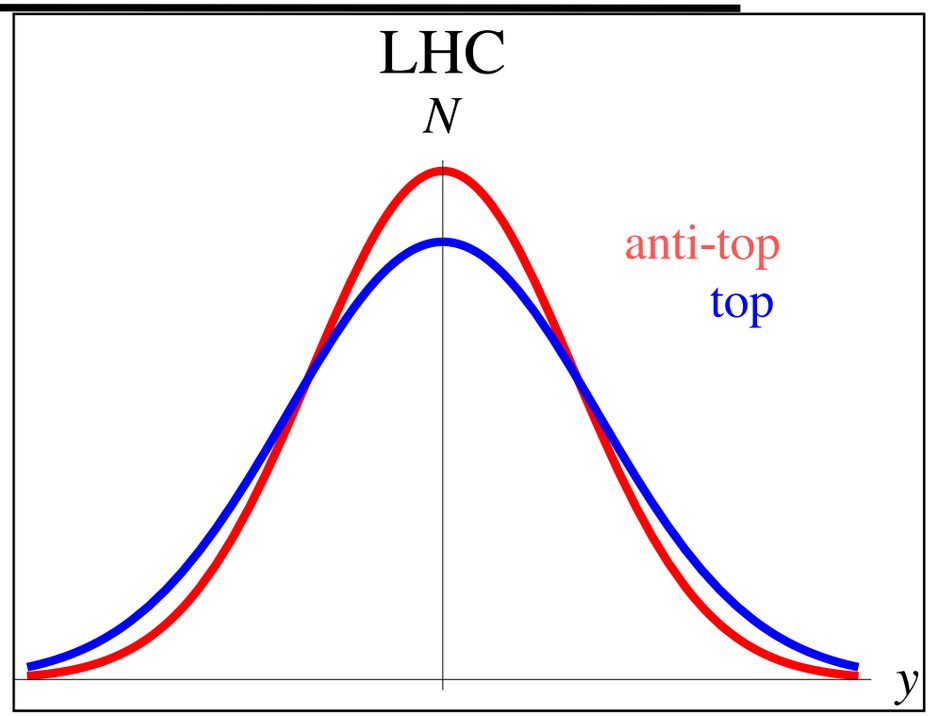
Backups - 8TeV mass plots





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

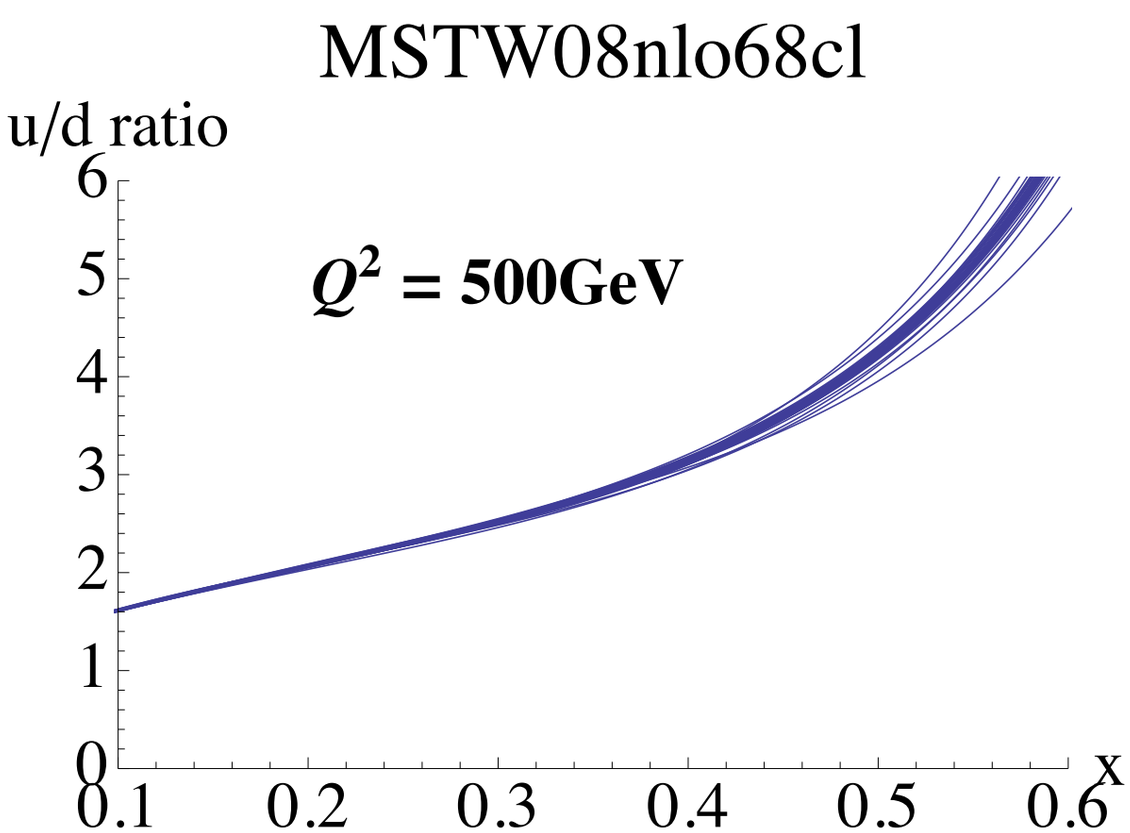
$$A_c^{ATLAS}(4.71 fb^{-1}) = 2.9 \pm 1.8 \pm 1.4\%$$

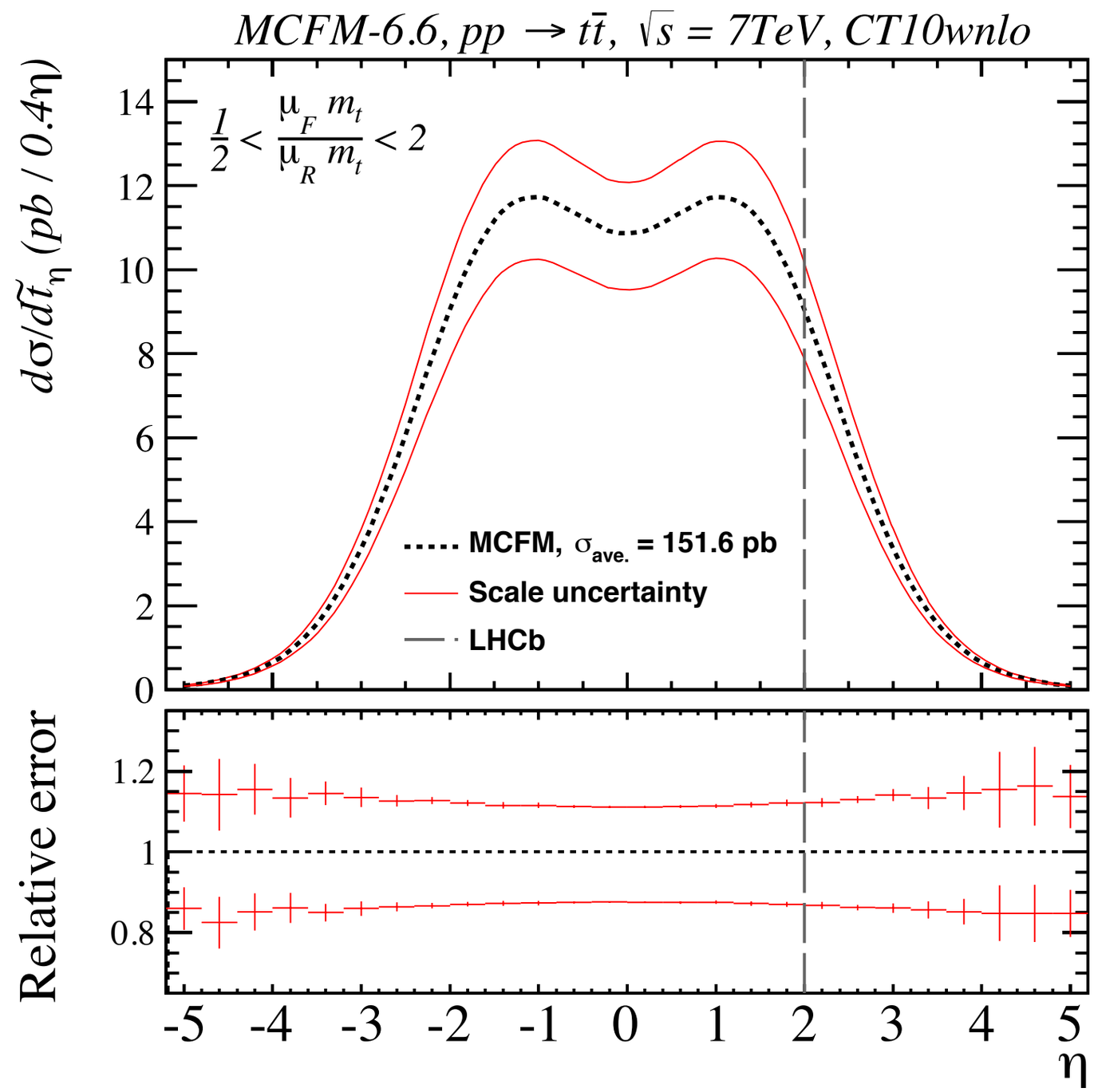
$$A_c^{CMS}(5.0 fb^{-1}) = 0.4 \pm 1.0 \pm 1.1\%$$

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

Backups - top distribution

u/d ratio of proton, large source of background asymmetries

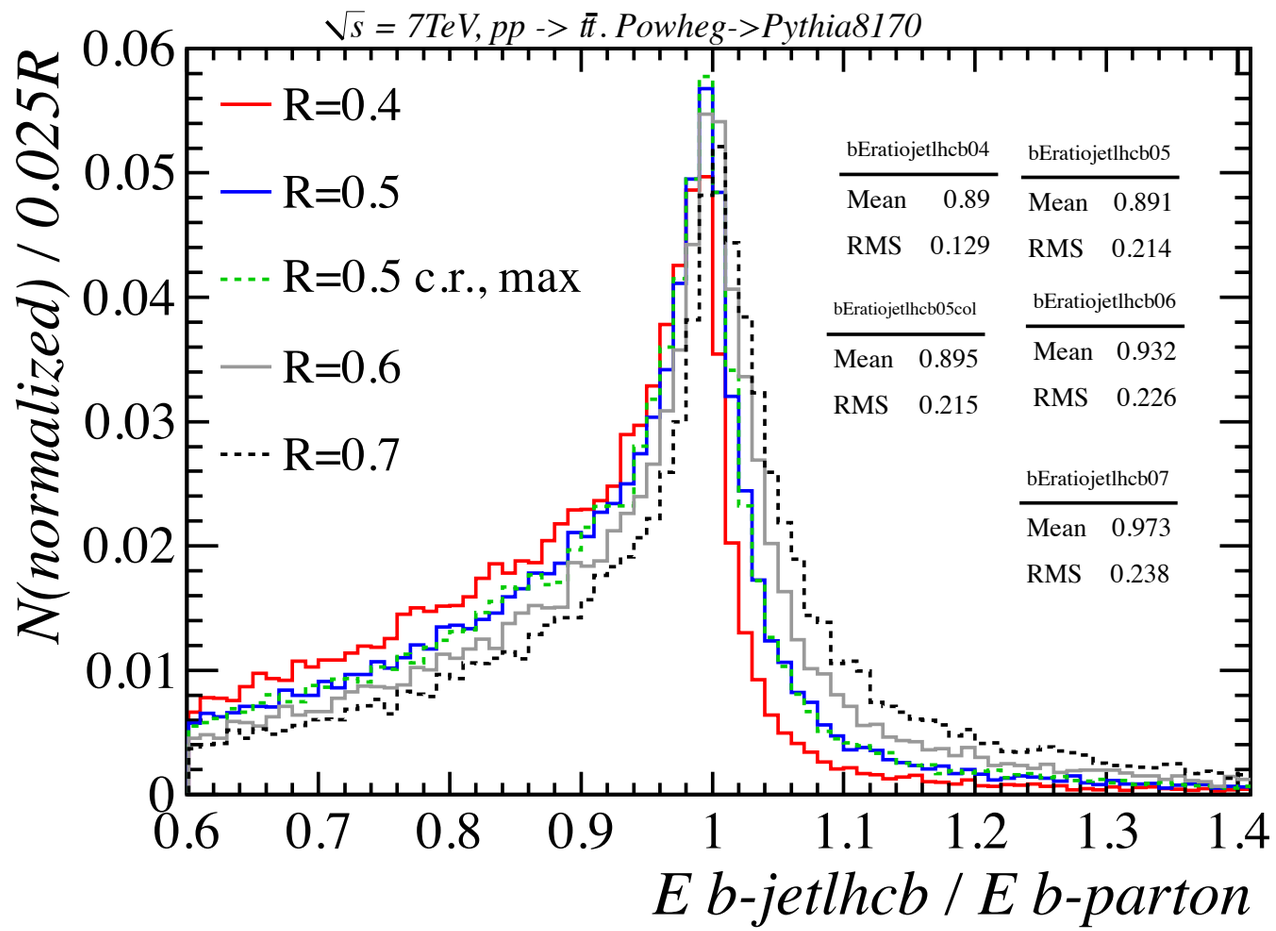


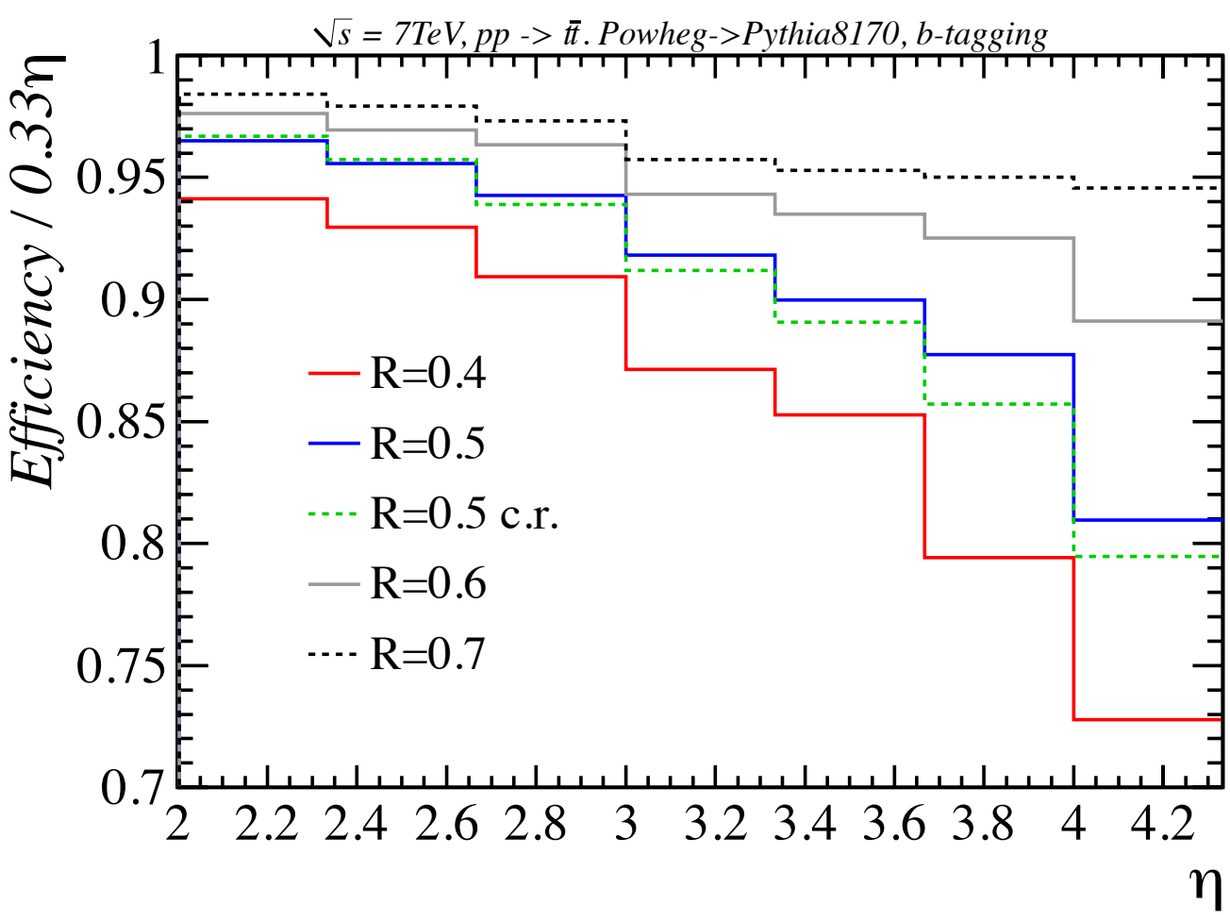


Backups - truth b-tag matching

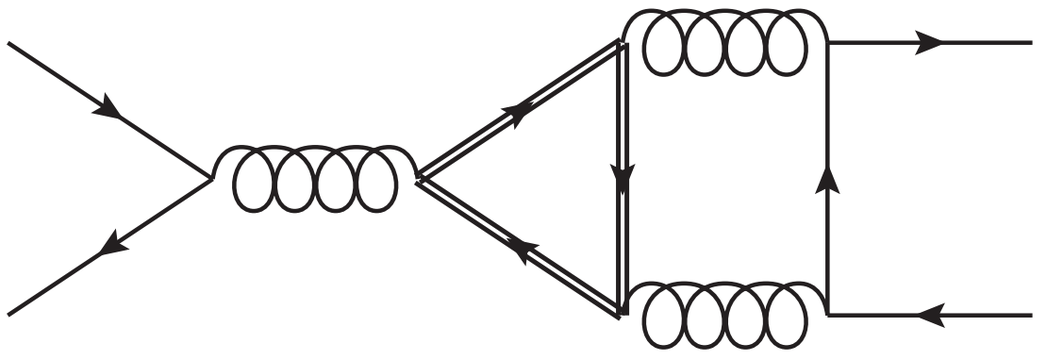
R - parameter tests for truth bjet matching to partons

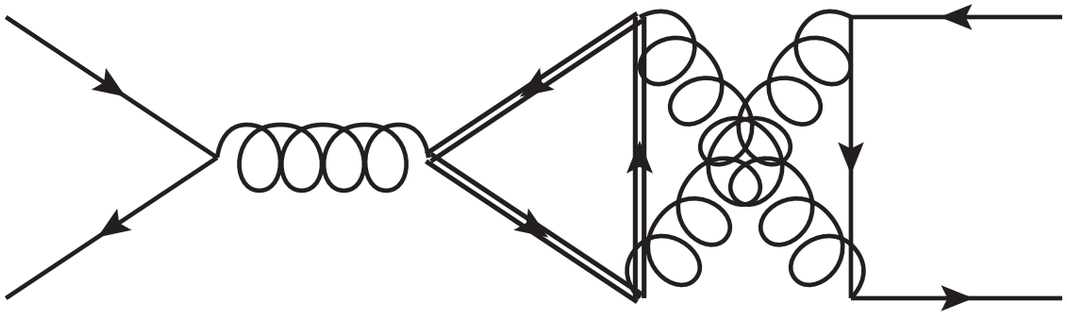
Energy (right), Efficiency(lower-left)





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,

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

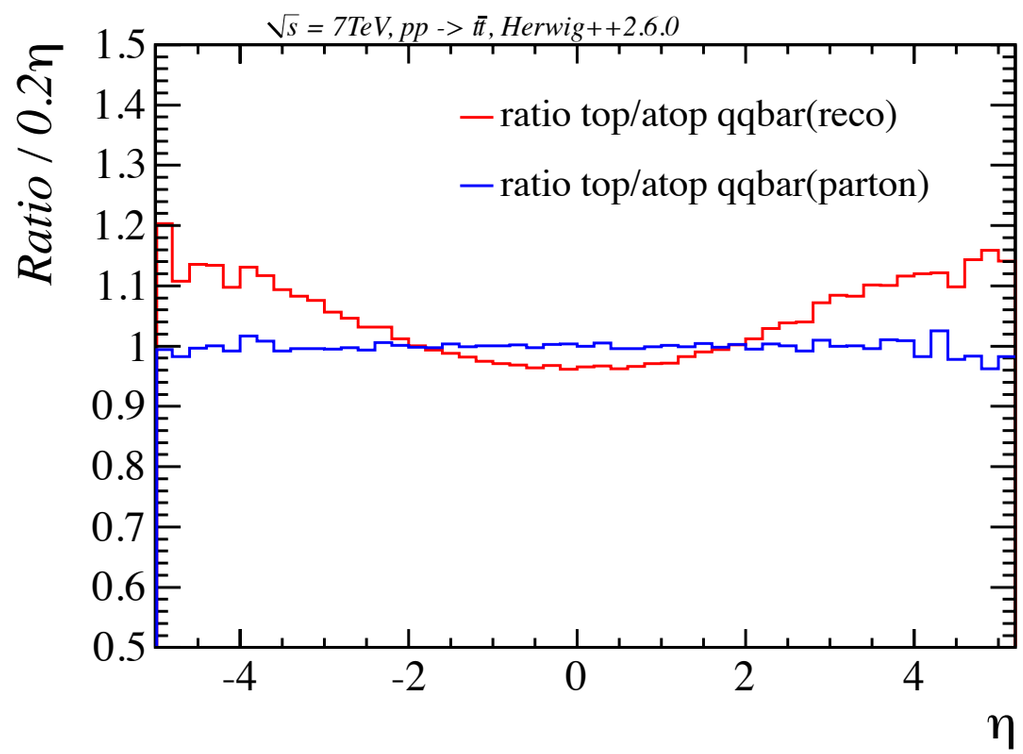
$$d_{abc}^2 = (N_c^2 - 1)(N_c^2 - 4)/N_c$$

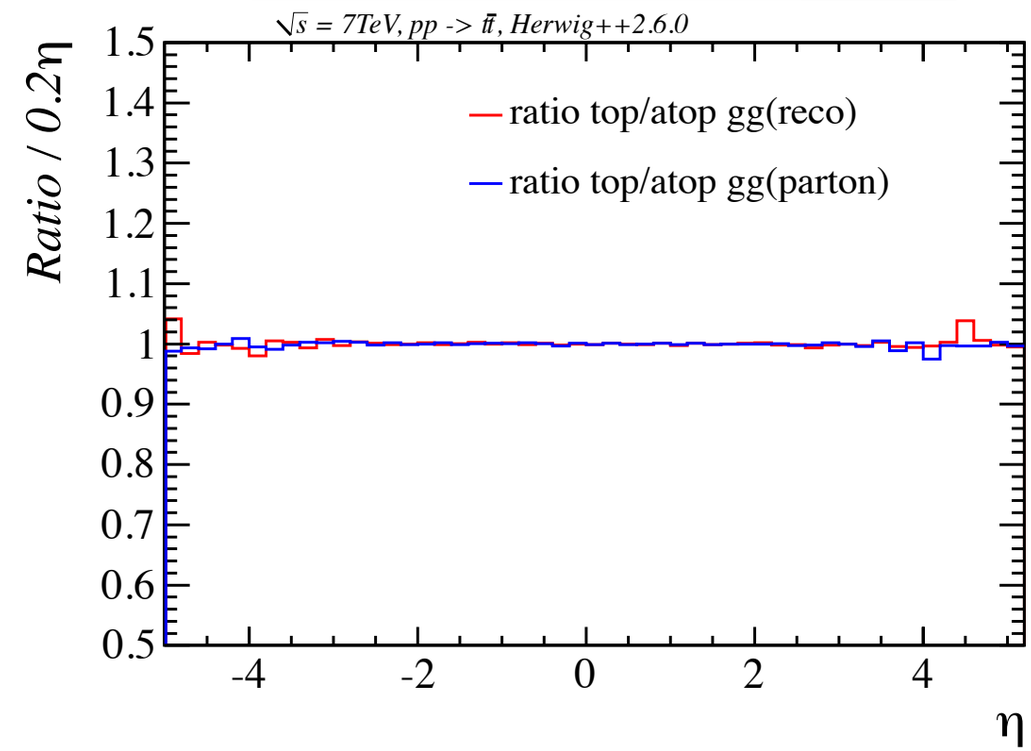
$$f_{abc}^2 = (N_c^2 - 1)N_c$$

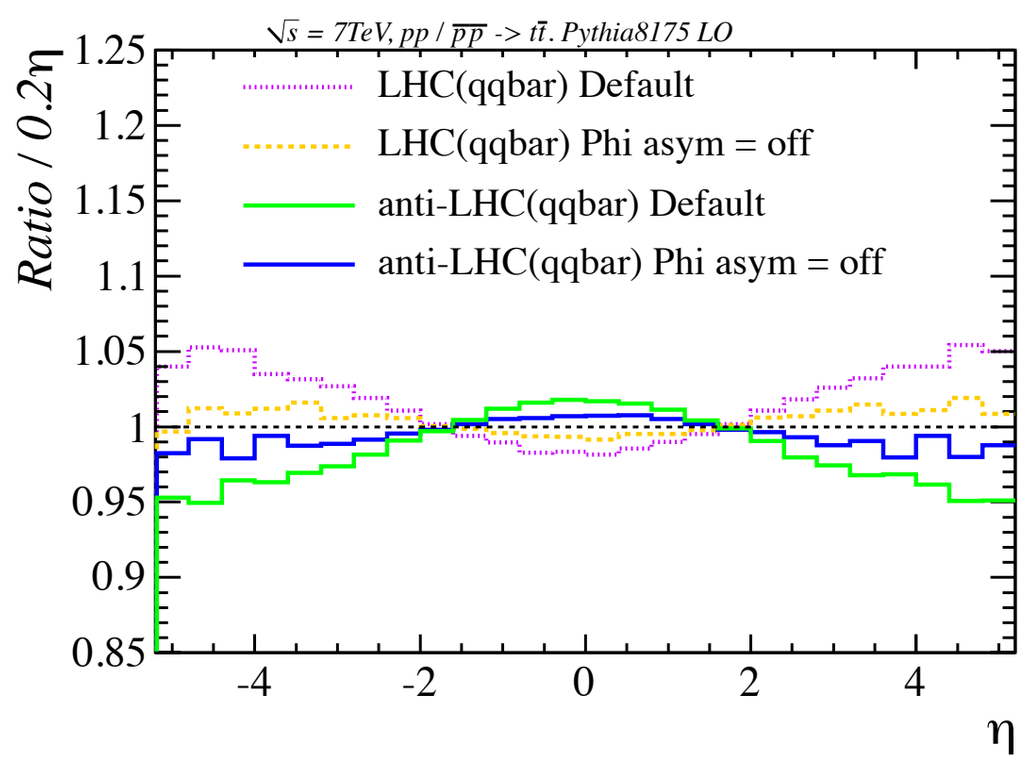
- comes from colour!
- effect is $\mathcal{O}(\alpha_s^3)$
- diluted by symmetric gg

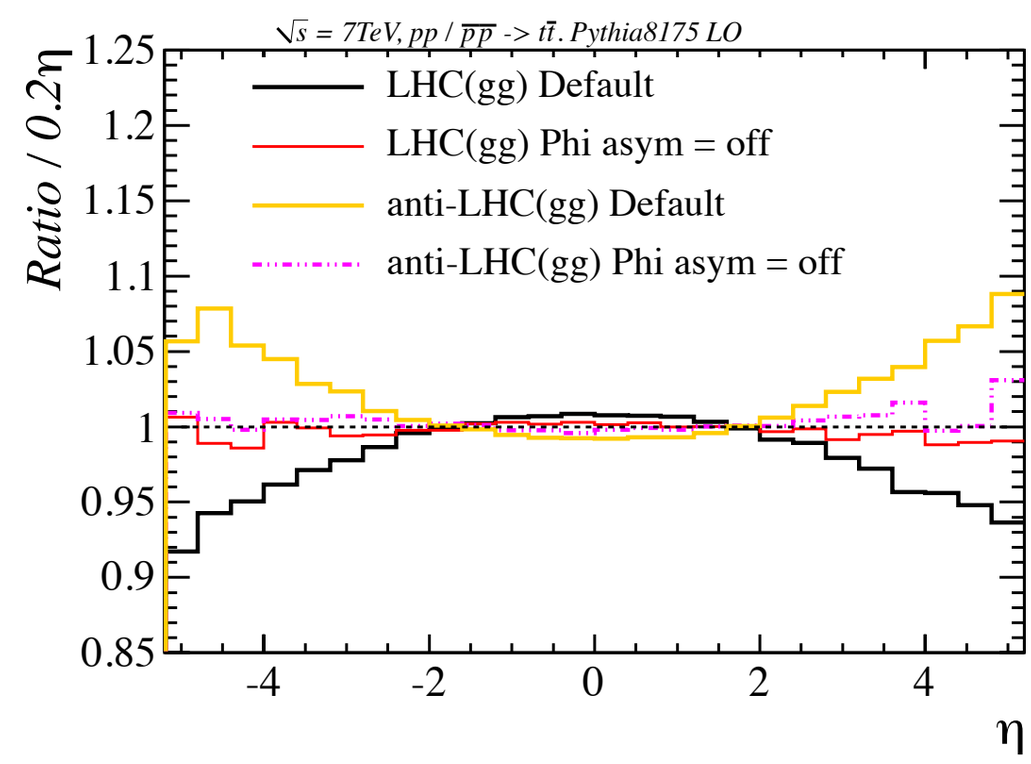
1. J.H.Kuhn, G. Rodrigo, arXiv:hep-ph/9807420 [hep-ph]

Backups - controlling shower effects





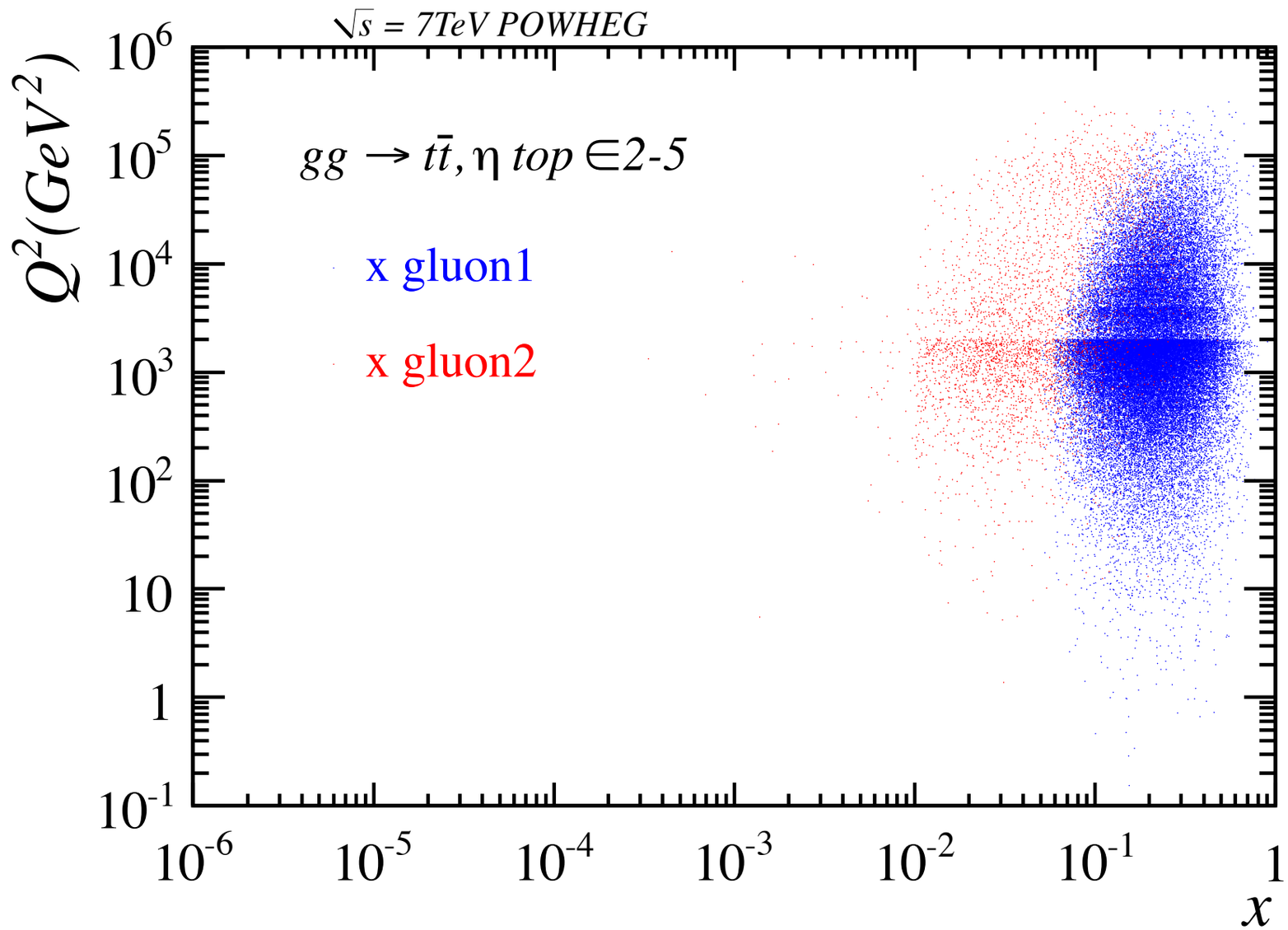




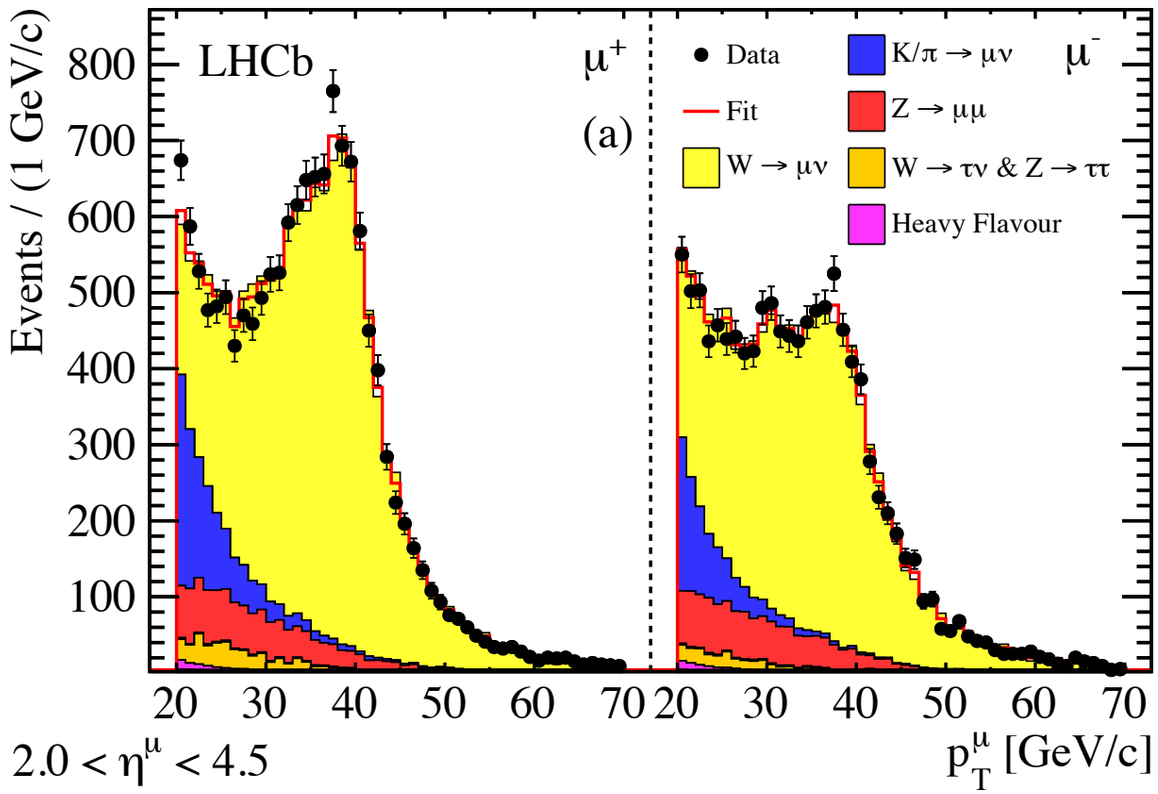
Backups

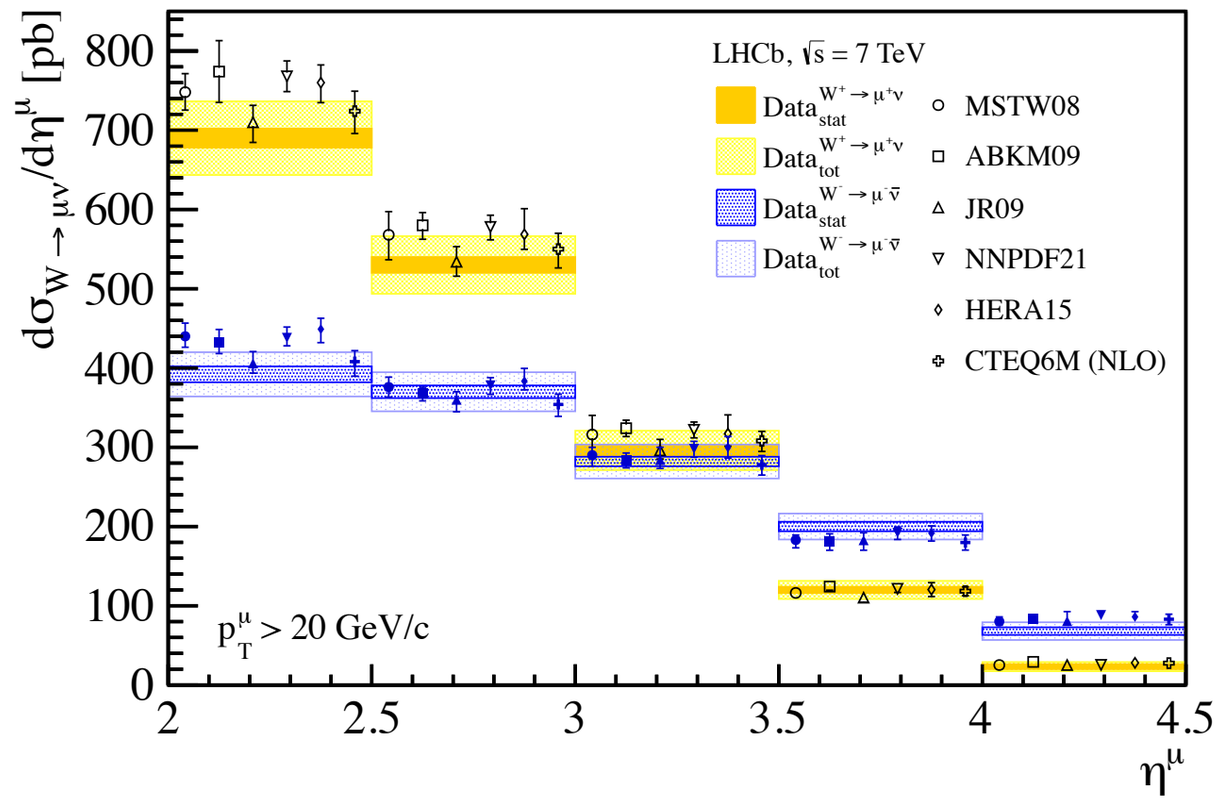
Bjorken x of gluons.

1 top in LHCb acceptance



Backups - W Analysis





Example of W reconstruction with muons at LHCb
[1]- arXiv:1204.1620, DOI:10.1007/JHEP06(2012)