TH perspective

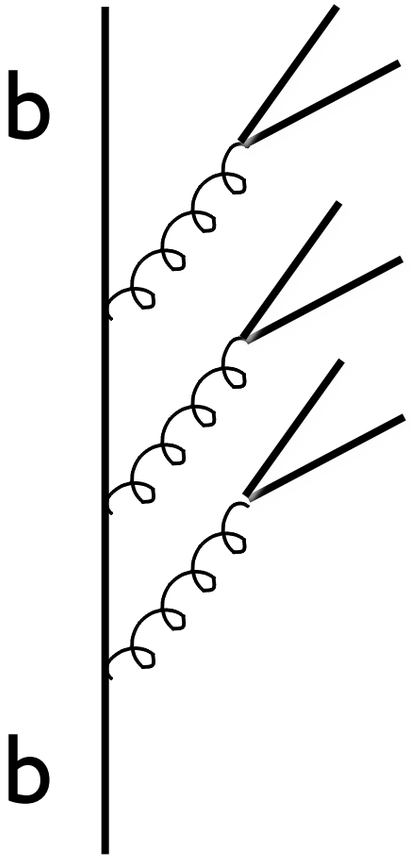
LHC Heavy Flavour WG
May 4 2017

M.L. Mangano
TH Department, CERN

- (non-)universality of b-hadron fragmentation fractions

- recent TH developments in relation to hvq production cross sections

Universality of fragmentation fractions at large p_T



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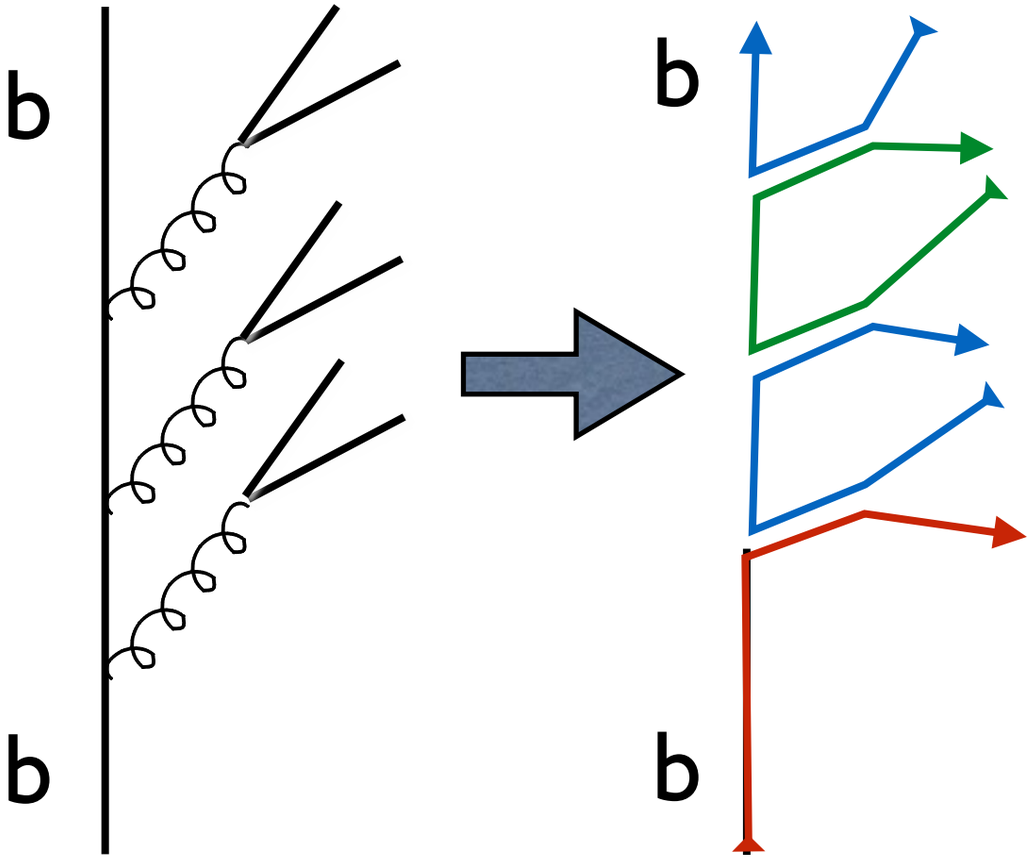

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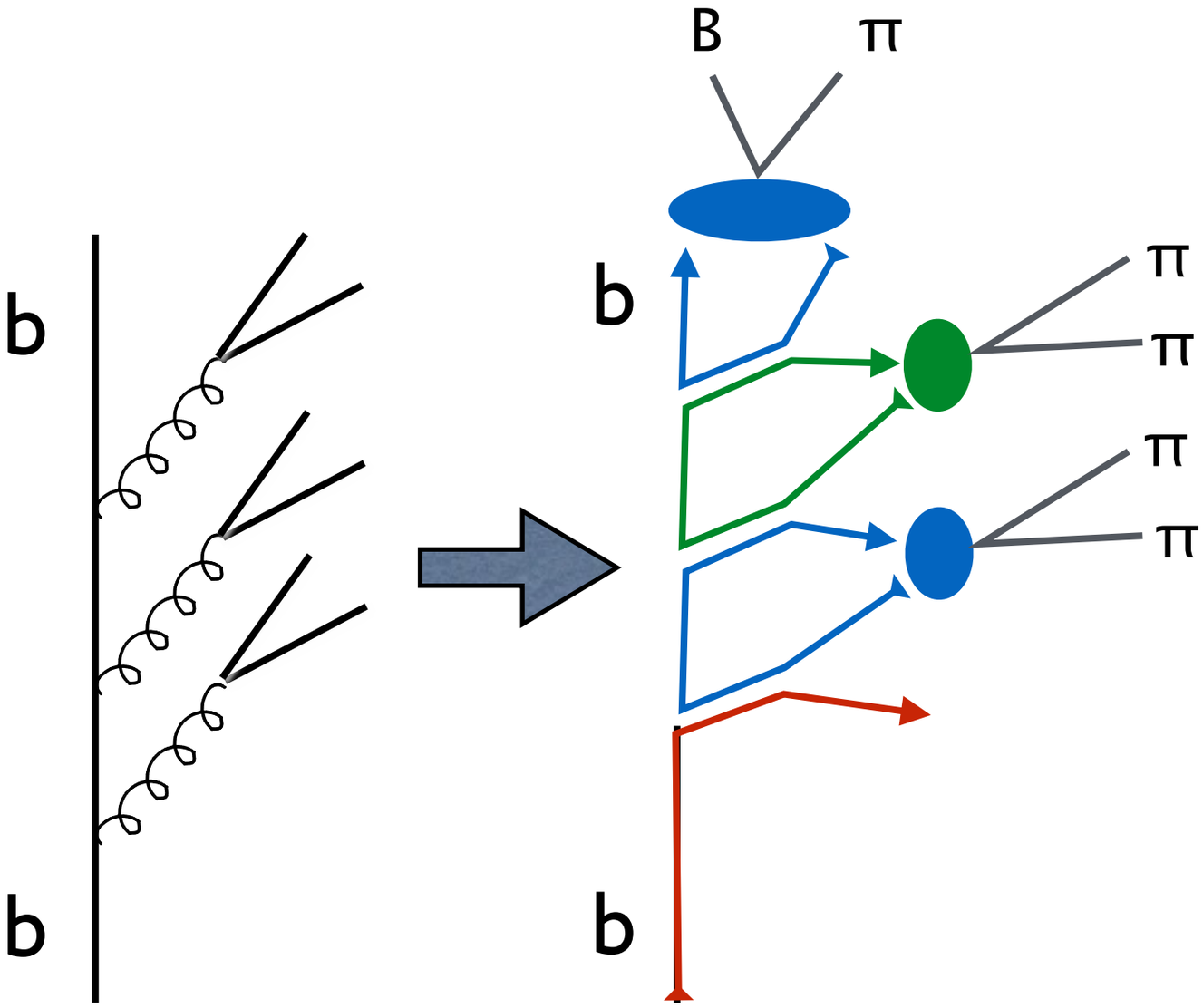

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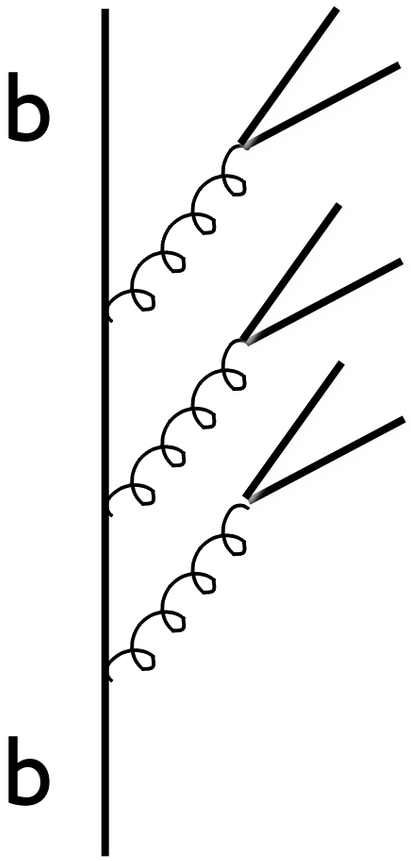

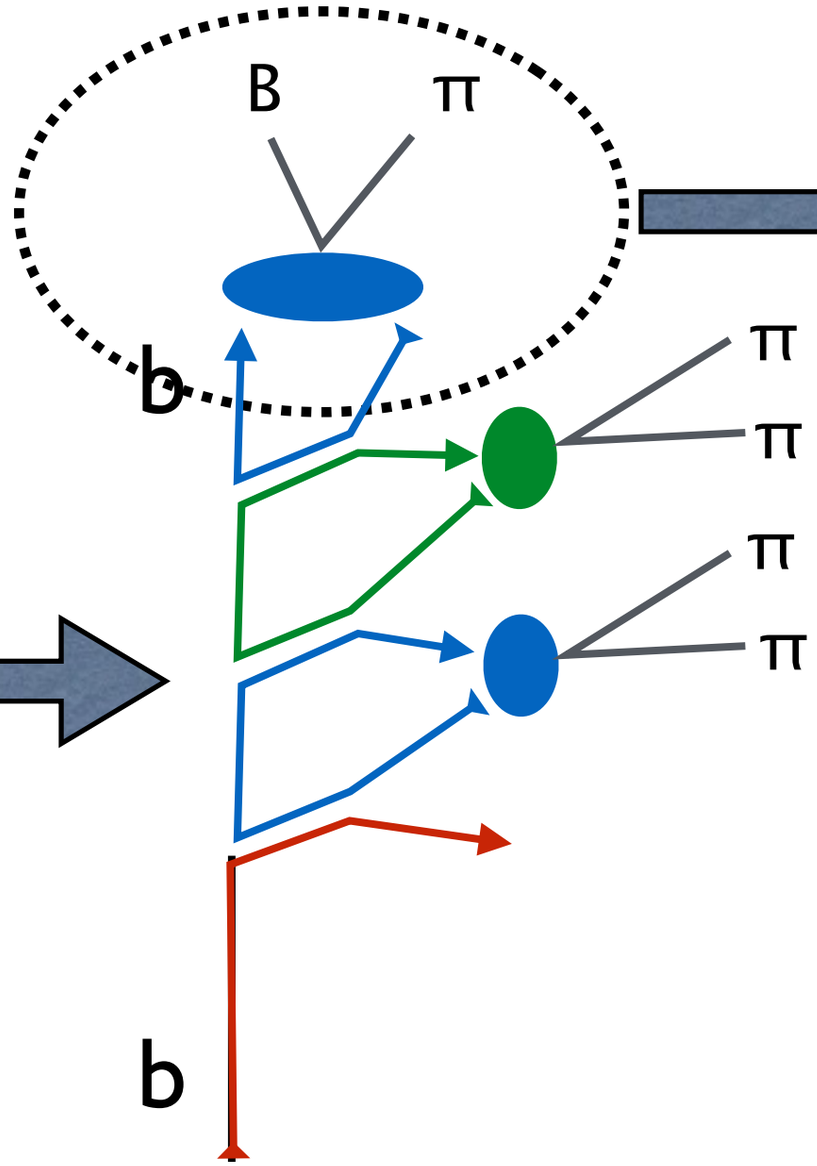

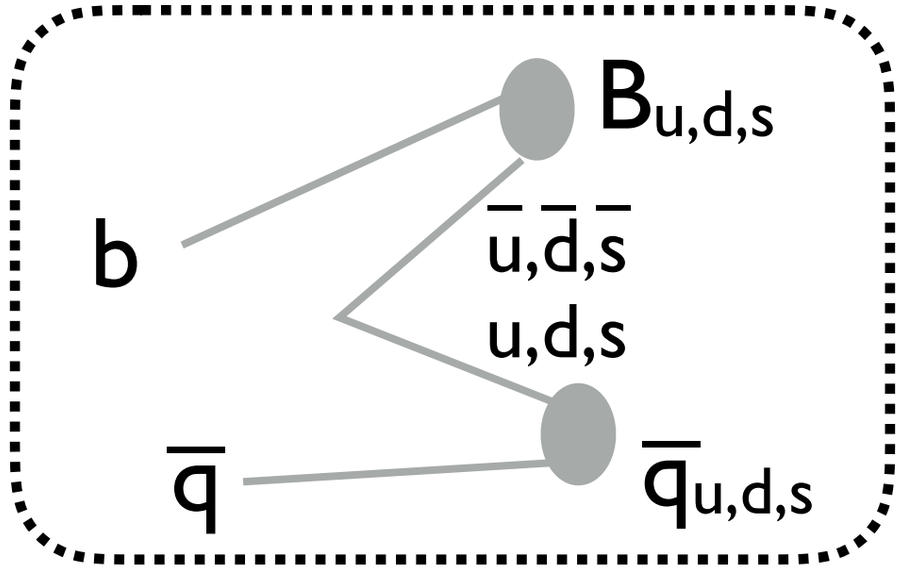

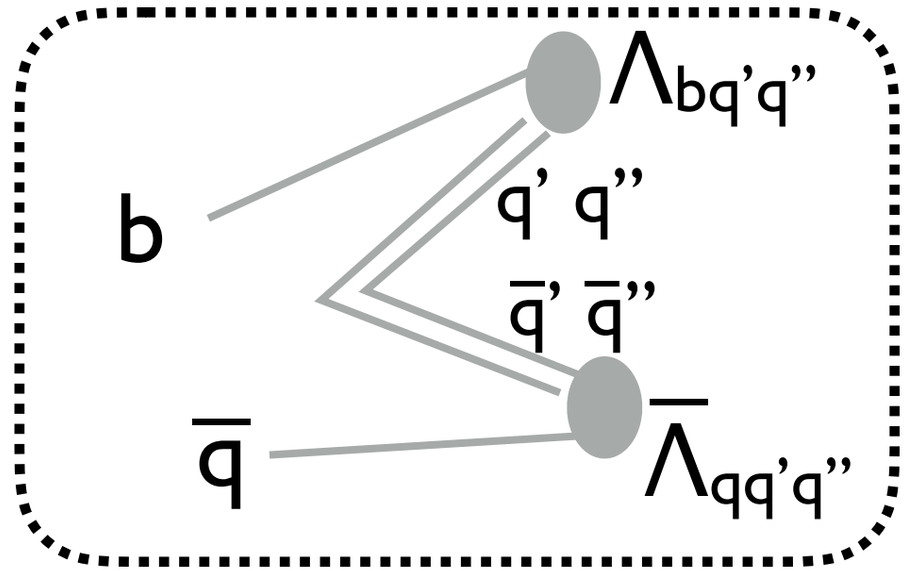

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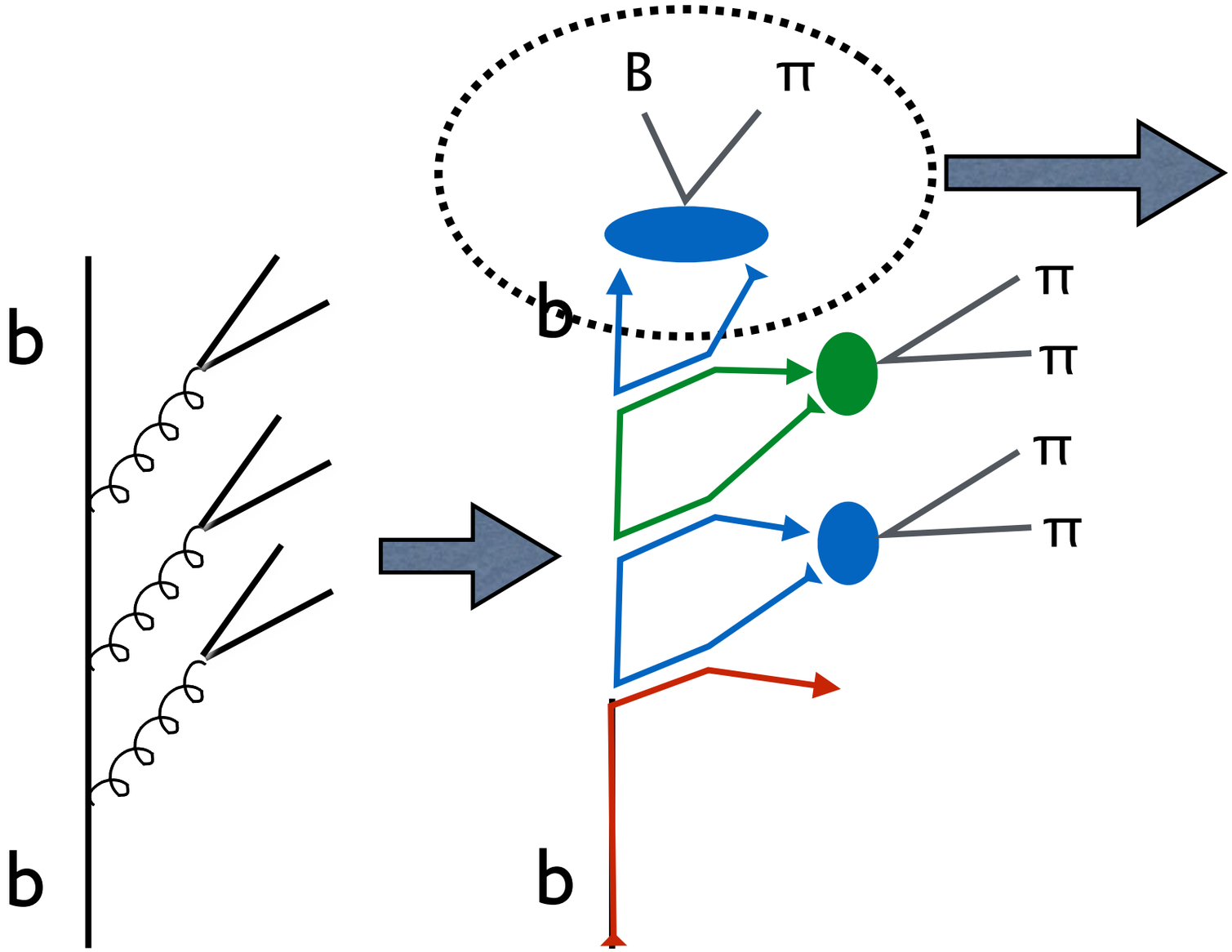
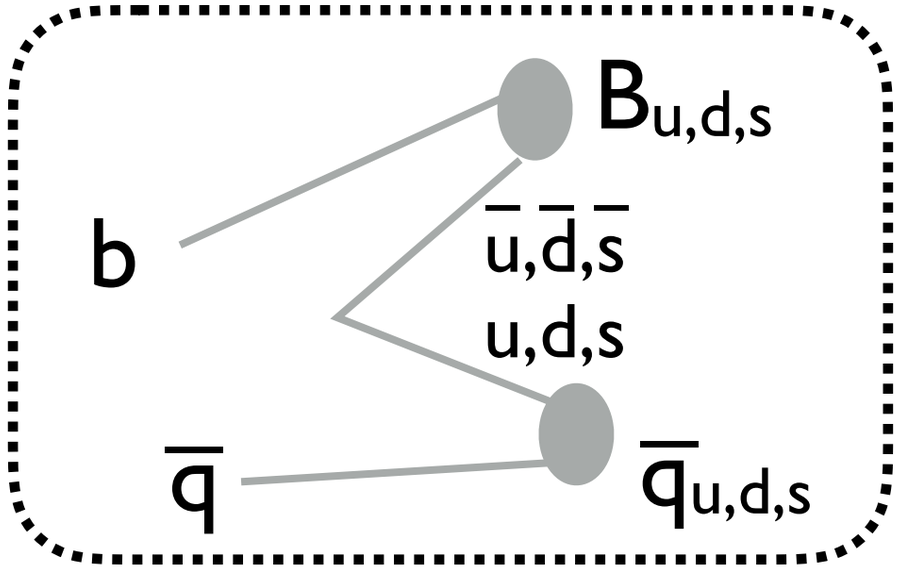
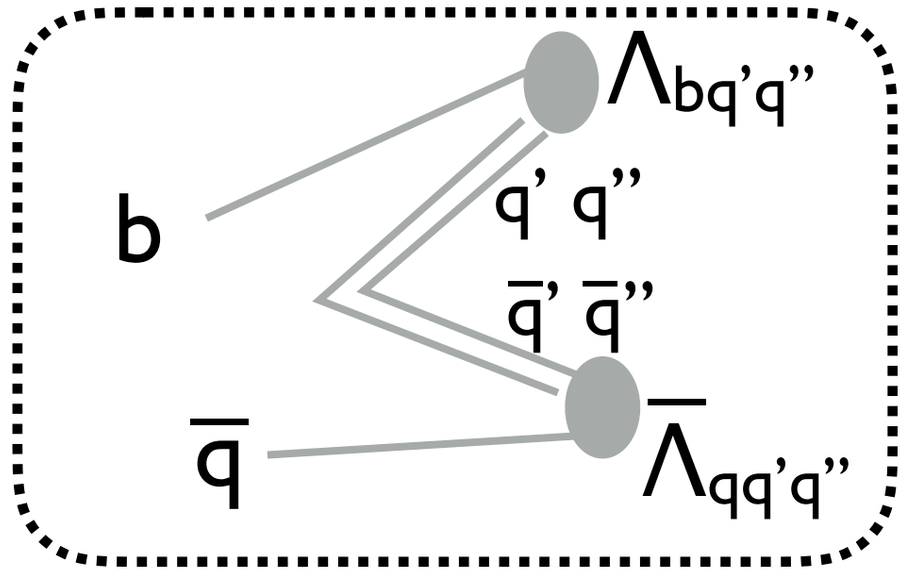
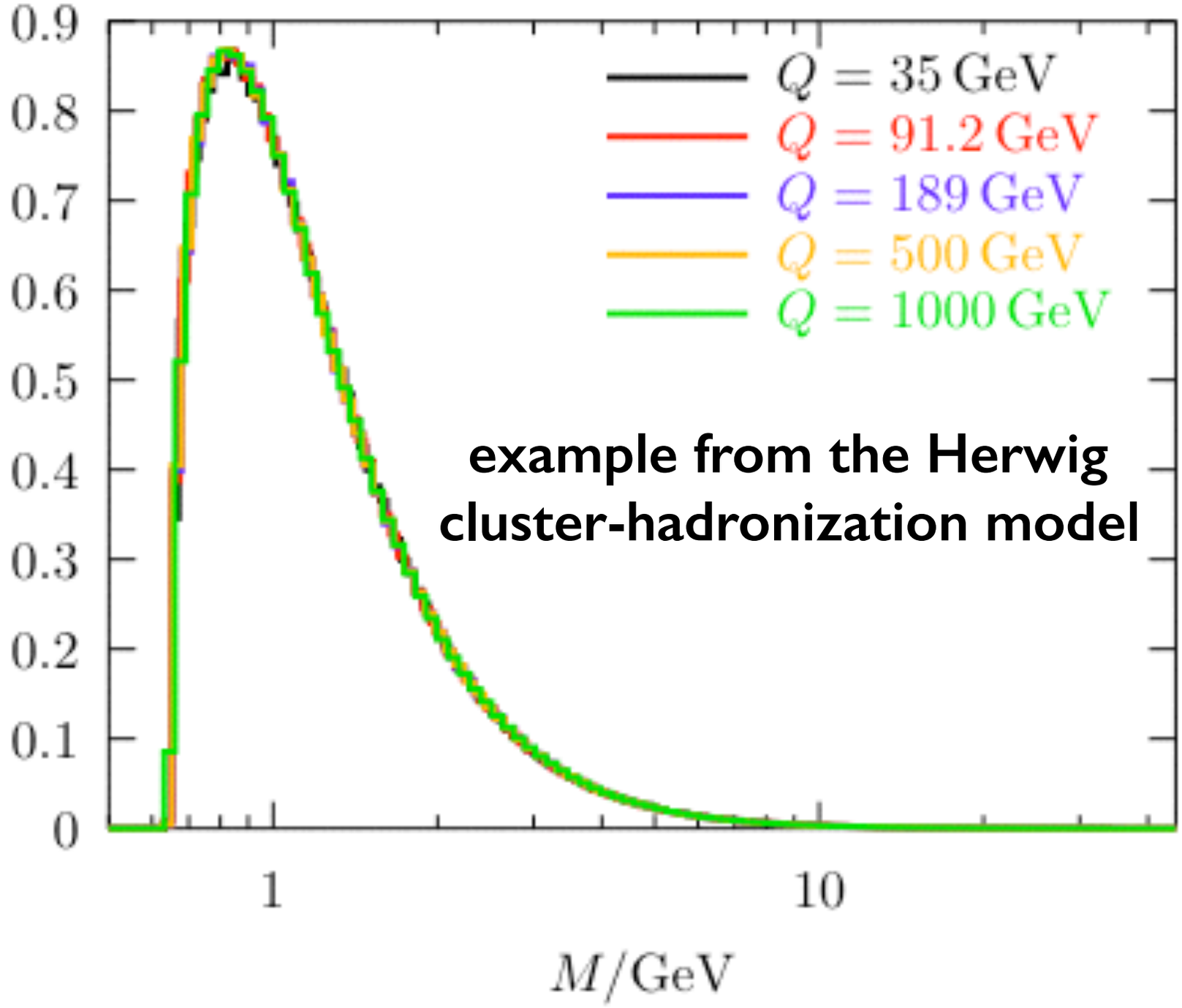
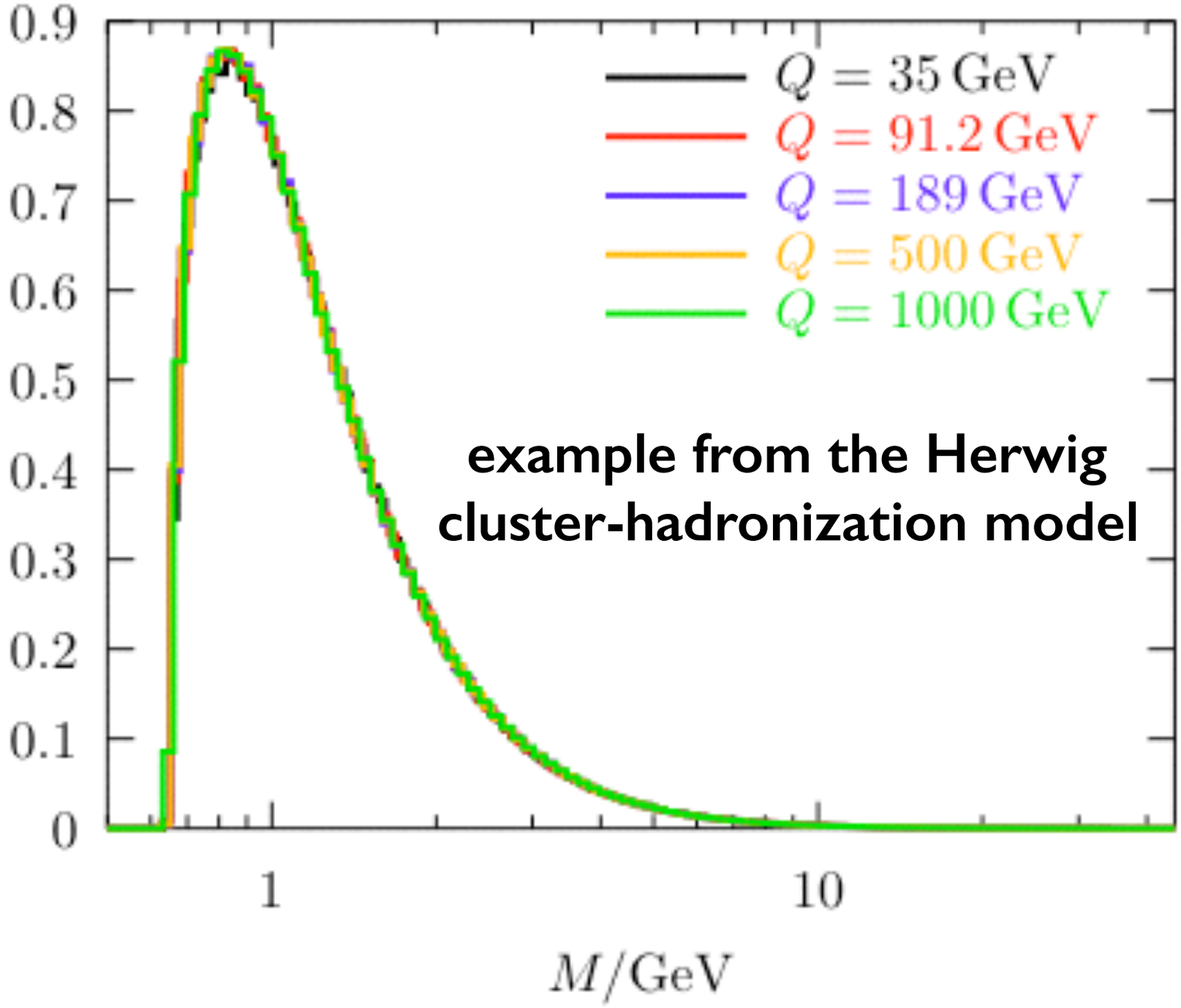






The relative probabilities of forming various hadron types are phenomenological parameters. They may depend on the mass of the color-singlet cluster. But since the mass distribution of these clusters is, at large p_T, independent of p_T, one can consider these fragmentation fractions as constant.


0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
10
M/GeV
$Q = 35\,\mathrm{GeV}$
$Q = 91.2\,\mathrm{GeV}$
$Q = 189\,\mathrm{GeV}$
$Q = 500\,\mathrm{GeV}$
$Q = 1000\,\mathrm{GeV}$
example from the Herwig cluster-hadronization model

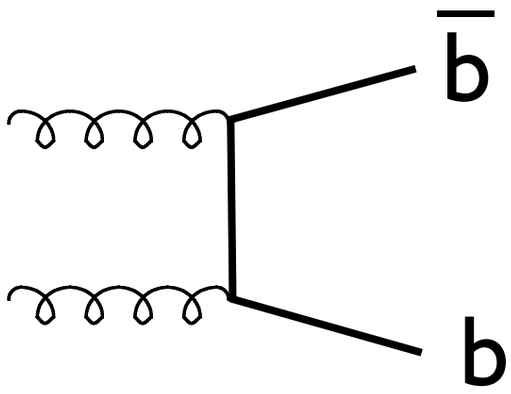


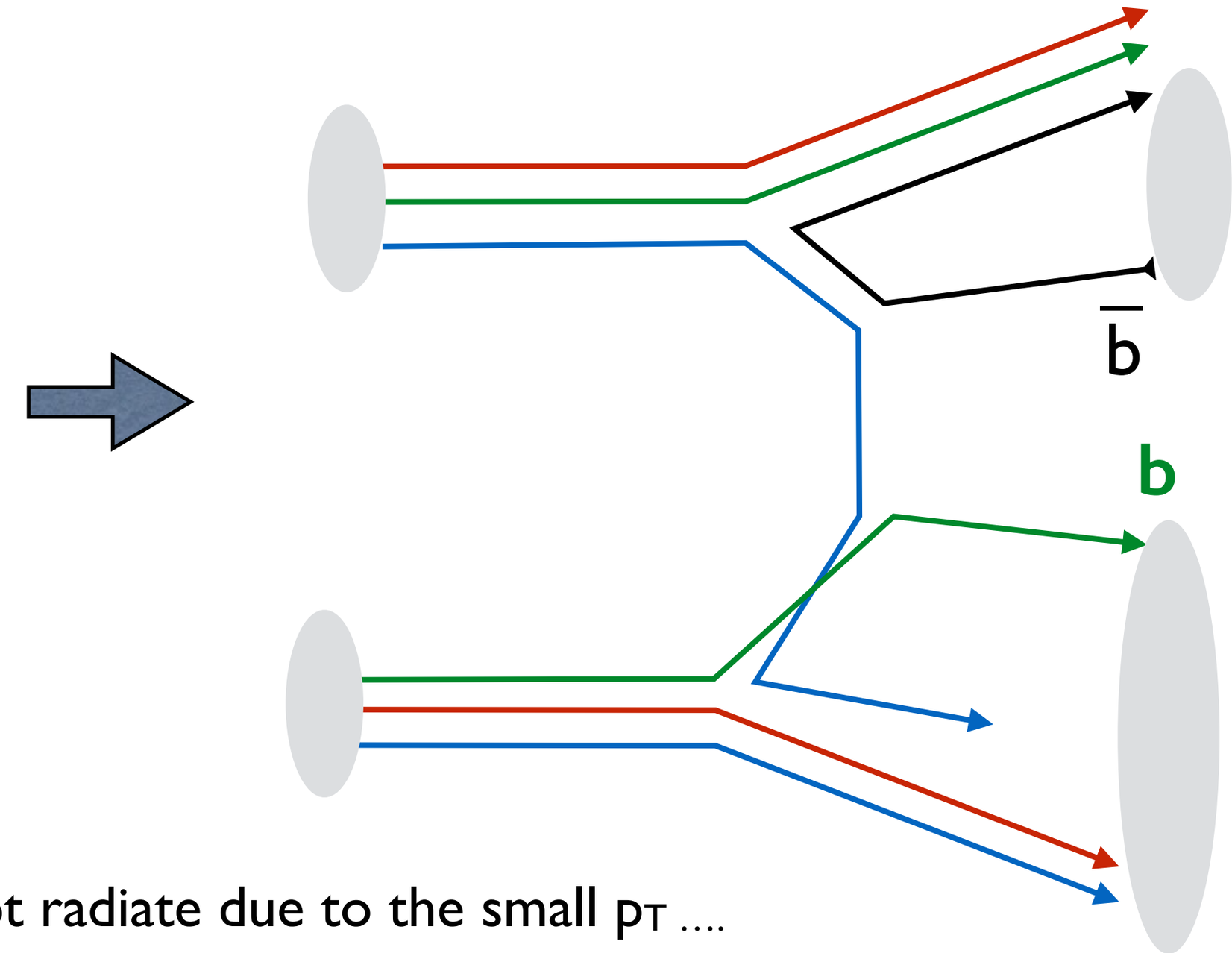
M=color-singlet cluster mass distributions, in $e^+e^- \rightarrow$ hadrons, for different CoM energies Q.

The shape is independent of Q, supporting the belief that at large p_T fragmentation fractions are constant and independent of production environment (eg LEP vs LHC)

Among other things, this implies that f_s/f_d or $f_{\Lambda b}/f_d$ should not grow at large p_T

At small p_T





- The b quarks may not radiate due to the small p_T ....
  - … and may find their color-partner outside the "b-jet"
- The hadronization is then more sensitive to interactions with the beam fragments, particularly at small p_T and large y:
  - the cluster invariant mass distribution may be different than at high p_T
  - differences can emerge in the hadronization of b and bbar quarks

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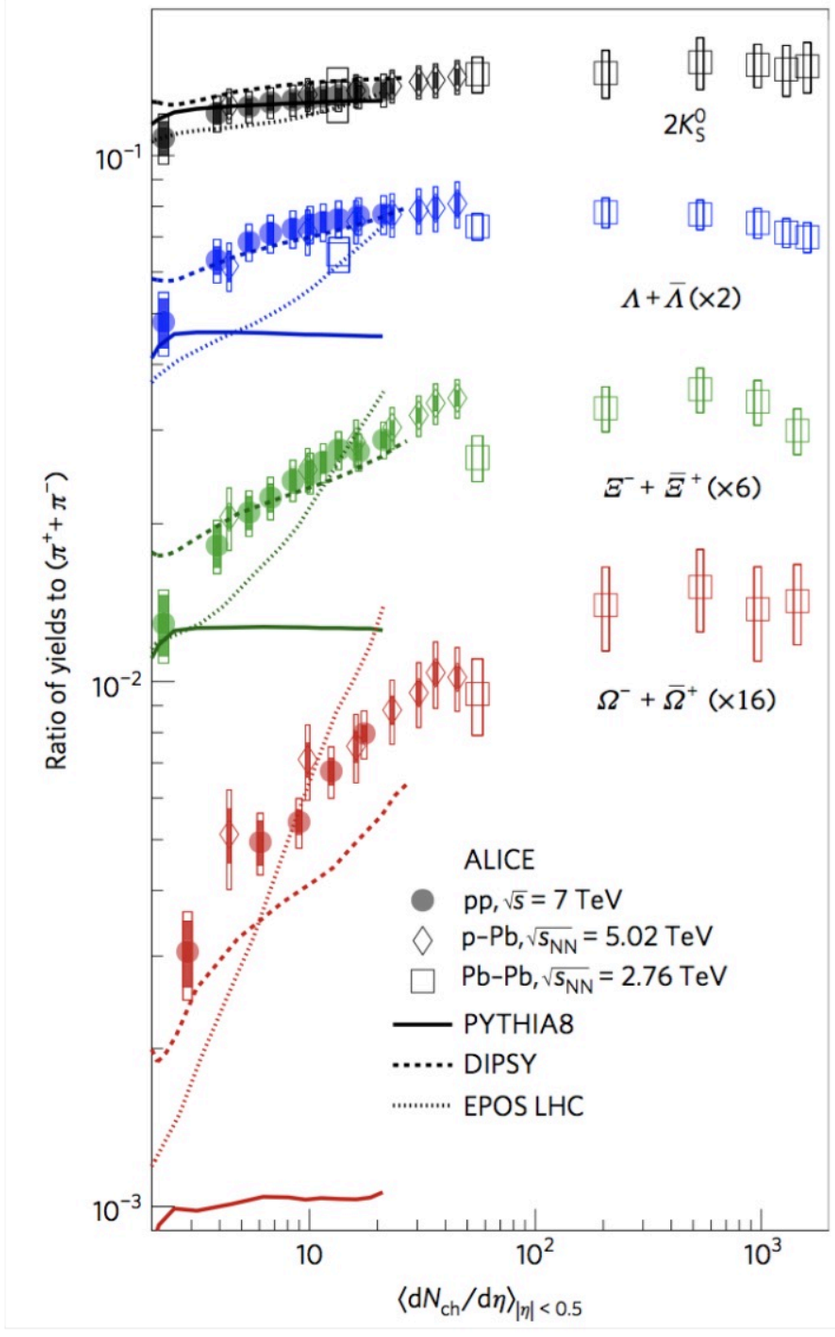
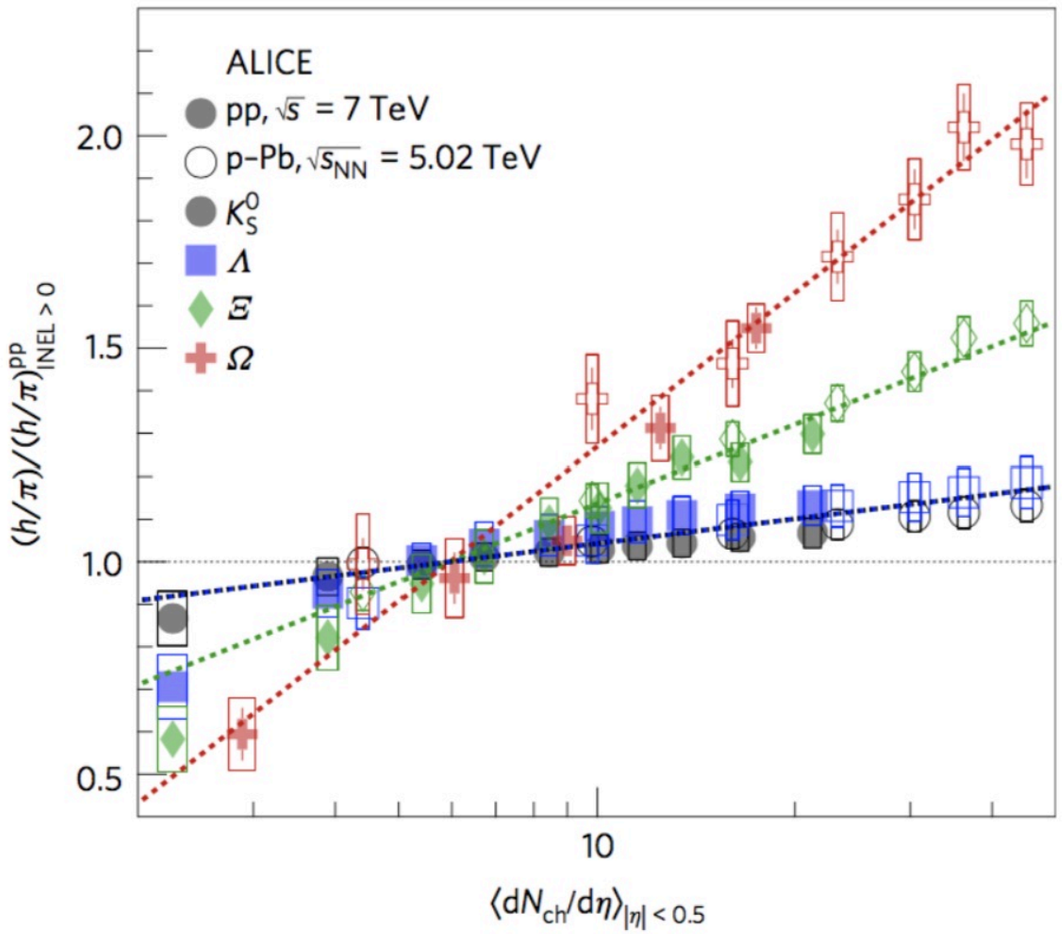
- It might be interesting to test universality more systematically, by looking at ratios of specific production/decay modes
- It might be interesting to consider different prodution environments, eg:
  - using b's from top decays
  - using charm from W decays in ttbar events (…. we are not discussing charm, but I guess that's also relevant?)

NB





Signs of QGP in high-multiplicity *pp* collisions? If not, what else? A whole new game!

Recent ALICE data on the relative production rate of strange hadrons show an increase with final-state event multiplicity. This is not predicted by standard QCD MCs. It would be interesting to search for a similar effect in f_s/f_d vs $dN_{ch}/d\eta$

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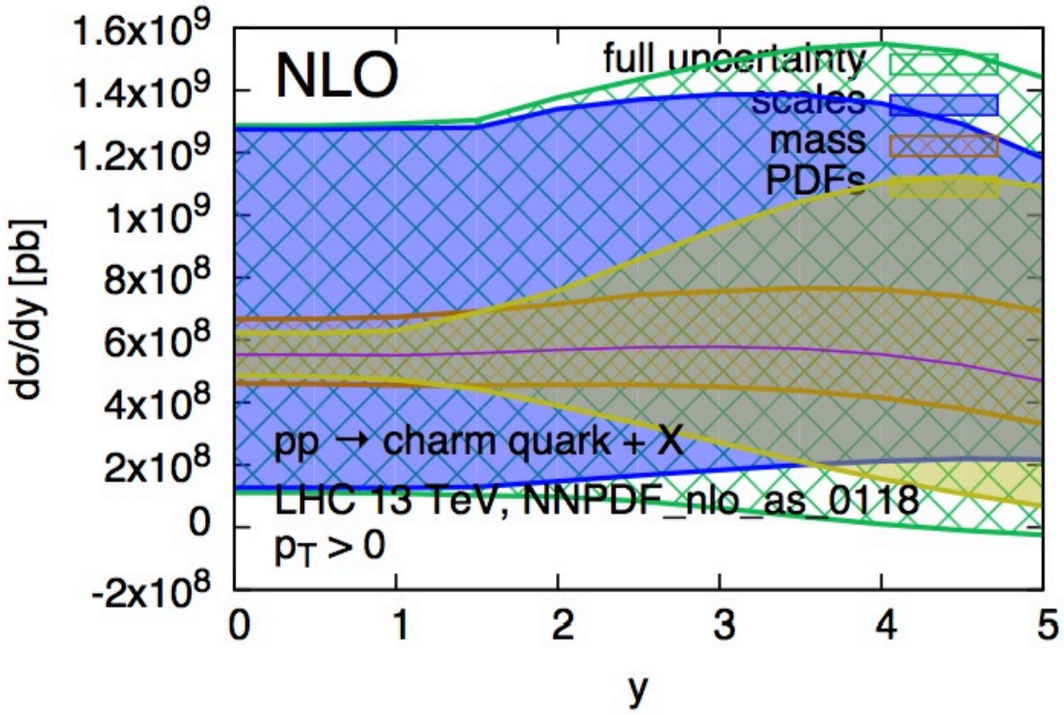
- At this time, we need to build confidence that our assumptions about theoretical systematics are robust

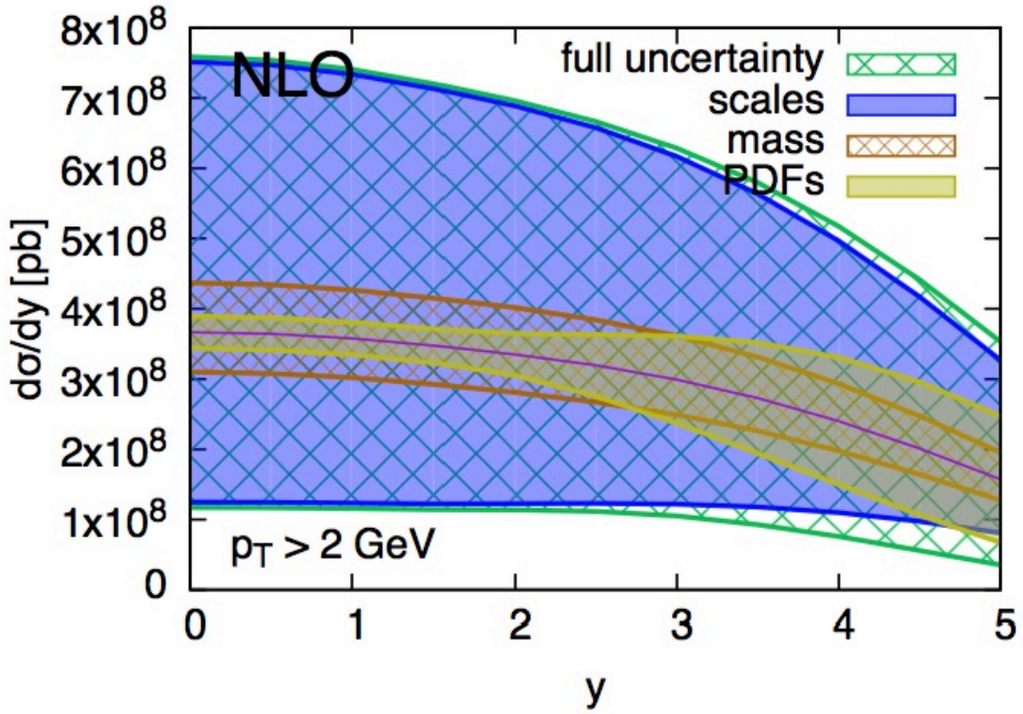
Key references to recent TH work exploring these ideas

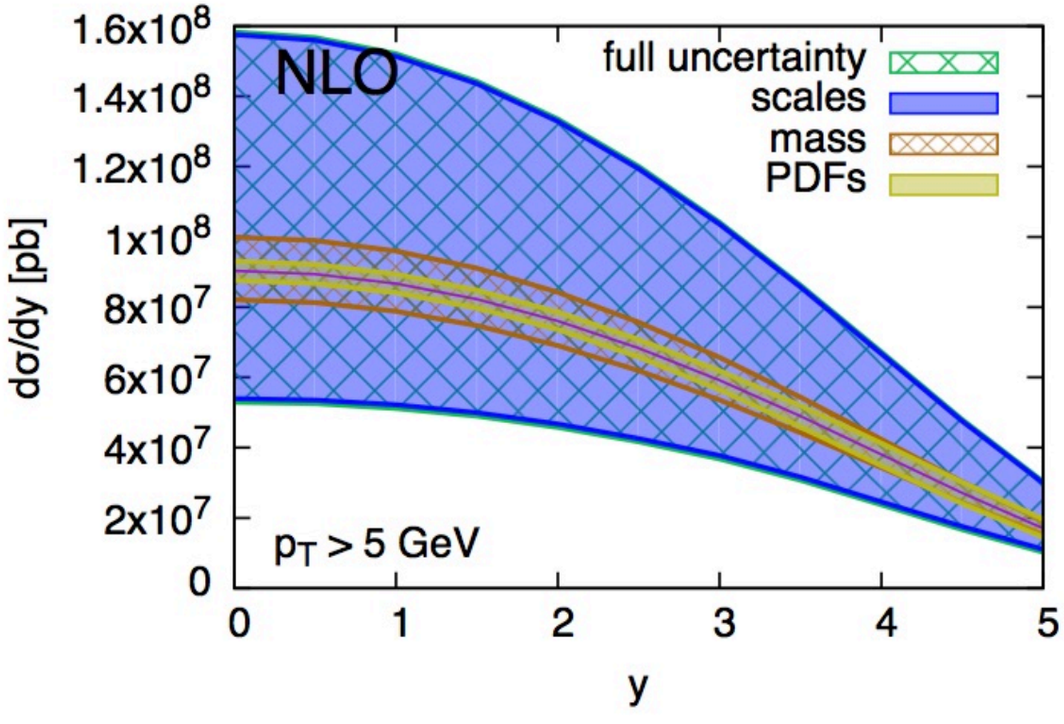
- Charm production in the forward region: constraints on the small-x gluon and backgrounds for neutrino astronomy. R.Gauld et al. arXiv:1506.08025
- [CMN] Gluon PDF constraints from the ratio of forward heavy-quark production at the LHC at root(S)=7 and 13 TeV, M.Cacciari M.Mangano and P.Nason, arXiv:1507.06197
- Impact of heavy-flavour production cross sections measured by the LHCb experiment on parton distribution functions at low x, PROSA Collaboration (Zenaiev et al.), arXiv:1503.04581
- [GR] Precision determination of the small-x gluon from charm production at LHCb, R.Gauld and J.Rojo, arXiv:1610.09373
- [G] Understanding forward B-hadron production, R.Gauld, arxiv:1703.03636

Systematics of charm XS's at 13 TeV

[CMN]







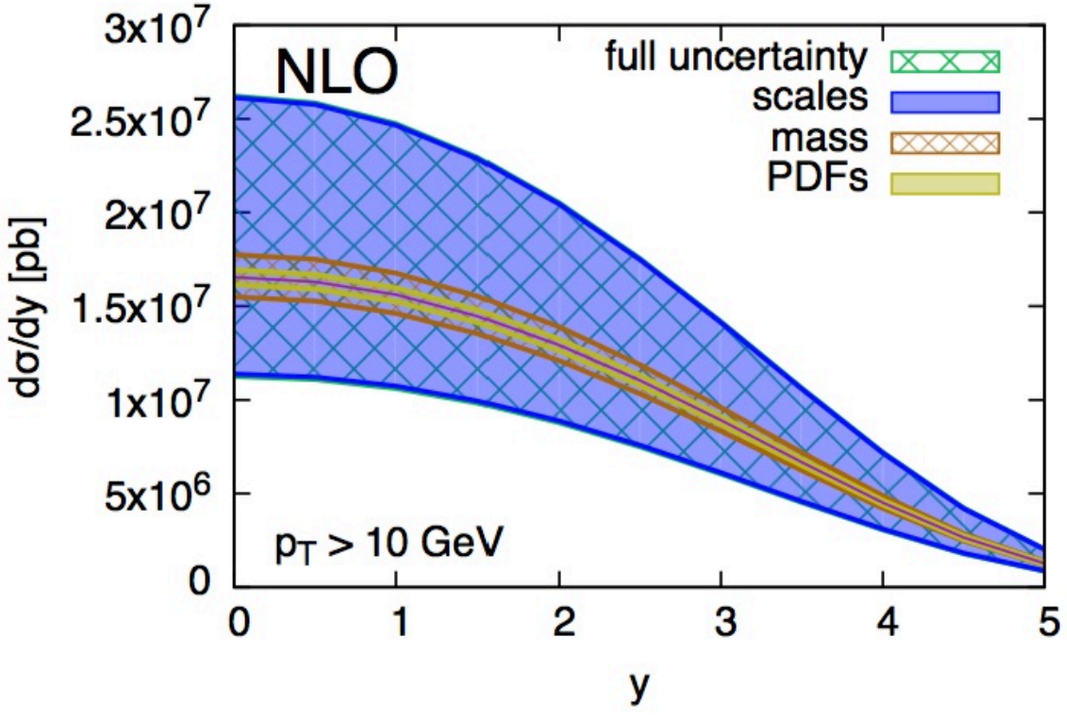
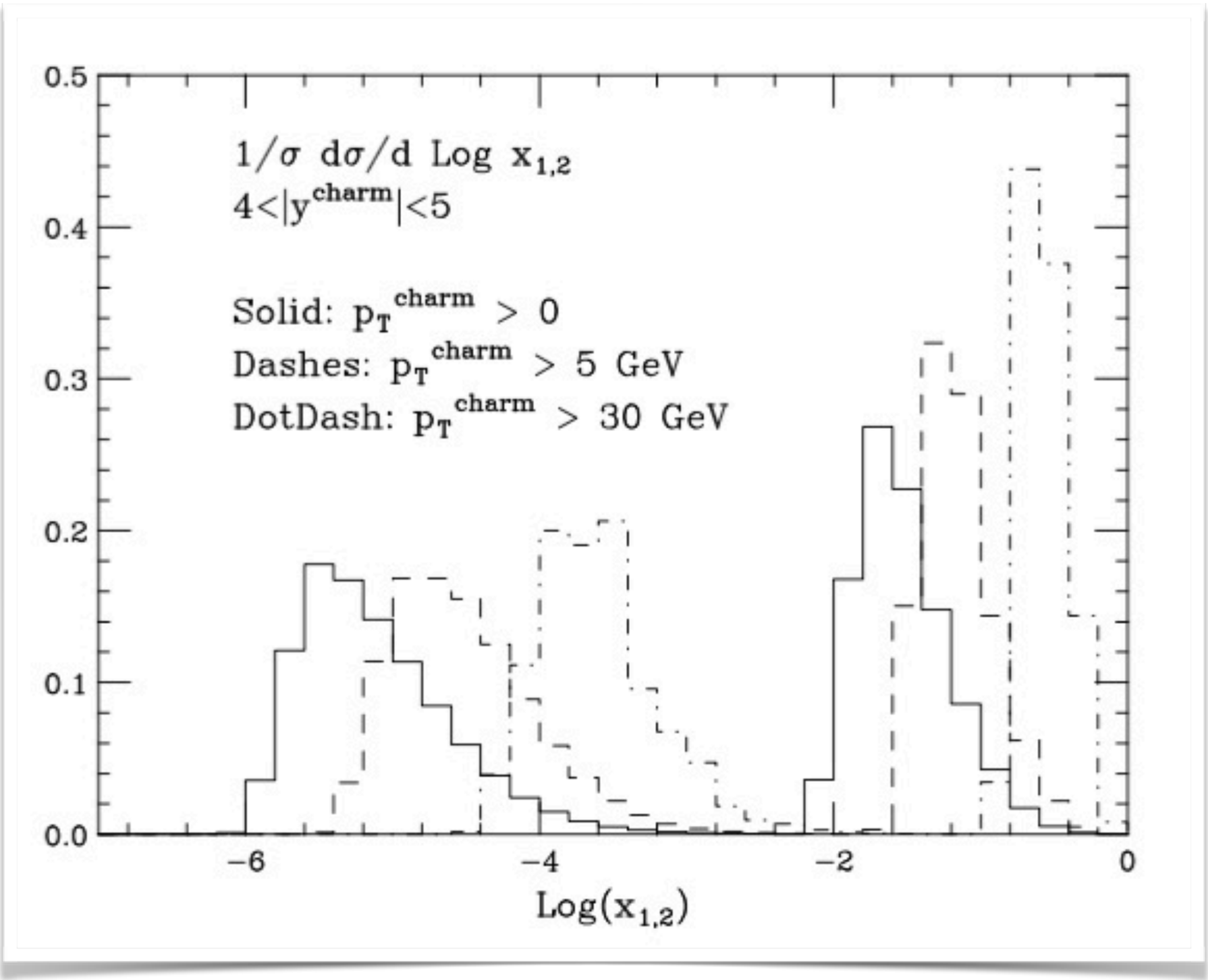


Figure 2: Charm quark rapidity distributions at $\sqrt{S} = 13$ TeV.

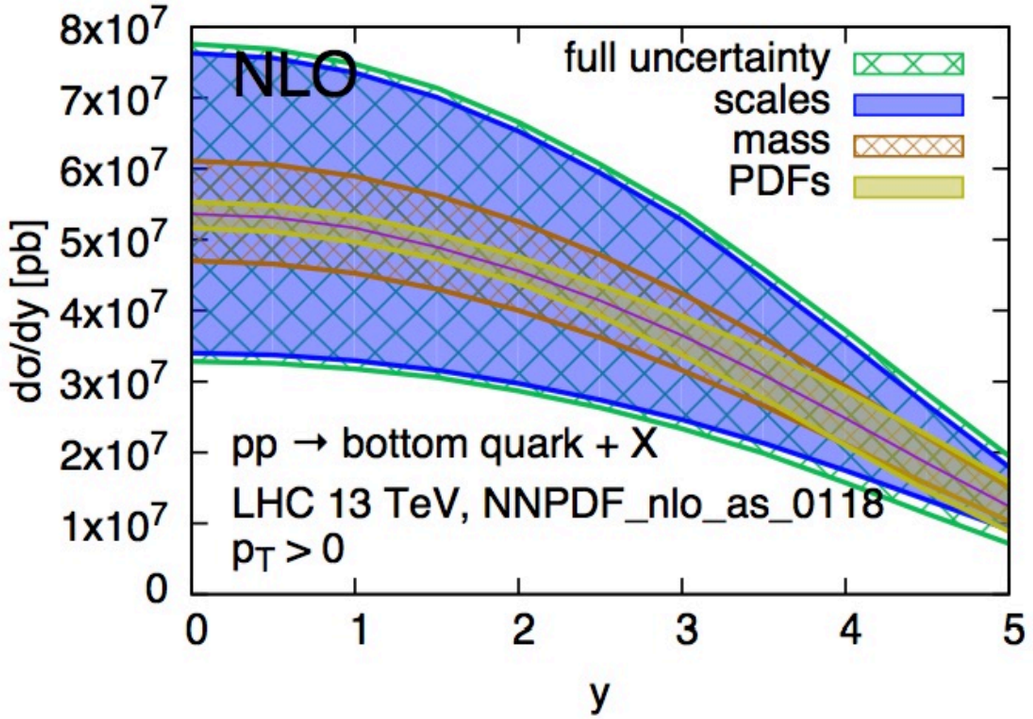
x range covered by gluon PDF

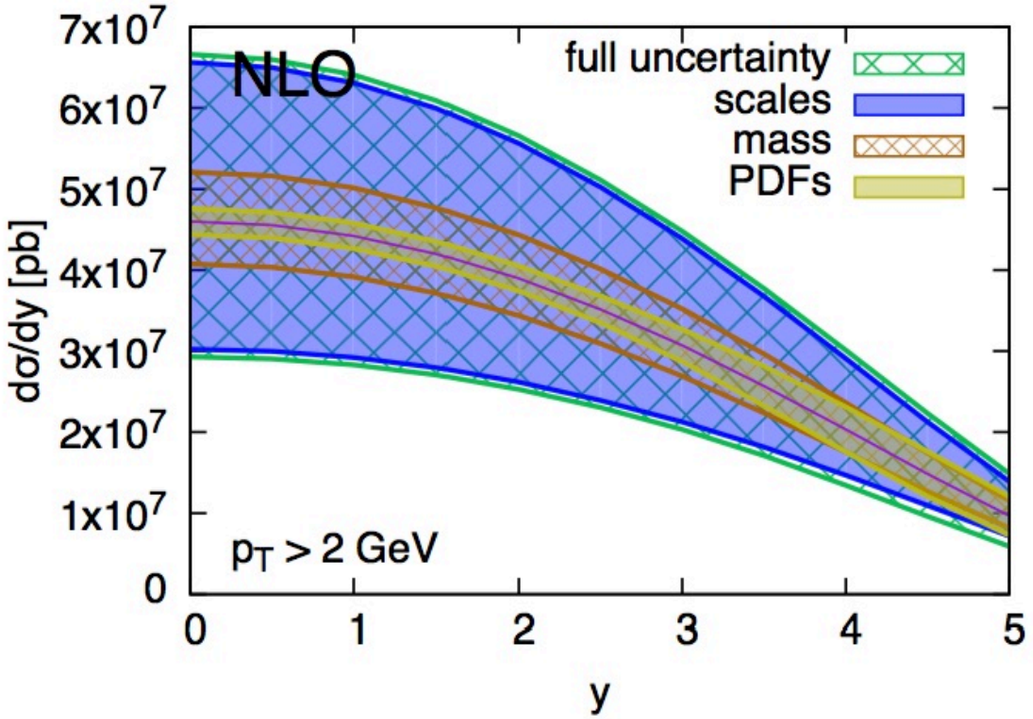
[CMN]

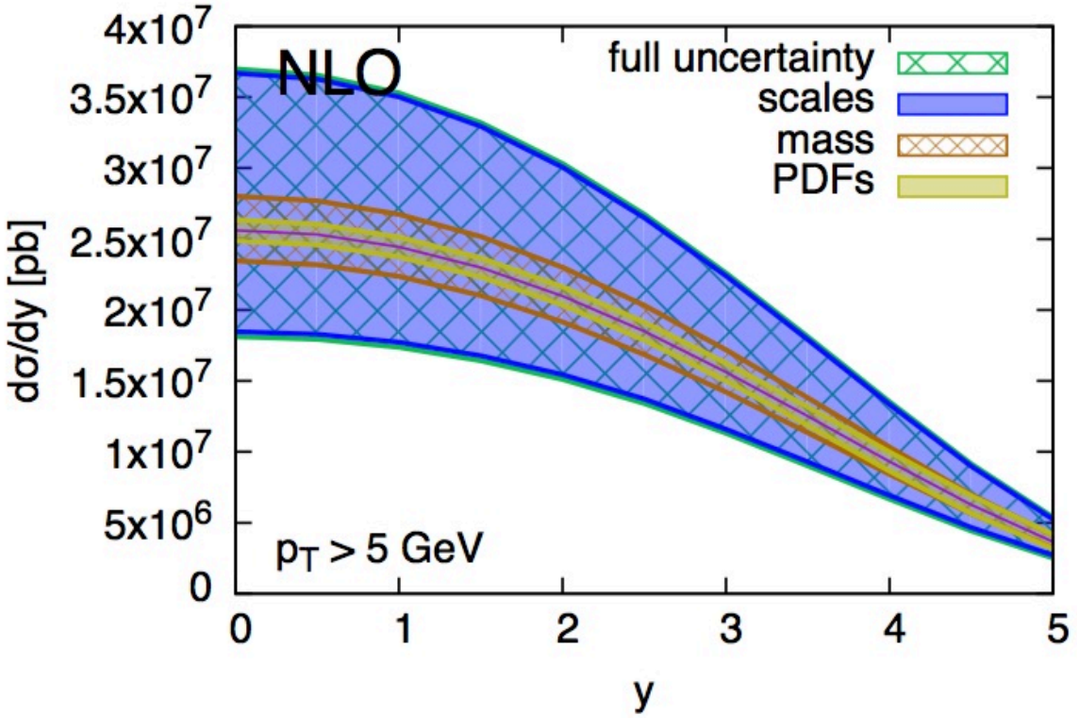


Systematics of bottom XS's at 13 TeV

[CMN]







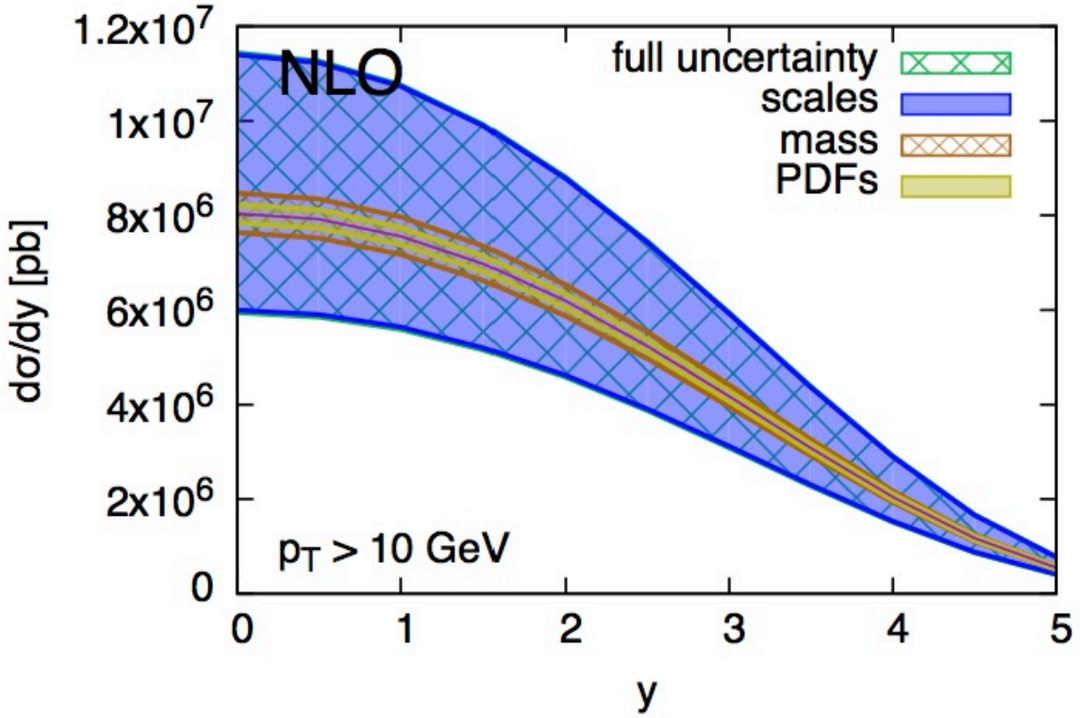
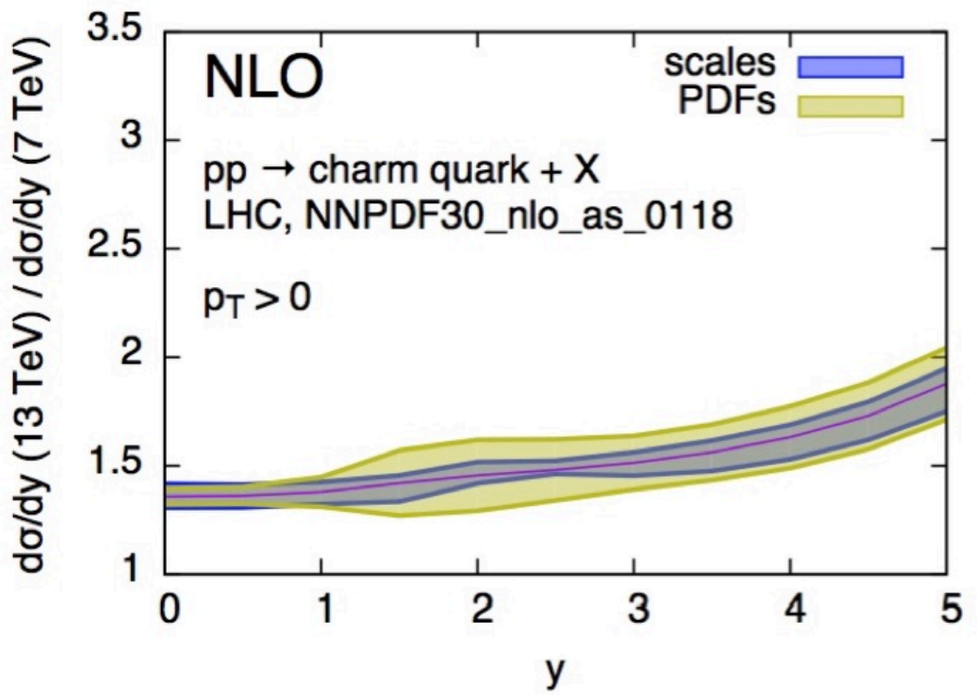
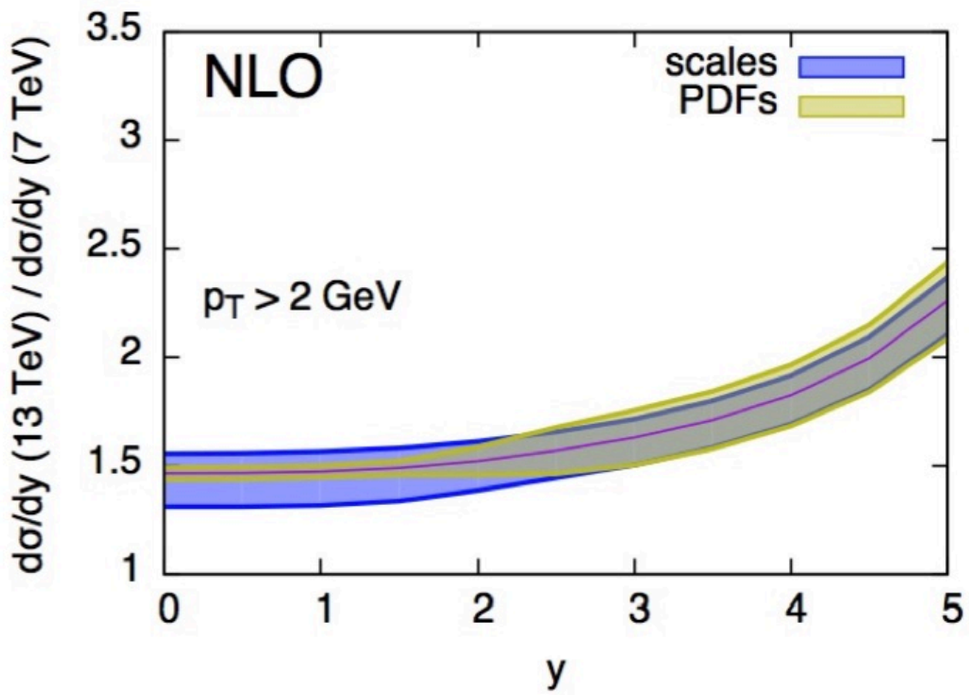
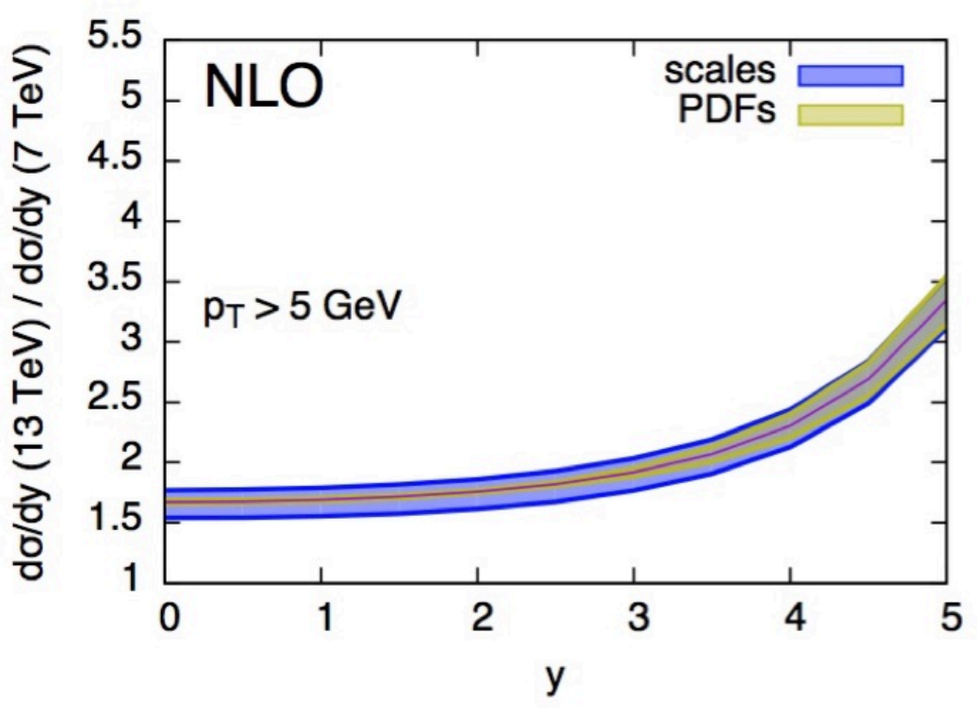


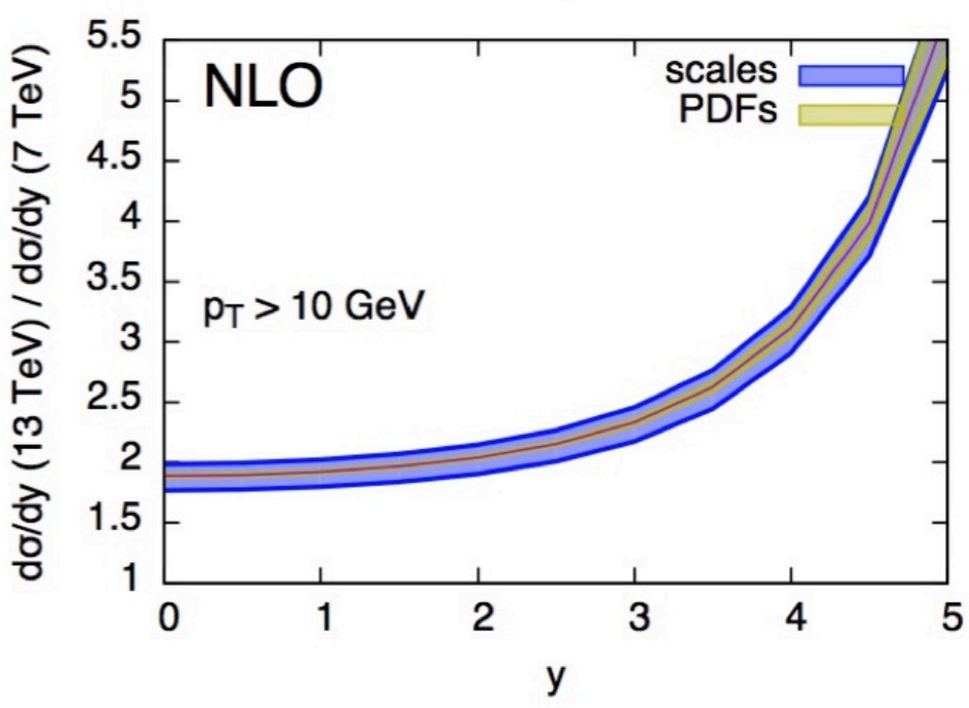
Figure 3: Bottom quark rapidity distributions at $\sqrt{S} = 13$ TeV.

Systematics of ratio of charm XS's at 13/7 TeV [CMN]



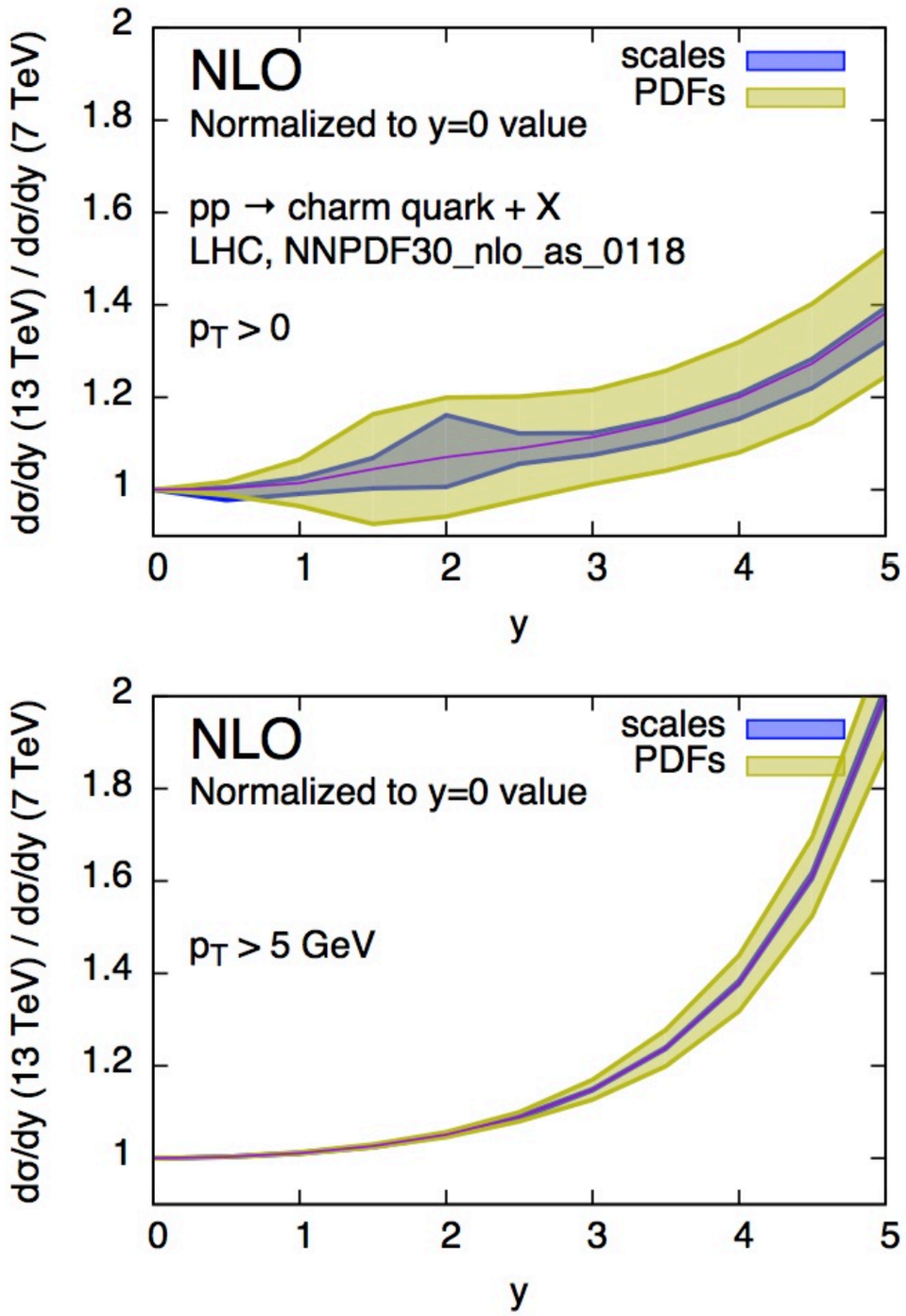


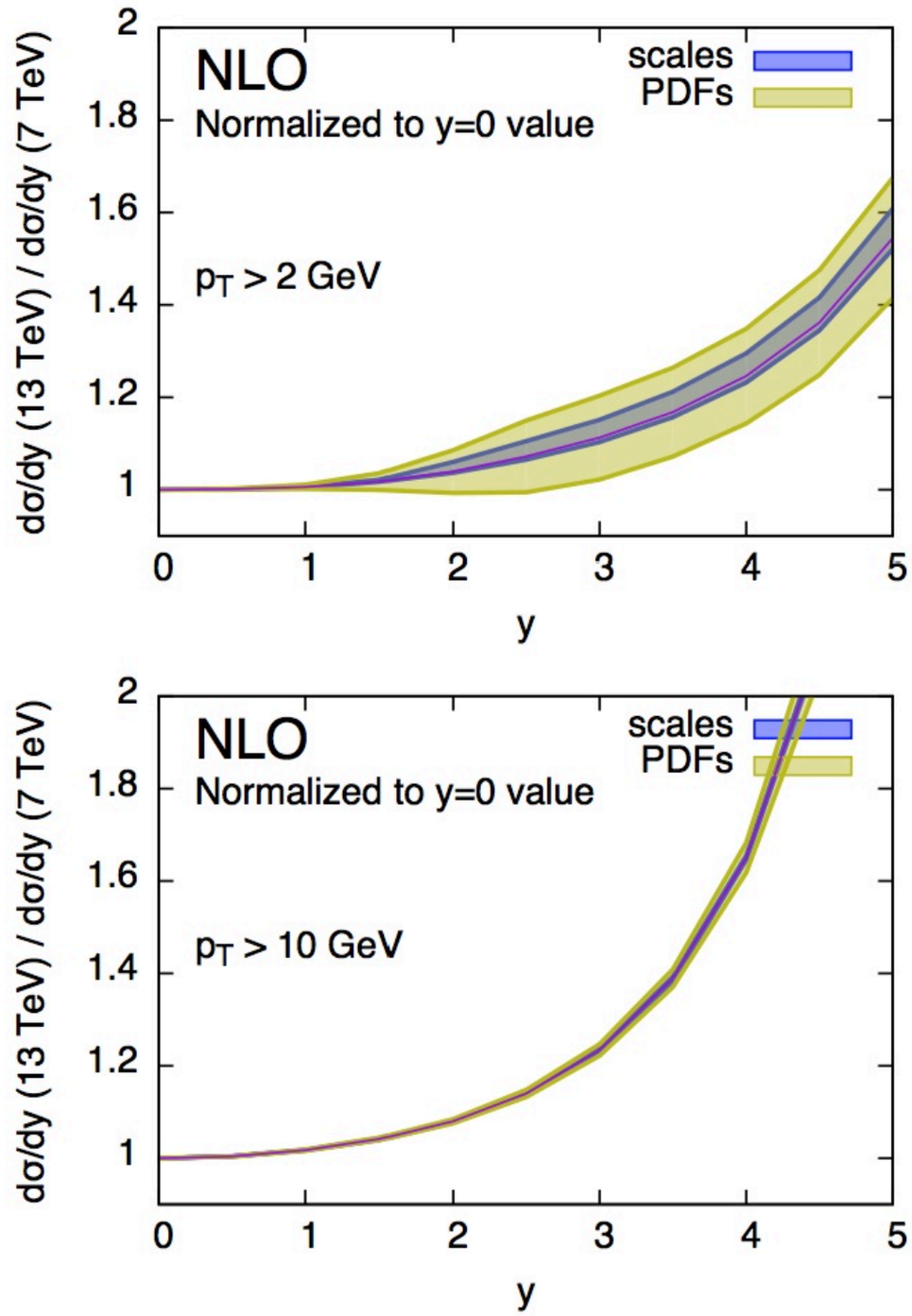




Systematics of ratio of charm XS's at 13/7 TeV, scaled to ratio at y=0

[CMN]

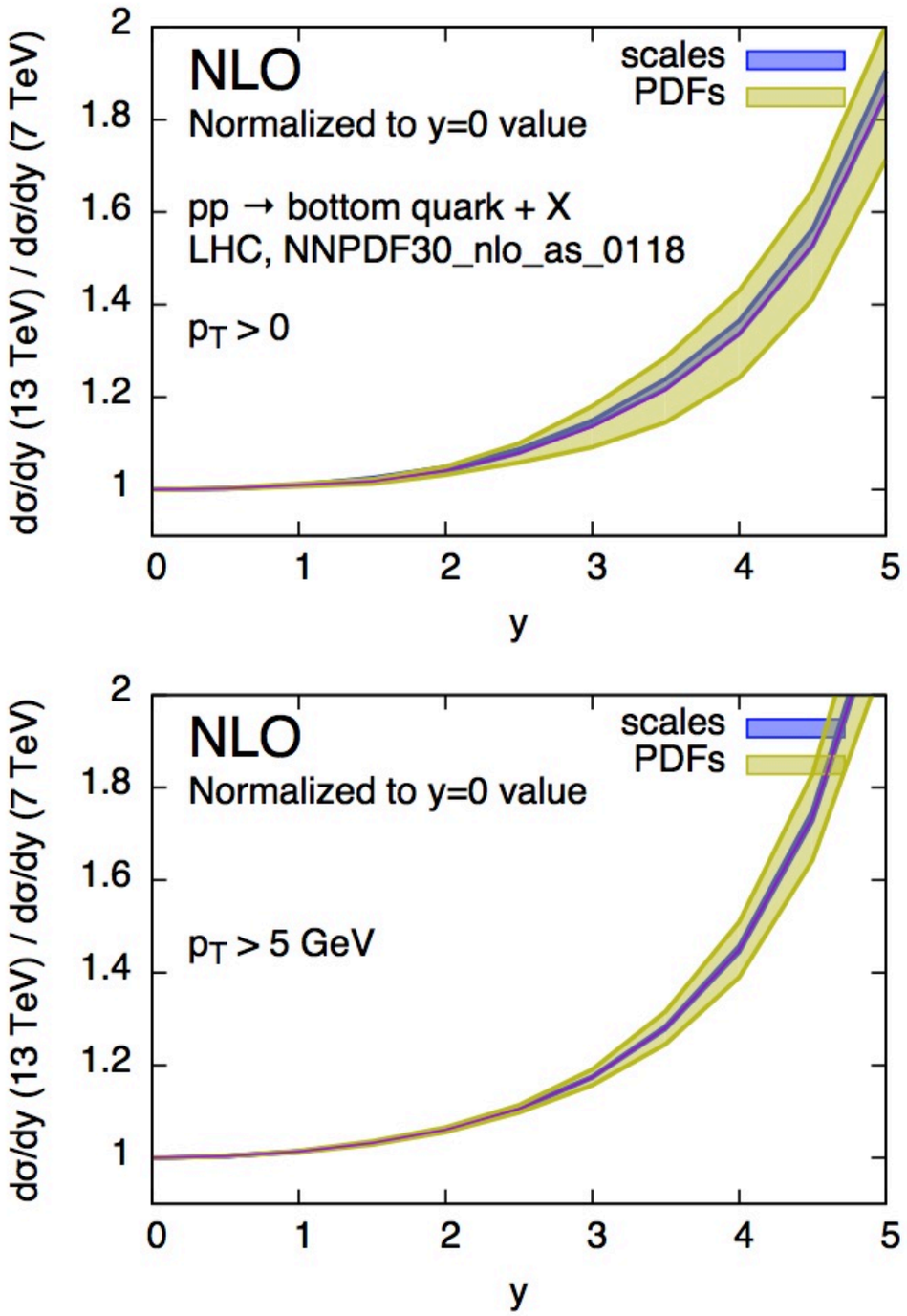


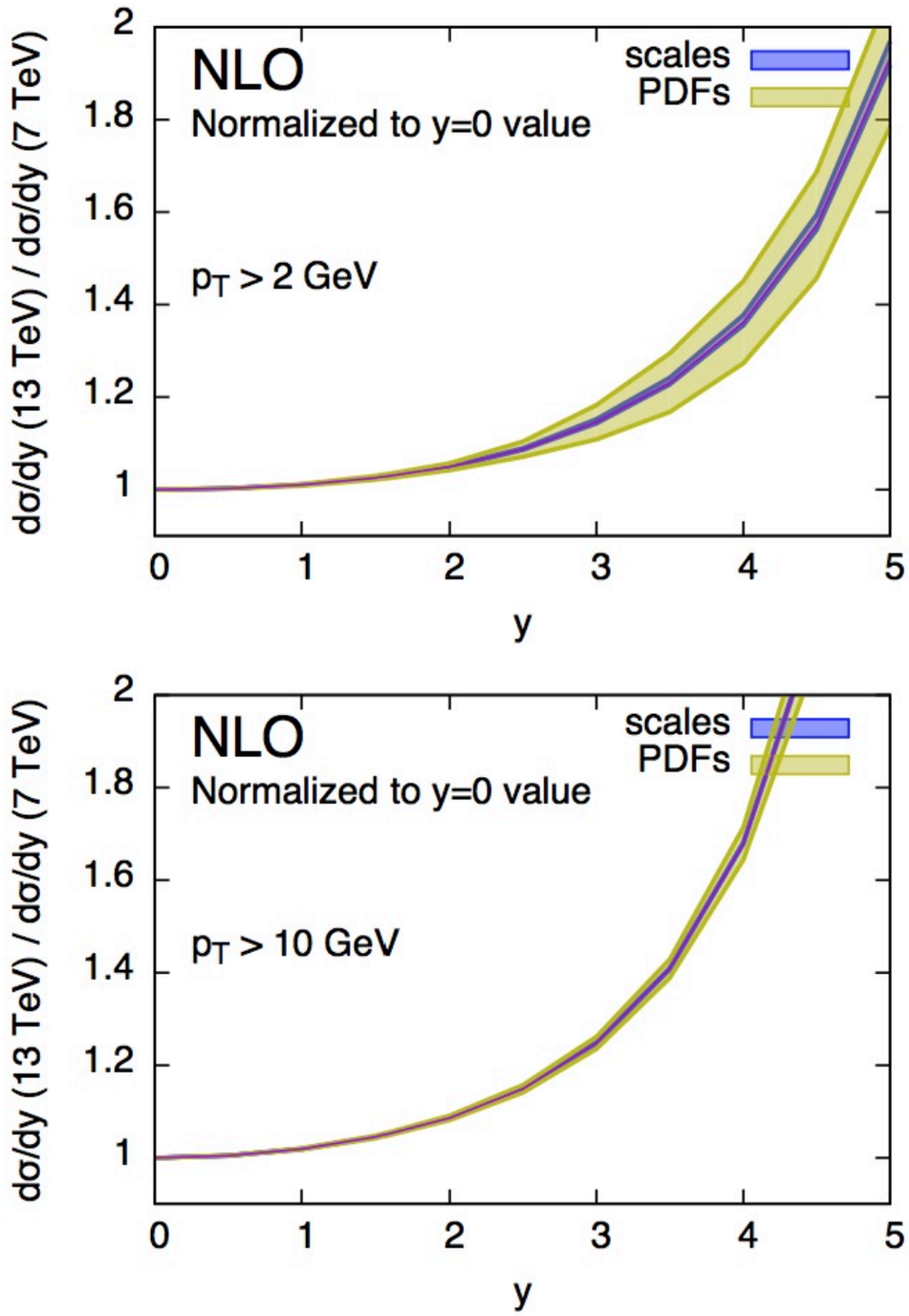


=> all that's left is the PDF systematics!

=> useful probe of PDF behaviour!

Systematics of ratio of bottom XS's at 13/7 TeV, scaled to ratio at y=0 [CMN]





Impact of LHCb charm XS measurements at 5, 7 and 13 TeV on gluon PDF

LHCb arXiv:1610.02230

[GR]

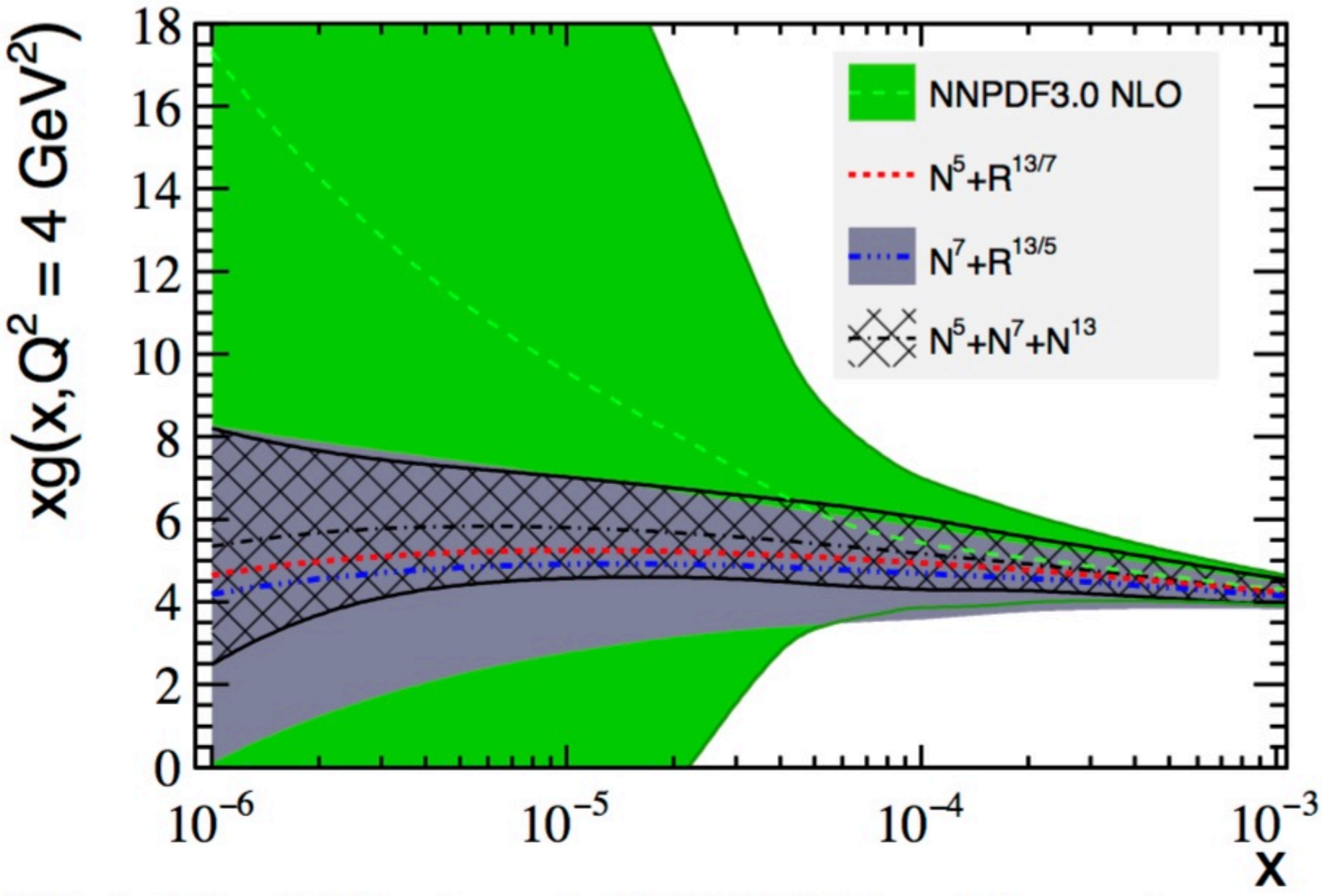
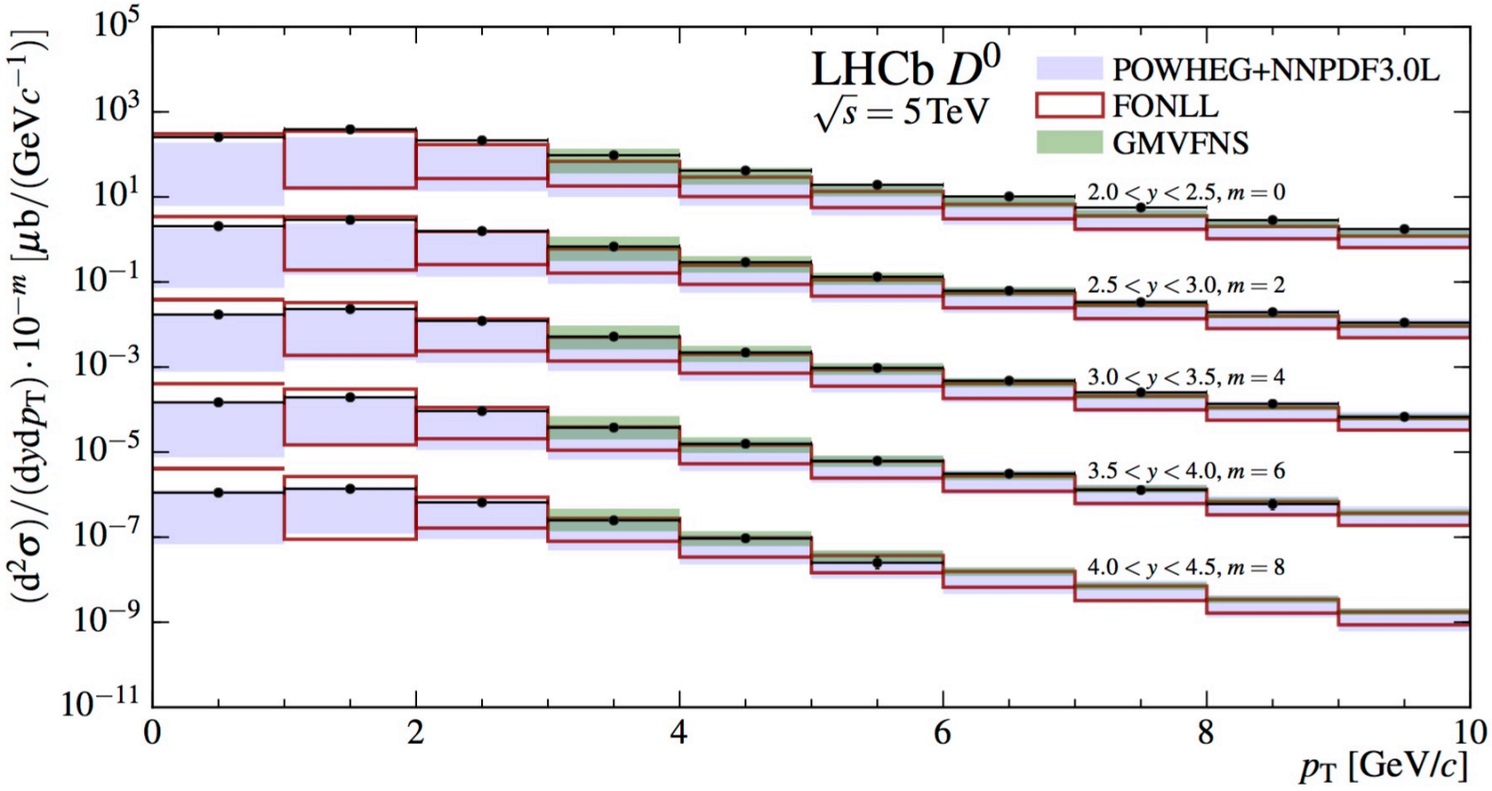
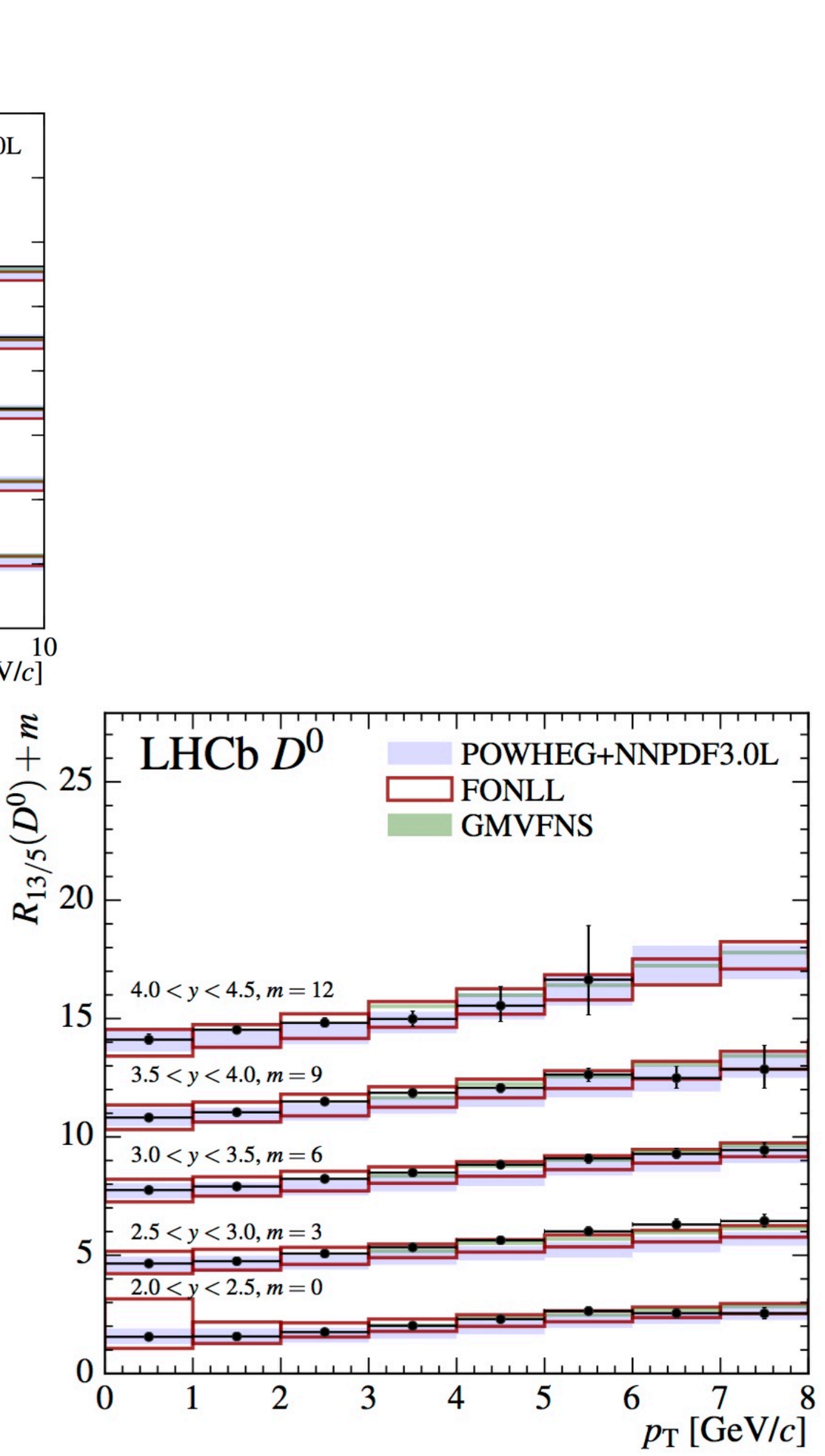


FIG. 2: The NLO gluon in NNPDF3.0 and for various combinations of LHCb data included, at $Q^2 = 4$ GeV^2.

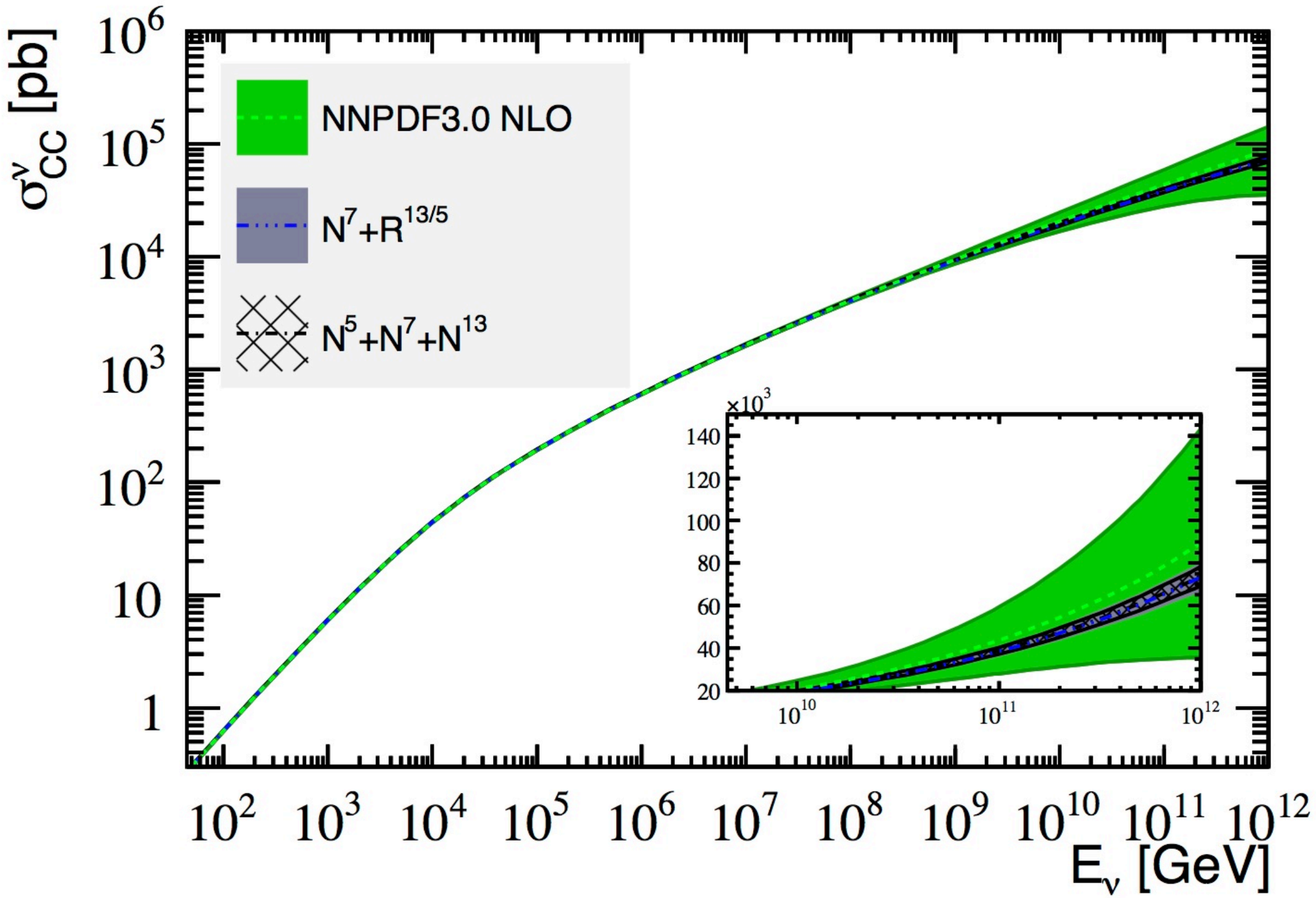
LHCb arXiv:1610.02230



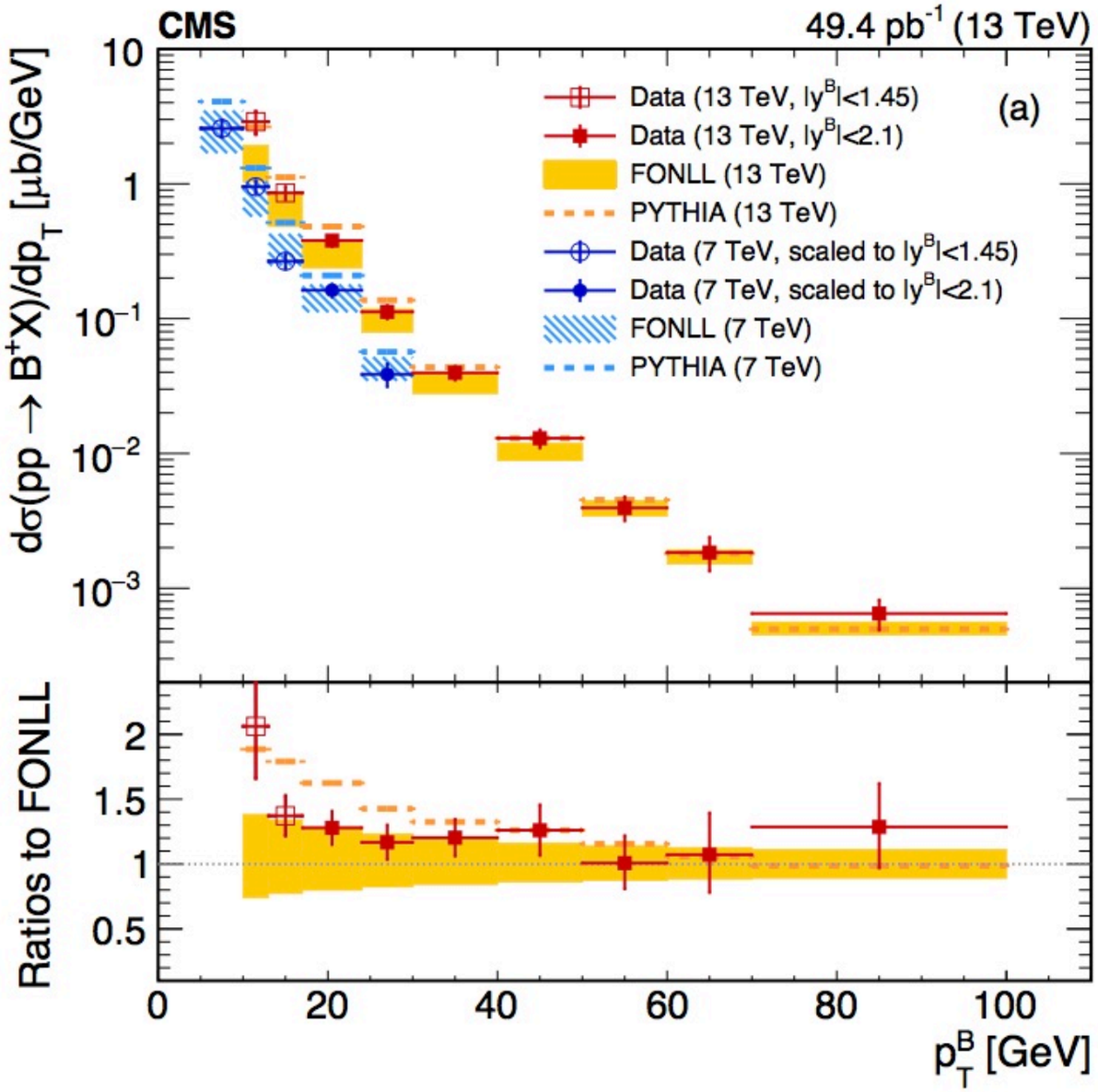


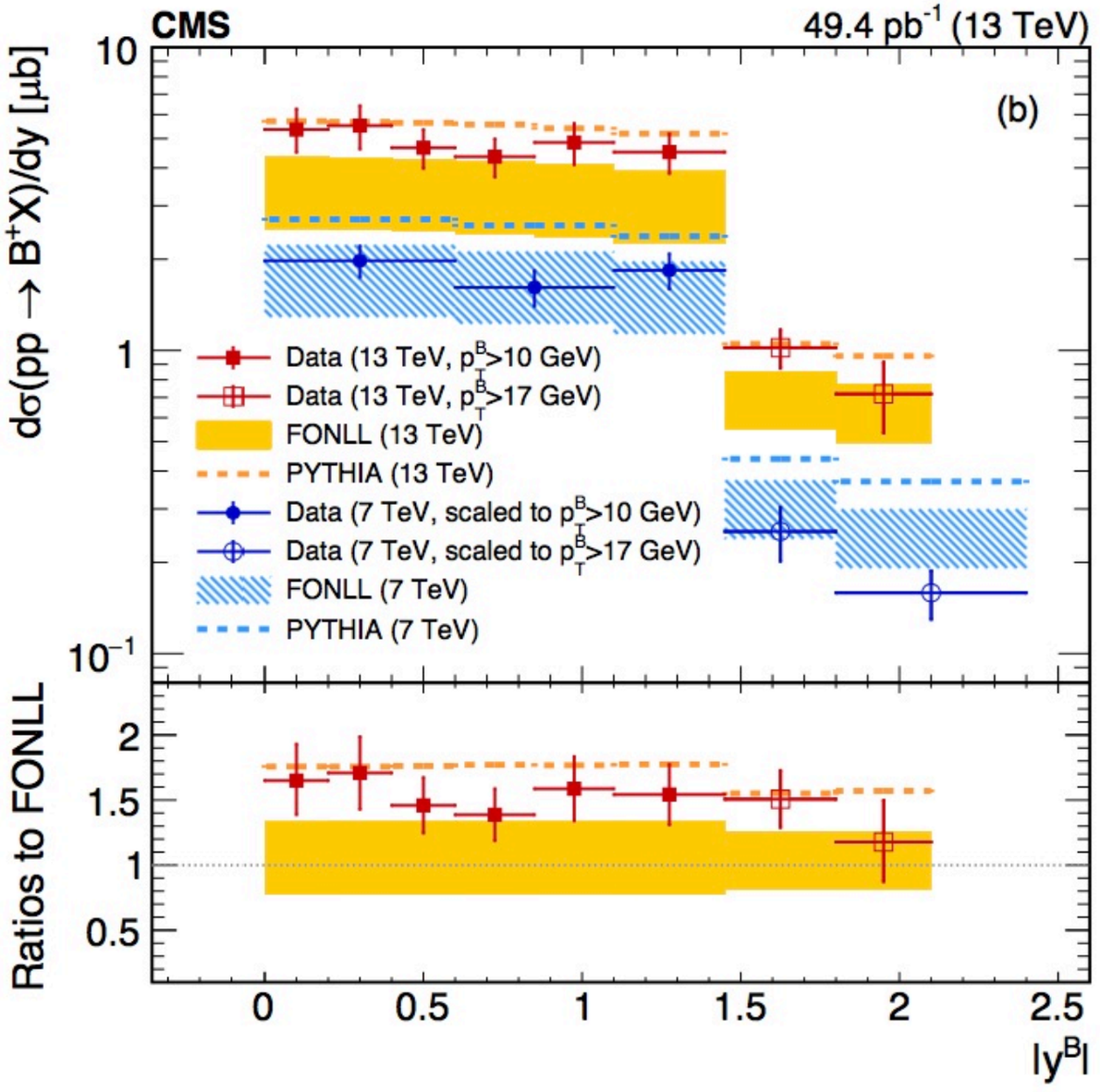
Impact of "charm-XS-improved" gluon PDF on $\sigma_{\nu N}$ at high energy

[GR]



CMS bottom XS's at 13 and 7 TeV





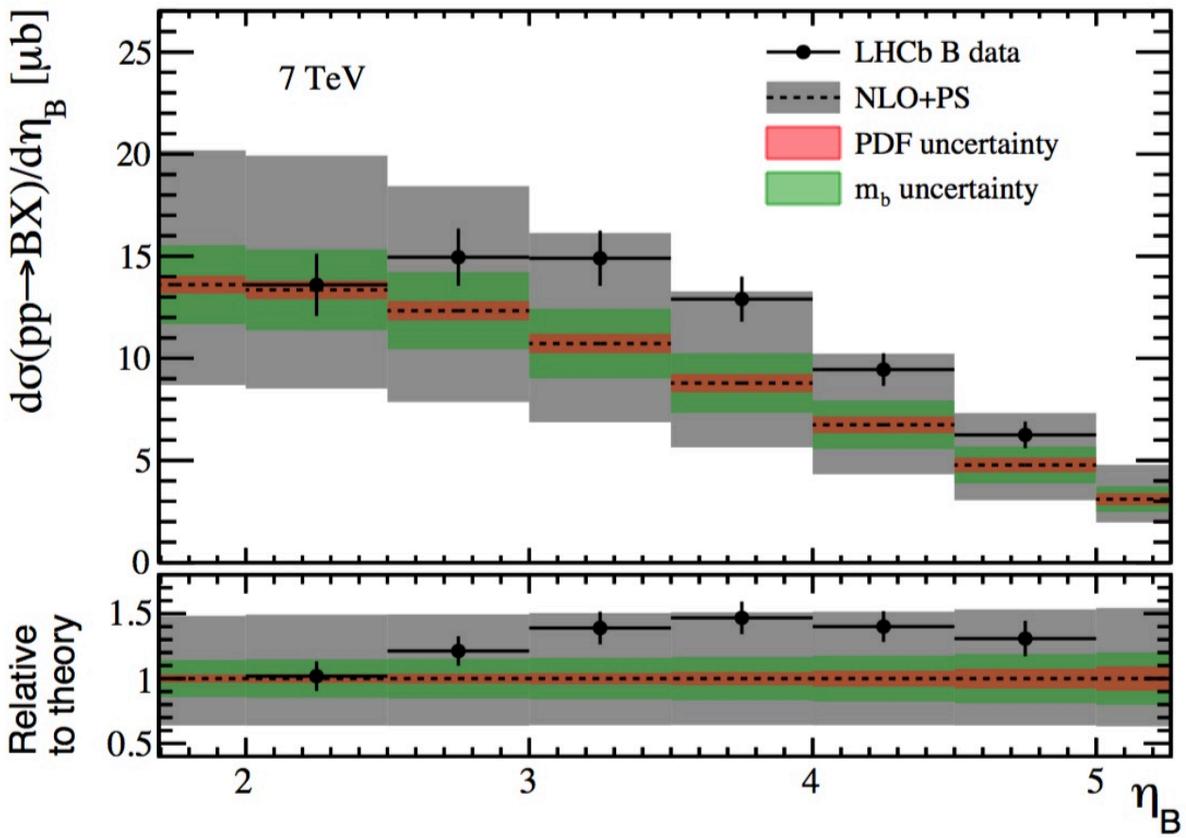
CMS, arXiv:1609.00873

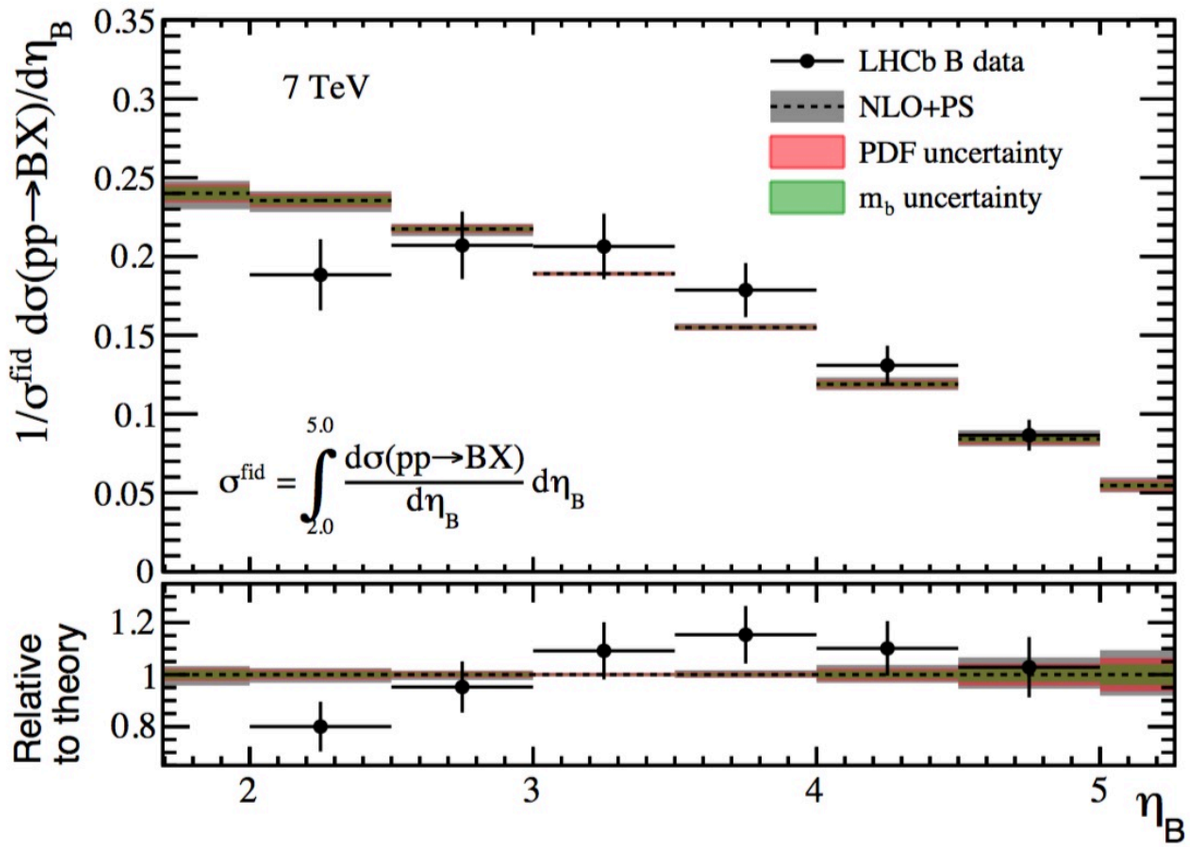
Outlook

- Match xs's at the ATLAS/CMS-LHCb boundary, η~2-2.5:
  - any way to use low-lumi data to push trigger threshold so that ATLAS/CMS can go down in p_T and match LHCb acceptance?

Data: LHCb arXiv:1009.2731

[G]





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- Verify consistency between charm and bottom XS ratios: e.g. double ratios [σ(b@13)/σ(b@7)] / [σ(c@13)/σ(c@7)] can reduce even further the exptl syst (e.g. lumi), and have a reduced PDF sensitivity
- NNLO, to validate assumptions abut scale correlations at NLO, to give more robust predictions
- Internal monitoring of further ingredients, such as fragmentation functions (study eg b-hadron momentum fraction in jets, along the lines of quarkonium-in-jet studies by LHCb)