

Brief summary of today's mtg of the LHC Heavy Flavour WG*

* http://lpcc.web.cern.ch/LPCC/index.php?page=hf_wg

May 4 2017

M.L. Mangano
TH Department, CERN

- b-hadron fragmentation fractions ($f_s, f_{\Lambda_b}, \dots$)
 - LHC input to HFLAV averages
- production cross section measurements

LHC HF WG mtg on B production

Thursday 4 May 2017, 09:00 → 13:00 Europe/Zurich

<https://indico.cern.ch/event/628495/timetable/>

09:05 → 10:35 **current measurements of production fractions and HF cross sections from the LHC experiments**


09:05 **ATLAS**

Speaker: Sandro Palestini (CERN)

 SP-ATLAS-HFWG.pdf

09:35 **CMS**

Speakers: Alberto Sanchez Hernandez (Centro de Investigación y de Estudios Avanzados del IPN (MX)), Ilse Kratschmer (Austrian Academy of Sciences (AT)), Stefano Argiro (Universita di Torino and INFN (IT))

 HFWG-Production-4...

10:05 **LHCb**

Speaker: Siim Tolk (University of Cambridge (GB))

 2017_04_LHC_HF_T...


10:35 → 10:55 **HFLAV perspective**

Speakers: Olivier Schneider (CERN), Olivier Schneider (Ecole Polytechnique Federale de Lausanne (CH))

 HFLAV_fractions_O...

10:55 → 11:15 **Theory perspective**

Speaker: Michelangelo Mangano (CERN)

 mangano-HFWG.pdf

11:15 → 12:00 **Round table: combining LHC results and plans**

Ongoing ATLAS XS analyses

Sandro Palestini
for the ATLAS Collaboration

Analysis ongoing: B hadron pair production

(to be made public very soon)

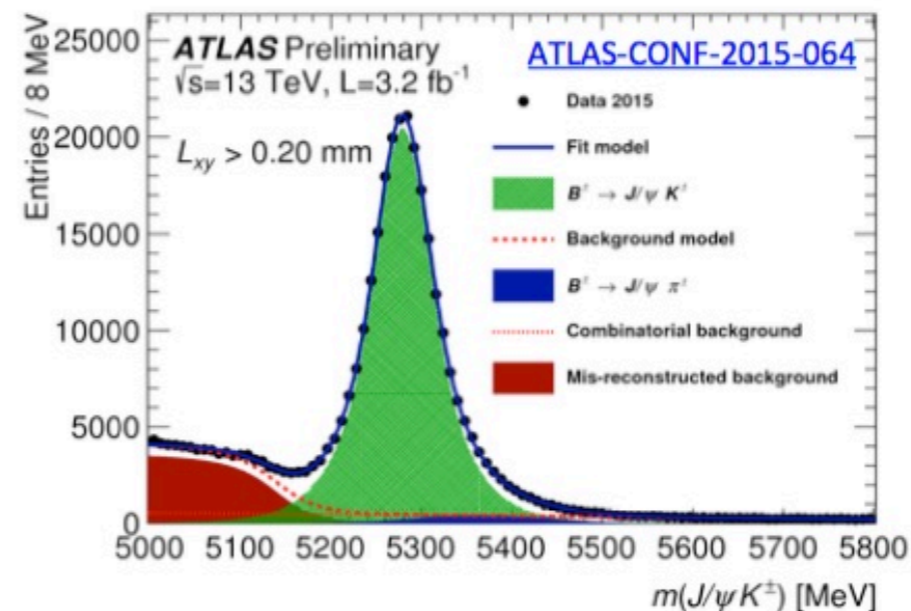
- 8 TeV data, 11 fb^{-1}
- B hadrons selected through: (a) inclusive decay to J/ψ and (b) inclusive decays to muons
- The distribution of correlated kinematical variables between J/ψ and 3rd muon (ΔR , total p_T , invariant mass, etc.) are studied and compared with generators: Pythia8 in different configurations, Herwig, Sherpa, MadGraph_aMC@NLO+Pythia8

Ongoing: B_c/B^+ relative production

- 8 TeV data, about 20 fb^{-1}
- $J/\psi \pi^+$ vs. $J/\psi K^+$
- Bins 13-22 GeV and $> 22 \text{ GeV}$ in p_T , < 0.75 and $0.75-2.3$ in $|\eta|$
- $\approx 800 B_c$ and $\approx 400,000 B^+$ candidates

Ongoing: B^+ production cross section at 13 TeV

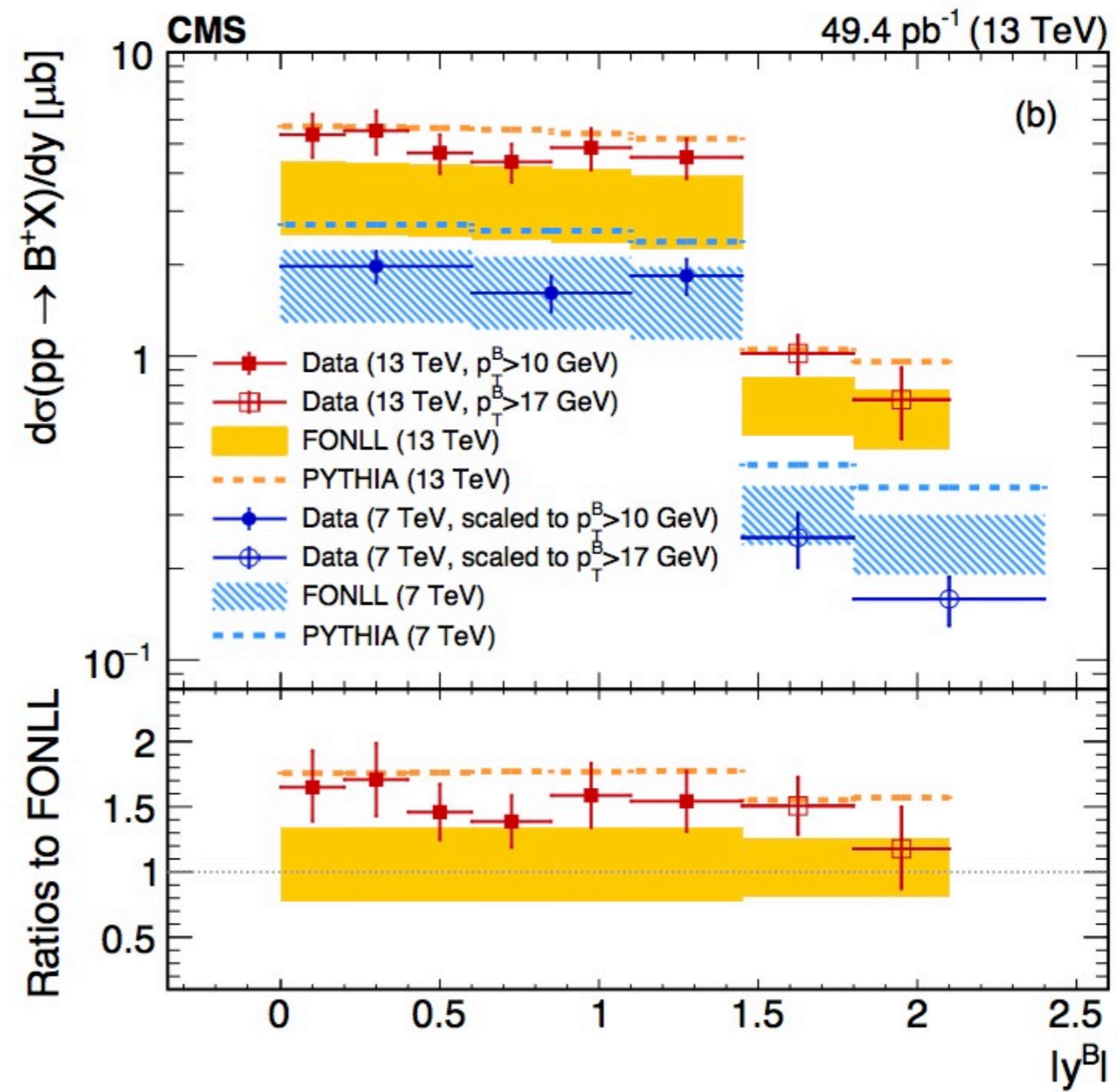
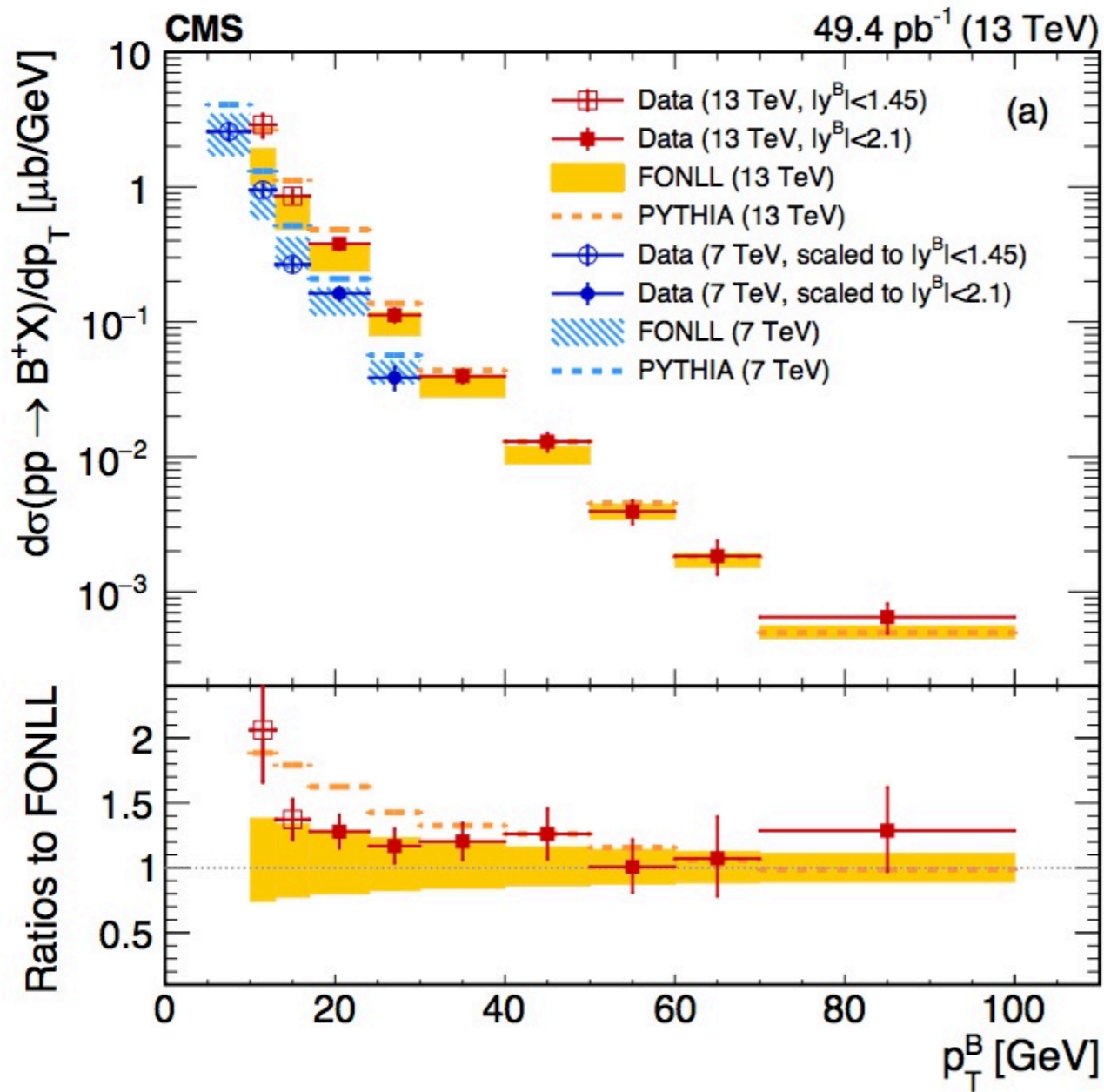
- $J/\psi (\mu^+\mu^-) K^+$ as usual
- 2015 data (3 fb^{-1}): 4 GeV p_T threshold on muons
- Expect $d\sigma/dp_T$ in 9-250 GeV range, and $d\sigma/d\eta$ in $|\eta| < 2.2$ range
- Expected uncertainties $\leq 10\%$



Recent CMS XS results

**Ilse Kratschmer,
Stefano Argiro,
Alberto Sanchez Hernandez**

CMS bottom XS's at 13 TeV



CMS B_c/B^+ XS ratio

- ✓ **Measurement of the ratio $B(B_c^+ \rightarrow J/\psi \pi^+ \pi^+ \pi^-)/B(B_c^+ \rightarrow J/\psi \pi^+)$ and the production cross sections times branching fractions of $B_c^+ \rightarrow J/\psi \pi^+$ and $B^+ \rightarrow J/\psi K^+$ in pp collisions at $\sqrt{s} = 7$ TeV - [J. High Energy Phys. 01 \(2015\) 063](#): B_c^+ mesons with $p_T > 15$ GeV and $|y| < 1.6$ are studied in a data sample with an integrated luminosity of 5.1 fb^{-1}**

$$R_{c/u} = \frac{\sigma(B_c^+) \mathcal{B}(B_c^+ \rightarrow J/\psi \pi^+)}{\sigma(B^+) \mathcal{B}(B^+ \rightarrow J/\psi K^+)} = \frac{Y_{B_c^+ \rightarrow J/\psi \pi^+}}{Y_{B^+ \rightarrow J/\psi K^+}}$$

Systematic uncertainties in the measurement

Systematic source	%
Fit variant	5.3
MC sample size	2.1
Efficiency binning	3.1
Total uncertainty	6.5
B_c lifetime	10.4

$$R_{c/u} = [0.48 \pm 0.05(\text{stat}) \pm 0.03(\text{syst}) \pm 0.05(\tau_{B_c})]\%$$

TH perspective

TH perspective

- Renewed interest in b and c cross sections

TH perspective

- Renewed interest in b and c cross sections
- Measurements at different energies, and over a broad rapidity range, provide an opportunity to constrain gluon PDF in the region of both large and small x , with important phenomenological implications

TH perspective

- Renewed interest in b and c cross sections
- Measurements at different energies, and over a broad rapidity range, provide an opportunity to constrain gluon PDF in the region of both large and small x , with important phenomenological implications
- Key ingredient is the assumed correlation between theoretical systematics at different beam energies and across the rapidity range:
 - m_Q is obviously fully correlated
 - QCD scale variations: correlated at any give p_T value
 - PDFs: fully correlated
 - BRs, fragmentation fractions and frag functions fully correlated

TH perspective

- Renewed interest in b and c cross sections
- Measurements at different energies, and over a broad rapidity range, provide an opportunity to constrain gluon PDF in the region of both large and small x , with important phenomenological implications
- Key ingredient is the assumed correlation between theoretical systematics at different beam energies and across the rapidity range:
 - m_Q is obviously fully correlated
 - QCD scale variations: correlated at any give p_T value
 - PDFs: fully correlated
 - BRs, fragmentation fractions and frag functions fully correlated
- 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 $\sqrt{s}=7$ 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]

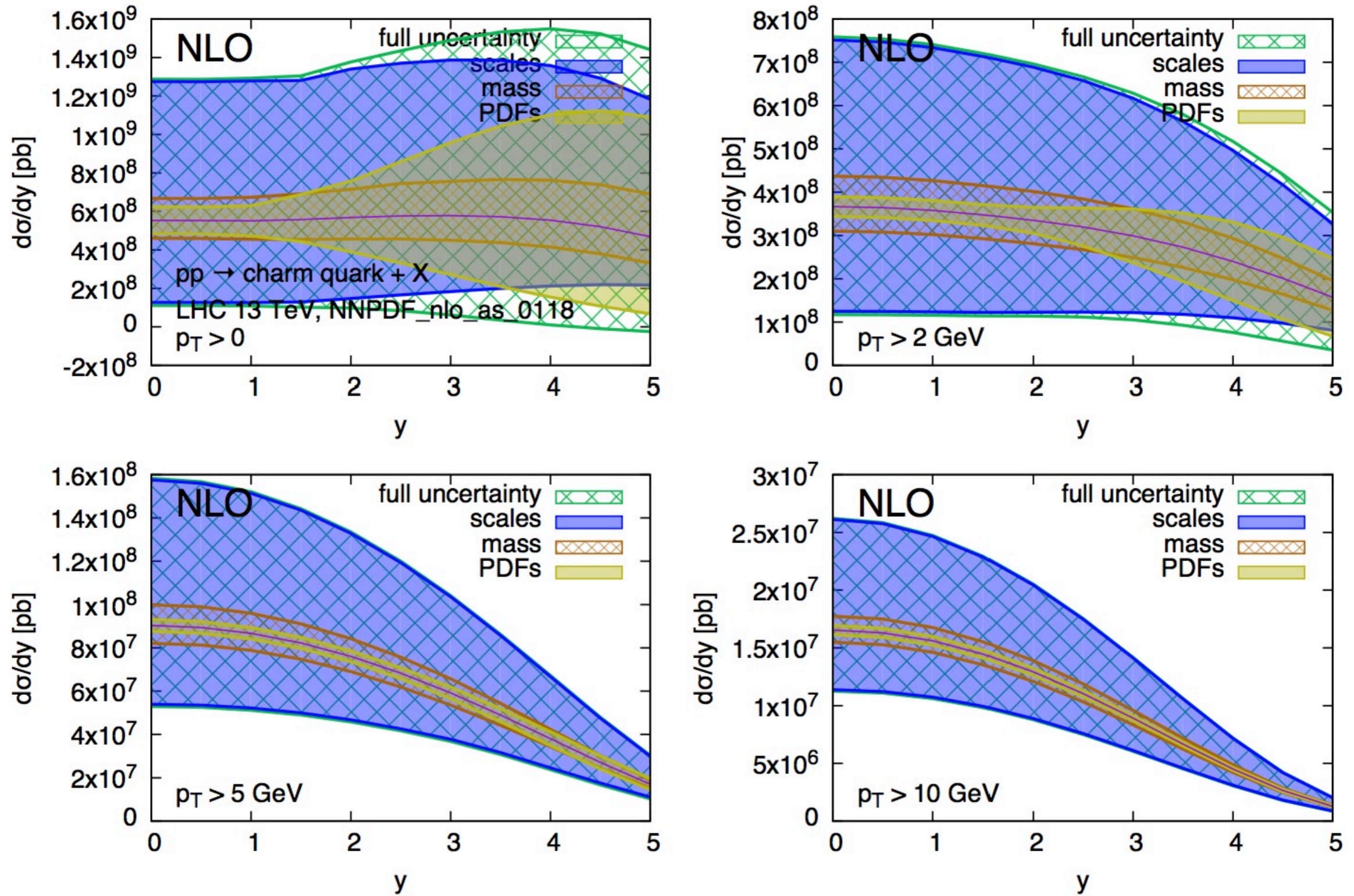
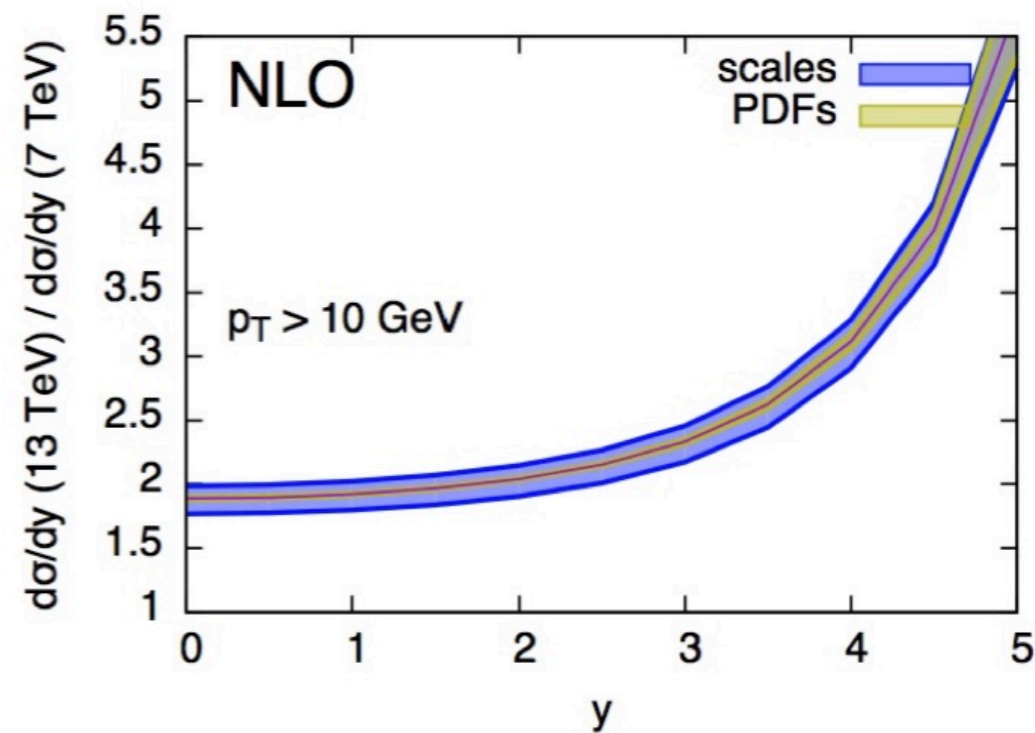
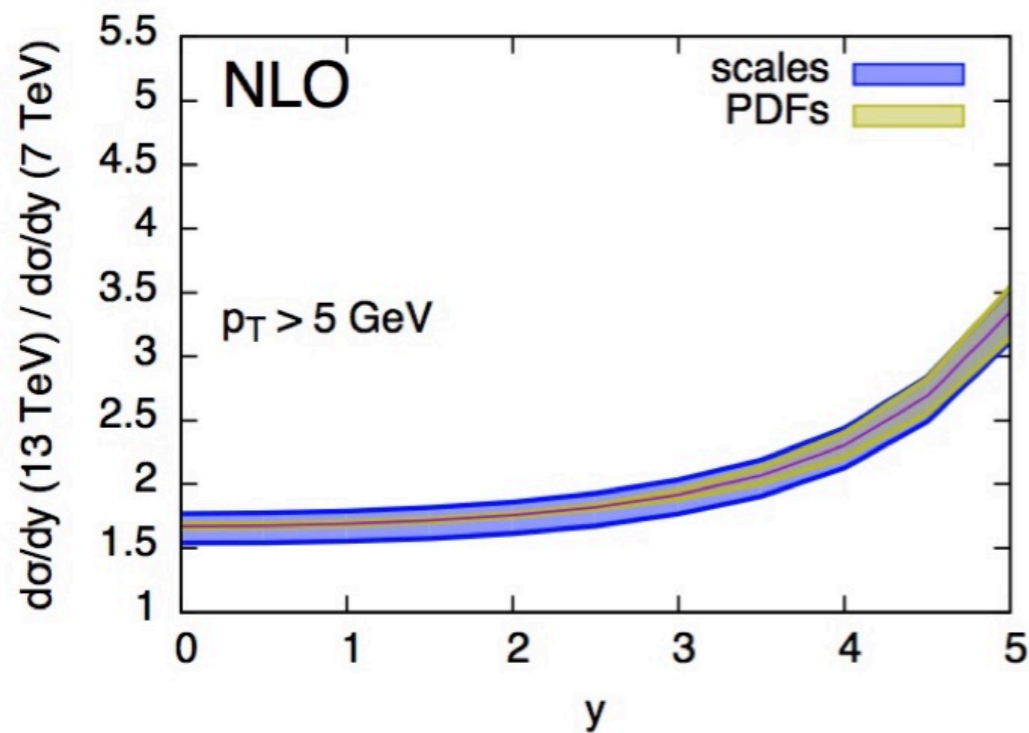
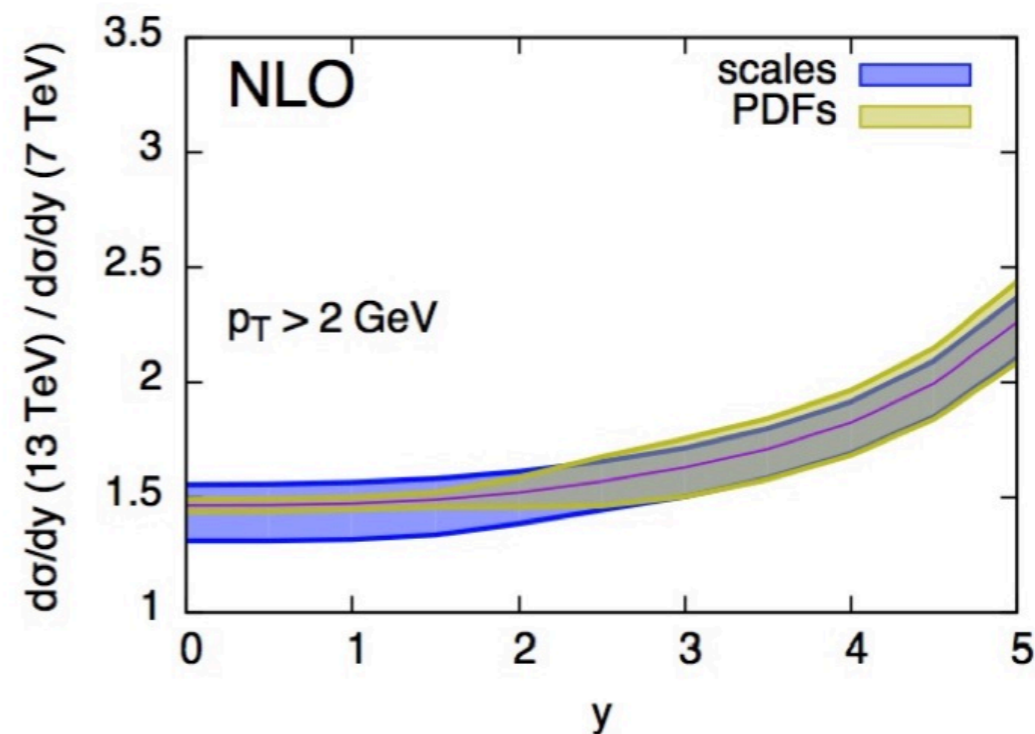
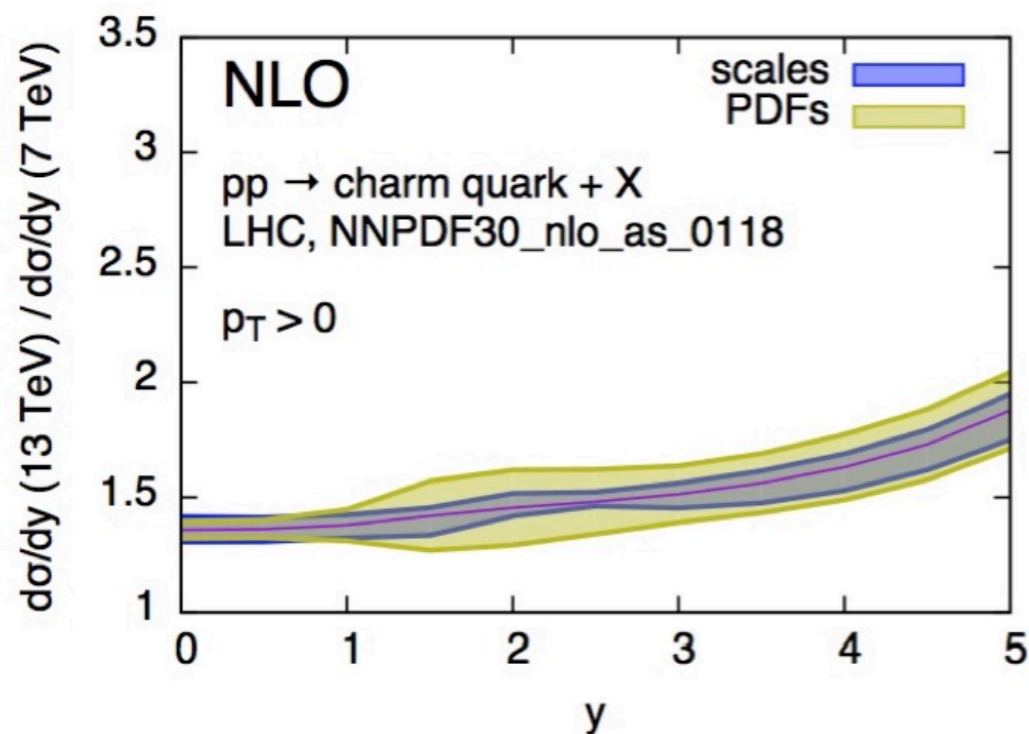


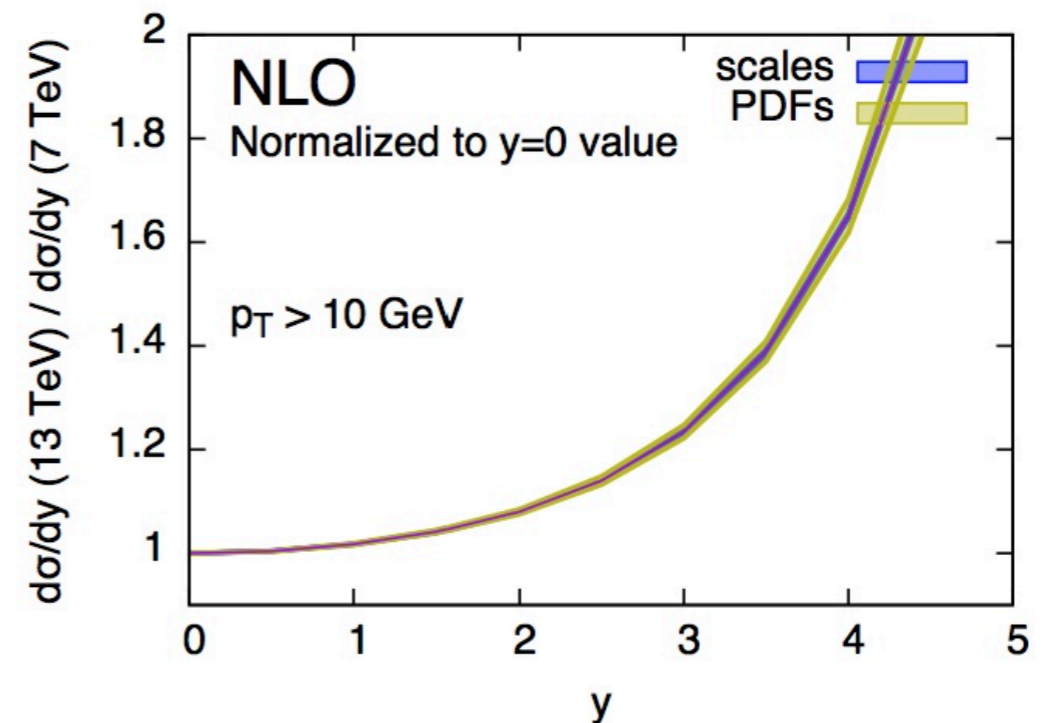
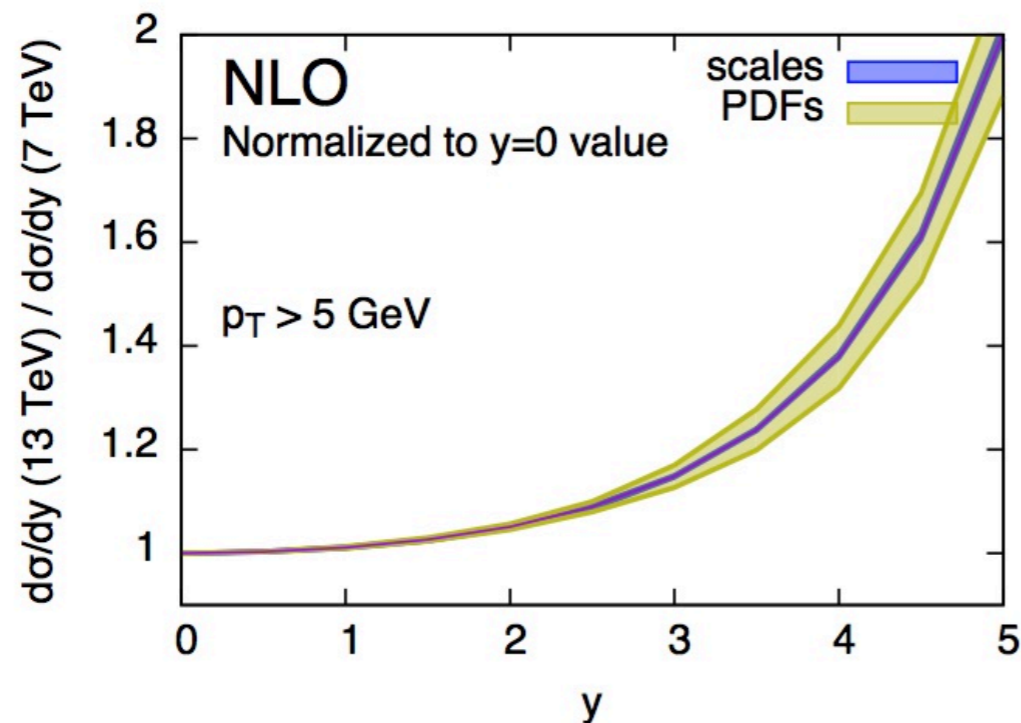
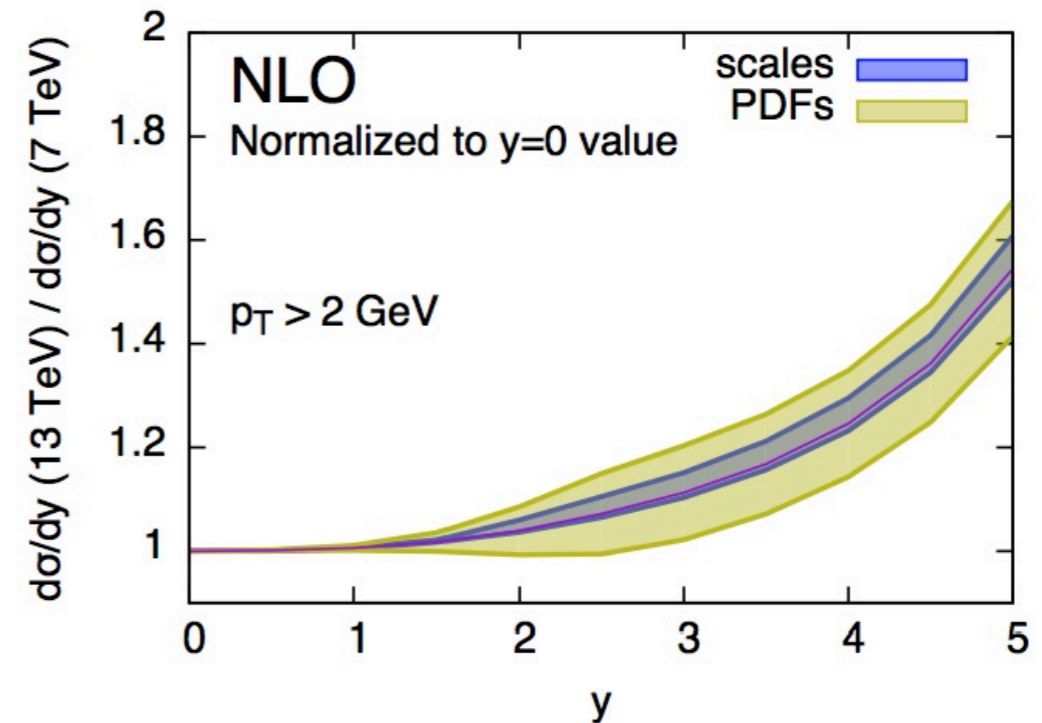
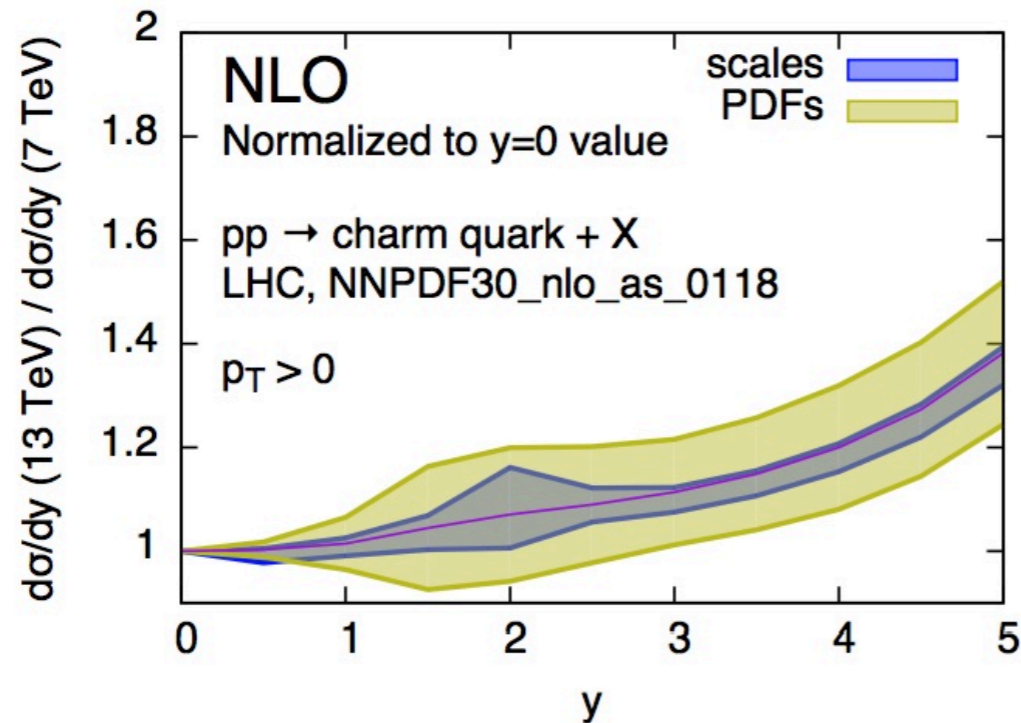
Figure 2: Charm quark rapidity distributions at $\sqrt{S} = 13$ TeV.

Systematics of **ratio** of **charm** XS's at 13/7 TeV

[CMN]



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



=> all that's left is the PDF systematics!
=> useful probe of PDF behaviour!

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

LHCb [arXiv:1610.02230](https://arxiv.org/abs/1610.02230)

[GR]

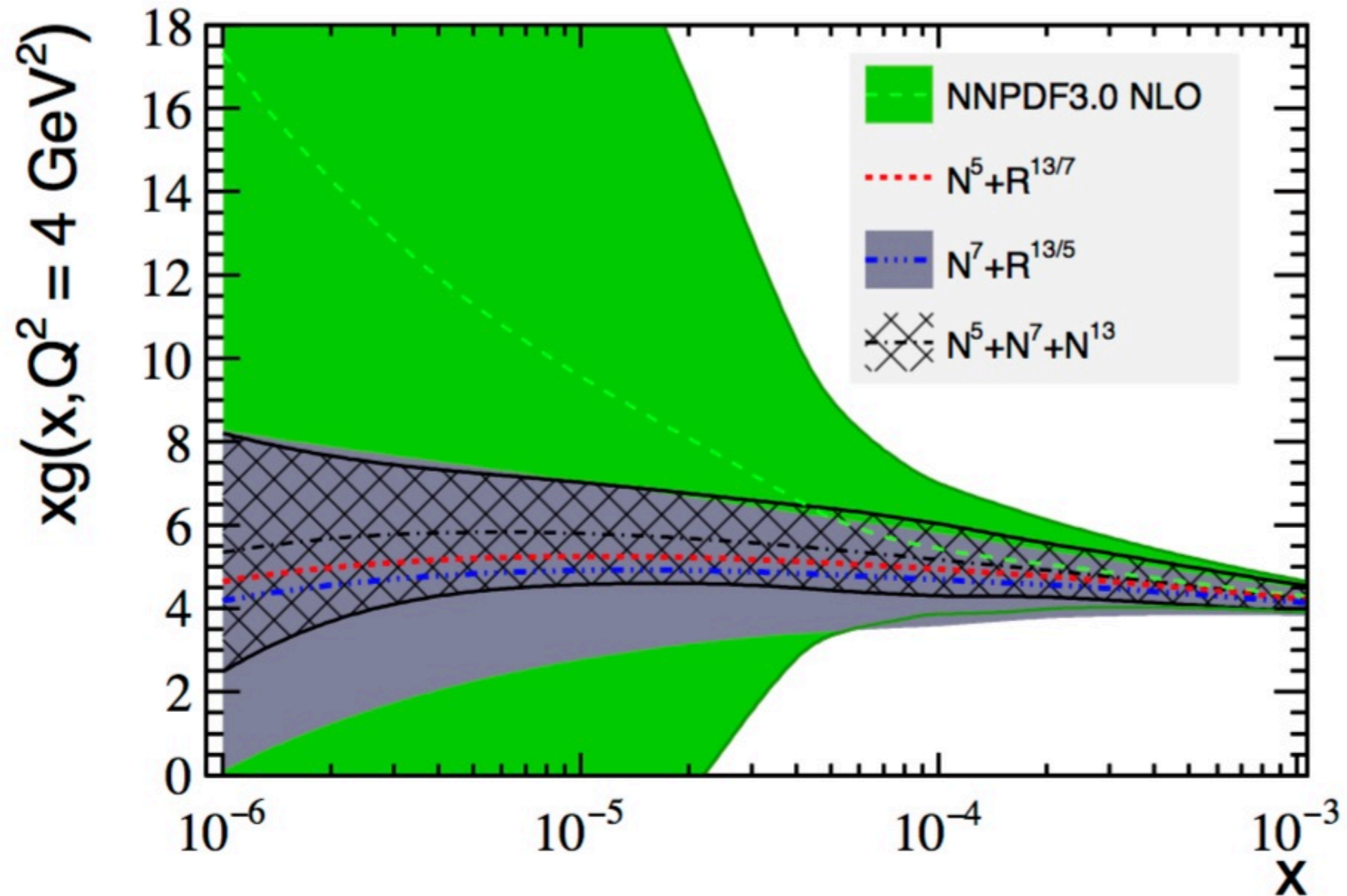


FIG. 2: The NLO gluon in NNPDF3.0 and for various combinations of LHCb data included, at $Q^2 = 4 \text{ GeV}^2$.

Discussion points at the mtg

Exptl side

- Match XS's at the ATLAS/CMS-LHCb boundary, $\eta \sim 2-2.5$:
 - should be possible for $p_T > O(10-20 \text{ GeV})$: triggerable at ATLAS/CMS, enough stat in run 2 for LHCb
 - explore use of low-pileup data (special runs, 5 TeV pp ref run for H1,...) and dedicated triggers to allow ATLAS/CMS can go down in p_T
- Measurement of fragmentation functions (eg b-hadron momentum fraction in b-jets, including bjets from top decays) for various b-hadron types (including frag function for polarized Λ_b)

TH side

- Verify consistency between charm and bottom XS ratios: e.g. double ratios $[\sigma(b@13)/\sigma(b@7)] / [\sigma(c@13)/\sigma(c@7)]$ can reduce even further the exptl syst (e.g. lumi), and have a reduced PDF sensitivity
- NNLO, to validate assumptions about scale correlations at NLO, to give more robust predictions

Fragmentation fractions

The (experimental) motivation

Siim Tolk
on behalf of LHCb

- Search for new physics fraction in any Bs branching fraction relies on the knowledge of the B-production fractions (e.g. Bs->mumu, but also many other analysis:
- 35 citations to the LHCb's relative Bs and Bd production fraction combination (LHCb-CONF-2013-011:<https://inspirehep.net/search?ln=en&p=refersto%3Arecid%3A1258307>)

HEP 22 records found Search took 0.11 seconds

1. Measurement of the $B_c^+ \rightarrow \phi\bar{\nu}$ branching fraction and search for the decay $B_c^+ \rightarrow \phi\bar{\nu}$
LHCb Collaboration (Ruel Aaij (CERN) et al.) Aug 4, 2015, 20 pp.
Published in *JHEP* 1514 (2015) 052
CERN-Ph-EP-2015-148, LHCb-PAPER-2015-028, CERN-Ph-EP-2015-198, LHCb-PAPER-2015-028
DOI: 10.1007/JHEP12(2015)052
e-Print: [arXiv:1508.02758 \[hep-ex\]](https://arxiv.org/abs/1508.02758) | PDF
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | ADS Abstract Service | Link to Article from SCOAP³
Detailed record
2. B Physics analyses for the Phase-II Upgrade Technical Proposal
CMS Collaboration 2015, 14 pp.
CMS-PAS-FTR-14-015
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | Link to Fulltext
Detailed record - Cited by 2 records
3. Study of charmless $B_{(s)}$ meson decays involving η' and ϕ intermediate states at the LHCb experiment
Jesica Pflüger (École Polytechnique, Lausanne) Dec 17, 2014, 104 pp.
CERN-THESIS-2014-272
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | Link to Fulltext
Detailed record
4. Study of the penguin-dominated decay $B_c^+ \rightarrow K^{*0}\bar{K}^0$ at LHCb
Paulo Alexandre Carvalho (Sorbonne Université) Sep 1, 2014, 222 pp.
CERN-THESIS-2014-203
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | Link to Fulltext
Detailed record
5. First observation of the decay $B_c^+ \rightarrow K^{*0}\bar{K}^0$ at LHCb
LHCb Collaboration (Ruel Aaij (CERN) et al.) Jul 2, 2015, 19 pp.
Published in *JHEP* 1507 (2015) 012
CERN-Ph-EP-2015-146, LHCb-PAPER-2015-018
DOI: 10.1007/JHEP07(2015)012
e-Print: [arXiv:1506.08634 \[hep-ex\]](https://arxiv.org/abs/1506.08634) | PDF
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | ADS Abstract Service | Link to Article from SCOAP³
Detailed record
6. Observation of the decay $B_c^+ \rightarrow \psi(2S)K^+\pi^+$
LHCb Collaboration (Ruel Aaij (CERN) et al.) Mar 24, 2015, 11 pp.
Published in *Phys Lett B* 347 (2015) 484-484
CERN-Ph-EP-2015-075, LHCb-PAPER-2015-010
DOI: 10.1016/j.physletb.2015.06.038
e-Print: [arXiv:1503.07152 \[hep-ex\]](https://arxiv.org/abs/1503.07152) | PDF
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | ADS Abstract Service | Link to Article from SCOAP³
Detailed record - Cited by 2 records
7. Measurement of the time-dependent CP asymmetries in $B_c^+ \rightarrow J/\psi K^+$
LHCb Collaboration (Ruel Aaij (CERN) et al.) Mar 24, 2015, 23 pp.
Published in *JHEP* 1508 (2015) 131
CERN-Ph-EP-2015-064, LHCb-PAPER-2015-005
DOI: 10.1007/JHEP08(2015)131
e-Print: [arXiv:1503.17058 \[hep-ex\]](https://arxiv.org/abs/1503.17058) | PDF
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | ADS Abstract Service | Link to Article from SCOAP³
Detailed record - Cited by 9 records
8. Measurement of CP asymmetries and polarisation fractions in $B_c^+ \rightarrow K^{*0}\bar{K}^0$ decays
LHCb Collaboration (Ruel Aaij (CERN) et al.) Mar 18, 2015, 29 pp.
Published in *JHEP* 1507 (2015) 108
LHCb-PAPER-2014-098, CERN-Ph-EP-2015-058
DOI: 10.1007/JHEP07(2015)108
e-Print: [arXiv:1503.05362 \[hep-ex\]](https://arxiv.org/abs/1503.05362) | PDF
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | ADS Abstract Service | Link to Article from SCOAP³
9. Measurement of the Branching Fractions of $B_c^+ \rightarrow D_s^+ K^0$, $B_c^+ \rightarrow D_s^+ \pi^0$ and $B_c^+ \rightarrow D_s^+ K^+$
Lennart Bai (Nikhef, Amsterdam) Aug 28, 2014, 63 pp.
CERN-THESIS-2014-112
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | Link to Fulltext
Detailed record
10. Measurement of the $B_c^+ \rightarrow K^{*0}\bar{K}^0$ decay branching fractions at the LHCb experiment
David Dobrek (Warsaw U.) Sep 23, 2013, 157 pp.
CERN-THESIS-2013-289
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | Link to Fulltext
Detailed record
11. $B_c^+ \rightarrow \mu^+\mu^-$ at LHC
Pavlo Anshel (CERN) Nov 18, 2014, 7 pp.
CMS-2014-03
Conference: C14.05.08
e-Print: [arXiv:1411.6884 \[hep-ex\]](https://arxiv.org/abs/1411.6884) | PDF
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | ADS Abstract Service
Detailed record - Cited by 2 records
12. Observation of the rare $B_c^+ \rightarrow \mu^+\mu^-$ decay from the combined analysis of CMS and LHCb data
CMS and LHCb Collaborations (Vardan Khachatryan (Yerevan Phys. Inst.) et al.) Nov 17, 2014, 48 pp.
Published in *Nature* 522 (2015) 68-72
CERN-Ph-EP-2014-220, CMS-EXO-13-007, LHCb-PAPER-2014-049
DOI: 10.1038/nature14174
e-Print: [arXiv:1411.4413 \[hep-ex\]](https://arxiv.org/abs/1411.4413) | PDF
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | ADS Abstract Service | Crossref | Scopus | Interactions.org article | Link to Fulltext | press release | Link to Los Angeles Times article | Link to NCS Open Access article
Detailed record - Cited by 123 records
13. Study of $\eta - \eta'$ mixing from measurement of $B_c^+ \rightarrow J/\psi\eta'$ decay rates
LHCb Collaboration (Ruel Aaij (CERN) et al.) Nov 4, 2014, 26 pp.
Published in *JHEP* 1501 (2015) 024
CERN-Ph-EP-2014-286, LHCb-PAPER-2014-056
DOI: 10.1007/JHEP01(2015)024
e-Print: [arXiv:1411.0843 \[hep-ex\]](https://arxiv.org/abs/1411.0843) | PDF
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | ADS Abstract Service | Link to Article from SCOAP³
Detailed record - Cited by 6 records
14. Standard model predictions and new physics sensitivity in $B \rightarrow D\bar{D}$ decays
Ming-Jung Park (U. of Colorado) & Shreshth Mishra (York U., University of Toronto) Oct 30, 2014, 19 pp.
Published in *Phys Rev D* 91 (2015) 034027
DOI: 10.1103/PhysRevD.91.034027
e-Print: [arXiv:1410.8298 \[hep-ph\]](https://arxiv.org/abs/1410.8298) | PDF
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
ADS Abstract Service
Detailed record - Cited by 4 records
15. Baryons with two heavy quarks: Masses, production, decays, and detection
Mark Karliner (Tel Aviv U.), Jonathan L. Rosner (Chicago U., EPFL & Chicago U.) Aug 25, 2014, 19 pp.
Published in *Phys Rev D* 90 (2014) 094007
EPJ: 14-28, TALP: 2088-14
DOI: 10.1137/PhysRevD.90.094007
e-Print: [arXiv:1408.5827 \[hep-ph\]](https://arxiv.org/abs/1408.5827) | PDF
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
ADS Abstract Service
Detailed record - Cited by 18 records
16. Observation of $B_c^+ \rightarrow K^{*0}\bar{K}^0$ and evidence for $B_c^+ \rightarrow K^{*0}\pi^+$ decays
LHCb Collaboration (Ruel Aaij (CERN) et al.) Jul 29, 2014, 22 pp.
Published in *New J Phys* 16 (2014) 12, 122001
CERN-Ph-EP-2014-188, LHCb-PAPER-2014-043
DOI: 10.1098/njph.2014.122001
e-Print: [arXiv:1407.7794 \[hep-ex\]](https://arxiv.org/abs/1407.7794) | PDF
References | BibTeX | LaTeXJULIA | LaTeXJULIA | HarvMol | EndNote
CERN Document Server | ADS Abstract Service | Link to Article from SCOAP³
Detailed record - Cited by 2 records

..and more.

— knowledge of b-hadron fractions still very important to measure branching fraction ratios of two different b-hadron species

- e.g. $B(B_s \rightarrow \mu^+\mu^-)/B(B^0 \rightarrow K^+\pi^-)$ and $B(B_s \rightarrow \mu^+\mu^-)/B(B^+ \rightarrow J/\psi K^+)$

Olivier Schneider

Key challenges for measurements

- Knowledge of absolute BRs for selected decay modes (from TH, data?)
- Modeling dependence of acceptance for different decay modes

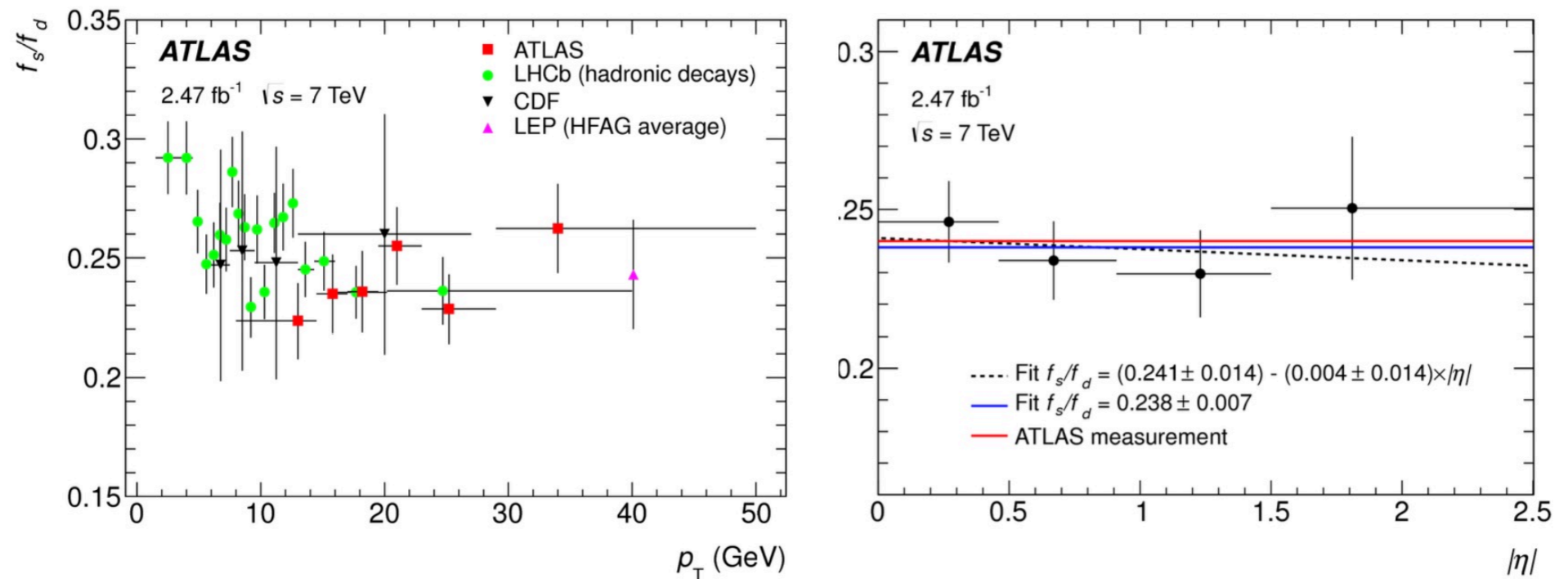
Key issue about frag fractions

- (non-)universality:
 - environment (e.g. ee vs pp vs ppbar vs Hl) and \sqrt{S} dependence?
 - kinematical dependence (p_T and η) dependence?
 - ...

Example: ATLAS

f_s/f_d ratio

- 7 TeV data, 2.5 fb^{-1}
- B_s^0 to $J/\psi(\mu^+\mu^-) \phi(\mu^+\mu^-K^+K^-)$ vs. B^0 to $J/\psi K^*(\mu^+\mu^-K^+\pi^-)$
- The directly measured quantity is $f_s \times \text{BR}(B_s^0 \rightarrow J/\psi \phi) / f_d \times \text{BR}(B^0 \rightarrow J/\psi K^*)$, which is measured with 5% total uncertainty.
(and found consistent with being uniform in $p_T = 8\text{-}50 \text{ GeV}$)
- Using a prediction of the ratio of the branching fractions, the ratio f_s/f_d is extracted, with an additional theory uncertainty of 7%
[X. Liu, W. Wang and Y. Xie, Phys.Rev. D89, 094019 (2014), pQCD computation]



[Phys.Rev.Lett. 115 \(2015\) 262001](#)

$f_s/f_d = 0.240 \pm 0.004(\text{stat}) \pm 0.010(\text{syst}) \pm 0.017(\text{theory})$ on average, lower but compatible with LHCb value of 0.259 ± 0.015 , which is measured in a different kinematical region.

Example: LHCb

- Determine f_s/f_d from the relative yield of
 - $B_s \rightarrow D_s^+ \pi^-$ and $B_d \rightarrow D^+ K^-$ (flavour symmetric);
 - $B_s \rightarrow D_s^+ \pi^-$ and $B_d \rightarrow D^+ \pi^-$ (abundant, small non-factorisable corrections from C and E).

- The f_s/f_d is calculated from:

$$\frac{f_s}{f_d} = 0.0743 \times \frac{\tau_{B^0}}{\tau_{B_s^0}} \times \left[\frac{1}{\mathcal{N}_a \mathcal{N}_F} \frac{\epsilon_{DK}}{\epsilon_{D_s \pi}} \frac{N_{D_s \pi}}{N_{DK}} \right] \frac{\mathcal{B}(D^-)}{\mathcal{B}(D_s^-)}$$

- The non-factorizable effects described by $N_a = 1.00(2)$ [**Nucl.Phys.B591:313-418**]
- The B-to-D form factor ratio, N_F can be calculated in lattice-QCD:

	$N_F(m_\pi^2/m_K^2)$	$N_F(m_\pi^2/m_\pi^2)$	
MILC	1.046(44) _{stat} (15) _{syst}	1.054(47) _{stat} (17) _{syst}	https://arxiv.org/pdf/1202.6346.pdf
HPQCD	1.000(23) _{stat} (57) _{syst}	1.046(23) _{stat} (57) _{syst}	https://arxiv.org/pdf/1703.09728.pdf (new)

- Additional correction due to W-exchange in $B_d \rightarrow D^+ \pi^-$: $N_E = 0.966(75)$

$$\begin{aligned} \frac{f_s}{f_d} &= (0.261 \pm 0.004 \pm 0.017) \times \frac{1}{\mathcal{N}_a \mathcal{N}_F} \\ &= 0.238 \pm 0.004 \pm 0.015 \pm 0.021, \end{aligned}$$

(stat) (syst) (theo)

Further alternative

PRD 85, 032008 (2012)

The B_s and Λ_b production relative to the light B mesons, B^0 and B^+ can be also determined from the **semi-leptonic decays**

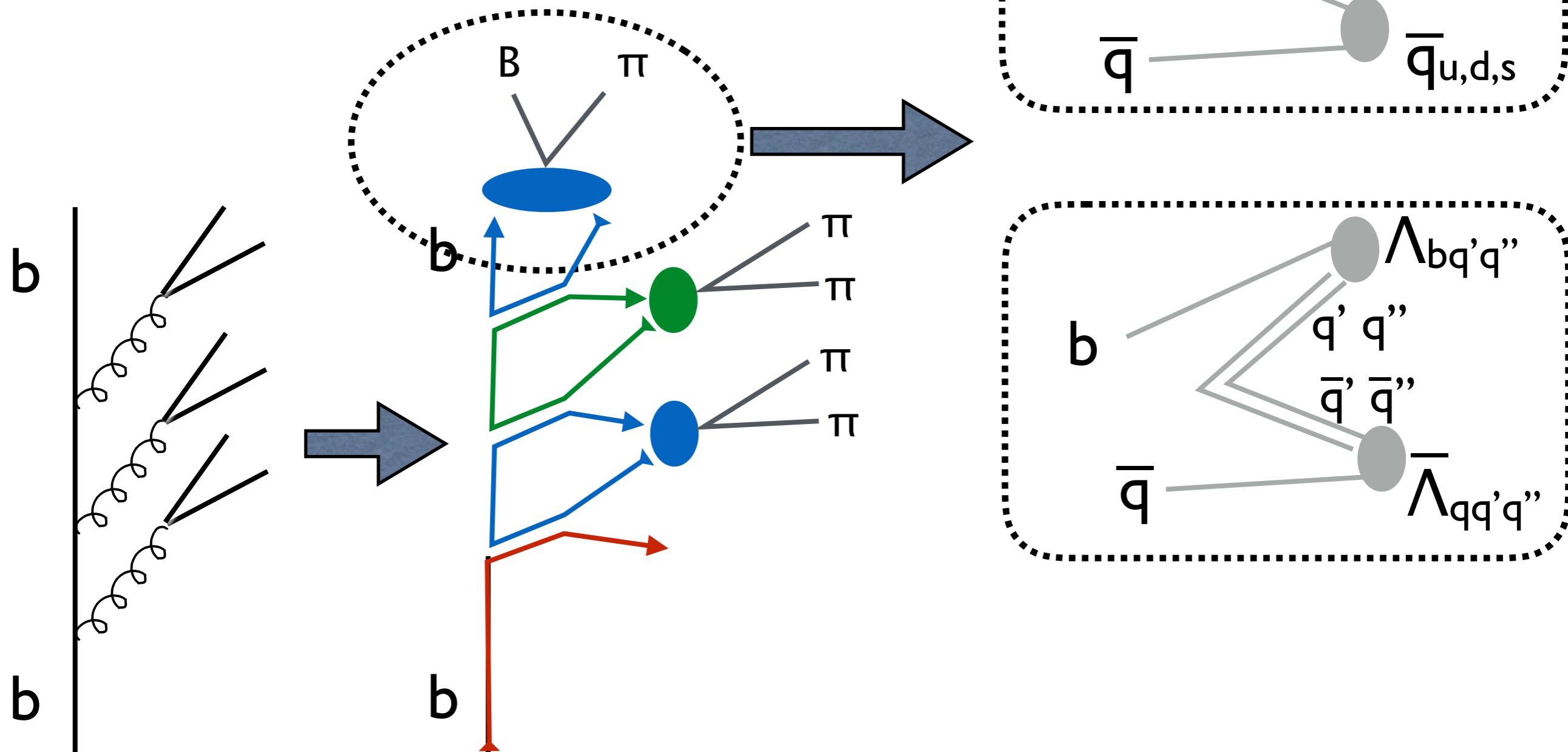
The equation for the ratio $f_s/(f_u + f_d)$ is

$$\frac{f_s}{f_u + f_d} = \frac{n_{\text{corr}}(\bar{B}_s^0 \rightarrow D\mu)}{n_{\text{corr}}(B \rightarrow D^0\mu) + n_{\text{corr}}(B \rightarrow D^+\mu)} \frac{\tau_{B^-} + \tau_{\bar{B}^0}}{2\tau_{\bar{B}_s^0}}. \quad (5)$$

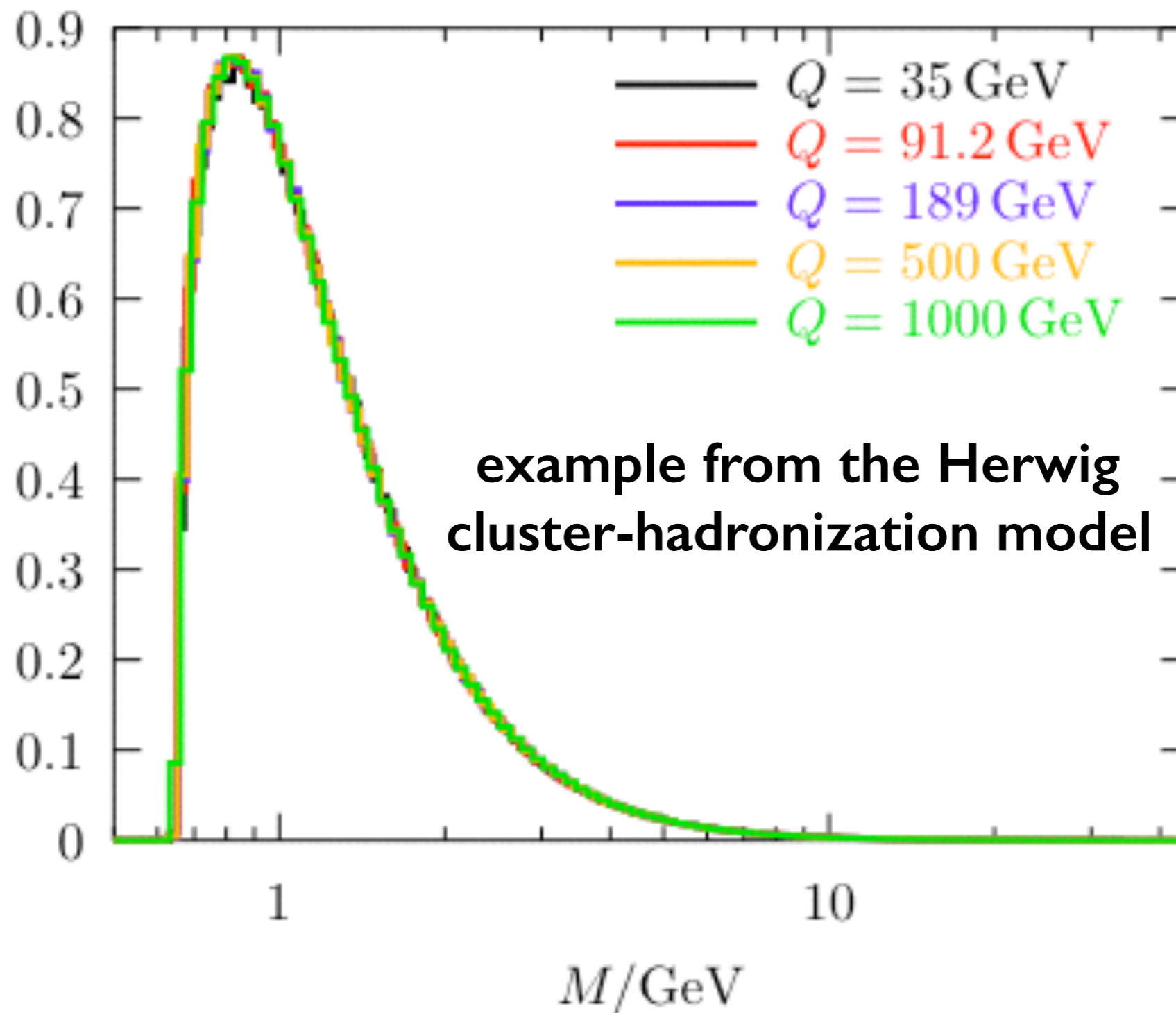
where $\bar{B}_s^0 \rightarrow D\mu$ represents \bar{B}_s^0 semileptonic decays to a final charmed hadron, given by the sum of the contributions shown in Eqs. 3 and 4, and the symbols τ_{B_i} indicate the B_i hadron lifetimes, that are all well measured [1]. We use the average \bar{B}_s^0 lifetime, 1.472 ± 0.025 ps [1]. This equation assumes equality of the semileptonic widths of all the b meson species. This is a reliable assumption, as corrections in HQET arise only to order $1/m_b^2$ and the SU(3) breaking correction is quite small, of the order of 1% [11, 12, 13].

[Bigi et al arXiv:1105.4574]

Universality of fragmentation fractions at large p_T



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.

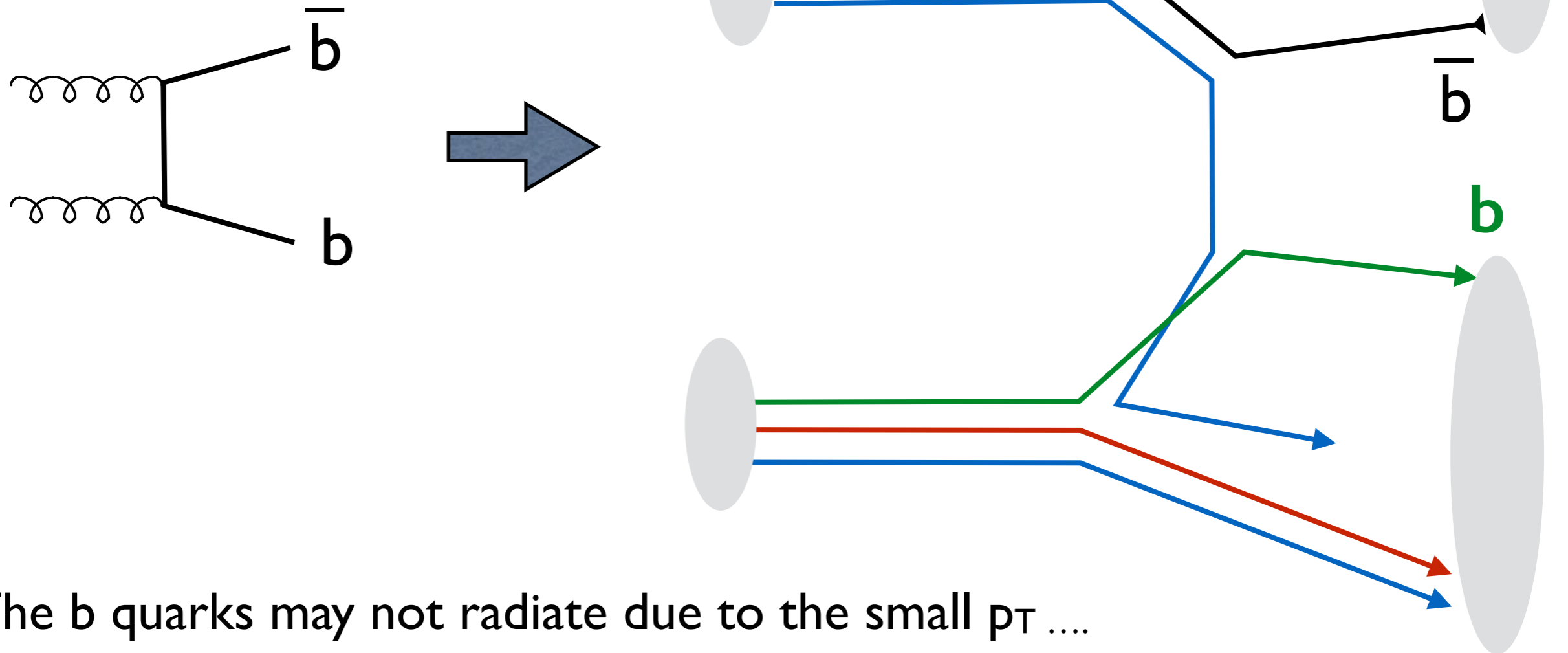


M =color-singlet cluster mass distributions, in $e^+e^- \rightarrow$ hadrons, for different CoM energies Q .

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_{Λ_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

p_T dependence

$f(\Lambda_b)/f(B^0)$ is clearly observed to depend on the p_T of the b hadron with respect to the colliding beams

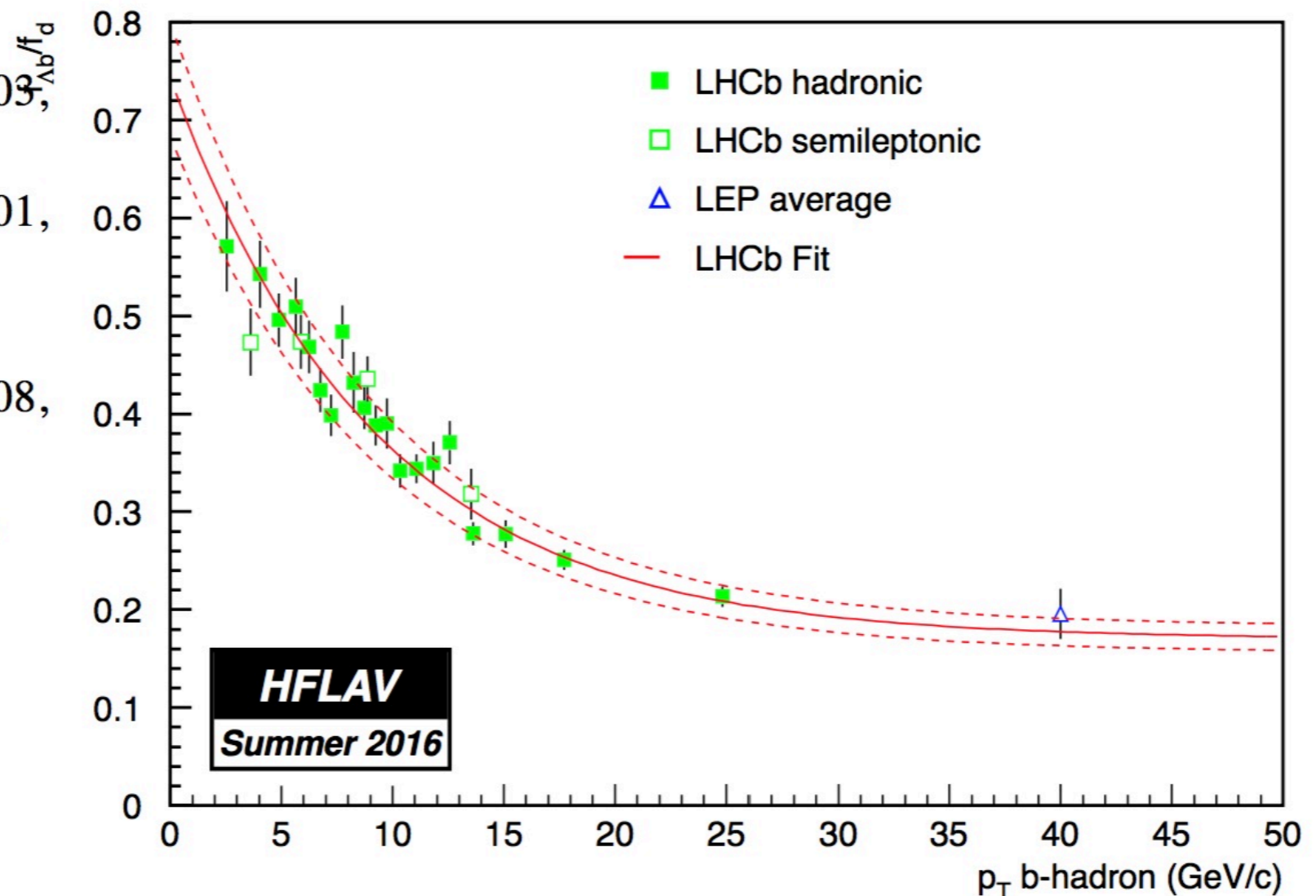
— CDF:

- PRD 77 (2008) 072003, arXiv:0801.4375
- PRD 79 (2009) 032001, arXiv:0810.3213

— LHCb:

- PRD 85 (2012) 032008, arXiv:1111.2357
- JHEP 08 (2014) 143, arXiv:1405.6842 (also η dependence)

This implies that $f(B_s)/f(B^0)$ must also depend on p_T



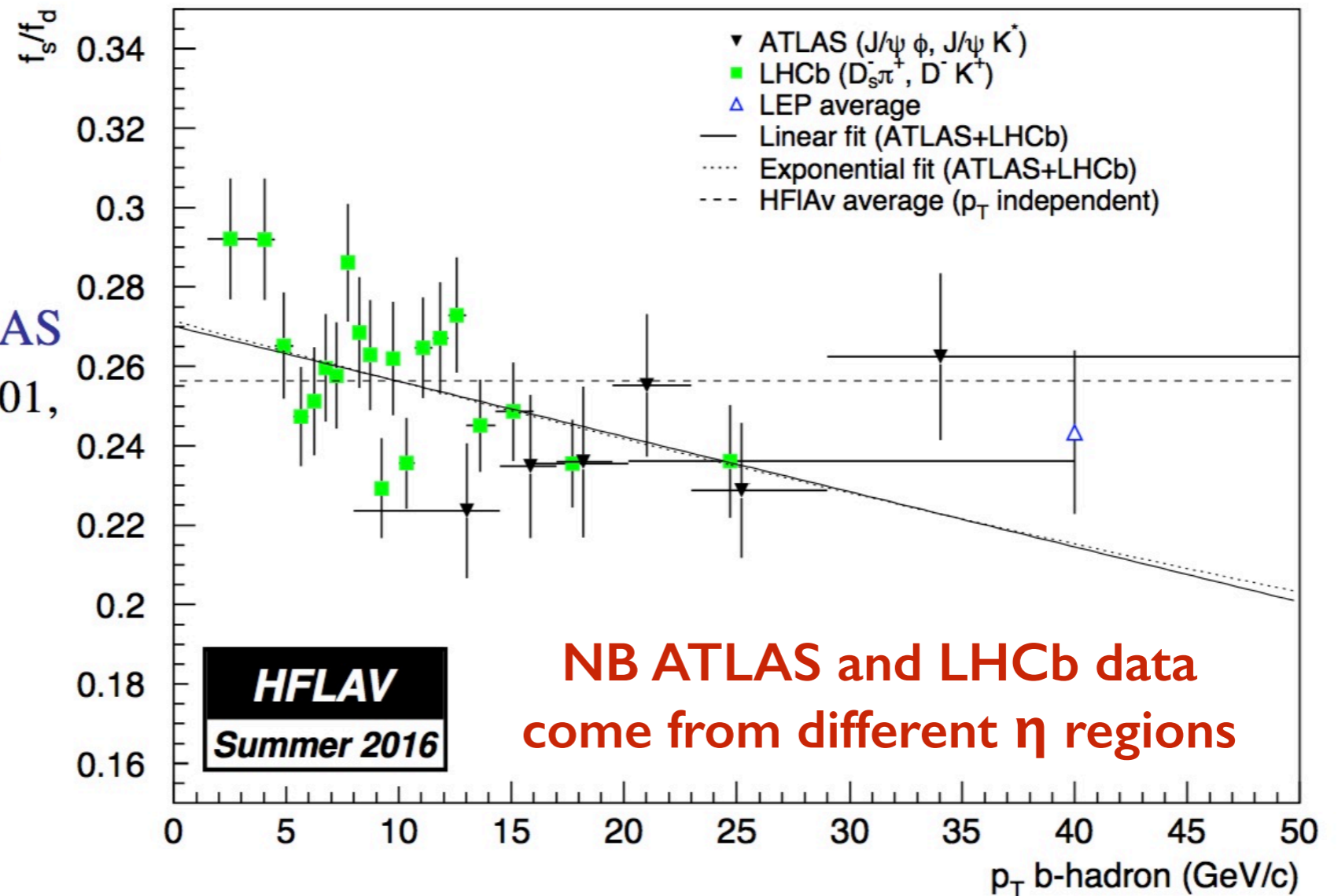
Observed p_T dependence of $f(B_s)/f(B^0)$ not very striking

— Evidence from LHCb

- JHEP 04 (2013) 001, arXiv:1301.5286

— No evidence from ATLAS

- PRL 115 (2015) 262001, arXiv:1507.08925



Up-coming f_s/f_d measurements @LHCb

- Semi-leptonic and hadronic f_s/f_d Run2 updates are planned (for the absolute f_s/f_d)
- The 13TeV / 7TeV f_s/f_d ratio will be also probed using the ratio of $B_s \rightarrow J/\psi \phi$ / $B^0 \rightarrow J/\psi K^+$ decays

remarks/comments from discussion

remarks/comments from discussion

- p_T shape of f_{Λ_b}/f_d in LHCb consistent with expectation that at $p_T \gg m_b$ (20- 30 GeV) rates at LHC reach a constant asymptotic value, consistent with LEP's.

remarks/comments from discussion

- p_T shape of f_{Λ_b}/f_d in LHCb consistent with expectation that at $p_T \gg m_b$ (20- 30 GeV) rates at LHC reach a constant asymptotic value, consistent with LEP's.
- Shape of f_s/f_d to be clarified by future studies

remarks/comments from discussion

- p_T shape of f_{Λ_b}/f_d in LHCb consistent with expectation that at $p_T \gg m_b$ (20- 30 GeV) rates at LHC reach a constant asymptotic value, consistent with LEP's.
- Shape of f_s/f_d to be clarified by future studies
- Absolute knowledge of BRs not crucial to extract kinematical dependence: can use high-statistics modes with small modeling dependence (acceptance correct's) to study kin-dependence over broadest ranges
 - ➔ test behaviour at large p_T , E_{beam} independence
 - ➔ consider different production environments, e.g.
 - ▶ in addition to p_T shape, study $f_{s,\Lambda_b}/f_d(z)$, $z=p_{T(b)}/p_{T(\text{jet})}$
 - ▶ use b's from top dec's, charm in W decays in $t\bar{t}$ events,...

remarks/comments from discussion

- p_T shape of f_{Λ_b}/f_d in LHCb consistent with expectation that at $p_T \gg m_b$ (20- 30 GeV) rates at LHC reach a constant asymptotic value, consistent with LEP's.
- Shape of f_s/f_d to be clarified by future studies
- Absolute knowledge of BRs not crucial to extract kinematical dependence: can use high-statistics modes with small modeling dependence (acceptance correct's) to study kin-dependence over broadest ranges
 - ➔ test behaviour at large p_T , E_{beam} independence
 - ➔ consider different production environments, e.g.
 - ▶ in addition to p_T shape, study $f_{s,\Lambda_b}/f_d(z)$, $z=p_{T(b)}/p_{T(\text{jet})}$
 - ▶ use b's from top dec's, charm in W decays in $t\bar{t}$ events,...
- These effects cannot be calculated from first principles, but can be described by MCs in a phenomenological way, subject to tuning. Measurements of $f_H(p_T, y, z, \dots)$ are crucial to shed some more light on the hadronization process and help improve the models