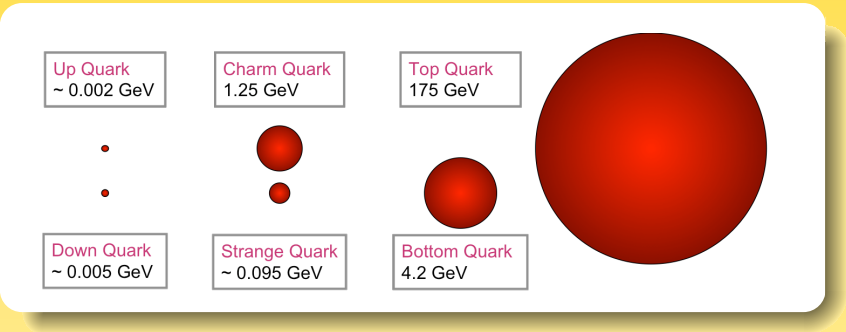
Mass effects in b quark associated production

04/04/17, DIS-Birmingham, Davide Napoletano

Outline

Introduction



$\Lambda_{QCD} \sim 250$ MeV,
A quark Q is **heavy** $\Leftrightarrow m_Q \gg \Lambda_{QCD}$.

$m_u, m_d, m_s \ll \Lambda_{QCD} \Rightarrow$ light quarks

$m_c > \Lambda_{QCD}$ but not by much!

- b quark only quark such that

$$\Lambda_{QCD} \ll m \ll M(m_W, m_Z, m_H, m_t)$$

- b phenomenology crucially important at the LCH, from flavour physics, to Higgs characterisation and measurements and as window to New Physics.
- From a theoretical viewpoint we need better control on this kind of processes which appear as both BSM signals and SM irreducible backgrounds.
- Important examples: H and Z associated production.
- Historically two approaches:

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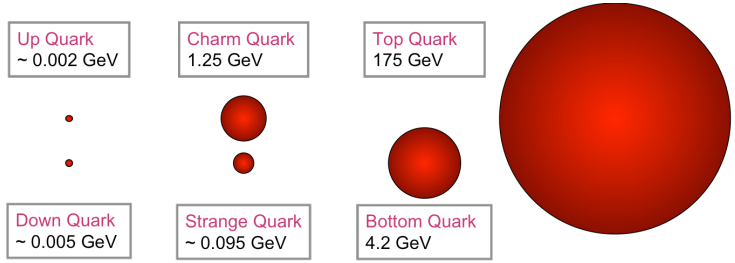

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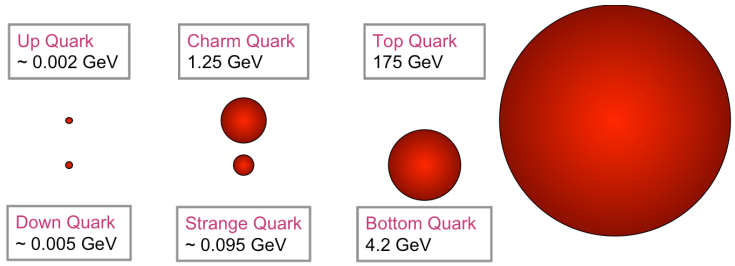

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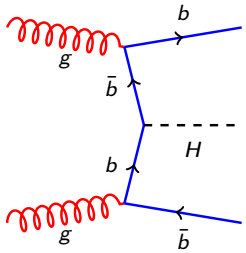
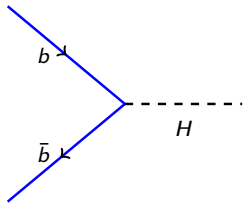
4F VS 5F scheme

4F scheme



- × Doesn't re-sum possibly large logs, but it does have them explicitly
- × Higher orders are computationally more difficult
- ✓ Mass effects present at any order
- ✓ MC@NLO no problem

5F scheme



- ✓ Stabler predictions, re-summation of IS large logs into b-PDF
- ✓ Higher order easily accessible
- × Differential features effects are pushed to higher orders
- × Implementation in MC depends on the $g \to b\bar{b}$ splitting implemented

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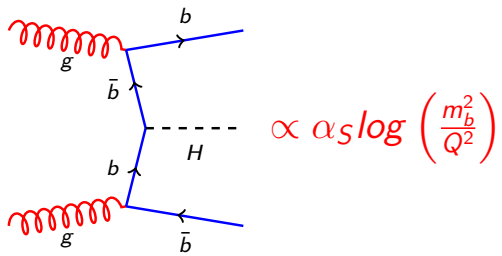

$\propto \alpha_S log\left(\frac{m_b^2}{Q^2}\right)$

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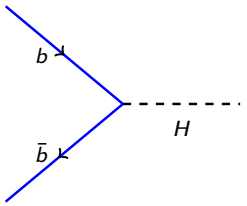
5F scheme



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Improved theoretical predictions

Directions

- Matching the two schemes, **FONLL, EFT, etc...**
- Somehow difficult to extend to differential distributions

- Design of a 5F-improved scheme to include mass effects
- In principle easy to do, but full of subtleties (**Factorisation, Parton-Shower...**)

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TOTAL RATES

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SHAPES

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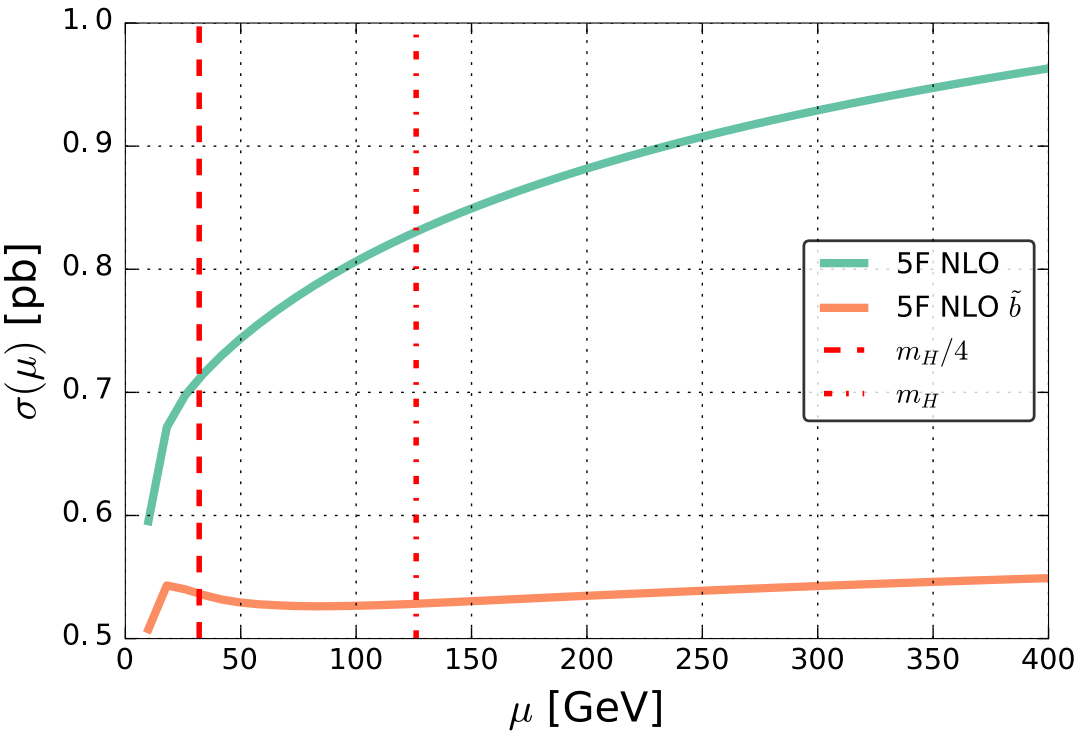
LL vs Full b-PDF

Total rate, 5F scheme



$\sigma_{b\bar{b}\to h}(\mu)$

Full 5F @ NLO vs 5F expanded b to $\mathcal{O}(\alpha_S^2)$

The Master Formula

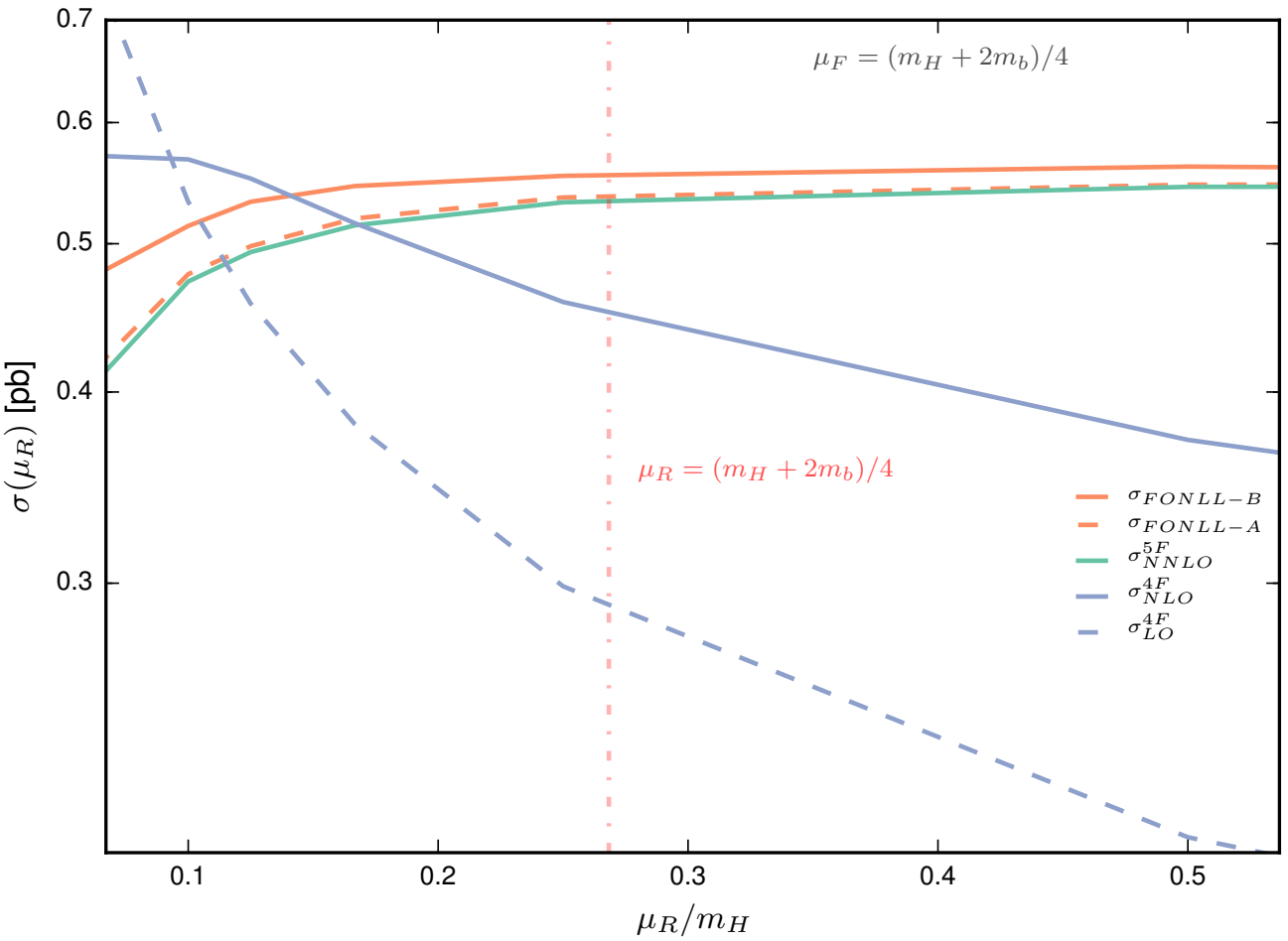
$$\sigma^{(FONLL)} = \sigma^{(4)} + \sigma^{(5)} - \text{ double counting}$$

$$= \mathcal{L}_{ij}(x_1, x_2, \mu^2) \otimes \sum_{p}^{N} \left(\alpha_S^{(5)}(\mu^2)\right)^p$$

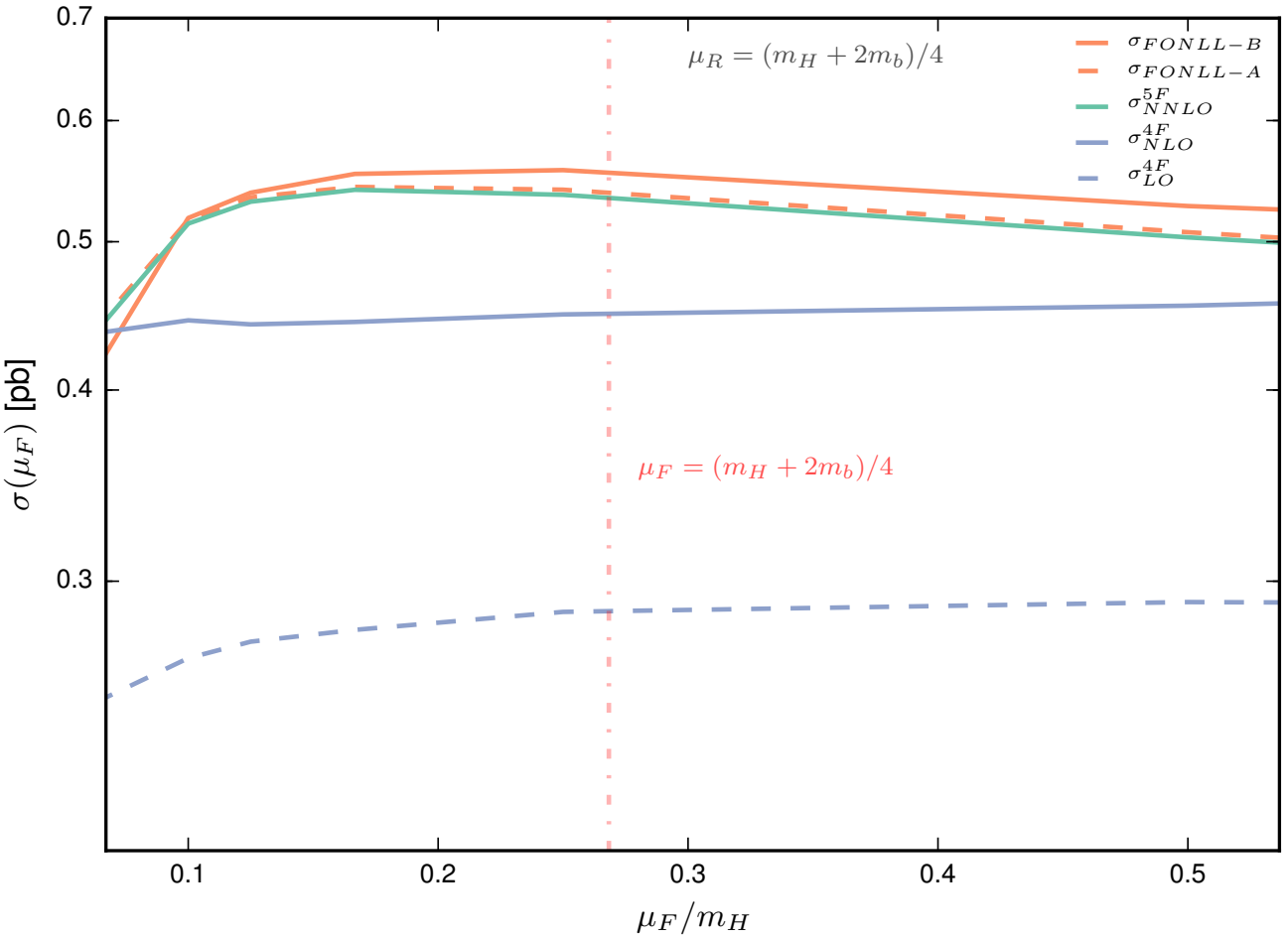
$$\times \left\{ \mathcal{B}_{ij}^{(p)}\left(x_1, x_2, \frac{\mu^2}{m_b^2}\right) + \sum_{k=0}^{\infty} \mathcal{A}_{ij}^{(p),(k)}(x_1, x_2)\left(\alpha_S^{(5)}(\mu^2) L\right)^k \right.$$

$$\left. - \sum_{k=0}^{p} \mathcal{A}_{ij}^{(p-k),(k)}(x_1, x_2) L^k \right\}$$

μ_R Variations



μ_F Variations



Outline

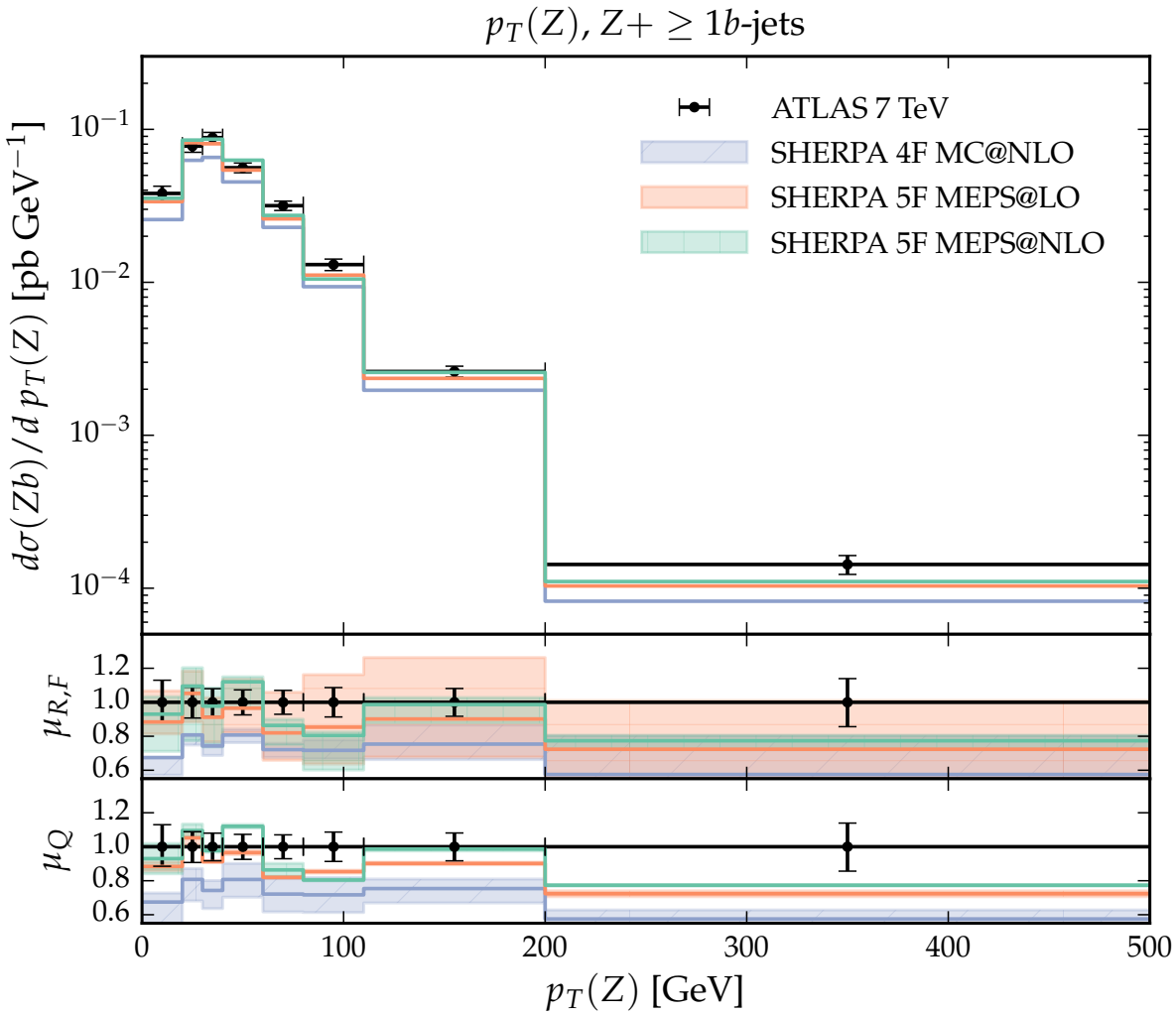
Set-up

$Zb\bar{b}$

- $pp \to Z + \{jjj\}$ (5F) or $pp \to Zb\bar{b}$ (4F).
  in 5FNLO, $pp \to Z$, $pp \to Z + j$ and $pp \to Z + jj$ are NLO
- $Z \to e^- e^+ \quad m_{\ell\ell} \in [76, 106]$ GeV
- $p_T(j) > 20$ GeV, central, $\Delta R_{j\ell} > 0.5$
- Separate sample in 1 b–jet and 2 b–jets, tagged

$Z+ \geq 1b$-jet

$p_T(Z)$



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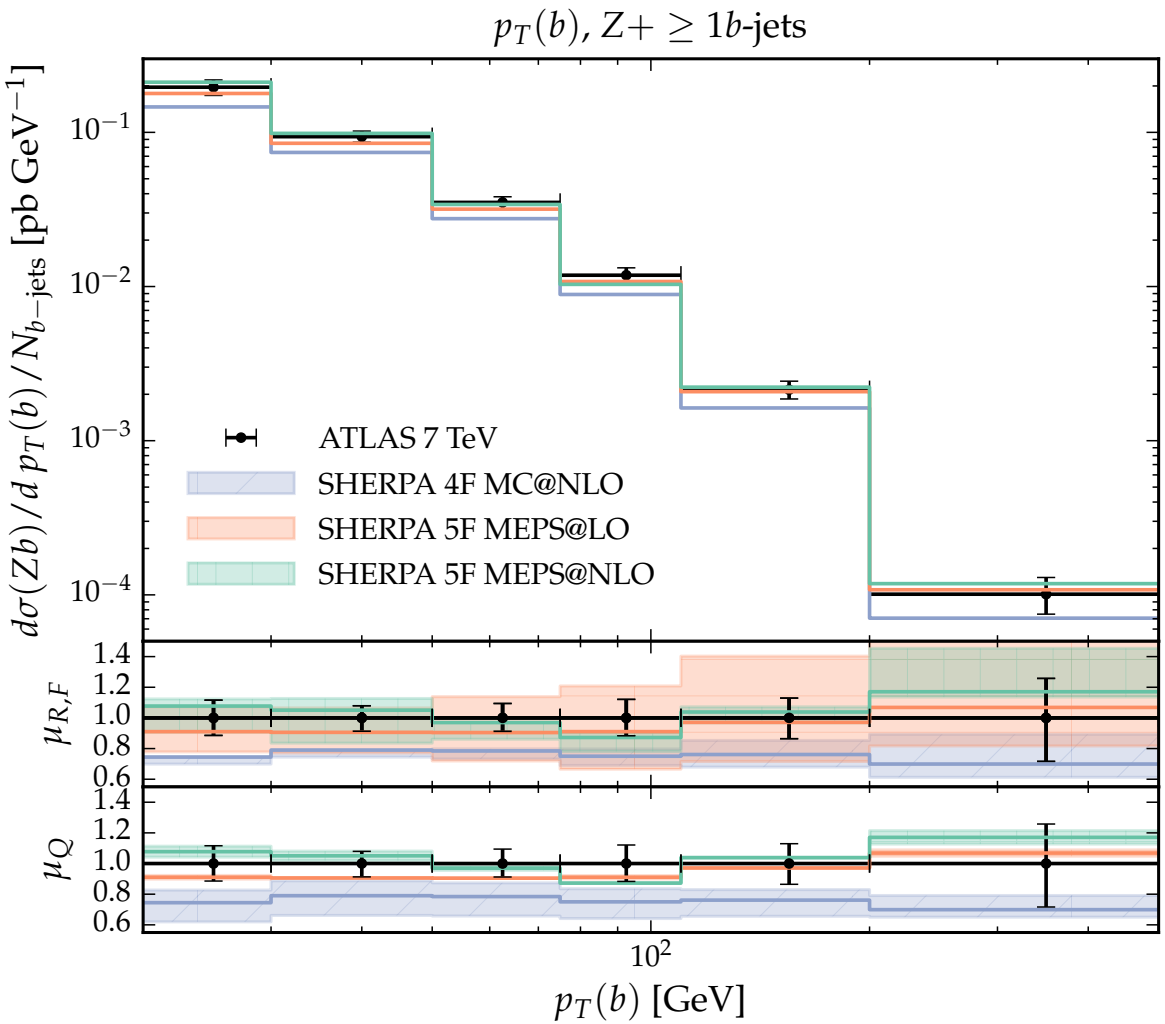
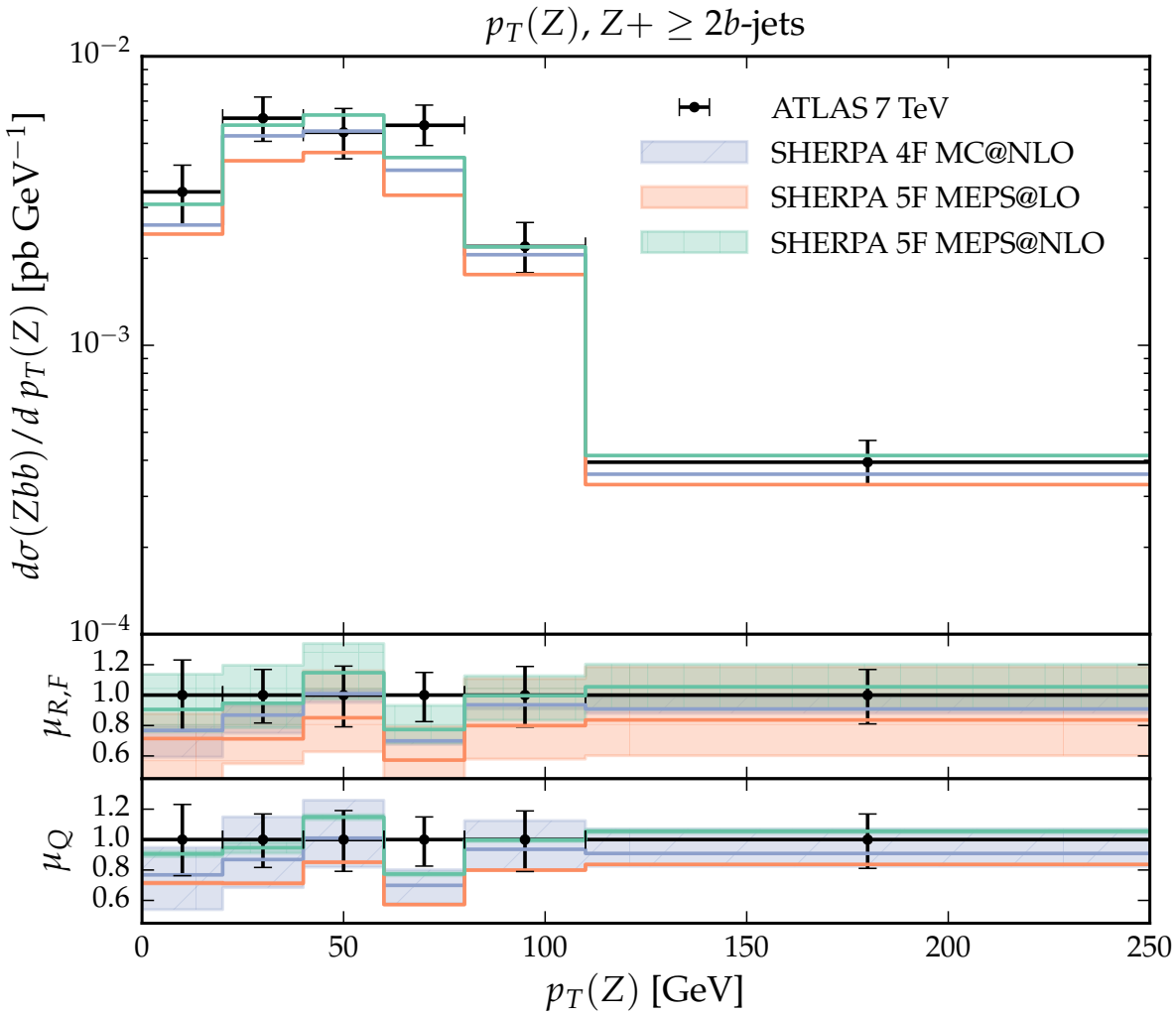


$Z+ \geq 2b$-jet

$p_T(Z)$



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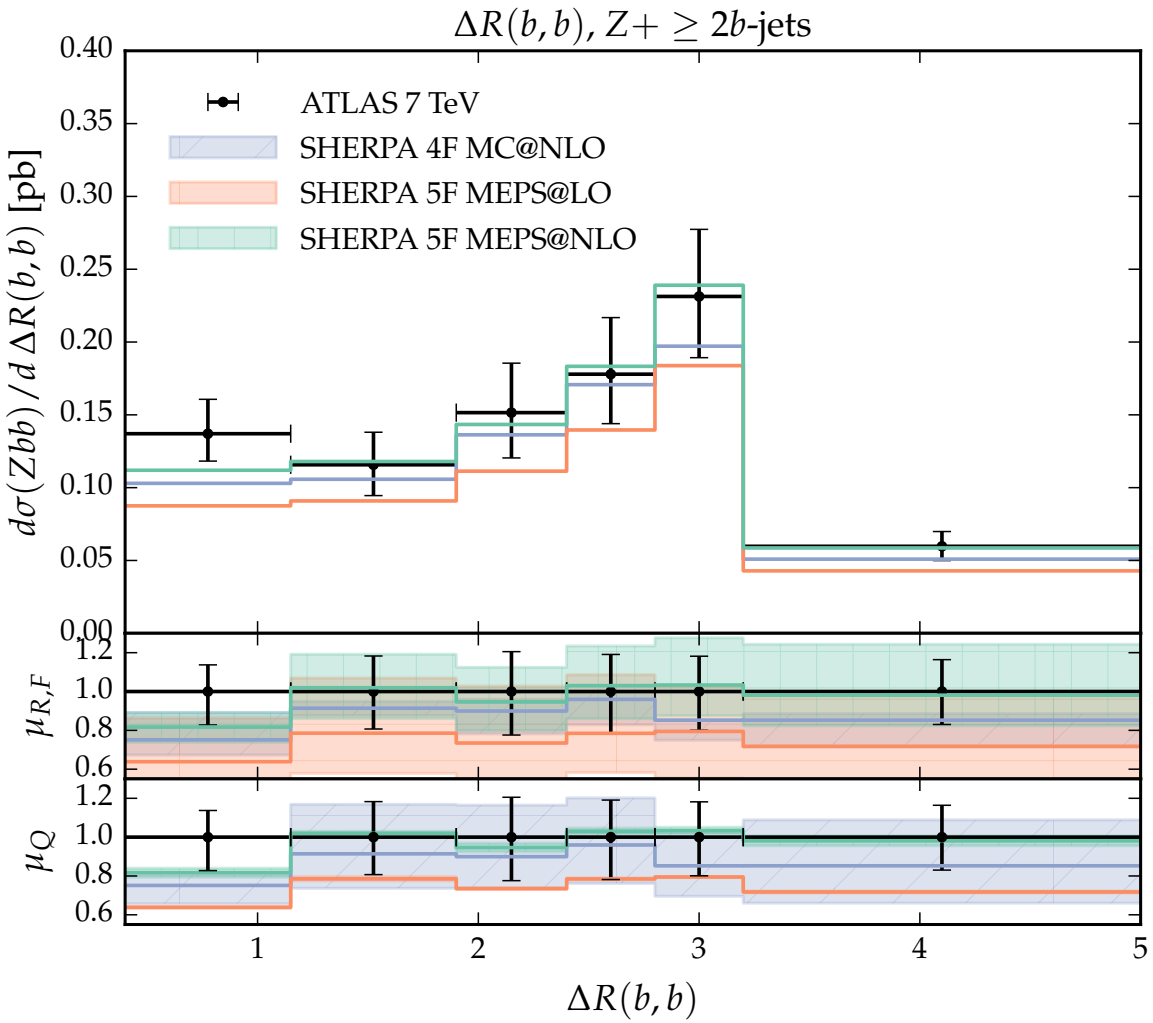
$\Delta R(b, b)$



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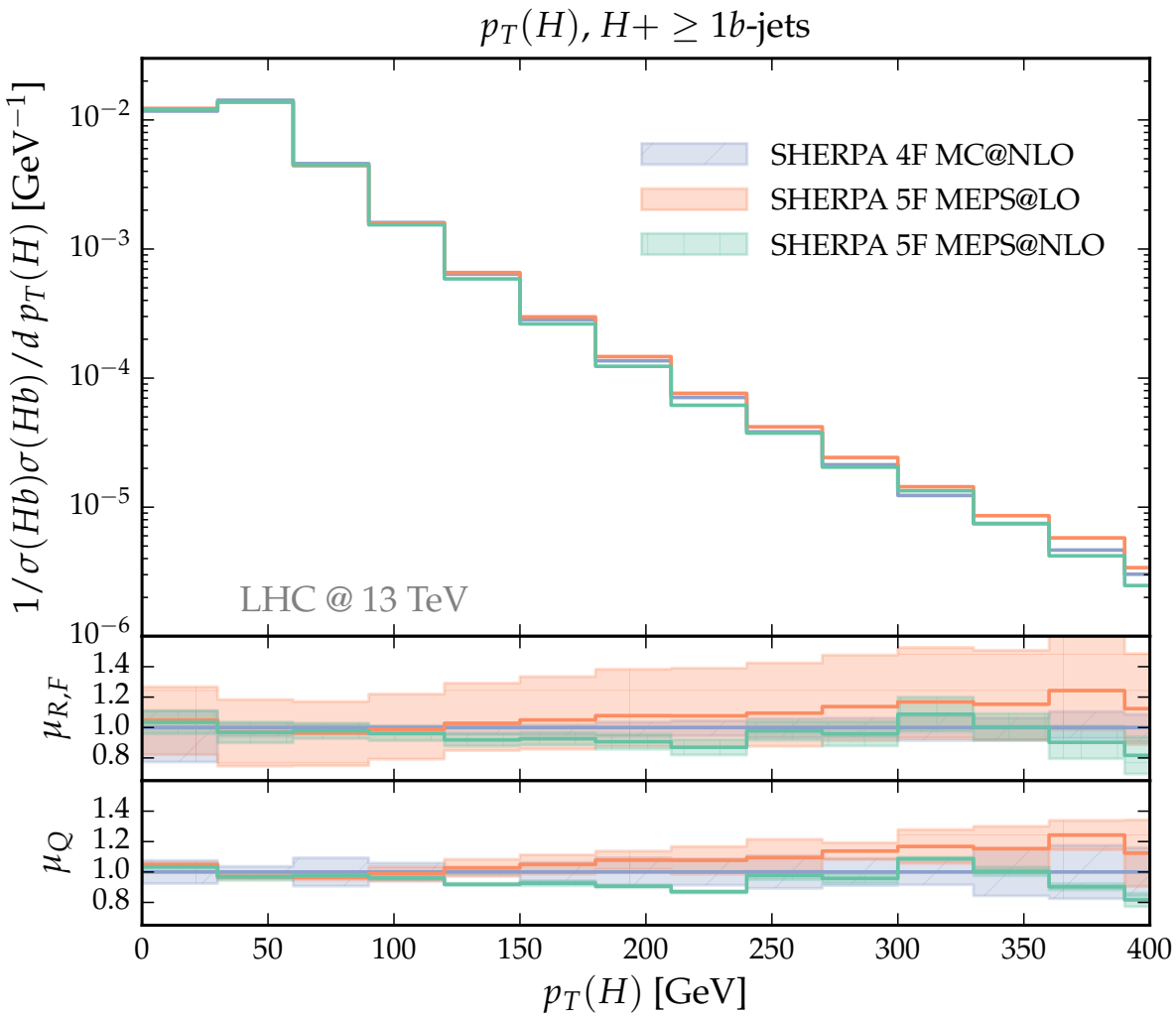
  in 5FNLO, $pp \to H$, $pp \to H + j$ and $pp \to H + jj$ are NLO
- Simulations at the parton–level only
- $p_T(j) > 25$ GeV, central, no intra-jet $g \to b\bar{b}$.
- Separate sample in 1 b–jet and 2 b–jets, tagged

$H+ \geq 1b$-jet

$p_T(H)$



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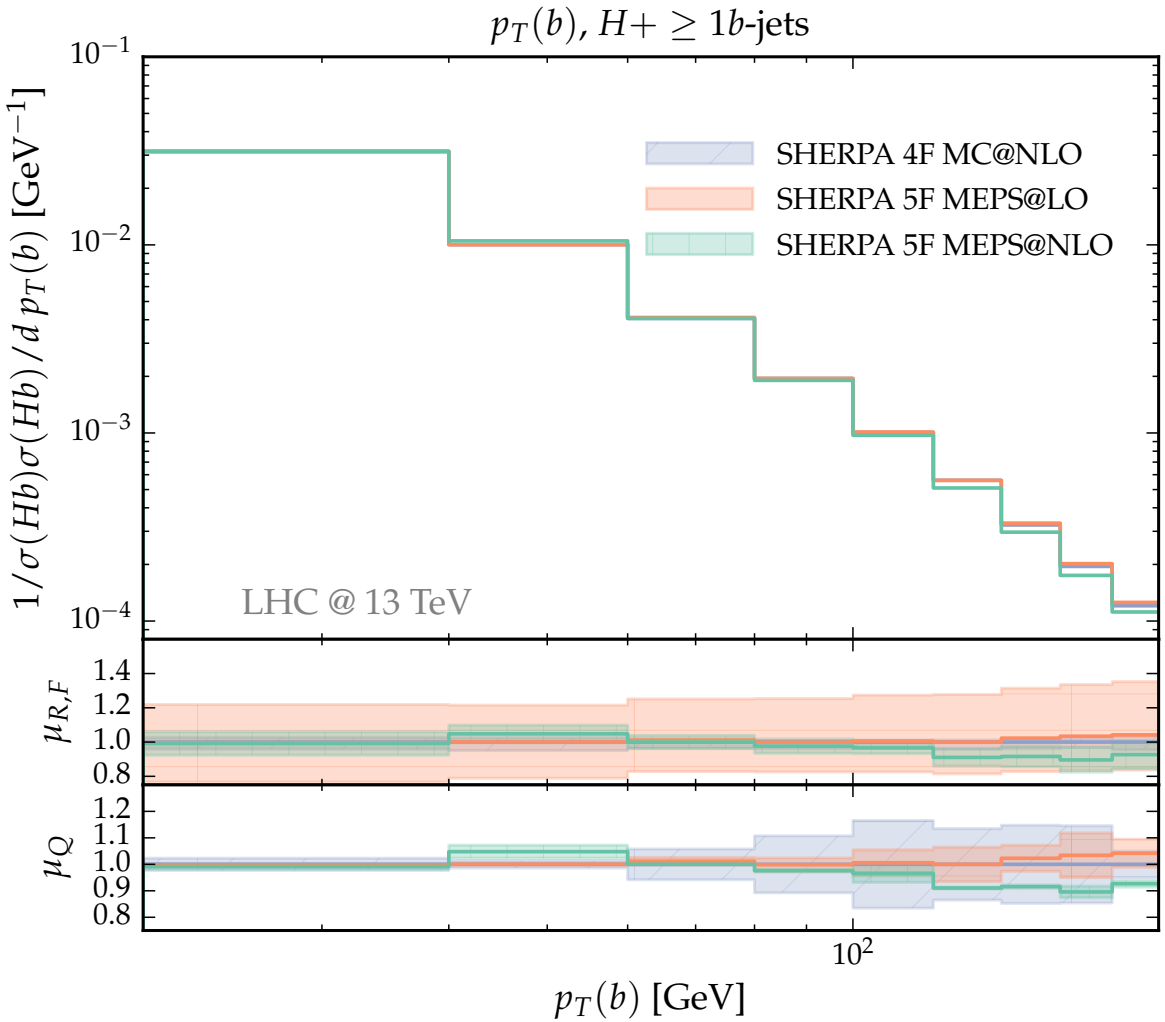

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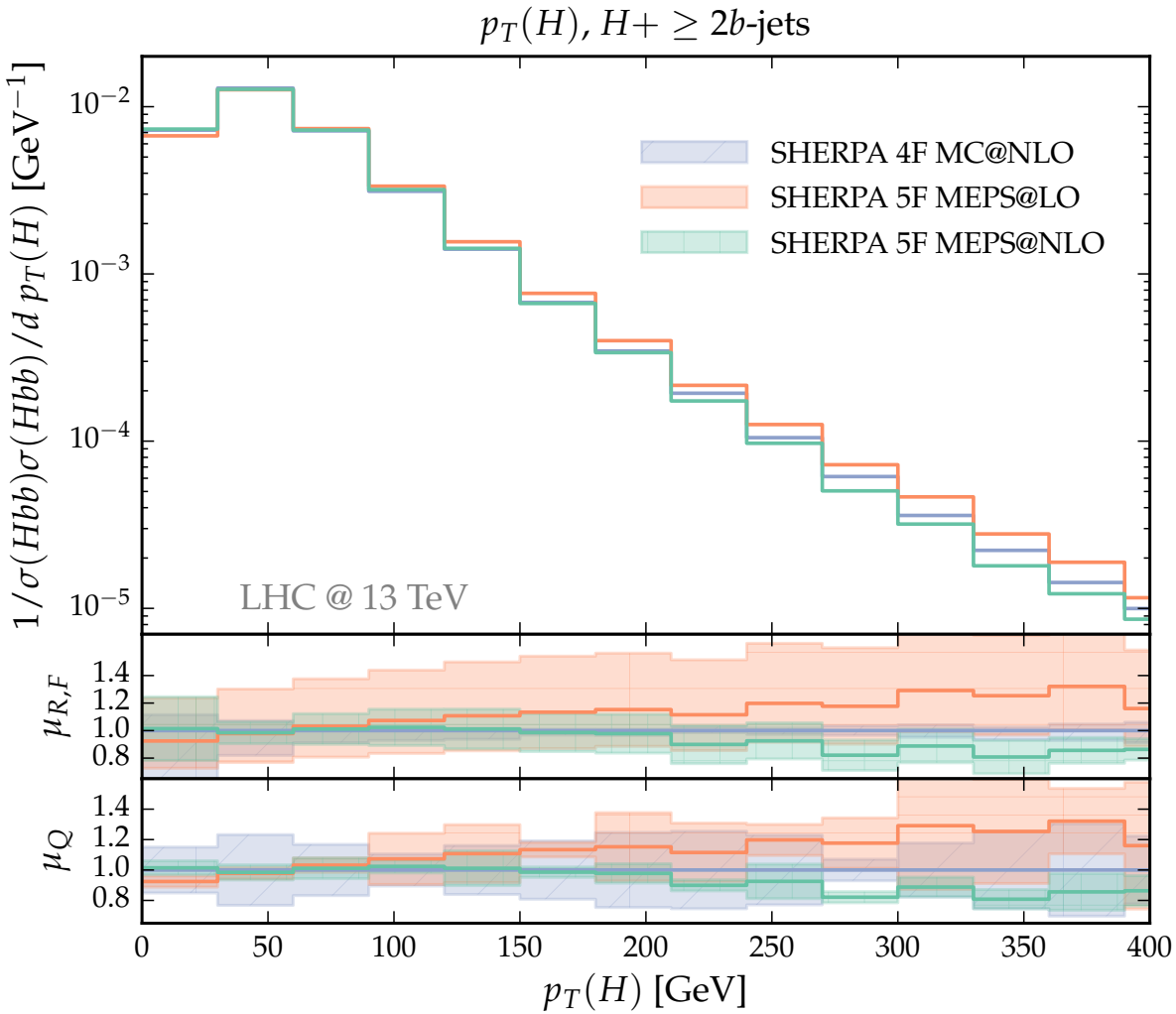

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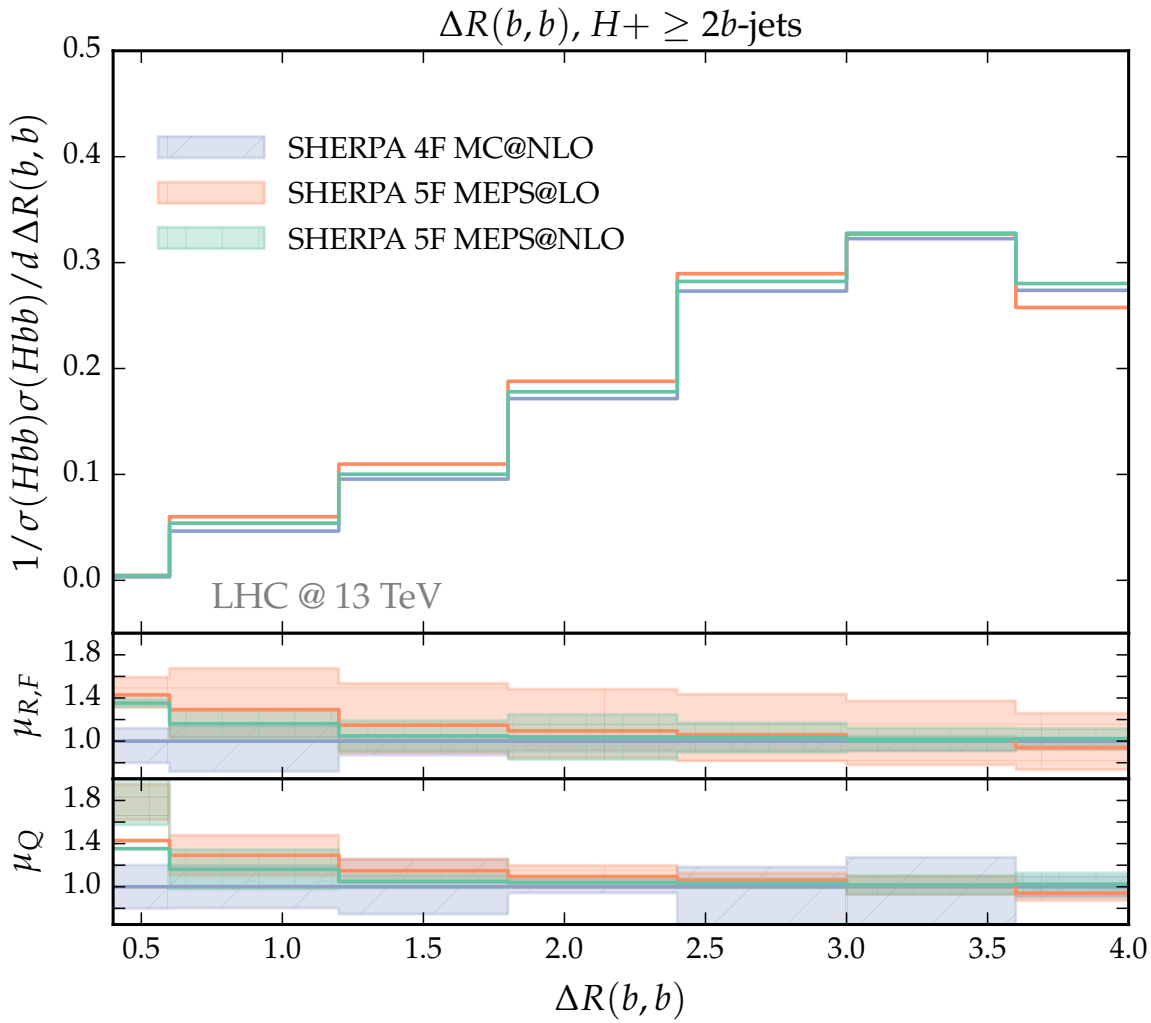

Conclusions

- 4FS or 5FS ?
- Inclusive: 5FS, logs dominate over mass effects
- Differential: No significant difference in terms of shape
- As long as you normalise for the 5FS (or a matched one), you can use either (possible problems for Vbj)

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