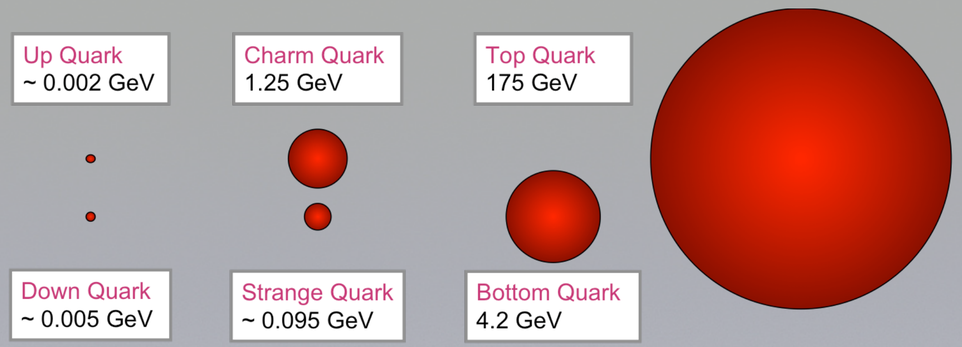
Theory perspectives in heavy quarks modelling

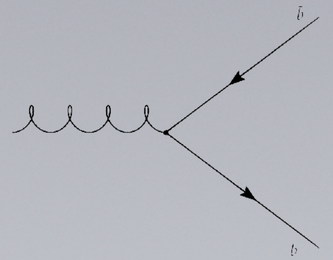
Davide Napoletano, ATLAS-CMS MC Workshop, 04/05/2017

Intro

- m_b somewhere in $\Lambda_{QCD} < m_b < m_{V,H,t}$



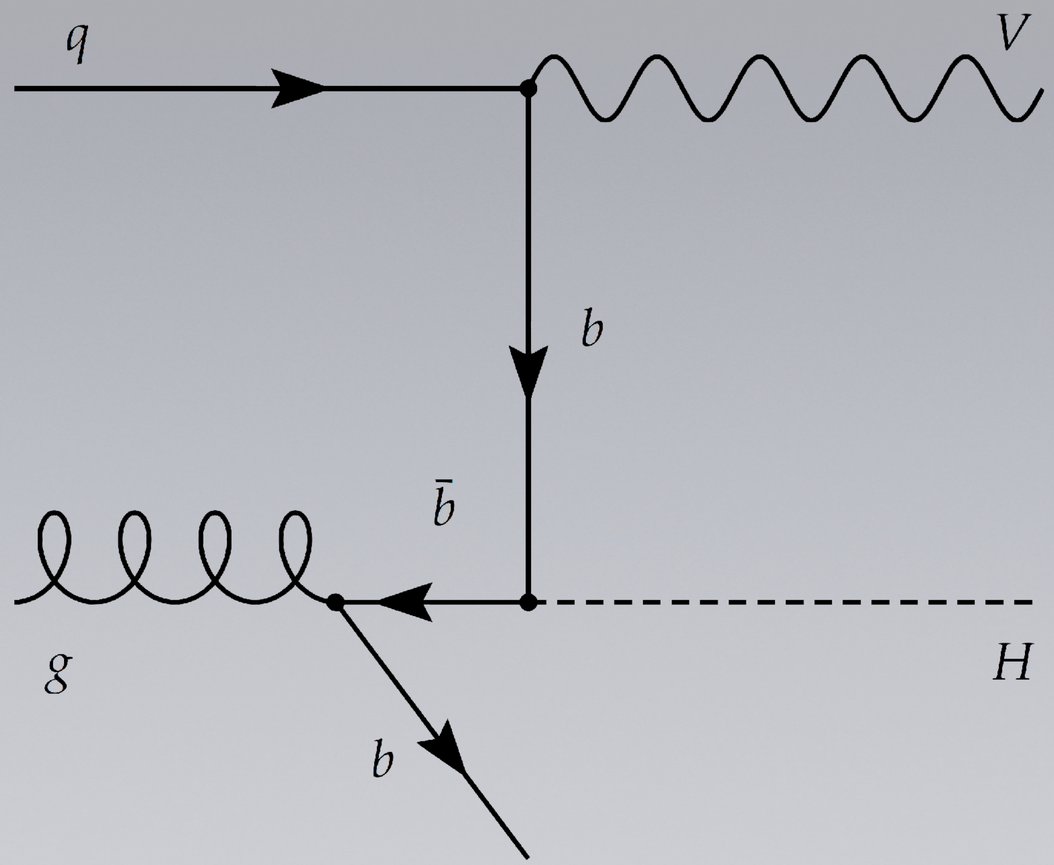
- main production through $g \to b\bar{b}$



- Problems so far are only theoretical/MC
  - There are still quite a few open questions on the topic…

4FS vs 5FS

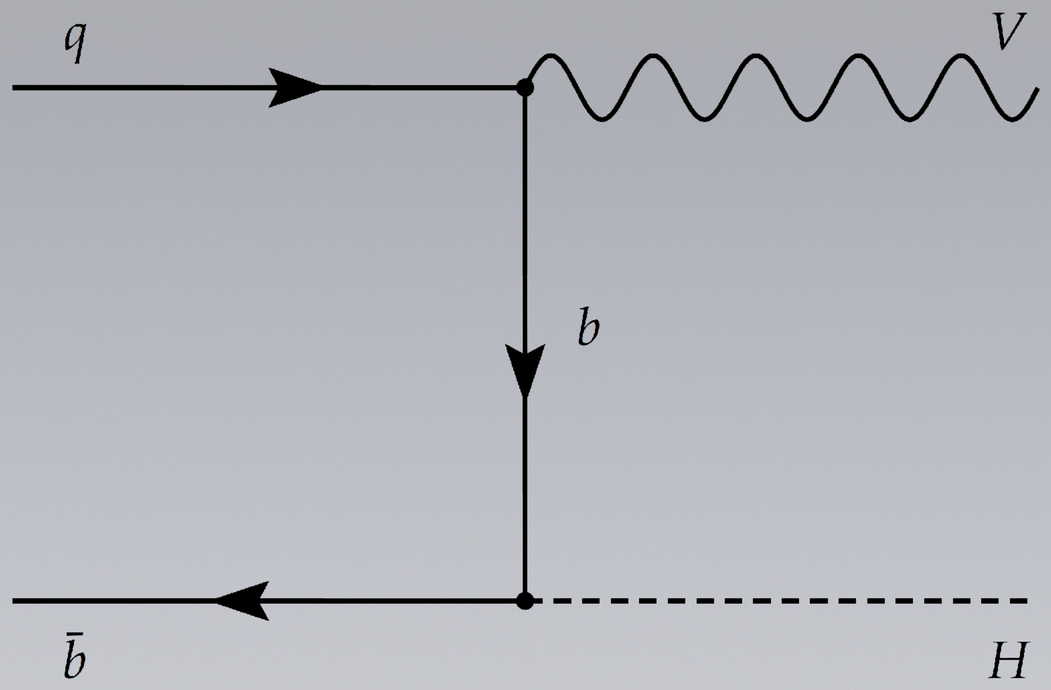
4F Scheme : VH



- $m_b \neq 0$ (Everywhere)
- $\sim \alpha_S \log \frac{m_b^2}{q^2}$, can be O(1)
- $g \to b\bar{b}$, no problem

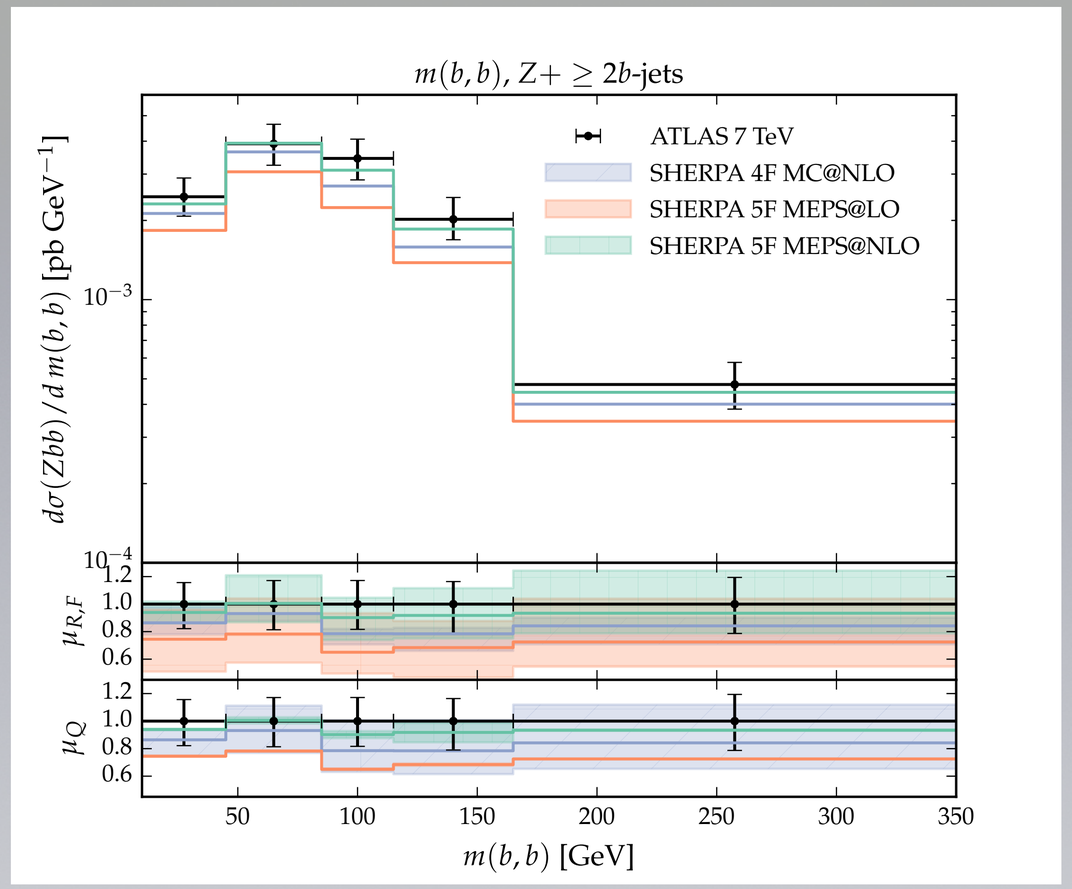
4FS vs 5FS

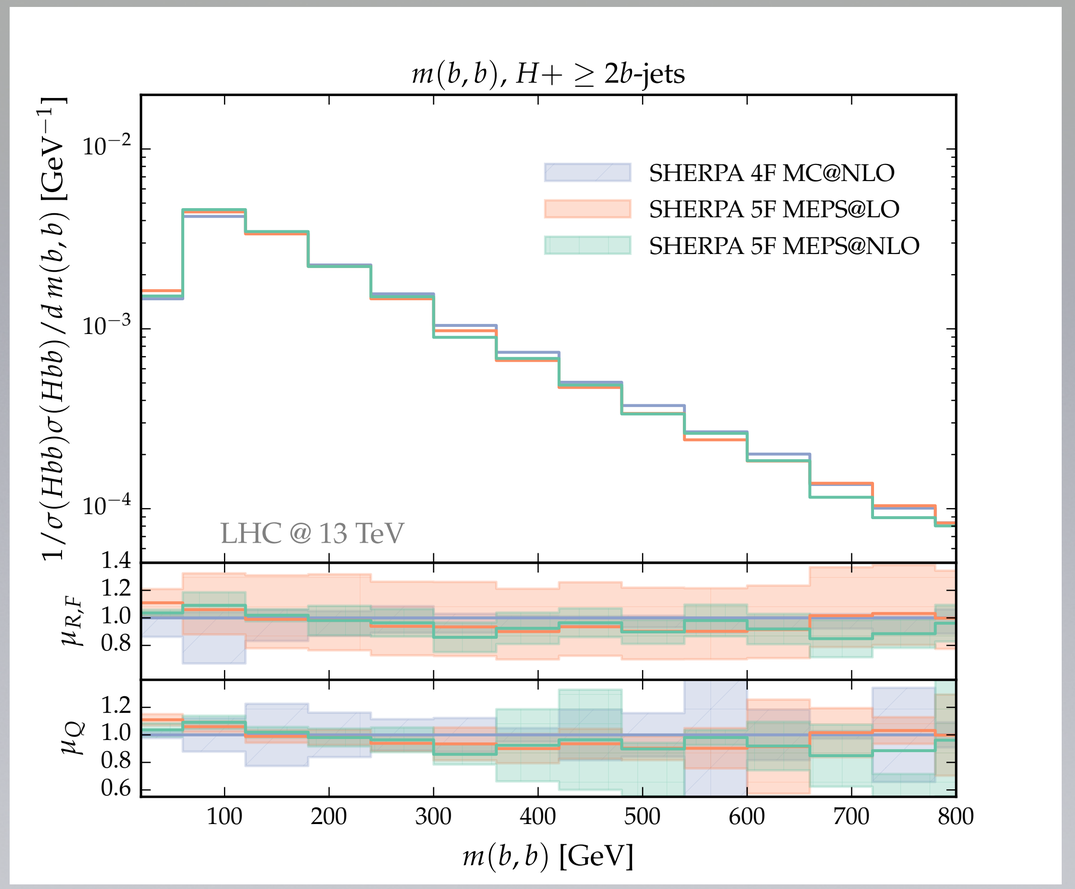
5F Scheme : VH



- $m_b = 0$
- Logs resummed in b-pdf
- $g \to b\bar{b}$, depends on PS

$pp \to VH(b\bar{b})$ arXiv:1612.04640

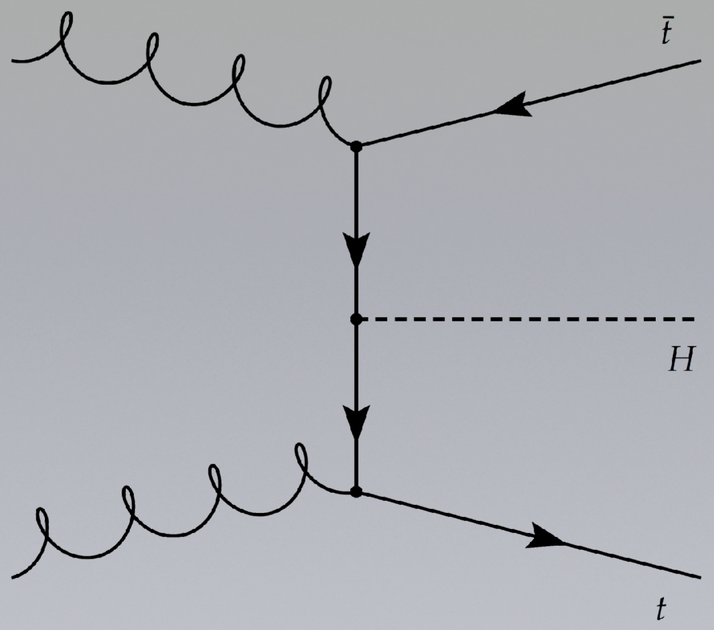




- Compare against Zbb data to understand Hbb

- As in Zbb, good shape agreement among schemes

$pp \to t\bar{t}H(b\bar{b})$



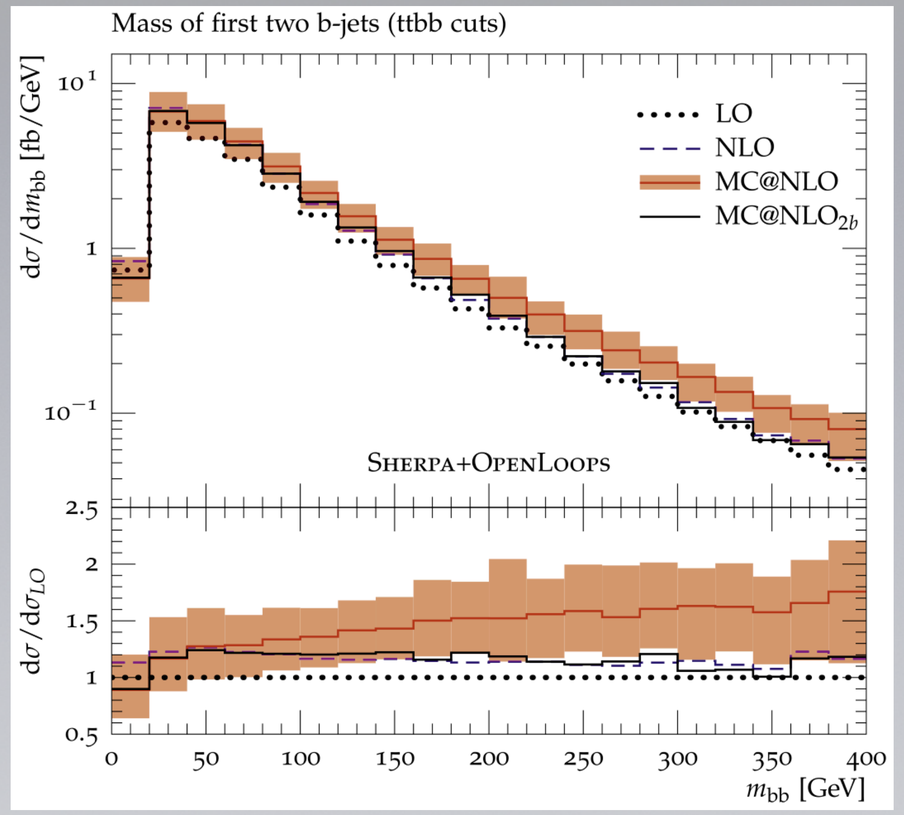
- Large irreducible bkg : ttbb
- Large MC uncertainties are limitation
- NLO+PS in 5FS and 4FS

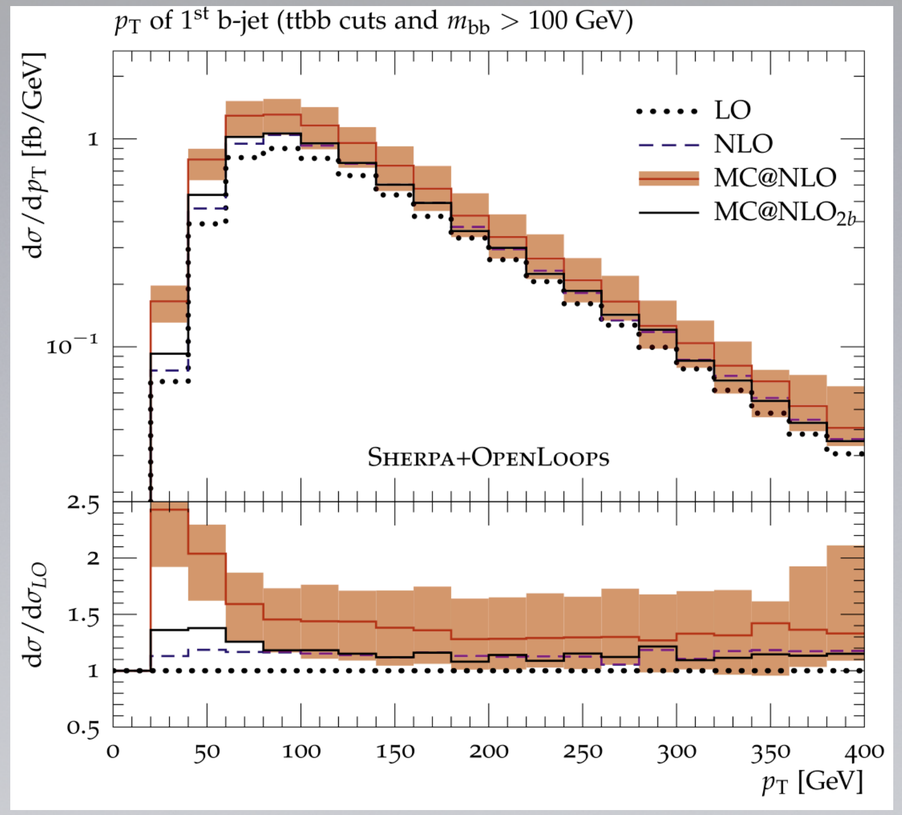
- 5FS can leads to collinear singularities, $g \to b\bar{b}$ depends solely on shower
- 5FS has to rely on merging, not very efficient…
- 4FS has at least the first $g \to b\bar{b}$ comes from MEs
- 4FS fully inclusive, but…

$pp \to t\bar{t}H(b\bar{b})$

Cascioli et al, arXiv:1309.5912v2

$pp \to t\bar{t}b\bar{b}$ NLO+PS with m_b





- Big $g \to b\bar{b}$ effects
- Different running couplings in 4FS and 5FS

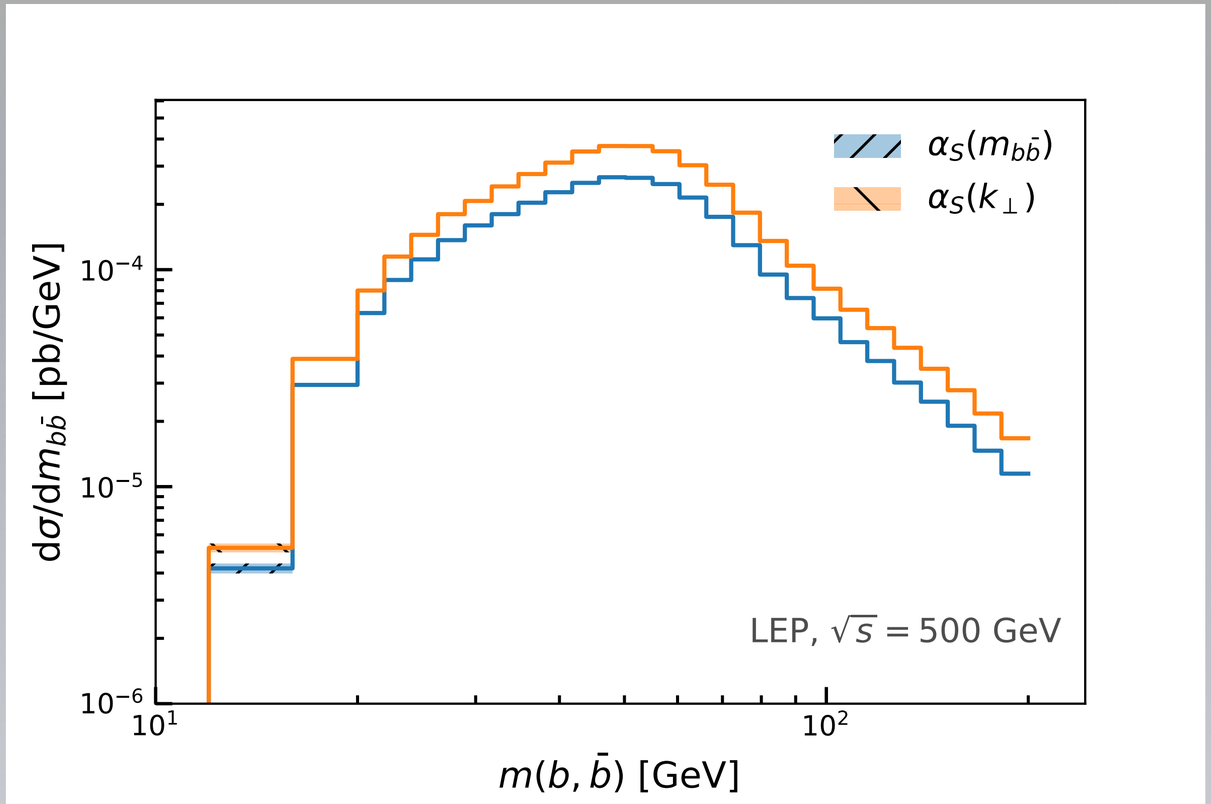
$g \to b\bar{b}$ Shower

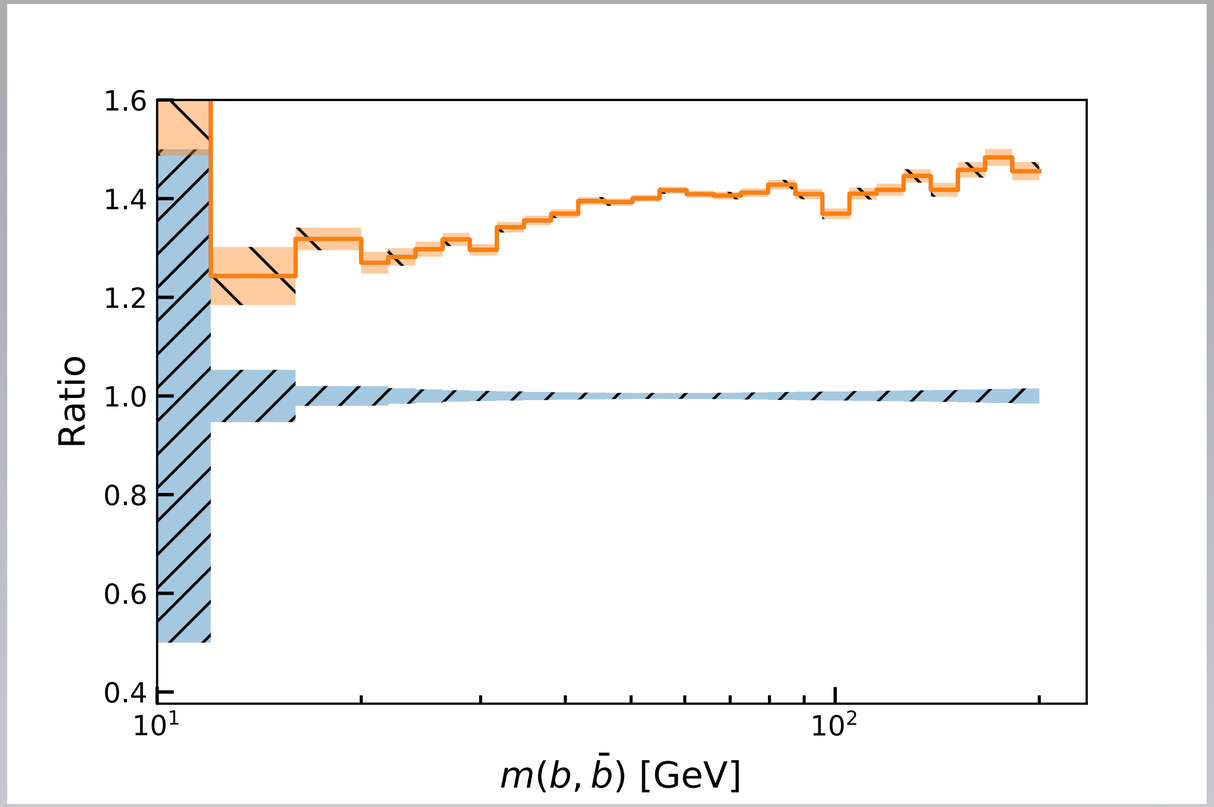
Different implementations

- SHERPA (2.2.3) : $\alpha_s(m_{Q\bar{Q}})$ + mass effects in FSR (ISR on-going)
    - DIRE : $\alpha_s(s_{ij}s_{jk}/s_{ijk})$ + mass effects in FSR,
- HERWIG 7.0 : $\alpha_s(m_{Q\bar{Q}})$ (virtuality) mass effects in FSR,
- PYTHIA 8: $\alpha_s(k_\perp)$, + many options for mass effects,
    - DIRE : $\alpha_s(s_{ij}s_{jk}/s_{ijk})$ + mass effects in FSR,
    - aMC@NLO : only massless

$g \to b\bar{b}$ Shower

… if I let bs coming only from the shower…

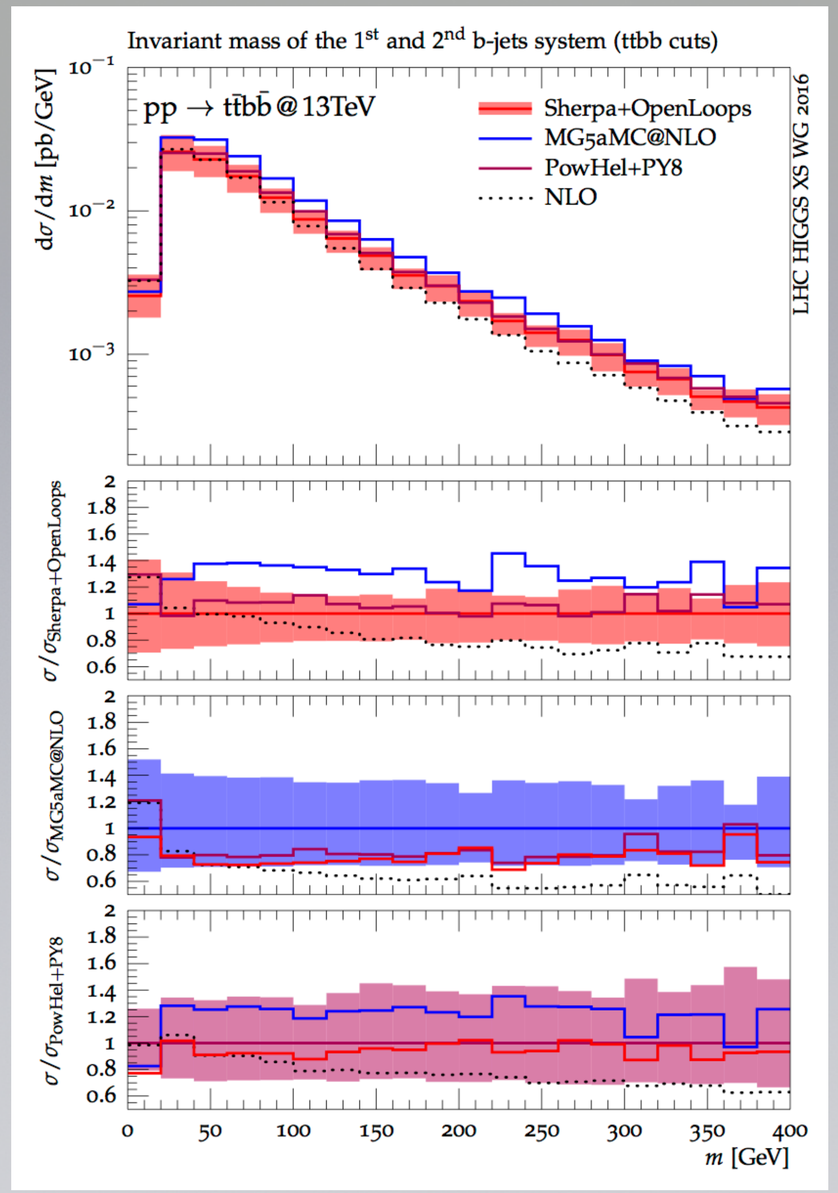


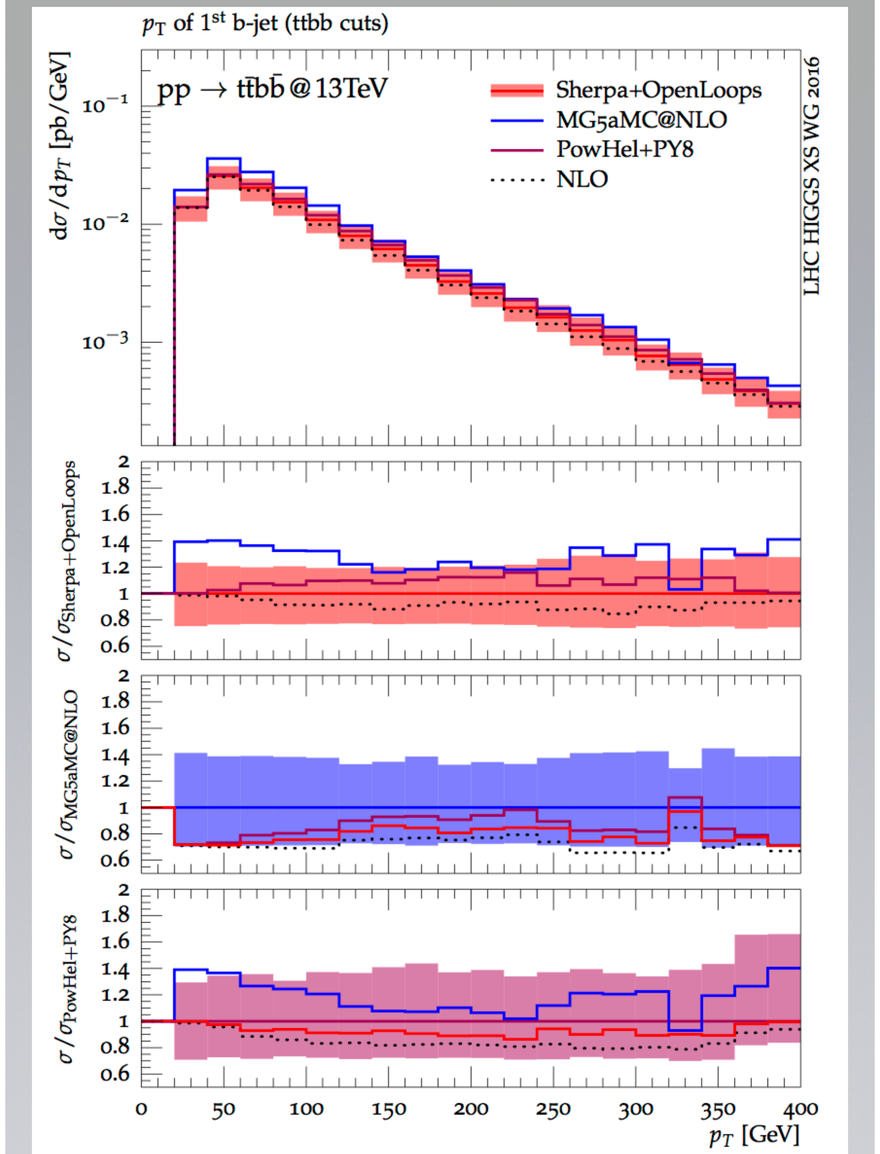


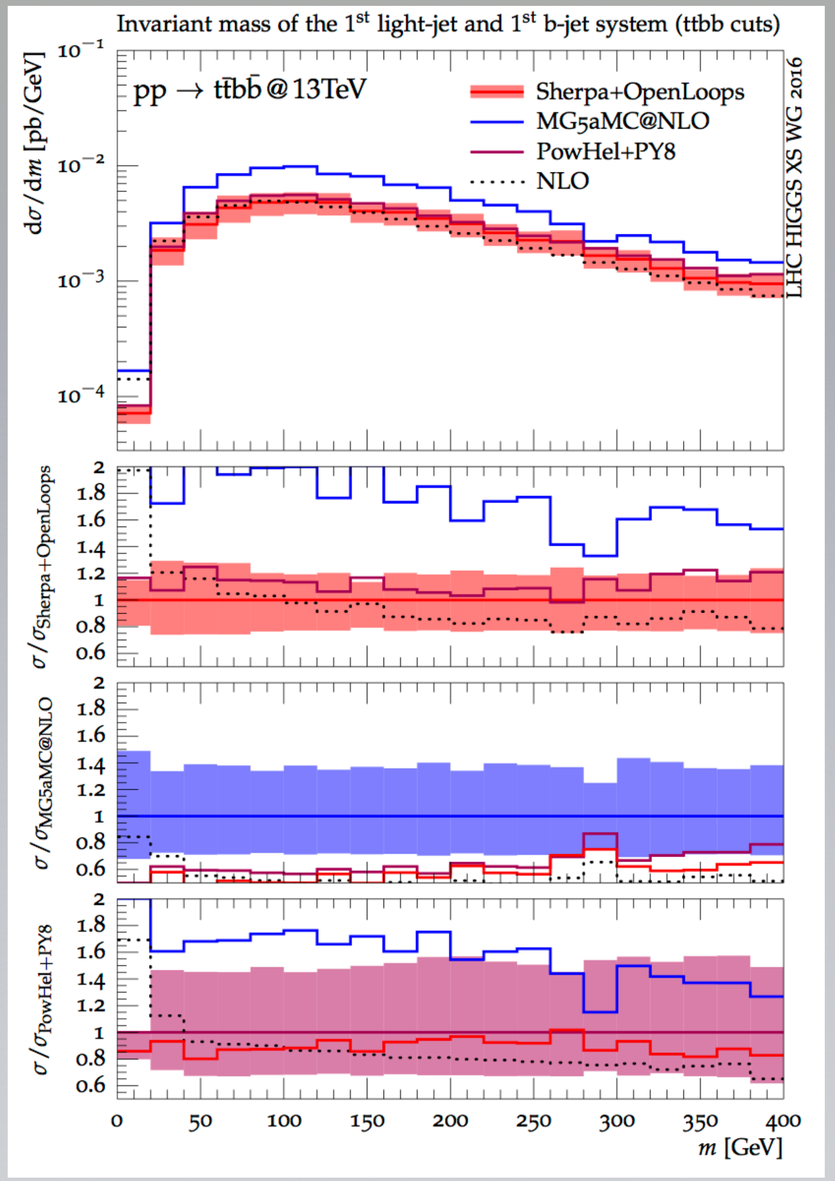
- $\alpha_S(k_\perp)$ gives a much harder spectrum
- $\alpha_S(m_{b\bar{b}})$ is generally the preferred options…

(this should really be taken as an uncertainties though…)

$pp \to t\bar{t}H(b\bar{b})$ YR4 Comparison

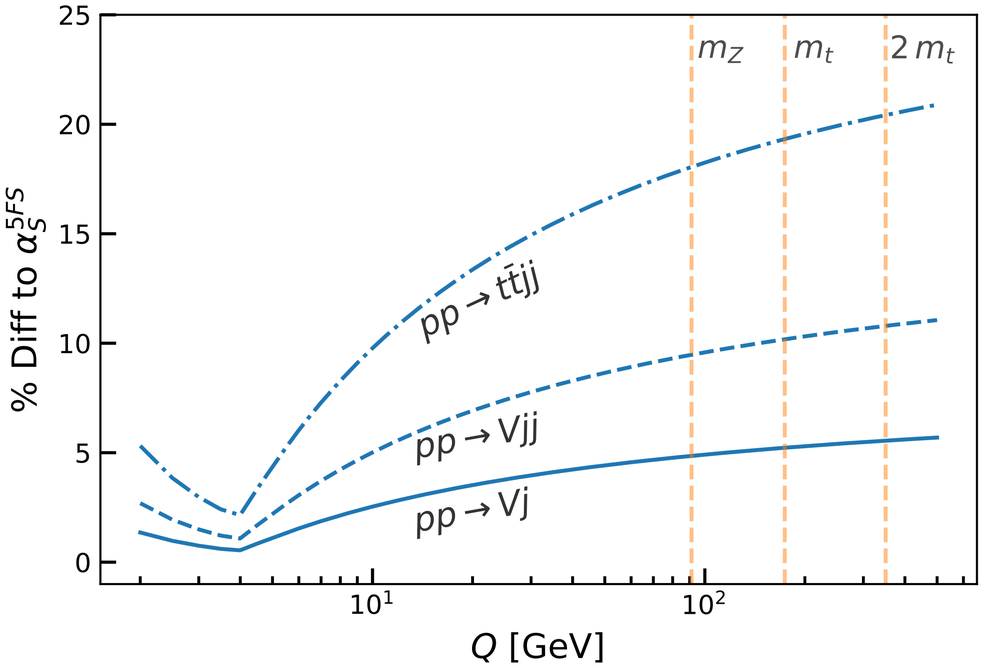






Running coupling

4FS vs 5FS: running coupling

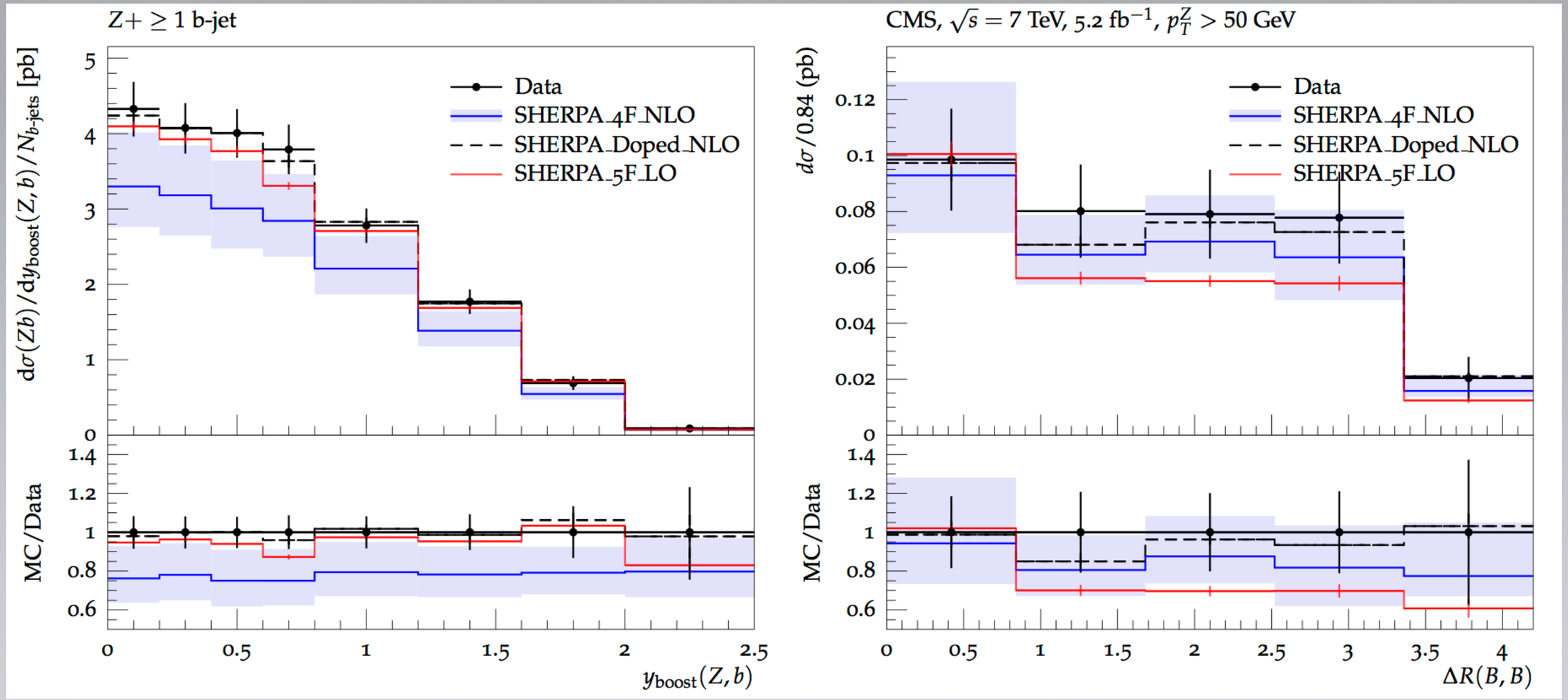


- Mass effects necessary
- but 4FS ~20% off…

- Doped PDFs
- Massive 5FS

Doped PDFs

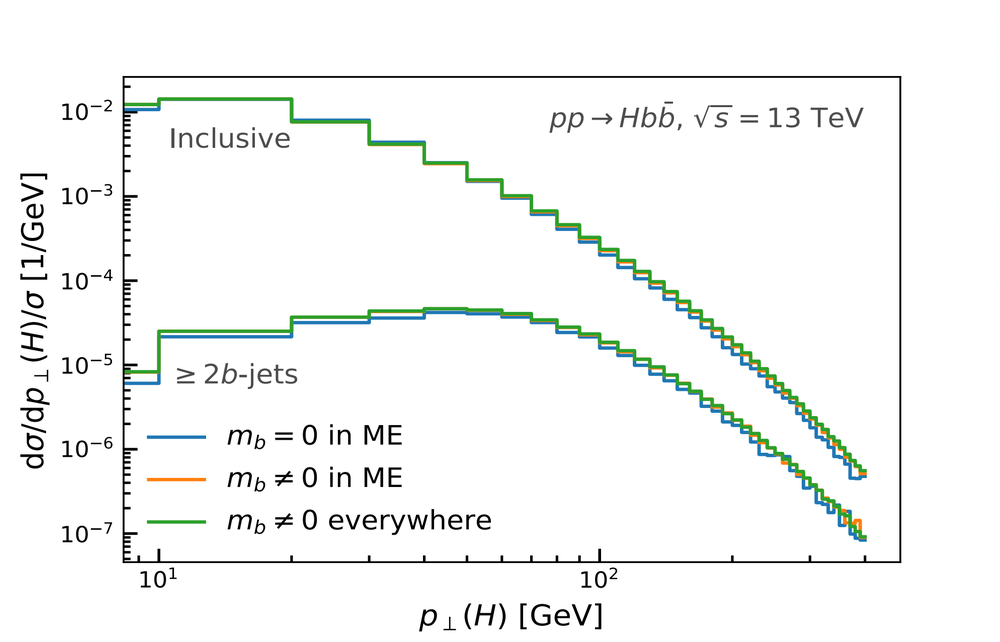
- Hybrid evolution: $\alpha_S^{5FS}(Q) \otimes P_{ij}^{4FS}$



Massive 5FS

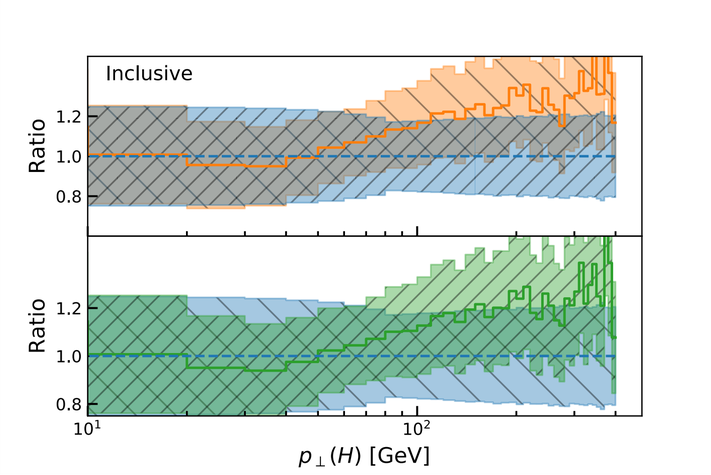
- Flavour scheme with 5 active flavour, with massive-bs
- Problem(s):
    - Factorisation beyond NLO
    - PDFs (must include massive splitting kernels)
    - Same for shower

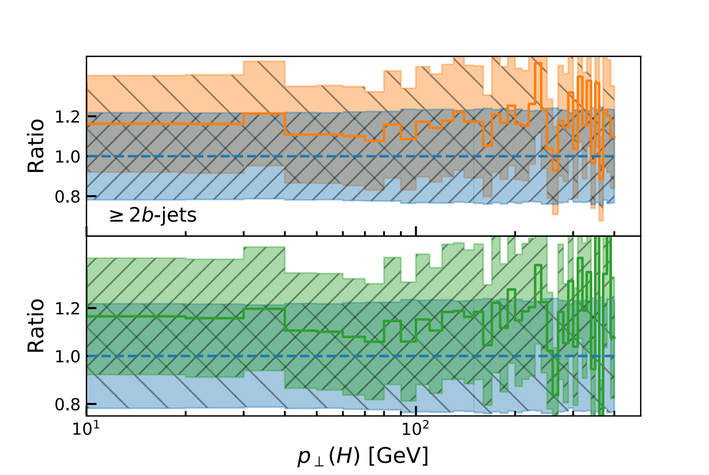
Massive 5FS @ LO, $pp \to Hb\bar{b}$



(Bands are 7-point scale vars)

- m_b in Matrix Elements (trivial)
- m_b in II/IF dipoles in shower
- not so negligible effects
- working to have massive 5F@MC@NLO





- fits with intrinsic b-PDF (Forte-Giani)
- will also remove m_b dep from PDF

Conclusions

- Still quite a few open questions:
  - How much difference does it make to choose 4FS or 5FS ?
  - Can we produce a recipe? Some studies seem to suggest yes… (Maltoni, Ridolfi, Ubiali)
- What's the effect of $g \to b\bar{b}$ splitting, really?
  - Probably more importantly: do we assess the various uncertainties right?
- Is there such a thing as a "sensible" scale choice?
  - or are we simply limited by the large scale dependency of our LO tools?