Heavy flavour (production) at the LHC in Run 2

An experimental perspective

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Heavy flavour in Run 2

▶ 8 TeV → 13 TeV: more energy = more
  σ_{bb}... but not really key, many other
  things grow at least as fast

▶ But increased emphasis on precision
  and rare processes, esp. Higgs → bb
  channels (ttH and VH)

▶ Also much-enhanced cross-sections
  in boosted phase-space: cool, but
  means signal and $g \rightarrow bb$ overlap

▶ **How well can we understand the
  background QCD b production
  (and decay ⇒ tagging/reco
  performance)?**

▶ And can being smart about SM
  physics complement "data mining"
 experimental techniques?

proton - (anti)proton cross sections
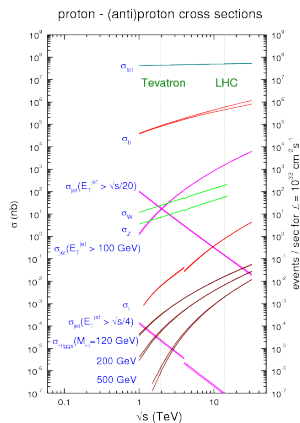
bb modelling in MC

- ▸ $g \to bb$ gluon splitting to HF not necessarily well modelled by parton shower: no divergence in splitting function, so is collinear expansion good?

- ▸ How about…
  - HF production in PDF evolution, and their interfacing to MEs and showers?
  - Flavour-number schemes? Is there a globally optimal scheme? Are there obviously *locally* optimal schemes?
  - Mass schemes? Scale choices? Matching details?
  - How to *realistically* minimise these theory uncertainties?

- ▸ *So many issues/channels/observables, so little (my) certainty!*
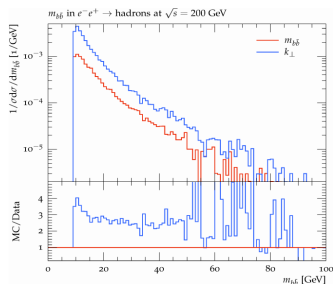
Gluon splitting scale-dependence, FK 2013?
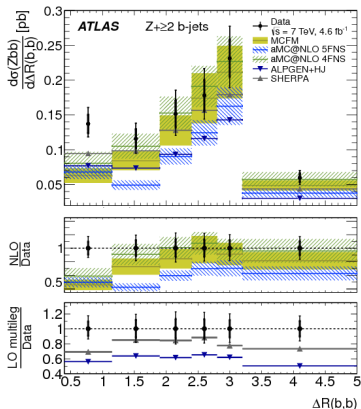
MC vs. data
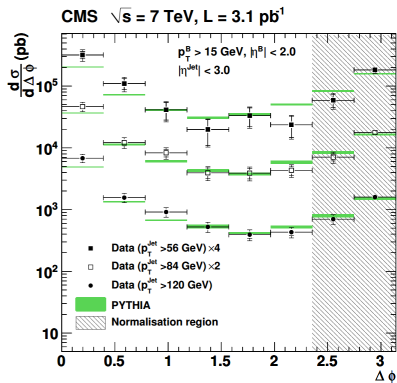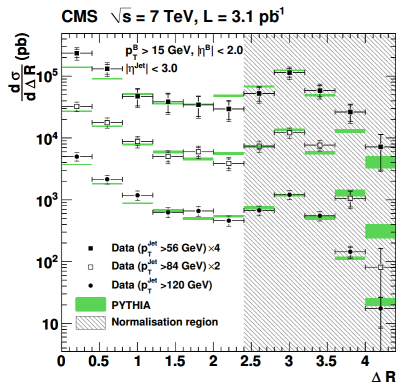
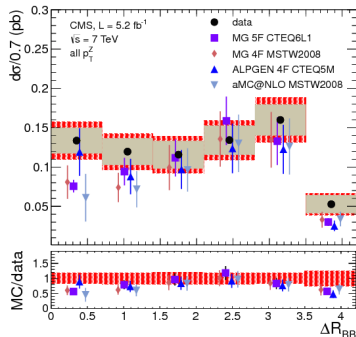CMS inclusive *bb* from secondary vertices [arXiv:1102.3194]

Rivet: CMS_2011_S8973270

MC vs. data

ATLAS $Z + bb$ [arXiv:1407.3643]
Rivet: ATLAS_2014_I1306294

CMS $Z + bb$ [arXiv:1310.1349]
Rivet: CMS_2013_I1256943

Questions for theorists

More questions from expt to theory than *vice versa*...so far

"If you like eating sausages..."

Questions for theorists
Experimental measurement strategy

- Which are are the most important analysis observables to tie down HF, particularly in $V + b(b)$? What precision is needed to be useful?
- Are particular kinematic regimes expected *a priori* to be either very sensitive or very insensitive to the HF schemes in MC generators?
- Both theory and experiment uncertainties reduce in ratio observables. Are the theory reductions "accidental", e.g. how independent are light and HF scale choices? Do more precise measurements via ratios just correspond to insensitive theory regions?

Questions for theorists
PDFs and matrix elements

- ▶ All HF flavour measurements for hadron colliders are in pole mass scheme. Is this the best scheme for LHC, cf. use of $\overline{\text{MS}}$ at LEP and renormalons in relating the two?
- ▶ How hard is it to generate asymmetric PDFs for charm (and strange)?
- ▶ How far can we trust scale variations to estimate uncertainties on processes that don't appear at leading order in 4-flavour schemes?
- ▶ How low in p_{T} should we trust pQCD predictions of HF jets? Can measurements at low-p_{T} constrain higher-p_{T} behaviour?

Questions for theorists

Flavour number schemes

- ▶ Should we be using 4- or 5-flavour scheme?! 4f significantly underestimates $Z + 1b$: is this fixable, or should we only use 4f for $2b$ final states?
- ▶ If we use 4f, what is the best way to do heavy flavour overlap removal (HFOR)? If we use 5f, what are we losing, and why?
- ▶ We are often told that for consistency with the PDF we should use a massless b in the ME for 5f calculations. Why does the b-mass have to be zero in the PDF? How significant would the mismatch effects be? How can it be best made consistent with massive bs further "downstream"?
- ▶ How do PDF and ME n_f interplay? We have Alpgen $V + $ jets samples using a 4f ME and a 5f PDF and they look fine!
- ▶ Why is the parton shower ISR evolution not good at producing the spectator b-quark kinematics in 5f, i.e. not a good approximation to 4f ME? Aren't these diagrams also contained in 5f?
- ▶ Should 4f vs. 5f always be used as (part of) HF theory systematics?

Questions for theorists

Shower HF production & decays

- ▶ What is the status of $g \to QQ$ in the shower MCs? Can we consistently get full/optimal coverage of model systematics?
- ▶ How well can low-p_T measurements of HF production kinematics (due to stats) constrain high-p_T behaviour?
- ▶ How does b-hadron decay mismodeling feed into tagging performance and the connected uncertainties? How best to address differences between generators? Would homogeneous use of EvtGen underestimate decay modelling systematics, and is there a lightweight way to perform variations?
- ▶ Could/would all MC generators standardise on a single decay table, collectively maintained?

And so we begin...

- Every workshop says that it's more about discussion than "push" presentations
- I hope it's actually true for this one!
- Please have fun, discuss lots, hopefully start off something productive...