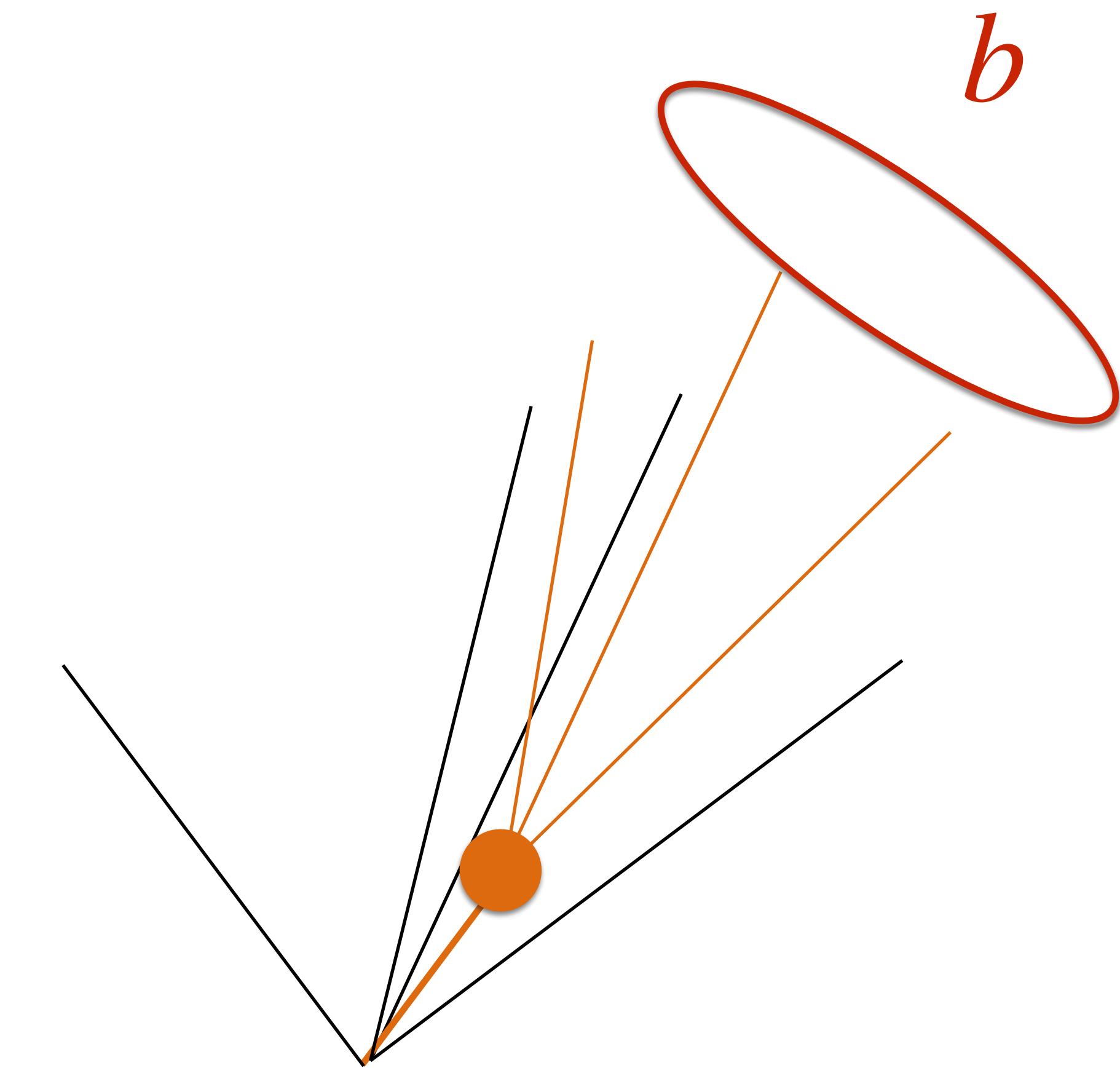


measuring b -fragmentation with ATLAS

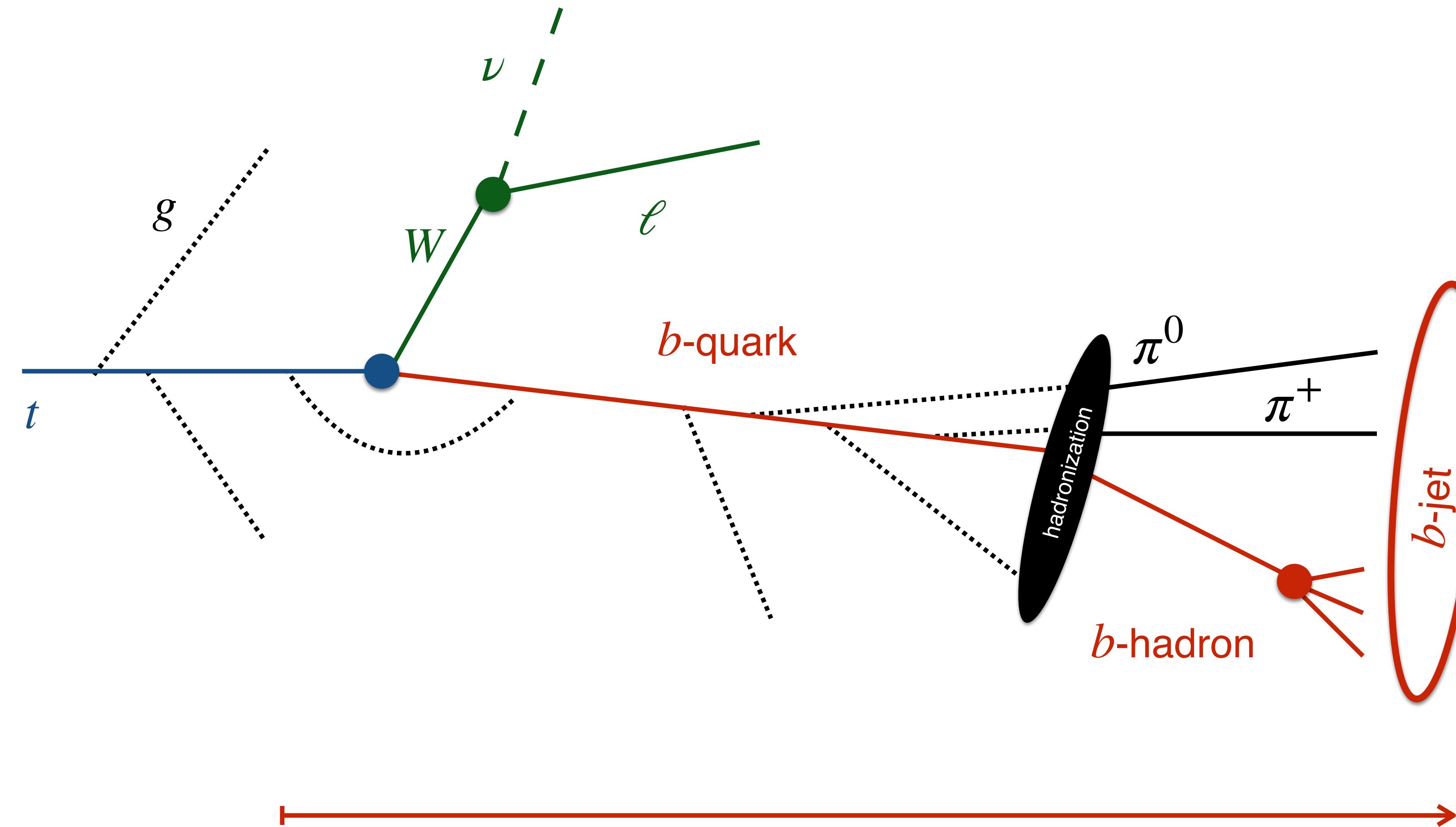


Chris Pollard
University of Warwick

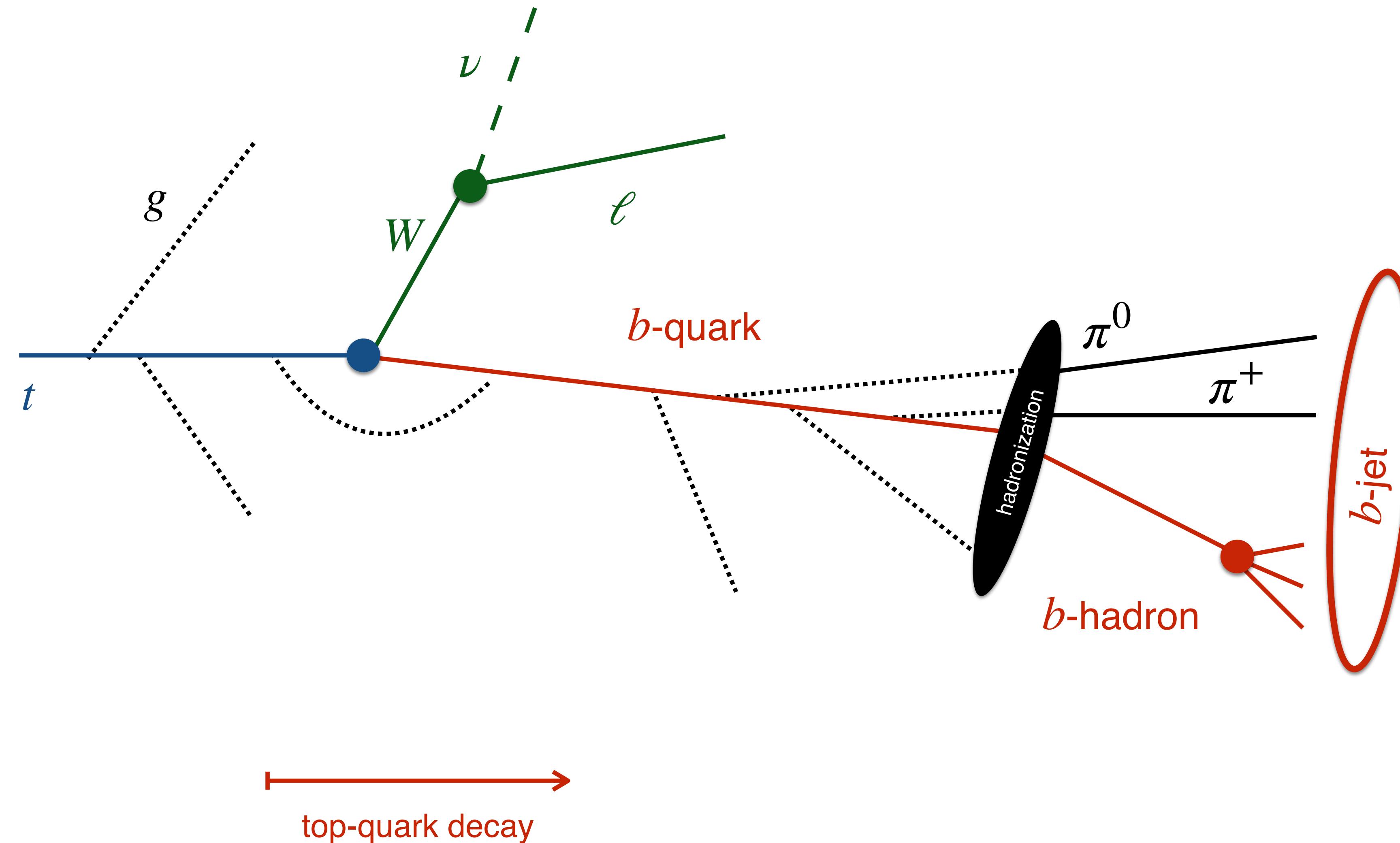
LHC EW WG meeting
2022 10 17



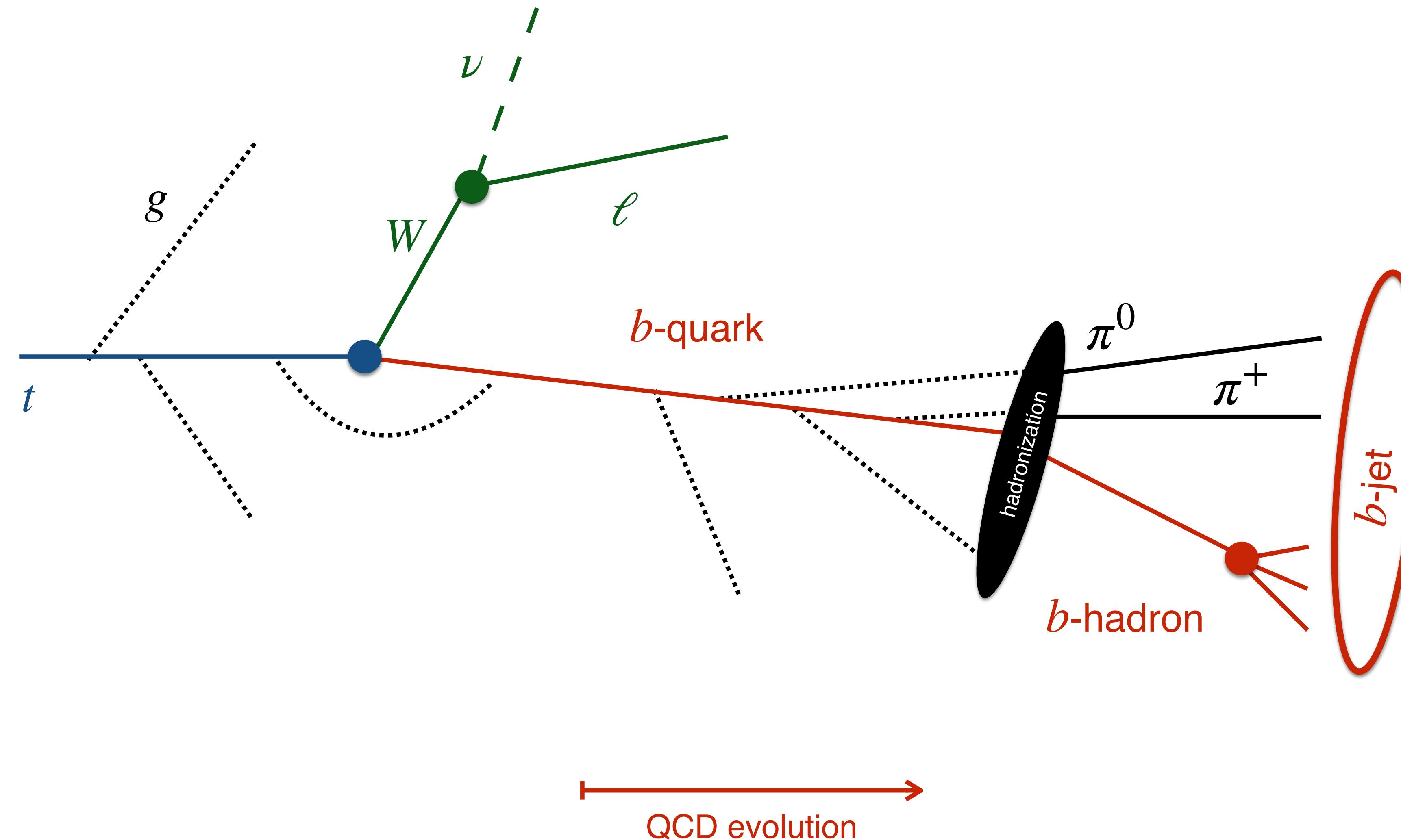
introduction



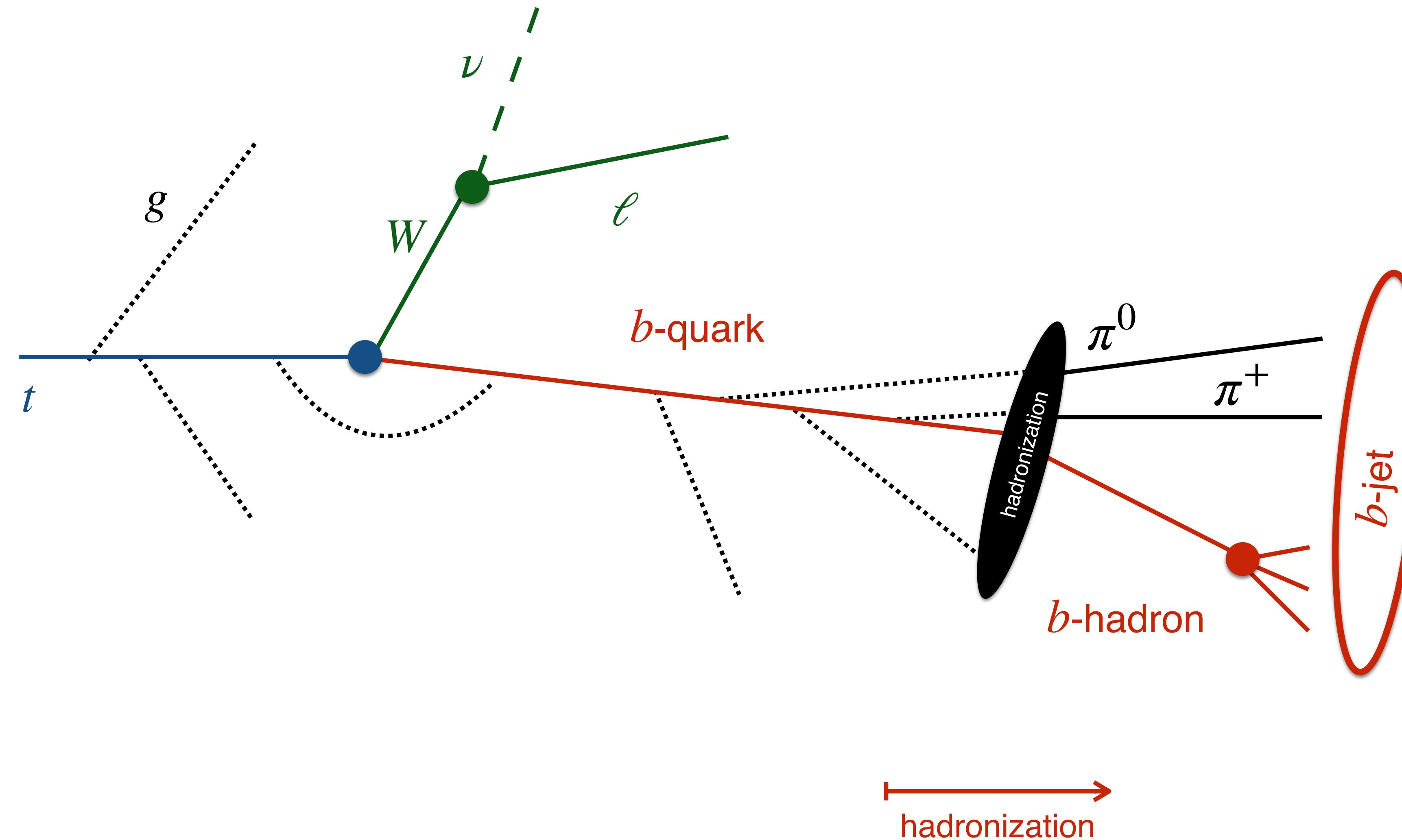
introduction



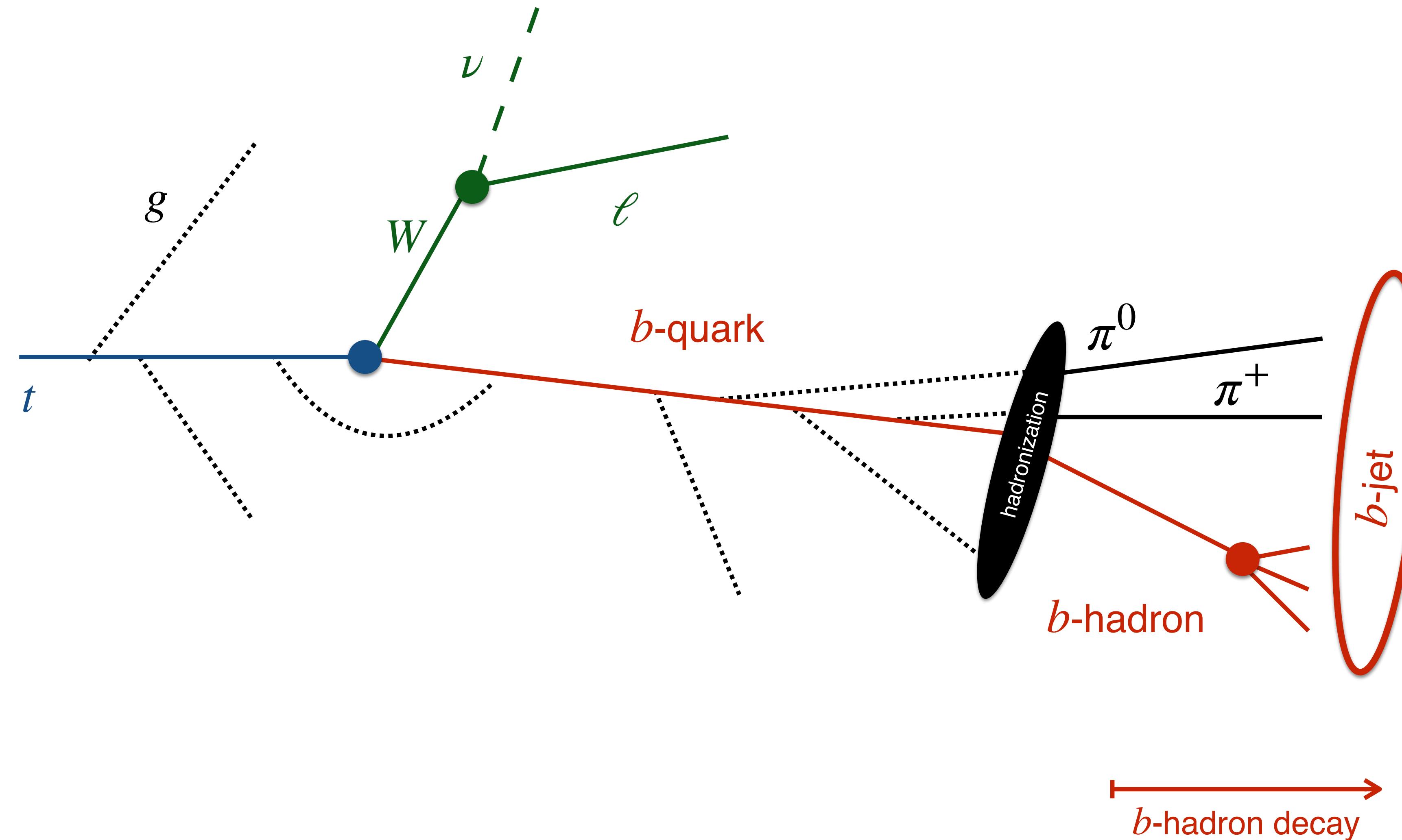
introduction



introduction



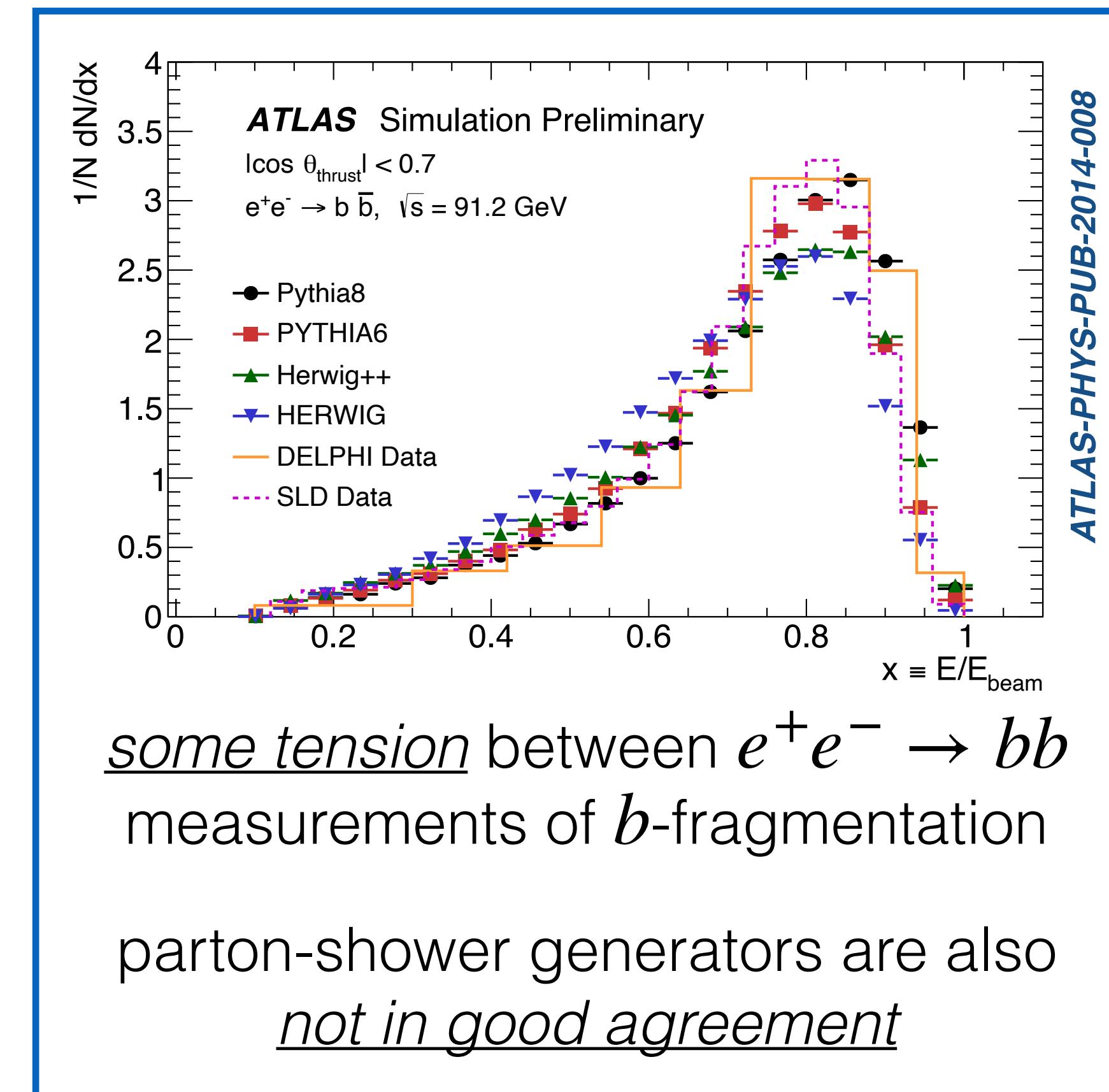
introduction



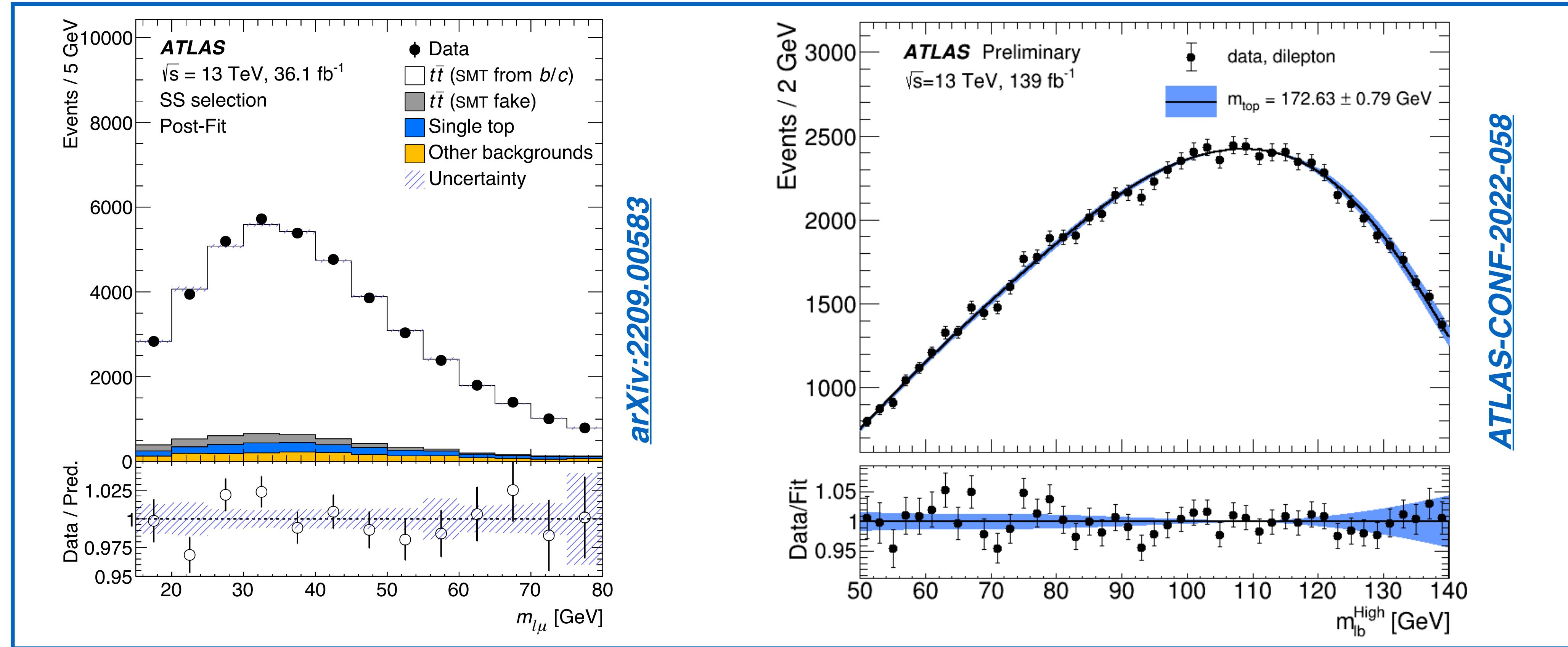
motivation I

the fragmentation of b -quarks into hadrons is of interest for many reasons.

- b -hadrons leave a striking experimental signature and...
- there is a unique correspondence to the originating b -quarks
 - ergo a precise probe of QCD
- b -fragmentation currently tuned to e^+e^- data (from $Z \rightarrow bb$ decays)
- ... then extrapolated to the LHC environment
 - to what degree is this correct?



motivation II



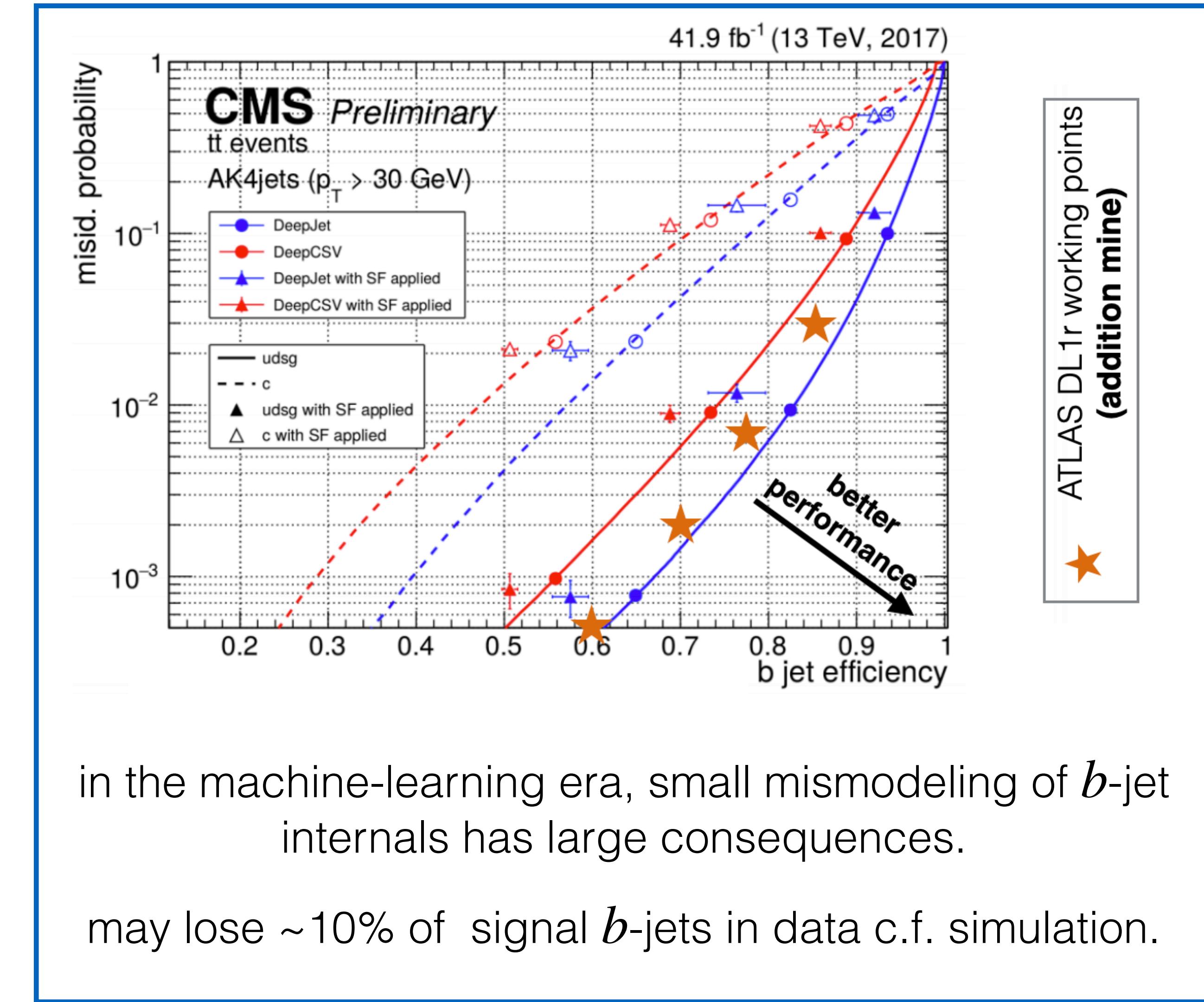
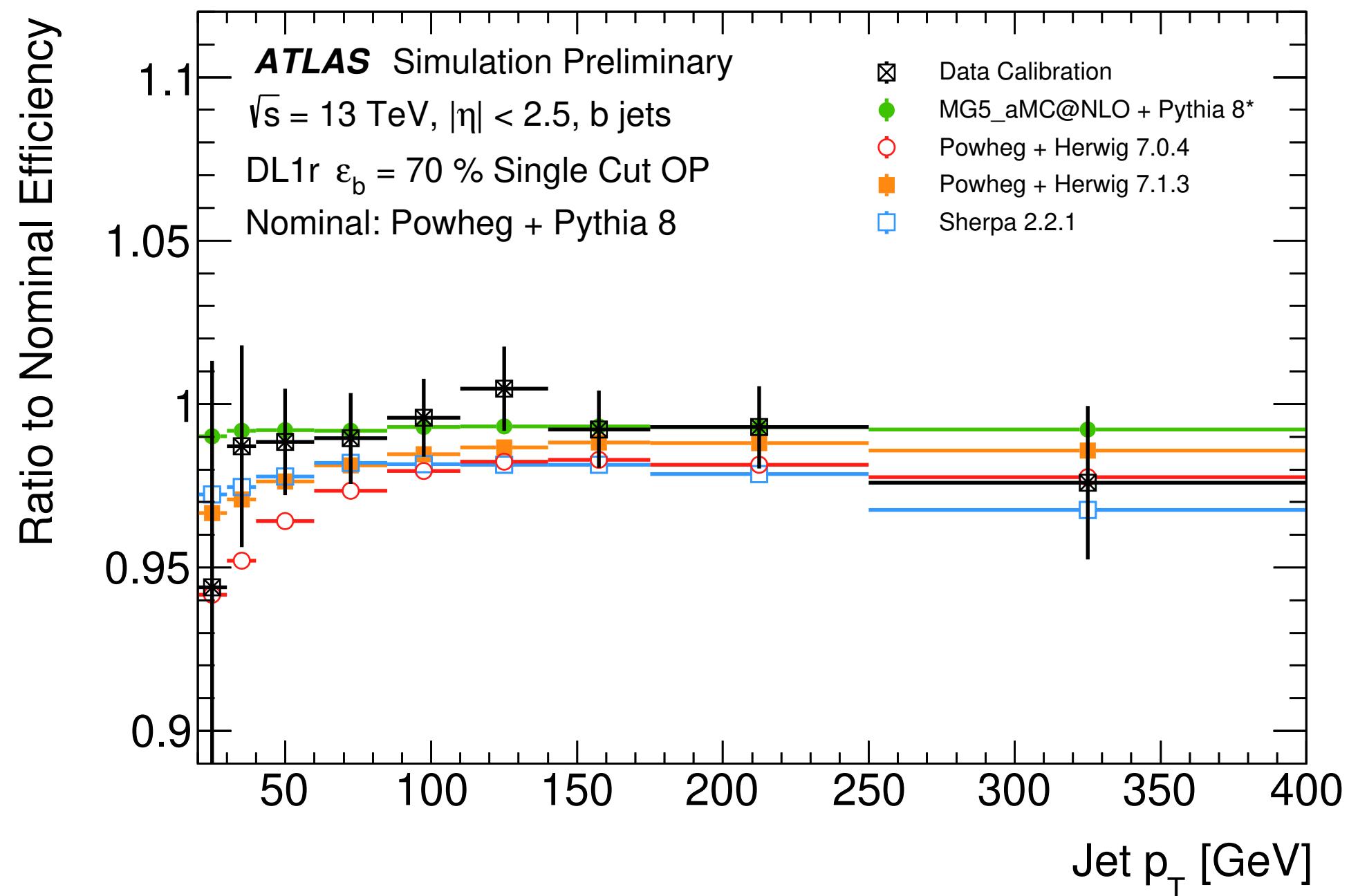
precision *direct top-mass measurements*
play a key role in the LHC's long-term m_t strategy.

top-quark $\rightarrow b$ -hadron momentum transfer is a key uncertainty!

motivation III

critical for delivering the best physics results with b -jets.

b -tagging efficiency and b -jet response are very sensitive to fragmentation.



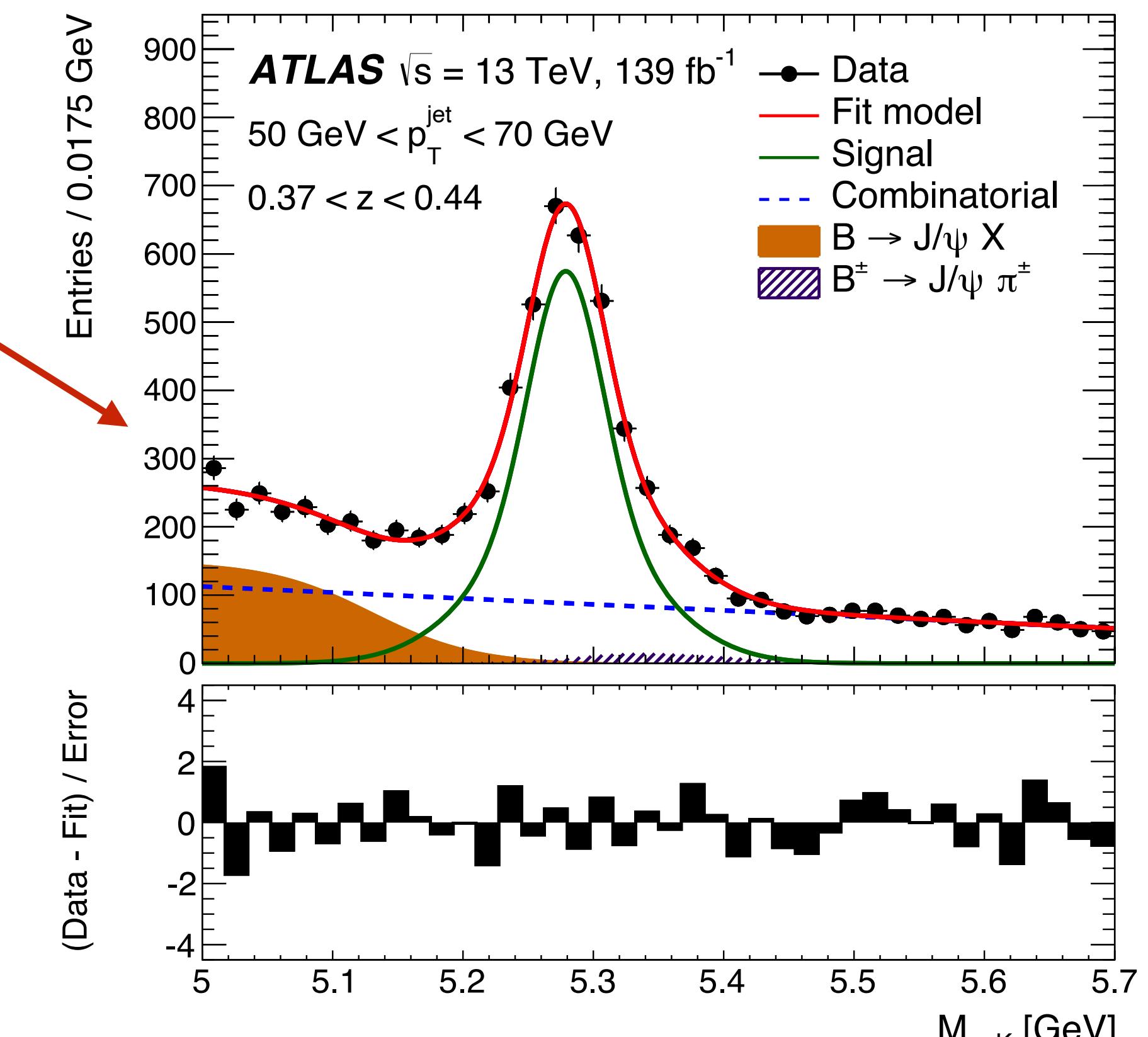
measurements

two recent measurements at ATLAS in dijet and $t\bar{t}$ final states

Short Title	Journal Reference	Date	\sqrt{s} (TeV)
b fragmentation in ttbar events at 13 TeV	Submitted to PRD	28-FEB-22	13
Exclusive b fragmentation at 13 TeV	JHEP 12 (2021) 131	26-AUG-21	13

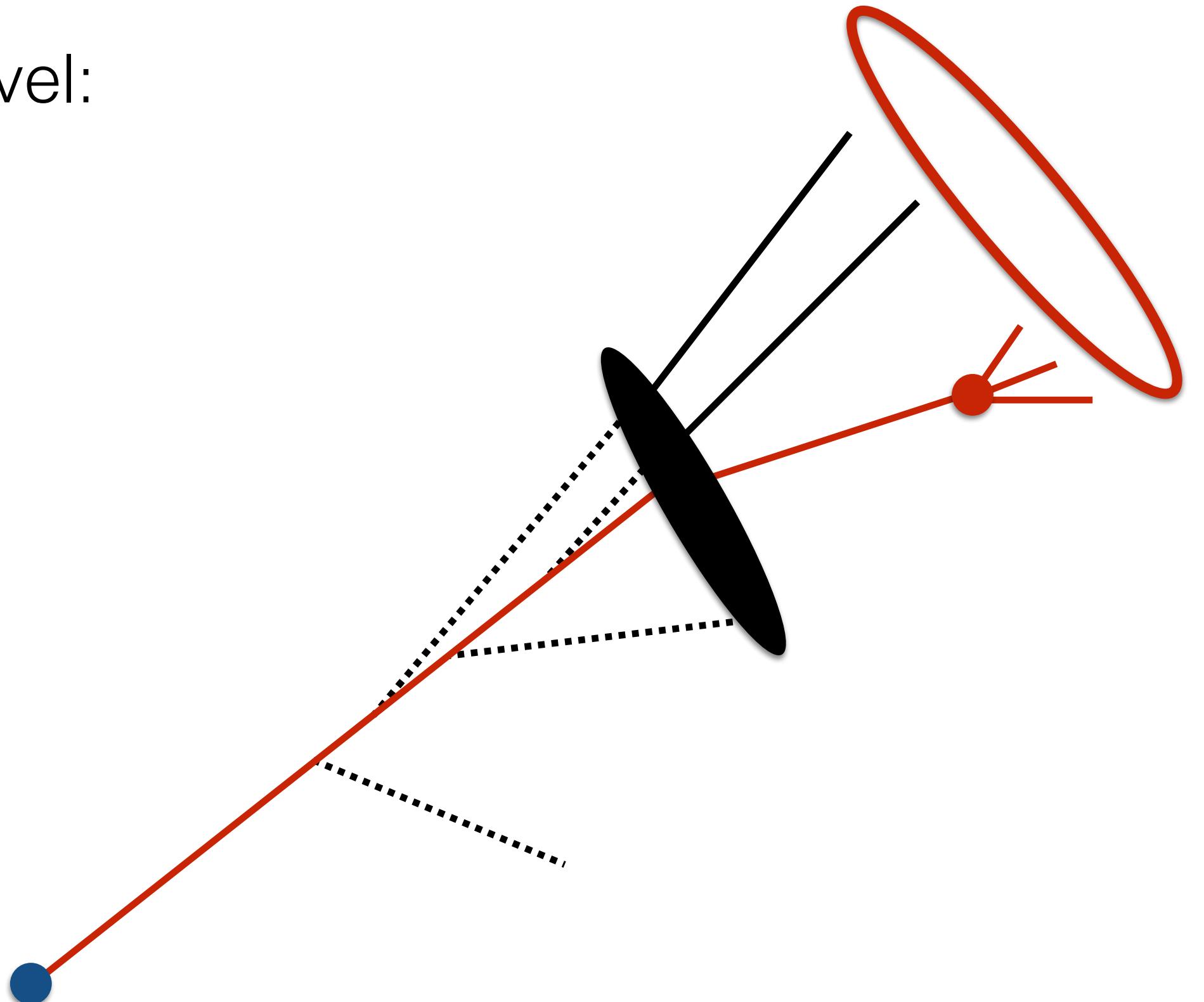
- provide excellent coverage where LEP data can't reach
 - and *extremely complementary* to each other
- this is the “first generation” of such measurements
 - many aspects could be improved!

[JHEP 12 \(2021\) 131](#), [PRD 106 \(2022\) 032008](#)

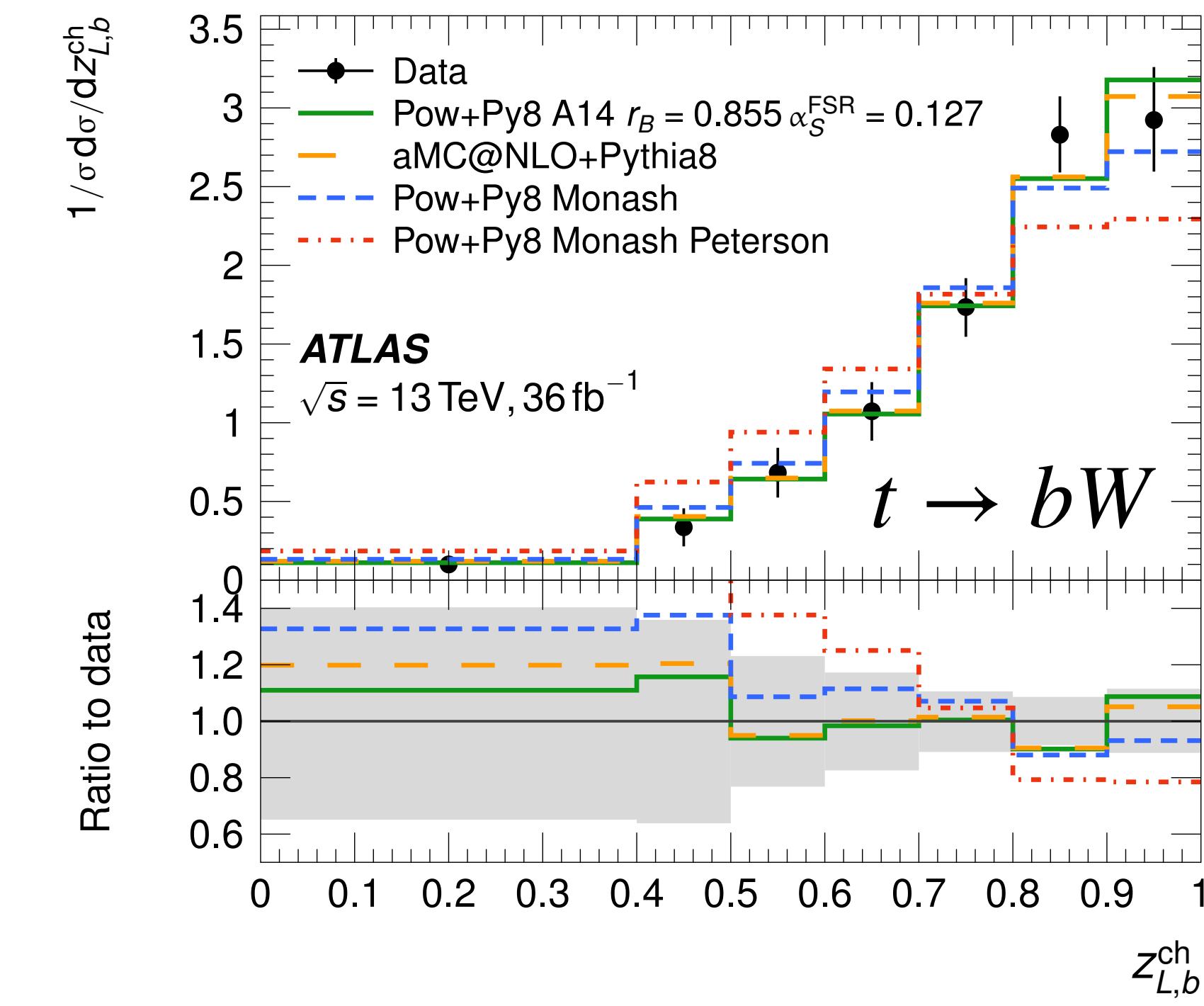
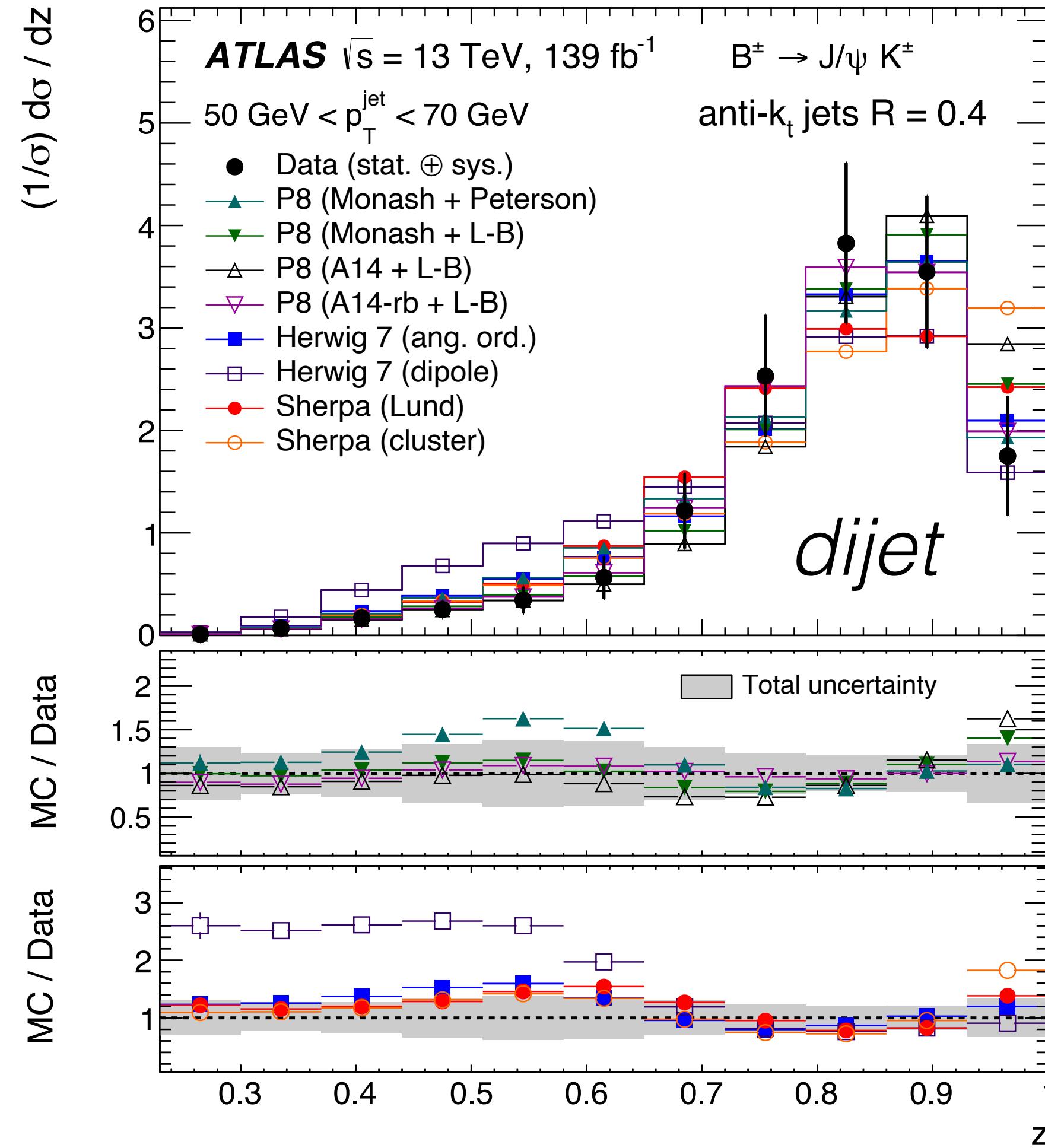


observables

- both measurements unfold related observables to particle level:
 - $z_{(L)} = \vec{p}_B \cdot \vec{p}_{jet} / p_{jet}^2$
 - $p_T^{rel} = |\vec{p}_B \times \vec{p}_{jet}| / |p_{jet}|$ (dijet only)
 - $\rho = p_T^B / \text{avg}(p_T^\ell)$ ($t\bar{t}$ only)
 - charged particle multiplicity, n_{ch}^B ($t\bar{t}$ only)
- dijet: measure full $B \rightarrow \mu\mu K$ and full jet momentum
- $t\bar{t}$: measure “charged momentum” of b -hadron and jet

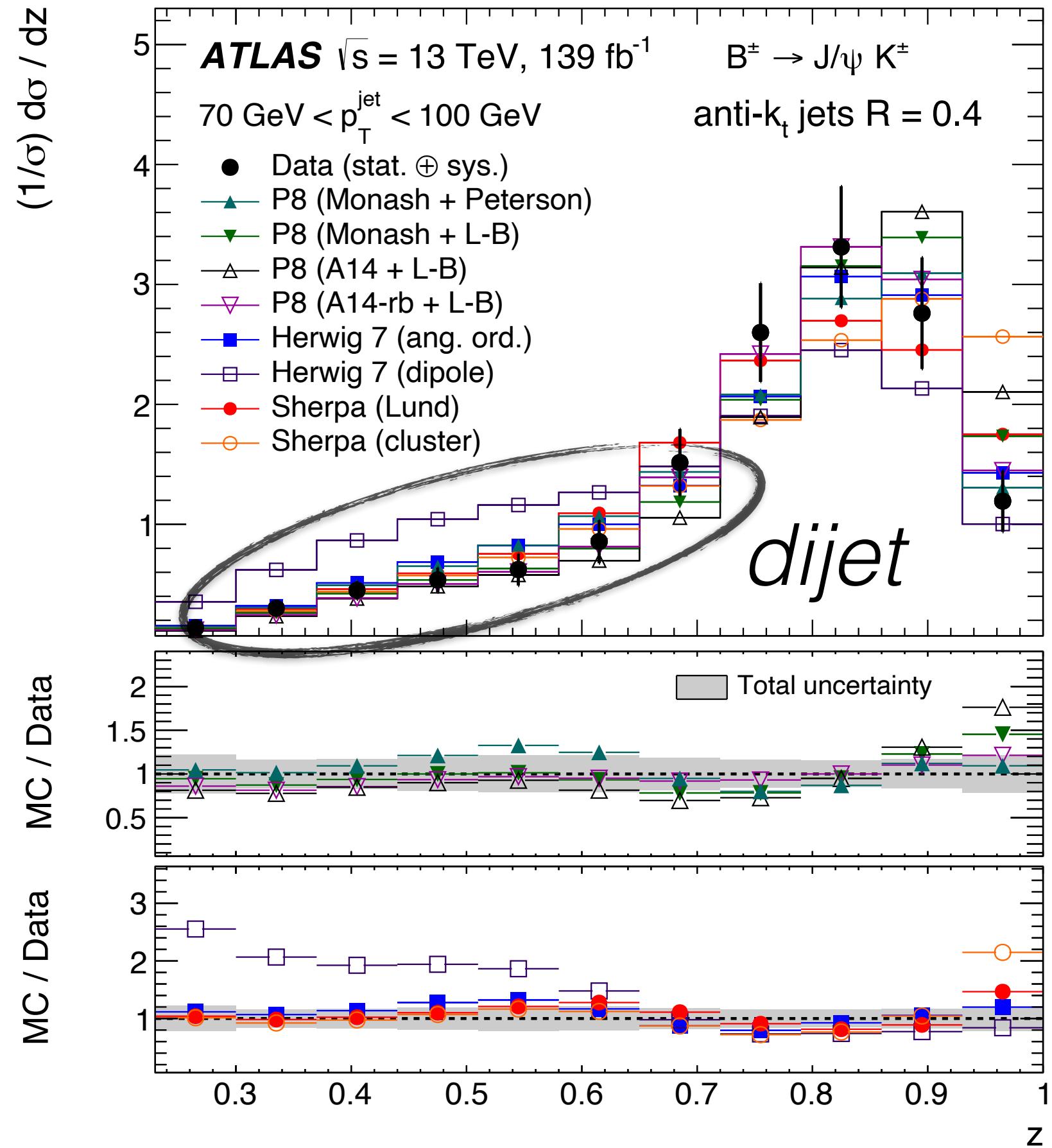


comparisons to data



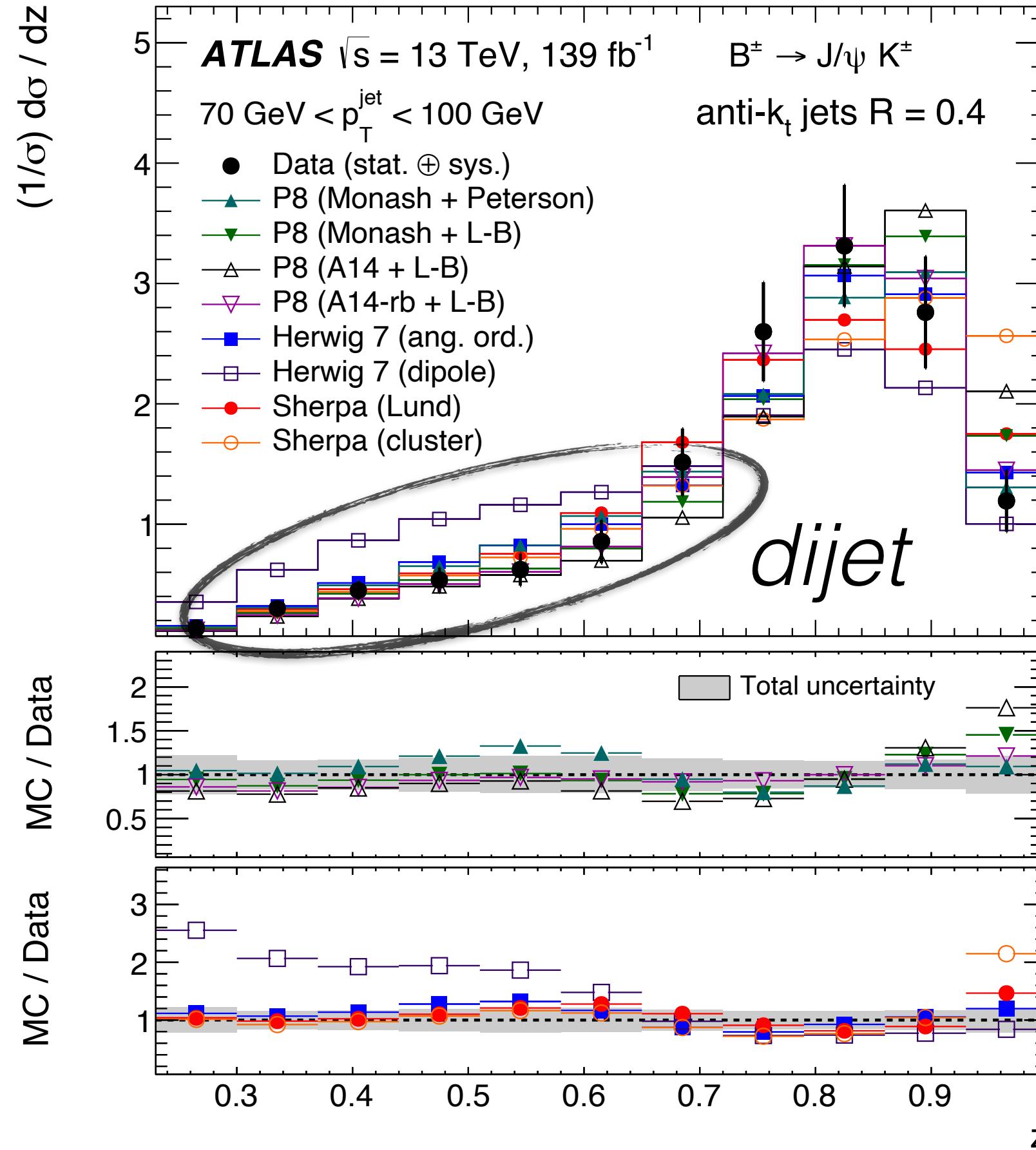
- ATLAS A14 tune + Lund-Bowler fragmentation tuned to A14 α_S^{FSR} performs best
- Peterson model strongly disfavored in both measurements
- Herwig 7.0 and some Sherpa versions are also disfavored, but improvement in later versions and with some tuning.

comparisons to data



clear issues with low- z
spectrum for some
generators

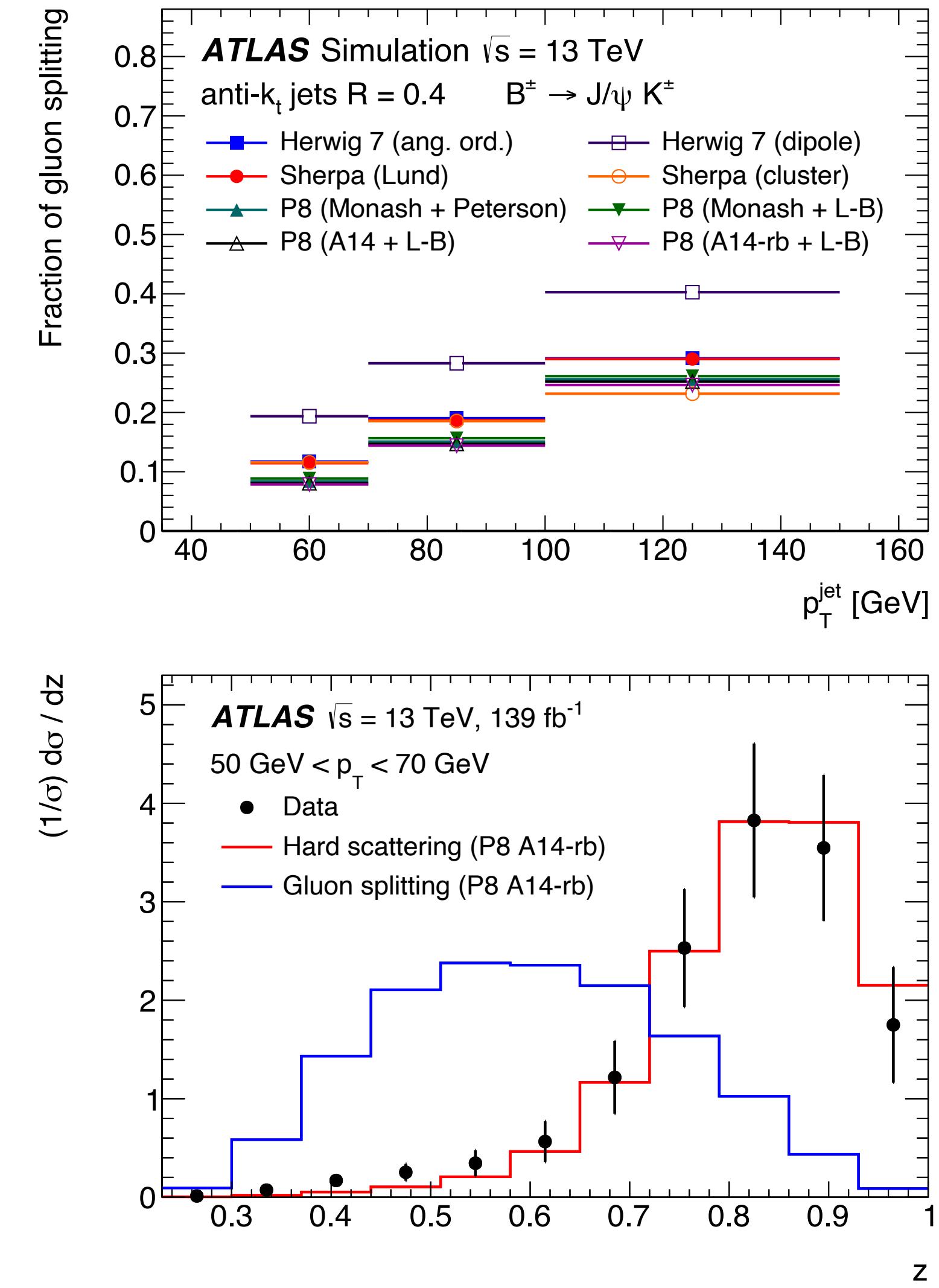
comparisons to data



clear issues with low- z spectrum for some generators

likely due to
mismodeled
 $g \rightarrow bb$ fractions

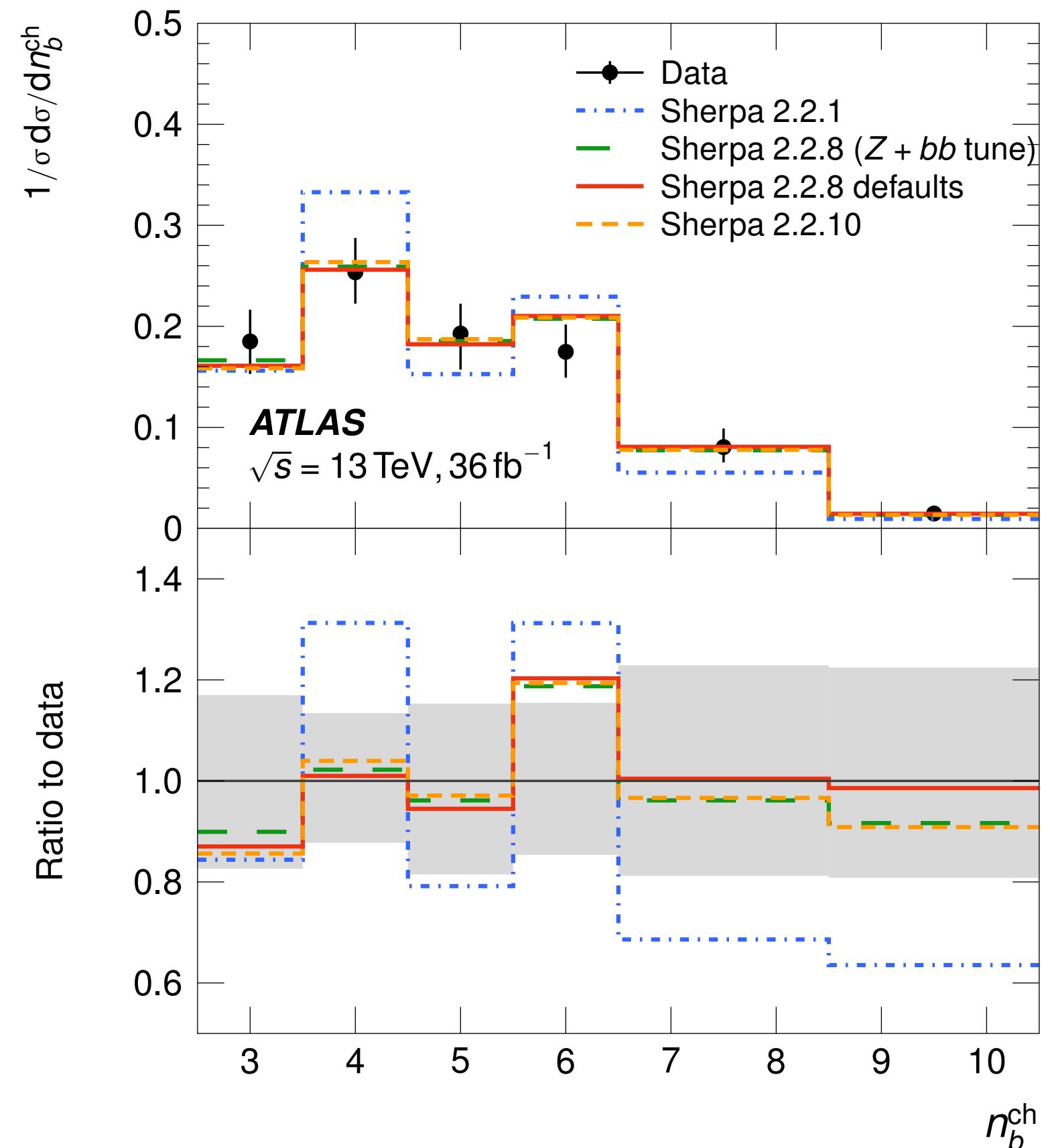
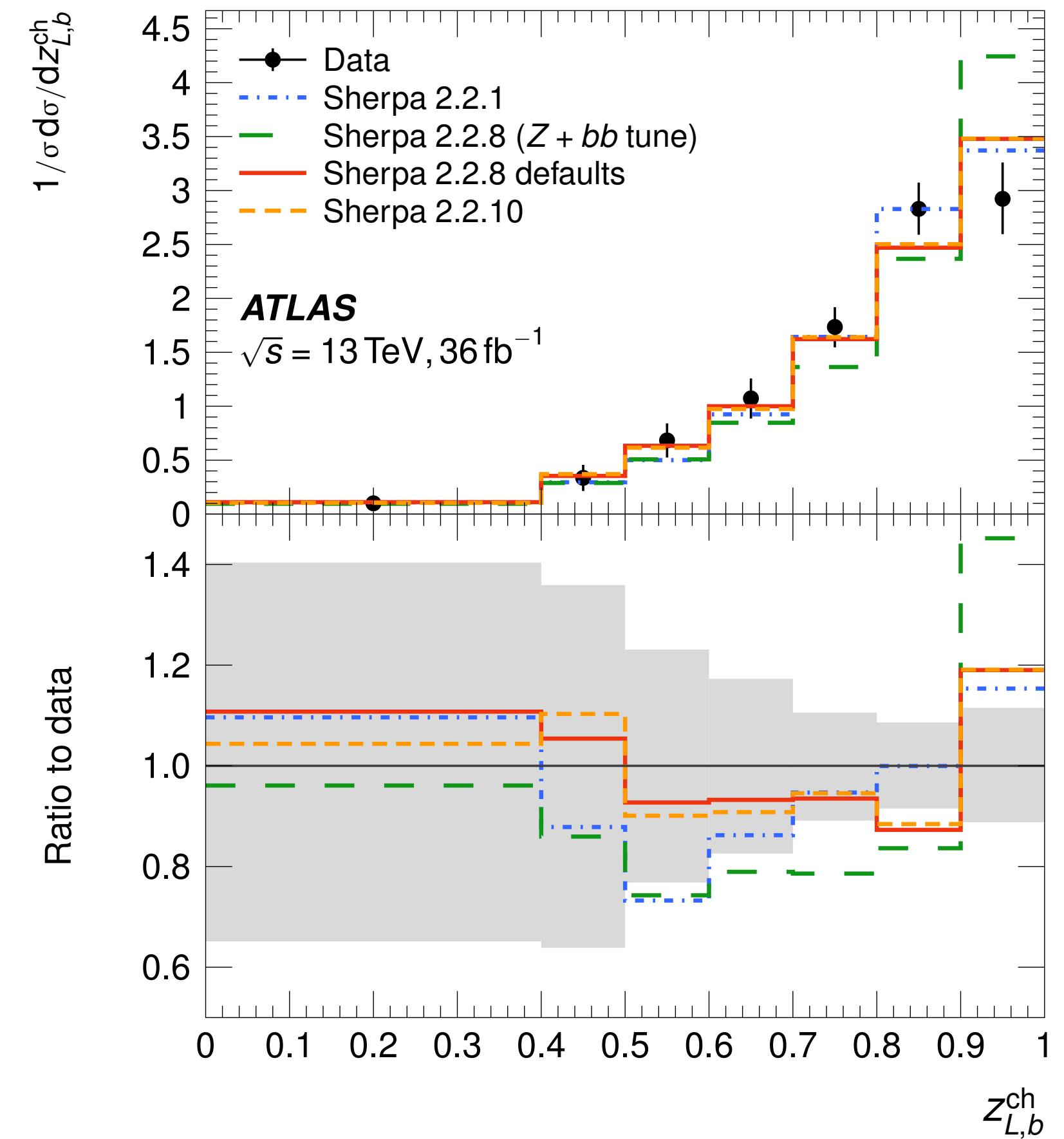
$t \rightarrow bW$ analysis can
help disentangle effects
(no $g \rightarrow bb$ jets)



comparisons to data

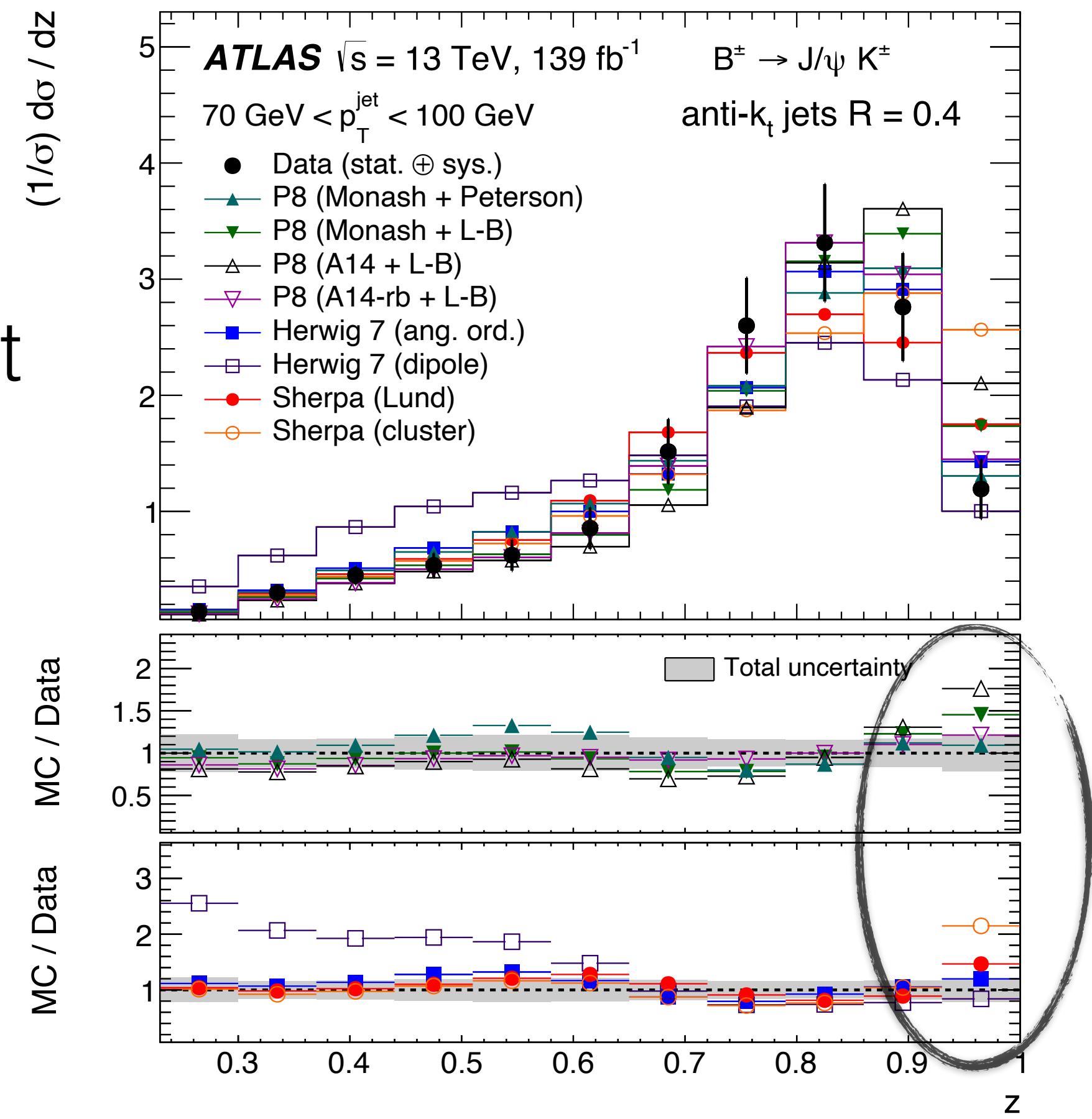
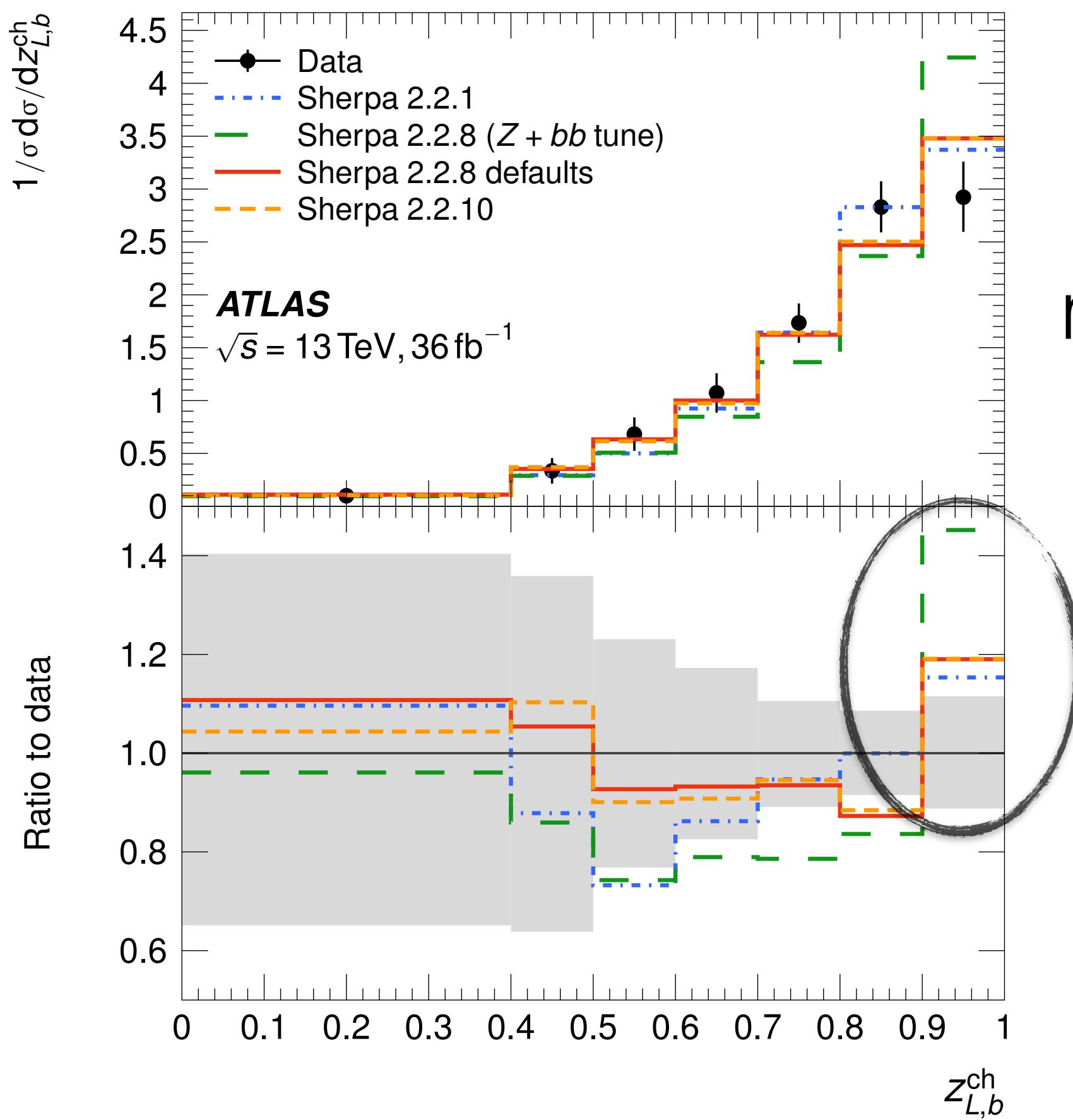
beware!

details of b -fragmentation
and top-quark decays
*depend strongly on
parameters that need
to be carefully chosen
in current MC generators.*



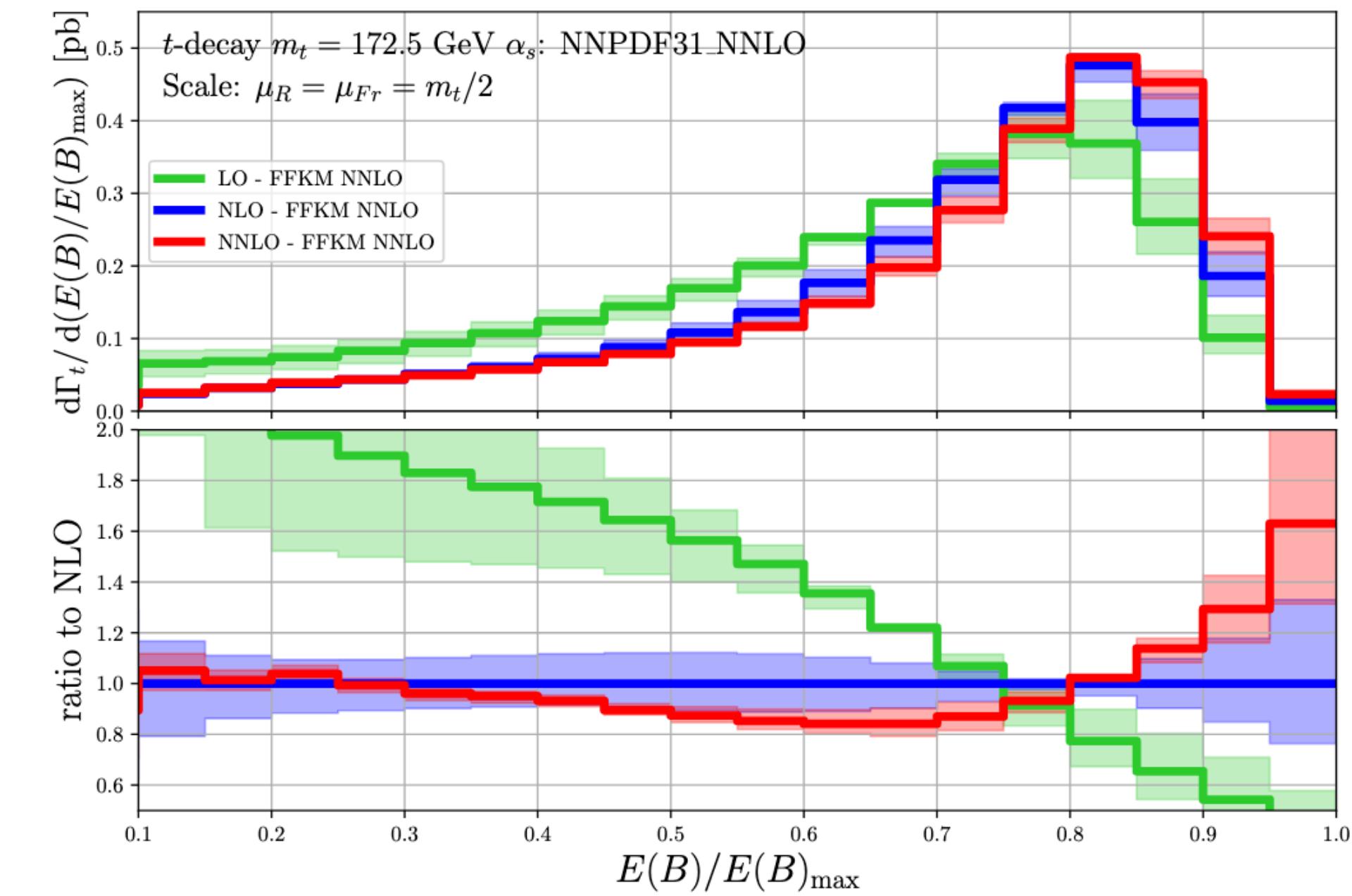
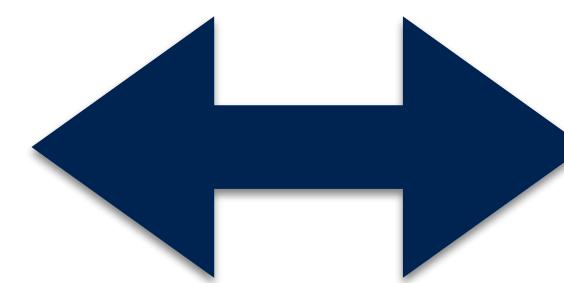
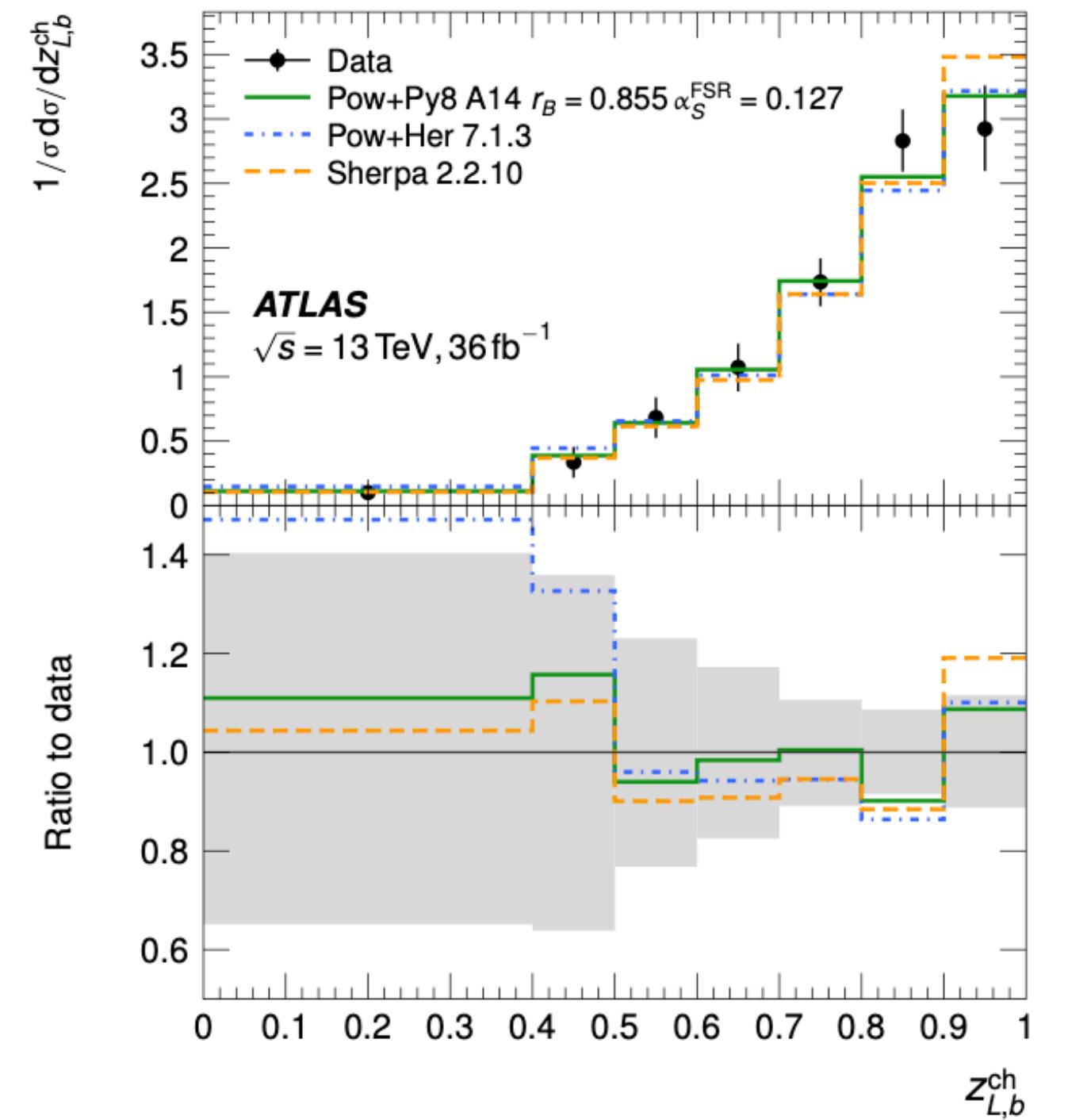
correlated mismodeling

some correlated
mismodeling independent
of b -quark source



comparisons to calculations

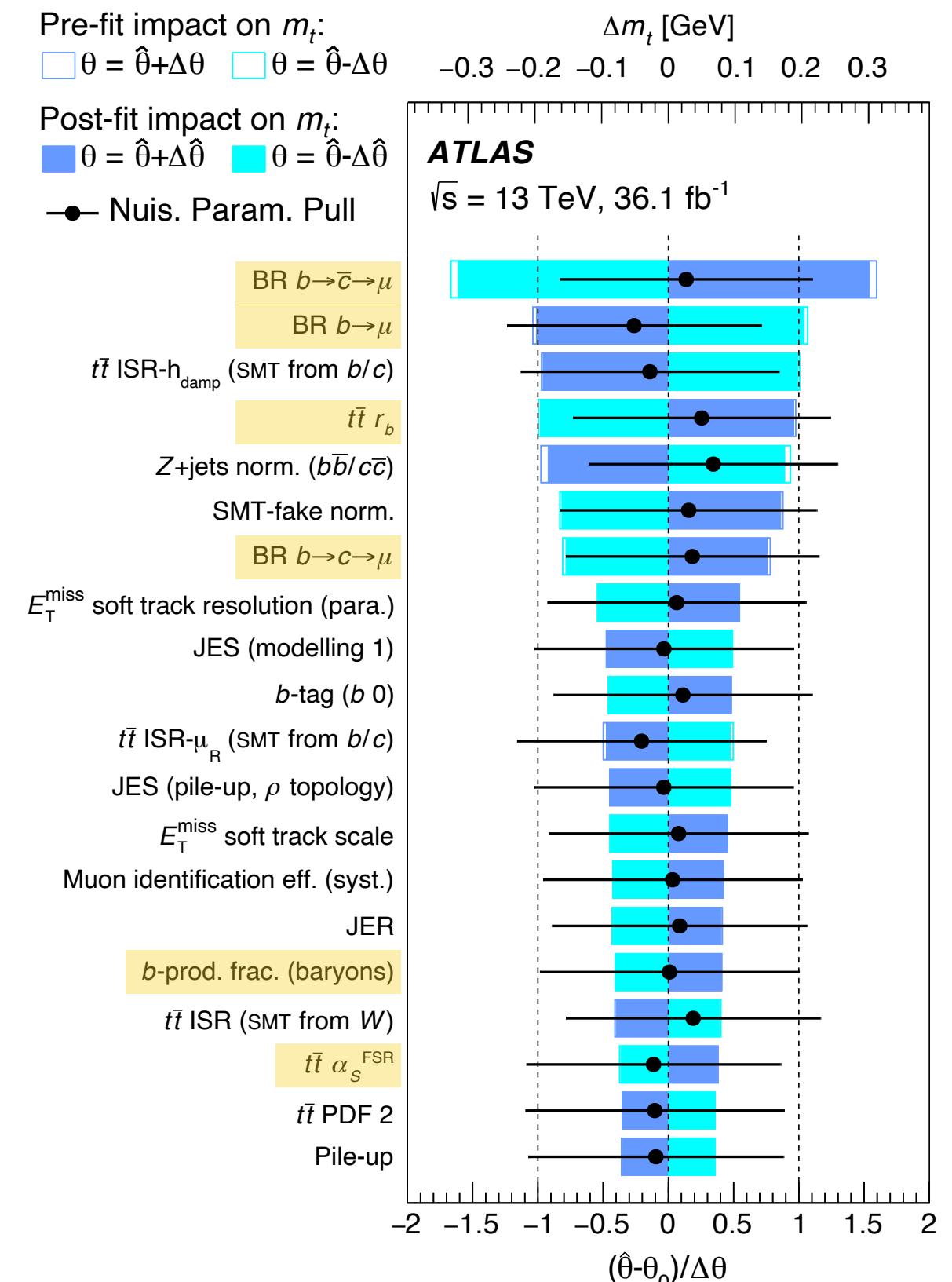
- to support more precise direct top-mass measurements, first ~analytic calculations of similar distributions
- substantial interest in comparing unfolded data
- challenging, though: probably needs interface to hadronization MC.



arxiv:2102.08267

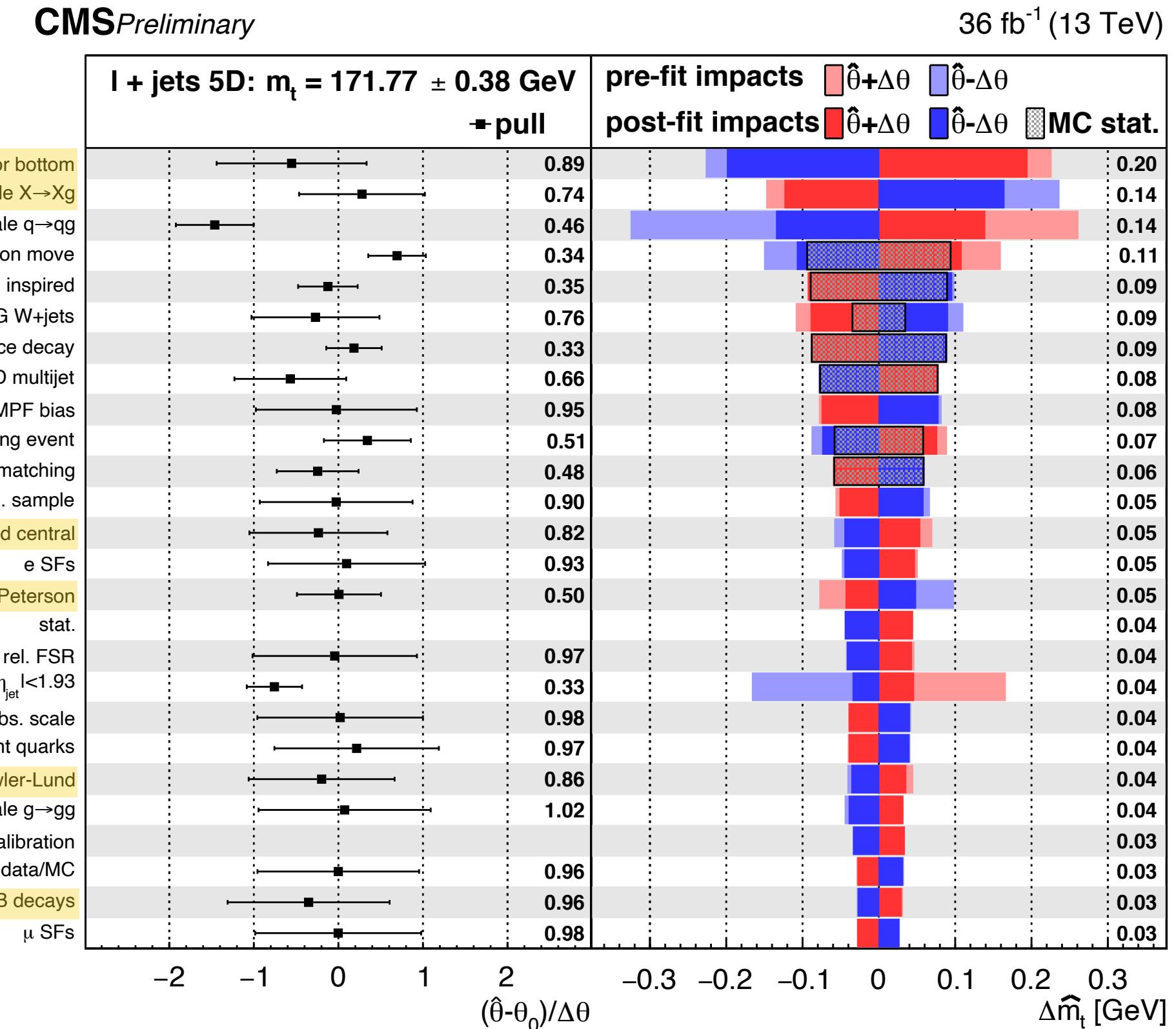
impact on top mass analyses

	m_{top} [GeV]
Result	172.63
Statistics	0.20
Method	0.05 ± 0.04
Matrix-element matching	0.35 ± 0.07
Parton shower and hadronisation	0.08 ± 0.05
Initial- and final-state QCD radiation	0.20 ± 0.02
Underlying event	0.06 ± 0.10
Colour reconnection	0.29 ± 0.07
Parton distribution function	0.02 ± 0.00
Single top modelling	0.03 ± 0.01
Background normalisation	0.01 ± 0.02
Jet energy scale	0.38 ± 0.02
b-jet energy scale	0.14 ± 0.02
Jet energy resolution	0.05 ± 0.02
Jet vertex tagging	0.01 ± 0.01
b-tagging	0.04 ± 0.01
Leptons	0.12 ± 0.02
Pile-up	0.06 ± 0.01
Recoil effect	0.37 ± 0.09
Total systematic uncertainty (without recoil)	0.67 ± 0.05
Total systematic uncertainty (with recoil)	0.77 ± 0.06
Total uncertainty (without recoil)	0.70 ± 0.05
Total uncertainty (with recoil)	0.79 ± 0.06



[ATLAS-CONF-2022-058](#)

[arXiv:2209.00583](#)



[CMS-PAS-TOP-20-008](#)

recent top mass analyses from ATLAS and CMS are dominated by uncertainties related to QCD radiation in top-quark decays, b -fragmentation, and b -decays.

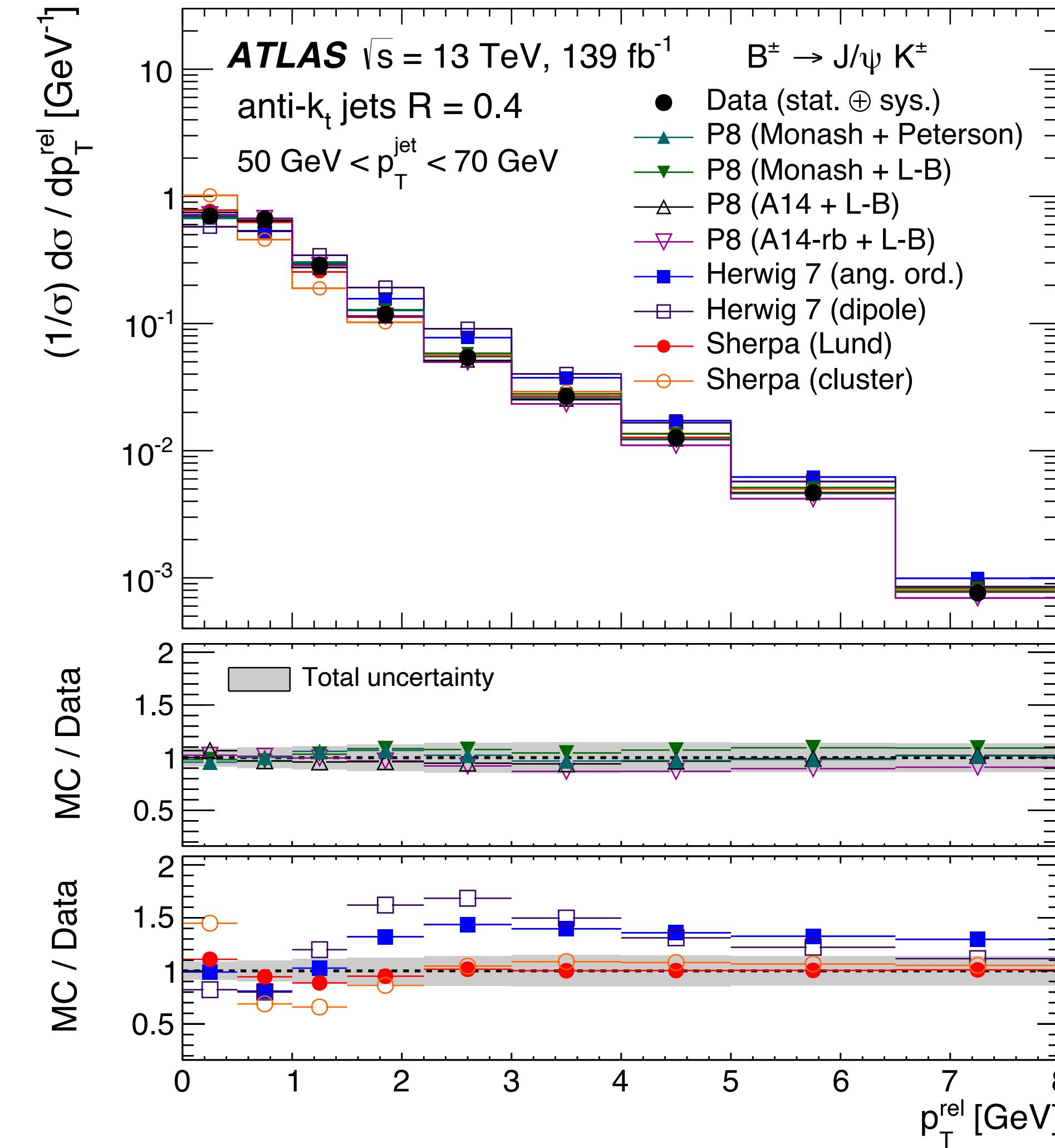
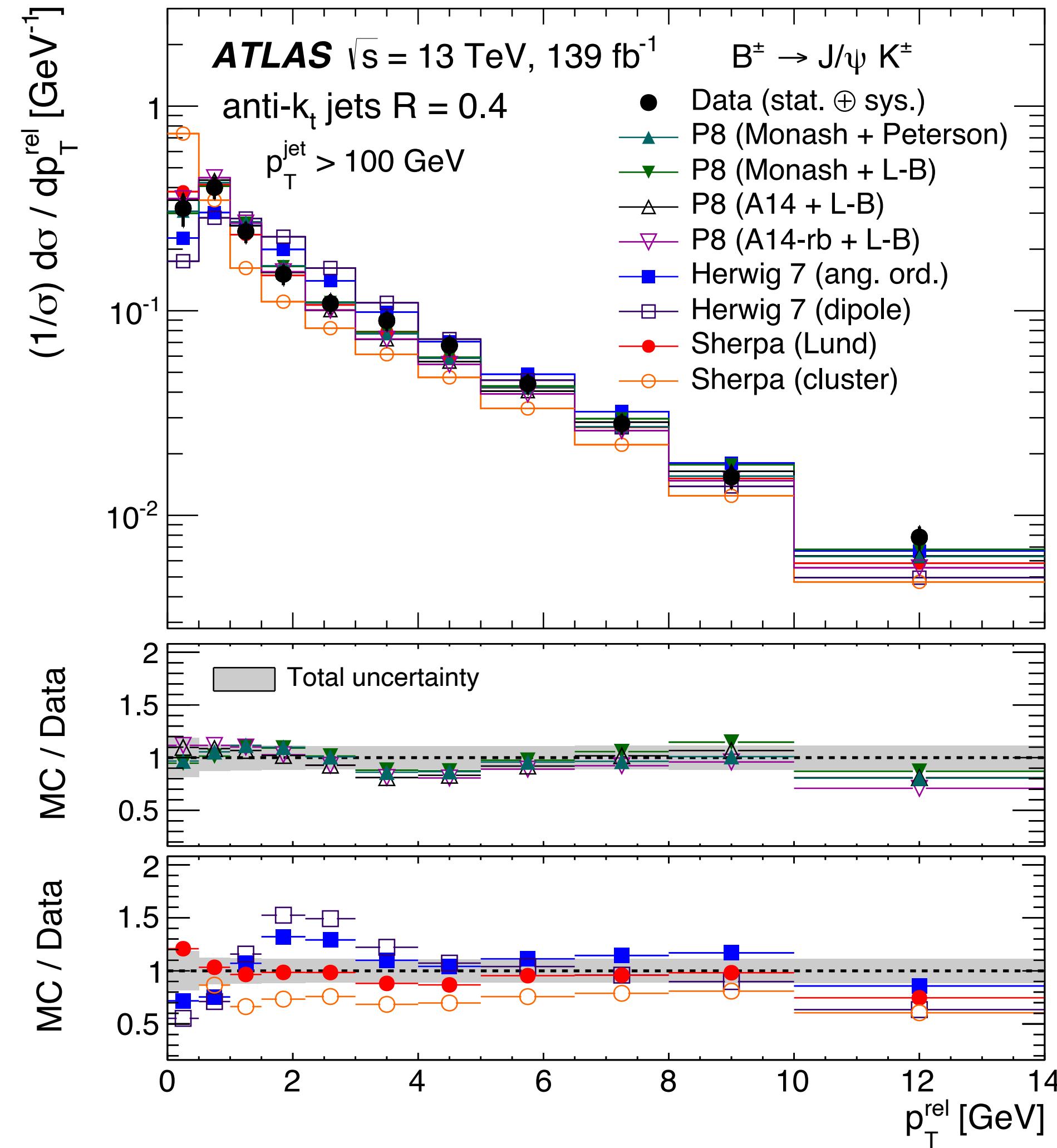
summary and outlook

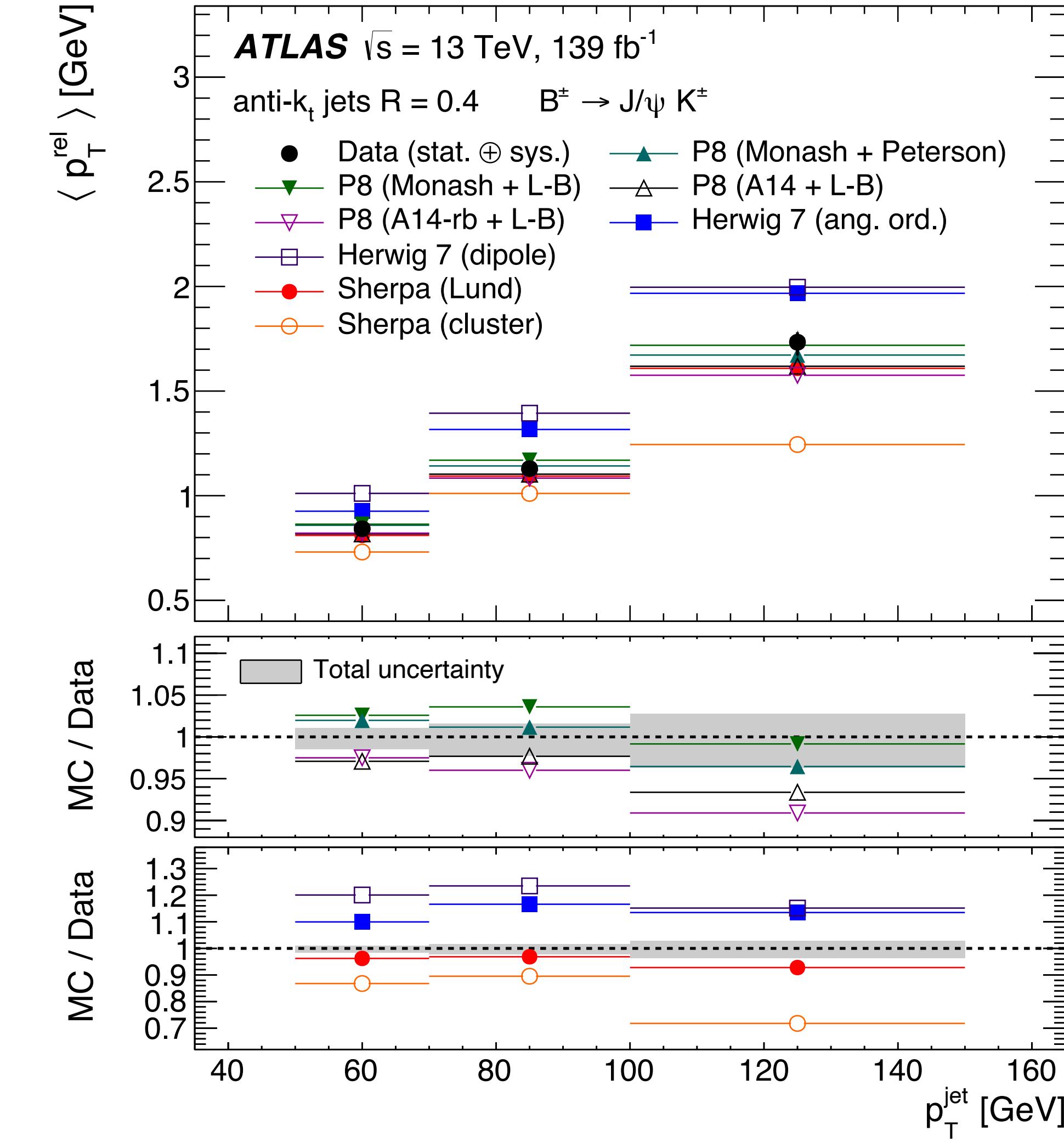
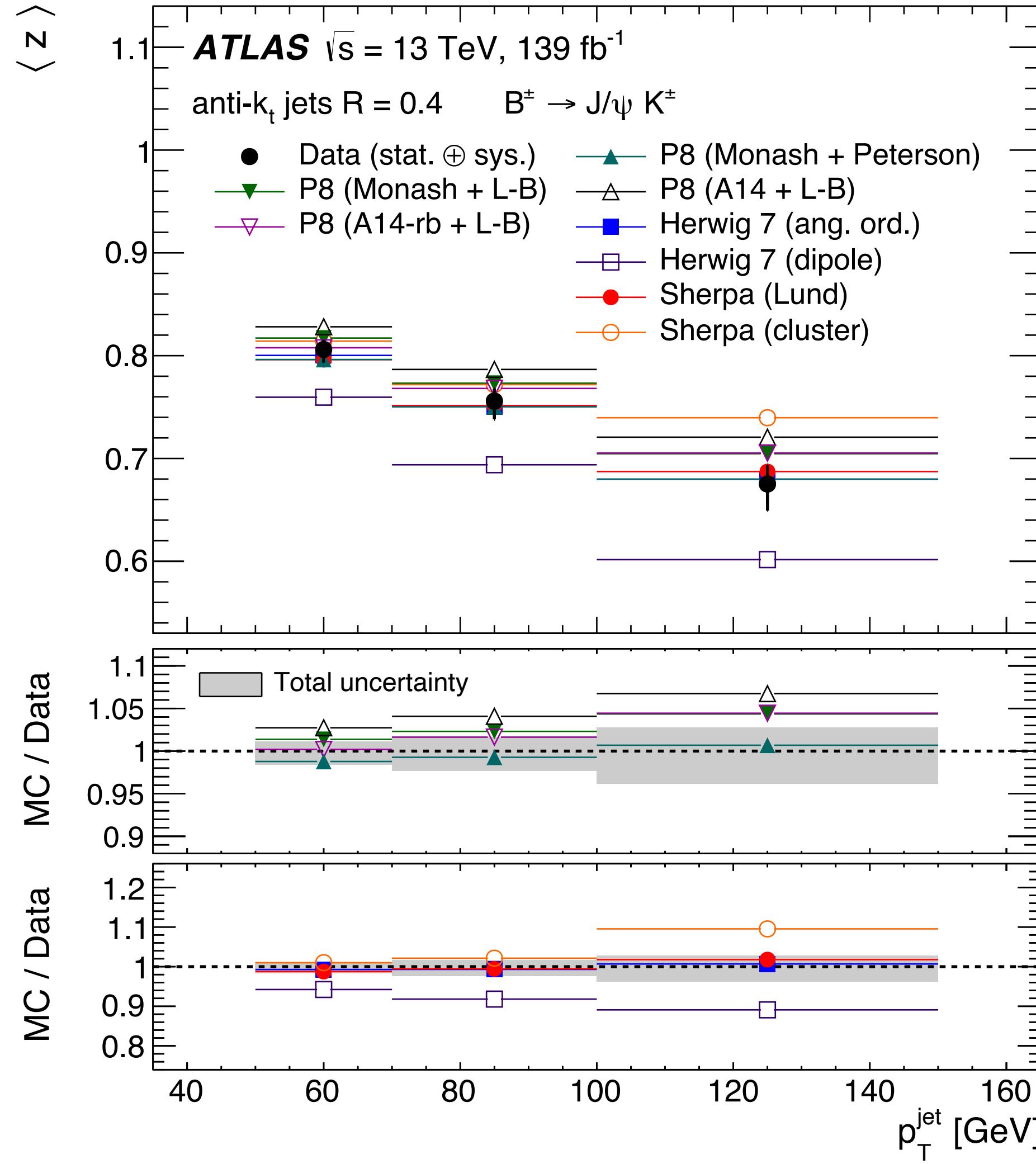
precision physics with b -jets in the final state requires an excellent understanding of b -fragmentation.

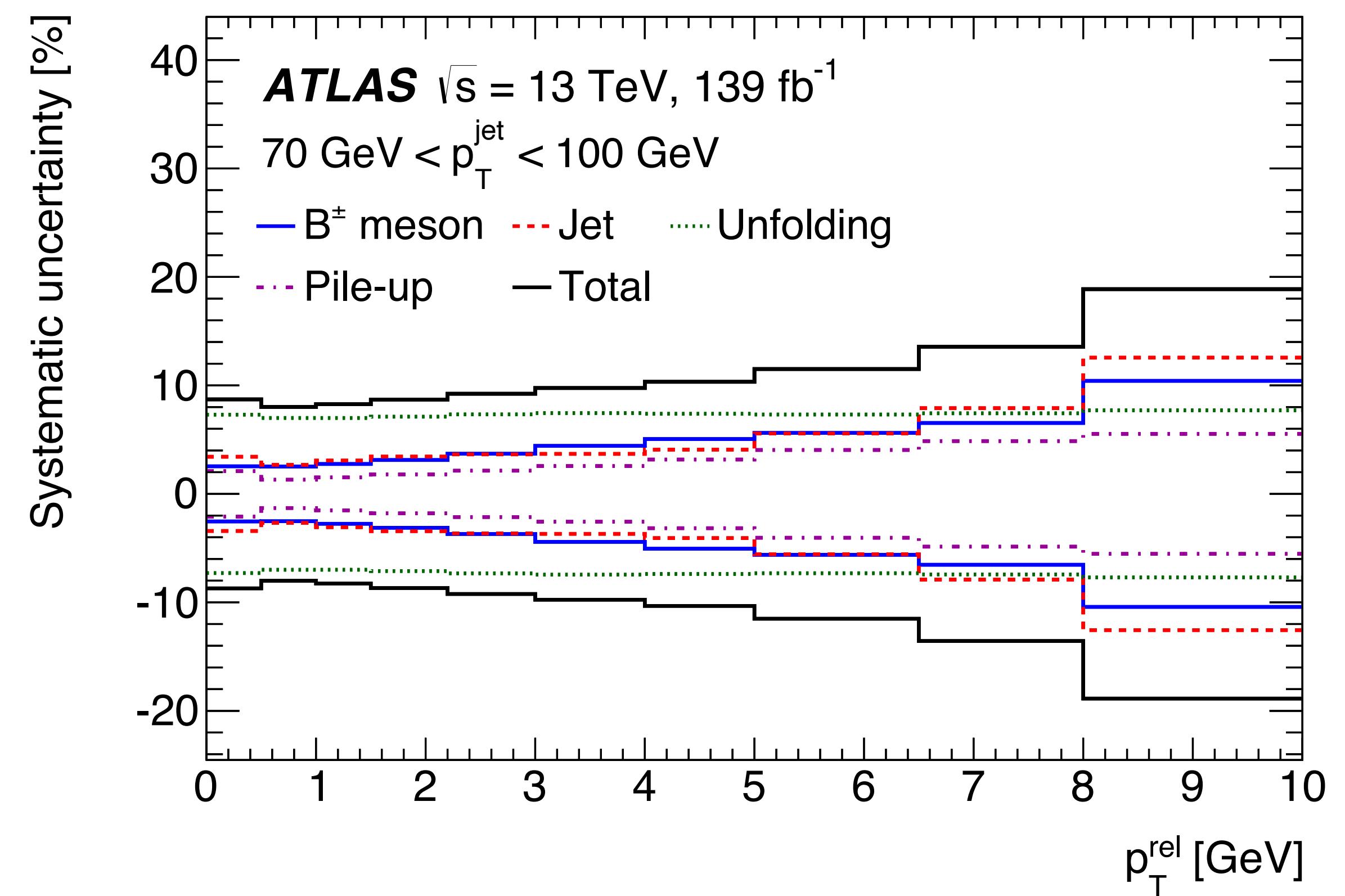
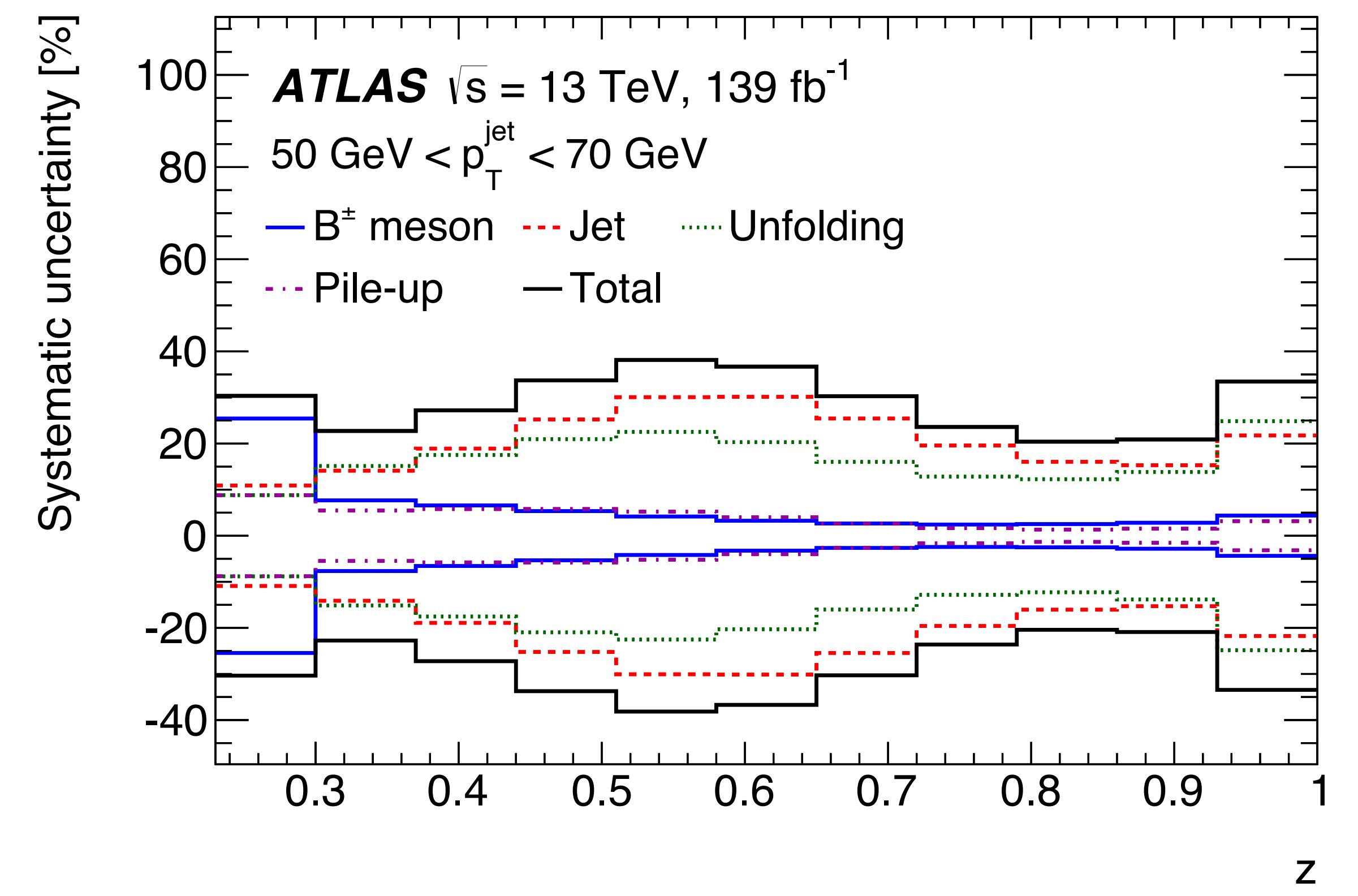
experimental methods at the LHC have been recently developed that can substantially improve this for the future.

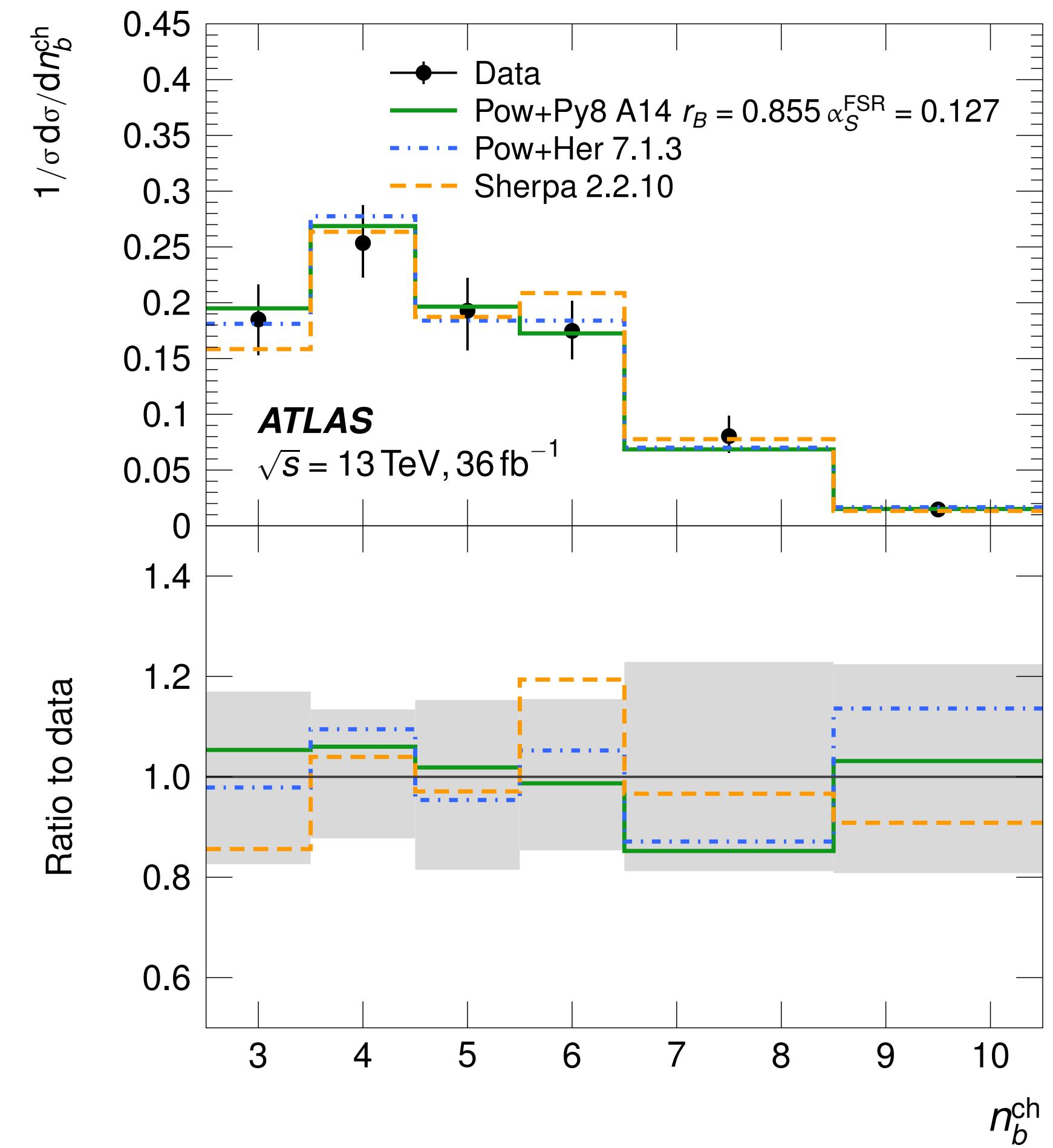
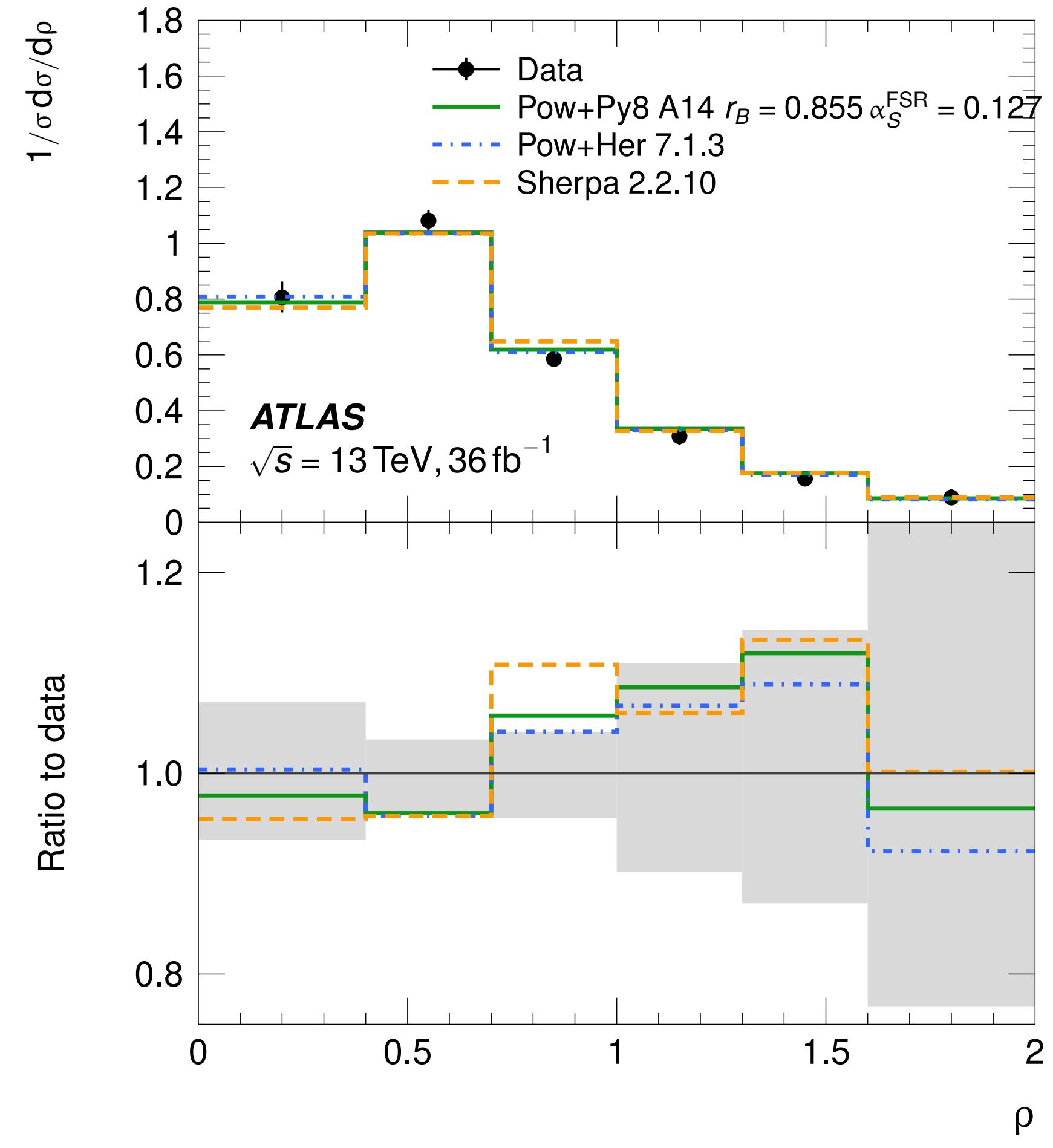
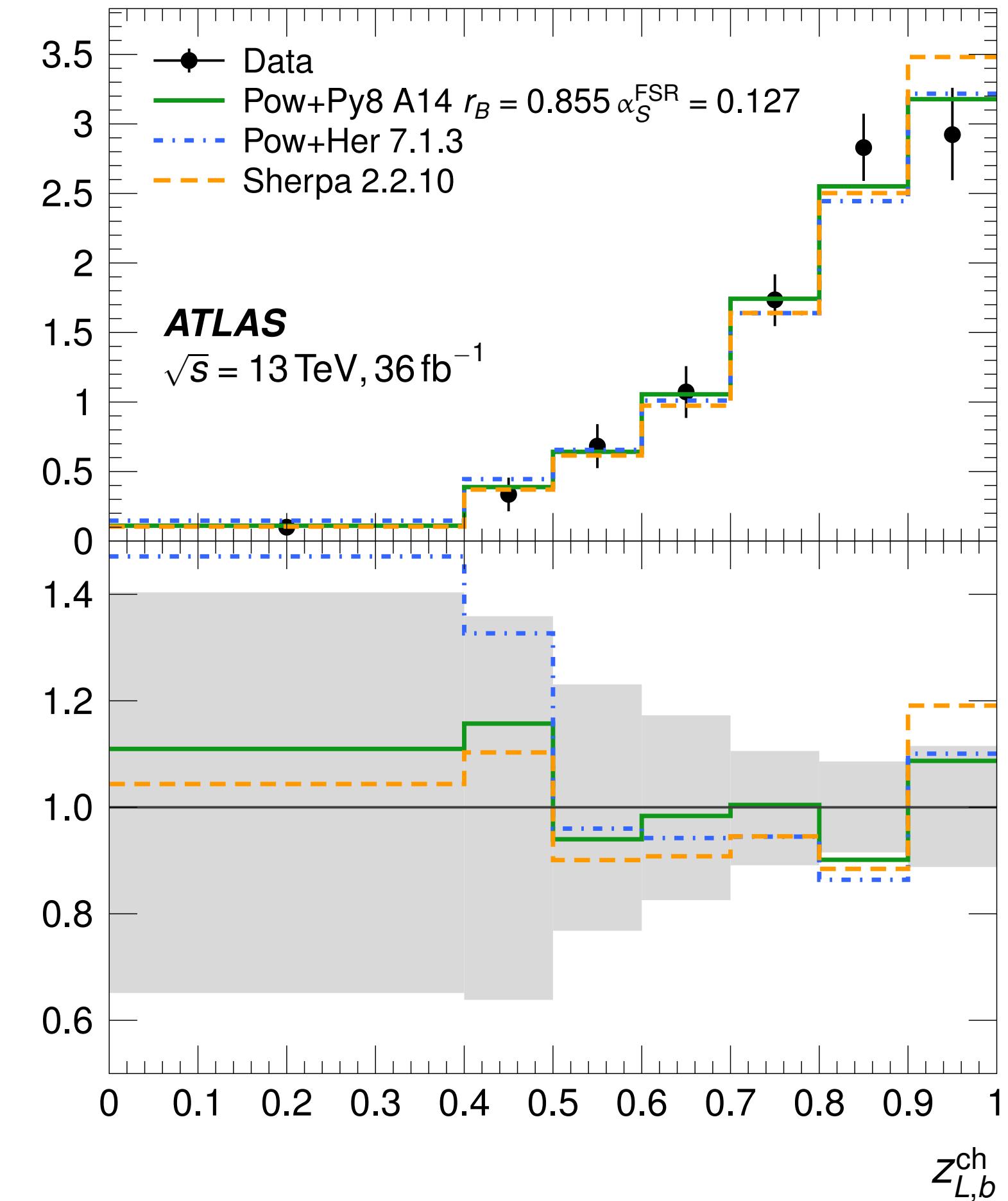
there's still enormous room for these to grow in the coming years.
→ cannot take this for granted.

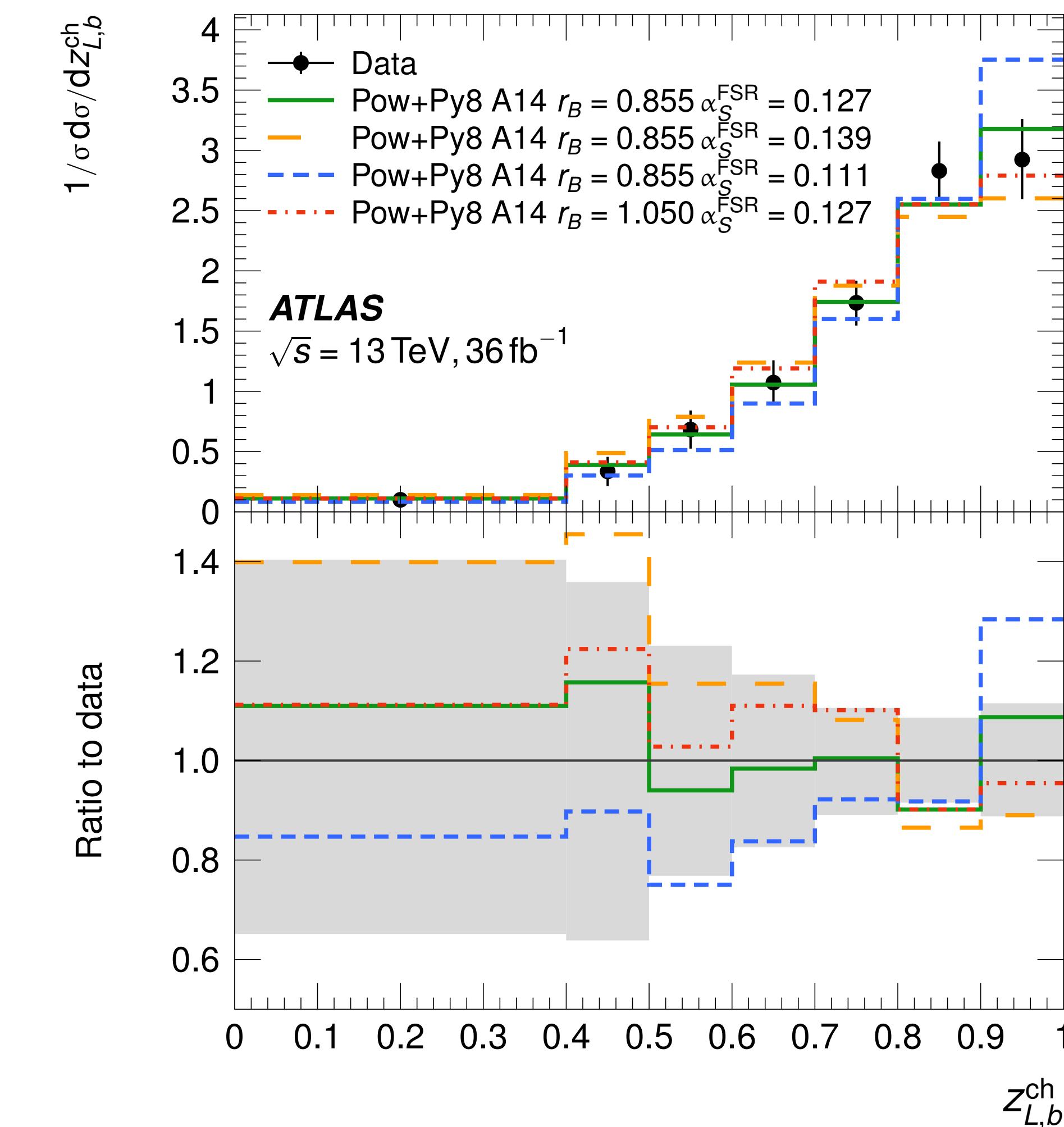
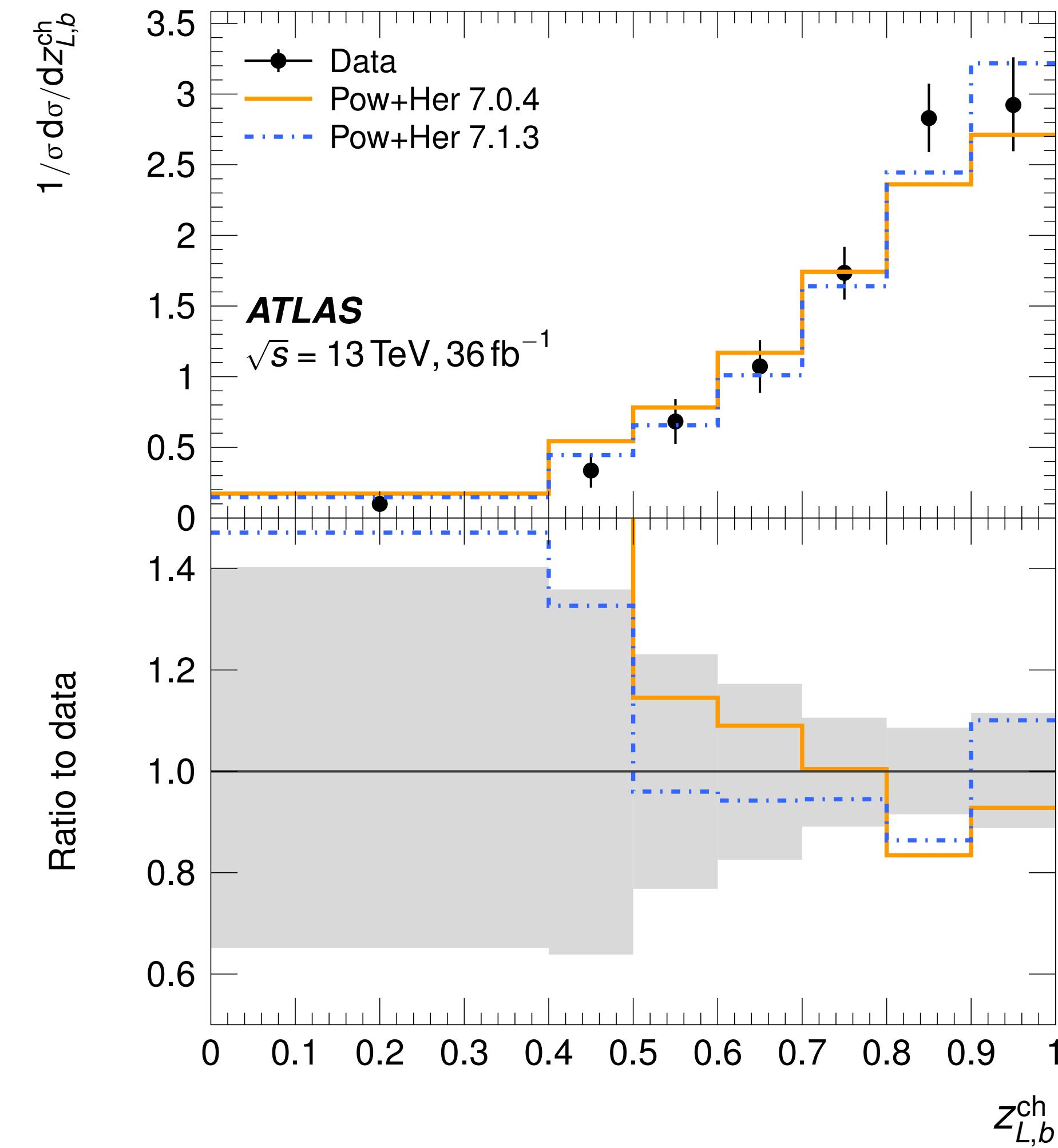
backup

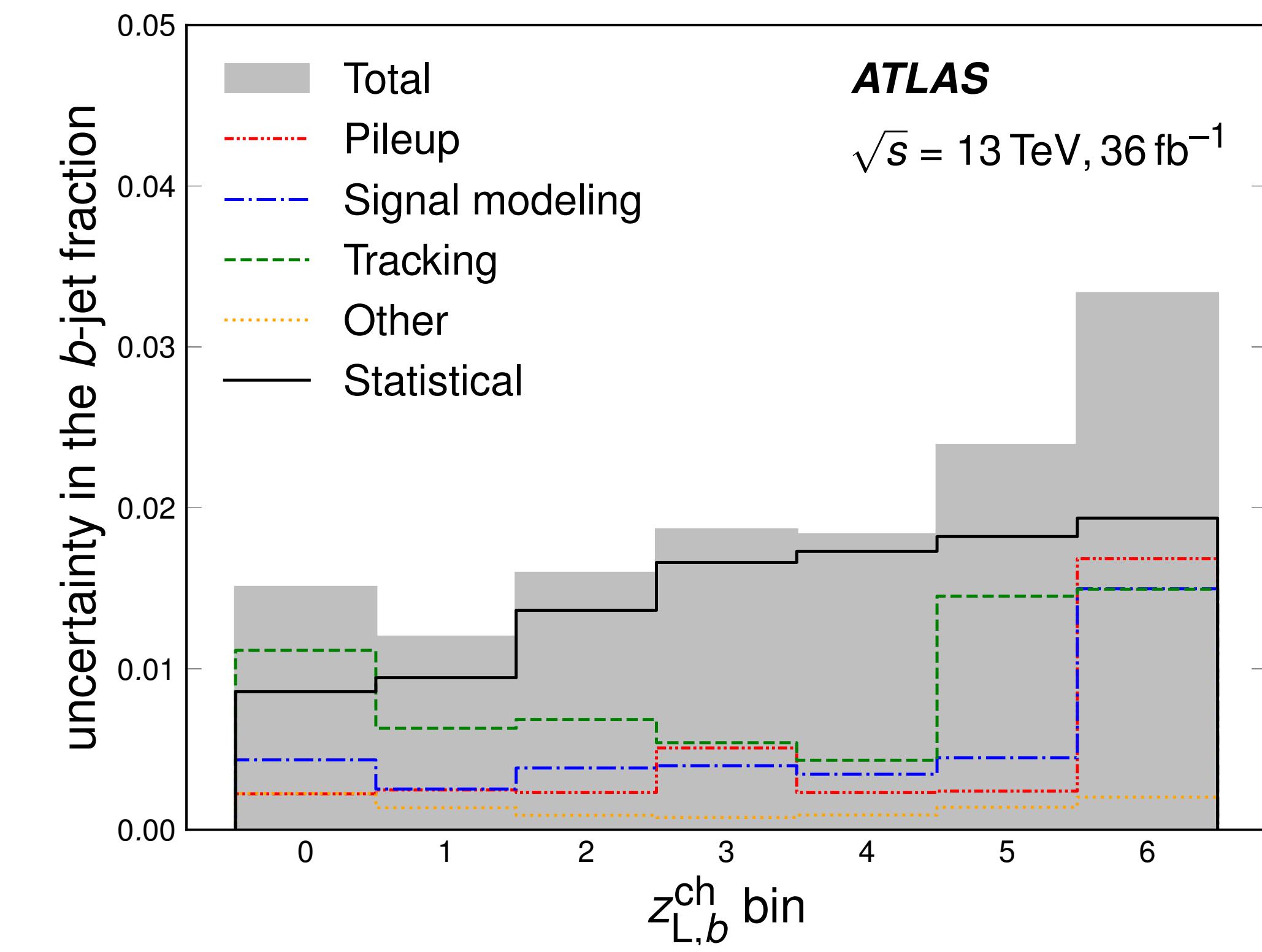
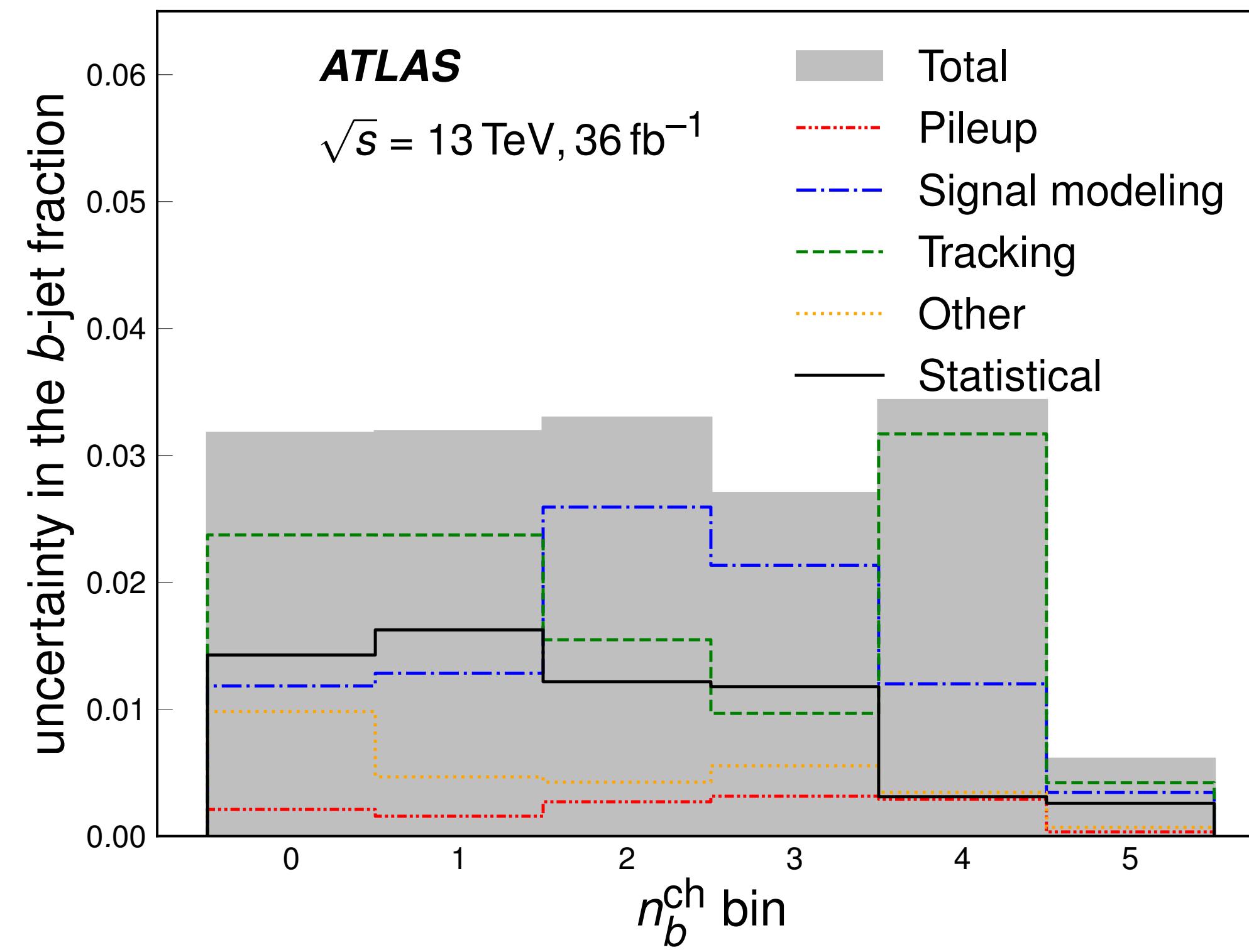


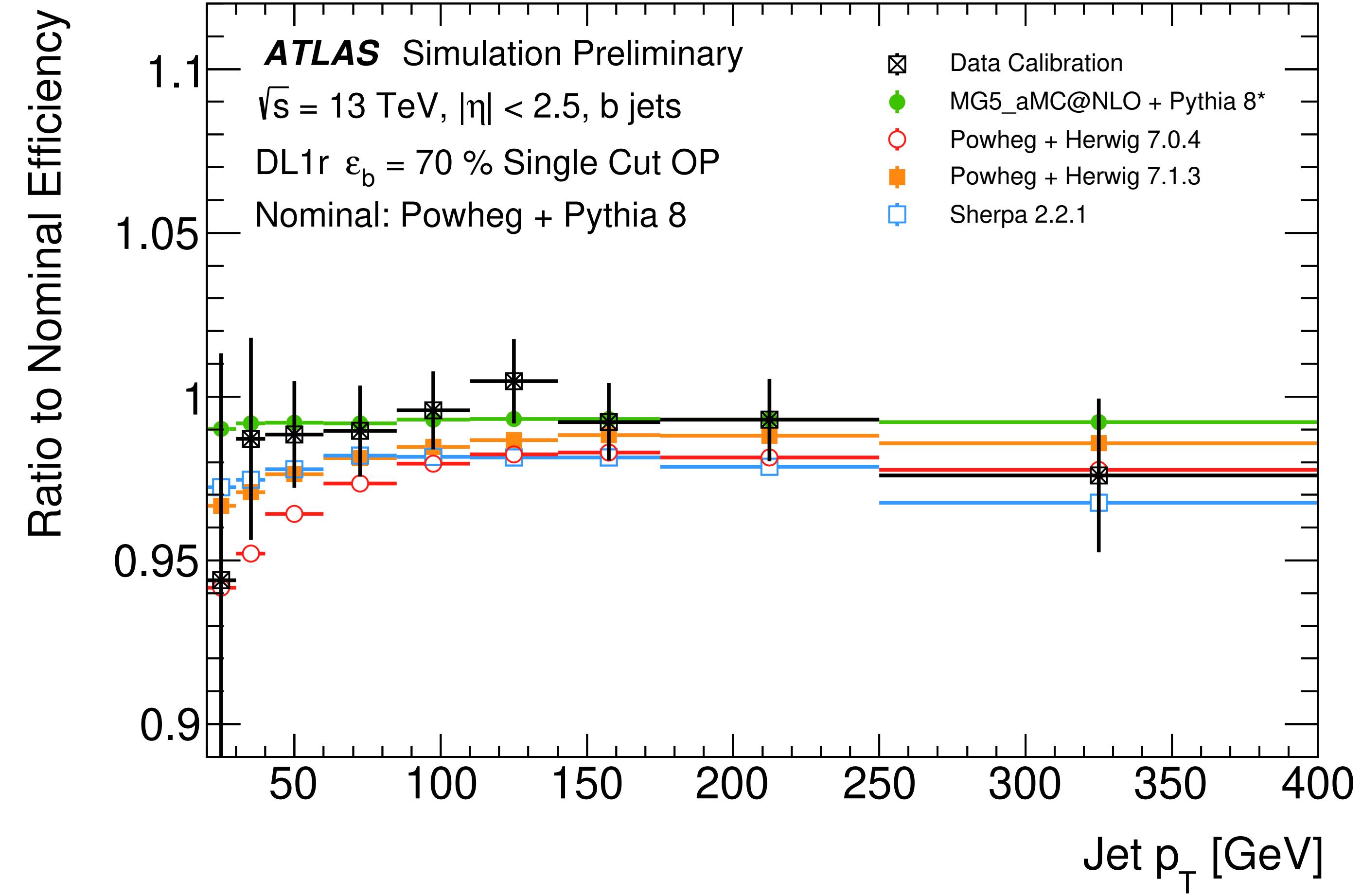
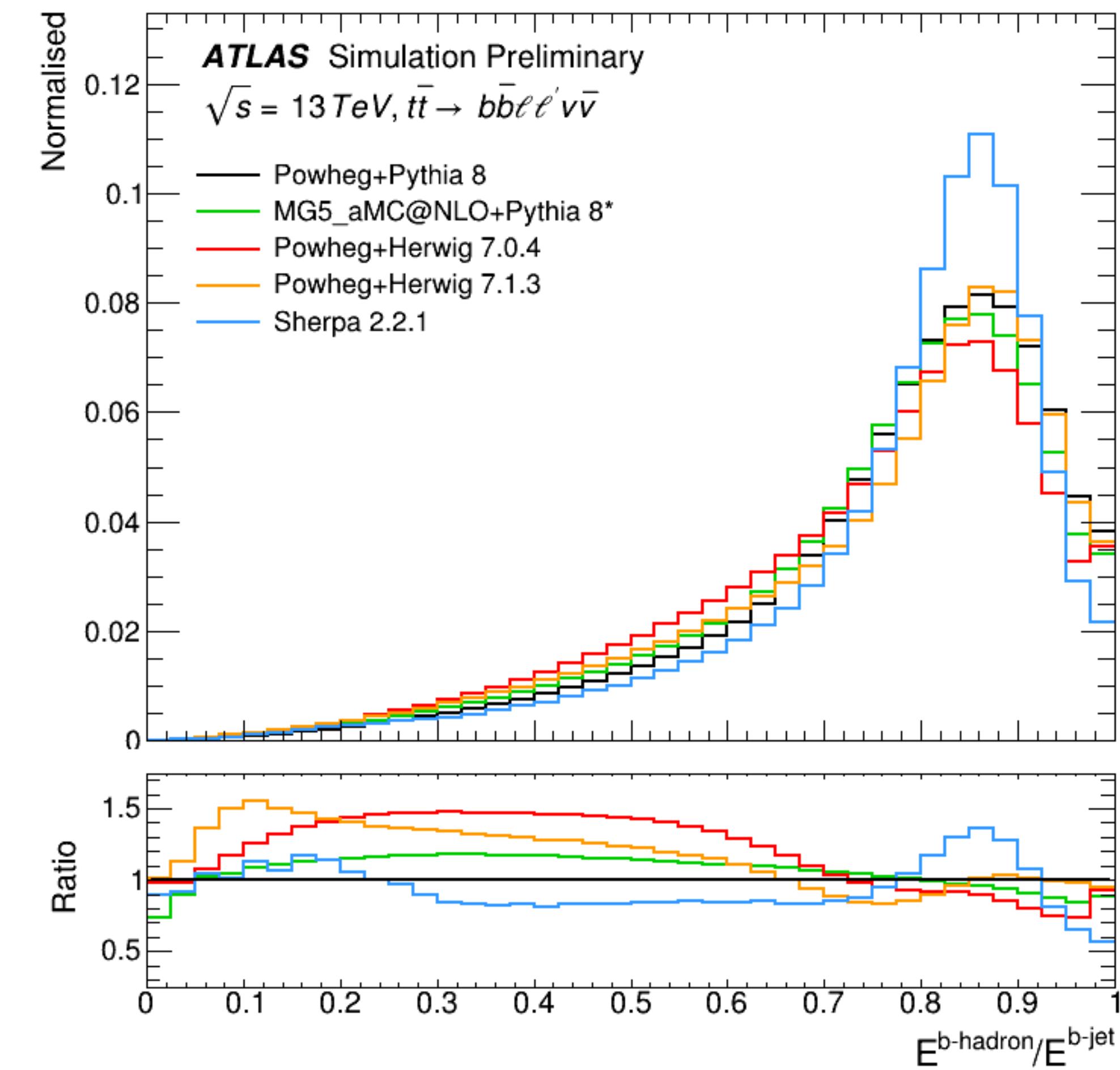


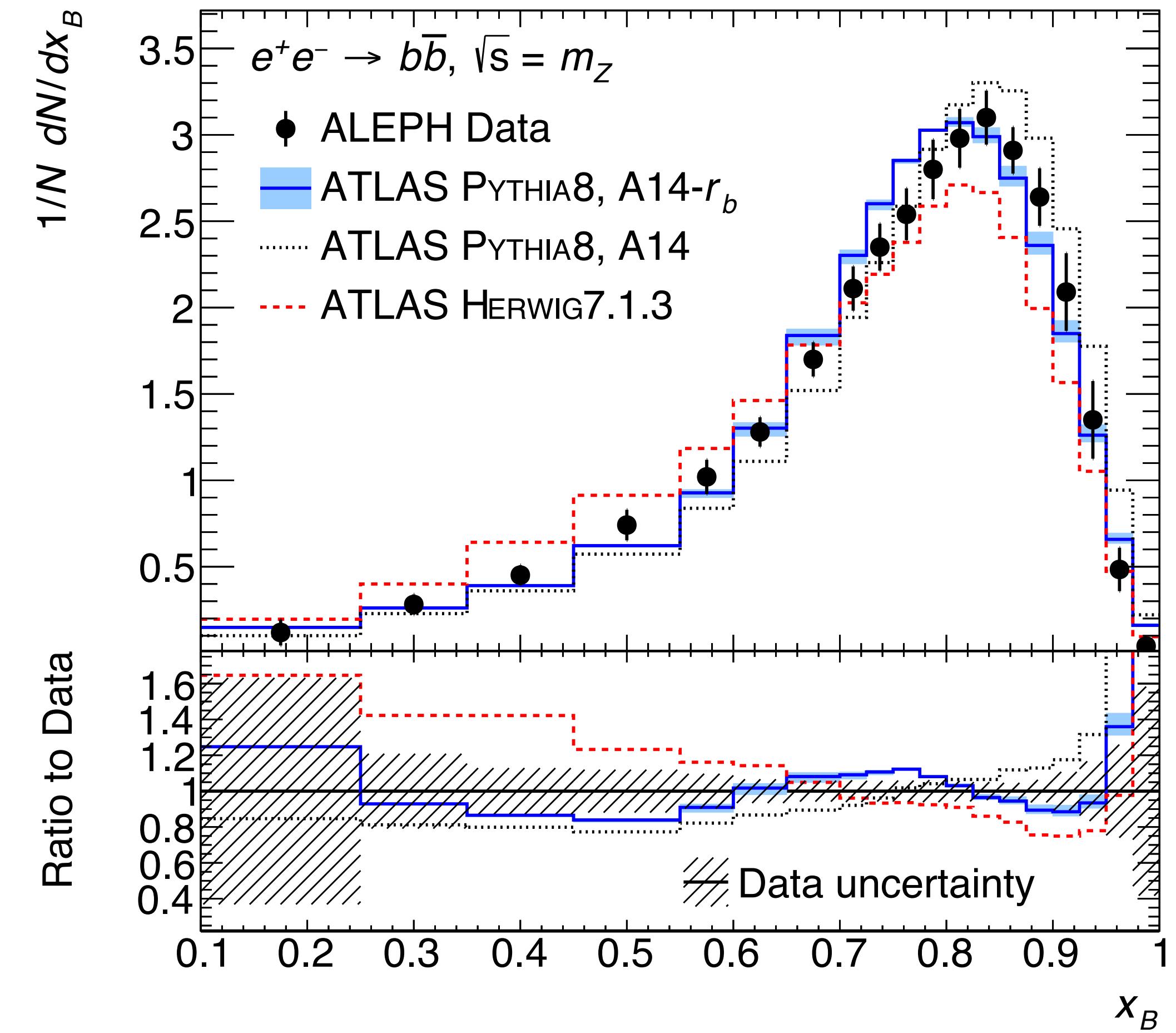
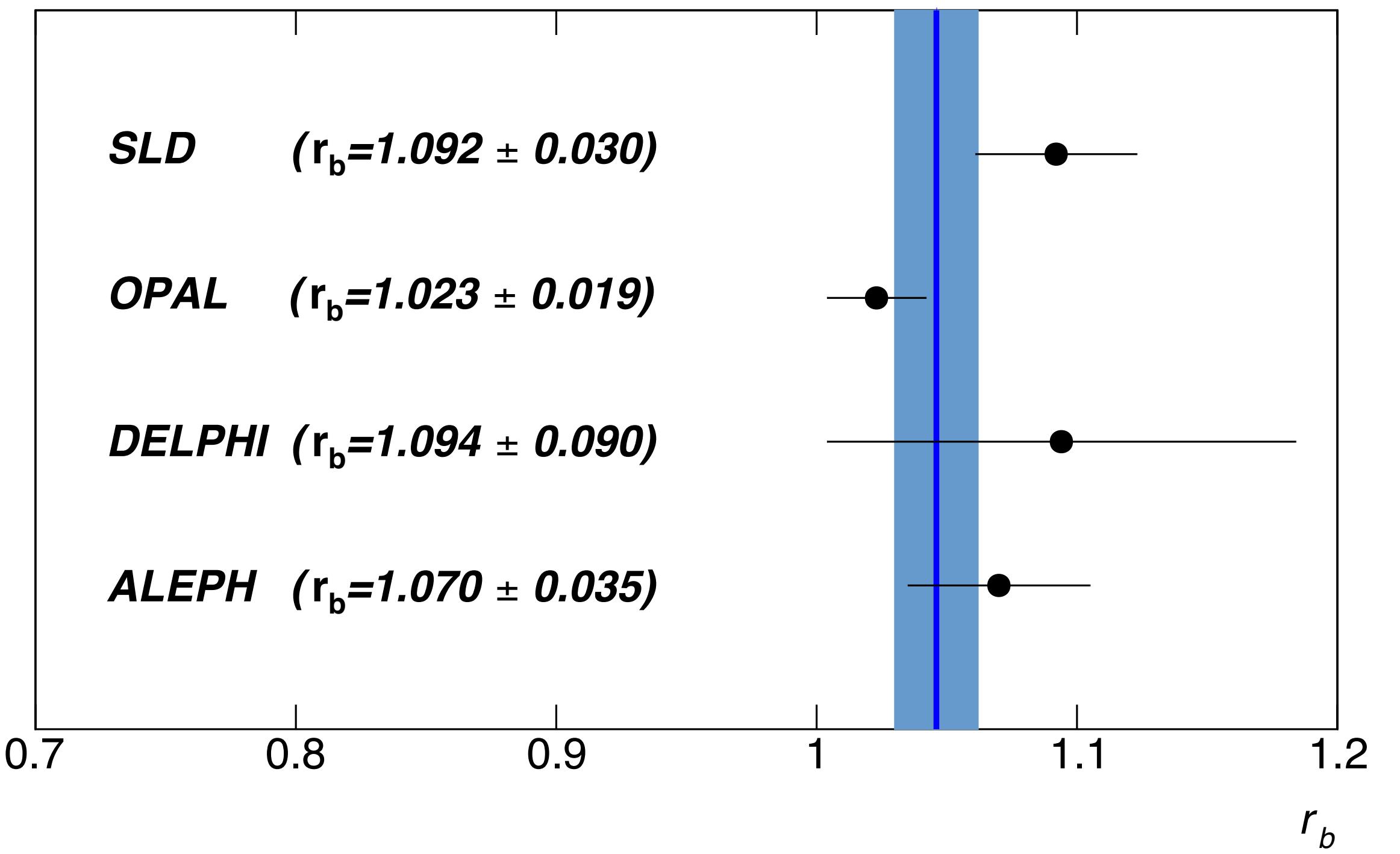


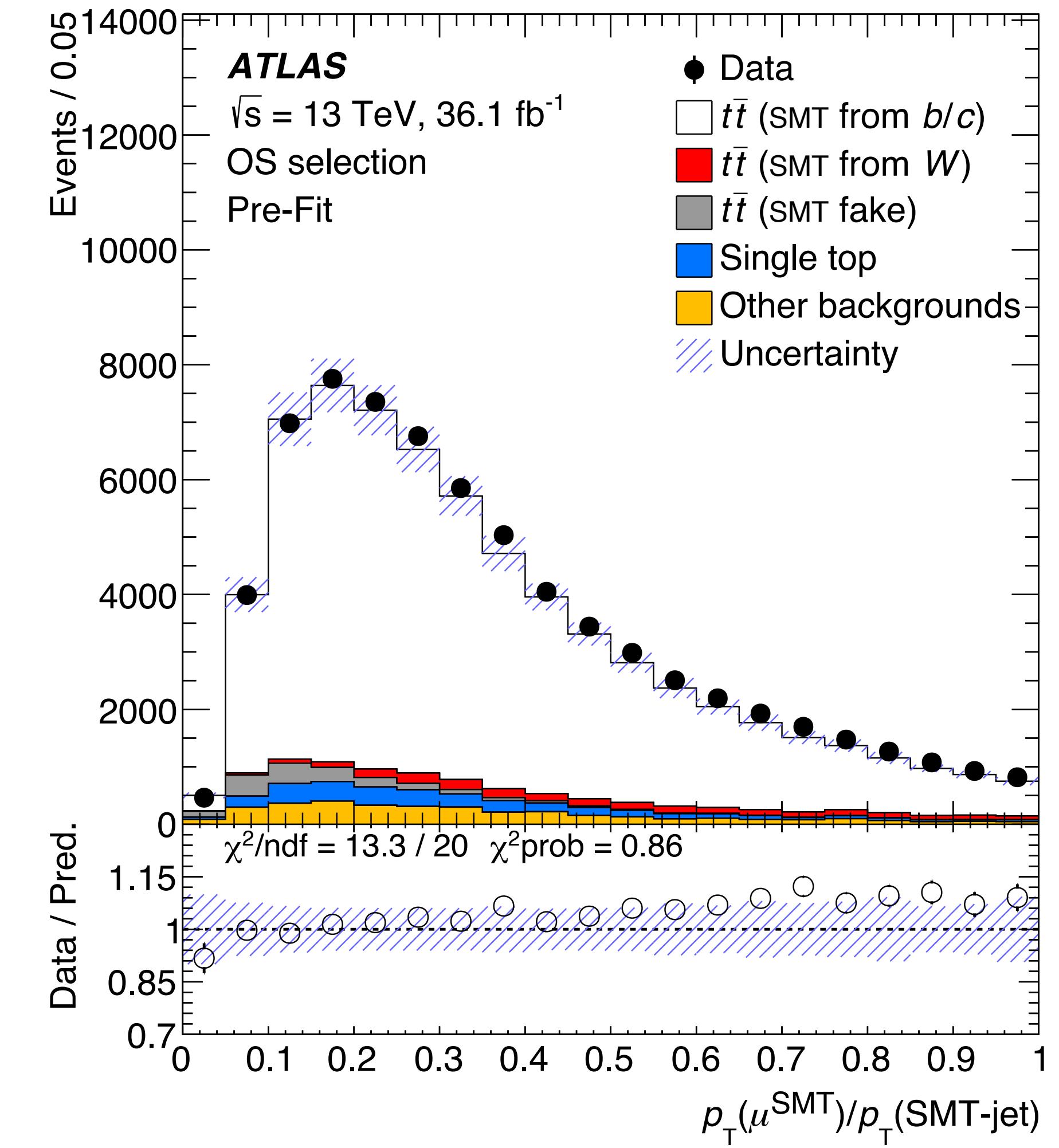
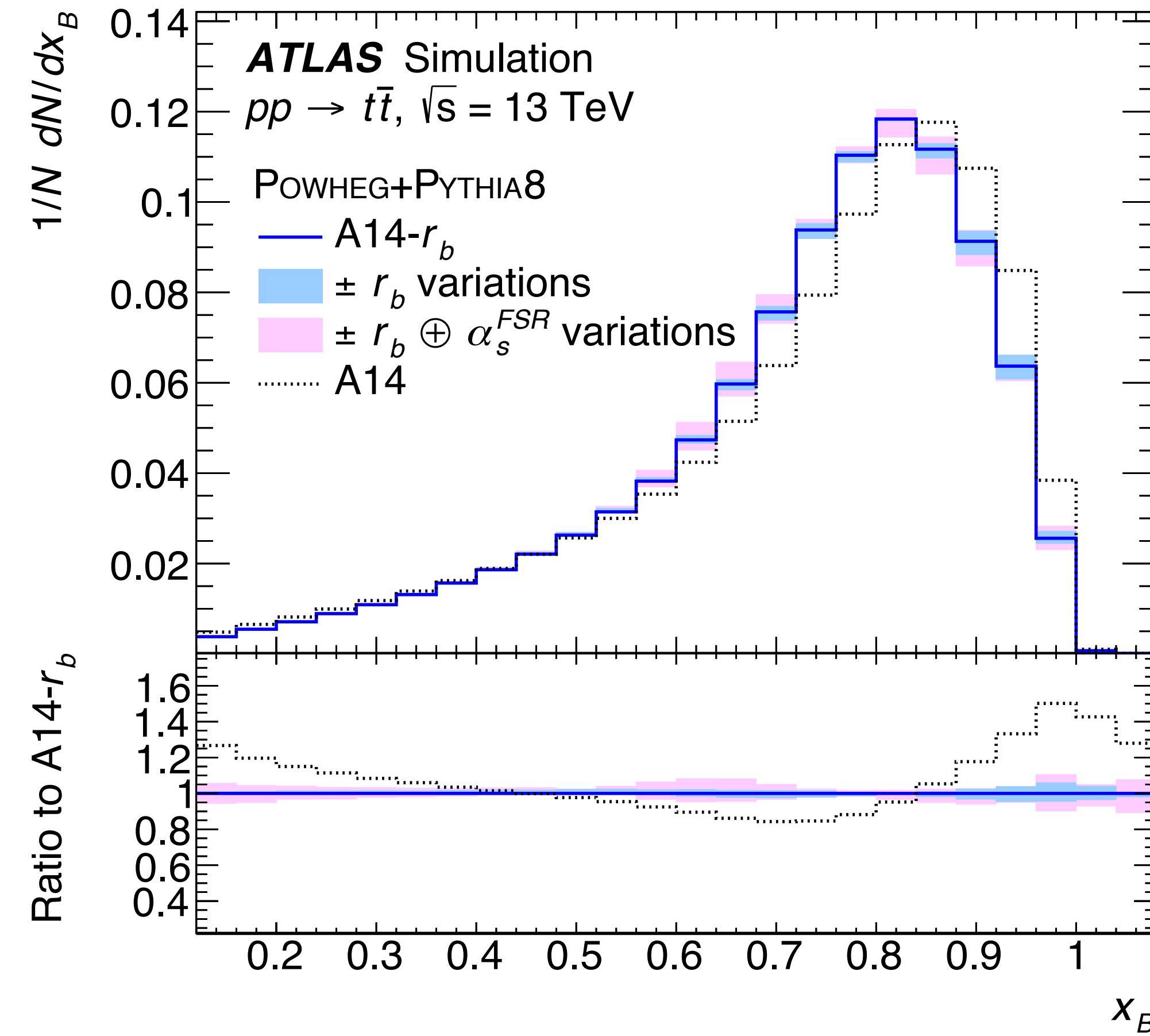












CMS *Preliminary*

36 fb^{-1} (13 TeV)

— post-fit

■ $\pm 1\sigma$

■ $\pm 2\sigma$

• data

