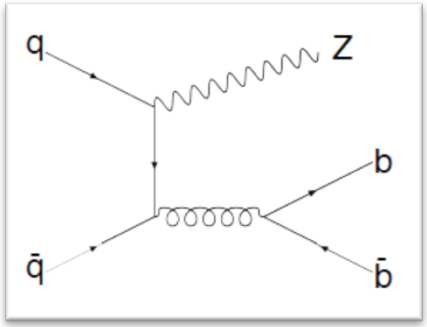
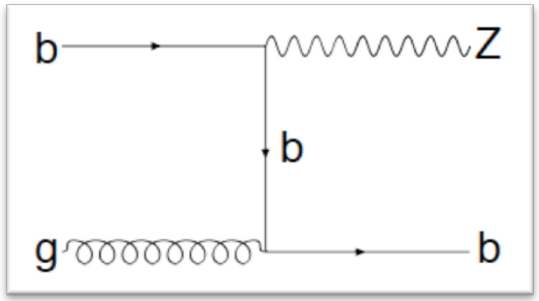
ATLAS Z+HF cross section

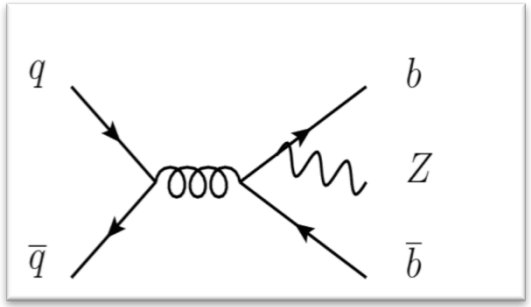
- Z+b and Z+bb inclusive and differential cross sections
- Comparison with 8 MC generators
- Data set: 2015+2916 data, $\sqrt{s}$ = 13TeV, 36/fb
- Paper in journal review: https://arxiv.org/abs/2003.11960
- Selected previous publications:

  CMS, 13TeV, 36/fb: Z+ b/c/light ratios vs pT(jet) and pT(Z),
  https://arxiv.org/abs/2001.06899

  ATLAS, 7TeV, Z+b(b) differential cross sections:
  https://arxiv.org/abs/1407.3643

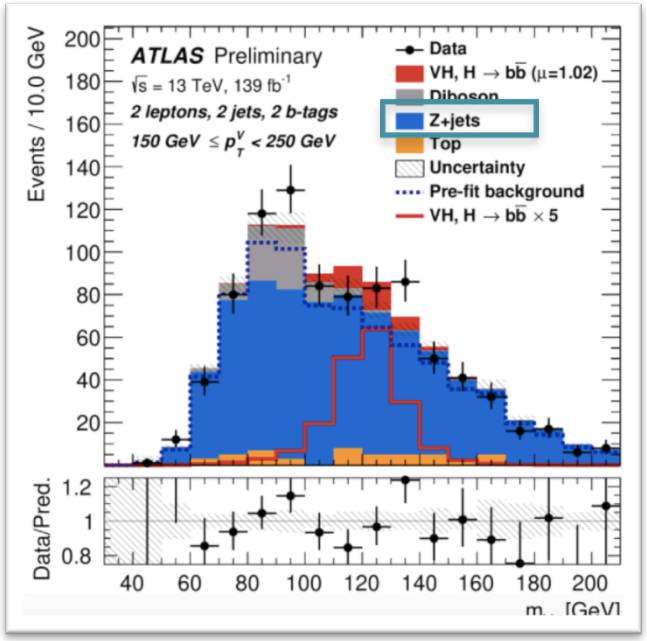






Motivation & Goals

- Theoretical predictions with competing approaches
  - 4FNS (b from gluon splitting) vs 5FNS (b in proton PDF)
  - massive/massless b
  - ME+PS merging at LO/NLO, different parton multiplicities
- Major background for Higgs & DM, SUSY or other searches. Often leading syst. uncertainty



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Measure unfolded cross sections for

- Inclusive Z(->ee/μμ) +b(b) cross sections
- Differential Z+b(b) cross sections as a function of:
  - b-jet pT/y, ZpT/y
  - $\Delta y / \Delta \Phi / \Delta R$ (Z, b)
  - m(bb), $\Delta y / \Delta \Phi / \Delta R$ (b, b), pT(bb)

Theory predictions

Generator	$N_{max}^{partons}$ NLO	LO	FNS	PDF set	Parton Shower
Z+jets (including *Z*+*b* and *Z*+*bb*)					
SHERPA 5FNS (NLO)	2	4	5	NNPDF3.0nnlo	SHERPA
SHERPA FUSING 4FNS+5FNS (NLO)	2	3	5 (*)	NNPDF3.0nnlo	SHERPA
ALPGEN + PY6 4FNS (LO)	-	5	4	CTEQ6L1	PYTHIA v6.426
ALPGEN + PY6 (rew. NNPDF3.0lo)	-	5	4	NNPDF3.0lo	PYTHIA v6.426
MGAMC + PY8 5FNS (LO)	-	4	5	NNPDF3.0nlo	PYTHIA v8.186
MGAMC + PY8 5FNS (NLO)	1	-	5	NNPDF3.0nnlo	PYTHIA v8.186
Z+*bb*					
SHERPA ZBB 4FNS (NLO)	2	-	4	NNPDF3.0nnlo	SHERPA
MGAMC + PY8 ZBB 4FNS (NLO)	2	-	4	NNPDF3.0nnlo	PYTHIA v8.186

MEPS@NLO, 0-5 partons 5FNS or Fusing

5FNS vs 4FNS LO ME+PS

5FNS Z+b, NLO

4FNS Z+bb, NLO

State of the art is multi-leg ME+PS merging, typical trade-offs:

- ME+PS: NLO with less partons vs LO with more partons
- Flavour/mass schemes: 4FNS with massive b vs 5FNS with massless b in ME (massive b in PS)
- Inclusive approaches vs specific Z+bb 4FNS

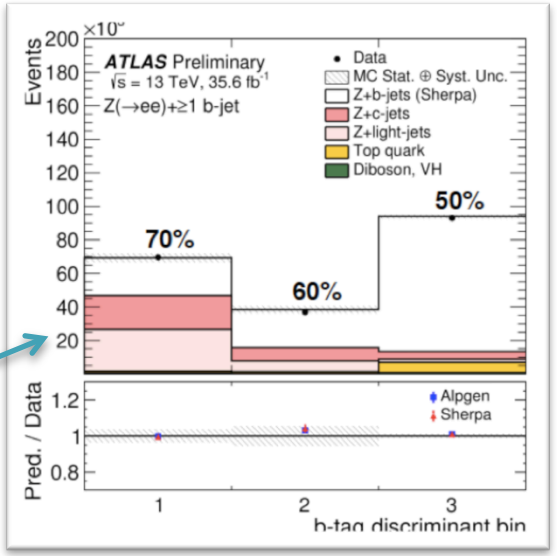
Analysis strategy

Selection

- 2 isolated leptons (ee/μμ), Z mass window
- ≥1/≥2 b-tagged jets (antikt4). pT> 20GeV
- ETmiss < 60 for pT(ll) < 150: reduce top

Backgrounds:

- Z+light/charm jets: from simulation but scale factor from flavour fit to b-tagger output
- Top pairs: simulation, validated in e+μ
- Other backgrounds from simulation

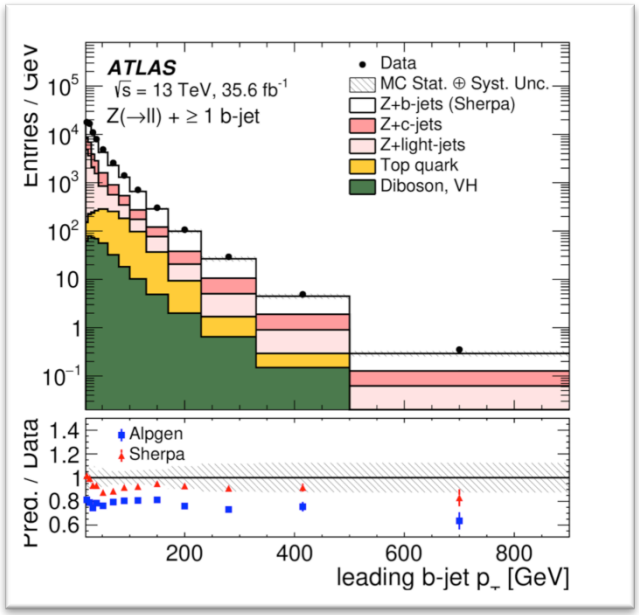


Correction for detector effects:

- Inclusive cross sec. : correction factors
- Differential cross sec. : iterative unfolding
- Based on Sherpa MEPS@NLO Z+jets

Systematics:

- Dominant: b-tagging efficiency, Z+light/charm bkg, Top bkg, unfolding

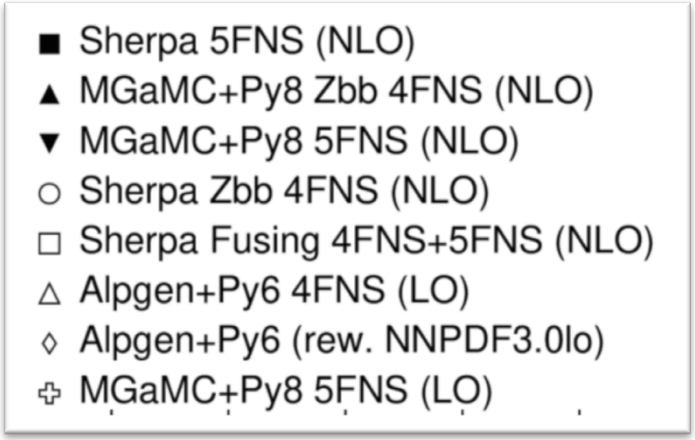


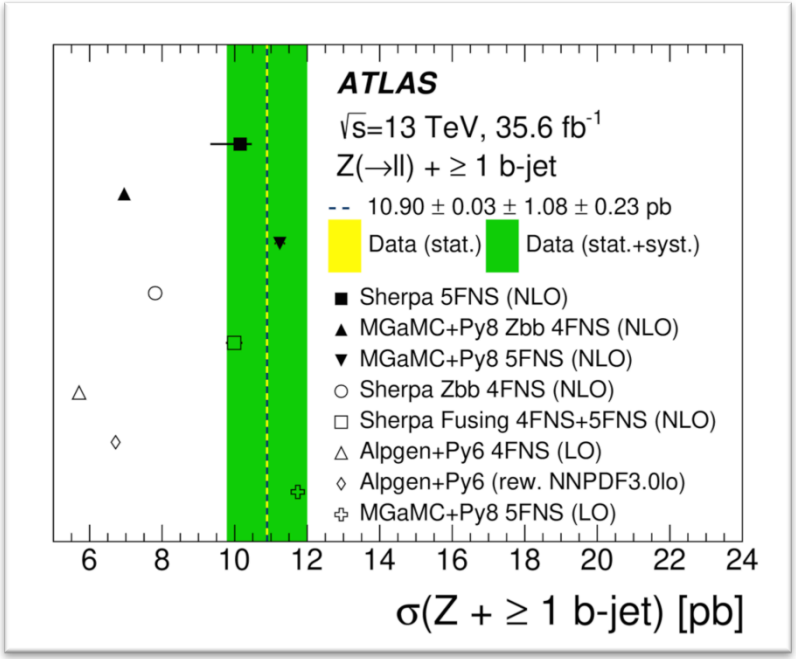
Inclusive cross sections

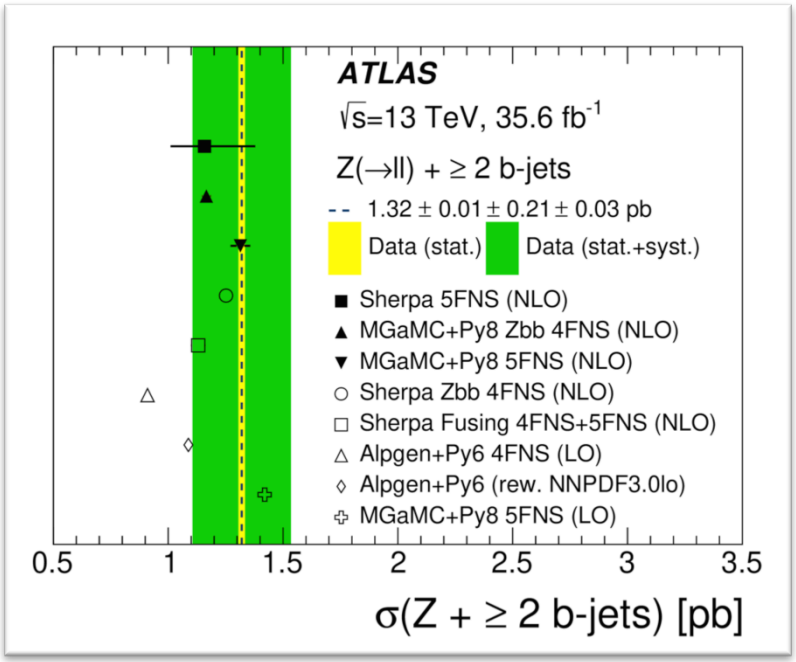
General trends

- 4FNS systematically lower than data for Z+≥1b
- 5FNS agree with both Z +≥1b and Z+≥2b

Confirm trends in previous results at lower center-of-mass energies





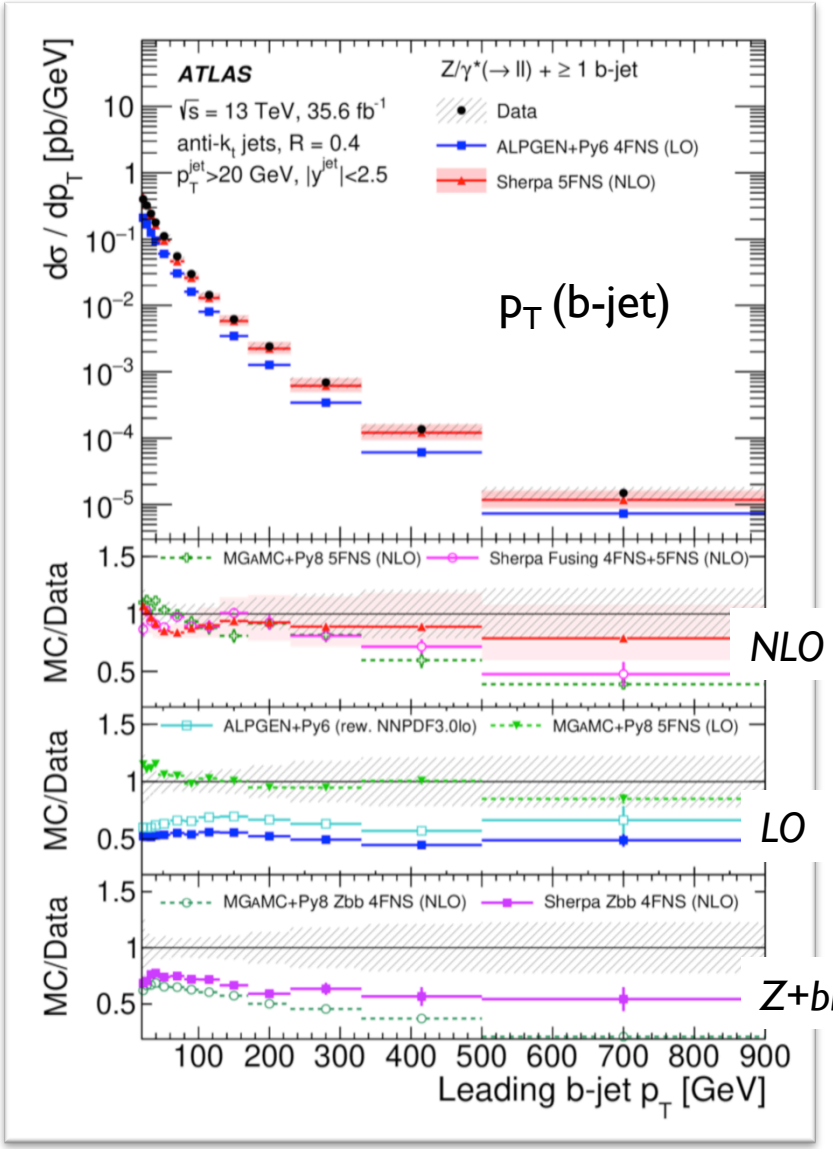


Z+ ≥1b: Leading b-jet pT

Test of perturbative QCD over a wide range including domains relevant for Higgs & searches

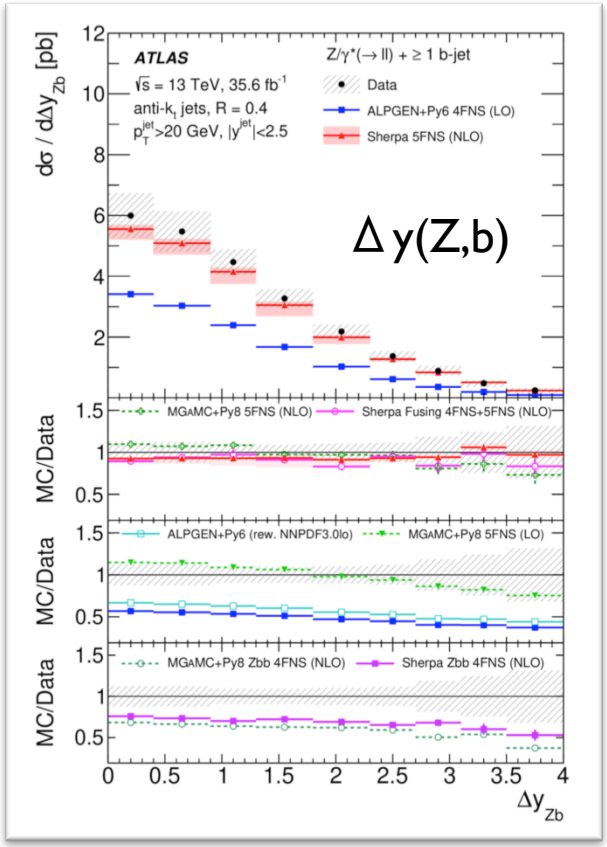
Results

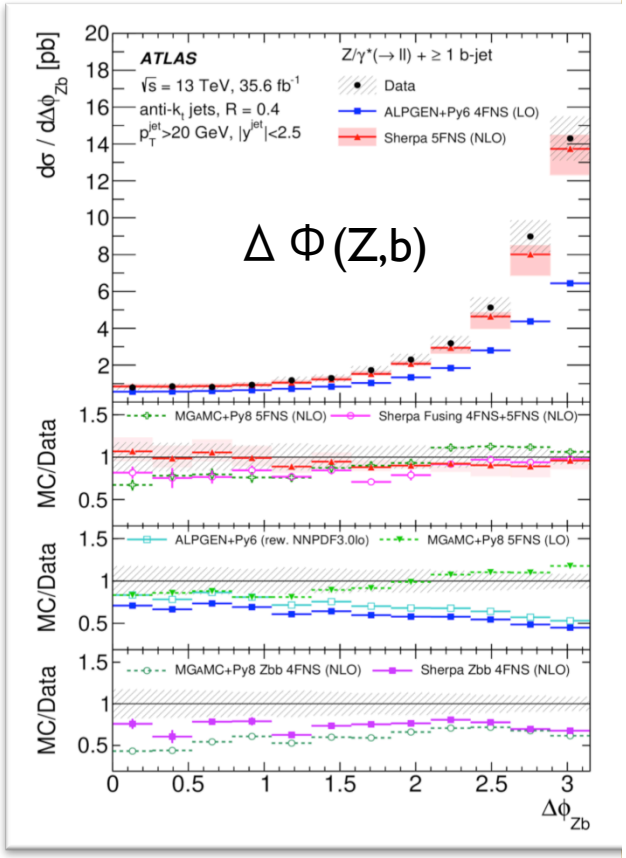
- Sherpa 5FNS has the best prediction
- Sherpa Fusing 4FNS+5FNS worse than Sherpa 5FNS
- MGaMC 1-4 partons LO performs better than MGaMC 1parton NLO



Z+≥1b: Angles between Z and b

- Test of b PDF and impact of higher orders
- Contributions from higher-order diagrams or PS populate region with $\Delta\Phi(Z,b) < \pi$





Results

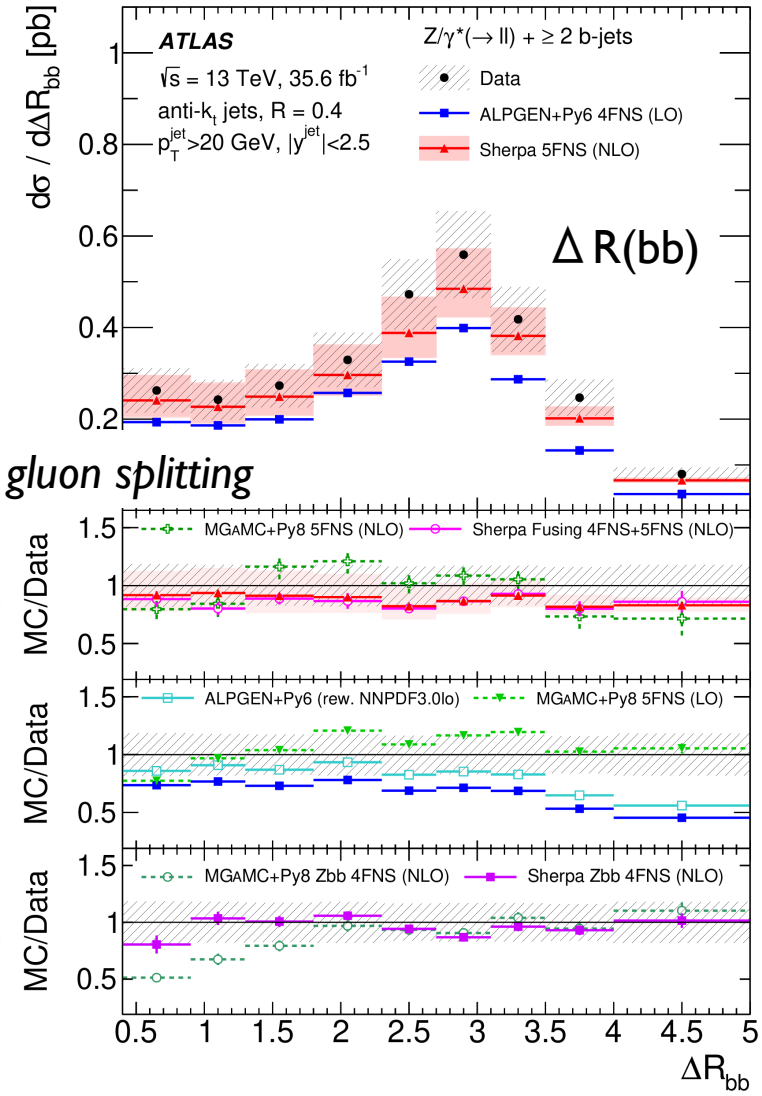
- Sherpa 5FNS and Sherpa Fusing provide the best prediction, Sherpa Fusing underestimates collinear region
- Most other generators predict a smaller rapidity separation and tend to under or overestimate the relation between collinear and back-to-back production

Z+bb: Δ R(bb)

Sensitive to the various b-jet production mechanisms. Low Δ R(bb) is sensitive to gluon splitting

Results

- Sherpa NLO provides the best prediction
- MGaMC 4FNS Zbb miss modeling in gluon-splitting region

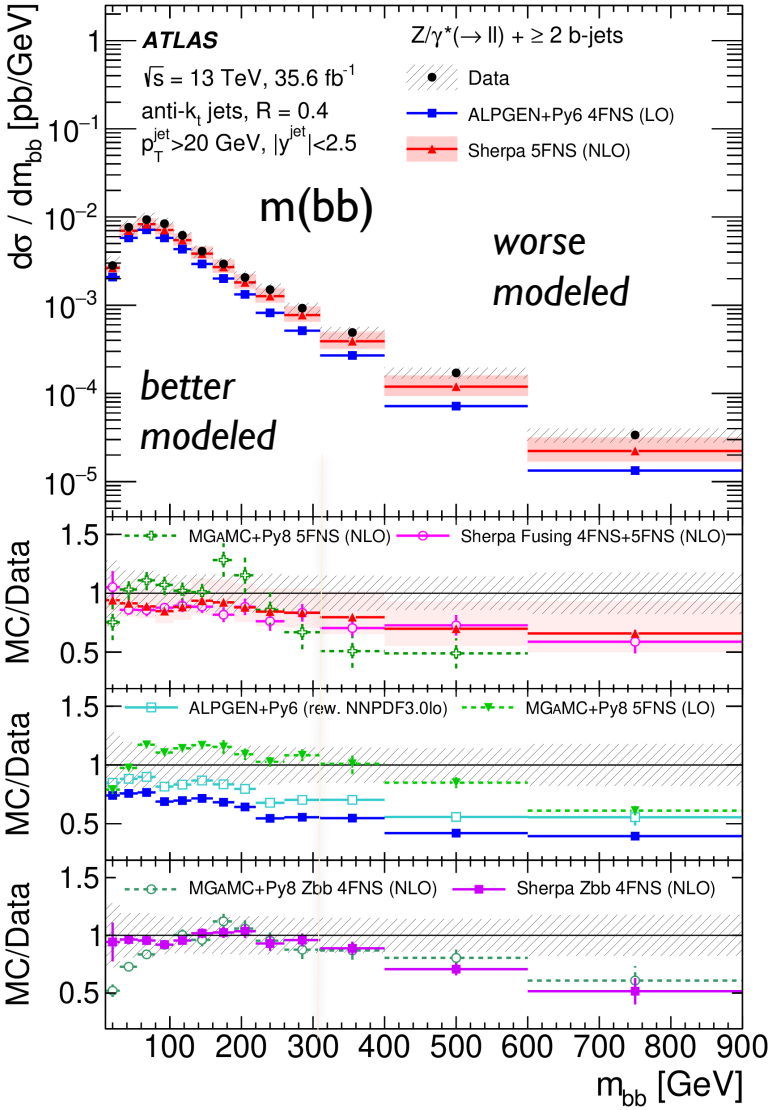


Z+bb: invariant mass of the two b

Important for H->bb and BSM searches

Results

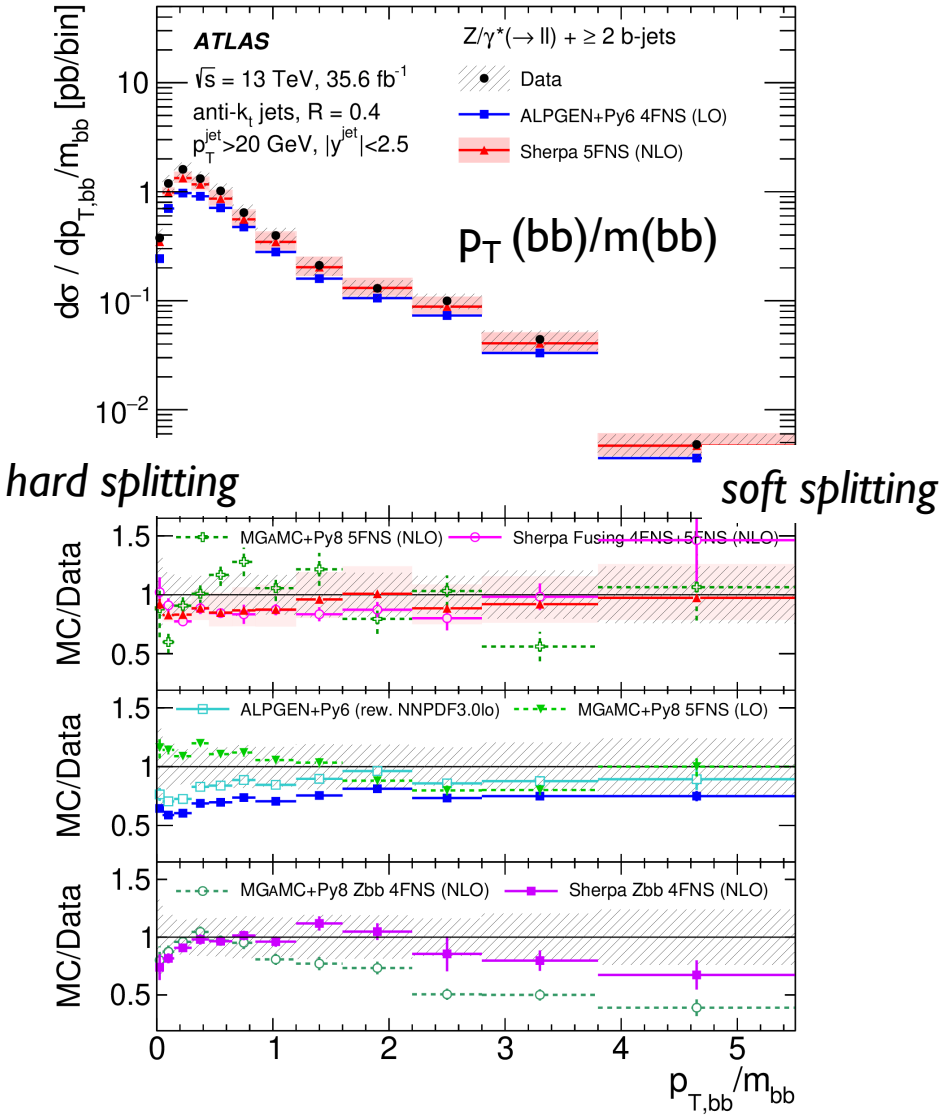
- Good performance of Sherpa predictions for m(bb) < 300 GeV
- MGaMC Z+bb 4FNS has problems for small m(bb), consistent with ΔR(bb) miss modeling



Z+bb: pT(bb)/m(bb)

Sensitive to gluon splitting:

Small (large) values correspond to hard (soft) splitting



Results

- Best performance from Sherpa 5FNS and Sherpa Fusing
- miss modeling for MGaMC NLO 4FNS

Summary

Inclusive cross sections

- 5FNS NLO or LO ME+PS describe both Z+≥1b and Z+≥2b
- 4FNS approaches struggle with Z+≥1b. Explicit 4FNS Z+bb generators describe only Z+≥2b cross section

Differential cross sections

- 5FNS MEPS@NLO (Sherpa) provides best description (problems at large m(bb))
- 5FNS-4FNS Fusing close to 5FNS, except worse performance for large p_T(b), small $\Delta\Phi$(Z,b)
- Multi-leg LO is often superior to fixed-order NLO
- Substantial miss modeling from Z+bb 4FNS

HEP data and Rivet routine will be available to check new predictions