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, $\sqrt{s} = 13$ TeV, 36/fb
- Selected previous publications:
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

Measure unfolded cross sections for

- Inclusive $Z(\rightarrow \ell\ell/\mu\mu) + b(b)\) cross sections
- Differential $Z+b(b)$ cross sections as a function of:
  - b-jet $p_T/y$, $Zp_T/y$
  - $\Delta y/\Delta \Phi/\Delta R$ ($Z, b$)
  - $m(bb), \Delta y/\Delta \Phi/\Delta R$ ($b, b), pT(bb$)

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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 $Z^+ \geq 1b$
- 5FNS agree with both $Z^+ \geq 1b$ and $Z^+ \geq 2b$

*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 1 parton 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: $\Delta R(bb)$

Sensitive to the various b-jet production mechanisms. Low $\Delta R(bb)$ 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
$Z+bb$: $p_T(bb)/m(bb)$

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

ATLAS
- $\sqrt{s} = 13$ TeV, $35.6$ fb$^{-1}$
- anti-$k_t$ jets, $R = 0.4$
- $p_T^{\text{jet}}>20$ GeV, $|y^{\text{jet}}|<2.5$

$Z/\gamma^*(\rightarrow\ell\ell) + \geq 2$ b-jets

Data
ALPGEN+Py6 4FNS (LO)
Sherpa 5FNS (NLO)

$Z/\gamma^*(\rightarrow\ell\ell) + \geq 2$ b-jets
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$Z/\gamma^*(\rightarrow\ell\ell) + \geq 2$ b-jets
Data
ALPGEN+Py6 4FNS (LO)
Sherpa 5FNS (NLO)

MC/Data
ALPGEN+Py6 (rew. NNPDF3.0a)
MGaMC+Py8 5FNS (LO)
Sherpa Fusing 4FNS+5FNS (NLO)

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Summary

Inclusive cross sections
- 5FNS NLO or LO ME+PS describe both $Z^+ \geq 1b$ and $Z^+ \geq 2b$
- 4FNS approaches struggle with $Z^+ \geq 1b$. Explicit 4FNS $Z+bb$ generators describe only $Z^+ \geq 2b$ 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