Z b-mass Uncertainty Study

AlphaS Group Meeting

Luca

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Goal and Strategy

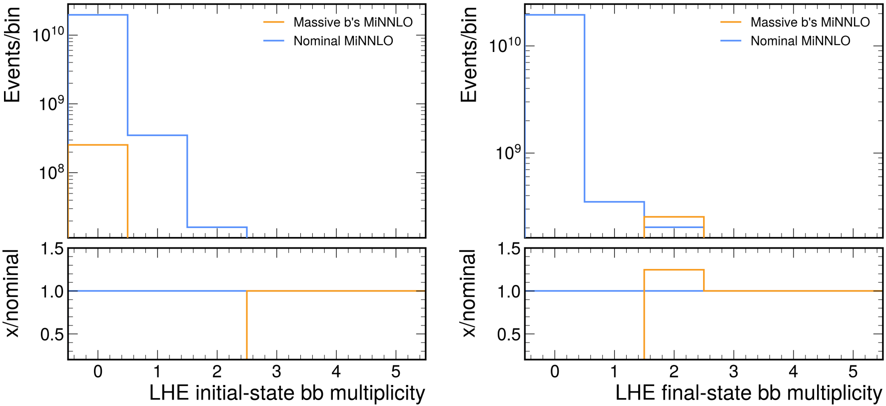
- Goal: derive a nuisance for MiNNLO Z (5FS, massless b quarks) using a comparison to Zbb MiNNLO (4FS, massive b quarks).
- Core method: compare distributions between the two samples and interpret differences as candidate nuisance content.
- Important context: 5FS vs 4FS scheme differences are part of the physical effect entering this nuisance.

Samples and Object Definitions

- Nominal sample: inclusive Zmumu MiNNLO (5FS, massless b).
- Alternate sample: Zbb MiNNLO (4FS, massive b). (Note: it seems this sample is actually $Z \to ee$.)
- Objects shown in this draft: LHE bb observables, gen b-jet observables, and B-hadron observables from GenPart-based definitions in the histmaker.

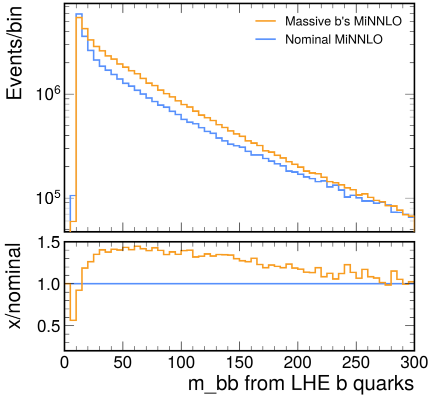
LHE Composition

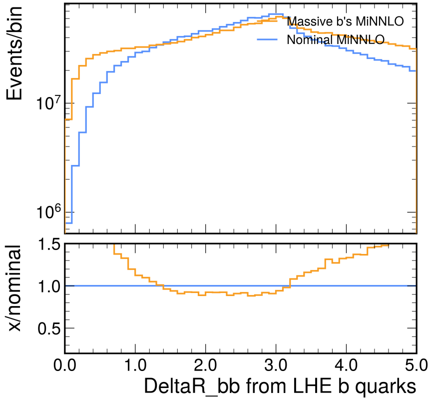
- Counts are built from LHEPart with b quarks identified by $|\mathrm{pdgId}| = 5$ and split by status: initial-state has status $= -1$, final-state has status $= 1$.



LHE Kinematics

- m_{bb}^{LHE} and $\Delta R_{bb}^{\mathrm{LHE}}$ are computed from LHE b and $\bar{b}$ quarks with $|\mathrm{pdgId}| = 5$; p_T observables use final-state LHE b quarks with status $= 1$.

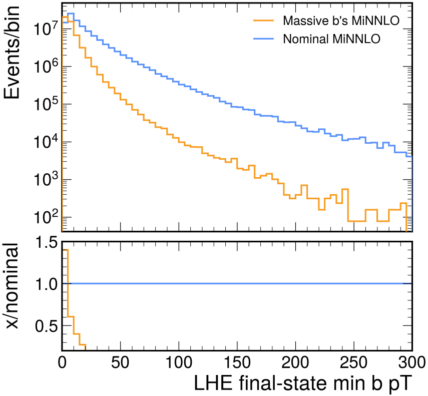


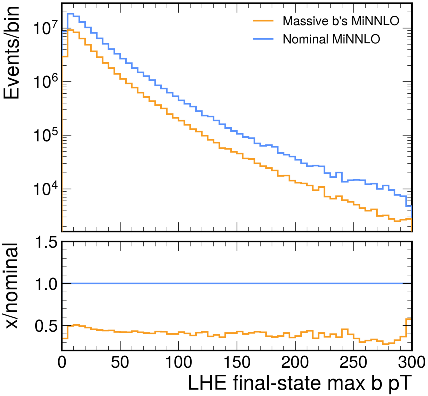


- Swapping at LHE-quark level is unphysical here because the two samples differ by flavor scheme (5FS vs 4FS), not just by a small kinematic perturbation.

LHE b-Quark pT Spectra

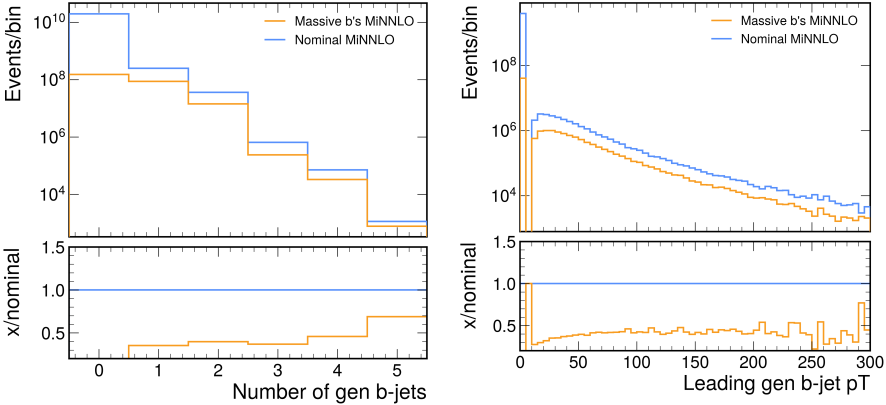
- Final-state LHE b quarks are selected with status $= 1$ and $|\mathrm{pdgId}| = 5$; shown are event-wise minimum and maximum p_T across final-state $b/\bar{b}$ quarks.





Jet-Level Composition and pT

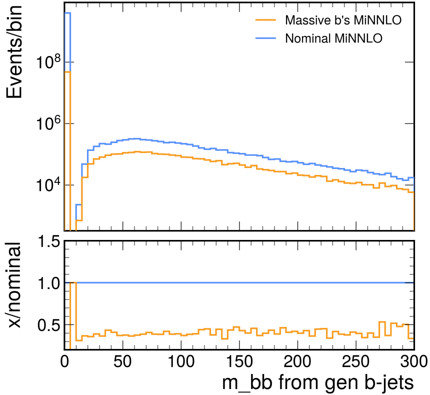
- A gen b-jet is defined by $\mathrm{hadronFlavour} = 5$; n_{bjets} uses $p_T > 20\,\mathrm{GeV}$ and $|\eta| < 2.5$, while the leading-jet p_T panel uses the loose ordered list with $p_T > 0$ and $|\eta| < 10$ (as stored in NanoAOD).

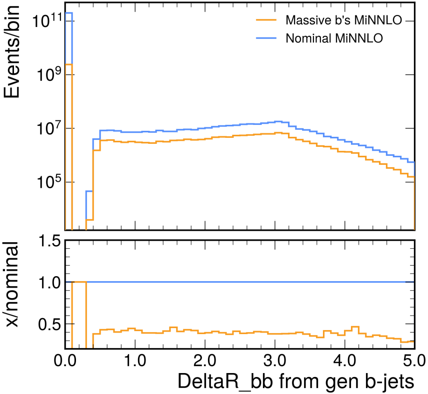


- Because gen jets in NanoAOD effectively have a threshold near $20\,\mathrm{GeV}$, many events in the Zbb sample still have no tagged b-jets, so this is not a robust swap handle.

Jet-Level bb Pair Kinematics

- m_{bb}^{jet} and $\Delta R_{bb}^{\mathrm{jet}}$ are computed from the leading two gen b-jets after requiring $p_T > 20\,\mathrm{GeV}$ and $|\eta| < 2.5$.

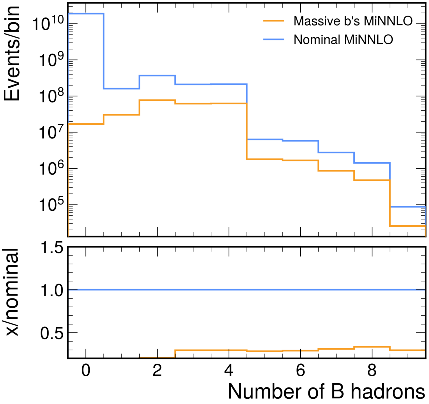


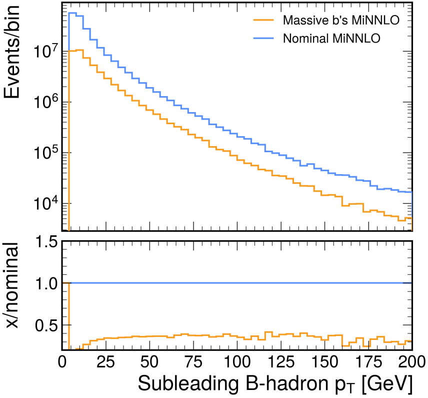


- The ratios are relatively flat between the two samples in these jet-pair observables.

B-hadron Multiplicity and pT

- B hadrons are selected from final-state GenPart objects using the B-hadron identifier; multiplicity and p_T observables on this slide require hadron $p_T > 5\,\mathrm{GeV}$.

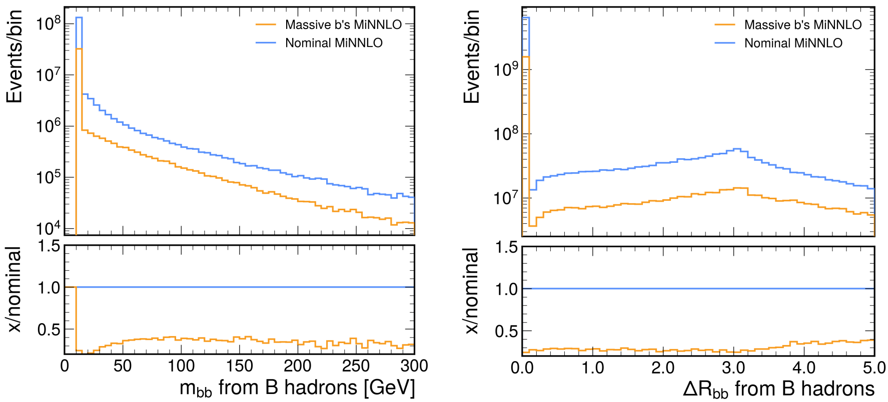




- Ratios are fairly flat in shape, but there is a sizeable normalization difference; unnormalized swapping would induce an overly large systematic, so a normalized-swap option is motivated.

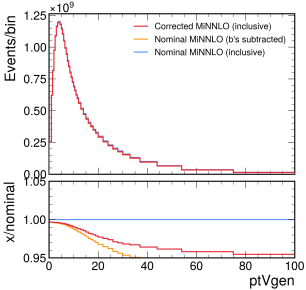
B-hadron Pair Kinematics

- This slide is restricted to events with at least two B hadrons above $5\,\mathrm{GeV}$; pair observables use the leading two selected B hadrons.



Swap Procedure on $p_T^{V,\mathrm{gen}}$ (Unnormalized)

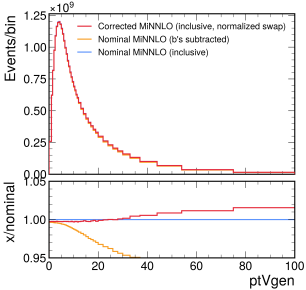
- Procedure: select events with at least two B hadrons above $5\,\mathrm{GeV}$ and subleading B-hadron $p_T > 10\,\mathrm{GeV}$ in both samples; replace the selected 5FS component with the selected 4FS component without extra scaling.



- Conclusion: this direct swap induces a too-large systematic because of the normalization difference.

Swap Procedure on $p_T^{V,\mathrm{gen}}$ (Normalized)

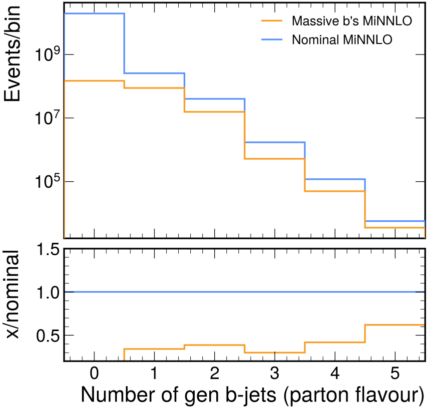
- Procedure: same event selection as previous slide, but normalize the selected 4FS component to the selected 5FS yield before replacement.

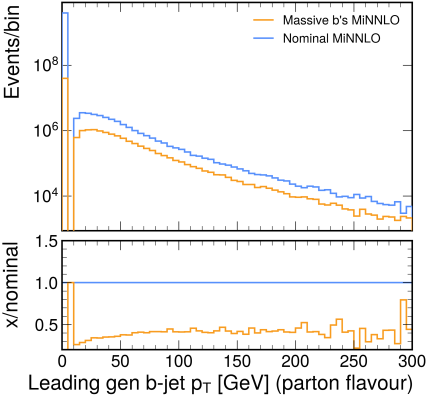


- With normalization, the ratio is much flatter and the effect is more shape-like, making this prescription more suitable as a nuisance candidate, though it may be unphysical.

Backup: Parton-Flavour Jet Multiplicity and Leading p_T

- Backup check: define jet tags with parton flavour ($|\mathrm{partonFlavour}| = 5$) and use the same jet kinematic cuts as in the hadron-flavour study.

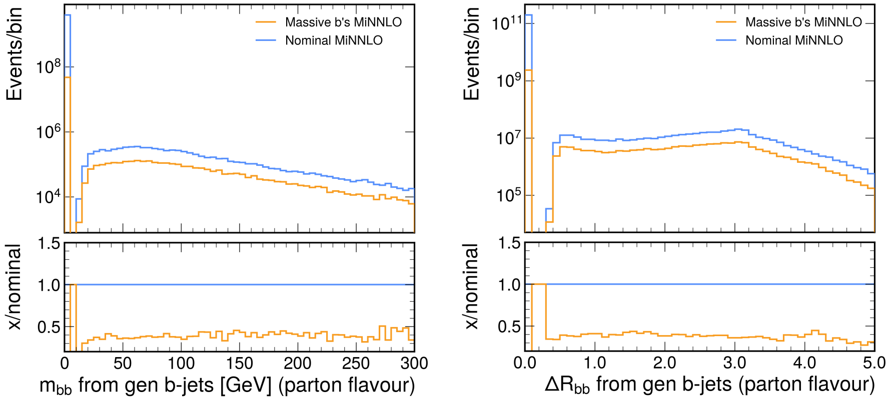




- These parton-flavour-tagged shapes are qualitatively very similar to the hadron-flavour-tagged ones.

Backup: Parton-Flavour Jet Pair Kinematics

- Backup check: compare m_{bb}^{jet} and $\Delta R_{bb}^{\mathrm{jet}}$ built from parton-flavour-tagged jets.



- Again, behavior is close to the hadron-flavour case, so this does not materially change the swap-handle conclusion.