Measurement of Z boson production in association with high-transverse-momentum jets in pp collisions at 13 TeV using full Run-2 data with the ATLAS detector

ISMD2022 Flash Talk

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ATLAS EXPERIMENT

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Motivation

New Results

Cross-section measurements for the production of a Z boson in association with high-transverse-momentum jets in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector

The ATLAS Collaboration

arXiv:2205.02597
STDM-2018-49
Submitted to JHEP

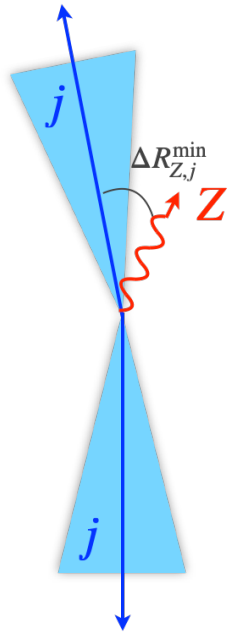
- Analysis of the full Run-2 ATLAS dataset.
  → *pp* collisions collected in 2015-2018 at $\sqrt{s} = 13$ TeV.
  → Full Run-2 dataset: $\mathcal{L} = 139$ fb^{-1}.

- Measurement of ***Z* boson** production in association with **jets.**
  → $\boldsymbol{p_T(jet) \geq 100}$ **GeV**.
  → Phase space poorly modelled by contemporary MC generators.
  → First full Run-2 analysis of this type!
  → Results unfolded to fiducial phase space.

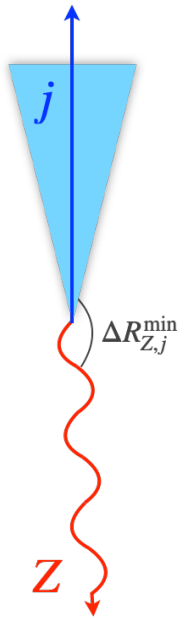
- Studies higher-order corrections from quantum chromodynamics (QCD) and electroweak (EW) theory.

- Focus on "*high-*p_T region": $p_{\mathrm{T}}(leading\ jet) \geq 500$ GeV.
  Enhances two event topologies:
  → Collinear emission of on-shell *Z* boson from a jet.
  → Back-to-back scatter of *Z* + jet

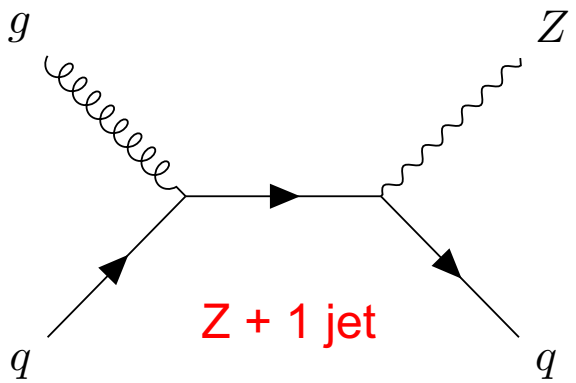
Collinear

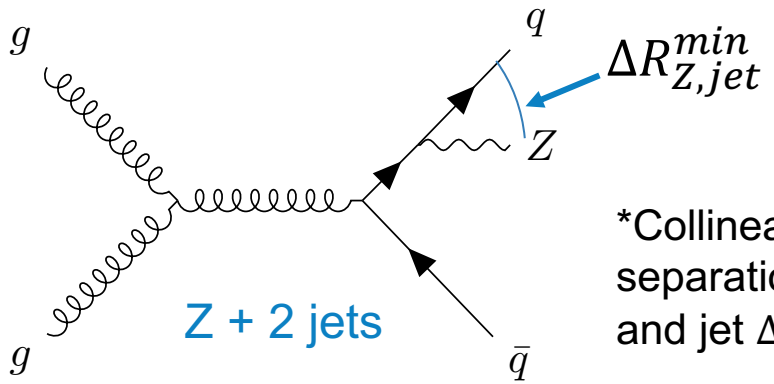


Back-to-back



Real Z boson radiation





*Collinear: Small angular separation between Z boson and jet $\Delta R^{min}_{Z,jet}$.

- **Real EW correction** to dijet production enhanced by $\alpha_s \ln^2(\frac{p_T(jet)}{m_Z})$ vs **Z + 1 jet**
- With large $p_{\mathrm{T}}(jet)$, **Z + 2 jets** no longer suppressed vs **Z + 1 jet**. *e.g.* $p_{\mathrm{T}}(leading\ jet) \geq 500$ GeV

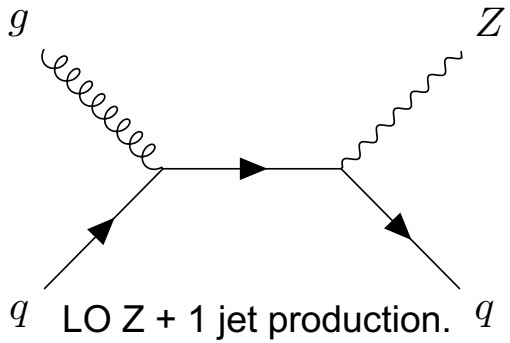
- **Z + 2 jets** offer unique event kinematics of **collinear Z boson emission** to study!
- Soft & collinear Z boson emission:
  → $p_{\mathrm{T}}(Z) \ll p_{\mathrm{T}}(closest\ jet)$.
  → Small distance between Z and closest jet.

★ Showcased in the poster.

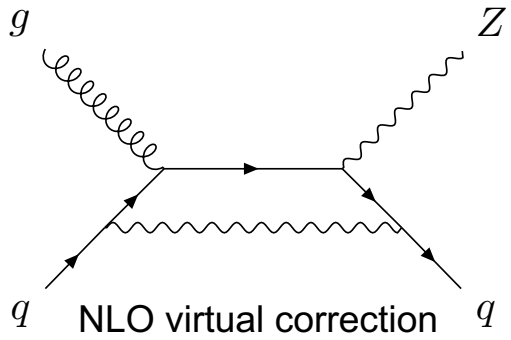
Virtual Electroweak Corrections

- $p_{\mathrm{T}}(leading\ jet) \geq 500\ \mathrm{GeV}$ enhances production of interesting Z + 1 jet events.
  → Z boson and jet travel in opposite directions (back-to-back).
  → $p_{\mathrm{T}}(jet)$ and $p_{\mathrm{T}}(Z)$ equal.

- NLO virtual EW corrections have large impact on these events.
- Effect grows as Q^2 .
  → Negative contribution.
  → Correction can reach ~20% in high $p_{\mathrm{T}}(jet)$ and $p_{\mathrm{T}}(Z)$ regions.

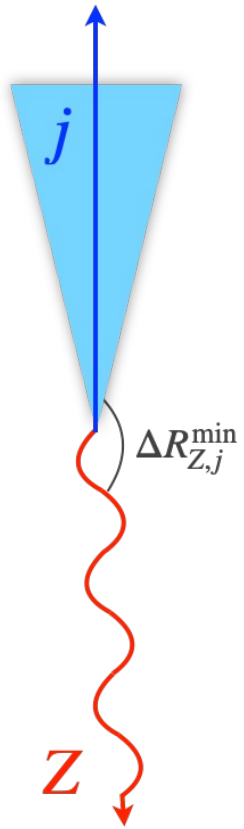


LO Z + 1 jet production.



NLO virtual correction to Z + 1 jet production.

Back-to-back



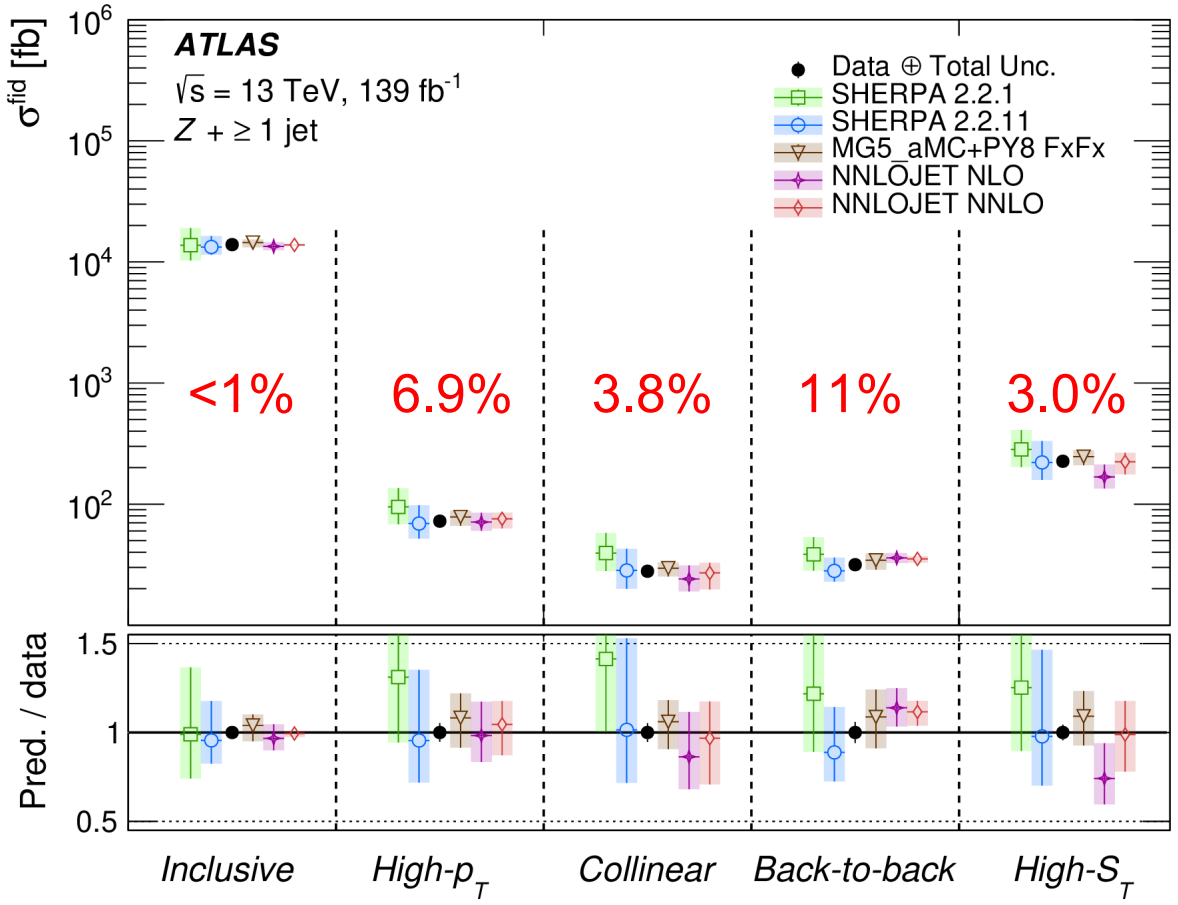
Sherpa2.2.11 includes NLO virtual EW corrections to the cross sections.
→ Brand new addition to Sherpa prediction!

Showcased in the poster.

Fiducial cross sections

arXiv:2205.02597

Region	Definition
Inclusive	$Z + \geq 1$ jet
High-p_{T}	*Inclusive* and $p_{\mathrm{T},j1} \geq 500$ GeV
Collinear	*High-p_{T}* and $\Delta R_{Z,j}^{\mathrm{min}} \leq 1.4$
Back-to-back	*High-p_{T}* and $\Delta R_{Z,j}^{\mathrm{min}} \geq 2.0$
High-S_{T}	*Inclusive* and $S_{\mathrm{T}} \geq 600$ GeV

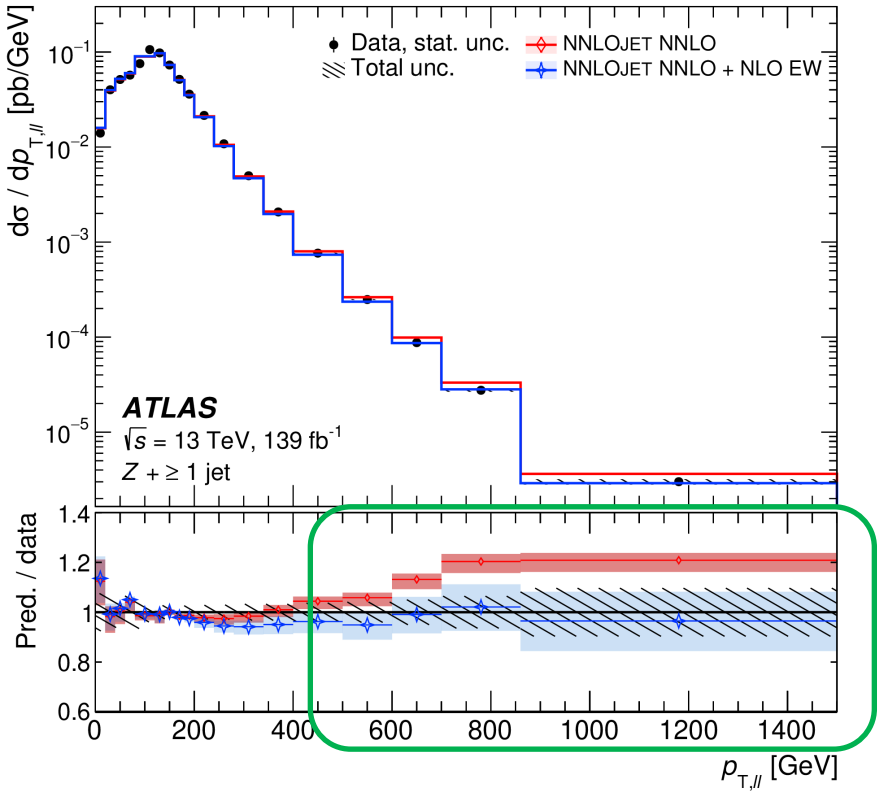


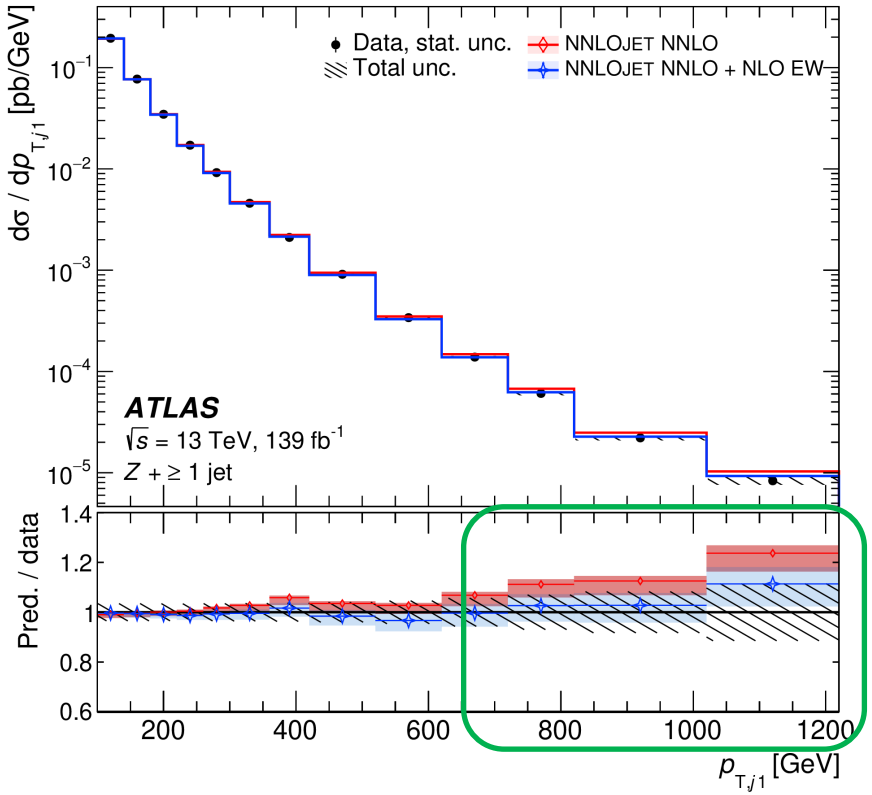
Impact of virtual NLO EW corrections shown in red. Always negative values. Only Sherpa2.2.11 includes these corrections.

- All theoretical predictions describe data in five signal regions.
- Precision of measurements much higher than of predictions.
- QCD scale uncertainties reaching 50-60% …
- **Differential cross sections give much more information on individual performance of predictions!**

Virtual Electroweak Corrections

- Only Sherpa2.2.11 includes NLO virtual EW corrections to the cross sections.
- Only NNLOjet @ NNLO (Z + 1 jet @ NNLO) is precise enough …
- NLO virtual EW corrections extracted from Sherpa2.2.11 and supplied to NNLOjet @ NNLO.





- Significant improvement in high pT(Z) and pT(jet) phase spaces.
- Distributions in agreement to data w/ corrections.

Conclusion

- **Come see my poster and talk to me!**

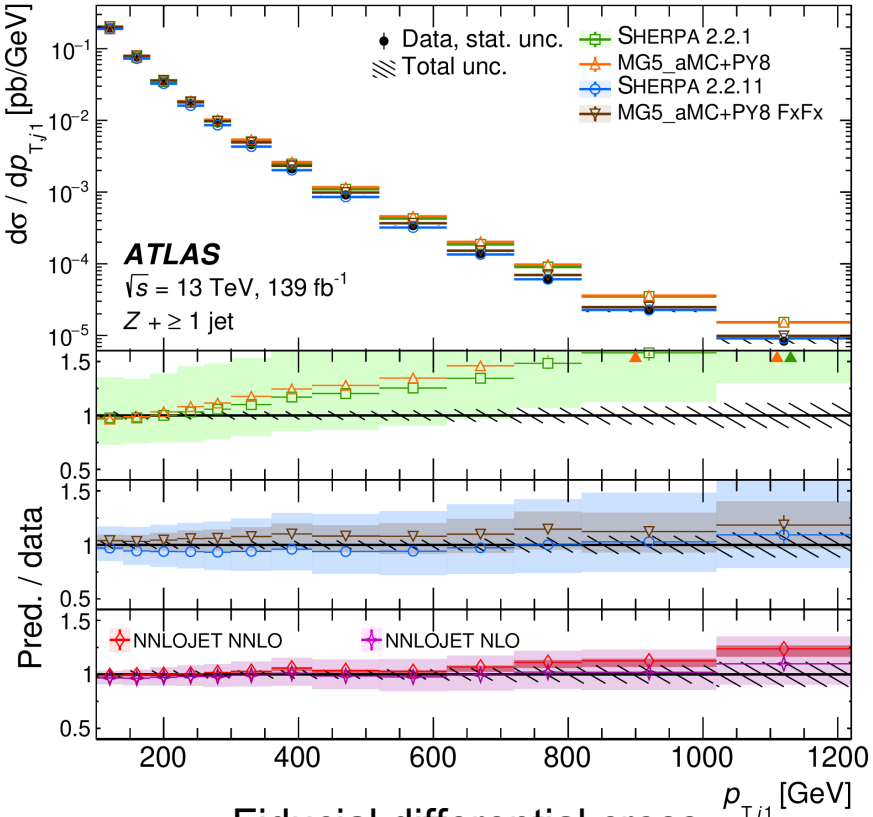
- The **first** measurement with the full Run 2 dataset measuring:
  → high transverse momentum jets,
  → collinear emission of a *Z* boson from a jet,
  → back-to-back Z+1 jet sensitive to NLO virtual EW corrections.

- Exciting results on performance of theoretical predictions!
  → **State-of-the-art predictions describe data.**
  → **High-p_T jets challenge to contemporary MC generators.**

- These measurements are crucial for Run-3 and forwards.
  → Theory predictions much less precise than measurements.
  → Studied the impact of important higher-order corrections.
  → Identified regions of phase space where MC predictions are strong or weak at describing data.

- More information here, here and with me at my poster.

arXiv:2205.02597



Fiducial differential cross section vs 6 predictions! Collinear and back-to-back processes showcased in **poster**!

★ Showcased in the poster.

Backup


AHH! IT'S 5:00PM AND I HAVEN'T DONE ANYTHING TODAY!
WHY!? WHY DID I WASTE THE WHOLE DAY DOING STUPID THINGS THAT DON'T MATTER!??
MUST... DO... SOMETHING... ANYTHING...
reads one paragraph of paper
PHEW..!
ANOTHER DAY IN GRAD SCHOOL.
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Collinear Z + Jets Signatures

- Energy & momentum conservation rules in collinear Z boson emission:
  - → Number of jets **always** $N_{jets} \geq 2$.
  - → $p_{\mathrm{T}}(Z) \ll p_{\mathrm{T}}(closest\ jet)$. $r_{Z,j} = \frac{p_{\mathrm{T}}(Z)}{p_{\mathrm{T}}(closest\ jet)}$: small values.
  - → $\Delta R_{Z,jet}^{min}$ small.

- Collinear emission **defined** as $\Delta R_{Z,jet}^{min} \leq 1.4$.
  - → Can broadly think of it as units of radians.