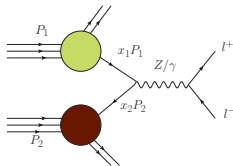# Electroweak corrections to the angular coefficients of Z-boson production and decay at finite-p_T [1]

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SM@LHC (online),
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[1] R. Frederix, T. Vitos, arXiv:2007.08867

Angular coefficients for the Drell-Yan process

Expansion for non-zero p_T

for some observable Σ:

$$\Sigma(\alpha, \alpha_S) = \underbrace{\alpha^2 \alpha_S \Sigma_{2,1}}_{\text{LO}} + \underbrace{\alpha^2 \alpha_S^2 \Sigma_{2,2}}_{\text{NLO QCD}} + \underbrace{\alpha^3 \alpha_S \Sigma_{3,1}}_{\text{NLO EW}} + \mathcal{O}(\alpha^4 \alpha_S^2)$$

○ **Differential cross section** in Z-boson kinematics expanded in **real spherical harmonics** $Y_{lm}(\theta, \phi)$:

$$
\begin{aligned}
\frac{\mathrm{d}\sigma}{\mathrm{d}p_{T,Z}\mathrm{d}y_Z\mathrm{d}m_{ll}\mathrm{d}\Omega} \propto \Big(& (1 + \cos^2\theta) + A_0 \frac{1}{2}(1 - 3\cos^2\theta) + A_1 \sin 2\theta \cos\phi \\
& + A_2 \frac{1}{2}\sin^2\theta \cos 2\phi + A_3 \sin\theta \cos\phi + A_4 \cos\theta \\
& + A_5 \sin^2\theta \sin 2\phi + A_6 \sin 2\theta \sin\phi + A_7 \sin\theta \sin\phi \Big)
\end{aligned}
$$

with eight **angular coefficients** $A_i(p_{T,Z}, y_Z, m_{ll})$

Lam-Tung relation

- Up to order $\alpha^2 \alpha_S$ (LO): Lam-Tung relation $A_0 = A_2$
- Predictions available [2] at order $\alpha^2 \alpha_S^3$ (NNLO QCD)
- LHC and Tevatron data all show **higher violation** of Lam-Tung than predicted by NNLO QCD at $p_{T,Z} \gtrsim 20$ GeV
- **NNLO QCD moves** SM prediction **closer to data**
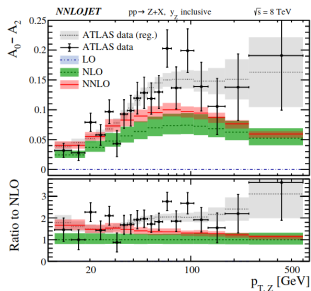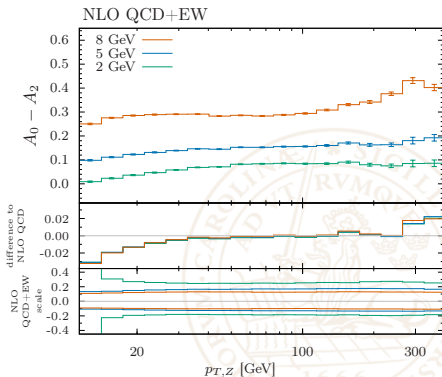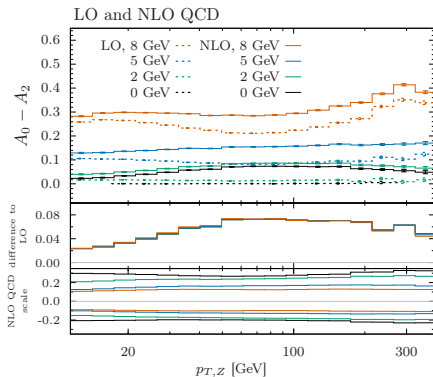- $\rightarrow$ Let us see the effects of NLO EW corrections!

Figure: Figure from R. Gauld *et al.*

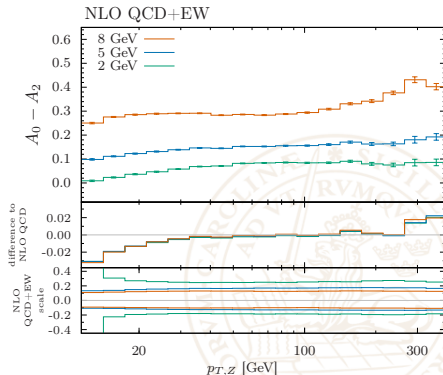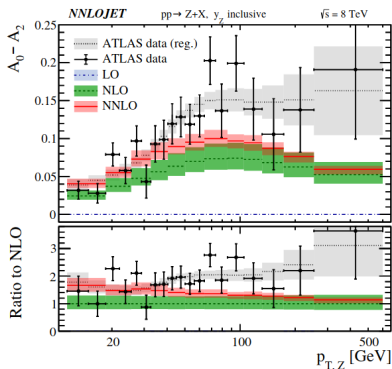---

[2] R. Gauld, *et al.*, arXiv:1708.00008

Angular coefficients: results

- **Fixed-order** results based on MadGraph5_aMC@NLO
- Lam-Tung relation $A_0 - A_2$
- **Difference** rather than ratio as K-**factor**

Angular coefficients: results

- Lam-Tung relation $A_0 - A_2$
- **Difference** rather than ratio as K-factor
- **Qualitative comparison** to **ATLAS** data and **NNLO QCD** prediction[3]

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[3]R. Gauld, *et al.*, arXiv:1708.00008

Summary

Technical cut

Lam-Tung relation difference K-factor: no dependence on the cut

Low-p_T range

Found sizeable effect on the Lam-Tung relation for $p_{T,Z} \lesssim 20$ GeV

High-p_T range

No electroweak effect for $p_{T,Z} \gtrsim 20$ GeV
$\rightarrow$ elecrtoweak logs are not expected to contribute largely

Thank you for listening!

Back-up slides

Calculational setup

- **Fixed-order**: $pp \rightarrow l^+ l^- j$ at 8 TeV with MadGraph5_aMC@NLO
- Electroweak parameters: **complex G_μ-scheme** and complex mass scheme
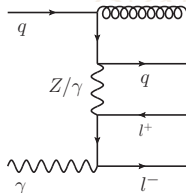
On the θ_w

- High sensitivity to θ_w
- Include one-loop correction to **ρ-parameter** [4]

$$\Delta\rho = \frac{\sqrt{2}G_\mu}{16\pi} 3m_t^2$$

in the LO and NLO QCD calculations

- **Double collinear singularity** for lepton + gluon
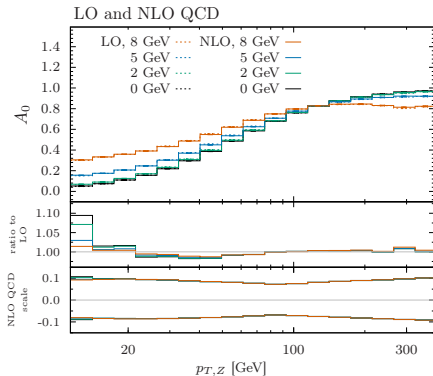- → Extrapolate to the full phase-space by varying the cut value:

$$(p_T)_{\text{cut}} \in \{2.0, 5.0, 8.0\} \text{ GeV}$$

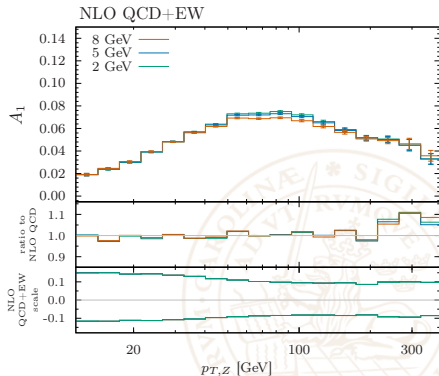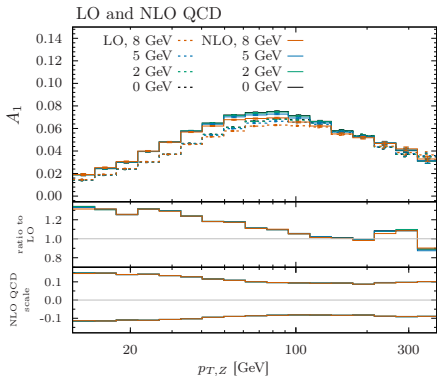[4] J Fleischer *et al.*, 10.1016/0370-2693(93)90810-5

Angular coefficients: results

- Distributions for A_0
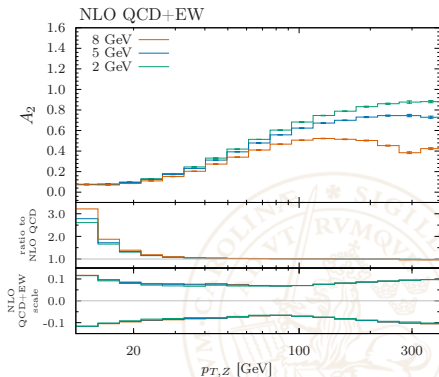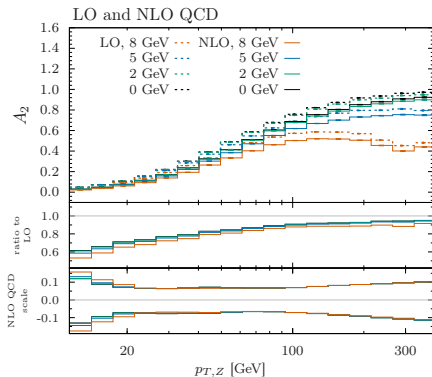- No safe extrapolation in low-$p_{T,Z}$ region

Angular coefficients: results

○ Distributions for **A_1**
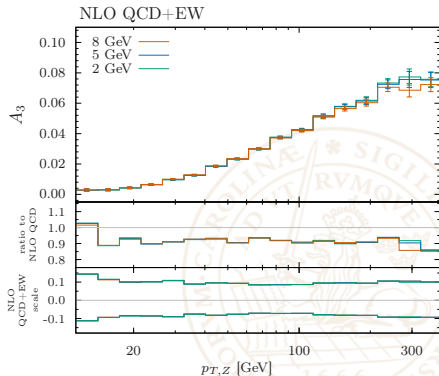
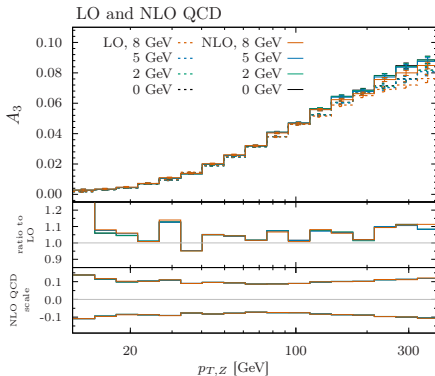○ Negligible electroweak corrections

Angular coefficients: results

○ Distributions for A_2

Angular coefficients: results

- Distributions for A_3
- Overall -10% electroweak corrections
- Would be **−30%** if **no one-loop** ρ-parameter in NLO QCD

Angular coefficients: results

- Distributions for A_4
- Same -10% electroweak corrections

LO and NLO QCD

NLO QCD+EW