Measurement of azimuthal decorrelation angle between the leading jet and the scattered lepton in deep inelastic scattering at HERA

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1. Status
2. Theory calculations
3. Final figures
4. Discussion
5. Summary
6. Backup

*They are in new institutions

Status

- Last presentation on 15 September 2020. All technical details were addressed so moving towards publication.
- However, theoretical calculation for final plots were missing.
- Initially waiting for Feng Yuan to provide the calculations.
- Also, contacted Mark Sutton and Claire Gwenlan (from APPLFast/NNLOJET) but still waiting for their calculations.
- Feng Yuan referred to Daniel de Florian “Jet production in Polarized DIS at NNLO” (arXiv:2005.10705)
- Contacted Daniel de Florian about our measurements, and they were already working with our preliminary results.
- I sent him the binning (not the measurement values) for the final results, and they provided most of the calculations needed.

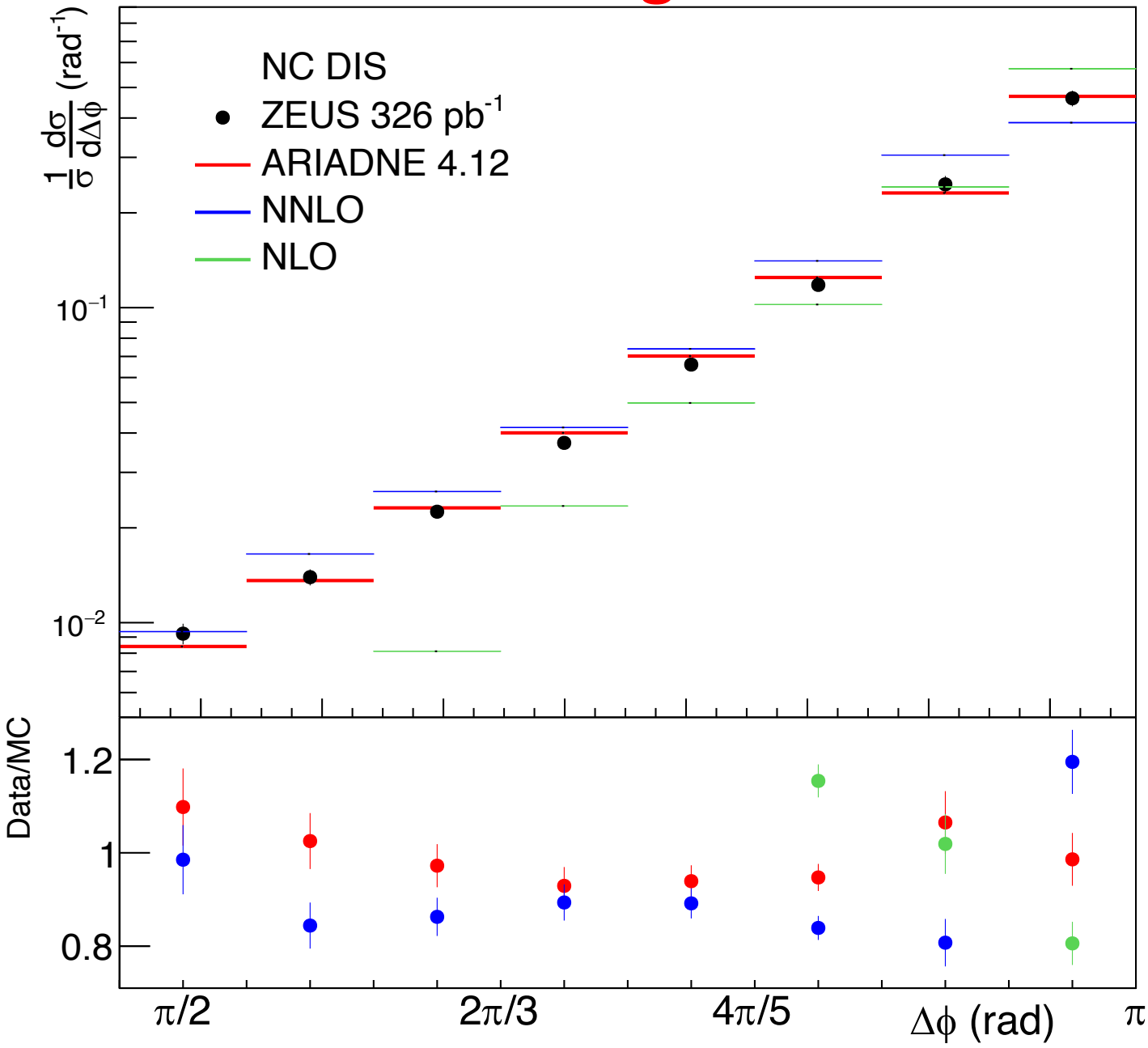
Theoretical calculations

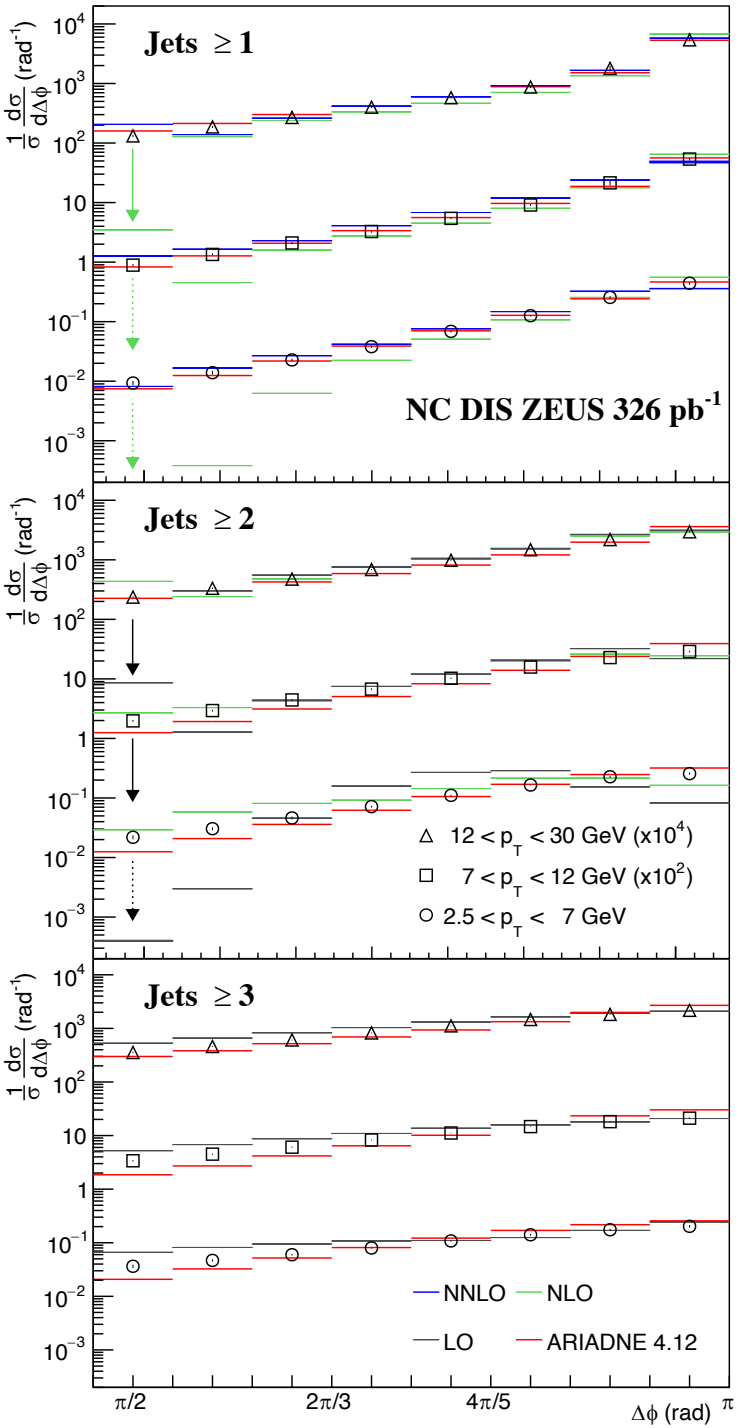
From de Florian's group:

- The calculations are done as arXiv:2005.10705 (for the EIC), but with the HERA parameters (E_p=920 GeV, E_e=27.5 GeV and kt algorithm with R=1)
- Up to order alpha_s^2
  - NNLO for single jet
  - NLO for di-jets
  - LO for 3 jets
  - Cannot produce results for 4 or more jets. We have this measurement (→ see backup)
- "MC uncertainties" (not sure what they are referring) are provided but are very small. Systematic uncertainties due variation of the renormalization and factorization factors are not (→ see backup)

Combined p_T and Q^2

Final figure?





Propose Final figure 1

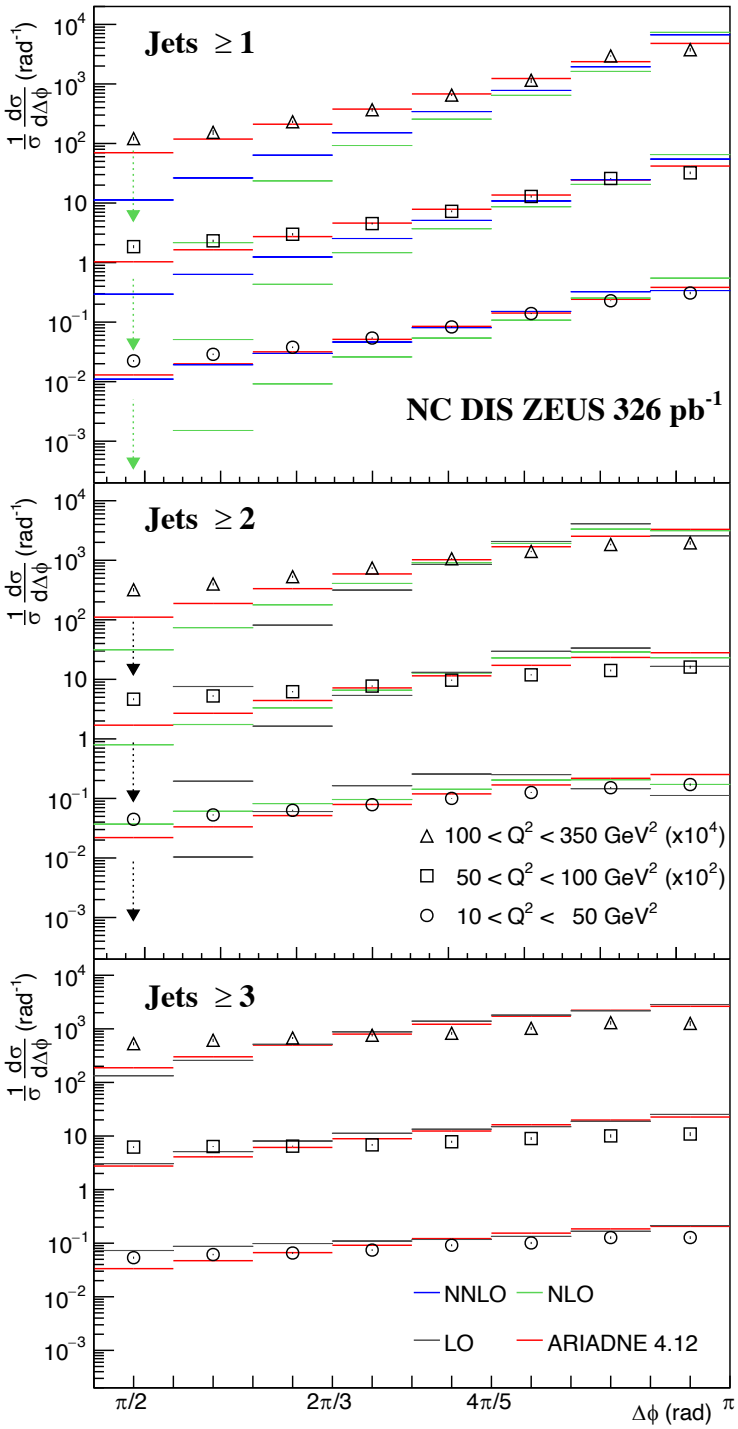
- Very good matching for NNLO
- First two bins for $12<p_T<30$ bin do not match but it looks like this is statistics
- NLO underestimates the data at dphi$<4\pi/5$ but improves at high p_T

- Good matching for NLO and gets better at higher p_T bins
- First two bins for $12<p_T<30$ bin do not match (missing statistics?)
- LO underestimates the data at dphi$<2\pi/3$ but slight improves at high p_T

- Fair matching for LO and jets>3
- Theory seems to overestimate the data at dphi $< 3\pi/4$

P_T bins

Dash arrow indicates the theory prediction is outside the plot range
Uncertainties of the theory calculations are included but are very small
Uncertainties of the measurements are included but are very small



Propose Final figure 2

- Good agreement of NNLO only for low Q^2
- Degrades for $Q^2 > 50$ GeV^2
- NNLO and NLO underestimate the data, except at dphi~π
- Seems like a higher order calculation will match the data at high Q^2

- Good matching of NLO only for low Q^2
- NLO and LO underestimate the data, except at dphi~π
- Again, a higher order calculations seems needed for high Q^2

- LO calculations seems to match Ariadne
- LO only seems to reproduce the lower Q^2 bin

Q^2 bins

Dash arrow indicates the theory prediction is outside the plot range
Uncertainties of the theory calculations are included but are very small
Uncertainties of the measurements are included but are very small

Conclusions

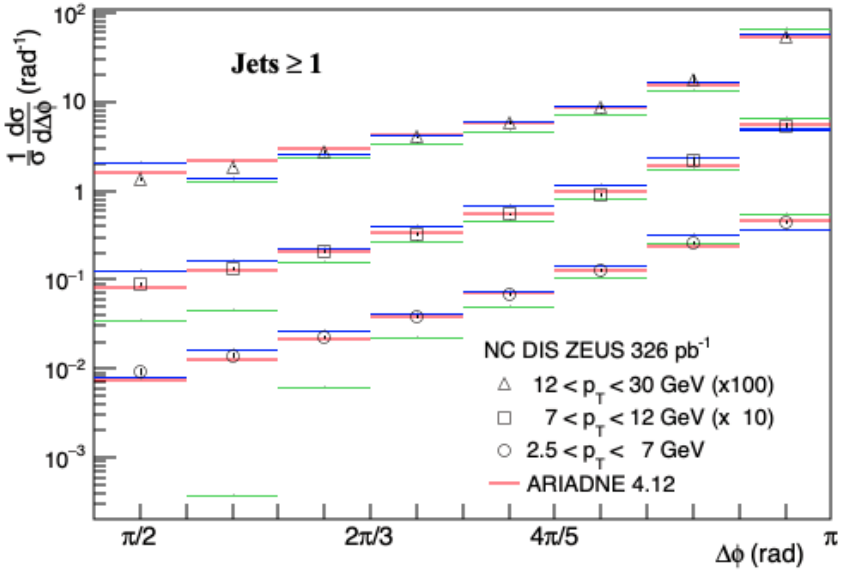
- High order corrections seem to have a clear impact to the jet production at the soft and hard gluon radiation region (dphi<3π/4).
- Good agreement only for low Q^2.
- Looks like higher order calculations are needed for $Q^2 > 50\ GeV^2$.

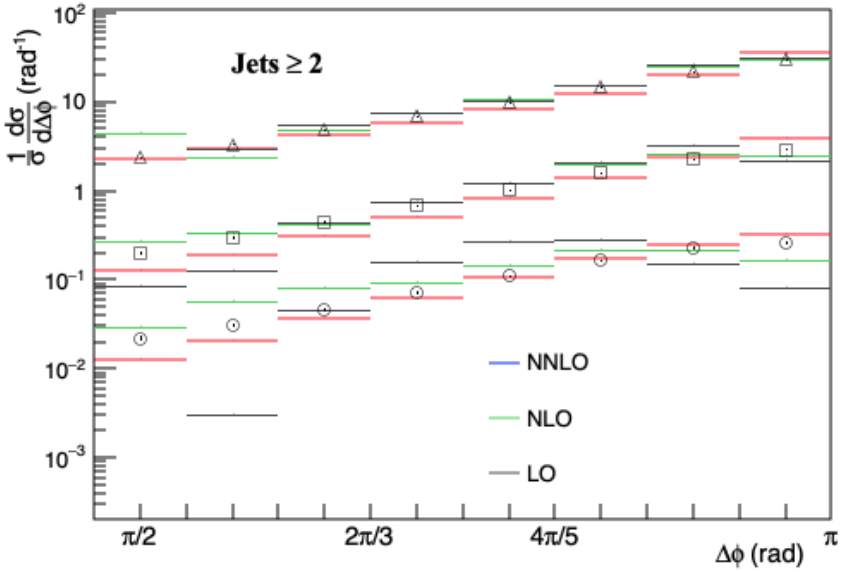
Moving forward

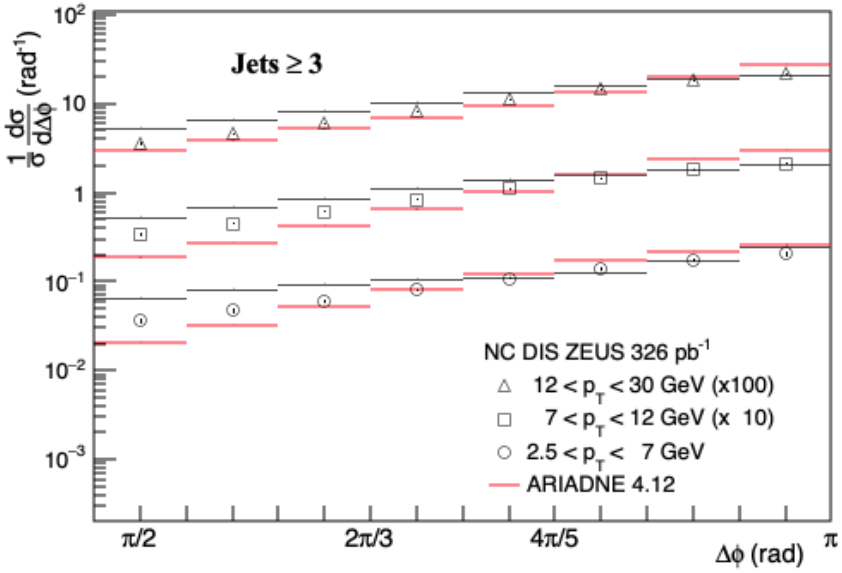
- Initial Tevatron, CMS and ATLAS papers compare data with MC generators and theory predictions, but they do not show results in different jet multiplicities
- CMS similar paper in 2018, with jet multiplicity (until 3-jets), does not compare data with theory. Only compares with MC generators.
- We address these two first bullets in our measurement. Also this is the first measurement in DIS.
- I am planning to meet with the de Florian's group to discuss these results and trim technical details (e.g. get theory systematic uncertainties) Can I show them these plots?
- A complete draft of a paper is already written but need to include a theory discussion paragraph(s).
- I would like to start the publication process with these two figures (targeting a letter) in the coming weeks.
- Accepted abstract for DIS 2021 in three weeks from now. Presenting preliminary results.

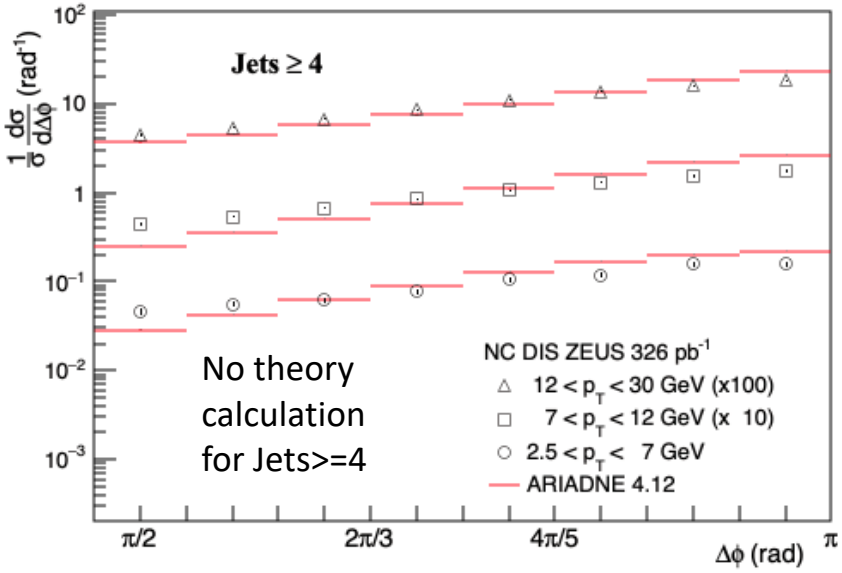
Backup

Previous figure

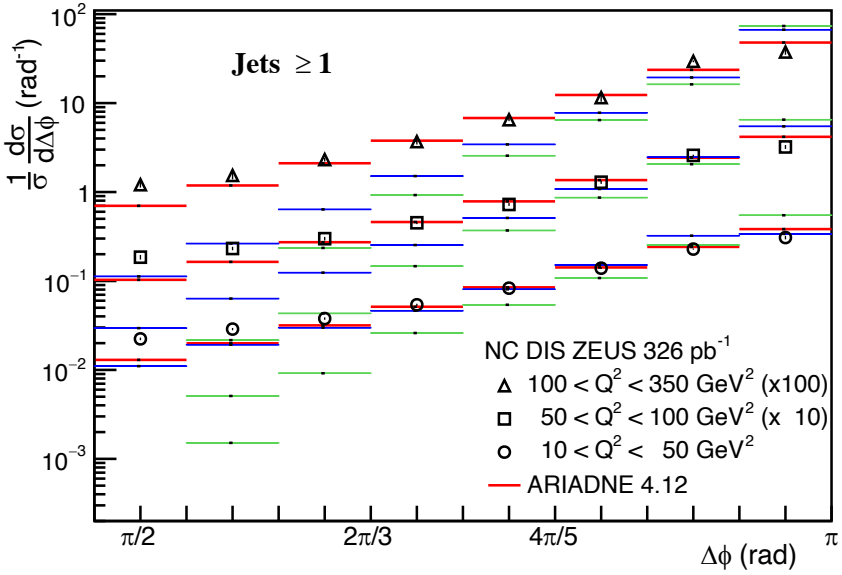


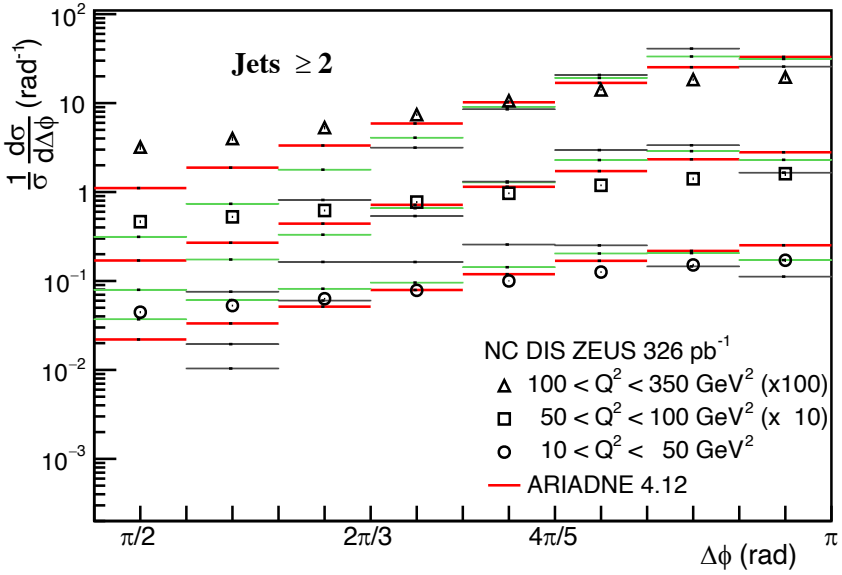


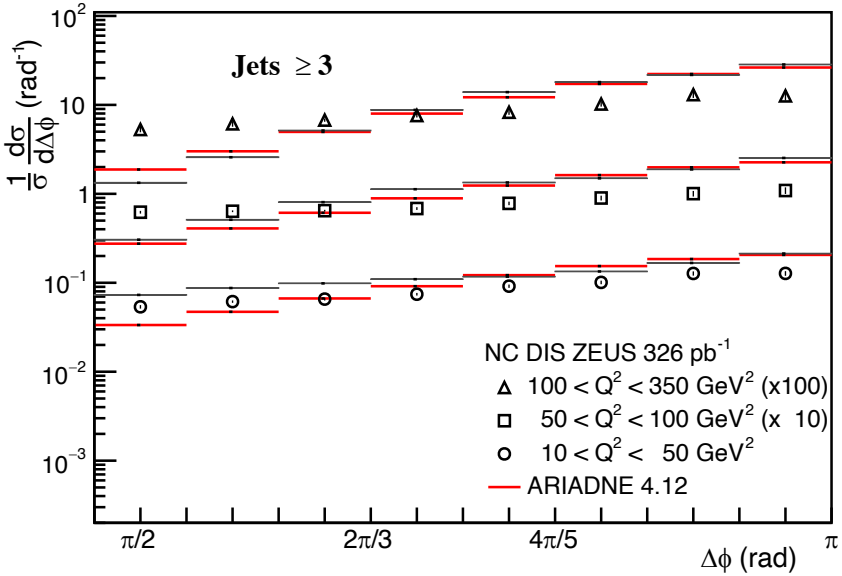


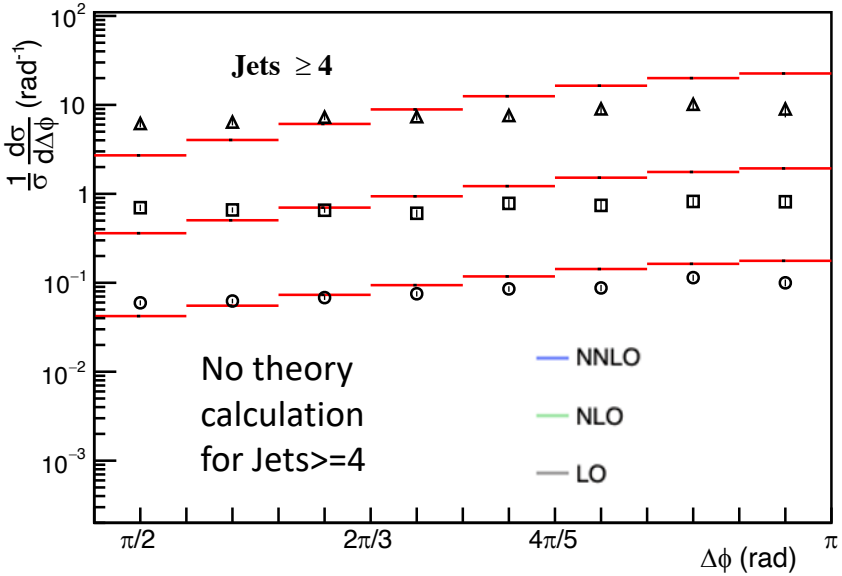


Previous figure



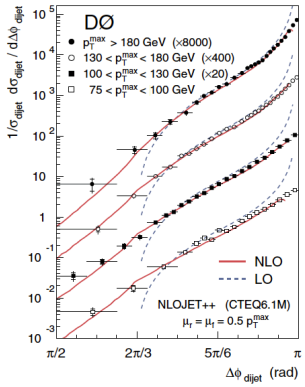






Other experiment results

[1]



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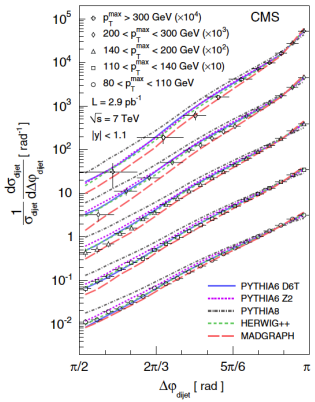

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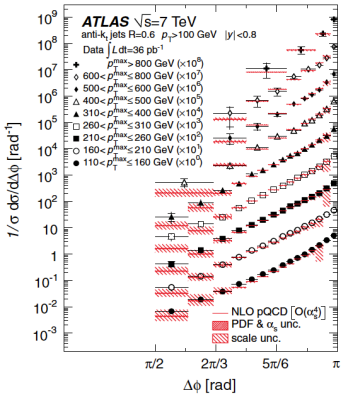

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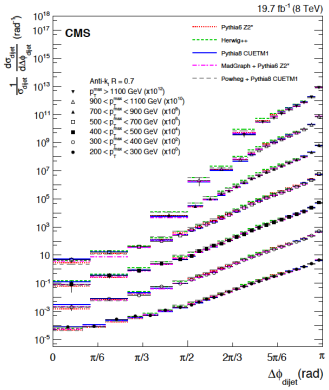

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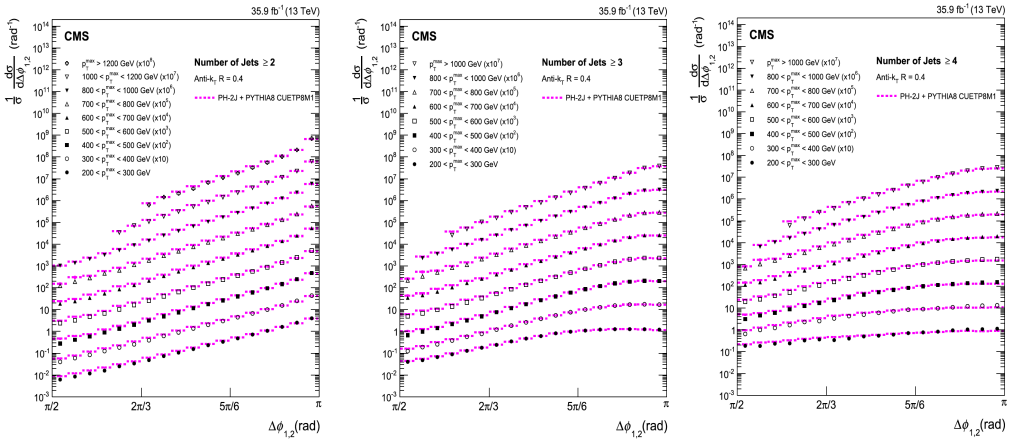

[1] Phys. Rev. Lett. 94, 221801 (2005). D0

[2] Phys. Rev. Lett. 106, 122003 (2011). CMS

[3] Phys. Rev. Lett. 106, 172002 (2011). Atlas

[4] Eur. Phys. J. C 76:536 (2016). CMS

[5] Eur. Phys. J. C 78:566 (2018). CMS

arXiv:2005.10705

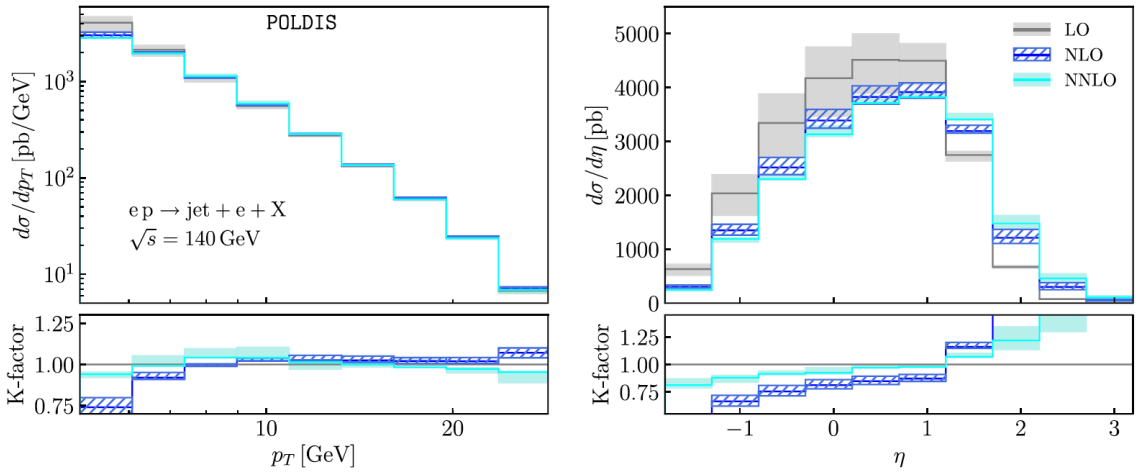

FIG. 1. Single-jet pseudorapidity and transverse momentum unpolarized distributions at LO, NLO, and NNLO. The bands reflect the variation in the cross section when changing the scales as $\mu_R = \mu_F = [1/2, 2]Q$. The lower inset shows the corresponding K factors as defined in the main text.

logical results involving more jets will be shown elsewhere [21].

In order to present the NNLO results for the EIC considering the configuration with a proton beam energy $E_p = 275$ GeV and electron beam energy $E_e = 18$ GeV, we rely on the following setup. For unpolarized and polarized parton distributions, we use the NLO PDF4LHC15 [29] and DSSV [5,30] sets, respectively, and fix the central factorization and renormalization scales to $\mu_F^2 = \mu_R^2 = Q^2$ with α_s evaluated also at NLO accuracy with $\alpha_s(M_Z) = 0.118$. Jets are reconstructed using the antik_T clustering algorithm with $R = 0.8$ using the E_T-weighted recombination scheme, and are required to satisfy

$$5 \text{ GeV} < p_T < 36 \text{ GeV} \quad \text{and} \quad |\eta| < 3. \tag{2}$$

Furthermore, on the leptonic side we request cuts similar to those of the Hadron-Electron Ring Accelerator (HERA), with

As it happens in the case of HERA [9], a clear trend can be observed on the effect of higher order corrections on pseudorapidity, with rather small corrections in the central region but larger contributions in the forward region $\eta > 1$, which becomes populated by the extra jets generated at NLO and NNLO. In that kinematical regime, higher order corrections become essential for an accurate description of the distribution. The *shift* in the distribution toward larger rapidities also results in a considerable reduction in the cross section in the electron beam direction ($\eta < -1$). In the same way, the transverse momentum distribution is also much affected by higher order corrections in the low p_T region. In Fig. 1, we also present a first estimate of the perturbative uncertainties by performing simultaneous variations of the renormalization and factorization scales as $\mu_R = \mu_F = [1/2, 2]Q$, represented by the corresponding bands. In general we observe a reduction in the size of the band when moving to higher orders and rather good overlap between the NLO and NNLO bands, anticipating an improvement in the convergence of the expansion.