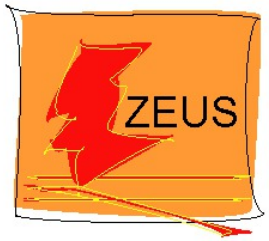
Investigation of collective effects in DIS with the ZEUS detector

Mariusz Przybycień

AGH University of Science and Technology, Krakow, Poland

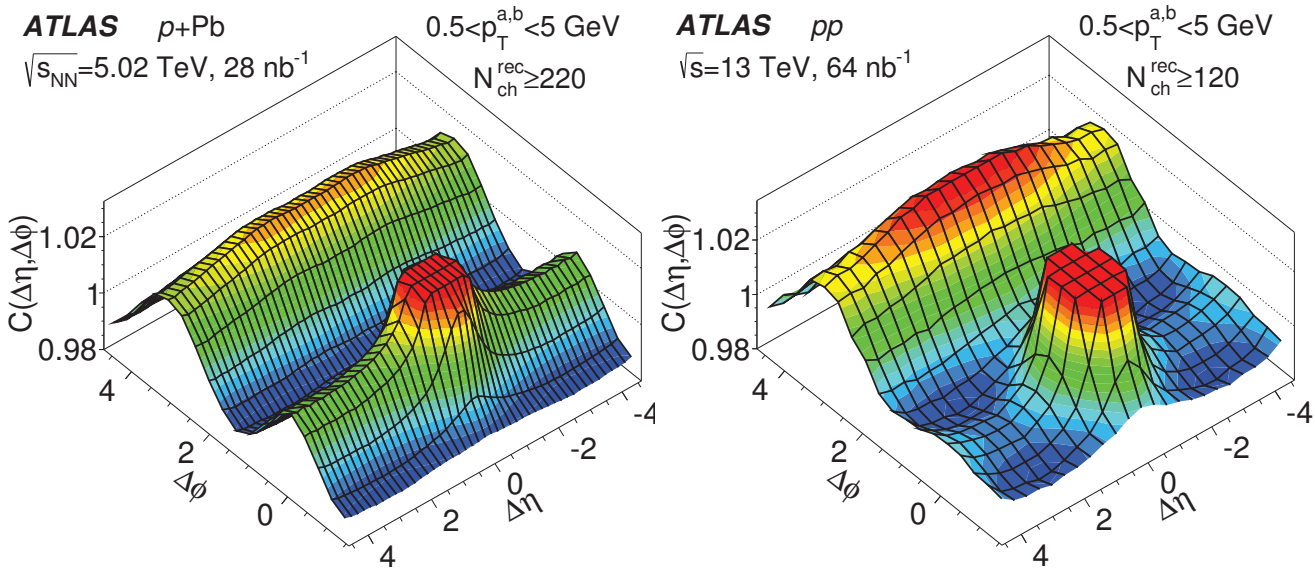


(on behalf of the ZEUS Collaboration)

Motivation and definition of observables

- Observation of "ridge" structure in two-particle correlations in heavy ion collisions.

- Evidence for long range correaltions in $\Delta\eta$ in case of particle pairs produced at small $\Delta\phi$ (ridge) in p+Pb and pp systems.
- Try to understand its origin - is it initial-, final- or mixed-state effect?



PRC 96, 024908 (2017)

- Single-particle azimuthal yields of particle production are usually quantified by Fourier series expansion:

$$E\frac{\mathrm{d}^3N}{\mathrm{d}p^3} = \frac{1}{p_\mathrm{T}}\frac{\mathrm{d}^3N}{\mathrm{d}\phi\,\mathrm{d}p_\mathrm{T}\,\mathrm{d}y} = \frac{1}{2\pi p_\mathrm{T}}\frac{E}{p}\frac{\mathrm{d}^2N}{\mathrm{d}p_\mathrm{T}\,\mathrm{d}\eta}\left(1+2\sum_{n=1}^{\infty}\mathrm{v}_n(p_\mathrm{T},\eta)\cos\left(n(\phi-\Phi_n)\right)\right)$$

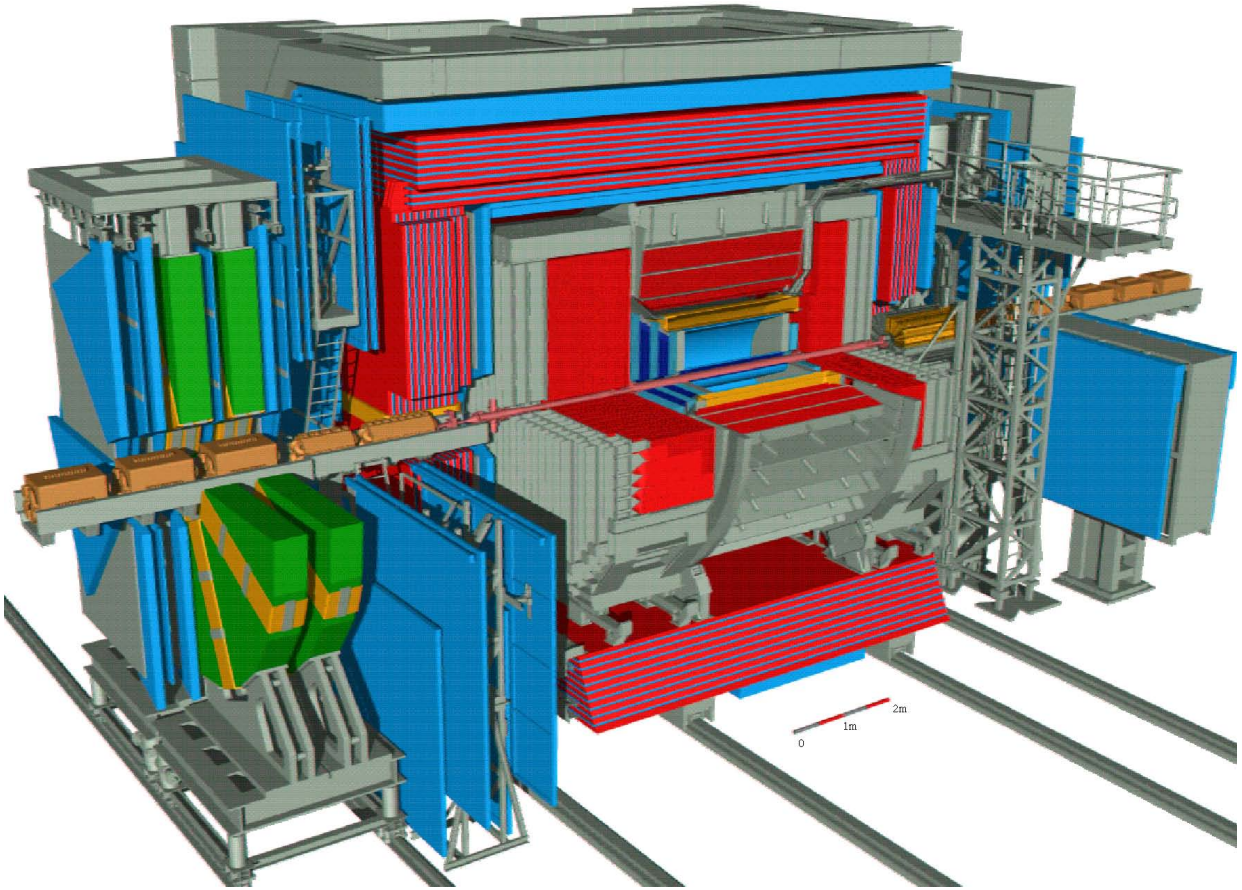
where v_n and Φ_n are the magnitude and phase of the n-th order anisotropy.

- The standard cumulant method is based on the k-particle azimuthal correlations, $\langle\{k\}\rangle$:

$$\langle\{2\}_n\rangle = \left\langle e^{in(\phi_1-\phi_2)}\right\rangle \quad\Rightarrow\quad c_n\{2\} = \langle\langle\{2\}_n\rangle\rangle \quad\Rightarrow\quad c_n\{2\} = \mathrm{v}_n^2+\delta_2$$

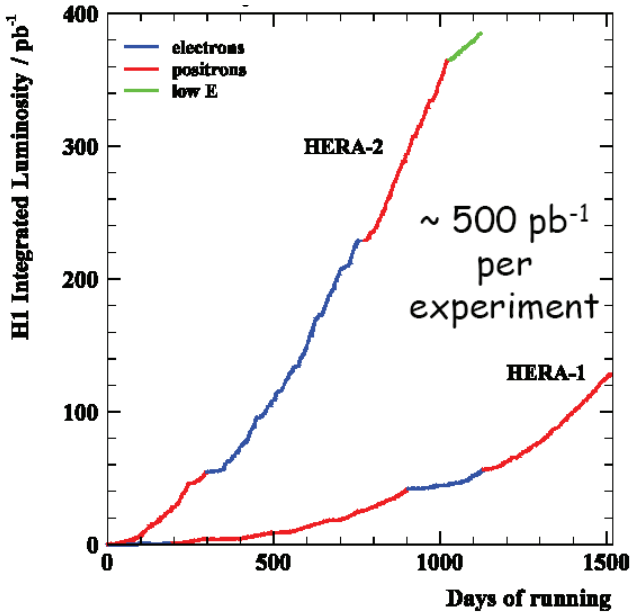
where δ_2 represents a significant nonflow contribution from jets and resonance decays.

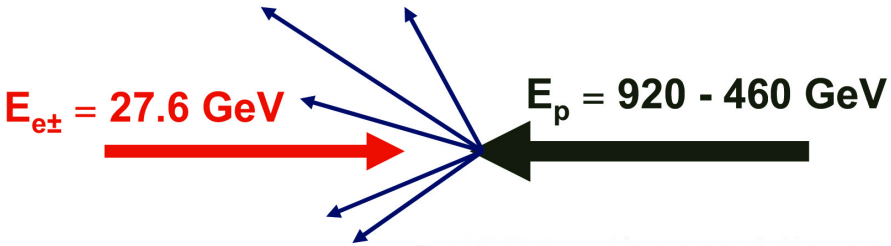
ZEUS experiment and deep inelastic ep scattering (DIS)



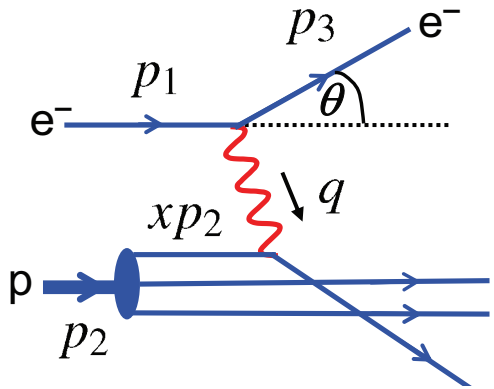
ZEUS experiment @ HERA

DESY, Hamburg, 1992 - 2007



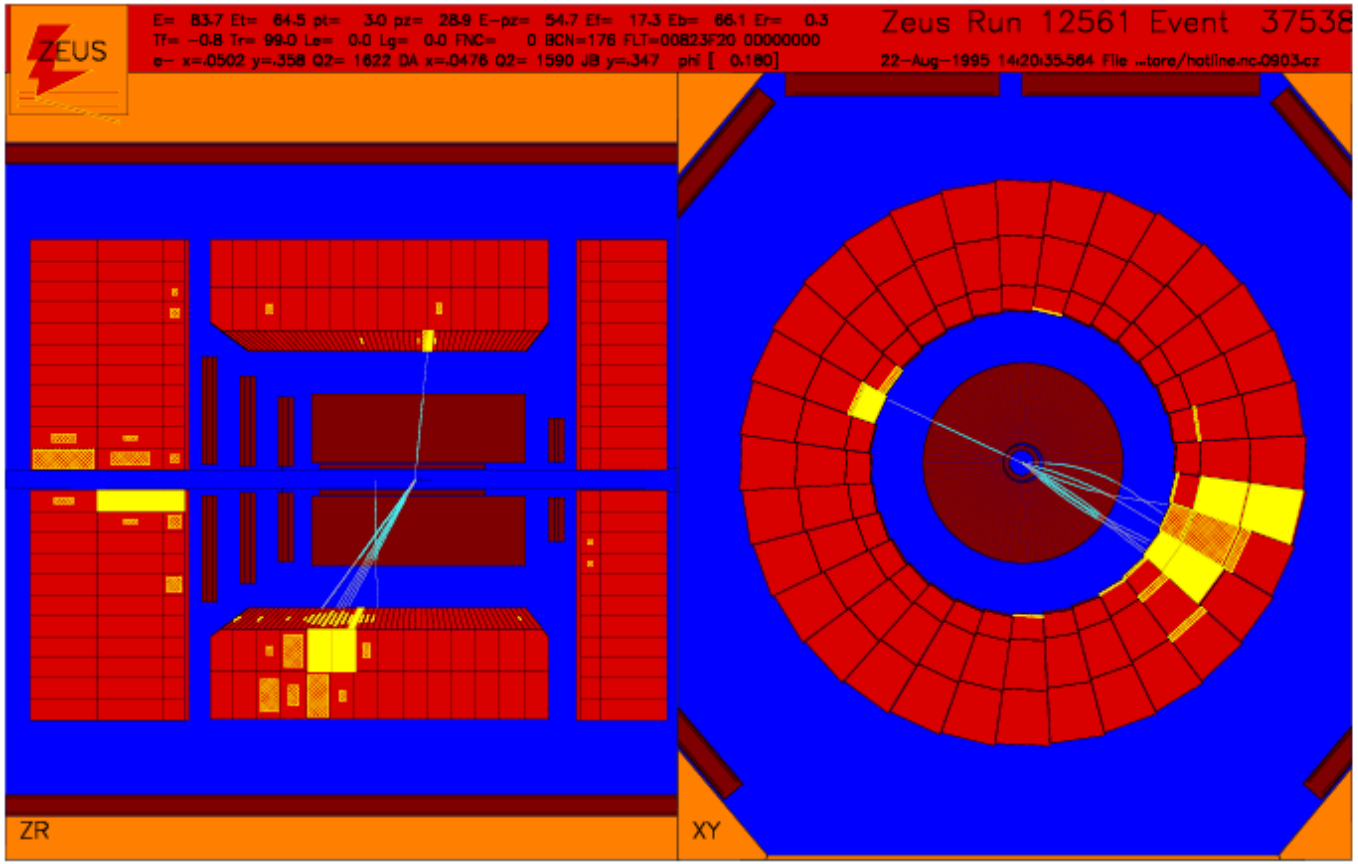


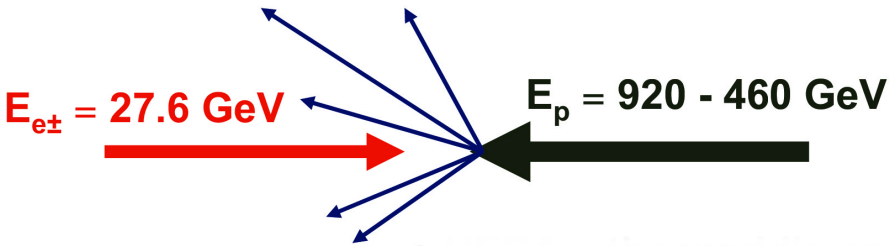
$$\Rightarrow \sqrt{s} = 318 \text{ GeV}$$



$$s = (p_1 + p_2)^2 \simeq 2p_1 \cdot p_2, \quad y = \frac{p_2 \cdot q}{p_2 \cdot p_2}, \quad x = \frac{Q^2}{2p_2 \cdot q}$$

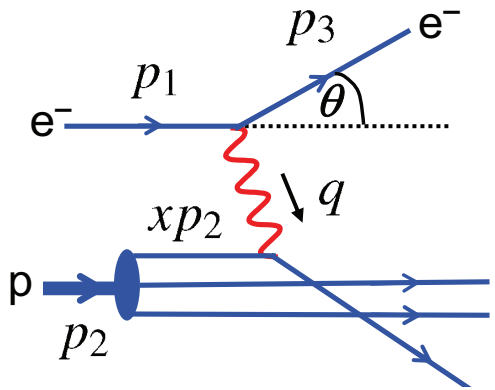
ZEUS experiment and deep inelastic ep scattering (DIS)





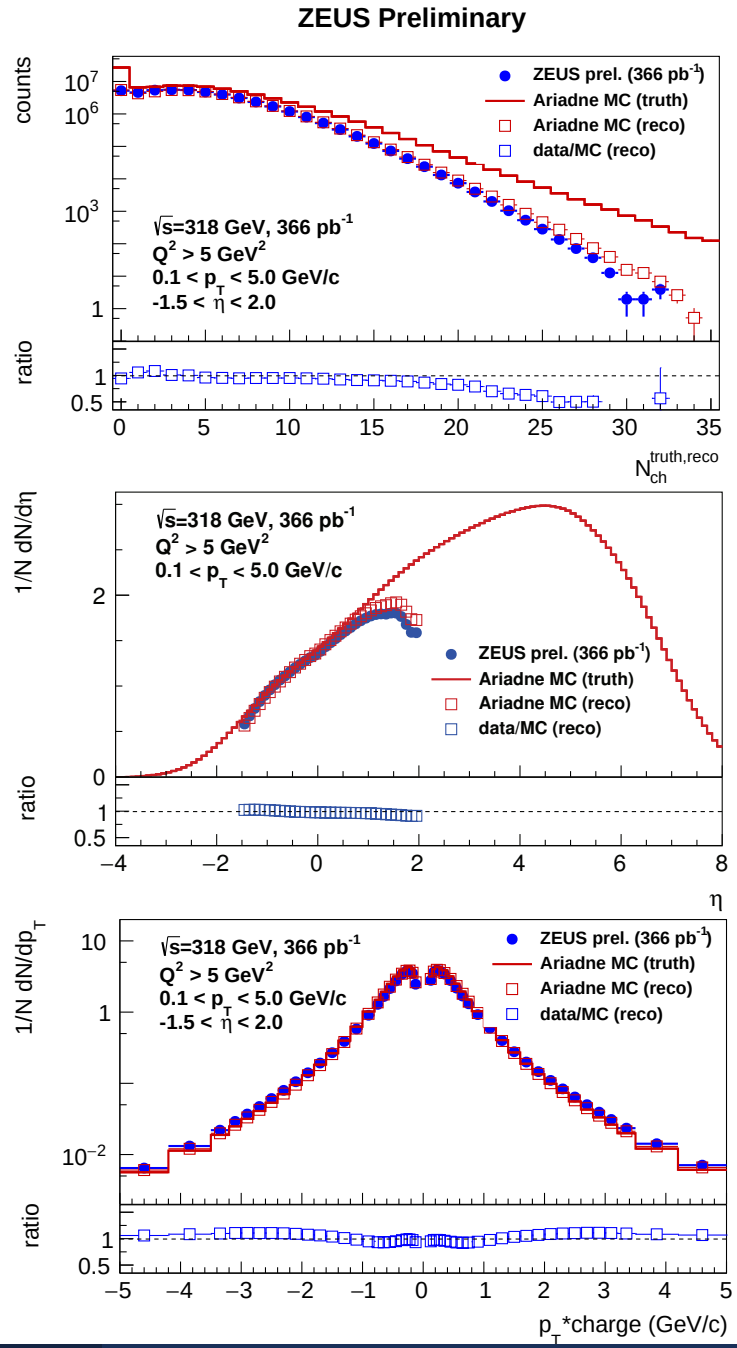
$$\Rightarrow \sqrt{s} = 318 \text{ GeV}$$

$$s = (p_1 + p_2)^2 \simeq 2p_1 \cdot p_2, \quad y = \frac{p_2 \cdot q}{p_2 \cdot p_2}, \quad x = \frac{Q^2}{2p_2 \cdot q}$$



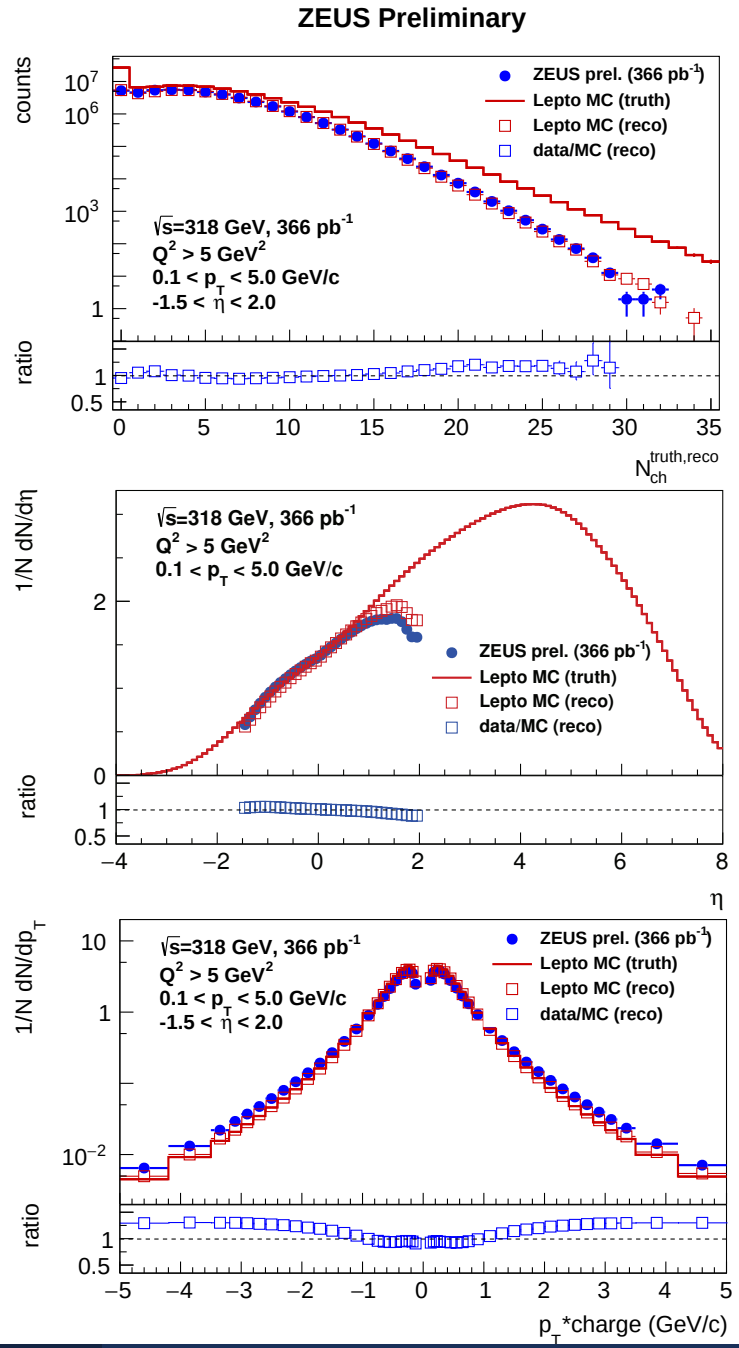
DIS event selection and comparison with models

- DIS selection requirements:
  - scattered electron: $E_e > 10$ GeV and $\theta_e > 1$ rad
  - exchanged photon virtuality: $Q^2 > 5$ GeV^2
  - remove remaining photoproduction background: $47 < \sum_h E_h - p_{z,h} < 69$ GeV
- Track selection:
  - $0.1 < p_{\mathrm{T}} < 5$ GeV
  - $-1.5 < \eta < 2$
- Monte Carlo models used:
  - ARIADNE: (color dipole model)
  - LEPTO: (Lund string model)
- True level particle selection: charge hadrons with $\tau > 1$ cm$/c$ or decay products of shorter living particles.
- Comparison of data with MC simulation:
  - LEPTO - better description of data for $N_{\mathrm{ch}} > 15$.
  - ARIADNE - better description of track distribution in the forward region and also of the shape of p_{T} distribution.

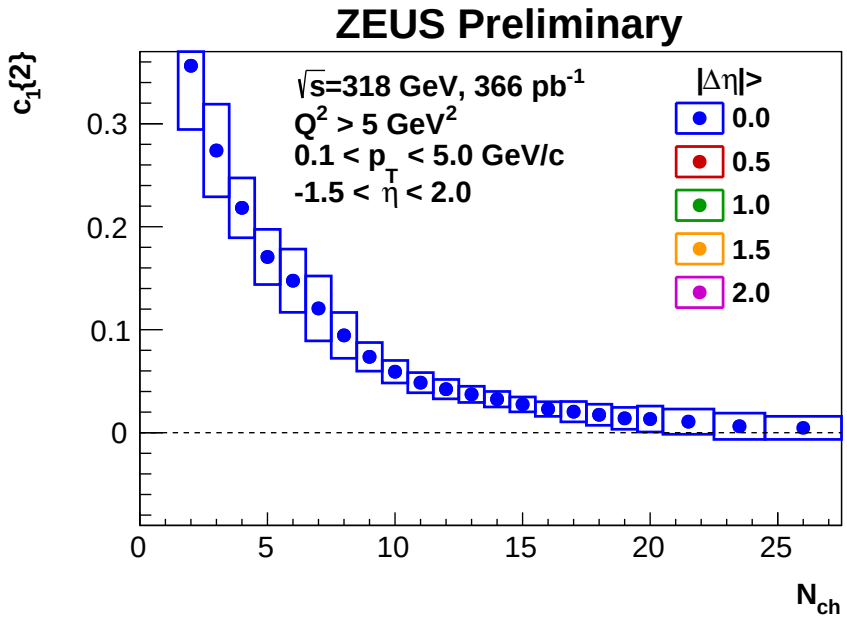


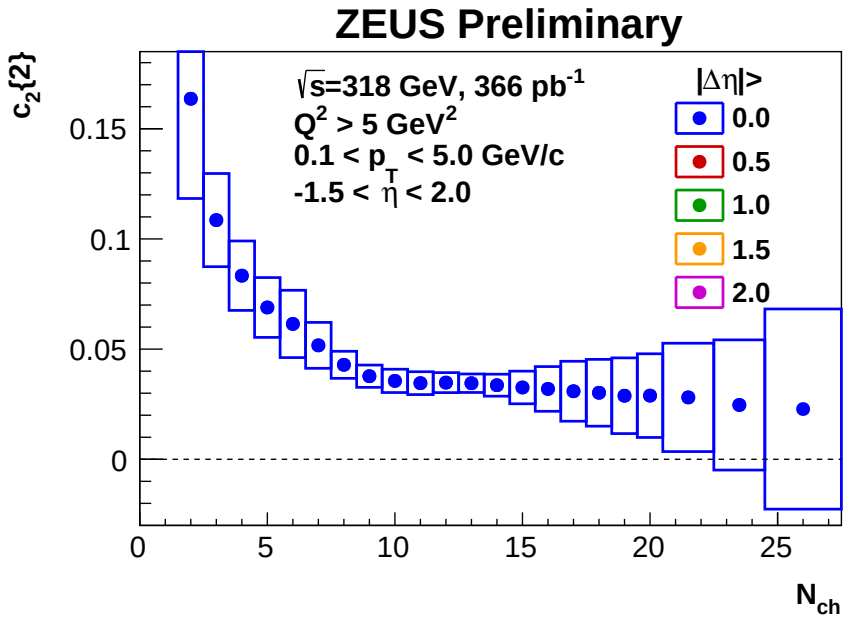
DIS event selection and comparison with models

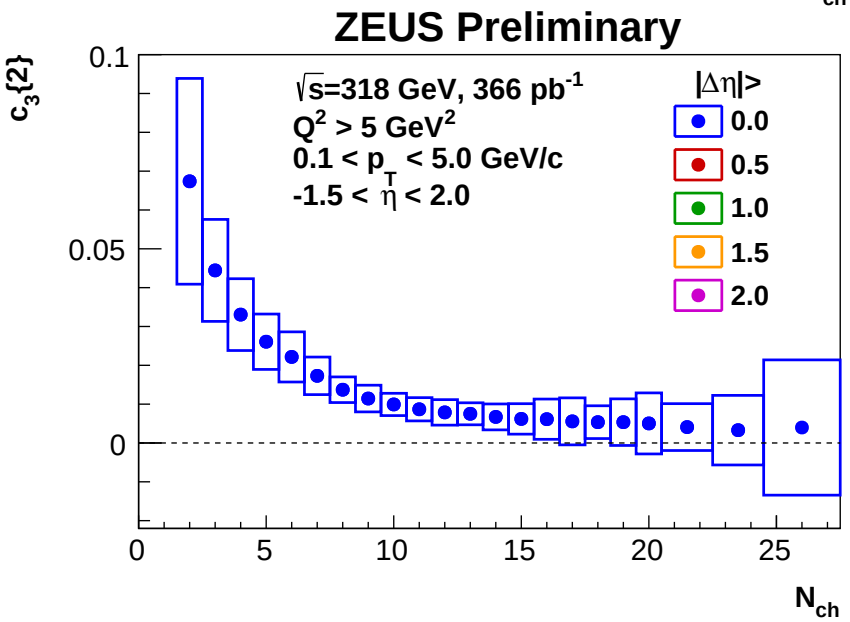
- DIS selection requirements:
  - scattered electron: $E_e > 10$ GeV and $\theta_e > 1$ rad
  - exchanged photon virtuality: $Q^2 > 5$ GeV^2
  - remove remaining photoproduction background: $47 < \sum_h E_h - p_{z,h} < 69$ GeV
- Track selection:
  - $0.1 < p_{\mathrm{T}} < 5$ GeV
  - $-1.5 < \eta < 2$
- Monte Carlo models used:
  - ARIADNE: (color dipole model)
  - LEPTO: (Lund string model)
- True level particle selection: charge hadrons with $\tau > 1$ cm$/c$ or decay products of shorter living particles.
- Comparison of data with MC simulation:
  - LEPTO - better description of data for $N_{\mathrm{ch}} > 15$.
  - ARIADNE - better description of track distribution in the forward region and also of the shape of p_{T} distribution.

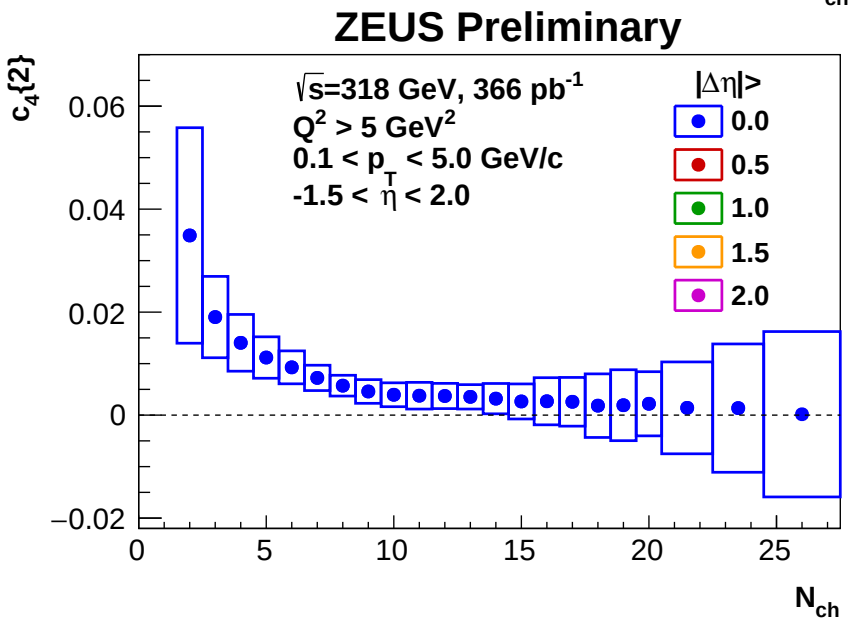


Two-particle cumulants of order $n = 1 - 4$

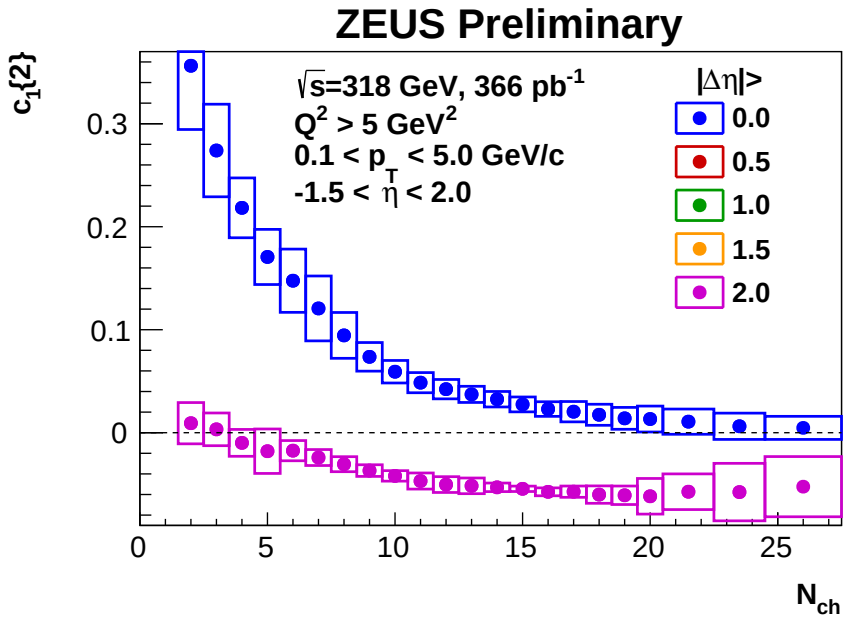


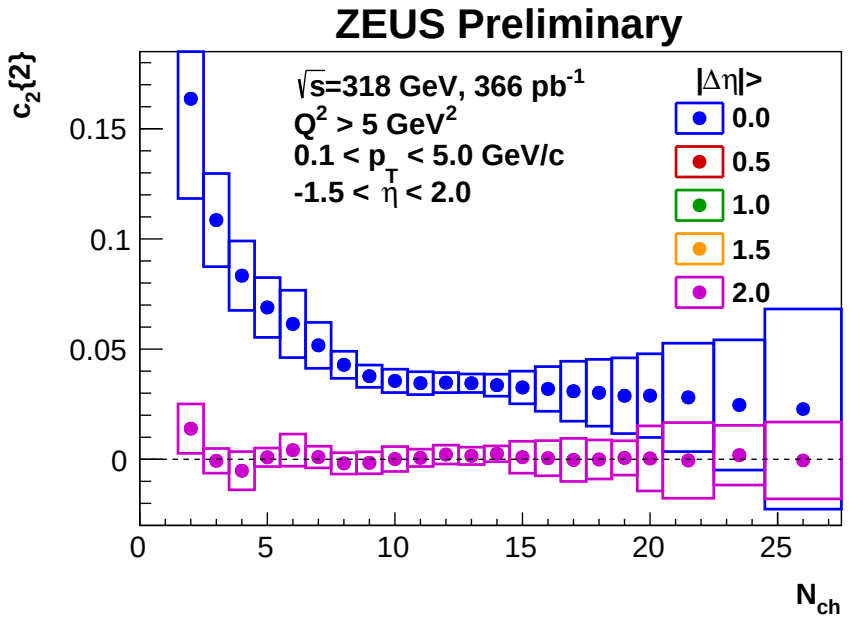


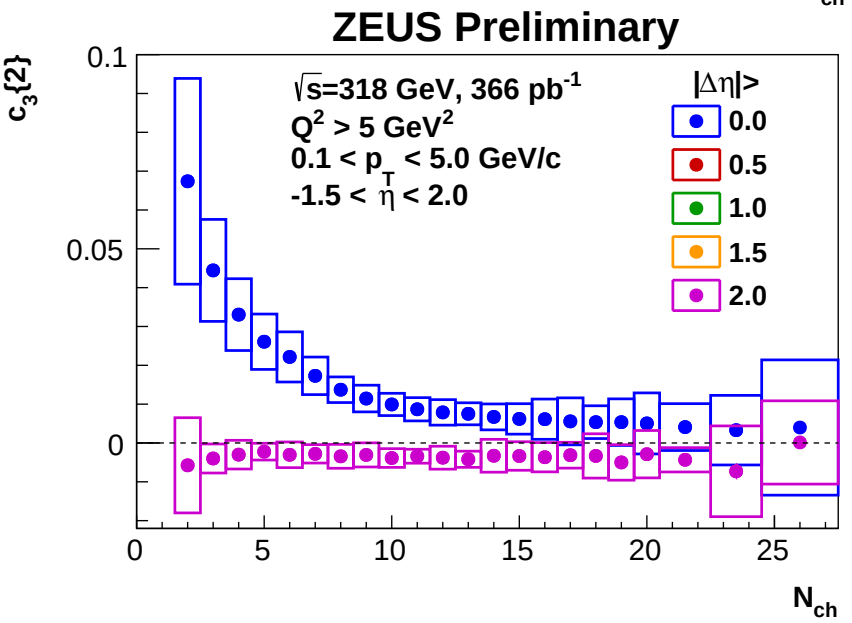


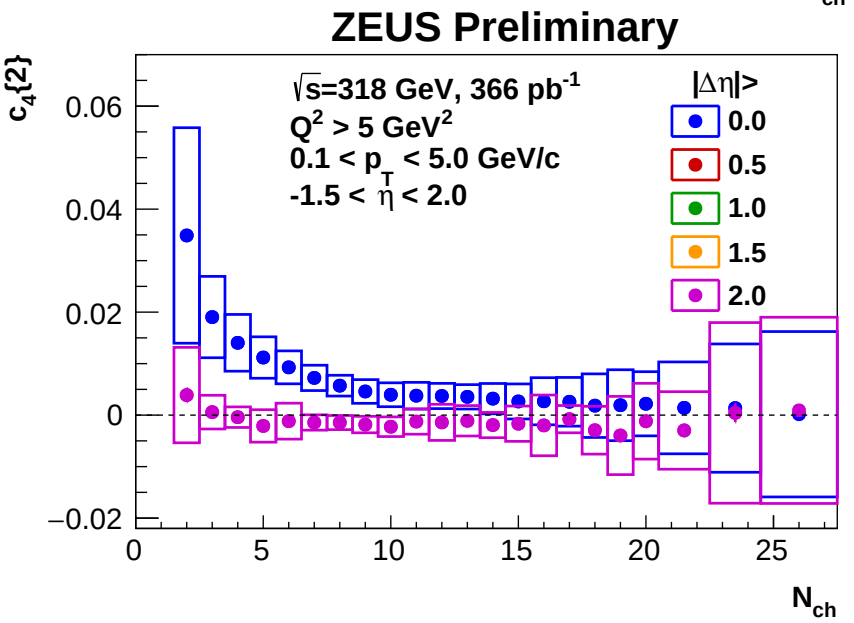


Two-particle cumulants of order $n = 1 - 4$



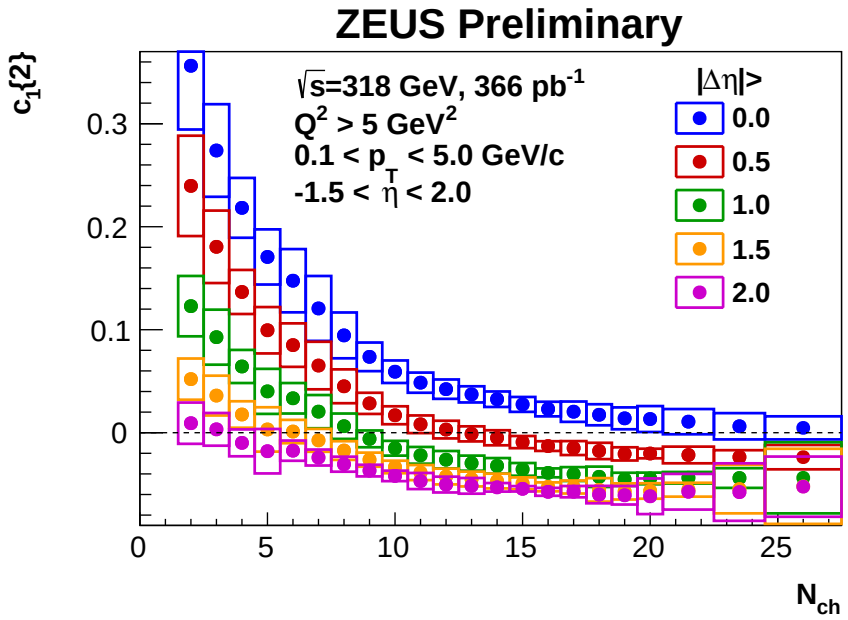


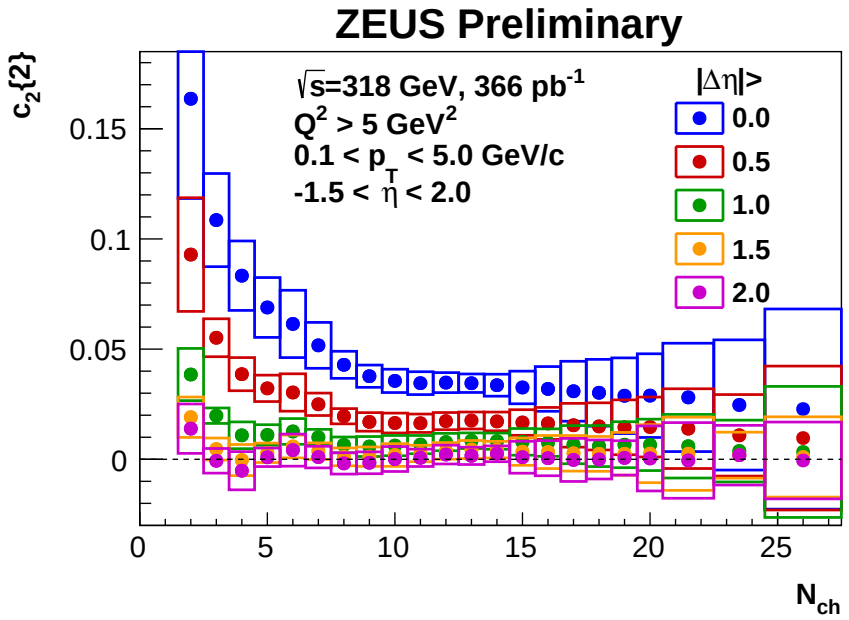


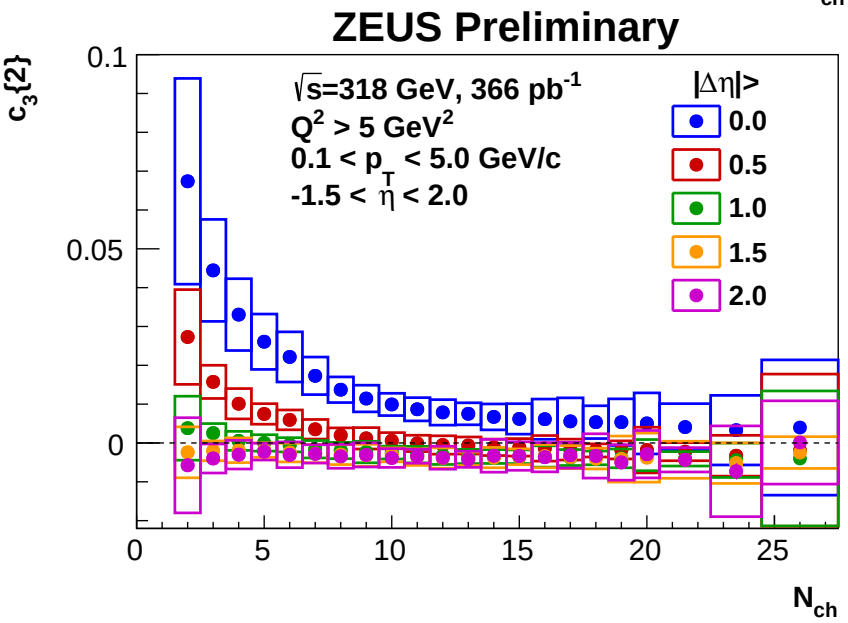


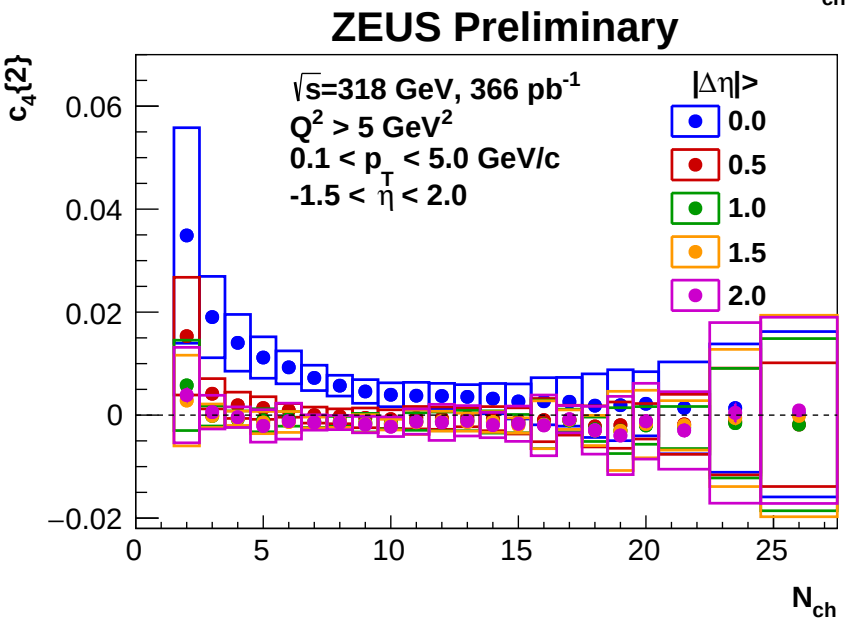
- For $|\Delta\eta| > 2$ all $c_n\{2\}$, but $c_1\{2\}$ (momentum conservation), are consistent with zero.

Two-particle cumulants of order $n = 1 - 4$





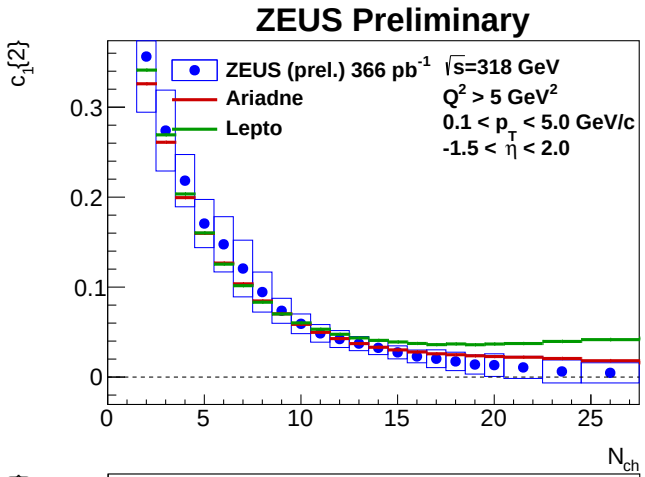


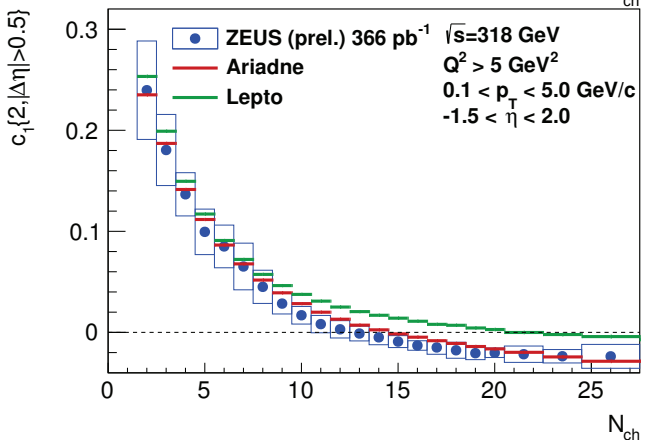


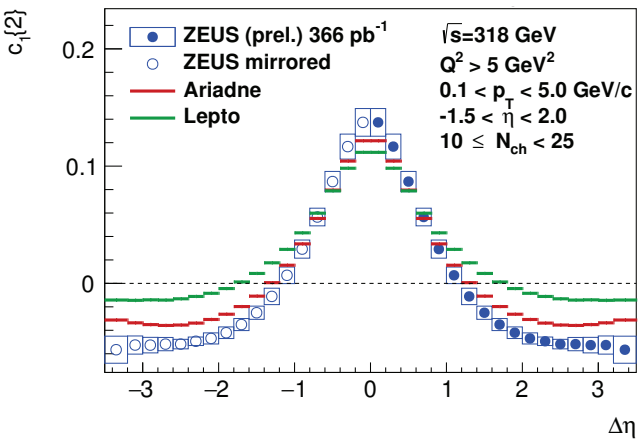
- For $|\Delta\eta| > 2$ all $c_n\{2\}$, but $c_1\{2\}$ (momentum conservation), are consistent with zero.

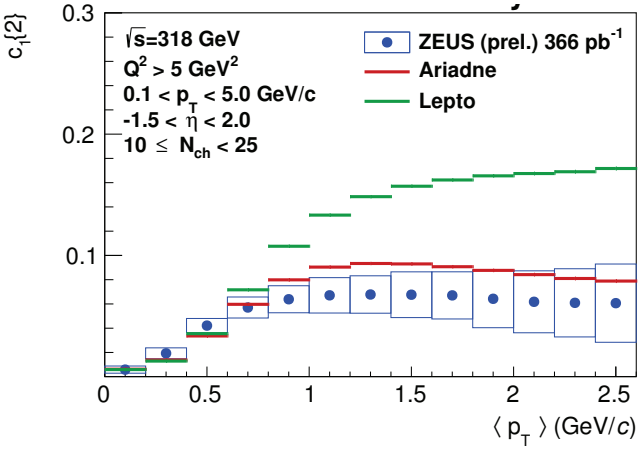
Comparison of $c_1\{2\}$ with MC models

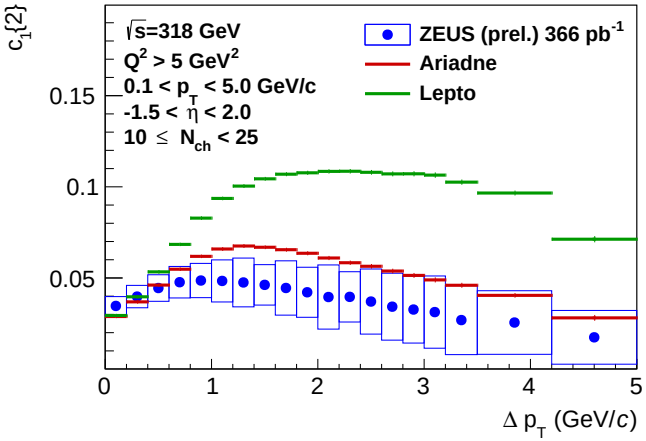
- $c_1\{2\}$ cumulant as a function of N_{ch}, $\Delta\eta$, $\langle p_{\mathrm{T}} \rangle$ and Δp_{T} is compared to model predictions.
- ARIADNE provides a reasonable description of N_{ch}, $\langle p_{\mathrm{T}} \rangle$ and Δp_{T}.
- In case of $\Delta\eta$ ARIADNE is not able to follow the data at $|\Delta\eta| > 1$.
- For all observables ARIADNE gives significantly better description of the measured $c_1\{2\}$ than LEPTO.





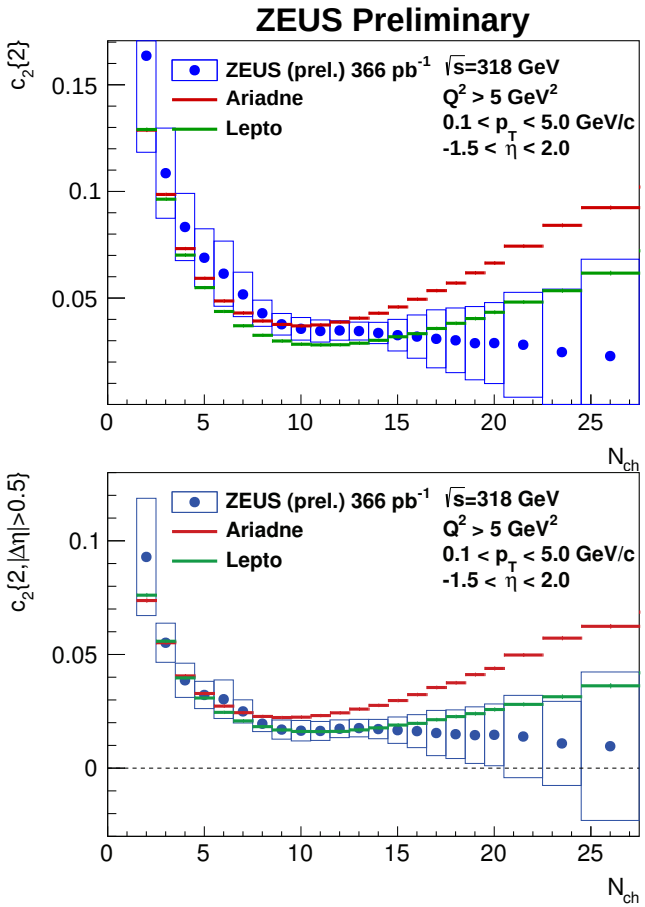


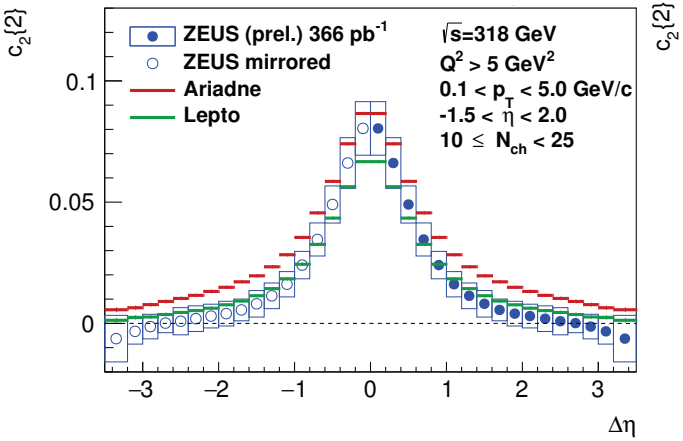


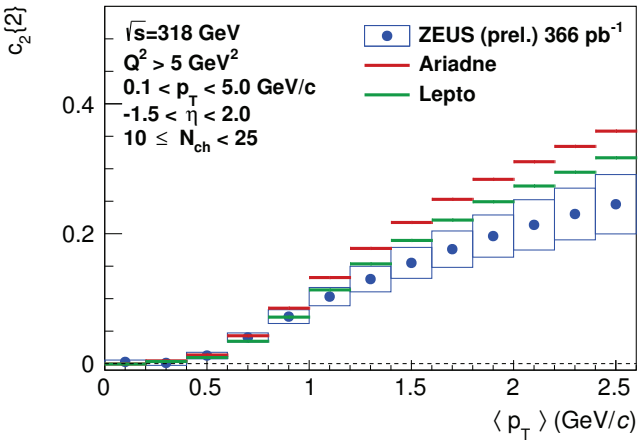


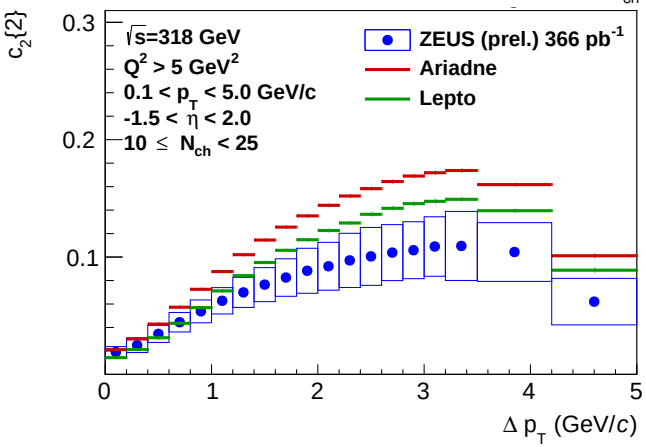
Comparison of $c_2\{2\}$ with MC models

- $c_2\{2\}$ cumulant as a function of N_{ch}, $\Delta\eta$, $\langle p_{\mathrm{T}} \rangle$ and Δp_{T} is compared to model predictions.
- LEPTO provides a reasonable description of N_{ch}, $\langle p_{\mathrm{T}} \rangle$ and Δp_{T}.
- In case of $\langle p_{\mathrm{T}} \rangle$ and Δp_{T} LEPTO is not able to follow the data at higher values of these observables.
- For all observables LEPTO gives significantly better description of the measured $c_2\{2\}$ than ARIADNE.









Summary

- First investigation of collectivity in deep inelastic electron-proton scattering.
- Measured two-particle cumulants $c_n\{2\}$ for $n = 2, 3, 4$ are consistent with zero for large multiplicity N_{ch} or pseudorapidity separation $|\Delta\eta|$.
- $c_1\{2\}$ becomes negative for large $\Delta\eta$, what is expected due to momentum conservation.
- Monte Carlo models (ARIADNE and LEPTO) tuned to HERA data are able to reproduce overall features of the measured cumulants.
- Plan to measure four-particle cumulants in DIS as well as to investigate possible signs of collectivity in photoproduction.

Thank you for your attention!