Diffraction and Low-x 2018

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Collective effects in DIS

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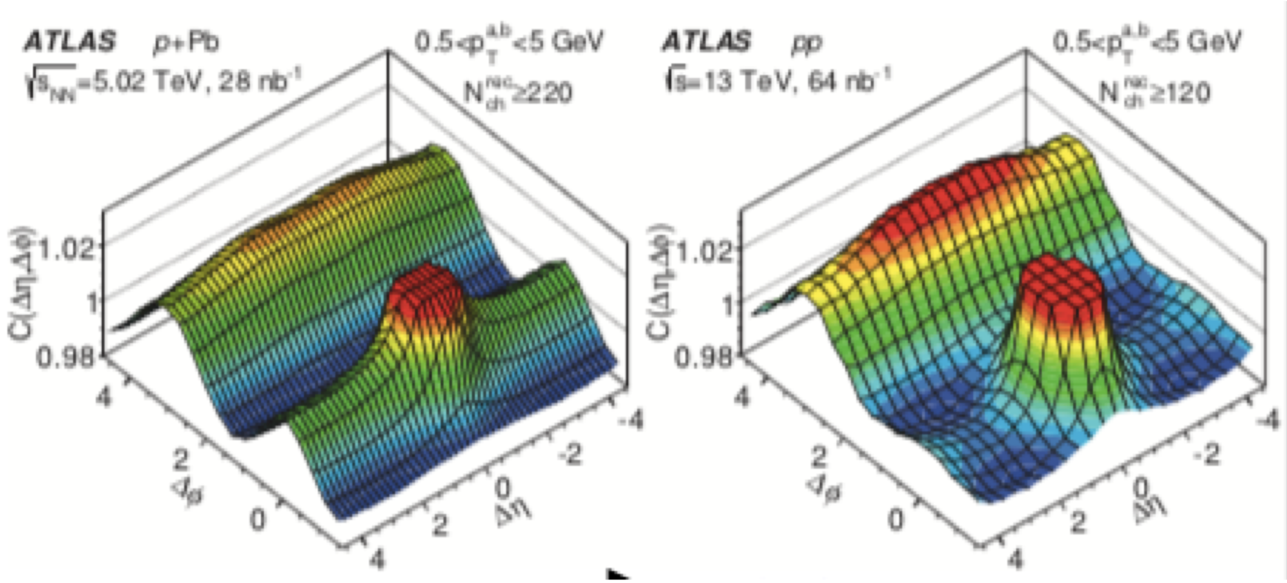
Motivation

Azimuthal anisotropies in the angular distribution of particles observed in **heavy ion collisions** → understood as **effects of collective expansion**

At LHC evidence for long-range correlations in Δη for particle pairs produced at small $\Delta\phi$ (ridge) in **pPb and pp systems**



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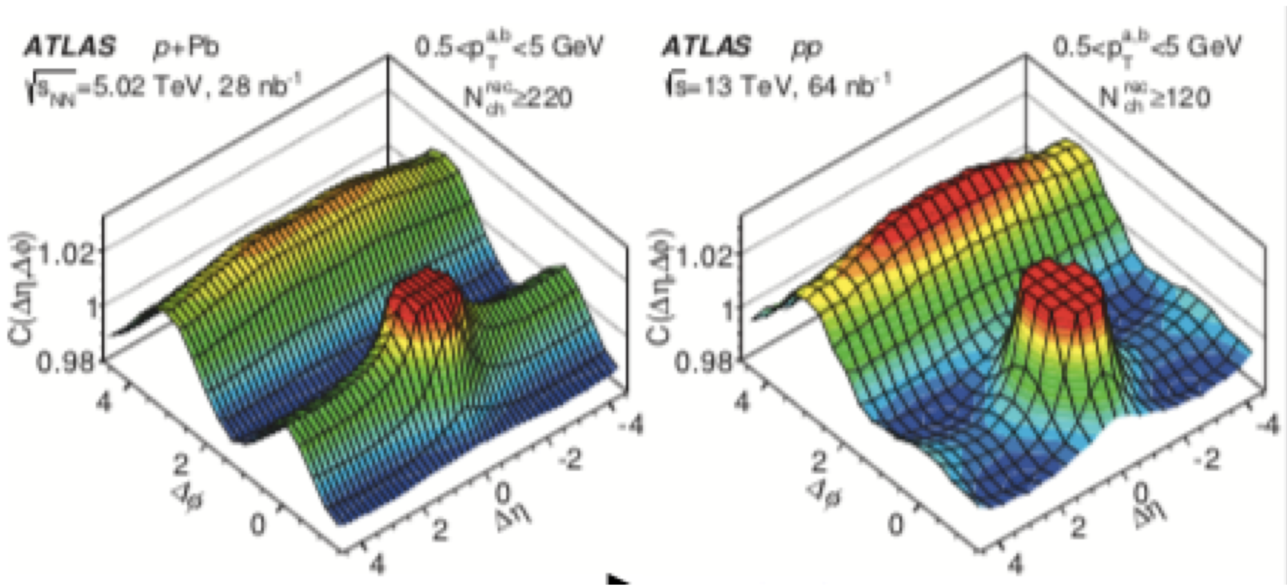


Is it initial-, final- or mixed-state effect?

What happens in an even smaller system, i.e. electron-proton collision?

Formalism (hydro-like system)

Amplitude of **single-particle anisotropies** quantified with Fourier decomposition

$$\frac{dN}{d\phi} = \left\langle \frac{dN}{d\phi} \right\rangle \left(1 + \sum_n 2v_n \cos[n(\phi - \Psi_n)] \right)$$

2-particle angular correlation functions, when evaluated wrt pair azimuthal angle distance, have similar expansion

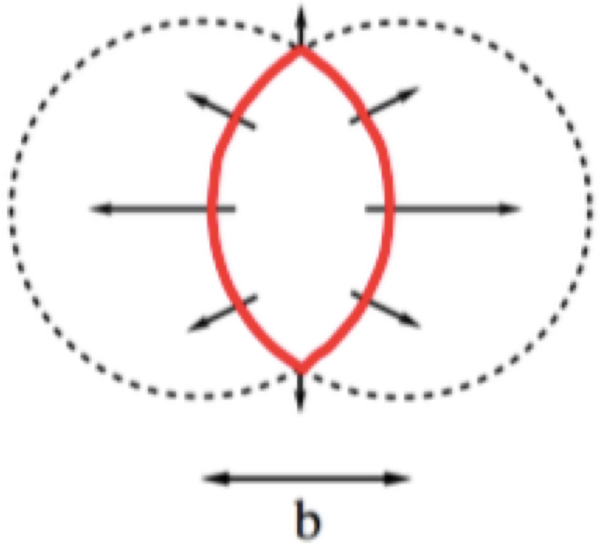
$$\frac{dN_{\text{pair}}}{d\Delta\phi} = \left\langle \frac{dN_{\text{pair}}}{d\Delta\phi} \right\rangle \left[1 + \sum_n 2v_{n,n} \cos(n\Delta\phi) \right]$$

If the modulation in the correlation function arises solely from the modulation of the single-particle distributions → $v_{n,n} = v_n^2 + \delta^2$

(δ^2 is contribution from hard scattering, e.g. jets, that has to be suppressed)

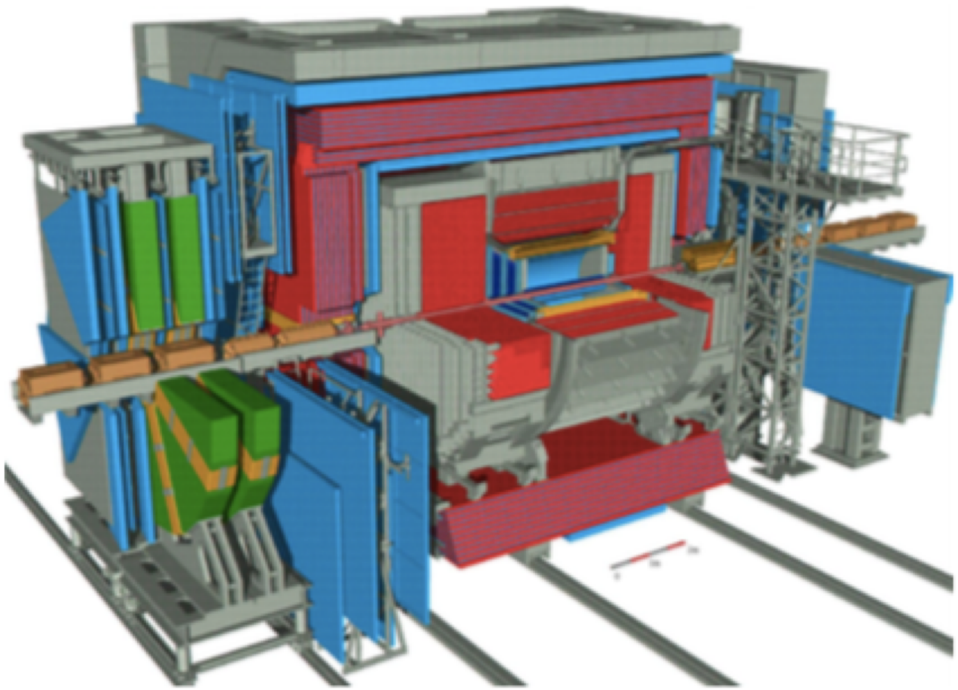
→ **only long-range part of the correlation functions, usually $\Delta\eta > 2$**

For instance…helliptic flow v_2



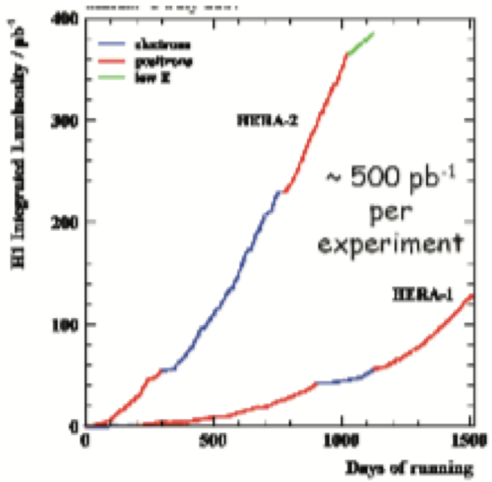
- Non-central collisions lead to deviations from rotation symmetry
- Pressure gradients larger in one direction
- Larger fluid velocity in this direction → more particles
- Quantified by v_2

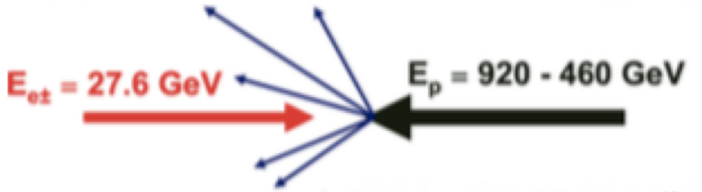
The ZEUS experiment and DIS at HERA



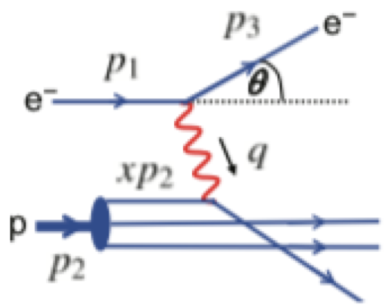
ZEUS experiment @ HERA

DESY, Hamburg, 1992 - 2007





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



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

Data and simulation

2003-2007 ZEUS data, 430 pb^{-1}

- Standard DIS selection ($Q^2 > 5$ GeV^2)

- Track selection

  $0.1 < p_T < 5$ GeV

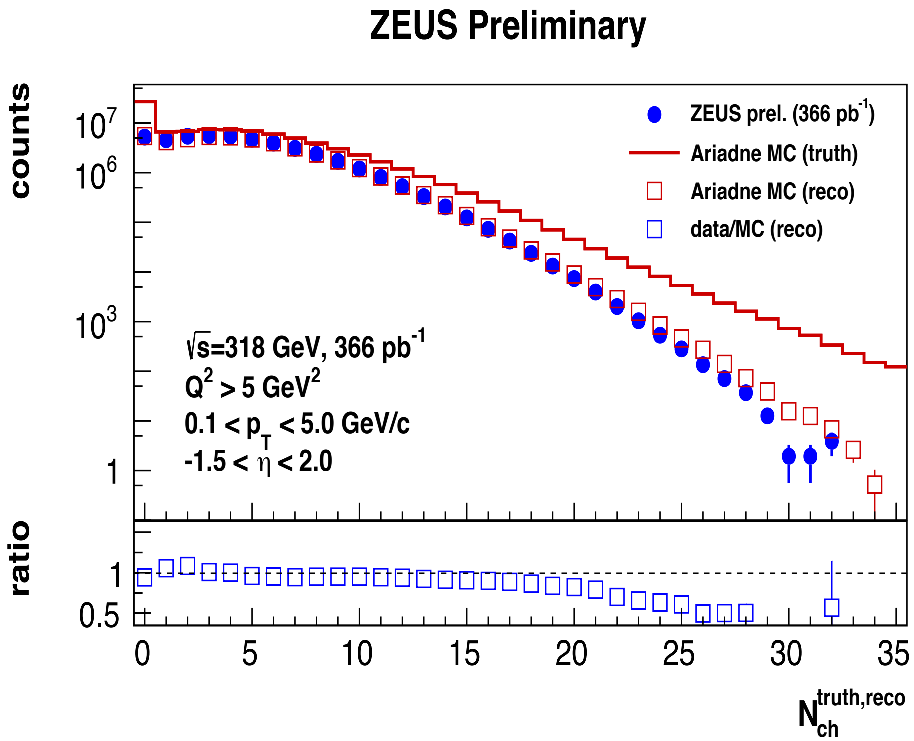
  $-1.5 < \eta < 2.0$

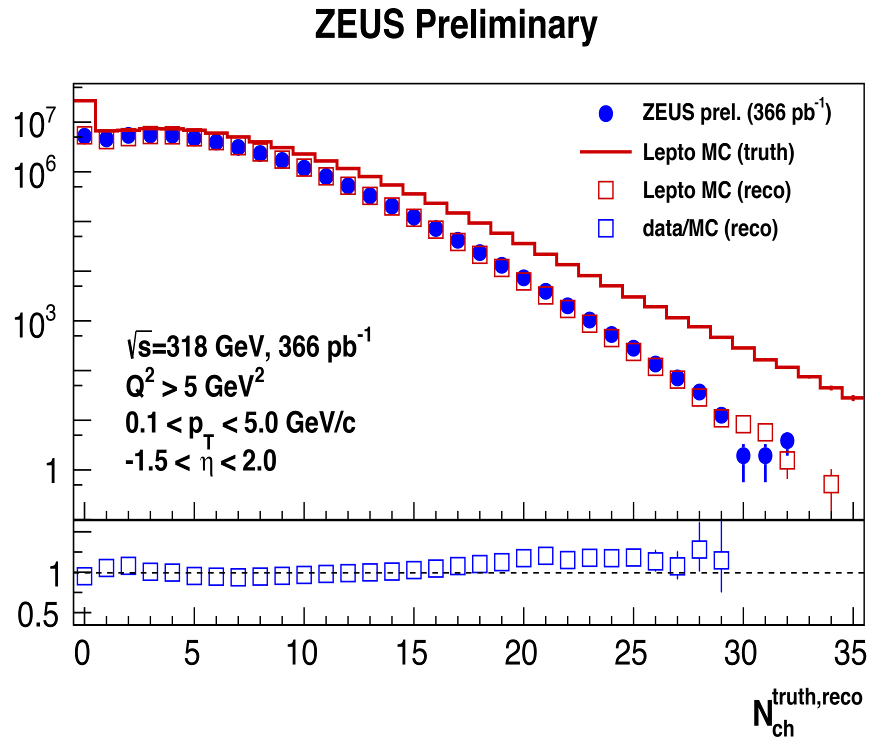
- True-level particle selection

  charged hadrons with $\tau > 1$ cm/c or decay products of short-living particles

Monte Carlo simulation: ARIADNE (color dipole model) and LEPTO (Lund string model)

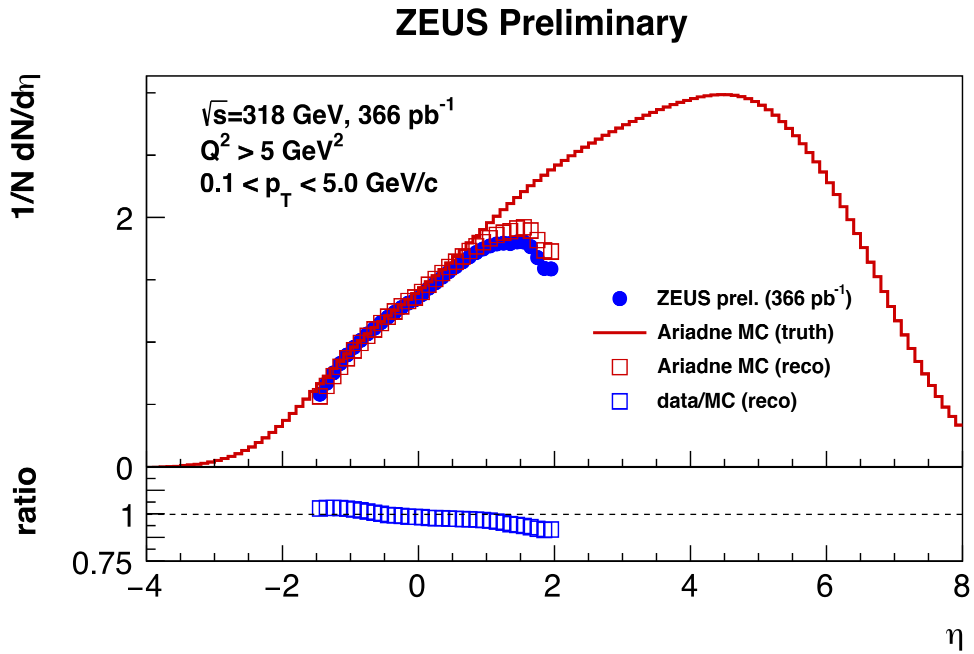
Comparison with models

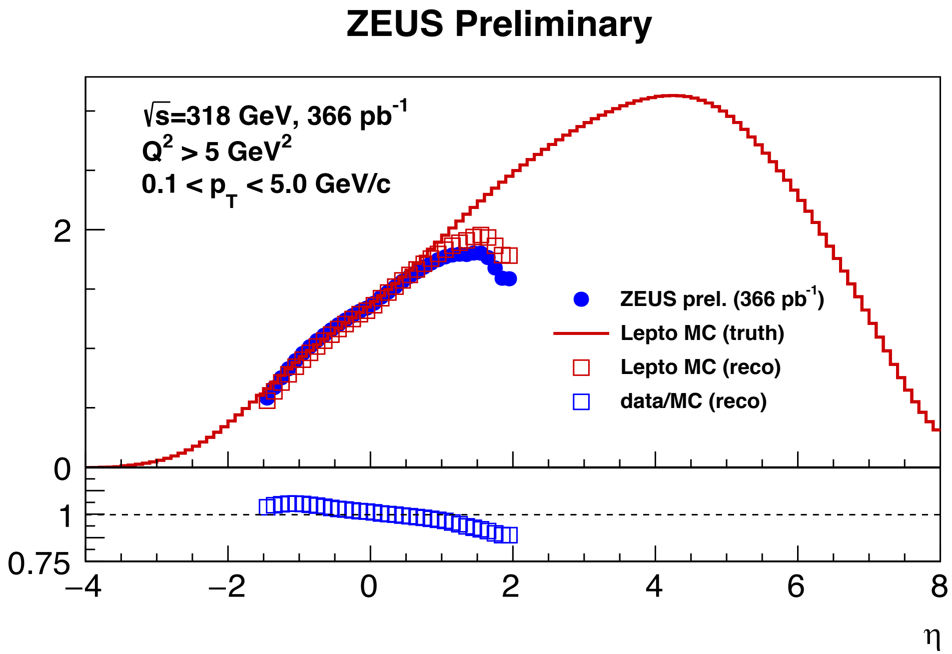




>> LEPTO: better description of data for $N_{ch} > 15$

Comparison with models





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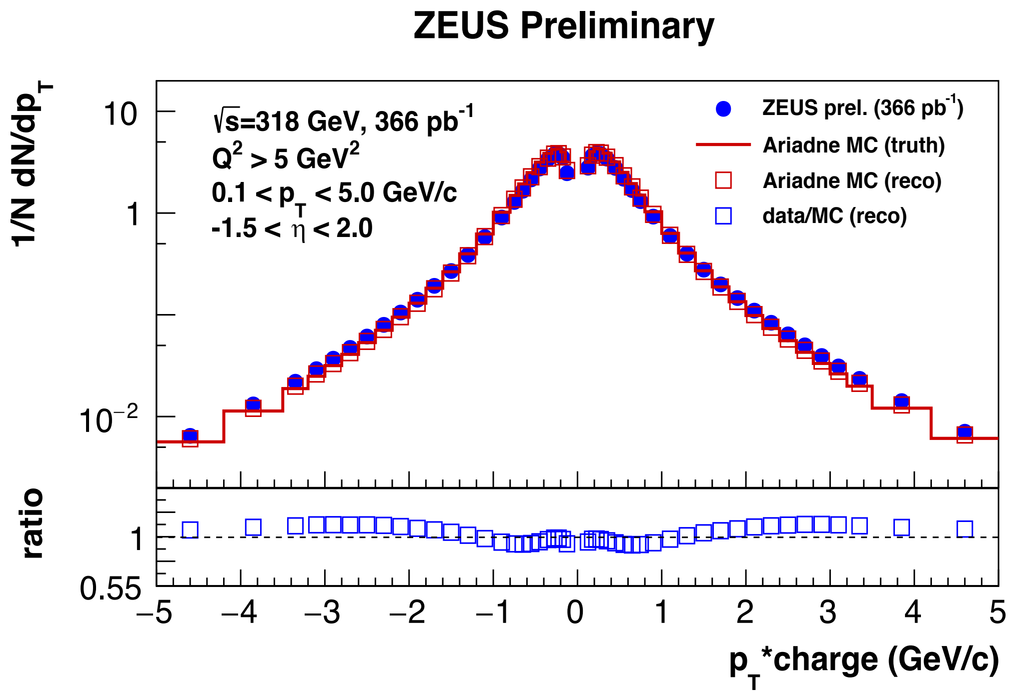

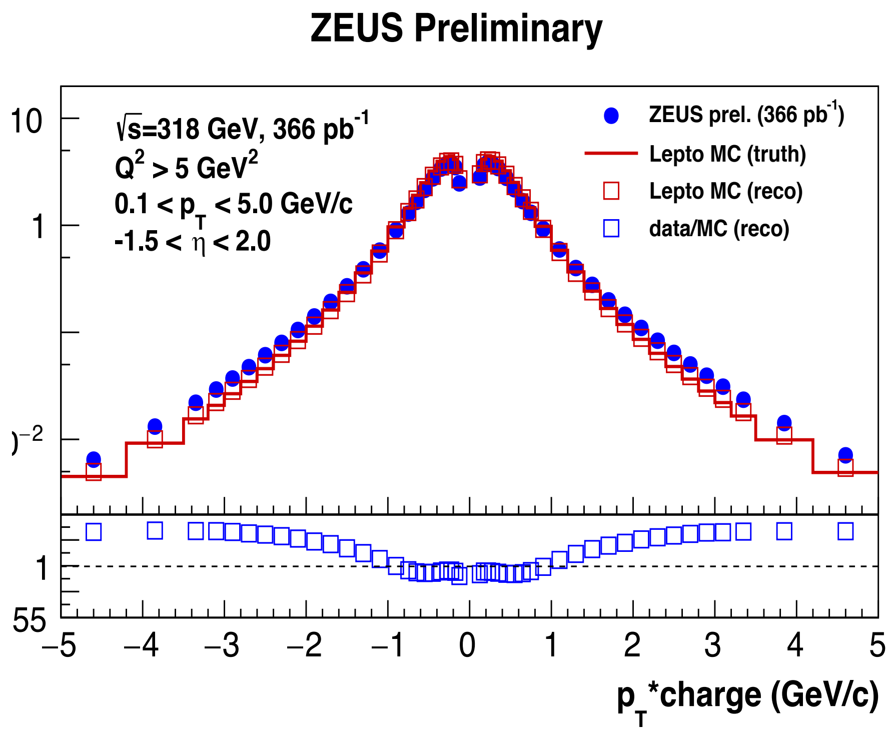

>> ARIADNE: better description of p_T distribution

Formalism

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(δ^2 is contribution from hard scattering, e.g. jets, that has to be suppressed)

→ **Only Long range part of the correlation functions, usually $\Delta\eta > 2$**

Correlation functions studied for charged hadrons vs multiplicity, p_T and $\Delta\eta$

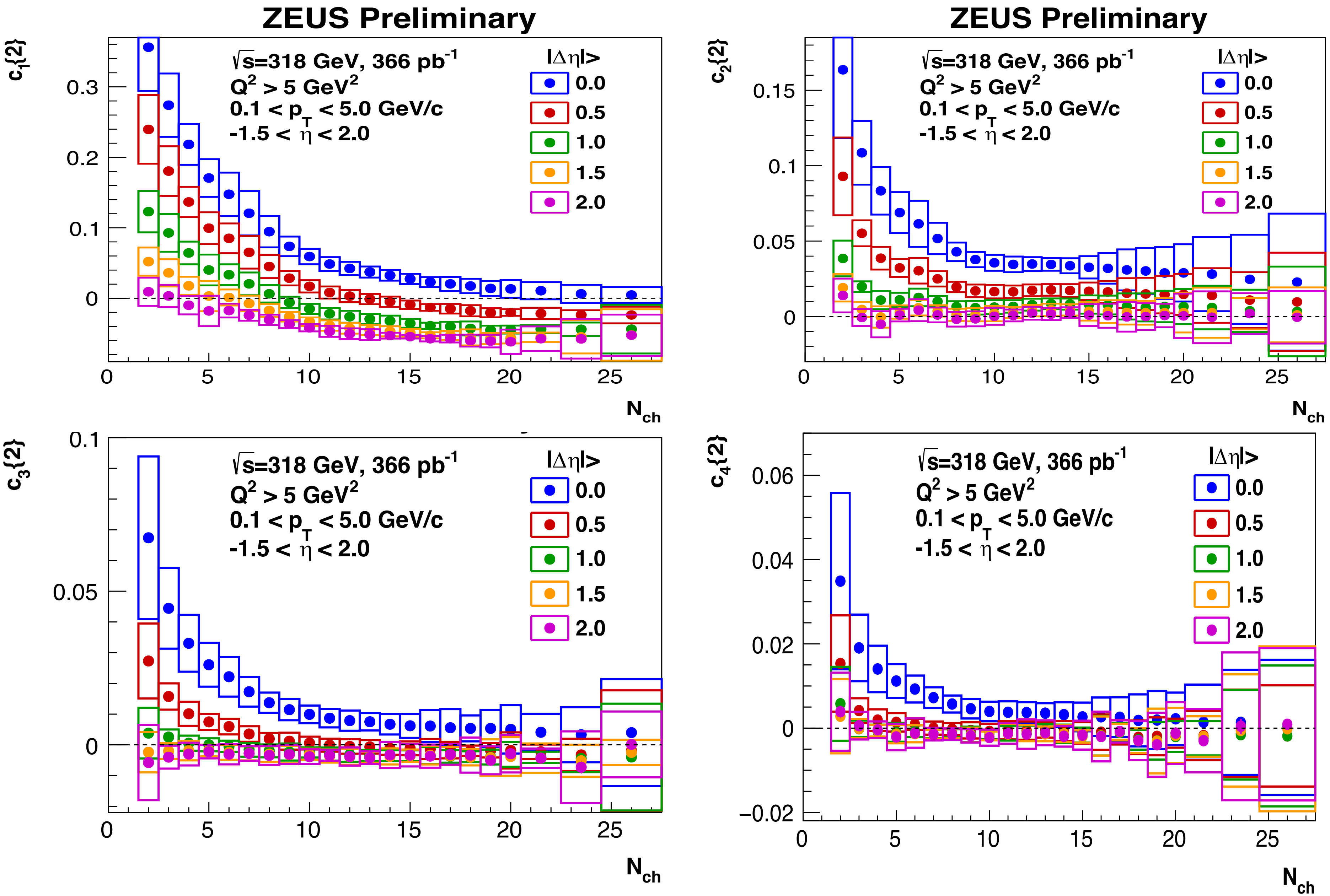
$c_n(2) = \cos(n\Delta\phi)$

reconstructed as $c_n(2) = (\Sigma_e w_e(\Sigma_i \Sigma_{j!=i} w_i w_j \cos(n(\varphi_i - \varphi_j))/\Sigma_{j!=i} w_i w_j))/\Sigma_e w_e$

- $\sum_e$ loop over events
- ω_i particle weight (used to apply efficiency corrections)
- ωj event weight (1 is used)

cos(n(Δϕ)) correlations

$c_n(2)$ = cos (nΔϕ) with Δϕ the azimuthal separation between the 2 particles



>> Increasing pseudorapidity separation suppresses correlations

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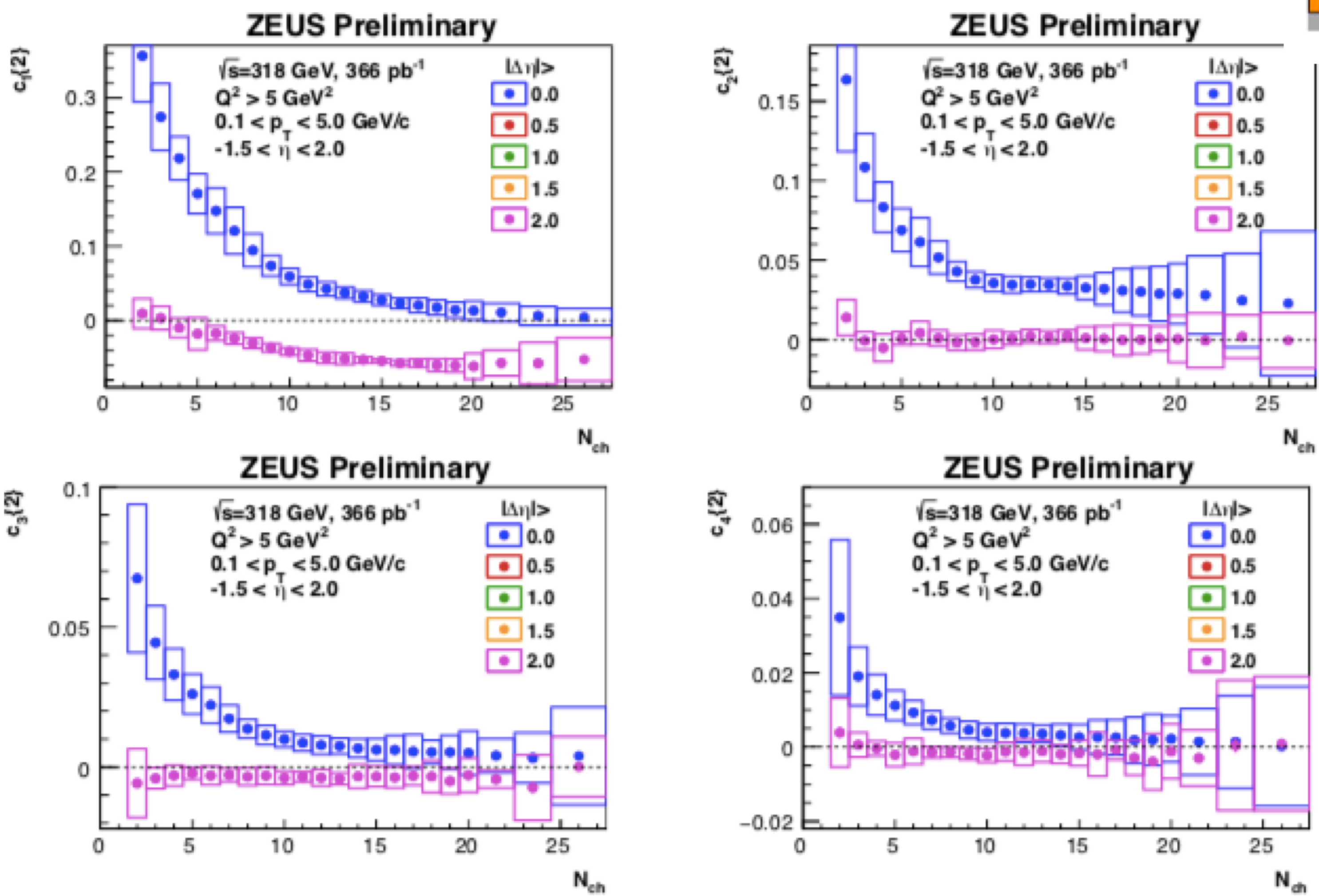
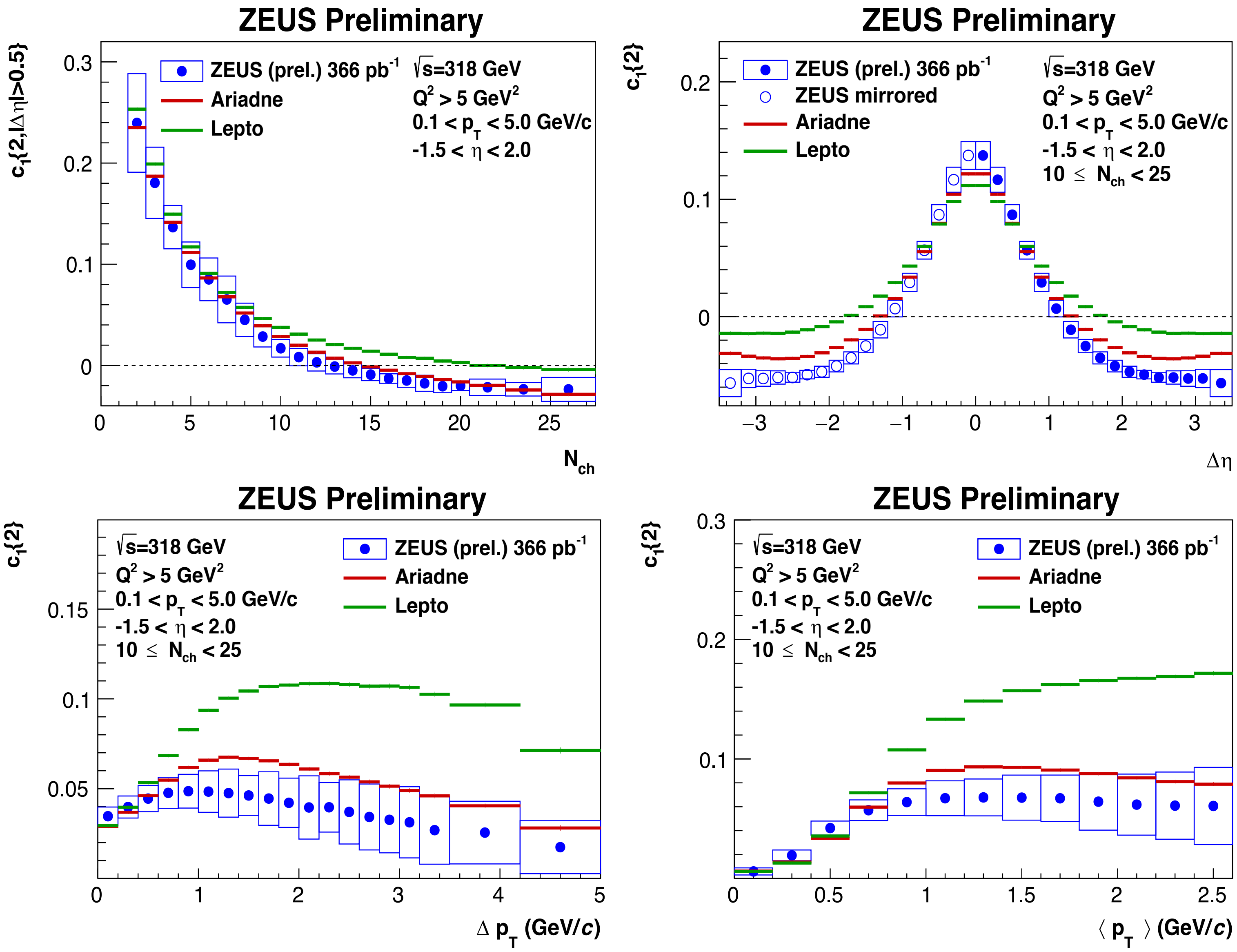


>> Increasing pseudorapidity separation suppresses correlations

>> For $\Delta\eta > 2$, harmonics n=2, 3, 4 consistent with zero

cos($\Delta\phi$) correlations vs Monte Carlo

10≤Nch<25 everywhere

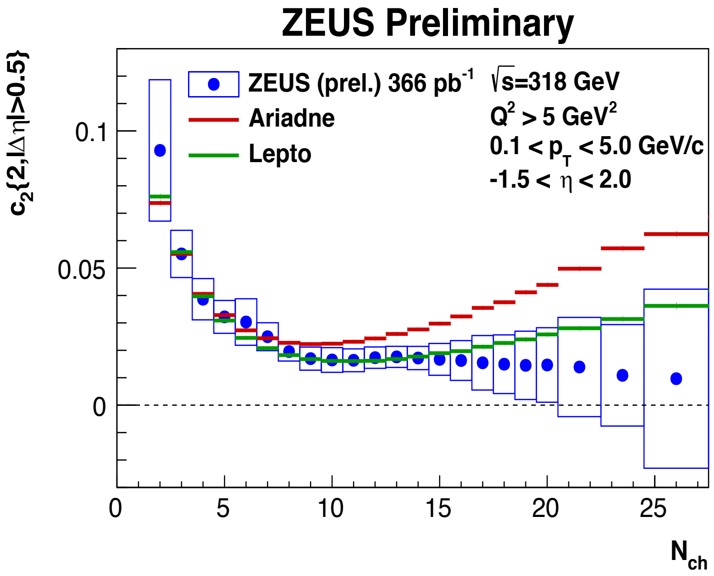


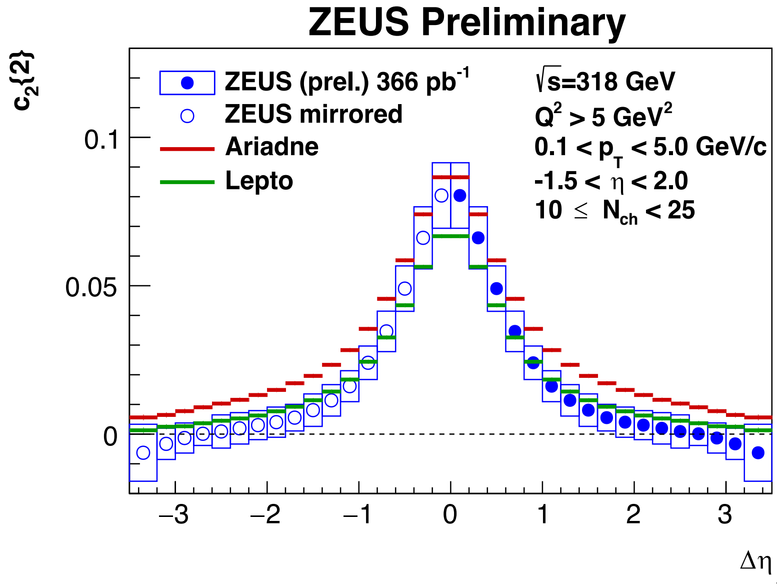
>> For all observables ARIADNE better than LEPTO

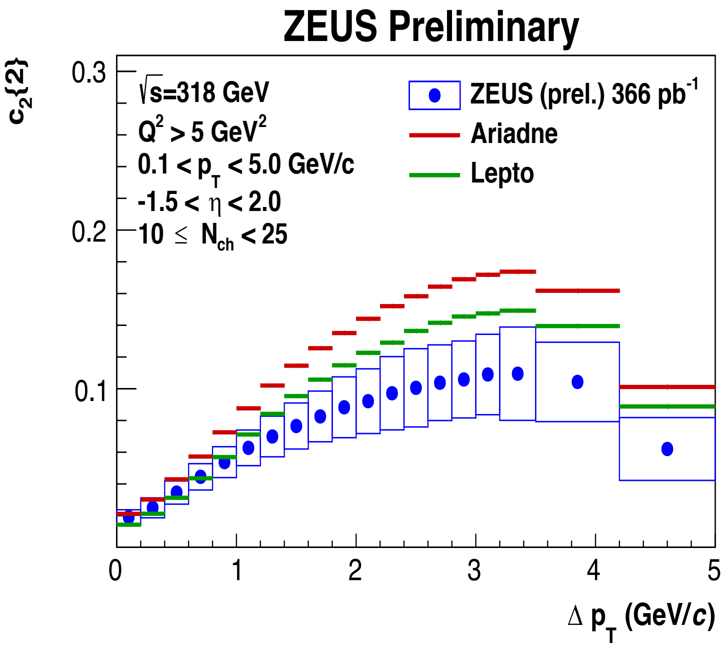
>> For $\Delta\eta > 1$ ARIADNE does not follow the data

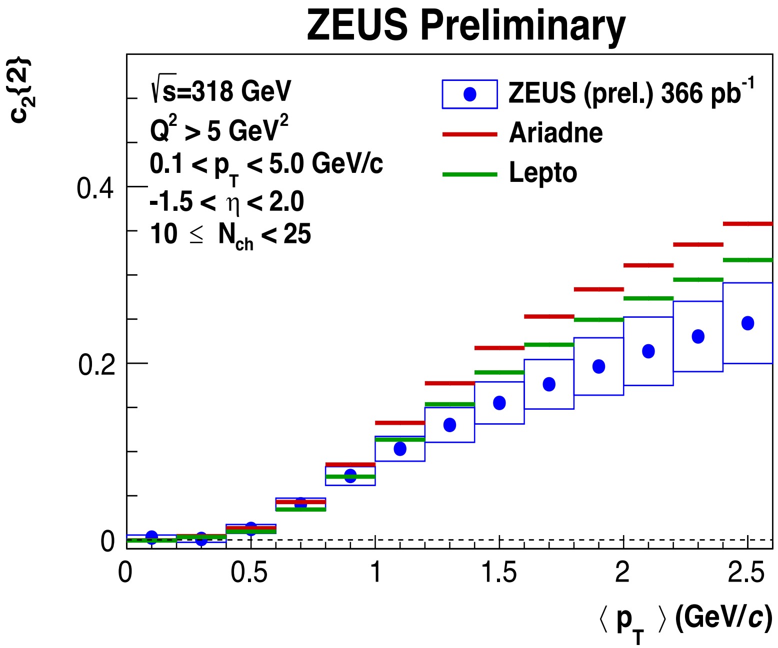
cos(2Δϕ) correlations vs Monte Carlo

10≤Nch<25 everywhere









>> For all observables LEPTO better than ARIADNE

>> At high values of p_T and Δp_T LEPTO does not follow the data

Summary

- **First investigation of collectivity in deep inelastic electron-proton scattering**

- 2-particle correlations show harmonics n = 2, 3, 4 consistent with zero for large multiplicity or pseudorapidity separation between the two particles

  → **No long-range correlations at large multiplicity visible**

- Monte Carlo models (ARIADNE and LEPTO) tuned to the HERA data able to reproduce overall features of measured distributions

- Plan to measure 4-particle correlations in DIS as well as to investigate possibile signs of collectivity in photoproduction