Azimuthal particle correlations as a probe of collectivity in deep inelastic ep collisions

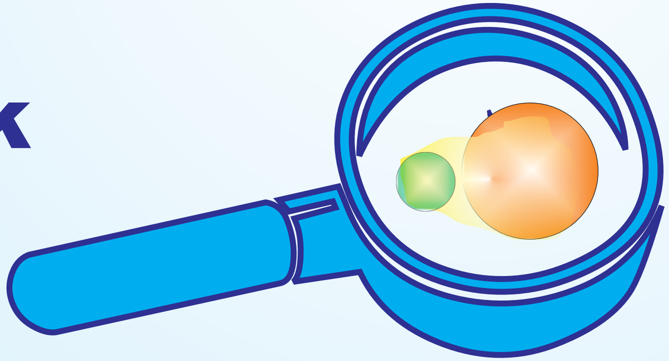
in  at HERA

I.Abt, MPI München

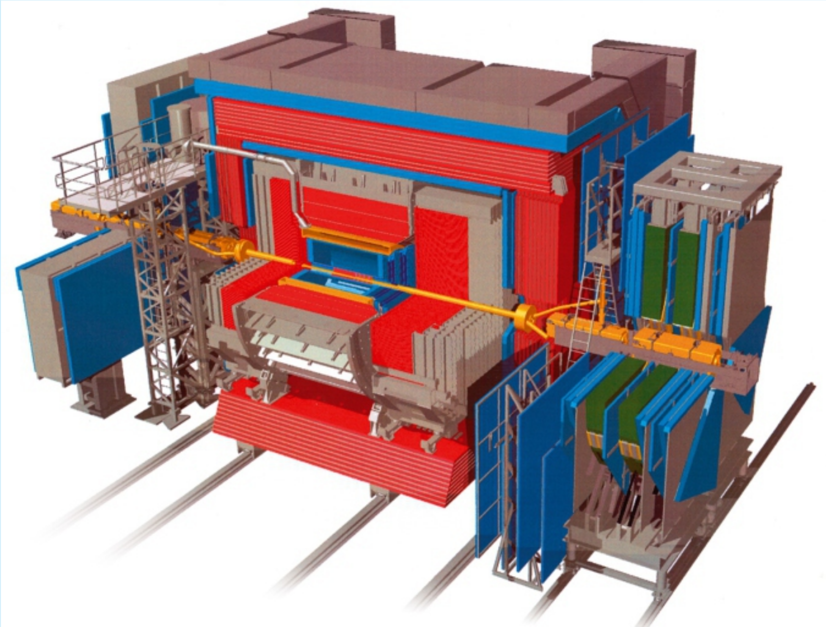
DIS Turin, April 11

Content

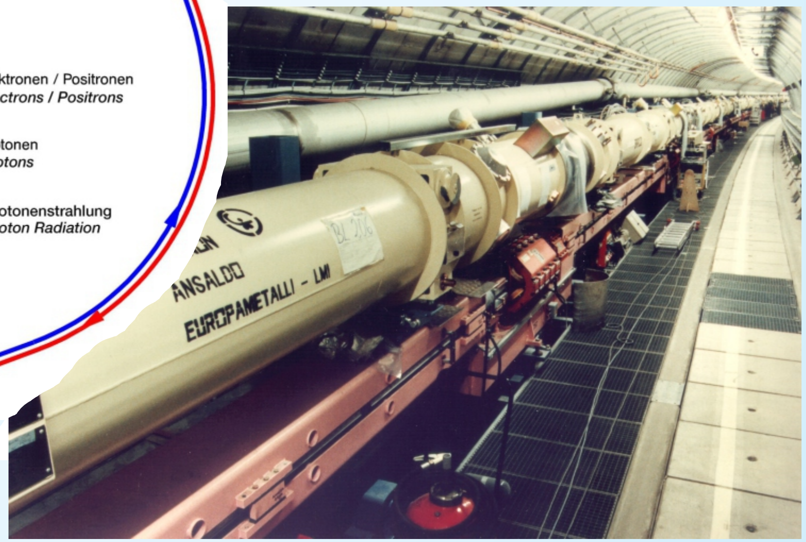
- ZEUS data from HERA
- correlations and collective effects
- correlations in ZEUS DIS data
- Outlook



HERA



ZEUS is in full data preservation mode and welcomes new collaborators and anlyses.



24.5.1993
Zeus DIS Lumi

HERA I – 2000

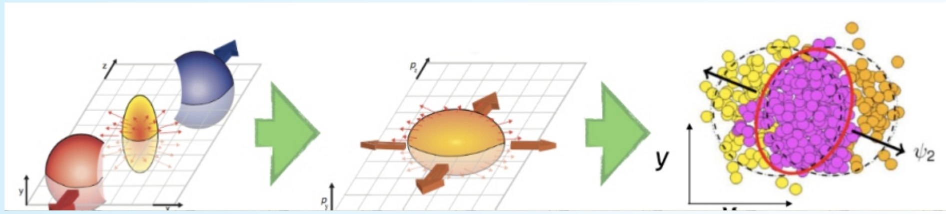
2003 –HERA II

last beam 30.6.2007

Collectivity in Large Systems

Collectivity: multiparticle correlation from a common physics mechanism

Non-central heavy-ion collisions



Initial collision geometry & event-by-event fluctuations cause an azimuthal asymmetry in momentum space wrt to a common symmetry plane.

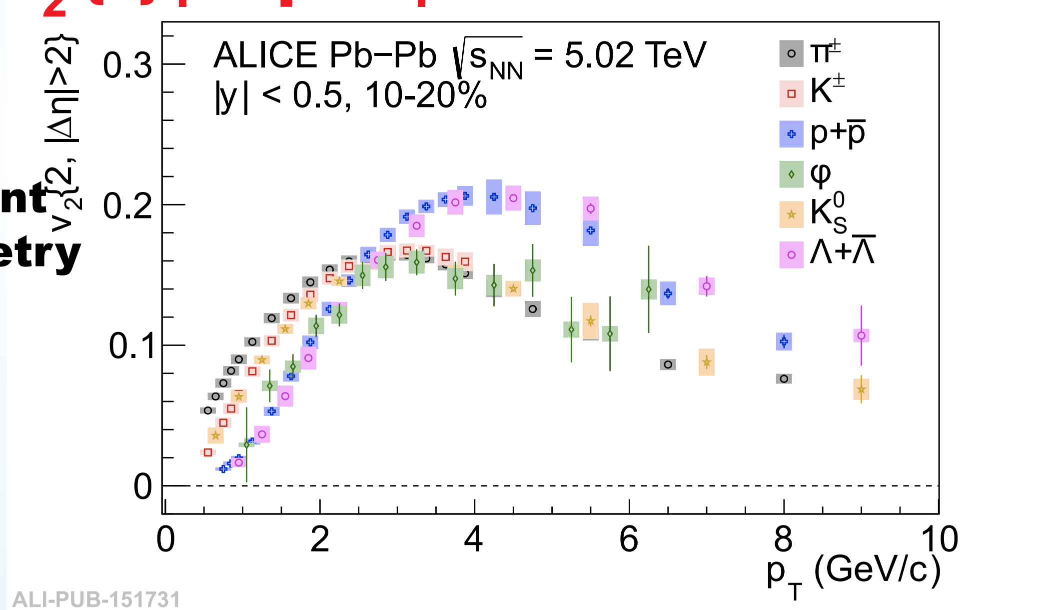
2-particle correlations

$$c_n\{2\} = \langle\langle \cos(n(\varphi_\alpha - \varphi_\beta))\rangle\rangle$$

Exact only in case of correlations
wrt the reaction plane of the collision.

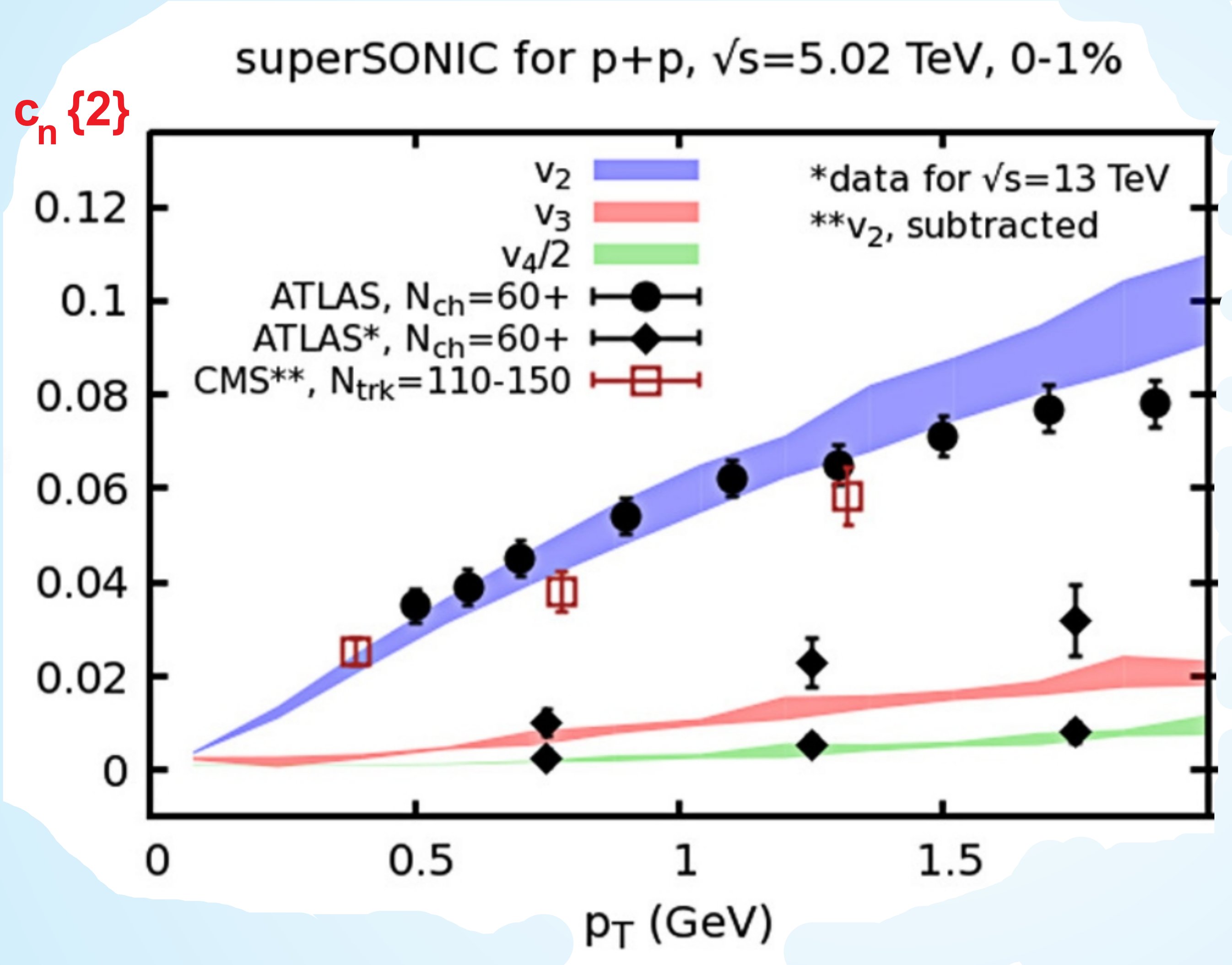
ALICE

$c_2\{2\} \, |\Delta\eta > 2|$



Several particle species show similar collective behaviour.

Collectivity in Smaller Systems



The system does not have to be so large.

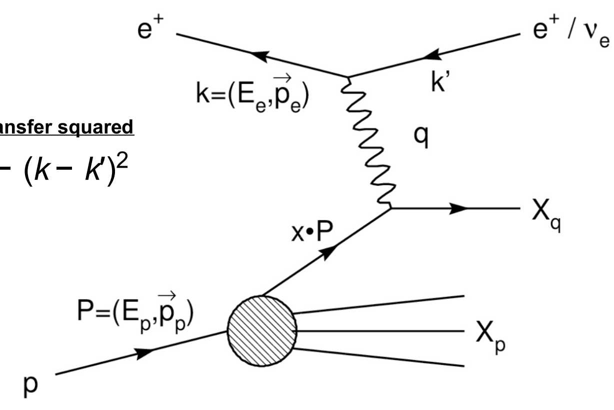
pp does it.

Could ep do?

Weller & Romatschke Phys.Lett. B774 (2017) 351-356

Could it happen in ep DIS

Hard to imagine how to create a collective system, but a first order picture might be inadequate.

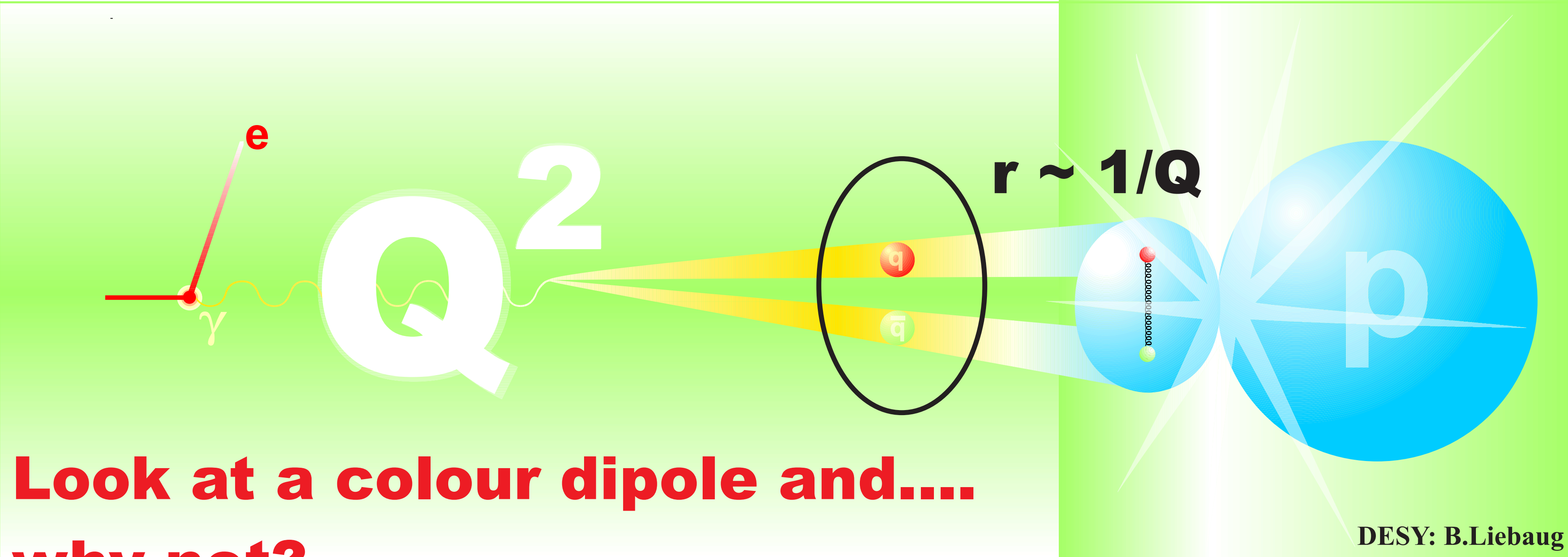


Four momentum transfer squared

$Q^2 = -q^2 = -(k - k')^2$

Bjorken x

$x_{Bj} = \frac{Q^2}{2P \cdot q}$



Look at a colour dipole and.... why not?

ZEUS ep DIS Data

HERA II:

355 M events

NC DIS: 46 M

Event selection:

$Q^2 > 5\ GeV^2$

$E_e > 10$ GeV

$\theta_e > 1.0$

Consistency with DIS:

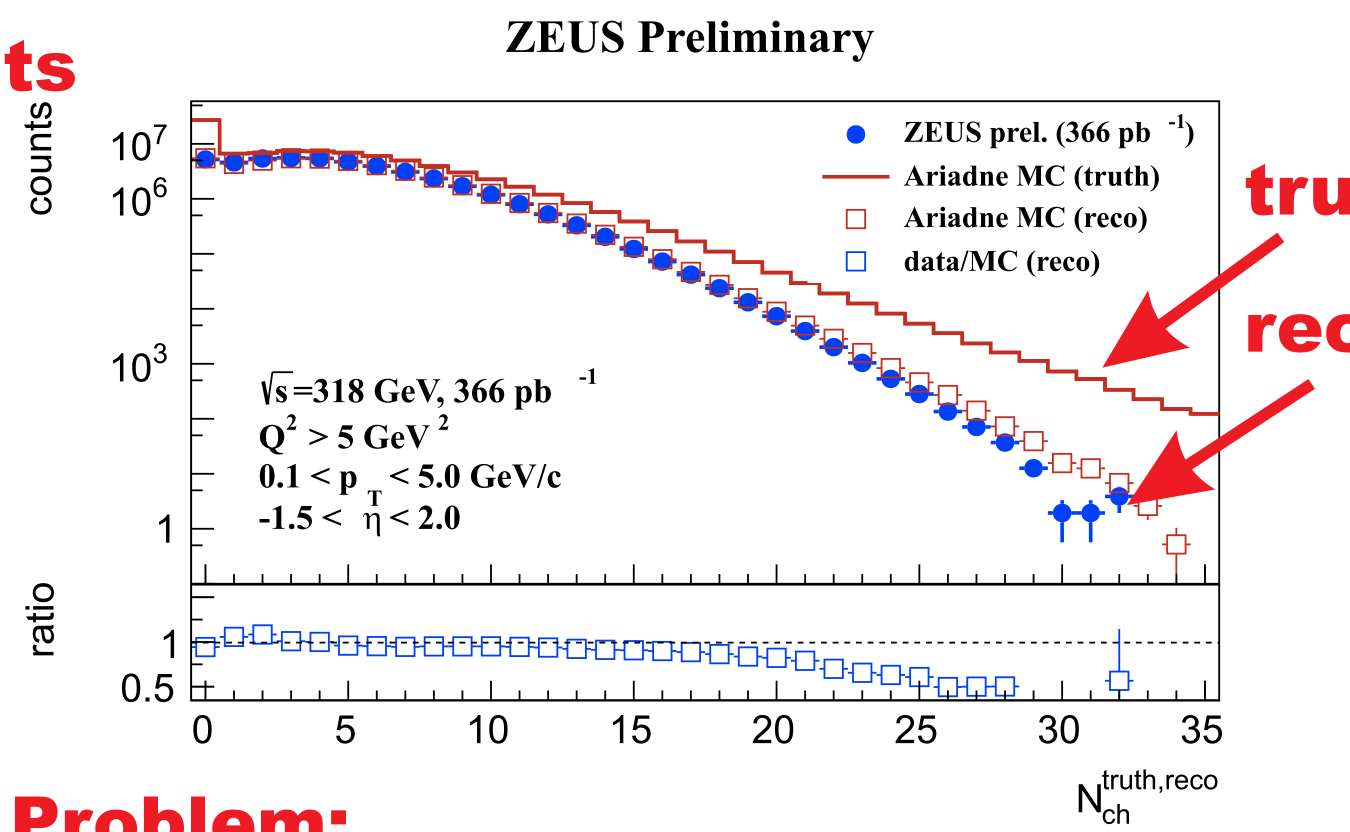
$47 < E - p_z < 69$ GeV/c

Track selection:

$0.1 < p_T < 5.0$ GeV/c

$-1.5 < \eta < 2.0$

Multiplicity



Problem:

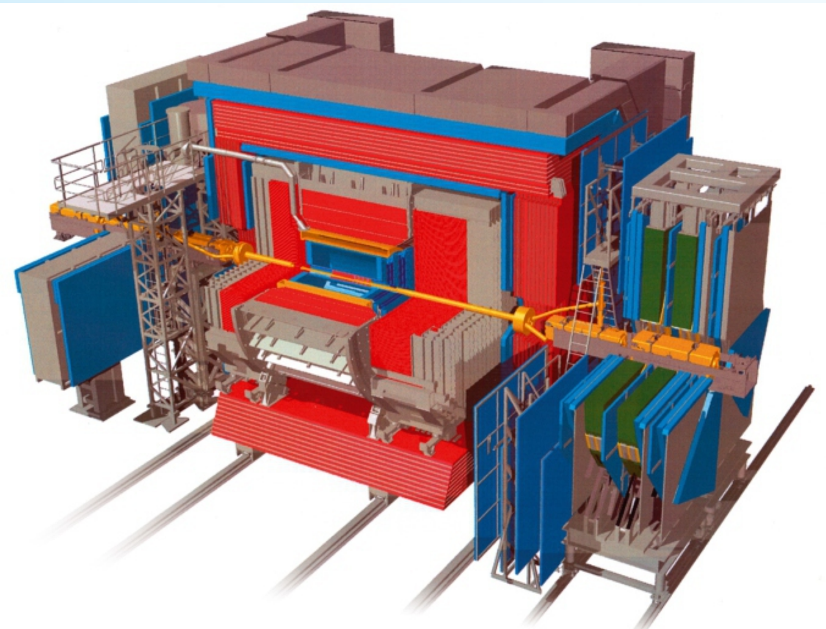
Looking for high multiplicity events

$\langle N_{ch} \rangle \approx 4.5$ and $N_{ch} > 30$ is rare.

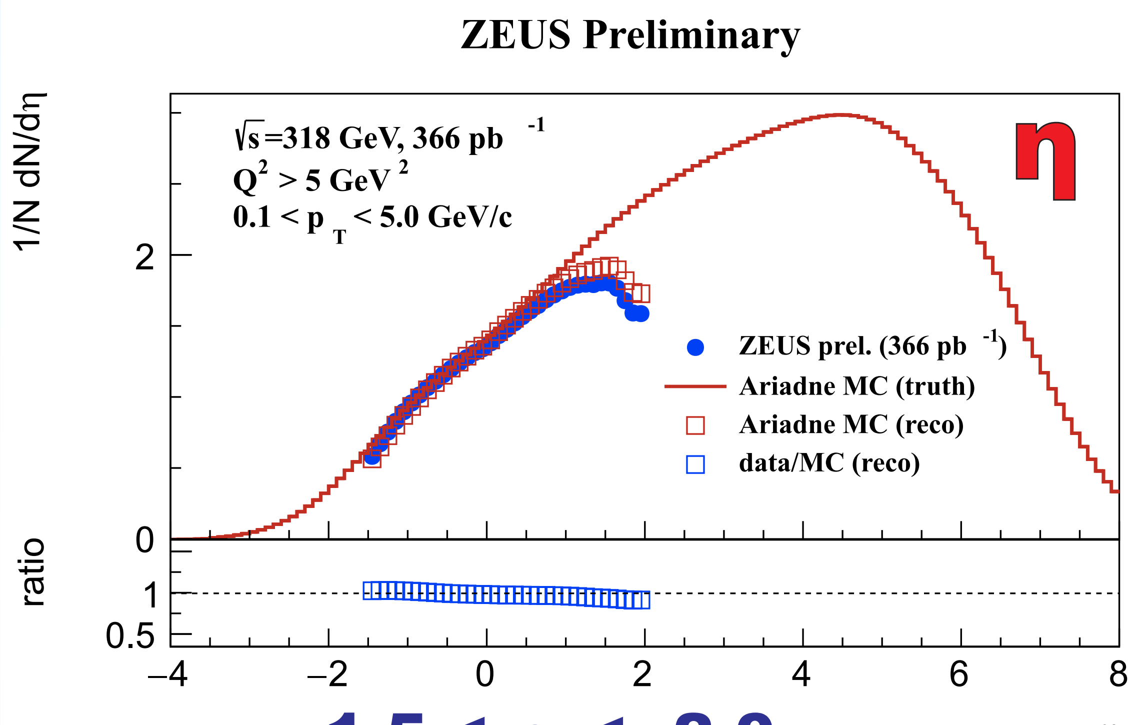
(Atlas > 60)

ZEUS track acceptance

Asymmetric collisions ==> tracks go forward



Detector compensates only modestly.



-1.5 < η < 2.0

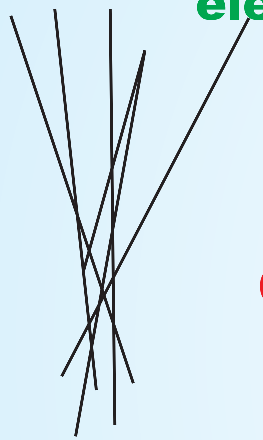
Proton remnant goes down the beampipe.

MC good to 15%

Azimuthal Correlations

2-particles: $c_n\{2\} = \langle\langle \cos(n(\varphi_\alpha - \varphi_\beta))\rangle\rangle$

excluding electron



The inner brackets denote the average in a single event.
The outer brackets the average over all events.

depending on N_{ch}, $\Delta\eta$, Δp_T

$$c_n\{2\} = \langle\langle \underbrace{w^\alpha_{eff}\, w^\beta_{eff}}\; \underbrace{w^\alpha_\varphi\, w^\beta_\varphi}\, \cos(n(\varphi_\alpha - \varphi_\beta))\rangle\rangle$$

Tracking and vertexing is not perfect. Was tuned to data.

MC ≈ 1.1

data 0.95 to 1.05

depend on charge, η, p_T or N_{ch}

$N_{ch} = \Sigma\, w_{eff} w_\varphi$

MC does not produce spurious tracks.

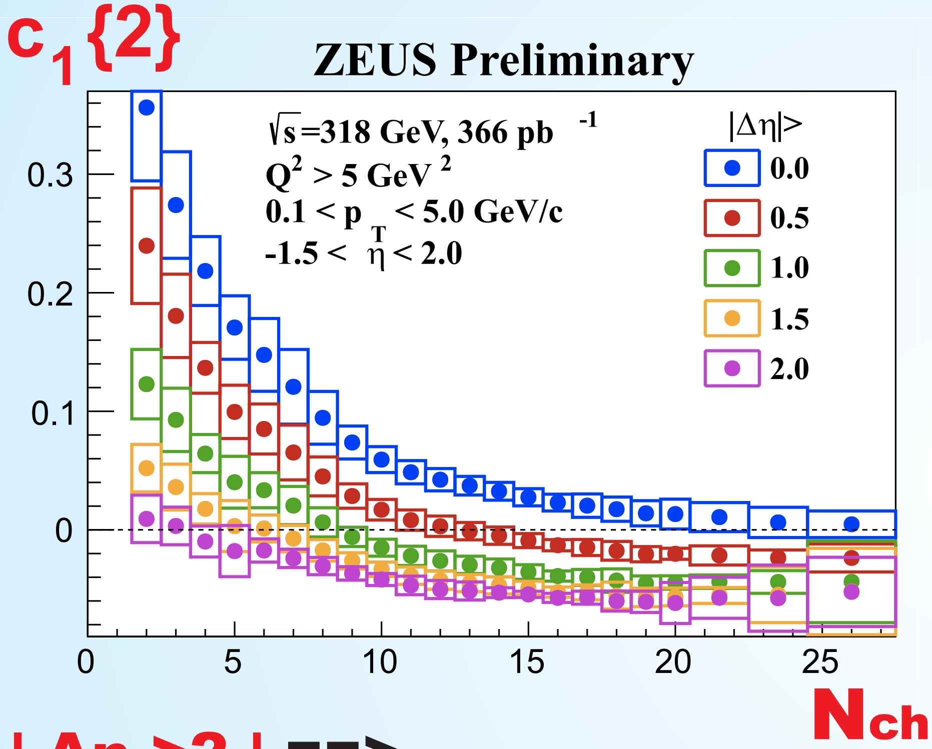
systematic uncertainties:

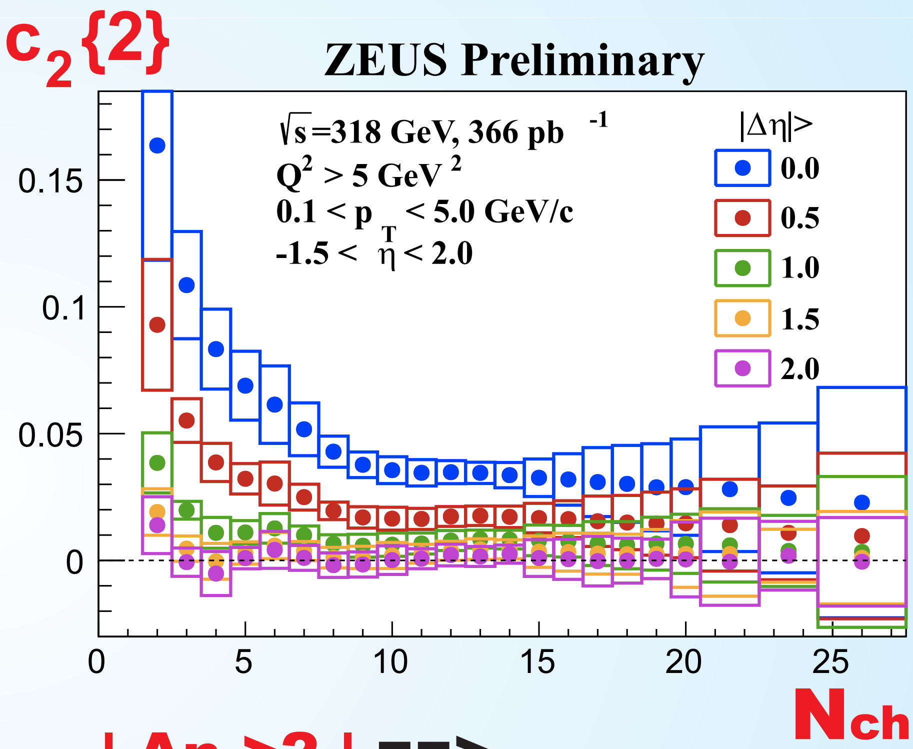
"MC closure"

DIS selection, trigger, tracking

Correlations versus N_{ch}

for increasing | Δη |





| Δη >2 | ==>

sign change reflects momentum conservation

| Δη >2 | ==>

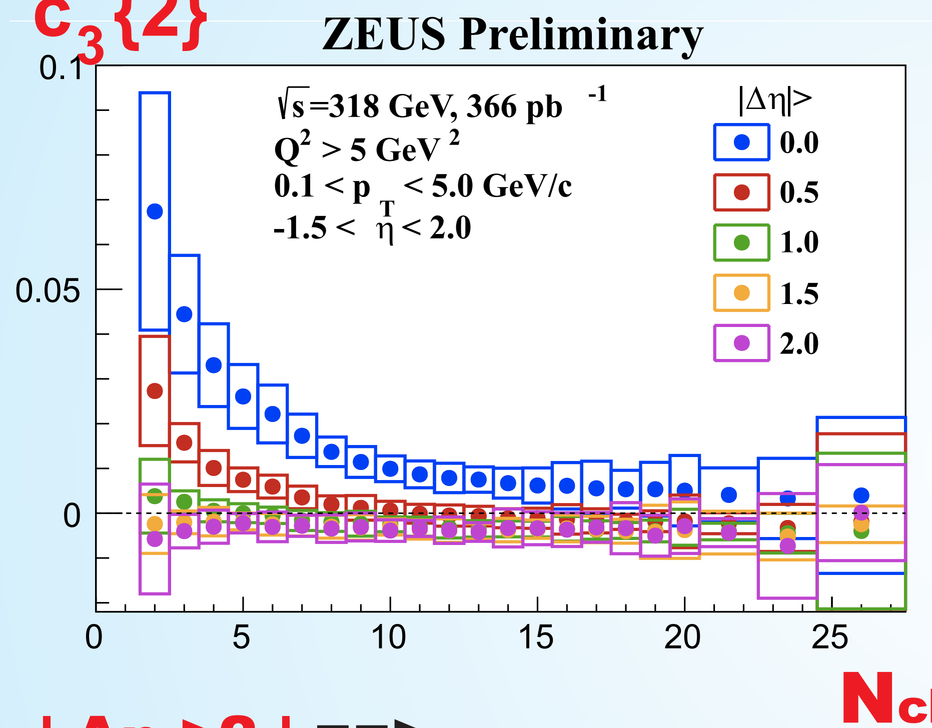
consistent with zero

$$c_n\{2\} = \langle\langle \cos(n(\varphi_\alpha - \varphi_\beta))\rangle\rangle$$

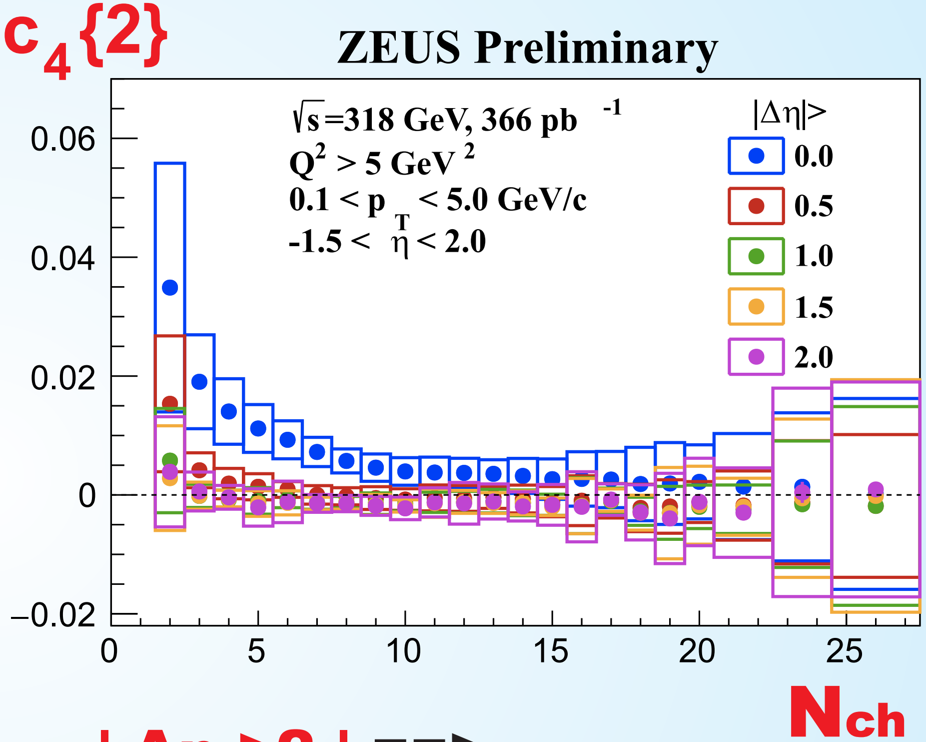
Correlations versus Nch

for increasing | Δη |

$c_3\{2\}$



$c_4\{2\}$



| Δη >2 | ==> consistent with zero

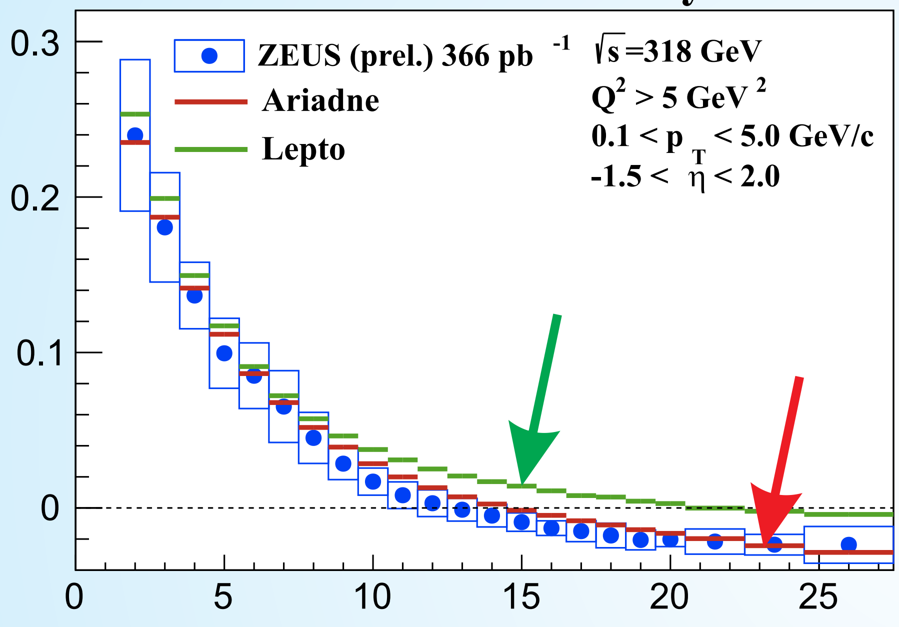
| Δη >2 | ==> consistent with zero

$$c_n\{2\} = \langle\langle \cos(n(\varphi_\alpha - \varphi_\beta))\rangle\rangle$$

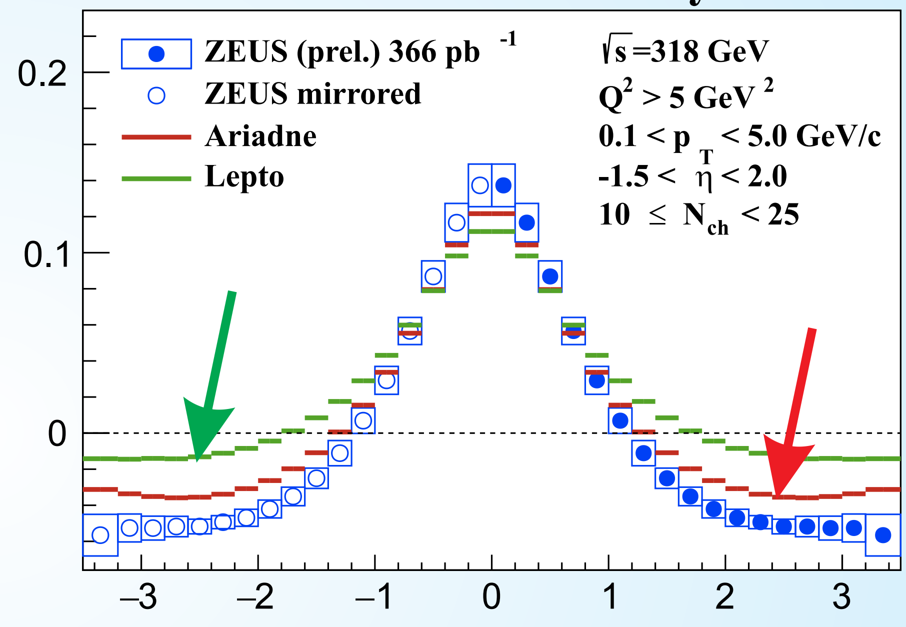
Comparing Data and Monte Carlo

MC not so bad

$c_1\{2,|\Delta\eta|>0.5\}$



$c_1\{2\}$



n=1: Ariadne does better than Lepto

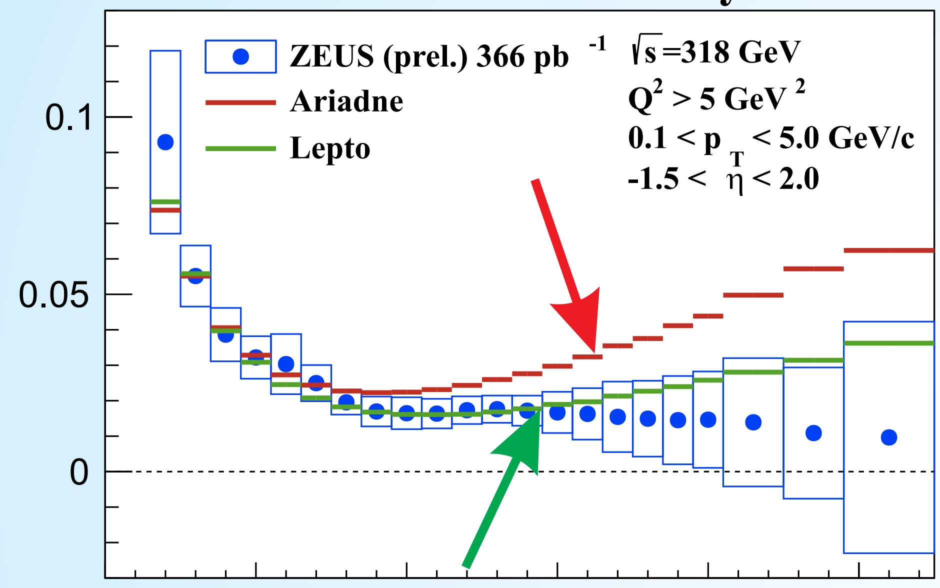
dipole cascade — **DGLAP cascade**

$$c_n\{2\} = \langle\langle \cos(n(\varphi_\alpha - \varphi_\beta))\rangle\rangle$$

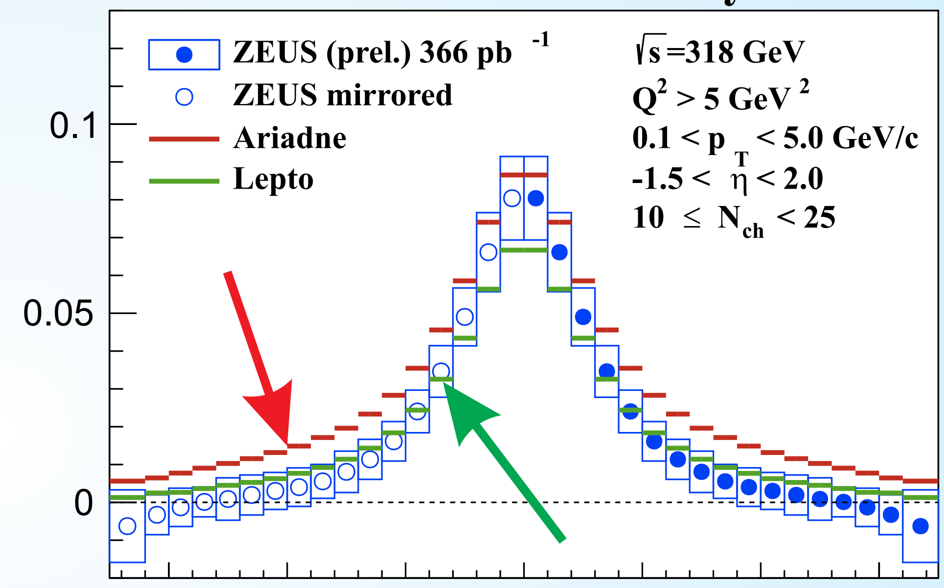
Comparing Data and Monte Carlo

MC not so bad

$c_2\{2,|\Delta\eta|>0.5\}$



$c_2\{2\}$



n=2: Ariadne does worse than Lepto

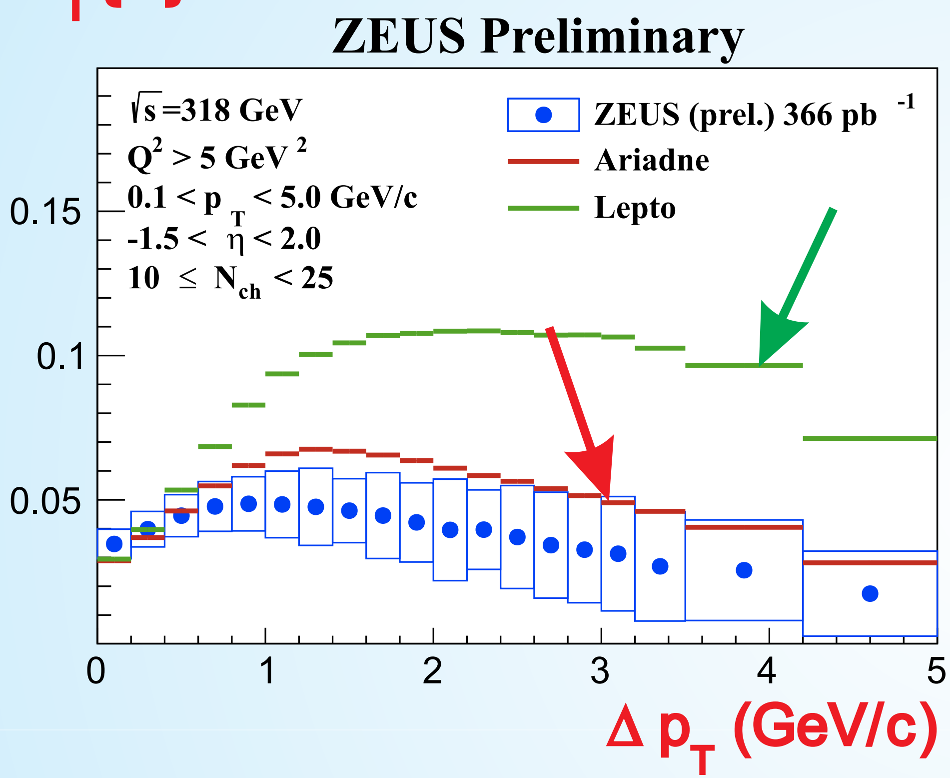
dipole cascade | **DGLAP cascade**

$$c_n\{2\} = \langle\langle \cos(n(\varphi_\alpha - \varphi_\beta))\rangle\rangle$$

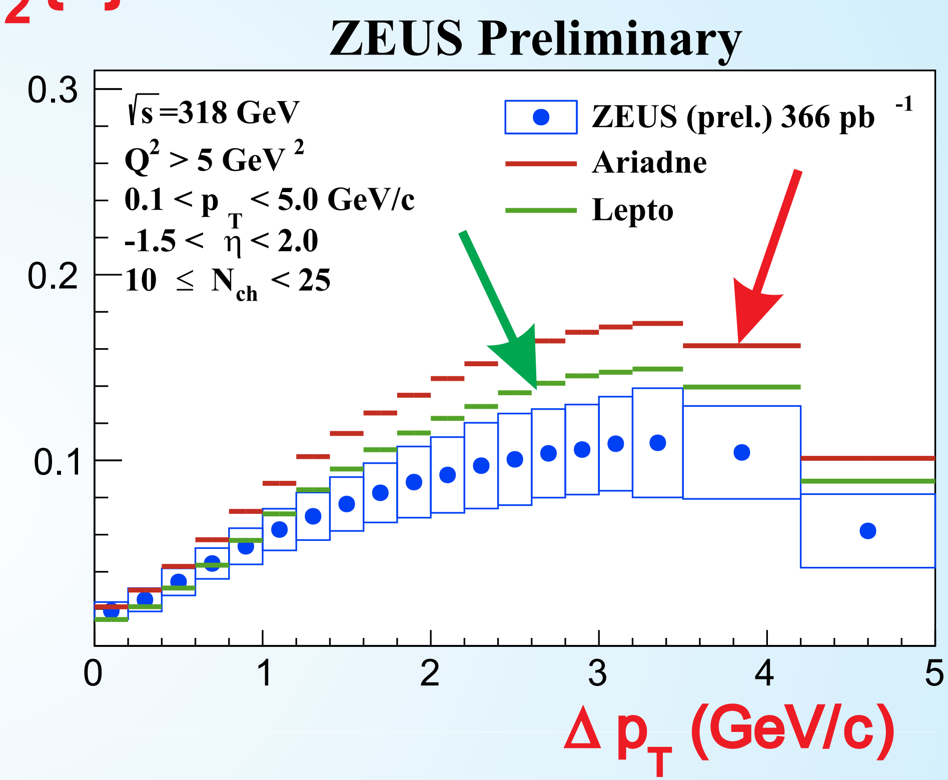
Comparing Data and Monte Carlo

MC not so bad

$c_1\{2\}$



$c_2\{2\}$



n=1: Ariadne does better than Lepto

n=2: Ariadne does worse than Lepto

Overall Monte Carlos describe main features.

Summary and Outlook

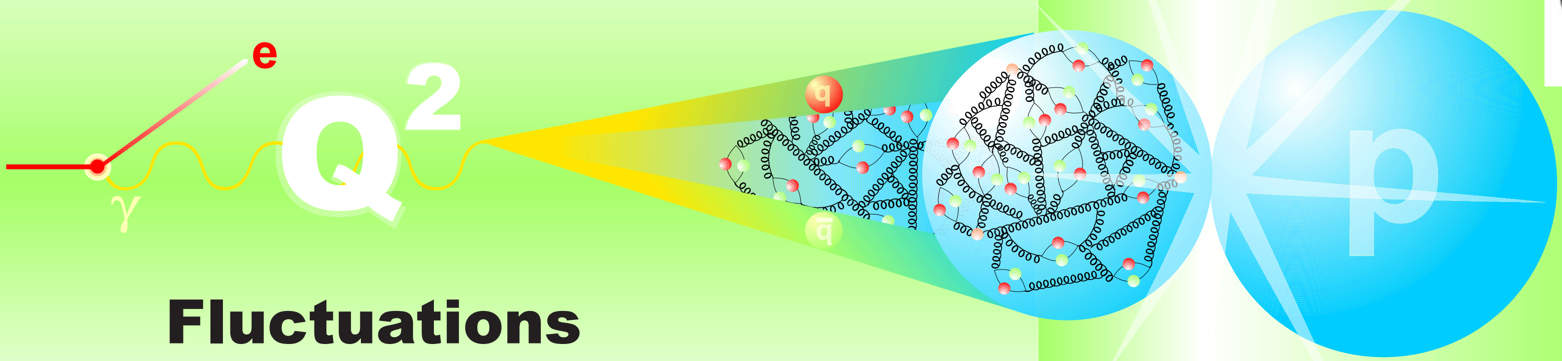
Correlations indicating collective effects were searched for in ZEUS NC DIS data.

Nothing beyond expectations [kinematics]

Well, perhaps DIS is not ideal.

ZEUS data is waiting.

Photoproduction

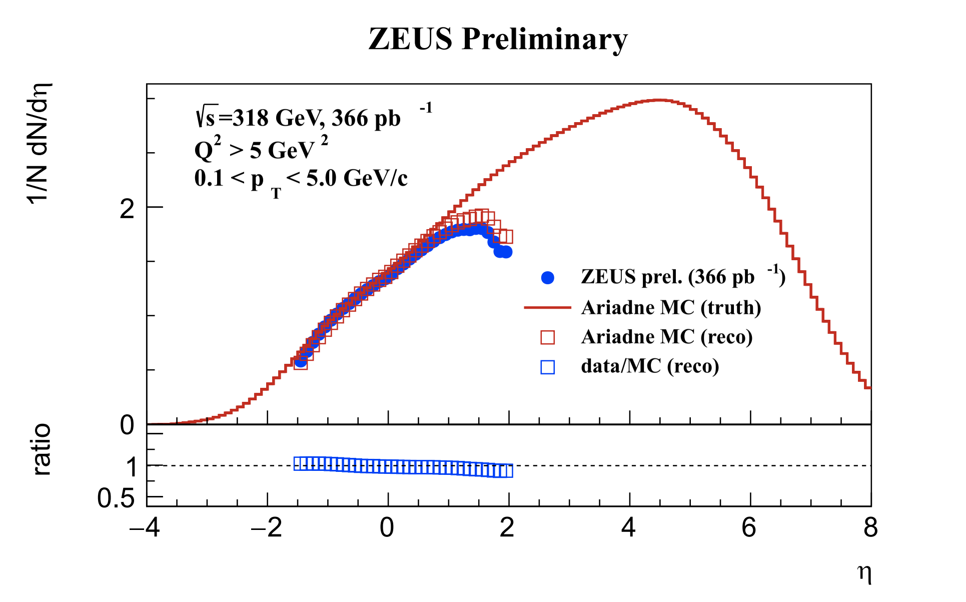


Fluctuations in the photon can grow.
For low Q^2 they live long and prosper.

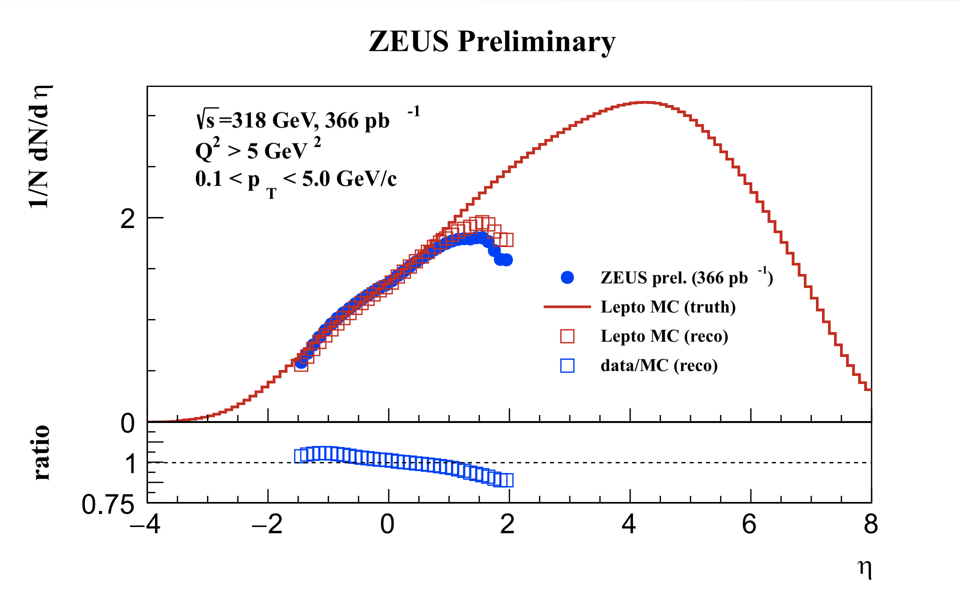
Additional Material

ZEUS track acceptance

ARIADNE



LEPTO

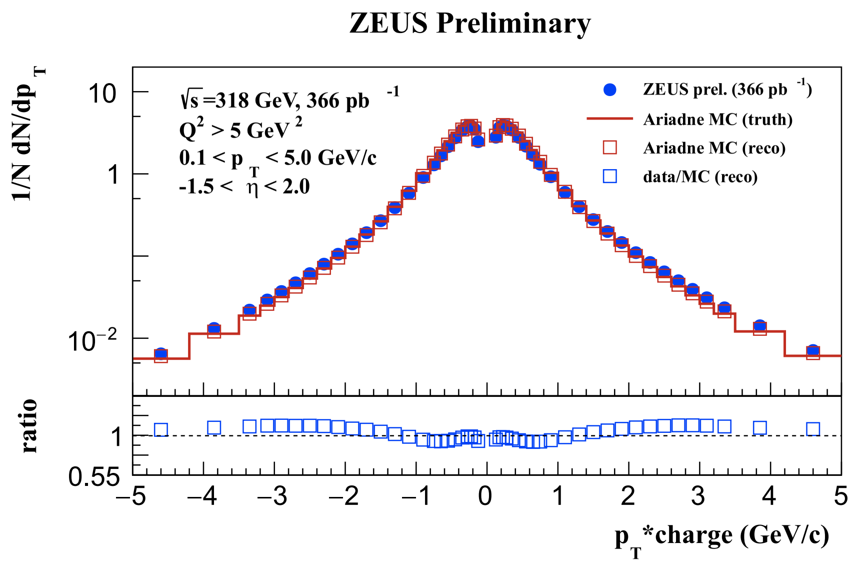


dipole cascade

DGLAP cascade

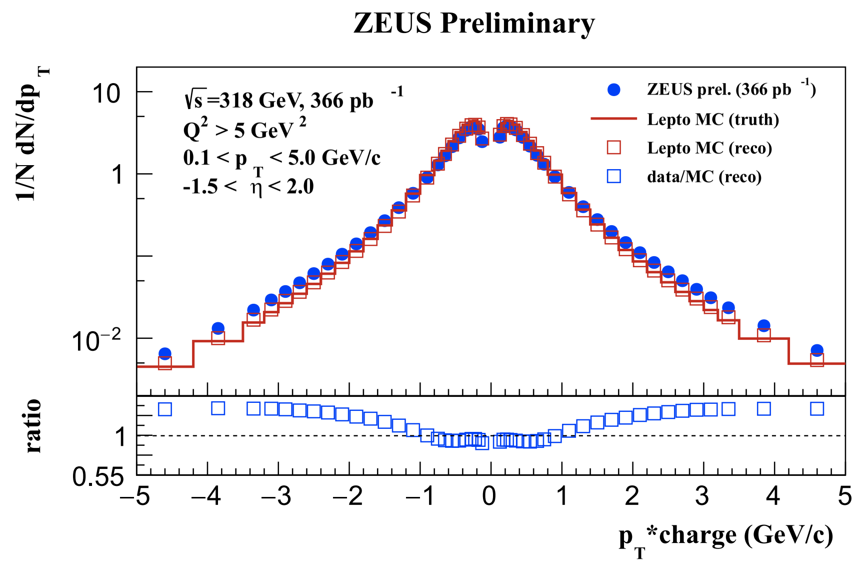
ZEUS p_T range

ARIADNE



dipole cascade

LEPTO



DGLAP cascade

Correlations versus p_T

$c_2\{2\}$ for high multiplicity events $10 < N_{ch} < 25$