Multiplicities & Factorial Moments

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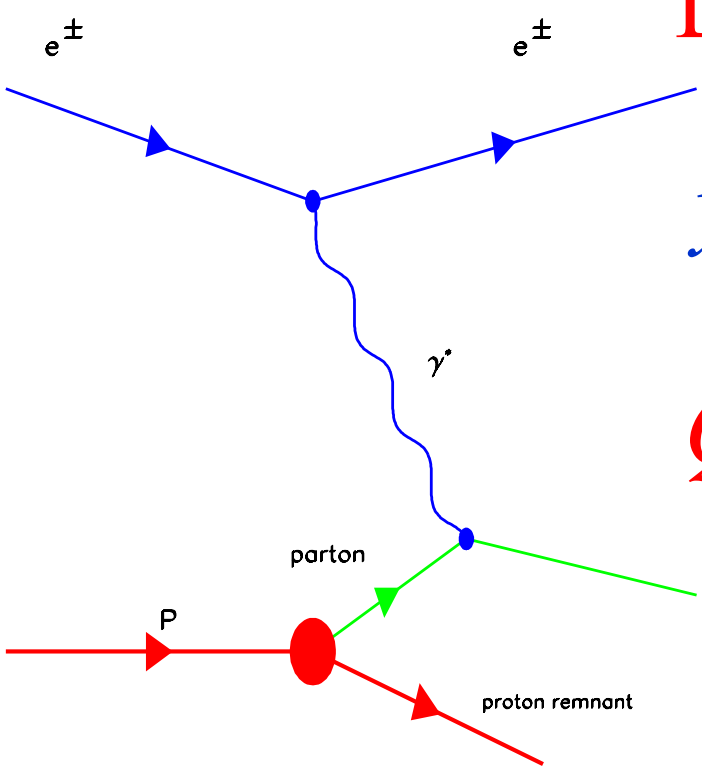
(on behalf of the ZEUS Collab.)

- Introduction & Motivation
- Results
- Conclusions

Naïve Quark Parton Model (QPM)



Lorentz scalars: y, Q^2,x

$$y = 1 - \frac{E_e'}{2E_e}(1 - \cos\vartheta)$$

$$Q^2 = 2E_e'E_e(1 + \cos\vartheta)$$

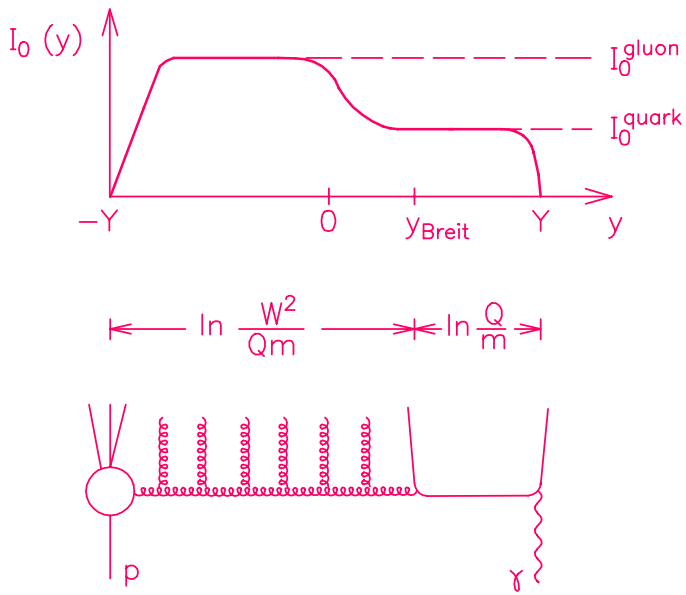
$$x = \frac{Q^2}{ys}$$

where $\sqrt{s}$ is the eP centre of mass energy

Multiplicity Distributions

Investigation of dynamics of hadronisation process - study the $\langle n_{ch} \rangle$ as a a function of invariant mass (M_{eff}) in a fixed rapidity range (in lab. frame)

M_{eff} is essentially measuring the rapidity "along" the gluon ladder



Gluon or quark initiated - measurement of colour charge

Factorial Moments

fractal dimension techniques (eg Rényi dimensions) to multiparticle production processes

investigation of cascading dynamics & “self-similarity” of branching processes

predictions exist within framework of pQCD

use of DLA and MLLA (in conjunction with LPHD)

[theoretical work: Dokshitzer, Ochs (MLLA)

Dremin, Wosiek (Factorial moments)]

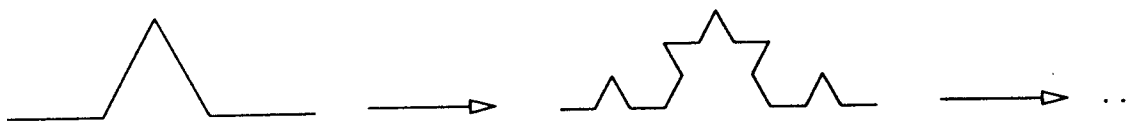
Mathematical Interlude

Fractal dimension, F_D

$$M \sim l^{F_D}$$

- M is mass & l is length. $F_D = 1$ for a line, $F_D = 2$ for a square…

Koch Curve



➞ self-similar curve with dimension $F_D = \ln(4)/\ln(3)$

Generalise to multi-fractals $F_D \rightarrow D_q$ (Rényi dimension)

(*cf* replace our homogenous stick with an inhomogenous one)

Factorial Moments

$$F_q(\Delta\Omega) = \langle n(n-1)\ldots(n-q+1)\rangle \Big/ \langle n\rangle^q , \qquad q = 2,3,\ldots$$

where n is number of charged particles inside a phase-space region of size $\Delta\Omega$ and <…> denotes average.

For uncorrelated particle production within $\Delta\Omega$, $F_q = 1$ (Poisson stats)
rise follows power law - "intermittency"

moments probe different dynamics depending on choice of $\Delta\Omega$

Kinematic Selections

Multiplicity: 1995 data (5.5 pb^{-1})

$8 < Q^2 < 1200\ GeV^2$

$70 < W < 260\ GeV$

Particles with angular acceptance of $|\eta(lab)| < 1.75$

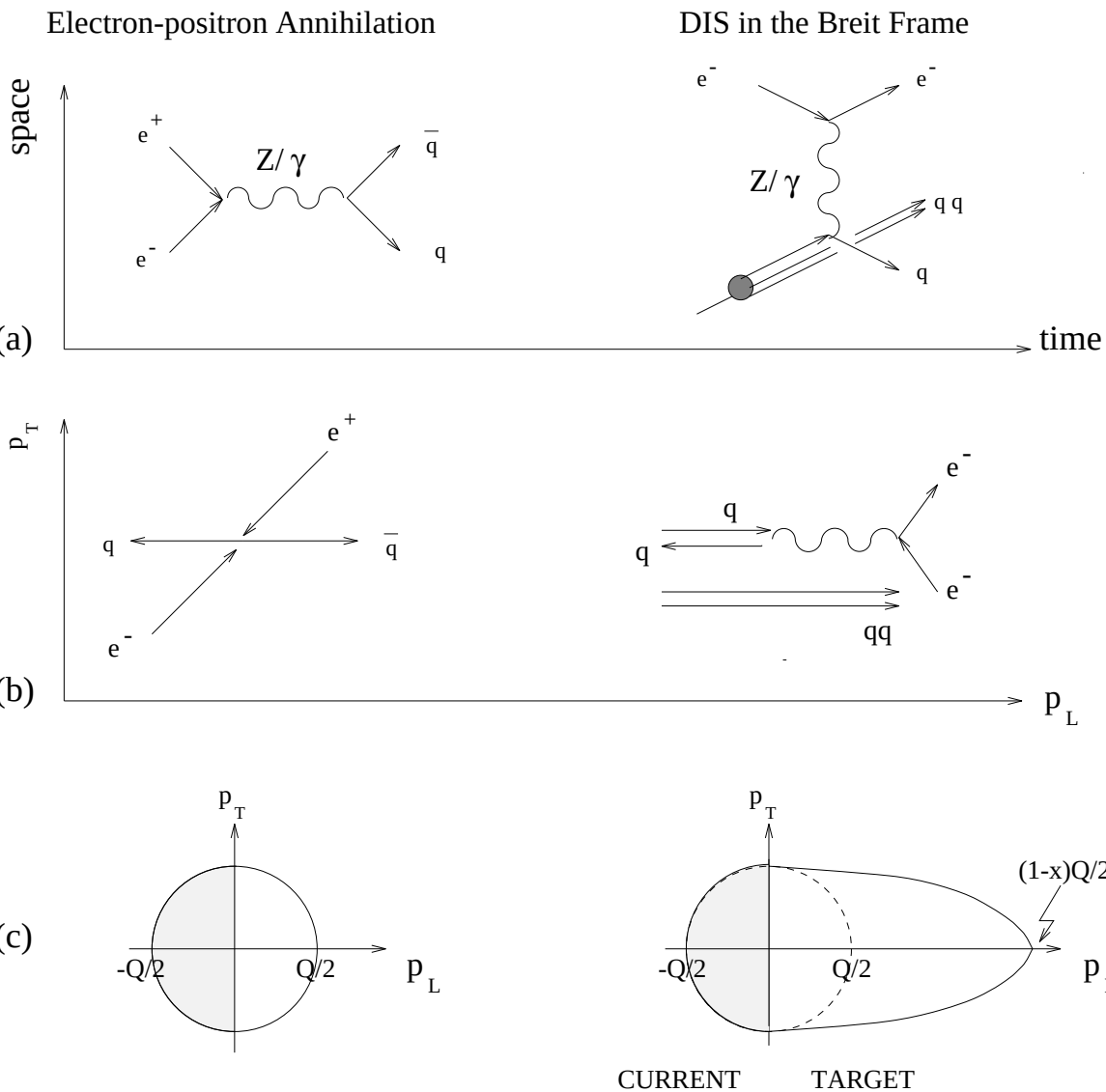
Moments: 96+97 (38.4 pb^{-1})

$Q^2 > 1000\ GeV^2$

Moments measured in
current region of Breit frame

The Breit Frame

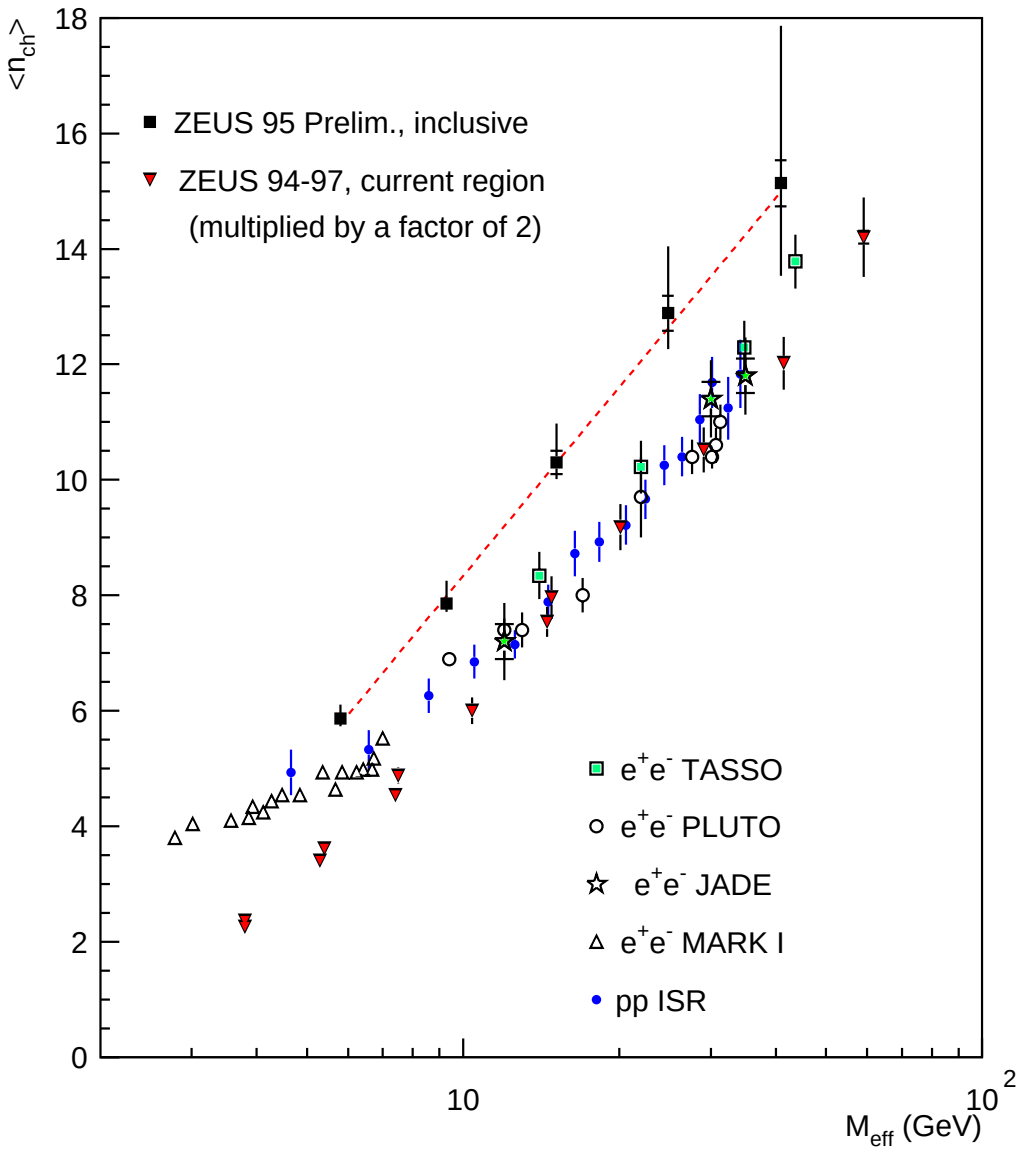
`Brickwall' frame



Phase space for e^+e^- annihilation evolves with $Q/2 = \sqrt{s}/2$

Current hemisphere of Breit frame evolves as $Q/2$

Current region ≡ e^+e^- annihilation



Data grows linearly with $\log(M_{eff})$

$\langle n_{ch} \rangle$ higher that e^+e^- data ($M_{eff} \equiv \sqrt{s_{ee}}$), low energy pp data and (Breit) current region in DIS ($M_{eff} \equiv Q$)

Data compatible with picture of additional coherent gluon radiation due to (octet) colour charge

Systematic Checks

Event Selection:

- checks on y_e(2%), y_{JB}(3%), E-p_z(1%), vertex cut(1%)

Trk selection:

- tightening of p_T cut (1%) and η cut (2%)

Monte Carlo dependence:

-LEPTO + POMPYT (up to ~16%)

Analytic QCD Results

$\Omega \equiv p_T^{cut}$ or p^{cut} ie $p_T > p_T^{cut}$ ($|p| > p^{cut}$)

$$F_q(p_T^{cut}) \approx 1 + \frac{q(q-1)}{6} \frac{\ln(p_T^{cut}/Q_0)}{\ln(E/Q_0)}, \qquad F_q(p^{cut}) \approx \text{const} > 1$$

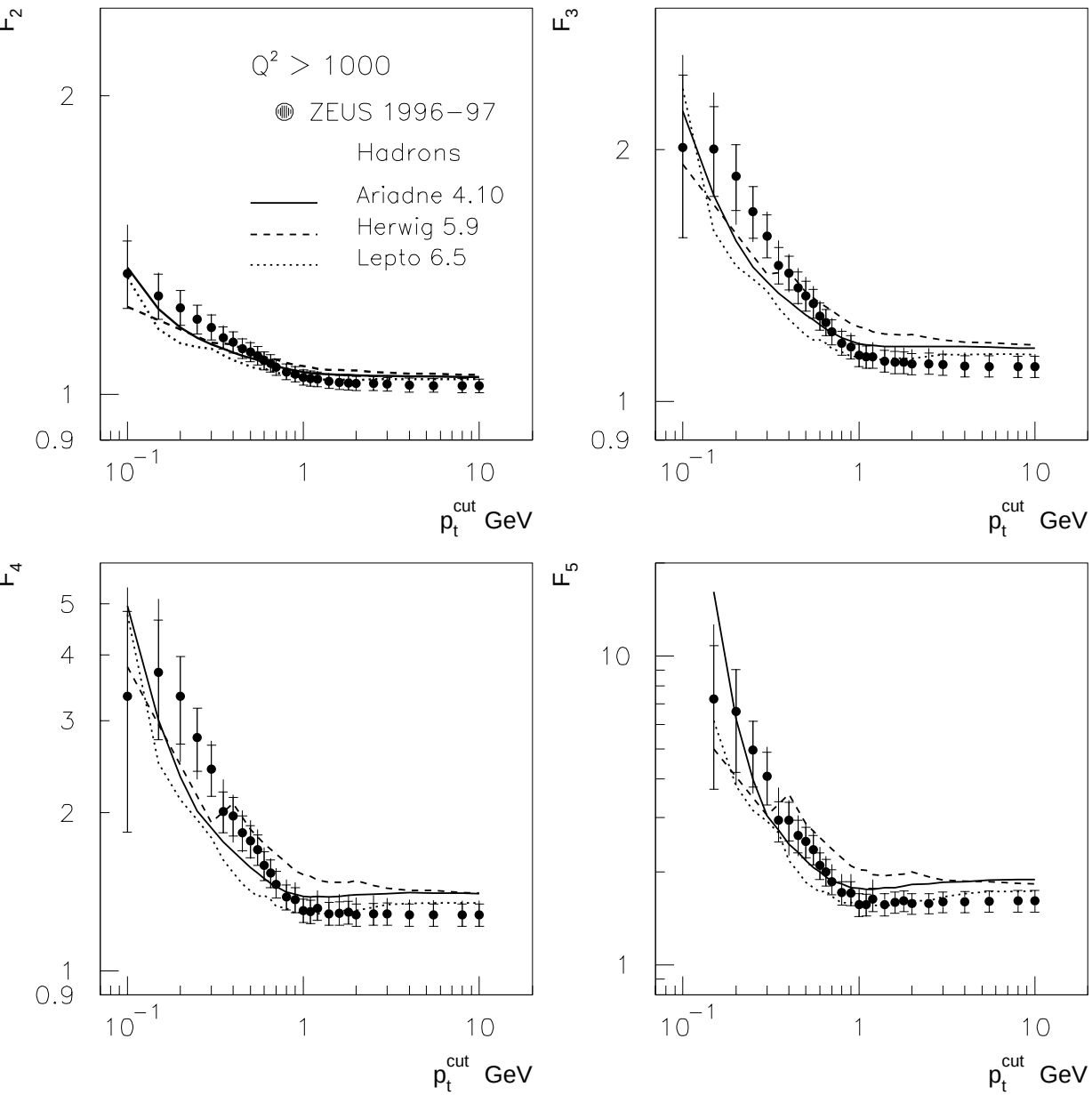
E = jet energy, Q_0 = parton shower cut-off. DLLA approx

(Lupia, Ochs & Wosiek)

p_T: prediction of correlations (presence of gluon enhances probability of emission of another one)

As $p_T \rightarrow Q_0$ correlations vanish due to coherence effects

p: dist^{bn} of soft gluons remains non-Poisson



MC models qualitatively describe the data (in detail there are discrepancies)

data in disagreement with theoretical predictions

Result for momentum look similar to p_t

Systematic Checks

Event Selection:

- checks on y_e, y_{JB}, $E\text{-}p_z$, vertex cut

Trk selection:

- tightening of p_T cut and η cut

Typically a few % change - but can be ~20% at low p, p_T or high z

Analytic QCD Results

$\Omega \equiv$ polar rings of size Θ around axis centred at Θ_0 (see fig↘)

$$\ln \frac{F_q(z)}{F_q(0)} = z(1-D_q)(q-1)\ln \frac{E\Theta_0}{\Lambda}$$

E = jet energy, Θ_0 = opening half angle of jet, Λ=QCD scale

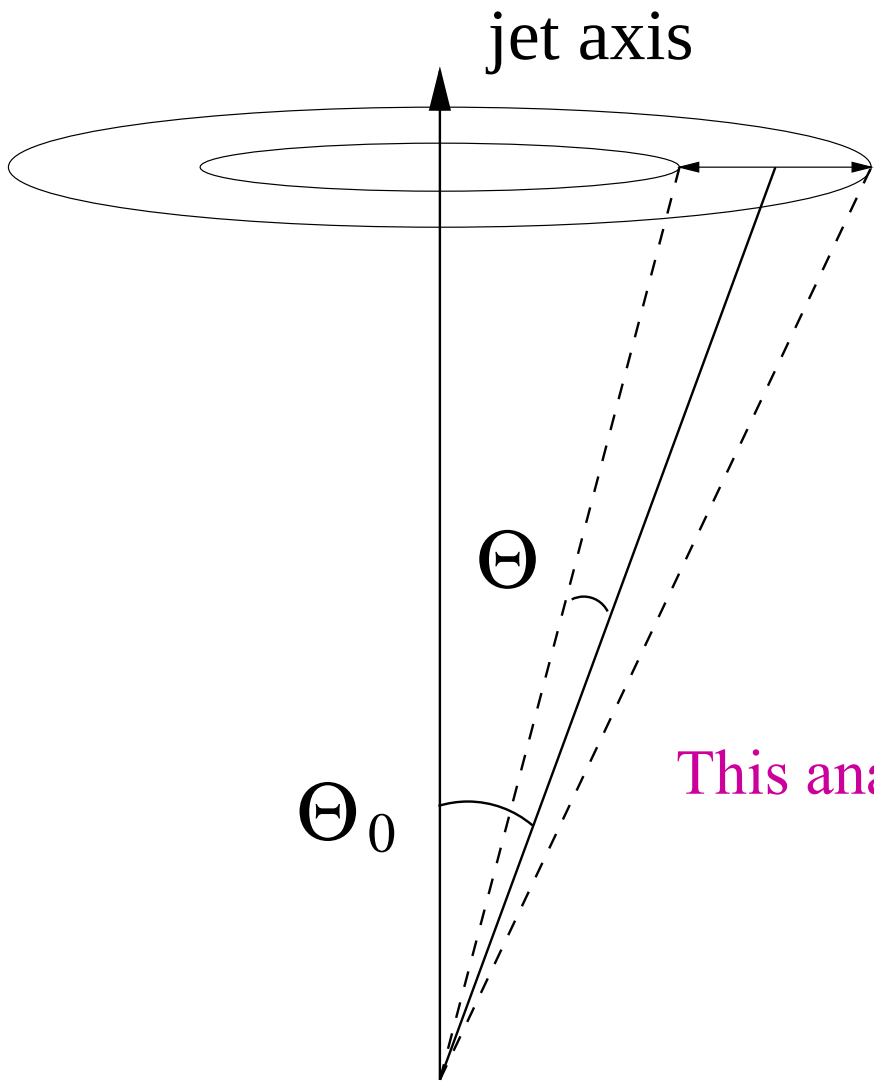
$$z = \frac{\ln(\Theta_0/\Theta)}{\ln(E\Theta_0/\Lambda)}$$

Number of predictions in DLA (Dokshitzer & Dremin; Brax, Meunier & Peschanski; Ochs & Wosiek) and in MLLA (Dokshitzer & Dremin) for the Rényi dimensions, D_q.

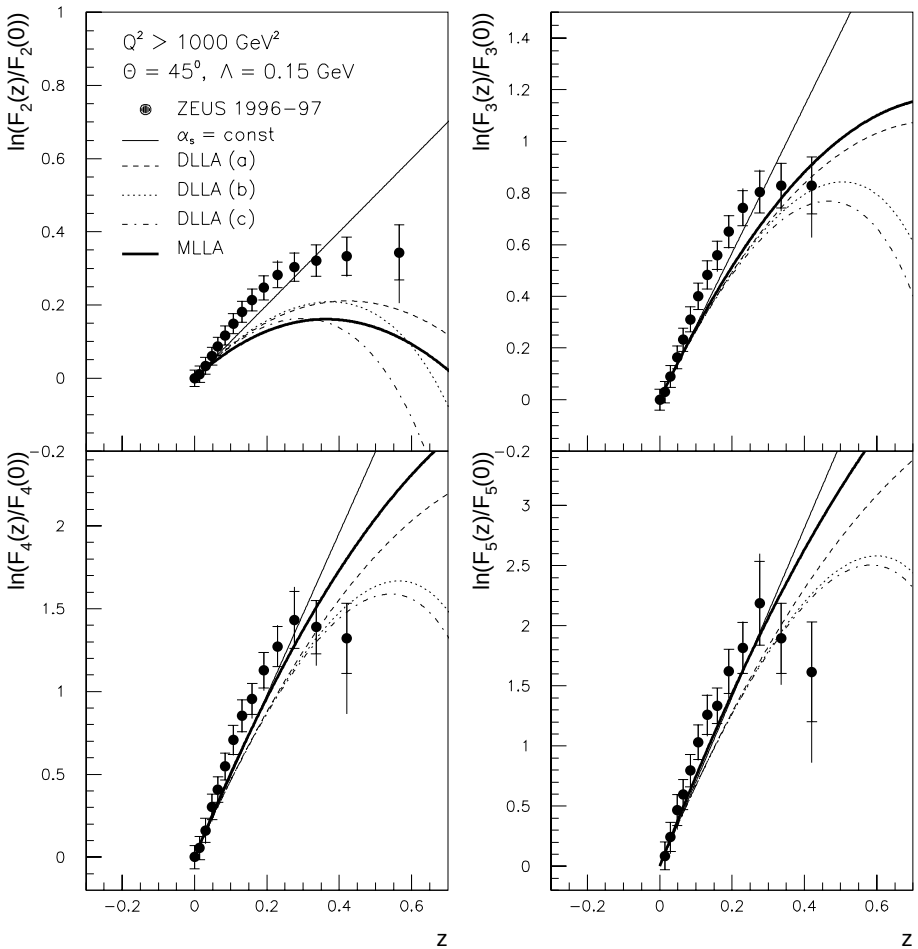
$$D_q \to 1 \quad \text{for Poisson dist}^{\text{bn}}$$

QCD predictions have $D_q = D_q(q,z)$

Def^{n} of angular variable

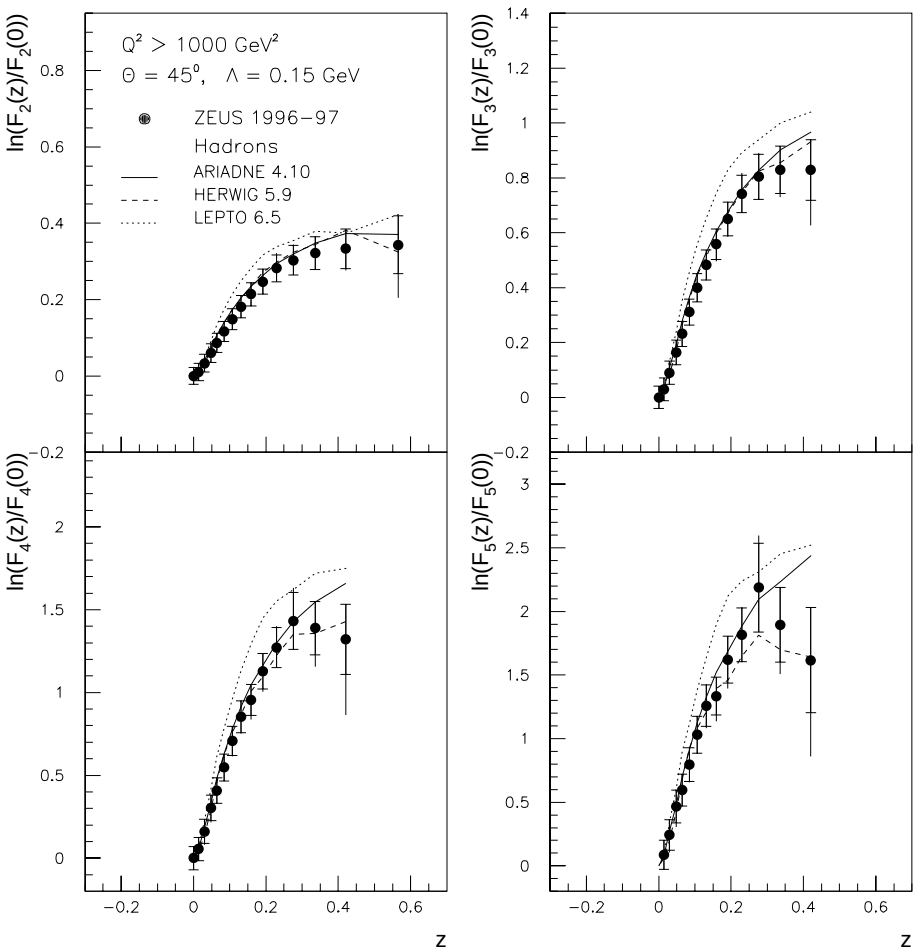


This analysis uses $\Theta_0=45^0$



For $\Theta_0 = 45^0$ & Λ=150 MeV, general trend of data & theory agree ie moments ↑ as z↑

Particular at lower order moments data & theory don't agree in detail.



ARIADNE & HERWIG reproduce the data

LEPTO overshoots the data

Non-negligible hadronisation effects

Conclusions

- $\langle n_{ch} \rangle$ higher than e^+e^-, low energy pp data & (Breit) DIS current region - colour charge effect ?
- Multiplicity factorial moments exhibit strong rise in restricted intervals as p_T, p & Θ decreases
- Analytic calculations (for partons) do not show the same increase for the factorial moments
- MC models (generally) reproduce the data
- Substantial contribution from hadronisation - LPHD hypothesis non-applicable