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Multiplicity Fluctuations in DIS

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DEEP INELASTIC SCATTERING AND QCD
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- Introduction
- Angular multiplicity fluctuations
- Multiplicity fluctuations in momentum space
- Conclusions

Introduction

- Multiplicity distributions of hadrons characterize multiparticle final state.

- Studies of multiplicity fluctuations in limited phase space regions :

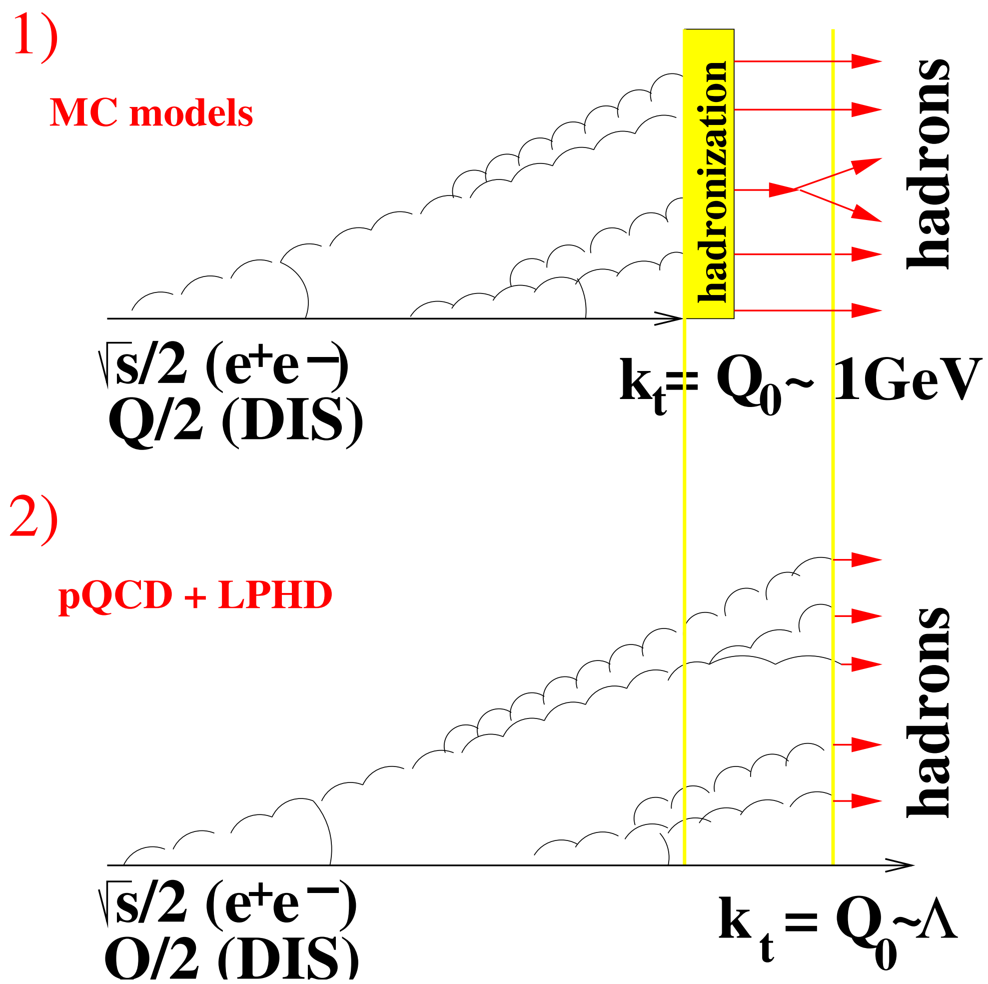
  1. are sensitive to multiparticle dynamics
  2. reveal the nature of particles correlations.

- Multiparticle production:
  - Data → different processes: DIS, e^+e^-, hh
  - Theory :
    1. QCD-based Monte Carlo
    2. Analytic QCD with Local Parton Hadron Duality (LPHD)

- LPHD is successful in description of inclusive single and two particle observables.
  Can it be used in multiplicity fluctuations studies?

- Compare analytical QCD predictions with DIS data

Theoretical approaches

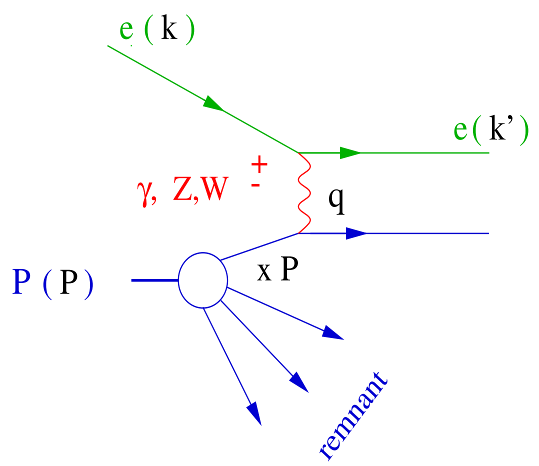


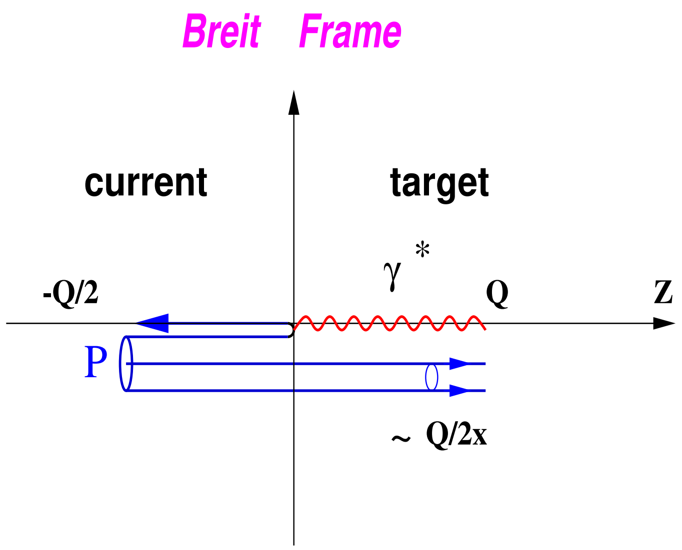
Analytic QCD + LPHD

- Partonic cascade is evolved down to a scale $Q_0 \sim \Lambda$ (a few 100 MeV)
- No particular hadronization model is involved
- Successful description of inclusive observables at high energy interactions
- Direct comparison with MC: set $Q_0 \sim \Lambda$ and switch off hadronization

DIS Kinematics at HERA

HERA: $p(820 GeV) \rightarrow\leftarrow e^{+}(27.6 GeV)$

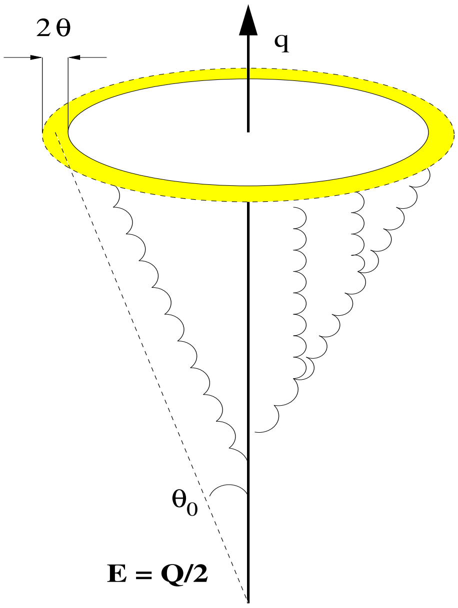




$$
\begin{aligned}
Q^2 &= -q^2 = -(k-k')^2 && \text{squared 4-momentum transfer;} \\
x &= Q^2/2p\cdot q && \text{fractional parton momentum } (0 \le x \le 1); \\
y &= p\cdot q/(p\cdot k) && \text{fractional energy transfer } (0 \le y \le 1); \\
W^2 &= (q+p)^2 \simeq \tfrac{Q^2}{x}(1-x) && \gamma^* P \text{ Center-of-Mass}
\end{aligned}
$$

Data selection: $\mathbf{L = 38.4\ pb^{-1}}$; $\quad Q^2 > \mathbf{1000\ GeV^2}$

Angular Moments



$P_n(2\Theta)$

is the probability to find **n gluons** in the ring of size 2Θ at Θ_0

New variable:

$$z = a^{-1}\, ln \frac{\Theta_0}{\Theta}$$
$$a = ln \frac{E\Theta_0}{\Lambda}$$

Factorial moments:

$$F_q(z) = < n >^{-q} \sum_{n=q}^{\infty} \frac{n!}{(n-q)!} P_n(z)$$

Experimental definition:

$$F_q(z) = < n >^{-q} < n(n-1)\ldots(n-q+1) > \qquad q = 2, 3, \ldots$$

n is the number of hadrons in corresponding rings

DLLA QCD:

$$\ln \frac{F_q(z)}{F_q(0)} = z\, a\, (1 - D_q)(q - 1)$$

Fluctuations are determined by D_q – the *Rényi* dimensions

For independently produced particles (no phase-space correlations)

Poisson statistics and $D_q = 1, F_q(z) = F_q(0)$

Angular moments - QCD calculations

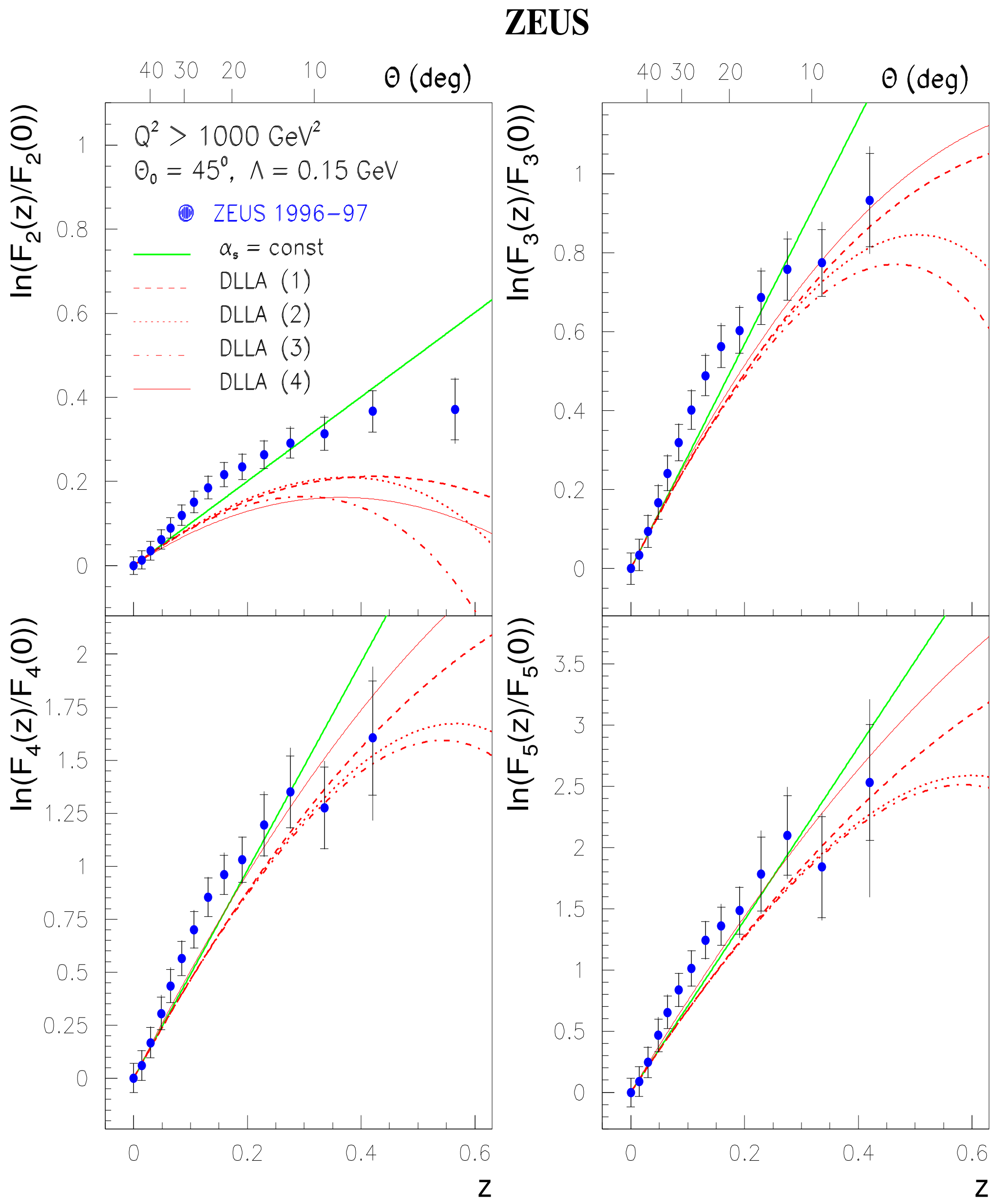
- α_s fixed at scale $Q \simeq E\Theta_0$
- the running coupling $\alpha_s(Q)$
  Several possibilities of the treatment of the non-leading DLLA contributions
- Monte Carlo based: Ariadne Parton MC:

  run down to: $Q_0 \sim \Lambda$ ($Q_0 = 0.27, \Lambda = 0.22$)

  consistent with the picture of LPHD.

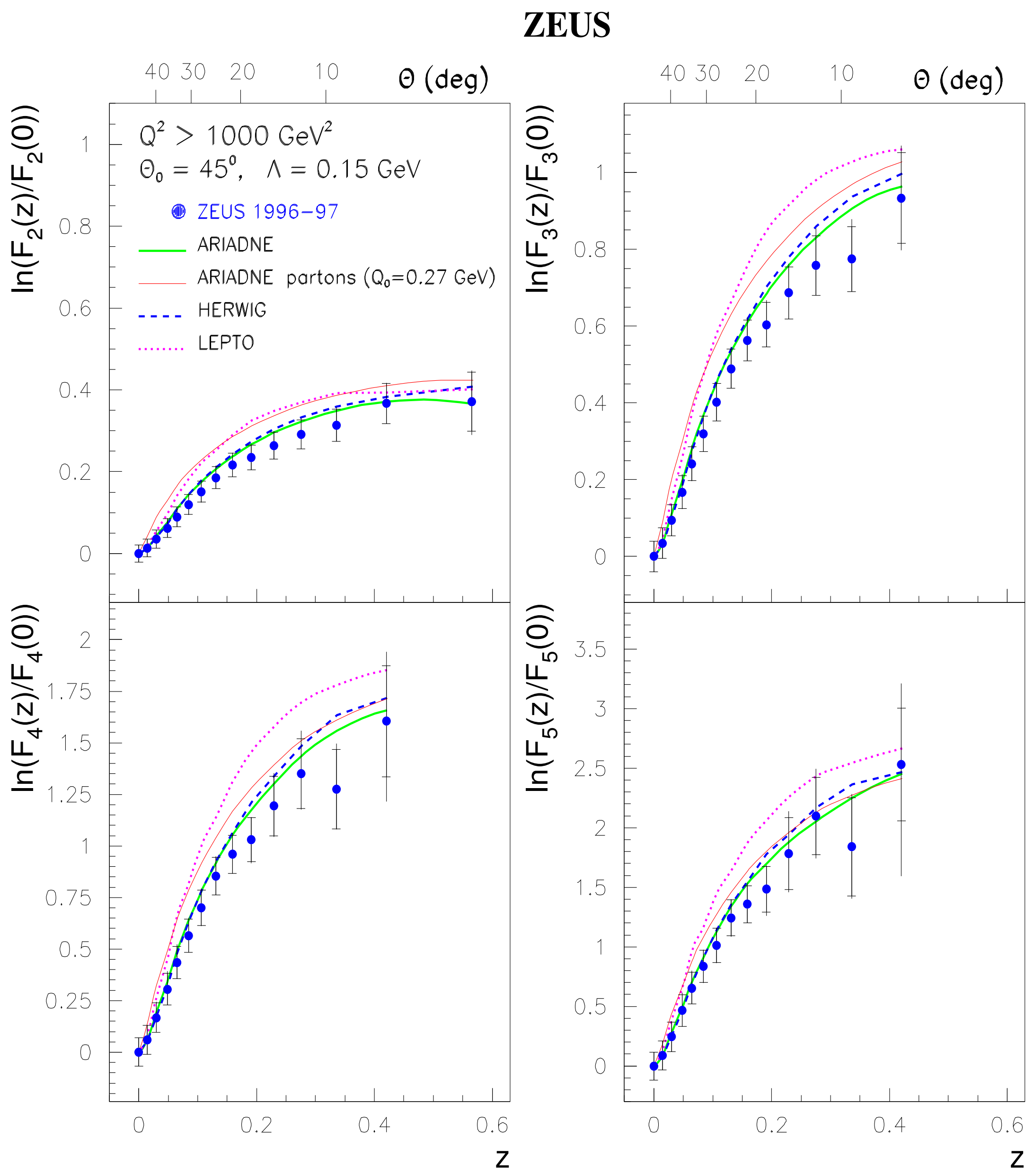
  number of partons close to number of hadrons.

Angular moments and DLLA predictions



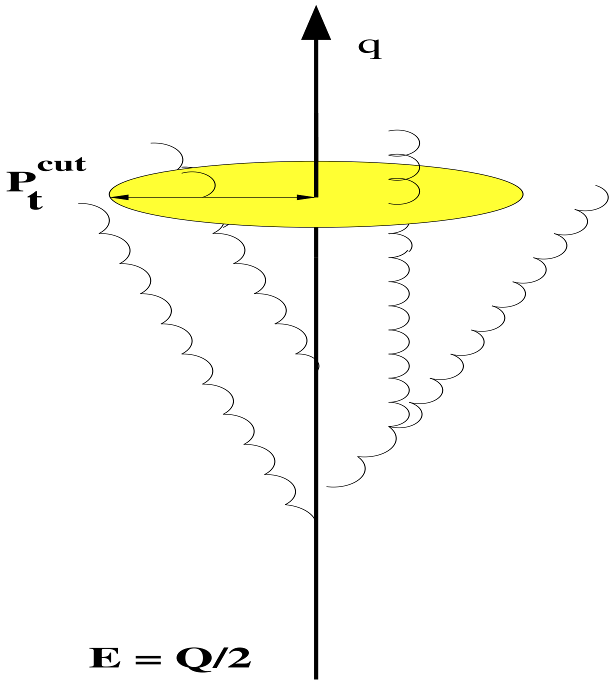
- Significant disagreement with data
- An improvement for higher order of moments

Angular moments and Monte Carlo



- Ariadne partons represents LPHD - well describes the trends
- MC models reproduce the trends
- Hadron and parton level closer to data for higher order moments
  $\rightarrow$ Is LPHD correct for fluctuations?

p_t^{cut} Moments



$P_n(p_t < p_t^{cut})$
is the probability to find **n gluons**
with $p_t < p_t^{cut}$

Factorial moments:

$$F_q(p_t < p_t^{cut}) =< n >^{-q} \sum_{n=q}^{\infty} \frac{n!}{(n-q)!} P_n(p_t^{cut})$$

n is the number of gluons with $p_t < p_t^{cut}$

Experimental definition:

$$F_q(p_t < p_t^{cut}) =< n >^{-q} < n(n-1) \ldots (n-q+1) >$$

n is number of hadrons with $p_t < p_t^{cut}$

DLLA QCD predictions:

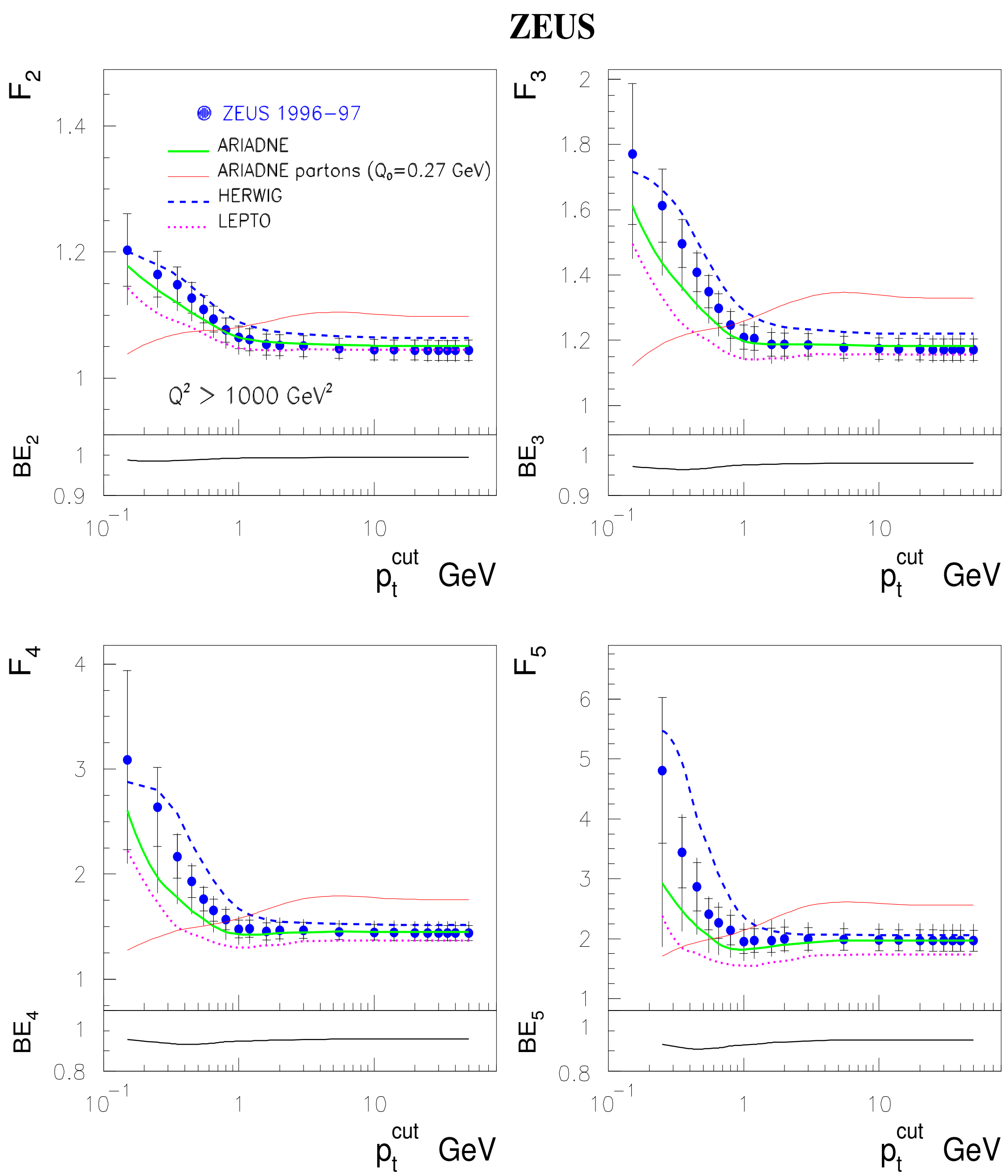
$$F_q(p_t^{cut}) \simeq 1 + \frac{q(q-1)}{6} \frac{\ln(p_t^{cut}/Q_0)}{\ln(E/Q_0)}$$

$$F_q(p_t^{cut} \to Q_0) \to 1 \text{ (Poisson statistics)}$$

Coherence of the soft gluons radiation and angular ordering

S. Lupia, W.Ochs, J. Wosiek, Nucl. Phys. B540 (1999) 405

p_t^{cut} Moments and Predictions



- All moments rise for $p_t < 1$ GeV $\rightarrow$ opposite to analytic QCD!
- MC models for hadrons show similar trends.
- Parton level MC shows opposite trend consistent with analytic QCD.
- First evidence of qualitative discrepancy with LPHD!

Conclusions:

- Moments in restricted phase space regions disagree with analytic QCD+LPHD calculations:
  - angular moments: $\rightarrow$ quantitative differences,
  - p_t^{cut} moments: $\rightarrow$ opposite trends.

Do we reach for the first time the limit of applicability of LPHD in multiplicity fluctuations studies?

- Is this related to simplifications in DLLA ?
  - possibly for angular moments:
    1. agreement better for MLLA corrections
    2. good agreement for parton level MC for higher order moments

  MLLA calculations would be very useful.

  - not for p_t^{cut} moments:
    1. reasonable agreement with hadron level
    2. discrepancies with parton level
    3. possible explanation of MC studies: dynamics of hadronization
  - similar conclusions for p^{cut} moments:

hep-ex/0104036