Analysis of the charged particle multiplicity distribution in Z decays at LEP with the L3 detector

Dominique Mangeol

University of Nijmegen/NIKHEF
The Netherlands

On behalf of the L3 collaboration

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Introduction

The multiplicity distribution of the hadronic final states contains information about the dynamics of the interaction

Analytical QCD calculations describing the shape of parton distributions in terms of correlation functions are available

$\Longrightarrow$ brought to the hadronic final states under the assumption of the Local Parton-Hadron Duality (LPHD).
LPHD claims the shape of the parton distribution is not altered by the hadronization phase

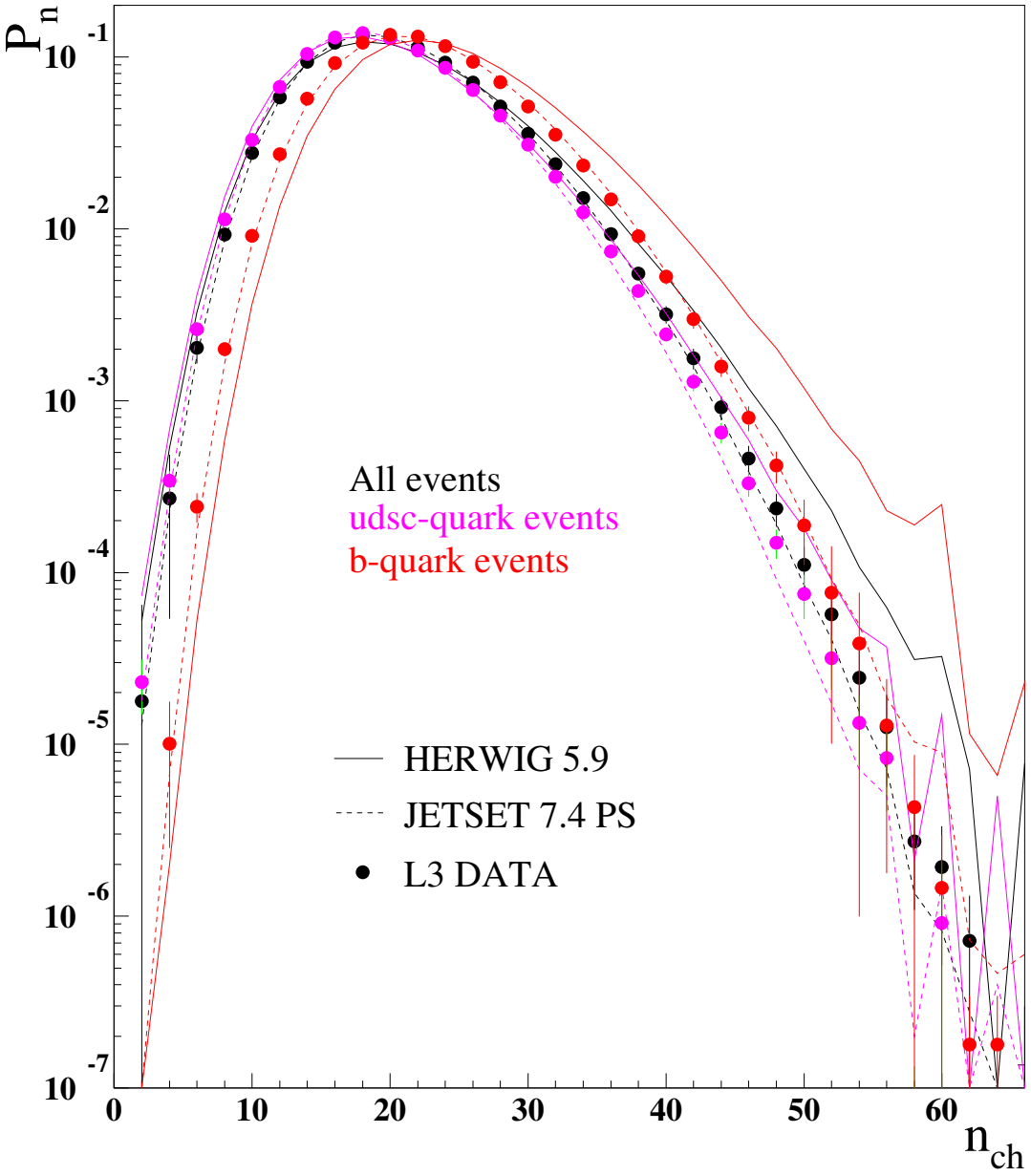
Predictions tested using the charged-particle multiplicity distributions (CPMD) of $e^+e^- \longrightarrow$ hadrons recorded in 1994 at LEP by the L3 experiment:

- For all events
- For tagged light(udsc)-quark events
  $\Longrightarrow$ Analytical QCD assumes massless quarks
- For tagged b-quark events
  $\Longrightarrow$ enable a check of the influence of heavy quark mass effect

Predictions also tested using jet multiplicity distributions obtained from the charged-particle multiplicity distribution, at various energy resolution

$\Longrightarrow$ Reduces the dependence on the LPHD assumption.
Allows a direct comparison with perturbative QCD calculation.

Charged-particle multiplicities



F_q, K_q, H_q moments

- Normalized factorial moment F_q

$$F_q = \frac{\sum_{n=q}^{\infty} n(n-1)....(n-q+1)P_n}{\left(\sum_{n=1}^{\infty} nP_n\right)^q}$$

P_n the normalized multiplicity distribution

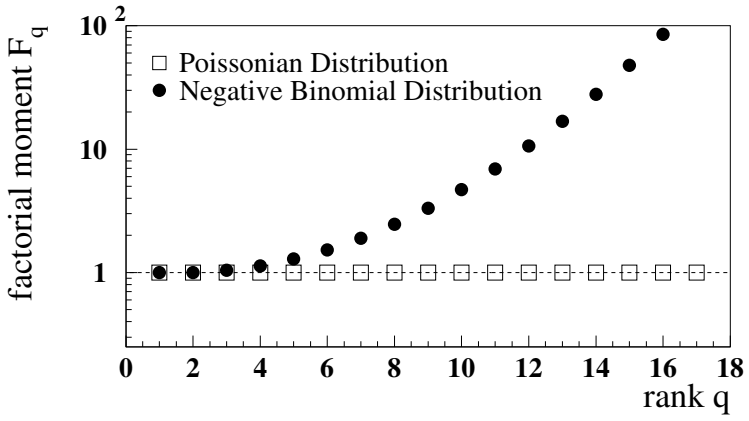
$\Longrightarrow$ F_q show the correlations in the multiplicity distribution

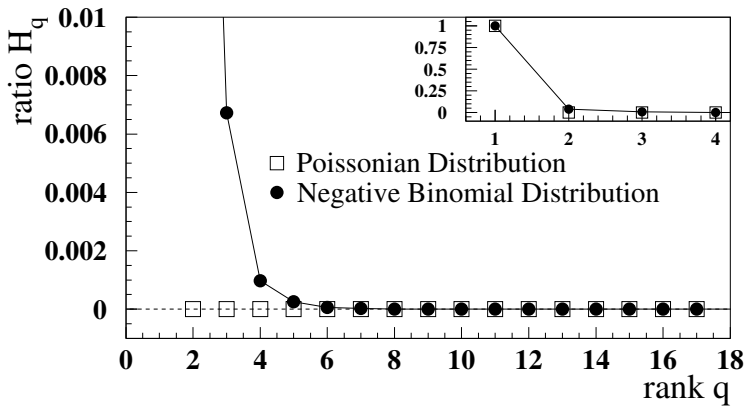
- Normalized cumulant factorial moment K_q

$$K_q = F_q - \sum_{m=1}^{q-1} \frac{(q-1)!}{m!(q-m-1)!} K_{q-m} F_m$$

$\Longrightarrow$ K_q show the genuine correlation functions of q order

- Ratio of cumulant to factorial moment $H_q = \frac{K_q}{F_q}$





QCD analytic predictions

- DLLA (Double Leading Logarithm Approximation)

  H_q decreases as q^{-2}

- MLLA (Modified Leading Logarithm Approximation)

  H_q has a first negative minimum for $q \approx 5$

  and increases slowly to 0 for $q > 5$

- NLLA (Next to Leading Logarithm Approximation)

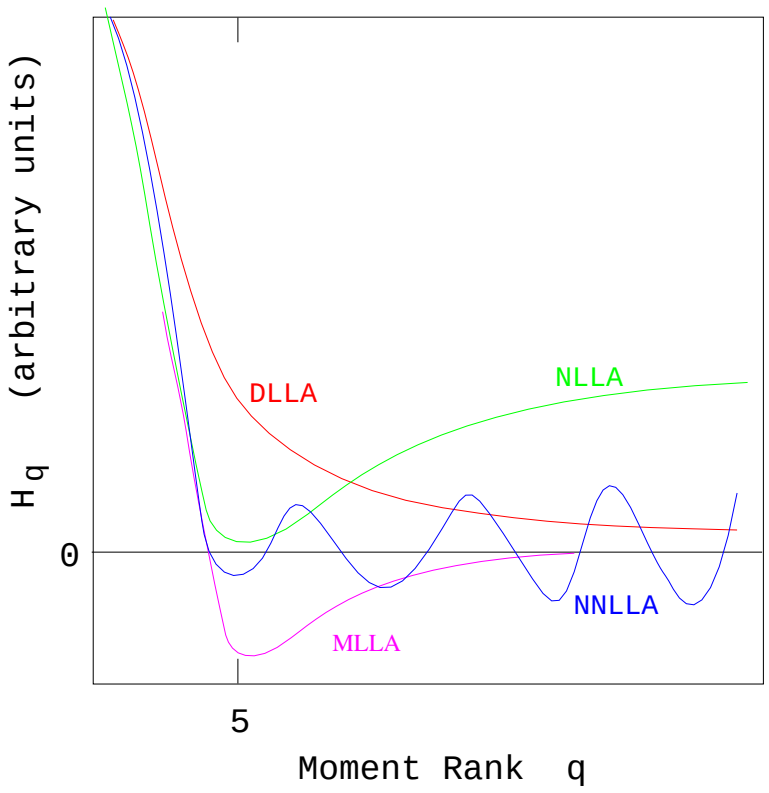
  H_q has a first negative minimum for $q \approx 5$

  a positive constant value for $q \gg 5$

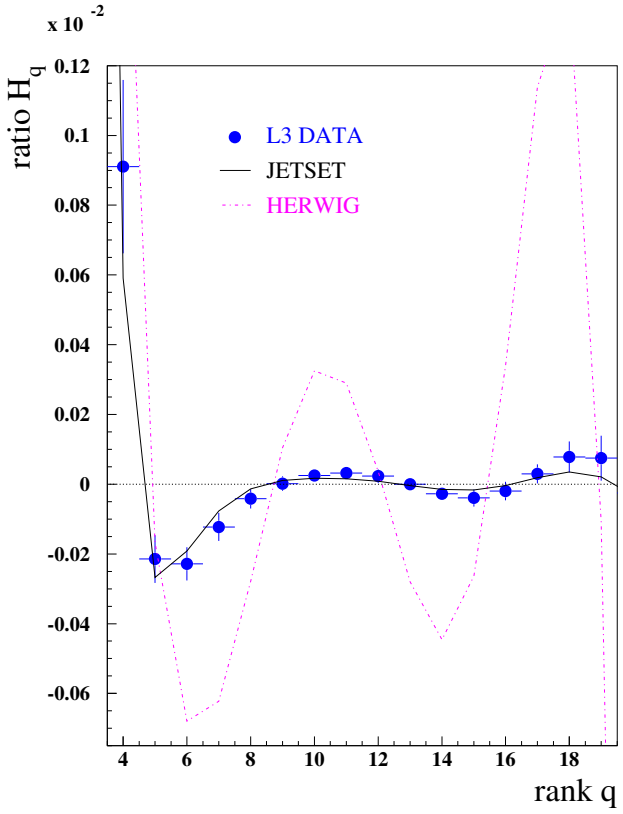
- NNLLA (Next to Next Leading Logarithm Approximation)

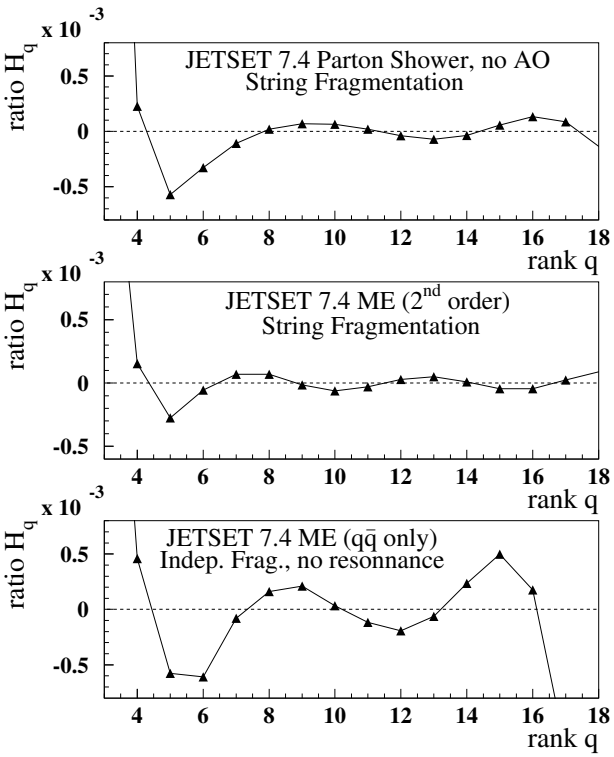
  H_q has a first negative minimum for $q \approx 5$

  quasi-oscillations about 0 for $q > 5$



H_q for the charged multiplicity





$\Longrightarrow$ "NNLLA behaviour" seen in L3 data

also good agreement with JETSET 7.4 PS and qualitative agreement with HERWIG 5.9

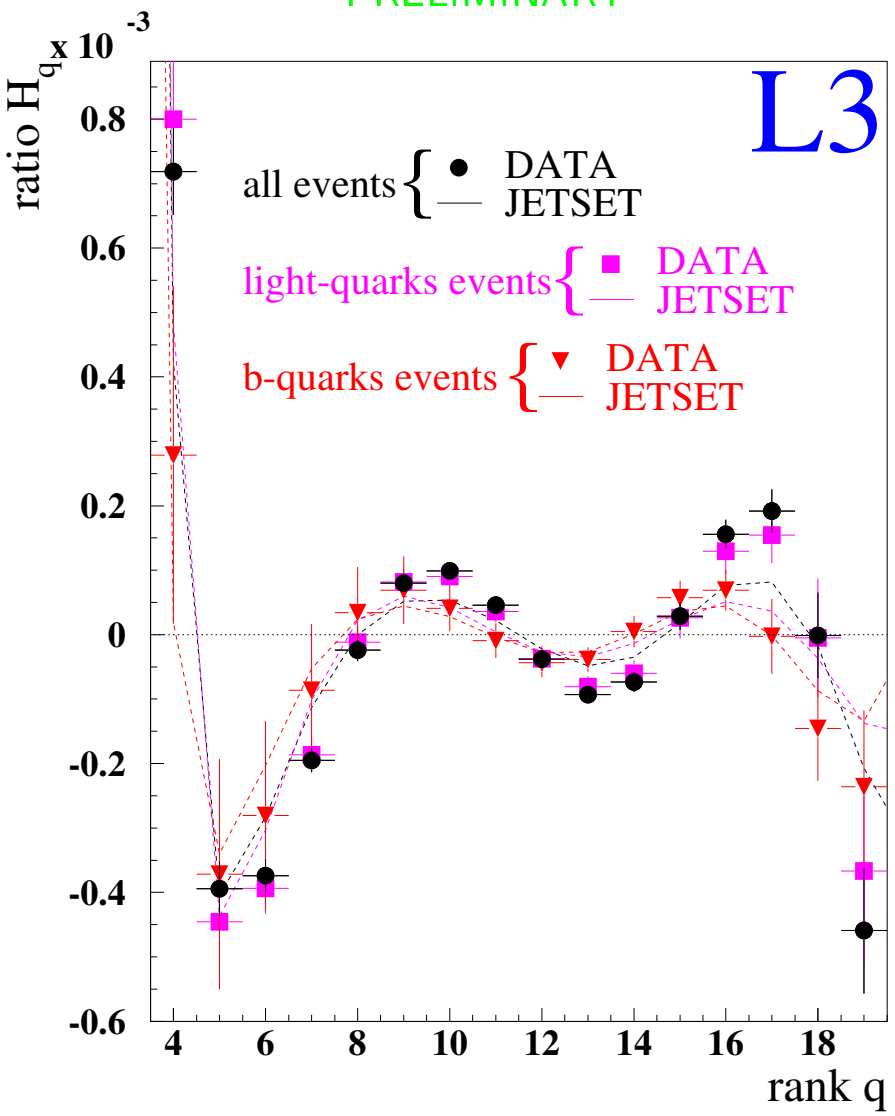
- JETSET PS and HERWIG generates partons using coherent parton showers ($\approx$ MLLA) with full energy momentum conservation
- Using various parton generations as different as:
  - No Angular Ordering parton shower($\approx$ LLA)
  - Matrix Elements:
    - $2^{\rm nd}$ order in α_s
    - $1^{\rm rst}$ order in α_s
    - $q\bar{q}$ only

    $\Longrightarrow$ The H_q oscillatory behaviour remains !!!

But energy momentum conservation is fully taken into account by Monte Carlo generator, but not by analytical QCD calculations

H_q for tagged events CPMD's

PRELIMINARY

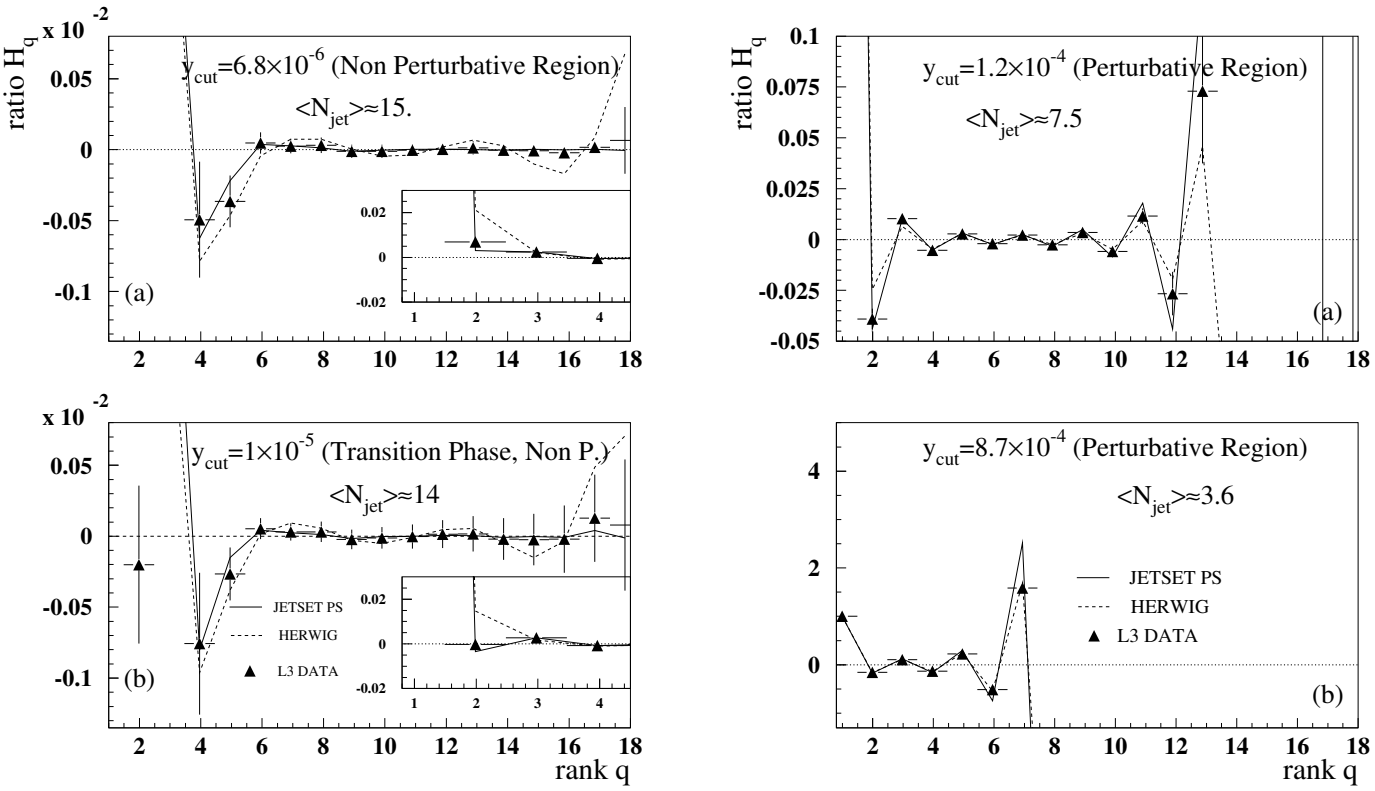


- Overall good agreement between the data and JETSET 7.4 PS
- light-quarks events have same characterics as for all events
- b-quarks events still have oscillations !!!
  Heavy-quark mass effect does not have any influence on the H_q behaviour.
  Major difference seen only for $q < 5$.

H_q for jet multiplicities

- Jet multiplicity is assumed to be related to the parton multiplicity at the energy scale of the jet resolution
- Using the Cambridge jet algorithm, destructive effects induced by hadronization are corrected

$\Longrightarrow$ Enables direct comparison with pQCD predictions
for $E_{\rm jet} \gtrsim 1$ GeV $\Longleftrightarrow$ $y_{\rm cut} \gtrsim 1.2 \times 10^{-4}$



Good agreement between data and Monte Carlo models
But No oscillation seen in the perturbative region
Oscillation and first negative minimum appear far away
from the perturbative region

Conclusions

- The H_q measured from charged particle multiplicity show the behaviour expected by NNLLA calculation, but JETSET using a coherent parton shower close to MLLA shows same behaviour
  - Almost same behaviour seen for all events, light-quarks and even b-quarks which are unlikely to be described by the LPHD.

- H_q behaviour reproduced by Monte Carlo models independently of the pQCD order used to generate partons and of the fragmentation model used.

  $\Longrightarrow$ Could be explained by full energy momentum conservation implemented in Monte Carlo models.

- none of the pQCD calculations describe the H_q obtained from jet multiplicities obtained at perturbative energy scales

  $\Longrightarrow$ The H_q behaviour unlikely to be related to pQCD.