Oscillating H_q,

Event Shapes

and

QCD

W. J. Metzger

(D. J. Mangeol, W. Kittel, W. J. Metzger, R. Smits)

University of Nijmegen

XXIX International Symposium
on
Multiparticle Dyanmics

11 Aug. 1999

Charged Particle Multiplicity

Multiplicity distribution, P_n is often analysed in terms of factorial and cumulant moments:

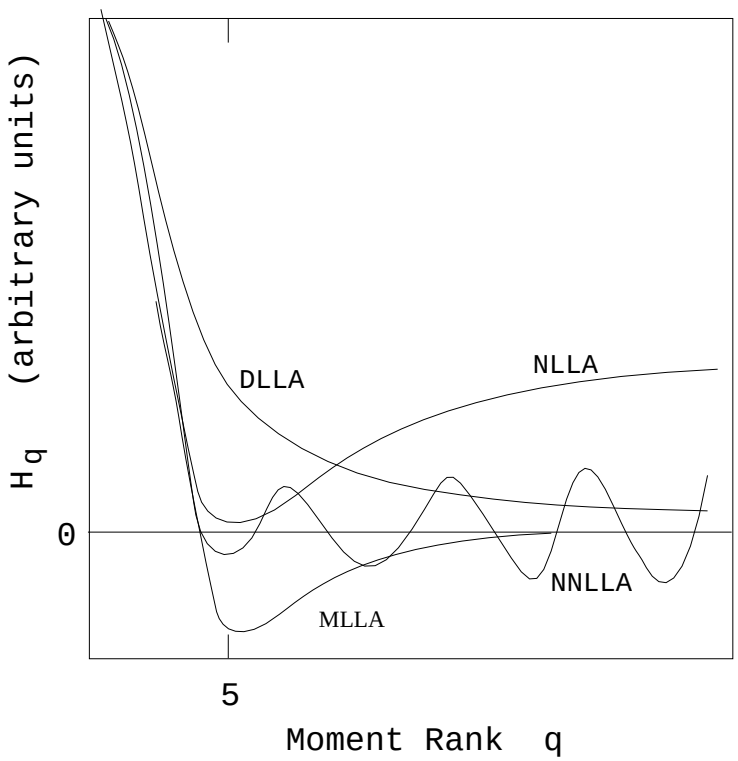
$$F_q = \frac{\sum_{n=q}^{\infty} \frac{n!}{(n-q)!} P_n}{\left(\sum_{n=1}^{\infty} n\, P_n\right)^q}$$

$$K_q = F_q - \sum_{m=1}^{q-1} \binom{q-1}{m} K_{q-m} F_m$$

and their ratio $H_q = \frac{K_q}{F_q}$

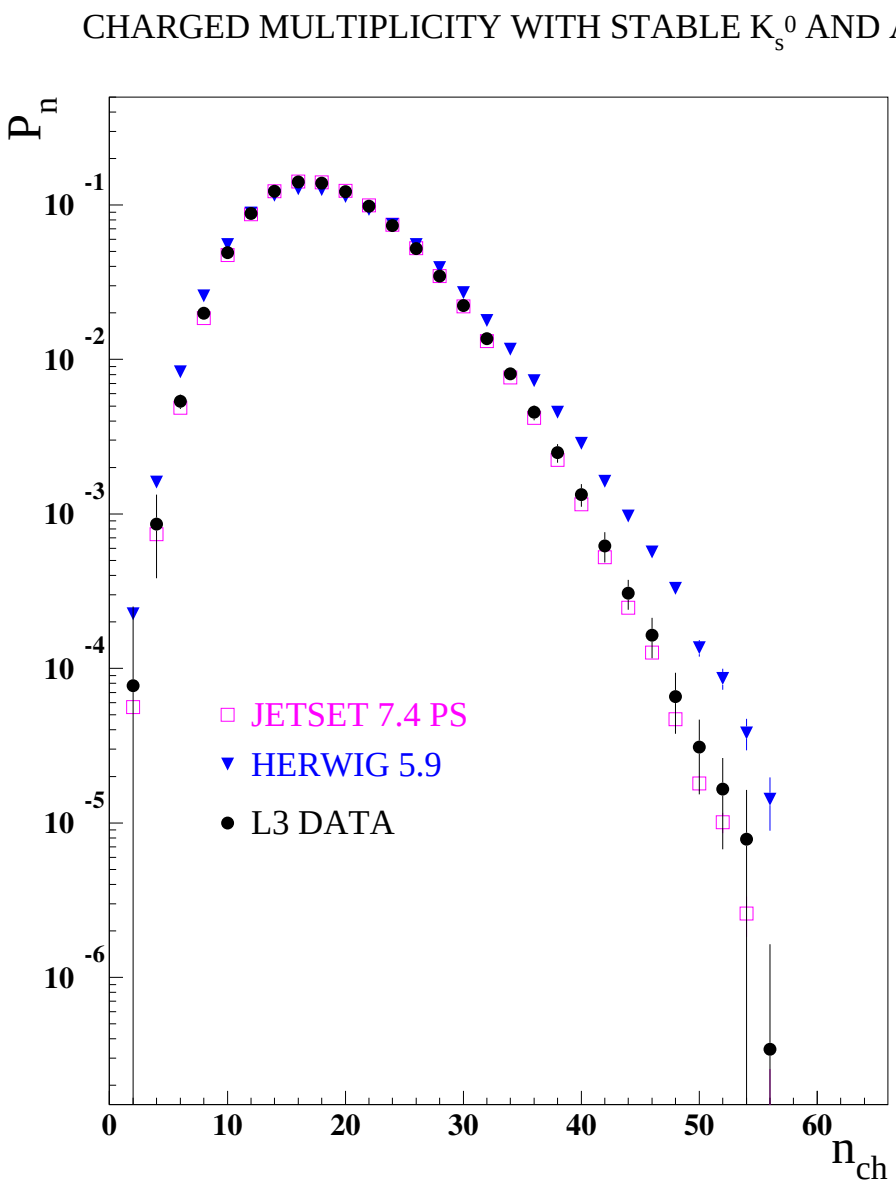
- H_q are calculable in pQCD
- assuming LPHD, can compare with H_q for charged particles

SLD observed the behaviour predicted by NNLLA,
i.e., min. + oscillations
(P.L. B371 (1996) 149)



Multiplicity Distribution

• L3 prefers not to include K^0,Λ decay products
Unfold the mult. dist. using iterative Bayesian method with a detector response matrix determined from MC
Use 2 MCs: JETSET, HERWIG



HERWIG P_n is too broad

H_q

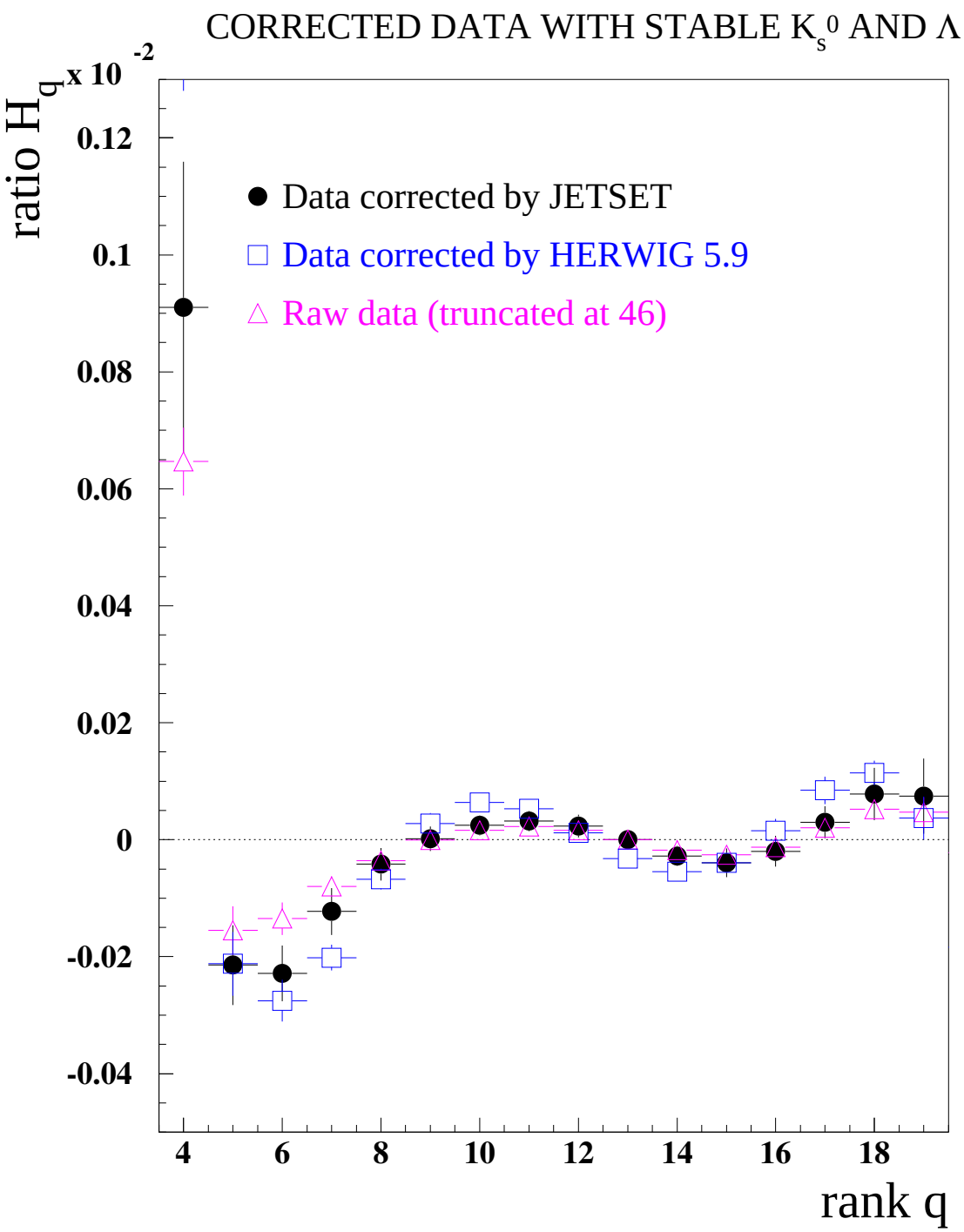
From P_n calculate H_q

- Stat. err. from propagation of covariance matrix of unfolded mult. dist.

- Syst. err. from
  - variation of selection cuts (largest)
  - JETSET/HERWIG for unfolding

- F_q is very sensitive to tails of dist.
  Truncate mult. dist. where errors become too large
  $i.e.$, events with $N_{\mathrm{ch}} > 53$ rejected

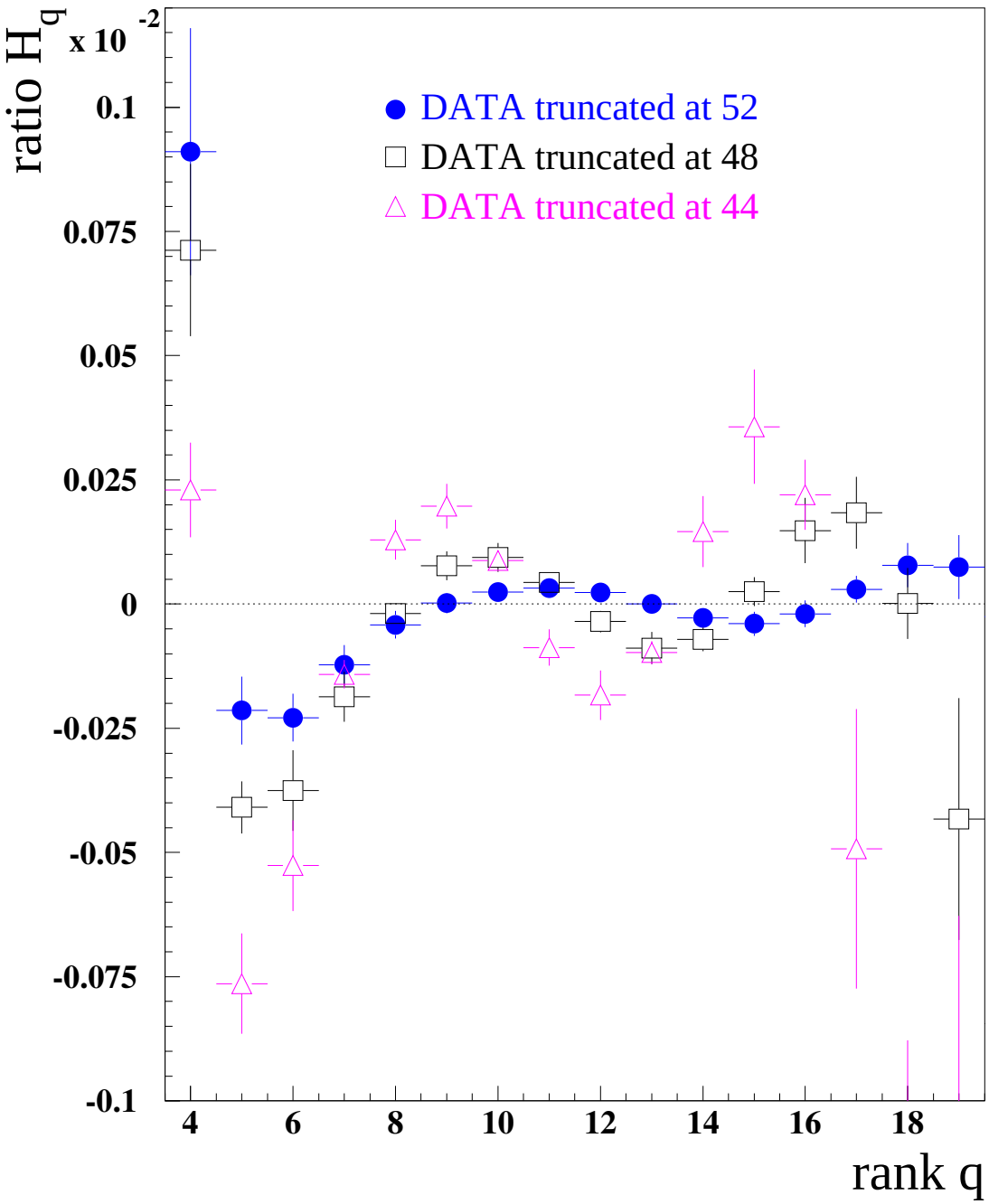
H_q L3 preliminary



H_q min. + oscillations ∼same
in raw data, data unfolded by JETSET, HERWIG
(even though generator distributions are different)

Effect of truncation

L3 preliminary



Truncation increases amplitudes

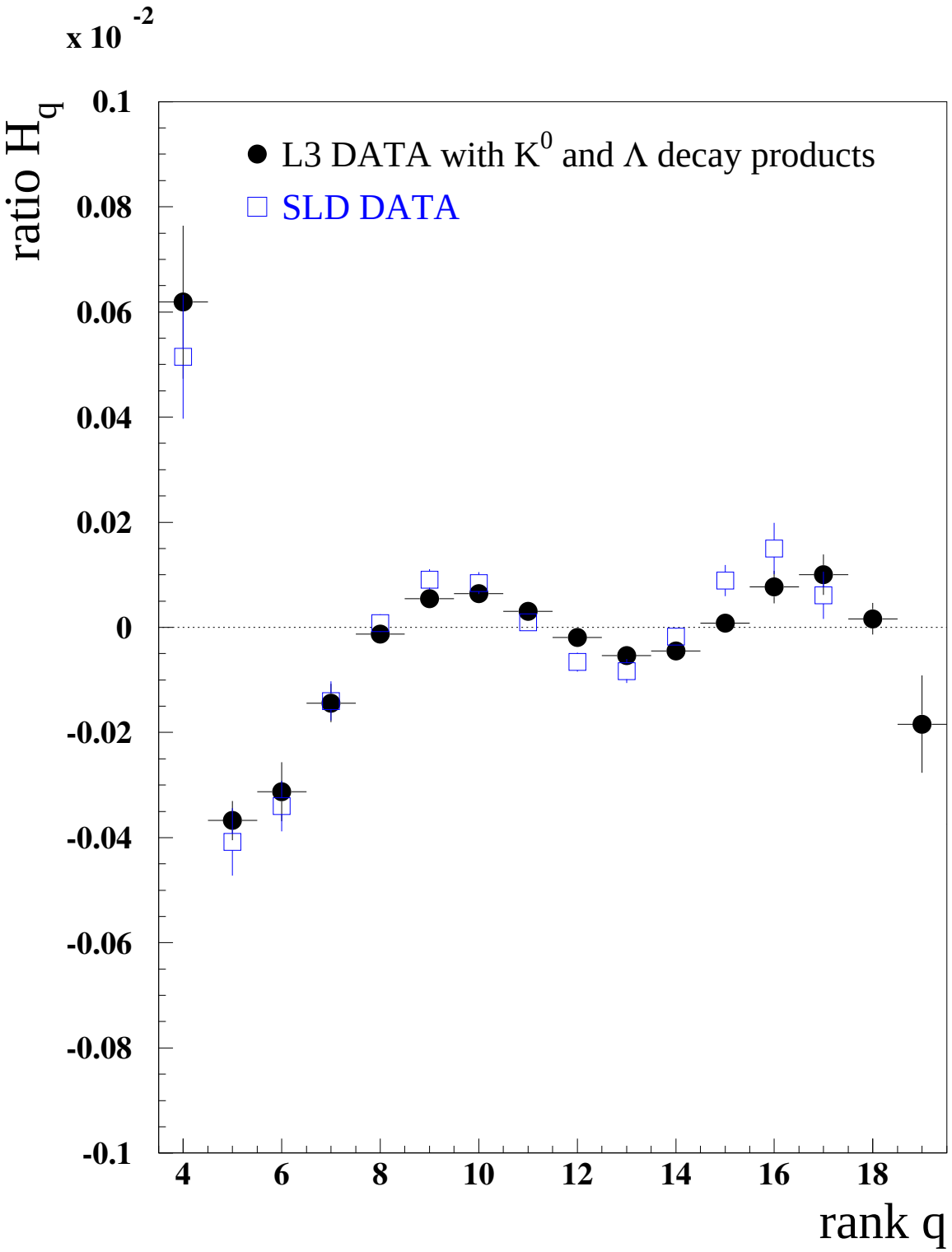
Positions of extrema shift to lower q

Period of oscillations decreases

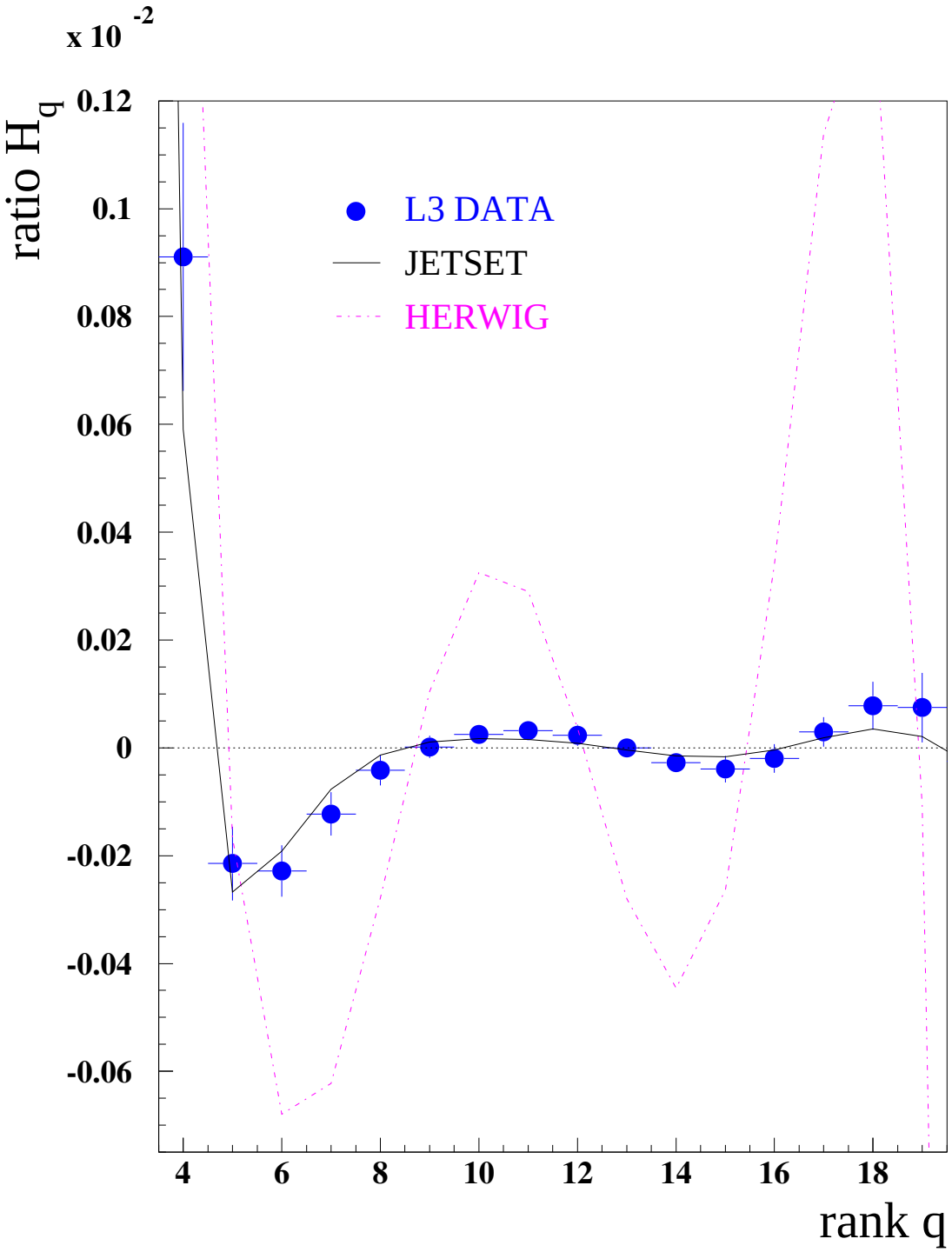
Comparison of H_q with SLD

L3 confirms the SLD result:

H_q from unfolded mult. dist. incl. K^0,Λ decay Preliminary



H_q L3 preliminary



- JETSET reproduces data
- HERWIG has min. + oscillations
  But much larger amplitude of oscillations

???

Why do MCs have oscillations?

- pQCD + LPHD has min.+osc. only at NNLLA
- MCs are only ∼MLLA

◇ Last year at Delphi (ISMD98), Dremin:
Big difference between DLA,...,NNLLA is
treatment of E-conservation.

◇ 2 years ago in Jerusalem (EPS97), Dokshitzer:
"L3 has rediscovered E-conservation"

◇ more recently, Ochs:
Ariadne parton shower to small cut-off
is similar to DLA calculation,
but with exact $E, \vec{p}$ conservation

ARIADNE without Hadronization

Lupia, Ochs, Wosiek, N.P. **B540** (1999) 405:

- 2 parameters:
  cut-off $Q_0 = 0.2\,\text{GeV}$ $\qquad\qquad$ $\lambda = \ln \frac{Q_0}{\Lambda} = 0.015$
- $(\Lambda = 0.197\,\text{GeV})$
- no hadronization
- $N_{\text{parton}} = \frac{3}{2} N_{\text{ch}}$

	Partons	OPAL
$< N >$	30.2	30.3 ± 0.6
F_2^{hemi}	1.09	1.082 ± 0.005
F_3^{hemi}	1.30	1.28 ± 0.02
F_4^{hemi}	1.68	1.64 ± 0.05

Remarkably good agreement

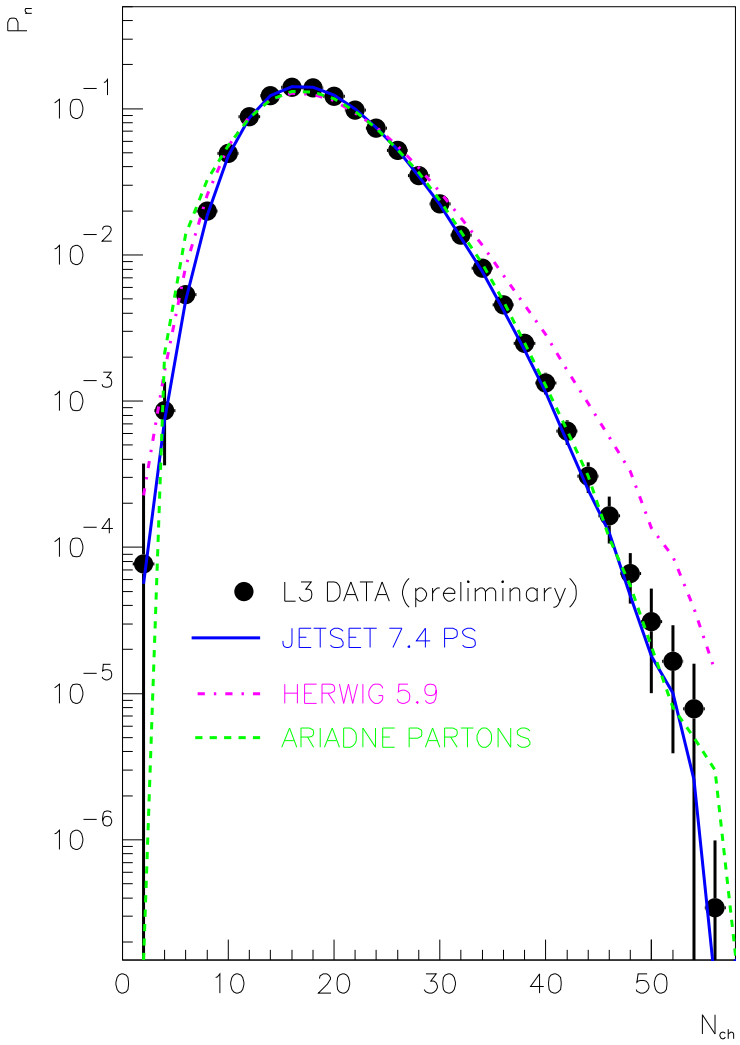
ARIADNE without Hadronization

L3 does not include K^0,Λ decay products in N_{ch}

Mult. dist.
$N_{ch} = \frac{2}{3} N_{parton}$
rounded to even number

best described with

Λ=0.388 GeV
Q_0=0.38801GeV

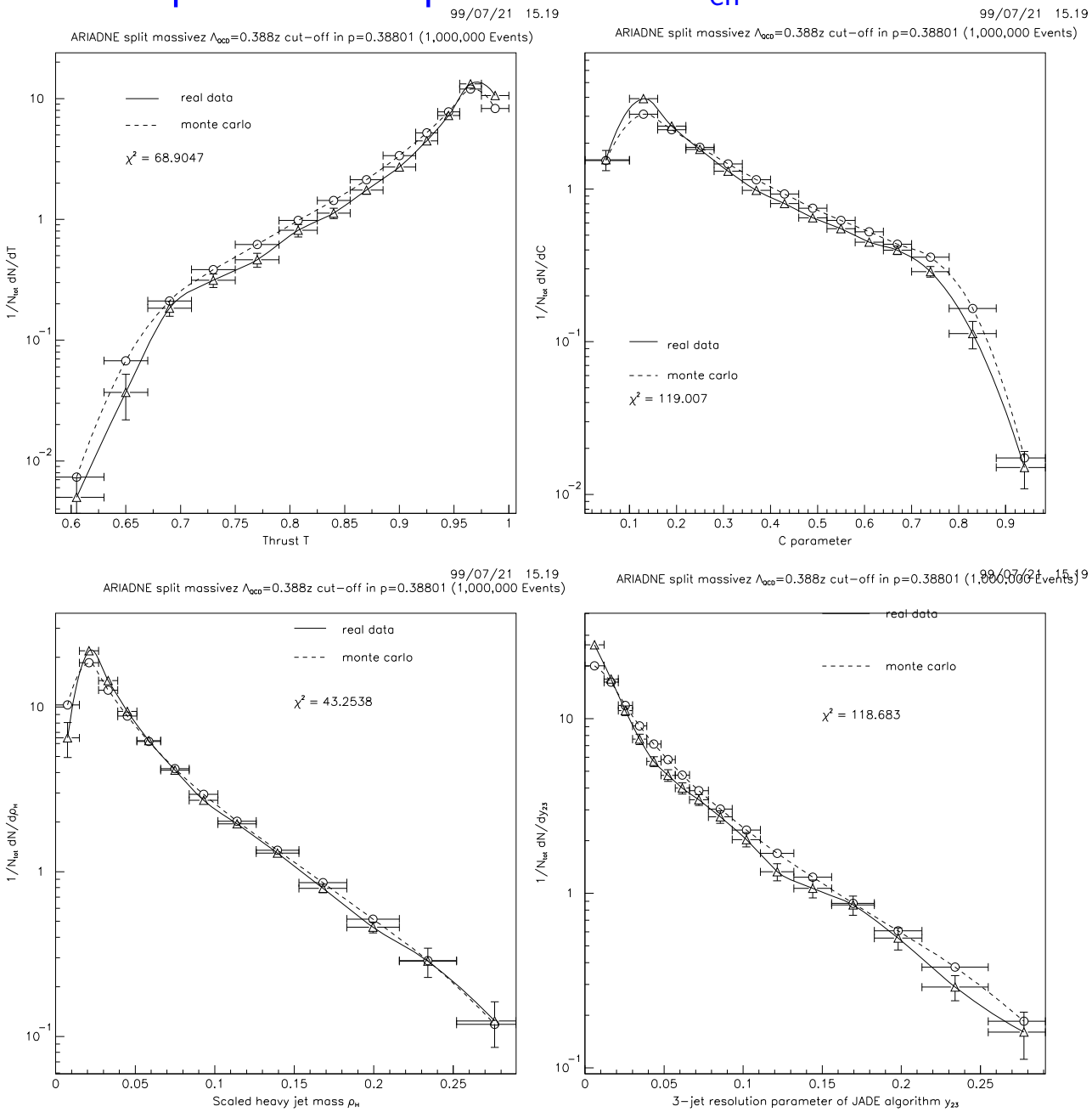


	Partons	L3
$< N_{ch} >$	18.5	18.65 ± 0.12
$< N_{ch}^2 >$	379	383 ± 5
$< N_{ch}^3 >$	8527	8559 ± 200
Dispersion	6.2	5.9 ± 0.1
$< N_{ch} > / D$	2.97	3.16 ± 0.04
skewness	0.47	0.60 ± 0.02
kurtosis	0.25	0.51 ± 0.06

Reasonable ... worse agreement

Shape variables

ARIADNE parameters optimized for N_{ch}

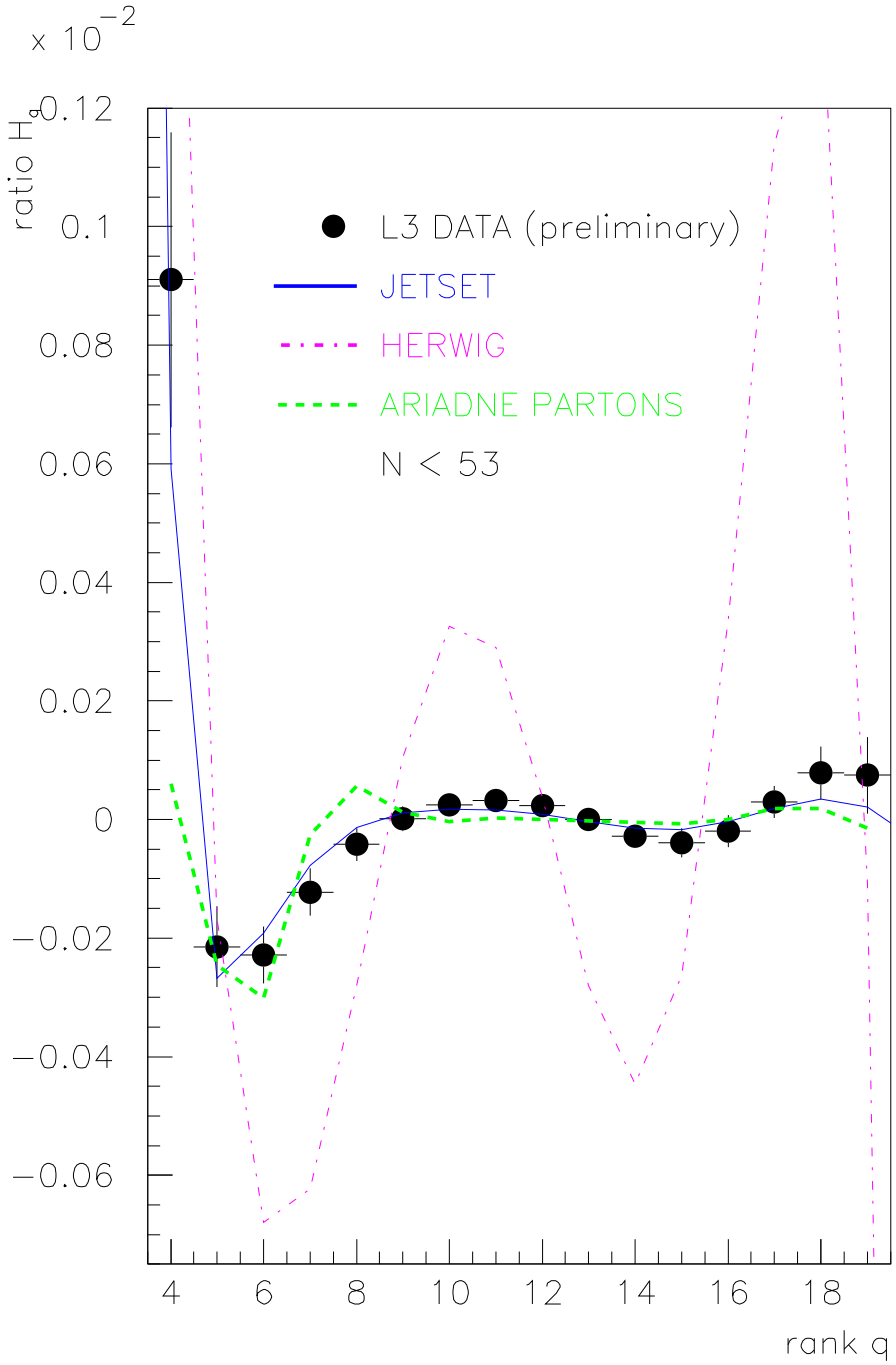


Ariadne partons qualitatively reproduce shape variables

Agreement better if use different Λ for each variable

But JETSET agrees much better Z. Phys. **C55**(1992)39

H_q L3 preliminary



- JETSET reproduces data
- HERWIG has much larger amplitude
- ARIADNE partons has min. + oscillations
  But somewhat different from data

Analytical QCD + LPHD or MC models

- QCD calculations are for partons, not particles

- to compare with data, must rely on
  - assumptions like LPHD
  - models like string fragmentation in JETSET

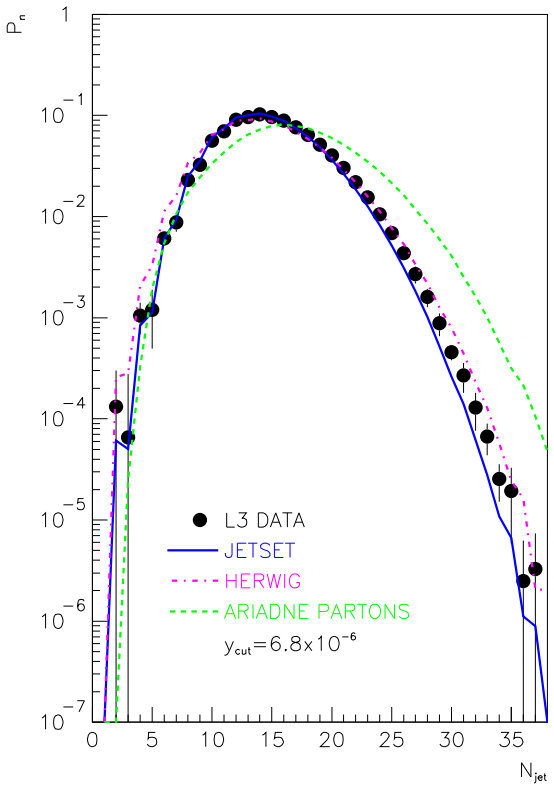
- So you do not really know if you are testing
  - QCD calculations
  - or hadronisation model
  - or hadronisation assumptions (LPHD)

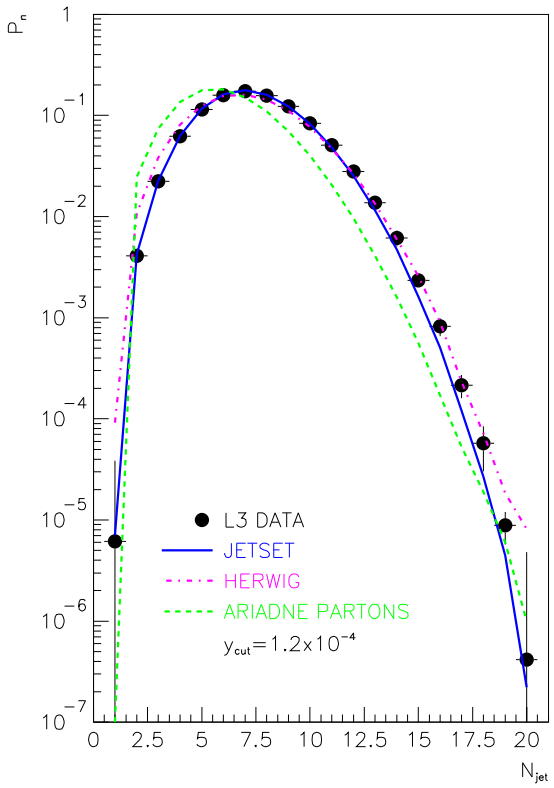
◇ Are the oscillations we see a
confirmation of NNLLA pQCD
or not ???

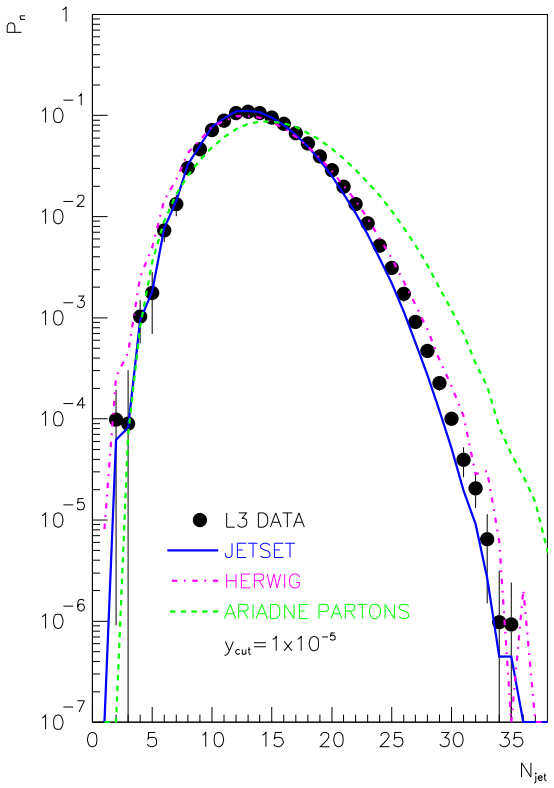
◇ Oscillations in MCs is suspicious
– their parton showers are only ∼MLLA, not NNLLA

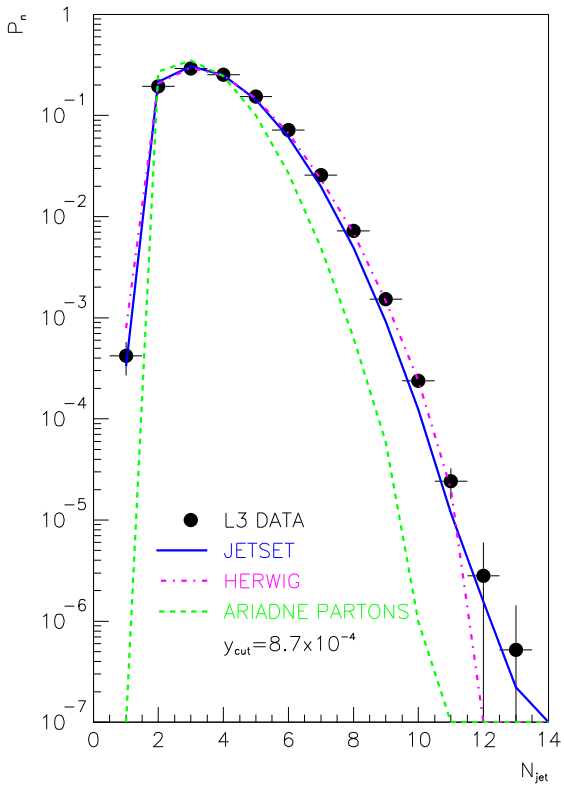
◇ Try to get away from LPHD and hadronisation models
by using jet multiplicity (at different scales)
instead of particle multiplicity.

Jet (Cambridge) Multiplicity L3 preliminary









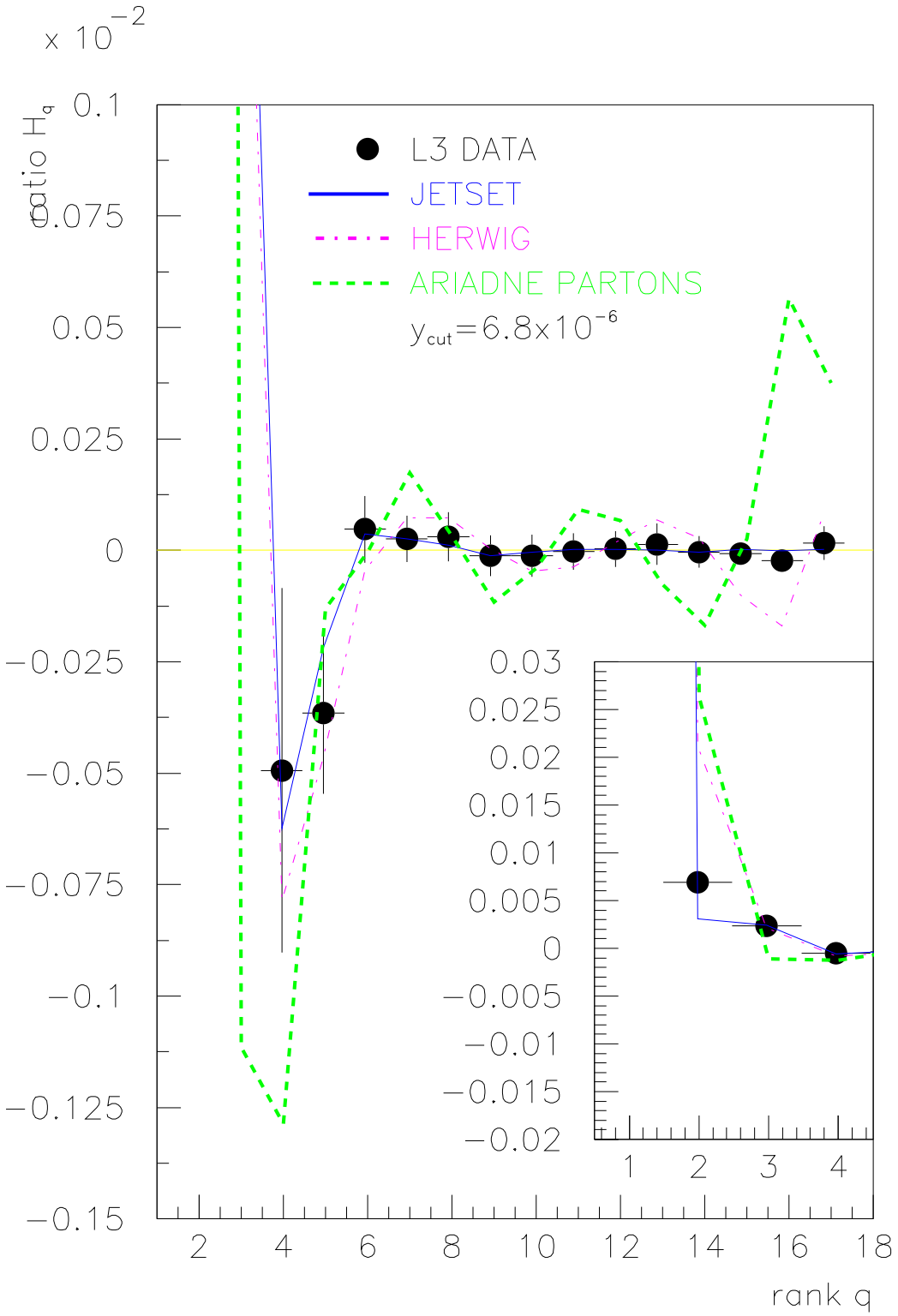
JETSET, HERWIG agree

ARIADNE disagrees

H_q from Jet (Cambridge) Multiplicity

$y_{\text{cut}} = 6.8 \times 10^{-6}$ (240 MeV)

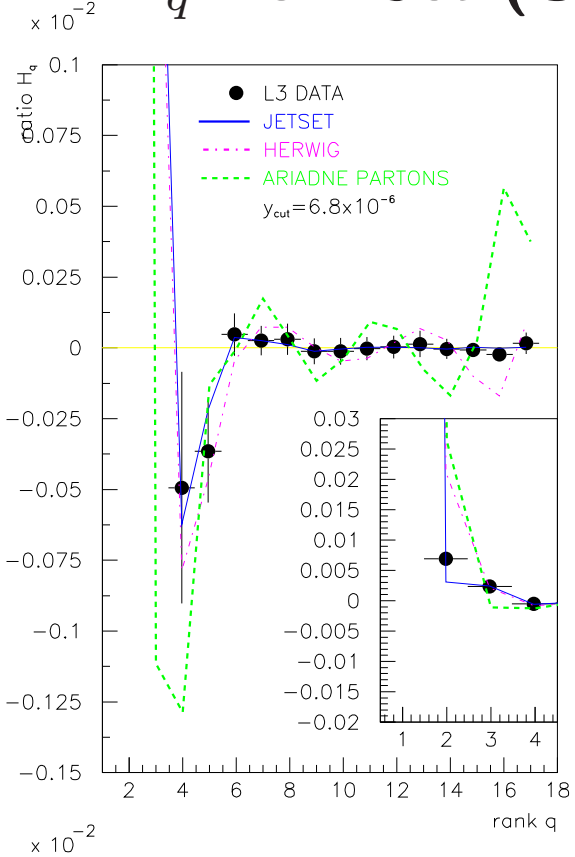
L3 preliminary

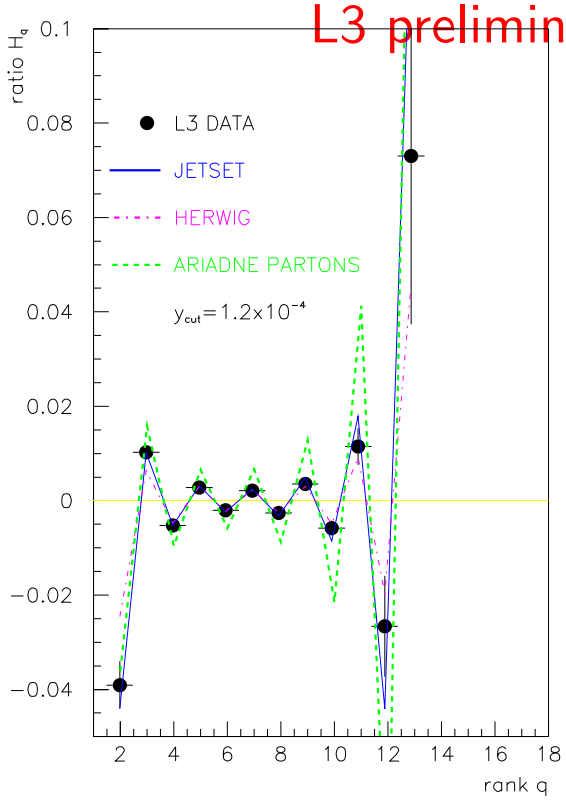


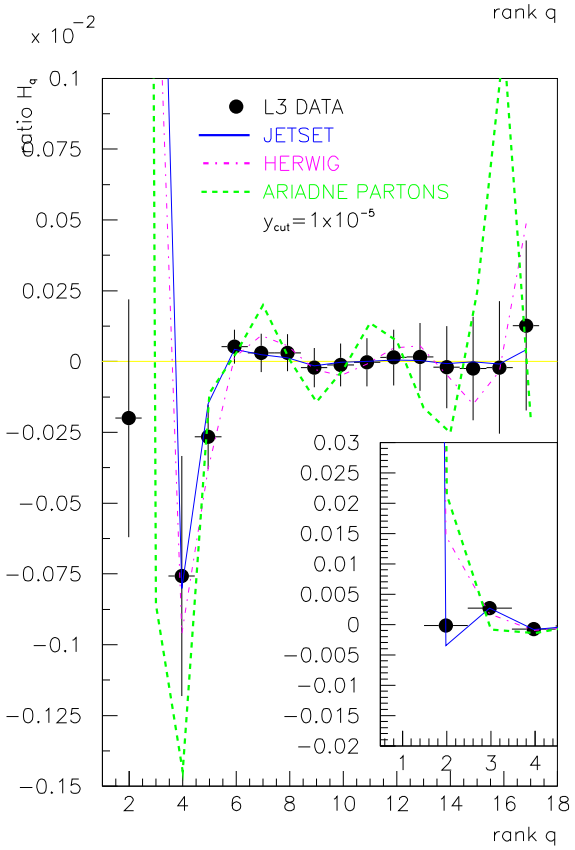
Minimum + oscillations for 'jets' at very small scale

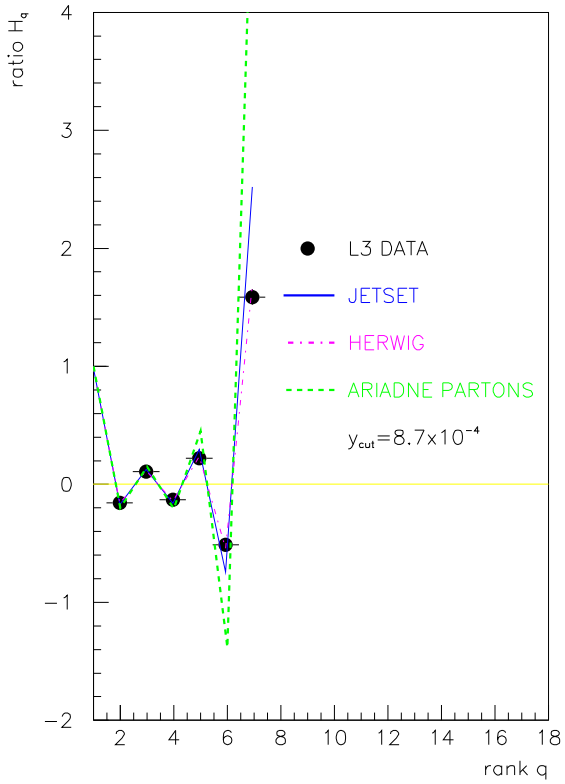
H_q from Jet (Cambridge) Multiplicity

L3 preliminary









As y_{cut} (E scale) increases, min. + oscillations disappear long before pert. region

Summary

- Charged Track Multiplicities:
  - L3 confirms H_q min. + oscillations observed by SLD
  - JETSET parton shower + Lund string hadronization agrees with data
  - HERWIG parton shower + cluster hadronization shows min. + oscillations, but much larger amplitudes
  - ARIADNE parton shower + LPHD shows min. + oscillations, but different from data

- Oscillations in MCs is puzzling since MCs are only ∼MLLA, not NNLLA

- Jet Multiplicities:
  - H_q min. + oscillations disappear as $y_{\text{cut}} \rightarrow$ pert. scales

- Event shapes:
  - ARIADNE partons agree qualitatively with data.
  - JETSET agrees much better.

Conclusions

- JETSET + string, decays gives very good description
  ARIADNE + string, decays also – see last year's talk
- ARIADNE + LPHD gives qualitatively fair description for tracks, but not for jets
- Min.+oscillations are not solely due to pert. QCD.
- Non-pert. hadronisation plays a strong role.
- The contribution from pert. QCD is largely due to E,$\vec{p}$ conservation.

for transparencies:

`http://home.cern.ch/~metzger/talks.html`