QCD Coherence
Correlations of particles with restricted momentum at LEP

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Correlations of particles with restricted momenta

(OPAL Preliminary Note OPAL-PN528, July 2005)

Motivation: Test perturbative QCD coherence effects and Local Parton-Hadron Duality (LPHD) hypothesis

⇨ Multiplicity distributions (MD) characterized by normalized factorial moments:

$$F_q(\Omega) = \langle n(n-1)....(n-q+1)\rangle / \langle n^q \rangle = \frac{\int_\Omega \rho_q(p_1,...,p_q)\prod_{i=1}^{q} d^3 p_i}{\left(\int_\Omega dp\,\rho_1(p)\right)^q}$$

where: n = multiplicity in the region Ω;
ρ_q=q-particle density

provide a sensitive tool to probe multiparticle correlations

⇨ Well-known that MD are wider than the Poisson distribution

Theory: analytical results

⇨ Study of factorial moments in restricted momentum regions[a] done in the Double Logarithmic Approximation (DLA):

- Cylindrically cut factorial moments: $F_q(p_{T,i} < p_T^{cut})$

  due to angular ordering (effect of QCD coherence), the MD becomes Poissonian for $p_T^{cut} \to Q_0$ (i.e. low p_T gluons are produced independently):

  $$\Rightarrow \mathbf{F_q \to 1} \qquad \text{for} \quad p_T^{cut} \to Q_0, \quad q > 1$$

  where: Q_0 = virtuality cut-off (~few hundred MeV)

- Spherically cut moments: $F_q(p_i < p^{cut})$

  the MD remain non-Poissonian even for small values of p^{cut}

  $$\Rightarrow \mathbf{F_q \to const > 1} \qquad \text{for} \quad p^{cut} \to 0, \quad q > 1$$

Results verified at parton level using the Monte Carlo program ARIADNE

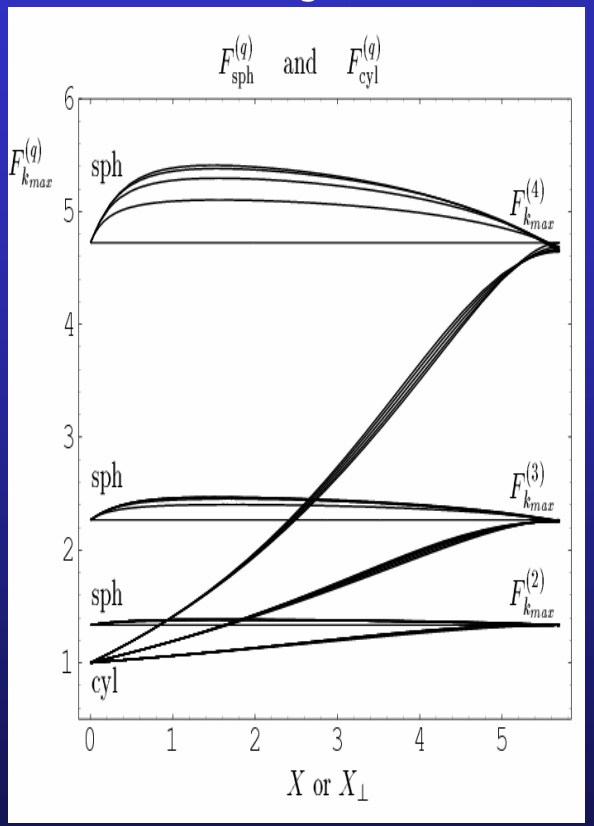
⇒ If Local Parton Hadron Duality is valid, same behavior in data

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

Analytical and MC results

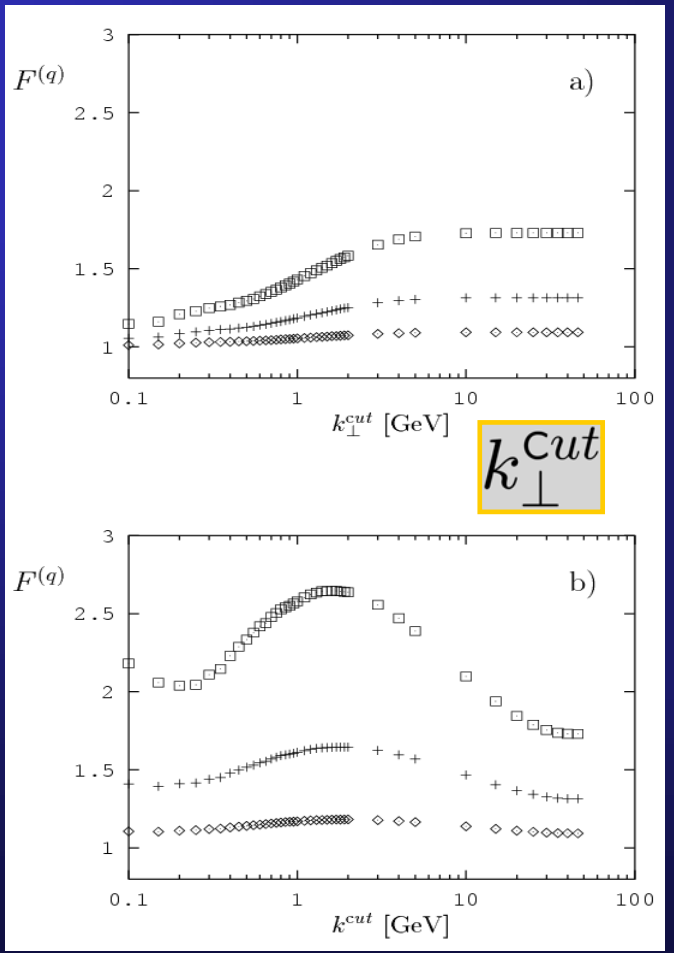
S.Lupia, W.Ochs, J.Wosiek, Nucl.Phys. B540 (1999) 405

Analytical



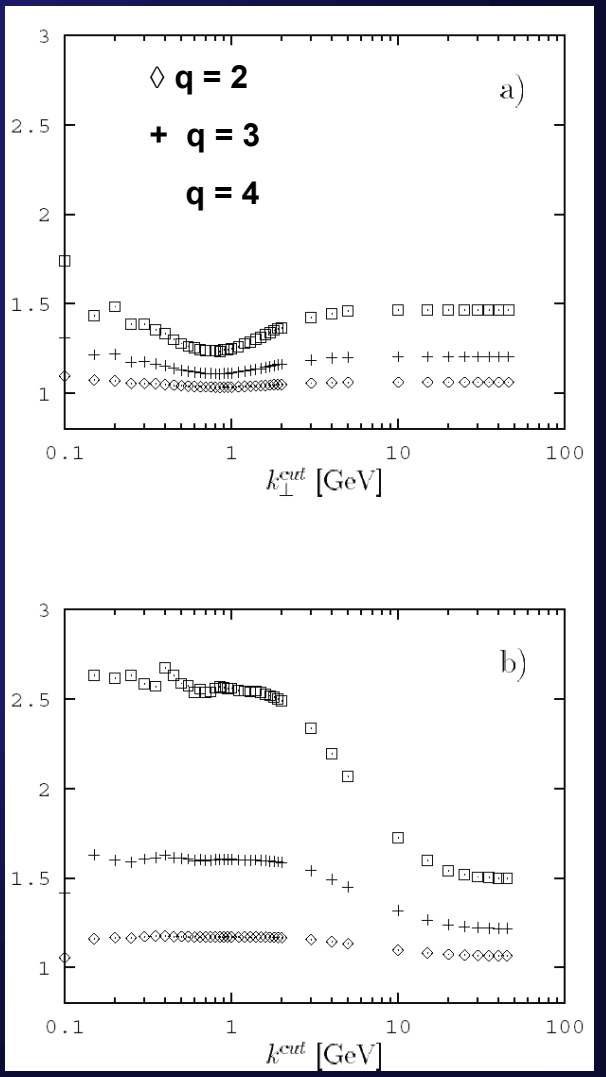
$$X_\perp = \ln \frac{k_\perp^{cut}}{Q_0}$$

MC Partons



k^{cut}

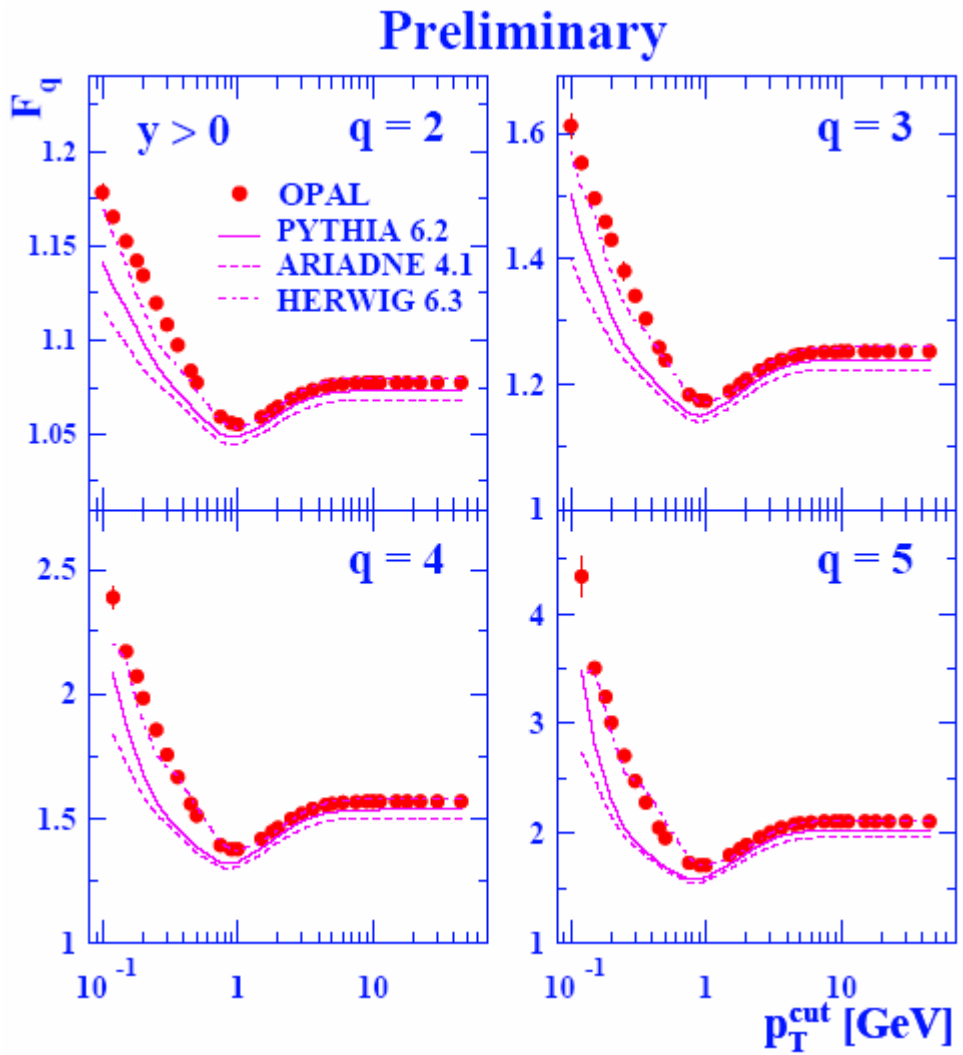
MC Hadrons



Analysis details

- ✓ Data sample: ~4M hadronic Z^0 decays collected with the OPAL detector (2.9M after cuts)
- ✓ Monte Carlo samples: Jetset/Pythia 6.2, Ariadne 4.1, Herwig 6.3
- ✓ Kinematic variables (y, p_T) defined w.r.t. thrust axis:
  - used hemisphere with $y = 0.5 \ln \frac{(E + p_{\parallel})}{(E - p_{\parallel})} > 0$
- ✓ Data corrected (detector effects,ISR,..) using bin-by-bin correction
  - correction factors from JETSET/PYTHIA

Cylindrically-cut factorial moments



No Poissonian limit observed:

$F_q \neq 1$ for $p_T^{cut} \rightarrow 0$

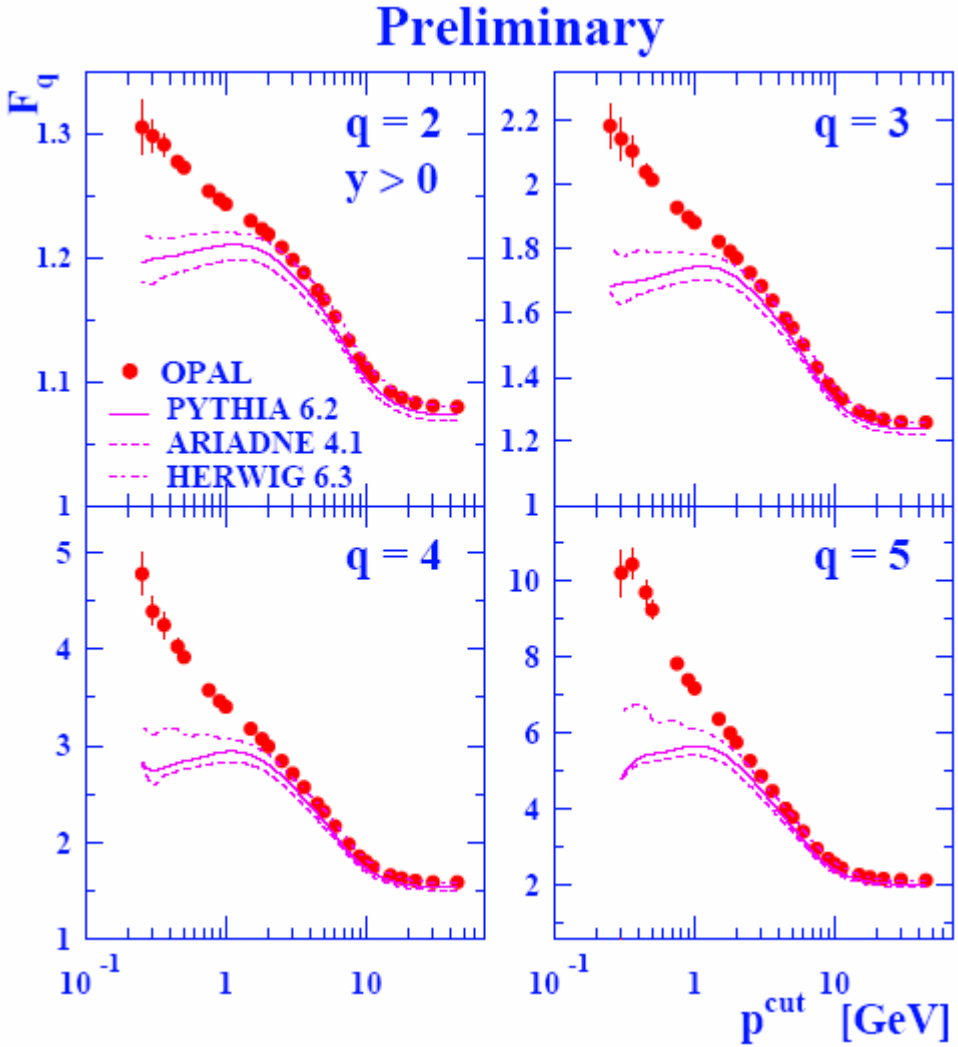
MCs follow data trend

⇨ strong hadronisation effects mask expected Poissonian behaviour but…

⇨ minimum at ≈1 GeV:

perturbative ↔ non-perturbative border-line?

Spherically-cut factorial moments

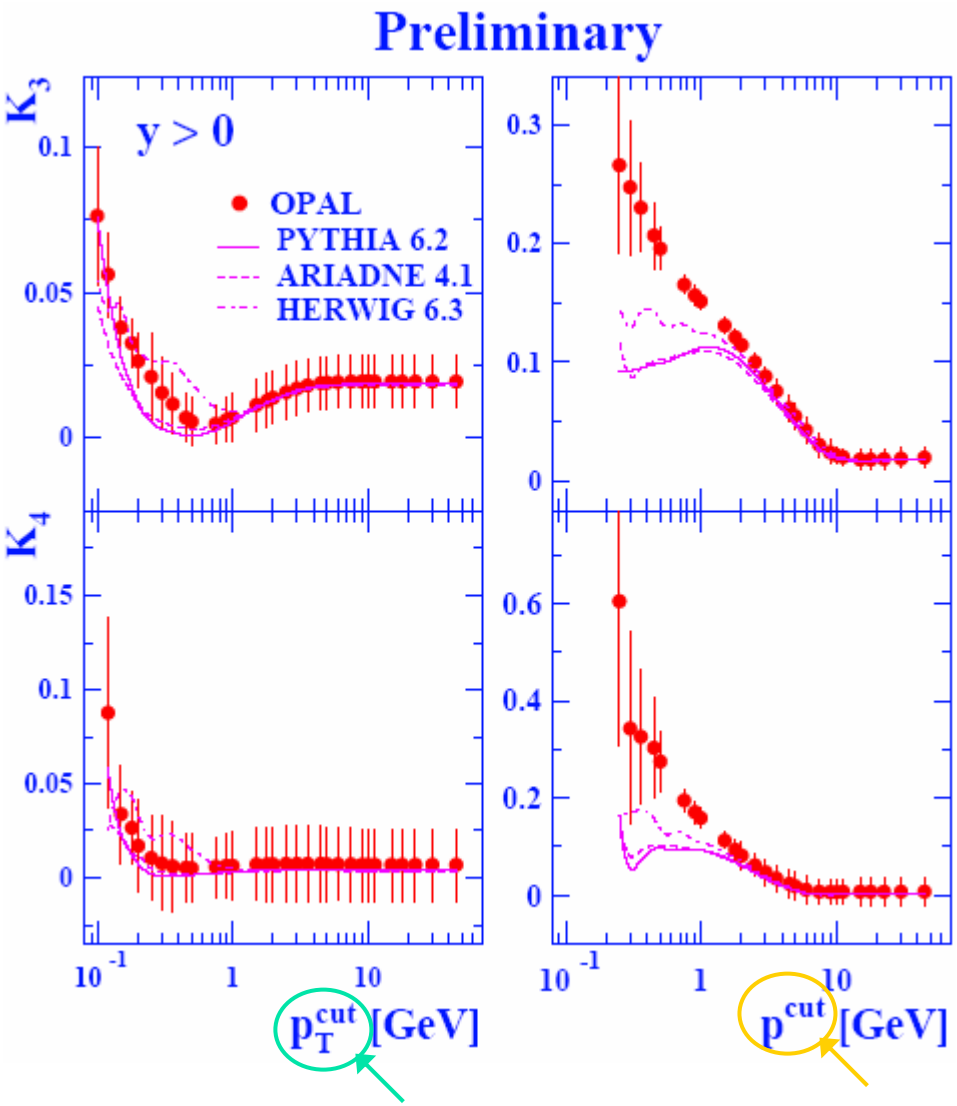


No constant value reached:

$F_q \neq \text{const} > 1$ for $p^{cut} \longrightarrow 0$

MCs don't follow data trend

Factorial cumulants K_q



Cumulants $K_q(\Omega)$

⇨ measure of genuine multiparticle correlations (more direct measurement)

⇨ for uncorrelated particle production:

$K_q=0$ for $q>1$

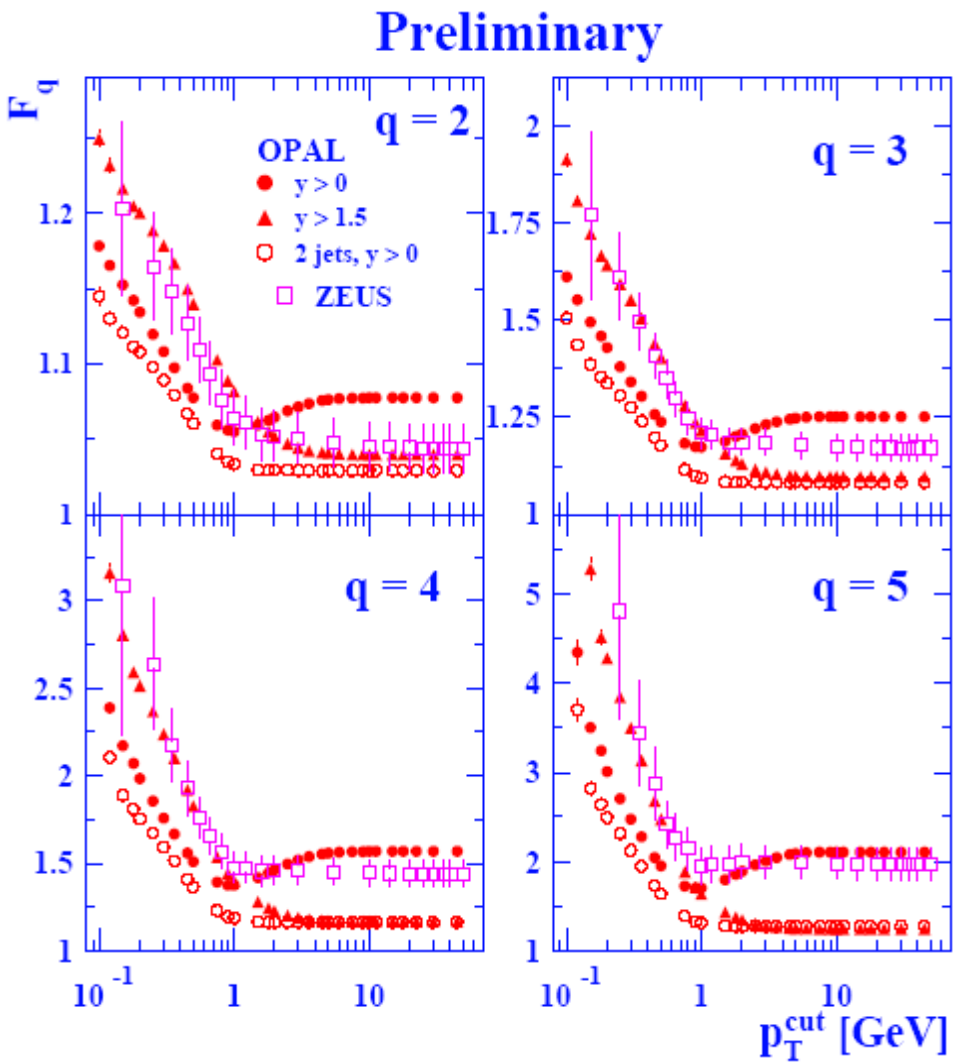
⇒ cylindrically cut: $K_q=0$ for $p_T^{cut} \rightarrow Q_0$

⇒ spherically cut: K_q= const > 0 for $p^{cut} \rightarrow 0$

Data: same behaviour as F_q

(First measurement of K_q)

Comparison to ep DIS results



ZEUS[b] measurement in e^+p collisions in current region (CR) of Breit Frame

No minimum at ≈ 1 GeV

OPAL analysis repeated:

⇨ rapidity intervals ($y>y_0\geq1$): central rapidity region largely excluded in ZEUS analysis

⇨ two-jet events ($T>0.96$): lower rate of hard jet production for ZEUS

Minimum at ~1 GeV disappears

⇒ hemisphere in e^+e^- ↔ C.R. of BRF in e^+p

misleading for soft particle production

b ZEUS Collaboration, Phys. Lett. B 510 (2001) 36

Summary

Analysis performed using 2.7M multihadronic events collected at the Z mass with the OPAL detector

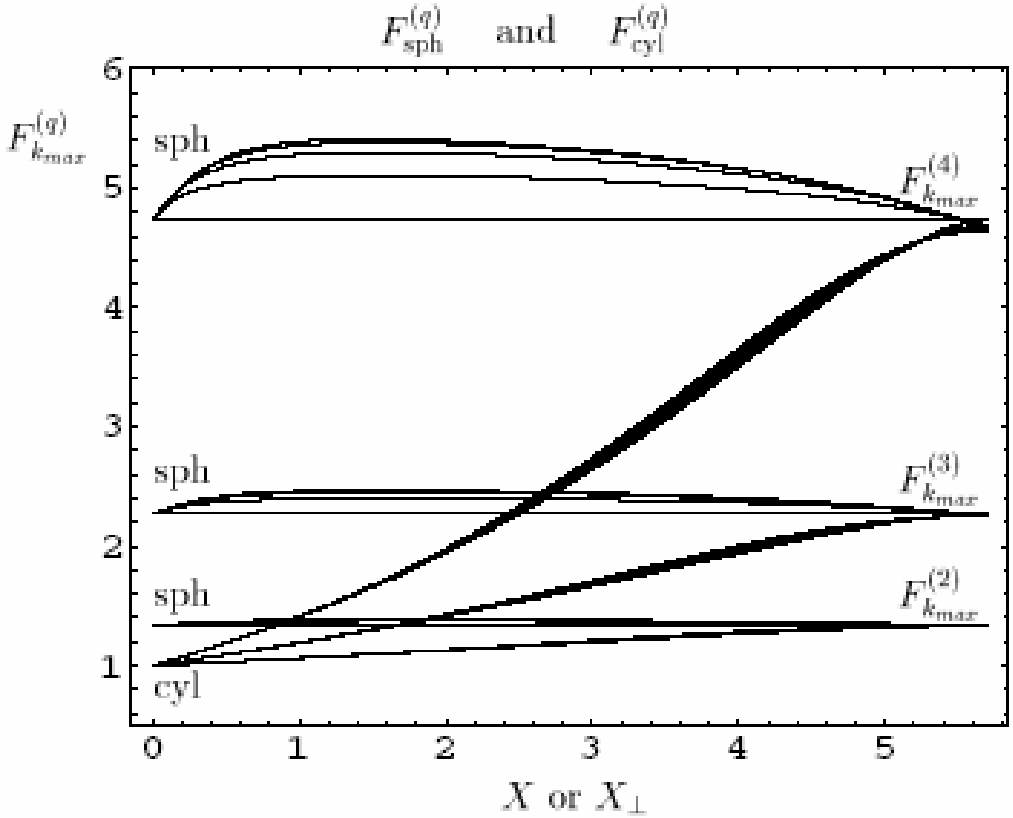
Correlations for particles with restricted p_T and p

- ⇨ minimum in $F_q(p_T^{cut})$ at ≈1 GeV: border-line between perturbative and non-perturbative region?
- ⇨ LPHD: problems with many-particle inclusive observables of soft hadrons (confirms ZEUS result)
- ⇨ first measurement of cumulants
- ⇨ Models have problems too…

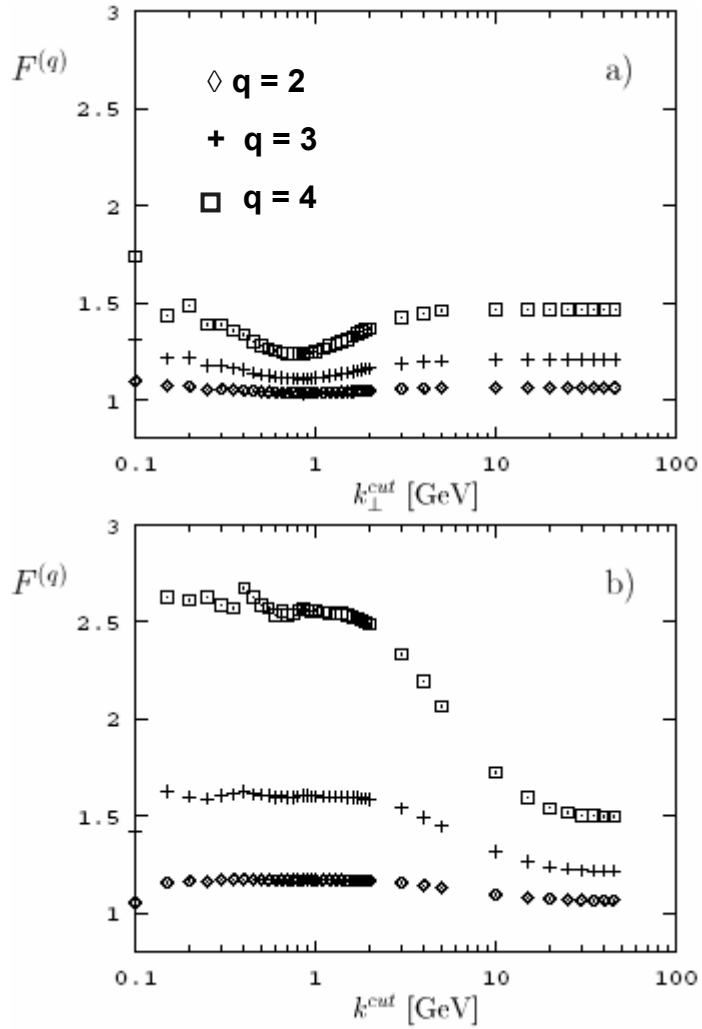
Backup slides

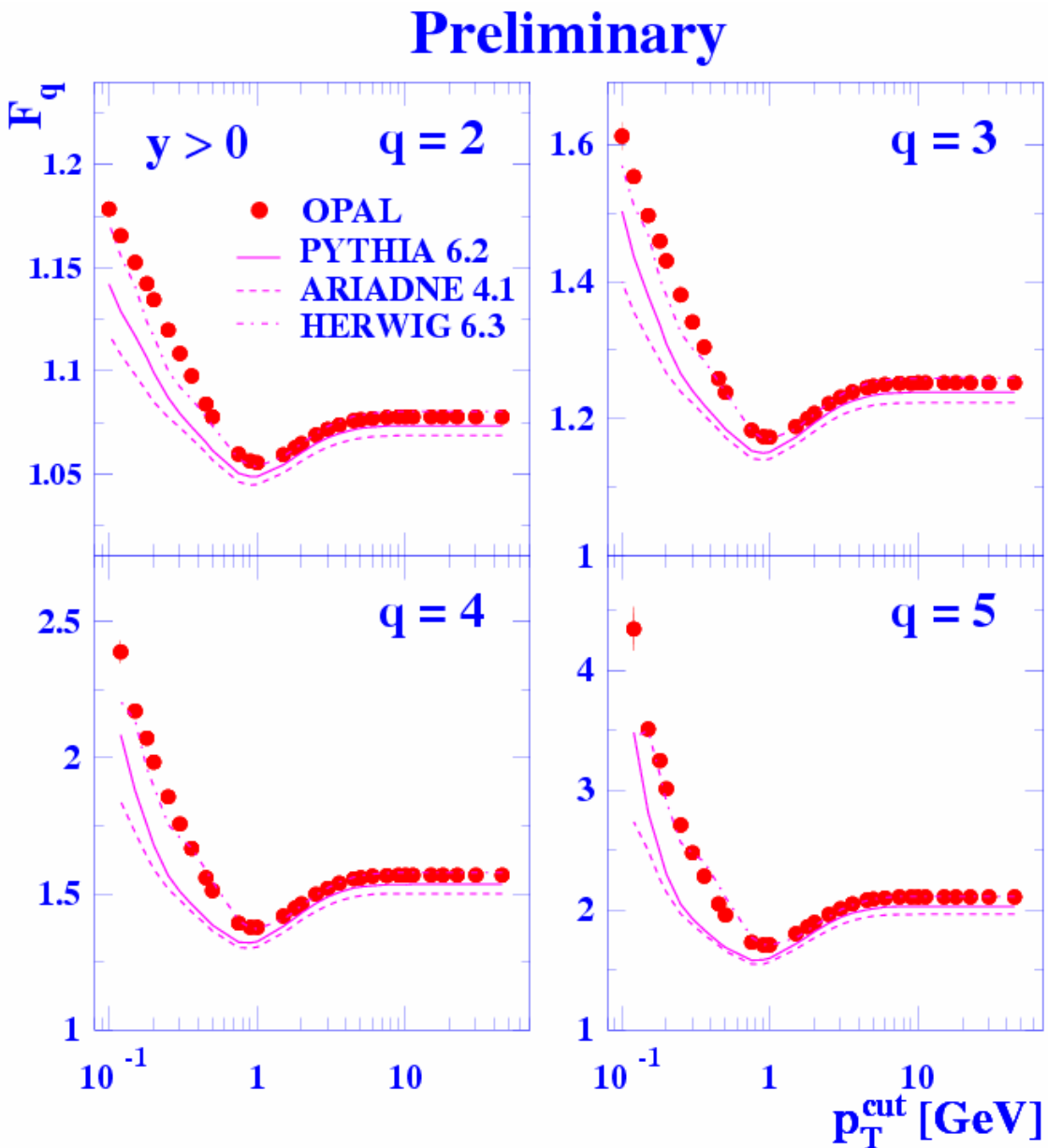
Analytical and MC results

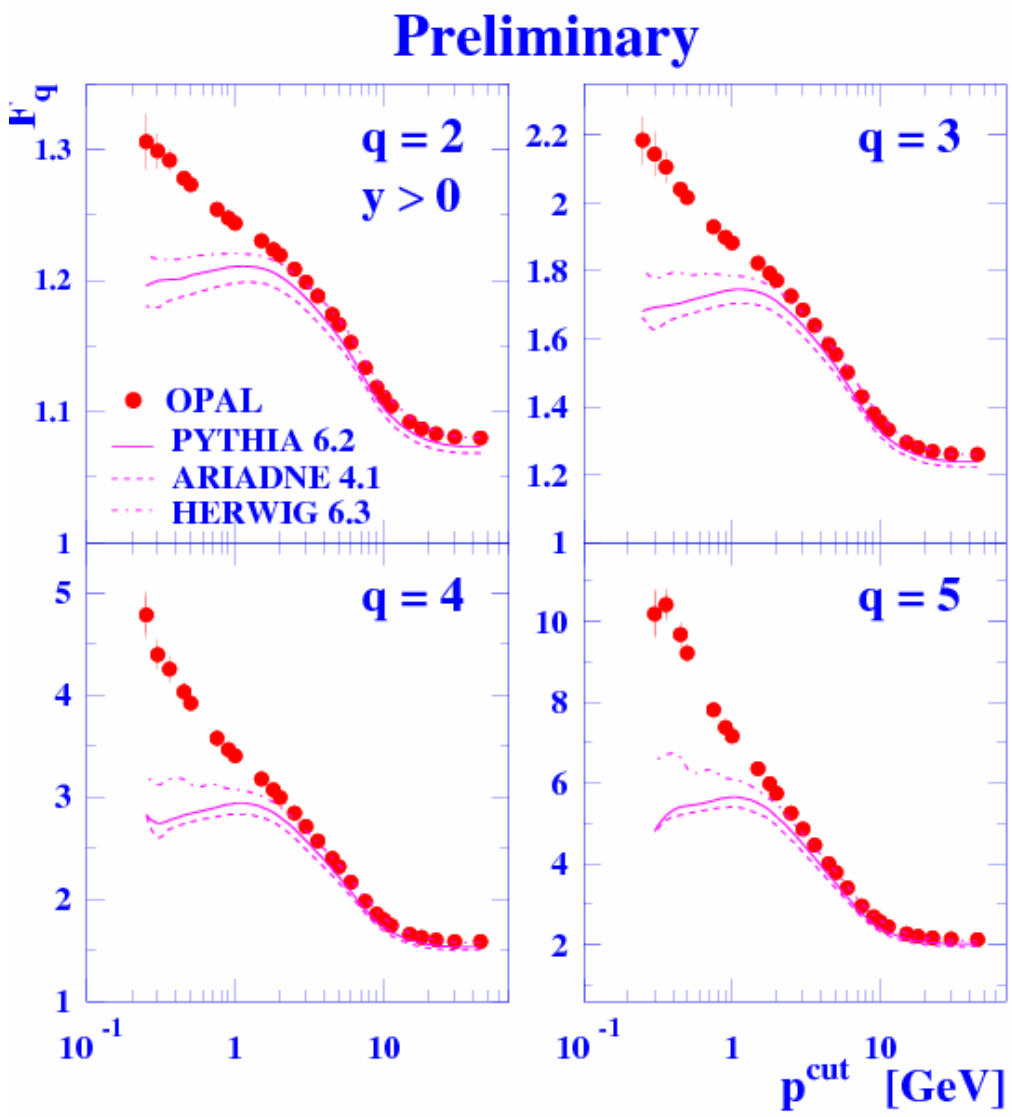
Analytical curves



Hadron level MC




Preliminary
F_q
y > 0
q = 2
OPAL
PYTHIA 6.2
ARIADNE 4.1
HERWIG 6.3
q = 3
q = 4
q = 5
p_T^{cut} [GeV]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OPAL
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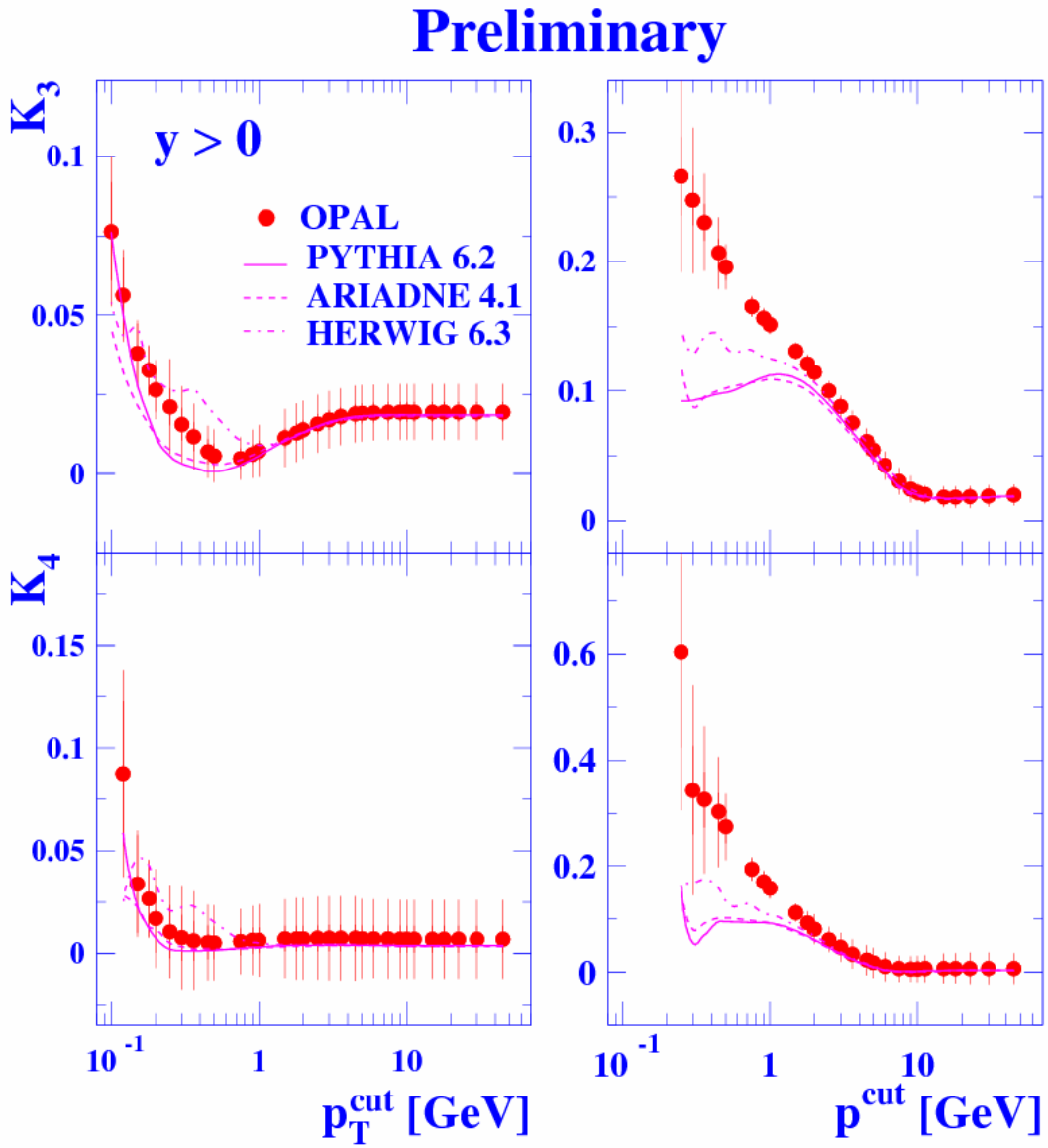
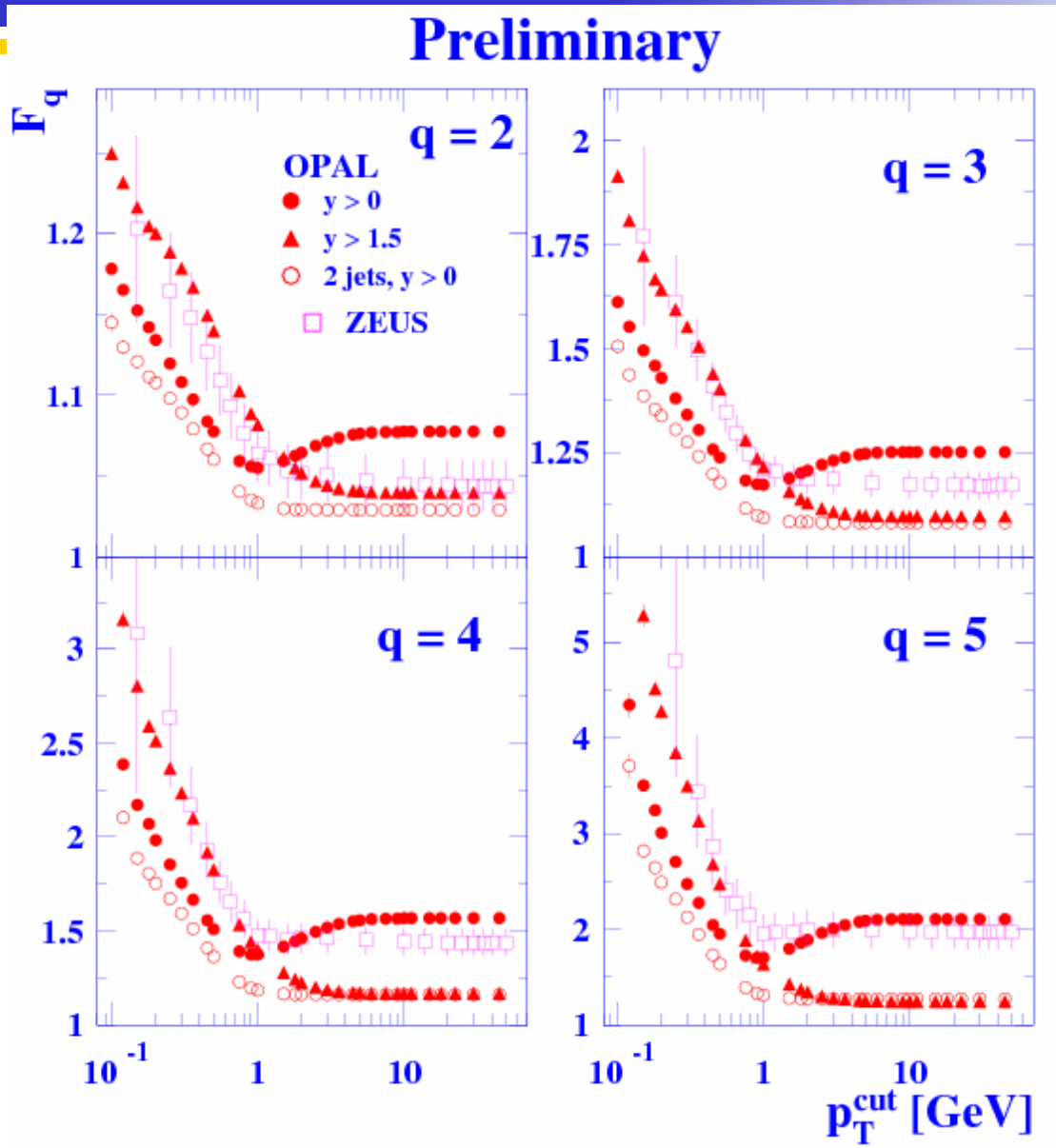
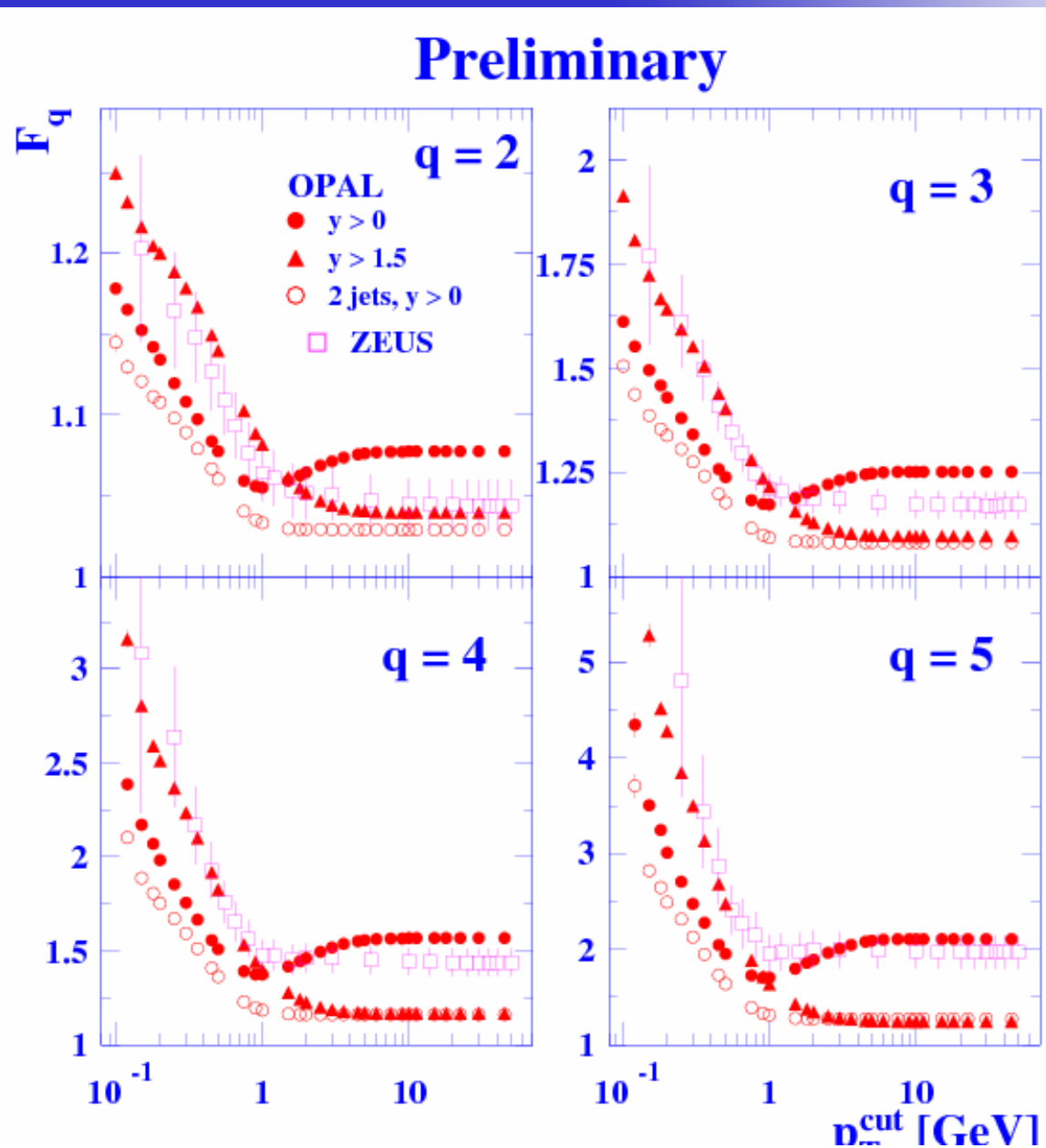
p^{cut} [GeV]


Preliminary
y > 0
OPAL
PYTHIA 6.2
ARIADNE 4.1
HERWIG 6.3
K3
K4
0.1
0.05
0
0.3
0.2
0.15
0.6
0.4
10 -1
1
10
p_T^cut [GeV]
p^cut [GeV]


Preliminary
F_q
q = 2
OPAL
y > 0
y > 1.5
2 jets, y > 0
ZEUS
q = 3
q = 4
q = 5
p_T^{cut} [GeV]


Preliminary
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OPAL
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y > 1.5
2 jets, y > 0
ZEUS
q = 3
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q = 5
p_T^{cut} [GeV]