PROCEEDINGS OF SCIENCE

Study of hadronic final states at LEP

Marina Giunta*
University of California Riverside, USA / CERN, Switzerland

E-mail: marina.giunta@cern.ch

Recent analyses, performed using multihadronic Z^0 decays collected with the OPAL detector between 1991 and 2000 at the Large Electron Positron (LEP) collider, are presented. The first one is a study of correlations of particles with restricted momenta, indicating some difficulties with the Local Parton-Hadron Duality (LPHD) hypothesis when applied to many-particle inclusive observables of soft hadrons. In the second analysis, unbiased gluon jet properties are studied using a new technique called jet boost algorithm.

International Europhysics Conference on High Energy Physics
July 21st - 27th 2005
Lisboa, Portugal

*Speaker.

PoS(HEP2005)049

1. Introduction

The analyses described in the following use multihadronic Z^0 decay events observed with the OPAL detector [1] at the LEP e^+e^-collider at CERN. In the second section, preliminary results of a study [2] of correlations of particles with restricted momenta are summarized; section three presents a study [3] of unbiased gluon jet properties.

2. Correlations of particles with restricted momenta

In order to extract the non-Poissonian nature of multiparticle *fluctuations*, it is convenient to characterize multiplicity distributions by normalized factorial moments:

$$F_q(\Omega) = \langle n(n-1).....(n-q+1)\rangle / \langle n\rangle = \frac{\int_\Omega \rho_q(p_1,\cdots,p_q)\prod_{i=1}^q dp_i}{(\int_\Omega dp\rho_1(p))^q}, \quad q \geq 1, \tag{2.1}$$

here n is the multiplicity in the phase space region Ω and ρ_q is the inclusive q-particle density of particles with momenta p_i. Normalised factorial cumulants $K_q(\Omega)$ are a measure of *genuine* multi-particle *correlations*: being related to the $F_q(\Omega)$, the $K_q(\Omega)$ become equal to zero for uncorrelated particle production.

It is well known that multiplicity distributions of hadrons produced in high energy collisions are wider than the Poisson distribution, but it was shown [2], within Double Leading Logarithmic Approximation (DLLA) calculations, that it is possible to select restricted regions of phase space where partons are less correlated and the multiplicity distribution is narrower. Two types of factorial moments are defined:

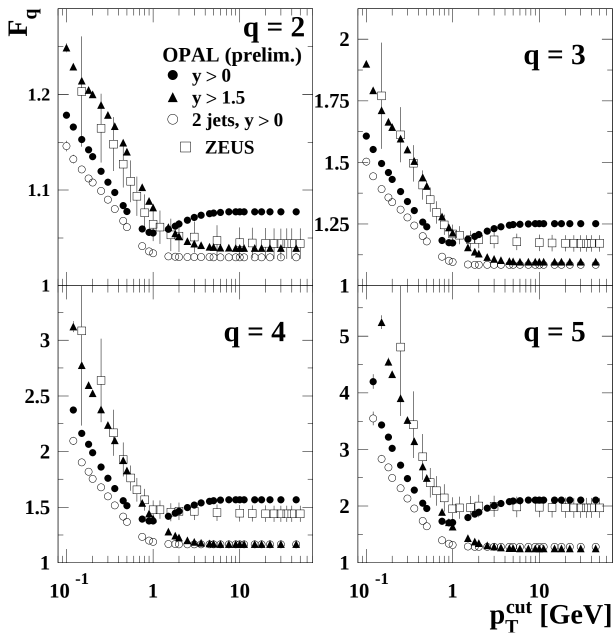

Figure 1: Factorial moments of charged particles with $p_T < p_T^{cut}$ as a function of p_T^{cut}, compared to those of 2-jet events, in the rapidity window y>1.5 and data from ZEUS. Only statistical uncertainties are shown.

- *cylindrically* cut factorial moments, $F_q(p_{T,i} < p_T^{cut})$: due to angular ordering (effect of QCD coherence) low transverse momentum (p_T) gluons are produced independently, so the multiplicity distribution becomes Poissonian: $F_q = 1, K_q = 0$, for $p_T^{cut} \to Q_0$ (Q_0, the virtuality cut-off, is few hundred MeV).

- *spherically* cut factorial moments, $F_q(p_i < p^{cut})$: the multiplicity distribution remains non-Poissonian for absolute momentum $p^{cut} \to 0$: $F_q \to const > 1$ and $K_q \to const > 0$.

If LPHD is valid, the same behaviour should be observed in experimental hadronic data.

The OPAL data on cylindrically cut factorial moments (full dots in Fig. 1) do not show the Poisson limit and the Monte Carlo (Pythia 6.2, Ariadne 4.1 and Herwig 6.3) predictions follow the data trend: with decreasing p_T^{cut} the moments decrease towards a minimum at $p_T^{cut} \approx 1$ GeV then they rise strongly, in disagreement with the perturbative QCD result for partons. The minimum could indicate a border-line between a region where perturbative approach is valid and a region where it is not, because of strong hadronisation effects that mask the expected partonic behaviour.

This result confirms a previous one by the ZEUS Collaboration, except for the minimum at $p_T^{cut} \approx 1$ GeV, absent in the ZEUS measurements. OPAL repeated the analysis in rapidity intervals and using only two-jet events, in order to mimic the ZEUS experimental conditions (Fig. 1); the minimum disappears, suggesting that the often assumed equivalence between one hemisphere in e^+e^-collisions and the current region of the Breit Reference Frame in e^+p collisions, used in the ZEUS analysis, can be misleading for soft particle production.

The OPAL data show a raise also in the spherically cut factorial moments for small value of p^{cut}, contrary to the theoretical predictions for partons.

The cumulants show the same behaviour as the factorial moments, proving that the effect is due to genuine correlations of hadrons.

The results obtained by OPAL, showing how the expected limit values are not reached for small values of p_T^{cut} or p^{cut}, indicates difficulties with the LPHD hypothesis when applied to many-particle inclusive observables of soft hadrons.

3. Unbiased gluon jets' properties using the jet boost algorithm

The *jet boost algorithm* [3] (BA) is a method to determine properties of unbiased gluon jets proposed by the Lund theory group. After testing the method, OPAL used it to study unbiased gluon jets at different energies and then compared the results with theoretical predictions.

The BA is based on the color dipole model of QCD and can be summarized in the following way: in three-jet events, symmetric with respect to the gluon direction, the two independent dipoles (one connecting the q and the g and the other going from the $\bar{q}$ and the g) can be boosted and combined to yield the dipole structure of a gg event.

Experimentally, three jets are reconstructed in each multihadronic event and the gluon jet is identified, obtaining a final sample of 25396 events with a gluon jet purity of 85%. Then each event was boosted to a frame where the angle between the q and the g was the same as the angle between the $\bar{q}$ and the g ($\theta_{qg} = \theta_{\bar{q}g} = \theta$), yielding a symmetric event. The multiplicity of the gluon jet is given by the number of particles lying inside the cone-like region defined by the bisectors of θ_{qg}

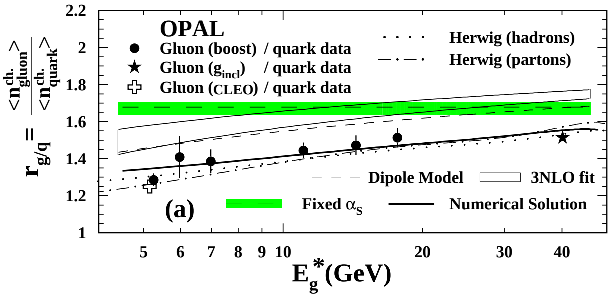

Figure 2: The ratio between the mean charged particle multiplicities of unbiased gluon and uds flavored quark jets, $r_{q/g}$, as a function of jet energy E^*_g.

and $\theta_{\bar{q}g}$and the corresponding energy scale of the unbiased gluon jet, E^*_g, is equal to the transverse momentum of the gluon jet, defined by:

$$p_{\perp,gluon} = \frac{1}{2}\sqrt{\frac{s_{qg}s_{\bar{q}g}}{s}} \tag{3.1}$$

where s_{ij} $(i,j = q,\bar{q},g)$ is the invariant mass squared of the ij pair and $s = E^2_{c.m.}$. The events are divided in 7 subsamples according to the gluon jet energy E^*_g.

Using Herwig 6.2, OPAL compare results obtained with the BA method on simulated three-jet events with results for unbiased gluon jets from simulated color singlet *gg* events. They compare the multiplicity distributions (in the 7 energy intervals) and found a good agreement for $E^*_g > 5$ GeV; they also measured the fragmentation functions which agreed for $E^*_g > 14$ GeV.

After establishing the validity of the method, many measurements of unbiased gluon jet properties are performed: the mean multiplicity (in the 7 energy bins), actually the most precise result for $5.25 < E^*_g < 20$ GeV; the first measurement of the factorial moments F_2 and F_3 of unbiased gluon jets multiplicity distributions over an energy range; the ratio between the mean charged particle multiplicities of unbiased gluon and uds flavored quark jets, $r_{q/g}$, as a function of jet energy (see Fig. 2). The measurements are compared to many different theoretical predictions and an overall global agreement was found. Finally, the fragmentation function was measured for jets with $E^*_g > 14$ GeV and was fitted using the DGLAP evolution equation. The fit gives a good description of the measurements and yields a result for the strong coupling constant consistent with the world average:

$$\alpha_s(m_Z) = 0.128 \pm 0.008(stat.) \pm 0.015(syst.) \tag{3.2}$$

which provides a unique consistency check of QCD.

References

[1] OPAL Collaboration, *The OPAL detector at LEP*, Nucl. Instr. and Meth. **A305** (1991) 275.
OPAL Collaboration, *The OPAL silicon strip microvertex detector with two coordinate readout*, Nucl. Instr. and Meth. **A346** (1994) 476.

[2] OPAL Collaboration, OPAL Physics Note OPAL-PN528, *QCD coherence and correlations of particles with restricted momenta*, July 2005, and references therein.

[3] OPAL Collaboration, *Experimental Studies of unbiased gluon jets from e+e- annihiltions using the jet boost algorithm*, Phys. Rev. **D69** (2004) 032002, and references therein.