# UNBIASED GLUON JETS FROM $e^+e^-$ ANNIHILATIONS USING THE BOOST ALGORITHM*

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We present the first experimental results based on the jet boost algorithm, a technique to define unbiased gluon jet samples in $e^+e^-$ annihilations, *i.e.* events free of any bias from event selection or jet finding criteria. The boost algorithm has been tested using the Herwig Monte Carlo event generator and then applied to hadronic $Z^0$ decays observed with the OPAL detector at the LEP collider. The gluon jet charged particle multiplicity distribution has been measured in seven jet energy bins from 5 to 20 GeV. From these distributions, the mean value and the first two non trivial normalized factorial moments have been extracted. The gluon jet fragmentation function has been measured in two jet energy bins between 14 and 20 GeV. The results have been compared with existing QCD predictions. In general, good agreement has been found between theory data.

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## 1. Introduction

Theoretical calculations define gluon jets inclusively, considering gluon–gluon ($gg$) systems, stemming from a point like color singlet, with the two gluons flying apart back-to-back. Such events can be divided in two hemispheres using the plane perpendicular to the direction of flight of the two gluons. The gluon jet can be defined summing up all the particles in one hemisphere. The properties of these jets, called "unbiased", depend on a single scale, the energy of the jet $E^*_g$. On the other hand, experimental analysis often define jets using a reconstruction algorithm (jet finder), based on a resolution scale. In this way, however, the jet properties strongly depend on the type of jet finder used. In addition, the choice of a fixed resolution

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parameter implies the truncation of higher order radiation. For these reasons, jets defined in such manner are called "biased" and their properties can not be easily compared with theoretical calculation. So far, only three measurements of unbiased gluon jet properties have been performed, from the CLEO [1] and OPAL [2, 3] collaborations. We present the first experimental study [4] employing the jet boost algorithm [5], a technique to extract unbiased gluon jet properties at different energies $E_g^*$.

## 2. Experimental analysis and test of the algorithm

The boost algorithm has been applied to multihadronic events collected by the OPAL detector at the $Z^0$ mass peak. Every event has been forced into a three-jet configuration using the Durham ($k_\perp$) jet finder. To determine which of the three is the gluon jet, secondary decay vertexes were reconstructed to identify $b$ quark jets. Only events with exactly two successfully reconstructed quark jets were retained. The third jet was assumed to be the gluon jet. The boost algorithm was applied to a final sample of 25 396 gluon jets with a purity of about 85%. The events were corrected for experimental effects (using the Herwig Monte Carlo event generator) and divided in seven energy bins.

A test of the boost algorithm was performed using a sample of events generated with the Herwig Monte Carlo. With simulated events it was possible to compare gluon jets from $e^+e^-$ hadronic $Z^0$ decays with unbiased gluon jets from color singlet $gg$ events. For the charged multiplicity distribution, good agreement was found for $E_g^* > 5\,\mathrm{GeV}$. The mean value, $\langle n_{\mathrm{gluon}}\rangle$, and the first two non trivial normalized factorial moments, $F_{2,\,\mathrm{gluon}}$ and $F_{3,\,\mathrm{gluon}}$, of the distributions were then measured in seven energy intervals between 5 and 20 GeV. For the fragmentation function, results from the boost algorithm have been found to be in good agreement with $gg$ hemispheres only for $E_g^* > 14\,\mathrm{GeV}$. Therefore the fragmentation function has been measured only in two intervals at about 14 and 18 GeV. No bias has been observed choosing different jet finders to define the jet directions.

## 3. Results

The results for the mean multiplicity $\langle n_{\mathrm{gluon}}\rangle$ are shown in Fig. 1. The results are seen to be consistent with previous measurements of unbiased gluon jets. Two different theoretical expressions [6] have been fitted to the data: a 3NLO result which takes into account the running nature of $\alpha_{\mathrm{s}}$ and a fixed $\alpha_{\mathrm{s}}$ prediction which incorporates more accurately higher order effects. Both expressions are found to describe the data well. For the factorial moments the 3NLO expression fitted to the three highest energy data

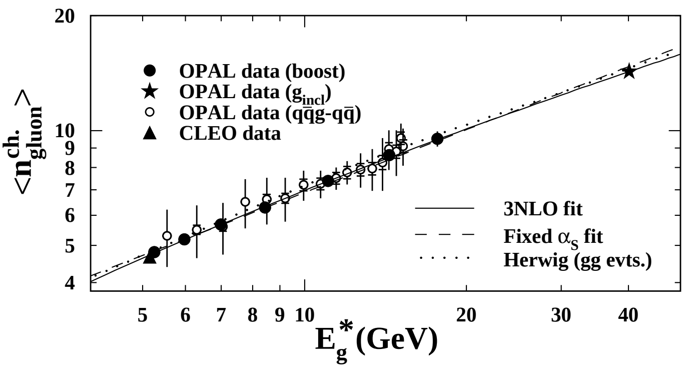


Fig. 1. The mean charged particle multiplicity value of gluon jets, $\langle n_{\mathrm{gluon}} \rangle$, as a function of the gluon jet energy $E_g^*$.

points provides a reasonable description of the $F_{2,\,\mathrm{gluon}}$ and $F_{3,\,\mathrm{gluon}}$ energy evolution for $E_g^*$ above 14 GeV. For lower energies the prediction lies below the data and this discrepancy could be due to hadronization effects. The fixed $\alpha_{\mathrm{s}}$ expression is in general agreement with the data for $F_{2,\,\mathrm{gluon}}$ (but presents fairly large theoretical uncertainties), while it lies above the data for $F_{3,\,\mathrm{gluon}}$, except for $E_g^* \approx 40$ GeV.

The gluon jet measurements have been compared with quark results from inclusive $e^+e^- \rightarrow q\bar{q}$ data at the same energy scale $E_g^*$, corrected (with Herwig) for the heavy quark jet contribution. Fig. 2 shows the results for the ratio of mean multiplicities, $r_{g/q}$. The 3NLO and fixed $\alpha_{\mathrm{s}}$ predictions are seen to lie 15–20% above the data. The analytic solution based on the dipole model [7] is also above the data but in somehow better agreement than the previous two. The numerical solution [8] of QCD evolution equations

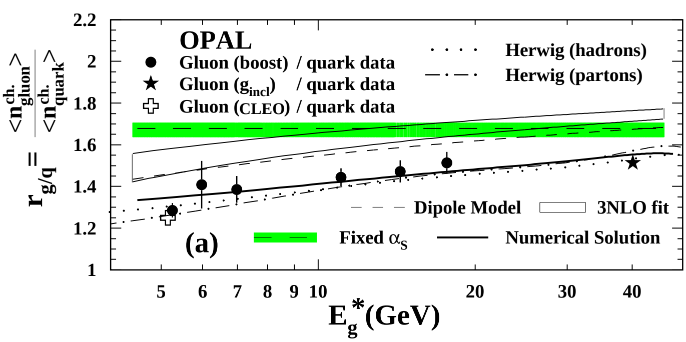


Fig. 2. The ratio between the mean charged particle multiplicities of unbiased gluon and $uds$ flavored quark jets, $r_{g/q}$, as a function of jet energy.

describes well the data over the entire energy range. This suggests that much of the discrepancy between data and analytic prediction is a consequence of technical difficulties (energy conservation and phase space limits) rather than shortcomings of QCD.

The fragmentation function was measured at $E_g^* = 14.24$ and 17.72 GeV. The two distributions were fitted using the DGLAP evolution equation, valid at NLO in the $\overline{\mathrm{MS}}$ scheme. The evolution was performed in conjunction with OPAL measurements of the unbiased gluon [2] and quark [9] jet fragmentation function. The fit provides a good description of the measurement and yields a result for the strong coupling constant, $\alpha_{\mathrm{s}}(m_Z) = 0.128 \pm 0.0008\,(\mathrm{stat}) \pm 0.015\,(\mathrm{syst})$, consistent with the world average.

## 4. Conclusions

We have shown measurements of the charged particle multiplicity distribution and the fragmentation function for unbiased gluon jets. The measurements of the mean multiplicity are the most precise in the range $5 < E_g^* < 20\,\mathrm{GeV}$. The results for $F_{2,\,\mathrm{gluon}}$ and $F_{3,\,\mathrm{gluon}}$ are the first to cover an energy interval. We have also presented the first measurement of $\alpha_{\mathrm{s}}$ from unbiased gluon jet fragmentation functions. While this result is not competitive with other measurements, it does provides a unique consistency check of QCD. Overall good agreement between data and theory has been found.

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