STUDY OF GLUON FRAGMENTATION AND COLOUR OCTET NEUTRALIZATION IN DELPHI

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Using the full statistics of the DELPHI experiment at √s = 91 GeV 3-jet events are selected and gluon respectively quark jet enriched subsamples are defined. The leading systems of the two kinds of jets are determined using rapidity gaps. The sum of charges of the leading systems is studied. It is found that for gluon-jets there is a significant excess of leading systems with total charge zero when compared to Monte Carlo simulations with JETSET. The corresponding leading systems of quark-jets do not exhibit such an excess. The mass spectra of the leading systems with total charge zero are studied.

1 Introduction

The study of the leading hadrons in gluon jets may give interesting insight into the mechanism of colour neutralization. In principle there could exist a direct neutralization of the colour octet field of the fast gluon by the creation of gluon pairs. This mechanism is called ‘colour octet neutralization’ [1]. As a consequence bound states with valence gluons (glueballs and gluonic mesons) might be eventually produced and observed. The existence of gluonic states is predicted by non-perturbative QCD and has been searched for since more than 20 years in different experiments [2]. The very existence of such states, however, is not yet established.

The present study is following a suggestion of Minkowski and Ochs [3] to search for colour octet neutralization (and for glueballs and gluonic mesons) in gluon jets, produced in 3-jet events in e+e− reactions, by defining a leading system followed by a rapidity gap ∆y empty of hadrons. The leading systems of both gluon- and quark-jets are then compared to the predictions of the Monte Carlo model JETSET which is not including the mechanism of octet neutralization. The price to pay for a selection of jets with a rapidity gap is however a strong reduction of the number of events because of the Sudakov form factor [4]. The sum of charges (SQ) in the leading particle system of gluon jets is compared with the resp. Monte Carlo prediction to search for a surplus of events with SQ=0. Furthermore the same investigation for quark jets should not result in a surplus of any charge.

In ref. [5] it has been observed that there were no significant deviations from
Monte Carlo predictions for resonance production - in particular that of the $\eta$ in quark- and gluon-jets. Therefore one can expect that octet neutralization is a relatively rare process - if it exists at all.

2 Data sample and 3-jet event selection

The data sample used has been taken by the DELPHI experiment at the LEP collider at $\sqrt{s} = 91$ GeV in the years 1992-1995. About 230000 3-jet-event have been selected, which have been obtained by using the appropriate cuts for track quality and for the hadronic event type as well as applying a $k_t$ cluster algorithm (Durham) with $y_{\text{cut}} = 0.015$. For the jet determination all topologies have been used with $\Theta_2, \Theta_3 = 135^\circ \pm 35^\circ$, where the jets had been numbered with respect to the calculated energy i.e. $E_3 \leq E_2 \leq E_1$ and with e.g. $\Theta_2$ being the angle between the first and third jet (so called "asymmetric events"). The jet with the highest energy $E_1$ (jet-1) is in most cases a quark-jet, that with the smallest energy $E_3$ (jet-3) the gluon jet. Monte Carlo simulations show for the above mentioned conditions for jet-1 a quark-jet contribution of $\geq 90\%$ and for jet-3 a gluon-jet contribution of about 70%. This is e.g. in agreement with the numbers quoted by L3 with similar jet energies and selections. Heavy quark (b- and c- quarks) events are classified using an impact parameter technique. In the present study events are only accepted if they do not exhibit a b-quark signal. The intention is to compare gluon jets only to 'light-quark' jets. A corresponding sample of Monte Carlo simulations (JETSET) of about twice the event-statistics has been created for comparisons. All comparisons are done at the detector level.

3 Preliminary Results for 3-Jet Events

3.1 Sum of Charges in the Leading System with Rapidity Gap

After the selection of 3-jet events and the determination of enriched quark and gluon jet samples the leading hadronic system of the jet is singled out by requiring a rapidity interval ($\Delta y \geq 2$) between the particles (charged and neutral) belonging to this system and the rest of hadrons produced in either kind of jet. For the charged particles the momenta are required to be larger than 0.2 GeV, for the neutrals this requirement is 0.5 GeV. The requirement of the rapidity interval $\Delta y \geq 2$ below the leading system to be empty of hadrons reduces the number of events to only 3%.

The sum of charges of the particles belonging to the leading system defined as above is given in Fig.1 for gluon-jets and in Fig.2 for quark-jets (full circles) and compared to JETSET Monte Carlo simulations (open circles).
The numbers $P(SQ)$ in the upper plots are defined as the number of events (or Monte Carlo events) with a certain SQ divided by the total number of selected $\Delta y \geq 2$ events - (or the corresponding Monte Carlo events). They are therefore an estimate for the probability of an event to have a certain SQ. The SQ distributions of the leading system for the gluon-jet (Fig.1) shows, for SQ=0, a striking difference between data and simulation. There is a significant enhancement of the SQ of the data at SQ=0 as expected (see Section 1, ref. [1], 3) when the process of colour octet neutralization is present (it is, as mentioned above, absent in the simulation). On the other hand, there is no significant difference of the SQ of the leading system, for SQ=0, between data and JETSET simulation in the case of quark-jets (Fig.2). The lower parts of Figs. 2 and 3 show the difference of the $P(SQ)$ between the data and the JETSET Monte Carlo simulation. This difference amounts, for the gluon-jet
Fig. 3 Effective mass distribution of the leading system for both gluon-jets (a) and quark-jets (c) as well as the respective ratios JETset Monte Carlo simulations (b resp. c) to about 9%, that is more than 4 standard deviations from zero, for the quark-jet (Fig. 2) this difference is compatible with zero!

3.2 Mass Spectra

Fig. 3 shows, for both the gluon-jet and the quark-jet, the effective mass distribution $M$ of the leading system, no neutrals included, with rapidity gap.
required for the charged particles $\Delta y \geq 2$ and the total charge of the system being zero. The number of charged particles in the leading system has to be 2, 4, 6 etc. Several peaks can be observed for the gluon-jet (Fig.3a). One peak around $M \sim 0.8$ GeV might be attributed to the $\rho$ resonance, another at $M \leq 0.5$ GeV to a reflection of $\eta$, $\eta'$ and $\omega$. Other peaks ($M \leq 1$ GeV, $M \sim 1.4$ GeV, ...) are not understood yet and their statistical significance is weak. The ratio of the $M$ distributions of the leading system data/simulation is given in Fig.3b. The $\rho$ peak and the enhancement at $M \leq 0.5$ GeV seem to be understood by the simulation. Besides the region at very low $M \leq 0.3$ GeV, the 2 enhancements in the $M$ distributions of the leading system of the gluon-jet at $M \leq 1$ GeV and $M \sim 1.4$ GeV are not reproduced by the JETSET Monte Carlo simulation.

Fig.3c shows the corresponding mass distribution of quark-jets and Fig.3d shows the ratio of the $M$ distributions of the leading system data/simulation for the quark-jet. Compared to the gluon-jet there is no enhancement at $M \leq 1$ GeV in Fig.3c and in Fig.3d no excess compared to the simulation at $M \sim 1.4$ GeV.

Since the effect of the neutrals are not well understood yet ($\gamma$'s, $\pi^0$'s, and neutral decay modes of $\eta$'s, $\eta'$'s, $\omega$'s etc.) and because of the limited statistics no conclusions can be drawn yet from the mass distributions.

4 Summary and Conclusions

In the present study first efforts have been undertaken to search for the existence of octet neutralization in the fragmentation of gluon-jets. The full statistics of 1992-1995 at $\sqrt{s} = 91.1$ GeV obtained by the DELPHI collaboration is used to select 3-jet events and to single out thereof quark-jets (purity $\geq 90\%$) and gluon-jets (purity $\geq 70\%$). A leading system of a jet is defined which is separated from the rest of the low energy particles by a rapidity gap of width $\Delta y \geq 2$ being empty of hadrons. The sum of charges of this leading system is studied. For the gluon-jets an enhancement of neutral leading systems over the Monte Carlo prediction of about 9% is seen (more than 4 standard deviations above zero), on the other hand, no such enhancement is seen in the quark-jet! An even more significant deviation is revealed (Fig. not shown) for the sum of charges of the 2 fastest tracks without demanding a rapidity cut (3.5% effect but with very high significance).

In order to assess the existence of colour octet neutralization further checks have to be done - determination of the quantum numbers of the leading system, better separation of the gluon-jet, better insight into the role of the neutrals etc. It can, however, be argued that there is an intrinsic shortcoming
for the JETSET Monte Carlo simulation describing the sum of charges in the leading system of the gluon-jet!

The effective mass of the leading system with sum of charges $SQ = 0$ is studied. An enhancement for the gluon-jet at $M \leq 1 \text{ GeV}$, which is not seen in the simulation nor for the quarkjet and another at $M \sim 1.4 \text{ GeV}$ is yet of only weak statistical significance.

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Signal for octet neutralisation:

leading particles:

double triplet:

octet:

sum of charges:

sum of charges:

\(-1, 0, 1\)

\(= 0\)