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RECENT RESULTS ON PARTICLE PRODUCTION FROM OPAL

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Three recent OPAL studies are presented in which the fragmentation process in quark and gluon jets and in identified up, down and strange flavour jets is studied. The first is a measurement of charged particle, π^0, η and K^0 multiplicities in quark and gluon jets. No evidence is found for a particle-species dependent multiplicity enhancement in gluon jets. In another study, leading $\pi^\pm$, $K^\pm$, K^0_S, $p(\bar{p})$ and $\Lambda(\bar{\Lambda})$ rates have been measured in up, down and strange flavour jets. The results confirm the leading particle effect in the fragmentation of light flavour jets. In addition, a direct determination of the strangeness suppression factor has been performed, yielding $\gamma_s = 0.422 \pm 0.049$ (stat.) $\pm$ 0.059 (syst.). In a third study, mean charged particle multiplicities were measured for up, down and strange flavoured Z^0 decays and found to be identical within the uncertainties of the measurement, as expected from the flavour independence of the strong interaction.

1 Introduction

The large number of hadronic Z^0 decays collected by the LEP experiments at $\sqrt{s} = M_{Z^0}$ allow for detailed studies of the dynamics of the strong interaction. In three recent OPAL studies presented in this paper, production rates of various hadron species in the fragmentation of quark and gluon jets and of identified up, down or strange flavour jets have been studied. The results constitute a detailed test of models describing the fragmentation of partons in to hadrons in the final state.

2 π^0, η, K^0 and charged multiplicities in quark and gluon jets

Because of the colour enhancement of the gluon-gluon coupling with respect to the quark-gluon coupling, the particle multiplicity in gluon jets is higher than in quark jets. As this multiplicity enhancement appears at the level of the couplings, it is expected to be largely independent of the particle species observed in the final state, with small corrections only due to e.g. the decay properties of heavy hadrons. In most fragmentation models, both for quark and gluon jet fragmentation, the neutralisation of colour fields occurs via the creation of quark-antiquark pairs. It has however been suggested [1] that in the fragmentation of a gluon jet, colour neutralisation could also occur via

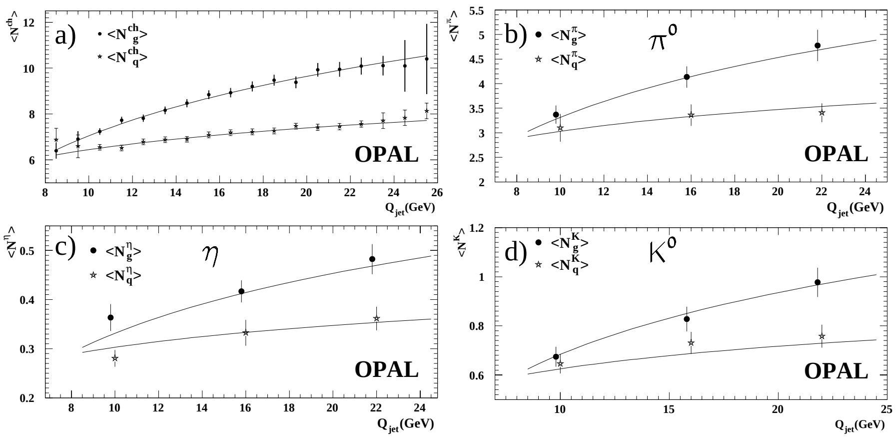

Figure 1. Mean charged particle, π^0, η and K^0 multiplicity in quark and gluon jets, as a function of $Q_{\rm jet}$. The curves are the result of a fit to the charged particle multiplicity, scaled by a normalisation factor in the figures b,c and d.

the creation of gluon pairs. In this case, an enhanced production of isoscalar mesons such as the η would be expected in the fragmentation of gluon jets and, if they exist, also of glueballs.

OPAL has measured π^0, η, K^0 and charged particle multiplicities in quark and gluon jets[2] as a function of the hardness scale of the jet[3] defined as $Q_{\rm jet} \equiv E_{\rm jet} \sin\frac{\theta}{2}$. From hadronic Z^0 decays with a 3-jet topology two samples of jets are selected consisting of the second and the third highest energy jet from each event, respectively. In the region 8 GeV $< Q_{\rm jet} <$ 26 GeV, these samples contain different fractions of quark and gluon jets and the mean π^0, η, K^0 and charged particle multiplicities measured for the jets in these samples can be used to unfold the multiplicities for pure quark and gluon jets.

In Fig. 1 we show the mean charged particle, π^0, η and K^0 multiplicities in quark and gluon jets as a function of $Q_{\rm jet}$. Also shown is the result of a fit to the charged particle multiplicities, which has been scaled by an appropriate normalisation factor in figures b,c and d.

Fig. 2 shows the ratio of the mean multiplicity in gluon and in quark jets for charged particles, π^0, η and K^0. All cases can be described by the fit result obtained for charged particles. The multiplicity enhancement in gluon jets is thus found to be independent of the studied particle species. These results do not confirm an enhanced η production in three-jet events reported by the L3 collaboration.[4]

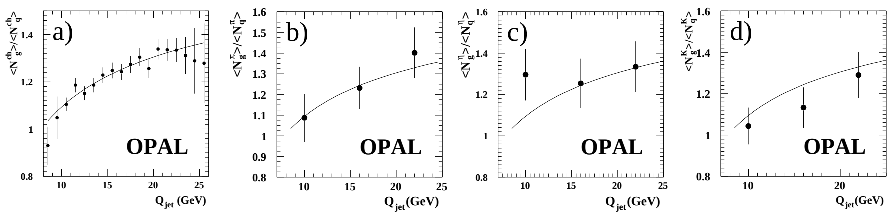

Figure 2. Ratio of the mean charged particle, π^0, η and K^0 multiplicity in gluon and in quark jets as a function of $Q_{\rm jet}$. The curves are the result of a fit to the charged particle multiplicities.

3 Leading particle production in light flavour jets

OPAL has measured leading $\pi^\pm$, $K^\pm$, K^0_S, $p(\bar{p})$ and $\Lambda(\bar{\Lambda})$ rates in up, down and strange flavour jets.[5] As suggested in [6], these highest energy particles in a jet often carry the flavour of the quark from which the jet originated. So far few experimental results[7] have confirmed this leading particle effect in the fragmentation of light flavour jets. The method used by OPAL to determine leading particle rates in light flavour jets was proposed in [8] and is based on counting all events in which a leading hadron is tagged in one of the event hemispheres and all events in which both hemispheres have a leading hadron tag. Using this information, our knowledge of the flavour composition of hadronic Z^0 decays and imposing some constraints based on isospin symmetry and flavour independence, the production rates for the different hadron species in up, down and strange flavour jets can be unfolded.

In Fig. 3, the leading $\pi^\pm$ and $K^\pm$ rates in up, down and strange flavour jets are shown as a function of $x_{\rm cut}$, the lower threshold applied on the scaled momentum of the particle. The rates are compared to the corresponding JETSET[9] and HERWIG[10] predictions. In accordance with the expected leading particle pattern, the highest rates are those of pions in up and down flavour jets and kaons in strange flavour jets. The kaon rate in up flavour jets is lower than would naïvely be expected from the leading particle effect. This is due to the suppressed production of strange quark-antiquark pairs from the hadronic sea. The strangeness suppression factor, associated with this effect, can be determined directly from the ratio of leading $K^\pm$ production in up and strange flavour jets and the ratio of leading K^0 production in down and strange flavour jets, shown in Fig. 4a and 4b. The strangeness suppression factor obtained is

$$\gamma_s \;=\; 0.422 \;\pm\; 0.049\ (\text{stat.}) \;\pm\; 0.059\ (\text{syst.}),$$

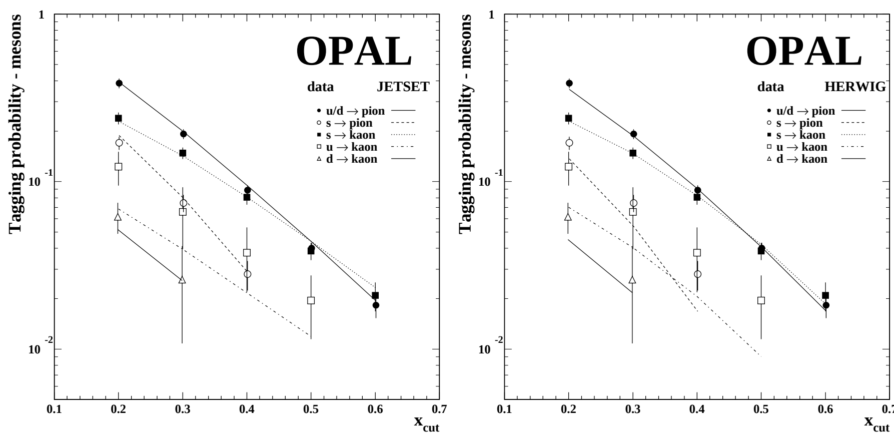

Figure 3. Tagging probabilities for pions and kaons in up, down and strange flavour jets, compared to JETSET (left) and HERWIG (right).

which is about one standard deviation high in comparison with other measurements,[11] in most of which γ_s was determined rather indirectly, however.

We have also studied baryon production in the final state. In the Monte Carlo models to which we compare our data, baryon production is governed by the creation of diquark pairs when breaking up strings (in JETSET) or when decaying colourless clusters (in HERWIG). In Fig. 5, the ratio of proton over pion production in up flavour jets and of lambda over kaon production in strange flavour jets are compared to JETSET and HERWIG. The HERWIG

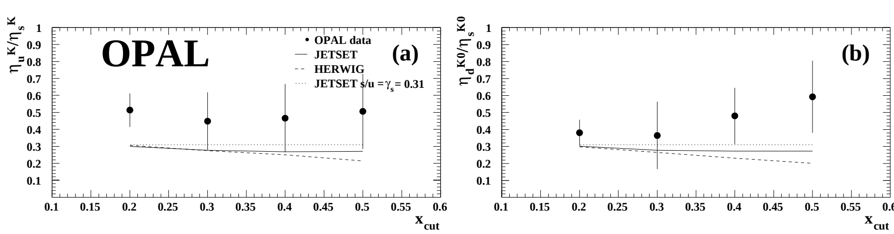

Figure 4. Ratio of tagging probabilities of $K^{\pm}$ in up and strange flavour jets (a) and of K^0 in down and strange flavour jets (b), compared to HERWIG and JETSET. The dash-dotted curves indicate the strangeness suppression factor ($\gamma_s = 0.31$) used in JETSET.

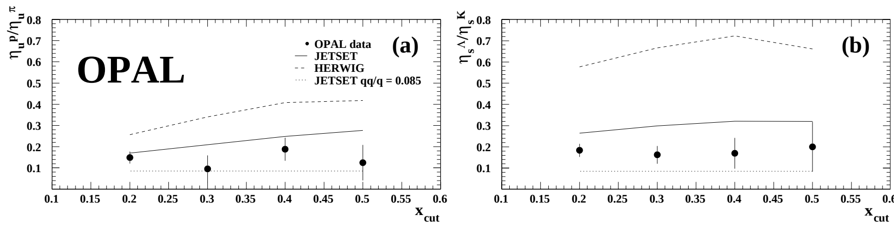

Figure 5. Ratio of tagging probabilities of protons and pions in up flavour jets (a) and of lambdas and kaons in down flavour jets (b), compared to HERWIG and JETSET. The dash-dotted curves indicate the diquark suppression factor (qq/q = 0.085) used in JETSET.

Monte Carlo significantly overestimates the fraction of baryons produced.

4 Charged particle multiplicity in up, down and strange flavoured Z^0 decays

OPAL has studied mean charged particle multiplicities in up, down and strange flavoured Z^0 decays.[12] Because of the flavour independence of the strong interaction, these multiplicities are expected to be identical, with small corrections only due to the decay properties of heavy hadrons.

For the purpose of the measurement, the charged particle multiplicity has been determined for three event samples, defined by the observation of a leading $K^{\pm}$ with fractional energy $x_E > 0.5$, of a leading K^0_S with $x_E > 0.4$, or of a leading charged hadron with $x_E > 0.7$, respectively. These samples differ in the relative fractions of up, down and strange flavoured events they contain and have been used to unfold the mean charged particle multiplicity for purely up, down or strange flavoured Z^0 decays. These are found to be

$$\langle n_{\mathrm{u}} \rangle = 17.77 \pm 0.51 \text{ (stat.) } {}^{+0.86}_{-1.20} \text{ (syst.)},$$

$$\langle n_{\mathrm{d}} \rangle = 21.44 \pm 0.63 \text{ (stat.) } {}^{+1.46}_{-1.17} \text{ (syst.)},$$

$$\langle n_{\mathrm{s}} \rangle = 20.02 \pm 0.13 \text{ (stat.) } {}^{+0.39}_{-0.37} \text{ (syst.)},$$

where we point out that in particular the results for up and down flavoured events are strongly anti-correlated. Within the uncertainties, the measured mean multiplicities are consistent with being identical, as expected from the flavour independence of the strong interaction.

5 Conclusions

Mean π^0, η, K^0 and charged particle multiplicities have been determined for quark and gluon jets. The multiplicity enhancement in gluon jets is found to be independent of the studied particle species.

We have measured leading hadron production rates for various hadron species in up, down and strange flavour jets. The results confirm the leading particle effect in the fragmentation of light flavour jets and have been used for a direct determination of the strangeness suppression factor, yielding $\gamma_s = 0.422 \pm 0.049$ (stat.) $\pm$ 0.059 (syst.). In addition the results constitute a detailed test of fragmentation models. In particular the HERWIG Monte Carlo model is found to strongly overestimate baryon production in the final state.

The mean charged particle multiplicity has been determined for up, down and strange flavoured Z^0 decays. The results are identical within the uncertainties of the measurement, as expected from the flavour independence of the strong interaction.

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