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Production of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ in Quark, Antiquark and Gluon Jets *

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Abstract

We present measurements of identified charged hadron production over a wide momentum range using the SLD Cherenkov Ring Imaging Detector. In addition to studying flavor-inclusive Z^0 decays, we compare particle production in decays into light, c and b flavors and compare production in gluon jets with that in light quark jets, where the jet flavors are selected using precision vertex information.

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1 Introduction

The fragmentation process by which hadrons are produced from final stage partons in $e^+e^- \rightarrow Z^0 \rightarrow q\bar{q}$ is not fully understood. Several phenomenological models of the process [1] [2] [3], in which the partons radiate gluons that are eventually transformed by different methods into primary hadrons have been tuned to reproduce data from e^+e^- collisions. To understand the hadronization process better and test these models further, we report a measurement of the production of $\pi^\pm$, $K^\pm$, p and $\bar{\text{p}}$ in inclusive events, *uds*, *c* and *b* events and *uds* quark and gluon jets.

2 PARTICLE AND EVENT IDENTIFICATION

We used 55,000 selected [4] hadronic Z^0 decays collected by SLD in 1993-98 within the acceptance of the Cherenkov Ring Imaging Detector(CRID). The CRID provides particle identification over a broad momentum range by measuring the opening angle of the cone of Cherenkov light emitted as a charged track passes through liquid and gas radiators. To identify a charged track as $\pi^\pm$, $\text{K}^\pm$, p or $\bar{\text{p}}$, a likelihood is calculated for each particle type and cuts are made on their ratios. In each momentum bin, identified π, K, and p were counted, and these were unfolded using the inverse of an identification efficiency matrix, and corrected for track reconstruction efficiency. The elements of the identification efficiency matrix were determined using a detailed MC simulation of the detector and calibrated with selected K^0_S, τ decay data.

To separate light, *c* and *b* quarks, we selected secondary vertices in each event hemisphere and counted tracks with large impact parameter. Since B and C hadrons produce the only secondary vertices and have larger mass and more tracks, we can obtain pure and efficient light, c and b quark samples [4].

3 INCLUSIVE HADRONIC FRACTIONS

The measured charged particle fractions for hadronic Z^0 decays as a function of momentum are shown in Fig. 1. Pions are seen to dominate at low momentum and to decline steadily in fraction as momentum increases. The kaon fraction rises gradually to about one-third at high momentum. The proton fraction rises to a maximum of about one-tenth at $\approx$ 10 Gev/c, then declines. Also shown in Fig. 1 are the predictions of three fragmentation models with default parameters. All the models reproduce the shape of each particle fraction qualitatively. The HERWIG and UCLA predictions for the pion fraction are high at intermediate monemtum. All three predictions for the kaon fracton are too low at high momentum. The JETSET prediction for the proton fraction is too high at all momentum and those of HERWIG and UCLA show structure in the proton fraction at high momentum that is inconsitent with the data.

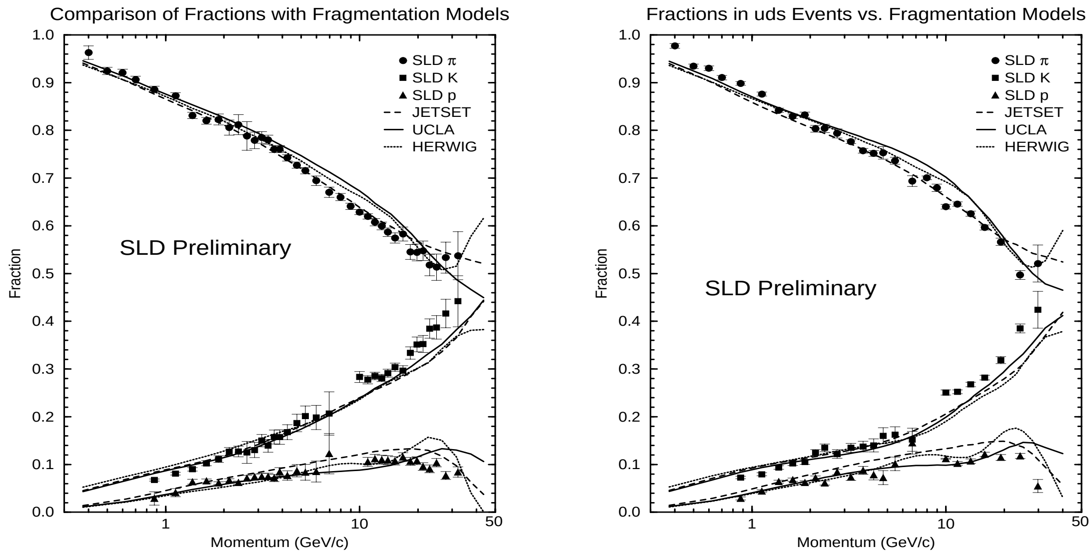

Figure 1: Comparison of the charged hadron fractions in flavor-inclusive(left) and light-flavor(right) events with the predictions of three fragmentation models

4 FLAVOR DEPENDENT ANALYSIS

The analysis was repeated separately on the high-purity light, c and b tagged samples and a complete flavor unfolding was done. Fig. 1 shows the charged hadron fractions in light quark flavor events. Qualitatively there is little difference between these data and those for the inclusive sample, however these are more relevant for comparison with QCD predictions based on the assumption of massless primary quark production. The same general differences between the predictions of the three models and the data were observed indicating that these deficiencies are in the fragmentation simulation and not simply in the modelling of heavy hadron production and decay.

In Fig. 2, the ratios of production in b- to light-flavor and c- to light-flavor events for the three species are shown. There is greater production of charged pions in b-flavor events at low momentum. The production of charged kaons is approximately equal in the two samples at $x_p = 2p/E_{cm} = 0.02$, but the relative production in b-flavor events increases with x_p, peaking at $x_p \approx 0.07$. There is approximately equal production of protons in b-flavor and light-flavor events below $x_p = 0.15$. For $x_p > 0.1$, production of all these particle species falls faster with increasing momentum in b-flavor events. These features are consistent with expectations based on the known properties of $b\bar{b}$ events and similar observations hold for $c\bar{c}$ events. The fragmentation models reproduce these features qualitatively, although HERWIG overestimates the pion and kaon ratios by a large factor at low x_p.

5 QUARK AND GLUON JET COMPARISON

For quark and gluon jets, differences in the inclusive particle production are predicted from QCD and have been observed. Only small differences are expected in identified particle

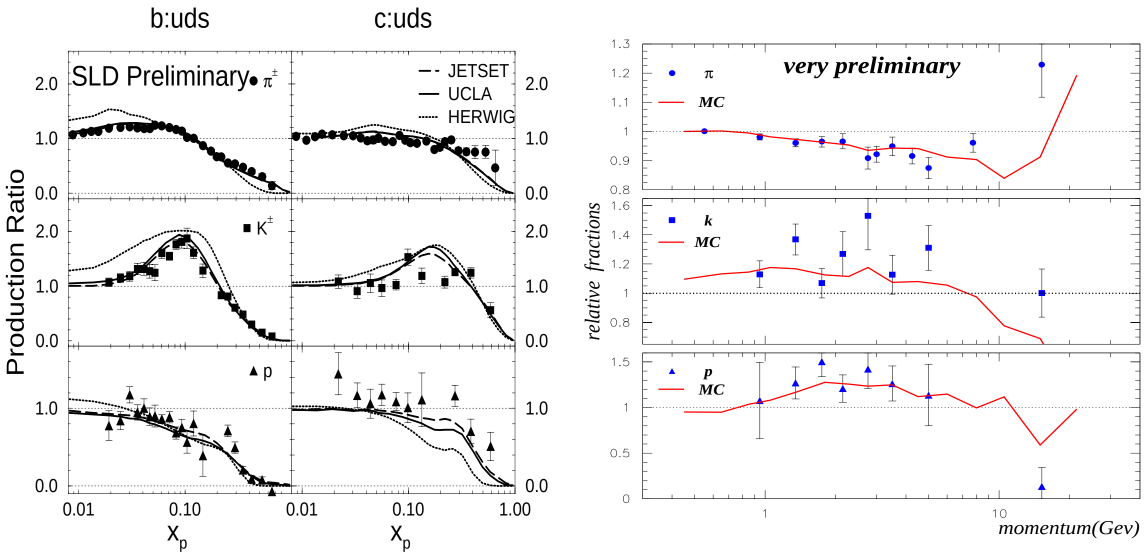

Figure 2: Ratios of production rates in b- and c-flavorevents to those in light-flavor events(left) and ratios in gluon and light-flavor jets(right)

production due to leading particle production and kinematics. Three-jet events are selected using the Durham algorithm with $y_{cut} = 0.005$. Jet energies are rescaled using the angles between the jet axes and ordered $E_1 > E_2 > E_3$. Four different samples of jets are defined by:

- Gluon sample: If one of the lower energy jets has a vertex which passes mass and momentum cuts, the other is tagged as a gluon jet with purity 92%.
- Light mixture: If no secondary vertex and no large impact parameter tracks are found in the event, the two lower energy jets are put into the light mixture sample with *udsg* purity 94%.
- $b(c)$ mixture: If the highest energy jet is tagged $b(c)$, the two lower energy jets are included in the $b(c)$ mixture 98(92)% $b(c)g$ purity.

The fractions analysis is repeated on all four samples. The ratio of each particle's fraction in the gluon and light mixture jet samples is shown in Fig. 2 and differs from unity. However the simulation is consistent with the data and shows a kinematic bias that must be reduced for future studies.

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