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Abstract

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Tagging the s quark in hadronic decays of the Z

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The DELPHI detector at LEP is equipped with RICH detectors which can be exploited for tagging decays of the Z boson into $s\bar{s}$ pairs. High momentum $K^\pm$ identified with the RICH have been used both for a double tag of the s quark and for a single tag using the $\phi(1020)$ meson.

1. INTRODUCTION

The process studied at LEP is the decay of the Z gauge boson:

$$e^+e^- \rightarrow Z \rightarrow f^+f^- \quad (1)$$

where f is a fermion. In about 70% of the cases this fermion is a quark. Many physical measurements rely on the identification of the flavour of this primary quark.

In particular tagging of the s quark is an important tool both in electroweak physics and in QCD studies.

The DELPHI experiment [1] is particularly suited to do these studies because it is equipped with Ring Imaging Cherenkov (RICH) detectors [2] [3] in most of the solid angle. These detectors allow the identification of $K^\pm$ that carry the s quark as a valence quark.

The measurement of $\Gamma_{s\bar{s}}/\Gamma_{had}$, the ratio between the production rate of s quarks in Z decays and the total hadronic branching fraction, and of A_{FB}^s , the forward-backward asymmetry in the production of s quarks, can be performed if s can be tagged. By comparing these measurements for different quark species the universality of the electroweak coupling can be checked.

Concerning QCD, the measurements of the multiplicity of identified states in $s\bar{s}$ events can be useful for a better understanding of the

hadronization mechanism. The parameters on which the different fragmentation models depend can be determined more precisely. Moreover, a measurement of the strong coupling constant α_s in $s\bar{s}$ can be done, allowing a check on the universality of α_s itself with respect to the quark flavour [4].

2. s QUARK TAGGING

The main background in the tagging of s quarks come from kaons produced in hadronization process.

According to the most reliable models, the probability to produce an $s\bar{s}$ pair in the fragmentation is about 1/3 of the probability of producing a $u\bar{u}$ or a $d\bar{d}$ pair, and it is an order of magnitude higher than same probabilities for the heavy quarks. Strange particles can thus be produced also in the fragmentation process, and are not an exclusive signature of the primary quark itself. This implies that a low purity is likely to be obtained when trying to tag the presence of the s quark as primary quark by means of the presence of strange hadrons.

2.1. Tagging methods

The best signature that the primary quarks are strange is the presence of a high momentum strange hadron in the final state.

The requirement of high momentum is essential

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in order to increase the purity of the tagging: it is connected to the presence inside the hadron of the primary quark, which in general carries the largest part of the original beam momentum.

High momentum $K^\pm, K^0, K^{0*}, \Lambda^0, \phi$, are all in principle suitable for this purpose. Of course the kaons are favoured by the statistics. The average multiplicity of $K^\pm$ is about 2.5, about 2 for K^0 , while the Λ^0 multiplicity is 0.3 and the ϕ one only 0.1.

Among kaons, the charged ones are favoured by DELPHI both because of higher statistics and due to the high detection efficiency that can be reached with the Ring Imaging Cherenkov detectors (RICH).

Summarizing, s quark tagging can be treated in the following manner: select a sample of events with one or more strange hadrons with given characteristics; then use hadronization models in order to compute the s quark purity of the sample and the tagging efficiency reached in this way.

2.2. Strange hadrons tagging

The tagging of strange hadrons, as a signature of s quark, can be performed following several possible techniques.

In the single tag technique one strange hadron with chosen characteristics is searched for in each event. The fraction of tagged s quark events over the total number of hadronic events is given by:

$$f_{s\bar{s}}^{(1)} = R_s \epsilon_s + (1 - R_s) \bar{\epsilon}_s \quad (2)$$

where $R_s = \Gamma_{s\bar{s}}/\Gamma_{had}$ and ϵ and $\bar{\epsilon}_s$ are the efficiencies of tagging the s quark and other quark types, respectively. In general these efficiencies must be estimated using a Montecarlo simulation of the process studied.

In the double tag technique each event is divided into two hemispheres by a cut on a plane perpendicular to the thrust axis. A signature of the s quark is searched in both hemispheres.

By a combination of single and double tagging one can add the following equation to the previous one:

$$f_{s\bar{s}}^{(2)} = R_s \epsilon_s^2 (1 + c_s) + (1 - R_s) \bar{\epsilon}_s^2 (1 + \bar{c}_s) \quad (3)$$

where the c coefficients accounts for possible correlations between the efficiencies of tagging a par-

ticle in one hemisphere and the other particle in the other hemisphere. Using the two equations together one of the parameters among efficiencies and correlation coefficient can be extracted directly from data, allowing a smaller dependence on the simulation.

The mixed tag technique consists of the tag of two different particles in the two hemispheres. This topic will not be treated here.

3. SINGLE TAG METHOD: $\phi(1020)$

A study has been started in the DELPHI collaboration in order to tag $s\bar{s}$ events with high momentum $\phi(1020)$.

Even if the available statistics is not large (the particle average expected multiplicity is about 0.1), a satisfactory purity can be reached by selecting high momentum ϕ . Moreover the ϕ is fully identified by the RICH through the $\phi \rightarrow K^+ K^-$ decay channel, whose branching ratio is 49.1%. The comparison of rates of events where only one or both the charged kaons are tagged can be exploited to determine the $K^\pm$ detection efficiency.

Montecarlo studies using the full simulation of the DELPHI experimental setup show that the single ϕ identification can give, for the s quark tagging, an efficiency of about 4% and a purity of 62%, better than what can be done for instance using the K_s^0 .

3.1. ϕ cross section measurement

The ϕ cross section has been measured using a sample of 430,000 hadronic events with RICH information collected by DELPHI during the 1992 LEP running period.

The $K^+ K^-$ invariant mass peak obtained through kinematical cuts has been improved using the $K^\pm$ identification performed with a *likelihood scan* algorithm [5]. In Figure 1, the clear improvement obtained in the ϕ signal due to charged kaon identification with the RICH is shown.

Figure 2 shows the ϕ differential cross section determined by extracting the invariant mass signal as a function of x_E , the fraction of the beam energy carried by the ϕ . There is a good agree-

Figure 1. K^+K^- invariant mass without and with $K^\pm$ identification.

ment with the prediction of JETSET, except possibly in the highest momentum region.

As a preliminary result, the average multiplicity measured for ϕ in hadronic events has been found to be:

$$\frac{N_\phi}{N_{had}} = 0.096 \pm 0.009(stat.) \pm 0.016(syst.) \quad (4)$$

This result is in good agreement with both the previous DELPHI measurement done with the energy loss tagging technique [6] and the latest OPAL measurement [7]. There is also a good agreement with the prediction of JETSET 7.3 PS with the DELPHI tuning of the parameters, which gives an average multiplicity of 0.091.

First checks on 1993 and 1994 runs (about 0.4 and 1.3 million events with RICH information respectively) confirm the above result.

4. $K^\pm$ DOUBLE TAG

The double tag of charged kaons seems to be a promising tool for tagging the s quark, in particu-

Figure 2. $\phi(1020)$ differential cross section.

lar when aiming at the measurement of $\Gamma_{s\bar{s}}/\Gamma_{had}$. The use of a double tag instead of the single one improves the purity of the sample that can be obtained, and it reduces the dependence on Monte Carlo simulations.

A study of this method has been started on the data collected by DELPHI in the 1994 LEP run (about 1.3 million hadronic events).

$K^\pm$ with momenta above 9 GeV/c (the gas radiator RICH threshold) have been identified in both hemispheres of the events, using a *weighted clustering* [5] algorithm. The measured Cherenkov angle is required to be within 2.5 standard deviations the kaon hypothesis and more than one standard deviation away from the expected π angle.

In order to suppress the heavy quark contamination further, the events were required not to contain any b hadrons by excluding secondary vertices using the microvertex detector [8].

The useful momentum range of the kaon tagging depends on the efficiency and the contamination which can be reached (see Figure 3). Above

Figure 3. $K^\pm$ tagging efficiency and contamination as a function of momentum.

Figure 4. s quark purity using single and double tag method.

18 GeV/c the pion contamination starts to be significant, and there is an evident loss in efficiency.

The obtained s tag purity and efficiency are shown in Figure 4. The double tag brings the efficiency of tagging the s quark down at the 0.55%, but allows to reach more than 65% in purity.

The analysis which exploits this technique for the $\Gamma_{s\bar{s}}/\Gamma_{had}$ measurement is in progress.

5. CONCLUSIONS

The DELPHI RICH detector proves to be an efficient tool to tag the s quark in hadronic decays of the Z gauge boson. Both single and double tag of strange hadrons have been used: a single ϕ tag for QCD studies, and the ϕ differential cross section has been extracted; a double $K^\pm$ tag is currently used for $\Gamma_{s\bar{s}}/\Gamma_{had}$ measurement.

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