Production properties of the orbitally excited mesons $f_0(980)$, $f_2(1270)$, $K_2^0(1430)$ and $f_2'(1525)$ in $Z^0$ hadronic decays

Vladimir UVAROV

Institute for High Energy Physics (IHEP), Protvino, Moscow region, Russia

DELPHI results are presented on the inclusive production of the neutral mesons $\rho^0$, $f_0(980)$, $f_2(1270)$, $K_2^0(1430)$ and $f_2'(1525)$ in hadronic $Z^0$ decays. They are based on about 2 million multihadronic events collected in 1994 and 1995, using the particle identification capabilities of the DELPHI Ring Imaging Cherenkov detectors and measured ionization losses in the Time Projection Chamber. The total production rates per hadronic $Z^0$ decay have been determined to be: $1.19 \pm 0.10$ for $\rho^0$; $0.164 \pm 0.021$ for $f_0(980)$; $0.214 \pm 0.038$ for $f_2(1270)$; $0.073 \pm 0.023$ for $K_2^0(1430)$; and $0.012 \pm 0.006$ for $f_2'(1525)$. The total production rates for all mesons and differential cross-sections for the $\rho^0$, $f_0(980)$ and $f_2(1270)$ are compared with the results of other LEP experiments and with models.

1. INTRODUCTION

At LEP it has been observed that a large fraction of primary produced particles in hadronic $Z^0$ decays are the orbitally excited states ($L=1$). For certain particles a significant disagreement with currently existing models has been observed. This is due to the fact that the physics of hadronization is not completely understood and these models cannot give sufficient guidance on possible differences in the production mechanisms of different mesons and on their dependences on spin and orbital momentum dynamics. In this view, studies of the production properties of the orbitally excited states are of particular interest.

This DELPHI analysis of the orbitally excited mesons $f_0(980)$, $f_2(1270)$, $K_2^0(1430)$ and $f_2'(1525)$ has recently been published [1] and only some key points and final results will be discussed here. Tight selection criteria were required to achieve the highest possible purities of particle identification of the DELPHI Ring Imaging Cherenkov (RICH) detectors and Time Projection Chamber (TPC). Good agreement between the data and about 3 million detector simulated hadronic $Z^0$ decays was observed.

2. RESULTS AND DISCUSSION

Figure 1 shows the final $x_p$ distributions obtained for $\rho^0$, $f_0(980)$ and $f_2(1270)$, compared to a previous DELPHI analysis [2] and to available data from ALEPH [3], OPAL [4] as well as the JETSET prediction. The previous DELPHI analysis was based on less statistics and did not apply particle identification. The DELPHI and OPAL results on the $f_0(980)$ $x_p$ spectra agree quite well. The $f_2(1270)$ $x_p$ spectra measured by DELPHI and OPAL agree in shape but differ by 1.3 standard deviations in the normalisation. The agreement
Figure 1: The differential cross-sections \((1/\sigma_h)(d\sigma/dx_p)\) for \(\rho^0\), \(f_0(980)\) and \(f_2(1270)\) mesons.

of the spectra in Figure 4 with the JETSET prediction is very satisfactory. The shapes of the \(\rho^0\), \(f_0(980)\) and \(f_2(1270)\) \(x_p\) spectra for \(x_p \leq 0.4\) appear to be approximately the same. For \(x_p > 0.4\), there is some indication that the \(f_0(980)\) and especially the \(f_2(1270)\) \(x_p\) spectra are harder than the \(\rho^0\) \(x_p\) spectrum, in agreement with JETSET expectations.

The total production rates per hadronic \(Z^0\) decay for \(\rho^0\), \(f_0(980)\), \(f_2(1270)\), \(K^*_0(1430)\) and \(f'_2(1525)\) are presented in Table 1. It is interesting to compare the total production rates of the tensor mesons with the respective rates of the vector mesons. Taking the \(K^*(892)\) and \(\phi\) total rates from [6]: \(f_2(1270)/\rho^0 = 0.180 \pm 0.035\), \(K^*_0(1430)/K^*(892) = 0.095 \pm 0.031\) and \(f'_2(1525)/\phi = 0.115 \pm 0.058\). The differences between these ratios might indicate, that this is a simple consequence of the difference in particle masses and the mass dependence of the production rates.

Table 1: The \(\rho^0\), \(f_0(980)\), \(f_2(1270)\), \(K^*_0(1430)\) and \(f'_2(1525)\) production rates extrapolated to the full \(x_p\)-range (with the combined statistical and systematic errors) and their comparison with the predictions of the thermodynamical model [5].

| Particle     | DELPHI results | Thermodynamical model |
|--------------|----------------|-----------------------|
| \(\rho^0\)   | 1.19 ± 0.10    | 1.17 ± 0.05           |
| \(f_0(980)\) | 0.164 ± 0.021  | 0.0772 ± 0.0076       |
| \(f_2(1270)\)| 0.214 ± 0.038  | 0.130 ± 0.015         |
| \(K^*_0(1430)\)| 0.073 ± 0.023  | 0.0462 ± 0.0041       |
| \(f'_2(1525)\)| 0.012 ± 0.006  | 0.0107 ± 0.0007       |

This suggestion is supported by Figure 2, where the total rates measured by DELPHI for the \(f_0(980)\), \(\rho^0\), \(K^*(892)\), \(\phi\), \(f_2(1270)\), \(K^*_0(1430)\) and \(f'_2(1525)\) are plotted as a function of
their mass squared. Anti-particles are not included in the $K^{*0}(892)$ and $K_2^{*0}(1430)$ rates. Both the scalar and vector data points and the tensor data points are well described by exponentials of the form $Ae^{-BM^2}$ (dashed lines). Figure 2 also shows that the mass dependence of the production rates is almost the same for three sets of data points: $\rho^0$ and $f_2(1270)$; $K^{*0}(892)$ and $K_2^{*0}(1430)$; $\phi$ and $f'_2(1525)$. These points are well fitted to the exponentials $Ae^{-BM^2}$ (solid lines), with three different normalisation parameters $A$ but the same slope parameter $B$. Thus the relation between the production rates of tensor and vector mesons indeed appears to be very similar for different particles if the mass dependence of these production rates is taken into account.

The total production rates of the tensor mesons $f_2(1270)$, $K_2^{*0}(1430)$ and $f'_2(1525)$ are found to be rather small in absolute value, when compared with the vector meson production rates. This agrees with common expectations that the production of orbitally excited states is suppressed. However, recently it was noticed [7] that the production rates of orbitally excited mesons are larger by factor of 5 than those of states with no orbital momentum if the universal mass dependence of the production rates for the pseudoscalar and vector mesons and the octet and decuplet baryons is accounted for.

Another indication for the excess of orbitally excited mesons can be seen from Table 1, where a comparison of the data with the recently proposed thermodynamical model [5] is presented. This model provides a very good description of the total production rates for the pseudoscalar and vector mesons and for the octet and decuplet baryons. This is illustrated in Table 1 by a very good agreement between the model prediction and the data for the $\rho^0$. However, comparison of the model predictions with the present DELPHI results for the total production rates of orbitally excited mesons indicates that the model underestimates their yields by about the same factor of 1.6–2.1, except for the $f'_2(1525)$, where the experimental uncertainties are quite large.

![Figure 2: The production rates of the scalar, vector and tensor mesons measured by DELPHI as a function of their mass squared.](image)

![Figure 3: The weighted production rates of the scalar, vector and tensor mesons measured by LEP as a function of their mass.](image)

The large excess of orbitally excited mesons with respect to the vector mesons can be explained by introducing the extra suppression factor $2^{-k}$, where $k$ is the number of $s$ and $\bar{s}$ quarks in the meson, as well as the spin factor $2J + 1$. This is seen from Figure 3 where the total production rates of the orbitally excited [1,4,8,9] and vector (see [7] and
references therein) mesons averaged from all available LEP measurements and weighted with factor $2^k (2J + 1)^{-1}$ are shown as a function of their mass. All data points are well described ($\chi^2/ndf=4.8/7$) by exponential of the form $2^k (2J + 1)^{-1} (n) = Ae^{-bM}$, with the parameters $A = 17.8 \pm 3.9$ and $b = 4.85 \pm 0.24$ (GeV/$c^2$)$^{-1}$. Thus there is no excess of orbitally excited mesons with respect to the vector mesons, if the dependence of their production rates on mass ($M$), spin ($J$) and number of $s$ and $\bar{s}$ quarks ($k$) is accounted for.

3. SUMMARY

The DELPHI results [1] on inclusive production of the $\rho^0$, $f_0(980)$, $f_2(1270)$, $K_2^*(1430)$ and $f_2'(1525)$ in hadronic $Z^0$ decays at LEP have been presented. They are based on a data sample of about 2 million hadronic events, using the particle identification capabilities of the RICH and TPC detectors, and supersede the previous DELPHI results [2], with which they are consistent. The following conclusions can be drawn.

- The total $f_0(980)$ and $f_2(1270)$ production rates per hadronic $Z^0$ decay are $0.164 \pm 0.021$ and $0.214 \pm 0.038$ respectively. The $f_0(980)$ and $f_2(1270)$ momentum spectra are well described by the tuned JETSET model. The shapes of the $f_0(980)$ and $f_2(1270)$ momentum spectra are similar to that for the $\rho^0$ for $x_p \leq 0.4$. For higher $x_p$ values there is some indication that the ratios $f_0(980)/\rho^0$ and especially $f_2(1270)/\rho^0$ may increase with $x_p$, in agreement with JETSET expectations. The total $f_0(980)$ and $f_2(1270)$ rates and their momentum spectra are consistent with the OPAL measurements [4].

- The total $K_2^*(1430)$ and $f_2'(1525)$ production rates per hadronic $Z^0$ decay amount to $0.073 \pm 0.023$ and $0.012 \pm 0.006$ and are about half the size of the rates predicted by the tuned JETSET model. The total $K_2^*(1430)$ rate is smaller by 1.8 standard deviations than the value $0.238 \pm 0.088$ measured by OPAL [8] for $x_E \leq 0.3$ and extrapolated by us to the full $x_E$ range.

- The ratios $f_2(1270)/\rho^0$, $K_2^*(1430)/K^*(892)$ and $f_2'(1525)/\phi$ are $0.180 \pm 0.035$, $0.095 \pm 0.031$ and $0.115 \pm 0.058$ respectively. They appear to be somewhat different. However, the relationships between the production rates of the tensor and vector mesons for the $f_2(1270)$ and $\rho^0$, $K_2^*(1430)$ and $K^*(892)$, $f_2'(1525)$ and $\phi$ are found to be very similar when the mass dependence of the production rates is accounted for.

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