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Observation of semileptonic B_s decays in the decay mode $B_s \to D_s^+ \ell^- \nu$ with $D_s^+ \to \Phi\pi^+\pi^0$

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Abstract

The B_s meson is observed via the decay channel $B_s \to D_s \ell\nu$ and $D_s \to \Phi\pi\pi^0$. After background subtraction, 14.2 $\pm$ 5.8(stat.) $\pm$ 1.1(syst.) B_s have been found in a sample of about 1.64 million hadronic Z^0 decays collected by ALEPH during 1991, 1992 and 1993 data taking. Monte Carlo studies show that the decay length and the boost resolutions are good enough to use these events in lifetime and oscillation measurements.

1 Introduction

Since the decay mode $D_s \rightarrow \Phi\pi\pi^0$ has a rather large branching ratio, (8 ± 4) % [1], one could expect to observe a signal with the 1991-1993 ALEPH data. On the other hand the amount of background will be important. The background is mainly due to the combinatorial background and to the fake π^0 reconstructions. In addition there is the usual physical background from D_s produced in B mesons disintegration ($B \rightarrow D_s^{(*)}\bar{D}^{(*)}$ X in which the lepton is coming from the $\bar{D}^{(*)}$ by $c \rightarrow \ell$). Furthermore it would be interesting to observe a signal also in view of measuring the B_s meson oscillation parameter x_s, via the $D_s - \ell$ events, in order to increase the statistics which are the limiting factor of this $D_s - \ell$ analysis.

To calculate the efficiency of this analysis we have used about 5000 Monte Carlo $b\bar{b}$ events with at least one B_s per event decaying semileptonically in D_s. The D_s is then forced to go in $\Phi\rho$ and the ρ in $\pi\pi^0$.

2 Selection

Events with VDET fully operational have been selected. Within this sample of events, leptons have been searched for as described in [2] adding a cut at 3 Gev for the electrons also. To select the D_s, the following set of cuts has been applied:

- Φ selection: The Φ is reconstructed via the K^+K^- decay mode. Two charged tracks with opposite charge and momentum greater than 200 MeV are searched for. In order to select kaons the quantity $(\chi_K + \chi_\pi)$, where $\chi_i = \frac{(I^{meas} - I_i^{th})}{\sigma}$, is required to be lower than 1, if the dE/dx information is available. The momentum of the reconstructed Φ candidates, formed combining these two kaons, is required to be at least 5 GeV and its mass is required to be within 9 MeV of the known Φ mass.

- The π is selected as a charged track with a momentum greater than 1 GeV.

- The π^0 is selected using the QPI0DO package. In addition, to clean the selected π^0 sample, the photons combined to reconstruct the π^0, are required to have some energy in the first stack of ECAL, and a momentum greater than 0.5 GeV. The momentum of the π^0 is required to be greater than 2 GeV.

- To form the D_s, the Φ and the π are vertexed using YTOP while the π^0 is simply added after that. The vertex probability is required to be greater than 1%. To increase the purity of the selected sample we ask that $X(D_s) > 0.3$, where $X(D_s) = \frac{P_{D_s}}{E_{beam}}$. Finally, to improve the B_s decay length resolution, at least two of the three charged tracks used to form the D_s are required to have at least one VDET hit.

Once selected, the lepton and the D_s candidates are vertexed to form the B_s vertex. Also for the lepton we ask for at least one hit in VDET. To reduce the fraction of D_s coming from B the $D_s - \ell$ invariant mass is required to be greater than 3.5 GeV and $X(B_s)$ is required to be greater than 0.55, where $X(B_s) = \frac{P_{D_s-\ell}}{E_{beam}}$. These two cuts retain the 30 % of the signal while rejecting the 87 % of the background D_s coming from B.
The efficiency for this set of cuts is 1.8 $\pm$ 0.2 % while for the background $B \to D_s^{(*)}\bar{D}^{(*)}X$ it is estimated to be 0.4 $\pm$ 0.2 %.

3 Results

The $\Phi\pi\pi^0$ invariant mass distribution for the right (opposite) and wrong (same) sign combinations is shown in figure 1a. After fixing the width accordingly to the Monte Carlo (29 MeV) the D_s mass is found to be 1959 $\pm$ 14 MeV in agreement with the value predicted by the Monte Carlo ($M_{D_s}^{MC}$ = 1970$\pm$4 MeV). The number of events found in the peak is 16.1 $\pm$ 5.7. Taking $Br(B \to D_s^{(*)}\bar{D}^{(*)}X)Br(D \to \ell\nu X) = 2.2 \pm 0.5$ % we evaluate, after background subtraction, that the number of B_s found is 14.2 $\pm$ 5.8 (stat.) $\pm$ 1.1 (syst.) where the systematic uncertainty includes the errors on $Br(D_s \to \Phi\pi\pi^0)$ and on $Br(B \to D_s^{(*)}\bar{D}^{(*)}X)Br(D \to \ell\nu X)$. The fraction of signal events found in the peak region ($M_{D_s} \pm 2\sigma$) is $f_s = \frac{14.2}{28} = 51\%$.

We have tried also to add a cut on the $\pi\pi^0$ invariant mass (figure 2) requiring the presence of a ρ. In particular we have required the mass of this combination to be within $M_\rho \pm 150$ MeV of the ρ mass [1] and the momentum to be greater than 5 GeV. After adding these cuts the efficiency goes to 1.5 $\pm$ 0.2 %.

In figure 1b are shown the distributions obtained for the right and the wrong sign correlations. We find, after background subtraction, 11.6 $\pm$ 4.6 (stat.) $\pm$ 0.8 (syst.) B_s mesons. The fit has been done fixing the width to 27 MeV as the Monte Carlo predicts. The mass is found to be 1955 $\pm$ 13 Mev, which is compatible with the D_s mass predicted by simulation ($M_{D_s}^{MC} = 1972 \pm 4$ MeV). In this case the fraction of signal events is $f_s = \frac{11.6}{20} = 58\%$.

Fixing the mass to the known value [1], the number of events found in the peak does not change for both the studied cases (15.5 $\pm$ 5.7 and 13.4 $\pm$ 4.8 respectively).

In figure 3 are shown the plots of the decay length and the boost [1] resolutions for both the cases described above (without and with the ρ cut). Looking at the pull of the decay length resolution (figure 3a) we found that without cutting on the ρ the 87% of the events is contained within a gaussian centered at zero (-0.17 $\pm$ 0.10) and of sigma 1.07 $\pm$ 0.08. In figure 3b is shown the same distribution for events passing the ρ cut. We found in this case that the 94% of events is inside

[1]The momentum of the B_s has been reconstructed as explained in [3]

a gaussian of mean -0.23 $\pm$ 0.12 and sigma 1.08 $\pm$ 0.10. Both these results are compatible with [3]. Also the results found for the κ factor distributions plotted in figure 3c and d are compatible with the values reported in [3]. We found for both studied cases that about the 95 % of events are within a gaussian centered at 1 (1.019 $\pm$ 0.007 and 1.023 $\pm$ 0.009) and of sigma of about 10% (0.08 $\pm$ 0.01 for both).

4 Conclusion

A signal of 14.2 $\pm$ 5.8 (stat.) $\pm$ 1.1 (syst.) events attributed to decay $B_s \rightarrow D_s^{(*)-}\ell^+\nu$ with $D_s \rightarrow \Phi\pi\pi^0$ has been seen. Maybe also a signal of 11.6 $\pm$ 4.6 (stat.) $\pm$ 0.8 (syst.) events due to the same B_s decaying channel with $D_s \rightarrow \Phi\rho$ has been detected. These events could be used for B_s lifetime and $B_s - \bar{B}_s$ time dependent mixing measurements since it has been shown, by Monte Carlo studies, that the decay length and the boost resolution are similar to what obtained for $D_s - \ell$ with $D_s \rightarrow \Phi\pi$ events.

References

[1] Particle Data Group: Phys. Review D50 Part I (August 1994)

[2] Heavy quark tagging with leptons in the ALEPH detector, Aleph Coll. NIM A 364 (1994) 461-475

[3] Measurement of the B_s^0 lifetime, ALEPH Coll. Phys. Lett. B322 (1994) 275, and the Aleph note, ALEPH 93-116

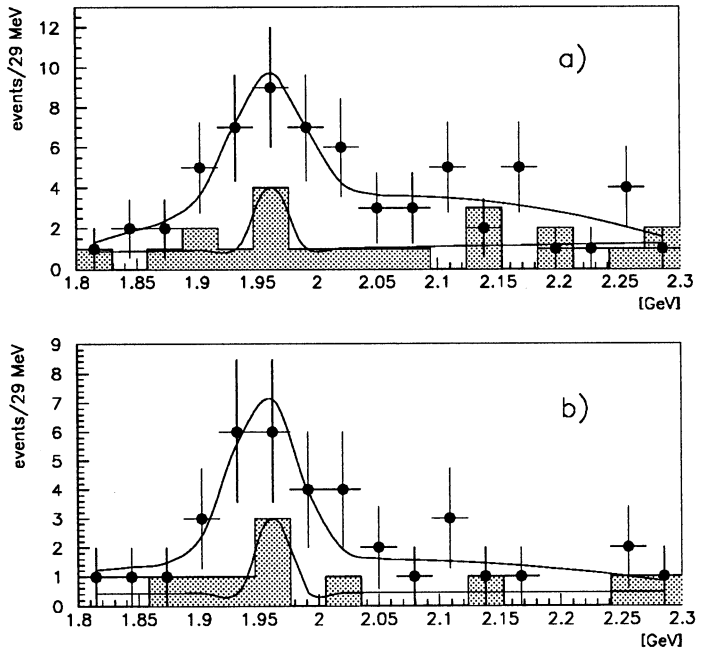

Figure 1: $\Phi\pi\pi^0$ invariant mass distribution. The points shows the right sign ($D_s^+ - \ell^-$, $D_s^- - \ell^+$) correlations while the shaded histogram represents the wrong sign combinations. The solid line shows the result of a fit to a second order polynomial for the background and a gaussian for the signal with the width fixed to the value predicted by the simulation (29 MeV). In figure a) and b) are plotted the distributions before and after the ρ cut, respectively.

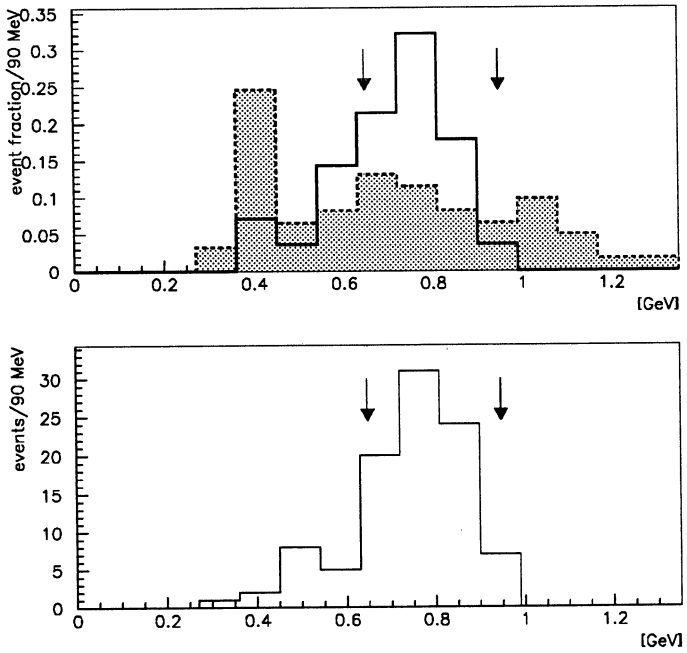

Figure 2: $\pi\pi^0$ invariant mass distribution. (a) The white area is referred to the events in the D_s peak ($M_{D_s} \pm 2\sigma$) while the shaded histogram refers to all the events found outside this region in figure 1a. (b) Monte Carlo distribution.

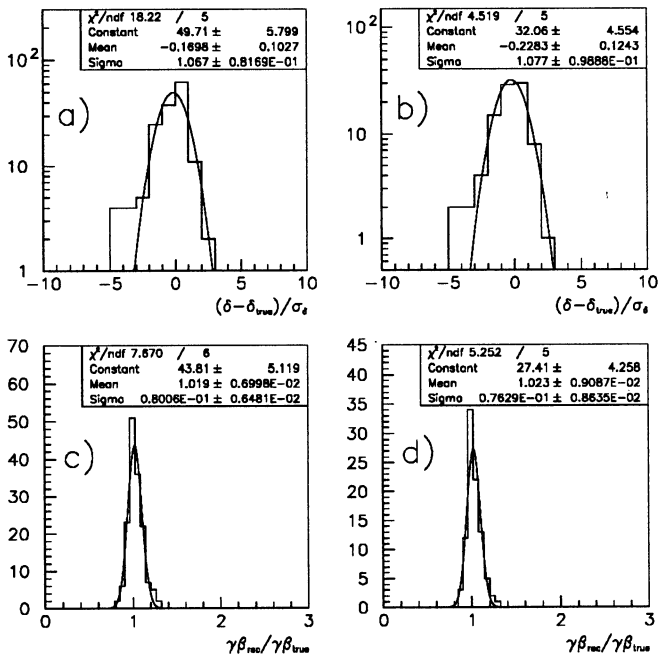

Figure 3: a) pull on the $D_s - \ell$ decay length resolution b) pull on the $D_s - \ell$ decay length resolution for the events passing the ρ cut c) reconstructed B_s boost d) reconstructed B_s momentum for the events passing the ρ cut.