MEASUREMENT OF THE B_d^0 MESON OSCILLATION FREQUENCY USING DILEPTON EVENTS WITH THE L3 DETECTOR

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As in the case of K-mesons, oscillations between particle–antiparticle states are expected in the system of neutral B-mesons.In the Standard Model, mechanism of mixing is a second order weak interaction through the box diagrams. Neglecting effects from the CP– violation (expected to be small) the probability to find B_d^0 decaying at proper time t, provided it was produced as $\bar{B}_d^0$ at $t = 0$, is given by

$$P(\bar{B}_d^0 \rightarrow B_d^0) = \frac{1}{\tau} e^{-\frac{t}{\tau}} \left(\frac{1 - \cos \Delta m_d t}{2} \right)$$

Then a measurement of the oscillation frequency gives a direct determination of the mass difference Δm_d between two physical states (τ is the life time of B-meson).

Here we present measurement of B_d^0 oscillation frequency with L3 detector. For this study we use dileptons in opposite hemispheres to tag the flavour of B–particle at production and decay time. Then the signature of mixing is the presence of the same sign pairs of leptons corrected for the background contribution. Proper time is measured by reconstructing secondary vertices. The dilepton sample corresponds to about 1507,000 hadronic Z^0-decays recorded in 1994 with L3 detector. Events are classified as dilepton ones if there is at least one lepton candidate in each thrust hemisphere. If there are several lepton candidates in the same hemisphere, only one with highest momentum is taken for further analysis (sign of charge and secondary vertex reconstruction).

To get decay length of B–hadron candidate one need to estimate the primary and decay (secondary) vertex positions. Vertexing is performed in the $r - \phi$ plane, and the direction of the jet containing lepton is used to get 3D-decay length. For vertexing, a subsample of good tracks is selected. We exclude badly reconstructed tracks, tracks with a small curvature and tracks from decays of long–lived particles. Also requirement on the number of hits and their spanning insures that tracks are passing through the sensitive volume of the microvertex detector (SMD). It gives in average 17 tracks in a dilepton hadronic event.

First of all, a primary vertex is reconstructed by an iterative procedure starting from the known average position of the collision point. Lepton candidates are excluded from the primary vertex reconstruction. For the primary vertex reconstruction only tracks with SMD inner φ-layer information are considered. Then the tracks with significantly big deviation from the candidate vertex are excluded. We require at least three tracks for the primary vertex reconstruction and this gives efficiency of 95%. Resolution for the primary vertex reconstruction for $b\bar{b}$-events described by a two-Gaussian fit gives 60 μm and 220 μm for widths of Gaussians and 84% of entries belong to the narrow Gaussian.

The secondary vertex reconstruction is performed for each lepton. Tracks from the same jet of the lepton which were not included into the primary vertex calculation are selected for the secondary vertex reconstruction.The lepton is always the secondary vertex track. With this approach we combine tracks from decay of B-particle and tracks from subsequent decays of B-particle decay products into one vertex. With a three-Gaussian fit we have 300 μm, 860 μm and 4.5 mm for a decay-length resolution with corresponding fractions of 0.39 ,

0.36 and 0.25. The reconstructed B-decay length has a bias to the higher decay lengths as the secondary vertex calculation includes tracks from the decay products of B-particle. This shift is compensated later on in the calculation of the proper time by assigning higher average momentum to the b-quark fragmentation. At least two tracks are required for the secondary vertex reconstruction and in average 2.9 tracks take part in the calculation of the B-decay vertex position. The efficiency of reconstructing the secondary vertex is 70 % and has a drop for the small decay lengths (close to the primary vertex).

The decay-length resolution is independent of the decay position while resolution on the proper time is a linear function of time as it should be since $t = l/\gamma\beta = lm_B/p_B$. Here t is the proper time, l is the decay length, m_B and p_B are the mass and momentum of B-particle. For the momentum of B-particle we have used estimation $P_B = 0.85P_{beam}$. Such an estimate of B-particle momentum optimises our resolution on the proper time and eliminates shift to the higher reconstructed times coming from the decay length reconstruction. An average resolution on the proper time with parametrization by three Gaussians has Gaussian sigmas of 0.3, 1.0 and 3.5 ps, and corresponding fractions are 0.46, 0.40 and 0.14.

The maximum likelihood method is used to fit the selected sample. The likelihood function is constructed for the like– and unlike–sign events. The total likelihood $\mathcal{L}$ for the full event sample is calculated as a product of likelihood functions $\mathcal{L}_{like}$ or $\mathcal{L}_{unlike}$ for each event and unbinned maximum likelihood fit is performed to extract the studied quantity. For the fit of B^0_d - $\bar{B}^0_d$ oscillation frequency, dilepton events with at least one proper time measured were selected. Additional quality cuts for the decay length measurement were applied. We required the error estimate on the decay length reconstruction to be less than 1 mm and, negative (due to resolution) values of the decay lengths should be not far than 3 sigma away of the primary vertex. Finally, for unbinned maximum likelihood fit 1107 (1340) dilepton events were selected with 1429 (1862) secondary vertices reconstructed. Shown in the brackets is quoted corresponding statistics without applying the decay-length reconstruction quality cuts. There are 483 reconstructed vertices in the like-sign events and 946 in the unlike-sign ones. To find Δm_d a four parameter fit was performed. Fitted parameters are $\Delta m_d, f_d, f_s, f_{bcl}$ where f_d and f_s are the fractions of B^0_d and B^0_s mesons in thr sample and f_{bcl} is the cascade decay fraction ($b \to c \to l$, $b \to \bar{c} \to l$, $b \to J/\Psi \to l^+l^-$). Oscillation frequency Δm_d is a free parameter, and for the last three parameters Gaussian constraints are applied with the following central values and ranges: $f_d = 0.384 \pm 0.03$, $f_s = 0.102 \pm 0.031$, $f_{bcl} = f^{MC}_{bcl}(1.0 \pm 0.15)$ where f^{MC}_{bcl} is the relative fraction of cascade decays as derived from a Monte Carlo calculation and the value for B^0_s fraction in $b\bar{b}$ events f_s is fixed to the world average derived from time integrated mixing measurements. In the case when a hemisphere has a decay time measurement, the Monte Carlo calculation shows 8% increase for the fraction of B^0_d-mesons (f_d) and 8% decrease for the fraction of B^0_s-mesons (f_s). This correction is applied in the fit. The result of the fit is the following

$$\Delta m_d = 0.473 \pm 0.066 \text{ ps}^{-1}$$

The error of Δm_d includes the statistical error as well as the contribution from systematic errors of fitted fractions. To determine the systematic error, we fixed all fitted fractions to

their fitted values and repeated the fit. This has given

$$\Delta m_d = 0.473 \begin{smallmatrix} +0.055 \\ -0.052 \end{smallmatrix} \text{(stat.)ps}^{-1}$$

for the statistical error estimate. Besides cascade decay fraction, the variation of the other fractions was ±30% for *fake* leptons and $c\bar{c}$ events and ±50% for light quarks events other than $c\bar{c}$. B-meson life time was fixed to the world average value $\tau_B = 1.57 \pm 0.05$ ps. In total the systematic error for Δm_d from all studied sources is $\begin{smallmatrix} +0.046 \\ -0.049 \end{smallmatrix}$ ps^{-1}.

The measurements of Δm_d are stable within errors to the P_t cut, and the best sensitivity was found for the cut value of 1 GeV. The fit to the Monte Carlo results gives $\Delta m_d = 0.438 \pm 0.044$ ps^{-1} and well reproduces the input Monte Carlo value of 0.452 ps^{-1}.

The fraction of the like–sign leptons is plotted in Fig. as a function of the proper time. Individual contributions to the plot from the different sources are shown on the same plot.

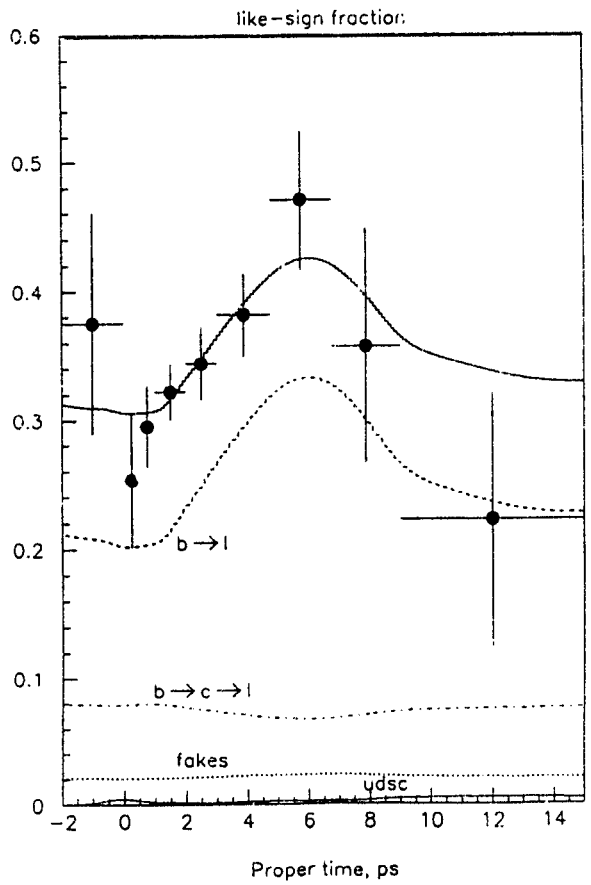

Fig. Fraction of the same–sign dilepton events and individual contributions of different sources of such events versus reconstructed decay proper time

REFERENCE

1. *Andreev V.P., Banicz K., Pinto J.C., Pohl M.* L3/Internal note 1913, February 1996 .