Search for Violation of CPT and Lorentz invariance in B_s^0 meson oscillations

(The D0 Collaboration)
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AUXILIARY MATERIAL

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I. COORDINATE SYSTEM

We choose (T, X, Y, Z) as coordinates in the standard Sun-centered frame with T being the time coordinate, the rotation axis of the Earth taken as the choice for the Z-axis and $X(Y)$ is at right ascension 0° (90°) (c.f. Ref. [7] of the paper). This coordinate system is illustrated in Fig. 1.

II. MEASURED ASYMMETRIES

The measured asymmetries, $A(i)$, used to extract the limits are given in Table I.

TABLE I. The measured asymmetries, $A(i)$ versus sidereal phase. The uncertainty on each value of $A(i)$ is the sum in quadrature of the statistical and systematic uncertainties.

Asymmetry	Sidereal Phase	Value (%)
$A(1)$	$0 \rightarrow (2\pi)/11$	$+0.74 \pm 1.03$
$A(2)$	$(2\pi)/11 \rightarrow 2(2\pi)/11$	$+0.15 \pm 1.03$
$A(3)$	$2(2\pi)/11 \rightarrow 3(2\pi)/11$	-0.20 ± 1.02
$A(4)$	$3(2\pi)/11 \rightarrow 4(2\pi)/11$	$+0.23 \pm 1.01$
$A(5)$	$4(2\pi)/11 \rightarrow 5(2\pi)/11$	-0.86 ± 1.02
$A(6)$	$5(2\pi)/11 \rightarrow 6(2\pi)/11$	-1.14 ± 1.02
$A(7)$	$6(2\pi)/11 \rightarrow 7(2\pi)/11$	-0.45 ± 1.02
$A(8)$	$7(2\pi)/11 \rightarrow 8(2\pi)/11$	-1.93 ± 1.03
$A(9)$	$8(2\pi)/11 \rightarrow 9(2\pi)/11$	-0.55 ± 1.03
$A(10)$	$9(2\pi)/11 \rightarrow 10(2\pi)/11$	-1.11 ± 1.03
$A(11)$	$10(2\pi)/11 \rightarrow (2\pi)$	$+0.68 \pm 1.03$

III. PERIODOGRAM ANALYSIS

As a cross check to fitting the data for a periodic signal, we also use the periodogram [18] method to measure the spectral power of a signal over a large range of frequencies. The spectral power at a test frequency ν is

$$P(\nu) \equiv \frac{\left| \sum_{j=1}^{N} w_j \exp\left(-2\pi i \nu \hat{t}_j\right) \right|^2}{N\sigma_w^2}, \tag{1}$$

where the data has N measurements each of weight w_j where the weight is the probability that the event is a signal event with a variance σ_w. The weight for each event depends on $Q_j \cos\theta_j$, and $M(K^+K^-\pi^\pm)$ for the event and is based on the fit to Eq. 7: $w_j = Q_j \cos\theta_j W_{D_s}[M(K^+K^-\pi^\pm)]/W_{\text{sum}}[M(K^+K^-\pi^\pm)]$. In the absence of an oscillatory signal, the probability that $P(\nu)$ at frequency ν would exceed an observed value S is $P(\nu) > S = \exp(-S)$.

The spectral power of this data sample is $P(\text{one sidereal day}) = 0.65$. The probability of obtaining a value of P greater than this is 52% which is consistent with no signal. The spectral power values for periods from 0.5 to 1.5 solar days in steps of 1 solar day/1000 are shown in Fig. 2. Sixty percent of these measurements are greater than the spectral power at one sidereal day. The 95% UL is obtained by injecting simulated signals into the data and determining the probability distribution of the spectral power as a function of the injected signal A_1. The resulting 95% UL on A_1 is 1.03%. This converts to a 95% UL of $\Delta a_\perp < 6.9 \times 10^{-13}$ GeV which is comparable to that obtained from the analysis of the amplitudes.

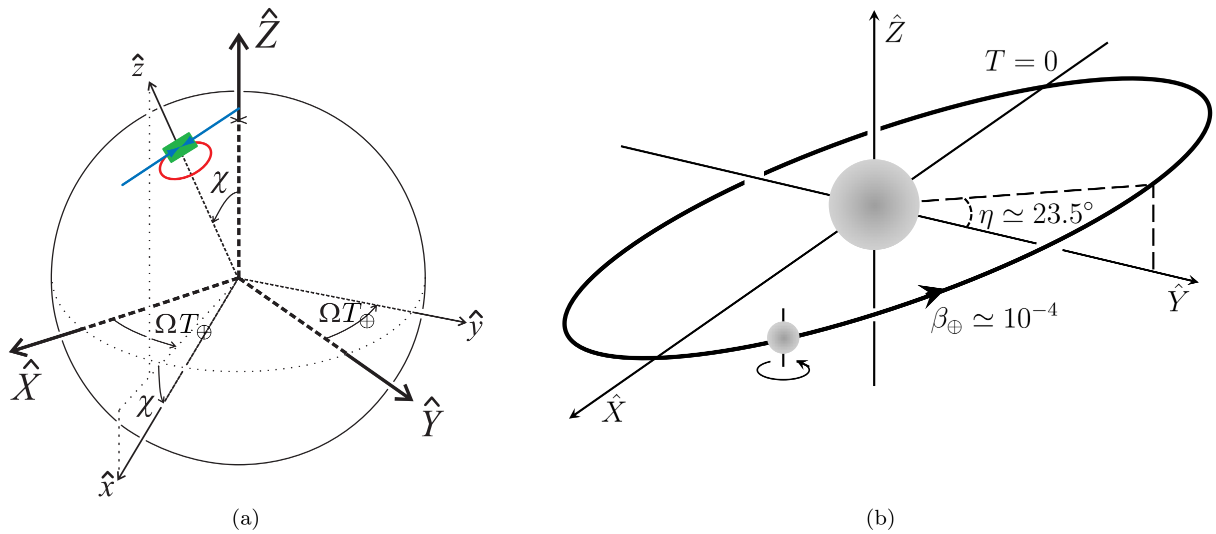

FIG. 1. Illustrations of the coordinate systems used in this analysis. (a) The small rectangle represents the position of the D0 detector on the earth. (b) Orbit of Earth in Sun-based frame (based on Fig. 1 from Ref. [7]).

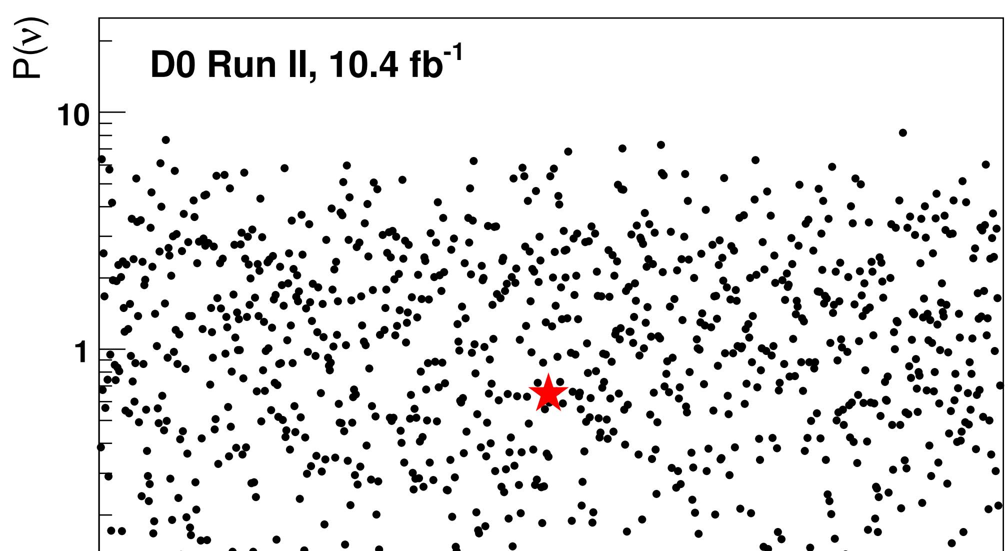

FIG. 2. The periodogram for the B_s^0 data sample over the range of 0.5 days to 1.5 days in steps of (1 day/1000). The red star indicates the spectral power calculated at one sidereal day.