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Measurement of the tau lepton lifetime

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HRS COLLABORATION

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Abstract

We report the measurement of the lifetime of the tau lepton. This measurement was made using the HRS spectrometer at PEP, operating at 29 GeV. The 3 prong decay vertices were measured using a four layer tubular cell vertex chamber. The lifetime of the tau was determined to be $\tau_{tau} = .28 \pm .02 \pm .03$ ps.

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The lifetime of the tau lepton has been measured by several groups at e^+e^- storage rings. [1 2] A precise measurement of this lifetime is an important check of $e^-\mu - \tau$ universality. The tau lifetime is predicted to be

$$\tau_{tau} = \tau_\mu (mu/m_\tau)^5 \beta_e = 2.8 \pm x10^{-13} s,$$

where τ_μ and m_μ are the muon lifetime and mass, and β_e is the tau branching ratio to $e\nu\bar{\nu}$, taken to be $\beta_e = 0.18 \pm 0.02$. We report a measurement of the lifetime of the tau based on a determination of the three track vertex distribution. For this measurement a vertex chamber was used along with the existing HRS detector. Details of the HRS detector are given elsewhere. [3] The vertex chamber consists of two double cylindrical layers of aluminized, mylar tubes. [4] The inner layer of the vertex chamber is approximately 0.09m from the interaction point. The outside layer is at a radius of 0.11 m. Altogether there are 352 tubes. The intrinsic resolution is 100μ. The tracking was done in a 1.62 T field over a radial length of 1.9 m. The technique of measuring the decay distance of the tau requires a detailed knowledge of the beam position for each event. The average beam center was located for each run by using all of the tracks in the combined wide angle Bhabha events. The typical statistical error in the average beam position was $< 50\mu$ horizontally and $< 30\mu$ vertically. The beam size was determined by using the impact parameter distributions for horizontal and vertical Bhabha tracks. The effective beam size was $\sigma_x = 350\mu$, $\sigma_y = 90\mu$. These numbers include effects due to movements of the beam during the run and small misalignments between the drift chambers.

Tau events with a 1-3 prong decay configuration were used for this lifetime measurement. They correspond to a data sample with a total integrated luminosity of $200pb^{-1}$. The detailed event selection criteria were the same as those used in our previous tau publications. [5 6] With these criteria we obtained 1632 candidate events. The hadronic contamination was estimated to be $< 5\%$. A typical event is shown in Figure 1a,b,c. Several additional cuts were imposed to ensure track quality and reduce systematic bias. Each of the 3 prong tracks was required to have at least

three hits in the vertex chamber. Events were removed if any of the three prong tracks shared one or more hits in the vertex chamber with any other reconstructed track. With these cuts we were left with 768 events. This rather severe restriction is necessary in order to eliminate the possibility of tracking confusion within a single vertex chamber cell, which can preferentially produce detached vertices and a longer apparent lifetime. For each event the vertex of the 3 prong decay was calculated by a least squares fit to a common point. The most probable decay distance from the beam center was then determined. [7] Events with a decay distance error greater than 1.5 mm were rejected, and a chi-squared cut of 5 per degree of freedom was imposed on the vertex fit. This reduced the tau sample to 626 events. The decay distribution and error distributions are shown in Figure 2a,b. The proper lifetime distribution of the tau lepton was then calculated from the decay distribution using the radiatively corrected average momentum of 13.7 GeV/c. This proper lifetime distribution is shown in Figure 3. The proper time distribution was then fitted using a maximum likelihood technique. An exponential decay distribution was convoluted with a normal distribution, with a width characteristic of each event. The resulting best fit to the proper lifetime is

$$\tau_{tau} = .28 \pm .02 \pm .02\text{ps}.$$

We estimate the systematic errors to be 0.02 ps, based on a variational study of our cuts and tracking errors. The best fit lifetime agrees with previous measurements and with $e-\mu-\tau$ universality. We hope to augment this sample in the near future by relaxing certain restrictions.

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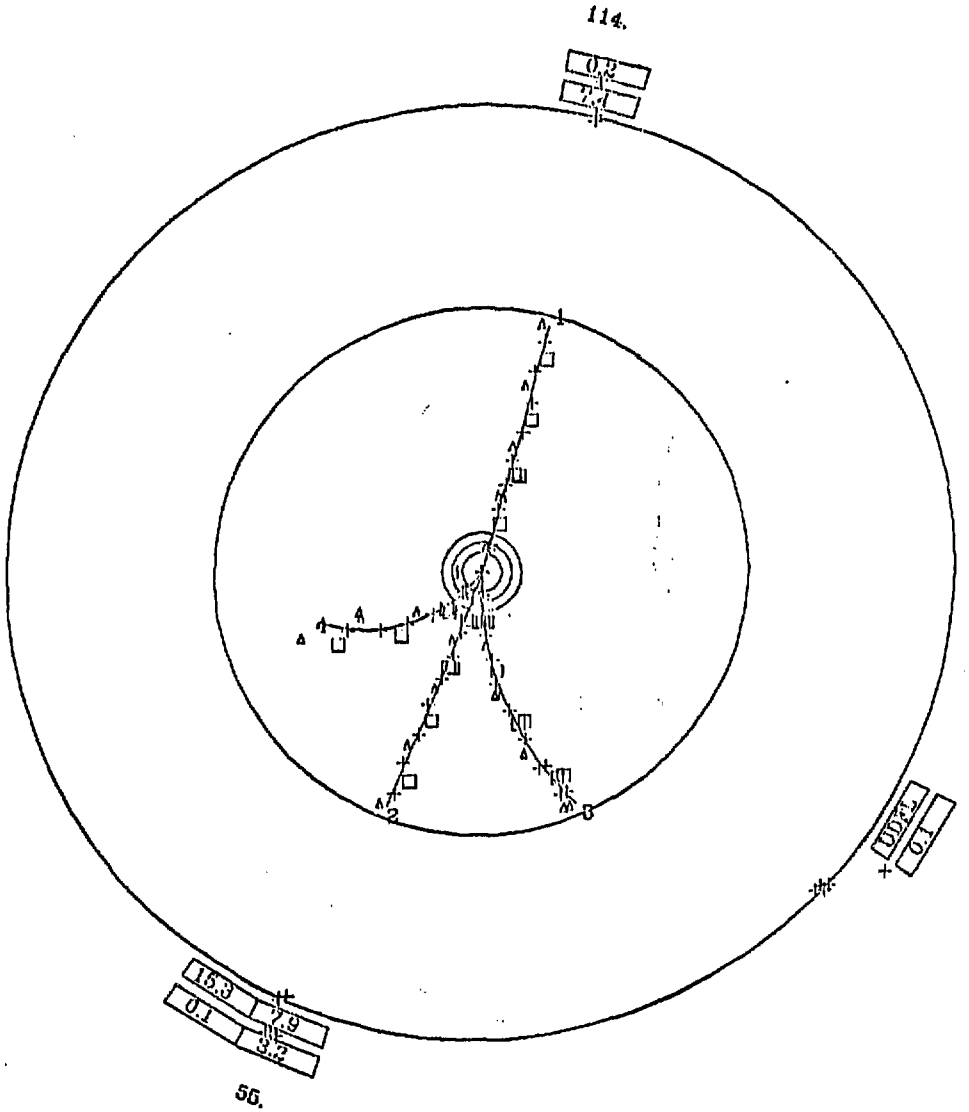
2. W.T. Ford et al., Phys. Rev. Lett. 49 (1982)106
3. D. Bender et al., Phys. Rev. D30 (1984)515
4. D. Rust, SLAC-PUB3311
5. K.K. Gan et al., Phys. Lett. 153B(1985)116
6. E. Beltrami et al., Phys. Rev. Lett. 54(1984)16
7. The most probable decay distance is the weighted distance between the vertex and the average beam center. For a precise definition see Amidie, LBL#17795, PhD thesis.

FIGURE CAPTIONS

1. a) A tau decay into 1-3 prongs is shown in the HRS central drift chamber. b) A view of the tracks in the vertex chamber. c) The extrapolated tracks near the interaction point (circle). A 1 mm grid is indicated.
2. a) The tau decay distance distribution. b) The error distribution of the tau decay length.
3. The tau proper lifetime distribution.



H R S RUN=8411

EVENT= 2994
DCHITS = 97
NPRNG = 4
SH SUM= 3.5 + 0.0

TRACK	MOMENTUM	THETA
1	−10.2	114.2
2	6.1	54.8
3	−0.7	55.5
4	0.6	29.2

TRIG.= F2 F3 S6 A2 D1 D2

Fig. 1a

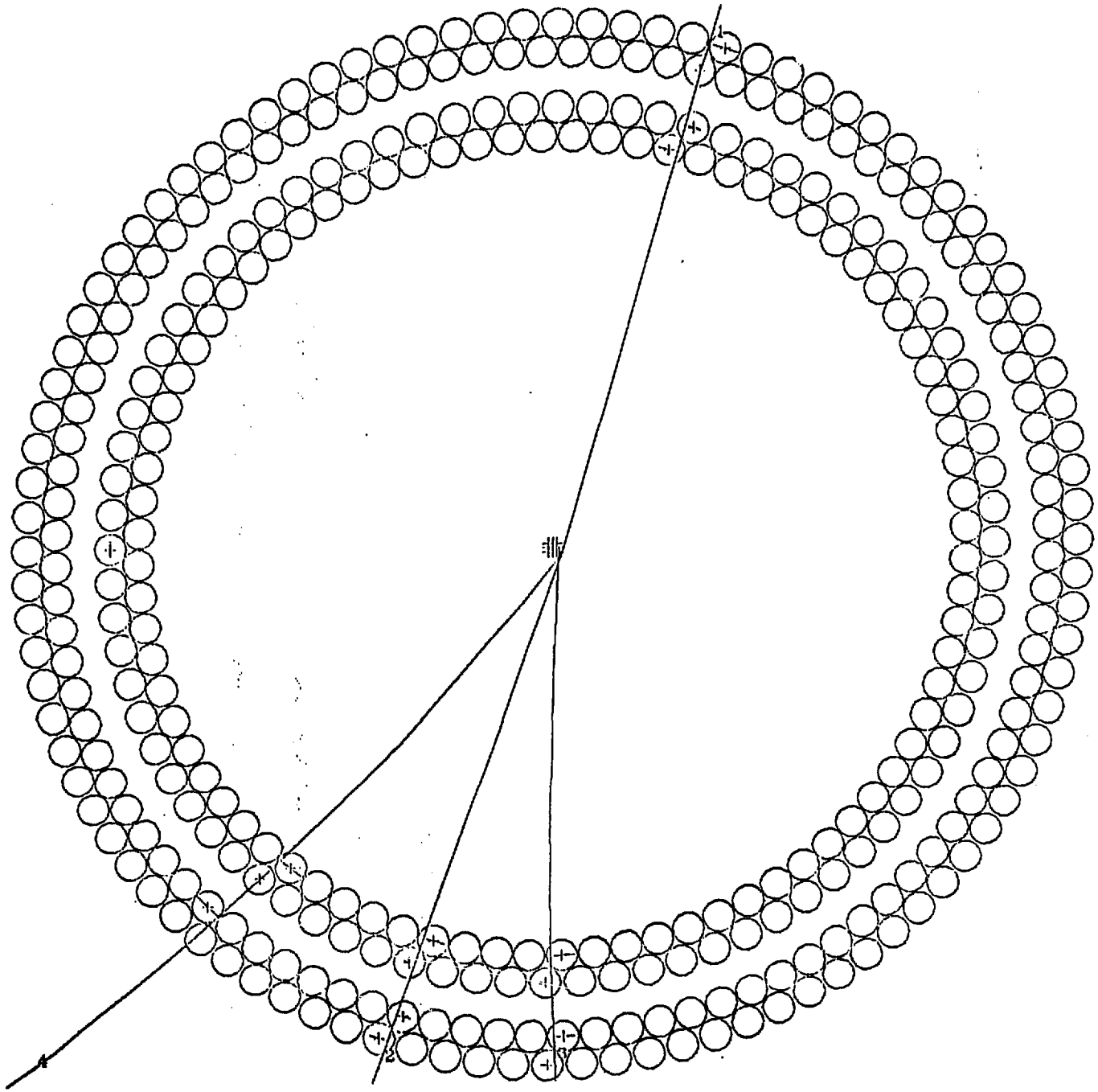


Fig. 1b

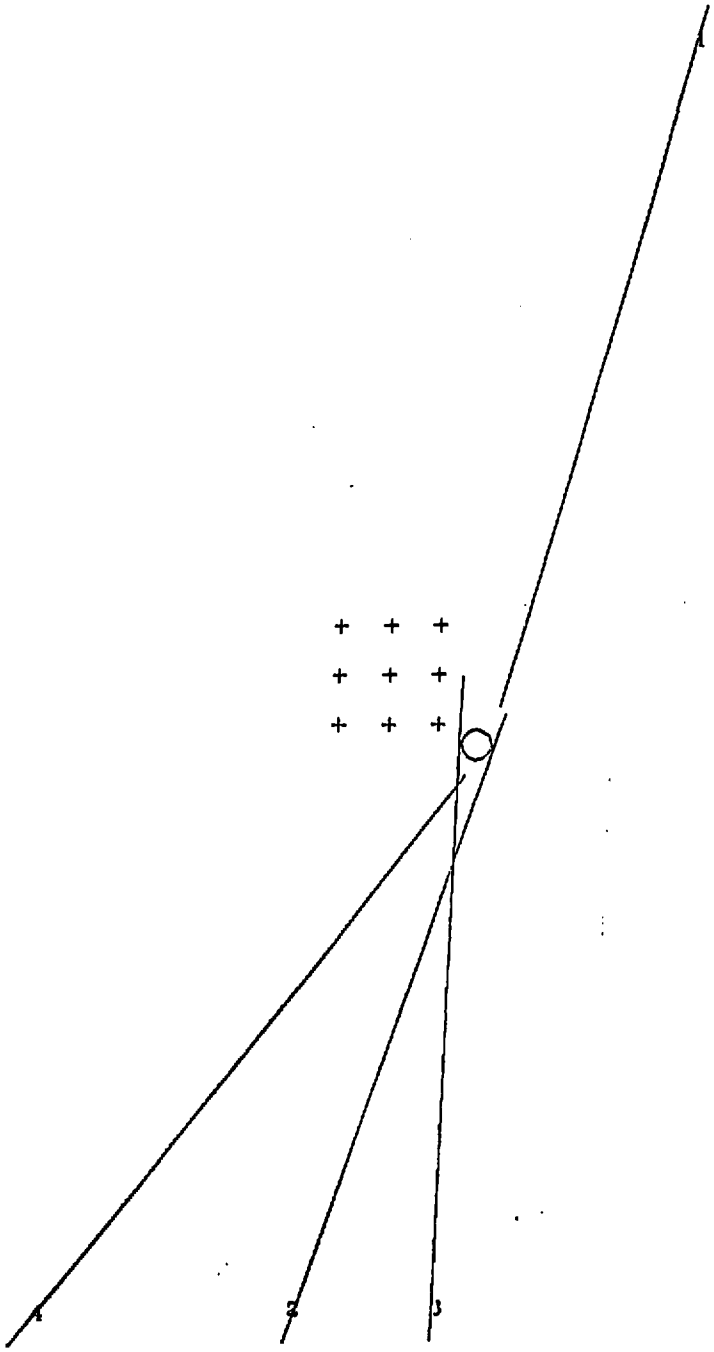


Fig. 1c

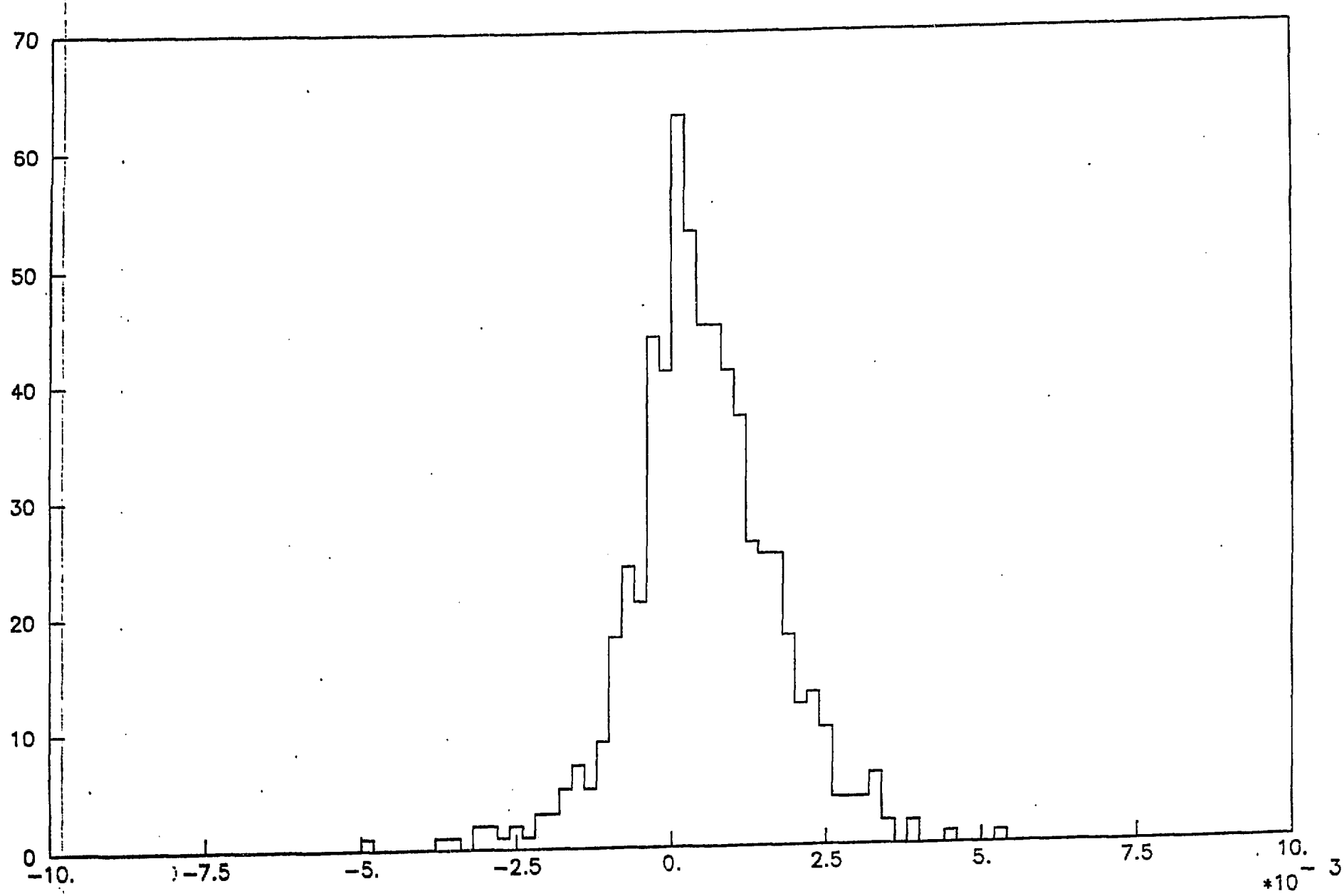


Fig. 2a TAU DECAY LENGTH XY PLANE–M.P.

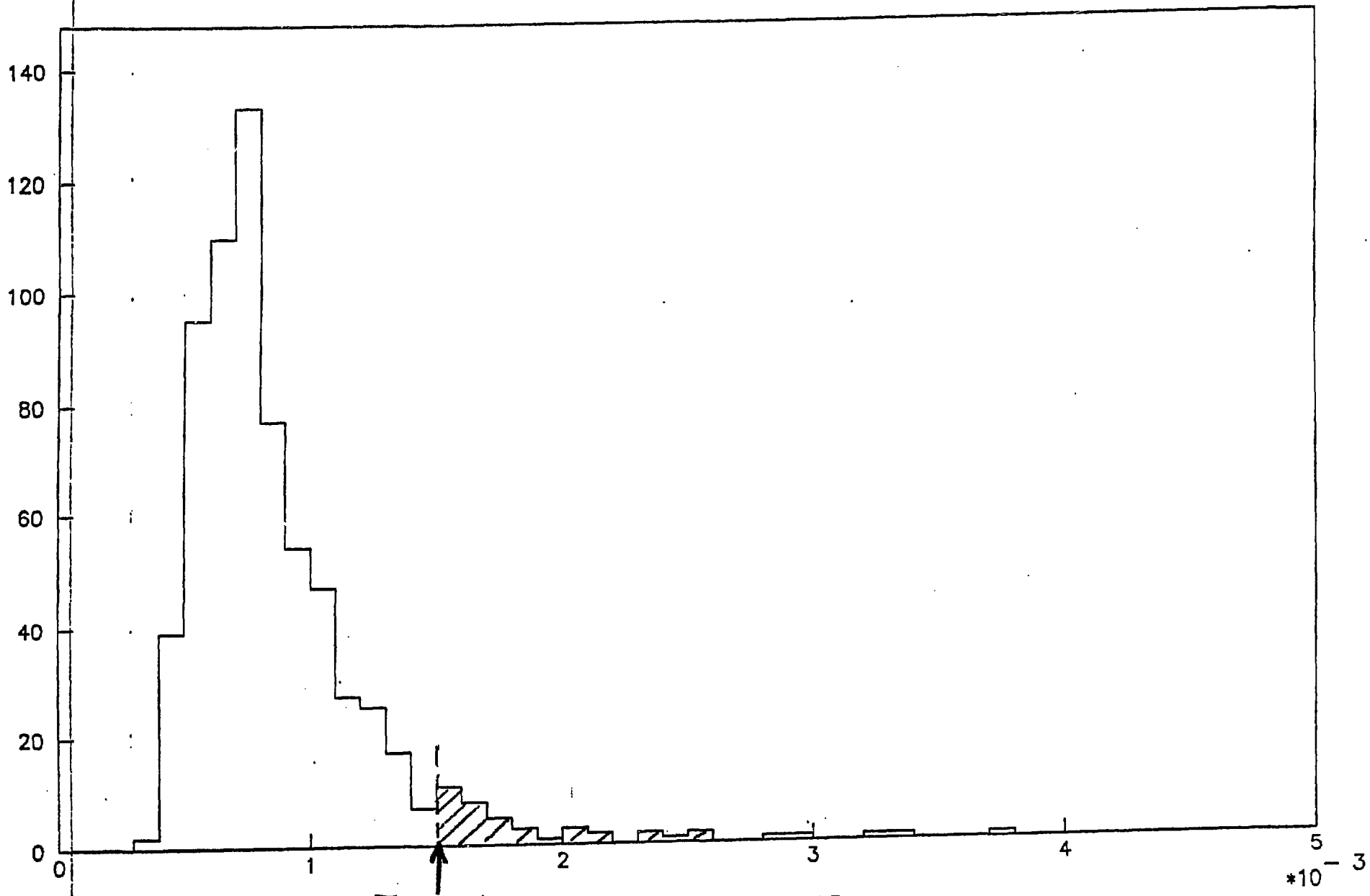


Fig. 2b ERROR IN D.L. XY PLANE–M.P.

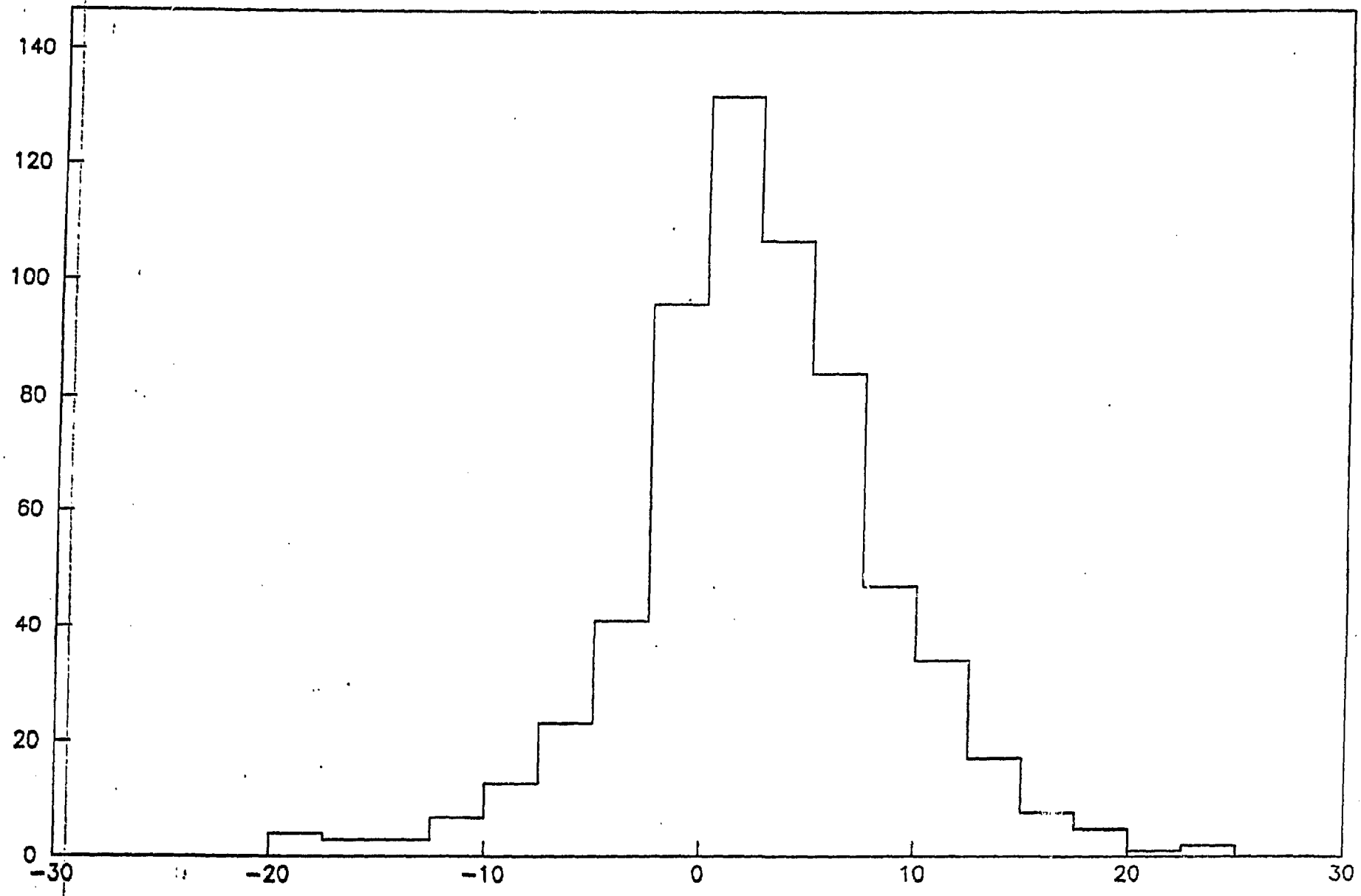


Fig. 3 TAU LIFETIME-M.P.(10E-13)