Comment on ‘Search for new particles decaying into electron pairs of mass below 100 MeV/c^2’

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Abstract

A re-analysis of data from electron-pair production following 160 A-GeV $^{207}$Pb bombardment of nuclear emulsions indicates the production and decay of neutral particles of significantly lower invariant mass and shorter lifetimes than previously claimed (J. Phys. G: Nucl. Part. Phys. 34 (2007) 129-138).

1 Introduction

Jain and Singh [1] report a study of electron-pair production following 160 A-GeV $^{207}$Pb bombardment of nuclear emulsions, in which the energy and opening angles of pairs produced at distances greater than 50 $\mu$m from identified interaction vertices were analysed to determine the invariant masses of presumed neutral particles $X$ decaying by the $X \rightarrow e^+e^-$ channel. Derived neutral particle masses from 2 to 84 MeV/c^2 were reported, with lifetimes ranging from $10^{-15}$ to $10^{-13}$ s (Fig. 1b, 2a, 3 and 4 of [1]). Such large derived masses do not appear to be consistent with the total pair energy and opening angle data that are reported (Fig. 1f of [1]). A re-analysis of the data presented in Fig. 1f indicates presumed neutral particle $X$ invariant masses of 1.5 to 21 MeV/c^2, with lifetimes between $10^{-16}$ and $10^{-14}$ s. This mass and lifetime range are consistent with previous indications of light neutral particles decaying to $e^+e^-$ from cosmic ray [2-3], emulsion bombardment [4-9] and nuclear decay [10-16] data.

2 Data and analysis

Figure 1f of [1] shows a scatter plot of total electron-pair energy $E_{tot}$ versus opening angle $\theta$. A total of 62 of the reported 1220 $e^+e^-$ pairs fall above Borsellino’s [17] most probable opening angle $\omega_P$ at an invariant mass 1.02 MeV/c^2 as plotted together with the data in Fig. 1f of [1].

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These 62 events are, therefore, the only events that can be interpreted as indicating the decays of massive particles into $e^+e^-$ pairs. The total energies and opening angles of these 62 events are reproduced in Fig. 1, together with plots of Borsellino’s most probable opening angle $\omega_P$ and 1.5 times Borsellino’s angle.

Figure 1: Total pair energy $E_{\text{tot}}$ versus opening angle $\omega$ for the 62 events reported to be above the Borsellino line in Fig. 1f of [1]. Also shown are the Borsellino line $\omega_P = 4m_e^2/E_{\text{tot}}$ (in radians) and 1.5 times the Borsellino line. Data were obtained manually from Fig. 1f of [1]. Uncertainties include the experimental uncertainties stated in [1] and the uncertainties associated with extracting the data from the published figures.

The invariant mass $m_X$ for a presumed neutral particle $X$ decaying to $e^+e^-$ pairs was computed as:

$$m_X^2 = 2m_e^2 + 4E_1E_2\sin^2(\omega/2) \quad (1)$$

where $m_e$ is the electron rest mass and $E_1$ and $E_2$ are the pair electron energies, here taken to be equal on the basis of the very small energy divergences reported in Fig. 1e of [1]. The computed invariant masses are shown in Fig. 2.

The $X$-particle lifetimes reported in [1] could not be confirmed directly, as the measured interaction vertex to pair vertex distances are not given and Figs 1b and 1f of [1] cannot be compared on
Figure 2: Computed invariant masses $m_X$ of presumed neutral particles $X$ decaying to $e^+e^-$ pairs, as derived from Fig. 1 using Eqn. 1. (a) 59 events in the range $1.5 \text{ MeV/c}^2 \leq m_X \leq 6.0 \text{ MeV/c}^2$. (b) Full mass range, showing 3 events above 6 MeV/c².

3 Discussion

Evidence for neutral particles with masses less than 10 MeV decaying into $e^+e^-$ pairs has previously been reported from cosmic ray [2,3], emulsion bombardment [4-9] and nuclear decay [10-16] data. The structure of these particles is unknown. However, the angular distributions of $e^+e^-$ pairs emitted in a 10.96 MeV $0^- \rightarrow 0^+$ magnetic monopole (M0) transition in $^{16}$O forbidden to both single-$\gamma$ and internal pair-conversion (IPC) modes indicates that an $X$-boson of approximately 10 MeV/c² is the primary decay product in this transition [13-14]. Similarly, the analysis...
reported in [4,5] suggests that 1.1, 2.1 and 9 MeV/c² bosons are primary products of ¹²C and ²²Ne bombardments of nuclear emulsions. These candidate light neutral bosons have been tentatively interpreted as potential components of light dark matter [18].

The present re-analysis of the 160 A-GeV ²⁰⁷Pb emulsion data reported by Jain and Singh [1] brings the majority of events observed in these reactions into a mass and lifetime range consistent with earlier reports of light neutral bosons decaying into $e^+e^-$ pairs. A comprehensive re-analysis of data from multiple sources indicating the existence of such particles is currently under way [19].

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5 Bibliography

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