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ANOMALOUS INTERNAL PAIR CREATION IN ^8Be
AS A SIGNATURE OF THE DECAY
OF A NEW PARTICLE*

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In a measurement of the angular correlation of e^+e^- pairs in the isovector M1 decay from 1^+ level at 17.64 MeV in ^8Be , a large deviation was found from quantum electrodynamics(QED)-prediction for internal pair conversion (IPC). By postulating the emission of a neutral particle with a mass of 12 (2.5) MeV/ c^2 the structure of the angular correlation can be described.

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1. Introduction

If a light exotic particle predicted by supersymmetric models of particle physics exists, it may be emitted in nuclear transitions. A light and weakly coupled neutral spin-1 gauge boson U was predicted by Fayet [1] and recently revisited by Boehm and Fayet [2]. It was argued by Boehm *et al.* [3] and recently by Fayet [4] and Beacom [5] that light dark-matter particles decaying through such bosons into e^+e^- pairs may be the source of the observed 511 keV emission line in the galactic bulge [6].

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In a search for possible signals of short-lived neutral bosons de Boer *et al.* [7] has found significant deviation from the QED-prediction in the angular correlation of the e^+e^- pairs originated from the decay of the 17.64 MeV M1 transition in ^8Be . The deviation was interpreted as a consequence of the creation and decay of a neutral boson with a mass of about $9\text{ MeV}/c^2$.

QED predict [8] that the angular correlation of e^+ and e^- emitted in IPC drops rapidly with the separation angle θ . In striking contrast, when the transition takes place by emission of a short-lived neutral particle decaying into an e^+e^- pair, the angular correlation becomes sharply peaked at larger angles. In the center-of-mass system the emission takes place back to back, but in the laboratory system the angle becomes smaller due to the Lorentz boost. Thus by measuring the angular correlation of the e^+e^- pairs, the relative branch of a particle to internal pairs can be determined.

In our previous work [9] we have studied the angular correlations of e^+e^- pairs emerging from the 10.96 MeV $0^- \rightarrow 0^+$ and 8.87 MeV $2^- \rightarrow 0^+$ transitions in ^{16}O and found some indications also for the 9 MeV boson.

The aim of the present work was to repeat the experiment performed previously by de Boer *et al.* [7] with better angular resolution, with more efficient detectors, check the existence of the aforementioned 9 MeV boson and determine their mass and branching ratio more precisely.

2. Experiment

In order to populate the 17.64 MeV 1^+ state strongly and selectively, we used the reaction $^7\text{Li}(p, \gamma)^8\text{Be}$ at the $E_p = 441\text{ keV}$ resonance. The experiments were performed at the 1 MV Van de Graaff accelerator of ATOMKI. A 1 mg/cm^2 LiF target evaporated onto a $10\text{ }\mu\text{m}$ thick Al backing was used with a beam current of $1\text{ }\mu\text{A}$.

The angular distribution of e^+e^- pairs was measured using a new pair spectrometer of better angular resolution. The e^+e^- pairs were detected by 6 plastic ΔE - E telescopes. ΔE detectors $52 \times 52 \times 1\text{ mm}^3$ are 3 times thinner than the ones used in Ref. [10], which was expected to give about 9 times better γ -ray suppression factor. The E detectors of $80 \times 60 \times 70\text{ mm}^3$ are similar to the large detectors in Ref. [10]. The telescope detectors were placed outside the vacuum chamber made of carbon fibre. The positions of the hits were measured by multiwire proportional counters (MWPC) [11] used in front of the ΔE and E detectors. The telescopes were set at 60° relative to each other in a close geometry.

The energy and efficiency calibration of the telescopes was made with respect to the 6.05 MeV transition in ^{16}O excited in the $^{19}\text{F}(p, \alpha)^{16}\text{O}$ reaction at the $E_p = 840\text{ keV}$ resonance. Extensive Monte Carlo (MC) simulations of the experiment were performed using the GEANT3 code with

target chamber, target backing, windows, detector geometries included, in order to model the detector response. The energy spectra and the efficiency curve as a function of the separation angle were well reproduced by the MC simulations.

3. Results

The results obtained for the angular correlation of the sum of the 14.64 and 17.64 MeV M1 transitions in ^8Be is shown in Fig. 1(a) together with the theoretical prediction by Rose [8].

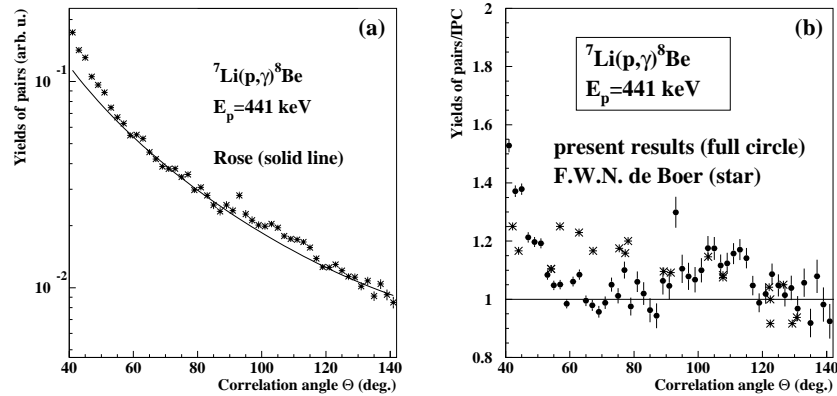


Fig. 1. (a) Measured angular correlation of the e^+e^- pairs compared with the theoretical one [8]. (b) Normalized angular correlation compared with the previous experimental data [7].

One can observe excess intensities at small angles and also at large ones around 110° . Fig. 1(b) shows the ratio of the experimental/theoretical data together with the values published previously by de Boer *et al.*, [7]. Both data sets show similar deviations from unity at small angles, which may be explained by the effect of the external pair creation (EPC) on the target frame and on the wall of the target chamber. The deviations at large angles might be explained by creation and subsequent decay of a new particle, introduced in Ref. [7]. In order to explain the deviation at large angles we have made extended MC simulations by assuming particles with different masses. Fig. 2(a) shows the difference of the measured and calculated angular correlations together with the result of a combined MC simulation for both transitions obtained by assuming a mass of $12\text{ MeV}/c^2$ for the hypothetical particle. The results of the full χ^2 analysis as a function of the mass of the assumed particle is shown in Fig. 2(b). The experimental results can be explained best if the mass of the particle is $12.0 \pm 2.5\text{ MeV}/c^2$. The

large error is due to the fact that no energy separation has been performed between the wide (1.5 MeV) 14.64 and the narrow (9 keV) 17.64 sum-peaks. However, it enables us to a valid comparison between the new data with the older ones, which were also unseparated.

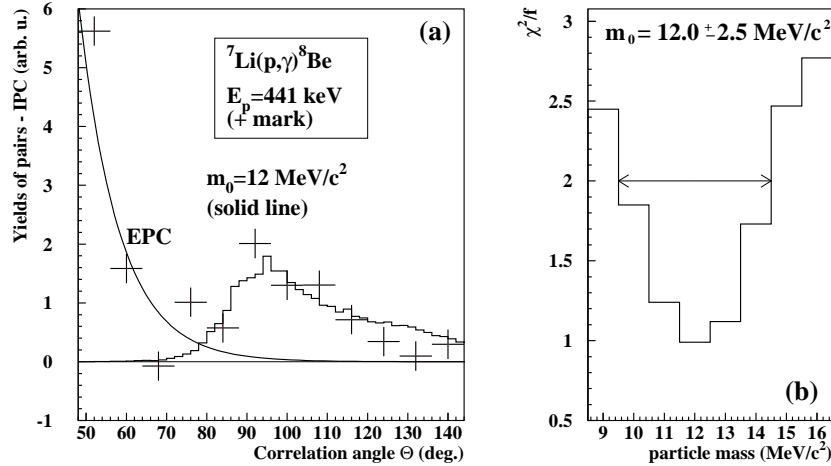


Fig. 2. (a) Difference of the measured and predicted angular correlation compared with the MC results obtained for the decay of a new boson. (b) Determination of the new particle by the χ^2/f method, by comparing the experimental data with the results obtained for different masses.

The obtained mass marginally differs from the previously published value. We are planning to repeat the experiment with thinner target to excite the 441 keV resonance more cleanly without the disturbing effects of the nonresonant capture transitions. We are also planning to modify the setup, to get more flat efficiency curve as a function of the correlation angle.

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