ARE THE POSITRON PEAKS CAUSED BY INTERNAL ELECTRON-POSITRON PAIR CONVERSION?

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1. INTRODUCTION

In this introduction we first indicate the significance of internal electron-positron pair conversion [1-7] as background process to the positron spectra from giant quasiatoms. The next section briefly deals with the basic theoretical formalism. The performed approximations are emphasized. After that we investigate the possible role of conversion processes a) in the actinide region (Z ≈ 90), b) in giant systems (Z > 150) and c) in heavy ion fragments (Z ≈ 20). Finally we present a brief conclusion.

In collisions of very heavy ions with $E_{Lab} > 3$ MeV/u both nuclei are Coulomb excited. Transfer reactions or even deep-inelastic nuclear reactions can take place which lead to additional excitations of the nuclei. This internal excitation energy may be carried away by a photon or may be transferred to a bound electron or to an electron of the negative energy continuum, which leads to ionization and electron-positron pair creation, respectively. The latter process requires nuclear transition energies $\omega$ larger than twice the electron rest mass. Nuclear E0-transitions are characterized by the absence of single photon emissions, because a photon must carry at least one unit of angular momentum. Such processes form the main source of non-atomic positrons, and they have to be well understood if one wants to draw firm conclusions about the presence or absence of spontaneous pair creation [8-9]. The basic processes under investigation are depicted schematically in fig. 1. The nucleus which makes an E0-transition is labelled by its initial and final state angular momenta $J_i$, $J_f = J_i$, and eigenenergies $E_i$, $E_f = E_i - \omega$ ($\hbar = 1$). Process a describes the electron-positron pair creation. An electron of the negative energy continuum ($\epsilon = -E < -m_0c^2$) with Dirac quantum number $\kappa$ is lifted to the positive energy continuum. The final state energy obviously amounts to $E' = \epsilon + \omega$, whereas the angular momentum quantum number remains unchanged. Since neither the initial state energy nor the final state energy are fixed one expects a continuous energy distribution for the emitted positrons. Process b indicates the conversion of a K-shell electron ($n = 1, l = 0, j = \frac{1}{2}, \kappa = -1$)
with energy eigenvalue $E_{1s\frac{1}{2}}$. Thus bound states with definite energies are involved. Energy conservation then simply causes monoenergetic lepton emission for a fixed nuclear transition energy $\omega$. Process c symbolizes monoenergetic positron production. Here an electron of the negative energy continuum is excited to a bound state, e.g., to the $1s\frac{1}{2}$-state. Thus we focus our attention on: i) The pair conversion coefficient $\beta$, defined as the ratio of the pair production probability (process a) compared with that of photon emission for a specific nuclear transition with energy $\omega$. Since the energy of the electron and the positron takes continuous values we may express $\beta$ also as integral of the differential pair conversion coefficient $d\beta/dE$. The lower bound of the integral is determined by the rest mass of the electron, which corresponds to vanishing kinetic energy, while the upper bound is given by the nuclear transition energy $\omega$ minus $m_0c^2$.

ii) The conversion coefficient $\alpha$, defined as the ratio of the probabilities of inner-shell vacancy formation (process b) and photon emission. In particular, this mechanism is important for low energy nuclear transitions. iii) The ratio $\eta$ of the two E0-conversion probabilities for electron-positron pair creation and for the ionization of bound state electrons. This ratio is completely determined by the density of the electron wave functions at the nuclear origin, thus being independent of the nuclear wave function.

![Diagram of electron conversion processes](image)

Fig. 1: Schematic representation of electron conversion processes accompanying nuclear E0-transition from a state $E_i, J_i$ to a state $E_f = E_i - \omega, J_f = J_i$: a) Electron-positron pair production leading to a continuous energy distribution of positrons and electrons. b) Conversion of K-shell electrons - a monoenergetic electron-production mechanism and c) Monoenergetic positron production.

The presence of these conversion processes as background contribution has been verified, e.g., in measurements of $\delta$-electron production. In figure 2 we compare our theoretical results [10] for the double differential cross section for $\delta$-electron emission with the experimental data of Herath-Banda et al [11] for the system I - U. The double