e^+e^- Pairs from ^{238}U + ^{206}Pb Collisions

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We present the results of a search for discrete Internal-Pair-Conversion (IPC) transitions, excited in heavy-ion collisions close to the Coulomb barrier, as possible candidates for previously observed weak e^+e^--sum-energy lines with cross sections of the order of a few μb for the ^{238}U + ^{181}Ta system and some tenth of μb for ^{238}U + ^{208}Pb collisions [1].

An improved experimental set-up at the double-ORANGE spectrometer of the GSI was used for e^+e^- coincidence measurements in the ^{238}U + ^{206}Pb collisions at 5.93 MeV/u projectile energy. The capability of our device of detecting IPC e^+e^- pairs from discrete nuclear transitions of a moving emitter was studied by investigating the known 1844 keV (E1) transition in ^{206}Pb and the 1770 keV (M1) transition in ^{207}Pb, excited via Coulomb excitation and a neutron transfer reaction, respectively [2].

Following an event-by-event Doppler-shift correction to the Pb-like recoiling ion, a pronounced γ line with a total excitation cross section of $\sigma_\gamma = (55 \pm 5)$ mb appears at (1844 ± 1) keV in the measured energy spectrum (Fig. 1a). A second γ line at (1770 ± 1) keV appears only in central collisions with distances of closest approach $R_{min} < 20$ fm (Fig. 1b). This line is assigned to a known M1 transition in ^{207}Pb excited by neutron transfer from ^{238}U to ^{206}Pb with a total cross section of $\sigma_\gamma = (1.1 \pm 0.3)$ mb.

The excitation probabilities per collision $P_\gamma(R_{min})$ as functions of distance of closest approach for the two γ transitions are shown in Fig. 1c and d. $P_\gamma(R_{min})$ for the 1844 keV transition in ^{206}Pb shows the typical behaviour for Coulomb excitation (Fig. 1c), while P_γ peaks for the ^{207}Pb transition within a narrow R_{min} interval (Fig. 1d), typical for transfer reactions, for which the transfer probability is expected to become large when the nuclei come into contact. This also means that the excitation function should exhibit a rather narrow structure at energies close to the Coulomb barrier with a width of about 0.3 MeV/u.

From the 1844 keV transition we expect IPC pairs with a sum energy of 822 keV. Multiplying the measured γ cross section with the theoretically predicted IPC coefficient of $\beta = 4 \times 10^{-4}$ [3], we expect a total cross section for IPC from the 1844 keV transition of $\sigma_{IPC} = (22 \pm 2)$ μb. The event-by-event Doppler-shift corrected e^+e^--sum energy spectrum obtained after reduction of the continuum is shown in Fig. 1e. At an energy of (815 ± 10) keV an excess of about 35 counts is obtained, in accordance with our estimate.

The corresponding IPC production cross section for the 1770 keV transition is expected to be $\sigma_{IPC} = (0.3 \pm 0.1)$ μb with $\beta = 2.8 \times 10^{-4}$, which should lead to a weak e^+e^--sum-energy line at $\approx$ 750 keV with a FWHM of $\approx$ 40 keV, and an intensity of about 10 counts. This is also weakly indicated in the corresponding Doppler-shift corrected e^+e^--sum-energy spectrum, shown in Fig. 1f.

In summary we conclude that IPC e^+e^- pairs from discrete nuclear transitions of a moving emitter, can be observed with production cross sections down to the μb level in heavy ion collisions. In some cases, in which the continuous distributions due to uncorrelated e^+e^- emission and nuclear background is not too high lines with production cross sections down to tenth of μb can be observed. The present sensitivity achieved is at the level of weak e^+e^--sum-energy lines or fluctuations observed in previous experiments.

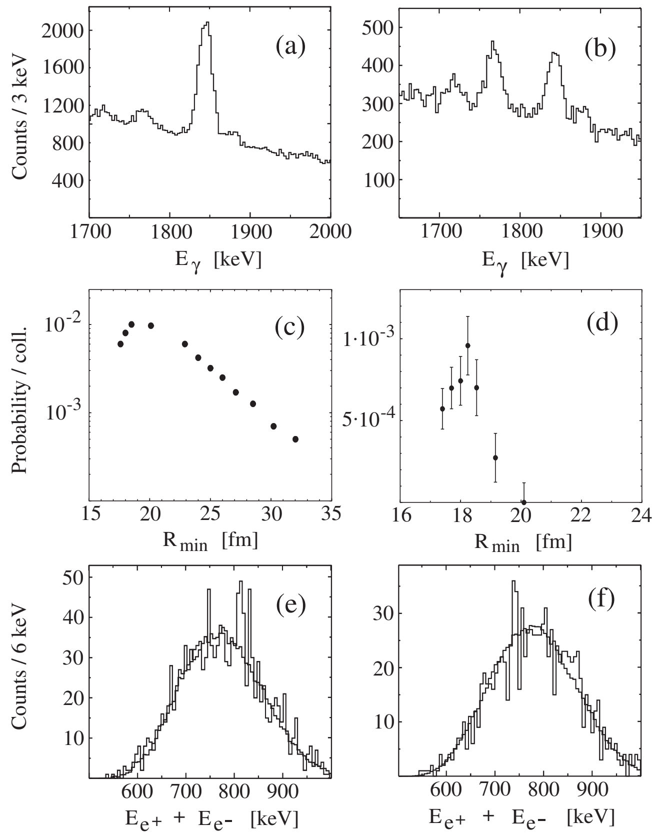

Fig. 1: Spectra of γ rays after Doppler-shift correction to the Pb-like ions, scattered in the R_{min} range from 17 to 32 fm **(a)** and for central collisions with $R_{min} < 20$ fm **(b)**. **(c)** and **(d):** Excitation probability as function of R_{min} of the 1844 keV (c) and 1770 keV (d) transitions in ^{206}Pb and ^{207}Pb, respectively. **(e)** and **(f):** e^+e^--sum-energy spectra dopplercorrected on the Pb-like ions for peripheral (e) and central (f) collisions. The continuous part of these spectra is well reproduced by a reference distribution (smooth solid curve), being gained by an event-mixing procedure.

References

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