Are the GSI Positron Electron Lines Due to E0 Transitions?

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During the past years two independent experiments at the GSI in Darmstadt have observed narrow positron- electron sum energy lines in collisions of very heavy ions at energies near the Coulomb barrier [1]. In the subcritical system ^{238}U + ^{181}Ta the ORANGE collaboration observed a pronounced sum energy line near 620 keV. At a similar energy a line was seen by the EPOS collaboration and in addition another line near 730 keV. The uncertainty of the energies is about 10 keV. The origin of these lines is still unclear. As one possibility internal pair conversion (IPC) of nuclear transitions has been discussed. But in the simultaneously recorded gamma spectra neither of the groups did detect a corresponding gamma line with energy $E = E_{sum} + 2m_0c^2$, although the ratio of IPC to gamma emission is expected to be in the order of $5 \cdot 10^{-4}$ or less. Therefore a corresponding gamma line should be observable, unless gamma decay is strictly forbidden as in the case of a $0^+ \rightarrow 0^+$ transition.

Since in general only even-even nuclei have a 0^+ groundstate, we have investigated whether an excited 0^+ state at an excitation energy corresponding to the sum energy of the lines observed in the ^{238}U + ^{181}Ta system might exist in even-even neighbours of ^{181}Ta, which could be populated in transfer reactions. The most likely candidates are reached with one-proton stripping or pickup reactions. Therefore we searched for such a state in the ^{181}Ta(d,^{3}He)^{180}Hf and ^{181}Ta(^{3}He,d)^{182}W reactions with good energy resolution. The ejectiles were momentum analyzed with the Q3D magnetic spectrograph. In the focal plane their position was measured as well as total energy and energy loss signals with two different detectors [2] [3] for the two reactions, both consisting of proportional counters and scintillation detectors. Ta targets with a thickness of 30 μg/cm^2 evaporated onto 5 μg/cm^2 ^{12}C foils were irradiated with beams of 28 MeV deuterons and 32 MeV ^{3}He, respectively. In both reactions we achieved an energy resolution of 10 keV or better.

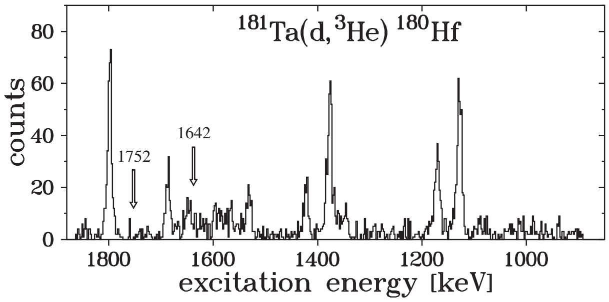

Fig. 1: Spectrum for the ^{181}Ta(d,^{3}He)^{180}Hf reaction at a scattering angle of 20° and a bombarding energy of 28 MeV.

Fig. 1 shows the spectrum for the (d,^{3}He) reaction at a laboratory angle of 20° for a range of excitation energies in ^{180}Hf between 900 and 1800 keV. For all states observed we find a correspondence with a known state, except for the strongest line at 1797 keV, which is produced with a cross section of about 1.5 μb/sr, but was not observed previously in inelastic or neutron transfer reactions. The known states provide us with an energy calibration, which has an uncertainty of about 1 keV. Known 0^+ states at 1102 keV or 1316 keV are only weakly excited - if at all - although the necessary large angular momentum transfer (L=4 from the $7/2^+$ ground state of the target) has been observed with L=5 to the 8^- state at 1141 keV. Apparently no strong peak is populated near 1752 keV or 1642 keV which could be related to the e^+e^- sum energy lines near 730 keV or 620 keV.

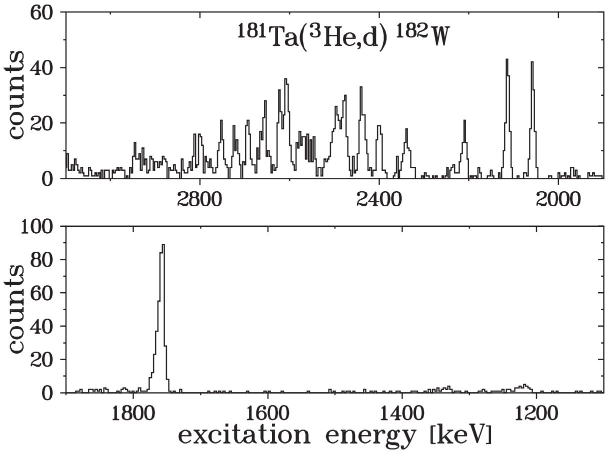

Fig. 2: Spectrum for the ^{181}Ta(^{3}He,d)^{182}W reaction at a scattering angle of 20° and a bombarding energy of 32 MeV.

For the (^{3}He,d) reaction the long detector was used and covered a range of excitation energies in ^{182}W from 0 to 5 MeV. The part between 1.1 and 3.1 MeV is shown for a scattering angle of 20° in fig. 2. The energy calibration was taken from a measurement of the ^{121}Sb(^{3}He,d)^{122}Te reaction, performed immediately afterwards. In the region of interest there is only one state strongly excited with a cross section of about 60 μb/sr. This line at 1757 keV could be related to the 730 keV e^+e^- sum energy line. But at this excitation energy a two proton $([404]7/2^+ \otimes [402]5/2^+)6^+$ state is known and can be expected to be strongly excited in one-proton stripping. Spectra taken at 10°, 30° and 40° have not sufficient statistics to extract uniquely L values for the transfer, but the cross section for the 1757 keV line decreases by a factor of two from 10° to 20°, supporting an L value of two and a 6^+ assignment to this state.

Summarizing, we did not find states in the nuclei neighbouring ^{181}Ta, which could be reached by simple one-proton transfer reactions and which could give rise to the e^+e^- sum energy lines observed at GSI.

References

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[2] H. Lindner et al., Nucl. Inst. and Meth. **A273** (1988) 444
[3] E. Zanotti et al., Nucl. Inst. and Meth. **A310** (1991) 706