Comment on "New Atomic Mechanism for Positron Production in Heavy-Ion Collisions"

In two recent experiments sharp lines have been observed in the spectra of positrons created in collisions of very heavy ions.[1,2] According to theoretical expectations, the combined nuclear charge of the systems studied is supercritical, i.e., the K shell of the united atom is unstable against spontaneous positron emission. Since the time scale of ordinary collisions is too short to expect a clear signal from this mechanism,[3] it has been suggested that the observed positron lines originate from long-lived nuclear compound systems.[4,5] Although at present there is no independent confirmation of this model and though it does not in a natural way predict the observed Z dependence of the effect, no plausible alternative has yet been found.

Here we want to argue that the mechanism proposed by Lichten and Robatino[6] also is not well founded and should be dismissed as an explanation for the observed positron lines. The argument of Ref. 6 is motivated by the idea (i) that multiple excitations have not been treated correctly up to now and (ii) that two-electron transitions play a key role in positron creation.

Regarding (i) we mention that Ref. 3 gives *an exact description of excitations of the many-particle systems as long as electron correlation interactions are neglected.* The main effect of the electron-electron interaction may be included by use of a mean screening potential V_s.[7] There is no indication that the explicit electron-electron two-body interaction $(H_{ee}-V_s)$ plays a substantial role in inner-shell processes. In fact, the proposed two-electron transitions have been found to lead to an exceedingly small transition width.[4] The claim that the strength of two-electron transitions is determined by the dynamical coupling matrix elements, thus being very large, is unfounded. Dynamical excitations are induced by the *one-body operator* $\dot{R}\,\partial/\partial R$ (and possibly rotational coupling). Multiply excited configurations can be reached only by the repeated action of this operator. This is fully accounted for in the coupled-channels calculations.

The explicit calculation presented in Ref. 6 is based on the assumption that positron excitation is restricted predominantly to a narrow region around $R=500$ fm internuclear distance, where the radial-coupling matrix element between the bound states $2p_{3/2}\sigma$ and $2p_{1/2}\sigma$ has a maximum.[8] For this postulate we can see no justification.

It is interesting to study the effect of the $2p_{3/2}\sigma \rightarrow 2p_{1/2}\sigma$ coupling within the correct coupled-channels framework. The result of two calculations for a central U+U collision at 5.9 MeV/u is shown in Fig. 1. The dashed line gives the spectrum of positrons emitted out of the $2p_{1/2}\sigma$ state only. Holes are fed into this state via radial coupling from the $2p_{3/2}\sigma$ level, which is considered to be initially empty. For comparison the figure also shows our earlier results (solid line) including six $np_{1/2}\sigma$ bound states (occupied initially up to $4p_{1/2}\sigma$) and the positive-energy continuum.[5]

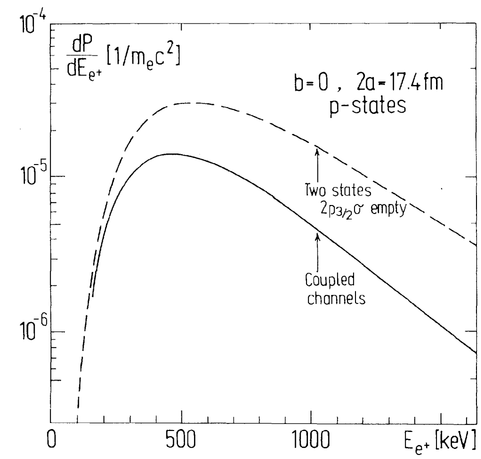

FIG. 1. Energy spectra of positrons emitted in head-on U+U collisions at bombarding energy of 5.9 MeV/nucleon.

It is noticed that the effects of a hole present in the $2p_{3/2}\sigma$ level before the collision would dominate the positron spectrum. This is due to the very large hole transfer rate into the $2p_{1/2}\sigma$ state, which in turn is quite strongly coupled to the positron continuum. Although the shapes of the two curves in the figure differ somewhat, obviously no oscillatory features are introduced. Our result emphasizes the need to perform quantitative calculations based on concrete models as demonstrated for the model of long-lived nuclear composites,[4,5] if any conclusions are to be drawn with respect to the origin of the positron lines. In conclusion, we have shown that the mechanism explicitly considered by Lichten and Robatino does not lead to narrow structures in the positron spectra.

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