Erroneous Wave Functions of Ciuchi *et al* for Collective Modes in Neutron Production on Metallic Hydride Cathodes

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There is a recent comment[1] concerning the theory of collective many body effects on the neutron production rates in a chemical battery cathode. Ciuchi *et al* employ an inverse beta decay expression that contains a two body amplitude. Only one electron and one proton may exist in the Ciuchi *et al* model initial state wave function. A flaw in their reasoning is that one cannot in reality describe collective many body correlations with only a two particle wave function. One needs very many particles to describe collective effects. In the model wave functions of Ciuchi *et al* there are no metallic hydrides, there are no cathodes and there are no chemical batteries. Employing a wave function with only one electron and one proton is inadequate for describing collective metallic hydride surface quantum plasma physics in cathodes accurately.

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I. INITIAL COMMENTS

In years past we have been working on weak interaction inverse beta decay while interacting with various collective modes of motion in condensed matter systems. Our considerations have been recently criticized[1]. The difference of opinion on the rate of neutron production in hydride battery cathodes has a brief history starting from a talk at Roma La Sapienza by Y. Srivastava cited by Ciuchi *et al*[1].

At this talk, a discussion arose where some of the authors of [1] mentioned disagreements with the results presented by YS by factors of 10^{40}, later reduced to a factor of 10^{20}. We pointed out that our estimates were based on an actual calculation of the collective process and directed them to references [2, 3] where inverse beta decay had been proposed as a mechanism to activate neutron production. Subsequently, some members of that group calculated the inverse beta decay and in an internal report concluded that we were still 10^7 high in our estimates of neutron production rates[4]. Towards the goal of reaching full agreement, we suggested that they work in analogy to the muon inverse decay process. As a result, [1] the initial disagreement in neutron production rates between us has presently mowed *way down from forty to a mere two orders of magnitude.*

Our purpose in this note is to give in public the last needed corrections to the Ciuchi *et al* model that would bring the results of their calculation in line with theoretical results in collective mode studies on this subject[2, 3] and most recent experimental[5] findings. A complete discussion of the issues involved is under preparation and will be presented shortly.

II. DANGER IN THE NUMBERS

The Ciuchi *et al* team asserts that the factor of two or three orders of magnitude would render the inverse beta decay unobservable. Fortunately they *are completely incorrect* in this regard. There are experiments carried out by those in D. Cirillo *et al*[5] that reside in Naples. They have actually observed both nuclear transmutations and actual neutrons in hydride metallic battery cathodes. Even if our theoretical neutron counting rates were high by a factor of 300, then Cirillo *et al* could still and indeed did experimentally observe nuclear transmutations.

Ciuchi et. al. use our numbers from papers dealing with other applications but *not* batteries. For example, they start from neutron production rate with the time honored formula

$$\Gamma(e^- p^+ \to n + \nu_e) = |\psi(0)|^2 v \sigma \qquad (1)$$

wherein the amplitude for finding one electron at position $\mathbf{r}$ and one proton at position $\mathbf{R}$ is

$$\psi = \psi(\mathbf{r} - \mathbf{R}), \qquad (2)$$

v is the relative velocity and σ is the $e^- p^+$ cross section.

The relative velocity value employed by Ciuchi *et al* is copied from our paper on exploding wires thus arriving at a theory of exploding batteries[6]. Absurdities would also arise from Ciuchi *et al* taking our numbers from a paper describing neutron rates in lightening bolts. All these papers of ours are cited and numbers copied from them even though they are clearly irrelevant for describing neutron production on metal hydride cathodes.

III. MANY BODY WAVE FUNCTIONS

The wave function problem not properly taken into account by Ciuchi *et al* is that the time honored Eqs.(1) and (2) hold true if and only if there is precisely one electron and one proton in the initial incoming quantum state. If one is trying to treat N protons and N electrons then the charge neutral wave function Eq.(2) would have to be replaced by

$$\Psi = \Psi(\mathbf{r}_1, \mathbf{r}_2, \ldots, \mathbf{r}_N, \mathbf{R}_1, \mathbf{R}_2, \ldots, \mathbf{R}_N) \qquad (3)$$

with spins and other degrees of freedom left implicit. Thus, for (say) $N \sim 10^{16}$ participating in a surface plasmon, the probability $|\psi(0)|^2$ employed by Ciuchi *et al* does not in reality exist. The many body version of the probability of finding an electron on top of a proton is described by the correlation function

$$C = \frac{1}{N} \langle \Psi | \sum_{i=1}^{N} \sum_{j=1}^{N} \delta(\mathbf{r}_i - \mathbf{R}_j) | \Psi \rangle \qquad (4)$$

or the quantum field theory equivalent. What is here crucial is that the cathode is hot. It is sufficient;y hot for the cathode to glow optically and light up the laboratory. Thus one must employ a thermal average

$$C_T = \frac{1}{N} \left\langle \sum_{i=1}^{N} \sum_{j=1}^{N} \delta(\mathbf{r}_i - \mathbf{R}_j) \right\rangle_T \qquad (5)$$

at an optical noise temperature that we have theoretically estimated[3] to be $T \sim 5000K^{\text{o}}$ in agreement with experiment[5]. As one must, we employ C_T and *not* $|\psi(0)|^2$ for the plasma physics problem at hand. It is this truncation from the many body collective aspect $[C_T]$ to the two body $[|\psi(0)|^2]$ which is at the heart of the difference in their and our estimate of the rates. The plasmon modes contributing to Eq.(5) determine the parameter β as shown in our work[2, 3] on metal hydride cathodes.

IV. CONCLUDING STATEMENT

No significant argument has been provided against our nuclear physics results. The experimental evidence of neutron production and nuclear transmutations in properly designed plasma discharge electrolytic cells[5] agrees with our theoretical analysis and belies the theoretical arguments given in[1] against a hefty production of neutrons in hydride cells.

[1] S. Ciuchi, L. Maiani, A. D. Polosa, V. Riquer, G. Ruocco and M Vignati, arXiv:1209.6501v1 [nucl-th] 28 Sep 2012.
[2] A. Widom and L. Larsen, *Eur. Phys. J.* **C 46**, 107 (2006).
[3] A. Widom and L. Larsen, arXiv:0608059v2 [nucl-th] 25 Sep 2007.
[4] A. D. Polosa and M. Vignati, Roma I Internal Report [June 4, 2012].
[5] D. Cirillo, R. Germano, V. Tontodonato, A. Widom, Y.N. Srivastava, E. Del Giudice, and G. Vitiello *Key Engineering Materials* **495**, 104 (2012).
[6] If compared with the Naples neutron production experiment, then the battery would have exploded and perhaps knocked out the laboratory or the first floor of the building.