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"Search for the observation of an internal clock or of Zitterbewegung in an electron channeling experiment"

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Beside the success of Quantum Mechanics, there have always been some attempts to test it more deeply, both theoretically and experimentally. A few examples of these experimental efforts are:

- The test of the optical theorem at higher energies.
- Interference experiments by means of cold neutrons, particularly in order to test the relation $\lambda = h/p$.
- "EPR" experiments for testing entanglement and the Bell's inequalities in various conditions.
- …

None has revealed any discrepancy with usual Quantum Mechanics.
On the theoretical side, the field of investigation seems to be very wide, unfortunately too wide. Keeping in mind an experimentalist point of view, we may just refer to the book of D.Bohm and B.J.Hiley "The Undivided Universe" Routledge(1993) p.345: "The chief difficulty in carrying out this sort of extension of our approach (i.e. the Quantum Potential) is that there is such a wealth of possibilities and such a dearth of experimental clues that might narrow them down."

The discovery of a result not foreseen by Quantum Mechanics would need some kind of luck. This is why we would like to confirm the experimental results that some of us have obtained a long time ago and that have been recently published [1] [2]. The starting idea is simple and refers to the beginning of Quantum Mechanics. A particle at rest has a self energy $E_0=m_0c^2$, which could also be equal to $h\nu_0$, if it has a self internal frequency $\nu_0=m_0c^2/h$, in parallel to the relation $E=h\nu$ valid for the photon. But, in order to respect the requirement of relativistic covariance, this led L. de Broglie [3] to postulate an amplitude in the particle rest frame all around it $\Psi_0(t)=a_0\exp(2\pi i\nu_0 t)$. This amplitude transforms in the laboratory frame like a plane wave, the wave length of which is calculated to be $\lambda=h/p$ whereas the frequency becomes $\nu=\nu_0\gamma$ (where γ is the Lorentz factor). However despite the success of the wave hypothesis, the idea of an internal clock frequency was forsaken. A different concept of internal clock reappeared in 1930 due to E.Schrödinger [4] as a consequence of the Dirac equation for a free particle, the Zitterbewegung to which a frequency equal to $2\nu_0$ is associated. Quite recently D.Hestenes has proposed a reformulation of the Dirac equation in the "Space Time Algebra" formalism and a mechanism, where the Zitterbewegung becomes observable [5].
Whatever it is, this internal frequency must be divided in the laboratory frame by the factor γ due to the relativistic delay of the clocks. This could lead to some resonance effect if a beam of charged particles (electrons for available energies) is directed along the major crystallographic axis of a thin crystal, and if the energy of the beam is tuned so that the

frequency of the successive collisions of the projectile with the target atoms matches this internal frequency. In our previous experiment (that was in fact a by-product of a channeling radiation experiment) we were interested in the angular distribution of electrons transmitted through a thin crystal in channeling conditions. We think that what we have observed is a resonance effect on this distribution. The most interesting feature with crystals is that this effect can be seen only inside a small momentum window (~1%) but smoothed and therefore not visible outside it, as shown by our calculation with a phenomenological model [2]. This property makes it more easily distinguishable from other more conventional effects if any.

We propose to run an experiment with 80 MeV/c electrons, i-e at the energy where we seem to have observed an effect and where it should be confirmed, and also at 160 MeV/c where the effect is predicted to be more intense (main resonance momentum) by our phenomenological model and by the Zitterbewegung theory.

Beam requirement:

-A collimated electron beam $\Delta p/p \sim 10^{-3}$. Divergence ~1 mrad or less.

-Momentum adjustable by small steps $\Delta p/p \sim 10^{-3}$.

-Intensity 10^4/s -10^5/s depending on the duty cycle (our detectors will be placed inside the beam transmitted through the crystal).

A possible set-up could be:

- a first set of collimators diameter=1mm, ~1 meter apart,
- an analysing magnet to provide the necessary momentum resolution,
- a second set of collimators diameter=1mm, ~1 meter apart,
- a thin silicon crystal mounted on a goniometer, located after the last collimator,
- a 2D location detector ~1 meter after the crystal, just after the vacuum window.

Everything should be under vacuum, except the detectors.

Time schedule:

A first period of ~3 days for setting up and a second period of ~3 days for data taking.

References:

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[2] P.Catillon, N.Cue, M.J.Gaillard, R.Genre, M.Gouanère, R.G.Kirsch, J.C.Poizat, J.Remillieux, L.Roussel, M.Spighel, Found.Physics **38**, 659 (2008).
[3] L. de Broglie, Thèse de Doctorat (1924).
[4] E.Schrödinger, "Über die kräftefreie Bewegung in der relativistichen Quantenmechanik". Berliner Ber. pp418-428(1930).
[5] D.Hestenes, "The Zitterbewegung interpretation of quantum mechanics", Found.Physics **20**, 1213 (1990). and "Reading the electron clock", arXiv:0802.3227 21Feb2008.

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The acronym of the experiment is: RICCE (Research for an Internal Clock by Channeling of Electrons)