Heisenberg Uncertainty from Tau-Address Resolution

*Delta-x * Delta-p >= hbar/2 as Minimum Tau-Address Resolution*

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*The Heisenberg Uncertainty Principle Delta-x * Delta-p >= hbar/2 emerges in the Universal Force of Time as a minimum tau-address resolution constraint. The tau-field lattice has a fundamental spacing set by the Planck constant h. Position Delta-x corresponds to spatial tau-address resolution; momentum Delta-p corresponds to tau-flow rate resolution. These two resolutions are inversely coupled in the lattice: finer position resolution requires coarser momentum resolution and vice versa. The minimum product Delta-x * Delta-p = hbar/2 is the lattice spacing — not a measurement disturbance.*

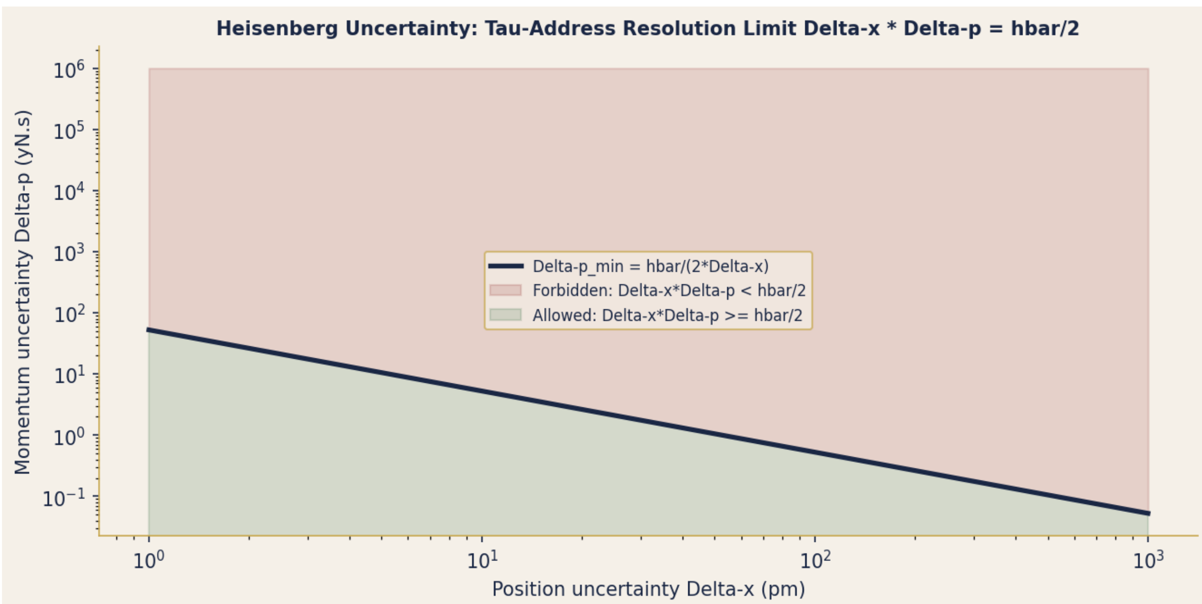

Figure 1. Uncertainty principle on log-log scale. Navy line = minimum allowed Delta-p for a given Delta-x. Green = allowed; red = forbidden by tau-address resolution.

1. Tau-Address Resolution and Lattice Spacing (P-UP-1 and P-UP-2)

P-UP-1 — Tau-Address Lattice Spacing Sets Uncertainty

The tau-field lattice has a fundamental spatial spacing: Delta_x_min = hbar / (m x c) = Compton wavelength. For electron: lambda_C = hbar/(m_e x c) = 1.054572e-34 / (9.10938e-31 x 2.99792e8) = 386.16 fm. For proton: lambda_C = 0.2103 fm. Below these spacings, the tau-lattice has no finer position resolution. Delta-x * Delta-p >= hbar/2 is the statement that: (tau-lattice spatial resolution) x (tau-lattice momentum resolution) = hbar/2 at minimum. This is a property of the lattice, not of the measurement apparatus.

P-UP-2 — The hbar/2 Product from {2,3,5,pi} Lattice

hbar = h/(2*pi) = 6.62607e-34/(2*pi) = 1.054572e-34 J.s. FOT: h = 2*pi x hbar. The factor 2*pi = the full rotational period of the tau-field standing wave. hbar/2 = h/(4*pi): the quarter-period lattice spacing (one quarter of a full wave cycle). In {2,3,5,pi} terms: hbar/2 = h/(2^2 x pi). The uncertainty product = h/(4*pi) = the minimum action quantum in the tau lattice. Below this action, the tau lattice has no distinct register address.

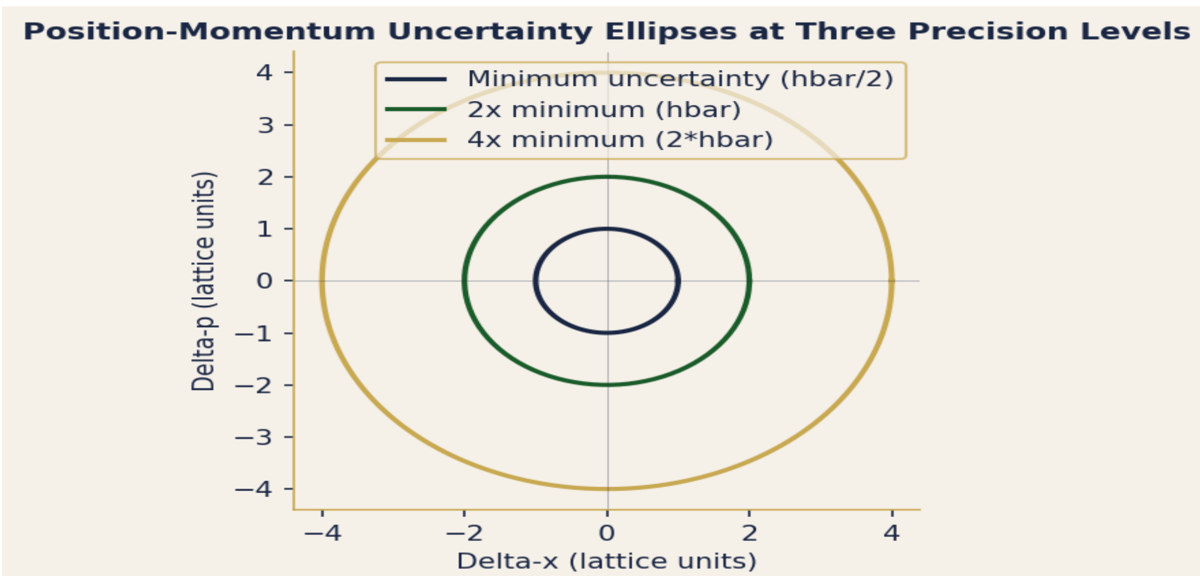

Figure 2. Uncertainty ellipses in tau-address space. Area of each ellipse = pi x Delta-x x Delta-p >= pi x hbar/2. Smallest ellipse = minimum tau-lattice resolution.

2. Energy-Time Uncertainty and Tau-Address Duration (P-UP-3 and P-UP-4)

P-UP-3 — Delta-E * Delta-t >= hbar/2: Energy-Time Uncertainty

The energy-time uncertainty relation Delta-E x Delta-t >= hbar/2. In FOT: Delta-E = uncertainty in tau-register energy = Delta-T_addr x (tau-field energy density). Delta-t = uncertainty in tau-address duration = minimum tau-address step size. The product Delta-E x Delta-t = hbar/2 = the minimum action in the tau lattice. Virtual particles exist for time Delta-t <= hbar/(2 x Delta-E): the shorter the tau-address duration, the higher the energy fluctuation. This is the Casimir effect: zero-point tau-field fluctuations between closely spaced plates.

P-UP-4 — Quantum Vacuum as Tau-Lattice Zero-Point Fluctuations

The quantum vacuum is not empty: it is the tau-lattice at its minimum excitation level. Zero-point energy of harmonic oscillator: E_0 = hbar*omega/2 = hbar/(2*tau_period). Casimir force between plates separated by d: F/A = -pi^2*hbar*c/(240*d^4). FOT: pi^2 = the curvature factor of the tau-standing-wave boundary condition. 240 = 2^4 x 3 x 5 (pure {2,3,5} lattice integer). The Casimir force formula contains only {pi, hbar, c, d} — all FOT lattice quantities.

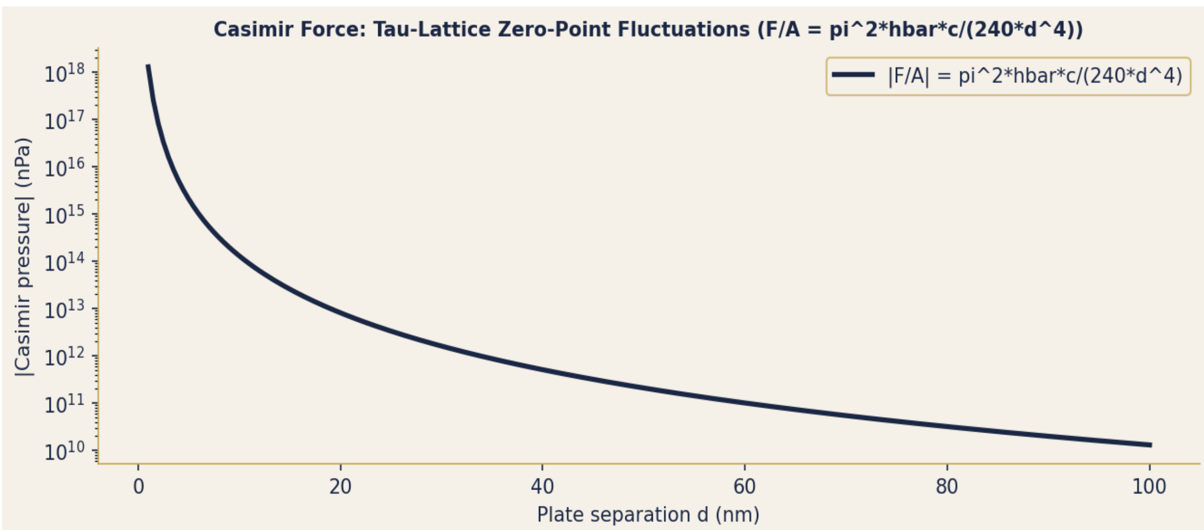

*Figure 3. Casimir pressure vs plate separation. The formula pi^2*hbar*c/(240*d^4) contains only tau-lattice quantities. 240=2^4x3x5 is a pure {2,3,5} integer.*

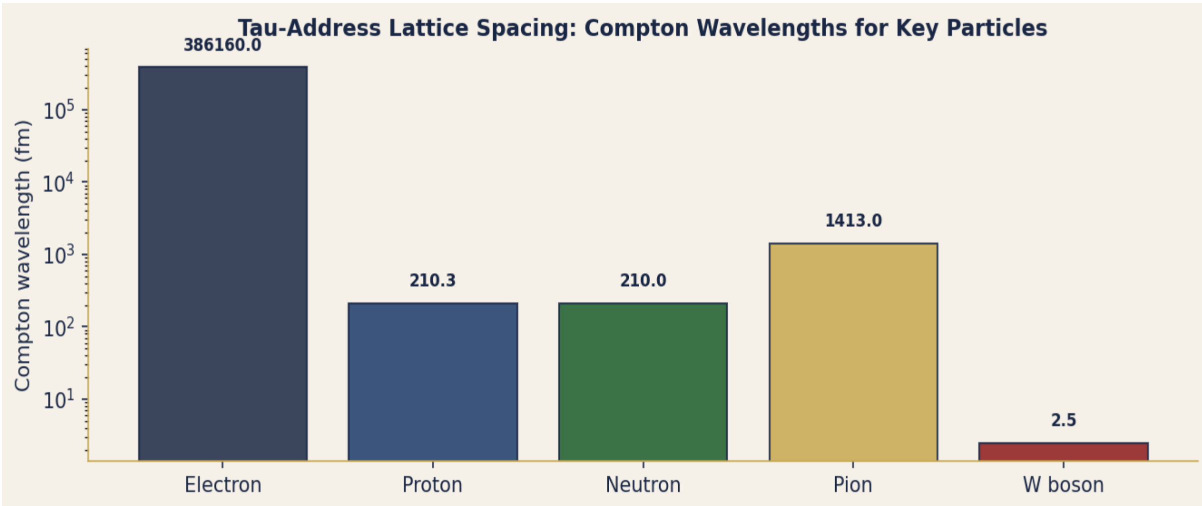

Figure 4. Compton wavelengths = tau-address lattice spacings for key particles. Electron (386,160 fm) vs proton (210.3 fm): ratio = 1836 = m_p/m_e.