21st Rencontres du Vietnam

100 YEARS OF THE QUANTUM PHYSICS

For objective reality, can we resolve the opposing categories between Classical Relativity and Quantum Mechanics?

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Contents

I- Complementarity principle (1)

Bohr Complementarity: In each experimental setup, only one of the two complementary properties can be measured or observed. When switching the experimental plan to collect information of the second property, the information of the first property immediately disappears.

Einstein-Bohr DEBATE at the 5th Solvay Conference 1927:
Quantum Physical Reality: Subjective or Objective ?

❑ **Copenhagen Interpretations (based on Bohr Complementarity):**
→ **One has NOWAY to get information simultaneously about both complementary properties (e.g. Wave and Particle)**
→ **Microscopic Structure is NOT Objective, except the Physical Reality appears only in Human Observation (Subjective).**

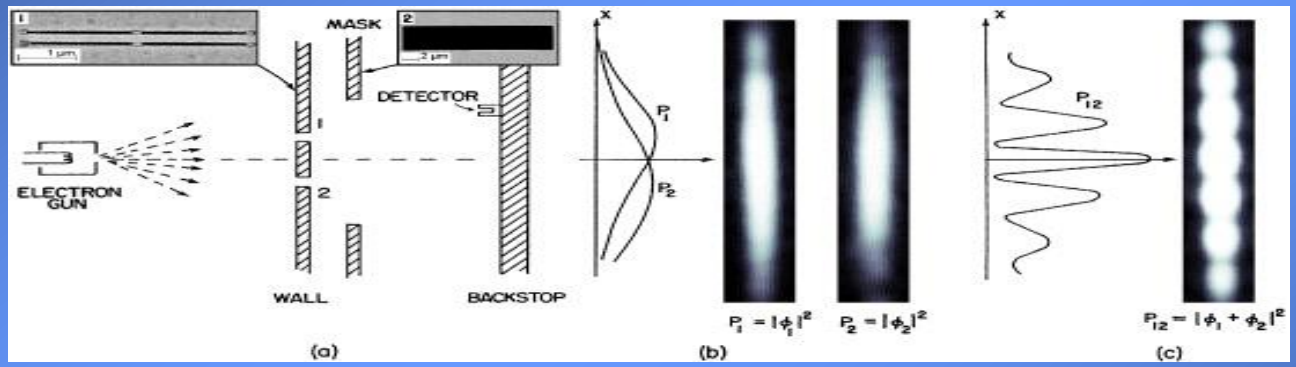
❑ **Einstein: Quantum Reality is Objective → QM is not wrong, but it seems Incomplete (Not Adequate) to explain Probability.**
→ An attempt in this trend: **de Broglie-Bohm (dBB)** theory with non-local hidden parameters with Dual Solution = **Quantum Equation** (Schrodinger) + **Classical Equation** (Haminton-Jacobi).

II-Complementarity principle (2)

- To **resolve the mystery of Quantum Mechanics, Feynman proposed to perform the Double-slit experiments with single particles**.

Wave function of single particle (sp): $|\psi_{sp}\rangle = \frac{1}{\sqrt{2}}(|\psi_V\rangle + |\psi_H\rangle)$

Single-electron interference buildup has been observed; Bach et al, New J.Phys. 15 (2013)

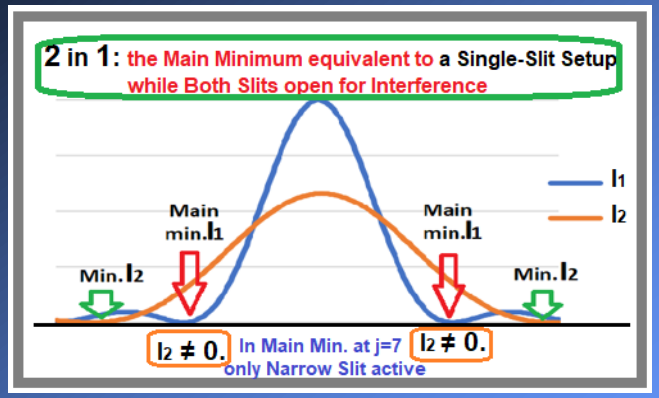


So far, **all Double-slit experiments have followed the complementarity principle, where some physical intervention is introduced to obtain both wave and particle information, by:**

Mobile mask, Wheeler Delay-choice Setups, Quantum Erasers etc.

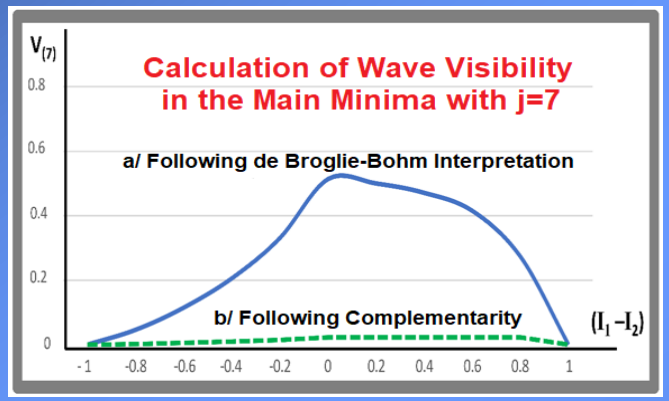
But, How about the Young-Feynman Double-Slit Experiments without any physical intervention?

II- Asymmetrical Double-slit experiments with single photons (1)



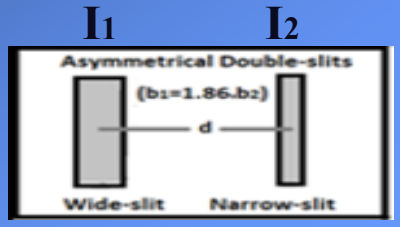
$$|\psi_{sp}\rangle = \frac{1}{\sqrt{2}}(|\psi_V\rangle + |\psi_H\rangle)$$

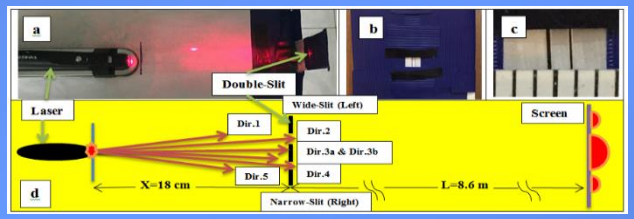
Self-Interference of I_2 is possible, Following dBB theory

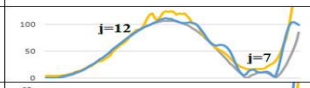
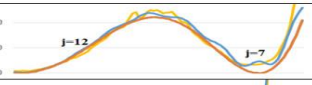
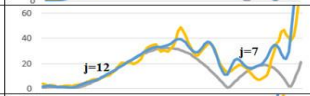
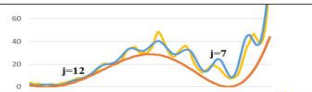
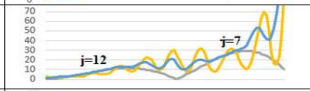
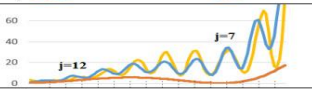
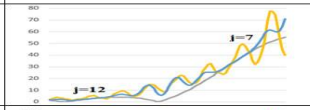
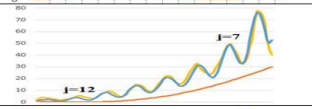
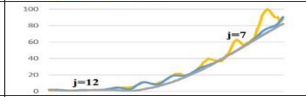
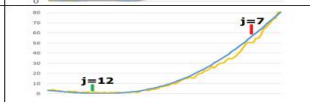
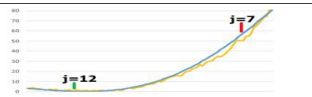


Complementarity principle with [D+V=1] expected: V(7) ≈ 0, then D(7) ≈ 1
→ at j=7 as photons passed through the only narrow slit.

Ref. Vo Van T. et al, Physica Scripta, 100 (2025) 055199

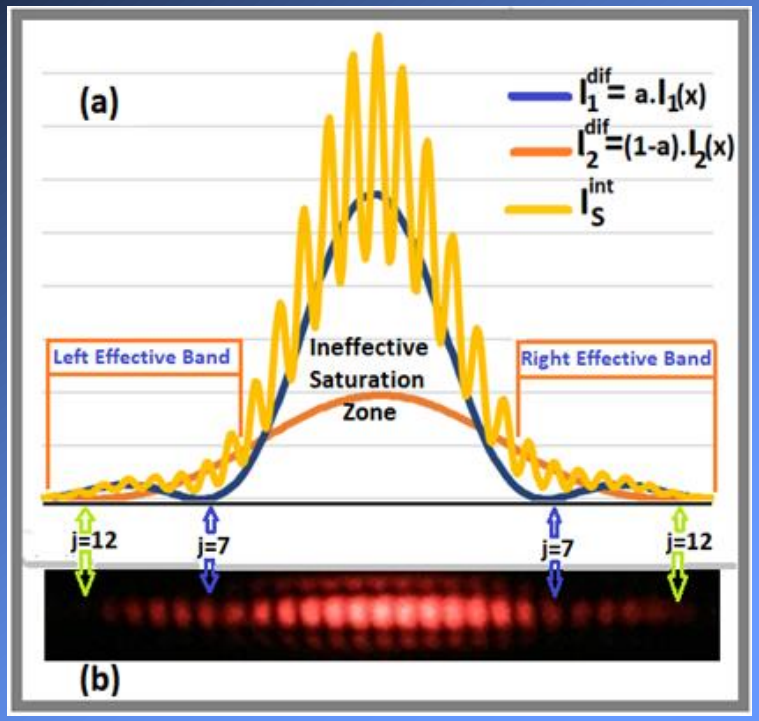




Spectra	(a)-DQ+V=1 Fitting	(b)-dBB-Fitting	(c)-DOF p-value for dBB
N1 I1=96% I2=4%			87 0.31
N2 I1=86% I2=14%			96 0.97
N3 I1=63% I2=37%			85 0.42
N4 I1=36% I2=64%			96 0.99
N5 I1=16% I2=84%			88 >0.99
N6 I1=0% I2≈100%			94 >0.99

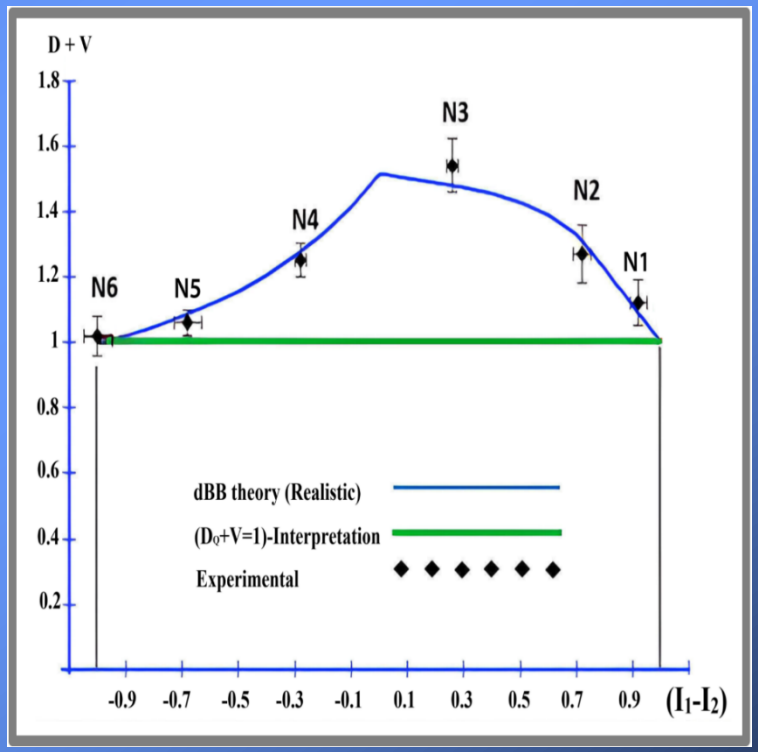
χ^2_ν-Square Test:
(a) Complementarity principle **Not** consistent;
(b) dBB consistent; (c) for dBB →all **p-values>>0.05**

II- Asymmetrical Double-slit experiments with single photons (2)



Ref. Vo Van T. et al, Phys. Scr., 100 (2025) 055199.

Sum (D+V) of Particle Distinguishability D and Wave Visibility V at j=7



Indeed, Interference Fringes have been observed at the Main minima!

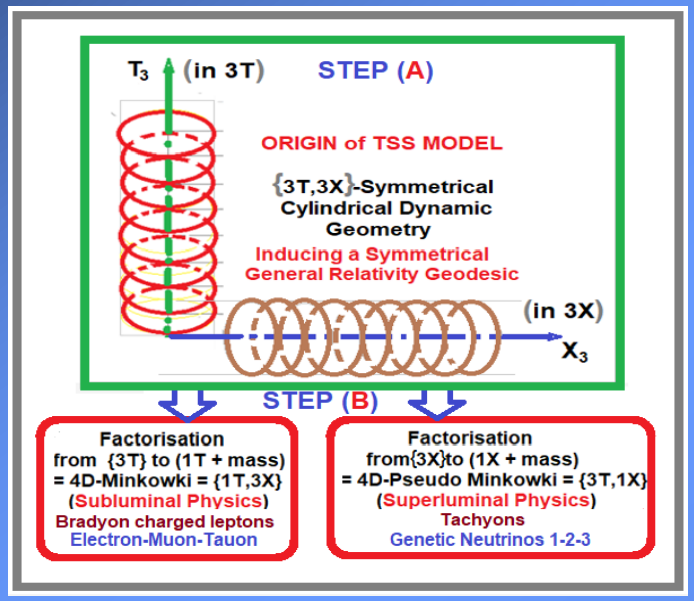
→ So, the Experiment with [D+V > 1] has proven Objective Quantum Reality, contrary to the Copenhagen interpretation.

Complementarity with [D+V = 1] (Green);
De Broglie-Bohm Theory (Blue);
Experiment N1-N6 (Black points).

III- Alternative interpretations to unify opposite issues (1)

- **For Objective Reality, we need an Alternative Interpretation, in particular, based on the Time-Space Symmetry TSS- Model:**
  Ref. Vo Van Thuan, Foundations of Physics, 47 (2017) 1559.

- **Step A =** in the original **6D-symmetrical Time-Space, we have an extended General Relativistic Geodesic solution,** in Copernican-like Laboratory Reference Frame.



Originally, the Extended Geodesic links two 3D-local sub-Geodesic conditions:

- ✓ **Helical evolution in the 3D phase (3T):**

$$\frac{\partial^2 \psi}{\partial {t_0}^2} - \left(\frac{\partial \varphi}{\partial t_0}\right)^2 \psi = 0,$$

- ✓ **Helicity in the 3D ordinary space (3X):**

$$\frac{\partial^2 \psi}{\partial {x_n}^2} - \left(\frac{\partial \varphi}{\partial x_n}\right)^2 \psi = 0.$$

Recall Centripetal acceleration: $a = \frac{\partial^2 R}{\partial t^2} = \omega^2 . R.$

- **Step B to get 4D Classical Mechanics**: in Ptolemaic-like Center-Mass Reference Frames: **We perform a Factorization of One of the Two 3D Sub-Spaces converting to 1D single pseudo-linear axis.**

III- Alternative interpretations to unify opposite issues (2)

➢ **Step B: e.g. Factorization to Classical 4D-Minkowski space-time**

→ In {1T,3X} :

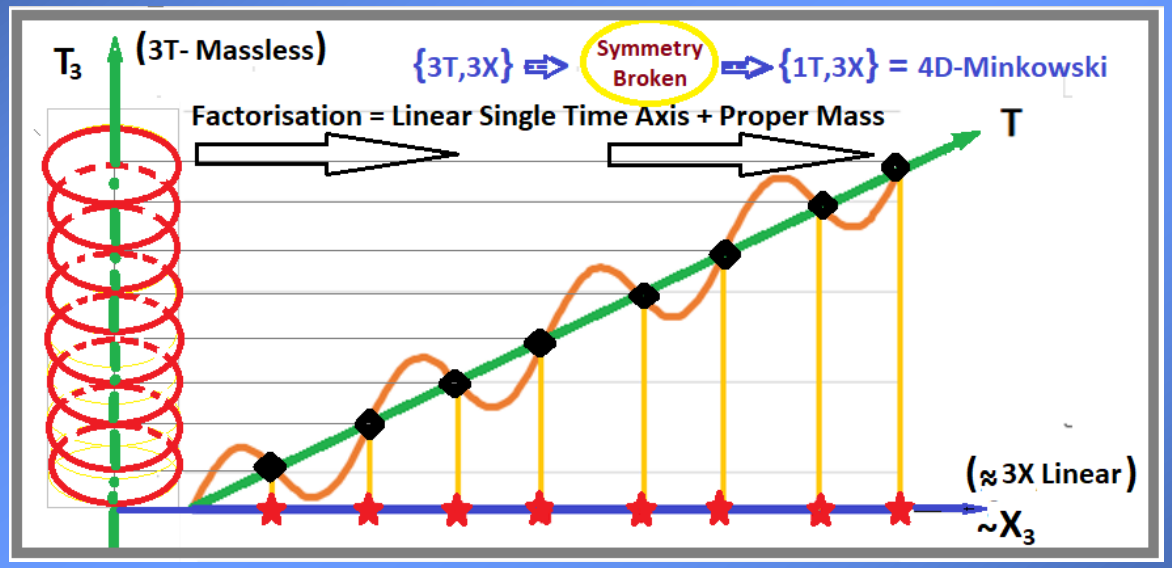
(Pseudo-Linear)

Special Relativity:

$dt^2 - dx^2 = dl^2$;

$E^2 - p^2 = m^2$

$(c = 1)$



➢ **Step C: Energy-Momentum Operators**: $\hat{E} \equiv i.\hbar\,\partial/\partial t$; $\hat{p} \equiv -i.\hbar\,\partial/\partial x$

→ equivalent to Superluminal Lorentz Transformation from 3D-Space (3X) to 3D-Phase (3T): $dt \to idt \equiv d\tilde{X}$ and $dx \to -idx \equiv d\tilde{T}$

➢ **Step D: Quantum KGF Equation**: $-\hbar^2.\frac{\partial^2\psi}{\partial t^2} + \hbar^2.\frac{\partial^2\psi}{\partial x^2} = m^2\psi$

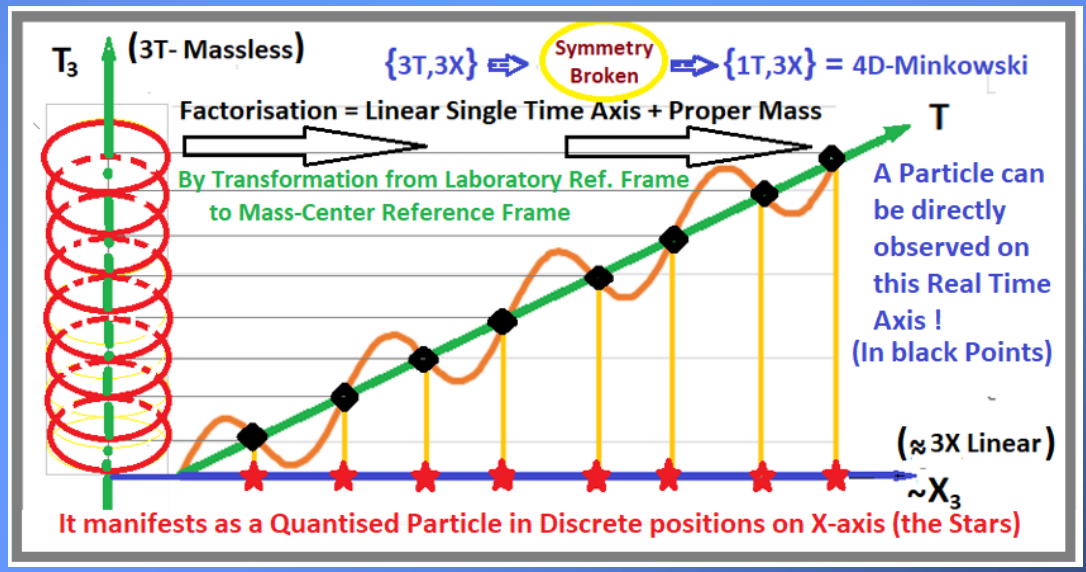
→ **Quantum Mechanics is a part of the Extended General Relativity !**

III- Alternative interpretations to unify opposite issues (3)

III.1- Linking Continuity with Discontinuity (Quantisation):

- After the Factorization, the **Hidden quantum Wave can still oscillate in extended 3D-time**, and **only when crossing the single physical time axis will it allow the electron to be observed discretely as a Quantised Particle of Apparent Reality**.

Even though, the particle still moves along a trajectory according to the Classical Relativistic Equations.



→ It also explains:

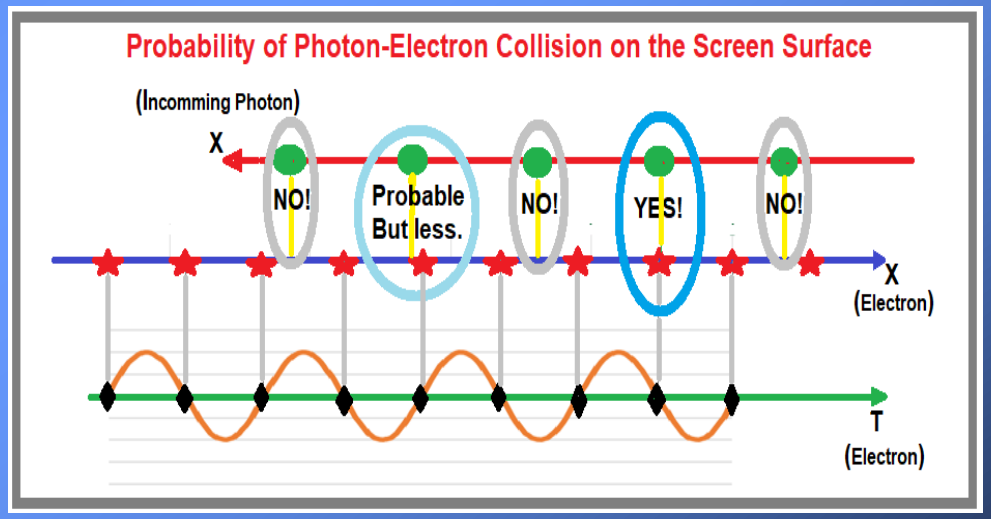
Why is a single electron recognized as a quanta containing a discrete energy portion (Quantization).

III- Alternative interpretations to unify opposite issues (4)

III.2- Linking Causality with Randomness (Statistical Probability)

Being quantized in time and space, electrons and photons can collide with each other for **registration** in a quantum measurement, only **when they are synchronized in time** and **superposed in space. But it happens randomly,** which **leads to Quantum Probability**.

Thus, **Quantum Probabilities are a consequence** of **our Limitation** in classical **Observations on a single physical time axis** (**1T**), **while Hidden Quantum waves continuously evolve in the 3D-time.**



→ New **explanation,** without **Wave function Collapse**, can **solve also the Problem of Quantum Measurement.**

III- Alternative interpretations to unify opposite issues (5)

III.3- **Linking Classical Determinism with Heisenberg's Uncertainty**:

Geodesic Equation {3T,3X} → 4D Equation Classical Mechanics (Deterministic) contains implicit 3D Local sub-Geodesic conditions→ separately independent in 3X Space and 3T Phase:

- Curved motion (helical rotation/spinning) in 3X Space leads to **Heisenberg coordinate-momentum uncertainty inequality**:

$$\frac{\partial^2\psi}{\partial {x_n}^2} - \left(\frac{\partial\varphi}{\partial x_n}\right)^2 \psi = 0 \qquad \rightarrow \qquad \Delta x.\Delta p \geq \pi\hbar,$$

[*See detail derivation in: ref.* Vo Van T., Found. Phys. 47 (2017) 1559]

- Similarly, Periodic oscillations in the 3D phase (3T Space) leads to the **Heisenberg time-energy uncertainty inequality**:

$$\frac{\partial^2\psi}{\partial {t_0}^2} - \left(\frac{\partial\varphi}{\partial t_0}\right)^2 \psi = 0 \qquad \rightarrow \qquad \Delta t.\Delta E \geq \pi\hbar.$$

Thus: **Heisenberg's Uncertainty originates from the Curvatures of Space-Time**, described by General Relativity ≡ a Deterministic Theory !

→ SO, There is NO contradiction between Uncertainty and Determinism.

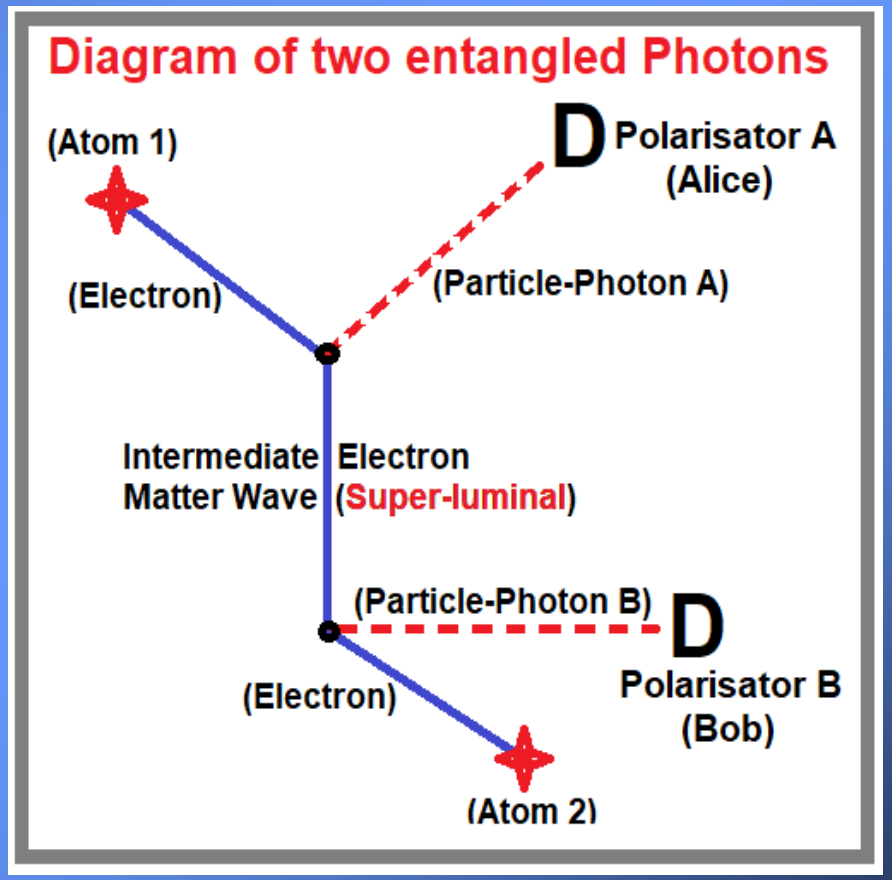
III- Alternative interpretations to unify opposite issues (6)

III.4- Linking Locality with Non-Locality:

An Atom emits two photons A and B, which are actually Particles of Apparent Reality.

But **their polarizations are still in Entanglement** through **electron's Super-luminal matter wave in 3D-time** (with Phase velocity faster than light: $v_{ph} > c$)

which helps to transfer any Non-local information between photons A and B.



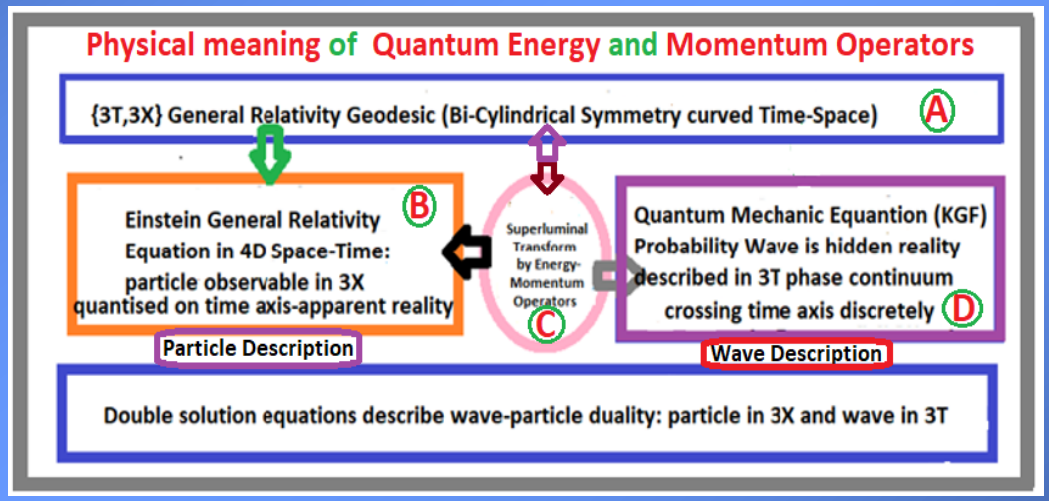
→ **So, TSS Model can resolve qualitatively all seemingly opposing categories between Classical Relativity and Quantum theory !**

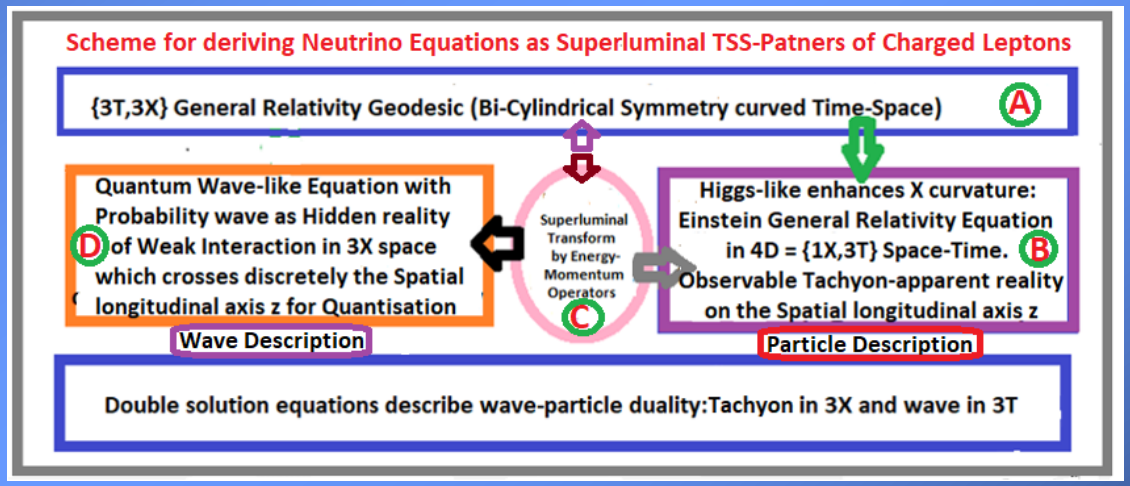
IV- TSS Model for Solution of Lepton mass hierarchy (1)

1. Consider that Tachyon Genetic Neutrinos as the TSS-partners of the Sub-luminal Charged Leptons:

- At **Step B**:

  Higgs-like potential makes the acceleration in 3D phase **(3T)** dominate: the **Factorisation to 4D-Minkowski space-time** {**1T,3X**} for classical **bradyons charged leptons {e-mu-tau}.**





Weak interaction as a Higgs-like potential makes acceleration in **3X** space dominate: the **Super-luminal Factorisation** to {**1X,3T**} for classical **tachyon-neutrino in 3D space**

IV- TSS Model for Solution of Lepton mass hierarchy (2)

2. Charge Lepton Mass hierarchy:

- Using the 3D local Geodesic condition in 3D phase:

$$\frac{\partial^2 \psi}{\partial {t_0}^2} - \left(\frac{\partial \varphi}{\partial t_0}\right)^2 \psi = 0$$

→ Formulate so-called **Micro-Cosmic Model in 3T**. Its de-Sitter-like exponential sub-solution lets to calculate the lepton's mass:

$$m_n = \rho_n . V_n,$$

with Comoving Volume V_n and Density ρ_n (proportional to Curvature C_n of the Hyper-Spherical surface S_n). Number of Generation is n = 1-2-3.

- Mass Calculation in the first order Approximation

Lepton (l_n)	*electron* (e)	*muon* (μ)	*tauon* (τ)
Density ρ_n	ϵ_0/ψ	ϵ_0/ψ^2	ϵ_0/ψ^3
Comoving volume, V_n	Φ	$4\pi\Phi^2$	$4\pi\Phi^3$
Formula of mass, m_n	$\epsilon_0 T$	$\epsilon_0 4\pi T^2$	$\epsilon_0 4\pi T^3$
$Exp-tal\ mass\ (m_n), [56]\ MeV$	0.510998928(11)	105.6583715(35)	1776.82(16)
$Calculated\ m_n,\ MeV$ $T = 16.5;$ $\epsilon_0 = 31.0\ keV$	**Calibrations** 0.511 $(*)$	106.0 $(*)$	**Prediction:** 1748.4 **(Differ ≈ 1.5%)**

The 2nd order Approximation much improves prediction:

$$m_\tau = 1774.82\ MeV$$

Differing only 0.11%

IV- TSS Model for Solution of Lepton mass hierarchy (3)

3. Mass hierarchy of Neutrinos:

By similar way, using the 3D local Geodesic condition:

$$\frac{\partial^2 \psi}{\partial {x_n}^2} - \left(\frac{\partial \varphi}{\partial x_n}\right)^2 \psi = 0$$

We formulate **Micro-Cosmic Model in 3D space** and calculate masses of genetic neutrinos as the tachyon partners. Neutrinos have tiny masses, but their absolute values are not known. Here **experimental masses are estimated based on neutrino oscillation data**.

(Ref. Vo Van T. Proceedings of 51st Rencontres de Moriond-Cosmology, 2016, p. 245).

Neutrino mass Calculation

in the First order Approximation:

Neutrino (ν_n)	ν_1	ν_2	ν_3
Density ρ_ν	ϵ_ν/ψ_ν	ϵ_ν/ψ_ν^2	ϵ_ν/ψ_ν^3
Comoving volume, V_ν	Φ_ν	$4\pi\Phi_\nu^2$	$4\pi\Phi_\nu^3$
Formula of $m_{\nu n}$	$\epsilon_\nu X_\nu$	$\epsilon_\nu 4\pi X_\nu^2$	$\epsilon_\nu 4\pi X_\nu^3$
$Exp-tal\ \Delta m^2,\ eV^2$	$\Delta m^2_{31} - \Delta m^2_{32}$ $= (1.0 \pm 7.0).10^{-5}$ $= {\Delta m^*_{21}}^2 \supset \Delta m^2_{21}$	$\Delta m^2_{21} =$ 7.50×10^{-5} $(\pm 2.3\%)$	$\Delta m^2_{31} =$ 2.46×10^{-3} $(\pm 1.9\%)$
a. *Calculated masses* $m_{\nu n}, eV$ $X_\nu = 5.728;$ $\epsilon_\nu = 2.10 \times 10^{-5} eV$	**Prediction** 1.20×10^{-4}	**Calibration** 8.66×10^{-3} $(\pm 1.2\%)$ $(*)$	4.96×10^{-2} $(\pm 1.0\%)$ $(*)$

V- Conclusions

- **The asymmetrical double-slit experiment** demonstrates that **D+V>1**, contrary to the Copenhagen interpretations.

→Therefore, **particles and quantum waves always exist objectively**, as **apparent** or **hidden Physical Reality**.

- It is **possible to link consistently all the opposing categories between Classical Relativity Theory and Quantum Mechanics**,

→ It has been achieved by applying **the Quantum Energy-Momentum operators** as **Super-Luminal Transformation in Extended {3T,3X}**.

→ Therefore, **Quantum Mechanics is a path of the Extended General Relativity.**

- **The Time-Space-Symmetry Approach** is quite **effective in resolving** different **Problems beyond Standard Model** of Quantum theory.

→ This **TSS Model** can be further **verified experimentally (e.g. with dark matter, dark energy etc.)**, in particular**, Neutrinos as Messengers from Extended 3D-time can help to verify the Hidden Quantum Reality**.

References

[1] Vo Van Thuan. A possible solution to the which-way problem by asymmetrical double-slit experiments. Phys. Scr. **96** (2021) 125101.

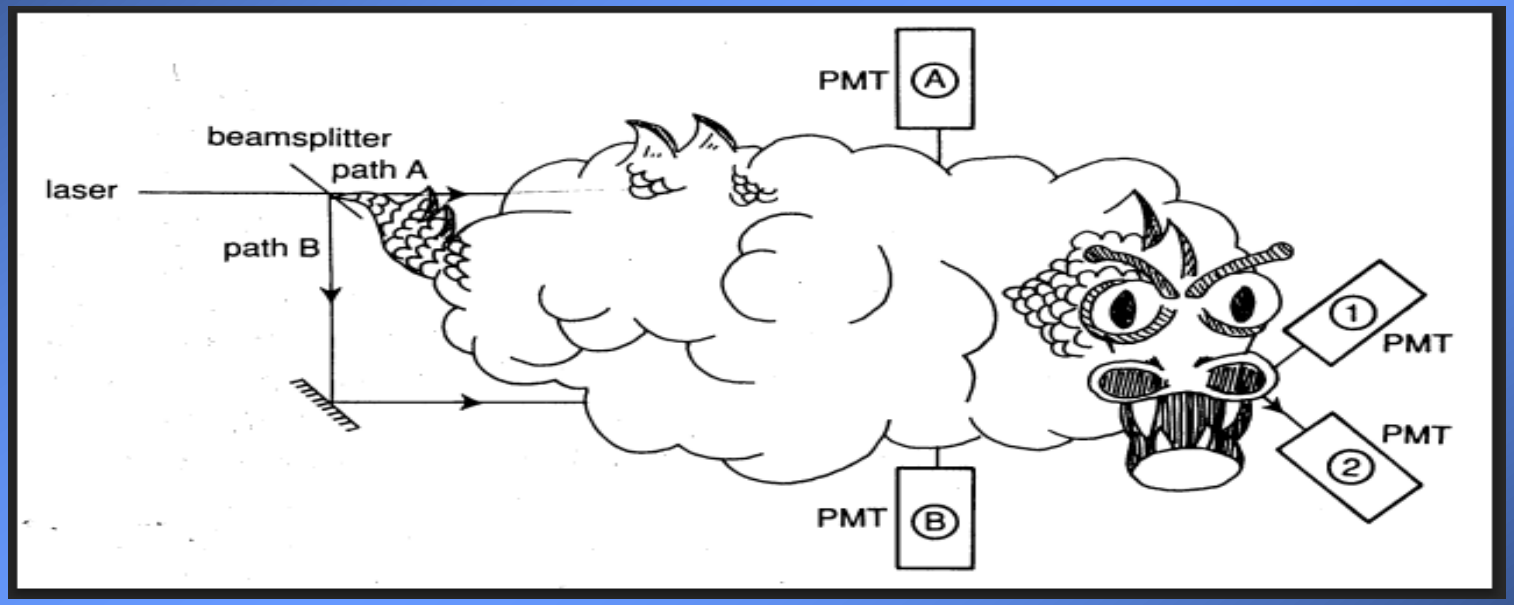
[2] Vo Van Thuan and Vu Duc Vinh. Which-way identification by an asymmetrical double-slit experiment with monochromatic photons. Sci. Rep. **12** (2022) 1008.

[3] Vo Van Thuan, Vu Duc Vinh, Nguyen Thanh Hung, Dang Quang Thieu. Wave-particle duality in asymmetrical double-slit interference experiments. Phys. Scr. **100** (2025) 055119.

[4] Vo Van Thuan. A Time-Space Symmetry based Cylindrical Model for Quantum Mechanics interpretations. Found. Phys. **47** (2017) 1559.

J. Wheeler's Great Smoky Dragon (1985) Havard Univ. Press, MA.

Does its body exist behind the smoke?



Thank you for your attention !