The Strand Hypothesis: One Law of Nature

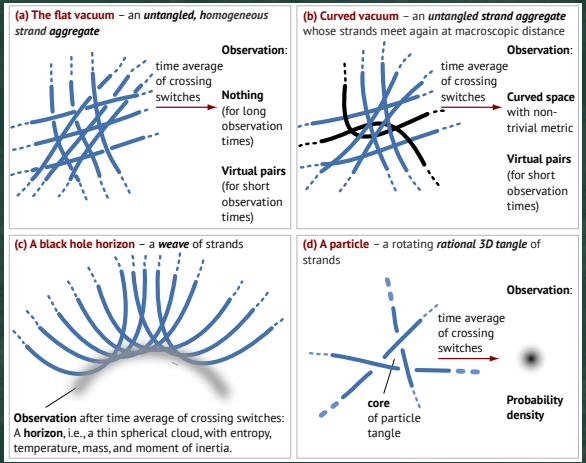
A single fundamental principle yields the Lagrangians of general relativity and of the standard model of particle physics with massive neutrinos, the principle of least action, particle mass estimates, and the fine structure constant

Louis H. Kauffman and Christoph Schiller
cs@motionmountain.net

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Small text is clickable:
Outreach at motionmountain.net/tiny and motionmountain.substack.com
Animations at motionmountain.net/videos
Publication list at motionmountain.net/strands
Preprints at researchgate.net/profile/Christoph-Schiller-2/research.

Hypothesis overview: Nature is made of strands of Planck radius - *fluctuating* and *unobservable* - whose crossing switches are observable.



Argued below: crossing switches of fluctuating strands of Planck radius yield *general relativity* and the *standard model with massive neutrinos* as limits of strand-based quantum gravity.

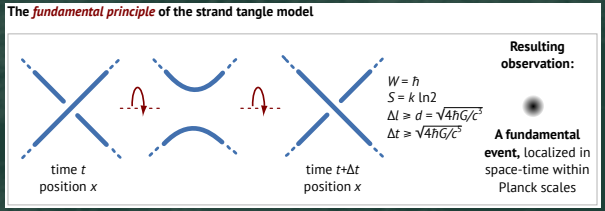
CS, Phys. Part. Nucl. 50 (2019) 259

CS, Eur. Phys. J. Plus 136 (2021) 79

Predictions & tests: only 3 dimensions; only one vacuum; no measurable deviations from the two Lagrangians; no unified Lagrangian; no unified equations; no other model for unification. So far, all correct.

Dirac 1929 (unpublished, see Gardner), Battey-Pratt and Racey 1980, Kauffman 1987, Kauffman and Schiller 2026 (submitted)

The fundamental principle and single law of nature of the strand hypothesis:
Planck's $\hbar$ is due to twist-induced *crossing switches* of strands (Kauffman, 1987)
and so are the Planck length, the Planck time and the Boltzmann constant (CS, 2019).



The strand hypothesis: the fundamental principle contains all laws of nature.

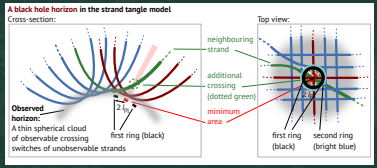
Predictions & tests: $\hbar$ is constant and invariant; quantum theory is valid without exception; no other model for $\hbar$ exists. So far, all correct.
Because *all* measurement apparatuses, *all* measurement units, and *all* measurement processes make use of $\hbar$, a correct model for $\hbar$ must *reproduce all observations in nature*. See next slides.

Details in preprint researchgate.net/publication/403963214 and in researchgate.net/publication/361866270.

List of experimental predictions at motionmountain.net/predictions.

Strands imply general relativity.

General relativity can be deduced in at least three ways from the fundamental principle:



1. The oldest derivation: crossing switches imply black hole entropy, temperature and energy. Following Jacobson (1995), this implies general relativity.

CS, Ind. J. Phys. 96 (2022) 3047

CS in K. Arun, "A Guide to Black Holes", Nova Science Publishers (2023)

2. The shortest derivation: the fundamental principle implies maximum force $c^4/4G$. The maximum force implies general relativity.

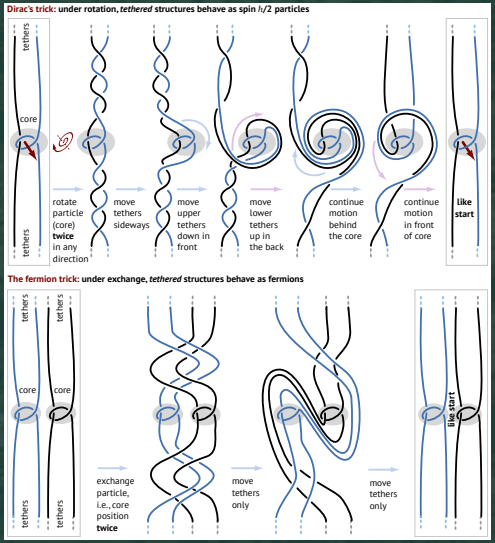
CS, Phys. Rev. D 104 (2021) 124079

AK, CS & CS, Int. J. Mod. Phys. D 31 (2022) 2242019

3. A further derivation: inhomogeneous crossing switches yield curved geodesics, space curvature, space elasticity, and the principle of least action. They imply general relativity.

Predictions & tests: no measurable deviation from general relativity and the Hilbert Lagrangian. No new measurable quantum gravity effects. So far, all correct.

Tangles of unobservable strands explain and model spin 1/2 fermions with Dirac's trick.



Spinning fermions are *rotating rational 3d tangle cores* continuously performing Dirac's trick. Antiparticles are mirror tangles with opposite rotation.

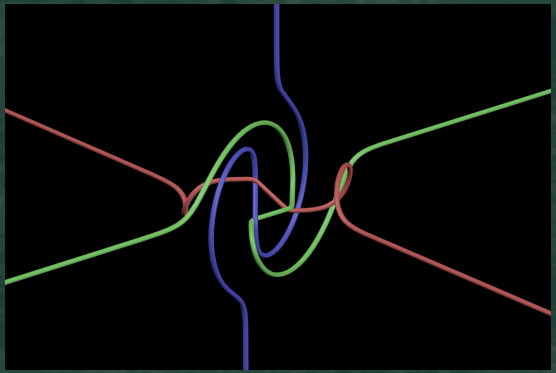
Tethered fermions *can orbit* each other continuously – also in atoms.

The spin-statistics theorem and Pauli's exclusion principle are valid.

Detailed arguments in preprint 403963214.

Predictions & tests: there are no elementary spin 3/2 particles, no particles with spin between 0 and 1/2, and no 3d anyons; no action below $\hbar$ is observable; there is no other model for spin 1/2. All confirmed.

Animation of a spinning electron, programmed by Ronwnor.



All animations also at motionmountain.net/videos.

The *central triangle* is the *chiral electron* core.

Elementary fermions are chiral.

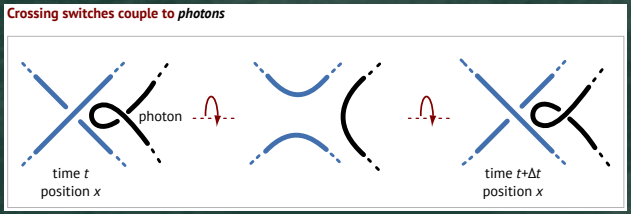
Particles move through the vacuum like propellers through the air - as Feynman told us.

Each outer chiral crossing yields an electric charge e/3.

Vacuum strands are not shown.

Predictions & tests: unique, calculable, and small mass (see later on).

Only strands explain the principle of least action - and why crossing switches are observable.



Crossing switches are observable because they couple to photons.

Least action means *fewest crossing switches*.

Crossing switches need volume to occur.

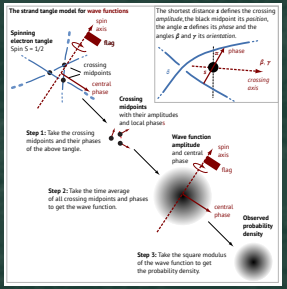
During Dirac's trick and motion, neighboring vacuum strands must also change shape.

The *more* strands remain parallel, the *less* volume is needed, the *fewer* strands need to change shape, and the *higher* the probability of a shape change to occur.

In simple words, *least action is due to volume optimization.* Details in preprint 403963214.

Predictions & tests: no observable deviation from least action; no alternative explanation or derivation of least action; all measurements are electromagnetic. All confirmed.

Only tangled strands imply spinors and the Dirac equation.



Dirac spinors arise from *oriented crossing densities* and the *four angles characterizing a crossing*.

Special relativity's three boost parameters can be incorporated into Dirac's trick. Doing so, in 1980, Battey-Pratt and Racey *derived the Dirac equation* from Dirac's trick. BPR, Int J Theor Phys 19, 437475 (1980) 437

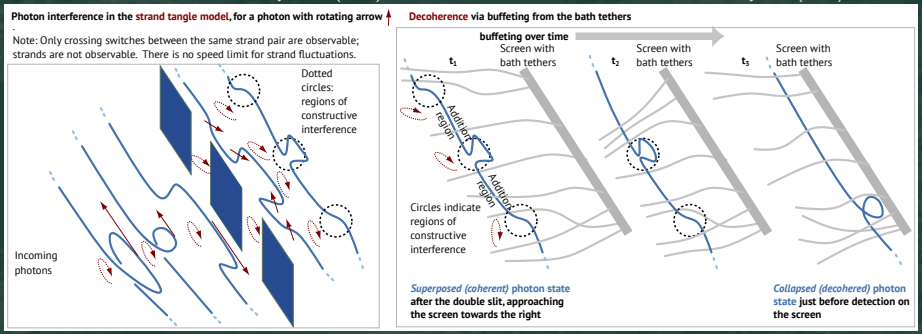
Only *rational tangles*, i.e., 3d braids, reproduce antiparticles, virtual particles, reactions, interactions, and decays. See preprint 403963214 and preprint 361866270.

Predictions & tests: no deviation from the free single-particle Dirac equation; no other ab initio derivation; no other explanation of spinor wave functions, of continuous transitions between particles and antiparticles, of virtual particles or of particle reactions. All confirmed.

Only strands explain why a photon only interferes with itself.

A *photon* is a rotating loop in a strand. Rotating loops explain spin 1, wavelength, boson behaviour, vanishing mass, parities, "infinite" lifetime, and U(1) invariance.

CS, J. Geom. Phys. 178 (2022) 104551 CS, Int. J. Geom. Methods Mod. Phys, 21 (2024) 2450057

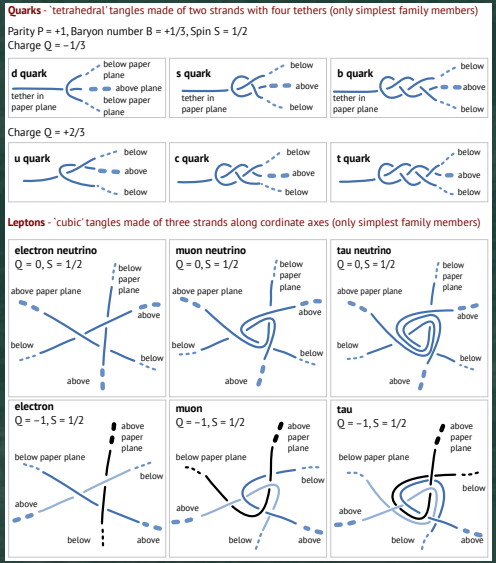


Interference is due to *hopping* of *partial* tangles. A Fock space arises.

Path integrals follow from moving rotating tangle cores assumed to be *point-like*.

Predictions & tests: no deviation from textbooks; no other model for interference possible; decoherence occurs; no non-contextual hidden variables. So far, all correct.

Only strands explain and derive the elementary fermions and their quantum numbers.



Classifying tangles allows classifying elementary particles, yielding *three generations* of *four fermions*.

Topology defines flavours.

Topological chirality - 1/3 of the signed crossing number - yields electric charge.

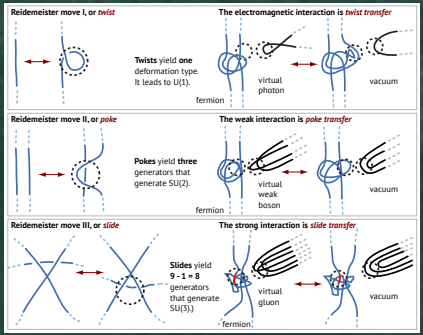
Geometric chirality yields C and P *parities* and, due to non-trivial topology, non-vanishing *masses*.

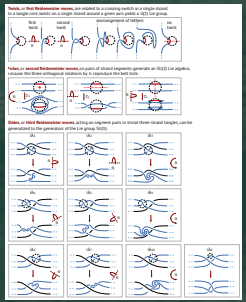
Predictions & tests: there is no other elementary fermion and no elementary dark matter; neutrinos have mass; there is no other model for the elementary particle spectrum. So far, all correct.

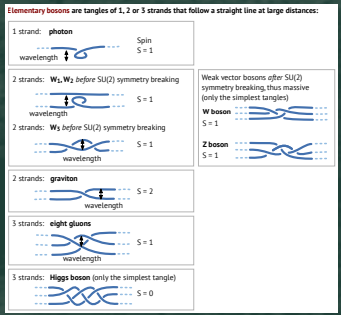
Only strands explain and derive the gauge interactions and their Lie groups.

Interactions change phases. Therefore, interactions are deformations of tangles. Reidemeister's theorem from 1926 allows the classification of deformations and thus of interactions and gauge bosons. *Only the three observed gauge groups arise.*

CS, Int. J. Geom. Meth. Mod. Phys. 21 (2024) 2450057

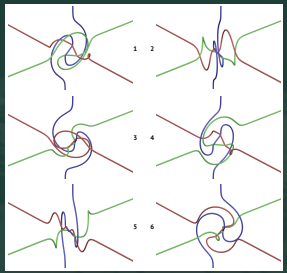






Predictions & tests: there are no other gauge interactions or gauge groups; SU(2) is broken; only the W is electrically charged; only one Higgs boson exists; no other elementary bosons exist; there is no other model for bosons. So far, all correct.

The only observable *pure* quantum gravity effects, part 1: particle masses (and mixings).



Mass is determined by the *probability of Dirac's trick* for a topologically chiral core moving through vacuum.

Mass *runs* with 4-momentum.

Boson motion implies a *mass estimate for the W boson* between $32\,\mathrm{GeV}/c^2$ and $8.4\,\mathrm{TeV}/c^2$.

Tether motion imply a *mass estimate for the Higgs* between $96\,\mathrm{GeV}/c^2$ and $3.9\,\mathrm{TeV}/c^2$.

Estimates from preprint 403963214 and preprint 361866270.

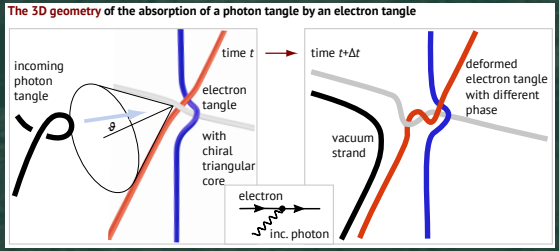
Dirac's trick (2 turns with 3 steps each) implies an *upper limit for lepton masses* given by

$$m_{\mathrm{lepton}} < \left(\frac{1}{6!}\right)^{2\cdot 3} \approx 7.2 \times 10^{-18} \approx 44\,\mathrm{GeV}/c^2$$

The observed tau mass is $1.78\,\mathrm{GeV}/c^2$. Strands *solve the mass hierarchy problem*.

Predictions & tests: no heavier lepton; no other ab initio model for elementary particle mass values is possible; inertial mass and gravitational mass are equal; more and better estimates for masses and mixing angles are possible. All confirmed.

The only observable *pure* quantum gravity effects, part 2: coupling constants – & summary.



The fluctuations of chiral fermion cores yield the fine-structure constant 1/137.035999095… (the de Vries formula), and the strong coupling constant within 30%.

Coupling constants *run* with four-momentum.

LK & CS, preprint 403963214, and CS, Int. J. Geom. Meth. Mod. Phys. 20 (2023) 2350095.

Prediction 1: *No deviation* from the Lagrangians of general relativity or of the standard model with massive neutrinos will ever be observed. Also no new quantum gravity effects.

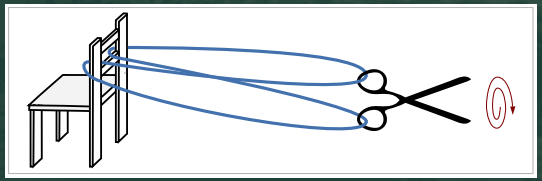
Prediction 2: *No other model* will reproduce perturbative QED and QCD, the fine structure constant, the electron g-factor and all other constants of the standard model.

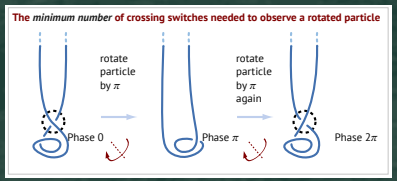
Prediction 3: Coupling constants, masses, and mixing angles and their running *can be calculated precisely,* and allow falsifying the strand model.

Thank you for your attention.

Appendix: Dirac's 1929 model of fermion spin uses strands and visualizes $\hbar$.

Objects tethered with strands behave like spin $\hbar/2$ particles: the strands can return to the original, untangled situation after a rotation by 4π, *not* after a rotation by 2π.

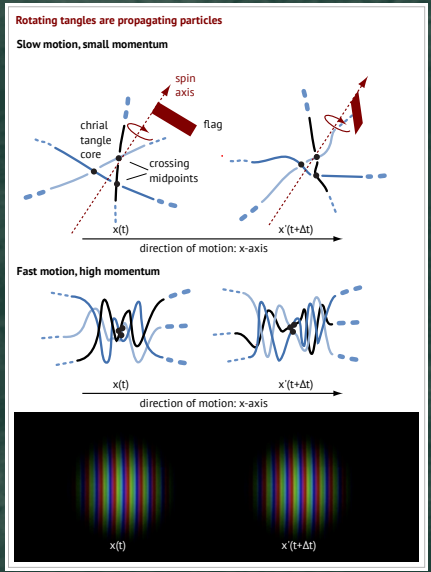




This requires: *Strands are unobservable*. Strands have an unobservably small radius – a *Planck radius* – and are uncuttable, extremely flexible, and permanently fluctuating.

As Louis Kauffman formulated in 1987, this also requires:
Crossing switches are observable and define $\hbar$ because they are related to non-commutativity and because a rotation of an elementary particle by 2π is the smallest observable change, and thus the smallest measurable action.

Appendix: Crossing switches of strands explain and derive wave-particle duality.



Moving fermions spin like a moving *maple seed.*

Each rotation implies a crossing switch.

Each crossing switch corresponds to $\hbar$.

This implies *de Broglie's relation*

$$\lambda = 2\pi\hbar/p$$

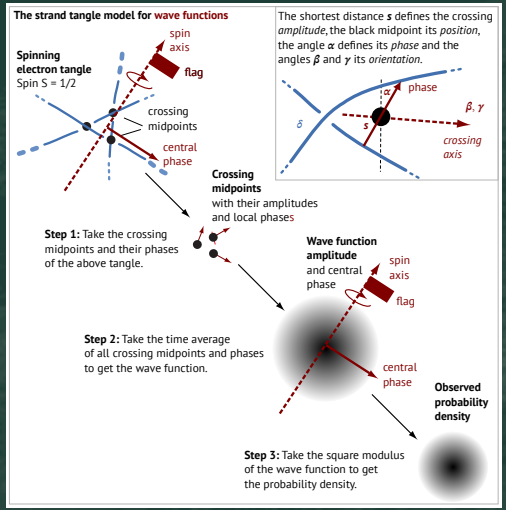
between wavelength λ and momentum p, and to the relation

$$f = E/2\pi\hbar$$

between energy E and frequency f.

Predictions & tests: no measurable deviation from wave-particle duality; no other model derives de Broglie's relations. All confirmed.

Appendix: Only strands imply wave functions and quantum mechanics.



More at motionmountain.net/strandsquantum.html

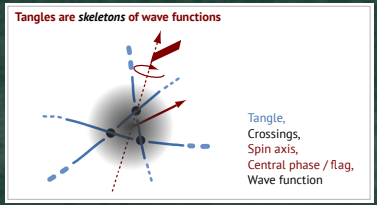
Spinning particles are rotating tangles.

Wave functions are *oriented crossing densities* and form a Hilbert space.

This leads to the *free Schrödinger equation.*

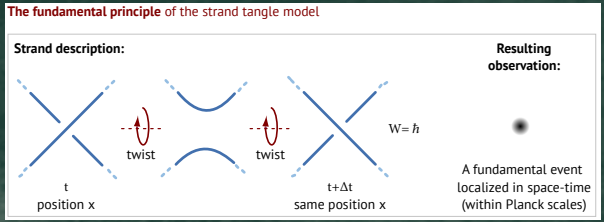
Proof in preprint 361866270.

Tangles are *skeletons* of wave functions:



Predictions & tests: no measurable deviations from quantum theory; no other model for wave functions. All confirmed.

Appendix: Strands explain Heisenberg's indeterminacy relation and his canonical commutation relation.



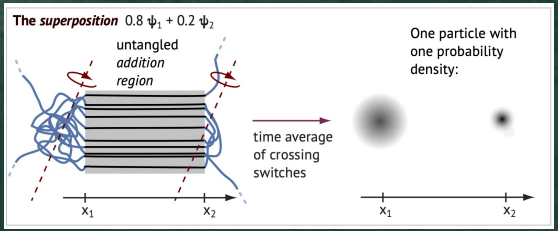
Distance is the number of smallest crossing switches and *momentum* is the number of action quanta per length. This explains the indeterminacy relation (uncertainty relation):

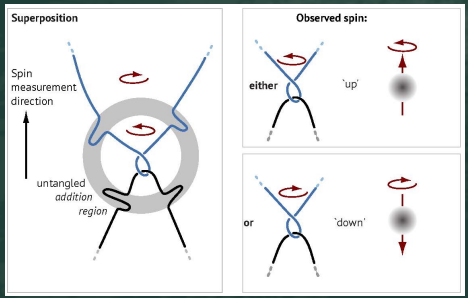
$$\Delta S \geqslant \hbar/2 \quad \text{and thus} \quad \Delta x \Delta p \geqslant \hbar/2$$

Crossing switches also explain the canonical commutation relation $[X, P_X] = i\hbar$.

Predictions & tests: no measurable deviation from both relations at any energy; no other model for the relations is possible. All confirmed.

Appendix: Strands explain superpositions, decoherence, and measurements.





Animation at youtu.be/-KGW3QvwFuE

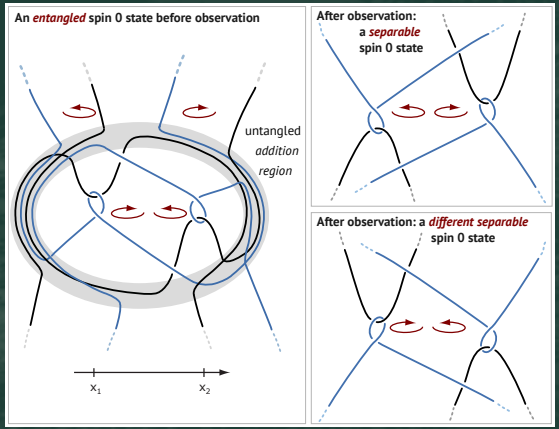
Superpositions are partial tangles connected by *untangled addition regions*.

In decoherence, the coupling to a bath *takes out* the addition region by buffeting.

Because strands are extended, they are *not* local hidden variables.

Predictions & tests: no measurable deviation from Born's rule and from decoherence; no *local* hidden variables; no other model for decoherence. All confirmed.

Appendix: Strands explain entanglement.



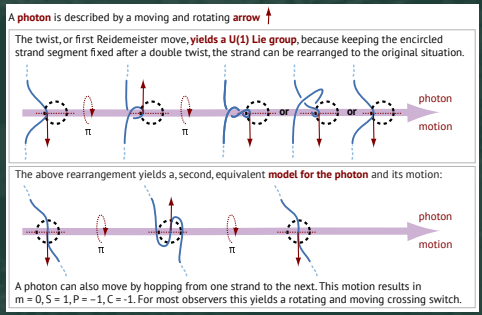
Quantum entanglement is due to *topological entanglement*.

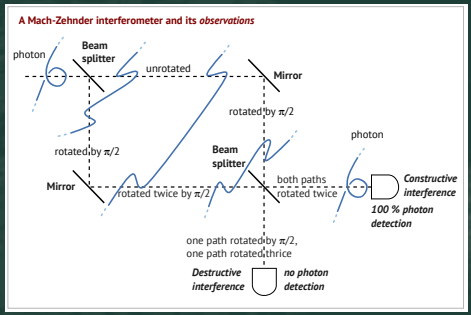
Measurements take out the addition region.

Three-particle entanglement is reproduced.

Predictions & tests: no measurable deviation from quantum entanglement; no other model for entanglement is possible. All confirmed.

Appendix: Strands define photon motion and explain Mach-Zehnder interferometers.





Predictions & tests: no measurable deviation from photon properties; no other model for photons is possible. All confirmed.

Appendix: Strands reduce the 9 lines of modern physics to a single one.

Line I: Nature is lazy: $\delta W = 0$.

Line II: Nature dislikes haste: $v \leqslant c$.

Line III: Nature dislikes excessive force: $F \leqslant c^4/4G$.

Line IV: Nature dislikes sloth: $W \geqslant \hbar$.

Line V: Nature dislikes perfect order: $S \geqslant k \ln 2$.

Line VI: Nature conserves electric charge: U(1).

Line VII: Nature has two nuclear interactions: SU(3) and broken SU(2).

Line VIII: Nature has 18 elementary particles.

Line IX: Nature has 27 fundamental constants: masses, couplings, mixings, 3 dimensions, Λ.

Only one law of nature: Crossing switches of stands with Planck radius determine the quantum of action $\hbar$, the Boltzmann constant k, and the Planck time.

Predictions & tests: no deviation from the standard model with massive neutrinos; no deviation from general relativity; no alternative unification of physics. All confirmed.

CS, Zeitsch. f. Naturf. A 78 (2023), 145-159 and preprint 397264142.

Appendix on AI.

Not a single idea,
not a single sentence,
nor a single graph
is due to artificial intelligence systems or to absent intelligence systems.