Quest for the ultimate automaton

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Abstract

A fully deterministic, Euclidean, 4-torus cellular automaton is presented axiomatically using a constructive approach. Each cell contains one integer number forming bubble-like patterns propagating at speeds at least equal to that of light, interacting and being reemitted constantly. The collective behavior of these integers looks like patterns of classical and quantum physics. In this toy universe, the four forces of nature are unified. In particular, the graviton fits nicely in this framework. Although essentially nonlocal, it preserves the no-signalling principle. This flexible model predicts three results: i) if an electron is left completely alone (if even possible), still continues to emit low frequency fundamental photons; ii) neutrinos are Majorana fermions; and, last but not least, iii) gravity is not quantized. Pseudocode implementing these ideas is contained in the appendix. This is the first, raw, version of this document. I expect to make corrections in future releases.

Keywords: cellular automaton, graviton, beyond standard model, unification, nonlocality, Majorana fermion

1 Introduction

Cellular automata are mathematical idealizations of physical systems in which space and time are discrete. The idea of modeling our universe using cellular automata is not new, discreteness is seen by many authors (Refs. [1–7] form a small list) as a cure for the divergences of the Standard Model (SM), and is supported by the existence of a fundamental Planck volume V_p, suggesting that structures smaller than this tiny volume should not be relevant to the theory. This cellular automaton can be regarded as a model beyond the SM.

Quantum mechanics (QM), despite its resounding success, gives us a slightly blurry image of the universe due to it being based on the uncertainty principle, in point particles and its most accepted interpretation be based on probabilities. Recent results of experimental physics, which surpasses by far the accuracy achieved by the predictions of QM, require a new model of the universe in which QM is just a limiting case.

Can nature be modeled as a cellular automaton? The model described here is meant to investigate this possibility. The emergence of a unified theory of physics is the ultimate goal of a final version based on this approach. Here the automaton is a couple of simple cubic grids closed on themselves as a 4-torus where one *tile* (formatted integer number) is attached to each cell. The cell has a processor, or logical circuit, and interacts with its eight nearest neighbors only (von Neumann convention). Preons are modified under the tick of a central clock. A reduced number of basic rules is analyzed and an even smaller number is presented in algorithmic form and implemented as a proof-of-principle computer program. The Planck length is the natural candidate to be used as the distance between the automaton cells. The outline of a pure hardware solution is also provided.

The approach adopted in this work is a constructive one. Whenever possible, I try to emulate directly the laws of physics, probing the most adequate heuristics. Notice that this line of research was apparently abandoned a long time ago as not promissing. See Zuse [1] for an early attempt.

On the other hand, I'm not saying that the Universe is a vast computer, in fact, I'm attempting to model Planck scale physics using a cellular automaton. Except for developing the basic principles, the construction of an automaton for directly solving cosmological problems, or even complex molecules, is inconceivable. Its complete usefulness will only be possible through statistical mechanics or direct mathematical analysis. Furthermore, this automaton can not be considered either quantum or classical. Actually, the regularities or patterns generated by the system is that might be considered quantum-like or classical-like. They have no *a priori* meaning.

This work is presented in five sections. In Section 1, I describe the context in which this work was done, the previous efforts by generations of researchers and the main idea. In Section II, general concepts are presented as gears of the automaton. In Section 3, the patterns associated with elementary particles were identified and classified. In Section 4, all the knowledge is compacted and systematized as a theory, including pseudocode in the appendix. Finally, I conclude in Section 5.

2 Concepts

In this Section, some concepts are loosely explored before the rigorous sistematization of the model in Section 4.

2.1 The cellular automaton

The cellular automaton is a dual Euclidean lattice 4-torus of dimension SIDE, where a single tile is attached to each cell. The distance between cells is L and the clock period (p_1) is T. Each lattice is alternatively principal (read-only) or dual (draft). D is the main diagonal of the lattice. When propagating as a spherical wavefront at the speed of light they are called a *preon*. When propagating as a superluminal wavefront at the maximum speed allowed in the automaton, they form a *burst*. Bursts are just low level messengers, so support the no-signalling principle. When propagating in isolation at the speed of light it is a graviton.

2.2 Tile properties

Tiles are formatted in many integer fields ($p_0 ... p_{26}$) representing signed or unsigned integer values of variable sizes or as vectors in 3d space.

2.3 Combinations of preons

Isolated preons act as fragments of charge (U). Two overlapping preons can form a preon pair (P). Three overlapping preons can form a preon triad (Tr). Us typically interact with other Us, Ps and Tr's. Ps can sometimes interact with other Ps or Tr's. Elementary particles are composite systems os Us, Ps and Tr's, carrying HBAR/2 quantity of intrinsic angular momentum, in the case of fermions, or HBAR, in the case of bosons. Ps are further subclassified as VCPs, forming the vacuum; EMP, are responsible by the static EM forces; GLP, form gluons; MSP, form mesons; MGP, contribute to the emergence of the mass of particles; PHP, form the photons; PMPs, are available for particle pairs formation. The table below shows detailed properties of all Ps.

$\mathbf{p}_2$		$\vec{p}_6$		$\vec{p}_7$		$\mathbf{p}_8$		$\mathbf{p}_9$		$\mathbf{p}_{10}$		$\vec{p}_{12}$		$\mathbf{p}_{13}$		$\mathbf{p}_{21}$	**Obs.**
1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2		$h = \{0, \pm 1\}$
V	V	$\vec{o}$	$\vec{o}$	Ø	Ø	q	$-q$	h_1	h_2	c	$\bar{c}$	Ø	Ø	0	0	**VCP**	$q = \{0, \pm 1\}$
R	R	$\vec{o}$	$\vec{o}$	$\vec{d}$	$\vec{d}$									e	e	**KNP**	$\vec{d} \neq \emptyset$
V	V	$\vec{o}$	$\vec{o}$	$\vec{d}$	$-\vec{d}$					c_1	c_2	$\vec{v}$	$-\vec{v}$	e	e	**GLP**	
R	R	$\vec{o}$	$\vec{o}$	$\vec{d}$	$-\vec{d}$			q	0			$\vec{v}$	Ø	e	e	**NTP**	$q \neq 0$
r	r	$\vec{o}$	$\vec{o}$	$\vec{d}$	$-\vec{d}$									e	e	**MGP**	
V	V	$\vec{o}$	$\vec{o}$			q	$-q$			c_1	c_2	$\vec{v}$	$-\vec{v}$	e	e	**MSP**	
r	r	$\vec{o}$	$\vec{o}$			q	$-q$			c	$\bar{c}$			e	e	**PHP**	$c = LEPT$
V	V	$\vec{o}$	$\vec{o}$			q	q					$\vec{v}$	$-\vec{v}$	e	e	**EMP**	$v \neq \emptyset$
r	r	Ø	Ø					h_1	h_2					0	0	**PMP**	$h = \{0, \pm 1\}$

2.4 Inertia

Definition KNPs are responsible for the spatial translation of fundamental particles and therefore contribute to the relativistic mass. Moreover. The KNP can be considered the unit of linear momentum and kinetic energy, and therefore contributes to the inertia of material bodies.

Simple inertial mechanism A KNP translates a U through 3d space. In the simplest scenario, the U and the KNP form a simple inertial system. The pair interacts with the U making it move one light step in the p_7 directions. This interaction is a privileged one, by passing the normal EM filtering due to the coincident entanglement fields of the U and one of the KNP. If left undisturbed, this system would cross the automaton forever following a statistically straight trajectory.

The role of EMPs The Us use EMPs as intermediates for expressing the static forces. It is an adiabatic proccess (one preon at a time and not chunks of HBAR/2). They carry electric polarity (*e.g.* Coulomb force) and spin information, so that the correct direction of the KNPs are defined at the destination system.

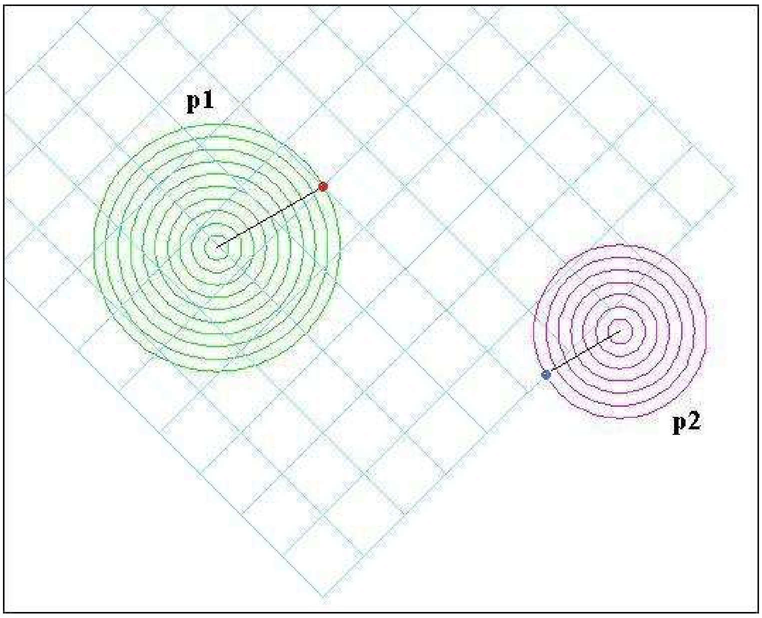

Figure 1: A preon and its twin.

2.5 Preon and its twin

Every preon has a twin preon with opposite spin direction. Whenever this property changes, this fact is comunicated to its twin by a burst, as illustrated in Fig. 1.

2.6 Isotropy

Isotropy is a consequence of the fact that preons propagate as a nearly perfect wavefront. With the solution above, I fully solved the isotropy problem. Clearly, isotropy granularity depends on the size SIDE of the universal cube. Considering all combinations of normalized 3d vectors that can be formed with that value, it can be stated that the number of possible directions N_D can be calculated as

$$N_D = 2\pi\,(SIDE/2)\,.$$

For $SIDE = 128$, we have approximately $N_D = 102,943$ bubble pairs. This number expresses the best isotropy possible in such a small automaton.

A key ingredient to achieve an isotropic behavior on an automaton is the generation of an isotropic wavefront. One difference between mine and most cited automata is that light speed is not one lattice spacing per clock tick, but is a larger count. Isotropic propagation of a wavefront is achieved in the limit when the number of cells tends to infinity by using the approach developed by Case, Rajan and Shende [11]. The novel feature of that work is that, to obtain the isotropy, is required for each expansion step, executing n steps of the basic algorithm of the automaton, where n is two times the diameter of the universe D (space diagonal). Henceforth we will refer either to lattice speed s or to light speed c. Then we have the relation

$$s = 2\,D\,c.$$

In order to synchronize the preons forming a wavefront, it receives the value

$$t = \lceil 2D\,|p_6|\, + 0.5\rceil.$$

Actually, to avoid undesired superposition of a preon wavefront with a burst or gravitons on a common shell (w address), the time frame is segmented in two steps: one, when the bursts are active, has a duration of BURST time units. The other, when preons and gravitons are active, has a duration of $2\,D$ time units. The entire frame is termed SYNCH.

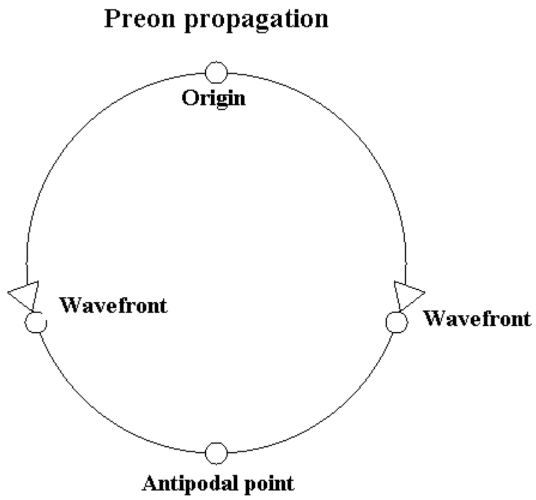

Figure 2: Preons elements composing a wavefront meet at the other side of the universe, as illustrated by the one-dimensional case shown.

2.7 Effect of the torus closing

This effect is best illustrated in a one-dimensional torus as shown in Fig. 2. The two components of the wavefront meet on the other side of the universe. When this limit is reached, burst and graviton tiles vanish, while preons are reemitted from a cell selected on the main diagonal of the lattice. This cell is calculated using the $p_{25} = BURST$ condition, where field p_{25} counts the number of positive steps executed by a preon tile.

2.8 Entanglement

Entanglement is one of the mechanisms responsible for the formation of preon clouds (particles), namely the entanglement field property designated p_{13}, with lenghth $3 \cdot SIDE$. When preons interact, they come to share a common entanglement field value given by

$$p_{13}^1 = p_{13}^2 = p_5^1 \cdot p_5^2 + SIDE.$$

This operation is possible only if the interacting preons have the same electric charge. In the case of interaction with a preon pair, only the half having the same electric charge matters.

At the particle level, entanglement is an average of the individual preon values. When two preon clouds interact, a common value for the entanglement fields is gradually spread by repeated application of expression 2.8. The gradual loss of entanglement due to interaction with the environment resembles a *decoherence* mechanism.

To test if two tiles are entangled, the following criterion is used:

$$\begin{cases} true & if\ |p_{13}^1 - p_{13}^2| > SIDE \\ \\ false & otherwise \end{cases}$$

Entanglement is an important component of the *cohesion force* and is the origin of non-classical correlations.

2.9 Electromagnetic sinusoidal phase

Overview The sine wave or sinusoid is a mathematical curve that describes a smooth repetitive oscillation, like in the electromagnetic case. In the automaton, there is a basic sine wave function implemented as a direct-form oscillator with the $\cos(\omega t)$ parameter calculated *a priori* to fit the entire universe. The evolution of this sine wave is controlled by the Ps during propagation and can be called

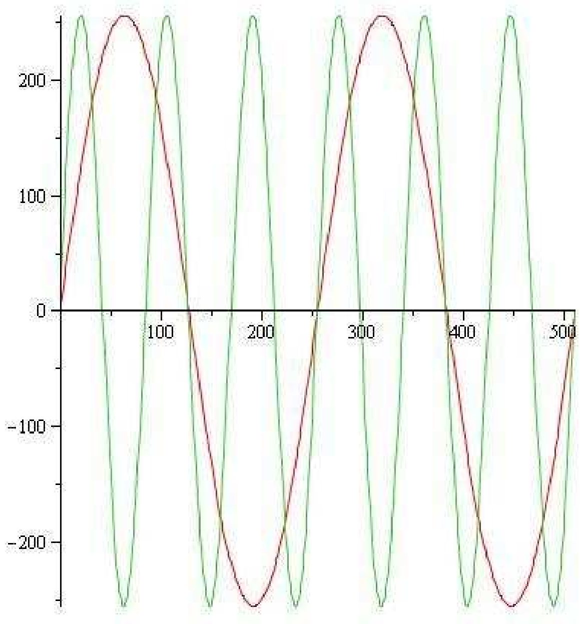

Figure 3: Sinusoidal patterns.

one or more times (higher frequency) in each light step. The phase value of a preon is stored in the p_{14} field, a five integer structure.

Direct-form oscillator The sinusoidal waveform is represented by a rational number based generator built especially to keep the accumulated error in amplitude within the limits of one length unit. Three constants are required for the sine wave generation. Clearly, they depend on the size of the automaton implementation.

$$\begin{aligned} k &= 2\cos(\omega T), \\ U_1 &= SIDE\sin(-2\omega T), \\ U_2 &= SIDE\sin(-\omega T). \end{aligned}$$

At the beginning of each wave do

$$u_0 = 1;\ u_1 = U_1;\ u_2 = U_2.$$

The evolution law is

$$\begin{aligned} u_3 &= k\,u_2 - u_1, \\ u_1 &= u_2, \\ u_2 &= u_3. \end{aligned}$$

Example The algorithm above was first tested in a small program developed outside the automaton. The graph in Fig. 3 shows the algorithm being called once and three times by light step in a grid of 512x512 points. The horizontal axis would be any direction in 3d space while the vertical axis could be associated with the value of the phase at one point.

2.10 Charge quantization

The reasoning that leads to quantization can be described as follows. Since the universe in this model is a system closed on itself, charge quantization is an emergent phenomenon. Us tend to group in clouds

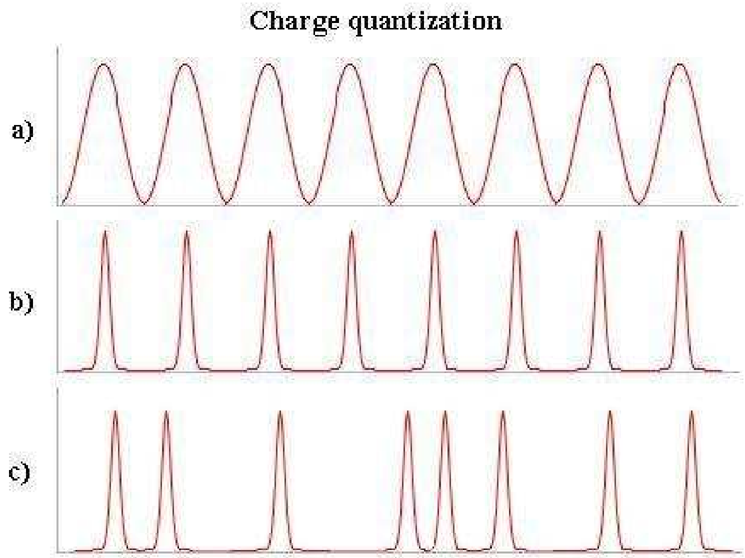

Figure 4: Unpaired preons with the same electric sign tend to form a stationary, sinusoidal pattern of longitudinal waves circumventing the universe (drawing a). In a second stage, due to the cohesion force, the original charge pattern shrinks in clumps of HBAR/2 preons like the configuration shown in b), preserving the segmentation of the unpaired preons, which in the three dimensional case, would be spherical islands of charge. Part c) shows the rich configuration of islands as the automaton evolves.

containing the same amount of elements. Let's call the total amount of Us UPTOTAL. It is expected that a random initial configuration of Us will stabilize in equal sized (HBAR / 2) islands of Us after a long enough number of clock ticks[1]. This conclusion can be inferred from experiments of Bose-Einstein condensates where magnetic vortices are quantized due to perfect fluid characteristics of the condensate and the fact that it is a closed system.

HBAR can be calculated from the input parameters as

$$HBAR = \frac{SIDE}{SIDE - CTOTAL}.$$

Considering charge space and assuming random initial distribution of preons that survived the massive annihilation that formed the initial Ps, and that the universe is a closed system, then the charge distribution tends to form a stationary, sinusoidal pattern of longitudinal waves circumventing the universe (drawing *a)* at Fig. 4).

In a second stage, due to the cohesion force, which tends to unite charges of equal sign in preon clouds, the original charge pattern shrinks in clumps like the configuration shown in *b)*, preserving the segmentation of the unpaired bubbles, which in the three dimensional case, would be spherical islands of charge.

Part *c)* shows the random configuration of quantized U islands as the automaton evolves.

Angular momentum quantization, therefore, can be seen as a consequence of charge quantization. Preservation of the primordial electric charge quantization is reinforced by the way vector bosons transport angular momentum in chunks of HBAR, resulting in a self correcting mechanism.

2.11 Spin

A fermion spin picture is shown in Fig. 10.

[1]The name HBAR was coined after Planck's reduced constant, which, strictly speaking, is not a constant, but since annihilation is a rare event, it may be safely considered so.

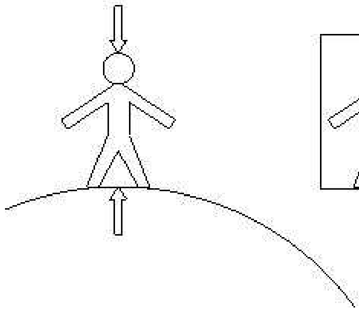

Figure 5: The Equivalence Principle says that the observer at the accelerated box experiments the same weight as the observer on the surface of the Earth. That is, gravitation force is equal to inertial force.

2.12 Equivalence principle

In the drawing of Fig. 5, all arrows represent an acceleration of absolute value g, the gravity acceleration, approximately 10 m/s^2.

The principle says that the observer at the accelerated box experiments the same weight as the observer on the surface of the Earth. That is, gravitation force is equal to inertial force.

Gravitons emitted by Earth's mass accumulate kinetic pairs on the body capable of accelerate it by g. To counter this effect, so that the body remains on the surface of the planet, a chain of KNPs are transmitted via electromagnetic forces through the feet of the observer up to his head. This chain of events gives the observer the feeling of weight.

In the box, the acceleration of 1 g caused by the rocket, is transmitted directly to the observer's feet, giving him the same feeling of heaviness as his twin on Earth.

The comparison between the two cases from the perspective of KNPs, apparently corroborates the principle of equivalence, which will now be considered a theorem.

2.13 Mass spectrum

The challenge One of the greatest challenges a new foundational theory of nature must face is figuring out a way to calculate the masses of elementary particles from first principles. In the SM they enter as *ad hoc* parameters. Attempts to resolve this long sought problem can be seen in Nambu [18] and Hansson [19].

In what follows, I contemplate the possibility that the enigma might be solved by considering the masses as consequence of the radial vibration of bubble clouds, with no need for a Higgs mechanism or Yukawa coupling.

Radial vibration modes Since leptons are, in this model, composite particles, they can possess radial vibration, like a pulsating sphere [20]. Leptons and quarks are resonant energy forms of a common type. The muon is the first excited state of the radial vibrational state of the electron, the tau is the second, so there is just one kind of lepton: the electron. Neutrinos carry away the excess angular momentum.

For quarks, the charm is the first excited state of the radial vibrational state of the up. The top is the second radial vibrational state of the up. The strange is the first radial vibrational state of the down. The bottom is the second radial vibrational state of the down. The down is formed when the up captures a charged lepton. We therefore are led to conclude that there is just one kind of quark, the up.

The decay of heavier quarks into lighter ones is done through virtual W bosons, which give or take the negative electric charge in the path of these decays as dictated by the SM and confirmed experimentally.

On the other hand, this explains the neutron structure: The neutron is essentially an electron stripped of angular momentum and very close to a proton, like an energetic hydrogen atom. It is glued to the proton by the electromagnetic force. Due to lepton number conservation, an antineutrino must be included in the balance. In other words, the neutron is a *udd* baryon.

Therefore, the amount of MGPs trapped in these resonance modes gives rise to the mass of the particles when they emit duo-gravitons in addition to the gravitons emitted by their Us.

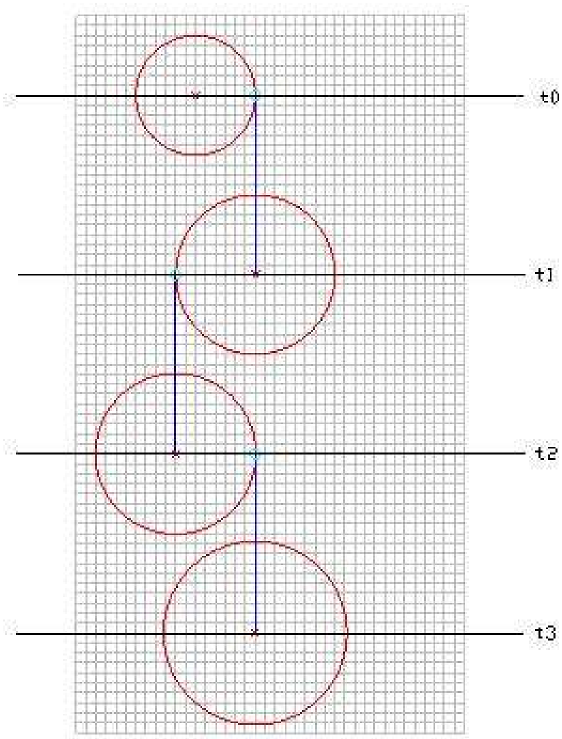

Figure 6: Elementary cohesion scheme.

2.14 Cohesion force

2.14.1 Definition

Mechanism that maintains a group of preons in clouds or, in other words, particles.

In Fig. 6, the preon is reemitted when interacts with the vacuum, capturing a VCP, changing it to a virtual pair (not shown). In average, the unpaired preon remains at the same region as a result of vacuum homogeneity. In each iteration, the U's spin is inverted, otherwise it would disperse rapidly.

The position of the successive reemissions resembles a random walk, suggesting a bridge to QM, *cf.* [21].

2.14.2 Interaction between Us

Clashing Us of same electric charge are both reemitted at the contact point. If their entanglement fields are different, both will be replaced by a common value given by Eq. 2.8. Fig. 6 shows this mechanism, which is the main component of the cohesion force.

2.14.3 MGP contribution

The MGPs associated with a group of Us (charge fragments), vibrate radially around the charges, giving the particle its rest mass. They follow the cohesion due to the interaction described above.

2.14.4 KNP contribution

By the same token, KNPs associated with the particles translation are driven by the cohesion dynamics of the charges. KNPs contribute to the cohesion force. In the absence of MGPs, they move the Us at the speed of light as shown in Fig. 6.

3 Particles

Elementary particles are self-organizing patterns formed by a huge number of preons. They are generally classified as

- Bosons, having integer intrinsic spin
- Fermions, having half integer intrinsic spin

They may be also classified as

- Real, if the energy used to create them came from a real vector boson
- Virtual, if the energy used to create them came from the vacuum

These basic particles cooperate to form stable systems, or bound states, such as atoms, or in exotic temporary configurations like mesons.

Particles are created or annihilated under many interactions possible. Their masses are a consequence of their capacity of generating gravitons.

3.1 Bosons

3.1.1 Boson fragments

Spare Ps (isolated bosons) are used as real and virtual bosons or as static pairs (EMP), such as in the case of the electrostatic force.

3.1.2 Virtual bosons

If the energy used to construct the boson comes directly from the vacuum, it is considered a virtual boson. It does not generate gravitons and quickly disappears, returning its energy to the vacuum.

3.1.3 Real bosons

Real bosons, on the other hand, are formed by pairs aggregated by an outgoing quantized angular momentum amounting at least one multiple of HBAR, as in the case of the photon. Additional properties, namely color charge and weak charge, contribute to the formation of other elementary bosons, the gluons, mesons and the W and Z weak bosons.

Bosons interact with other bosons or with itself through the footprint p_{18} field. Their collective behavior follows a Bose-Einstein statistics distribution.

3.1.4 The boson of gravitation

A different type of boson is responsible for the force of gravity, the graviton. Gravitons are remnants of the reemission of real preons. When a real preon is reemitted, a graviton is released from the contact point, tangentially to the preon spherical surface.

3.1.5 The photon

A photon is a compact, concentric, sequence of a variable number of PHPs released from a single electrically charged cloud. At the time of its creation, all its preons share a common entanglement field (p_{13}) value inherited from the emitter particle. The photon carries exactly one HBAR quantity of intrinsic angular momentum besides linear momentum, which is a direct function of its energy.

Photon emission Emission of the forming photon is triggered when the amount of collected angular momentum reaches exactly one HBAR. In other words, when all Us have an associated P, forming triads (Tr), thereby avoiding mutual inhibition.

Some of the Ps populating an electron are synchronized with the Us, that is, they form one and the same wavefront (Tr). Since there are HBAR / 2 unpaired preons, there may be at most this amount of synchronized pairs. When these pairs eventually get all their spins aligned, they stop to inhibit each other, as well as some of the KNPs associated with the electron through their entanglement fields. Since each of them have a basic unit of angular momentum, at the instant they are released, they carry exactly HBAR units of angular momentum. This process characterizes the creation of a photon and its frequency is the *zitterbewegung*. The rapid response (preons don't grow too much) in the case of the strong force explains the small size of the nucleus.

The released PHPs can then be classified in two groups: one in which all spin directions are aligned and the other in which the directions are diverse, *i.e.*, statistically random.

During expansion, the PHPs update the sinusoidal phase structure (p_{14x}). A capture event is transmitted to the whole wavefront by a burst, so that all preons in a wavefront have the same phase value. Each PHP in a photon contributes to advance the algorithm in all their siblings, thereby guaranteeing that all of them operate at the same frequency. This mutual reconaissance is done via a burst.

The simultaneity of the advance operation is avoided since each captured P is in its own expanding sphere (w address).

Fundamental photon Us in an elementary particle (preon cloud) are constantly harvesting VCPs and forming Tr's, accumulating their angular momentum. When they are simultaneously released, they form a photon that can aggregate more Ps, if available (similar entanglement fields). If not available, it is considered a *fundamental photon*. In terms of fundamental units (automaton units), this fundamental photon has square root of HBAR units of energy, HBAR units of angular momentum, HBAR units of linear momentum and SIDE / HBAR grid units wavelength.

It can be concluded that the model, although still mostly incomplete, is able to make the remarkable prediction that if an electron is left completely alone (if even possible), still continues to emit weak (low frequency) fundamental photons exactly alike at an approximately constant rate. Moreover, if the fundamental photon can explain the Casimir effect deserves further investigation.

The travelling photon A travelling or freely propagating photon is a group of concentric PHPs where all have the same entanglement field value. At least one multiple of HBAR / 2 pairs have their spins with the same orientation, the remaining pairs are pointing randomly.

Light-matter interaction When the travelling photon interacts with an U belonging to a distant particle, the following chain of events happens:

- the target U (belonging to a fermion, for instance) emits a burst
- the collapsing wave interacts with all preons with the same entanglement field (p_{13}) value
- all affected Ps are reemitted at the impact point.
- linear momentum and angular momentum are naturally transferred to the target system
- it is also possible that the photon is reemitted, leaving part of its energy in the target system
- the photon can also be shattered into Us (pair formation)

If the target is an atom, three typical interactions can happen, with probabilities depending on the photon's energy and the atomic number Z.

- photoelectric effect
- Compton scattering
- pair production

Photon polarization The photon is circularly polarized since the component PHPs are also polar (linear polarization, for instance, is an emergent feature of systems of photon beams). The photon described here is a naive entity, while photons found commonly in experiments are actually beams of these pure photons, acquiring additional properties, such as orbital angular momentum and elliptic polarization.

3.1.6 The Z and W bosons

The W and Z bosons are known as the weak vector bosons. The W boson is formed by a quantity of HBAR/2 electrically charged ($W^{\pm}$), left-handed, unpaired preons (Us), plus a huge number of weak MGPs resonating around the weak Us, and are each other's antiparticles. In the caso of the Z, the Us have no electric charge, so the Z is electrically neutral and is its own antiparticle. All W bosons are left-handed so they interact only with left-handed quarks.

3.2 Boson decay

Bosons, except the photon, decay by implosion. This implosion can be retarded by several mechanisms. While photons evolve always growing the distances between their components, other bosons have their distances shortened, until they melt in a single cell, becoming raw material.

3.2.1 Neutrinos

Neutrinos are leftovers of weak interactions. They balance angular momentum in these interactions. They are composed of NTP pairs, which carry the weak charge.

3.3 Fermions

3.3.1 Definition

An elementary fermion in the automaton model is an object composed of many preons. It carries exactly HBAR / 2 Us and a definite number of MGPs besides available KNPs. At rest, the total amount of MGPs expresses the rest mass m_0 of the fermion. When it accelerates, additional KNPs are incorporated to the fermion, thereby increasing its mass (relativistic mass). The intrinsic angular momentum of the system is exactly HBAR / 2, *i.e.*, equals the number of Us. Additional processes related to the weak and strong forces occur simultaneously. Fermions can combine to form nuclei, atoms and higher order structures. They also produce Fermi-Dirac statistics [22].

If the spin fields distribution is not perfectly spherically symmetric, it can exhibit a stable magnetic moment.

3.3.2 Combinations of fermions

The table below exemplifies the relation between color and matter / antimatter particles.

	c+	**c-**
e+		n2
e-	n1	
p+	n1	
p-		n2

c-color
e-electron
p-proton

n1-matter
n2-antimatter
n1 > n2

3.3.3 Classification of fermions

Fermions are grouped into leptons and baryons. Leptons are further subdivided in two types: electrons and neutrinos (three flavors each). Electrons are charged while neutrinos are neutral. The proton and the neutron are baryons, which are also classified as hadrons of spin 1/2.

3.3.4 Bosonic behavior of composite fermions

When a pair of fermions are entangled, their Us form partial Ps, changing the behavior of the system from fermionic to bosonic. The bosonic behavior is a function of the number of entangled constituents. A study of this phenomenon based on QM can be seen in [23].

3.3.5 Lepton number conservation

It arises naturally in the automaton operation, caused by the weak interaction. Conservation of angular momentum requires that lack or excess of angular momentum be transported by neutrinos or embedded in a photon.

$$\begin{aligned} \mu^- &\rightarrow e^- + \bar{\nu}_e + \nu_\mu \\ \mu^- &\rightarrow e^- + \gamma \end{aligned}$$

The first expression can be (simplifying) described in automaton terms as folows: A virtual *W*- starts to take shape around the *muon*, extracting energy from the vacuum. When emitted, it desarms the electromagnetic properties of the muon. The angular momentum and part of the massgen and kinetic pairs of the destroyed muon will be used to build the new electron. When the W disappears, returning to the vacuum, two situations may arise concerning the remnant massgen and kinetic pairs: they either divide in opposite angular momenta and opposite colors, forming a pair of neutrinos, or they come together to form a photon.

3.3.6 Electron

The electron is a fermion where all Us have negative charge and neutral colors. Its accompanying MGPs vibrate radially in the fundamental E.M. mode, which amounts to its rest mass (m_e). Higher order modes give rise to the muon and the tau.

Its HBAR / 2 Us have spins in average pointing inward or outward (spin up, spin down).

The drawing shows a simplified view of an electron. Two kinds of objects are present: Us (green circles) with negative charge (magenta square) and MGPs (cyan circles), where both charges are present. The preons are shown at different stages of evolution.

In the electron, either free or forming a hydrogen atom, the bits of color are set to RGB, while in the case of the positron, they are set to R'G'B'.

Moreover, for each electron version there also exists a corresponding neutrino. Equally, for each these six leptons, there are their six antimatter couterparts (complementary color bits). Additional kinetic pairs can be incorporated to the electron accelerating it.

An alternative study on non-punctual electrons can be checked in [24].

3.3.7 Neutrino

The neutrino is a particle formed by Ps alone, that's why it is a neutral particle. It carries exactly HBAR / 2 of orbital angular momentum, leftover from weak interactions.

Neutrinos are a partial mass version of its partner particle (e, μ, τ), but with the same frequency (a bold assertion necessary to explain the difference between ν_e, ν_μ and ν_τ), they are required to close the angular momentum balance in the weak force interactions.

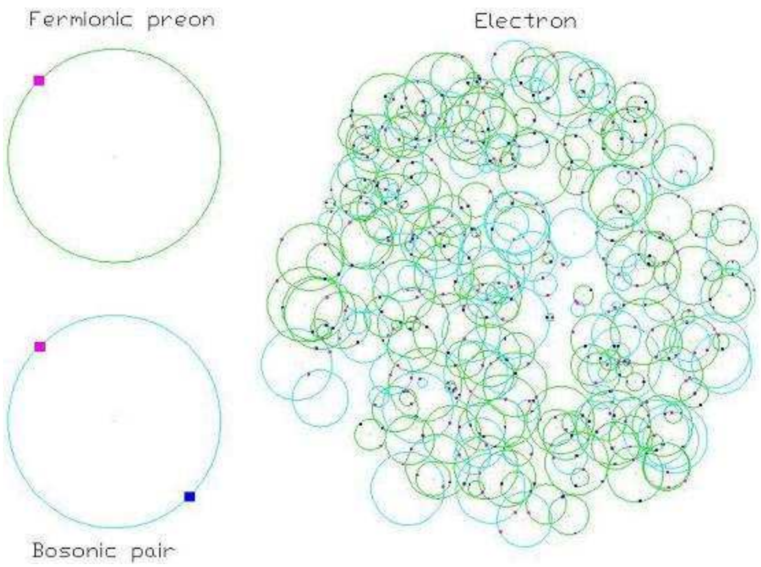

Figure 7: Preons forming an electron.

When released in a weak force process, like during free neutron decay, the neutrino carries with it the weak charge, since this is the only force neutrinos interact with. This weak charge causes the neutrino becomes continuously emitting virtual Z bosons, allowing them to elastically scatter with other weak charged particles.

This model does not predict the existence of sterile neutrinos [25]. On the other hand, a running automaton will confirm if "neutrinoless double-beta decay" really happens and provide a possible answer to why the observable universe is made of matter and not antimatter.

Due to their simple structure, neutrinos are their own antiparticles. In this sense, they can be considered Majorana fermions.

3.4 Hadrons

3.4.1 Definition

A hadron is a composite particle made of quarks held together by the strong force in a similar way as molecules are held together by the electromagnetic force [25].

3.4.2 Baryons

Overview In particle physics, a baryon is a composite subatomic particle made up of three quarks. It participates in the strong interaction.

Proton The proton is a particle (bubble cloud) much like the electron's cloud, but with a crucial difference: color force is involved. The colored charges inside the proton tend to group in patterns called quarks. Gluons serve as the vector bosons of the strong force, keeping the proton's parts tightly cohesive. The proton's mass derives in part from massgen pairs associated with the positive electric charge (unpaired bubbles) and in part by its component gluons. The 'recipe' for a proton follows:

- HBAR/2, strong, positive, entangled, baryonic Us, equally divided between colors R, G and B;
- Spins are spherically aligned on average;
- The Coulomb repulsion generated by UXV and UXP interactions tend to keep the Us apart;
- Cohesive UXU interactions tend to keep all Us together, generating the respective KNPs;
- Strong UXU interactions tend to form three groups (quarks) of equal color Us, forming converging KNPs;

- MGPs coexist in the fundamental mode of vibration about the Us (quarks' mass), contributing to the proton's mass;
- Gluons form a cloud due to PXP interaction, and also contribute to the mass of the proton;
- Gluons interact with quarks, generating KNPs by color exchange between the cloud and the quarks, helping in the attraction of the baryonic Us;
- Since the strong force acts aggressivelly, compacting the colored components, the volume of the proton is then much smaller than that of the electron and the proton's net mass is high, since the frequent reemissions will generate a great quantity of gravitons;
- Additional KNPs can give the proton momentum.

There is an antimatter version of the proton, the antiproton, carrying positive electric charge and complementary white (neutral) combination of colors.

Neutron The neutron is a particle (bubble cloud) formed by a definite number of unpaired bubbles endowed with positive electric charge and equal proportion of the three color charges mixed with the number of massgen pairs and gluons needed to approximately form the proton's mass. This cloud is surrounded by a shell of the same number of negative unpaired bubbles without color charge, bounded to the protonic core by a number of virtual pairs sufficient to approximately form the electron's mass.

both in the case of the neutron and in the proton, kinetic pairs can give them speed.

The neutron can be imagined as a proton where a smashed electron, lacking angular momentum, is closely bounded to. This crushed electron is so close to the proton, that it is influenced by the intense electric attraction of the positive core keeping the electron constituents tightly bound to the proton. There are two mechanisms to undo this rigid system. One is through high energies collisions. The other is under the action of the W boson using weak interactions.

Free neutron decay Under the action of the weak charges, the unpaired bubbles start to harvest vacuum pairs, causing radial vibration around the weak charges. This harvesting process takes about 14 minutes for the free neutron, the time needed to gather vacuum pairs to form virtual massgen pairs amounting one hundred protons ($\sim 80\,GeV$), which is the fundamental resonance mode of the radial vibration about the weak charges. Weak MGPs collected after resonance propagate away until timeout (WTTL). When one HBAR of angular momentum units is collected, we have a W boson. The W starts to propagate but lasts for a short period. During this time it inhibits the electromagnetic properties of the negative charges preons only, because they don't have color charge, setting them free. Finally, the temporary Ps forming the W revert automatically to VCP.

In order to conserve angular momentum, a small amount of KNPs carrying the weak charge and the excess angular momentum (HBAR / 2) needed to balance the angular momentum carried by the electron is released, the antineutrino. Additional KNP might give the antineutrino kinetic energy. Although quantized, this angular momentum (HBAR / 2), is of orbital nature, not intrinsic as in the case of charged fermions.

The W starts to propagate, but lasts for a short period due to its huge mass. During this time, it inhibits the electromagnetic properties of the negative charged preons only, because they don't have color charge, setting them free. Finally, the temporary Ps forming the W revert automatically to the vacuum type pair.

In order to restore the released electron spin, the MGP with the excess HBAR/2 AM is released as an antineutrino, kept united by weak virtual PXP interactions and therefore carrying the weak charged preons. Additional KNPs might give the antineutrino kinetic energy. Although quantized, this angular momentum (HBAR / 2), is of orbital nature, not intrinsic, as in the case of charged fermions.

3.4.3 Hadrons and the IGM model

Following the IGM model in [26], a high energy hadron can be visualized as two or three valence quarks around a compact group of gluons. Momentum is divided between the gluons and quarks, so valence quarks are fast while gluons are stopped in the central rapidity region. That study is, therefore, a good reference for the expected behavior of hadrons in my model.

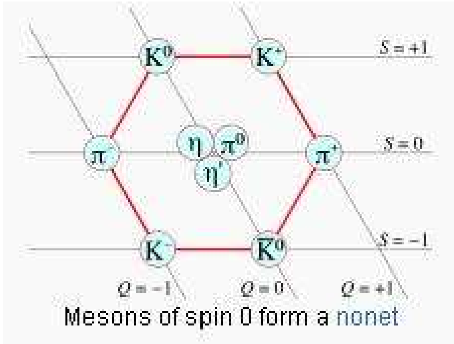

Figure 8: Mesons from the Standard Model.

3.5 Mesons

3.5.1 Overview

In particle physics, a meson is a strongly interacting boson, that is, a hadron with integer spin. In the Standard Model, mesons are composite (non-elementary) particles composed of an even number of quarks and antiquarks. All known mesons are believed to consist of a quark-antiquark pair, the so-called valence quarks, plus a "sea" of virtual quark-antiquark pairs and virtual gluons.

In the automaton, charged mesons can be imagined as part of a fractured baryon and as such are short lived particles, products of very high-energy interactions in matter, between particles made of quarks. These bosons are responsible for the nuclear force gluing protons and neutrons in nuclei. The exchange of pions can be viewed in terms of the more fundamental interaction of quarks exchanging gluons.

Figure 8, taken from Wikepedia, shows how mesons are organized according to the standard model exhibiting a well defined Lie group structure.

3.5.2 The pion

In particle physics, a pion (or a pi meson, denoted with the Greek letter pi: π) is any of three subatomic particles: π_0, π_+, and π_-. Each pion consists of a quark and an antiquark and is therefore a meson. In the automaton, the pion is formed by the amount of quarks to the three varieties with spin 0 and electric charges ± 1 or 0. The $\pi-$ decays to a $\mu-$ which is a particle of spin 1/2. So, in order to enforce spin conservation, an antineutrino must carry away the same inverse amount of angular momentum in orbital form.

3.6 Annihilation

In annihilation, partners are identified by their opposite properties (charge etc.). In order to keep momentum balance, a pair of bosons (generally photons) must be created. The direction of the spins of each pair is 180° apart, which forces the separation of the resultant particles. These directions are calculated (cross product) from the origin $\overrightarrow{p}_6$ fields of the two source photons. One of those photons can be immediatelly absorbed by a nearby system, resulting in single photon formation.

The entanglement is propagated to all preons of both particles. The electric attraction continues inexorably until complete annihilation of the partners. The original linear momentum must somehow be carried by the particles or transferred to a nearby system.

3.6.1 Partial annihilation

Partial annihilation occurs when a fermion and an antifermion with some different properties interact. This is a special kind of decay, as in the case of an electron and an antimuon.

4 Theory

In this section, the concepts presented above are rigorously stated, forming the model's theoretical description, using a constructive approach [8, 9].

4.1 Ontology

Definition 1. Property *formats*: SI, signed integer; SI3, 3-bit SI; UI, unsigned integer; SV, signed 3d-vector, with $N_D = \pi\,(SIDE/2)^2$ possible directions. The default length is SIDE. Pulse width modulation (PWM)[2] is used to encode some properties, using the constants $STEP = log_2\,(SIDE)\ and NSTEPS = SIDE/STEP$.

Definition 2. Sine constants: $K = 2\,cos\,(2\pi/SIDE)$, $U_1 = SIDE \cdot sin\,(-2\,2\pi/SIDE)$, $U_2 = SIDE \cdot sin\,(-2\pi/SIDE)$.

Definition 3. *Tile* is a formatted (p_1, p_2, ...) N-integer (see Table 1).

Definition 4. The *cellular automaton* is a dual Euclidean lattice 4-torus of dimension SIDE, where a single tile is attached to each cell. The distance between cells is L and the clock period (p_1) is T. Each lattice is alternatively principal (read-only) or dual (draft). D is the main diagonal of the lattice.

Definition 5. A *light step* is the time interval LIGHT between consecutives $p_1\,mod\,(6 \cdot SIDE) = 0$ events.

Definition 6. A *preon* is a spherical wavefront of tiles ($p_2 \equiv REAL$ or $VIRT$), expanding at the speed of light $c = L/LIGHT$.

Definition 7. *Graviton* (G) is a wavefront where ($p_2 \equiv GRAV$, $p_{11} \equiv OFF$), except at one tile, where $p_{11} = ON$.

Definition 8. Schedule time (ST) is the time a tile waits to synchronize with the rest of the wavefront. Activation time (AT) is the moment when all tiles in a wavefront are synchronized.

Definition 9. Contact point (CP) is the x, y, z address where two preons start an interaction. Origin point (OP) is the initial cell of a preon.

Definition 10. A *burst* is a cubic wavefront ($p_3 \neq NONE$), expanding at the maximum speed $s = L/T$, a superluminal messenger. Indices T and V mean T*ransported* and V*isited* tiles, respectively. Also $s = 2\,D\,c$.

Definition 11. *Unpaired* (U) is a non-overlapping preon ($p_2 \equiv REAL$ or $VIRT$). It works like a charge fragment.

Definition 12. *Pair* (P) are two overlapping preons classified as:

VCP: $p_2^1 = p_2^2 = VIRT$, $\vec{p}_7^{\,1} = \vec{p}_7^{\,2} = \vec{0}$, $p_8^1 = p_8^2 = 0$, $p_9^1 = p_9^2 = 0$, $p_{10}^1 = \bar{p}_{10}^2$, $\vec{p}_{12}^{\,1} = \vec{p}_{12}^{\,2} = \vec{0}$, $p_{13}^1 = p_{13}^2 = 0$

EMP: $p_2^1 = p_2^2 = VIRT$, $\vec{p}_7^{\,1} = \vec{p}_7^{\,2} = \vec{0}$, $p_8^1 = -p_8^2$, $p_9^1 = p_9^2 = 0$, $p_{10}^1 = \bar{p}_{10}^2$, $\vec{p}_{12}^{\,1} = \vec{p}_{12}^{\,2} \neq \vec{0}$

GLP: $p_2^1 = p_2^2 = VIRT$, $p_{10}^1 \neq 0$, $p_{10}^2 \neq 0$, $p_{10}^1 \neq \bar{p}_{10}^2$, $\vec{p}_{12}^{\,1} = -\vec{p}_{12}^{\,2}$

MSP: $p_2^1 = p_2^2 = VIRT$, $p_8^1 = \{0, \pm 1\}$, $p_8^2 = \pm p_8^1$, $p_9^1 = \{0, \pm 1\}$, $p_9^2 = \{0, \pm 1\}$, $p_{10}^1 \neq 0$, $p_{10}^2 \neq 0$, $p_{10}^1 = \bar{p}_{10}^2$, $p_{12}^1 = \pm p_{12}^2$

KNP: $p_2^1 = p_2^2 = REAL$, $\vec{p}_7^{\,1} = \vec{p}_7^{\,2}$

NTP: $p_2^1 = p_2^2 = REAL$, $p_9^1 \neq 0$, $\vec{p}_{12}^{\,1} \neq 0$, $\vec{p}_{12}^{\,2} = 0$

MGP: $\vec{p}_7^{\,1} = -\vec{p}_7^{\,2}$

PHP: $p_8^1 = -p_8^2$, $p_9^1 = -p_9^2$, $p_{10}^1 = (ANTI)LEPT$, $p_{10}^2 = \bar{p}_{10}^1$, $\vec{p}_{12}^{\,1} = -\vec{p}_{12}^{\,2}$

Definition 13. *Triad* (T_r) are three overlapping preons where two form a virtual pair (B)read and the third (C)heese works like a U. The Bs can be complementary leptonic tiles (photonic T_r), or strong/antistrong (gluonic T_r, a mix of 3 colors/anticolors e.g. $RG\overline{B}$), or yet chiral/antichiral tiles.

[2] The use of PWM precludes the use of a pseudorandom generator whatsoever.

Definition 14. The *Vacuum* is the set of all VCPs.

Definition 15. *Energy* is the square root of the number of real and virtual preons in a region. *Kinetic energy* is represented by KNPs.

Definition 16. *Particles* are classified as bosons (HBAR intrinsic spin) and fermions(HBAR/2 intrinsic spin). They are *real*, if their energy comes from a real boson ($p_2 \equiv REAL$), or *virtual*, if their energy comes from the vacuum ($p_2 \equiv VIRT$). Some may carry additional KNPs and orbital angular momentum (OAM).

Definition 17. Meson is a boson made of MSPs. It can be electrically charged.

Definition 18. A *fermion* is formed by HBAR/2 Us, plus a number of MGPs defined by resonances around the charges and a variable number of KNPs.

Definition 19. *(Anti)Lepton* is a fermion where all their Us are (anti)leptonic.

Definition 20. *(Anti)Baryon* is a fermion with neutral net color, where all their Us are (anti)strong.

Definition 21. A *neutrino* is a special fermion made of HBAR/2 $NTPs$.

Definition 22. *Mass* is the rate of gravitons released by a particle.

Definition 23. Linear momentum (LM) of a fermion is the resultant of all KNPs contained therein, while bosons carry a quantity of LM directly related to their frequency.

Definition 24. Charge distribution

`SF:` $\sum_t^{SIDE} \left(p_{10}^{bit} = 1\right) = SIDE$, $\sum_t^{SIDE} p_{10}^t = \sum_t^{SIDE} \bar{p}_{10}^t$.

`EMF:` $\sum_t^{SIDE} \left(p_8^t = +1\right) = {SIDE}/{2}$, $\sum_t^{SIDE} \left(p_8^t = -1\right) = {SIDE}/{2}$.

`WF:` $\sum_t^{SIDE} \left(p_9^t = 0\right) = {SIDE}/{2}$, $\sum_t^{SIDE} \left(p_9^t = +1\right) = {SIDE}/{4}$, $\sum_t^{SIDE} \left(p_9^t = -1\right) = {SIDE}/{4}$.

Definition 25. The *input parameters* (most with proposed values) are $SIDE = 1 \cdot 10^{62}$, $L =$ *one Planck length*, $T = Planck\,time/3 \cdot SIDE$, $RAMP = 1 \cdot 10^{10}\,Planck\,lengths$, $LOST = log_2\,(SIDE)$ and *HBAR*. They are used for mapping to the real world.[3]

4.2 Dynamics

The main concepts exploited in order to give life to the automaton are succintly described:

- Most low level patterns (e.g. pair detection and UXG interaction) are detected by mutual comparisons in the w dimension in three steps of SIDE clock ticks each
- The *Reciprocity Principle* states that preons occupying the same 3d address, composing, for example, a Tr, all arrive at the same results independently
- Vector rotation uses the CORDIC method *cf.* [10]
- Isotropy and spherical wavefront generation are achieved applying the method described in Ref. [11]
- A visit-once-tree (see Fig. 12) is used to avoid cell access conflicts
- The sinusoidal phase is done by means of a *Direct Form Oscillator cf.* [12]
- KNPs translate other preons in space
- Energy is borrowed from the vacuum when a particle accelerates (VCP→KNP)
- Energy is returned to vacuum when a particle decelerates (KNP→VCP)
- Quantization is achieved with the help of triads (Tr), entanglement and bursts

[3] HBAR must be inferred from experimental data. Since it varies extremely slowly and reflects the present cosmological era of the universe, it is represented by a constant.

- Static forces manifest themselves at the tile level, not at the particle (quantized) level, through EMPs which generate KNPs
- Energy return to vacuum can be retarded by vector bosons. The photon being a long range case (Bremsstrahlung)
- Self-interference derives from a track left by the preons on the visited cells, inspired by work of Sciarretta [7]
- A mechanism converts opposite KNP pairs to VCP pairs, thereby avoiding unbounded accumulation
- The p_{13} entanglement field is the main mechanism used to give dynamic identity to elementary particles
- When real preons are reemitted, their wavefronts continue propagation as a G
- Gs induce a KNP formation on all Us encountered, until the Gs vanish by wrapping
- A superluminal collapse mechanism, always involving HBAR basic units of AM, induces both low energy interactions, pair formation and hadronization
- MGPs form stationary patterns around Us, contributing to the mass spectrum
- Spontaneous decay happens with the help of virtual preons
- When annihilation occurs, the formed pairs reorganize in variable configurations
- The weak and strong interactions follow rules inspired in the Standard Model
- Neutrinos are used for AM conservation in weak interactions

The pseudocode in the Appendix is the full axiomatic representation of this dynamics. When omitted, most arguments apply *mutatis mutandi* to antiparticles.

5 Conclusion

The construction of a cellular automaton describing the basic laws of nature is a long-term goal, requiring the contribution of many researchers. In this work, I presented a tentative solution developed in five sections.

Interpretation of the present, flexible, model, as well as the first results of an implementation under construction (see Fig. 9), suggest some qualitative resemblance to QM, the Standard Model and experimental data [13–17]. Charge quantization gives rise to AM quantization. Spherical wavefront and isotropy are perfectly achieved. The results also suggest that the relativistic energy-momentum relation emerges naturally (see Fig. 11) and that ensembles can produce definite expected values (Ehrenfest theorem). The no-signalling principle is preserved, fundamental photons are emitted constantly by matter, and neutrinos are Majorana fermions. Since graviton emission is not conditioned to AM transfer, gravity is therefore not quantized.

Except for developing the basic principles, the construction of such an automaton for directly solving cosmological problems, or even complex molecules, is inconceivable. Its complete usefulness will mainly come through statistical mechanics or direct mathematical analysis in the approximation of large numbers. A full-fledged implementation, carried out after thorough review by leading scientists, is an undertaking worthy of a great university.

With this toy model, incomplete, inaccurate, I began the first attempt at a unified model of nature using this constructive approach.

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Table 1: Tile fields

Field	Name	Type	Values
p_1	Universal clock	UI	Incremented in unison after T seconds
p_2	Role	UI3	NIL, REAL, VIRT, GRAV
p_3	Messenger	UI2	IDLE, PLAIN, FORCING, COLL, FORMING
p_4	Helicity	UI1	0, right; 1; left
p_5	Level (4^{th} coordinate)	UI	$0..SIDE$
$\overrightarrow{p}_6$	Origin	SV	*null* or N_D possible directions. $\lvert\overrightarrow{p}_6\rvert$ =preon radius
$\overrightarrow{p}_7$	Momentum direction	SV	*null* or N_D possible directions
p_8	Charge	SI2	0, ± 1
p_9	Chirality	SI2	0, ± 1 (RMLAM, RM, LM)
p_{10}	Color and conjugation	UI6	R G B R' G' B' (LEPT: 111000, ANTILEPT: 000111)
p_{11}	Gravity	UI1	ON, OFF
$\overrightarrow{p}_{12}$	Spin	SV	*null* or N_D possible directions
p_{13}	Entanglement	3 UI	$0..SIDE^3$, avoids conflicts and allows decoherence
p_{141}	Sinusoidal phase	SI	$-SIDE/2..+SIDE/2$ (*Direct Form Oscillator*, DFO) [12]
p_{142}	Cosine phase	SI	Auxiliary value
p_{143}	Frequency	UI	Combined energy/LM
p_{144}	Modified	UI1	0, 1 (avoids multiple increments of DFO)
p_{145}	Ramp	UI	$0..log_2(SIDE)$
p_{15E}	Electric polarization	UI1	ON, OFF
p_{15M}	Magnetic polarization	UI1	ON, OFF
p_{16}	Interaction	UI3	ND, U, P, B, C, G, UXP, CXP, UXC, UXU, PXP, UXG, WZ, HADRON
p_{17}	Last visit	UI	Number of LIGHTs (property of the cell)
p_{18}	Interference	SI	$-SIDE/2..+SIDE/2$
$\overrightarrow{p}_{19}$	Return path	SV	Used to find OP
p_{200}	Current direction	UI3	Used to avoid concurrent access
p_{201}	Depth	UI	Wavefront tree
p_{202}	Initial time	UI	Wavefront t_i
p_{203}	Final time	UI	Wavefront t_f
p_{21}	Pair type	UI4	Complements p_{16} info, cf. Definition 12
p_{22}	Invite	UI	Used in pair formation logic
p_{23}	Timeout	UI	Timeout of virtual particles
p_{24}	Distance	UI	Distance in the w dimension

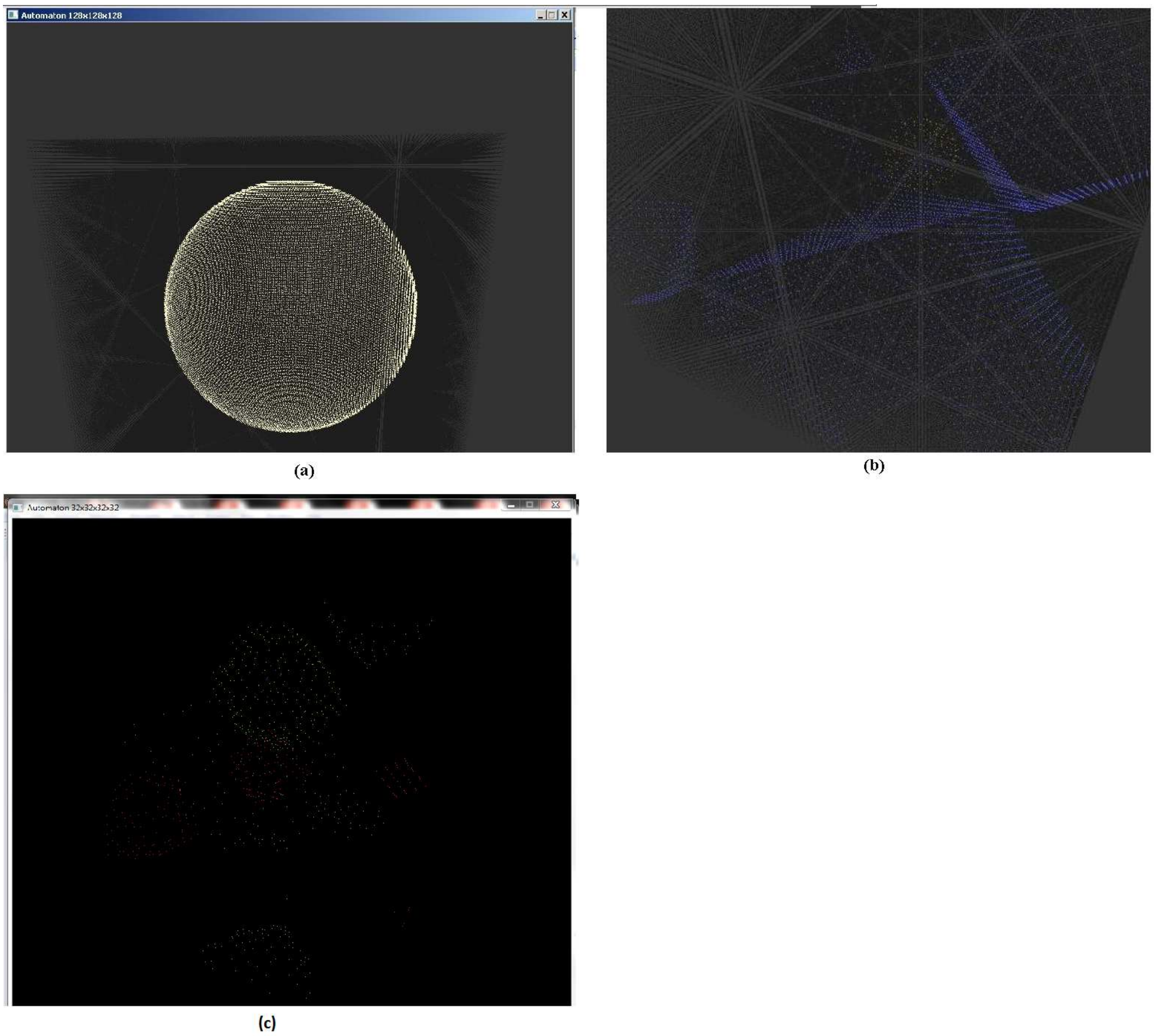

Figure 9: Results obtained by a C-language implementation: In (a) it is shown a pure wavefront; in (b) a burst, distorted by wrapping and a preon near the center; in (c) it is shown the vacuum, an ST based image, so preons don't look so round as in (a), taken AT.

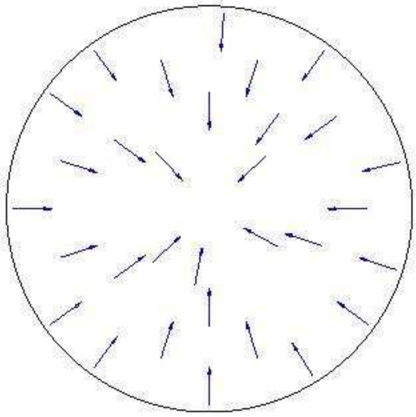

Figure 10: Fermions tend to align their spin components (a conjecture by now) either as spin down, as shown, or spin up, pointing outward, as envisioned by Hofer [17]. Each arrow represents a preon.

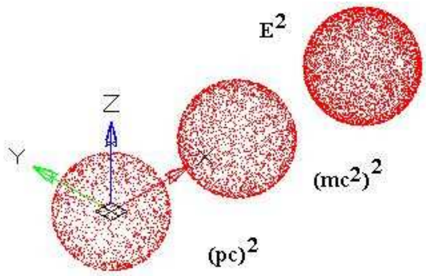

Figure 11: Energy-momentum relation as preon concentration. Each point represents a preon origin. Since the automaton tiles forming the particles are essentially spherical preons, they are more or less confined to the region of the particle. In average, either the preons that form the rest mass and those contributing to the kinetic energy (or momentum) have approximately the same radii. It can be visualized as two superimposing spherical surfaces with different numbers of preons. If those surfaces were allowed to inflate to give the same density of preons on their surfaces, the pythagorean relation ($R_c^2 = R_a^2 + R_b^2$) would be restored.

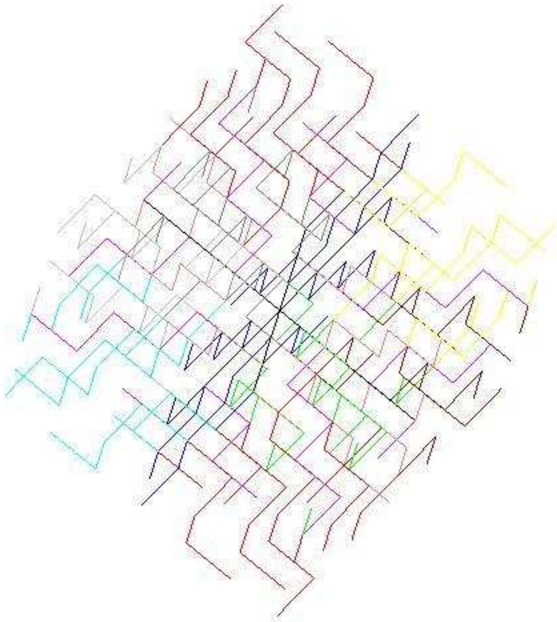

Figure 12: Exploration tree. This scheme guarantees that each cell is visited just once.

Appendix: pseudocode

Can be implemented as a central processor (this version), one processor per cell, or logic gates only solutions, with appropriate adaptations. In practice, a GPU-based solution proved sufficient to study and visualize the basic processes.

▷ Top routine (assuming the automaton has already been initialized)
function *automaton* () **begin**
  loop
    cycle()
  end loop
end

▷ One automaton cycle
function *cycle* () **begin**
  for each cell **do**
    pairClassification ()
  end do
  for each cell **do**
    *patterns*2 ()
  end do
  for each cell **do**
    *patterns*3 ()
  end do
    if $p_3 \neq UNDEF$
      expandBurst ()
    else if $p_2 = GRAV$
      expandGraviton ()
    else
      expandPreon ()
    end if
  end do

$flipLattices\,()$
end

function $flipLattices\,()$ **begin**
$xchg = dual_0$
$dual_0 = pri_0$
$pri_0 = xchg$
end

▷ Burst, P, G detection
▷ Field p_{16} is resolved by mutual comparison in the w dimension
function $pairClassification\,()$ **begin**
$dual \leftarrow principal$ ▷ Start with a copy of last value
if $pairFormation\,()$ **or** $interference\,()$ **or** $isGraviton\,()$ **then**
return
end if
$p^1_{16} = U$
if $burstInteraction\,()$ **then**
return
end if
▷ Mutual visit to resolve p_{16} (indices: 1, principal; 2, neighbor)
$neighbor = principal - p_5$
$nual = dual - p_5$
for all $neighbor \neq principal$ **do**
if $p_2 = REAL$ **or** $p_2 = VIRT$ **then**
if $p^1_6 = p^2_6$ **then**
if $tangled\,(t_1,\, t_2)$ **and** $p^2_{144} = 1$ **then** ▷ Evolve sinusoidal phase
$p^2_{144} = 0$
$incrDFO\,(t_2)$
end if
▷ Timeout of virtual pairs (P→ VCP)
if $p_{23} = 0$ **and** $p_2 = VIRT$ **then**
$p_{13} = 0$
$\vec{p}_{12} = \vec{0}$
end if
if $p^1_2 = VIRT$ **and** $p^2_2 = VIRT$ **and** $\vec{p}^{\,1}_{12} = \vec{0}$ **and** $\vec{p}^{\,2}_{12} = \vec{0}$ **then**
$p^1_{16} = P$
$p^1_{21} = VCP$
return
▷ Neutrino detection NTP
if ($\vec{p}^{\,1}_{12} = \vec{0}$ **or** $\vec{p}^{\,2}_{12} = \vec{0}$) **and** ($\vec{p}^{\,1}_{12} \neq \vec{0}$ **or** $\vec{p}_{12} \neq \bar{0}$ **or** $p^1_2 = REAL$) **then**
$p^1_{16} = NTP$
end if
if $\vec{p}^{\,1}_{12} \neq \vec{0}$ **and** $\vec{p}^{\,1}_{12} = -\vec{p}^{\,2}_{12}$ **then**
▷ Spins are defined
if $p^1_2 = p^2_2$ **then**
$p^1_{16} = P$
▷ Detect weak MGP
if $p^1_9 = LM$ **and** $conjug\left(p^1_{10}\right) = 1$ **and** $p^2_9 = LM$ **and** $conjug\left(p^2_{10}\right) = 1$ **then**
$p_{21} = MGP$
else if $p^1_9 = RM$ **and** $conjug\left(p^1_{10}\right) = -1$ **and** $p^2_9 = RM$ **and** $conjug\left(p^2_{10}\right) = -1$ **then**
$p_{21} = MGP$
▷ Detect GLP
else if $p^1_{10} = RED$ **and** $p^2_{10} = ANTIGREEN$ **then**
$p_{21} = GLP$
else if $p^1_{10} = GREEN$ **and** $p^2_{10} = ANTIRED$ **then**

$p_{21} = GLP$
else if $p_{10}^1 = BLUE$ **and** $p_{10}^2 = ANTIRED$ **then**
$p_{21} = GLP$
else if $p_{10}^1 = RED$ **and** $p_{10}^2 = ANTIBLUE$ **then**
$p_{21} = GLP$
else if $p_{10}^1 = GREEN$ **and** $p_{10}^2 = ANTIBLUE$ **then**
$p_{21} = GLP$
else if $p_{10}^1 = BLUE$ **and** $p_{10}^2 = ANTIGREEN$ **then**
$p_{21} = GLP$
▷ Detect KNP
else if $p_2^1 = REAL$ **and** $p_2^2 = REAL$ **and** $\overrightarrow{p}_7^1 \neq \overrightarrow{0}$ **and** $\overrightarrow{p}_7^1 = \overrightarrow{p}_7^2$ **then**
$p_{21} = KNP$
▷ Detect MSP
else if $p_{10}^1 = RED$ **and** $p_{10}^2 = ANTIRED$ **then**
$p_{21} = MSP$
else if $p_{10}^1 = GREEN$ **and** $p_{10}^2 = ANTIGREEN$ **then**
$p_{21} = MSP$
else if $p_{10}^1 = BLUE$ **and** $p_{10}^2 = ANTIBLUE$ **then**
$p_{21} = MSP$
▷ Detect PHP
else if $p_{10}^1 = LEPT$ **and** $p_{10}^2 = ANTILEPT$ **then**
$p_{21} = PHP$
else if $p_{10}^1 = ANTILEPT$ **and** $p_{10}^2 = LEPT$ **then**
$p_{21} = PHP$
▷ Detect EMP
else if $p_2^1 = REAL$ **then**
$p_{21} = EMP$
end if
end if
end if
end if
end do
end

▷ Resolves p_{16} for additional cases
▷ (PXP, UXP, UXG interactions; WZ; HADRON)
function $patterns2\,()$ **begin**
if $p_2 = NIL$ **then**
return
end if
if $p_{16} = P$ **then**
▷ Mutual visit to resolve p_{16}
$neighbor = principal - p_5$
$nual = dual - p_5$
for all $neighbor \neq principal$ **do**
if $principal = neighbor$ **then**
continue
end if
if $p_{16}^2 = P$ **then**
$PXPinteraction\,(neighbor, nual)$
end if
end do
return
else if $p_{16} \neq U$ **then**
return
end if

▷ Mutual visit to resolve p_{16}
$neighbor = principal - p_5$
$nual = dual - p_5$
for all $neighbor \neq nual$ **do**
if $p_{16} = P$ **then**
$UXPinteraction\,()$
else if $p_{16} = GR$ **then**
$UXGinteraction\,()$
end if
end do
end

▷ UXU, UXTr detection
function $patterns3\,()$ **begin**
if $p_2 = NIL$ **then**
return
end if
▷ Mutual visit to resolve p_{16}
$neighbor = principal - p_5$
$nual = dual - p_5$
for all $neighbor \neq principal$ **do**
if $p_{16}^1 = WZ$ **and** $p_{21}^2 = VCP$ **then**
$p_{16}^2 = MGP$
continue
end if
if $p_{16}^1 = HADRON$ **and** $p_{21}^2 = VCP$ **then**
$p_{16}^2 = MGP$
if $p_5^1 > p_5^2$ **then**
▷ VCP2 → GLP_bar
$p_{21}^2 = GLP$
$p_{10}^2 = p_1^1 \bmod 8$
else
▷ VCP2 → MSP-
$p_{21}^2 = MSP$
$p_8^2 = -1$
end if
continue
end if
if $p_{16}^1 \neq U$ **or** $p_{16}^1 \neq CH$ **then**
continue
end if
if $p_8^1 \neq 0$ **then**
if $p_8^1 = p_8^2$ **then**
$cohesion\,(neighbor, nual)$
else
$annihilation\,(neighbor, nual)$
end if
end if
$entangle\,(dual, nual)$
end do
end

function expandBurst() **begin**
if $p_1^1 = SYNCH$ **then**
$p_1^2 = 0$
if $p_2^1 = REAL$ **then**
$\bar{p}_1^2 = INFINITY$

$p_2^2 = GRAV$
end if
else if $p_1^1 = BURST$
return ▷ p1 must complete one full SYNCH
end if
for each dir **in** $NDIR$ **do**
if $isAllowed\left(dir, p_{26}^1, p_{260}^1\right)$
Tile *nual = getNual(dir)
boolean gr = nual->p2 == GRAV
int p1 = nual->p1
Tuple p6
tupleCopy(&p6, nual->p6)
copyTile(nual, dual)
if dual->p2 = GRAV
nual->p2 = REAL ▷ must transport to OP
nual->p1_ = 1000000
if gr
nual->p2 = GRAV
nual->p1_ = p1
tupleCopy(&nual->p6, p6)
end if
nual->p260 = dir
addTuples(&nual->p26, dirs[dir])
end if
end for
dual->p3 = UNDEF
if isEqual(pri->p19, pri->p0)
▷ Reemit
dual->p25 = BURST
end if
else if dual->p1 = 0 **and** dual->p2 = GRAV
tupleCross(pri->p12, pri->p6, &dual->p12)
normalizeTuple(&dual->p12)
resetTuple(&dual->p6)
dual->p203 = BURST
else if pri->p2 != GRAV
cleanTile(dual)
end if
end

▷Visit-once-tree, as shown in Fig. 12
function $expandTree$ () begin
if $(p_2 = NIL$ **and** $p_3 = IDLE)$ **or** $(p_1 - p_{202} \leq p_{203})$ **then**
return
end if
▷ Reemit from OP when maximum expansion
if $p_3^1 = IDLE$ **and** $p_6.x = SIDE/2$ **then**
$\overrightarrow{p}_{19}^{1*} = \overrightarrow{p}_0^1 - \overrightarrow{p}_6^1$
$burst\,(false)$
return
end if
▷ Activation time (AT)
for $i = 0$ **to** 5 **do**
if $p_6^{1*}.x + dirs[i].x = SIDE/2 + 1$ **or** $p_6^{1*}.y + dirs[i].y = SIDE/2 + 1$ **or** $p_6^{1*}.z + dirs[i].z = SIDE/2 + 1$ **then**
continue

```
            end if
            if p_6^{1*}.x + dirs[i].x = -SIDE/2 or p_6^{1*}.y + dirs[i].y = -SIDE/2 or p_6^{1*}.z + dirs[i].z = -SIDE/2 then
                continue
            end if
            if isAllowed(dir) then
                nual = getNual(i)
                nual = dual
                p_6^{nual} = dirs[i]
                p_200^{nual} = i
                p_201^{nual} = p_201^{nual} + 1
                p_202^{nual} = p_1
                if p_3^{nual} = IDLE then
                    p_203^{nual} = 2 · D · |p→_6^{nual}|
                else
                    p_203^{nual} = 0
                end if
            end if
        end do
        if p_3^1 ≠ IDLE and p_19^1 = p_0^1 then
            reemit()
        else
            dual ←∅
    end

    function updateDual(b) begin
        if p_3 ≠ IDLE then
            updateMessenger(b)
        else
            updateWavefront(b)
        end if
        dual ←∅
    end

    function updateMessenger(b) begin
        if |p_6.x| = SIDE/2 or |p_6.y| = SIDE/2 or |p_6.z| = SIDE/2 then
            b ← ∅
        else
            p_200 = dir
            p_201 = p_201 + 1
            p_202 = p_1
            p_203 = 0
            if p_2 = REAL then
                p_2 = GRAV
            end if
        end if
    end

    function updateWavefront() begin
        if |p_6| < SIDE/2 then
            if p_201 = 0 and dir = 0 then
                p_200 = 1
            else if p_200 = 1
                p_200 = 0
            end if
            p_201 = p_201 + 1
            p_202 = p_1
```

```
        p_203 = 2D|p_6|
    else if p_2 ≠ GRAV and p_200 = 1 then
        burst(IDLE)
        p_203 = 4 · SIDE · D
    else
        dual ←∅
    end if
    p_144 = 1    ▷ Sine phase changed
        p_201 = p_201 + 1
        p_202 = p_1
        p_203 = 2D|p_6|
    if p_2 = GRAV then    ▷ Graviton extinction
        if p_6^G = 0⃗ then
            p_2^G = NIL
            p_11^G ≡ OFF
        else if
            calculate unique tile where p_11 = ON
        end if
    end if
end

function burstInteraction() begin
    if p_3^T ∈ {PLAIN, FORCING, COLL} and p⃗_19^T = CP then    ▷ Reemission point found
        p⃗_6^T = 0⃗
        if p_3^T = COLL then
            p_3^T = FORMING    ▷ Not superluminal
        else
            p_3^T = IDLE
        end if
    ▷ Photon formation I
    else if p_3^T = FORCING and p_16^T = U_1 and p_16^2 = U_2 and tangled(U_1, U_2) then
        reemit(U_2, PLAIN, OP_U2)
    else if p_3^T = COLL and p_16^V = P and tangled(T, P) then    ▷ Photon is collapsing
        reemit(P, PLAIN, CP_emitter)
    ▷ Photon formation II
    else if p_3^T = FORCING and p_16^T = C and p_16^V = B and tangled(C, B) then
        reemit(B, PLAIN, OP_C)
    else if p_3^T = PLAIN then
        if p_2^T = REAL and p_6^T = p_6^V and p_5^T = p_5^V then    ▷ Graviton emission
            p_2^V = GRAV
            p_11^V = OFF
        else
            p_2^V = NIL
            resetDFO(V)
        end if
        if p_13^T = p_13^V and p⃗_12^V = −p⃗_12^emitter (old) then    ▷ Pairment of twin tiles spin
            p⃗_12^V = −p⃗_12^emitter (new)
        end if
    end if
end

function UXPinteraction() begin    ▷ Non-leptonic Ps act like a U in the KNP case
    p_16^U = UXP
    if p_6^U = p_6^P then
        ▷ Tr detected
        p_16^P = BR
        p_16^U = CH
```

if $|\overrightarrow{p}_6^C| \geq LOST$ **then** $\triangleright$ The triad is undone
$p_{16}^C = U$ $\triangleright$ Cheese →U
$p_{16}^B = P$
$\triangleright$ Fundamental photon
$reemit(C, PLAIN, OP_C)$
$reemit(B, PLAIN, OP_B)$
end if
end if
if $p_{21}^P = KNP$ **then** $\triangleright$ Inertia
$p_{19}^P = \hat{p}_7^P |\overrightarrow{p}_6^P| + \overrightarrow{p}_6^P$
$p_{19}^{UC} = p_{19}^P + \overrightarrow{p}_6^U - \overrightarrow{p}_6^P$
$\triangleright$ Move the preons
$reemit(P, PLAIN, p_{19}^P)$
$reemit(U|C, PLAIN, p_{19}^{U|C})$
else if $p_{21}^P = EMP$ **then** $\triangleright$ Static EM forces
if $EMFilter(U, P)$ **then** $\triangleright$ Electric force
$\overrightarrow{p}_7^P = sgn\left(p_8^U p_8^P\right) \cdot \left(\overrightarrow{p}_6^P - \overrightarrow{p}_6^U\right)$
$entangle(U, P)$
$p_8^P = 0$ $\triangleright$ EMP is just a messenger
$\triangleright$ Generate KNP
$reemit(U, PLAIN, OP_U)$
$reemit(P, PLAIN, CP)$
else if $EMFilter(U, P) \wedge pwm(|p_{12}^P \cdot p_{12}^U|)$ **then** $\triangleright$ Magnetic force
$\overrightarrow{p}_7^P = sgn\left(p_8^U p_8^P\right) \cdot \left(\overrightarrow{p}_{12}^U \times \overrightarrow{p}_6^P\right)$
$p_{12}^U = \overrightarrow{p}_7^P$
$entangle(U, P)$
$\triangleright$ Generate KNP
$reemit(U, PLAIN, OP_U)$
$reemit(P, PLAIN, CP)$
end if
else if $p_{21}^P = PHP$ **then** $\triangleright$ Light-matter interaction
$\overrightarrow{v} = \overrightarrow{p}_{12}^P \times \overrightarrow{p}_6^P$
$rotate(\overrightarrow{v}, p_{141}^P)$
$c = \overrightarrow{v} \cdot \overrightarrow{p}_{12}^U$
$p_{15E}^U = pwm\left(c^2\right)$
$p_{15M}^U = pwm\left([SIDE - c]^2\right)$
if $EMFilter(U, P) \wedge \left(p_4^U \neq p_4^P\right) \wedge p_{15E}^P$ **then**
$reemit(P, COLL, CP)$
$reemit(U, PLAIN, OP_U)$
else if $EMFilter(U, P) \wedge \left(p_4^U \neq p_4^P\right) \wedge p_{15M}^P$ **then**
$reemit(P, COLL, CP)$
$reemit(U, PLAIN, OP_U)$
end if
else if $p_{21}^P = MGP$ **then** $\triangleright$ Charged-bosons interaction with matter
if $p_8^P \neq 0$ **or** $p_{10}^P \neq LEPT$ **or** $p_9^P \neq 0$ **then**
$p_{18}^P = SIDE$
$\triangleright$ Neutrino emission
if $p_8^U \neq 0$ **and** $p_9^U = -1$ **and** $p_9^P = -1$ **and** $\overrightarrow{p}_{12}^U = \overrightarrow{0}$ **then**
$\overrightarrow{p}_{12}^U = \overrightarrow{p}_{12}^P$
$p_2^P = REAL$
$p_{21}^P = NTP$
$reemit(U, PLAIN, OP_U)$ $\triangleright$ Reemit weak charge
$reemit(P, PLAIN, OP_U)$ $\triangleright$ Generate neutrino
end if
end if

else if $p_{21}^P = GLP$ **and** $p_{10}^U \neq LEPT$ **then** ▷ Gluon-quark interaction
  if $p_{10}^U = p_{10}^{P2}$ **then** ▷ Color exchange
    $p_{10} = p_{10}^{P2}$
    $p_{10}^{P2} = p_{10}^U$
    $p_{10}^U = p_{10}$
    p_{21}^P=VCP ▷ Virtual gluon returns to vacuum
  end if
else if $p_{21}^P = MSP$ **and** $p_{10}^U \neq LEPT$ **then** ▷ Meson-matter interaction
  if $p_{10}^U = p_{10}^P$ **or** $p_{10}^U = \bar{p}_{10}^P$ **then**
    $p_{21}^P = KNP$
    $p_7^P = p_6^U$
  end if
else if $p_{16}^P = VCP$ **then** ▷ Vacuum-charge interactions
  ▷ Define spins for all cases
  if $p_5^U < p_5^P$ **then**
    $\overrightarrow{p}_{12}^P = \overrightarrow{p}_{12}^U$
  else
    $\overrightarrow{p}_{12}^P = -\overrightarrow{p}_{12}^U$
  end if
  if $p_{11}^U = ON$ **then** ▷ Graviton processing
    $p_{11}^U = OFF$ ▷ Start KNP formation
    $p_7^P = p_7^U$ ▷ Radial direction was defined previously
    $p_{13}^P = p_{13}^U = p_{13}^U - 1$ ▷ Decoherence
    ▷ Release attractive KNP
    $reemit\,(U, PLAIN, OP_U)$
    $reemit\,(P, PLAIN, CP)$
  else if $p_9^U = 0$ **and** $p_{10}^U = LEPT$ **then** ▷ Electric charge
    $p_2^P = VIRT$
    $p_{13}^P = p_{13}^U$ ▷ Inherit entanglement
    $p_8^P = p_8^U$ ▷ Both tiles of pair inherit U's charge!!
    ▷ Release EMP
    $reemit\,(U, PLAIN, OP_U)$
    $reemit\,(P, PLAIN, CP)$
  else if $p_{16}^U \neq CH$ **then** ▷ Triad formation I
    if $p_5^U > p_5^P$ **then**
      $p_{10}^P = p_{10}^U$
      $p_8^P = p_8^U$
      $p_9^P = p_9^U$
    else
      $p_{10}^P = \bar{p}_{10}^U$
      $p_8^P = -p_8^U$
    end if
    $p_{13}^P = p_{13}^U$ ▷ Inherit entanglement
    if $p_{12}^U \cdot p_6^U > 0$ **then** ▷ Update helicity
      $p_4^U = p_4^P = 0$
    else
      $p_4^U = p_4^P = 1$
    end if
    ▷ Release triad components
    $reemit\,(U, PLAIN, CP)$
    $reemit\,(P, PLAIN, CP)$
  else if $p_{10}^U \neq LEPT$ **then** ▷ Strong charge
    $p_{18}^P = SIDE$
    $p_{13}^P = p_{13}^U$
    if $p_1 \mod 2 = 0$ **then** ▷ Color exchange
      $p_{10}^{V2} = p_{10}^U \gg 4 \mid p_{10}^U \ll 2$

else
$p_{10}^{V2} = p_{10}^{V2} = p_{10}^{U} \ll 4 \mid p_{10}^{U} \gg 2$
end if
$p_{10}^{V1} = p_{10}^{U}$
$p_{10}^{U} = p_{10}^{V2} \gg 3 \mid p_{10}^{V2} \ll 3$
▷ Release gluon components
$reemit\,(U,\, PLAIN\,, OP_U)$
$reemit\,(P,\, PLAIN\,, CP)$
else if $p_9^U \neq 0$ **then** ▷ Weak charge x VCP
$p_9^P = p_9^U$ ▷ Temporarily inherits weak charge
$p_{18}^P = SIDE$ ▷ Reset decay TTL
$p_{13}^P = p_{13}^U$
if $p_5^U < p_5^P$ **then**
$\overrightarrow{p}_{12}^{P} = \overrightarrow{p}_{12}^{P}$
$\overrightarrow{p}_{7}^{P} = \overrightarrow{p}_{6}^{U}$
else
$\overrightarrow{p}_{12}^{P} = -\overrightarrow{p}_{12}^{U}$
$\overrightarrow{p}_{7}^{P} = -\overrightarrow{p}_{6}^{U}$
end if
▷ Release weak MGP
$reemit\,(U,\, PLAIN\,, OP_U)$
$reemit\,(P,\, PLAIN\,, CP)$
end if
else if $p_{16}^P = BR$ **and** $p_{13}^U = p_{13}^B \neq 0$ **and** $p_{17}^B > 0$ **then**
if $p_8^U \neq 0$ **or** $p_{10}^U \neq LEPT$ **or** $p_9^U \neq 0$ **then**
$p_{17}^B = SIDE$
end if
else if $p_8^U \neq 0$ **and** $\overrightarrow{p}_{12}^{U} = -\overrightarrow{p}_{12}^{P}$ **and** $p_{21}^P = NTP$ **then** ▷ Neutrino absorption
$\overrightarrow{p}_{12}^{U} = \overrightarrow{p}_{12}^{P} = \overrightarrow{0}$
$p_{16}^P = VCP$ ▷ $NTP \rightarrow VCP$
$p_9^U = p_9^P$ ▷ Preserve weak charge
end if
end

function $UXUinteraction()$ **begin** ▷ Includes UXC interactions
if $p_8^1 = -p_8^2$ **and** $p_{10}^1 = \bar{p}_{10}^2$ **then** ▷ Fermions annihilation
$\overrightarrow{v} = \overrightarrow{p}_{6}^{1} \times \overrightarrow{p}_{6}^{2}$
if $p_5^1 > p_5^2$ **then**
$\overrightarrow{p}_{12}^{1} = \overrightarrow{v}$
$\overrightarrow{p}_{12}^{2} = -\overrightarrow{v}$
else
$\overrightarrow{p}_{12}^{1} = \overrightarrow{v}$
$\overrightarrow{p}_{12}^{2} = -\overrightarrow{v}$
end if
▷ Reemit Us to from CP to form a P
$reemit\,\big(U^1,\, COLL,\, CP)\big)$
$reemit\,\big(U^2,\, COLL,\, CP)\big)$
$p_{13}^{U1} = p_{13}^{U2} = SIDE/2$
else if $p_8^1 = p_8^2$ **and** $p_{10}^1 = p_{10}^2$ **then** ▷ Cohesion force
if $p_5^1 > p_5^2$ **then**
$p_{19}^1 = OP$
$p_{19}^2 = CP$
else
$p_{19}^1 = CP$
$p_{19}^2 = OP$
end if

$entangle(U_1, U_2)$
▷ Reemit interacting Us
$reemit\left(U_1, FORCING, p^1_{19}\right)$
$reemit\left(U_2, FORCING, p^2_{19}\right)$
end if
end

function $PXPinteraction()$ **begin**
if $tangled\,(P_1, P_2)$ **then**
if $p^{P1}_{21} = PHP$ **and** $p^{P2}_{21} = KNP$ **and** $EMFilter()$ **then** ▷ KNP accretion by photon
$p^{P1}_{143} = p^{P1}_{143} + 1$
$p^{P2}_{143} = p^{P2}_{143} + 1$
▷ *Reemit Ps*
$reemit(P_1, PLAIN, CP)$
$reemit(P_2, PLAIN, CP)$.
else if $p^{P1}_{21} = p^{P2}_{21} = KNP$ **then** ▷ KNP excess cancellation
$proj = \overrightarrow{p}^1_7 \cdot \overrightarrow{p}^2_7$
if $proj > 0$ **and** $pwm(proj.SIDE)$ **then** ▷ KNPs →VCPs
$p^{P1}_2 = p^{P2}_2 = VIRT$
$\overrightarrow{p}^{P1}_{12} = \overrightarrow{p}^{P2}_{12} = \overrightarrow{0}$
$\overrightarrow{p}^{P1}_7 = \overrightarrow{p}^{P2}_7 = \overrightarrow{0}$
end if
else if $p^1_{10} \neq LEPT$ **and** $p^2_{10} \neq LEPT$ **then** ▷ Gluon-gluon interaction
▷ Reemit gluons
$reemit\,(P_1, PLAIN, CP)$
$reemit\,(P_2, PLAIN, CP)$
end if
else if $p^1_{21} = MGP$ **and** $p^2_{21} = MGP$ **and** $p^1_9 = LEFT$ **and** $p^2_9 = LEFT$ **and** $p^1_8 \neq 0$ **and** $p^1_8 = -p^2_8$ **then** ▷ W pair annihilation
$reemit\,(P_1, PLAIN, CP)$
$reemit\,(P_2, PLAIN, CP)$
else if $p^1_{21} = KNP$ **and** $p^2_{21} = KNP$ **then** ▷ Head-on collision
$proj = \overrightarrow{p}^1_7 \cdot \overrightarrow{p}^2_7$
if $proj > 0$ **and** $pwm(proj.SIDE)$ **then**
$p^{P1}_2 = p^{P2}_2 = REAL$
$p^{P1}_7 = -p^{P2}_7$
▷ MGP formation
$reemit(P_1, PLAIN, CP)$
$reemit(P_2, PLAIN, CP)$.
end if
endif
end

function $UXGinteraction()$ **begin**
$p^U_{11} = ON$ ▷ KNP formation promise
$p^U_7 = -p^G_6$ ▷ Direction of future KNP
end

boolean function $pairFormation\,()$ **begin**
if $\overrightarrow{p}^1_6 \neq \overrightarrow{0}$ **then**
return false
end if
for all forward w-neighbor t_2 **do** ▷ Preserve the reciprocity principle
if $\overrightarrow{p}^2_6 = \overrightarrow{0}$ **and** $tangled(t1, t2)$ **then**
if $p^1_8 = -p^2_8$ **then**
▷ $l\,\bar{l}$ or $q\,\bar{q}$ formation
$p^1_{22} = p^2_5$

```
            if $p^1_{10} \neq LEPT$ and $p^1_{10} \neq ANTILEPT$ and $p^1_{10} = \bar{p}^2_{10}$ then
                $p^1_{16} = U$
            else
                $p^1_{16} = U$
            end if
        else $p^1_8 = p^2_8 = 0$ and $p^1_9 \neq 0$ and $p^2_9 = -p^1_9$ then
            $p^1_{16} = WZ$
        else $p^1_8 = p^2_8 = 0$ and ($p^1_9 \neq 0$ or $p^2_9 \neq 0$) then
            $p^1_{16} = P$
            if $p^1_5 > p^2_5$ then
                $p^1_{21} = MGP$
            else
                $p^1_{16} = WZ$
            end if
        else $p^1_8 = p^2_8 = 0$ and $p^1_{10} = \bar{p}^1_{10}$ then
            $p^1_{16} = HADRON$
            if $p^1_1 \bmod 2 = 0$ then
                if $p^1_5 > p^2_5$ then
                    $p^1_{21} = GLP$
                else
                    $p^1_{21} = \overline{GLP}$
                end if
            else
                if $p^1_5 > p^2_5$ then
                    $p^1_{21} = MSP+$
                else
                    $p^1_{21} = MSP-$
            end if
                end if
        end if
        ▷select one option
        if $p^1_{22} > p^2_{22}$
            $p^1_{22} = p^2_{22}$
        end if
    end if
  end do
    return true
  end if
  return false
end
```

▷ Tests whether the direction dir is a valid path in the visit-once-tree.

```
boolean function isAllowed(dir) begin
  $x = p6.x + dirs[dir].x$
  $y = p6.y + dirs[dir].y$
  $z = p6.z + dirs[dir].z$
  $level = abs(x) + abs(y) + abs(z)$
  ▷ x-axis
  if $x > 0$ and $y = 0$ and $z = 0$ and $dir = 0$ then
    return true
  else if $x < 0$ and $y = 0$ and $z = 0$ and $dir = 1$ then
    return true
  end if
  ▷ y-axis
  else if $x = 0$ and $y > 0$ and $z = 0$ and $dir = 2$ then
    return true
```

```
else if x = 0 and y < 0 and z = 0 and dir = 3 then
    return true
end if
▷ z-axis
else if x = 0 and y = 0 and z > 0 and dir = 4 then
    return true
else if x = 0 and y = 0 and z < 0 and dir = 5 then
    return true
end if
▷ xy plane
else if x > 0 and y > 0 and z = 0 then
    if level mod 2 = 1 then
        return (dir = 0 and p_200 = 2)
    else
        return (dir = 2 and p_200 = 0)
    end if
else if x < 0 and y > 0 and z = 0 then
    if level mod 2 = 1 then
        return (dir = 1 and p_200 = 2)
    else
        return (dir = 2 and p_200 = 1)
    end if
else if x > 0 and y < 0 and z = 0 then
    if level mod 2 = 1 then
        return (dir = 0 and p_200 = 3)
    else
        return (dir = 3 and p_200 = 0)
    end if
else if x < 0 and y < 0 and z = 0 then
    if level mod 2 = 1then
        return (dir = 1 and p_200 = 3)
    else
        return (dir = 3 and p_200 = 1)
    end if
end if
▷ yz plane
else if x = 0 and y > 0 and z > 0 then
    if level mod 2 = 0 then
        return (dir = 4 and p_200 = 2)
    else
        return (dir = 2 and p_200 = 4)
    end if
else if x = 0 and y < 0 and z > 0 then
    if level mod 2 = 0 then
        return (dir = 4 and p_200 = 3)
    else
        return (dir = 3 and p_200 = 4)
    end if
else if x = 0 and y > 0 and z < 0 then
    if level mod 2 = 0 then
        return (dir = 5 and p_200 = 2)
    else
        return (dir = 2 and p_200 = 5)
    end if
else if x = 0 and y < 0 and z < 0 then
    if level mod 2 = 0 then
```

```
        return (dir = 5 and p_200 = 3)
      else
        return (dir = 3 and p_200 = 5)
      end if
    end if
    ▷ zx plane
    else if x > 0 and y = 0 and z > 0 then
      if level mod2 = 1 then
        return (dir = 4 and p_200 = 0)
      else
        return (dir = 0 and p_200 = 4)
      end if
    else if x < 0 and y = 0 and z > 0 then
      if level mod2 = 1 then
        return (dir = 4 and p_200 = 1)
      else
        return (dir = 1 and p_200 = 4)
      end if
    else if x > 0 and y = 0 and z < 0 then
      if level mod2 = 1 then
        return (dir = 5 and p_200 = 0)
      else
        return (dir = 0 and p_200 = 5)
      end if
    else if x < 0 and y = 0 and z < 0 then
      if level mod2 = 1then
        return (dir = 5 and p_200 = 1)
      else
        return (dir = 1 and p_200 = 5)
      end if
    else
    ▷ spirals
      x_0 = x + SIDE/2
      y_0 = y + SIDE/2
      z_0 = z + SIDE/2
      switch level mod 3 do
        case 0
          if x_0 ≠ SIDE/2 and y_0 ≠ SIDE/2 then
            return (z_0 > SIDE/2 and dir = 4) or (z_0 < SIDE/2 and dir = 5)
          end if
          break
        case 1
          if y_0 ≠ SIDE/2 and z_0 ≠ SIDE/2 then
            return (x_0 > SIDE/2 and dir = 0) or (x_0 < SIDE/2 and dir = 1)
          end if
          break
        case 2
          if x_0 ≠ SIDE/2 and z_0 ≠ SIDE/2 then
            return (y_0 > SIDE/2 and dir = 2) or (y_0 < SIDE/2 and dir = 3)
          end if
          break
      end switch
    end if
    return false
end
```

boolean function *interference* () **begin**
  if $p_1 - p_{202} \leq p_{203}$ **then**
    if $p_1\, mod\, (3\, SIDE) = 0$ **then**
      ▷ The cell was not visited
      $p_{17} = p_{17} + 1$ ▷ Count steps since last visit
      ▷p_{18} decays absolutely and exponentially
      if $p_{18} > 0$ **then**
        $p_{18} = p_{18} \cdot \left(SIDE - \frac{SIDE}{2\, p_{17}} \right)$
        if $p_{18} < 0$ **then**
          $p_{18} = 0$
        end if
      else if $p_{18} < 0$ **then**
        $p_{18} = p_{18} \cdot \left(SIDE + \frac{SIDE}{2\, p_{17}} \right)$
        if $p_{18} < 0$ **then**
          $p_{18} = 0$
        end if
      end if
      return true
  else
      ▷ The cell was visited
      $p_{17} = 0$
      $p_{18} = p_{18} + p_{14}$ ▷ Track left
      return false
  end if
end

boolean function *isGraviton* () **begin**
  if $p_2 = GRAV$ **then**
    if p_{11} **then**
      $p_{16} = GR$
      ▷ G extinction
      if $\overrightarrow{p}_6 = \overrightarrow{0}$ **then**
        $p_{16} = ND$
        $p_2 = NIL$
        $p_{11} = OFF$
      end if
    else
      $p_{16} = ND$
    end if
    return true
  end if
  return false
end

function *EMFilter* (U, P) **begin**
  return $p_{11}^U \wedge pwm\left(p_{14}^U\right) \wedge pwm\left(p_{15}^P\right) \wedge pwm\left(p_{18}^P\right)$
end

boolean function *pwm*(n) **begin**
  return $(n\, \mathbf{mod}\, STEP < n/NSTEPS)$
end

function *entangle*$(t1,\, t2)$ **begin**
  $p_{13}^{t1} = p_{13}^{t2} = p_5^{t1} \cdot p_5^{t2} + SIDE$
end

boolean function *tangled*$(t1,\, t2)$ **begin**
  if $|p_{13}^{t1} - p_{13}^{t2}| > SIDE$ **then**

return false
else
return $pwm\left(\frac{\left(p_{13}^{t1}-p_5^{t1}\cdot p_5^{t2}\right)\left(p_{13}^{t2}-p_5^{t1}\cdot p_5^{t2}\right)}{SIDE}\right)$
end if
end

▷ Prepares the tile as the seed of a new preon or burst expansion.
function $reemit\,(t,\, p_3,\, \overrightarrow{p}_{19})$ **begin**
$p_3^t = p_3$
$p_{200}^t = 0$
$p_{201}^t = 0$
$p_{202}^t = 0$
if $p_3 = IDLE$ **then**
$p_{203} = 0$
else
$p_{203} = 2 \cdot D + 0.5$
end if
$\overrightarrow{p}_6^t = \overrightarrow{0}$
$p_{11} = OFF$
$\overrightarrow{p}_{19}^t = \overrightarrow{p}_{19}$
$resetDFO\,(t)$
end

function $resetDFO\,(t)$ **begin**
$p_{141}^t = U_1$
$p_{142}^t = U_2$
end

function $incrDFO\,(t)$ **begin**
$u_3 = K \cdot p_{142}^t - p_{141}^t$
$p_{141}^t = p_{142}^t$
$p_{142}^t = u_3$
end

▷ Rotates vector $\overrightarrow{v}$ about $\overrightarrow{p}_6$ by the angle θ,
function $rotate(\overrightarrow{v},\, \theta)$ **begin**
rotates $\overrightarrow{v}$ about $\overrightarrow{p}_6$ by the angle θ, using a 3d CORDIC resolver ▷ *cf.* [10]
end

▷ Returns +1 if matter, -1 if antimatter, 0 otherwise
boolean function $conjug\,(c)$ **begin**
if $c \odot LEPT \neq 0$ **and** $c \odot ANTILEPT = 0$ **then**
return +1
else if $c \odot ANTILEPT \neq 0$ **and** $c \odot LEPT = 0$ **then**
return -1
else
return 0
end

▷ Emits a burst preserving the origin tile if CP.
function $burst\,(cp)$ **begin**
for $i = 0$ **to** 5 **do**
$nual = getNual(i)$
$nual \leftarrow dual$
$p_3^{nual} = PLAIN$
$p_{200}^{nual} = i$
$p_{201}^{nual} = 1$
$p_{202}^{nual} = p_1 - 1$

$p_{203}^{nual} = 0$
$p_{6}^{nual} = dirs[i]$
end do
if not cp **then**
$dual \leftarrow \varnothing$
end if
end