Deriving the Standard Model in VERSF

A plain language guide to particles forces and the progress so far

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A summary for the general reader

The atoms in your body, the light reaching your eyes and the reactions that power the Sun depend on the particles and interactions described by the Standard Model. Built over decades, it is an extraordinary scientific achievement. Yet a deeper question remains: why does nature have this particular collection of particles, with these particular properties? The theory needs many numbers from experiment, including particle masses, whose values it does not itself explain. [11,12,17,19]

A successful derivation would be a major advance in fundamental physics. It would reveal why the ingredients of our world fit together as they do. Imagine knowing every note a musical instrument can play, then discovering why its construction produces exactly those notes. VERSF seeks that deeper explanation for the Standard Model: physical principles from which the particles, forces and their numerical properties follow.

VERSF already offers a proposed physical explanation. It begins with differences that nature can register and the lasting records those differences leave. Their relationships form its proposed underlying structure, from which space, time and particles emerge. The question now is whether this physical account determines the Standard Model we observe. Explaining that connection would turn an account of nature's ingredients into an explanation of why those ingredients arise. [1,2,5]

The progress is encouraging because the physical ideas are producing calculations with definite results. Recent neutrino work, for example, reports a pattern of relative masses under additional assumptions. Those assumptions and the full calculation still need independent checking. Newer work also provides a first calculated proposal for the shared structure behind the matter families, under stated assumptions. How each particle type connects to it remains to be derived. [36] That is the distinction from numerology: the numbers must follow from physical reasoning, rather than being selected simply because they resemble measurements. The programme's internal progress review places progress towards a full derivation at **about 75%**. This is an approximate planning judgement, not a measured completion fraction or a probability that the theory is correct. [5,10]

Substantial work remains. The same foundation must determine the full particle masses, force strengths and the ways related particle states combine, and the results must survive comparison with experiment. Some of those steps may be among the hardest. Even so, developing a physical explanation far enough to produce connected, checkable calculations is a meaningful stage in an ambitious undertaking. The possibility being investigated is profound: that the Standard Model's apparently separate ingredients follow from a common underlying logic. [5]

1 What the Standard Model describes

Look at your hand. Its skin, bones and blood contain different molecules, but those molecules are arrangements of atoms. An atom has a small central nucleus and electrons associated with it. The nucleus contains protons and usually neutrons. Inside protons and neutrons are smaller constituents called quarks.

The Standard Model describes the elementary particles and how they interact. **Elementary** means that a particle has no smaller constituents within the theory. An electron is elementary; a proton is not, because it contains quarks. Here **interaction** means a way particles affect one another, such as attracting, repelling or changing into other particles. [11]

The word model can sound tentative. In this case it means a precise mathematical theory tested in an enormous range of experiments. Any deeper explanation must reproduce those successes.

The ingredients of matter

The everyday chemical world mainly uses electrons and two kinds of quark, named up and down. Nature also provides related particles, organised into three sets called **generations**, or families. Figure 1 shows the family pattern; there is no need to memorise the names. [11]

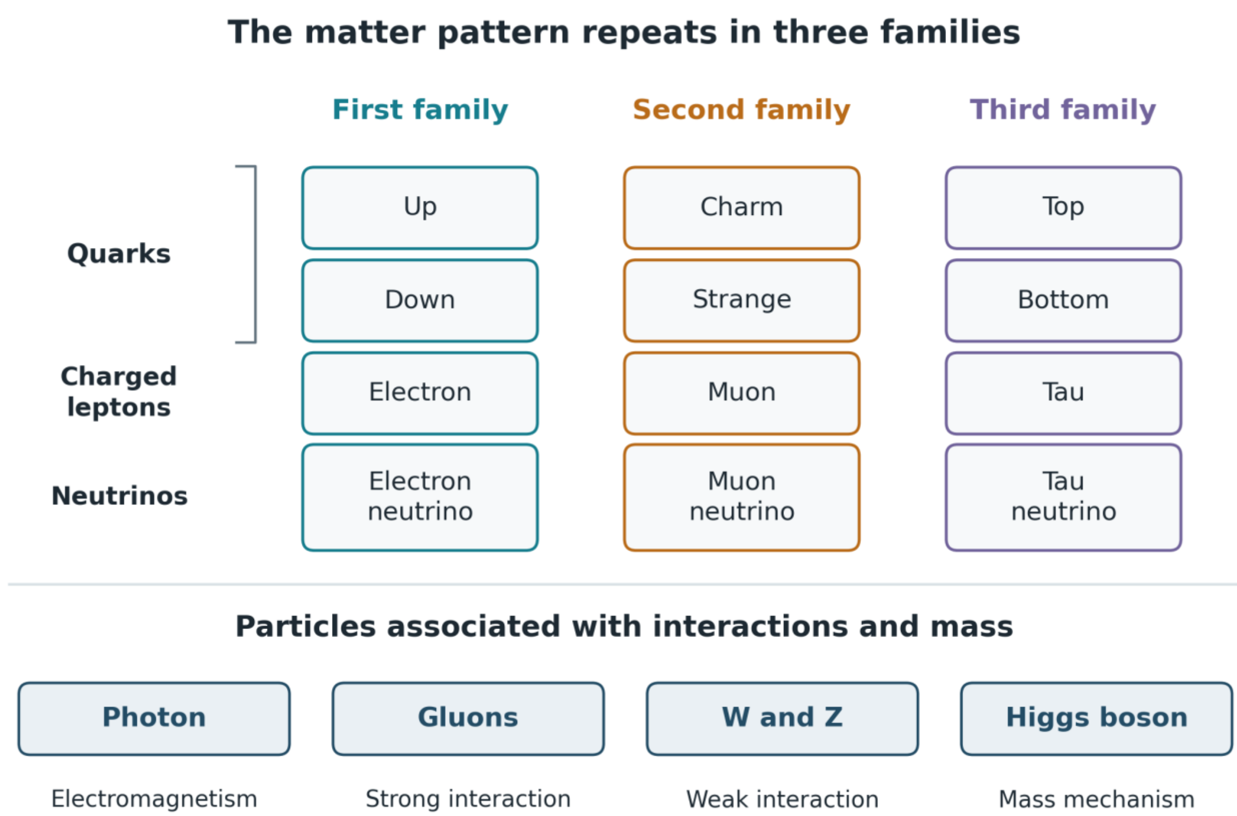

Figure 1. A map of the Standard Model. The columns show the three matter families. The lower row introduces particles associated with forces and the Higgs mechanism, explained below. Antimatter partners are not shown. This is a map of particle types, not a count of all the fields in the theory. [11–13]

Electrons, muons, taus and neutrinos are grouped under the name **leptons**. The three matter columns contain six types of quark and six types of lepton. Neutrinos have no electric charge and interact very weakly with ordinary matter. The neutrino labels tell us how they are produced and detected; their relationship to mass is explained later. [11,13]

Why there are these related families, and why their members have such different masses, are among the questions a deeper theory would need to answer.

What quantum means

Quantum physics describes atoms, light and the processes beneath everyday appearances. The word quantum refers to a discrete amount: light can be emitted or absorbed in individual packets called photons. These packets also show wave-like behaviour. [16]

Consider an experiment that sends electrons towards a screen. Each detected electron leaves one mark, but the theory generally gives the chances of a mark appearing in different places. Repeating the experiment many times reveals the pattern of those chances. [32]

To picture how waves affect the pattern, imagine two sets of ripples meeting on a pond. Where two raised parts meet, they can make a bigger rise. Where a raised part meets a hollow, they can partly or completely cancel. This strengthening and weakening is called interference.

Quantum calculations combine contributions in a similar wave-like way to work out the chances of different outcomes. The waves are not literal water: what changes is the likelihood of each recorded result. A quantum state is the description used to calculate those possibilities. Section 7 shows how this connects to an actual electron experiment. [32,34]

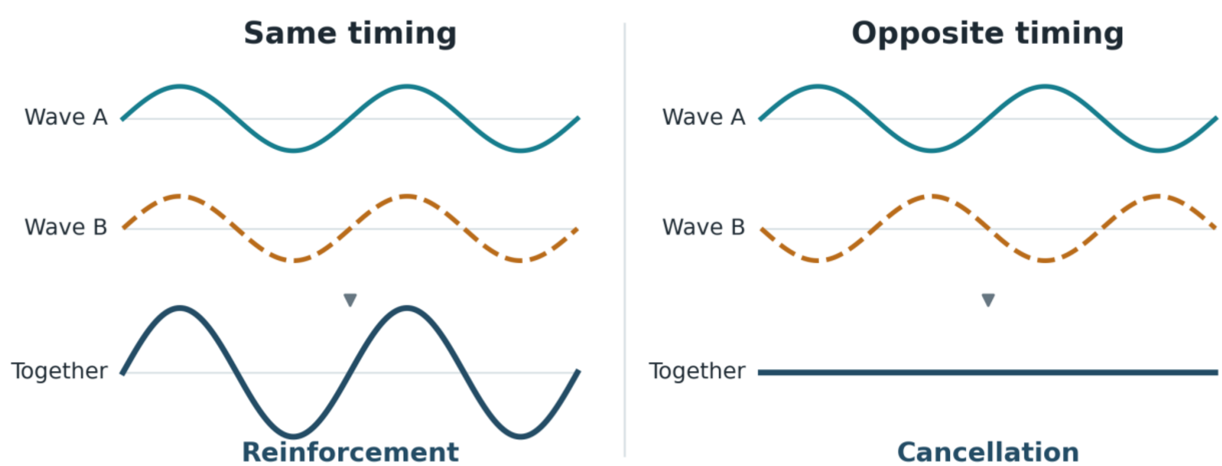

Figure 2. Why the timing of waves matters. When equal waves rise together, they reinforce one another. When one rises as the other falls, they cancel. These simple wave shapes build intuition; they are not a calculated neutrino signal. In quantum experiments, interference changes the chances of particular detection results. [32,34]

What a field means

To understand the particles, we need one more idea: a **field**. Think of the temperature in a room. Every position can have a temperature, whether or not a thermometer is there. A field similarly assigns a physical quantity throughout space.

In this quantum description, a particle is a particular kind of disturbance in a field. A ripple in a pond gives a useful picture: the ripple is something the water is doing. An electron is a disturbance of the electron field, and light consists of disturbances of the electromagnetic field. These fields are not literal fluids, but the analogy helps explain how a particle can be an activity of something that extends through space. [16]

There is a field description for each elementary particle type, rather than a new field for every individual particle. All electrons belong to the same electron field. An electron in your hand and one produced in a distant star have the same intrinsic mass and electric charge, although their locations and motions differ. The field descriptions can overlap in space and interact. [16]

The detailed mathematics includes linked components and mixtures, so counting boxes on a particle chart is not a precise count of independent fields. The useful starting picture is that the theory describes different particle types through fields and specifies how they affect one another. [15,16]

Light binding and changes of particle type

The Standard Model describes three fundamental interactions: electromagnetism, the strong interaction and the weak interaction. Gravity is outside it. The particles associated with these interactions are often called **force carriers**: a shorthand for how particles exchange energy and influence one another. [11]

Photons are packets of light. Sunlight reaches your eyes in photons. They belong to electromagnetism, which also accounts for electrical attraction and repulsion. The attraction between negatively charged electrons and positively charged nuclei helps hold atoms together. Light, electricity and magnetism are aspects of this same interaction. [11]

Gluons bind quarks into protons and neutrons. They carry the strong interaction. Their name suggests glue, although no sticky substance is involved. A remaining effect of the strong interaction also helps hold protons and neutrons together in atomic nuclei. [11]

W and Z particles carry the weak interaction. W particles allow certain changes of particle identity. For example, a neutron can become a proton and release other particles in one form of radioactivity. Z particles participate in encounters where, for example, a neutrino changes direction or transfers energy while remaining a neutrino. [27,28]

The Higgs boson helps us investigate the origin of elementary-particle mass. The Higgs field has a background present throughout space. Elementary particles that interact with this background acquire mass, which affects how hard it is to change their motion. The Higgs boson is a detectable disturbance of that field. Finding it provided evidence for this mass mechanism. [12]

The particle chart therefore brings together the ingredients of matter, the particles associated with their interactions, and the Higgs boson. VERSF's ambition is to explain why this whole arrangement arises.

2 How the theory grew over decades

The Standard Model developed through a long exchange between experiments and mathematical ideas. Some discoveries demanded new explanations. Some mathematical proposals predicted particles that experiments found much later.

Quantum mechanics and relativity supplied foundations in the early twentieth century. By the late 1940s, physicists had a successful quantum account of light and electrically charged matter. Feynman, Schwinger and Tomonaga made central contributions, with Dyson helping connect their approaches. The weak and strong interactions took further decades to bring into a coherent theory. [17,25]

Period	Milestone
1961 to 1968	Glashow, Weinberg and Salam developed a shared mathematical account of electromagnetism and the weak interaction. [17]
1964	Gell-Mann and Zweig proposed quarks. Brout and Englert, Higgs, and Guralnik, Hagen and Kibble developed the mass mechanism. [17,22]
Early 1970s	Physicists made the combined electromagnetic and weak theory calculable with controlled quantum corrections. The quark and gluon theory of the strong interaction took shape. [17,25]
1973 and 1983	An electrically neutral form of the weak interaction was observed, followed by discovery of the W and Z particles. [20]
1995	CDF and DZero at Fermilab discovered the top quark, completing the six-member quark family. [21]
2012	ATLAS and CMS at CERN discovered the Higgs boson, the last missing particle of the minimal Standard Model. [22]

In his 1979 Nobel lecture, Sheldon Glashow described the achievement with the words **“the patchwork quilt has become a tapestry.”** Previously separate ideas had become parts of one connected account. [18]

Steven Weinberg also explained its remaining limitation. Speaking to NOVA in 2003 about numbers in the theory, he said that **“they just have to be put in to make the theory fit the observation.”** He singled out particle masses among the quantities whose values the theory did not explain. These remarks concerned the Standard Model, not VERSF. [15]

The resulting theory does far more than catalogue discoveries. Its rules connect different experiments, so measurements made in one setting allow predictions in another. That success is the standard against which a deeper account must be judged.

3 The numbers we still have to supply

Think of a musical instrument. Knowing that it has vibrating strings does not tell you every note it will produce. The strings' lengths, masses and tensions matter too. A theory can likewise explain how a system works while still needing numerical settings.

Physicists call such settings **parameters**. The conventional count for the minimal Standard Model is **19 independent parameters**. In this count, neutrinos are treated as massless and gravity is excluded. The settings can be organised in different equivalent ways; the table uses one common choice. [19,26]

What needs a value	Number	What it describes
Quark masses	6	The masses of the six kinds of quark.
Charged lepton masses	3	The masses of the electron, muon and tau.
Higgs quantities	2	The Higgs boson mass and the size of the Higgs background.
Interaction strengths	3	Settings for the strong and combined electromagnetic and weak interactions.
Quark mixing	4	How quark types are connected through the weak interaction, including a matter–antimatter difference.
Strong interaction asymmetry	1	A possible effect involving matter, antimatter and mirror reflection, tightly limited by experiment.
Total	19	This count treats neutrinos as massless and excludes gravity.

How many masses are put in

For charged matter, the answer is **nine**: the six quark masses and the masses of the electron, muon and tau. The equations can instead express these through nine strengths of interaction with the Higgs background. Those strengths are called Yukawa couplings. Either way, their values must be supplied. [19,26]

Including the Higgs boson gives **ten independent particle-mass values** in the choice shown here. The size of the Higgs background is a further input. The W and Z masses are related to that background and the interaction strengths, so they are not two additional independent mass inputs. [19,26]

Real neutrinos require a further step. Experiments show that they cannot all be massless. A description with three light neutrinos adds three mass values and settings for how the neutrino states combine, called mixing. Section 10 explains that idea. The familiar count of 19 therefore does not include the full neutrino problem discussed in this paper. [13]

Finding the Higgs boson confirmed a mechanism through which elementary particles acquire mass. It did not explain why each particle interacts with the Higgs background by just the amount it does. To return to the instrument, discovering that strings produce notes does not determine each string's tension. [12]

These measured inputs do not make the Standard Model an arbitrary fit to every experiment. The same settings must work across many different processes. The deeper question is whether the settings themselves can follow from more basic physical rules.

4 What it would mean to derive the answer

Imagine receiving a guitar with its tuning pegs concealed. You listen to its notes, measure them and work out the string tensions. You now have a useful account of that instrument.

Now imagine that you could start with the instrument's construction and explain why it must have those tensions and notes. This is closer to what VERSF is trying to do with particles. It seeks rules that determine their properties before their measured values are used to choose the answer.

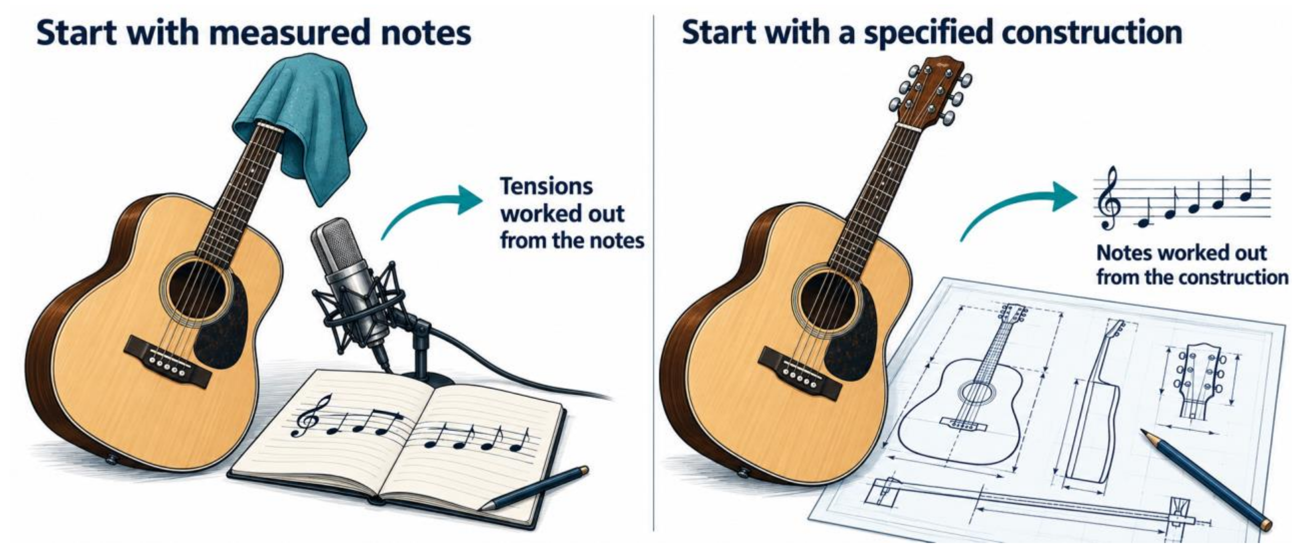

Figure 3. Working backwards and working forwards. On the left, observed notes help us infer hidden string tensions. On the right, specified construction, string properties and tensions let physical rules determine the notes. VERSF seeks the further step: explaining why the corresponding particle properties and numerical settings follow from its own foundations.

A simple mathematical example shows what deriving a number means. Every square has four equal sides, so its perimeter is four times its side length. The number four follows from the structure of a square. We did not adjust it to fit a collection of measurements.

But applying that result to an object still requires showing that the object really is a square. VERSF faces the same two tasks: calculate what follows from a proposed structure, and establish that its physical rules select that structure.

This distinction explains what a conditional result means. If a garden is square and each side is ten metres long, its perimeter must be forty metres. The arithmetic is settled; whether the garden really has that shape still needs checking. Some VERSF results are at this stage: the calculation works if the proposed physical assumptions are right.

A candidate prediction is a proposed answer ready to be checked, with some of its basis still unfinished. These descriptions concern what has been established so far. A separate question is whether the measured answer was already known when the calculation was developed. Section 11 uses a weather example to explain why that matters.

5 The starting assumptions of VERSF

VERSF stands for **Void Energy-Regulated Space Framework**. It begins with a question about physical facts: what must be possible for one outcome to differ from another, and for that difference to leave a lasting record?

The assumptions below are the foundations used in this account. Some define the framework's terms; others make claims about how nature works. The technical papers also state extra conditions for particular calculations. Mathematics can show what follows from these conditions, but comparison with nature must establish whether they are the right ones.

A physical difference must be distinguishable

Distinguishability means that two physical alternatives differ in a way some physical process could register. Imagine two settings on a machine. If switching between them could never affect any result or record, writing different labels on the settings would not create an additional observable difference. [1,23]

This does not require a person to watch. A detector can record an event in an empty room. Nor can changing our description change the event itself: calling a detector channel A instead of B does not alter what happened.

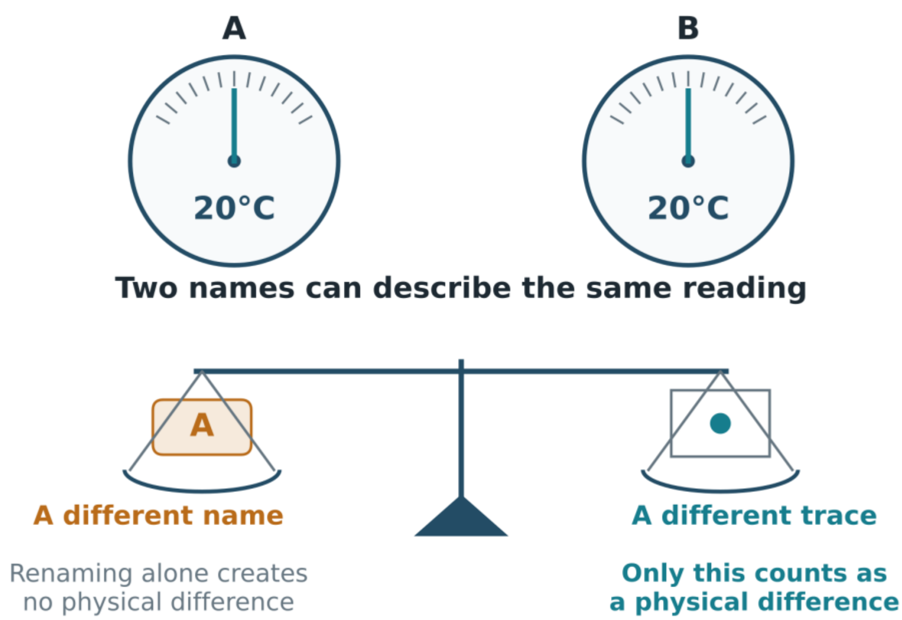

Figure 4. A new name or a new physical fact. The letters represent alternative names for the same reading. Renaming adds no new measured fact. In VERSF, a physical difference must be capable of leaving a different trace, such as a click or a mark. The scales compare ideas; they are not a weighing experiment. [1,23]

Consider a bead beside a mark on a table. One description says it stays still. Another says it moves at an extraordinarily small, nonzero speed. If its movement and every other effect of that movement are too small to resolve during the observation, that observation cannot distinguish the two descriptions, even though the equations do.

This captures the intuition behind comparing rest with "infinitely slow" motion. A small nonzero motion may, however, become detectable if we wait longer or use a more sensitive test. VERSF's stronger requirement concerns a difference that **could never affect any allowed physical record**, rather than one our present experiment happens to miss. [1,23]

Only some possibilities are admissible

Admissible means allowed under the physical rules being used. A chess rook may move along a row or column, but it cannot make a knight's move. The rule identifies the available moves without deciding which move happens next. Physical admissibility plays a similar logical role; it requires no player or conscious choice.

VERSF assumes that a bounded physical system has a finite capacity for genuinely distinguishable alternatives. A mathematical dial can be assigned endlessly many decimal settings. That does not mean a physical device can support unlimited distinguishable settings. The restriction is a premise of the framework. It does not by itself determine which settings exist or their probabilities. [23]

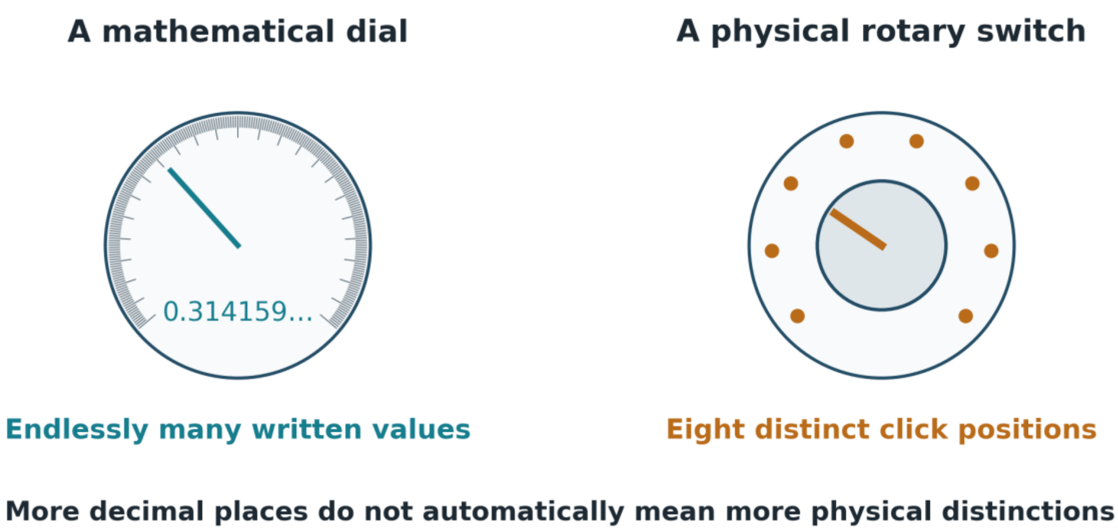

Figure 5. Written settings and physical alternatives. Mathematics can specify endlessly many dial values. This switch offers eight distinct click positions. It illustrates VERSF's finite-capacity premise; it does not prove that every physical dial is fundamentally a stepped switch. The question is how many alternatives a system can physically distinguish. [23]

Three examples make the exclusions concrete. **Giving the same physical state two names** does not create two distinguishable states. **Claiming unlimited distinguishable information in a bounded system** violates the finite-capacity premise. And **allowing a new fact to remove every trace of an earlier committed distinction** violates the requirement that the underlying record persist. Erasing a note on an ordinary device is different: copies or physical traces may remain elsewhere. [1,23]

An inadmissible outcome is one that conflicts with a stated rule. It does not simply mean something unlikely, unfamiliar or beyond the reach of today's instruments.

Facts must leave records that can accumulate

In VERSF, a **Fact** is an outcome that has become physically settled. **Commitment** is its becoming settled, and a **record** is the retained physical trace. These words describe physical processes, not decisions by a mind.

The framework requires committed distinctions to survive subsequent allowed developments. Records must also be capable of combining into meaningful joint records and remaining distinct enough to count and relate. A notebook that loses its entire history whenever a new sentence is written could not do this job. Neither could one that became unusable after its first entry. [1]

Figure 6. Records must remain usable as they accumulate. The first notebook loses its history. The second accepts no further entries. The third retains earlier entries, accepts new ones and keeps them distinct enough to compare and count. These are the record-keeping requirements illustrated by the analogy. [1]

The information paper makes an additional assumption: resolving a yes-or-no alternative into a fact has a minimum physical cost. Its particular cost rule is a stated premise, not a general claim that every measurement must release the same amount of heat. The model separately describes changes that can be reversed between commitments. [23]

The Void supports possibilities and retained facts

The **Void** is VERSF's name for the underlying capacity from which physical distinctions can become actual. It is not ordinary empty space, which already has fields and physical properties.

VERSF assigns two roles to this underlying foundation: allowing new outcomes to become settled and supporting the continued existence of records. A notebook offers an analogy because it must accept a new inscription and retain an old one. Treating both roles as aspects of one foundation is a further VERSF commitment. It is not established simply by defining distinguishability. [1]

A finite interface beneath the world we experience

A television picture looks smooth from the sofa, but up close it resolves into separate pixels. A solid object looks continuous, but it is built from atoms. These familiar examples show how an apparently seamless whole can arise from separate units. They provide an intuitive starting point for VERSF's proposal about the underlying structure of the physical world.

VERSF takes the view that the universe need not contain unnecessary physical detail. Its finite-capacity assumption says that a bounded physical system supports only a finite number of distinguishable alternatives. An endlessly divisible mathematical description need not correspond to endlessly many physical distinctions. Pixels and atoms illustrate this reasoning; they do not by themselves prove that space and time form a grid. [1,23]

An interface is where two descriptions meet. In VERSF, it connects unresolved possibilities with settled, recorded physical events. The proposed interface is two-dimensional: its basic relationships are organised as on a surface. Two coordinates locate a point on the surface of a globe; a third is needed to locate a point throughout its volume. This two-dimensional organisation is part of the proposed physical foundation. [2,24]

A hologram helps us picture how a surface pattern can encode relationships that produce a three-dimensional image. VERSF proposes that the three-dimensional world similarly arises from the interface's underlying relationships. Its calculations must recover real distances, motion and interactions. The interface is the proposed foundation of space, rather than an ordinary sheet sitting inside an already existing room. [2,5]

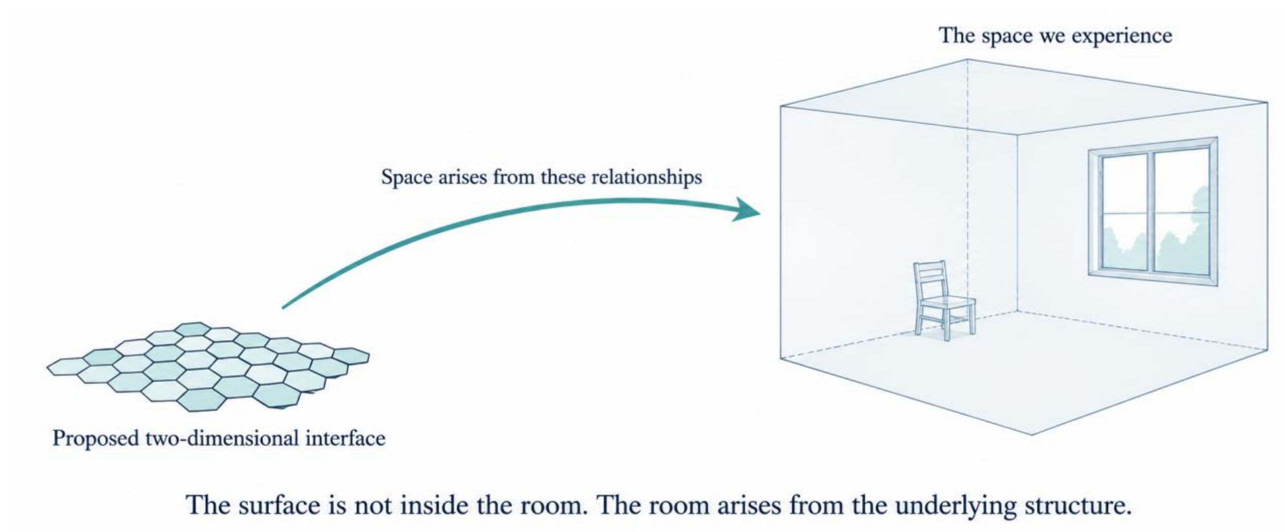

Figure 7. A proposed foundation for space. The detached pattern represents the proposed interface; the room represents the space we experience. The arrow shows an explanatory relationship, not a projector or light beam. The surface is not a floor or a sheet inside the room: VERSF proposes that spatial relationships arise from the underlying structure. [2,5,24]

Why hexagons enter the picture

Suppose we divide a flat surface into cells of equal area and want the least total boundary between them. Regular hexagons provide that arrangement. Like the cells of a honeycomb, they fit together without gaps and use less boundary than a tiling by squares or equilateral triangles of the same area. This is a proved mathematical result, known as the honeycomb theorem. [29]

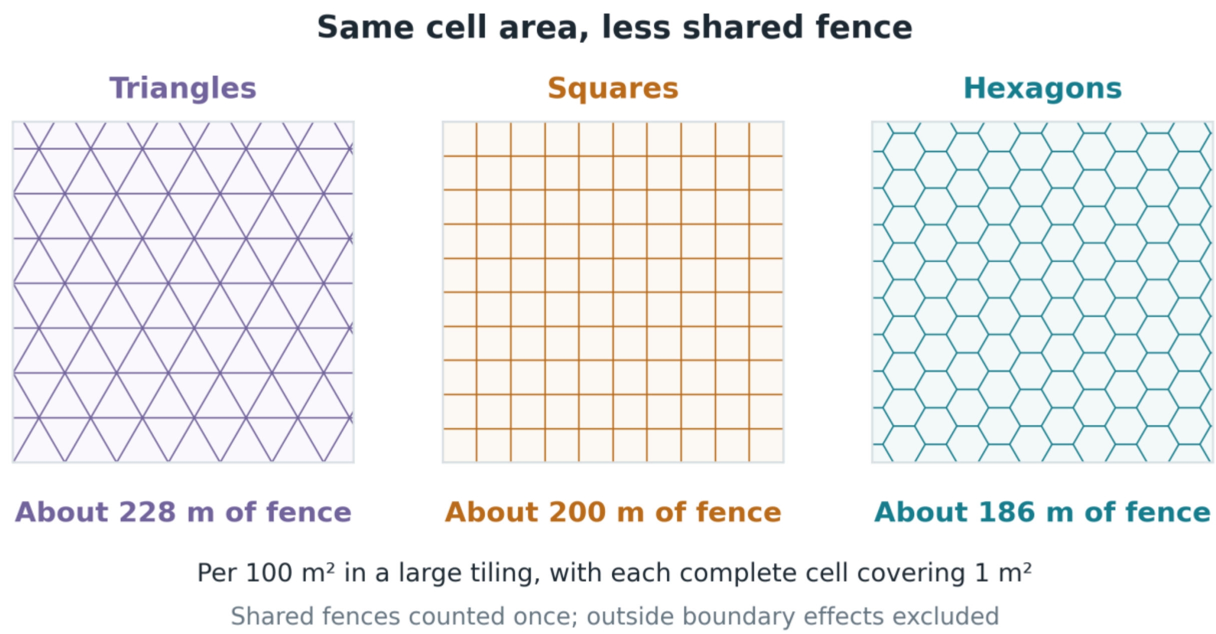

Figure 8. Same area and equal-sized cells need different amounts of fence. The three windows show equal areas of regular tilings with one-square-metre cells. The numbers give shared fence per 100 square metres in a large tiling: half the perimeter of one cell, multiplied by 100. Outside boundary effects are excluded. Hexagons minimise boundary under the conditions described in the text. [29]

The hexagonal interface picture applies this idea of economy to VERSF's finite physical distinctions. If boundaries carry the same cost per unit length, using less boundary also reduces that cost. In this sense, hexagons offer an efficient organisation for the proposed interface. The physical rules must establish why equal areas and this boundary cost are the appropriate conditions; discreteness alone does not select a cell shape.

This gives "most efficient" a precise meaning that can be examined. The honeycomb result concerns a flat surface; curvature or different physical costs can change the answer. The research question is whether VERSF's physical principles select the proposed organisation and, through its behaviour, determine the particles and forces of the Standard Model. [29]

The interface calculations also specify a finite capacity to pass information, ways of transporting records that can be reversed, and the removal of labels that add no physical distinction. They assign a scale to one bit, the information needed to distinguish two alternatives such as yes and no. These conditions form part of the calculations connecting the physical picture to numerical results. [24]

All the parts must share one physical foundation

VERSF adds a **single-source requirement**: the calculations for particles, forces and records must describe compatible parts of one underlying physical system. This is an additional condition, rather than a result already obtained from distinguishability alone. [1]

The framework also rejects hidden extra distinctions. The smallest physical distinction cannot secretly contain further unrecorded differences that are then counted as separate physical facts. This premise has a direct role in the current neutrino calculation. [10]

These commitments do not yet provide every rule of quantum physics. The information paper separately assumes rules for combining independent systems and grouping alternatives. Additional mathematical structure is needed to describe their quantum evolution. Particular calculations must also supply rules for motion, physical scales and connections between components. The starting assumptions constrain the task; they do not complete it. [23]

6 Folds and the emergence of space and time

VERSF calls its minimal physical structure for a committed distinction a **Fold**. The name suggests a crease that changes what a sheet can do. It is an image of structure becoming established, not a literal claim that ordinary paper or already existing space is being folded.

The distinction, the event that establishes it and the record it leaves have different roles. Think of a notebook: there is the capacity to hold a mark, the act of making it and the mark that remains. VERSF needs an account of all three. [1,2]

Folds can make space without making particles

In VERSF, a fold does not automatically make a particle. What we might call “regular” folds contribute to the underlying network of recorded distinctions. Their relationships provide the proposed basis for space itself: what is next to what, and how distance arises. Even a region containing no matter particles can have this underlying structure. [2,35]

A matter particle requires something more: folds organised into a closed, bounded pattern that retains its identity. “Closed” means that the connections complete a persistent arrangement. “Bounded” means that this organisation forms an identifiable part of the wider structure. Such a pattern is called a closure. A loop drawn in a diagram is not enough: the arrangement must survive the changes allowed by the framework. [35]

Imagine a woven fabric with a knot tied in it. The fabric exists across a wide area; the knot is a particular organisation within it. The knot is made from the same threads, but their arrangement gives it an identity of its own. In the VERSF picture, regular folds play the role of the fabric, while a particle closure plays the role of the knot. The analogy distinguishes the underlying structure from a persistent feature within it.

The proposed distinction is therefore between folds contributing to space and closed, bounded arrangements giving matter its particle identities. It does not require a different substance for each.

The next section asks how the permitted arrangements could become the particular particles we observe. [35]

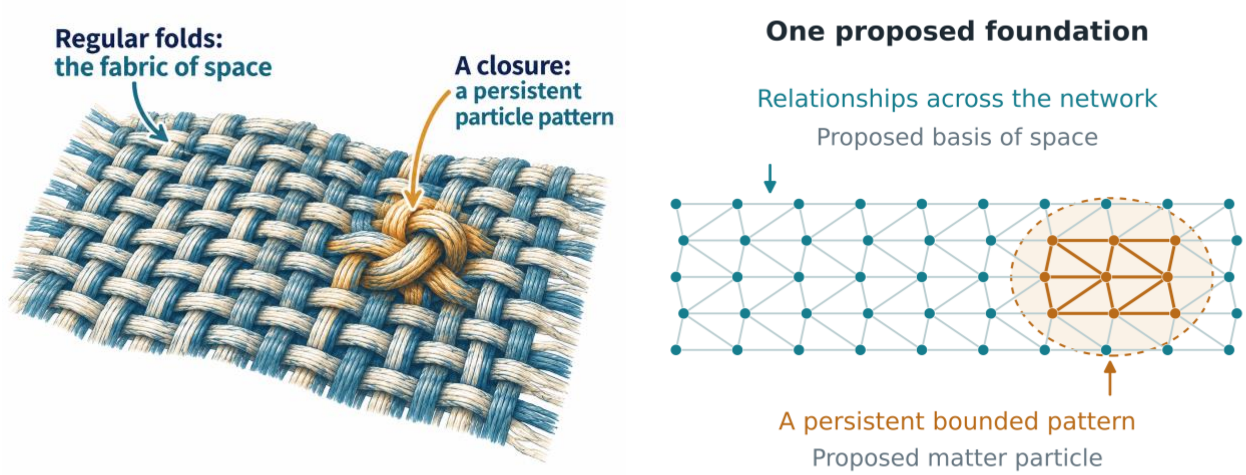

Figure 9. Fabric and knot beside the proposed fold relationships. The cloth offers the everyday picture: the knot is an organisation of the same threads. The network expresses the proposed distinction more carefully: relationships contribute to space, while a persistent bounded arrangement could have a particle identity. Neither drawing specifies a literal shape or a fixed fold count; persistence must follow from the physical rules. [2,35]

How folds contribute to time

The accumulation and ordering of commitment events provide VERSF's proposed basis for **time**. Instead of beginning with a universal clock already ticking, VERSF seeks to build time from relationships between changes and the records they leave.

A flip book helps explain this. An ordered sequence of pages can represent a changing scene. Counting pages tells us their order, but not the number of seconds between events. VERSF has calculated local connections between event opportunities and physical time under specified conditions; establishing a common physical scale remains part of the work. [5,8]

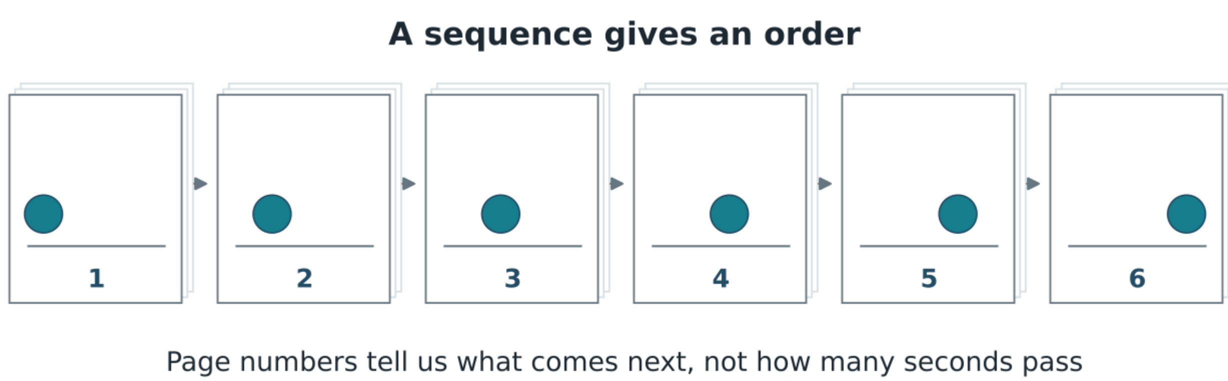

Figure 10. Order without seconds. The pages put changes in sequence, but their numbers do not tell us how long a step lasts. VERSF has to supply that connection to measured seconds. The analogy does not imply one universal page-turning clock for the whole universe. [5,8]

The analogy does not imply that the whole universe turns one page simultaneously, or that motion is unreal. It illustrates how an ordered history might support change. The theory must recover the timing and motion that actual observers measure.

We can now see the next question. If the foundation consists of physical distinctions and their relationships, how could those relationships produce the stable things we call particles?

7 From reliable records to particle patterns

Requirements about records can restrict the possible underlying structures. Consider an instrument: requiring its parts to hold together, transmit vibrations and continue functioning rules out many designs. Once the parts and their permitted connections are specified, such requirements can have precise mathematical consequences.

Within its stated mathematical conditions, VERSF identifies a minimal **seven-part structure**, often written K equals 7. Seven counts parts of this construction. It is not a count of particles or spatial dimensions. Further work connects the primitive Fold to the larger structure under specified attachment assumptions. Why the physical system must supply those assumptions remains a question to resolve. [1,6]

Here is a simple way structure can produce a number. One yes-or-no label allows two choices. Two independent labels allow four combinations. With seven such labels, repeated doubling gives **128 combinations**. This counting does not itself make all combinations equally probable or turn a probability into a force. Those links need additional physical rules. [4,5]

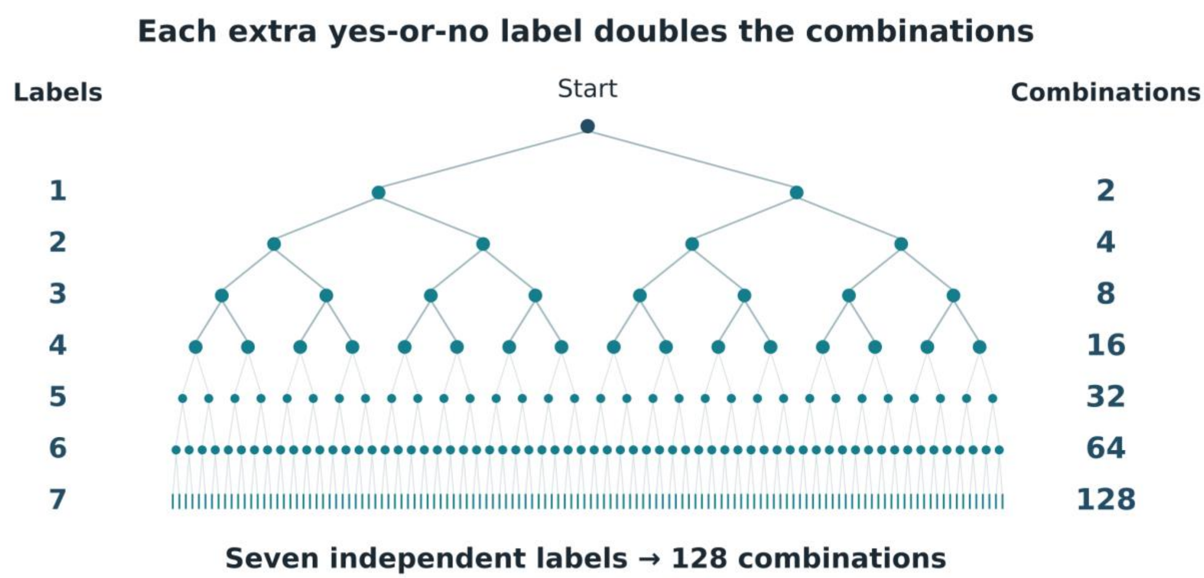

Figure 11. Seven independent yes-or-no labels give 128 combinations. Each new label splits every existing possibility into two. The final row compresses the 128 possibilities into a strip. Counting them does not make them equally likely: assigning a probability of one in 128 requires an additional rule. Section 8 shows where that factor enters the force example. [4,5]

To picture how a particle pattern can persist, consider a whirlpool. It can remain recognisable while the water passing through it changes. Its identity lies in a persistent pattern. VERSF proposes that matter particles similarly maintain their identities through the organisation of their closed, bounded fold structures. [3,35]

Figure 12. A recognisable pattern with changing contents. Water passes through while the whirlpool's organisation remains recognisable. The analogy helps picture a particle identity maintained through ongoing activity. In VERSF, the proposed fold pattern must also have the particle's measured properties and survive the changes allowed by the theory. [3,35]

Persistence is only the first requirement. An electron pattern must also have the electron's electric charge, mass and ways of interacting. A quark pattern must have the different properties appropriate to a quark. VERSF contains mathematical constructions for aspects of this organisation and tests of whether the patterns survive allowed changes. It still has to establish why its foundation produces the complete observed list of particles. [5,6]

Ordinary quantum field theory already treats particles as disturbances of fields. VERSF's proposed advance is to explain why the required fields and patterns exist, and why their properties have their particular values. A picture of a persistent pattern helps us imagine the goal; the calculations must identify which patterns nature permits.

Many folds and one observed particle

Does one Fold make one particle? The closure picture describes a matter particle as an organised pattern of many folds. The earlier paper From Paths to Folds also explores how many folds can contribute to one particle's quantum state. Think of a wave: many parts of the water participate in one recognisable pattern. The collective state belongs to one particle, even though many folds contribute. [31,35]

A primitive Fold is the smallest structure capable of carrying a committed physical distinction. That does not require every particle to consist of just one Fold. Nor does it prevent several folds from supporting a shared range of possibilities. The rule against hidden extra distinctions inside one primitive Fold still applies. [10,31]

Before a particular outcome is committed, the model allows different joint arrangements of the participating folds. Their contributions can reinforce or cancel one another. This is the proposed connection to superposition: several alternatives contribute together to one quantum state. They are not treated as little switches whose answers are already secretly fixed. [31,34]

Calling the particle pattern closed and bounded does not mean assigning it one exact position at every moment. Its internal organisation and its possible locations are different questions. The many-fold account must still explain the spread of possibilities and the interference described below. [31,35]

How this connects to what experiments show

Imagine sending electrons one at a time through an arrangement offering two routes to a detector. Each detected electron leaves one small mark. After many repetitions, the marks build up bands with many hits and bands with few. This interference pattern has been observed even when there is at most one electron in the apparatus at a time. [32]

Overlapping water ripples help us picture the bands. Where two crests meet, they reinforce each other; where a crest meets a trough, they can cancel. In the electron experiment, the interference changes the chance of a mark appearing at each position. A single mark does not draw the whole pattern. Many repeated detections reveal it. [32,34]

The many-fold proposal gives a possible physical reading of these observations. Its alternatives belong to the shared fold structure supporting one particle. The folds contribute to the overall chances of different outcomes; they are not being counted as additional electrons. The distinction between the observations and their proposed explanation is: [31–34]

What experiments show	The proposed VERSF connection
One local mark for each detected electron.	A detection records an outcome of the collective particle state. It does not count each contributing Fold separately.
Many individual marks build an interference pattern.	Alternative joint fold arrangements contribute to the chances of detection, reinforcing some outcomes and suppressing others.
Recording which route was taken reduces the interference.	An interaction makes the alternatives distinguishable through information in the detector or surroundings. Their interference in the observed pattern is suppressed.

A route detector changes the experiment by physically interacting with the electron. The interference becomes weaker as the routes become more distinguishable, and can disappear when they are fully distinguished. Nobody has to read the detector for that interaction to matter. This loss of observable interference is called decoherence. [33,34]

VERSF describes an outcome becoming settled and leaving a lasting physical record as commitment. A detector mark is such a record at the laboratory scale; producing and storing it may involve many underlying events. Explaining why interference fades and explaining why one particular result is recorded are distinct tasks. The many-fold picture must account for both, including how often the different results occur. [1,31,34]

What this tells us about the number of folds

The picture allows many folds to support one particle's state, but it does not yet supply a fixed number of primitive Folds for an electron or a muon. Counting the folds included in a region of the calculation is not automatically the same as counting permanent constituents of a particle. Likewise, the muon's greater mass in the later worked example is not obtained by assigning it 207 times as many folds. [30,31]

The experiments already agree with ordinary quantum theory. VERSF is seeking a deeper physical account of the shared possibilities, their interference and the records they produce. To establish that account, the same physical model must reproduce the measured patterns and outcome frequencies. The observations show what the explanation has to achieve; they do not by themselves demonstrate that folds exist. [31–34]

8 How the proposal connects to forces

A particle's identity includes how it responds to its surroundings. To explain an electron, for example, VERSF must explain its electrical and weak interactions, while preserving the fact that it does not participate in the strong interaction.

The closure paper makes a further distinction here. Matter particles are described as persistent fold arrangements; force carriers, such as photons, are described as travelling changes in the fold network. The proposal therefore does not require every entry in the particle chart to be the same kind of closed structure. [35]

The force calculations examine how the model's connections and flows respond to disturbances. They also compare what happens when a particle pattern is carried along different routes. In field physics, differences between such routes can contain information about an interaction. VERSF seeks to obtain those comparisons from its own underlying relationships. [5,7]

Some comparisons must preserve wave timing. Think of two sounds arriving together: their waves may reinforce one another or partly cancel depending on how they line up. The tested VERSF construction retains the corresponding information and produces responses in all the required force directions. [7]

There is a further question: **how strong is the response?** Two strings may vibrate in similar patterns but require different forces to stretch them. Describing the possible response does not determine its physical strength. VERSF must calculate the energy associated with changes, using rules supplied by the same underlying theory.

The programme now has methods that work backwards from specified rules of motion to differences in stored energy. It also has calculations that follow a sequence of recorded impulses and motion between them. These are concrete parts of the explanation. The physical choice of the motion rules and their numerical scale still needs to be established. [7,8]

A number connected with electromagnetism

One proposed answer discussed in the programme's progress review combines the seven-part counting structure with a calculation of what the interface transmits. Under their stated assumptions, these supply factors of one in 128 and fourteen fifteenths. Their product is seven divided by 960. [4,5]

Turning that fraction over gives approximately **137.143**. The corresponding low-energy number used to describe electromagnetic strength is about **137.036** in that review's comparison. The two are close, but closeness alone does not establish a physical derivation.

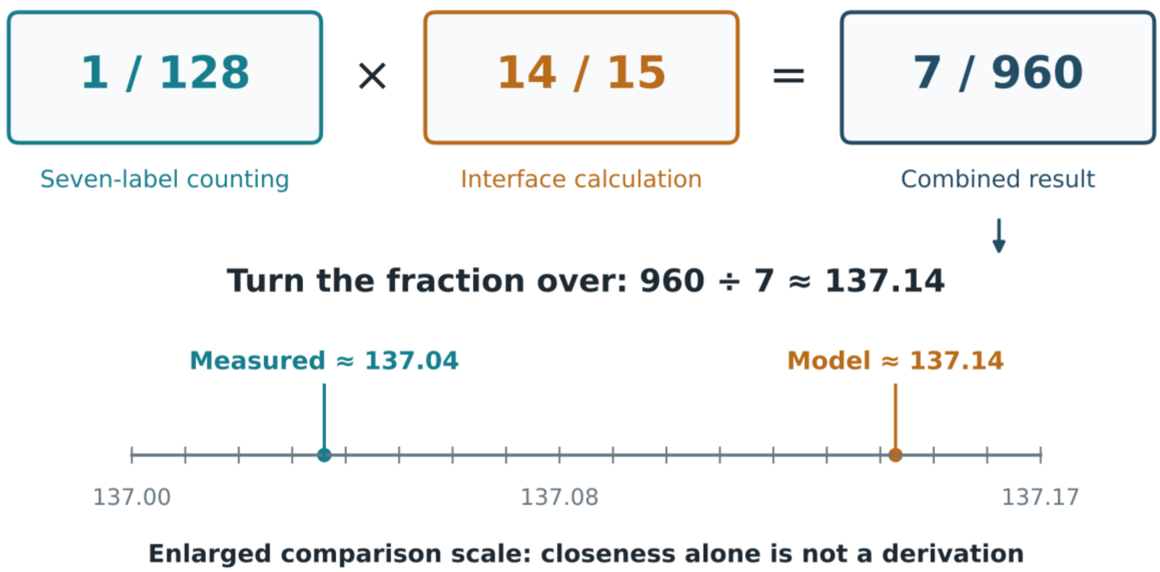

Figure 13. Where the electromagnetic number comes from. The two reported factors multiply to seven divided by 960; turning that fraction over gives about 137.14. The ruler enlarges its separation from the review's measured comparison, rounded here to 137.04. Closeness is not a derivation: the physical assumptions producing both factors and their connection to electromagnetism still need justification. [4,5]

The remaining step is to show that the actual interface has the assumed transmission properties and that the calculated quantity becomes the measured interaction strength. This example shows both how a number can arise from the construction and why its connection to the laboratory matters.

9 Where mass enters the explanation

Mass is often described as heaviness. Here, its useful role is resistance to a change of motion. An empty shopping trolley and a loaded one respond differently to the same push.

In the Standard Model, interaction with the Higgs background gives elementary particles mass. It should not be imagined as sticky syrup slowing them down. It changes their response to forces without acting as ordinary friction. [12]

VERSF's proposal can again be pictured through an instrument. Its construction permits certain patterns of vibration. A shared background helps set their overall scale, while the way each pattern connects to that background affects its relative mass. The task is to calculate those connections from the common physical rules.

For the Higgs itself, VERSF identifies a shared change in linked quantities that can behave like an oscillation. To determine its physical mass, the calculation needs both the energy cost of disturbing the pattern and the rule governing its motion. Knowing a string's tension alone would not determine its vibration rate; its other physical properties matter too. [4,5]

One structural result gives the Higgs mass, relative to the common Higgs background scale, as **32 divided by 63**, or about **0.50794**. The progress review places this about **0.05 per cent** from its measurement-based comparison. The result still depends on assumptions: the conversion to a complete laboratory mass prediction, including the required quantum effects, is still unfinished. [5]

The Higgs also does not account for all everyday mass simply by adding up particle masses. Most of a proton's mass comes from the energy of the strong interaction within it. A full account of the matter in your hand therefore needs the strong interaction as well as the Higgs mechanism. [14]

A worked example of why the muon is heavier than the electron

An electron is one of the particles found in atoms. A muon is a heavier relative with the same electric charge. Its mass is about 207 times greater. The Standard Model uses measured values for these masses. VERSF asks whether a shared physical rule can explain their relationship. Here is how one proposed calculation works. [5,30]

1 Start with two related patterns. VERSF proposes that a particle is a pattern that can maintain its identity as physical activity continues. For the pattern to last, it must obey the theory's rules about what can physically persist. The electron–muon calculation adds a specific proposal: the two particles are related patterns, with the muon pattern concentrated into a smaller region. [30, §11]

Think of a drawing reduced on a photocopier. Its arrangement stays recognisable even though it occupies less space. In the VERSF model, related particle patterns follow the same reduction rule. This compares two kinds of particle; it does not describe squeezing an actual electron into a muon.

2 Work out how much smaller the pattern becomes. Shape and arrangement can place limits on what something can do. The arrangement of a tent's poles, for example, limits the shapes the tent can hold. In this calculation, VERSF uses the proposed internal arrangement of the particle pattern to obtain a proposed reduction in size. Under the stated assumptions, the next pattern is about 14.4 times smaller across. [30, §11]

The number 14.4 is the rounded result of that technical calculation. The paper reports that measured particle masses were not used to obtain it. One important step remains: establishing that the calculated property of the internal arrangement really determines how tightly the physical pattern is concentrated. [30, §§11,18]

3 Connect that smaller size to mass. First, picture a drawing reduced to half its width and half its height. Four copies of the smaller drawing would cover the original: two across and two down. So the smaller drawing occupies one quarter of the original area.

The mass rule used in this VERSF model says that a pattern occupying one quarter of the area has four times the mass, provided its other energy contribution stays the same. The drawing helps us picture the change in area; the connection to mass is a physical rule of the model. [30, §11.2]

Now apply the reduction of about 14.4 in each direction. Multiplying 14.4 by 14.4 gives roughly 207. Using the paper's unrounded numbers, the resulting mass factor is 207.127. That is how the proposed change in the pattern's size becomes a definite comparison between the muon and electron. [30, §§11,18]

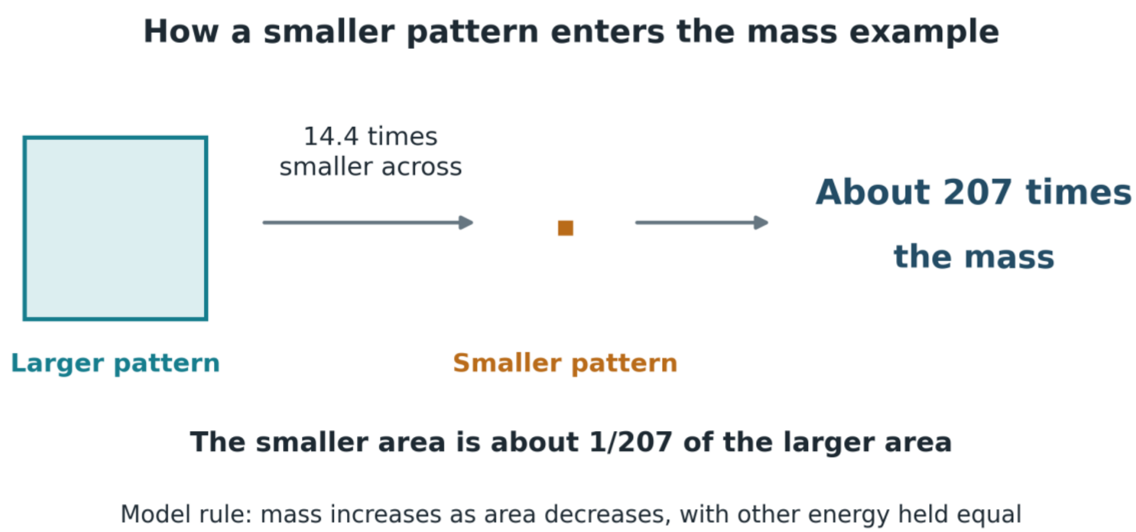

Figure 14. From a change in size to a mass comparison. The squares help us compare areas; they are not pictures of particles. Reducing both width and height by about 14.4 reduces the area by about 207. Under the model's stated assumptions, its mass rule then gives about 207 times the mass. [30, §11]

4 Compare with measurement. If we count the electron's mass as one unit, the comparison is: [5,30]

Comparison	Muon mass in electron units
VERSF calculation under the stated assumptions	207.127
Measured value used in the progress review	206.768

The calculated result is about 0.17 per cent higher. That is close enough to encourage further work, but the difference still needs to be explained. This comparison concerns how many times heavier one particle is; it does not yet determine either particle's mass on its own.

What remains to be established

The calculation addresses a mass relationship already known from experiments. Its physical explanation still needs completing. In particular, VERSF must justify the proposed amount of shrinkage. The simple calculation also treats another contribution to the patterns' energy as equal; the detailed model finds nearly equal values. A complete comparison must account for those differences and for the effects of interactions when connecting the model to laboratory measurements. [5,30]

The encouraging step is that the model connects a proposed physical structure to a number we can check. If that connection can be completed and withstands testing, the muon's greater mass would follow from the same underlying rules as the electron's. We would then have an explanation for a relationship that currently has to be supplied from measurement.

10 Why nature has particle families

The electron, muon and tau are relatives: they share some basic properties but have very different masses. The quarks and neutrinos also come in families. Why does nature repeat these patterns, and why are there three generations?

VERSF explores whether the same underlying Fold structure can produce related particles in a regular way. Think of one musical instrument producing several notes. The instrument provides a shared explanation for the notes, even though they sound different. VERSF has proposed rules linking the generations, but still needs to show why those rules produce exactly the families we observe. [9,10]

Two ways to describe the same neutrino

Neutrinos have two sets of labels. Electron neutrino, muon neutrino and tau neutrino describe how a neutrino is produced or detected, through its connection to an electron, muon or tau. Physicists call this its flavour; the word has nothing to do with taste. A different set of labels, usually just 1, 2 and 3, identifies the three quantum states with definite masses. [13,37]

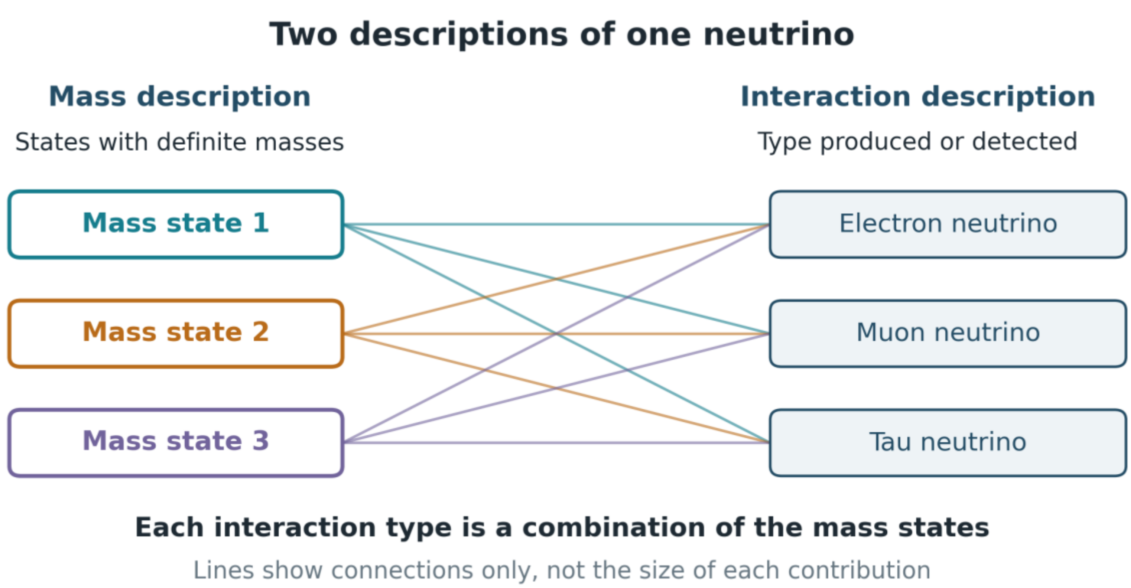

Figure 15. Two sets of labels for the same particle. Each interaction type combines contributions from all three mass states. These are two descriptions of one neutrino, not three smaller particles inside it. The lines show the known mixing relationship, not the sizes of the contributions or a VERSF calculation of them. [13,37]

These are two ways of describing the same neutrino, but the labels do not match one for one. An electron neutrino is not simply the neutrino with one particular mass. Its quantum state combines contributions from all three mass states. This describes one particle, not three smaller particles inside it. [37]

A chord makes the relationship easier to picture. We can name the whole chord, or describe the individual notes contributing to its sound. Similarly, a neutrino's interaction type corresponds to a particular combination of its mass contributions. Mixing is the relationship between those combinations and the individual mass states. [13]

Why the detected type can change

Now imagine two playground swings moving together. If one takes slightly longer to complete each swing, they gradually fall out of step: eventually one is moving forwards while the other moves backwards. Nothing needs to change the length of either swing for their timing relative to one another to change. Physicists use the word phase for where something has reached in a repeating cycle.

The neutrino's mass contributions have a comparable difference in their wave timing as they travel. Recall the pond ripples: changing how the rises and falls line up changes how they reinforce or cancel. For a neutrino, this changes the chances of detecting each interaction type. [13]

A neutrino made as an electron neutrino can therefore later be detected as a muon or tau neutrino. The definite masses themselves have not changed; the combined state has evolved. This observed change in detection probabilities is called neutrino oscillation. VERSF needs to explain both the masses and how they combine. [13]

VERSF has calculated an example of neutrino mixing under specified assumptions. The task is to obtain both masses and mixing from the same physical explanation. Quarks have related mixing relationships that also remain to be fully explained. [4,5,9]

A common origin for the families

The newer Universal Flavour Geometry paper takes a further step. Under its stated assumptions, the different groups of matter particles inherit their family patterns from one shared underlying structure. This links questions that otherwise look like separate puzzles. [36]

One engine driving several machines through different gearboxes offers an analogy. The engine is shared, while the connections produce different outputs. In VERSF, the shared structure would play the role of the engine. The ways each particle group connects to it would help determine their different masses and mixing.

The paper calculates a first numerical proposal for that shared structure. This gives the proposal something definite to build on. The next step is to establish that the physical rules require both this structure and the connections to the particles. Those connections cannot simply be chosen to give the desired answers. A complete calculation of the masses and mixing together remains to be done. [36]

11 What the neutrino result tells us

The neutrino calculation gives a concrete example of the kind of result VERSF is trying to obtain. Under its assumptions, it gives the three mass states described in Section 10 a pattern: two quite similar masses and a third about twice the lightest. It does not yet determine the actual size of those masses. [10]

Imagine being told that two parcels weigh almost the same and a third weighs about twice as much. You have learned a relationship, but you still need a set of scales to know their weights in grams. The VERSF result supplies that sort of relationship for neutrino masses.

Experiments provide a way to test the pattern by measuring a particular relationship between the masses. The calculated value is about five per cent below the measured value used for comparison in the paper. That is close enough to make the comparison interesting, but it does not yet establish agreement: a small difference can matter when measurements are precise. [10]

What still needs to be checked

One important assumption needs a clearer physical justification. Calling the same object by different names should not change what it does. The neutrino calculation goes further by replacing several mathematical descriptions with an average before working out the response. That extra averaging rule does not follow from a change of labels alone. The paper identifies it as an assumption still to be justified. [10]

The paper reports no direct adjustment of its numerical settings to fit neutrino measurements. However, those measurements were already known while the model was being developed. Why does that distinction matter? [10]

Why knowing the answer changes the test

Suppose a weather forecaster reads that ten millimetres of rain fell yesterday. They adjust their model until it produces ten millimetres, then announce that it has "predicted" yesterday's rain. The match shows that the model can reproduce that result. It does not yet tell us whether the method will work when the answer is unknown.

Explaining an already known result is often called a postdiction. It need not involve adjusting the model to fit: a theory may explain an old observation from well-supported physical rules, which can be a substantial achievement. The caution is that a known answer can influence which assumptions or methods are chosen, even without anyone deliberately tuning a number.

For a stronger test, the forecaster fixes the method, writes down tomorrow's forecast and then checks what happens. They could also test it on past days whose rainfall records have been kept hidden from them. That is the idea of a blind test here: settle the calculation before revealing the answer. Repeated success on unseen cases gives us more reason to trust the method. One correct forecast alone would not prove it.

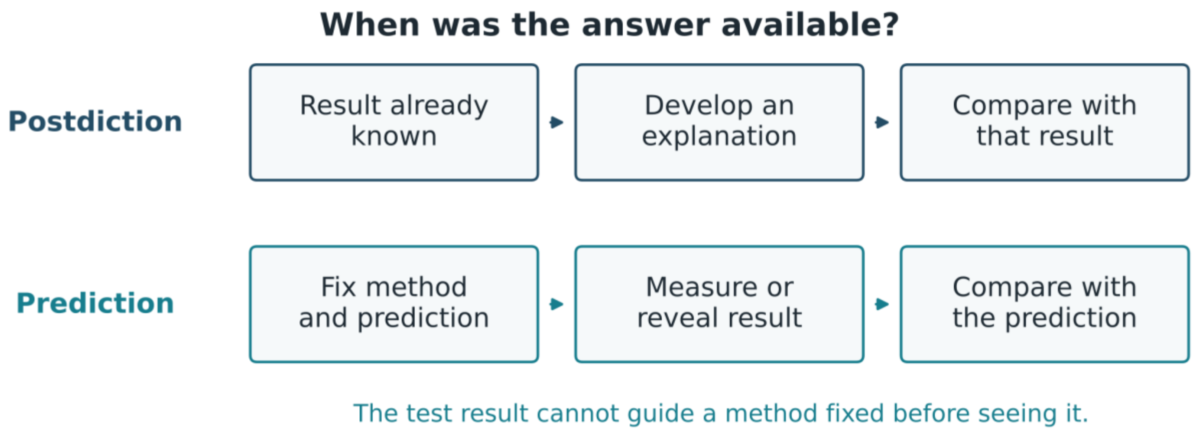

Figure 16. Explaining a known result and testing an unseen one. A known result can support a physical explanation without having been fitted. Fixing the method before seeing the test result gives a more independent check: the answer cannot guide the choices used to obtain it.

The neutrino result currently helps test whether VERSF can explain a measured relationship. Its value depends on whether the physical rules justify the choices that produced it. A further result tested against data that did not guide those choices would provide stronger evidence. Some details of the present calculation also need to be recovered and checked so that another researcher can repeat it. [10]

The encouraging advance is that the proposal now produces a definite mass pattern that can be challenged and tested. To turn it into a complete prediction, VERSF must justify the remaining assumptions, supply the full calculation, determine the actual masses and explain the mixing as well. The newer common-origin paper carries this neutrino result forward; it does not provide a second independent confirmation. [10,36]

12 What holds the centres of atoms together

Protons and neutrons contain quarks. The strong interaction binds those quarks together and also holds protons and neutrons in atomic nuclei. A complete VERSF derivation must explain how strong this interaction is and why quarks remain bound. The cited work contains calculations of parts of the proposed explanation; the full account remains unfinished. [3–5]

There is also a puzzle about matter and antimatter. Antimatter particles are partners of familiar particles: for example, the electron's partner has the same mass but the opposite electric charge. Physicists can compare a process with a version in which matter is replaced by antimatter and the arrangement is reflected as in a mirror.

For the strong interaction, the Standard Model allows a numerical setting that could make those versions behave differently. Experiments show that this setting must be extremely small. Why should nature choose a value so close to zero?

In the VERSF calculation included in the progress review, the corresponding setting comes out exactly zero because of the proposed structure. That offers a possible reason for its smallness. Further calculations must show that the result survives the effects of quantum physics and remains compatible with the differences between matter and antimatter already observed in the weak interaction. [4,5]

13 What has been achieved and what comes next

VERSF has reached the stage where parts of its physical explanation produce definite calculations. That is a meaningful advance towards its larger goal: explaining why nature has the ingredients listed in the Standard Model. The remaining question is whether the same underlying rules determine the whole observed pattern. [5,10,36]

Question	What VERSF has so far	What still needs to follow
Why these particles and forces?	A proposed physical picture, with calculations of parts of it.	The complete particle list and measured force strengths from the same rules.
Why these masses?	Worked examples and a neutrino mass pattern, under stated assumptions.	All masses, including their actual size, from physically justified assumptions.
Why families and mixing?	A first calculated proposal for a common origin of the particle families.	The observed families and mixing, explained together with the masses.
What would complete the derivation?	Several parts can now be calculated and tested.	One connected account that matches observations and can be checked independently.

The results have to work together, like a guitar whose strings and body belong to one design. VERSF must obtain the particle masses and their behaviour from one consistent physical account.

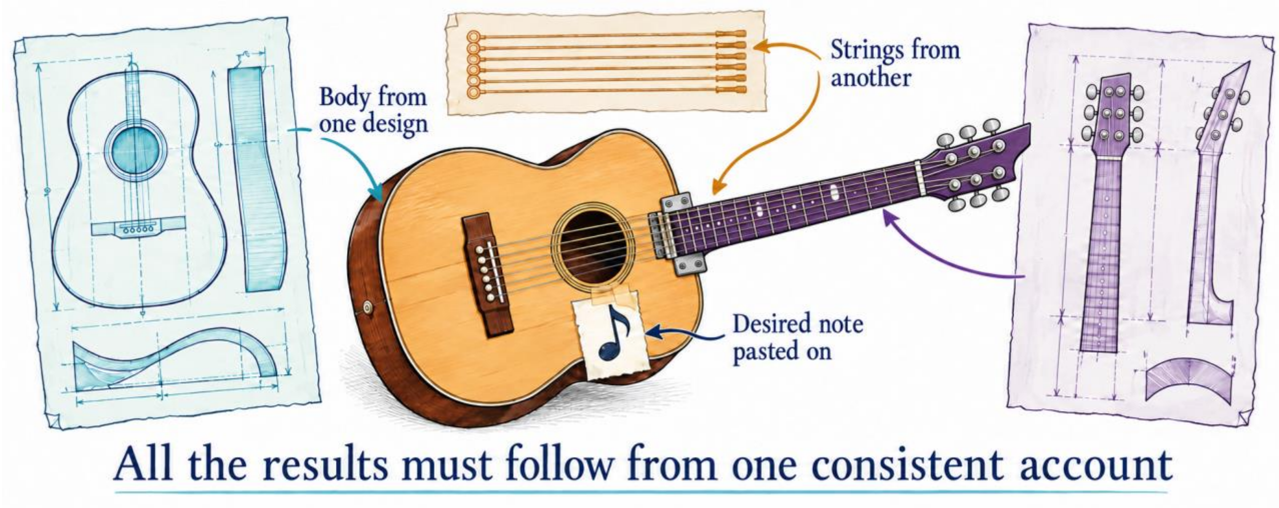

Figure 17. The parts must belong to one consistent account. Pasting a desired note onto a guitar does not explain its sound. Likewise, choosing separate assumptions to obtain each desired particle result would not complete the derivation. VERSF must show how the different parts and their connections follow together from the same physical foundation. [5–10]

That account must work under the different conditions tested in experiments. Other researchers must be able to repeat the calculations, with every measured input identified. Disagreement with observation requires revising the claim. [5–10]

VERSF now offers a proposed common explanation with calculable parts. Completing it would show why many numbers currently supplied from measurements follow from shared physical rules. That possibility gives the work its significance.

A short glossary

Admissibility Whether an outcome or structure is allowed by the stated physical rules.

Bit The information needed to distinguish between two alternatives, such as yes and no.

Blind test A test in which the method and calculated answer are fixed before the comparison data are revealed.

Candidate prediction A proposed answer offered for testing while some of its physical basis is still being established.

Closure In VERSF, a closed, bounded arrangement of folds proposed to give a matter particle its persistent identity.

Coherence The relationship between quantum wave contributions that allows them to strengthen or weaken one another.

Commitment In VERSF, an outcome becoming physically settled and leaving a retained distinction.

Conditional result A calculation that is correct if its stated assumptions hold; those assumptions may still need checking.

Decoherence The loss of visible interference as a quantum system interacts with its surroundings.

Distinguishability A difference that some physical process could register.

Field A physical quantity defined throughout space; in quantum physics, particles are disturbances of fields.

Fold VERSF's proposed minimal physical structure for a committed distinction. Folds can contribute to space without forming a particle closure.

Generation One of the three related families of matter particles.

Interface In VERSF, the proposed surface-like organisation where possibilities become recorded physical structure.

Mass A property that determines an object's resistance to a change of motion.

Mixing How the states with definite masses combine to give the neutrino types produced or detected in interactions.

Parameter A numerical setting needed before a theory can make particular predictions.

Postdiction An explanation of a result already known when the theory or calculation was developed.

Quantum The physical rules behind packets such as photons and the wave-like combination of possible outcomes.

Record A retained physical trace of an outcome; no conscious observer is required.

Superposition Several alternatives contributing together to one quantum state, so that they can reinforce or cancel one another.

Void VERSF's proposed underlying capacity for physical distinctions to become actual and records to persist.

Sources and scope

This paper explains the current proposal and selected results in the supplied VERSF papers. It is not a new technical proof. Numerical comparisons use the measured values used for comparison in those papers. Analogies illustrate the ideas; they do not establish the physical assumptions. The programme's September progress review, the revised neutrino paper and Universal Flavour Geometry Revision 3 determine the status described here. The references below provide the technical details for readers who want to follow them.

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