Temporal extension of particles to interpret and intuitively describe quantum symmetries and related quantum and relativistic phenomena

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Abstract. The paper proposes the theory of temporal extension for fundamental particles as a key to intuitively interpret and understand quantum symmetries and related quantum and relativistic phenomena. While space-time as a principal world view is accepted and utilized in fundamental theories, certain traditional concepts of time have not been challenged before. Such a conception is the view that physical objects can only have a point like feature on the time line. When introducing a more space like quality of time, which allows the temporal extension for physical objects and particles, a fundamentally new world view arises. In this view quantum symmetries and certain relativistic phenomena become more intuitive to describe and deal with and “realism” gets a new definition. As a result the temporal length theory also offers to eliminate the tension between the nonlocality of quantum physics and the locality of relativistic phenomena. The paper provides a detailed description of the theory.

1. Introduction
Intuitivity is not a primary requirement for mainstream theories in Physics, meaning, they do not require an intuitive picture and some even explicitly state to ignore such understanding, like in case of the Copenhagen interpretation of quantum physics. It has lead to the famous objections of great Physicists, but did not stop the trend that intuitivity is regarded secondary to mathematical correctness or even to mathematical “beauty”. In light of this fact it is ironic how important intuitivity is considered by some mathematicians. While the major theories do not require an intuitive view, many believe that to develop further from the present status quo in modern physics, it will require fundamentally new understanding and correspondingly new intuitive views of the world.

This paper suggests an alternative for such fundamentally new intuitive world view. It is proposed here that certain observations in QM and Special Relativity point to the intuitive idea of temporal extension of physical objects and fundamental particles. These observations include formulations for quantum symmetries, such as the interpretations of Boost matrices in Lorentz group and similarly in Special relativity the Lorentz factor. In simple words, instead of a point like feature on the time line objects could have a temporal length like a moving train has a length on the train track. The main motivation of this paper when proposing the idea of temporal extension is the hope to provide an inspiration to experts on the field, by throwing light on a new perspective of quantum symmetries and

1 University of Pécs celebrates its 650th anniversary in 2017: http://www.jubileum.pte.hu/index.php
related quantum and relativistic phenomena. The temporal length idea has recently inspired a numerical technique for coupled numerical simulations by the author [1] who wishes to share his thoughts with the Physics community. The mathematical formulation of this numerical analysis might also serve as a recommendation on how to treat new physical models with temporal extension.

In the followings the paper explains the “Obvious Consequences” of temporal extension, as the “simple view” of the theory. This is followed by the “Emerging consequences” of temporal extension, with its corresponding complexity. The theory and its consequences are shortly discussed for: Quantum Symmetries, Special relativity, the Double slit experiment, the Heisenberg uncertainty principle, Bell’s theorem, and potentially provide an intuitive, classical mechanical Spin analogy.

It is also hoped that the paper will inspire a “ping-pong” of thoughts between theoretical physicists and the developers of numerical methods for electromagnetic field computation, when considering suitable mathematical models for the modeling of temporal length either as a physical reality or just as a simulation technique.

The paper is concluded with a summary and a proposal for a roadmap to validate this idea.

2. The intuitive picture of the world and the lack of it.
As it was mentioned in the introduction, mainstream Physics theories do not aim to provide an intuitive picture of the world. Some of these intuitively hard to comprehend but closely connected theories include:

- Wave Particle duality: The Double slit experiment
- Heisenberg Uncertainty principle and the Probability wave function
- Bell’s Theorem

and in some level:
- Special relativity

Those “trained in the art” often summarize the greatest challenge in comprehending these ideas as the fight between the views of: “Locality” vs. “Non-locality” and the existence of “Realism” and “Local Realism”. Many believe that the need for a new understanding emerges from the present status quo and the corresponding efforts include String theory, E8 theory, and other TOE candidates.

It is inspiring that even some of the inventors of these theories strived to provide an intuitive picture as the quotes from Bob Samples and John Steward Bell demonstrate:

“Albert Einstein called the intuitive or metaphoric mind a sacred gift. He added that the rational mind was a faithful servant. It is paradoxical that in the context of modern life we have begun to worship the servant and defile the divine.”
Bob Samples, 1976

“…continue to inspire those who suspect that what is proved by the impossibility proofs is lack of imagination.”
John Stewart Bell

3. Observations in QM and Special Relativity pointing to temporal extension.
The following observations hint, that temporal extension of physical objects and particles might well be a physical reality:

1. Space-Time is a generally accepted concept which suggests that Space and Time cannot be separated.
2. Symmetries in QM are defined for both spatial and temporal coordinates.
3. Special and General relativity shows ”strong coupling” between space and time. (e.g.: Lorentz factor)
4. Quantum space time - quantized time (and space) theories [2,3,4,5] (Could it mean extension in time?) Figure 1.
5. Particles in QM must occupy several spatial coordinates at the same time. (Probability wave function, Schrödinger, Bell Theorem, Copenhagen interpretation)

Contemplating the above facts, one can wonder, why not to allow an extension in time the same way as we experience in spatial directions?

3.1. Formulations in Quantum Symmetries and Special Relativity pointing to temporal extension.
Contrary to pure rotations which transform spatial coordinates into each other in space time, Boost matrices in Lorentz group describe a transformation of temporal coordinates to spatial and vice versa to describe transformations between frames with relative velocity (1).

The Boost transformation would allow – and could also be interpreted as – a transformation of spatial extensions in a certain dimension into temporal length and back between moving frames. Such interpretation also points to the possibility of temporal extension of physical objects.

3.2. Special relativity in Euclidian space time.
Introducing a temporal length of an object and an observer, allows the definition of "perpendicularity" / orthogonality in a space time plane. Even when sticking with a simple Euclidian Space-Time a curious observation can be made. As a consequence of perpendicularity an ordinary wave could be defined to have the same speed in a “space- time aether” relative to observers moving at different speeds as presented in Figure 2.
3.3. *An alternative meaning of the Lorentz factor in Special relativity, in Euclidian space time.*

If the observer and the observed both have temporal length, an intuitive meaning for the Lorentz factor can be derived with simple geometrical assumptions in Euclidian space-time. Similarly some of the hard to comprehend ideas of special relativity and the Lorentz term can be self explanatory when the temporal length of the observers and observed objects – not only point like features on the time line – is admitted. In this model, two boats are travelling parallel with a speed of “c” on Lake Balaton. Suddenly one of the captains sets his boat on a collision course at a speed of “v” towards the other boat. If the total speed of each boat remains equal and constant c, the parallel distance traveled by the boats associated with the “virtual passing of time”, t’ can be computed from one boat’s perspective of the other. Independently from which boat is used as reference Fig.2 shows that the ratio of the perceived passing of time becomes the Lorenz factor.

![Figure 2. An intuitive picture of special relativity and constant speed of light orthogonally to the observers who are moving at relative speeds to each other.](image)

4. **Basic and Emerging Consequences of Temporal length**

The consequences of temporal length of particles and physical objects can be grouped as “obvious consequences” and “emerging consequences”.

The obvious consequences of temporal length of particles and physical objects can be listed as follows:

1. Particles become 4D physical objects with corresponding 4D symmetries. (SO(4))
2. A particle can actually occupy several spatial locations along its temporal length
3. Particles can interact with each other along their temporal length
4. Quantum symmetries get new intuitive meaning, considering one more "space like" dimension in 4D.

The emerging consequences which can be seen from the symmetry perspective:

1. Local realism gets a whole new meaning: by the spatial distribution along temporal length.
2. The tension between the non-locality of quantum physics and the locality of relativistic phenomena could be reduced / eliminated, together with the re-definition of “Realism”.
3. 4D Rotation along planes including the temporal axis keeps temporal symmetry unchanged
4. 4D Rotation along planes including only spatial axes might interchange temporal extension into spatial and vice versa
5. "Coupling” between space and time gets a new intuitive meaning
6. Rotation along temporal axis, or more correctly in mathematical terms: along a spatio-temporal plane is a ‘new’ property. (Or could it actually be related to spin?)
7. “Real 4D cross section” exists intuitively for advanced theories. (E8)

5. The intuitive implications of temporal extension on hard to comprehend theories
We can state that the introduction of temporal length brings new intuitive perspective to interpret not so intuitively explainable phenomena. The following phenomena will be discussed in detail:

1. Quantum symmetries
2. Special relativity
3. Wave particle duality: the Double slit experiment
4. Heisenberg uncertainty principle, Realism and Locality
5. Bell’s theorem

5.1. Quantum symmetry and an intuitive perspective: temporal extension.
In light of temporal extension, while “Pure Rotations” transfer length along spatial dimensions “Boost Matrices” in Lorentz group can be seen as transforming spatial extensions to temporal length and vice versa between observation frames. In Lorentz group, Boost matrices could be interpreted as representing temporal extensions mixed into a spatial ones and back.

As demonstrated by the boat example an alternative explanation from Euclidian space can be created by utilizing temporal length to demonstrate certain aspects of the well known “Minkowski topology” consequences:

- Direct correlation to 4D rotations (SO(4)):
- New intuitive meaning of the “time like” dimension
- Spatial and temporal extensions might interchange and intuitively mix up for moving observers.

An intuitive explanation for “Realism” is defined by the spatial multi location along the temporal length. A “quasi - hidden variable” model arises as the spatial distribution along the temporal length characterizes the particle, but when interacting with it, with another 4D object in a measurement, such topology remains “quasi-hidden” from a “3D classical mechanical” point of view.

The symmetry of a particle along rotations about temporal-spatial planes gives an intuitive view for new theories, e.g.: intuitive view of spin. Previously there has been another intuitive view of spin described in [6], where a hyper sphere rolling along the world line of a particle is proposed. However, contrary to that proposal where the use of “world line” for the location of a particle limits its spatio temporal location in one instant, a little more complex picture is proposed in this paper. Consisting of “actual” 4D geometries in all “instants” due to temporal length of particles, does not restrict the particles location in one “instant” of time to a point on the world line, like it is proposed in [6].
The spatial distribution along temporal length offers alternatives for new intuitive ways to view quantum symmetries, e.g.: "hyper" objects such as hyper sphere, 4D spirals, 4D strings, etc.

5.2. Special relativity and temporal extension
As it was explained above in the boat example, calculating the relative passing of time, gave the Lorentz factor as a result. Next to the advantage of getting an intuitive picture introduced by the "temporal length" there is a good chance that with a proper choice and tuning of the following parameters in the Euclidian space time model:
- Speed of "boats"
- Speed of waves in the "space time aether"
- Geometrical surface of the "lake"
we could match special relativistic and maybe even general relativistic predictions. If this would fail there is an alternative to extend the temporal length theory to other, more complex non-Euclidian space time geometries.

5.3. Wave Particle Duality: the Double slit experiment and temporal length.
The new local realism with the possibility of several spatial locations along the temporal extension we can ask the question: How one 4D particle could be perceived as a wave and how it can interact with two slits in 4D? The spatial distribution along the temporal length allows an intuitive perspective to perceive wave like properties of a particle – for example – if it rotates along its temporal extension.
The possibility of temporal length opens a multitude of possibilities for physical interactions between the 4D particle and the 4D pair of slits. The interference picture explained as the interference of probabilistic wave functions can be the result of a complex mechanics resulting from the interactions of two 4D objects.

![Figure 4](image)

A demonstration device in Heureka Science Center in Helsinki, Finland. A straight object flying through a “curved” hole in a plastic sheet in swiping a 3D surface.

A macro world phenomenon in 3D giving an intuitive hint of such “multi-dimensional” interaction is presented in Heureka Science Center in Helsinki. A straight “1D” object flying through a curved “2D” hole by a rotation swiping a “3D” surface in space.

5.4. Heisenberg uncertainty principle and the probability wave function
The uncertainty when determining a single spatial location and momentum of a particle in a “moment of time” can be translated to an uncertainty of interaction with the spatiotemporal distribution / volume
of the given particle with the temporal length theory. Position and momentum are considered as complementary according to the Heisenberg principle. If particles and physical objects would have temporal length, their “location” and “momentum” would be associated with an interaction with another 4D particle in a measurement, which would have consequences on “Realism”.

The so-called “measurement problem” in quantum mechanics – whether and how the wave function collapses – could also be intuitively represented by the temporal length theory. The measurement – when interacting with the particle at a spatial location along its temporal extension – would directly correlate with the collapse of the wave function to “one” location. This could be very complex, imagining two rotating 4D spirals colliding with one another or the case of two hyper spheres.

The role of the “momentum” associated with the uncertainty principle hints that temporal length of particles might also be related to the mass of particles.

5.5. Bell’s inequality and temporal length

Bell’s theorem has been considered by Henry Stapp as the most profound discovery of science and it unifies the major statements about the nature of quantum physics. However as it was quoted before, John Stewart Bell stated his hope as: “… continue to inspire those who suspect that what is proved by the impossibility proofs is lack of imagination.” The theory of “temporal length” of particles could well be a theory providing a new perspective as Bell hoped for. The main question is:

What is the consequence on Bell’s theorem and on Realism if the “hidden variable” represented by the spatio-temporal distribution of the particle is actually equivalent with the probability wave function predictions? How the change of definition for Realism affects the measurement?

There have been attempts to re-evaluate the effect of time on the Bell theorem but they were debated or have been fairly complicated. The spatial distribution along the temporal length elegantly creates a “quasi-local” spatial distribution in the time extension and provides a new alternative for the explanation of the outcome of the measurements due to the new “Quasi-Realism”.

If the particle’s spatial distribution along its temporal length is equivalent to the probability wave function, the Bell inequality could simply be a proof of that shape and corresponding consequences – like spin due to rotation along temporal length as explained above – without further consequences for super luminal speeds of communication between pairs of entangled particles. This interpretation could help to resolve the great divide between the locality and nonlocality perspectives by simply giving an intuitive picture for the hard to comprehend spatial distribution of a single particle along its temporal length and translating Bell inequalities as a consequence of that fact.

There is one more somewhat intuitive picture, which arises from temporal length for the Bell theorem, that the entangled particles could actually be connected along their temporal length. Although such theory might be similarly hard to comprehend as the original Bell statement.

6. A Numerical method inspired by the temporal length idea from QM.

In 2013 at the Computmag 2013 conference in Budapest a numerical technique has been presented [1], based on increased “temporal length” of numerical sub-domain and component models, to handle computational challenges which are typical in engineering for “multiphysics” and system simulation problems. The computational challenges include numerical oscillations when the coupling / interfacing technique between different domains and subsystems is not adequate or not easy to select in advance.

General methods to keep the interaction models in electromagnetic system and multi-physics simulations physically meaningful and correct, within required accuracy, are of great interest.

The paper suggested the introduction of “temporal length” for sub-domain and component models, which reach and “comb” through several time steps at once. These enable new advanced monitoring, error estimation, convergence verification, relaxation and interaction modeling techniques where many consecutive time steps can interact. The temporal length as a simulation technique has been inspired by some thoughts on modern physics.

Figure 5. shows a schematic model of the typical formulation in the time stepping analysis of coupled problems [7, 8, 9, 10]. Traditionally only two consecutive time steps are linked in the
formulation to model time derivatives. The figure represents how different domains affect each other in such formulations.

![Figure 5](image)

**Figure 5.** Schematic picture of the traditional view of interaction in coupled problems between domains. Only consecutive time steps affect each other. “Virtual temporal length” of the model: 2 time steps.

It is important to notice that in many cases in electromagnetic field computation – like in eddy current problems and hysteresis modeling – the affecting time step from the past is not only the one before the present, but a “history of the system” affects as well. This does not mean that the formulation must include the values of variables from previous time steps directly, because such history can be carried on in the energy of the computed fields and/or by hysteresis models which also carry the information about such “historical” data.

Introducing longer than 2 time step temporal length can improve monitoring, control and even the formulation of the solution process. As an example numerical oscillations are typically visible when observing at least three or more consecutive time steps. In a 3 time step temporal length model the second derivative of the time function is available momentarily and could warn of numerical oscillations like those which are typical in multi-conductor eddy current problem with Crank-Nicolson time stepping method [11, 12].

Oscillations and divergent solutions can also be caused by unwisely/unluckily calibrated coupling techniques typical in indirect coupling. A schematic picture of a four time step long model is presented in Fig. 6.

![Figure 6](image)

**Figure 6.** A schematic picture of a 4 time step long model. Only the effects of the time step “-3” are indicated, with arrows, but other time steps can have similar effects. The model with temporal length acts as a “comb” with “4 teeth” smoothing the time functions on the fly, removing oscillations.
Fig. 6. hints that the time steps before the present can affect each other and the value of a variable “in
the past” can change within the temporal length of the model. When “past time steps” are affected also
by the preceding steps, the formulation is like in (2), with a 3 time step temporal length model. Here
An and Bn are the traditional system matrices and an and bn are variable vectors of sub domains
and/or components in the n-th time step toward the past. The n>1 An and Bn matrices could be unit
matrices in some formulations. The C matrices represent the coupling between the domains and the T
matrices represent the coupling between different time steps along the temporal length. If the
formulation requires that future time steps must affect, and suitably “comb” the past time steps to
shape, than the zero matrices in (2) would also be replaced by corresponding T coupling matrices. If
the past time steps only affect the present time step, the formulation is like in (1) but TAA23, TBC23,
TAC23, TBB23 are 0 matrices.

7. Summary & Proposal for validation
Temporal length of particles and all physical objects is hinted by existing theories including
formulations in quantum symmetries and relativity. Wedding QM and Relativity has proven to be a
significant challenge and the temporal length of particles seems to promise a way forward. 4D objects
and their interaction in space-time might not be that easily intuitive as those in 3D but would offer an
alternative to reduce the tension between “locality” and “non-locality” by redefining “Realism”.

The temporal length theory can have a couple of strange but verifiable predictions depending on
what space time geometry is selected. Supposing Euclidian Space-Time, the temporal length suggests
that antiparticles could potentially be actually travelling backward in time – as represented in Feynman
diagrams – because the temporal length could provide an “interface” for particles travelling in
different directions in space time to interact. The strange prediction is that in a particle accelerator we
could be able to observe anti-particles which instead of flying out from the location of a collision
should be flying inwards before it happens. This strange prediction however, might not hold if the
supposed space time geometry is not Euclidian.

Another prediction is related to neutrino research. As it was stated in the discussion of the
Heisenberg uncertainty principle, temporal length might be associated with the mass of the particles
also. This means that neutrino oscillations could be equivalent to neutrinos changing their temporal
extension to “spatial” in-flight which might be causing them to effect their flight time to a detector.

8. Conclusions
We can conclude that the temporal length hinted by quantum symmetry formulations and special
relativity, as presented above, holds promise to provide an intuitive perspective for hard to
comprehend theories. While there are a few verifiable predictions, only time will tell whether this idea
will inspire new theories. In any case the temporal length idea itself has already motivated the
development of numerical techniques for electromagnetic field computation in mutiphysics and
system simulation. The author hopes that the temporal length idea will be able to stand the test of time,
and it will also inspire other novel ideas and this way it will further benefit the scientific community.
References

[1] Aron Szucs, 2013, Temporal Length for Sub-Domain Models in Multi-Physics and System Analysis, COMPUMAG 2013
[2] Hartland S. Snyder, Quantized Space-Time, Phys. Rev. 71, 38 – Published 1 January 1947
[3] Achim Kempf, Gianpiero Mangano, and Robert B. Mann, 1995, Hilbert space representation of the minimal length uncertainty relation, Phys. Rev. D 52, 1108 – Published 15 July 1995
[4] Sándor Benczik, Lay Nam Chang, Djordje Minic, and Tatsu Takeuchi, 2005, Hydrogen-atom spectrum under a minimal-length hypothesis, Phys. Rev. A 72, 012104 – Published 5 July 2005
[5] M. M. Stetsko and V. M. Tkachuk, 2006, Perturbation hydrogen-atom spectrum in deformed space with minimal length Phys. Rev. A 74, 012101 – Published 5 July 2006
[6] R. Malcor, 1985, Lettere al Nuovo Cimento 16 Aprile 1985, Volume 42, Issue 8, pp 435-437, On the spatio-temporal extension of elementary particles
[7] Aron Szucs, 2000, Macro Elements In the Finite Element Analysis of Multi-Conductor Eddy-Current Problems, IEEE Transactions on Magnetics, Volume 36, Number 4, July 2000
[8] Aron Szucs, 2001, Macro Element Method for Modeling Eddy Currents in the Multi-Conductor Windings of Electrical Machines, Acta Polytechnica Scandinavica, Electrical Engineering Series No. 106
[9] Sami Kanerva, Jukka Kaukonen, Aron Szucs, Terttu Hautamaki, Coupled FEM-Control Simulation in the Analysis of Electrical Machines and Converters, Power Electronics and Motion Control Conference, 2006. EPE-PEMC 2006. 12th International, On page(s): 1925-1930
[10] Aron Szucs, 2012, Macro Element Approach for Electromagnetic Simulations in Multi-physics and System Analysis, at SPEEDAM 2012, “Symposium on Power Electronics, Electrical Drives, Automation & Control”, Sorrento, Italy
[11] Yatchev I., Arkkio A., Niemennmaa A., “Eddy-current losses in the stator winding of cage induction motors”, Helsinki University of Technology, Laboratory of Electromechanics, Report 47, Espoo 1995, 34 p.
[12] Aron Szucs, Antero Arkkio, 1999 Consideration of Eddy Currents in Multi-Conductor Windings Using the Finite Element Method and the Elimination of Inner Nodes, IEEE Transactions on Magnetics, Volume 35, Number 3, Part I of two parts, May