Some unexpected findings in hadron and nuclear physics from TGD point of view

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Abstract

This article discusses some recent unexpected findings related to hadron- and nuclear physics.

1. The recent experiments of Dove et al confirm that the antiquark sea is asymmmetric in the sense that the ratio anti-d/anti-u is larger than unity. A model assuming that proton is part of time in a state consisting of neutron and virtual pion seems to fit at qualitative level into the picture.

   The TGD based model relies on the already existing picture developed by taking seriously the so called X boson as 17.5 MeV particle and the empirical evidence for scaled down variants of pion predicted by TGD. Virtual mesons are replaced with real on mass shell mesons but with p-adically scaled down mass, and low energy strong interactions at the hadronic and nuclear level are described topologically in terms of reconnections of flux tubes.

2. That final state nuclei from the fission of heavy nuclei possess a rather high spin has been known since the discovery of nuclear fission 80 years ago but has remained poorly understood. The recent surprising findings by Wilson et al was that the final state angular momenta for the final state nuclei are uncorrelated and must therefore emerge after the decays.

   The TGD proposal is that the generation of angular momentum is a kind of self-organization process. Zero energy ontology (ZEO) and h_{eff} hierarchy indeed predicts self-organization in all scales. Self-organization involves energy feed needed to increase $h_{eff}/h_0 = n$ serving as a measure for algebraic complexity and as a kind of universal IQ in the number theoretical vision about cognition based on adelic physics.

   The final state nuclei have angular momenta $6-7\ \hbar$. This suggests that self-organization increases the values of h_{eff} to nh, $n \in \{6,7\}$. Quantization of angular momentum with new unit of spin would force the generation of large spins. Zero energy ontology (ZEO) provides a new element to the description of self-organization and a model for quantum tunnelling phenomenon.

3. Eric Reiter has studied the behavior of gamma-rays emitted by heavy nuclei going through a beam splitter splitting the photon beam to two beams. Quantum theory predicts that only one detector fires. Therefore the pulses in the two detectors occur at different times. This has been verified for photons of visible light. The experiment studied the same situation for gamma-rays and the surprise was that one observes mostly half pulses in both detectors and in some cases also full pulses. Reiter has made analogous experiments also with alpha particles with the same conclusion.

4. Quite recently, empirical support for a particle christened Odderon has emerged. As the name tells, Odderon is not well-understood in QCD framework.

   Odderon is a cousin of Pomeron which emerged already about half century ago in the so called Regge theory to explain the logarithmically rising (rather than decreasing) cross sections in proton-proton and proton-antiproton collisions. Pomeron is part of low energy phenomenology and perturbative QCD cannot say much about it.

These findings pose a challenge for TGD, and in this article a TGD based model for the findings is developed.

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1 Introduction

This chapter discusses some recent unexpected findings related to hadron- and nuclear physics.

1.1 The asymmetry of antimatter in proton from TGD point of view

The recent experiments of Dove et al [C4, C6] confirm that the antiquark sea is asymmmetric in the sense that the ratio anti-d/anti-u is larger than unity. A model assuming that proton is part of time in a state consisting of neutron and virtual pion seems to fit at qualitative level into the picture.

The TGD based model discussed also in [L30] relies on the already existing picture developed by taking seriously the so called X boson as 17.5 MeV particle and the empirical evidence for scaled down variants of pion predicted by TGD. What TGD can give is the replacement of virtual mesons with real on mass shell mesons but with p-adically scaled down mass and a concrete topological description of strong interactions at the hadronic and nuclear level in terms of reconnections of flux tubes.

1.2 The strange fissions of heavy nuclei

That final state nuclei from the fission of heavy nuclei possess a rather high spin has been known since the discovery of nuclear fission 80 years ago but has remained poorly understood.

The recent surprising finding by Wilson et al [L31] was that the final state angular momenta for the final state nuclei are uncorrelated and must therefore emerge after the decays. This represents a challenge for TGD inspired model of nuclei as nuclear strings, and one ends up to a rather detailed model for what happens in the fissions.

The TGD proposal discussed also in [L31] is that the generation of angular momentum is a kind of self-organization process. Zero energy ontology (ZEO) and h_{eff} hierarchy indeed predicts self-organization in all scales. Self-organization involves energy feed needed to increase $h_{eff}/h_0 = n$ serving as a measure for algebraic complexity and as a kind of universal IQ in the number theoretical vision about cognition based on adelic physics.

The observation that the final state nuclei have angular momenta $6 - 7\ \hbar$ suggests that self-organization increase the values of h_{eff} to nh, $n \in \{6, 7\}$. Quantization of angular momentum with new unit of spin forces the generation of large spins. Also zero energy ontology (ZEO) is involved: ZEO provides a new element to the description of self-organization and a model for quantum tunnelling phenomenon.

1.3 The strange findins of Eric Reiner

Eric Reiner [L29] has studied the behavior of gamma-rays emitted by heavy nuclei going through a beam splitter splitting the photon beam to two beams. Quantum theory predicts that only one detector fires. This implies that the pulses in the two detectors tend to occur at different times. This has been verified for photons of visible light. The experiment studied the same situation for gamma-rays and the surprise was that one observes mostly half pulses in both detectors and in some cases also full pulses. Reiner has made analogous experiments also with alpha particles with the same conclusion.

These findings pose a challenge for TGD, and in this chapter a TGD based model for the findings discussed also in [L29] is developed.

1.4 Pomeron and Odderon in TGD framework

Quite recently, empirical support for a particle christened Odderon [C5] emerged. As the name tells, Odderon is not well-understood in QCD framework.

Odderon is a cousin of Pomeron which emerged already about half century ago in the so called Regge theory to explain the logarithmically rising (rather than decreasing) cross sections in proton-proton and proton-antiproton collisions. Pomeron is part of low energy phenomenology and perturbative QCD cannot say much about it.

These four findings pose a challenge for TGD, and in this chapter a TGD based model for the findings discussed also in [L29] is developed.

2 The decays of heavy nuclei as support for nuclear string model

Nuclear string model is more than 20 years ago old applicationof TGD [L1]. The model identifies nuclei as string-like objects i.e. flux tubes carrying nucleons represented as space-time sheets topologically condensed at the larger flux tube. Nucleon space-time sheets are also connected by short flux fube bonds carrying quark and antiquark and having total quantum numbers of a pion or ρ meson. The model has several variants but is surprisingly successful and also the connection with the shell model can be understood. The basic prediction is that nuclear reactions and decays should have a topological description based on reconnection as basic reaction vertex.

2.1 Angular momentum generation in nuclear fission is not understood

I encountered a highly interesting link to a popular article (`https://cutt.ly/XlLnNB5`) to a work of a large international research group studying the fission of heavy nuclei. The article "*Angular momentum generation in nuclear fission*" [L31] (`https://cutt.ly/hlLn86c`) reporting the research findings is published in Nature (February 24). Unfortunately, the article is behind the paywall.

The work involved studying the fragments that resulted from fission of several types of unstable elements, such as uranium-238 and thorium-232. That the final state nuclei from the fission of heavy nuclei possess a rather high spin has been known since the discovery of nuclear fission 80 years ago but has remained poorly understood.

The recent surprising finding was that the final state angular momenta for the final state nuclei are uncorrelated and must therefore emerge after the decays. This represents a challenge for TGD inspired model of nuclei as nuclear strings, and one ends up to a rather detailed model for what happens in the fissions.

2.1.1 Recent findings

The fragments resulting in the scission of heavy nuclei possess relatively high rotational angular momenta, which are typically 6-7 using $\hbar$ as a unit. Why the nuclei should have so large angular momenta looks like a mystery. There are many theories for how this angular momentum is generated. The natural guess is that the angular momentum is possessed by the fragments already before the scission. This predicts that the fragments have opposite angular momenta.

The recent experiments [L31] studying the gamma ray spectrum emitted by the nuclei convincingly demonstrate that the angular momenta for the fragments are independent and therefore must be generated after the scission. This looks very strange from the point of view of angular momentum conservation.

What comes first in mind is that the gamma ray emission takes care of angular momentum conservation. The generation of angular momenta is however analogous to a self-organization process and in standard physics framework it looks strange that this would take place for nuclei.

The classical model proposed by the experimenters relies on an analogy with a rubber band. The nuclei resulting in the splitting of heavy nuclei to two parts are proposed to be highly elongated before the scission.

In the splitting of a rubber band the resulting ends of the rubber band generate opposite torques giving them angular momenta. The energy liberated as the fragment returns from an excited state to an approximately spherical shape would be transferred to rotational energy. Here the proposed analogy is soap bubble with surface tension and pressure difference determining its dynamics: minimal energy corresponds to a spherical shape. The emission of gamma rays would take care of the conservation of the angular momentum.

Elongation makes possible the scission (on could also compare the decay to a decay of water droplet). What could be the mechanism of the elongation?

The TGD based model for scission relies on the model of nuclei as nuclear strings [L1]. Also other other elements of the new physics predicted by TGD are involved. The first element is the identification of dark matter as phases of ordinary matter labelled by effective Planck constant [K4] $h_{eff}/h_0 = n$, ($h = 6h_0$ [L6]), with n identified as the dimension of extension of rationals determined by the degree of a polynomial characterizing a given region of the space-time surface by $M^8 - H$ duality [L19, L20]. Also zero energy ontology (ZEO) [L18] is involved: ZEO provides a new element to the description of self-organization [L16] and a model for quantum tunnelling phenomenon as a pair of BSFRs with the time-reversed period between them identified as tunneling period.

The first guess was that flux tubes, which have much longer length than nuclear size, could explain the mysterious finding that in nuclear decay the fragments manage to generate their angular momenta after the reaction: the flux tubes would make possible the exchange of angular momentum required by angular momentum conservation. The prediction would be that the flux fragments have opposite angular moment but the discovery was that they angular momenta are independent.

A more realistic guess is that the nuclear flux tubes themselves correspond to MB and that the generation of angular momentum is a kind of self-organization process - something usually not expected to be possible at the level of nuclear physics.

1. Zero energy ontology (ZEO) and h_{eff} hierarchy indeed predicts self-organization in all scales [L16] and time reversal plays a key role in this process: dissipation with a reversed arrow of time looks like self-organization for an observer with the standard arrow of time.

2. Self-organization involves energy feed needed to increase $h_{eff}/h_0 = n$ serving as a measure for algebraic complexity and as a kind of universal IQ in the number theoretical vision about cognition based on adelic physics [L11, L12]. The energy feed would be from the vibrational excitations of the flux tube to the rotational degrees of freedom.

3. The observation that the final state nuclei have angular momenta $6 - 7\ \hbar$ suggests that self-organization increases the value of h_{eff} to nh, $n \in \{6, 7\}$. The quantization of angular momentum with unit $\hbar_{eff}$ forces the rotation.

2.1.2 The basic ideas of the TGD based model for the scission

In TGD nuclei are modelled as closed nuclear strings [L1]. The counterpart for an elongated nucleus would be a loop looking like a highly flattened square, possibly having helical linking making it a helical knot. This suggests a description of the scission as a reconnection of the flux tube - in the approximation of the flux tube as a closed string this would be basic string vertex.

Also the analogy with DNA is useful. In TGD Universe DNA [L13, L34, L32, L33, L26] and also other basic information molecules are accompanied by flux tubes carrying dark protons (ordinary protons with $h_{eff} = nh_0 > h$) controlling them: dark means that the protons at the flux tubes. The elongation of the nucleus could be analogous to the process of DNA unfolding.

The opening of the helical DNA double strand in transcription forces the rotation of DNA: same would happen for the nuclei. If the value of h_{eff} as a unit of angular momentum increases to say $h_{eff} = 6h$, the torque generating the rotation is necessary to realize minimal non-vanishing value of angular momentum.

2.2 Nuclear string model briefly

TGD based description of nuclei is as nuclear strings containing nucleons along string [L1]. Nucleons from sequences at the magnetic flux tube so that a string like object is in question. Rubber band is indeed analogous to a string.

1. Nucleons correspond to space-time sheets topologically condensed at magnetic flux tube and connected by flux tube bonds representing scaled down pion or ρ meson quantum number-sexcept that the mass is p-adically scaled down to MeV range.

2. There are three options for what nuclear string could mean:

   (a) Neutrons and protons from separate nuclear strings and the flux tube bonds correspond to neutral pionor ρ. Thiswould conform with the treatmentof protons and neutrons in the nuclear shell model.

   (b) Protons and neutrons reside at the same flux tube.

   (c) Neutronlike space-time sheets are not actually ordinary neutrons but correspond to a proton + negatively charged pion-like flux tube bond connecting protons together.

   One can also consider the possibility that there are several closed linked and knotted loops present in the nucleus. Reconnections between the loops could generate knotting and linking. For instance, alpha particle could correspond to such a loop.

3. The analogy with strings suggests as the first guess a correlation between masses and angular momenta of the fragments idealized by the mass formula $J = kM^2$. Here k would be determined by the nuclear string tension.

4. Nuclear reactions would proceed by reconnection of flux tubes which for ideal closed strings define the basic vertex. Same applies to nuclear decays. A closed loop representing say alpha particle would be emitted via a reconnection process.

2.3 Scission as reconnection

Consider now the scission of heavy nuclei in this framework.

1. Suppose that in standard configuration nuclear strings are flux tube tangles - kind of flux tube spaghettis. This would correspond to the analogy with a bee nest used in the popular article. The Universe of the TGD is fractal and flux tubes appear in all scales. Galaxies, stars, planets, etc would involve flux tube tangles. Even DNA and other linear bio-molecules would involve flux tubes.

   A flux tube as a volume filling spaghetti is an object analogous to blackhole-like. Since the thickness of the flux tube can vary having values determined by p-adic length scale hypothesis, a hierarchy of blackhole-like entities are predicted [L15]. Ordinary blackholes would have flux tube thickness equal to proton Compton length and consist of nuclear strings. Also stars could be analogous to blackholes. In the csae of Sun the thickness of the flux tube would be of order electron Compton length [**?**, L17].

   Also nuclei would be analogous to mini blackholes. If they are volume filling, the reconnections could occur all the time and the topology would be highly dynamical involving changes of knottedness and decay to disjoint and linked knots.

Consider first the decay of the nucleus in the general case.

1. In the general case, the flux tube spaghetti is knotted. How can the decay to two separate tangles proceed? An arbitrary reconnection does not lead to two separate sub-tangles but changes only the knotting and linking. Even if this happens, the subtangles remain knotted and linked and the decay is not possible without further reconnections.

   If the nucleus manages to evolve by reconnections to two mutually unknotted and unlinked sub-knots, the situation changes. The nucleus would decompose to 2 sub-knots connected by a pair of parallel closely spaced flux tubes for which the reconnection can take place and yield two final state nuclei. A decomposition into a connected sum of two knots would precede the decay in the general case.

2. The hypothesized elongated nucleus could correspond to a more specific situation. A maximally elongated nucleus would correspond to an opened flux loop with a shape of say flattened square. The flux loop could also be helical and stability might favor this. Rubber band analogy would be therefore justified. The scission would correspond to the splitting of this flux loop by reconnection. It is however enough to assume the formation of two separate knots connected by pair of parallel flux tubes close to each other.

The generation of the rotational angular momentum after the decay would correspond to a generation of a rotation of the flux tube as a string-like entity. A helical configuration analogous to DNA double strand is highly suggestive. The elongated nucleus would correspond to this kind of configuration.

The splitting would kick the stringy flux tube to an excited state. The liberated energy would generate the rotational motion. Why the motion would be collective rotation is not at all obvious.

The emission of gamma rays having spin would take care of angular momentum conservation. This however requires that gamma rays tend to have parallel spins. It is not obvious why this should be the case.

2.4 DNA opening as analogue for the scission process

Why the fragments generate angular momenta? Flux tubes appear in all scales in TGD Universe. In particular, the TGD based model for DNA invovles besides ordinary DNA strand also dark DNA strand parallel to it and identifed as a magnetic flux tube carrying dark proton sequence [L13, L34]. Genetic code is realized for dark DNA as dark proton triplets: this realization involves only protons and codons are entangled 3 proton states which do not allow reduction to letters. These dark proton sequences can be regarded as dark nuclei. The nuclear realization of the genetic code would be the fundamental one and the chemical realization would be kind of mimicry.

The model predicts also the dark counterparts of RNA, amino-acids and tRNA as dark proton triplets. One cannot completely exclude the possibility that the genetic code is realized already at the level of ordinary nuclei. This motivates the question whether the opening of the ordinary DNA double strand controlled by dark DNA strand might provide a useful analogy for understanding what happens in the scission.

1. The opening of DNA double strand in the replication or transcription must eliminated the helical linking of strands to give pair of parallel straight strands so that the replication can take place. The opening requires the rotation of strands and generates angular momentum.

2. Could the parallel flux tube portions form an analog of DNA double strand? Amusingly, the spin and isospin states of nucleon give rise to 4 states so that 3 nucleons would form analogs of genetic codons. The "dark" realization as entangled 3-nucleon states is however more plausible.

   DNA/protein unfolding as a self-organiation process is a biological analog for the step leading to an elongated state. The return to the highly tangled state after reaction would be analougs to DNA/protein folding.

2.5 Does non-standard value of h_{eff} explain the values of final state angular momenta?

One should also understand the large angular momenta of the final state nuclei and why these values are around $6\hbar$.

1. The intermediate state in the first BSFR would correspond to a dark nucleus having $h_{eff} = nh_0 > h = 6h_0$. This could be true also after BSFR and the angular momentum could be reduced to its standard value in the final state. This suggests that the angular momentum is quantized with $\hbar_{eff}$ as unit.

2. The observation that the angular momenta are around $6h$ suggests that in the final state one has $\hbar_{eff} = Nh$: $N \in \{6, 7\}$. This would explain why the rotational angular momentum must be generated.

In standard quantum theory it is very difficult to understand why the emitted ordinary gamma rays could have correlated spins so that the total spin would be N units. If the emitted dark gamma rays are dark they would have angular momentum unit $\hbar_{eff} = N\hbar$ and would decay to ordinary gamma rays.

3. A connection with the notion of dark 3N-protons and 3N-photons of TGD inspired quantum biology [L13, L23, L26] is highly suggestivbe. Dark 3N-protons would be cyclotron condensates analogous to nucleons as color triplets behaving like a single particle. 3N-photons would be analogous to Bose-Einstein condensates of 3N photons [L32, L33]. The mechanism leading to these states would be Galois confinement possible in TGD framework [L9, L25, L27].

4. Since the energies of quantum states quite generally increase with h_{eff}, the increase of h_{eff} would require a "metabolic energy" feed. The excitation of the stringy degrees of freedom could provide this energy and transform to rotational energy. One could think that in the scission the flux tube as string is heated to high temperature and this energy is liberated to collective rotational motion. The minimal value of the angular momentum would be $\hbar_{eff} = N\hbar$ and would force coherent rotation.

2.6 ZEO based view about scission

It is also interesting to consider the description of the scission process could be in zero energy ontology (ZEO) [L18].

1. Quite generally, tunnelling phenomenon in nuclear reactions could correspond to a pair of "big state function reductions" (BSFRs) [L17]. BSFR is the counterpart of the ordinary SFR and changes the arrow of time [L18, L27]. The intermediate period with an opposite arrow of time would correspond to the tunnelling in nuclear reactions.

   This model emerged from a model "cold fusion" as nuclear reactions for dark nuclei with protons and neutrons having nonstandard value of h_{eff} increasing their Compton lengths [L3, L10, L21, ?].

2. When the state of the system is near the threshold for scission, the system is quantum critical and experiences long scale quantum fluctuations with varying balue of h_{eff}. Given fluctuation increases the Compton radius of nucleons by factor $h_{eff}/h = n/6$. Nuclear string would be scaled up in size. This might be true even for ordinary nuclear reactions. Nuclear binding energies would be scaled down like $1/h_{eff}$. After the second BSFR, h_{eff} would return to the original value, perhaps in a stepwise manner.

3. The decay process leading to an elongated nucleus as an intermediate state could emerge in the first BSFR leading instantaneously to the elongated state. In ZEO quantum states are superpositions of classical time evolutions and at the classical level this looks to an observer with a standard arrow of time classically like a deterministic time evolution leading from a roughly spherical initial to a highly elongated state. This interpretation explains the strange looking findings of Minev et al for state function reductions in an atomic system [L14] [L14].

   The state to which the classical time evolutions of the superposition apparently lead would correspond to the elongated nucleus. Actually it would be the initial state of the time reversed time evolution. The classical model of the authors would describe this period.

4. Second BSFR would re-establish the original time direction and correspond to the splitting of the elongated state to fragments in the manner already described.

3 The asymmetry of antimatter in proton from TGD point of view

I encountered a highly interesting popular article *"Decades-Long Experiment Finds Strange Mix of Antimatter in The Heart of Every Proton"* (`https://cutt.ly/BlZtNne`).

The popular article tells about the article "*The asymmetry of antimatter in the proton*" of Dove et al [C4] published in Nature (`https://cutt.ly/BlZt8sV`). This article is behind the paywall but the same issue of Nature has an additional article "*Antimatter in the proton is more down than up*" [C6] (`https://cutt.ly/blZyT4u`) explaining the finding.

What is found is an asymmetry for u and antiquarks in the sense that there are slightly more d-type antiquarks (anti-d) than u type antiquarks (anti-u) in quark sea. This asymmetry does not seem to depend on the longitudinal momentum fraction of the antiquark: the ratio of anti-down and anti-up distribution functions is smaller than one and constant.

A model assuming that proton is part of time in a state consisting of neutron and virtual pion seems to fit at qualitative level into the picture. Unfortunately, the old-fashioned strong interaction theory based on nuclei and pions does not converge by the quite too large value of proton pion coupling constant.

I looked at the situation in more detail and developed a simple TGD based model based on the already existing picture developed by taking seriously the so called X boson as 17.5 MeV particle and the empirical evidence for scaled down variants of pion predicted by TGD [L8]. What TGD can give is the replacement of virtual mesons with real on mass shell mesons but with p-adically scaled down mass and a concrete topological description of strong interactions at the hadronic and nuclear level in terms of reconnections of flux tubes.

3.1 TGD inspired model for the asymmetry

3.1.1 Basic data about quark and nucleon masses

To get a quantitative grasp about the situation, one can first see what is known about masses of u and d quarks.

1. One estimate for u and d quark masses (one must taken the proposals very cautiously) can be found (`https://cutt.ly/dlZukKC`).

   The mass ranges are for u 1.7-3.3 MeV and and for d 4.1-5.8 MeV.

2. In the first approximation n-p mass difference 1.3 MeV would be just d-u mass difference varying in the range 1.2 MeV-4.1 MeV and has a correct sign and a correct order of magnitude. 4.1 MeV for d and 3.3 MeV for u would produce the n-p mass difference correctly.

3. Coulomb interactions give a contribution E_c, which is vanishing por proton and and negative for neutron

   $$E_c(p) = 0 \ \ , \quad E_c(n) = -\alpha \times \hbar/3R_e \ \ .$$

   R_e is proton's electromagnetic scale.

   This contribution reduces neutron mass. If R_e is taken to be proton Compton radius this gives about $E_c \simeq -3.2$ MeV. This would predict mass n-p difference in the range -1.1-0.9 MeV. This favors maximal n-p mass difference 4.1 MeV and m(u)= 1.7 MeV and md =5.8 MeV: d-u mass difference would be 4.1 MeV roughly 4 times electron mass.

3.1.2 TGD based picture about hadronic an nuclear interactions

Consider first the TGD inspired topological model for hadronic an nuclear interactions implicitly contained in the model of nuclei as nuclear strings [L1] further developed in applications to "cold fusion" [L3, L10, L21] and by using input from the anomaly assignable to the nuclear physics of solar core [L17, L15].

1. The notion of magnetic body (MB) assignable to color and em and electroweak interactions is essential. The interactions are described by virtual particle exchanges in quantum field theory (QFT). In TGD they are described by reconnections of U-shaped flux tubes which are like tentacles.

   In interaction these tentacles reconnect and give rise to a pair of flux tubes connecting the particles. The flux tubes would carry monopole flux so that single flux tube cannot be split.

These flux tube pairs serve also as correlates of entanglement replacing wormholes as their correlates in ER-EPR picture.

This picture looks rather biological and was developed first as a model of bio-catalysis [L34] [K3]: reconnections of U-shaped tentacles would make possible for reactants to find each other and their shortening in phase transitions reducing h_{eff} would bring them near to each other. The picture should apply quite generally to short range interactions at least.

2. The U-shaped flux tubes of color MB replace virtual pion and and ρ meson exchanges in the old fashioned picture about strong interactions. They represent in TGD framework real particles but with p-adically scaled down mass. For instance, pions are predicted to have scaled down variants with masses different by a negative power of 2 from pion mass. Same is true for rho. Now the masses would be below MeV range, which is the energy scale of nuclear strong interactions. Also nuclear strong interactions would occur in this manner [L1] [L17].

3.1.3 A model for the anti-quark asymmetry

Consider now a model anti-quark asymmetry for sea quarks.

1. Quarks and antiquarks would appear at these flux tubes. The natural first guess is that meson like states are in question.

   The generation of u-anti-d type pion or ρ would transform proton to neutron if the valence u transforms to valence d and W boson with scaled down mass.

   Note that the scaling down would make weak interaction stronger since weak boson exchange amplitude is proportional to $1/m_W^2$ and scaled by up by a factor of order 10^{10} if m_W has mass in MeV range.

   This would give the analog of neuron plus charge virtual pion. Taking two sea quarks would lead to trouble with the too large Coulomb interaction energy about -10 MeV of negatively charged sea with positively charged valence part of proton if the sea is of the same size as proton.

2. Does the scaled down W$^+$ decay to u-anti-d forming a scaled down meson π^+ or ρ^+? Or should one regard u-anti-d as a scaled down W$^+$ having also the spin zero state analogous to pion since it is massive?

3. Here comes a connection with old-fashioned and long ago forgotten hadron physics. Thep-artially conserved axial current hypothesis (PCAC) gives a connection between strong and weak interactions forgotten when QCD emerged as the final theory. PCAC says that the divergence of axial weak currents associated with weak bosons are proportional to pions.

   Are the two pictures more or less equivalent? Virtual pion exchange could be regarded as a weak interaction! Also conserved vector current hypothesis (CVC) is part of this picture. This is not new: I have developed this picture earlier in an attempt to understand what the reported X boson with 17.5 MeV mass is in the TGD framework. Scaled down pion would be in question [L8].

4. What about the masses of quarks and proton? Since the flux loop would have considerably greater size than proton, the mass scale of u-anti-d state would be smaller than say MeV, and the contribution to mass of proton would be small.

5. Why the asymmetry for anti-quarks of sea? The generation u-anti-d loop would increase the charge of the core region by two 2 units and transform it to Δ. This looks neither plausible nor probable. Proton would be a superposition consisting mostly of the proton of good old QCD and neutron plus flux loop with quantum numbers of a scaled down pion.

6. Also the presence of scaled down ρ meson loops can be considered. Their presence would turn the spin of the core part of the proton opposite for some fraction of time. One can wonder whether this could relate to the spin puzzle of proton.

4 Pomeron and Odderon from TGD point of view

The following comments were inspired by a popular article telling about the empirical support for a particle christened Odderon (`https://cutt.ly/2xd7M7Y`). The article about Odderon by Csörgö et al is published in European Physics Journal C [C5]. As the name tells, Odderon is not well-understood in QCD framework.

Odderon is a cousin of Pomeron which emerged already about half century ago in the so called Regge theory to explain the logarithmically rising (rather than decreasing) cross sections in proton-proton and proton-antiproton collisions. Pomeron is part of low energy phenomenology and perturbative QCD cannot say much about it. Since the charge parity (see `https://cutt.ly/ixd78aS`) is $C = 1$ for Pomeron $C = -1$ for Odderon, these states are analogous to pion with spin 0 and ρ meson with spin 1.

Pomeron and Odderon have not been in the interests of the frontier of theoretical physics: they represent for an M-theorist a totally uninteresting and primitive low energy phenomenology - as all that we used to call physics before the first superstring revolution -, and does not therefore deserve the attention of an ambitious superstring theorist more interested in the marvels of brane words, landscape, swampland, and multiverse.

I have written about Pomeron for years ago. The following is something different since the view about low energy strong interactions according to TGD [L24] has developed considerably [L30, L28].

One can go first to Wikipedia to learn about Pomeron [C8, C1] (`https://cutt.ly/Wxd5eFq`).

1. Pomeron exchange appearing in the t-channel in elastic scattering was postulated to explain the slowly (logarithmically) rising scattering cross sections in proton-proton and proton-antiproton collisions. For quarks and gluons the scattering cross sections fall down rather rapidly with energy (by dimensional argument like inverse $1/s$ of cm energy squared) so that something else would be in question.

2. The total cross sections do not depend on the charges of the colliding baryons. The usual shower of Cerenkov radiation was missing from Pomeron exchange events. The absence of pions usually present was interpreted as absence of color charge.

   This suggests that quarks and gluons do not participate the Pomeron events. There is often also a large rapidity gap in which no outgoing particles are observed.

3. In the Regge theory which later was concretized in terms of the hadronic string model. Pomeron would correspond to a Regge trajectory for which the Reggeon would have quantum numbers of vacuum except for mass and angular momentum. Regge trajectory would satisfy the formula $M^2 = M_0^2 = \alpha(s)J$, M mass, J angular momentum. The exchange of the entire Regge trajectory would give rise to approximately constant cross section. Odderon would be Pomeron like state with an odd charge parity $C = -1$ instead of $C = 1$. Pomeron and Odderon could correspond $C = \pm 1$ parts of a Regge trajectory.

4. In the QCD picture Pomeron and Odderon are assumed to be associated with the gluonic exchanges, which should form Regge trajectories: this suggests a stringy picture and non-perturbative QCD. Pomeron *resp.* Odderon would be a many-gluon states with an even *resp.* odd number of gluons.

In the many-sheeted space-time of TGD, hadrons are many-sheeted objects.

1. There is a hadronic space-time sheet and quark and gluon space-time sheets are glued at this. There is a magnetic body (MB) of hadron having a layered structure. In particular, there are em/color/weak MBs consisting of flux tubes and "tentacles", which are U-shaped flux tubes.

   Low energy hadron physics would be described in terms of reconnections of these tentacles. This is a rather new element in the picture. In a reasonable approximation, flux tubes are strings and the reconnection of closed strings appears as a basic reaction vertex for closed strings. This gives a connection with the hadronic string model. TGD indeed emerged as a generalization of the hadronic string model 43 years ago (and also as a solution of the energy problem of GRT).

2. Most of the energy of hadron is assumed to be carried by color MB: quarks and gluons carry only a small part of energy. In QCD space-time dynamics is not present and the analog of hadron as space-time surfaces would be a gluon condensate of some kind.

3. Low energy hadron reactions would consist of reconnections of the U-shaped flux tubes of the colliding color MBs. Besides this there are also the collisions of quarks and gluons having approximate description in terms of QCD. The already mentioned connection with hadronic string model suggests a connection with Regge and string model descriptions of Pomeron/Odderon.

4. Hadrons have U-shaped flux tubes acting like tentacles and reconnect to form a bridge of two flux tubes between colliding hadrons. This topological interaction mechanism would be universal and occur in all scales. In biology the ability of reacting biomolecules to magically find each other in the dense molecular soup would rely on this mechanism. It would be also a mechanism of high Tc - and biological superconductivity.

Could this explain the basic properties of the Pomeron?

1. Charge independence and the absence of pion emission assignable to quark-gluon reactions can be understood. Gluons and quarks of colliding hadrons would not meet each other at all. The two colliding hadrons would just touch each other with their "tentacles" which would transfer some momentum between them in elastic collisions. This would explain the rapidity gap.

2. What about the slow dependence on collision energy? Why the cross section describing the probability of the formation of reconnection would not depend on collision energy?

   (a) One could visualize the cross section in cm frame geometrically as the area of a 2-D surface cylinder parallel to the line connecting the colliding particles. The area of this cylinder would tell the probability for the formations of reconnection. If I try to touch some object in darkness, its area tells how probable the success is.

   (b) In elastic scattering the t-channel momentum exchange would be orthogonal to this cylinder and have vanishing energy component. It would not change in Lorentz boosts increasing the cm collision energy. If the contribution to the cross section depends only on t, it would be independent of collision energy.

5 TGD based interpretation for the strange findings of Eric Reiter

I learned of rather interesting findings claimed by Eric Reiter hosting a public group "*A serious challenge to quantum mechanics*" (`https://cutt.ly/VlBgFk4`). There is a published article [L29, H2] `https://cutt.ly/rlBgOl1`) about the behavior of gammas emitted by heavy nuclei.

5.0.1 Background

Eric Reiter has studied the behavior of gammas emitted by heavy nuclei going through two detectors in tandem. Quantum theory predicts that only one detector fires.It is however found that both detectors fire with the same pulse height and firings are causally related. Depending on wavelength, the effect is reported to increase or decrease with distance between the source and detector. The pulse rate depends on the chemistry of the source, which does not conform with the assumption that nuclear physics and chemistry decouple from each other. Reiter has made analogous experiments also with alpha particles with the same conclusion. These findings pose a challenge for TGD, and in this article a TGD based model for the findings is developed.

On the basis of these findings, Reiter makes the rather provocative proposal that quantum theory is an illusion, and suggests a semiclassical theory known as loading theory represented originally by Max Planck. The theory states that the detectors fire only after they have loaded a sufficient amount of energy. The theory assumes that quantization of energy holds true only at the moment of emission but after that the energy disperses to the em fields describing the radiation.

In order that loading theory can explain the almost simultaneous and causally related firings, the loaded electromagnetic energy should achieve a critical value at the same time for both detectors. It seems that both detectors must start always in preloaded state and preloadings must be identical. It is not obvious to me how the loading theory can explain the success of quantum theory for visible photons. Reiter claims that this is possible.

Before continuing, let us make clear that although I am not a proponent of unquantum theory, I take the observations of Reiter seriously and regard them as an extremely interesting challenge also for TGD.

5.0.2 Basic observations of Reiter

The basic observations claimed by Reiter [L29, H2] `https://cutt.ly/rlBgOl1`) are the following.

1. Full pulses and half-pulses, which by definition have height smaller than 2/3 of the height of full pulse are recorded in both detectors. This in conflict with the prediction that only one detector should fire if pulses are caused by the absorbtion of the gamma. The pulses are causally related. The probability for half pulse pairs is by factor of 100 higher than by change. The probability for full pulse pairs is 4 times higher than by change. Both observations should correspond to 2 gammas in standard quantum theory. Only full pulses are considered in the analysis.

   Remark: One can ask whether the secondary gammas associated with the Compton scattering of gamma can propagate to the second detector and cause a pulse in it. The situations could correspond to half pulses whereas full pulses could correspond to the absorption of gamma.

2. For full pulses two gammas are absorbed. This challenges energy conservation and the assumption that single gamma enters the detector system. The proposal based on loading theory is that some kind of threshold effect is in question. When the loaded energy reaches a critical value, absorption occurs. Not only the energy of the secondary gamma but also the energy loaded to the D2 would be released and give rise to pulse pairs with total released gamma energy exceeding the energy of the incoming gamma. Preloading is the term used: preloading would be a continuous parameter,call it P. The values of P for the two detectors should be the same. P should be analogous to temperature and the detectors should be in state analogous to thermal equilibrium.

5.0.3 Can one explain the unquantum effect in standard physics?

The experiment of Reiter uses gamma scintillators (`https://cutt.ly/BvRdE1e`) to the primary detection of gammas. The signal is mostly generated by photoelectric absorption inducing ionization producing in turn photoelectrons and by Compton scattering of gamma inside an NaI crystal in the experiment to be considered in the following. The basic question is whether one can understand causal pulse pairs with the same pulse heights in the standard physics picture assuming a single incoming gamma.

1. Energy conservation challenges the standard physics explanation. The estimates for the total gamma release of gamma energy give total energy exceeding that for the incoming gamma. This has motivated the idea that energy is loaded to the D2 so that the total energy released exceeds the energy of the incoming gamma.

2. If the gamma is absorbed in the first detector (D1), a causal pulse pair is not obtained. Since the gamma must get through as a secondary gamma, one can restrict the consideration to Compton scattering. Note that Compton scattering produces also ionized atoms but this is not essential for what follows.

3. The pulse height is assumed to be determined by the part E_1 of the energy E_{lost} lost by the gamma to which the detector responds. If the detection is a local process, $E_1 < E_{lost}$ is true. $E_{lost} = E$ is true if the detector is thick enough. If the detection is a local process, Compton scattering can produce pulses with constant heights.

4. From **Fig. 1** of Appendix one learns that the D1 is 4 mm thick and much thinner than the attenuation length of the detector which is of order 10 cm. This means that the pulse height for Compton scattering in D2, which is thicker than the D1 differs from that in D1. Could a gamma, which is Compton scattered in D1 and absorbed in D2, produce an equal height pulse pair? This would require $E_{lost} = E/2$ in D1. The maximum of E_{loss} in the Compton scattering from a free electron is however $2E/7$ for $D = 100$ kV (see Appendix) and occurs for back-scattering so that this situation is not possible.

   The gamma which gets through the detectors spends 1.2×10^{-12} seconds to get through the D1. Several sub-pulses from Compton scattering are possible and they sum up to a single pulse from the entire detector. If the pulse were produced locally, the time resolution of the detector should be about $\tau = 10^{-12}$ seconds. The actual resolution is about $\tau = 10^{-7}$ seconds. During this time the gamma propagates 30 meters, which strongly suggests that the pulse detection is non-local process in both detectors.

5. One can therefore assume that the energy E_{lost} indeed determines the pulse height. In the D1 only part of E is lost and the energies of causal pairs are in general different and one does not have a natural explanation for the causal pulse pairs with equal pulse height.

5.1 Basic ideas concerning the TGD based explanation of the Reiter's effect

I am not an experimentalist and I am not at all sure whether I have understood correctly the description of the experiments and results. With these cautions in mind, consider first a thought experiment forgetting the belief that the incoming particles are ordinary gammas and quantum theory holds true.

1. In 2-1 cases the pulses correspond to separate incoming gammas. At least two gammas should arrive at the D1.

2. One can understand simultaneous pulses with equal pulse heights, if a considerable number of gammas instead of a single gamma arrive the detector simultaneously. The particle from gamma source would not be gamma but a particle decaying to N nearly parallel gammas with the energy of ordinary gamma. These photons for a subset of them would be distributed between the detectors and average pulse heights could be identical.

The challenge is to see whether this picture can be realized in TGD framework. The key questions are the following.

1. What are the particles which would decay to N gammas before the detector or inside it.

2. Why pairs of full pulses and pairs of half pulses are observed?

5.1.1 Hierarchy of effective Planck constants and the notion of N-photon and N-nucleus

The TGD inspired model involves two new physics effects predicted by TGD.

1. In the TGD framework classical physics is an exact part of quantum physics and essential for the interpretation of quantum theory. $M^8 - H$ duality which is central element of TGD realizes kind of quantum-classical duality: both M^8 and $H = M^4 \times CP_2$ are needed. At the level of M^8 having interpretation as analog of momentum space, everything is quantal: there are no classical fields and space-time is analog of Fermi ball. At the level of $H = M^4 \times CP_2$ one has space-time as dynamical entity and classical fields.

2. TGD predicts a hierarchy of Planck constants $h_{eff} = nh_0$, $h = 6h_0$ is the value of h_0 suggested by the findings of Randel Mills [D1] [L6]. For a given frequency $E = h_{eff}f$ means that the frequency for a given energy is scaled down by $h/h_{eff} = 1/n$ in $h \to h_{eff}$. $n = 2$ would give period doubling.

3. Large values of h_{eff} allow quantum coherence in arbitrarily long scales since quantum coherence lengths increase with h_{eff} [L34]. This makes possible Bose-Einstein (B-E) condensate like N-particle states behaving like single particle: N-protons, N-ions, N-photons... A number theoretical phenomenon that I have christened as Galois confinement would be in question.

   N-photon as analog of BE-condensate-like state of N photons behaving like a single particle. Quantum coherent state can be regarded as superposition of N-photon B-E condensates of this kind.

   N-photons play a central role in TGD inspired quantum biology. For instance, biophotons would be ordinary photons resulting from decay of dark 3N-photons to ordinary photons [L23, L26]. Baryons as 3-quark states provide the analogy: color confinement forces the 3 quarks to behave like a single particle.

   Also condensed matter could realize these N-particle states states. Ordinary DNA would be accompanied by dark DNA which would consist of sequence of dark 3-protons realizing genetic code and providing also counterparts for RNA, tRNA, and amino-acids [L13].

   The dark 3-protons combine to form similar 3N-proton states representing genes and emitting 3N-photons in collective cyclotron transitions and providing representations of genetic codons and coupling resonantly to corresponding genes. An interesting possibility is that for $h_{eff}/h_0 = n > N$ the N nuclei reside at different sheets of n-fold covering defined by the space-time region.

These considerations motivate the question whether the gammas could originate from N-gammas, which decay to ordinary gammas possibly having $h_{eff} > h$? Could this guarantee that both detectors receive a signal and average pulse heights are same.

5.1.2 Quantum criticality and unquantum effect

The proposed model assumes that the response of the detector is yes-no response. In critical systems the response is almost independent of the stimulus, kind of yes/no response. The incoming stimulus is like a small perturbation generating a phase transition.Therefore the intuitive idea is that quantum criticality is crucial.

A good metaphor is control knob: the response does not depend on how hard you push the knob. The role of the magnetic body in TGD inspired biology is to control the biological body. The control action pushes a knob generating a phase transition.

How to realize the control action?

1. Quantum criticality is accompanied by long range correlations and fluctuations implied by the quantum coherence in long scales. $h_{eff} = nh_0 > h$ indeed increases the scale of quantum coherence. The natural first guess is that $h_{eff} > h$ is true for the N gamma rays from N-gamma. $h_{eff} > h$ photons behave like dark photons in the sense that they do not interact directly with the ordinary matter.

2. The interaction with ordinary matter requires the transformation of the dark photon to ordinary photon with $h_{eff} = h$ after which the interaction can occur in the usual manner. The Feynman diagrams describing the interaction containing in the incoming photon line a vertex describing this transition.

   A very rough description of the transformation of the dark photon to ordinary photon is in terms of a transition probability p, which does not depend on the detector. A more refined description would be in terms of mixing of ordinary and dark photons. This requires that the mass squared of dark photon is non-vanishing but very small. Nothing happens in the detector unless this transition takes place.

3. Consider now what happens in the detector if the probability p is very small: $p << 1$. The dark photon detection rate $R_{d,1}$ in the D1 is given in the first approximation by $R_{d,1} = pR_1$, where R_1 characterizes the rate for the detection of ordinary gamma.

   In the D2 the "dark" detection rate is $R_{d,2} = p(1-p)R_2 \simeq pR_2$. $1-p$ characterizes the attenuation of the "single photon beam". If the detectors are ideal yes/no detectors then

$R_1 = R_2$ and the ratio of the dark rates is $(1 - p_1) \simeq 1$. This requires that the detector response is determined only by the first dark photons of the conical dark gamma beam serving in the role of control knob.

To sum up, the prediction is that for ideal detectors of dark gammas the detection rates are the same in both detectors and independent of the values d_i of the detector thickness. This prediction allows the testing of the dark photon hypothesis.

There is an interesting connection of quantum criticality with an effect discovered by Podkletnov and Modanese [H4] discussed from TGD point of view in [L4]. In Modanese-Podkletnov effect the electric discharges of a capacitor for which the second plate is super-conductor are reported to generate a pulse of unidentified radiation inducing the oscillation of test penduli. What is strange is that the beam of radiation does not seem to be attenuated. This suggests that the effect is caused by a dark photon beam which serves in the role of control knob in a quantum critical system and does not provide energy causing the oscillation of the penduli. Therefore the effect would have obvious resemblance to what is reported to happen in the tandem experiment of Reiter.

5.2 TGD based model for the findings of Reiter

In the experiment of Reiter [H2] detectors are in series. The detectors are scintillators in which the incoming gamma can suffer Compton scattering, become absorbed, or transform to an electron-positron pair. Electron can also absorb gamma. It is assumed that full pulses are due to the gamma absorption and that Compton scattering gives rise to what is called half-pulses.

The scintillators are crystals. Compton scattering and gamma absorption by electron lead to secondary processes, which can generate gammas. For instance, after the absorption of gamma the electron dissipates its energy and this effect is amplified in photo-multipliers. Scattered gamma can suffer further scatterings.

The surprising observation is that the responses of the two detectors identical in the measurement resolution used [H2].

1. If there is only a single incoming gamma, it should be absorbed in either detector. If the secondary gammas created in the D1 do not enter the D2, the presence of pulses of same pulse height in both detectors does not conform with the standard physics picture. Even if they enter to theD2, the pulse heights are not expected to be the same.

2. If the N-gamma decays to N ordinary or dark gammas, it might be easier to understand why the pulse heights are the same.

It is a good to start with an objection. That pulse heights are the same for both detectors, could be simply due to the fact that detectors are ideal yes-no detectors, which are (quantum) critical systems in the sense that incoming gamma rays serve as a control acting producing the same response irrespective of their number and energies. In this case, the secondary gamma rays from the D1 could induce the same response in the D2.

It turns out that the detectors could be ideal for the detection of dark gammas but not not for the detection of the ordinary gammas. The detailed model shows that standard physics picture cannot explain the causal pulse pairs with the same pulse height.

There are other observations of Reiter, which strongly suggest that new nuclear physics is involved.

5.2.1 The dependence of the unquantum effect on the chemistry of the gamma source

Unquantum effect depends on the chemistry of the source [H2]. This is observed when ^{109}Cd is used as a source. ^{109}Cd appears as salt or metal and salt produces 5 times larger unquantum effect, i.e. the rate of counts is 5 times higher. The proposed interpretation is that gamma waves from salt are more coherent. This behavior suggests that gamma emission is not a single-nucleus effect as standard nuclear physics would predict but involves many nuclei. Hence new nuclear physics would be involved.

Why would the nuclei of ^{109}Cd salt form larger quantum coherent structures? What these structures could be?

1. That several nuclei would be involved with the emission of gammas conforms with the N-gamma model in which N parallel gammas are emitted simultaneously as N-gamma in quantum coherent N-nucleus transition. N-gamma beam is analogous to B-E condensate of N gammas that is an N-photon state with identical photons. Intensity of N-gamma beam from different nuclei higher.

2. Also coherent states of gammas as superpositions of N-gammas for various values of N can be considered. This state would behave as classically as possible. Intuitively the unquantum effect indeed corresponds to effective classicality.

   Putting it more precisely, coherent state is an eigenstate of the annihilation operator of the photon and has the form $exp(\alpha a^\dagger)|0\rangle$, where α is a complex parameter. The expectation value and variance of photon number N are given by $|N| = |\alpha|^2$ and $|\Delta N^2| = |\alpha|^2$. $|\alpha|^2$ is analogous to field intensity. The larger its value, the more classical the state is.

   The value of $|\alpha|^2$ should be larger for ^{109}Cd salt than for ^{109}Cd metal. The coherence of gammas would directly reflect the quantum coherence of ^{109}Cd as a many-nucleon system: this coherence is impossible in standard physics picture.

The larger the size of quantum coherence length in the gamma source, the larger the value of N if every nucleus emits identical gamma simultaneously. The scale of quantum coherence scales like h_{eff} and N like $(h_{eff}/h)^3(L_n/L_a)^3$ if the coherence region is spherical. Here $L_n \sim 10^{-14}$ m is nuclear scale and $L_a \simeq 10^{-10}$ m is atomic scale. One must $h_{eff}/h >> h_{eff,min}/h = (L_n/L_a)^3 = 10^{12}$ for the spherical option and $h_{eff}/h >> h_{eff,min}/h = (L_n/L_a) = 10^4$ for the linear option.

A couple of remarks are in order.

1. In TGD inspired quantum biology [L34] flux tubes carrying dark protons define linear coherence regions giving $N \propto (h_{eff}/h) \times (L_n/L_a)$.

2. In cold fusion the distance of dark protons at flux tube is about electron Compton length $L_e \simeq 10^{-12}$ m, one has $h_{eff}/h \simeq m_p/m_e \simeq 2000$ [L21, L3].

5.2.2 The dependence of the unquantum effect on the detector-source distance and gamma wave length

The intensity of the unquantum effect depends on the wavelength λ of gamma and distance d between source and detectors [H2].

1. ^{241}Am emits gammas with energy $E = 59.5$ keV, which corresponds to wave length $\lambda = 2.1 \times 10^{-11}$ m. The UQ effect is enhanced as the distance d between the source and detector decreases.

2. ^{1}37Cs produces gammas with a shorter wavelength λ (gamma energy and wavelength are $E = .6617$ MeV and $\lambda 1.86 \times 10^{-12}$ m). UQ effect is enhanced when d increases.

What enhanced UQ effect means is not quite clear. Does the height or the rate for pulses increase? From private communications I learned that the correct identification of enhancement is as an increase for the rate of pulses.

How to understand this behavior? Distance d is certainly a relevant variable. But is this true for λ? N correlates with the size of the nuclear quantum coherent state. Could N be the relevant variable instead of λ. It is best to build a concrete view for what happens in the decay of N-gamma to N gammas.

1. N-gamma is analogous to B-E condensate of N gammas which have $h_{eff} > h$. B-E condensate is formed from ordinary photons which in general do not have parallel momenta and identical energies. The phase transition however creates this kind of state. The phase transition occurs by addition of photons to the B-E condensate and takes some time.

2. Does this phase transition occur before the detectors or inside the detectors and is perhaps induced by the interaction with the detector materials?

Consider the option for which the decay occurs before the detector.

1. The decay of N-gamma is the reversal of Bose-Einstein condensation. Therefore the N-gamma must decay during some time interval to N gammas which do not have exactly parallel momenta. These gammas move inside a cone with some opening angle. The intensity of the gamma beam decreases with distance like $1/r^2$, where r is the distance from the point of phase transition. The number of (possibly dark) gammas, which arrive the detector decreases with the distance d of the detector from the phase transition region. If more than one gamma contributes to the pulse, one can understand why the height of the peak is reduced with the distance. If only one, the reduction does not occur.

2. On the other hand, the detector must be far enough from the source so that the phase transition to ordinary gammas has already occurred. If the decay of N-gamma to gammas takes place gradually and only the gammas interact with the detector the peak height increases with the distance from the phase transition. This is true if the interaction of the still existing M-gamma state ($1 < M < N$) with the detector is so weak that it goes through the detector without interaction with a high probability.

The prediction of the model depends on whether the N gammas produced by the decay of N-gamma produce single pulse or separate pulses which can be distinguished from each other.

1. Suppose that the the gammas interact simultaneously to produce a single pulse. In this case, the two constraints imply that there is some distance at which the *pulse height is maximal.* For Am having larger gamma wavelength d would be larger than the optimal distance and forCs with smaller gamma wave d would be smaller than optimal distance d_{opt}. Note that the optimal distance depends on N and therefore the size scale of coherent regions of nuclei. Intuitively it seems clear that the optimal distance increases with N since the decay time of a larger B-E condensate is expected to be longer. The dependnce of pulse height on distance does not conform with Reiter's report.

2. If the gammas have slightly different directions within the cone, they arrive at slightly different times to the detector. If the gammas give rise to separate pulses, the *pulse rate* should depend on the distance as reported by Reiter. The time to travel a distance of say 30 cm defining the detector's transversal scale is about 1 ns. Therefore the gammas resulting from single N-gamma would give rise to separate pulses.

Consider next a more concrete model based on a modification of Reiter's own interpretation. The transversal width of the gamma wave packet is proportional to $d\lambda$, $d = ct$ is the distance travelled. This what Schrödinger equation as a diffusion type equation suggests for massive particle - λ would be in this case Compton wave-length $\hbar/m$. Reiter argues that maximal effect is obtained when $d\lambda$ is equal to theCompton area of the electron.

TGD inspires a modification of Reiter's idea.

1. Massless extremals (MEs) serve as classical correlates for radiation. They are very general 4-surfaces of form $F(s, k \cdot m, \epsilon \cdot m) = 0$. m denotes M^4 coordinates, s CP_2 coordinates, k is light-like vector in M^4 and ϵ is a polarization vector orthogonal to wave vector. More general MEs with $\epsilon \cdot m$ replaced with arbitrary function of coordinate of plane orthogonal to k meaning local polarization orthogonal to k are also possible.

2. The simplest ME would be cylindrical but much more general - say cone-like - MEs are possible. Quantum classical correspondence suggests that the area S of the transversal cross section of ME increases during the propagation like $\lambda t = \lambda d/c$: an analog of conical wave would be in question.

3. Suppose that ME contains N dark gammas produced by the decay of BE-condensate. All dark gammas should reach the detector to obtain maximum number of pulses. S should be as small as possible but contain the detector area. This implies optimal values $S = S_{opt}$ and $d = d_{opt}$ for S and d.

4. If ME contains the N gammas from the decay of N-gamma, the different directions of motion for gammas could imply that the gammas generate separate pulses. 1 ns was the rough estimate for the time difference of pulses.

One can consider also the option that the N-gamma decays inside the detector volume rather than before it and produces a *single* pulse consisting of N simultaneous pulses. In this case the N-gamma delocalized into the transversal cross section of ME does not always interact with the detector material for $S > S_{opt}$ minimal so that the rate decreases with increasing $d > d_{opt}$. For $d < d_{opt}$, one has $S < S_{min}$ and the number of N-gammas entering detector does not depend on d so that the pulse rate should not decrease with decreasing d. This does not conform with the report of Reiter.

5.2.3 Why the pulse heights in the two detectors are the same?

Pulse heights in the two detectors are reported to be the same. This explanation might involve both new physics and understanding of the functioning of the detector.

It would seem that the conical beam consisting of N gammas is not considerably attenuated in the D1 which is a thin crystal. If the gammas are dark, the interaction with the detector would involve transformation of dark gamma to ordinary gamma and the probability for this process is expected to be low. This alone could explain why the beam is not considerably attenuated in the D1.

Since the D2 is thicker, also an additional condition must be satisfied. Only the gammas arriving absorbed by electrons (or possibly Compton scattered for half pulses) during some time interval ΔT can contribute to the pulse. The detector would therefore have a time resolution ΔT in the sense that the gammas arriving after this time would not affect the height of the pulse. Detector would be analogous to a neuron which has some dead time after the arrival of the nerve pulse.

Effectively the detector would serve as a yes-no detector telling whether dark N-gamma arrived or not and would be analogous to a quantum critical systemwhose response does not depend on the strength of control action but only on its existence.

Suppose that a conical beam of N (possibly dark) gammas arrives the D1.

1. If only the gammas arriving during ΔT and interacting with electrons of the detector contribute to the pulse, the same pulse height is obtained in both detectors if the number M of interacting gammas is high enough. This suggests that N must be large enough so that the product $M = pN$ is large enough. Here p is the probability of dark-to-ordinary transition. The detector would not react to later gammas.

2. The value of M decreases with the distance of the detector from the phase transition regions by the conical character of the beam. It is however essential that the detectors are not too far from each other. This could be tested.

One cannot exclude the possibility that the secondary gammas, which are ordinary gammas, from the D1 cause a pulse in the D2. In this case, one cannot expect identical pulse heights.

If $h_{eff} > h$ is true for gammas, one can imagine that one prevents the arrival of the secondary gammas from the D1 to the second one. Dark gammas could however get through and cause detection. This could be used to see whether the primary gammas are dark.

5.2.4 Does unquantum effect disappear as the source is aged?

The basic feature of quantum coherence is that it is eventually lost. Since the energy of the state increases with h_{eff} as other parameters are kept constant, the increase of h_{eff}requires energy feed. Since h_{eff} tends to be reduced spontaneously, its preservation requires energy feed. In living matter this corresponds to metabolic energy feed [L2, L34].

This predicts that quantum coherence of the source is gradually lost so that for an old enough source the effect is eventually lost. If the number N of dark nuclei gradually decreases with time, the height of the maximal pulse gradually decreases.

What could induce the quantum coherence by energy feed?

1. In Pollack effect induced by energy feed by say photons [I2, L2, I4, I3] called exclusion zones (EZs) having negative charge are formed. IR photons with an energy corresponding to room temperature are the most effective.The effective stoichiometry of water molecules is $H_{1.5}O$ suggesting that every fourth water molecule loses a proton and becomes negatively charged.

2. The TGD based interpretation is that every fourth water molecule loses a proton which transforms to a dark proton with $h_{eff} = nh_0 > h$ sequences of dark protons - dark nuclei - are formed at the flux tubes. Quantum coherence would be caused by a feed of photons. The sequences of dark protons have a total energy slightly larger than the energy for protons bound to water molecules.

3. A dark analog of the nuclear binding energy would be involved but would be scaled down by the ratio of p-adic length scales of the nucleus and dark nucleus. eV as the scale of molecular binding energies would be a natural unit for the dark nuclear binding energy.

   The binding of dark protons at the flux tube would be by meson-like flux tube bonds in a shorter scale. The energy of the bond would be inversely proportional to its length and therefore much smaller than for ordinary nuclei which would also be nuclear strings [L1].

4. Also the TGD based model of "cold fusion" [L3, L10, L21] involves the analog of Pollack effect. The spontaneous transformation of dark nuclei to ordinary ones would liberate almost all nuclear binding energy. The model suggests a generalization also to the case of dark ions.

In principle, one can also consider the possibility that the loaded states of Reiter correspond to N-gammas formed at detectors. The dependence of the pulse rate on the chemistry of the source and on the distance between the source and detector are however not consistent with this hypothesis.

5.2.5 Quantitative model for the unquantum effect

TGD based model assumes N-gamma decaying to N dark gammas with $h_{eff} > h$ before the D1. Both Compton scattering and absorption are preceded by a transformation of dark gamma to ordinary gamma occurring with probability p. These events follow binomial distribution $B(p, N)$.

One can also consider a situation in which 2 or more gammas are absorbed within a time interval Δt so short that they create only a single pulse but with a height, which is twice the height of a single gamma pulse. Higher multiples with n-fold pulse height are also possible.

A rough estimate for Δt is of order 1 ns. Let the probability for the co-incidencebe p_{coind}. The probability distribution of this kind of events for a sample of M pulses from N-gamma obeys binomial distribution $B(p_{coind}, M)$. In the following only the first case is considered.

1. Assume that N dark gammas enter the D1 and $M_{1,a} \equiv M_1 < N$ dark gammas transform to ordinary gammas and are absorbed. Besides this there are $M_{1,c}$ gammas suffering Compton scattering and possibly ending up to the D2. This gives a contribution similar to that of a beam of $M_{1,c}$ Compton scattered gammas. In the following only the situation in which $M_{1,c} = 0$ is considered. The number of dark gammas entering the D2 is in this case $N_1 = N - M_1$. Assume $M_1 << N$.

   If the pulse height depends on $E_{lost} = E$ only and does not depend on the detector thickness d, the pulse heights of single absorbed dark gamma is the same in the two detectors. This would give rise to causal pulse pairs with the same pulse height.

   If the D2 is so thick that $E_{lost} = E_1$ in Compton scattering, the pulse heights are nearly the same if $E_1 \simeq E$ is true.

2. Restrict the consideration to M absorbed gammas in both detectors. For a linear response,the absorbed energy is $E_{lost,1} = M_1 E$ in the D1 and $E_{lost,2} = M_2 E$ in the D2. The total pulse height is N_i times that for a single gamma. The linearity assumption is not essential: also non-linear response function gives a quantized response.

3. The detection gives rise to causal pulse pairs (M_1, M_2) labelled by the numbers M_1 and M_2 of absorbed dark gammas. By previous arguments the individual M_i pulses should sum up to a single pulse.

4. One should explain the dominance of (M_1, M_1) causal pairs. The probability that M_1 dark gammas are absorbed depends on M_1 and and a good first guess is that one obtains a Gaussian distribution concentrated around $M_{1,max}$ and $M_{2,max}$ in the two detectors. $M_{1,max} = M_{2,max}$ is in good approximation true if N and $N - N_1$ are nearly the same.

The estimation of M_{max} is straightforward by noticing that the number of absorbed dark gammas obeys binomialdistribution.

1. The probability that M_1 dark gammas are absorbed and nothing happens to the remaining $N - M_1$ gammas is given by

$$P(M_1 : N) = Bin(N, M_1)p^{M_1} \times (1-p)^{N-M_1} \quad , \quad Bin(N, M_1) = \frac{N!}{M_1!(N-M_1)!} \quad . \tag{5.1}$$

p is the probability that a single dark gamma transforms to ordinary gamma.

2. One can estimate the maximum of $P(M_1 : N)$ by approximating M_1 with a continuous variable so that maximum satisfies the condition$dP(M_1 : N)/dM_1 = 0$. This gives the following condition for the logarithmic derivative of binomial coefficient $Bin(N, M_1)$:

$$\frac{dlog[Bin(N, M_1)]}{dM_1} = log(\frac{1-p}{p}) \quad . \tag{5.2}$$

By using Stirling approximation for $log(M!) \simeq log(c) + M^{M+1/2} - M$, where c is constant, one obtains in the case$N >> 1$ ja $M_1 >> 1$

$$M_{max:N} = pN \quad . \tag{5.3}$$

The result could have been guessed.

3. An improved approximation can be obtained by iterating the formula

$$M_{max:N} = pN \times exp(-\frac{1}{2M_{max:N}}) \quad .$$

The next approximation is

$$M_{max:N} = pN \times exp(-\frac{1}{2pN}) \quad . \tag{5.4}$$

4. The ratio of the probabilities $P(M_1)$ and $P(M_1 + 1)$ is given by

$$\frac{P(M_1 + 1 : N)}{P(M_1 : N)} = \frac{p}{1-p}\frac{N - M_1}{M_1} \quad .$$

At the maximum this gives in the first approximation

$$\frac{P(M_{max} + 1)}{P(M_{max})} = \frac{p}{p + \frac{1}{N}} < 1 \quad .$$

By stationarity the values are near to each other.

5. Binomial distribution concentrates strongly around the maximum and allows an approximation as Gaussian distribution with mean (maximum) $M_{max:N} = pN$ and variance $\sigma^2 = Np(1-p)$ (`https://cutt.ly/ovOQZ3o`). The Gaussian approximation is given by

$$P(M_1 : N) \simeq \frac{1}{\sqrt{2\pi Np(1-p)}} exp[\frac{(M_1 - pN)^2}{2Np(1-p)}] \quad . \tag{5.5}$$

6. The probability distribution $P(M_1, M_2)$ for the pulse heights of causal pairs is a product of gaussians associated with N and $N - N_1 \simeq N$ and strongly concentrated around $M_{1,max}, M_{2,max}$ with $M_{1,max} \simeq M_{2,max}$. Hence the model predicts the observed causally related pulse pairs of the same height.

The discussed model is over-simplified since all M dark gammas transforming to ordinary gammas were assumed to suffer absorption.

1. The model based on the binomial distribution applies to the number of M gammas transforming to ordinary gammas also when $M_c \leq M$ of these gammas suffer Compton scattering.

2. Also the $M_c \leq M$ Compton scattered pulses obey binomial distribution. The parameter p is replaced with the probability p_c for Compton scattering. $1 - p_c$ is the probability for the absorption.

   In this case the most probable number of Compton scattered photons is

$$N_{c,max} = p_c M = p_c N_{max} = p_c p N \quad . \tag{5.6}$$

3. In Compton scattering, the energy lost in the detector volume is in general smaller than in the absorption and the total energy lost in the detector is smaller. Therefore causal pulse pairs can have different energies and pulses have a height lower than maximal.Theformulafor $N_{c,max}$ allows to estimate the energy lost in the most probable event and therefore also the pulse height in terms of average energy lost in Compton scattering parameterizable as $E_{lost,c} = xE$, where E is gamma energy.

4. Pulse pairs of the same full pulse height could correspond to the most probable pairs with lost energy which is the sum of the energy $E_{lost,a}$ lost by absorption and the energy $E_{lost,c}$ lost in Compton scattering:

$$E_{lost} = E_{lost,a} + E_{lost,c} = pN[1 - p_c + p_c x]E \quad . \tag{5.7}$$

   This phenomenon could relate to the appearance of half pulses (with height, which is by definition less than 2/3 of that for full pulse) although also gammas which leak from the D1 couldbe involved.

5.2.6 Beam splitter experiments involving gammas and alphas

Reiter has also carried out experiments involving beam splitter causing thesplitting of the beam to reflected and refracted beams going to two separatedetectors. Experiments with both gamma beam splitter [**?**]nd with alpha ray beams (appendix II of [**?**]plitter have been carried out. For alpha rays only half pulse heights are observed.

Standard quantum theory predicts that either a reflection or refraction occurs and for single gamma either detector fires.

1. In 2-1 cases when energy is conserved, the pulses correspond to separate incoming photons. At least two photons arrive at the beam splitter.

2. One can understand simultaneous pulses with equal pulse heights, if a N gammas instead of a single gamma-ray arrives at the beam splitter simultaneously. The incoming particle couldbe N-gamma decaying to N gammas either before the beam splitter or in the beam splitter. The N gammas would be distributed between the two detectors and two separate pulses would be obtained. The average pulse heights would be identical if the probability p for the reflection is the same as the probability $1 - p$ for transmission. This would give $p = 1/2$.

   The total energy going to detectors should correspond to the energy of gamma and this is found for half-pulses. The numbers k and $N - k$ are determined by binomial distribution having appromation as Gaussian distribution and the numberof gammas going to the two detectors would be pN gammas and $1-pN$. Same height for pulses would require $p=1/2$. It is not clear why $p=1/2$ is favored but it is not clear how this could be possible.

3. One can also consider the possibility that N-gamma splits in physical sense into $N-k$- and k-gammas in the beam splitter and that the two parts go to separate detectors. In this case the average pulse heights should be identical. The maximum of the Gaussian pulse height distribution would correspond to $N/2$ in both detectors.

The model should also explain similar beam splitter findings for alpha particles [?]ehaving like bosons. The direct generalization of the N-gamma model in the case of beam splitter would require that atoms in the alpha source ^{241}Am (Americium is used as alpha source in smoke detectors) form a quantum coherent state in a scale longer than atomic size scale. This state could be an atomic B-E condensate of N atoms and emit N entangled possibly dark alphas simultaneously. This B-E condensate would decay to dark or ordinary alphas.

The decay could happen before the detector, or inside the beam splitter as a genuine physical decay of N gamma to $N-k$ gamma and k-gamma caused by the interaction with the beam splitter. In this case one would not have a quantal beam splitting and the reported energy conservation supportsthis. If the probability distribution for the pair $(k, N-k)$ gamma is a Gaussian centered around $k-N/2$, then $k=N/2$, and for the most probable pulse pulses have the same heights.

To my opinion, the notions of gamma and alpha beam splitter are far from trivial since the wavelengths for gammas are about 10^{-11} m and far below the optical range 10 nm -1 mm and for 5 MeV alpha equal 1.1 fm.

For optical mirrors (`https://cutt.ly/ebQqdJs`), the wavelength range varies from 10 nm to 1 mm. Quite generally, beam splitting involves notions like reflection and refraction which require coherence in scales much longer than atomic length. More precisely, a selection of single direction in the elastic Compton scattering from the beam splitter requires destructive interference and this is possible only if there is quantum coherence in a scale of few hundred atoms so that amplitudes from separate atoms, which are essentially Fourier transforms along the coordinate parallel to the beam splitter interfere. This coherence looks far from obvious for wavelengths considerably shorter than 10 nm.

X-ray mirrors and beam splitters and even gamma ray mirrors exist [D3] (`https://cutt.ly/dbQqbXR`). Also a discovery of a gamma ray lense [C2] (`https://cutt.ly/ObQqQn3`) has been reported. Gamma ray lense has been regarded as impossible and the discovery was a total surprise.

These observations raise the question whether gamma ray mirrors are possible in standard physics. Could it be that the required coherence is provided by a large value of h_{eff} at the space-time sheet of the dark gamma. Although the interaction with ordinary matter would probably involve reduction $h_{eff} \rightarrow h$, the quantum coherence would induce the needed coherence. $h_{eff} \sim 10^5$ would imply that gamma coherence length would be of order μm and one would have optics. In the case of α particles the quantum coherence scale would be of order atomic length scale.

The difference between X-ray mirrors and gamma-ray mirrors is that, unlike in the case of optical mirrors, the grazing angle θ of the beam must be very small so that the beam is almost parallel to the plane of the mirror.

If one imagines the beam as a tube having a finite transversal area, the length r of the projection of the tube to the mirror stretches to $R = r/tan(\theta)$ so that the coherence area S scales to $S/tan(\theta)$ and makes possible interference effects for small enough θ. If the transverse cross section is disk, it stretches to an ellipsoid.

Optical wavelengths are above $d_{opt} = 10$ nm, which suggests that one must have $R \geq d_{opt}$. If the radius r of tube is of order $r = \lambda = 10^{-11}$ m, the maximum grazing angle corresponds to $R = r/tan(\theta) \sim d_{opt}$ or $\theta \sim 10^{-3}$ or $\theta_{max} \sim .006$ degrees.

The thinness of the tube is a possible problem: $r \sim \lambda = 10^{-11}$ m allows gamma the tube to cover the Bohr radius of valence electron proportional to $(Z/n)^2$ but the fraction of the covered atomic volume with radius $a \sim 10^{-10}$ m is $(n/Z)^6(a_0/a)^3$, which is very small number for $Z = 53$ and $n = 5$ so that most tubes fail to hit the atom.

In the TGD framework, quantum classical correspondence suggests that flux tube corresponds to ME with transversal scale determined by λ scaling like h_{eff}/h so that for dark gammas $tan(\theta_{max})$ is scaled by a factor h_{eff}/h. For $h_{eff}/sim10^5$, one has $\lambda \sim 1$ μm so that the situation would reduce to optics for visible light. Even $h_{eff}/sim10^3$ is enough to guarantee this.

5.3 Connection with TGD based views about superfluidity, nuclear physics, and quantum biology

In this section possible connections with the h TGD based views about superfluidity, nuclear physics, and quantum biology are discussed.

5.3.1 Is quantum coherence associated with dark superfluidity?

What comes to mind is that the quantum coherence is associated with a dark variant of superfluid with ^4He or ^3He atoms replaced by heavy atoms. An old proposal is that since TGD predicts the possibility of long range classical Z^0 fields, the superfluidity could have interpretation as Z^0 superconductivity and relate to the large weak isospin due to the neutron surplus possible for heavy nuclei.

1. The dimension analytic estimate for the critical temperature for the transition to 3-D superfluidity is of the following general form [D2] (`https://cutt.ly/4v619RJ`):

$$T_{cr} = k\frac{\hbar M}{n}{}_3^{2/3} \quad M = Am_p \quad k = 3.31 \ . \tag{5.8}$$

   The value of k follows from a model assuming ideal gas above critical temperature. For ^4He mass number is $A = 4$. The density $\rho = 125$ kg/m^3 of ^{4}He gives $n_3 = \rho/Am_p$ and the resulting estimate is $T_{cr} \simeq 3$K to be compared to the actual critical temperature $T_{cr} = 2.17$ K.

2. In 1-D case corresponding to dark flux tube superfluidity for heavy nuclei or atoms, the formula generalizes

$$\begin{array}{lll} T_{cr} = \frac{k}{A}r\frac{\hbar}{m_p}n_1^2 & r = \frac{\hbar_{eff}}{\hbar} & n_1 = \frac{X}{a} \ , \\ a = 10^{-10} \ m \ , & m_p = .938 \times 10^9 eV \ . & \end{array} \tag{5.9}$$

3. The condition that the critical temperature exceeds room temperature gives

$$\begin{array}{ll} T_{cr} = \frac{kX^2}{A}rYm_p \geq T_{room} \ , & Y = (\frac{\hbar}{m_p a})^2 \ . \\ T_{room} = 3 \times 10^{-2} \ eV & Ym_p = 4.1 \times 10^{-3} \ eV \ . \end{array} \tag{5.10}$$

   The condition gives

$$r \geq \frac{7.32}{kX^2} \times A \ . \tag{5.11}$$

   For $k = 3.31$ (this estimate need not be realistic) this would give $r \geq 2.2A/X^2$. For $A = 137$ this gives $r \geq 301/X^2$. The value is consistent with the earlier estimate of order $2^8 = 256$.

4. For N-dimensional case with $N = 2, 3$ the formula generalizes to

$$r \geq \frac{7.32}{kX^{2/N}} \times A \ . \tag{5.12}$$

   Since X is near unity, the estimate is not expected to change much.

The condition that the quantum coherence length increases in the scaling by $r = h_{eff}/h$ from the size scale of heavy nucleus about 10^{-14} m (this corresponds to the nuclear p-adic length scale $L(113)$) to at least atomic scale about $a = 10^{-10}$ m (this corresponds to p-adic length scale $L(137)$) gives the condition $r \geq L(137)/L(113) = 2^{137-113}/2 = 2^{12} \sim 4000$. This would give

$$T_{cr} \geq \frac{2^{12}kX^2}{7.32A}T_{room} \ .$$

Critical temperatures higher than room temperature are possible. For $A = 137$ one has $T_{cr} \geq kX^2 \times 4.1 \times T_{room}$.

5.3.2 Connection with "cold fusion" and TGD view about nuclear reactions

What could be the mechanism leading to the formation of superfluid regions consisting of gamma emitting isotope (https://cutt.ly/1bwAjTe)? The sources used (57Co, 109Cd,137Cd) can be obtained by an irradiation of a sample of a material which is an isotope with the same atomic number by thermal neutrons in a nuclear reactor. It is also possible to a nucleus with different mass number and charge by protons or deuterons inducing nuclear reactions leading to the source nucleus, which canbe in an excited state and can suffer gamma emission or beta decay or electron capture followed by gamma emission. 137Cd is also obtained in the fission of a heavier nucleus such as uranium or plutonium induced by a neutron bombarded in a nuclear reactor.

The mechanism for the formation of the superfluid state should be general and independent of the production mechanism.

One can imagine at least two mechanisms.

1. The superfluid state is created by electron capture occurring coherently. If the electrons- say conduction electrons - form a macroscopic quantum state with h_{eff}, which is so large that it corresponds to a length scale larger than atomic size scale for the nuclei, N-capture of electrons could occur and lead to a super fluid state of a nuclear isomer.

2. The energy needed to create the superfluid state comes from the irradiation process. The formation of the superfluid state is analogous to a local melting of the crystal state.

   One can guess that the energy needed for the melting is of the order of 10 keV per nucleus since this energy corresponds to the energy assignable to a photon with wavelength given by atomic length scale $a = .1$nm by Uncertainty Principle. To generate a volume containing $N \sim 100$ dark nuclei, an energy of order MeV is needed and this is the nuclear energy scale.

Consider in more detail the latter option. What can one say of the detailed mechanism for the formation of the superfluid regions by - say - neutrons coming from a nuclear reactor?

1. Since isotope number and even atomic number change, the formation of an N-nucleon state requires absorption of N-something: N-neutron, N-proton, N-deuteron, etc.. The standard picture about nuclear reactions does not support this. The TGD based model for "cold fusion" [L17, L10, L21] based on the notion of dark nucleus however inspires the notion of dark super-nucleus - N-nucleus- as a sequence of dark protons, neutrons, and even heavier nuclei at magnetic flux tube and behaving like single quantum coherent unit - just like N-gamma.

   In the Pollack effect the dark nuclei - N-protons - would be created from ordinary protons and the nuclear binding energy would be scaled down to energy measured using eV as a natural unit. The decay of dark nuclei to ordinary nuclei would liberate almost all nuclear binding energy.

   What would happen as crystal N-absorbs (say) N-neutron and N-neutron absorption occurs? The scaled up Compton length of dark neutrons of N-neutron should be atomic scale. The neutrons of the dark nuclear flux tube should fuse with the nuclei of the irradiated crystal. The target nuclei must become dark before fusion: this requires their transfer to the dark flux tube of N-neutron. This picture generalizes to more general N-nuclear reactions.

2. There is an important delicacy involved. The dark protons of N-proton are connected by flux tube bonds behaving like mesons. They can be analogs of neutral pions but also charged pions are possible.

   A long-standingopen question [L1]is whether the neutrons inside nuclei are actually protons accompanied by a negatively charged flux tube bond.For large values of h_{eff} also weak boson Compton scales are scaled up and they behave like massless particles below Compton length which can be even biological scale.

   This could explain the mystery of large parity breaking effects in biology manifesting themselves as chiral selection. This would make possible fast change of the charge of the flux tube bonds by an emission of effectively massless dark W boson.

3. The findings of Prof. Holmlid [C3, L7] were important in the development of the model. Holmlid proposed that "cold fusion" involves a formation of a super dense phase of deuterium nuclei. The distance between nuclei would be of order electron Compton length and by roughly two orders of magnitude smaller than atomic size scale .1 nm.

   The TGD explanation [L3, L7, L10, L21] is that sequences of dark nuclei at flux tubes are formed as "super-nuclei" (N-nuclei). For nucleon (p or n) sequences - dark nuclei - the nuclear binding energy associated with the bonds connecting nucleons of the ordinary nucleus is reduced by the ratio m_e/m_p of proton and electron Compton lengths. For a sequence of heavier nuclei the bonds carry the dark nuclear energy but nuclei have the ordinary binding energy.

4. This picture led to a model for the tunneling [L17, L22] assumed to make possible nuclear reactions at energies roughly two orders of magnitude below the Coulomb wall. As a matter of fact, this model of tunneling applies to all interactions. In phenomenological potential models tunneling is described in terms of Schrödinger equation. The TGD based model also providesa new vision about pre-stellar and stellar evolution [L17].

   In TGD framework tunneling would correspond in zero energy ontology (ZEO) a pair of "big" (ordinary) state function reductions (BSFRs) in which the arrow of time changes. The first BSFR would createthe intermediate "tunneling" state from the initial state nuclei and the second BSFR would initiate its decay to the final state nuclei. In the intermediate quantum critical state one would have $h_{eff} > h$ making possible long range correlations characterizing critical state. Super-nuclei (N-nuclei) would be formed also in the ordinary nuclear reactions in intermediate states.

   The formation of these dark time-reversed intermediate states is possible in ordinary nuclear reactions only if the colliding nuclei have high enough kinetic energies so that the nuclear bond energy can be reduced in the scaling induced by $h \rightarrow h_{eff}$. The formation of N-nuclei as an explanation of "cold fusion" would be the basic mechanism behind all nuclear reactions. In "cold fusion" there would be no nuclear binding energy in the initial state so that it could occur at low temperatures: "cold fusion" would serve as a "warm-up band" in prestellar evolution [L17].

   This picture would suggest that dark N-nuclei assequences of dark protons, neutrons, deuterons or even heavier nuclei - N-protons, N-neutrons, N-deuterons, etc... can be produced also in nuclear reactions as intermediate states. They can emit N-gammas and can split into lighter N-nuclei. Ordinary nuclear physics could be perhaps replaced in these states by the physics of N-nuclei.

5. Prof. Holmlid [L7] has reported some "impossible" observations supporting this view. He found that in "cold fusion" also muon with mass of 105.6 MeV and mesons such as kaon with mass around 490 MeV are observed. This is impossible in the ordinary nuclear reactions, where 1 MeV is the natural energy scale.

   Hadronic interactions are clearly required. Could N-nucleus consisting of N nuclei emit N-gamma which transforms to ordinary gamma, which annihilates to hadrons? N-gamma with $N = 200$ and single gamma energy of 1 MeV would have energy of 1000 MeV - about proton mass - and decayto a kaon pair.

5.3.3 Connection between Pollack effect and bio-superconductivity

The model in terms of superfluidity was inspired by the model of Pollack effect involving flux tubes carrying dark protons. Could the model for Pollack effect in turn be formulated in terms of superfluidity/superconductivity?

1. The model of genetic code based on dark proton triplets as a representation for genetic codons correctly predicts the numbers of various basic biomolecules as also genetic code [L5, L13]. There is however a problem: Bose-Einstein condensate requires Cooper pairs but proton triplets are fermions.

2. The TGD based model of high Tc bio-superconductivity [K1, K2] and possibly also of bio-super-fluidity as Z^0 superconductivity relies on flux tube pairs, which are also associated with DNA double strands. Cooper pairs are pairs of dark fermions located at separate parallel flux tubes.

3. The number theory based model [L34] for the dark variant of DNA double strand as a helically winded pair of magnetic flux tubes assumes that the dark 3-proton codons at flux tubes are paired. This pairing would induce the base pairing of the ordinary DNA strands accompanying the dark strands. The paired dark codons would represent the Cooper pairs.

4. The number theoretic interpretation is in terms of Galois confinement analogous to color confinement [L34, **?**]. Codons themselves are analogous to baryons as color confined quark triplets.

   There is a hierarchy of Galois groups correspond to a hierarchical representation of an extension E of rationals as extension E_n of extension E_{n-1} of ... extension E_1 of rationals giving rise to the Galois group G of E as an extension of rationals. G is the product of Galois groups $G(E_i, E_{i-1})$characterizing E_i as extension of E_{i-1} in the sequence [L25].

   Color confinement is replaced with Galois confinement with respect toa Z_3 subgroup of G. The pairs of two dark proton triplets in turn form Galois singlets with respect to a Z_2 subgroup of G. Genes correspond to Galois singlets with respect to a larger subgroup of G assignable to the 4-surface defined by the gene.Genes and smaller sub-units behave as quantum coherent units.

   Also the dark photon realization of the genetic code relies on Galois confinement so that dark N-photons behave like a single particle as would also dark N-codons do. N-nucleus and N-gamma could be even more than analogs of genes since in the TGDUniverse genetic code could be realized universally in terms of the hyperbolic geometry of the light-cone hyperboloid H^3 [L26] and be based on the tetra-icosahedral tessellation defining the simplest tessellationof H^3.

5.4 Conclusions

One can divide the findings of Reiter into two classes.

1. The observations that the pulse rate depends on the chemistry of the gamma source and on the distance between detector and source strongly suggest the presence of new nuclear physics and nuclear quantum coherence above atomic scale. In the TGD framework, the notion of N-gamma as an analog of B-E condensate and the model for its decay to N gamms explain these findings.

   What is important that these findings can be made without the presence of the D2.

2. The observation that the pulse heights for causal pairs are the same, does not have an explanation in terms of a secondary gamma from the D1 generating a pulse in the D2.

3. TGD based model explains the the causal pairs with identical pulse heights but predicts a distribution of pulse height pairs which is product of two binomial distributions with nearly the same maximum and variance and allowing approximation as bimnomial distributions. Causal pairs of same height correspond to maxima of these distributions.

The TGD based explains also the reported dependence of the pulse rate on the chemistry of the source and and on the distance between source and detectors. One can imagine two experimental arrangements for testing this explanation.

1. One can imagine at least a thought experiment using a scintillator, which is a network of conducting wires allowing to observe the positions of gammas inducing response and to see whether the input contains several gammas. This could directly provide support for the N-gamma hypothesis.

2. If it is possible to prevent the leakage of the secondary gamma rays from the D1 to the D2 (simply by making the first NaI detector thicker than the attenuation length L), the observation of causally related pulses in both detectors could be seen as a direct support for the hypothesis that N-gamma decays to N dark gammas.

5.4.1 Could X ray fluorescence of Iodine cause co-incidences?

In private communications I learned that the X ray fluorescence of Iodine could cause X rays passing from D1 through the tin foil to D2 or vice versa and cause pulses which might be perhaps confused with the gamma ray pulses.

Fluorescence is due to the dropping of an electron to the vacancy created by the ionization of an electron of the Iodine atom. This can happen only for the inner electrons below the $n = 5$ valence shell, where n is the principal quantum number labelling the rows of the Periodic Table. In the Bohr model, the energy for the shell labelled by n is given by $E(n) = (Z/n)^2 E_H$, $E_H = 13.6$ eV.

For Iodine one has $Z = 55$. X ray with s maximal energy is liberated if $n = 1$ electron is kicked out in the ionization and $n = 5$ valence electron fills the vacancy. In the Bohr model the energy of the X ray is very near to 34 keV, which is roughly 1/3 times the energy of 100 keV gamma ray. If the detector response is linear in energy, the pulse height is about 1/3 from that of gamma so that the experimental arrangement should exclude these pulses.

Acknowledgements: I want to thank Marko Manninen for the information about Reiter's experiments and for interesting discussions.

5.5 Appendix: About Compton scattering and absorption of gammas

In the following simple quantitative picture about Compton scattering and absorption of gammas is developed. Also the attenuation of the gamma beamis discussed.

5.5.1 Quantitative estimates related to the absorption and Compton scattering of gammas

Some comments about gamma absorption and Compton scattering are in order to clarify the physical situation.

1. For the absorption of gamma the cross section is proportional to $\alpha \simeq 1/137$ whereas for Compton scattering it is proportional to α^2. The very rough estimate is that the cross section is by two orders of magnitude higher for absorption. The energy dependence for the graph of attenuation coefficients for low enough energies is consistent with this.

2. Does the absorption of gamma lead to ionization of the atom of the detector material? In the Bohr orbit model, the binding energy for the valence electron with principal quantum number n labelling the row of the periodic table for atomic number Z is $E_n \simeq (Z/n)^2 E_H$, $E_H = 13.7$ eV. For 109Cd *resp.* 57Co the gamma energies are 88 keV *resp.* 122 keV. The condition $E_n < E_\gamma$ gives $(Z/n)^2 < E_{gamma}/E_H$. For 57Co the condition is $Z/n < 80$ and for 109Cd $Z/n < 95$. For Iodine with $Z = 53$ and $n = 5$ one has $Z/n = 53/5 \simeq 10$ so that the condition is satisfied and gamma absorption leads to ionization.

3. One can consider the situation also at the level of condensed matter. Photoelectrons in photoelectric effect can correspond to free electrons from a surface of conductor produced by ionizing absorption or Compton scattering of gamma rays. In this case, the final state electron can be regarded as a free electron outside the surface of the detector material.

   For conductors the energies of valence electrons form conduction bands, the situation is effectively continuous as far energy is considered, Compton scattering of gamma can kick the electron to a higher conduction band or lead to ionization.

   Diffraction effects are possible only if the momentum change in Compton scattering corresponds to a wavelength about atomic size scale. This is possible for X rays but not for gamma rays. For gamma rays interference terms in the scattering rate as a modulus squared $|A|^2$ of the scattering amplitude A as a sum over scattering amplitudes over the lattice atoms sum up to zero and the situation reduces to the level of single atom.

It is instructive to study the situation for the absorption in more detail.

1. The absorption of gamma by a free electron is kinematically impossible but possible for atomic electrons since momentum conservation does not pose and additional condition. For the absorption of gamma the energy given to the detector is maximal and leads to ionization whereas in the case of Compton scattering the energy is not totally lost. The atom can be however ionized. th this.

2. The ionized state of electron behaves like Bessel function at large distances and has a period determined by radial wave vector k. At large distances the energy of the final state electron is given by $E_{e,f} = \hbar^2 k^2/2m_e$. Energy conservation gives $E_\gamma - E_{e,B} = E_{e,f}$, where E_γ is gamma energy and $E_{e,B}$ is the binding energy of electron in the initial state.

   The energy of gamma is 88 keV or 122 keV in the situations considered and considerably larger than the binding energy $E_B \simeq 1.5$ keV for $n = 5$ state for Iodine. Therefore the approximation $E_\gamma \simeq E_{e,f}$ is good.

3. Interference effects are not significant at the level of a single atom. The wavelengths of gammas with 100 keV energy is 1.24×10^{-11} m. The atomic size as the radius of the Bohr orbit of the valence electron is $r_n = (n/Z)^2 a_0$. The scale of this orbit determines the size of the region which contributes to the transition amplitude significantly. This is the case also in ionization although the final state wave function has considerably larger size.

   For Iodine with $n = 5$ and $Z = 53$ this gives $r_5 \simeq 5.3 \times 10^{-13}$ m so that gamma wave function is essentially constant inside atom and the absorption amplitude can be calculated by using dipole approximation as a matrix element of dipole moment operator between the initial and final states.

5.5.2 Attenuation for a beam of gammas

Suppose that a beam of ordinary gammas enters the D1. In TGD picture gammas could be also dark.

1. The leakage of gammas through a good scintillator is small meaning that gamma loses its energy by Compton scattering and photoelectric effect. If the gamma scintillator is good in this sense, the generation of causally related pulse pairs should be small. The first NaI detector used by Reiter is however thin and and not good in this sense.

   Remark: Photoelectric effect need not mean absorption of gamma: also the analog of Compton scattering producing an ionization is possible.

2. The response of a good scintillator depends strongly on gamma energy to optimize energy resolution and is linear in the energy region of interest. **Fig. 1** gives various attenuation coefficients as a function of gamma energy E for NaI detector.

   Since the density ρ of the detector material is known, one can estimate the attenuation length L.

3. **Fig. 1** represents also the total attenuation coefficient A for gamma rays as a function of energy for various processes for an NaI crystal scintillator.

   From **Fig. 1**, one finds that for Compton scattering the attenuation coefficientdepends only weakly on the energy whereas for photo-electric effect the attenuation coefficientincreases sharply with decreasing energy.

   In the case Cd109 (88 keV) and Co57 (122 keV), the gamma ray energies are in the range .01, .1 MeV and near to .1 MeV for which attenuation coefficient is $A \sim .4$ cm^2/g for photoelectric absorption and .16 cm^2/g for Compton scattering. For Cs109 with $E = .662$ MeV, the coefficients for photoelectric absorption and Compton scattering have same values.

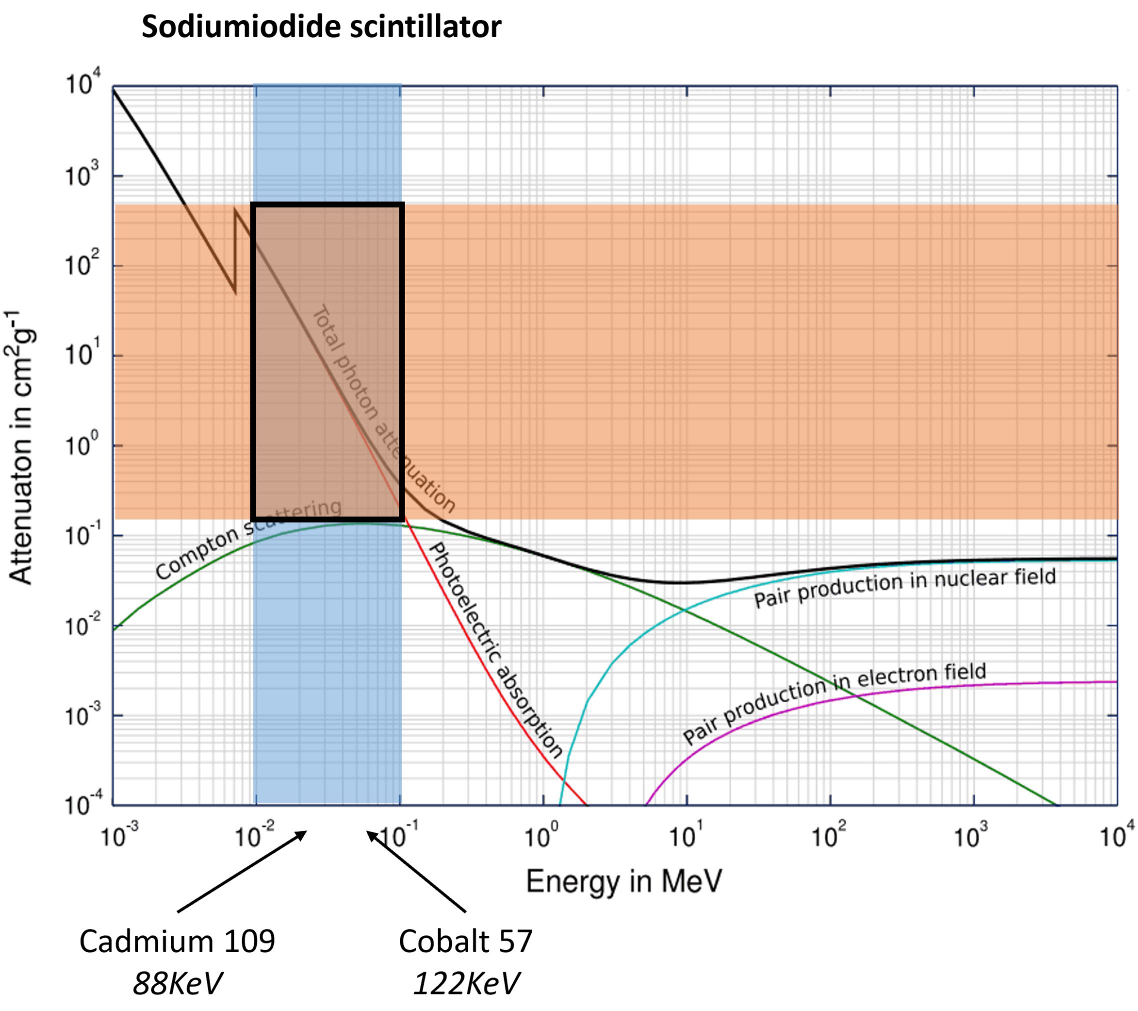

Figure 1: The attenuation coefficients for NaI detector used in Reiter's experiment

Nucleus	E/keV	A/cm^2g^{-1}	L/cm	p
Cd109	88	.4,	.7	.57
Co57	122	.4	.7	.57
Cs137	662	.06	4.5	.91

Table 1: Gamma ray energy E, attenuation coefficient A for NaI scintillator, and attenuation length L for photoelectric effect for Cd109, Co57 and Cs137. Also the probability p to get through the D1 with thickness $d = 4$ mm without photoelectric effect is given

The number $N(x)$ of arriving gammas of beam is reduced exponentially in the detector as a function of the travelled distance:

$$\frac{dN}{dx} = -\frac{x}{L} \quad , \quad L = \frac{1}{A\rho} \quad .$$

ρ is the density of the detector material. The density of NaI is 3.67 g/cm^3.

From the thickness d of the detector volume, one canestimate the probability for the leakage of gamma without interactions. The D1 should have $d_1 < L$ and D2 $d_2 > L$.

Table 1 gives gives the attenuation length for Cd109, Co57 and Cs137. The $d_1 = 4$ mm, $d_1 < L$ is true for all cases. For Cd and Cs the D2 satisfies the condition $d_2 > L$. For Cs137, L is slightly larger than d_2.

5.5.3 Gamma ray cascades from beta decays and Reiter's findings

Multiple gamma emissions of excited states of nuclear isomers (`https://cutt.ly/fbOZbqc`) can produce correlated pairs of gamma rays. A final state nuclear isomer with two excited states resulting in a beta decay would be enough to produce a correlated pair. Could this explain the findings of Reiter?

The burst would be initiated by a beta decay producing an excited isomer of the nucleus decaying by gamma emission. If the spins of the initial and final state differ by one unit, the ages of these states by gamma decay are or order 10^{-12} s. If the difference of the nuclear spins of the initial and final states is higher than one unit, the emitted gamma ray must carry orbital angular momentum, so that the rate is lower. Typically the rates of the metastable states are of order 1 ns but can be so long that the decays cannot be detected.

Since 1 ns corresponds to a distance of 33 cm, one can ask whether subsequent gammas from the decay of an excited isomer could induce a correlated firing of the two detectors in the tandem experiment of Reiter. In this case, the energies of the gamma rays in general differ. Shell model predicts that the excitation energies obey a harmonic oscillator spectrum and are thus multiples of the basic unit so that the energies are the same in the most probable case. Also pulses with a height, which is double or even higher multiple of the basic pulse height are in principle possible, although they are predicted to be rare.

In this case, the members of the correlated gamma pair can have widely different momentum directions. Reiter however reports that gamma pairs with different momentum directions have not been detected. Note that this finding conforms with the notion of N-gamma predicting that its decay produces nearly parallel gammas.

5.5.4 The interpretation of Δt histograms?

The time differences between the pulses in the two detectors mean that the scale of time differences is by a factor of order 10^3 longer than expected on the basis of dimensions of detectors. Can this be true or is there something wrong in the determination of the time differences?

1.Coincidence counting

The identification of the correlated pulse pairs is performed by a coincidence counting. This method is however not completely straightforward.

1. In the picture of Reiter one would expect that the classical wave associated with gamma moves with light velocity. Also in the TGD based model it is assumed that gammas resulting from N gamma move with maximal signal velocity.

2. If the absorption of gamma ray or the first Compton scattering can be located into a definite position x_i inside detector D_i, $i = 1, 2$, the distance d_{12} between these positions is $x_{12} + x_1 - x_2 + d_{12}$, where d_{12} is the distance between the detectors.

   If the thickness for the detector is $d_1 = .4$ cm *resp.* $d_2 = 4$ cm and the mutual distance is $d_{12} = 1$ cm x_{12} varies in the range $[x_{12,min}, x_{12,max}] = [d_{12}, [d_1 + d_2 + d_{12}] = [1.0, 5.4]$ cm. The time t_{12} between pulses varies in the range $[t_{12,min}, t_{12,max}] = [x_{12,min}/c, x_{12,max}/c] = [.03, .18]$ ns.

What is the criterion for being a co-incident pair?

1. The criterion for accepted pulse pairs is statistical. Pulse pairs must be correlated and even causal in both models. If there is no correlation, the rate for the pairs can be written as $R_{12} \propto R_1 R_2$ in the two detectors. If not, the product form does not apply. If the pulses are in a causal relation, the rate for pairs is $R_{12} = R_1$.

2. One can also use the following criterion for being a correlated pair. Source can emita pair during interval T and if this possibility is neglected and only external sources are considered, these pairs can be counted as correlated pairs. If the rate of these pairs is subtracted from the observed rate of pairs, only correlated pairs remain.

   Accept all pairs in the time window T so narrow that the rate for gamma pairs from the source during T is low enough. If R is the activity of the source and Ω the solid angle spanned by the detector with respect to source, the rate for single gamma detections is $R_1 = R\Omega$.

3. To estimate the rate for a detection of pairs during time interval T, one must characterize the detector by its dead time τ following a detection. The model is obtained by dividing detection time T to intervals of length $\tau = T/N$. τ could also correspond to time bin used. It cannot be smaller than τ.

   The probability for a detection of just a single pair in intervals i and j is given $p^2(1-p)^{N-2}$, where one has $p = R_1\tau$. Since the pair can correspond to any pair of N intervals the total probability to observe a pair during T is given by binomials $P(N, 2) = Bin(N, 2)p^2(1-p)^{N-2}$. The rate for pairs is therefore given by

$$\begin{array}{l} R_2 = \frac{p(N,2)}{T} \simeq \frac{N^2}{2}p^2(1-p)^{N-2} = R^2T(1-R\tau)^{\frac{T}{tau}-2} \simeq R^2T(1-RT)/2 \ , \\ , \\ p = R_1\tau \ , \\ N = \frac{T}{\tau} \ . \end{array} \tag{5.13}$$

   This rate should be smaller than the background and this gives an estimate for T. If N is large enough, R_2 is independent of τ in a good approximation and conforms with the naive guess $R_2 = R_1 RT$. This contribution to the background has been indeed taken into account as chance rate R_c.

4. If one believes this picture, t_{12} for accepted pulse pairs should be restricted to be below, say, .5 ns. However, the reported co-incidence distribution for $\Delta t \equiv t_{12}$ varies in the range with duration about 200 ns, which is roughly 1000 times longer than $t_{12,max}$. If the real time difference for accepted pulse pairs were so long, a lot of false pairs could be accepted. As will be discussed below, the pulses are delayed and this explains the widening of the Δt histogram.

5. The determination of t_{12} involves also problems since the identification of t_1 and t_2 is problematic. The produced pulses have a duration below 200 ns. How can one tell when the pulse begins? If I have understood correctly, the "construction" of the pulse guarantees that it is

a square pulse so that one can identify the time for the beginning of the pulse precisely. I do not know how much information processing this involves and how largeerrors this brings in.

One can get rid of the problem by giving up the attempt to identify t_i and increase the acceptance window to say 200 ns but this brings in the possibility of false pairs and one must rely on statistics.

2. Delay of pulses explains the widening of Δt histograms

Δt histograms giving the distribution for t_{12} for the correlated co-incidences are discussed in [H1]. Their width is of order 300 ns. In the ideal situation with the assumptions described, the diagram should look like a bar of width of order .1 ns. How can one understand this?

The only reasonable interpretation is that the process leading to a representation of the co-incidences scales up t_{12} by a factor order 1000. Could a delay for the pulse from detector 2 or different delays for pulses from both detectors be involved and induce a lengthening of Δt by a constant amount of about, say, 300 ns?

This seems to be the correct interpretation (`https://cutt.ly/xny3XDi`). Reiter indeed mentions (`https://cutt.ly/0ny3BFq`) "In preparation for the Δt plot, adjustments on delay controls on SCA1 and SCA2, and a gate delay adjustment on the DSO must be performed".

3. Why Δt histograms allow negative values of $t_2 - t_1$?

There is still one interpretational problem. The Δt histogram looks like a Gaussian symmetric with respect to the origin of Δt axis. One would naively expect a bar starting at origin is widened to half-Gaussian caused by the processing. It could of course happen that the processing causes errors and leads to change of the sign of Δt.

The criterion for co-incidence is that the pulses from D1 and D2 overlap and the scaled up time difference can be defined as difference $\Delta t = t_1 - t_2$ with t_i identified for instance as center point or the pulse. If the pulse widths are different, the sign of Δt can become negative. t_i could be also defined as time for starting of the square pulse. Also in this case the information processing could change the order of pulses which are actually very near to each other temporally.

The order of pulses could however change also at the fundamental level.

1. What comes to mind is that 2 gammas arrive in D2. γ_1 is absorbed and γ_2 experiences a Compton scattering in backwards direction, travels to D1 since the tin foil cannot stop gamma rays like electrons, and is absorbed in D1.

   The differential cross section for the backwards Compton scattering is proportional to $(E_f/E_i)^2$ times an expression symmetric with respect to E_i and E_f. Energy-momentum conservation gives $E_f/E_i = 1/(1+2E/m_e) \simeq 5/7$ for $E = 100$ keV so that the differential cross section is by a factor $(5/7)^2$ smaller in the backward direction as forward directions [B2]. The energy of backwards scattered γ_1 in D1 would be by a factor 5/7 smaller than the energy of γ_1 so that the pulses have roughly the same height.

   This picture is natural in the N-gamma model, which also explains the observed double pulses which can occur in both detectors. Also $n > 2$-pulses are possible but their probability decreases rapidly with n.

   One expects that the fraction of time reversed events is smaller than for events in which absorption occurs in both detectors in the normal time order. The cross section for the backwards Compton scattering is proportional to α^2, $\alpha = 1/137$. Since the rate for the absorption is proportional to α. The ratio for the rates of these two kinds of event pairs would be proportional to α. It is not clear whether the ratio of the remaining factors in the cross section can compensate for α. Note also that backwards Compton scattering must occur to a rather small solid angle which further reduces the size of the cross section.

2. The time reversed event pair has an interpretation also in ZEO. Ordinary state function reductions change the arrow of time in ZEO. In the above model the arrow of time of the backwards scattered γ_1 in D2 would change. From the point of view of an observer with a standard arrow of time would travel from D2 to D1, where it would be absorbed. γ_2 would be absorbed in D2.

4. Estimate for the probability of Compton backscattering

One must estimate the probability for the reflection of the incoming (dark) gamma by backward scattering from D2 so that it can return to D1 where it can be absorbed or Compton scatter.

One must specify first the geometry. The radius r of the hole through which the gammas arrive from detector to D1 is typically $r = 1$ cm. Both D1 and D2 have rectangular cross sections with a side with length $l = 4$ cm. D1 has length $D1 = .4$ cm and D2 has length $D2 \equiv D = 4$ cm in the experiments considered. To simplify the order of magnitude estimates, assume that the cross sections of D1 and D2 are circular disks of radius $d = 4$ cm, say.

The point at the midline of the cylinder of radius d with distance $L < d$ from the hole has a solid angle which corresponds to $cos(\theta) \equiv u = L/\sqrt{L^2 + d^2}$. The corresponding solid angle is

$$\Omega(L) = 2\pi(1-u) = 2\pi \frac{L}{\sqrt{L^2 + d^2}} \quad . \tag{5.14}$$

One must estimate the total probability that the gamma is reflected back from D2. This probability is the sum over the probabilities for back-scattering to $\Omega(L)$ from the atoms in a cylinder of atomic radius and length D.

1. The atomic volume $V = 4\pi a^3/3 = 1/n_{atom} = Am_p/\rho$ contains Z electrons. The generalization to the case of NaLi detector is obvious. Since the energy of gamma is rather large, one can assume that the backscattering occurs as if atomic electrons were free. This makes it possible to use a well known expression for Compton scattering cross section [B2] to get at least a rough estimate.

2. Geometric intuition suggests that the backscattering probability for a single atom at position L inside the cylinder can be taken to be the ratio of the total backward scattering cross section to the transversal area:

$$P(\Omega(L)) = \frac{\sigma(\Omega(L), tot)}{S} \quad , \quad \sigma(\Omega(L), tot) = Z\sigma(\Omega(L)) \quad , \tag{5.15}$$

   The backscattering can occur from Z electrons and the total cross section is Z times the cross section fora single electron.

   If the photon is dark with $h_{eff} = nh_0 > h$, one must multiply P with p:

$$P \rightarrow pP \quad , \tag{5.16}$$

   where p is the probability for the dark photon to transform to the ordinary gamma.

3. One can think that one has $N = D/a$ scattering planes of transversal area $S = \pi a^2$. The number of scattering planes in the cylinder of atomic radius is $N(L) = n_{atom}SL$ and there density is $dN/dL = n_{atom}S$.

   The total backscattering probability is sum over products of probabilities $P_{free}(L)$ for getting to a distance L without interaction and $P(\Omega(L))$:

$$P(D) = \int_0^D P_{free}(L)P(\Omega(L))\frac{dN}{dL}\, dL \quad . \tag{5.17}$$

4. $P_{free}(L)$ is the product of probabilities to progate without interactions through the $N(L) = L/a$ scattering planes and is given by

$$\begin{aligned} P_{free}(L) &= (1-P_{tot})^{L/a} exp(log(1-P_{tot})\frac{L}{a}) \ , \\ P_{tot} &= Z\frac{\sigma_{tot}}{S} \ . \end{aligned} \tag{5.18}$$

Since $P_{tot} << 1$ is true one can write in good approximation $log(1-P_{tot})) \simeq -P_{tot}$ and one obtains

$$P_{free}(L) = \ exp(-P_{tot}\frac{L}{a}) = \ exp(-Z\frac{\sigma_{tot}L}{Sa}) = exp(-\frac{4}{3}Z\sigma_{tot}n_{atom}L) \ . \tag{5.19}$$

This factor gives an exponential damping for large values of L. The damping is not very significant for $L = 4$ cm. In the case of dark gammas, the presence of the multiplicative factor p in σ_{tot} reduces the damping further. In the first approximation, one can assume $P_{free}(L) = 1$ for dark gammas.

5. With these assumptions one obtains

$$P(D) = \int_0^D \frac{4}{3}pZ\sigma(\Omega(L))n_{atom} \ dL \ . \tag{5.20}$$

Consider now a quantitive estimate for the backscattering probability.

1. The differential cross section for Compton scattering [B2] is given by

$$\begin{aligned} \frac{d\sigma}{d\Omega} &= \frac{\alpha^2}{4m_e^2}x_{if}^2(x_{if} + \frac{1}{x_{if}} + 4(\epsilon_i\cdot\epsilon_f)^2 - 2) \\ x_{if} &= \frac{E_f}{E_i} \ , \end{aligned} \tag{5.21}$$

Conservation of energy and momentum gives

$$x_{if} = \frac{1}{1+(E_i/m)(1-u)} \ , \quad u = cos(\theta) \ , \tag{5.22}$$

The energy loss $E_i - E_f$ of gamma is given by

$$E_i - E_f = E_i(1-x_{if}) \tag{5.23}$$

is maximal for backwards scattering. One has for $E_i = 100$ keV $E_f/E_i \simeq 5/7$ for backwards scattering so that 29 % of the energy is lost. Therefore the absorption of the backscattered photon in D1 preceeded by an absorption of second dark photon in D2 before the backscattering may give a pulse pair with heights which do not differ too much.

2. The cross section $\sigma(\Omega(L))$ in laboratory frame is given by

$$\begin{aligned} \sigma(\Omega(L)) &= \frac{\alpha^2 2\pi}{4m_e^2}\int_0^{u(L)} x_{if}^2(x_{if} + \frac{1}{x_{if}} + 4(\epsilon_i\cdot\epsilon_f)^2 - 2)du \ , \\ u(L) &= \frac{L}{\sqrt{L^2+d^2}} \ . \end{aligned} \tag{5.24}$$

ϵ_i *resp.* ϵ_f is the polarization of initial *resp.* final gammas.

3. The integrand is a rational function and can be integrated analytically. The dependence of the integrand on u is rather weak so that one can make the approximation $u = -1$ giving $x_{if} = 5/7$. One obtains

$$\begin{aligned} \sigma(\Omega(L) &= \frac{\alpha^2 2\pi}{4m_e^2} x_{if}^2 (x_{if} + \frac{1}{x_{if}} + 4(\epsilon_i \cdot \epsilon_f)^2 - 2)(1 - u(L)) \ , \\ u(L) &= \frac{L}{\sqrt{L^2+d^2}} \ . \end{aligned} \tag{5.25}$$

4. One obtains for the total back-scattering probability the following expression:

$$\begin{aligned} P(D) &= XY \ , \\ X &= p\frac{4}{3} Z n_{atom} \frac{\alpha^2 2\pi}{4m_e^2} x_{if}^2 (x_{if} + \frac{1}{x_{if}} + 4(\epsilon_i \cdot \epsilon_f)^2 - 2) \ , \\ Y &= \int_0^D (1 - \frac{L}{\sqrt{L^2+d^2}}) dL \ = D - dlog(\frac{L^2+d^2}{d^2}) \ . \end{aligned} \tag{5.26}$$

For $d = D/2$ and gives $Y = 4 - 2log(5) = .782D$

5. The order of magnitude is determined by the factor

$$pZ\frac{4}{3}\frac{\alpha^2 2\pi}{4}\frac{L_e^2}{a^2}\frac{D}{a} \simeq 1.0 \times pZ \ . \tag{5.27}$$

For NaI detector the basic unit is NaI molecule for which one has $Z = 53 + 11 = 64$. In this approximation, the probability of backscattering could be near unity $pZ \sim 1$ and one cannot exclude the possibility that the correlated pairs with a wrong arrow of time can be explained as backscattering. Of course, the attenuation reduces the probability of backscattering.

6. This calculation is only a rough order of magnitude estimate and has neglected the rapid increase of the photoelectric absorption cross section after then back-scattering. The backscattered gamma can suffer photoelectric absorption in D2 and never reach D1. From **Fig. 1** one sees that the attenuation length decreases by a factor 1/6 in $E = 100$ kV $\rightarrow$ 71 kV taking place in backscattering.

   If the attenuation for ordinary gamma ray for travelled distance L is e^{-kL}, it is scaled to e^{-6kL}. For $kD \simeq 1$ the probability that the backscattered gamma gets back to D1 is $exp(-6L/D)$ in this case.

   The total probability for a return to D1 by back-scattering has the same approximate expression as above but with Y replaced with

$$Y = \int_0^D exp(-\frac{6L}{D})(1 - \frac{L}{\sqrt{L^2+d^2}}) dL \ = D - dlog(\frac{L^2+d^2}{d^2}) \ . \tag{5.28}$$

   Instead of $Y = .782D$, the approximation for Y obtained by replacing $\sqrt{L^2+d^2}$ with $d = D/2$ is $Y/D \simeq (2 - e^{-6})/18 \simeq .11D$. The value is about 14 per cent from the naive estimate. Backscattering probability with a successful return would be about $.11pZ$ and equal to $7p$ for $Z = 64$ (NaI). This does not kill the hypothesis.

A couple of comments are in order.

1. The small value of p for dark photons might be essential. Otherwise, the attenuation of the gamma beam could reduce the backscattering probability considerably.

2. According to Reiter, the number of detection events in D1 is by an order of magnitude larger than in D2. This looks strange. The trivial explanation would be that only the events for which count appears in D1 are counted. A partial explanation is that a considerable part of the beam from D1 misses D2 as becomes clear by visualizing the geometric situation. On the other hand, the length 4 cm of D2 is by a factor 10 longer than the length .4 cm of D1. If these explanations fail, one must seriously consider the possibility that the backscattering from D2 plays a significant role.

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