TGD based interpretation for the strange findings of Eric Reiter

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Abstract

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. The pulse rate depends on wavelength and distance between the source and detector and also 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.

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1 Introduction

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 [H3, H2] `https://cutt.ly/rlBgOl1`) about the behavior of gammas emitted by heavy nuclei.

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.

1.1 Basic observations of Reiter

The basic observations claimed by Reiter [H3, 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 (D2) and cause a pulse in it. The situations could correspond to half pulses whereas full pulses could correspond to the absorption of gamma. Note also that by Bose-statistic Compton scattering is symmetric with respect to forward and backward directions.

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.

1.2 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 transfer of electron between conduction bands 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.

2 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?

2.1 Hierarchy of effective Planck constants and the notions 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] [L5]. 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 $h\rightarrow h_{eff}$. $n=2$ 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} [L14]. 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 [L12, L13]. Baryons as 3-quark states provide the analogy: color confinement forces the 3 quarks to behave like a single particle.
4. 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 [L8].

   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.

2.2 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 [L3]. 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.

3 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.

3.1 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 gives rise to 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 more or 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.

   The basic parameter could be the density of N-nuclei and would be 5 times larger for the salt than metal. This would suggest that the formation of N-nuclei depends on whether electrons are conduction electrons or not.

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 [L14] 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 $h_{eff}/h \simeq m_p/m_e \simeq 2000$ [L10, L2].

3.2 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 lanedr that the rate of pulses is the correct identification.

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.

   The decay of N-gamma is the reversal of this phase transition. 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 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.

These 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. 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.

Reiter's own interpretation is as follows. The transversal width of the gamma wave packet is proportional to $d\lambda$, $d = ct$ is the distance travelled. This what Schrödinger equation as 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 suggests a modification of this 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 of transversal cross section S of ME increases during the propagation like λt: 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. S should be as small as possible but contain the detector area. This implies optimal value for S and therefore for d .

If pulse height is proportional to the total number of gammas reaching the detector simultaneously, the pulse height should depend on the distance and have maximum, which does not seem to conform with Reiter's report.

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, one could understand this. The time to travel a distance of say 30 cm defining the detector's transversal scale is about 1 ns: it is not clear to me whether this is enough to guarantee separate pulses.

A more elegant possibility is that the N-gamma delocalized inside ME decays in the detector volume rather than before it. This would due to the interaction with the detector material. The condition for the maximal signal remains the same as above.

3.3 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.

3.4 Does unquantum effect disappear or get more pronounced 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 [L1, L14].

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. Note however that also the ordinary nuclei decay and it can happen that the loss of N-nuclei by decay and loss of quantum coherence is slower in which case the effect can become easier to detect.

What could induce the quantum coherence by energy feed?

1. In Pollack effect induced by energy feed by say photons [I2, L1, 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 [K3].

4. Also the TGD based model of "cold fusion" [L2, L7, L10] 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.

It came as a surprise to me, that the ageing of the source can make the effect more pronounced. If the dark N-nuclei have a considerably longer life-time than ordinary nuclei, the exponential decay of ordinary nuclei can lead to a situation in which only dark N-nuclei decay and the firing of both detectors due to gamma pair from a simultaneous decay of two ordinary nuclei or due to gamma from an ordinary nucleus and cosmic gamma ray is negligible.

The following simple model describes the situation quantitatively

1. For ordinary gammas the production rate is

   $$R_1 = \frac{d\gamma_1}{dt} = -k_1 n_1 = -k_1 n_1(0) e^{-k_1 t} \quad ,$$

   where n_1 refers to the number of ordinary nuclei.

For N-gammas γ_N one has

$$d\frac{d\gamma_1}{dt} = k_N n_N = k_N n_N(0)e^{-k_N t} \ .$$

n_N is the density of the N-nuclei in the source. In both cases, the rate decreases exponentially.

2. The ratio of the rates is

$$\frac{R_1}{R_N} = \frac{k_1}{k_N} \times \frac{n_1(0)}{n_N(0)} \times Ne^{(-k_1+k_N)t} \ .$$

$n_N(0)$ is expected to be much smaller than $n_1(0)$.

3. For small values of time t exponentials not matter and one has

$$\frac{R_1}{R_N} = \frac{k_1}{k_N} \times \frac{n_1(0)}{n_N(0)} \ .$$

For $(k_1/k_N) * (n_1(0)/n_N(0)) < 1$, the rate of firings of both detectors due to pairs of photons associated with N-gammas can be masked by the accidental pairs of this kind.

For large values of t N-gammas dominate for $k_N < k_1$ and double firings due to N-gammas becomes more pronounced. N-gammas begin to dominate for

$$t > t_{cr} \sim \frac{1}{k_1} \times log[\frac{k_1}{k_N} \times \frac{n_1(0)}{n_N(0)}] \ .$$

Here $t_1 = 1/k_1$ ja $t_N = 1/k_N$ are the lifetimes for ordinary nucle and N-nuclei. Since the logarithm grows very slowly this can happen even for $n_N(0)/n_1(0) \leq\leq 1$.

It would be interesting to check what one can conclude from the known life times for various sources.

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.

3.5 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.

(a) 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.

(b) 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.

(c) 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.

(d) 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.

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

$$P(M_1 : N) = Bin(N, M_1)p^{M_1} \times (1-p)^{N-M_1} \quad , \quad Bin(N, M_1) = \frac{N!}{M_1!(N-M_1)!} \quad . \tag{3.1}$$

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

(b) 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 $Bin(N, M_1)$:

$$\frac{dlog[Bin(N, M_1)]}{dM_1} = log(\frac{1-p}{p}) \quad . \tag{3.2}$$

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 $M_1 >> 1$

$$M_{max:N} = pN \quad . \tag{3.3}$$

The result could have been guessed.

(c) 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

$$M_{max:N} = pN \times exp(-\frac{1}{2pN}) \quad . \tag{3.4}$$

(d) 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.

(e) 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

$$P(M_1 : N) \simeq \frac{1}{\sqrt{2\pi Np(1-p)}} exp[\frac{(M_1 - pN)^2}{2Np(1-p)}] \quad . \tag{3.5}$$

(f) 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.

(a) 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.

(b) 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

$$N_{c,max} = p_c M = p_c N_{max} = p_c p N \quad . \tag{3.6}$$

(c) 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.

(d) 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:

$$E_{lost} = E_{lost,a} + E_{lost,c} = pN[1 - p_c + p_c x]E \quad . \tag{3.7}$$

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.

3.6 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 [H1] and with alpha ray beams (appendix II of [H2] splitter 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.

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

(b) 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.

(c) 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 [H2] behaving 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 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 [C1] (`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 bylarge value of h_{eff} at the space-time sheet of a 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.

4 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.

4.1 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.

(a) 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`):

$$T_{cr} = k\frac{\hbar M}{n}{}^{2/3}_{3} \quad M = Am_p \quad k = 3.31 \ . \tag{4.1}$$

The value of k follows from a model in terms of ideal gas. 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.

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

$$\begin{array}{lll} T_{cr} = \frac{k}{A}r\frac{\hbar}{m_p}n_1^2 & r = \frac{\hbar_{eff}}{\hbar} & n_1 = \frac{X}{a} \ , \\ a = 10^{-10} \ m \ , & m_p = .938 \times 10^9 eV \ . & \end{array} \tag{4.2}$$

(c) The condition that the critical temperature exceeds room temperature gives

$$\begin{array}{ll} T_{cr} = \frac{kX^2}{A}rYm_p \geq T_{room} \ , & Y = (\frac{\hbar}{m_p a})^2 \ . \\ T_{room} = 3 \times 10^{-2} \ eV & Ym_p = 4.1 \times 10^{-3} \ eV \ . \end{array} \tag{4.3}$$

The condition gives

$$r \geq \frac{7.32}{kX^2} \times A \ . \tag{4.4}$$

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 $2^8 = 256$.

(d) For N-dimensional case with $N = 2,3$ the formula generalizes to

$$r \geq \frac{7.32}{kX^{2/N}} \times A \ . \tag{4.5}$$

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 $T_{cr} \geq kX^2 \times 4.1 \times T_{room}$.

4.2 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.

(a) 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.

(b) 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?

(a) 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" [L9, L7, L10] 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.

(b) 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 [K3]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

(c) The findings of Prof. Holmlid [C2, L6] 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 [L2, L6, L7, L10] 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.

(d) This picture led to a model for the tunneling [L9, L11] 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 [L9].

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 $h \to h_{eff}$. 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 [L9].

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.

(e) Prof. Holmlid [L6] 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.

4.3 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?

(a) 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 [L4, L8]. There is however a problem: Bose-Einstein condensate requires Cooper pairs but proton triplets are fermions.

(b) 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.

(c) The number theory based model [L14] 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.

(d) The number theoretic interpretation is in terms of Galois confinement analogous to color confinement [L14, **?**]. 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 [**?**]

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 [L13] and be based on the tetra-icosahedral tessellation defining the simplest tessellationof H^3.

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. This suggests that 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.

5 Conclusions

One can divide the findings of Reiter to two classes.

(a) 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.

(b) 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.

(c) 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.

(a) 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.

(b) 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.

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

6 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.

6.1 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.

(a) 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.

(b) 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.

(c) 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.

(a) 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.

(b) 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.

(c) 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.

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

6.2 Attenuation for a beam of gammas

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

(a) 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.

(b) 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.

(c) **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.

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.

6.3 Could correlated pulse pairs with the same height have a standard physics explanation?

If the gamma suffers Compton scattering in nearly forward direction in the D1 such that its energy is reduced from E to $E/2$, and a photoelectric absorption in the second detection,

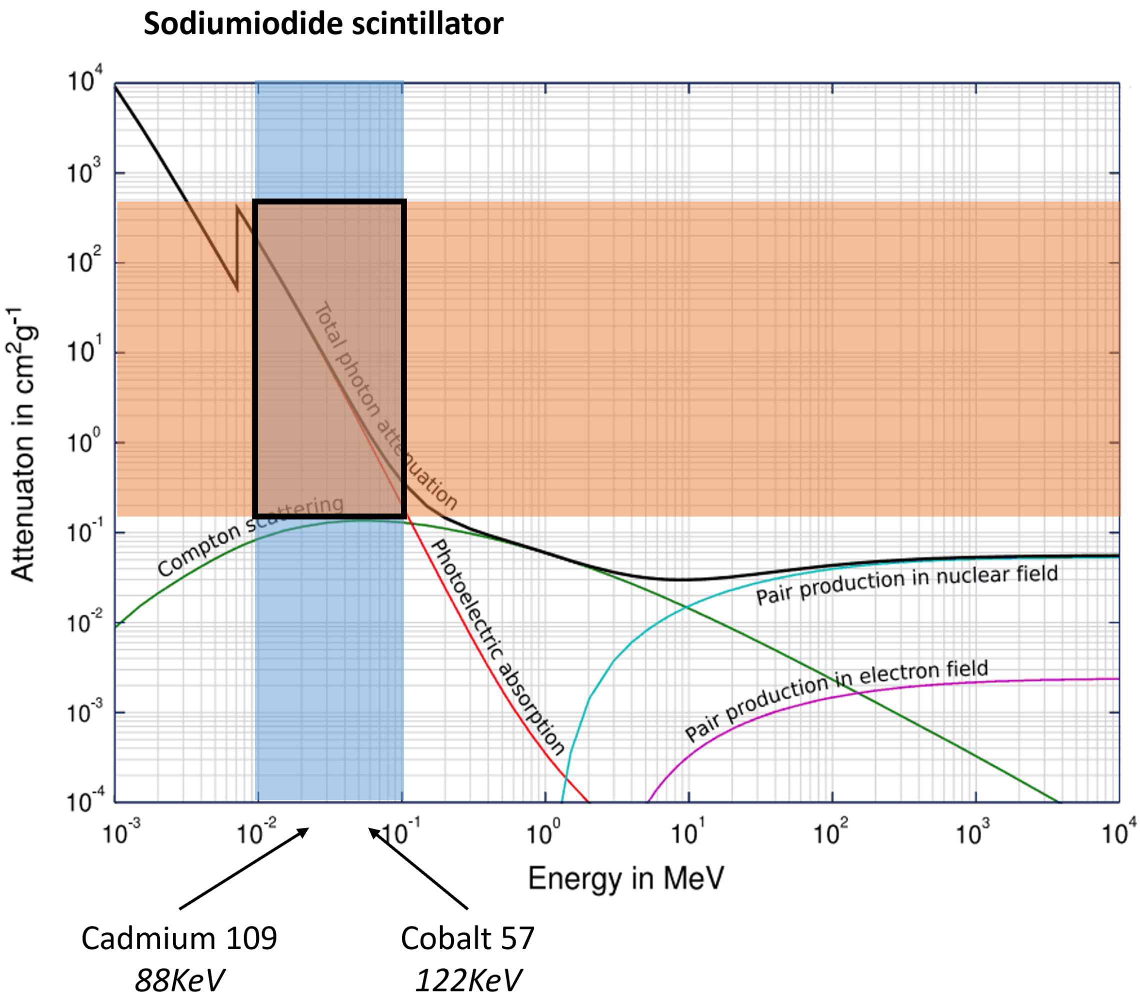

Figure 1: The attenuation coefficients for NaI detector used in Reiter's experiment

single gamma can produce correlated pulse pairs with equal pulse height if the pulse generation is a local process not depending on the thickness of the detector. Could this process be somehow special and possibly explain unquantum effect?

Suppose that one considers only pulses for which the pulse height is *maximal* in the D1, and takes care that only gammas scattered in the forward direction get to the D2. What is the upper bound for the energy given to the D1 in single Compton scattering? It turns out to be $E/2$. Is the proper interpretation that half pulse pairs are really half pulse pairs (rather than convention) and correspond to Compton scattering + photoelectric absorption and full pulse pairs correspond to a new physics effect?

The little calculation using energy and momentum conservation shows that $E \rightarrow E_1 = E/2$ corresponds to the boundary of the kinematic region for which Compton scattering is in the forward direction.

(a) The incoming and outgoing energy-momenta in the scattering plane are (units with $c = 1$ are used):

$$\begin{array}{lll} & \gamma & e \\ in & E(1,1,0) \ , & (m_e,0,0) \ , \\ out & E_1(1,cos(\theta_1),sin(\theta_1)) \ , & \gamma m_e(1,\beta cos(\theta),\beta sin(\theta)) \ . \end{array} \tag{6.1}$$

θ_1 *resp.* θ are the scattering angles of gamma *resp.* electron with respect to the direction of the incoming γ. $\beta = \frac{v}{c}$ denotes the velocity of electron.

(b) The conservation conditions are following:

$$\begin{array}{l} E + m = E_1 + m\gamma \ , \\ E = E_1 cos(\theta_1) + m\beta\gamma cos(\theta) \ , \\ 0 = E_1 sin(\theta_1) + m\beta\gamma sin(\theta) \ . \end{array} \tag{6.2}$$

$\gamma = \frac{1}{1-\beta^2}$ denotes the time dilation factor.

(c) Conservation conditions allow to deduce $c_1 \equiv cos(\theta_1)$ in terms of $y = E/E_1$, and $u = cot(\theta)$:

$$c_1 = \frac{y}{1+u^2}\left[1 \pm u\sqrt{-1+y^{-2}(1+u^2)}\right] \ . \tag{6.3}$$

(d) The condition that the gamma scattering takes place in forward direction $\theta_1 = 0$ is

$$c_1 \equiv cos(\theta_1) = 1 \ . \tag{6.4}$$

This gives

$$u = \frac{y^2-1}{\sqrt{1-(y-1)^2}} \ . \tag{6.5}$$

Denominator is real for $|y-1| < 1$. This gives $y \geq 2$ that is

$$E_1 \leq E/2 \ . \tag{6.6}$$

$E_1 = E/2$ therefore corresponds to the boundary of the kinematic regions and maximal energy of gamma Compton scattered in forward direction.

(e) If the energy and pulse height is maximized in the D1 and gamma is absorbed in the D2, the pulse heights are identical. Optimistic interpretation is that these pairs correspond to correlated half-pulse pairs.

6.4 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.

6.5 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?

6.5.1 Coincidence counting

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

(a) 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.

(b) 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?

(a) 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 $R_{12} = R_1$.

(b) One can also use the following criterion for being a correlated pair. Source can emit a 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 $R_1 = R\Omega$.

(c) 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

$$\begin{array}{l} R_2 = \frac{p(N,2)}{T} \simeq \frac{N^2}{2}p^2(1-p)^{N-2} = R^2T(1-R\tau)^{\frac{T}{tau}-2} \simeq R^2T(1-RT)/2 \ , \\ , \\ p = R_1\tau \ , \\ N = \frac{T}{\tau} \ . \end{array} \quad (6.7)$$

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 $R_2 = R_1RT$. This contribution to the background has been indeed taken into account as chance rate R_c.

(d) 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.

(e) 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 large errors 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.

6.5.2 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".

6.5.3 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.

(a) 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 [B1]. 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.

(b) 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.

6.5.4 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

$$\Omega(L) = 2\pi(1-u) = 2\pi\frac{L}{\sqrt{L^2+d^2}} \quad . \tag{6.8}$$

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.

(a) 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 [B1] to get at least a rough estimate.

(b) 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:

$$P(\Omega(L)) = \frac{\sigma(\Omega(L),tot)}{S} \quad , \quad \sigma(\Omega(L),tot) = Z\sigma(\Omega(L)) \quad , \tag{6.9}$$

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:

$$P \rightarrow pP \quad , \tag{6.10}$$

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

(c) 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 $P(\Omega(L))$:

$$P(D) = \int_0^D P_{free}(L)P(\Omega(L))\frac{dN}{dL}\; dL \quad . \tag{6.11}$$

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

$$P_{free}(L) = (1-P_{tot})^{L/a} exp(log(1-P_{tot})\tfrac{L}{a}) \quad ,$$
$$P_{tot} = Z\frac{\sigma_{tot}}{S} \quad . \tag{6.12}$$

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

$$P_{free}(L) = exp(-P_{tot}\frac{L}{a}) = exp(-Z\frac{\sigma_{tot}L}{Sa}) = exp(-\frac{4}{3}Z\sigma_{tot}n_{atom}L) \quad . \tag{6.13}$$

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.

(e) With these assumptions one obtains

$$P(D) = \int_0^D \frac{4}{3} pZ\sigma(\Omega(L)) n_{atom}\, dL \ . \tag{6.14}$$

Consider now a quantitive estimate for the backscattering probability.

(a) The differential cross section for Compton scattering [B1] is given by

$$\begin{aligned} \frac{d\sigma}{d\Omega} &= \frac{\alpha^2}{4m_e^2} x_{if}^2 (x_{if} + \frac{1}{x_{if}} + 4(\epsilon_i \cdot \epsilon_f)^2 - 2) \\ x_{if} &= \frac{E_f}{E_i} \ , \end{aligned} \tag{6.15}$$

Conservation of energy and momentum gives

$$x_{if} = \frac{1}{1+(E_i/m)(1-u)} \ , \quad u = cos(\theta) \ , \tag{6.16}$$

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

$$E_i - E_f = E_i(1 - x_{if}) \tag{6.17}$$

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.

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

$$\begin{aligned} \sigma(\Omega(L)) &= \frac{\alpha^2 2\pi}{4m_e^2} \int_0^{u(L)} x_{if}^2 (x_{if} + \frac{1}{x_{if}} + 4(\epsilon_i \cdot \epsilon_f)^2 - 2) du \ , \\ u(L) &= \frac{L}{\sqrt{L^2+d^2}} \ . \end{aligned} \tag{6.18}$$

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

(c) 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

$$\begin{aligned} \sigma(\Omega(L) &= \frac{\alpha^2 2\pi}{4m_e^2} x_{if}^2 (x_{if} + \frac{1}{x_{if}} + 4(\epsilon_i \cdot \epsilon_f)^2 - 2)(1 - u(L)) \ , \\ u(L) &= \frac{L}{\sqrt{L^2+d^2}} \ . \end{aligned} \tag{6.19}$$

(d) One obtains for the total back-scattering probability the following expression:

$$P(D) = XY \ ,$$
$$X = p\frac{4}{3}Zn_{atom}\frac{\alpha^2 2\pi}{4m_e^2}x_{if}^2(x_{if} + \frac{1}{x_{if}} + 4(\epsilon_i \cdot \epsilon_f)^2 - 2) \ , \tag{6.20}$$
$$Y = \int_0^D (1 - \frac{L}{\sqrt{L^2+d^2}})dL \ = D - dlog(\frac{L^2+d^2}{d^2}) \ .$$

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

(e) The order of magnitude is determined by the factor

$$pZ\frac{4}{3}\frac{\alpha^2 2\pi}{4}\frac{L_e^2}{a^2}\frac{D}{a} \simeq 1.0 \times pZ \ . \tag{6.21}$$

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.

(f) 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

$$Y = \int_0^D exp(-\frac{6L}{D})(1 - \frac{L}{\sqrt{L^2+d^2}})dL \ = D - dlog(\frac{L^2+d^2}{d^2}) \ . \tag{6.22}$$

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.

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

(b) 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.

6.5.5 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.

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