Annihilation mechanisms: Intermediate processes in the conversion of electron and antielectron into photons

Pons, D.J. [1]

Abstract

The outcomes of annihilation are known, including some of the intermediary products, and the process can be represented by Feynman diagrams and modelled mathematically. However the mechanisms of annihilation at a deeper fundamental level are unknown. How exactly does matter and antimatter convert into photons? How does mass change into energy? This paper develops an answer by providing a theory for the annihilation process based on mechanics derived from the cordus conjecture. The particular area under examination is the annihilation of an electron and antielectron (positron) to gamma photons. In this model matter and antimatter annihilate by transforming their field structures - called hyff - into those of the photon. The process is more one of remanufacture than destruction. The model proposes the stages of annihilation and identifies the mechanisms for each. The reverse of the process gives a physical description of leptogenesis: the creation of separate electron and antielectron particules out of two initial photons. It also explains why the proton and electron do not annihilate. We show that a deeper common mechanism exists for annihilation, leptogenesis, and bonding.

Keywords: annihilation, fundamental physics, positronium, QCD, leptogenesis

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1 Introduction

How do matter (M) and antimatter (aM) annihilate? *Why* does it happen at all? Unfortunately these questions are at the edge of, or even beyond, our conventional theories of physics. We do not know the *mechanisms* of annihilation, though the outcomes and some of the intermediary products are known.

Existing models of annihilation

The dominant explanation for antimatter is quantum mechanics (QM). However QM cannot explain the *structure* of antimatter to the extent that

[1] *Please address correspondence to Dr Dirk Pons, University of Canterbury, Christchurch, New Zealand.*

we would like, and has practically nothing to say about the *process* of annihilation. *That* annihilation occurs is not a problem to QM, and the process can even be represented, by Feynman diagrams, albeit at a high level of abstraction, see Figure 1. However the details are not understood nor the deeper question of *why* it should occur at all.

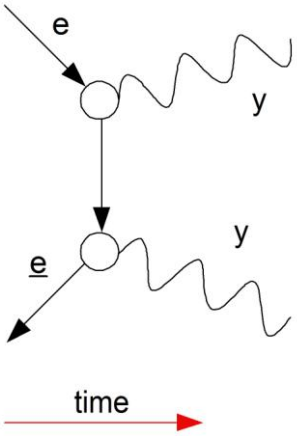

Figure 1: Feynman diagram for electron-antielectron annihilation to two gamma photons. The inputs are on the left and comprise an electron e and an antielectron e (with reversed arrow). These two interact, in ways uncertain, to produce two output photons y.

Feynman diagrams do not represent the underlying mechanisms at the deeper level, nor all the intermediate structures. In this way at least, the diagrams are consistent with empirical observed tracks where certain intermediates are not detected until a transformation to another particle occurs, i.e. there are gaps in the tracks. The diagrams encapsulate the idea that these unobservable structures are 'virtual' particles. Thus we have various virtual bosons identified as part of the deconstruction process, and even the photon is repurposed as a virtual photon for the electromagnetic effect.

Existing approaches to understand annihilation are primarily the refinement of mathematical models such as quantum chromodynamics (QCD) to accommodate the diversity of observed results. Most of the focus is on the combinations of outcomes and the conditions under which they arise [1], or the characteristics thereof [2], hence 'production channels' [3]. A common approach is the fitting of mathematical models to empirical observations, e.g. size of jet width [4], or the environmental conditions [5], or energies involved [6], or the output characteristics [7, 8].

Mathematical models have been constructed to account for production rates under various types of annihilation, e.g. for e+e- into photons [9-11], leptons or muons [9, 10]. There is also work on hadrons [11-13], positronium output states [14], or hydrogen-antihydrogen annihilation [15]. These approaches are sometimes called 'descriptions' of the process, but they are better understood as mathematical models seeking to find

factors and coefficients [18, 19] or statistical fit [16, 17] to empirical data. In general these require adjustment factors to fit to empirical observations.

Overall, the resulting aggregation of mathematical methods has empowered the QCD model with good fit to the data. The ultimate hope with this particular modelling line of enquiry is that it 'may provide insight into the hadron production mechanism' [11](p45). Indeed the models may be applied in the inverse direction, back to other observations, e.g. astronomical emission, to infer the environmental conditions at the source [18]. However the production *mechanisms* themselves remain obscure, even if the outputs can be predicted and modelled accurately.

The practical measurement of annihilation data often involves smashing particles together in colliders, and this introduces additional complexity into the process. For a start, the input particles are not always pure electrons and antielectrons. Instead they may be proton vs. proton. Secondly, the input particles have considerable kinetic energy. Thus experiments in high energy physics may produce complex showers of various short-lived particles and antiparticles that further decay into other outputs [19].

While the term 'process' is often applied to models of annihilation, this is a misnomer, at least from an engineering perspective, because the *mechanisms* that give rise to the outputs are still unknown. The output results are known for various inputs of particle type and energy, but the mechanisms that transform the inputs into the outputs are hidden in a black box. Thus an important piece of knowledge of the production process is missing. It is like watching the assembly of a motor car from a distance, so that the overall phases can be discerned, but not the tools, parts, and operating procedures.

To sum up the existing body of knowledge, QCD provides a mathematical theory and there are good mathematical models to fit the annihilation data, but the descriptive understanding of the underlying mechanism is lacking. It is this gap that the present paper targets, by providing a conceptual model.

Approach

In this paper we focus on that most basic of annihilation events, that of an electron and antielectron. Several basic principles become evident in this simpler process, and we believe that the mechanisms are applicable to more complex particle combinations too.

The approach we take is totally different to the conventional mathematical modelling described above. We argue that the prevailing mathematical methodology shows good quantitative outcomes, but has been unable to create a coherent descriptive narrative of the process of annihilation. We seek a descriptive explanation that is grounded in the physical realm, not merely an abstract mathematical model.

We take the premise of physical realism: that the study of Physics is the description of the physical realm, and that the mathematical representation on its own is inadequate. Thus there *should* be a physical explanation of the internal process of annihilation, if the right concept can be found. Therefore we take a different approach, one that is totally independent of quantum mechanics. Instead it is based on conceptual design principles adapted from engineering. We apply this method to the cordus conjecture [20] and thereby develop a theory for the annihilation process. Specifically, we join the concepts from the existing model for antimatter [21], and that for the photon [22], to create a new model for the details of the annihilation process.

2 Cordus Background

The cordus conjecture [20] provides a novel reconceptualisation of fundamental physics. It is radically different to quantum mechanics, and a brief explanation is therefore necessary. We acknowledge that it is a conjectural and untested concept. Even so, it has shown ability to provide a coherent explanation for many of the enigmatic phenomena of fundamental physics [20], that QM itself cannot explain. Thus it is worth exploring antimatter from this alternative fringe perspective.[2]

The cordus conjecture is that all 'particles', e.g. photons and electrons, have a specific internal structure of a *cordus,* comprising two *reactive ends*, with a *fibril* joining them. The reactive ends are a small finite *span* apart, and energised (typically in turn) at a frequency, at which time they behave like a particle. When energised they emit a transient force pulse along a line called a *hyperfine fibril (hyff),* and this makes up the field. We avoid the use of the term ‘particle’ as it is too cognitively laden with the zero-dimensional point construct of orthodox physics, which we argues is a fundamental flaw in QM [23]. Instead we use the noun ‘cordus’ or ‘particule’ to describe this entity, or sometimes ‘particuloid’ where we seek to emphasise that it looks like a particle at certain levels.

The main difference between matter and antimatter (M-aM), according to cordus [21], is that the hand is inverted. However ‘hand’ has a particular meaning in the cordus context, and is called *ma* [21], described as follows. Each reactive end for a stable matter particule, e.g. the electron, has three orthogonal hyff, in the axes [r,a,t]. The hand of these is held to be the same for all matter particules, whether positive or negative charge, and nominated as *forma*, see Figure 2. The hand is presumably created by the sequence of energisation of the hyff. For all antimatter particules the hand is inverted, and is termed *hyarma*. The inversion of the hand also changes the direction of the hyff, and thus reverses the charge, but this is a secondary effect. Thus from the cordus perspective annihilation is not a

[2] The title 'fringe' is peculiar to modern physics. Unlike engineering design, music, arts, architecture, and even accounting, physics has an uneasy relationship with conceptual innovation.

charge effect: positive and negative charges (of like ma hand) do not destroy each other. Annihilation is instead a hand effect.

Having established the cordus position that ma is the distinguishing feature of matter and antimatter, we now develop a more detailed cordus mechanics for the *process* of annihilation. The particular area under examination is the annihilation of an electron (e) and antielectron (e̲, positron). Note that the cordus notation uses an underscore for the antiparticle, to show that it is conceptually different to the conventional idea of antimatter.

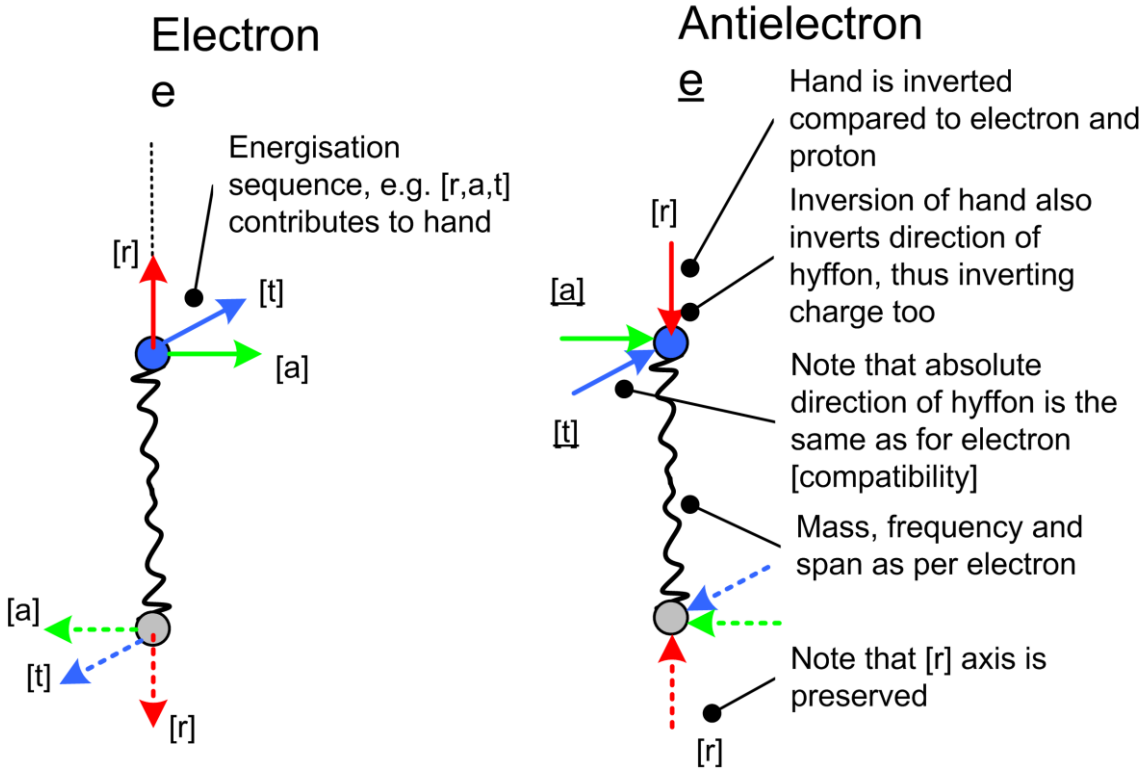

Figure 2: The hand of the hyff is the differentiating factor in the cordus model for matter and antimatter.

3 Cordus mechanics for annihilation

3.1 Complementarity of ma hand is the underlying principle

An implication of the cordus hand lemma is that matter particules (which have the same forma hand) cannot annihilate each other: they can only balance their charges at assembly, i.e. neutralise net electrostatic force. (But even that does not neutralise all the hyff effects, according to the cordus gravitation model [24, 25]). Thus an electron and a proton cannot

annihilate each other, but only dance around each other's hyff. Via the hyff they exert forces on each other (more accurately position re-energisation constraints). This encourages them to negotiate complementary hyff emission directions and synchronised frequency thereof, which are the cordus SHED [26] and CoFS [27] principles. The result is that the electron and proton are *bonded* together.

Thus cordus explains why the proton and electron do not annihilate: they are the same hand, and therefore can only share space. Merging and then collapsing their hyff is not available.

We propose the following criterion for annihilation: It occurs when all the hyff of both particules are co-linear and in the same direction. This requires that the hyff at the reactive end are pumping in the same absolute direction but from opposite sides of the reactive end. In effect this requires opposite charge *and* opposite hand. Thus a forma electron and a hyarma antielectron (positron), when placed close together, can simply merger their hyff and transform back into photon energy from which they were made. It is the details of that process to which we now turn.

3.2 Annihilation of matter and antimatter

The antielectron e̲ has hyff that are in opposite in hand and direction *relative* to the reactive end, compared to the electron. In cordus notation this is shown as hyff being in the same *absolute* direction but on opposite sides of the reactive end. The collapse sequence is surmised as follows, with reference to Figure 3.

(1) Initial engagement.

When the e and e̲ come within proximity, their hyff start to engage - well before the reactive ends themselves are close. This engagement aligns the two cordi parallel and draws the reactive ends into geometric coincidence, see Figure 3.1. The mechanisms for this part of the process are electrostatic and magnetic forces [24] mediated through the hyff.

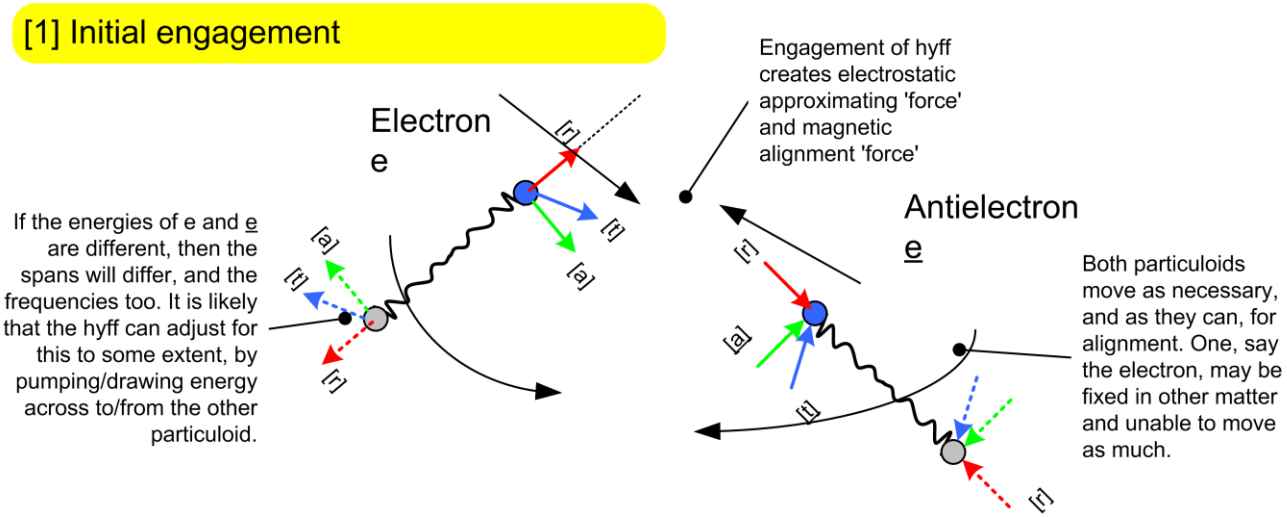

Figure 3.1 Initial engagement of electron and antielectron is a process of mutual alignment.

(2) Synchronisation process.

It is one thing for the participating particules to be near each other, and sufficiently aligned, but the next necessary step in the process, according to this cordus model, is synchronisation. The phases of the hyff of the two particules needs to be suitable, see Figure 3.2.

In this model we define a suitable phase as opposite, i.e. when the reactive end of the one particule is active while that of the other particule is dormant, i.e. 180 degree phase offset. We emphasise this is only the current working model, and we have selected this construct as it seems to work better than a 0^{o} phase offset.

A suitable phase also requires that the frequency of the two particules be sufficiently similar: the hyff need to be in complementary states for the annihilation process to proceed. The cordus model specifically includes the mechanisms to accomplish this: (a) the hyff and the span (hence frequency) are interconnected within one particuloid, and (b) hyff of neighbouring particuloids negotiate their existence (the cordus SHED principle) and thereby transfer energy between them.[3] Thus the two particuloids can balance their energies and hence their frequencies and spans, and get them into the correct phase. In this condition they are in a bound state, albeit temporary. We identify this as the bonding mechanism for positronium.

[3] It is precisely because of this rapid sharing of external loads that bound particules are stability. According to cordus, stability, including the resistance to decay, arises because external forces (more accurately positional constraints on the location of re-energisation of reactive ends) cannot peel off one particule from the assembly. This applies also to the internal sub assemblies within particules. Hence the neutron is stable when bonded with a proton, but decays when isolated on its own.

So the initial engagement is a process of geometric alignment, whereas the synchronisation is of frequency and its phase. We anticipate that the two processes occur concurrently, so our differentiation of them into distinct processes is for descriptive clarity rather than temporal accuracy.

Another simplification is that the diagrams show one set of hyff as active (solid lines) and the other as inactive (dashed lines). However this should not be interpreted as implying a step on-off change between the two sides of the cordus. Instead it is more likely that there is a progressive transition. For one moment there will be all the hyff at the one reactive end and none at the other, but for the rest of the half-cycle there will be an overlap.

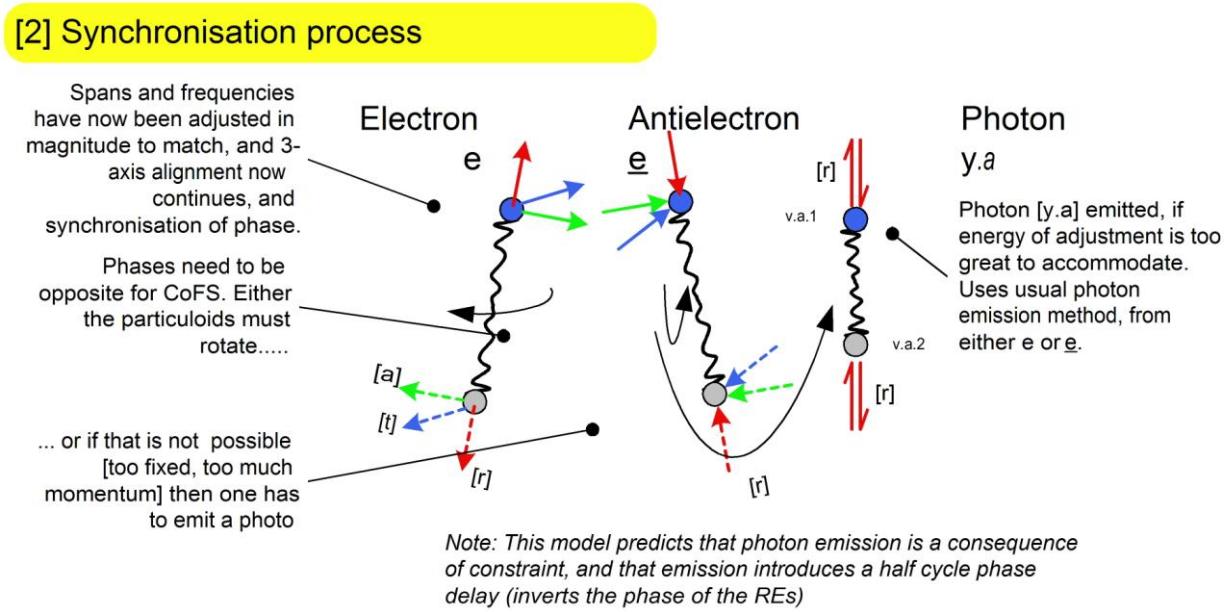

Figure 3.2 In parallel with geometric alignment, the electron and antielectron also synchronise their frequencies: both the magnitude and phase thereof. Photon emission may occur if necessary for synchronisation.

There is also an important other effect that we believe occurs at this synchronisation stage, and that is the occasional emission of a photon. We propose, as already stated, that the hyff of the two particules need to be in complementary states. Sometimes this does not occur, and instead the SHED principle drives the assembly into a metastable state whereby the two reactive ends are energised at the same time: 0^{o} phase offset. We anticipate reasons for this situation:

- A natural outcome of the SHED negotiation process, i.e. the result of the process is either 180^{o} or 0^{o} phase offset, nothing in between. The two particules rotate to access whichever of these states is geometrically closest.
- The particules do not have sufficient degrees of freedom to rotate. Loss of freedom is in turn expected to occur for situations such as (a) a particule being fixed by its existing bonding agreements with

an atom, or (b) a particule having too much momentum to be able to make the necessary adjustment manoeuvre in the time available.

In passing, we note that all of these reasons are ultimately geometric in origin, and indeed the cordus conjecture suggests that 3D geometric effects are the root causes of many fundamental effects.

Photon-emission phase-offset

Next we make the assumption, which we mark with a lemma, that emission of a photon causes a cordus to delay the re-energisation of its reactive end by half a frequency cycle, i.e. to change its phase by 180^{o}.

Thus a particule-pair that is caught in the metastable 0^{o} phase, may escape that state by emitting a photon. In a sense the emission is a type of decay process. A separate part of the cordus conjecture elaborates on the emission of photons. We anticipate that either the electron or antielectron may emit the photon, and that it will probably be whichever is more geometrically constrained or higher energised. Emission is an energy-discard mechanism. It also discards energy from the joint system, and may require further energy balancing subsequently.

The particules operate at the hyffon level, and so each round of force and energy balancing requires another hyffon emission round, i.e. another frequency cycle. Frequency cycles *are* time -the two are indistinguishable [25]- and therefore the process of forging compatibility takes time.

This cordus model predicts that particules with greater disparity in energy or less degrees of freedom, will take longer to annihilate. Also, for cases where both particles have the same energy, higher-frequency is expected to result in faster reactions. Possibly both of these may be testable.

We acknowledge that our proposed photon-emission phase-offset is a convenient supposition of synthesis, i.e. we sought mechanisms to match the observed behaviour that annihilation can cause emission of two or sometimes three photons, and this seemed to be the most obvious and conceptually parsimonious solution. If it seems a contrived solution, or an artefact of the subjective synthesis method, then that is true. Nonetheless, and to our surprise, we note that perhaps the effect has already been observed: the somewhat obscure Sokolov–Ternov effect is that electrons or antielectrons can invert their spin by synchrotron radiation. More work would need to be done to confirm the convergence of these concepts, but it would seem that cordus may explain the mechanisms underpinning the Sokolov–Ternov effect. This also means that the cordus principle of photon-emission phase-offset is not as preposterous as it might first seem.

(3) Docking process

Once the reactive ends are within range of each other, geometrically aligned, at complementary frequencies, and in phase, then the docking process is complete, see Figure 3.3. We surmise that the necessary geometric spacing is the length of the hyffon (which in turn is the pulse that travels on the hyff).

As docking progresses, so the reactive ends continue to approximate (come closer) and the increasingly overlap of the hyffons causes a confused CoFS state. This starts to take on some of the features of a fibril. Thus there is a growing connection between the e1 and e1 reactive ends, i.e. an inter-action at the expense of the intra-action. The identities of the original participating cordi become weaker, and a temporary square structure arises. This readies the system for the next transition.

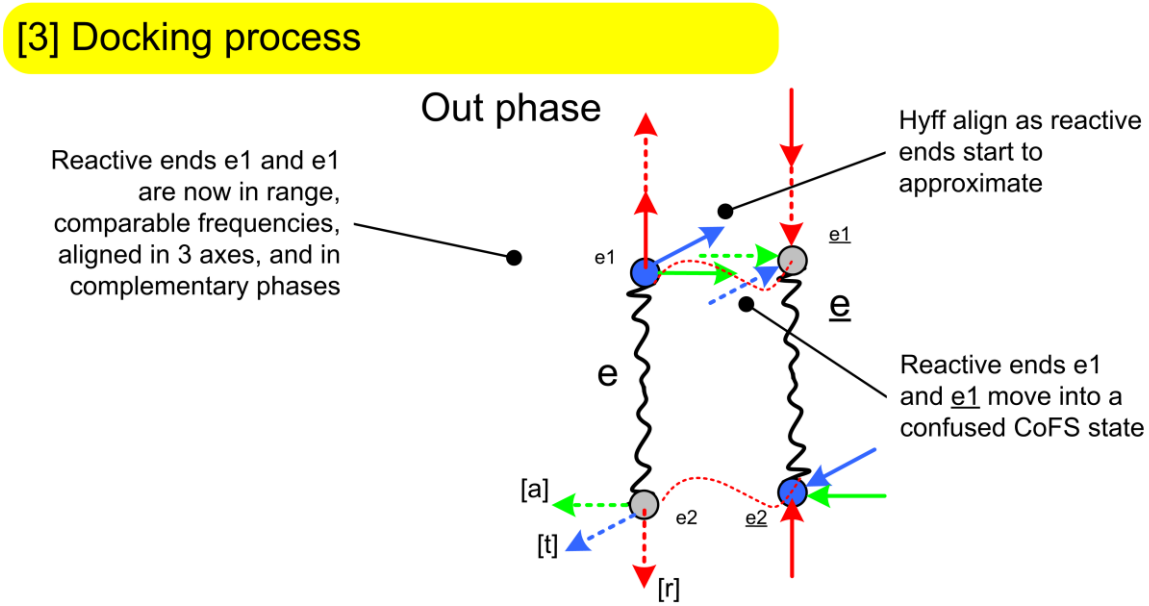

Figure 3.3 Docking process involves the geometric alignment of the reactive ends and a growing interaction between the e1 and e1 reactive ends at the expense of the intra-connections.

(4) Cross-over fibril process

We assume that a fibril is formed between reactive ends when their hyff are sufficiently co-incident, co-linear, at the same frequency, and suitable phase. We note this as lemma Ma.3.4. In this specific case under consideration, the e1 and e1 reactive ends thereby form a new fibril, see Figure 3.4.

The original fibrils fade out. These had been of the pulsatile type: discrete hyffon pulses moving in one direction. Also, the two reactive ends were out-of-phase (180^{o} phase offset), so that one reactive end was energised while the complementary one was not.

In contrast the new fibril is the fibrillating type: two hyffon pulses moving in the same direction, then reversing. Both the new reactive ends are active at once (in-phase or 0^{o} offset). This is shown in the figure for the hyff in the [a] axis and is presumed to simultaneously incorporate the other axes. See also lemma Ma.3.5.

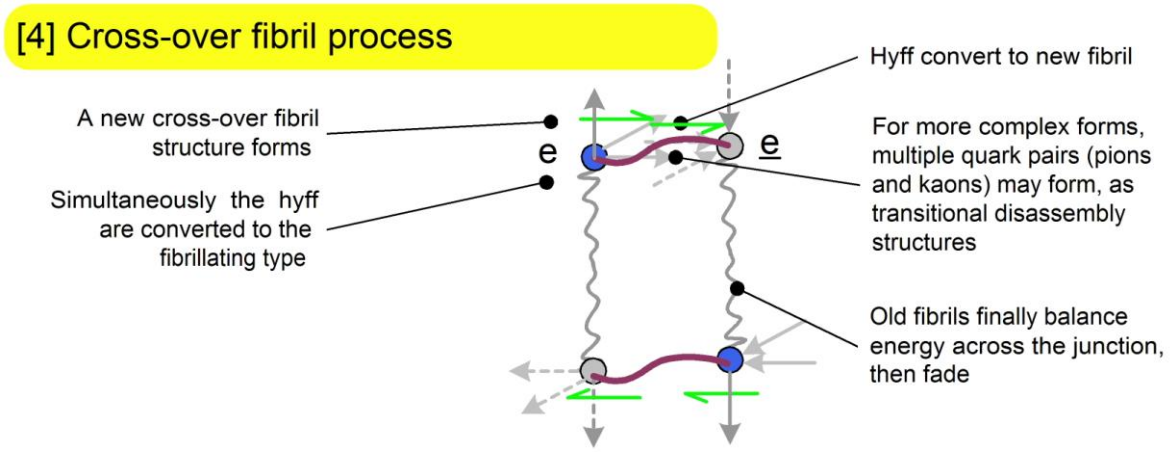

Figure 3.4 Cross-over involves the formation of transverse fibrils.

We assume that the condensation of the original [r,a,t] and [r,a,t] hyff can result in transitional structures, particularly for more energy rich input particuloids like protons and antiprotons.

(5) Conversion to photons

The in-phase fibrillating structure is that of the photon. Thus the outcome of this process is a photon from each pair of reactive ends, shown as y.b and y.c in Figure 3.5. Note that in the cordus conjecture the hyff arrangements define the particule. Thus function defines form, see Ma.3.7. The conservation of hyff required that two photons be produced (Ma.3.8).

The final stage of the process involves clearing up the transitional structures: the original fibrils dry up as the hyff are withdrawn and repurposed into the new structures. Note that according to this model of events, the reactive ends are the most enduring structures: the pegs around which the rest of the changing tapestry is woven.

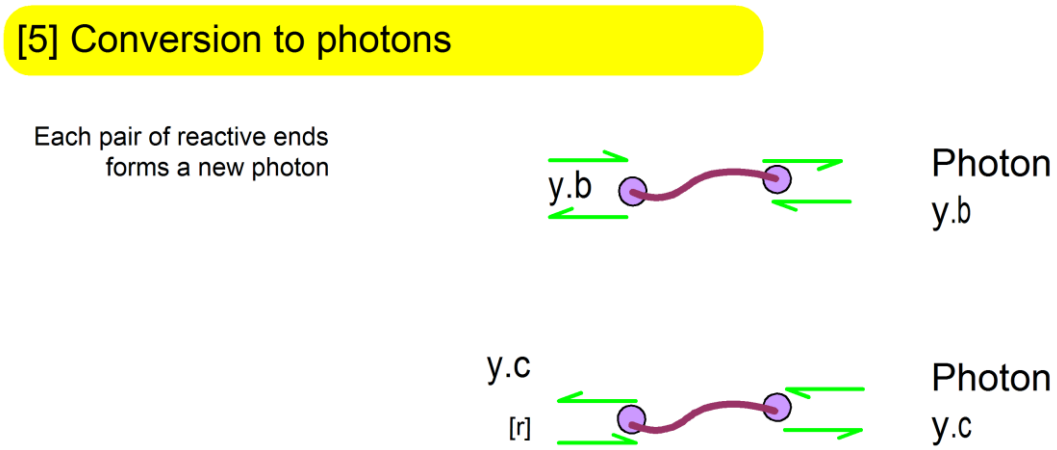

Figure 3.5 Reactive ends strengthen the transverse fibril links and the original fibrils decay, resulting in two output photons.

The two photons y.b and y.c emerge simultaneously, not sequentially, in this particular cordus model.[4] These two photons are predicted to be of opposite polarity but identical energy. The polarity arises because the original participating particules were of the oscillating frequency type (180° phase). The identical energy arises because (a) the initial synchronisation process balances the energy between the electron and antielectron, and (b) the fibrils distribute and balance the energy between the reactive ends. So there is a balancing of energy across all four reactive ends involved, and this carries forward to the photons.

If there is sufficient energy then additional photons or other transitional particules may be produced at this stage by the production of complementary hyff pairs (Ma.3.8) and their allocation to particules (Ma.3.7).

Details of the conversion to photons

The proposed details of the conversion are shown in Figure 4.

[4] If we had taken an in-phase model at synchronisation (#2) then the photons would be sequential, and the original fibrils would need to persist for one half-frequency cycle longer, re-energising the other pair of reactive ends, collapsing their hyff, and creating a second photon out of the hyff. However this is not the preferred model here, though we mention it as it the evidence for its exclusion is not overwhelming.

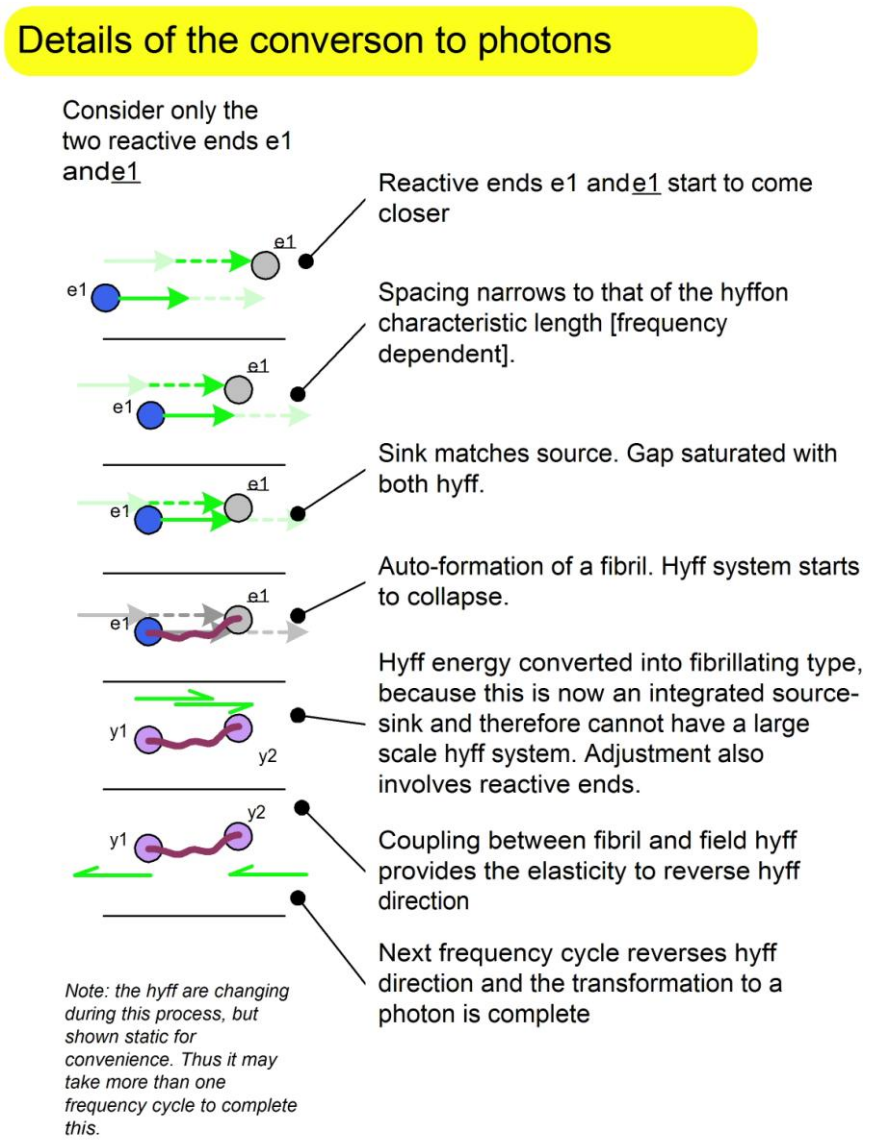

Figure 4 Conversion details for photons. This diagram shows only one reactive end, and the other follows a complementary process to also produce a photon.

The very last stage, reversal from one direction to the other, is held to be a consequence of the dynamic the coupling between hyff field and fibril nature of the particule. The energy shuttles from one to the other. The photon cannot release its hyffon into the wild, unlike the electron, because it is an integrated source-sink. Consequentially the propagation of the hyffon, i.e. the discrete field, is pushed one way (towards the right in the figure), elastically recoils from the fabric, and reverses direction (leftwards). The fibril allows the two hyff to be instantly coordinated, so that what happens at one reactive end also happens at the other, (or at least the complementary action occurs, because the hyff are in different directions relative to the reactive end).[5]

[5] Time does not exist within the fibril, because time is only generated at the next level up, which is the frequency oscillations of the cordus as a whole.

3.3 Lemma

The following lemmas summarise the assumptions in this annihilation model, and the principles of the basic mechanics.

Ma.3 Annihilation lemma

Ma.3.1 Cordus principle of Convergent hyff emission: Annihilation occurs when the hyff of two separate particules are, at their adjacent reactive ends, pumping in the same absolute direction but from opposite sides of the reactive end.

Ma.3.2 In this model we define a suitable complementary phase for the annihilation of electron and antielectron as opposite, i.e. when the reactive end of the one particule is active while that of the other particule is dormant, i.e. 180 degree phase offset. It may take frequency cycles to accomplish this, hence time. See also O.3.13 [28].

Ma.3.3 Cordus Principle of photon-emission phase-offset: emission of a photon from a particule will delay the re-energisation of its reactive end by half a frequency cycle, i.e. change its phase by 180^{o}.

Ma.3.3.1 This is equivalent to flipping the QM 'spin'.

Ma.3.3.2 The concepts of spin, hand, chirality, and ma are not identical, and should not be confused. However they are expected to be related at a deeper level.

Ma.3.4 A fibril is formed between reactive ends when their hyff are sufficiently co-incident, co-linear, at the same frequency, and suitable phase.

Ma.3.5 When hyff form such a fibril, they can change from the pulsatile type (discrete pulses moving in one direction) and 180^{o} offset (out-of-phase), to the fibrillating type (both move in the same direction, energised at once, and then reverse) and 0^{o} offset (in-phase).

Ma.3.6 Cordus principle of Complementarity of bonding and annihilation. Bonding and annihilation are complementary processes for same- and contrary-handedness respectively.

Ma.3.6.1 Same-hand ma structures can interact to form bonds, by sharing hyff emission directions.

Ma.3.6.1.1 When the charges are the same (++ or - -) then the particules can co-exist, but only providing they also take opposite phase in their frequency cycles. Hence the Pauli exclusion principle for electrons. If they are in phase then electrostatic repulsion results.

Ma.3.6.1.2 For opposite charges (+ -) the particules form attractive interactions (bonds) when the reactive ends are in phase with each other (electrostatic attraction).

Ma.3.6.1.3 Annihilation is not available for same-hand ma particules.

Ma.3.6.2 Hyff from contrary ma handed particules can interact.

Ma.3.6.2.1 Particles can annihilate by merging hyff emission directions. However they have to align and get into complementary 180^{o} phase, and this make take frequency cycles and hence time. The particles may need to have the same form, e.g. electron and antielectron. The principles for annihilation of different form particles are uncertain.

Ma.3.6.2.2 Particles can form bonded structures, at least temporarily, when they are in phase with each other. Hence positronium, kaons, and other exotic mesons.

Ma.3.7 Cordus principle that *Hyff Function defines Particule Form*. The hyff *functional* variables are identified as: the quantity of hyff (charge), their direction (sign of charge), colour or direction in the [r,a,t] axes (hyff emission directions, HEDs), phase offset across the two reactive ends (pulsatile vs. fibrillating), and ma hand (energisation sequence). These factors determine what the particule will be, thus its *form*.

Ma.3.8 Hyff are conserved in annihilation and bonding, though complementary hyff may collapse each other. If a new hyff is created then a complementary hyff is also created.

Ma.3.9 The annihilation process itself is fast (125E-12 s for parapositronium), whereas the geometric pre-positioning is relatively slower.

4 Discussion

4.1 What has been achieved?

We have developed a candidate model for the annihilation process between an electron and antielectron (positron). This explains the process in terms of the ma handedness of matter and antimatter, the interaction of the two particules as they approach, the collapse of their hyff structures and their reformation into photon hyff. This is a deeper level of explanation than provided by conventional physics, and thus goes into new territory.

Compared to QCD, the present work offers a *conceptual* theory for annihilation as compared to the *mathematical* modelling of QCD. It is possible that the two might be complementary.

Overall, cordus now provides a more logically consistent descriptive explanation across a wider range of phenomena than any other theory,

QM included. Cordus has already been used to explain wave-particle duality, optical reflection and refraction, entanglement effects, superfluidity & superconductivity, and a variety of other effects. This work on antimatter and annihilation extends its coherence further. That does not necessarily make it valid of course, but it does make it more interesting.

4.2 What are the implications?

We can use the cordus annihilation model to explain some of the other empirical evidence regarding annihilation of electrons and positrons.

Various output photon scenarios

The annihilation of an electron and antielectron is known to produce two photons (or less often 4, 6..) or three (less often 5). It is known to depend on the relative spins: antiparallel or parallel spins respectively. Note that spin refers to the quantised angular momentum of the particules, and is not the same as chirality nor even the ma hand. Output of a single photon is possible, but only if there is other matter nearby to absorb some of the energy.

Applying the cordus model allows these various outcomes to be explained. The final outcome of the annihilation of the electron and antielectron is one of these cases:

- One photon. Single photon, nominally y.b, is emitted. Its companion y.c is emitted and immediately absorbed by nearby matter (e.g. other electrons) before detection.[6] This effect may also remove photons from any of the following cases.
- Two photons, y.b. and y.c are produced from each pair of reactive ends. This occurs if the original e and e were in a suitable phase at the outset: the cordus working model suggests this is opposite energisation (180^o phase offset).
- Three photons. The first photon, y.a is produced as an initial adjustment to get the e and e into in a suitable initial phase. The y.b and y.c photons are subsequent outcomes when the reactive ends rearrange their hyff. If this is true then we would expect the y.a photon to have a different energy to the y.b and y.c (which should be identical in energy).
- Four or six photons. This is an extension of the two-photon model, where transitional structures (e.g. more electron-antielectron pairs) form at stage #4 cross-over.
- Five photons. This is an extension of the three-photon model, with additional pair production at stage #4 cross-over.

The criteria are uncertain for transition into the multiple photon production process at stage #4. We presume this route is determined by

[6] Another possibility is that the hyff are absorbed by another particuloid, even as they are created. Thus absorption before photon v.c is created. However this is not the preferred current model.

the energy content of the original electron and antielectron, i.e. the energy in the e1 and e1 coalescence, and perhaps the degree of external constraint/freedom (see the cordus fabric concept [29]).

The conventional explanation for the production of two photons, rather than one, is that this is necessary for conservation of energy and momentum. The cordus explanation is consistent with this, and suggests a mechanism: at initial engagement (#1) the interaction of the hyff repositions the reactive ends of the electron and antielecton, and this repositioning is set into the motion of the resulting photons at #5.

Positronium

It will be evident that the cordus model also explains the different annihilation outcomes of parapositronium and orthopositronium, but space does not permit elaboration here, and we leave this to a companion paper.

Genesis

There is nothing stopping the annihilation process running in reverse: if two photons come close together (stage 5) they can entangle each other's reactive ends to form cross-over fibrils (stage 4), and then undock those form separate electron and antielectron particules (stage 3) which can then be pulled out of engagement by the surrounding fabric (stage 1). Thus we have also given a physical description of leptogenesis.

Complementarity of bonding and annihilation

The cordus conjecture suggests that bonding and annihilation are similar effects, both involving mutual coordination of hyff, and the primary differentiating factor is the ma hand. Same-hand structures can bond together, by sharing hyff emission directions. This providing their cordus frequencies are sufficiently similar. This is so for electrons, especially as they are flexible about the energies, hence frequency, they adopt. This makes the electron an ideal bonding medium. If the frequencies are dissimilar then the high-frequency partner has spare off-duty cycles in which to do things, including forming liaisons elsewhere, hence instability. Thus we interpret the instability in the non-nucleon hadrons as an example of this cordus principle, and the relationship between the electron and the nucleus as another example.

Thus cordus proposes that same-hand particules can bond, whereas contrary handed particules can annihilate. In a sense bonding and annihilation are complementary processes for ipsilateral and contralateral handedness respectively. The common deeper mechanism is the way the hyff behave at the reactive end.

What happens to the information at annihilation?

Before the particuloids annihilate they are sending out electromagentogravitational (EMG) hyffons into the surrounding space, advertising their existence [25]. The hyffons propagate distally on the hyff

at the speed of light. Thus a remote mass may become aware of one of the particuloids, and an EMG force, say of gravitational attraction starts to act. (Force is more accurately a prescribed constraint on re-energisation position of the reactive end, i.e. an incremental displacement effect.) The hyffons for matter particuloids are discrete structures, and their production is pulsatile, alternating between the two reactive as they re-energise. Note that the reactive ends are separated by a span, and this plus the conservation of hand, means that the two reactive ends are not identical in their field behaviour. Thus a mirror image of any particule is not identical to itself, about every mirror plane. Hence parity violation only occurs at small scales where the span becomes evident [26].

However, what happens when the particules annihilate? According to this cordus model, the *production* of new hyffons (EMG force pulses) ceases when the reactive ends change over to the fibrillating production method for photons. What then happens to the particule's responsibility to the remote mass? The answer, according to this view of events, is that the existing hyffons that are in-transit continue to propagate outwards, and the remote mass continues to respond to the force while those hyffons continue to be supplied. When the flow ceases then the force also ceases. So the remote mass continues to feel the force after the particules have annihilated. One could say that the information about the cessation in production also travels outward at the speed of light. All knowledge of the existence of the two annihilated particuloids is thus progressively wiped from the universe.

In quantum mechanics the information contained in matter, such as its quantum numbers, cannot vanish. By comparison the cordus model suggests that the information about the electron and antielectron does vanish, being replaced by photons with some of the information (but not necessarily all). However this is not really a problem because the initial process of genesis, which manufactured photons into electrons and antielectrons introduced variables that were only temporary anyway: those two particuloids had lives with greater degrees of freedom, which the annihilation subsequently collapsed. It does not matter that the annihilating particuloids were not the same as those original created.

4.3 What are the limitations and implications for further research?

We acknowledge that the validity of this cordus annihilation model is untested. Furthermore, the model is built on prior cordus models, and we acknowledge those might have flaws too. The lemmas introduced here are logically consistent with the whole codex of prior lemmas, thus providing coherence across the wider work, but this does not make it valid.

What we have presented here is a conceptual contribution. For validation it will be necessary to check the model against the known empirical evidence for other annihilation events, i.e. go beyond electron-antielectron interactions. It would also be necessary to enumerate the

cordus mathematics, which would be a large and interesting project of its own. At this time we cannot make a direct comparison between cordus and QCD, since their mechanics are formulated differently. However we expect there to be a basic compatibility.

This particular model purports to describe the process of annihilation itself. This is way beyond the reach of all other theories of fundamental physics, most of which are still working on how to produce a working concept for the discretisation of the electromagnetic field. If cordus was found to be a valid, then the consequences would be significant, as it would open up new lines of enquiry into fundamental physics.

5 Conclusions

To what extent has the original purpose been met?

The original purpose was to tease out the mechanics of annihilation. We have now achieved that, with the process decomposed into stages and the proposed mechanisms identified for each. Yes, we can now explain *how* matter and antimatter annihilate: they transform their field structures - called hyff - into those of the photon.

We can also attempt an answer to the deeper philosophical question of *why* annihilation happens at all: because matter and antimatter are segregated forms of energy - segregated by ma hand that is - and annihilation is simply the reversal of that process. We tend to anthropomorphise 'annihilation', and the conventional construct and terminology, suggests a destructive loss. Yet cordus suggests that at a deeper level there is a conservation at work, one of hyff and reactive ends and energy, so that the process is better thought of as 'remanufacture'. We also show that a deeper common mechanism exists for annihilation, leptogenesis, and bonding.

References

1. Barbiellini, G., B. Borgia, F. Eraelini, M. Conversi, M. Grilli, M. Nigro, L. Paoluzi, R. Santonico, P. Spillantini, V. Valente, R. Viseutin and G.T. Zorn: *A short note on the two photon annihilation processes at `Adone'*. 1972, Ithaca, NY, USA: Cornell Univ.

2. Bhattacharyya, S.: New approach to multihadron production in e+e- annihilation processes. *Fizika*, 1982, 14(3): p. 177-85.

3. Bardin, D. and T. Riemann: Off-shell W pair production in e+e- annihilation: the CC11 process. *Nuclear Physics B*, 1996, B462(1): p. 3-28. http://dx.doi.org/10.1016/0550-3213(95)00645-1.

4. Adachi, K., H. Hayashii, K. Miyabayashi, S. Noguchi, A. Miyamoto, T. Tauchi, K. Abe, T. Abe, I. Adachi, M. Aoki, R. Enomoto, K. Emi, H. Fujii, K. Fujii, T. Fujii, J. Fujimoto, N. Fujiwara, H. Hirano, B. Howell, N. Iida, et al.: Measurement of the jet width in collisions and in e+e- annihilation

process at TRISTAN. *Physics Letters B*, 1999, 451(1-2): p. 256-66. http://dx.doi.org/10.1016/S0370-2693(99)00142-2.

5. Honda, Y., T. Shimada, M. Tashiro, N. Kimura, Y. Yoshida, G. Isoyama and S. Tagawa: Study of annihilation processes of positrons in polystyrene-related polymers. *Radiation Physics and Chemistry*, 2007, 76(2): p. 169-171. http://dx.doi.org/10.1016/j.radphyschem.2006.03.029.

6. Abak, M.: S-matrix theory of weak interactions and the electron-positron pair annihilation process e-+e+N+N. *Lettere al Nuovo Cimento*, 1976, 16(8): p. 245-51.

7. Kurihara, Y., J. Fujimoto, T. Munehisa and Y. Shimizu: Hard photon distributions in e+e- annihilation process by QEDPS. *Progress of Theoretical Physics*, 1996, 96(6): p. 1223-35.

8. Lampe, B. and G. Kramer: Application of Gegenbauer integration method to e+e- annihilation process. *Physica Scripta*, 1983, 28(6): p. 585-92.

9. Lyuboshitz, V.: Spin correlations of muons in the process of electron-positron pair annihilation e+e- +. *European Physical Journal Special Topics*, 2008, 162: p. 43-51. http://dx.doi.org/10.1140/epjst/e2008-00774-y.

10. Gronau, M., C.H.L. Smith, T.F. Walsh, S. Wolfram and T.C. Yang: Lepton energy spectra in e+e- annihilation and other processes. *Nuclear Physics B*, 1977, B123(1): p. 47-60.

11. Pei, Y.-J.: A simple approach to describe hadron production rates in e+e− annihilation. *Zeitschrift für Physik C Particles and Fields*, 1996, 72(1): p. 39-46. http://dx.doi.org/10.1007/s002880050221.

12. Field, R.D. and S. Wolfram: A QCD model for e+e- annihilation. *Nuclear Physics B*, 1983, 213(1): p. 65-84. http://www.sciencedirect.com/science/article/pii/055032138390175X.

13. Kazama, Y. and Y. York-Peng: High-energy inclusive annihilation processes. II. Quantum chromodynamics. *Physical Review D (Particles and Fields)*, 1979, 19(10): p. 3121-34. http://dx.doi.org/10.1103/PhysRevD.19.3121.

14. Frolov, A.M., S.I. Kryuchkov and V.H. Smith, Jr.: (e-,e+)-pair annihilation in the positronium molecule Ps2. *Physical Review A (Atomic, Molecular, and Optical Physics)*, 1995, 51(6): p. 4514-19. http://dx.doi.org/10.1103/PhysRevA.51.4514.

15. Jonsell, S., A. Saenz, P. Froelich, B. Zygelman and A. Dalgarno: Stability of hydrogen-antihydrogen mixtures at low energies. *Physical Review A (Atomic, Molecular, and Optical Physics)*, 2001, 64(5): p. 052712-1. http://dx.doi.org/10.1103/PhysRevA.64.052712.

16. Buchl, R.A. and B.P. Nigam: Annihilation process e++e-+hadrons. *Particles and Nuclei*, 1973, 6(4): p. 113-18.

17. Chao, W., T. Meng and J. Pan: What does the observed rapidity dependence of the multiplicity distribution in e+e- annihilation processes

tell us? *Physics Letters B*, 1986, 176(1-2): p. 211-14. http://dx.doi.org/10.1016/0370-2693(86)90952-4.

18. Jean, P., J. Knodlseder, W. Gillard, N. Guessoum, K. Ferriere, A. Marcowith, V. Lonjou and J.P. Roques: Spectral analysis of the Galactic e+e- annihilation emission. *Astronomy & Astrophysics*, 2006, 445(2): p. 579-89. http://dx.doi.org/10.1051/0004-6361:20053765.

19. Renard, F.M.: Threshold effects in annihilation processes. *Lettere al Nuovo Cimento*, 1976, 16(17): p. 519-24.

20. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J.: Cordus Conjecture: Overview. *vixra*, 2011, v. 1104.0015. Available from: http://vixra.org/abs/1104.0015.

21. Pons, D.J.: Mirror images: Cordus reconceptualisation of Matter and Antimatter. *Vixra*, 2011, v. 1109.0009. Available from: http://vixra.org/abs/1109.0009.

22. Pons, D.J.: Contrasting internal structures: Photon and electron. *vixra*, 2011, v. 1109.0045, 1-9. Available from: http://vixra.org/abs/1109.0045.

23. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J.: Why does quantum mechanics not scale up? *vixra*, 2011, v. 1107.0019. Available from: http://vixra.org/abs/1107.0019.

24. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J.: Cordus in extremis: Part 4.1 Electromagnetism. *vixra*, 2011, v. 1104.0027. Available from: http://vixra.org/abs/1104.0027.

25. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J.: Cordus in extremis: Part 4.3 Gravitation, Mass and Time. *vixra*, 2011, v. 1104.0029. Available from: http://vixra.org/abs/1104.0029.

26. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J.: Cordus in extremis: Part 4.4 Quarks. *vixra*, 2011, v. 1104.0030. Available from: http://vixra.org/abs/1104.0030.

27. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J.: Cordus optics: Part 2.1 Frequency. *vixra*, 2011, v. 1104.0019. Available from: http://vixra.org/abs/1104.0019.

28. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J.: Cordus optics: Part 2.2 Reflection. *vixra*, 2011, v. 1104.0020. Available from: http://vixra.org/abs/1104.0020.

29. Pons, D.J., Pons, Arion. D., Pons, Ariel. M., & Pons, Aiden. J.: Cordus in extremis: Part 4.2 Fabric of the universe. *vixra*, 2011, v. 1104.0028. Available from: http://vixra.org/abs/1104.0028.