Why observations of ultrashort-lived unstable particles cannot be claimed

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Abstract — The physics literature contains many claims that ultrashort-lived unstable particles have been observed: the use of the word 'observation' is then based on a convention. This paper, however, contends against these observational claims by arguing that existential knowledge of ultrashort-lived unstable particles is beyond the epistemic limit of the scientific method: the argument leans in essence on the truth condition of knowledge. Given that an observational claim implies a claim of existential knowledge, it then follows by modus tollens that the observation of an ultrashort-lived unstable particle cannot ever be claimed. That implies, of course, that such observational claims in the literature have to be dismissed as overstatements. A further implication is expressed by two incompleteness theorems for physics, respectively stating (i) that experiments cannot prove completeness of a physical theory predicting ultrashort-lived unstable particles, and (ii) that experiments cannot prove correctness of such a theory—one can at most test its empirical adequacy. On a general note, the conclusion is that the importance of philosophical arguments for physics is herewith demonstrated: the interaction between philosophy and physics is, thus, not one in which the philosopher's task is limited to understanding physics, not criticizing it.

Keywords: observation, existential knowledge, inference to the best explanation, truth condition of knowledge, particle physics, ultrashort-lived unstable particles, Higgs boson

1 Introduction

In recent years, the claim that a Higgs boson has been observed at the LHC has had an enormous impact on the physics community. Chronologically, at a press conference at CERN in 2012 where the preliminary results of the hunt on the Higgs boson were presented, first the claim was made that "we have observed a new boson with a mass of 125.3 ± 0.6 GeV at 4.9σ significance"; see Figure 1. This claim was repeated in two papers in *Physics Letters B*: in these papers, "observation of a new boson" and "observation of a new particle" was claimed right in the titles (CMS Collaboration, 2012; ATLAS Collaboration, 2012). These claims were followed by the claim that the new boson is indeed the Higgs boson (CERN, 2013). The leading journals *Science* and *Nature* hailed the discovery of the Higgs boson as the "Breakthrough of the Year" (Cho, 2012) and "the biggest particle-physics discovery in a generation" (Chalmers, 2012). In addition, the 2013 Nobel prize for physics was awarded to Peter Higgs and François Englert "for the theoretical discovery of a mechanism that contributes to our

Figure 1: Slide shown at a press conference at CERN in July 2012. Source: public domain.

understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle" (Nobel Media AB, 2013).

But even (or better: especially) in the midst of a cheering crowd we have to apply self-reflection, and ask ourselves this question: can it *really* be claimed that a Higgs boson, or any other ultrashort-lived unstable particle with an expected lifetime of less than 10^{-20} s for that matter, has been observed? That is, aren't we grossly overstating matters here? The purpose of this essay is to argue for the latter: while not questioning the *existence* of Higgs bosons and other ultrashort-lived unstable particles[i], the present essay questions the claim that these have been *observed* by arguing that existential knowledge of ultrashort-lived unstable particles is beyond the epistemic limit of the scientific method. Communication with experimental physicists has revealed that the observational claims concerning ultrashort-lived unstable particles are based on the following convention in elementary particle physics, which will henceforth be called the '5σ convention':

> **5σ convention**: the observation of an ultrashort-lived unstable particle can be claimed if the predicted decay products with the predicted properties have been observed with a significance of 5σ.

The next section argues that this 5σ convention is untenable by showing that the alleged existential knowledge it produces doesn't satisfy the definition of knowledge—ever. The section thereafter discusses implications of the present findings, as well as implications of a scenario in which the disputed observational claims are simply maintained by pure power arguments. Furthermore, some interesting replies by physicists to criticism of the 5σ convention are treated, and the conclusions are presented.

It is emphasized that this essay is purely about **the physicists' use** of the term 'observation', which—physicists insist on it!—should not be confused with potentially different definitions of "observation" in philosophy, e.g. by Maxwell (1962), Van Fraassen (1980), Shapere (1982), Falkenburg (2007), and Fox (2009). Furthermore, it is emphasized that this essay is **absolutely not** meant to belittle the theoretical and experimental work involved in preparing and performing the experiments: the calculations involved in deriving testable predictions, the experimental work itself and the statistical analyses of the results are all state-of-the-art, and are not questioned—this paper only questions the conclusions that the experimental results can be called "observations".

2 The argument against the 5σ convention

Let us begin with some definitions. First of all, we will use the *truth condition of knowledge*: although a precise definition of knowledge, such as the JTB-definition, is still debated, it is undisputed that knowledge has to be true. An 'object of knowledge' is that what is known. So for a statement S to be an object of knowledge, S has to be *necessarily* true: it is not possible to *know* that S while S is *not true*—this is the truth condition of knowledge. Furthermore, 'existential knowledge' is knowledge, the object of which is an existential proposition (Cheyne, 1998), e.g., 'cows exist'. Finally, we will use the acronym 'IBE' for 'inference to the best explanation'. That being said, the present argument against the 5σ convention consists of three premises and a conclusion:

(i) **First premise**: an observational claim implies a claim of existential knowledge.

(ii) **Second premise**: to verify the existence of a predicted ultrashort-lived unstable particle, the scientific method is limited to IBE.

(iii) **Third premise**: the existential propositions concerning ultrashort-lived unstable particles that are inferred on the basis of IBE cannot possibly be objects of existential knowledge.

(iv) **Conclusion**: by modus tollens, observational claims concerning ultrashort-lived unstable particles are not justified.

Below each of these premises (i-iii) will be substantiated. The conclusion is then inevitable: **if** the above three premises (i-iii) are true, **then** the conclusion (iv) is true. And **if** the conclusion is true, **then** the 5σ convention is necessarily false: the 5σ convention, namely, states that the observation of an ultrashort-lived unstable particle **can** be claimed, but if these observational claims are not justified then the convention is false.

2.1 On the first premise

Regardless of how we define the term 'observation' precisely, an act of observation always has an epistemic consequence: **if** one has *observed* something, **then** one *knows* that it exists. It is abject nonsense to suggest that one can claim to have observed something without knowing that it exists. E.g. it is nonsense to suggest that a physicist can say "I have observed a J/Ψ-meson, but I do not know whether J/Ψ-mesons exist". In other words, it is not the case that one can claim to have observed something **and** claim to not know that it exists.

Therefore, any observational claim *necessarily implies* a claim of existential knowledge: this holds, thus, **also** for observational claims by physicists. Thus: when physicists claim that they have *observed* an ultrashort-lived unstable particle, they implicitly claim to *know* that the ultrashort-lived unstable particle exists in the system under observation.

2.2 On the second premise

In this section, the second premise is substantiated by the following statements:

(i) to verify the existence of a predicted ultrashort-lived unstable particle, one will have to test predictions about a measurable signal generated by the predicted decay products of that particle;

(ii) when the predicted signal of the decay products has been observed, the existence of the ultrashort-lived unstable particle cannot be *logically inferred* from what we know;

(iii) the existence of the ultrashort-lived unstable particle can thus only be inferred on the basis of IBE.

Below these statements will be proven.

Ad (i): the point is that the lifetime ($\lesssim 10^{-20}$ s) of ultrashort-lived unstable particles is too short to generate a measurable signal: as their speed is bound by the speed of light ($3\cdot10^8$ m/s), they cannot possibly leave a trace of more than 10^{-10} m (the size of an atom) in a cloud chamber. So to test the predicted existence of an ultrashort-lived unstable particle, one will have to design an experimental set-up that can yield an output signal that indicates the existence of the predicted decay products of that ultrashort-lived unstable particle in the system under observation.

Ad (ii): the crux here is that the relation between the existence of an ultrashort-lived unstable particle and the existence of its predicted decay products has the logical form of an if-then relation. Considering that an ultrashort-lived unstable particle u may have several modes of decay, this can be formalized as a proposition of the form

$$\mathfrak{u} \Rightarrow \mathfrak{d}_1 \wedge \mathfrak{d}_2 \wedge \ldots \wedge \mathfrak{d}_n \tag{1}$$

where the proposition letter $\mathfrak{u}$ stands for the existential proposition 'the ultrashort-lived unstable particle u exists in the system under observation', and each of the n proposition letters '$\mathfrak{d}_j$' stands for the existential proposition 'the predicted decay product d_j with the predicted properties exists in the system under observation'.

Experimentally, each decay mode is analyzed separately: in each analysis a hypothesis $\mathfrak{d}_j$ is tested versus $\neg\mathfrak{d}_j$. That is, what is tested in each analysis is the predicted-decay-product-d_j-exists hypothesis versus the no-predicted-decay-product-d_j hypothesis. If that goes well (with the required significance), the hypotheses $\neg\mathfrak{d}_j$ can be rejected, so the proposition

$$\mathfrak{d}_1 \wedge \ldots \wedge \mathfrak{d}_n \tag{2}$$

(with the above interpretation of the proposition letters $\mathfrak{d}_j$) can be inferred from the empirical data. (It can then be said that the predicted decay products have been observed.)

In the search for the Higgs boson, for example, the diphoton mass spectrum of Figure 2 was obtained. From the analysis it can then be concluded that the system under observation contained an

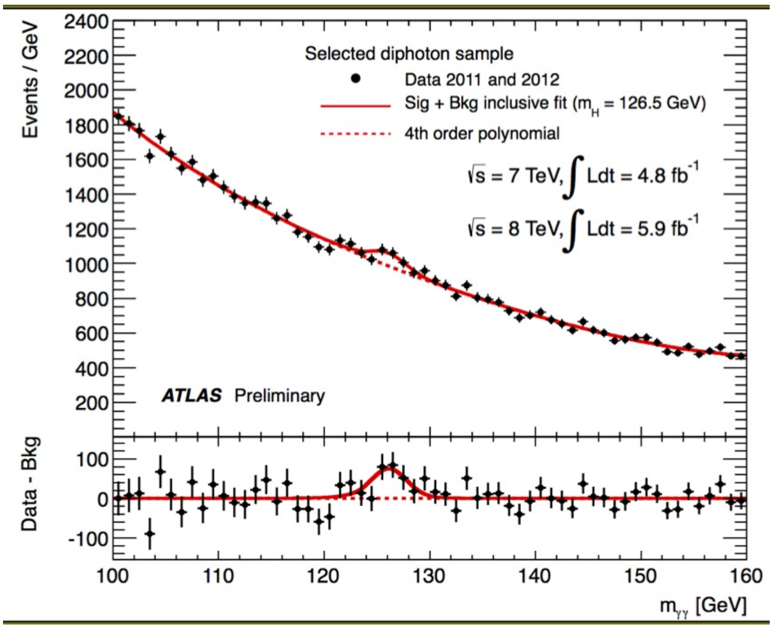

Figure 2: Diphoton mass spectrum obtained in the hunt for the Higgs boson. The lower curve with the peak at around 125 GeV is obtained from the upper one by substraction. Source: public domain.

excess of photon pairs with a total mass of ±125 GeV, as predicted from the decay mode $H \to \gamma\gamma$ of the Higgs boson. So this counts as one proposition $\mathfrak{d}_j$, since a Higgs boson has several decay modes.

So after the experiment is done and the results have been analyzed, the premises (1) and (2) are what we know. The desired conclusion is then

$$\mathfrak{u} \tag{3}$$

with the above interpretation of the proposition letter $\mathfrak{u}$. But this desired conclusion cannot be logically inferred from what we *know*, that is, from premises (1) and (2): that would be a logical fallacy called **affirming the consequence**—which is when a conclusion P is drawn from premises $P \Rightarrow Q$ and Q. In other words: premises (1) and (2) are objects of knowledge, but from there we cannot logically infer that **thus** the desired conclusion (3) is also an object of knowledge.

One might object that premise (1) is too weakly formulated, and should be a logical equivalence (so that not only premise (1) is true, but also the reverse implication). In that case, namely, it is *logically correct* to infer the desired conclusion (3) from what we know by Modus Ponens, as in

$$\mathfrak{d}_1 \wedge \ldots \wedge \mathfrak{d}_n, \mathfrak{d}_1 \wedge \ldots \wedge \mathfrak{d}_n \Rightarrow \mathfrak{u} \vdash \mathfrak{u} \tag{4}$$

The problem, however, is the assumption that the implication $\mathfrak{d}_1 \wedge \ldots \wedge \mathfrak{d}_n \Rightarrow \mathfrak{u}$ is true. From the analysis we *know* that $\mathfrak{d}_1 \wedge \ldots \wedge \mathfrak{d}_n$ holds, so that implication can then only be true if $\mathfrak{u}$ holds, see the truth table below. But $\mathfrak{u}$ is what we want to prove. In other words, it is true that the inference (4) is *logically* correct, but *ontologically* it is a **circular reasoning** because we have tacitly assumed what has to be proven—we have *tacitly* assumed the existence of the ultrashort-lived unstable particle u, whose existence we want to prove.

Ad (iii): from the above we have to conclude that the desired conclusion (3) *cannot* be logically deduced. So it has to be understood, for example, that the inference of the existential proposition "Higgs bosons exist" from the statement "we have observed the predicted properties of the predicted decay products of the Higgs boson" is **not logically valid**. That means that we are left with IBE: the *only* conclusion that we can draw is that the existence of the ultrashort-lived unstable particle is the best explanation for the empirical data. But IBE is weaker than logical inference: the next section shows that drawing the desired conclusion (3) on the basis of IBE doesn't justify a claim of existential knowledge. In other words: in the case of the Higgs boson, the fact that the existence of

$\mathfrak{d}_1 \wedge \ldots \wedge \mathfrak{d}_n$	$\mathfrak{u}$	$\mathfrak{d}_1 \wedge \ldots \wedge \mathfrak{d}_n \Rightarrow \mathfrak{u}$
1	1	1
1	0	0

Table 1: Truth table. From the analysis we know that the antecedence $\mathfrak{d}_1 \wedge \ldots \wedge \mathfrak{d}_n$ is true (left column). If we then assume that the implication $\mathfrak{d}_1 \wedge \ldots \wedge \mathfrak{d}_n \Rightarrow \mathfrak{u}$ is true (right column, value 1), then we have tacitly already assumed that the consequence $\mathfrak{u}$ is also true (middle column). For if $\mathfrak{u}$ wouldn't be true (middle column, last row), the implication $\mathfrak{d}_1 \wedge \ldots \wedge \mathfrak{d}_n \Rightarrow \mathfrak{u}$ wouldn't be true either (right column, last row).

Higgs bosons in the system under observation is the *best explanation* for the empirical data **does not** justify the claim that we henceforth *know* that Higgs bosons exist. And by modus tollens, that means that an observational claim is thus not justified.

2.3 On the third premise

In this section, the third premise is substantiated by the following statements:

(i) if we infer the existence of an ultrashort-lived unstable particle on the basis of IBE, then the truth condition of knowledge is **not** satisfied;

(ii) if we add general consensus, the truth condition is still not satisfied.

Below these statements will be proven; recall that for an existential proposition to be an object of existential knowledge, the existential proposition must be necessarily true—that is, an existential proposition cannot be an object of existential knowledge if it is possible that the existential proposition is false. So, one cannot have *existential knowledge* of a particle that may not exist.

Ad (i): suppose an experiment has been performed, and we have inferred (3), that is, that the predicted ultrashort-lived unstable particle u exists, on the basis of IBE. The inferred existential proposition is then **not** an object of existential knowledge: the crux is that the existence of the ultrashort-lived unstable particle u is **currently** the best explanation of the empirical data, but it may **later** turn out that u doesn't exist and that the empirical data are caused by an object about which currently not even a theory exists. That is, if we infer the desired conclusion (3) on the basis of IBE, then (3) is not necessarily true—it is possible that (3) is false even though it is the best explanation now. Thus speaking, the existential propositions concerning ultrashort-lived unstable particles that are inferred on the basis of IBE cannot possibly be objects of (existential) knowledge because they are not necessarily true.

In analytical philosophy one shouldn't indulge in metaphors, but the following illustrates the previous point. Suppose the phone rings in someone's house: the signal is clearly distinguishable from the background noise, so there is no doubt that it is the phone that generates the signal. The person in the house then infers on the basis of IBE that there is a person who is calling him/her. But s/he doesn't *know* that. In fact, this author has worked at a technical services department of a telecommunication company, which has sold phones that could ring due to current fluctuations in the device. This led to a flood of complaints about stalking and disrupted calls: all those who filed a complaint were thinking that someone was calling. Yet that wasn't the case: there was no one calling, the signal had a completely different explanation (in this case: a technical error in the telephone device). Of course a ringing phone isn't a metaphor for a particle physics experiment that is comparable in every detail, but the essence is the same: on the basis of the observed signal one infers an existential proposition on the basis of IBE, but that existential proposition is not necessarily true.

Ad (ii): Based on the fact that the post-World War II physics community has gradually replaced the traditional notion of *truth* by *general consensus* (Prugovecki, 1993), one might argue that the truth condition for existential knowledge is satisfied when there is *general consensus* about the existence of an ultrashort-lived unstable particle. For example, one might argue that it is true that Higgs bosons exist **because** the general consensus is that Higgs bosons exist. However, one ought to realize that history provides numerous counterexamples to the idea that 'there is general consensus about X' implies 'X is true': an equivalence between truth and general consensus should thus be rejected. In other words: it should be realized that reaching general consensus about the existence of Higgs bosons is **not** equivalent to having existential knowledge of these bosons!

One may ask: how can we *then* get to existential knowledge of ultrashort-lived unstable particles? The answer is then: (absent divine intervention) we can't—existential knowledge of ultrashort-lived unstable particles is *beyond* the epistemic limit of the scientific method. Existential propositions concerning ultrashort-lived unstable particles remain, thus, always an object of *existential belief*— an existential belief is a belief in the truth of an existential proposition (Armstrong, 1973). This notion is **fundamentally different** from existential knowledge: an existential belief, even if justified **now** on the basis of IBE, may turn out to be false **later**. But existential knowledge, which we have now (e.g. 'cows exist'), cannot turn out to be false later—that's the truth condition of knowledge.

Thus speaking, the experimental confirmation of the predictions of the Standard Model provides a justification for a belief in the existence of the ultrashort-lived unstable particles postulated by the Standard Model—this is an existential belief on the basis of IBE—but **does not** yield a justification for a claim of existential knowledge of these particles. By modus tollens an observational claim is thus not justified; and therefore, the 5σ convention is untenable.

3 Discussion

3.1 Implications of the present findings

Obviously, the direct implication of the untenability of the 5σ convention is that *all* published observational claims concerning ultrashort-lived unstable particles have to be dismissed as overstatements: in fact, these claims should be *retracted*. Examples of such particles and corresponding observational claims are given in table 2; the list is not exhaustive but the point is that none of these particles can be said to have been "observed".

particle	**lifetime**	**observational claim**
Higgs boson*	$1.56 \cdot 10^{-22}$	(ATLAS Collaboration, 2012) (CMS Collaboration, 2012) (CERN, 2013)
$W^{\pm}$ bosons*	$3 \cdot 10^{-25}$	(CERN, 1983a)
Z^0 boson*	$3 \cdot 10^{-25}$	(CERN, 1983b,c)
Υ meson	$1.21 \cdot 10^{-20}$	(E288 Collaboration, 1977)
J/Ψ meson*	$1.56 \cdot 10^{-22}$	(Aubert *et al.*, 1974)
Ω_b^-	$1.13 \cdot 10^{-12}$	(DØ Collaboration, 2008)
$Z(4430)^-$	?	(LHCb Collaboration, 2014)

Table 2: examples of unstable particles that are claimed to have been observed on the basis of the 5σ convention; an asterisk in the first column marks cases where the observational claim led to a Nobel prize award. It is true that the Ω_b^- baryon has a lifetime longer than 10^{-20} s and that the tetraquark $Z(4430)^-$ has an unknown lifetime, but both observational claims are based on the 5σ convention.

Further implications are far more general and can be stated in the form of two incompleteness theorems for physics. These concern the *completeness*[ii] and the *correctness*[iii] of a physical theory, two notions that were introduced in the EPR-paper as important for the evaluation of the success of a physical theory (Einstein, Podolsky & Rosen, 1935).

Theorem 3.1. No experiments can prove *completeness* of a physical theory predicting the existence of short-lived unstable particles.

Theorem 3.2. No experiments can prove *correctness* of a physical theory predicting the existence of short-lived unstable particles.

Proof: To prove completeness, one has to prove that the particles predicted by the theory exist. But as demonstrated in Section 2, the existence of ultrashort-lived unstable particles cannot be proven by any experiment—**regardless of the research effort**. Hence a theory predicting such particles cannot be proven to be complete by experimental physical research. Likewise, to prove correctness one has to prove that the predictions of the theory are true. But a prediction that an ultrashort-lived unstable particle exists cannot be proven to be true by any experiment. Hence, a theory predicting such particles cannot be proven to be correct by experimental physical research. Q.e.d.

Consequently, all we can do with physical theories that predict ultrashort-lived unstable particles is testing their *empirical adequacy.* This notion has been defined by Van Fraassen: a theory is *empirically adequate* if and only if all observations—past, present *and future*—in its area of application can be described as predictions of the theory (1980). So this is a somewhat weaker notion than correctness as defined in the EPR-paper: correctness implies empirical adequacy, but the converse is not necessarily true. What is important then is that the fact that the ultrashort-lived unstable particles postulated by the Standard Model are fundamentally unobservable does not render the empirical adequacy of the Standard Model any less.

3.2 Implications of maintaining the disputed claims by pure power arguments

Of course, the physicists c.q. the collaborations involved in the disputed observational claims can refuse to give up their pride, and can refuse to admit that using the term 'observation' was wrong: this is even the most likely scenario. And they can do so by pure power arguments. That is, the disputed observational claims can be maintained simply because the claimants have the power to do so: there is no law that obliges the claimants to address any criticism at all, nor is there any law that obliges the claimants to use scientific arguments in case they *do* address criticism. That means that the claimants have the power to simply ignore or gainsay the present criticism.

But it is emphasized that this is not just a word game: the concern is that by maintaining the observational claims, by proxy a system of **pseudo-knowledge** is being created—that is, a system of statements that are falsely believed to be objects of knowledge.[iv] For example, by maintaining the Higgs claim it is by proxy maintained that the existential proposition 'Higgs bosons exist' is an object of existential knowledge, that is, is something that we know. But as reasoned in Section 2, this existential proposition is not an object of existential knowledge. So by maintaining the observational claim, the statement 'Higgs bosons exist' becomes an object of pseudo-knowledge. Ceteris paribus, that also holds for existential propositions concerning other ultrashort-lived unstable particles.

This system of pseudo-knowledge is not limited to existential propositions. For example, by claiming that a Higgs boson has been observed, one also creates the false belief that the mechanism thought to "give mass" to particles has been experimentally confirmed. An indication that this is widely believed among physicists can be found in the statement by the Nobel committee, expressing the motivation for awarding the 2013 Nobel prize for physics to Peter Higgs and François Englert:

> "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle" (Nobel Media AB, 2013)

Here 'which' refers to the mechanism, so let there be no doubt about it that the claim that a Higgs boson has been observed is widely believed to be an experimental confirmation of the Higgs mechanism. In other words, by maintaining the Higgs claim, the statement "the Higgs mechanism gives mass to particles" also becomes an object of pseudo-knowledge.

The disadvantage of creating a system of pseudo-knowledge is that it is detrimental not only for the physics curriculum, which then effectively produces university graduates who falsely believe that the ontology of the Standard Model has long since been experimentally proven, but also for fundamental physics research: since any new physics must correspond to what is known, an overstatement of what is known creates a too narrow window for research aimed at identifying the most fundamental laws of nature.

3.3 Replies by Physicists

A few dozen top physicists have been confronted with earlier versions of the present argument. Some of the replies are worth a discussion: these replies are paraphrased below and discussed.

Reply 3.3. *Huh, what? No Higgs, no J/Ψ-mesons, no $W^{\pm}$ bosons, no Z^0 boson? This is naive and bad philosophy, a golden opportunity for every physicist who wants to show how irrelevant and pompous philosophy is [sic].*

Emotional reactions like this, received several times, stem from a gross misinterpretation of the paper: what is disputed is not the *existence* of these particles, but the claims that they have been *observed*. This should not be mistaken for an attempt to prove that the ultrashort-lived unstable particles postulated by the Standard Model do not exist, or that the Standard Model is at fault in some way, or anything like that.

Reply 3.4. *The statement that a new boson has been observed is in essence based on testing the hypothesis that the measured diphoton mass spectrum is only due to known processes ("background") versus the hypothesis that it is due to background plus the production of a new particle (here a boson). On account of the analysis the no-new-particle hypothesis can be rejected, and the convention is to call this an observation of a new state decaying in the particular decay channel $H \to \gamma\gamma$. This is a perfectly valid statistical procedure.*

The physicists thus seem to think that they can conclude to the existence of the Higgs boson because of the formulation of the hypotheses. However, the above formulation of the hypotheses is **false**: each decay mode is analyzed separately, and by each such analysis one tests a hypothesis 'predicted-decay-product-exist' versus 'no-predicted-decay-product'. E.g. with the obtained diphoton mass spectrum of Figure 2 one accepts the hypothesis 'the 125 GeV photon pairs predicted by Higgs decay exist', and rejects the hypothesis 'the predicted 125 GeV photon pairs do not exist': this is, thus, **not** a matter of testing 'Higgs bosons exist' versus 'no Higgs boson exist'! The combined result of the analyses yields the conjunction of accepted hypotheses (2): the whole point of Section 2 is thus that this **cannot** be called an 'observation' of a new state!

Reply 3.5. *The enhanced signal at 125 GeV in the diphoton mass spectrum stems from something. If this something did not exist, there would be no enhancement. So of course, the observation of the enhancement can be called an 'observation' of a Higgs boson, but with the understanding that an **indirect** observation is meant.*

As stated in the Introduction, it is not questioned that an excess of photon pairs with a combined mass of 125 GeV has been found. It is also not questioned that this excess comes from something. But that doesn't mean that the observation of the peak in the diphoton mass spectrum can be called an indirect observation of a new boson. The crux is namely—as already remarked by Fox (2009)—that a claim of an indirect observation **presupposes** knowledge of the cause of the observed phenomenon. In other words, if the observed signal is called an *indirect* observation of a Higgs boson, then the existence of Higgs bosons is tacitly assumed. In other words: by calling it an indirect observation of a Higgs boson one *tactitly* assumes what has to be proven, and as such it is a form of circular reasoning. Thus speaking, the Higgs boson is (currently) the best explanation for the data, but it cannot be claimed that a Higgs boson has been observed.

Reply 3.6. *The stance of physicists is that if you observe the decay products, you observe the thing that has decayed. For a physicist, to claim that you accept the observation of a photon in your detector but to deny that these photons stem from a resonance if the diphoton mass spectrum is consistent with the existence of a resonance is* ***perverse*** *[sic]. Hardly any physicist would agree with making a distinction between the excess and the thing causing the excess.*

The crux is that the peak at 125 GeV in the diphoton mass spectrum evidences the presence of lots of photon pairs with a combined mass of 125 GeV in the system under observation: **it doesn't evidence anything else**—in other words: the peak is caused by the presence in the system under observation of an excess of pairs of photons with a combined mass of 125 GeV, **not** by a Higgs boson. Of course the presence of Higgs bosons in the system under observation is currently the best explanation for the observed excess of 125 GeV photon pairs, but that doesn't justify a claim that Higgs bosons have been 'observed'. So, the whole point is to sharply distinguish between an *observed* excess of photon pairs and the thing *assumed* to have caused that excess, analogous to distinguishing between an *observed* sound wave of a phone and the caller *assumed* to have caused that sound wave by dialling that phone's number, and to sharply distinguish between '*knowing that Higgs bosons exist*' and '*believing that Higgs bosons exist on the basis of IBE*', analogous to distinguishing between *knowing that someone has called* and *believing that someone has called on the basis of IBE.*

3.4 Conclusions

The main conclusion is that the observation of ultrashort-lived unstable particles cannot be claimed on the basis of empirical data obtained in particle accelerators—erroneous claims stem from confusing 'observation' and 'inference to the best explanation' and not realizing that an observational claim is then inconsistent with the widely accepted truth condition of knowledge. In the Higgs case, at best one can claim that the predictions of the Standard Model, including the Higgs boson, have been confirmed by the CMS and ATLAS experiments at the LHC. This is a substantially different claim: an observational claim implies a claim of existential knowledge while the latter doesn't.

The present result does absolutely not mean that the Standard Model should be viewed as a pseudo-scientific theory: even when the existence of the ultrashort-lived unstable particles postulated by the Standard Model cannot be proven experimentally, the theory (including these particles) still leads to verifiable predictions. Furthermore, the argument in the present paper is strictly limited to existential propositions concerning ultrashort-lived unstable particles that are inferred on the basis of IBE: by no means is this intended to imply that existential propositions that can be inferred from direct observation—e.g. 'cows exist'—cannot possibly be objects of existential knowledge either. However, the physics literature contains many more observational claims where in fact the *observation of a thing* and the *inference of the existence of a thing based on IBE* have been confused; a recent example is the claimed observation of a gravitational wave (LIGO and Virgo Collaborations, 2016).

Another conclusion is that the testing of predictions that have been derived from assuming the existence of ultrashort-lived unstable particles *at best* yields a justification for a belief in the theory postulating these particles: absent divine intervention, any proposal for a correct and complete fundamental theory of physics can thus *at best* be an object of a justified belief. This raises the question whether the scientific method isn't bound to leave us on the long run with a *postmodernism in physics*—a scenario where several empirically adequate theories coexist without the possibility to decide between these theories.

On a more general note, the final conclusion is that this paper demonstrates the importance of philosophical arguments for elementary particle physics. The papers claiming observations of ultrashort-lived unstable particles have received so much attention precisely because of the use of the word 'observation', but the present paper has demonstrated that this use is not justified. Decades ago Heisenberg already noted that it is a widely held "misconception" among particle physicists that philosophical arguments can be avoided altogether (1976): hasn't the time now come for the physics community to finally say goodbye to this "shut-up-and-calculate!" attitude?

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standing: why it cannot be inferred from empirically acquired information that the Higgs boson has been observed' (2013) and 'Unobservability of short-lived unstable particles and its implications for observational claims and theories in physics' (2015). This study has been facilitated by the Foundation Liberalitas.

Notes

[i]Throughout this essay the term 'particle' refers to individuals in the ontology of the Standard Model: the term 'particle' is thus **not** used in the classical sense as a small massive object with definite position and momentum. E.g. the Higgs boson is a quantum excitation of the Higgs field, but is referred to as an ultrashort-lived unstable 'particle'.

[ii]A theory is *complete* if and only if (i) every element in the physical world has a counterpart in the theory, and (ii) every element in the physical world, predicted with certainty by the theory, indeed exists.

[iii]A theory is *correct* if and only if all its predictions are true.

[iv]Note that this definition of pseudo-knowledge does not imply that the statements that are believed in are necessarily false!

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