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Standard Model: A theory of almost everything

Aaj se 16 saal pehle ki baat hei. Particle physicists in Britain were demanding continued government support for funding CERN – the European Organization for Nuclear Research. They were actively looking for an elementary particle called Higgs Boson. The hunt for this elusive particle is still on (read Vyas's article in this issue). Anyways, getting back to the story, in 1993 the accelerator at CERN was one of the very few places where such a particle could be detected. Now, being of the opinion that scientists often ask for too much taxpayers' money for doing research that very few people can actually understand, Mr. Waldergrave, who was science minister in the British government then, challenged physicists of his country to answer a simple question. The question was "What is the Higgs Boson, and why do we want to find it?" The answer was to be in a language that even a lay person can understand, and on a single sheet of A4 size paper. The prize for successfully meeting this challenge was a bottle of champagne. Many physicists responded to this challenge, and out of them five were declared winners. Later in this article, I will share with you one of these winning responses. This is not just because it is a very interesting response and uses politics as a metaphor, but also, and more importantly, because Higgs bosons are a crucial part of the topic of this article – the standard model of particle physics.

So in writing a short article on standard model, I feel that, in a way, I too am responding to Mr. Waldergrave's challenge. So what if I am just 16 years late? Now, I am not hoping for a bottle of champagne from the editors. But frankly wouldn't mind some delicious gulab jamuns from …….. (Rajesh, I am forgetting the name of that halwai on the ghat from where we used to get the gulab jamuns – please put that guy's name here) of Sethani Ghat, Hoshangabad. Well, that is … if I meet the challenge because writing a short article on something that is often claimed to be a theory of almost everything is anything but easy.

I wouldn't be too off the mark in saying that development of the standard model of particle physics was the most significant achievement of physics research in 20th century. When I counted the number of Nobel prizes offered since beginning (i.e. 1901) for research that contributed to the development of this model, I was surprised to find that this number came up to 74. That is, since inception, this field of research has accounted for roughly 69% of all Nobel prizes awarded in physics![1] The reason is simple: research that led to building of Standard Model was aimed at understanding the nature of matter and energy. Now, at least in physics, what can be more important than coming to understand the stuff that you, me, plants, animals, earth, sun and the whole universe is made of? Standard model represents the result of this more than a century old and still ongoing effort. It describes, and to a large part also explains, everything that we know about matter and energy. It is indeed a theory of almost everything in the material world. That is, everything excluding gravity.

[1] Refer: http://careerchem.com/NAMED/NobelPhysics.pdf to see the research area wise distribution of Nobel Prize in Physics. 74 Nobel prizes include 29 in particle physics, 20 in quantum theory, 16 in atomic structure, 8 in nuclear physics and 1 in atomic physics.

Now, if you ask me that if it is a theory of almost everything, can I use it to describe the table I am writing this paper on, the answer would be a big NO. What it does is to allow me to reductively analyze the table down at the most fundamental level so that I can understand my table in terms of its constituting building blocks, how they are configured with respect to each other and how they interact with each other to endow the observable material properties that my table so obviously has. That is, standard model would be able to offer an *in principle* explanation of the table at its most fundamental level.

As you can imagine, a theory with such a promise and scope would necessarily be huge and very, very complex. To do full justice to it, one would need to write a whole fat book and that too in mathematics – the language of choice in physics. Since, I can't do that in a journal like Sandarbh, I have made certain choices. First, out of many issues this model deals with, I have chosen to focus on the two that I find most fascinating. They are: (a) what is matter made of? (b) What is mass? Second, good and accurate answers to these questions would need lots of crazy, complicated equations and abstract terms that you probably don't wish to hear about. So I have tried to respond to these two questions as simply as I could. In doing so I have tried to follow Einstein's advise that "Everything should be made as simple as possible, but not simpler." However, in this effort I do run the risk of over-simplifying the model.

What is matter made of?

You must have heard that we, earth, and in fact all matter in this universe is made of tiny particles called atoms. You may have also heard that the atoms are themselves built of still tinier particles that are truly the smallest possible building blocks of matter. These particles are not made up of further smaller pieces of matter, and thus are called the elementary particles. As physicists were able to probe deeper and deeper into the matter both conceptually as well as experimentally, understanding of what these elementary particles are evolved with time. For instance, at the dawn of 20th century, it was thought that atoms and thus everything in this universe was made of just two kinds of elementary particles – electrons and protons. After a gap of a few decades, the existence of neutrino was predicted in 1930, and neutron and positron were discovered in 1932. A deluge of discovery of many more elementary particles followed after these amazing finds. And for quite some time physicists had such a hard time making sense of this ever increasing mélange of new exotic particles and to decide which ones were truly elementary. So much so that, in 1955, speaking of the prevailing sentiment on this issue in physics labs across the world, the physics Nobel prize winner Willis Lamb in his Nobel lecture reported that "I have heard it said that the finder of a new elementary particle used to be rewarded by a Nobel Prize, but such a discovery now ought to be punished by a $10,000 fine".

Some of these particles were later found to be made up of further smaller particles and thus lost their status as elementary particles. Standard model helped to impose some kind of order among those that remained truly elementary. Thus, Table 1 shows 17 particles that are now recognized by physicists as elementary particles (refer Table 1). As this table shows, these 17 particles can be broadly classified as fermions and bosons. Thanks to the standard model, the 12 fermions are can be further classified into 3 families or generations (refer Table 2).

Table 1: List of elementary particles in standard model

		Fermions		
Leptons				
Name	Symbol	Antiparticle	Charge (e)	Mass[2] (MeV/c^2)
Electron	e^-	e^+	- 1	0.511
Electron neutrino	?$_e$	?$_e$	0	< 2.2
Muon	μ^-	μ^+	- 1	105.7
Muon neutrino	?$_\mu$	?$_\mu$	0	< 0.170
Tauon	τ^-	τ^+	- 1	1777
Tauon neutrino	?$_\tau$	?$_\tau$	0	< 15.5
Quarks				
Up	u	u	+2/3	1.5–3.3
Down	d	d	- 1/3	3.5–6.0
Charm	c	c	+2/3	1,160–1,340
Strange	s	s	- 1/3	70–130
Top	t	t	+2/3	169,100–173,300
Bottom	b	b	- 1/3	4,130–4,370
		Bosons		
Photon	?	Self	0	0
W boson	W^-	W^+	- 1	80,000.4
Z boson	Z	Self	0	91,000.2
Gluon	g	Self	0	0
Higgs boson	H0	Self?	0	> 112,000

Table 2: The 3 families of fermions

Family 1	**Family 2**	**Family 3**
Electron	*Muon*	*Tau*
Electron-Neutrino	*Muon-Neutrino*	*Tau-Neutrino*
Up Quark	*Charm Quark*	*Top Quark*
Down Quark	*Strange Quark*	*Bottom Quark*

[2] For elementary particles, it is convenient to give masses in MeV/C^2.
1 MeV/C^2 = 1.783 x 10^{-30} kg.

So, are we and other things in this universe made of that many type of elementary particles? Surprisingly, the answer is no. Thanks to the standard model, we now know that all the known and observable matter in this universe (and that definitely includes us) is made of just three types of elementary particles - the electrons, the 'up' quarks and the 'down' quarks – interacting with each other with the help of gluons and photons. Just imagine … it take just these few kinds of particles to make this incredibly beautiful and complex universe.

Now, here you may well recall some science from your school years may say – hey wait, atoms are made up of protons, neutrons and electrons. So what about protons and neutrons? Well, as I mentioned above as scientists probed these particles more deeply, they realized that many of the particles that they earlier thought as elementary weren't really that elementary. They were found to be made up of still smaller particles. This was the case with neutrons and protons. Thanks to the contributions of Murray Gell-Mann, George Zweig and others who made seminal contributions to the building of standard model, we now know that a proton is made of two 'up' quarks and one 'down' quark, and a neutron is made of one 'up' quark and two 'down' quark. The electron on the other hand has been able to retain its well-deserved reputation as an elementary particle. In fact, like all other elementary particles it is so small that it has no size at all, and is called a point particle. It has a distinct mass though. Now, that is something truly bizarre, right? A particle with mass but no size! I know how you are feeling right now. But wait, …. if you continue reading you will realize that reality gets even weirder at these ultra-tiny scales.

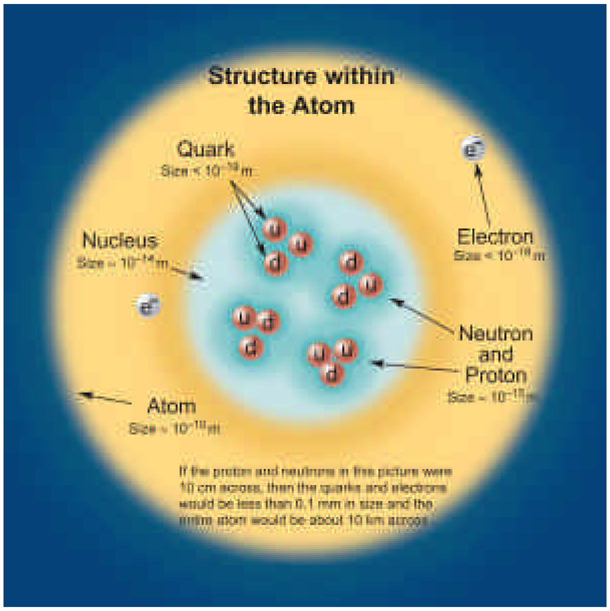

Figure 1: Peeping inside an atom (adapted from: http://www.cpepweb.org/cpep_sm_large.html)

Now a word about the other elementary particles that according to scientists don't constitute the matter we see around us. Out of these let's leave bosons out as they don't constitute matter but only exist to mediate the interactions between matter constituting fermions. The thing about the remaining fermions - electron neutrino, muon, muon neutrino, tauon, tauon neutrino, charm, strange, top and bottom quarks - is that they don't contribute in making matter in this universe. Though, their existence has been verified in science labs innumerable times throughout the world. The major reason why they don't get to contribute to making matter is that these particles, except for neutrinos, have a very short life and, thus, decay into other particles rather too quickly for this role. As for neutrinos, they are too light to decay into anything. But since they barely interact with other particles that compose ordinary matter, they don't contribute in making matter either. You may be wondering now that why do they even exist if the universe has no need for them to make all the stuff that is all there. Well, here you may be happy to know that you aren't alone. As I mentioned above, standard model is able to classify all fermions in three particle families. It can account for the first particle family (electron, electron-neutrino and 'up' and 'down' quarks belong to this family). But physicists still not understand very well ~~for all its power, it can't really explain~~ why particles belonging to the other two families exist.~~, even if it is for a few fleeting moments~~. ~~What physicists do know however is that if the number of particle families was less than 3, they would not be able to understand some important and intriguing aspects of our universe, such as the preponderance of matter over antimatter. In fact, the 2008 Nobel prize for Physics~~

~~was awarded to Yoichiro Nambu, Makoto Kobayashi and Toshihide Maskawa for discovering this very interesting aspect of our universe.~~

Standard model is a great theory and has been tested innumerable times to an amazing accuracy for some decades now. I don't think anyone is even suggesting that it is incorrect. But still there are some important things about matter that it can't explain. This indicates to physicists that standard model is still incomplete or it is a part of a still bigger and more complete theory that will be able to not only describe but also explain many unresolved questions, such as the existence of so many elementary particles.

OK, now let's get back to our five stable elementary particles – electron, up quark, quark, gluon and photon - that constitute this universe and all the things you find in it[3]. As you may remember from your textbooks, all atoms have a nucleus at the center and one or more electrons hovering around it. The nucleus contains protons and neutrons. And as I mentioned earlier, protons and neutrons are composed of quarks. Now it may amaze you to learn that though physicists are absolutely sure that quarks exist and make up protons and neutrons, nobody has observed an isolated quark yet. Yes, they truly, truly love their homes and absolutely hate to be alone. As the case of quarks shows, over time scientists have become rather good at not just guessing the content but actually reading the content of a letter without opening the envelope (translate roughly as – lifafa khole bina khat ka muzmuun keval bhaanpna hee nahi pure khat ko par lene me bhi mahir ho gaye hein)[4].

The elementary particles, and in fact all bodies in this universe, interact with each one another in four fundamental ways. This interaction is in terms of attraction, repulsion, decay and annihilation. These fundamental interactions are: gravitational, electromagnetic, strong and weak interaction[5]. Any physical interaction or force that you can think of between objects or particles in this world can be shown to instances of one or more of these four fundamental interactions. These interactions are governed by the laws of special relativity as well as those of quantum mechanics. Standard model integrates both these pillars of modern physics to offer relativistic quantum field theories of three of these fundamental interactions – electromagnetic, strong and weak interactions. ~~Gravitational interactions remain outside the purview of standard model.~~

~~Thus, a crucial strength of the model is its integration of electromagnetic, weak and strong interactions in a common mathematical framework. Thanks to the seminal work by Glashow, Weinberg and Salam, electromagnetic and weak interaction are completely integrated in the sense that they are now~~

[3] You will notice that I am still not saying anything about Higgs boson. It is the most interesting particle, but its role can only be appreciated once we have discussed all the remaining particles. So let's save its story for later.

[4] In fact, I have heard that to help students understand how such research is done, some physics professors give a closed box with some things inside to students and ask them to find out what is in the box without opening it.

[5] Force is often used as a synonym for interaction, but sometimes its usage is confusing so physicists prefer to use the term *interaction* more than the more common word *force*.

~~considered to be different components of the same unified electroweak interaction[6]. Strong interaction is still not that well integrated with electroweak interactions. But physicists are working hard to overcome this handicap.~~

Table 3: Fundamental interactions of standard model (adapted from http://www.particleadventure.org/inter_summary.html)

	Weak (Electroweak)	Electromagnetic	Strong
Carried By	W^+ W^- Z^0	Photon	Gluon
Acts on	Quarks and Leptons	Quarks and Charged Leptons and W^+ W^-	Quarks and Gluons

Gravitational interactions remain outside the purview of standard model.~~As I mentioned, standard model doesn't account for gravitational interactions.~~ But for the remaining three, it provides good enough language and framework for description as well as prediction. The Standard Model describes each type of particle in terms of a mathematical field defined at all points in space and time. What is a field? Let us discuss some examples that you may be more familiar with. We cannot see fields but can certainly feel, observe and record their effects. One simple example is the gravitational field. It is what makes you hit the ground when you slip on a banana peel. When you find your dry hair trying to stick to your plastic comb, it is the electric field that is making them does so. Similarly, it is the electromagnetic repulsion between your atoms and that of a closed door caused by electromagnetic fields that doesn't let you walk through it and gives you a painful bump in the head instead. Fields are the most fundamental quantities in our universe. In classical physics, you can think of a field as a real physical quantity that is spread over all points in a region, and which can change with time.

However, in standard model, the notion of a field becomes more abstract. Here, the field becomes a mathematical tool that acts on the vacuum to create elementary particles. The field then emerges as a more fundamental concept than matter. It gives rise to matter in the sense that it is common in standard model to think of elementary particles as little quantized ripples or wavelets of fields. These

[6] ~~They jointly won the Nobel prize for physics in 1979 for their contribution.~~

ripples carry energy and momentum and are identified in laboratories as elementary particles. Thus, electrons are seen as quanta of *electron field*, quarks as quanta of *quark field*, gluons are quanta of a strange, unusual field called *color field*, and photons are quanta of more familiar *electromagnetic field*.

But that's not all. The standard model also tells us how these fields interact with each other. In standard model, the fundamental interactions between particles or bodies are considered to be caused by exchange of energy and momentum (and thus, force) carrying particles. Thus, for instance, electromagnetic interactions are caused by exchange of photons, strong interactions by exchange of gluons, and weak interactions by exchange of W+, W- and Z^0 bosons[7]. Based on our everyday experiences, it is indeed difficult to see how two particles can exert force on one another by exchanging (always another type of) article. However, for the case of mutual repulsion, at least, there is an analogy that may help in understanding this esoteric process. Imagine two persons wearing skates on a very, very smooth surface. If one person throws a football to another who catches it, you will find that because of this football exchange these two persons start moving away from one another. The faster the ball is thrown, the more energy gets transferred from one person to the other, and the faster will they recede from one another. Now, if this football becomes invisible or it is night and you can't see it, but can see the two persons clearly, you will see a situation in which some mysterious force is repelling these two persons away. Admittedly, this is a crude analogy, since it can't be stretched for the case of mutual attraction or for other esoteric interactions. But, exchange of particles is still a more understandable way to see how particles or bodies can affect one another without touching than the spookier Newtonian action-at-a-distance perspective.

To most persons, the aforementioned description of matter would indeed seem a very strange and counter-intuitive. How can quantum fields that are entirely abstract and mathematical and defy any realistic physical interpretation without running into paradoxes (such as faster than light speeds) give rise to something as concrete as matter? It defies ones imagination and common sense, especially when we grow up seeing these particles represented as little bricks or small spherical balls of matter in our textbooks. In fact, the world at the level of these elementary particles is indeed very, very strange and there is no way we can understand it in terms of our everyday existence. Physicists still accept standard model as a good enough description of reality at the level of elementary particles because it works to an extraordinary degree of precision. For instance, the experimental value of magnetic moment (μ_e) of an electron is: 1.00115965218073 $\pm$ 0.00000000000028 μ_{dirac}. Now, compare it with the theoretical value from the standard model: 1.00115965218279 $\pm$ 0.00000000000771 μ_{dirac}. This is greater accuracy than you will need to shoot a bottle on the moon from earth!

What is mass?

[7] Gravitational interaction is thought to be caused by exchange of gravitons. But gravitons are not part of the standard model and these particles have not been detected yet.

We all have an intuitive understanding of mass. It is the amount of matter in an object that gives it weight and inertia, you will say. For most of us, mass is indeed the fundamental property of matter and there is nothing more to it. You may be surprised to know that mass continues to be a serious research topic in physics. Standard model does a good job in explaining what mass is and why particles have it. However, it still can't explain why particles have the mass values that experiments show them to have.

So, let's begin by taking account of the mass of any object in our universe. As example, let me take my own mass. However, before we dig deeper a clarification is in order. As Einstein showed through his theory of special relativity, our mass is not an invariant property of matter – it increases with speed. That is, the kinetic energy of a moving body also adds to its mass. Of course, in our everyday world, we don't see that happening as for the speeds that we see or experience in our daily existence, the increase in mass is too low to be significant or even be measurable. So, in this section when I talk about mass, I am basically referring to the intrinsic, rest-mass of a body, i.e. the mass of a body at rest.

Now as we discussed earlier, our universe is made up of just six elementary particles – two types of quarks, electrons, photons, gluons, and Higgs bosons. Of these six, photons don't contribute as they have a zero rest-mass and they aren't really whizzing around in our body with great energies. We will talk more in detail about Higgs bosons later, but here it suffices to say that they also don't directly contribute to my mass as they don't constitute the stuff of any object but exist in the background to endow the particles constituting my body with some very specific property (about which I will talk in a moment). So the particles that contribute to my mass are basically electrons, the two ('up' and 'down') quarks and gluons. Quarks and gluons reside in the protons and neutrons of my body. Since, electrons are much, much lighter than protons and neutrons, they account for only 0.5% of my mass. Rest, i.e. 99.5%, of it comes from protons and neutrons.

We know that protons and neutrons are made of up quarks and gluons. So, perhaps you may be thinking that since gluons have zero rest-mass, we only need to add the masses of all the quarks in our body to come up with amount contributed by protons and neutrons. Wrong! The total rest-mass of the two quarks constituting a proton or a neutron account for only 1% of its mass! Then what about the 99% of the mass? Well, that comes from the kinetic energies of the quarks and gluons whirling around at fantastic speeds inside the neutron or the proton. Isn't it amazing to know that almost all of our mass comes from something as non-mass like as motion and is not an intrinsic property of matter?

And now you would think that being a fundamental property at least the rest-mass of quarks and electrons comes intrinsically from the stuff they are made of. Well, wrong again! What?! Yes, it so happens that according to the standard model, these particles are actually massless. But, you would ask that they do have a rest-mass that has been experimentally verified, don't they? Yes, that's correct. So how can something that theoretically shouldn't be having any mass, when measured is found to have some definite mass (and always the same value)? Is standard model flawed on this account then? No, it isn't, and the situation isn't an irresolvable paradox either. Remember, all this while, we have hardly said anything about Higgs boson. It is here that Higgs bosons reveal themselves as a solution to this apparent enigma. And so, for the remainder of this article you will find these particles playing the lead role.

Standard model works only if we assume the rest-masses of electrons and quarks to be zero. However, fortunately for itself, the model also provides a way for these particles to acquire mass – not as an intrinsic property but as an effect of their environment. According to the standard model, besides the pulsating activity of the electroweak, strong and gravitational fields, the entire universe is filled by another kind of quantum field called the Higgs field (sometimes also called Higgs condensate). This field is there even if there is no particle around, and thus, it is there even in vacuum. In fact, Nobel Prize winning physicist Frank Wilczek likens it to the *ether* of yore that was believed to exist throughout the universe in years before Einstein arrived on the scene and disproved its existence[8]. Just like photons are the quanta of electromagnetic field, the Higgs bosons too are quanta of this background pervading Higgs field. These Higgs bosons are said to interact with electrons and quarks to endow them with some mass. And it is in this way that mass arises not as an intrinsic property but rather as an environmental effect of Higgs field.

It all sounds very, very ~~strange and~~ eerie, right? Fortunately, there are a few analogies from other fields of physics that makes it all plausible. For instance, we know that photons are massless. That's why they travel at the speed of light. After all, they are the light. But, physicists have discovered ways to slow them down, and even make them come to a halt. They have found that within materials called super-conductors, the electromagnetic fields can be so arranged that when photons interact with them they acquire an *effective* mass as a result of this interaction and thus slow down. A more understandable but also more crude and inexact analogy would be to see Higgs field as cosmic treacle pervading this universe. If electrons and quarks didn't interact with this background, they would have remained mass-less, and thus would have been zipping around the universe at the speed of light. But as we know from countless experiments they don't travel at the speed of light. So, metaphorically speaking what happens is that the viscosity of this cosmic treacle of Higgs field slows them down and makes them behave as if they have some acquired an *effective* rest-mass.

Let me reiterate as this is an important point - in the standard model, the intrinsic mass of these particles is zero; the mass they have is an effective mass, acquired through their interaction with the Higgs field~~the mass these particles have is an effective and not an intrinsic mass; their intrinsic mass is just zero~~. And that's how we get "mass without mass" – a provocative term coined by Physicist John Wheeler to argue that perhaps physicists should try to remove mass as a term from the basic equations of physics as it is not really that fundamental property of matter.

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[8] There are some other contenders qualifying as 'ether' too, such as quark-antiquark condensate and metric field (the cosmological constant or the dark energy). But, that would be another exciting story for another article.

Now, let's see how Prof. David Miller, one of the five winners of Mr. Waldergrave's challenge, explained Higgs boson and its importance on one piece of paper, and in a language that even a politician could understand. This was his response:

*"**1. The Higgs Mechanism***

Imagine a cocktail party of political party workers who are uniformly distributed across the floor, all talking to their nearest neighbours. The ex-Prime- Minister enters and crosses the room. All of the workers in her neighbourhood are strongly attracted to her and cluster round her. As she moves she attracts the people she comes close to, while the ones she has left return to their even spacing. Because of the knot of people always clustered around her she acquires a greater mass than normal, that is, she has more momentum for the same speed of movement across the room. Once moving she is harder to stop, and once stopped she is harder to get moving again because the clustering process has to be restarted. In three dimensions, and with the complications of relativity, this is the Higgs mechanism. In order to give particles mass, a background field is invented which becomes locally distorted whenever a particle moves through it. The distortion - the clustering of the field around the particle - generates the particle's mass. The idea comes directly from the Physics of Solids. Instead of a field spread throughout all space a solid contains a lattice of positively charged crystal atoms. When an electron moves through the lattice the atoms are attracted to it, causing the electron's effective mass to be as much as 40 times bigger than the mass of a free electron. The postulated Higgs field in the vacuum is a sort of hypothetical lattice which fills our Universe. We need it because otherwise we cannot explain why the Z and W particles which carry the Weak Interactions are so heavy while the photon which carries Electromagnetic forces is massless.

2. The Higgs Boson.

Now consider a rumour passing through our room full of uniformly spread political workers. Those near the door hear of it first and cluster together to get the details, then they turn and move closer to their next neighbours who want to know about it too. A wave of clustering passes through the room. It may spread out to all the corners, or it may form a compact bunch which carries the news along a line of workers from the door to some dignitary at the other side of the room. Since the information is carried by clusters of people, and since it was clustering which gave extra mass to the ex-Prime Minister, then the rumour-carrying clusters also have mass. The Higgs boson is predicted to be just such a clustering in the Higgs field. We will find it much easier to believe that the field exists, and that the mechanism for giving other particles mass is true, if we actually see the Higgs particle itself. Again, there are analogies in the Physics of Solids. A crystal lattice can carry waves of clustering without needing an electron to move and

> *attract the atoms. These waves can behave as if they are particles. They are called phonons, and they too are bosons. There could be a Higgs mechanism, and a Higgs field throughout our Universe, without there being a Higgs boson. The next generation of colliders will sort this out."*

What a creative way to explain such an esoteric subject, don't you think? It is indeed important to help politicians as well as other citizens understand the importance of explorations that physicists and other scientists take as such explorations have become increasingly expensive over the years. According to an estimate, Large Hadron Collider where such explorations are being conducted has so far cost an estimated $6 Billion US dollars. I am sure most of us can think of several priority areas where such amounts of money can be put to a worthy use. Though, it would be helpful to keep in mind here that almost all the great discoveries of the last two centuries sprung from curiosity driven research - just like the hunt for Higgs bosons. After all, transistors weren't invented because somebody wanted to develop computers and televisions. They emerged from the quantum theory of solids.

Higgs bosons, so critical to standard model, haven't been detected yet. It is hoped that the Tevatron accelerator in USA and Large Hadron Collider in Europe may be able to reveal these ultra-exotic particles in near future. Their detection would not only put our understanding of matter and mass on a firmer footing, but may also reveal ways to extend standard model into a more extensive theoretical framework that would be able to explain several mysteries that still elude standard model. Such mysteries include dark matter, mass value of electrons and quarks, and the observed family structure of elementary particles. Resolution of such mysteries would take us closer to developing a theory of *everything* one day, besides leading to many anticipated as well as unanticipated inventions and discoveries. That should be *paisa vasool,* don't you think?

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