How to Determine the Probability of the Higgs Boson Detection

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Abstract

The Higgs boson is the most important, though yet undiscovered ingredient of the standard model of particle physics. Its detection is therefore one of the most important goals of high energy physics that can guide future research in theoretical physics. Enormous efforts have been undertaken to prove the existence of the Higgs boson, and the physics community is excitedly awaiting the restart of the Large Hadron Collider at CERN. But how sure can we be that the Higgs exists at all? The German philosopher Immanuel Kant recommended betting at such controversial questions, and Stephen Hawking announced a $100 bet against the Higgs. But seriously, online prediction markets, which are a generalized form of betting, do provide the best possible probability estimates for future events. It is proposed that the scientific community uses this platforms for evaluation. See also an online description www.Bet-On-The-Higgs.com.

A simple analogy and fundamental problems. The Higgs boson, predicted in 1964 by Peter Higgs [1], is nowadays considered the cornerstone of the Standard Model of particle physics. Nobel award winner Leon Lederman called it the ‘God particle’, and as one of a few science problems, it has been publicised with the following analogy:

The British Prime Minister Margaret Thatcher holds a cocktail party. As she moves through the room, the cluster people around her, corresponding to the Higgs field, creates resistance to her movement, which appears as inertia or mass. As single Higgs particle instead corresponds to a rumor which causes clusters of people standing close to each other.

Though this story has also been told with John Major, Tony Blair and Gordon Brown, the detection of the Higgs particle is still missing. Since the old ideas of Mach [2] and Dirac [3], the question to the origin of mass puzzles fundamental physics. In the context of the standard model, progress is expected with the detection of a scalar boson like the Higgs which provides a mechanism for inertia mass. However, even if the Higgs should be detected, no prediction of mass ratios like \( \frac{1836.15}{15} \) (proton-electron) is expected. Instead of not calculable masses, physics would be left with only measurable couplings with the Higgs field. Nonetheless, there are few other ideas in theoretical physics concerning the mass problem.

Experimental efforts. The energy at which the Higgs is expected ranges from 115 to 190 GeV [4]. However, recent experiments at Tevatron have excluded the range 160-170 GeV on a 3σ-level [5]. While a heavy Higgs should quite easily be detected at the Large Hadron Collider (LHC) at CERN, a mass below 150 GeV would increase the background signal problem. However, once it becomes fully operational, the best chances for the Higgs detection rest on the Large Hadron Collider: after all, the Higgs detection was the main goal for its construction. LHC documentation videos claim that physics would be shocked by an "earthquake" if the Higgs is not detected. With the restart of the LHC in 2009, the question becomes topical [6].
Public interest. The amount of research funds spent for the Higgs detection is extraordinary. A Superconducting Super Collider project was cancelled in 1993 in the US, but also the three billion dollar LHC construction has raised criticism on high energy physics receiving unproportional funding. Thus besides the scientific interest of the high energy community, other physicists, scientists, taxpayers and politicians may have a legitimate interest in the main purpose of the LHC. A central parameter to evaluate these efforts is the probability of the Higgs detection.

Existence or detection? A couple of unfortunate incidents, most importantly the short circuit damage on Sept 10th, 2008 caused a delay of the experiments which hopefully restart in late 2009. Obviously, one has to distinguish the probability of the existence of the Higgs from the probability of its detection, which can be defined for a certain period only. However, given that the LHC has all the capacities to cover the energy range not yet excluded, sooner or later the Higgs must be detected if it exists at all. It is a delicate task to interpret partial negative results. Given that Tevatron results exclude a Higgs in the range from 160 to 170 GeV, does that mean that the absolute probability for a lighter Higgs has increased (as it was stated) or did the overall probability for the existence decrease? To carry to the extremes, can the non-discovery be a hint or even ‘proof’ the existence of a Higgs multiplett at higher energies? Since supersymmetric theories usually do not predict mass ranges, they seem to be ‘earthquake-safe’ against falsification. All these questions require reliable estimates of a priori probabilities for the existence of a given particle.

The standard procedure: polling.

‘Prediction is very difficult, especially about the future.’ Niels Bohr

Elections are a well-known example where the probability is of public interest. The outcome is usually forecasted by polls. This can be done with some success since elections follow a well-defined procedure and due to the one man-one vote principle, do not need a weighting of the asked persons. But how to do a poll on the Higgs particle detection? Among the average population, any poll would be completely useless, but even when asking scientists or physicists, such a poll wouldn’t generate a reliable result. One has to ask the experts. But which experts? CERN technicians, theoretical physicists which worry about the nature of mass, or Nobel award winners? An appropriate weighting of opinions is obviously impossible. Then, elections are anonymous, and voters are not forced to comply with expectations of the questioner. Scientists sometimes are, for an expert it could be embarrassing to state in public that the goal of a recent grant applicationan is unlikely.

Prediction markets. An interesting alternative to polls are prediction markets [7]. They work similar to stock markets, a generalized form of betting. Even in the case of elections, they have been remarkably successful [8]. As stocks, prediction markets are anonymous. Most importantly, an opinion is naturally weighted by the amount of money one is willing to stake. On the other hand, prediction markets do not consider themselves as gambling platforms, since the outcome is not determined primarily by chance but by the ability of the user to foresee developments. However, there is an obvious adjacency to the suspicious sports betting business. In most countries, bets and gambling contracts do not constitute a legal commitment, thus it is not easy to place a real money bet on the discovery of the Higgs boson. Though Stephen Hawking announced his $100 bet against the Higgs, no one can go to a court in case he’s wrong (though his motives are surely honest). [1] However, the prediction market Intrade.com is located in Ireland where legislation does not inhibit operating, and it is one of the few platforms with scientific topics. Therefore, a brief explanation how to trade there is given in the next section.

[1] Another interesting science bet takes place between John Horgan and Michio Kaku (http://www.longbets.org/12). The former is convinced that there will be no Nobel award for a unified theory until 2020. The betting platform however requires a donation of a possible win.
How to trade the Higgs at a prediction market.  

A prediction market like Intrade is based on the trade of contracts on given events. The idea is that the actual price is a measure of the probability that the event will happen. If you believe for instance that the Higgs boson will be discovered until the end of 2011, you may buy the contract HIGGS.BOSON.DEC11. It is noteworthy that you may even sell contracts that you do not hold, in case you don’t believe the event will happen.

After opening an account and uploading a deposit with a credit card one may start betting immediately. Contracts have a nominal value of $10 corresponding to 100 points. You may buy one of the contracts HIGGS.BOSON.DEC2010 or even HIGGS.BOSON.DEC2013 if you believe the discovery will occur within the period or sell, if you don’t believe. As in a stock market, there is a bid and an ask price. If the event happens, the contract achieves the value 100, if not, zero. This relates the current rate directly to the percent probability that the event will happen.

A concrete example. After logging in, the keyword search ‘Higgs’ among others shows the contract HIGGS.BOSON.DEC11. Suppose that the Bid is 40 and the Ask is 44. If you believe in the discovery, you may buy the contract immediately for 44 or place a buy order at 43. If you bought the contract for 44 and the particle is discovered, the price rises to 100, your win is 56 points or 5.60 Dollars. If you do not believe in the discovery by the end of 2011, you may sell it right now for 40 and get 4.00 Dollars or place a sell order for 42. If somebody accepts this 42 offer, you get 4.20 Dollars, but if the particle is discovered, you have to pay 10 Dollars to the purchaser. Therefore, you have to deposit this amount until the contract ends. There are moderate fees for trading, usually fractions of a percent.

Figs. 1 and 2 show typical screenshots of an order book (offers not yet accepted) and an position book (sold/bought contracts).

Summary and outlook. Trading on prediction markets is an interesting procedure that yields an approximate probability for the detection of the Higgs boson. The value of the long-term contracts seems to be the best possible guess about the existence of the Higgs. Of course, an appropriate volume (number of traded contracts) is desirable to increase reliability, and at the same time the trading volume could become a measure of importance the scientific community is willing to give to an open problem. It would be interesting to extend the proposed method to other expected discoveries like gravitational waves or extraterrestrial life. On the other hand prediction markets can throw light on

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2A online description is given at the site www.Bet-On-The-Higgs.com. There, every month the most optimistic bets on the Higgs are accepted for US$ 100.

3The deadline is the date of publication.

4http://en.wikipedia.org/wiki/Ask_price
speculative theories: who would seriously bet on the discovery of micro black holes or supersymmetric particles? String theory, which has been accused of being non-falsifiable any more [9] [10] would indeed have difficulties to define a contract about the evidence to be discovered in its favor.

Prediction markets could become an useful instrument for research funding procedures. The German philosopher Immanuel Kant said, the bet naturally distinguishes between real conviction and simple opinion. Prediction markets are a modern version of such bets.

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