PROFESSOR: So far so good. So here is the kind of very entertaining thing that happens when you try to do some physics with this. And this was done by two physicists, Elitzur and Vaidman in Tel Aviv, they invented or fantasized about some sort of bombs-- things that explode. So they're called Elitzur-Vaidman bombs.

And you could invent different things, but here is what an Elitzur-Vaidman bomb is-- some sort of bomb, and the way it works is with a photon detector. So there's a little tube in the bomb, and there's a photon detector.

And you have your bomb, and you want to detonate it-- you send the photon in, you send the photon in through the tube. And the photon, it's detected by the detector. And the bomb explodes.

On the other hand, if the bomb is defective, the photon goes in, and the detector doesn't work. The photon goes out. Just goes through.

So that's an Elitzur-Vaidman bomb. And here is the puzzle for you-- suppose you have those bombs, and unfortunately, those bombs, after time, they decay. And sometimes the detectors go wrong, and they don't work anymore.

So you have 10 bombs, and you know, maybe five have gone wrong. And now, you have maybe a very important mission and you need the bomb that really works. So what do you do?

Let's assume you cannot break apart the detector-- it's just too complicated. So you have the bombs, and you want to test them. If you send in a photon and nothing happens, the bomb is not working. But if you send in a photon, and the bomb is working-- explodes. So you cannot use it anymore.

So the question that Elitzur and Vaidman pose, is there a way to certify that the bomb is working without exploding it? Can you do that?

The answer looks absolutely impossible. And certainly, in classical physics, it's completely impossible. You either do the measurement to see if the detector works, and if it works, your lab goes off. It's totally destroyed. And if it doesn't work, well, OK, it's not a good bum anyways. So there's no way out.

But there is a way out, and it is to insert this bomb in the mass [? center ?] interferometer. So here we go. We put the mass [? center ?] interferometer, and we insert the bomb here with the detector along this place. D 0 and D 1 are still here.

And now, you put this, and you send in a photon. So let's see what happens if you send in a photon.

Suppose the bomb is defective-- bomb is defective. So what are the possible outcomes? Outcome and probability.

Photon goes to D 0-- 0. Photon to D 1, bomb explodes. Well, we said the bomb is defective. So if the bomb is defective, we said it's like a detector that doesn't work, and lets the photons go through. So if the bomb is defective, it's as if there no bomb here, and you have the situation where all is open.

So there will be a probability of 1 to get the photon to D 0-- a probability of 0 to get the photon to D 1. And the bomb, of course, doesn't explode-- probability of 0.

On the other hand, suppose the bomb is good-- bomb is good. And then, what are the outcomes? And what are the probabilities?

Well, you know, more or less, what's happening already. The bomb is good means there is a detector that never fails to detect the photon. And if a photon comes in, it will capture it-- it will block it. The bomb will explode. So you have your mass [? center ?] interferometer, and you've really done the equivalent of this-- if the bomb is really working. You've put a block of concrete-- it's going to absorb the photon.

So if the bomb is really working, the outcome are the following-- well, I'm sorry to say, your lab will explode half of the times, because the photon on the block happens, and bomb explodes with probability 1/2. On the other hand, in this situation, it is possible that the photon-- photon-- at D 0, and bomb doesn't explode-- not explode. And there is a probability 1/4.

And there is a probability, 1/4, that the photon is at D 1, and the bomb does not explode. But here is the catch now-- yes, half of the bombs exploded, we're sorry about that. But if the bomb doesn't work, there is no way a photon can reach D 1, because if a bomb doesn't work, all photons go to D 0.

So the fact that some photons, a quarter percent of the time, 1/4-- 25% of the time-- reach D 1 implies that photon is at D 1, and bomb did not explode. But the bomb is good.

So look what has happened-- it's really strange. The photon went-- the bomb was here, it was ready to explode. The photons kept the bomb, and ended at D 1, and you still know that the bomb works now-- even though the photon never went through the detector. It never touched here, it never went inside and get detected. Somehow it went through the other way, but you know that the bomb is working, with a quarter percent efficiency.

We will do exercises, and it's possible to raise the efficiency to 50%. And if you put the bomb inside a cavity, a resonant cavity with photons going around, you can reach 99% efficiency. So the probability of blowing up MIT goes down to 1%.

[LAUGHTER]

I don't know if we can live with that-- I don't think so. But anyway, this is a true fact-- experiments without bombs have been done, and it shows that in quantum mechanics, you can do very surprising measurements.