

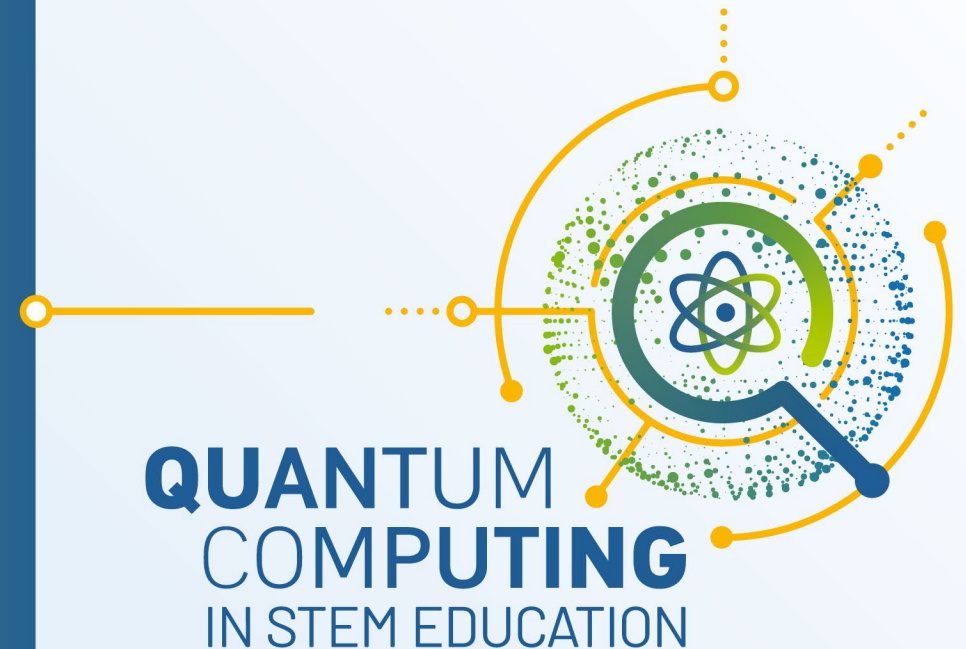
A thought experiment: detecting quantum bombs

The Elitzur-Vaidman bomb tester

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Taken from
QUANTUM COMPUTING
IN STEM EDUCATION

SCIENCE ON STAGE
GERMANY
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Task: Identify whether a bomb is defective or working

- ▶ Think of a batch of light-sensitive bombs: some of them are working and will explode when hit by a photon, while others are defective and will not explode.



Defective Bomb

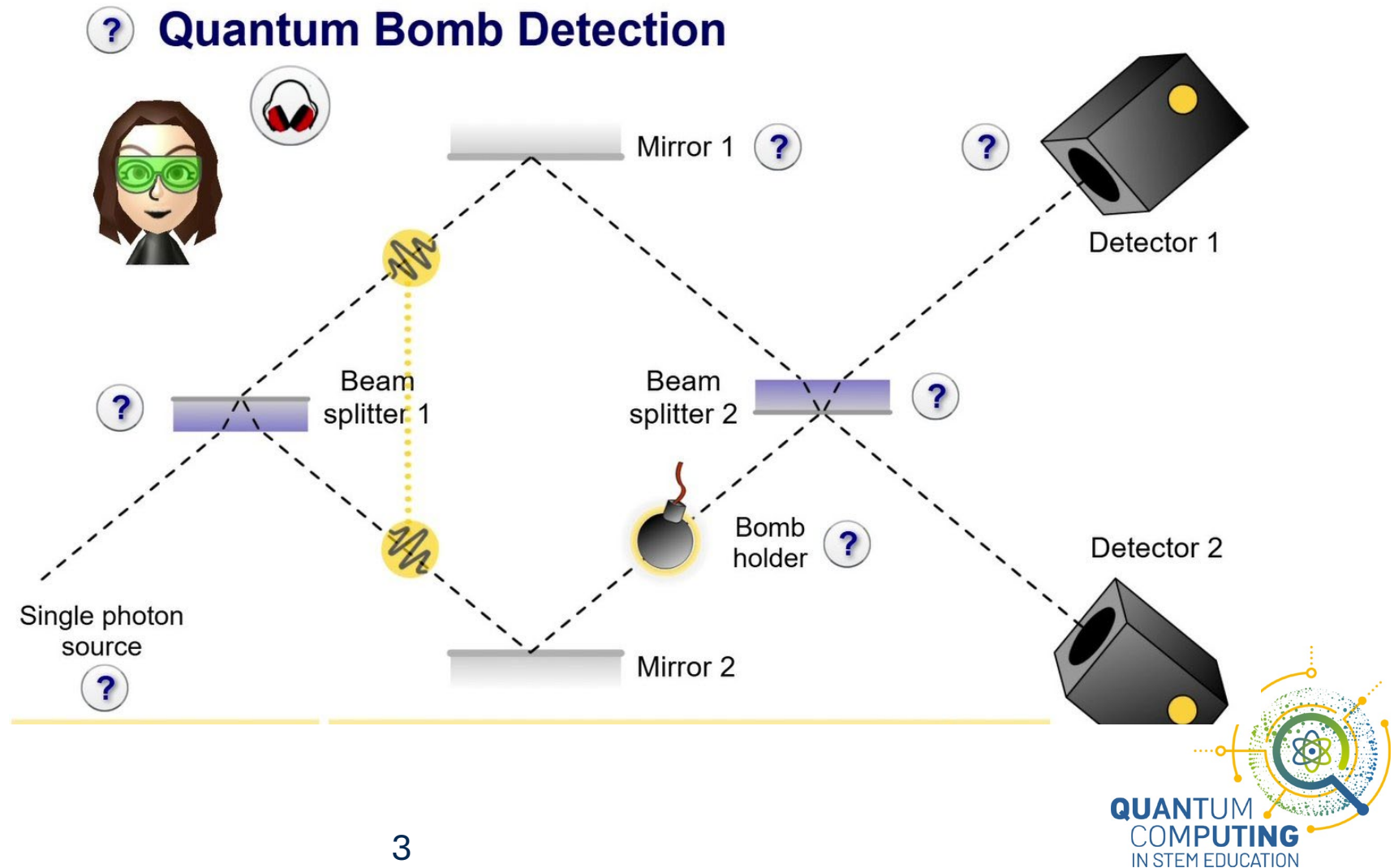


Working Bomb

- ▶ Can you identify some of the working bombs without causing them to explode?
- ▶ Classically, that is not possible. **But with quantum physics, it is!**

With quantum physics we can do better!

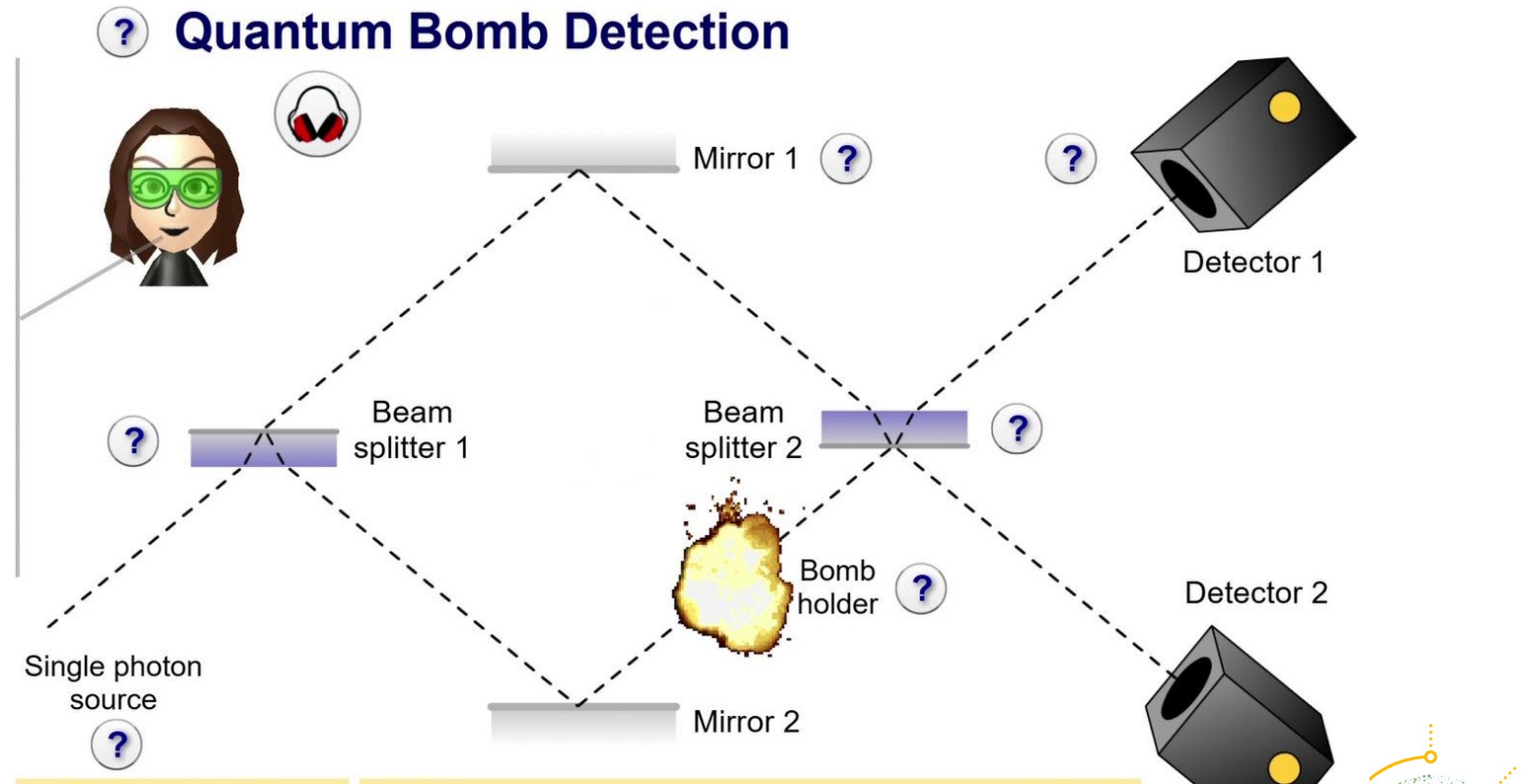
- Place the bomb to be tested in the path of a Mach-Zehnder interferometer and „fire“ a single photon.



What happens when the bomb is working?

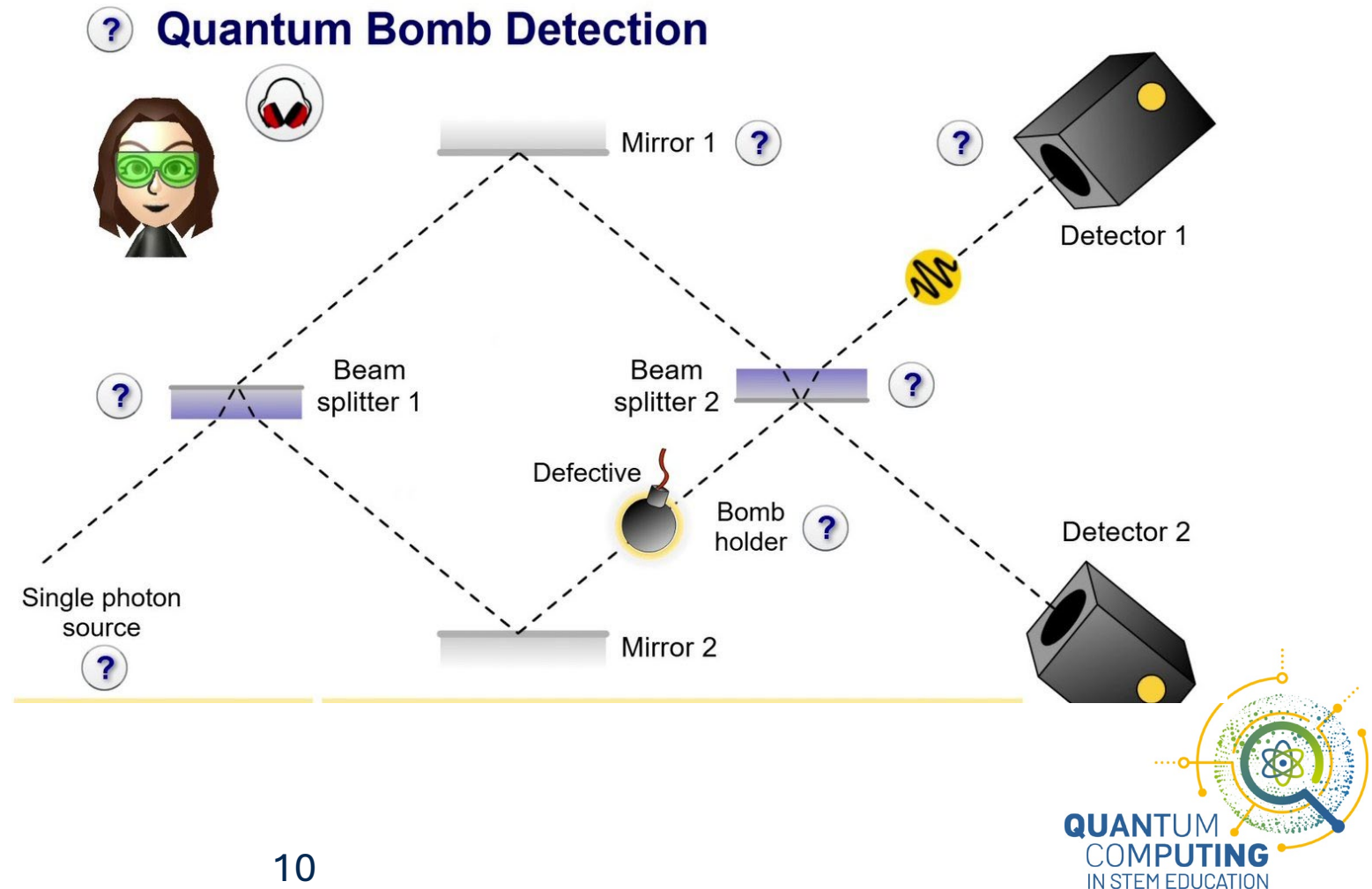
SUMMARY

- ▶ There is a 50% probability that the bomb will explode.
- ▶ If the bomb explodes, we definitely know that the photon took the lower path.
- ▶ This is equivalent to measuring “Which path did the photon take?”.



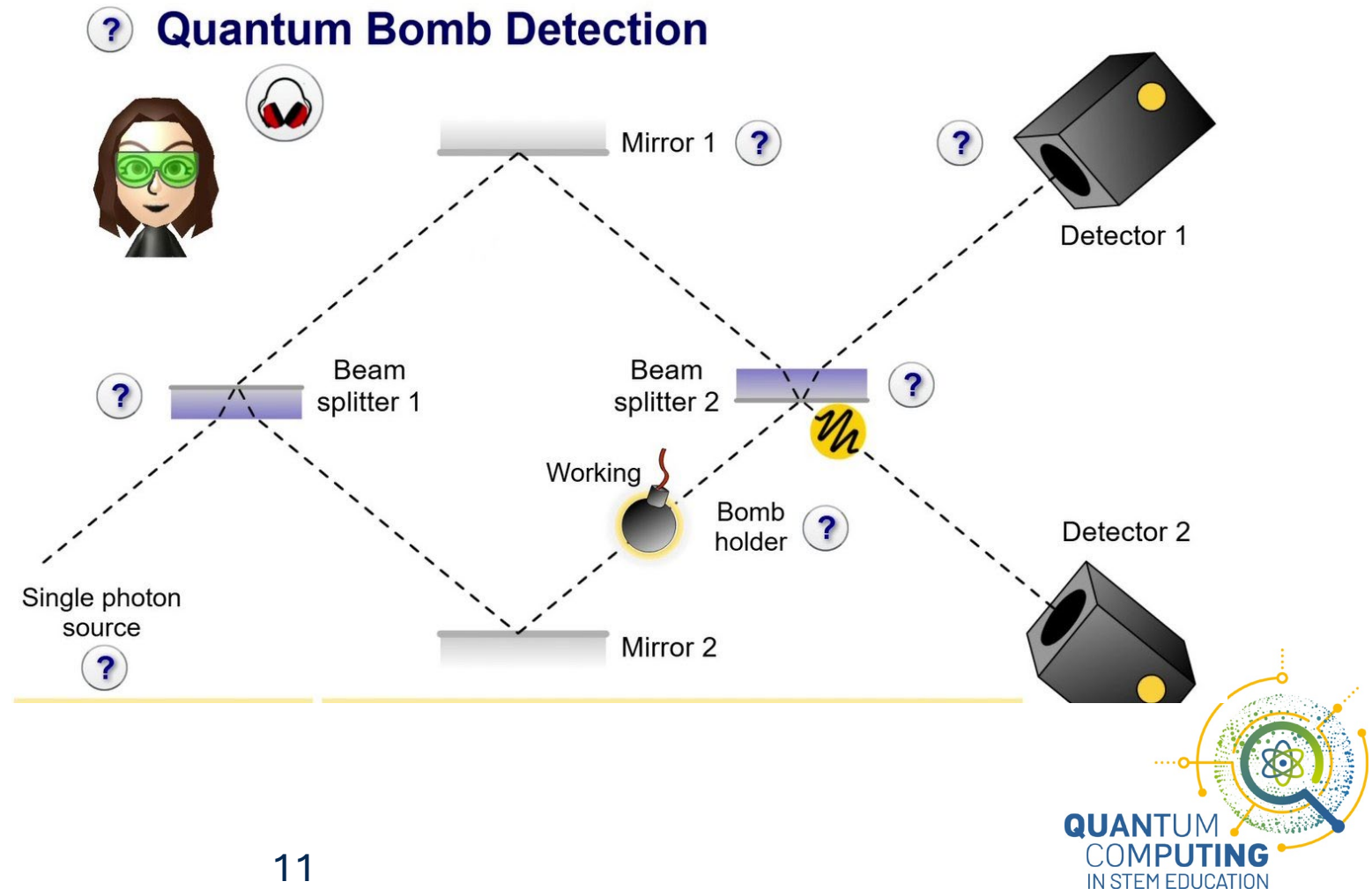
The bomb does not have to explode...

- ▶ Let's assume the photon took the upper path: it is in the state $|up\rangle$.
- ▶ The bomb does not explode and the photon reaches beam splitter 2, where a new superposition state is created.
- ▶ There is a 50% probability that the photon reaches detector 1, and likewise, a 50% probability that it reaches detector 2.



... for it to be identified as a working bomb

- ▶ Observing the photon in detector 2 is only possible if the bomb is working. Hence, if the photon is detected in detector 2, we know for sure that the bomb is working – even if it didn't explode.
- ▶ **This would not have been possible in classical physics!**



Can we also identify defective bombs?

- ▶ A single photon reaching detector 1 does not rule out that the bomb is working: there is still a 25% chance that the bomb is working.
- ▶ When repeating this “measurement” and constantly obtaining the same result (the bomb does not explode and the photon reaches detector 1), the probability that the bomb is working gets lower with every “measurement”.
- ▶ The probability that the bomb is working will get lower and lower, but it will never be zero. That is due to the probabilistic aspect of a measurement in quantum physics.

Use and test your knowledge!

- ▶ Use the „Quantum Bomb Detection“ animation of St. Andrews University (UK).



1. Detect 10 bombs in a „Real Facility“.
2. Answer the questions about quantum bomb detection by clicking on the tab „Challenges“.

Training | **Real Facility** | **Challenges** | THOMPSON RIVERS UNIVERSITY | University of St. Andrews | QuVirs

Quantum Bomb Detection

Place bombs you are certain are working onto the conveyor belt to the right, others go onto the conveyor belt to the left. I'll let you know how you do.

You are wearing virtual reality goggles which allow you to "see" the photons. Pay careful attention to the photons as that will help you understand how bombs are sorted.

Please familiarize yourself with the interferometer by clicking the ? symbols near each the components.

Once you have explored, send photons through the interferometer with and without bombs in the bomb holder. By placing bombs in the bomb holder learn to distinguish between working and defective bombs.

When you are confident you understand the process, please click on the Real Facility tab to remove the glasses and get sorting for real!

Main Controls

- Single photon
- Continuous Fire
- Show bomb state
- Detector Counts

Recycle | Working