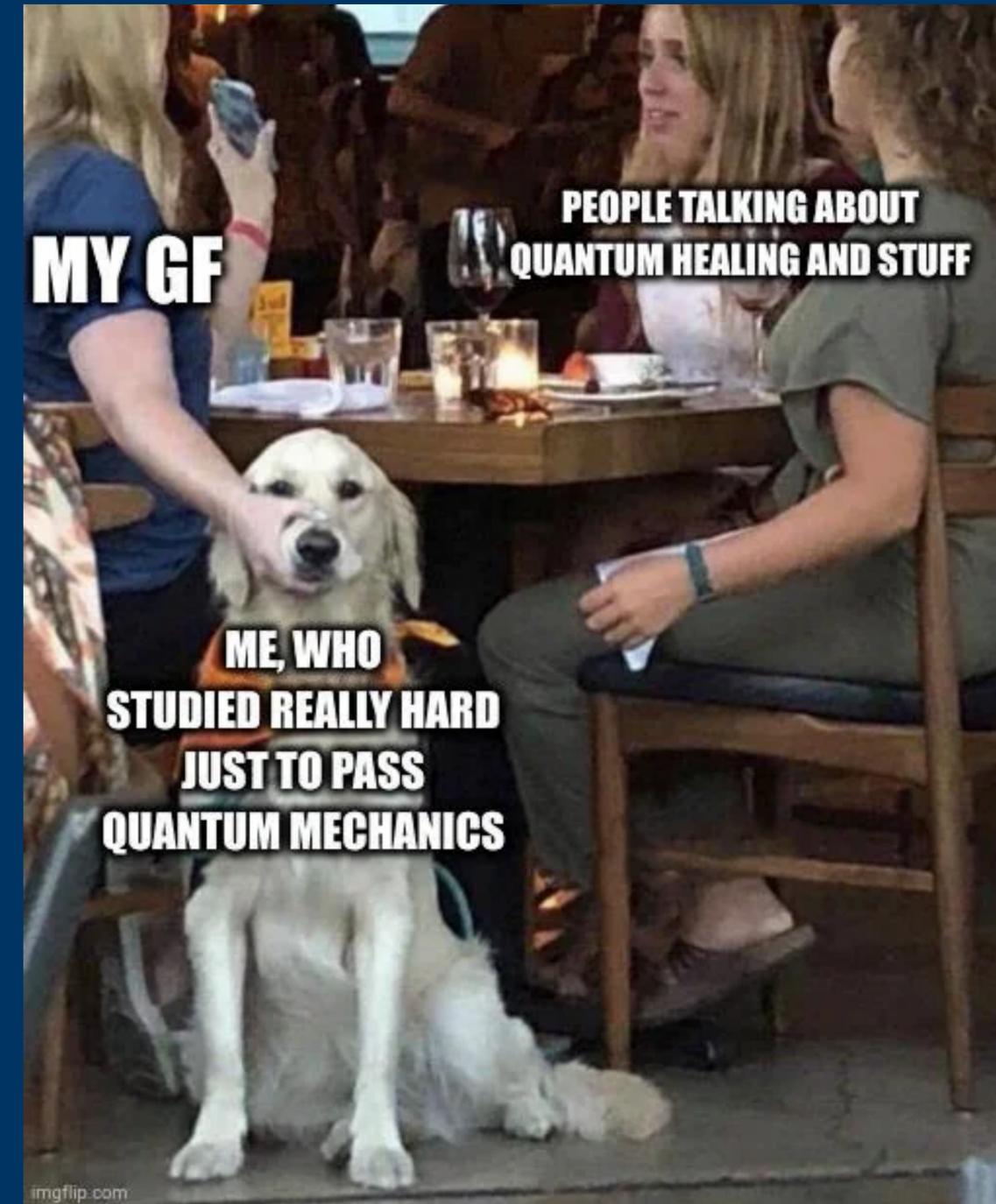


An Armchair Guide:

To Quantum Mechanics



Jonathan Allday

Session 1:

Not even wrong...



That's not right. That's not even
wrong.

— *Wolfgang Pauli* —

Quantum Quotes

*My point, which you'll hear me rant about again, is that at **both the conceptual and the mathematical level**, quantum mechanics is not just a funny-looking reformulation of classical physics. The two physical theories are **fundamentally, physically different**.*

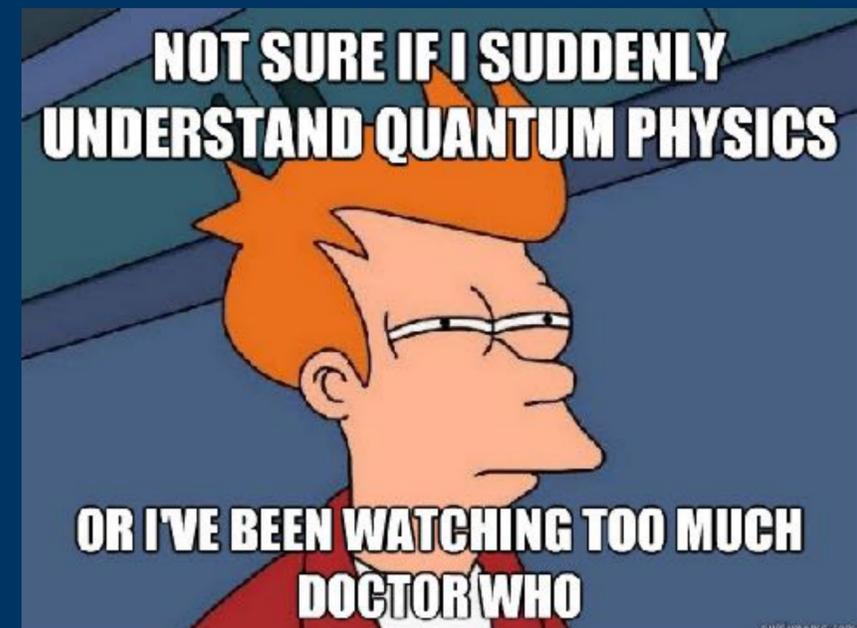
Michael A. Morrison

*The average quantum mechanic is **no more philosophical** than the average **motor mechanic**.*

Rev. Dr. Sir John Polkinghorne FRS

Don't Panic

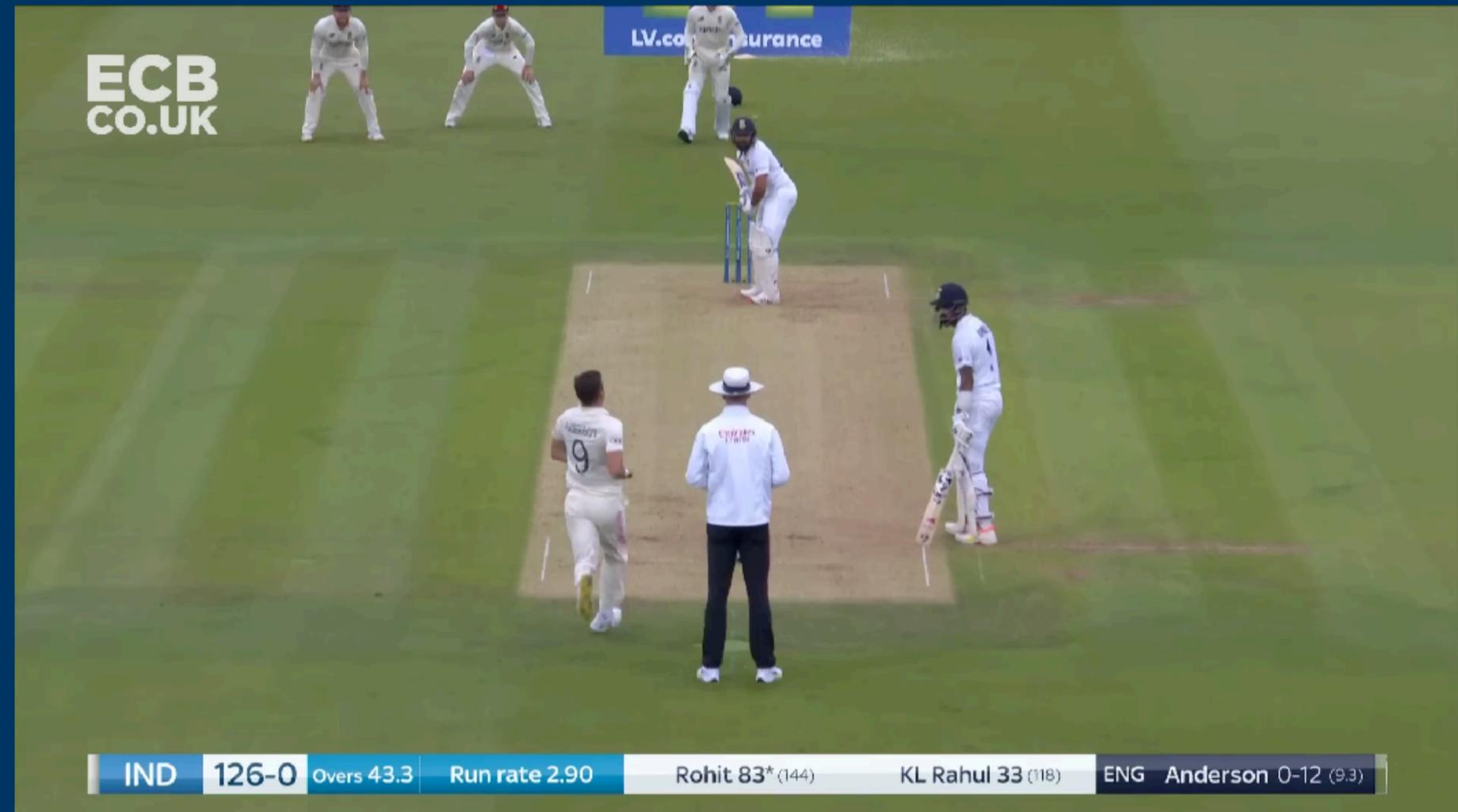
Douglas Adams



What is a wave?

A wave is a **transfer of energy** from A to B
without an accompanying **transfer of matter**...

This is **not** a wave...





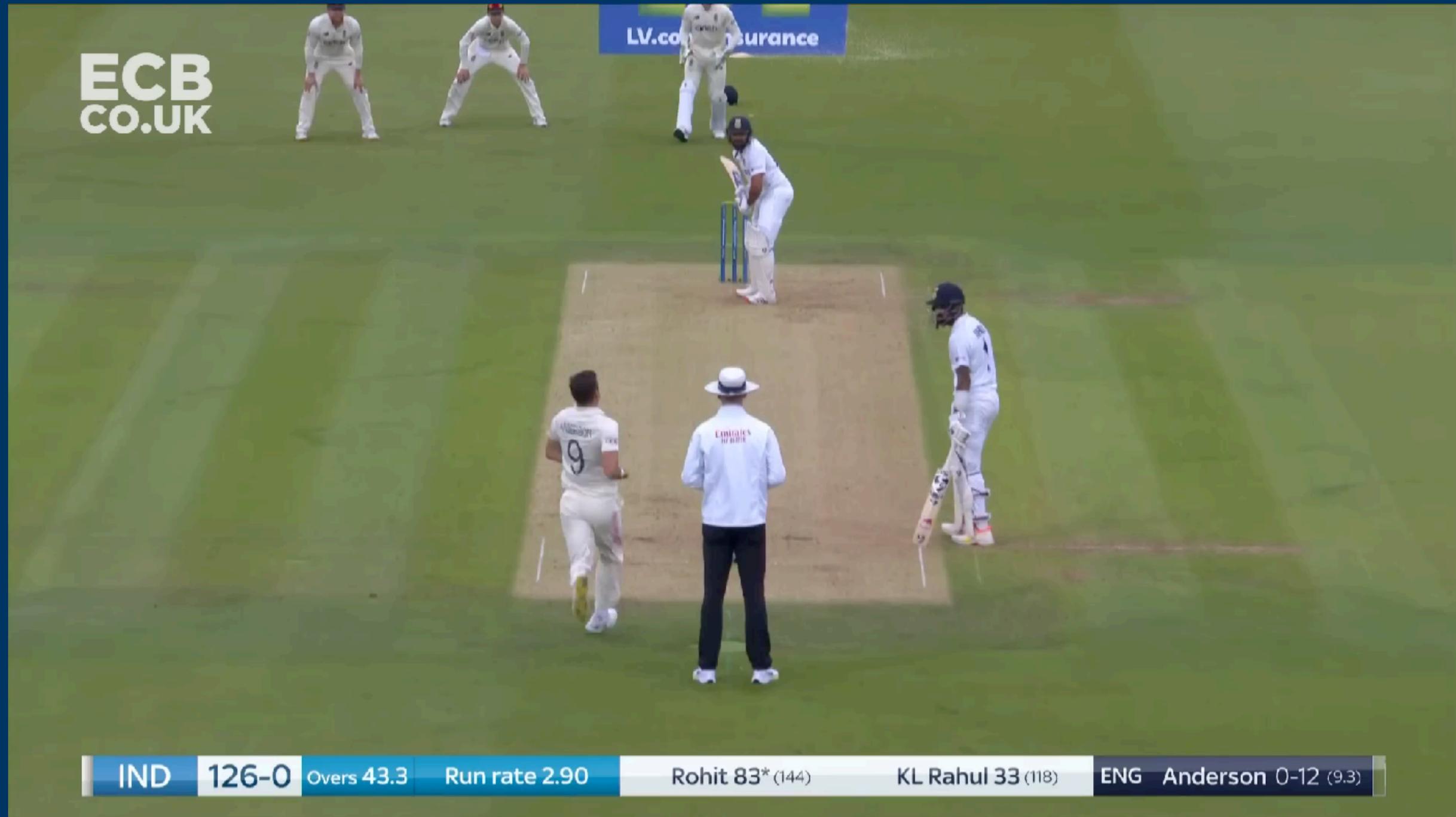
overs 43.3 Run rate 2.90 Rohit 83* (144) KL Rahul 33 (118) ENG Ander

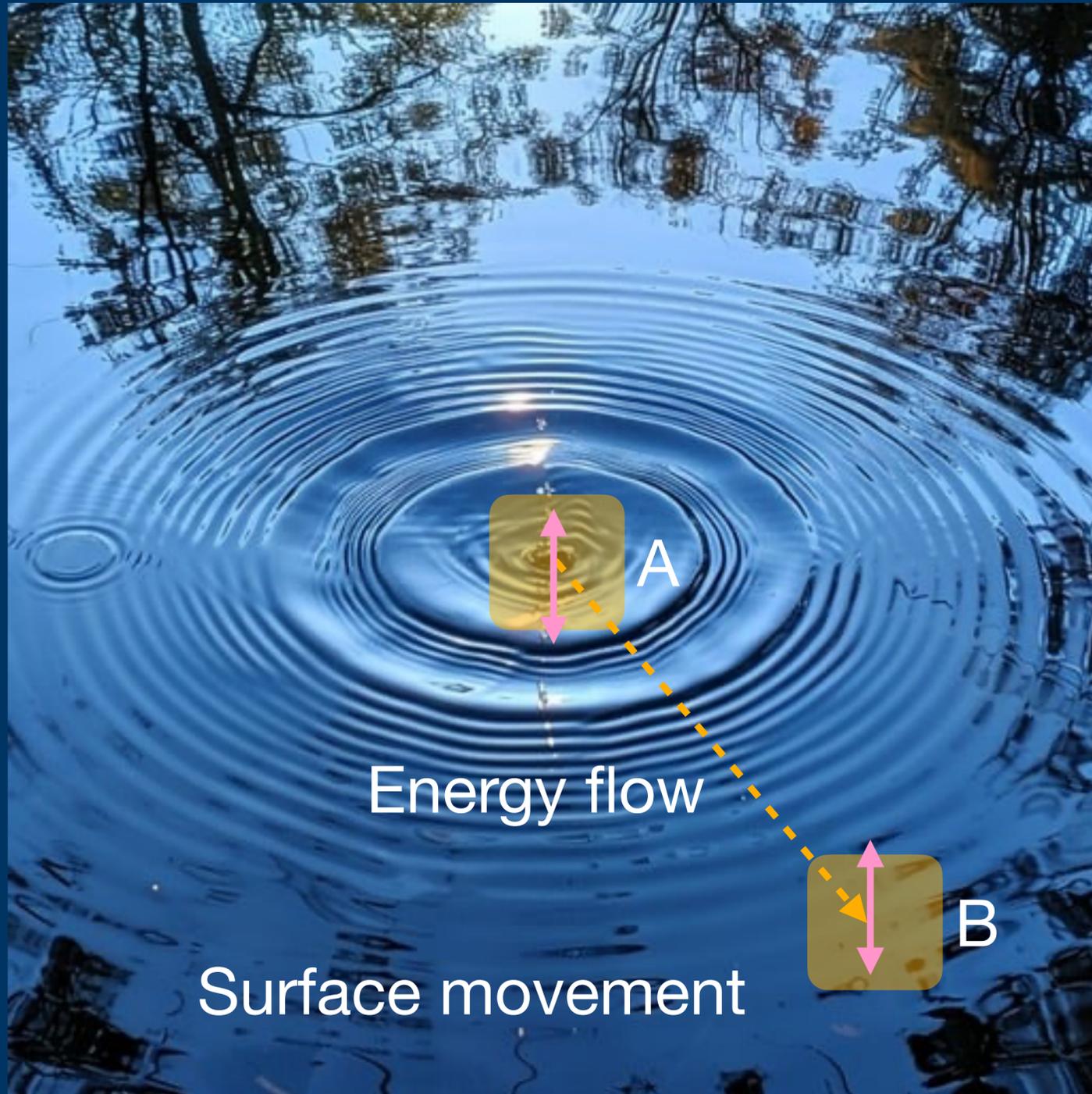
Energy is moving from A to B, but...

There is a lump of matter carrying the energy...

For Alan.....

Ball swung *away* and then seamed *in*...





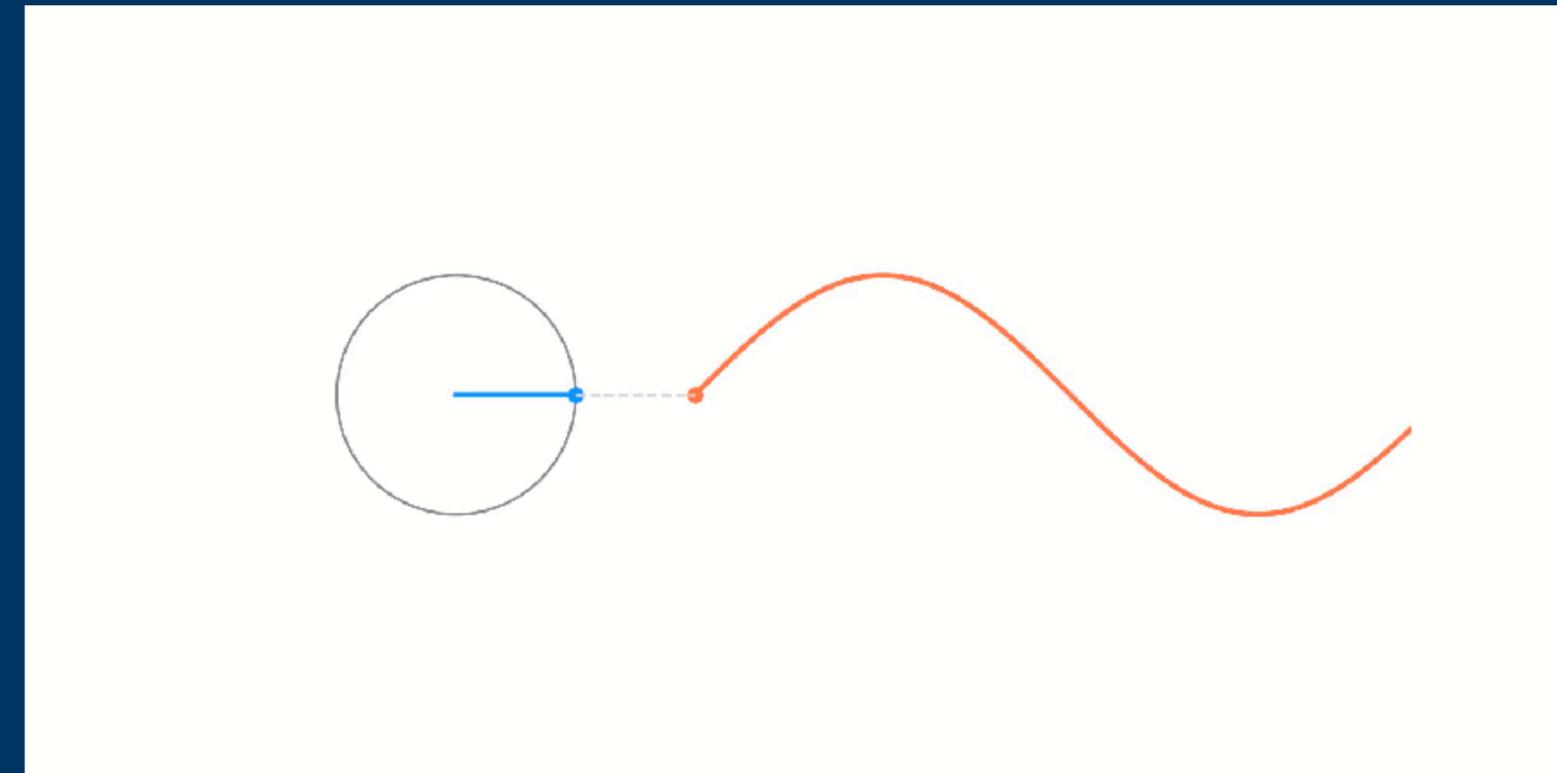
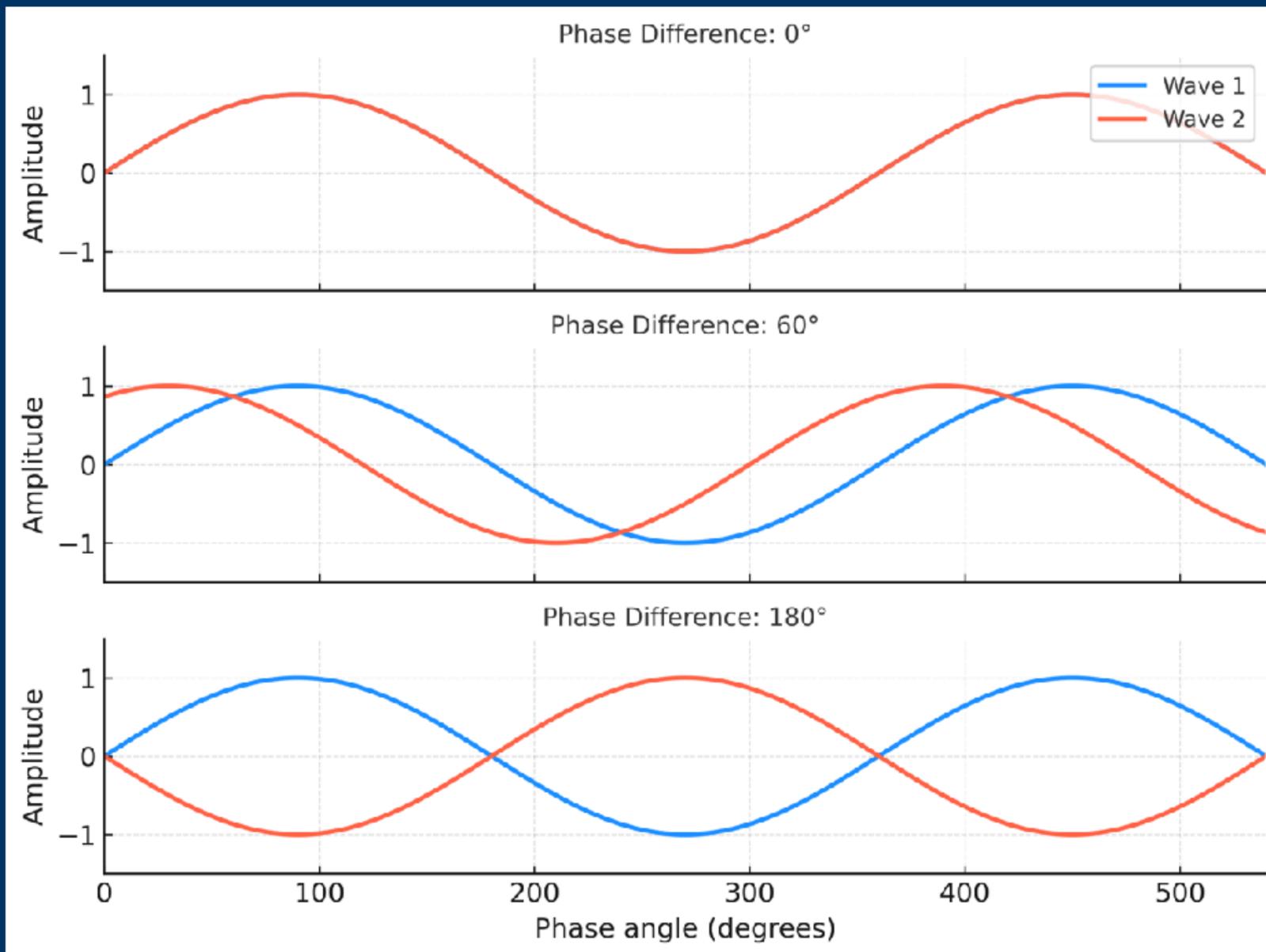
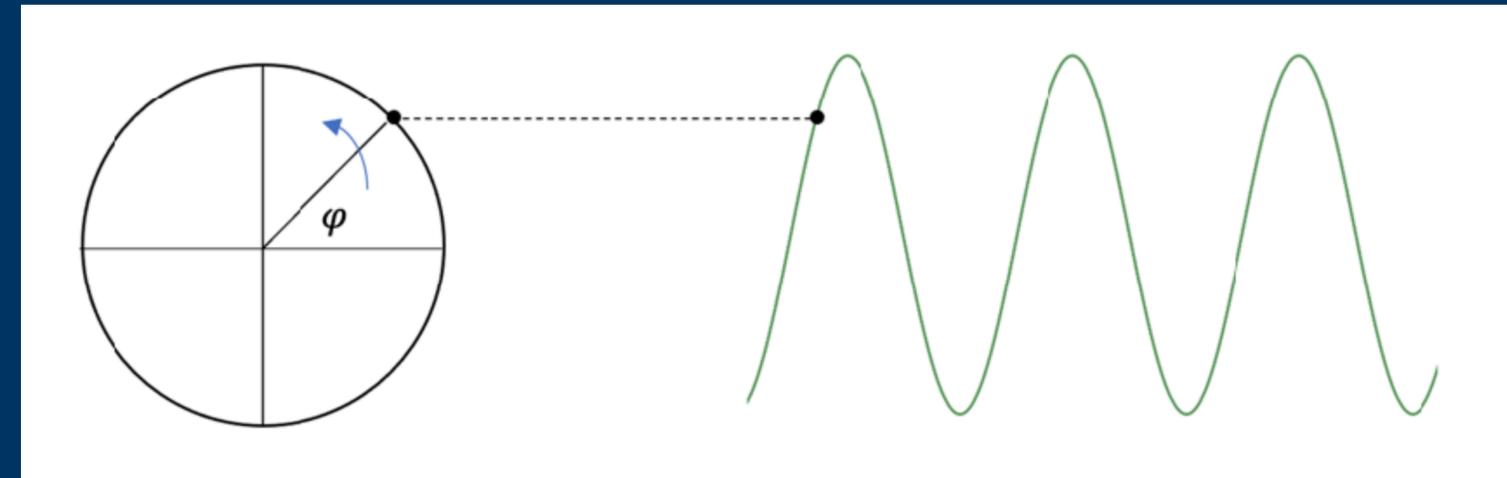
These are waves



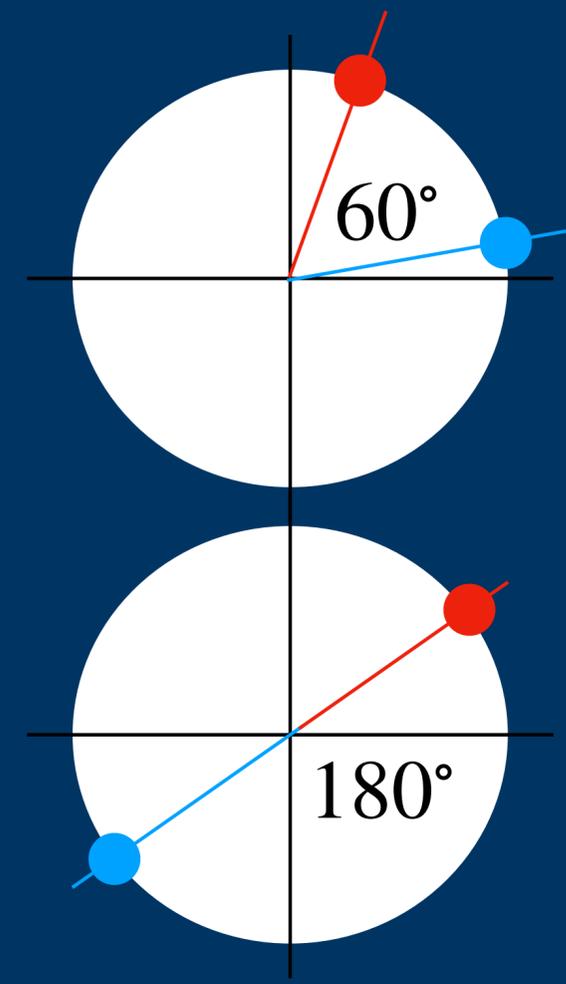
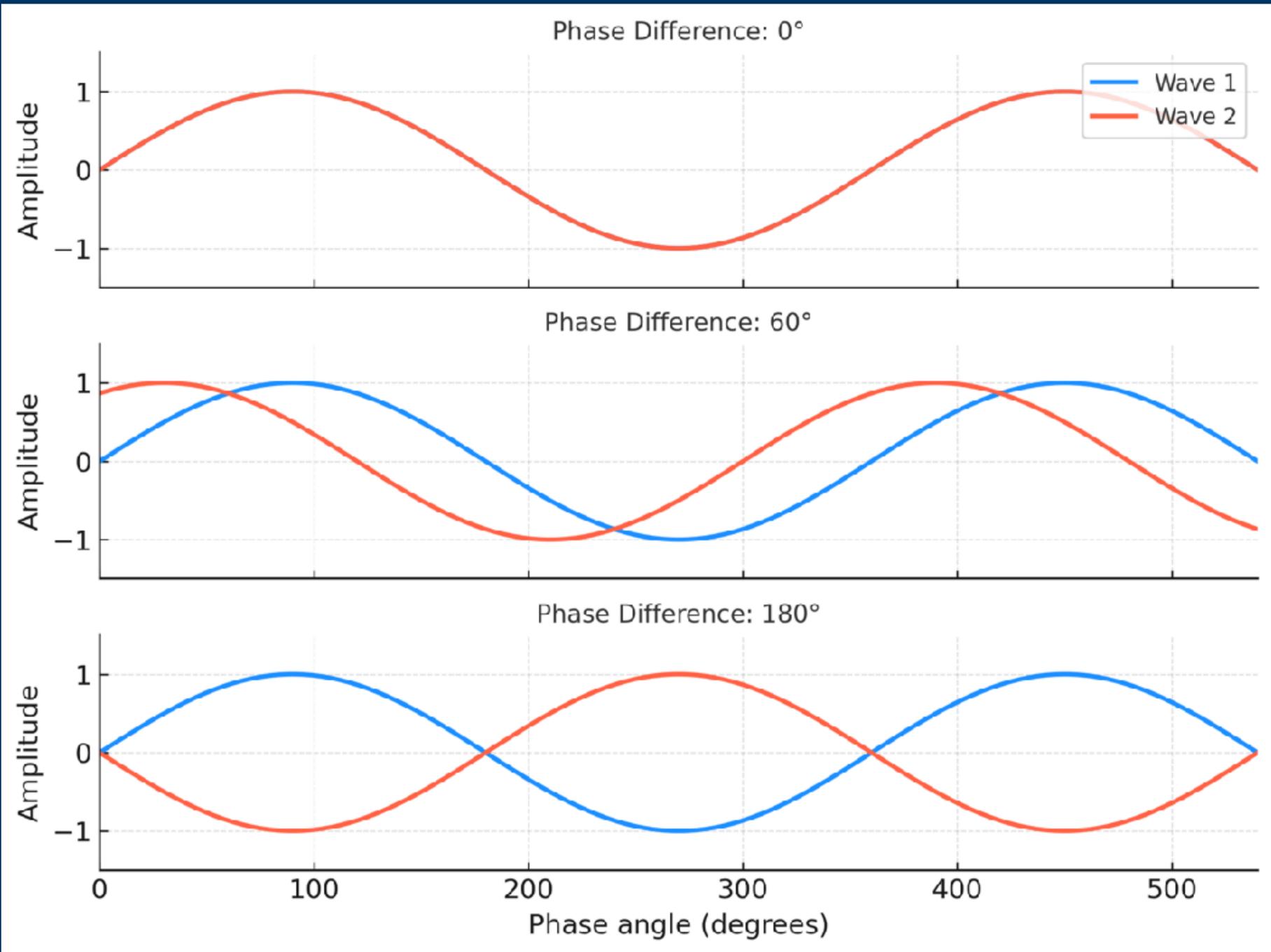
These are **not waves** - matter is moving

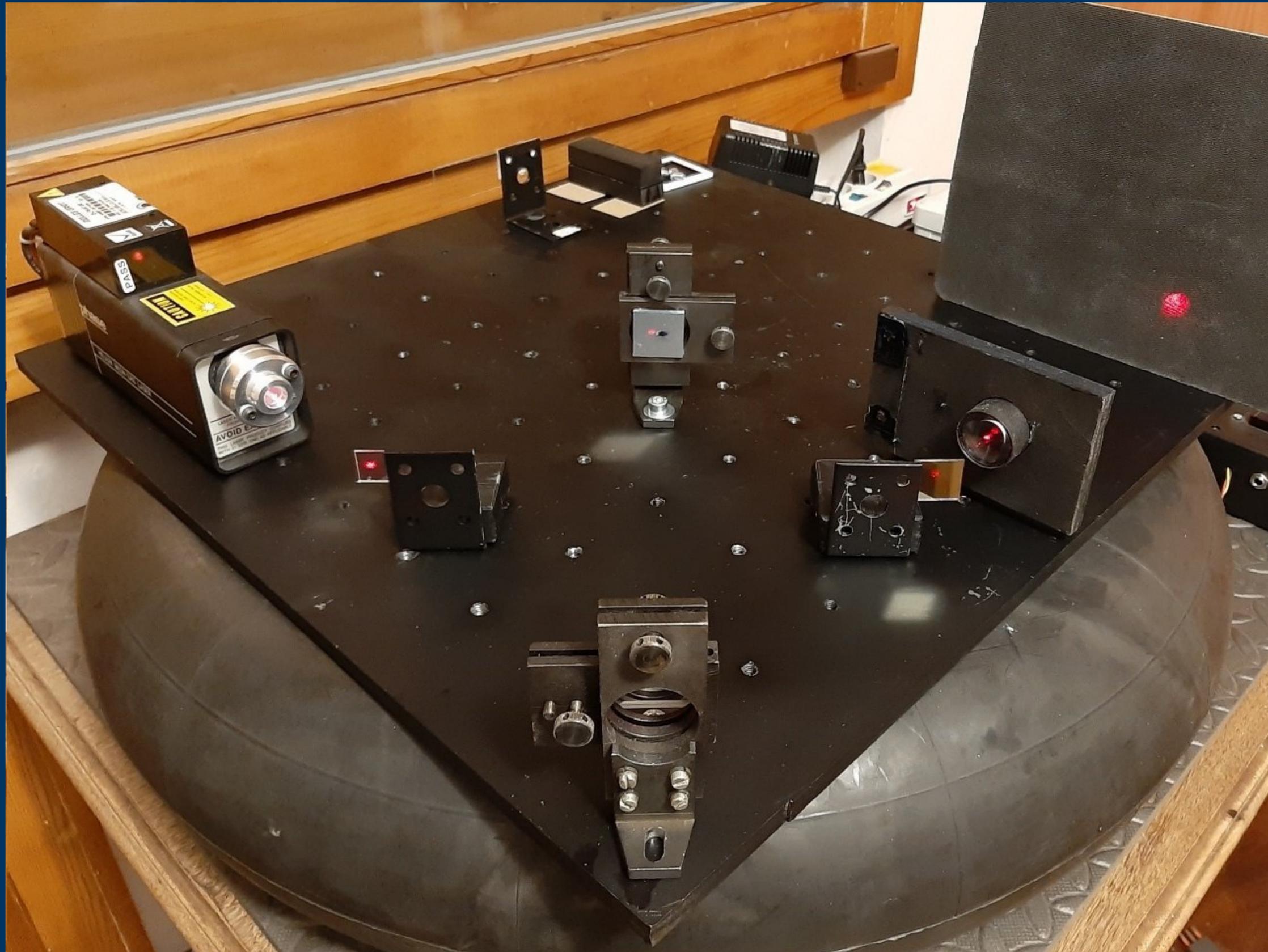
Wave **phase** - what part of the cycle

Specified as an **angle**...

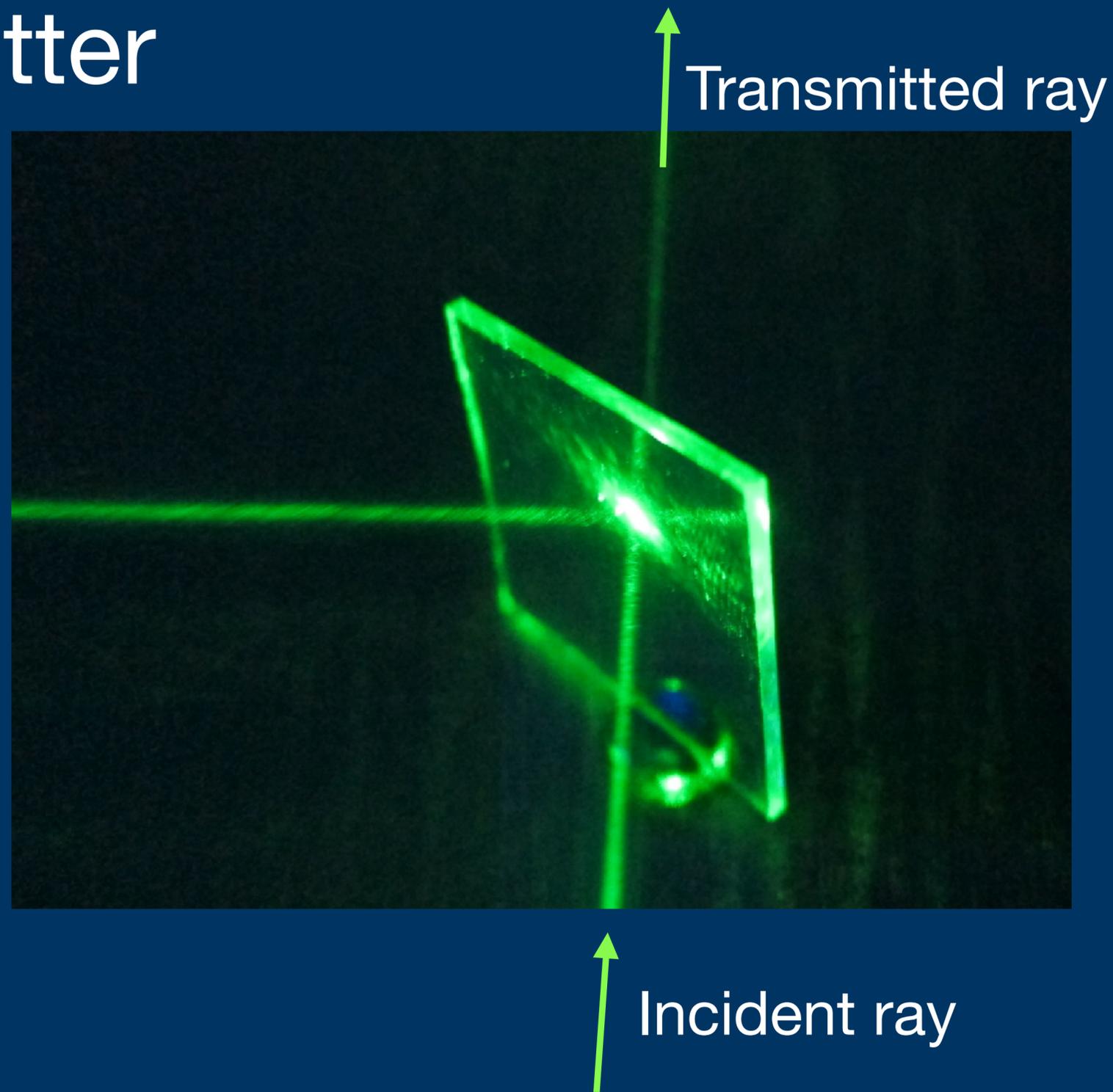


Waves that are 180° out of phase **cancel**



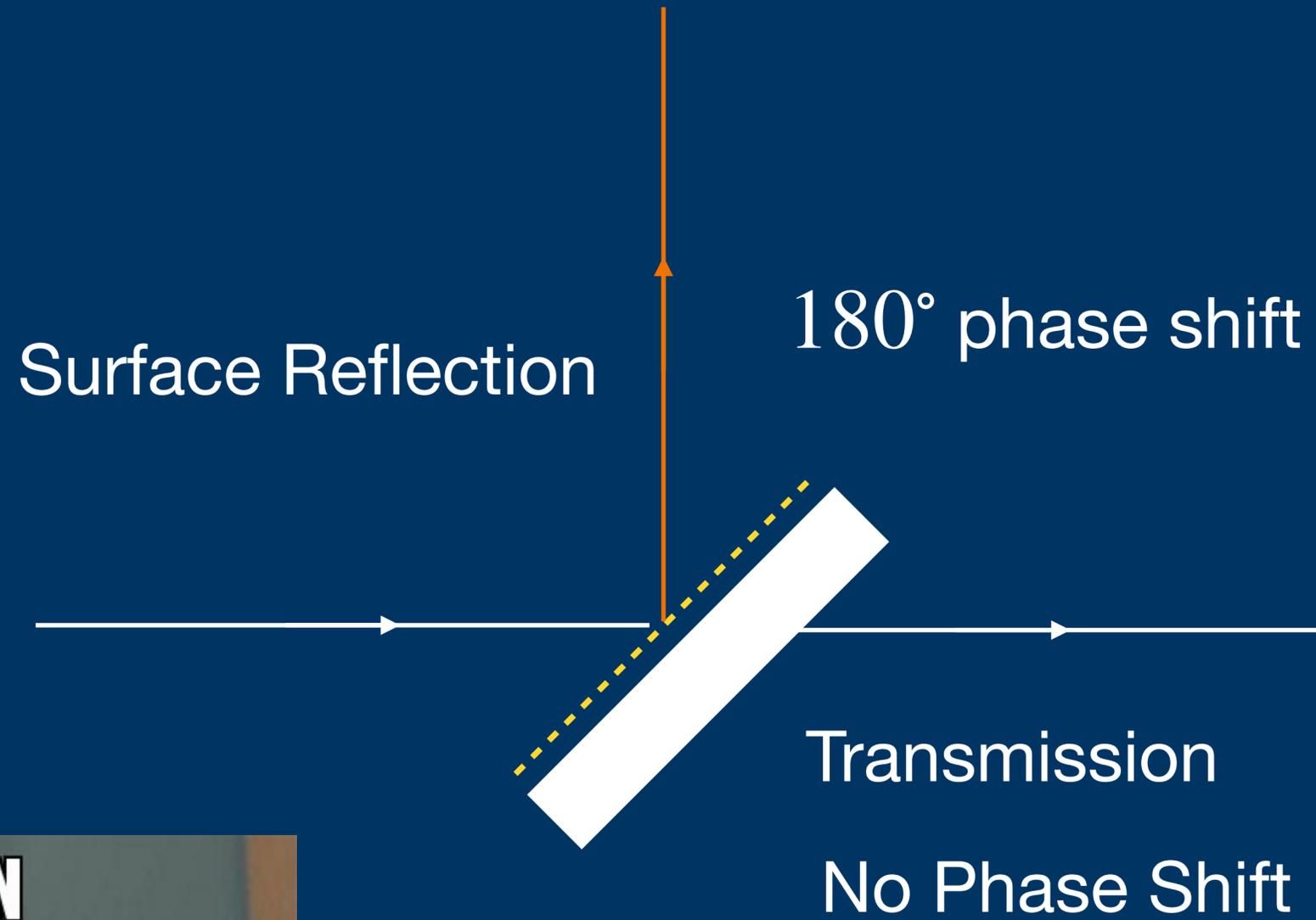


Beam Splitter



Illustrated splitter:
80% reflective

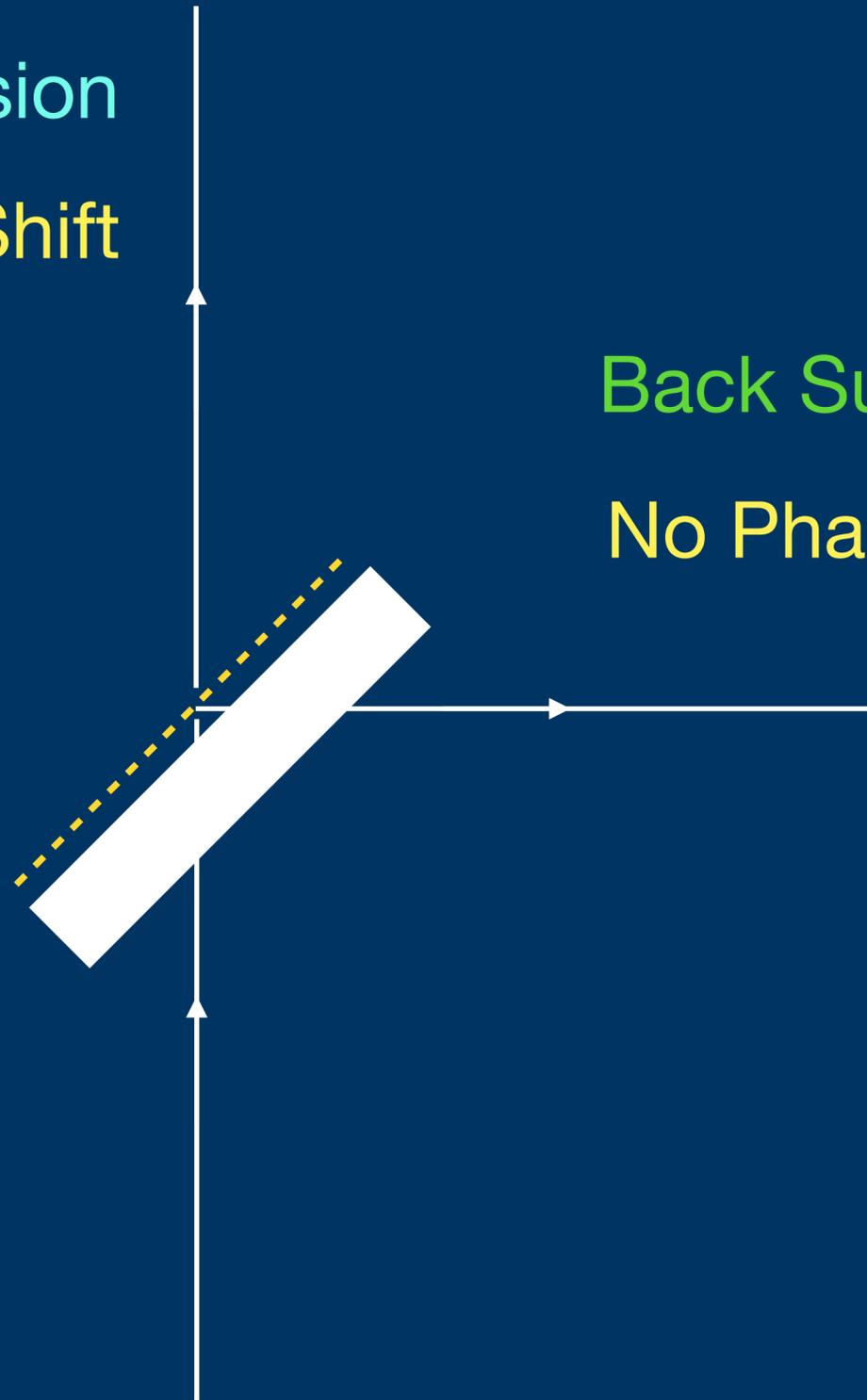


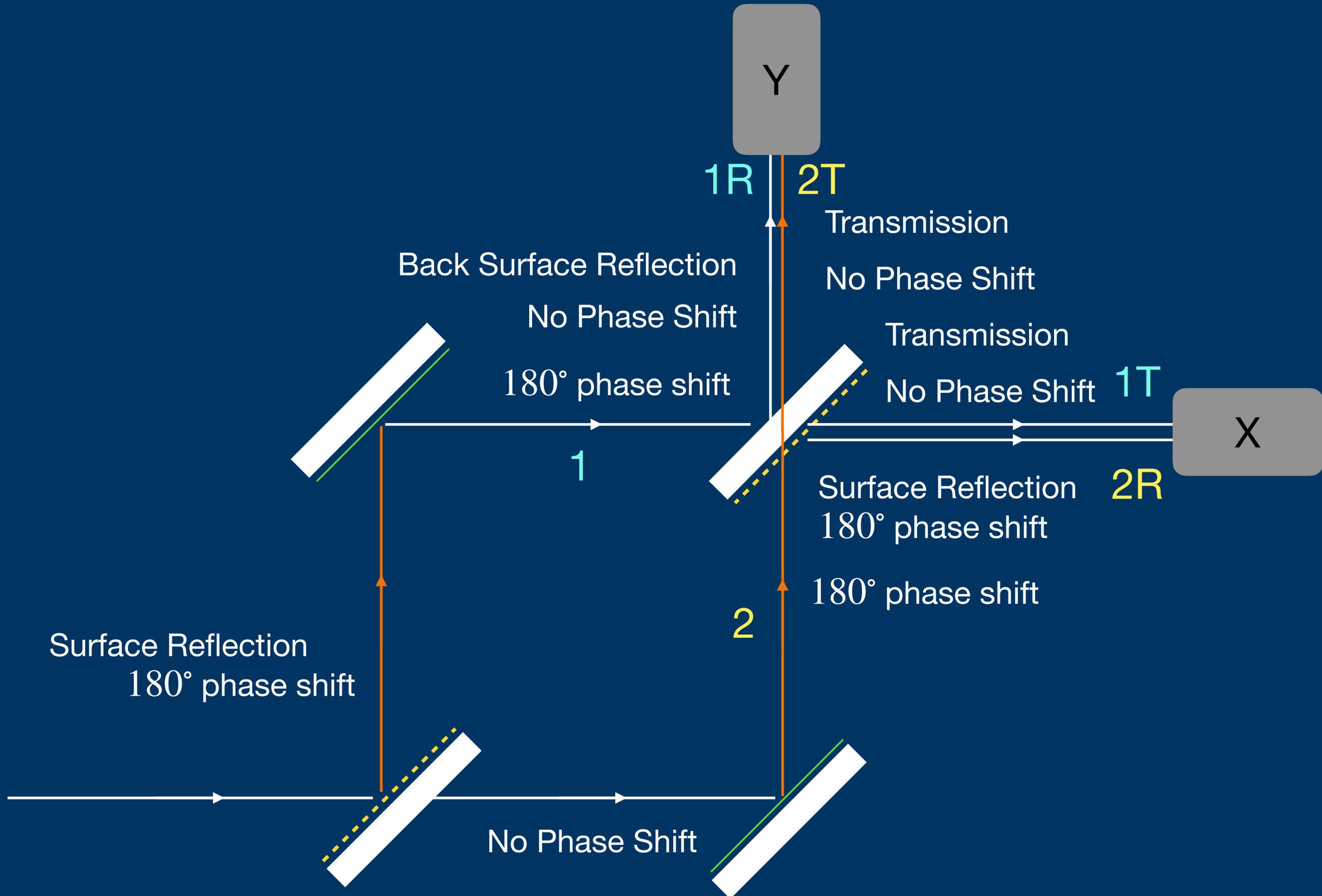


There's another way...

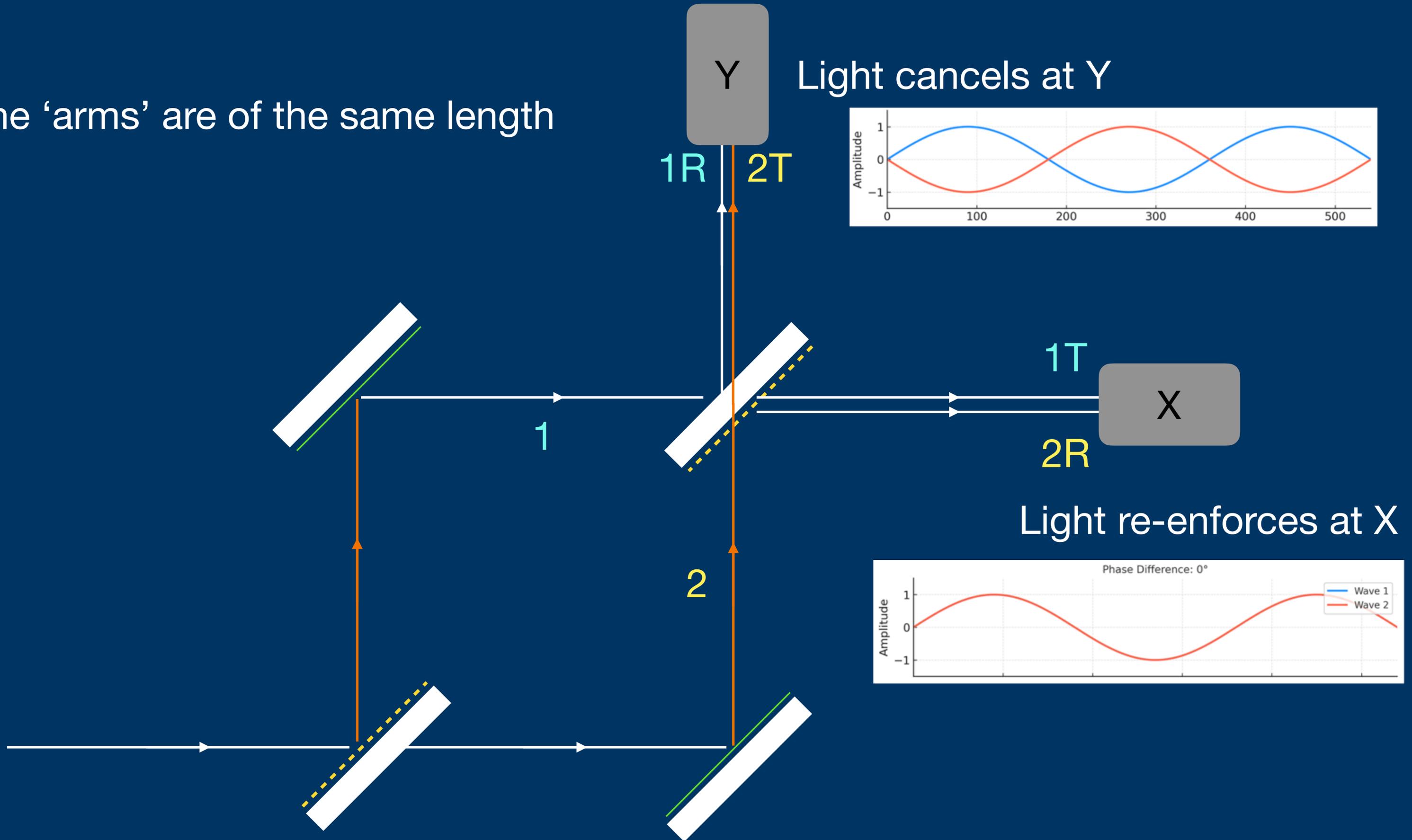
Transmission
No Phase Shift

Back Surface Reflection
No Phase Shift

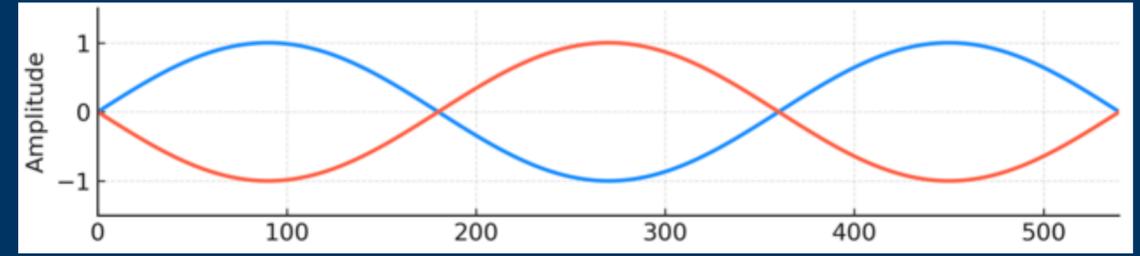




If the 'arms' are of the same length

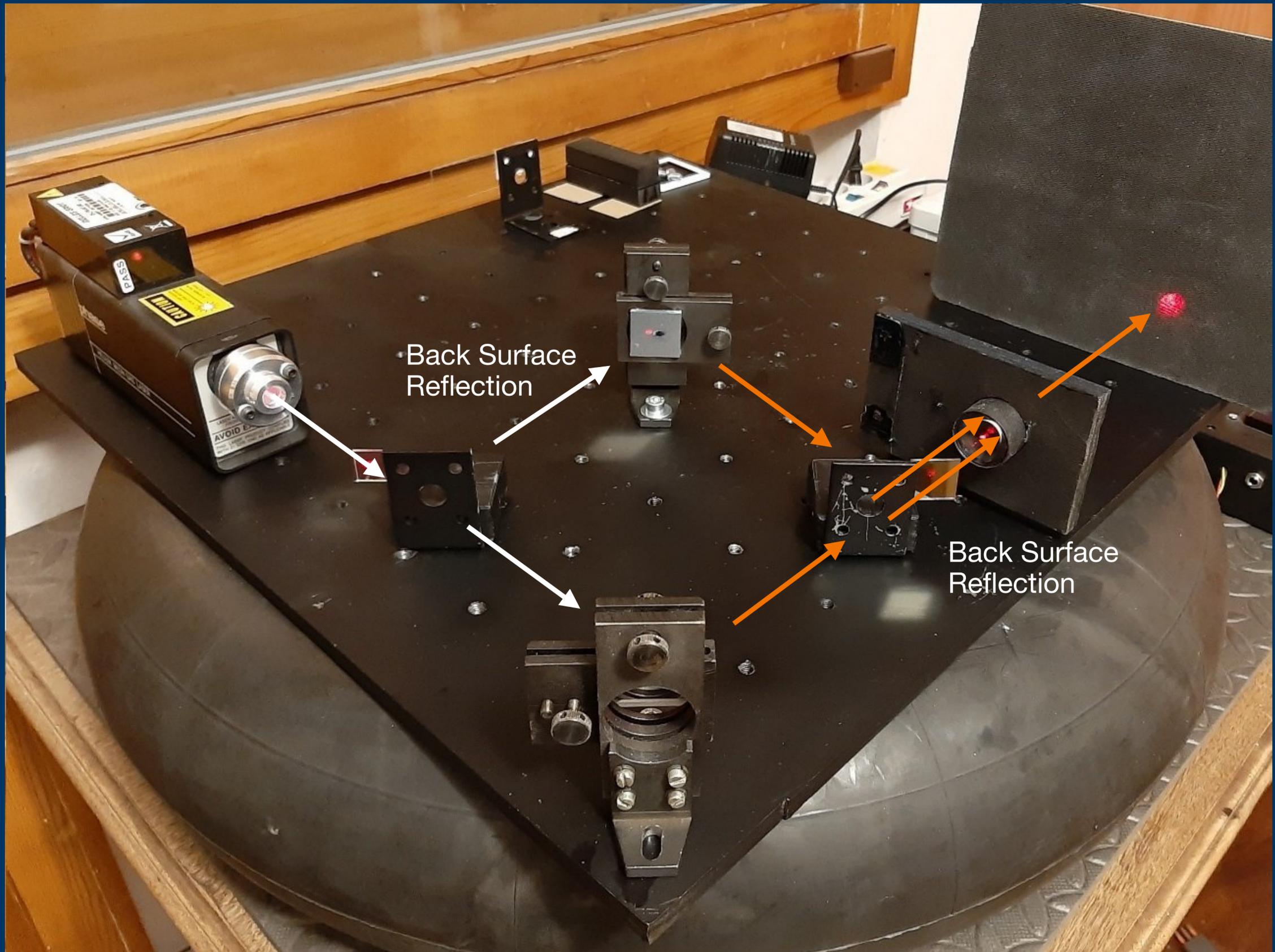


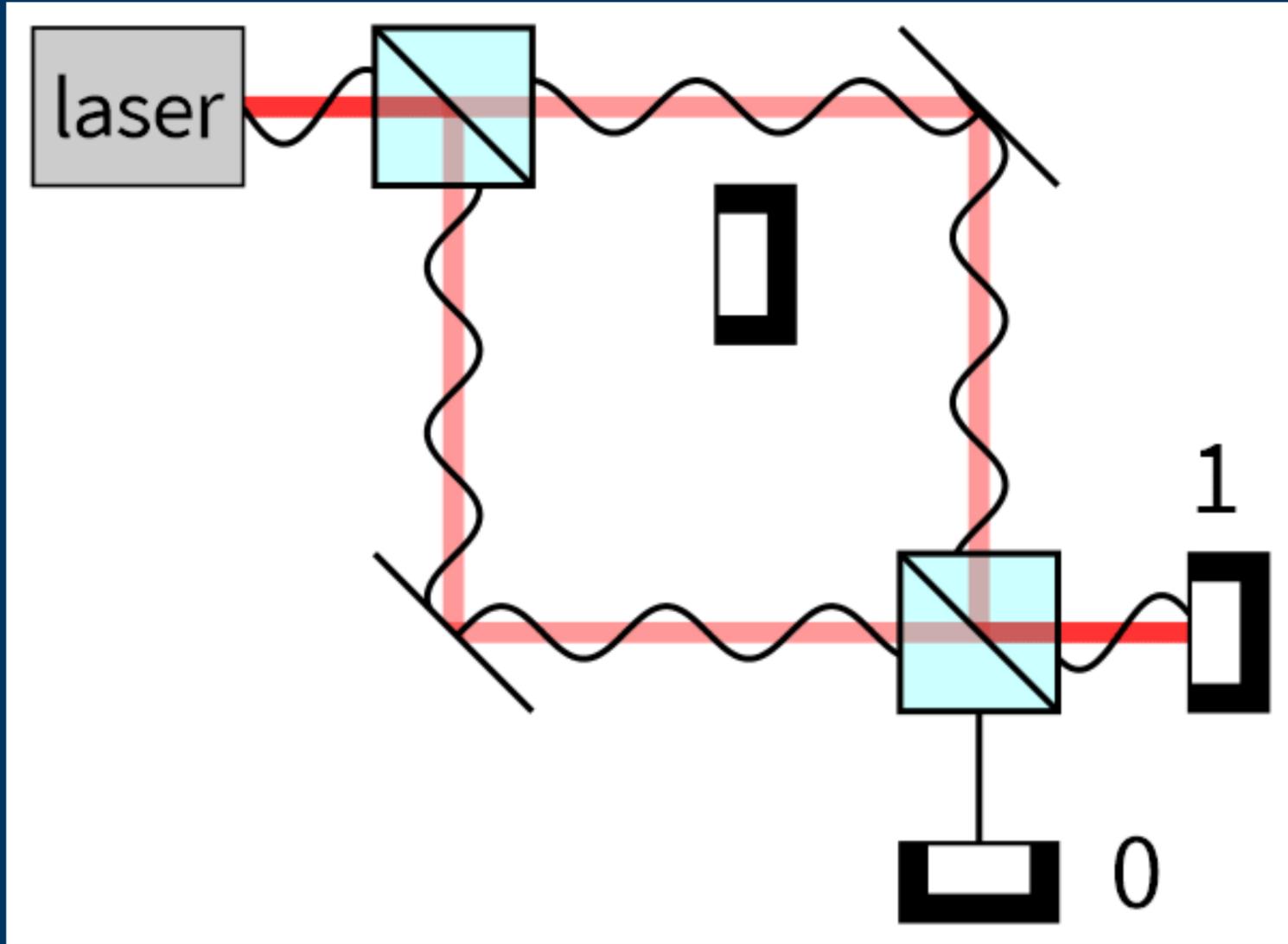
Light cancels at Y



Light re-enforces at X

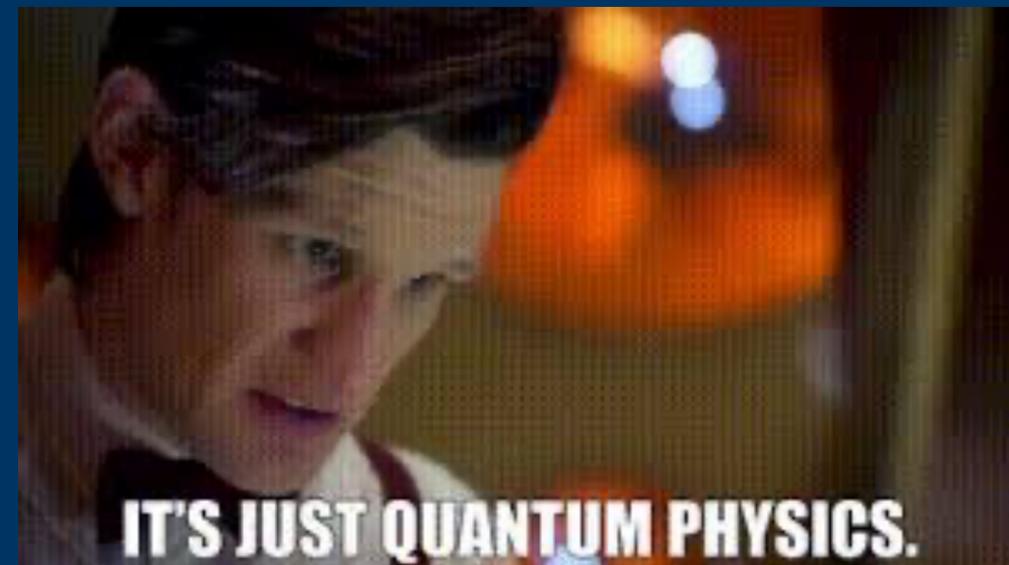
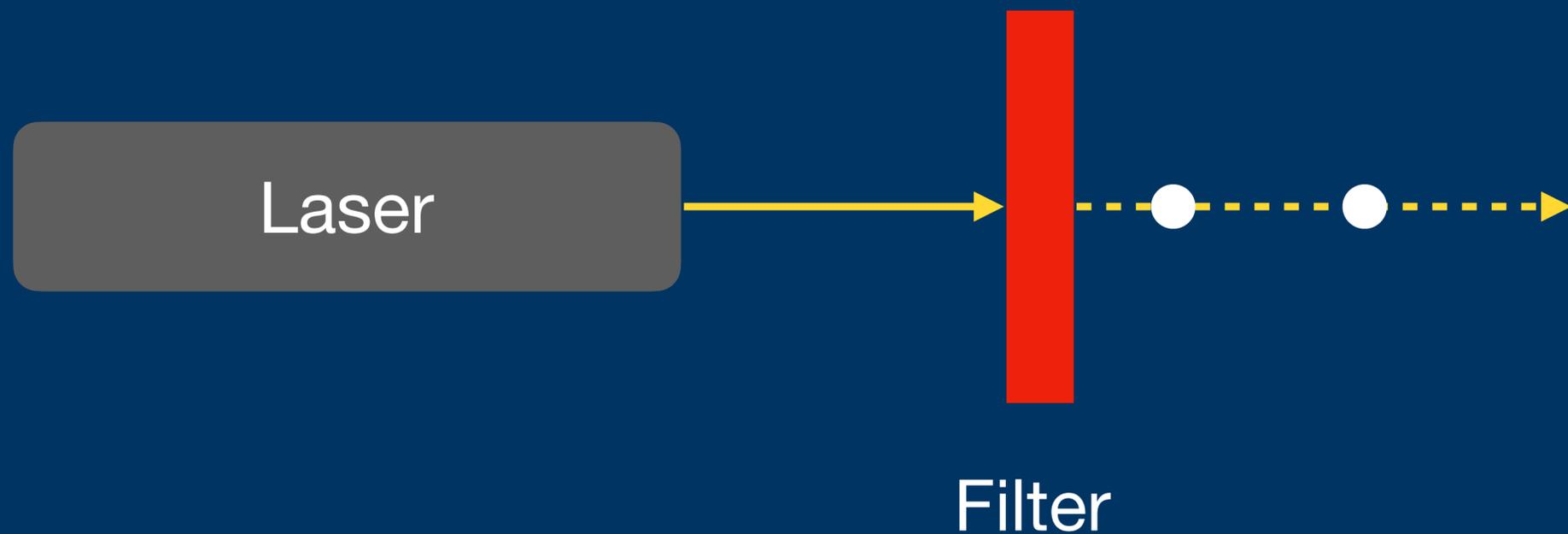


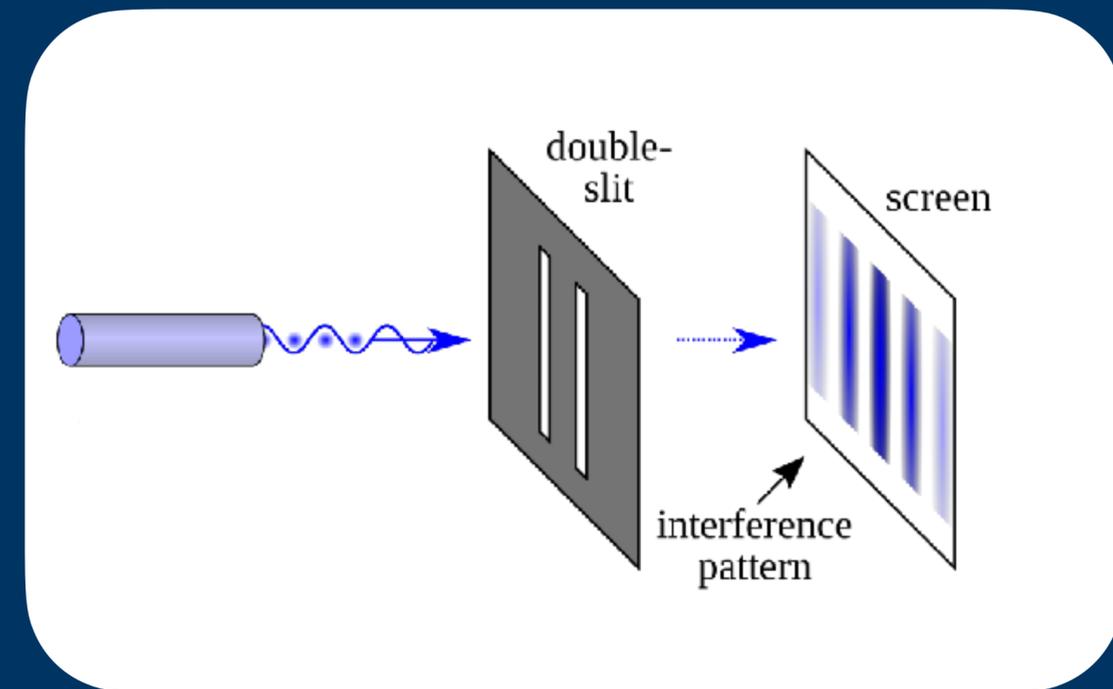
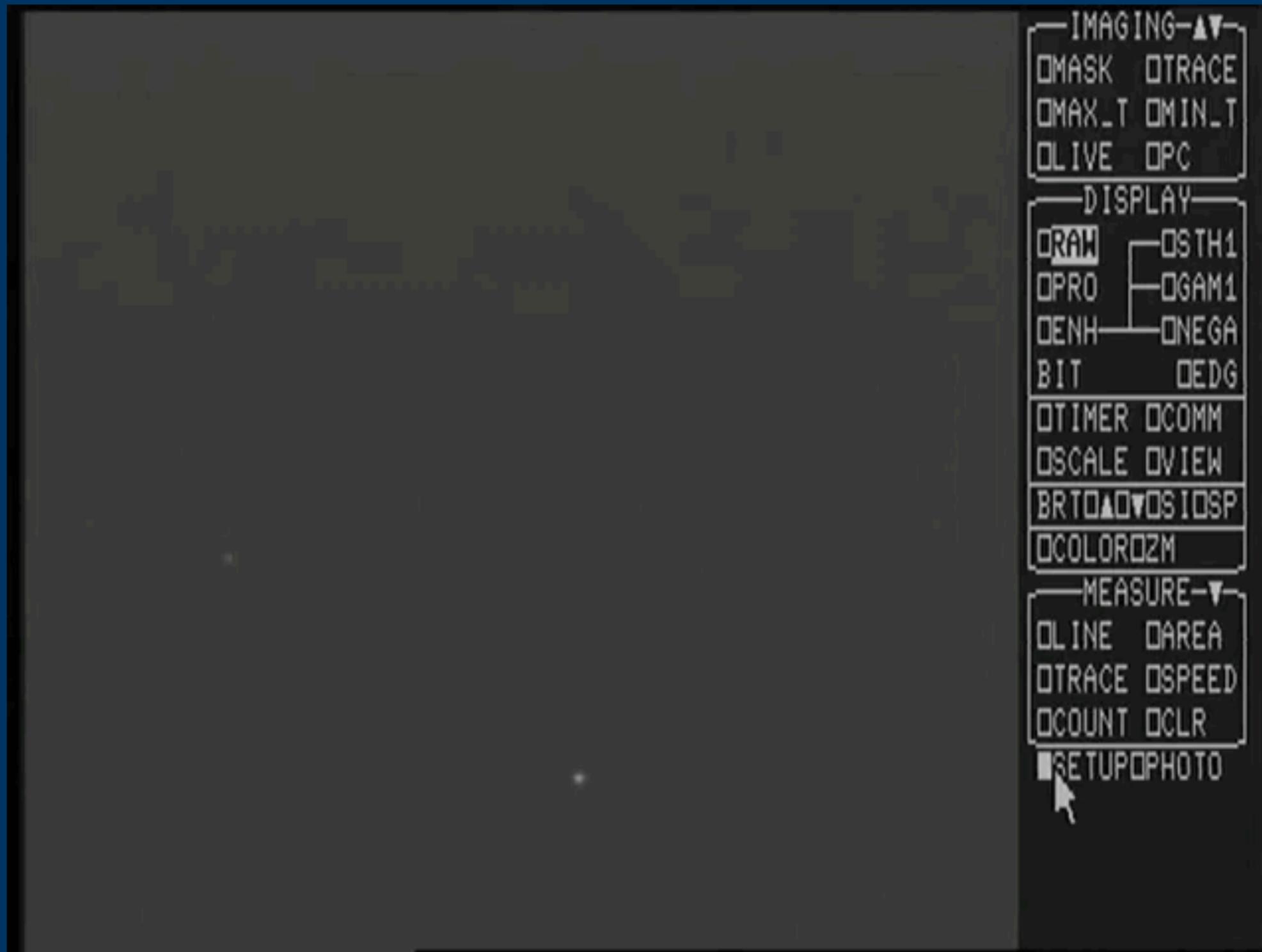




Things get quantum...

- Turn down the wick on the laser...
 - Reduce intensity so **only one photon in the device at a time**....





Photon arrives at splitter



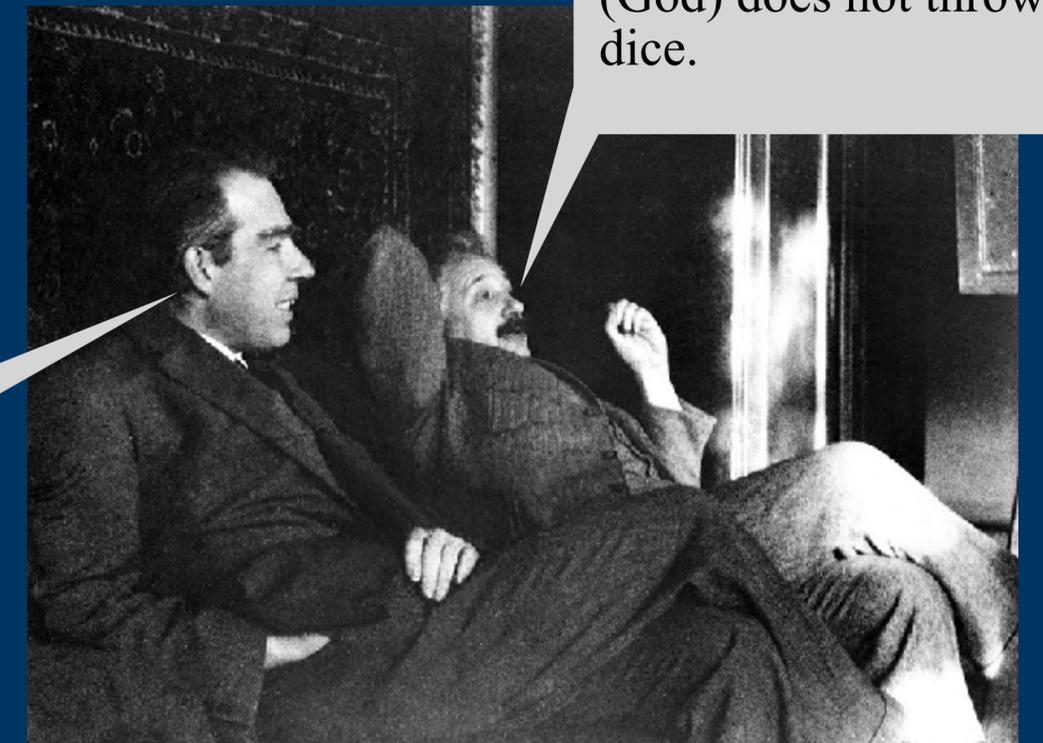
Either **reflects** or **transmits**

As a **whole** - does not split in two...

Nothing about the photon **prior to arriving** allows us

to **predict** what it will do

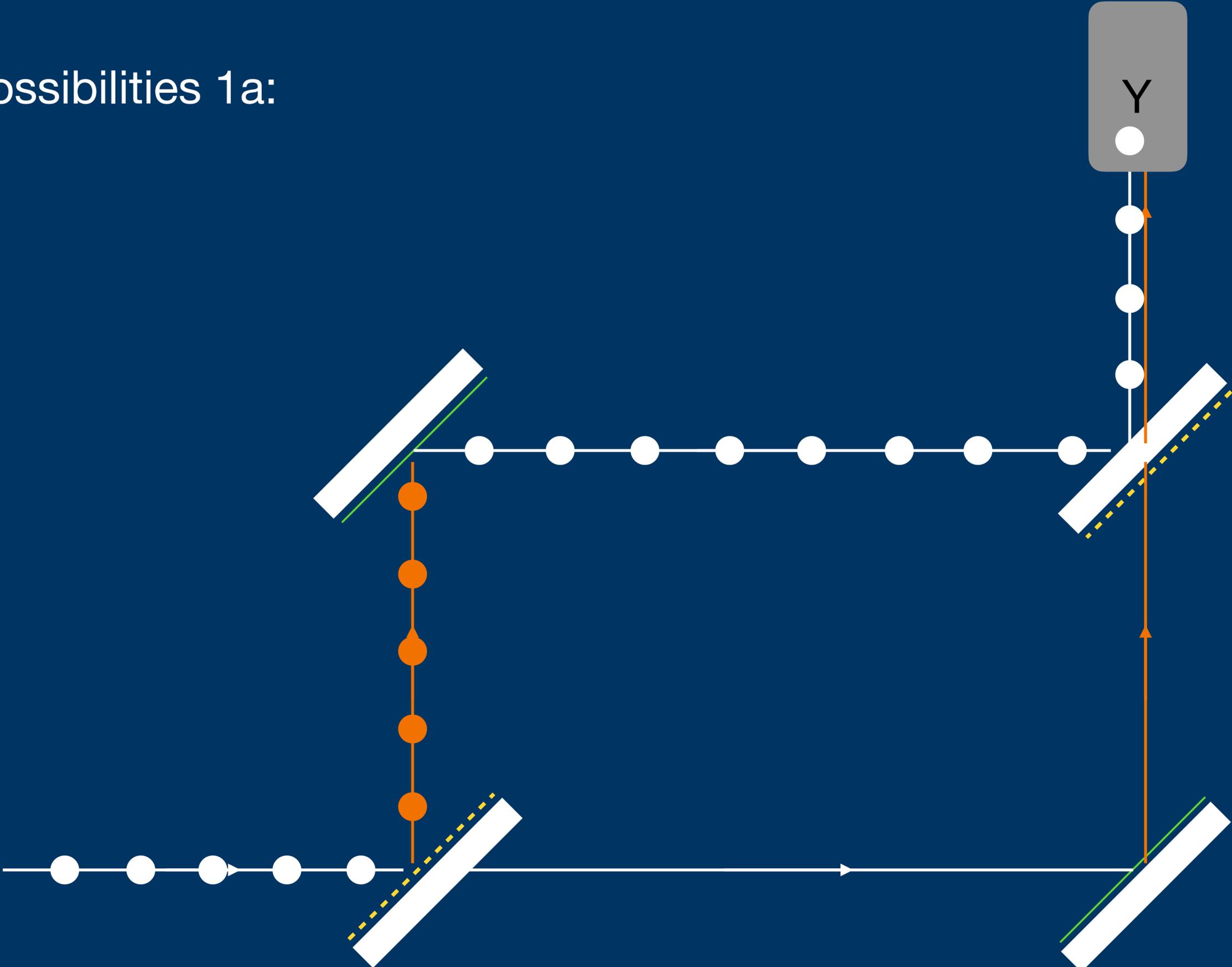
Inherently **random**....



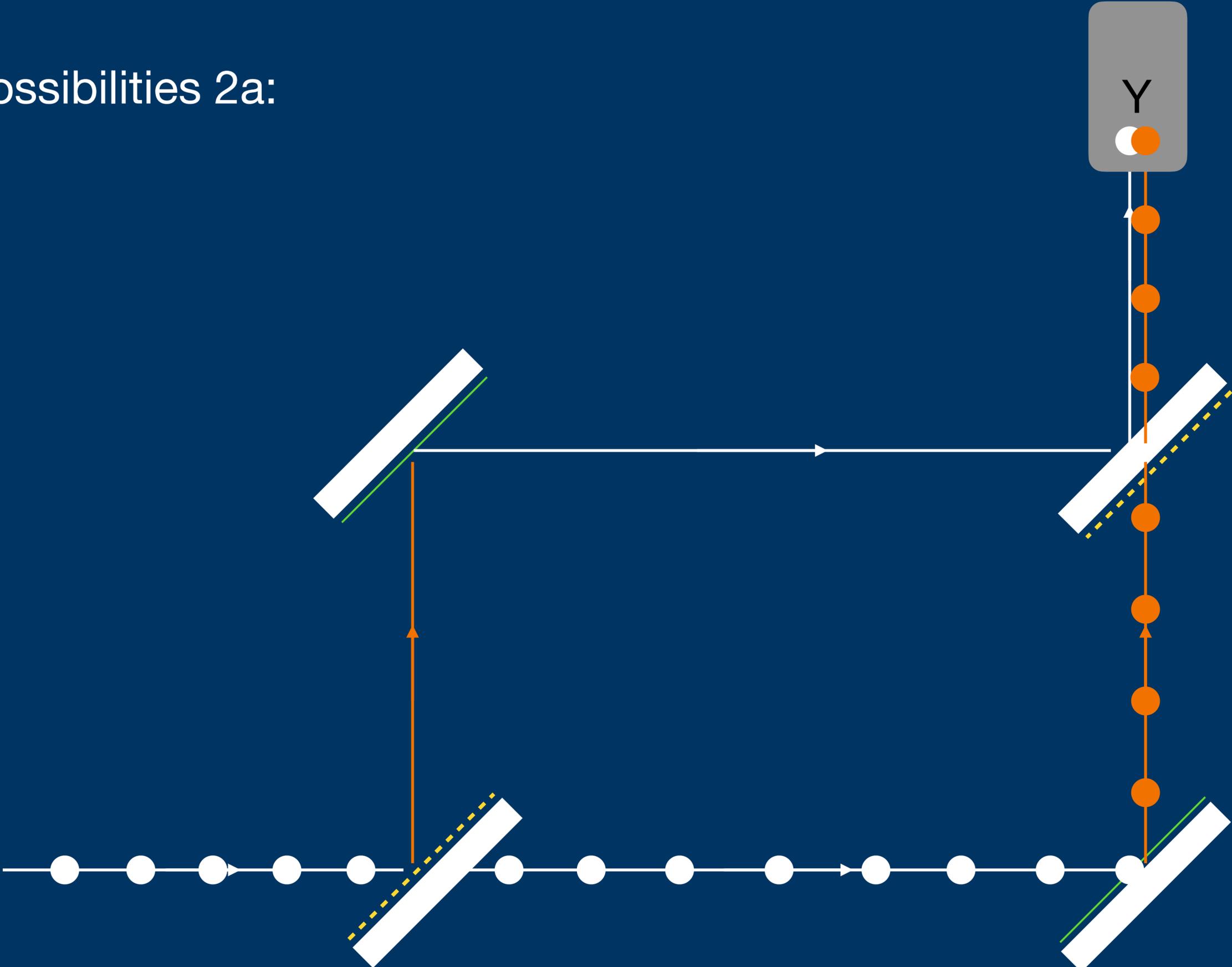
I, at any rate, am convinced that He (God) does not throw dice.

Einstein, stop telling God what to do...

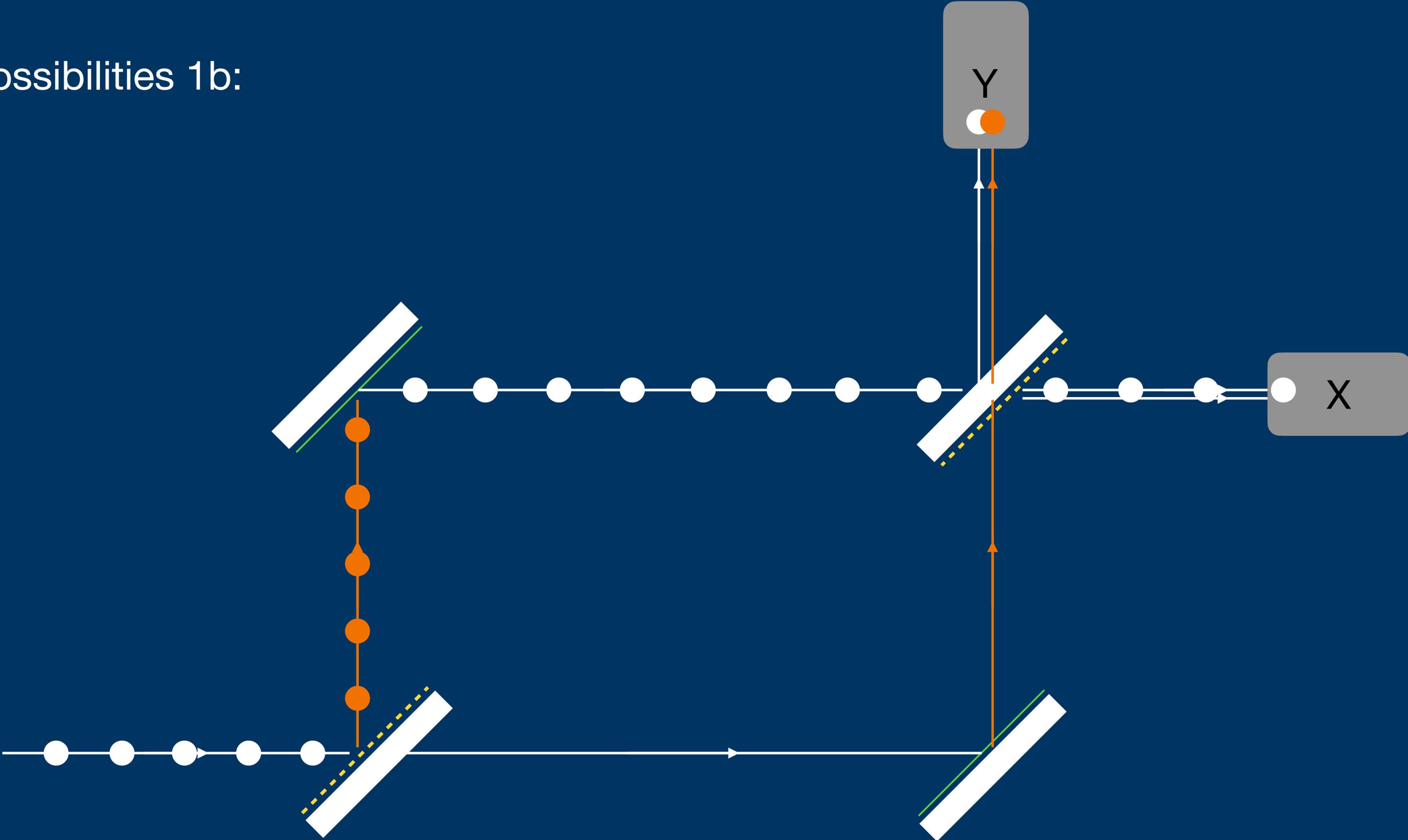
Possibilities 1a:



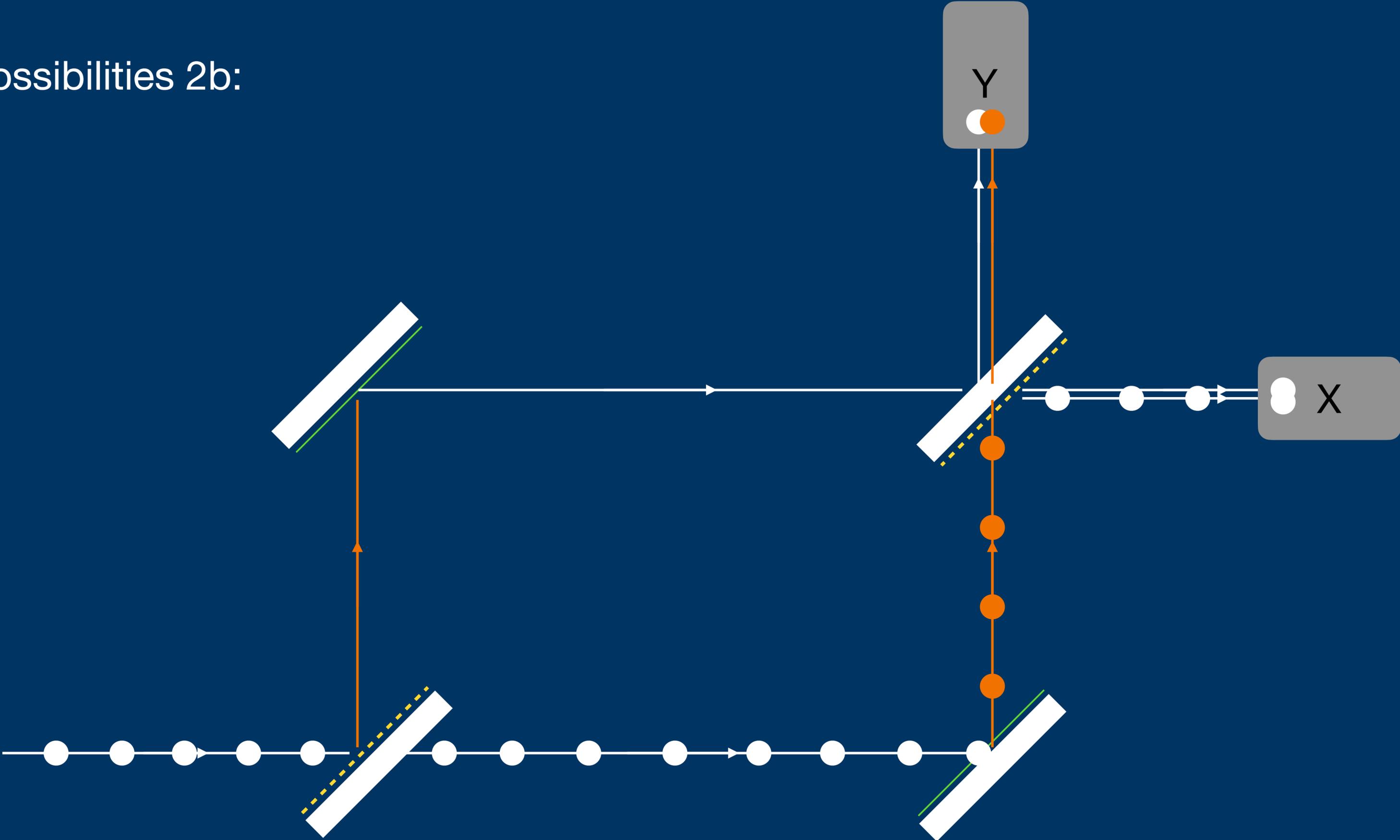
Possibilities 2a:



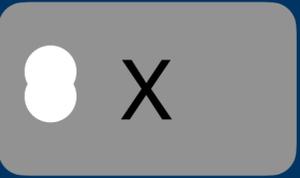
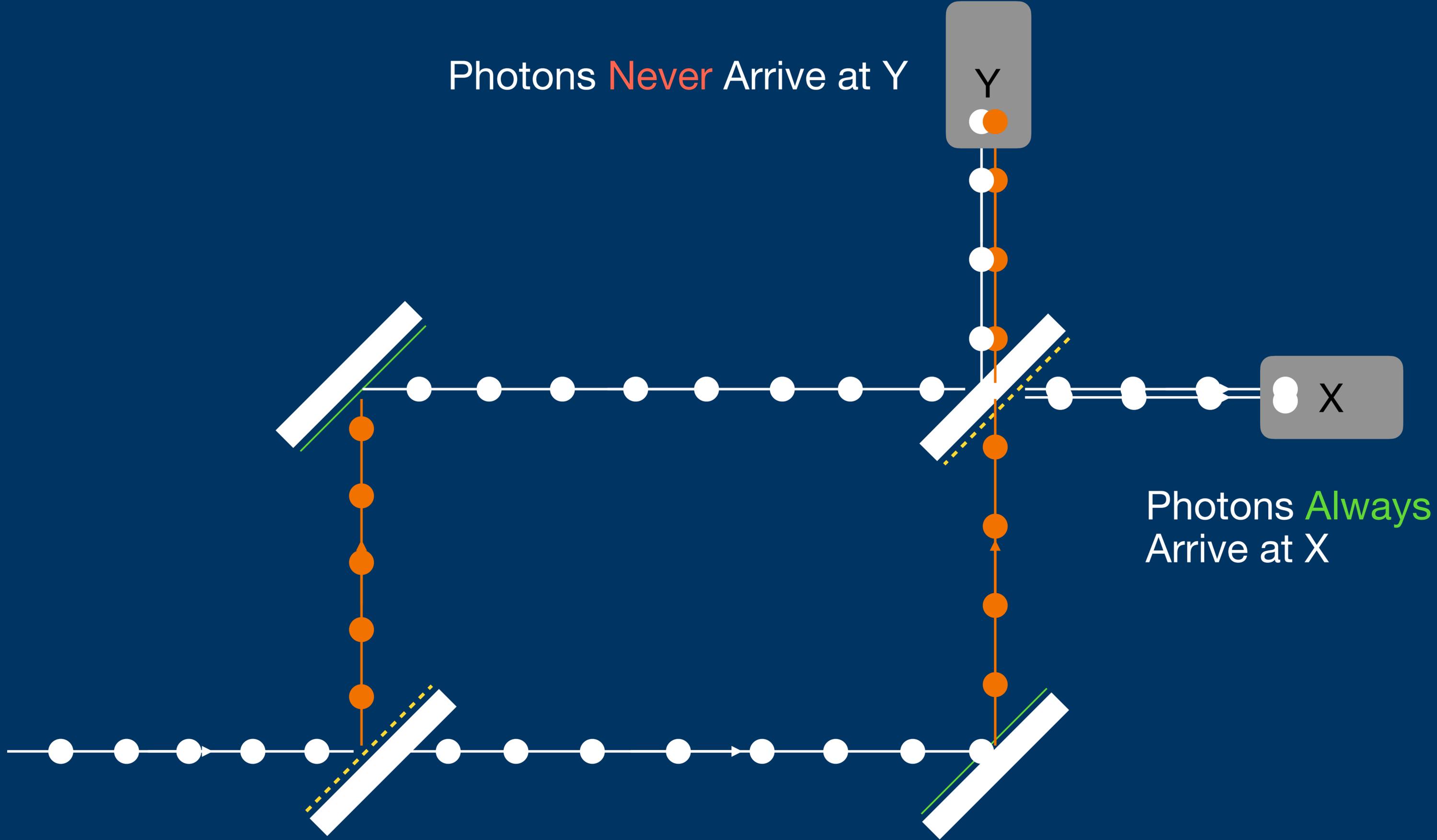
Possibilities 1b:



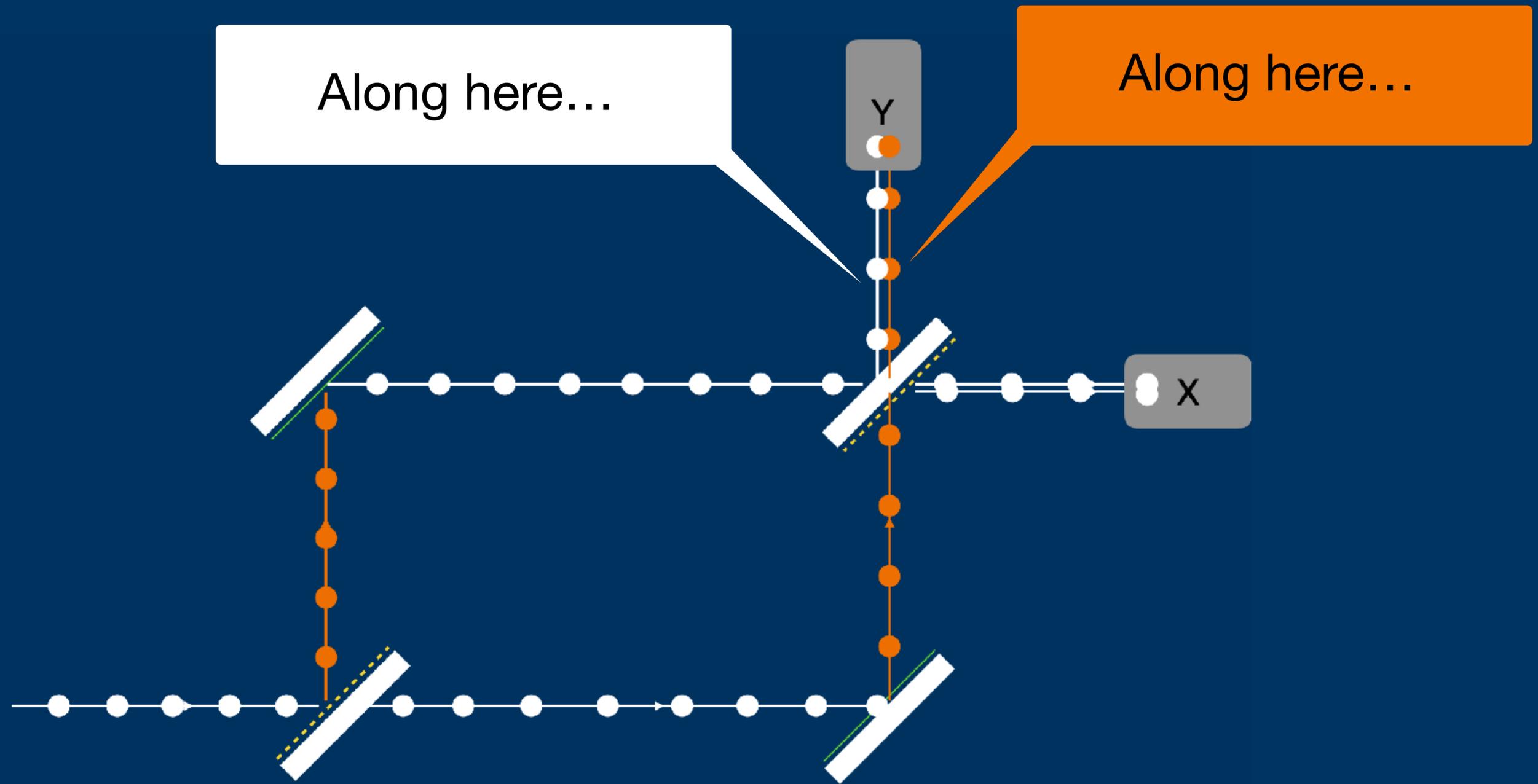
Possibilities 2b:



Photons **Never** Arrive at Y



Photons **Always** Arrive at X



If there is only **one** photon **at a time**...

Only 2 ways it can arrive at Y



So what is it interfering with????

So...

- Does the photon **travel both paths at the same time**?
- The problem is actually with the **words**:
 - Travel
 - Arrive
 - Path...
- There are no 'paths' in QM....



Catch 'em at it....

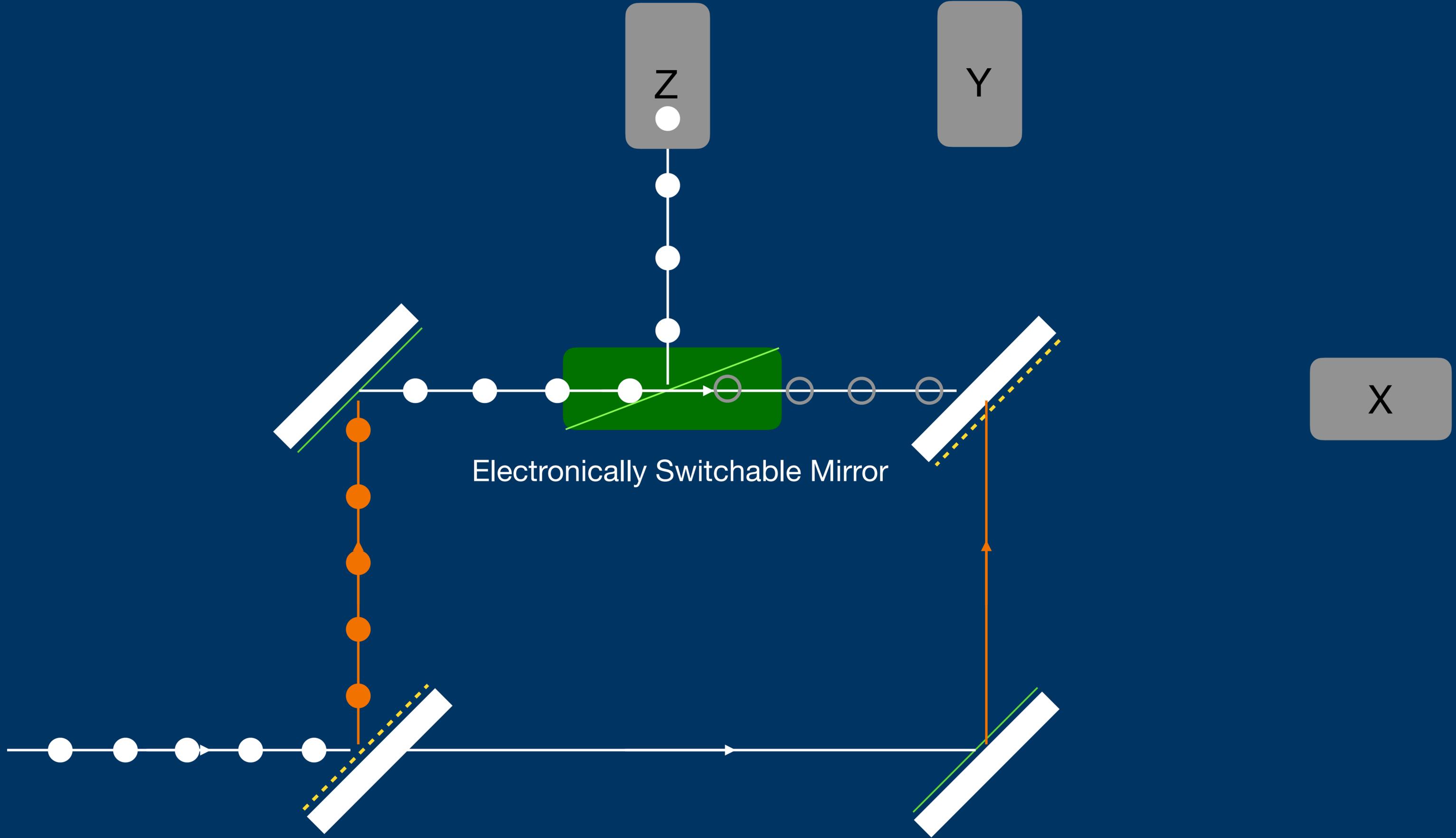
Intercept them along one of the paths

Photon: * Existing in dual state *

physicist: * observes *

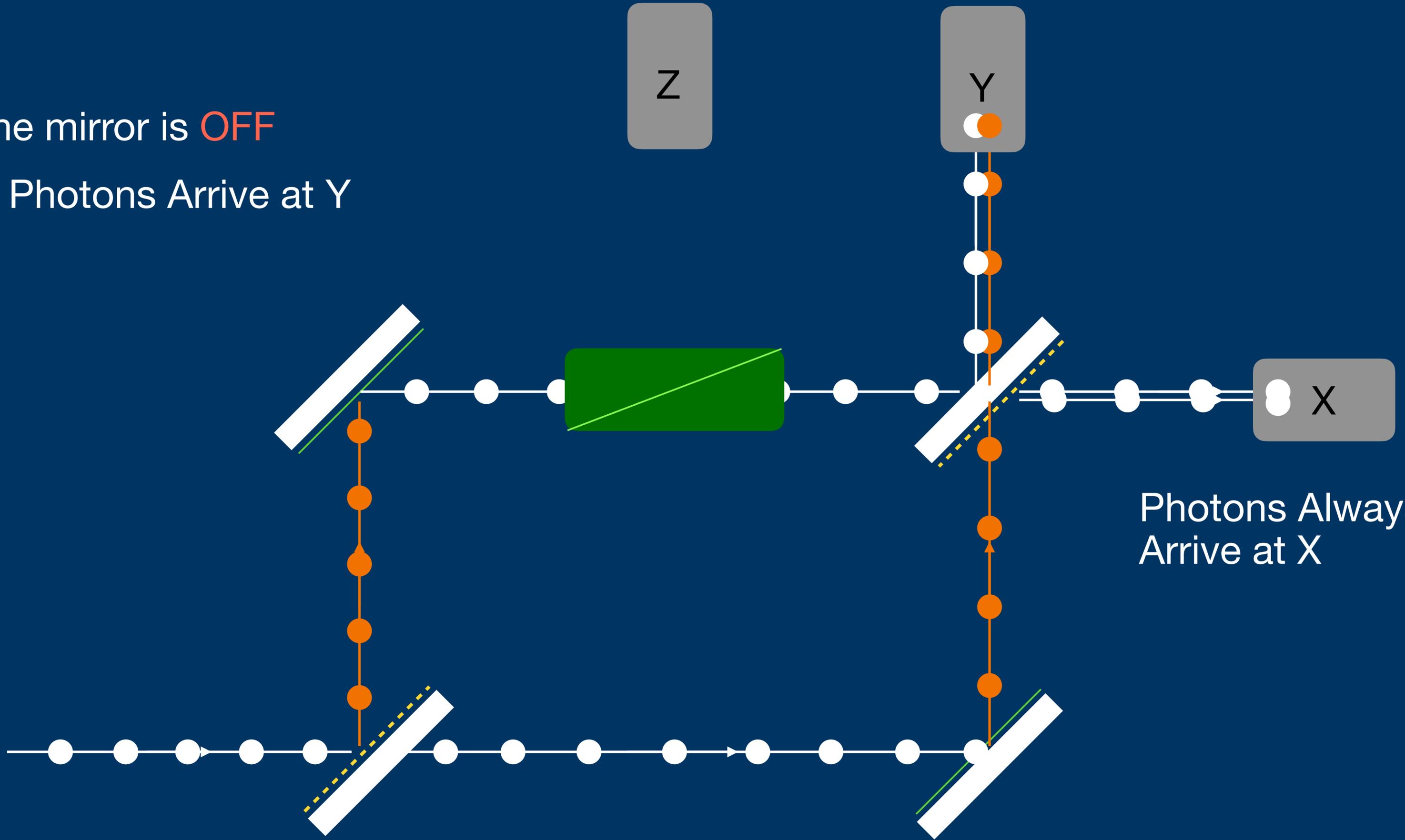
photon:





If the mirror is **OFF**

No Photons Arrive at Y



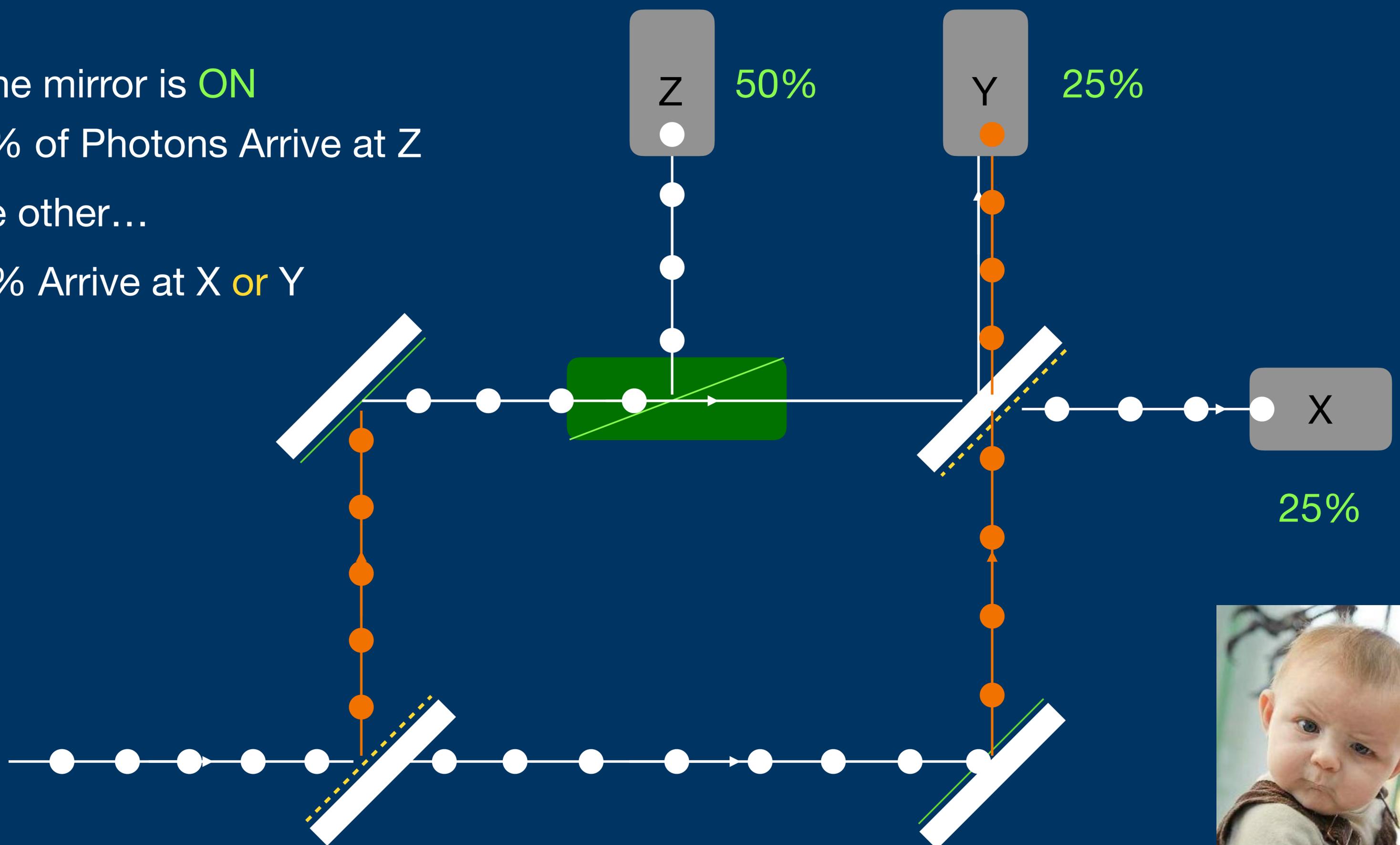
Photons Always Arrive at X

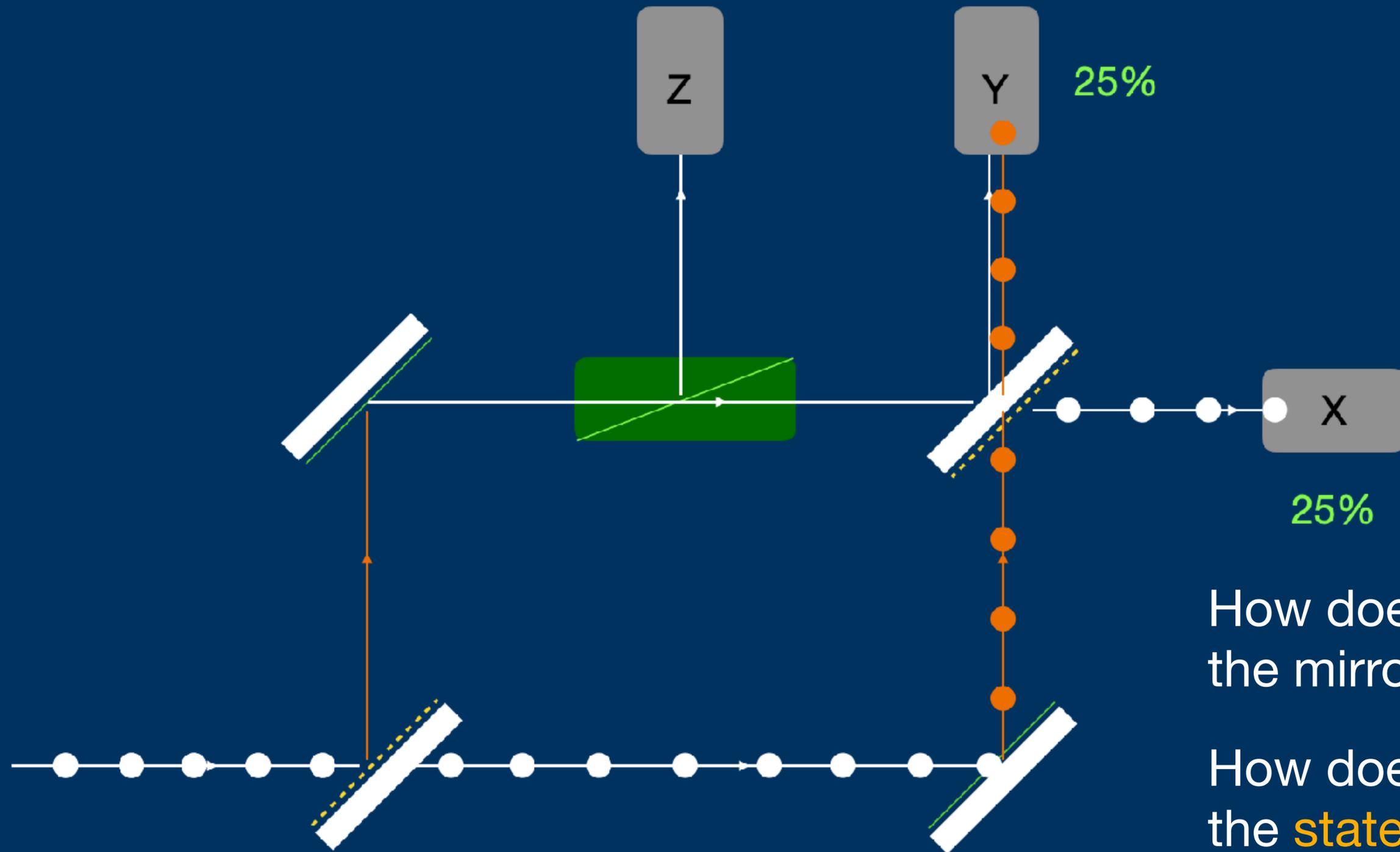
If the mirror is **ON**

50% of Photons Arrive at Z

The other...

25% Arrive at X **or** Y





How does it know about the mirror?

How does it know about the **state** of the mirror?

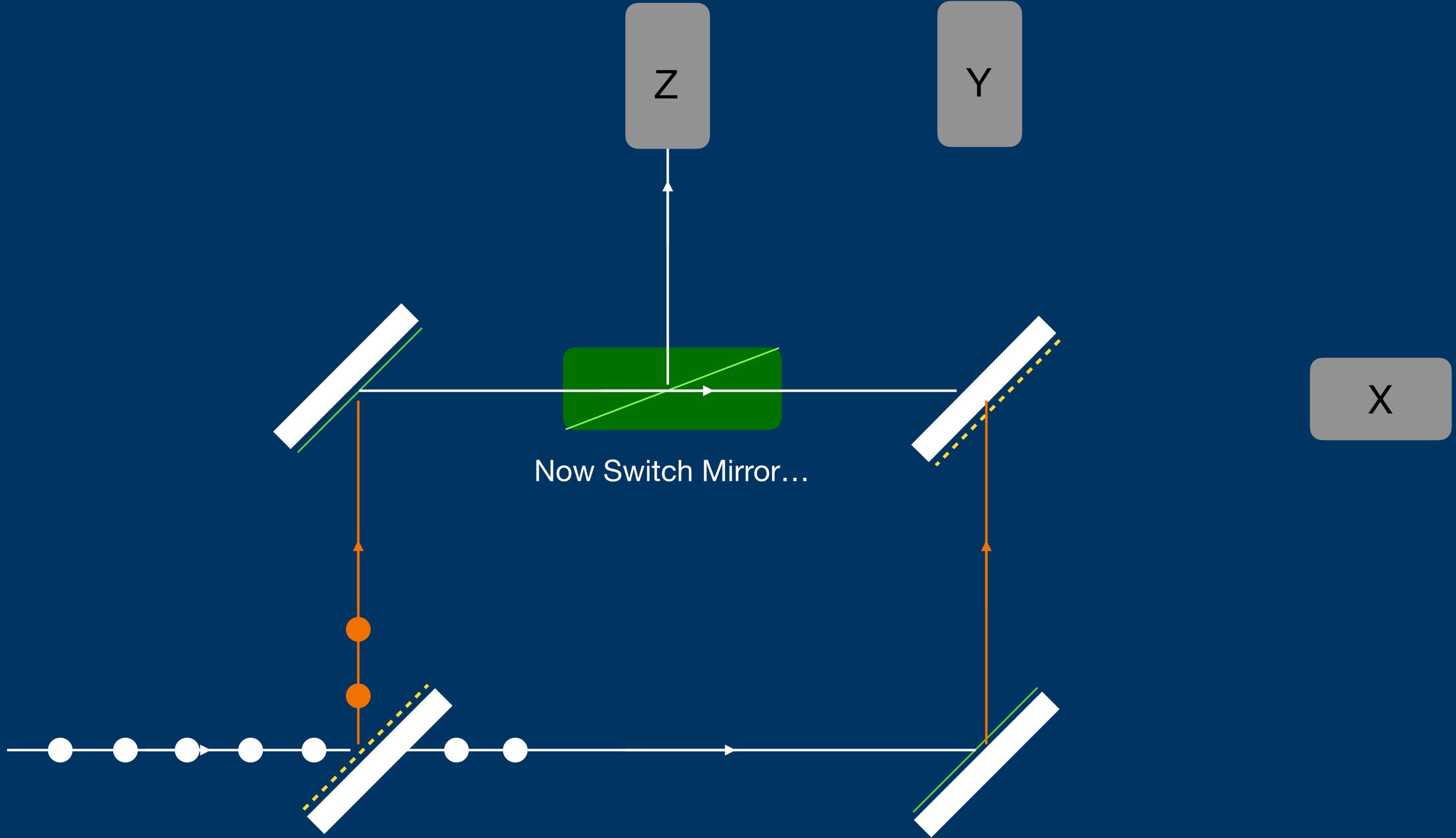
If the photon transmits here...



What if we delay switching the mirror?

Until **after** the photon has **passed the first splitter...**



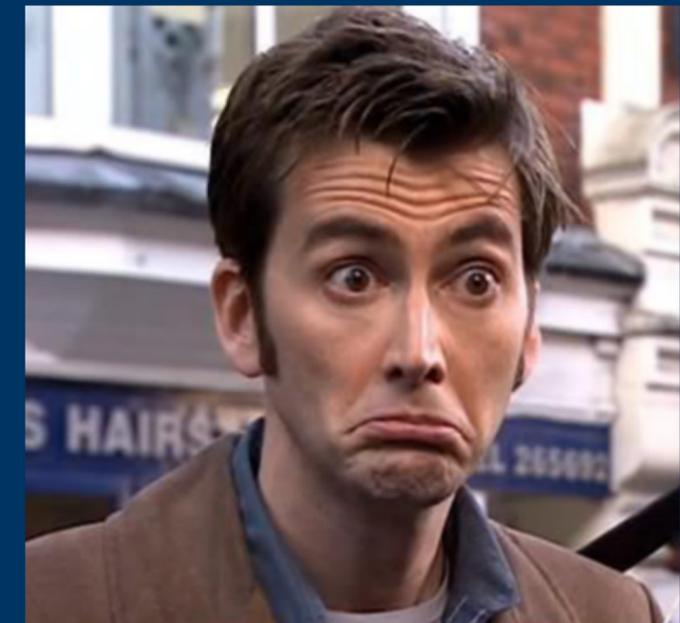
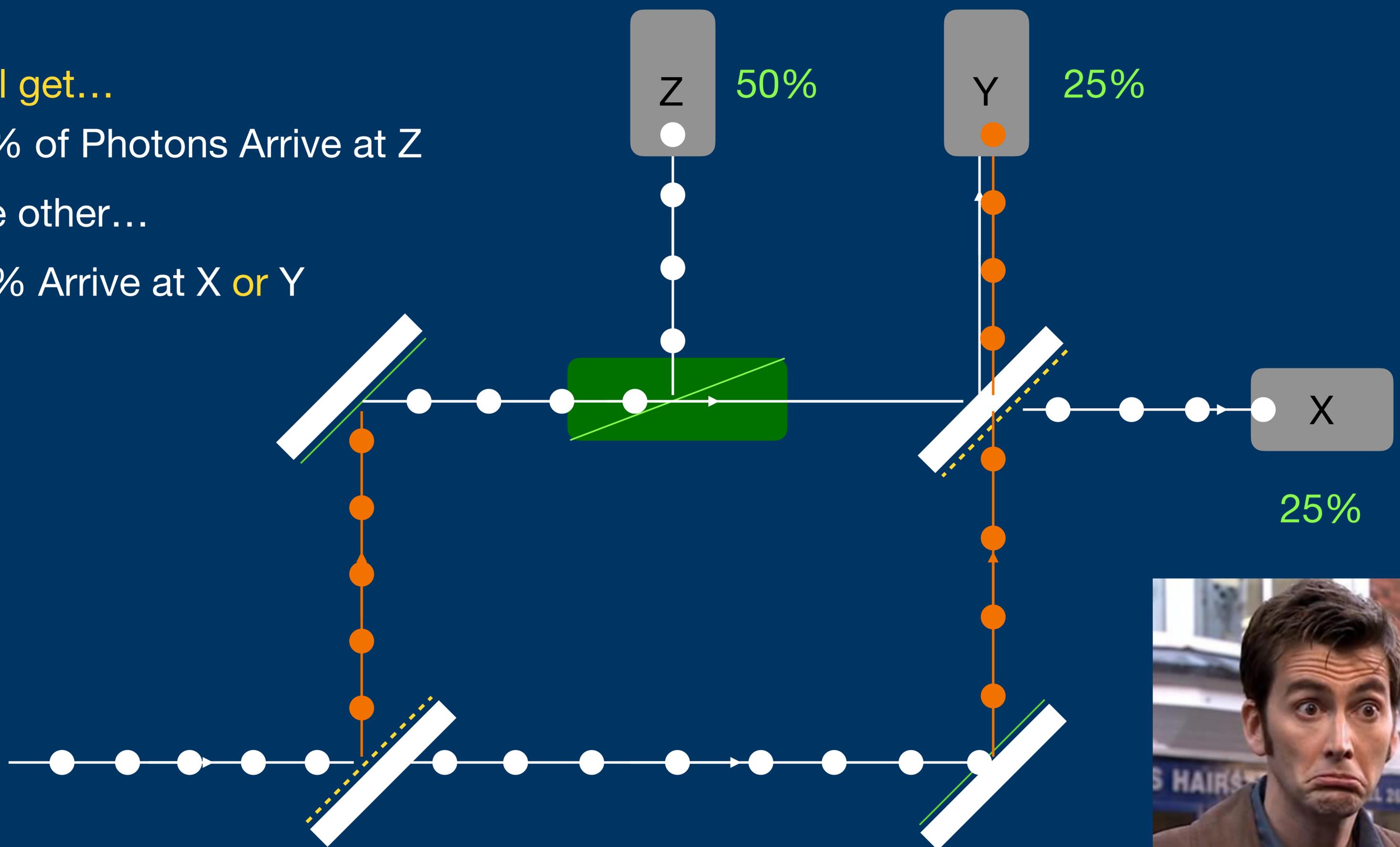


Still get...

50% of Photons Arrive at Z

The other...

25% Arrive at X or Y





Wheeler

The elementary quantum phenomenon is a great **smoky dragon**.

The **mouth** of the dragon is **sharp**, where it bites the **counter**.

The **tail** of the dragon is **sharp**, where the photon **starts**.

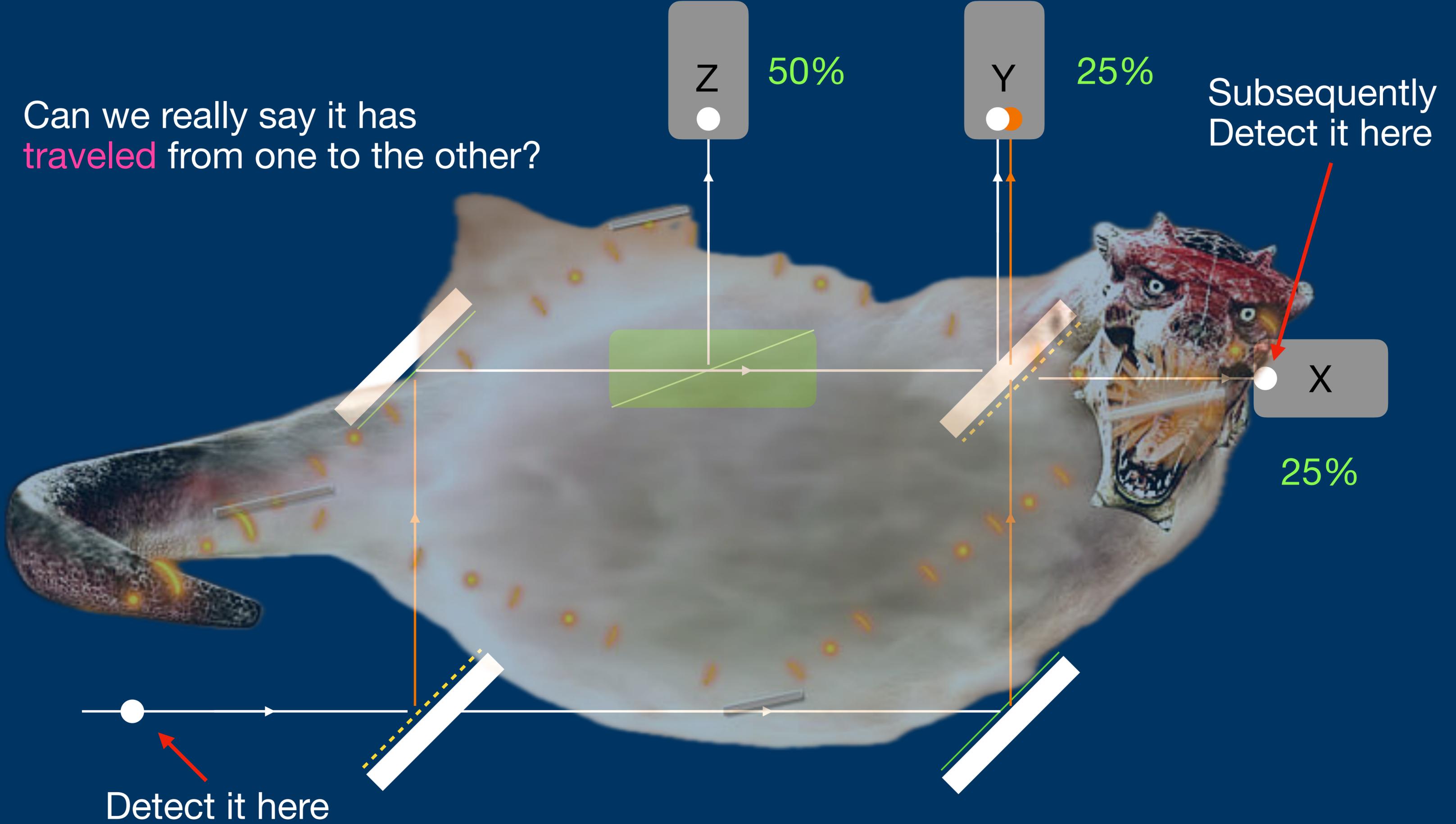
But about **what the dragon does or looks like in between** we have **no right to speak**, either in this or any delayed-choice experiment.

We get a counter reading but we **neither know nor have the right to say how it came**.

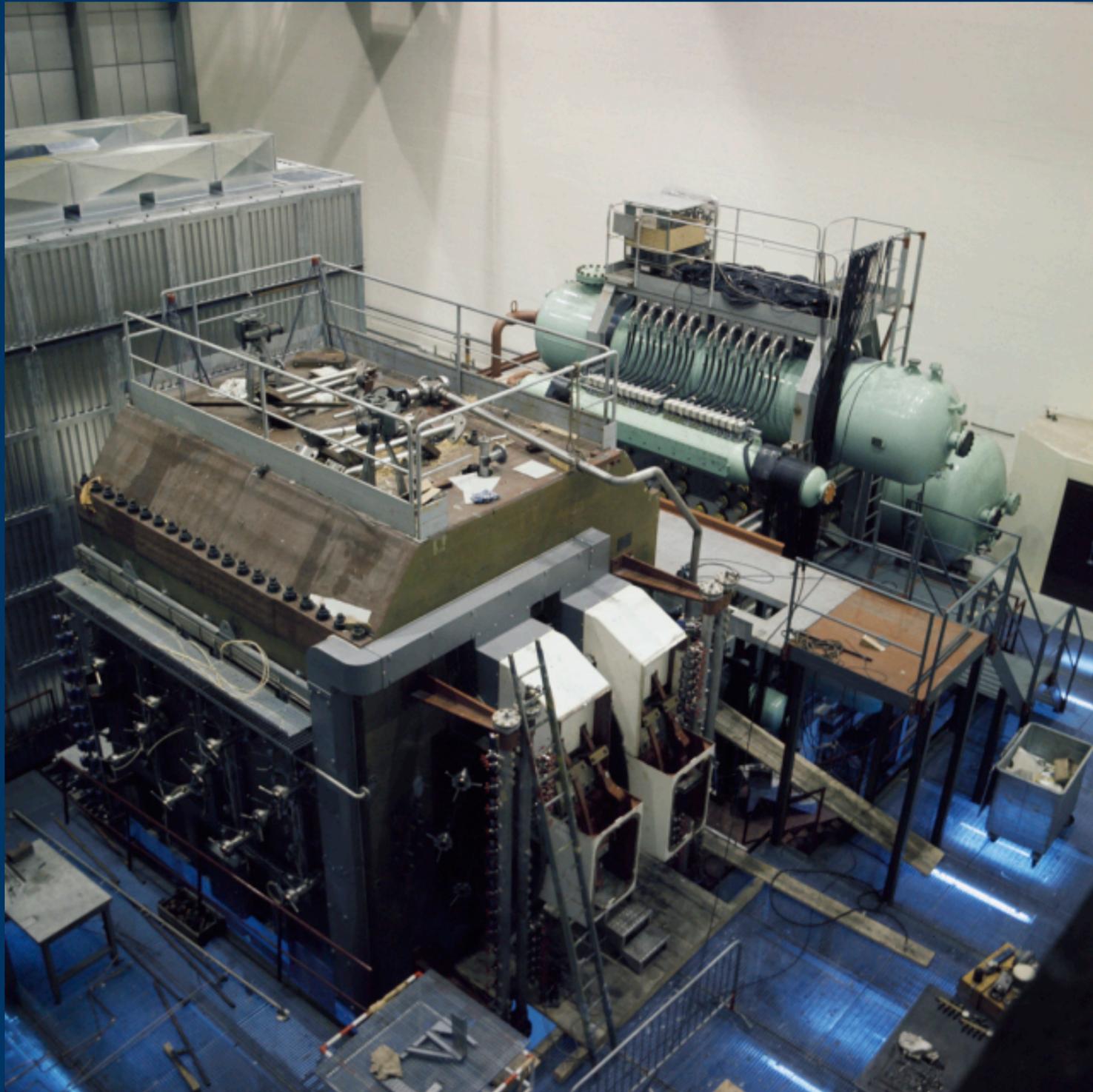
The elementary quantum phenomenon is the strangest thing in this strange world.^[1]

^[1] W A Miller & J A Wheeler, “Delayed-Choice Experiments and Bohr’s Elementary Quantum Phenomenon” S Kamefuchi et al., eds., Proceedings of the international symposium on foundations of quantum mechanics, Tokyo: Physical Society of Japan, 1984 140-52.

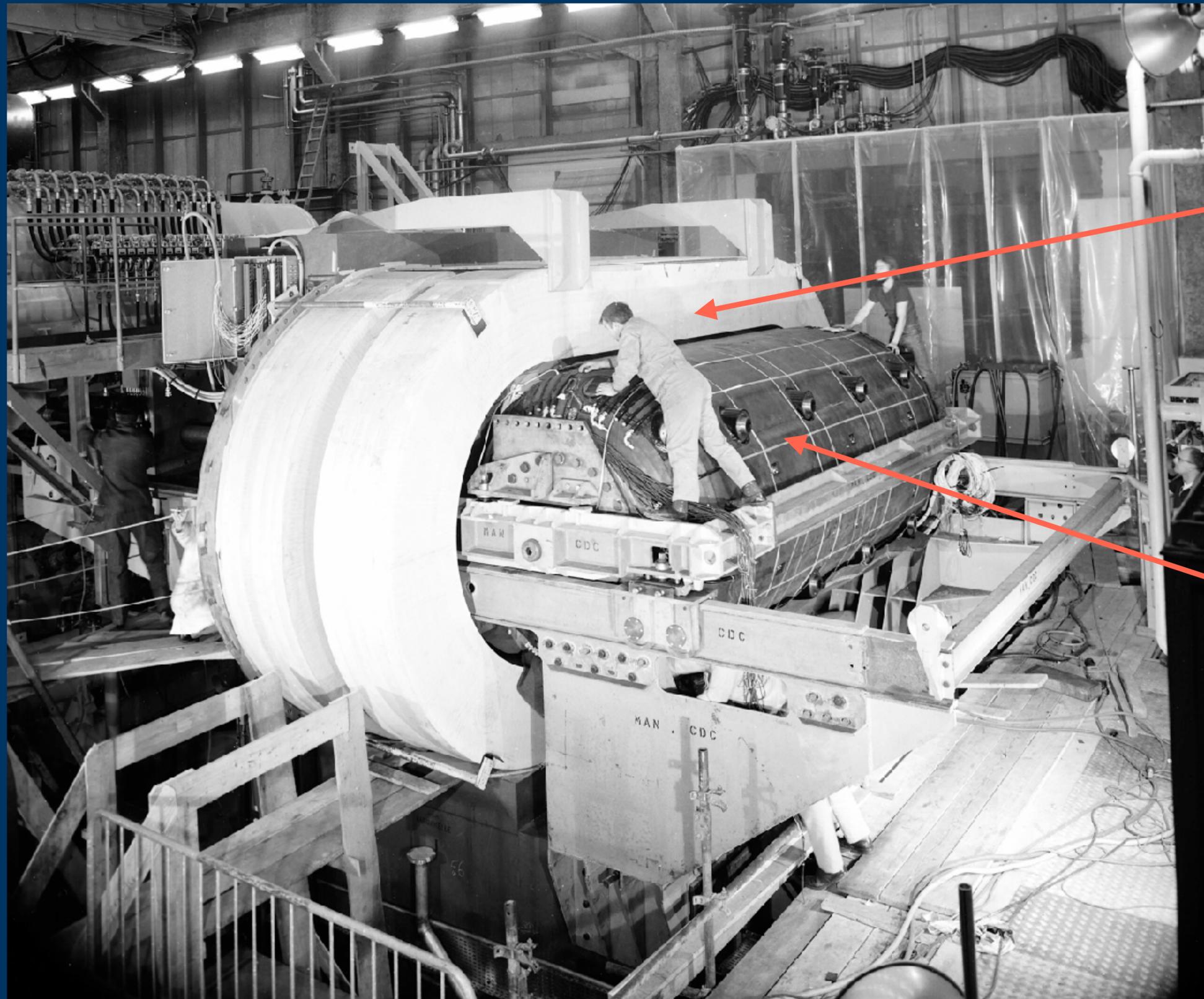
Can we really say it has traveled from one to the other?



No Paths in Quantum Theory



Don't we see tracks in experiments?



Electromagnet

Bubble chamber

Typical image...



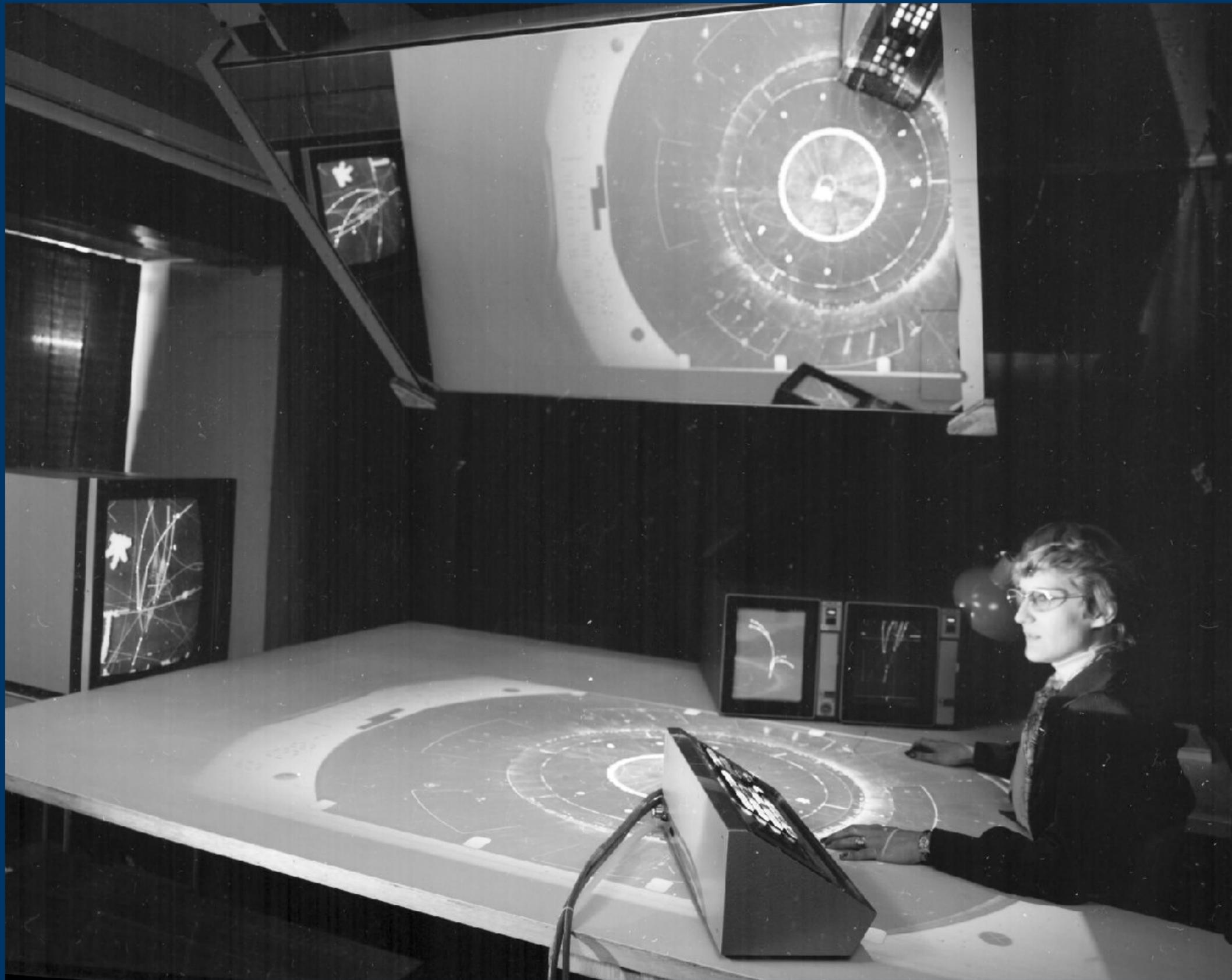
Low mass particle (electron) spiralling in field

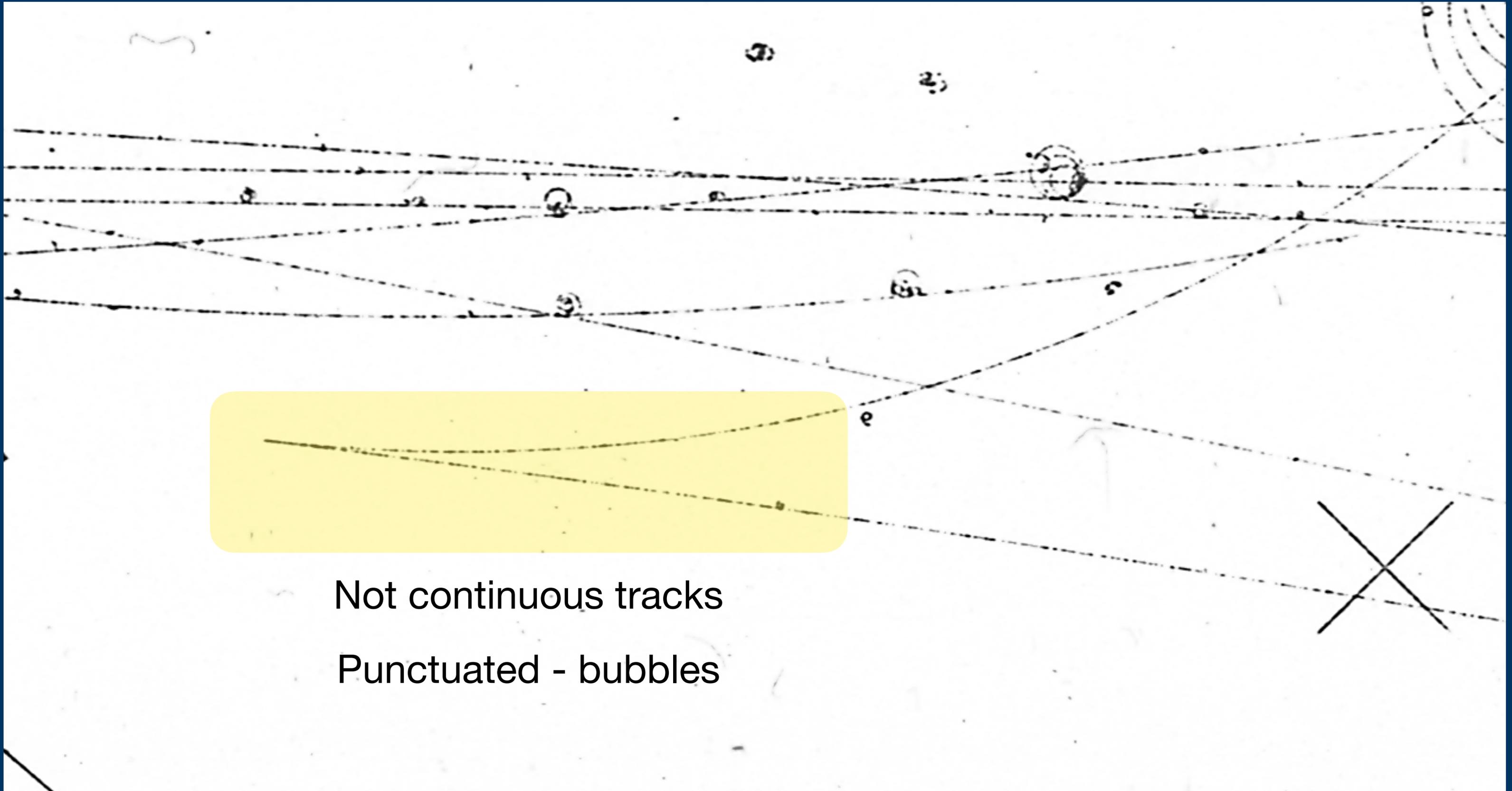


Neutral particle decaying into 2 charged particles

Tracks bend (magnetic field) in opposite sense

Another neutral decay





Not continuous tracks

Punctuated - bubbles

Heisenberg

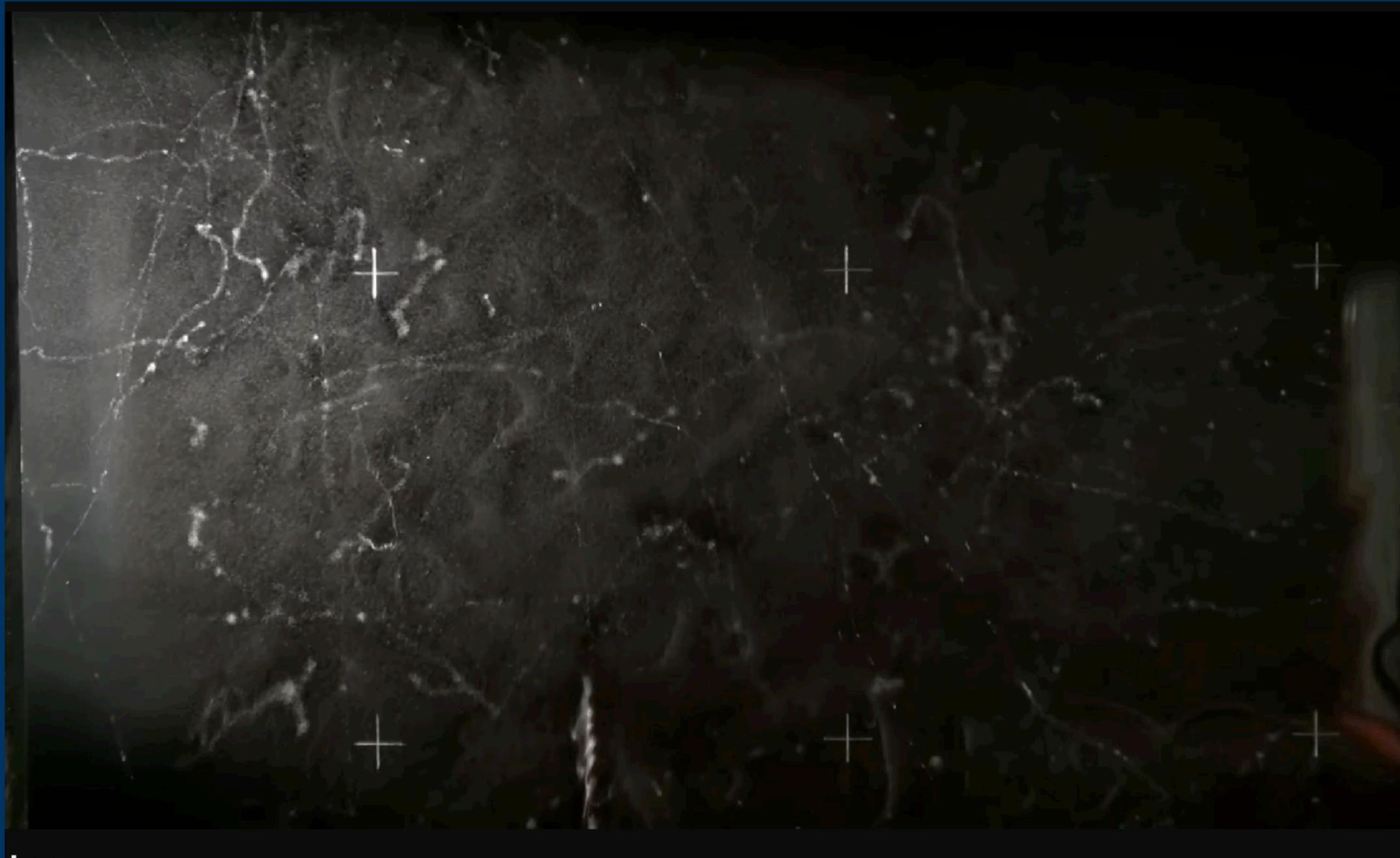


Wrong Heisenberg

I believe that one can formulate the emergence of the classical 'path' of a particle pregnantly as follows:

the 'path' comes into being only because we observe it

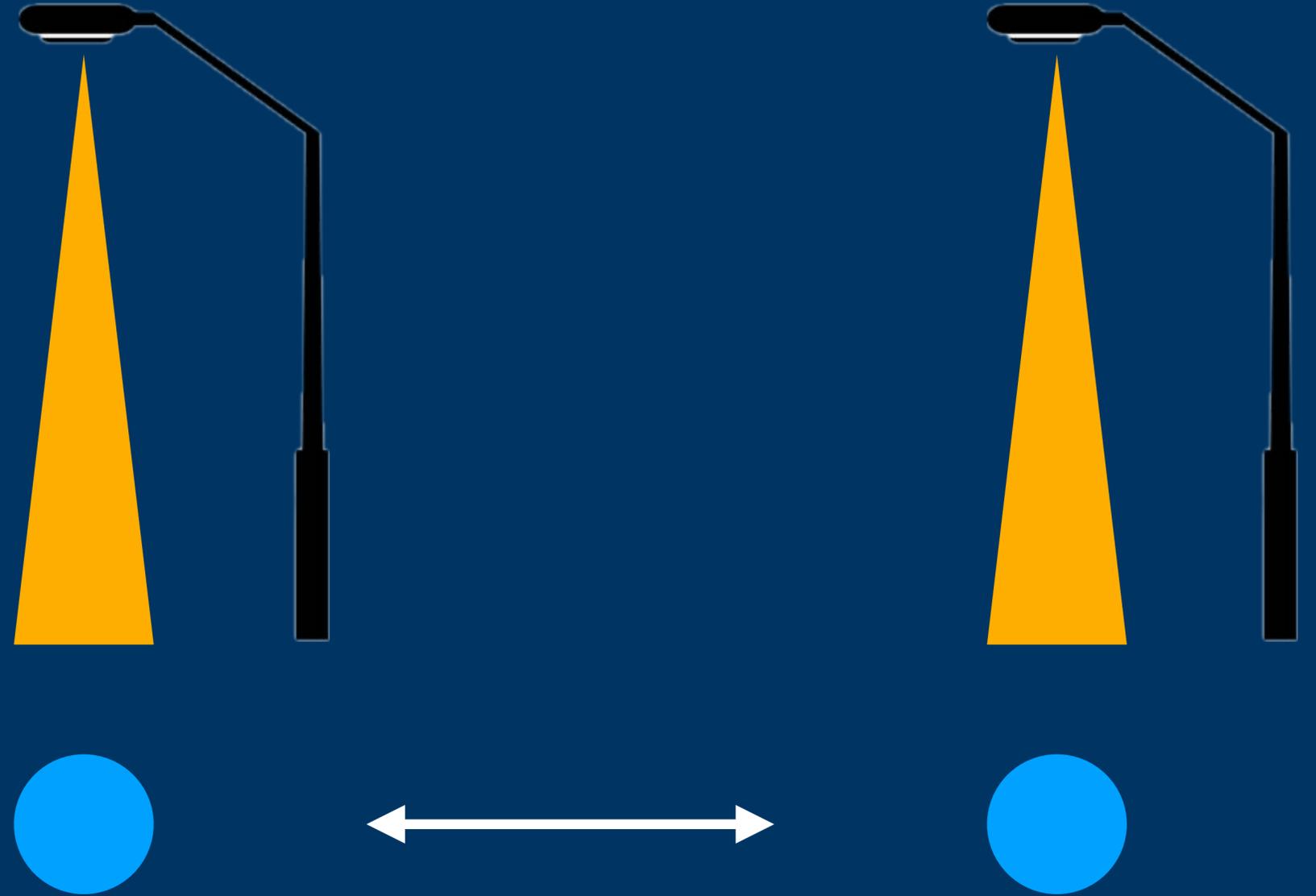




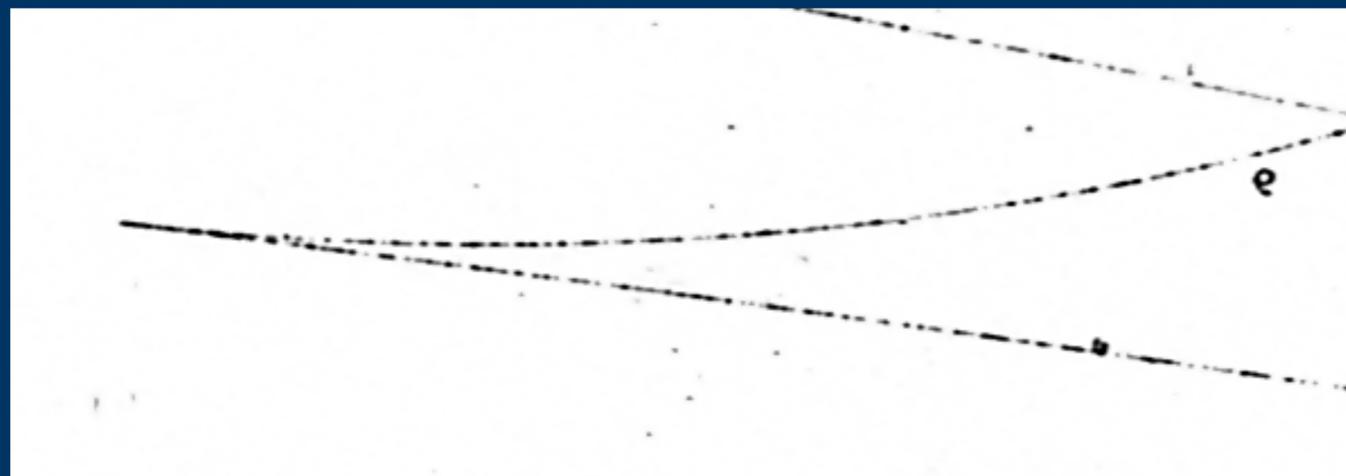
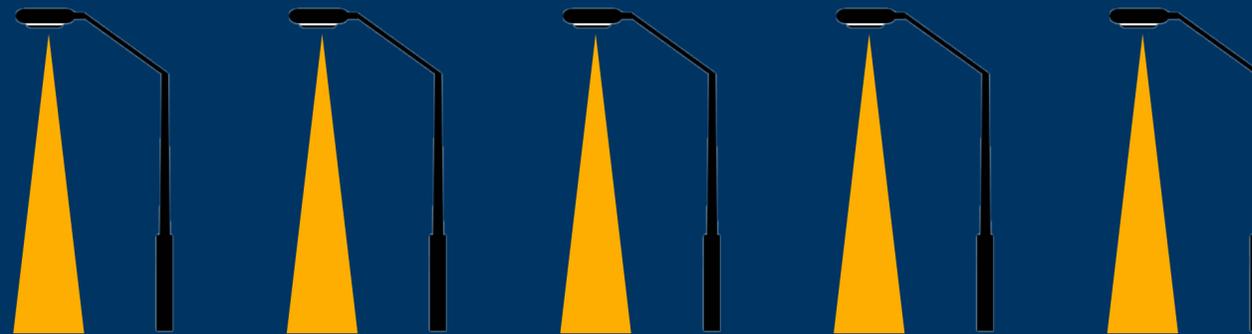
Cloud chamber tracks

May have seen at school...

Heisenberg lamps in Fælledparken...



What happens between?



Each bubble is a lamp in the park

We (incorrectly) infer an actual 'flown' path between

Lessons

In the Quantum World:

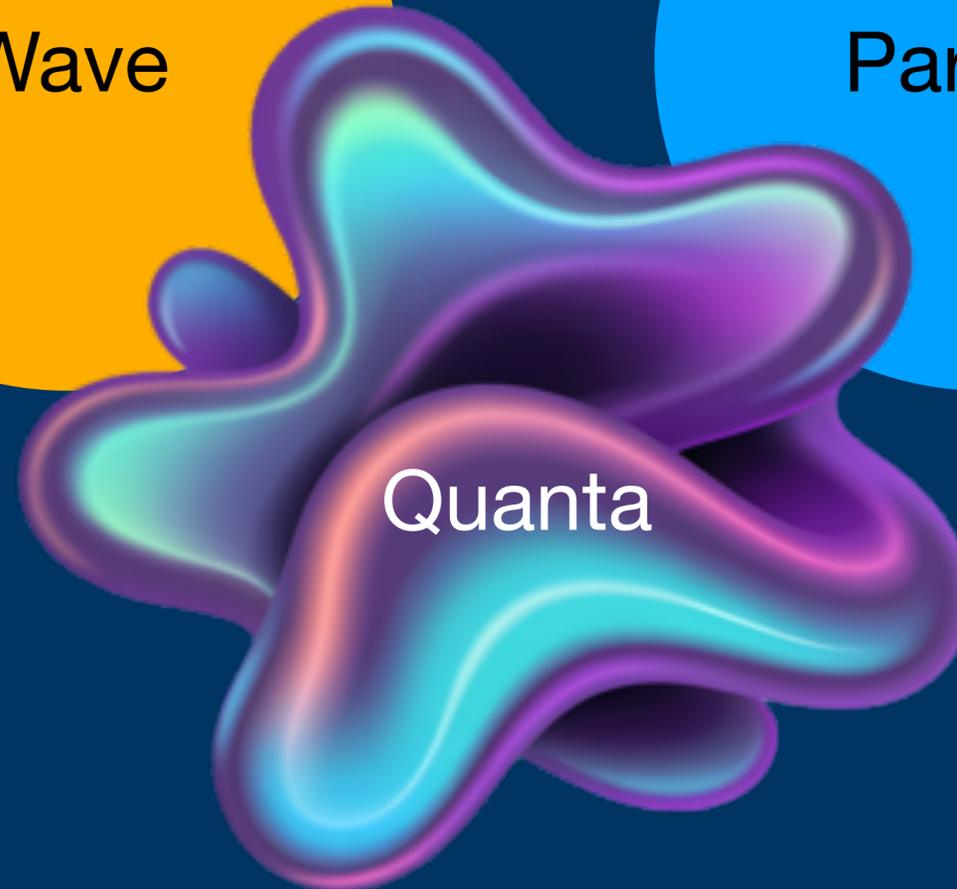
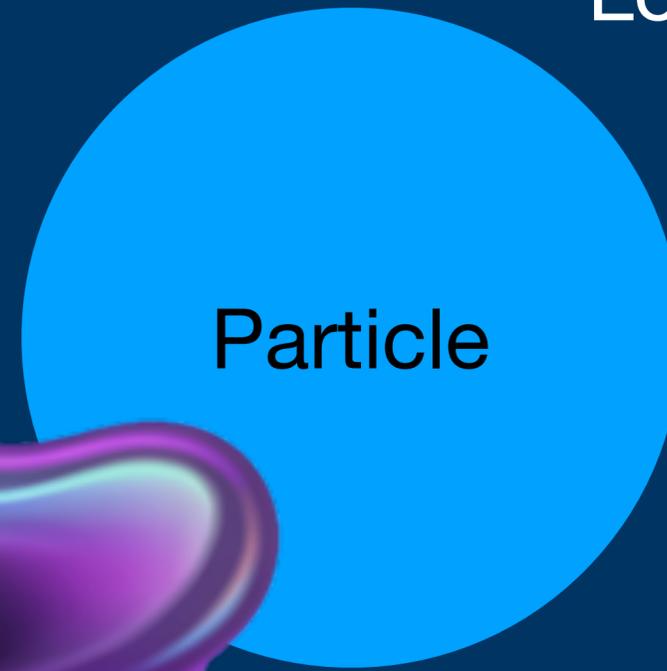
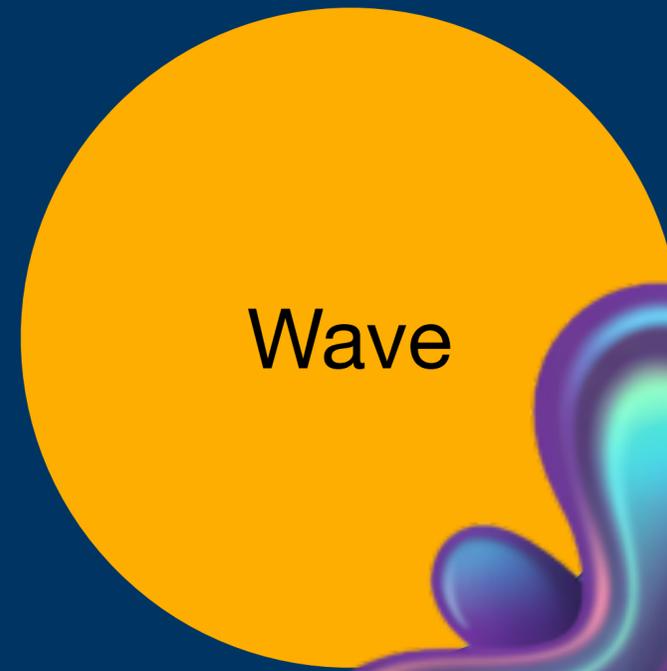
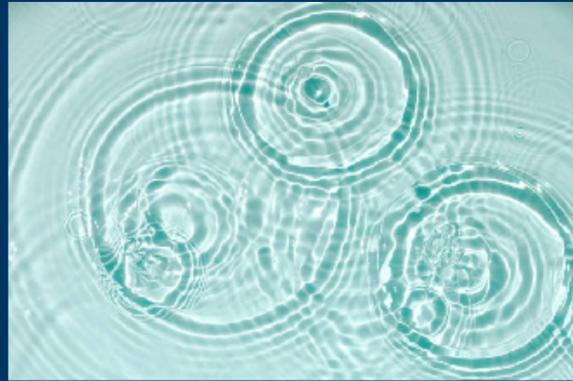
- **Context** is everything
- Experimental data
 - Is **where the smoky dragon touches unfolded reality**
- What can we say about the **dragon** itself?
 - The **enfolding** part...
 - That's the issue of **interpretation**...
 - Its the **wave function**



"Look, I'm a big-picture guy. I say 'Let there be light,' you guys figure out if it's a wave or a particle."

Wave-particle duality

Spread out and flappy



Localised and rigid



Just a hint...



Structure-process