How can we “see” the elusive neutrinos in a mine 1000 m below ground?

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Doctoral student, Lund University

Why does matter exist?
Swedish Big Science Forum 2024

ESS neutrino Super Beam plus

Refresher: What are we trying to do?

1. “See” neutrinos passing through the Zinkgruvan mine
2. Count and study them

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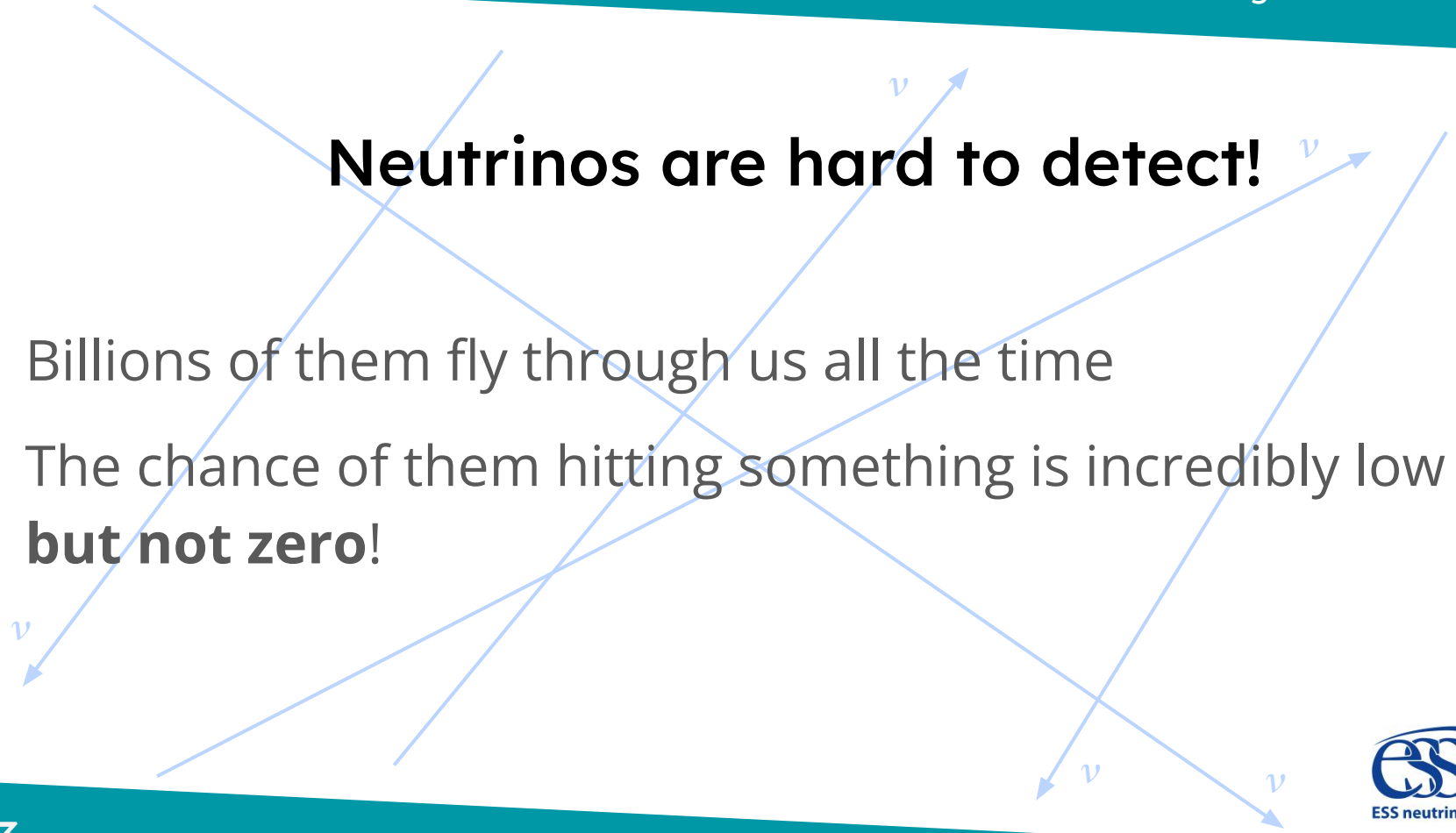
Neutrinos are hard to detect!



Billions of them fly through us all the time

The chance of them hitting something is incredibly low - **but not zero**!

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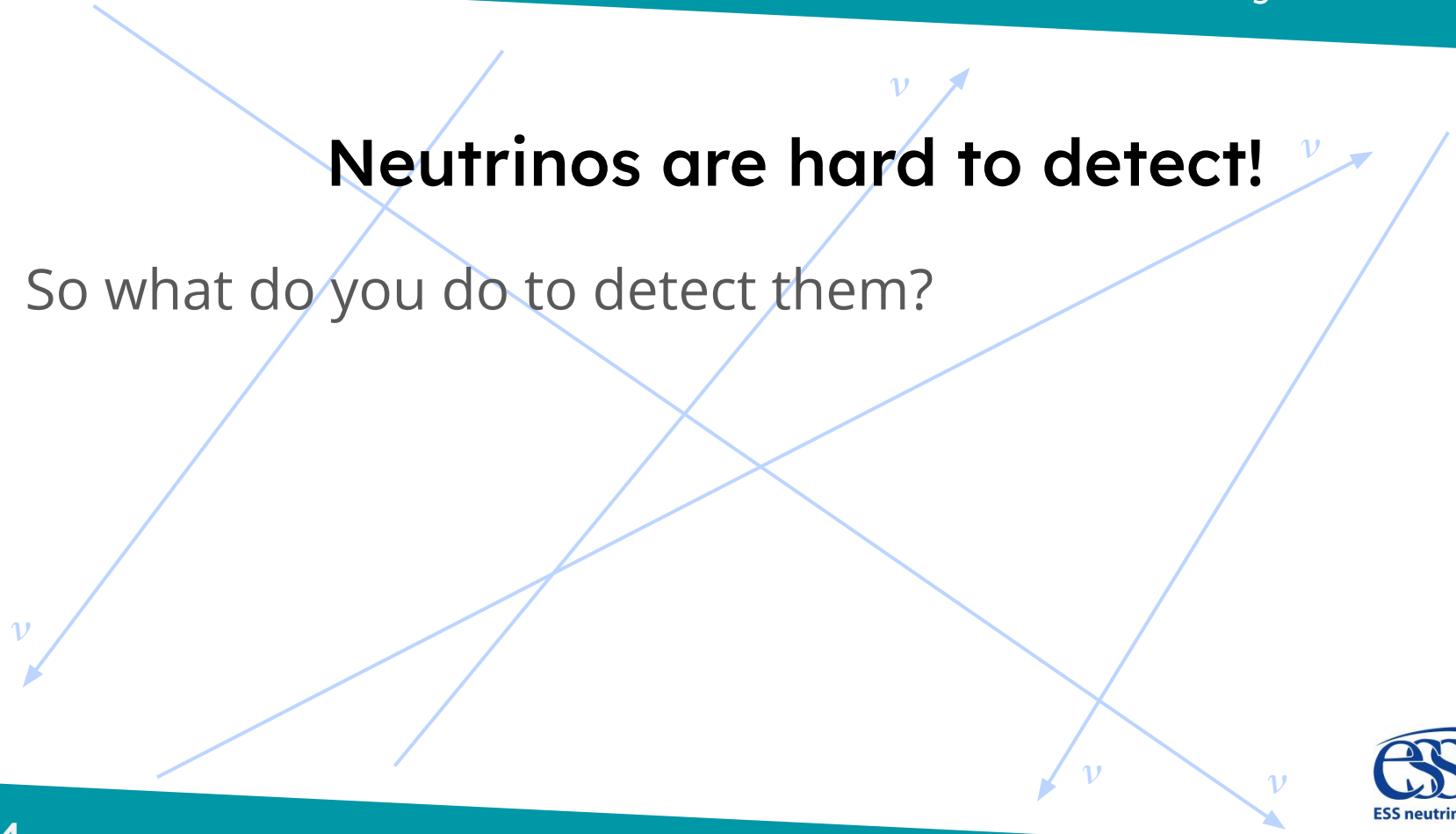
Neutrinos are hard to detect!

So what do you do to detect them?



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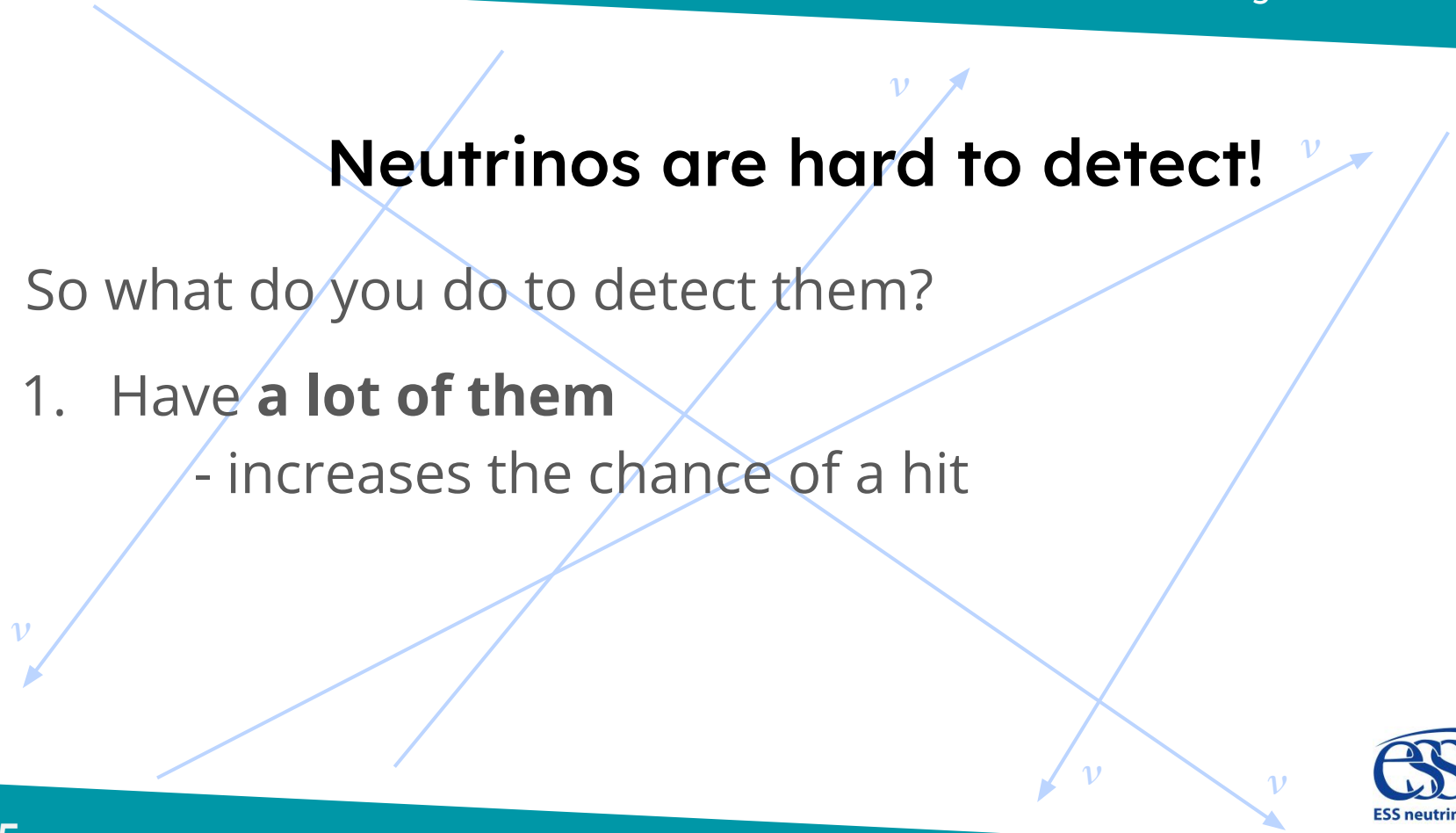

So what do you do to detect them?

1. Have **a lot of them**
   - increases the chance of a hit

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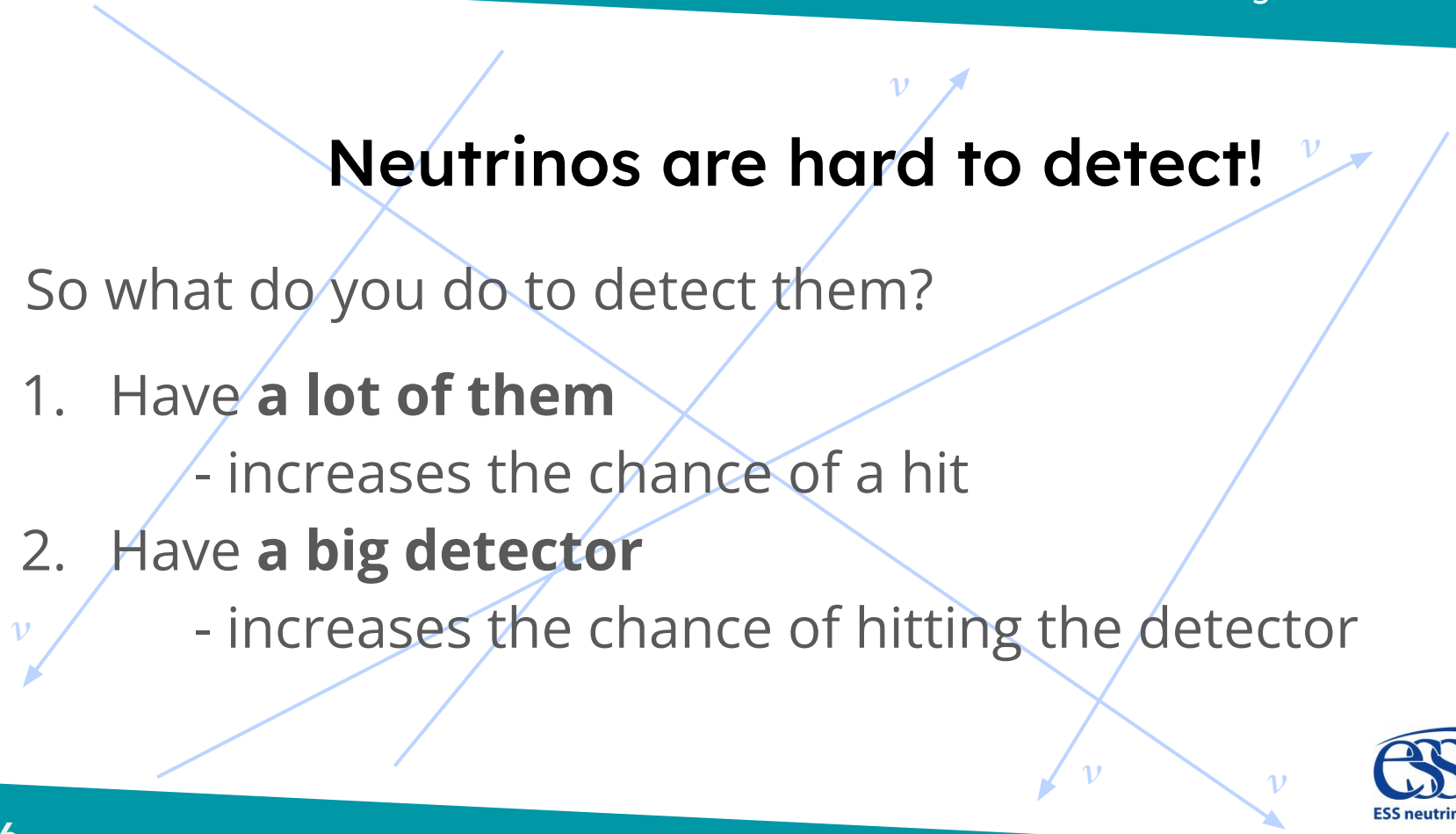
Neutrinos are hard to detect!

So what do you do to detect them?

1. Have **a lot of them**
   - increases the chance of a hit
2. Have **a big detector**
   - increases the chance of hitting the detector



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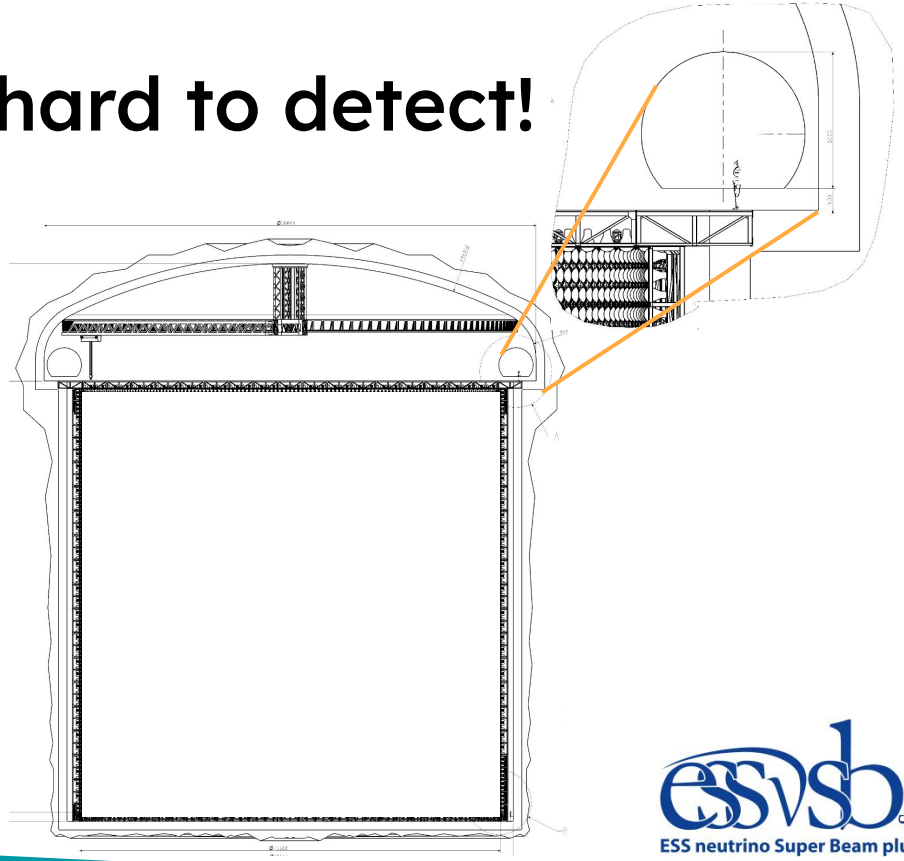
Neutrinos are hard to detect!

First requirement for our detector

1. It needs to be **large**



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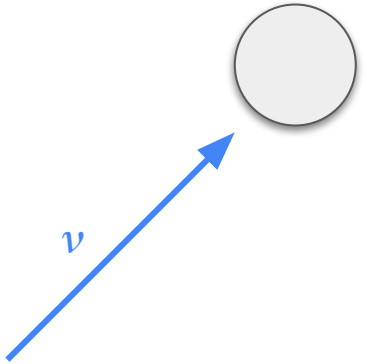
What happens when a neutrino “finally” hits an atom?



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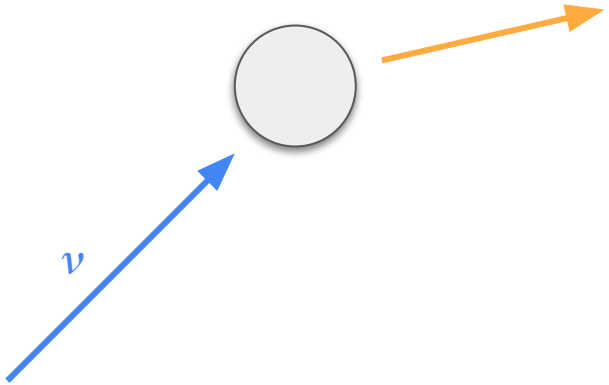
What happens when a neutrino “finally” hits an atom?

A new particle is produced!

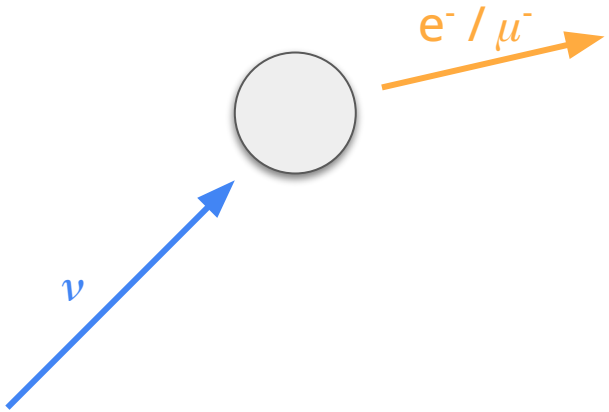


What happens when a neutrino “finally” hits an atom?

A new particle is produced!

Typically **an electron** or it’s heavier cousin **the muon**

It has **electric charge**!



How do we see this tiny new particle in our detector?

Good news: **It's fast**

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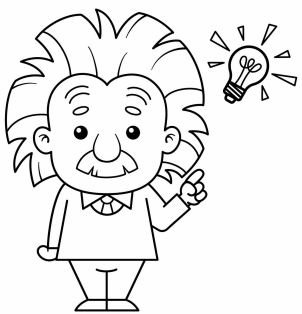
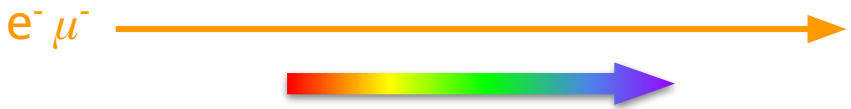


Good news: **It's fast**

Einstein: Nothing can be faster than light (**in vacuum**)



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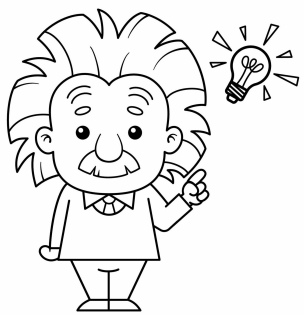

Good news: **It's fast**

Einstein: Nothing can be faster than light (**in vacuum**)

- In a material, some particles can go faster than light

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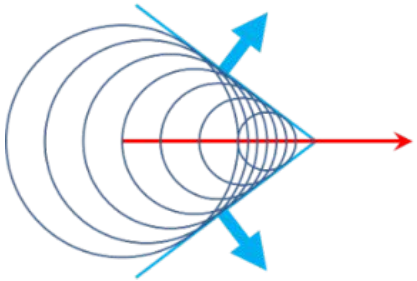
Charged particles faster than light emit light!

Cherenkov Light: Shaped like **a cone** behind the particle



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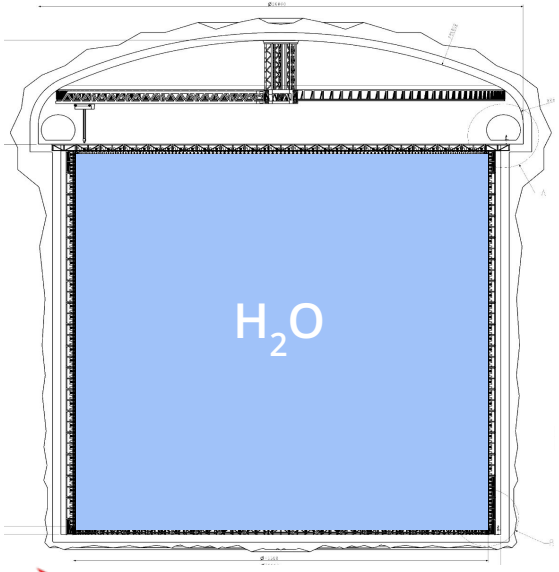
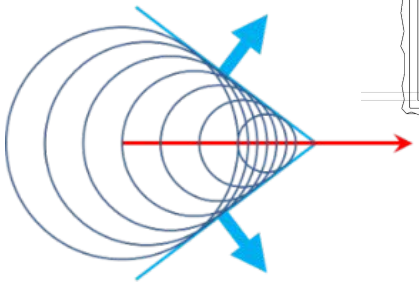
Charged particles faster than light emit light!

Cherenkov Light: Shaped like **a cone** behind the particle

Another requirement for our detector:

2. It has to be **transparent**!





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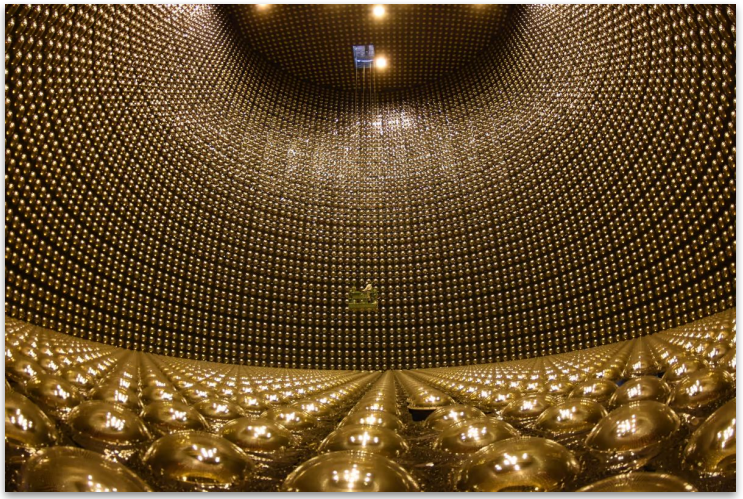
So how do we collect the light?

Light sensors cover the walls of the detector

Photomultiplier Tubes: Digital cameras that can enhance very small signals



Superkamiokande, Japan

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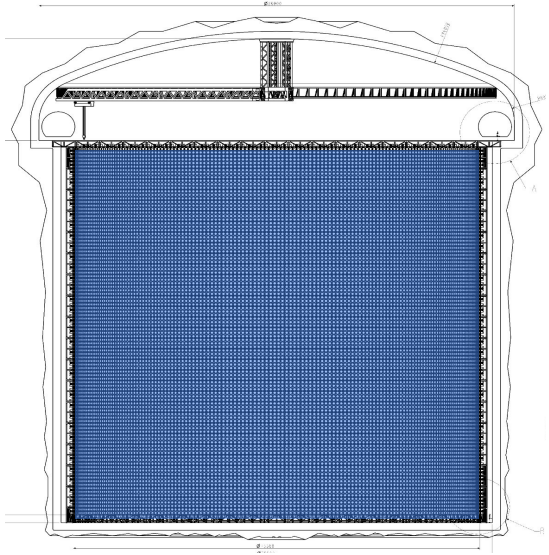
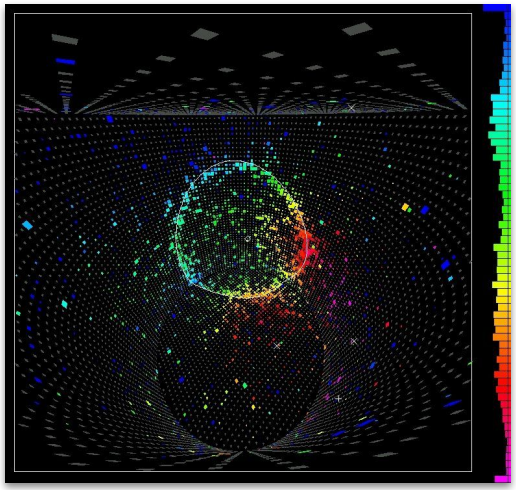
Now we know what our detector should look like



Signal

Superkamiokande, Japan



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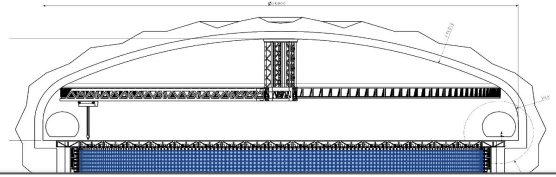

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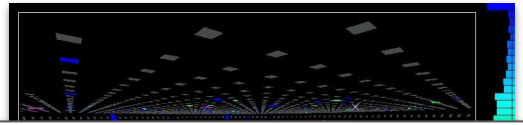
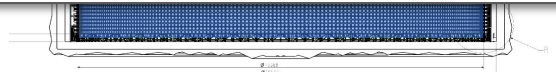
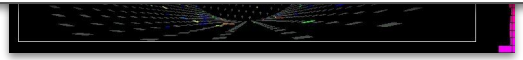


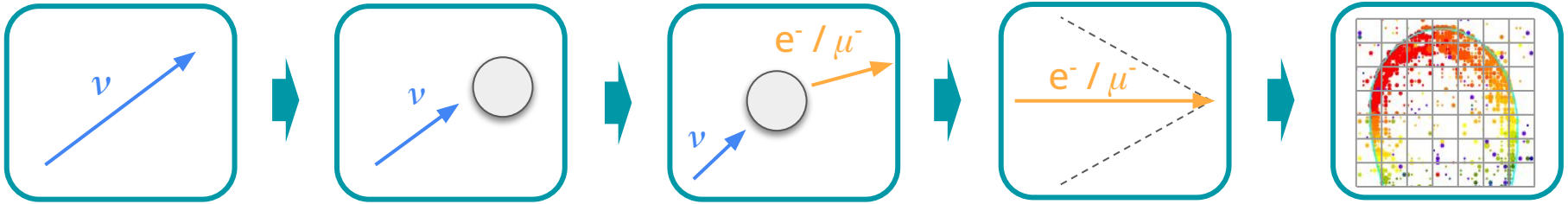
But how do we know anything **about the neutrinos** from this ring-shaped light?





Reconstruction: Going backwards

Physics



Neutrino | Atom hit | Charged particle | Cherenkov light | Detector signal

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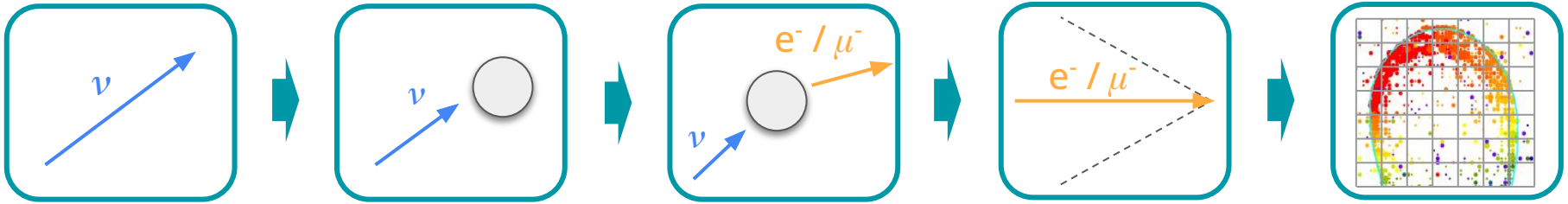

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Reconstruction

Simulations

Our knowledge of what happens in the detector is good!

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2.
3.

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1. Make a **computer model** of the detector
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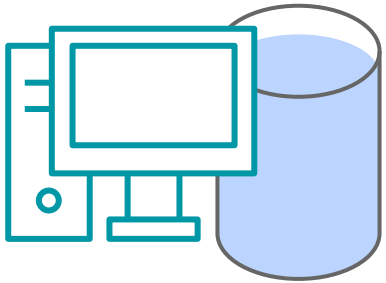
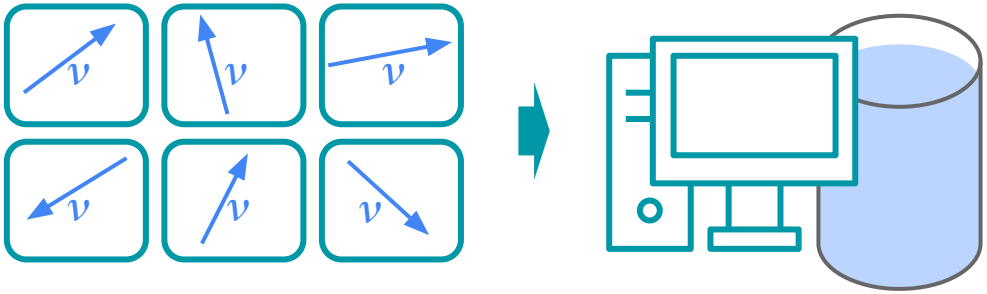


Simulations

Our knowledge of what happens in the detector is good!

1. Make a **computer model** of the detector
2. Simulate **a lot of neutrinos** with different properties
3.



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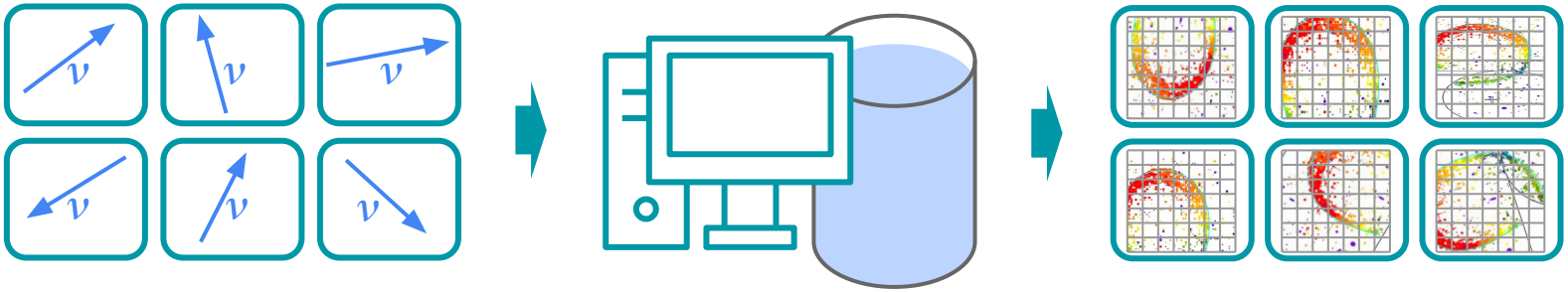
Simulations

Our knowledge of what happens in the detector is good!

1. Make a **computer model** of the detector
2. Simulate **a lot of neutrinos** with different properties
3. **Compare** real measurements with the simulations



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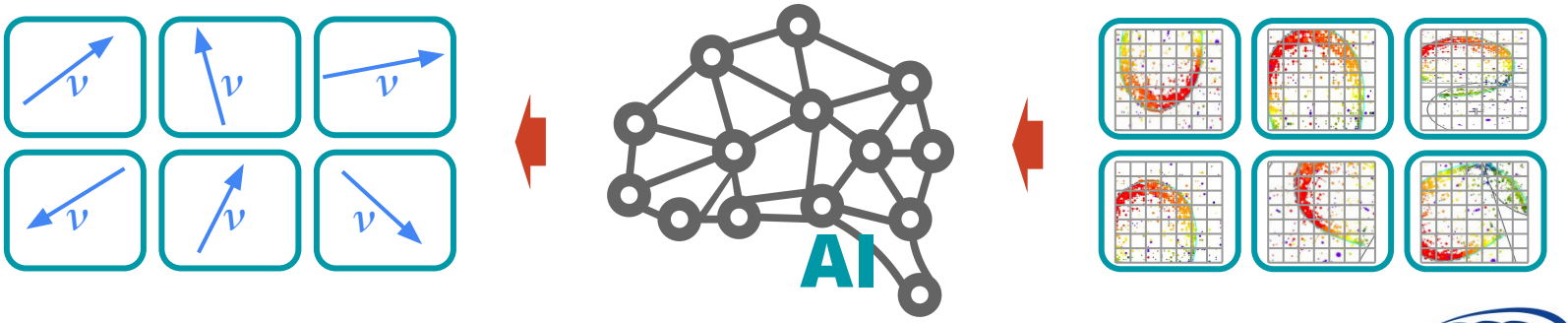
Can we do this using AI?

We can use AI to compare real measurements to simulations

Other methods exist, but AI is **very fast**



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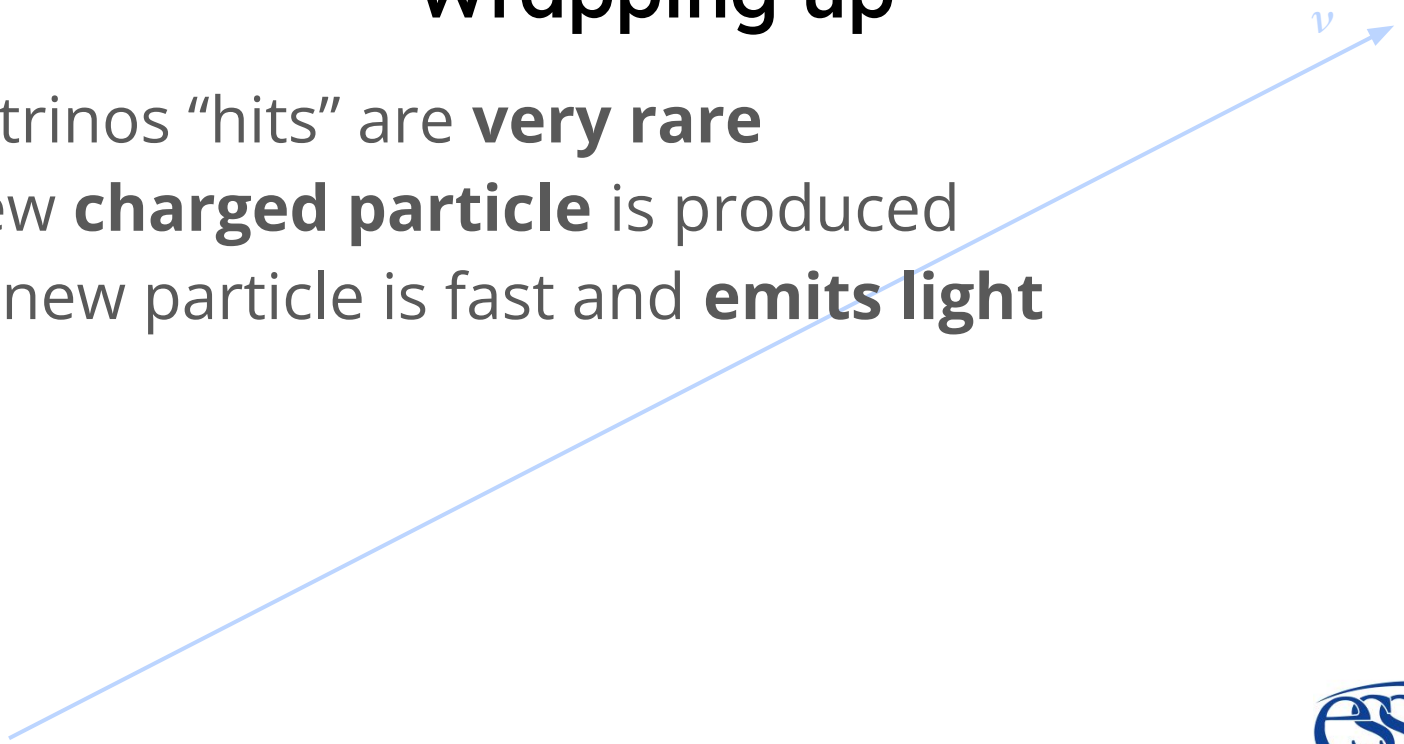
Wrapping up

- Neutrinos “hits” are **very rare**
- A new **charged particle** is produced
- The new particle is fast and **emits light**



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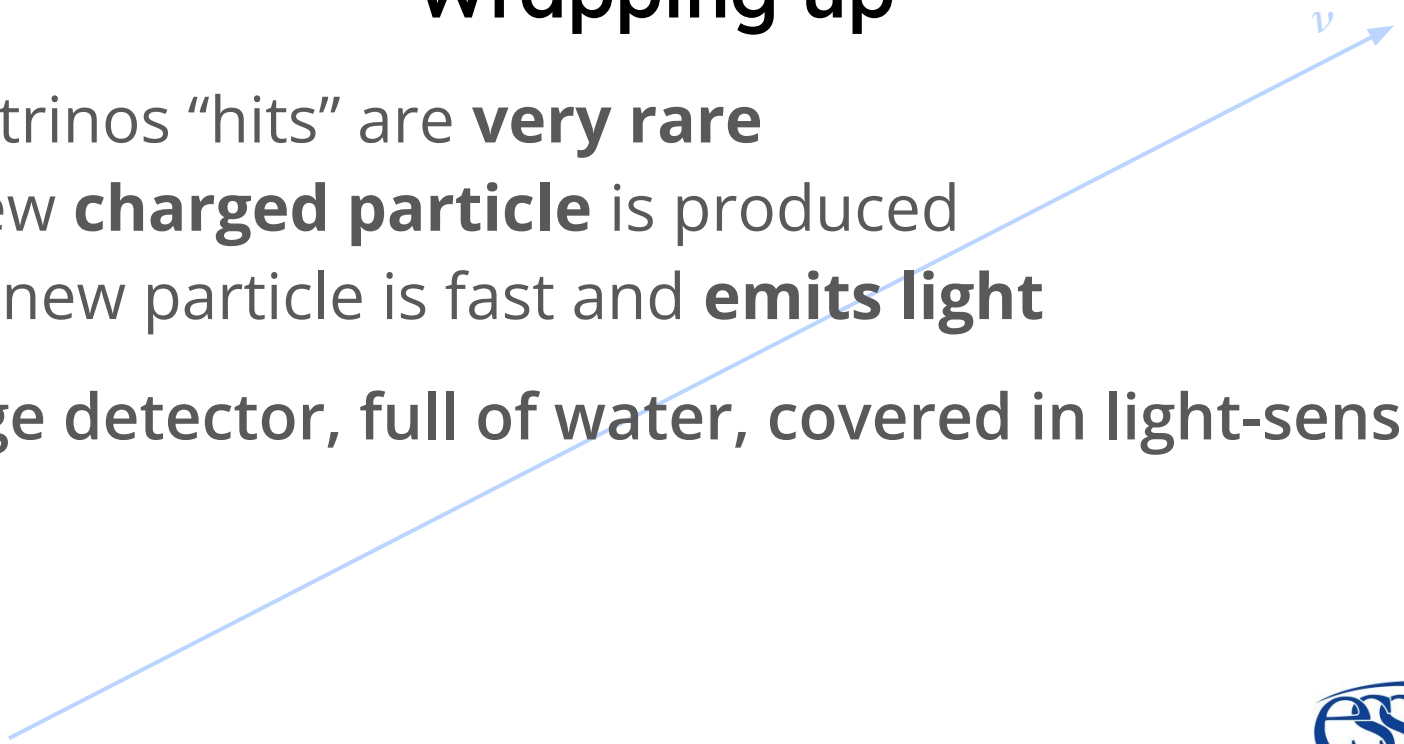

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Large detector, full of water, covered in light-sensors

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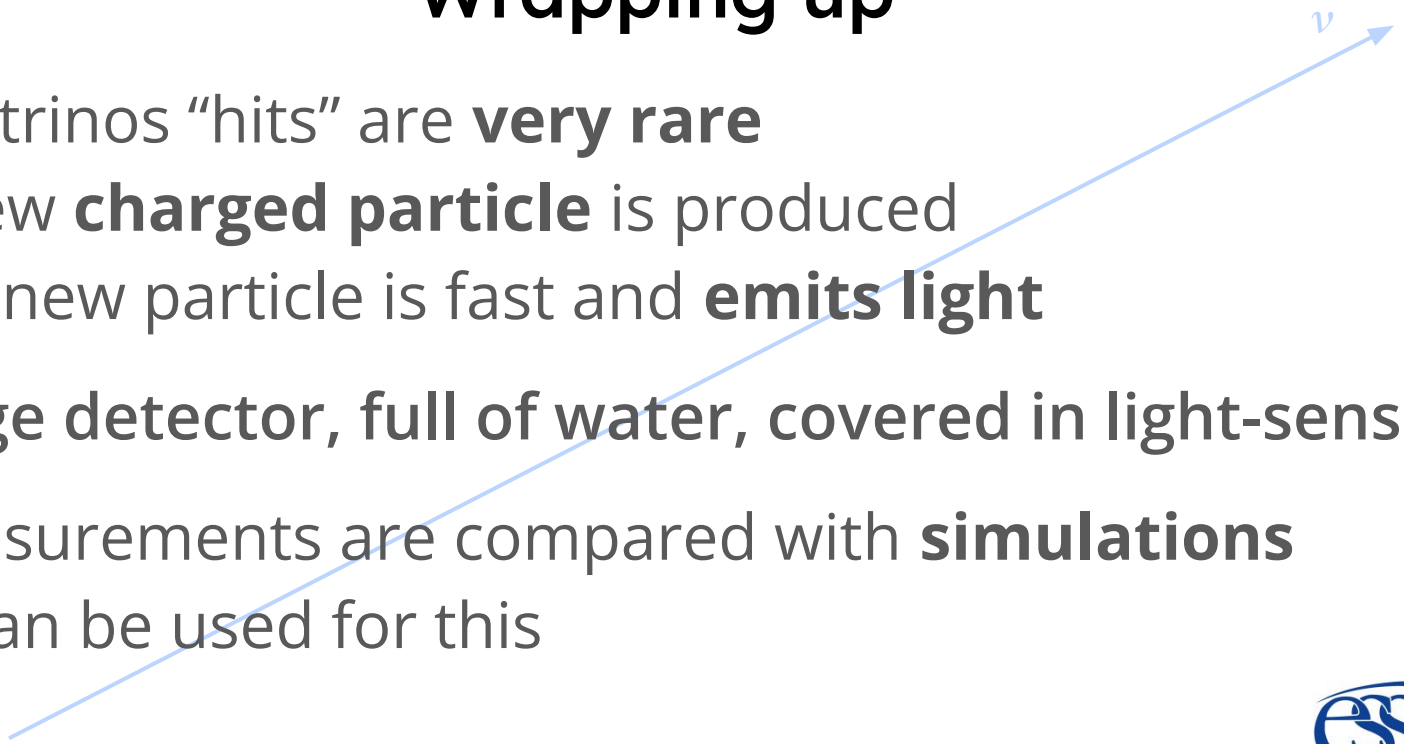

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Large detector, full of water, covered in light-sensors

- Measurements are compared with **simulations**
- **AI** can be used for this

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