Introduction to Particle Detection

Liverpool@CERN Particle Physics School

Dr. Vinícius Franco Lima - CERN

About Me

- Vinícius Franco Lima
- I did my Bsc and M.Sc. in Physics at UFRJ (Rio de Janeiro).
- Ph.D. at Liverpool working in R&D for LHCb.
- Research Associate @Liverpool for 2 years building the VELO Upgrade detector for LHCb.
- Currently I am a CERN Fellow working in the ATLAS Pixel detector.
- When not physics-ing: Music, Climbing, Hiking.

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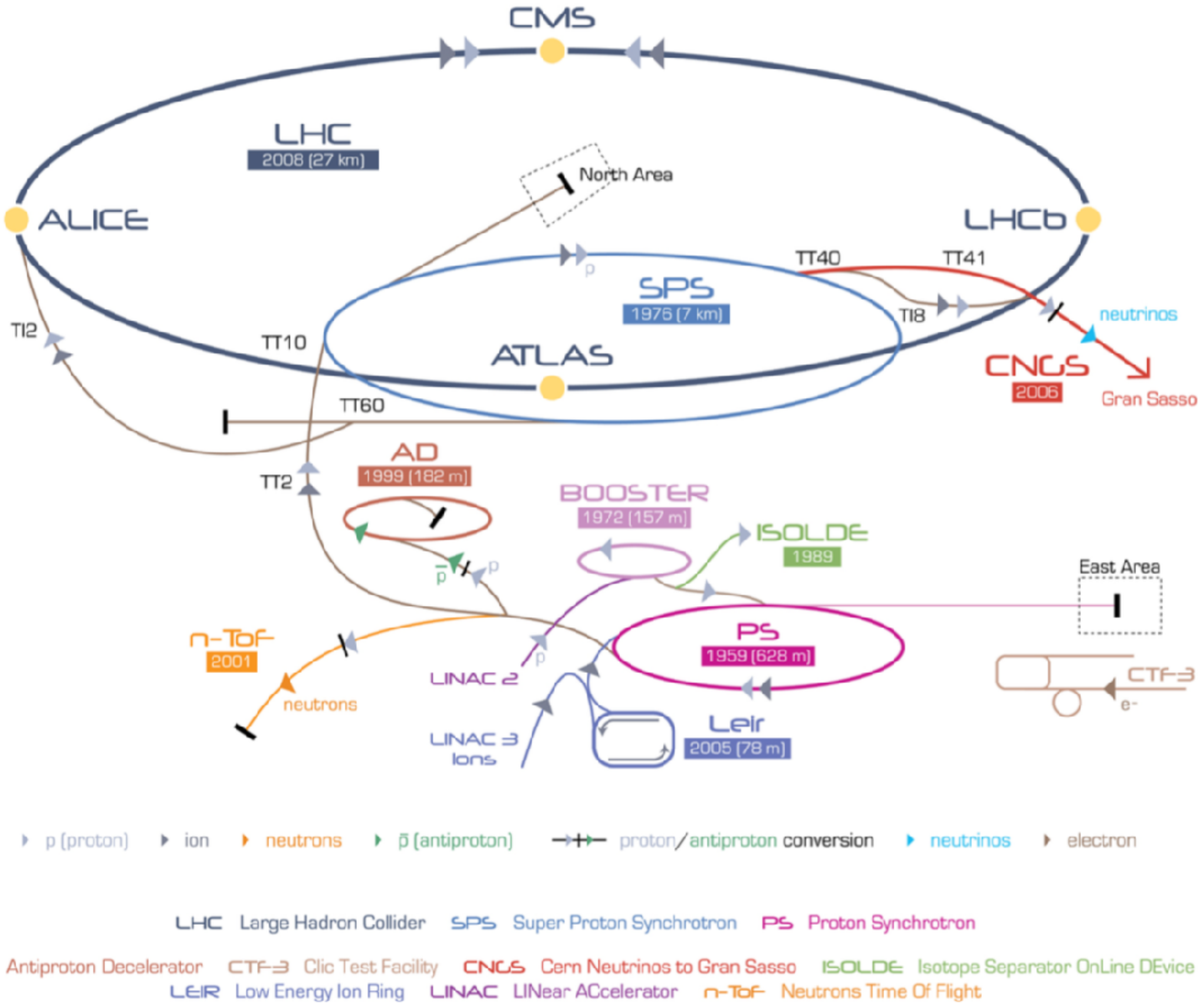

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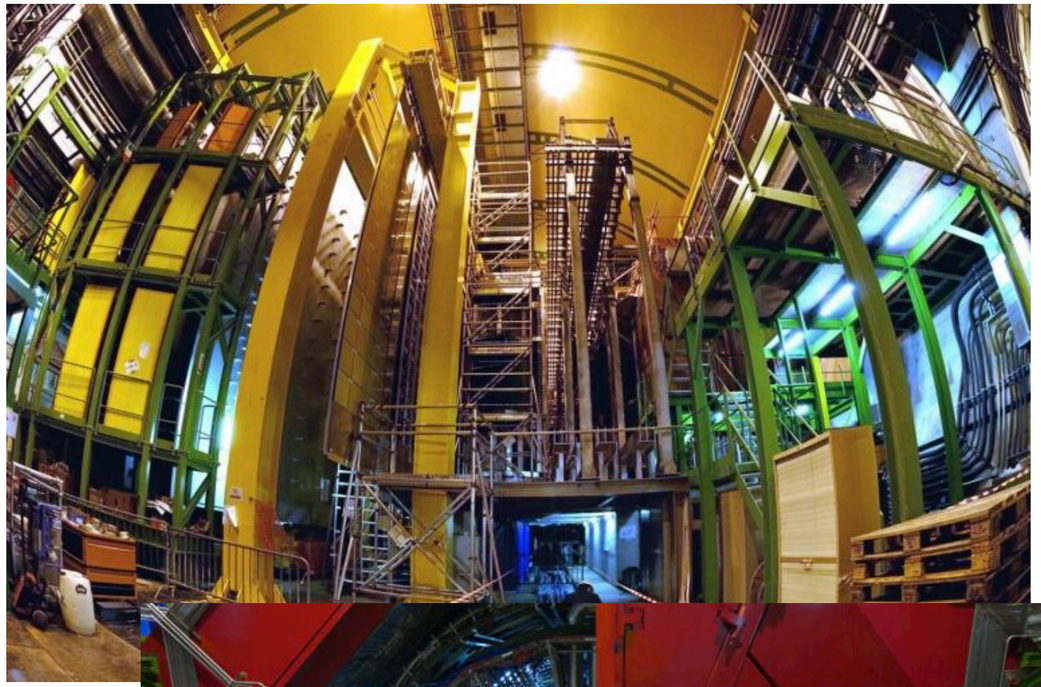
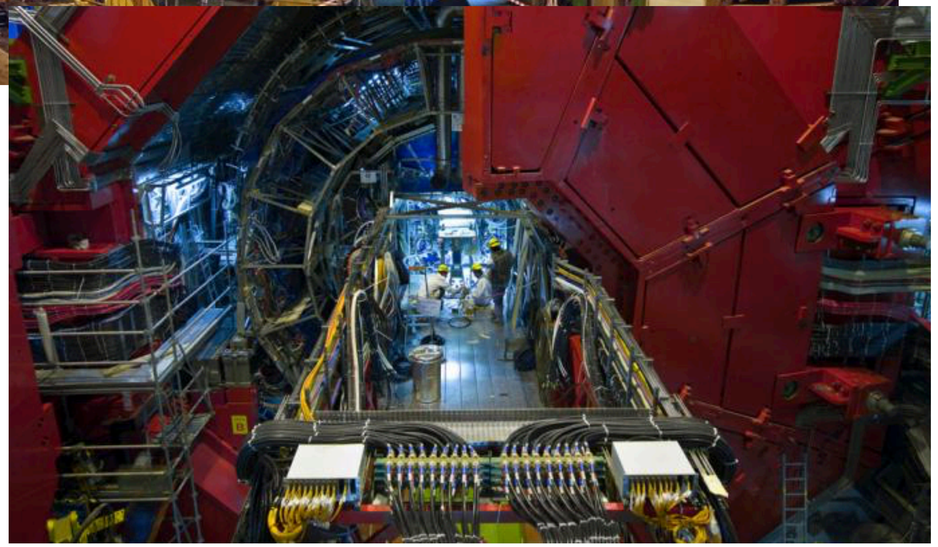
Hunters

Farmers





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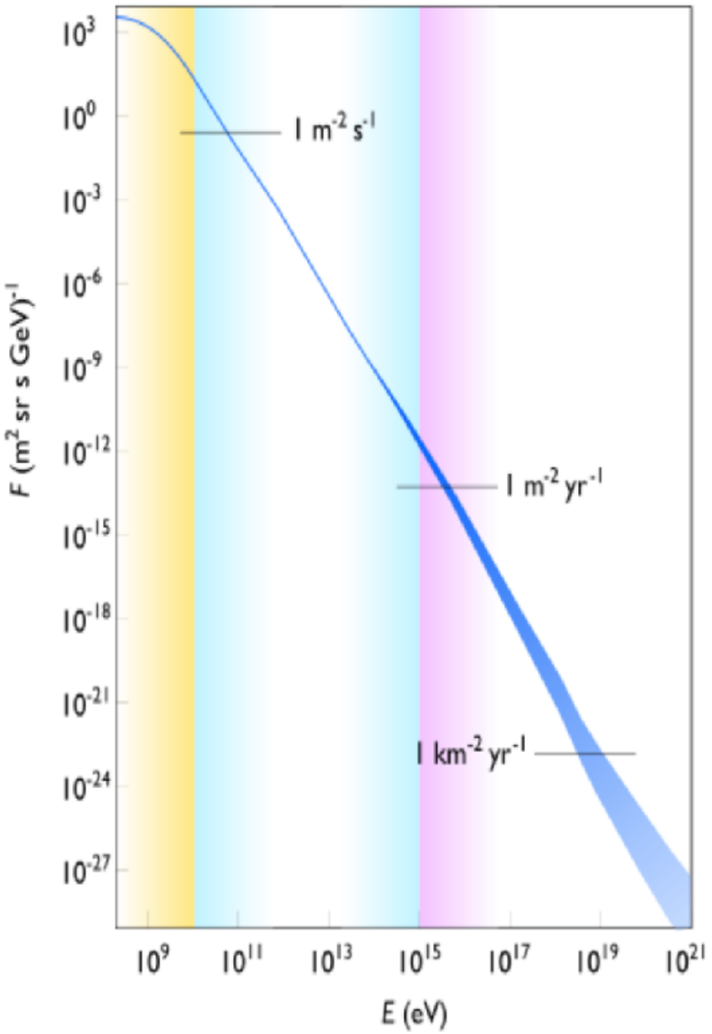

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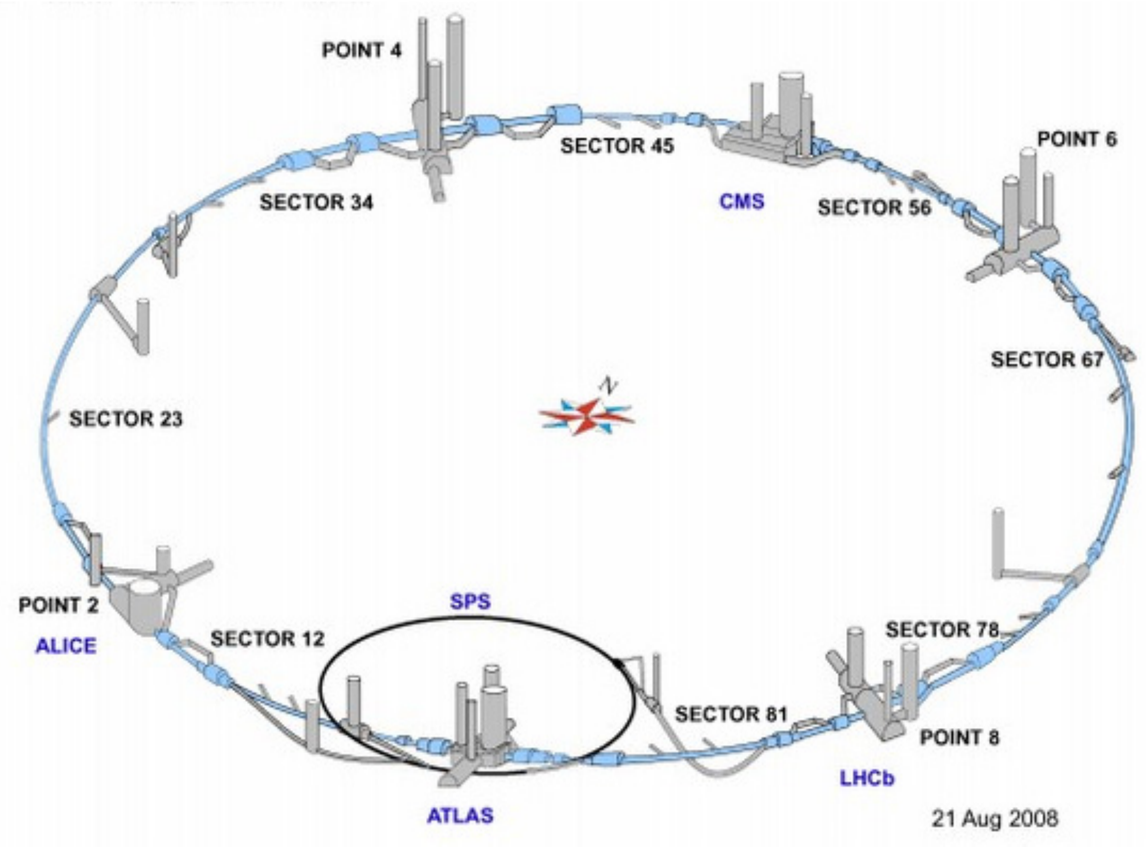

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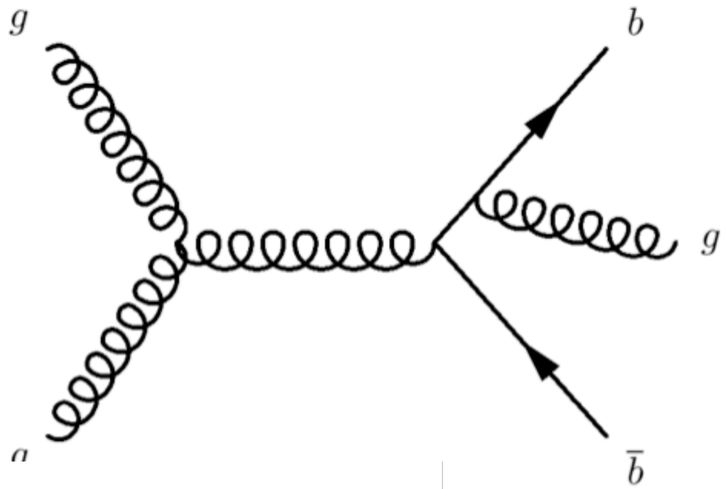
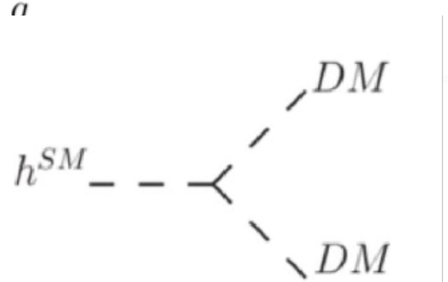
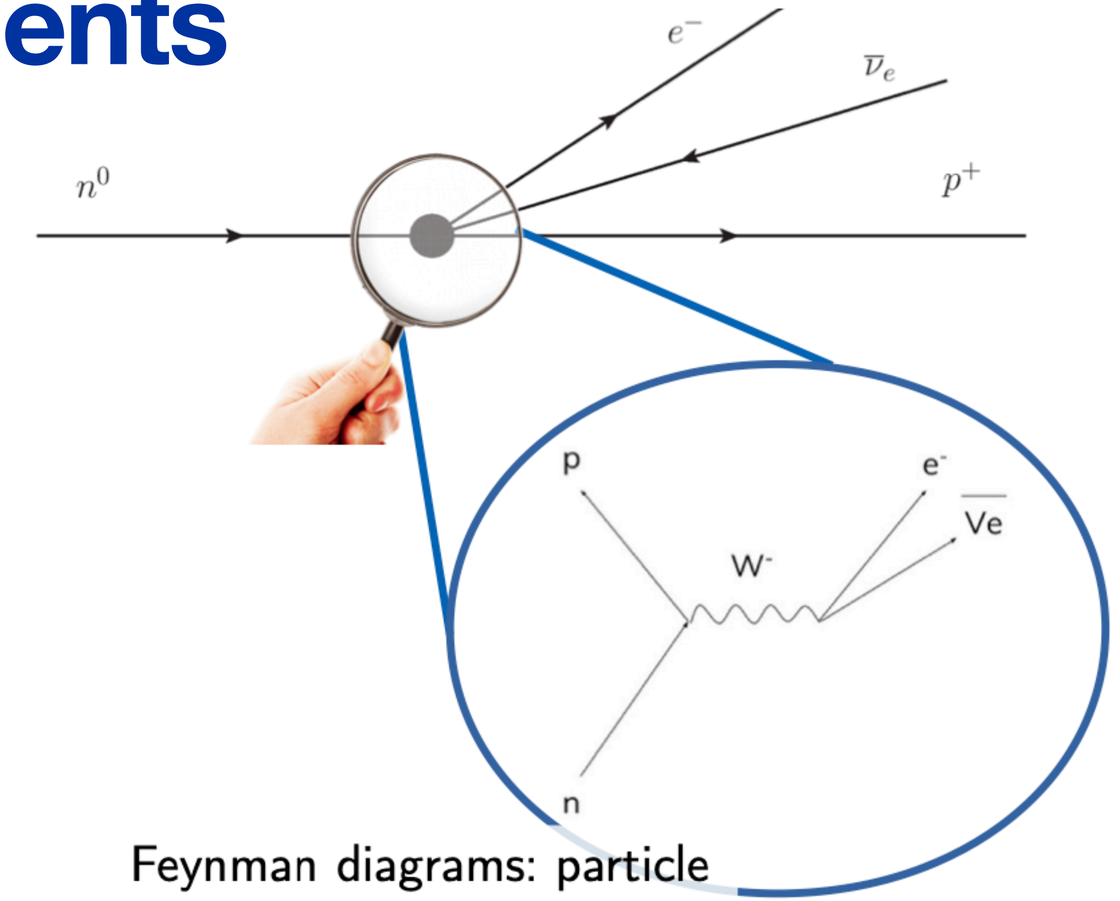
Particle Physics Experiments

What are we trying to do here?







Feynman diagrams: particle physicists' best friends to understand interactions

Many squiggly lines in particle physics talks. What do they mean?

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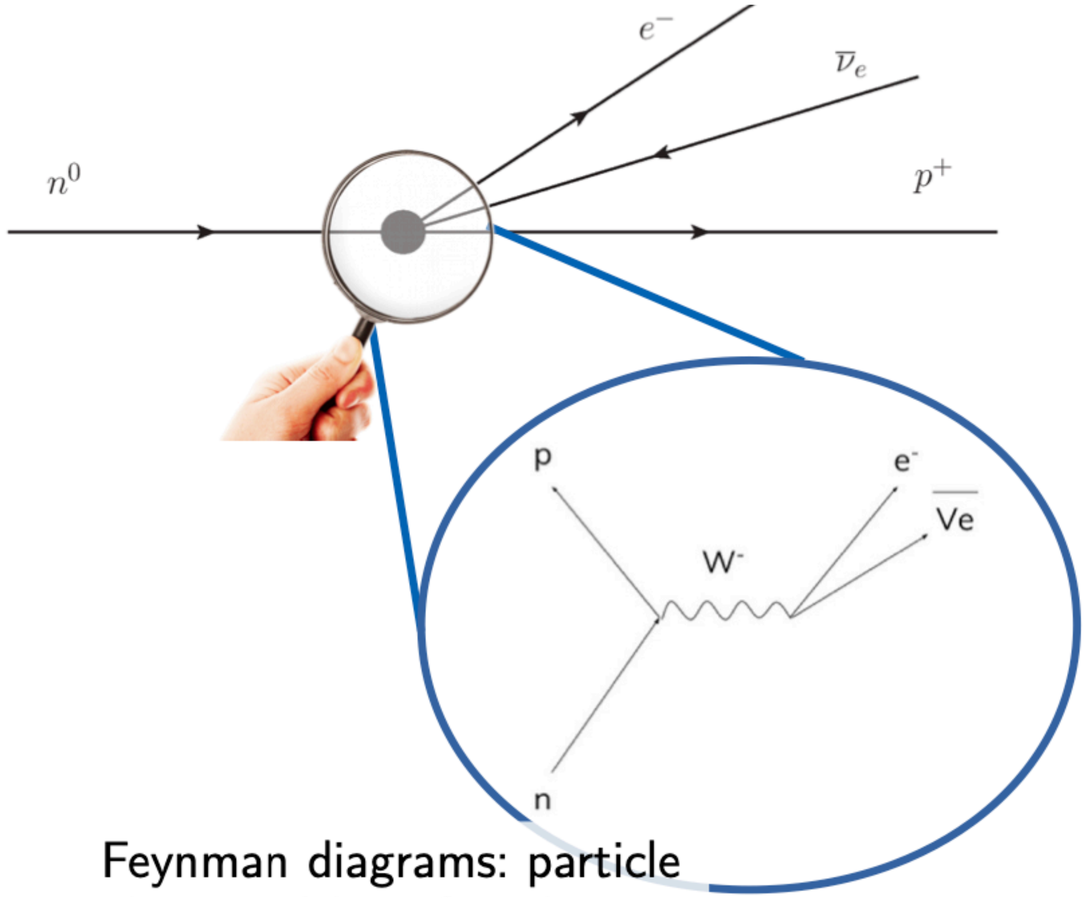
Particle Physics Experiments

What are we trying to do here?



Feynman diagrams: particle physicists' best friends to understand interactions

This picture is great, but it is not quite correct .

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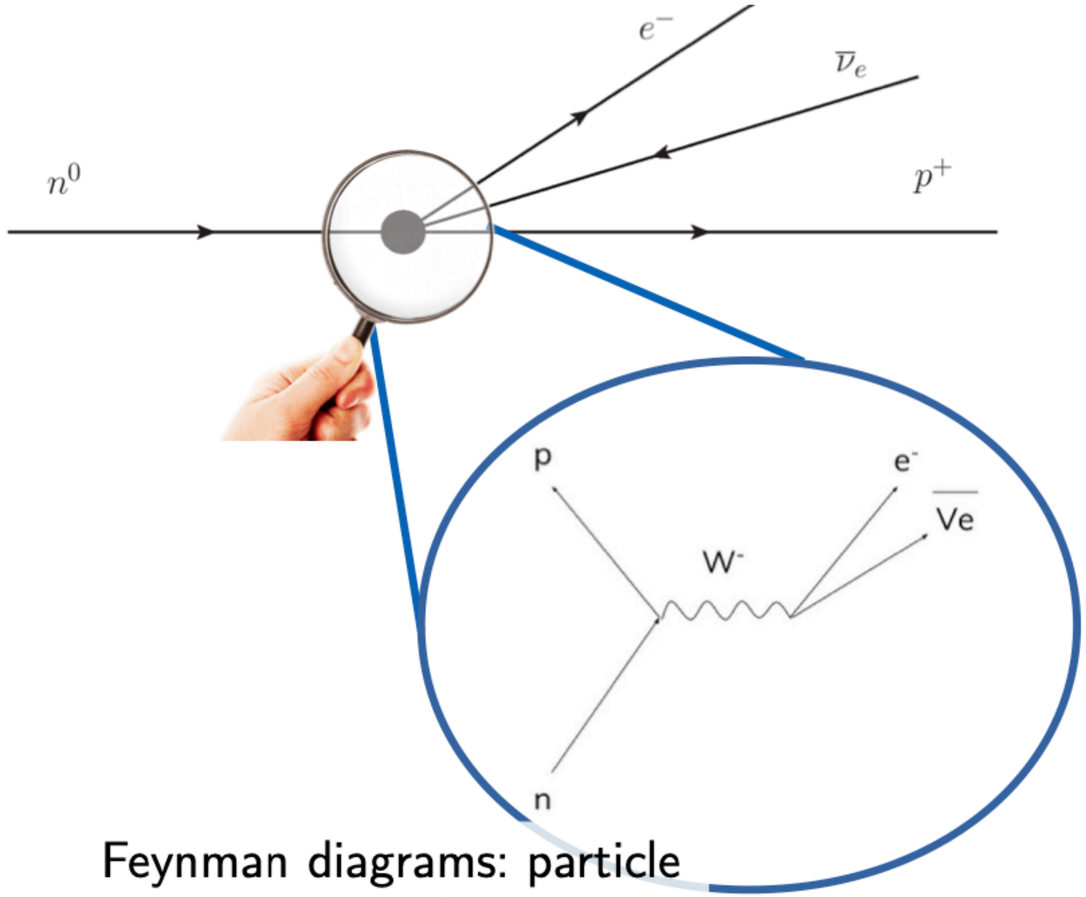
Particle Physics Experiments

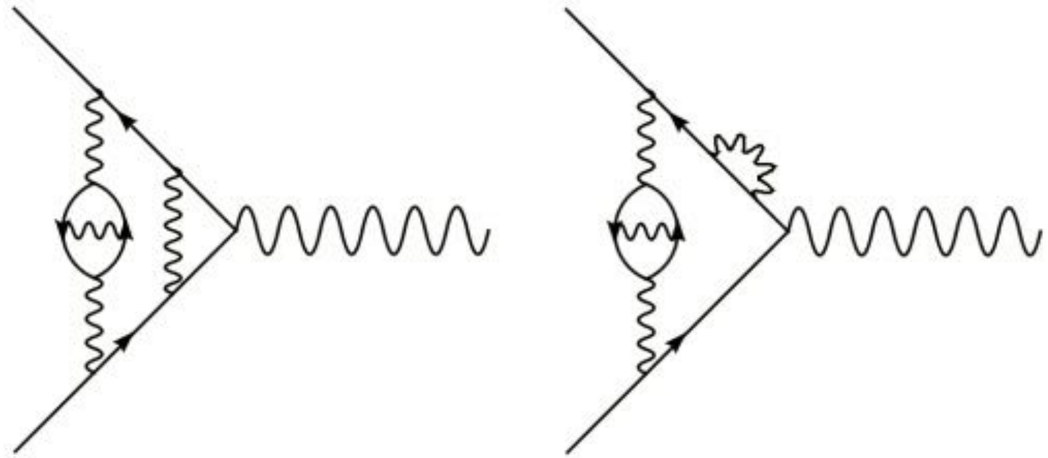
What are we trying to do here?



Feynman diagrams: particle physicists' best friends to understand interactions

This picture is great, but it is not quite correct.

Quantum Field Theory is that circle.



From an experiment point of view, these squiggles are the same thing

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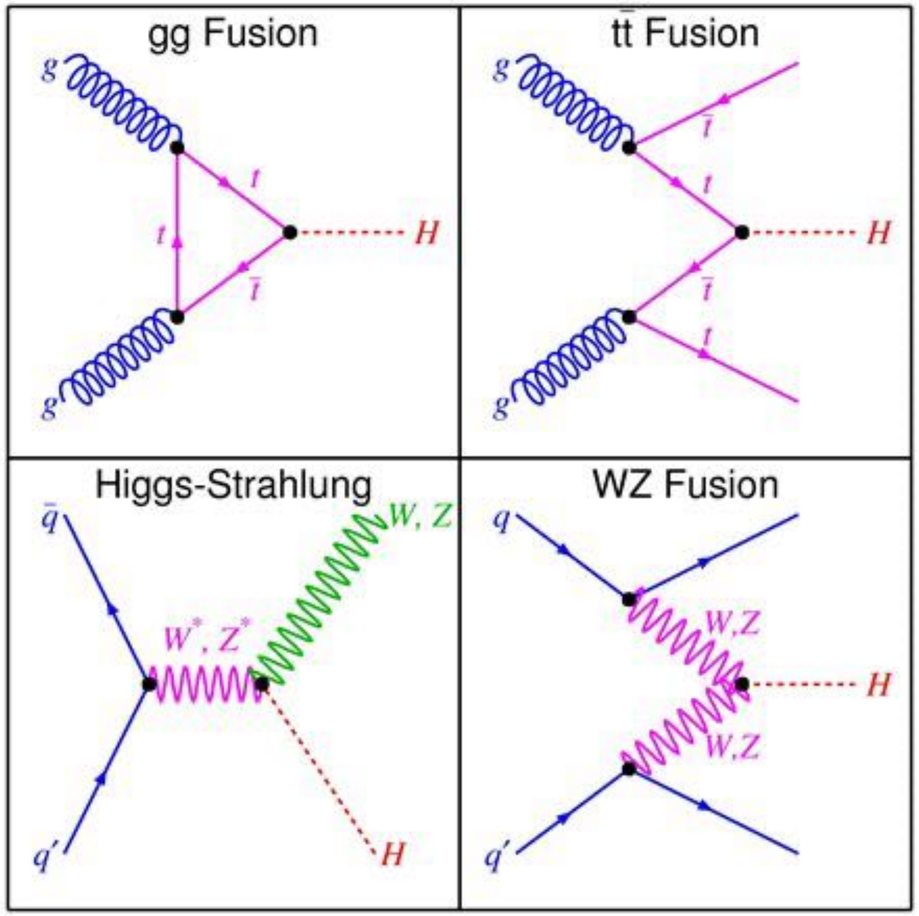
Particle Physics Experiments

What are we trying to do here?



We are trying to precisely determine the occurrence of a particular process, or precisely measure properties of this process.

This is an example of processes for Higgs production @ LHC

This information gives you insight to what fundamental interactions are occurring "under the hood".

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In LHC...

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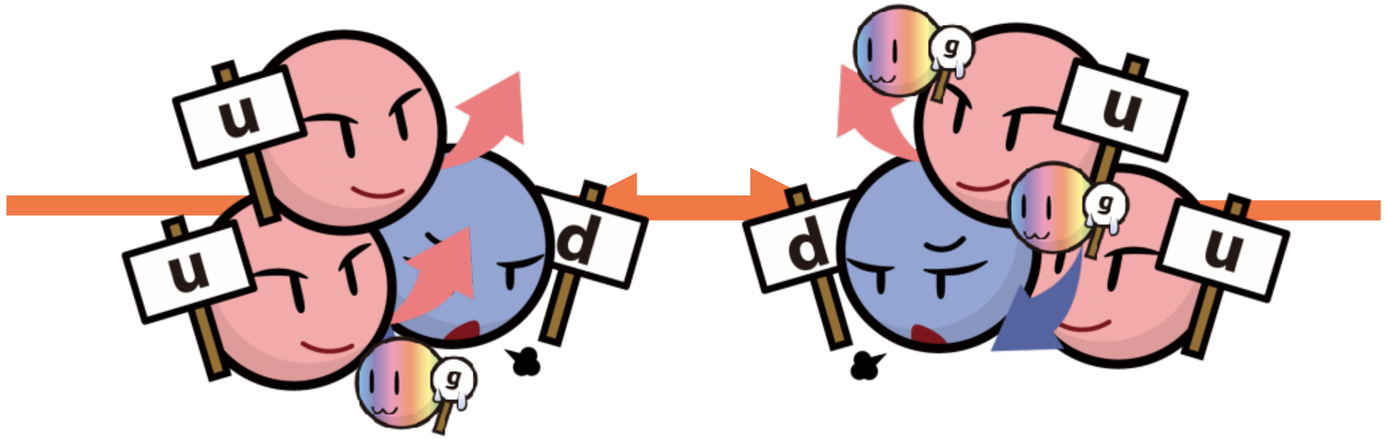
In LHC...



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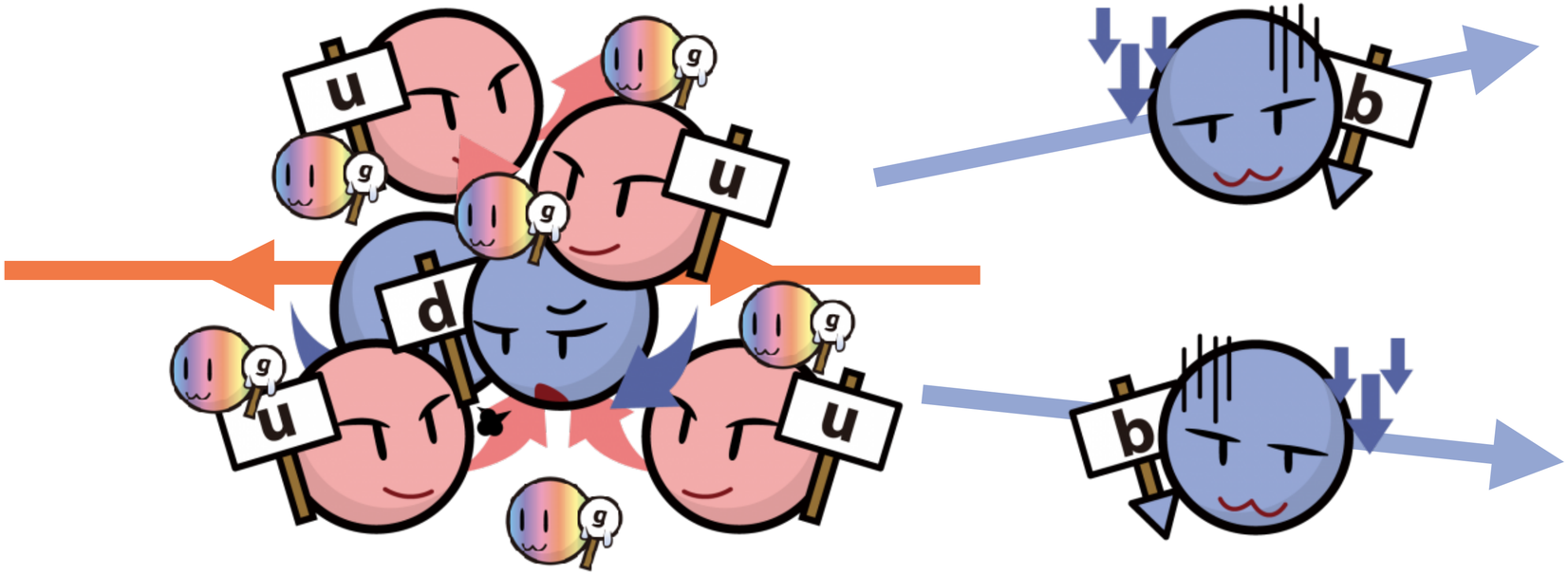
In LHC...



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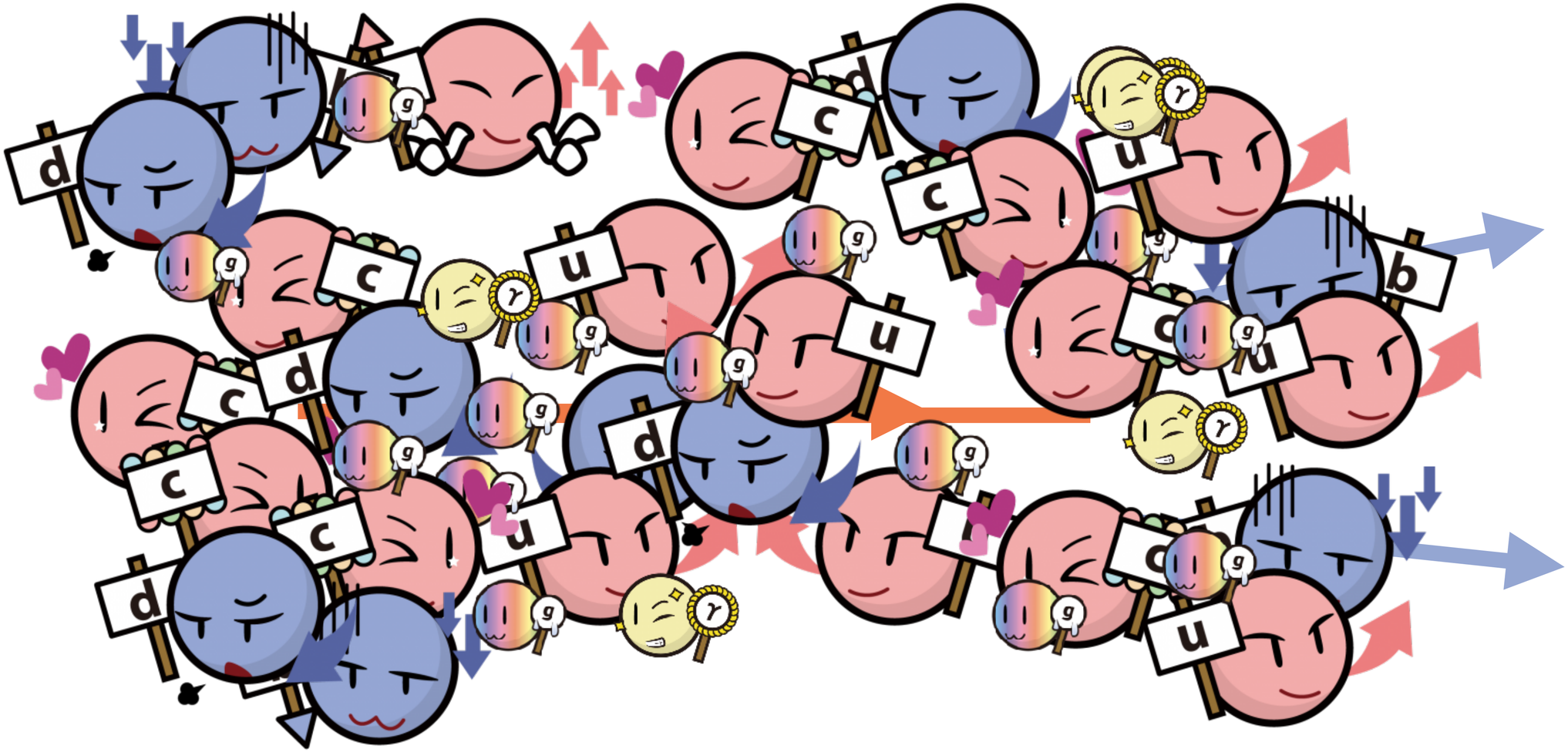
It really looks way worse than this!



Average number of simultaneous proton-proton interactions in ATLAS is ~50.

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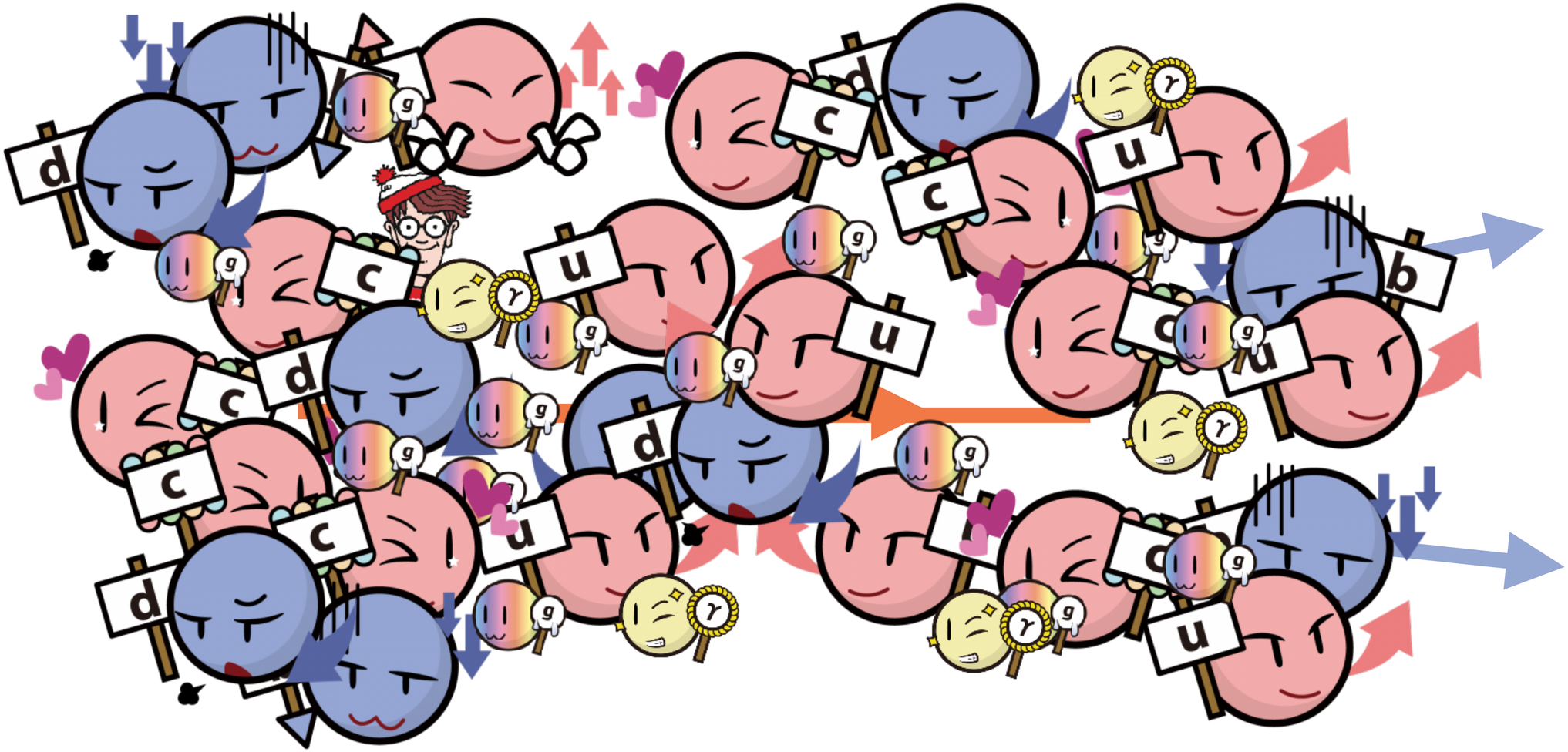

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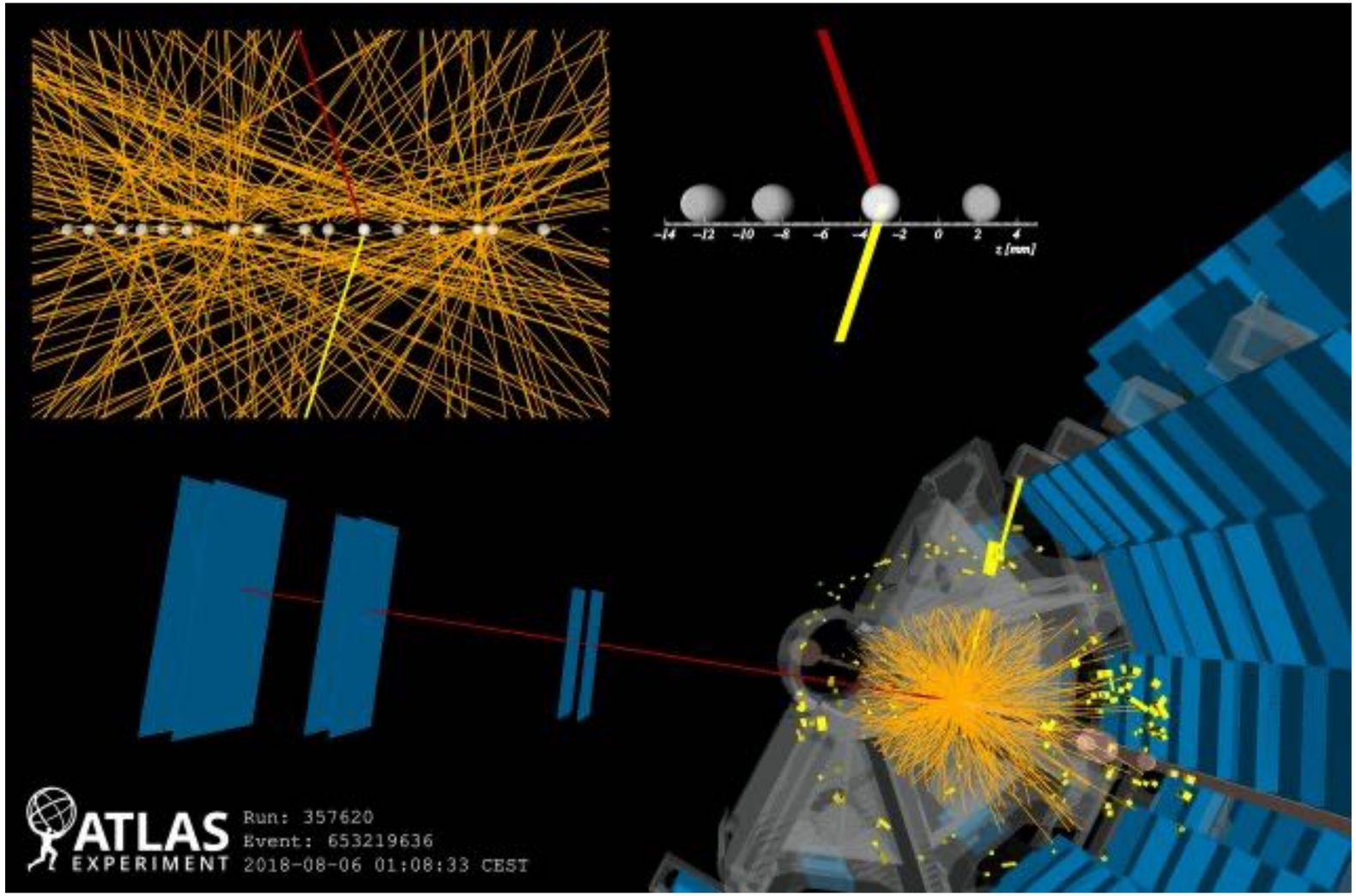

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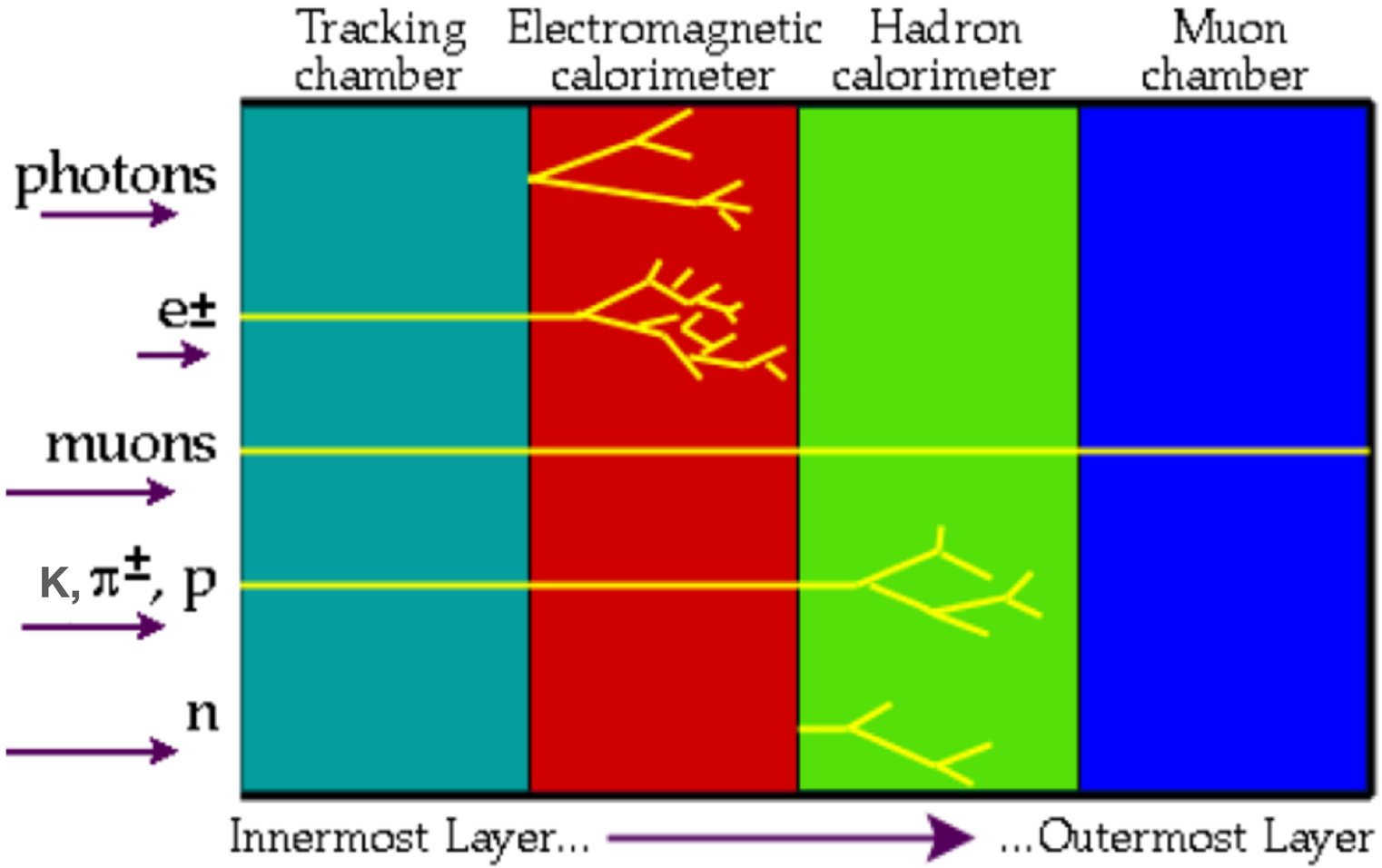
The one slide to remember



7 Different "stable" particles leave signals.

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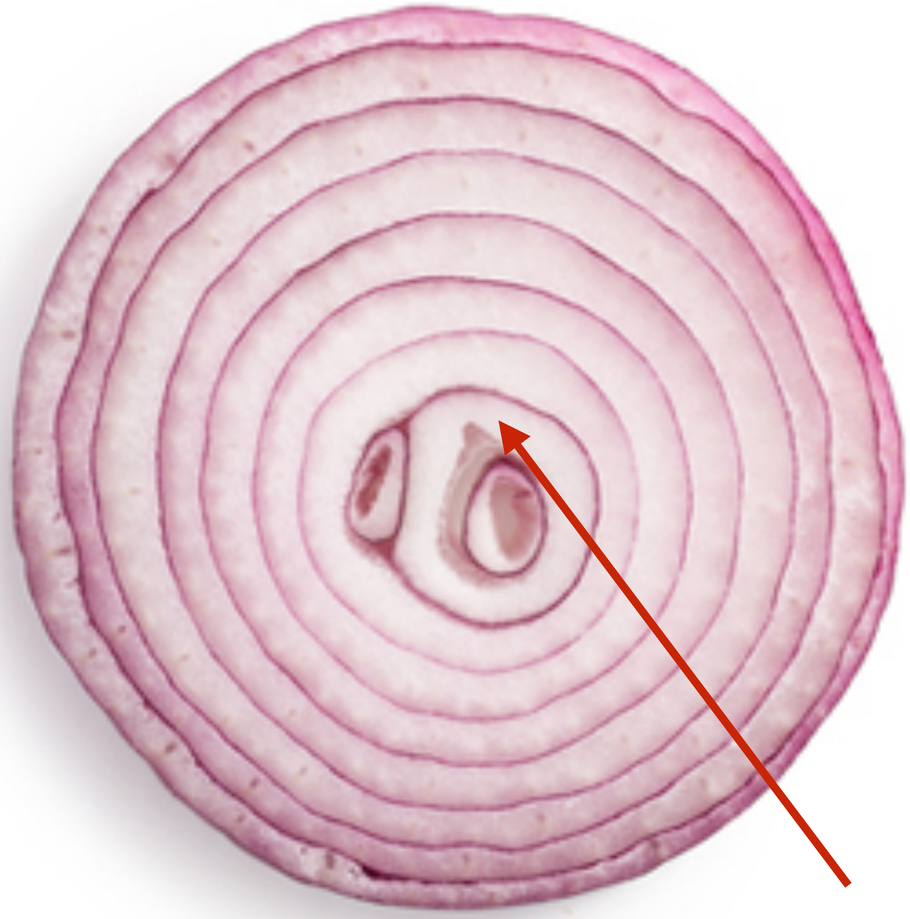
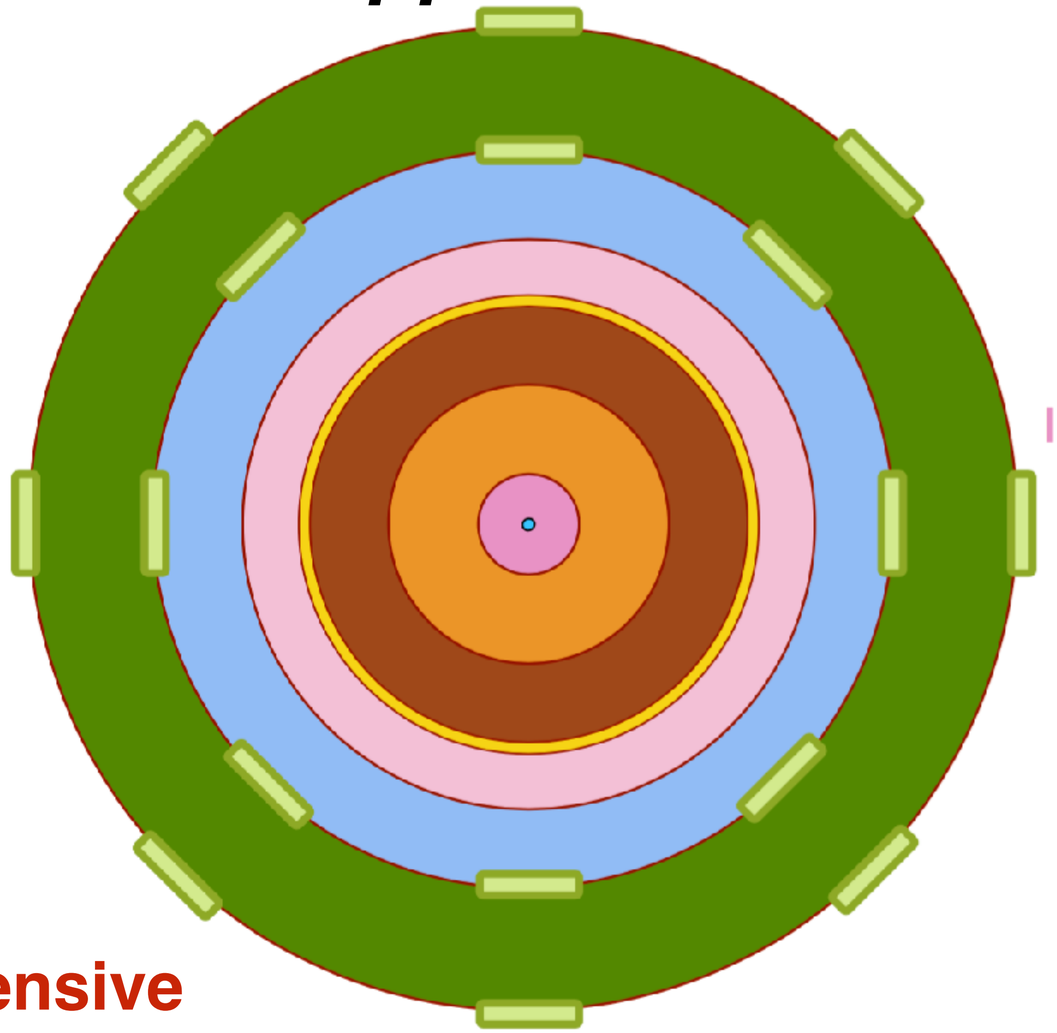
Detectors allow us figure out what happened





More expensive

Less Expensive

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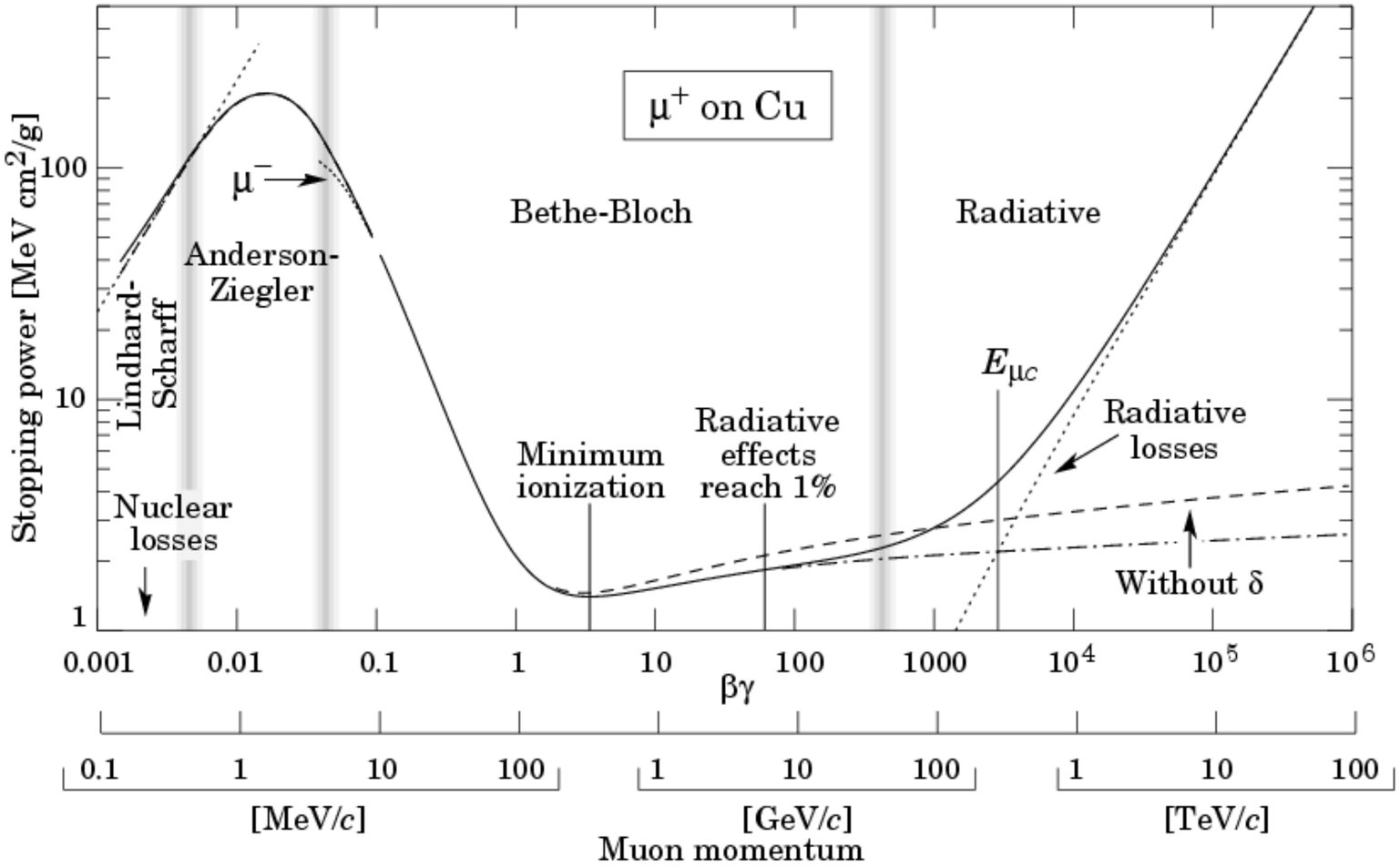
Bethe-Bloch Equation



How do charged particles interact with matter?

Ionisation!

$$-\frac{dE}{dx} = \frac{4\pi e^4 z^2 NZ}{(4\pi\varepsilon_0)^2 M_e v^2}\left[\ln\left(\frac{2M_e v^2}{I}\right) - \ln(1-\beta^2) - \beta^2\right]$$

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Did a particle pass through here?

Did it generate any charge ?

We have to collect this charge to figure it out!

Detector Volume

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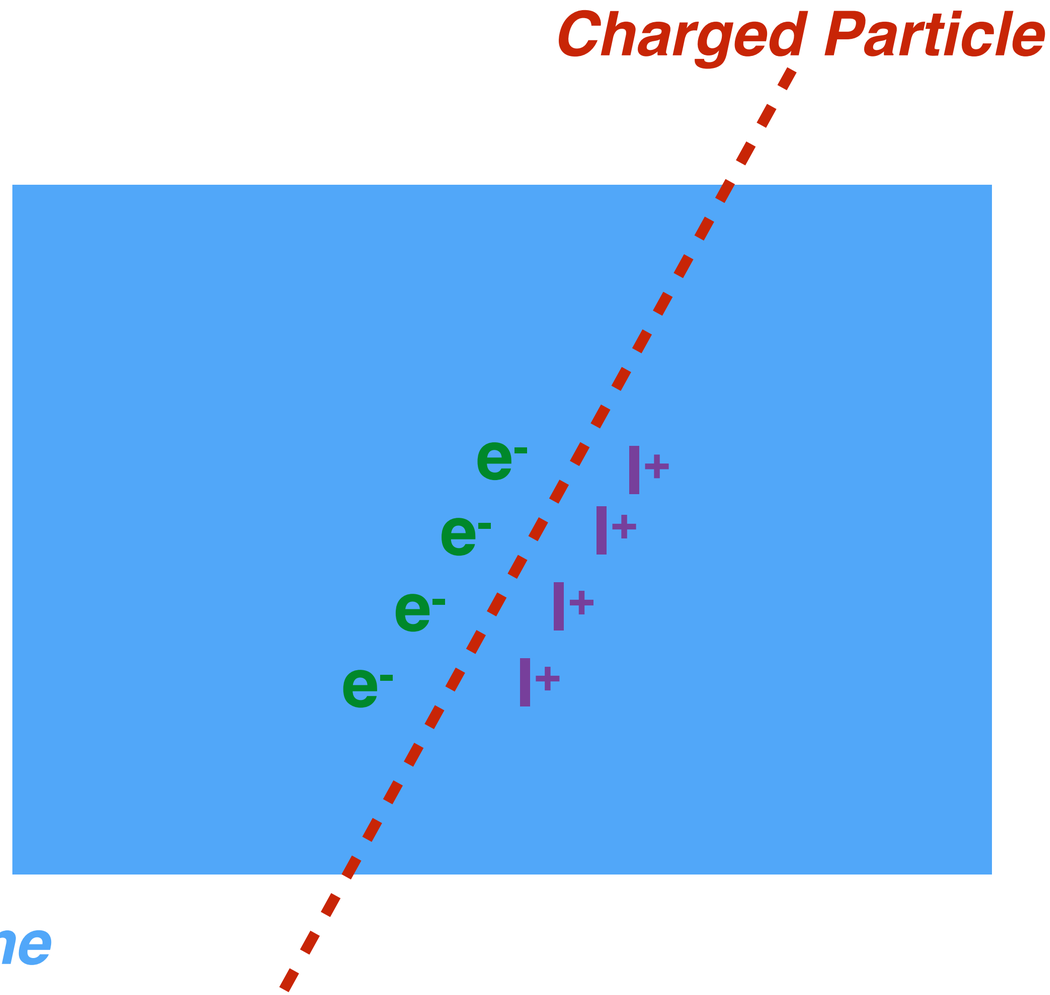

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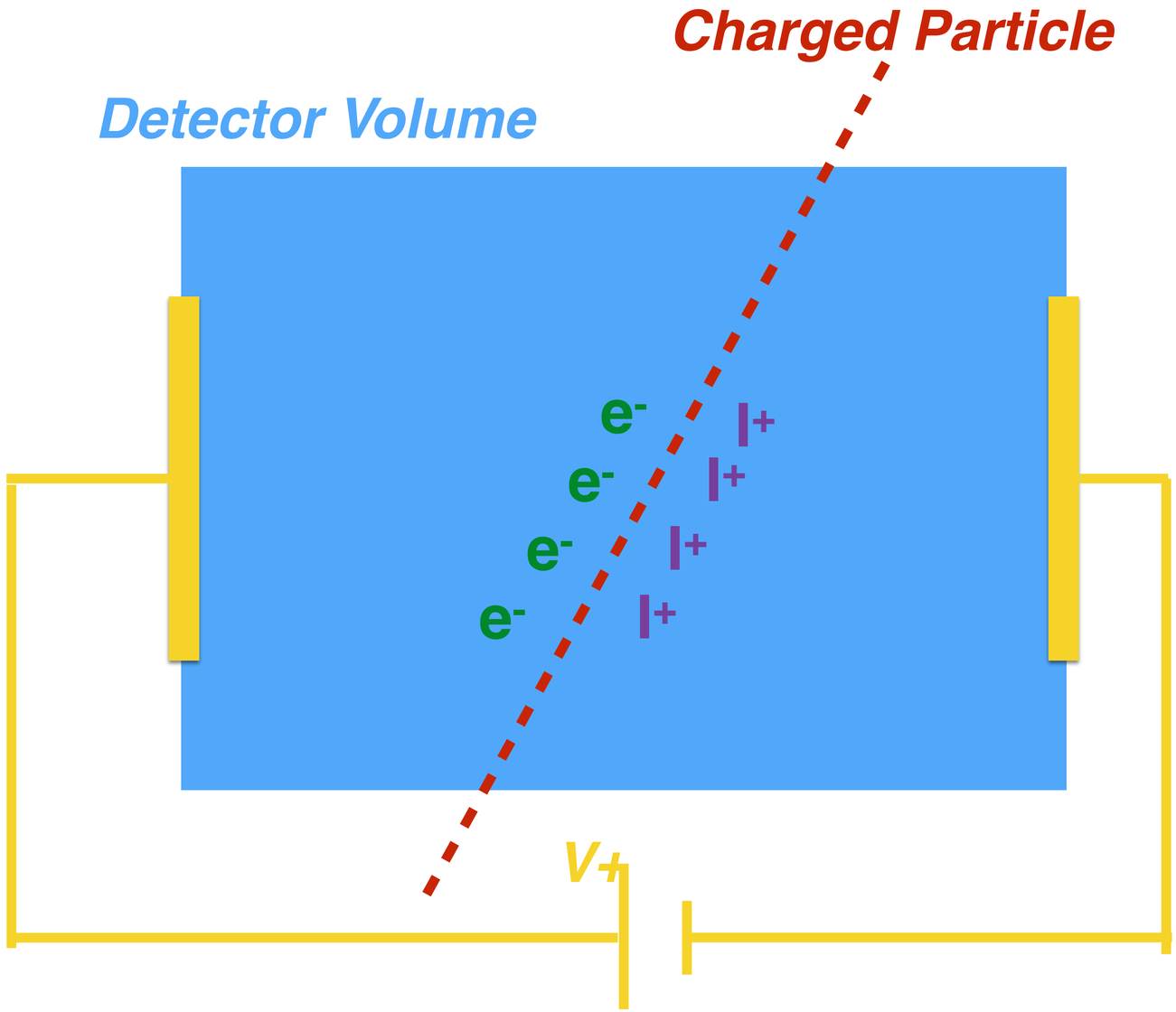

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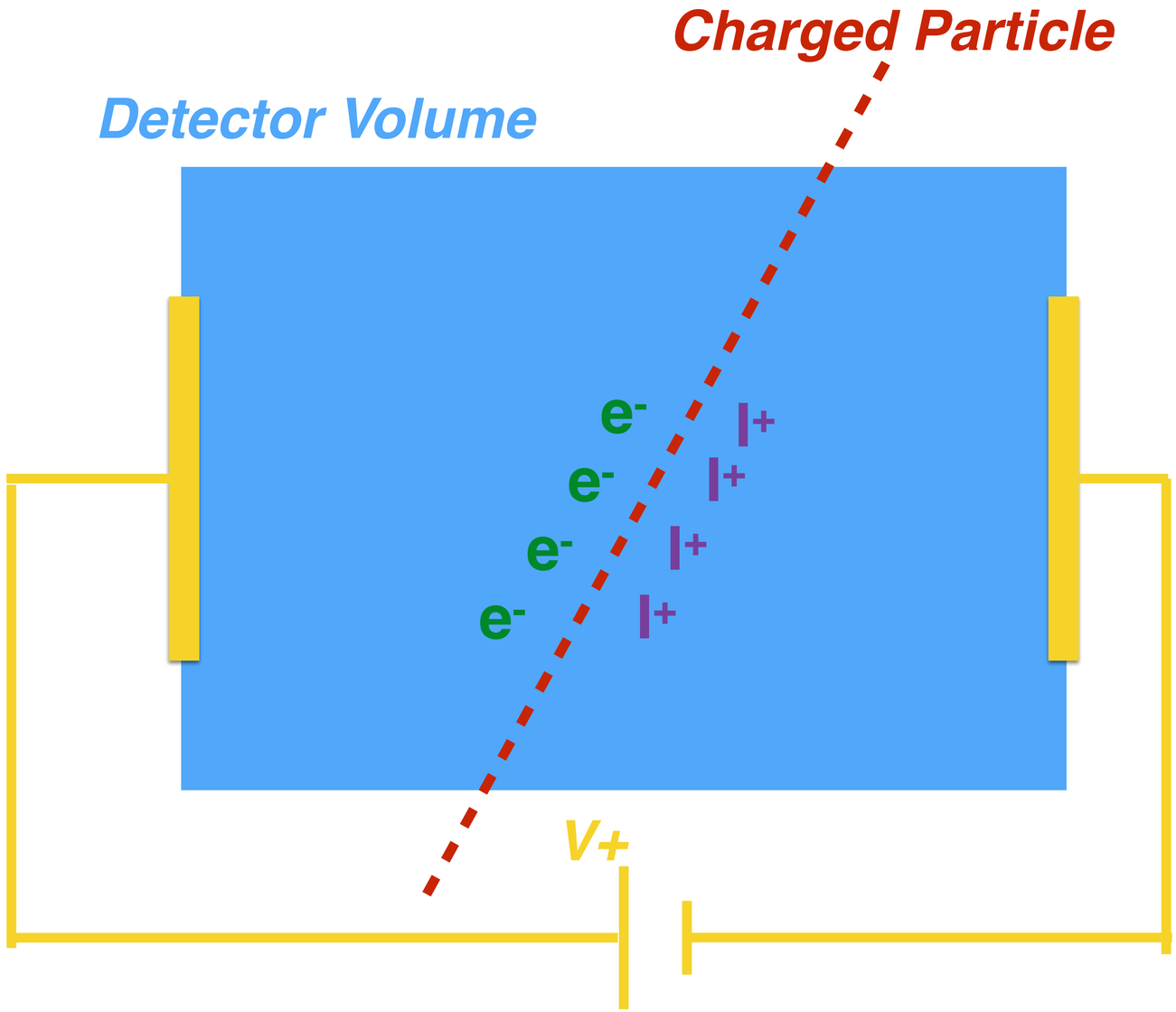
Did a particle pass through here?

Did it generate any charge ?

We have to collect this charge to figure it out!

Electric field drifts free charges away.

Eletronics measure how much charge drifted at any point in time.



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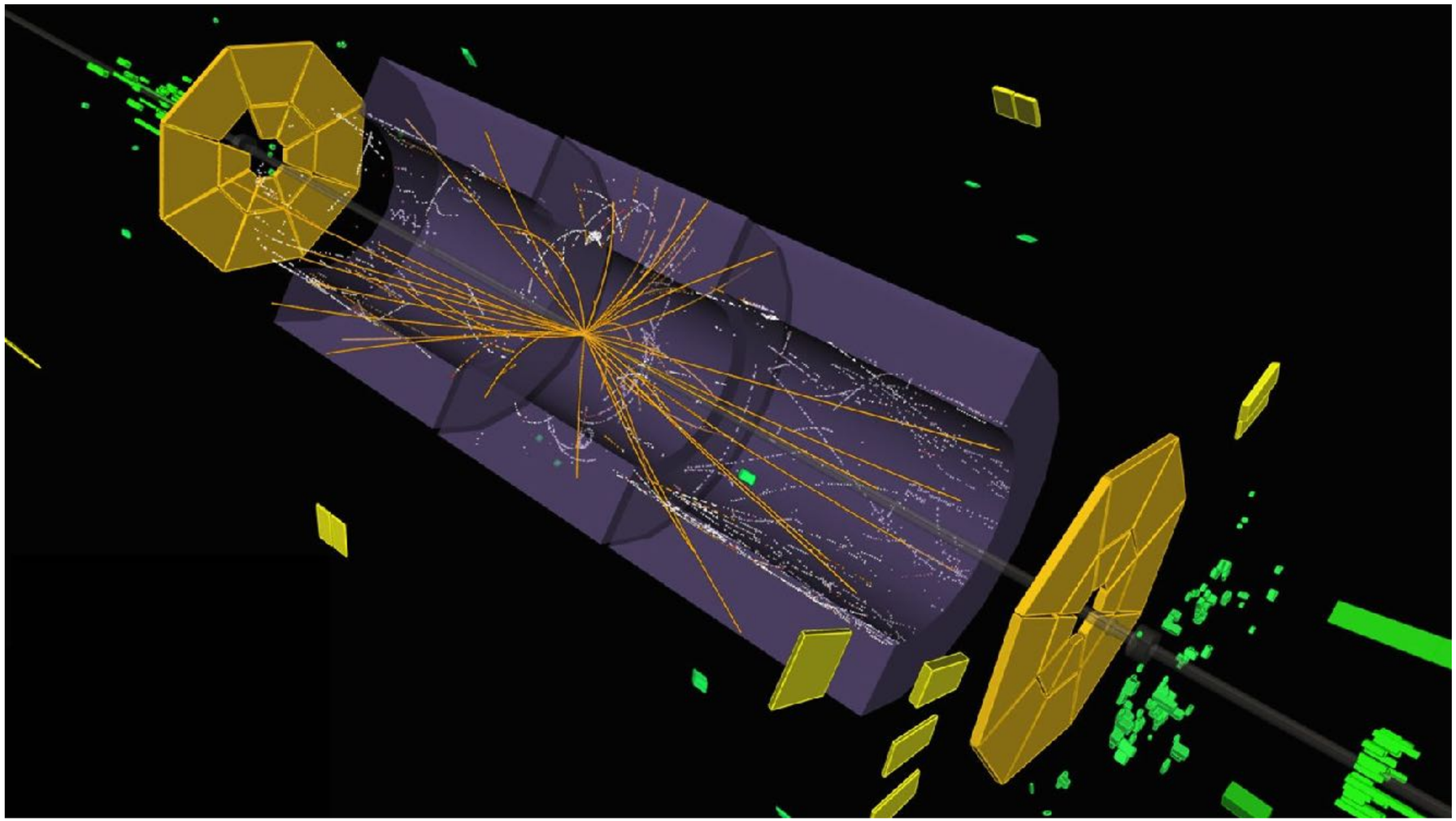
Did a particle pass through here?

With many of these detections one can figure out accurately the path of a particle through the detector.

If you are really smart you can put a magnetic field in there and get…



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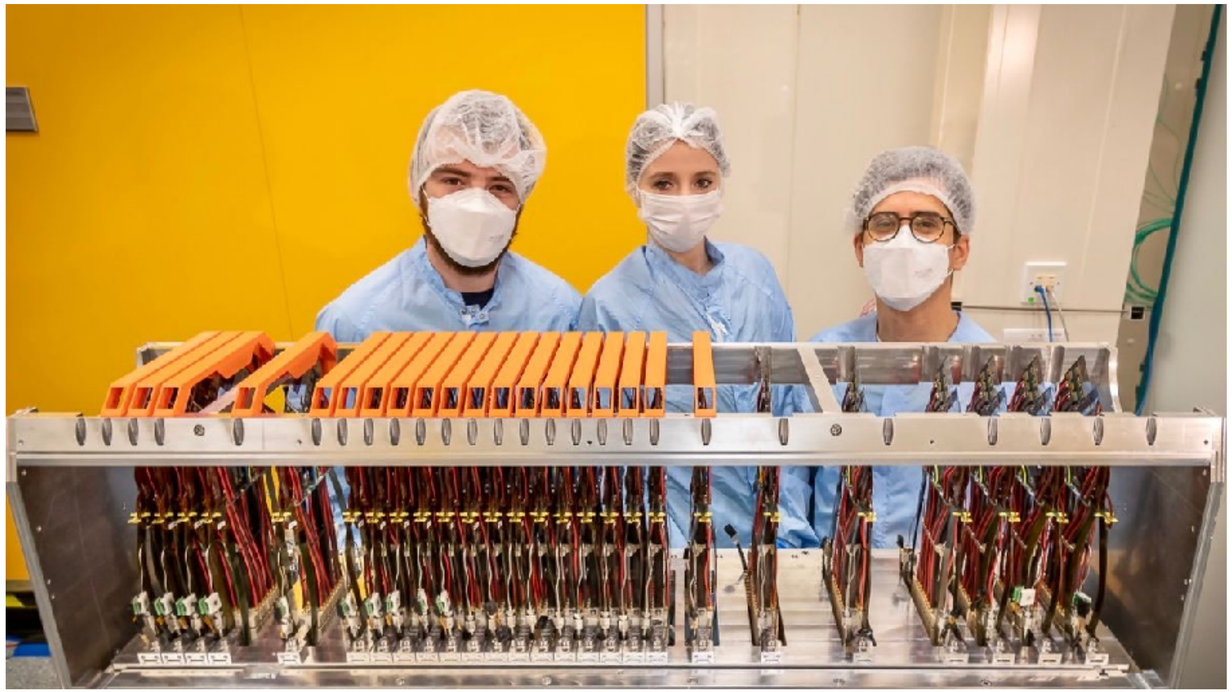
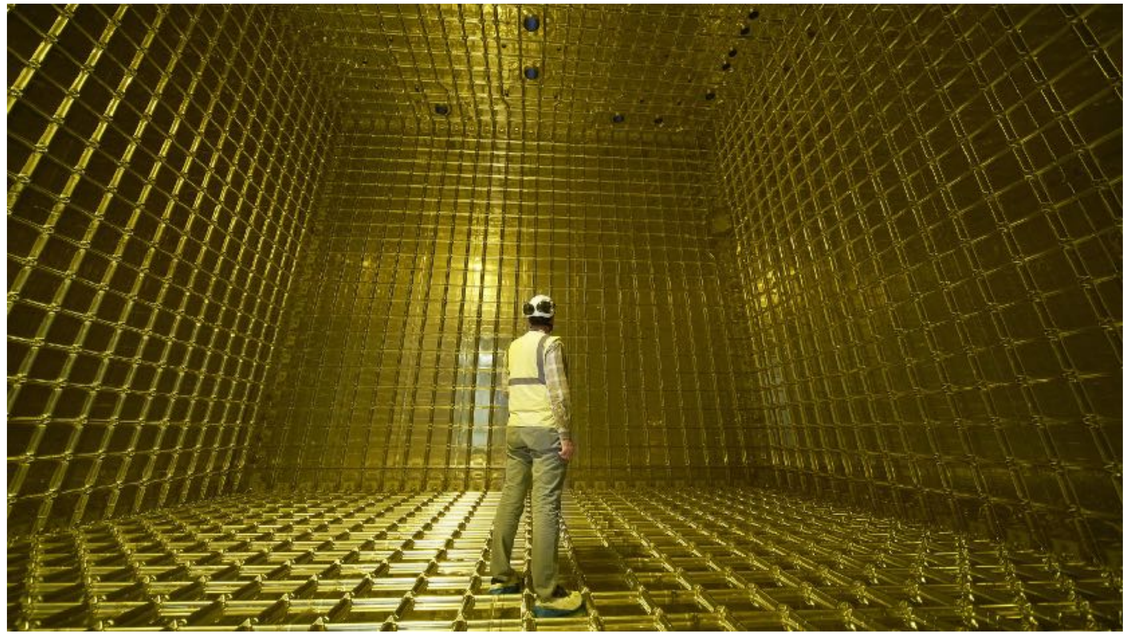
Did a particle pass through here?

Now you know how to make a tracking detector!





Choose an appropriate volume, and the correct density of channels, design special readout electronics, probably cry at some point.

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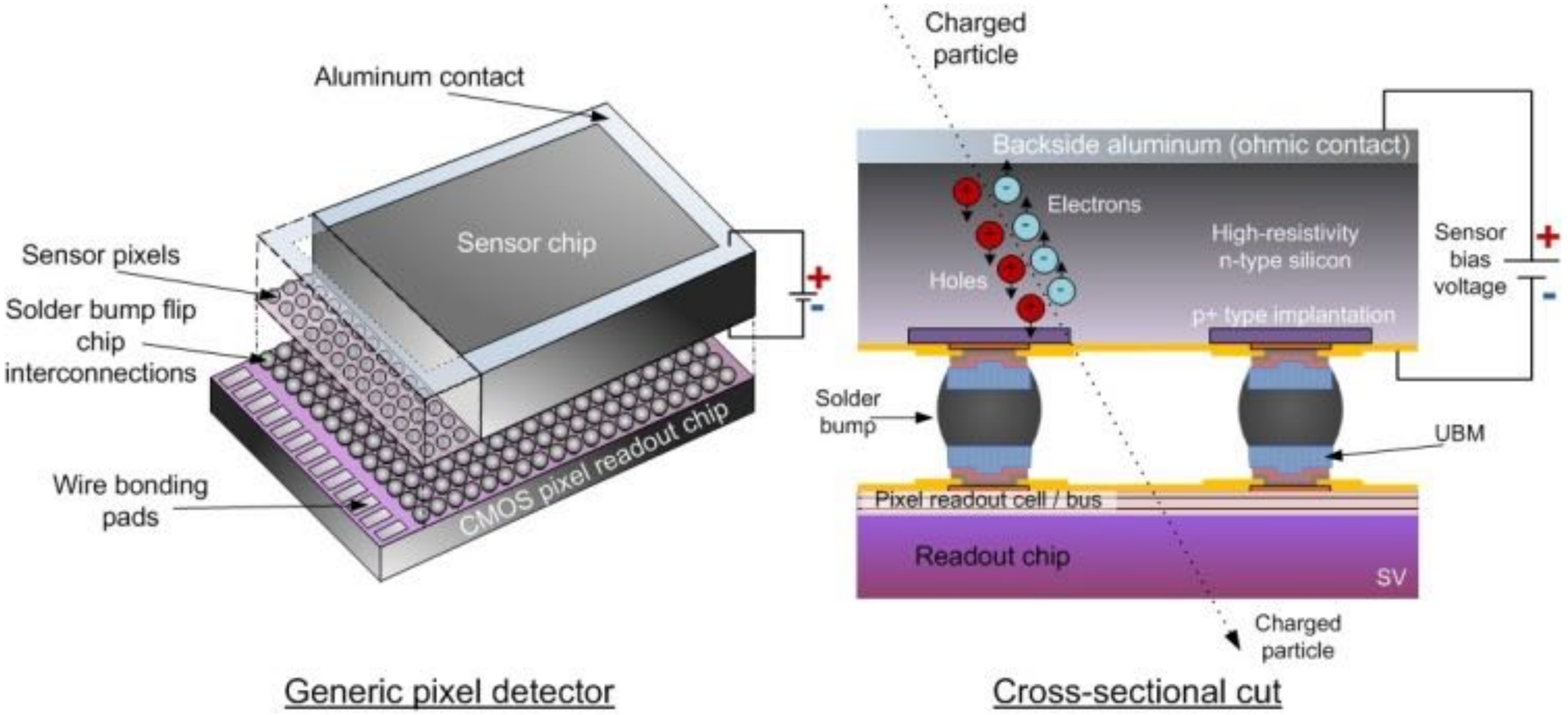
Hybrid Silicon Pixel Detectors



Generic pixel detector

Cross-sectional cut

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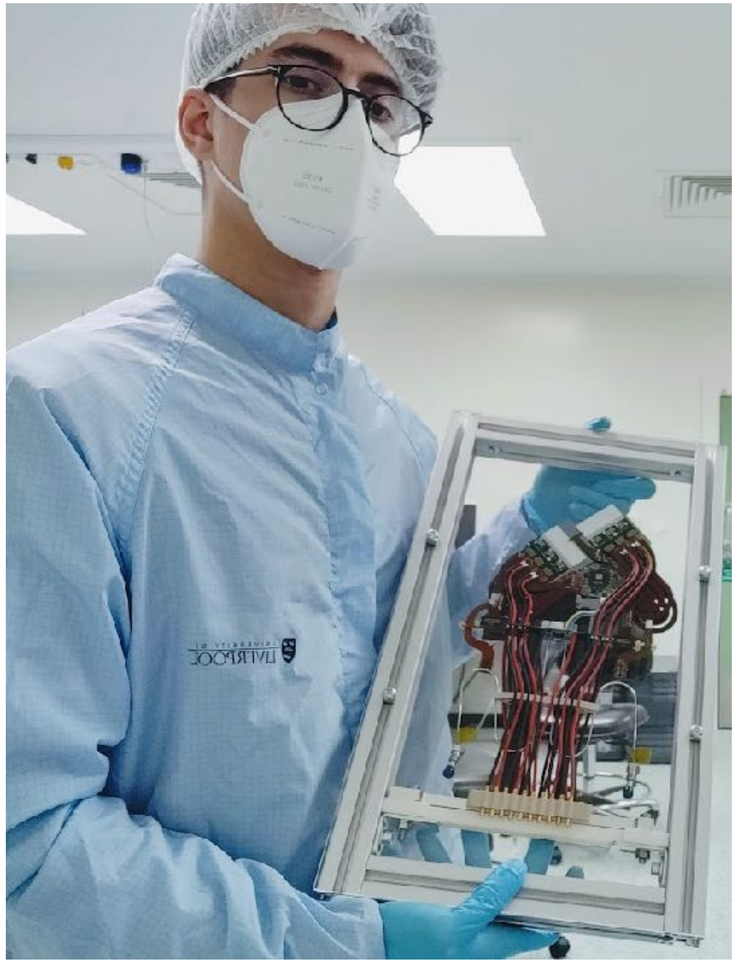
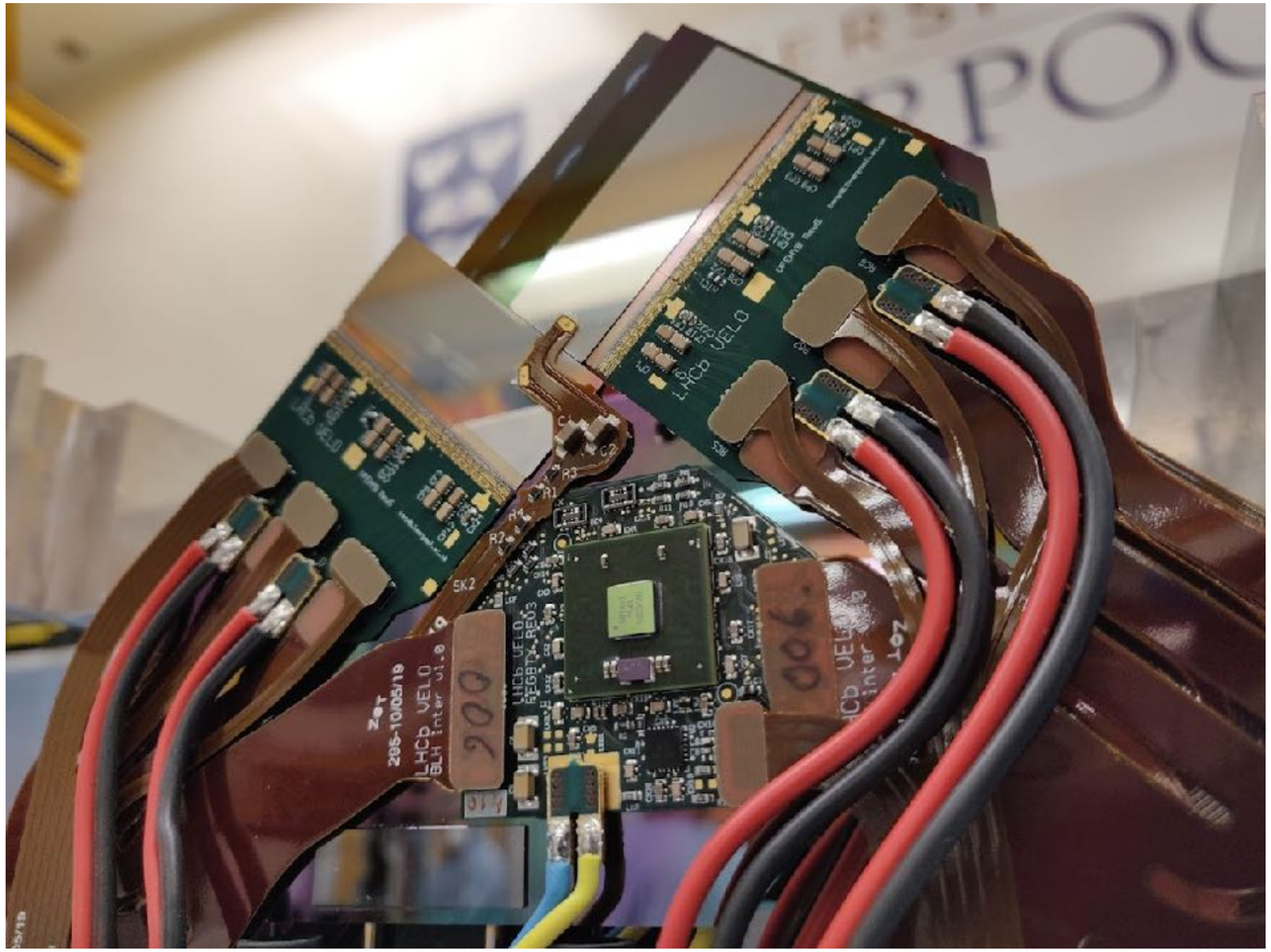
Hybrid Silicon Pixel Detectors





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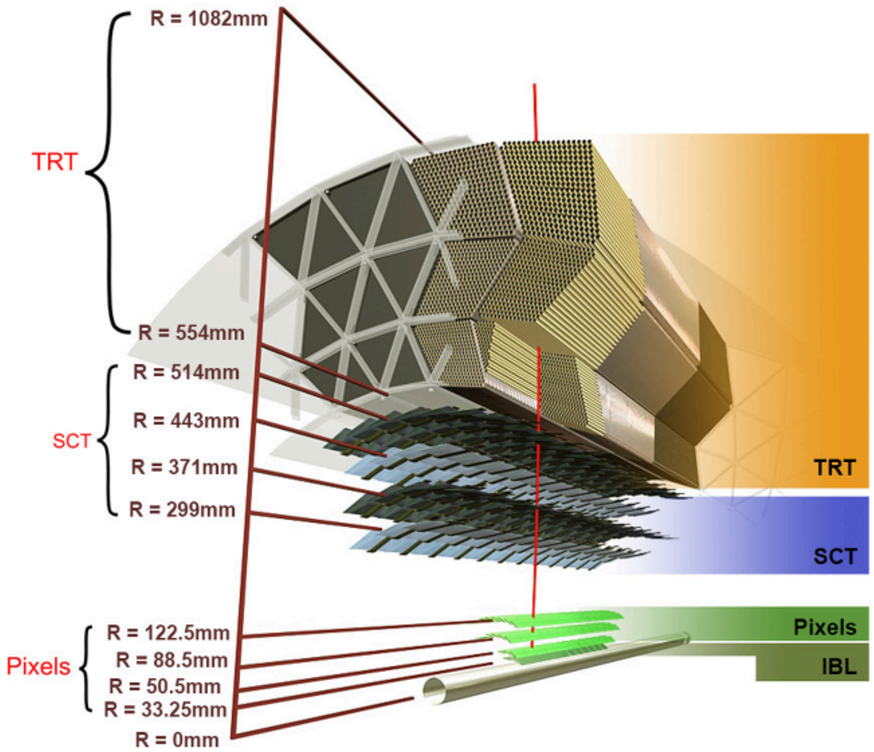

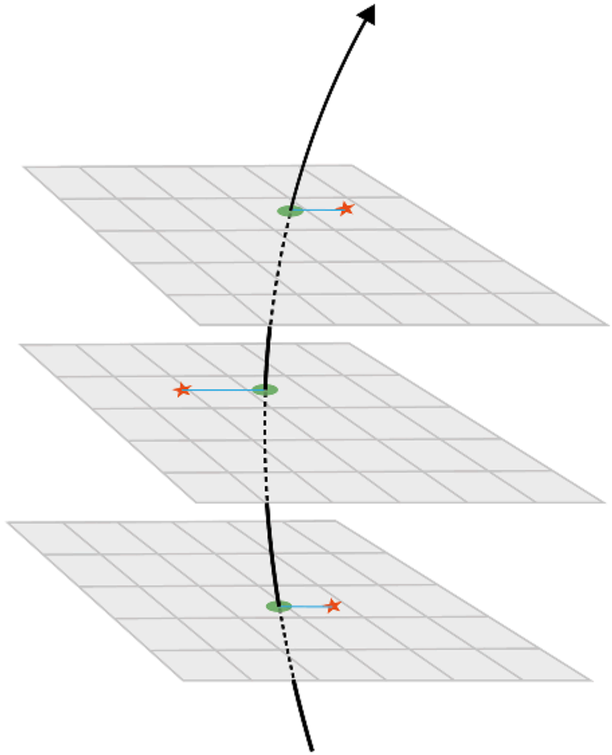

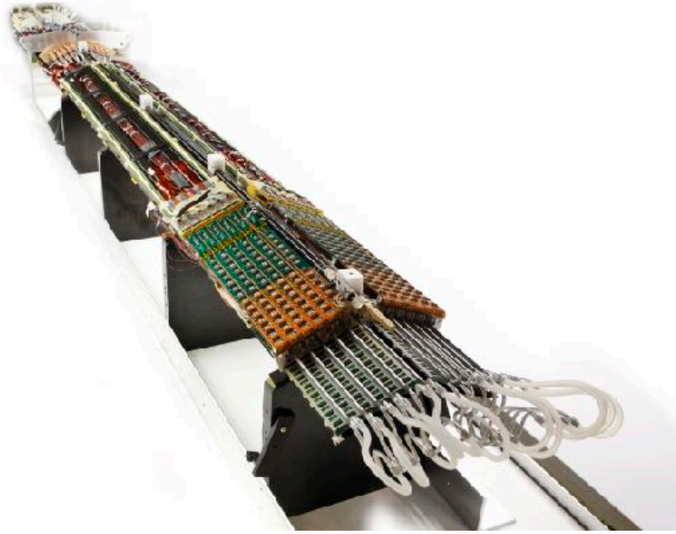

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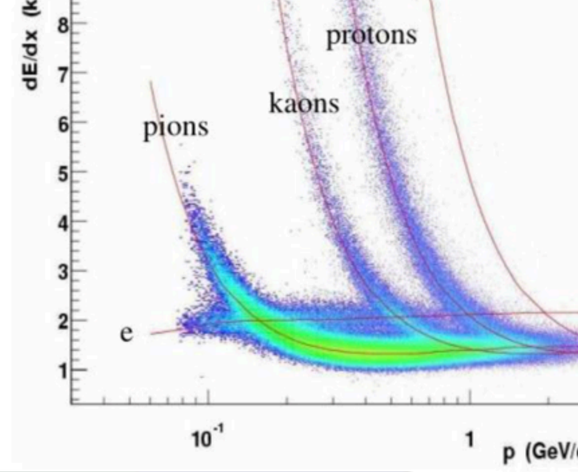
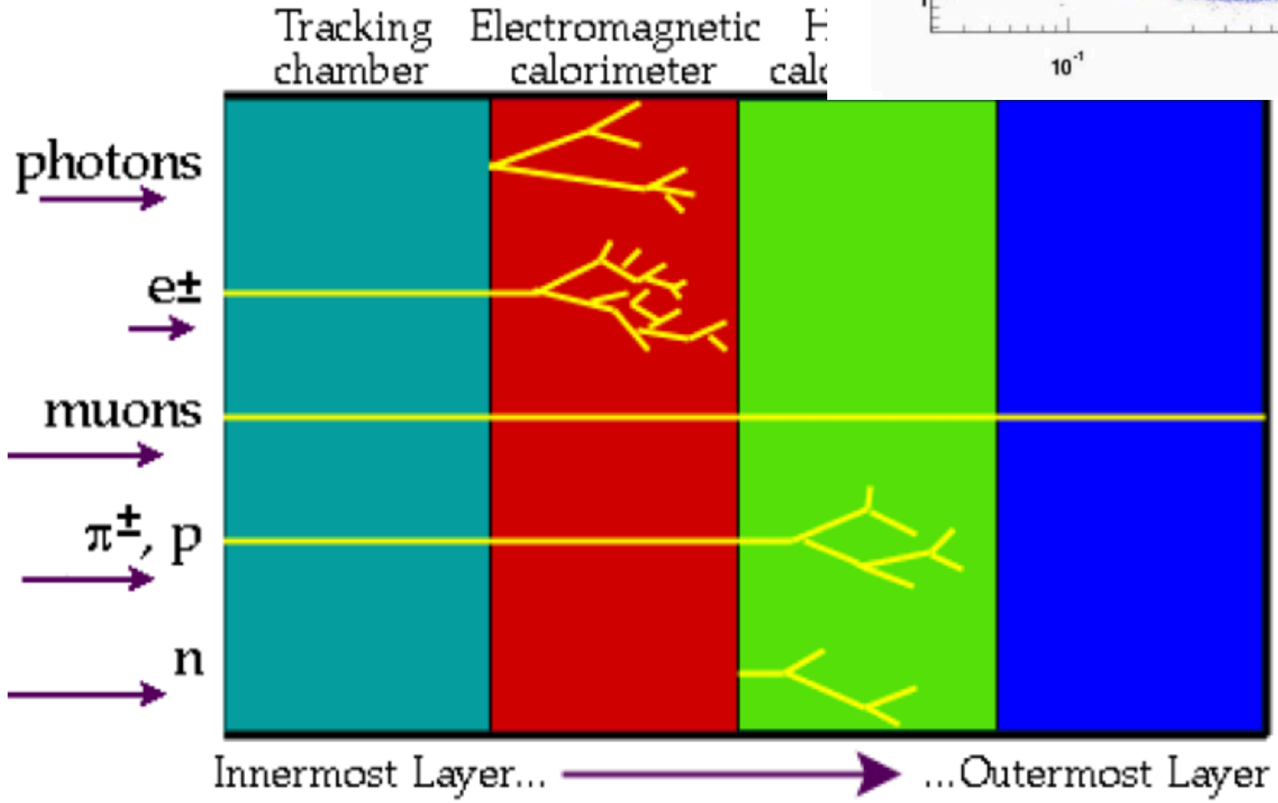
Which particle though ?

Once you reconstructed a trajectory, you need to know its identity!

Calorimeters identify particles by stopping them.

Cherenkov detectors identify particles by looking at their Cherenkov light.





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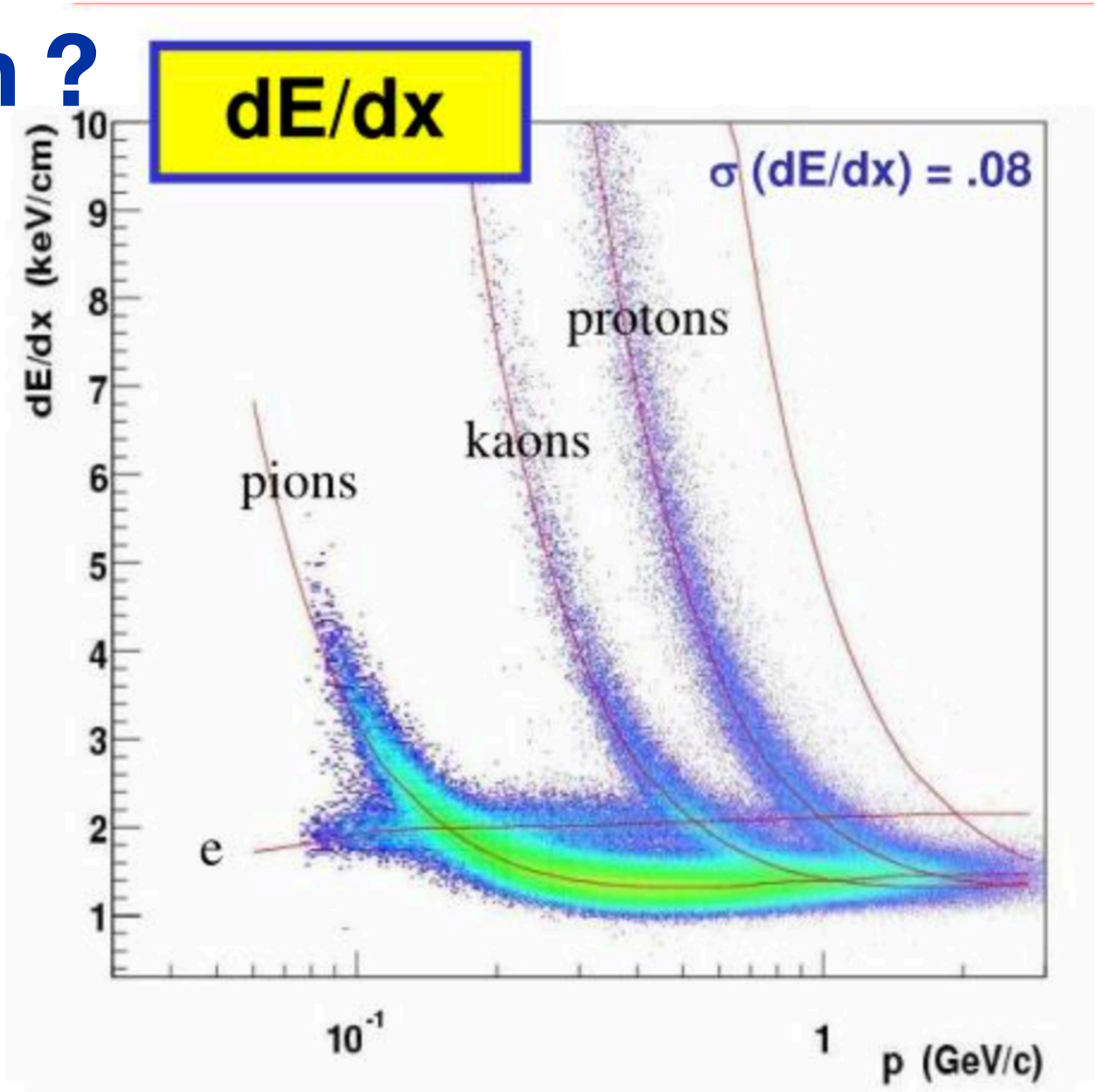

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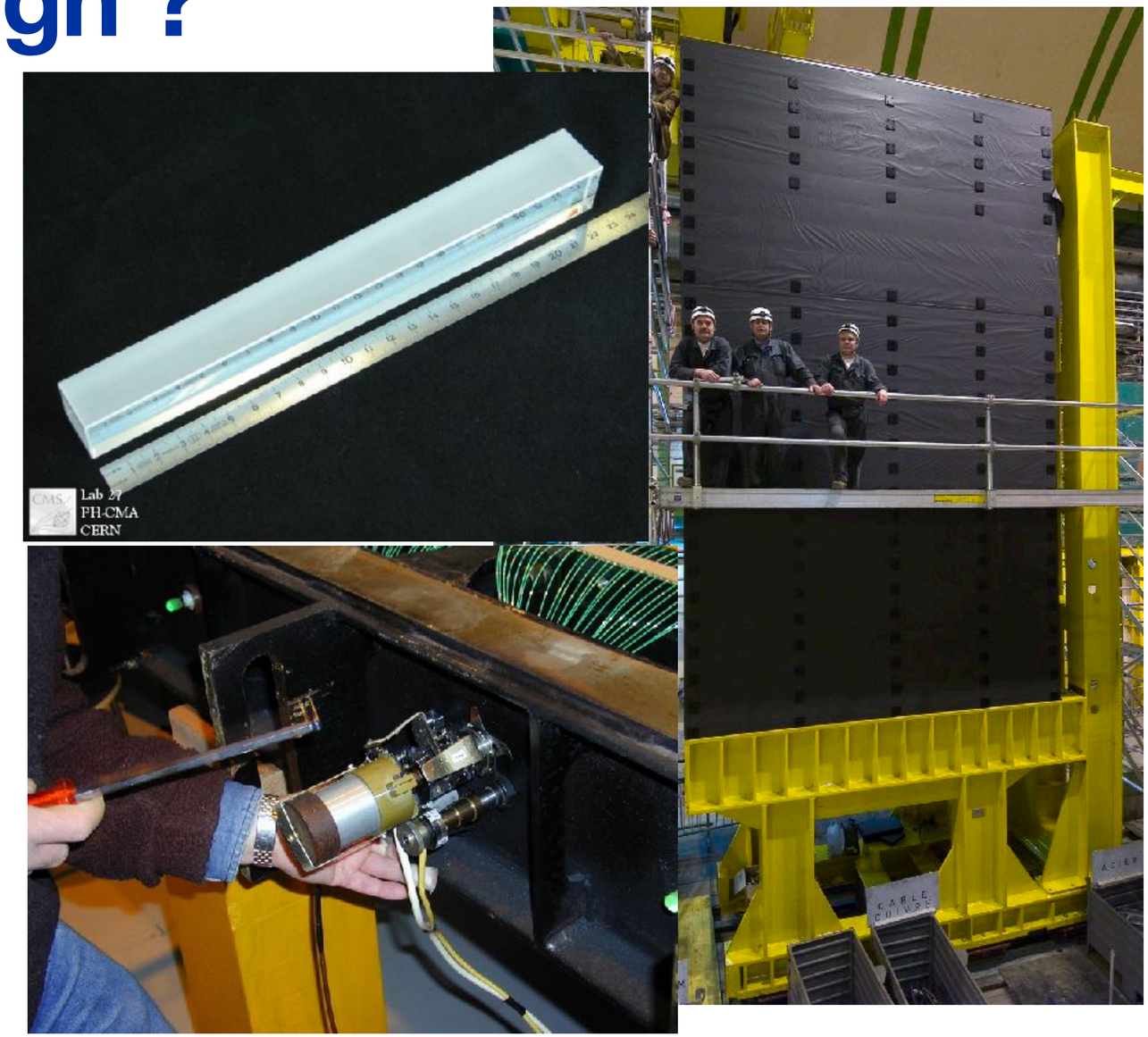
Which particle though ?

Calorimeters identify particles by stopping them.

Main different between electromagnetic and hadron calorimeters is their density.

In general hadrons penetrate much deeper and will leave signals in both EM and Hadron calorimeters.



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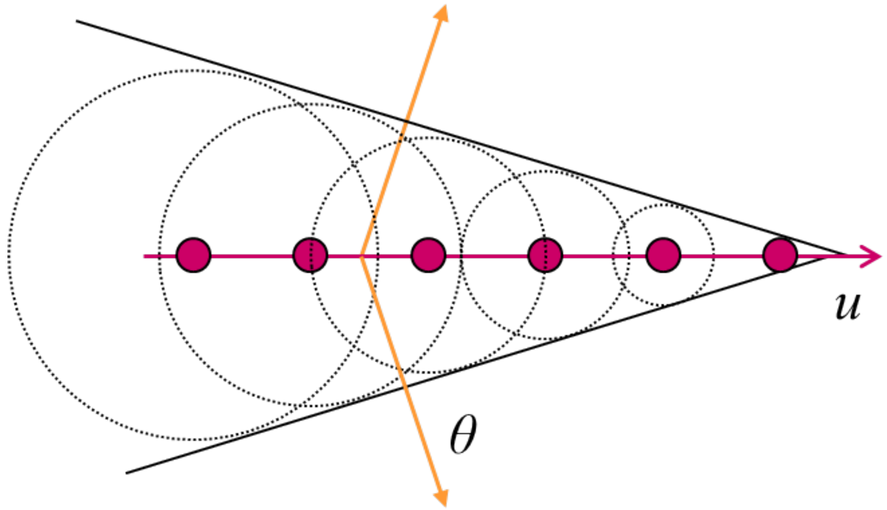
Which particle though ?

Cherenkov light for particle identification.



Generated by particles traversing a medium at a speed higher than the speed of light in that medium.

Angle of the wake depends on the speed of the particle.

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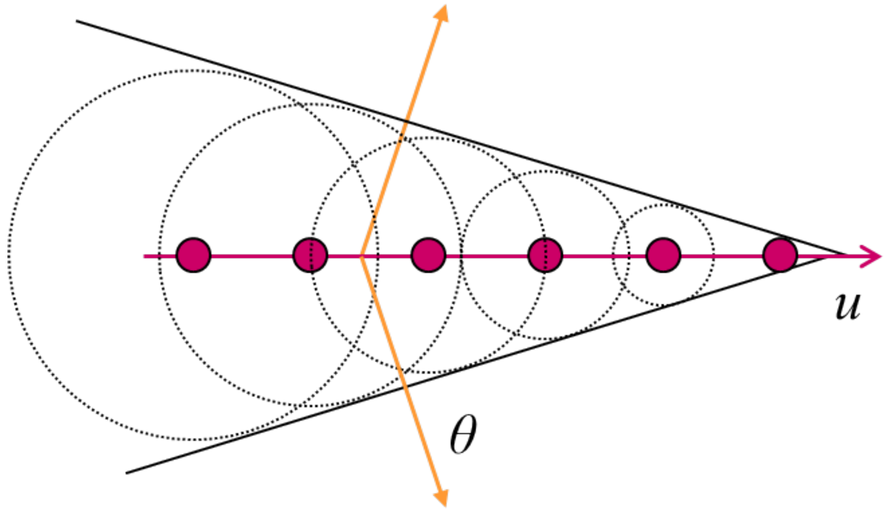
Which particle though ?

Cherenkov light for particle identification.



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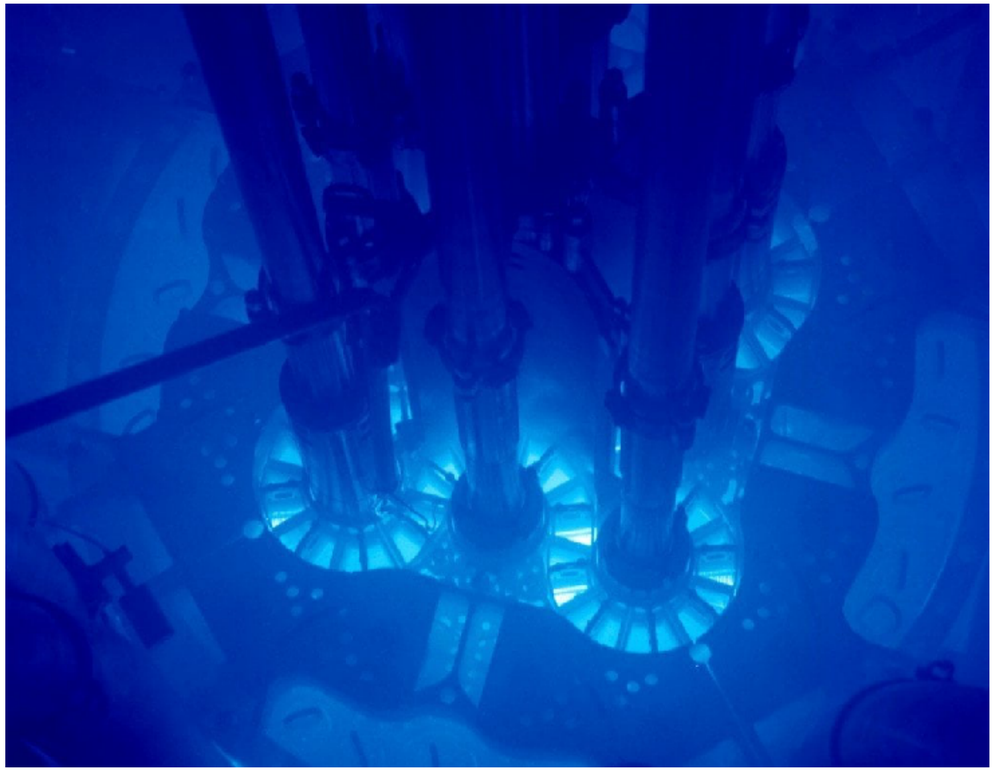

As seen in Water cooled reactors.

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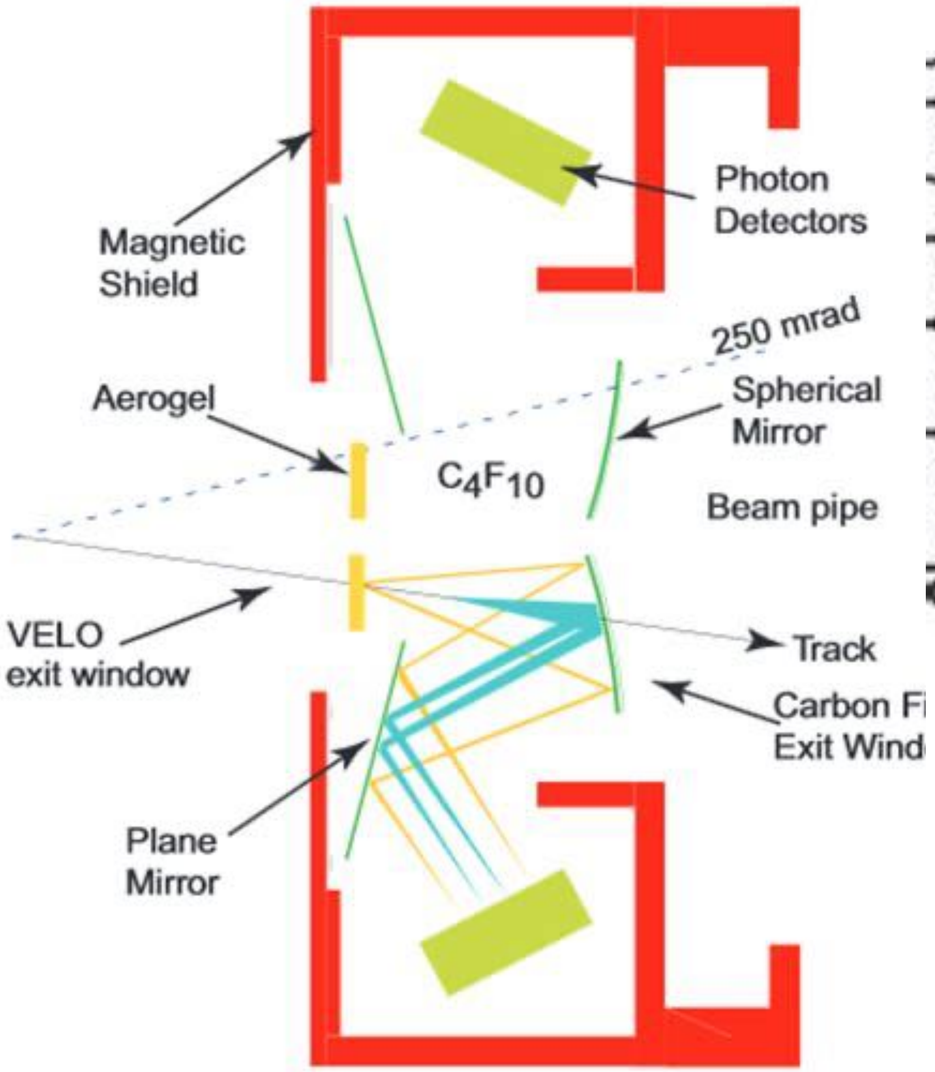
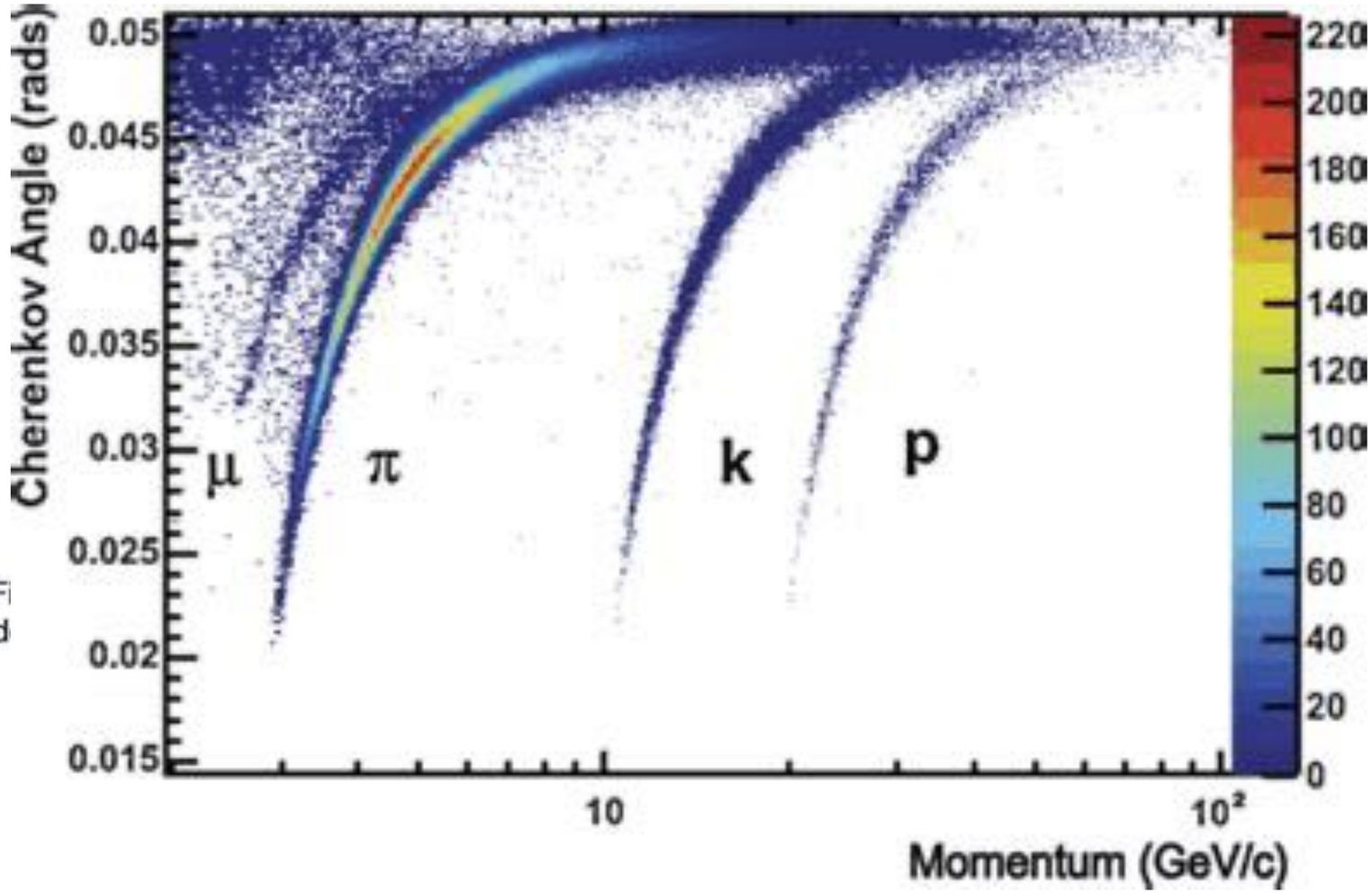
Which particle though ?





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Which particle though ?

How to detect light ?

PMTs : Photomultiplier tubes!

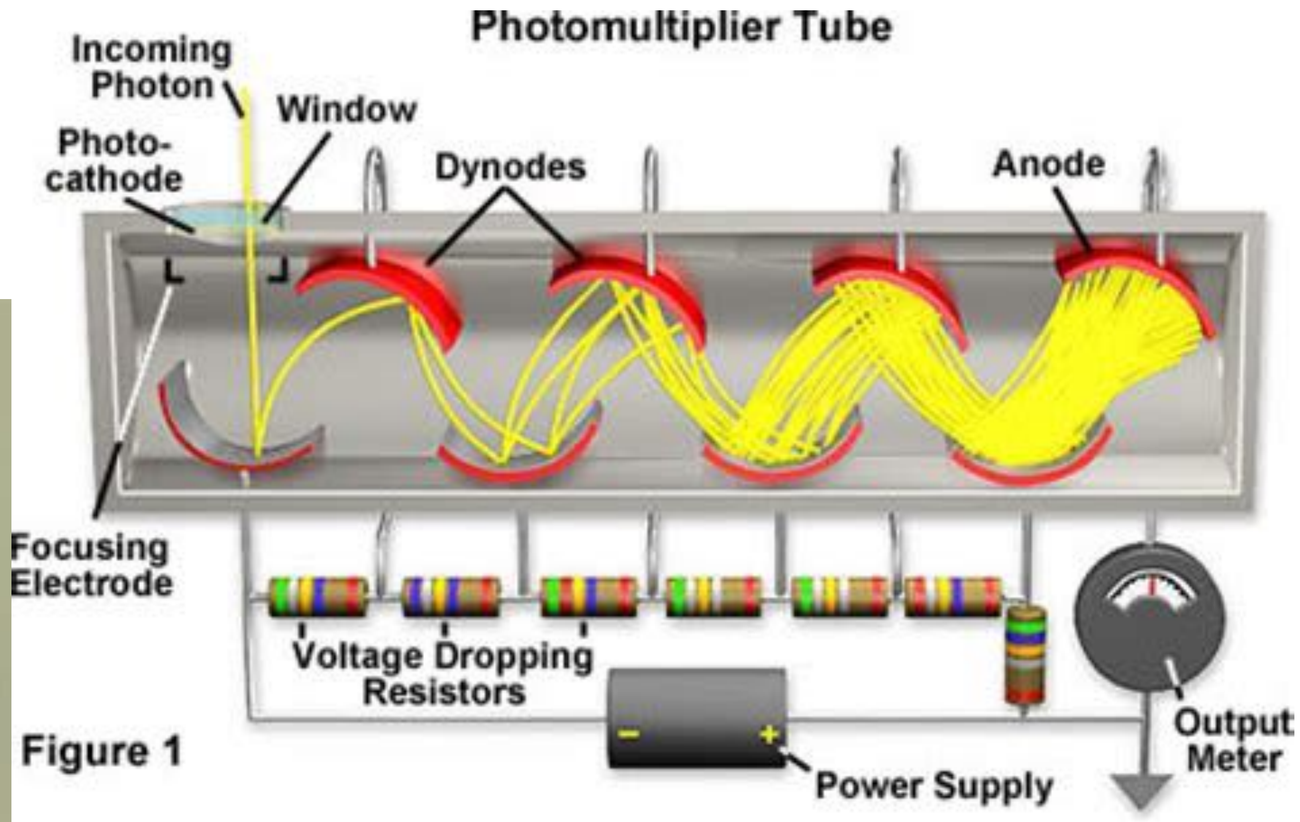

Figure 1

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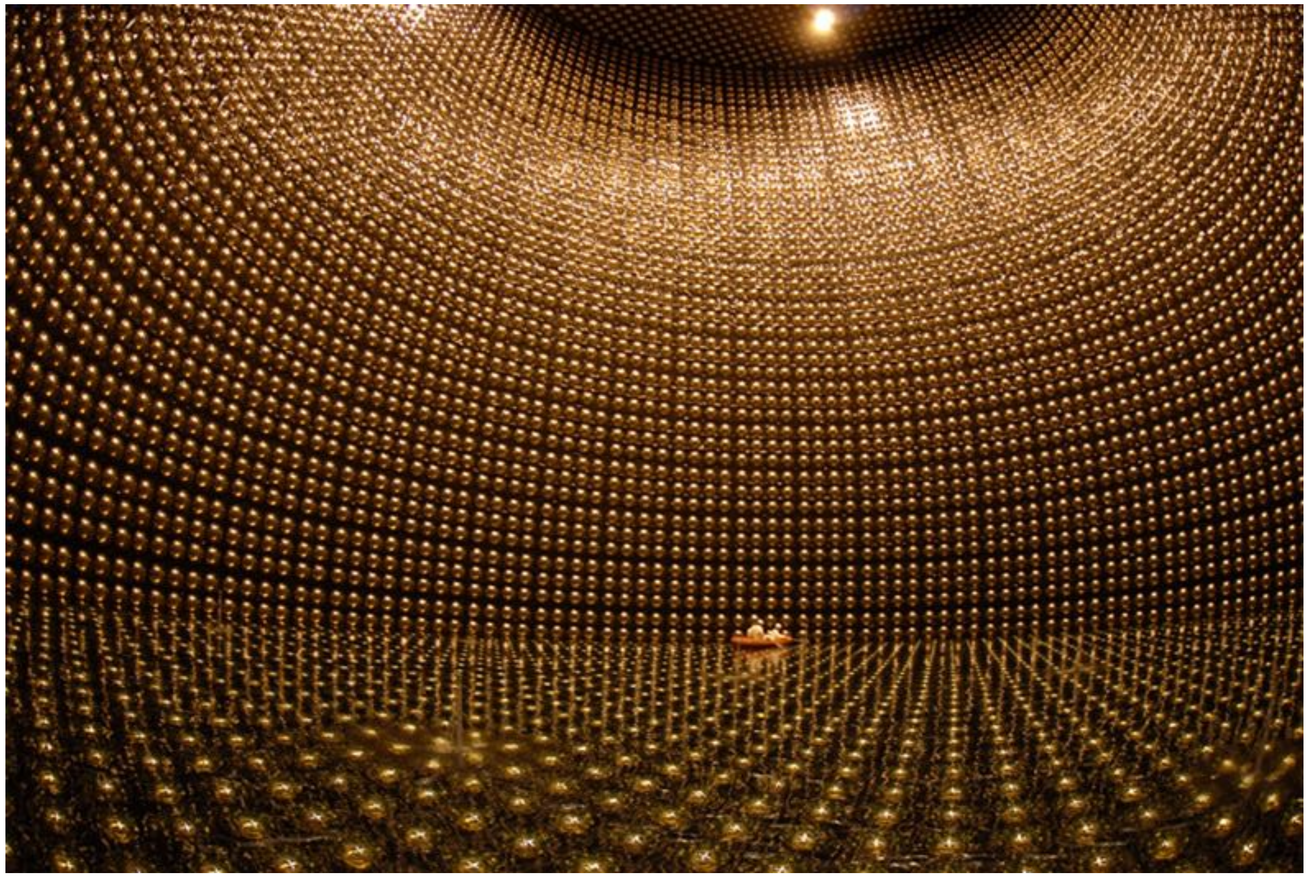
Which particle though ?

How to detect light ?

PMTs : Photomultiplier tubes!

Sometimes, many of them….



Super - Kamiokande, Japan

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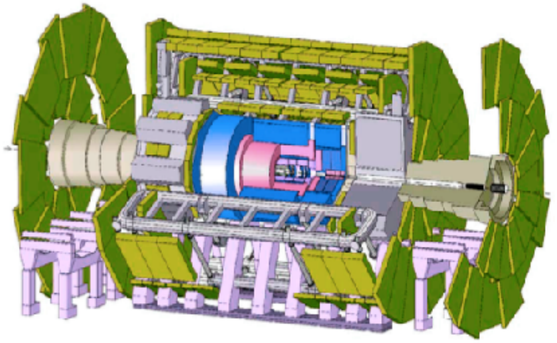
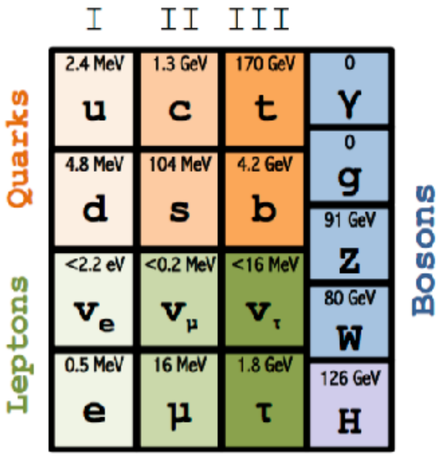
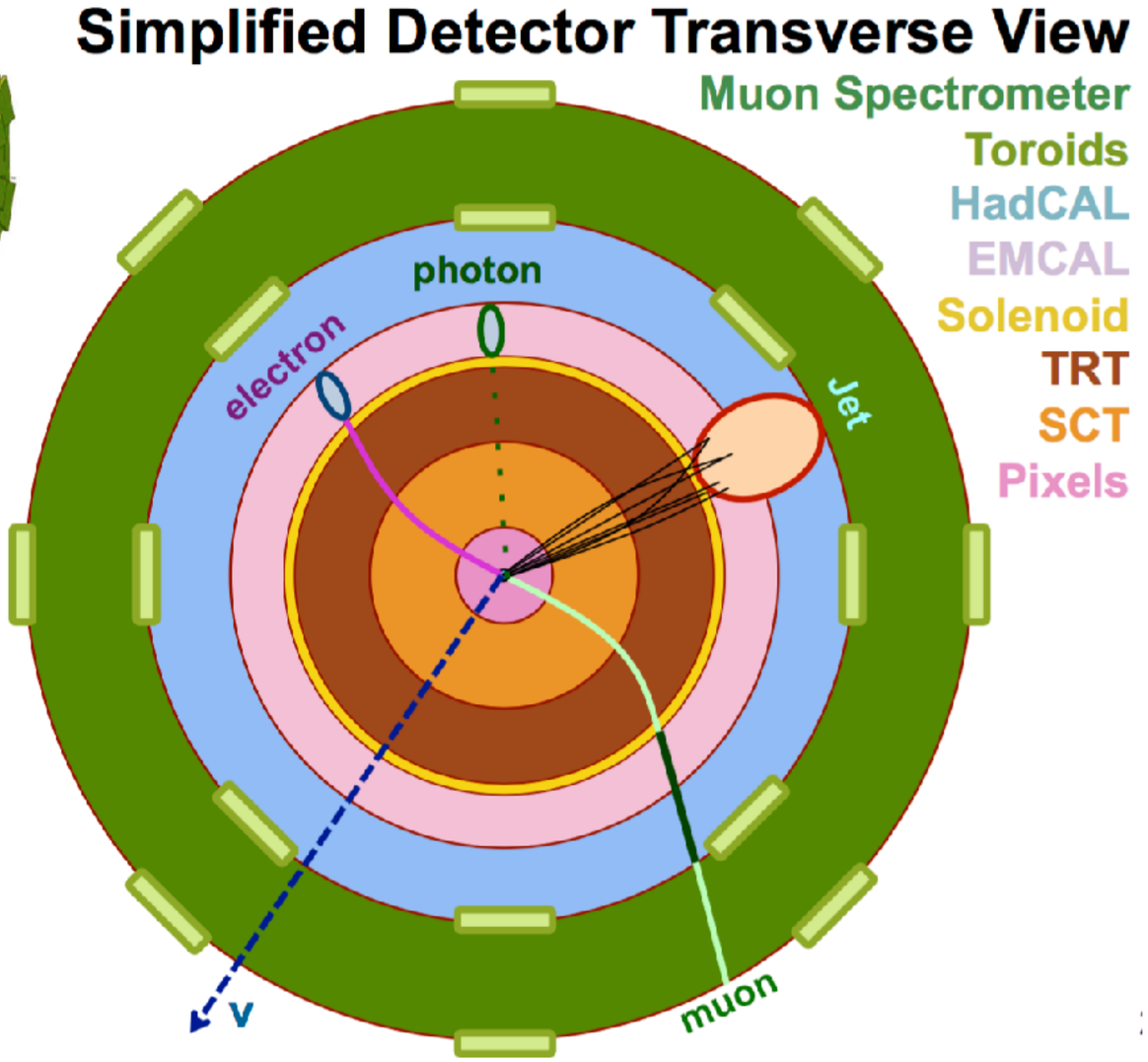
A DETECTOR (E.G. ATLAS)







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