

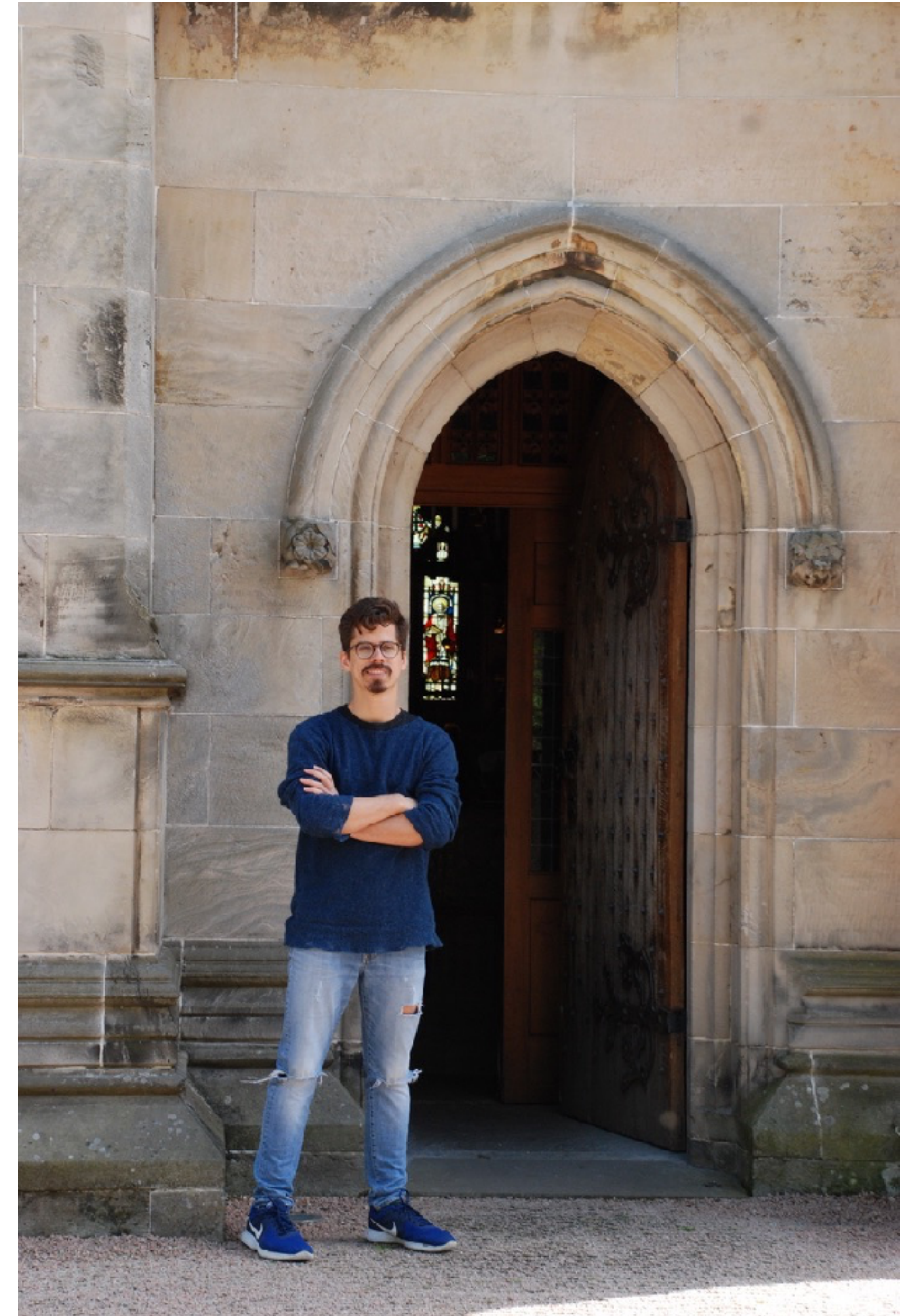
# Introduction to Particle Detection

Liverpool@CERN Particle Physics School

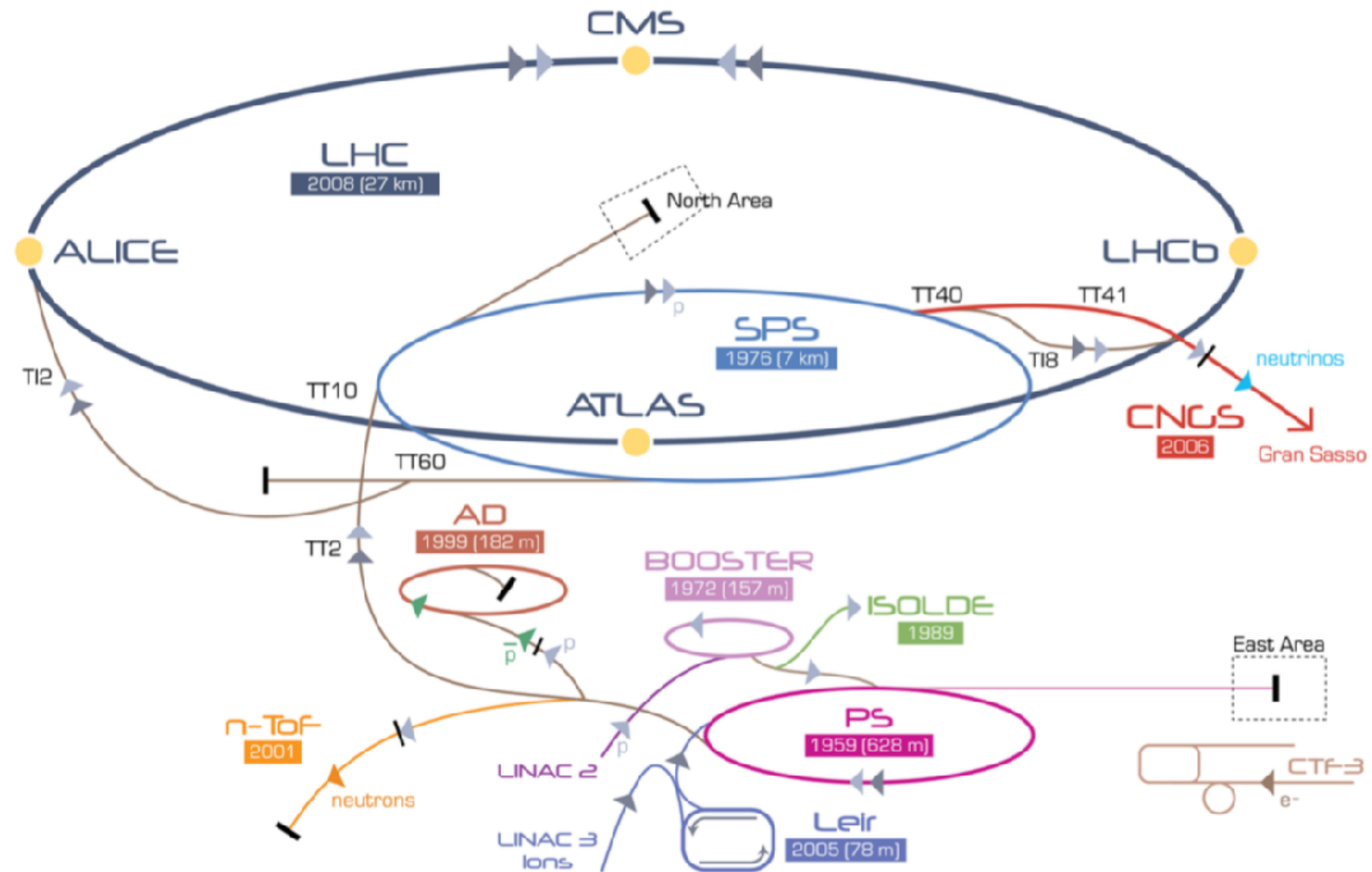
Dr. Vinícius Franco Lima - CERN

# 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.
- Currently I am a CERN Fellow working for the ATLAS Pixel detector.
- When not physics-ing: Music, Martial Arts, Hiking.







▶ p (proton)   ▶ ion   ▶ neutrons   ▶  $\bar{p}$  (antiproton)   ▶ proton/antiproton conversion   ▶ neutrinos   ▶ electron

LHC Large Hadron Collider   SPS Super Proton Synchrotron   PS Proton Synchrotron

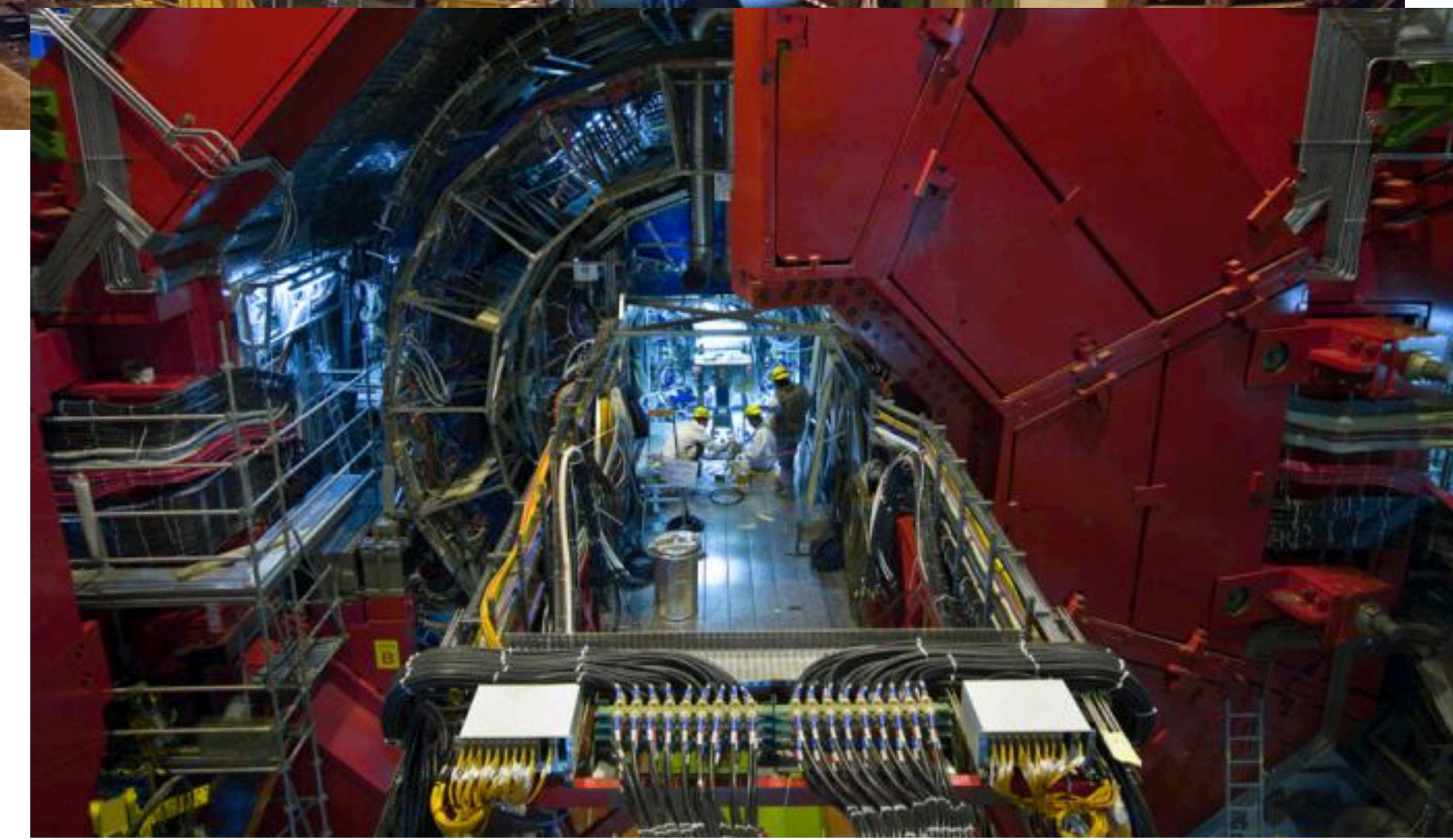
AD Antiproton Decelerator   CTF-3 Clic Test Facility   CNCS CERN Neutrinos to Gran Sasso   ISOLDE Isotope Separator OnLine DEvice

LEIR Low Energy Ion Ring   LINAC LINear ACcelerator   n-ToF Neutrons Time Of Flight

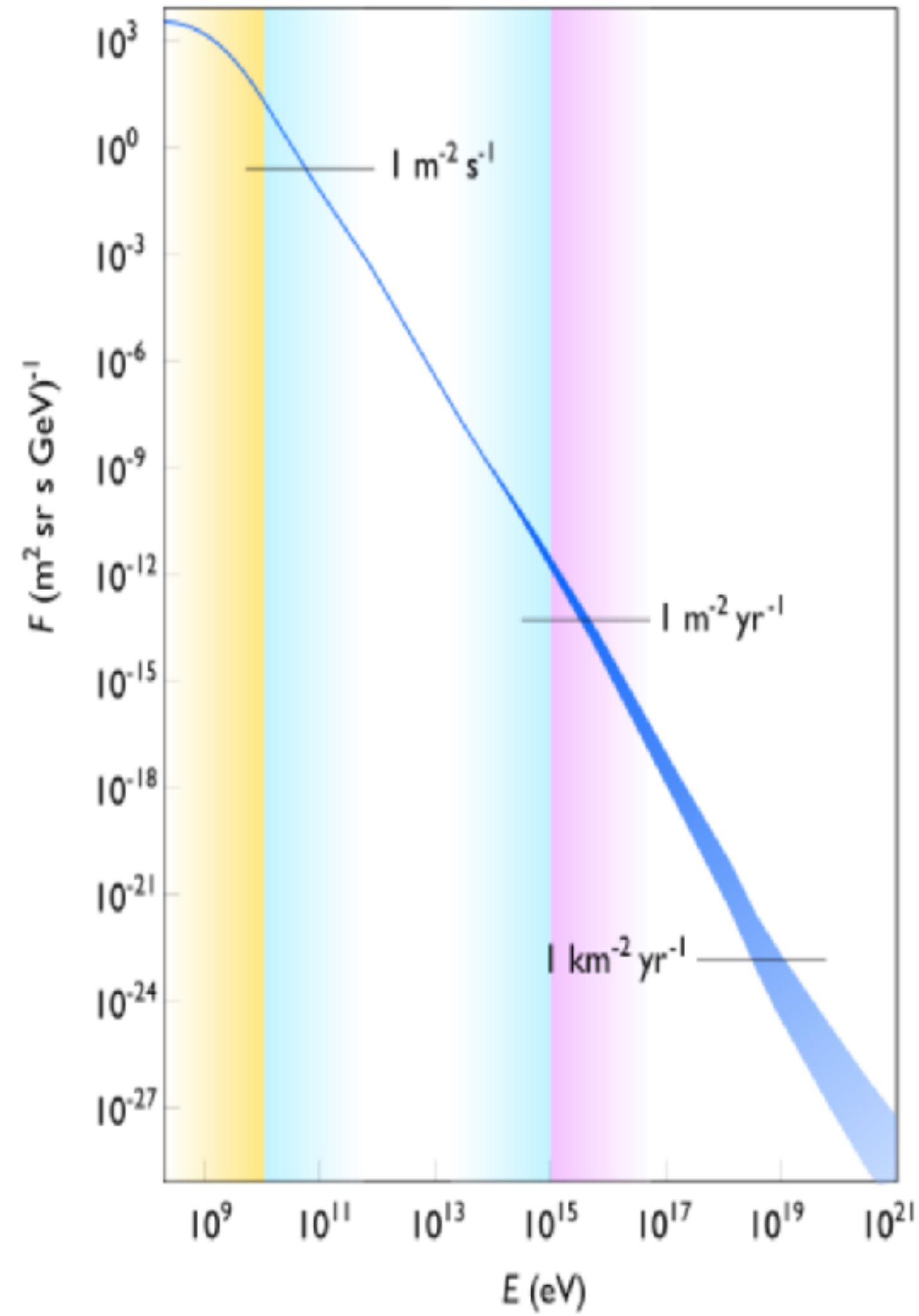
# Hunters



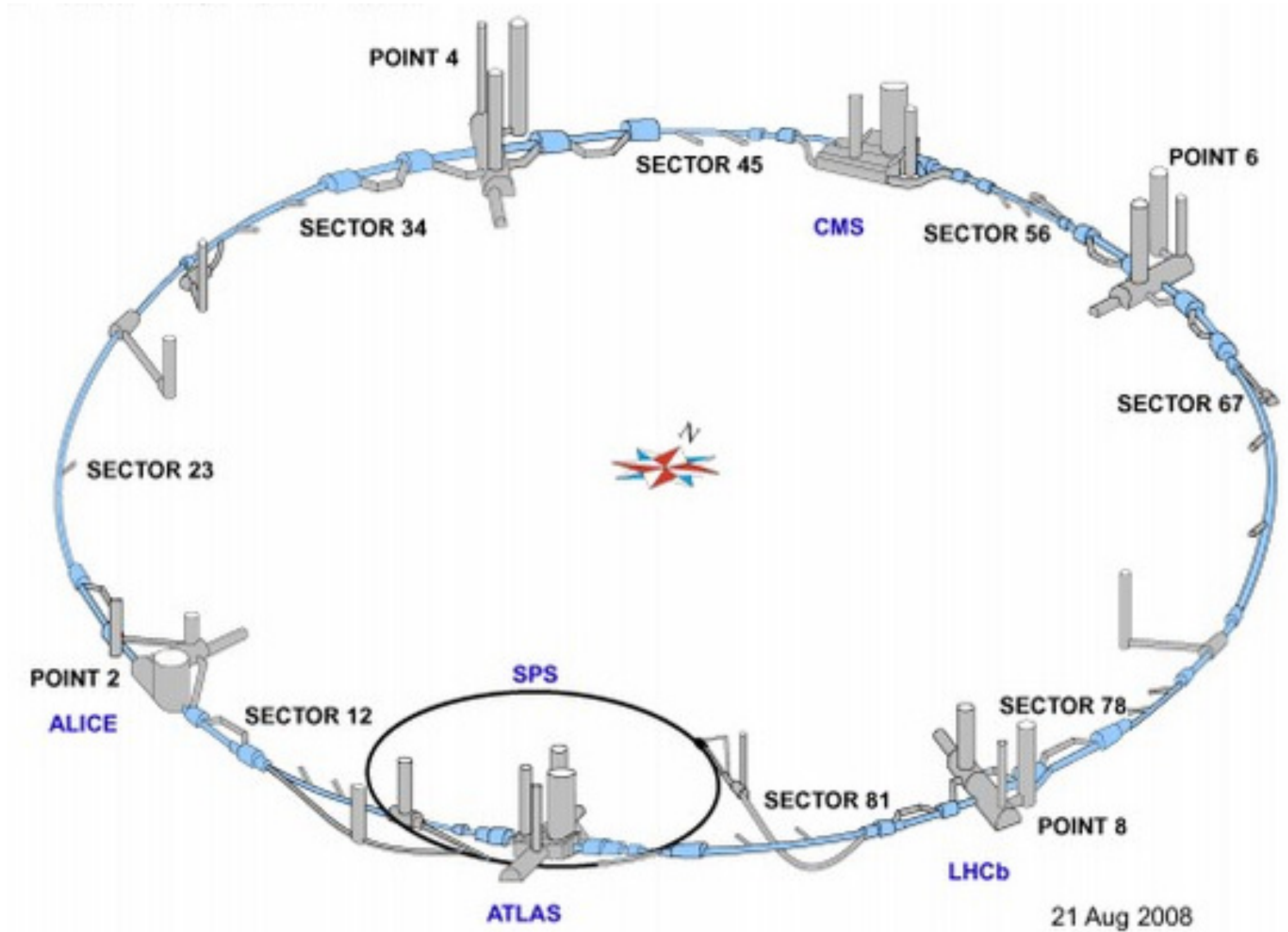
# Farmers



# Hunters

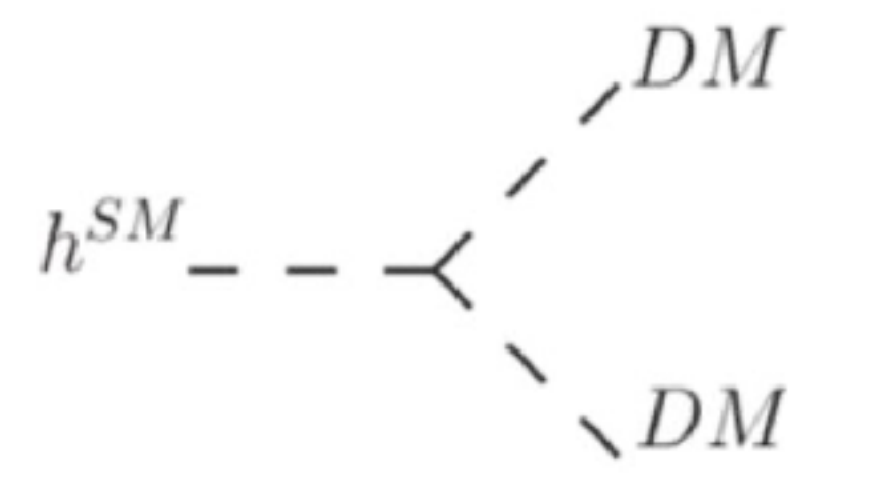
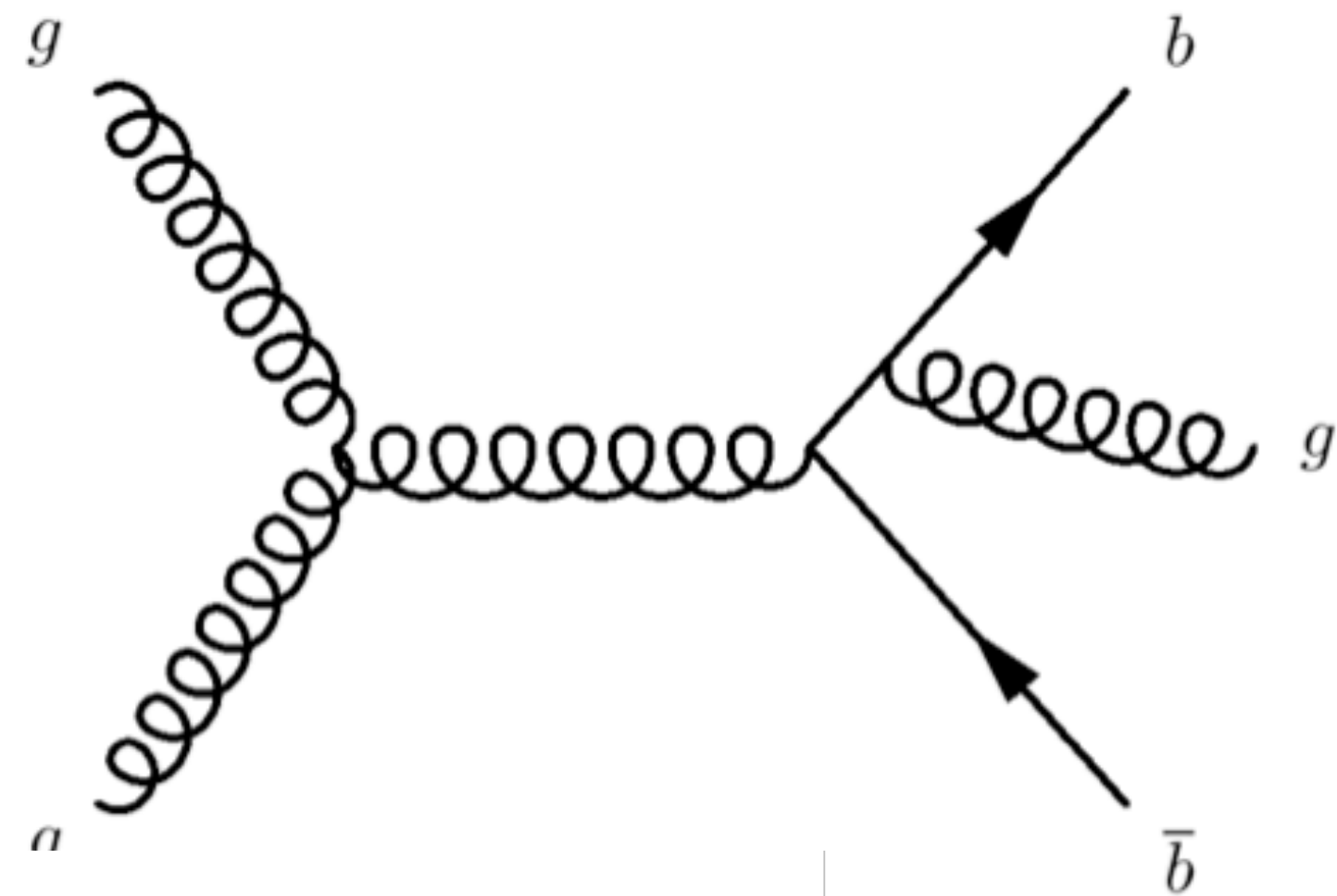


# Farmers

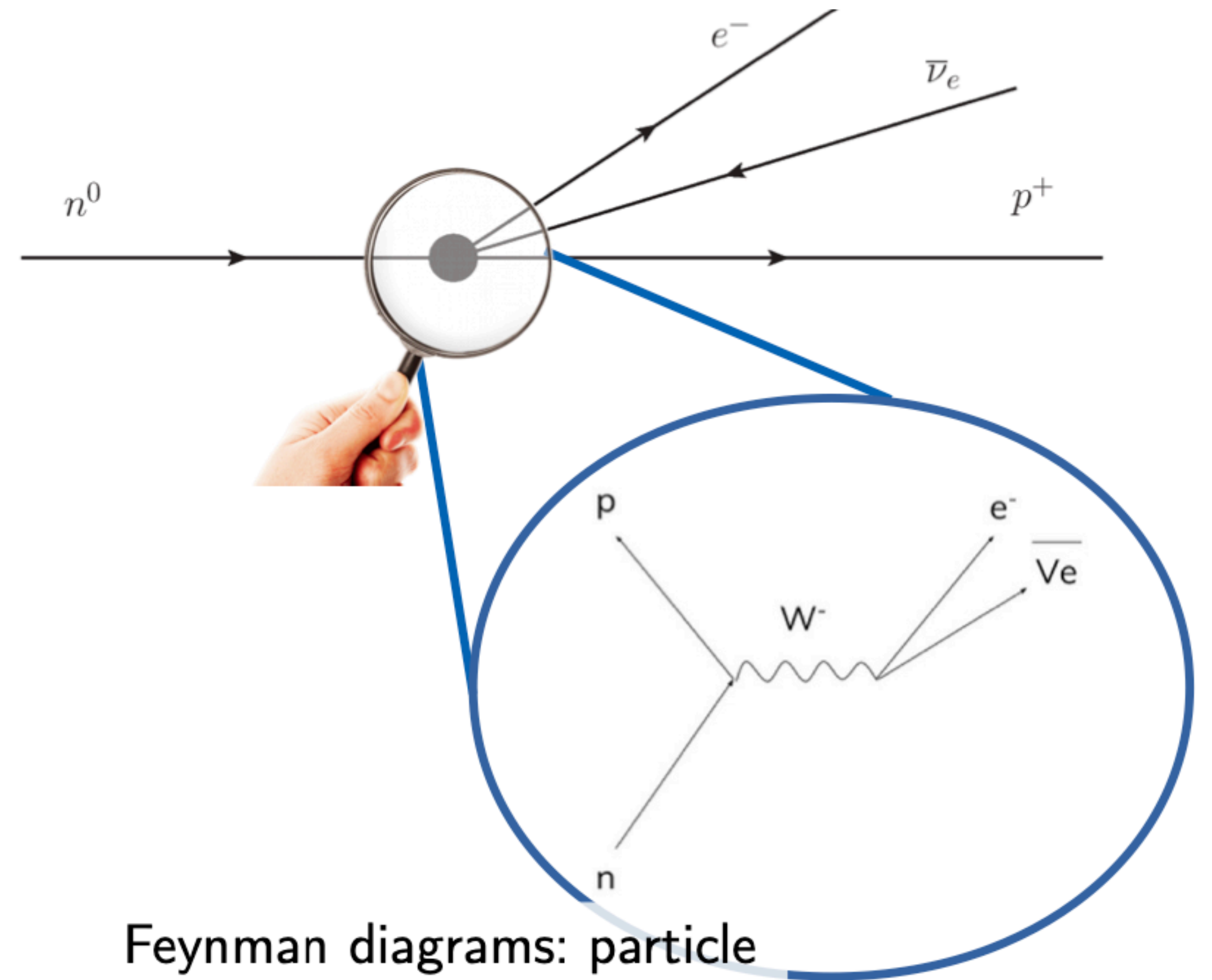


# Particle Physics Experiments

What are we trying to do here?



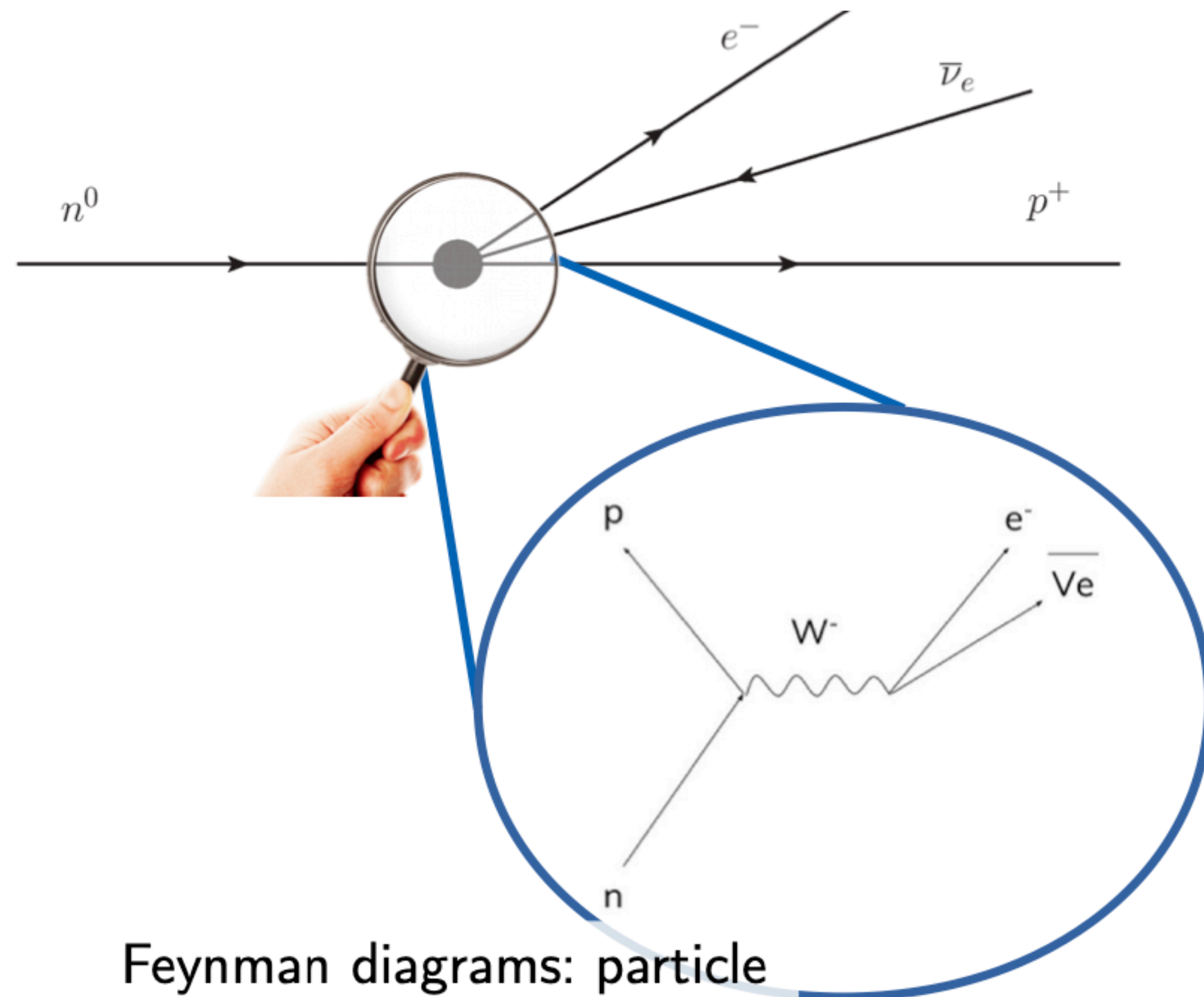
*Many squiggly lines yesterday!  
What do they mean?*



Feynman diagrams: particle physicists' best friends to understand interactions

# Particle Physics Experiments

What are we trying to do here?



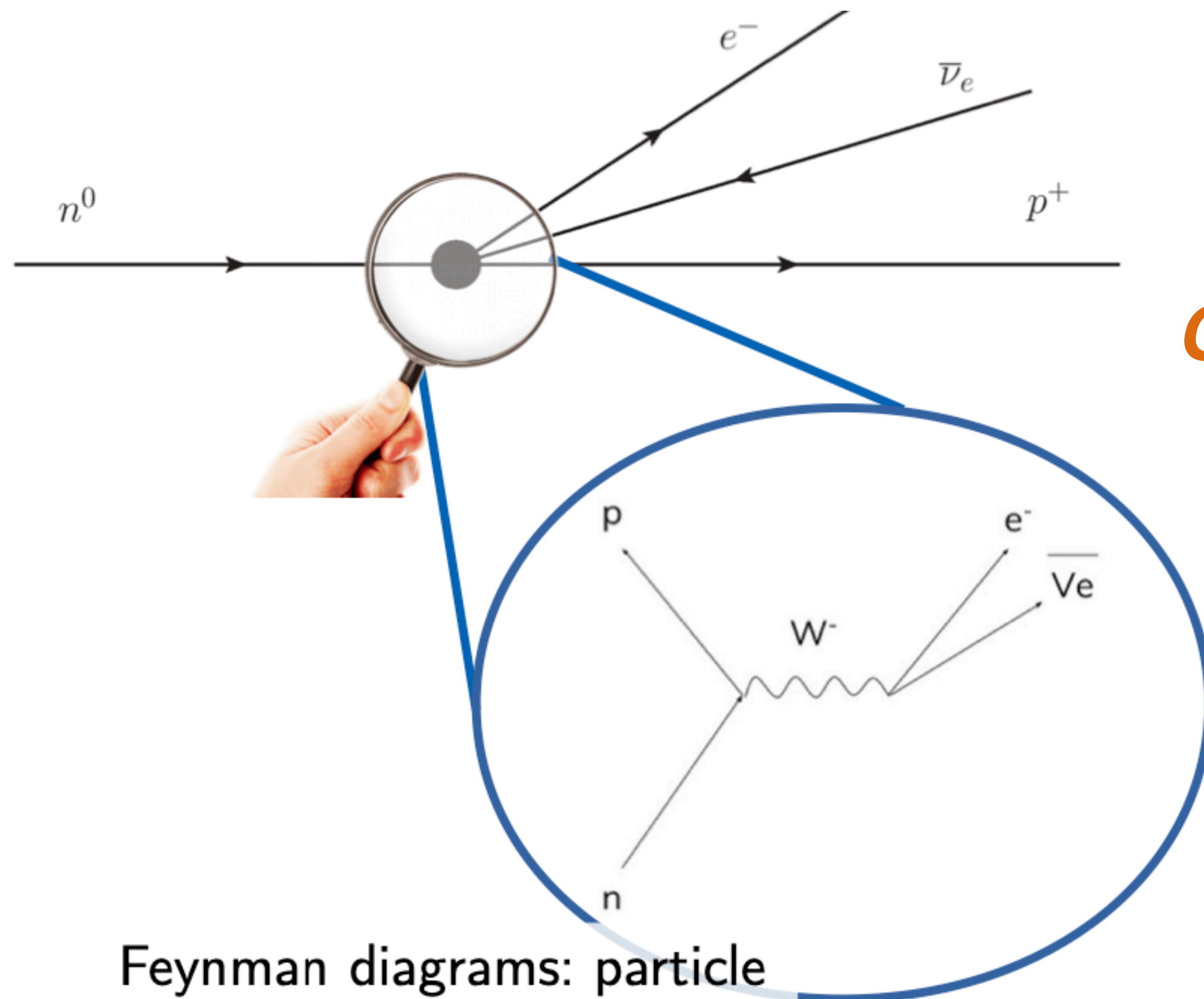
*This picture is great,  
but it is not quite correct .*

Feynman diagrams: particle  
physicists' best friends to  
understand interactions



# Particle Physics Experiments

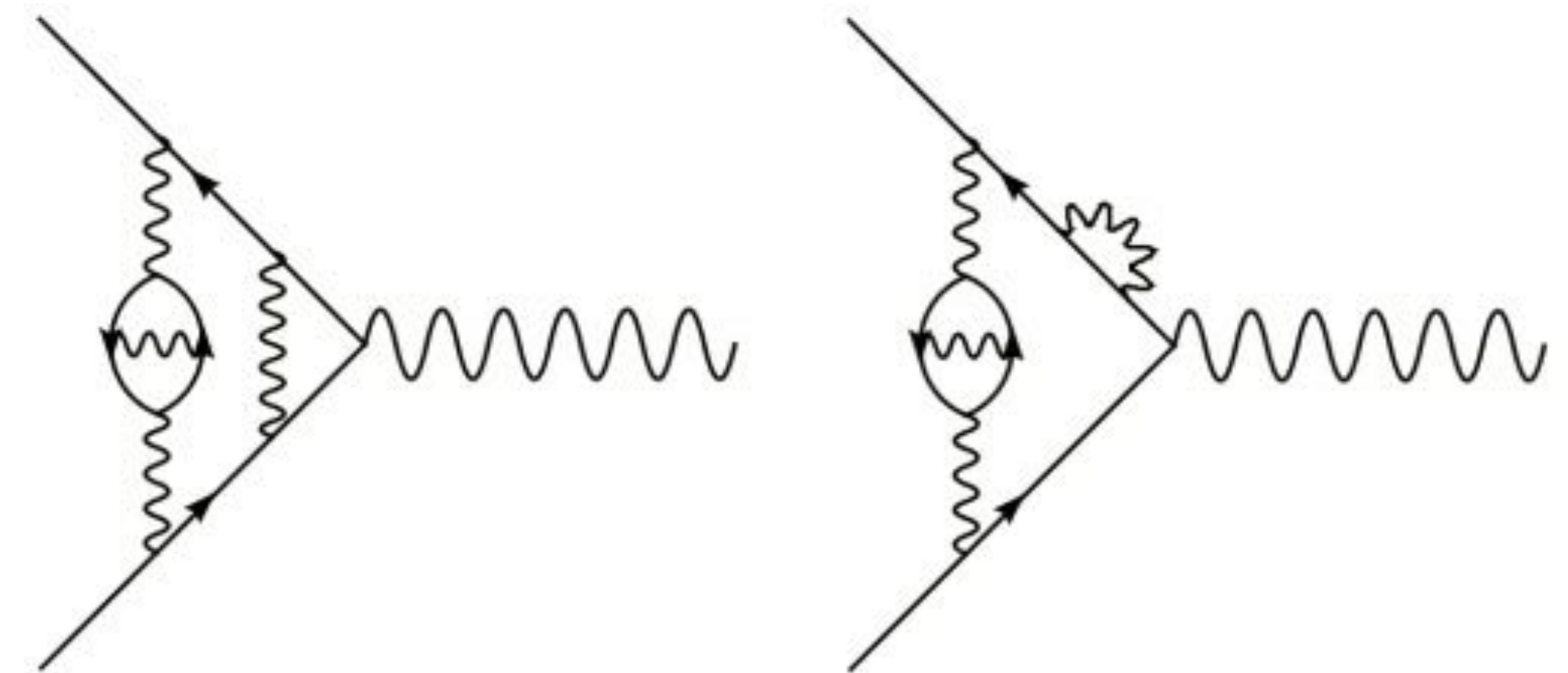
What are we trying to do here?



Feynman diagrams: particle physicists' best friends to understand interactions

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

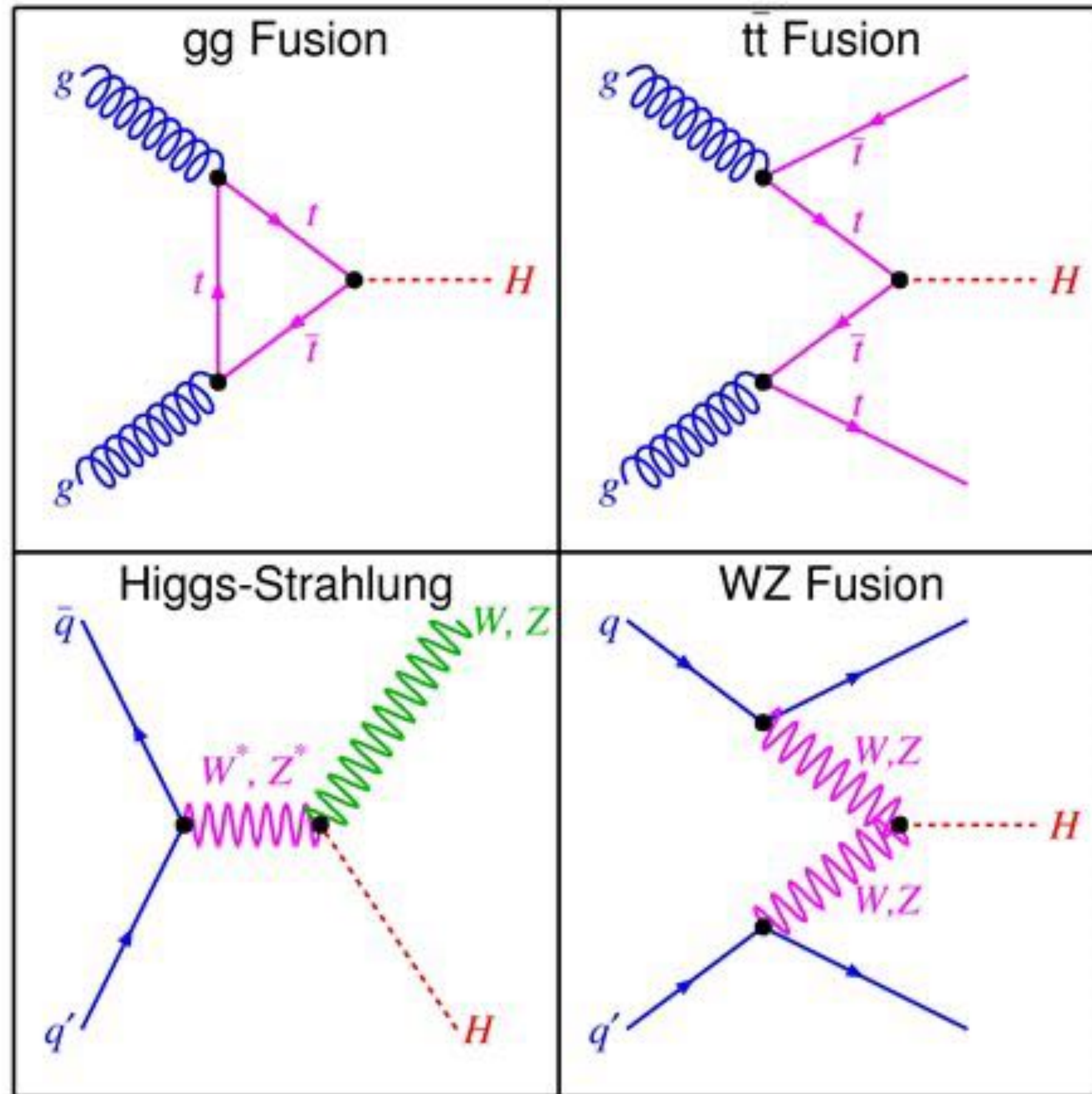
*Quantum Field Theory is that black circle.*



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

# 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.*

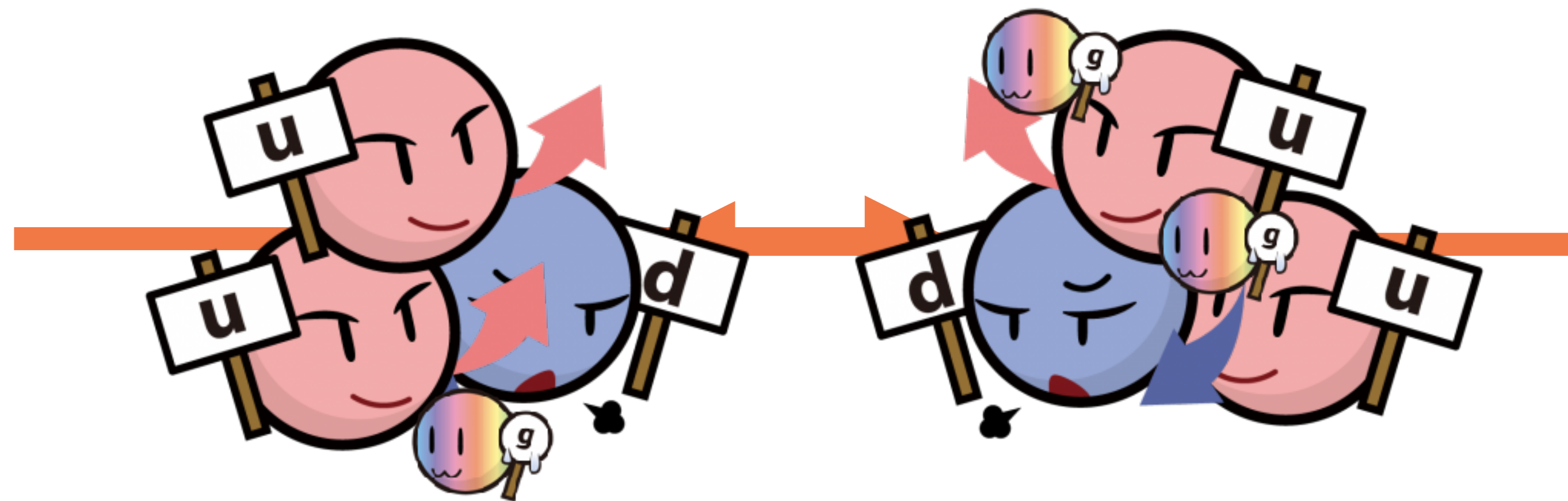
***This is an example of two processes for Higgs production @ LHC***

*This information gives you insight to what fundamental interactions are occurring “under the hood”.*

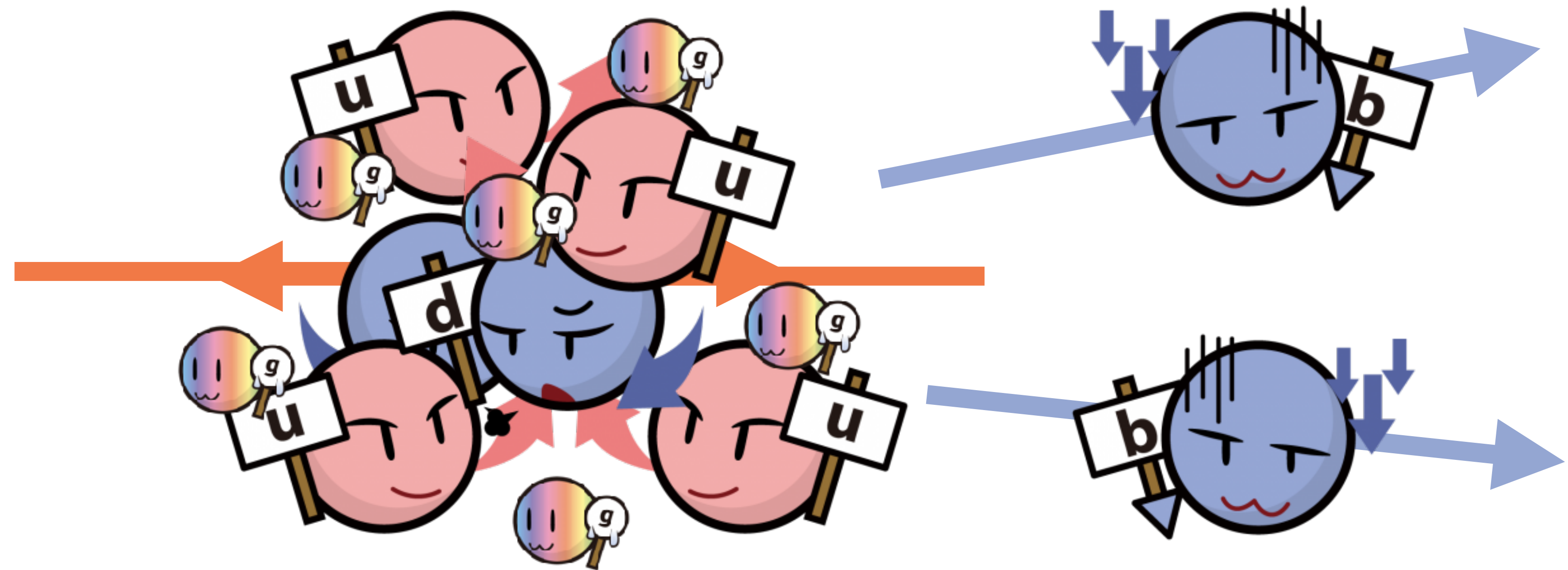
*In LHC...*



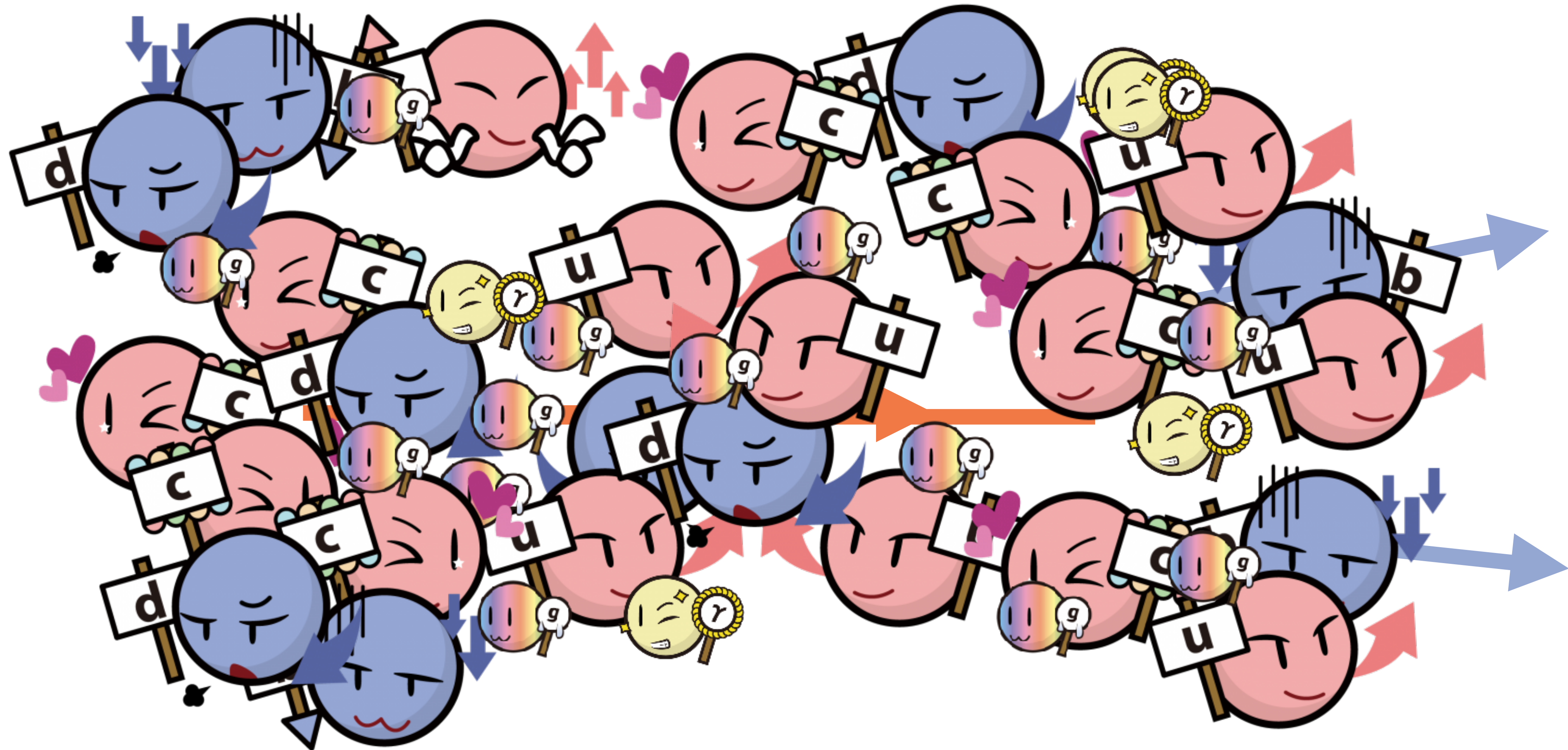
# *In LHC...*



# *In LHC...*

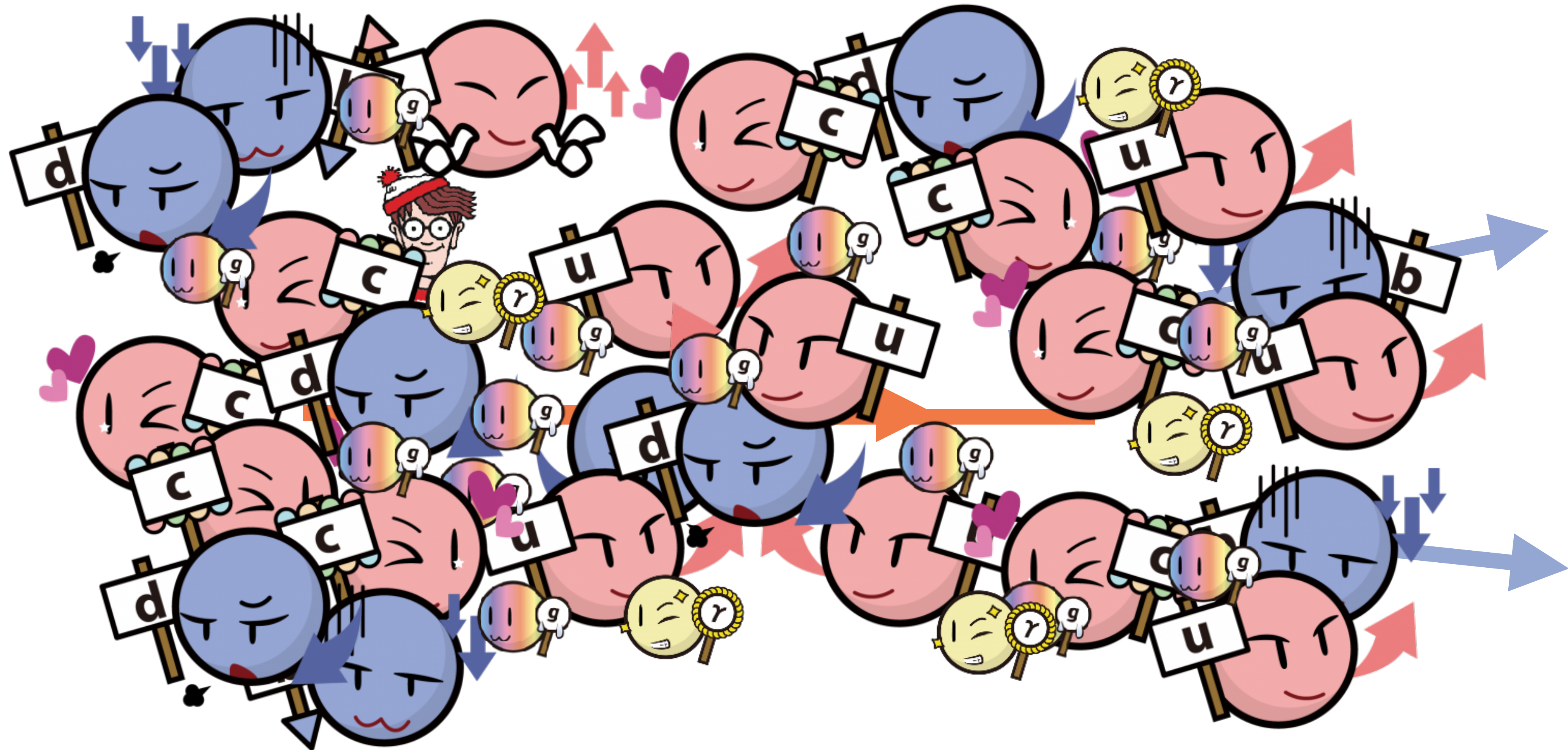


***It really looks way worse than this!***



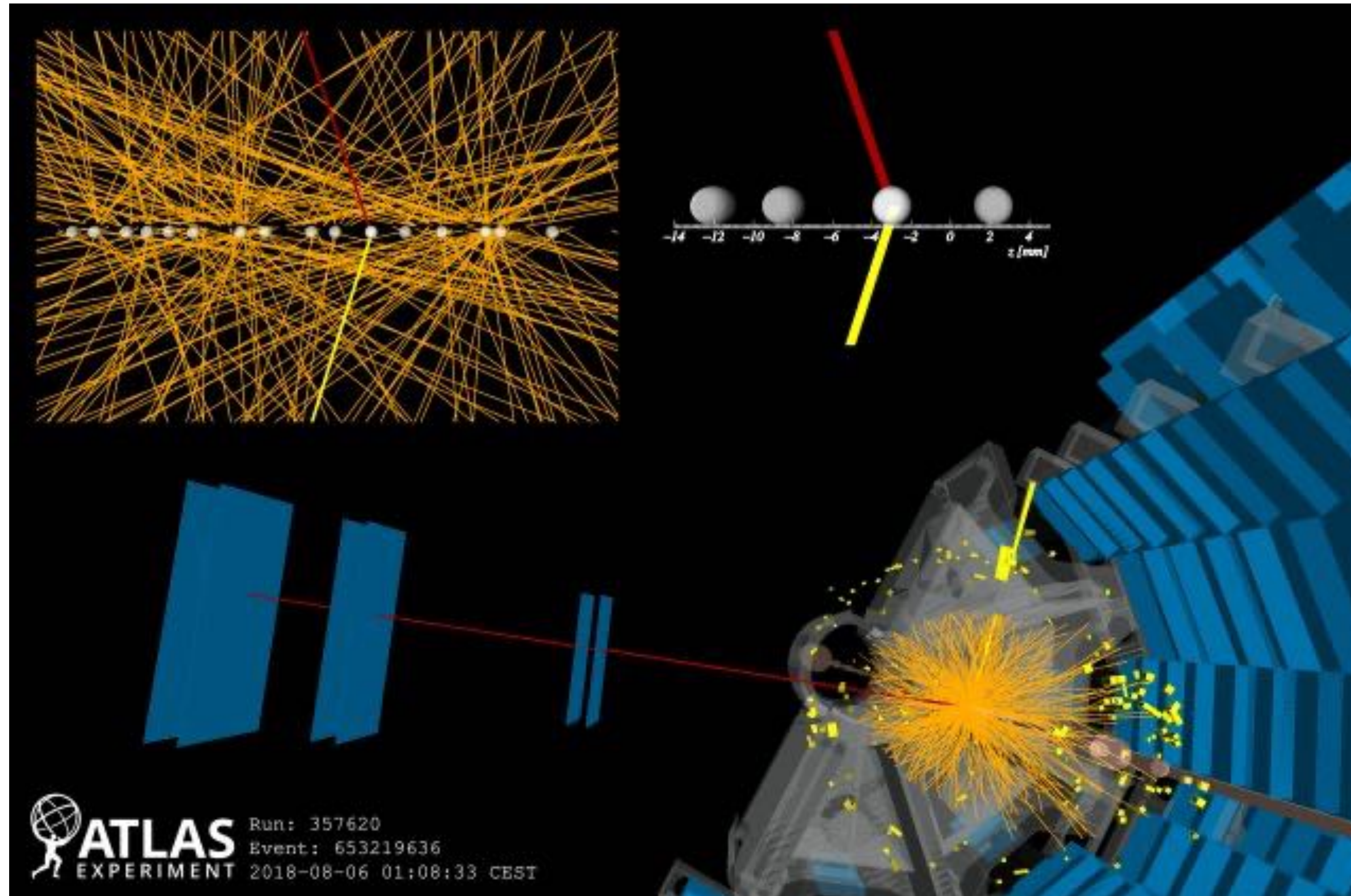
***Average number of simultaneous proton-proton interactions in ATLAS is ~50.***

***It really looks way worse than this!***



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

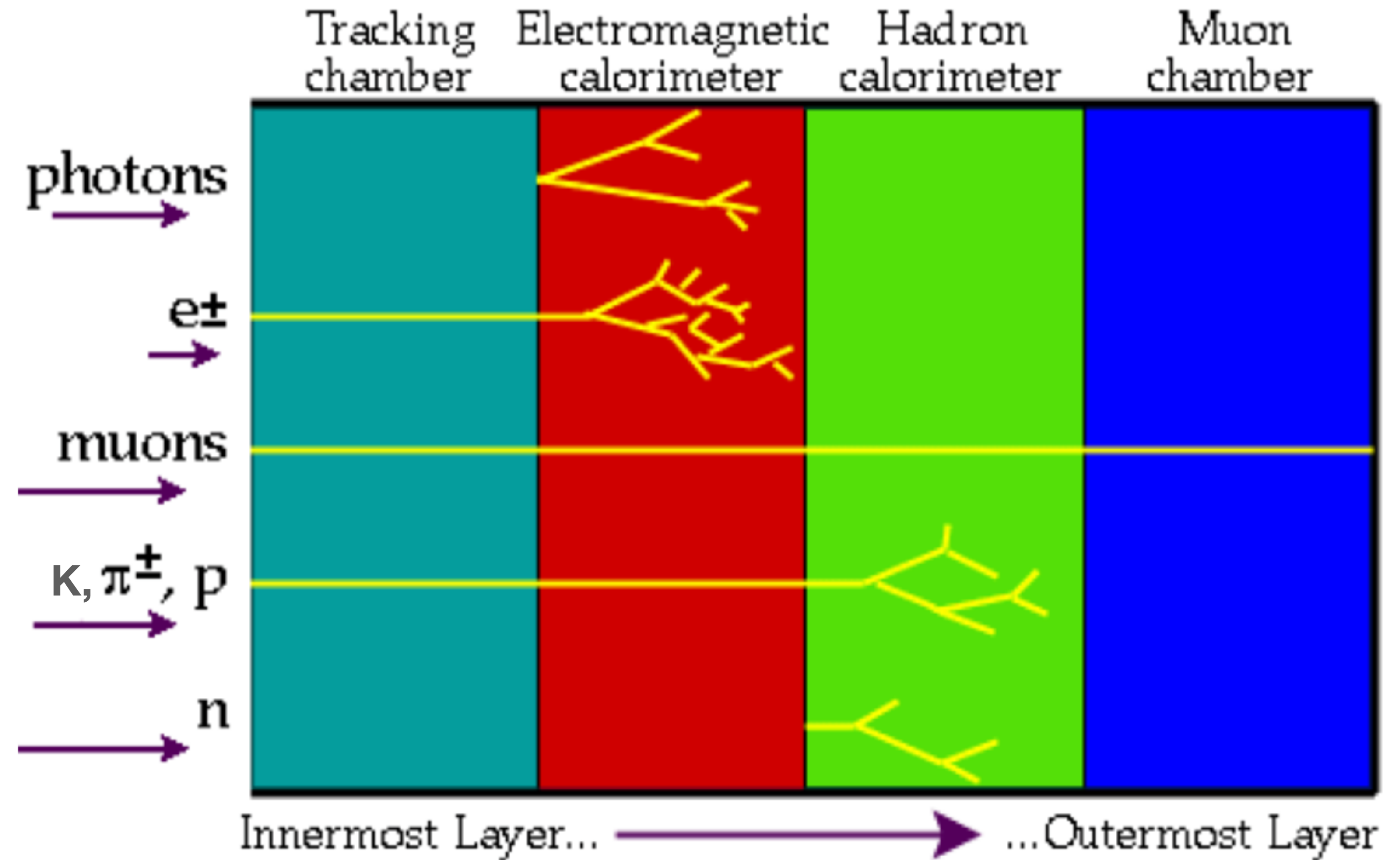
***It really looks way worse than this!***



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

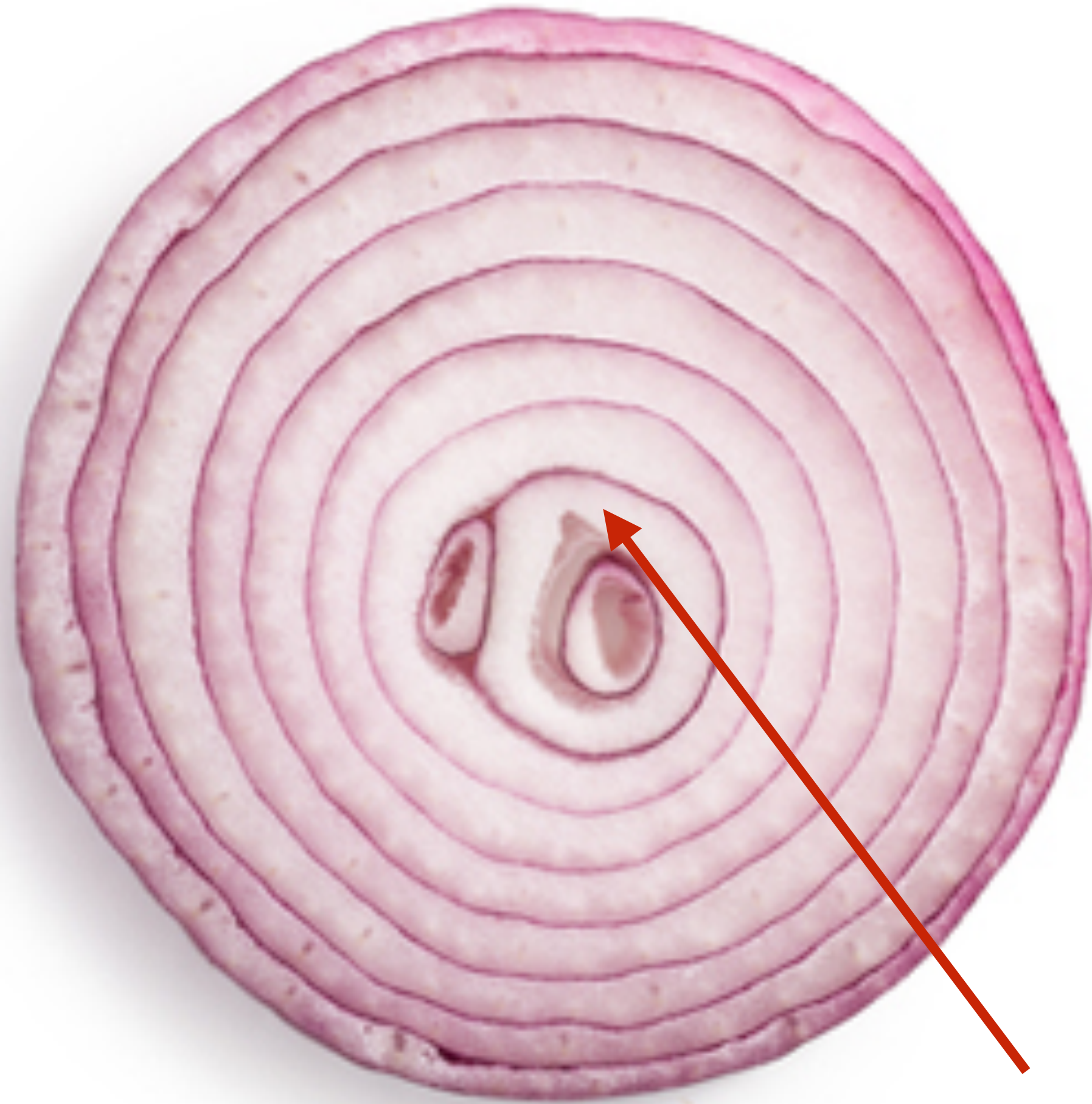


# The one slide to remember



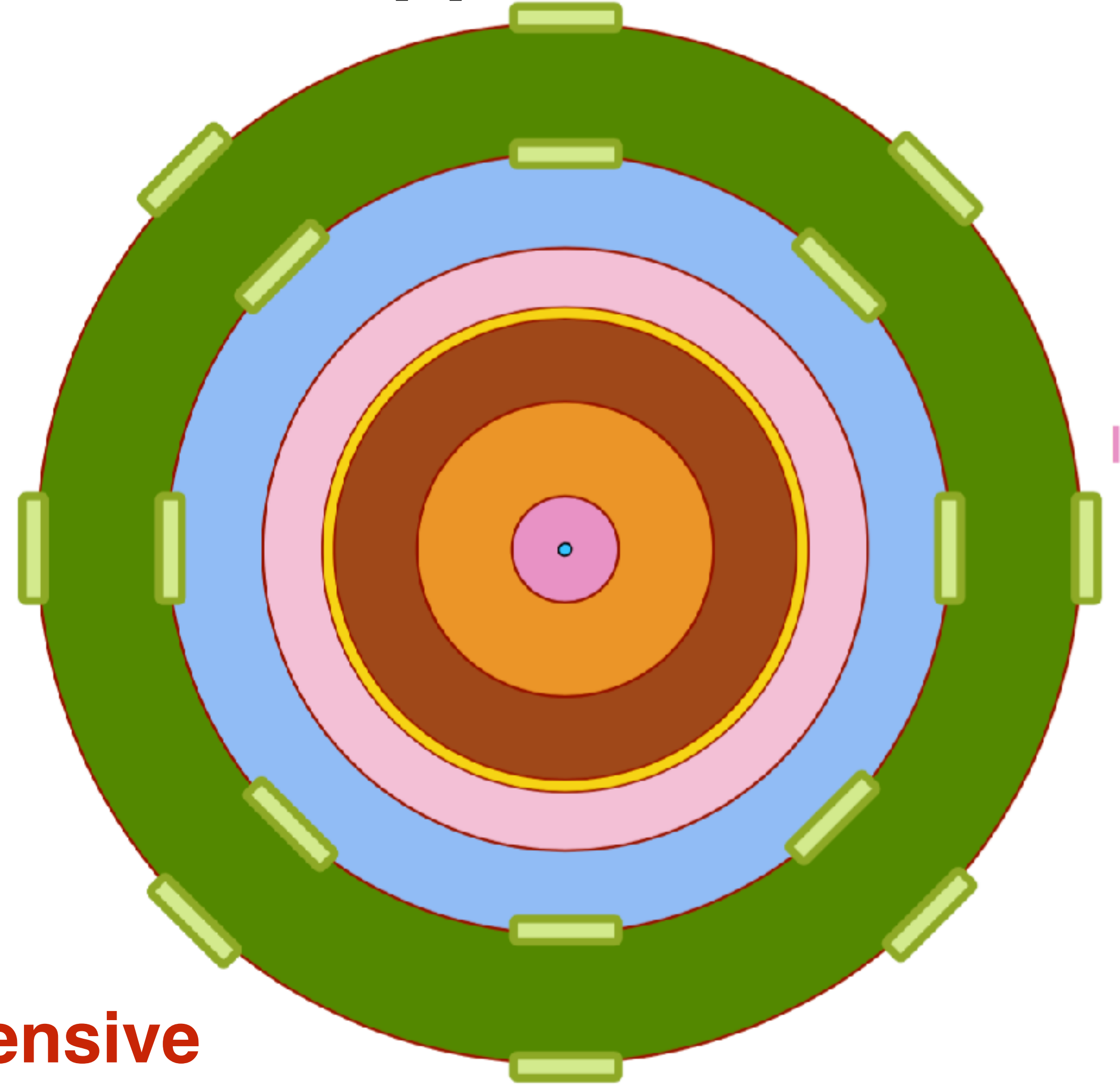
***7 Different “stable” particles leave signals.***

# ***Detectors allow us figure out what happened***

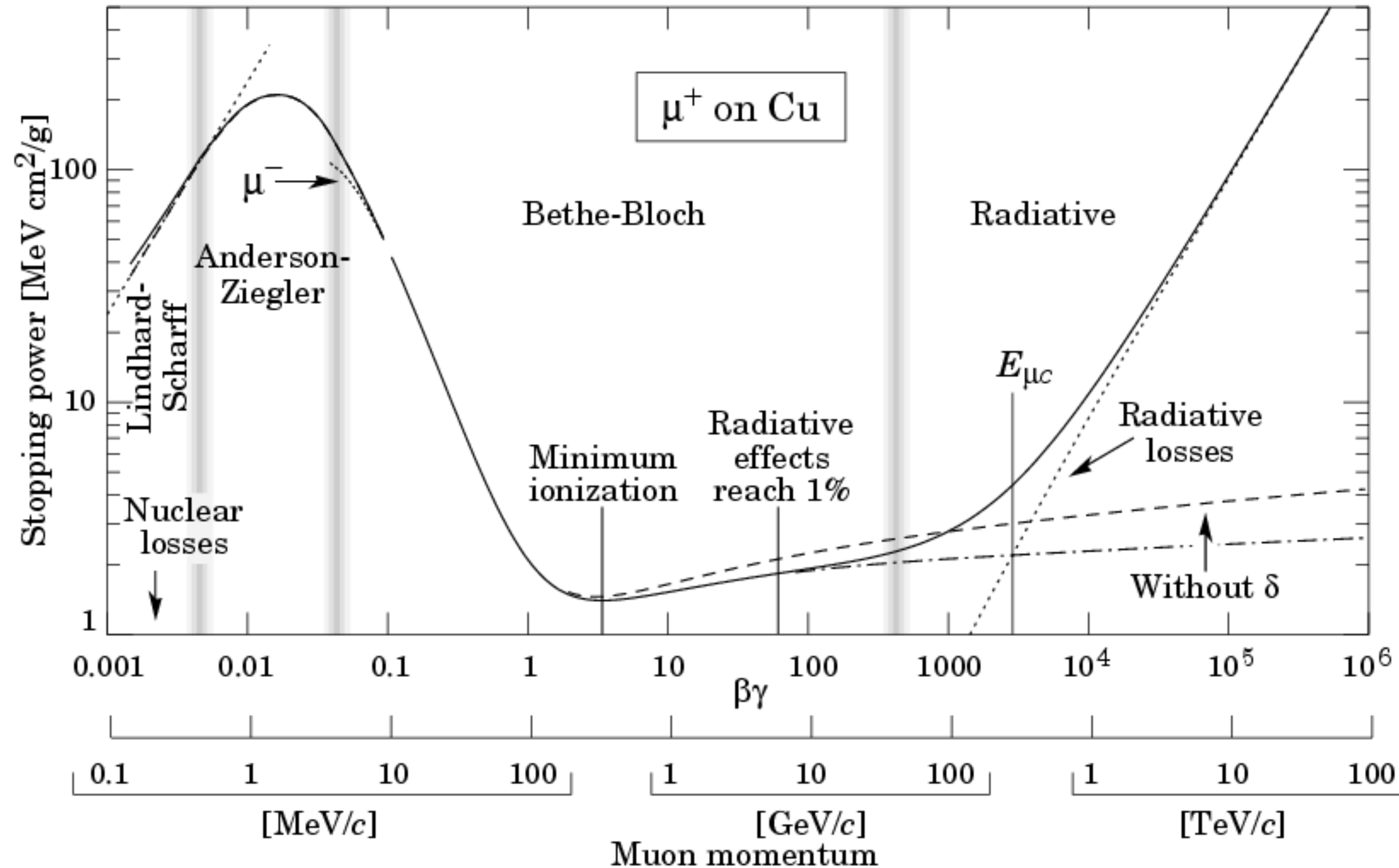


**Less Expensive**

**More expensive**



# Bethe-Bloch Equation



*How do charged particles interact with matter?*

***Ionisation!***

$$-\frac{dE}{dx} = \frac{4\pi e^4 z^2 N Z}{(4\pi\epsilon_0)^2 M_e v^2} \left[ \ln \left( \frac{2M_e v^2}{I} \right) - \ln(1 - \beta^2) - \beta^2 \right]$$

# Did a particle pass through here?

*Did it generate any charge ?*

*We have to collect this charge to figure it out!*



*Detector Volume*

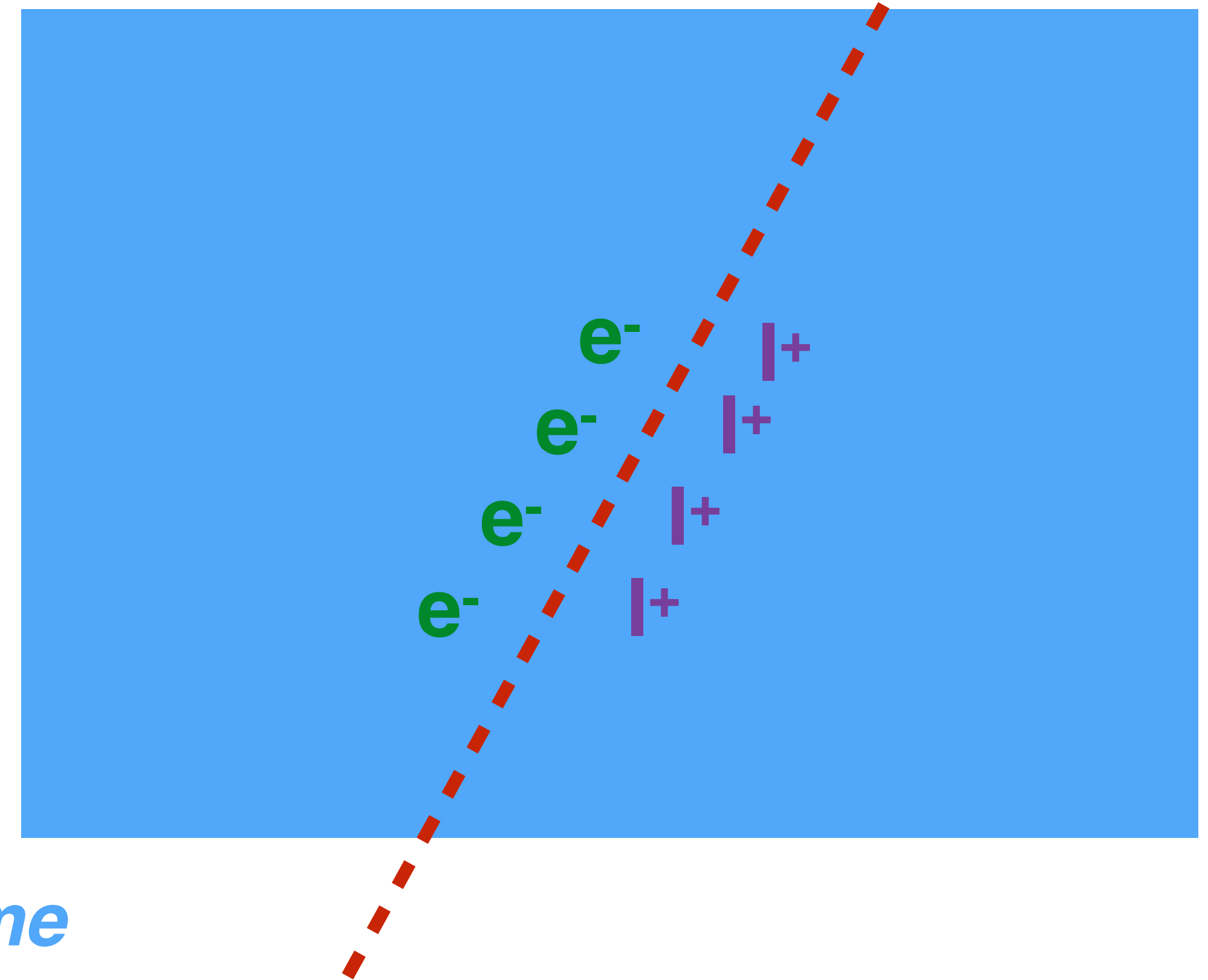
# Did a particle pass through here?

*Did it generate any charge ?*

*We have to collect this charge to figure it out!*

*Detector Volume*

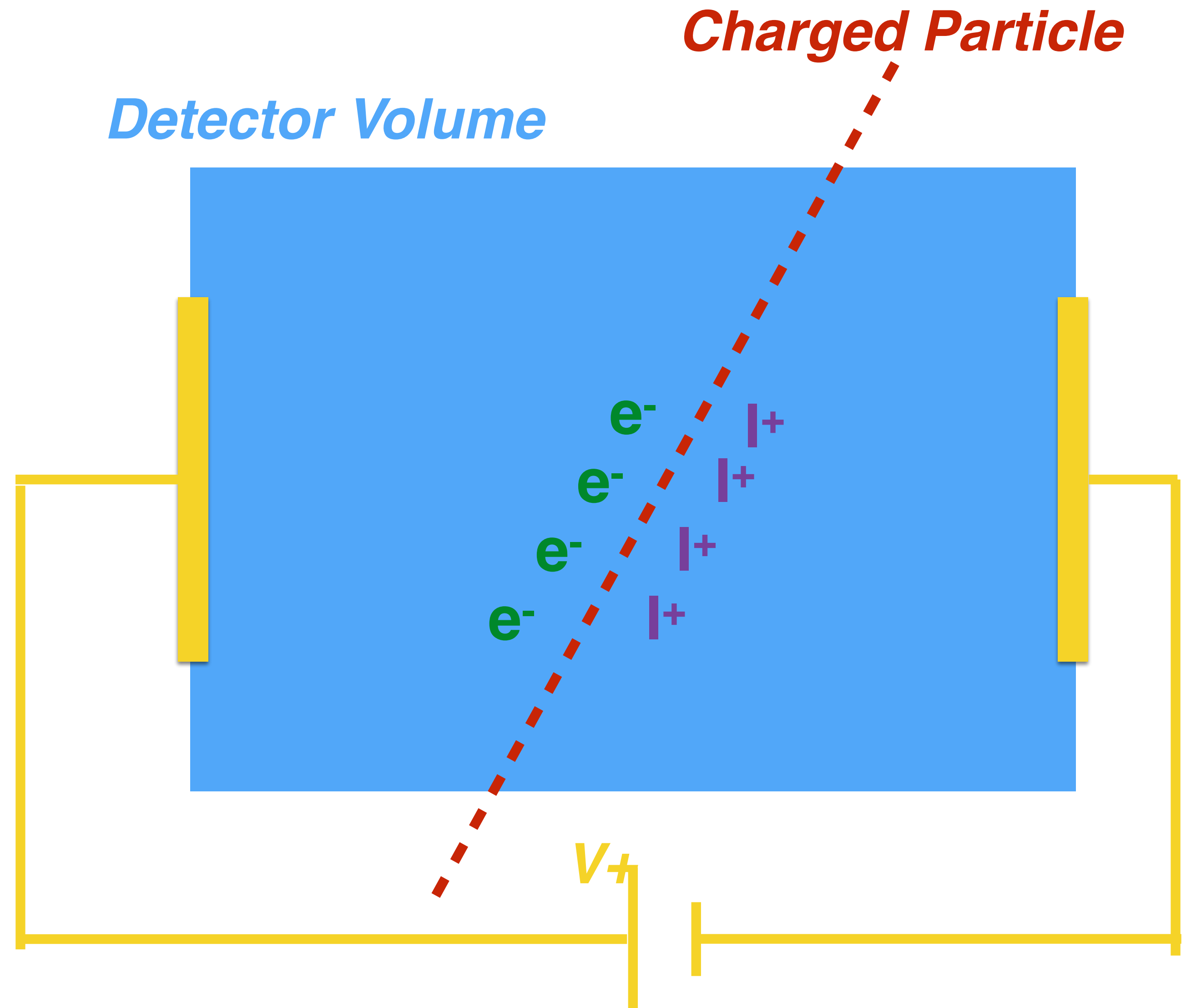
*Charged Particle*



# Did a particle pass through here?

*Did it generate any charge ?*

*We have to collect this charge to figure it out!*



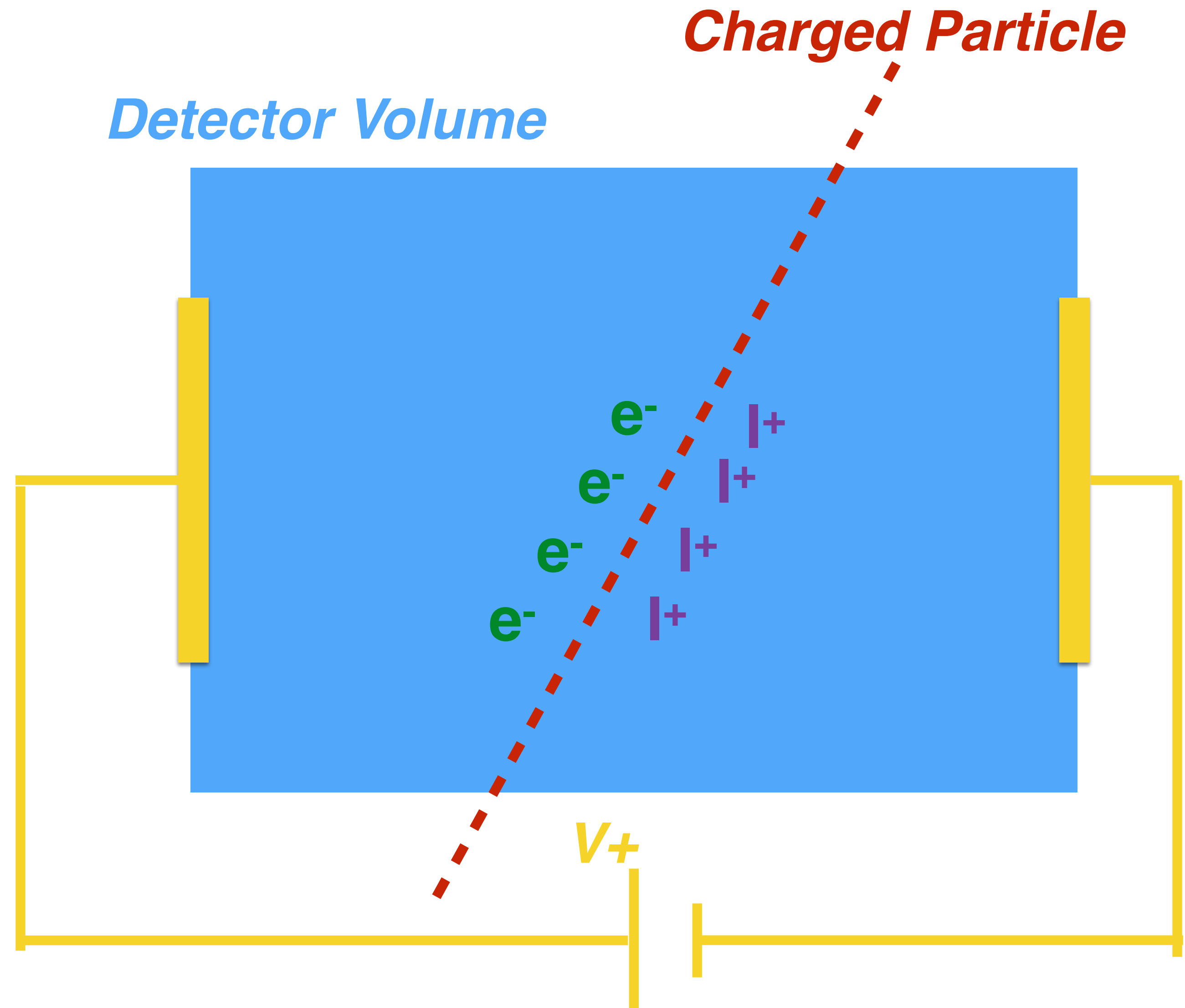
# Did a particle pass through here?

*Did it generate any charge ?*

*We have to collect this charge to figure it out!*

*Electric field drifts free charges away.*

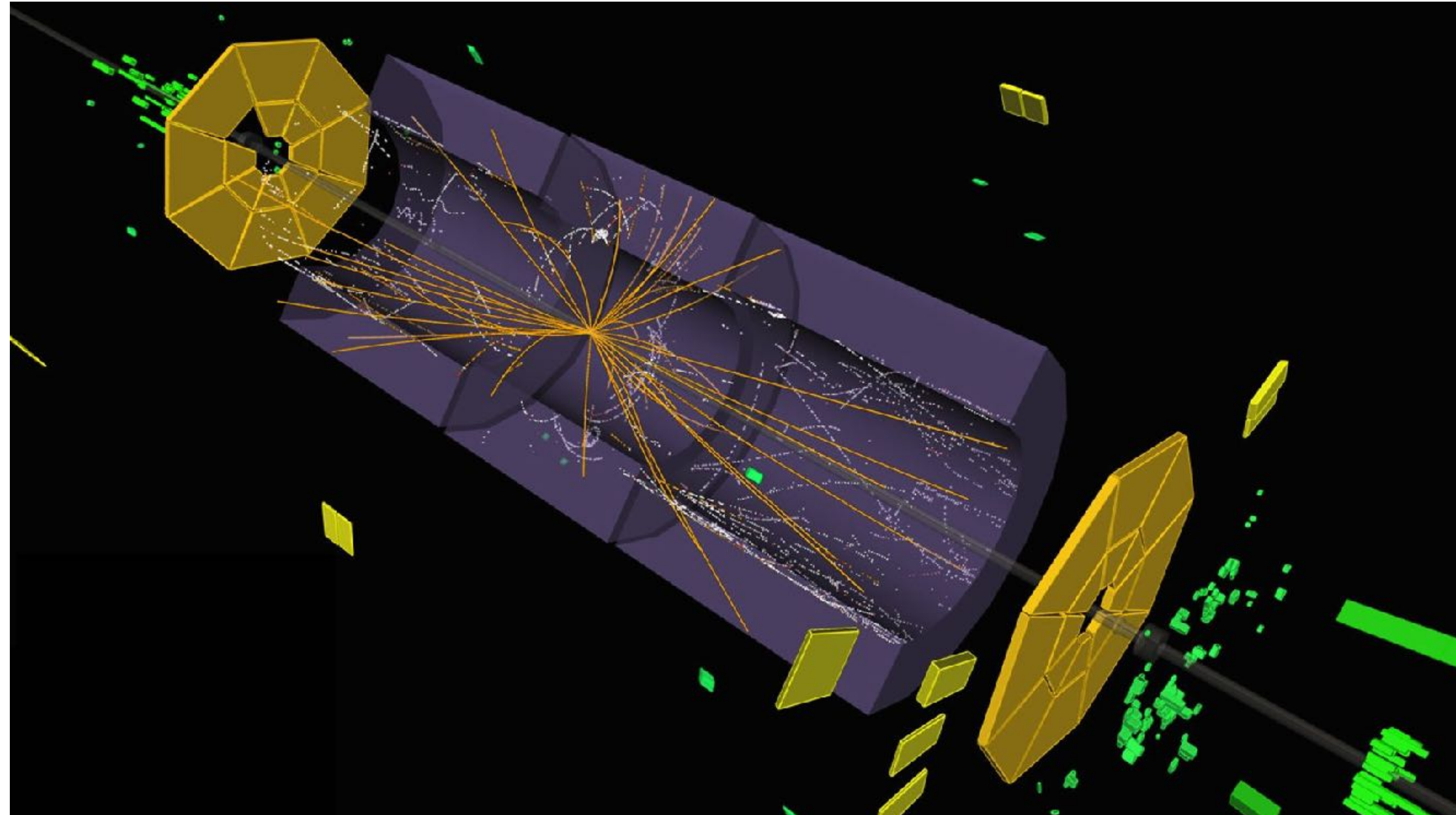
*Electronics measure how much charge drifted at any point in time.*



# 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...*





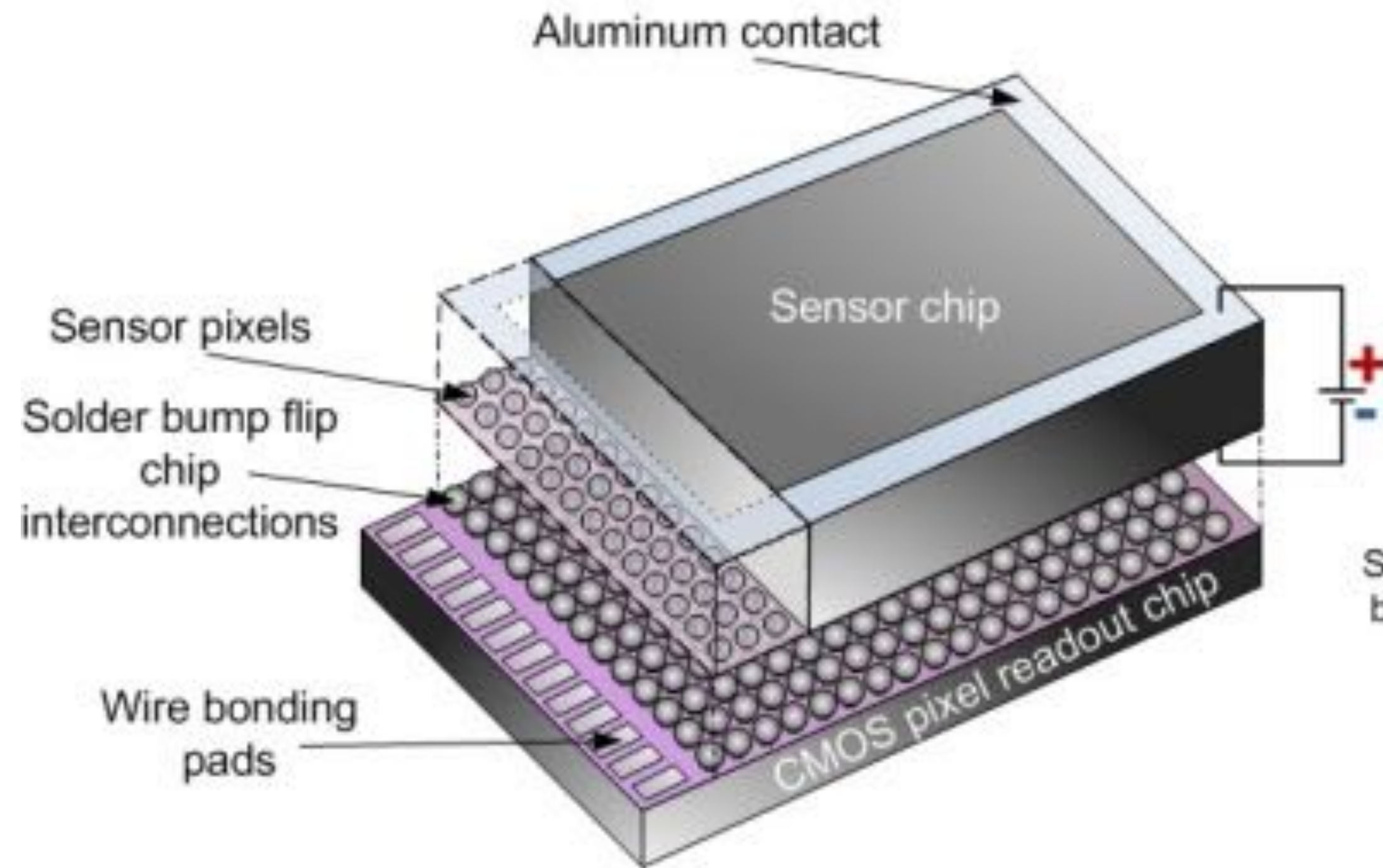
# Did a particle pass through here?

*Now you know how to make  
a tracking detector!*

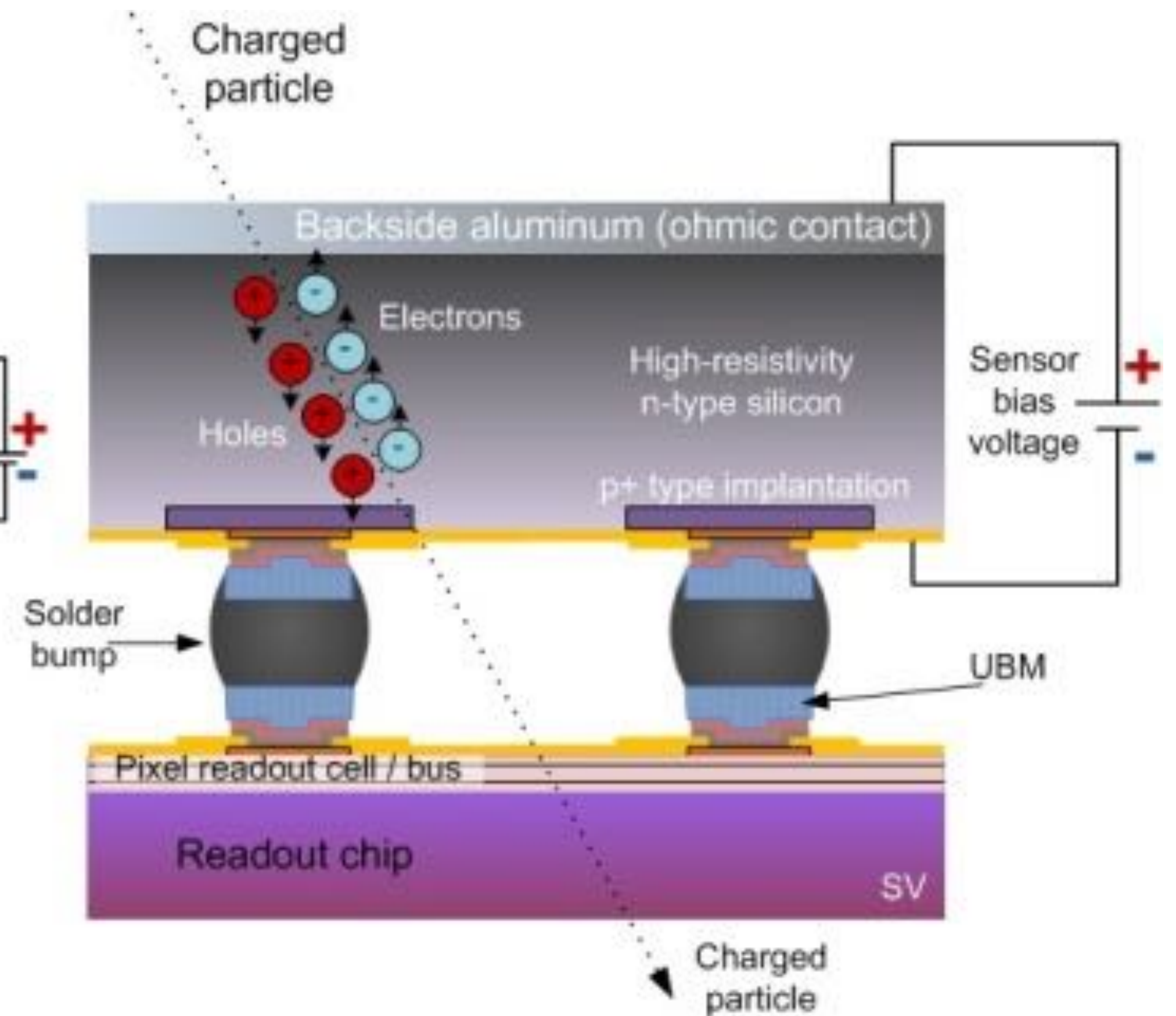


*Choose an appropriate  
volume, and the correct  
density of channels, design  
special readout electronics,  
probably cry at some point.*

# Hybrid Silicon Pixel Detectors

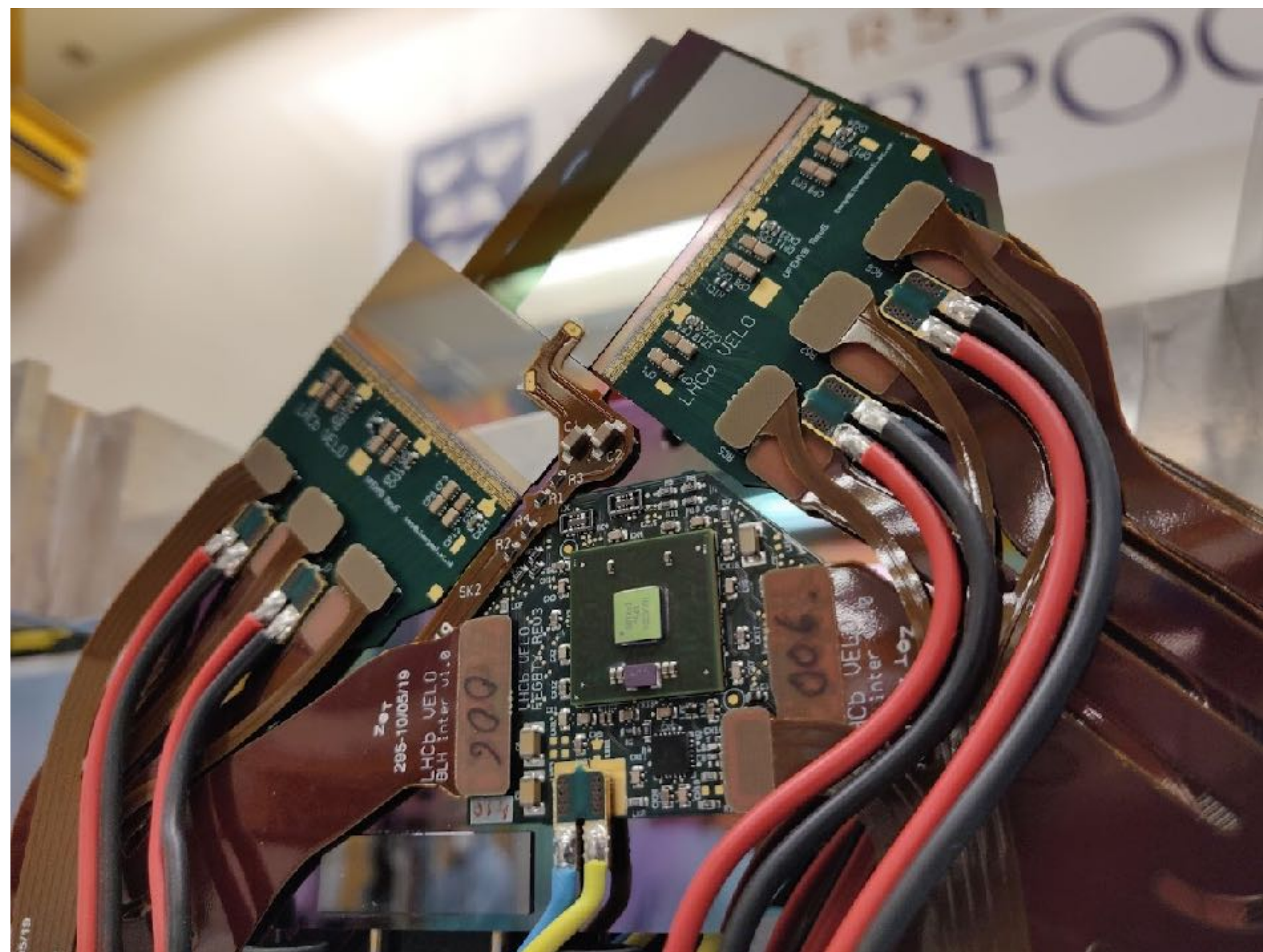
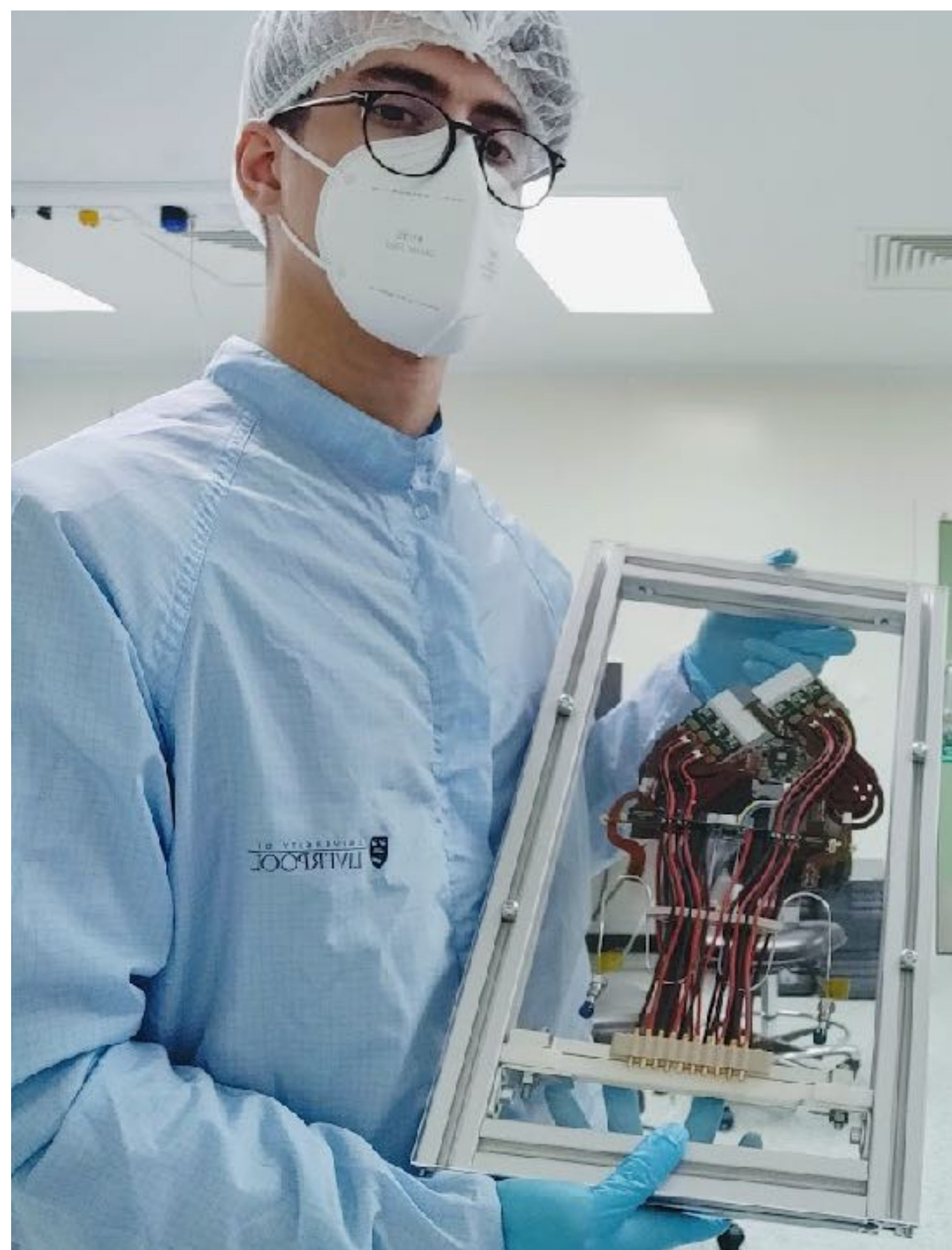


Generic pixel detector



Cross-sectional cut

# Hybrid Silicon Pixel Detectors

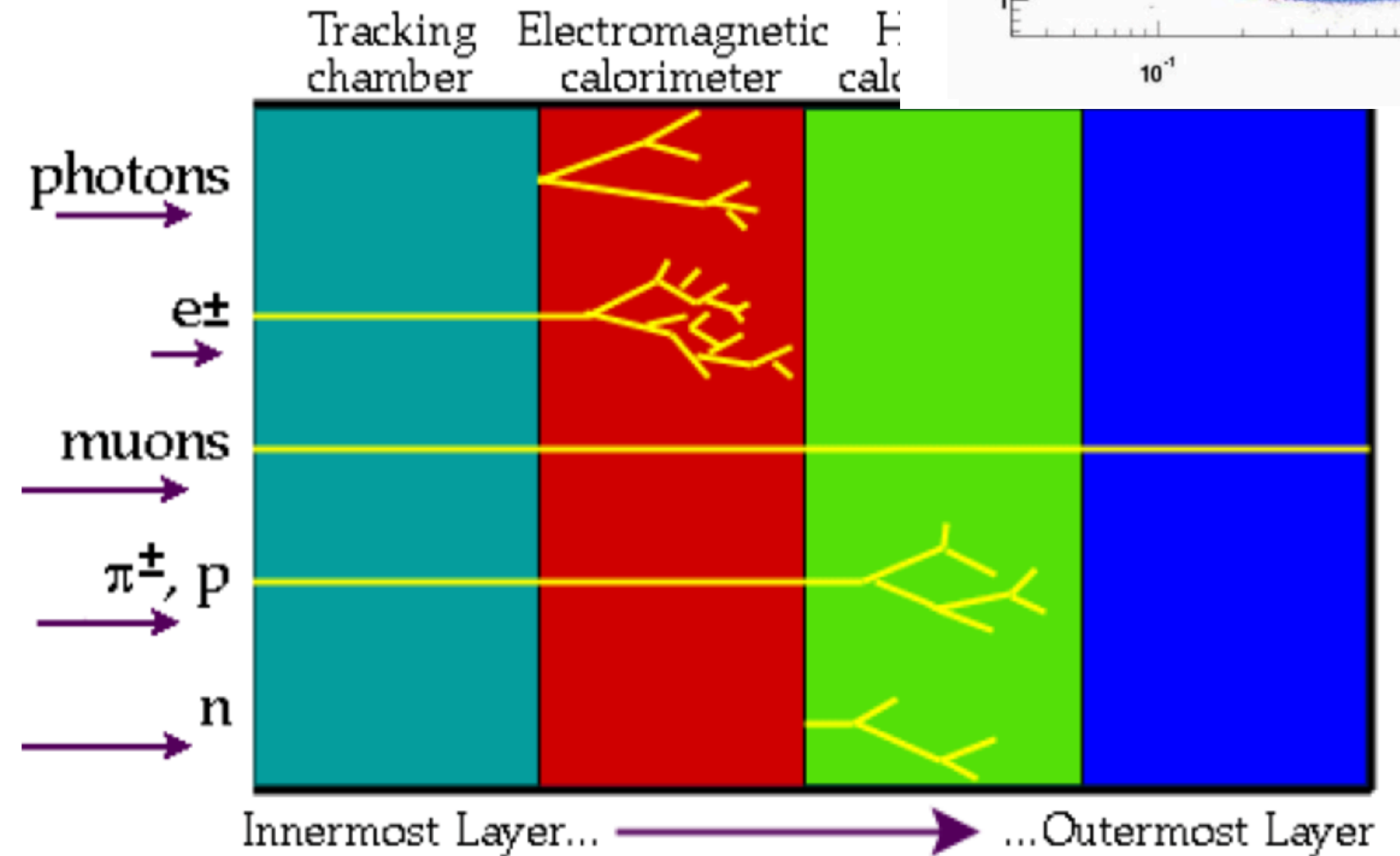
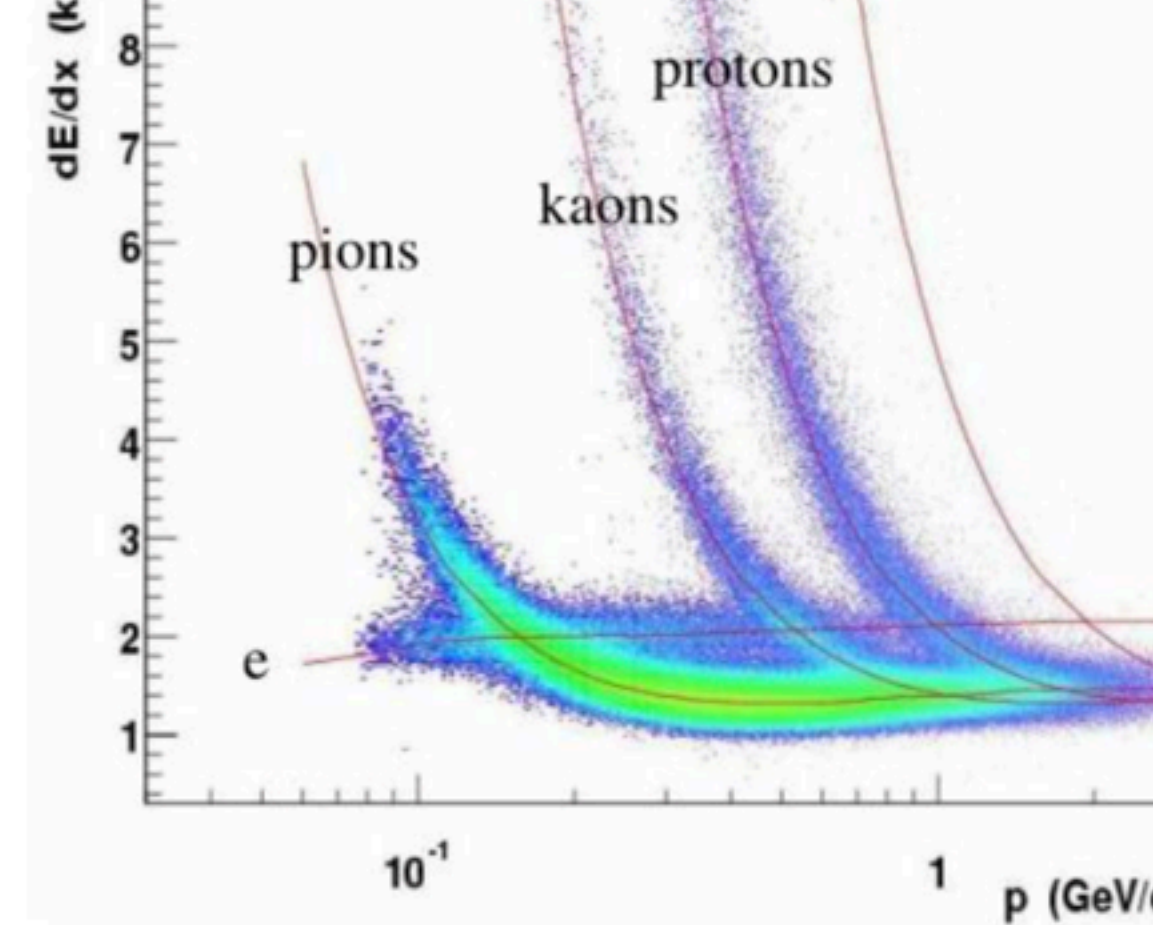


# Which particle though ?

*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.*

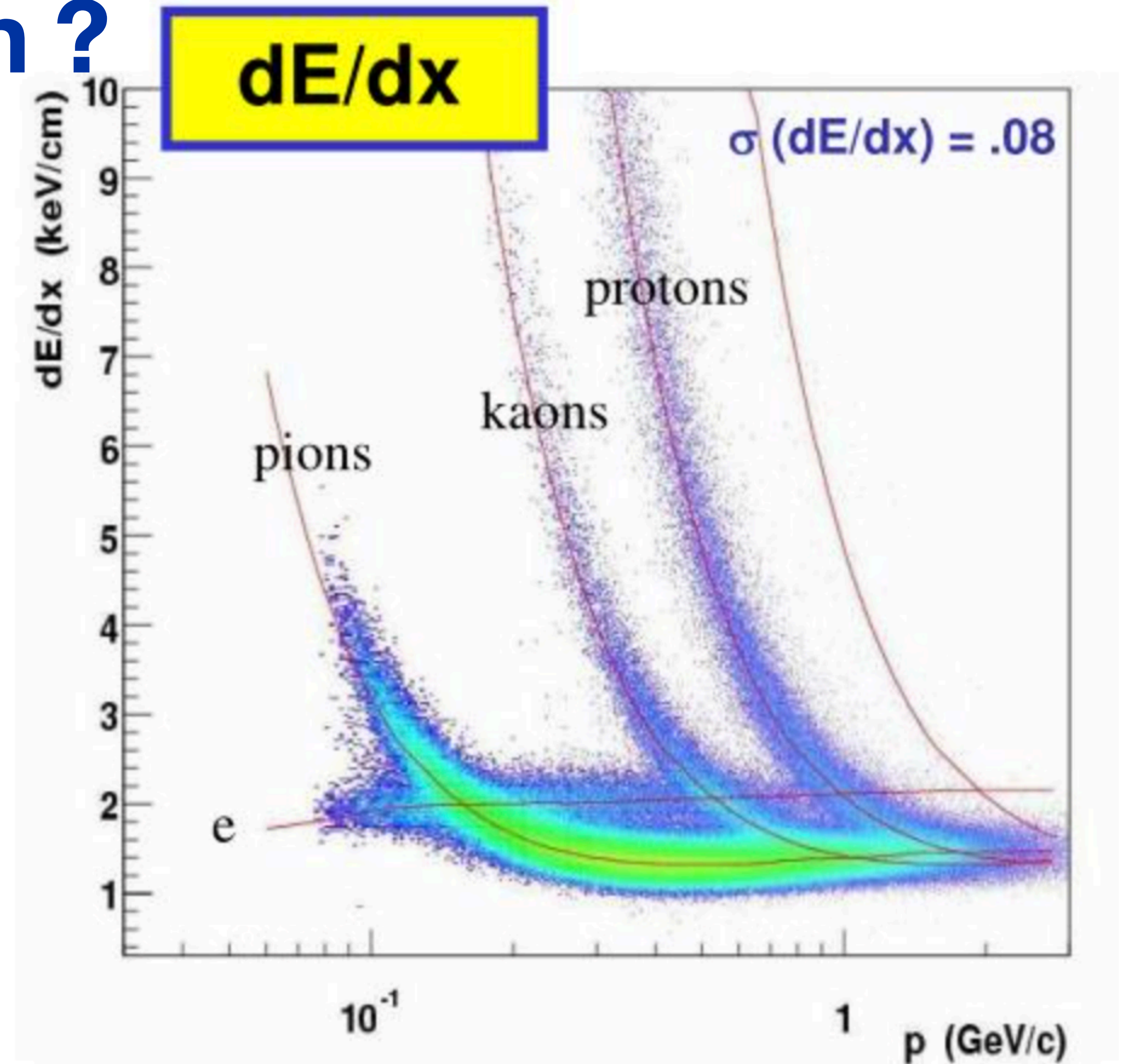


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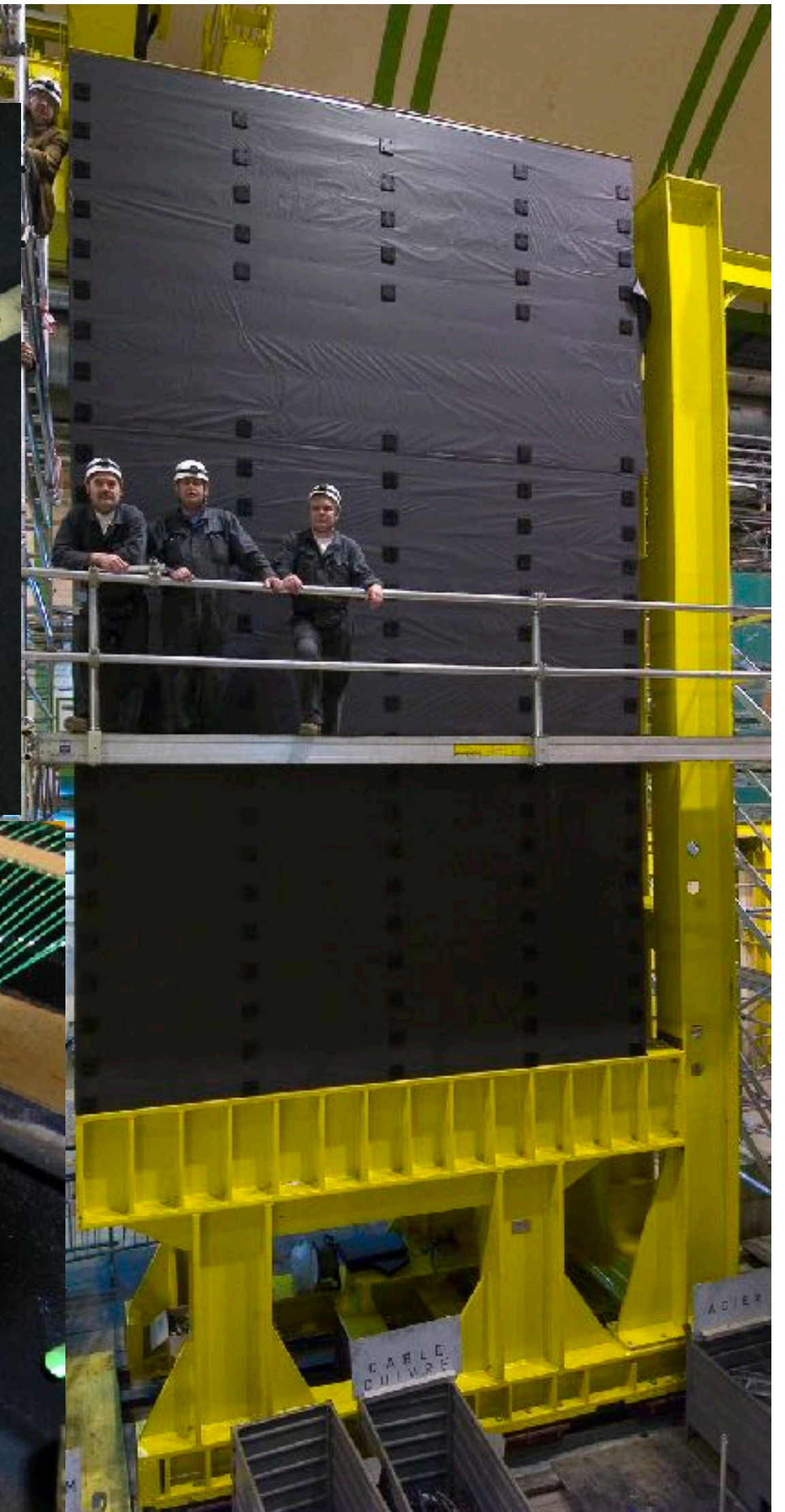
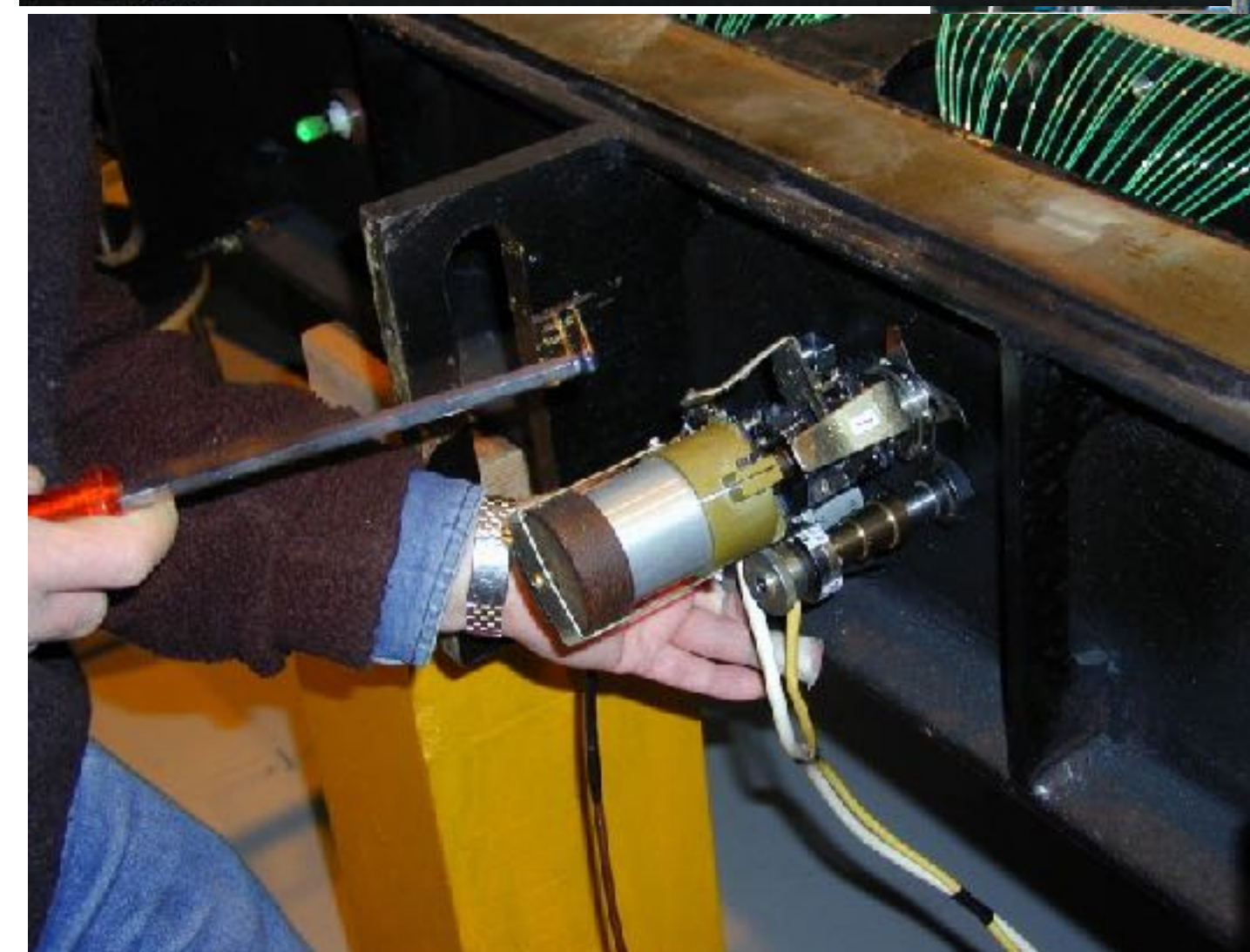
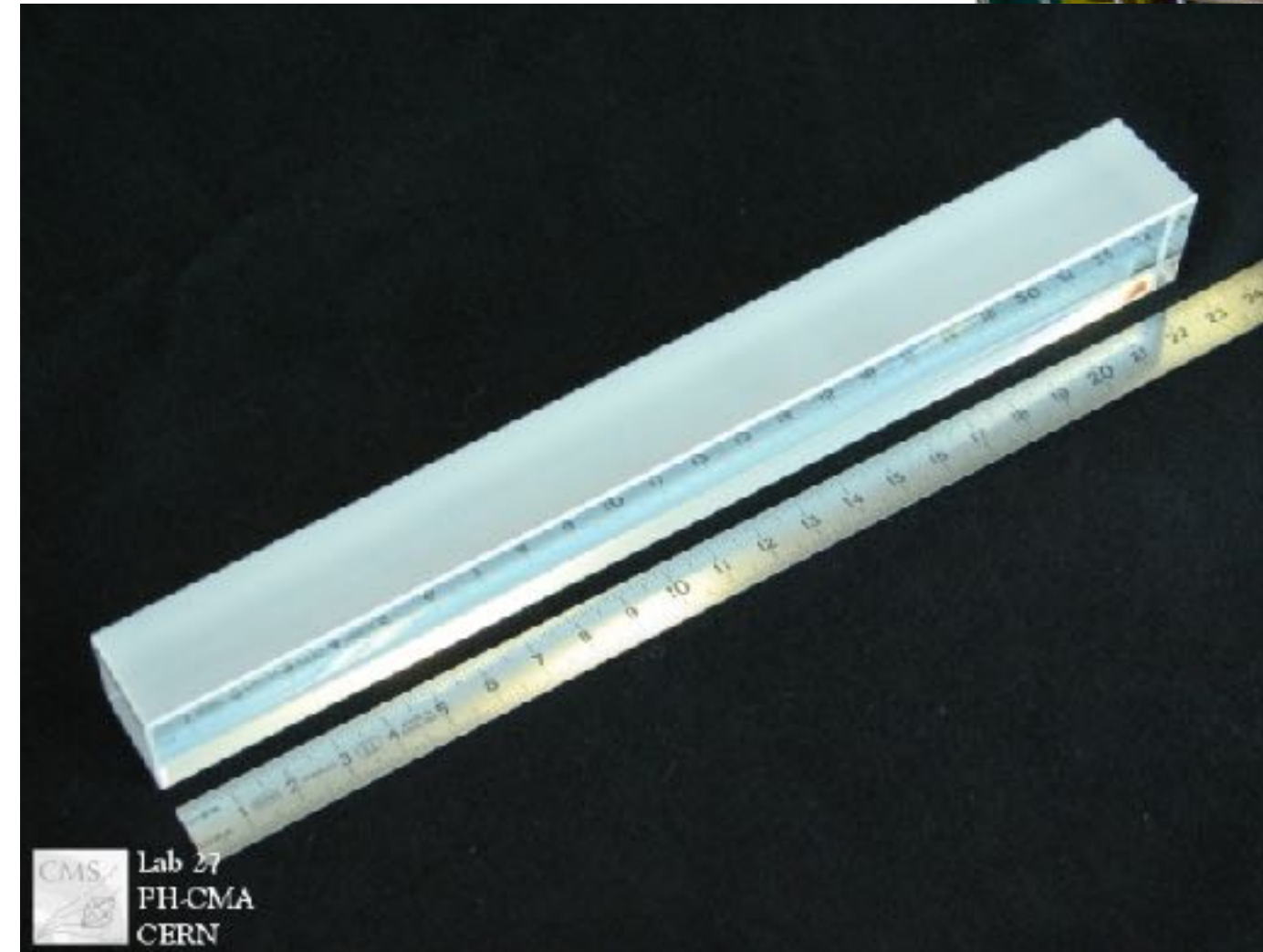


# Which particle though ?

*Calorimeters identify particles by stopping them.*

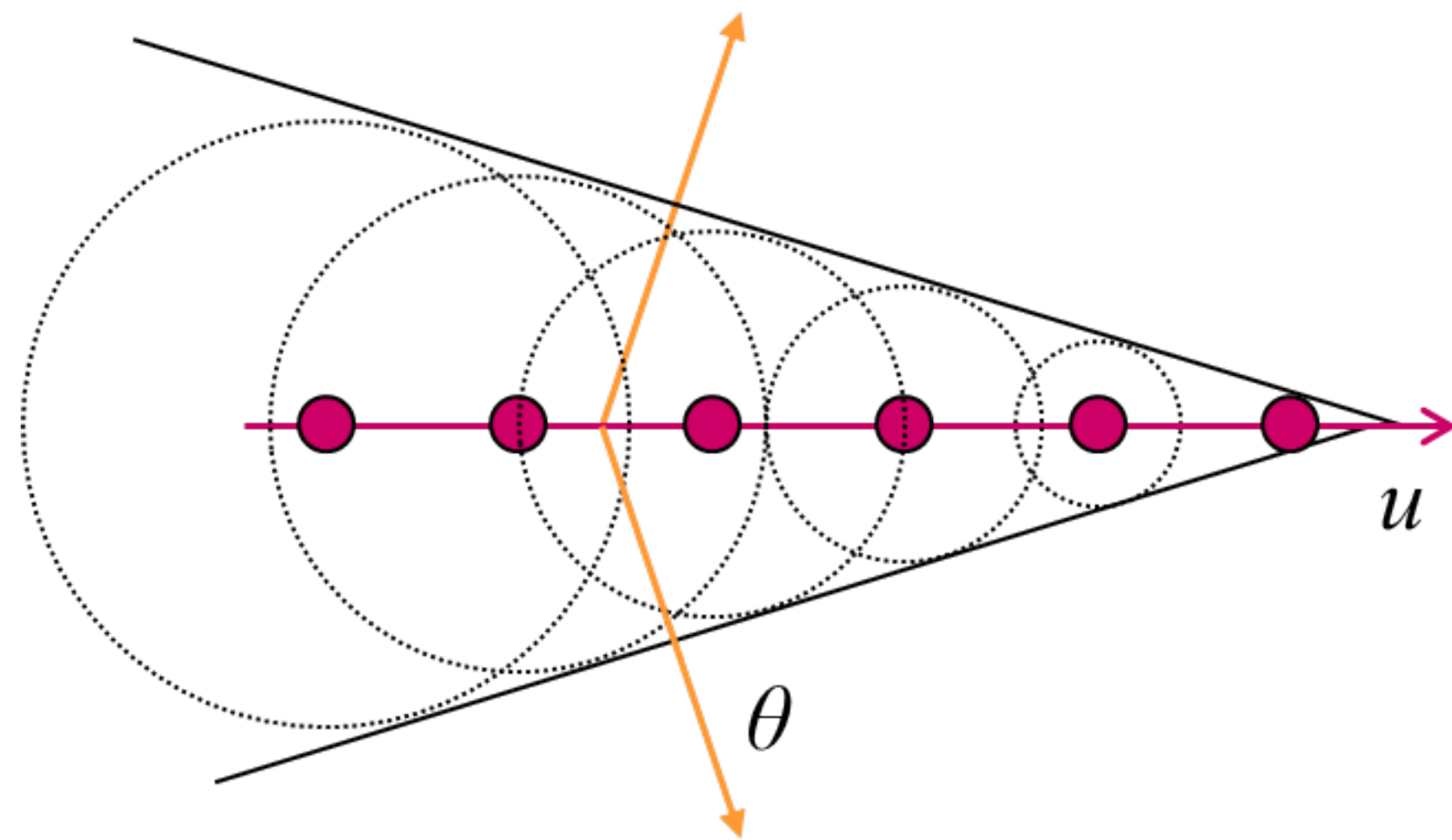
*Main different between electromagnetic and hadron calorimeters is their density.*

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



# Which particle though ?

*Cherenkov light for particle identification.*

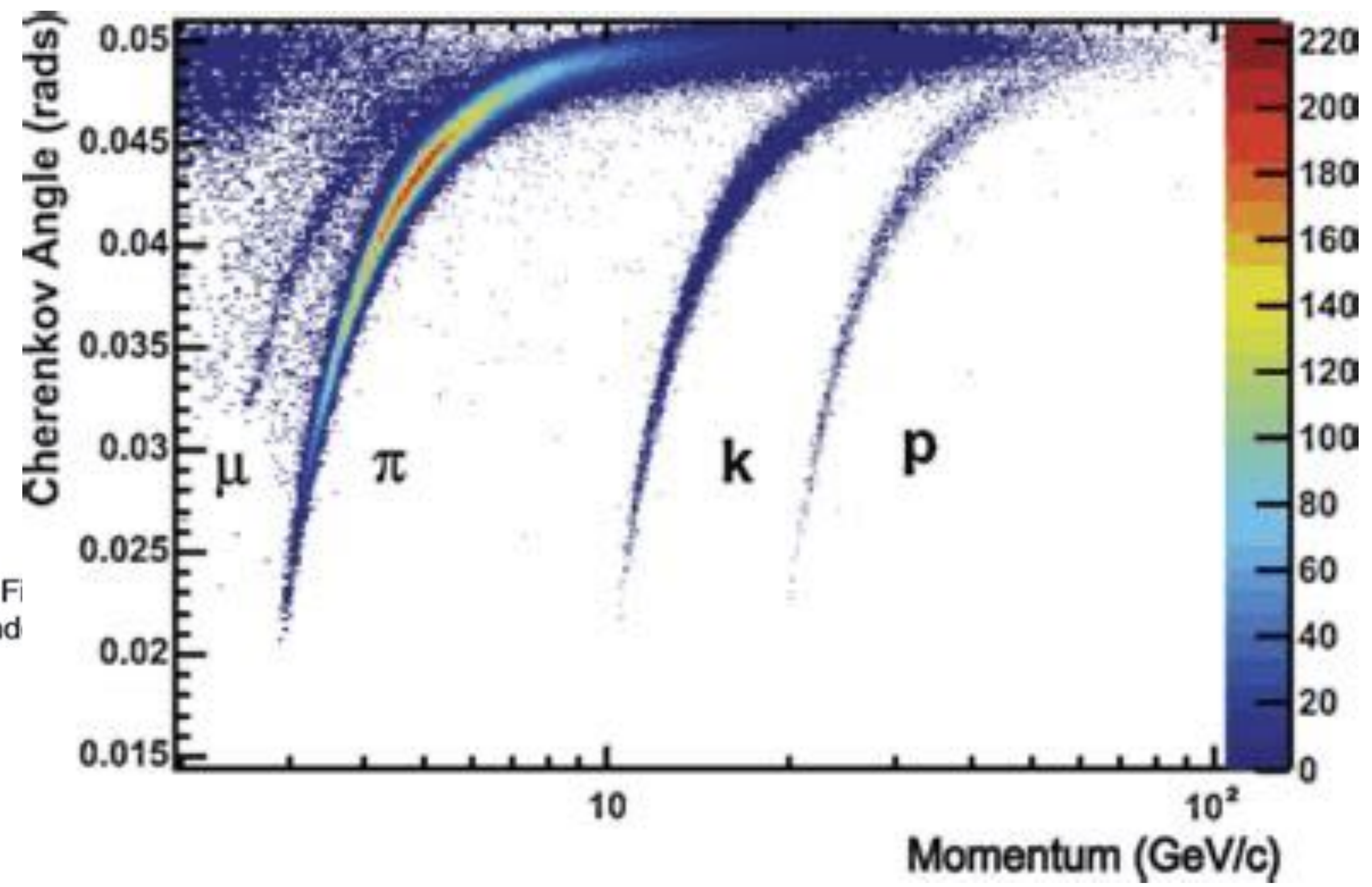
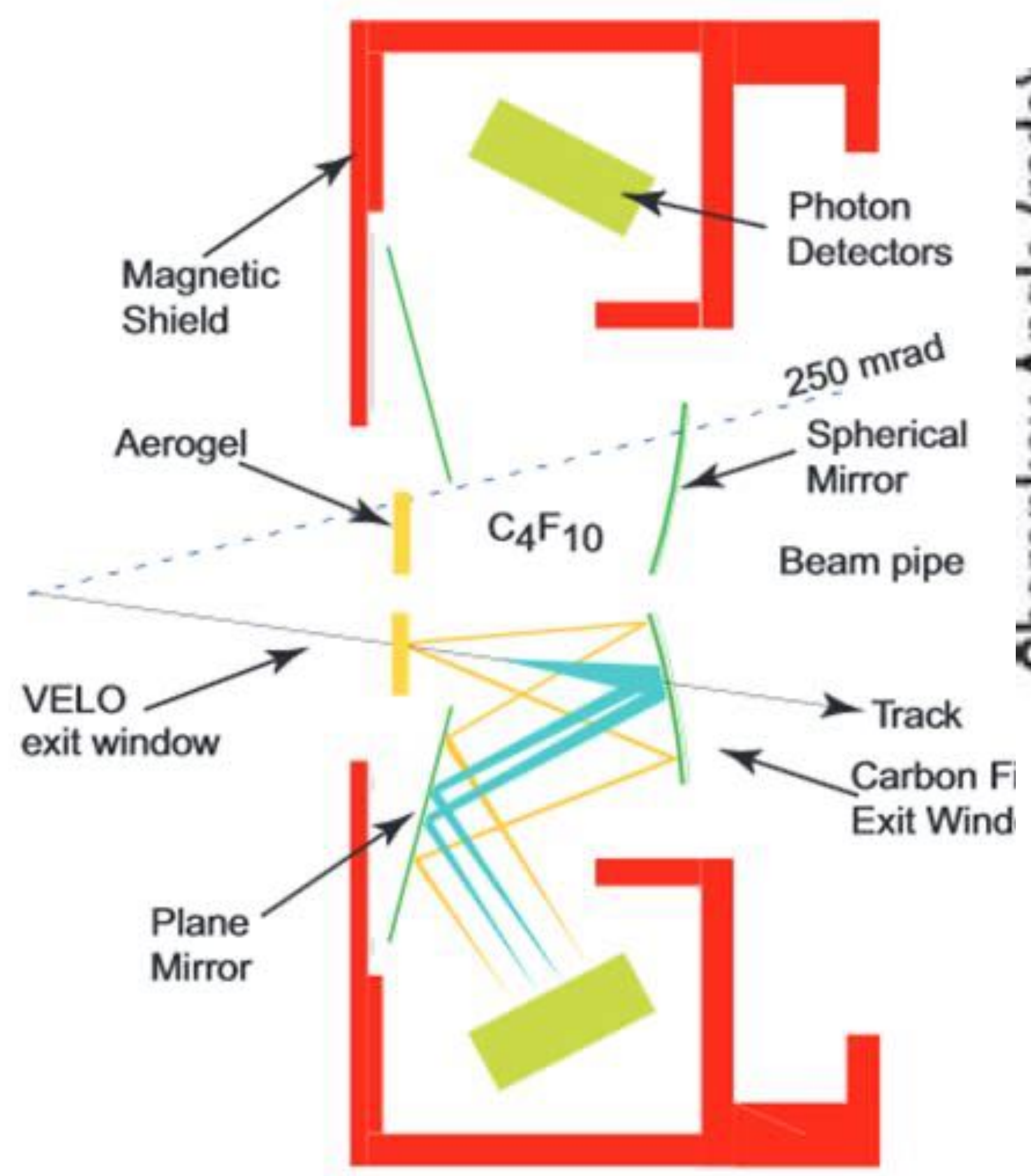


*Generated by particles traversing a medium at a speed higher than the speed of light in that medium.*



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

# Which particle though ?

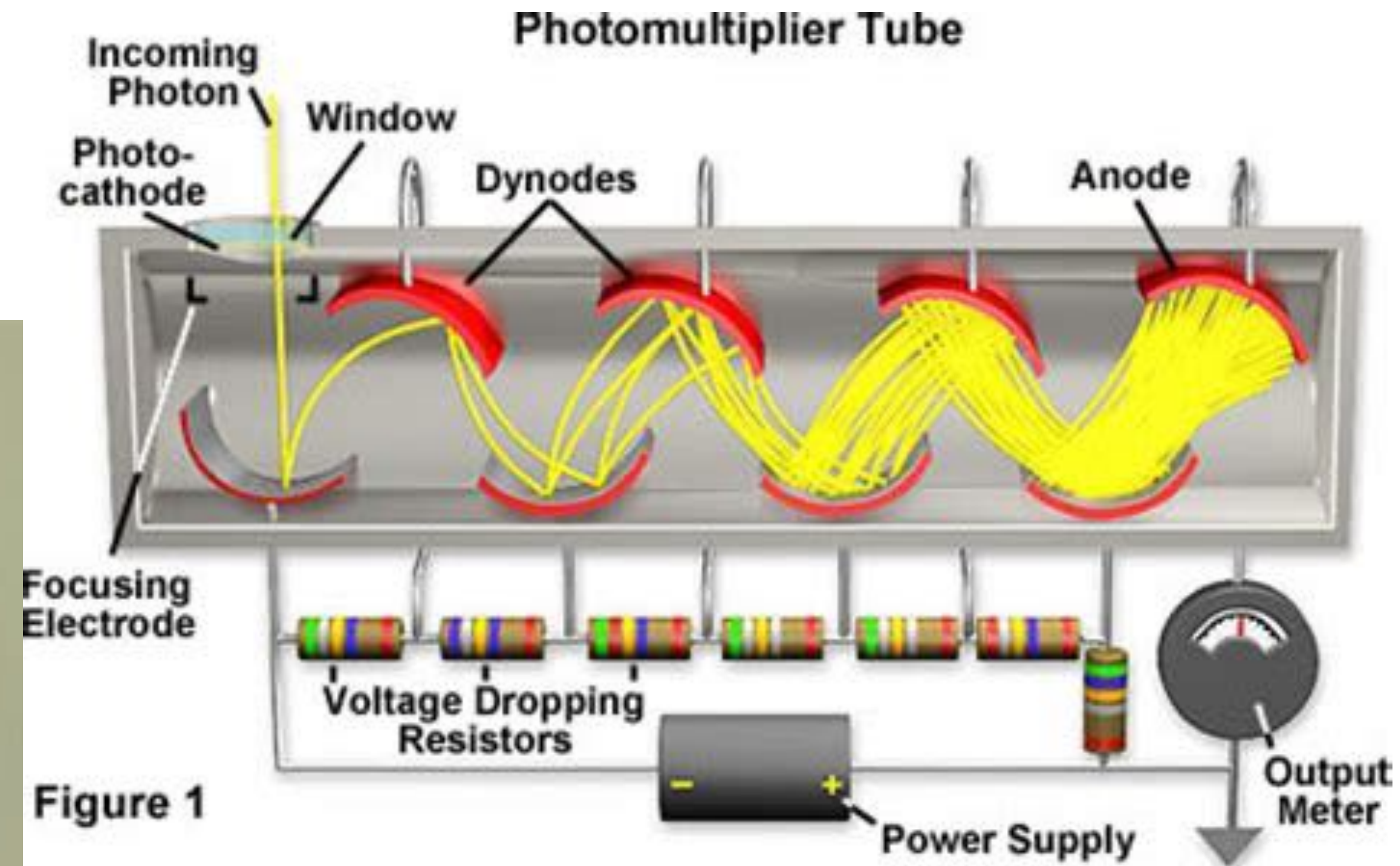




# Which particle though ?

*How to detect light ?*

*PMTs : Photomultiplier tubes!*

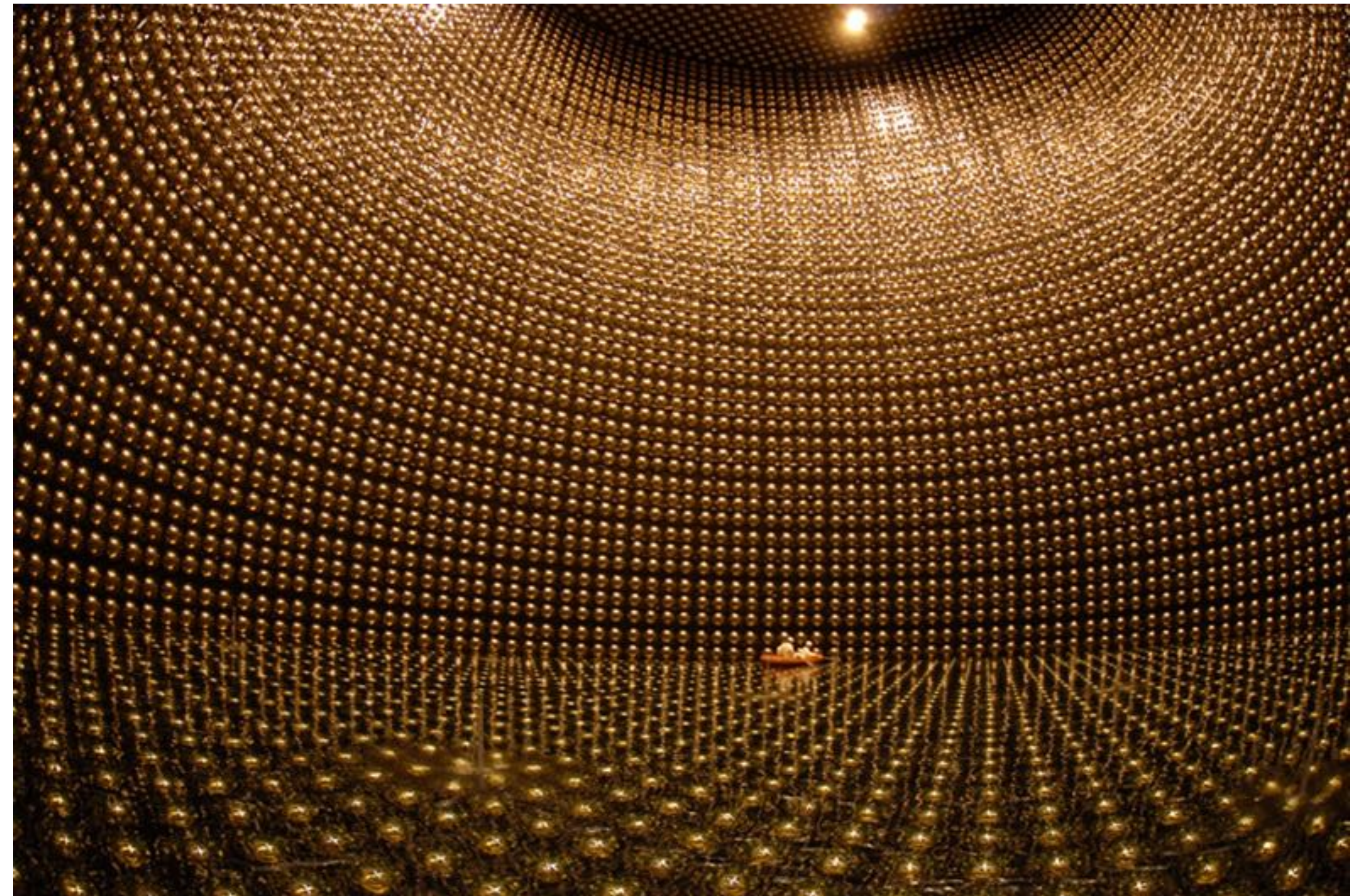


# Which particle though ?

*How to detect light ?*

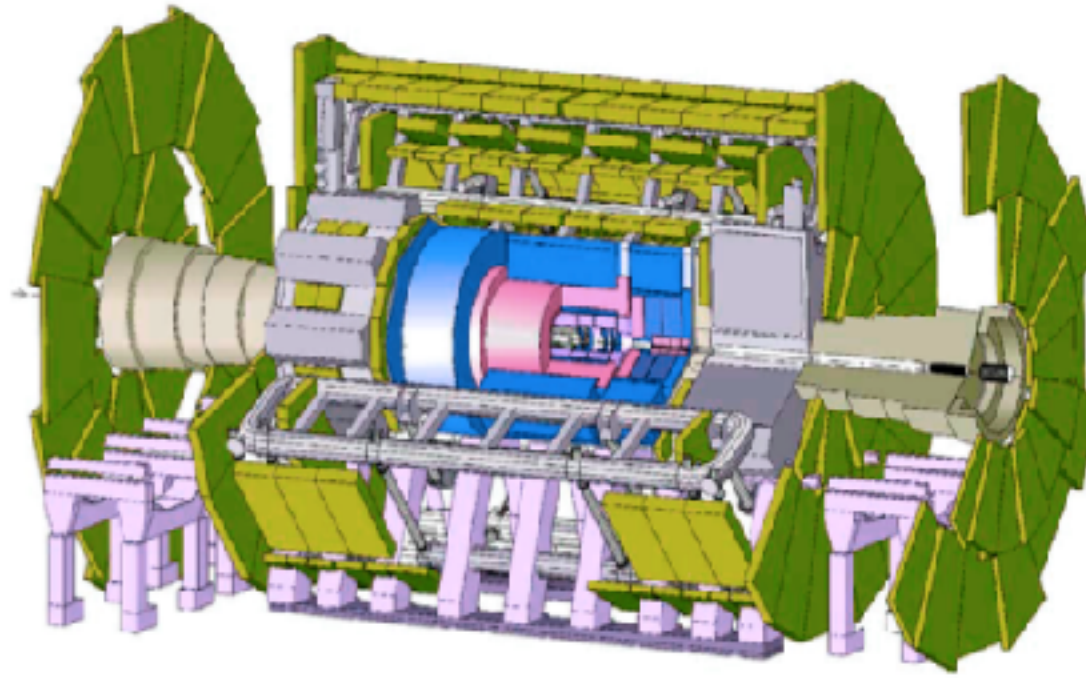
*PMTs : Photomultiplier tubes!*

*Sometimes, many of them....*

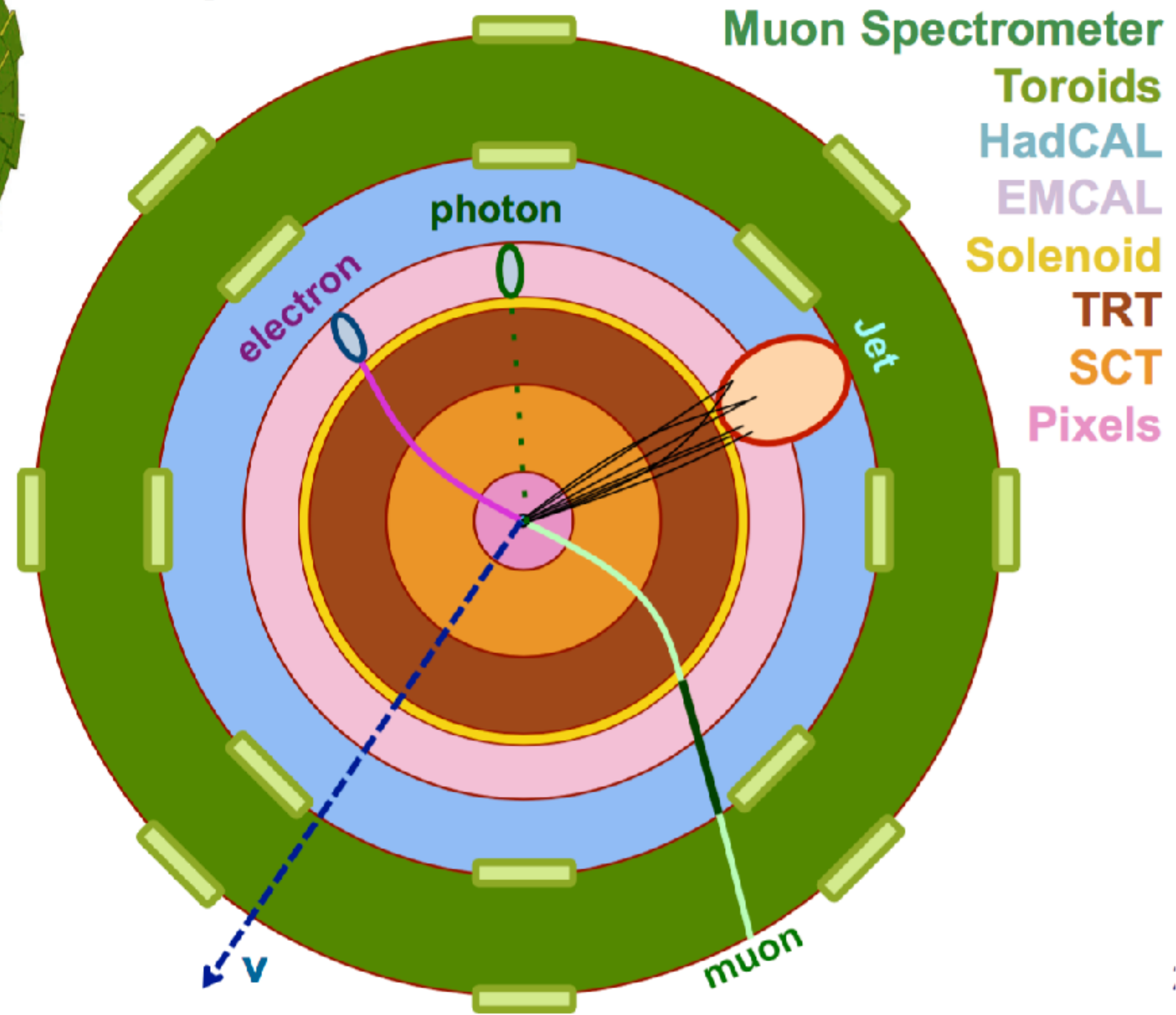


Super - Kamiokande, Japan

# A DETECTOR (E.G. ATLAS)



## Simplified Detector Transverse View



	I	II	III	
Quarks	2.4 MeV <b>u</b>	1.3 GeV <b>c</b>	170 GeV <b>t</b>	0 <b>γ</b>
	4.8 MeV <b>d</b>	104 MeV <b>s</b>	4.2 GeV <b>b</b>	0 <b>g</b>
	<2.2 eV <b>ν<sub>e</sub></b>	<0.2 MeV <b>ν<sub>μ</sub></b>	<16 MeV <b>ν<sub>τ</sub></b>	91 GeV <b>Z</b>
Leptons	0.5 MeV <b>e</b>	16 MeV <b>μ</b>	1.8 GeV <b>τ</b>	80 GeV <b>W</b>
				126 GeV <b>H</b>
				Bosons