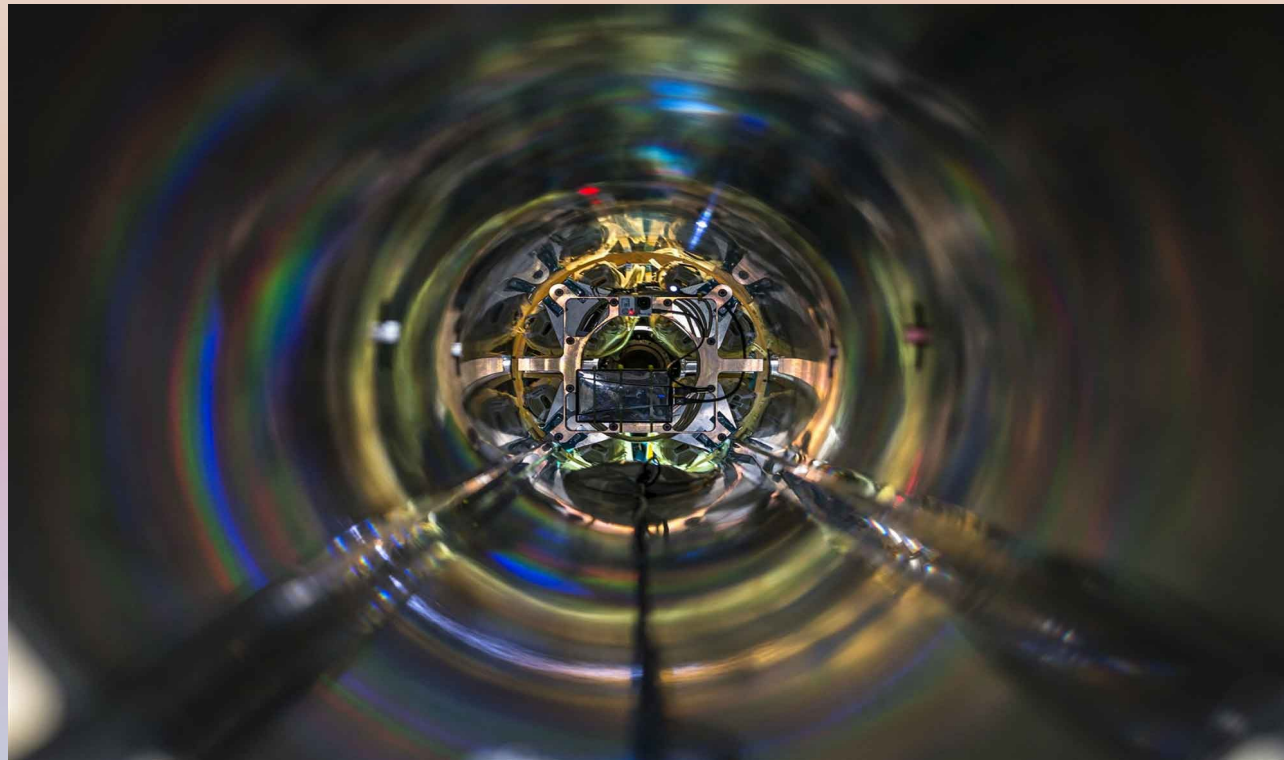


# *3D Silicon sensors*

## *For the ATLAS IBL pixel detector upgrade*

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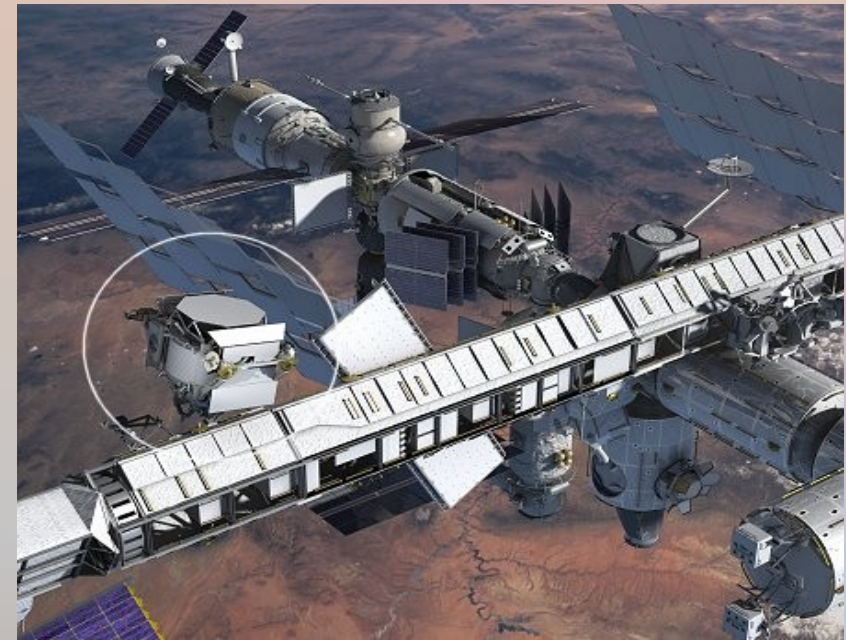
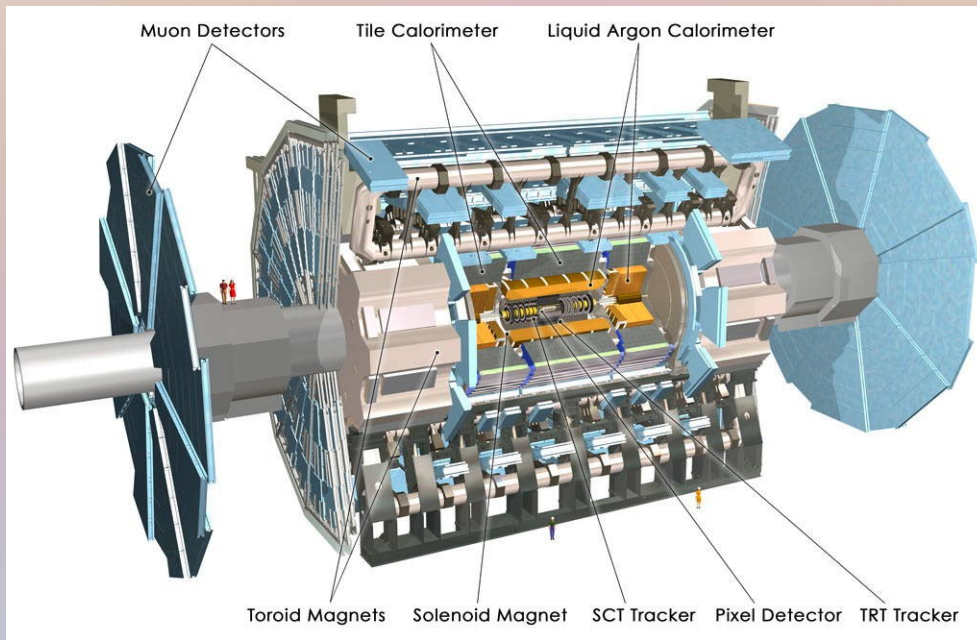
View of the ATLAS pixel detector as it is pushed into position inside the ATLAS detector

# *Detectors*

- A detector is a device that records the existence of something.
- The scientific method relies upon experimentation
- Experimentation relies upon measurement
- Detectors are used across different fields of science

# Detectors

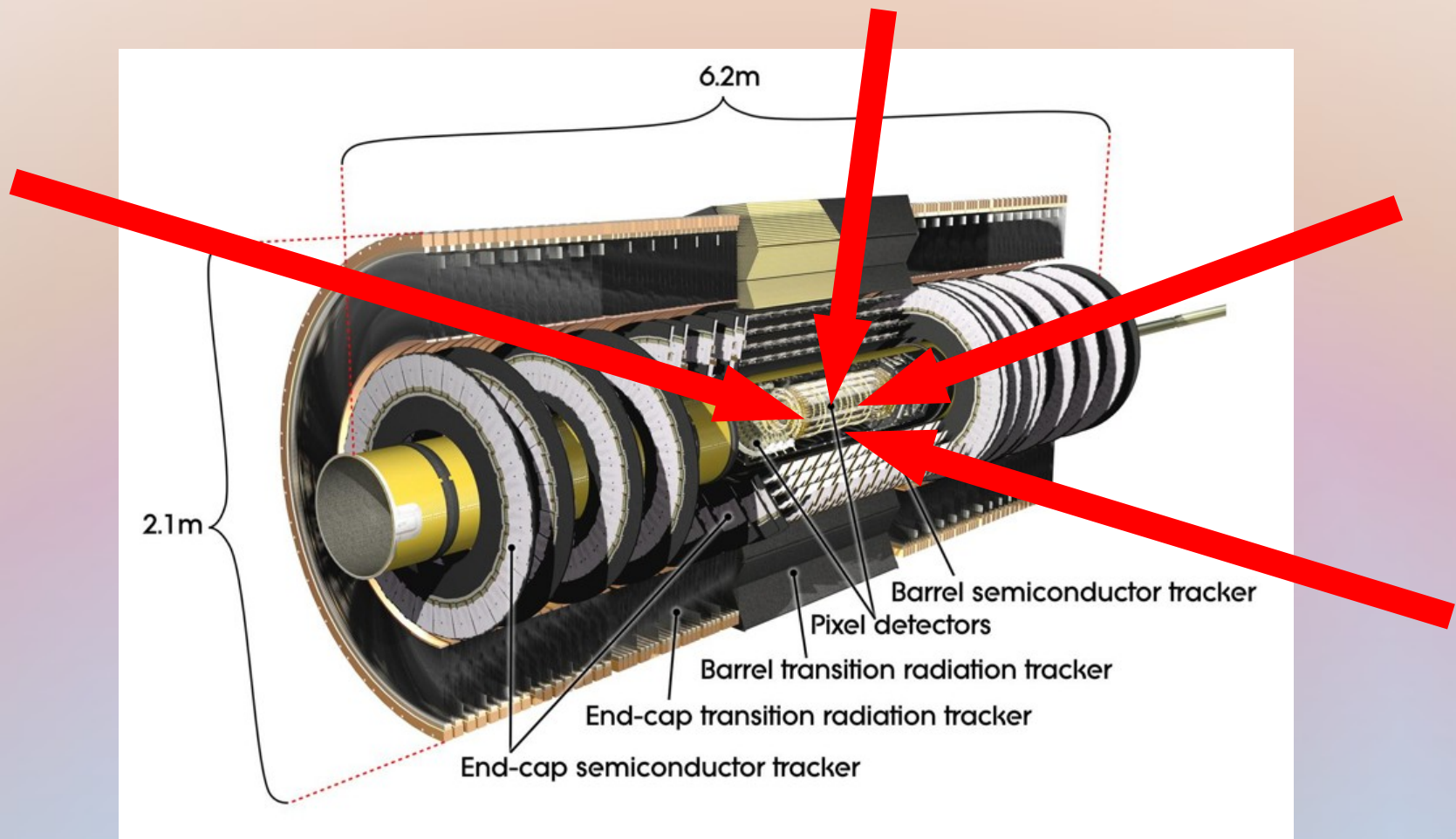
- Particle physics (particle tracks, beam monitoring)
- Nuclear physics
- Astrophysics (cosmic rays, dark matter)
- Medical Physics (hadronic therapy)





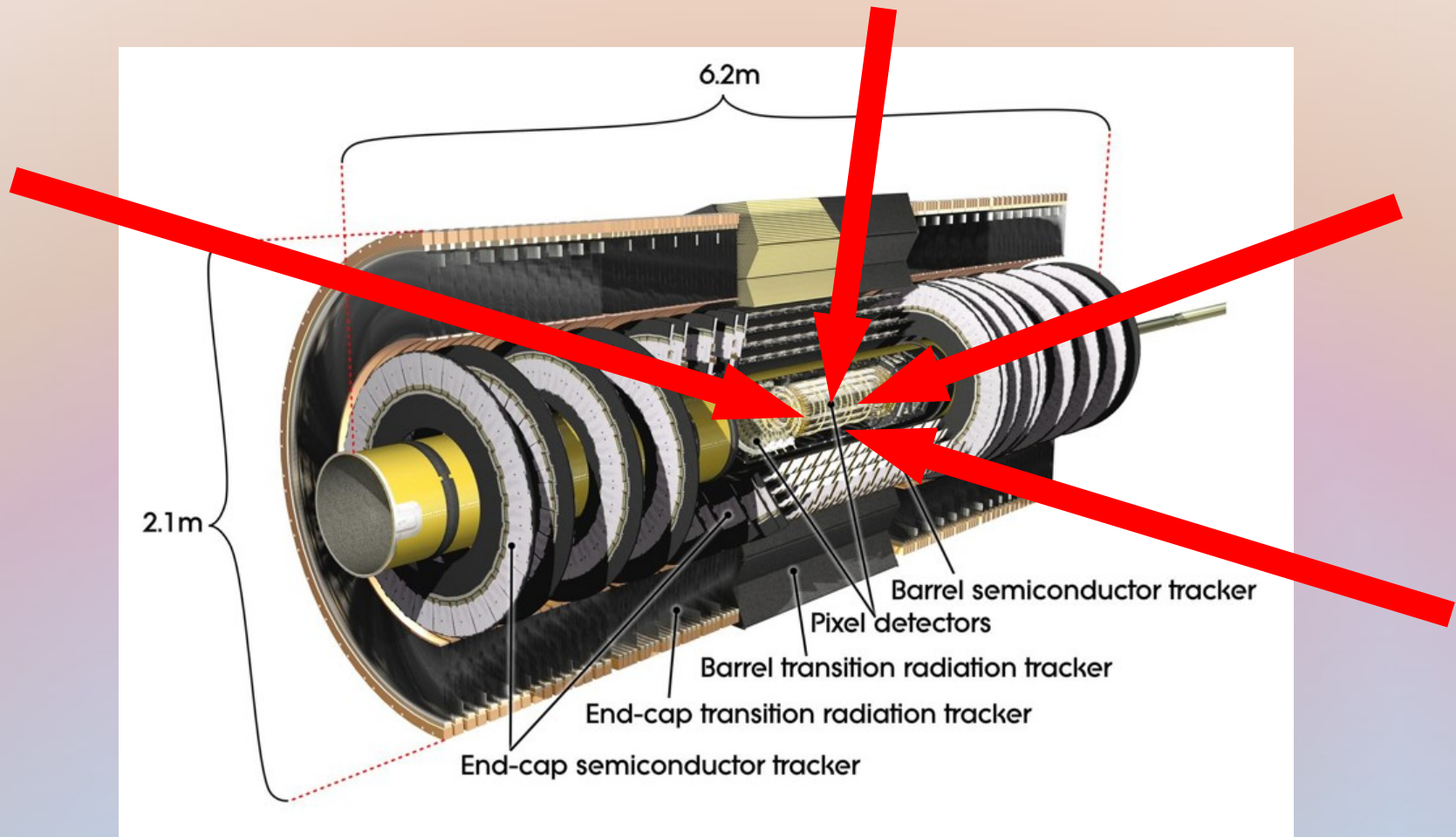
# The Pixel Detector

This is the basic structure of the detectors in ATLAS:



# The Pixel Detector

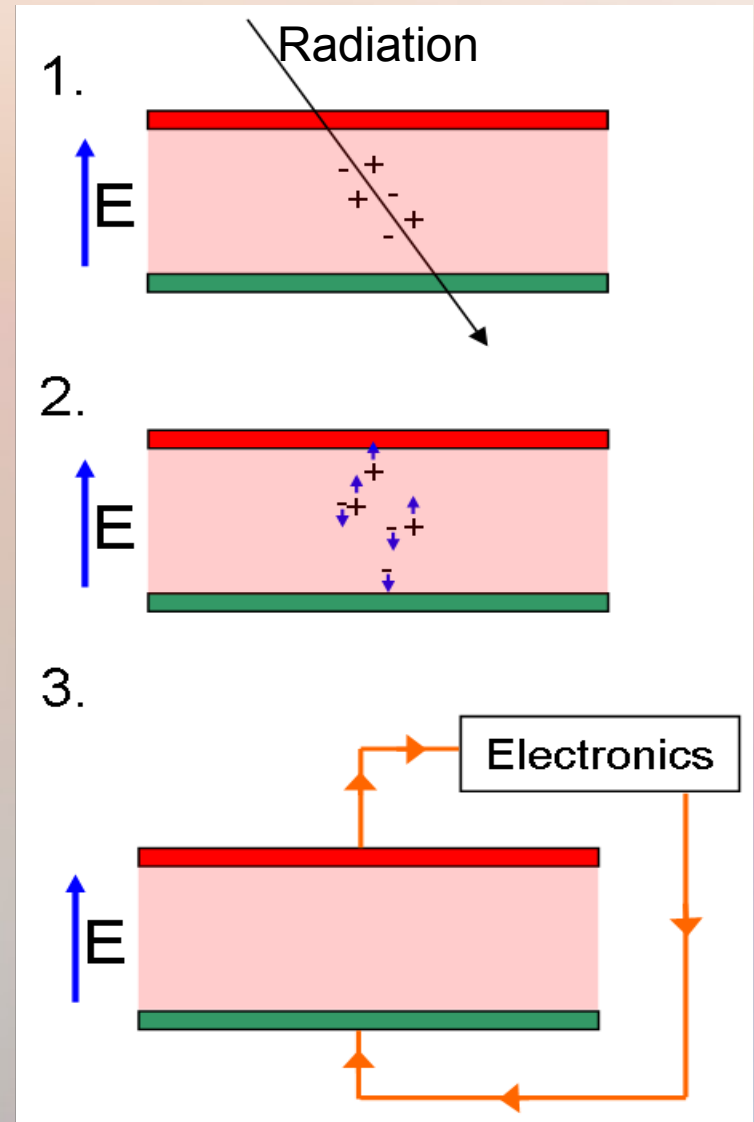
The pixel detector is the first produced particles meet



# How detectors work

- Transfer of all or a part of the energy of the radiation to the detector
- All modern detectors provide essentially a type of electrical response, ie information from the detector is transferred into electrical impulses
- If the detector is large enough to fully absorb the radiation, then this gives a measure of the energy of ionization radiation.

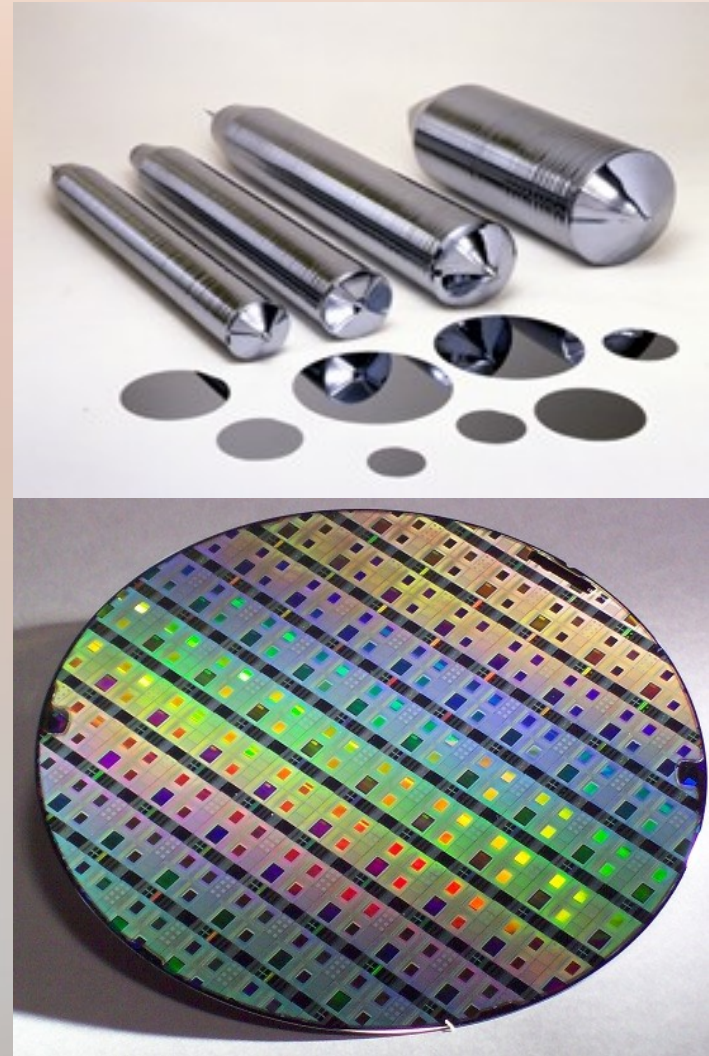
$$Q_{tot} = \int i(t) dt$$





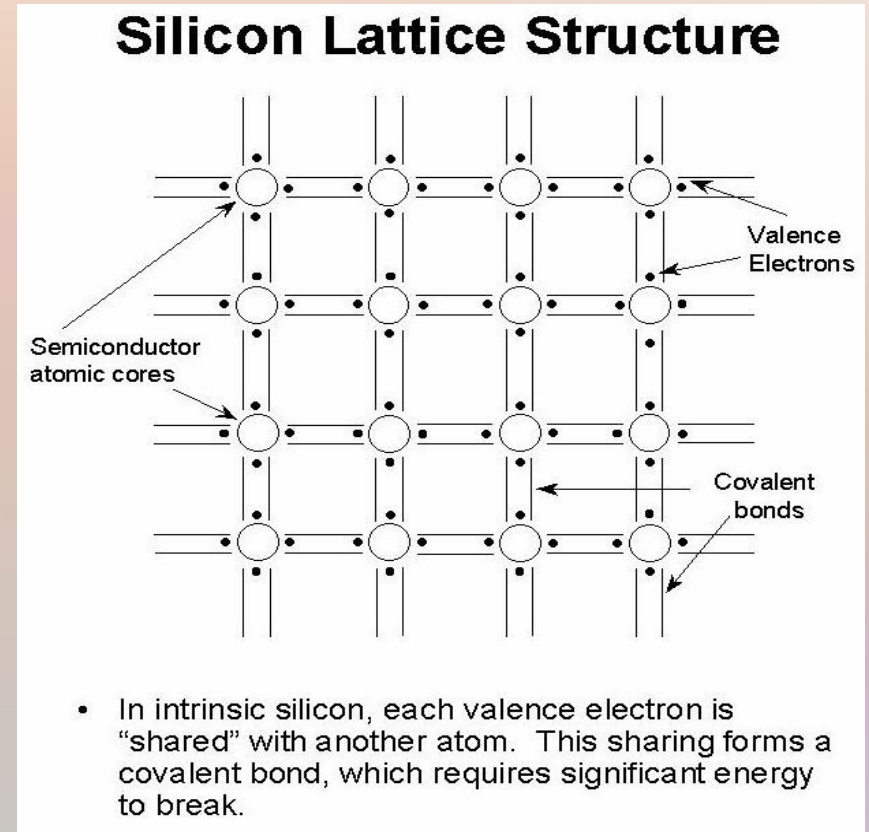
# Why silicon?

- Can be operated at room temperature
- Much higher resolution in tracking charged particles than older technologies
- High density (great loss of energy on small paths)



...But

- It's a more expensive material than older technologies
- **It suffers ageing!**  
Radiation can damage silicon moving some atoms of the lattice





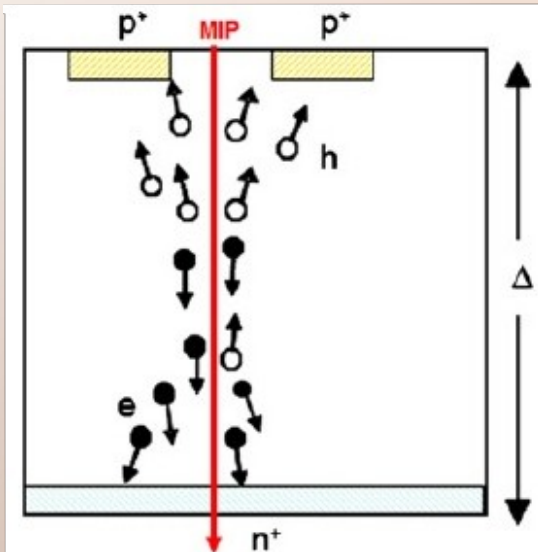
# Ageing of the silicon

- Natural silicon sensor damage:
  - Increase of depletion voltage
  - Decrease resistivity
  - Decrease of mean free path
  - Increase of trapping



Extracting the pixel detector from the heart of ATLAS, complete with the beam pipe, which is to be replaced.

# 2D planar design



This is a schematic cross section of a planar sensor with the active thickness ( $\Delta$ )

	2D planar sensor
Collection path	200-300 $\mu\text{m}$
Depletion Voltage	30-100 V
Charge collection time	Tens of ns

How can we improve our technology, and so, our measures?

- Shortest collection path  $\rightarrow$  reduction of charge collection time.
- Decrease the depletion voltage  $\rightarrow$  Less energy to toggle free carriers

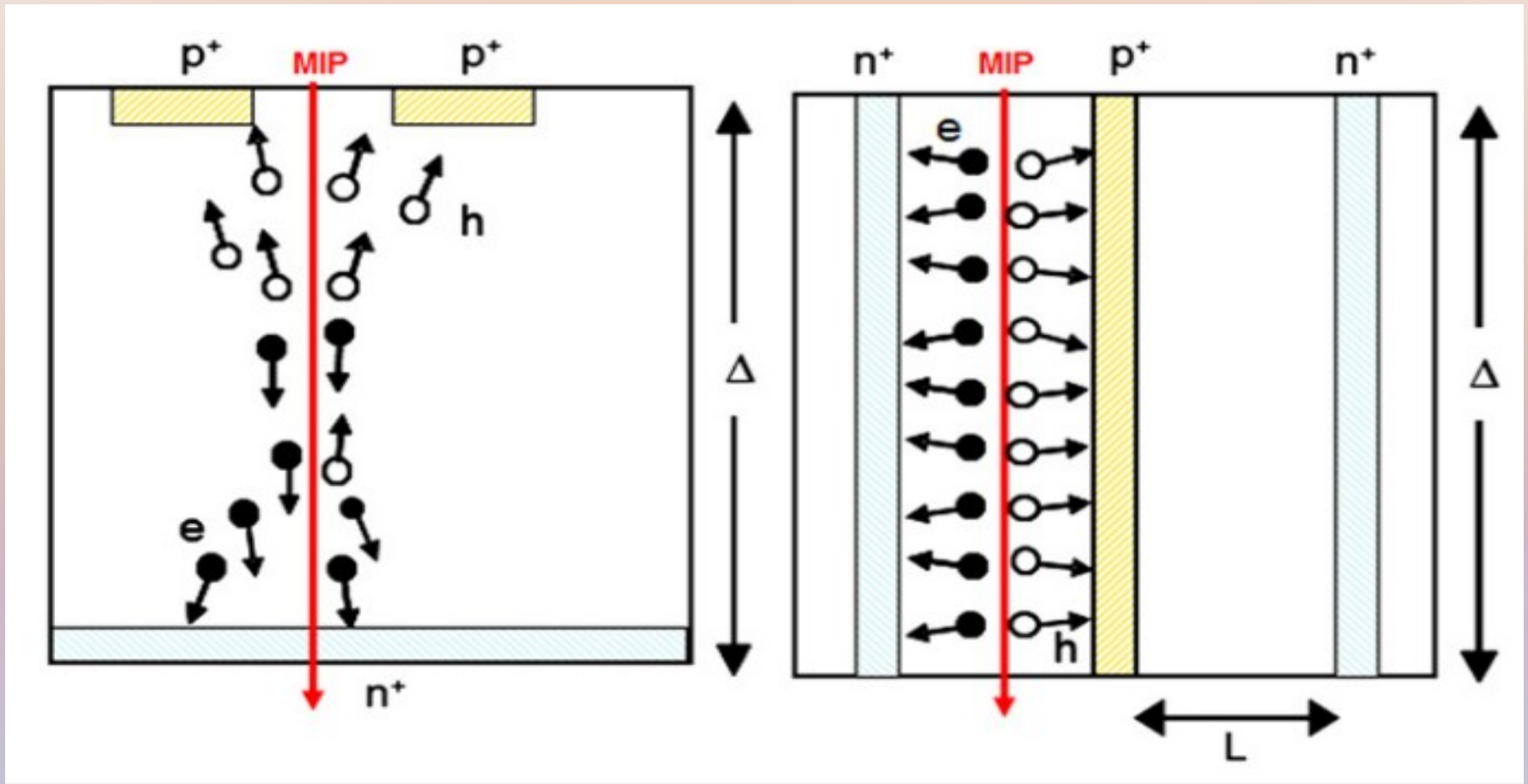
## What's a possible solution?

# 3D design

- In 1994, a new type of silicon sensor was proposed to try and overcome these problems
- The orientation of the depletion region and the electrodes is changed
- The depletion region now grows in a different direction to the distance between the electrodes



# 3D design



Cross sections of a planar (L) sensor and 3D sensor design.

# *The advantages of 3D design*

- The depletion voltage is much smaller than in the planar sensors
- This means that the 3D sensors will age much slower
- Charge collection times can also be much faster
- As a result, these sensors are now replacing the old planar sensors in the detectors at CERN

## *To conclude:*

- The current silicon sensors used in pixel detectors in ATLAS suffer from ageing
- The 2D planar design is particularly vulnerable, as when the depletion region grows, the voltage across the electrodes increases
- In the 3D design, the orientation of the depletion region is changed so that the depletion voltage is reduced
- These new sensors are replacing the old planar ones in the ATLAS detector