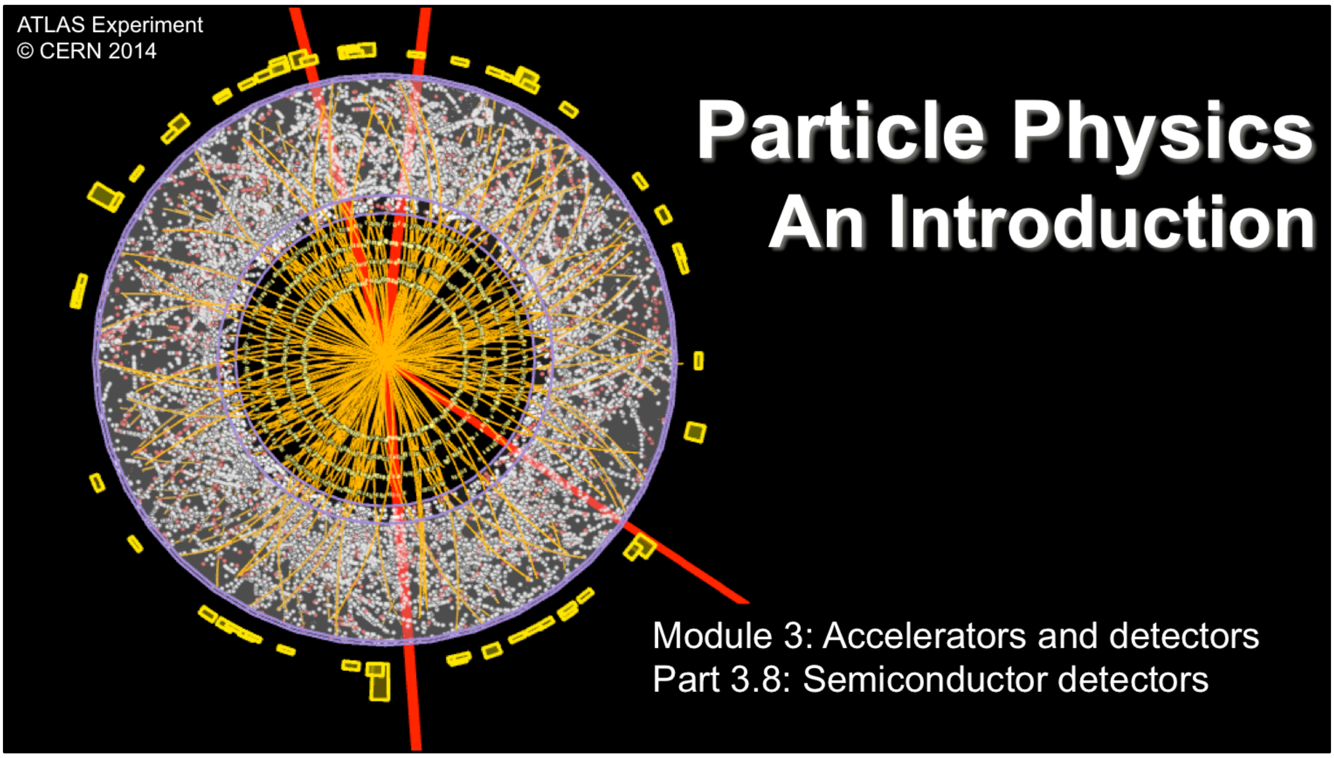
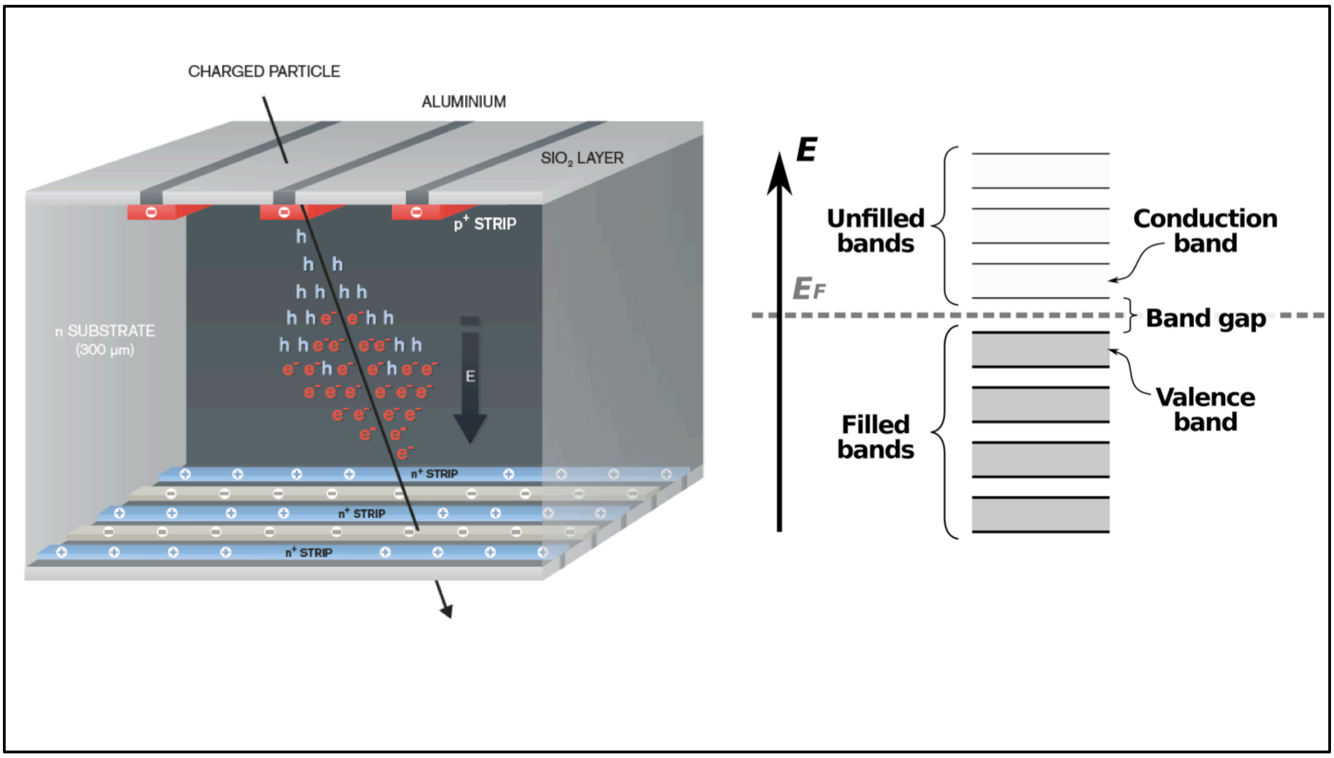


In this module, we touch the basics of particle acceleration and detection methods.

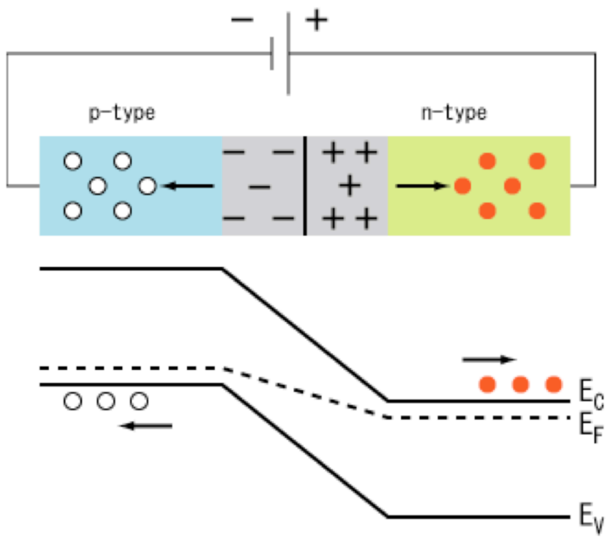
In this video, we continue our discussion of particle detection techniques with semiconductor devices.

After watching this video, you will know:

- How semiconductor detectors measure the ionization caused by traversing charged particles;
- How this is used to identify charged particles and measure their trajectories.



- This particular type of ionization detectors uses the properties of **semiconductors** to detect and measure *dE/dx* of charged particles. When a charged particle traverses a semiconductor, it will create **electron-hole pairs**.
- Since the conduction band is close to the valence band, it takes **only 3 eV of *dE/dx*** to create a pair (compared to 30 eV for the ionization of a gas atom). The charges can be detected by applying an electric field.
- Advantages :
  - Very good energy solution;
  - Compact since it is made of a solid;
  - Thin with a required thickness << X_0;
  - Spatial solution O(µm) (micro-strips or pixels), ideal for a tracking detector;
  - Produce fast signals.
- Disadvantages:
  - Expensive;
  - Fragile to mechanical, chemical and electrical impacts;
  - Performance is degraded by irradiation.

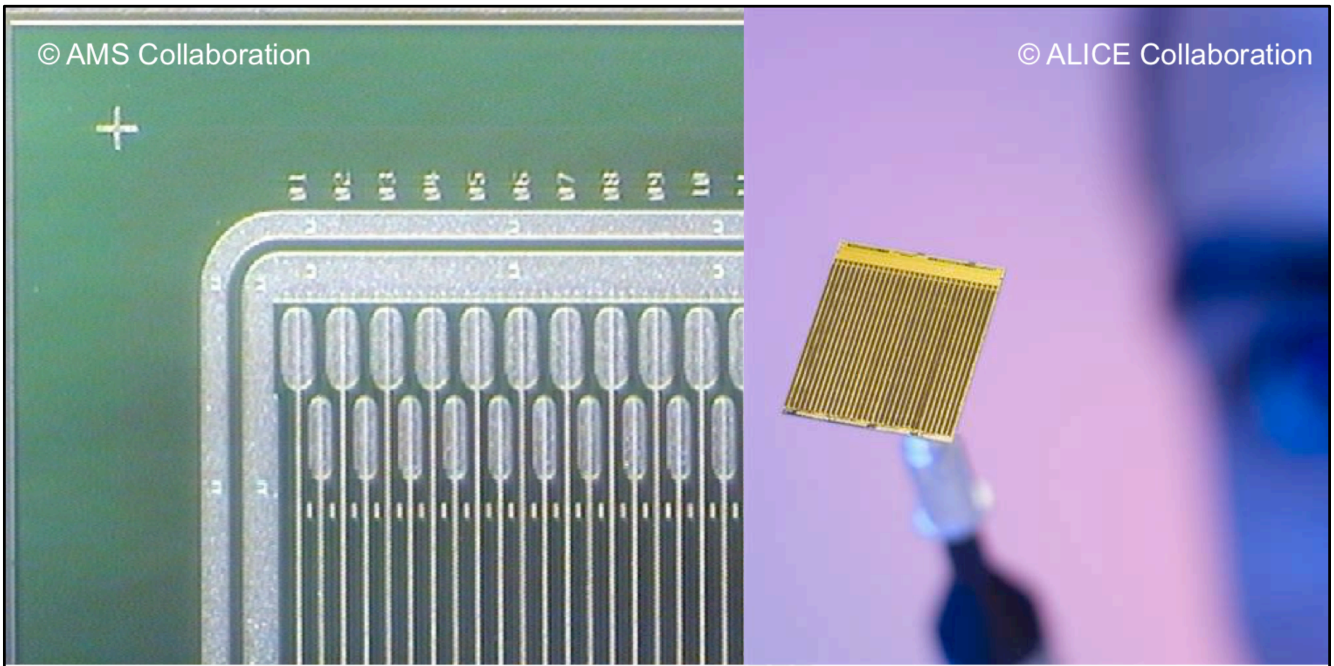


The basis of a semiconductor detector is a **p-n junction with reverse bias:**

- When two different semiconductor types, n and p, are in contact, diffusion creates a **zone free of charge carriers** around the contact surface. A **depletion zone** forms at the junction, creating a **potential barrier**. It prevents **conduction** between the two semiconductors.
- The application of a **reverse bias voltage** (V_n>V_p) **widens the depletion** zone. This is how semiconductor **diodes** work.
- The passage of ionizing particles **liberates electron-hole pairs** in the depletion zone. Charges are collected to both ends. The **diode conducts a small current** for a short time.

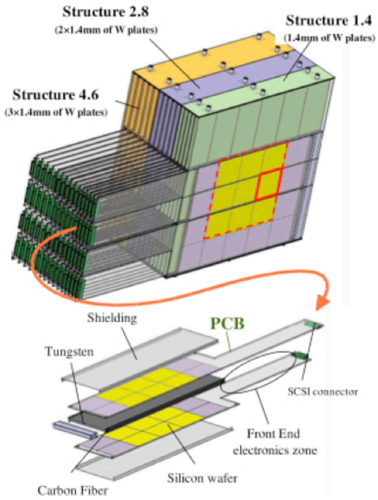
Characteristics of semiconductor detectors:

- **Efficiency:** only ~ 3 eV are necessary to create a single electron-hole pair. A semiconductor detector is thus **10 times more sensitive than a gas,** 100 times more sensitive than a scintillator. It therefore has a lower detection threshold and a **better energy resolution** since more primary ionization means less signal fluctuations.
- **Lin**earity**:** The threshold for the *dE/dx* is very low, so there is **good linearity.** Measuring highly ionizing particles, **heavy ions with *dE/dx* ~ Z^2,** however requires a large dynamic range of the read-out electronics.
- **Leakage** current: Even if the junction is in reverse bias, there is a small current



- The energy deposition by *dE/dx* **is very local**. Therefore the **electrodes can be structured** on one or both sides to **locate the passage** of particles. The distance of metalized structures is typically of the order of 50 µm.
- Each channel of the metallic structure must be connected to the readout electronics through micro-bonding.

Show **samples:** silicon wafer, cut sensor, assembly with readout electronics.



Applications of semiconductor detectors in particle physics include the following:

- Semiconductor sensors are arranged in layers to measure the **trajectory** of charged particles. These profit from the developments in micro-electronic technology to fabricate precise structures on Si and other semiconductor materials. Examples are:
    - Microstrip detectors (e.g. for the ATLAS SCT, and AMS);
    - Pixel detectors (used for the first time at the LHC);
    - Charge Coupled Devices, CCD, used for digital cameras, and many others.
- Semiconductor detectors also measure the **deposited energy**. Their excellent resolution allows the identification of the charge of the penetrating particle in a tracking device. They can also be the sensitive elements in a calorimeter.
- Applications are only limited by the thickness of the depletion zone, 50 μm<Δx<O(mm), and the maximum chip size that can be produced (50 cm^2).

We show more examples for the use of semiconductor sensors in video 3.10. In the next video we will first talk about scintillation and Cherenkov detectors.