

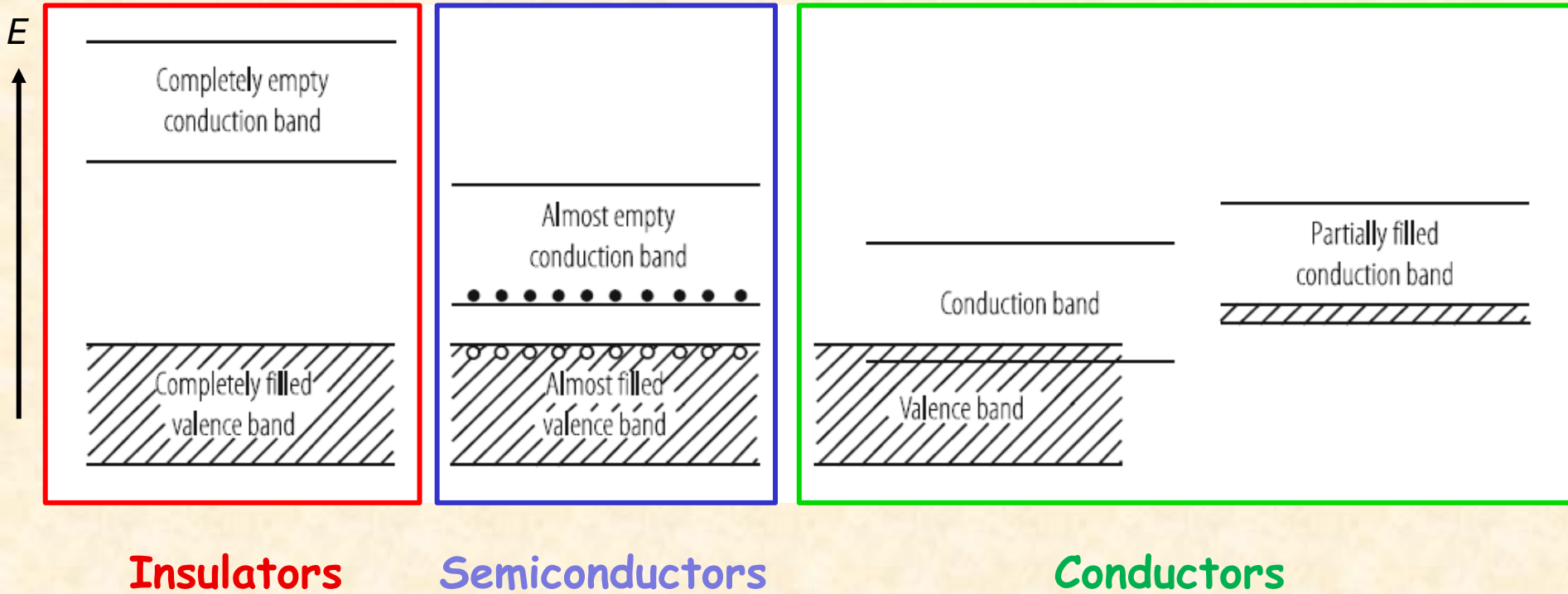


Solid State Detectors

A. Trifirò

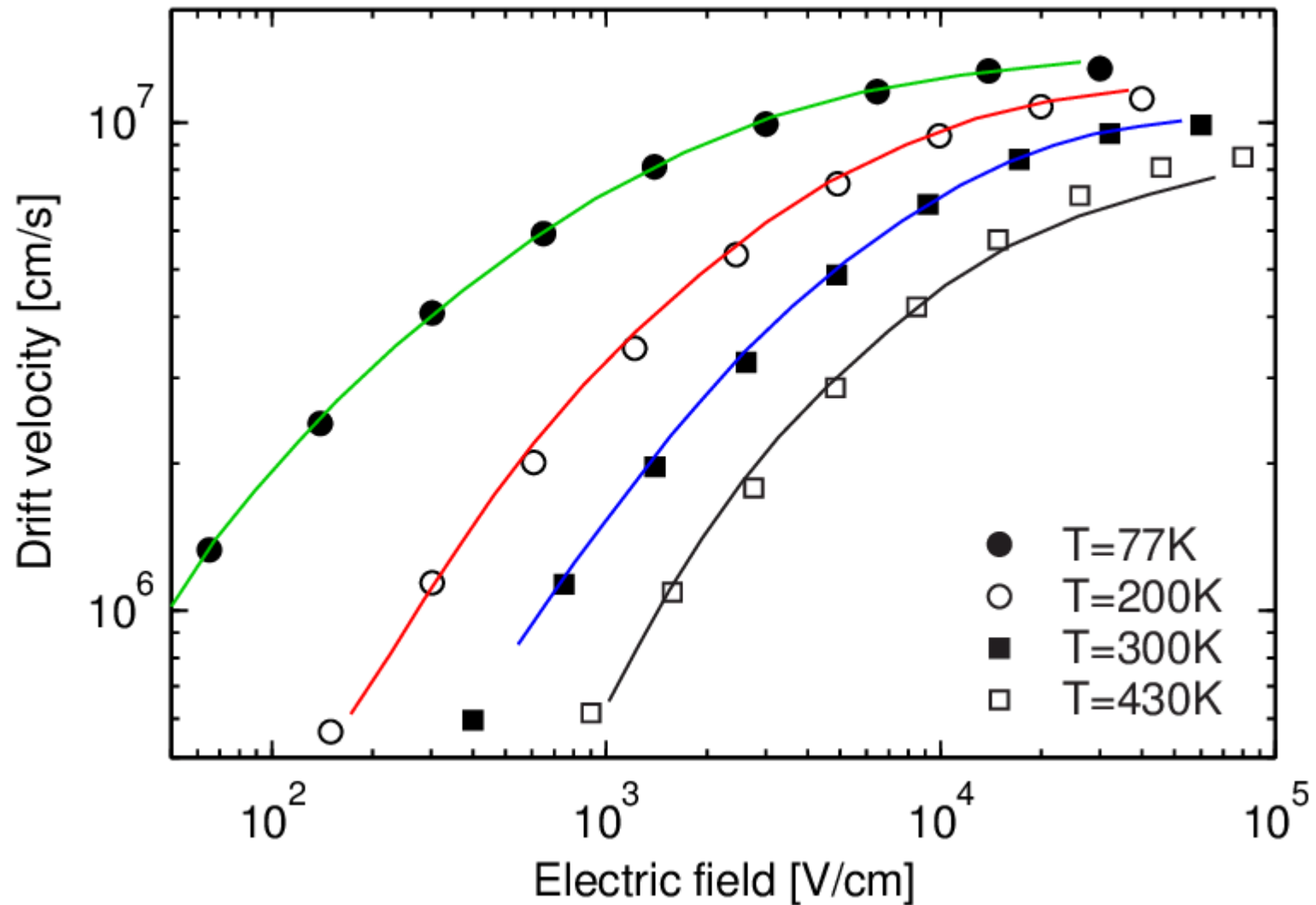
XIX Seminar on Software for Nuclear,
Subnuclear and Applied Physics

Energy Band Structures

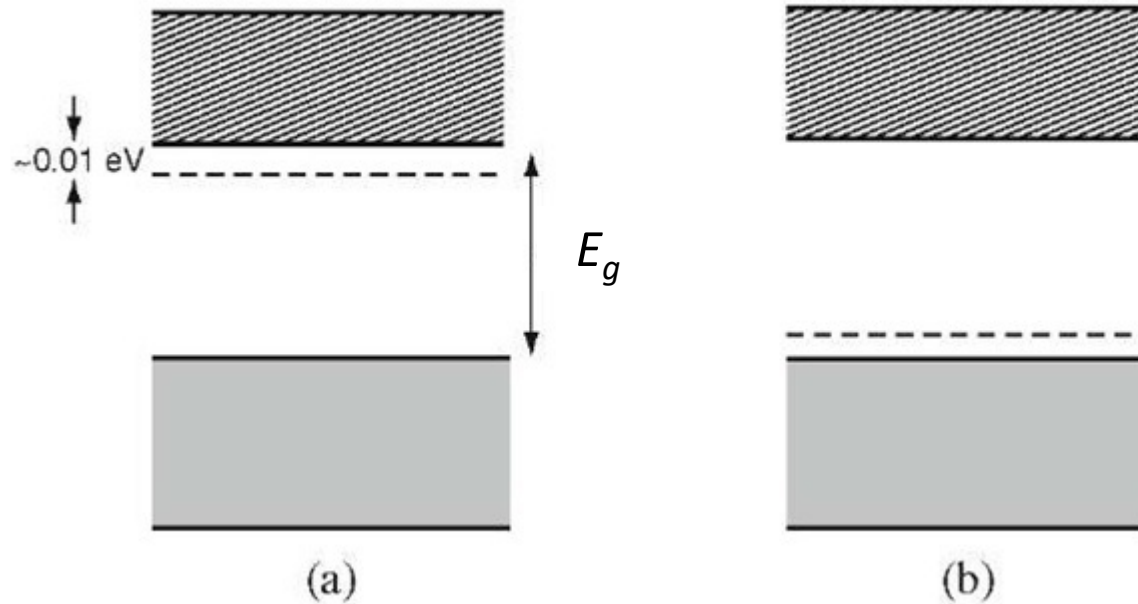
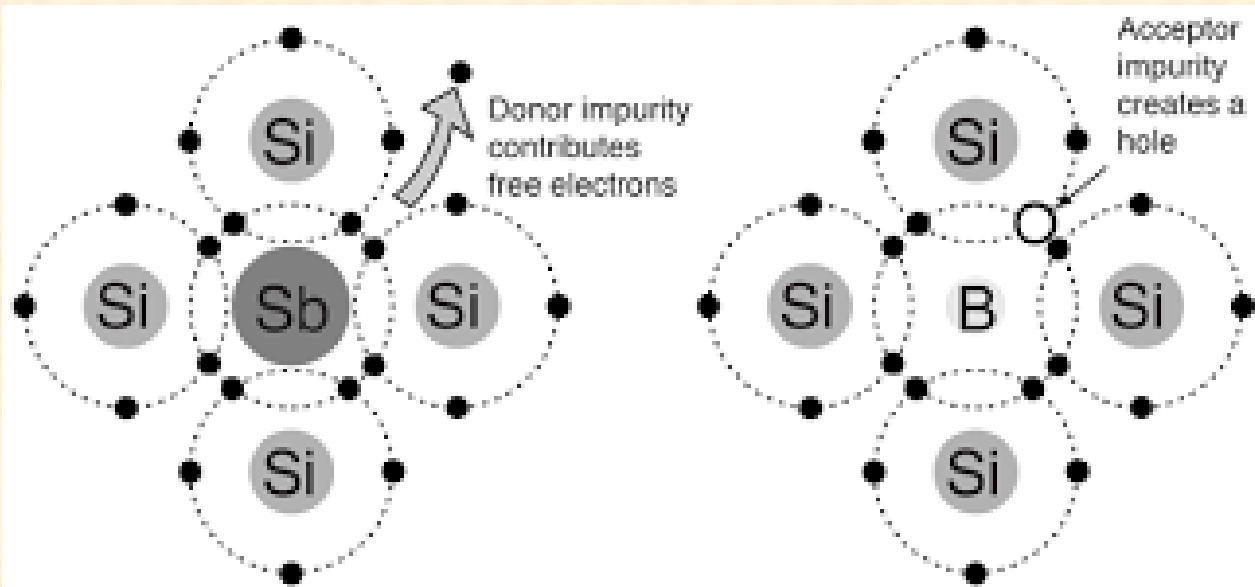


$$P(T) = CT^{3/2} \exp\left(\frac{-E_g}{2kT}\right)$$

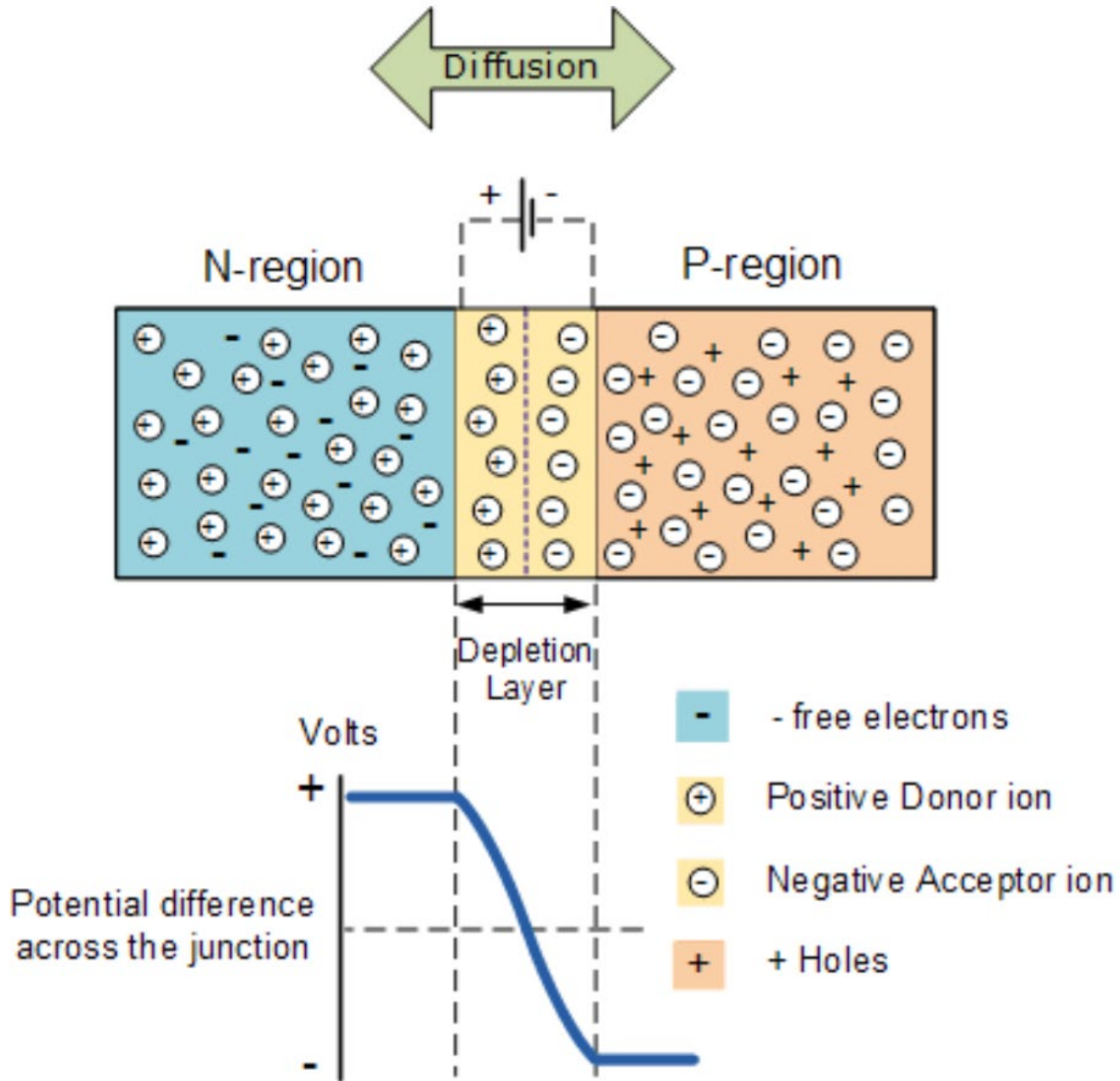
Electron drift velocity vs. electric field in silicon



Effect of doping

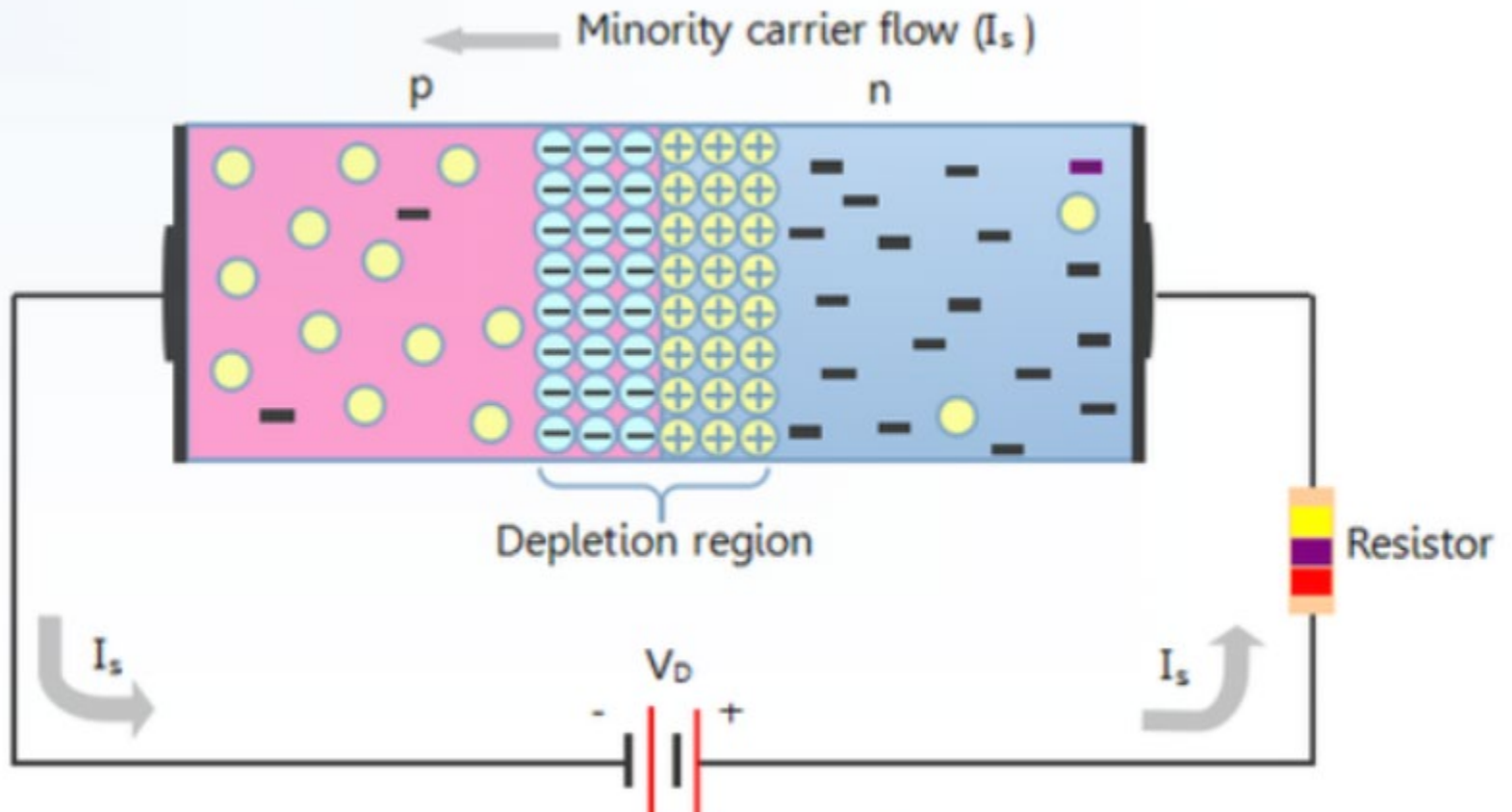


P-N junction

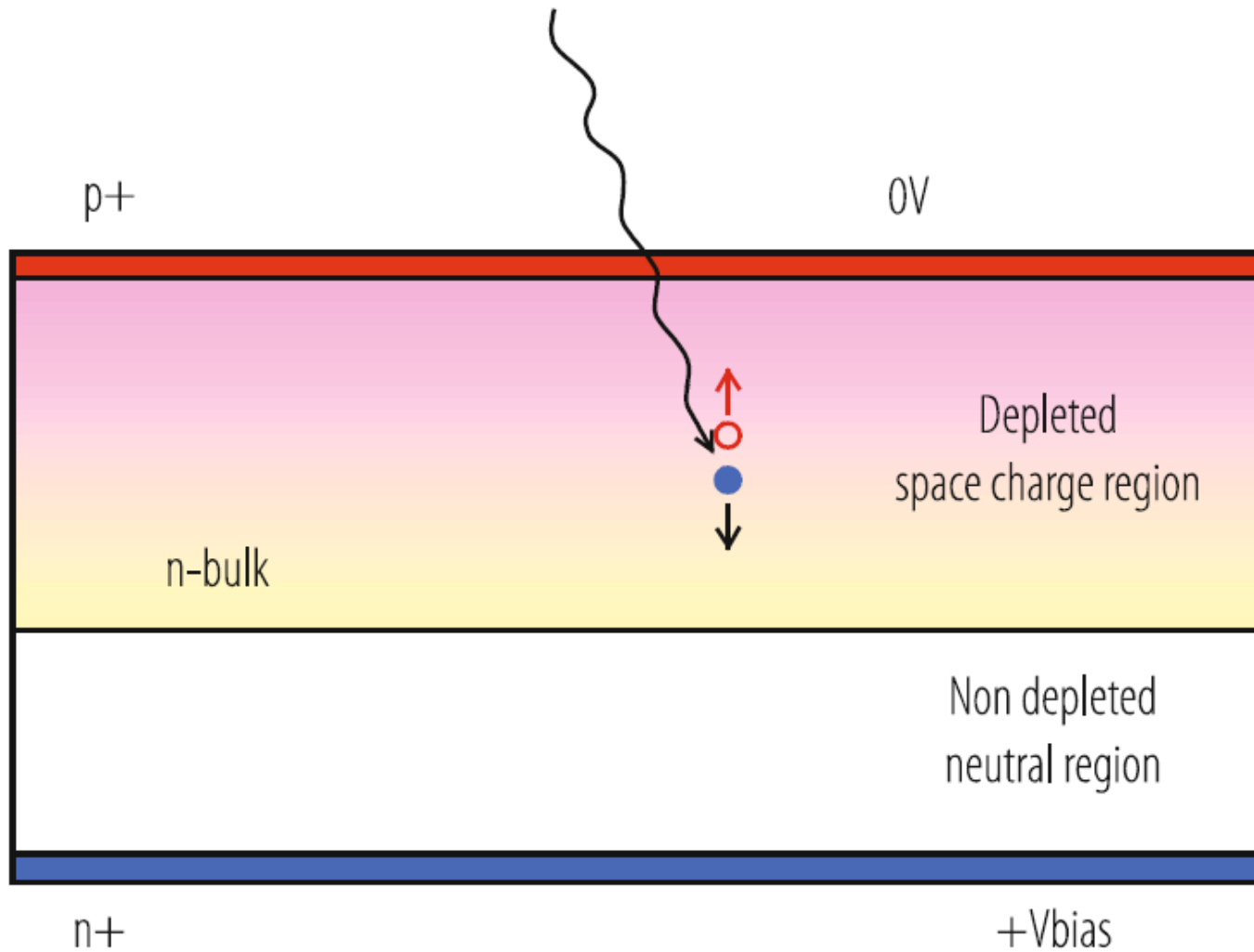


Reverse biased P-N junction

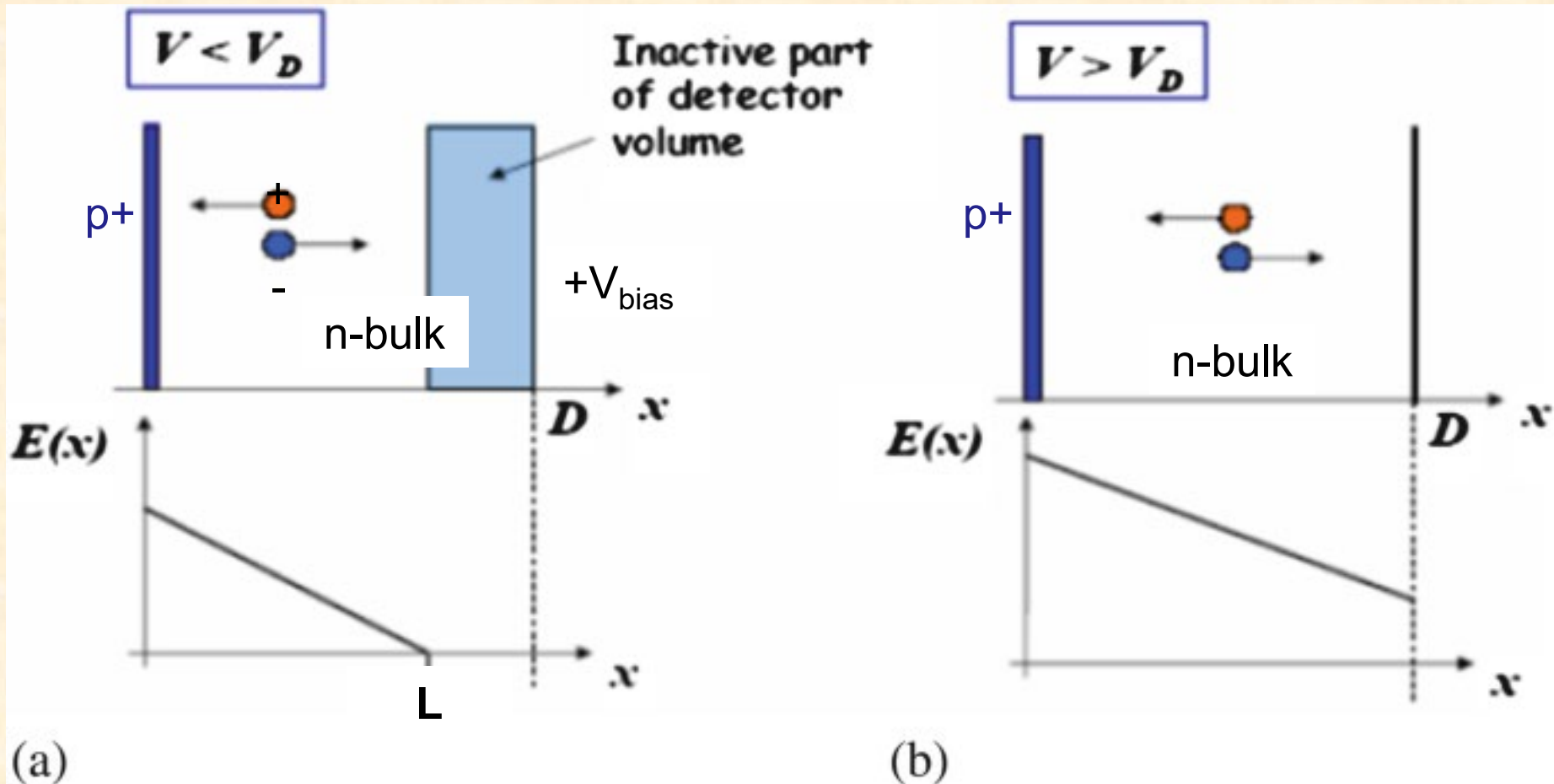
© ConceptsElectronics.com

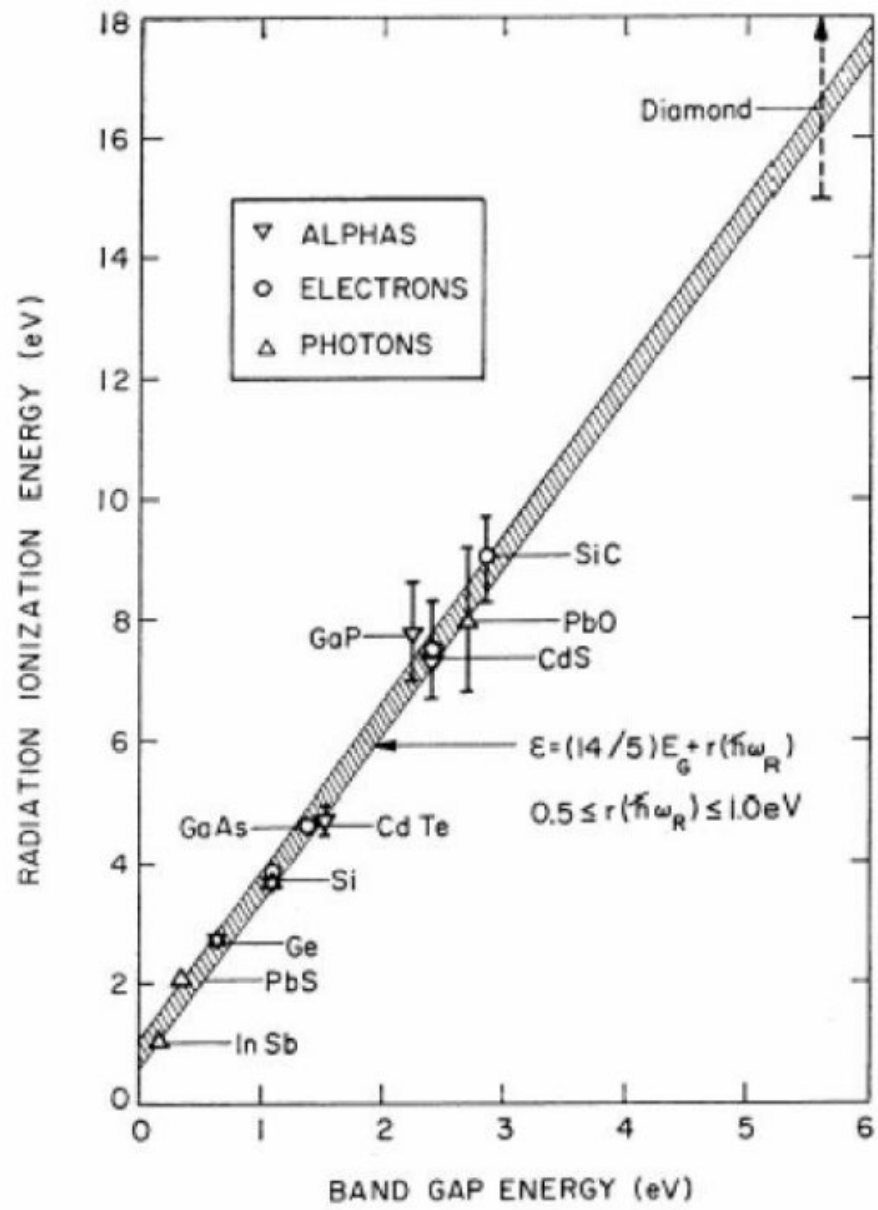


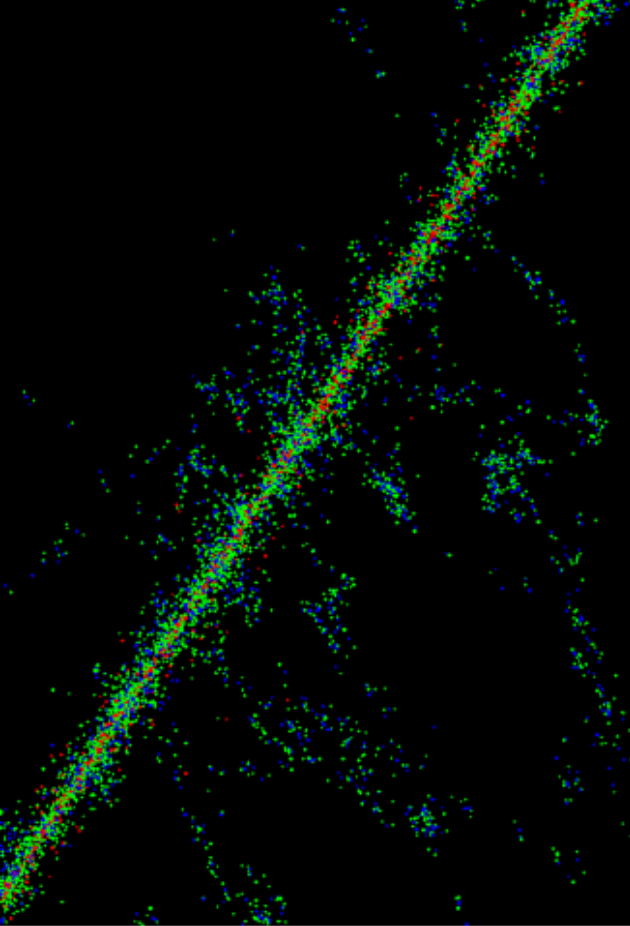
Reverse-biased semiconductor diode



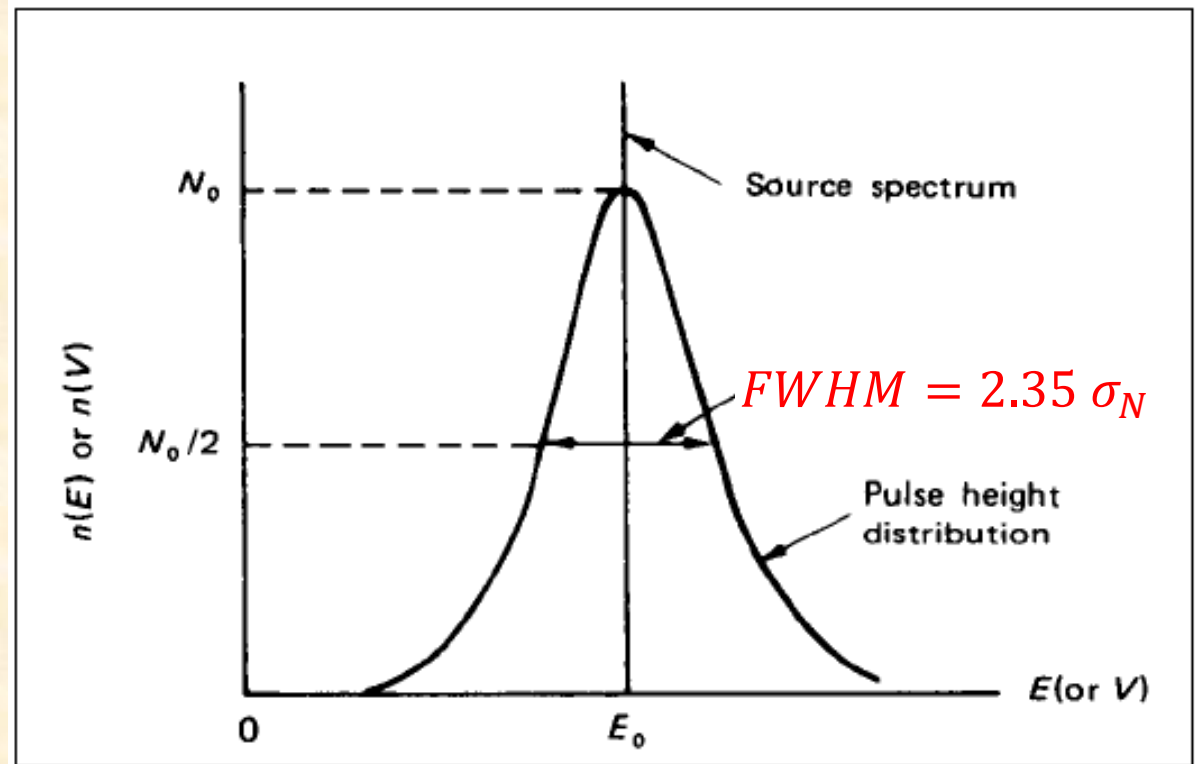
Depletion of a surface barrier detector





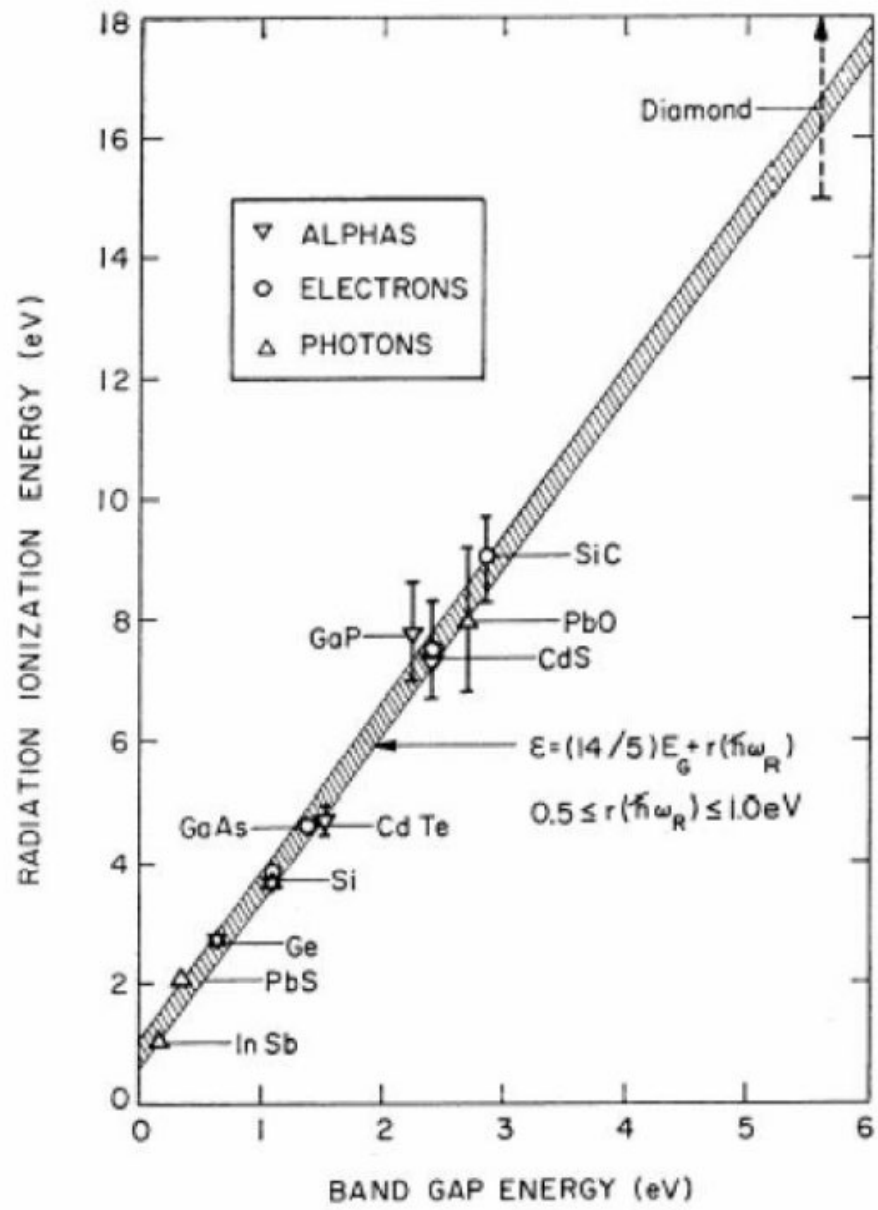


$$\text{Poisson} \rightarrow \text{Fractional St. Dev.} = \frac{\sigma_N}{N} = \frac{1}{\sqrt{N}}$$

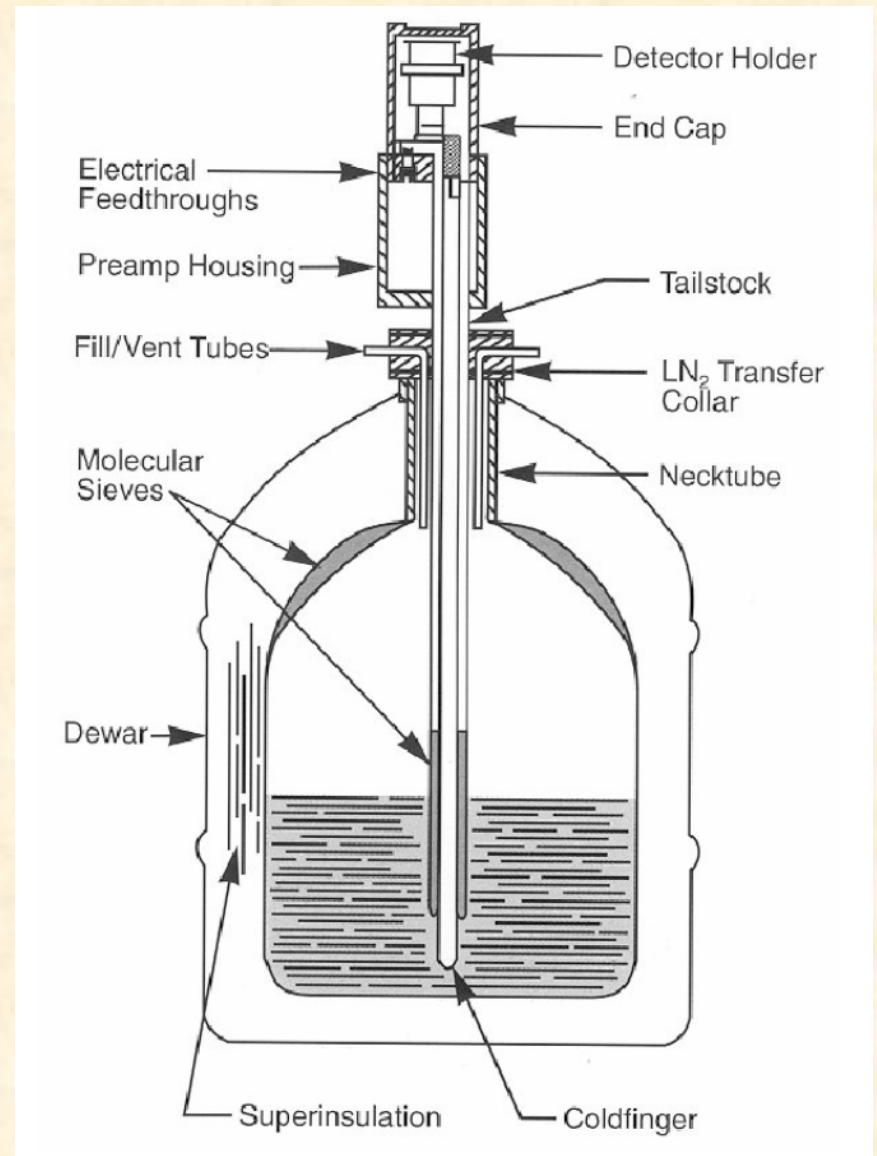


$$F \equiv \frac{\text{observed } \sigma_N}{\text{Poisson } \sigma_N (=N)}$$

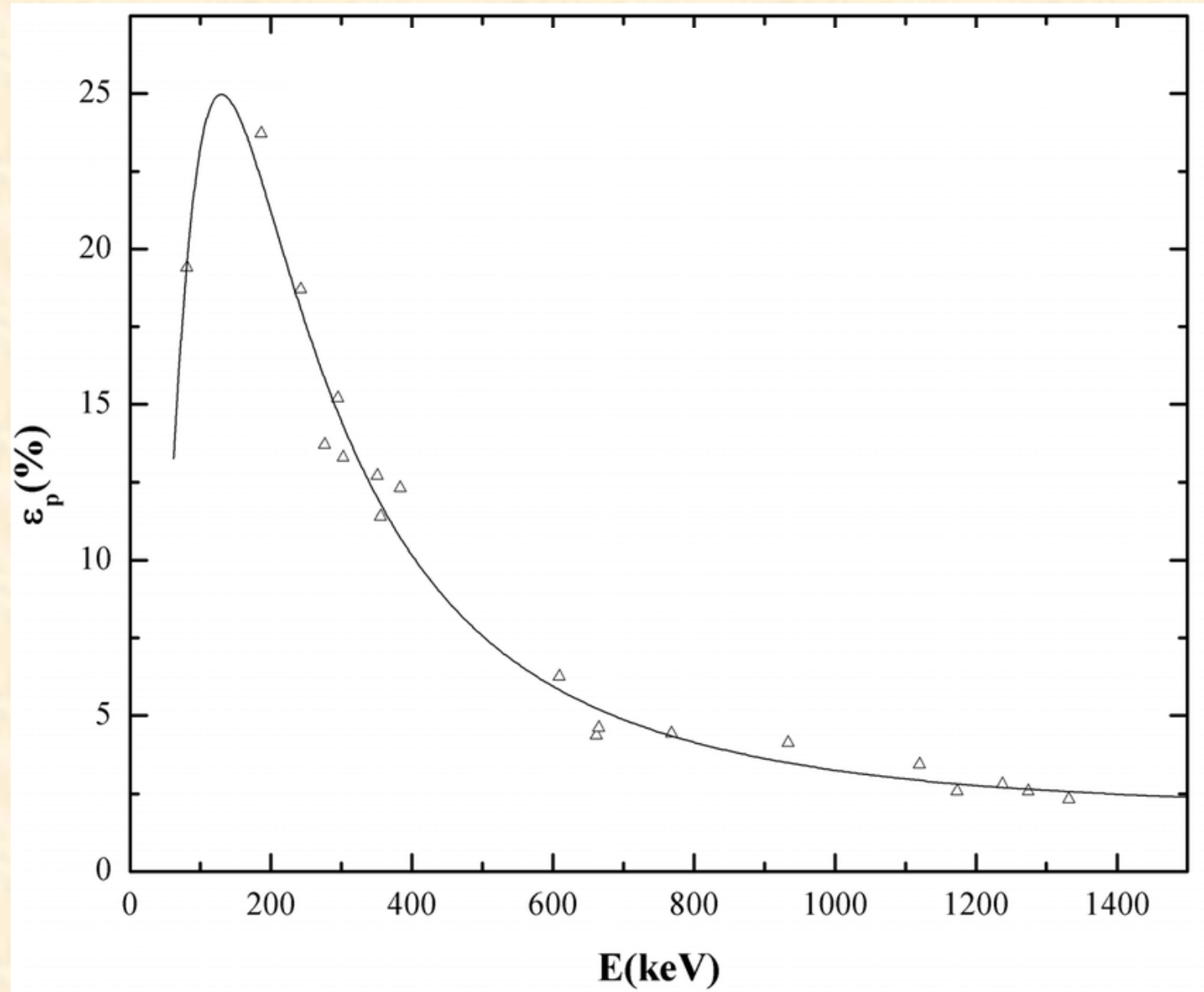
$$\Rightarrow R_{stat.} = 2.35 \sqrt{\frac{F}{N}}$$



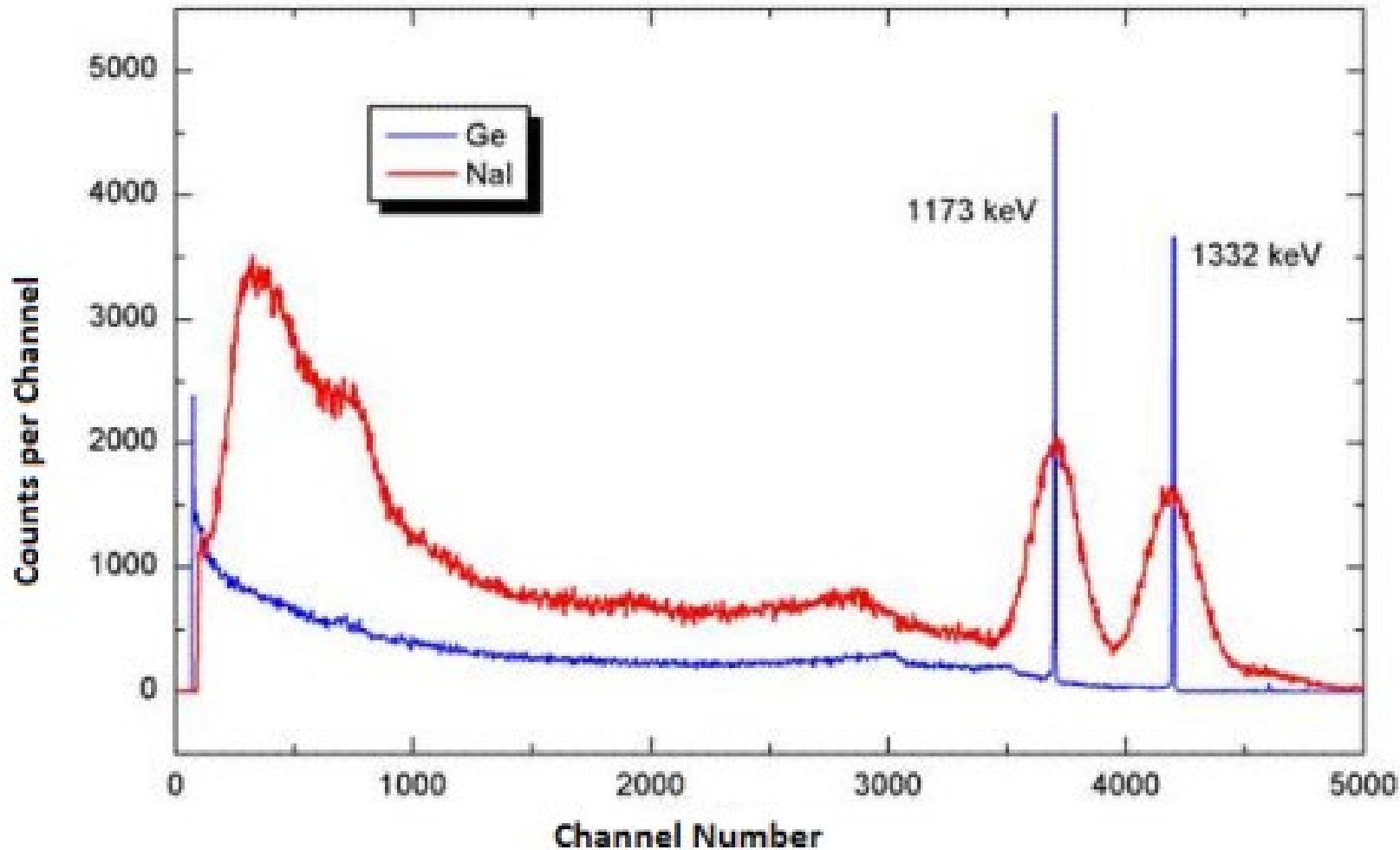
Ge Detectors

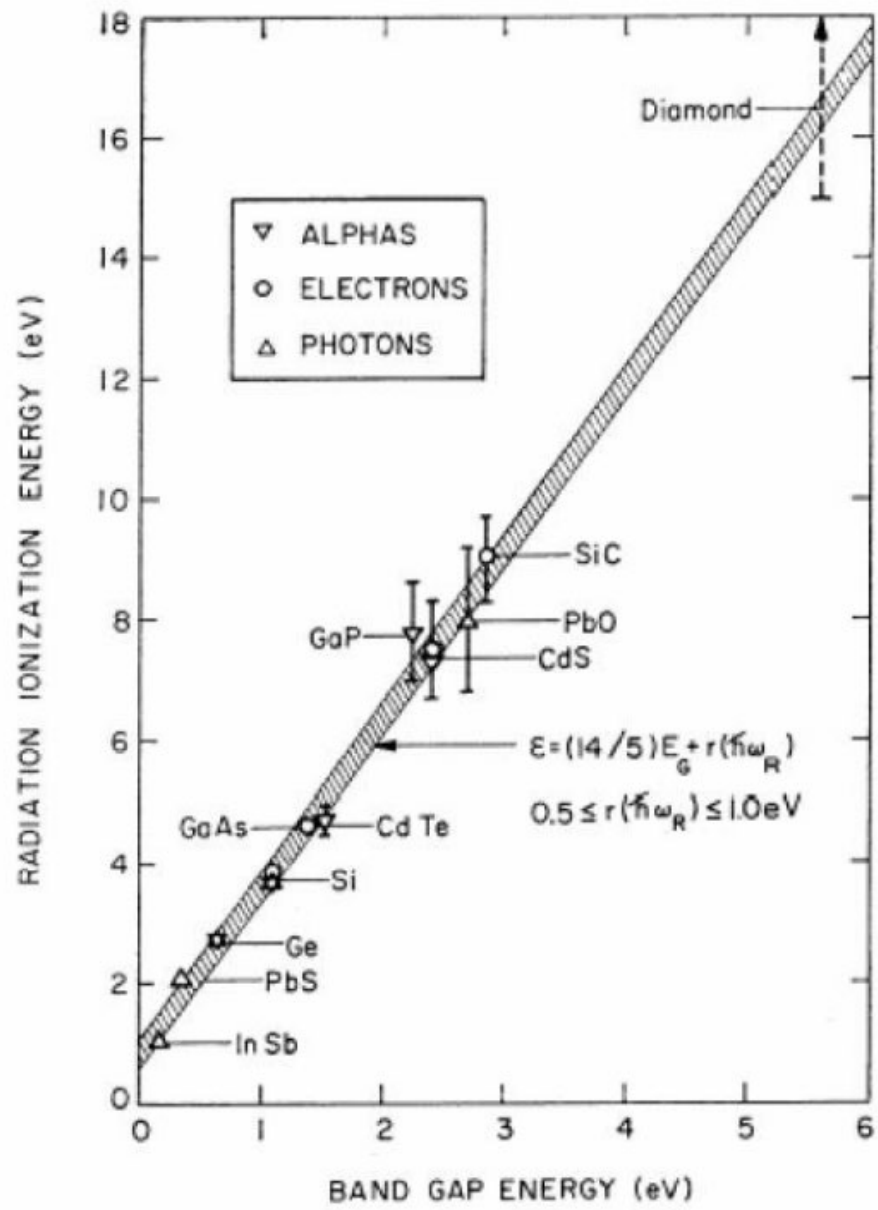


Efficiency of a high-purity germanium detector



HPGe Resolution: $\frac{FWHM}{E} \approx \frac{2keV}{1332keV} = 0.15\%$

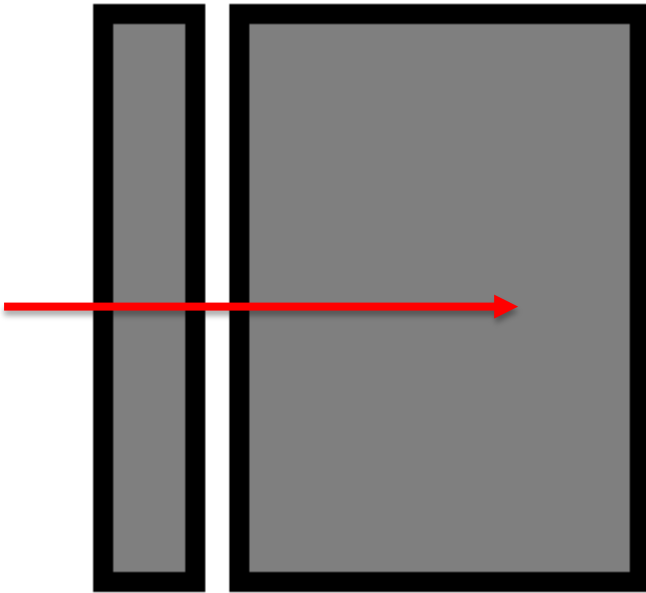




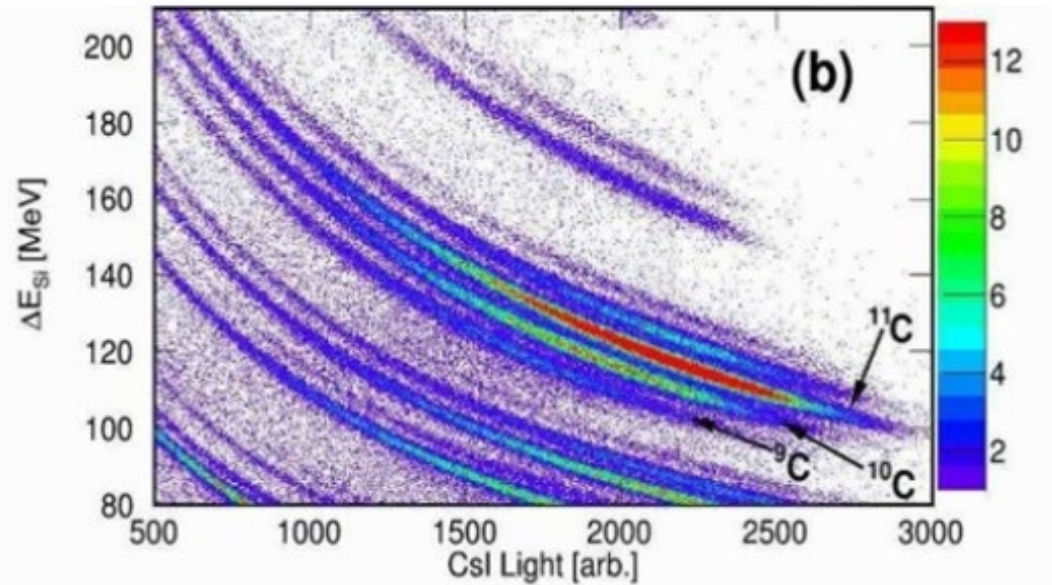
Si detectors

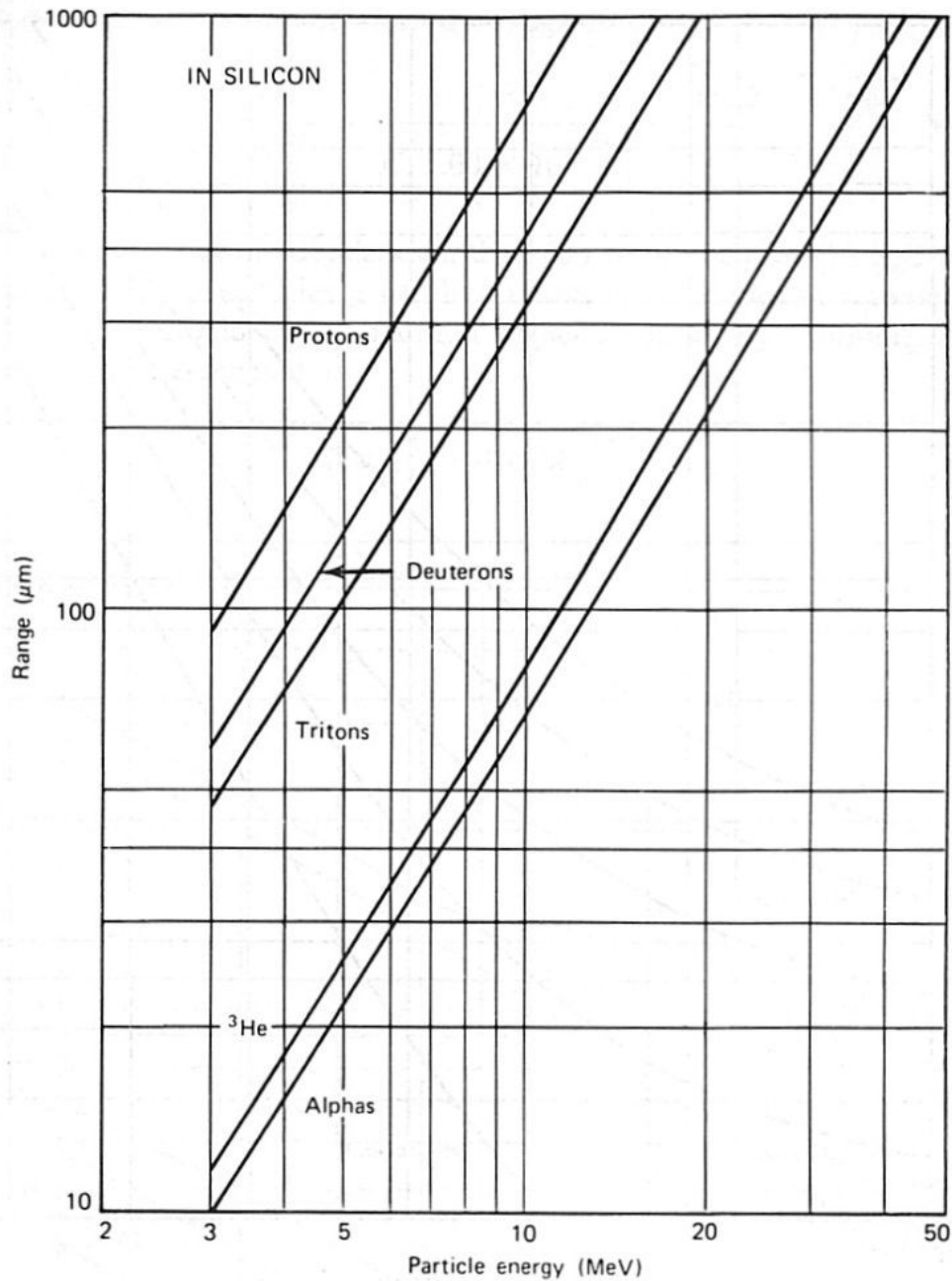


ΔE - E telescope for particle identification



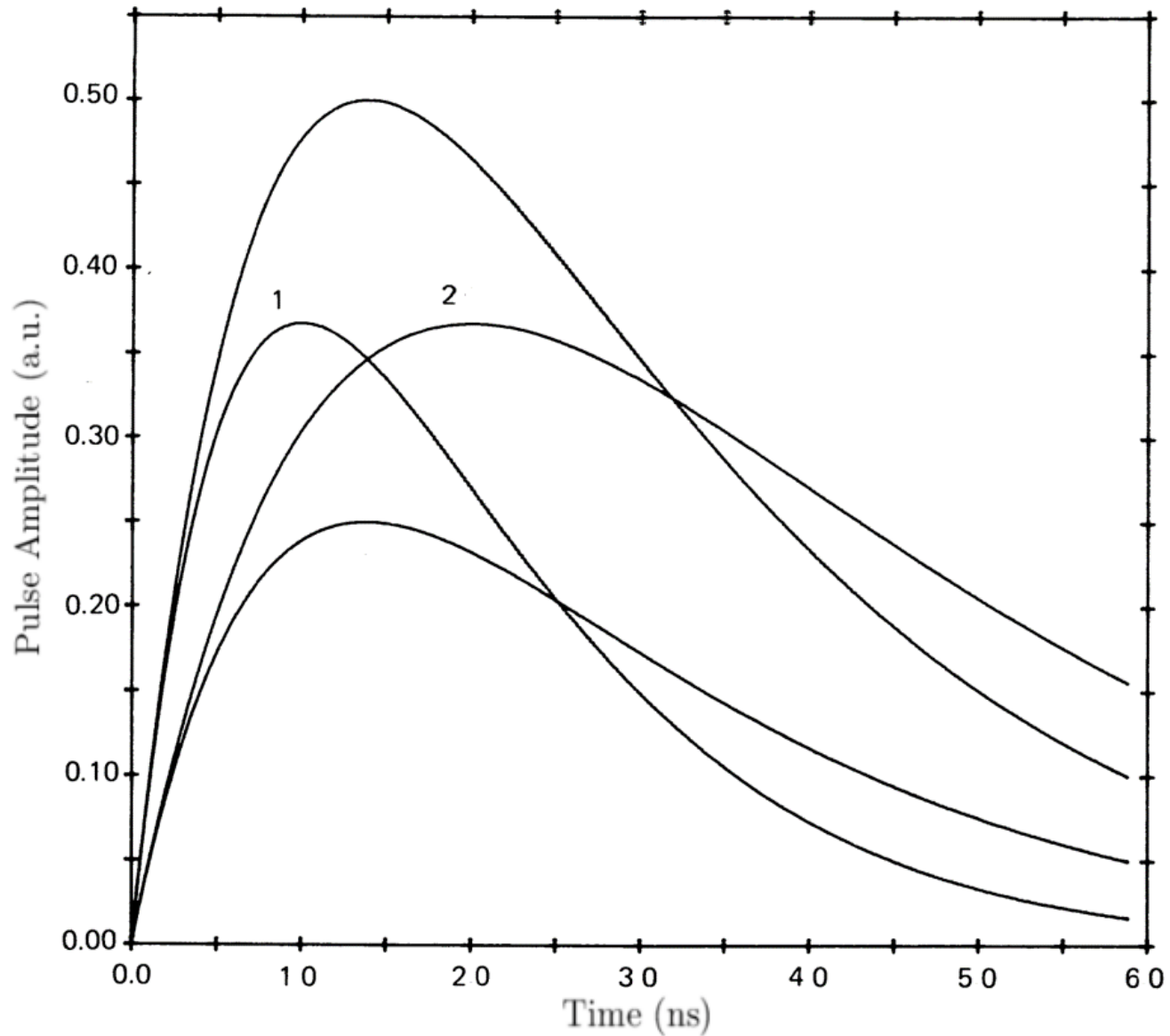
$$\Delta E \propto n\Delta x \cdot \frac{AZ^2}{E}$$



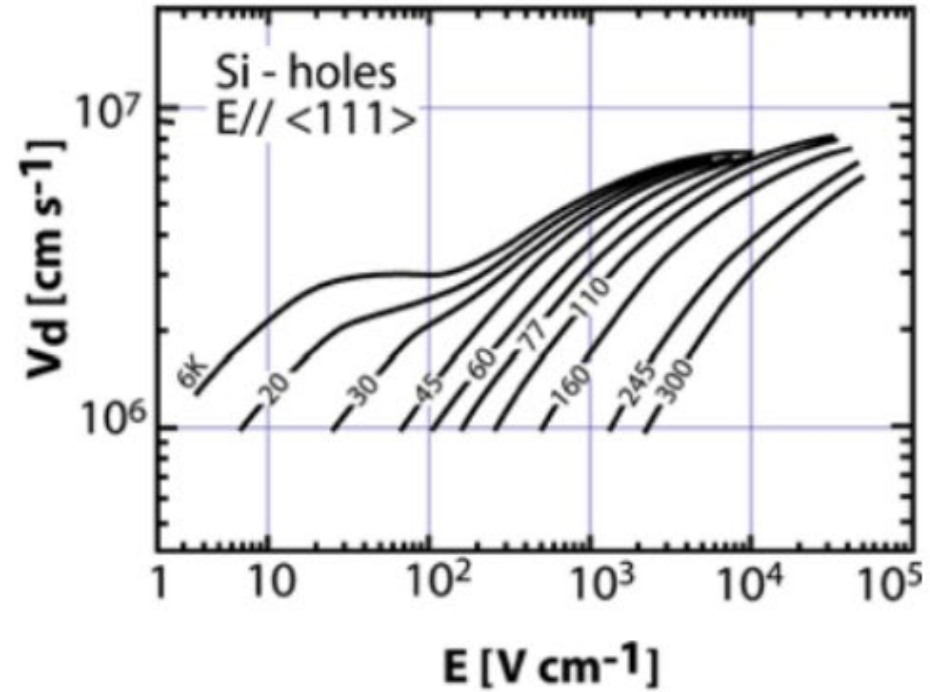
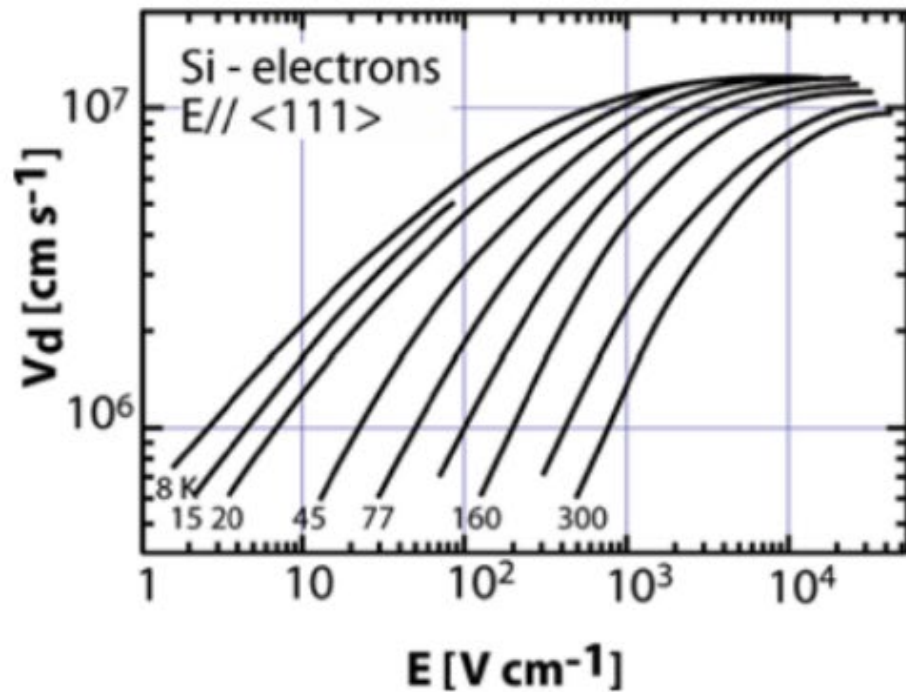
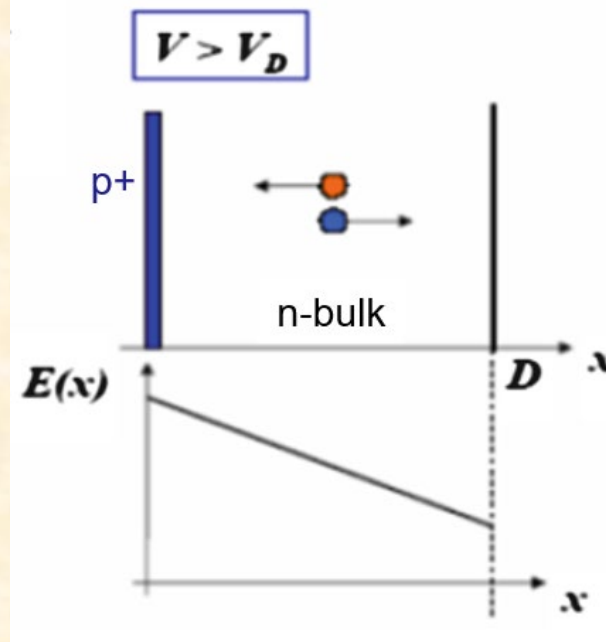


$$t \cong 1.21 \times 10^{-7} R \sqrt{\frac{A}{E}}$$

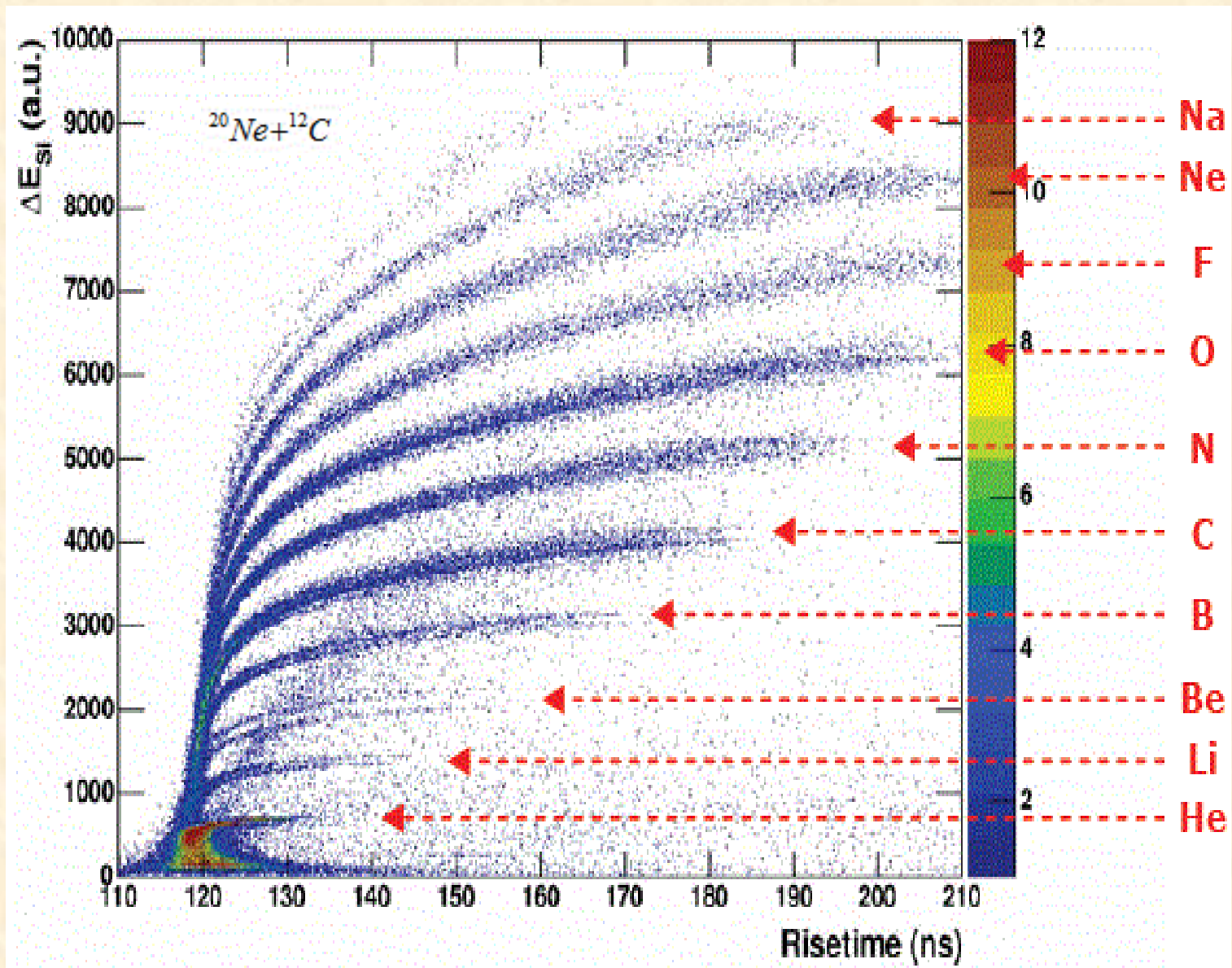
Pulse Shape Discrimination



Reverse-mount Si transmission detector

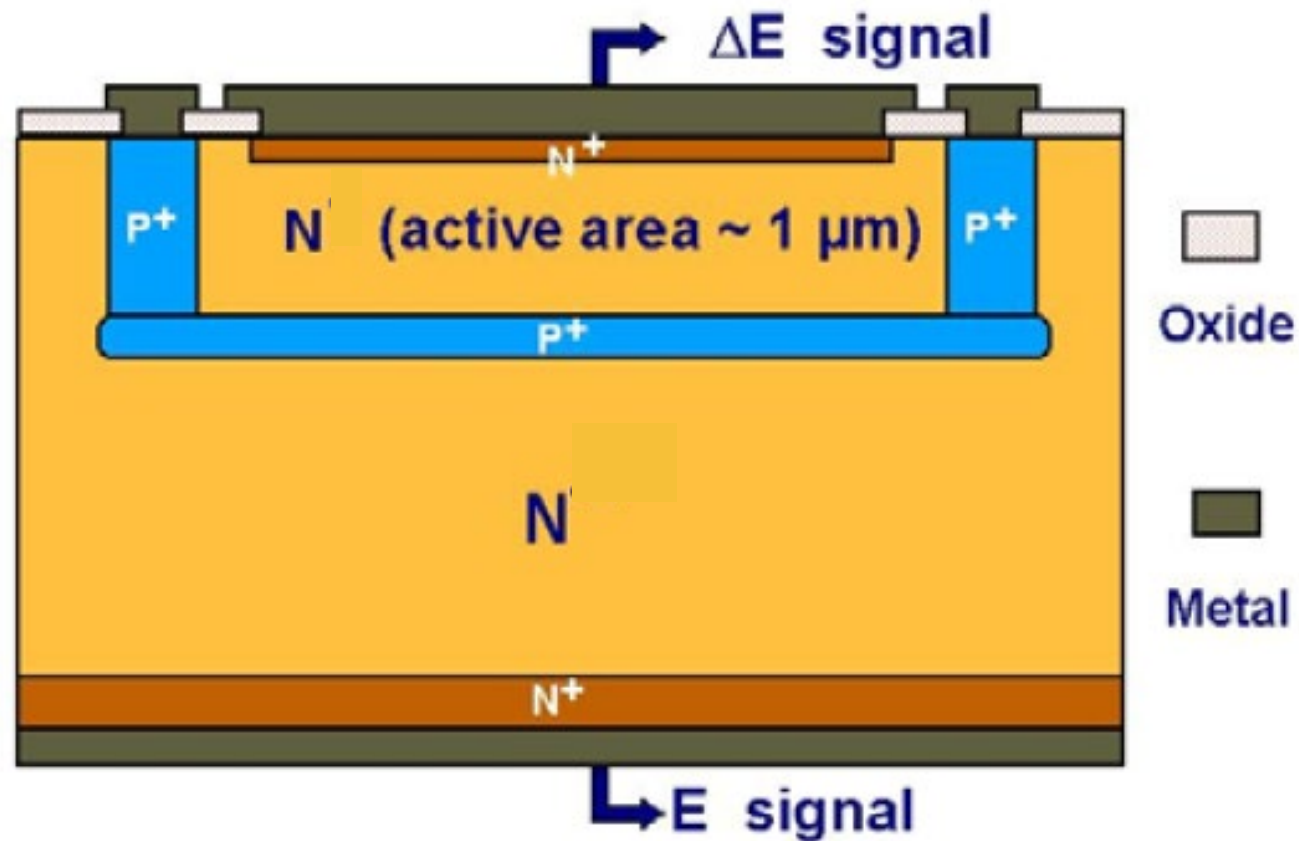


Pulse Shape Discrimination in Si



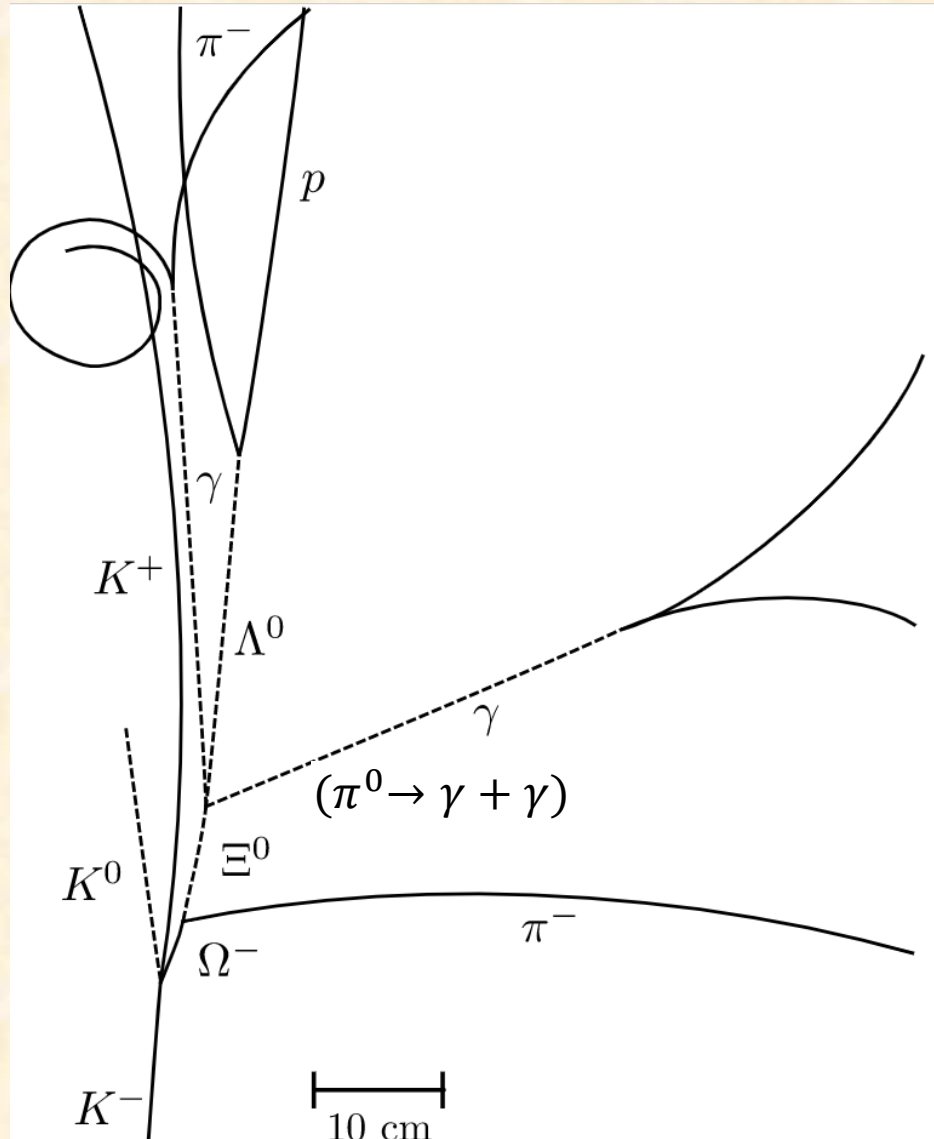
MONOLITHIC SILICON DETECTOR TELESCOPE

Buried anode:
1MeV Boron Ion
Implantation

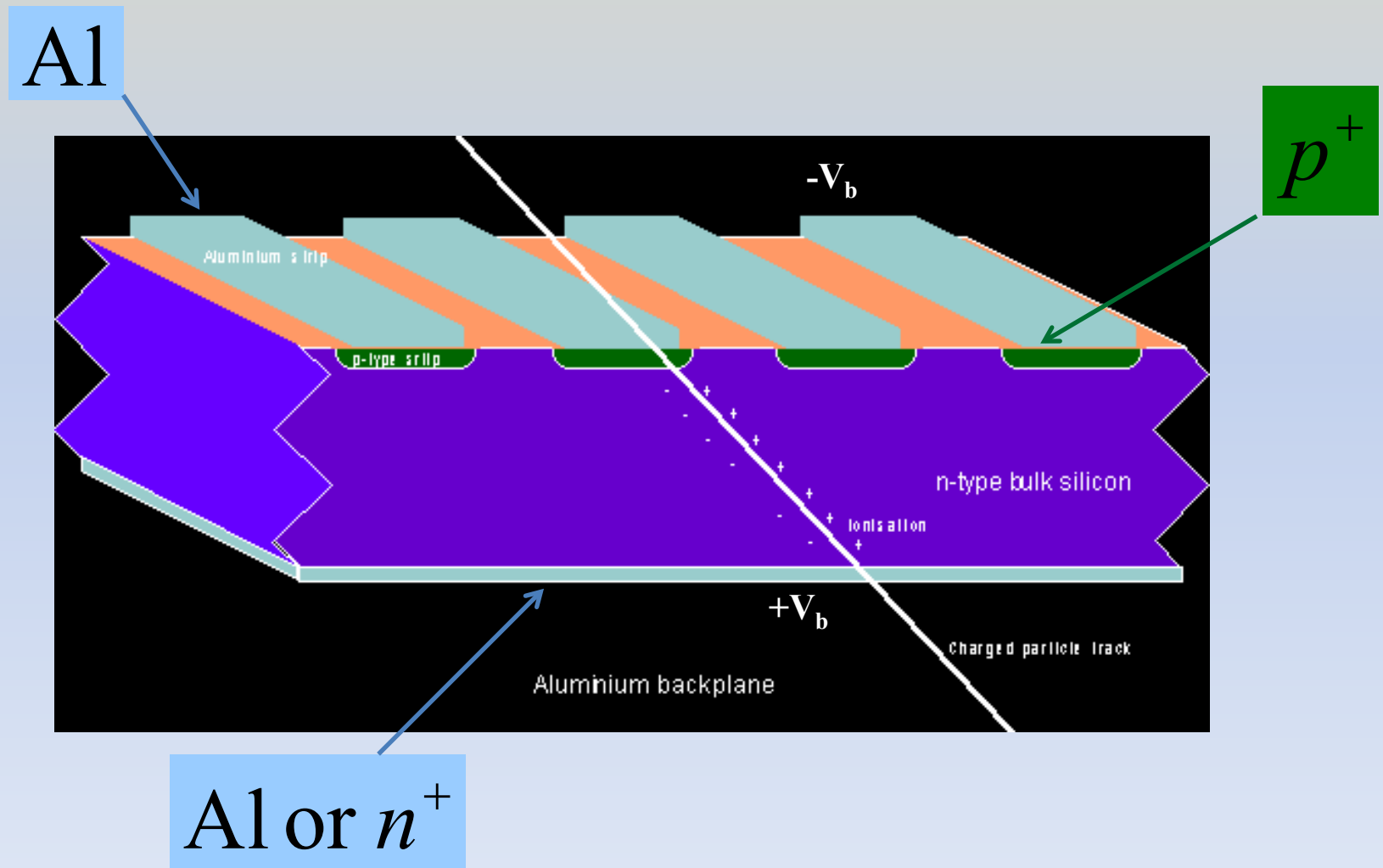


Ω Barion Discovery

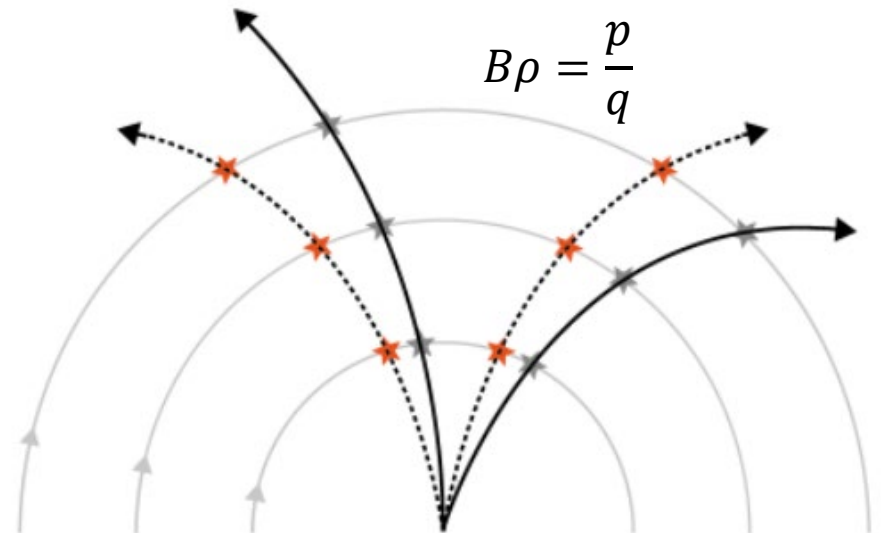
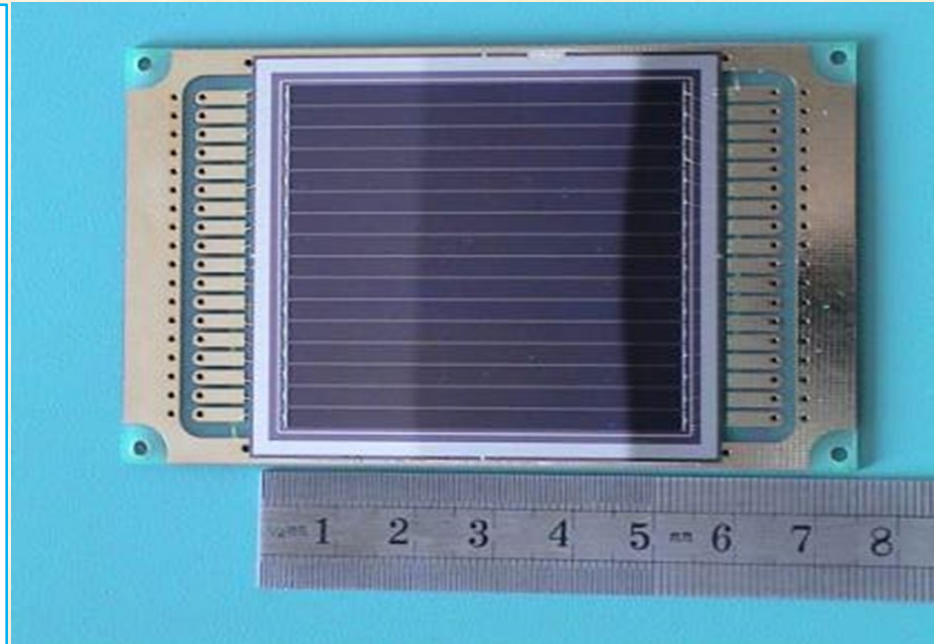
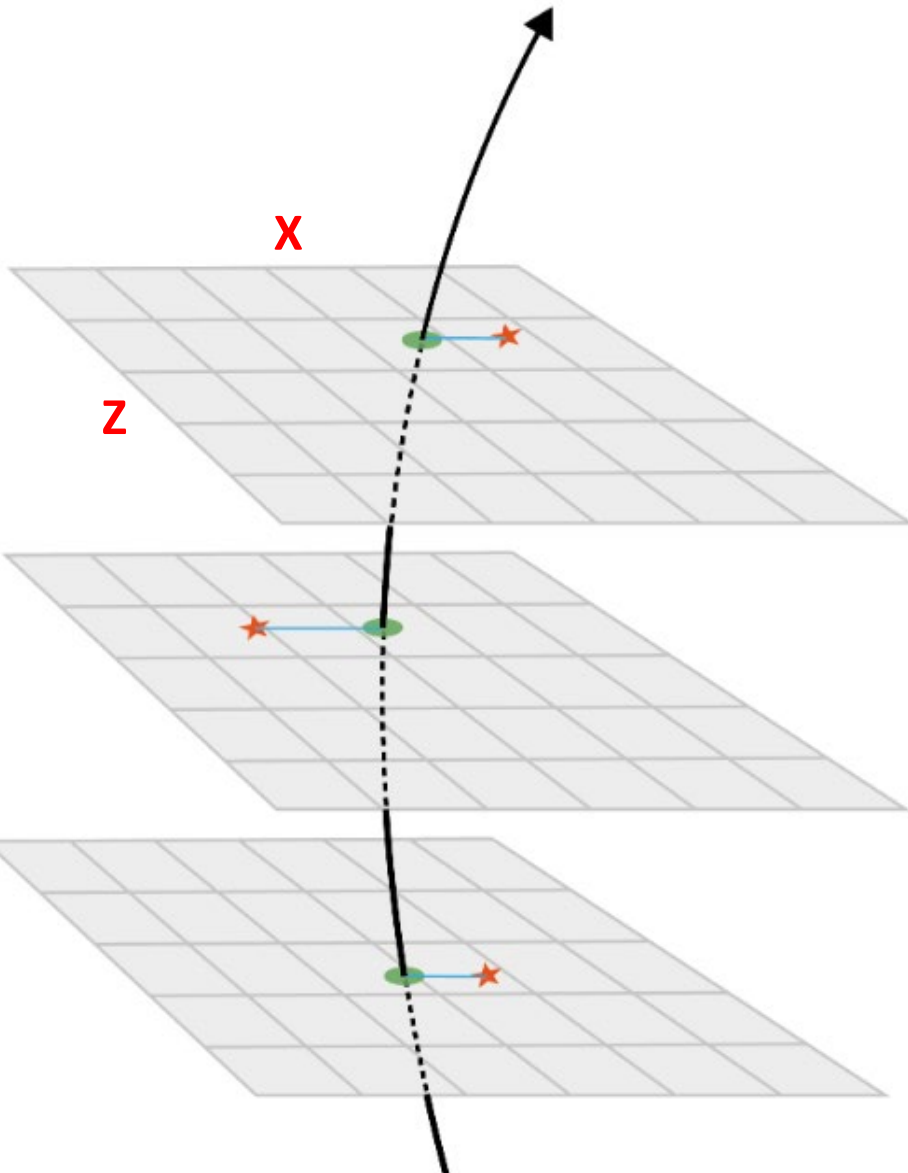
(Brookhaven National Laboratory, 1964)



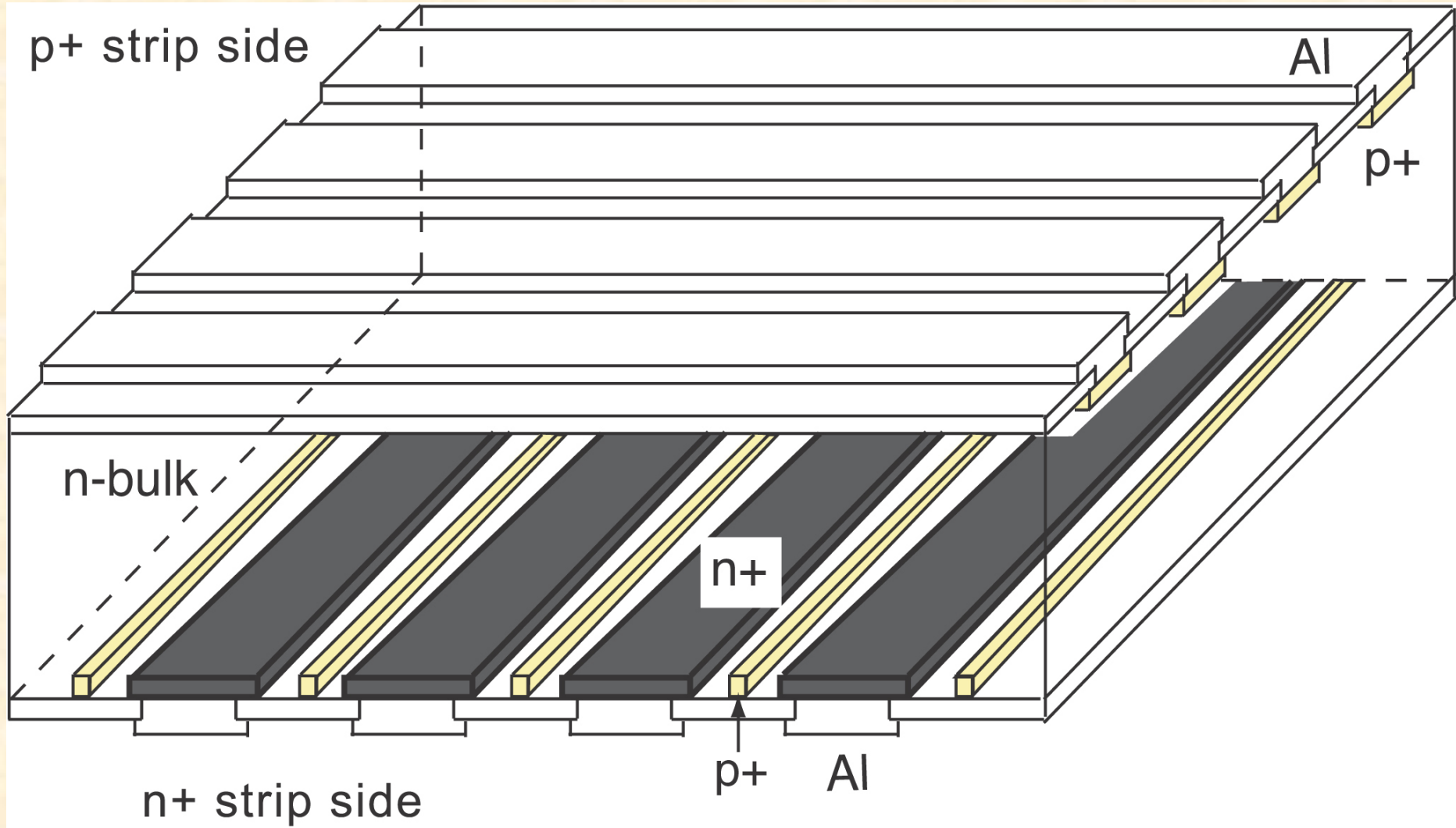
Single-sided Position-sensitive Silicon Strip Detector



Single-sided Position-sensitive Silicon Strip Detector

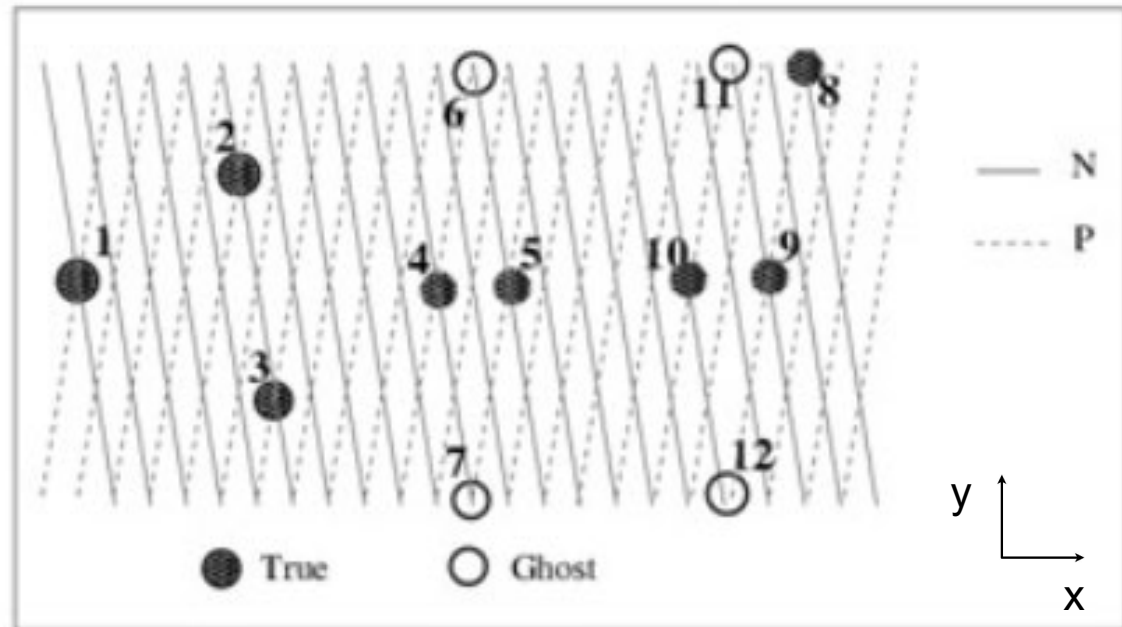
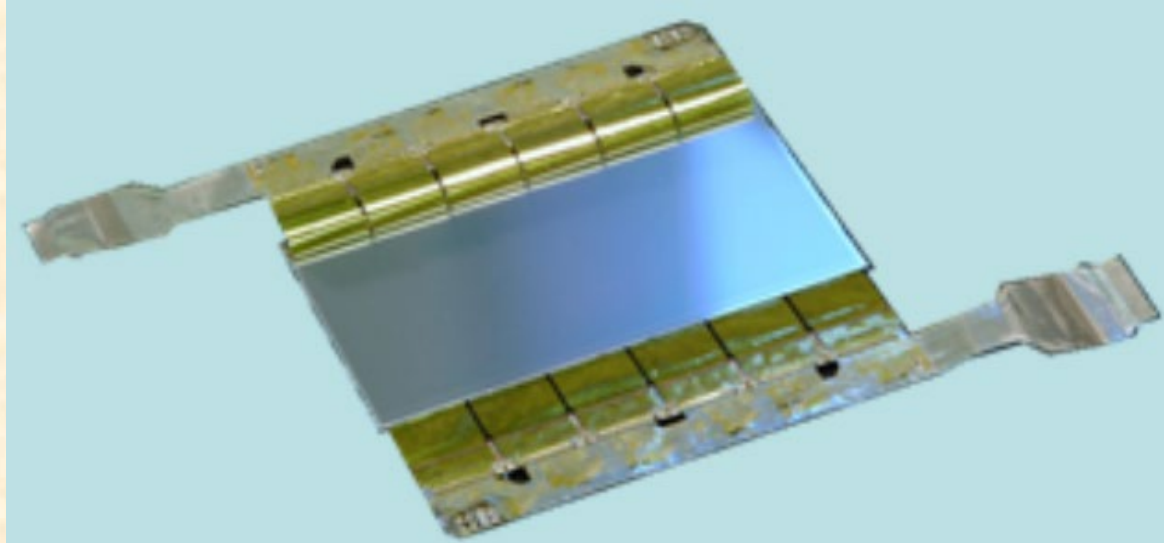


Double-sided Silicon Strip Detector



ALICE-ITS Silicon Strip Detectors

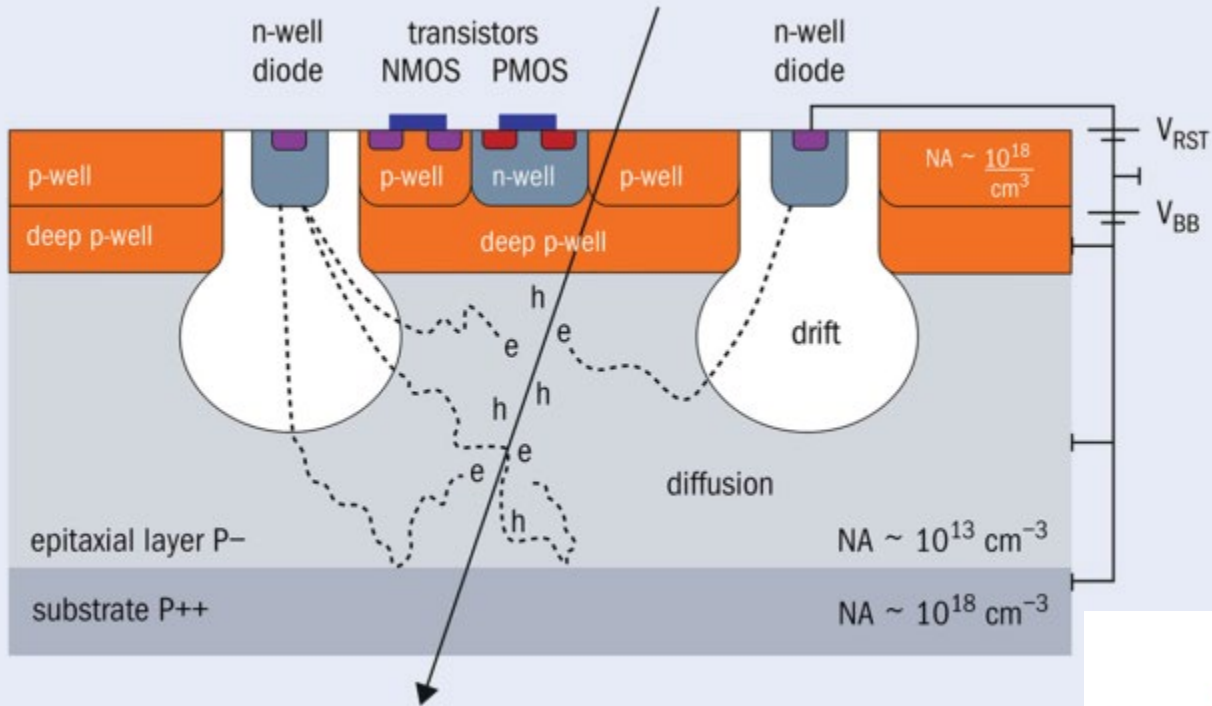
- Area = $73 \times 40 \text{ cm}^2$
- $300 \text{ }\mu\text{m}$ thick
- 768 strips per side
- Strip pitch: $95 \text{ }\mu\text{m}$
- P-to-N stereo angle:
 35 mrad ($\sim 2^\circ$)
- Resolution:
 - $x \rightarrow 15 \text{ }\mu\text{m}$
 - $y \rightarrow 700 \text{ }\mu\text{m}$



ALICE-ITS

SPD

(Silicon Pixel Detectors)



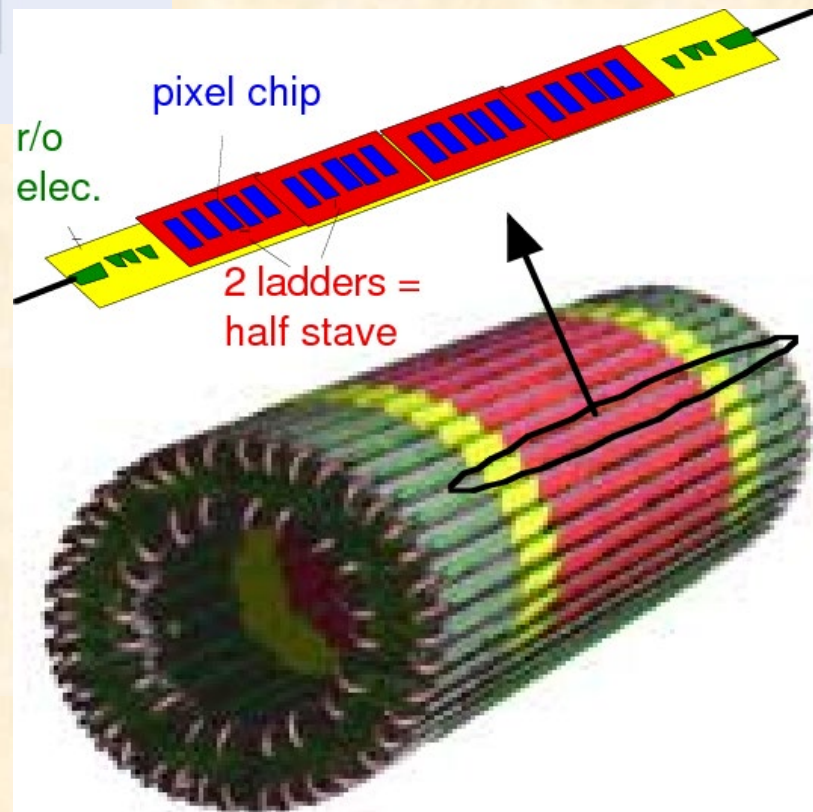
Radius: 3.9cm (L1), 7.6cm (L2)

Length: 14 cm

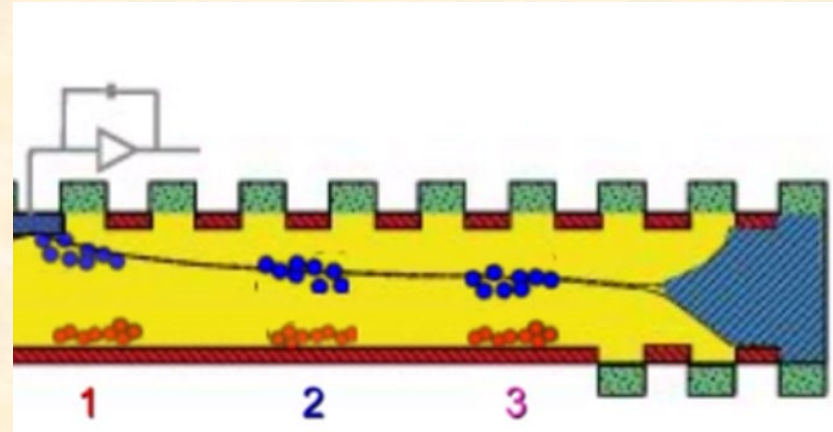
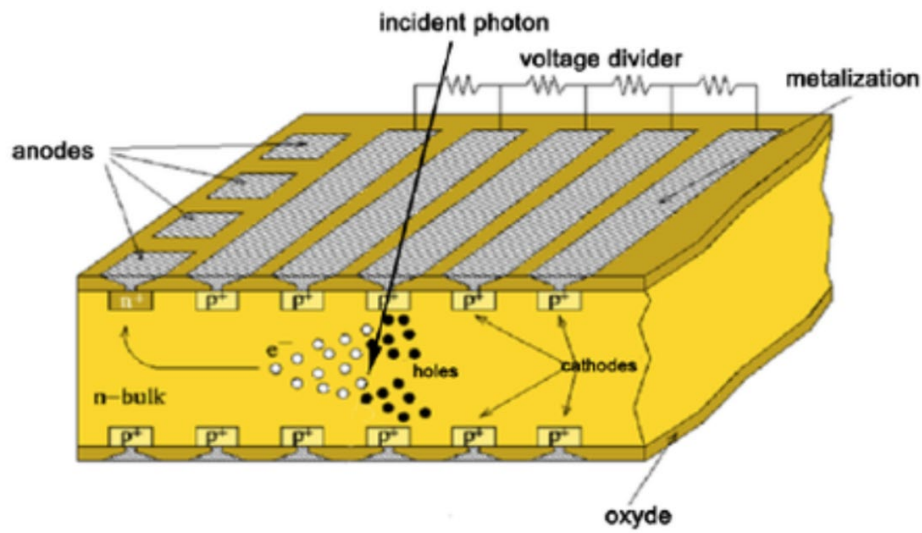
1 chip: 32x256 (8192) pixels

1 pixel: $50\mu\text{m} \times 425\mu\text{m}$ ($200\mu\text{m}$ th.)

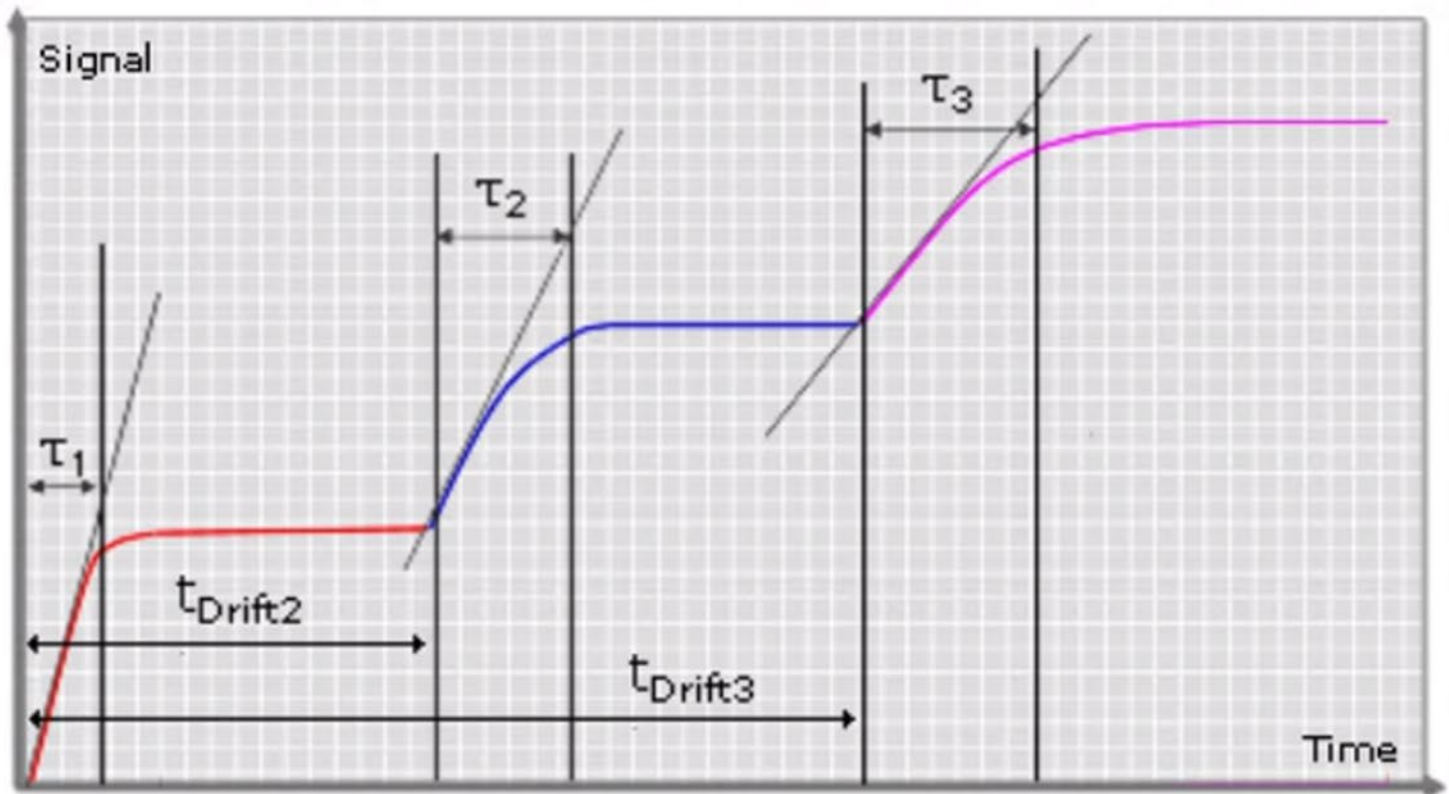
Total n. of Pixel: 9.8×10^6



Silicon Drift Detector

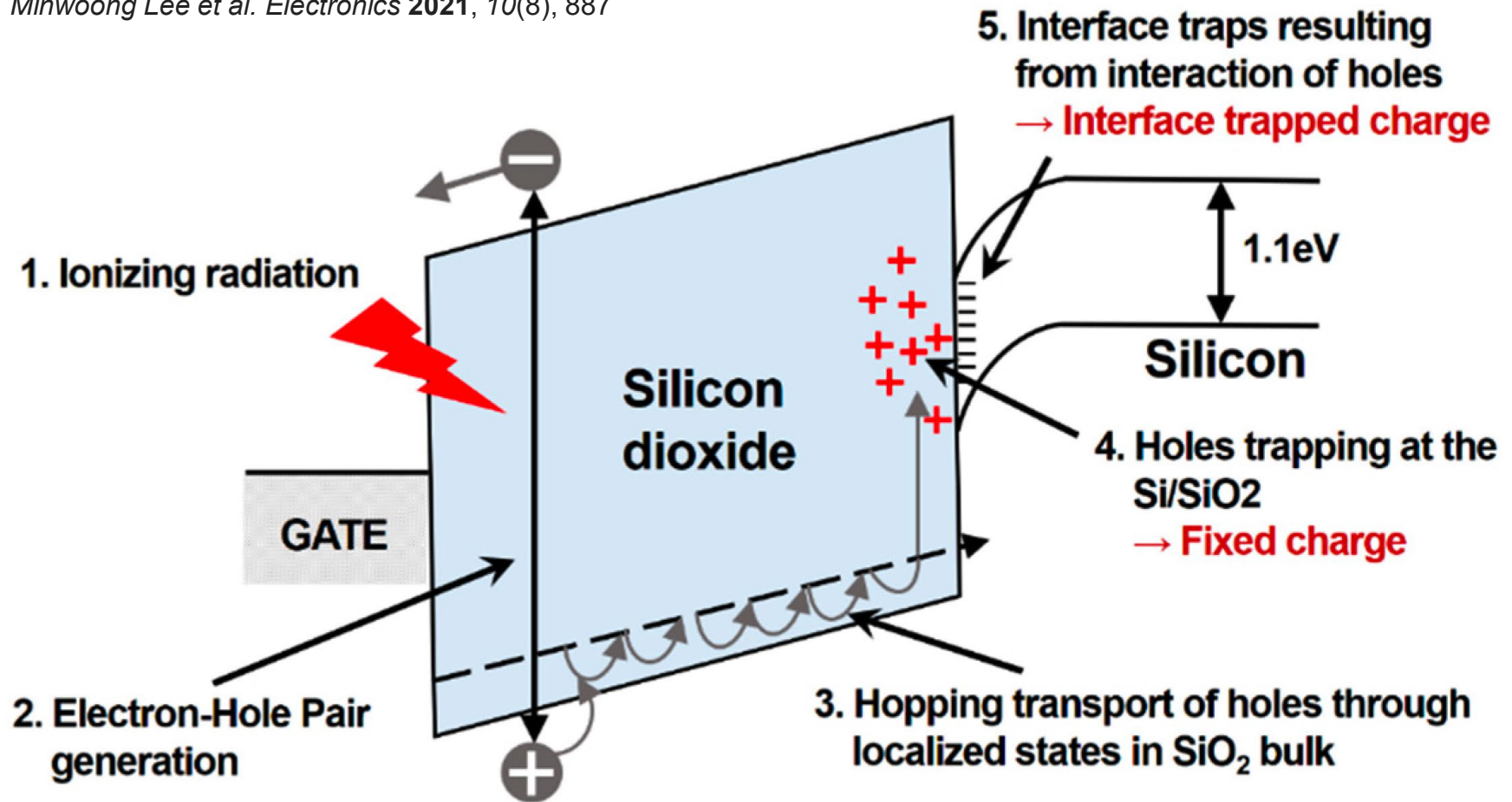


- Event 1 **Signal 1**
- Event 2 **Signal 2**
- Event 3 **Signal 3**

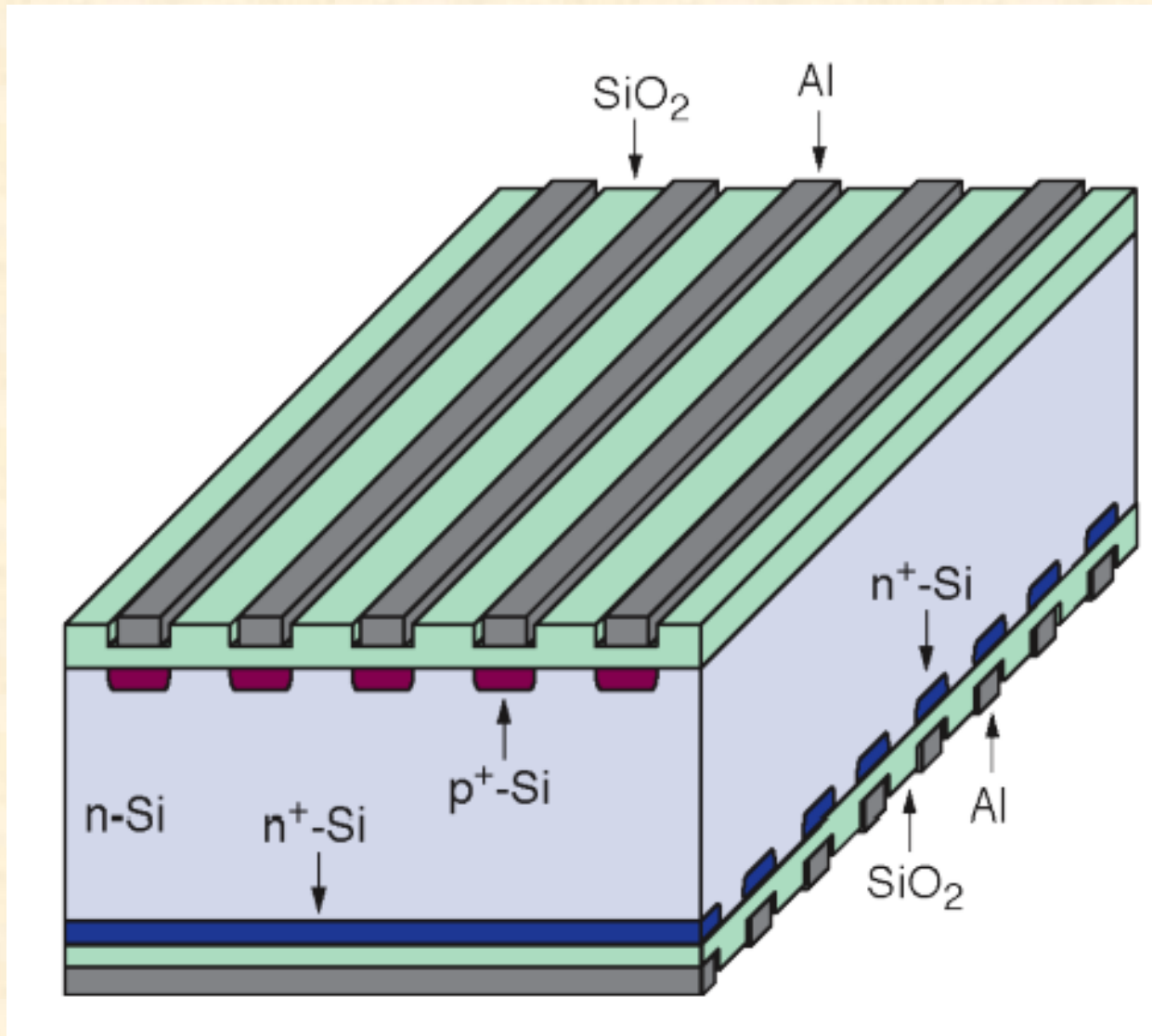


Radiation Damage: Surface Effects

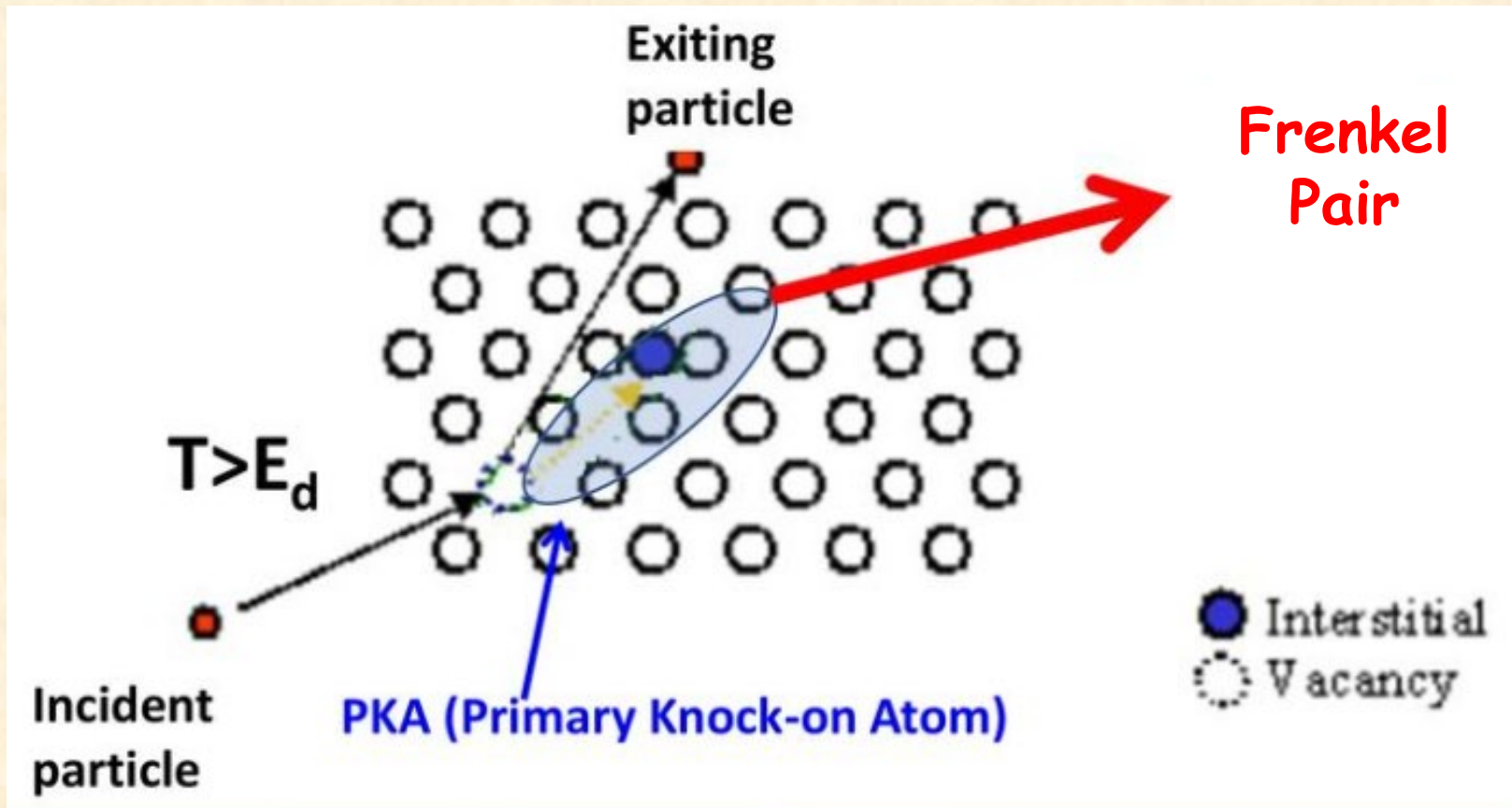
Minwoong Lee et al. *Electronics* 2021, 10(8), 887



Radiation Damage: Surface Effects

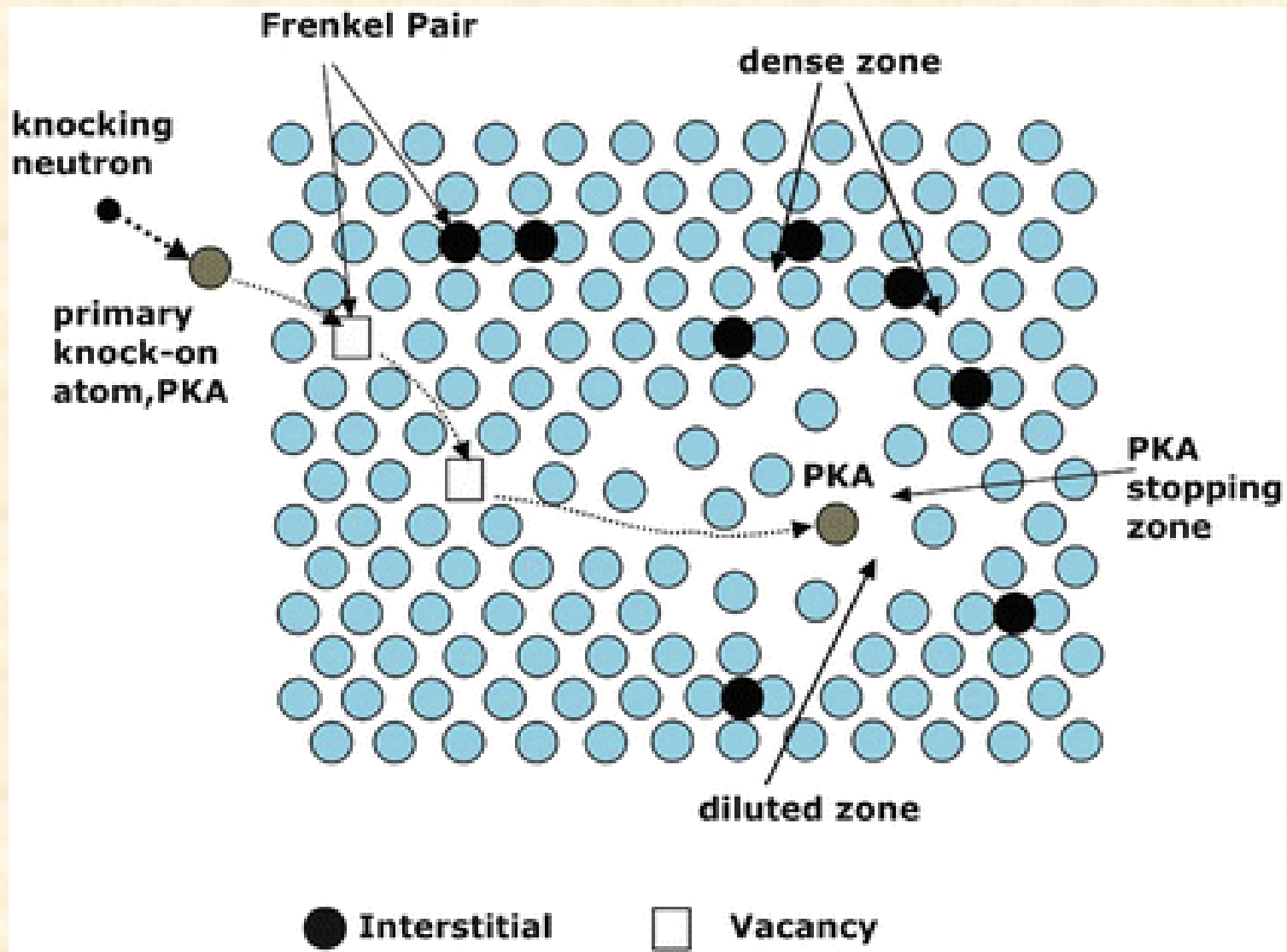


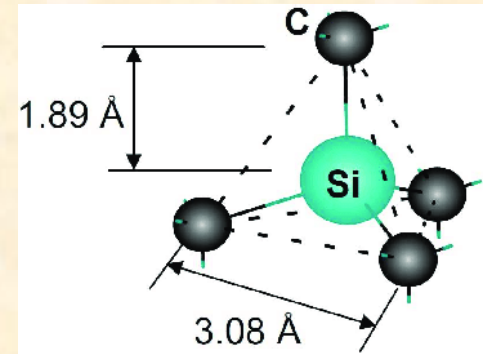
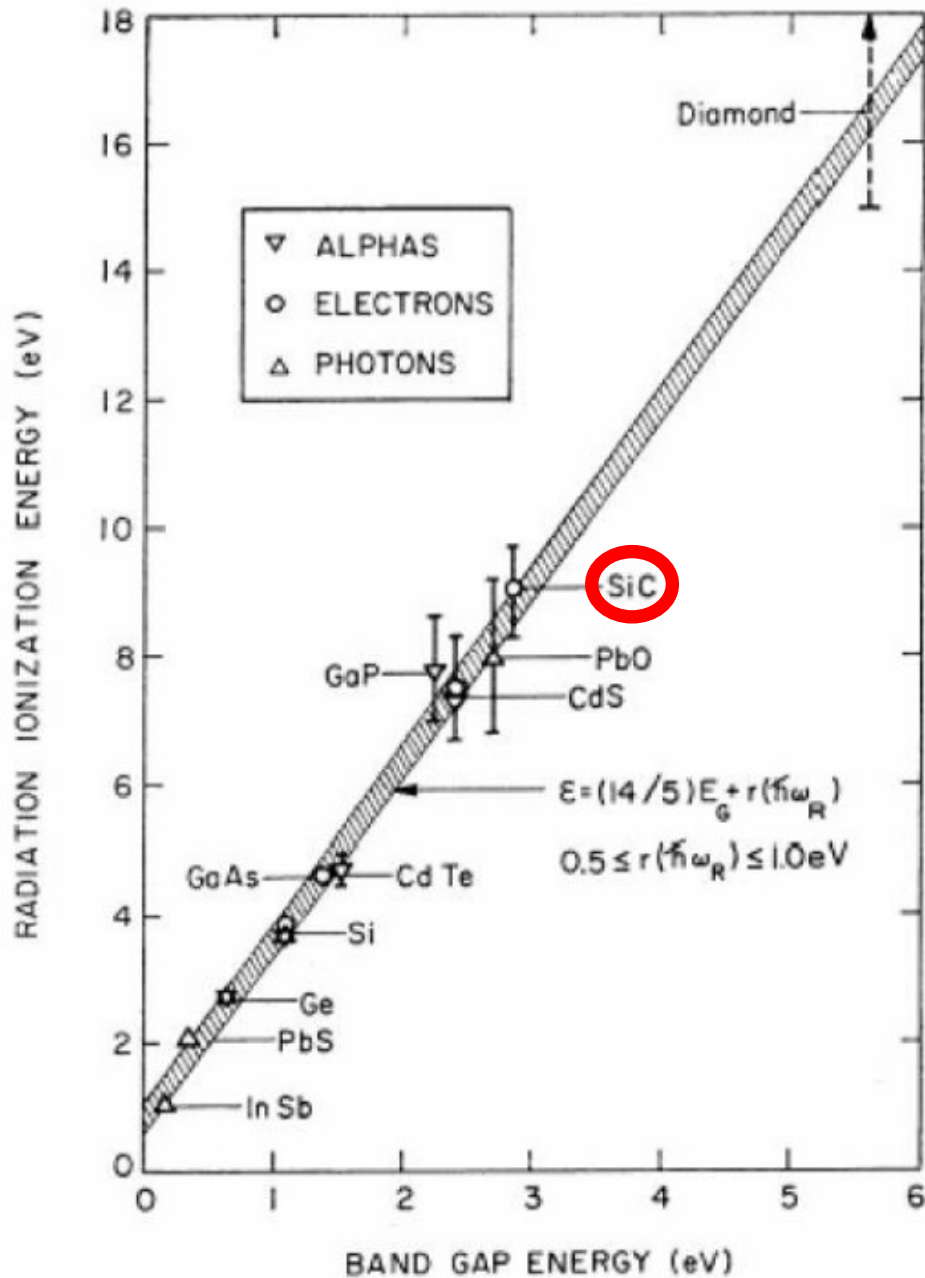
Radiation Damage: Bulk Effects



$$E_{\text{dis}} \approx 10 \div 100 \text{ eV}$$

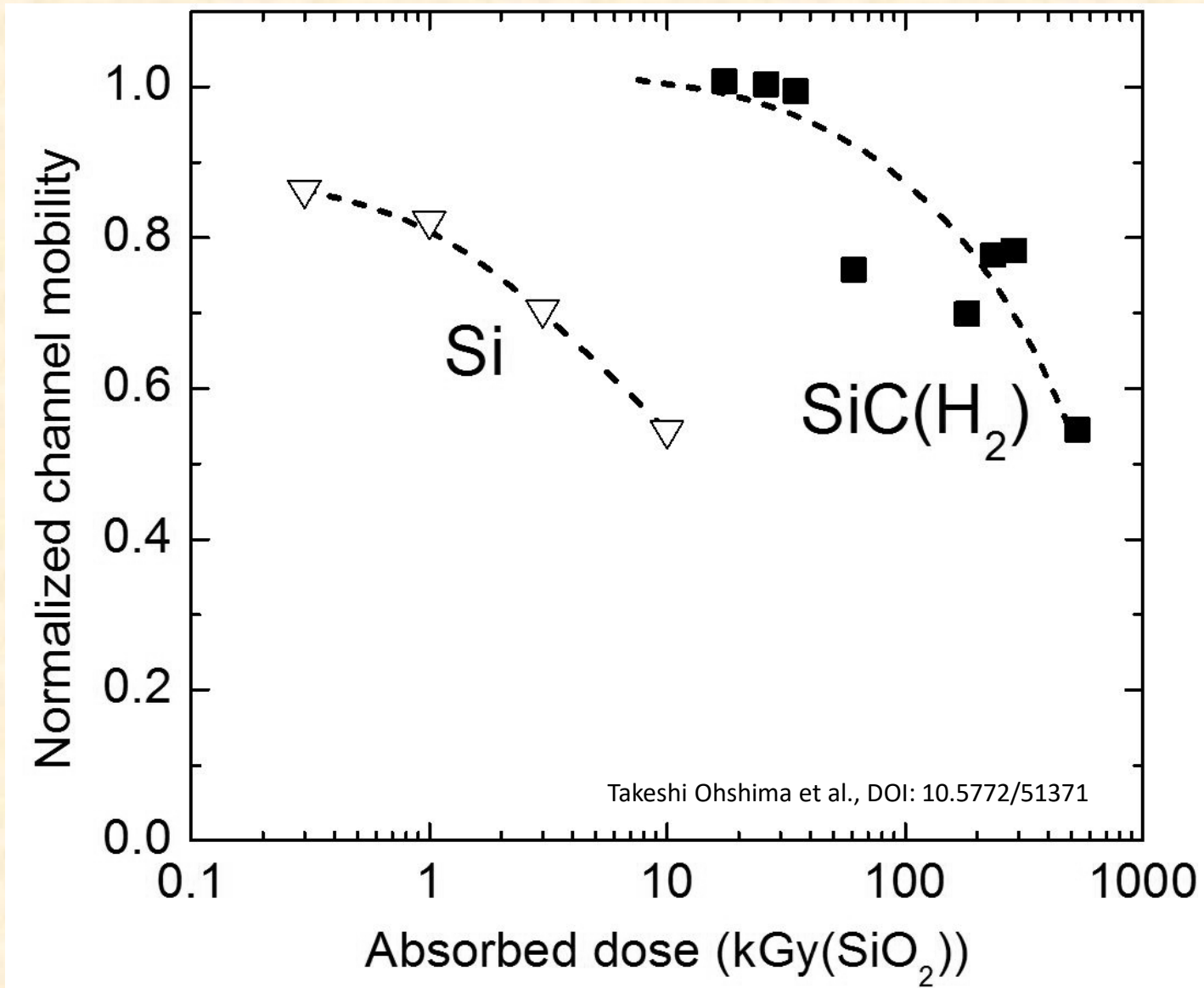
Radiation Damage: Bulk Effects

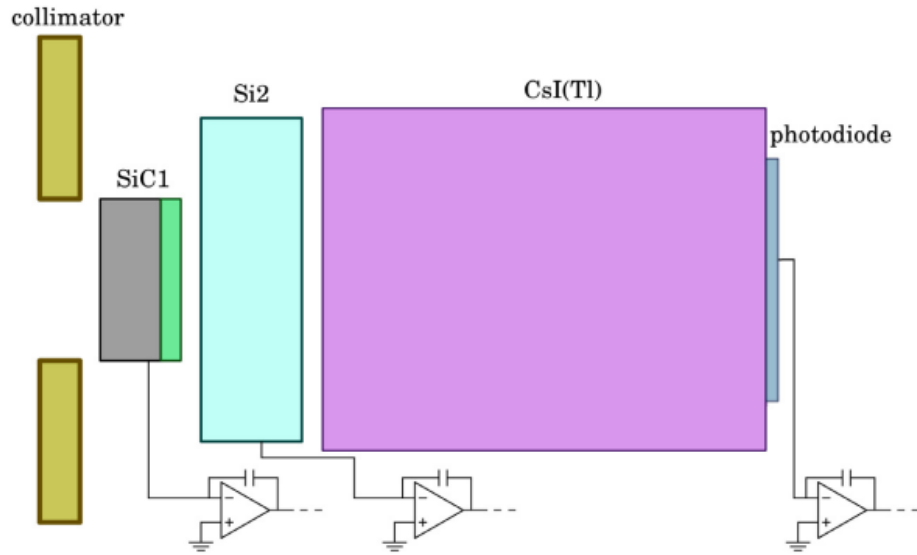




- High strength & hardness
- Low thermal expansion
- High thermal conductivity
- Chemical inertness
- Displacement energy:
30÷40 eV (Si: 13÷15 eV)
- Breakdown Field:
3÷4MV/cm (Si: 0.3MV/cm)
- Saturated $v_{drift}(e)$:
 2×10^{-7} (Si 1×10^{-7})

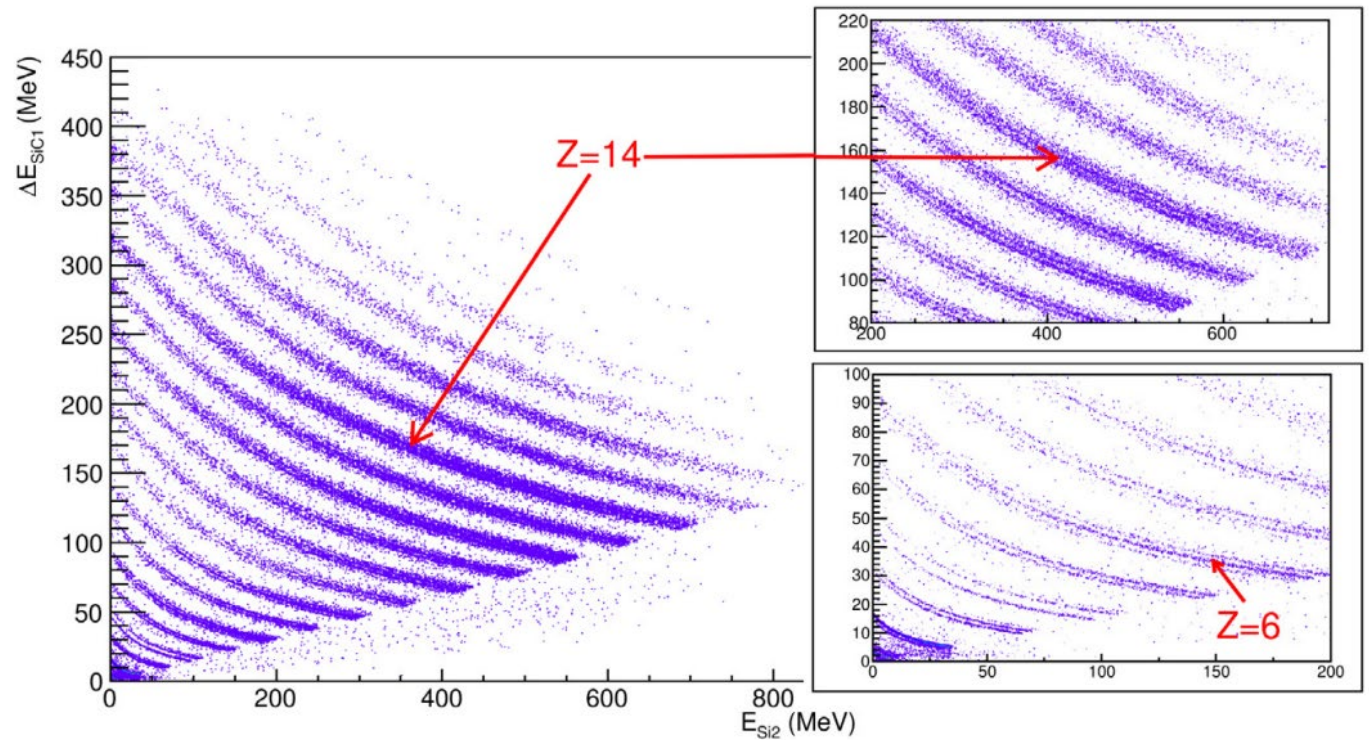
Radiation Hardness: SiC vs Si





Excellent
Isotope Identification
(comparable to Si)

SiCILIA
Silicon Carbide
Detectors for
Intense
Luminosity
Investigations &
Applications



**Thanks for
your attention.**