Experimental techniques II

Wednesday, November 8, 2017 2:51 PM

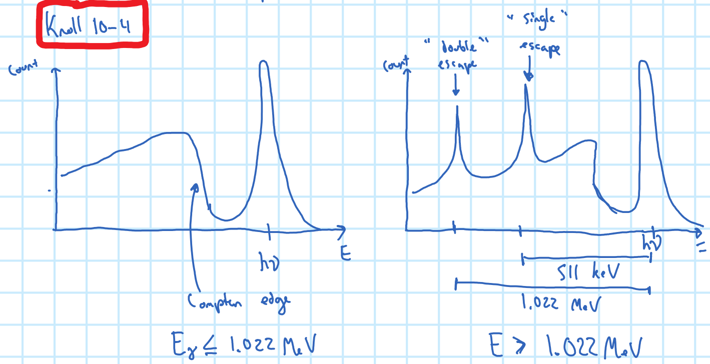
Review of last week: Detecting γ-rays

- What are the three main methods of γ-matter interactions?
  <open for discussion>

  ↳ 1) Photosorption → complete deposition of E_γ
  2) Compton scattering → partial deposition, $E_{measured} = E_\gamma - E_\gamma'$
  3) pair production → produces e^+e^- pair, KE of $e^{\pm}$

- Detector volumes are important!
  ↳ based on γ-ray range in detector
  ↳ characteristic spectra are as much a reflection of radiation type as detector specs

Knoll 10-4



Knoll 10-3

← purely a theoretical spectra, where we can collect all e^- & E_γ interactions.

NaI (Tl) - type detectors
↳ scintillator detectors (see last session

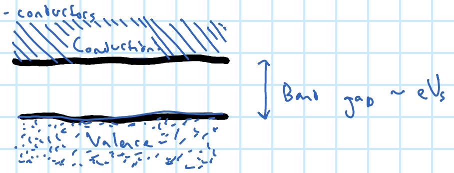
Knoll 10-13 & Knoll 12-6

↳ 120 keV/division = inability to resolve $\Delta E \sim 50$ keV

BUT, w/ semiconductor-type detectors (specifically Ge), we can resolve ~1 keV!!!
↳ The high E efficiency >> cost for larger volumes, lower probability γ-matter interaction.

Basics of Semi-conductor detectors

- Semi-conductors



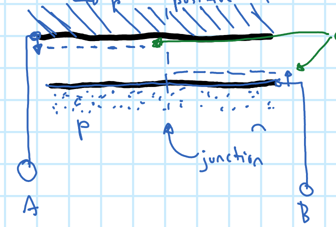
↳ semiconductors are insulators where the ΔE between the valence band (in the bulk, a "sea of e⁻") & the conduction band (the next set of states that allow e⁻ to move) is ~1 eV

↳ E_{gap} is tunable w/ dopants

↳ n & p junctions

↳ "n": negative (dopants w/ excess of e⁻)

↳ "p": positive (" " holes)



- When you apply (+) @ "A" & (-) @ "B", encouraging the flow of e⁻ from n → p

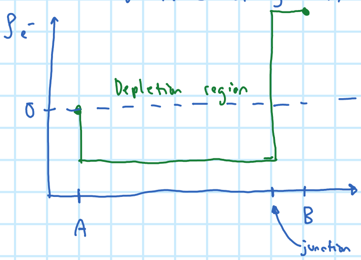
<u>Reverse bias</u>

↳ apply (-) @ "A", (+) @ "B" to deplete the semiconductor of charge

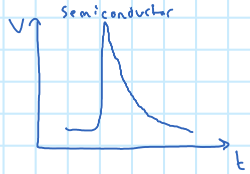
↳ Very little charge migration (μAs)

↳ high $\vec{E}$-fields in semiconductor creates quick e⁻ response

↳ instead of junction, we now think about charge depletion volume



↳ Measure the resulting e⁻ when the radiation interacts w/ biased semiconductor



ΔV due to difference in mobility of e⁻, holes in depleted region

↳ $V \propto \#_{e^-} \propto E_{deposited}$

<u>Materials & design</u>

↳ Si (~1.2eV bandgap) & Ge (~0.7 eV bandgap)

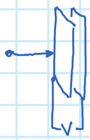
↳ lower bandgap = better energy sensitivity

↳ contend w/ thermal fluctuations

$$P(T) \propto e^{-\frac{E_{gap}}{2kT}}$$

k_BT of room temp ~25 meV

↳ <u>Planar</u>



- implantation (completely stop)
- ΔE (partial E deposited as it passes through)

advantages

↳ easily segmented / pixelated

disadvantage

↳ planes don't make for large, uniform volumes

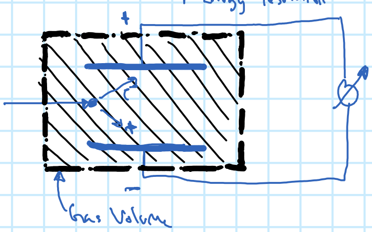
↳ Coaxial

Knoll 12-2

HPGe & cryostats

Charge collection in gas

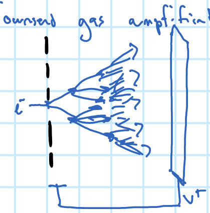
- Gas chambers have easily tuneable volumes, density, & versatile response to wide E ranges
  - gas much more "radiation hard" than solid-state detectors
  - Energy resolution



$$\vec{V}_{charge} = \mu \frac{\vec{E}}{P}$$

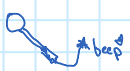
$\vec{V}$ = velocity of charge
$\vec{E}$ = Electric Field
P = pressure of gas volume
μ = mobility

- Townsend gas amplification



- depending on V, $E_{deposited}$, the resulting current I can either be "proportional" to the $E_{deposited}$ or get saturated = "Geiger-Müller"
  - as V increases, you become responsive to lower $E_{deposit}$ but lose E sensitivity to higher $E_{dep.}$

- Geiger-Müller Counters



- small volume of gas between 2 charged plates. Sensitive to a wide range of E/types of radiation, but only for counting.

- Multi-wire set-ups
  - provide spatial resolution as well as E/counting