PSD With SiPMs and Organic Scintillators

James Kingston (Slides made by Jianyang Qi)
University of California, Davis
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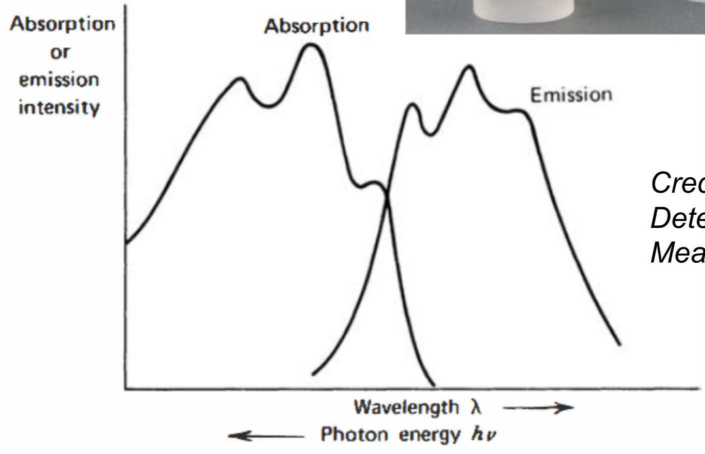
Scintillators in general

- ❖ Converts energy into light
  - ➢ Done by excitation of material
  - ➢ Fluorescence: prompt emission
  - ➢ Phosphorescence: emission of longer wavelength (compared with fluorescence)
  - ➢ Delayed fluorescence: same wavelength as fluorescence, but emitted later
- ❖ Must be transparent to its own emitted light

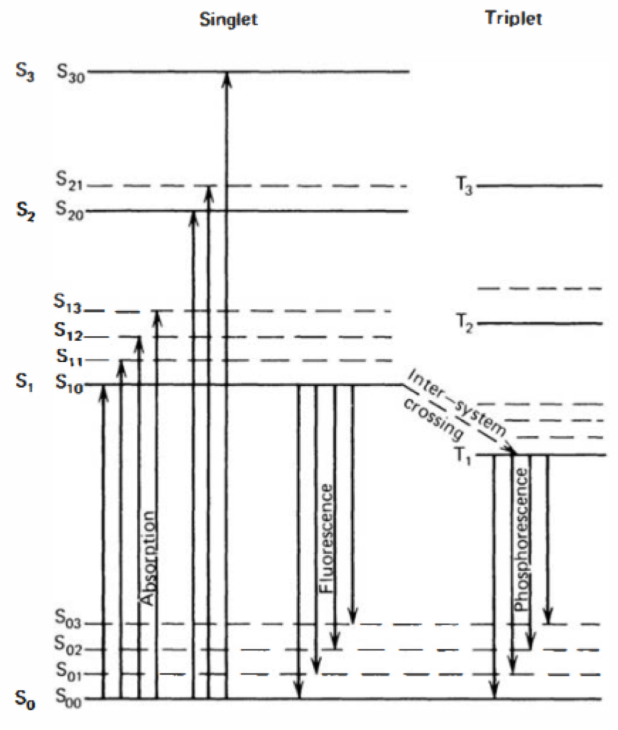
Credit: US DHS



Credit: Knoll, Radiation Detection and Measurement

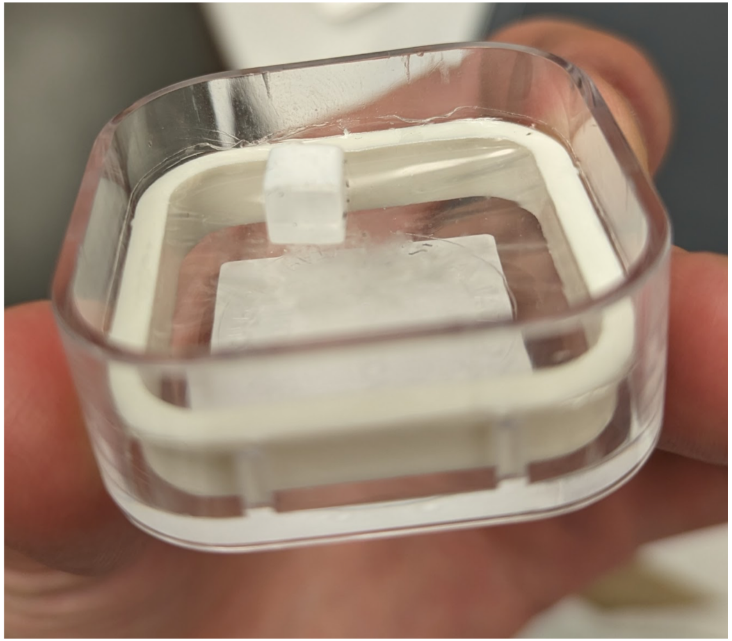
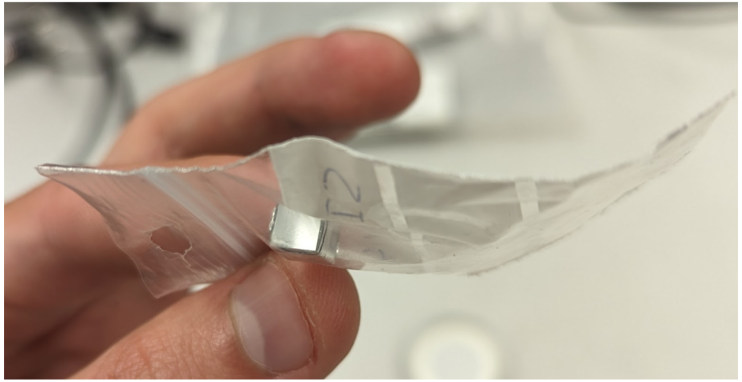
Organic Scintillators

- ❖ Emits light from excited molecular states
- ❖ Singlets and triplets:
  - ➢ Singlet: spin 0, contributes most of the light
  - ➢ Triplet: spin 1, long lifetime, some excited singlets transition to triplets
- ❖ Two components to waveform:
  - ➢ Fast: prompt, singlet decay
  - ➢ Slow: delayed, related to transitions into the triplet



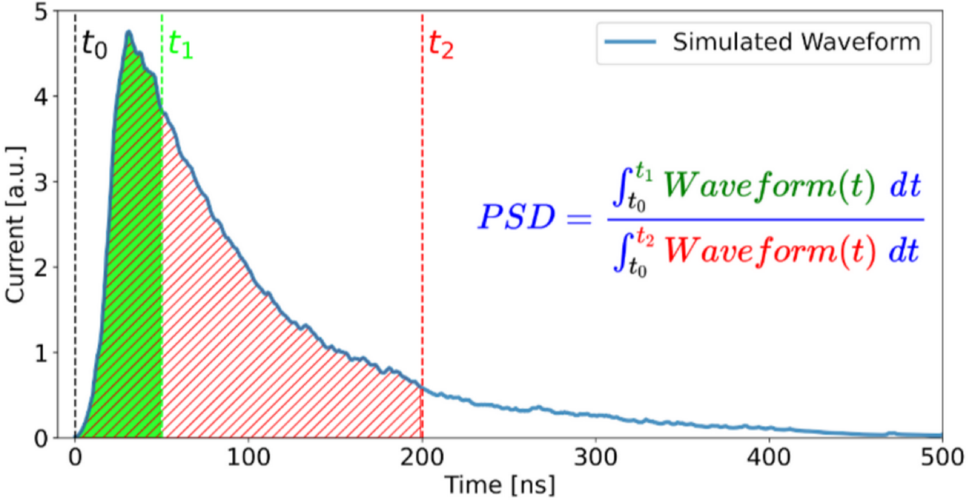
Credit: Knoll, Radiation Detection and Measurement

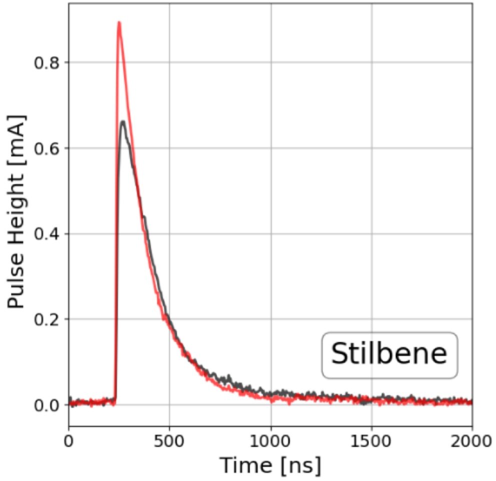
Types of scintillators in this lab

	
<u>Stilbene:</u> ❖ Organic crystal	**<u>EJ-276</u>** ❖ Plastic scintillator

Pulse Shape Discrimination

- Different particle interactions create different ratios of the fast and slow component
  - Used to discriminate gammas from neutrons!
- PSD parameter: Q-ratio





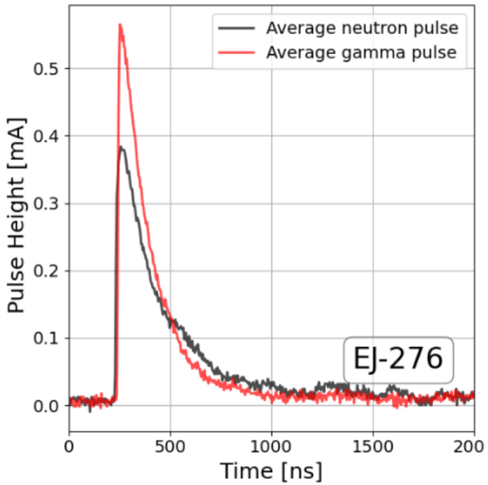


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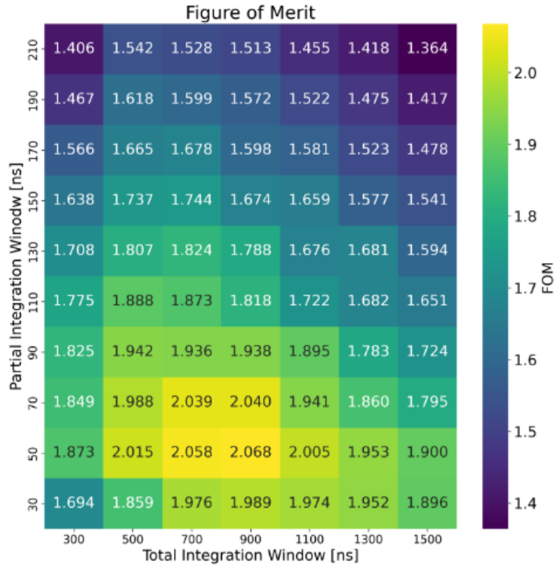
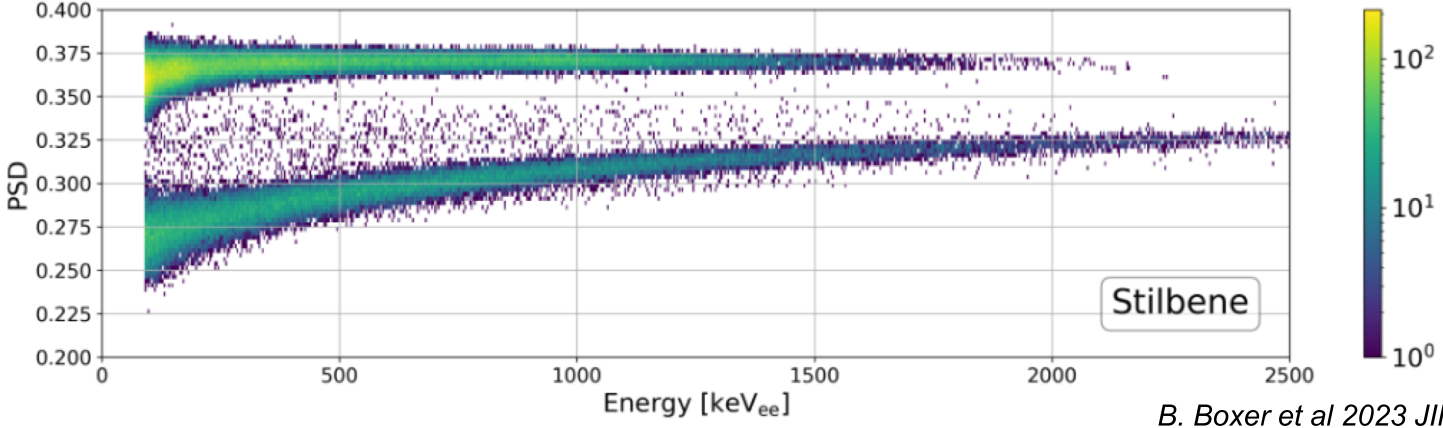
Figure of Merit

- How well separated are the gamma and neutron populations?
- $$\mathrm{FOM} = \frac{\mu_\gamma - \mu_n}{2.355\,(\sigma_\gamma + \sigma_n)}$$





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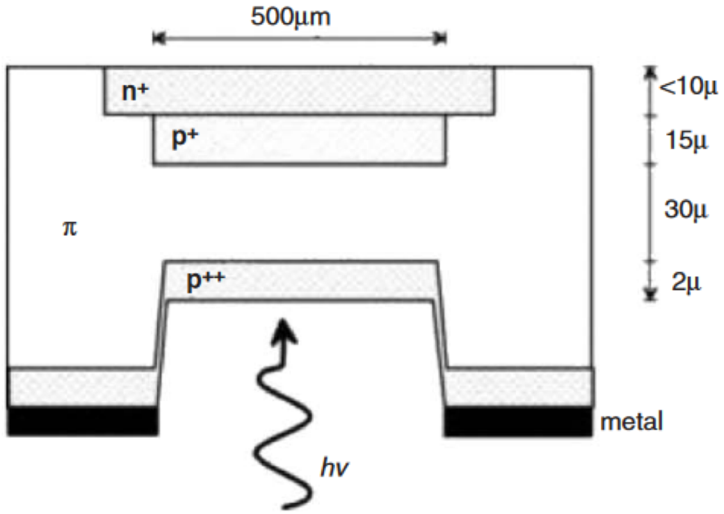
Avalanche photodiodes (APD)

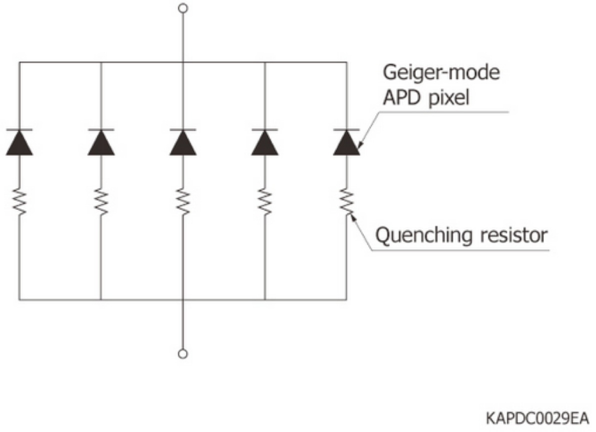
- ❖ Light creates electron-hole pair in π region
- ❖ Electron drifts to region of high field
- ❖ Avalanche:
  - ➢ One electron gains enough energy (via the field) to create more e-h pairs
  - ➢ Which creates more e-h pairs…

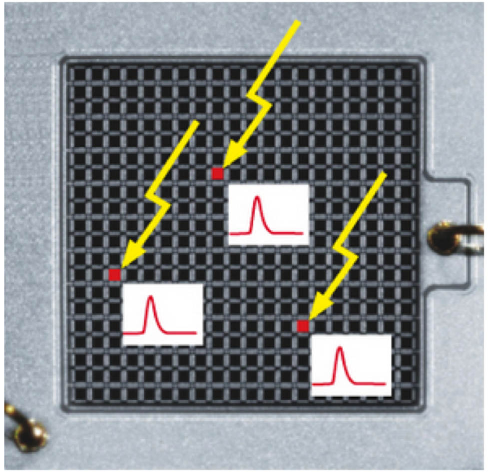


Credit: Renker, NIM-A 67 (2006) 48–56

Single photon detection: SiPMs

- ❖ High enough voltage (breakdown) ⇒ avalanche without limit
- ❖ Avalanching without limit ⇒ no longer sensitive to initial amount of e-h pairs
- ❖ Called “Geiger-mode”, just counts photons
- ❖ SiPM: Array of Geiger-mode APDs
  - ➢ Each APD is small, probability that 2 photons hit a single APD is small
  - ➢ Multiple photon hits are added up





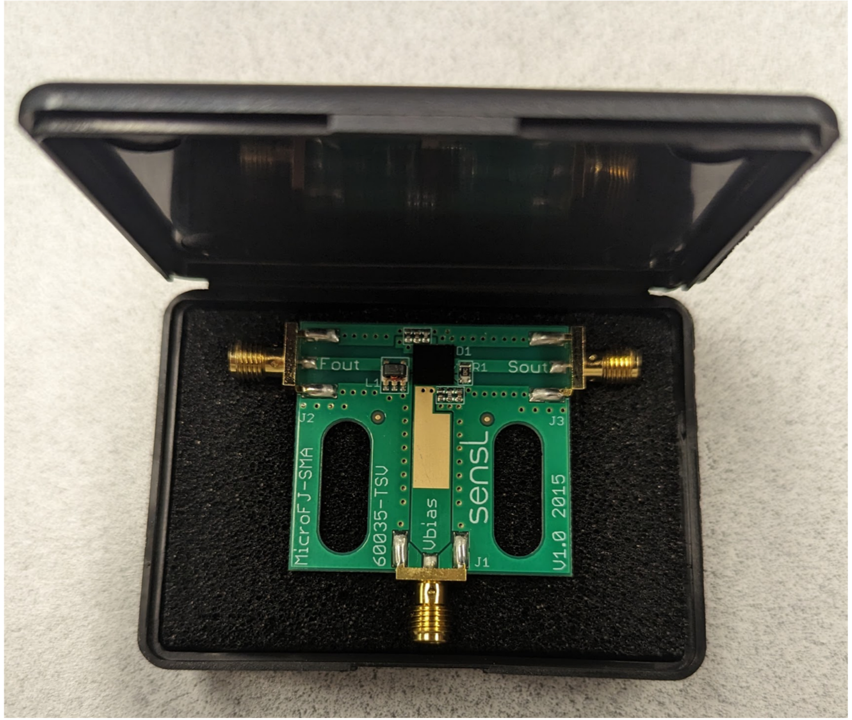
Credit: Hamamatsu, What is MPPC (SiPM)?

Lab Setup: The House

- ❖ Dark box houses SiPM and scintillator
- ❖ ^{137}Cs sealed source placed to see some events
  - ➢ Neutrons will be taken over the weekend

Lab Setup: The SiPM and Readout Board

- SiPM is the black square
- SOUT: Signal out, area is proportional to energy
- FOUT: Fast signal, used for trigger
- SiPM biased to 29 V (~3 V overvoltage)
- Scintillator is placed on SiPM with optical grease



Lab Setup: Data Taking

- 10-bit desktop digitizer
- Used to take data from SOUT and FOUT
- Python script + Jupyter notebook used to do analysis
  - Make those PSD plots shown earlier!