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SCINTILLATORS
a short introduction

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ORGANIC SCINTILLATORS

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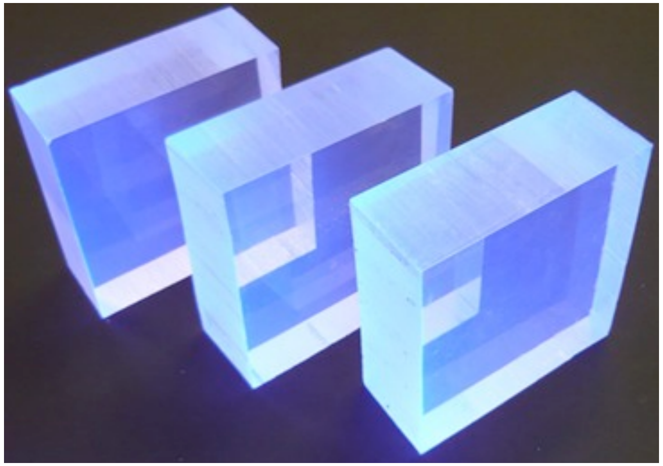
SCINTILLATORS

- Three types of scintillators : crystalline, liquid, and plastic.
- Plastic scintillators are the most widely used in HEP.
- The working principle is the same: dE/dx converted into visible light detected by photosensors [1].
- Materials density range from 1.03 to 1.20 g cm^{-3}
- Typical photon yield is 1 photon/100eV (deposited energy) [2].
- A mip crossing 1 cm thick scintillator generates ≈ 2 x 10^4 photons (effective signal will be less due to collection, transport efficiency, optical package and photodetector quantum efficiency



MAIN REQUIREMENTS

- HIGH EFFICIENCY for conversion of excitation energy to fluorescent radiation
- TRANSPARENCY to its fluorescent radiation to allow transmission of light
- EMISSION of light in a spectral range detectable for photosensors
- SHORT DECAY TIME to allow fast response

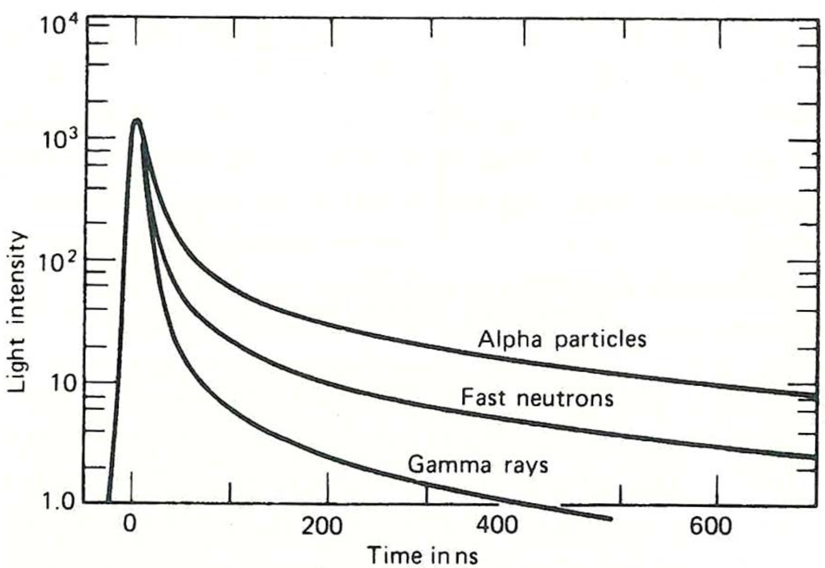
PLASIC SCINTILLATORS

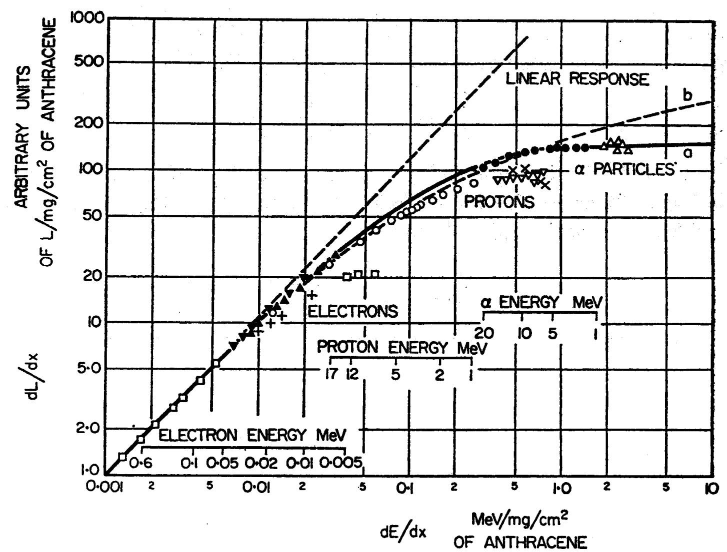
SCINTILLATORS ARE MULTI PORPOSE DETECTORS.THEY ARE USED IN:

- Calorimetry (*)
- Time of flight measurement
- Trigger counter
- Veto counter
- Particle identification (**)

* in plastic scintillator base material very dense ionization zones emit less light than expected from mip dE/dx. The effect is a function of the density of excited molecules (Birks semi-empirical model [3]).

** The fraction of the light emitted during the decay can depend on the exciting particle





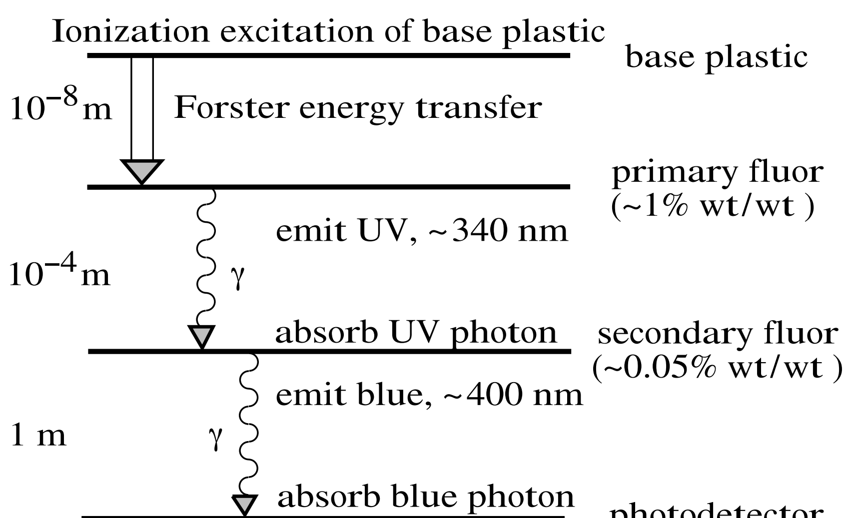
SCINTILLATOR MECHANISM

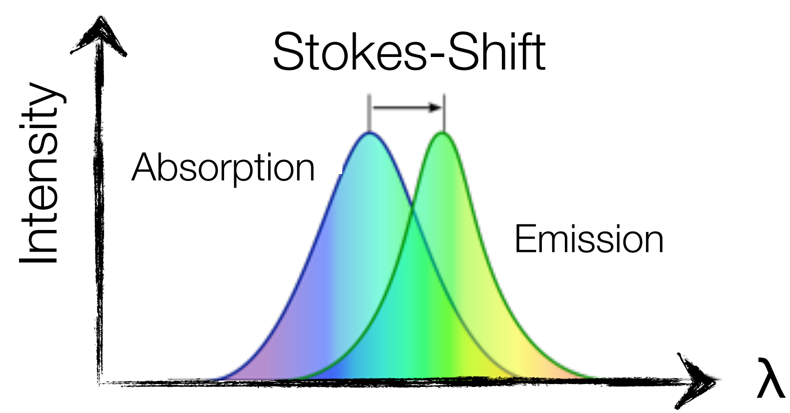
SCINTILLATION

- Charged particle through a medium generates a track of excited molecules.
- Some type of molecules releases a small fraction (≈ 3%) of energy as optical photons. The scintillation process is particularly marked in substances containing aromatic rings (polystyrene, polyvinyltoluene etc)

FLUORESCENCE

- The excitation is generated by the absorption of a photon while de-excitation generates the emission of a longer wavelength photon.
- The effect of wavelength difference between absorption and emission peaks is called Stokes' shift (greater Stokes' shift is better as it minimize self-absorption).
- Fluors are used as "waveshifter"





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SCINTILLATOR MECHANISM

SCINTILLATORS

- Plastic scintillators used in high-energy physics are binary or ternary solutions of fluors in a plastic base containing aromatic rings
  - The plastic base make up the ionization-sensitive section of plastic scintillator
  - High concentration of fluors (concentration ≈ 1%) increase the attenuation length of emitted UV photons (base material is selected to be transparent to the longer waveform photons)
  - Fluors allows to decrease the base scintillator decay time (16 ns in pure polystyrene) by an order of magnitude. The mechanism that increase both the speed and the light yield of plastic scintillator has been described by Foester [4].
  - The fluor required by the mechanism described by Foester generally do not match the requirements in terms emission wavelength or attenuation length, then a second waveshifter is added to the base material.

EXTERNAL WAVELENGTH SHIFTER

- Ligth emitted from plastic scintillator can be absorbed in external material doped with wave-shifting fluor. Such wave-shifting base must be insensitive to ionizing radiation and Cerenkov light.
  - External wave-length shifter are based on acrylic material (because the good optical qualities) and a single fluor to shift ligth to the blue-green wavelength. Generally it contains also ultra-violet absorbing additives to decrease response to Cerenkov ligth.

PLASTIC SCINTILLATORS CAUTIONS

AGING

- Aging reduce the light yield (the process can be worsened by exposure to solvent vapors, high temperature, irradiation, mechanical flexing, rough handling …)
- The scintillator surface is a fragile region; it can develops micro-cracks then reducing the plastic scintillator light transmission by total internal reflection (NB: fingerprints can generate such micro-cracks)

ATTENUATION LENGTH

- Besides the Stokes' shift other factors such as fluors concentration, optical clarity, bulk material uniformity, surface quality and additives can influence the attenuation length.

AFTERGLOW

- A low level of luminescence (10^{-4} level) can persist for hundred of ns [5]

RADIATION DAMAGE

- Irradiated plastic scintillators show a reduction in the light yield and attenuation length. Besides integrated dose, radiation damage depends also on dose rate, environmental conditions and base material properties [6].
- The effect is generated by "absorption center" and can be mitigated by shifting emissions to longer wavelength (i.e. utilizing fluors with larger Stokes' shift)

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SCIONIX EJ200 PLASTIC SCINTILLATOR

Physical and Scintillation Constants:

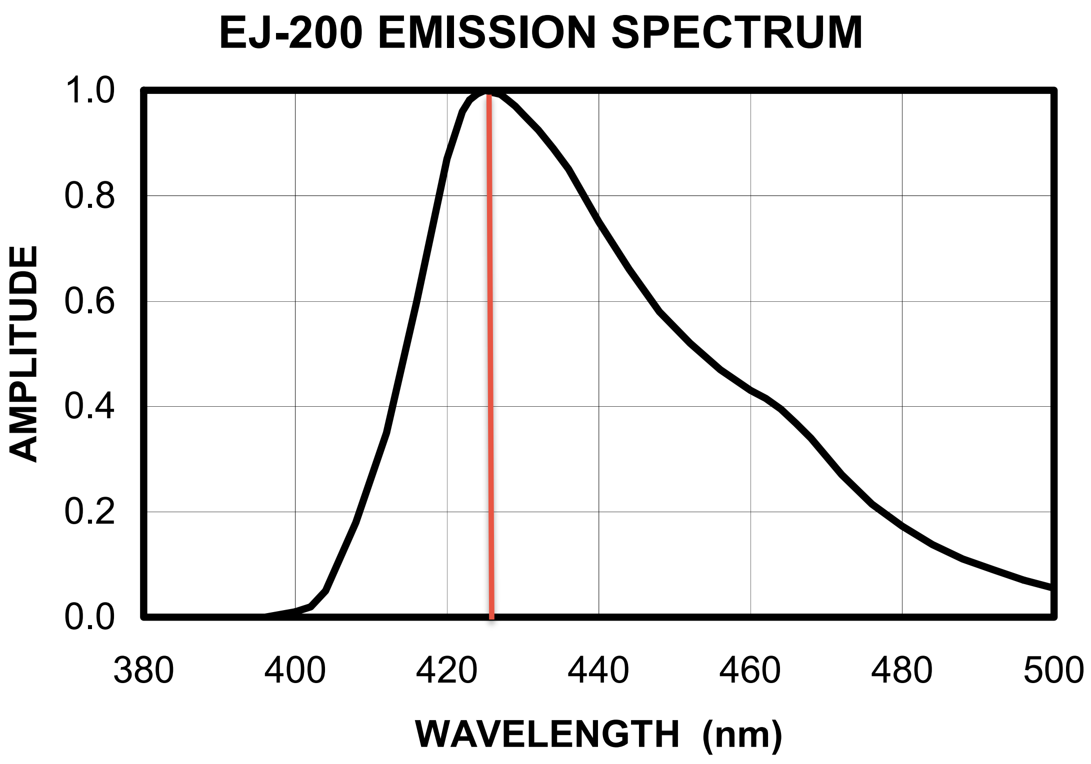
Light Output, % Anthracene	64
Scintillation Efficiency, photons/1 MeV e^-	10,000
Wavelength of Max. Emission, nm	425
Rise Time, ns	0.9
Decay Time, ns	2.1
Pulse Width, FWHM, ns	~2.5
No. of H Atoms per cm^3, x 10^{22}	5.17
No. of C Atoms per cm^3, x 10^{22}	4.69
No. of Electrons per cm^3, x 10^{23}	3.33
Density, g/cc:	1.023

Polymer Base: . Polyvinyltoluene
Refractive Index: .1.58
Vapor Pressure: .. Is vacuum-compatible
Coefficient of Linear Expansion: 7.8 x 10^{-5} below +67°C

Light Output vs. Temperature:
At +60°C, L.O. = 95% of that at +20°C
No change from +20°C to -60°C

Chemical Compatibility: Is attacked by aromatic solvents, chlorinated solvents, ketones, solvent bonding cements, etc. It is stable in water, dilute acids and alkalis, lower alcohols and silicone greases. It is safe to use most epoxies and "super glues" with EJ-200.

SCIONIX EJ200 PLASTIC SCINTILLATOR



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