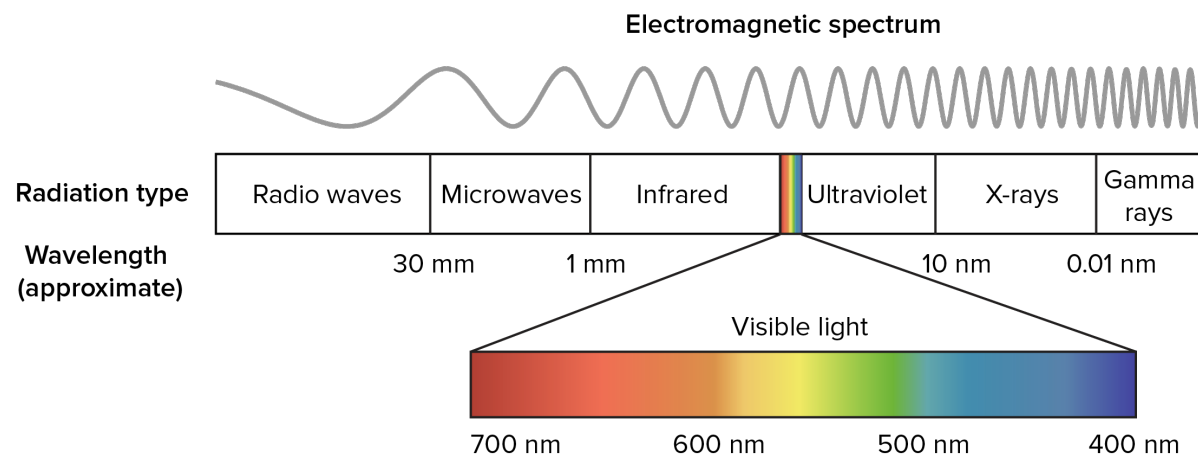


Lecture: Scintillation Detectors

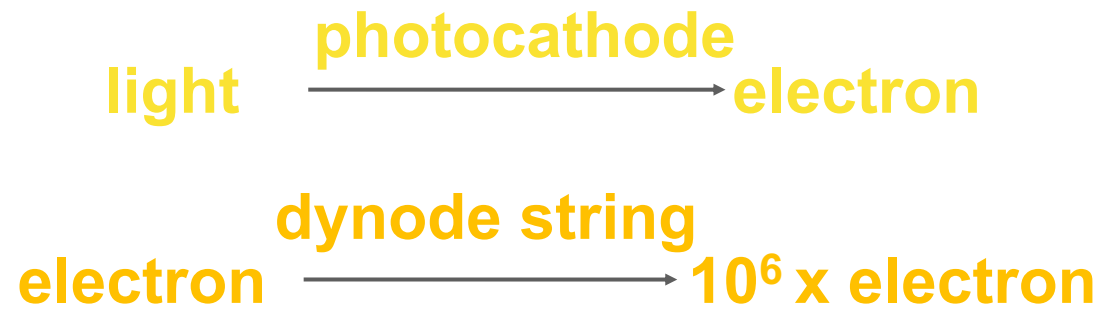
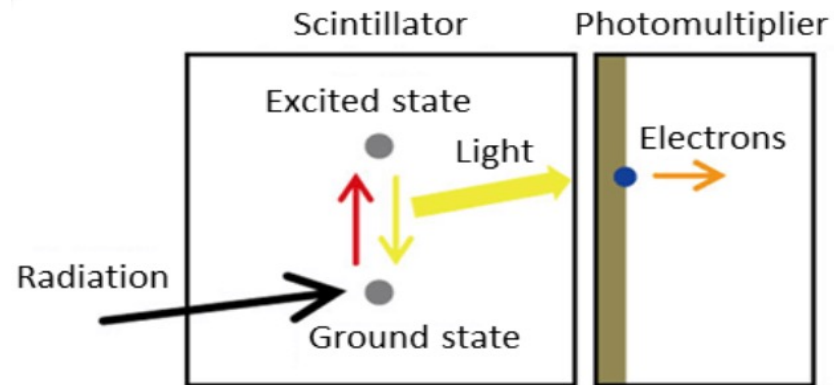
**Chapters 7, 8.1, 8.2, 8.5, 8.6, 8.7
except 7.4 and 7.5,
(8.8, 8.9 and 9.7 are optional)**





Wavelength is one of the characteristics we know about each scintillation material.

Scintillation mechanism:



Organic scintillators

Low-Z materials

Fast response time

High hydrogen content

Best for β particles and fast neutrons

Inorganic scintillators

High-Z materials

Dense

Slow response time

Best for γ rays

Note that for heavy charged particles, gas and semiconductor detectors are often preferred when good energy resolution or particle identification is required.

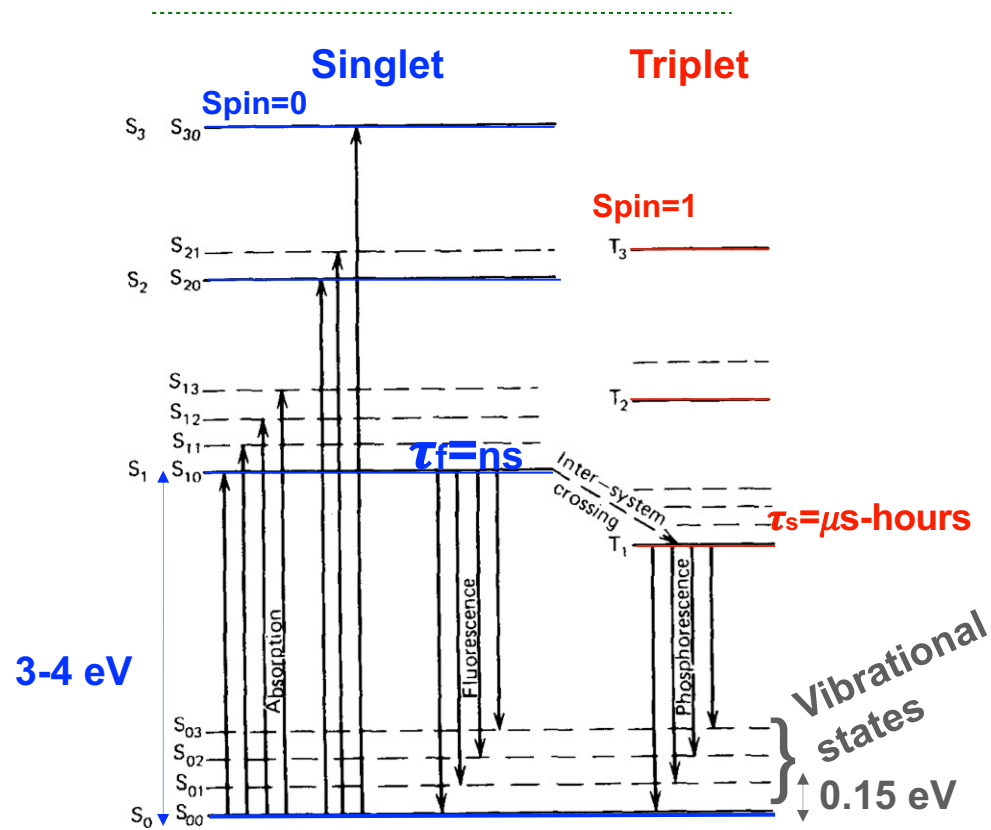
Today

- Scintillation
 - Organic scintillators
 - Anthracene
 - Stilbene
 - Plastic
 - Liquid
 - Inorganic scintillators
 - NaI(Tl)
 - CsI(Tl)
 - LaBr₃(Ce)
 - BGO
- PMTs (Photomultiplier Tubes)
 - Mechanism
 - Photocathode
 - Quantum efficiency
- Time response
 - Organic
 - Inorganic
- Pulse shape discrimination
 - Organic
- Light output
 - Organic
 - Inorganic
- Energy resolution
 - Inorganic
- Detector efficiency
 - Heavy charged particle
 - Electrons
 - Gamma rays
 - Neutrons

Today

- Scintillation
 - Organic scintillators
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 - Inorganic
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 - Heavy charged particle
 - Electrons
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 - Neutrons

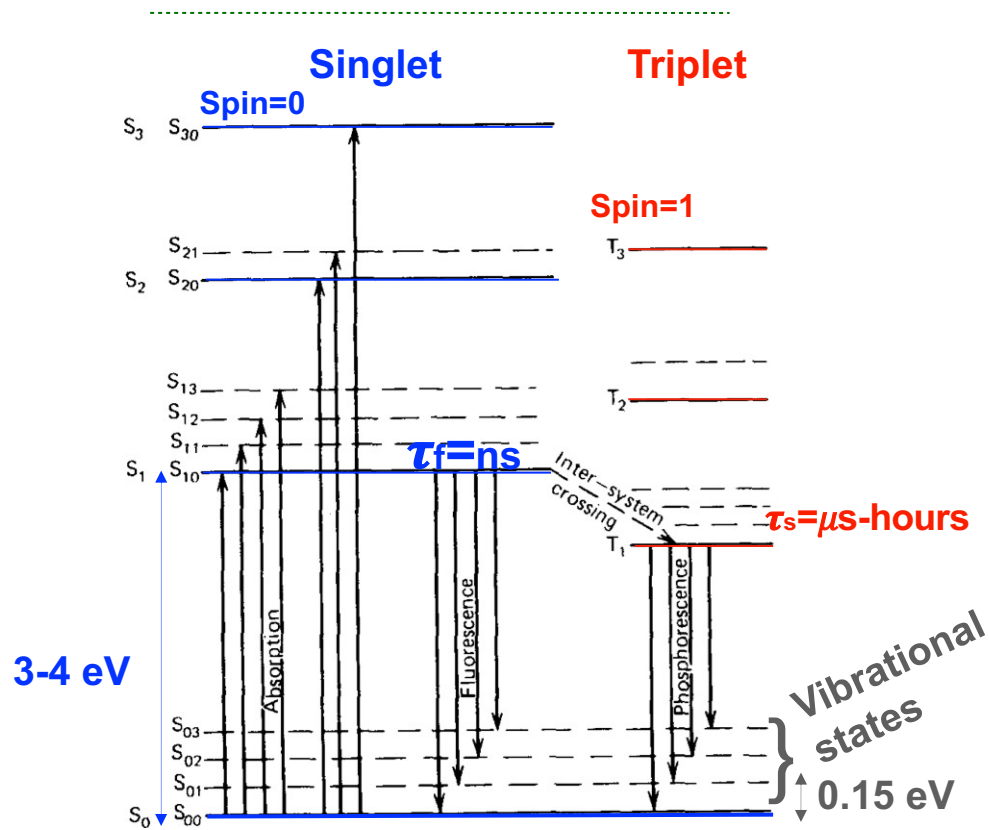
electronic structure of a molecule



Thermal energy: 0.025 eV
In room temperature almost all molecules are in S_{00}

Singlet states: States with shorter lifetimes
Triplet states :Meta-stable states

electronic structure of a molecule



Fluorescence
Phosphorescence
Quenching

Singlet states: States with shorter lifetimes
Triplet states :Meta-stable states

Reading material for later

Absorption is the energy (kinetic) given by the charged particle to the single molecule.

Higher lying states, such as S_2, S_3 , decay to S_1 via radiationless internal conversion after 1 ps.

States with excess vibrational energy, such as S_{11}, S_{12}, S_{13} , lose their energies via vibrations.

The net effect of the excitation process in a simple organic crystal is to produce, after a negligibly short time period, a population of excited molecules in the S_{10} state.

Once the excited molecules are in the S_{10} state two processes might occur:

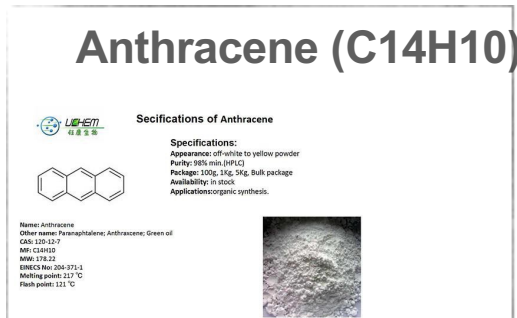
1- Fluorescence: emission of light by a substance that has absorbed light or another electromagnetic radiation of a different wave length. In most cases the emitted light has a longer wavelength. Emission occurs after **10ns! Prompt light emission**

2- Phosphorescence: Similar to Fluorescence, however the re-emission is not immediate. The transition between energy levels and the photon emission is delayed (**ms up to hours**). **Delayed light emission**

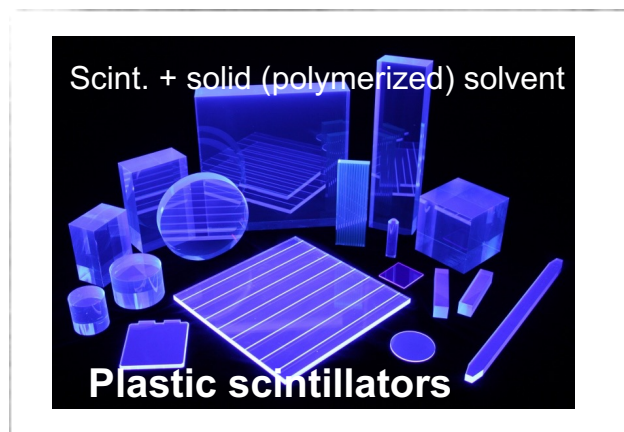
3- Not all the kinetic energy by a charged particle is lost in a scintillator via fluorescent energy. Unfortunately. The remainder is dissipated non-radiatively, primarily in the form of lattice “vibrations” or “heat”. These radiationless de-excitation processes are called “quenching”. Impurities such as dissolved Oxygen in the organic scintillator creates quenching. Needs to be taken care.

organic crystal scintillators

Highest light output
Fragile



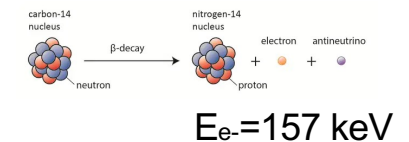
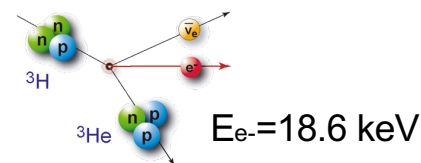
Low light output/fragile
Best separation between charged particles and electrons



Can be used in large volumes
not fragile=flexible



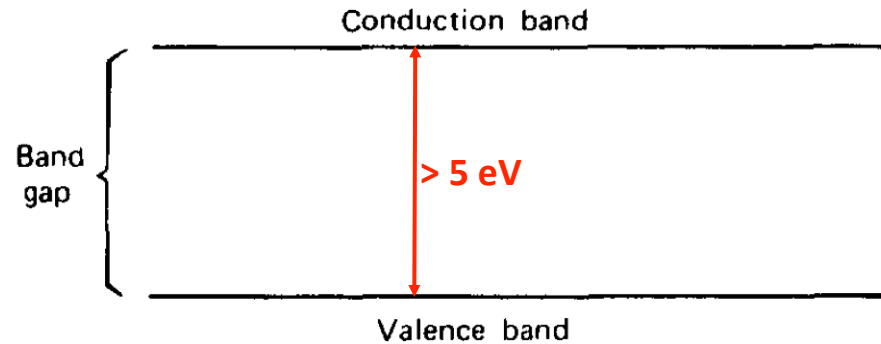
Low radiation damage
Good for tritium and ¹⁴C in low-level β activity



Today

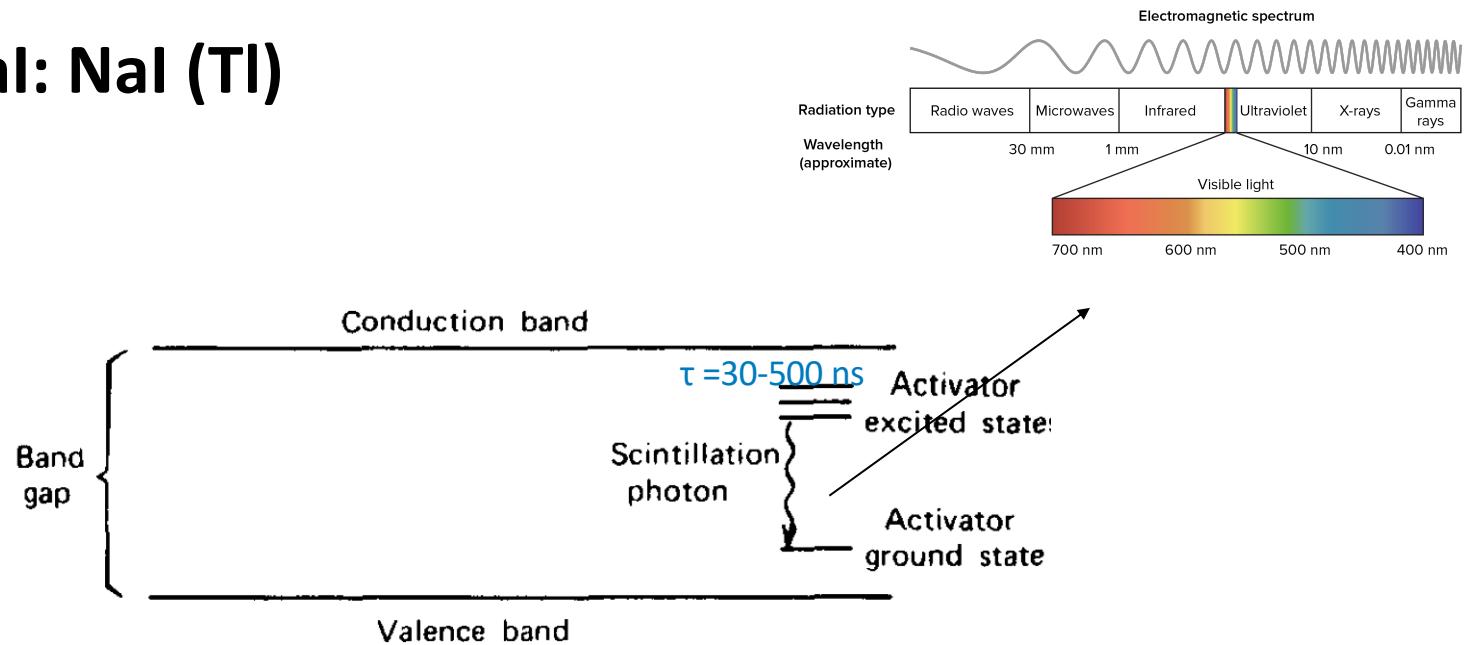
- Scintillation
 - Organic scintillators
 - Anthracene
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- Light output
 - Organic
 - Inorganic
- Energy resolution
 - Inorganic
- Detector efficiency
 - Heavy charged particle
 - Electrons
 - Gamma rays
 - Neutrons

pure NaI



- Valence band, conduction band and forbidden band in between = NaI
- Inorganic scintillators are **insulators** where the forbidden band gap is larger than 5 eV
- Photons will not be emitted in the visible light range.

Tl doped NaI: NaI (Tl)



- We add impurity or so-called activator and obtain activator excited states in the forbidden gap. Now the de-excitation of the electrons happen through these states and scintillation photon will be emitted in the visible light range!
- Very little amount is sufficient: Tl in NaI is 0.1% of total NaI concentration.
- Activator state's decay time is long: 30-500 ns.
- This is the time which determines the decay time of the inorganic crystals.

Figure: taken from Knoll

- Inorganic crystals are slower due to phosphorescence, i.e., slow timing response
- Longer decay time $\tau \sim 500$ ns
- But high density and stopping power thus high efficiency --> gamma rays
- Highest light output, better energy resolution (compared to organic scintillators)
- A major disadvantage of certain inorganic crystals is **hygroscopicity**. NaI, in particular, is a prime example.

They get water molecules attached easily from the moisture in air. They are thus put into a protective airtight housing.

Photoelectric absorption cross section

$$\tau \cong \text{constant} \times \frac{Z^n}{E_\gamma^{3.5}}$$

n=4 or 5

NaI(Tl):
Na (Z=11) } $Z_{\text{eff}}: 50.8$
I (Z=53)

Ge: Z=32

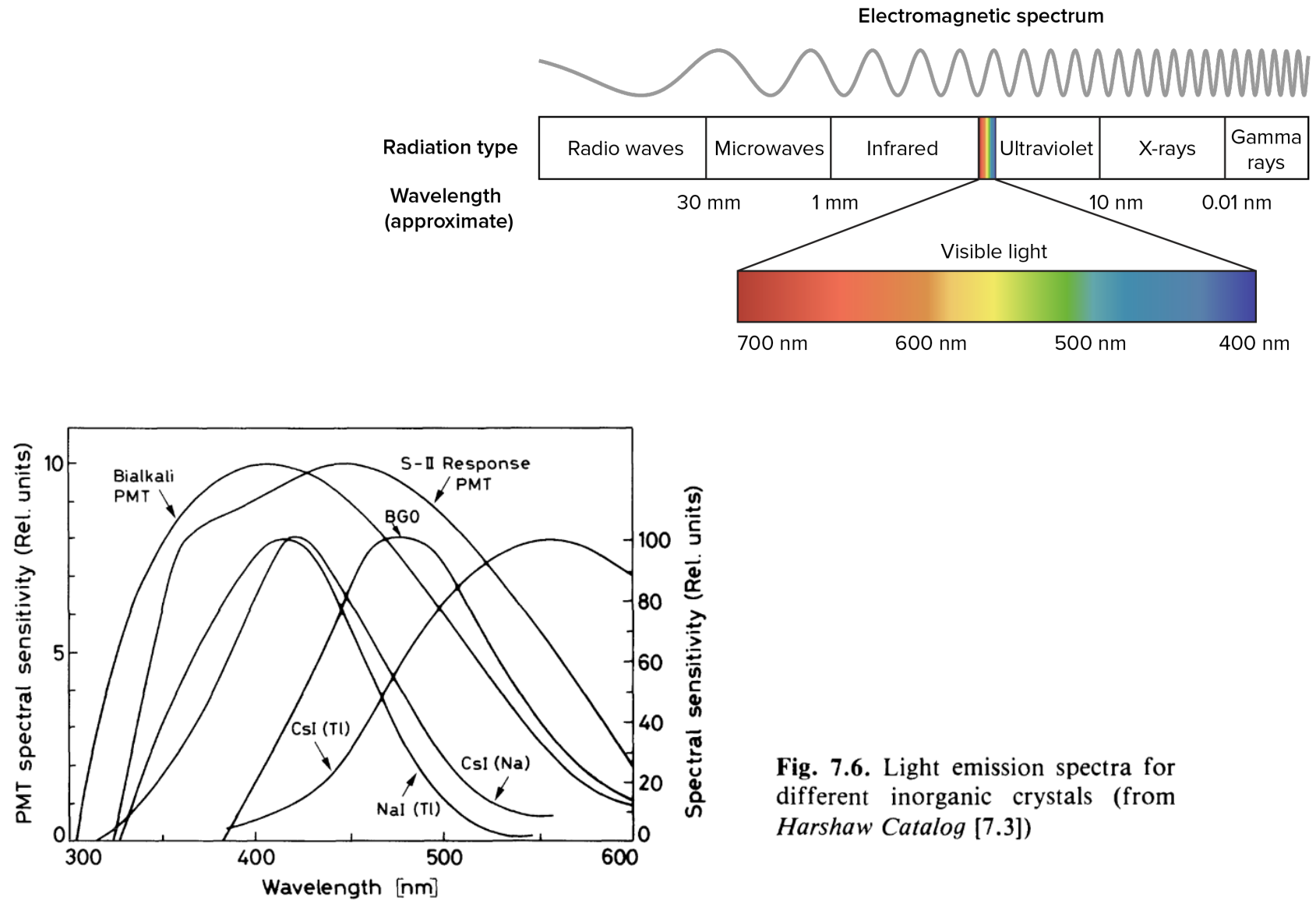


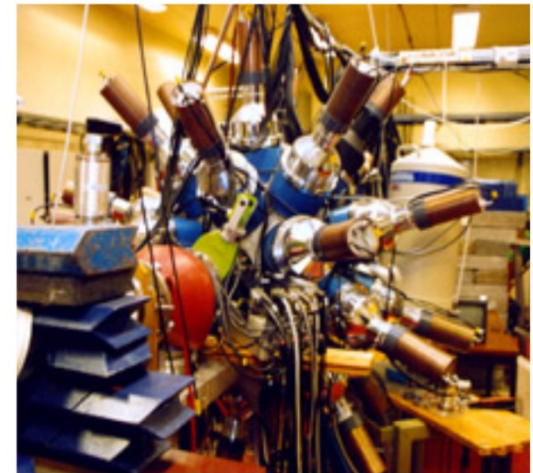
Fig. 7.6. Light emission spectra for different inorganic crystals (from *Harshaw Catalog* [7.3])

NaI (TI)

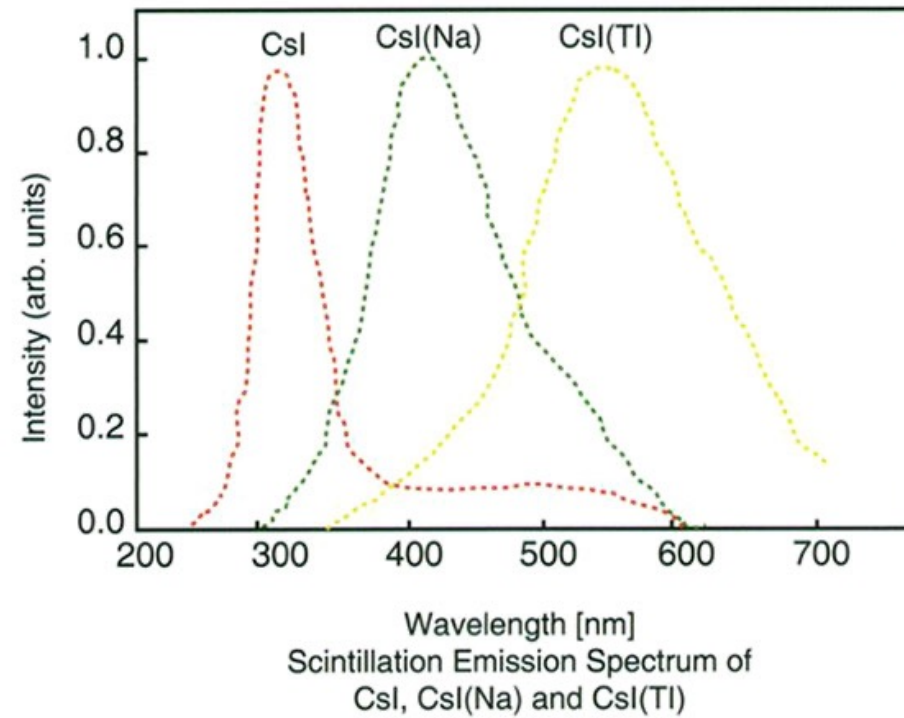
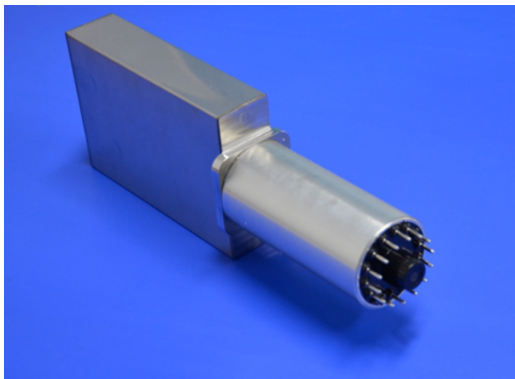
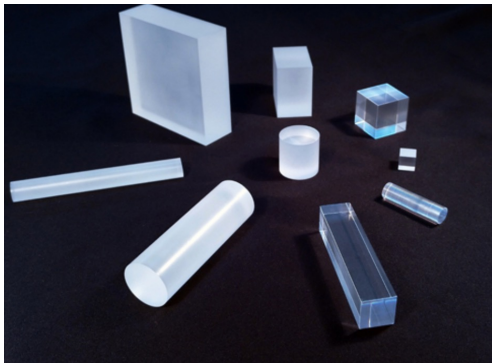


CACTUS

Gamma ray
array at OCL
until 2019



CsI (Tl)



Lanthanum Bromide Scintillation Radiation Detectors

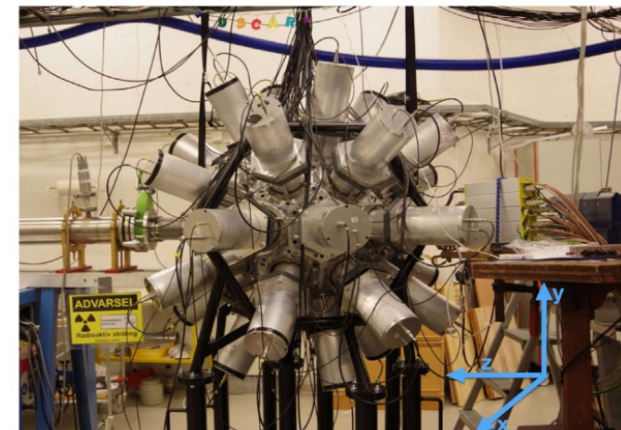
- High light output, and fast decay time output pulse.
- Better energy resolution and stability than NaI(Tl).
- Higher maximum throughput at high input count rates.

Lanthanum Bromide, or $\text{LaBr}_3(\text{Ce})$, is one of the new generation of inorganic scintillation gamma-ray detectors. LaBr detectors exhibit improved resolution and faster light decay time.

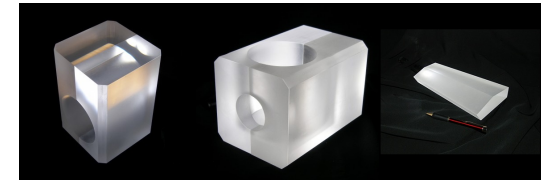


When used with the latest ORTEC digital electronics, these detectors provide improved resolution, pulse shape, and temperature stability compared to NaI(Tl) types.

OSCAR
Gamma ray
array at OCL
since 2019!!



BGO ($\text{Bi}_4\text{Ge}_3\text{O}_{12}$)



High Z ($Z=83$), high density ($d=7.13 \text{ g/cm}^3$) scintillation material.

Only inorganic scintillator without activator

BGO is a very **efficient gamma ray absorber**.

High Z values cause large the **photo-fraction** for gamma ray absorption
very **good peak-to-total** ratios are observed.

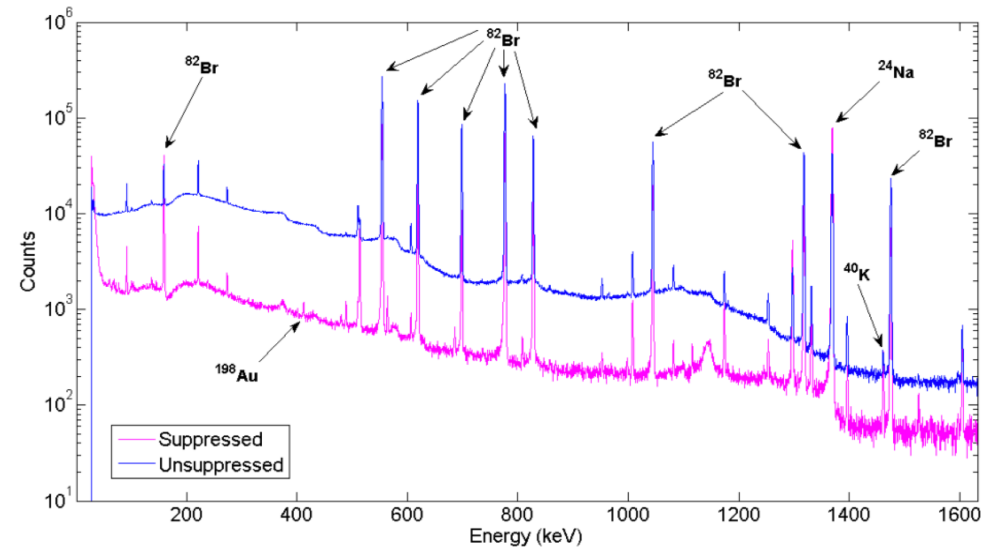
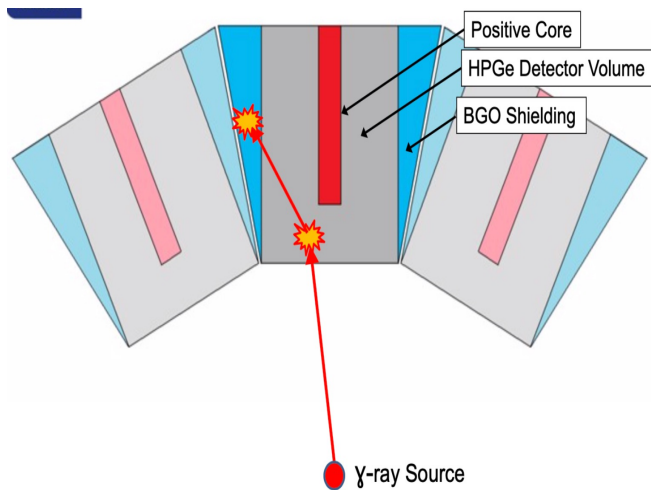
$$\tau \cong \text{constant} \times \frac{Z^n}{E_\gamma^{3.5}}$$

$n=4 \text{ or } 5$

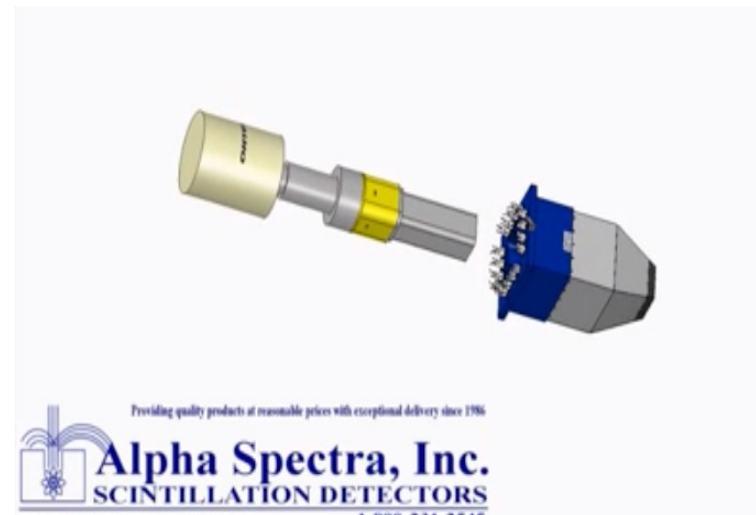
Poor resolution. Why?? We will see it soon.

BGO ($\text{Bi}_4\text{Ge}_3\text{O}_{12}$)

Compton Suppression Anti Compton Shields Calorimeter



[https://www.rsec.psu.edu/assets/PDF/8-RSEC_Book_Compton Suppression.pdf](https://www.rsec.psu.edu/assets/PDF/8-RSEC_Book_Compton%20Suppression.pdf)



Scintillation properties of inorganic materials

TABLE 6.1
Properties of Certain Inorganic Scintillators

Material	Wavelength of Maximum Emission (nm)	Scintillation Efficiency (Relative, %)	Decay Time (μ s)	Density (10^3 kg/m^3)
NaI(Tl)	410	100	0.23	3.67
CaF ₂ (Eu)	435	50	0.94	3.18
CsI(Na)	420	80	0.63	4.51
CsI(Tl)	565	45	1.00	4.51
Bi ₄ Ge ₃ O ₁₂	480	8	0.30	7.13
CdWO ₄	530	20	0.90	7.90
⁶ LiI(Eu)	470	30	0.94	3.49

Scintillation properties of organic materials

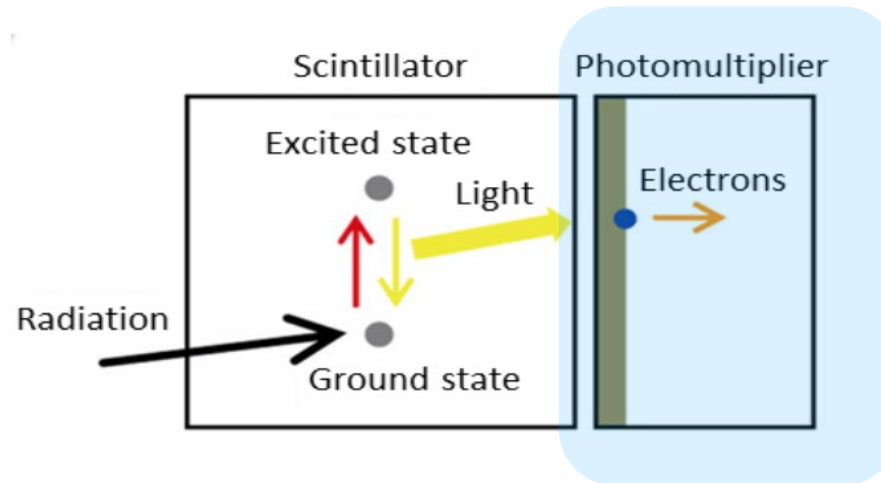
TABLE 6.3
Properties of Certain Organic Scintillators

Material	Wavelength of Maximum Emission (nm)	Relative Scintillation Efficiency (%)	Decay Time (ns)	Density (10^3 kg/m^3)
Anthracene	445	100	~30	1.25
<i>trans</i> -Stilbene	385	~60	4–8	1.16
NE 102	350–450	~65	2	1.06
NE 110	350–450	60	3	1.06
NE 213 (liquid)	350–450	~60	2	0.867
PILOT B	350–450	68	2	1.06
PILOT Y	350–450	64	~3	1.06

Today

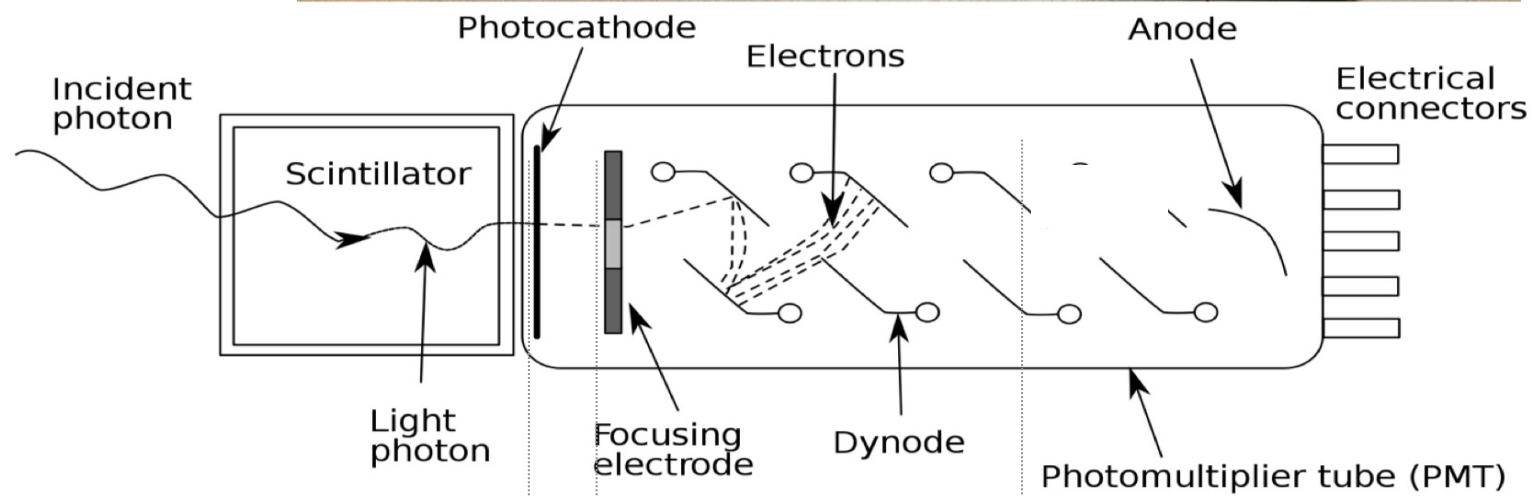
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 - Inorganic
- Energy resolution
 - Inorganic
- Detector efficiency
 - Heavy charged particle
 - Electrons
 - Gamma rays
 - Neutrons

Photo multiplier tubes (PMTs)



- Scintillation material (organic and inorganic) will not work as a detector without a PMT tube
- Photocathode before PMT
- Anode after PMT

- I) Light (photon) creation
- II) Photoelectron creation
- III) Electron multiplication
- IV) Electron collection on Anode



25

(I)

(II)

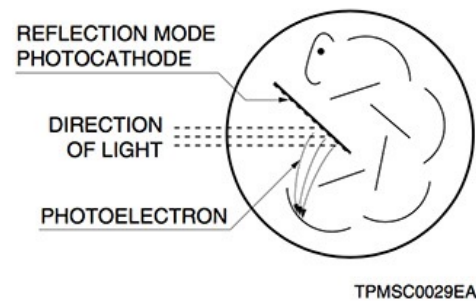
(III)

(IV)

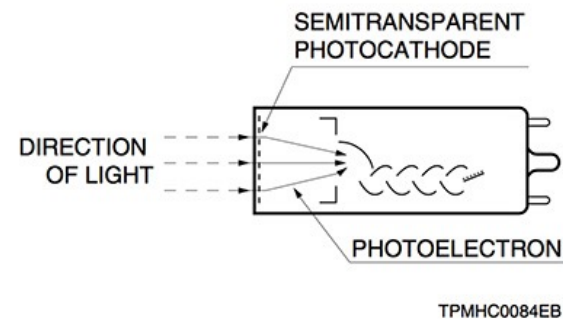
Photocathode

Types of Photocathode

a) Reflection Mode



b) Transmission Mode



<https://www.hamamatsu.com/jp/en/support/glossary/p.html>

not all photoelectrons will escape!! ~20-30% eff.

Photocathode Quantum efficiency: 20-30% in NaI(Tl)

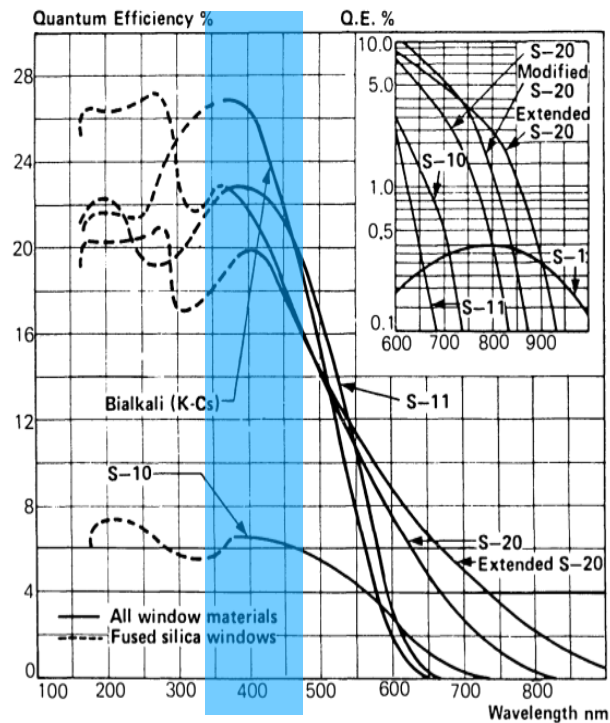


Table 8.1. Photocathode characteristics (from RTC catalog [8.3])

Cathode type	Composition	λ at peak response [nm]	Quantum efficiency at peak
S1 (C)	Ag – O – Cs	800	0.36
S4	SbCs	400	16
S11 (A)	SbCs	440	17
Super A	SbCs	440	22
S13 (U)	SbCs	440	17
S20 (T)	SbNa – KCs	420	20
S20R	SbNa – KCs	550	8
TU	SbNa – KCs	420	20
Bialkali	SbRb – Cs	420	26
Bialkali D	Sb – K – Cs	400	26
Bialkali DU	Sb – K – Cs	400	26
SB	Cs – Te	235	10

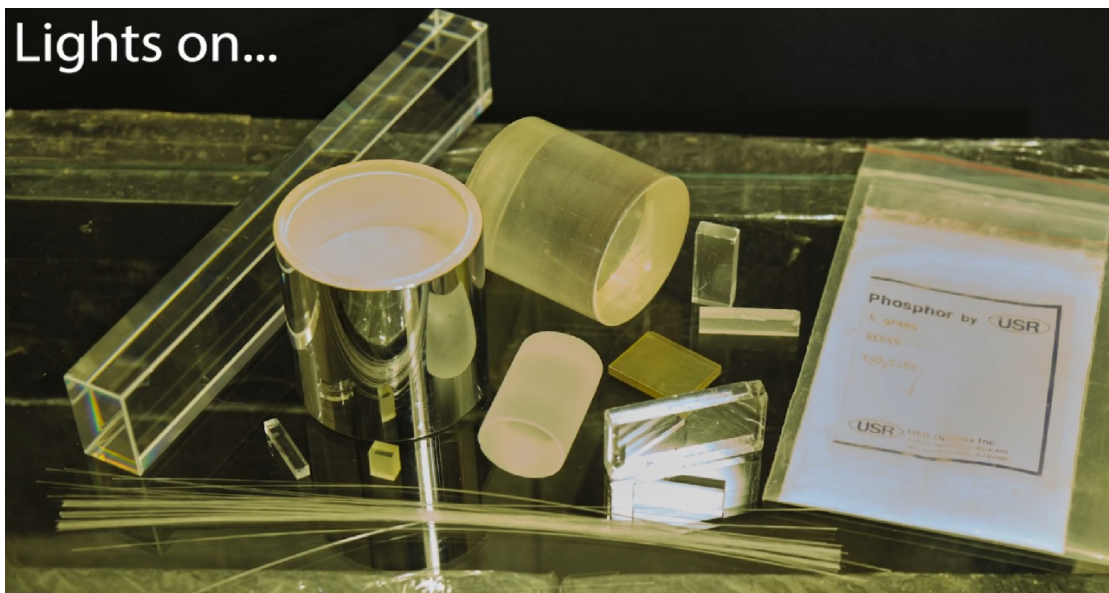
Most of the Photocathods used today are **semiconductor** materials where the QE is changing between 10 to 30%.

Photocathods in **metal** form have very low QE around 0.1%! **Why?**

Answer

Answer: Photoelectron needs to escape from the PC. If it experiences a lot of free electrons, which is the case of metals, it will lose its energy due to the collisions with these free electrons. This will reduce the probability of the photoelectron to reach the surface with enough energy to overcome potential barrier and eventually escape.

Lights on...



NaI (TI)

NP & HEP

CsI(TI)

BaF₂ : Barium fluoride

Plastic

BGO: Bismuth Germanate (B₄Ge₃O₁₂)

YSO :Yttrium Silicon Oxide (Y₂SiO₅:Ce)

PET

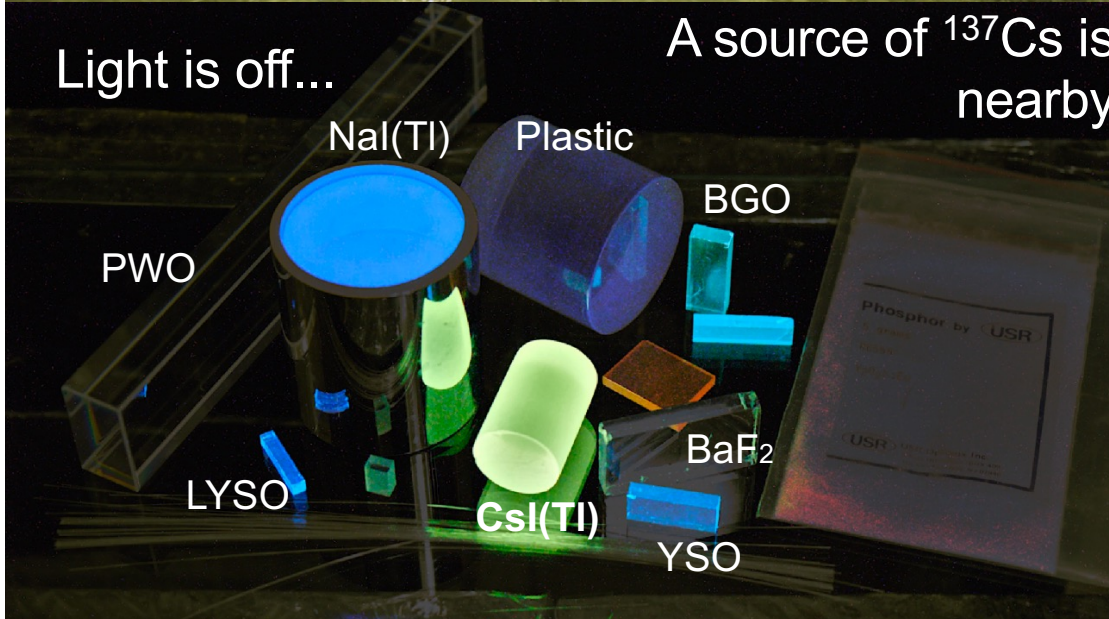
LYSO: Lutetium Yttrium Silicon Oxide
Lu_{1.8}Y_{0.2}SiO₅:Ce)

PWO: Lead Tungstate (PbWO₄)

HEP (CERN)

Light is off...

A source of ¹³⁷Cs is nearby



Properties	BGO	LYSO
Density (g/m ³)	7.13	7.3
Melting Point (°C)	1050	2047
Index of Refraction	2.15	1.82
Radiation Length (cm)	1.10	1.16
Attenuation (cm-1)	0.96	0.87
Decay Constant (ns)	300	50
Light Yield (%) NaI (TI)	25	75
Photofraction (%)	40	30
Energy Resolution (511 kev,%)	16	20
Radioactivity	No	Yes

Youtube video:

<https://www.youtube.com/watch?v=Gza6Cc8XOCA&t=537s>

Today

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 - Inorganic
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organic scintillators

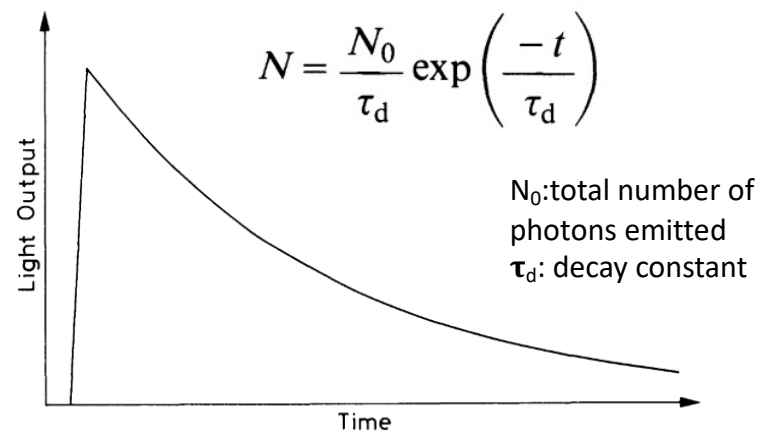


Fig. 7.2. Simple exponential decay of fluorescent radiation. The rise time is usually much faster than the decay time

Population of the optical levels, i.e. Excitation
Rise time

Decay from the optical levels

- Fast component
- Slow component

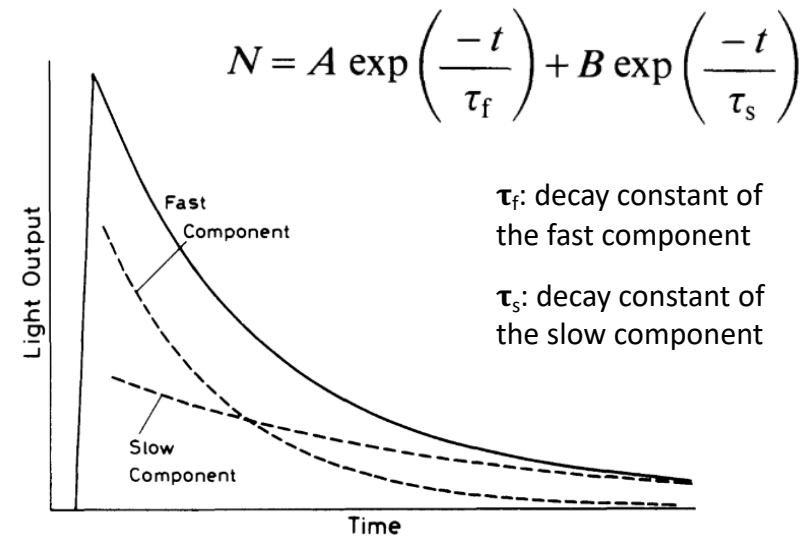


Fig. 7.3. Resolving scintillation light into *fast* (prompt) and *slow* (delayed) components. The *solid line* represents the total light decay curve

organic scintillators

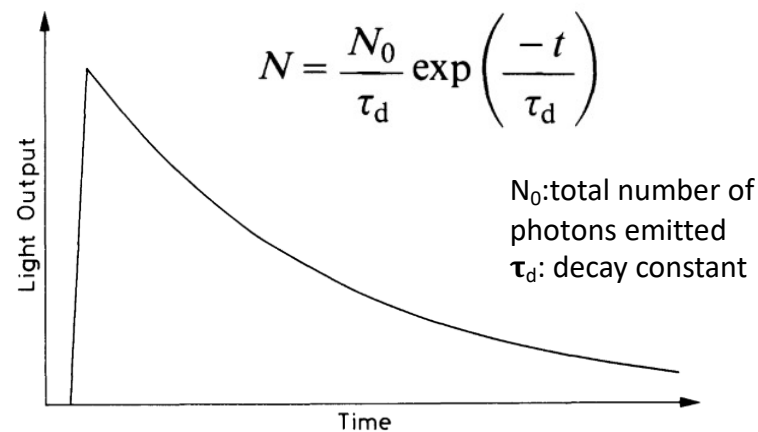


Fig. 7.2. Simple exponential decay of fluorescent radiation. The rise time is usually much faster than the decay time

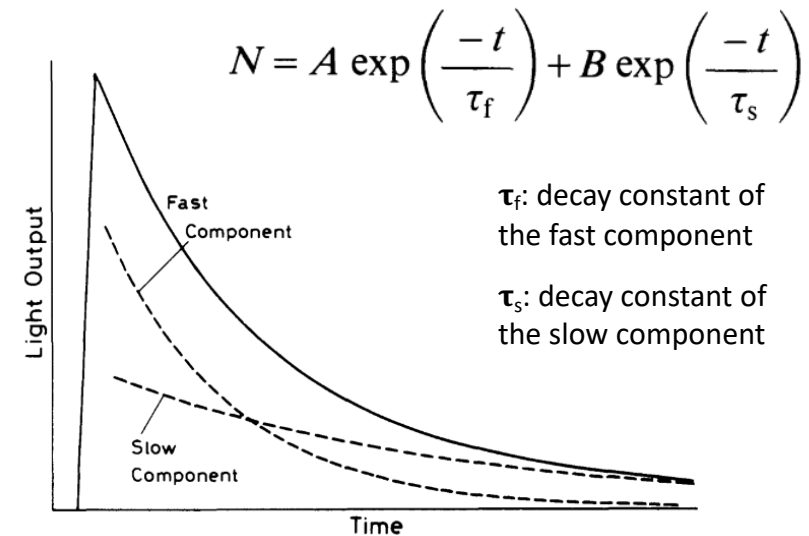


Fig. 7.3. Resolving scintillation light into *fast* (prompt) and *slow* (delayed) components. The *solid line* represents the total light decay curve

Population of the optical levels, i.e. Excitation
Rise time

Decay from the optical levels

- Fast component
- Slow component

N_0 : total number of photons emitted
 τ : decay constant

$$N(t) = N_0 f(\sigma, t) \exp\left(\frac{-t}{\tau}\right)$$

Table 7.2. Gaussian and exponential parameters for light pulse description from several plastic scintillators (from *Bengston and Moszynski* [7.2])

Scintillator	σ [ns]	τ [ns]
NE102A	0.7	2.4
NE111	0.2	1.7
Naton 136	0.5	1.87

organic scintillators

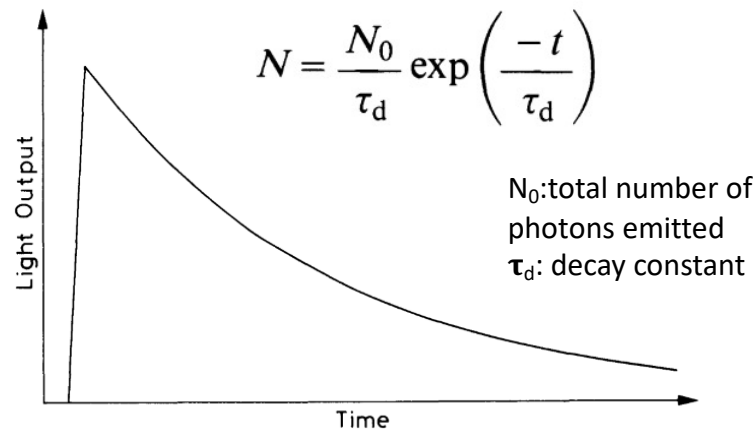


Fig. 7.2. Simple exponential decay of fluorescent radiation. The rise time is usually much faster than the decay time

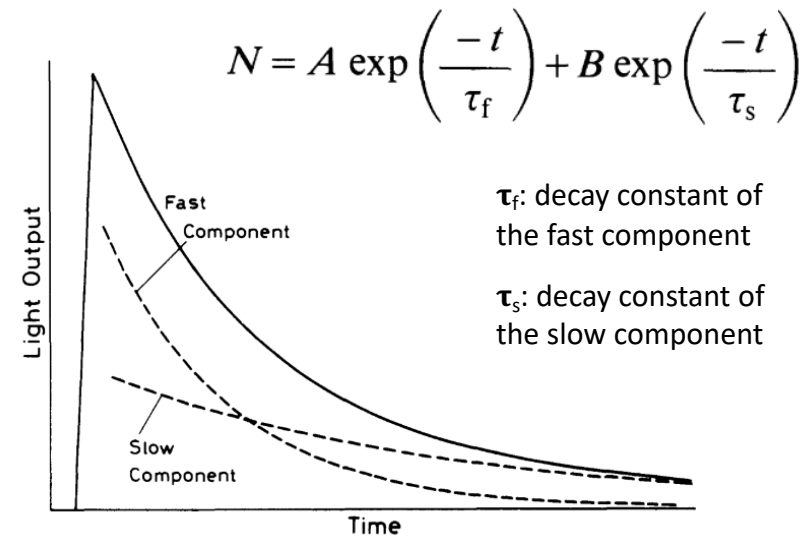


Fig. 7.3. Resolving scintillation light into *fast* (prompt) and *slow* (delayed) components. The *solid* line represents the total light decay curve

Population of the optical levels, i.e. Excitation

Rise time

Decay from the optical levels

- Fast component
- Slow component

$$I = I_0(e^{-t/\tau} - e^{-t/\tau_1})$$

Table 8.2 Some Timing Properties of Fast Plastic Scintillators

	Parameters for Eq. (8.10)		Parameters for Eq. (8.11)		Measured FWHM
	τ_1 (rise)	τ (decay)	σ_{ET}	τ	
NE 111	0.2 ns	1.7 ns	0.2 ns	1.7 ns	1.54 ns
Naton 136	0.4 ns	1.6 ns	0.5 ns	1.87 ns	2.3 ns
NE 102A	0.6 ns	2.4 ns	0.7 ns	2.4 ns	3.3 ns

Data from Bengtson and Moszynski.⁴⁵

N_0 : total number of photons emitted
 τ : decay constant

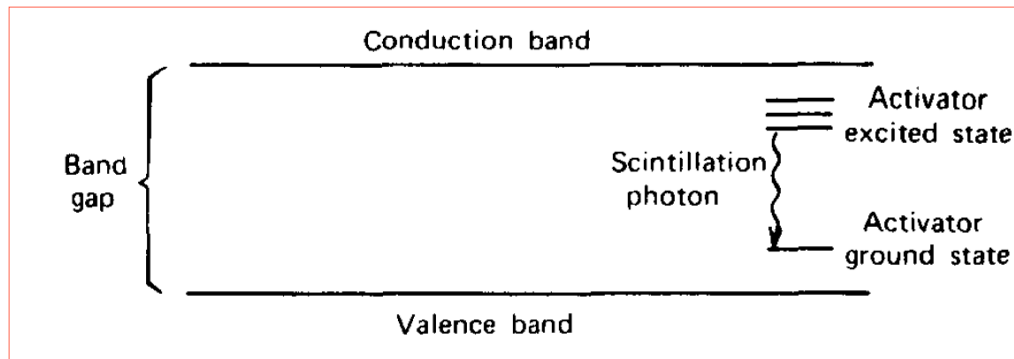
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Scintillator	σ [ns]	τ [ns]
NE102A	0.7	2.4
NE111	0.2	1.7
Naton 136	0.5	1.87

inorganic scintillators

The dominant decay time of the scintillation pulse is **230 ns for NaI(Tl)**, uncomfortably long for some fast timing or high counting rate applications. What determines this slow decay time? The pure crystal or the activator?



In addition to this prompt yield of NaI(Tl) (230 ns), a **phosphorescence** with characteristic **0.15 s decay time** has also been measured which contributes about 9% to the overall light yield.

Today

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 - Organic scintillators
 - Anthracene
 - Stilbene
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 - Liquid
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 - Gamma rays
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Pulse shape discrimination

Slow light output component as a function of time produces a long tail which depends on the nature of the exciting particle/radiation.

The slow component fraction should depend primarily on the rate of energy loss dE/dx of the exciting particle and should be greatest for particles with large dE/dx . ($\alpha > \beta > \gamma$)

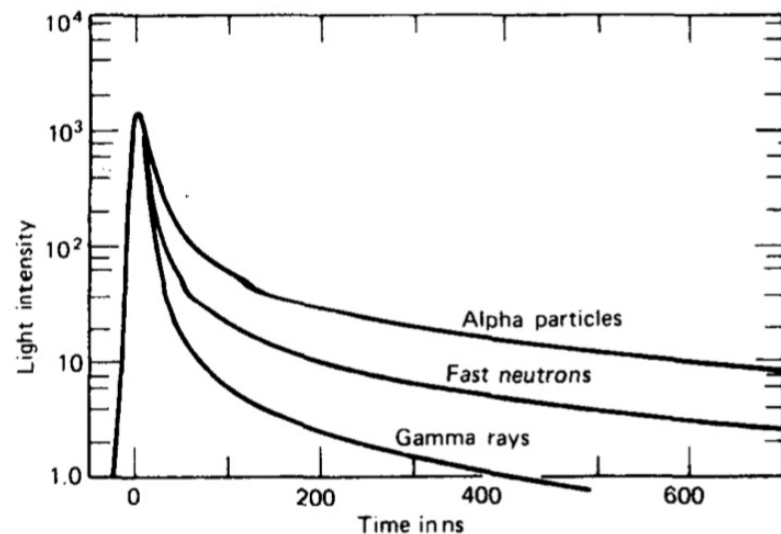
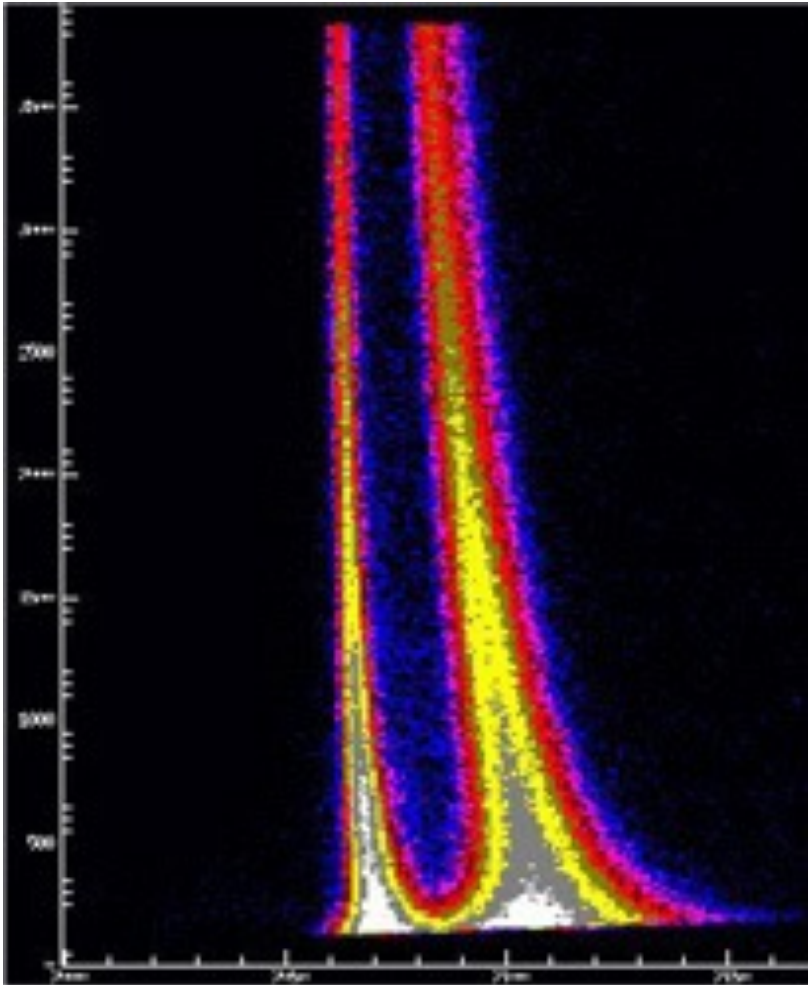


Figure 8.5 The time dependence of scintillation pulses in stilbene (equal intensity at time zero) when excited by radiations of different types. (From Bollinger and Thomas.⁶⁰)

PSD is used to **eliminate gamma-ray-induced events when organic scintillators are used as neutron detectors.**

stilbene and liquid scintillators

What about inorganic scintillators?



Otherway around:

LaBr₃(Ce) detectors have fast timing, i.e. good time resolution, compared to NaI(Tl).

We can then use them to **eliminate neutron induced events as LaBr₃(Ce) is used as gamma-ray detectors (OSCAR array at OCL).**

Example: Fission reaction produces a lot of neutrons in addition to gamma rays from the reaction products

Q: Which one is a gamma peak, and which one is a neutron peak?

Today

- Scintillation
 - Organic scintillators
 - Anthracene
 - Stilbene
 - Plastic
 - Liquid
 - Inorganic scintillators
 - NaI(Tl)
 - CsI(Tl)
 - LaBr₃(Ce)
 - BGO
- PMTs (Photomultiplier Tubes)
 - Mechanism
 - Photocathode
 - Quantum efficiency
- Time response
 - Organic
 - Inorganic
- Pulse shape discrimination
 - Organic
- Light output
 - Organic
 - Inorganic
- Energy resolution
 - Inorganic
- Detector efficiency
 - Heavy charged particle
 - Electrons
 - Gamma rays
 - Neutrons

Table 7.3. Average energy loss per scintillator photon for electrons

Material	ϵ [eV/photon]
Anthracene	60
NaI	25
Plastic	100
BGO	300

- The light output of a scintillator refers more specifically to its efficiency for converting ionization energy to photons.
- The fraction of all incident particle energy which is converted into visible light is called “*scintillation efficiency*” or “*light output*”
- *Light output depends on the type of the radiation and energy*

Q: Can you tell the which type has the largest light output in Table 7.3?



Answer:

Answer: Since $\epsilon (=w)$ is lowest for NaI(Tl), NaI(Tl) has the largest light output which gives the best energy resolution compared to Anthracene, Plastic and BGO in the table

However, we have to remember that photocathode/photomultiplier has its efficiency about 20-30% which we have to take into account for the resolution of this detector and for any given scintillator!

BGO versus NaI(Tl)

- Which is more dense? Z number
- Which one has larger detection efficiency? (intrinsic detection efficiency ϵ_{int})
- Which one has larger light output? $J=E/w$
- Which one has better energy resolution?

Answers

Table 7.3. Average energy loss per scintillator photon for electrons

Material	ϵ [eV/photon]	
Anthracene	60	
NaI	25	→ Best resolution (Highest light output)
Plastic	100	
BGO	300	→ Highest efficiency (Highest Z)

Light output or light yield has affect on the energy resolution.
While density of the scintillator has affect on its efficiency.

We thus use NaI(Tl) for detecting energy of the gamma rays (gamma-ray spectroscopy)
BGO for absorbing gamma-rays for reducing Compton background (Compton suppression)

Examples of light output for plastic (organic) scintillator

- Light output decreases for heavier particles
- Linearity is worsen for heavier particles.

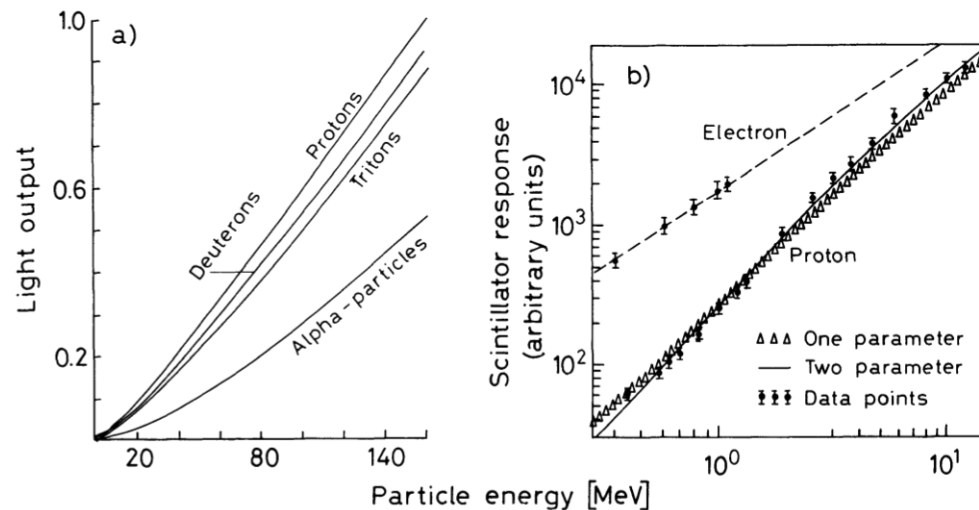


Fig. 7.8a, b. Response of NE102 plastic scintillator to different particles ((a) from Gooding and Pugh [7.6]; (b) from Craun and Smith [7.7])

Quenching interactions: Some energy loss is dissipated non-radiatively, primarily in the form of lattice “vibrations” or “heat”. These radiationless de-excitation processes are called “quenching”

Examples of light output for inorganic scintillators

- Deviations from linearity are less for inorganic scintillators.
- Non-linearity becomes more pronounced at low energies, especially around atomic absorption edges.
- This non-linearity must be taken into account in energy calibration.

Perfectly linear response would correspond to a horizontal line

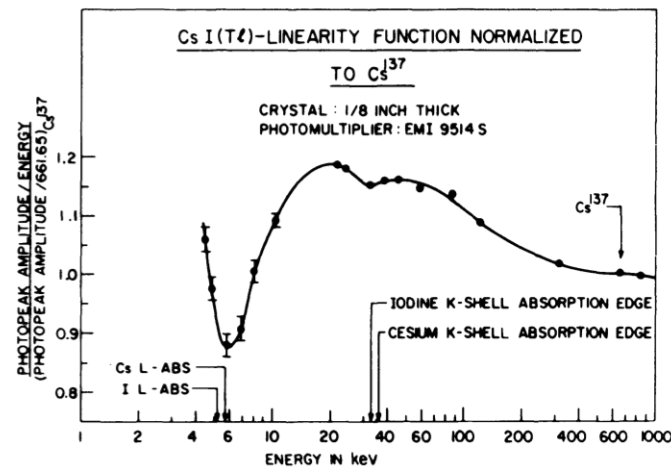
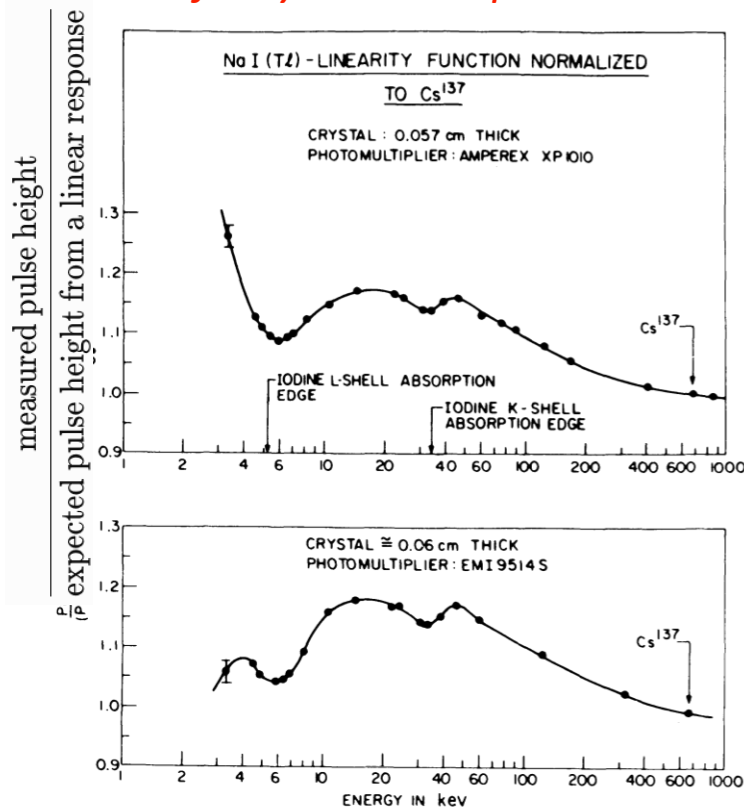


Fig. 7.9. Response of NaI(Tl) and CsI(Tl). The pulse height of the 661 keV gamma ray line from ^{137}Cs is defined as 1.0 (from Aitken et al. [7.14]). Note the nonlinearities that appear particularly at energies corresponding to the *K*- and *L*-edges in Iodine. This is because photoelectrons ejected by incident gamma rays just above the *K* energy have very little kinetic energy so that the response drops. Just below this energy, however, *K*-shell ionization is not possible and *L*-shell ionization takes place. Since the binding energy is lower, the photoelectrons ejected at this point are more energetic which causes a rise in the response. A similar argument applies to the *L* shell, etc. (Picture © 1967 IEEE)

Temperature dependence

The plot shows how sensitive is the decay time with temperature changes

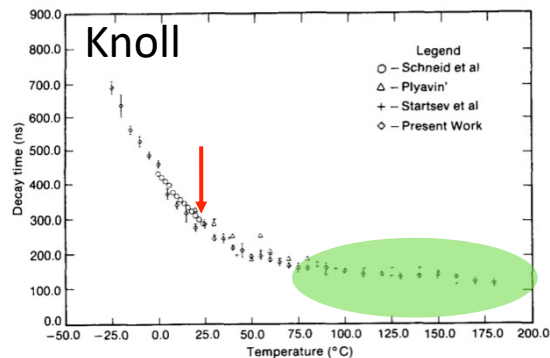
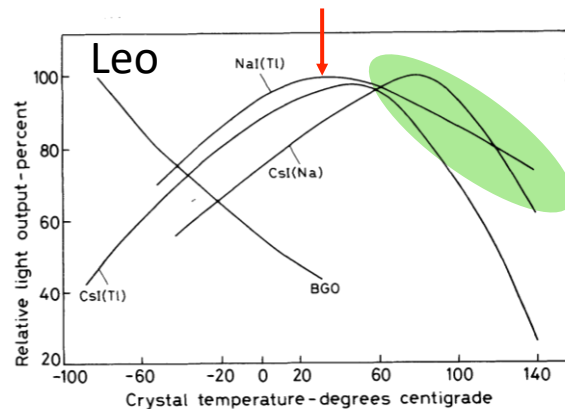


Figure 8.10 Temperature dependence of the scintillation decay time in NaI(Tl). (From Schweitzer and Ziehl.⁸³)



Inorganic scintillators work mostly in room temperatures.

- For some applications low decay time is desired.
- Can be obtained via high temperature
- However, light yield decreases significantly.

Organic scintillators have the same light output between the temperatures -60 to 20 °C i.e. less temperature dependent

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 - Inorganic
- Detector efficiency
 - Heavy charged particle
 - Electrons
 - Gamma rays
 - Neutrons

Let's calculate energy resolution for a 662 keV gamma ray on a NaI(Tl) Detector

Table 7.3. Average energy loss per scintillator photon for electrons

Material	ϵ [eV/photon]
Anthracene	60
NaI	25
Plastic	100
BGO	300

$$E_\gamma = 662 \text{ keV}$$

$$N_{\text{photons}} = J = \frac{E_0}{\epsilon} = \frac{E_0}{w}$$

$$= \frac{662 \text{ keV}}{25 \text{ eV}}$$

$$= 26480 \text{ photons}$$

What about Fano factor?

Case 1:

For a detector in which the radiation energy is **not totally absorbed**, the number of signals producing reactions is given by a **Poisson distribution**. **Fano factor=1**

Scintillator

Case 2:

If the energy of the radiation is **fully absorbed** as is the case for detectors used in spectroscopy experiments, the Poisson statistics is incorrect. **Fano factor $\ll 1$**

**Gas
Solid-state
detectors**

Let's calculate energy resolution for a 662 keV gamma ray on a NaI(Tl) Detector

Table 7.3. Average energy loss per scintillator photon for electrons

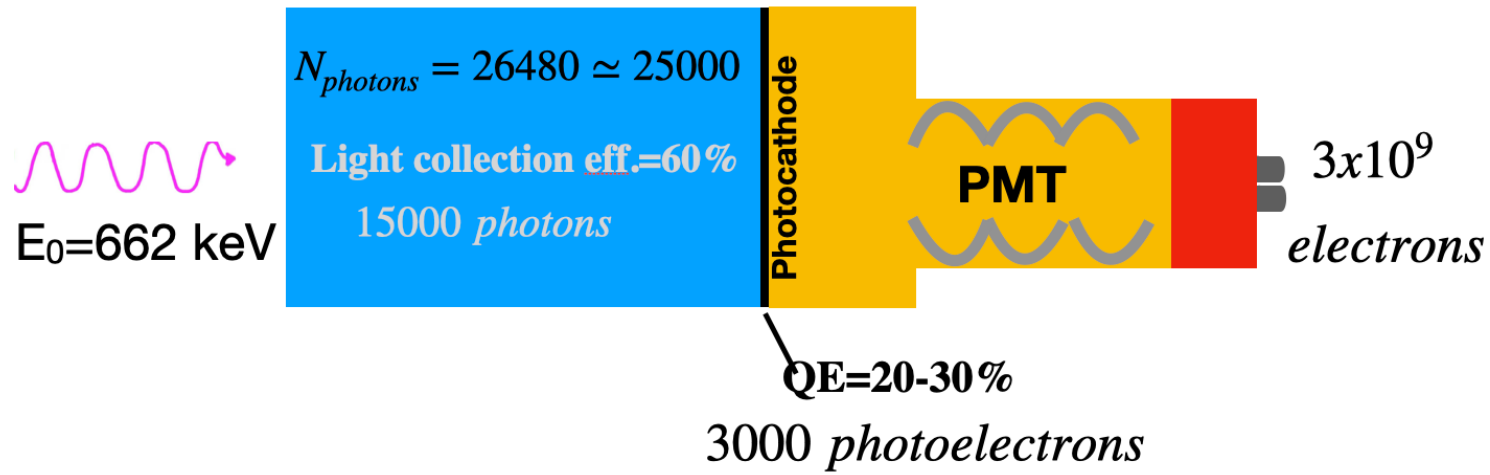
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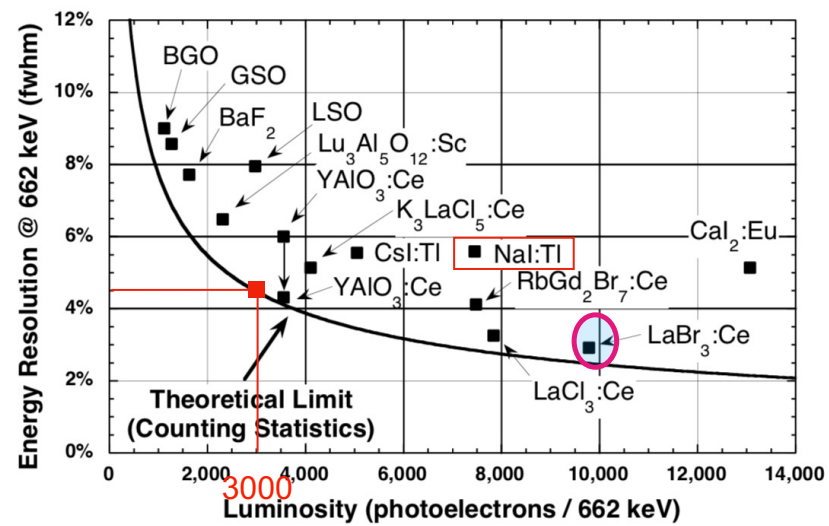
$$N_{photons} = J = \frac{E_0}{\epsilon} = \frac{E_0}{w}$$

$$= \frac{662 \text{ keV}}{25 \text{ eV}}$$

$$= 26480 \text{ photons}$$



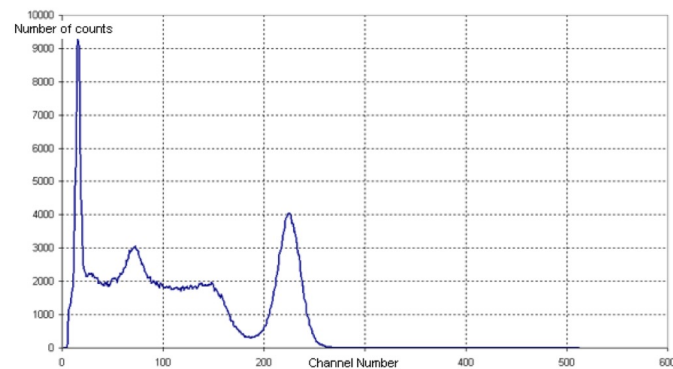
$$\frac{\Delta E_{FWHM}}{E_0} = 2.35 \frac{\sigma_I}{J} = 2.35 \frac{\sqrt{(3000)}}{3000} = 0.043 = 4.3\%$$



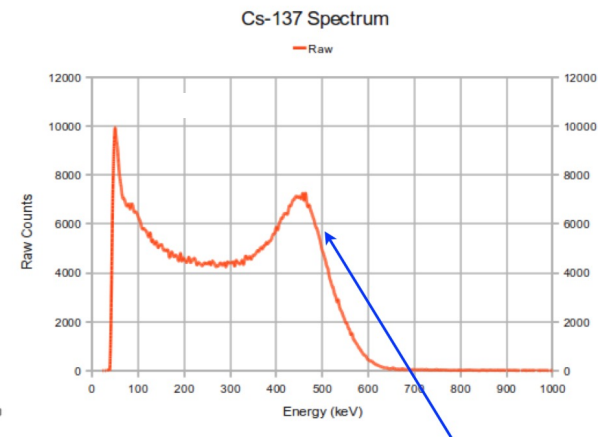
Resolution is never reached to the optimum value due to different losses in Scint. detectors.

Inorganic vs Organic

- ^{137}Cs spectrum in NaI crystal



same in plastic scintillator



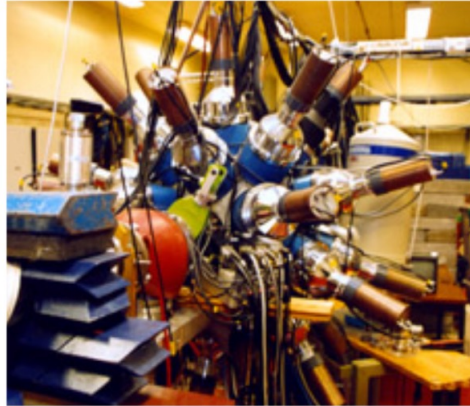
Compton edge or full peak?

Organic scintillators have low density (low-Z) (C and H only) while Photoelectric absorption is proportional to Z^4 or Z^5

CACTUS vs OSCAR

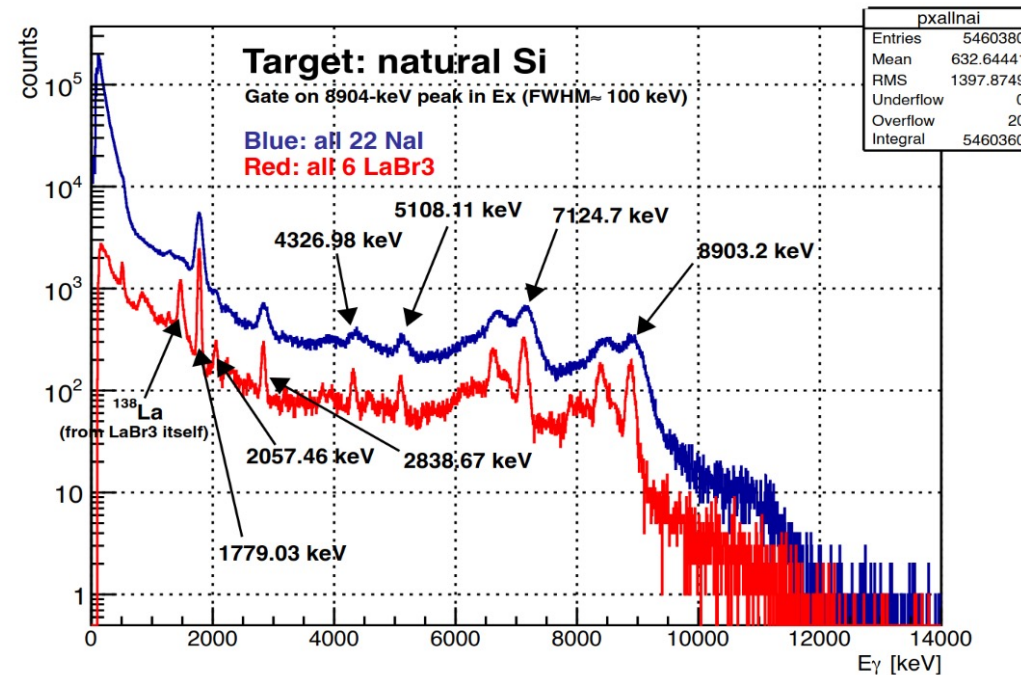
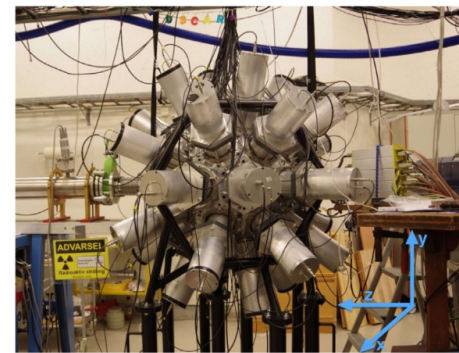
CACTUS Array

- 30 large volume NaI (TI) detectors.
- Dimension: ($\varnothing 5 \times 5$ inches)



Oslo Scintillator Array (OSCAR)

- 30 large volume LaBr₃(Ce) detectors.
- Dimension: ($\varnothing 3.5 \times 8$ inches)



Comparison of energy resolutions

Which one has better energy resolution?

Which one has higher efficiency for the same volume?

Which one has faster time response ?

Which one is way more expensive?

Detector Type	Resolution @622 keV (%)	Density (g/cc)	Photoelectron Yield Relative to NaI	Primary Decay Time (usec)
LaBr ₃ (Ce)	2.8 - 4.0	5.29	130	0.026
NaI(Tl)	7	3.7	100	0.230

Which one has better energy resolution? $\text{LaBr}_3(\text{Ce})$

Which one has higher efficiency for the same volume? $\text{LaBr}_3(\text{Ce})$

Which one has faster time response ? $\text{LaBr}_3(\text{Ce})$

Which one is way more expensive? $\text{LaBr}_3(\text{Ce})$

Detector Type	Resolution @622 keV (%)	Density (g/cc)	Photoelectron Yield Relative to NaI	Primary Decay Time (usec)
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 - Inorganic
- Detector efficiency
 - Heavy charged particle
 - Electrons
 - Gamma rays
 - Neutrons

In-class activity sometime in October

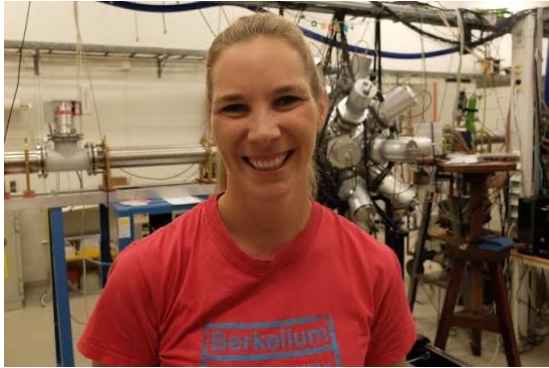
Figure out detection efficiency for different types of radiation (for scintillation detectors).

Heavy-ions

Electrons

Gammas

Neutrons

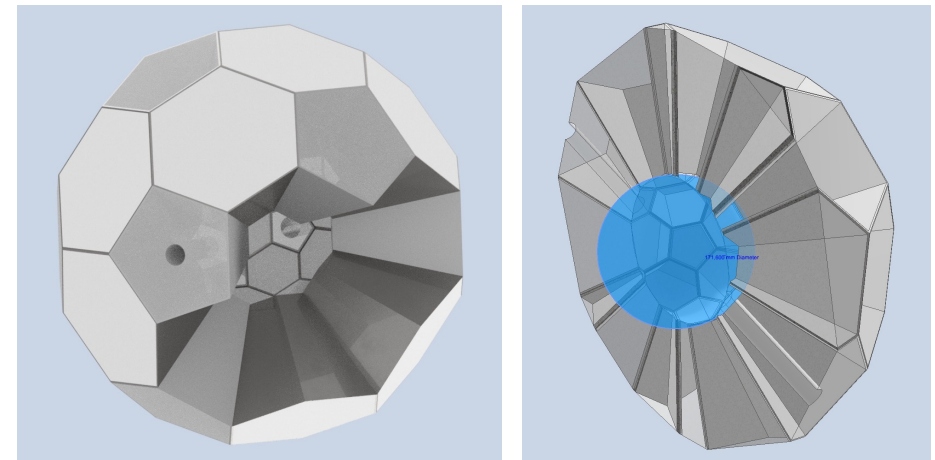


Ann-Cecilie Larsen 😊

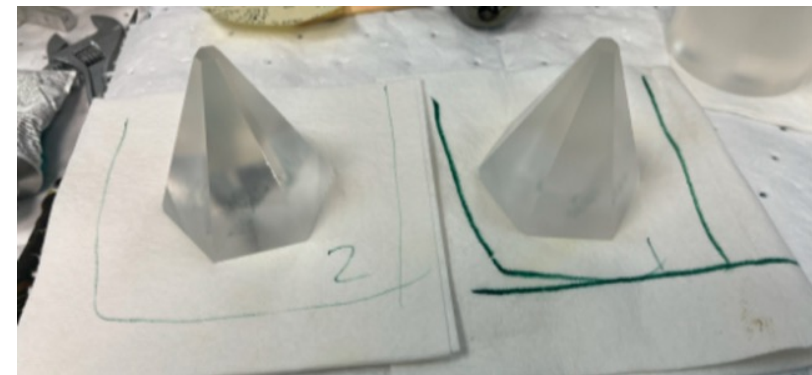
Beta-Oslo method for neutron-capture cross sections for nuclear astrophysics

Q: How are elements heavier than Iron made?

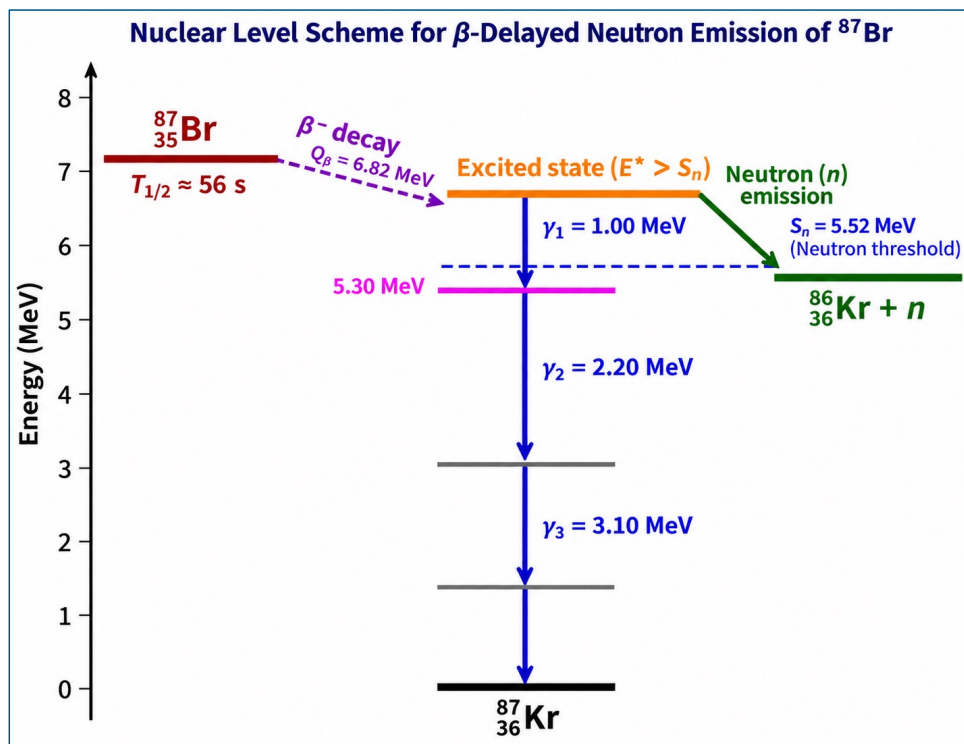
STARLIGHT 😊



Design drawings by Maren Lithun, UiO; “StarLight”, NaI(Tl+Li)

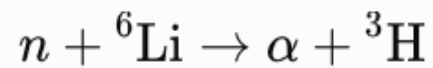


First successful cutting tests, 3" x 3" NaI(Tl+Li), 22 May 2026



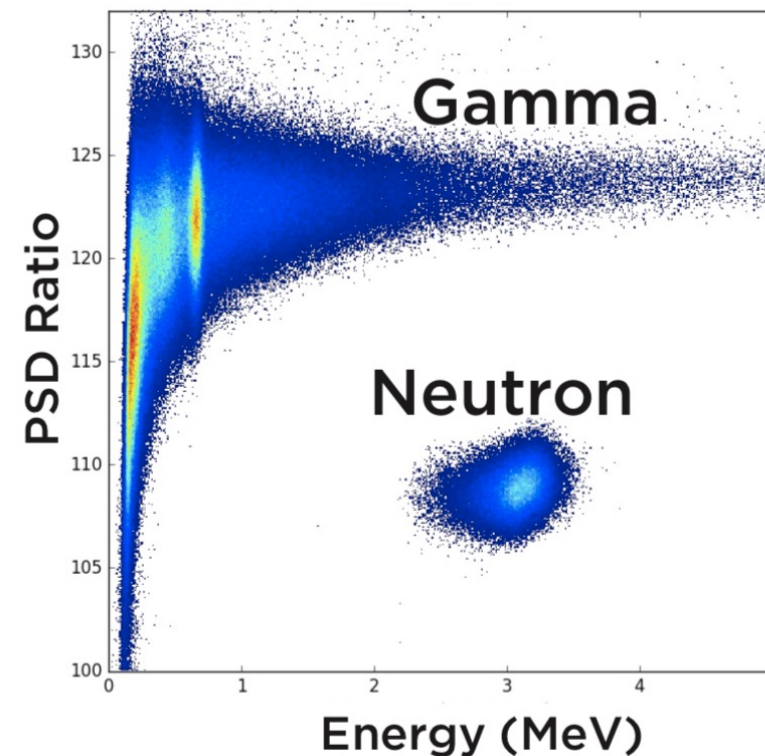
Nal (Tl+Li), also called NaIL:

${}^6\text{Li}$ is the key to making NaI sensitive to thermal neutrons. How?



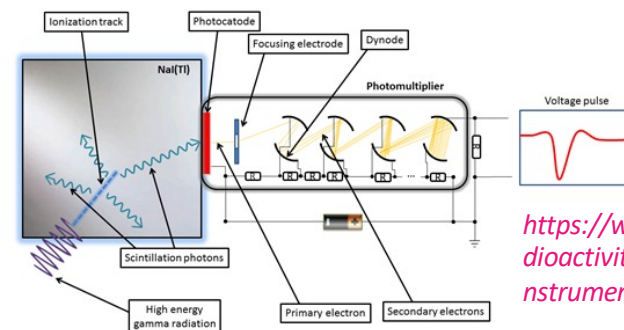
${}^6\text{Li}$ enables thermal-neutron capture. The resulting α and triton produce a different scintillation time profile from γ -induced electrons. In NaIL, this difference in the fast and slow scintillation components enables neutron–gamma pulse-shape discrimination.

${}^{252}\text{Cf}$ source: fission (gammas + neutrons)



Questions to you

- How do scintillator detectors work? What is the mechanism of a scintillator detector independent from its type? What properties are important to look at when comparing various types of scintillator materials?
- Explain how scintillation light is produced in inorganic scintillator materials and why we dope inorganic scintillators.
- Explain how an organic scintillator produces light. What is the desired process?
- Compare organic and inorganic scintillators. List main differences.
- How can you estimate the energy resolution of an inorganic scintillator detector? Feel free to give numerical explanations.
- Which scintillator detector is optimum for:
 - beta particles
 - alpha particles
 - gamma rays
 - Neutrons



<https://www.fe.infn.it/radioactivity/educational/instrumentation.html>

- What are the advantages of LaBr₃ detectors compared to NaI(Tl) detectors?
- Compare a typical gamma-ray pulse-height spectrum in organic and inorganic scintillator detector. Which one would you choose?
- Explain how a PMT works and what it is used for. Draw and explain.