PMT and HV control

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PMT

Photo multiplier is used to detect weak light.

Q1: What does “weak” mean?

Scintillation light generated by radiation detector, such as Plastic scintillator, is very weak. PMT is used to detect such weak light.

PMT

You can learn PMT with “PMT handbook” from Hamamatsu, which is at
http://www.hamamatsu.com/resources/pdf/etd/PMT_handbook_v3aE.pdf
Figures on this text is copied from the handbook.

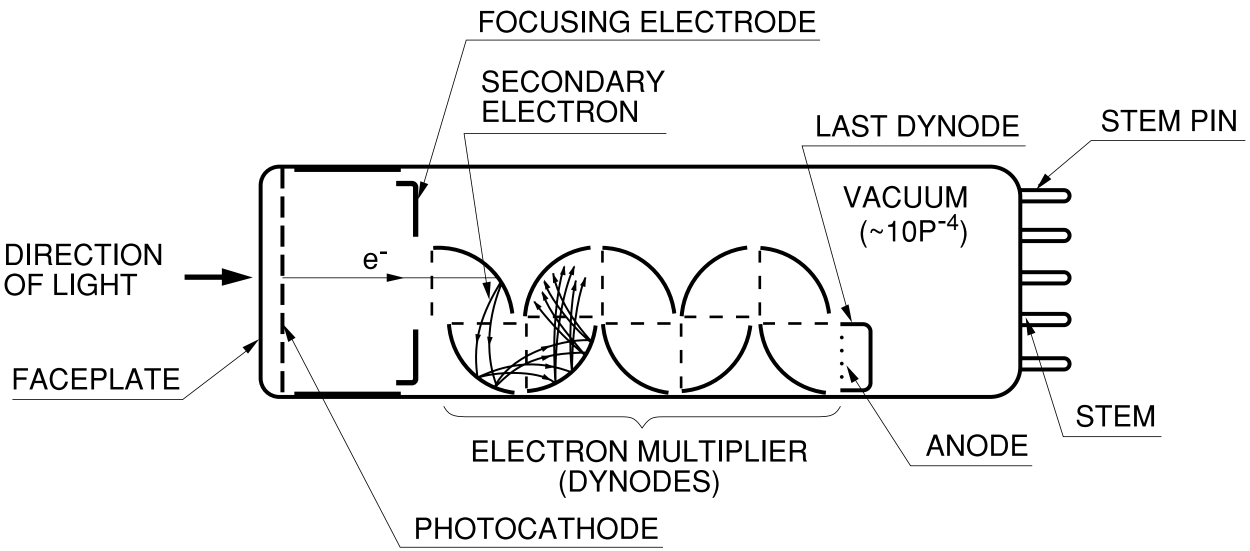
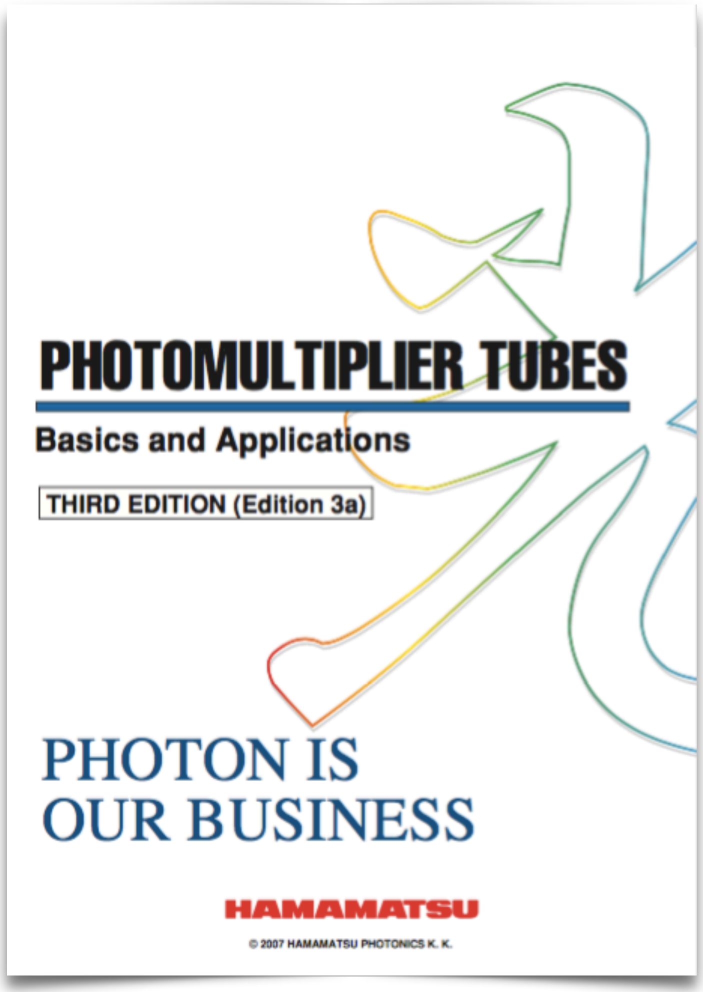
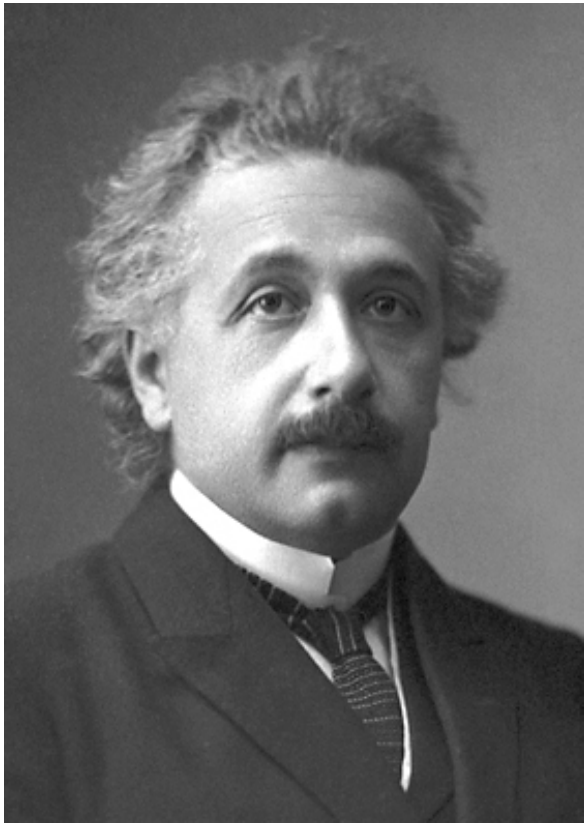


Figure 2-1: Construction of a photomultiplier tube



Photoelectric effect



1921 Nobel prize

If metal electrodes are exposed to light, electrical sparks between them occur more readily. For this **"photoelectric effect"** to occur, the light waves must be above a certain frequency, however. According to physics theory, the light's intensity should be critical. In one of several epoch-making studies beginning in 1905, Albert Einstein explained that light consists of quanta - "packets" with fixed energies corresponding to certain frequencies. One such light quantum, a photon, must have a certain minimum frequency before it can liberate an electron.

https://www.nobelprize.org/nobel_prizes/physics/laureates/1921/einstein-facts.html

PMT is a device which can observe single photon.

photoelectric effect

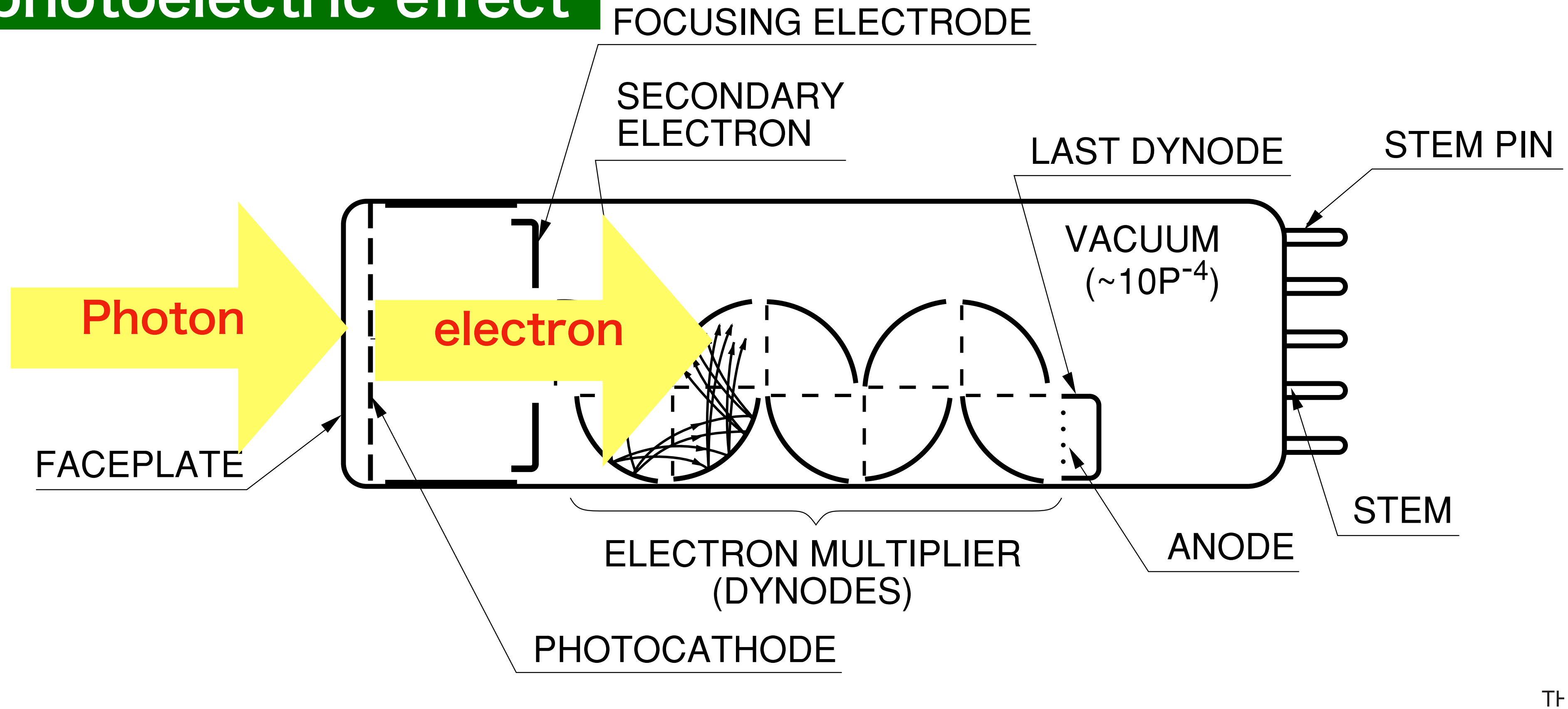
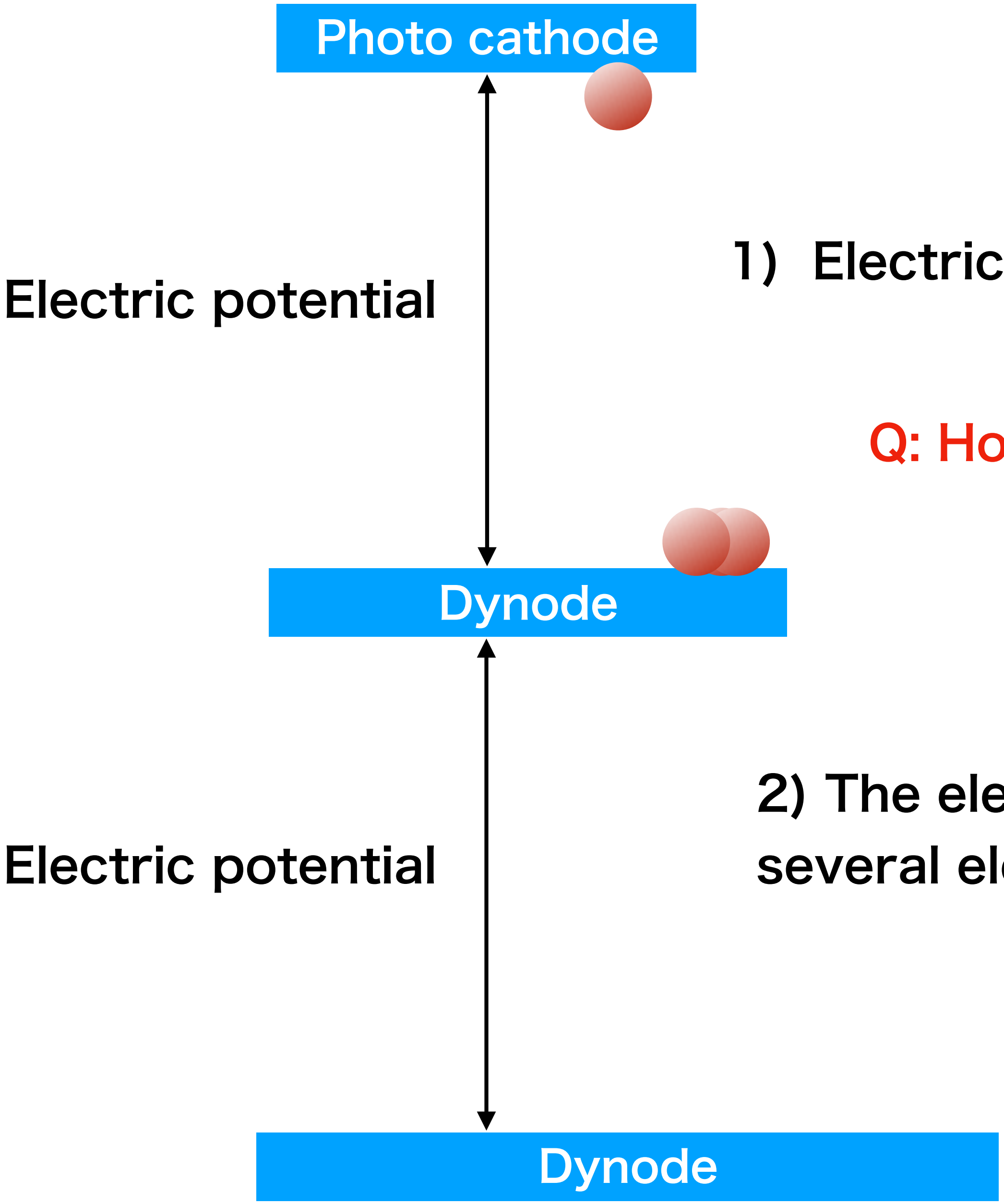


Figure 2-1: Construction of a photomultiplier tube

Multiplication at Dynode



1) Electric field accelerate an electron.

Q: How much energy is obtained?

2) The electron kicks out
several electrons in a dynode.

Multiplication at Dynode

The number of secondary electron is

$$\delta = a \cdot E^k$$

Where a is a constant and k is determined by the structure and material of the dynode and has a value from 0.7 to 0.8.

The anode current Ip is given by the following equatior

$$Ip = I_k \cdot \alpha \cdot \delta_1 \cdot \delta_2 \cdots \delta_n \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$

$$(a \cdot E^k)^n = a^n \left(\frac{V}{n+1} \right)^{kn} = A \cdot V^{kn}$$

Exercise: Measure "kn"

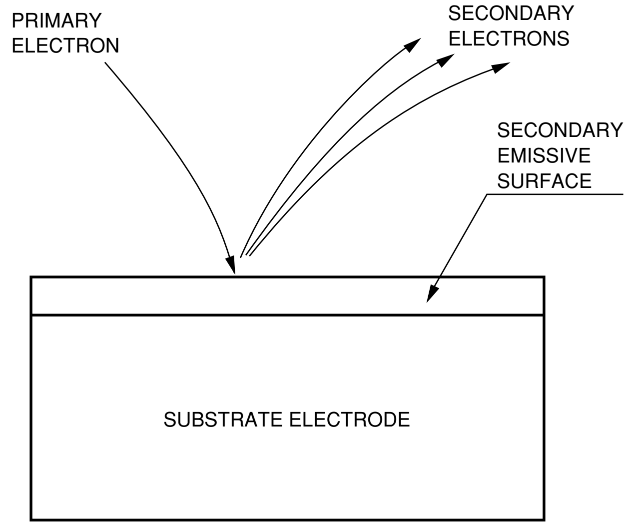


Figure 2-6: Secondary emission of dynode

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SPECIFICATIONS

GENERAL

Parameter		Description / Value	Unit
Spectral response		300 to 650	nm
Wavelength of maximum response		420	nm
Photocathode	Material	Bialkali	—
	Minimum effective area	ϕ46	mm
Window material		Borosilicate glass	—
Dynode	Structure	Linear focused	—
	Number of stages	12	—

Exercise: Measure “kn”. n=12

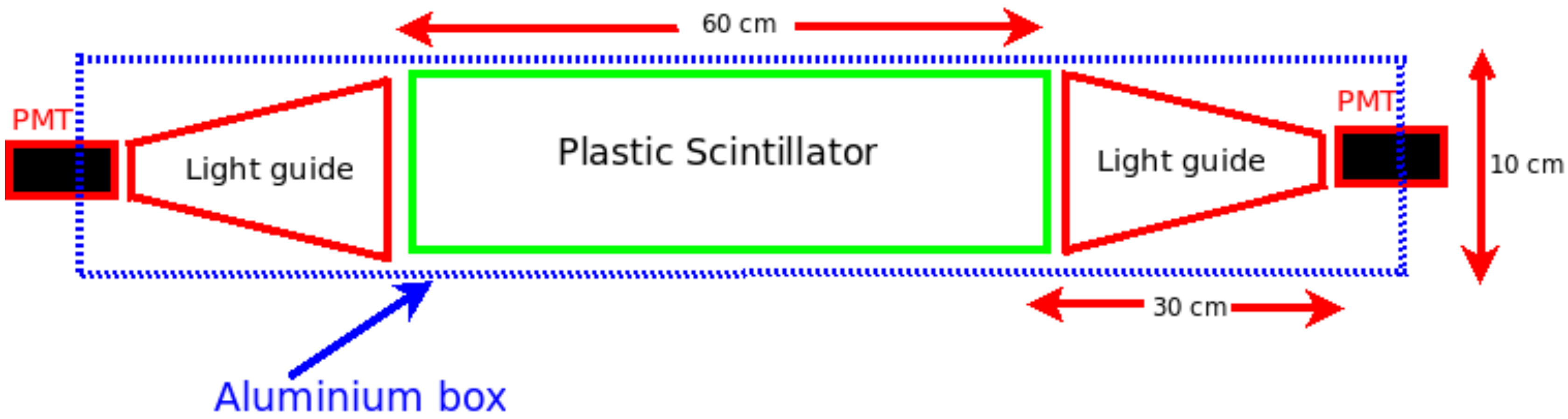
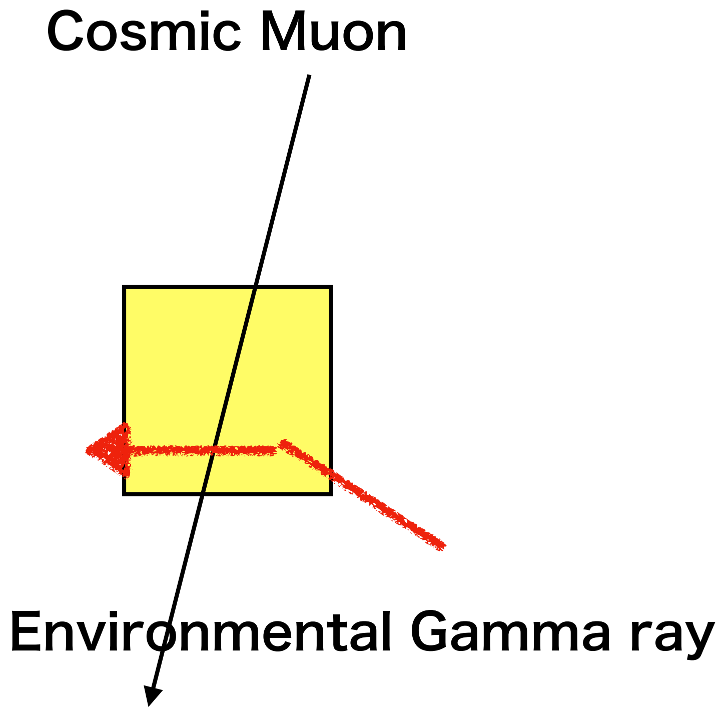


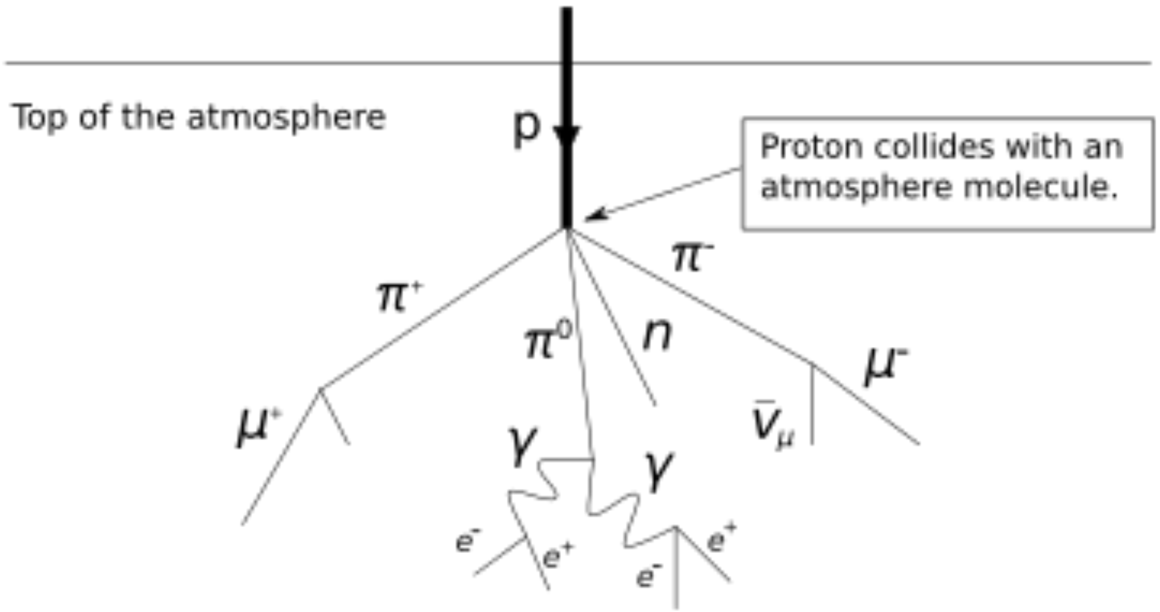
Figure 3.3: Schematic of a large-volume neutron detector.

Cosmic muons and environmental gamma rays cause "scintillation light".

Environmental gamma ray energy is less than ~3MeV. It causes Compton scattering in the plastic. The energy deposit will be less.

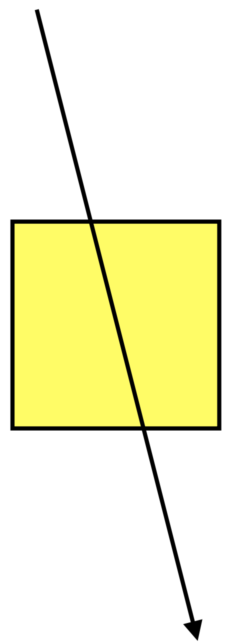


Cosmic ray



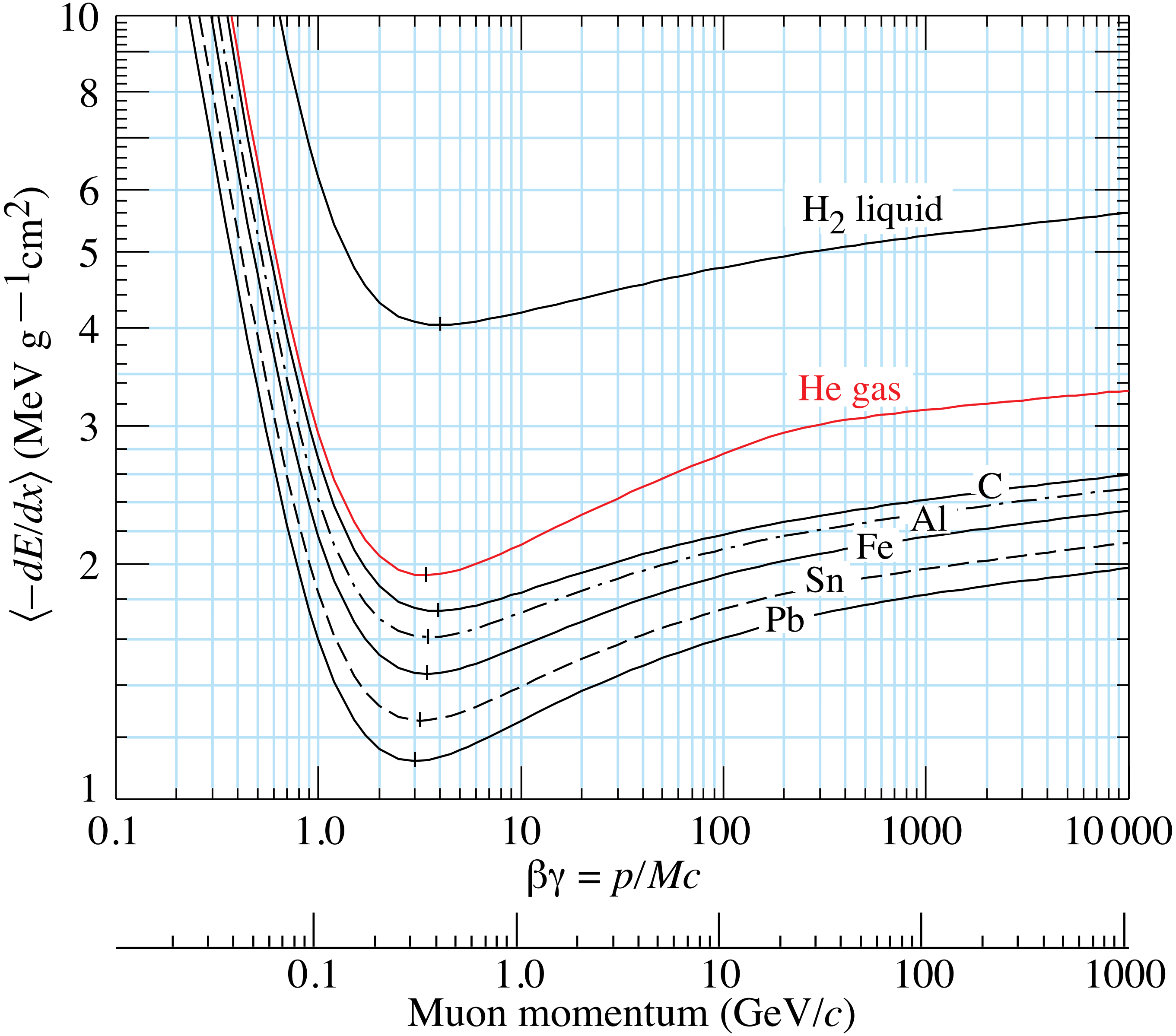
From Wikipedia, the free encyclopedia

Cosmic Muon



Cosmic muons are energetic (~GeV)
However, they pass through the plastic.
How much energy deposit is on the plastic?

Mean energy loss rate



about 2 MeV/cm

Particle Data Group Booklet

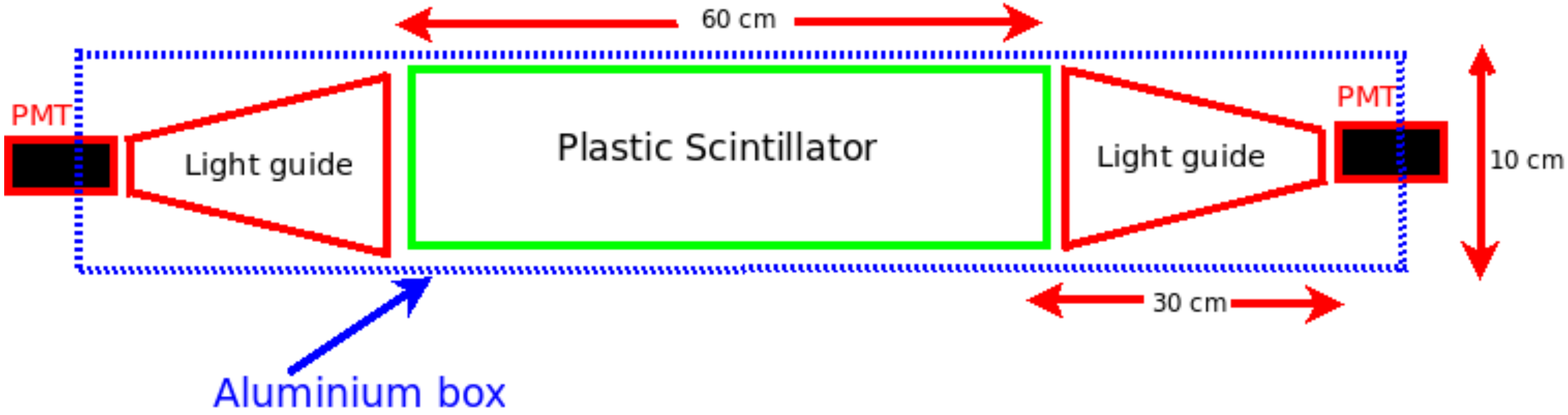


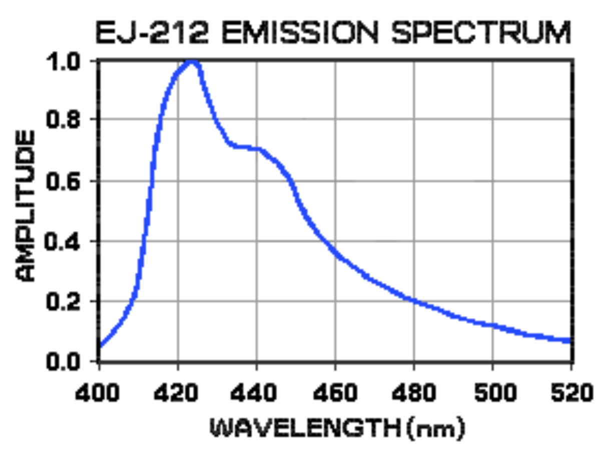
Figure 3.3: Schematic of a large-volume neutron detector.

Use one signal (PMT at window side) to select a set of signals.
Measure average pulse height of the set of signals at the other PMT.
High Voltage and threshold should be fixed to select the same signals.

Plastic scintillator

Physical and Scintillation Constants:

Light Output, % Anthracene	65%
Scintllation Efficiency, photons/1MeV e^-	10,000
Wavelength of max emission, nm	423
Rise Time, ns	0. 9
Decay Time, ns	2. 4
Pulse Width [FWHM], ns	2. 7
No. of H atoms per $cm^3 \times 10^{22}$	5. 23
No. of C atoms per $cm^3 \times 10^{22}$	4. 74
No. of electrons per $cm^3 \times 10^{23}$	3. 37
Density, g/cc	1. 03



Polymer Base:	Polyvinyltoluene
Refractive Index:	1. 58
Vapor Pressure:	Is vacuum-compatible
Coefficient of Linear Expansion:	7.8×10^{-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 Compatability:	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-212.

Figure 2: Typical gain characteristics