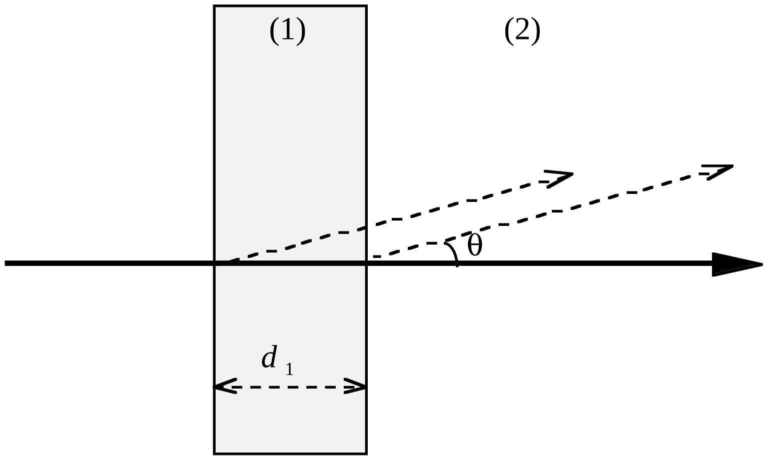
Transition Radiation Detectors

When a particle crosses between two regions of very different dielectric constant, transient currents and fields arise due to the changing polarisation of the media. This can lead to the emission of radiation known as transition radiation.

Consider a particle traversing a thin foil of material (1) in an environment of material (2).



If the γ of the particle is much greater than 1, then for radiation of frequency ω (much greater than the plasma frequency ω_p of the media) at an angle θ, the differential expression for the energy of transition radiation emitted, in terms of solid angle and frequency, is

$$\frac{d^2E_{TR}}{d\omega\, d\Omega} = \frac{\hbar\alpha}{\pi^2}\left(\frac{\theta}{\gamma^{-2}+\theta^2+\left(\omega_{p1}/\omega\right)^2} - \frac{\theta}{\gamma^{-2}+\theta^2+\left(\omega_{p2}/\omega\right)^2}\right)\times 4\sin(\varphi_1)$$

where $\varphi_1 =$ the phase angle, due to interference between the two boundaries

$$= \frac{d_1\omega/2c}{\gamma^{-2}+\theta^2+\left(\omega_{p1}/\omega\right)^2}$$

The result is radiation in the X-ray region, which is strongly forward peaked, with $\theta \approx 1/\gamma$.

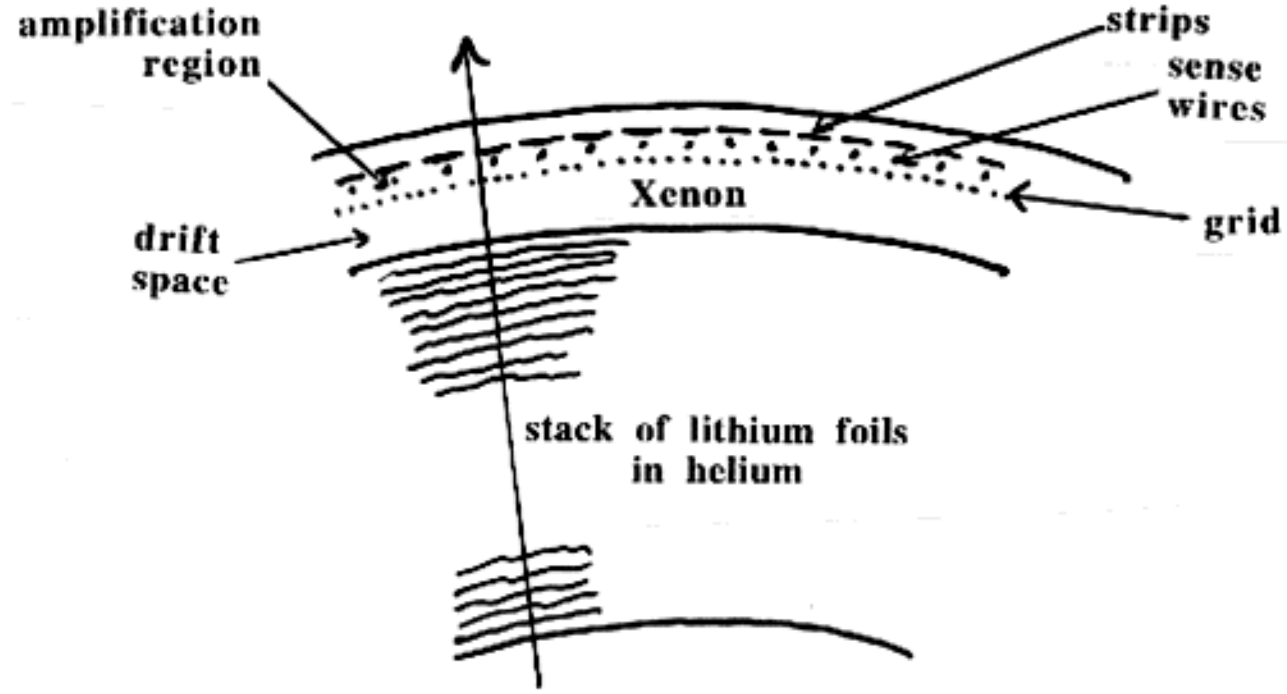
The total energy radiated (for $\omega_{p1} \gg \omega_{p2}$) is $$E_{TR} = \frac{2}{3}\alpha\hbar\omega_{p1}\gamma$$

where α is the fine structure constant, $\frac{1}{137}$. In other words, the amount of transition radiation is proportional to the γ of the particle, and so for most particle energies is only significant for electrons, with their very small mass.

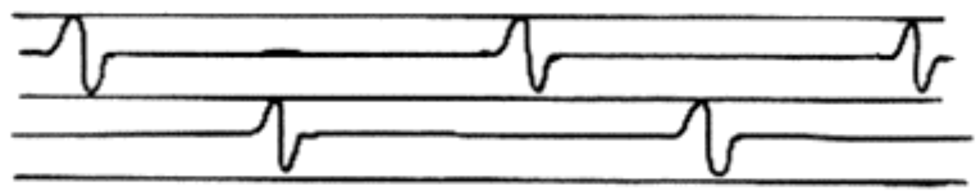
Practical Transition Radiation Detectors

A practical transition radiation detector consists of two parts:

- a stack of thin foils of radiator (to produce the TR X-rays)
- followed by a special multiwire proportional chamber (to detect them)



The radiator is made of a low atomic number material, to minimise absorption of the X-ray photons. Lithium foils in a helium atmosphere is ideal, for example 400 foils of thickness 40 microns, spaced 160 microns apart by corrugations on alternate foils.



Other materials such as polypropylene can also be used.

In contrast, the MWPC must be very efficient at absorbing X-rays, so it is normally filled with a high-*Z* gas such as Xenon. It must also be able to distinguish between the signal produced by an ordinary ionising particle and that due to transition radiation. For this reason, an asymmetric chamber is often used, as described below.

- *Any* charged particle passing through the transition radiation detector will produce ionisation uniformly across the multiwire proportional chamber (about 0.4 keV on average).
- A high energy electron also produces transition radiation photons, which are preferentially absorbed early in the drift region of the MWPC. (A 40 GeV electron will produce 2 to 3 detected photons on average, each of energy about 6 keV.) This then gives a **large** signal at a **late** time (due to the longer drift distance).