Cherenkov Detectors

A charged particle causes polarisation of any surrounding medium. When the particle is moving, the changing polarisation causes an electromagnetic wave to spread out. When the particle is travelling faster than the speed of light in that medium, constructive interference occurs, and coherent radiation is emitted. For a medium of refractive index n, the threshold velocity is therefore

$$\beta_{Th} = \frac{1}{n}$$

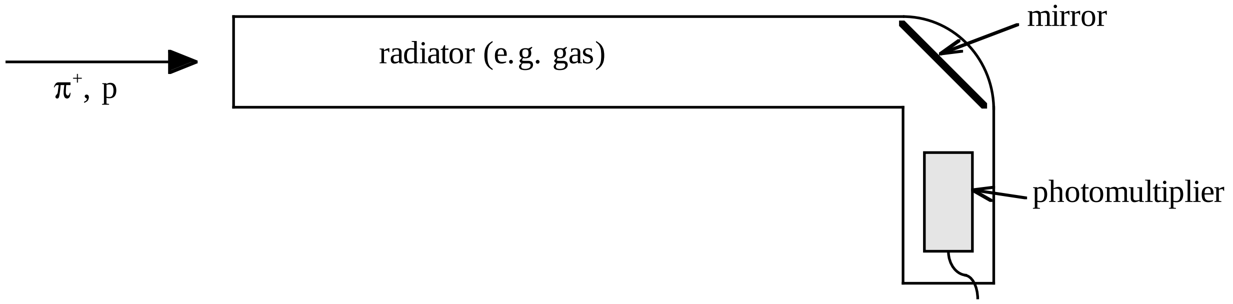
A cone of light is emitted from each point on the particle's track, of half angle θ_C given by

$$\theta_C = \cos^{-1}\left(\frac{1}{\beta n}\right)$$

and the number of photons emitted from a path of length L is proportional to $L \sin^2 \theta_C$.

Threshold Cherenkov Counters

Threshold Cherenkov Counters only give a signal for particles with $\beta > \beta_{Th}$, and are used for identifying particles, for example in a beam line where a mixture of particle types are produced with a common momentum. A typical geometry might be as shown in the figure.



Refractive indices vary in the range of 1 to 2.

Material	n	γ_{Th}
glass	1.46 to 1.75	1.22 to 1.37
scintillator	1.4 to 1.6	1.3 to 1.4
water	1.33	1.52
silica aerogel	$1 + (2 \text{ to } 10 \times 10^{-2})$	2 to 5
pentane (at S.T.P.)	$1 + 1.7 \times 10^{-3}$	17
carbon dioxide (at S.T.P.)	$1 + 4.3 \times 10^{-4}$	34
helium	$1 + 3.3 \times 10^{-5}$	123

Example materials, with their refractive index and threshold values of the relativistic γ factor

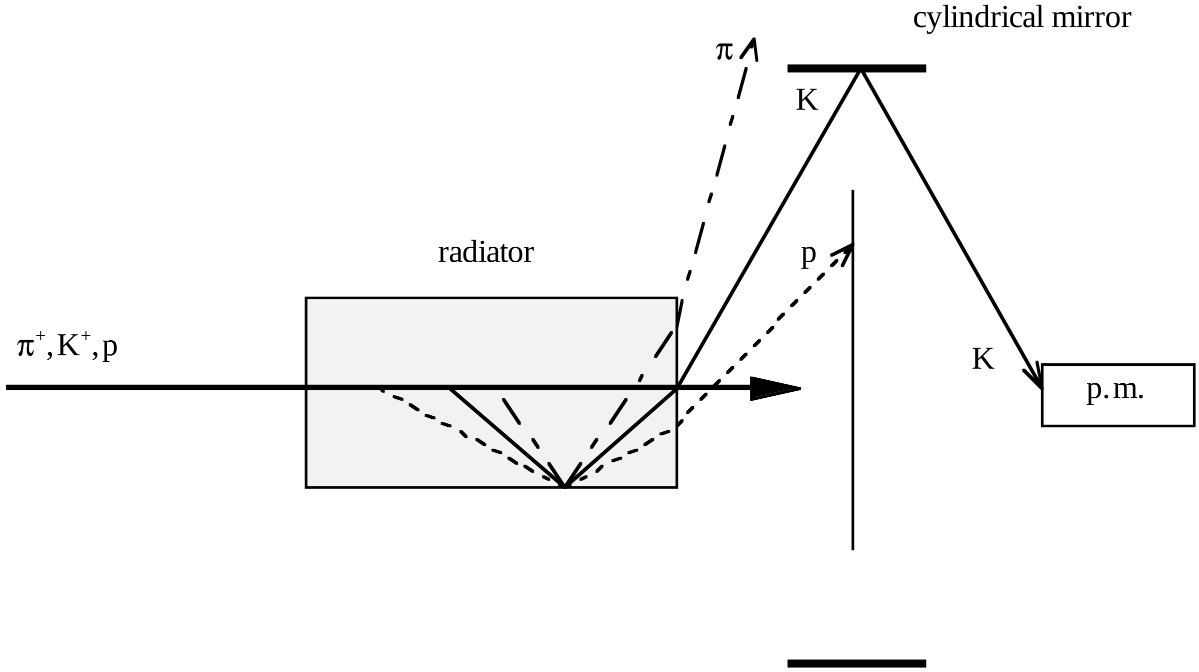
Note:
- For a gas, the refractive index can be tuned by varying the pressure P, according to

$$(n-1) = (n_0 - 1) \cdot \frac{P}{P_0}$$

- Aerogel is a very fine silica foam.

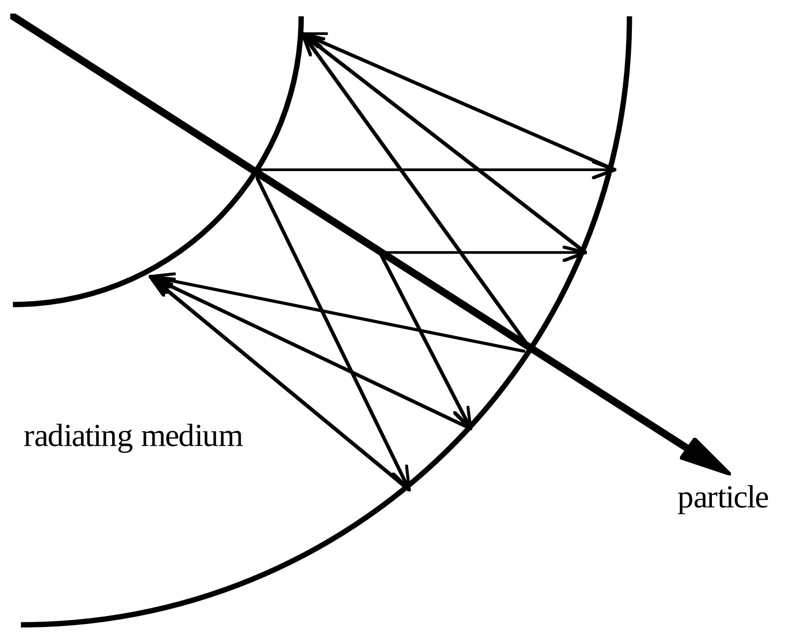
Differential Cherenkov Detectors

A Differential Cherenkov detector only gives a signal for particles with a certain range of β (corresponding, for a given momentum, to a given range in mass).



Ring Imaging Cherenkov (RICH or CRID)

A Ring Imaging Cherenkov (or Cherenkov Ring-Imaging Device – CRID) has a spherical mirror following the radiating material (normally a gas) which focuses the cone of light from all points along the track of a radiating particle, to form a ring. The radius of the ring depends on the half-angle of the cone θ_C, and therefore can be used to measure β for the particle.



There are a number of possible ways detect the focused Cherenkov light on the inner surface. An array of small photomultipliers can be used, but this results in rather poor resolution. More usually, a multiwire proportional chamber (or multi-step chamber, for higher gain) is used, with special gases added to the mixture to improve the detection of ultraviolet photons. Two such gases are TMAE – tetrakis (dimethylamine) ethylene – and TEA – triethylamine.

The figure below shows the detected photons from the superposition of fifty 10 GeV/c pions. (Note the additional signals at the centre of the ring from the ionisation due to the pions themselves.) About 27 useful hits arise from each pion.