12.4. Transition radiation detectors (TRD's)

It is evident from the discussion in the Passages of Particles Through Matter section (Sec. 10 of this *Review*) that transition radiation (TR) only becomes useful for particle detectors when the Lorentz factor $\gamma \gtrsim 10^3$. In practice, TRD's are used to provide e/π separation when $p \gtrsim 1$ GeV/c. (The momentum is usually measured elsewhere in the detector.) Since a soft x ray is radiated with about 1% probability per boundary crossing, practical detectors use radiators with several hundred interfaces, *e.g.* foils of lithium or plastic in a gas. Absorption inside the radiator and interference effects between interfaces are important [18,19].

A practical detector is composed of several similar modules, each consisting of a radiator and an x-ray detector. The radiator is made of foils or fibers of a low-Z material (for low absorption) in a low-Z gas such as helium. The x-ray detector is usually a wire chamber operated with a xenon-rich mixture in order to obtain a high conversion efficiency. As transition radiation is emitted at small angles, the chamber usually detects the sum of the ionization of the particle and of converted TR photons. The discrimination between electrons and pions can be based on the charges measured in each set, or on more sophisticated methods using pulse-shape analysis. The TRD in the DØ experiment serves as an example [20,21].

The major factor in the performance of a TRD is its overall length. Very roughly, the pion rejection factor for a detector with 90% electron efficiency is $10\,(L/20\ \text{cm})$, where L is the overall length of a radiator with foils. Radiators with fibers are easier to build, but generally provide a rejection factor which is at least a factor of two lower.

12.5. Silicon photodiodes and particle detectors

Silicon detectors are p-n junction diodes operated at reverse bias. This forms a sensitive region depleted of mobile charge and sets up an electric field that sweeps charge liberated by radiation to the electrodes. The thickness of the depleted region is

$$W = \sqrt{\frac{2\epsilon\,(V + V_{bi})}{ne}} = \sqrt{2\rho\mu\epsilon(V + V_{bi})}\ , \tag{12.6}$$

where $V =$ external bias voltage

$V_{bi} =$ "built-in" voltage (≈ 0.8 V for resistivities typically used in detectors

$n =$ doping concentration

$e =$ electron charge

$\epsilon =$ dielectric constant $= 11.9\ \epsilon_0 \approx 1$ pF/cm

$\rho =$ resistivity (typically 1–10 kΩ cm)

$\mu =$ charge carrier mobility

$= 1350\ \text{cm}^2\ \text{V}^{-1}\ \text{s}^{-1}$ for electrons (n-type material)

$= 450\ \text{cm}^2\ \text{V}^{-1}\ \text{s}^{-1}$ for holes (p-type material)

or