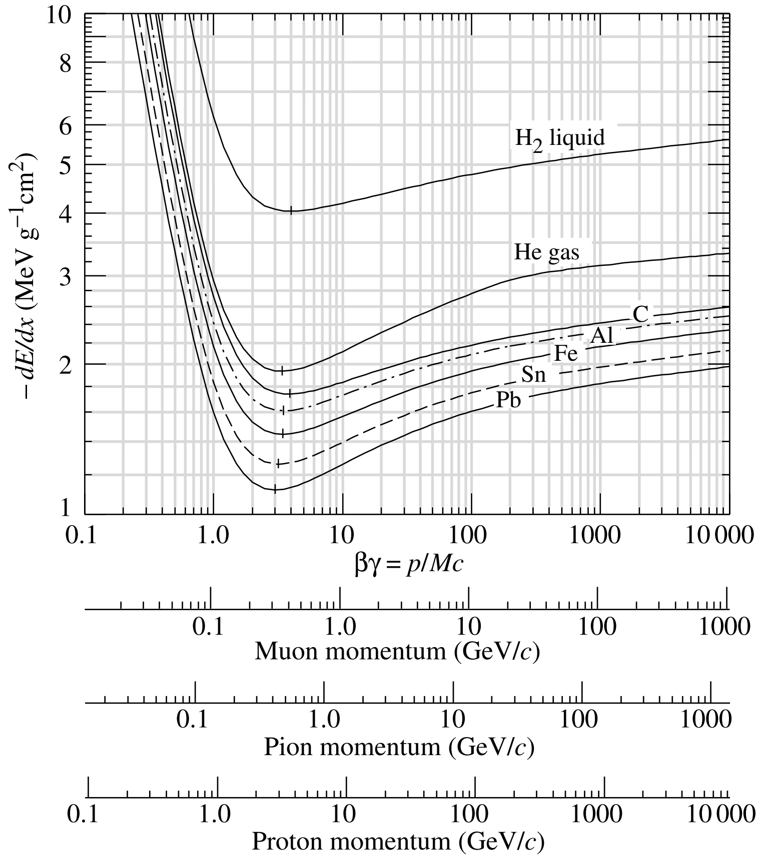

Figure 23.2: Energy loss rate in liquid (bubble chamber) hydrogen, gaseous helium, carbon, aluminum, tin, and lead.

bremsstrahlung is the dominant source of energy loss. This important case is discussed below. The contributions of various electron energy-loss processes in lead are shown in Fig. 24.4.

23.2.1. ***The density effect***: As the particle energy increases, its electric field flattens and extends, so that the distant-collision contribution to Eq. (23.1) increases as $\ln \beta\gamma$. However, real media become polarized, limiting the field extension and effectively truncating this part of the logarithmic rise [4,11–14]. At very high energies,

$$\delta/2 \to \ln(\hbar\omega_p/I) + \ln \beta\gamma - 1/2 \ , \tag{23.3}$$

where $\delta/2$ is the density effect correction introduced in Eq. (23.1) and $\hbar\omega_p$ is the plasma energy defined in Table 23.1. A comparison with Eq. (23.1) shows that $|dE/dx|$ then grows as $\ln \beta\gamma$ rather than $\ln \beta^2\gamma^2$, and that the mean excitation energy I is replaced by the plasma energy $\hbar\omega_p$. The stopping power as calculated with and without the density effect correction is shown in Fig. 23.1. Since the plasma frequency scales as the square