PARTICLE DETECTORS, ABSORBERS, AND RANGES (Cont'd)

Mean Electron Range in Lead, Copper, Carbon, and Liquid Hydrogen

Mean range of electrons in the continuous-slowing-down approximation, taking into account energy loss by collisions with atomic electrons and by bremsstrahlung; strong fluctuations are to be expected for individual tracks. This range is the total path length; the "practical range" — a common measure of straight-line penetration distance — is shorter because of multiple Coulomb scattering, which becomes increasingly important as the electron slows down. E.g., for a fast electron the rms projected angle due to multiple Coulomb scattering reaches 1 radian by the time the electron has slowed to 0.4 MeV in hydrogen, 1.5 MeV in carbon, 9 MeV in copper, and 24 MeV (off scale) in lead. Electron energy deposition and penetration probability vs. range are discussed by L. V. Spencer, "Energy Dissipation by Fast Electrons," NBS Monograph #1, 1959, and S. M. Seltzer, "Transmission of Electrons through Foils," NBSIR 74, 457 (1974). Electrons which have energy less than 0.2 MeV in Ar, 1.5 MeV in Cu, 3.5 MeV in Sn, and 5 MeV in Pb are likely to deposit 10% of their energy behind their starting plane. The practical range, R_p, is defined as that absorber thickness obtained by extrapolating to zero the linearly decreasing part of the curve of penetration probability vs. absorber thickness. Data for Al in the T range of the figure are available, and fit (to ~±10%) $R_p = AT[1-B/(1+CT)]$ mg cm^{-2} [a form suggested by K.-H. Weber, Nucl. Inst. Meth. 25, 261 (1964)], with A=0.55 mg cm^{-2} keV^{-1}, B = 0.9841, and C = 0.0030 keV^{-1}. At this penetration depth, 90 - 95% of the incident electrons have stopped. Data for other elements are sketchy, but suggest that higher-Z ($\lesssim$50) elements have $1 \lesssim R_p/R_p(\mathrm{Al}) \lesssim 1.4$ below ~10 keV, and $0.6 \lesssim R_p/R_p(\mathrm{Al}) \lesssim 1$ above ~100 keV. The "critical energy" (above which the energy loss due to bremsstrahlung exceeds that due to ionization, and showering becomes important) is 400 MeV for hydrogen, 100 MeV for carbon, 25 MeV for copper, and 10 MeV for lead. The mean positron range may differ from the mean electron range by several percent. See Berger and Seltzer, NASA SP-3012 (1964) and SP-3036, and P. Trower, UCRL-2426, Vol. III, Rev. (1966). 1 - 10 keV range was obtained by linear extrapolation; in this region the true range may actually lie above the curves.