The microtron

The operation principle of the microtron, another type of electron accelerator, is shown in figure 1a. Let us assume that a bunch of electrons of energy $E_0 = m_e + T$ is injected into the accelerating cavity (radiofrequency of period τ), where the electrons get the additional energy U before being deflected by the homogeneous magnetic field B. At the exit of the cavity the momentum is

$$p\,[\mathrm{GeV/c}] \simeq (E_0 + U)\,[\mathrm{GeV/c}] = 0.3\,B\,[\mathrm{T}]\,\rho\,[\mathrm{m}] \tag{1}$$

according to (*9.11*), and assuming highly relativistic electrons. The magnetic field is chosen in such a way that the revolution time t of the electrons in the first turn is an integer multiple μ of the radiofrequency period τ:

$$t = 2\pi\rho = \frac{2\pi E_0}{0.3B} + \overbrace{\frac{2\pi U}{0.3B}}^{\nu\tau} = \mu\tau \tag{2}$$

(with c = 1). Further acceleration occurs for the second and following turns if U is chosen such that the additional revolution time $\frac{2\pi U}{0.3B}$ per turn is also an integer multiple of τ. Obviously, $\mu > \nu$ and from (2) the energy acceleration per turn must be equal to

$$U = E_0 \left(\frac{1}{\frac{\mu}{\nu} - 1} \right). \tag{3}$$

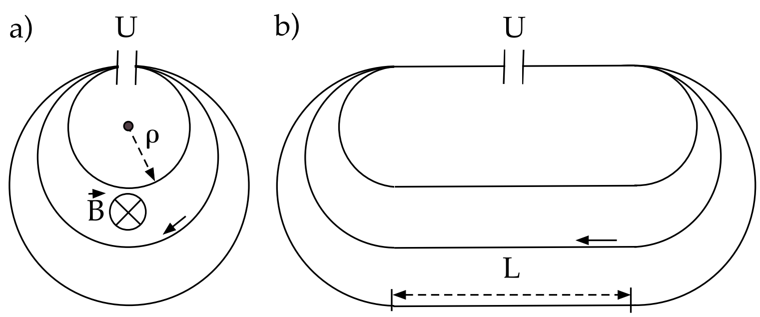

Figure 1: Principle of the classical (a) and of the racetrack microtrons (b).

After n turns the energy is

$$E_n = E_0 + nU = \left(\frac{\mu}{\nu} - 1 + n \right) U. \tag{4}$$

The required magnetic field is

$$B\,[\mathrm{T}] = \frac{2\pi U}{0.3\nu\tau} = \frac{2\pi E_0\,[\mathrm{GeV}]}{0.3\,(\mu - \nu)\tau\,[\mathrm{m}]}. \tag{5}$$

As a numerical example let us choose $\mu = 2$, $\nu = 1$, E_0 = 511 keV and the radiofrequency $1/\tau$ = 3 GHz. Then B = 0.1 T (using the unit conversion 1 s = 3 $\times$ 10^8 m, see (*1.17*)).

Thus an extraction energy of 20 MeV (n = 39 turns) would correspond to a final radius of 0.66 m.

The classical microtron is often replaced by the **racetrack** microtron (figure 1b). Following the previous derivation it is easy to show that the denominator in (3) has to be replaced by $\frac{\mu}{\nu} - 1 - \frac{2L}{\nu\tau}$, where L is the length of the straight section. Hence the energy gain U per turn can be boosted by increasing L. The straight section also makes room for an injector LINAC to increase the initial energy E_0. Figure 2 shows a photograph of the MAMI-B racetrack microtron of the University of Mainz.

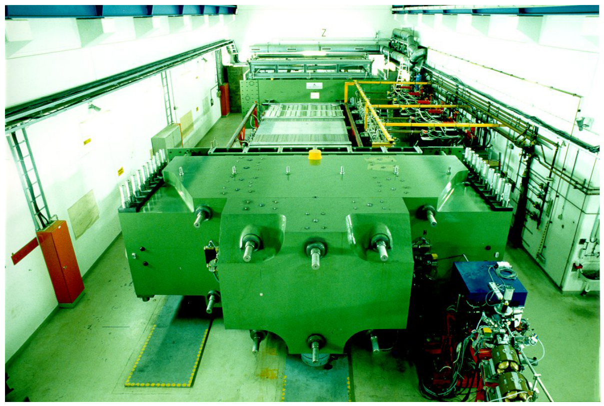

Figure 2: The racetrack microtron MAMI-B delivers electron beams of 855 MeV (courtesy of the University of Mainz).