The new μE4 separator

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The deflection angles ϕ_E and ϕ_B by the electric field E and the magnetic field B of an idealized separator are given by (see Sec. 1 and [1])

$$\phi_E \approx \frac{e \cdot l \cdot E}{p \cdot v} = \eta_E \cdot \frac{E}{\beta p} \quad (1)$$

$$\phi_B \approx \frac{e \cdot l \cdot B}{p} = \eta_B \cdot \frac{B}{p}. \quad (2)$$

Here, e is the electric charge, l the effective length of the field ($\sim$ 0.8 m for `SEP61` in μE4), v is the velocity of the particle, p the momentum, and $\beta \equiv v/c$. The electric field $E = V/d$ is defined by the voltage difference V between the electrodes and the gap $d = 18$ cm. The parameters $\eta_{E,B}$ have for $l^E = 0.803$ m and $l^B = 0.824$ m values of

$$\eta_E = 0.803 \, \frac{\text{mrad (MeV/c)}}{\text{kV/m}} \quad (3)$$

$$\eta_B = 24.70 \, \frac{\text{mrad (MeV/c)}}{\text{G}}. \quad (4)$$

The total deflection angle ϕ_{tot} of a particle is then simply given by

$$\phi_{tot} = \phi_B - \phi_E. \quad (5)$$

The maximum fields of the new μE4 separator will be 22.22 kV/cm (400 kV voltage difference between the electrodes, $\pm$ 200 kV at the electrodes) and about 415 G.
The following table gives a short overview on deflecting angles for muons and positrons at 28 MeV/c and 40 MeV/c ($\Delta\phi$ is the angle of muon spin precession):

p [MeV/c]	particle	β	E [kV/m]	B [G]	ϕ_B [mr]	ϕ_E [mr]	ϕ_{tot} [mr]	$\Delta\phi$ [^{o}]
28	μ	0.2562	1666	210	185	185	0	10.6
28	e	1	1666	210	185	47	138	
28	μ	0.2562	2220	281	248	248	0	14.2
28	e	1	2220	281	248	63	185	
40	μ	0.354	2220	204	126	126	0	7.2
40	e	1	2220	204	126	44	82	

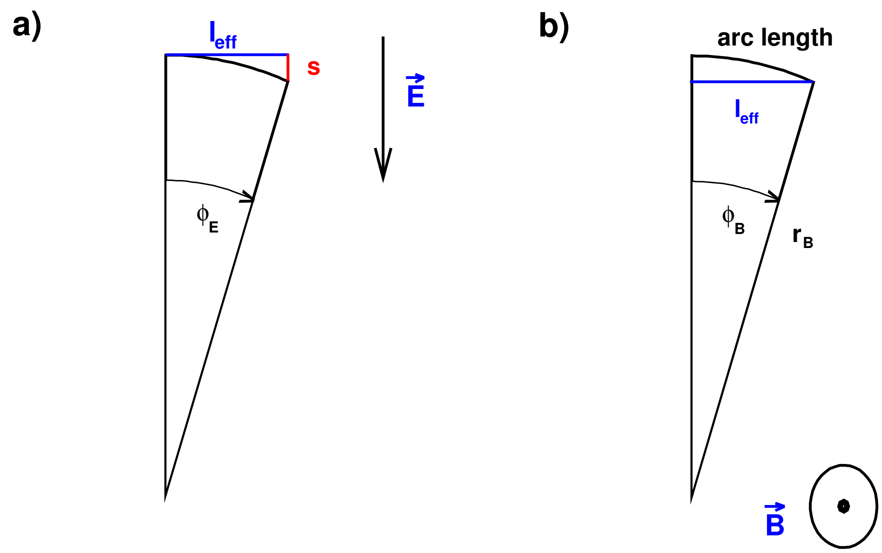

Figure 1: Illustration of deflection angles in homogeneous a) electric and b), magnetic fields of length l_{eff}.

1 Deflection angles of electric and magnetic fields

In this section we present the derivation of deflection angles in electric and magnetic fields. Figure 1 illustrates the deflection of charged particles in fields of effective lengths l_{eff}. For the electric field the particle moves on a parabola, and the deflection s in the electric field is given by

$$\begin{aligned} s &= \frac{1}{2}at^2 \\ &= \frac{1}{2}\frac{e \cdot E}{m} \cdot \frac{l_{eff}^2}{v^2}. \end{aligned} \tag{6}$$

The slope of the particles trajectory is then given by

$$\begin{aligned} \tan\phi_E &= \frac{ds}{dl} = 2 \cdot \frac{1}{2}\frac{e \cdot E}{m} \cdot \frac{l_{eff}}{v^2} \\ &= e \cdot l_{eff} \cdot \frac{E}{p \cdot v} \qquad (7) \\ &\Longrightarrow (\phi_E \ll 1) \\ \phi_E &\cong \frac{e \cdot l_{eff}}{c} \cdot \frac{E}{\beta \cdot p} = \eta_E \cdot \frac{E}{\beta \cdot p}. \qquad (8) \end{aligned}$$

For the deflection in the magnetic field one obtains from Fig. 1b):

$$\begin{aligned} \sin\phi_B &= \frac{l_{eff}}{r_B} \\ &= e \cdot l_{eff} \cdot \frac{B}{p} \qquad (9) \\ &\Longrightarrow (\phi_B \ll 1) \\ \phi_B &\cong e \cdot l_{eff} \cdot \frac{B}{p} = \eta_B \cdot \frac{B}{p}. \qquad (10) \end{aligned}$$

References

[1] R. Frosch, *Beam Optics with Electrostatic Separators*, **TM-11-95-01**, PSI (1995).