# New $\mu$E4: vertical beam shift at the end of the beamline due to horizontal tilting of `WSX`

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Considering the beam line vertically as a simple drift the total vertical shift $\Delta y$ of the beam for an initial vertical deflection $\phi_{tot}$ due to the two solenoids `WSX61` and `WSX62` is given by

$$\Delta y = \phi_{tot} \cdot L = (\phi_{WSX61} + \phi_{WSX62}) \cdot L, \tag{1}$$

where $L$ is the total length of the beam line, and $\phi_{WSX61}$ and $\phi_{WSX62}$ are the vertical deflection angles of `WSX61` and `WSX62` , respectively.

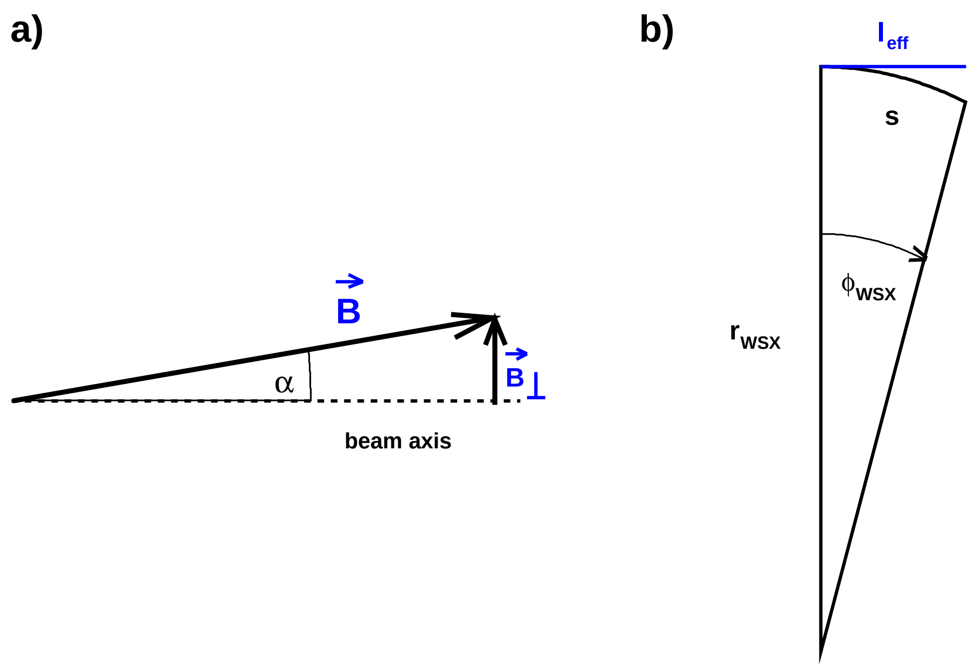


Figure 1: a) Magnetic field component $B_\perp$ due to horizontal tilting of `WSX` by an angle $\alpha$. $B_\perp$ causes a vertical deflection (out of the plane of view) of the beam. b) Vertical deflection angle $\phi_{WSX}$ and radius $r_{WSX}$ of the central trajectory. For small $\phi_{WSX}$ the arc length $s$ equals to good approximation the effective length $l_{eff}$ of the `WSX` solenoid.

The deflection angle $\phi_{WSX}$ is given by

$$\phi_{WSX} = \frac{s}{r_{WSX}} \simeq \frac{l_{eff}}{r_{WSX}}, \tag{2}$$

see Fig. 1. The radius $r_{WSX}$ of the central trajectory is determined by the particle momentum $p$ and the magnetic field $B_\perp$:

$$r_{WSX} = \frac{p}{e \cdot B_\perp} \simeq \frac{p}{e \cdot \alpha \cdot B}. \tag{3}$$

Inserting Eq. (3) in (2) and Eq. (2) in (1) yields finally for the vertical deflection of the central trajectory at the end of the beam line

$$\Delta y = (B_{WSX61} + B_{WSX62}) \times \frac{e \cdot \alpha \cdot l_{eff} \cdot L}{p} \tag{4}$$

$$= 0.03 \times (B_{WSX61} + B_{WSX62}) \times \frac{\alpha \cdot l_{eff} \cdot L}{p} \tag{5}$$

$$[B] = \mathrm{kG},\ [\alpha] = \mathrm{mrad},\ [l] = \mathrm{m},\ [p] = \mathrm{MeV/c}.$$

The following table gives an overview on the total bending angle $\phi_{tot} = (\phi_{WSX61} + \phi_{WSX62})$ of the two `WSX` and the vertical shift $\Delta y$ of the beam at the channel end point for different tilt angles $\alpha$. The effective length of each `WSX` solenoid is 0.666 m, $B_{WSX61} = 2.6$ kG, $B_{WSX62} = 1.35$ kG, $p = 28$ MeV/c and $L = 18$ m.

| $\alpha$ | $\phi_{tot} = (\phi_{WSX61} + \phi_{WSX62})$ | $\Delta y$ |
|---|---|---|
| 0.1 mrad (= 0.1 mm / 1m) | 0.28 mrad | 0.005 m |
| 0.2 mrad (= 0.2 mm / 1m) | 0.56 mrad | 0.010 m |
| 0.5 mrad (= 0.5 mm / 1m) | 1.41 mrad | 0.025 m |
| 1.0 mrad (= 1.0 mm / 1m) | 2.82 mrad | 0.051 m |

The deviation of the beam center should be less than 5 mm in the area which requires the `WSX` axis to coincide with the beam axis by better than 0.1 mrad ! The vertical beam steering proposed by D. George (current flowing asymmetrically through the first three `QSM`'s) possibly can help if there are any problems with the adjustment of `WSX`. The vertical deflection angle is estimated to 6.5 mrad at 10 A additional current in two of the four `QSM` coils. However, since we do not know how the steering with the `QSM`'s will work it's better to try to **adjust horizontally the `WSX` axis to $\leq$ 0.1 mrad with respect to the beam axis.**