



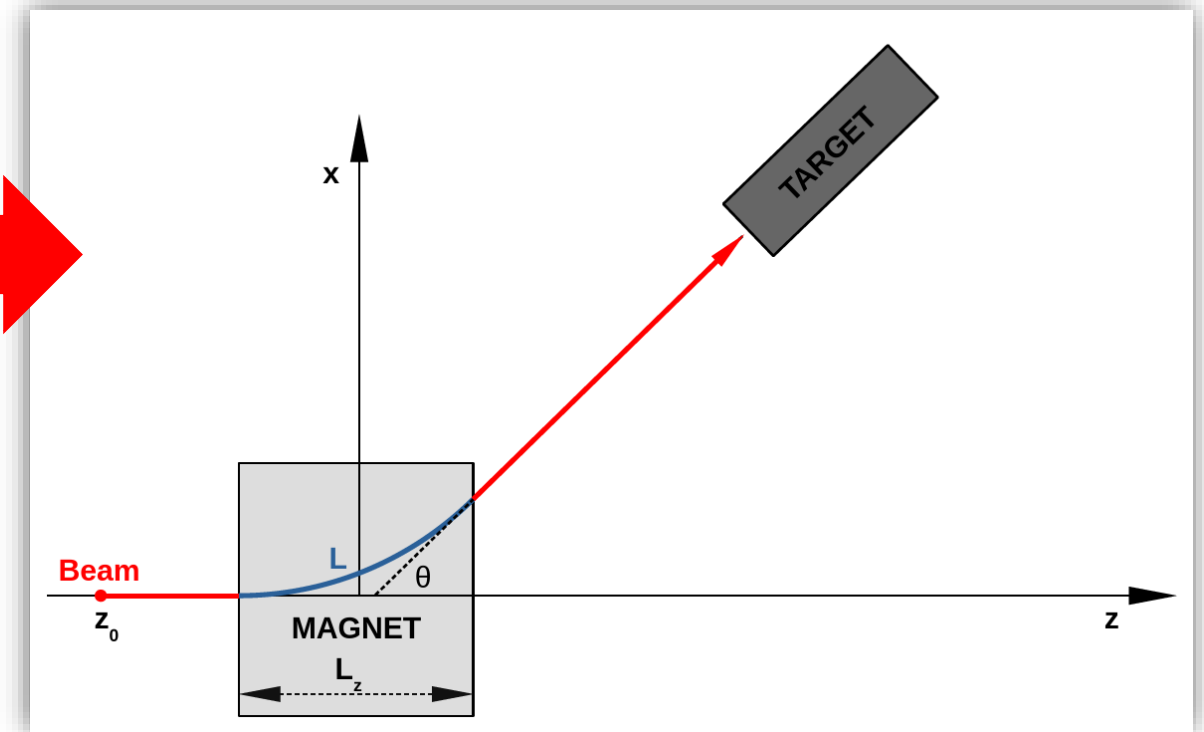
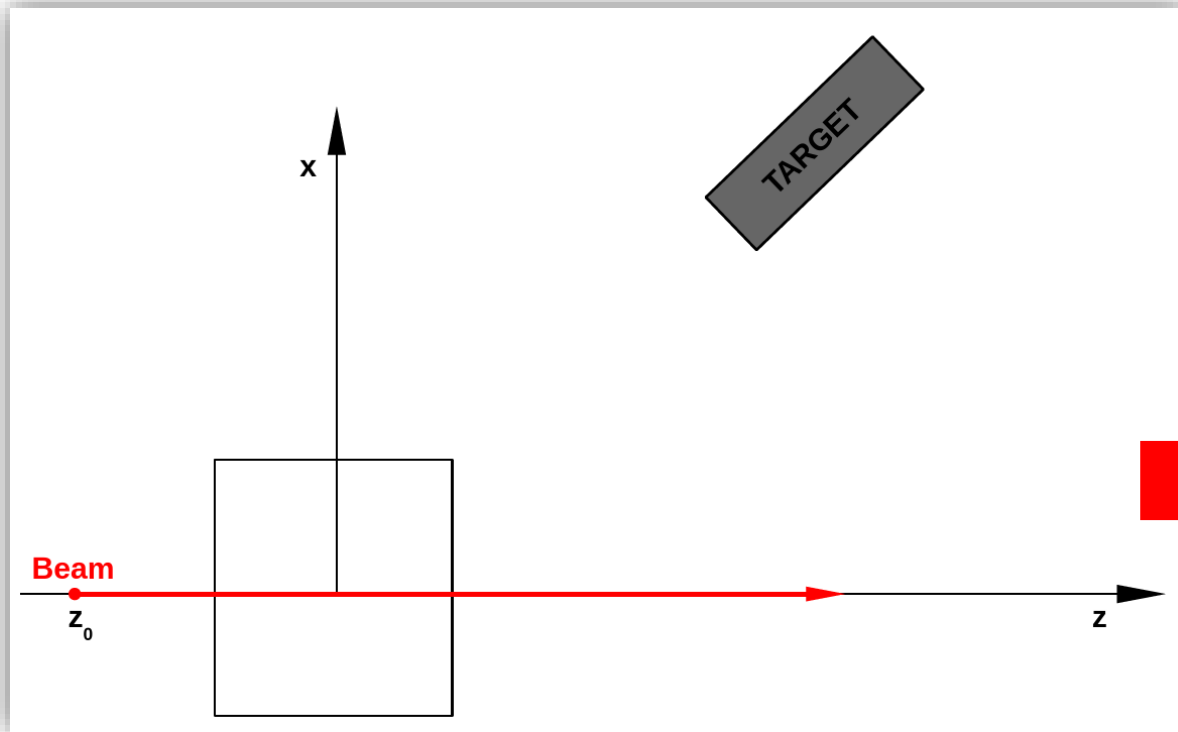
Exercise: Magnetic Field

Aim of the exercise:

- Define a dipole field which deviates the beam on a target
- Plot the field
- Visualize the effect of the field on the beam trajectory

Goal of the exercise

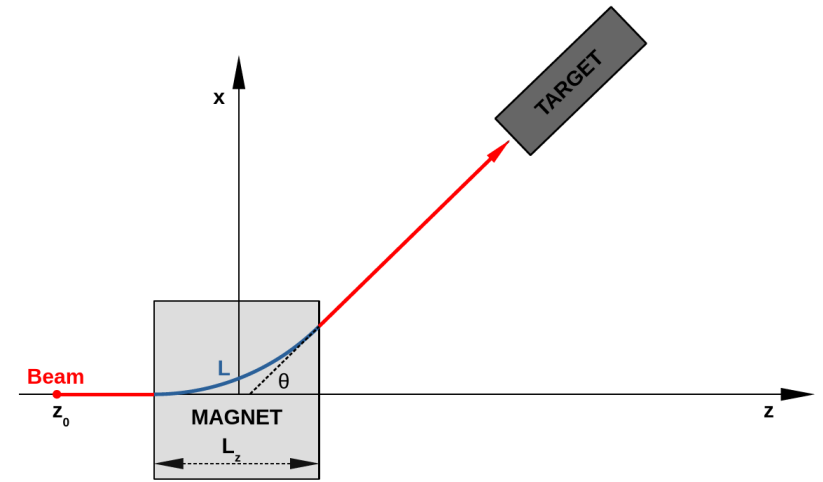
- Introduce a dipole field in order to deflect a given beam on a pre-defined target



- Proton pencil beam with **600 MeV/c**
- Starts at $z_0 = -50$ cm, in positive **z-direction**

Steps

- The beam, regions and scoring is pre-defined
 - Note that all regions except the target are set to VACUUM (including the magnet)



- Exercise steps:

1. Activate a magnetic field in the pre-defined region called **MAGNET** (**ASSIGNMA** card)
2. Introduce a **MGNFIELD** card and define a B field such that:
 - a. the beam is deflected in the **x-z plane** as illustrated in the figure (hint: the B field direction can be determined from the Lorentz force).
 - b. the deflection angle θ is **25 deg**; use the formula on slide 5 to determine the required $|B|$. Note that the magnet is **$L_z=50$ cm** long in z-direction.
3. Verify that the field is correctly activated by plotting the field intensity and field vectors:
 - a. see lecture slides for instructions how to plot a field
 - b. make sure to chose an appropriate plotting plane which contains the field vectors
4. Run one cycle (1 primary) and plot the particle fluence in the x-z plane
 - a. use the *pre-defined* **USRBIN** scoring in the Plot tab of Flair

For simplicity, let's keep the default transport settings

Did you manage to hit the target?

Lorentz force

- Use following expression to determine which B field component needs to be set on the **MGNFIELD** card in order to deflect the beam on the target:

$$\begin{pmatrix} F_x \\ F_y \\ F_z \end{pmatrix} = q \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix} \times \begin{pmatrix} B_x \\ B_y \\ B_z \end{pmatrix} = q \begin{pmatrix} v_y B_z - v_z B_y \\ v_z B_x - v_x B_z \\ v_x B_y - v_y B_x \end{pmatrix}$$

- (F_x, F_y, F_z) = Lorentz force
- q = Particle charge
- (v_x, v_y, v_z) = Particle velocity
- (B_x, B_y, B_z) = Magnetic field (magnetic flux density) components

Required $|B|$

- Use the following expression to determine the required $|B|$ in order to deviate the beam on the target:

$$\frac{p \text{ [GeV/c]}}{0.299792 Q \text{ [e]}} = \frac{|B| \text{ [T]} L_z \text{ [m]}}{\sin \theta}$$

- p = Particle momentum in GeV/c
- Q = Particle charge (as multiple of elementary charges)
- $|B| = \sqrt{B_x^2 + B_y^2 + B_z^2}$ in Tesla
- L_z = Length of the magnetic field in z-direction (i.e. in the original beam direction)
- θ = Deflection angle in rad

Note: this formula can be simply derived from the Lorentz force and applies for a homogenous dipole field with $L_z < R$, where R is the bending radius.

