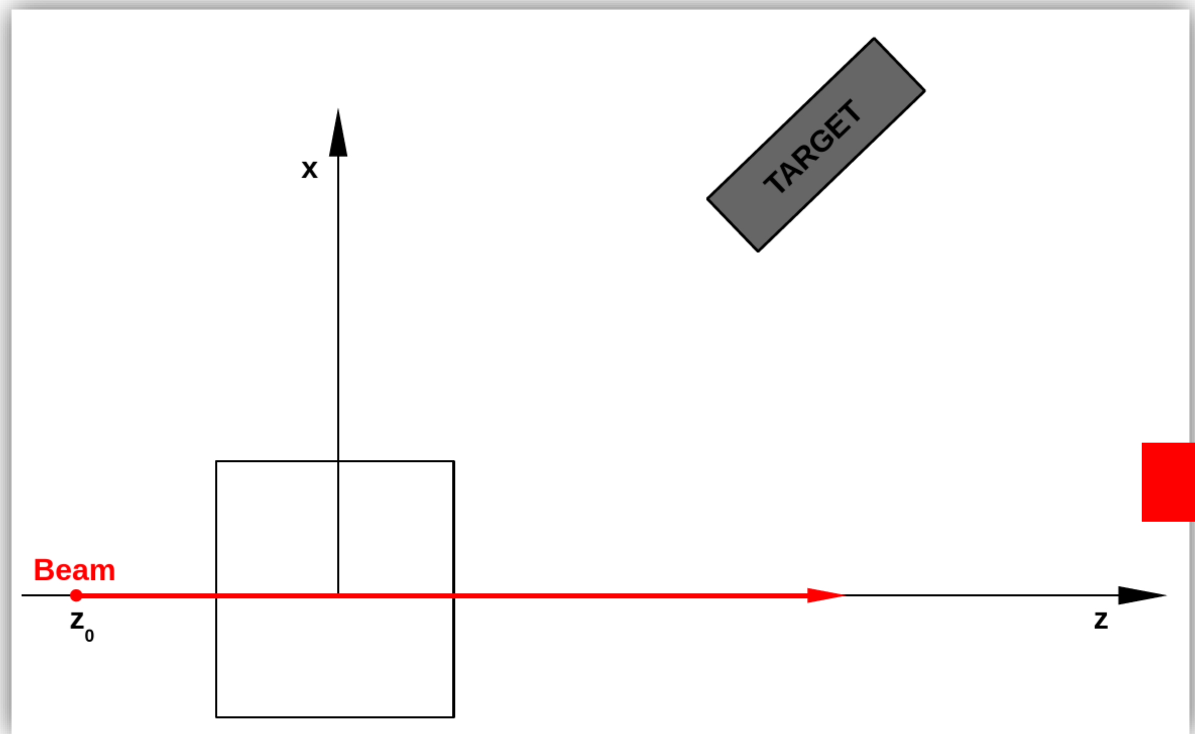
Exercise: Magnetic Field

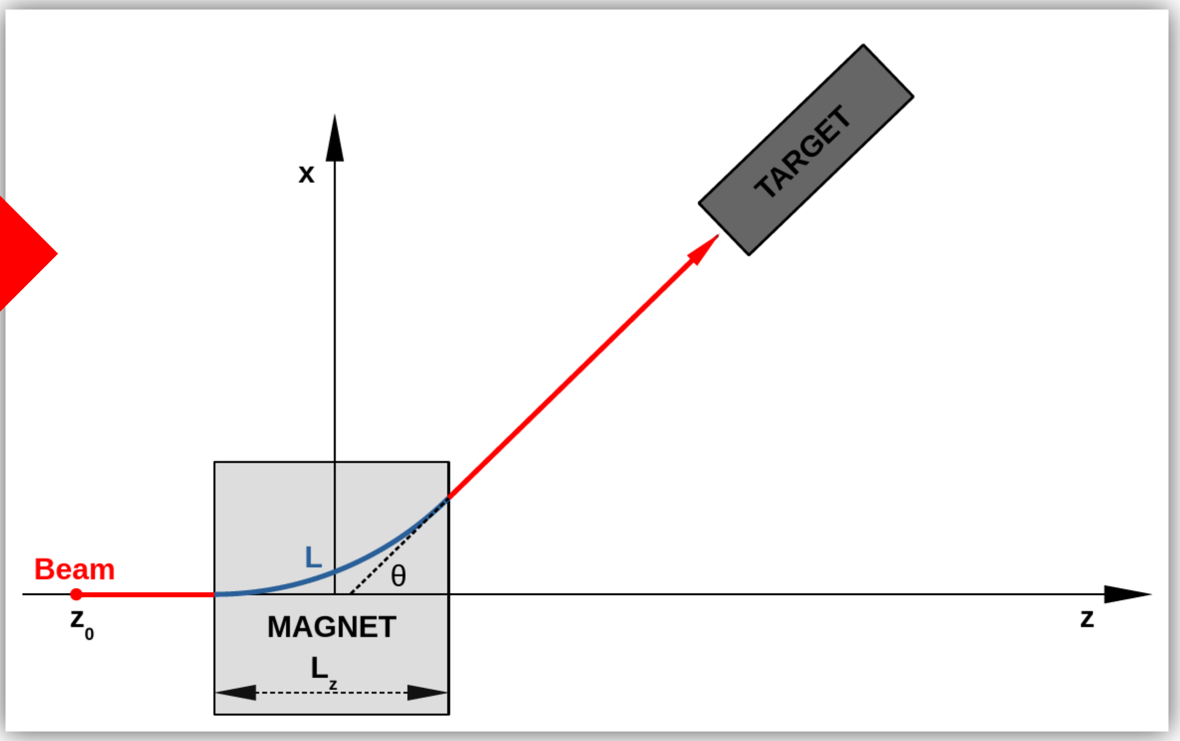
Aim of the exercise:

- 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

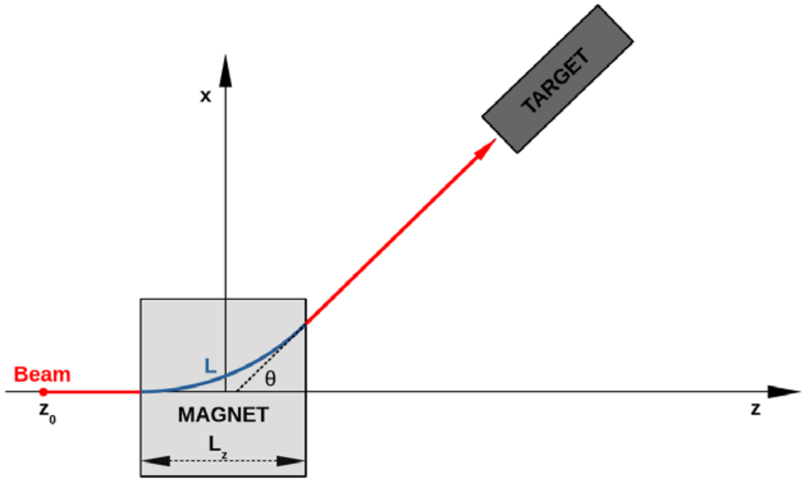
- Introduce a dipole field in order to deflect a given beam on a pre-defined target





- Proton pencil beam with **600 MeV/c**
- Starts at $\mathbf{z_0 = -50\ cm}$, 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:

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

  - 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.

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