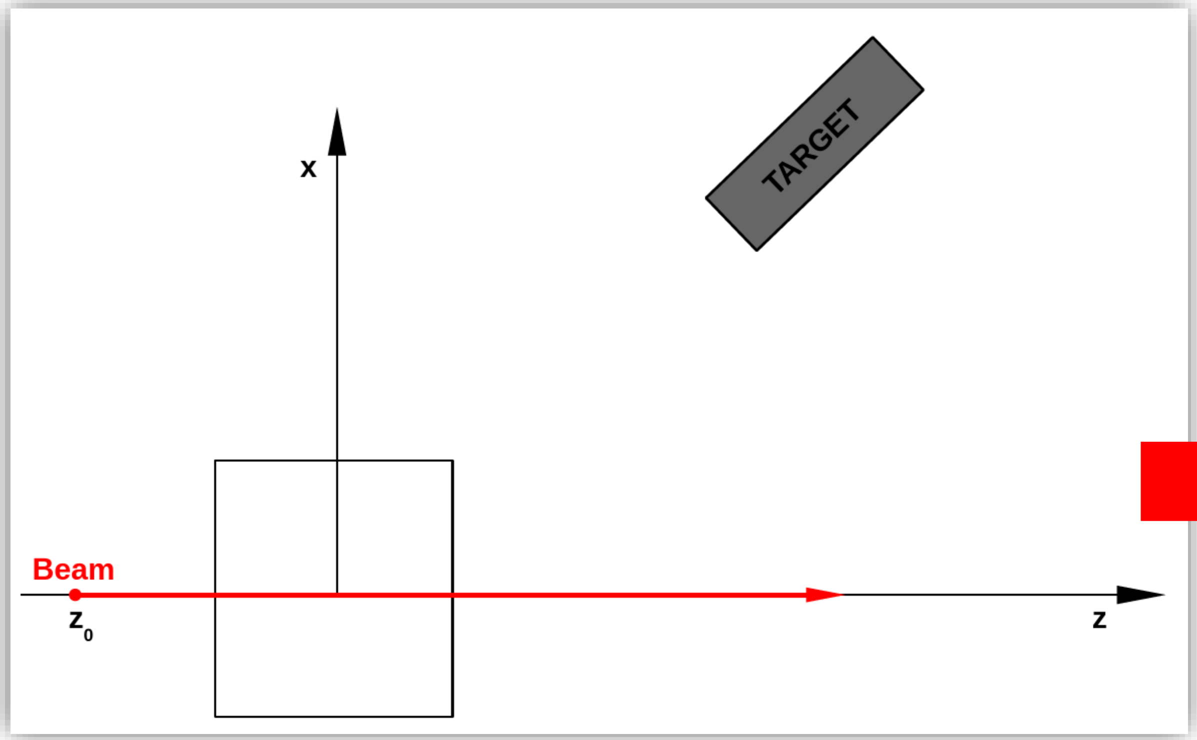
Exercise: Magnetic Field

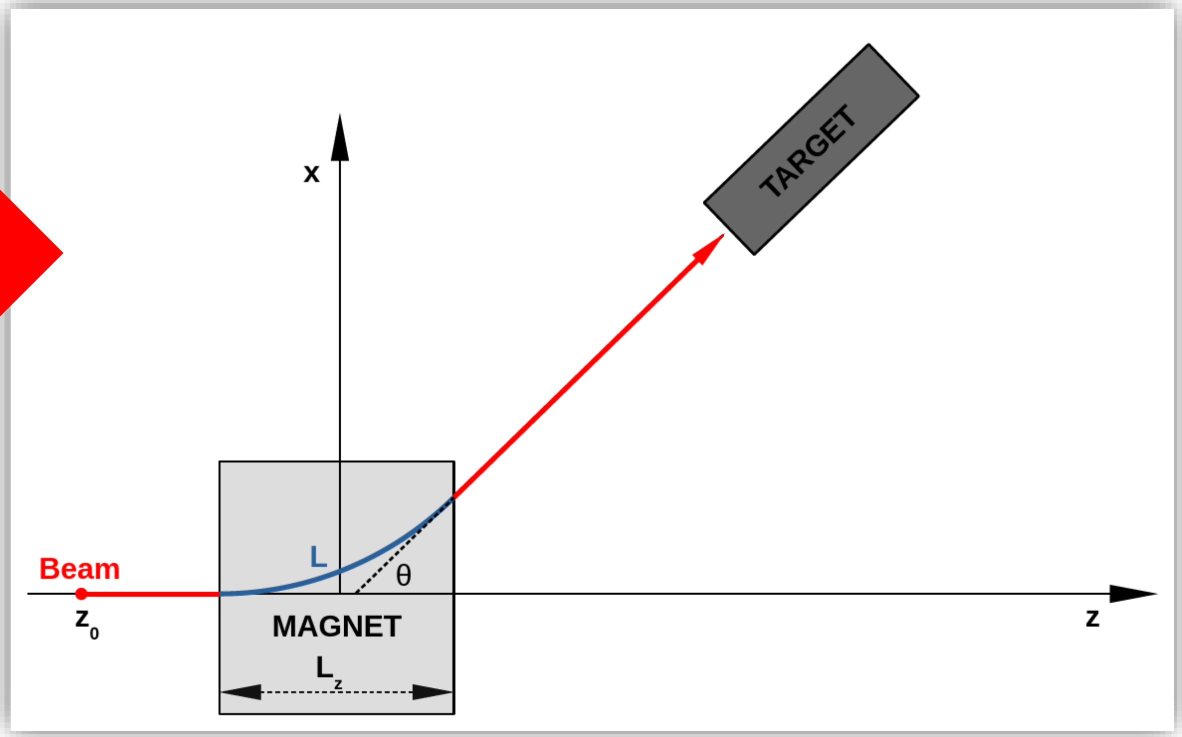
Aim of the exercise:

- 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

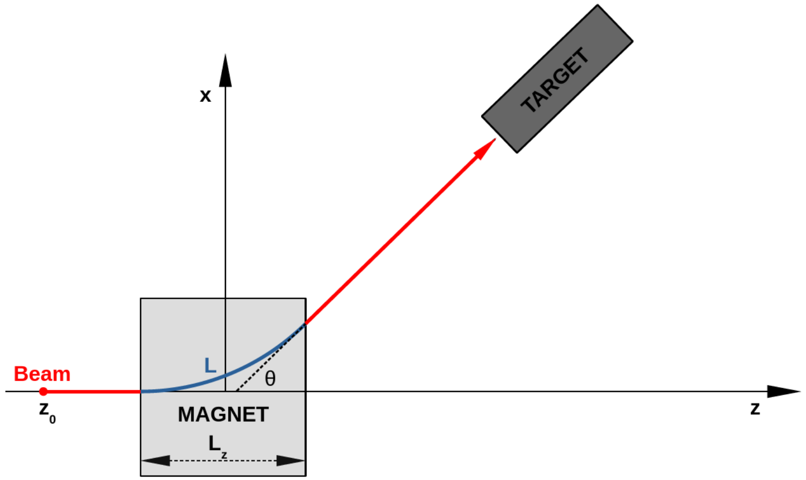




- Proton pencil beam with **600 MeV/c**
- Starts at $\mathbf{z_0 = -50}$ **cm**, in positive **z-direction**

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 $\mathbf{L_z}$**=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*|

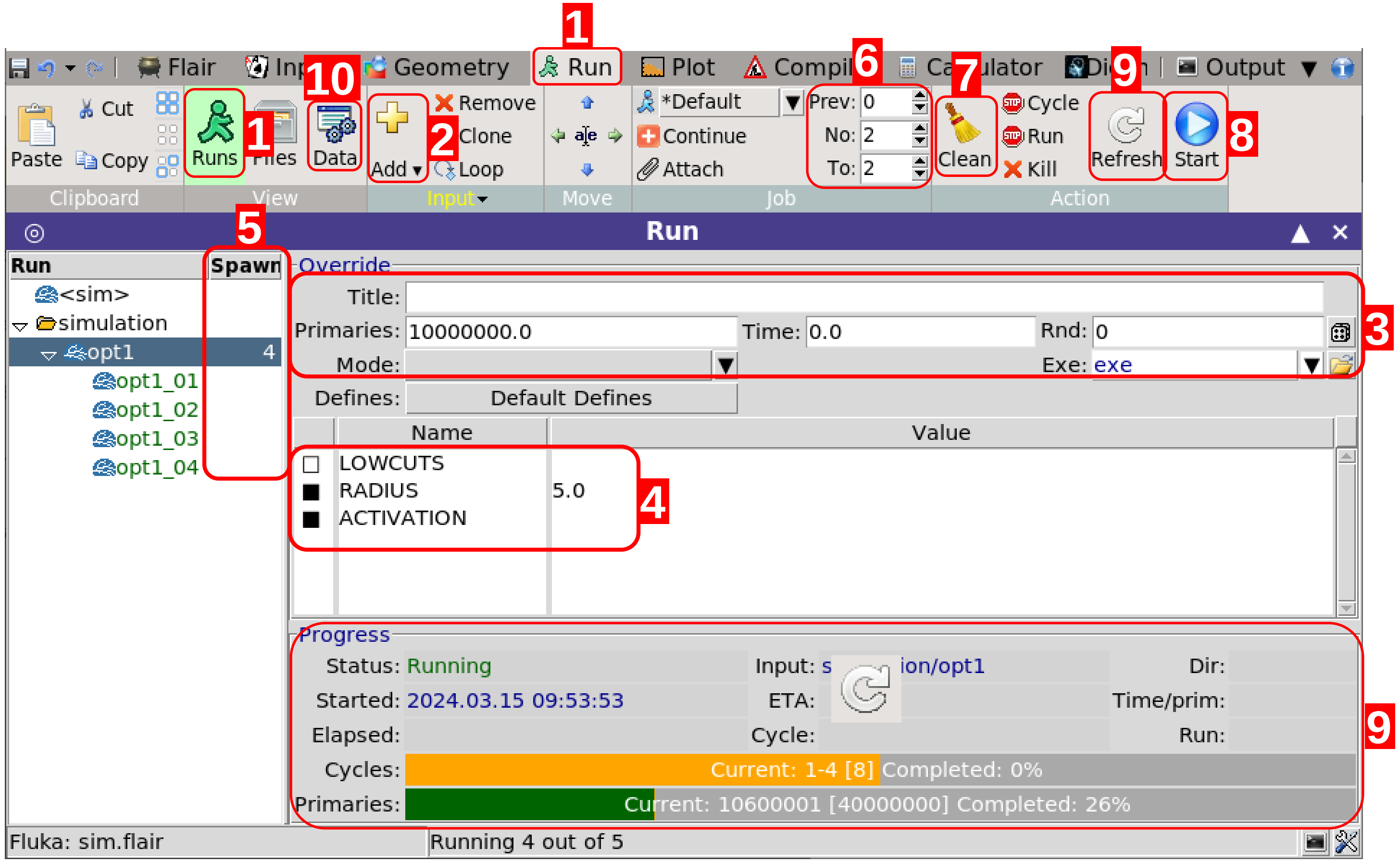
- Use the following expression to determine the required |*B*| in order to deviate the beam on the target:

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

- 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.

Flair Cheat Sheet



Remember!

- You can **STOP** or **KILL** the run.
- You can edit your input while the simulation runs.

!!! WARNING !!!

- Mind the memory and CPU usage of your simulations!

1. Go to the ***Run*** **tab**, select ***Runs*** **view**.
2. Add **new folder** + Add **new run**.
3. Override the input run info:
   - **Number of primaries**
   - Title / Max. time per cycle / Seed / Exec.
4. Override/Define variables.
5. **Recommended:** Increase number of spawns
6. Set number of cycles per spawn
   - Recommend at least 5 cycles in total.
   - `num_cycles_tot = num_cycles_per_spawn * num_spawns`

7. ***Clean*** run files after change to input or run settings.
8. Click ***Start*** to launch the simulations.
9. Monitor the progress. Click ***Refresh*** to force update.
10. After all cycles end:
    - Go to the ***Data*** ( ) tab.
    - Click ***Process*** ( ) to combine all cycles and create simulation data files.
    - You may need to refresh ( ) and scan ( ) if detectors are missing.

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