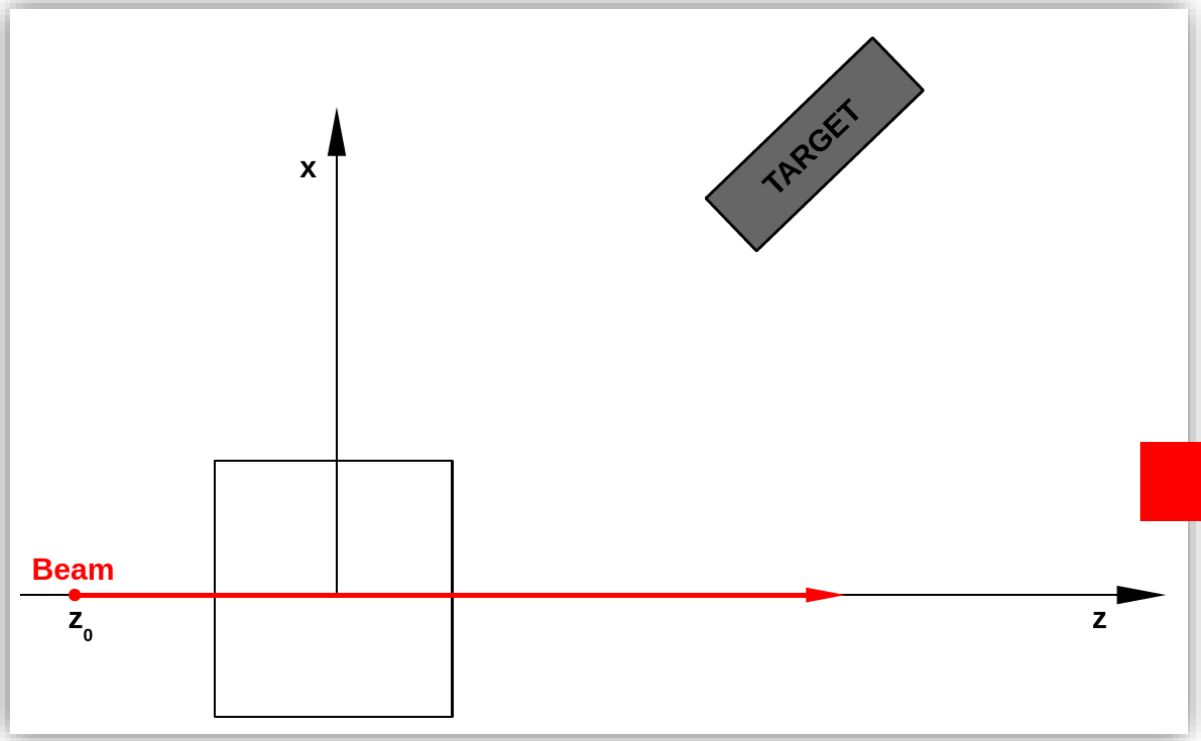
Exercise: Magnetic Field - Solution

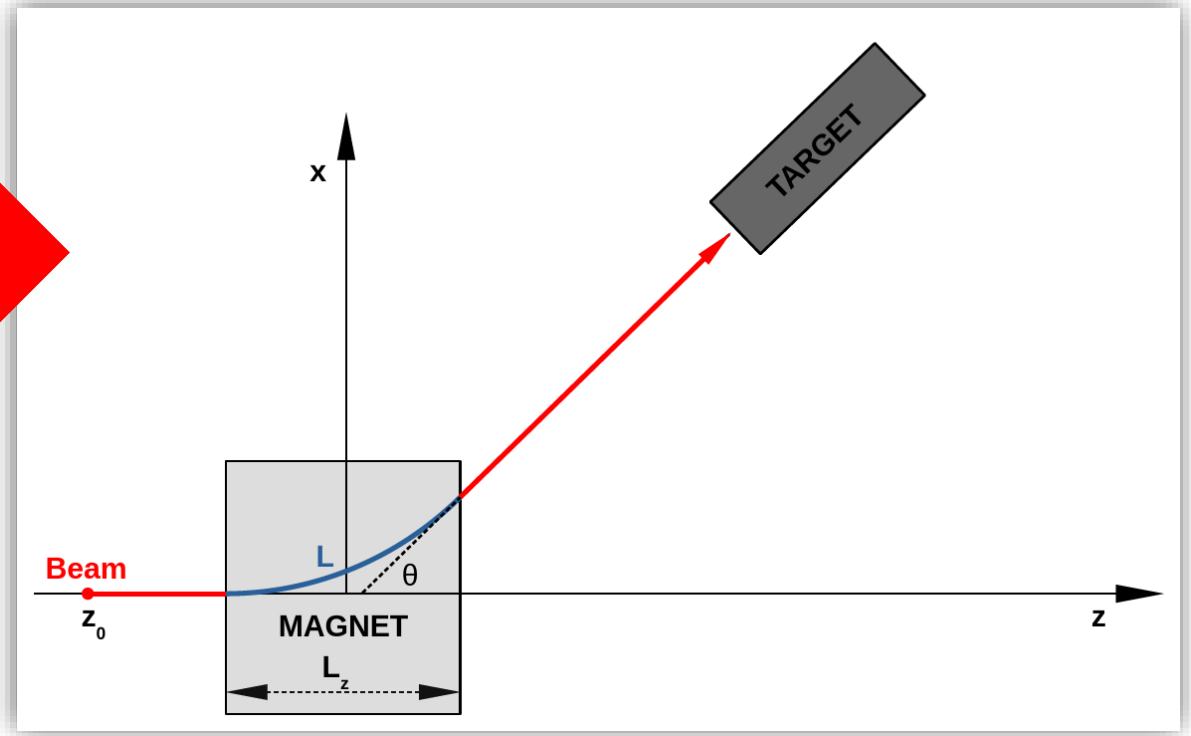
Aim of the exercise:

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

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**

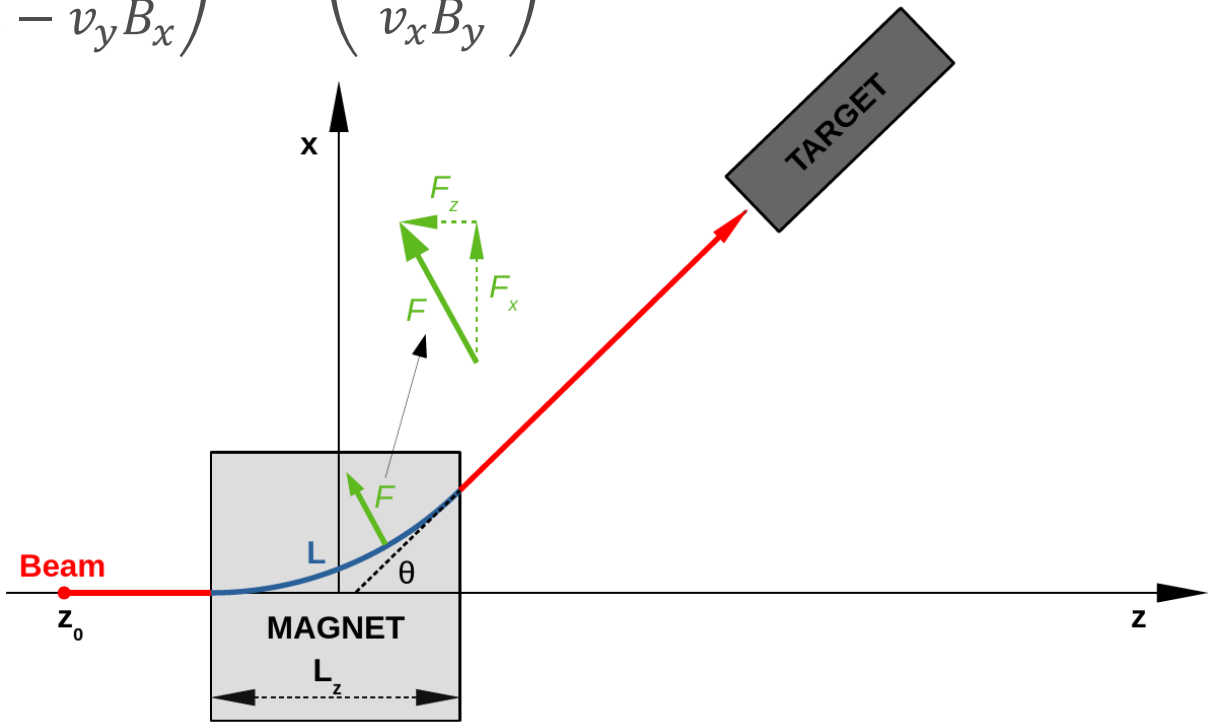
B field direction

- The B field is perpendicular to the plane of movement - hence only B_y can be non-zero if the particle shall move in the x-z plane:

$$\begin{pmatrix} F_x \\ 0 \\ F_z \end{pmatrix} = q \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix} \times \begin{pmatrix} B_x \\ B_y \\ B_z \end{pmatrix} = q \begin{pmatrix} v_y B_z - v_z B_y \\ v_z B_x - v_x B_z \\ v_x B_y - v_y B_x \end{pmatrix} = q \begin{pmatrix} -v_z B_y \\ 0 \\ v_x B_y \end{pmatrix}$$

  - (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 components

- Protons are positively charged (q>0):
  - As shown in the figure: $F_x > 0$ and $F_z \leq 0$
  - Since $v_z > 0, v_x \geq 0$, B_y must be negative



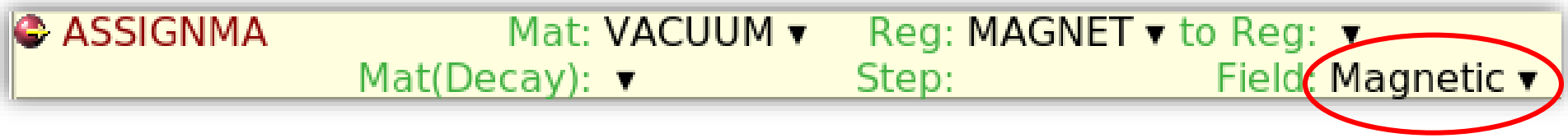
Required |*B*|

- Required B field strength of a **50 cm** long dipole to deviate a **600 MeV/c** proton beam by **25 deg**:

$$|B|\ [T] = \frac{0.6\ [GeV/c]}{0.299792\ * 1\ [e] * 0.5\ [m]} \sin\left(\frac{25}{180} * \pi\right) = 1.69164\ [T]$$

The cards

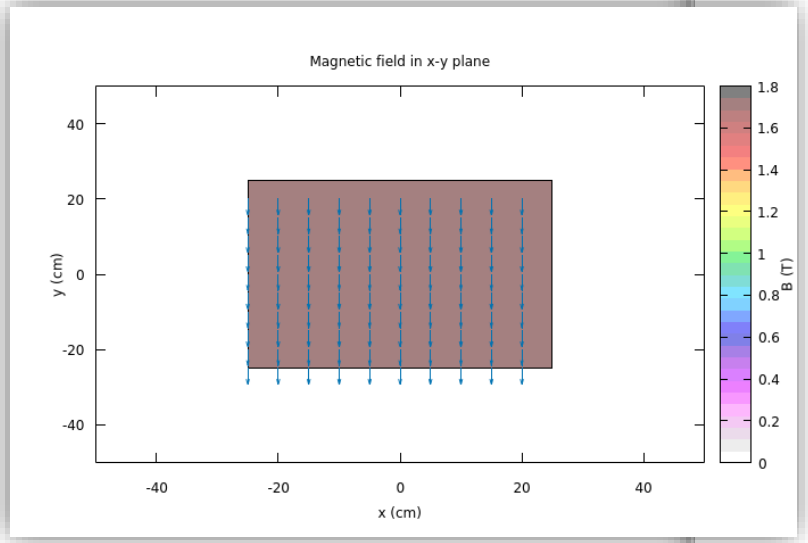
- **ASSIGNMA** (under “Media”):



- **MGNFIELD** (under “Transport”):

Plotting the field

- Since the B-field only has a y component, let's for example chose the x-y plane for plotting:



Flair Input Geometry Run Plot Output

Paste Cut Copy Add Oz Move Up Move Down Rename Delete Clone Save Print Notes Clean Plot

Clipboard Plot List Action

Plot

Fluence
Magnetic Field

Title: Magnetic field in x-y plane Display: 0

Axes

	Label	Log	Min	Max
x:	x (cm)			
y:	y (cm)			
cb:	B (T)			

Center: x: 0. y: 0. z: 0.

Basis: Axes X:Y x-y y-z -u x-z swap -v

Extends: Δu: 50.0 Δv: 50.0 Get

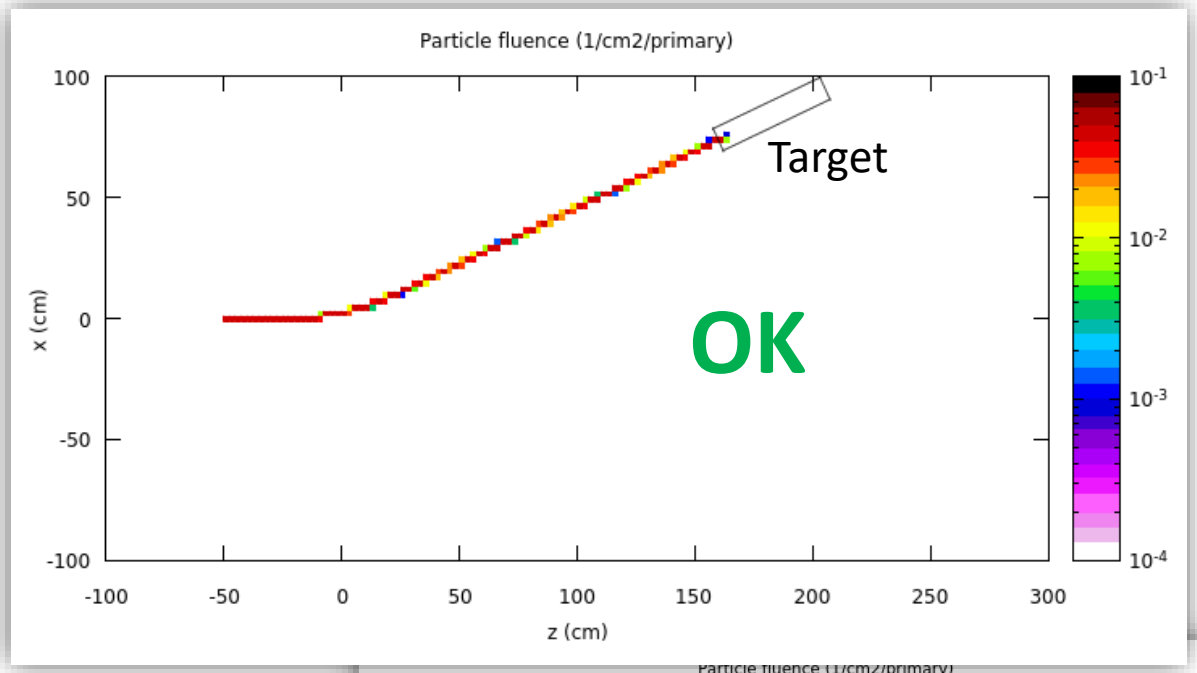
Plot: Type: Field Run: <default> Advanced

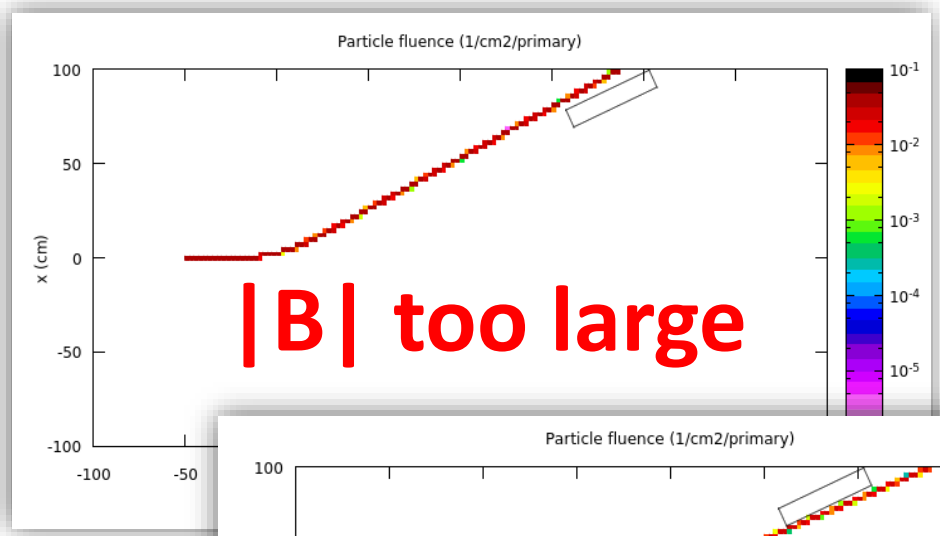
Grid: Nu: 100 Nv: 100

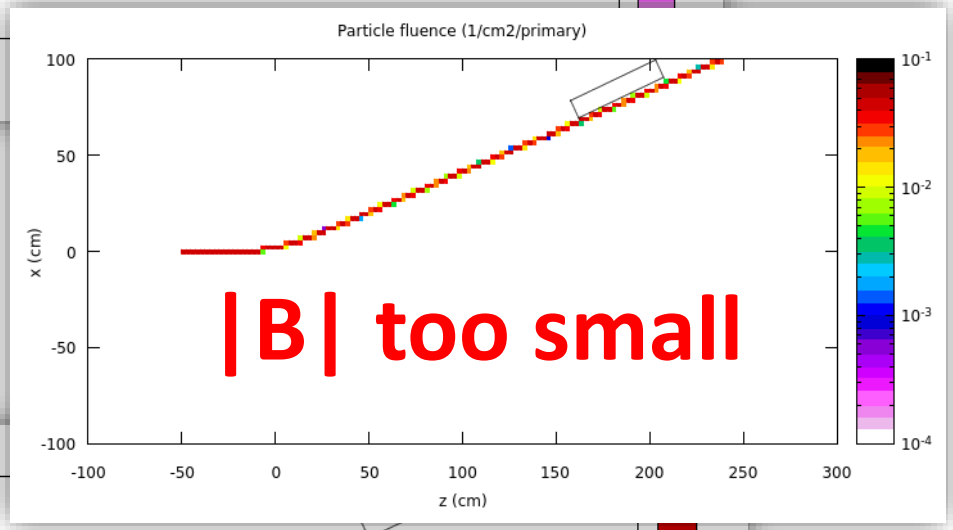
Options: Vector Scale: 2.5 boundaries Plot Coordinates: X-Y labels

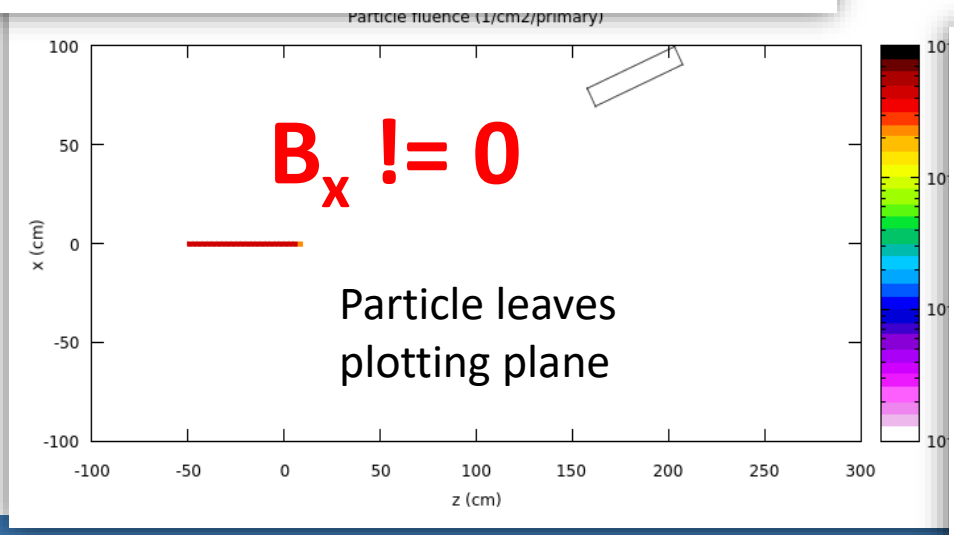
Fluka: ex_magfield.flair Plot completed

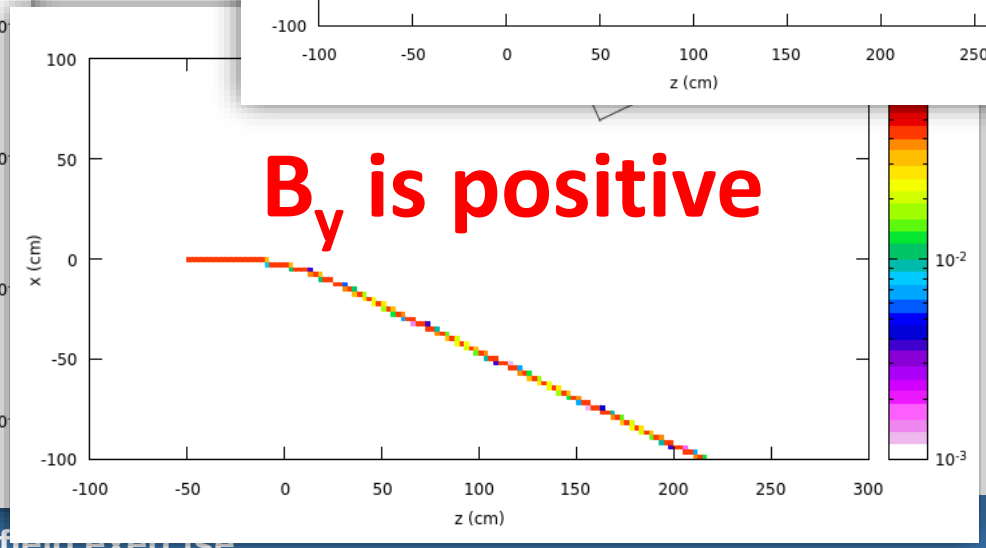
Particle fluence in x-z plane









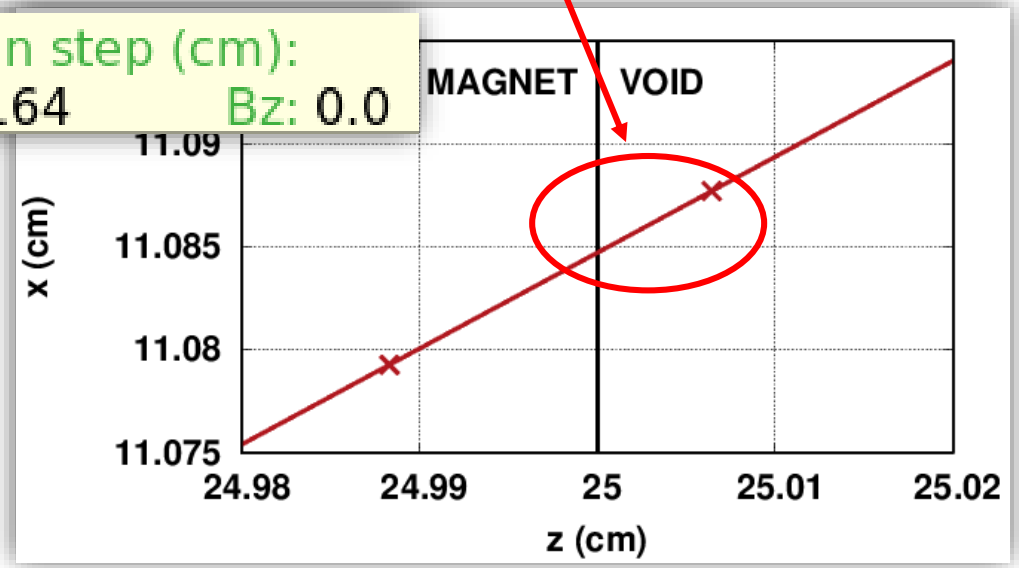


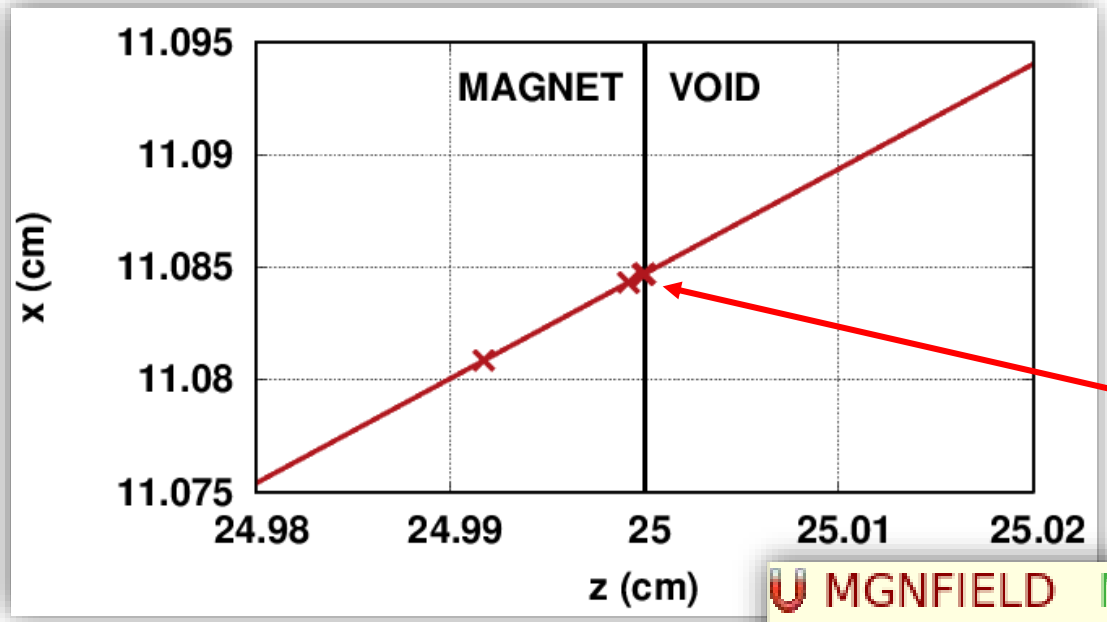
Tracking accuracy (boundary crossing)

- (was not part of the exercise)
- Pay attention to accuracy vs tracking speed

Default settings

MGNFIELD Max Ang (deg): Bound Acc. (cm): Min step (cm):
Bx: 0.0 By: -1.69164 Bz: 0.0





MGNFIELD Max Ang (deg): Bound Acc. (cm): 0.0001 Min step (cm):
Bx: 0.0 By: -1.69164 Bz: 0.0


FLUKA