Practical example

MedAustron: ion therapy facility near Vienna/Austria

Providing beam energies from 120 to 400 MeV/u for carbon ions (C^{6+}) and from 60 to 220 MeV for protons

16 synchrotron bending magnets:

- Bending angle: 22.5°
- Bending radius: 4.231 m
- Field ramp rate: 3.75 T/s
- Max. current*: 3000 A
- Overall length: < 2 m
- Field quality: $\frac{\Delta\int B \cdot dl}{\int B \cdot dl} = 2 \cdot 10^{-4}$

Magnet aperture:

- Horizontal GFR: ±60 mm
- Vertical GFR: ±28 mm
- Vacuum chamber thickness: 5 mm

Requested:

- Max. required B = ?
- Excitation current NI = ?
- Number of turns N (per pole) = ?

*) which can be delivered from the power converter

Beam rigidity & Flux density

Beam rigidity ($B\rho$) [Tm]:

$$(B\rho) = \frac{1}{qc}\sqrt{T^2 + 2T\,E_0}$$

– max. beam energy: _____ MeV/u for _________
– particle charge number $q =$ ___
– kinetic beam energy (per nucleon) $T =$ _______ eV
– particle rest mass (per nucleon) $E_0 =$ ________eV

$B\rho =$ ________ Tm

Dipole bending field B [T]:

$$B = \frac{(B\rho)}{r_M}$$

– Bending radius: _______ m

$B =$ ________ T

Aperture & Ampere-turns

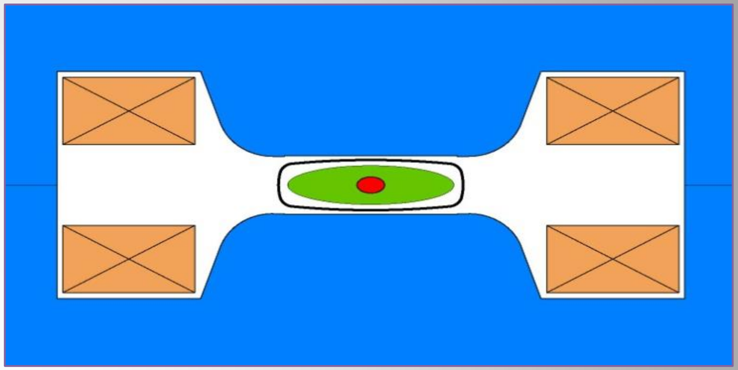
Magnet aperture:

Vertical GFR: _____ mm

Vacuum chamber thickness: _____ mm

Tolerances for installation: ______ mm

Insulation thickness: ______ mm



Total aperture height: _____ mm

Excitation current (= magneto-motive force): $NI_{(per\ pole)} = \frac{Bh}{2\eta\mu_0}$

Efficiency η = 99%

$NI_{(per\ pole)}$ = ______ A

Current & Number of turns

Current I [A]:

- I_{max} power converter: 3000 A
- I_{nom} magnet: ______ A (leave ___ % margin)

Number of turns N (per pole):

- N = ______ A

Current density j [A/mm^2]:

- Cooling water available → water cooled coils
- Assumption for reasonable economic design: j = ____ A/mm^2