Improving ion gantries

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Present

Only one gantry worldwide: \( L = 25 \text{ m} \times \phi = 13 \text{ m}, 600 \text{ t} \)

It has everything, but it is

Very large, very heavy, very expensive

Fixed Isocenter
360° rotation
Parallel scanning
200 mm x 200 mm
140 t magnets
120 t shielding-counterweight
600 t total rotating mass

(Udo Weinrich, GSI)
Can we make it better?

- As usual we want everything and its opposite at the same time…
  - Small aperture final magnet to lower power consumption, but scanning upstream
  - Small radius, but space around isocenter
  - Light magnets, but possibly non superconducting
  - Maximum performance, but cheap
  - …
Aspects and ideas to be considered

- Scanning or scattering
  
  Not really a choice
Aspects and ideas to be considered

- Scanning
- SAD and scanning magnets position
Scanning magnets position

- Large aperture dipole: weight and power consumption
- Large gantry radius and large room size
Aspects and ideas to be considered

- Scanning
- SAD and scanning magnets position
- 360° vs 180°
360° vs 180°

- By rotating the couch by 180°, all the beam directions are possible also with only 180° of rotation of the gantry

- Saves on room size, but no counterweight opposite to dipole (mechanics and shielding)
Aspects and ideas to be considered

- Scanning
- SAD and scanning magnets position
- 360° vs 180°
- Field patching
Field patching

Scan in one go | Scan and move (~PSI gantry 1)

Reduces magnet aperture, but
Slower procedure and
Difficulties somehow similar to simultaneous
optimisation of multiple fields with IMPT
Aspects and ideas to be considered

- Scanning
- SAD and scanning magnets position
- 360° vs 180°
- Field patching
- Fixed or mobile isocenter
Fixed or mobile isocenter

- Most of the existing gantries have a fixed isocenter on the rotation axis of the gantry. This implies large masses rotating at large radius.
An isocenter, through which all the directions pass, exists but its position depends on gantry orientation.
Mobile isocenter - 2

Patient positioned in a small room “somewhere”

Side access, PIMMS

Gantry is longer than just the last magnet but at small r
Carbon ion gantry, ‘a la’ PSI gantry-

(M. Kats, 2002)
Considerations

- Shielding: No counterweight on the beam path
- Access to patient
- Shielding: surface of the room
  \[25 \times 15 \times 15 = 1950 \text{ m}^2\]
  \[10 \times 17 \times 17 = 1258 \text{ m}^2\]
- Room volume (to dig, to cool)
  \[25 \times 15 \times 15 = 5625 \text{ m}^3\]
  \[10 \times 17 \times 17 = 2890 \text{ m}^3\]
- Smaller masses and masses on axis
Aspects and ideas to be considered

- Scanning
- SAD and scanning magnets position
- 360° vs 180°
- Field patching
- Fixed or mobile isocenter
- Multi-room system
Multi-room system

- Proposed by A. Brahme
Aspects and ideas to be considered

- Scanning
- SAD and scanning magnets position
- 360° vs 180°
- Field patching
- Fixed or mobile isocenter
- Multi-room system
- Divergent scanning
Divergent scanning

- Last drift 2m
- Quad g = 8 T/m
- SAD 5.5 m (1 plane only!)
- Gap reduced by 30%
Aspects and ideas to be considered

- Scanning
- SAD and scanning magnets position
- 360° vs 180°
- Field patching
- Fixed or mobile isocenter
- Multi-room system
- Divergent scanning
- Superconducting magnets
Superconducting magnets

If possible no He, use cryo-coolers

Priano et al, 2001
Straight coil heads
difficult to wind

GFR 200 mm x 60 mm
(field patching)
## Aspects and ideas to be considered

- Scanning
- SAD and scanning magnets position
- 360° vs 180°
- Field patching
- Fixed or mobile isocenter
- Multi-room system
- Divergent scanning
- Superconducting magnets
- FFAG gantry
FFAG Gantry

150-400 MeV/u
1500 kg of magnets
Very large
**FFAG Gantry**

**Direct Wind Combined Function Gantry Magnet**

![Diagram of FFAG Gantry Magnet]

Even without shielding coil, fringe field < 2 gauss @ 3 m.

Aperture required:

\[
\sigma = 0.58 \text{ mm} \quad \beta = 2.3 \text{ m}
\]

\[
A = 18.9 + 8.2 \frac{m}{T} + 12\sigma = 37.7 \text{ mm}
\]

\[
B(x) = 18\sigma + 11\beta
\]

\[
B = 1.8 \text{ T} + 52 \text{ T/m} \times 18.9 \text{ mm} = 2.78 \text{ T}
\]

\[
B = 1.8 \text{ T} - 52 \text{ T/m} \times 8.20 \text{ mm} = 1.37 \text{ T}
\]

\[
A = 18.9 + 1.5 \frac{m}{T} + 12\sigma = 18.8 \text{ mm}
\]

\[
B_{min} = 3.717 \text{ T} + 45.5 \text{ T/m} \times 1.5 \text{ mm} = 3.9 \text{ T}
\]

\[
B_{max} = 3.717 \text{ T} - 45.5 \text{ T/m} \times 6.9 \text{ mm} = 3.4 \text{ T}
\]

(D. Trbojevic)

M. Pullia - Improving ion gantries - PTCOG 48
FFAG Gantry

- (complicated) scanning upstream gantry?
Other ideas

- Active alignment
- Active compensation of magnetic defects (scanning quadrupoles and sextupoles)
- Scanning by moving magnets
- …
Conclusions

- There are margins to improve the present schemes
- There are embrional ideas for new schemes
- There are large margins for compromise solutions and combinations of ideas
That's all Folks!

Thank you for your attention.