PAUL SCHERRER INSTITUT

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Paul Scherrer Institute

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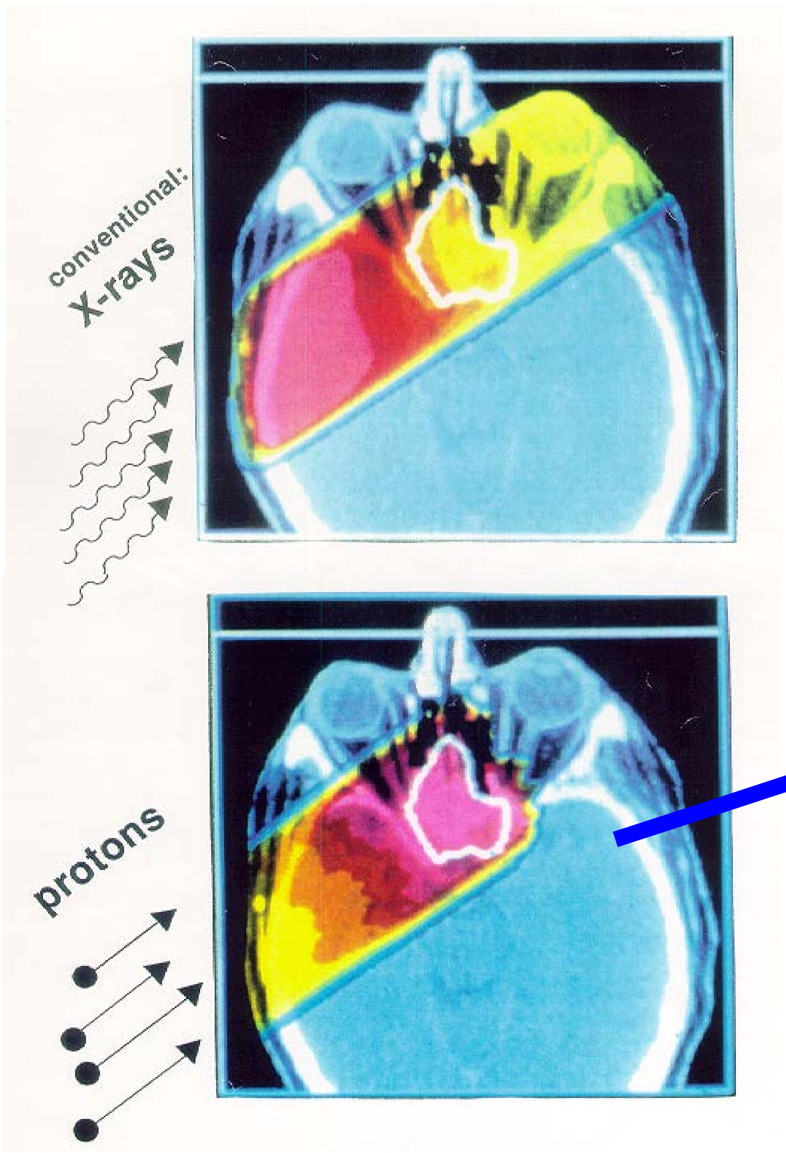
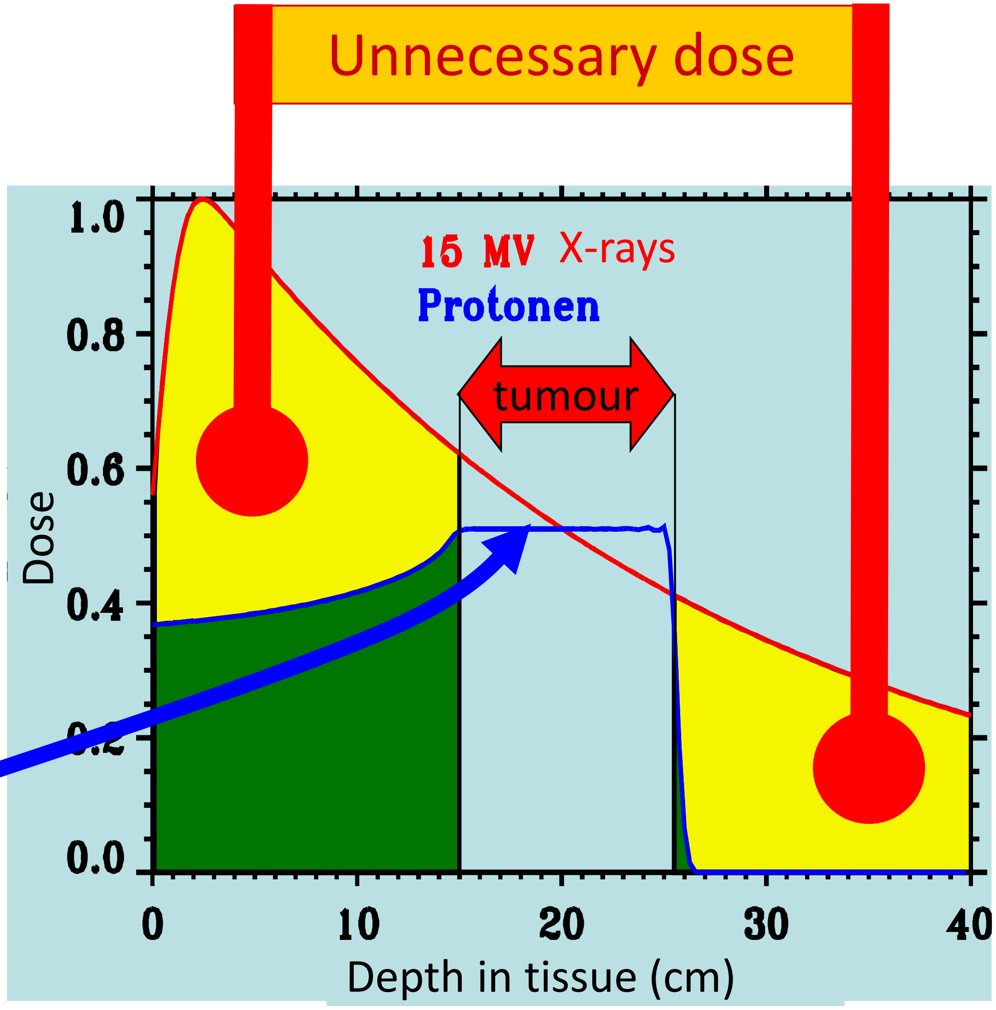
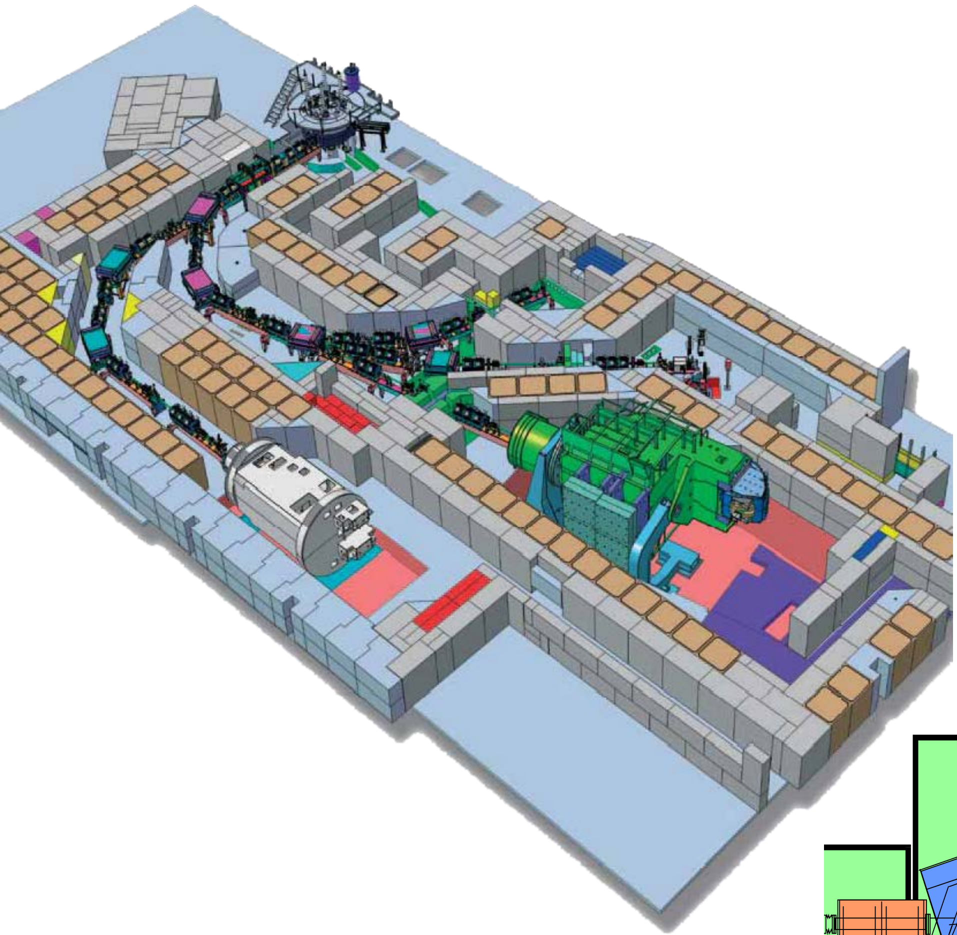
Advantages and challenges of SC magnets in gantries

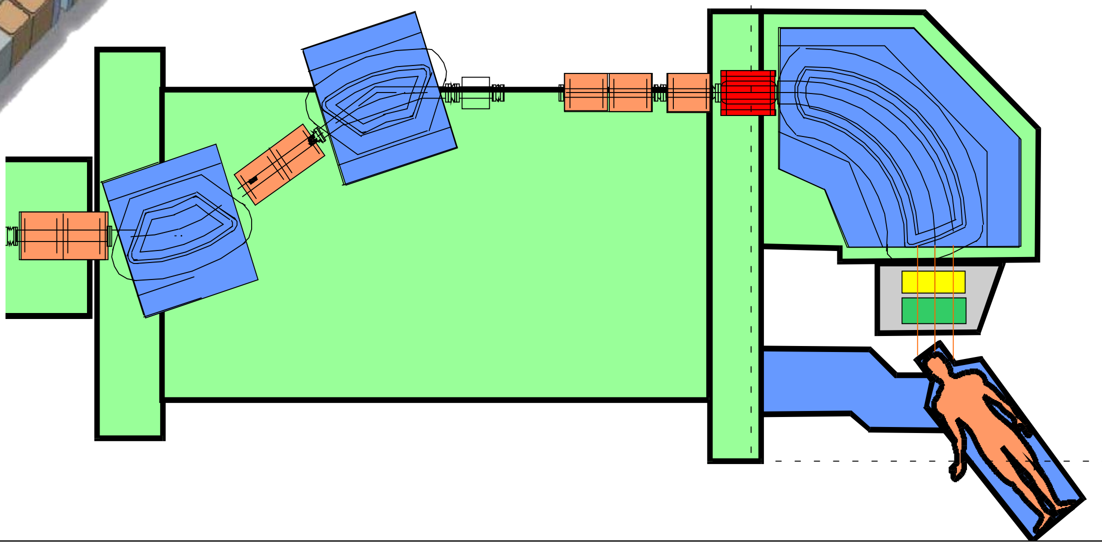
Particle therapy





Particle therapy gantries



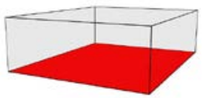


- Size: up to 13 m x 25 m
- Weight: up to 600 t
- Cost: ~ 10’s MCHF

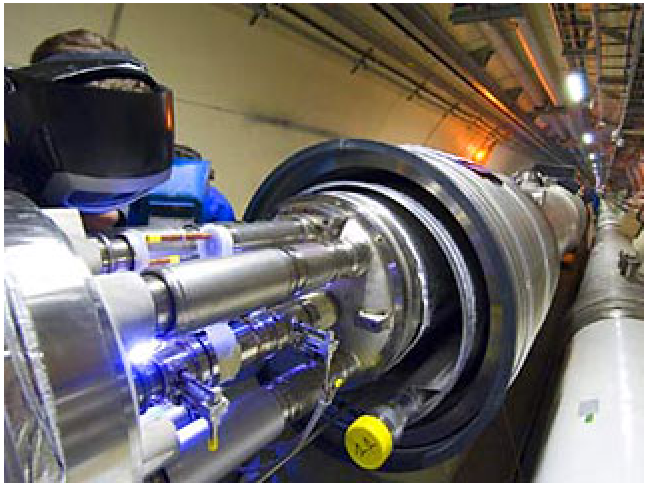
Superconductivity in particle therapy

- Motivation: reduce facility's
  - Cost
  - Weight
  - Footprint
  - Height






- Use of superconductivity:
  - Potential to fulfill the criteria,
  - Advantages result from the strong fields (e.g. high momentum acceptance),
  - Additional costs from cooling,
  - Additional risks from quenching,
  - Challenges dealing with stray fields.



Particle therapy customers

Consider changing customer composition

Research centers …

… give way to large hospitals.

⇒ Major interest in treating the maximal number of patients

⇒ Require

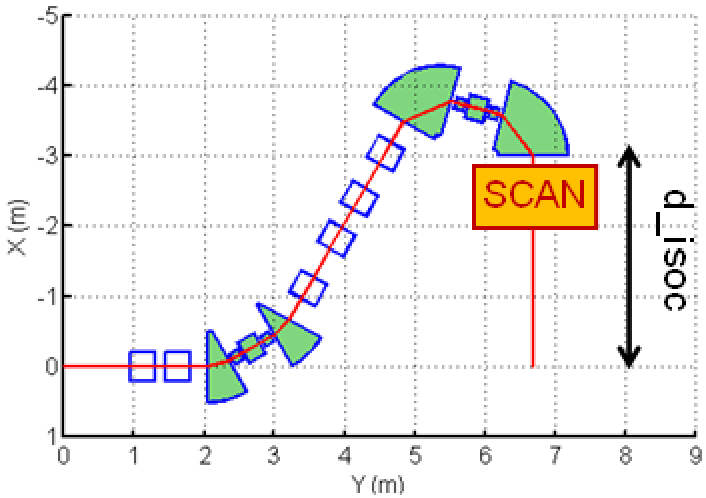
- High reliability of the machines
  - Maximal treatment interruption of couple of days
  - No quenching / good quench protection / fast recovery
- Easiness of service
  - Minimal warm up and cool down times

Advantages of SC magnets in gantries

Proton gantries

Reduction of:
- *power consumption*
- *weight   => cost*

Example: ProNova SC360, 25t



250 MeV p: $B\rho = 2.4$ Tm

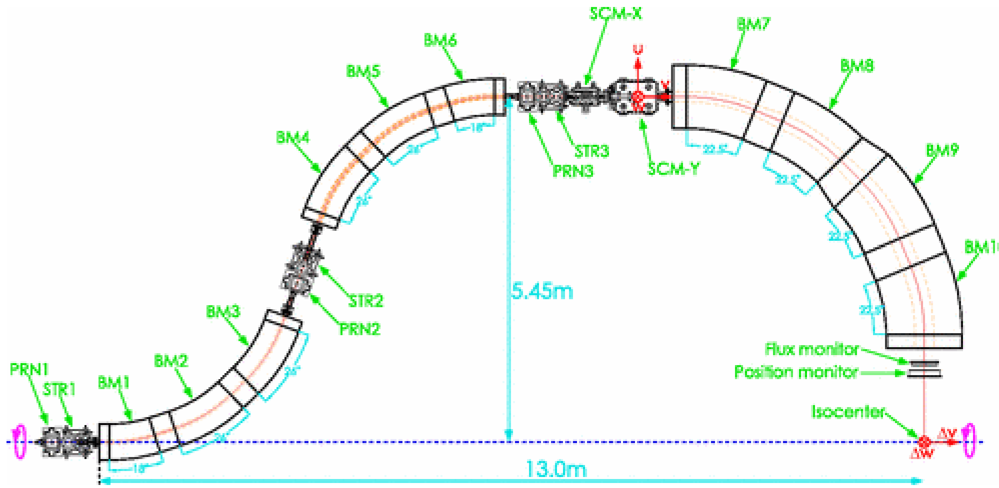
=> Most distances dictated by the purpose of the gantry:
- d from final bend to the patient
- Scanning system
- Beam focussing
- Dispersion suppression

Carbon ion gantries

Reduction of:
- *power consumption*
- *weight   => cost*
- *size*

Example: Toshiba-gantry at NIRS, 300t

r = 5.45, l =13 m (compare to HIT: r= 6.5 m, l= 25 m)



450 MeV/nucl C^{6+}: $B\rho = 6.8$ Tm

=> Large share of distances dictated by the beam bending radius

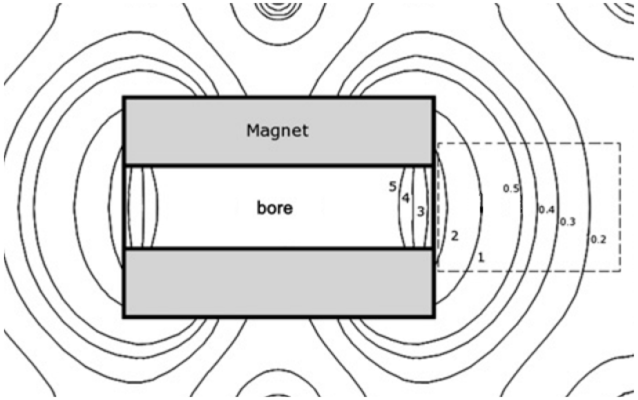
Challenges of SC magnets in gantries

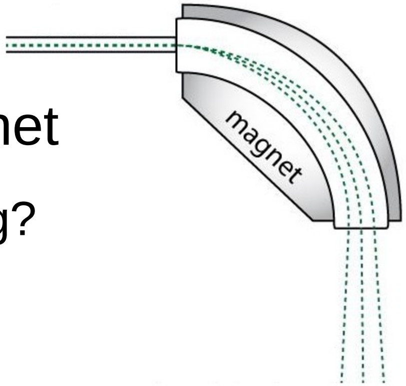
- Strong electromagnetic fields in the magnet
  - Need high mechanical stability to counteract the effects of $\vec{F}_{Lorentz}$
  - Strong and extended stray fields

    Effect of iron in the surroundings

    B must be < 0.5 mT at the iso-center

    => Require passive/active shielding



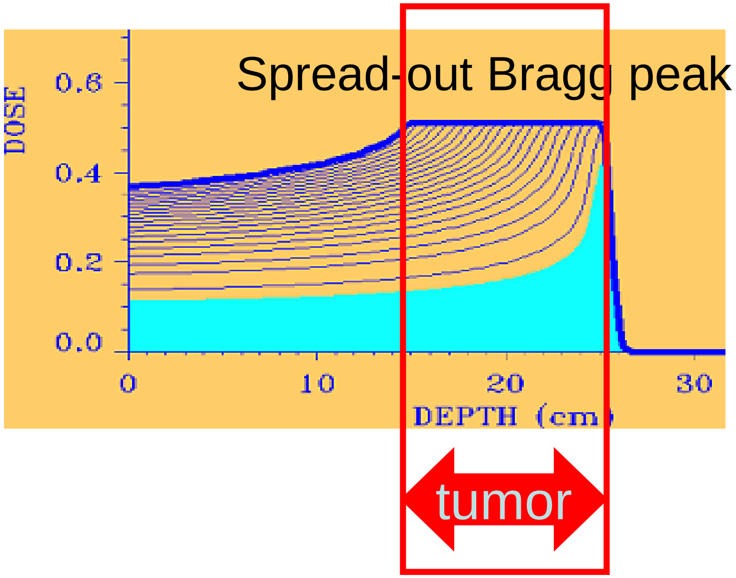


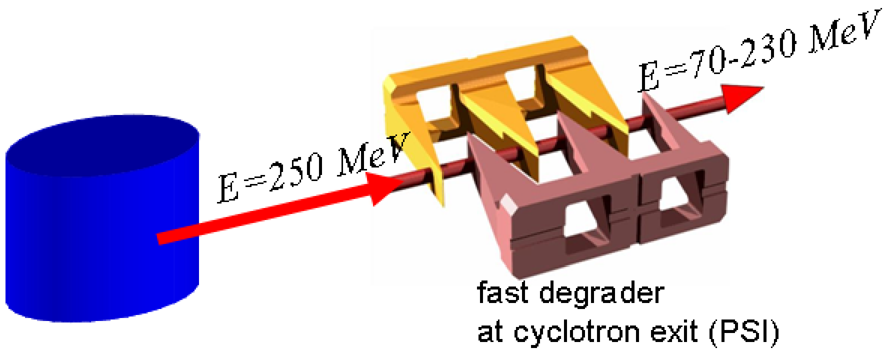
- Beam scattering in magnet

    => Possible quenching?

- Maintenance
  - Requires dedicated know-how

Energy modulation - ramping





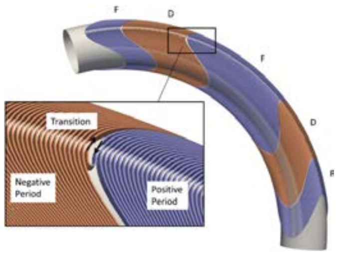
- Scanning is performed in layers
- The energy change between two layers should be ideally performed in <100 ms
- The momentum step between two layers is ~1%

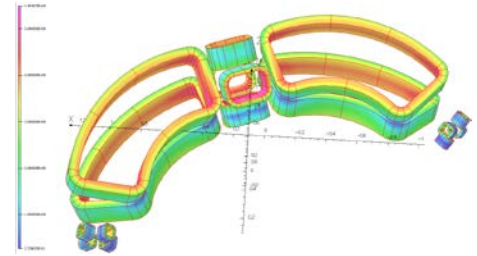
  => Two options:

  - Magnet ramping speed of ~1% dB/B in 100 ms
  - Gantry momentum acceptance very large (Δp/p > 10-20%)

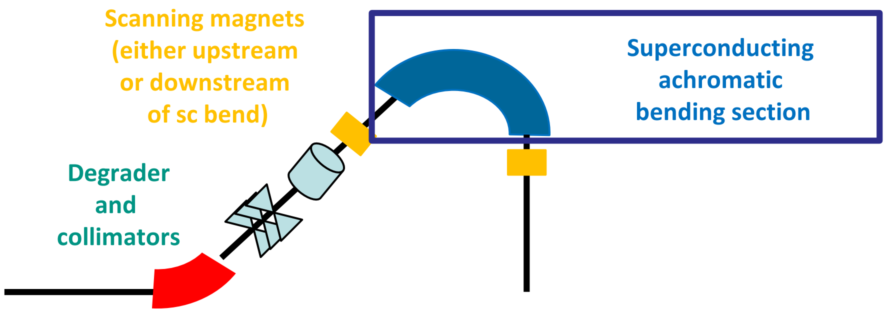
SC gantry design – PSI & LBNL

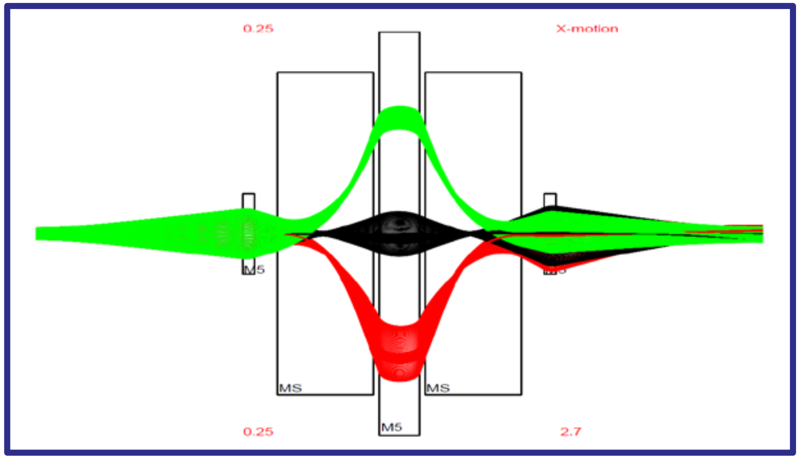
- Combined function magnets, e.g.
  - CCT magnets with alternating gradient
  - 3-5 racetrack magnets





- Momentum acceptance of ±12.5%
  - No energy selection needed
  - Degrader can be mounted on the gantry





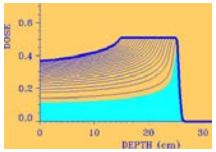
  - Treatment of small tumors without SC field change (~ 50 % of cases)
  - Treatment of large tumors with only one or two of such changes
  - Can be used i.e. for volumetric rescanning on a very fast time scale

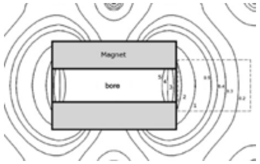
Summary

- The weight and, for the heavy ions, the size advantage of SC gantries promises significant cost and footprint reduction

  => particularly important for the commercial particle therapy

- Some challenges remain
  - Fast ramping of the magnetic field,
  - Limited options for cooling and SC material choice,
  - Patient located near the strong magnetic fields,
  - Need to keep high reliability and availability.





- Use of SC magnets gains popularity and promises to give a big push in development regarding
  - Cost efficiency,
  - Practicality of such facilities,
  - Better accuracy via new treatment and diagnostic techniques.

Thank you very much for your attention!