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The Status of Ion Beam Therapy

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PASI 2015 – Working Group 3, Medical Applications

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Early Years - US

- Bevalac
  - 1975 – 1993
  - 1200 patients (majority with neon)
  - Treatment program funding was secure
  - But operating funds for Bevalac itself were discontinued due to startup of RHIC and CEBAF

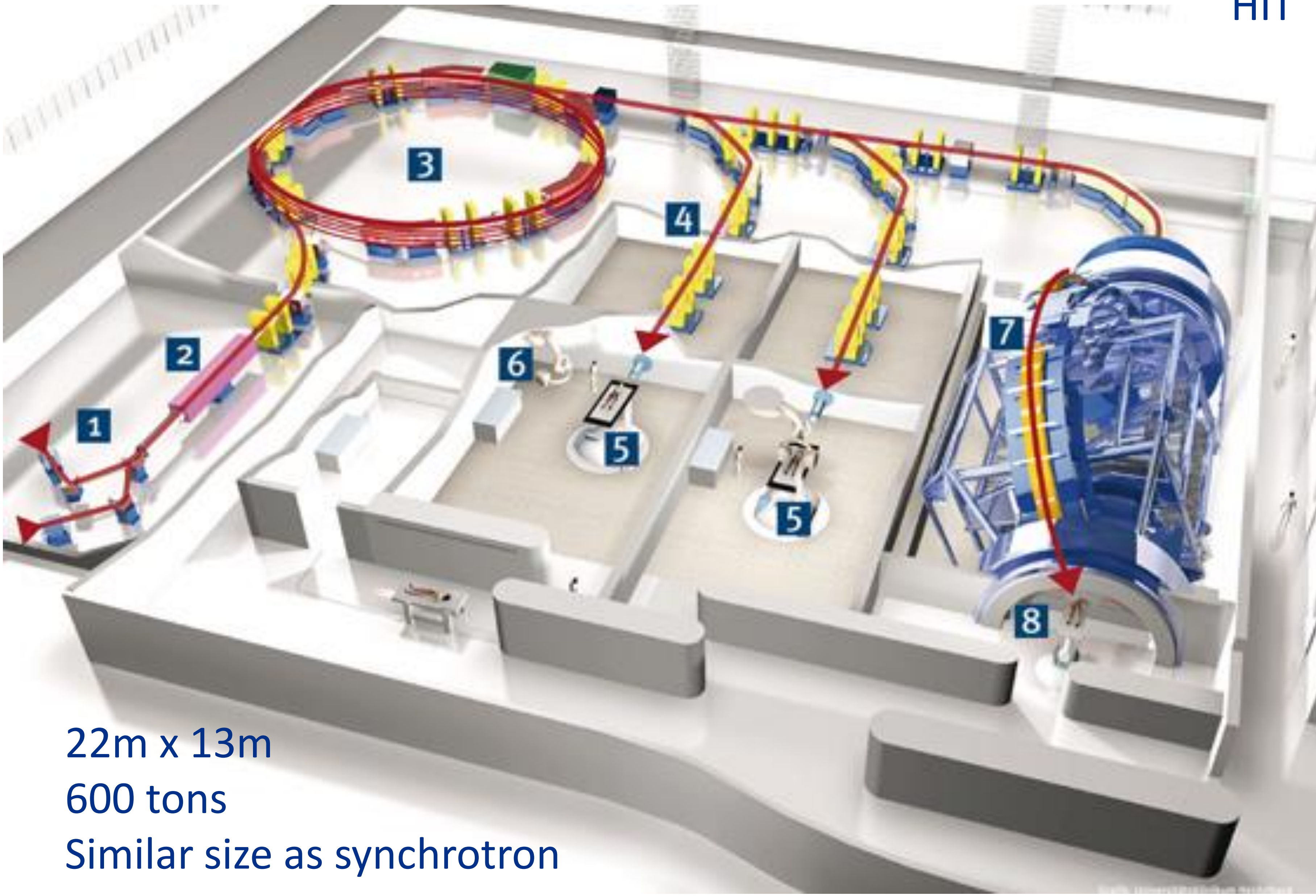
HIMAC - Japan

- Celebrated 20 years this January
- World leader in carbon ion therapy
- Has moved beyond development
  - 5 carbon ion centers

Other ion therapy sites

- Heidelberg – Germany
- CERN/Enlight
  - CNAO – Italy
  - MedAustron – Austria
  - ~~France~~
- China
  - Lanzhou
  - Shanghai

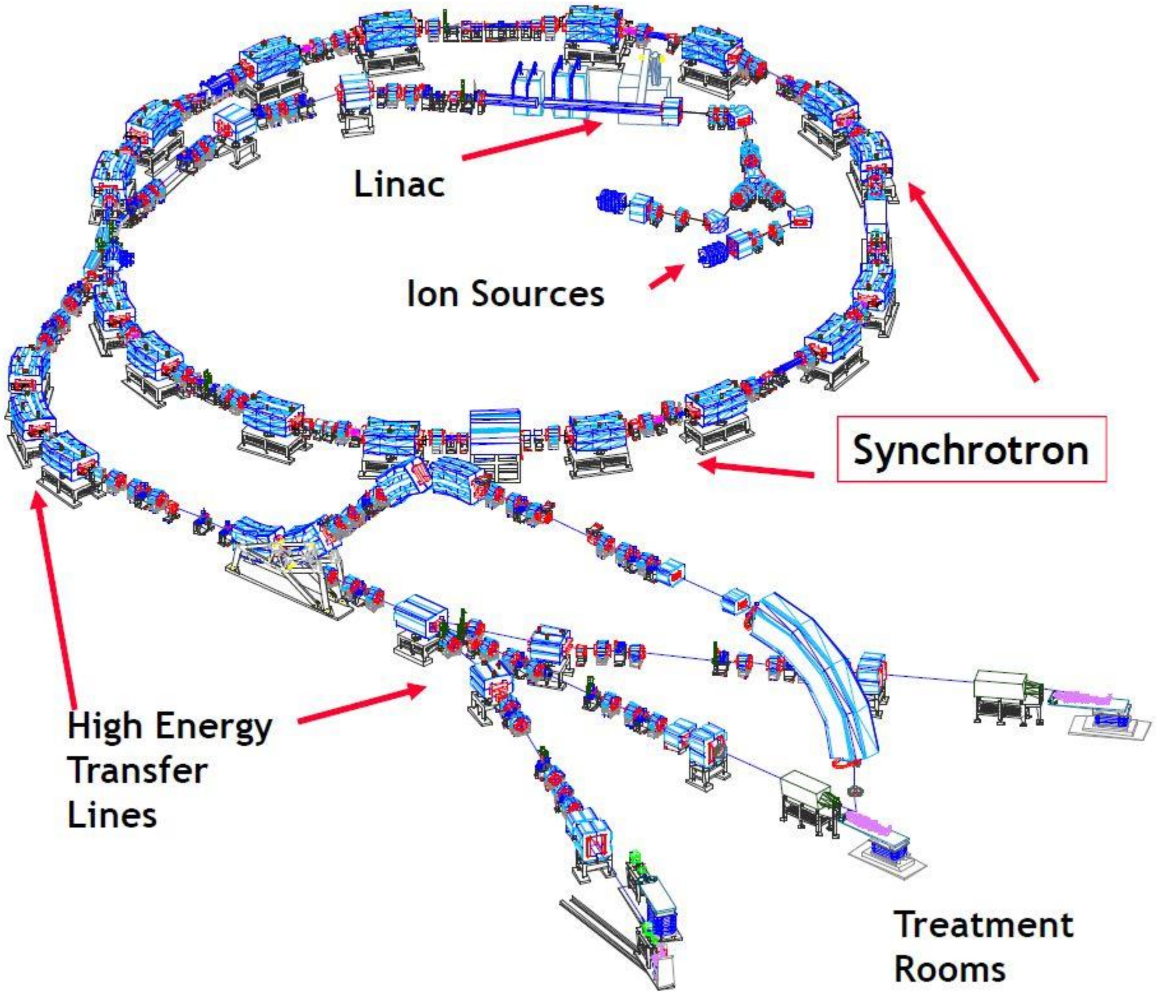
HIT



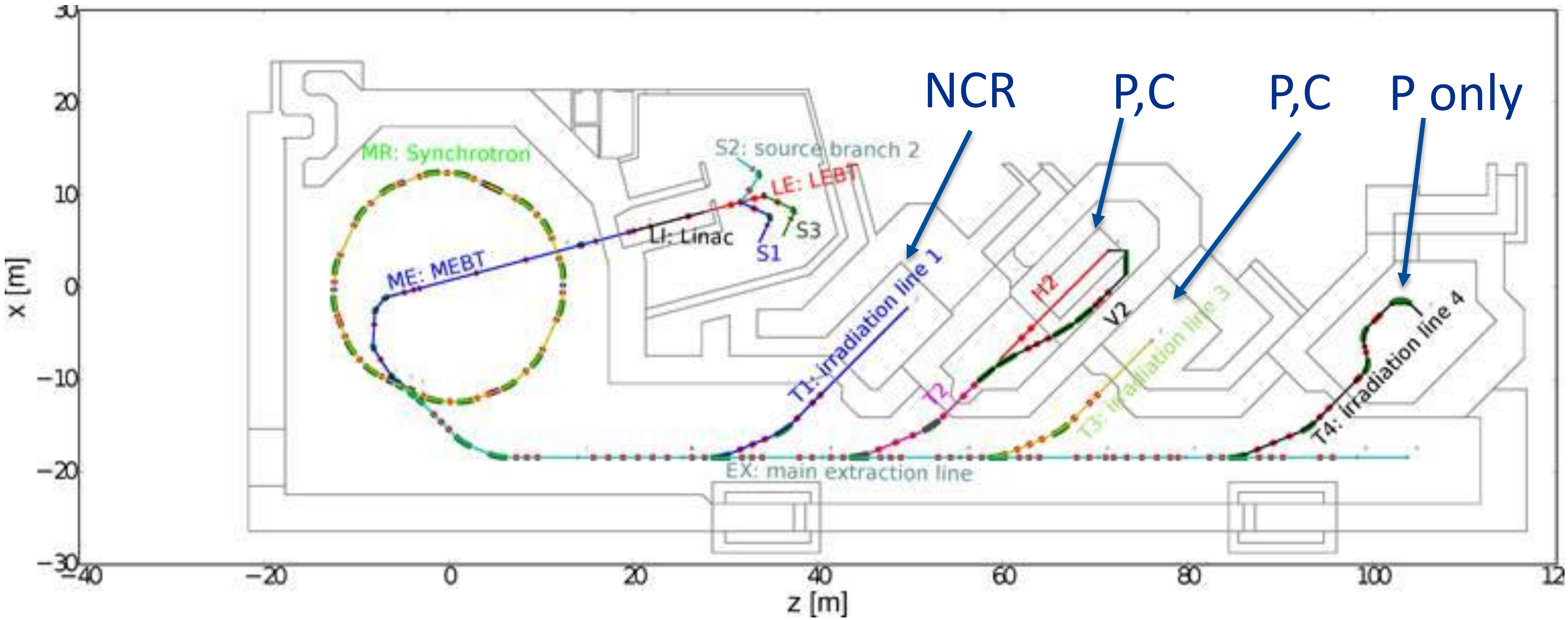
22m x 13m

600 tons

Similar size as synchrotron


Linac
Ion Sources
Synchrotron
High Energy
Transfer
Lines
Treatment
Rooms

CNAO



NCR
P,C
P,C
P only
MR: Synchrotron
S2: source branch 2
LE: LEBT
LI: Linac
S1
S3
ME: MEBT
T1: irradiation line 1
H2
V2
T2
T3: irradiation line 3
T4: irradiation line 4
EX: main extraction line
x [m]
z [m]

MedAustron

Issues for ion therapy vs protons

- Charge/mass twice that of protons
  - Doubles magnetic field or radius of magnets
  - Requires switching if doing proton CT with ion therapy
- Desired range requires higher MeV/nucleon
  - 240 MeV – proton
  - 300 MeV/nucleon – ions
- Multiple ion sources
- More complex radiobiology
  - More complex treatment planning
  - Iso-killing power vs isodose

What are the issues for this group?

- Can we make an order of magnitude reduction in size/cost?
- Is it really an accelerator issue ?
  - How important is size/cost?
  - Any lessons from Kirby, Beltran, Pankuch?
  - Will it become a control/complexity issue?

Recent US efforts

- DOE/NCI Workshop on Ion Beam Therapy
  - Jan. 2013
- Nov, 2012 – Feb, 2013
  - Multi-Lab working group for a proton/ion center at Walter Reed Hospital
  - 0’th order cost estimate effort spread across 6 national labs
    - FNAL
    - SLAC
    - LBNL
    - BNL
    - JLAB
    - ANL

Recent US efforts

- DOE LAB 14-1142
  - Accelerator Stewardship Topical Areas
    - Particle Therapy Beam Delivery Improvements
      - Lawrence Berkeley National Laboratory, The Paul Scherrer Institute, and Varian Particle Therapy, Inc.
        - develop light weight superconducting magnet technology that will reduce the size and weight of particle beam delivery systems by nearly a factor of 10.
      - Massachusetts Institute of Technology and ProNova Solutions, LLC
        - Develop an innovative design for an ironless superconducting cyclotron
- DOE LAB 16-1438
  - Proposals due this month

- NCI PAR-13-371
  - Planning for a National Center for Particle Beam Radiation Therapy Research (P20)
    - The Center must be planned to operate as a research center adjunct to an independently created and funded, sustainable clinical facility for PBRT.
  - 2 Awards
    - National Particle Therapy Research Center
      - Specifications for research line
      - Monte Carlo Dose Engine
      - Management/infrastructure development
    - NAPTA: Optimizing clinical trial design & delivery of particle therapy for cancer
      - Integration of existing research
      - Range uncertainty/radiobiology
      - Management/infrastructure development

The Center must be planned to operate as a research center adjunct to an …

…an independently created and funded, sustainable clinical facility

- Other interests
  - Mayo Clinic
    - Joint Symposium on Carbon Ion Therapy – May, 2013
  - Walter Reed National Military Medical Center – 2012/2013
    - Effort involving 6 national labs to develop cost estimate and white paper for ion therapy center
    - Looked at synchrotron, cyclotron, and cyclinac options

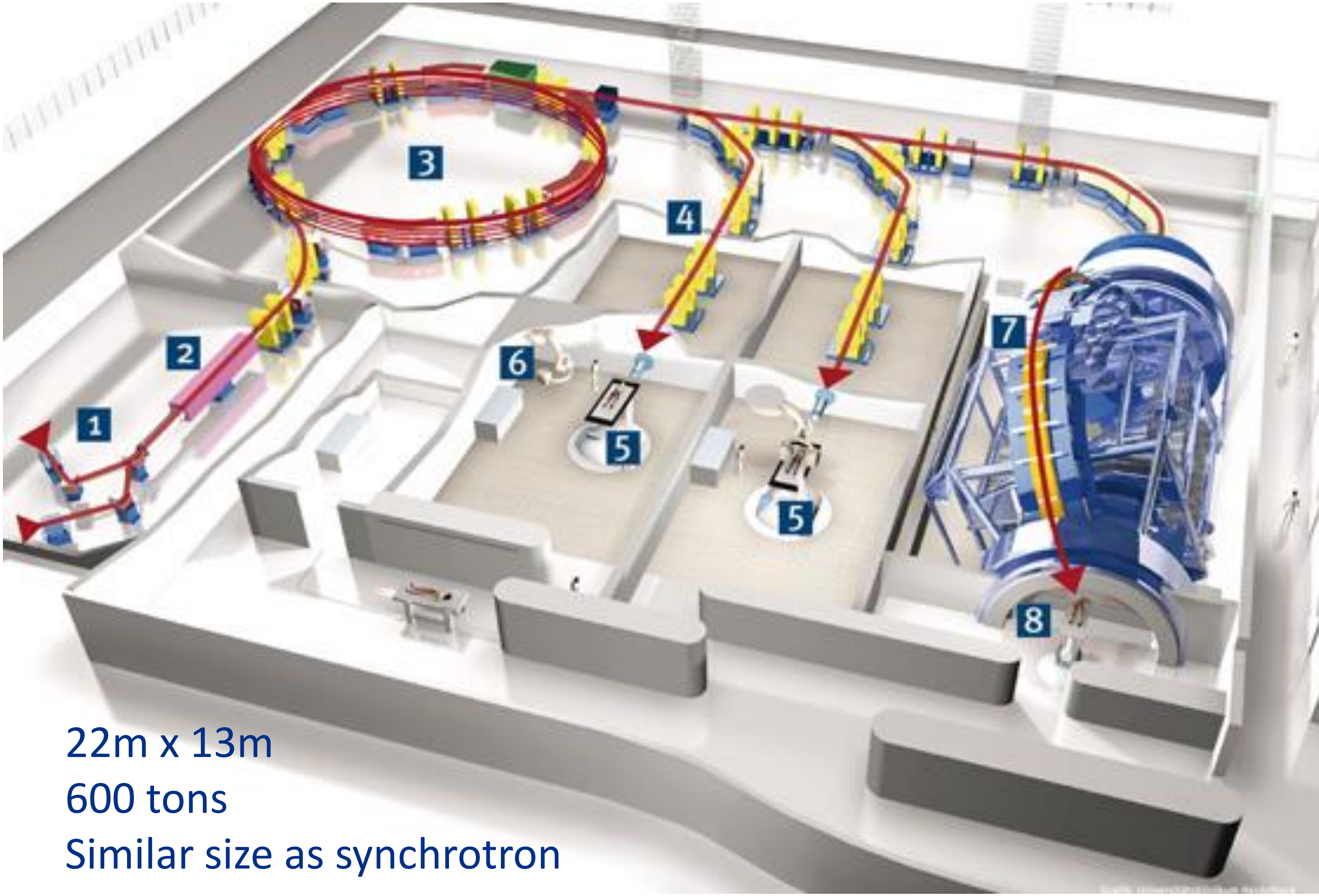


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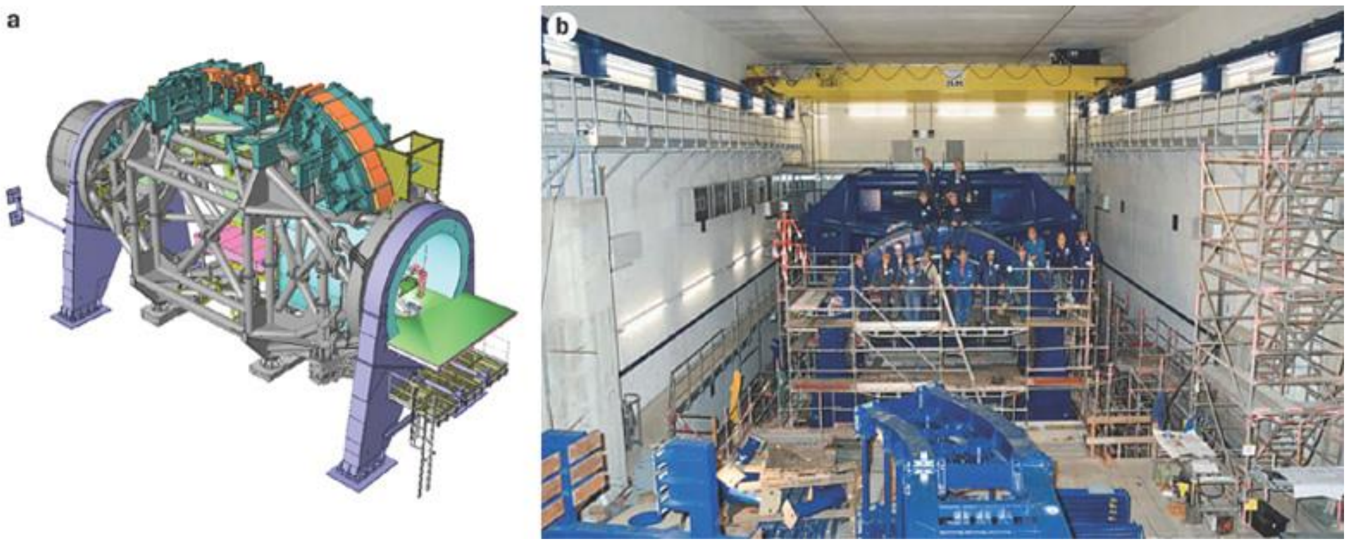
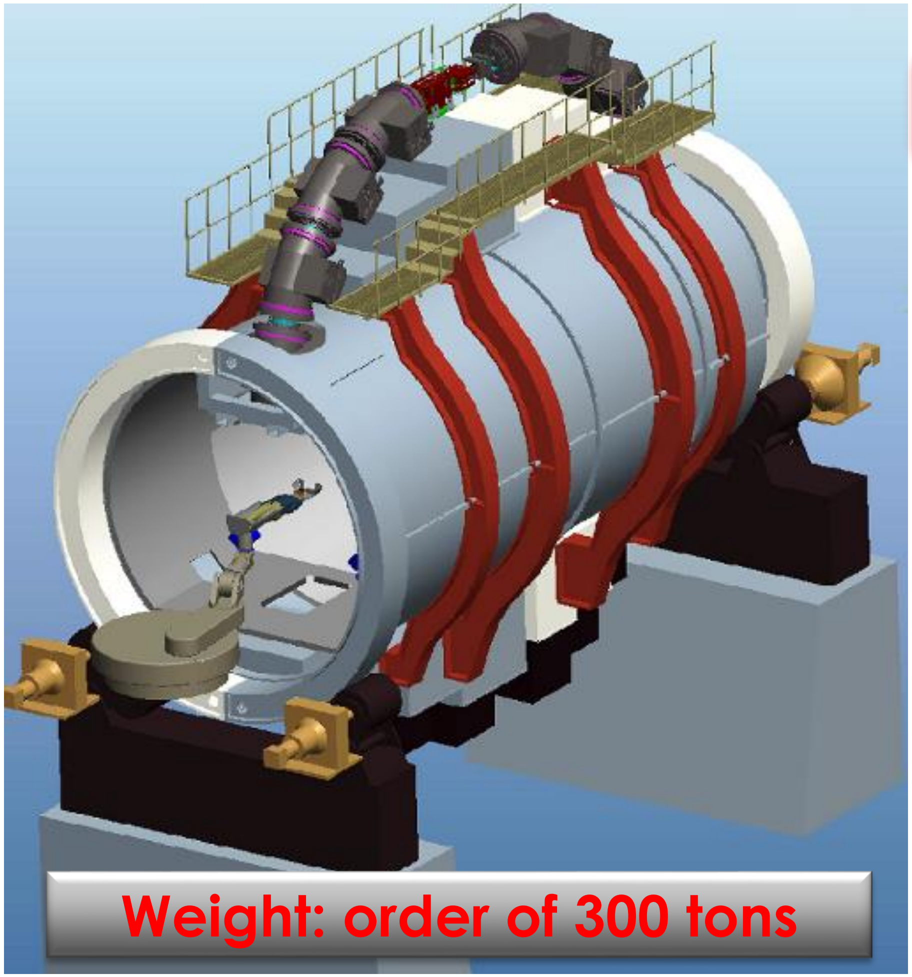
Figure 5 The rotating gantry installed at the Heidelberg Ion Therapy Center facility



Durante, M. & Loeffler, J. S. (2009) Charged particles in radiation oncology
Nat. Rev. Clin. Oncol. doi:10.1038/nrclinonc.2009.183

nature REVIEWS CLINICAL ONCOLOGY

Superconducting rotating-gantry



Use of superconducting (SC) magnets

Ion kind	: ^{12}C
Irradiation method	: 3D Scanning
Beam energy	: 430 MeV/n
Maximum range	: 30 cm in water
Scan size	: □200×200 mm^2
Beam orbit radius	: 5.45 m
Length	: 13 m

The size and weight are considerably reduced

Conclusion

- Medical applications straddle too many boundaries to get much traction in the US
- The National Cancer Institute does not build hardware
- The Department of Energy does not perform medical research
- As can be seen in the history of proton therapy, the US model leaves late stage development and commercialization to industry
- While there are significant accelerator technology challenges yet to be faced, the larger issue for wide-scale utilization of ion beam therapy will be the economic integration of all the necessary functions – imaging, guidance, control, patient management, immobilization, etc.

So what do we need from an accelerator?

- Conform dose
- Change energy rapidly
- Range of ions ?
- Spot scanning
- Number of beams - gantry
- Compact
- Cheap
- Looks like photon treatment

What do we need from an accelerator?

- Maximum dose to tumour
- Minimise effects to normal tissue
- Conform dose to tumour
- Hypo-fractionation – dose escalation?
- Spot scanning
- Multiple beams – Gantry design
- Range of ions
- Compact
- Cheap
- Easy to operate
- Faster throughput
- Reliable