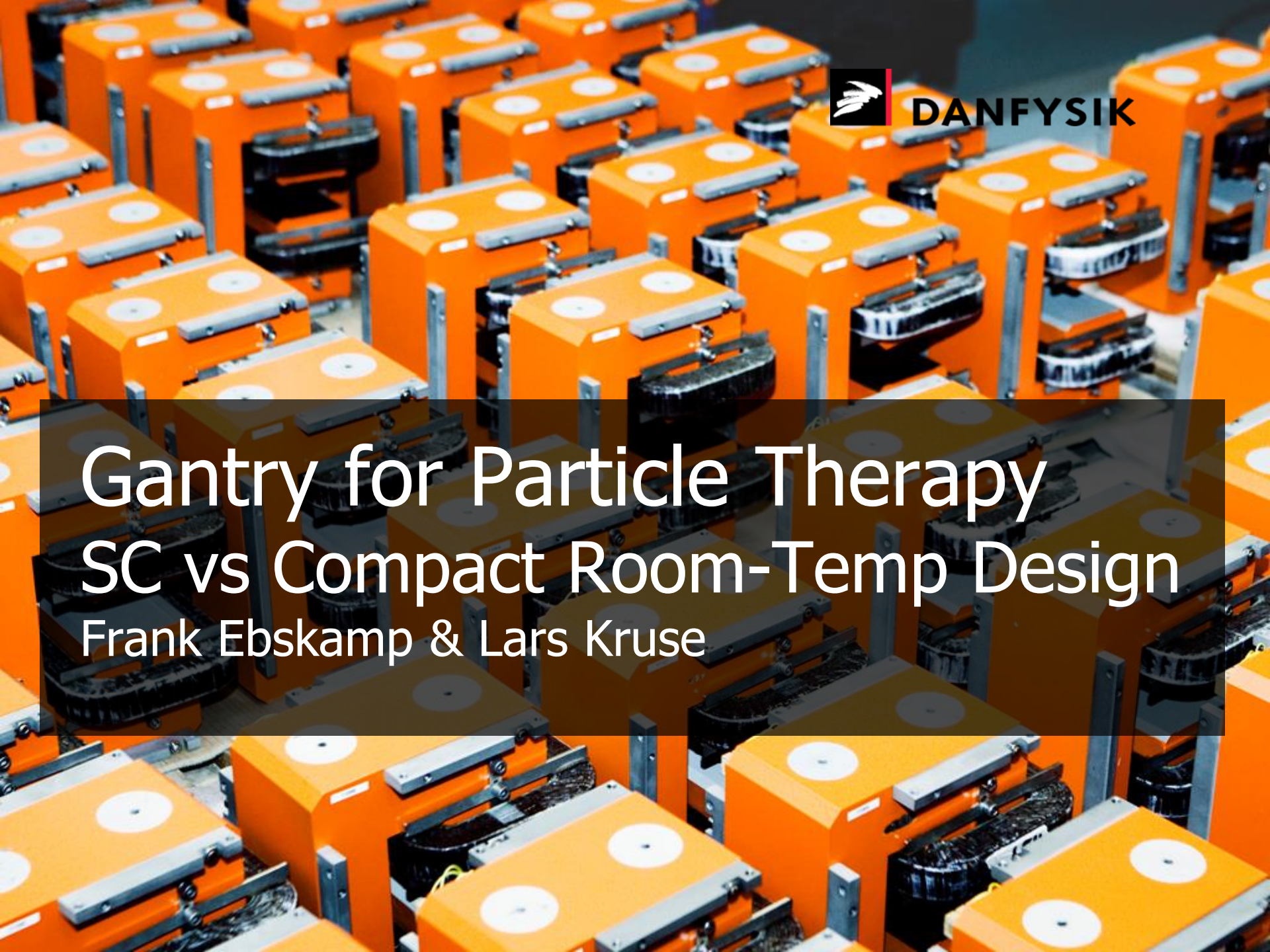

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Gantry for Particle Therapy

SC vs Compact Room-Temp Design

Frank Ebskamp & Lars Kruse

Introduction questions …

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- (Why) do we need a gantry for carbon Particle Therapy?
- Which treatments need a carbon gantry?
  - (… that cannot be achieved with 0 degree, 45 degree and 90 degree beams)
- Which alternative methods exist for these?
  - Rotate patient, rotating chair, send to other hospital …
- Technical challenges, extra cost
  - Isocentric vs Riesenrad
  - Superconducting or room-temparture
- Are hospitals willing to pay for the extra investment?
  - Can they charge more for the treatment?

Overview of presentation

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- Introduction to Danfysik
- Danfysik Particle Therapy history
- Carbon gantry: superconducting vs room-temperature
- Economic factors, comparison
- Compact gantry (for proton & Helium)
- Conclusion

Danfysik Products

DANFYSIK

50 YEARS
excellence in acceleration technology
DANFYSIK

- Supplier of technology for particle accelerators
- Magnets (fast, slow, compact, PM, SC), Insertion Devices
- Ultra-stable power supplies
- Turn-key accelerator systems
- Installation, commissioning and after-sales service
- Customers: research, industry, health-care

System Design → Detailed Design → Production & Procurement → Test & Validation → Installation + Com-missioning → After Sales & Service

DANFYSIK worldwide customer base

Danfysik PT history

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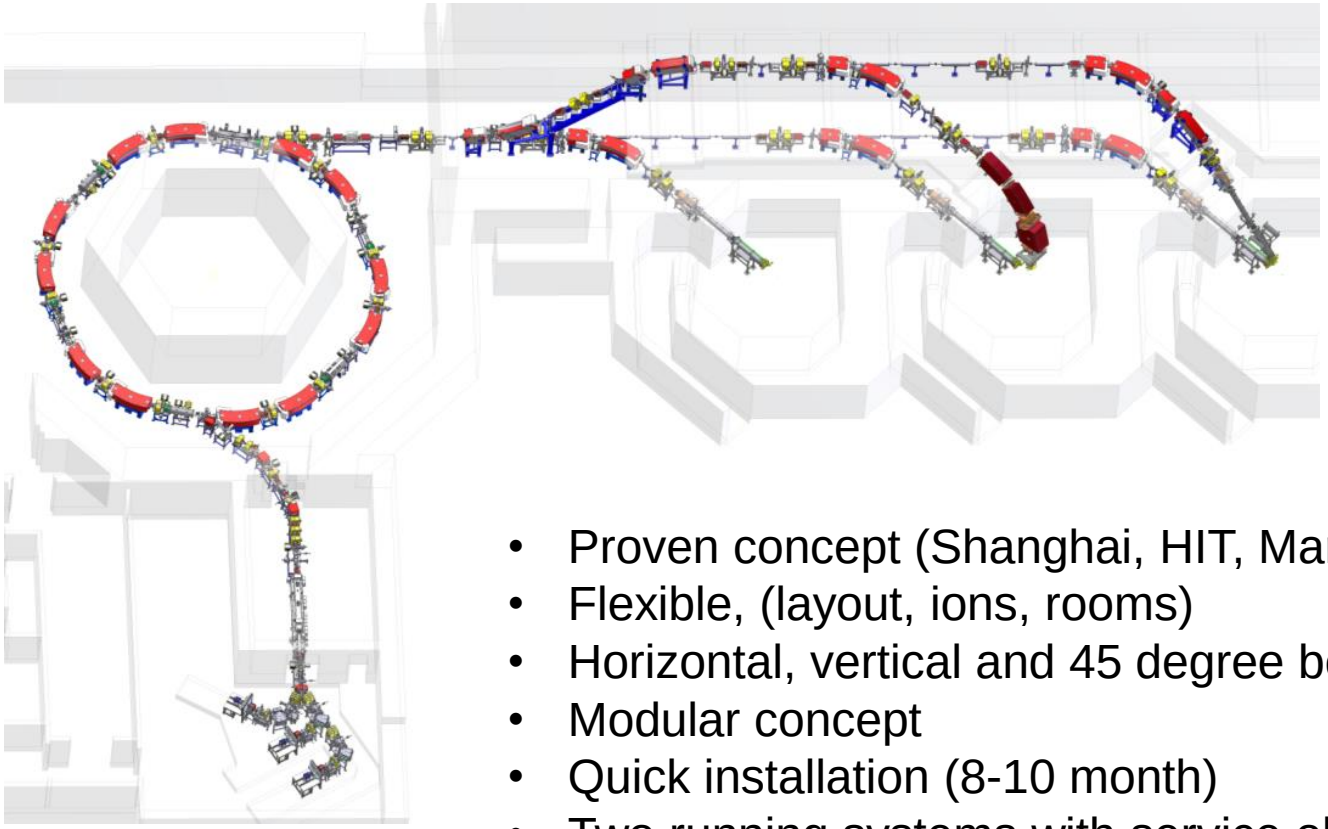
Danfysik has since 1997 supplied complete accelerator systems

- 6 complete accelerator systems installed
- For these deliveries Danfysik provided:
  - System design
  - Product design
  - Production, sourcing, integration, test
  - Installation and commissioning
- 3 of these are complete C+/P particle therapy systems with Siemens in
  - Marburg
  - Kiel
  - Shanghai
- Integrated in the medical ”front end”
- Shanghai accelerator uptime >95% since November 2013
- In dialogue with other healthcare providers to extend our capabilities in PT

Danfysik PT accelerator



- Proven concept (Shanghai, HIT, Marburg)
- Flexible, (layout, ions, rooms)
- Horizontal, vertical and 45 degree beams
- Modular concept
- Quick installation (8-10 month)
- Two running systems with service obligations 10-15 years

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Gantry

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Carbon Gantry: SC vs RT

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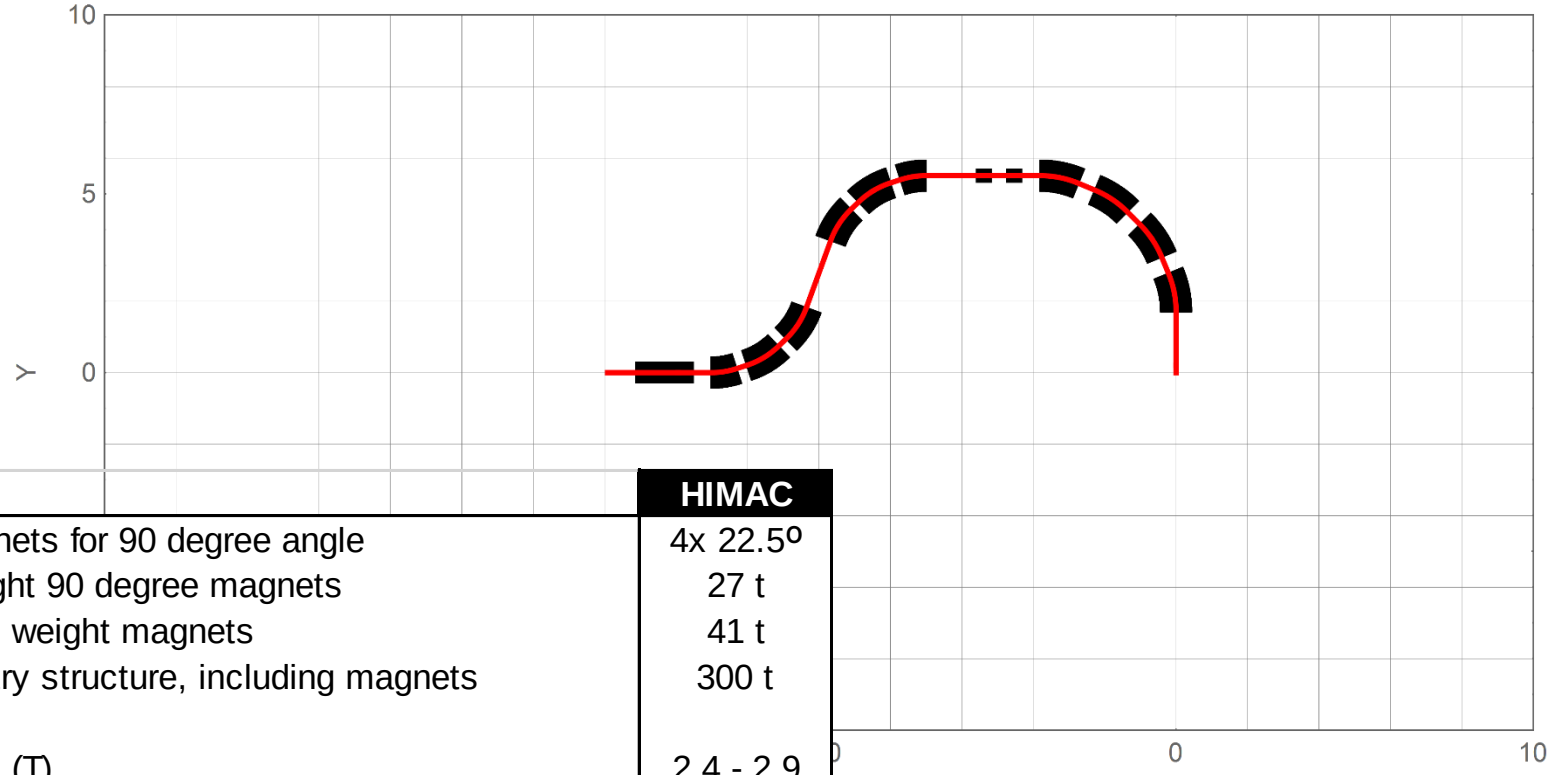
- SC magnets advantage: smaller size, lower weight, lower power (?)
- Added complexity for cryo cooling – on a rotating structure
- Ramping speed:
  - Does this impact the operation & the number of patients per year ?
- Reliability:
  - Failure rate for room-temp magnets is very low,
  - Failure rate for mature SC magnets is very low, what about new type SC ?
  - Recovery from quench can be very long

- Compare three cases: HIMAC SC, HIT RT, Danfysik RT

SC Carbon gantry (HIMAC)



	HIMAC
Magnets for 90 degree angle	4x 22.5º
Weight 90 degree magnets	27 t
Total weight magnets	41 t
Gantry structure, including magnets	300 t
Field (T)	2.4 - 2.9
Scanning area (mm)	200x200
Source to axis distance	>30
Size of gantry	19 x 12 m
Power consumption estimate (MW)	0,3
Energy estimate (GWh/y)	2,6

- 10 SC magnets
- 90º magnet = 4x 22.5º
- Power consumption from cryo pumps (always on)

Room temp C gantry (HIT)

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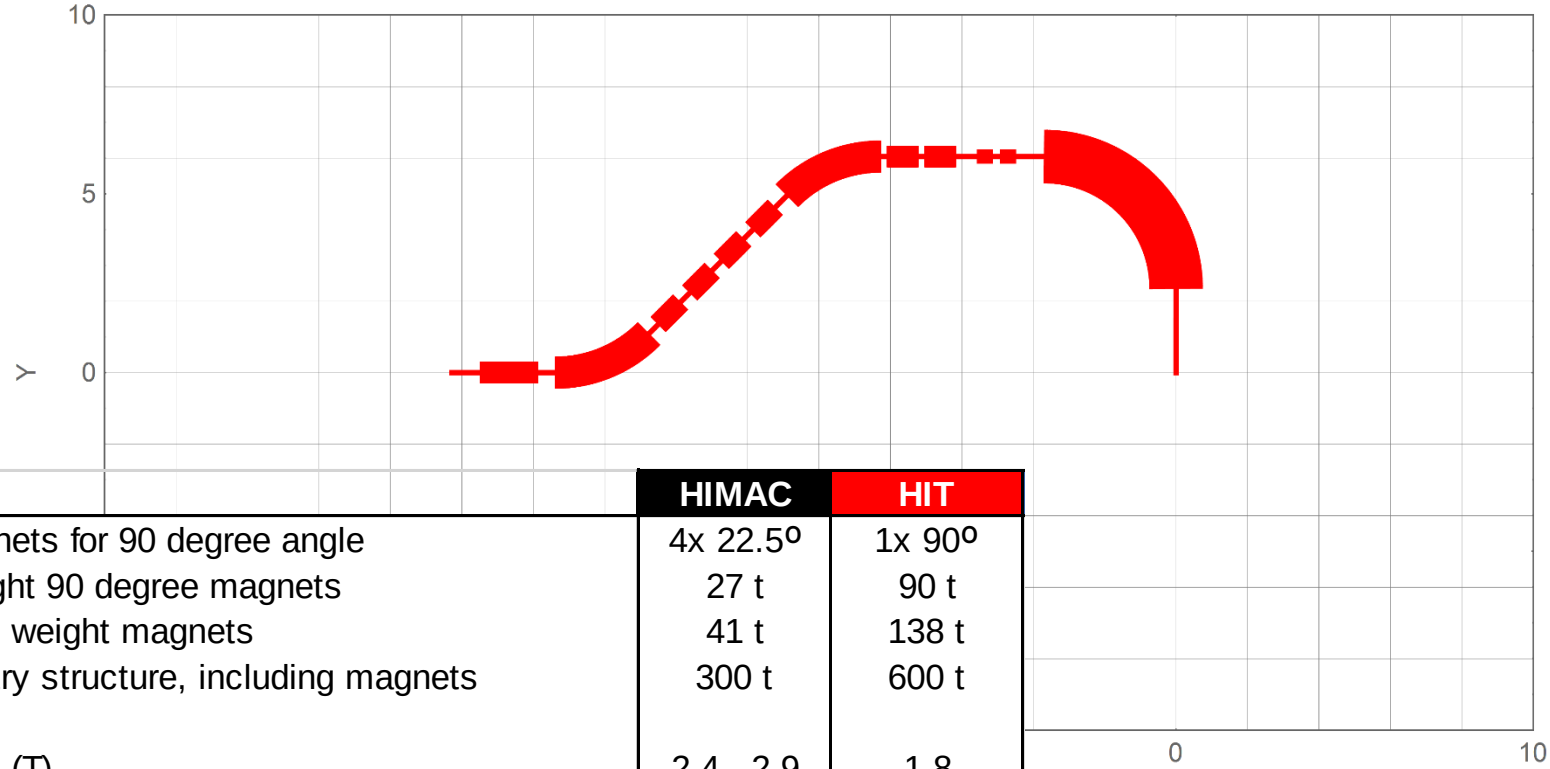
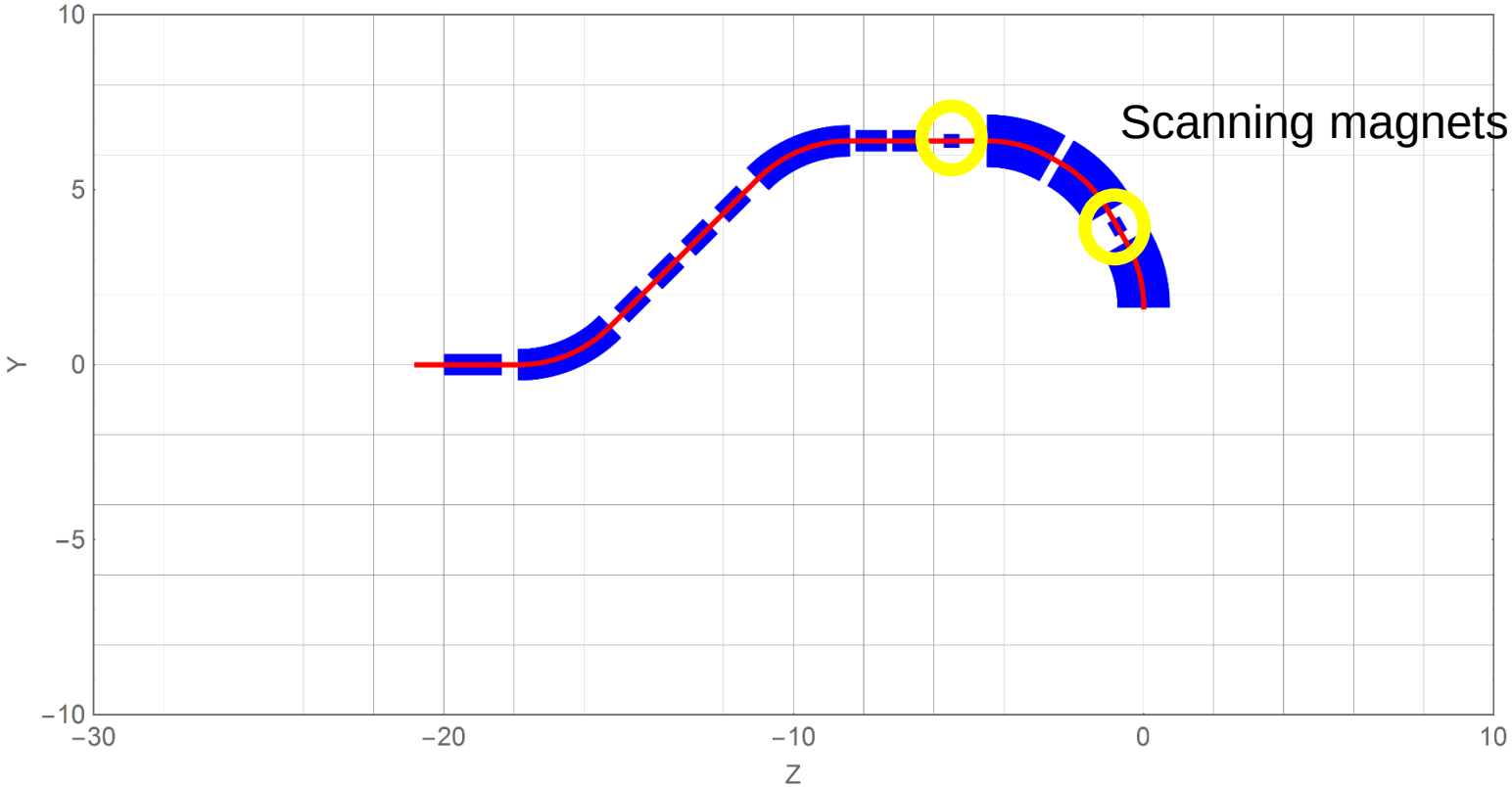


	HIMAC	HIT
Magnets for 90 degree angle	4x 22.5º	1x 90º
Weight 90 degree magnets	27 t	90 t
Total weight magnets	41 t	138 t
Gantry structure, including magnets	300 t	600 t
Field (T)	2.4 - 2.9	1.8
Scanning area (mm)	200x200	200x200
Source to axis distance	>30	>30
Size of gantry	19 x 12 m	25 x 13 m
Power consumption estimate (MW)	0,3	0,8
Energy estimate (GWh/y)	2,6	2,1

- 90º magnet one single device
- Power consumption from electromagnets, only on during treatment

Room temp C gantry (Danfysik)



- Similar to HIT, 90º magnet split into three 30º magnets
- Scanning magnet before the last 30º magnet
- Reduction of weight of the magnets and the gantry structure

Room temp gantry magnets

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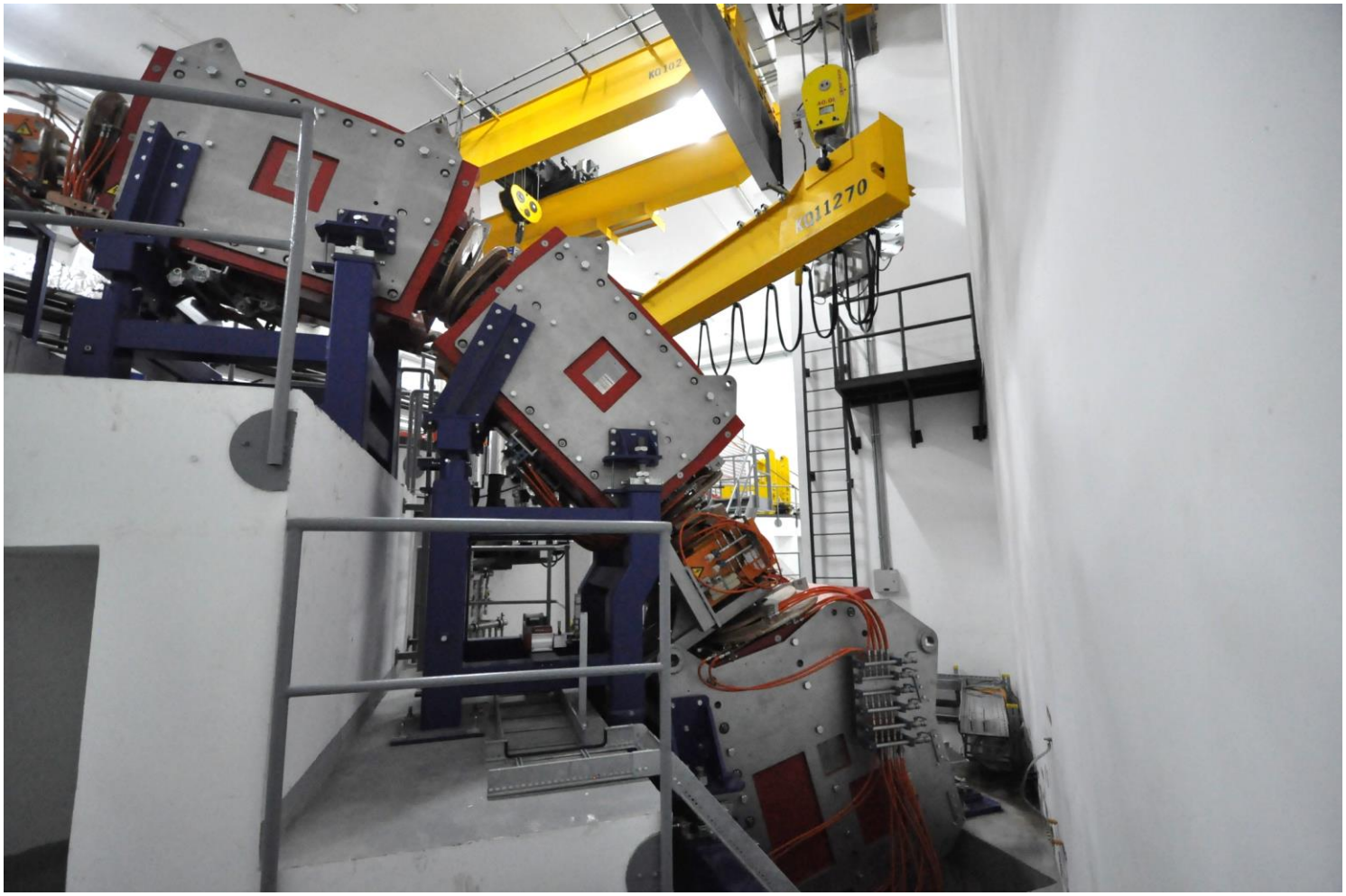
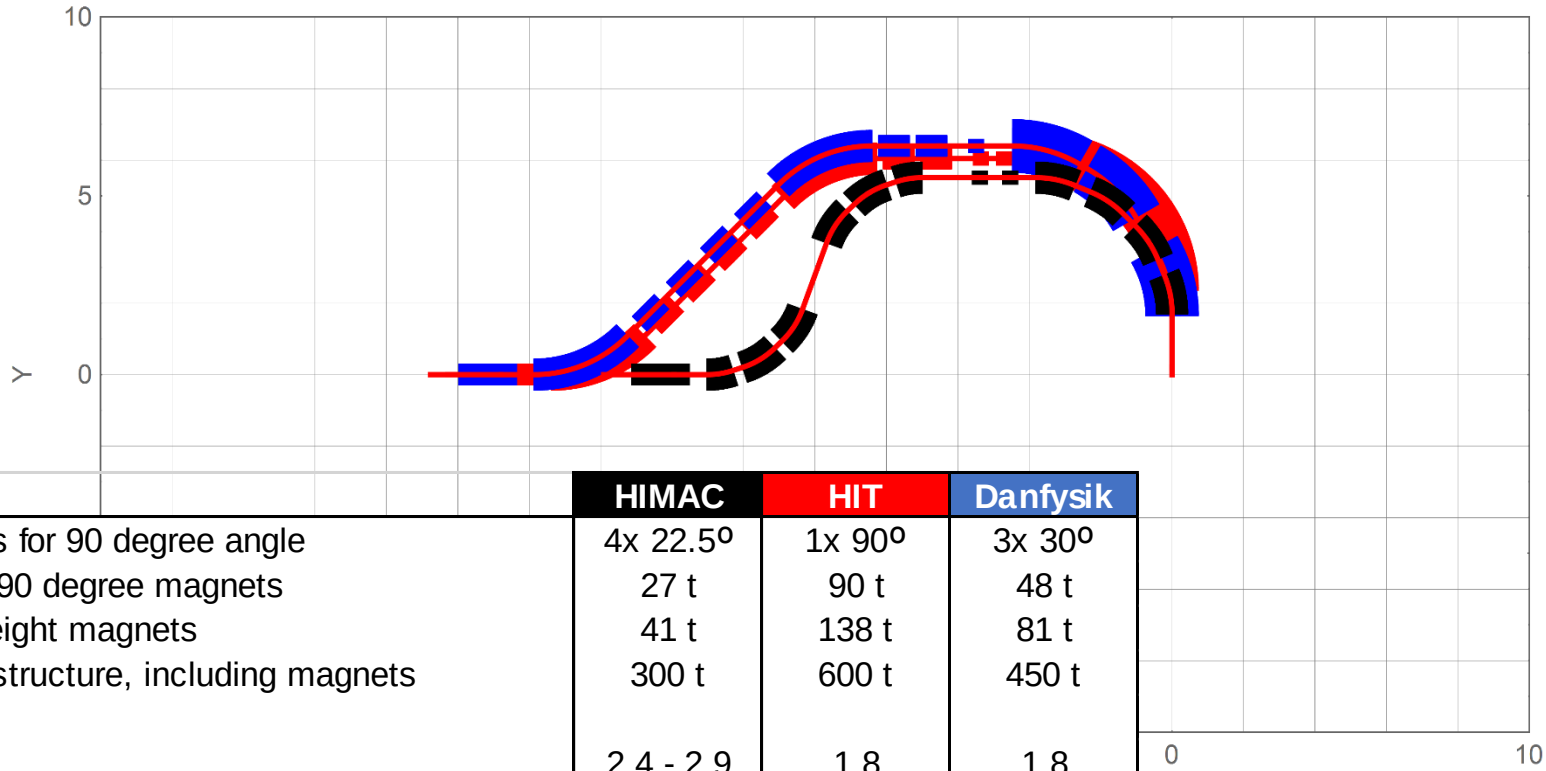


- Photograph of installed vertical beam-line

Comparison C gantries



	HIMAC	HIT	Danfysik
Magnets for 90 degree angle	4x 22.5°	1x 90°	3x 30°
Weight 90 degree magnets	27 t	90 t	48 t
Total weight magnets	41 t	138 t	81 t
Gantry structure, including magnets	300 t	600 t	450 t
Field (T)	2.4 - 2.9	1.8	1.8
Scanning area (mm)	200x200	200x200	200x200
Source to axis distance	>30	>30	4.5; >30
Size of gantry	19 x 12 m	25 x 13 m	25 x 14 m
Power consumption estimate (MW)	0,3	0,8	0,7
Energy estimate (GWh/y)	2,6	2,1	1,9

- Danfysik vs HIT:
- Smaller weight
- Similar size
- Lower power

Comparison: economic estimates

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	HIMAC	HIT	Danfysik	Δ
CAPEX (MEUR)				
Magnets	14,0	7,0	6,0	8,0
Gantry structure	5,0	10,0	8,0	-3,0
Gantry room (additional concrete)	3,4	4,3	4,5	-1,1
Gantry room relative to entire building	*9%*	*11%*	*11%*	
Cryo systems	2,0			2,0
Power supplies	1,0	2,0	2,0	-1,0
Total CAPEX	**25,4**	**23,3**	**20,5**	
OPEX (MEUR/year)				
Electricity	0,8	0,6	0,6	0,2
Maintenance (15% of Equipment Capex)	3,3	2,9	2,4	0,9
Other	0,2	0,2	0,2	
Total Opex	**4,3**	**3,7**	**3,2**	
10 Year total cost	**68,3**	**60,1**	**52,2**	
Total for 10 years, if price of SC magnets = 7 MEUR	*50,8*	*60,1*	*52,2*	

- Numbers reflect our best estimate and assumptions:
- SC magnets higher price than room-temp magnets, cryo systems: 0.2 M€ per magnet
- Gantry structure smaller for HIMAC, therefore lower price
- Investment for gantry room building structure, relative to entire building (~40 M€)
- SC magnets run continuously (cooling), room-temp magnets 20 min/h, 10 h/day
- Maintenance per year: 15% of Capex

Compact One-Room solution

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- Integrated accelerator and gantry in one
- Proton energy range 70 – 250 MeV
- 3He energy Range: 410 MeV (137 MeV/u)
  - Equal to 10 cm penetration
- Rotating gantry with a rotation angle larger than 240°
- Synchrotron based accelerator:
  - Energy variation without degradation of the beam
  - No radiation from Energy reducing degrader
  - Optimized for protons and Helium ions, No other compact system can provide Helium
  - Inter-treatment switching of Ions
  - R&D with other Ions
- IMRT PBS Raster scanning, Adjustable beam size 5 – 20 mm
  - Easy and flexible adaptation of treatment plan to tumor geometry
- One room setup
  - Compact size, low civil engineering cost
  - Modular build up, fast installation and easy logistics
  - Less secondary radiation and shielding requirements

Patent pending

Conclusion

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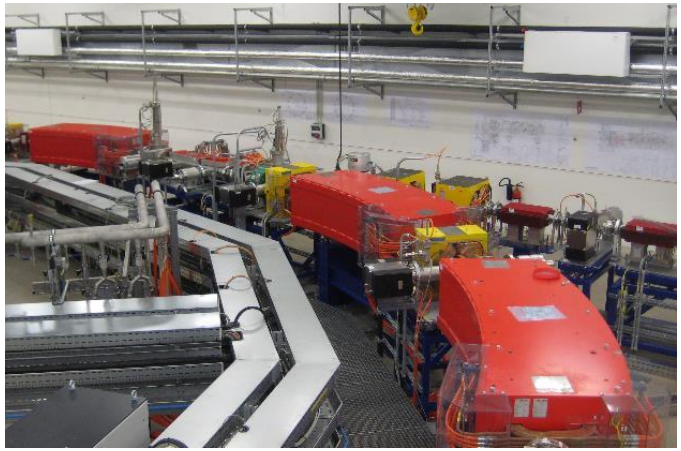
- Choice of gantry technology: *technical* and *economical* considerations
- Superconducting magnets: stronger field, smaller size and lower weight
- Size of magnets -> size of gantry -> size of gantry room building structure: only a *minor difference*, relative to entire building
- Superconducting magnets run continuously, *room-temperature* magnets only run during treatment, and have thus *lower power* consumption
- *Economic* arguments (Capex & Opex) seem to *favour room-temperature* gantry
- Room-temperature solution based on *field proven* technology
- One-Room very compact synchrotron gantry solution for proton & Helium



Questions ?

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