

Ion Beam Therapy Facilities – A Perfect Working Environment for Accelerator Physicists

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*Heidelberg Ion Beam Therapy Centre (**HIT**)*

4th LA³NET Topical Workshop –
Scientists go Industry

Some words to my person

- Studied physics in Bonn (1981-1988)
- Started as scientists in accelerator division at GSI in Darmstadt (operation section)
- By 1993 became deputy group leader for beam diagnostics
- In 1999 I shared the team for the HIT accelerator, being responsible for the beam diagnostics equipment
- End of 2000 I became the group leader → FAIR project
- Break in 2006, offer to become head of operation at HIT → switched over to Heidelberg
- Since 2011 we work on spreading the ion beam therapy method to another site, three years of negotiations
- 2014: Start to build up another team for MIT in Marburg

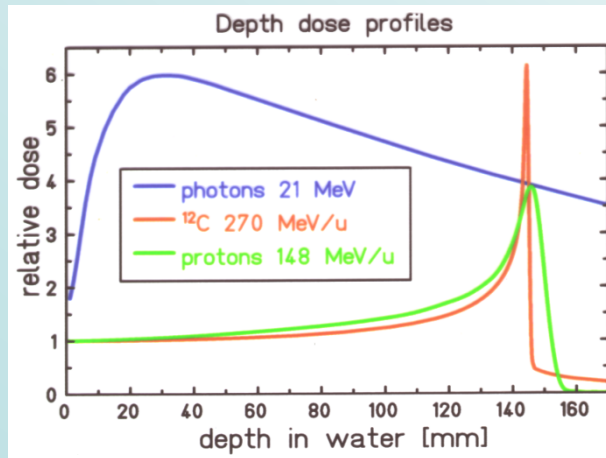
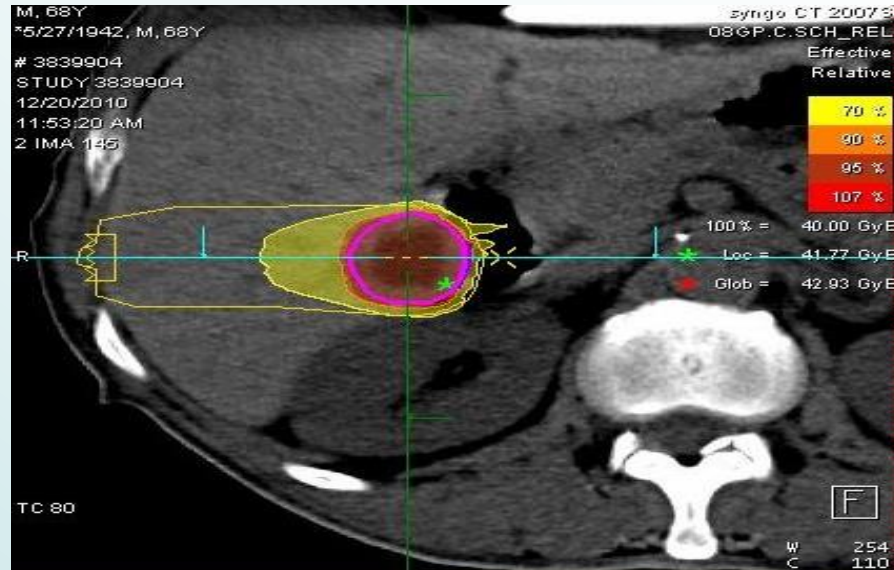
Outline

- Motivation for Ion Beam Therapy
- Combined Linac / Synchrotron Technology used for Particle Therapy
- The *HIT* Facility and its Specialities, e.g. the first world-wide Scanning Ion Gantry
- *HIT* Accelerator and its Tasks: Operation, Maintenance and Developments
- Doubling the Capacity: **MIT**, a second Site at Marburg (Germany) → Commissioning and Recruitment of Accelerator Personnel

Motivation for Ion Beam Therapy

→ Dose reduction in Normal tissue

Therapy beam



X-Rays (photons)
do not slow down

Protons and Ions
stop in the tumor

Motivation for Ion Beam Therapy

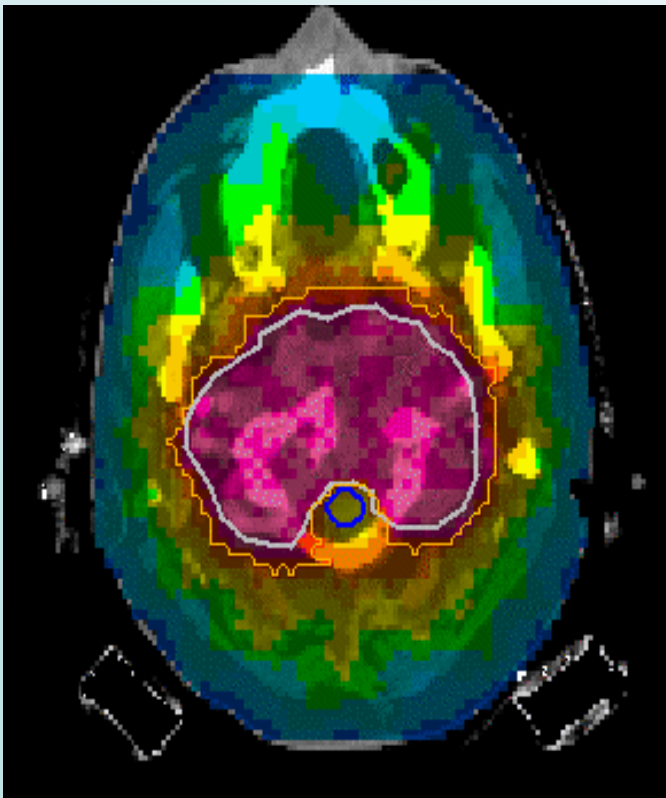
X-Ray Treatment (Rhabdomyosarkom)



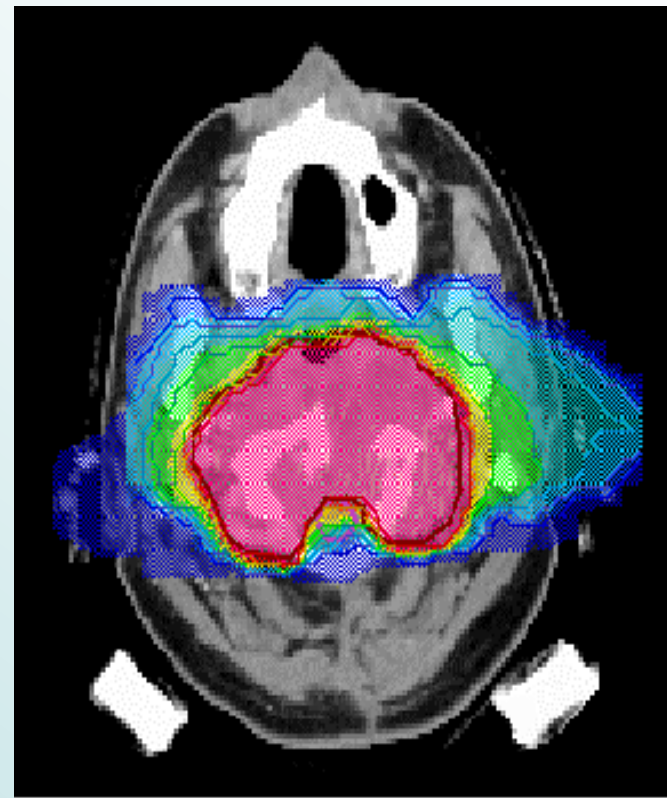
Tumor was successfully treated (photos 5 years later),
but assymetrical face growth remains as a side effect

Motivation – Tumour Conformal Irradiation

X-Rays / IMRT (9 fields)

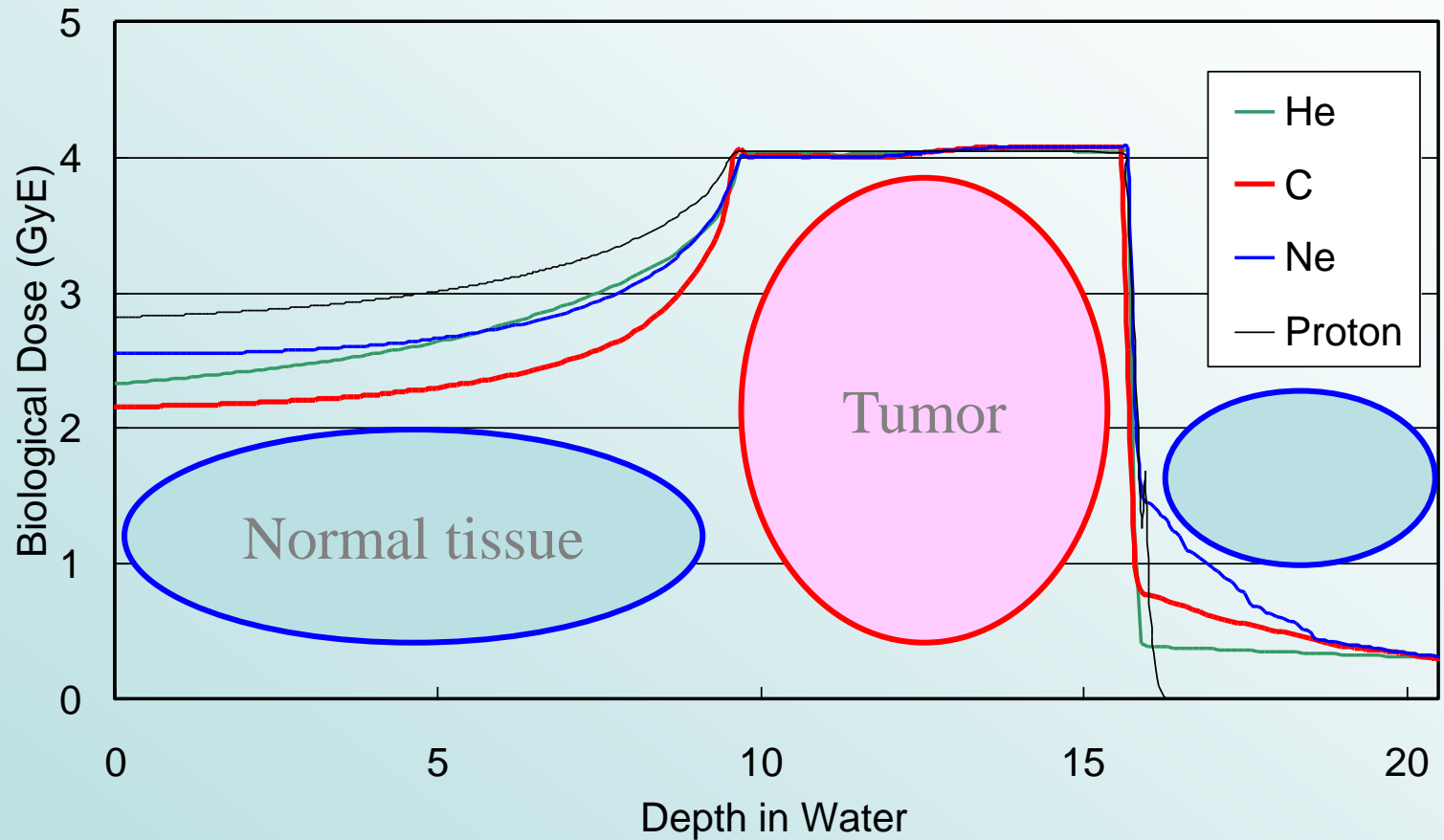


Carbon ions (2 fields)



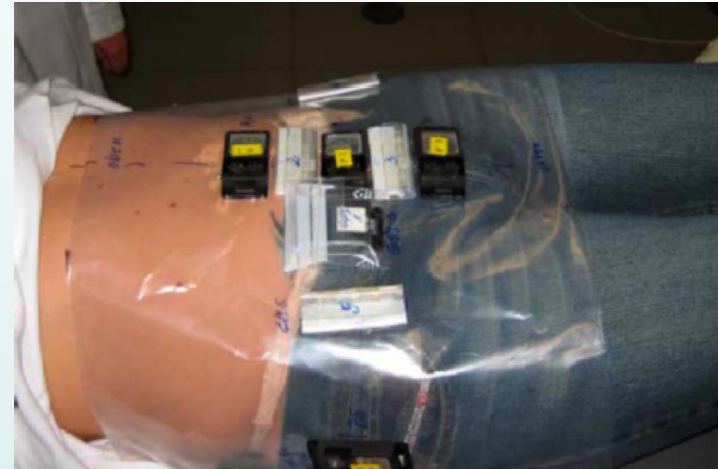
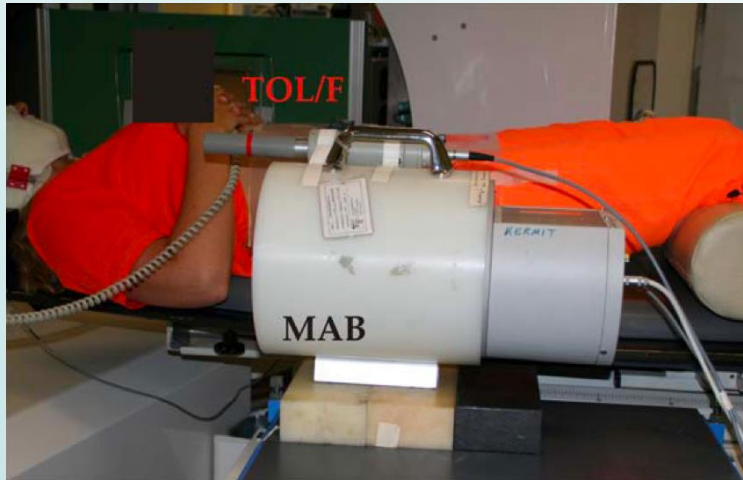
Physics and Biology of radiation therapy

Biological Depth-Dose Distribution of 6cm SOBPs



Motivation for Ion Beam Therapy

Ion beam therapy of a pregnant patient with a subcranial tumor



	photon dose ($\mu\text{Sv}/\text{fraction}$)	neutron dose ($\mu\text{Sv}/\text{fraction}$)	Number of fractions	Total dose (μSv)
Normal field	3.0 *	1.4	15	66
Boost field	2.2 **	1.0	5	16
Total treatment			20	82

Total therapy: Fetal dose corresponds to a 8 hour long-range flight

It does not need an accelerator like this...

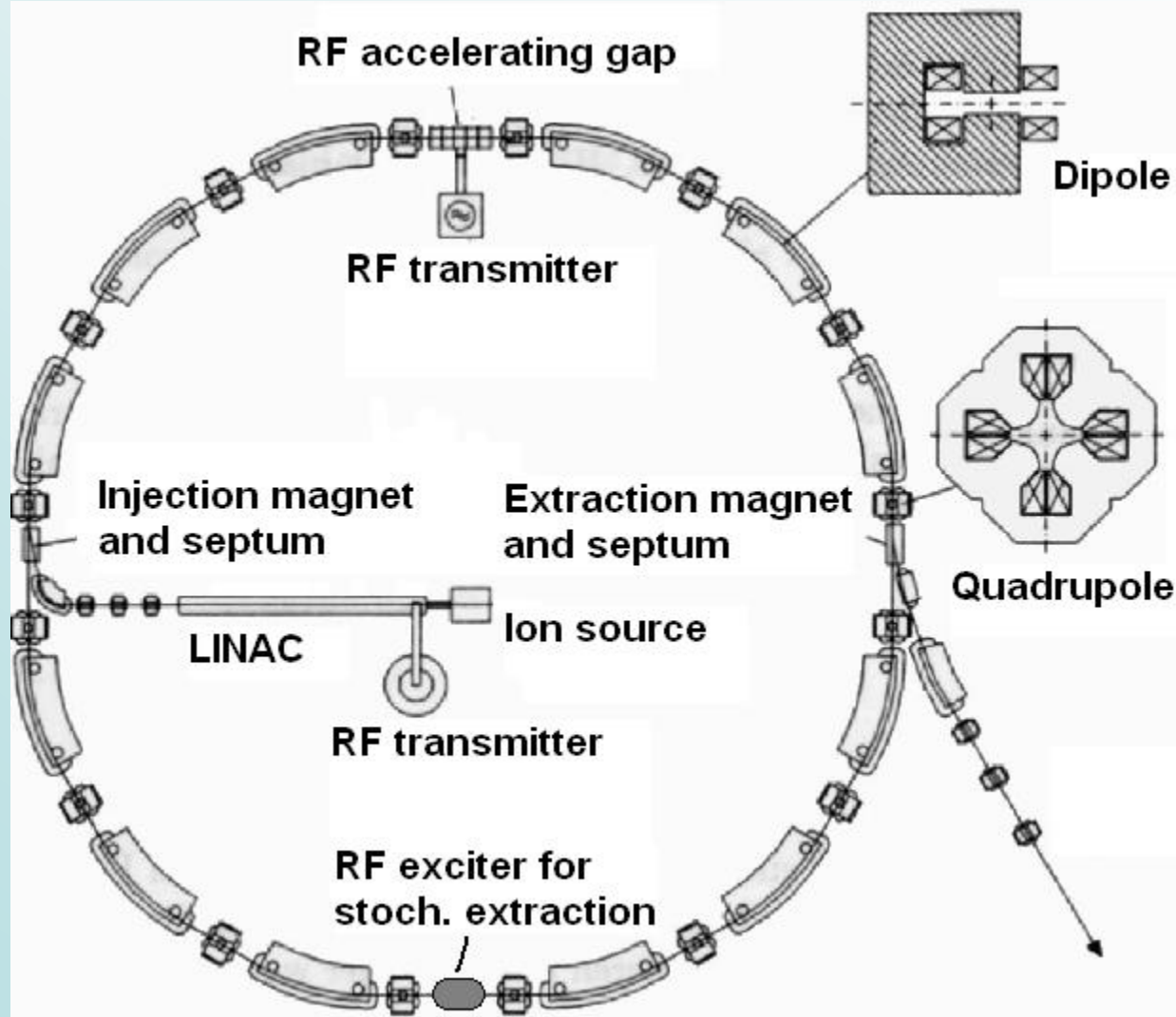
LHC at CERN,
27 km circumference



Superconducting magnets
with up to 8 Tesla

...to carry out cancer therapy

Synchrotrons – principle layout



Injector linac with energies of some MeV/u:

→ $v \sim 10\% c$

Magnetic rigidity:

$p \rightarrow 2,26 \text{ Tm}$

$C \rightarrow 6,6 \text{ Tm}$

With $\sim 50\%$ fill factor for dipoles:

$p \rightarrow \varnothing_{\text{Sync}} \sim 6 \text{ m}$

$C \rightarrow \varnothing_{\text{Sync}} \sim 18 \text{ m}$

Synchrotron facility – operating parameters

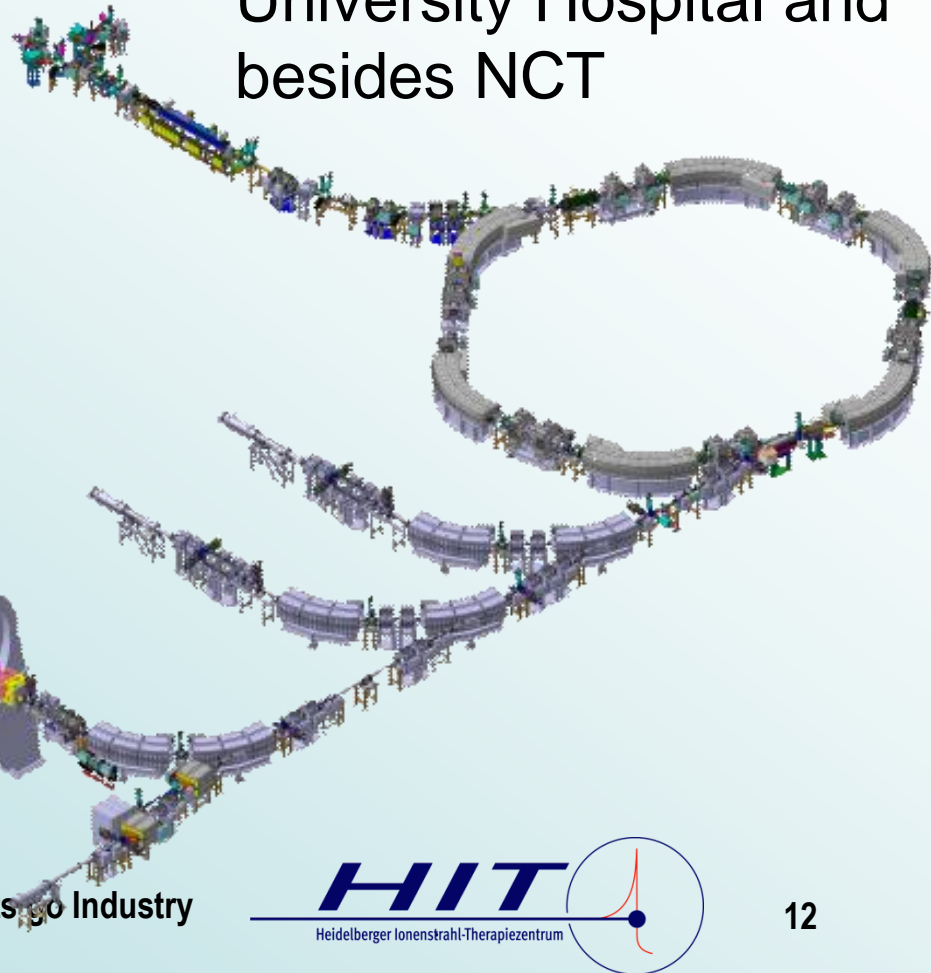
- | | | | |
|---|---|------------------------------------|---------------------------------|
| Ions | : | p | $^{12}\text{C}^{6+}$ |
| • Energies (MeV/u)
(255 Steps) | : | 48
-220 | 88
-430 |
| • Variety of Beam Focus
(4/6 Steps) | : | 4 - 10 mm (2D-gaussian) | |
| • Intensities (Particles/s)
(10/15 Steps) | : | $8 \times 10^7 - 2 \times 10^{10}$ | $2 \times 10^6 - 5 \times 10^8$ |
| • Beam line settings for several treatment/research rooms | | | |

Settings have to be found semi-automatically (good physical theory support needed!) and stored in flash memory libs in the front-end controllers (with database backup).

HIT – An Overview



Compact building (60 x 70 m², 3 levels), directly linked to the “Head Clinics” of the University Hospital and besides NCT

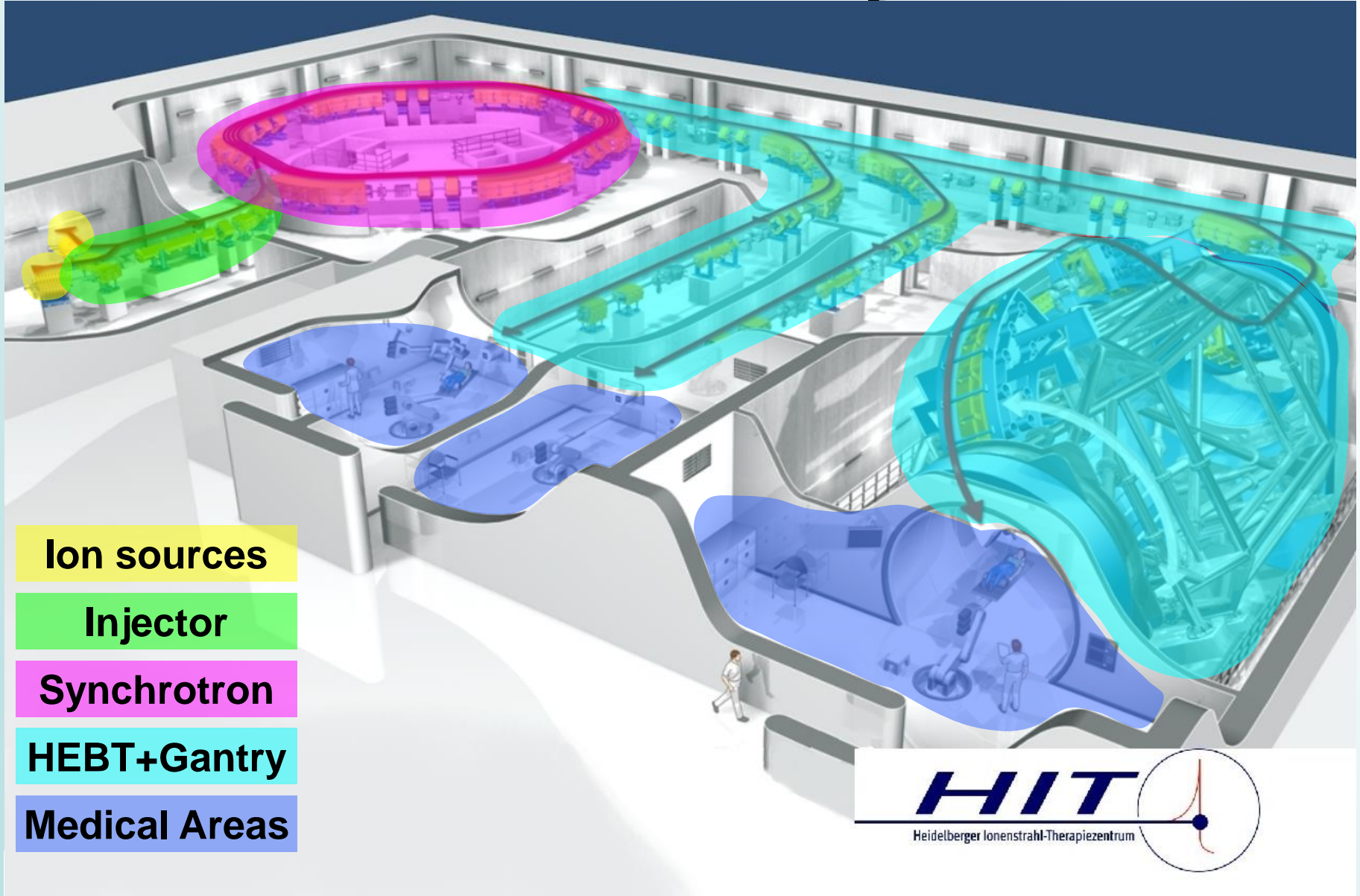


Patient treatment started at 15th November 2009

Layout of the accelerator facility



HIT Accelerator System



Ion sources

Injector

Synchrotron

HEBT+Gantry

Medical Areas



HIT – The Injector

Injector: 2 ECR ion sources (8 keV/u) for proton and carbon ions...

... and following a RFQ and an IH-DTL linac → 7 MeV/u end energy



HIT - Synchrotron and HEBT

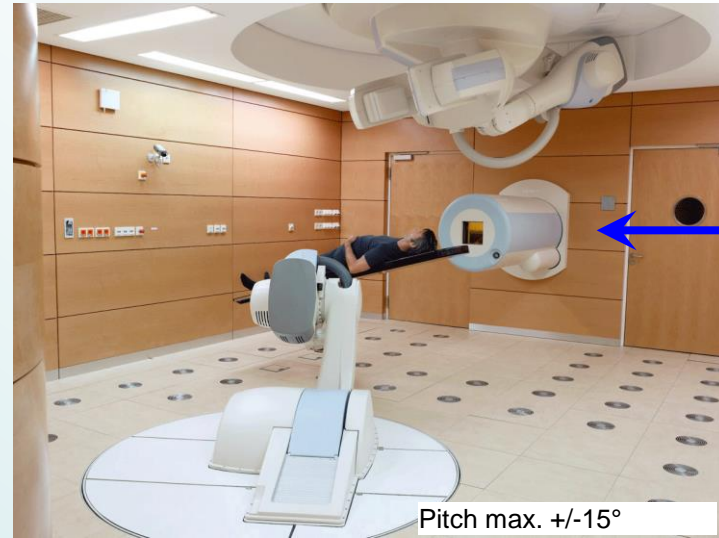


Synchrotron: 6 dipoles with 60° bending and 12 quadrupoles

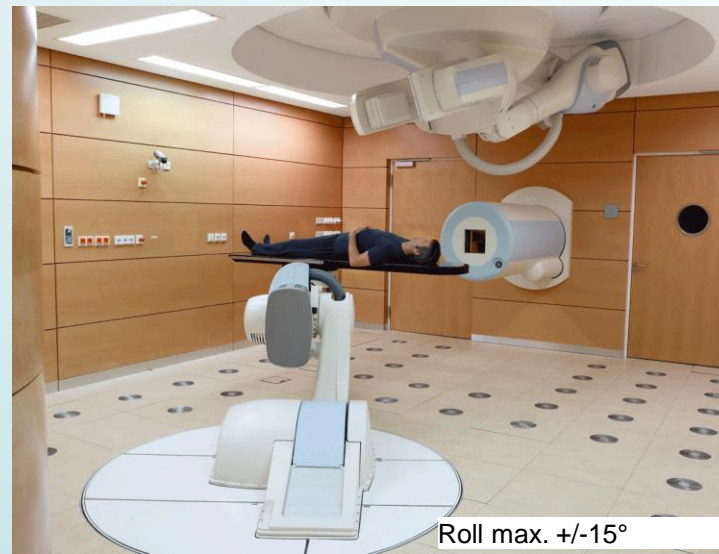
High energy beam transport (HEBT) to fixed beam treatment rooms, gantry and research facility



HIT – Fixed Beam Treatment Rooms



Beam exit



HIT – Ion Gantry Treatment Room



... and what is behind the wall!



Worldwide first isocentric ion gantry – including a scanning system:

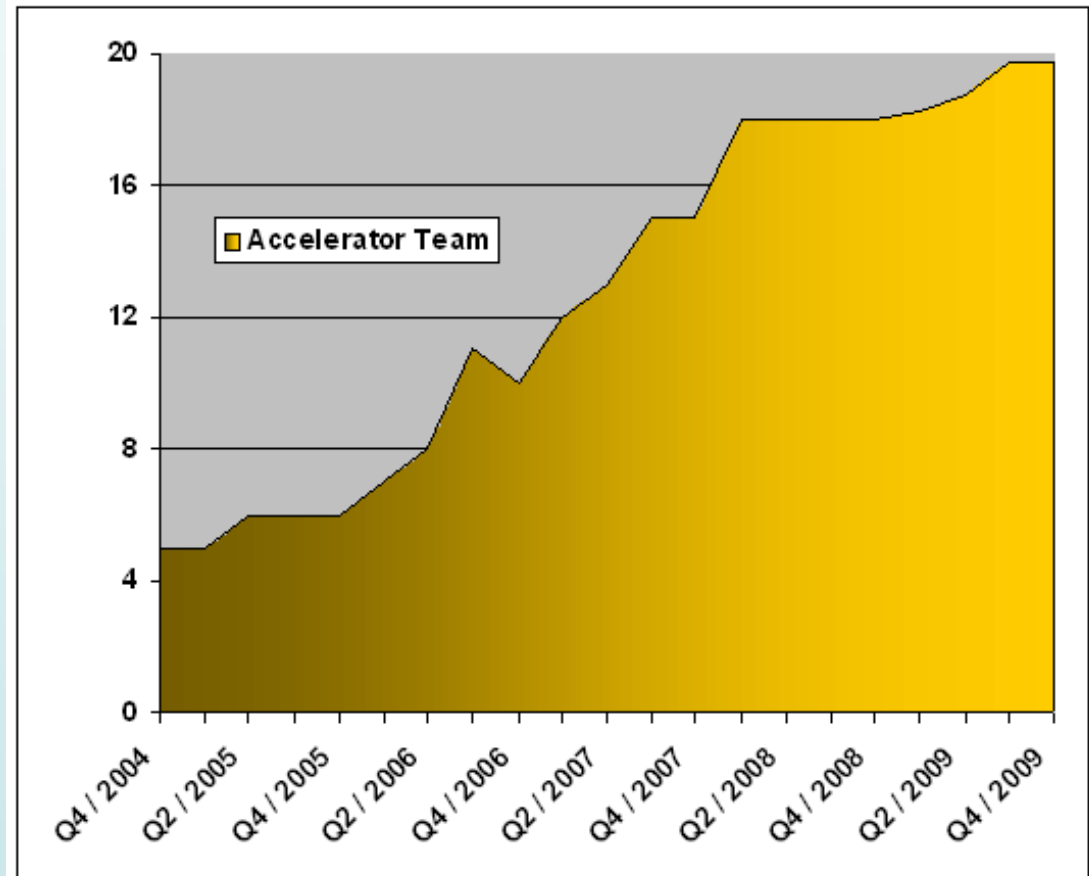
**Ø = 13m
25m long**

600 tons overall weight

0.5 – 1 mm max. deformation

HIT Accelerator Team

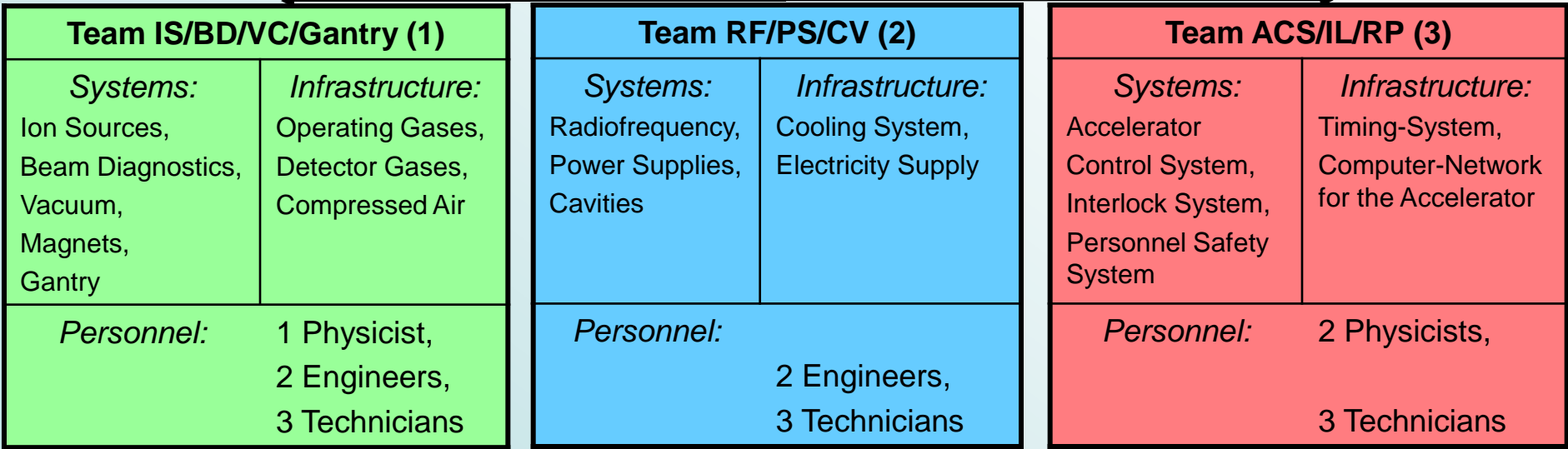
- First employments directly after HIT GmbH foundation in 2004
- Building up of the accelerator team from a core to the full operating crew within four years
- Training of the team done at first by GSI, later on also by companies and especially “in-house”
- Internal organization of three technical teams and a machine tuning crew



Structure of the HIT Accelerator Staff

Head Accelerator Operations
(Physicist)

3 Technical Teams



In total 20 employees: 7 Physicists, 4 Engineers and 9 Technicians
(plus 2 Working Students with mini-jobs)

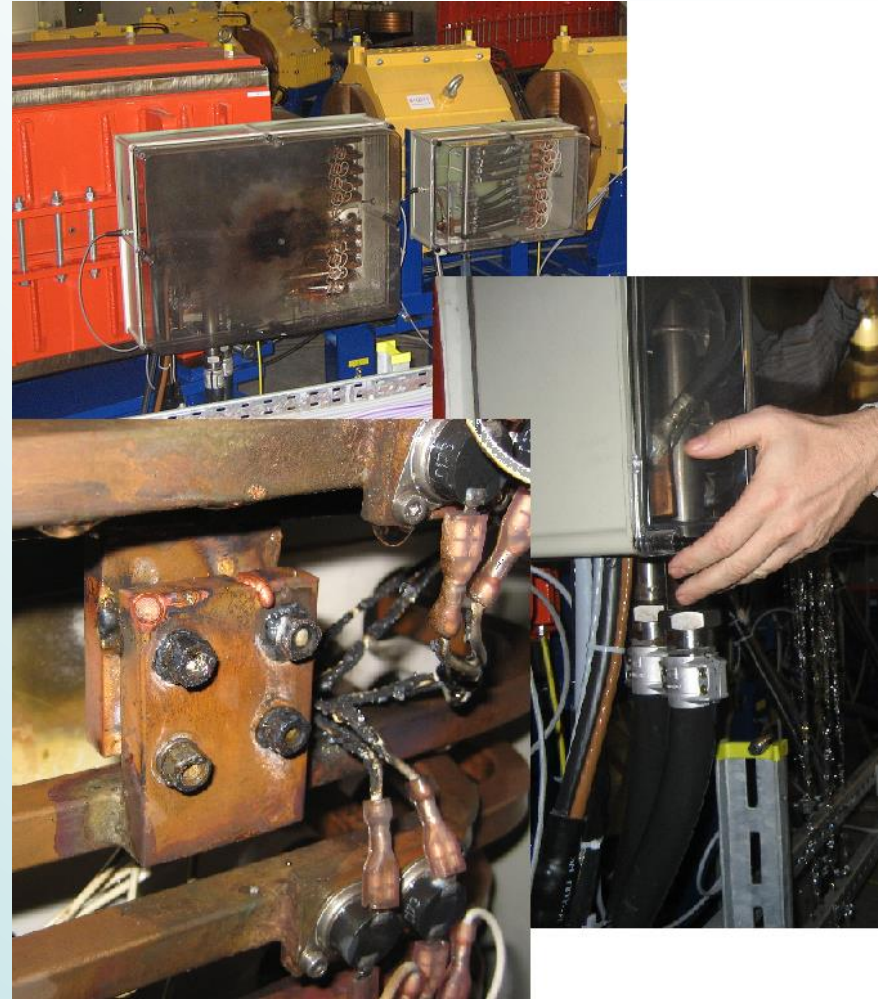
3 Physicists with special tasks, e.g. radiation safety → all physicists form the machine tuning crew

Responsibility for the Accelerator Subsystems

<i>Accelerator subsections</i>	<i>On-call Duty (1st Level Support)</i>	<i>2nd Level Support</i>	<i>Maintenance</i>
Ion Sources, Vacuum, Magnets, Beam Diagnostics, Mechanics	Team 1	No	Team 1
Gantry	Team 1	Yes (partly)	Supplier (HIT)
Power Supplies	Team 2	No	Suppliers
RF-Systems	Team 2	No	Team 2
Control System, PSS, Interlock Systems	Team 3	Supplier	Team 3 (Supplier)
Technical Infrastructure	KTG (Clinics Technics Company)	(Suppliers)	Suppliers, ext. Coord.

HIT Accelerator Shift Operation

- Starting in 2007: Establish regular shift operation from 16/5 to 24/7 mode for further commissioning steps including therapy control system evaluation
- Daily operation consists of supplying beams for different purposes, doing “Therapy Protocols”, analysing and fixing errors, etc.
- In the first two years one main task was to help the supplier company to consolidate the control system
- Troubleshooting: e.g. a destroyed magnet connection box – managing repair within two days



Typical Day at HIT

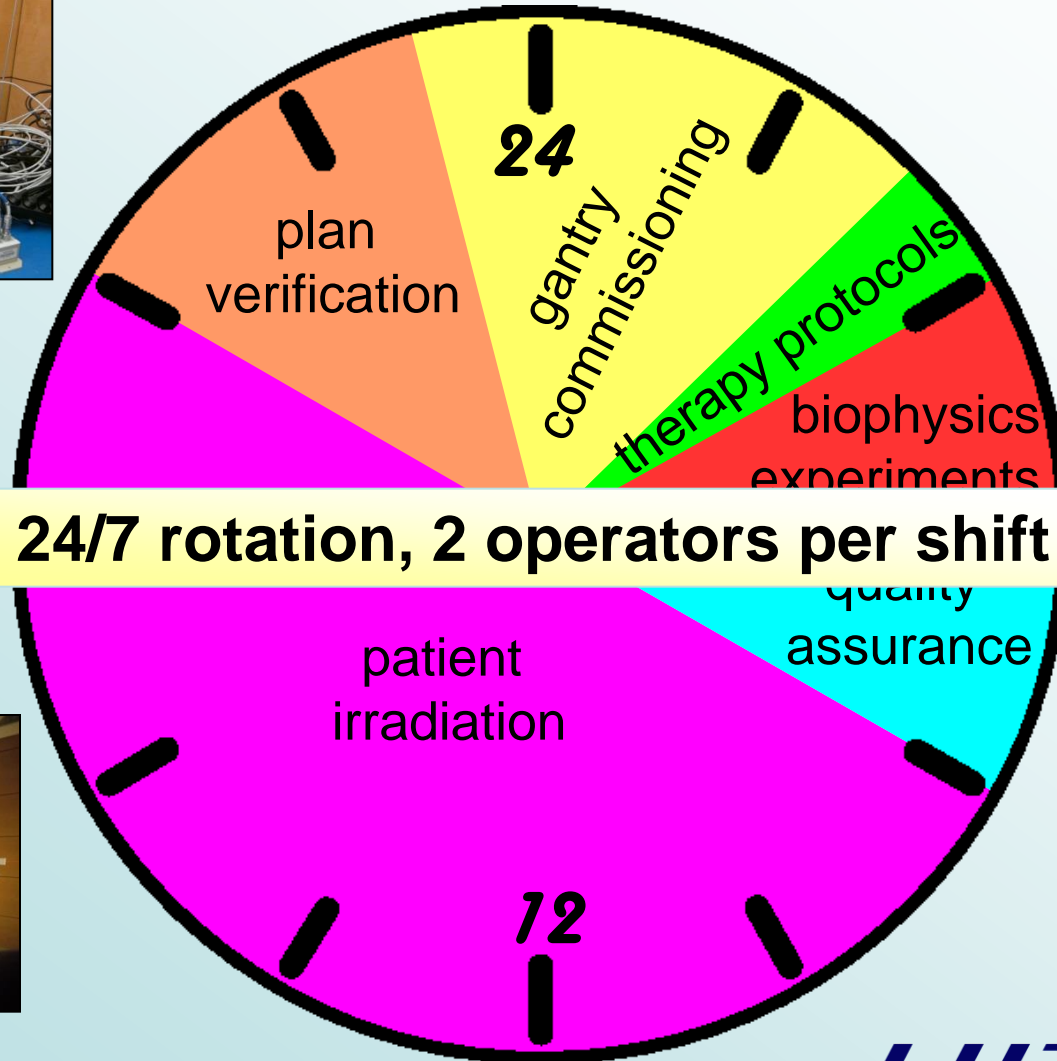
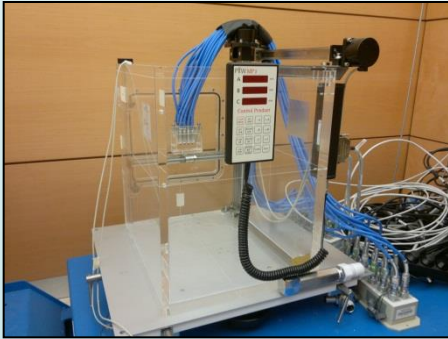
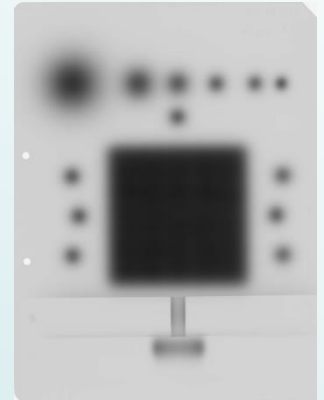


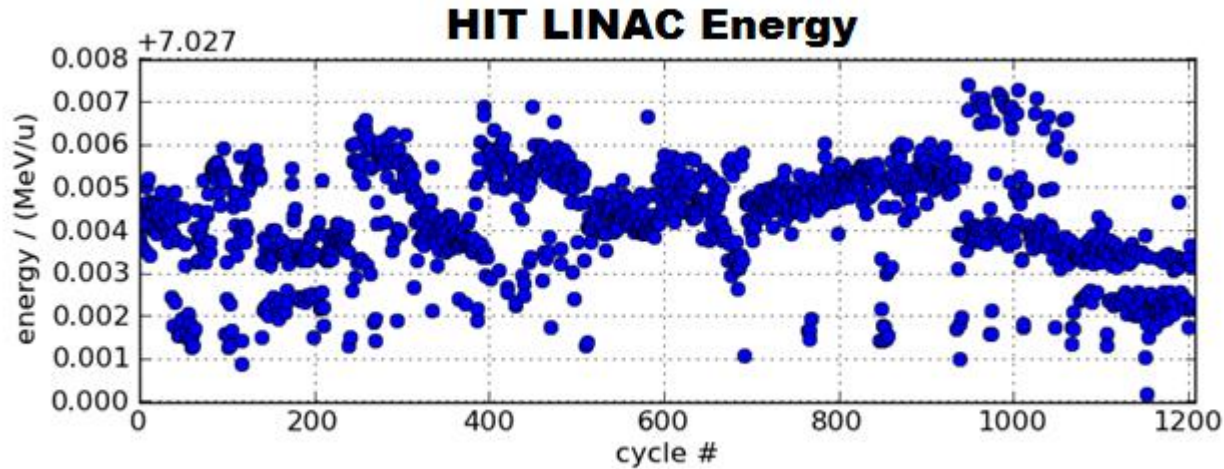
photo by R. Cee



film by P. Heeg

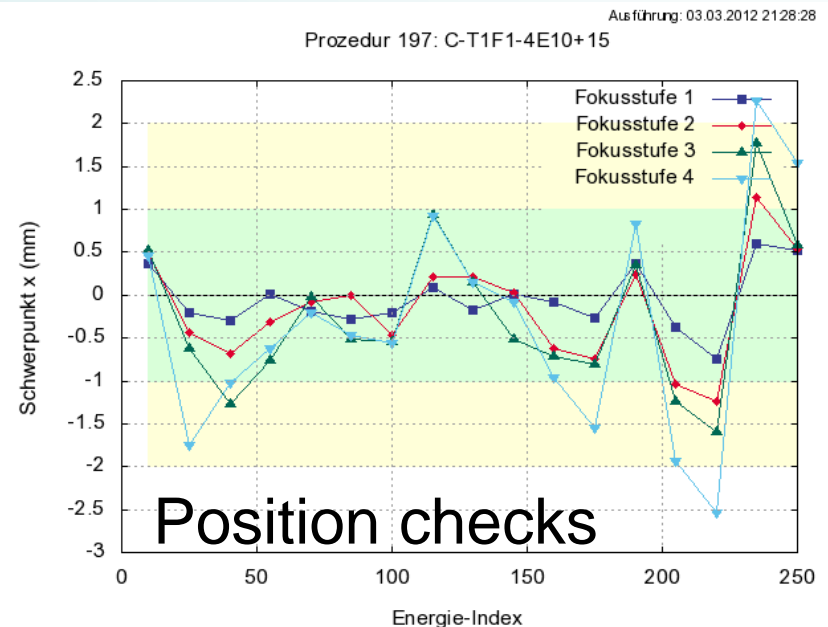
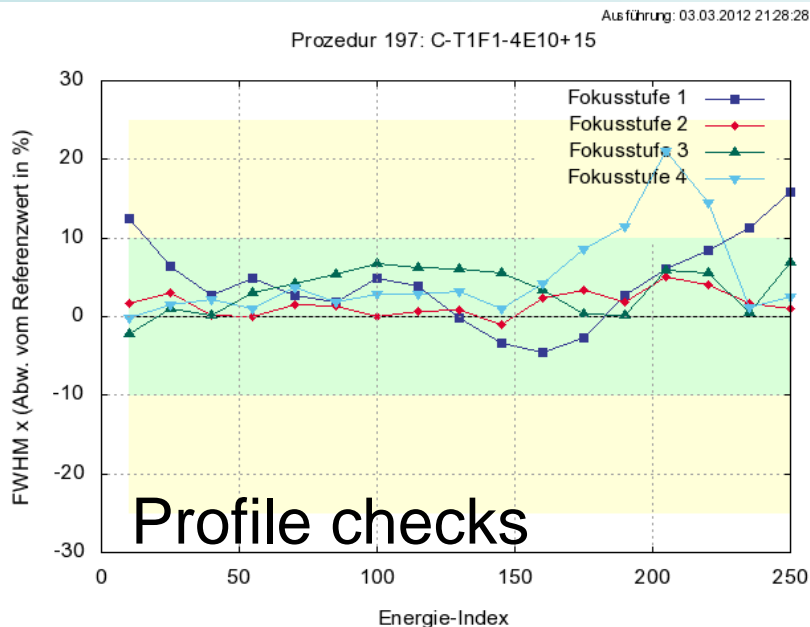


Online and Daily Checks of Beam Parameters

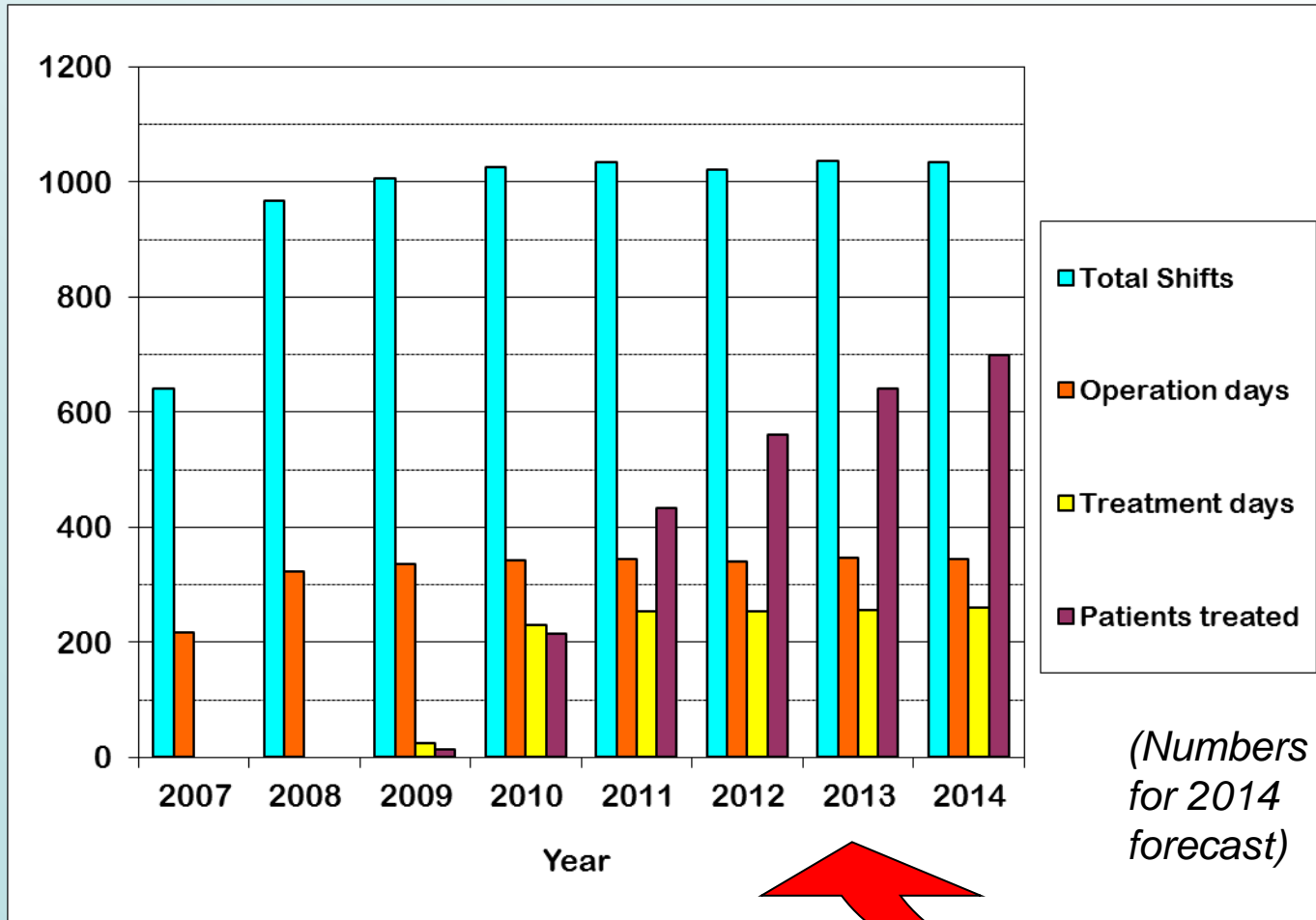


Online measurement of LINAC energy stability

(Data of 5th March 2012)



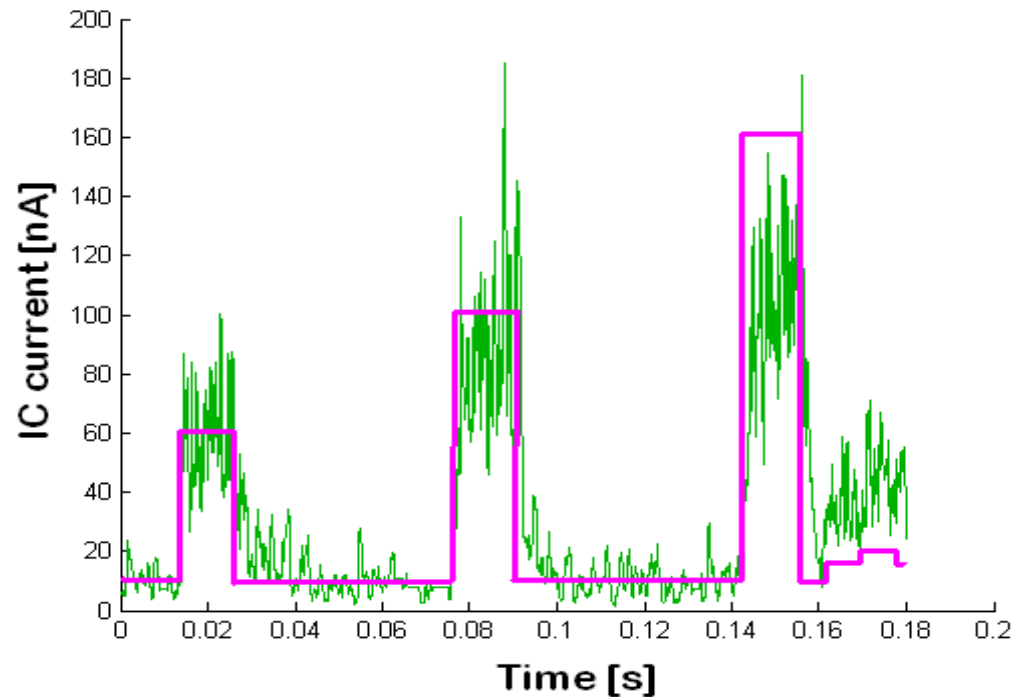
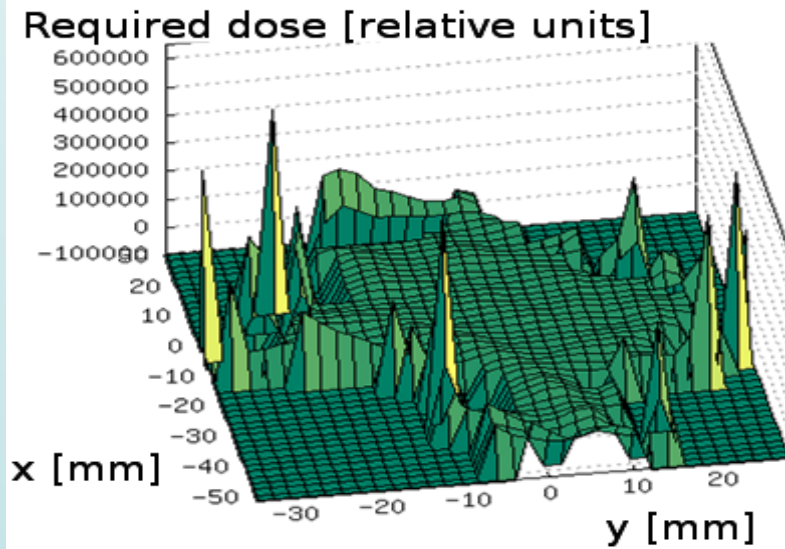
HIT Operation - Statistics



Now 5 years of medical operation → in total: ~2500 patients treated !

2013: Major Upgrade of IONTRIS Treatment Software

An Example for Research and Development at HIT: Dynamic Intensity Control



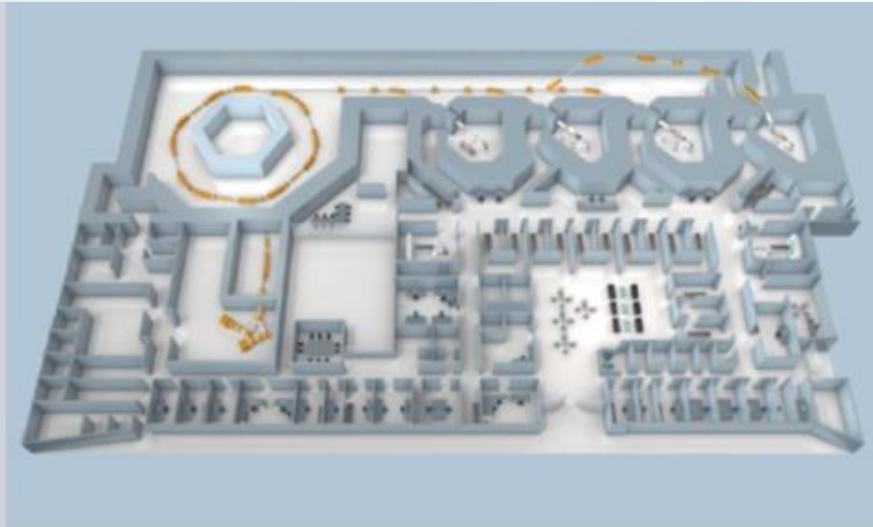
Marburg Ion Beam Therapy Centre (MIT)



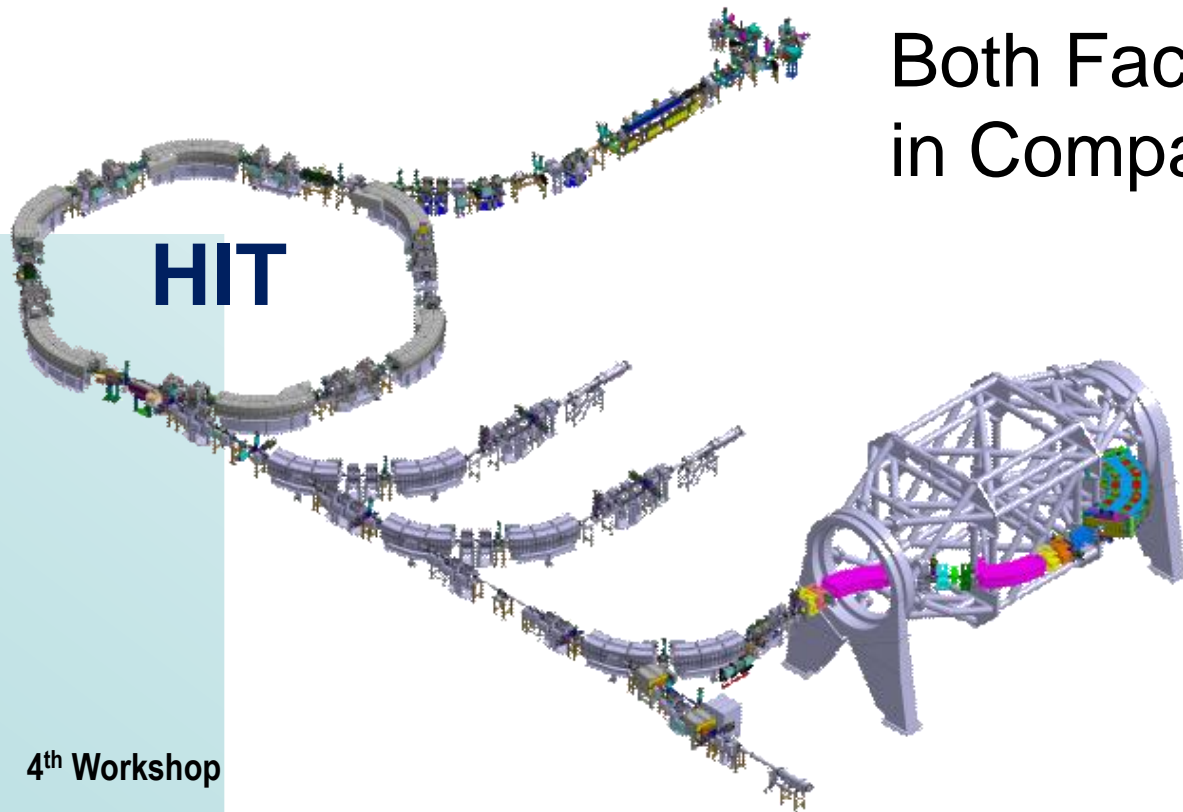
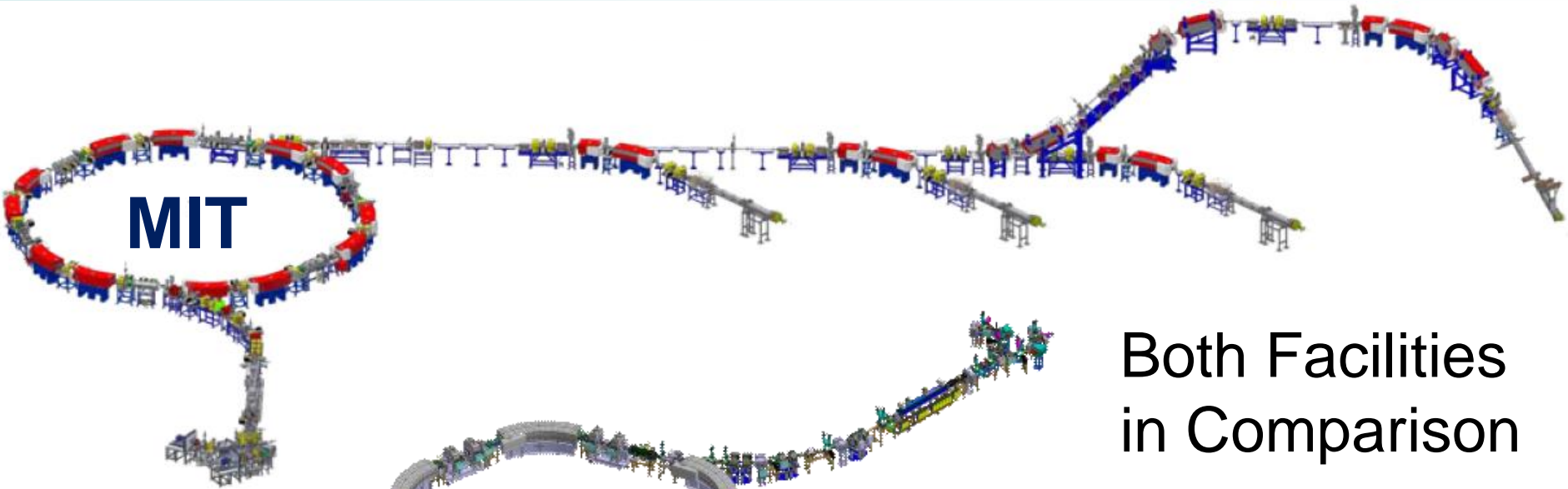
All particle therapy equipment will be provided by Siemens

- 3 rooms with horizontal beams
- 1 room with semi vertical beam

Project start	September 2006
Ground breaking	August 2007
Start of construction	August 2007
Start of installation	August 2008
Start of commissioning	January 2009
Hand over planned	August 2011



Marburg Ion Beam Therapy Centre (MIT)

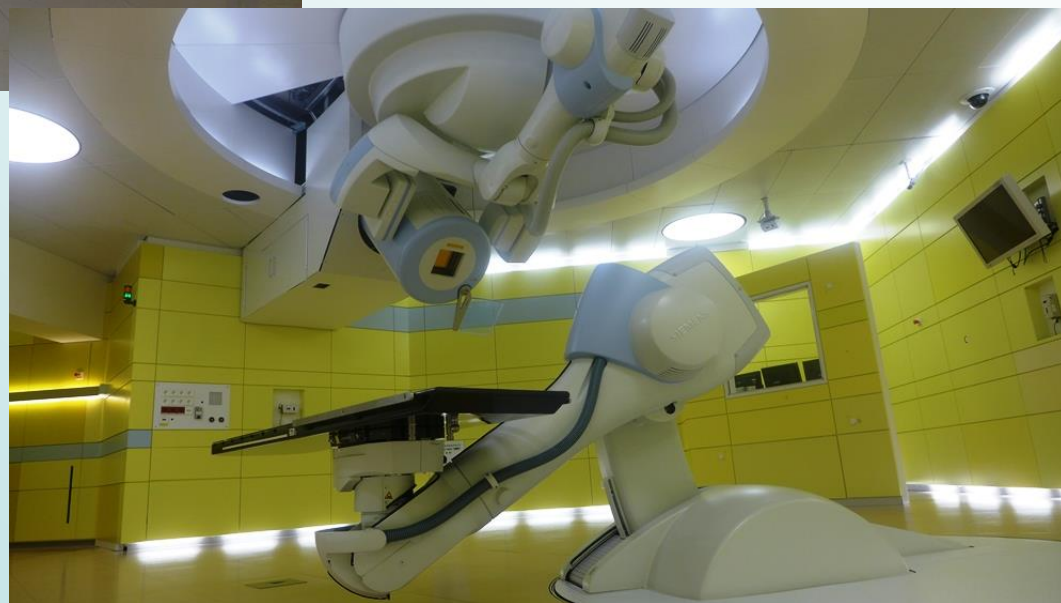


Marburg Ion Beam Therapy Centre (MIT)



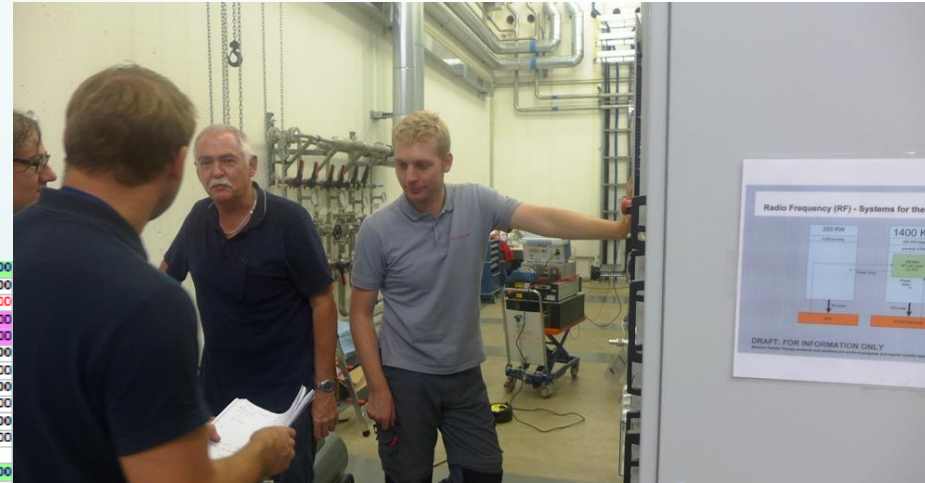
Horizontal
Treatment Rooms

Treatment Room
with 45° Beam

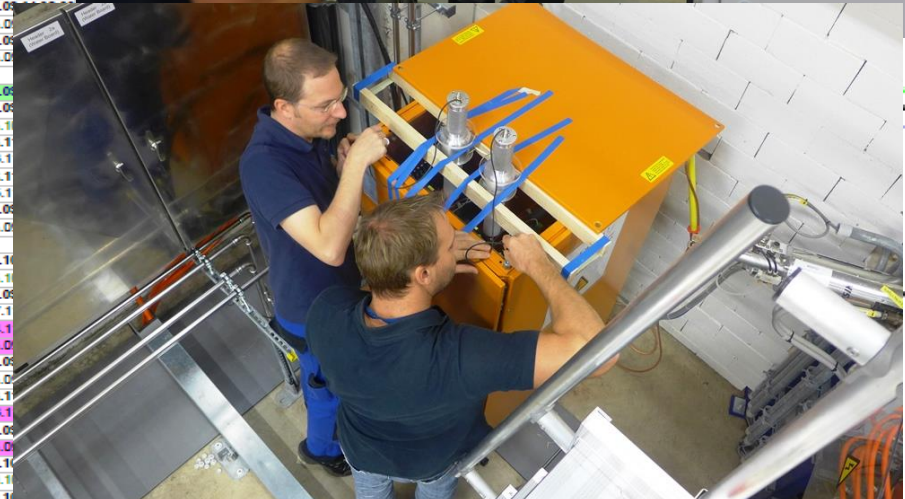


Marburg Ion Beam Therapy Centre (MIT)

Actually: Maintenance,
Commissioning Planning
and



87	77		BKS		17 Tage?	DI 16.09.14 08:00
88	78	27%	System/ Hardware		17 Tage?	DI 16.09.14 08:00
89	79	80%	Einrichtung Accounts und Passwörter		1 Tag	Do 09.10.14 08:00
90	240	0%	Reparatur Lüfter Rechnerraum???		1 Tag?	DI 16.09.14 08:00
91	241	0%	Beseitigung Verpackungsmaterial Rechnerraum		1 Tag?	DI 16.09.14 08:00
92	84	0%	Controls		0 Tage?	DI 16.09.14 08:00
93	85	0%	keine geplanten Arbeiten		0 Tage?	DI 16.09.14 08:00
94	92	0%	Sicherheit und Strahlenschutz		0 Tage?	DI 16.09.14 08:00
95	93	0%	keine geplanten Arbeiten		0 Tage?	DI 16.09.14 08:00
96	94	0%	Softwarearbeiten		5 Tage?	DI 16.09.14 08:00
97	95	0%	Update auf Version 4.??		5 Tage?	DI 16.09.14 08:00
98						
99	199		Bestrahlungstechnik		0 Tage?	DI 16.09.14 08:00
100	200	0%	Mechanik		0 Tage?	DI 16.09.14 08:00
101	207	0%	keine geplanten Arbeiten		0 Tage?	DI 16.09.14 08:00
102	202	0%	Controls		0 Tage?	DI 16.09.14 08:00
103	203	0%	keine geplanten Arbeiten		0 Tage?	DI 16.09.14 08:00
104	96					
105	97		LINAC		46,5 Tage?	DI 16.09.14 08:00
106	98	0%	Qualien		38 Tage?	DI 16.09.14 08:00
107	208	0%	Bestandsaufnahme		1 Tag	Do 16.10.14 08:00
108	99	0%	Quelle1		3 Tage	Mo 03.11.14 08:00
109	100	0%	Wartungsarbeiten		3 Tage	Mo 03.11.14 08:00
110	101	0%	Quelle2		2 Tage	Do 06.11.14 08:00
111	102	0%	Wartungsarbeiten		2 Tage	Do 06.11.14 08:00
112	107	0%	Quellenbetrieb		0 Tage?	DI 16.09.14 08:00
113	108	0%	kein geplanter Betrieb		0 Tage?	DI 16.09.14 08:00
114						
115	110	0%	Vakuumsystem		2 Tage	Do 16.10.14 08:00
116	111	0%	Vorbereitung Standardwartung		2 Tage	Do 16.10.14 08:00
117	114	0%	Magnete		48,5 Tage?	DI 16.09.14 08:00
118	115	0%	Standardwartung		1,5 Tage	Mo 17.11.14 08:00
119	224	0%	Interlocktests global		0,5 Tage	Mo 24.11.14 08:00
120	223	0%	Interlocktests Einzelgeräte		1 Tag?	DI 16.09.14 08:00
121	116	0%	Ein-/ Aus-/ Umbauten		0 Tage?	DI 16.09.14 08:00
122	117	0%	keine geplanten Arbeiten		0 Tage?	DI 16.09.14 08:00
123	118	0%	Strahlidiagnose		2 Tage	Mo 03.11.14 08:00
124	119	0%	Wartung mech. Bauteile		2 Tage	Mo 03.11.14 08:00
125	120	0%	Netzgeräte		26 Tage?	DI 16.09.14 08:00
126	121	0%	Einweisung durch Danfysik		2 Tage	DI 16.09.14 08:00
127	195	0%	HF		0 Tage?	Mo 20.11.14 08:00
128	196	0%	Wartung RFQ, IH, BB NG		0 Tage?	Mo 20.11.14 08:00
129	193	0%	Magne#IG		3 Tage	Mo 20.11.14 08:00
130	216	0%	Wartung JaegerNG		2 Tage	DI 21.10.14 08:00
131	126	99%	Sicherheit / Strahlenschutz		19,1 Tage?	DI 16.09.14 08:00
132	237	100%	Freimessung		0,1 Tage	DI 14.10.14 08:00
133	128	0%	keine geplanten Arbeiten		0 Tage?	DI 16.09.14 08:00
134	131					
135	132		Synchrotron/HEST		49 Tage?	DI 16.09.14 08:00
136	133	0%	Vakuumsystem		4 Tage	Mo 20.10.14 08:00
137	134	0%	Standardwartung		4 Tage	Mo 20.10.14 08:00
138	135	0%	Strahlidiagnose		2 Tage	Mo 03.11.14 08:00
139	209	0%	Wartung mech. Bauteile		2 Tage	Mo 03.11.14 08:00
140	138	0%	Magnete		49 Tage?	DI 16.09.14 08:00



4th WORKSHOP IN BERLIN – SCIENTISTS GO INDUSTRY

Heidelberger Ionenstrahl-Therapiezentrum

Marburg Ion Beam Therapy Centre (MIT)

We are looking for personnel!



Since 2009 we run the nationwide unique accelerator facility for high-precision tumour therapy with ion beams at the University Hospital Heidelberg (HIT), Germany. In Marburg we will now put a second accelerator facility of this type into operation, the "Marburger Ionenstrahl-Therapiezentrum (MIT)".

For the accelerator crew we are looking for young

Physicists (male/female)

for the following tasks:

- Commissioning and retuning of Linac, Synchrotron and transfer lines
- Organization of the accelerator operation and maintenance periods
- Optimization of the accelerator equipment and settings
- Radiation safety tasks (training will be offered)
- Participation in the rotating shift operation (7/24) of the accelerator facility
- Involvement in the on-call duty for technical systems or radiation safety

Please convince us with a qualified university degree and with excellent knowledge and experiences in:

- Accelerator physics, e.g. application of beam optics codes like MAD-X
- Up-to-date soft- and hardware skills with respect to accelerator control systems
- Usage of modern measurement techniques and data analysis tools
- Project management and documentation
- Good skills in German language

After an introduction period at HIT in Heidelberg (www.hit-hd.de) your place of work will be the ion beam therapy facility in Marburg. A regular exchange of operation experiences between both facilities HIT and MIT will be organized and part of your work.

If you have a self-reliant and problem-solving working style, if you are flexible and team-oriented, please send us your application. Your contact partner is Andreas Peters (E-Mail: Andreas.Peters@med.uni-heidelberg.de), head of the accelerator operation at HIT.

