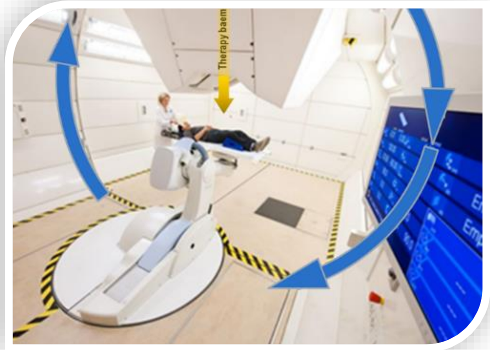
HEIDELBERG UNIVERSITY HOSPITAL

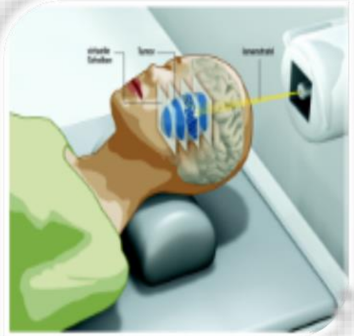
HIT Heidelberger Ionenstrahl-Therapiezentrum

Ion-Beam Therapy at HIT: Options for Multi-Ion Treatment and Research

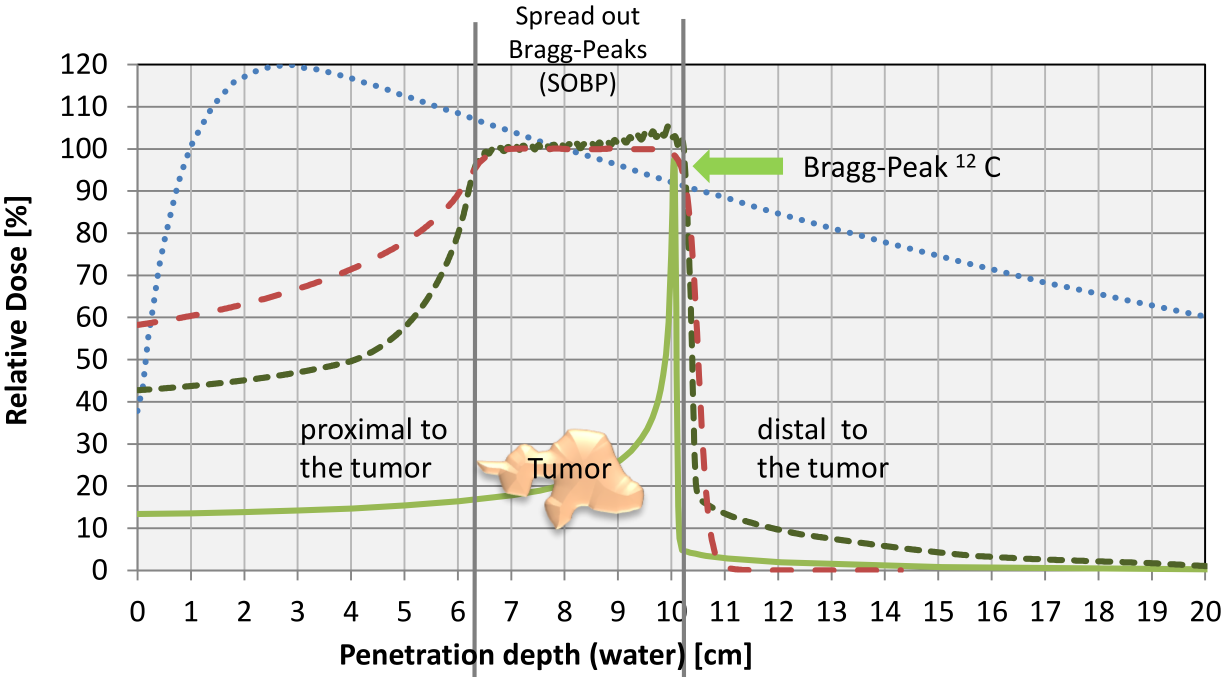
Riga-Workshop, 28.06.2023

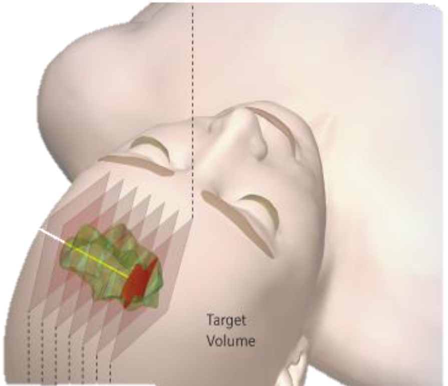
Thomas Haberer, CTO HIT

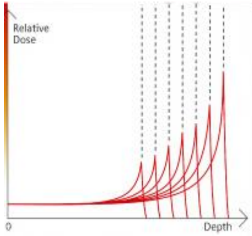




Rationale for charged particle therapy



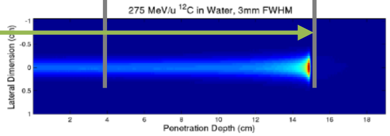




Target volume coverage by active variation of

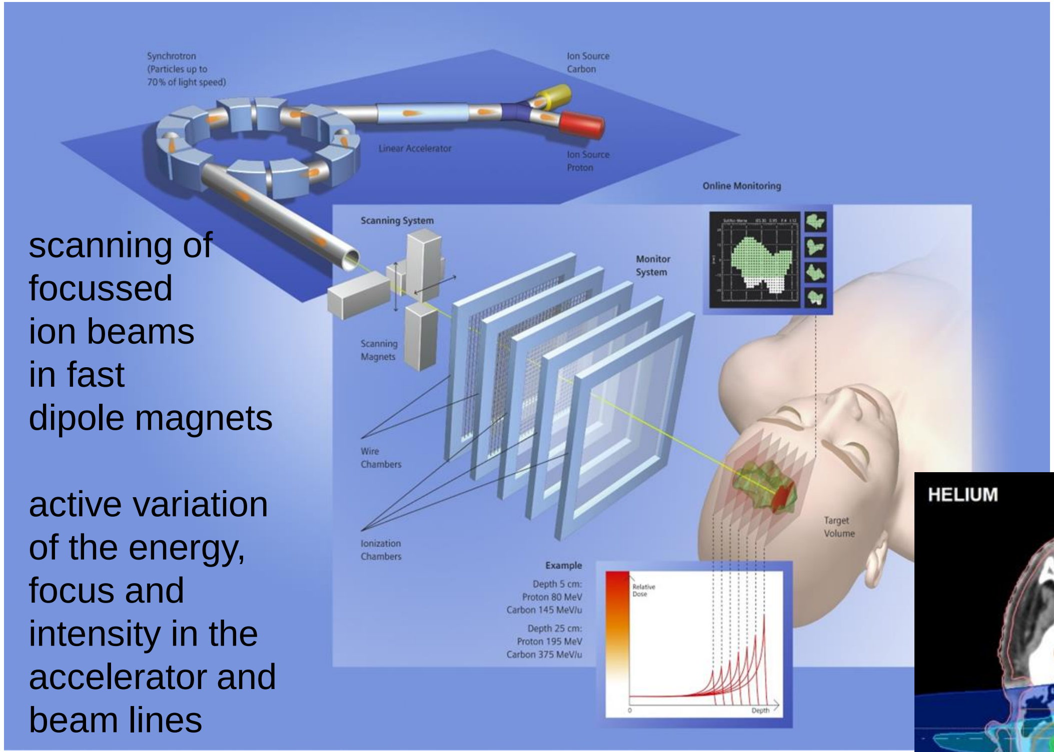
* beam energy
* focus
* intensity

^{12}C Ion beam



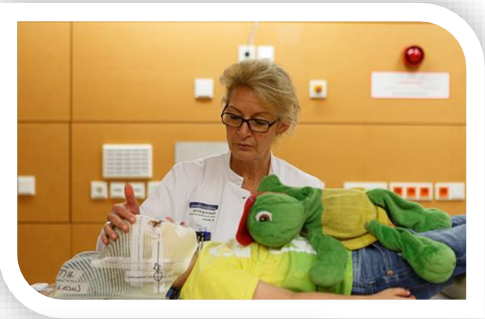
Sparing of healthy tissue by
- reducing doses (due to steep dose gradient →lower NTCP)
- reducing irradiated volume → lower risc of secondary cancer

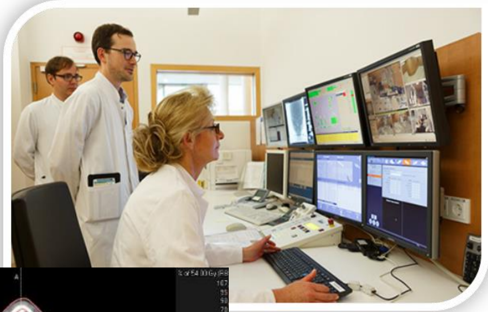
Rasterscanning Dose Delivery

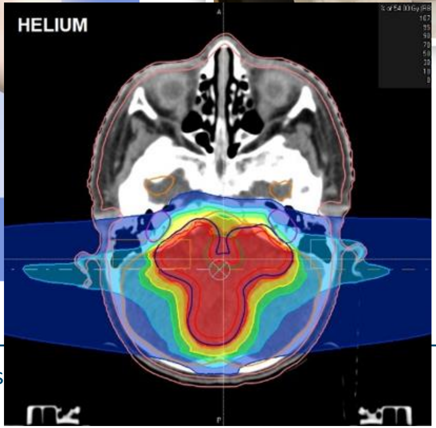


scanning of
focussed
ion beams
in fast
dipole magnets

active variation
of the energy,
focus and
intensity in the
accelerator and
beam lines



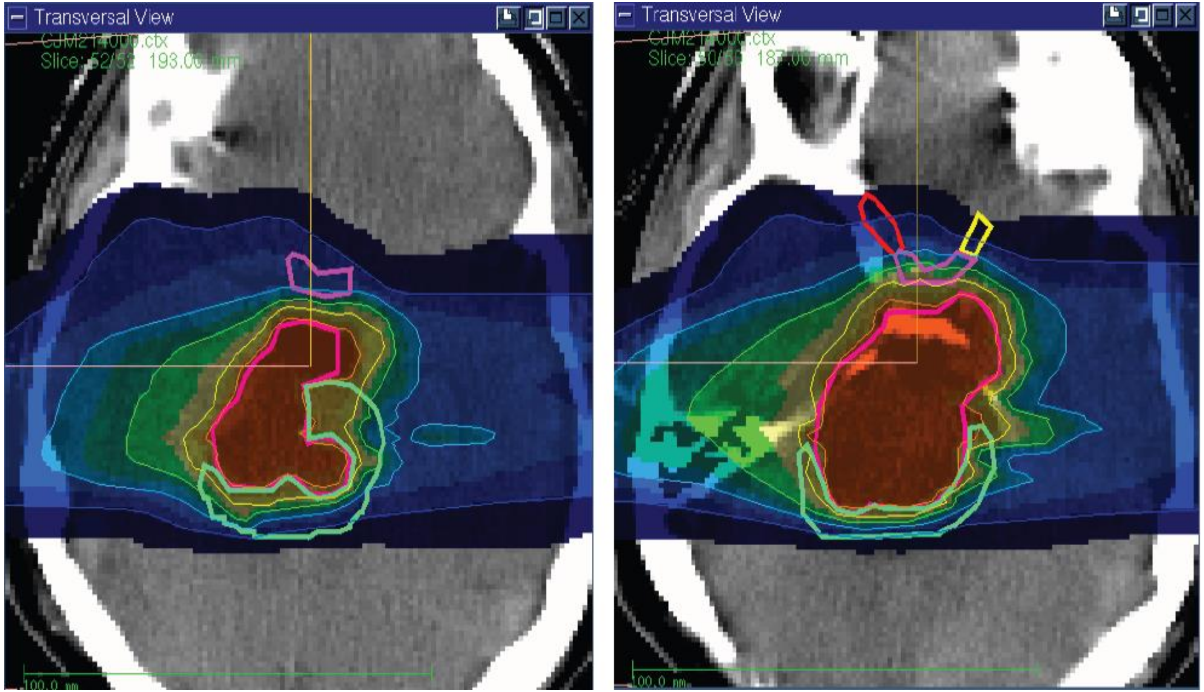




Heidelberger Ionenstrahl-Therapiezentrum

Haberer et al., NIM A , 1993

Dose Conformation via Rasterscanning
e.g. Skull Base Chordomas

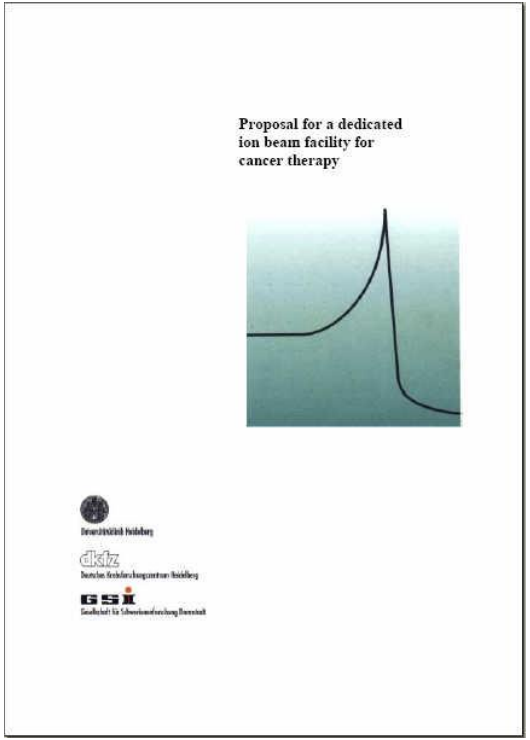


Excellent sparing of normal tissue and organs at risk

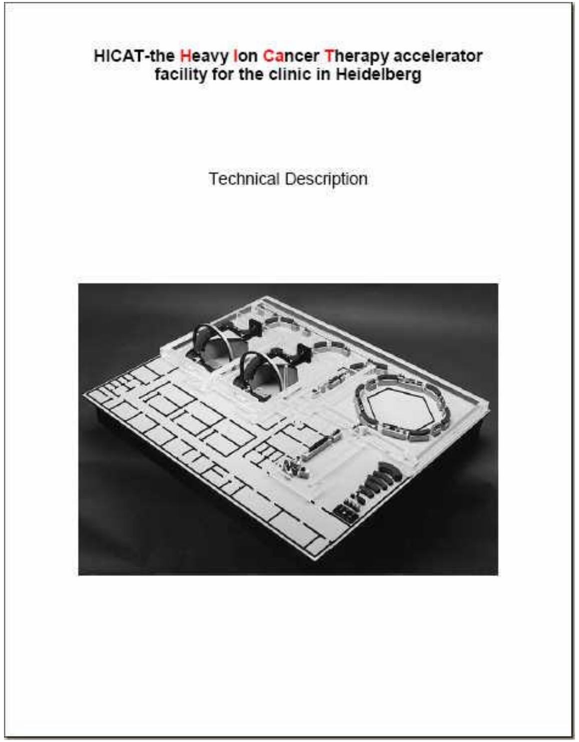
GSI, 1997 – 2008, 440 Patienten, C12

1stRx@GSI: 13.December 1997

Design Phase

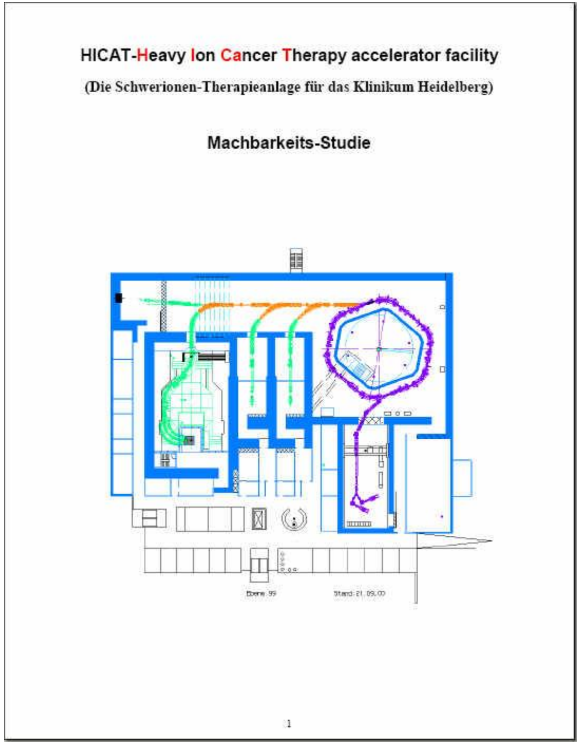

Proposal for a dedicated
ion beam facility for
cancer therapy

Proposal 1998


HICAT-the Heavy Ion Cancer Therapy accelerator
facility for the clinic in Heidelberg

Technical Description

Technical Design 2000


HICAT-Heavy Ion Cancer Therapy accelerator facility

(Die Schwerionen-Therapieanlage für das Klinikum Heidelberg)

Machbarkeits-Studie

1

Feasibility Study 2000

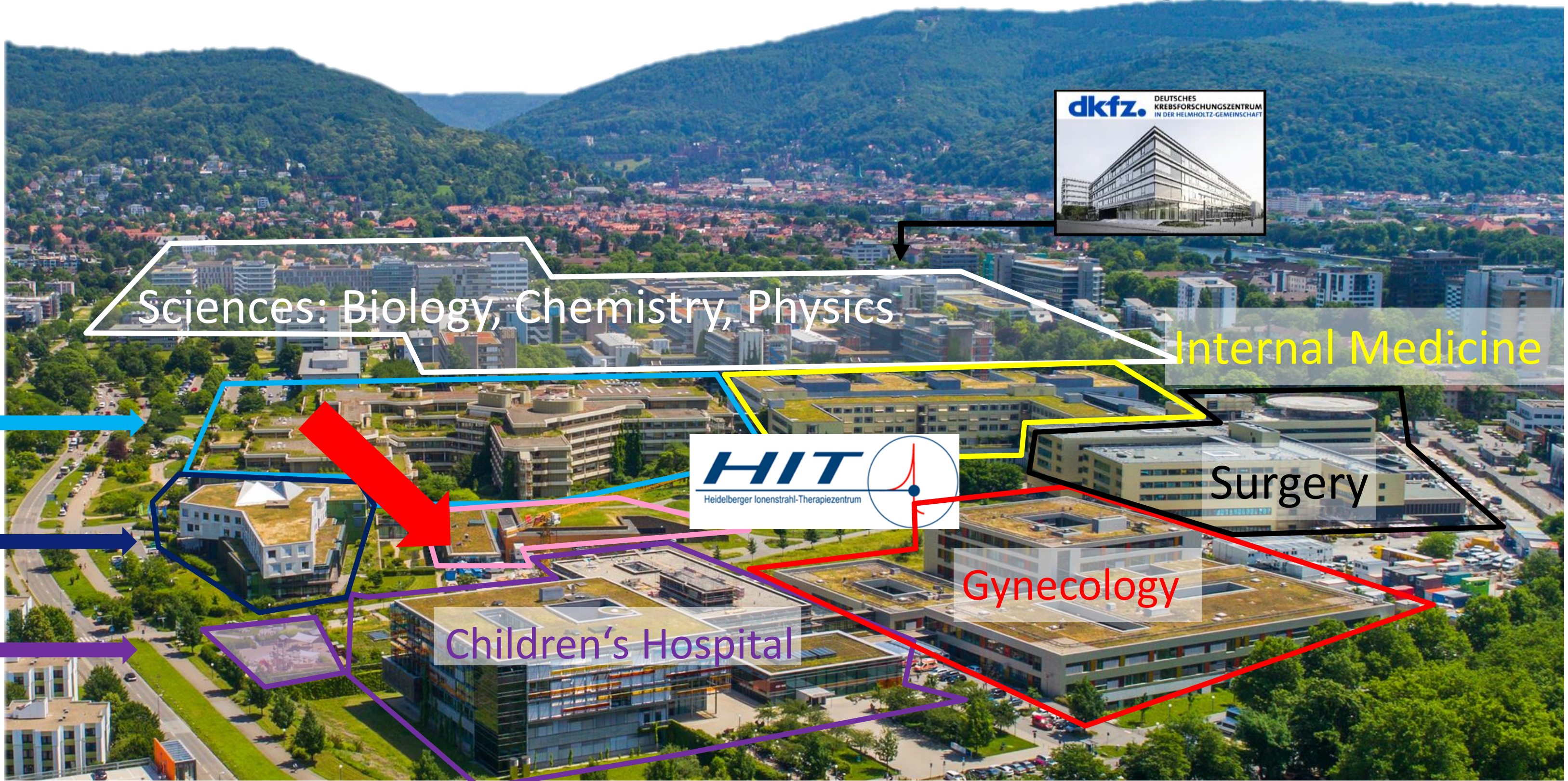
Heidelberg - Campus Neuenheimer Feld

- ✓ Radiation-Oncology and HIT is integrated in the clinic ring
- ✓ Translational and academic research are in close neighbourhood

Kopfklinik:
Radiation
oncology

NCT

KiTZ
Hopp Children's Cancer Center
Heidelberg



Department Radiation Oncology



Radiotherapy Equipment

- 5 Linear accelerators (Elekta) at Kopfklinik
- 1 TomoTherapy
- 1 Ethos (Varian) at DKFZ
- 1 MR-Linac (MRIDian)
- 1 CyberKnife
- 1 Brachytherapy unit
- 1 Intraoperative radiotherapy (IOERT) unit
- Ion beam therapy at HIT with 3 treatment places

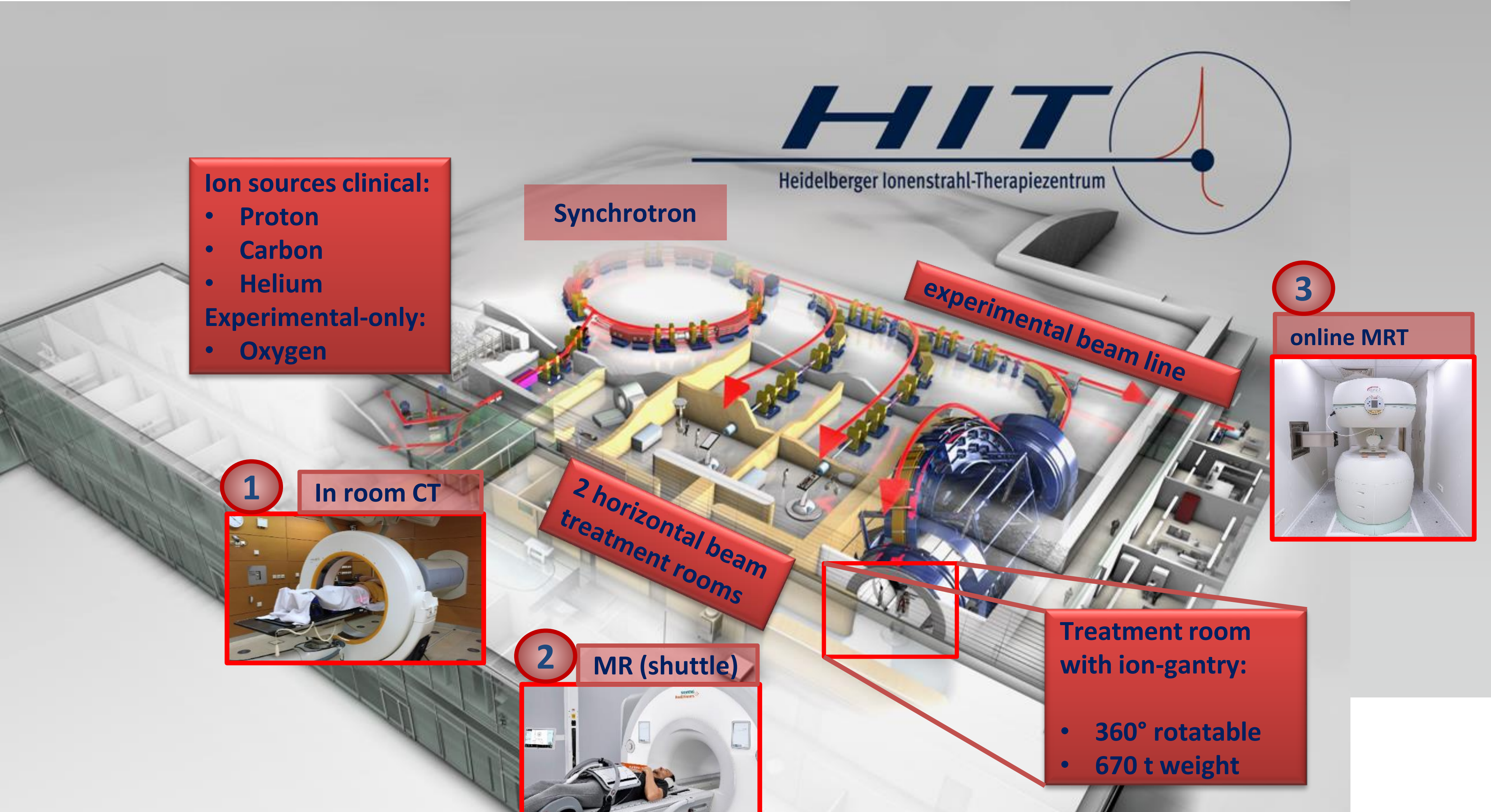
Structure of the Clinic

- ~4500 patients per year
- Ward with 62 beds for in-patients
- Out-patients at NCT
- 27 Tumor conferences
- 14 Specialized consultations

Diagnostic Equipment:

- 2 CT
- 2 MRI
- 1 PET /CT
- Sonography

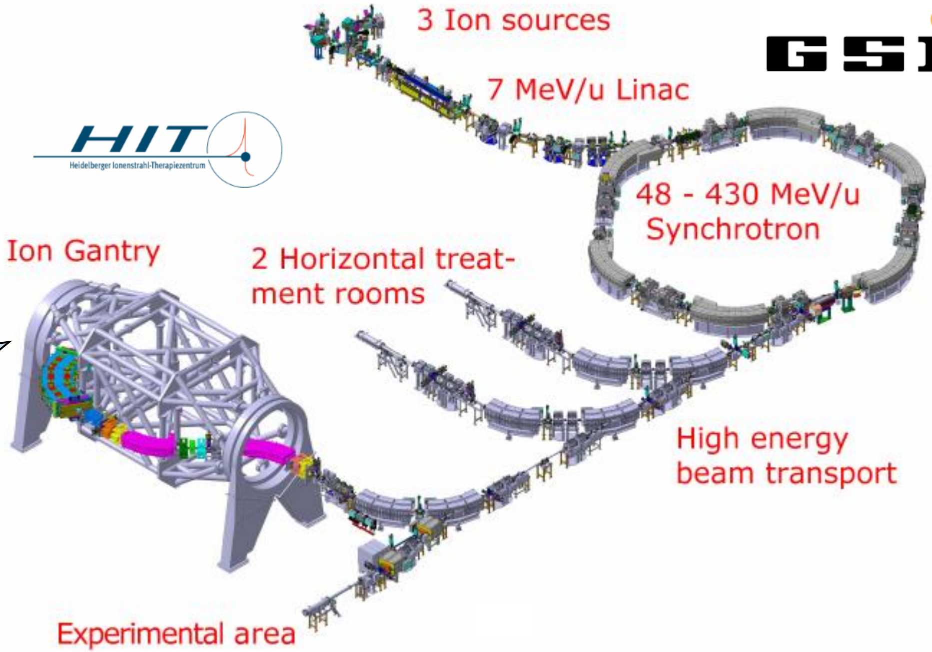
Coverage of the complete spectrum of radiation therapy treatments
Expansion of therapy options through participation in clinical studies



HIT
Heidelberger Ionenstrahl-Therapiezentrum
Ion sources clinical:
• Proton
• Carbon
• Helium
Experimental-only:
• Oxygen
Synchrotron
experimental beam line
3
online MRT
1
In room CT
2 horizontal beam treatment rooms
2
MR (shuttle)
Treatment room with ion-gantry:
• 360° rotatable
• 670 t weight

HIT-Accelerator, Beam Delivery and Gantry

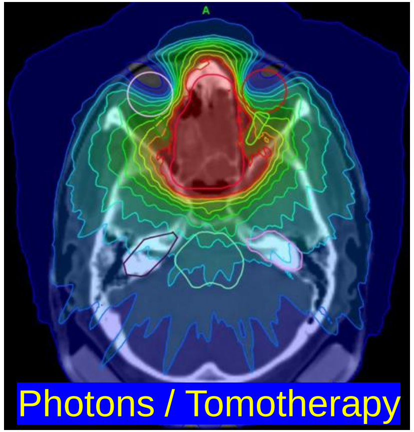
SIEMENS MT MECHATRONICS

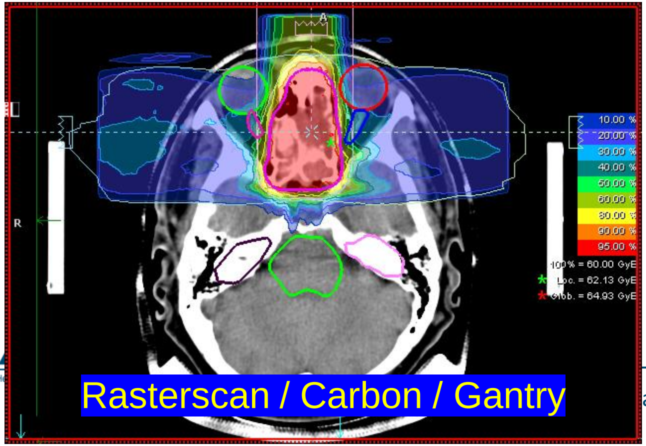


Scanning ion gantry:

- isocentric barrel-type
- world-wide first ion gantry
- 2D beam scanning upstream to final bending, minimum divergence due to edge focussing
- ± 180° rotation, 3° / second
- 13m diameter
  25m length
  600 to rotating
  (145 to magnets)

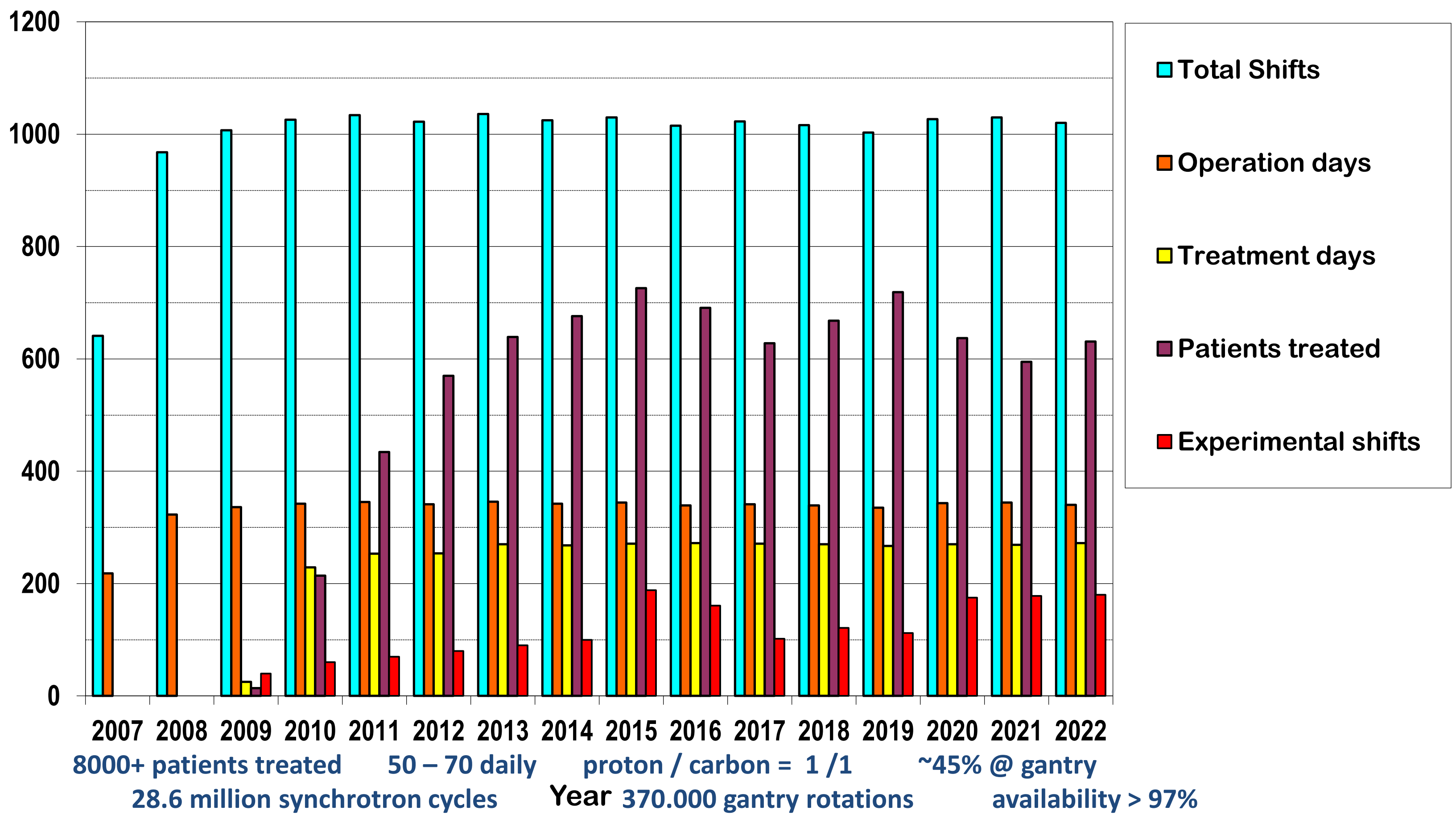
Scanning Ion Gantry @ HIT





HIT is the world's first heavy ion treatment facility with a **360° rotating beam delivery** system (gantry)

1st Rx: Oct 19th, 2012, oligo-astrocytoma



8000+ patients treated 50 – 70 daily proton / carbon = 1 /1 ~45% @ gantry

28.6 million synchrotron cycles 370.000 gantry rotations availability > 97%

39.000 hrs patient treatment 19.000 hrs research and development only 8 days lost since 2009

Clinical trials at HIT, recently finished

Over 7000 patients were treated with protons or carbon ions since 2009

Area	Name	Entity	Phase	Beam modality	Status
Sarkoma	OSCAR	Osteosarkoma	II	Protons and C12	submitted
CNS	CINDERELLA	Glioblastoma (recurrent)	II	C12	analysis
	CLEOPATRA	Glioblastoma	II	Boost: Protons vs. C12	analysis
Head & Neck	TPF-C_HIT	HNSCC of Larynx	II	C12 Boost	analysis
	COSMIC	Adenoid cystisc carcinoma	II	C12 Boost	published
	ACCEPT	Adenoid cystisc carcinoma	II	C12 Boost	published
Prostate	KOLOG	Prostate carcinoma (recurrent)	II	C12	analysis
	PROLOG	Prostate carcinoma (recurrent)	II	Protons	analysis
	IPI	Prostate carcinoma	II	Protons vs. C12	published
GI	PANDORA	rectal carcinoma (recurrent)	II	C12	closed

Haberer, HIT: Multi-Ion Treatment and Research Options, HIT Seminar,

Clinical trials at HIT

Area	Name	Entity	Phase	Beam modality	Status
Chordoma & Chondro-sarcoma	ISAC	sacral chordoma	II	Protons vs. C12	recruiting
	HIT Chordom	skull base chordoma	III	Protons vs. C12	recruiting
	HIT Chrondrosarkom	skull base chondrosarcoma	III	Protons vs. C12	recruiting
	RETRO-ION	Sarcom of posterior abdominal wall	II	C12	recruiting
CNS	MARCIE	Atypical meningeoma	II	C12 Boost	recruiting
	GRIPS	Glioma (high-grade)	III	Protons vs. IMRT	recruiting
H&N	ACCO	Adenoid cystisc carcinoma (H&N)	II	C12 vs. IMRT+C12 Boost	recruiting
	IMRT HIT-SNT	HNSCC of sinus	II	C12 Boost	recruiting
	CARE	Re-irradiation for recurrent or progressive locally advanced head and neck tumors	II	C12	recruiting
Lung	INKA	Pancoast tumor of the lung	II	C12	recruiting
GI	PROMETHEUS	Hepatocellular carcinoma	II	C12	recruiting
	PACK	pankreas carcinoma	II	C12	recruiting
Prostate	PAROS	Prostate carcinoma (recurrent)	III	IMRT vs. Protons	recruiting

Haberer, HIT: Multi-Ion Treatment and Research Options, HIT Seminar,

Salivary gland tumours / Adenoid cystic carcinoma

C12 pilot project, patients treated before 2009, mainly T4 (R1/2 or inoperable)

- 58 patients treated with C12 at the GSI (18 GyE C12 + 54 Gy Photons)
- 37 patients treated with photons (66 Gy)
  - ➢ Significantly **higher LC in the C12 group**

<u>3y-LC:</u>
C12: 84 %
Photon IMRT: 56 %

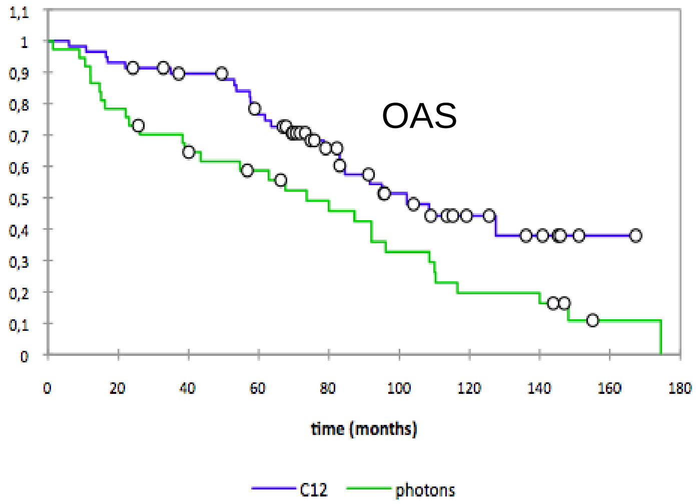
Cancer

Original Article

Combined intensity-modulated radiotherapy plus raster-scanned carbon ion boost for advanced adenoid cystic carcinoma of the head and neck results in superior locoregional control and overall survival

Alexandra D. Jensen MD, MSc, Anna V. Nikoghosyan MD, Melanie Poulakis DDS, Angelika Höss MSc, Thomas Haberer PhD, Oliver Jäkel PhD, Marc W Münter MD, Daniela Schulz-Ertner MD, Peter E. Huber MD, PhD, Jürgen Debus MD, PhD

First published: 4 June 2015 Full publication history
DOI: 10.1002/cncr.29443 View/save citation

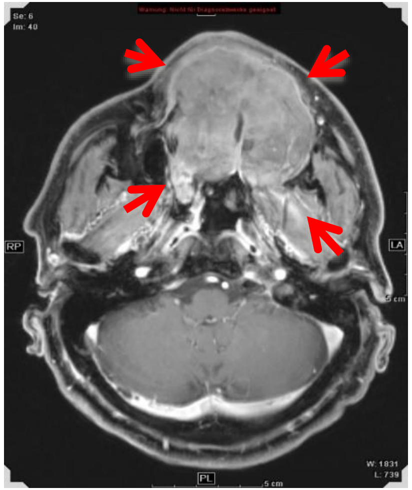


COSMIC-Trial

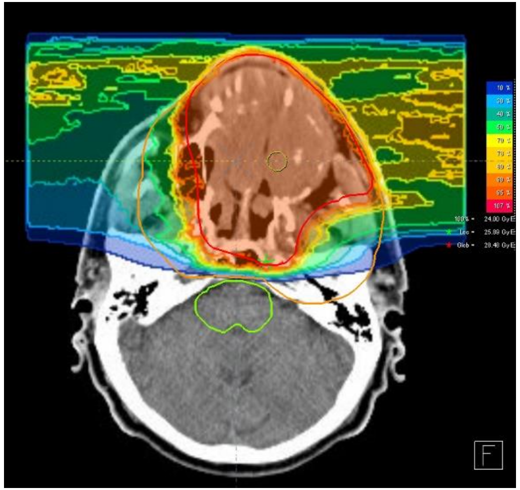
COmbined therapy of malignant **S**alivary gland tu**M**ors with **I**MRT and **C**arbon ions

- Phase II feasibility study, dose escalation (**18GyE to 24 GyE** C12 boost)
  - ➢ 54 patients treated at HIT from 2010 to 2011, 89% ACC
  - ➢ No dose limiting acute toxicity
  - ➢ Late Toxicity > CTC°2 : < 5%

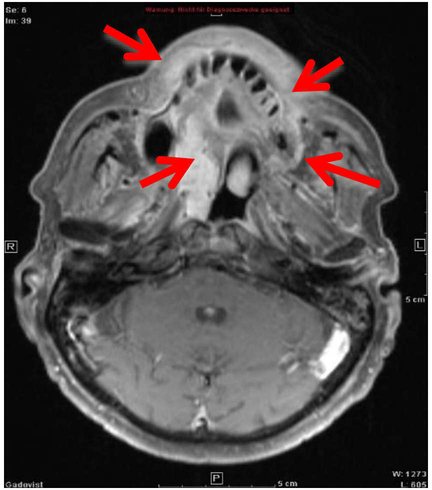
LC after 3 years: 82 %



Pre-treatment situation



Treatment planning
C-12 boost

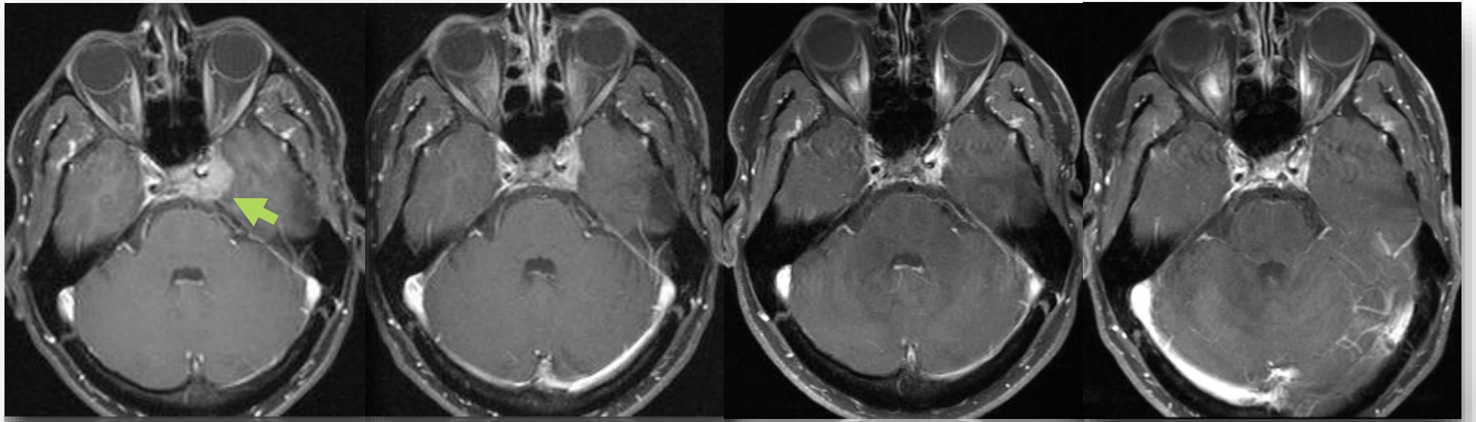


6 weeks post RT

Haberer, HIT: Multi-Ion Treatment and Research Options, HIT Seminar,

Skull Base Chondrosarcoma
Long-term Follow-up

2005 2007 2011 2015



Skull Base Chondrosarcoma

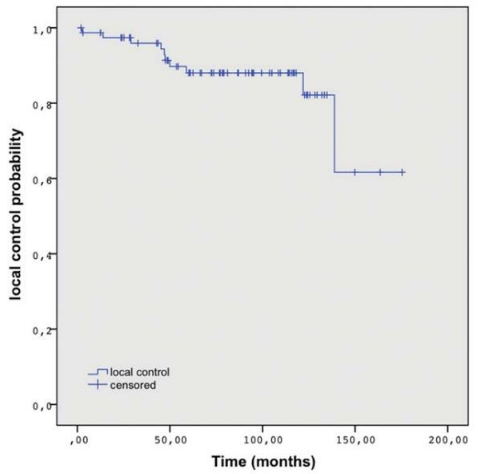
- Rare bone tumors, 5-12 % are localized at the skull base
- **Resection is often incomplete due to localisation**
- G1-G2 tumors are relatively radioresistent, rarely metastatic disease
- Symptoms: cranial nerve deficits (most commonly double vision)

Cancer. 2014 May 15;120(10):1579-85. doi: 10.1002/cncr.28606. Epub 2014 Feb 5.

High control rate in patients with chondrosarcoma of the skull base after carbon ion therapy: first report of long-term results.

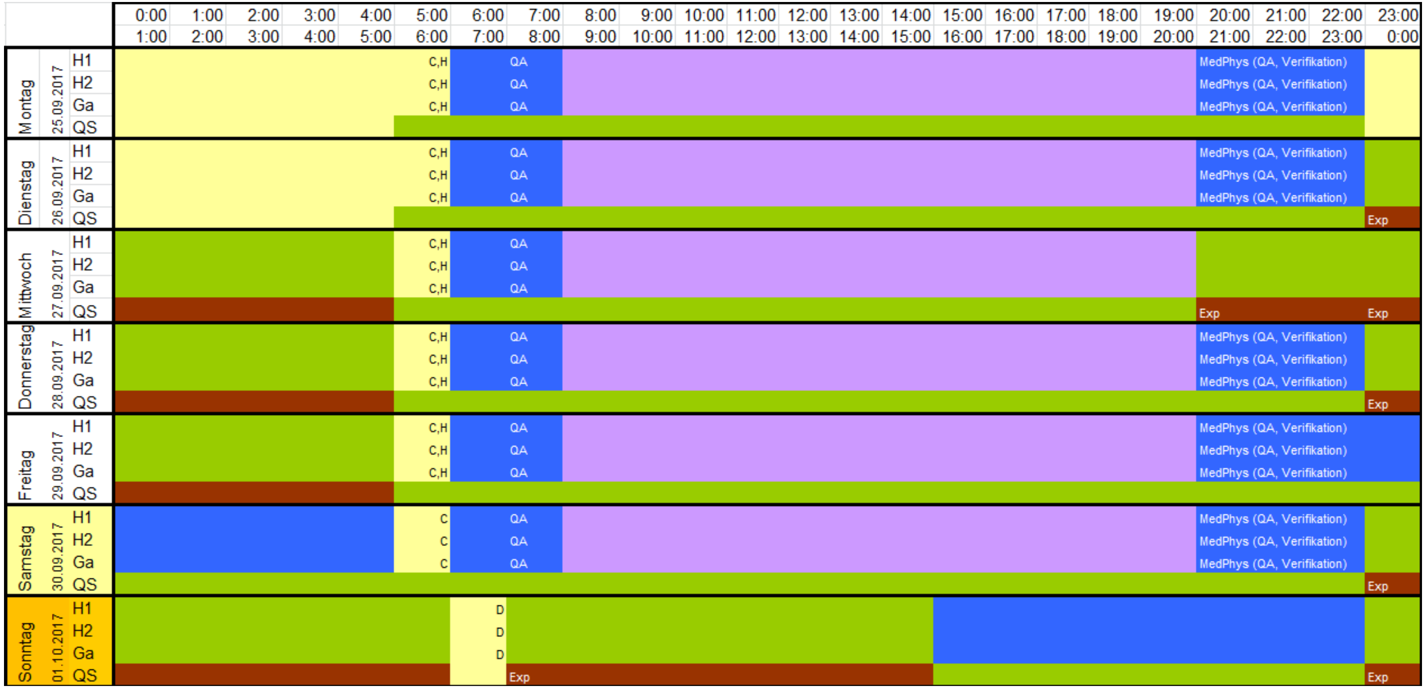
Uhl M[1], Mattke M, Welzel T, Oelmann J, Habl G, Jensen AD, Ellerbrock M, Haberer T, Herfarth KK, Debus ...

- ➢ 79 pat. after biopsy/ incomplete resection (R2)
- ➢ Median follow-up 91 months
- ➢ C12 treatment @ GSI 60 GyE in 3 GyE/fx
- ➢ 10 yrs LC: 88 %
- ➢ 10 yrs LC (<45 J): 98%

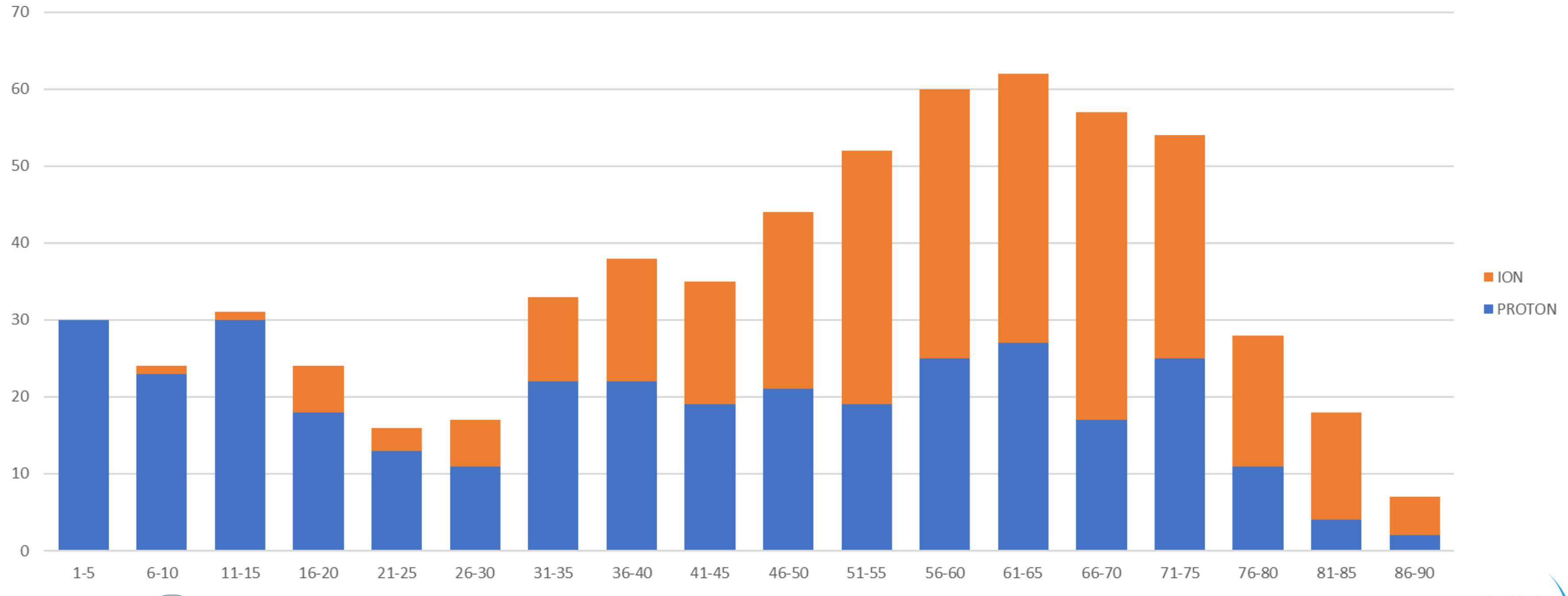


HIT‘s Weekly Schedule

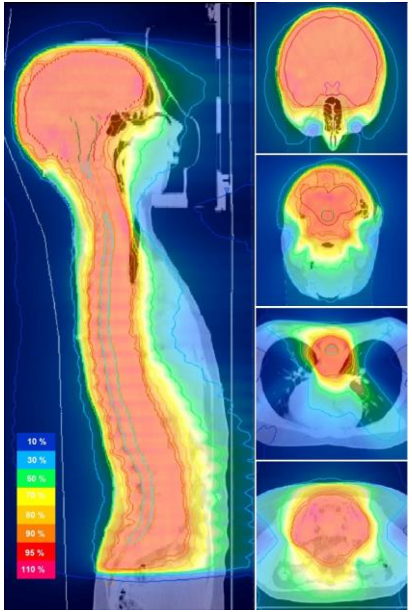
Experiments QA Patient Treatment QA



Carbon ions and Protons: Age distribution Children > Protonen



Pediatric and Young Patients



- Reduced integral dose to non target regions
- Dose escalation at the target volume
- Reduced risk of secondary malignancies / late side effects

Haberer, HIT: Multi-Ion Treatment and Research Options, HIT Seminar,

Journal of Clinical Oncology
Official Journal of the American Society of Clinical Oncology

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nstitution: Universitaet Heidelberg

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Radiation Dose-Response Relationship for Risk of Coronary Heart Disease in Survivors of Hodgkin Lymphoma

Frederika A. van Nimwegen, Michael Schaapveld, David J. Cutter, Cècile P.M. Janus, Augustinus D.G. Krol, Michael Hauptmann, Karen Kooijman, Judith Roesink, Richard van der Maazen, Sarah C. Darby, Berthe M.P. Aleman and Flora E. van Leeuwen

This Article

Published online before print November 16, 2015, doi: 10.1200/JCO.2015.63.4444
JCO January 20, 2016 vol. 34 no. 3 235-243

Abstract *Free*
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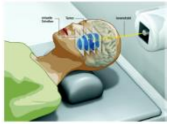
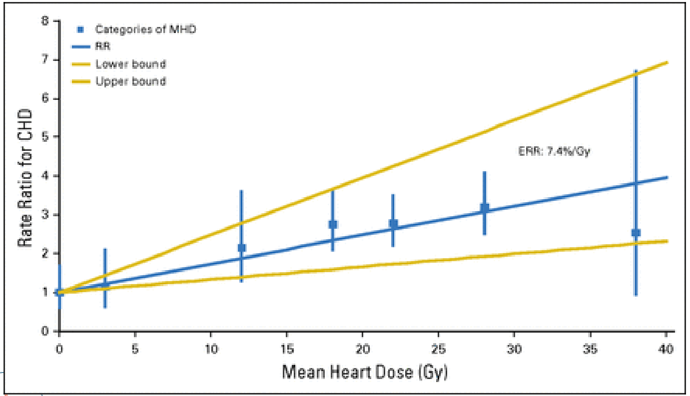
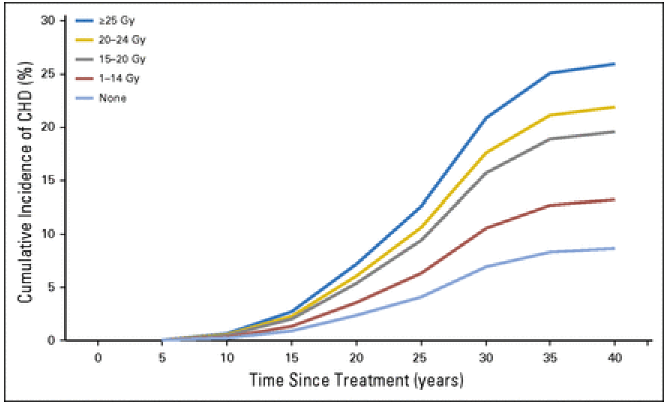
PDF



Deterministic Late Effects

- additional relative risk for CHD: 7,4% / 1 Gy MHD
- younger patients face higher risks





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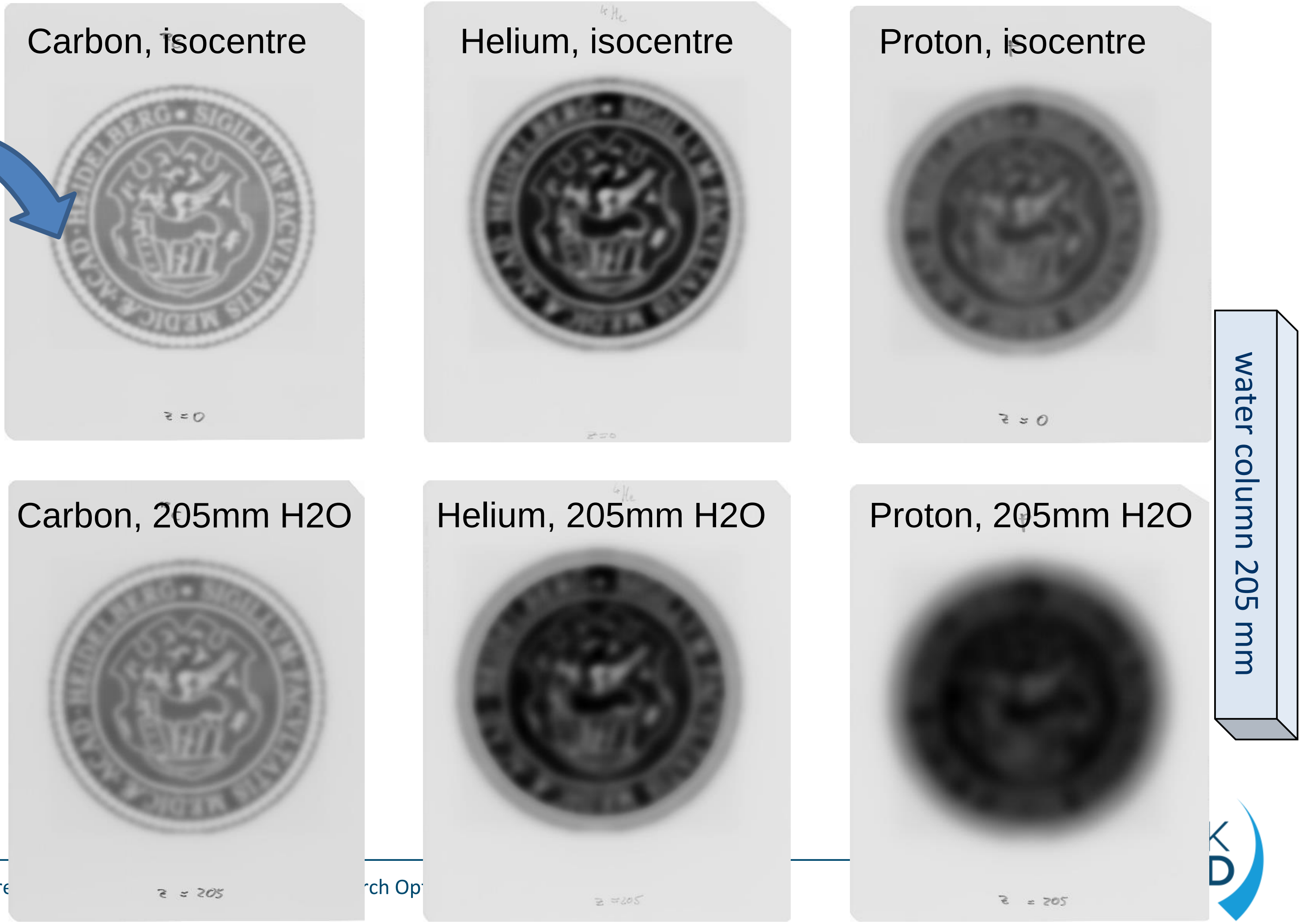
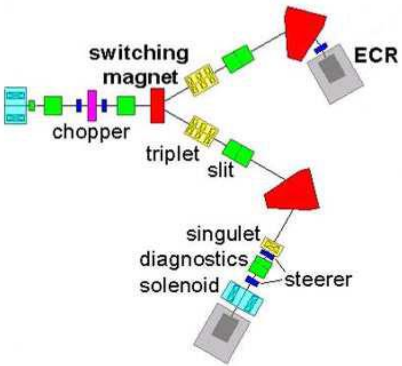
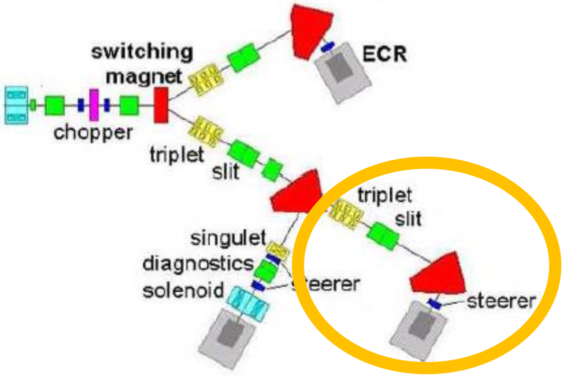
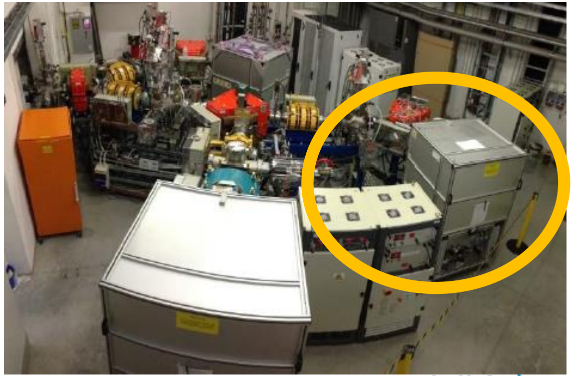


Helium-Ionsource Integration

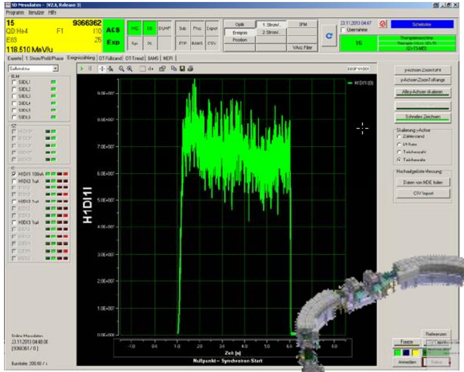


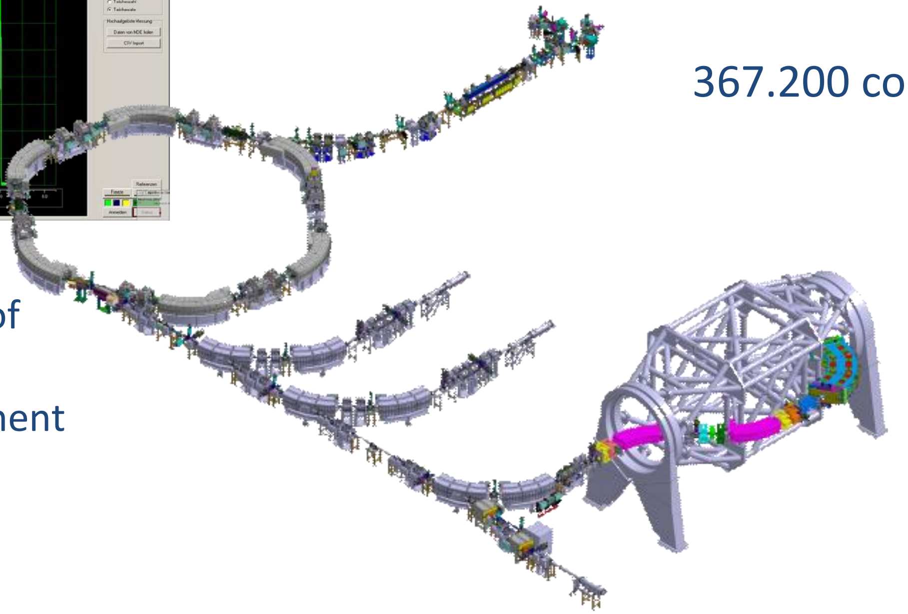


Helium
Ionsource



Accelerator- and Beamline-Tuning

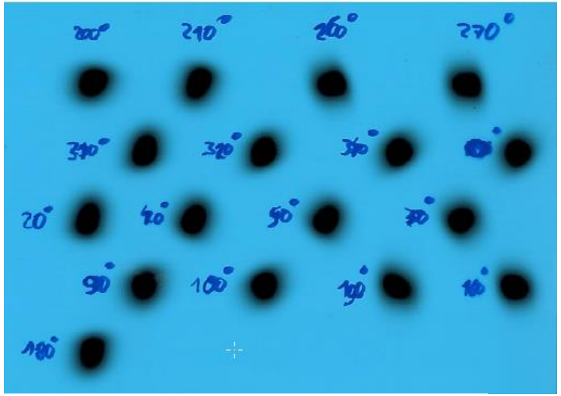




4 isocenters 255 energies each,
4 spot sizes, 10 intensities
and 18 gantry angles:

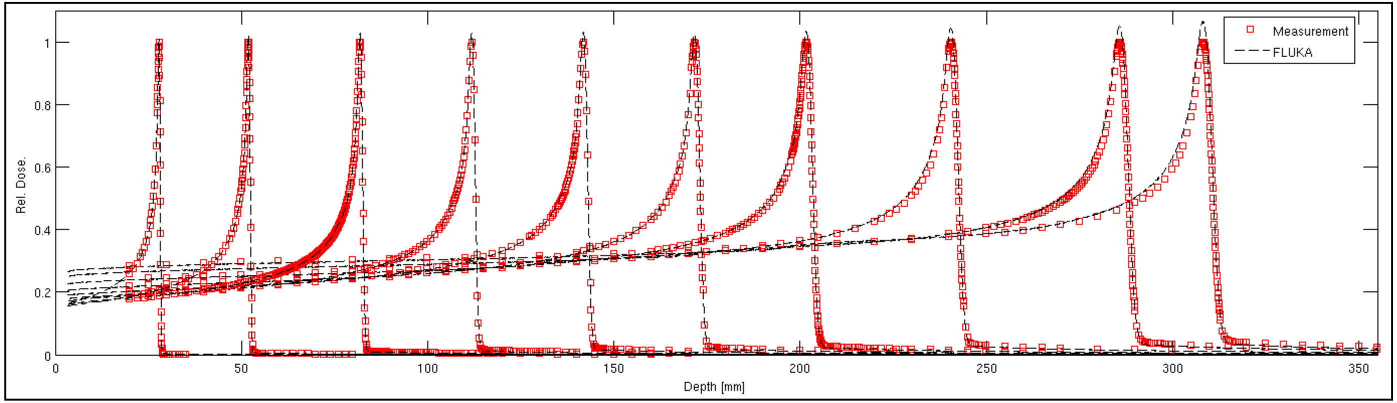
367.200 combinations

early extraction of Helium into a horizontal treatment room



Helium beam spots at gantry, all angles

Helium Depth-dose distributions: data vs MC



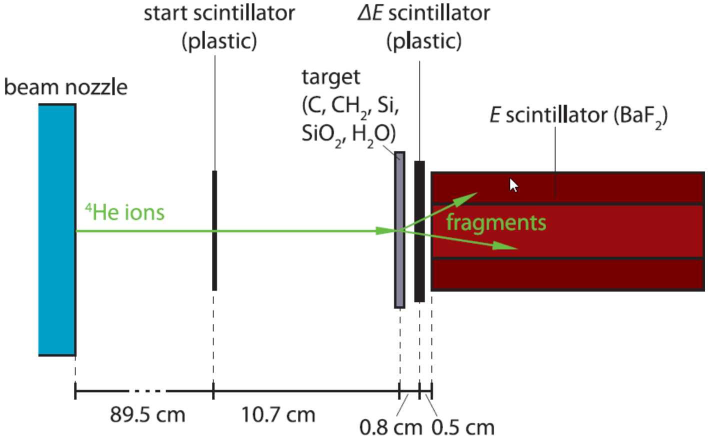
- Overall **good agreement** between simulations and measurements
- Range differences **< 0.10 mm**
- Dose differences **from 0.5 to 6%** in the high dose region
- Average dose-weighted dose-difference **from 0.4 to 2.5%**

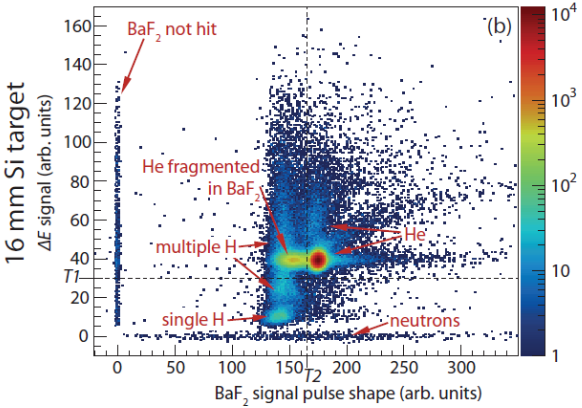
→ **Good results** of the **FLUKA models**

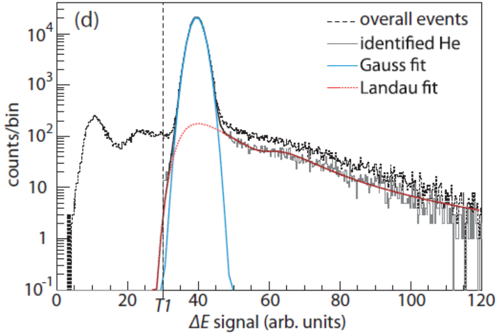
→ Room for **improvements**, **reaction cross section measurements** see next slide

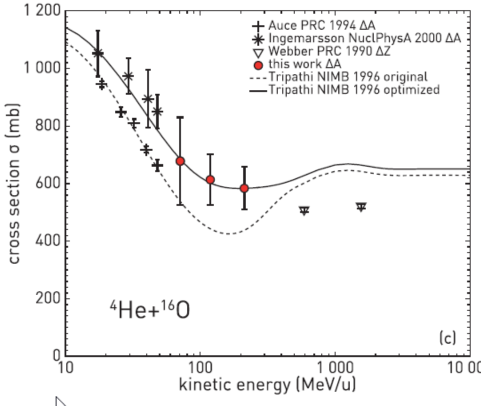
T Tessonnier , A. Mairani, et al Physics in Medicine Biology, 2017, 62(16): 6784

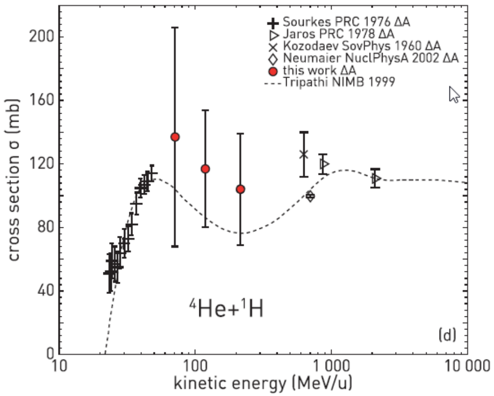
Helium Fragmentation in Water Measurements@HIT







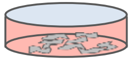


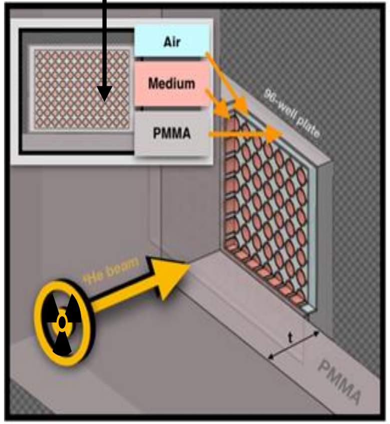


Horst et al., PhysRevC99

Radiobiological Studies / *in-vitro* Validation of Treatment Planning Outcome for 3 Models

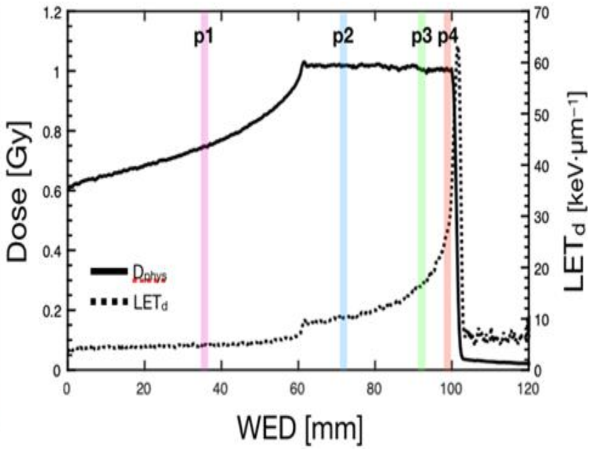
cultivated cells



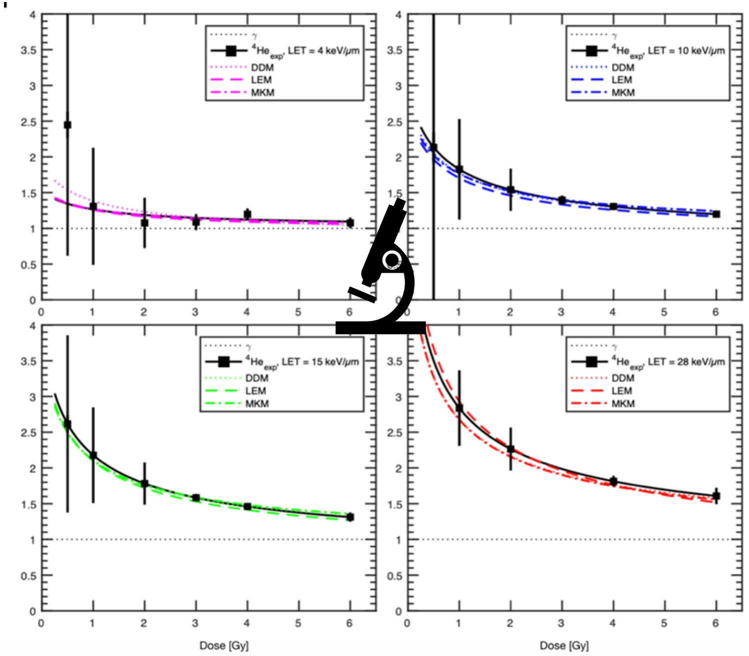


Irradiation He-Ions

Depth in water (p1-p4)



Cell Survival



Dose (0,5 bis 6,0 Gy)

Biophysical modeling and experimental validation of relative biological effectiveness (RBE) for ^{4}He ion beam therapy

Stewart Mein, Ivana Dokic, Carmen Klein, Thomas Tessonnier, Till Tobias Böhlen, Giuseppe Magro, Julia Bauer, Alfredo Ferrari, Katia Parodi, Thomas Haberer, Jürgen Debus, Amir Abdollahi & Andrea Mairani

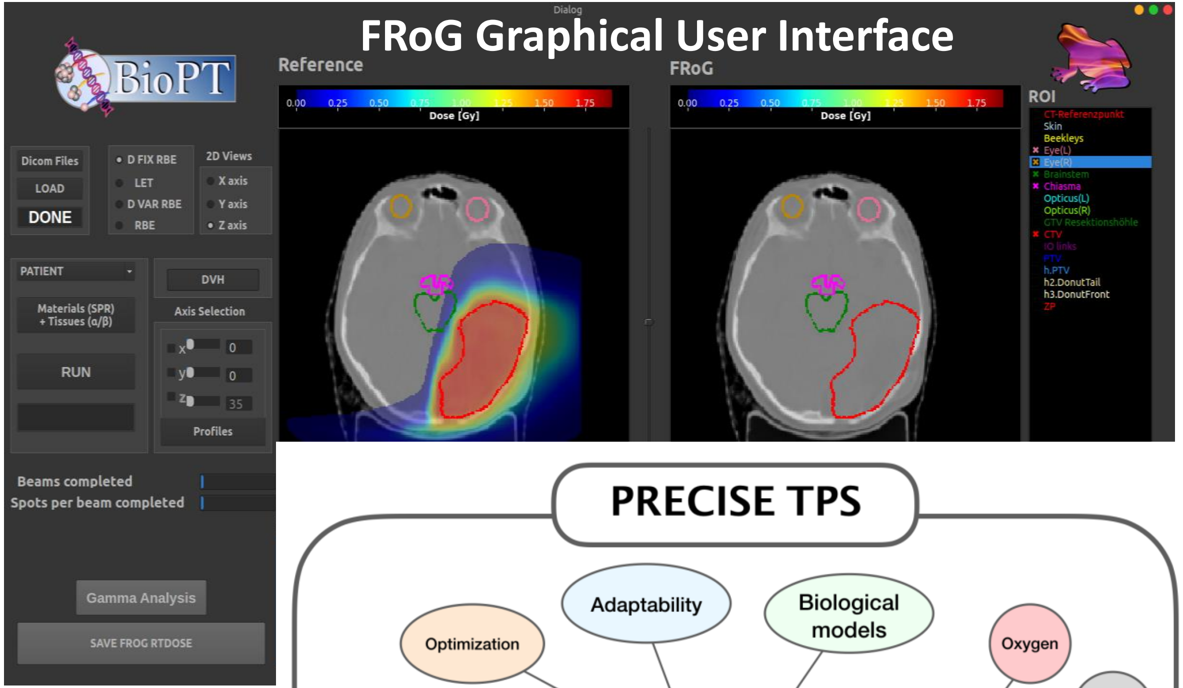
Radiation Oncology **14**, Article number: 123 (2019) | Cite this article

HIT Heidelberger Ionenstrahl-Therapiezentrum

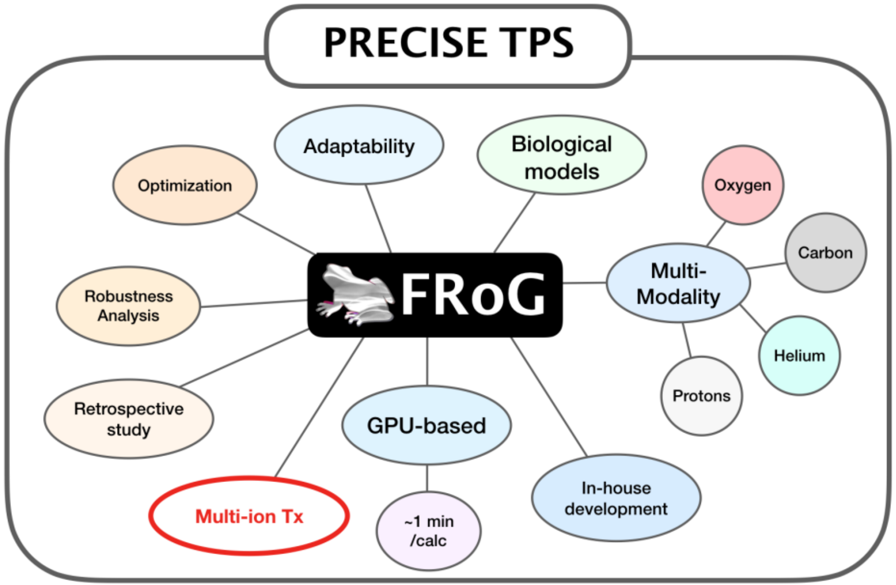
UK HD

GPU-based Modelling

- QA routines
- Plan robustness analysis
- Automatic cohort analysis
- Dose* Volume Histogram (DVH) analysis
- Multi-tissue radio-sensitivity (α/β) assignment
- Gamma analysis
- Multi biological models
- Scoring: LET_d, D_{RBE}, RBE…



PaRticle thErapy using single and Combined Ion optimization StratEgies



Andrea Mairani et al., HIT
S. Mein et al. 2018 Sci Rep.;
K. Choi et al. 2018 Cancers 10, 395;
S. Mein 2019 Phys. Med. 64, 123.

Recent Literature (*BioPT*): ^{4}He RBE modeling

Data-driven RBE parameterization for helium ion beams

A Mairani[1,2], G Magro[1,3,4], I Dokic[2,5,6,7], S M Vall…
T Tessonnier[7,8], R Galm[2,5,6,7], M Ciocca[1], K Par…
A Ferrari[9], O Jäkel[2,6], T Haberer[2], P Pedroni[4]
and T T Böhlen[10]

[1] Medical Physics Unit, CNAO Foundation, Via Strada Campeggi…
Italy
[2] Heidelb…
Heidelber…
[3] Departm…
[4] Istituto…
[5] German…
Center for…
(HIRO), 6…
[6] German…
[7] Departm…
Feld 400,…
[8] Ludwig…
D-85748 G…
[9] Europea…
Switzerlan…
[10] Medica…
A-2700 W…

Optimizing the modified microdosimetric kinetic model input paramete… and ^{4}He ion beam therapy ap…

A Mairani[1,2], G Magro[1], T Tessonnier…
S Molinelli[1], A Ferrari[6], K Parodi[2,3,4], …
and T Haberer[2]

…oundation, Via Str…
…enter, Im Neuenh…
…ogy, Heidelberg U…
…20 Heidelberg, G…
…t München, Am C…
MedAustron Gm…
…ear Research CE…

…017

Biologically optimized helium ion plans: calculation approach and its *in vitro* validation

A Mairani[1,2], I Dokic[2,3,4,5], G Magro[1], T Tessonnier[5,6],
F Kamp[7], D J Carlson[8], M Ciocca[1], F Cerutti[9], P R Sala[10],
A Ferrari[9], T T Böhlen[11], O Jäkel[2,4], K Parodi[2,5,6], J Debus[2,5],
A Abdollahi[2,3,4,5] and T Haberer[2]

[1] Medical Physics Unit, CNAO Foundation, Via Strada Campeggi 53, I-27100 Pavia, Italy
[2] Heidelberg Ion Beam Therapy Center, Im Neuenheimer Feld 450, D-69120 Heidelberg, Germany
[3] German Cancer Consortium (DKTK), Translational Radiation Oncology, National Center for Tumor Diseases (NCT), Heidelberg Institute of Radiation Oncology (HIRO), D-69120 Heidelberg, Germany
[4] German Cancer Research Center (DKFZ), Im Neuenheimer Feld 280, D-69120 Heidelberg, Germany
[5] Department of Radiation Oncology, Heidelberg University Hospital, Im Neuenheimer Feld 400, D-69120 Heidelberg, Germany
[6] Department of Medical Physics, Ludwig-Maximilians-Universität München, Am Coulombwall 1, D-85748 Garching b. Munich, Germany
[7] Department of Radiation Oncology, Ludwig-Maximilians-Universität München, Marchioninistr. 15, D-81377 Munich, Germany
[8] Dept. of Therapeutic Radiology, Yale University School of Medicine,

Mein *et al. Radiation Oncology* (2019) 14:123
https://doi.org/10.1186/s13014-019-1295-z

Radiation Oncology

RESEARCH Open Access

Biophysical modeling and experimental validation of relative biological effectiveness (RBE) for ^{4}He ion beam therapy

Check for updates

Stewart Mein[1,2,3,4,5], Ivana Dokic[1,2,3,4], Carmen Klein[1,2,3,4], Thomas Tessonnier[2,6], Till Tobias Böhlen[7], Guiseppe Magro[8], Julia Bauer[2], Alfredo Ferrari[9], Katia Parodi[2,10], Thomas Haberer[2], Jürgen Debus[1,2,3,4,5], Amir Abdollahi[1,2,3,4] and Andrea Mairani[2,8*]

Abstract

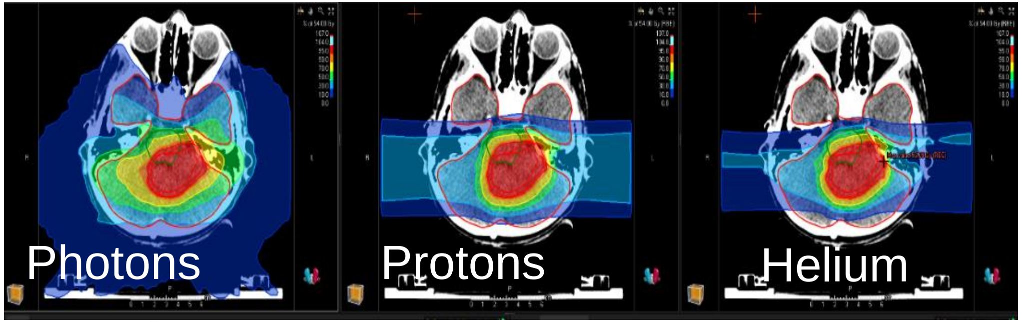
Background: Helium (^{4}He) ion beam therapy provides favorable biophysical characteristics compared to currently administered particle therapies, i.e., reduced lateral scattering and enhanced biological damage to deep-seated tumors like heavier ions, while simultaneously lessened particle fragmentation in distal healthy tissues as observed with lighter protons. Despite these biophysical advantages, raster-scanning ^{4}He ion therapy remains poorly explored e.g., clinical translational is hampered by the lack of reliable and robust estimation of physical and radiobiological uncertainties. Therefore, prior to the upcoming ^{4}He ion therapy program at the Heidelberg Ion-beam Therapy Center (HIT), we aimed to characterize the biophysical phenomena of ^{4}He ion beams and various aspects of the associated models for clinical integration.

Methods: Characterization of biological effect for ^{4}He ion beams was performed in both homogenous and patient-…

In-silico Studies - RayStation - Helium-Module

Analysed entities so far:

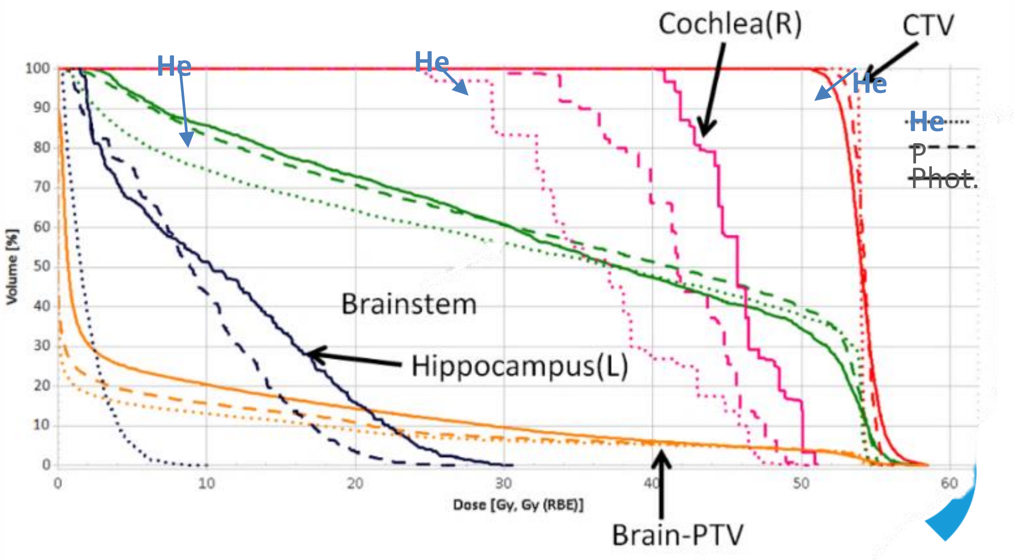
- Meningioma
- Low-grade Glioma
- **Ependymoma**
- Head-and-neck
- Prostate



Normal tissue complication probability (NTCP)

Superior sparing of brainstem and Cochlea

Coverage of clinical target volume (CTV) best for Helium

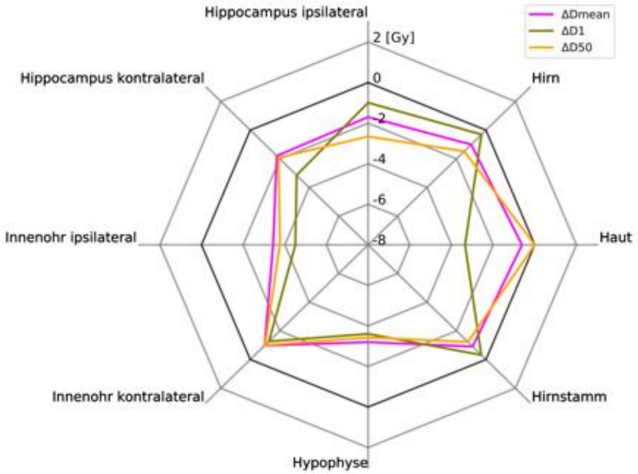


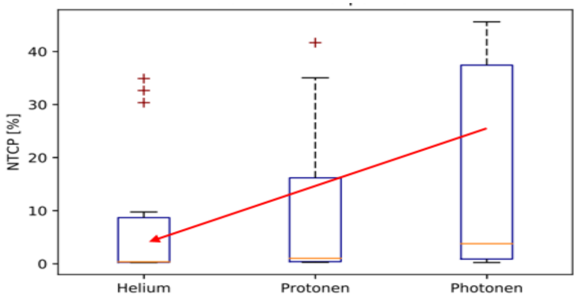
Clinical Rationale Helium

- Low-grade glioma:
  dosereduction up to 5 Gy(RBE)
- Superior organ-at-risk sparing:
  f.e. pituitray gland and inner ear

Risikoorgan		Helium	Protonen	Photonen	He vs Pr Differenz absolut
Hypophyse	D_{mean}	14 ± 4	18 ± 4	27 ± 4	-3,2 ± 0,6*
	D_1	24 ± 5	28 ± 5	32 ± 5	-3,6 ± 0,8*
	D_{50}	14 ± 4	17 ± 4	27 ± 4	-3,4 ± 0,8*
	ID	7 ± 2	8 ± 2	12 ± 2	-1,5 ± 0,4*
Innenohr ipsilateral	D_{mean}	13 ± 4	16 ± 4	22 ± 4	-3,4 ± 0,6*
	D_1	23 ± 5	27 ± 4	32 ± 4	-5 ± 1*
	D_{50}	12 ± 4	16 ± 4	22 ± 4	-3,8 ± 0,7*
	ID	16 ± 5	21 ± 5	29 ± 5	-4,6 ± 0,9*

Notiz: D_{mean}, D_1 und D_{50} in Gy, ID in Gy · cm^3. * bedeutet statistisch signifikant mit p-Wert $< 0,05$. Die Tabelle zeigt die sich ergebenen Mittelwerte mit den Standardfehlern des Mittelwerts (n = 15).





Wickert et al. submitted

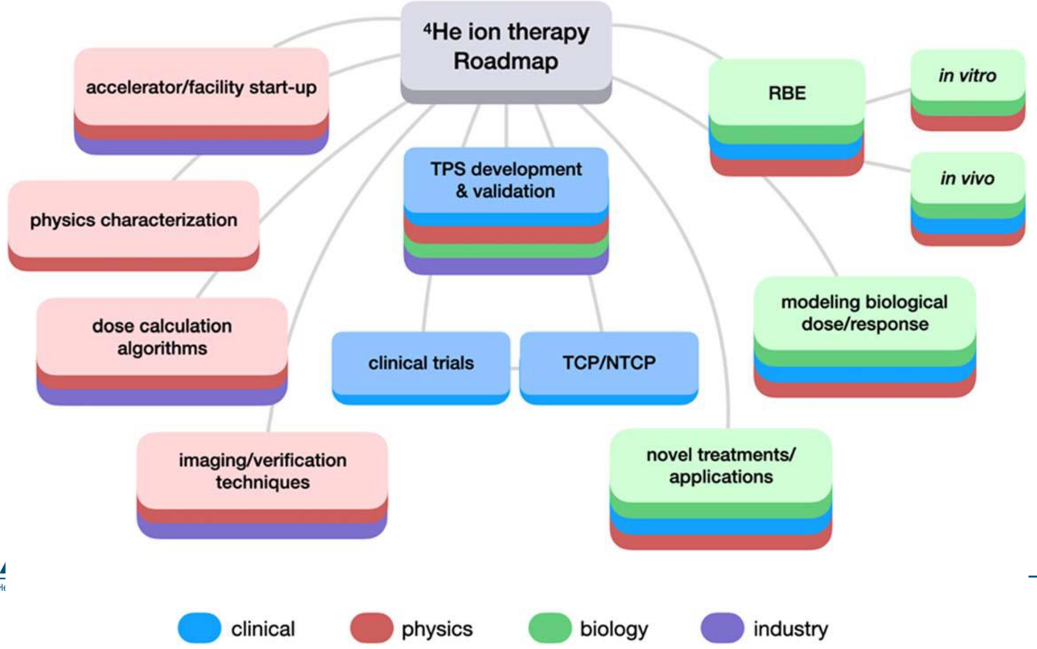
ROADMAP

Physics in Medicine & Biology

IPEM Institute of Physics and Engineering in Medicine

Roadmap: helium ion therapy

Andrea Mairani[1,2,3,4], Stewart Mein[1,3,4,5], Eleanor Blakely[6], Jürgen Debus[1,3,4,5,7], Marco Durante[8,21], Alfredo Ferrari[1], Hermann Fuchs[9,10], Dietmar Georg[9,10], David R Grosshans[11], Fada Guan[11,19], Thomas Haberer[1], Semi Harrabi[1,4,5,7,20], Felix Horst[8], Taku Inaniwa[12,13], Christian P Karger[4,18], Radhe Mohan[11], Harald Paganetti[14,15], Katia Parodi[16], Paola Sala[17], Christoph Schuy[8], Thomas Tessonnier[1], Uwe Titt[11] and Ulrich Weber[8]



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3. Kopp, B., et al., ***Development and Validation of Single Field Multi-Ion Particle Therapy Treatments***. Int J Radiat Oncol Biol Phys, 2020. 106(1): p. 194-205.
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7. Mairani, A., et al., ***Optimizing the modified microdosimetric kinetic model input parameters for proton and (4)He ion beam therapy application***. Phys Med Biol, 2017. 62(11): p. N244-n256.
8. Mairani, A., et al., ***Roadmap: helium ion therapy***. Phys Med Biol, 2022. 67(15).
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10. Mein, S., et al., ***Biophysical modeling and experimental validation of relative biological effectiveness (RBE) for (4)He ion beam therapy***. Radiat Oncol, 2019. 14(1): p. 123.
11. Mein, S., et al., ***Dosimetric validation of Monte Carlo and analytical dose engines with raster-scanning (1)H, (4)He, (12)C, and (16)O ion-beams using an anthropomorphic phantom.*** Phys Med, 2019. 64: p. 123-131.
12. Mein, S., et al., ***Spot-scanning hadron arc (SHArc) therapy: A proof of concept using single- and multi-ion strategies with helium, carbon, oxygen, and neon ions.*** Med Phys, 2022. 49(9): p. 6082-6097.
13. Mein, S., et al., ***Spot-Scanning Hadron Arc (SHArc) Therapy: A Study With Light and Heavy Ions***. Adv Radiat Oncol, 2021. 6(3): p. 100661.
14. Mein, S., et al., ***Biological Dose Optimization for Particle Arc Therapy Using Helium and Carbon Io****ns*. Int J Radiat Oncol Biol Phys, 2022. 114(2): p. 334-348.
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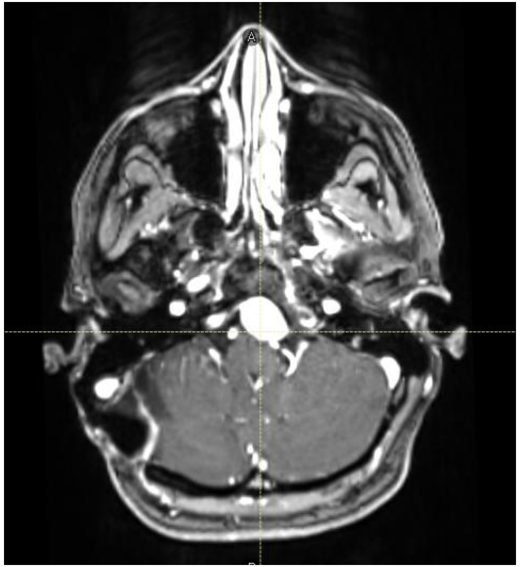
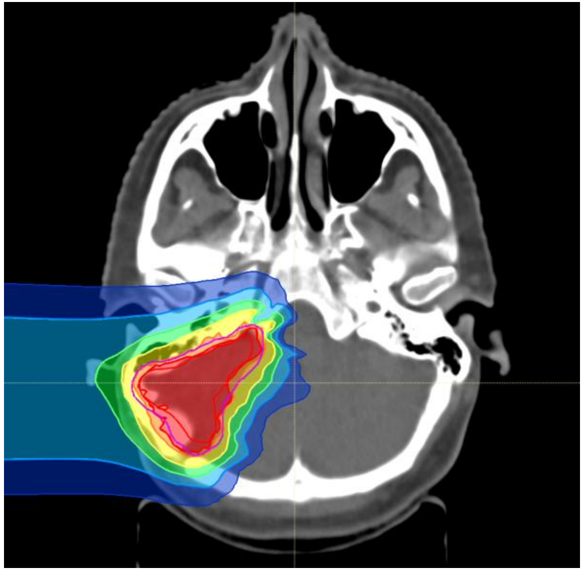
16. Tessonnier, T., et al., ***Proton and helium ion radiotherapy for meningioma tumors: a Monte Carlo-based treatment planning comparison***. Radiat Oncol, 2018. 13(1): p. 2.
17. Tessonnier, T., et al., ***FLASH Dose Rate Helium Ion Beams: First In Vitro Investigations***. Int J Radiat Oncol Biol Phys, 2021. 111(4): p. 1011-1022.

First Rx using Rasterscanned He-Ions

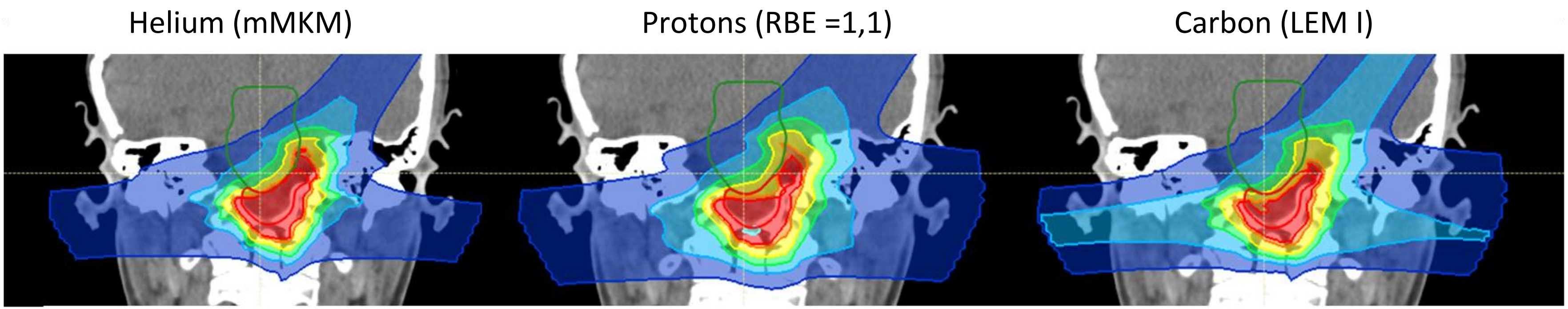
female patient 30 yrs
recurrent anaplastic
soft-tissue sarcoma, 2021



pretreated in 2015
60 Gy(RBE) Carbon



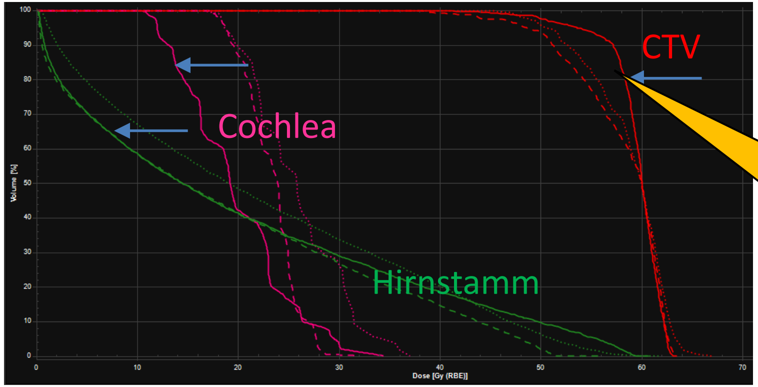
First Rx using Rasterscanned He-Ions



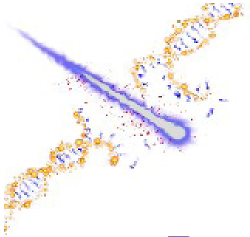
Helium ——

Protons ········

Carbon - - - -

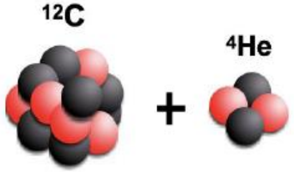


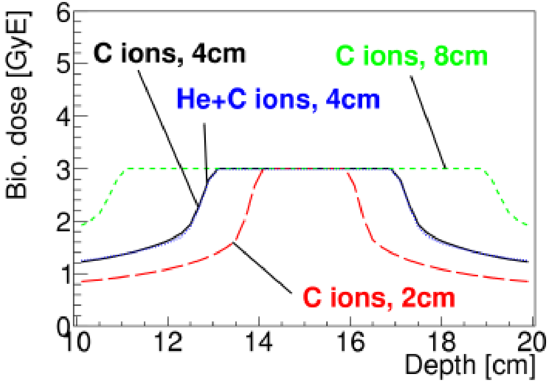
HIT, July 20th, 2021:
First patient treatment with rasterscanned Helium beams
Full remission after 1yr

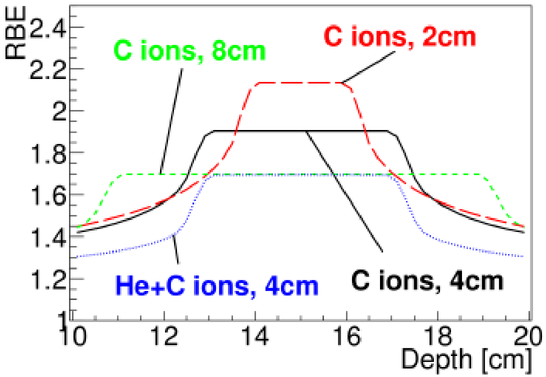


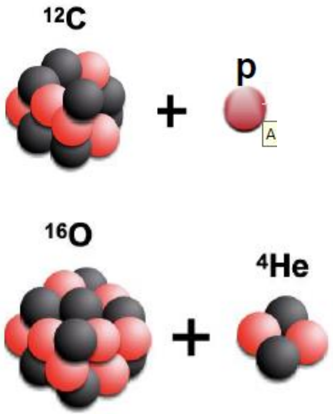
Dual ion fields

Example: He+C fields with const. RBE in PTV to have a constant radiation quality as a function of field size









+ Reduces risk for possible relative misestimations as a function of field size (and also field depth)

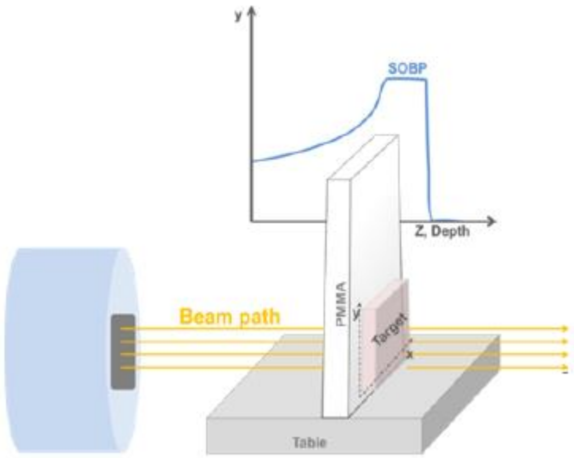
– Dilutes (the probably advantageous) high-LET component of C ions.

+ However for treatments with higher-LET ions, such as oxygen, the mixture with lower-Z ions could additionally help to reduce the fragmentation tail.

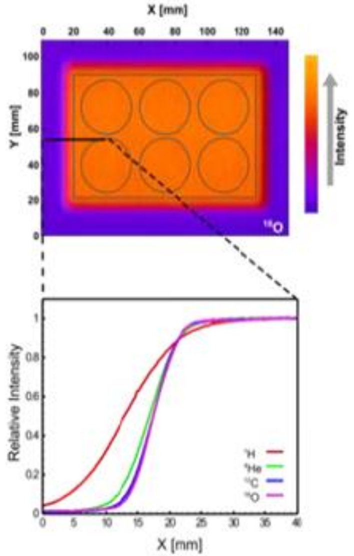
Böhlen,…,Mairani PMB 57 2012

Different irradiation modalities at HIT (1H, 4He, 12C, 16O)

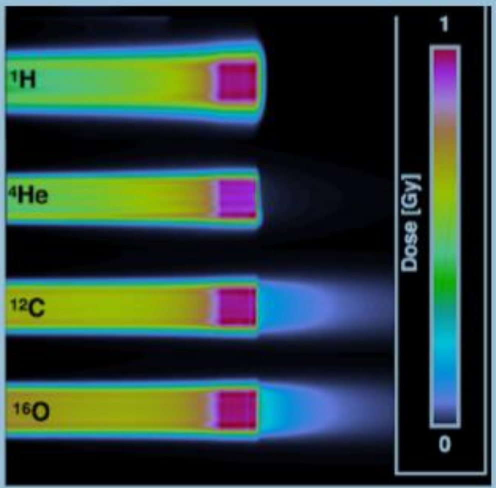
Experimental setup



Lateral scattering



Fragmentation tail

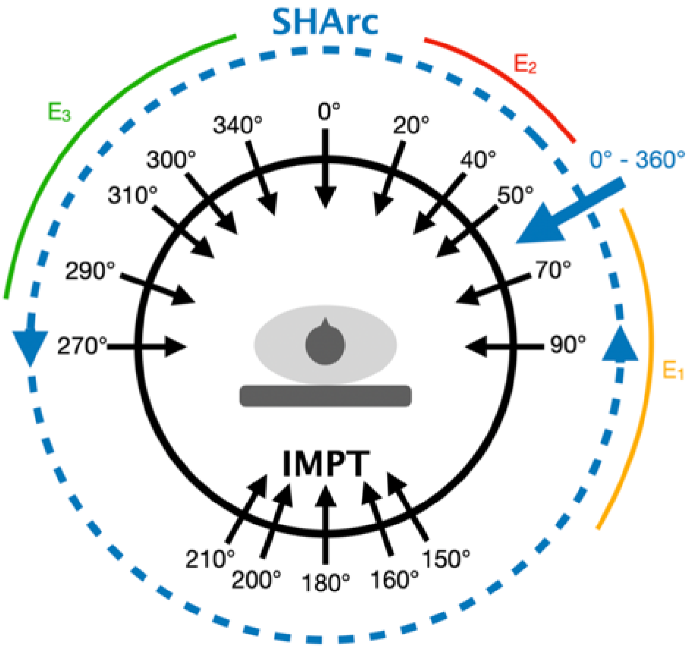


Dokic et al. 2021

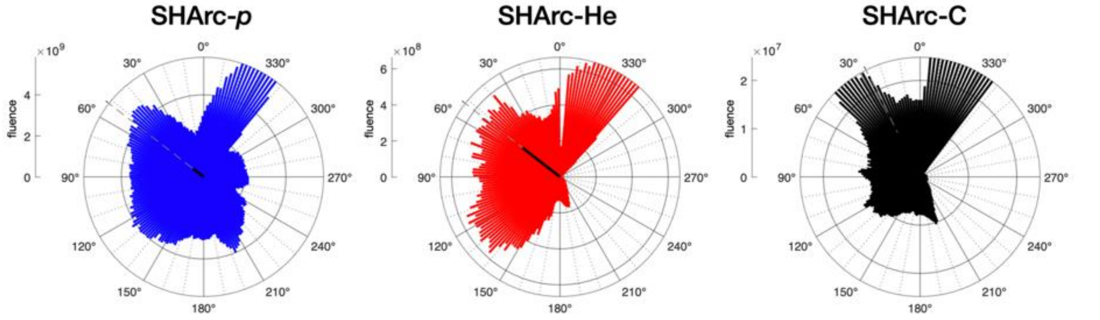
SF30 RBEs:

^{1}H	1.1
^{4}He	1.7
^{12}C	2.7
^{16}O	3.5

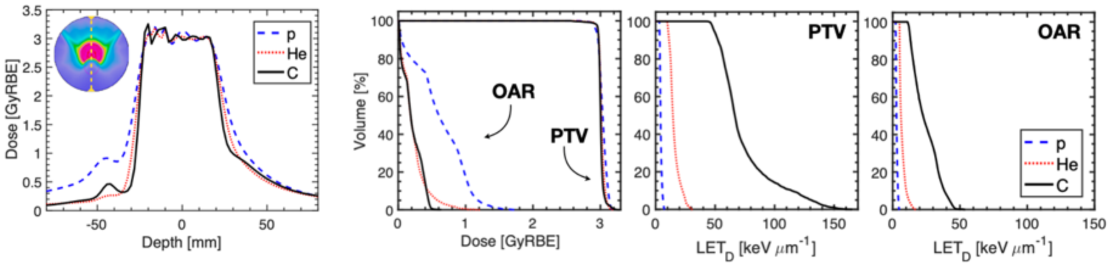
Spot-scanning Hadron Arc (SHArc) Therapy Study

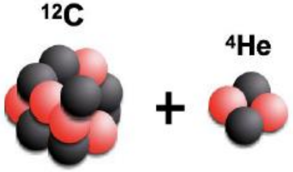


angular fluence maps



Depth-dose, D_VH, LET_VH





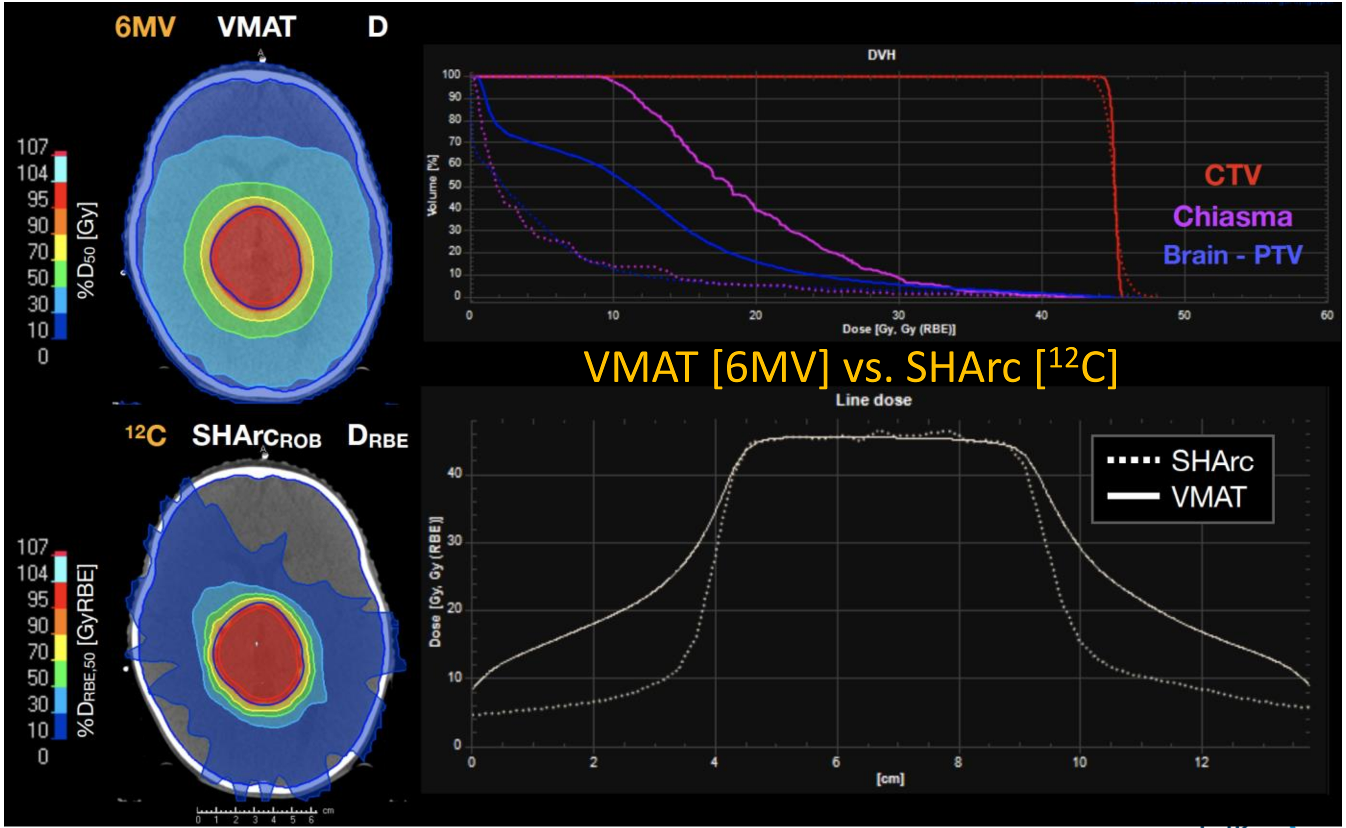
Haberer, HIT: arch Options, HIT Seminar,

Mein et al.; AdvRadOnc 2021 (6)

Spot-scanning Hadron Arc (SHArc) Therapy Study

SHArc

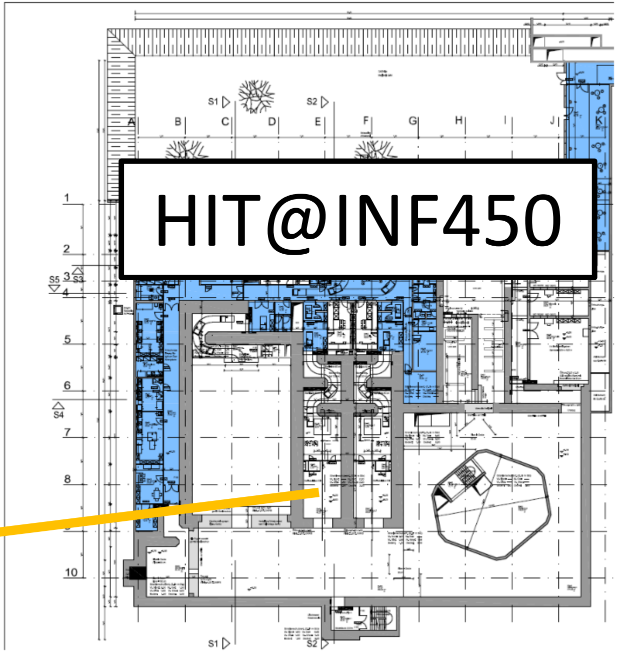
- Outperformes VMAT
- Robust plans
- Normal tissue and organs at risk sparing
- LET-VH can be tailored to the oxygenation status of the target
- Longer irradiation times
- Technical challenges ahead

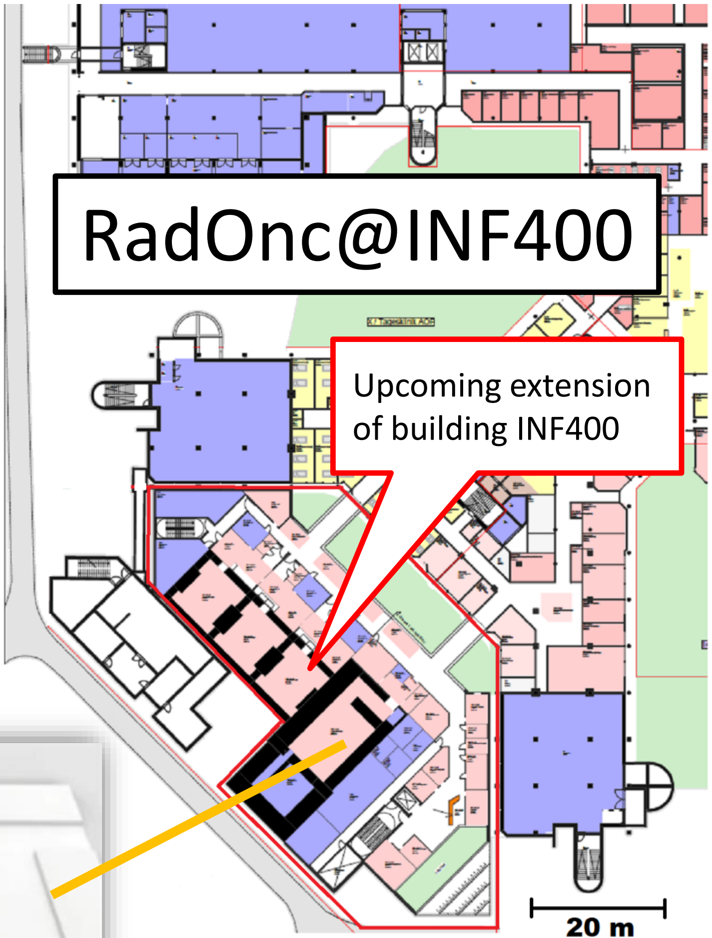


Mein et al. IJROBP (under review)

New Modalities

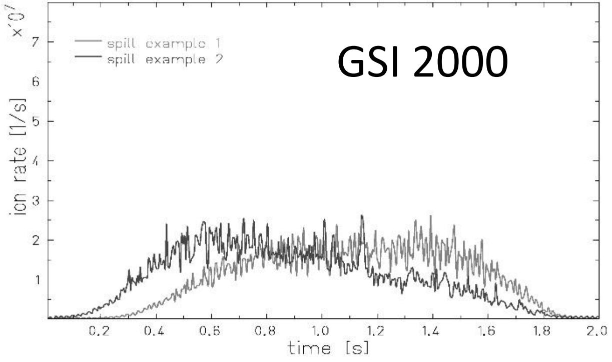
Chair with CT

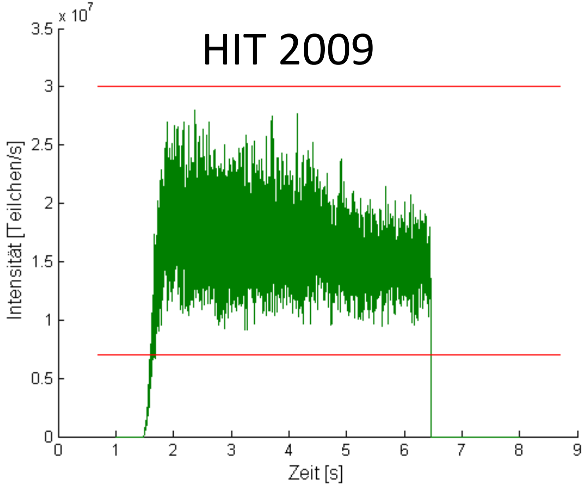


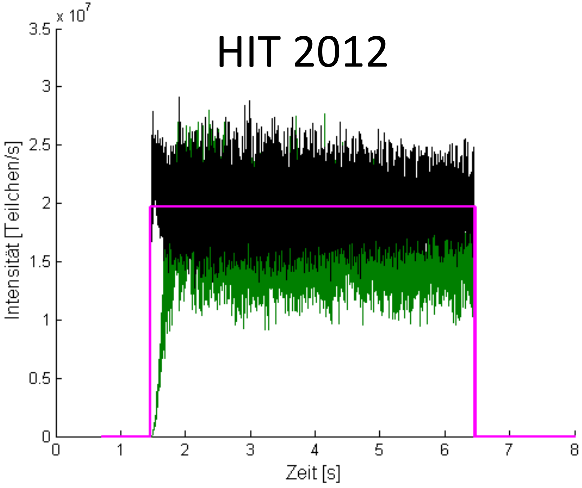


Single-room Proton system

Synchrotron Slow Extraction Optimization

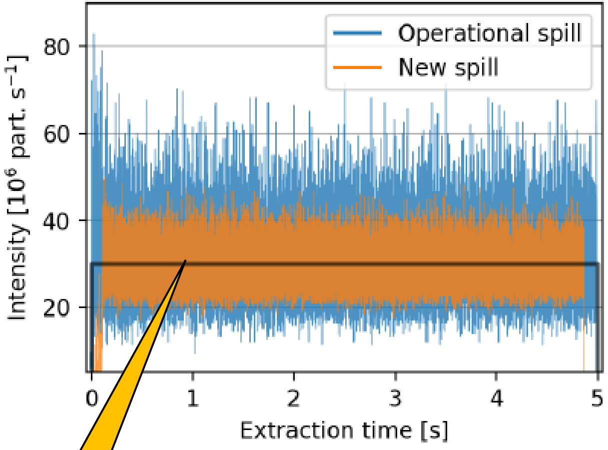






Ph.D.
Christian Schömers

HIT 2022



Master-Thesis
Christopher Cortéz

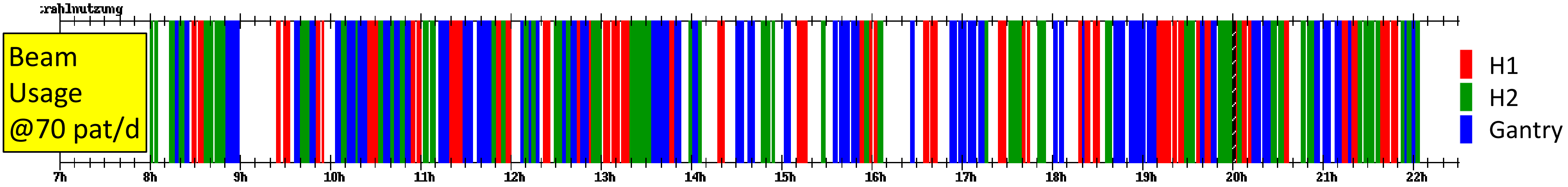
Smoothest extraction ever!

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
Volume 1040, 1 October 2022, 167137

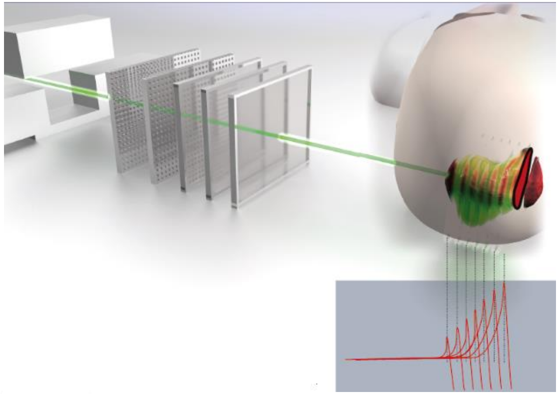
Optimization of the spill quality for the hadron therapy at the Heidelberg Ion-Beam Therapy Centre

E.C. Cortés García, E. Feldmeier, M. Galonska, C. Schömers, M. Hun, S. Brons, R. Cee, S. Scheloske, A. Peters, Th. Haberer

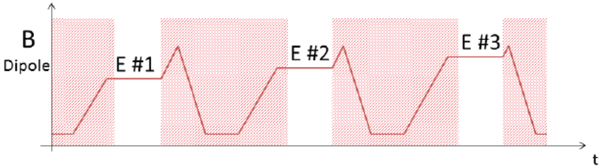
Ongoing Upgrades



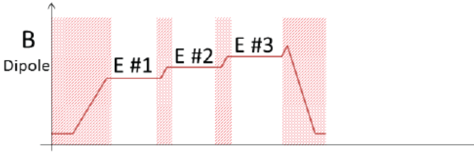
Enable multi-energy extraction:
New Accelerator Control System
Irradiation time reduction ~ 40%
Energy saving ~ 15%



one extraction per synchrotron-cycle



multiple extractions per synchrotron-cycle



Intensity upgrade:
New RFQ c
Transmissi

C. Schoemers et al.
"Reacceleration of ion beams for particle therapy."
Proc. of IPAC2014, Dresden.

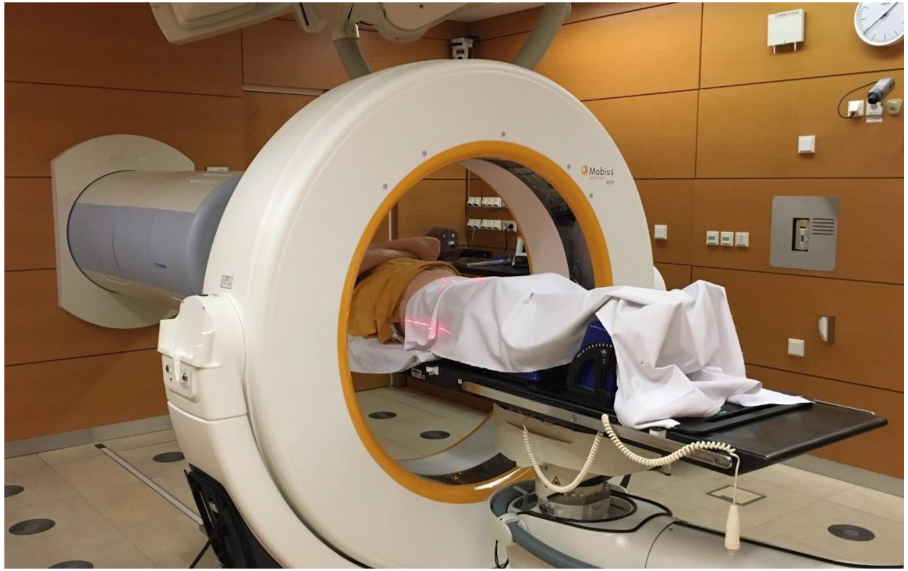
HITRI plus
Heavy Ion Therapy Research Integration

HIT
Heidelberger Ionenstrahl-Therapie

UKHD

In-room Imaging / See what you treat!

HIT – H1 sliding CT



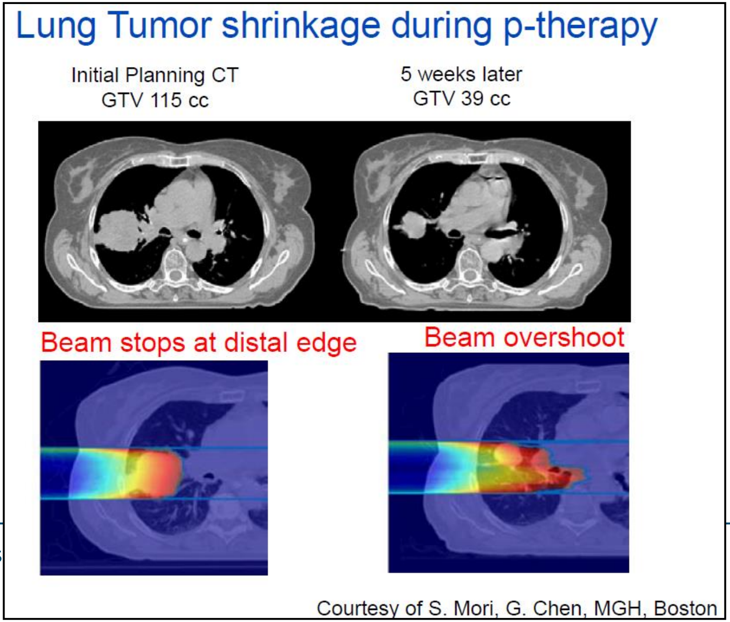
6.5 mm margin (peel) represents a volume comparable with the target!

Volumetric information defines patient set-up
Reduction of margins
Plan of the day
Fast replanning

Combining proton/ion beams with MRI

Motivation :

- **"Seeing what you treat" → Online diagnostics would be favorable**
- **CT is almost standard today, but MRI causes no further radiation dose (especially important in pediatric treatments!)**
- **Tumor shrinkage during therapy – avoidance of errors in adapted dose allocation**



- **MR-Linac Systems (photons) are currently being introduced in radiotherapy**

MR guided Ion beam Therapy: ARTEMIS Project

Adaptive RadioThErapie mit MR gesteuerten IonenStrahlen

funded by:

Bundesministerium für Bildung und Forschung

Aims

- Capture anatomical changes & changes in the tumor

to allow for

- offline, online or weekly customization,

>> providing optimal protection of the OAR

Within ARTEMIS **a demonstrator system** consisting of several components will be developed , which enables MR-guided irradiation with ions and protons.

ARTEMIS Vision:

- **Turn the patient, not the beam**
- **Plan & adapt based on MRI**

HEIDELBERG UNIVERSITY HOSPITAL

HIT Heidelberger Ionenstrahl-Therapiezentrum

dkfz. GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

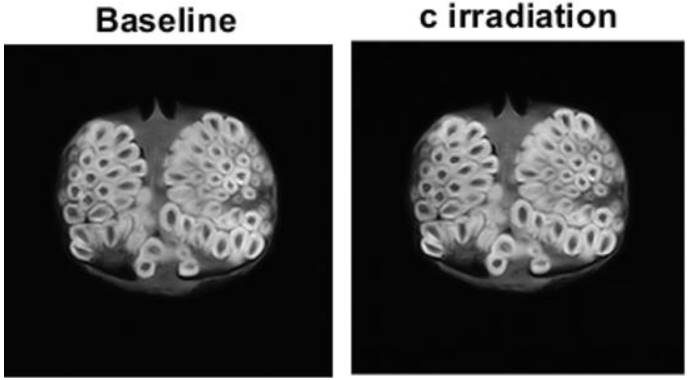
associated partner:

SIEMENS Healthineers

UK HD

The „on-line“ MRT at HIT

Sequence: 3D GRE $(0.4 \times 0.4 \times 2.5) mm^3$
Irradiation: 10 x 10 cm raster grid ,
1 cm distances



Increasing Demand For Radiotherapy In Europe / Germany

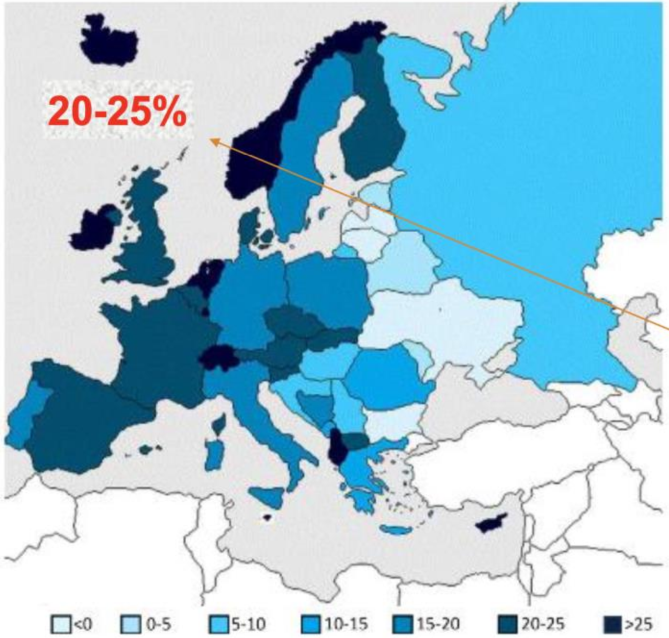
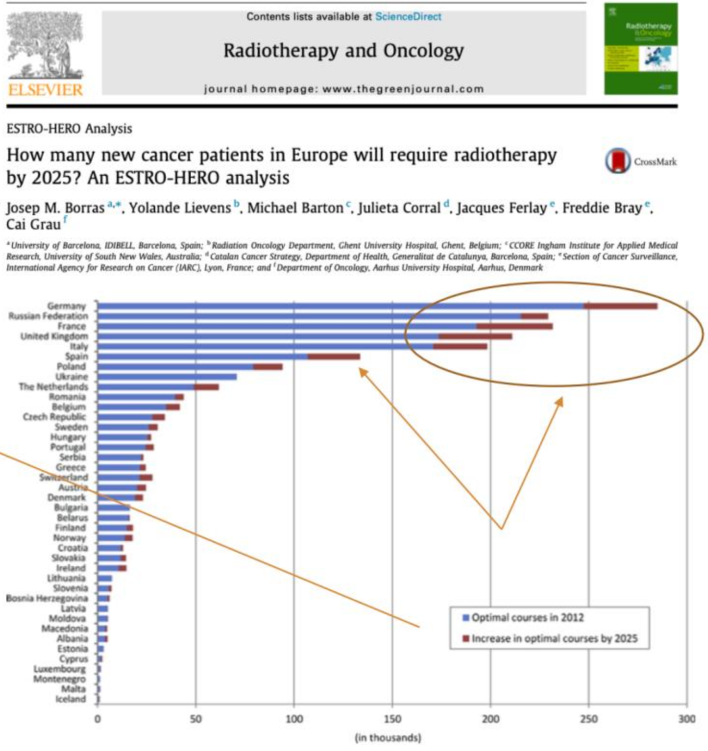


Fig. 1. Increase in new cancer patients that would require radiotherapy by 2025 by country (%).



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ESTRO-HERO Analysis

How many new cancer patients in Europe will require radiotherapy by 2025? An ESTRO-HERO analysis

Josep M. Borras[a,*], Yolande Lievens[b], Michael Barton[c], Julieta Corral[d], Jacques Ferlay[e], Freddie Bray[e], Cai Grau[f]

[a] University of Barcelona, IDIBELL, Barcelona, Spain; [b] Radiation Oncology Department, Ghent University Hospital, Ghent, Belgium; [c] CCORE Ingham Institute for Applied Medical Research, University of South New Wales, Australia; [d] Catalan Cancer Strategy, Department of Health, Generalitat de Catalunya, Barcelona, Spain; [e] Section of Cancer Surveillance, International Agency for Research on Cancer (IARC), Lyon, France; and [f] Department of Oncology, Aarhus University Hospital, Aarhus, Denmark

Fig. 2. Optimal number of courses of radiotherapy in 2012 and estimated absolute increase in optimal number of courses by 2025.

Molecular Oncology

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REVIEW

What will radiation oncology look like in 2050? A look at a changing professional landscape in Europe and beyond

Michael Baumann[1,2,3], Nadja Ebert[1,2], Ina Kurth[1], Carol Bacchus[1] and Jens Overgaard[4]

7. Conclusions

First of all, we firmly believe that radiation oncology will be at least as important in 2050 as it is today. A

and Hanahan, 2012). Radiotherapy has an impressive track record that demonstrates its curative potential in a wide variety of cancers. Given its unique features, radiotherapy will very likely remain a key component in the multidisciplinary, anticancer treatment arsenal of the future.

primary cancer care.

Another advance has come from the increased use of particle and proton irradiation (see Box 1) because of the higher precision of these techniques and because of other radiobiological considerations (Dutz *et al.*, 2019a; Dutz *et al.*, 2019b; Lühr *et al.*, 2018). Numerous new facilities that offer these treatment techniques

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Review › Mol Oncol. 2020 Jul;14(7):1577-1585. doi: 10.1002/1878-0261.12731. Epub 2020 Jun 30.

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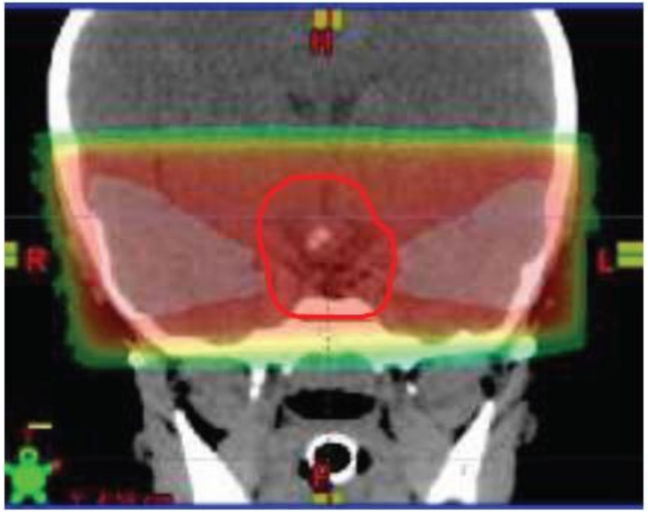
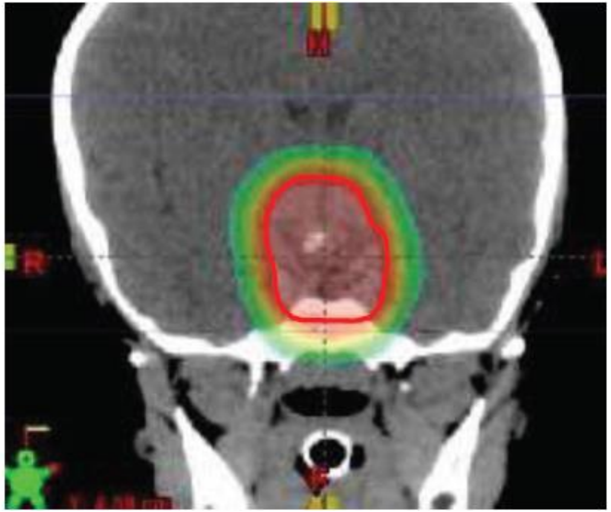
Progress

Photons 1980



Particles 2020



- Ion beam therapy is extremely precise
- Challenged by costs
- Image guidance and motion mitigation need to be improved
- Huge potential is evident

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Haberer, HIT: Multi-Ion Treatment and Research Options, HIT Seminar,

Image: courtesy N. Mendenhall, D. Louis, D Yeung, Z. Li, C. Li; Jacksonville

Thank You!

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