Cancer therapy with ion beams

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photo in Risø 1998
Cancer therapy with ion beams

- Ion source: p, $^{12}$C ion
- Accelerator: (p~100MeV, $^{12}$C~200MeV/u for 10cm water)
- Beam delivery: (active: scan, passive: collim.)
- Beam monitors: pos, N
- dE distribution: (treatment plan)
- $\gamma$-ray detection: (PET)

Image from http://www.medical.siemens.com
62 years old

- 1946 "Radiological use of fast proton", Robert R. Wilson
  "... because one could hurt people with protons, one could probably help them too."*

- 1954 First treatment with proton (Berkley Rad Lab)

- 1957 Treatment with He beam at Berkley

- 1975 Heavier ions Ar, Si, Ne at Berkley
  (1994 C ion at NIRS (Japan), 1997 C ion at GSI Darmstadt, ...)

* Advances in Hadrontherapy, proceedings of International Week on Hadrontherapy (1997)
Ion beam therapy

27 facilities have treated patients, about 20 coming soon *

* data at 2006
Advantage of ion beams

Radiation therapy
photon (γ, X-ray) ↔ ion

Excellent dose distribution for deep-seated tumor

- Localized dose profile (Bragg peak)
- Precise beam control

→ protect important part of organ
Carbon ion therapy at GSI

1997 - 2008 : ~ 380 patients were treated at GSI (pilot project)
2008 - : Heidelberg Ion-beam Therapy center (HIT)
Why $^{12}\text{C} \text{ ion}$?

$^{12}\text{C} \text{ beam}$
- Better dose profile (Biologically Effective Dose)
- Less lateral scattering
- $^{12}\text{C}, ^{11}\text{C}, ^{10}\text{C}$ Fragmentation (tail)
- Beam position by PET

**Biological effective dose**

**Lateral scattering**

Active beam delivery

GSI 3D raster-scan system with $^{12}$C beam FWHM ~6mm

- 80-430 MeV/u
- pulsed T~5s

Fast scanning magnets

Power supplies

Operator

Therapy Control System

Intensity + position feedback

Safety Interlocks

Target volume

grid space ~ 3 mm

irradiation: ~ 10ms/spot

G. Kraft, NIM A 454 (2000) 1
Image of Albert Einstein produced with the GSI rasterscan system using a 430 MeV/u carbon beam of 1.7 mm width (FWHM). The picture consists of 105x120 pixel filled by 1.5.10^{10} particles given in 80 spills (5 sec. each) of the SIS accelerator. Original size of the picture: 15 x 18 cm
Positron emission tomography (PET)

FZ Dresden
PET camera (BGO) 2048x2 crystals
$\gamma-\gamma$ coin. (off-beam~2s, T~5s)


29th Feb. 2008
Geirr 70 at NBI
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Positron emission tomography (PET)

Activity & washout effect

measured

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W. Enghardt et al., FZ Dresden,
NIM A 525 (2004) 284

simulated
Cancer treatment at GSI

- **Tumor**: Static tumor in head, neck, etc. (~380 patients)
- **Beam time**: 3 blocks/year, (1 block ~ 1 mo., inc. Sat. Sun.)
  ~15 patients/block, ~20 fractions/patient,
  30-60 min /fraction (~ 5-15 min beam on)
• Clivus Chondrosarcomas

• Patient: 23 years old
• Diagnosis: Chondrosarcoma
• Subtotal surgery
• Postoperative radiation therapy: 60 Gy e
• 3 fields with 20 fraction

before irradiation

6 weeks after the 12C irradiation, 60 Gye
Tumor control in Chordomas

- Conventional RT
- Protons
- C-Ions

5y-local control probability (%) vs Median dose (CGE)

- Romero 1993: n=18, 1.5-2 CGE/Fx
- Zorlu 2000: n=18, 2 CGE/Fx
- Debux 2000: n=37/1.8-2 CGE/Fx
- Castro 1994: n=53/2 CGE/Fx
- Munzenrider 1999: n=169/1.8-1.92 CGE/Fx
- Terahara 1999: n=115/1.8-1.92 CGE/Fx
- Hug 1999: n=33/1.8 CGE/Fx
- Schulz-Ertner 2007: n=84/2 CGE/Fx
- Schulz-Ertner 2007: n=12/2 CGE/Fx

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Schulz-Ertner, IJROBP 2007
Development for future

moving tumor (lung cancer)

X', Y' : beam shift,  Z' : Range correction by E'

3D Online Motion Compensation system

4DCT data by E. Rietzel
Prototype 3DOMC system

Motion team: C.Bert, N.Saito, A.Schmidt, N.Chaudhri, D. Schardt and E.Rietel
Prototype 3DOMC system

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Lateral compensation

Respiratory like lateral motion compensation by 3DOMC system
- Irradiation on X-ray films
- Optical density profiles

Lat. & Depth compensation

Respiratory like Motion:
T~3s, lat. ±2cm, dep. ±7.6mm
Bragg curve (400MeV/u $^{12}$C at GSI)

Bragg curve well reproduced with 0.2mm peak shift
3D motion compensation
Thank you Geirr at NBI TAL!

We are always with you!