Unique Aspects of Accelerators for Medical Application:

What is so special?

Marco Schippers, Mike Seidel
Application: Particle Therapy

- Introduction
- How to apply the radiation dose
- Accelerators and beam transport
- Operational aspects
- Safety
X-rays vs. Protons

Depth-dose curve:

15 MV X-rays
Protonen

Tumour

Conventional: X-rays

Protons
X-ray beams (IMRT) from 7 directions

Proton beams from 3 directions

pictures: Medaustro
The boost in particle therapy

Mostly in labs

More at hospitals

nr of facilities


year
Dose delivery techniques: Depth

Spread-out Bragg peak

Tumor thickness
- spread-out Bragg peak
- energy modulation

During trmt → „fast“ (<0.1-0.2 sec)

Tumor rear edge
→ Range
→ Maximum Energy per field → „slow“ (sec)
Vary energy at accelerator

**Synchrotron:** Set energy at each **spill:**

- Sets range only
- energy modulation in nozzle

**Cyclotron has fixed energy** => slow down (degrade) to desired energy

- Sets range

*And*, if fast enough

+ fast magnets:

- also energy modulation

: 5 mm ΔRange in 100-200 ms
Scatter technique

Best dose distribution

pencil-beam scanning

Scatter system

Collimator
Pencil beam scanning

**Spot scanning: step&shoot**

- continuous scanning
- kHz-Intensity modulation

**Continuous scanning**

- requires fast target repaintering: 15-30 scans / 2 min.

**Requirements for accelerator:**
- stable beam position

**Spot scanning:**

- step and shoot
- requires stable beam position

**Continuous scanning:**

- continuous and stable beam
- fast adjustable beam intensity
- fast adjustable beam energy

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Present accelerator choice

Protons in use, $\varnothing 3.5-5\ m$

Carbon ions in design, $\varnothing 6\ m$

cyclotron

synchrotron in use, $\varnothing 8-10\ m$
in use, $\varnothing 25\ m$

e.g.: Boston, Florida, Seoul, Wanjie, PSI, München, Orsay

e.g.: Loma Linda, Houston, Tsukuba
Gantries

At Gantry coupling:
- Phase space symmetric
- No dispersion

~90 t  Loma Linda (Optivus)
PSI Gantry-2: fast 3D scanning

PSI-"Gantry-2"
Eros Pedroni
David Meer
Gantry as seen from patient side

Patient table

NOZZLE

Varian
Particle therapy facility

230 or 260 MeV cyclotron

treatment rooms (gantry or fixed horizontal line)
beam transport and switch yard

accelerator
energy selection
beam transport
gantry / fixed hor. line
Operators
Technicians
Experienced workshops
More improvised actions

New beam tunes need more procedures
(operator) radiologist operates
Technicians: only small repairs
Service by equipment company
CE/FDA-certification: PROCEDURES
Fractionated treatment to spare healthy tissue

Cell killing

Surviving fraction vs. dose (Gy)

- C-ions
- photons
- protons

Surviving fraction vs. dose (Gy)

But: DO NOT interrupt treatment for more than 3-5 days
~6 weeks

Full treatment
Full treatment
Full treatment
Full treatment
Full treatment
Full treatment
Full treatment

1 week SERVICE

STOP
new treatments
Effectively: a loss of 8-10 weeks
So...

no long services =>

- well scheduled short services
- know what to do
- easy access

=> low dose level

many prepared spare parts
Operational aspects

- Dose application within 1-2 %: REPRODUCIBILITY
  => beam intensity, on/off, positioning accuracy
- «just retune and do a test»: NOT allowed
- Operational MODES: THERAPY / SERVICE
- Operation by medical staff
- More control rooms => MASTERSHIP concept

with (CE / FDA) certification:

- Procedure for designing / building / repair / testing
- Standardized documentation
- Only certified staff for certain tasks
At Psi: Separate interlock systems:

**Machine interlocks:**
all components technically OK

**Area access & area dose:**
Doors closed, dose rate < µSv/h

**Patient safety:**
Dose delivery as planned
Fast kicker magnet: beam on/off
Deflector plate: sets intensity
- within 50 µs
- 3% accuracy

Possible ON / OFF:
- RF Voltage low or off
- Ion Source off
- Deflector plate 2 kV
Hierarchy of Interlock signals

Patient safety system at PSI:

- Machine interlocks
- Area access & area dose
- Patient safety

STOP

Kick into dump

STOP

Blocker in line

STOP

RF off

STOP

Ion Source off
Patient safety system at PSI:

- **Machine interlocks**
- **Area access & area dose**
- **Patient safety**

Hierarchy of Interlock signals:

- **STOP**
  - Kick into dump
  - Blocker in line
  - RF off
  - Ion Source off
  - REDUNDANCY

Acc. for Medical Applications: What is so Special?

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Redundancy

measurement → BEAM off

Redundancy

Patient safety interlock system

Redundancy
Operation: non-accelerator experts

What happened?

Strong need for ERGONOMIC display of: Status Instructions

NO BEAM
SUMMARY

Unique Aspects of Accelerators for Medical Application:

What is so special?

- **Technics:** dedicated, but not on the limit ....but...
  Reliable, Reproducible, Reliable, Reproducible

- **Operation:** by non accelerator experts
  strictly according procedures
  NO long services or shut down

**Control and safety:**

  VERY DEDICATED and SPECIAL :
  Reliable, redundant, but not too sensitive
first scanning gantry: PSI, 1990

Gantry: Eros Pedroni

Tumours in kids: Beate Timmermann, Gudrun Goitein

.... Motivation ....

Thank you!!