The Proton Beam Therapy Facility at PSI

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Talk outline

Tradition of radiotherapy @ PSI
Some remarks on scanning techniques
Motivation for, and brief description of, PROSCAN project
- description of the COMET cyclotron
New treatment gantry and scanning improvements
Conclusions

Why use protons for radiotherapy?

Radiation dose should be delivered to tumour while sparing the healthy cells that surround the tumour. The existence of the Bragg “peak” makes protons an attractive choice for therapy.

Generic proton therapy facility components

accelerator
energy selection
beam transport
gantry

Control system:
- accelerator + beam transport
- treatment delivery + verification
- interlocks + safety systems
Parasitic use of research facility for patient treatment.

Ring cyclotron
590 MeV, 2 mA

Gantry 1 (1996)
~ 400 patients treated.

Injector I cyclotron - eye treatment (1984)

> 5000 patients treated at OPTIS-1.

Classical "scattered" proton beam delivery technique

Passive scattering – essentially for eye treatments.

Energy modulator

Shaped collimator

Scatter foils

Spot scanning technique developed at PSI

Better for larger, deep seated tumours. Allows a "pencil" proton beam to deliver a high dose with high precision for a precisely specified period of time.

Spot scanning: step & shoot

Results in better dose distribution.

Beam size 7 mm FWHM
5 mm steps
10,000 spots/liter (21 x 21 x 21)
Dose painted only once
~1 Gy/litre/minute

Transverse motions via fast scanning magnet and patient table movement.
Depth variation by range shifter (lucite plates) in front of patient.

Compact "Gantry-1" at PSI (1996)

Lucite plates set depth

scanning proton pencil beam

Table motion

Eros Pedroni
Gantry 1 – in use at PSI for treatment since 1996.

Most compact of all existing gantry designs, φ ~ 4 m

Limitations of spot-scanning technique with Gantry 1

- Beam spreading due to multiple scattering in the lucite plates.
  - Less sharply demarcated dose distributions
- Relatively slow motion of table movement
- Dynamic treatment suffers from tumour or organ movement during scan
  - Under/over dosage may occur

Motivation for the construction of the PROSCAN Facility

- Difficulties of parasitic use of Ring Cyclotron in a multi-user research environment
- Ring cyclotron and spallation neutron targets require long maintenance shutdowns ~ 4 months per year during which no treatment is available.
- Further development of PSI spot-scanning technology
  - Fast scanning techniques to deal with organ motion
- Transfer of technology to industry and radiation therapy centers

The PROSCAN facility consists of:

A 250 MeV proton cyclotron – COMET (COmpact MEdical Therapy cyclotron)
An energy “degrader”
Beam lines equipped with diagnostics
Therapy equipment
  - previously existing gantry 1
  - new gantry
  - new eye treatment facility – OPTIS-2
  - experimental beam line.
Cyclotron (1930)

Ernest Lawrence
(1901-1958)

RF System
- Frequency: 72.8 MHz (h = 2)
- RF power: 100 kW
- Dee voltage: 80 – 130 kV

Beam properties
- Energy: 250 MeV
- Extracted current (max.): 800 nA
- Extraction efficiency: 80%
- Vert. emittance: < 3 mm-mrad
- Horiz. emittance: < 5 mm-mrad
- Momentum spread: ± 0.2%
- # of turns: 650

* Important for activation issues.

The 250 MeV Cyclotron

Based on a design from NSCL (H. Blosser).
Delivered by ACCEL/Varian.
Strong ACCEL/PSI Collaboration.
Ordered – April 2001
First extracted beam – April 2004
Beam to gantry – June 2006

Main components of cyclotron

- Iron yoke: shapes field
- Proton source
- Coils (super conducting)
- RF: accelerates protons

Characteristics of the COMET cyclotron

COMET is a compact 4-sector AVF isochronous cyclotron employing a superconducting magnet.

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Internal proton source

- Cathode at +HV
- Anode at -HV
- Chimney with slit
- ~5 cm

Intensity control

- Max. intensity set by: proton source
- Deflector plate: sets requested intensity within 50 μs
- 5% accuracy

Central region

- Vertical deflection plate: - Beam on/off
- - Intensity modulation
Cryogenics: closed He-system 4x1.5 W

Extraction from COMET

- Electrostatic extraction elements
- Low activation
- 24 h after beam off (extracted beam integral: 200 µA h)
  - on pole: 400 - 500 µSv/h
  - mid plane: 250 - 400 µSv/h
  - 10 cm unshielded deg.: 500-1000 µSv/h
  - next to shielded degrader: 10-20 µSv/h
Degrader for fast beam energy change.

Main disadvantage of cyclotron is its “fixed” energy. “Degrader” is used to alter energy of beam delivered to patient. Variable thickness of material is inserted in front of beam to vary energy from 70 to 238 MeV. 5 mm range variation produced in 50 ms.

Carbon wedge degrader 238–70 MeV 5 mm Range in 50 ms

Colimating apertures define acceptance of beam transport system and limit emittance of degraded and “scattered” beam.

Translatable carbon wedge degrader Colimator for emittance limitation

Dipole magnet and energy selection slits limit ΔE/E to ± 0.7%

Availability 2008 (first 9 months)

Unplanned DownTime UpTime

3516 hours 95%
The problem in dynamical treatments:

- Danger of underdose and/or overdose

**PROSCAN approach:**
- Multiple scans of tumor
- Increase scan speed
- Intensity modulation

**Fast pencil beam scanning & IMRT**
- Cont. scanning “TV” mode
- kHz-Intensity modulation
- After each layer:
  - Energy change in 80 ms

**3D Pencil beam scanning**
- Proton energy
- Depth (scan plane)

**New Gantry 2 at PSI (2009)**
- Scanning magnets (x & y) for 2D scanning
- No patient specific components in nozzle
- Eros Pedroni
Gantry - 2

Gantry - 1 connection: check point

Beam verification by user:
Measurements at Check point

Connection to Gantry-1

Intensity monitor
Profile monitor
collimator
Halo monitor

DIAGNOSTICS

Conclusions

• The long tradition of radiotherapy at PSI is strengthened by the PROSCAN project.
• The choice of a superconducting cyclotron as a dedicated accelerator has proven to be judicious.
• COMET is performing in a satisfactory and reliable fashion.
• The installation of such a facility in a hospital environment could be envisaged.

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Thank you for your attention!