Overview of Proton Beam Cancer Therapy with Basic Economic Considerations

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Proton Therapy Project, Houston

Cyclotron
235 MeV
300 nA
Extraction Channel
Radial Probe
Energy Degrader Wheel

High-Precision Robotic Couch
Hitachi Gantry

13 m diameter
220 tons
SAD ≥ 2.7 m

Gantry Pit (Tsukuba University)

Roller Bearings
Rotating Mass
~200 T!!!
~12 m dia.

NPTC First Patient Treatment on 8 November, 2001
Proton Bldg Construction, NCC Korea

NCC, Korea
Hospital (existing)
Research complex (under construction)
Proton therapy facility (under construction)

Ion beam laboratory

RFQ injector
200 kV platform
Proton therapy beamline
Decelerator sector cyclotron
5 MV van de Graaff injector
Emerging Trends in Proton Therapy

For-Profit Financial Model
- Reduce Time to Market (~ 3 y)
- Minimize Cost (< 100 M)
- Minimize Risk!!!

Facility designs, planning software will continue to improve dramatically
New Ion Facilities

About 10 new facilities will open in the next 3-4 years.

<table>
<thead>
<tr>
<th>INSTITUTION</th>
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<th>TYPE</th>
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<tr>
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<td>Proton Development N.A. Inc.</td>
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From Protons Newsletter

Proton Therapy Center - Houston

• Facility Overview
  • Treat approx. 3400 pt/y (treating 12 h/d, 6 d/wk)
  • Stand-alone facility (with CT, CT-sim, PET, MRI, …)
  • 88,000 ft² of clinical space

• Beam Scanning Clinical Goals (IMPT)
  • Treat 240 patients/y with scanned beams (8% of total)
  • 30 min/patient (two fields)
  • 24 patients/d
Linac Injector and Synchrotron

- Linac
- Septum Magnet
- Electro Static Deflector
- Electro Static Inflector
- Bending Magnet
- RF Cavity
- Uni. of Tsukuba

70-250 MeV
8 x 10^10 p/spill
2 - 6.7 s rep.
0.5 - 5 s/spill
Stable beam properties (no feedback)
High reliability

Rotational Gantry

- 13 m diameter
- 200 tons
- SAD ≥ 2.5 m
Results of 7 Measurements

Physics Review: Objectives
• Review basic proton interaction physics
• Understand how protons can be used to provide a clinical advantage
• Introduce equipment and technology
Energy Transfer Mechanisms

- Excitation
- Elastic scattering with nucleus
- Ionization
- Bremsstrahlung

Most energy loss is via coulombic interactions with atomic electrons. Small deflections are caused by coulombic interactions with nucleus. Nuclear reactions play only a small role.

Energy-Loss Rate, Proton Range

Range straggling: \( \sigma = 0.012 R^{0.65} \)

Range Straggling
Range Straggling Smears out the Bragg Peak

Enough Physics, now for some engineering …

Making a Spread-Out Bragg Peak
Dynamic Beam Scanning
• Sweep small proton beam over a large tumor using magnetic beam deflection.
• Modulate beam range and fluence for each spot.

A full set, with a homogenous dose conformed distally and proximally
Summary of Key Points

1) Proton beams stop - no exit dose
2) Laterally, proton beams have sharp penumbra
3) Proton beams provide uniform target dose distributions
4) Proton dose distributions can be made to conform tightly to irregular target shapes in all three dimensions
5) Lower integral dose with marked reduction of low-dose volume or "dose-bath"
4) Clinical radiobiology of proton beams is almost identical to that of photon beams
5) Hence, protons offer a significant clinical advantage and it is mainly due the ability sharpen dose.