AAPM 51th Annual Meeting

CE - Therapy

PROTON Physics and Technology

Alfred Smith, Ph.D.

M. D. Anderson Cancer Center
Houston, TX

Topics Covered

- Rationale for Proton Therapy
- Physics of Proton Beams
- Treatment Delivery Techniques
- Proton Therapy Technology

Rationale for Proton Therapy

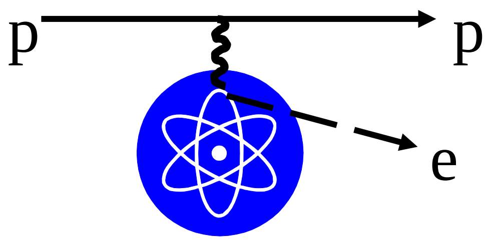
Potential Advantages of Proton Therapy

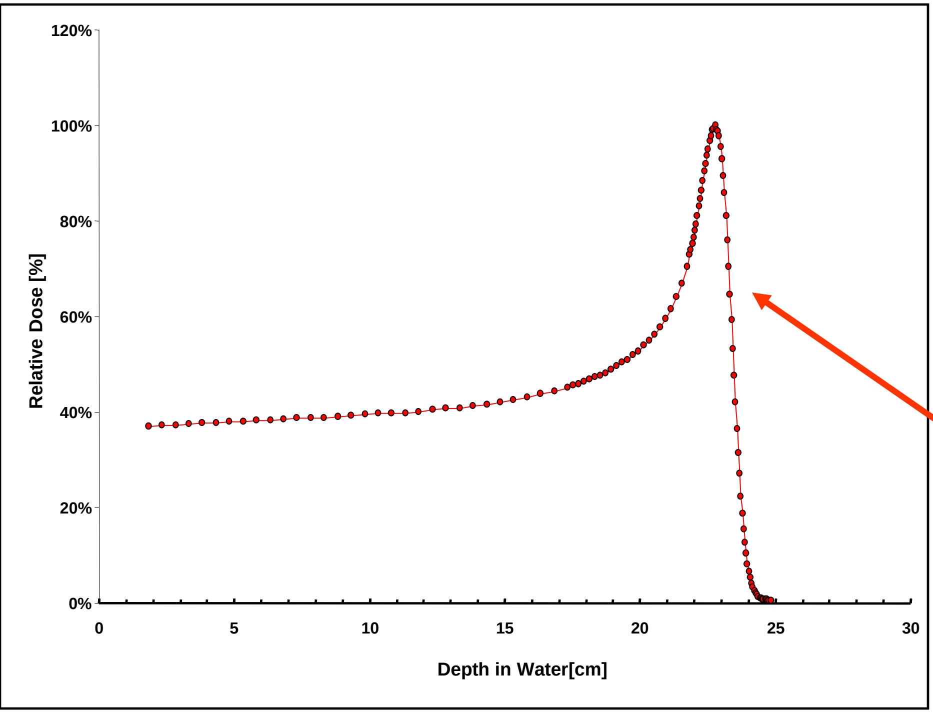
- Improved dose distributions
- Increased local control of tumors
- Decreased treatment-related side effects
- Improved Quality of Life

Proton Physics

- The physics of proton beams
- Passive scattering systems
- Pencil beam scanning systems

Electromagnetic energy loss of protons





The Bragg peak is "broadened" by:

1. **The incident beam has a narrow energy spread (not monoenergetic)**
2. **Range straggling caused by statistical differences in energy losses in individual proton paths.**
3. **Nuclear interactions of protons with the nuclei of atoms in the medium**

Mass Electronic Stopping Power is the mean energy lost by protons in electronic collisions in traversing the distance dx in a material of density ρ.

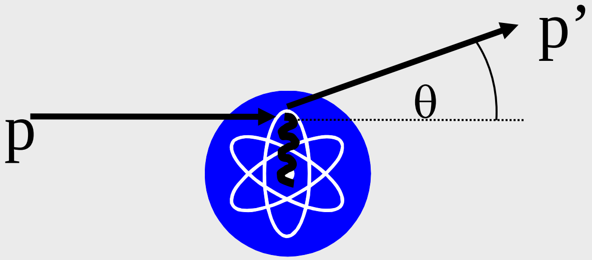
$$S/\rho = 1/\rho[dE/dx] \propto 1/v^2$$

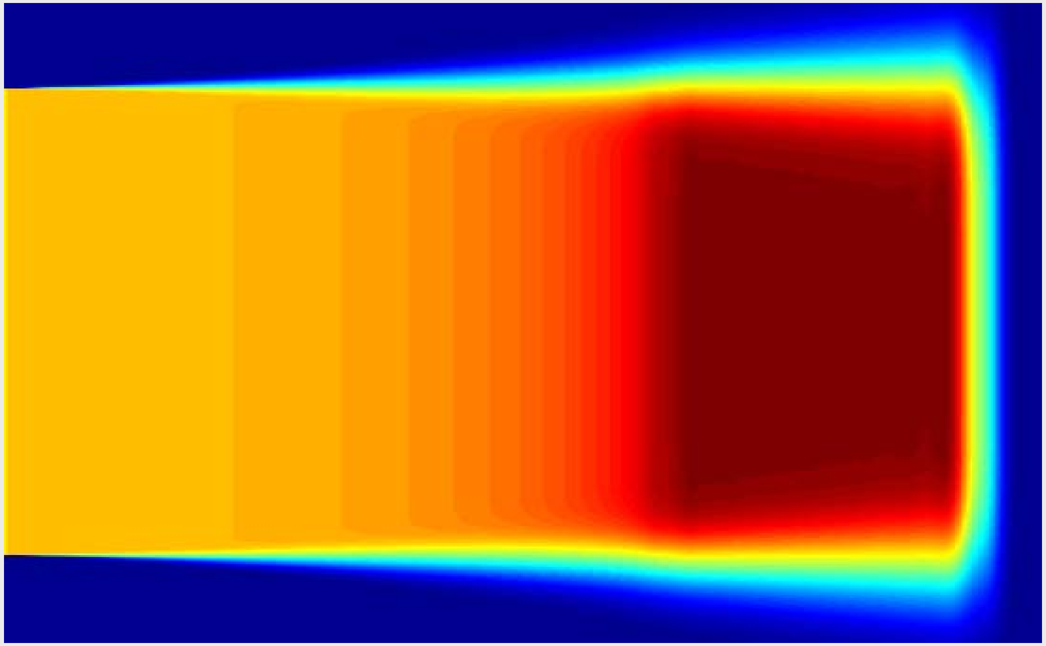
Where v = proton velocity

This is the main interaction that causes formation of Bragg peak.

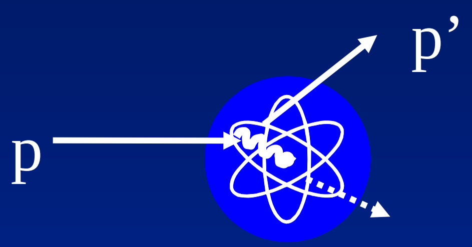
Multiple Coulomb Scattering (MCS) leads to broadening of lateral penumbra as beam penetrates in depth.

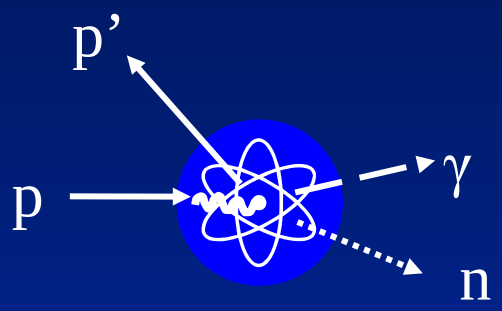
- Protons are deflected frequently in the electric field of the nuclei
- Beam broadening can be approximated by a Gaussian distribution





Nuclear interactions of protons





- **A certain fraction of protons undergo nuclear interactions, mainly on ^{16}O**
- **Nuclear interactions lead to secondary particles and thus to local and non-local dose deposition, including neutron.**

In passive scattering systems neutrons are produced in the first and second scatterers, modulation wheel, aperture, and range compensator in addition to those produced in the patient.

Proton Therapy
Beam Delivery Technology

1. Proton Accelerators

2. Isocentric Gantries

3. Typical Facility

Robotic Applications

New Technologies

- Single Room Proton Therapy Systems
- Laser Acceleration
- Dielectric Wall Acceleration

Potential advantages of single room proton therapy solution

- Reduced floor space and building costs - lower cost entry into proton therapy
- Most components mounted on the rotating gantry thus reducing the length of the beam transport system
- No competition for beam with other treatment rooms
- If multiple rooms are used, the entire proton treatment capability is not lost of one accelerator goes down.

What is the advantage of Proton Therapy?

0% 1. Improved physical dose distributions

0% 2. Greatly increased biological effects

0% 3. Lower costs

0% 4. Decreased size of facility

0% 5. Decreased complexity in technology

Answer: 1 – Improved physical dose distributions

Ref: H. Suit, “The Gray Lecture 2001: Coming technical advances in radiation oncology.” Int. J. Radiat. Oncol. Biol. Phys. 53, 798-809 (2002)

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What is the main contribution to growth of lateral penumbra in proton dose distributions?

0%	1. Range straggling
0%	2. Type of accelerator used
0%	3. Multiple Coulomb scattering
0%	4. Length of beam transport line
0%	5. Whether a gantry or fixed beam line is used

Answer: 3 – Multiple Coulomb scattering

Ref: M. Goitein, “Radiation Oncology: A Physicist’s-Eye View” Springer, 2007

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What kind of accelerators are currently used in proton therapy?

0%	1. Dielectric wall accelerators
0%	2. Cyclotrons and synchrotrons
0%	3. Laser accelerators
0%	4. Linacs
0%	5. Fixed Field Alternating Gradient machines

Answer: 2 – Cyclotrons and synchrotrons

Ref: A. Smith, “Proton Therapy.” Med. Phys. 36, 556-568 (2009).

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Thank You!