Quantifying the depth-dose curve in hadron therapy: a computational approach - D. Sardari

SRI Azad University – Tehran – IRAN

Quantifying the depth-dose curve in hadron therapy: a computational approach

The 1st Romanian Society of Hadrontherapy (RSH) Workshop

26 FEBRUARY – 1 March 2009

DARIUSH SARDARI

E-MAIL: sardari@srbiau.ac.ir

1

PURPOSE

To develop physical-mathematical description for variation of depth-dose curve in charged particle therapy

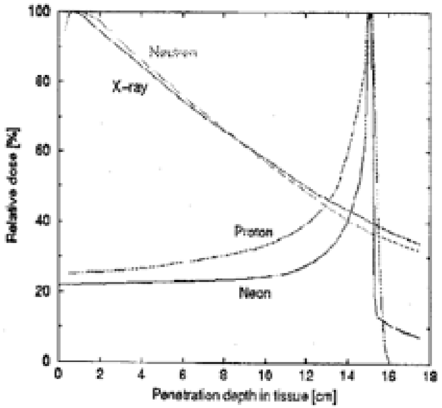
QUESTION 1

WHAT WOULD BE THE ENERGY OF PROTON WHEN IT BEGINS THE DISTAL FALL-OFF REGION?

QUESTION 2

- How much the diameter of beam increases while passing through the soft tissue?

4

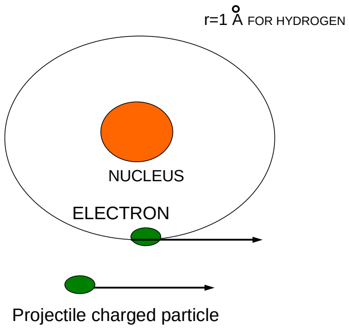


5

As a rule of thumb:

fall-off begins when the proton velocity becomes equal to the velocity of orbital electrons

CHARGED PARTICLE CAN EXCHANGE ELECTRON WITH TARGET ATOMS AND



17 May 2009 Prepared by D.SARDARI 7

Approximate electron velocity around the nucleus

- Angular momentum is a multiple of planck constant

$$m_e v r = n \frac{h}{2\pi}$$

8

Electron orbital radius

$$r = \frac{ze^2}{4\pi\varepsilon m_e v^2}$$

Electron velocity

$$v = \frac{2\pi z e^2}{4\pi\varepsilon n h}$$

For water $z_{eq} \approx 8$

10

Since the proton interacts mostly with outer electrons, n=4 is considered

$$v_e = 4.6 \times 10^{21}\ fm/s$$

11

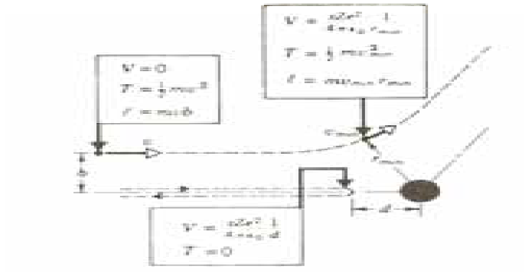
A proton with 3.4 MeV energy has velocity comparable with that of an orbital electron.

Another problem

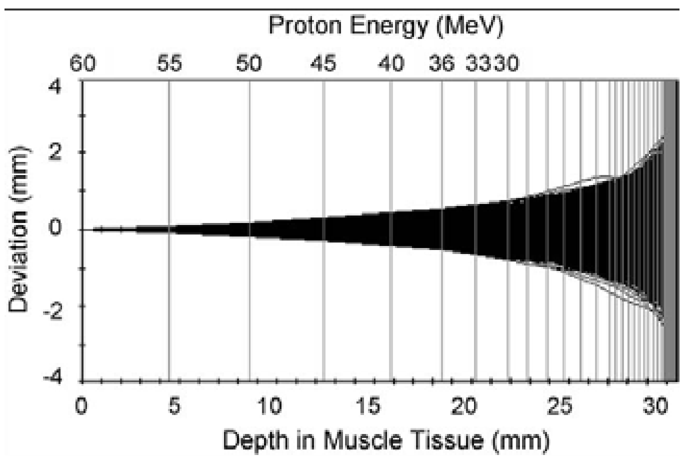
CHRGED PARTICLE BEAM DIVERGENCE

13

Schematic of particles collision



$$d = \frac{Zz.e^2}{2\pi\varepsilon_0 (m v_0^2)} \longrightarrow 2T_a$$



15

BEAM DIVERGENCE IN SOFT TISSUE

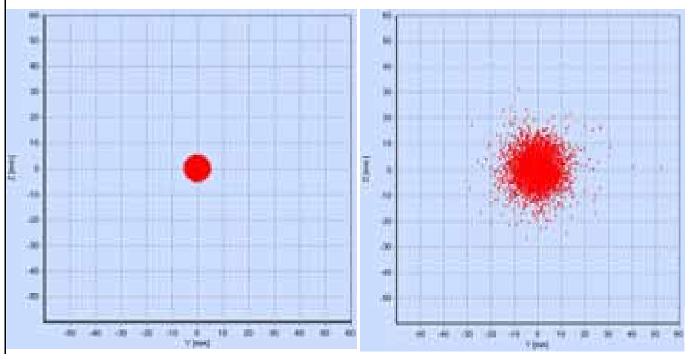
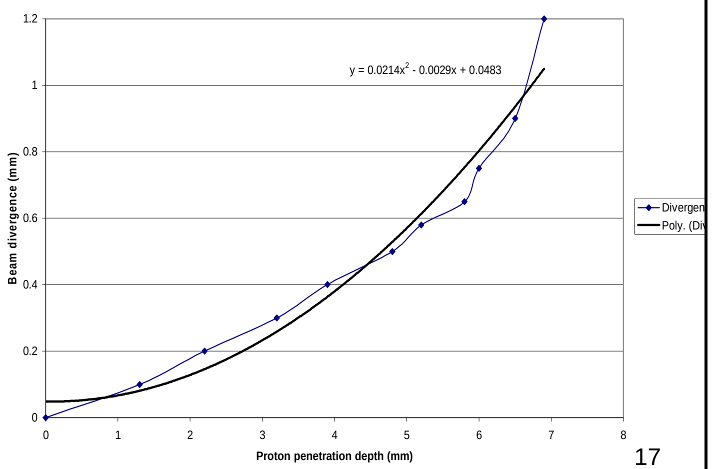
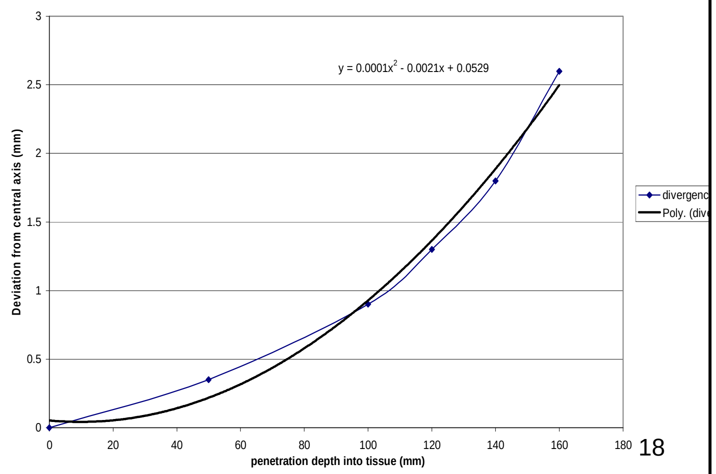


Fig. 1- Widening of 60 MeV proton beam as function of penetration depth



17

Fig 2- Widening of 3.5 GeV carbon ion beam as function of penetration depth

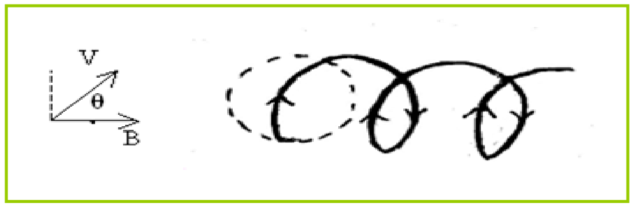


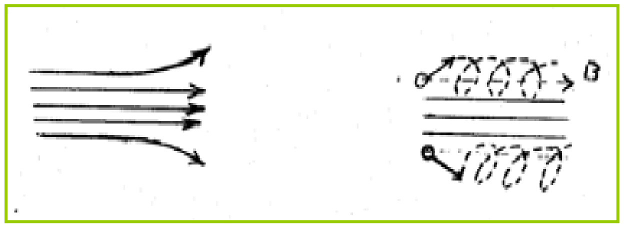
18

SOLUTION

AXIAL MAGNETIC FIELD MIGHT
BE APPLICABLE

(IS IT REALLY FEASIBLE?)





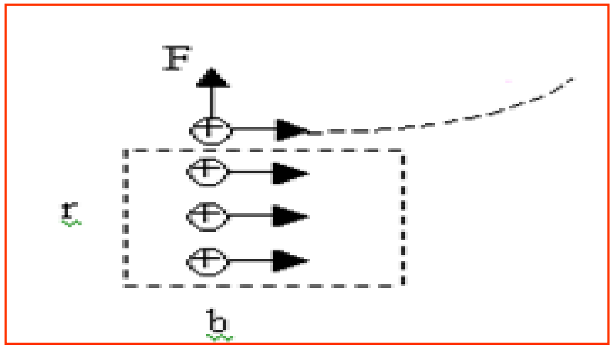
20

NOT POSSIBLE TILL PRESENT

50 TESLA IS REQUIRED

ANOTHER SOURCE OF BEAM WIDENING

REPULSION FORCE BETWEEN PROJECTILE PARTICLES (SIMILAR ELECTRIC CHARGES)



23

WE HAVE SHOWN THAT

DIVERGENCE DUE TO SPACE

CHARGE EFFECT IS NEGLIGIBLE

24

RESULTS

- Theoretical atomic physics predicts the location of Bragg peak. It appears when proton slows down to 3 MeV.
- Proton and carbon ion beam suffer from widening due to repulsive force between projectile particle and atomic nucleus inside the tissue.

25

RESULTS(CONTINUED)

- Proton beam radius increases 1- 1.5 mm in the target volume, mostly in the Bragg peak region.
- Carbon ion beam get 2.5 – 3 mm wider in the Bragg peak.
- The effect of space charge (self-repulsion) in beam divergence is negligible.

26

NOTE:

The width of Bragg peak might cover energy range 13 MeV down to 2 MeV, depending on the chemical constituents of the material and the kind of electrons taking part in the charge exchange interaction, i.e. inner, outer or free electrons.

27

From figures 1 and 2, it might be inferred that for the same amount of diameter increase, penetration depth is proportional to mass of projectile particle. For example, carbon ion beam at the depth of 100 mm and proton beam at depth of 7 mm experience 1mm widening.

28

THANK YOU

SPECIAL THANKS TO Dr. VERGA and OTHER ADMINISTRATORS OF RSH

-QUESTIONS

-COMMENTS