Accelerators for Medical Science

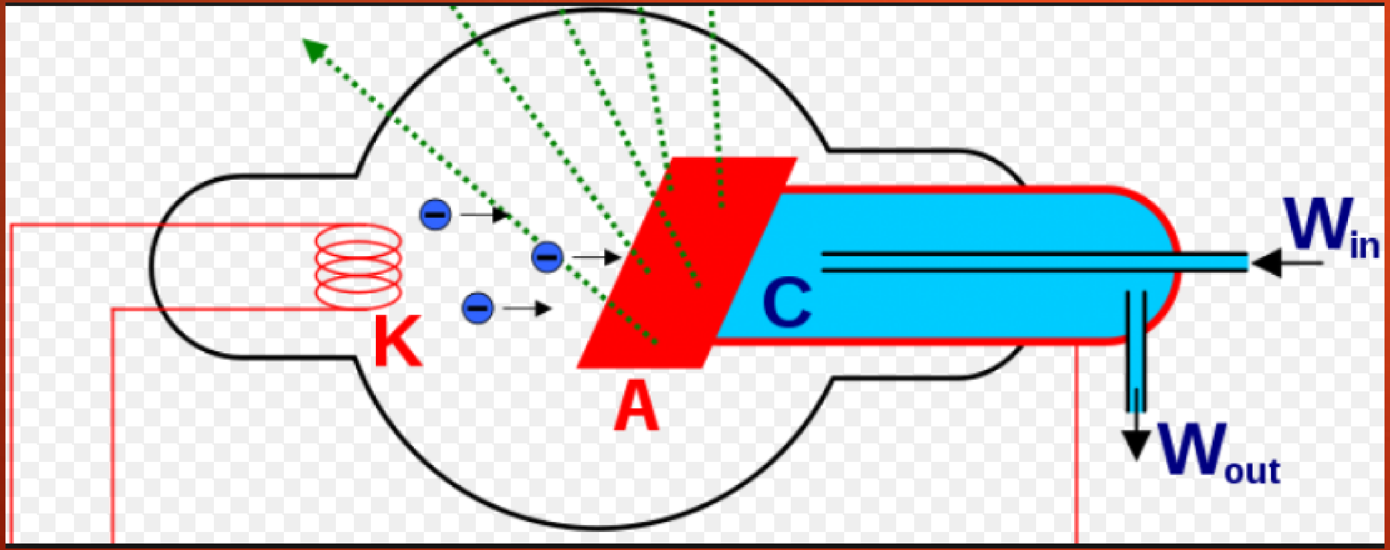
A SHORT PRESENTATION BY YVES SCHIEBER

Outline

- 1. historical development of accelerators in medical science
- 2. Basic types of Accelerators
  - 2.1 linear Accelerators
  - 2.2 circular Accelerators
- 3. Applications
- 4. Example Treating cancer
  - X-Ray Therapy
  - Hadron Therapy
- 5. Refrences

1.Historical developments of accelerators for medical Apllications

- 1895 W.K Röntgen discovers X-ray/röntgen rays
- First attemps of treating maligant tumors

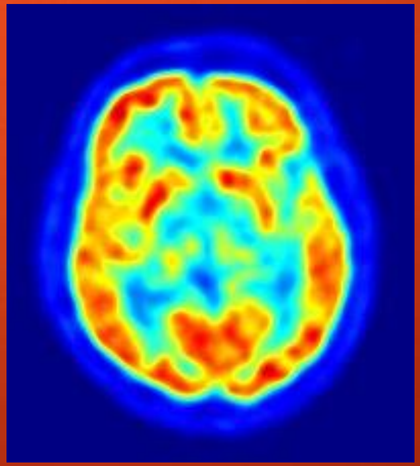


BQ(2)

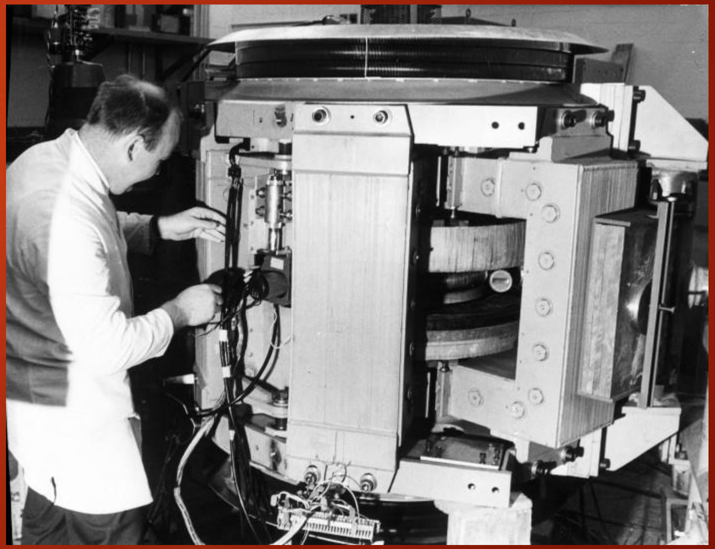
BQ(1)

1.Historical developments of accelerators for medical Apllications

- 1913 W.D Coolidge vacuum Tube with tungsten cathode
- 1912 first radium cannon with radium 226
- 1930's focus on megavoltage theraphy
- 1949 first patient treated with x-rays from betatron
- 1973 first Positron camera
- 1990 first hospital used proton synchroton for radiotherapie



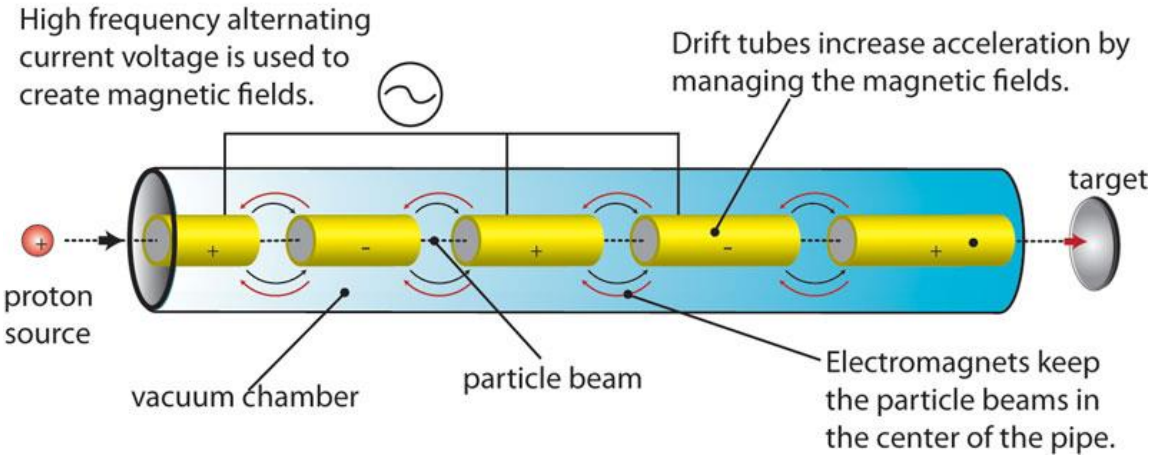
BQ(3)



BQ(4)

2.1 linear Accelerators

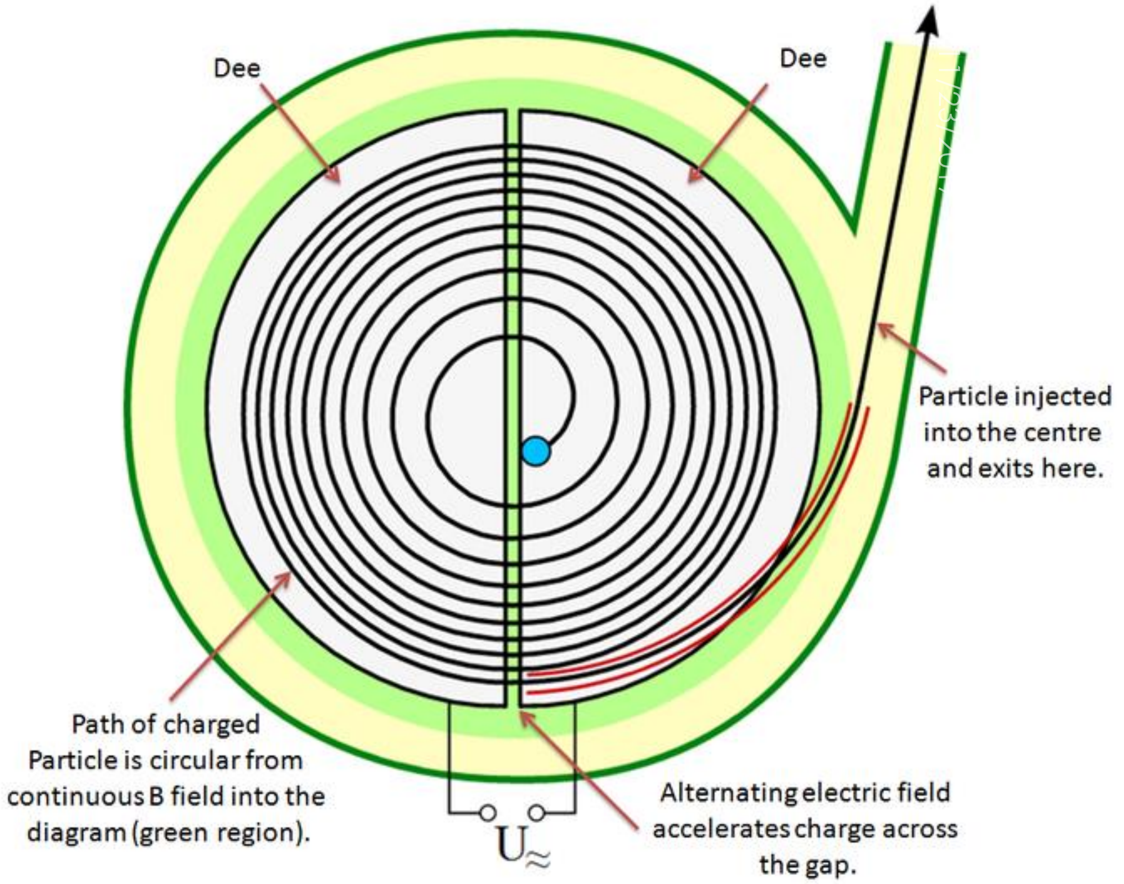
- capable of accelerating heavy ions
- Produces a continuous stream of particles
- can produce electrons at relativistic speed



BQ(5)

2.2 circular Accelerators

- allows continuous acceleration
- particles emit synchrotron radiation
- smaller than a linear accelerator
- Periodically output of particles



BQ(6)

3. Applications of Accelerators

- Radiation Therapy
- Hadron Therapy
- Medical Imaging
- Isotope Production
- Equipment Sterilization

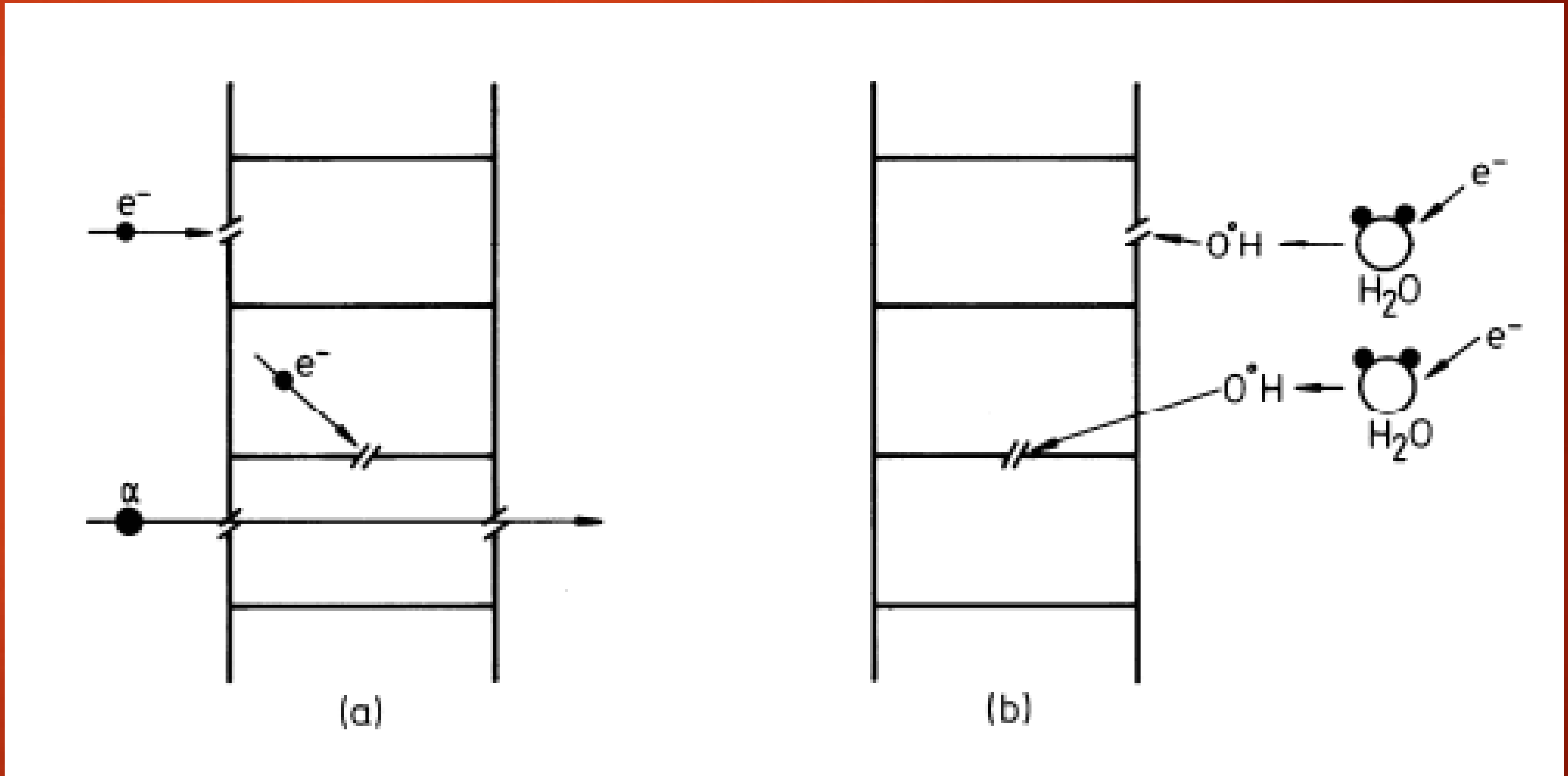
BQ(7)

BQ(9)

BQ(8)

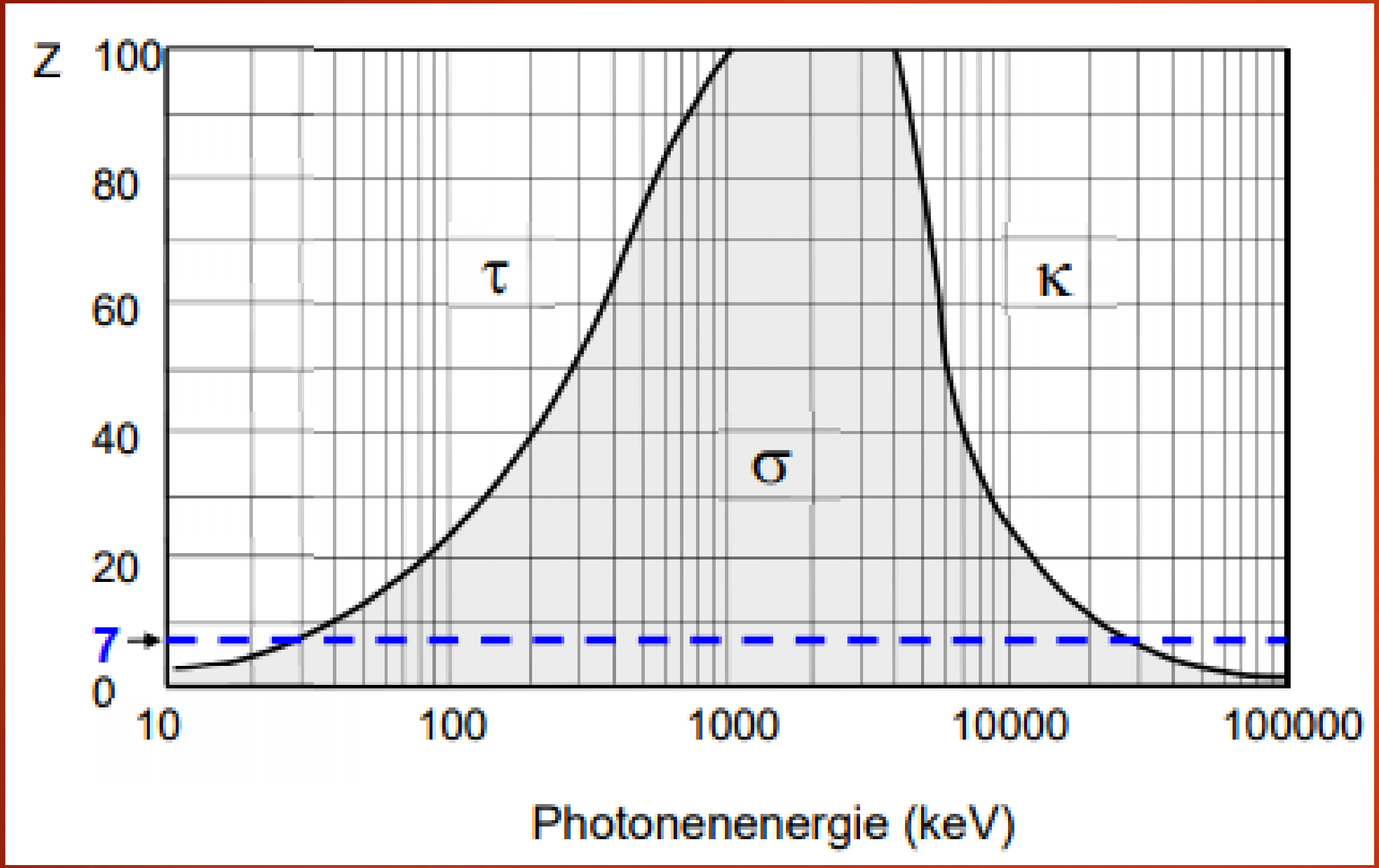
4.1 Basic Idea

- a) direct radiation effect
- b) indirect radiation effect



BQ(10)

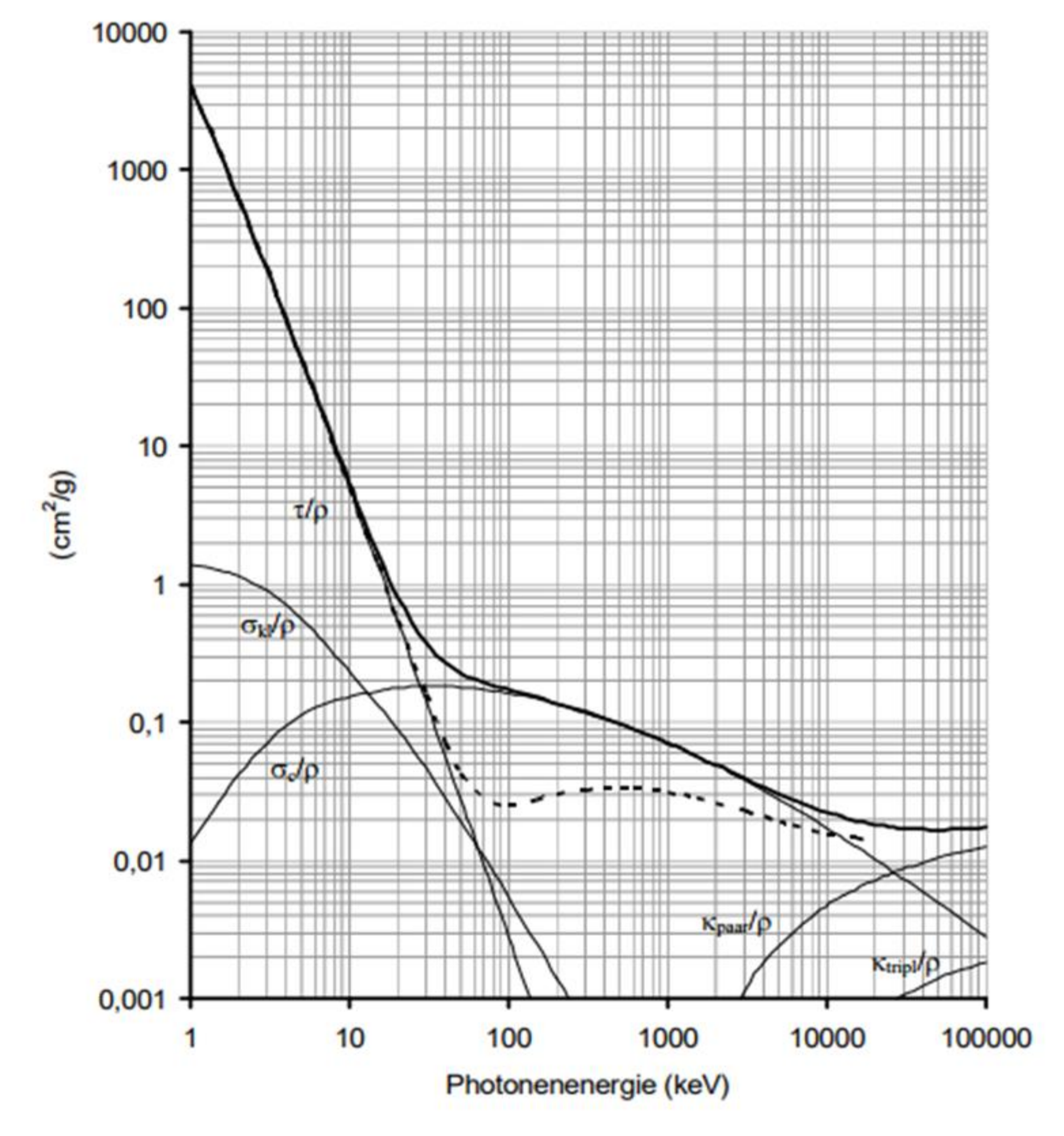
4.2 X-Ray theraphy



- Mass attenuation coefficient μ
- τ ... Photoeffect
- σ ... $Comptoneffect$
- k ... $Pairproduction$
- line follows the path where neighbouring effects have same probability

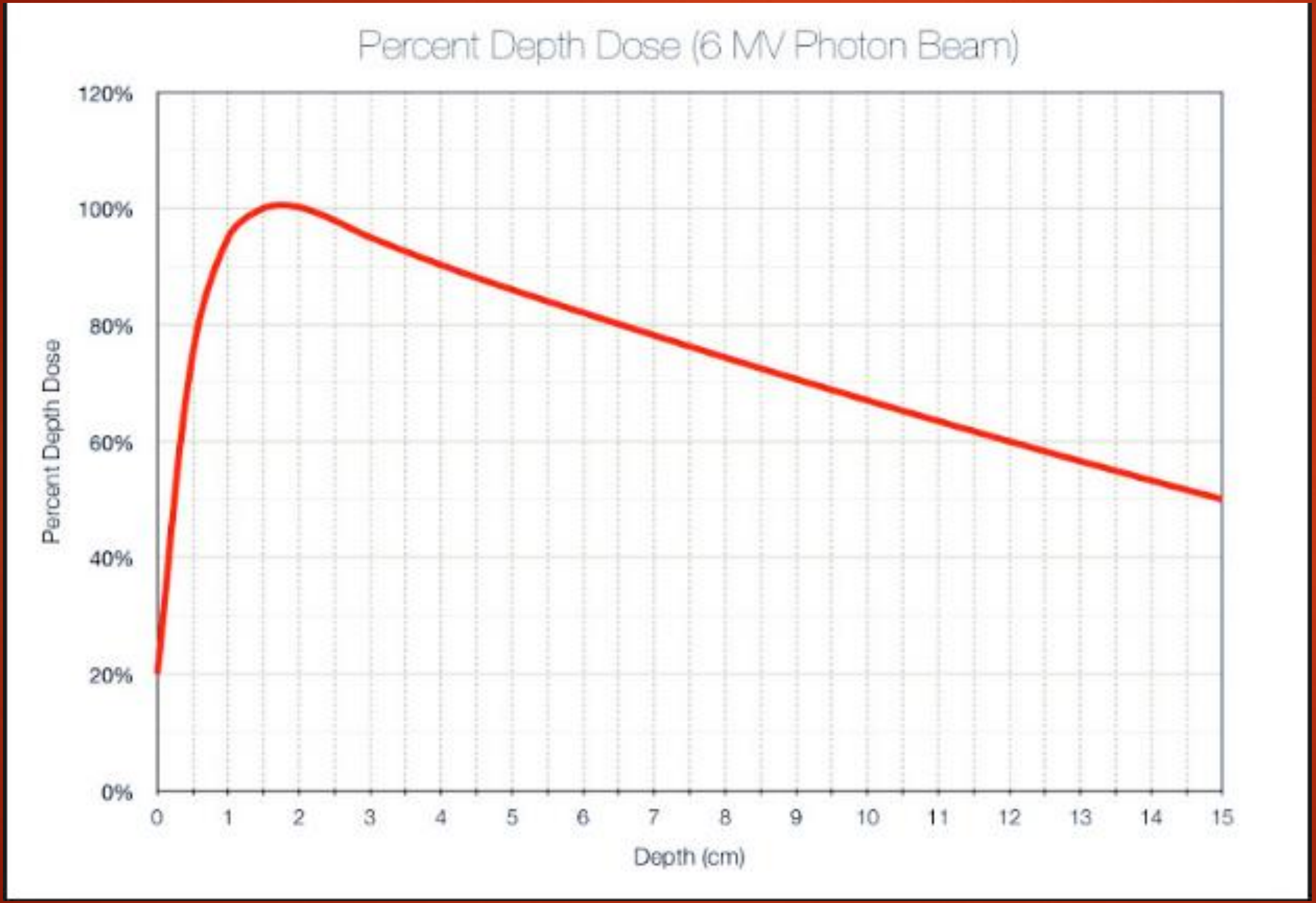
4.2 X-Ray theraphy

- $\frac{\mu}{\rho}$ as a function of the energy of the photn
- resulting curve is sum of contributions of single effects
- For hight energie pair production overweights



BQ(12)

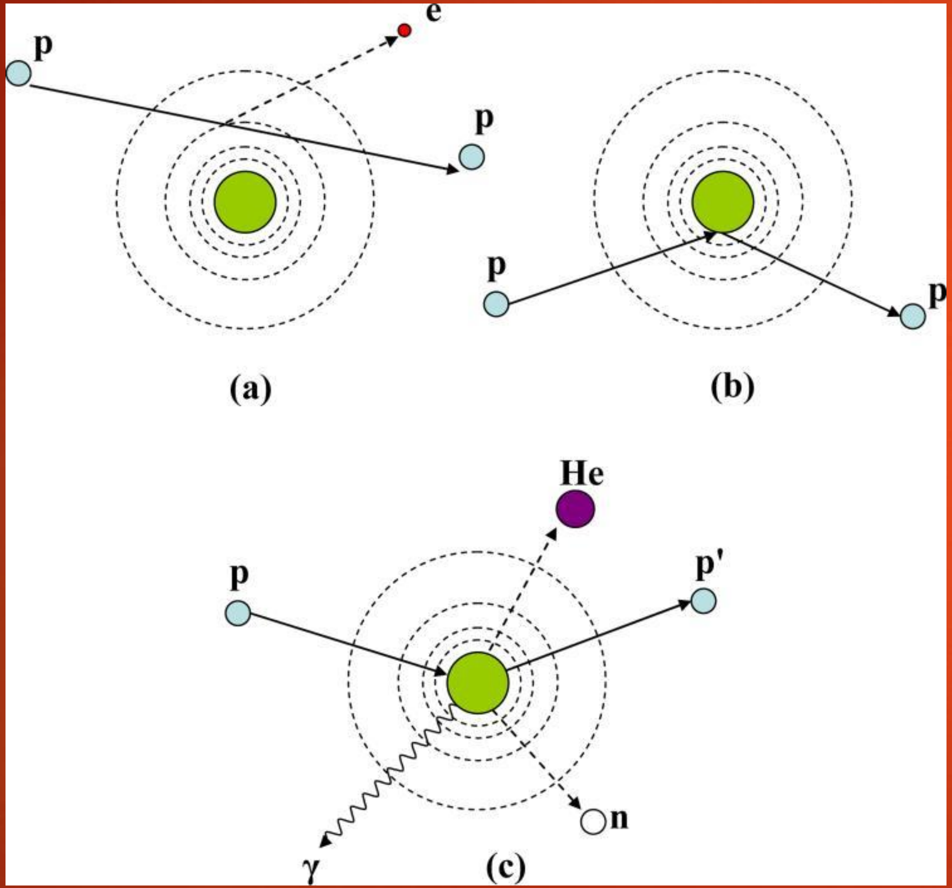
4.2 X-Ray theraphy



- Delivered dose varies with exponential decay
- healthy tissue in front and behind gets high dose
- Reduced by rotating the x-ray source

BQ(13)

4.3 Hadron theraphy



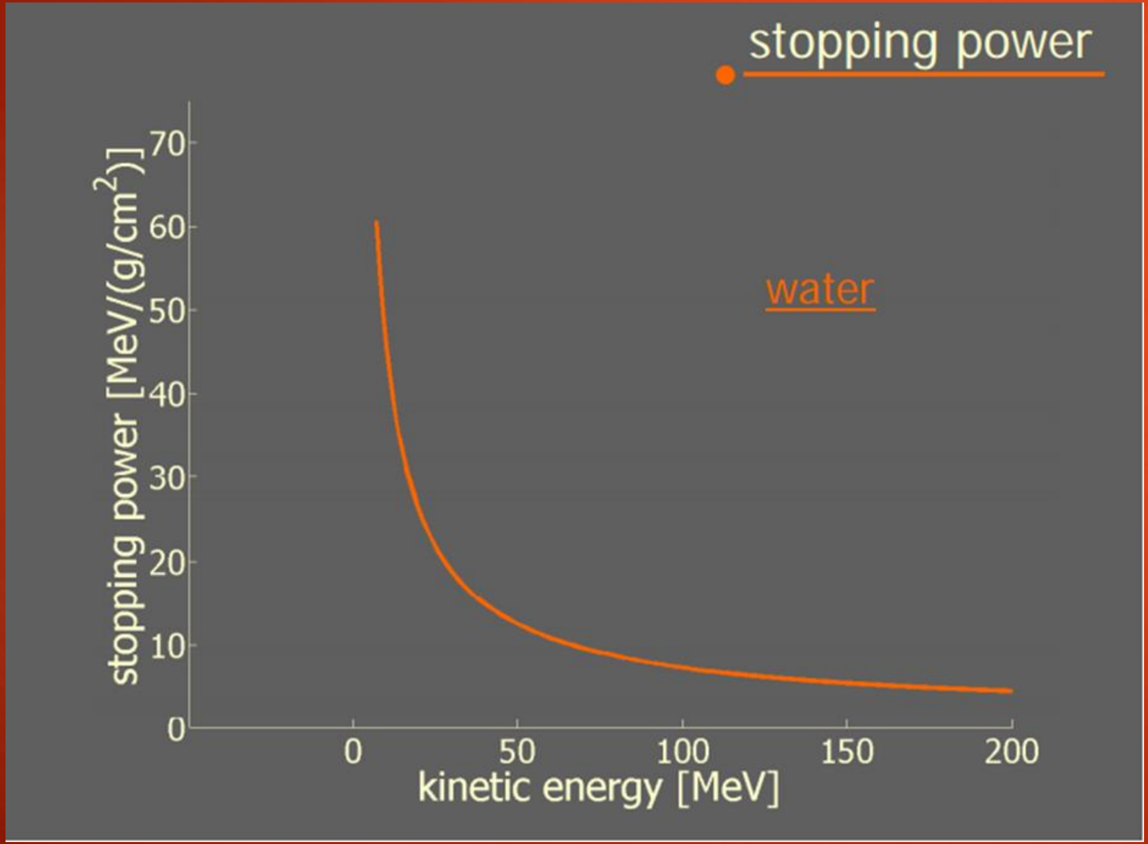
BQ(14)

- Primarly loss due coulomb interactions
- Define Stopping power as Quotient of energy loss and travelled distance
- $S(E) = -\frac{dE}{dx}$
- $\frac{dE}{dx} \propto (dp)^2 \propto \frac{1}{v^2}$

4.3 Hadron theraphy

$$-\left\langle \frac{dE}{dx} \right\rangle = \frac{4\pi}{m_e c^2} \cdot \frac{nz^2}{\beta^2} \cdot \left(\frac{e^2}{4\pi\varepsilon_0}\right)^2 \cdot \left[\ln\left(\frac{2m_e c^2 \beta^2}{I \cdot (1-\beta^2)}\right) - \beta^2\right]$$

BQ(19)



BQ(15)

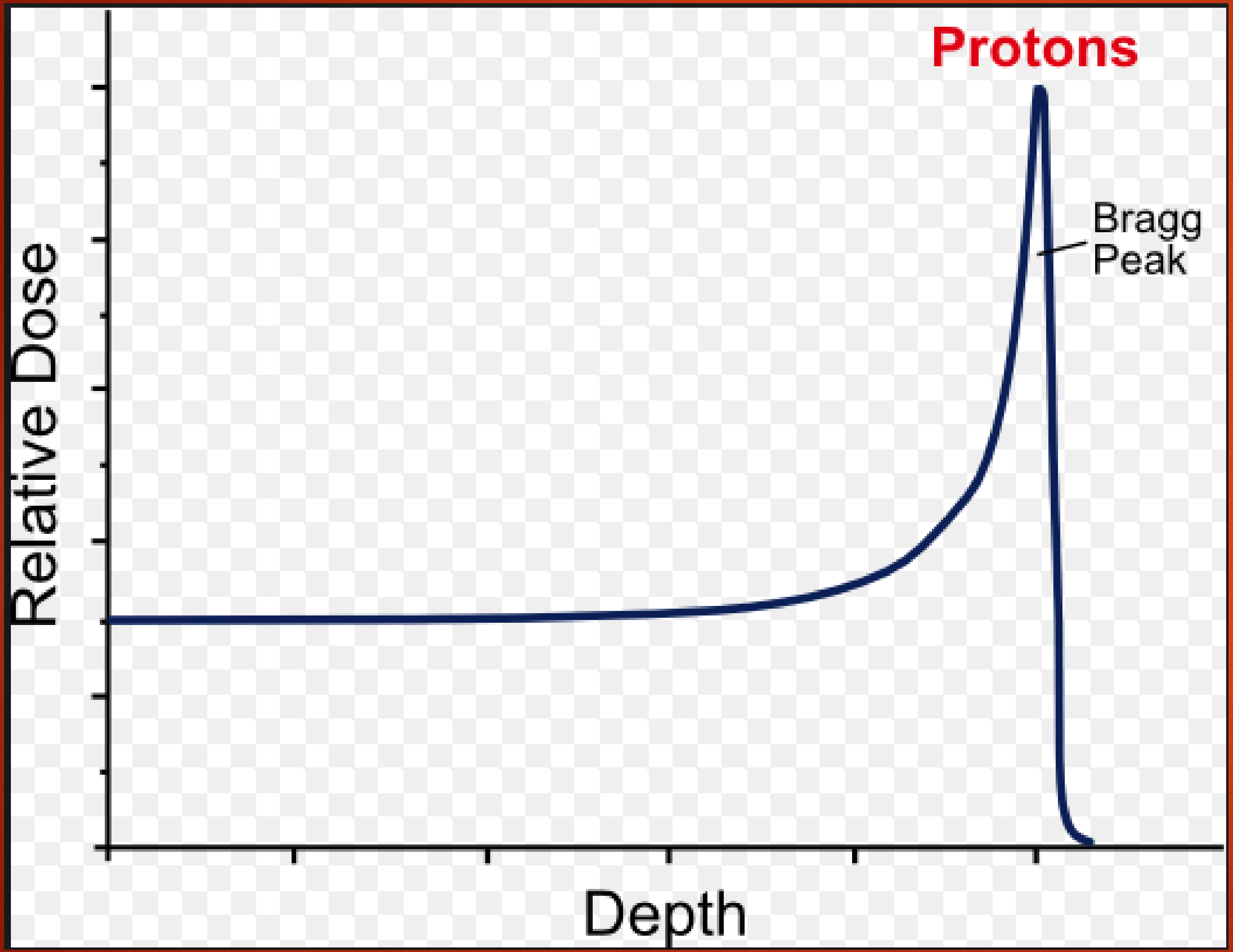
- For small velocities $\beta \ll c$:

$$-\frac{dE}{dx} = \frac{4\pi nz^2}{m_e v^2} \cdot \left(\frac{e^2}{4\pi\varepsilon_0}\right)^2 \cdot \left[\ln\left(\frac{2m_e v^2}{I}\right)\right]$$

BQ(19)

- Decreases approximatly like v^{-2}
- Minimum for protons at about 3000 MeV"

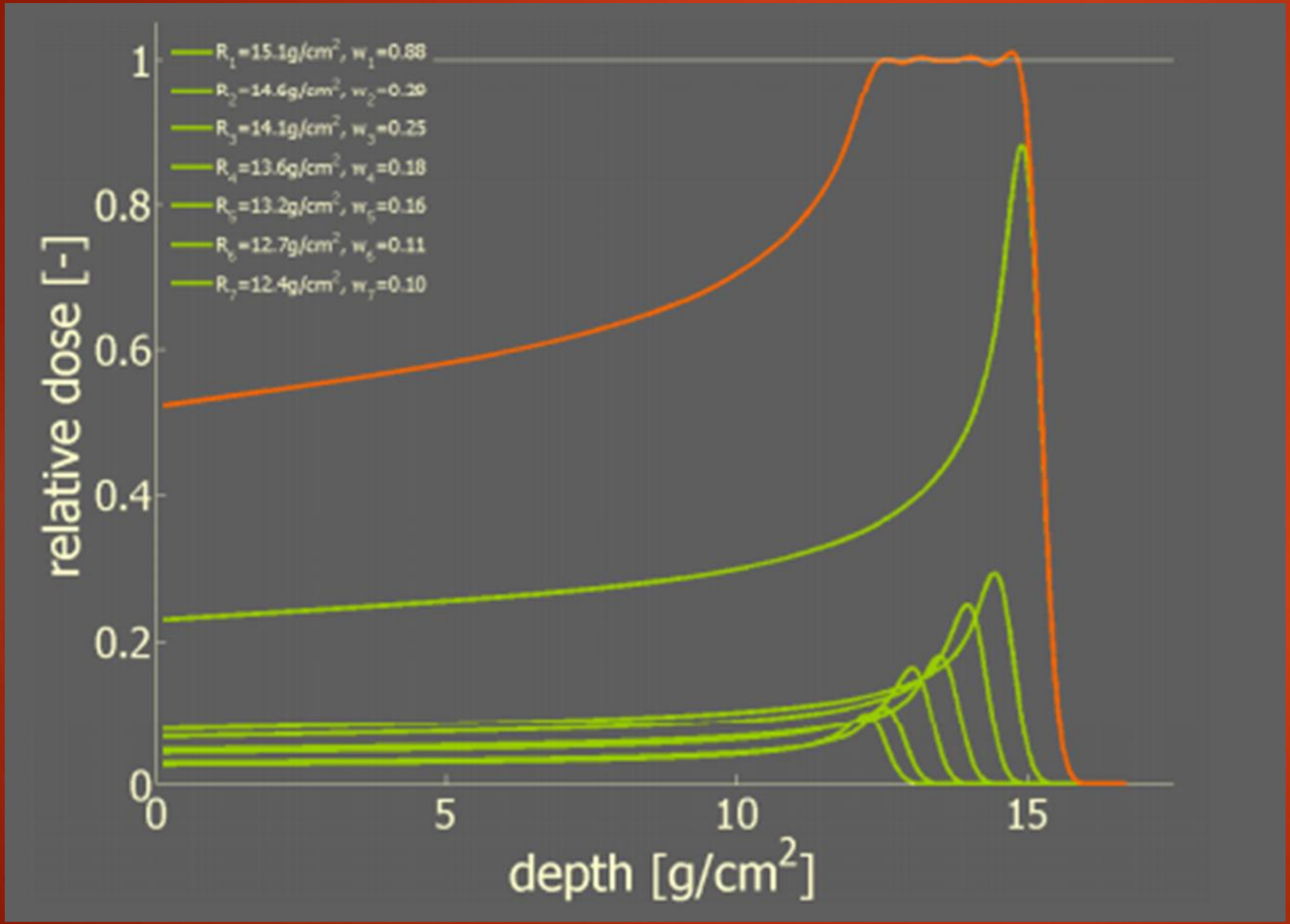
4.3 Hadron theraphy



BQ(16)

- dose as function of the depth for a proton
- proportionality to v^{-2} results in braggpeak for low kinetic energies
- delivered dose is focused on a small range

4.3 Hadron theraphy

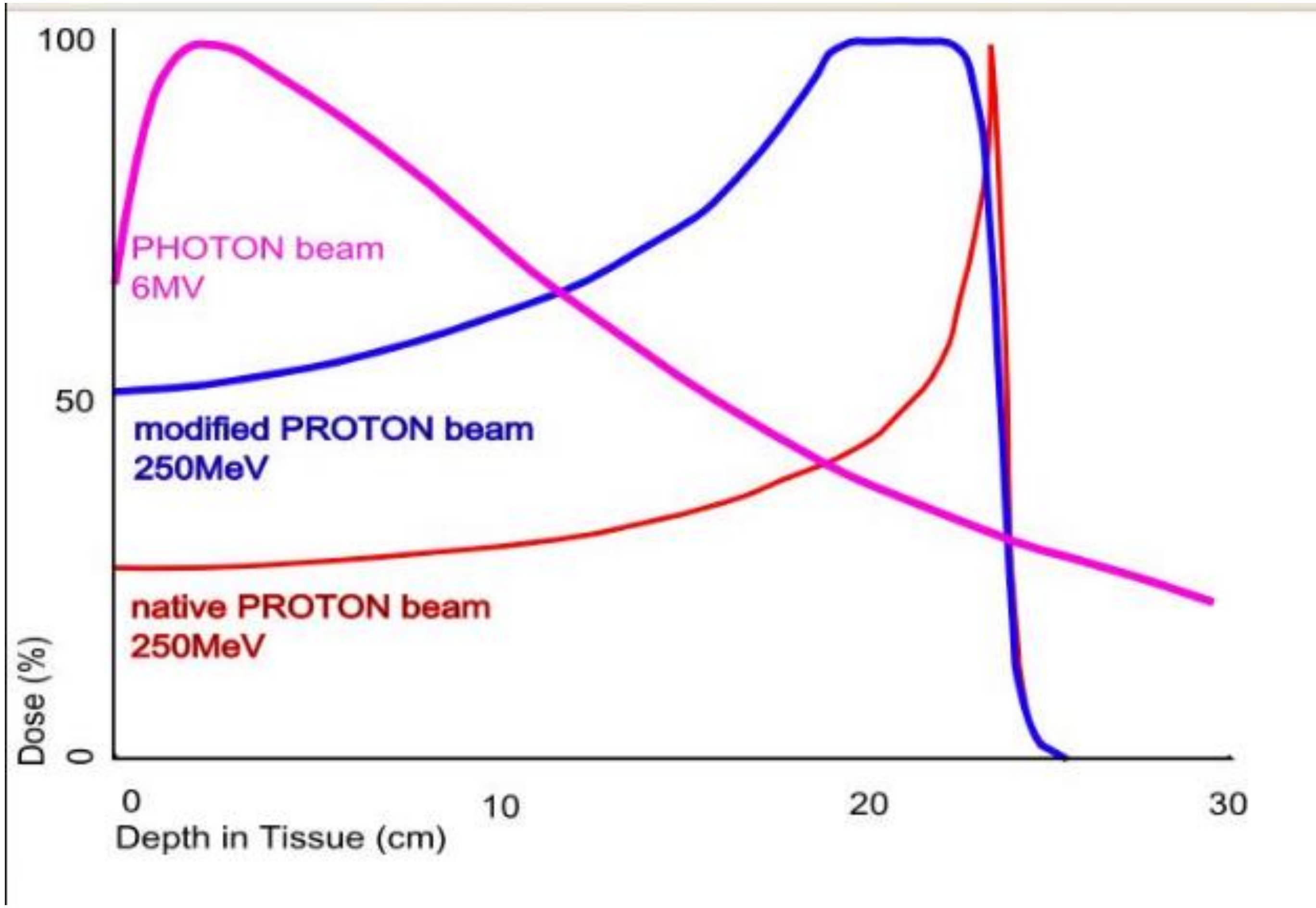


BQ(17)

- Adding shifted bragg peaks to creat spreadout bragg peak

4.3 Hadron theraphy

- Delivers radiation dose more precisley
- Reduces probability of side effects on surrounding health tissue
- Appropriate for some cancers where x-ray radiotherapie to riskfull



BQ(18)

5.Refrences

- Pictures:
  - (1) https://www.google.de/imgres?imgurl=https://upload.wikimedia.org/wikipedia/commons/7/71/Roentgen2.jpg&imgrefurl=https://de.wikipedia.org/wiki/Wilhelm_Conrad_R%25C3%25B6ntgen&h=1280&w=911&tbnid=go4rxkzs70UL4M:&tbnh=186&tbnw=132&usg=__ttgxwDoltVsDtn6wvxBf7crlMWY%3D&vet=10ahUKEwjOhvzDysjXAhWCYVAKHXzSBhsQ_B0IejAK..i&docid=0WDNHTioNwQS0M&itg=1&sa=X&ved=0ahUKEwjOhvzDysjXAhWCYVAKHXzSBhsQ_B0IejAK
  - (2) https://www.google.de/imgres?imgurl=https://upload.wikimedia.org/wikipedia/commons/thumb/8/89/Roentgen-Roehre.svg/220px-Roentgen-Roehre.svg.png&imgrefurl=https://de.wikipedia.org/wiki/R%25C3%25B6ntgenr%25C3%25B6hre&h=130&w=220&tbnid=aQM_LbL7F8PyFM:&tbnh=118&tbnw=200&usg=__9qHW9gf0URP1iV0m51oheWzy10c%3D&vet=10ahUKEwicpL2Xis7XAhWDlxoKHYilDsUQ_B0IjwEwCg..i&docid=2oYGUUqC7K17-M&itg=1&sa=X&ved=0ahUKEwicpL2Xis7XAhWDlxoKHYilDsUQ_B0IjwEwCg#h=130&imgdii=4lXFaM9Y1S8-mM:&tbnh=118&tbnw=200&vet=10ahUKEwicpL2Xis7XAhWDlxoKHYilDsUQ_B0IjwEwCg..i&w=220
  - (3) https://en.wikipedia.org/wiki/Positron_emission_tomography
  - (4) https://www.google.de/search?q=betatron&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj1-t-Gj87XAhUF1BoKHbFTAFsQ_AUICygC#imgrc=w3POcFZ7R8sdsM:
  - (5) http://atomic.lindahall.org/what-is-an-atom-smasher.html
  - (6) https://www.google.de/imgres?imgurl=https%3A%2F%2Falevelphysicsnotes.files.wordpress.com%2F2015%2F01%2Fcyclotron.png&imgrefurl=https%3A%2F%2Falevelphysicsnotes.wordpress.com%2Ftag%2Fcyclotron%2F&docid=ts5t1FJY8Ux5DM&tbnid=ICROi2NUxhjK4M%3A&vet=10ahUKEwj7trXqoJvXAhXJ0xoKHaXgD0cQMwhVKBcwFw..i&w=684&h=537&bih=626&biw=1350&q=cyclotron&ved=0ahUKEwj7trXqoJvXAhXJ0xoKHaXgD0cQMwhVKBcwFw&iact=mrc&uact=8#h=537&imgdii=ICROi2NUxhjK4M:&vet=10ahUKEwj7trXqoJvXAhXJ0xoKHaXgD0cQMwhVKBcwFw..i&w=684
  - (7) https://www.google.de/search?q=radiotherapie&tbm=isch&tbs=rimg:CU33Z9wDIbxpIjhnyztLu_1abl4cT6xQrWDOaq0gUHSk1wya4RfDWRx5dfNzPojx6QG67U7vfFbgbluvY5gIoMrnnKSoSCWfLO0u79puXEZCv5nQubf80KhIJhxPrFCtYM5oRpjOfLn8BCqAqEgmrSBQdKTXDJhEMWqxzD2iWwSoSCbhF8NZHHI18ERILO_1StnjwKKhIJ3M-iPHpAbrsRPITjMSerf-qqEgITu98VuBuW6xHWj4wHWJz9VCoSCdjmAigyuecpEZKeREh3SRVM&tbo=u&sa=X&ved=0ahUKEwjWspGbj8_XAhXKh7QKHY4CBv0Q9C8IHA&biw=1350&bih=675&dpr=1#imgrc=z4uXqOUnTNLw1M:

5.Refrences

- (8) https://www.google.de/search?q=Equipment+sterilization+with+x+ray&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjGt_utm8vXAhUGthoKHUvuCfgQ_AUICigB&biw=1350&bih=675#imgrc=6dXkDDkvhN6xKM:
- (9) http://www.ct-mrtinstitut.de/de/ct-leistungen/ct-des-kopfes-bzw-der-nasennebenhoehlen
- (10) https://link.springer.com/content/pdf/10.1007%2F978-3-662-55760-0.pdf S. 411
- (11) https://link.springer.com/content/pdf/10.1007%2F978-3-662-55760-0.pdf S. 202
- (12) https://link.springer.com/content/pdf/10.1007%2F978-3-662-55760-0.pdf S. 209
- (13) https://www.google.de/search?biw=1350&bih=675&tbm=isch&sa=1&ei=lVUTWsW5NMS4abqOIYAE&q=X-ray+dosis+over+depth&oq=X-ray+dosis+over+depth&gs_l=psy-ab.3...108569.111595.0.112014.11.11.0.0.0.0.71.589.11.11.0....0...1c.1.64.psy-ab..0.0.0....0.RPm-CZRJxBA#imgrc=tOGFBj8j_z7w-M:
- (14) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4407514/figure/F1/
- (15) https://www.aapm.org/meetings/09PRS/documents/Slopsema.pdf
- (16) https://www.google.de/search?q=Bragg+peak+proton&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjok7252c3XAhXH2hoKHVhxDisQ_AUICigB&biw=1350&bih=675#imgrc=DX7E2q_RbxQIYM:
- (17) https://www.aapm.org/meetings/09PRS/documents/Slopsema.pdf
- (18) https://en.wikipedia.org/wiki/Bragg_peak#/media/File:BraggPeak.png
- (19) https://en.wikipedia.org/wiki/Bethe_formula

5.Refrences

- Literary sources/ internet sources
  - Grundlagen der Strahlungsphysik und des Strahlenschutzes 4. Auflage
  - Biomedical Partical Accelerators by Waldemar H. Scharf
  - http://www.accelerators-for-society.org/health/index.php?id=7
  - https://www.slac.stanford.edu/slac/sass/talks/aiden_sass.pdf
  - http://www-pub.iaea.org/MTCD/publications/PDF/trs465_web.pdf S. 7-9
  - https://en.wikipedia.org/wiki/Bragg_peak
  - https://www.nibib.nih.gov/science-education/science-topics/computed-tomography-ct