Proton therapy

Press release

Government commits £250 million for innovative cancer treatment to save lives and reduce side effects

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Sectors:

A major new cutting edge radiotherapy treatment will be available in the UK thanks to £250 million of government funding.

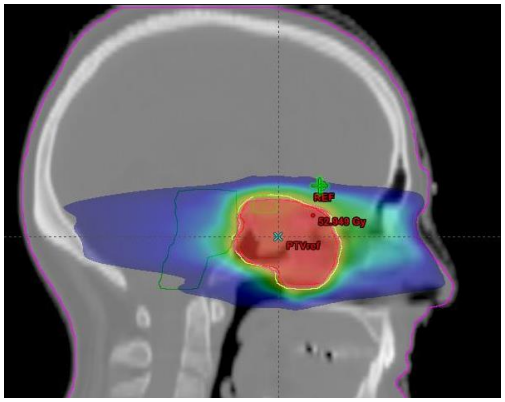
A major new cutting edge radiotherapy treatment will be available in the UK thanks to £250 million of government funding to build two new facilities in Manchester and London, Public Health Minister Anna Soubry confirmed today.

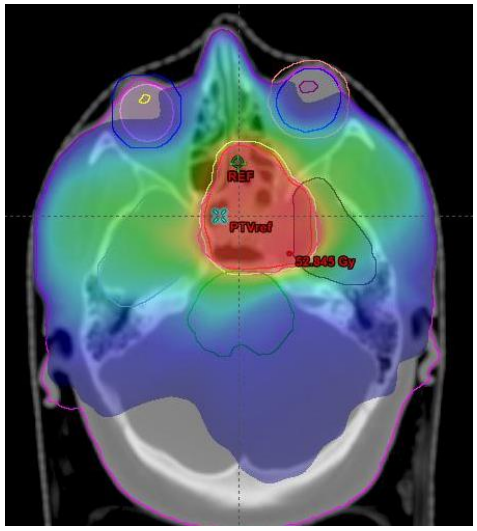
The therapy – Proton Beam Therapy – is a particularly important form of cancer treatment as it targets tumours more precisely with less damage to surrounding tissues. This can improve the quality of life following cancer treatment, reduces side effects, especially for children and, because the NHS will be able to treat more people, it will save lives.

UCL Hospital Proton Therapy Centre

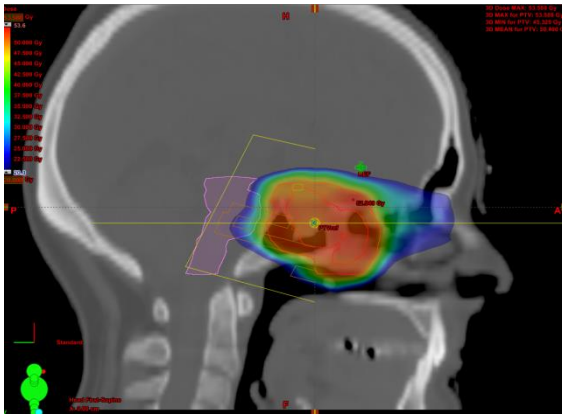
Clinical benefit

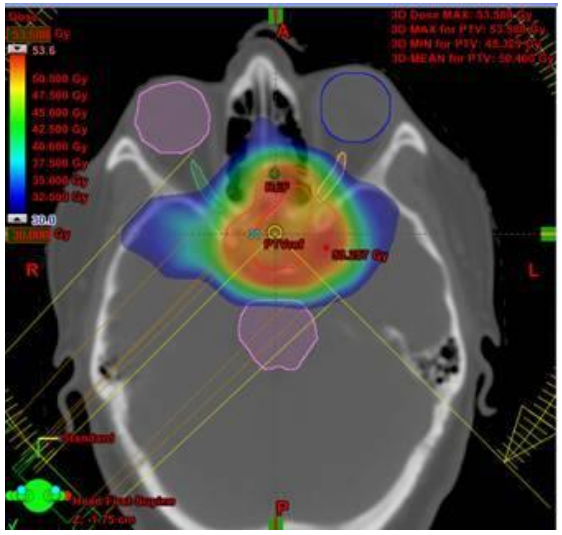
X-ray





Proton

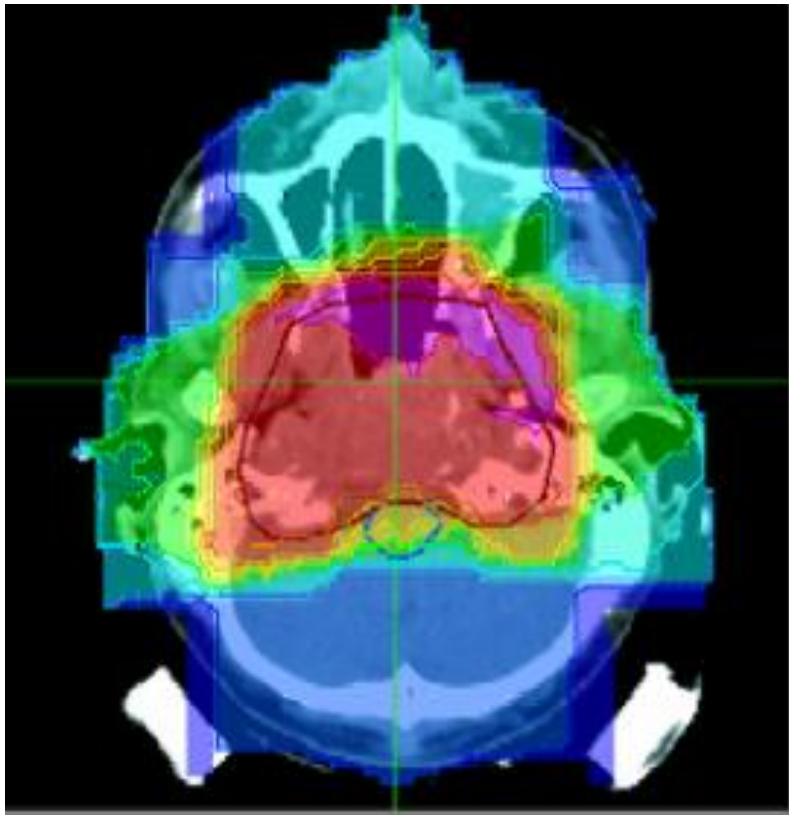




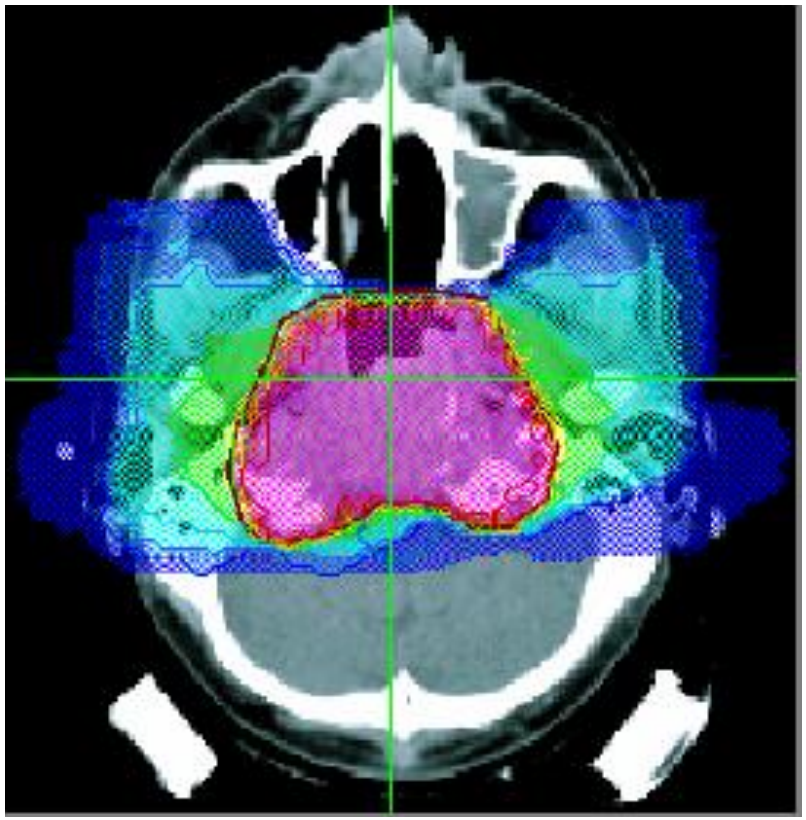
- **Brain treatment behind the eye**
- **Proton treatment minimises radiation to healthy tissue**

Clinical benefit

X-ray



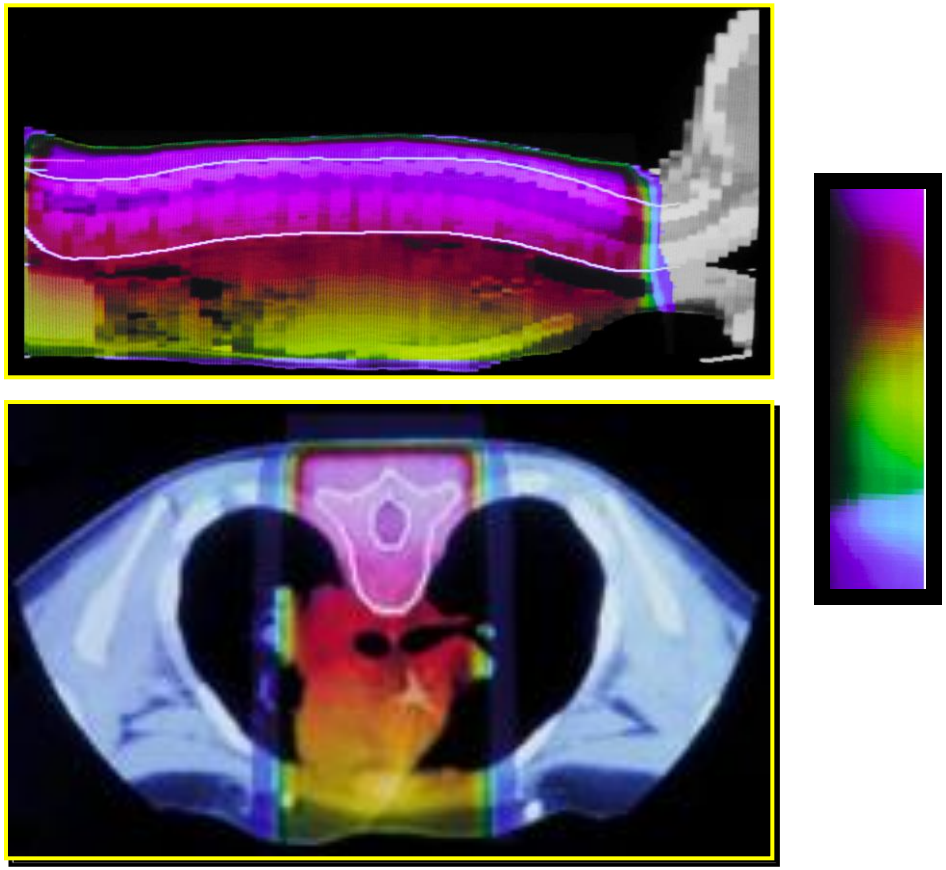
Proton



Clinical benefit

X-ray

Proton



Summary of clinical benefits

Proton therapy offers a far more effective form of treatment when:

- **Treating tumours near critical structures (e.g. brain, spinal cord) – use distal fall off to minimise dose to organ at risk**

- **Treating paediatric cancers – proven to reduce side effects (secondary cancers, growth and IQ deficiency)**

Any disadvantages?

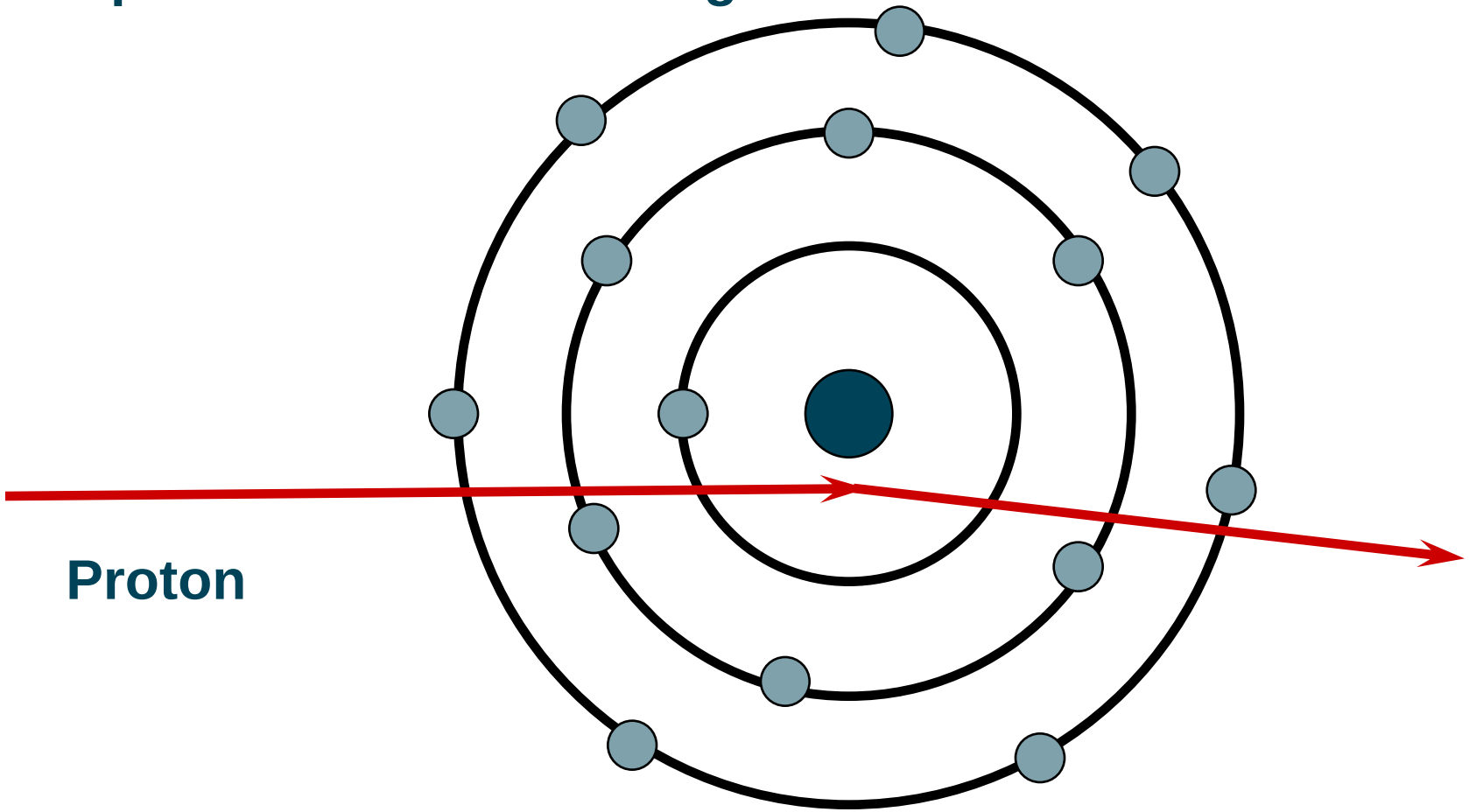
- No clinical disadvantages have yet been identified.
- Does not offer improved treatment in all clinical cases.
- Very expensive.
- Very difficult to perform randomised clinical trials.

Proton interactions with tissue

Either:
Electromagnetic interactions – positive proton interacts with positive nucleus or negative electron
or,
Nuclear interactions – proton collides directly with nucleus

Electromagnetic proton interactions

Multiple Coulomb Scattering

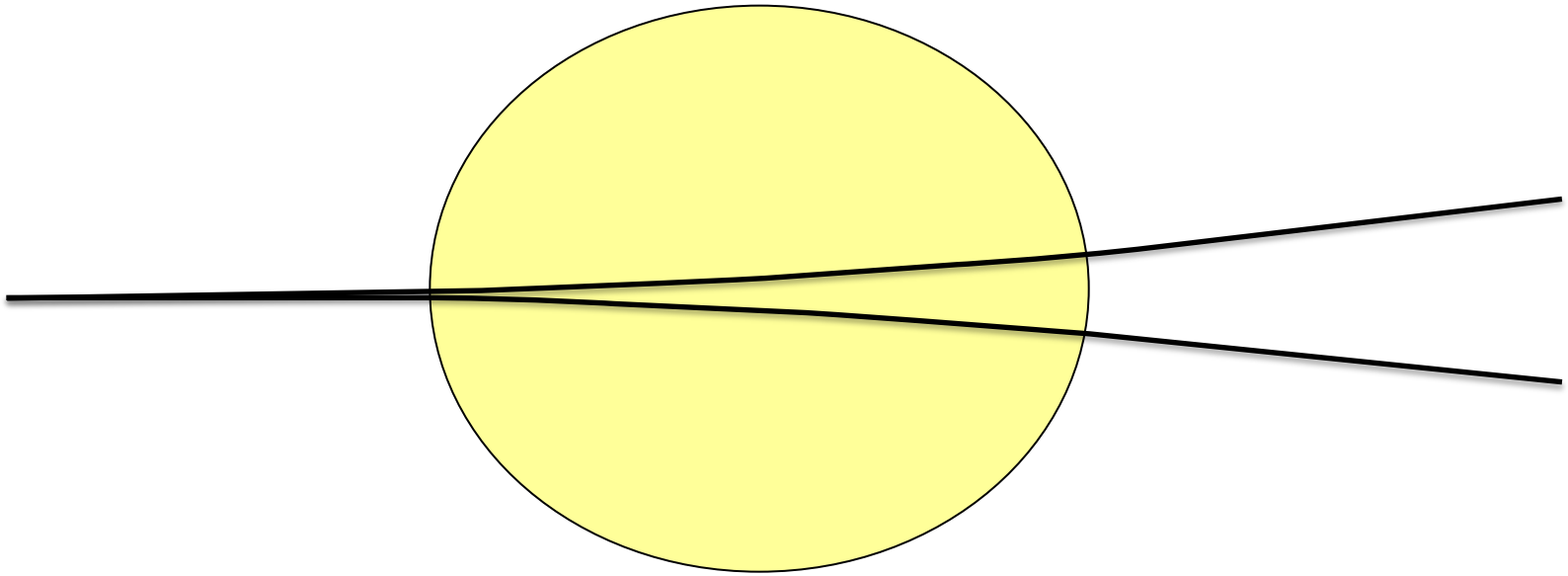


Positive proton changes direction slightly as it comes close to positive nucleus

Electromagnetic proton interactions

Multiple Coulomb Scattering

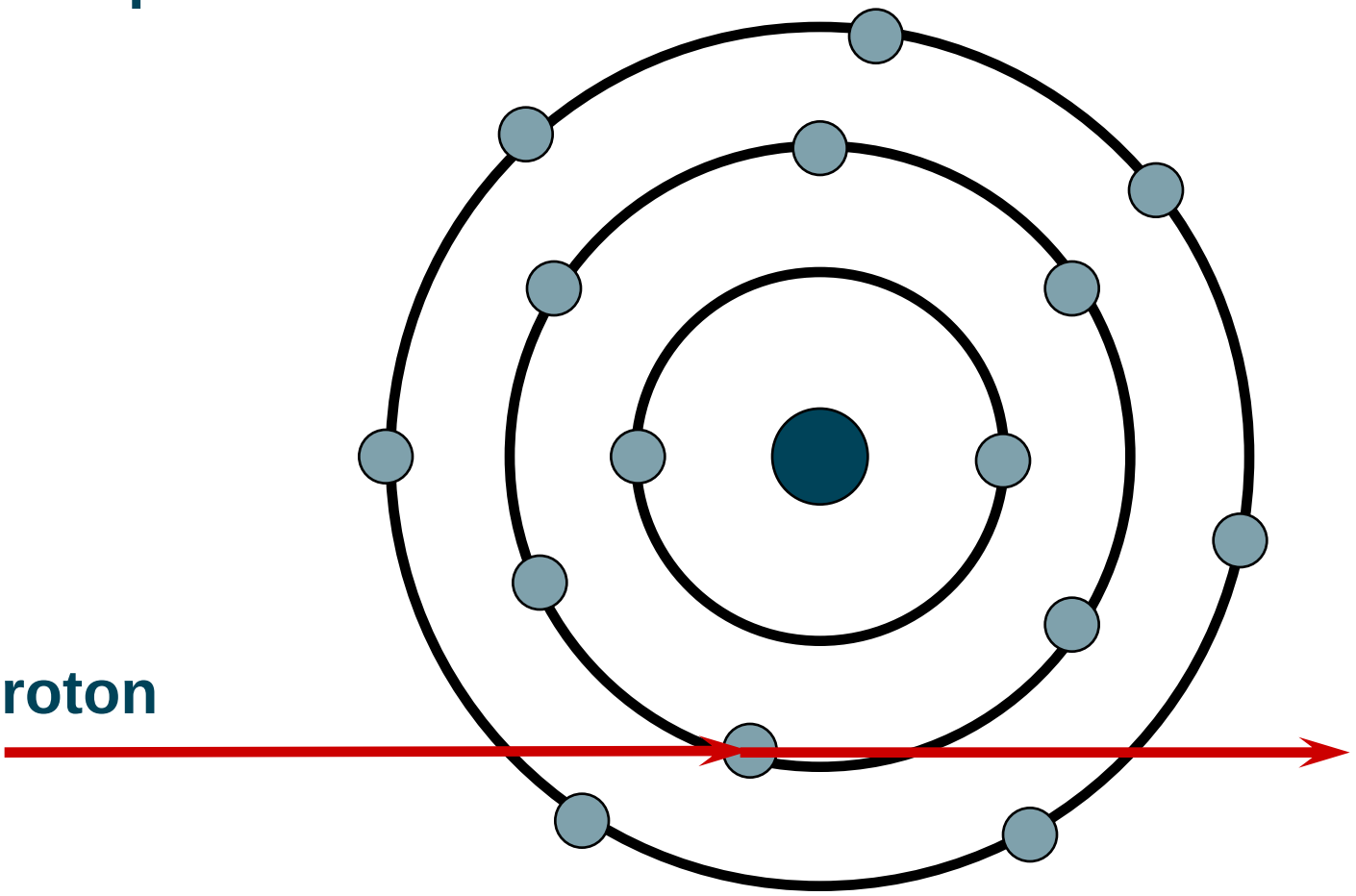
Effect of 1 interaction is very small but it occurs many times in crossing a patient causing the beam to deviate



Problem – it causes the proton spot to broaden

Electromagnetic proton interactions

Inelastic proton interactions

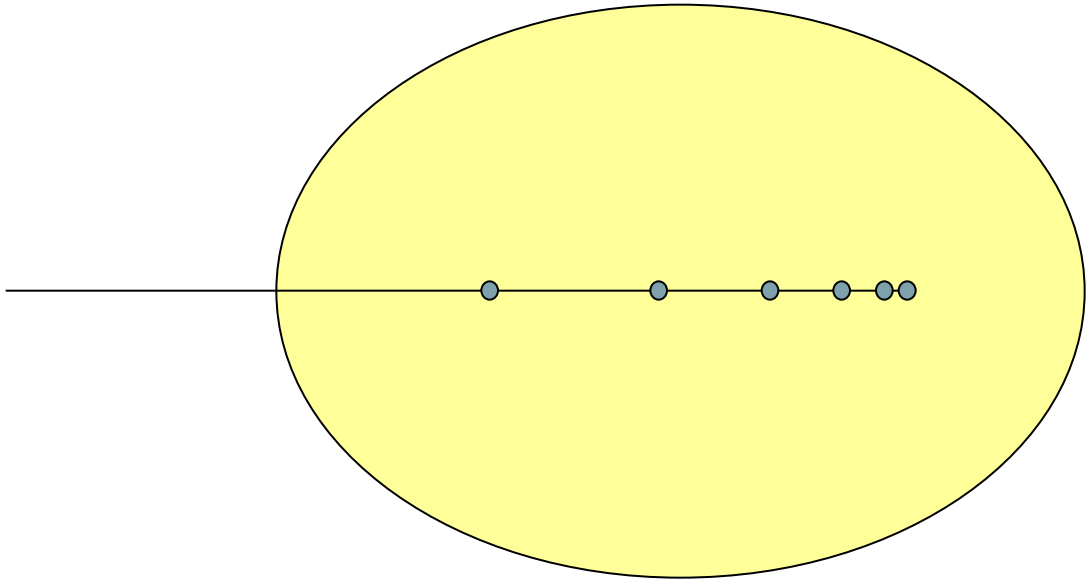


No change in direction but proton slows down

Electromagnetic proton interactions

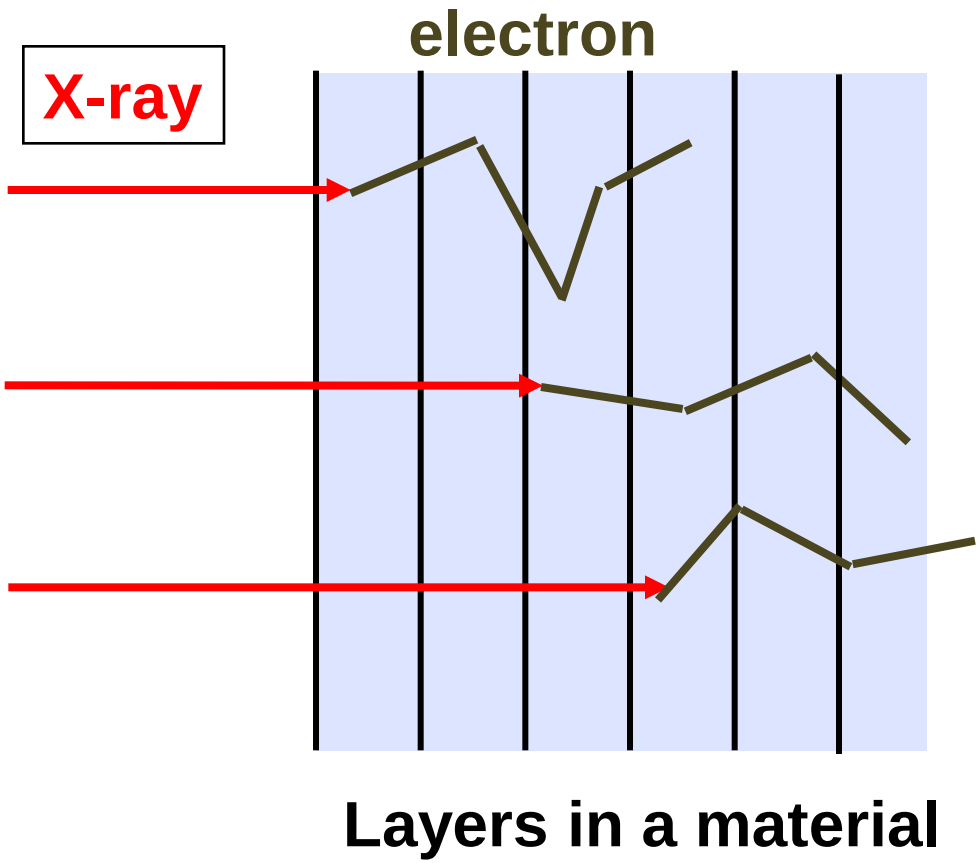
Inelastic proton interactions

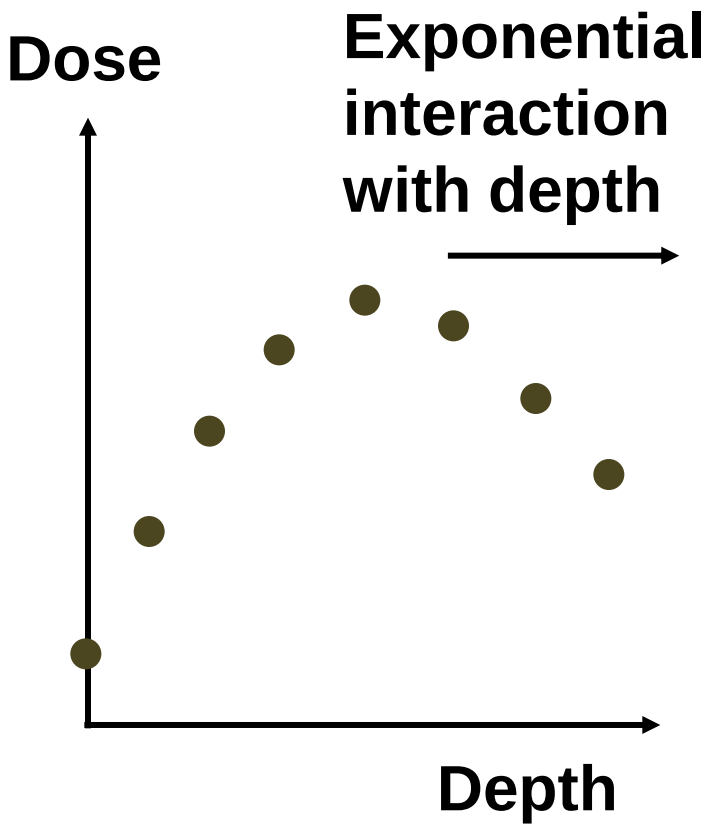
Effect of 1 interaction is very small but it occurs many times in crossing a patient causing the beam to slow down and eventually stop



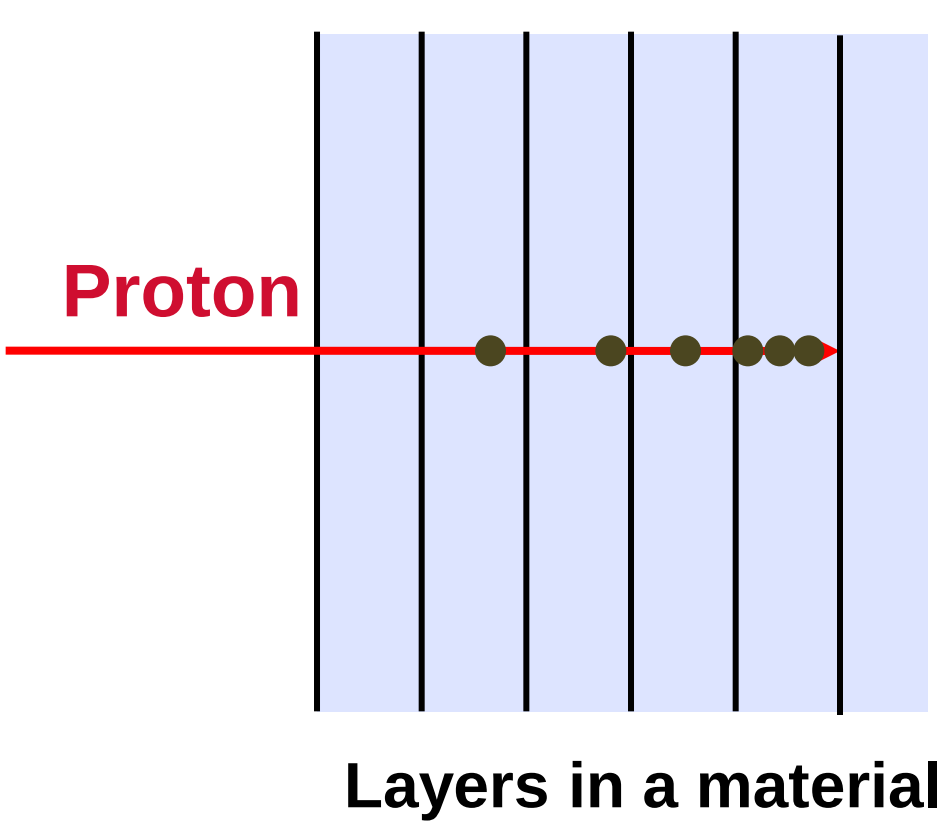
Reason for the Bragg peak

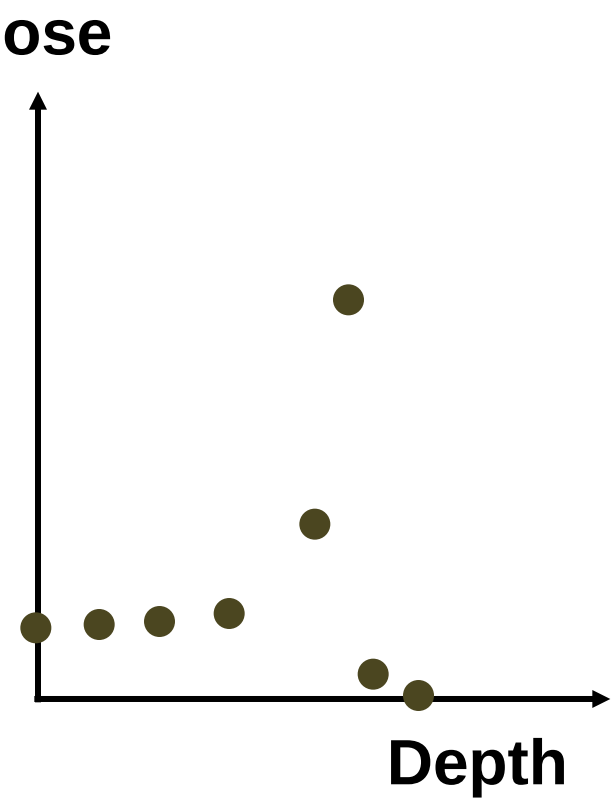
X-Ray Depth Dose



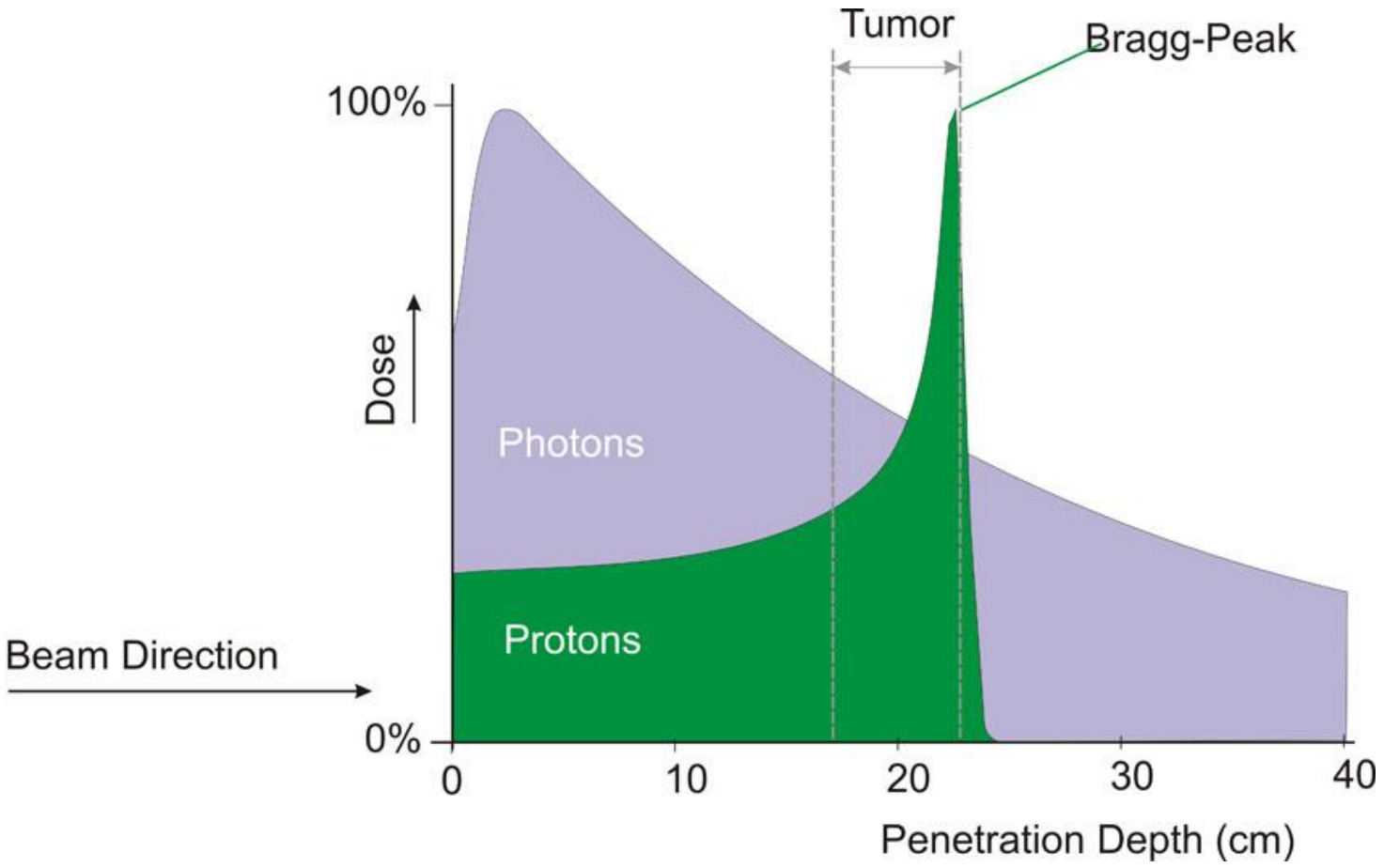


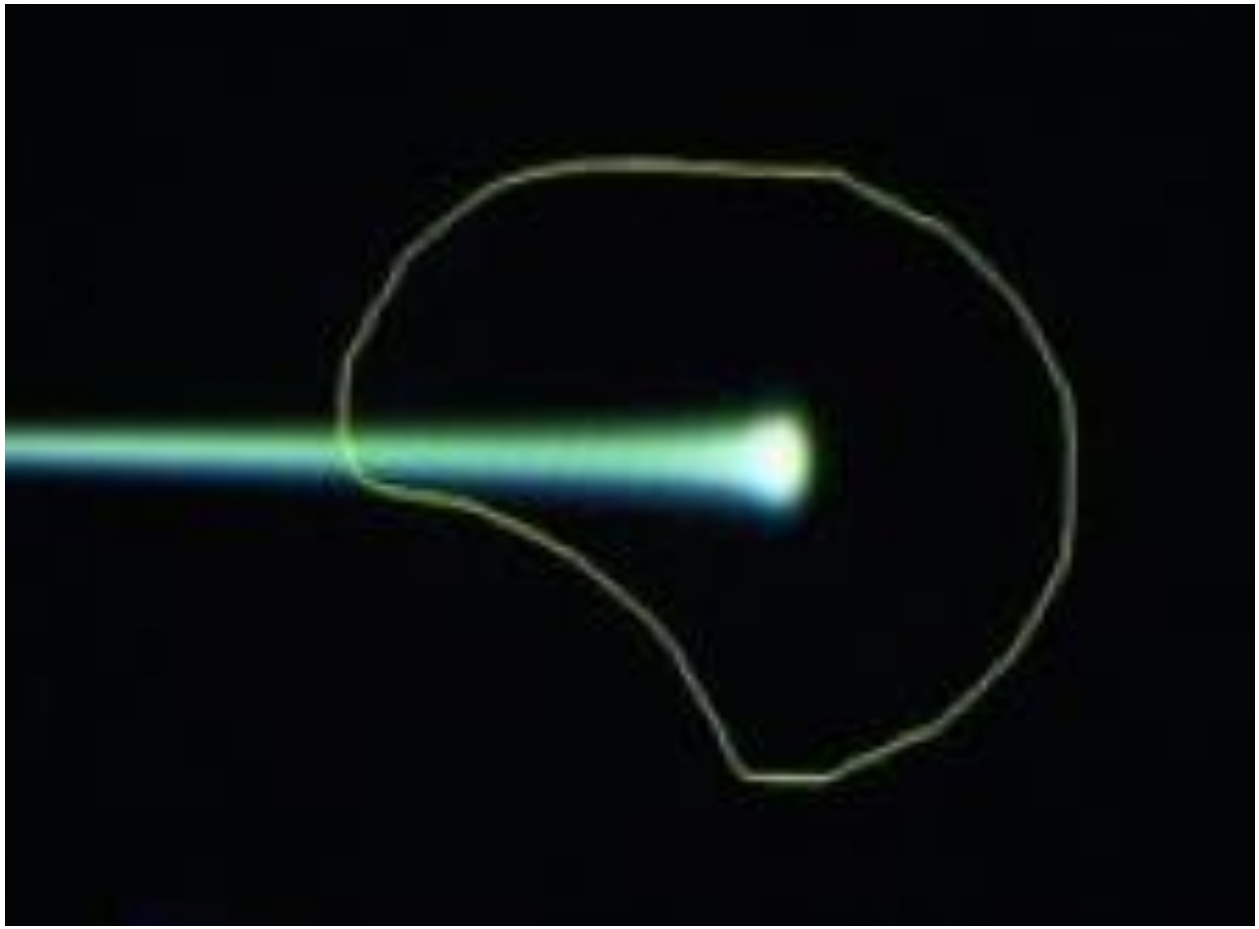
Proton Depth Dose



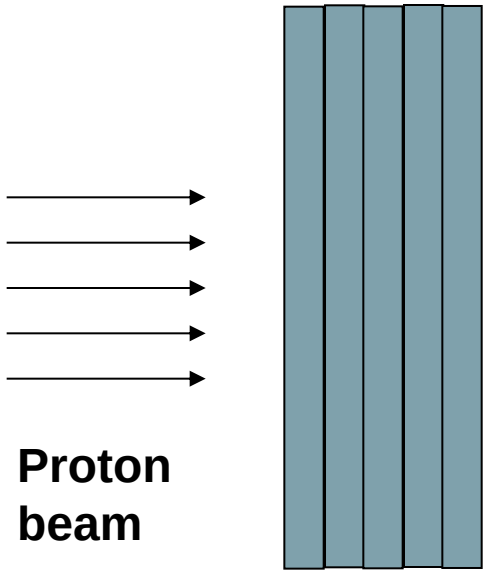


Physics of Proton Therapy

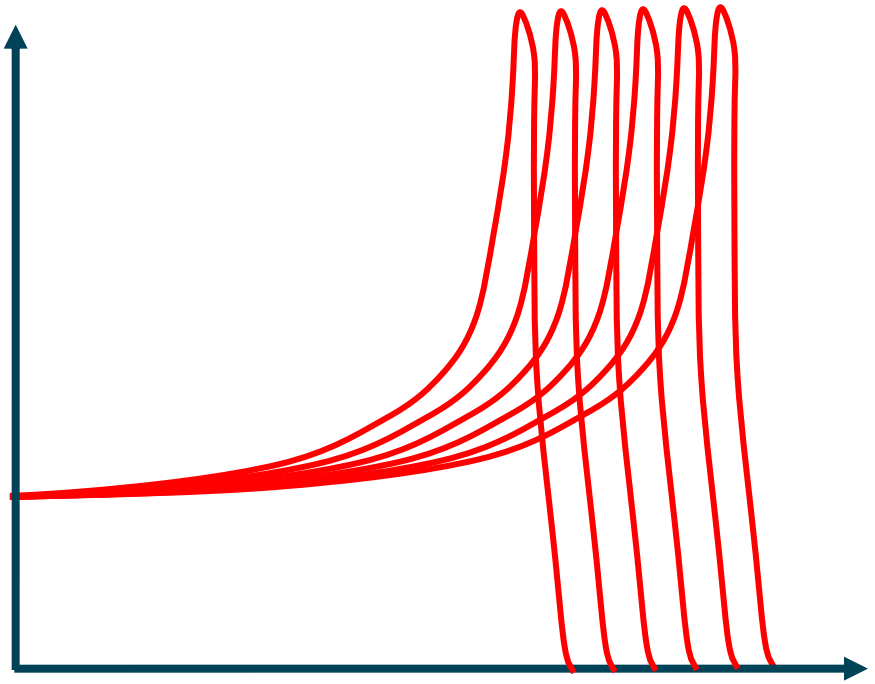




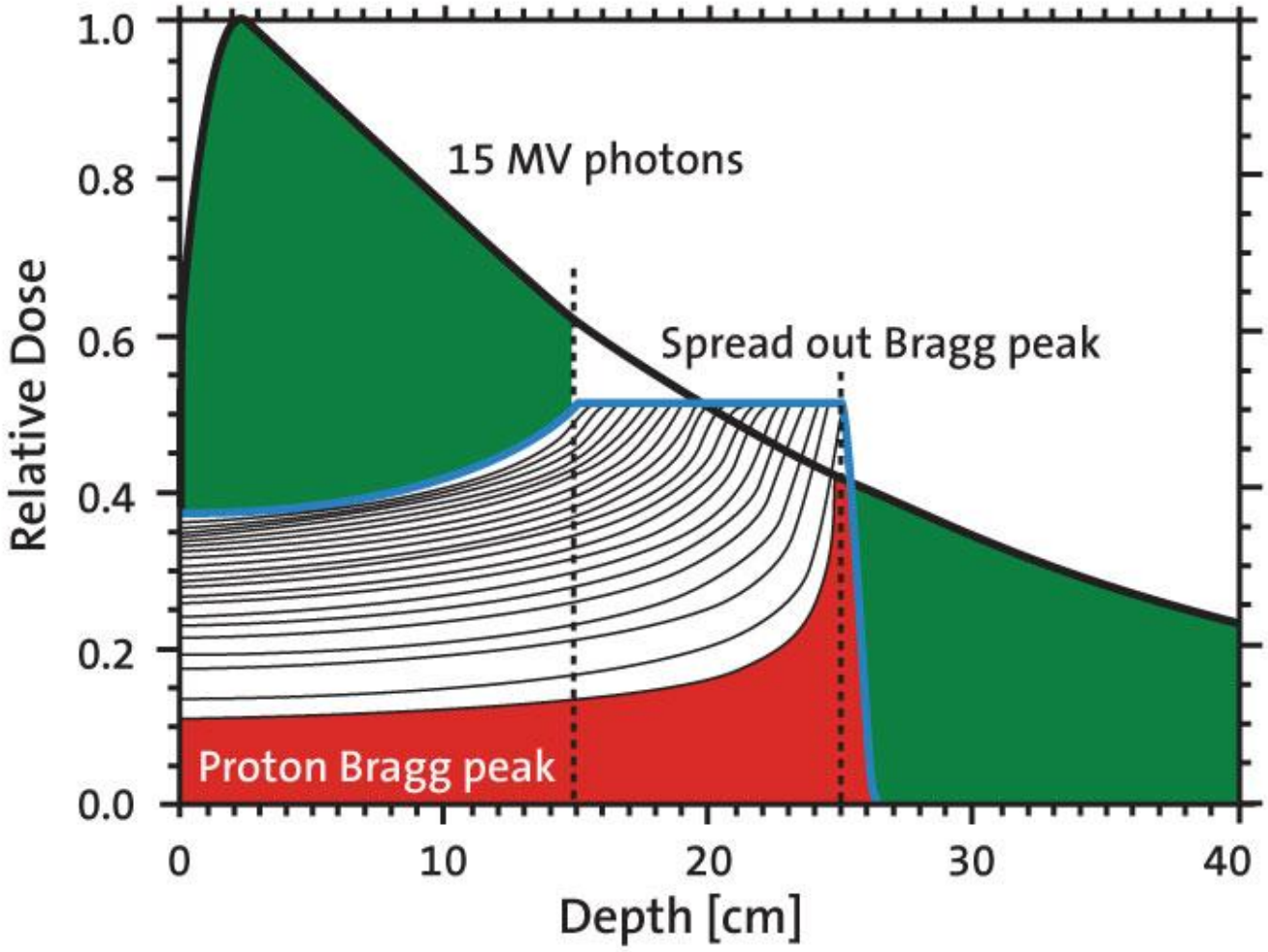
Use of beam energy to vary penetration depth



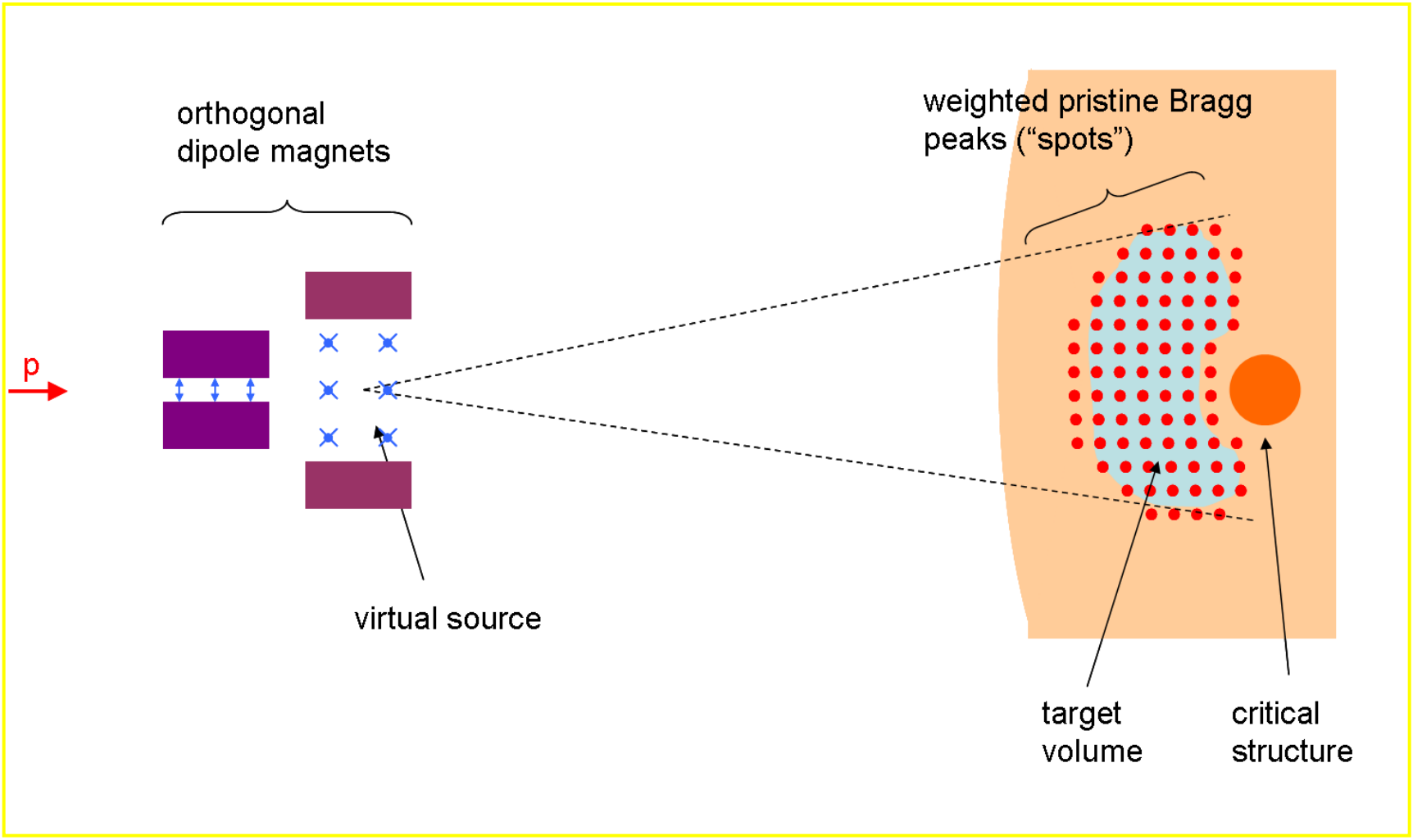
Proton beam

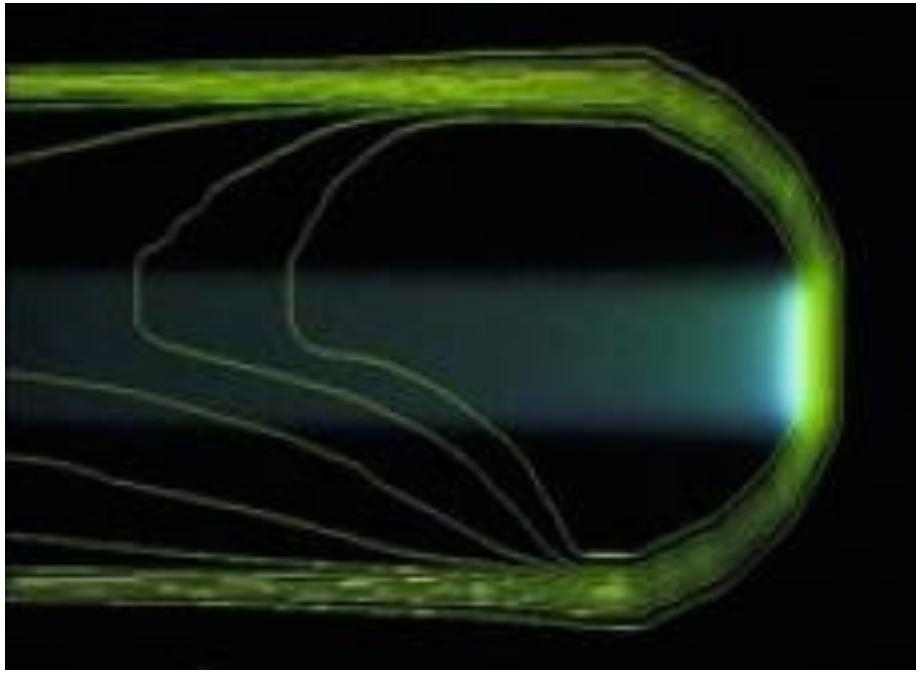


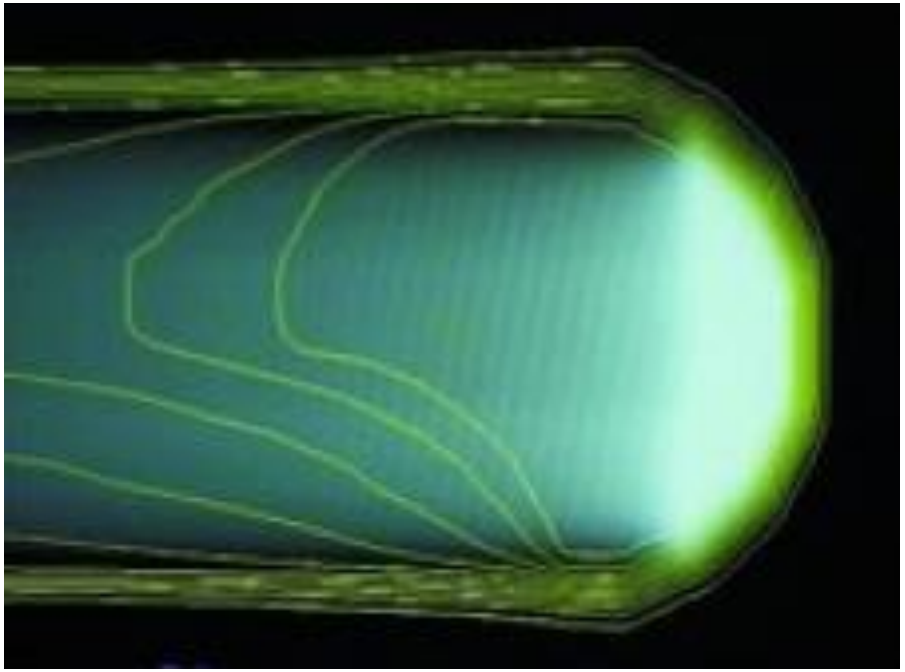
Penetration depth


1.0
0.8
0.6
0.4
0.2
0.0
Relative Dose
15 MV photons
Spread out Bragg peak
Proton Bragg peak
0
10
20
30
40
Depth [cm]

Beam delivery methods - Active scanning

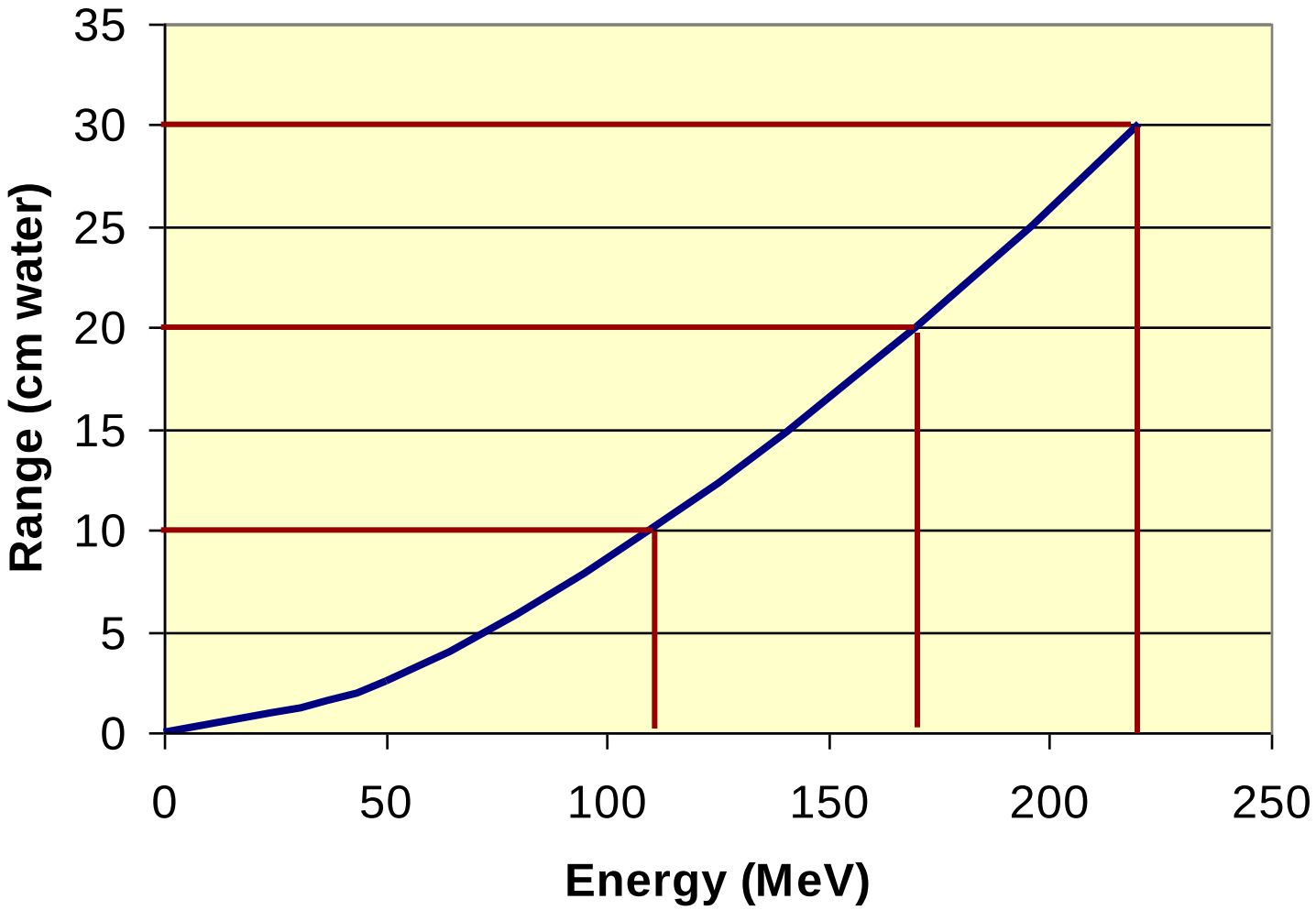






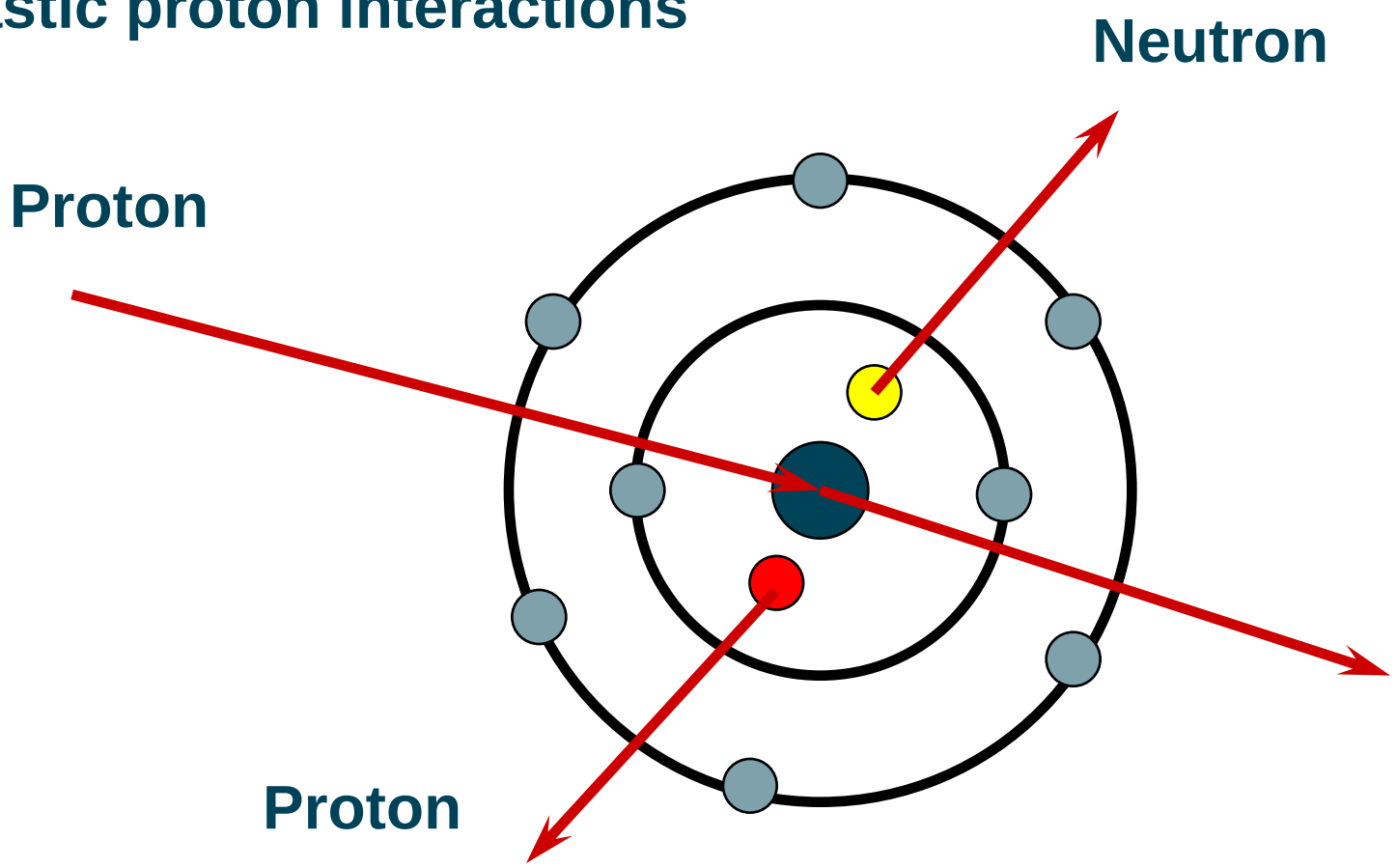
Movie

Required proton energies



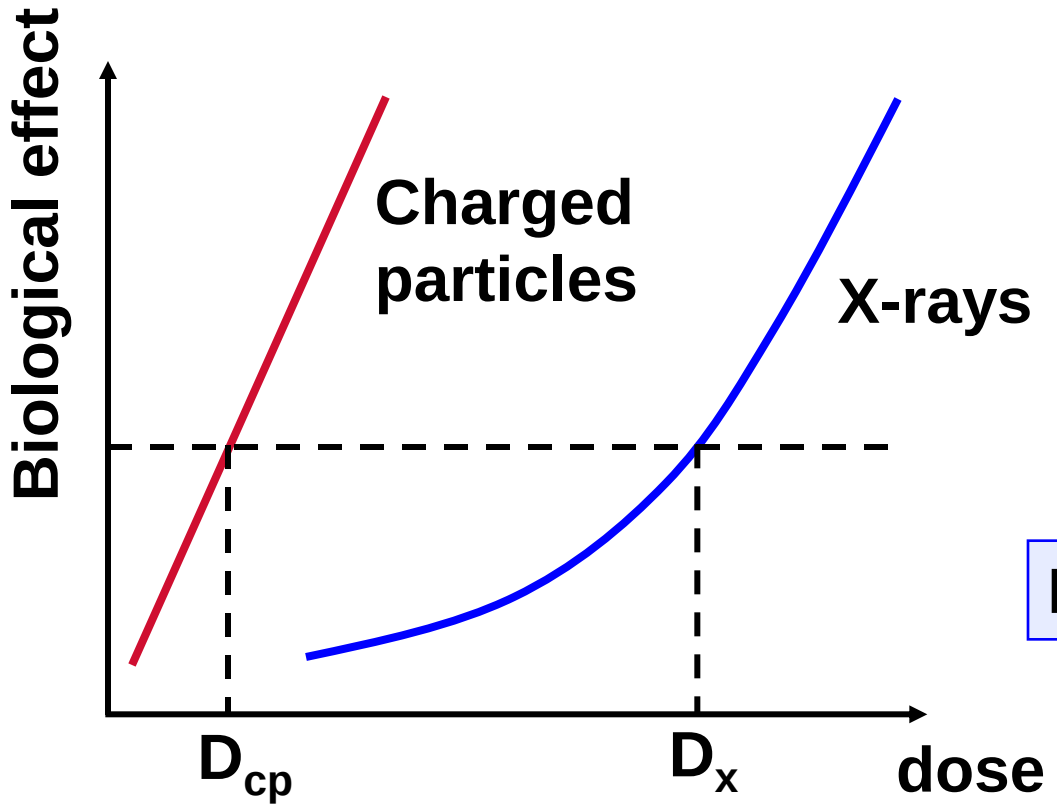
Nuclear proton interactions

Inelastic proton interactions



Atom becomes radioactive – occurs in both the treatment head and the patient

Dose-effect and Relative Biological Effectiveness (RBE)



$$RBE_{cp} = D_x / D_{cp}$$

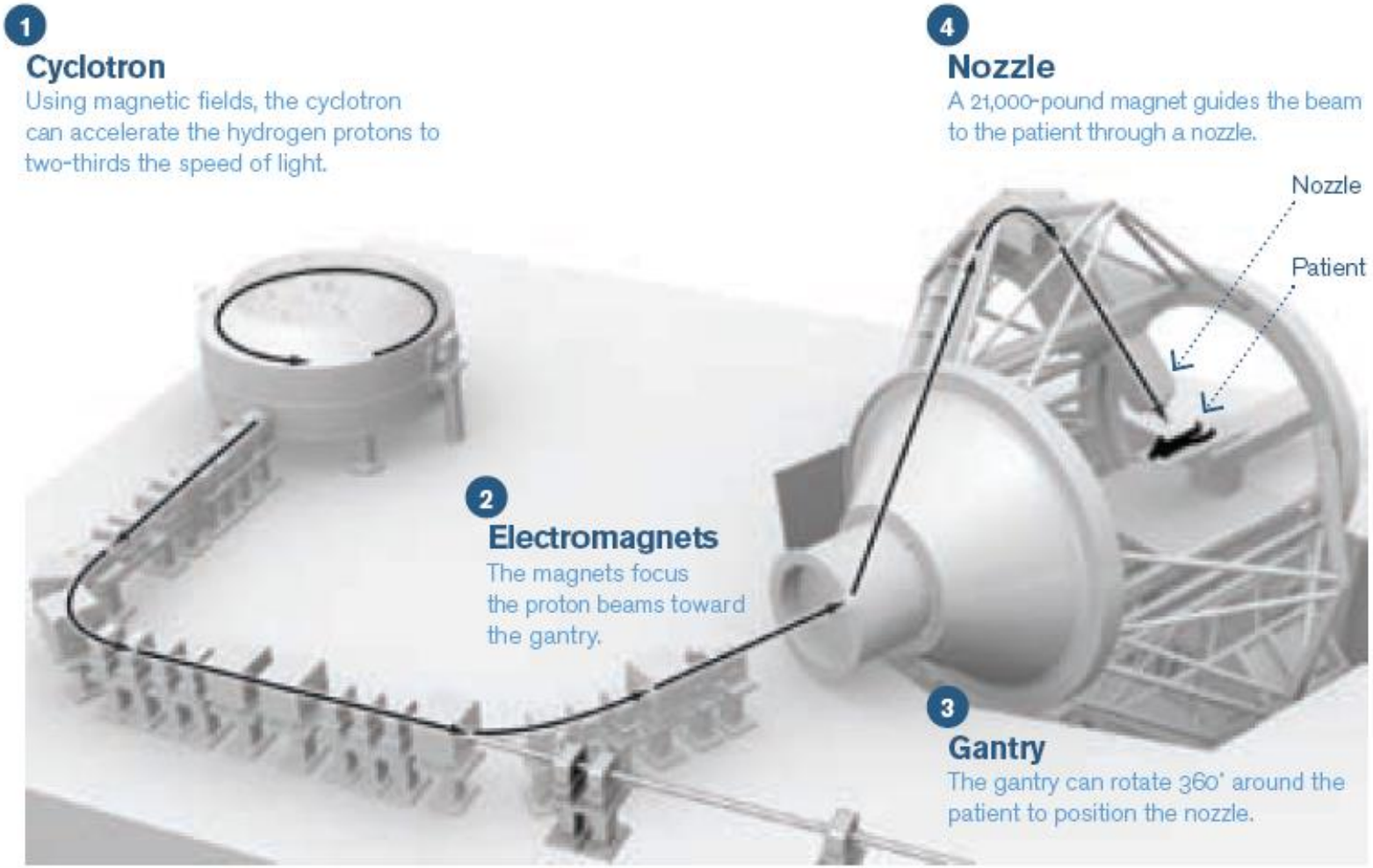
RBE for protons is approximately 1.1 (so 10% more effective than x-ray)

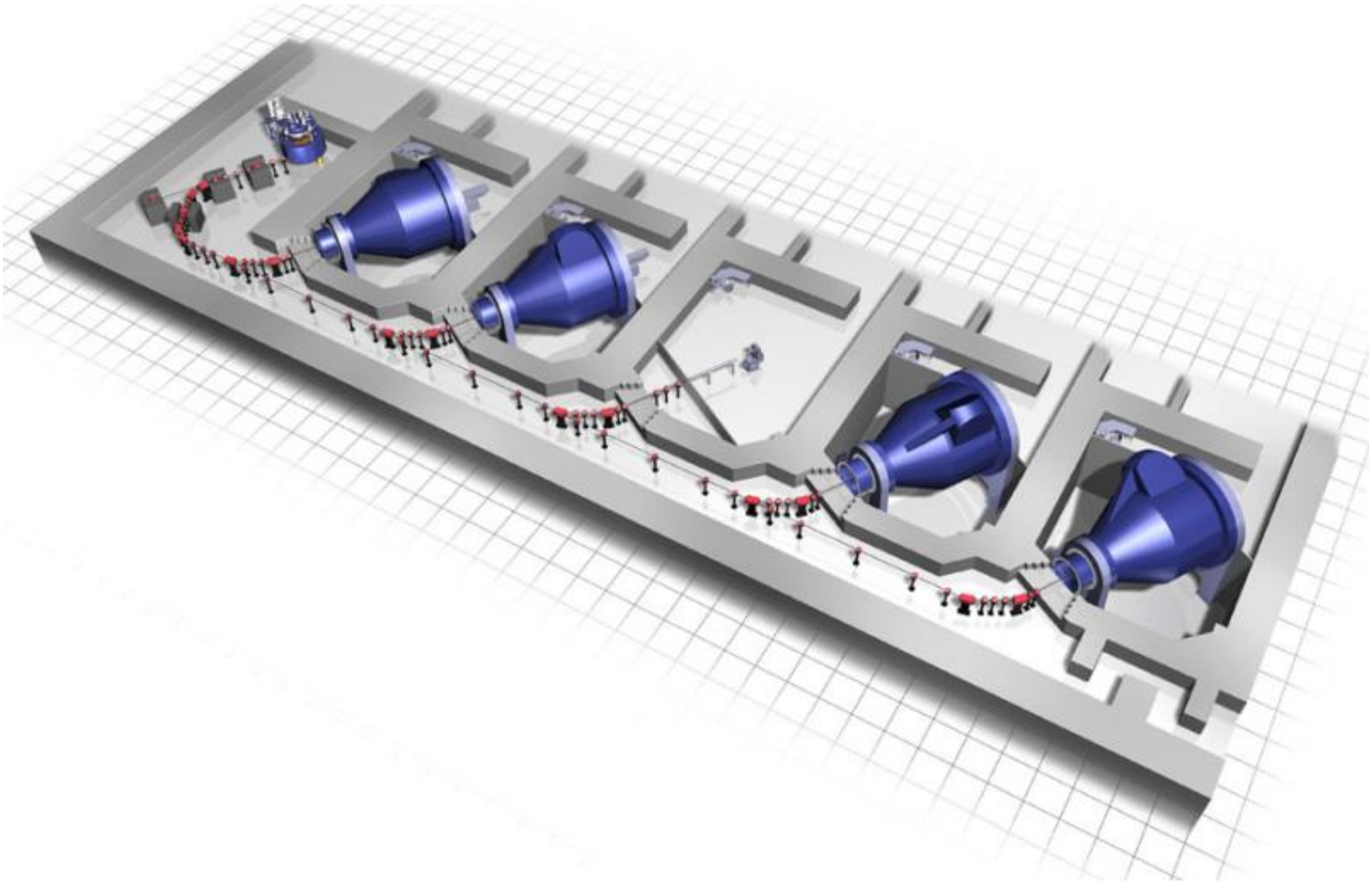
How do we deliver proton therapy?

- What equipment do we need?

- What are the differences with x-ray therapy?

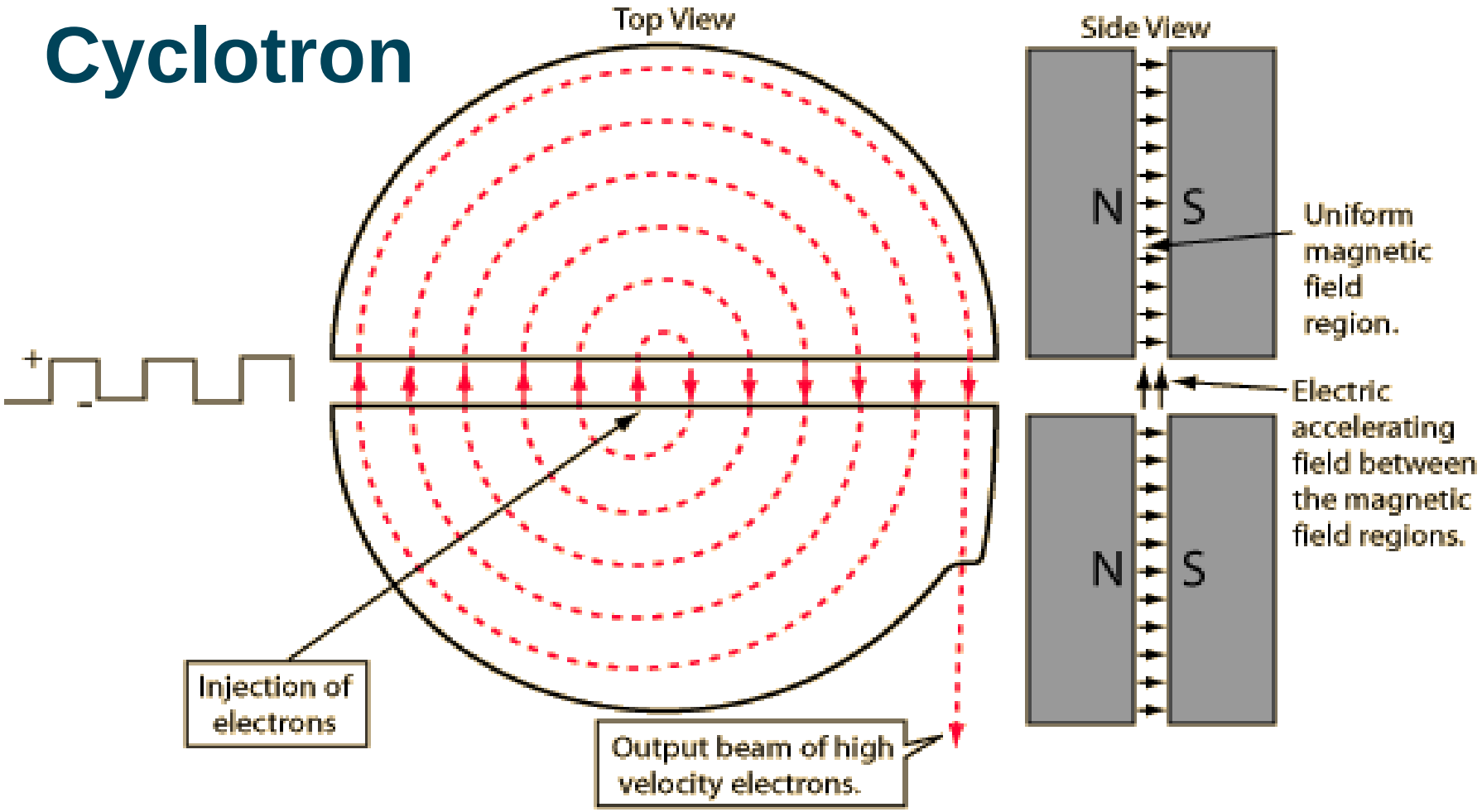
Components of a proton therapy system





How do we produce the particle beam?

Cyclotron



The magnetic field applies a force on the particle causing it to curve,

So,

$$\frac{mv^2}{r} = Bqv$$

(Where m is the mass of the particle, q is its charge, v is its velocity and r is the radius of its path.)

Therefore,

$$\frac{v}{r} = \frac{Bq}{m} = \omega$$

And, Time to complete one orbit

$$T = \frac{2\pi m}{Bq}$$

So time independent of radius

When a square wave of angular frequency

$$\omega_{cyclotron} = \frac{qB}{m}$$

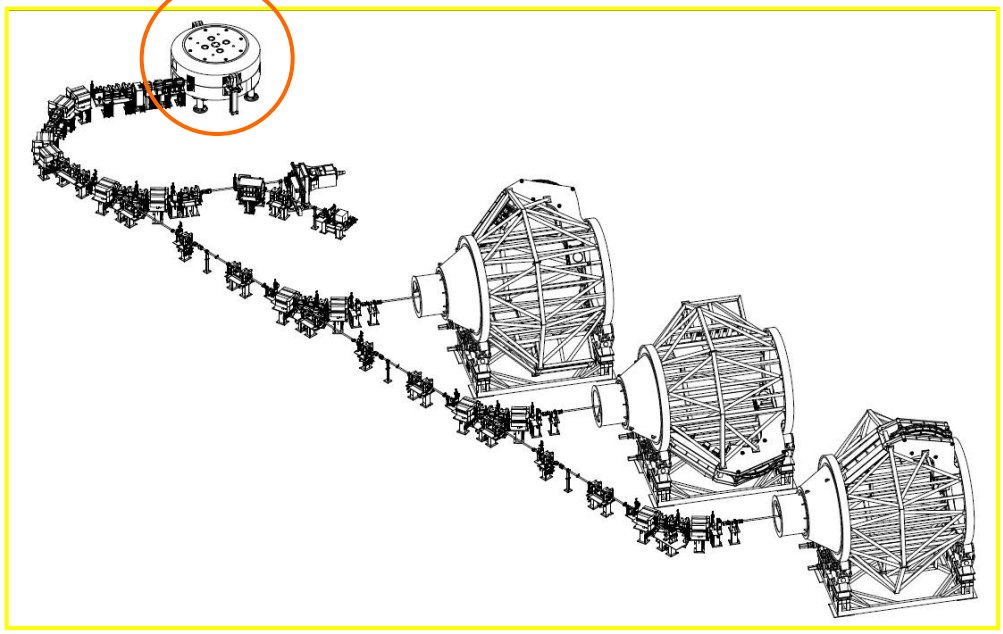
is applied between the two sides of the magnetic poles, the charge will be boosted again at just the right time to accelerate it across the gap.

Constant cyclotron frequency accelerates the charge.

A beam of 3.5 GeV Carbon ions are required for a radiotherapy treatment. They are to be produced by a cyclotron. The final orbit of the carbon ions in the cyclotron has a radius of 4m. [5]
Calculate the field strength required in the magnet.

(atomic number of Carbon is 6; proton charge = 1.6×10^{-19}C, rest mass of carbon ion = 1.99×10^{-23} kg, 1eV = 1.602×10^{-19}J)

A stroll along the beam line



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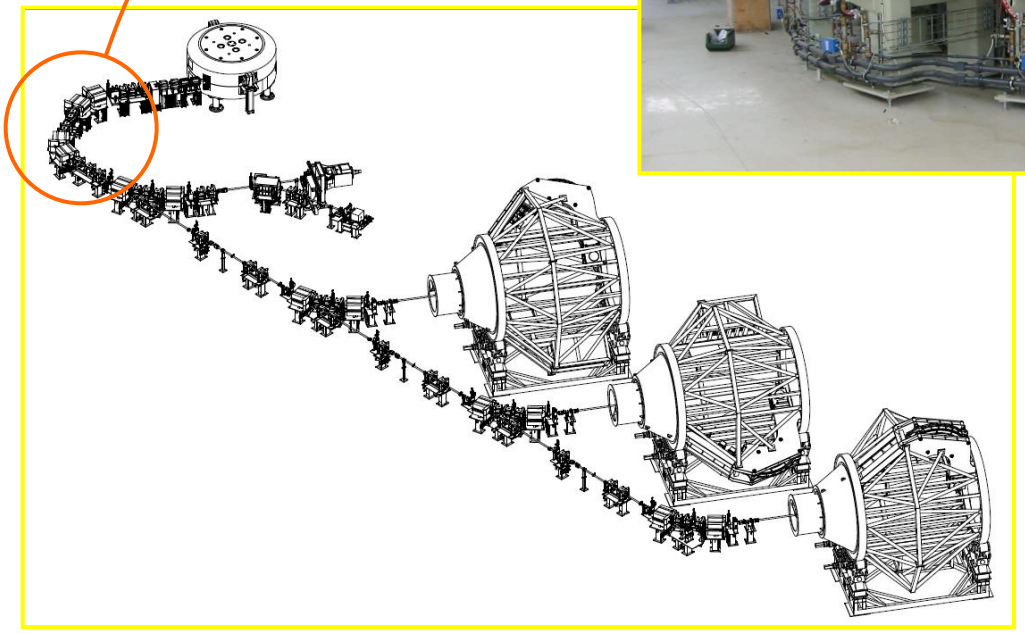

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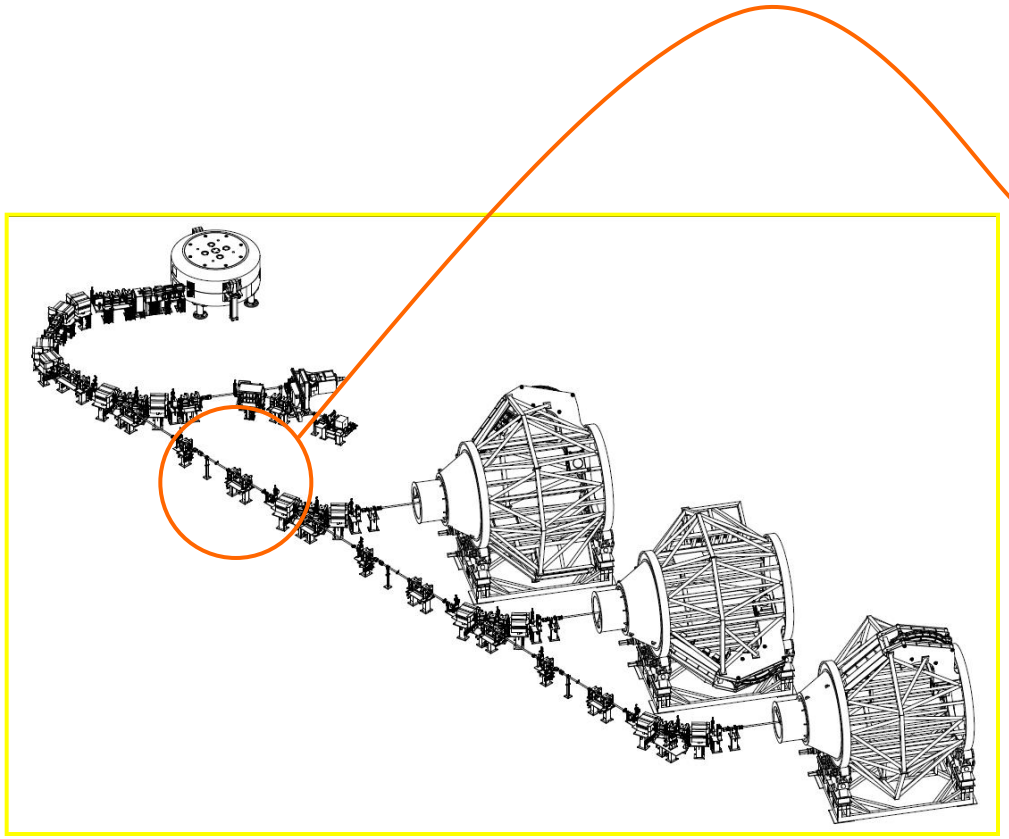

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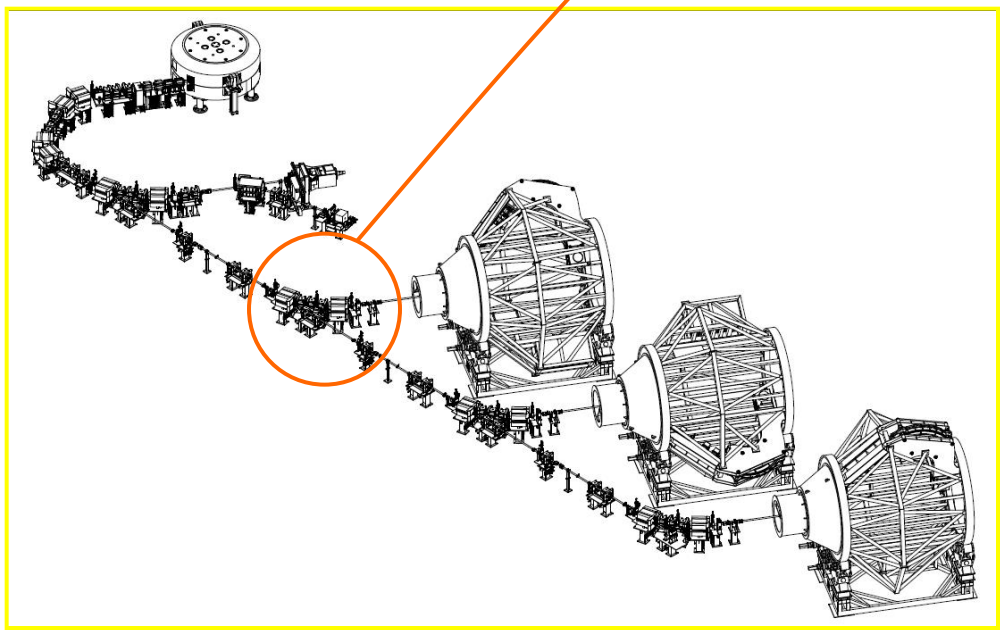

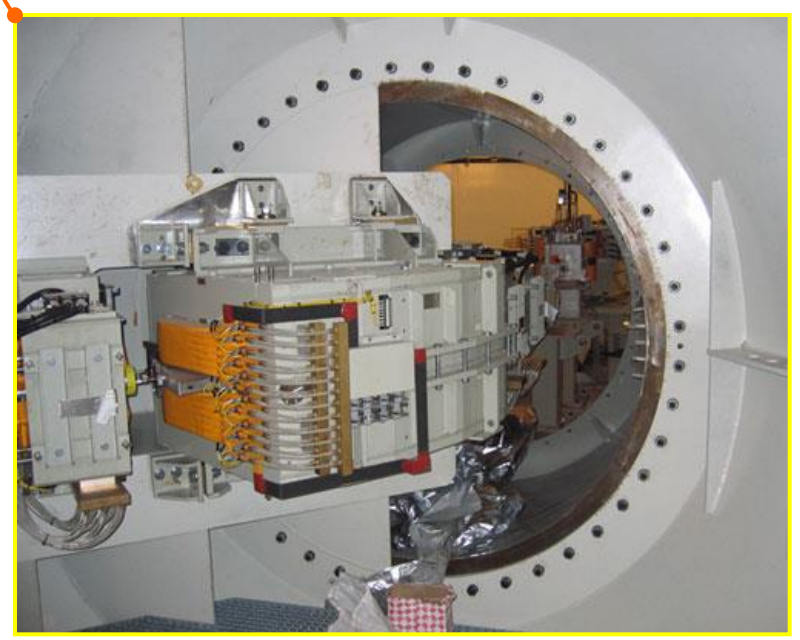

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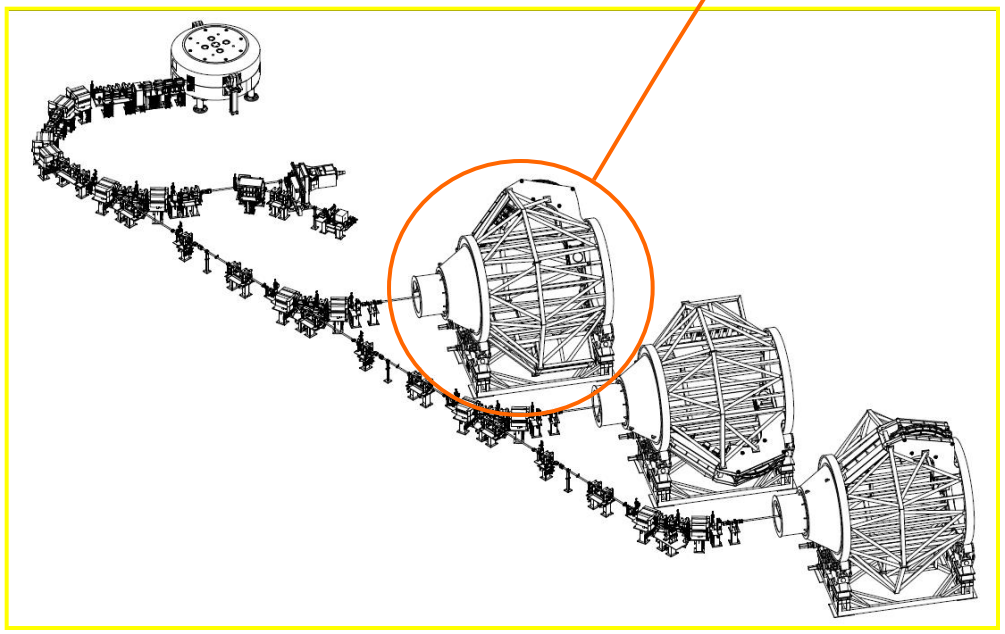
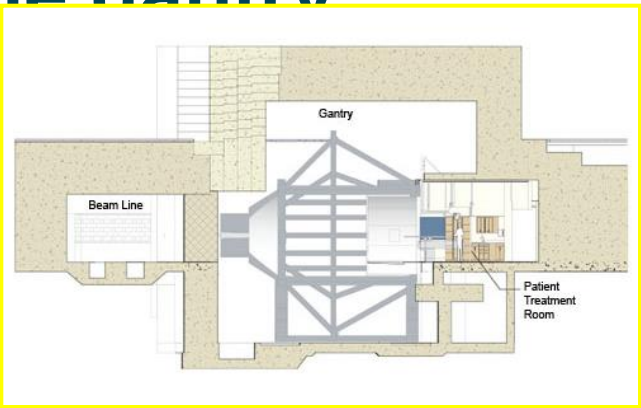
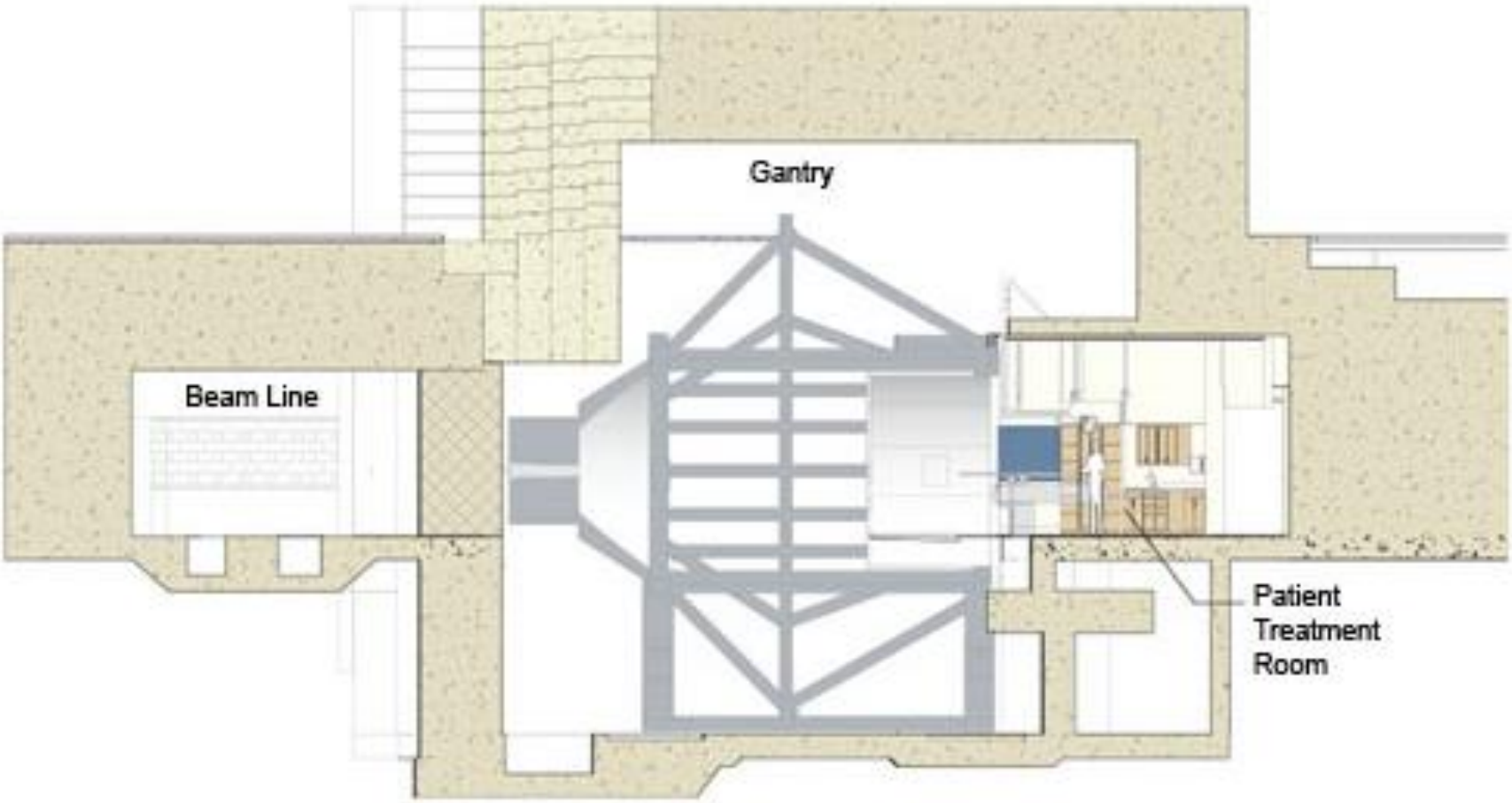


The gantry



Side view of gantry and treatment room



Treatment delivery system