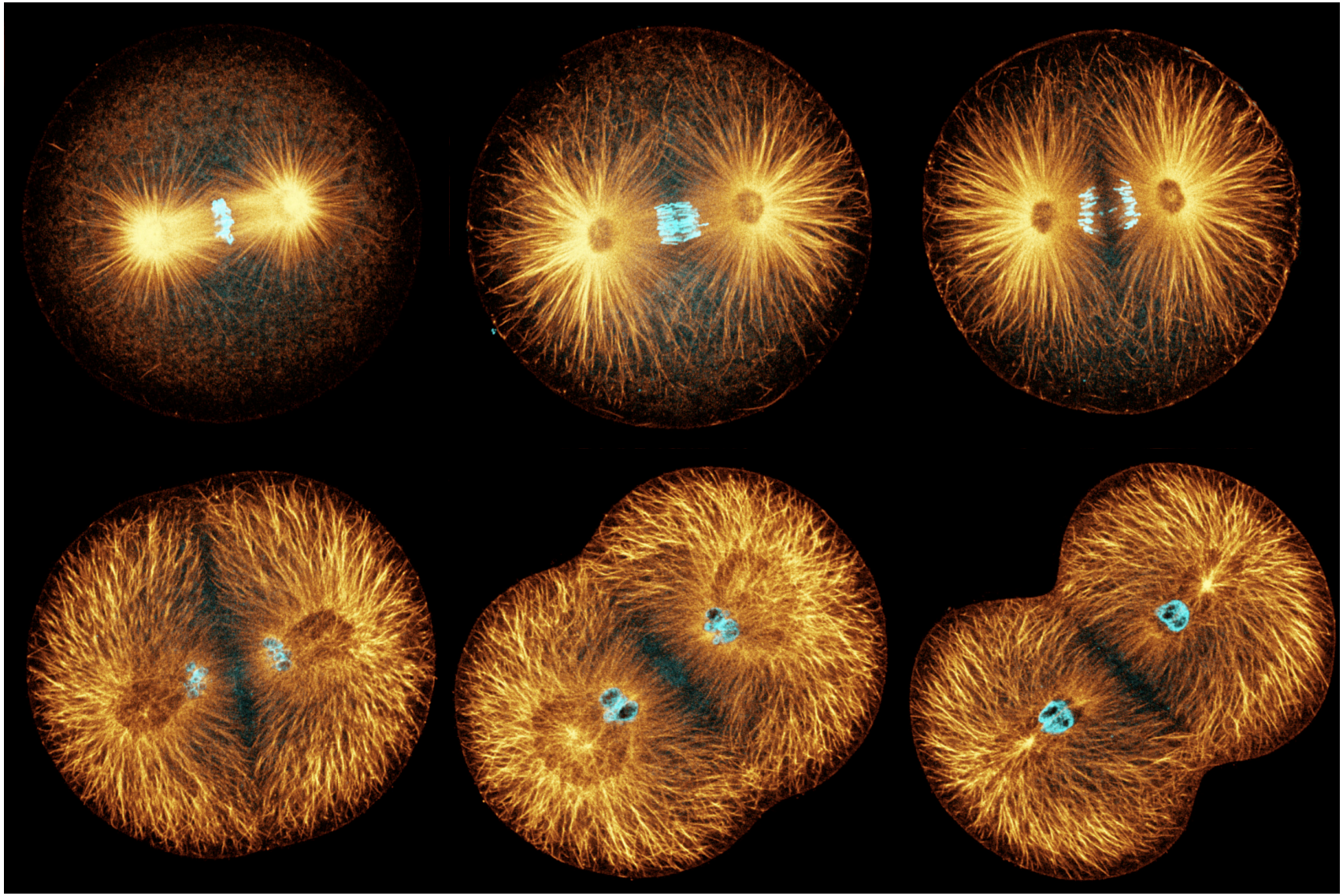
Proton Beam Therapy: How The Large Hadron Collider Cures Cancer

Simon Jolly

University College London

Cell Mitosis: Born To Live

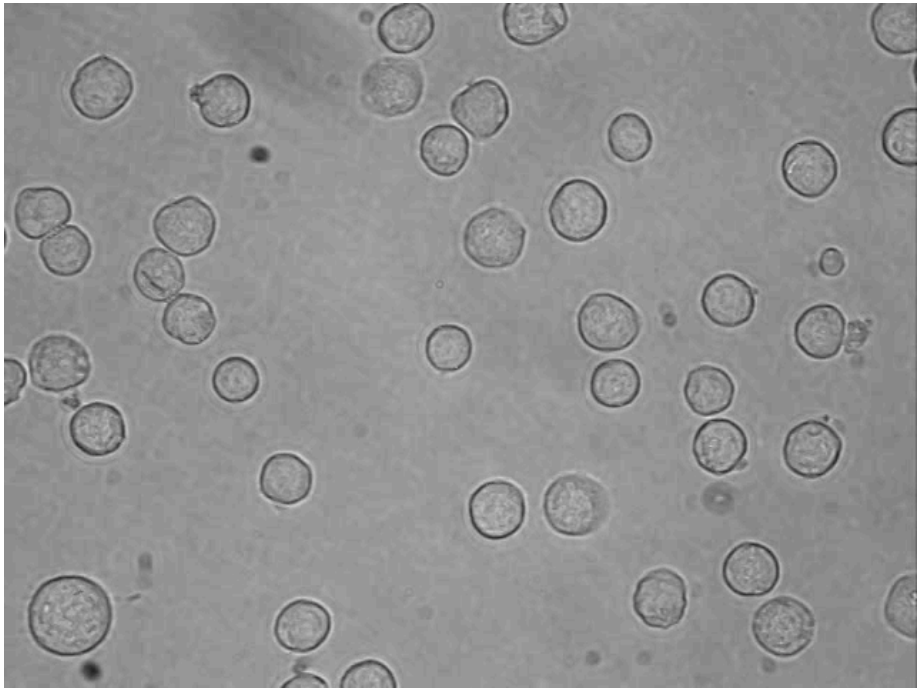


http://maggiesscienceconnection.weebly.com/mitosis.html

Cell Apoptosis: Born To Die

All cells in the body have a pre-programmed lifespan:

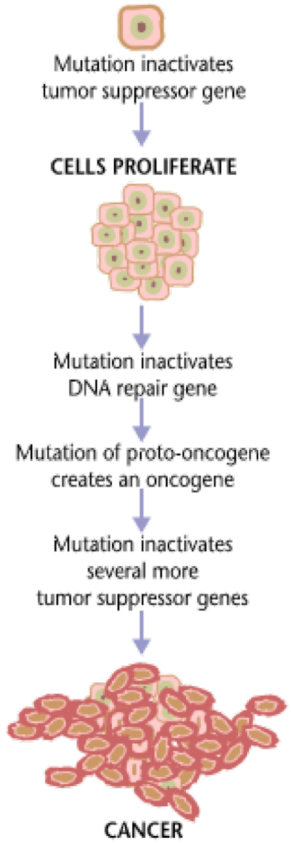
- White blood cells: <1 day
- Stomach lining: 2 days
- Sperm cells: 3 days
- Platelets: 10 days
- Skin cells: 4 weeks
- Red blood cells: 4 months
- Pancreas cells: 1 year
- Bone cells: 25-30 years
- Neurons: lifetime
- Egg cells: lifetime



If cells become abnormal, they **self-destruct** via **apoptosis**.

Cancer: Life Uncontrolled

- Cell growth balances 2 genes:
  - **Oncogenes** promote cell growth and reproduction.
  - **Tumour suppressor genes** inhibit cell division and survival.
- They both have to work in harmony for a healthy cell!
- Oncogene mutation: **cell division goes into overdrive**.
- Tumour suppressor gene mutation: **uncontrollable replication**.
- Apoptosis signalling pathway blocked: **cells immortal**.
- This is the basis of **cancer**.

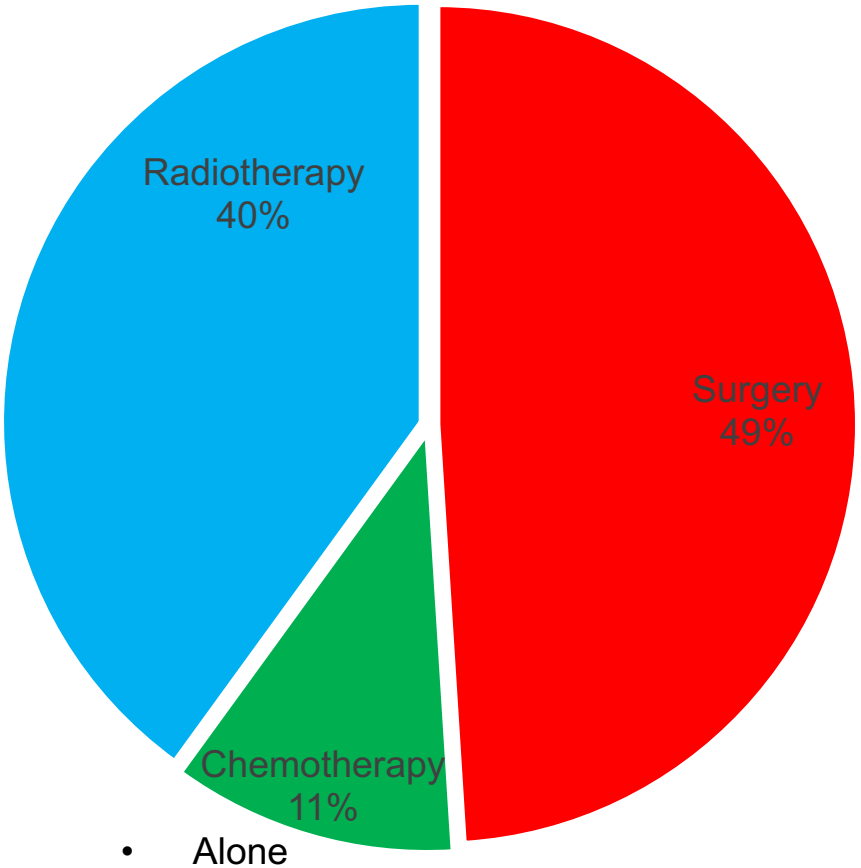


Tumour Evolution

https://www.dnalc.org/resources/3d/31-tumor-growth.html

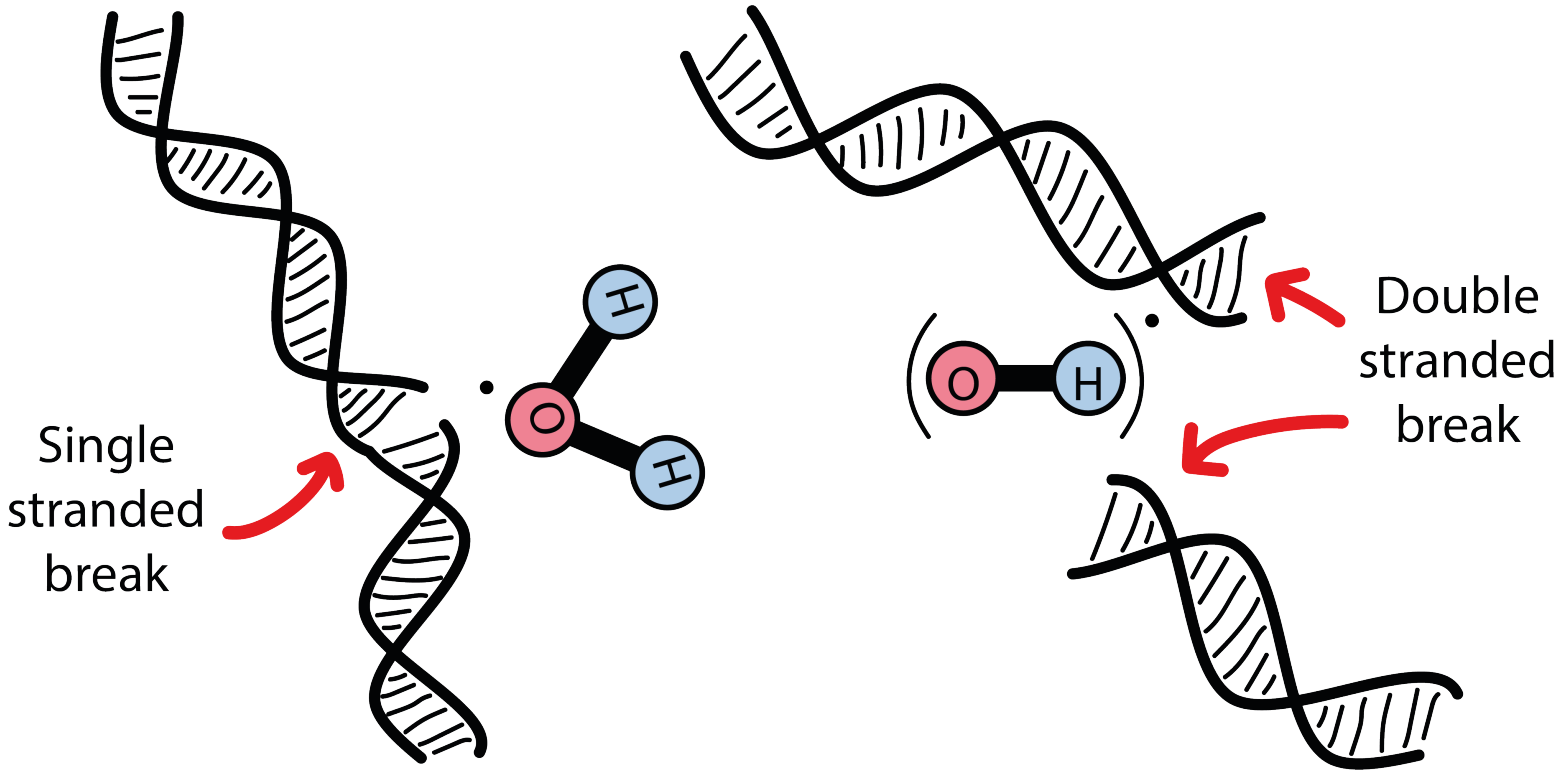
Cancer Treatment

Treatment Modalities: Contribution to Cure



- Cancer treated with 3 different modalities:
  - Surgery
  - Chemotherapy
  - Radiotherapy
- Each has advantages and disadvantages…
- If you want to cure cancer, be a surgeon!
- If you can't remove it with surgery, radiotherapy is the next best option…

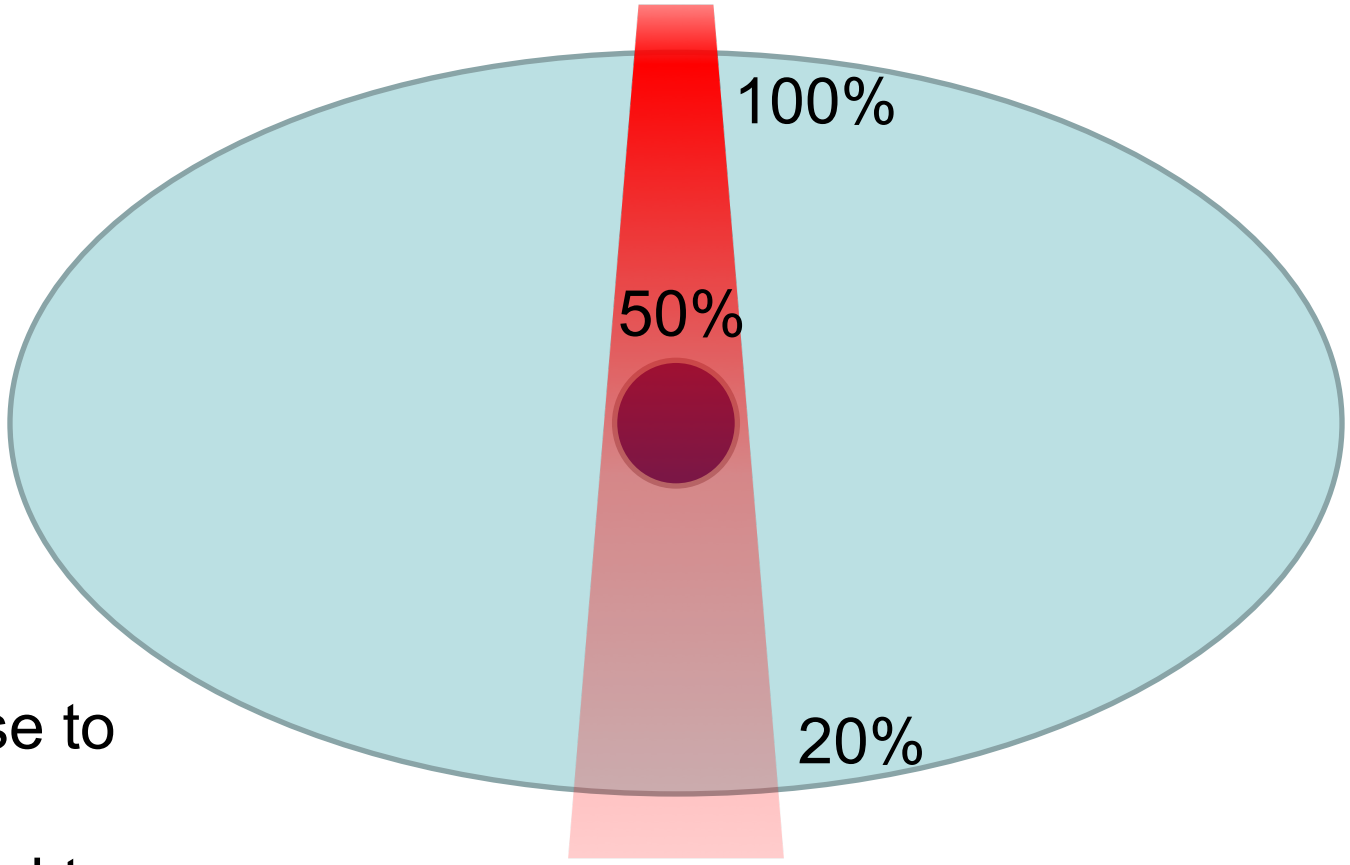
Killing Cancer by DNA Damage



- Cell death occurs through DNA damage:
  - Single strand breaks: healthy cell can self repair.
  - Double strand breaks: self-repair much more difficult.
- Optimise clustering of breaks with targeted radiation intensity.
- With enough damage, apoptosis takes over…

Ionising Radiation: Localised Damage

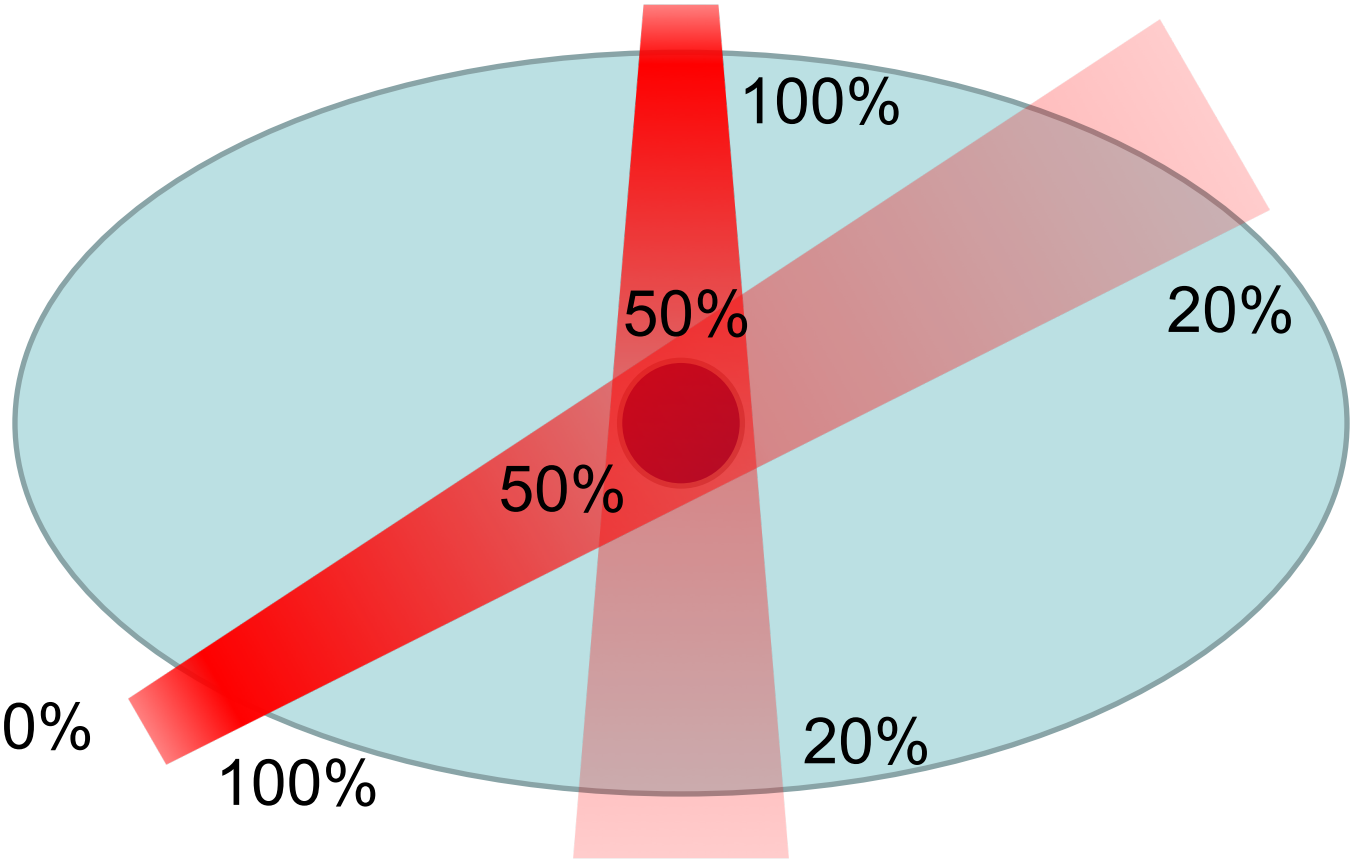
Percentage Dose



50% dose to tumour compared to maximum

Ionising Radiation: Localised Damage

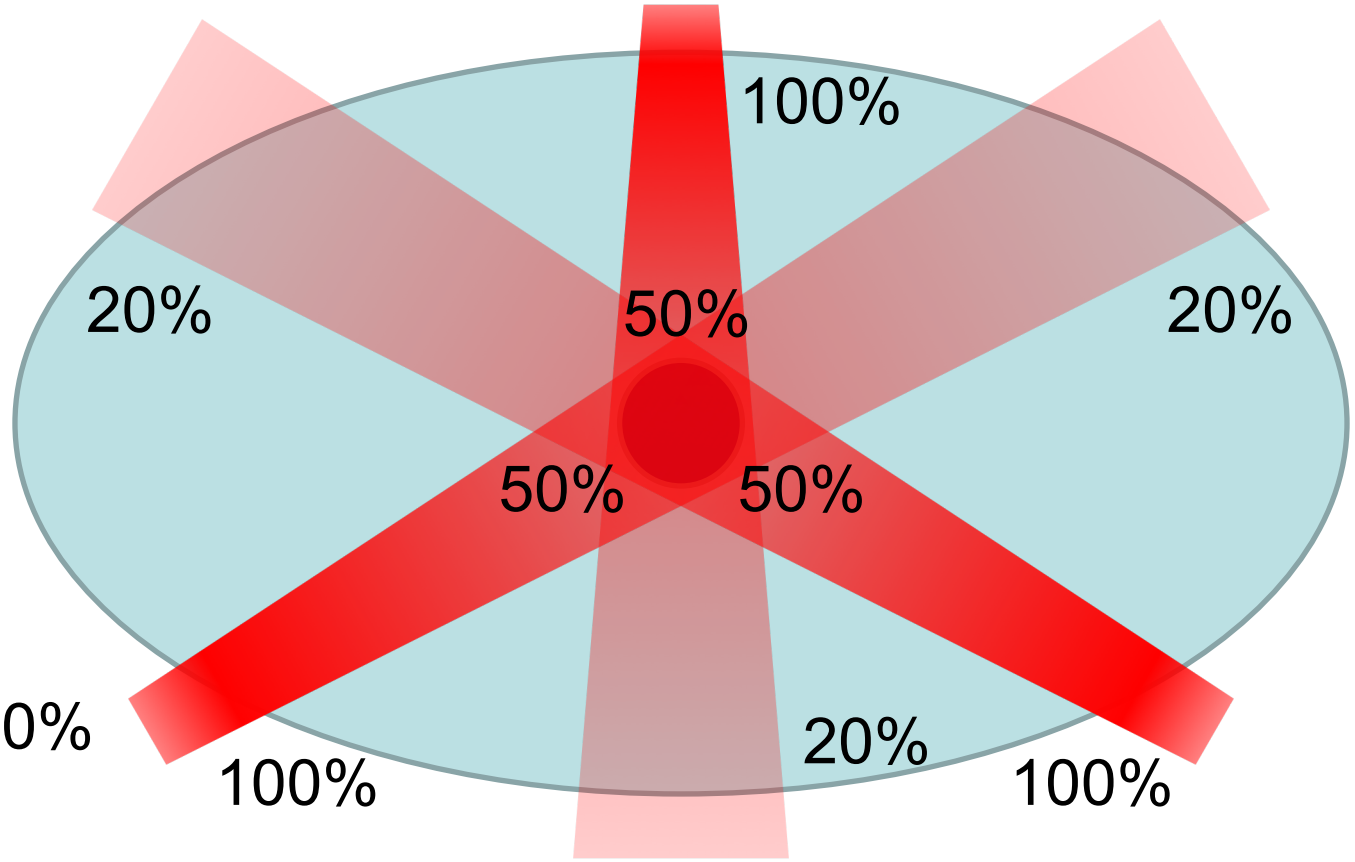
Percentage Dose



50% + 50%
= 100%
dose to
tumour

Ionising Radiation: Localised Damage

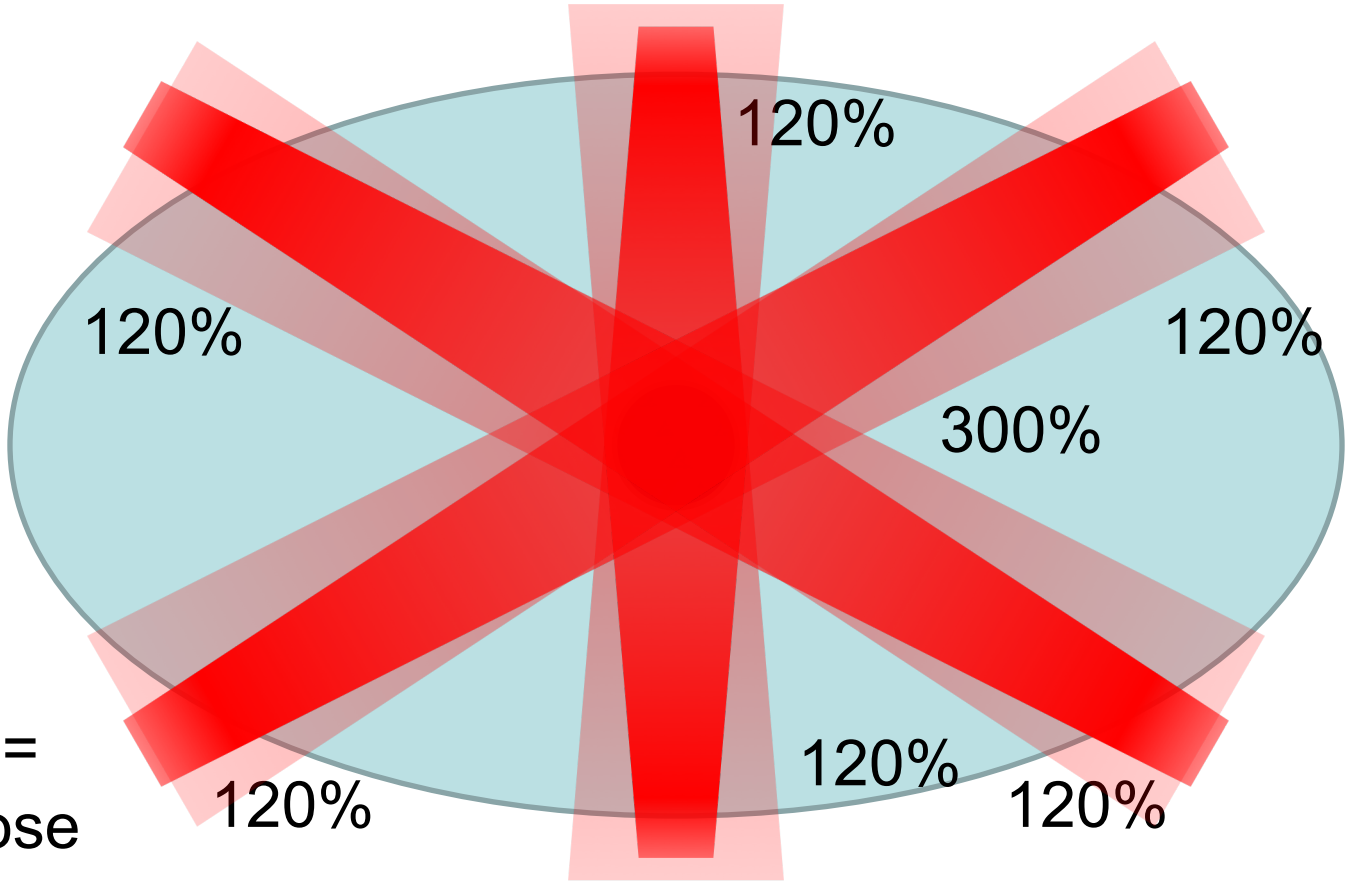
Percentage Dose



50% + 50% + 50% = 150% dose to tumour

Ionising Radiation: Localised Damage

Percentage Dose

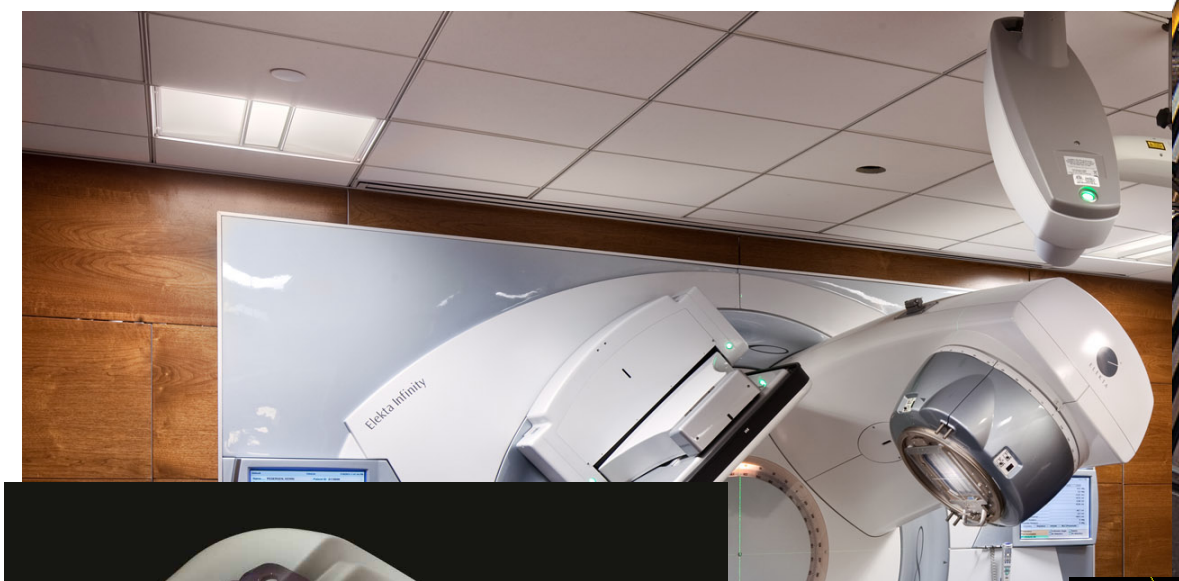


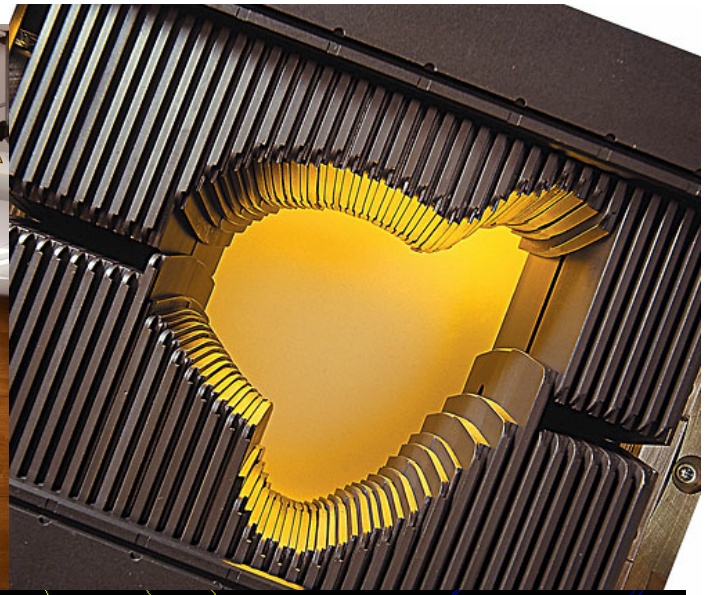
6 * 50% =
300% dose
to tumour

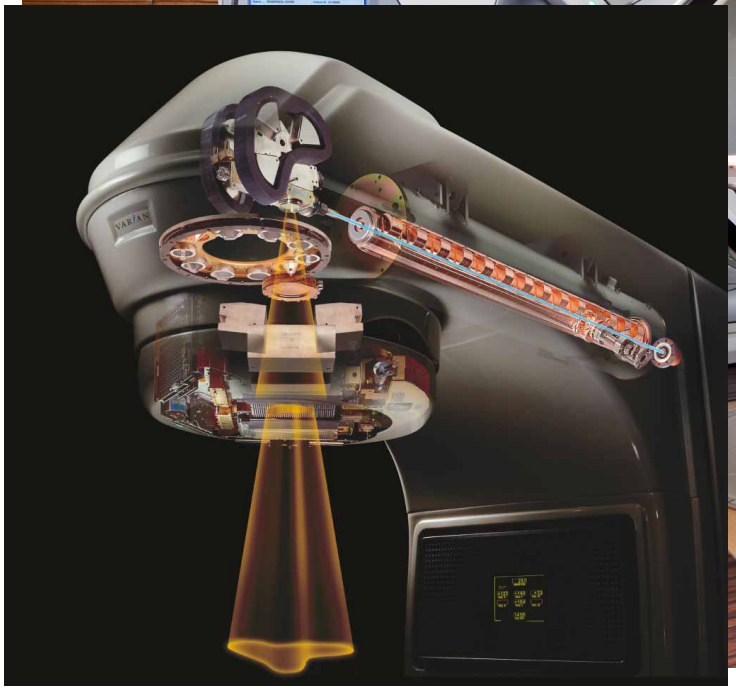
Radiotherapy Treatment Room

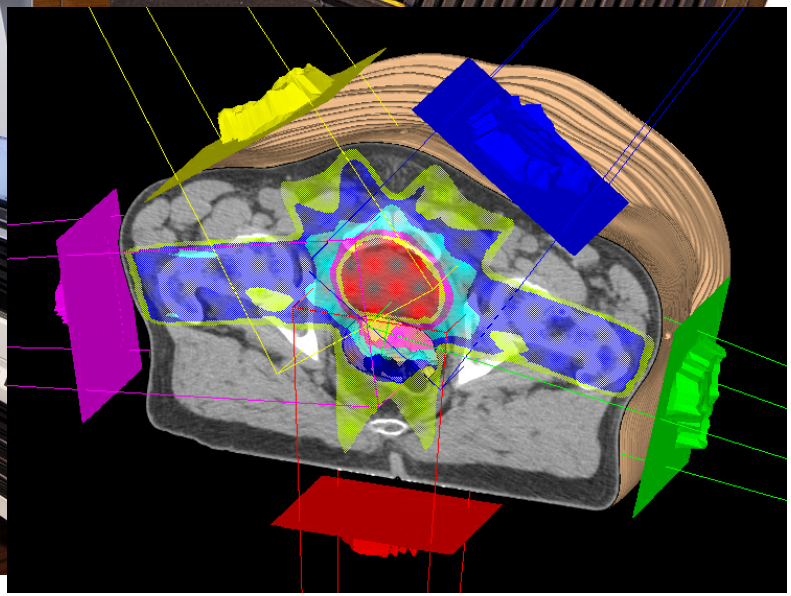
http://thefarbercenter.com/blog/wp-content/uploads/2011/10/linac-room.jpg

Radiotherapy Treatment Room







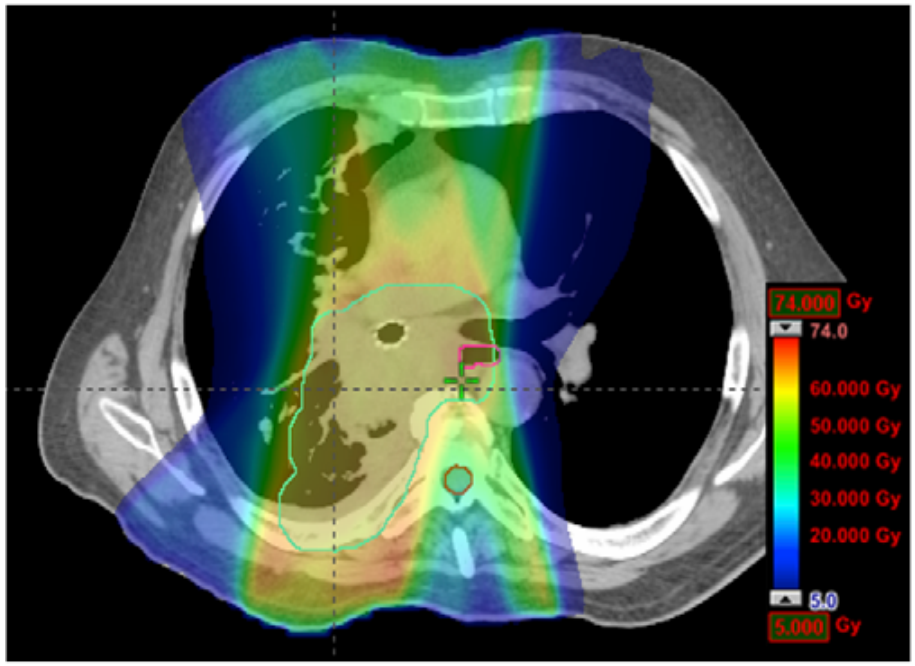


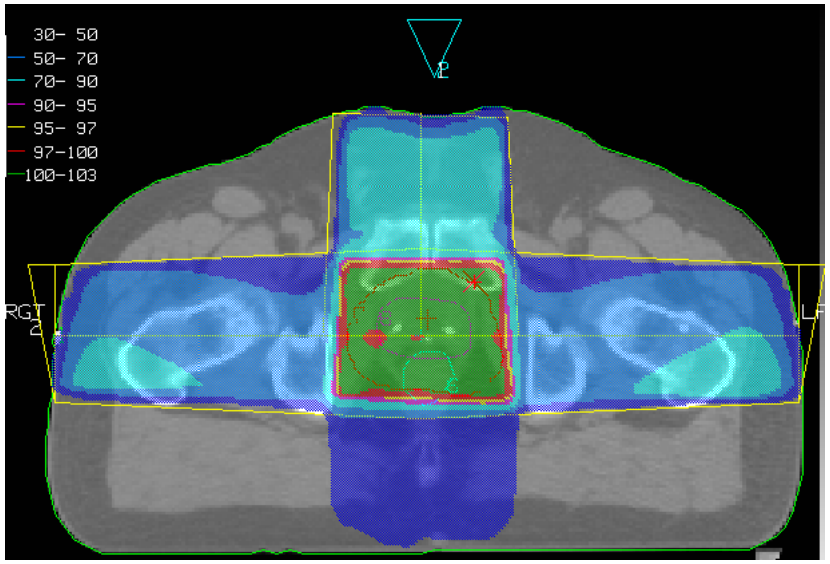
http://thefarbercenter.com/blog/wp-content/uploads/2011/10/linac-room.jpg

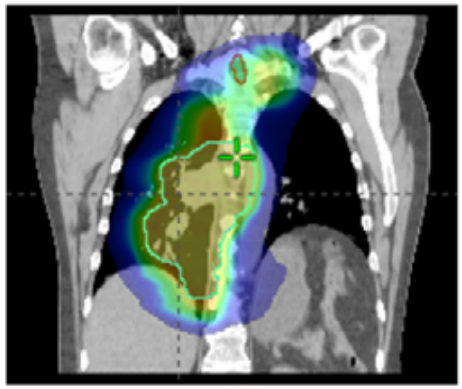
RapidArc 360º Conformal Treatment

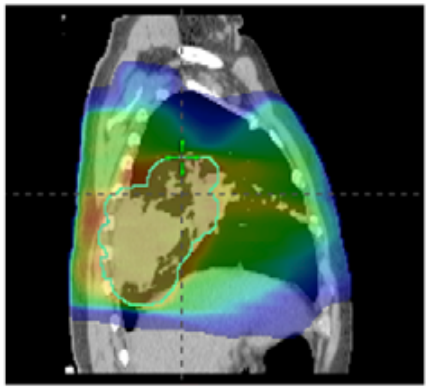
https://www.varian.com/en-gb/oncology/treatment-techniques/external-beam-radiation/vmat

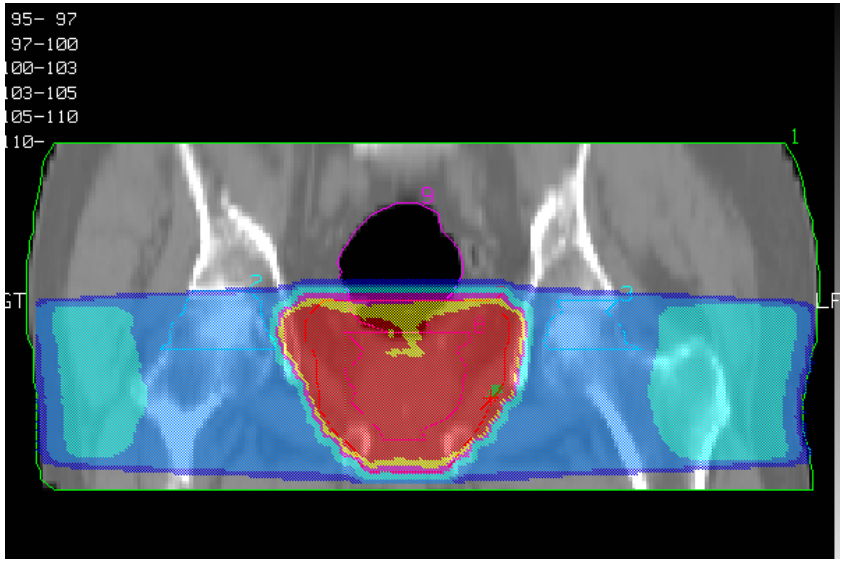
Radiotherapy Dose Distribution





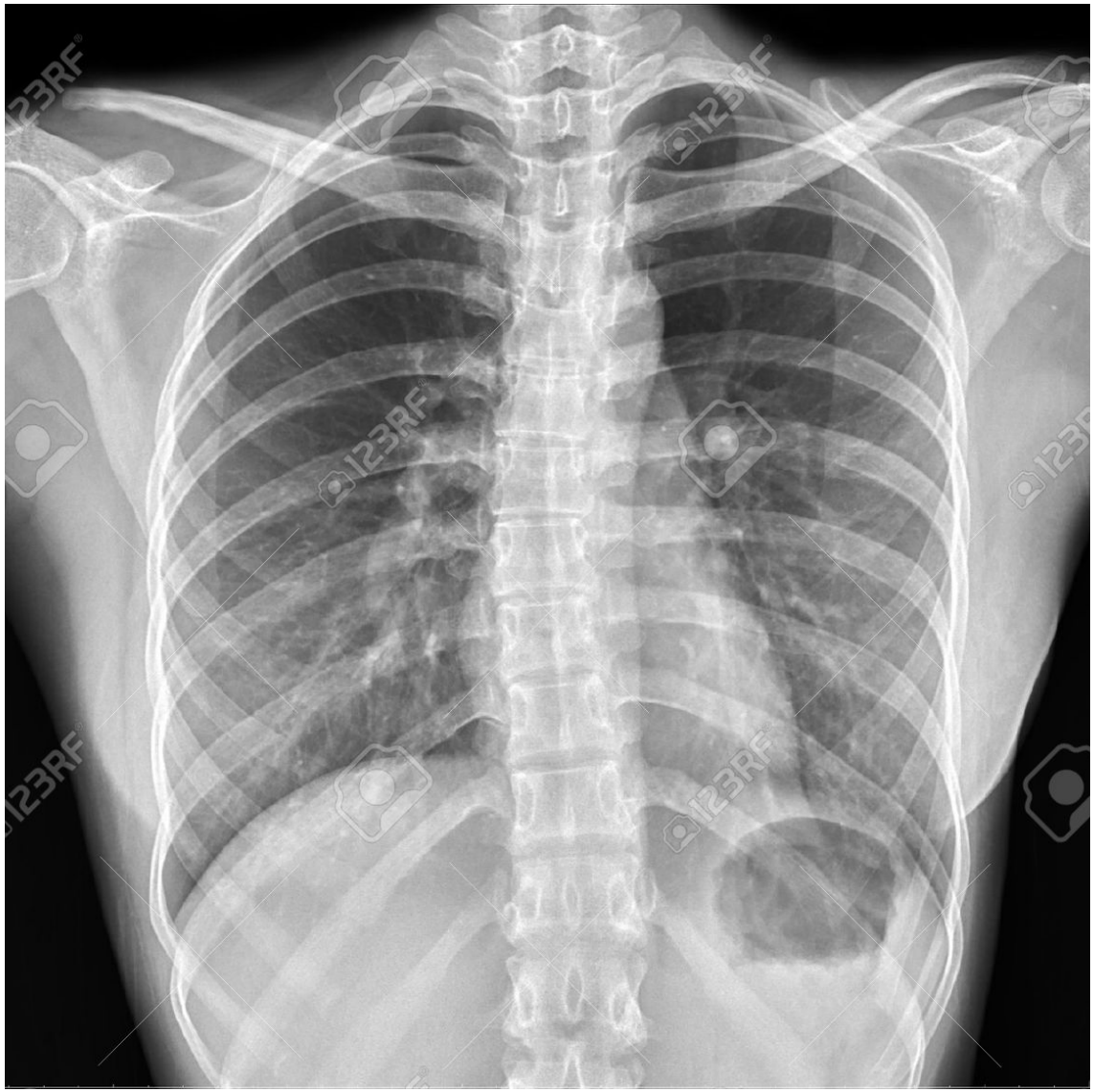






Zhang X, Li Y, Pan X, et al. *Int J Radiat Oncol Biol Phys.* 2009;77(2):357-366

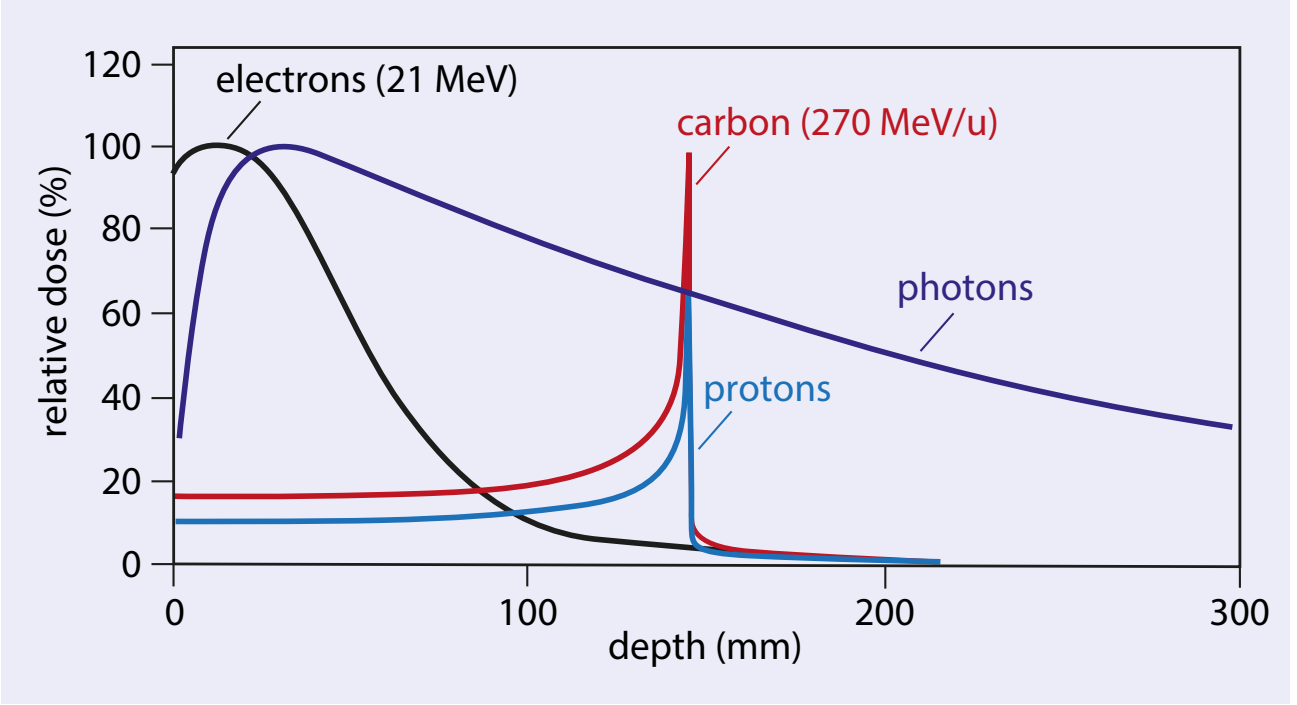
X-rays Pass Through The Body!



- The problem with treating with X-rays is that they don't stop at the tumour.
- Beams of X-rays several centimetres across: much bigger than tumour.

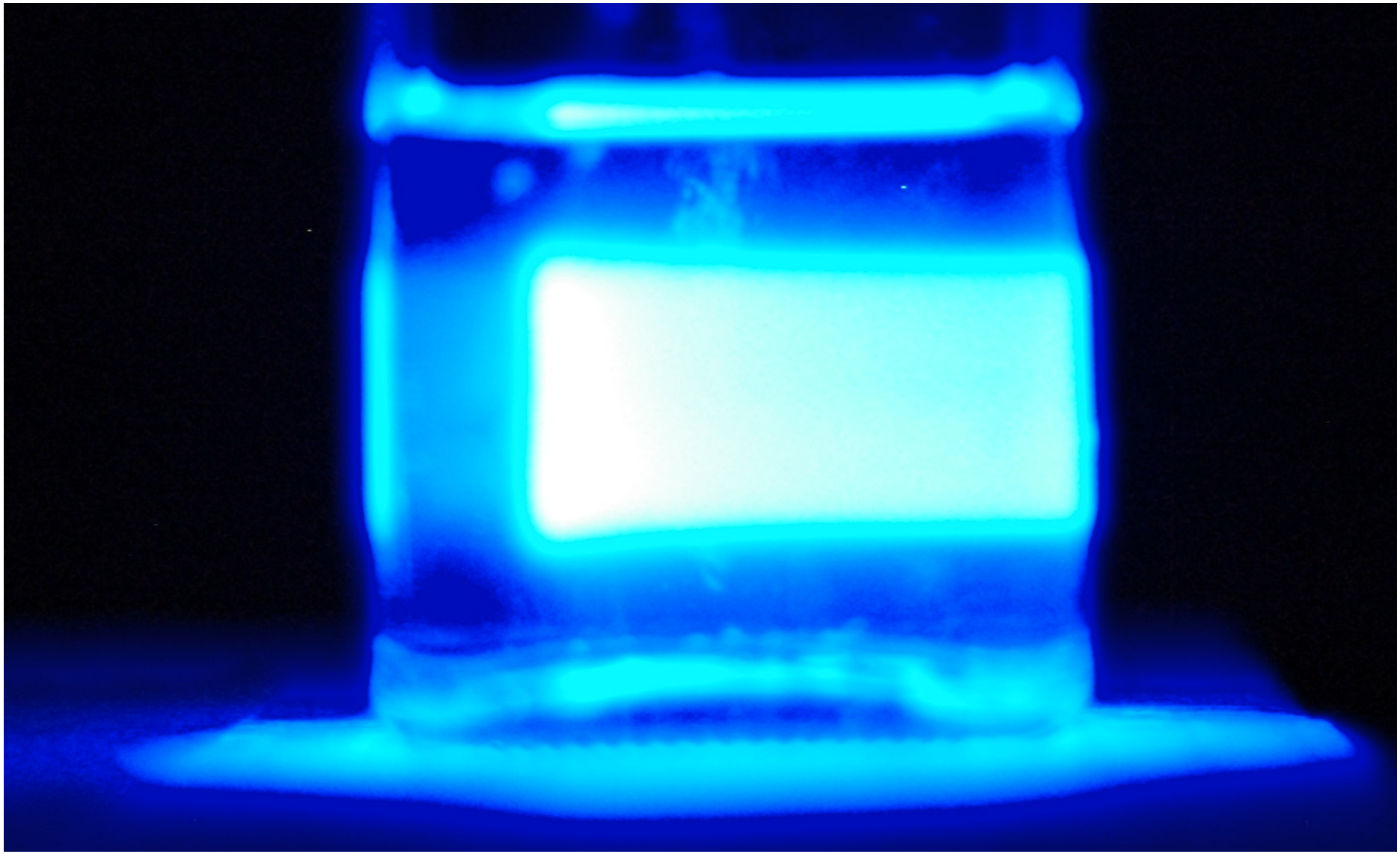
The Bragg Peak

- Unlike X-rays, charged particles stop!
- Electrons, being lighter, scatter and spread out.

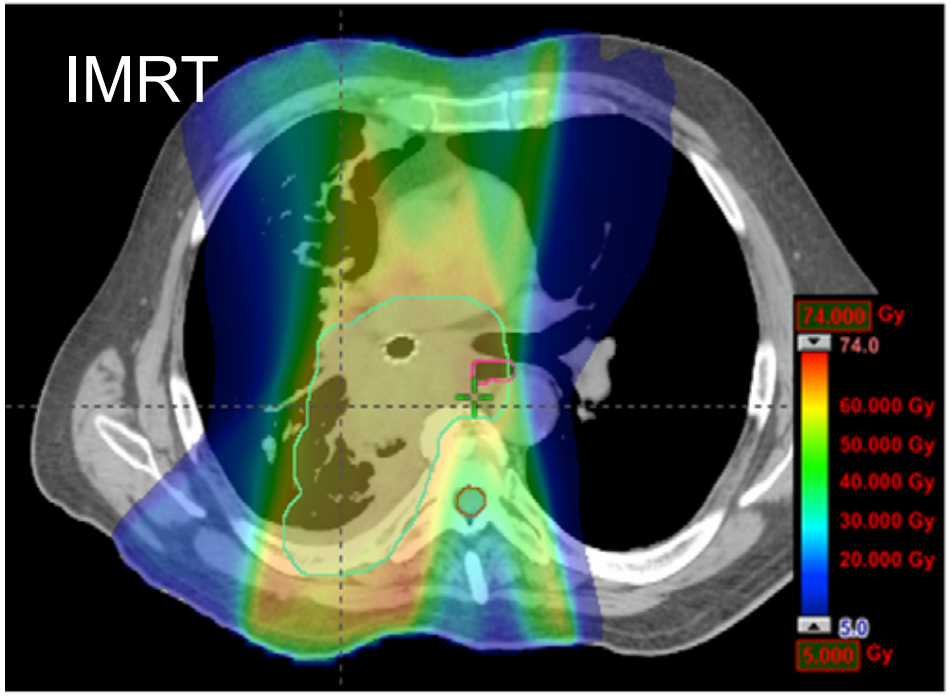


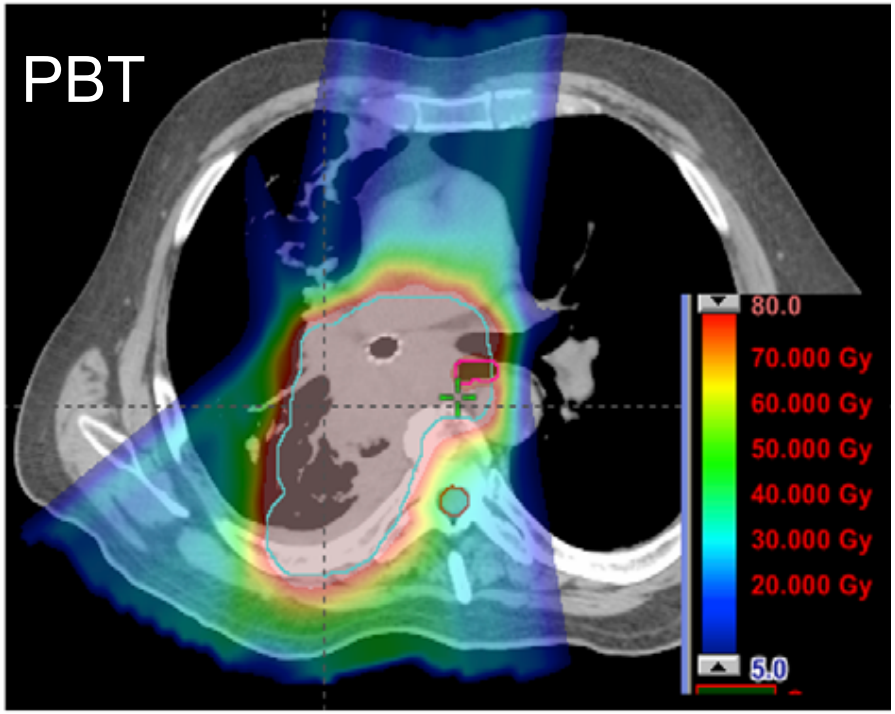
- Protons deposit most dose at the *end* of their path: the **Bragg Peak**.

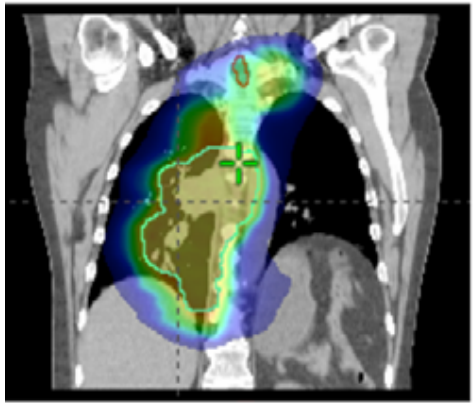
A Real Bragg Peak!

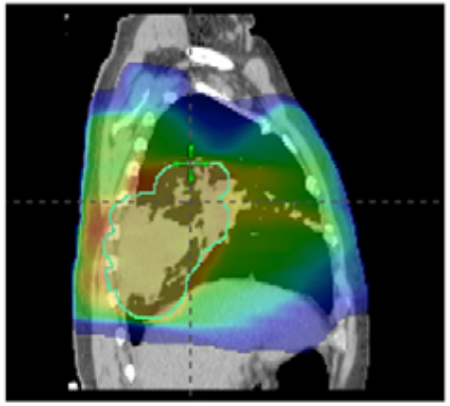


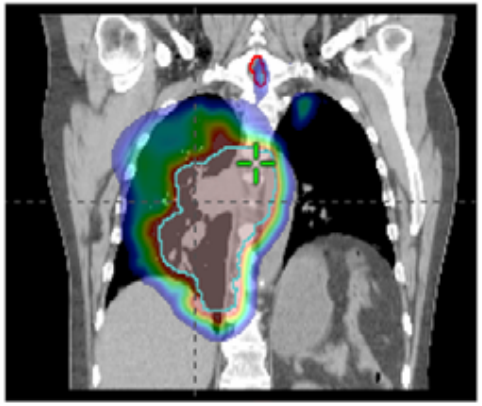
Non Small Cell Lung Cancer

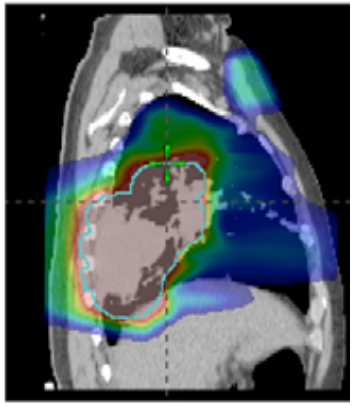












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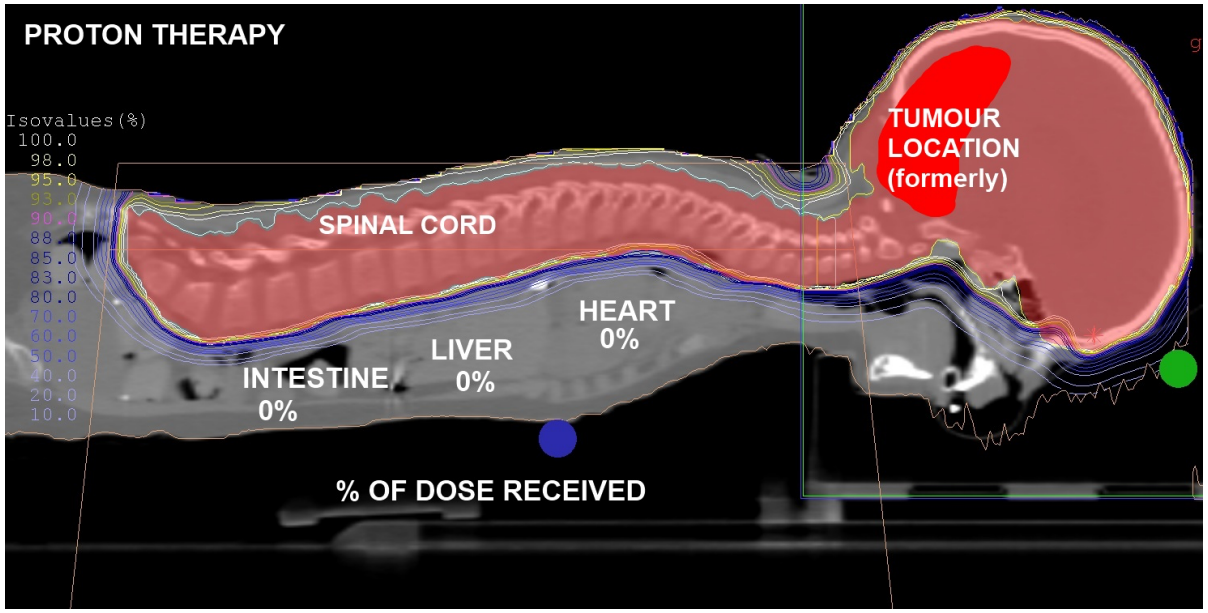
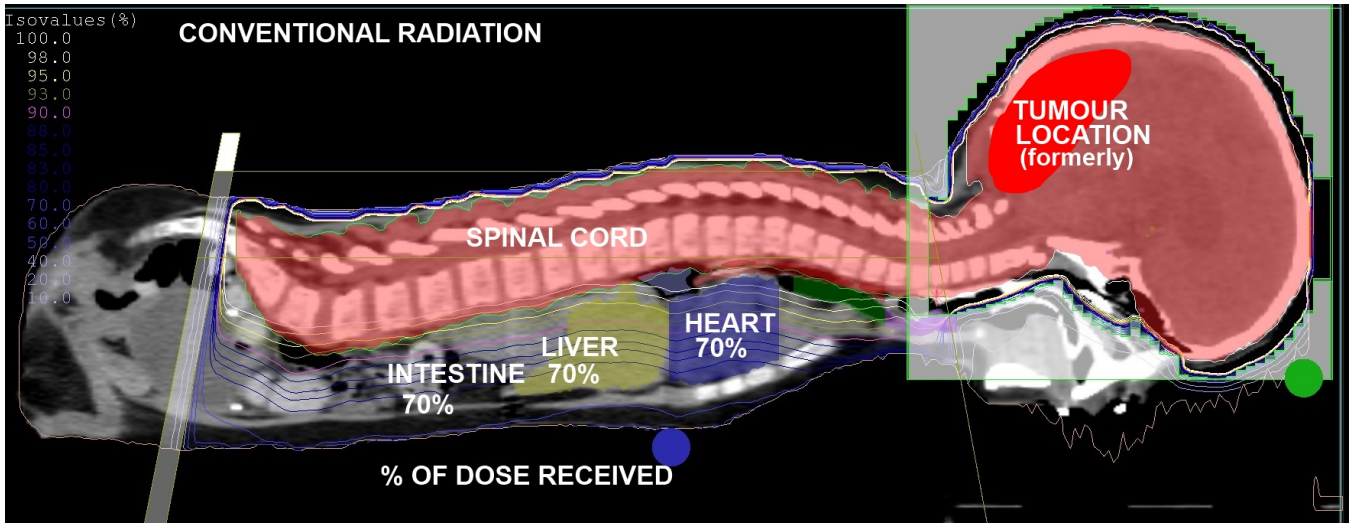
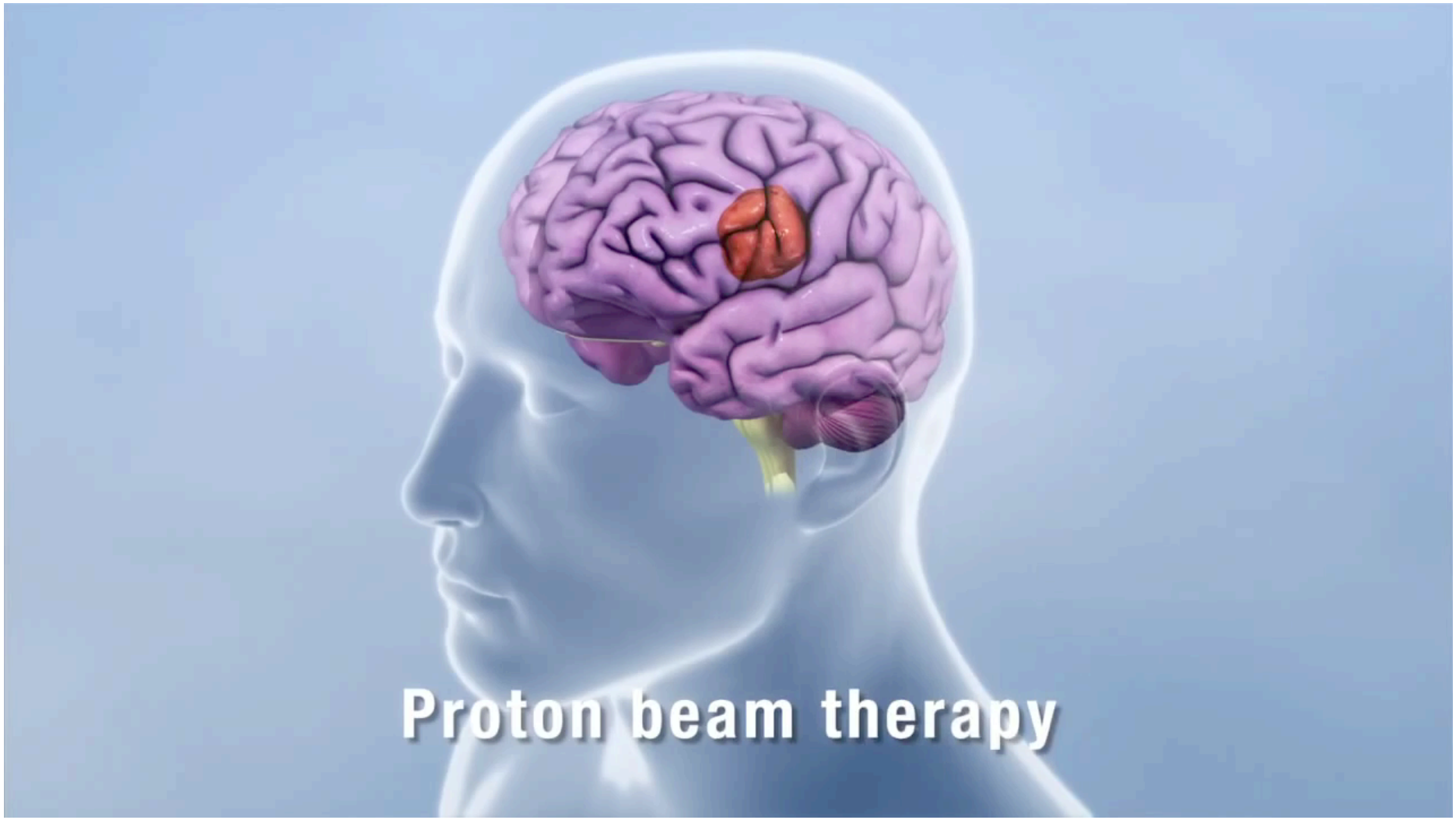
Medulloblastoma Comparison



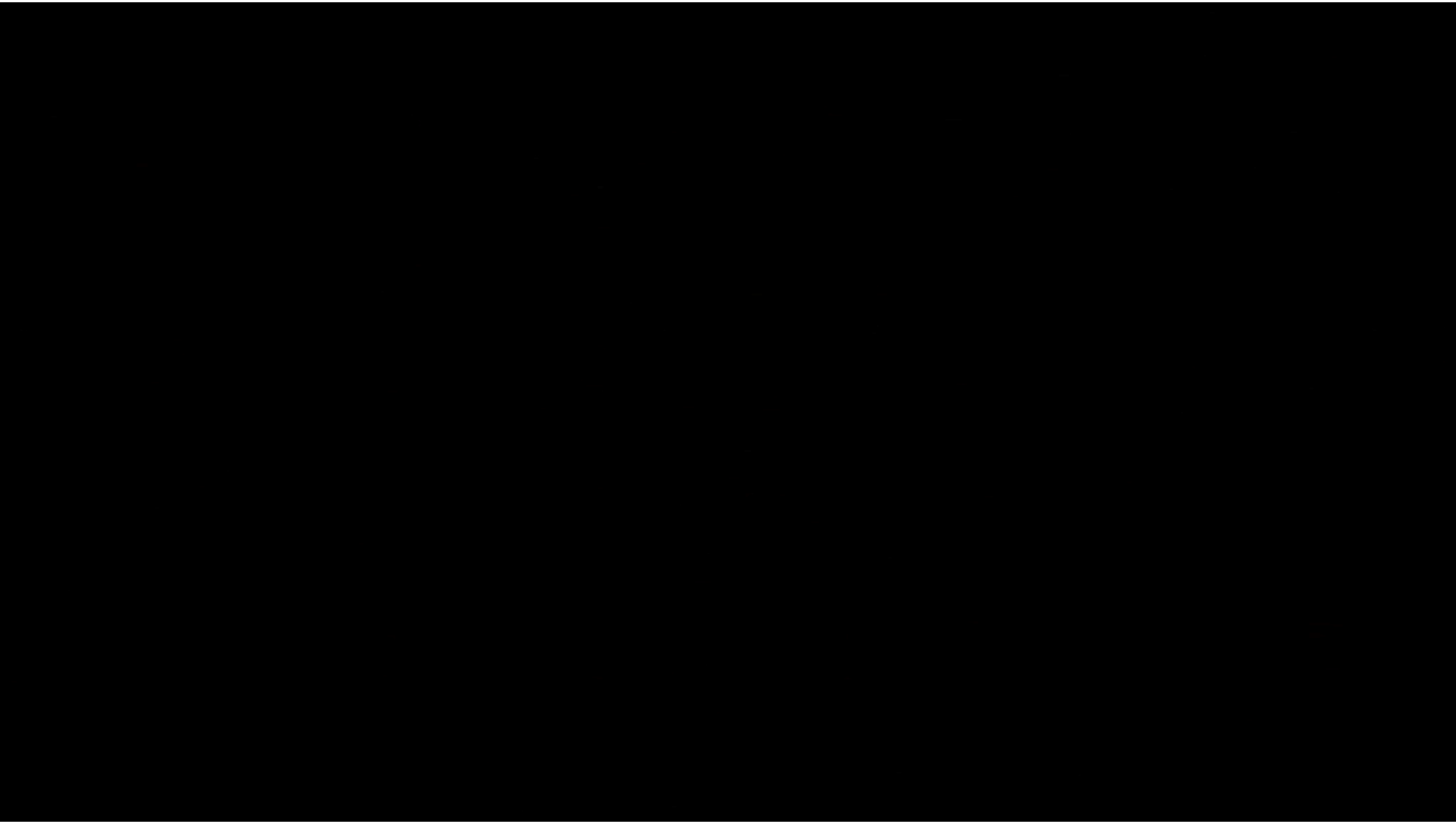


http://www.proton-cancer-treatment.com/media/press-releases/proton-treatment-plan-for-ashya-is-ready/

Conformal Dose Delivery



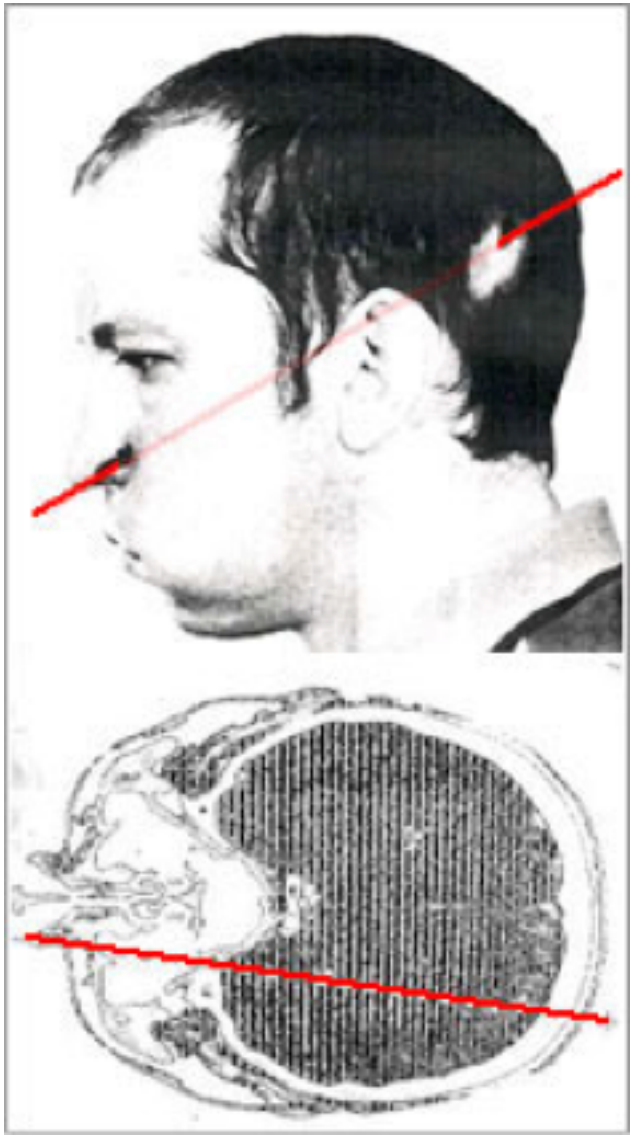
The Large Hadron Collider



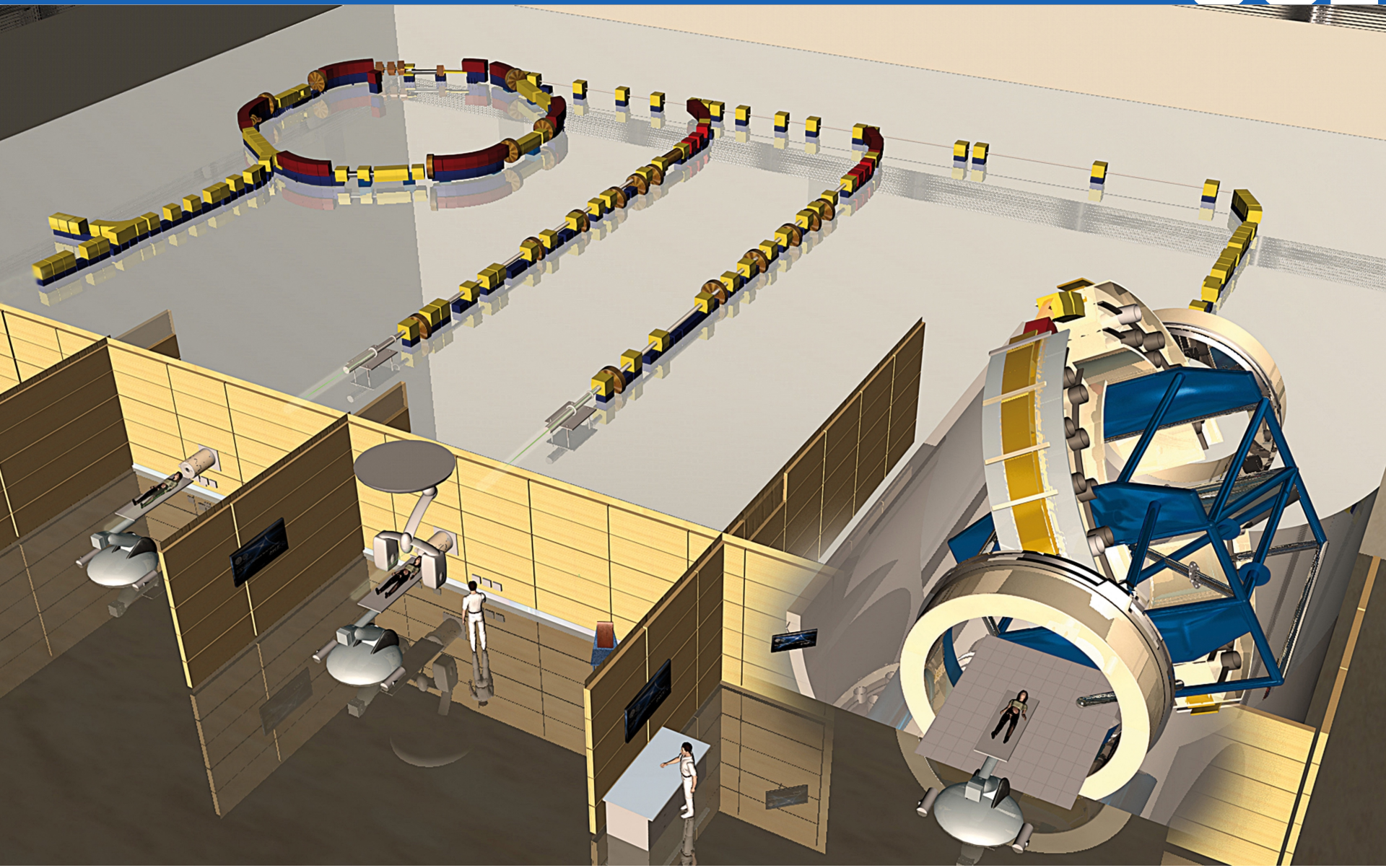
http://dx.doi.org/10.17181/cds.1125472

Anatoly Bugorski

- Anatoly Bugorski was a researcher at the Institute for High Energy Physics in Protvino, working on U-70 synchrotron.
- On 13 July 1978, safety mechanisms failed while Bugorski was leaning over some malfunctioning equipment when he stuck his head in the path of the proton beam.
- He reportedly saw a flash "brighter than a thousand suns" but did not feel any pain.
- The left half of his face swelled up beyond recognition, and over the next several days, started peeling off, revealing the path that the proton beam had burned through parts of his face, his bone, and the brain tissue underneath.
- The dose was expected to be far in excess of fatal! However, he survived and even completed his Ph.D.
- There was virtually no damage to his intellectual capacity, but the fatigue of mental work increased markedly.
- He completely lost hearing in his left ear and only a constant, unpleasant internal noise remained.
- The left half of his face was paralysed, due to the destruction of nerves. He was able to function well, except for the fact that he had occasional complex partial seizures and rare tonic-clonic seizures.
- http://en.wikipedia.org/wiki/Anatoli_Bugorski



Heidelberg Ion Therapy Centre



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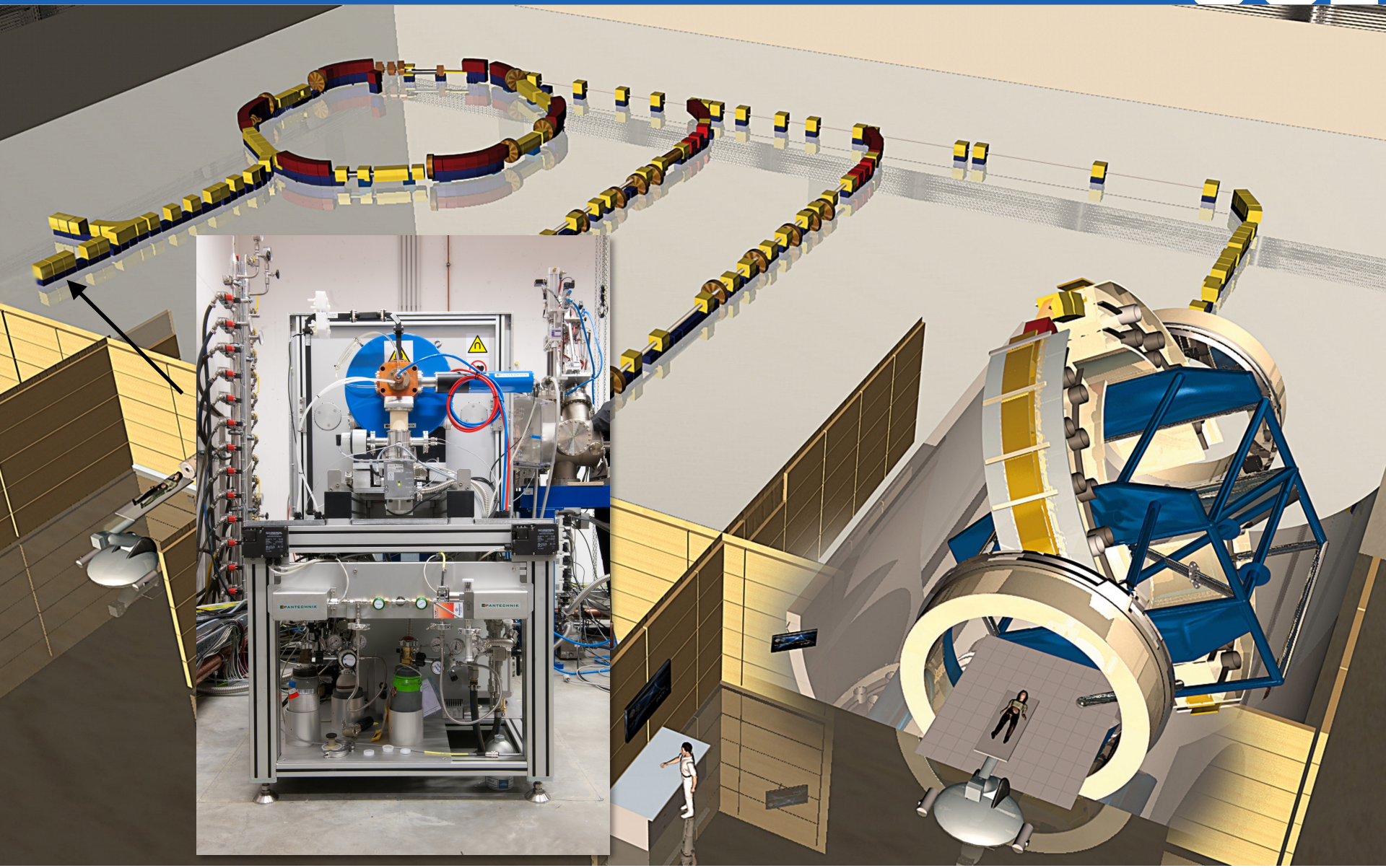

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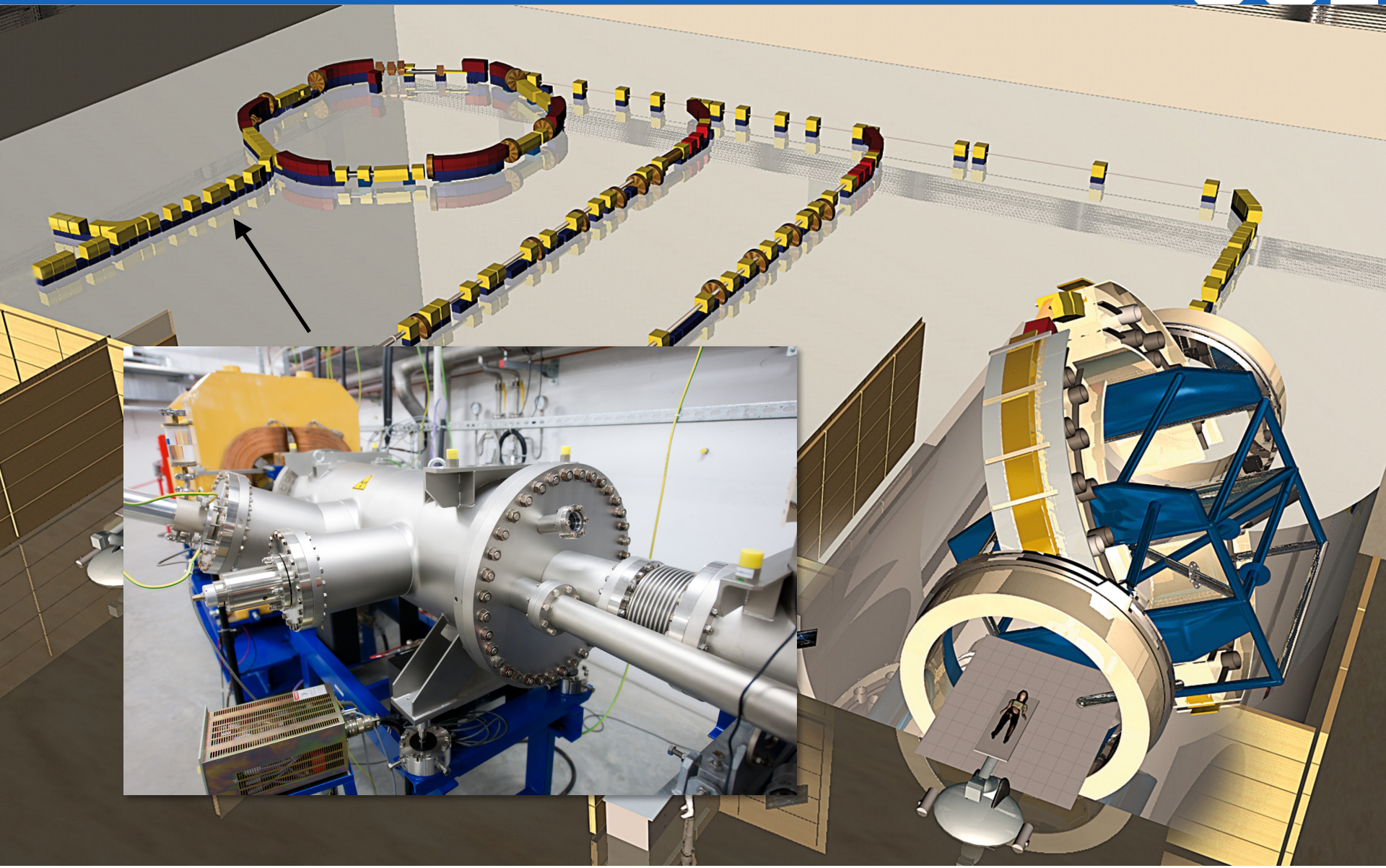

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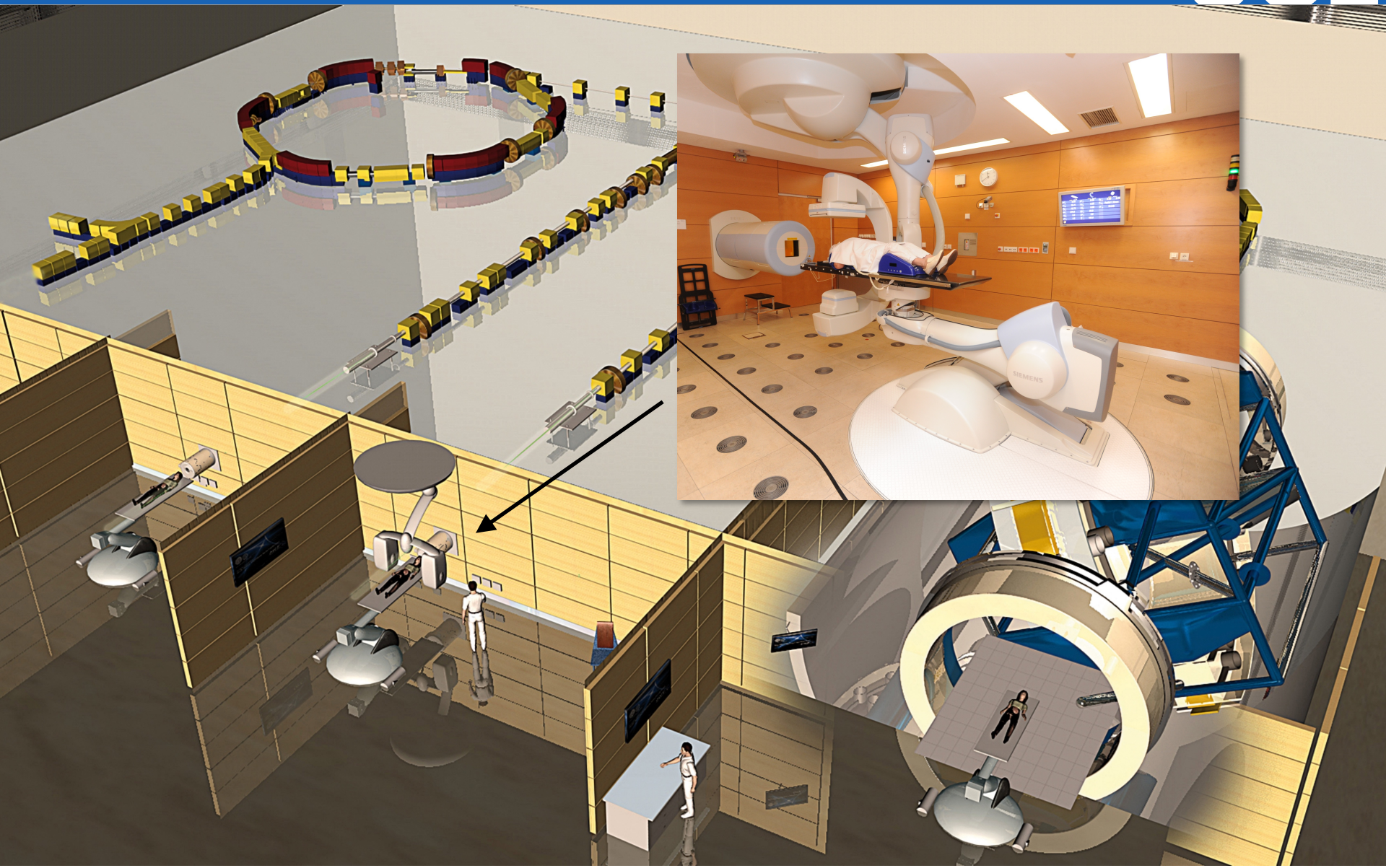

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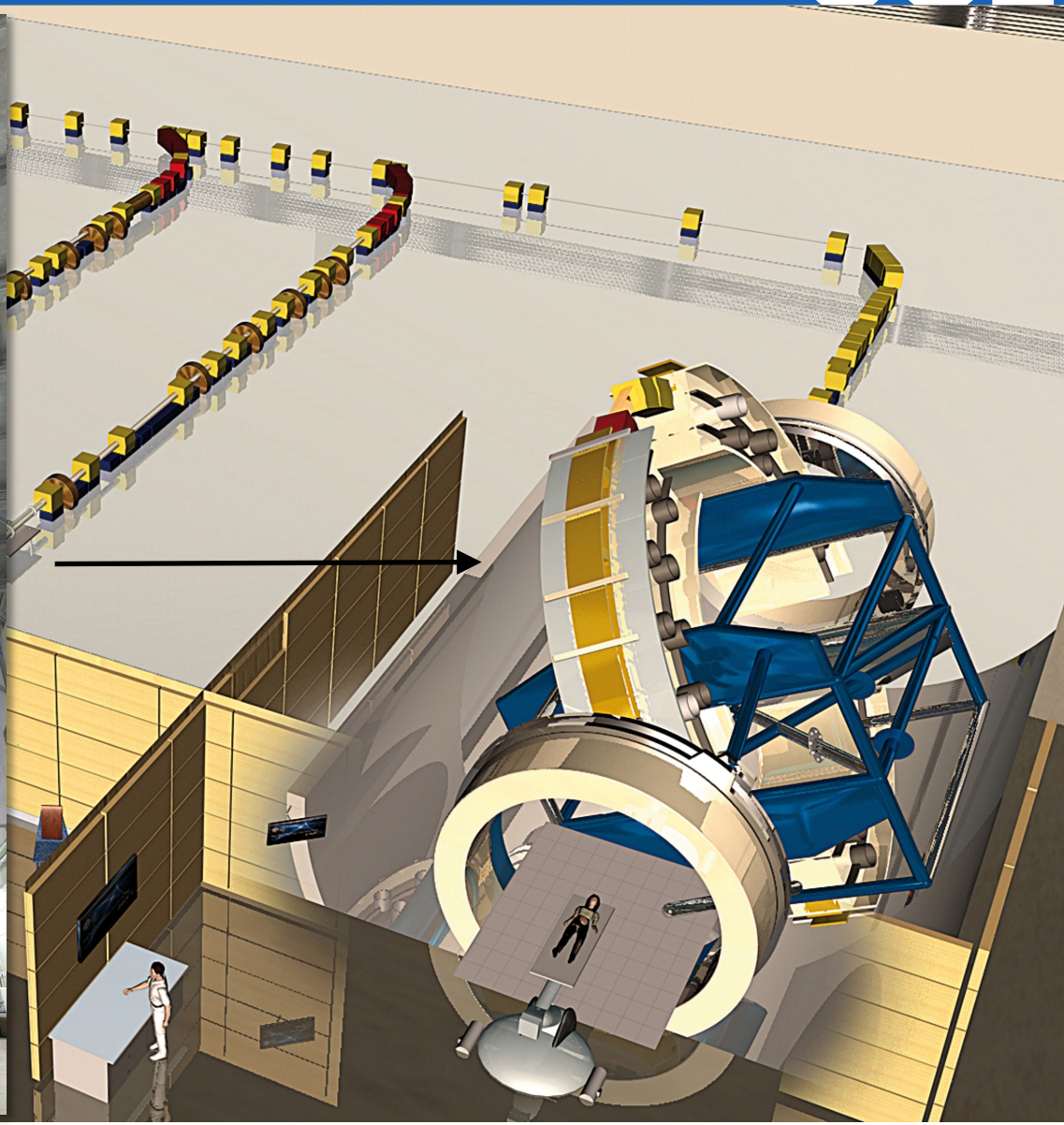
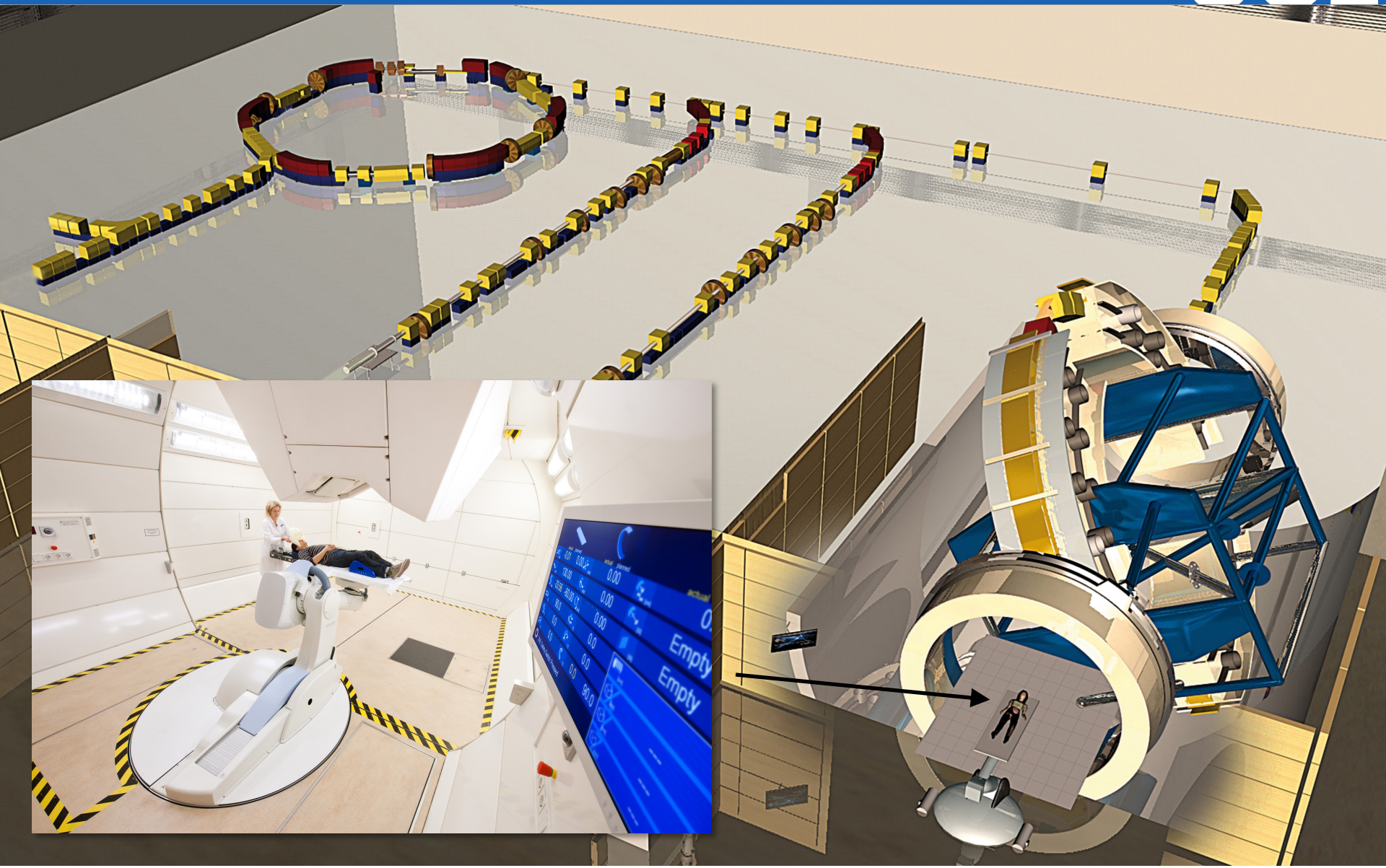
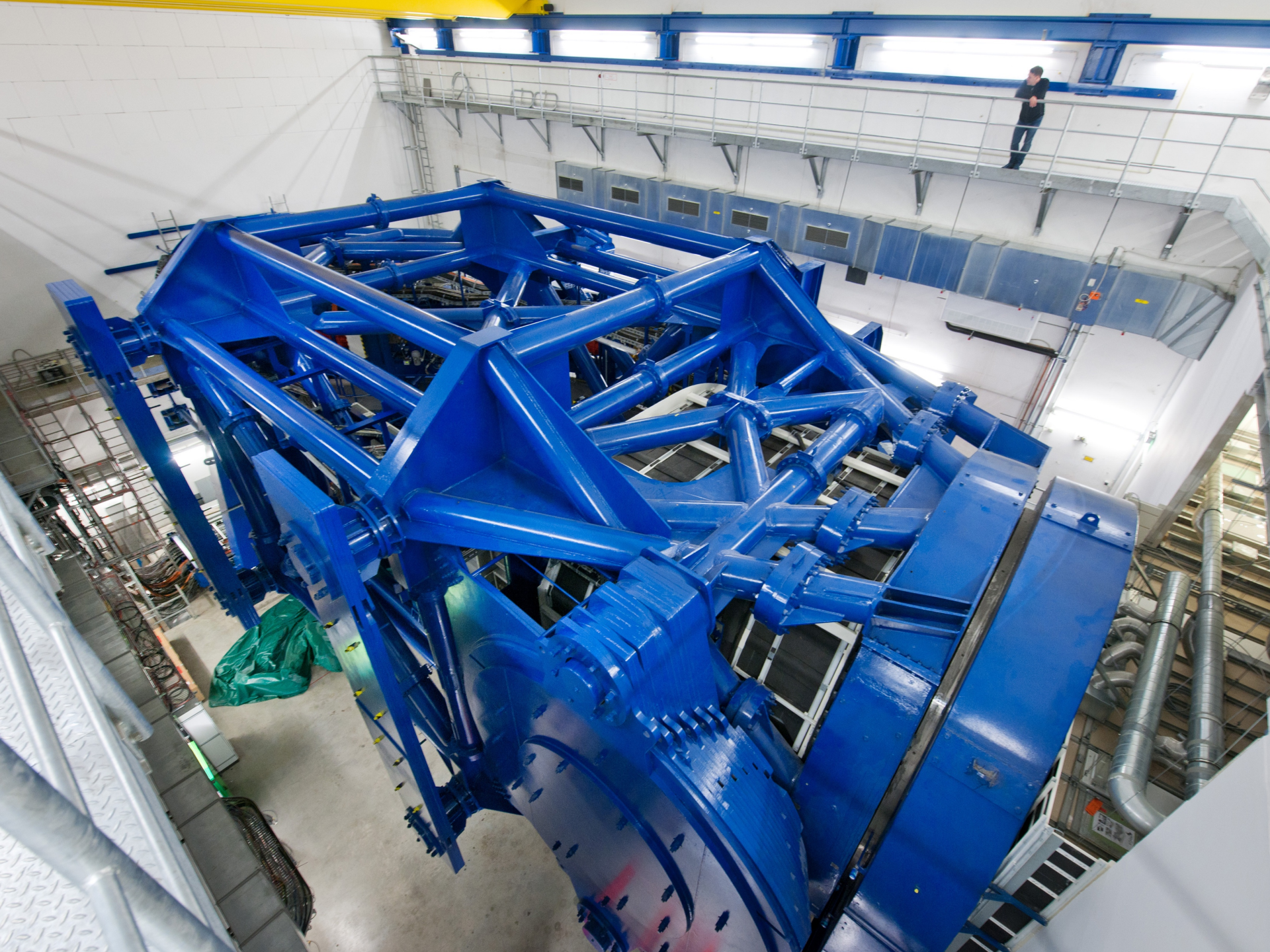


Heidelberg Ion Therapy Centre



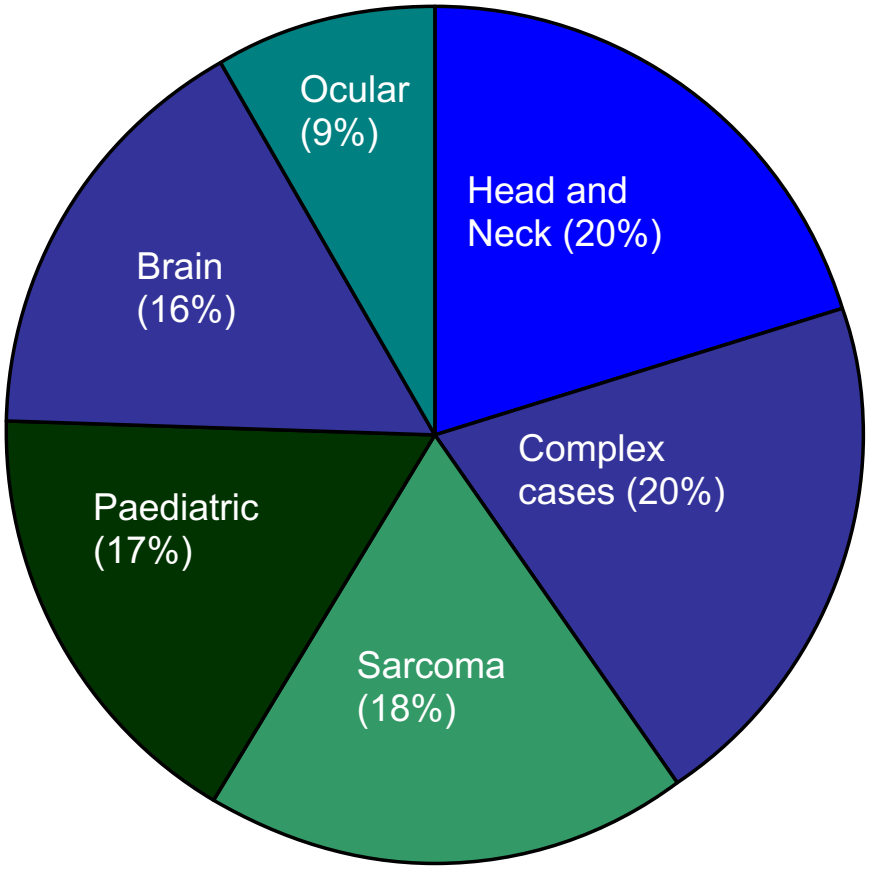



25.0t

Heidelberg Treatment Room

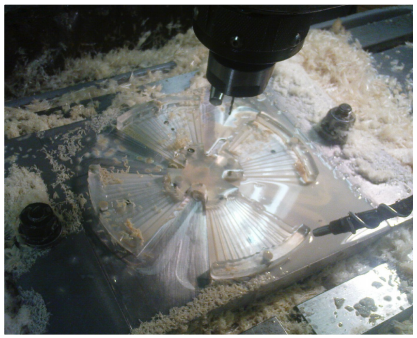
NHS England Patient Mix

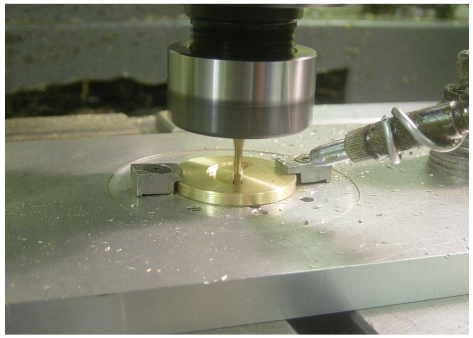
Cancers approved for proton therapy in England
(Total = 1,666)

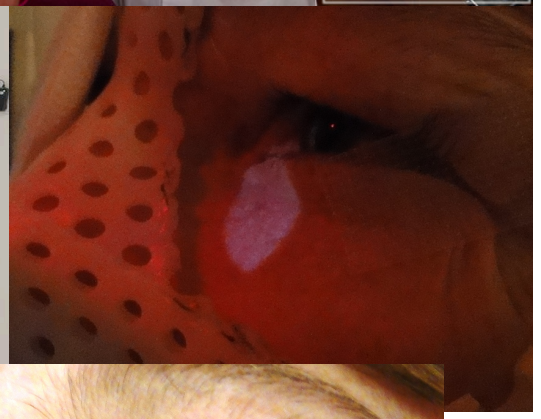


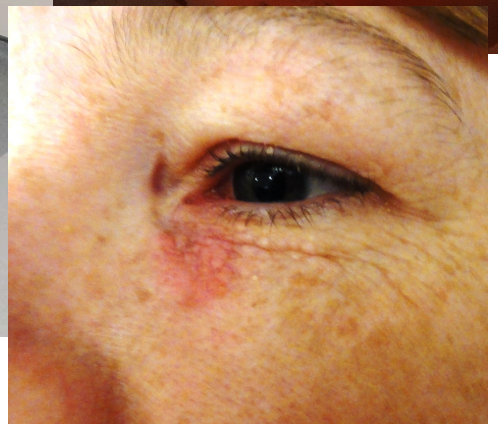
- Paediatric:
  - Chordoma
  - Chondrosarcoma
  - Rhabdomyosarcoma
    - Parameningeal
    - Pelvic
    - Orbit
    - H&N
  - Osteosarcoma
  - Ewing's
  - PPNET
  - Ependymoma
  - Low Grade Glioma
  - Optic pathway Glioma
  - Craniopharyngioma
  - Medulloblastoma
  - Hodgkins
  - Retinoblastoma
- Adult:
  - Choroidal Melanoma
  - Ocular / Orbital
  - Chordoma
  - Chondrosarcoma
  - Para-spinal Sarcoma
  - Paranasal Sinuses
  - Meningioma
  - Acoustic Neuroma
  - Craniospinal RT – pineal
  - Teenage & Young Adult
  - Atypical Cases Common Indications

Clatterbridge Cancer Centre









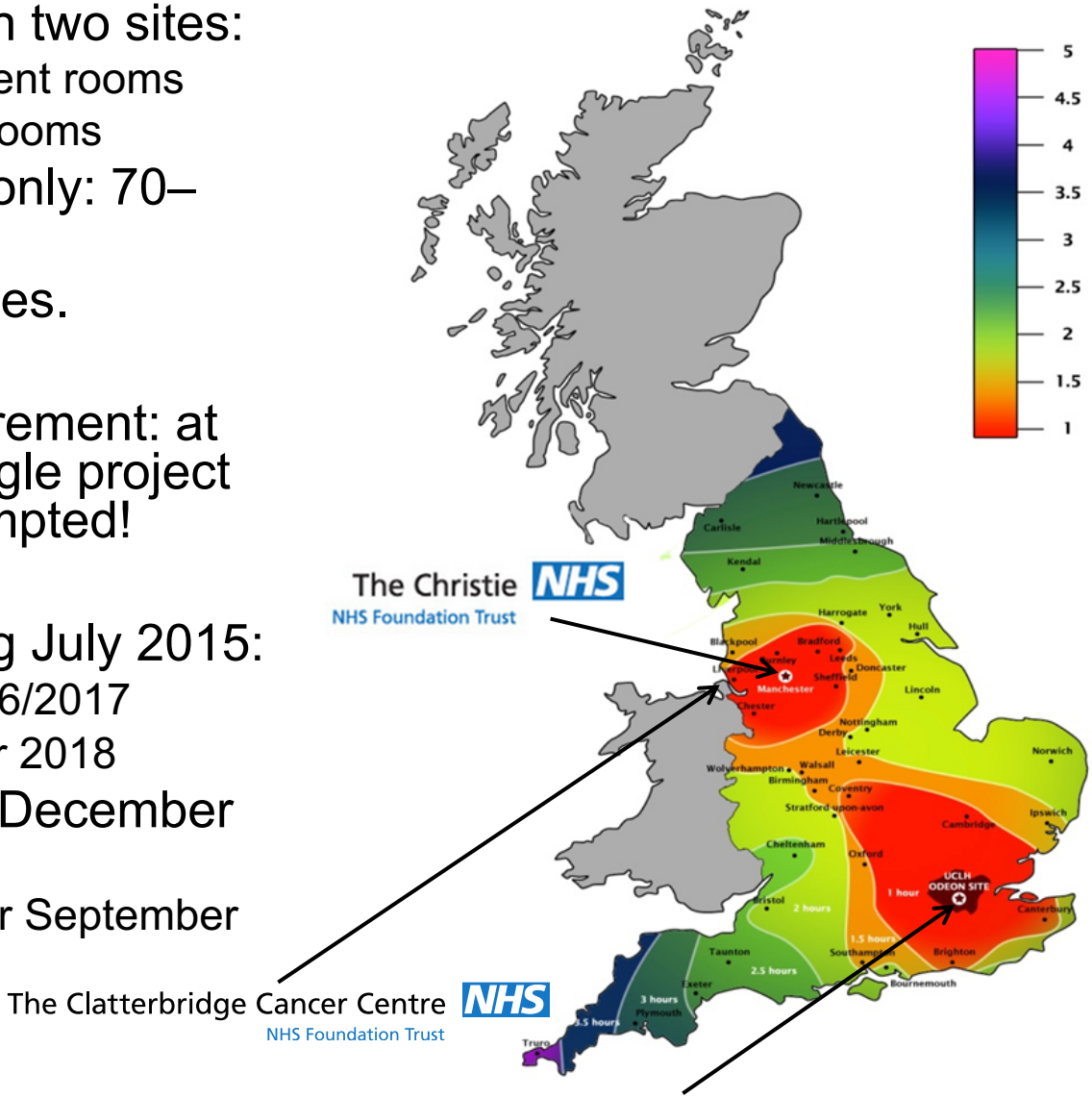
Simon Jolly — UCL

NHS England PBT Service

- New national service on two sites:
  - Manchester – 3 treatment rooms
  - London – 3 treatment rooms
- Pencil beam scanning only: 70–245 MeV.
- Full 360º rotating gantries.

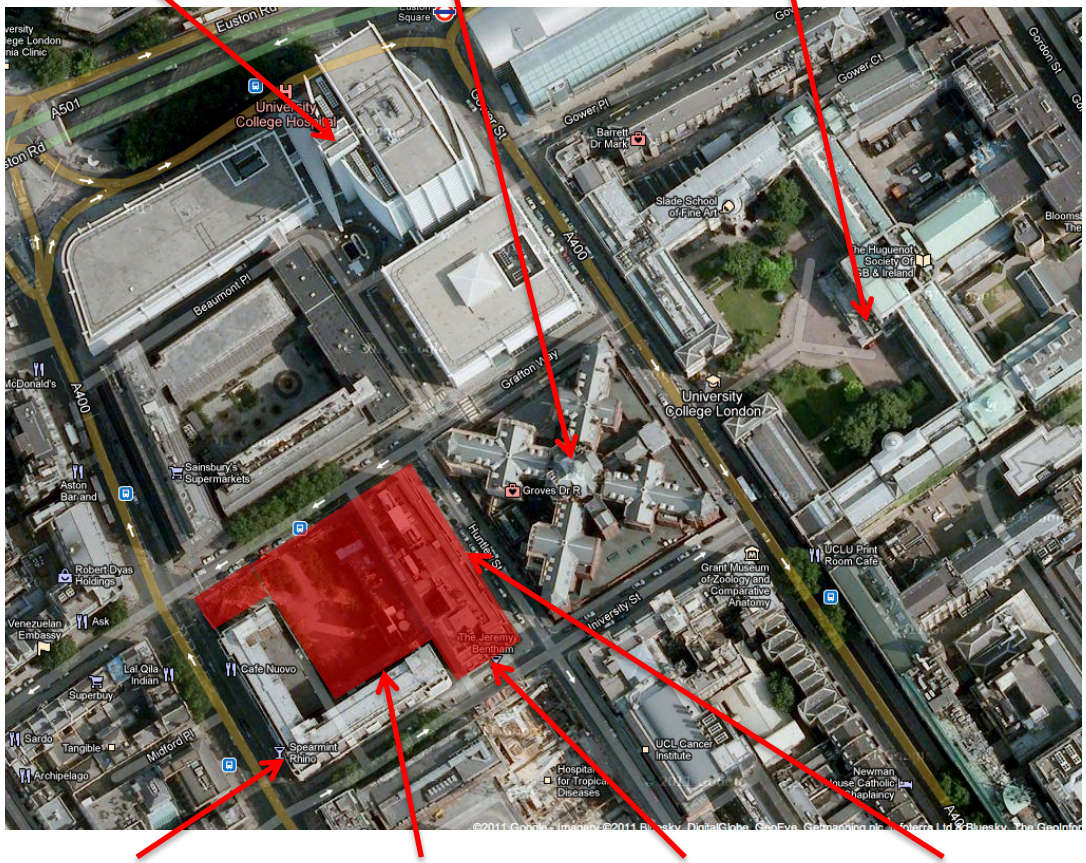
- Joint Equipment Procurement: at £250 million largest single project the NHS has ever attempted!

- Christie Started building July 2015:
  - Cyclotron delivery 22/06/2017
  - First patient September 2018
- UCLH Started building December 2015:
  - First patient planned for September 2020

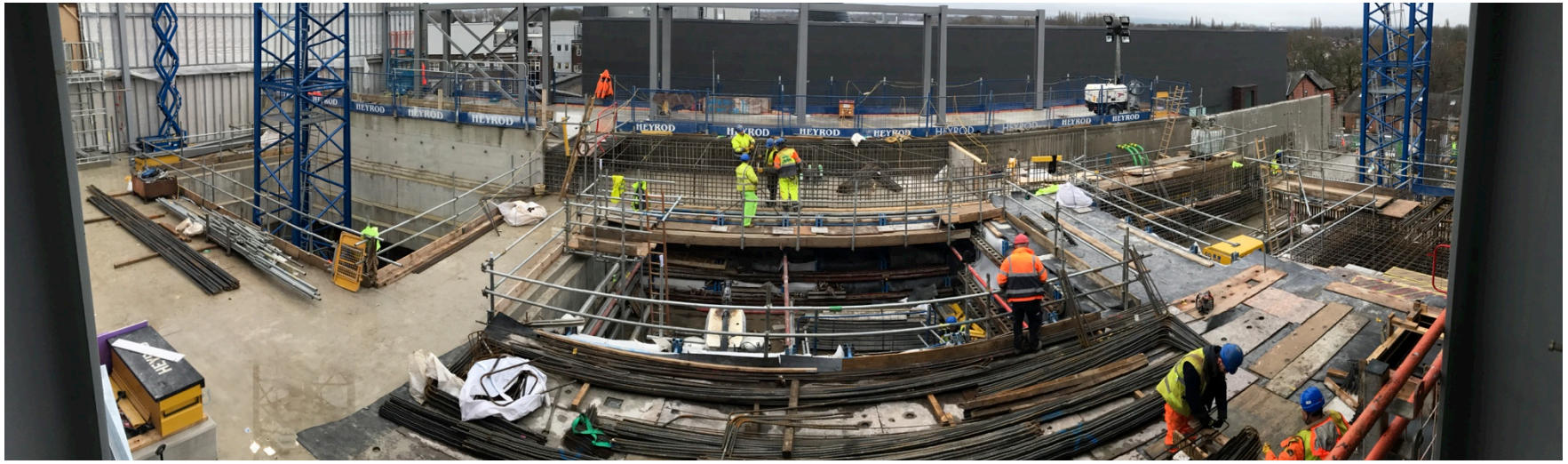


UCLH Proton Beam Therapy Site

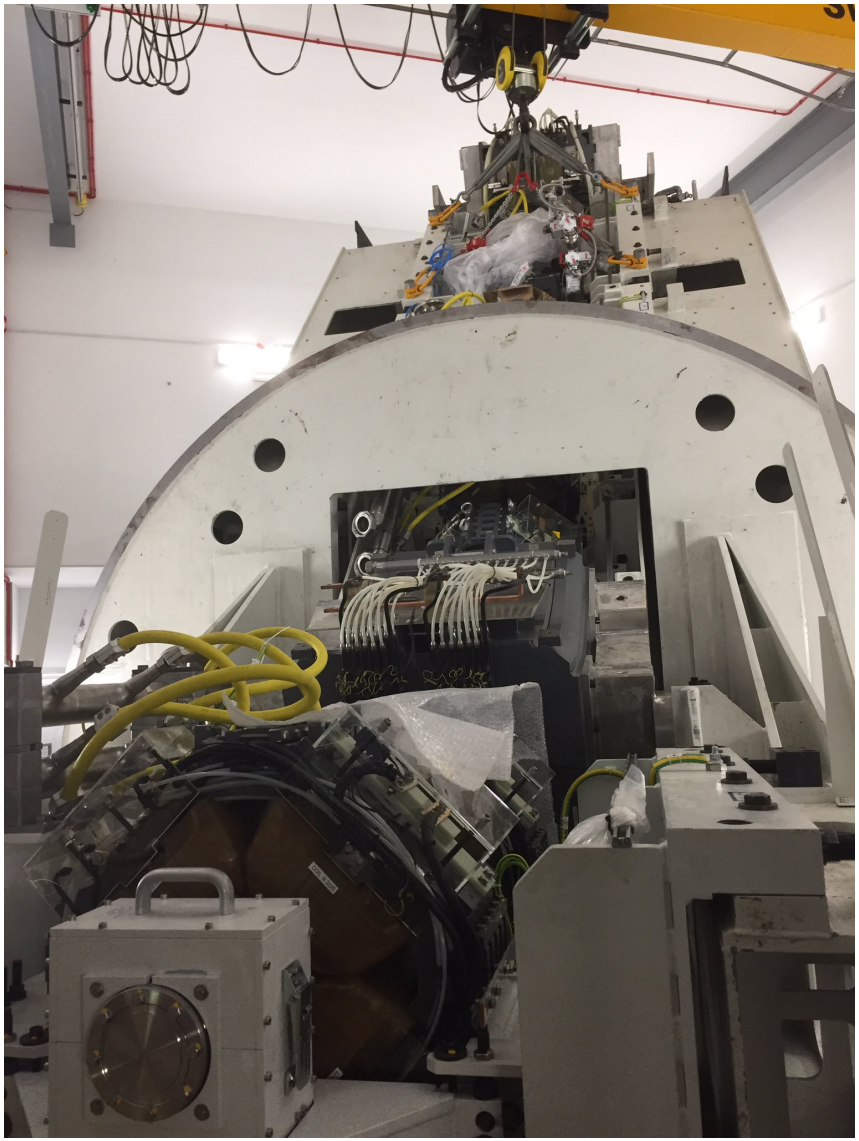
- Unlike countries which require health insurance (which is most of them), UCLH will be treating the most difficult cases.
- New facility is on existing UCLH site, next to Tottenham Court Road.
- Linked to UCLH via walkways to allow easy patient transfer.
- Planning to treat ~750 patients a year.
- 1 proton accelerator feeding 4 gantries.

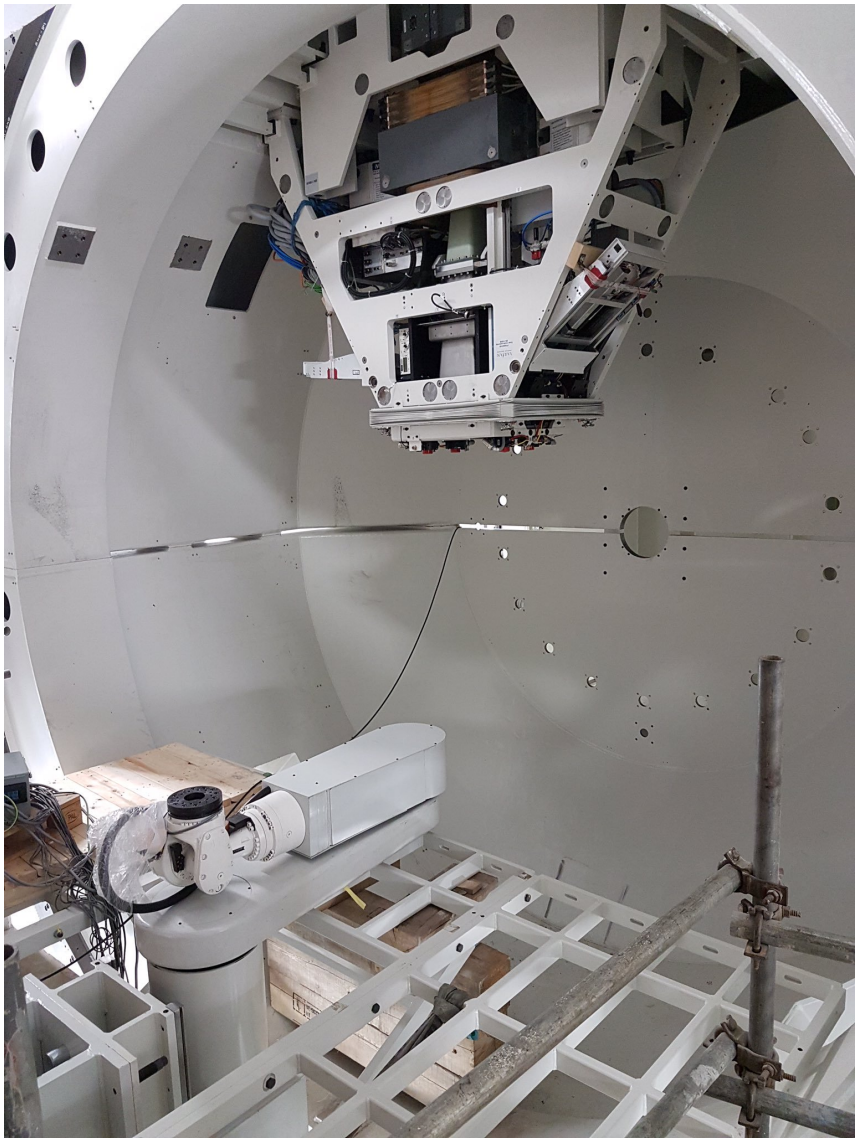


The Christie PBT Construction

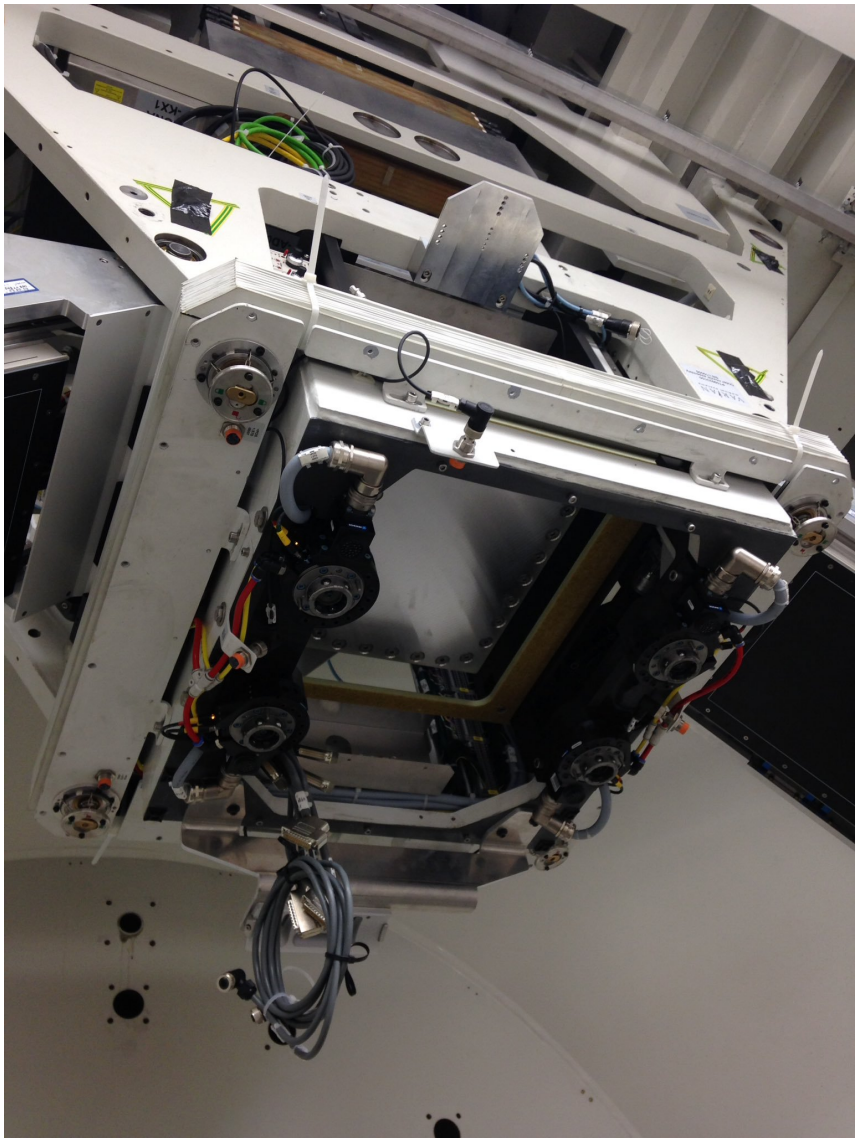


The Christie PBT Installation (May)

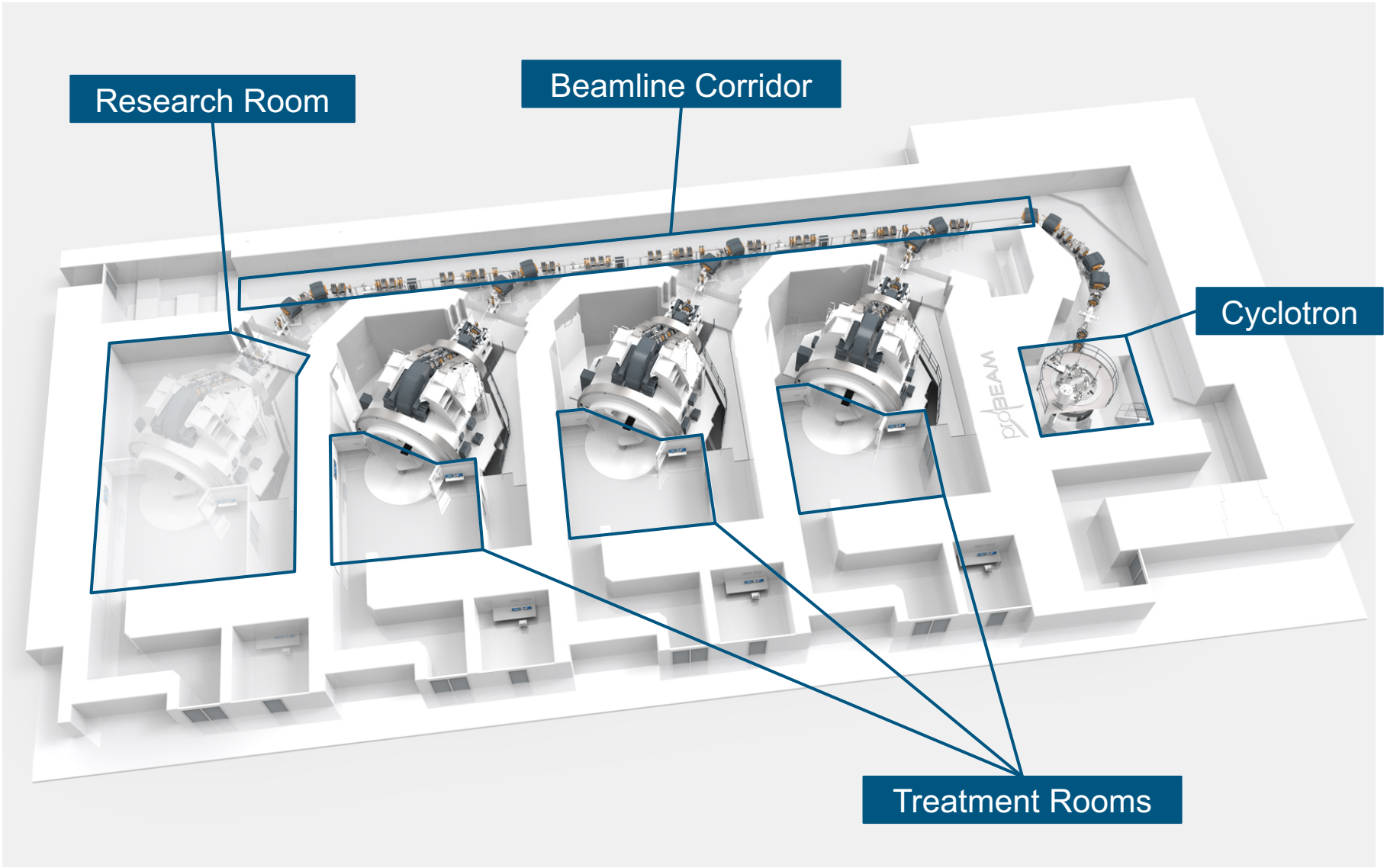




The Christie PBT Installation (June)

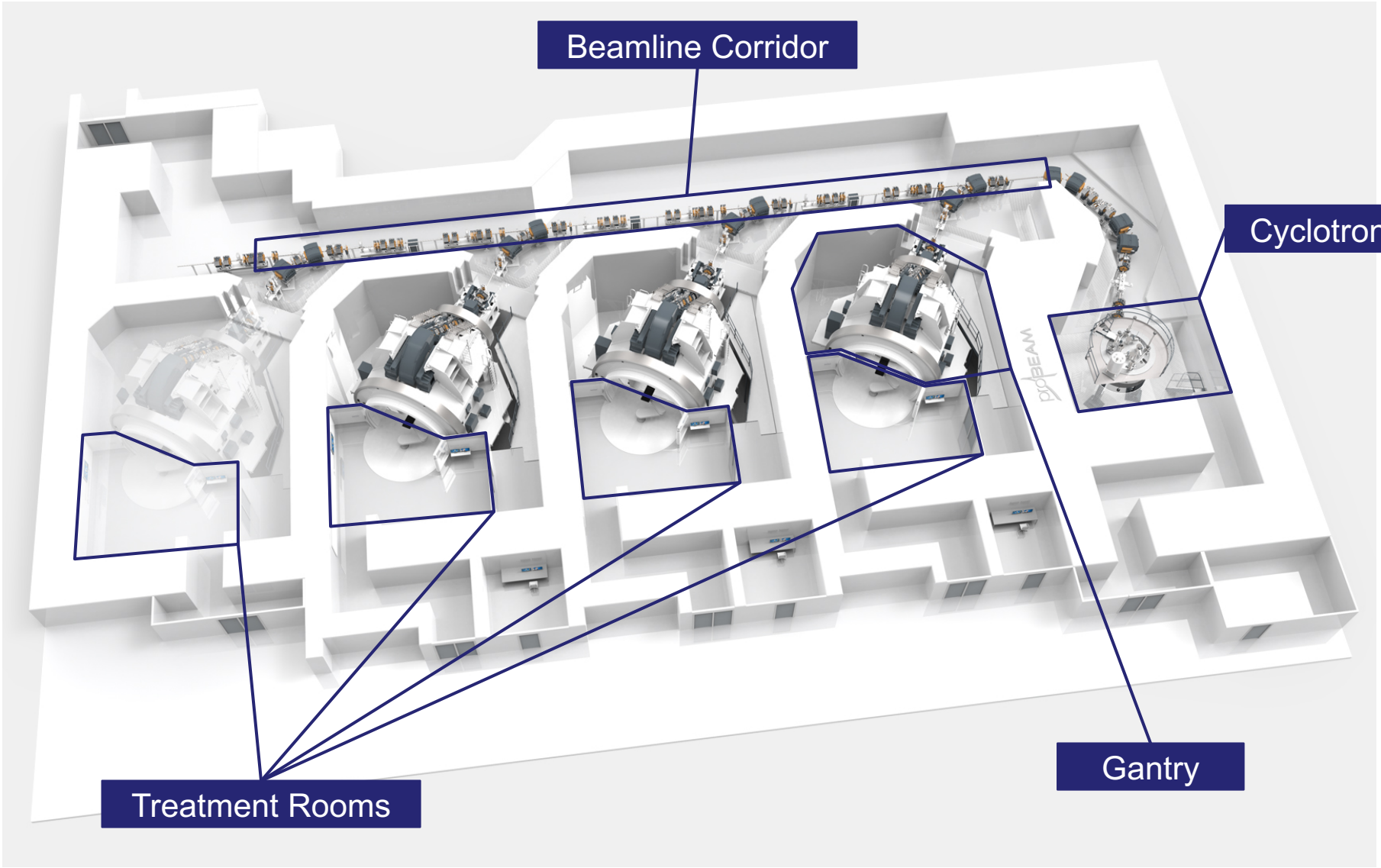


The Christie Proton Therapy Facility

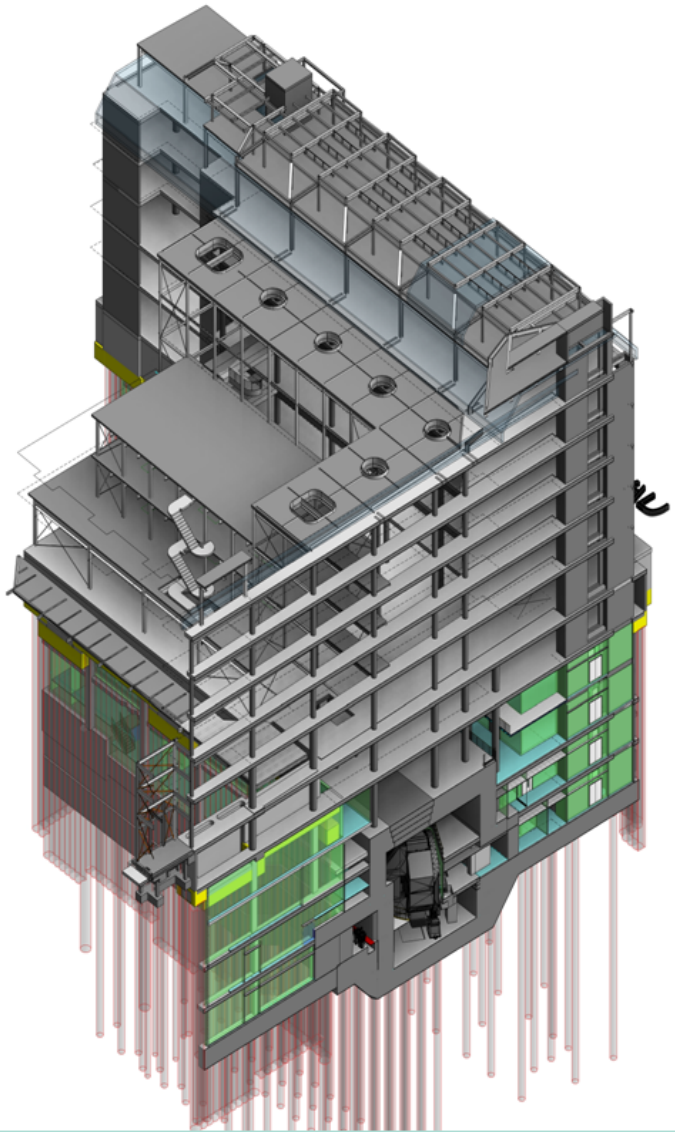


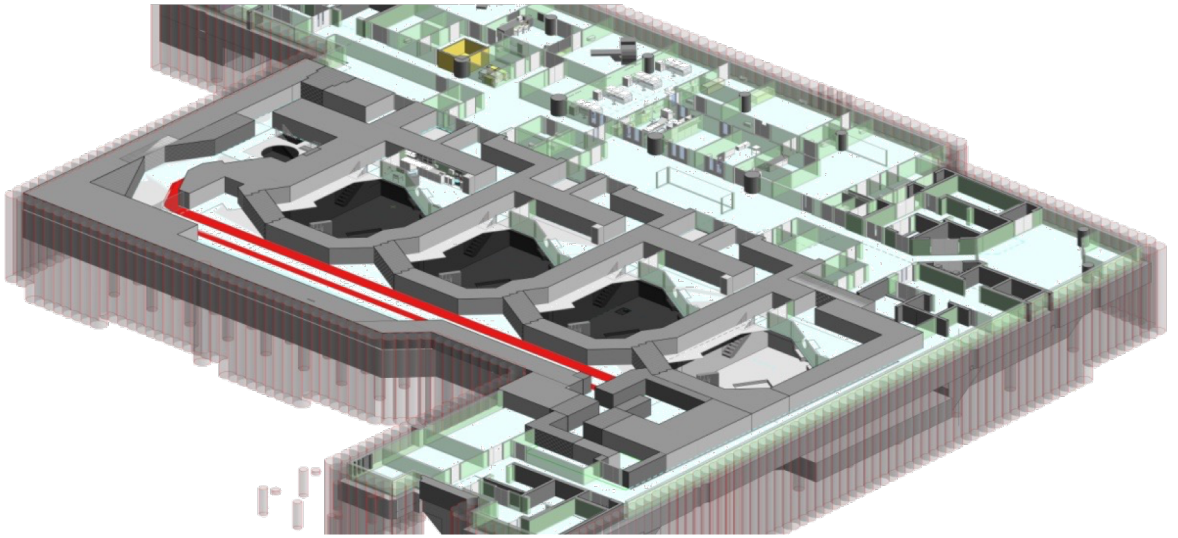
Images courtesy of UCLH/Jan Timmer, Varian Inc.

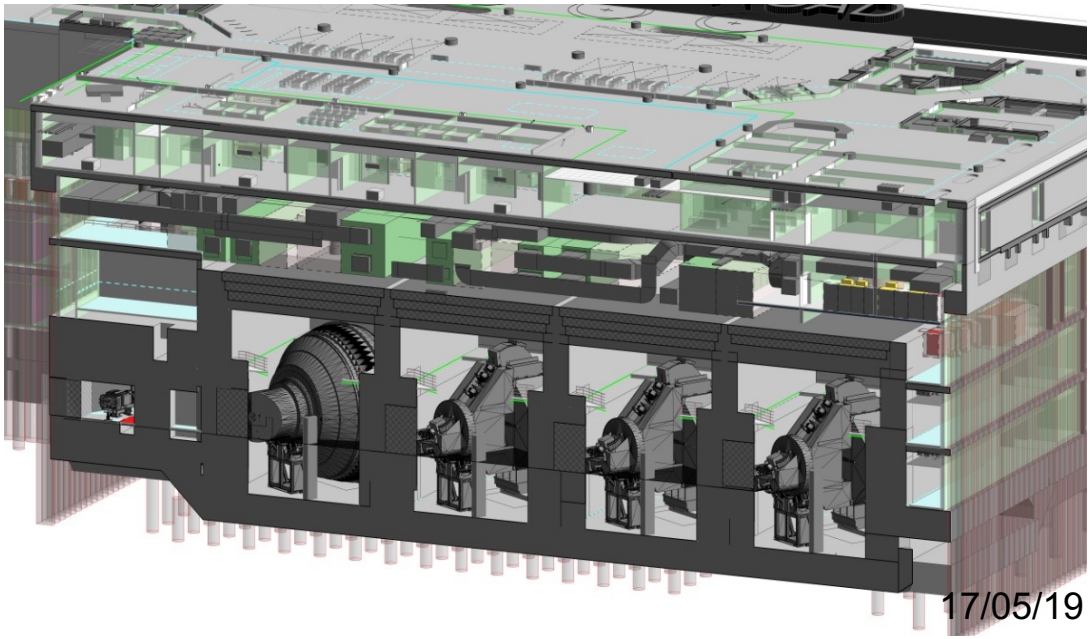
UCLH Proton Therapy Facility



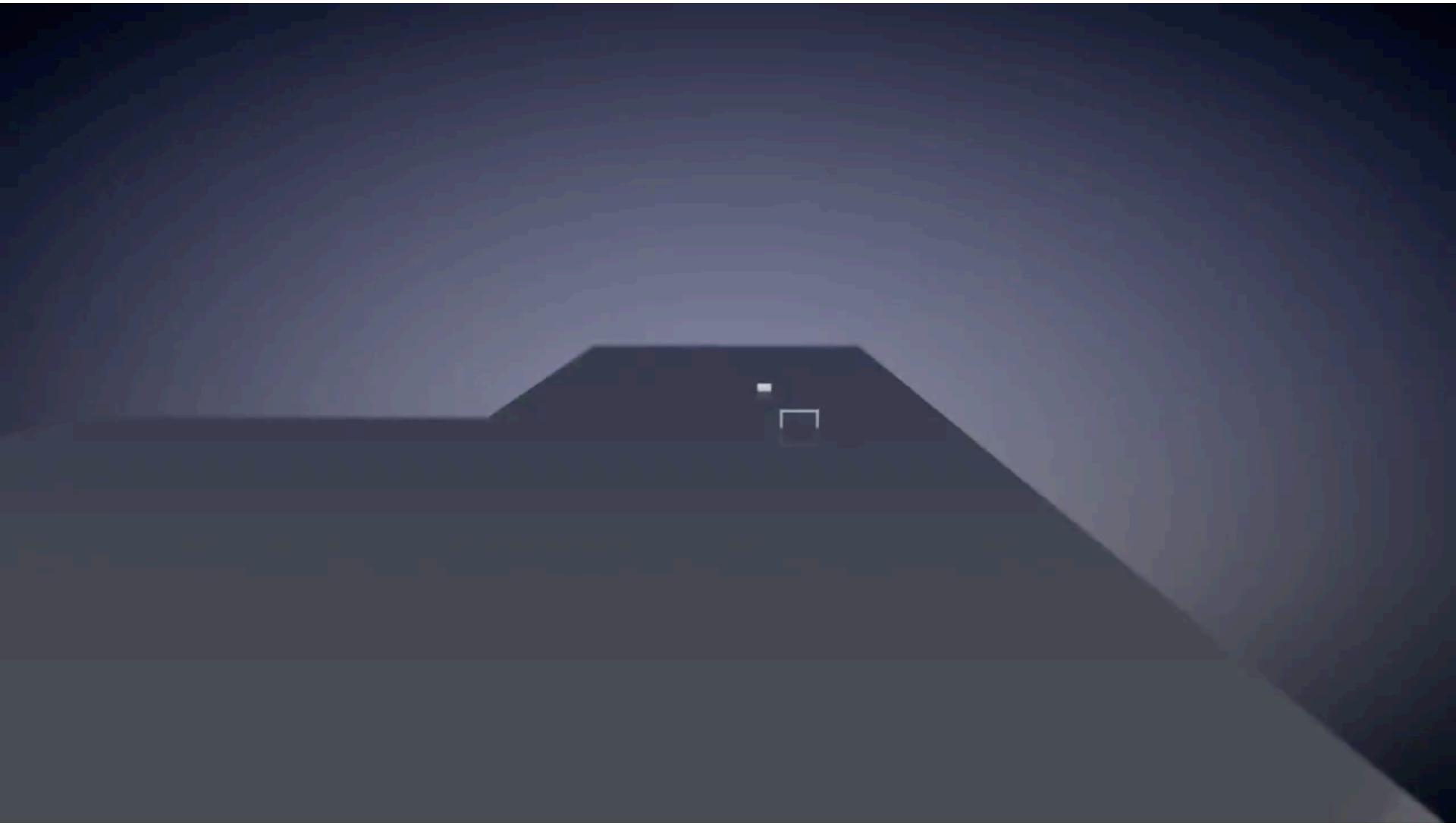
UCLH PBT Construction



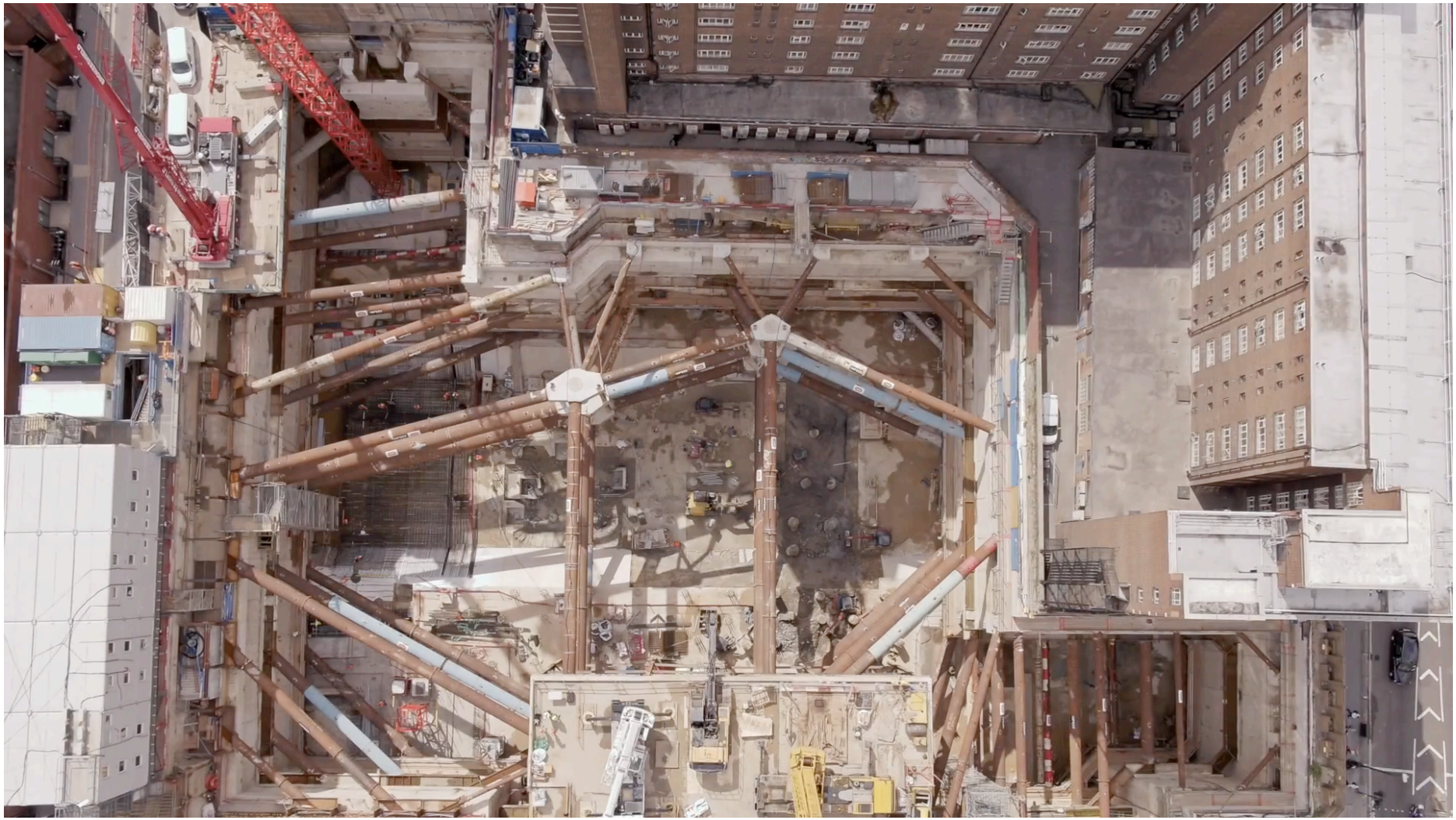




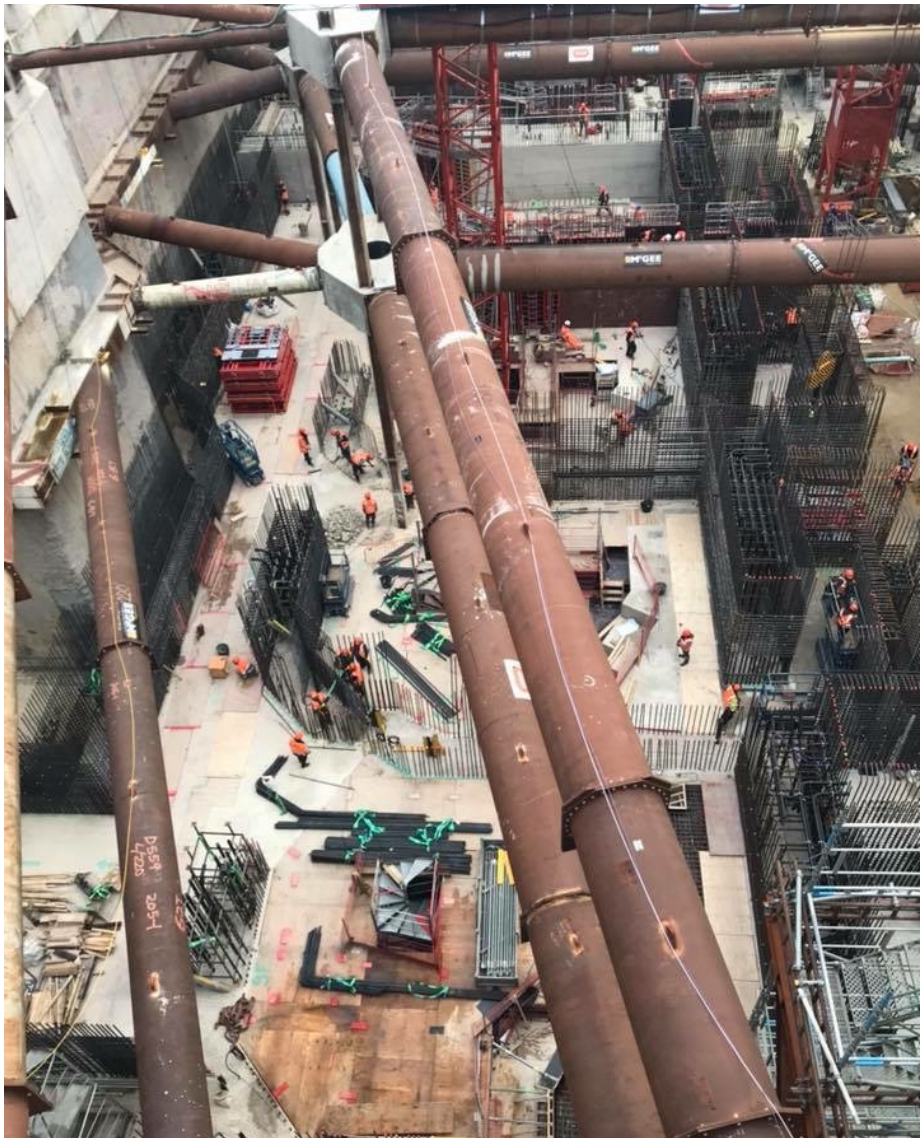
UCLH PBT Facility



UCLH PBT Site Drone Footage



UCLH PBT: Filling The Hole



UCLH Protons: Channel 4 News

https://www.channel4.com/news/proton-beam-cancer-therapy-to-be-available-on-nhs

UCLH PBT (TCR/Grafton Way)