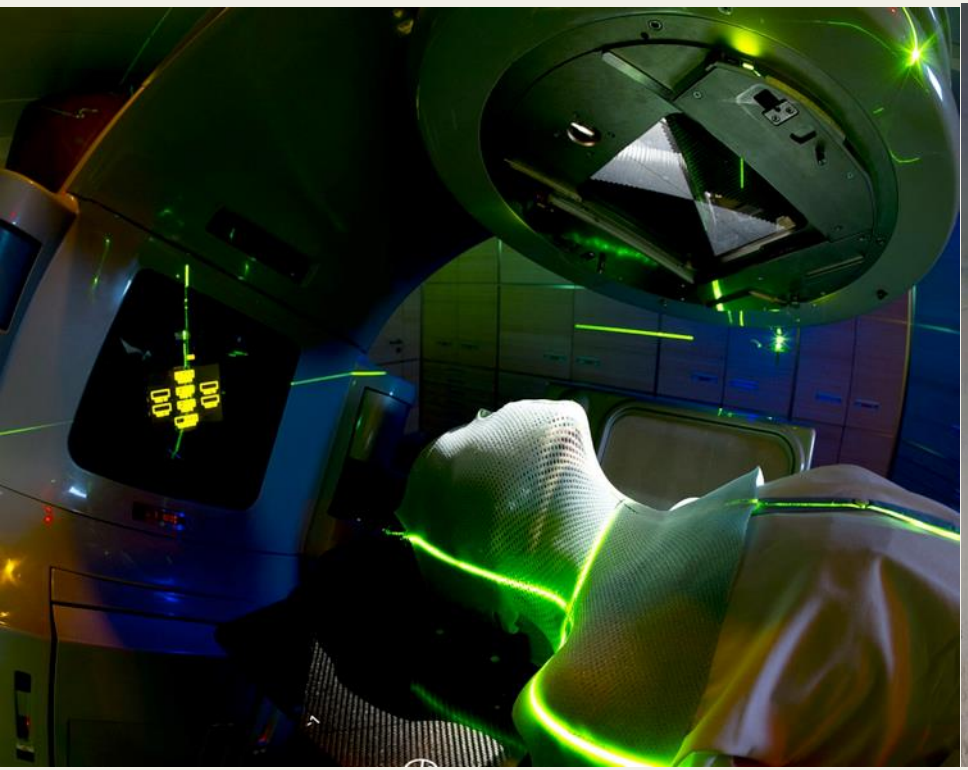
Medical Applications of Particle Physics



Sparsh.Navin@cern.ch

Sparsh Navin
CERN – Knowledge Transfer
Life Sciences Section

Knowledge transfer – X-rays

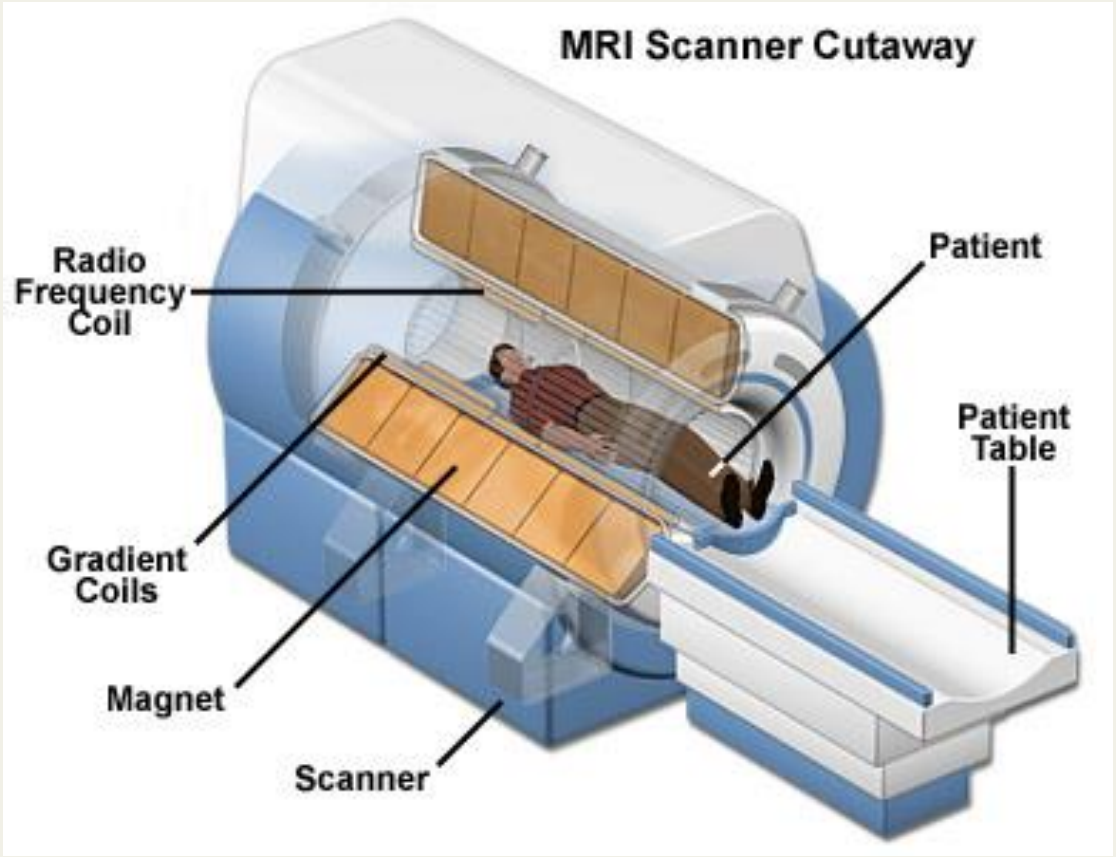
Wilhelm Röntgen

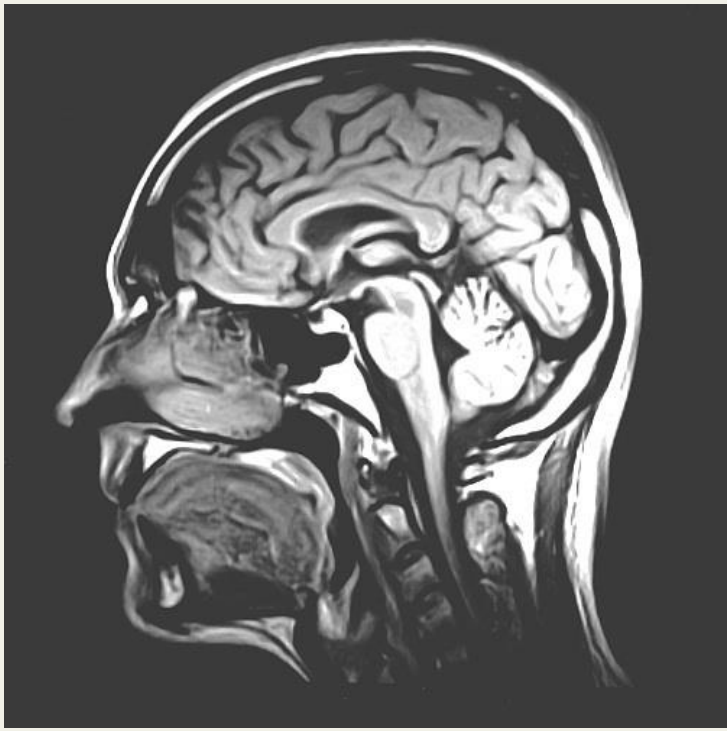
8/11/1895

22/12/1895

1901

Magnetic Resonance Imaging





First human body scan

1940 1950 1960 1970 1980 1990 2000 2010

NMR

Nobel prize in physics and first image

First clinically useful image

Nobel prize in medicine

CERN's Mission

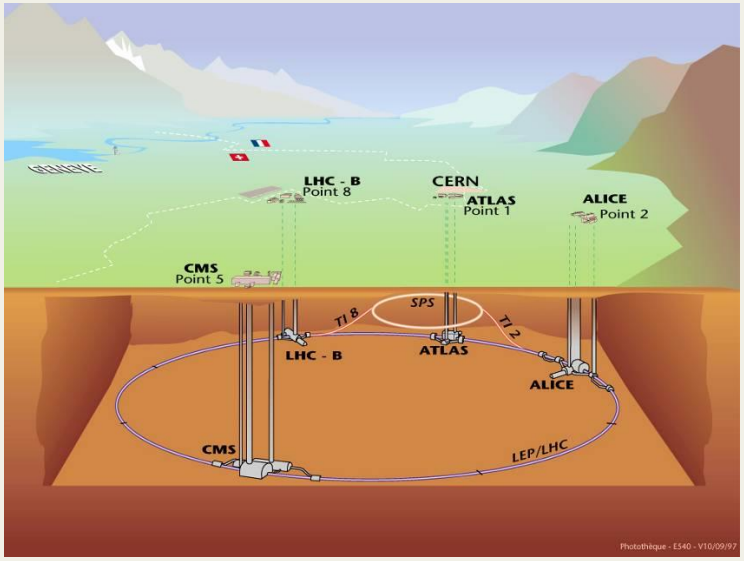
RESEARCH

INNOVATION

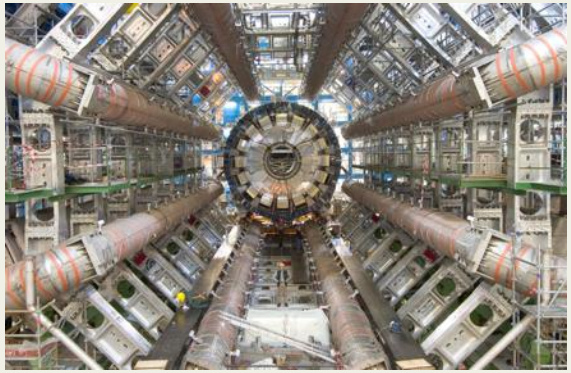
EDUCATION

UNITING PEOPLE

Tools of the trade



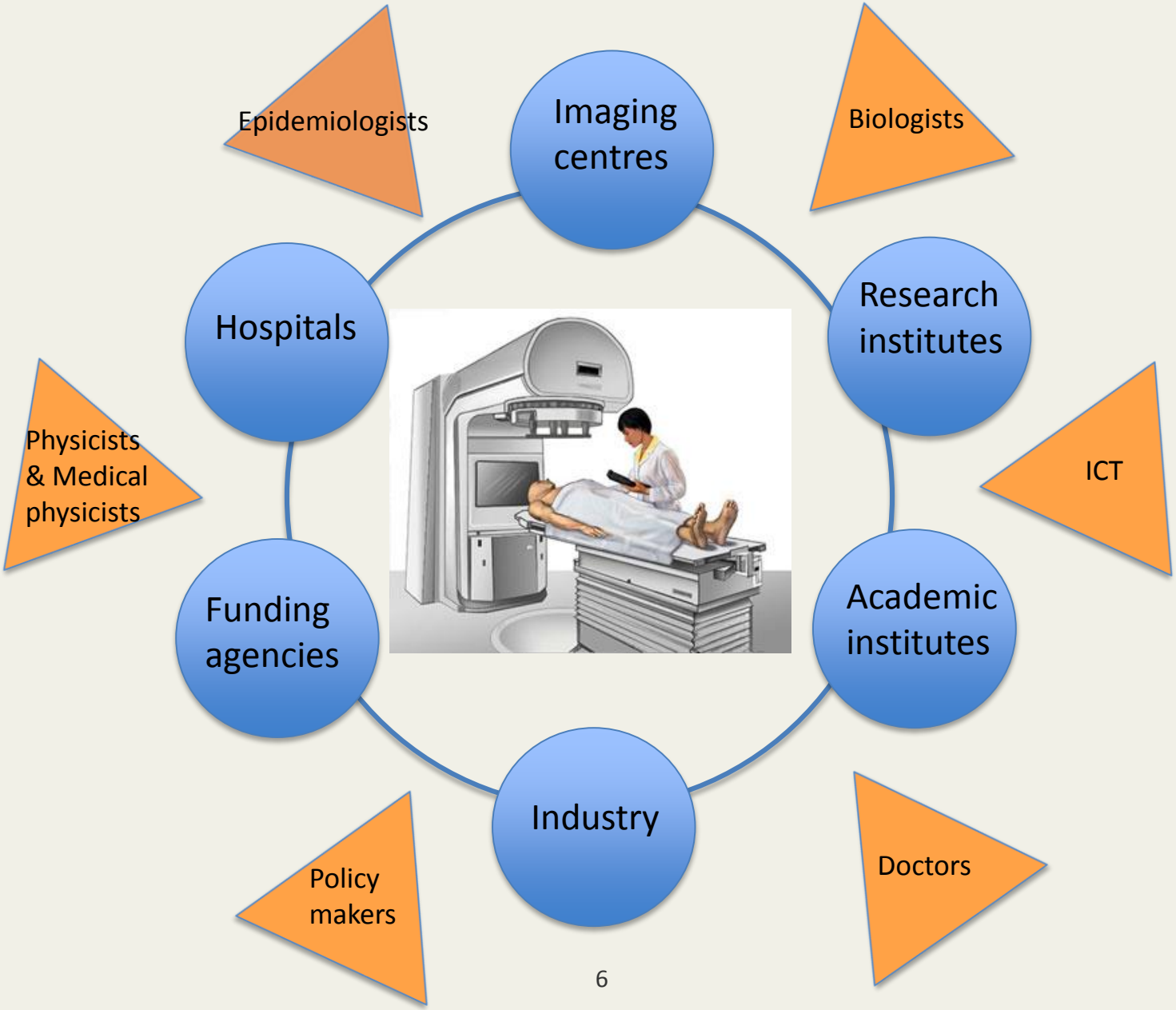
Accelerators



Detectors

Computing

4th pillar of technology - collaboration



Birth of medical physics

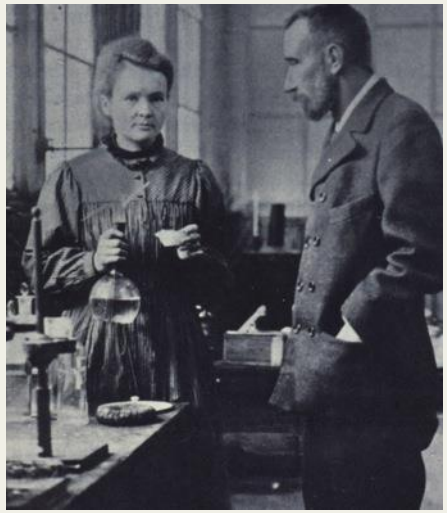
- 1896: natural radioactivity

Henri Becquerel

1903 Noble prize

- 1898: radium and polonium ("brachytherapy")

Pierre and Marie Curie



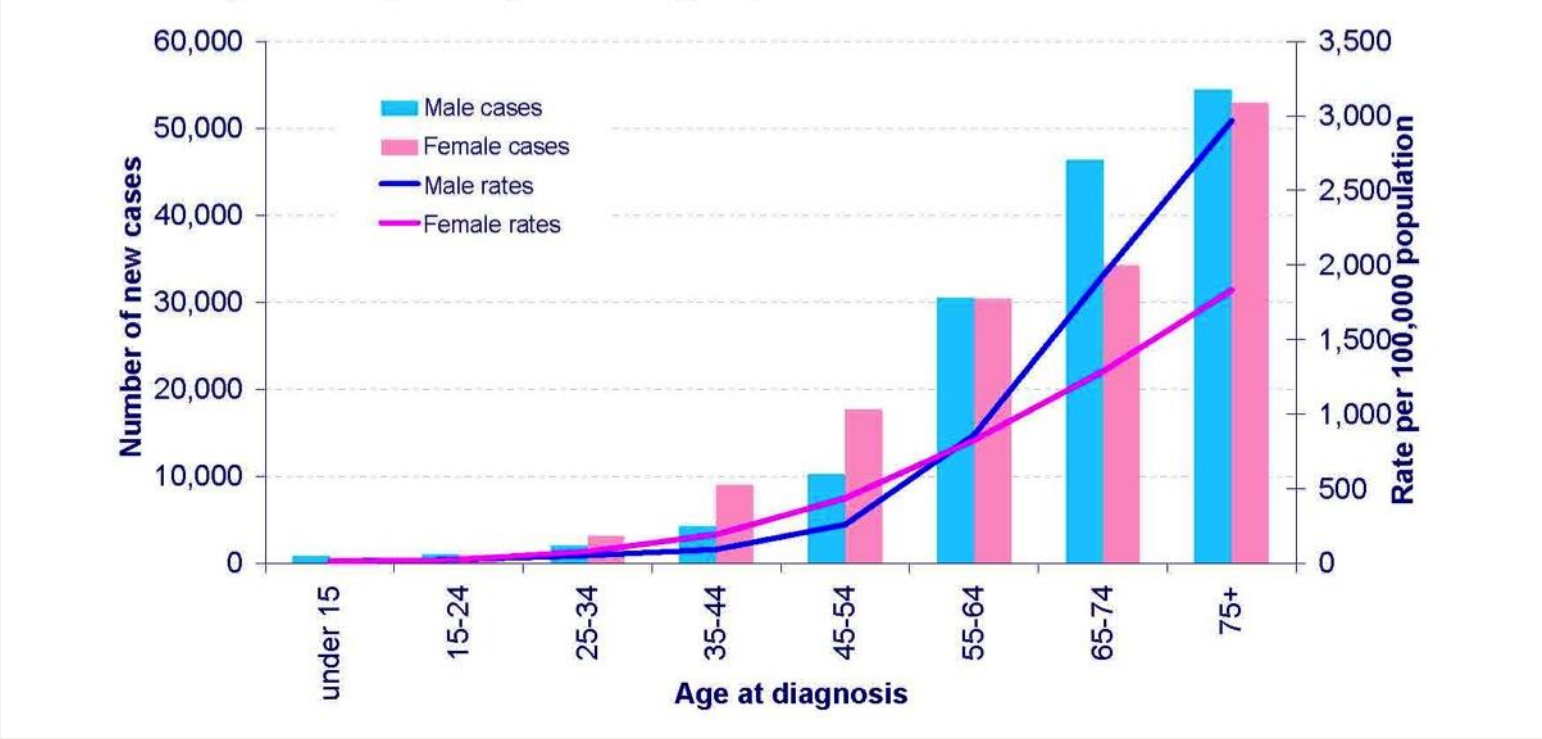
Do NOT try this at home!

First radiobiology experiment

Cancer – a growing challenge

More than 3 million new cancer cases in Europe each year and 1.75 million associated deaths

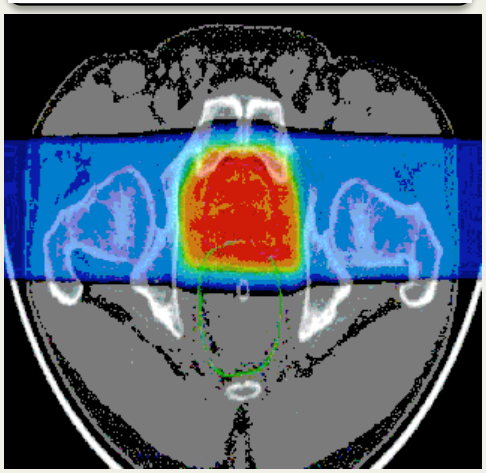
Increase by 2030: 75% in developed countries and 90% in developing countries



Treatment options

Surgery

Radiotherapy



X-ray, IMRT, Brachytherapy, Hadrontherapy

Chemotherapy (+ others)

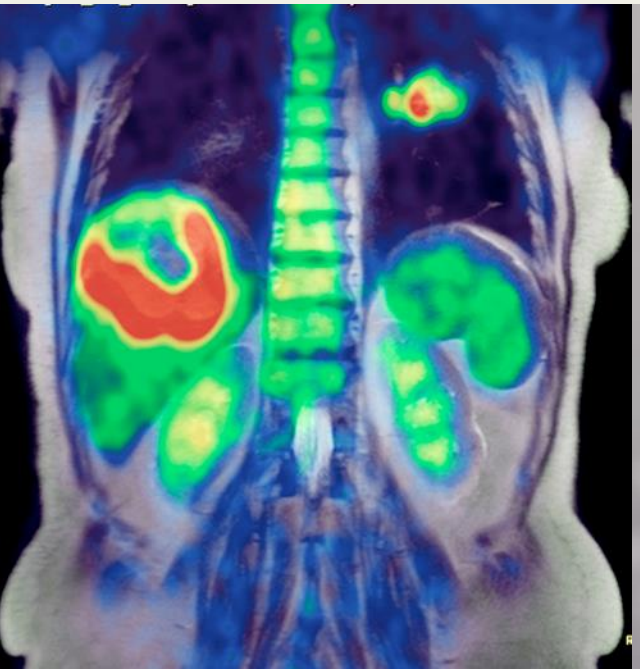
Hormones; Immunotherapy; Cell therapy; Genetic treatments; Novel specific targets (genetics..)

AIM:
Survival, Quality of life

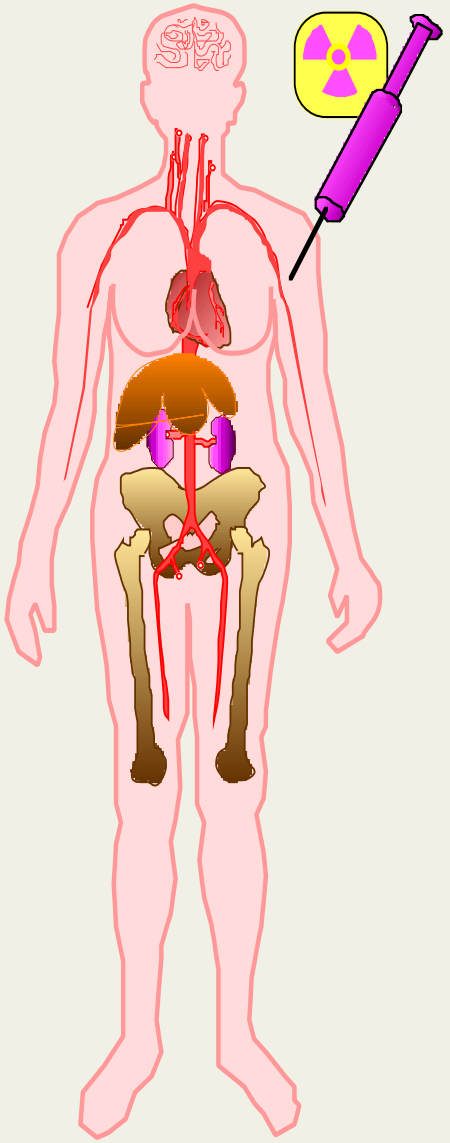
First step: Detection

Antimatter – ~~science fiction~~?

PET



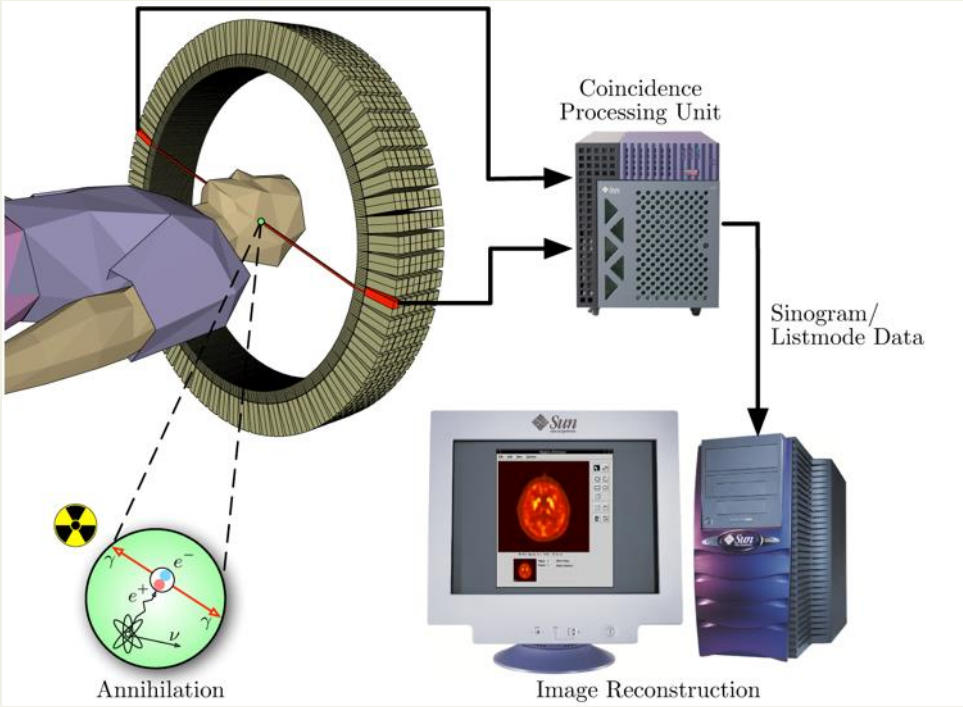
PET: how it works

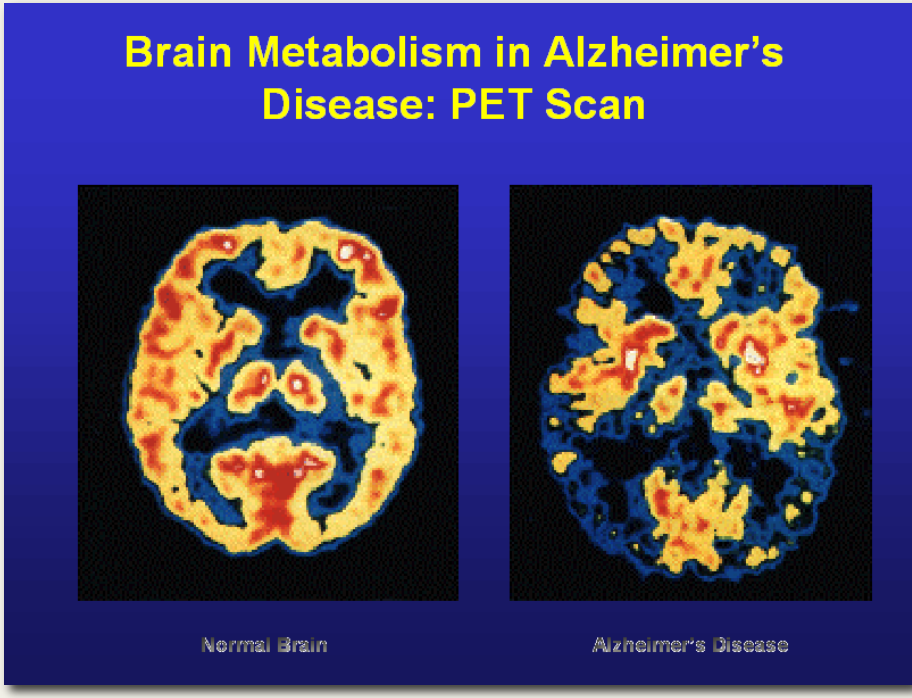


- Drug is labeled with positron (β+) emitting radionuclide.
- Drug localizes in patient according to metabolic properties of that drug.
- Trace (pico-molar) quantities of drug are sufficient.
- Radiation dose fairly small (<1 rem = 0.01 Sv).

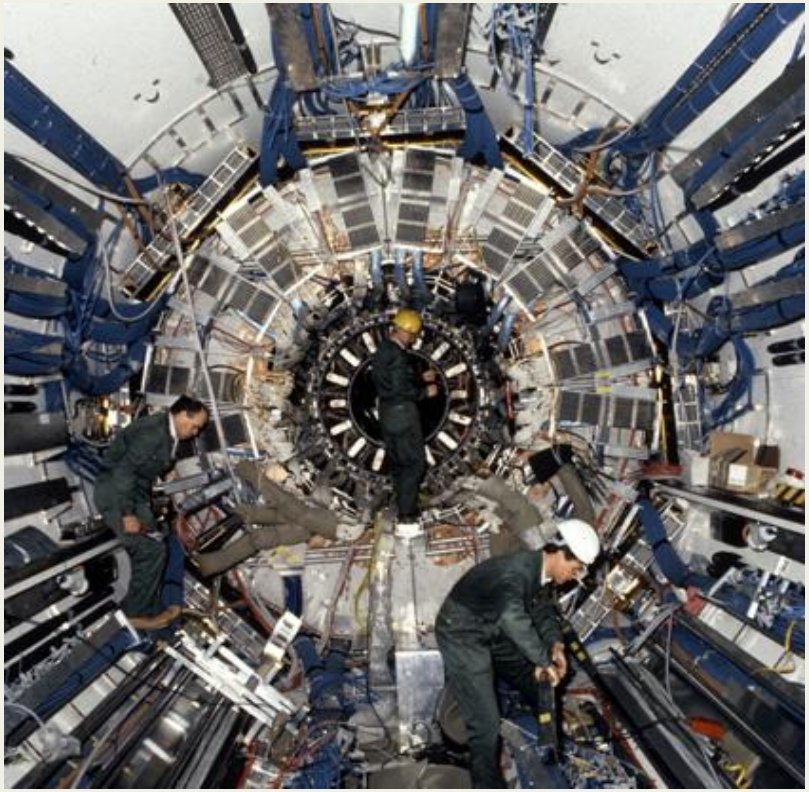
PET – How it works

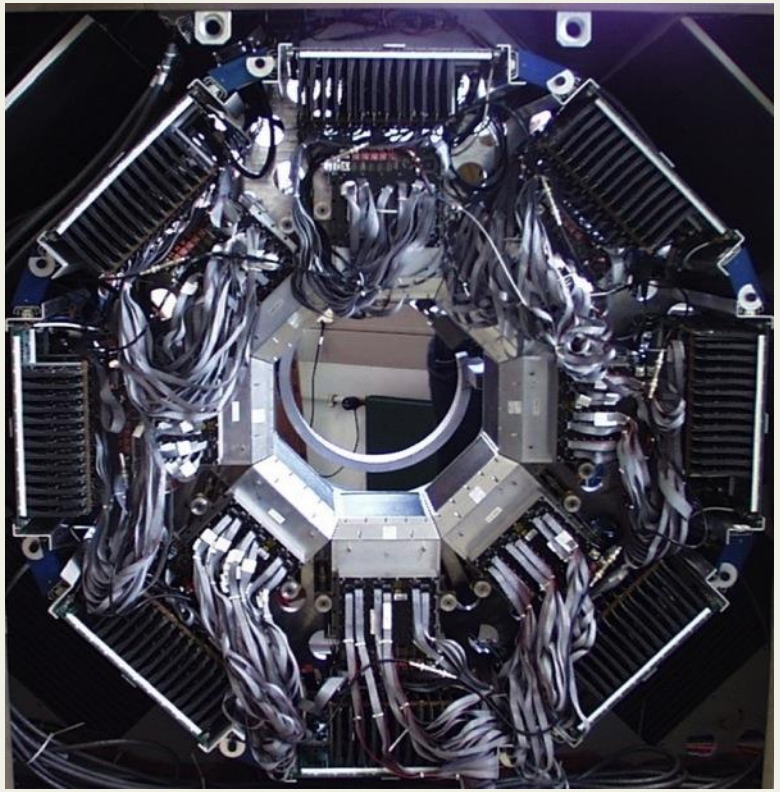
PET Scan


Coincidence
Processing Unit
Sinogram/
Listmode Data
Annihilation
Image Reconstruction


Brain Metabolism in Alzheimer's Disease: PET Scan
Normal Brain
Alzheimer's Disease

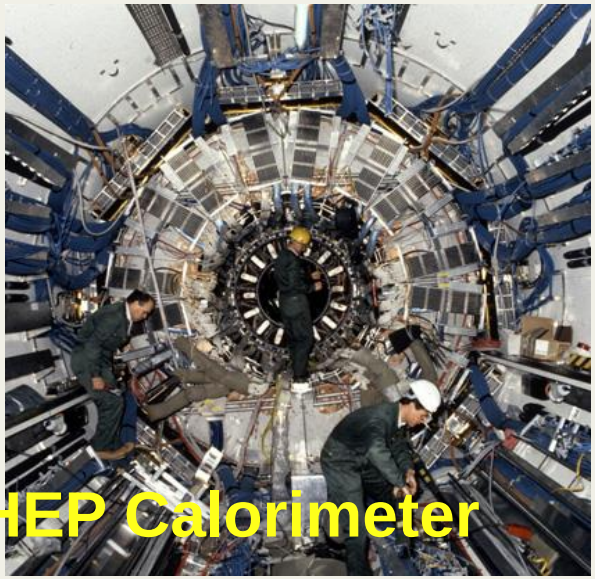
The detector challenge





Similar challenges

- New materials
- Compact
- low noise electronics
- Algorithms



Multimodal imaging

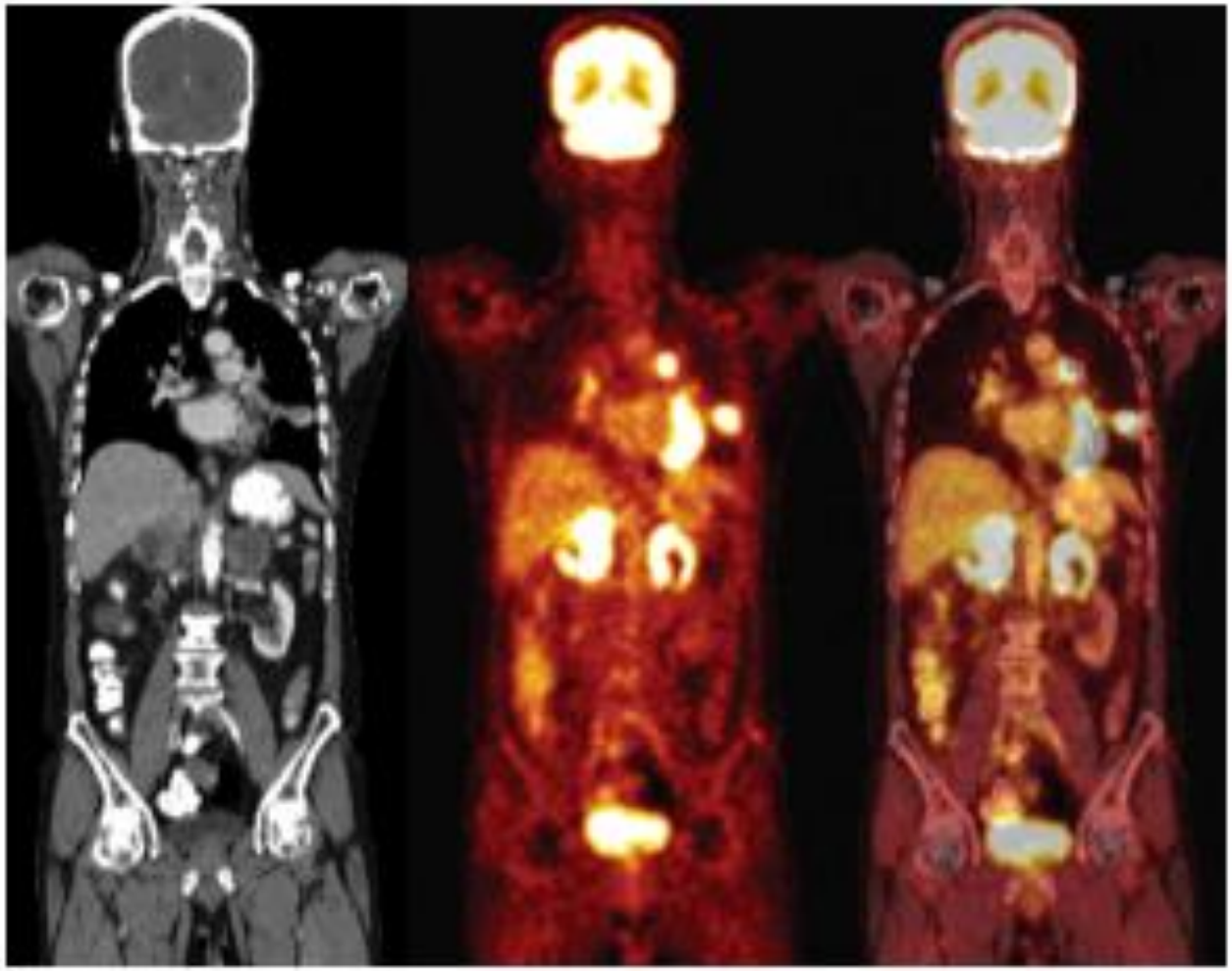
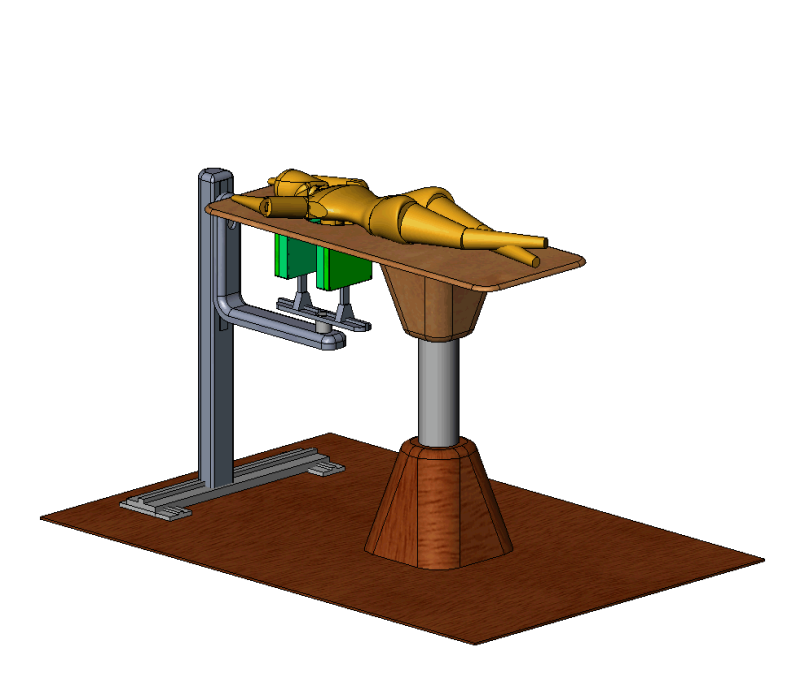


FIGURE 1. CT, PET, and PET/CT of lung cancer with adrenal metastases.

Proposed by David Townsend

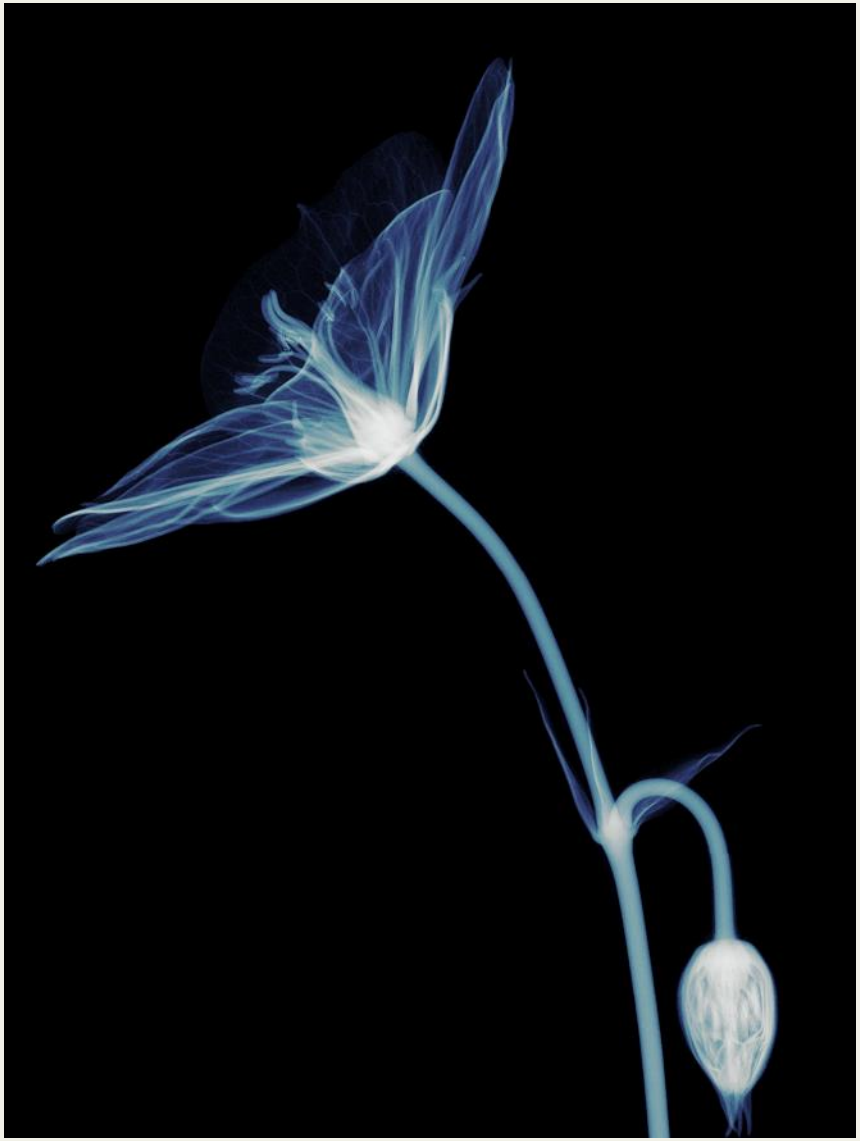
Crystal Clear

ClearPEM

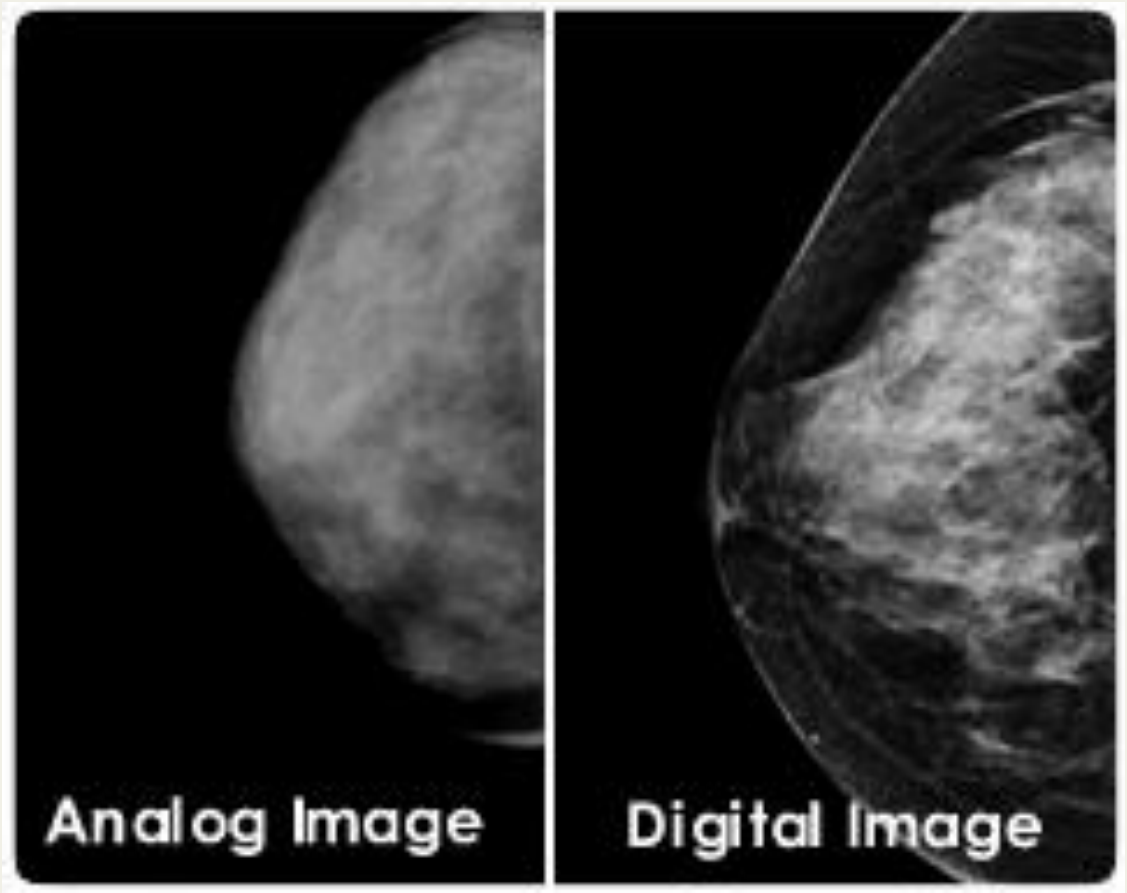


Extremely sensitive to small tumour masses

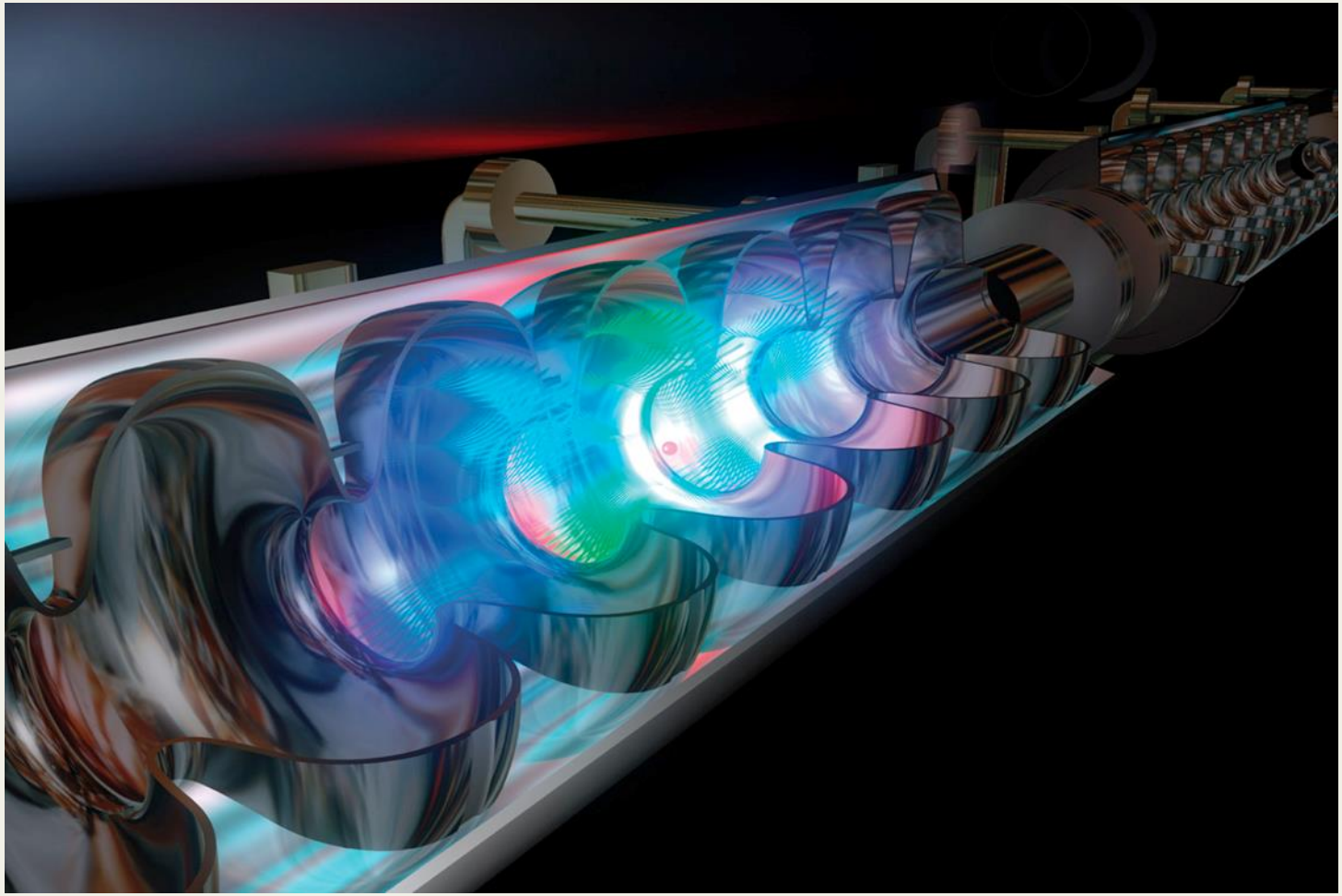
MEDIPIX



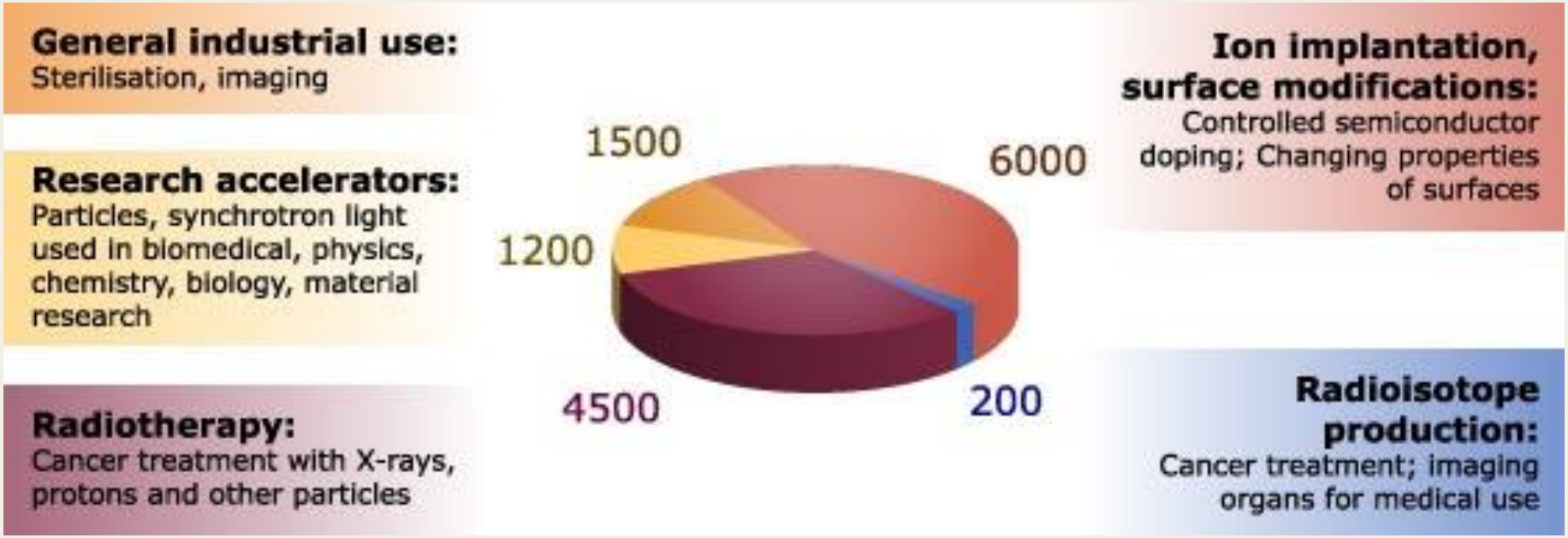
Towards digital imaging



Accelerators for cancer treatment



Use of accelerators today

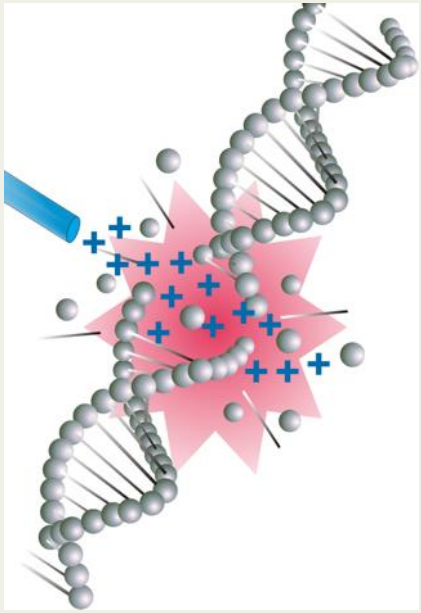


~ 9000 of the 17000 accelerators operating in the World today are used for medicine.

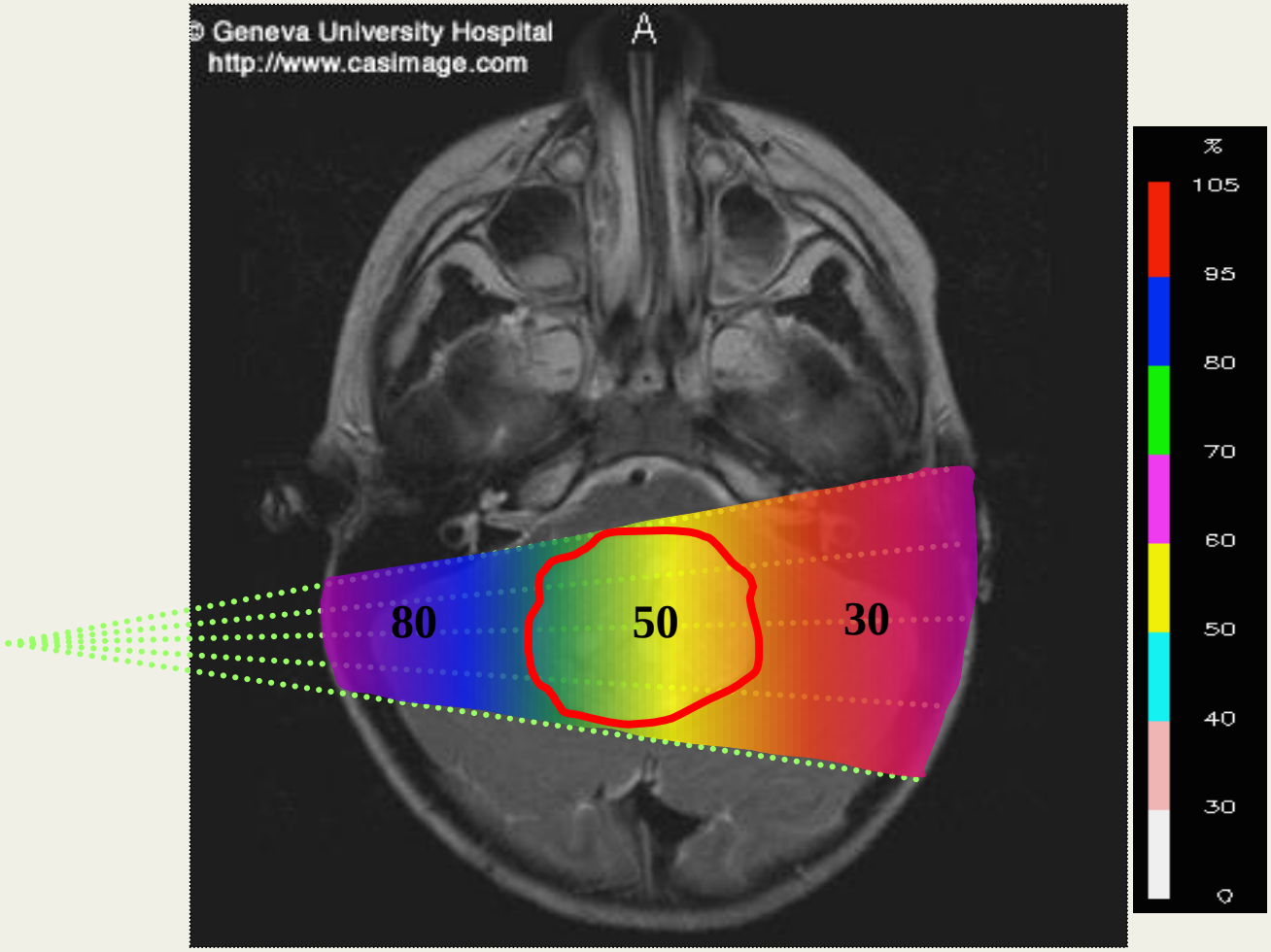
Conventional radiotherapy

- least expensive cancer treatment method
- most effective
- no substitute for RT in the near future
- rate of patients treated with RT is increasing

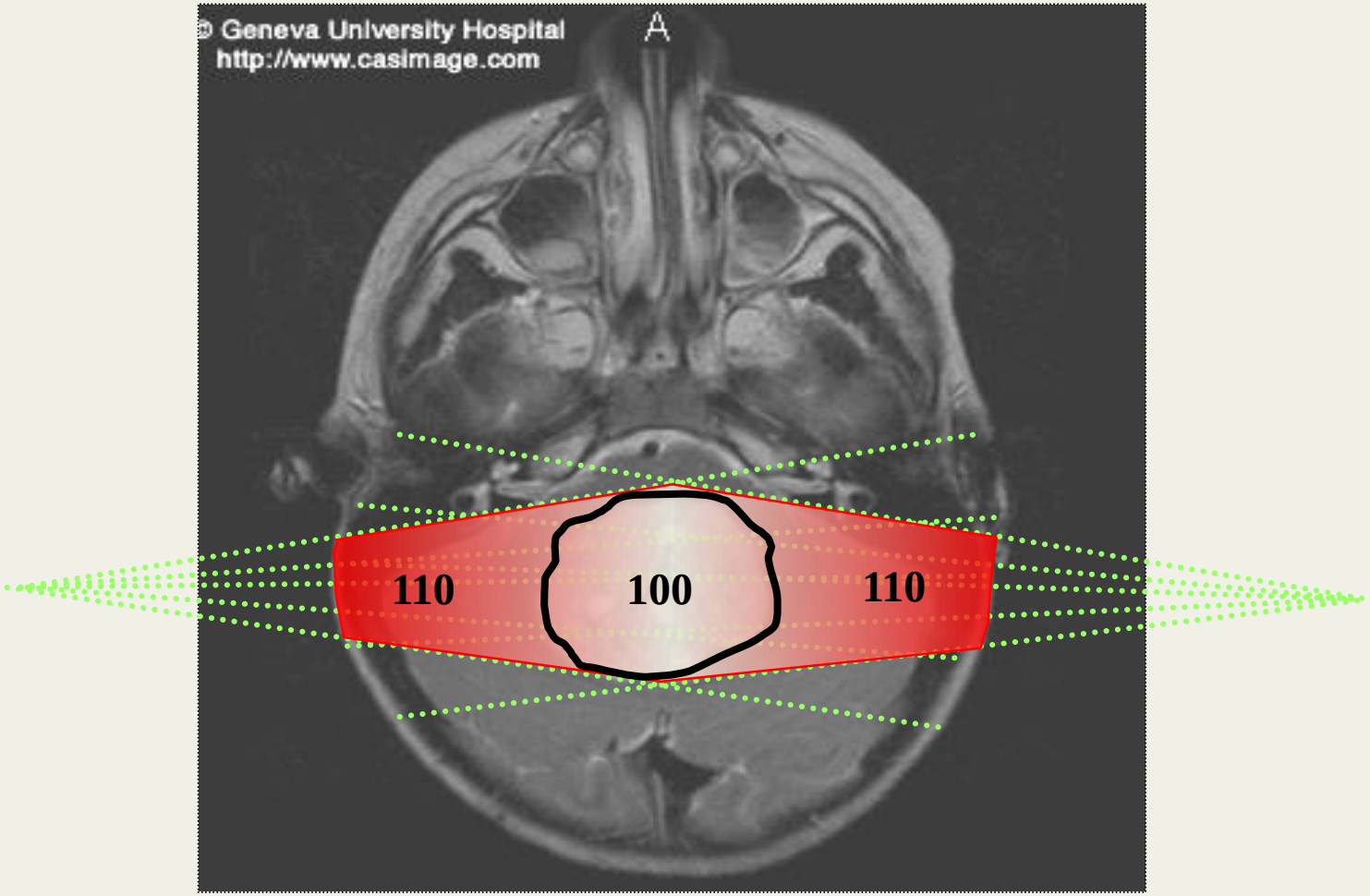
30% of patients cancer comes back in the same location after RT



Single beam of photons



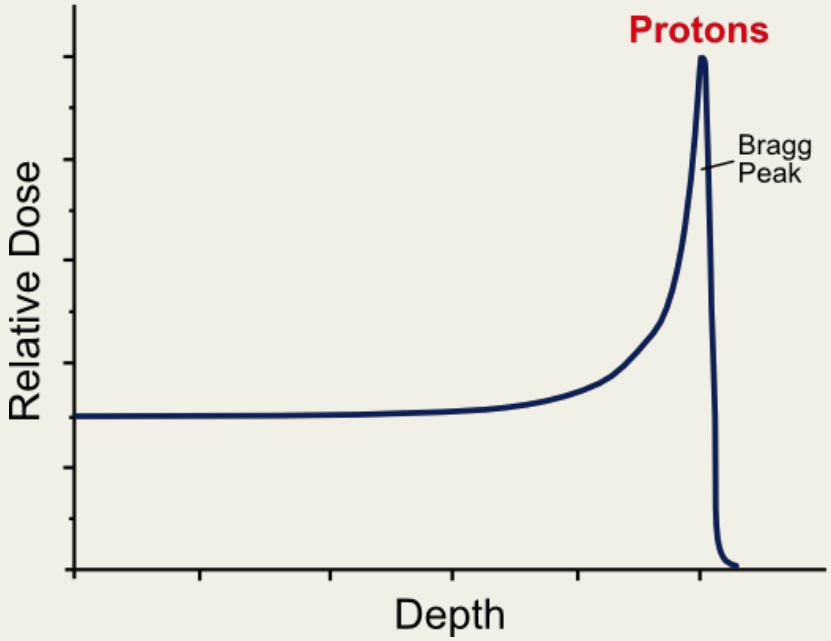
2 opposite photon beams



Alternative – Hadron Therapy

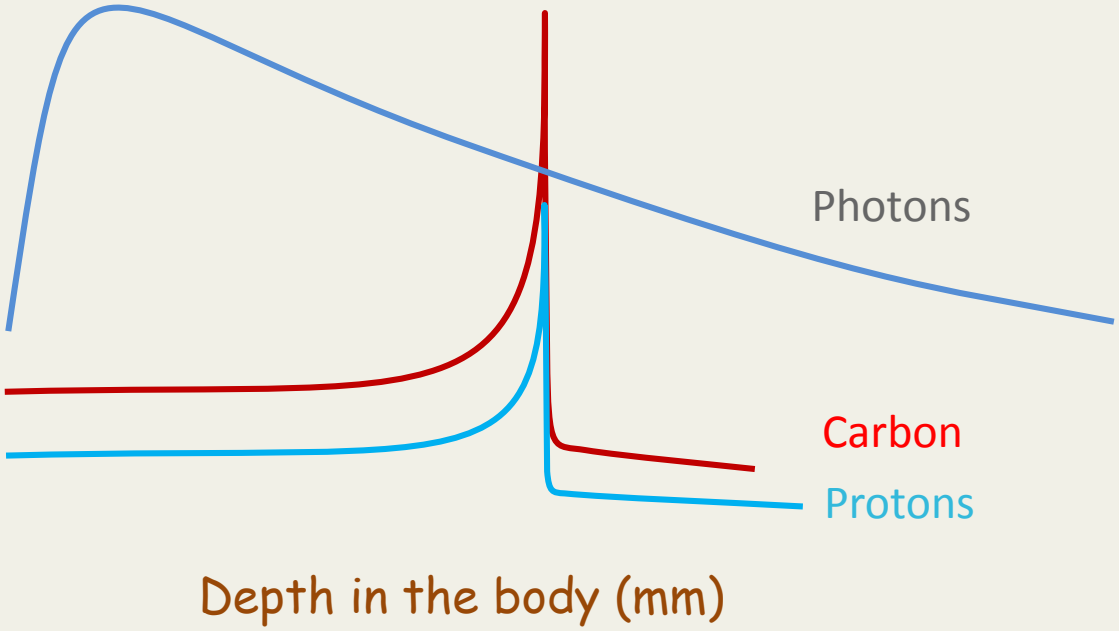
- 1946: Robert Wilson

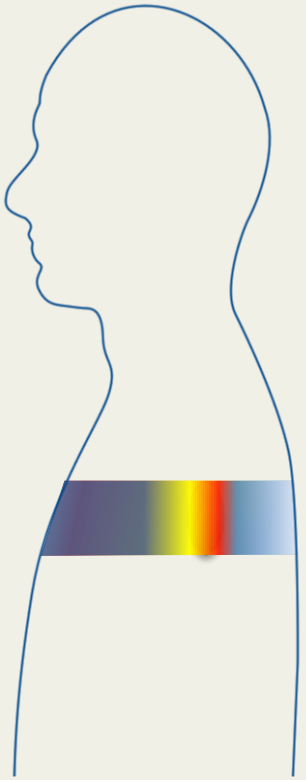
  Protons can be used clinically



Robert Wilson

Why hadron therapy



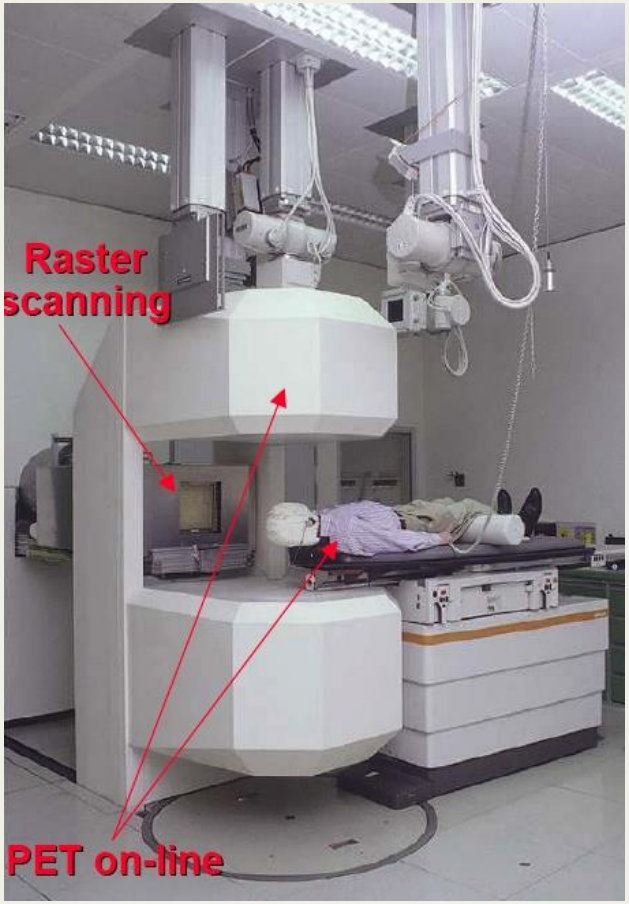


Tumours near critical organs
Tumours in children
Radio-resistant tumours

Carbon ions: pilot project in Europe

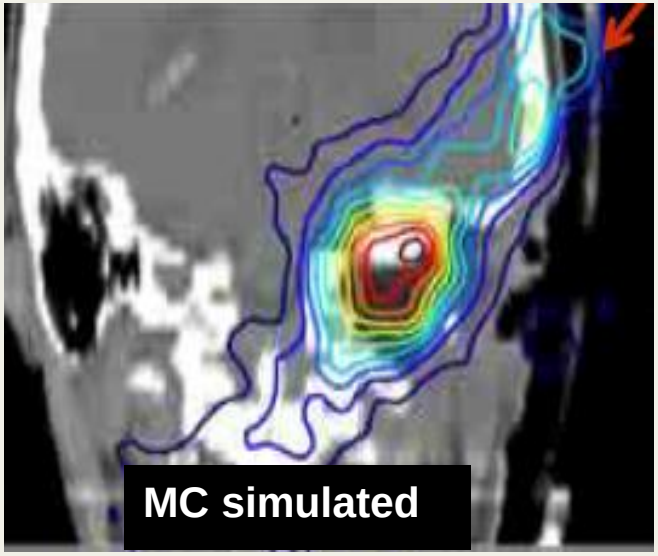
GSI & Heidelberg

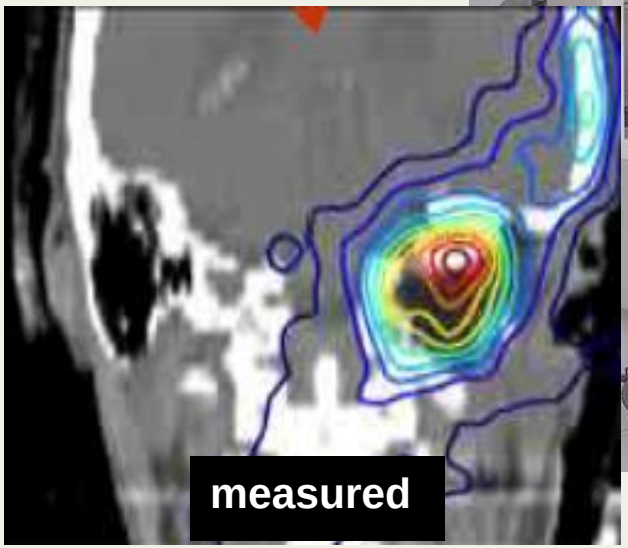
– 450 patients treated



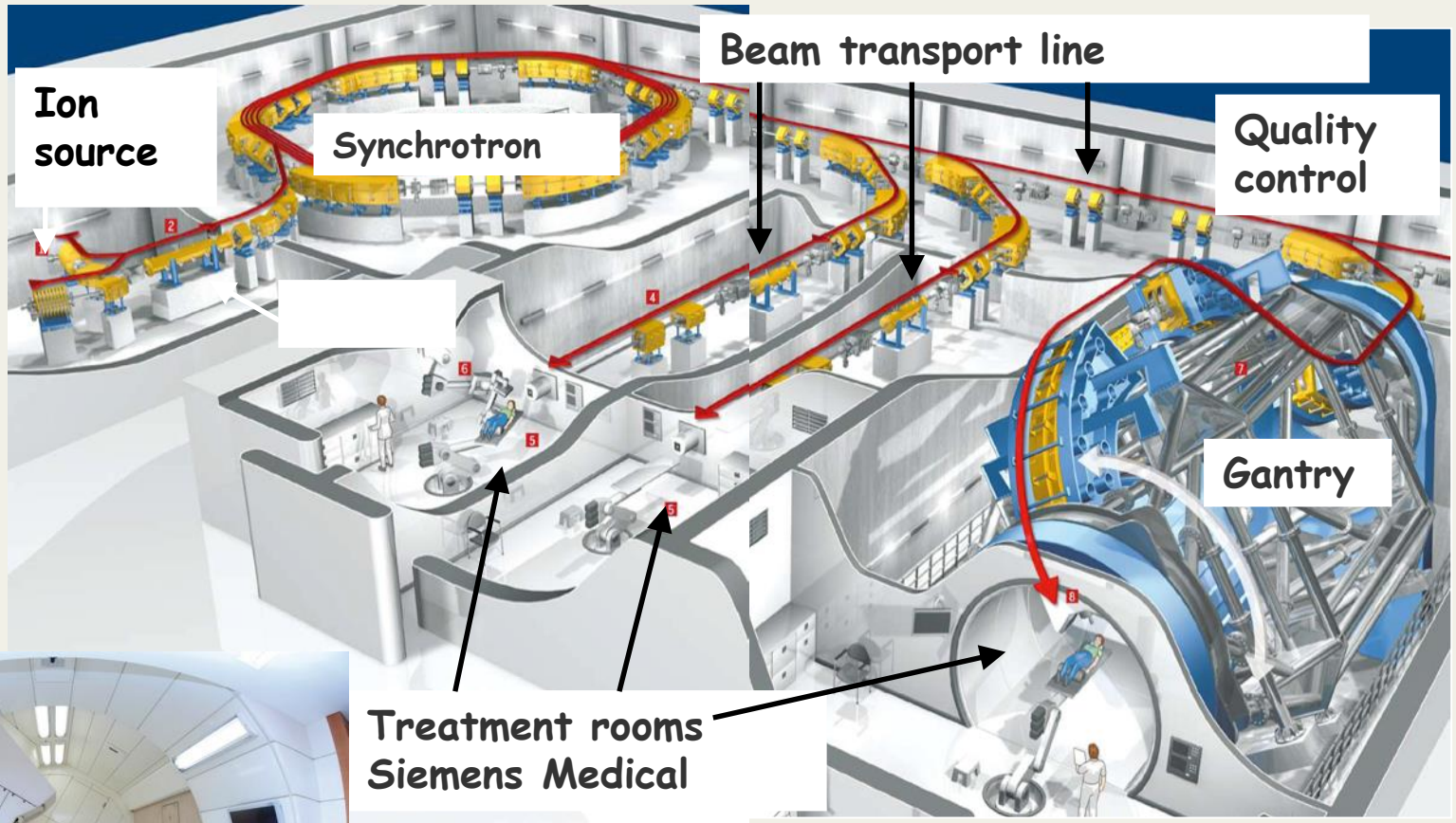
Real-time monitoring

- In-beam PET @ GSI (Germany)
- MonteCarlo simulations
- Organ motion

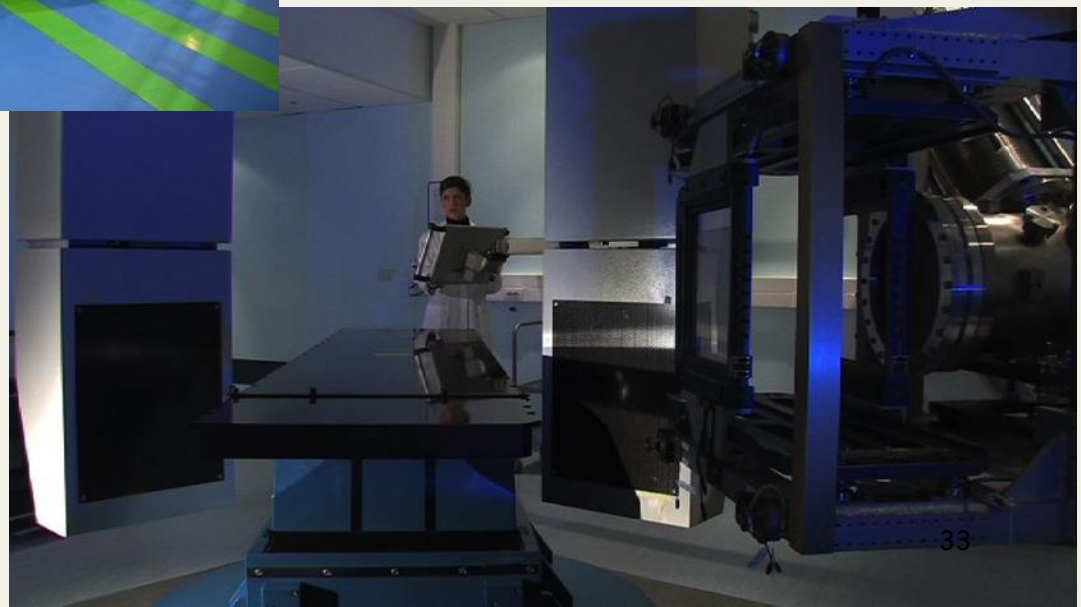




HIT - Heidelberg



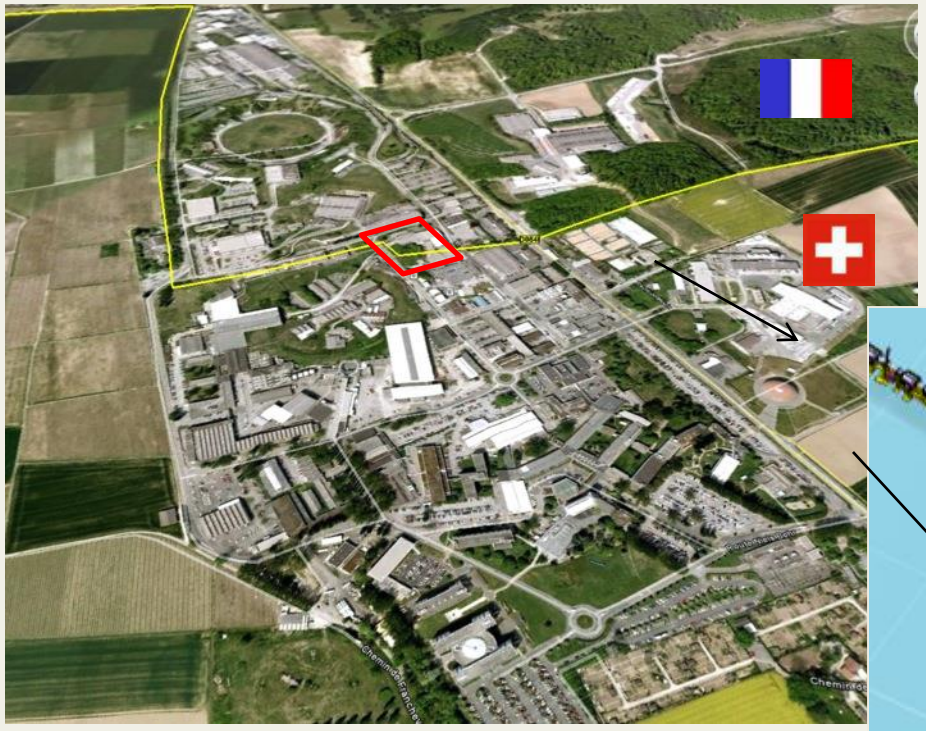
CNAO – Italy (Pavia)

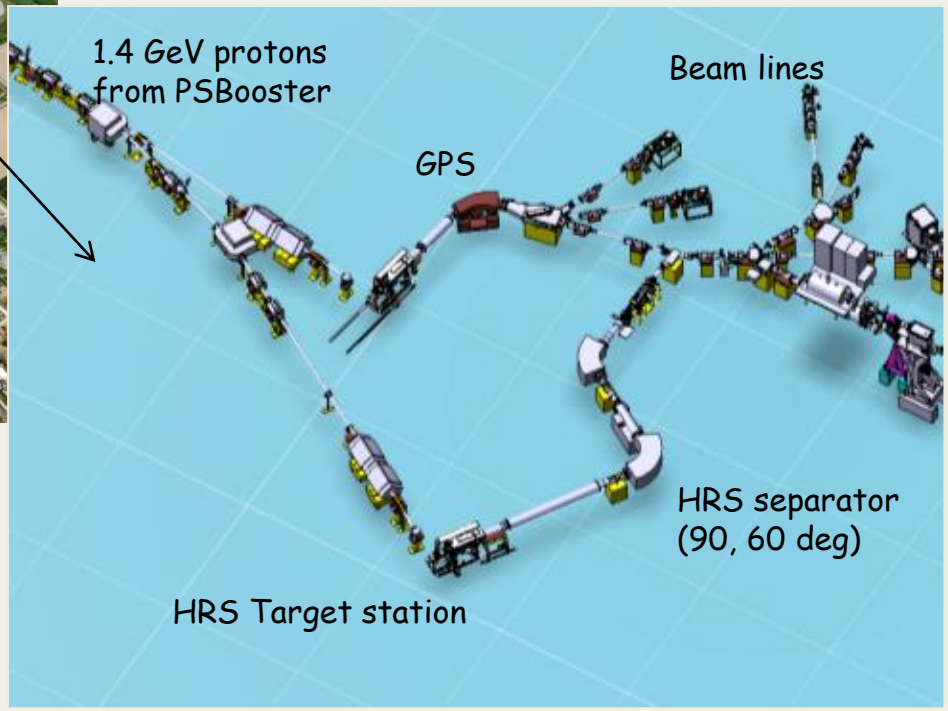


cern.ch/virtual-hadron-therapy-centre

ISOLDE

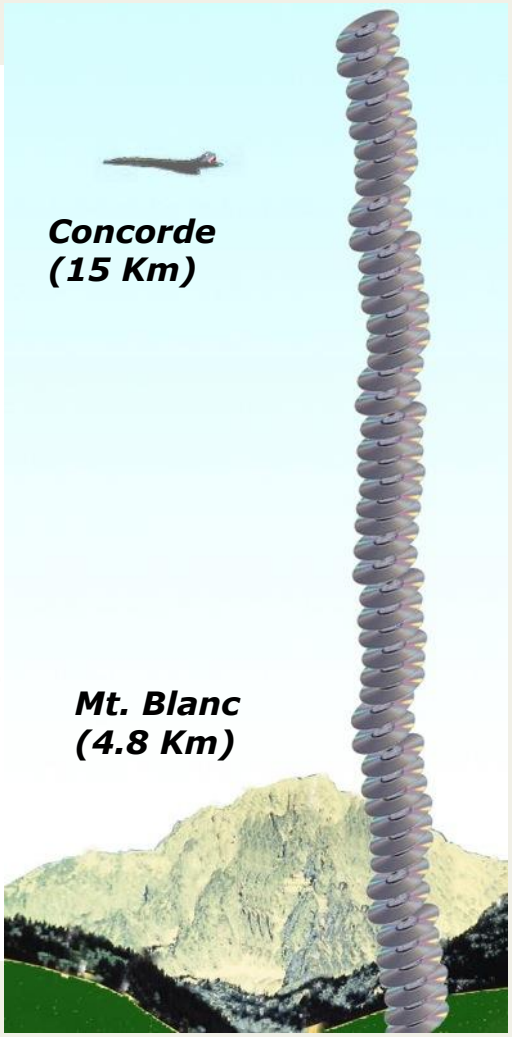
isotopes for detection & treatment



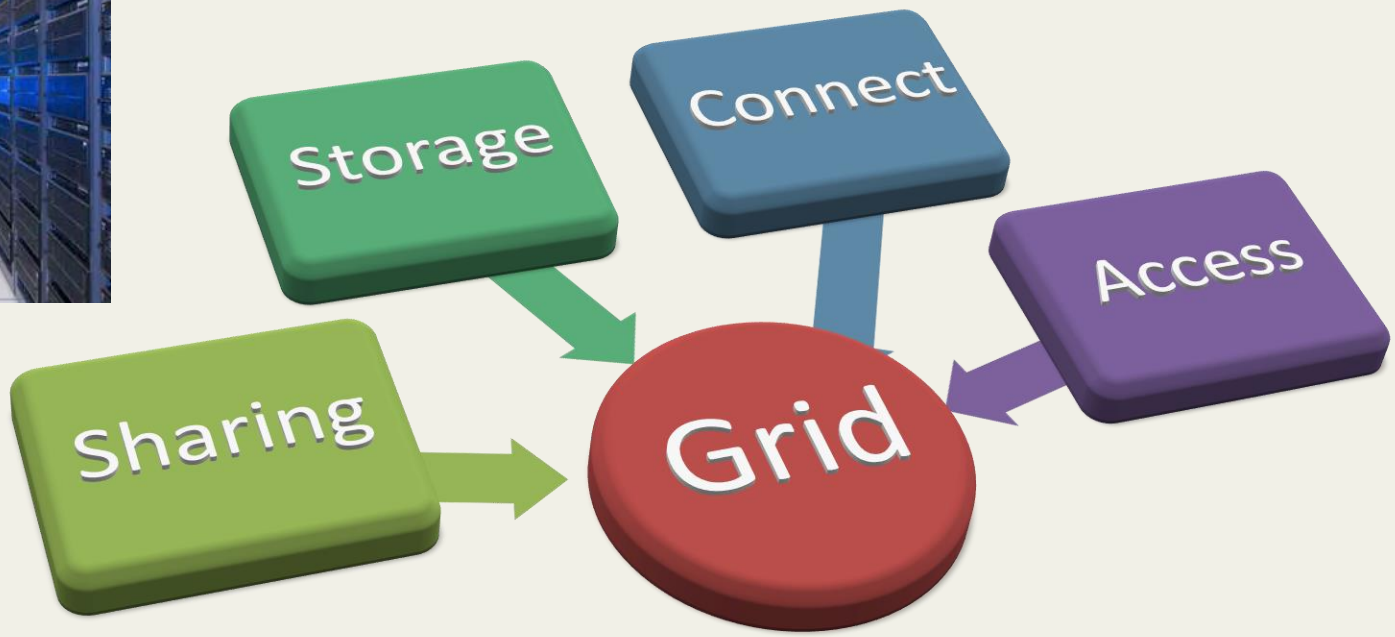


In collaboration with
University Hospital Geneva

Computing for medical applications



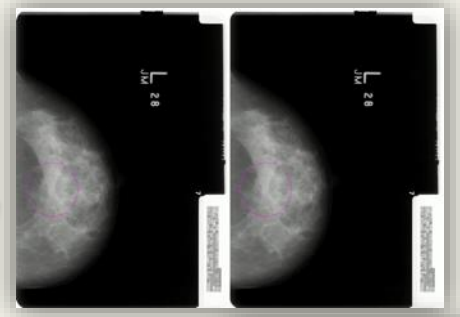
The Grid

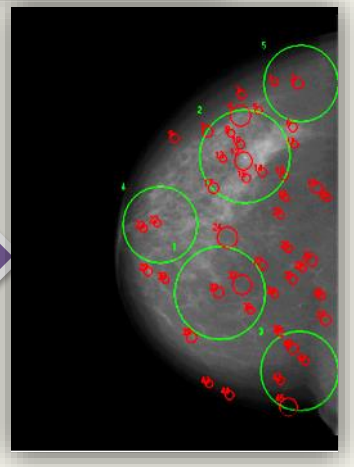


Data and Resources

Mammogrid - a grid mammography database

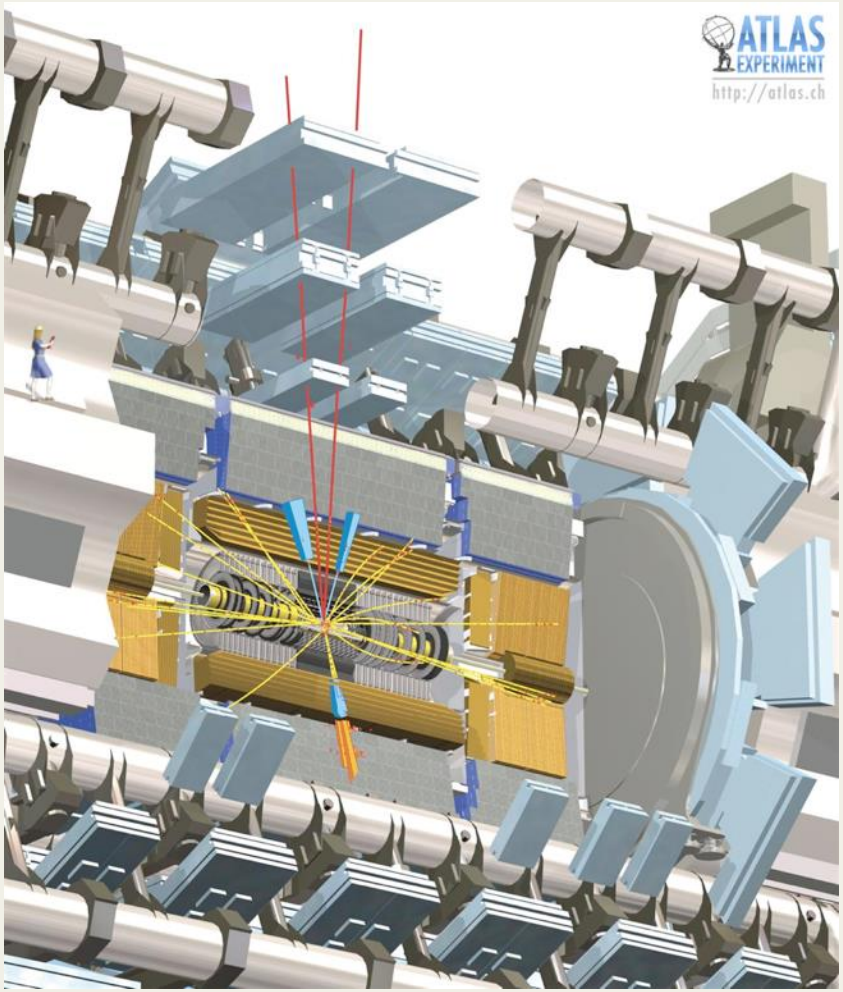
- Second Opinion
- Cancer Screening
- Education and Training
- Reference Database / Repository

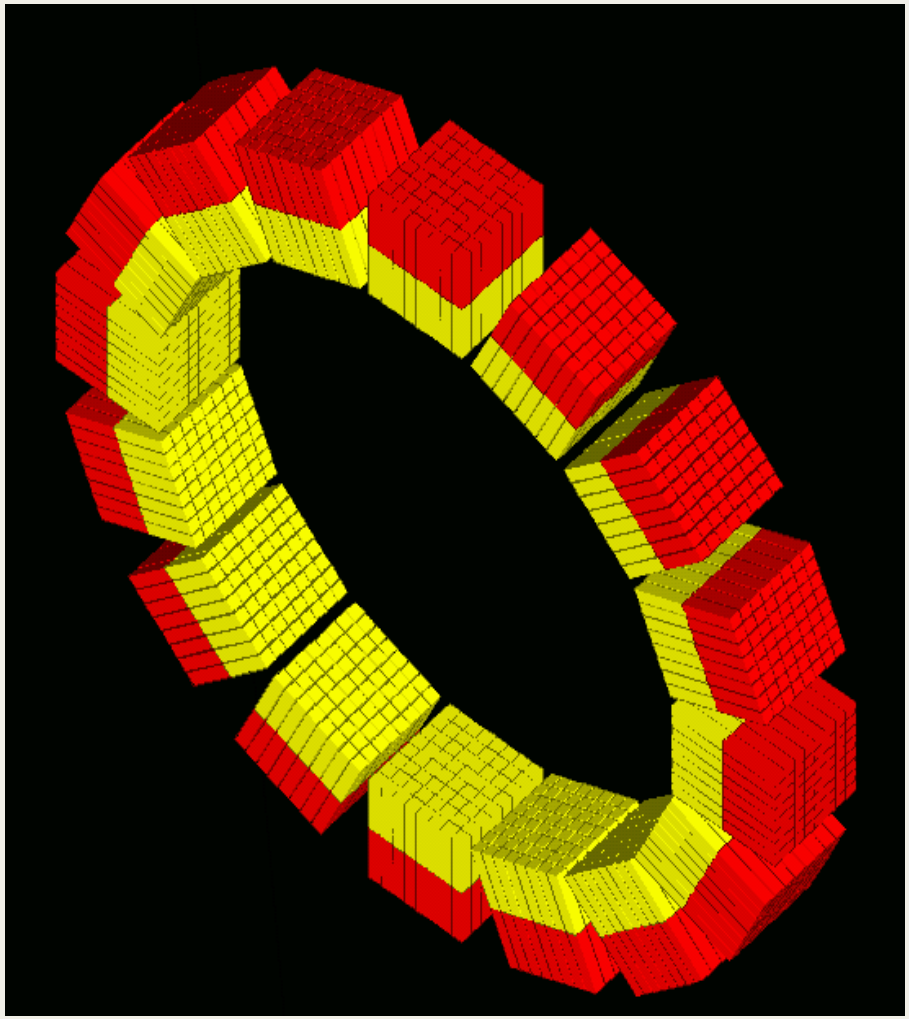


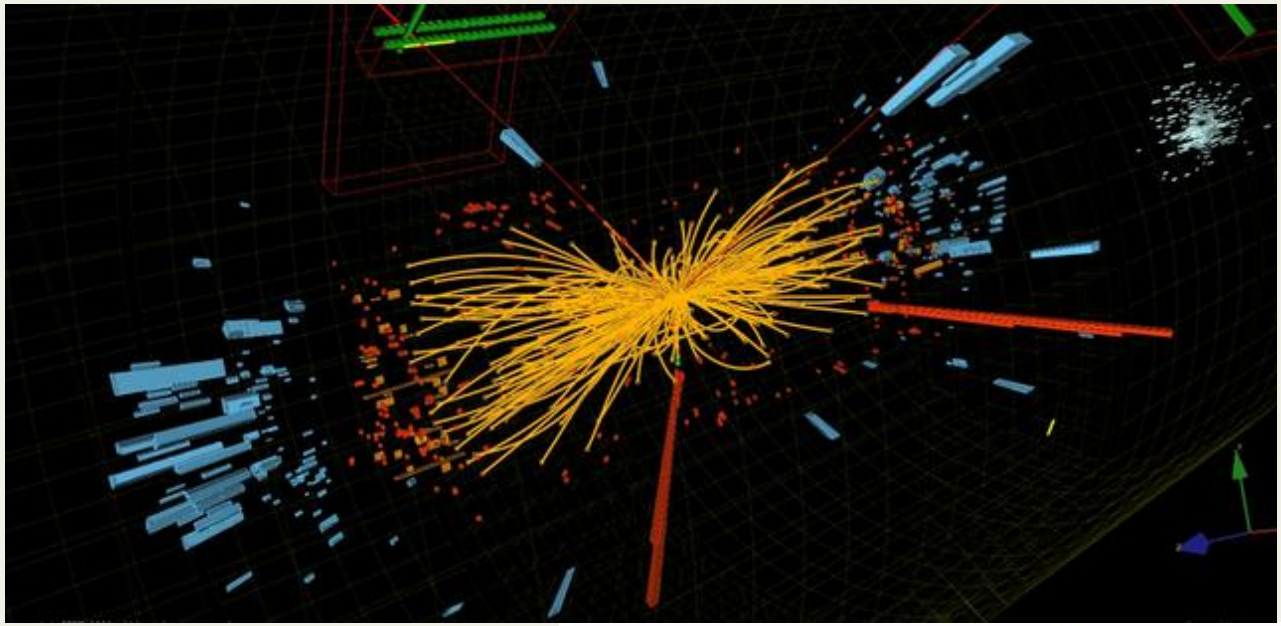


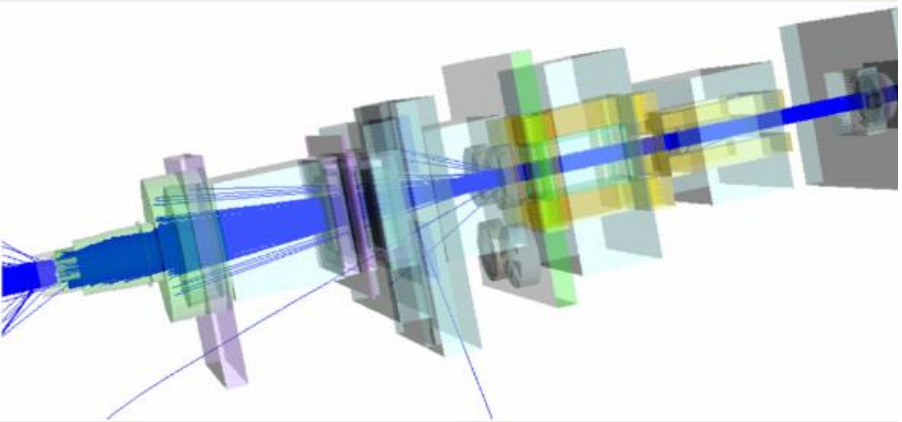
From: David MANSET, CEO MAAT France, www.maat-g.com

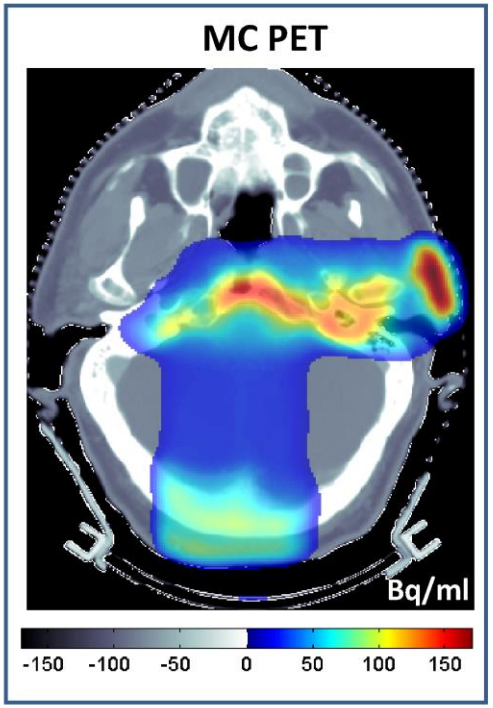
Simulation

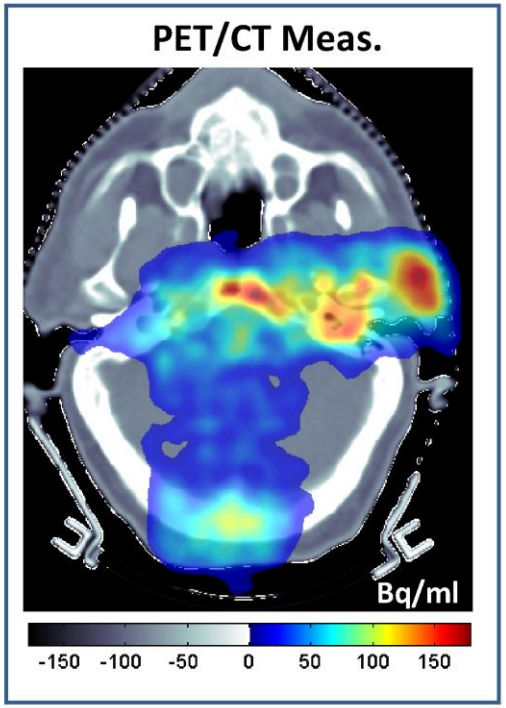






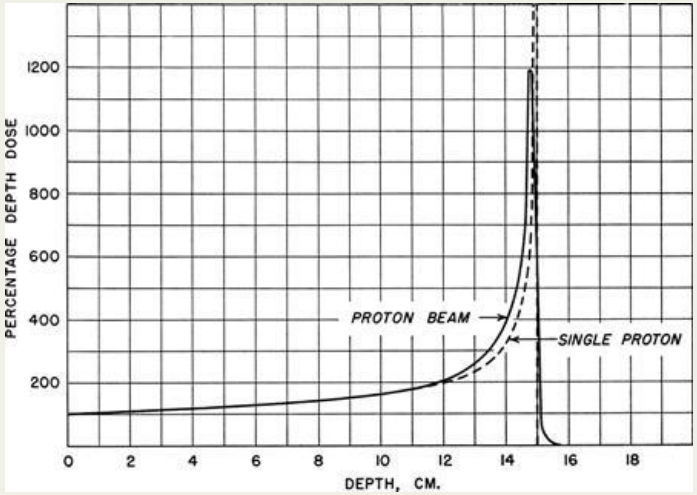



MC PET
Bq/ml
-150 -100 -50 0 50 100 150


PET/CT Meas.
Bq/ml
-150 -100 -50 0 50 100 150

From physics…

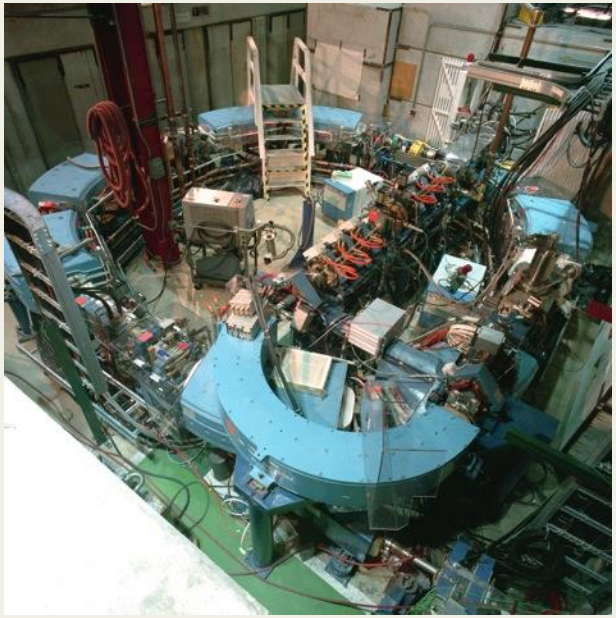
1932 – first cyclotron developed by Ernest Lawrence



1946 – proton therapy proposed by Wilson, exploiting the properties of the Bragg peak

1954 – Berkeley treats the first patient and begins extensive studies with various ions

…to clinics



1993 – patients treated at first hospital-based facility at Loma Linda

1994 – first facility dedicated to carbon ions operational at HIMAC Japan

1997 – First patient treated with carbon ions at GSI


ENVISION
European NoVel Imaging Systems
for ION therapy

Collisions and collaborations

References

- cern.ch/crystalclear
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- www.fluka.org/fluka.php
- cern.ch/wwwasd/geant
- cern.ch/wwwasd/geant/tutorial/tutstart.html