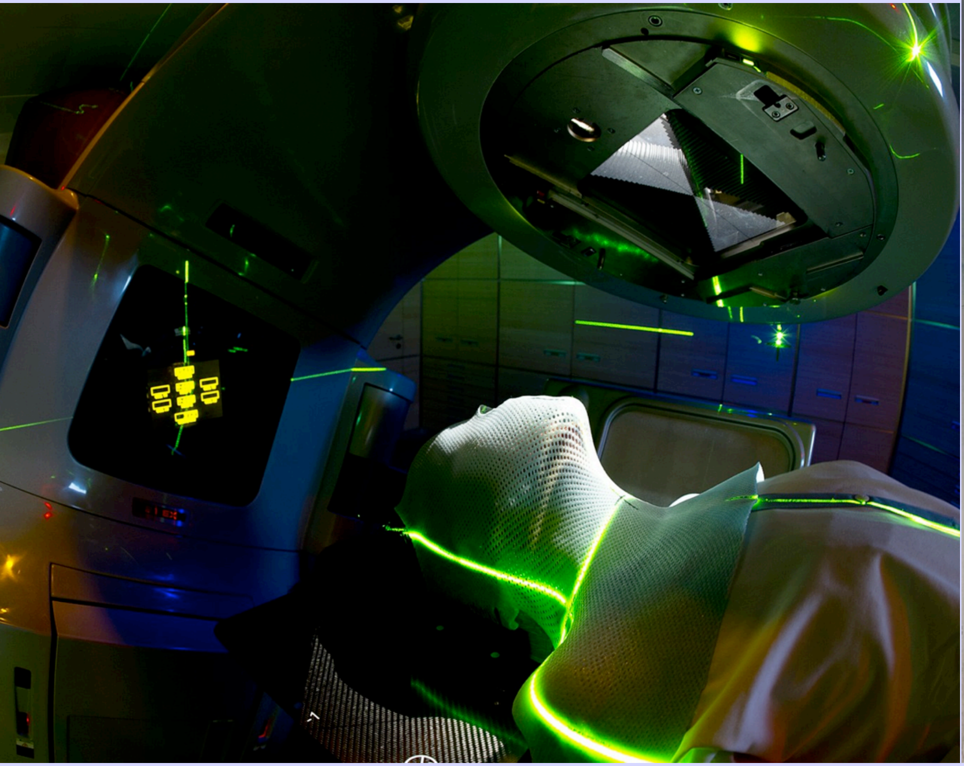
CERN:
from particle physics to medical applications



Manjit Dosanjh
Knowledge Transfer- Life Sciences

X-Rays, the fastest technology transfer

- November 8, 1895 Röntgen discovered X-Rays
- December 22, 1895 he takes the first image of his wife's hand

Röntgen received the <u>first</u> Nobel prize in <u>physics</u> in 1901

Beginning of modern medical physics

Radio waves	Microwave	Infrared	Visible	Ultraviolet	X-Ray	Gamma Ray

Energy, E

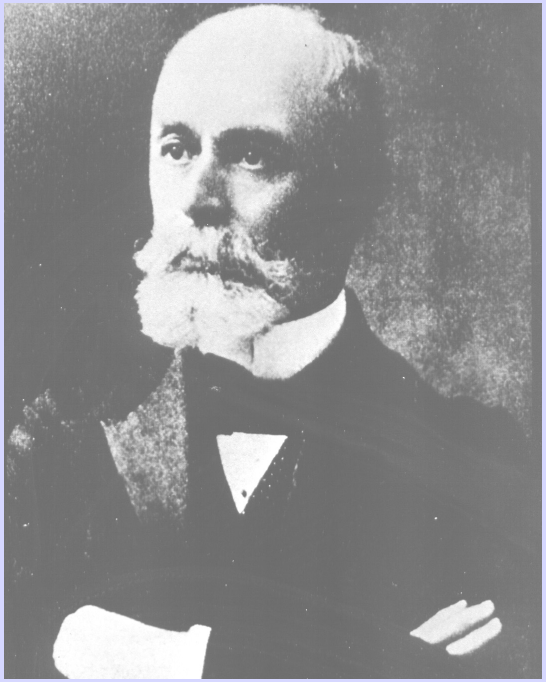
1 me

10

Wilhelm Röntgen

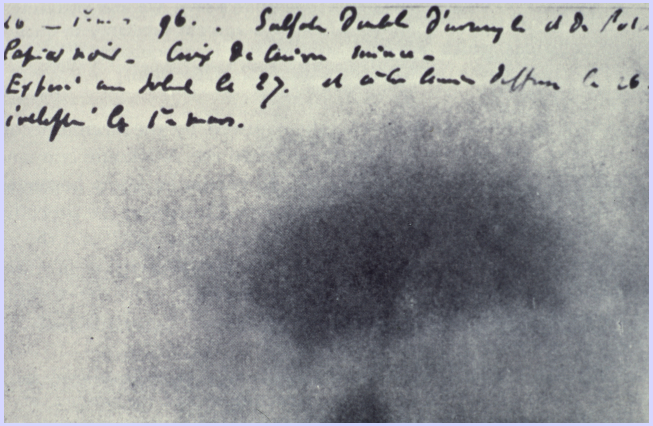
8/11/1895 — 22/12/1895 — 1901

..........beginning of medical physics

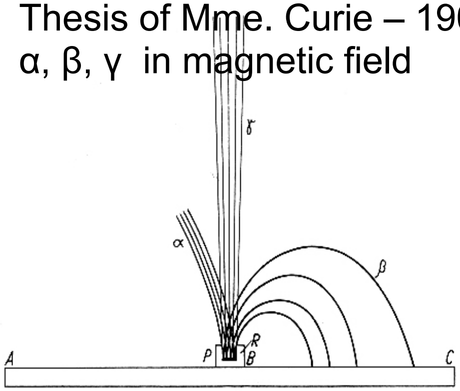


Henri Becquerel

1896:
Discovery of natural radioactivity



Thesis of Mme. Curie – 1904
α, β, γ in magnetic field



1898: Discovery of radium

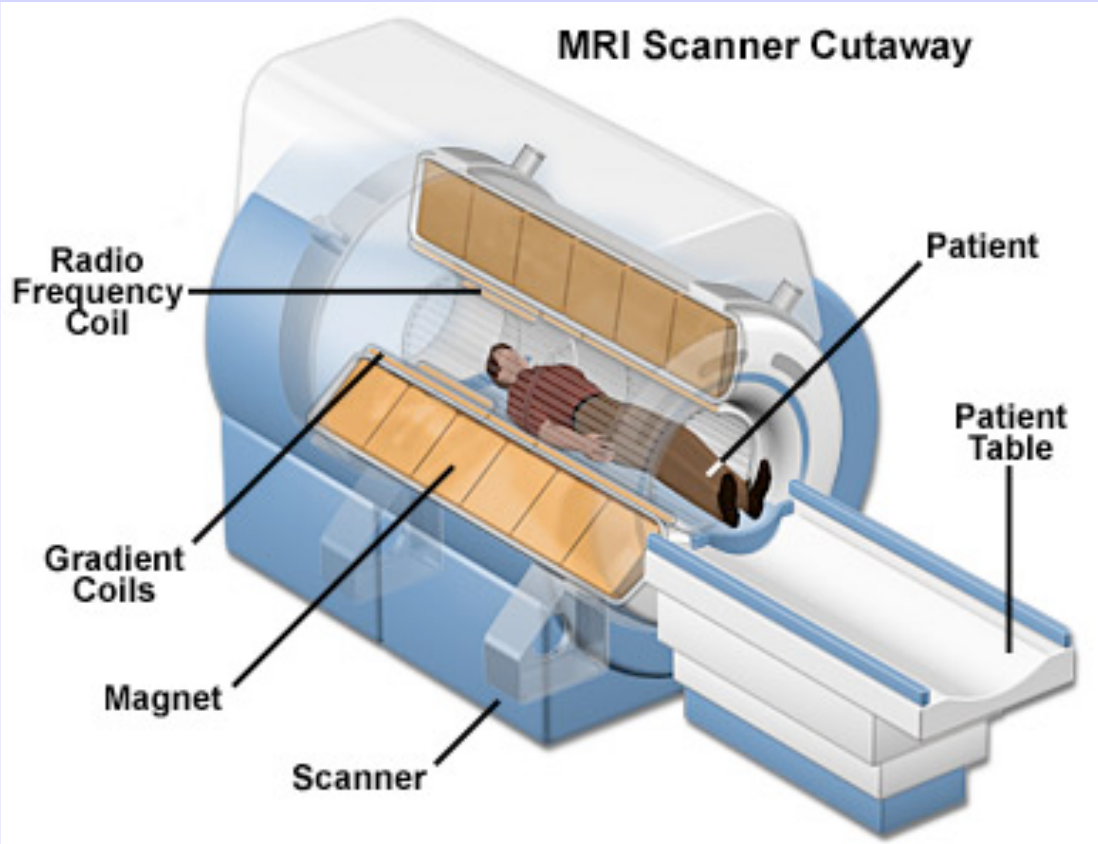
used immediately for “Brachytherapy”

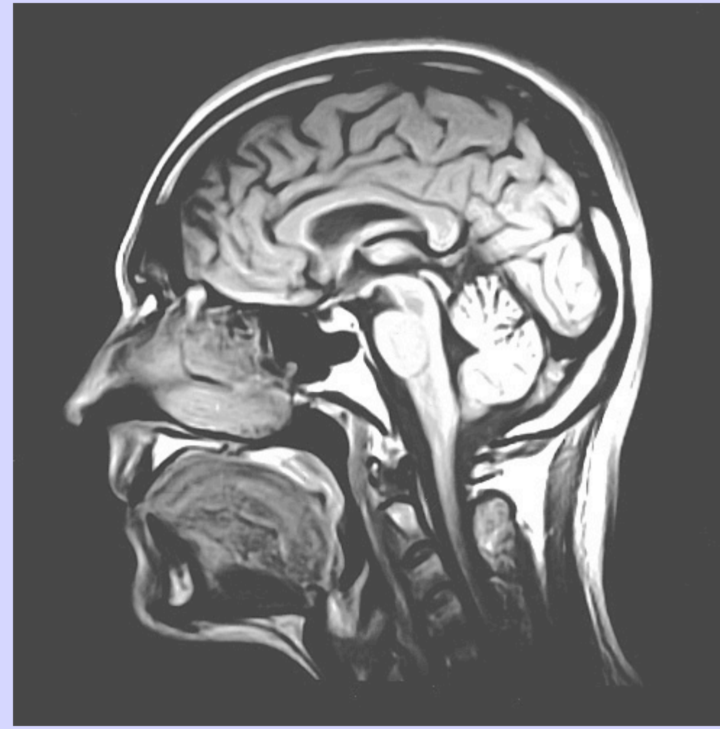
Marie Curie (1867 – 1934) Pierre Curie (1859 – 1906)

First radiobiology experiment: Pierre Curie

The first radiobiology experiment. Pierre Curie using a radium tube to produce radiation ulcer on his arm. Hall fig. 1-2

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

Innovation Education
CERN uniting people
Research

The Mission of CERN

- Push forward the frontiers of knowledge

  E.g. the secrets of the Big Bang … the matter like within the first moments of th… …xistence?

- Develop new tech… accelerators an…

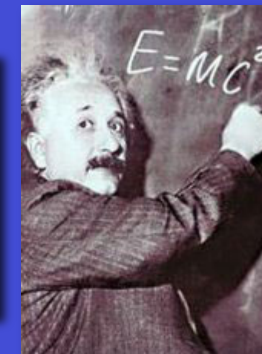
  Information technology - the Web and the GRID

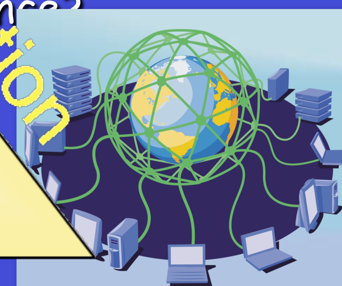
  Medicine - diagnosis and therapy

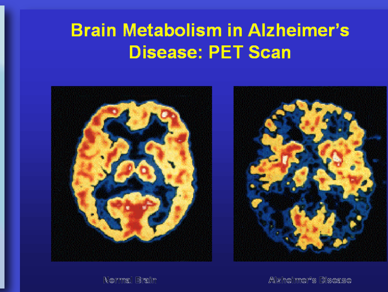
- Train scientists and engineers of tomorrow

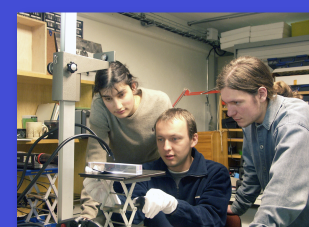
- Unite people from different countries and cultures

Innovation Education
CERN uniting people
Research



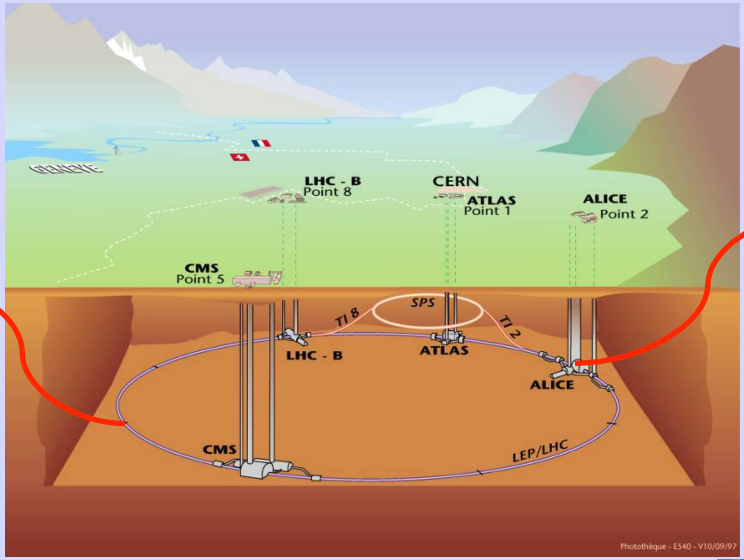




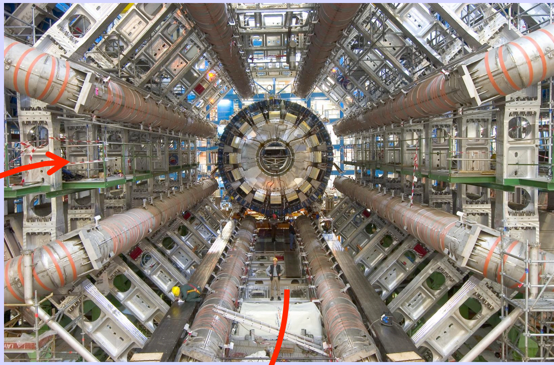


3 pillars of the trade ………

Accelerators



Detectors

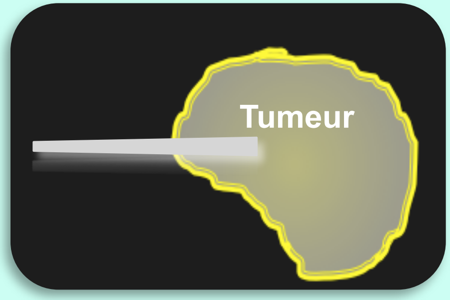


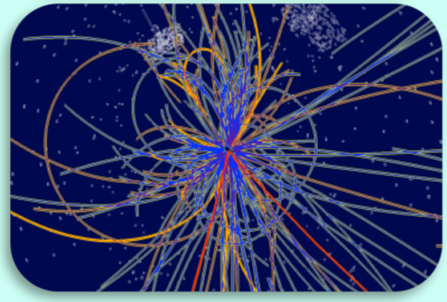
Computers

Brain behind the web

The 4th pillar of technology

Collaboration

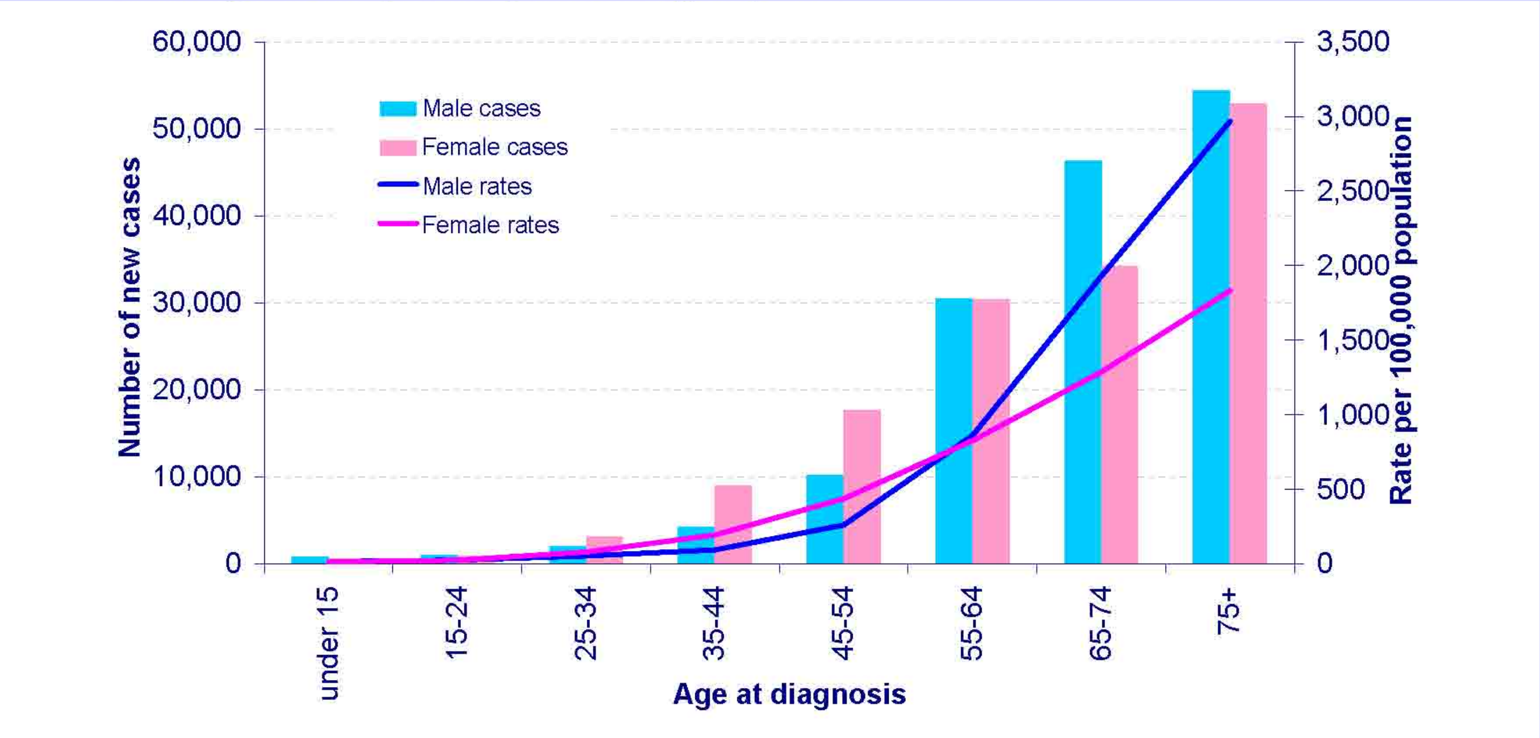




Cancer – a growing challenge

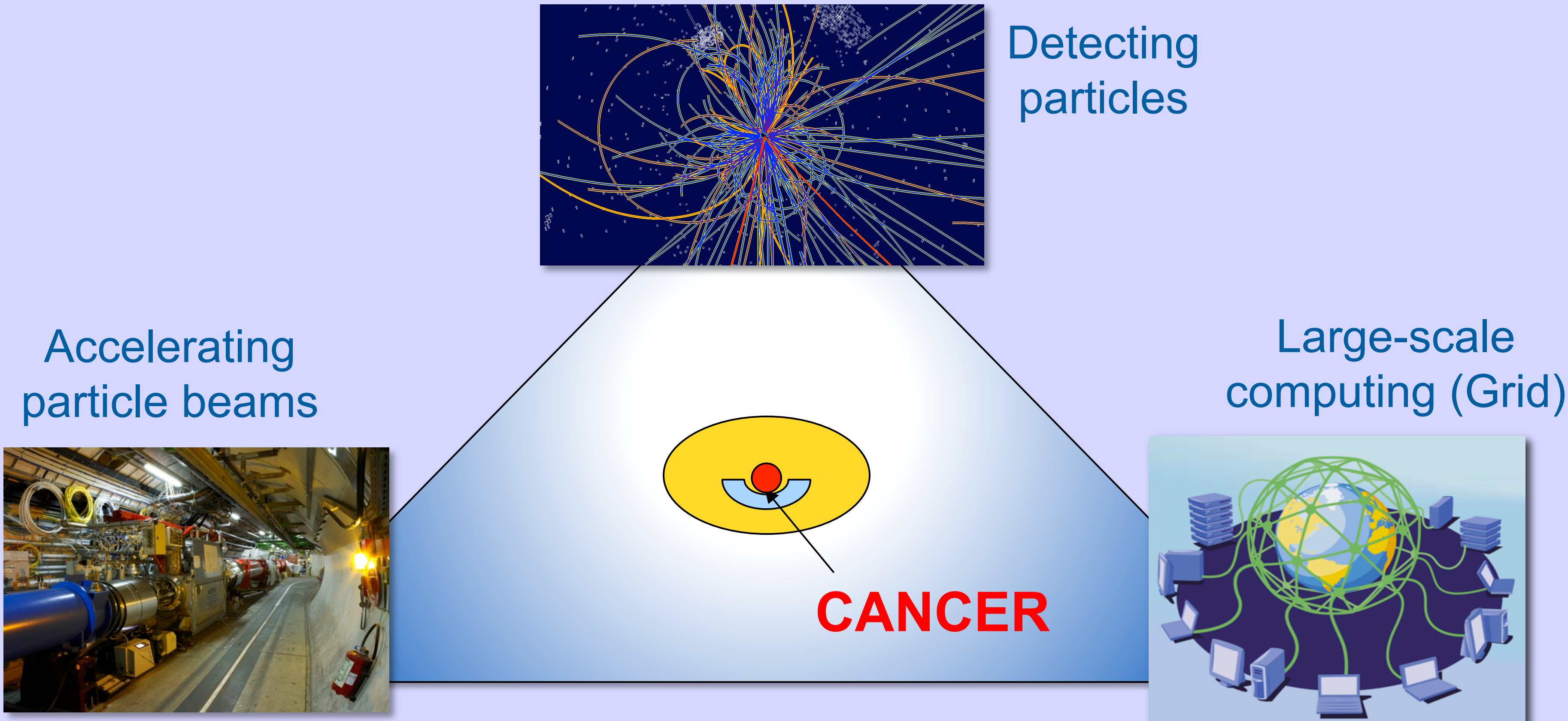
More than 3 million new cancer cases in Europe each year and 1.75 million associated deaths

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



CERN Technologies and innovation

accelerators, detectors and IT to fight cancer

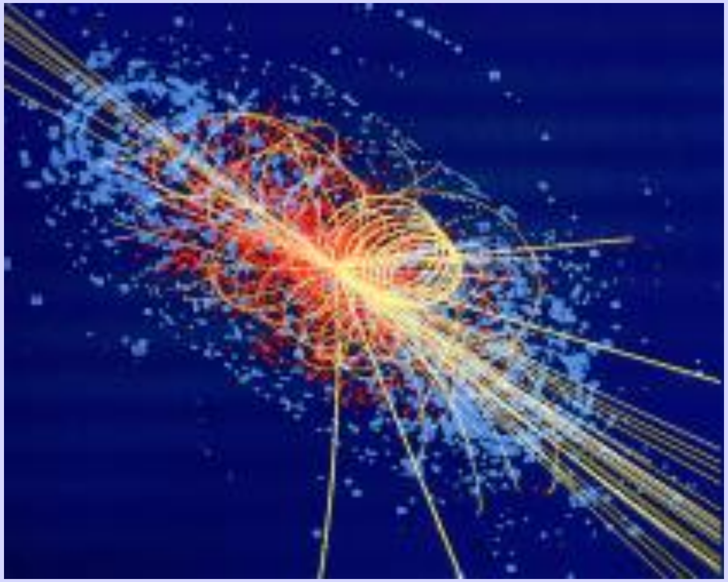


Medical Imaging

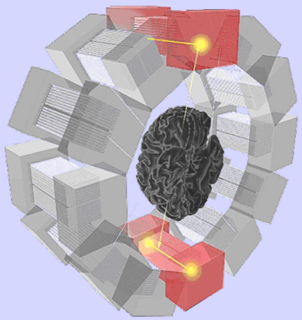
First step: Detection

No treatment without detection!

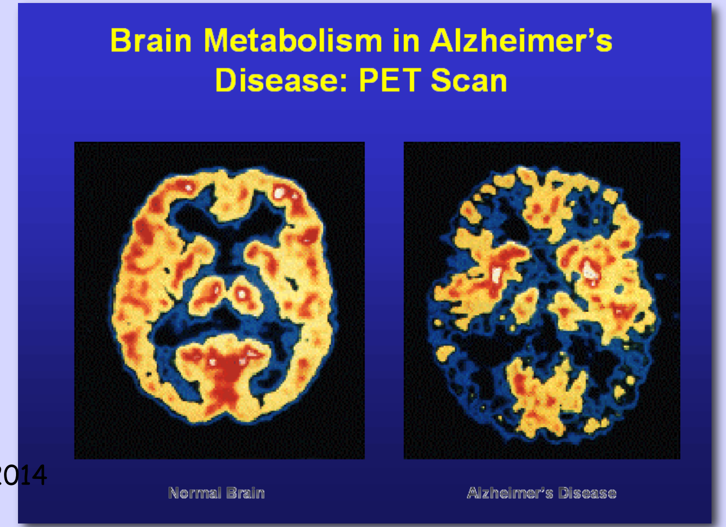
Particle Detection



Imaging

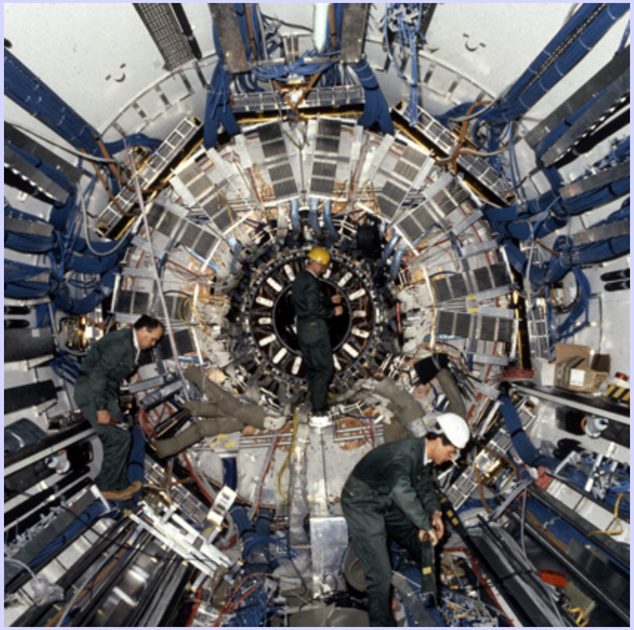


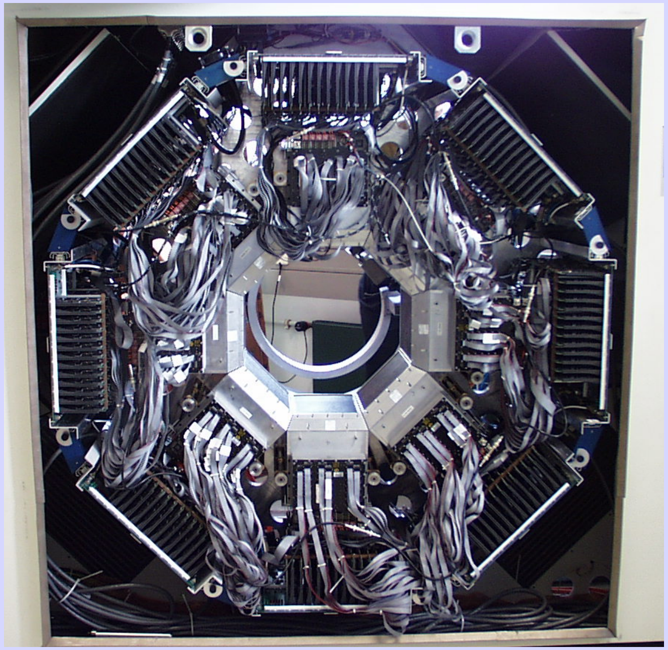
PET Scanner



Breast imaging (ClearPEM)

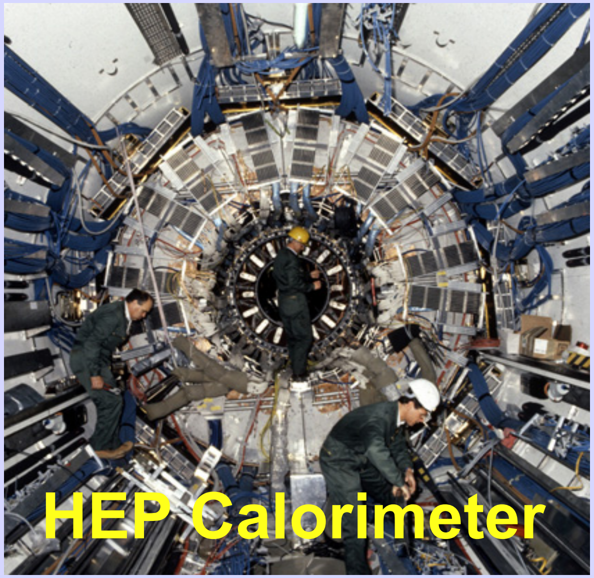
Similar challenges for detectors

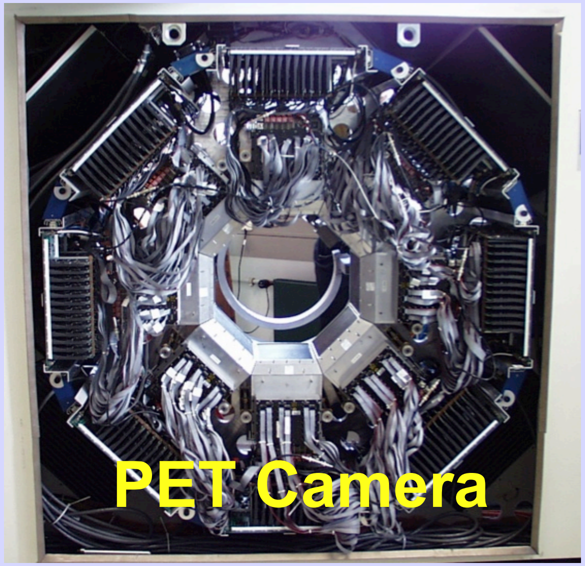




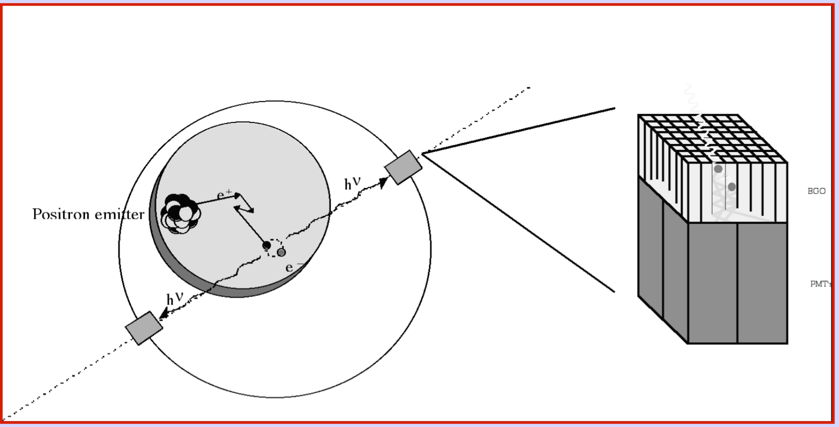
Similar challenges

- New materials
- Compact
- low noise electronics
- Algorithms

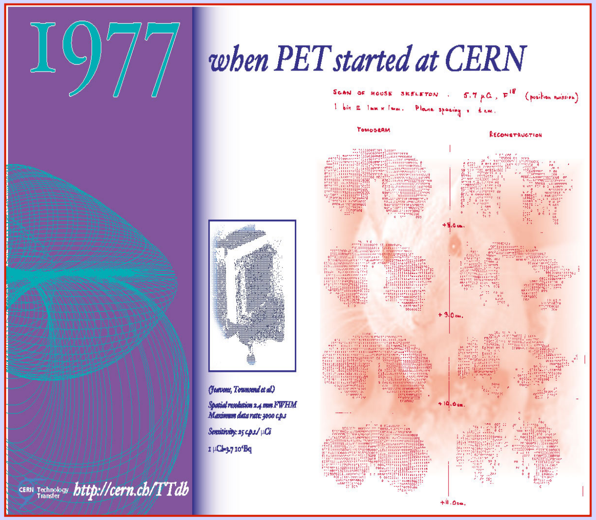




PET Imaging

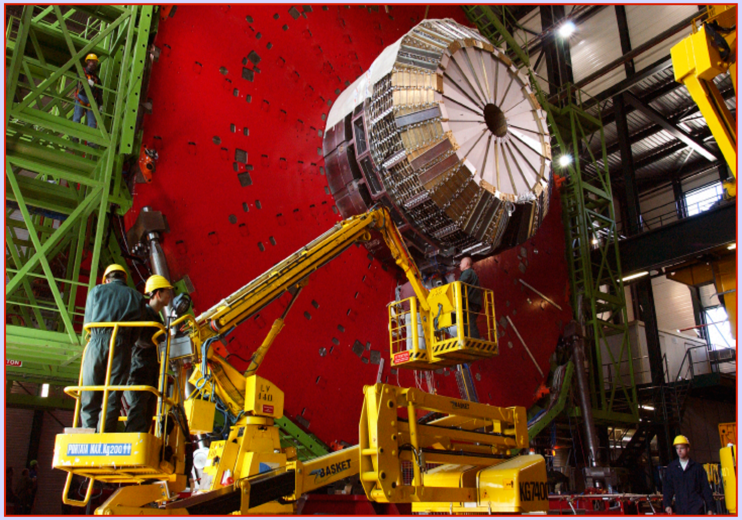


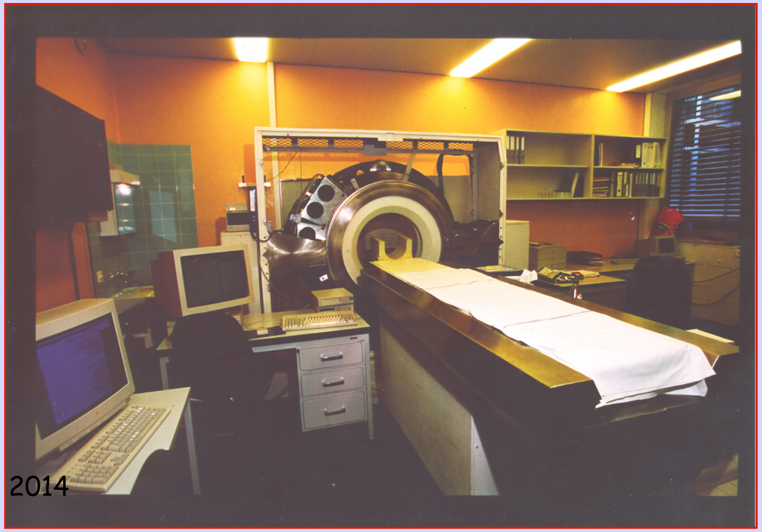
Idea of PET



Photon detection used for calorimetry

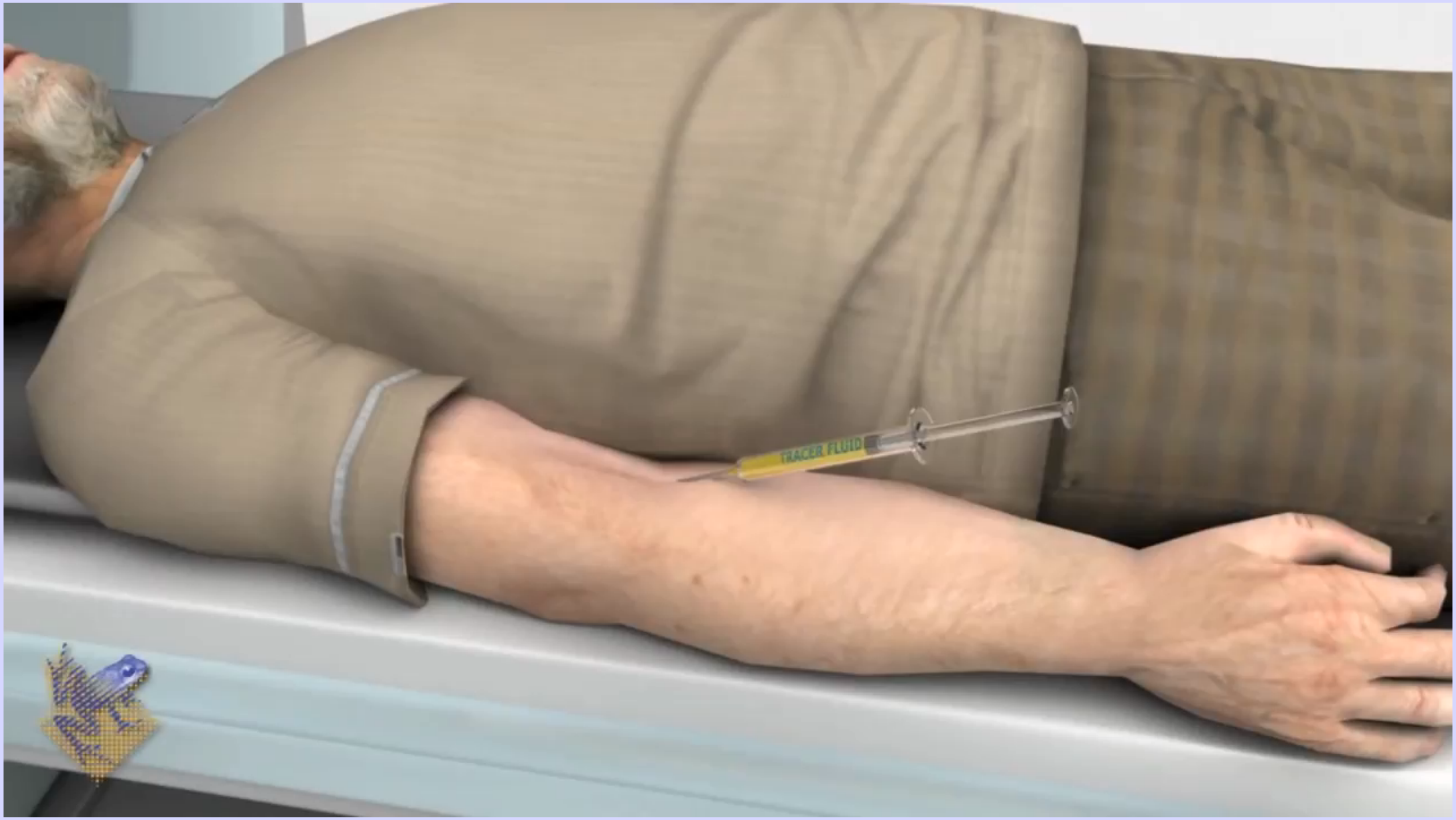
PET today





CMS calorimeter

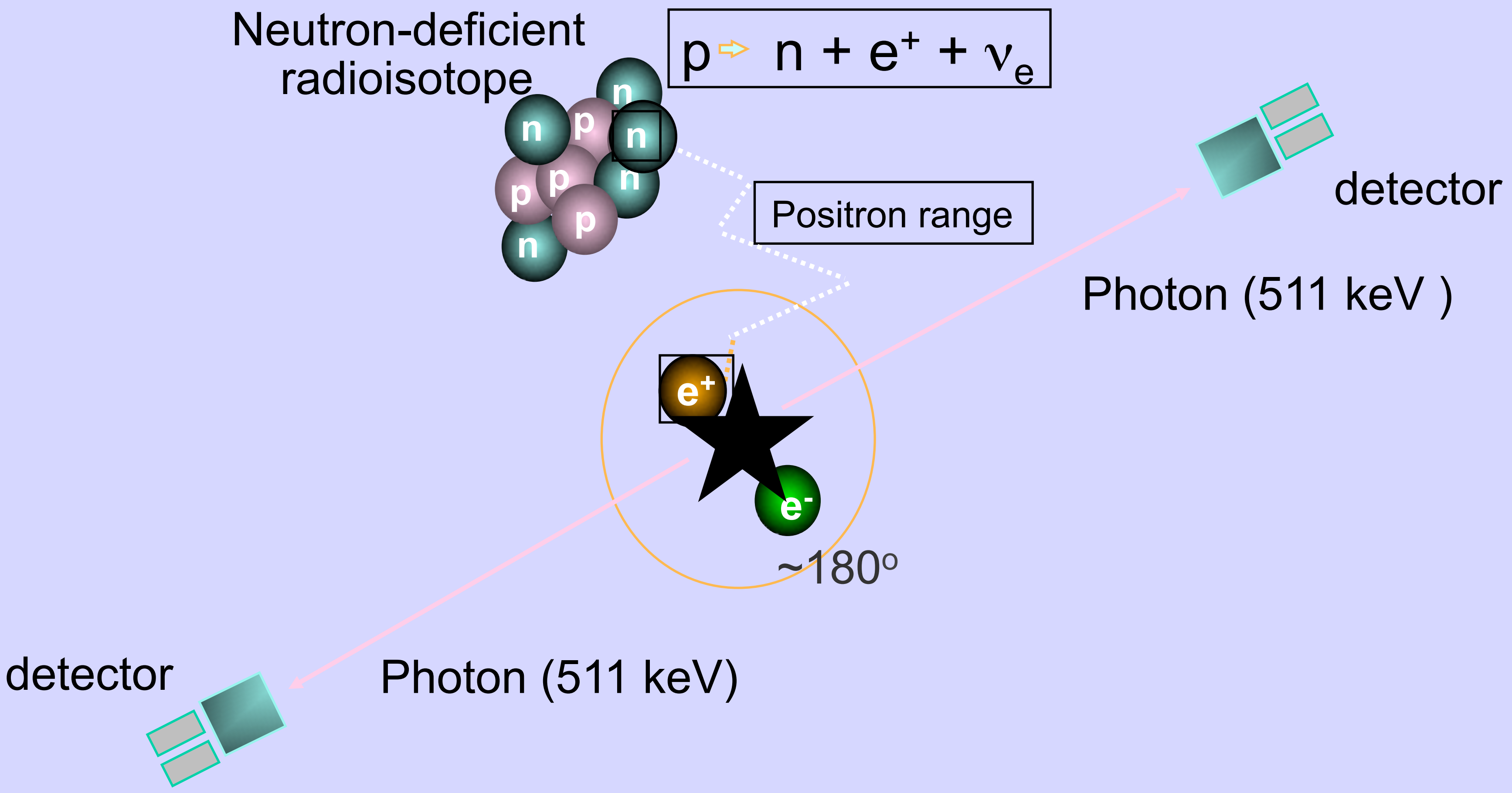
PET – How it works



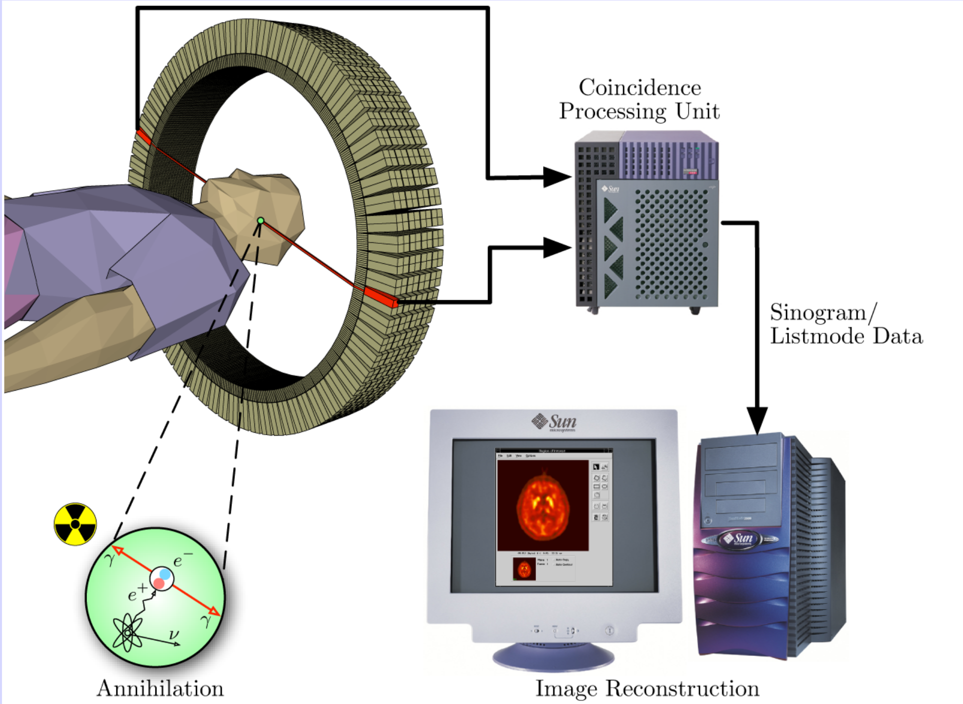
http://www.nymus3d.nl/portfolio/animation/55

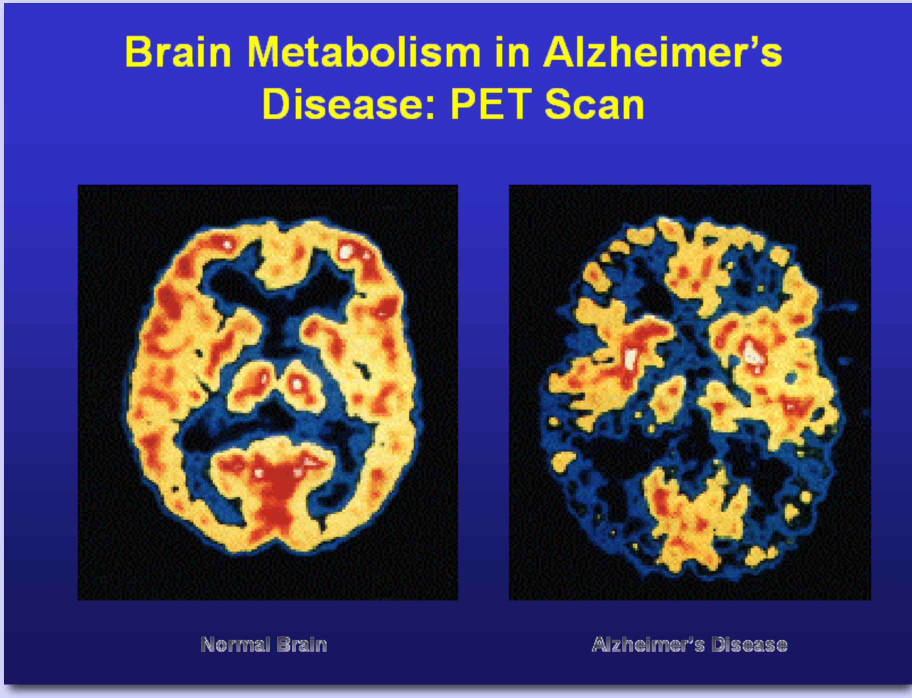
PET – How it works

PET: detection



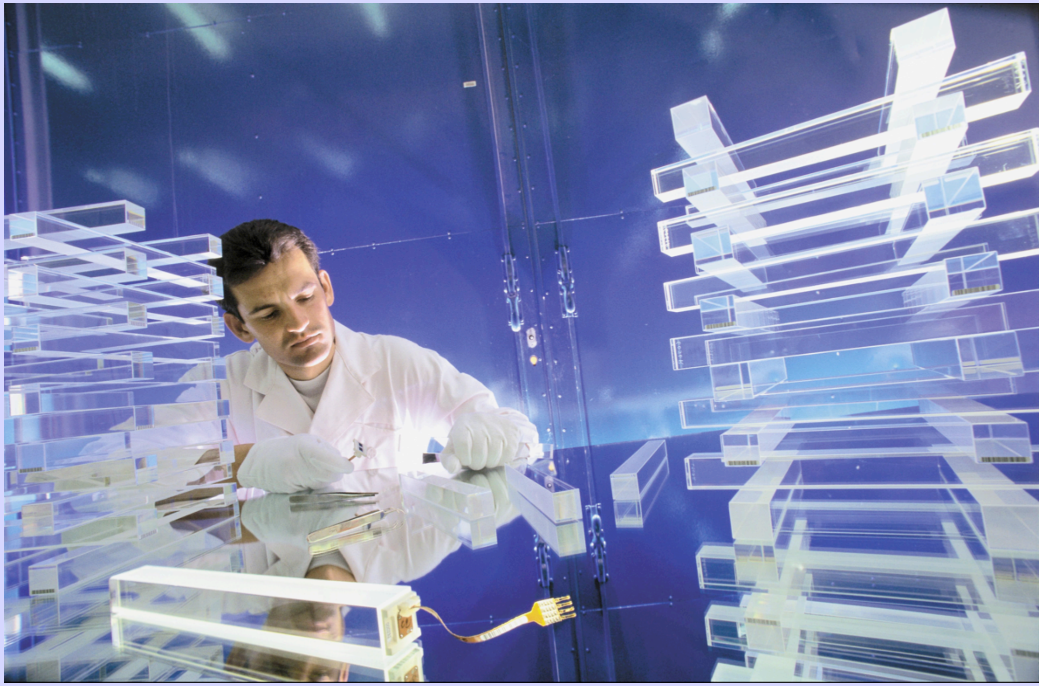
PET Scan


Coincidence Processing Unit
Sinogram/ Listmode Data
Annihilation
Image Reconstruction

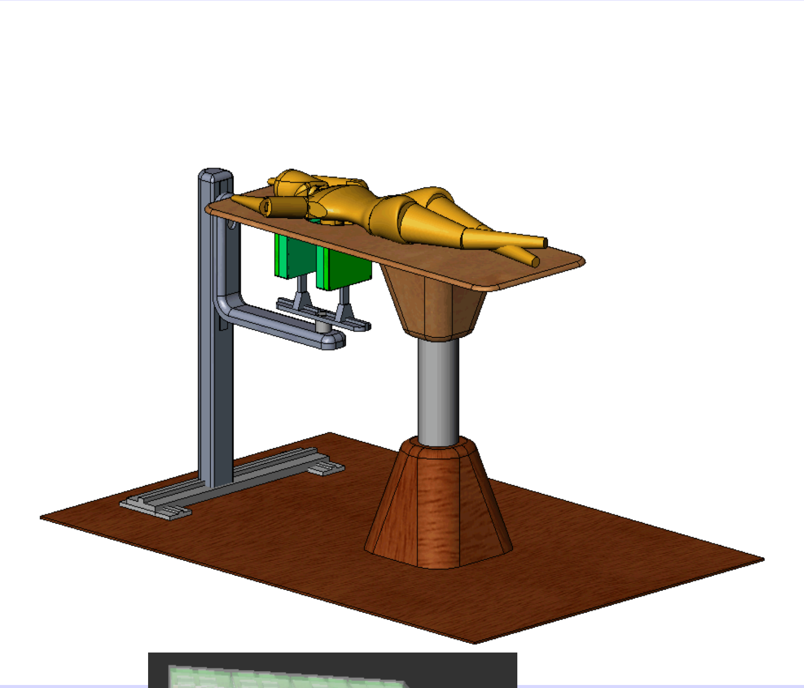

Brain Metabolism in Alzheimer's Disease: PET Scan
Normal Brain
Alzheimer's Disease

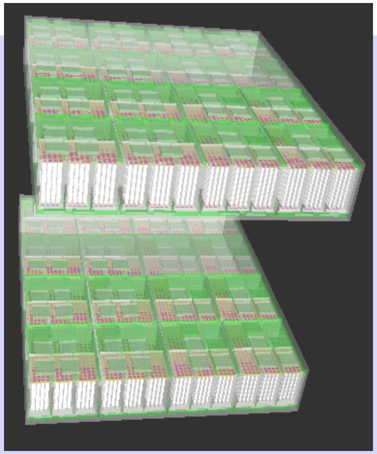
Crystal Clear Collaboration

- New scintillating materials
  - LuAP, phoswich LuAP-LSO (CERN patent)
  - Other crystals
- New photodetectors (Avalanche PhotoDiodes)
- New low noise electronics
- New intelligent DAQ systems with pipeline and parallel architectures
- better simulation GEANT 4
- better reconstruction algorithms



CRYSTAL CLEAR Collaboration (PEM)

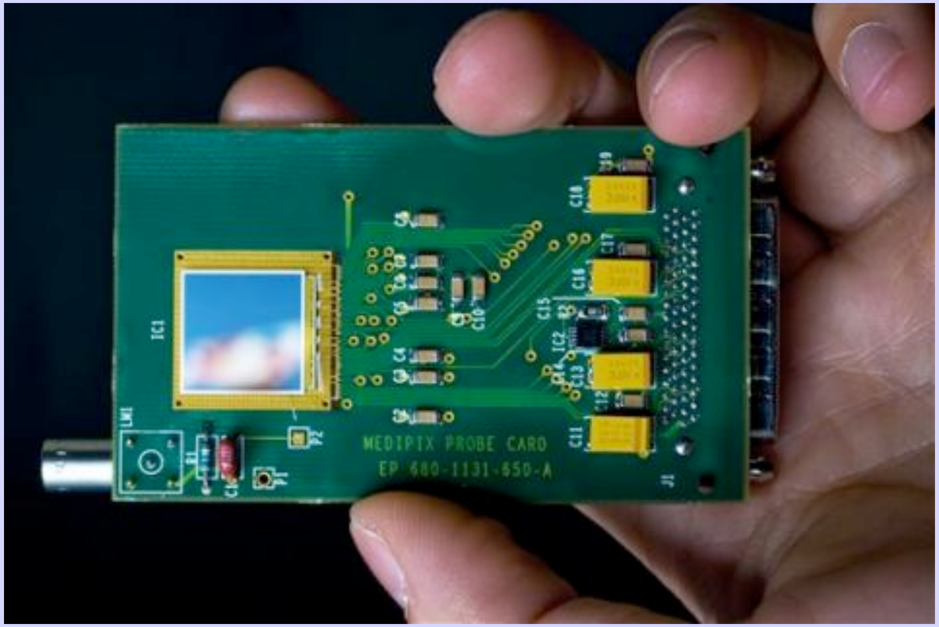




- PET dedicated to breast cancer screening
  - Extremely sensitive to small tumour masses
- Spatial resolution (1-2mm)
- High counting sensitivity
- Short PET exam
- Coupled to ultrasound

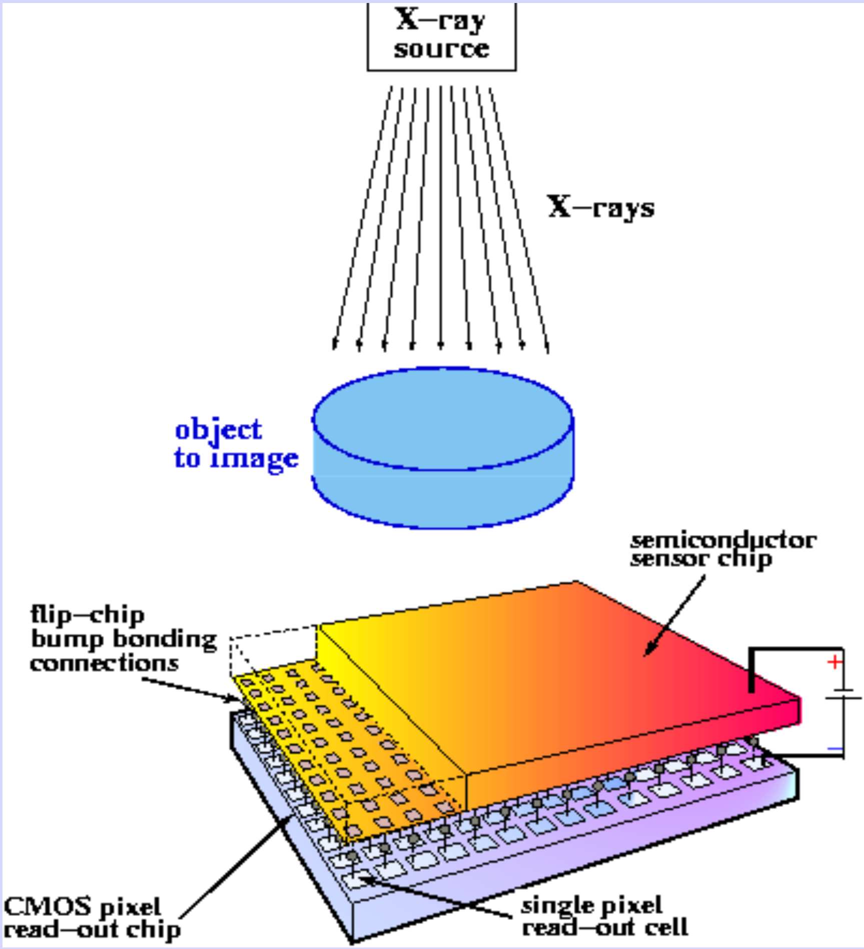
MEDIPIX

- High Energy Physics original development:
  - Particle track detectors
- Allows counting of single photons in contrast to traditional charge integrating devices like film or CCD
- Main properties:
  - Fully digital device
  - Very high space resolution
  - Very fast photon counting
  - Good conversion efficiency of low energy X-rays



What is Medipix?

- an electronic chip similar to the electronic imaging chip in a digital camera
  - sensitive to x-rays instead of visible light.
- it can create the first true colour images with x-rays.
  - it permits us to move from black and white x-ray images to full colour x-ray images.
- can be read out very rapidly.
  - allows the use of the chip for colour x-ray digital movies or for fast colour x-ray CT scans



A changing tide: digital imaging

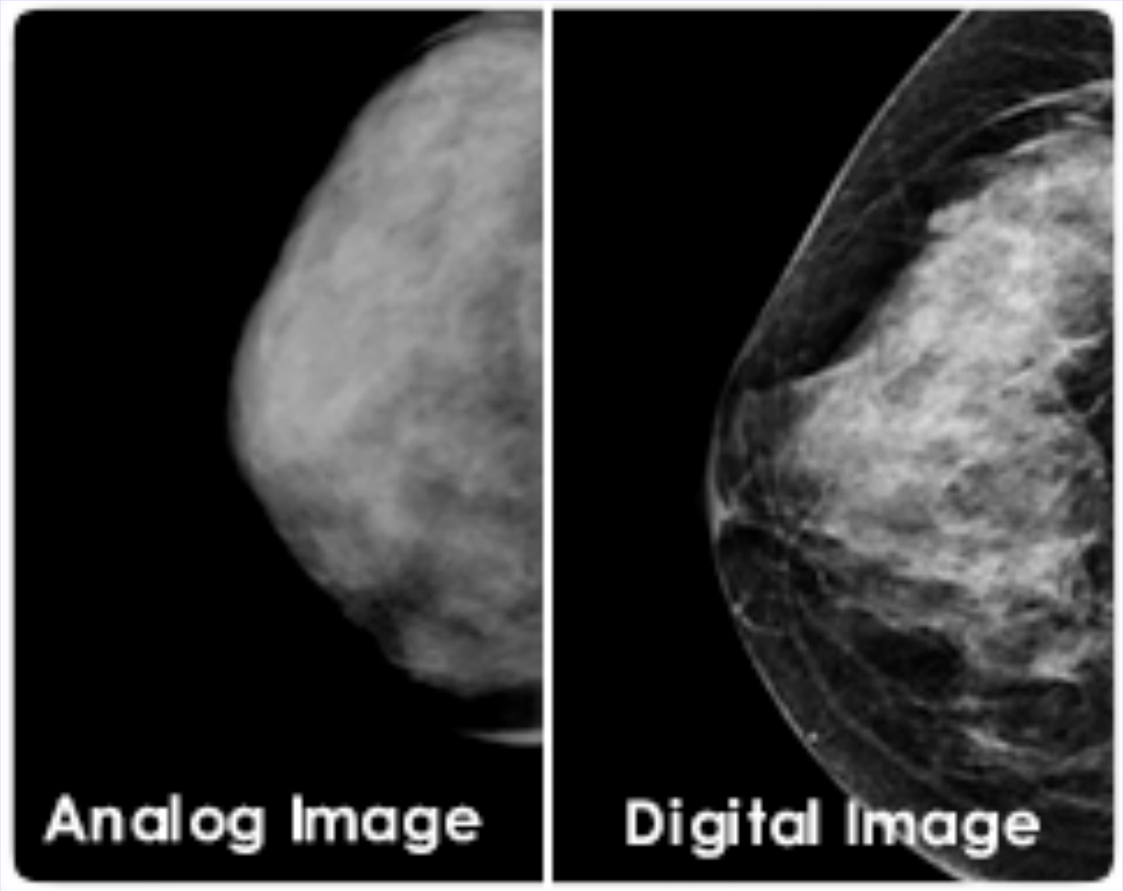
Current

- Limited contrast
- High dose
  - Restricted screening
  - Limited access to preventive health care

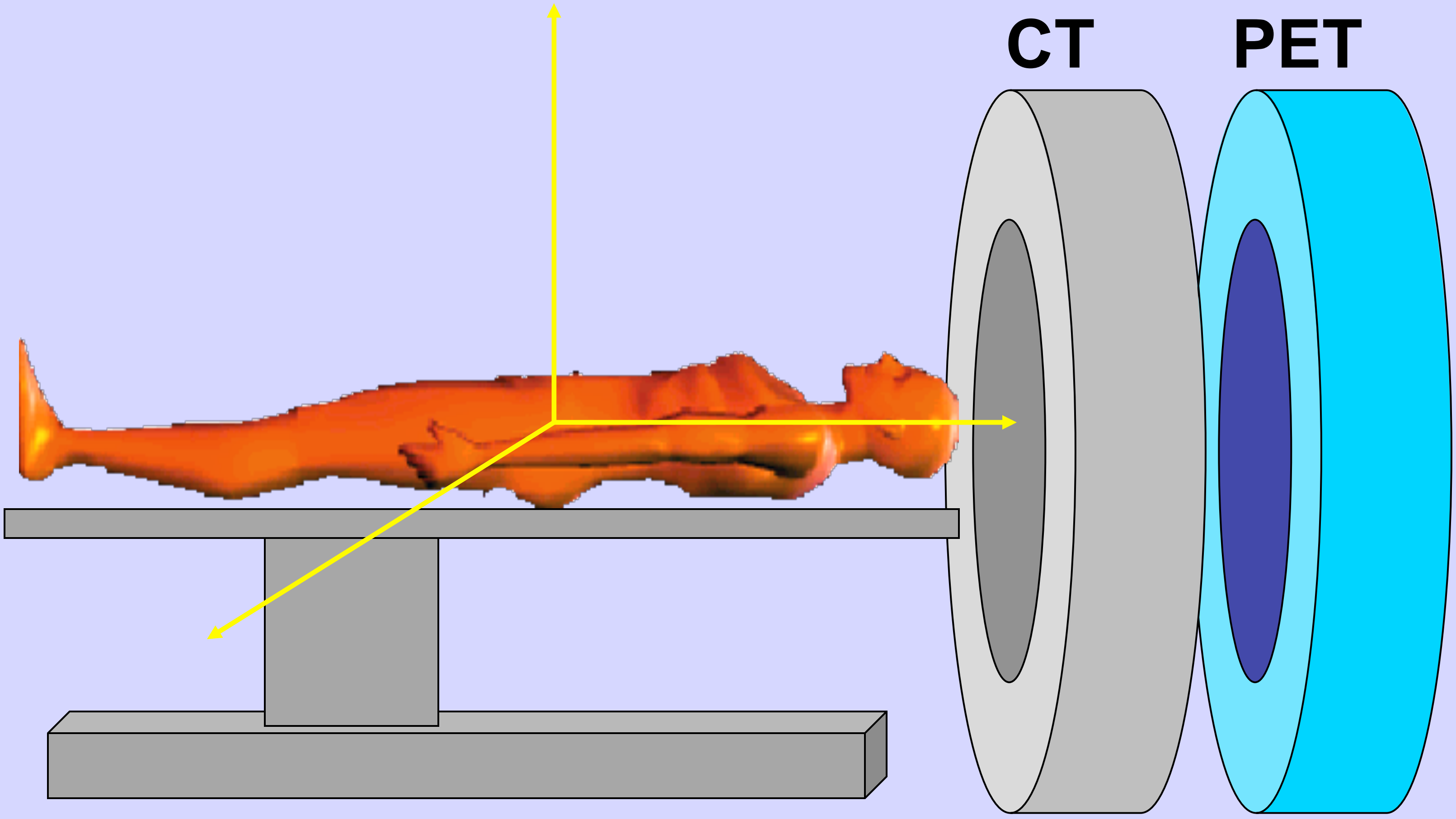
Digital

- High contrast
- Lower dose
  - Opportunity for screening
  - Access to preventive health care

Towards digital imaging

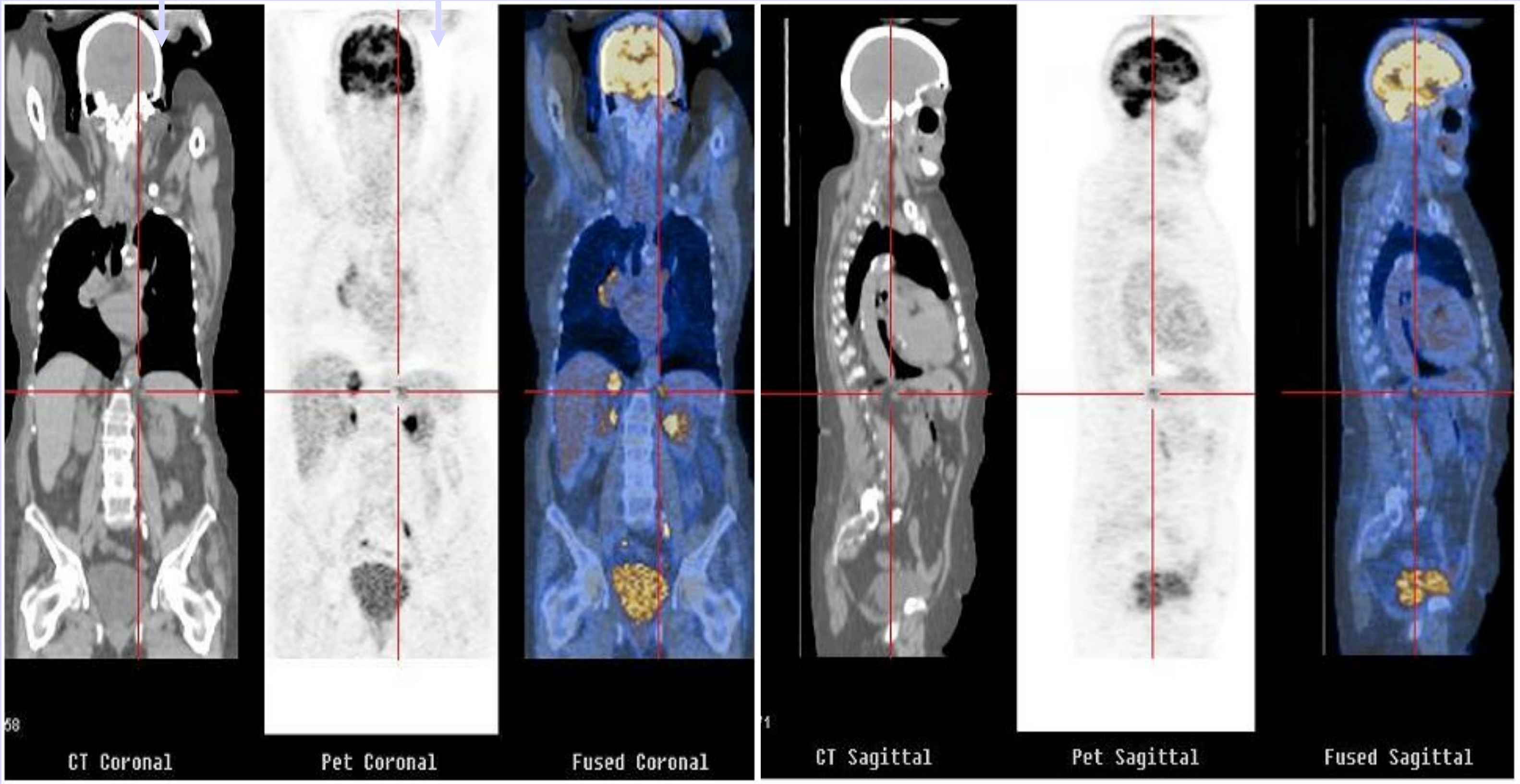


Towards multimodality imaging
(PET-CT - *David Townsend)*

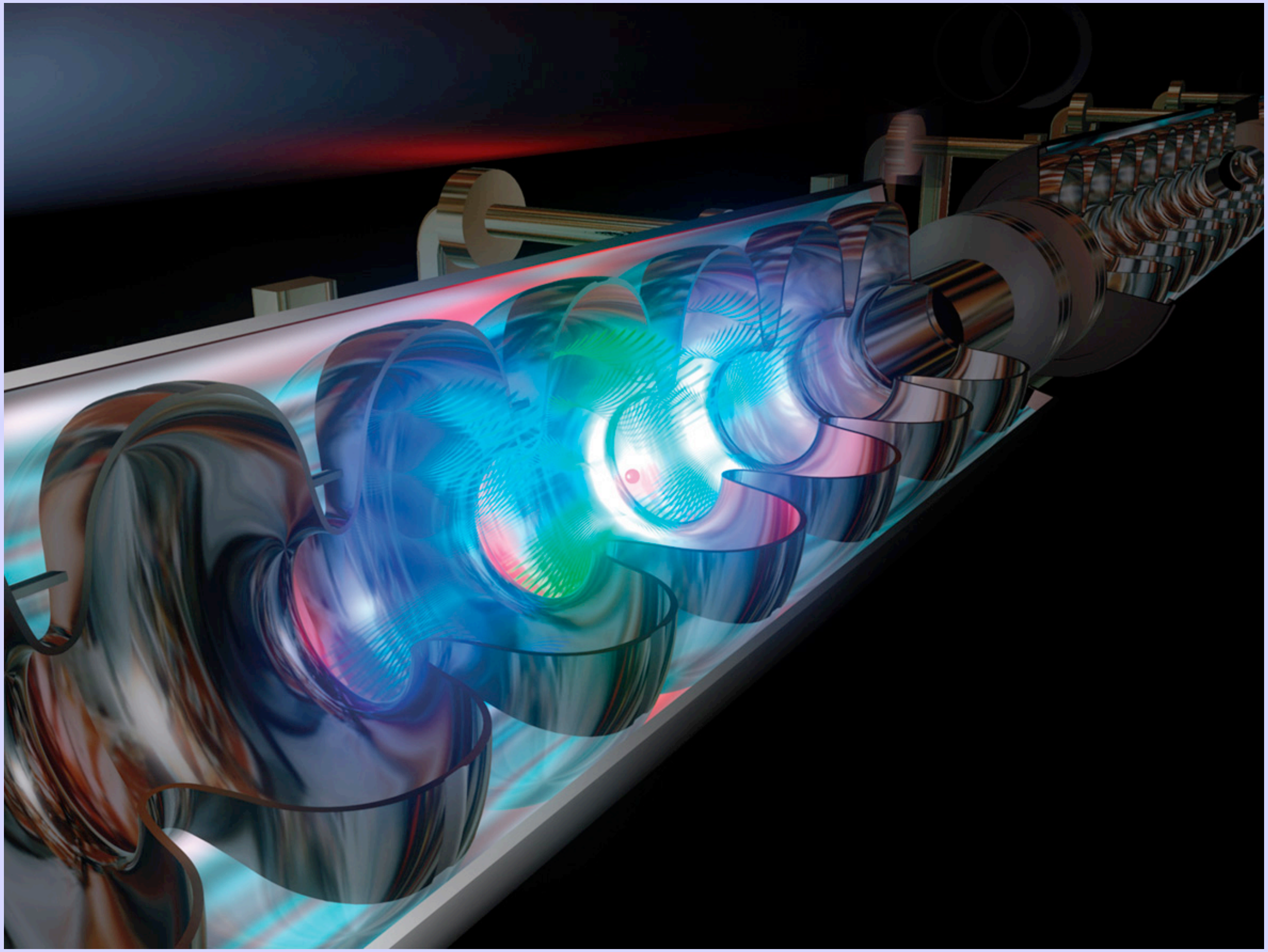


Multimodality imaging: CT with PET

morphology **metabolism**

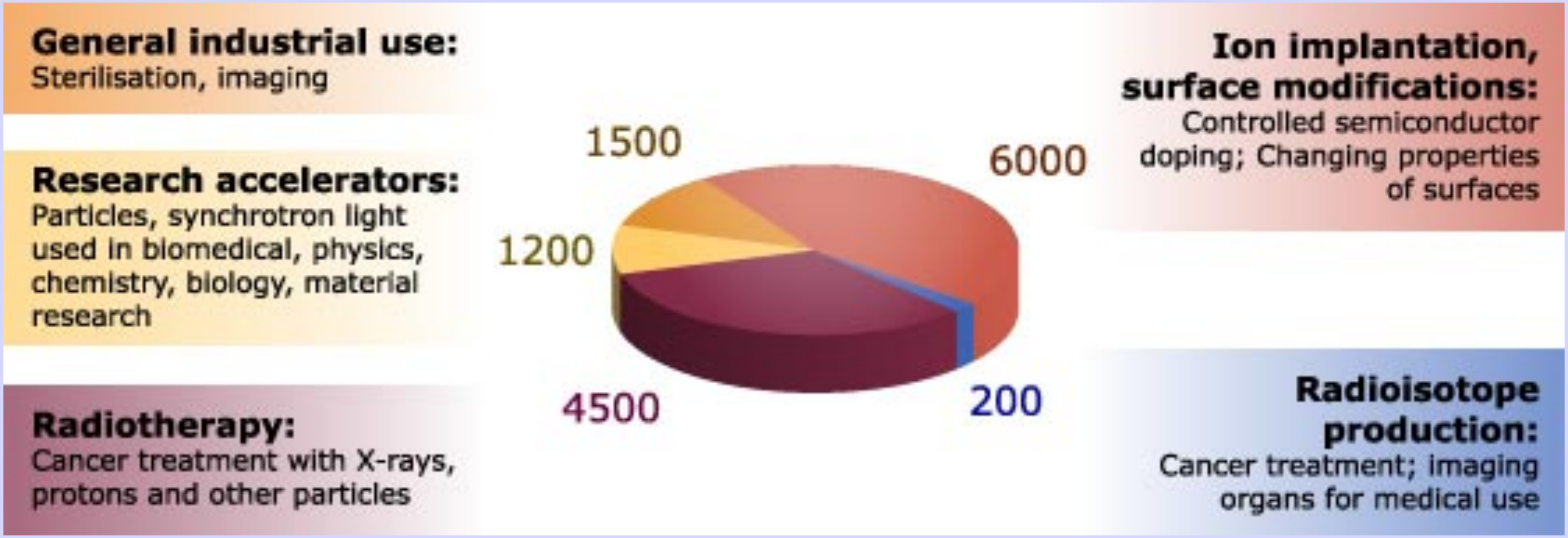


Accelerators for cancer treatment



Manjit Dosanjh, Teachers, 23 July 2014

Use of Accelerators Today



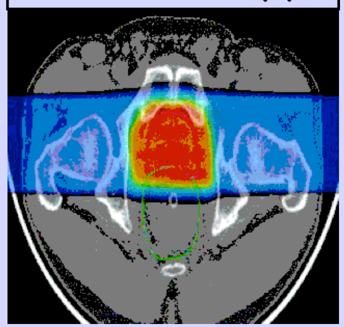
Cancer – a growing societal challenge!

Over 3 million cancer cases in Europe each year

Surgery

Local control

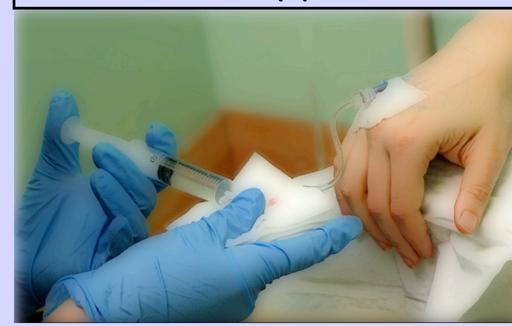
Radiotherapy



X-ray, IMRT, Brachytherapy, Hadrontherapy

Local control

Chemotherapy & others

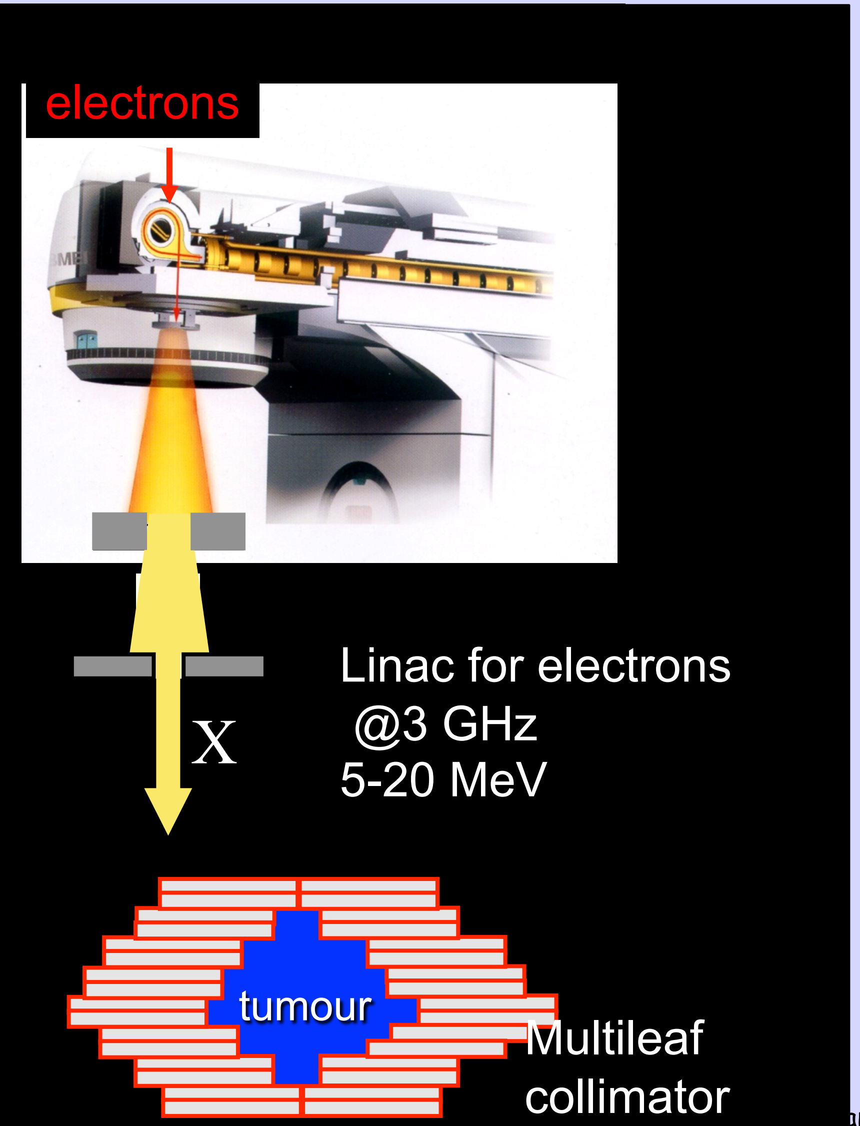


Hormones; Immunotherapy; Cell therapy; Genetic treatments; Novel specific targets (genetics..)

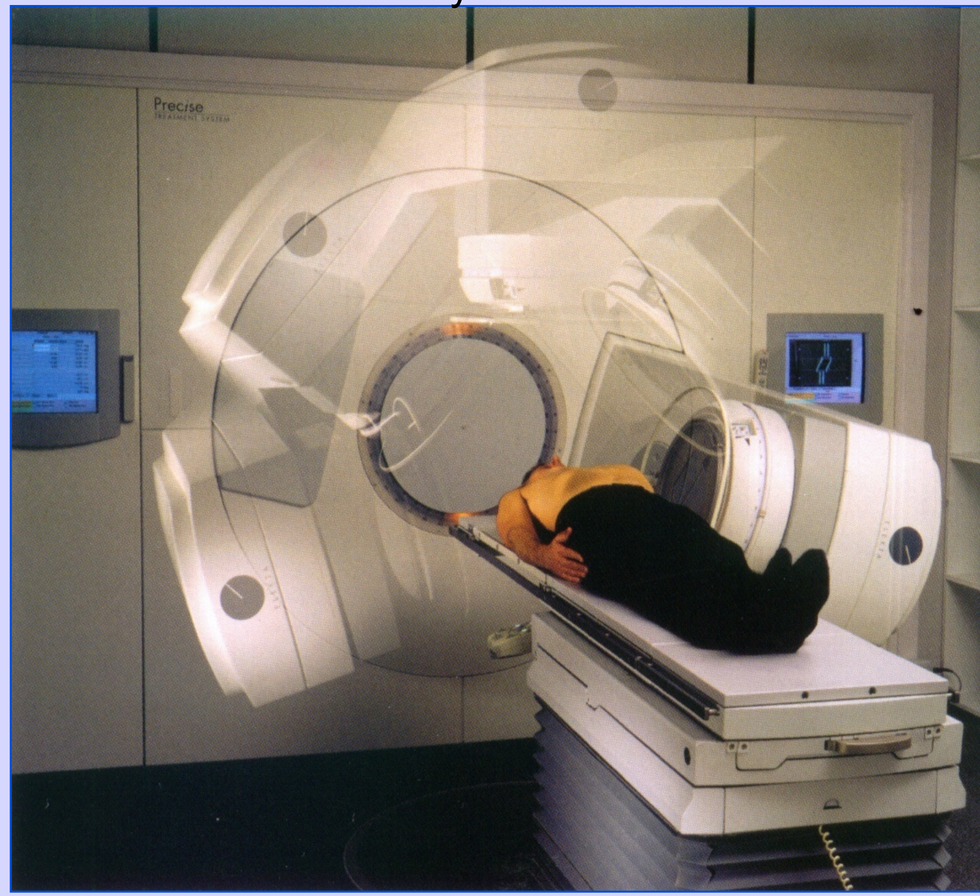
Limited Local control

Survival
Quality of life

'Conventional' radiotherapy: linear accelerators dominate



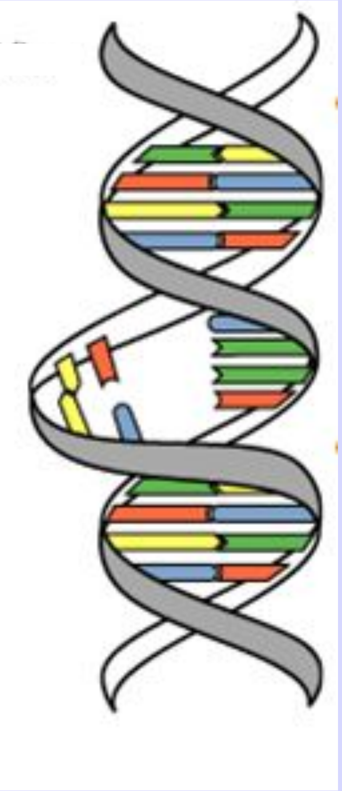
Courtesy of Elekta



20 000 patients per year every
10 million inhabitants

1 linac every <250,000 inhabitants

Radiotherapy in the 21st century



3 "Cs" of Radiation

Cure (~ 45% cancer cases are cured)

Conservative (non-invasive, few side effects)

Cheap (~ 5% of total cost of cancer on radiation)

There is no substitute for RT in the near future

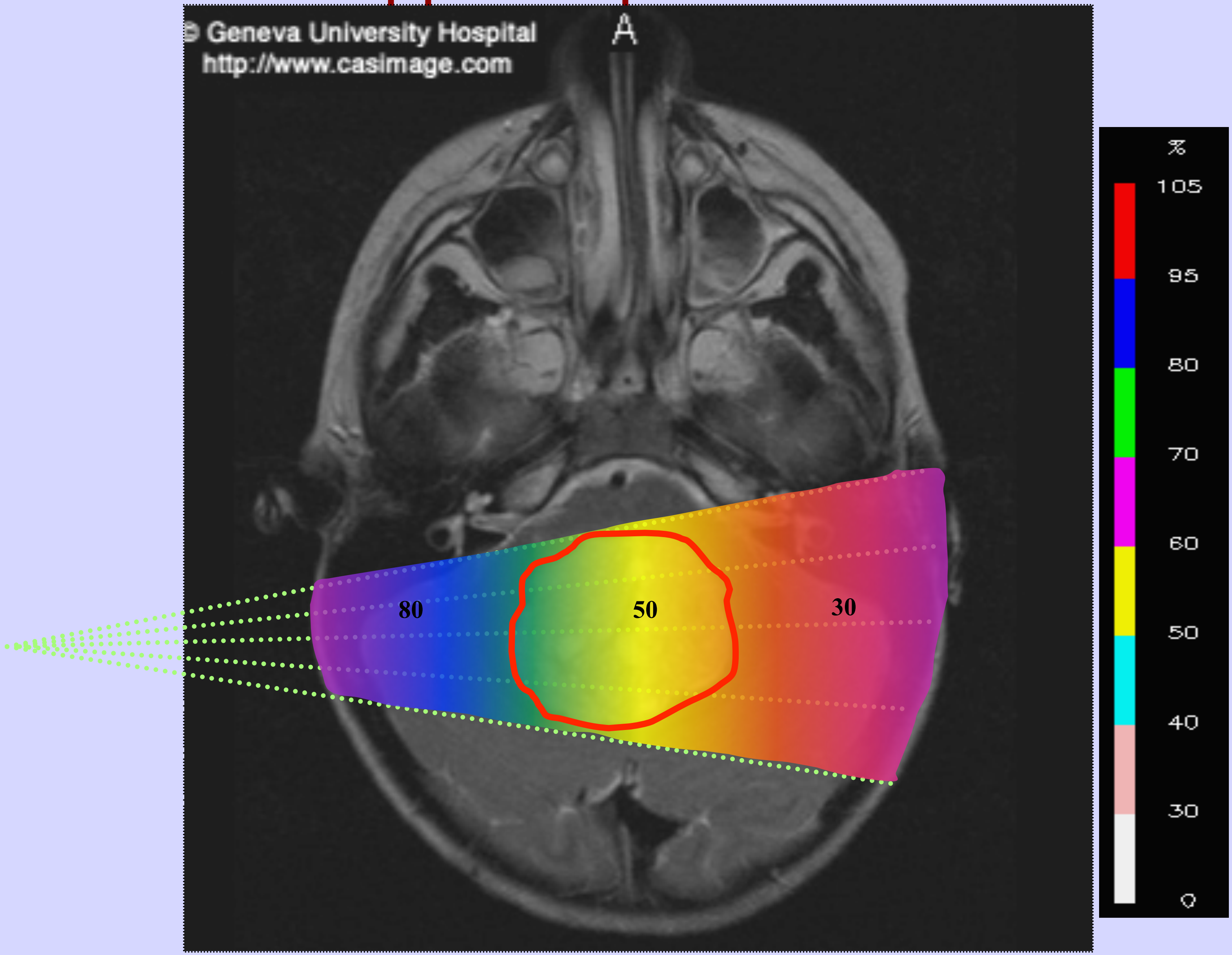
The rate of patients treated with RT is increasing

Present Limitation of RT:

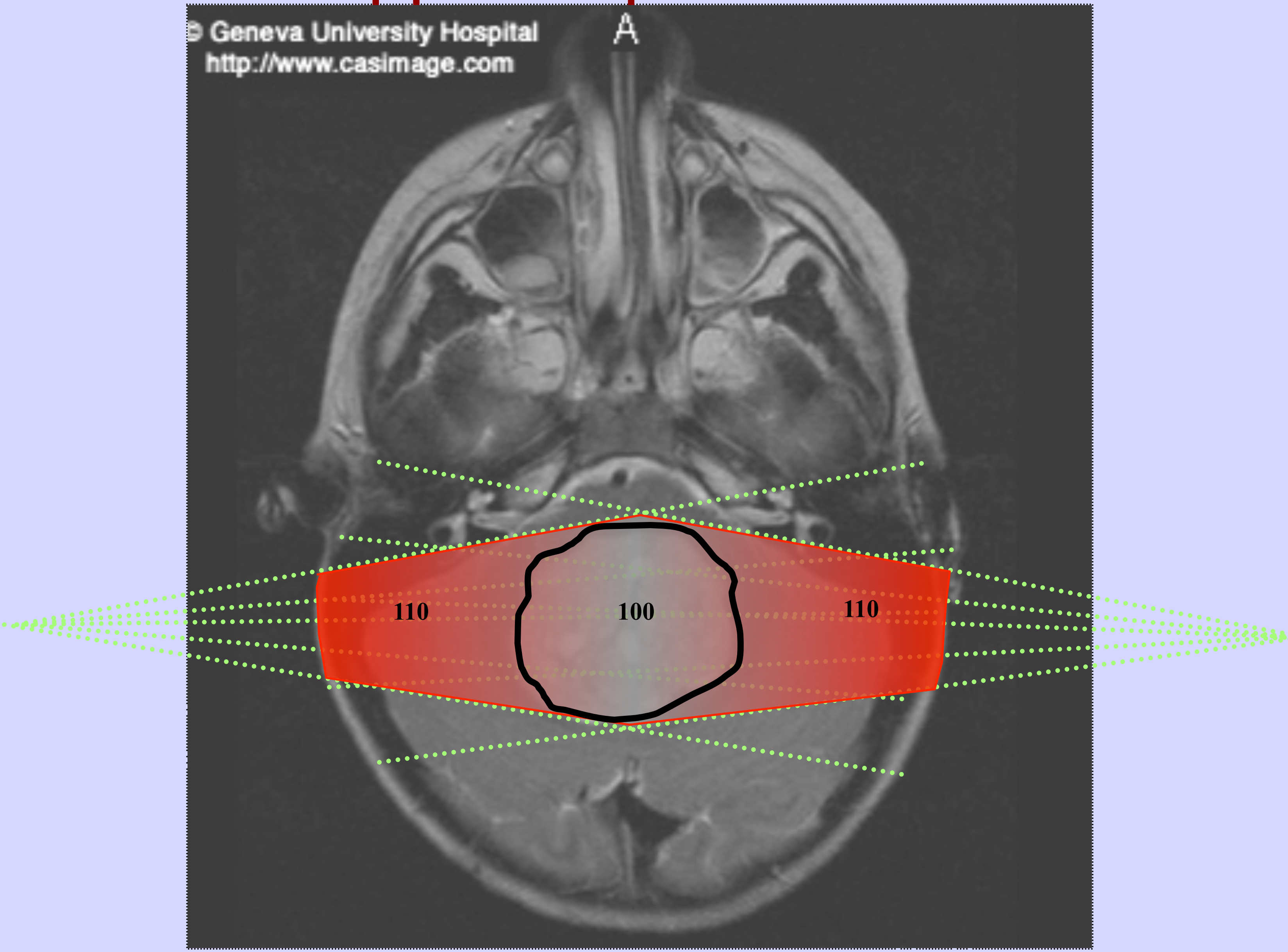
~30% of patients treatment fails locally

(J.P.Gérard)

Two opposite photon beams



Two opposite photon beams



How to decrease failure rate?

- Accelerator technologies to improve treatment: higher dose
- Detectors/imaging: accuracy, multimodality, real-time, organ motion
- Biology: fractionation, radio-resistance, radio-sensitization
- Data: storage, analysis and sharing
- Collaboration in this multidisciplinary field is key

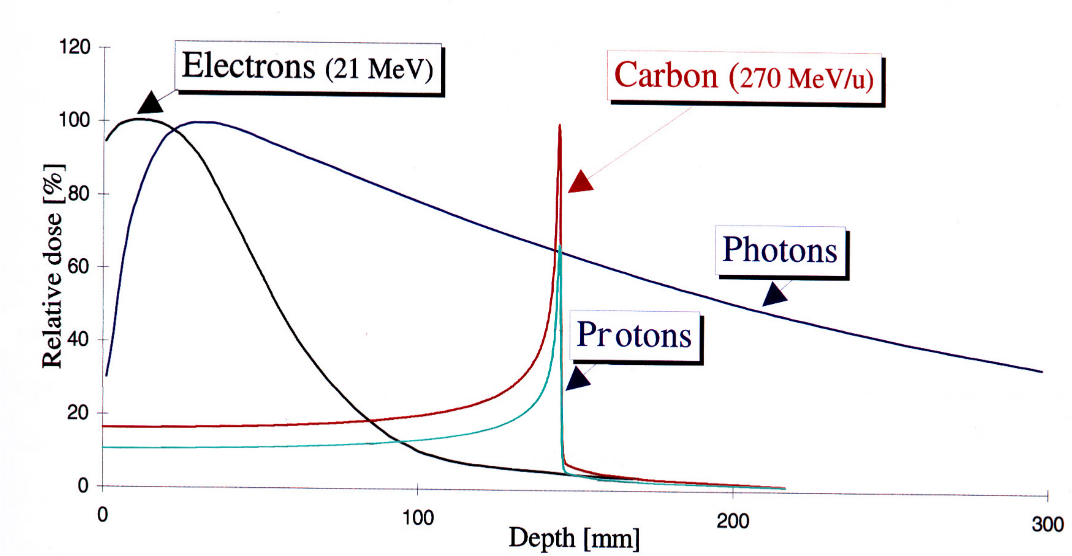
Raymond Miralbell, HUG

Hadrontherapy: all started in 1946

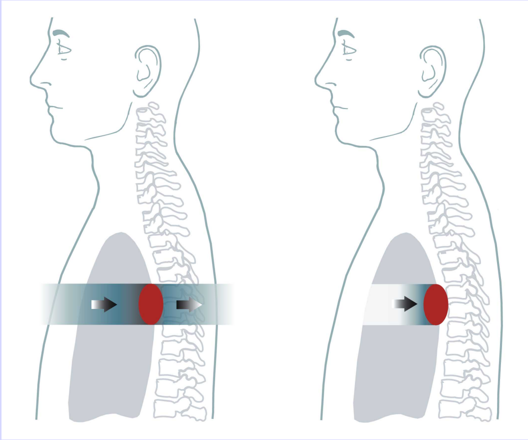
In 1946 Robert Wilson:

- **Protons can be used clinically**
- **Accelerators are available**
- **Maximum radiation dose can be placed into the tumour**
- **Particle therapy provides sparing of normal tissues**

- Tumours near critical organs
- Tumours in children
- Radio-resistant tumours

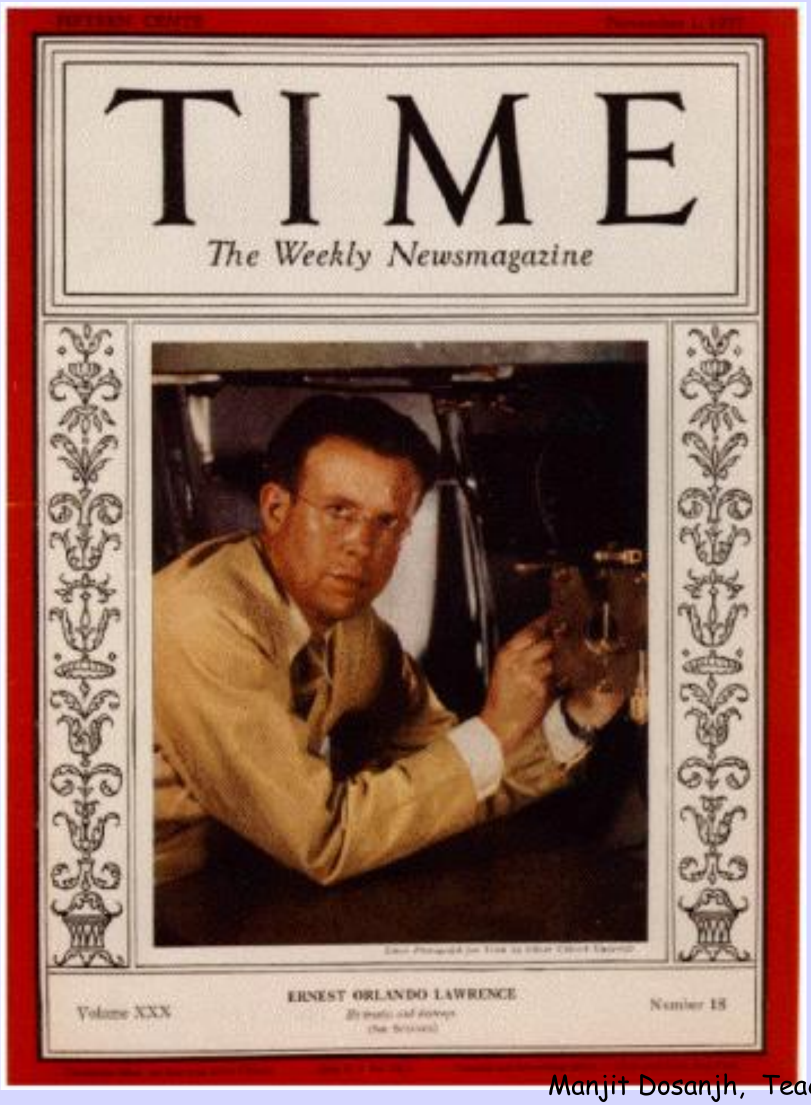


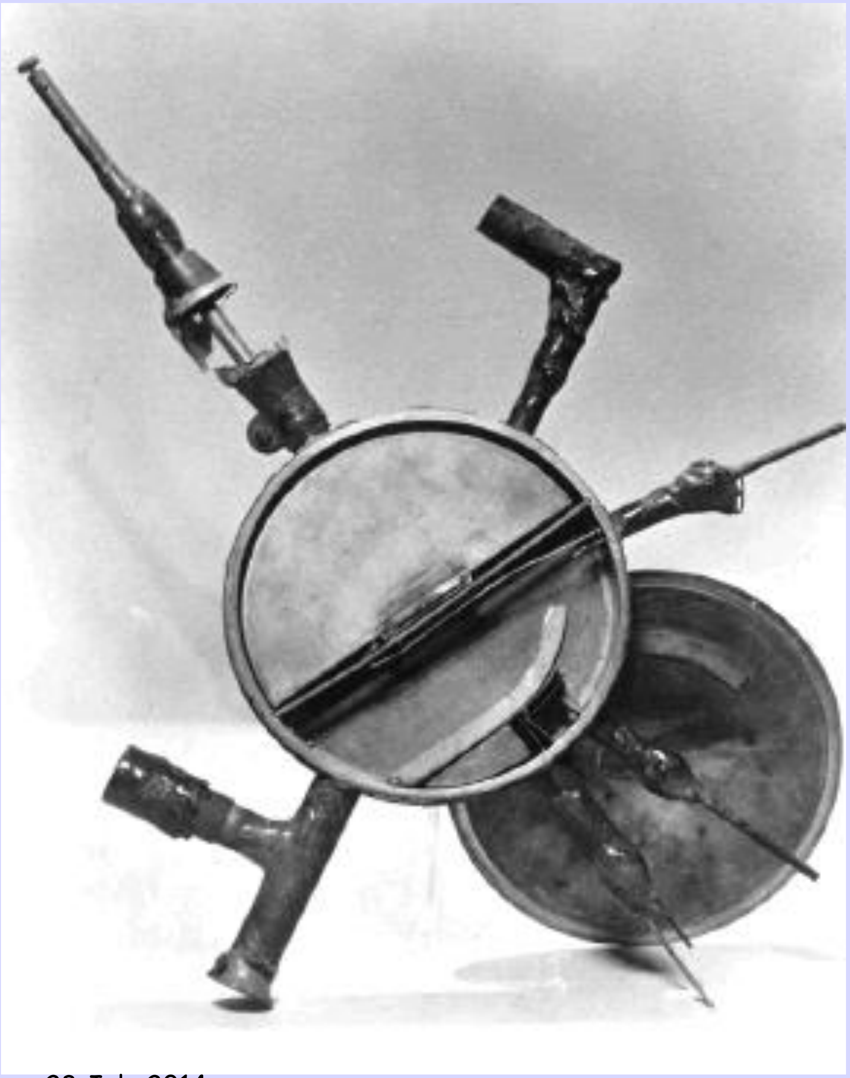
Depth in the body (mm)



Conventional: X-Rays
Ion Radiation

E. O. Lawrence is awarded Nobel Prize in 1939 for inventing the cyclotron

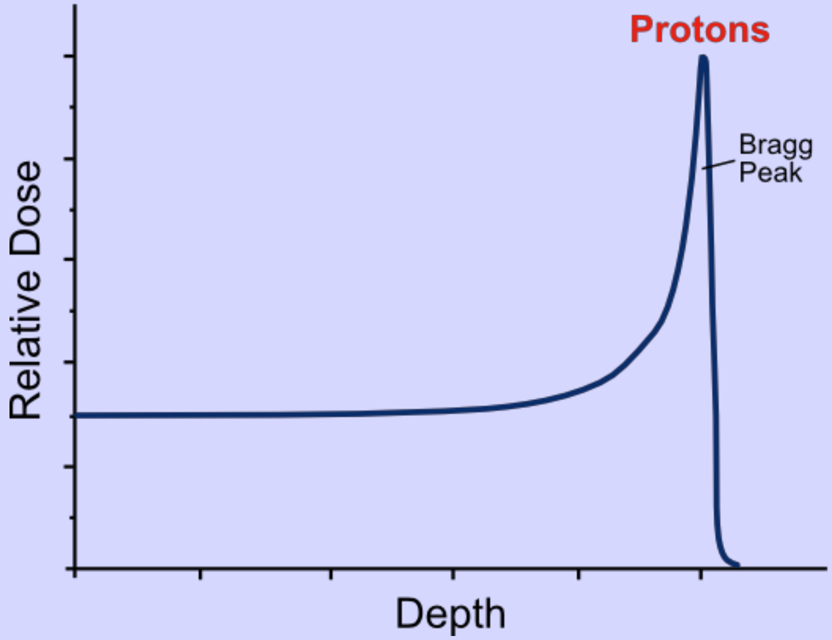




Hadron Therapy

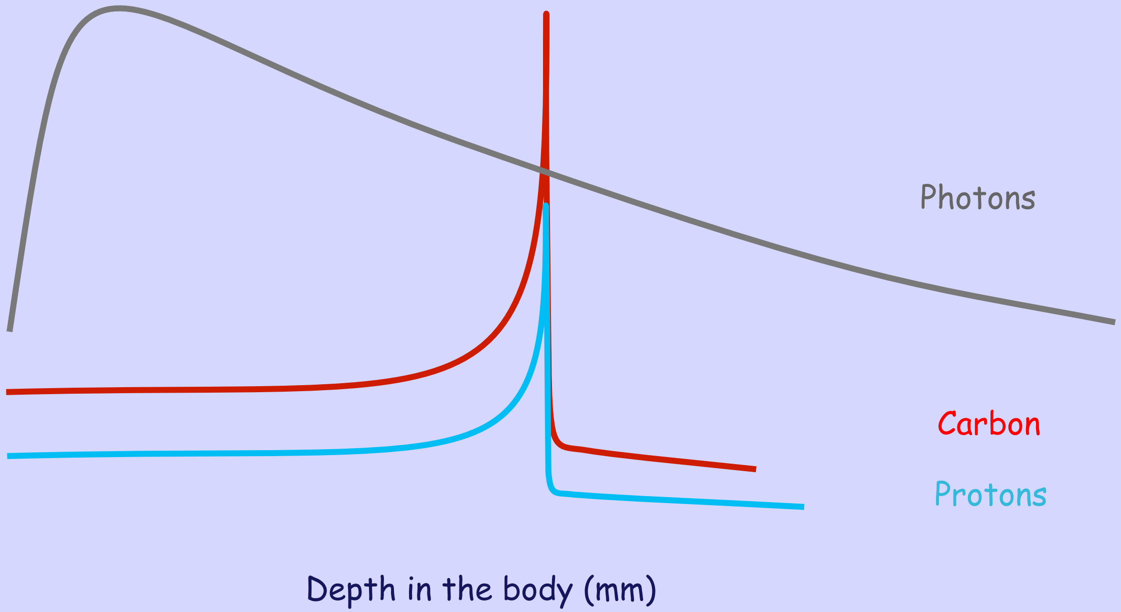
- 1946: Robert Wilson

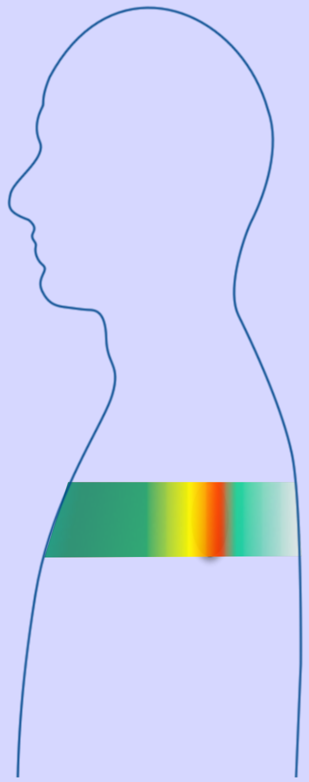
  Protons can be used clinically



Robert Wilson

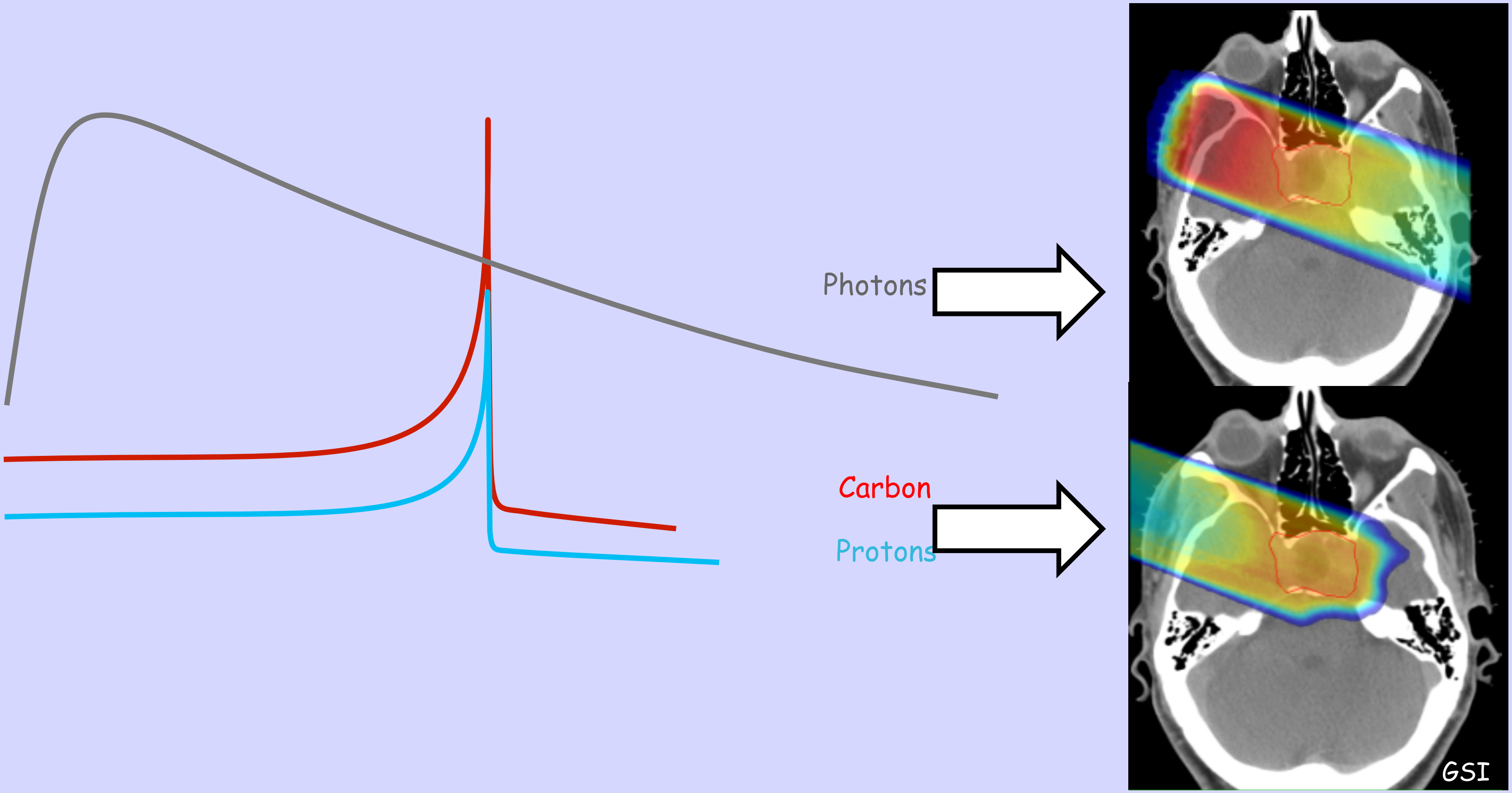
Why hadron therapy





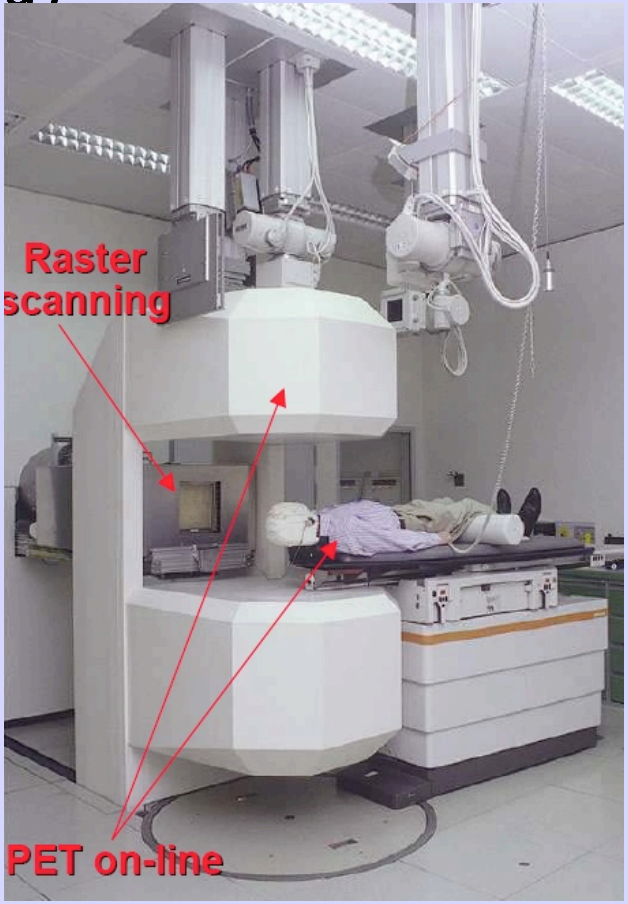
Tumours near critical organs
Tumours in children
Radio-resistant tumours

Photons vs. Hadrons

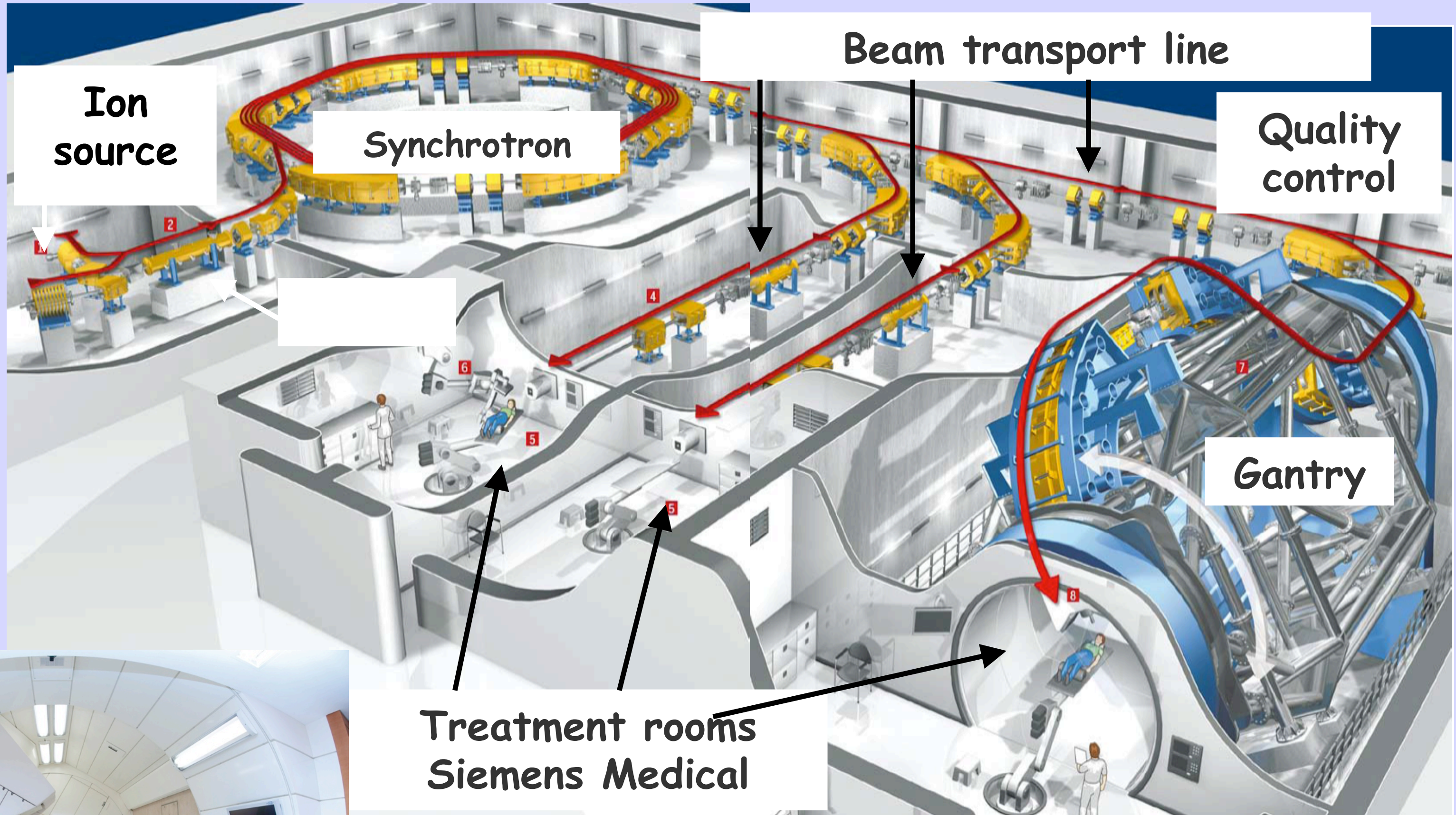


Carbon ions: pilot project in Europe

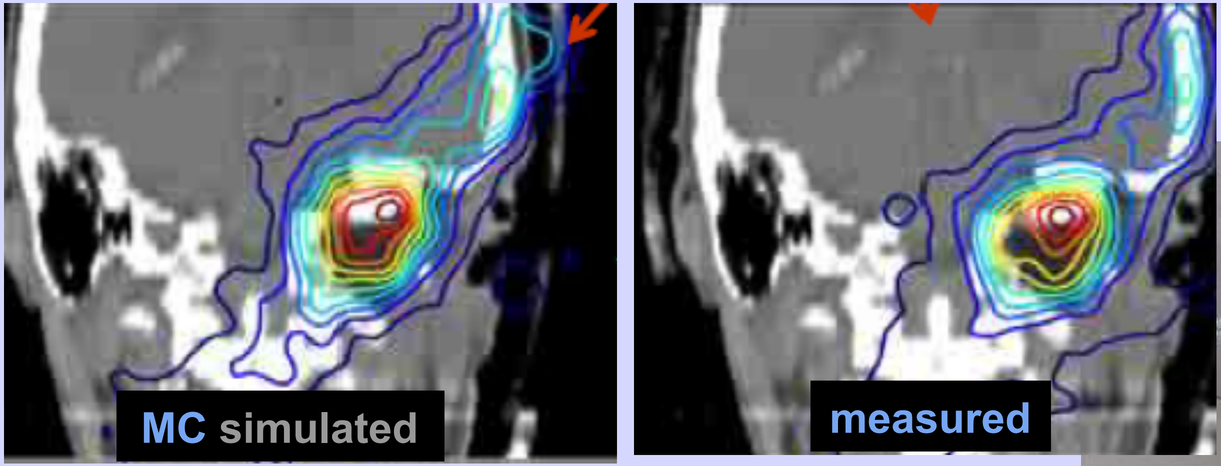
- GSI – Darmstadt (1997 – 2008)
- G. Kraft (GSI) & J. Debus (Heidelberg)
  - 450 patients treated with carbon ions



HIT - Heidelberg



Real time monitoring



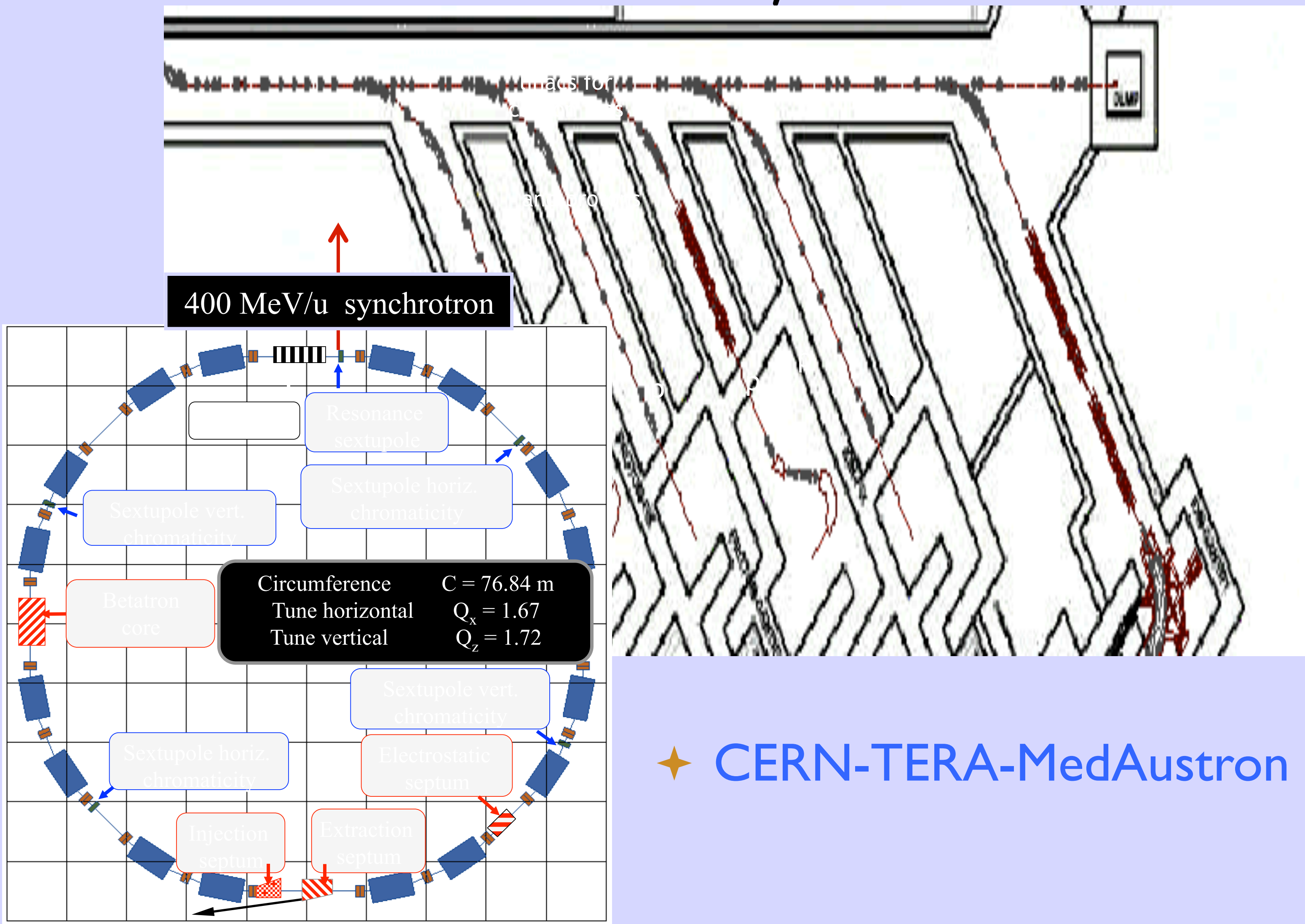
On-line determination of the dose delivered
First time in 110 years!

Modelling of beta^{+} emitters:

- Cross section
- Fragmentation cross section
- Prompt photon imaging
- Advance Monte Carlo codes

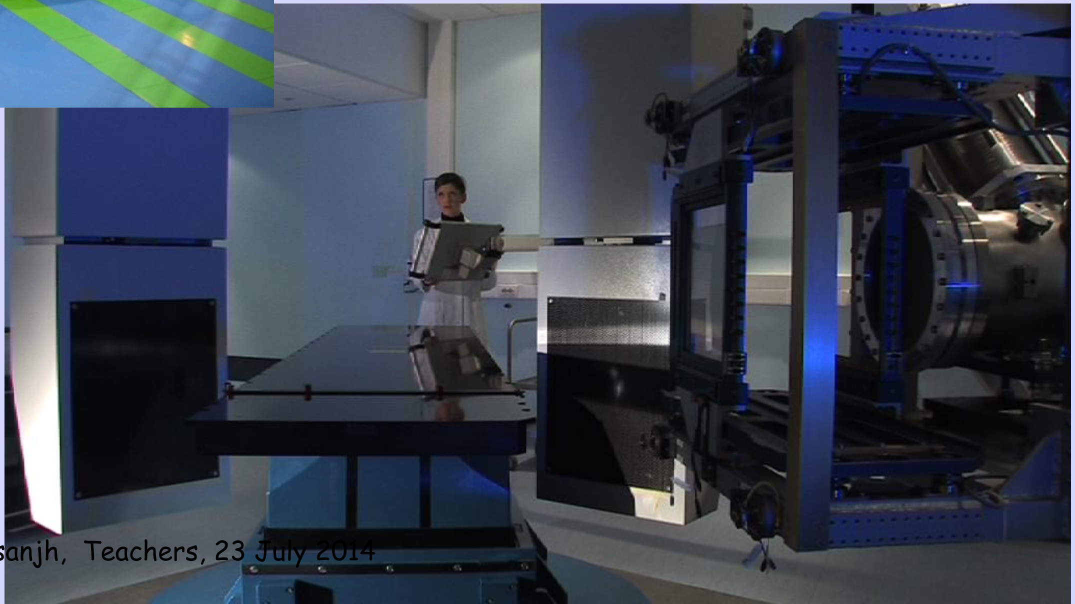
PIMMS at CERN (1996-2000)

- Proton Ion Medical Machine Study

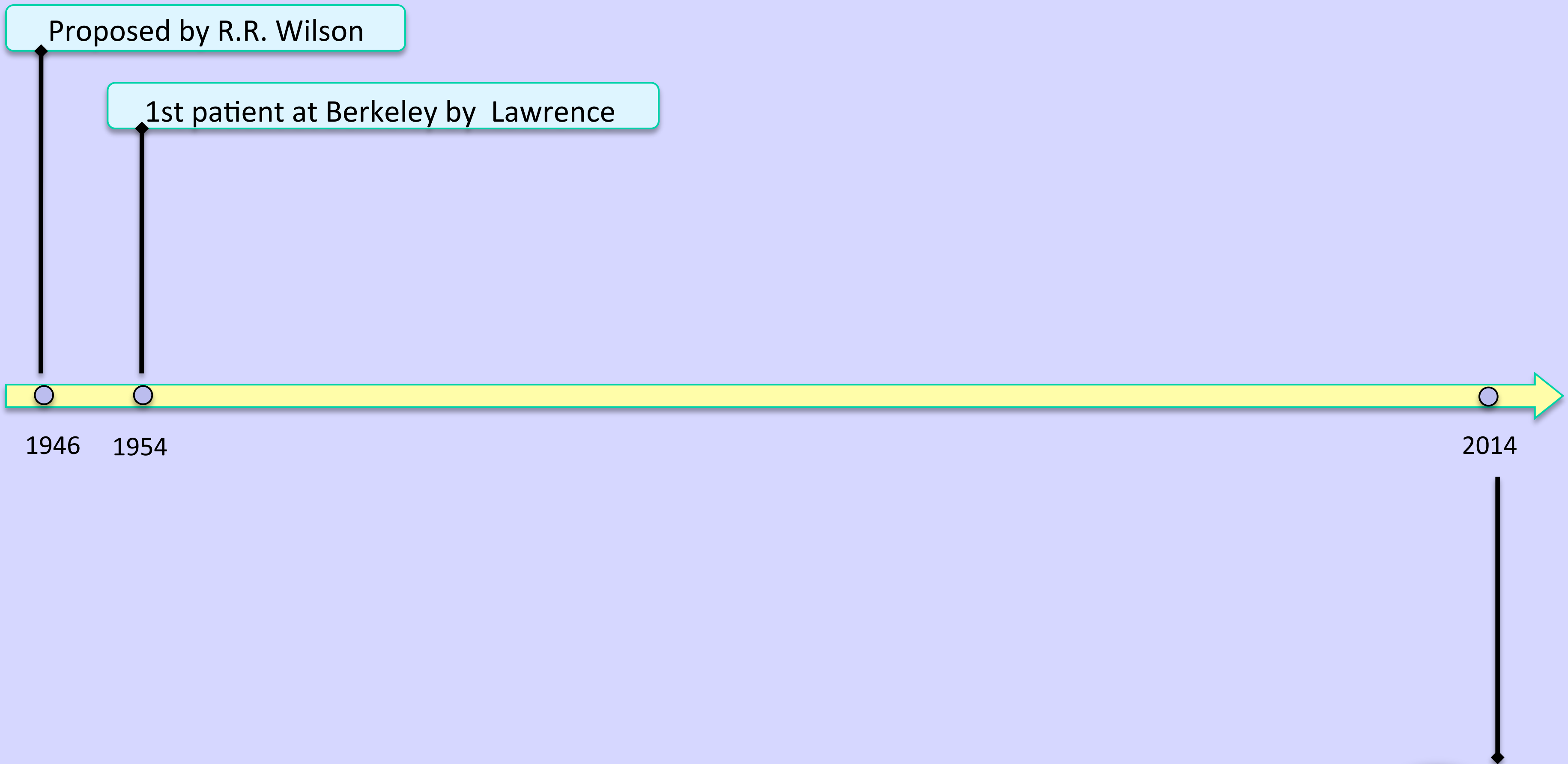


✦ CERN-TERA-MedAustron

CNAO – Italy (Pavia)

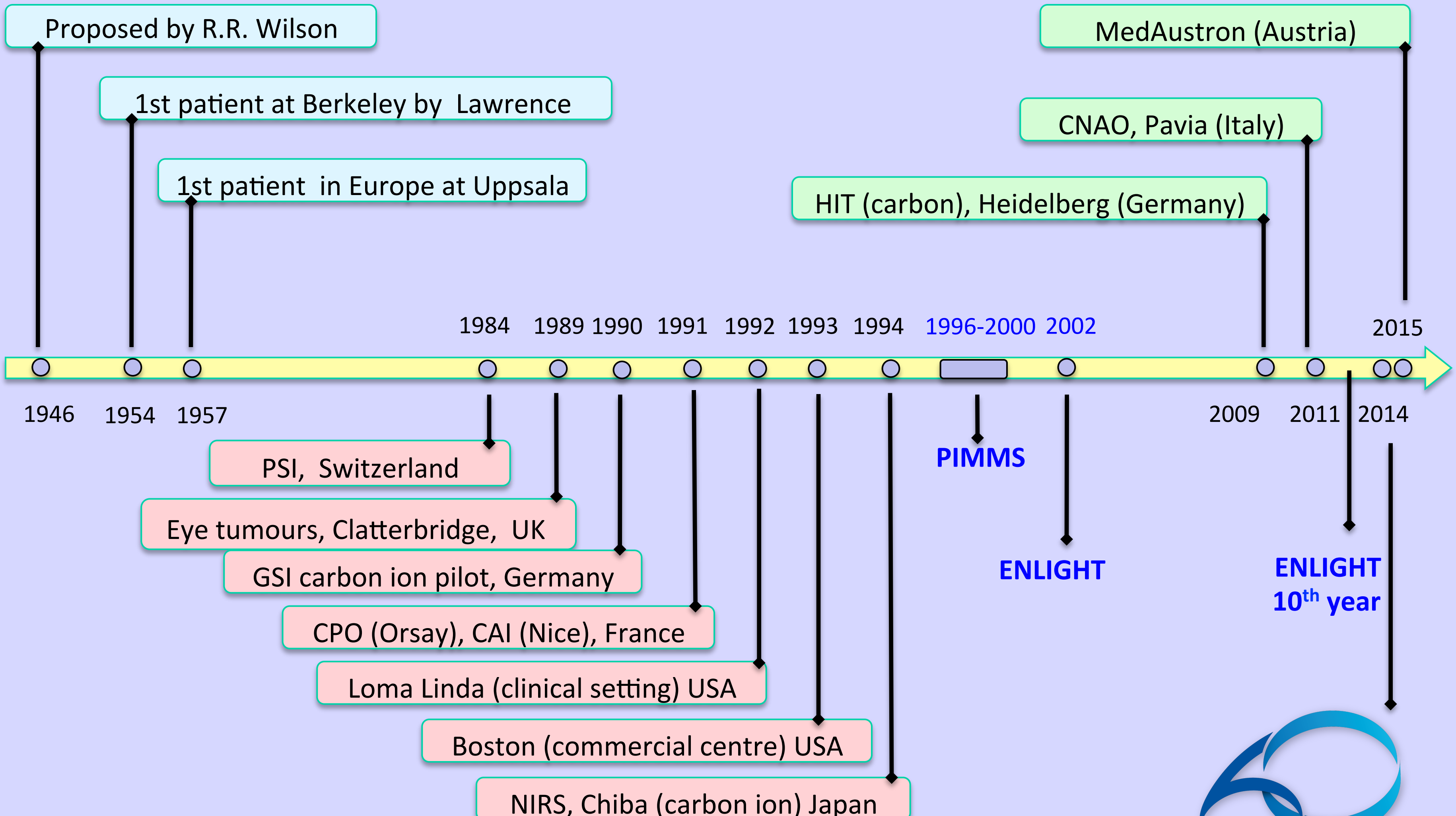


Hadrontherapy Timeline



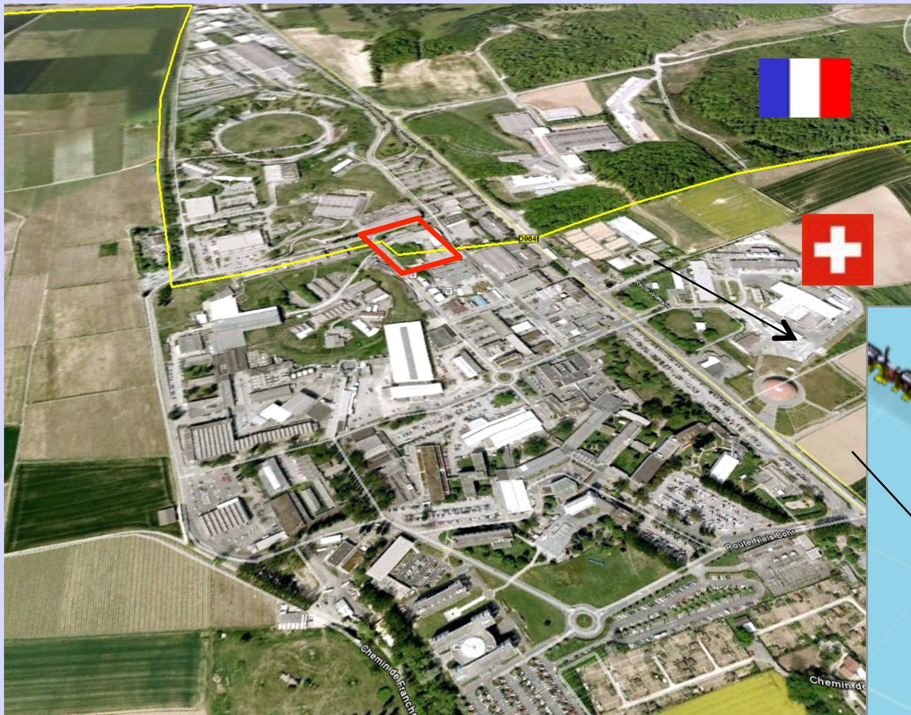
ÅR CERN

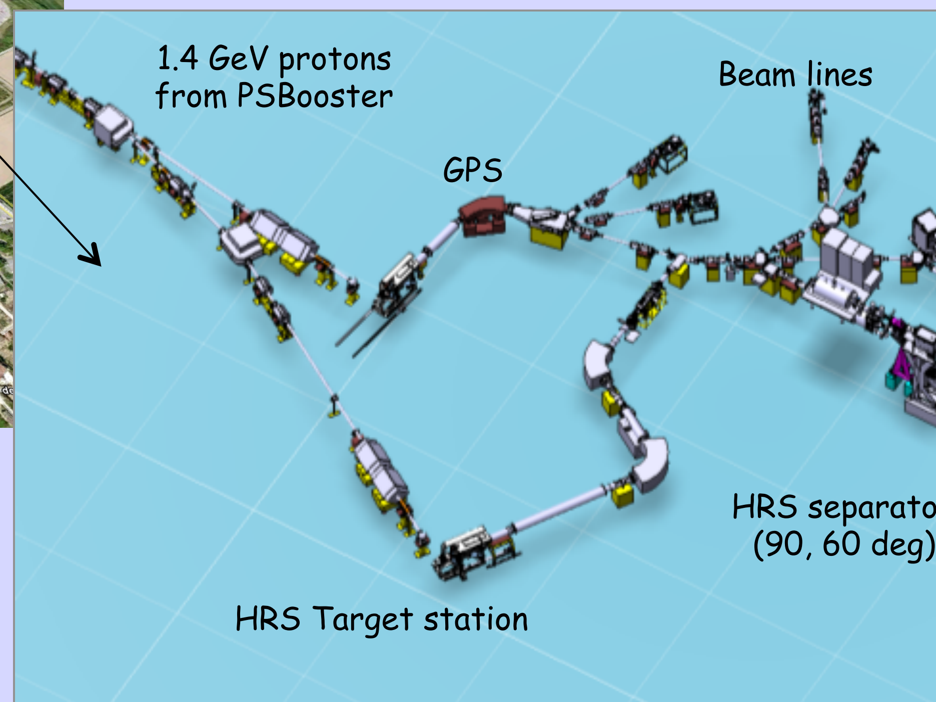
Hadrontherapy Timeline



ISOLDE

isotopes for detection & treatment

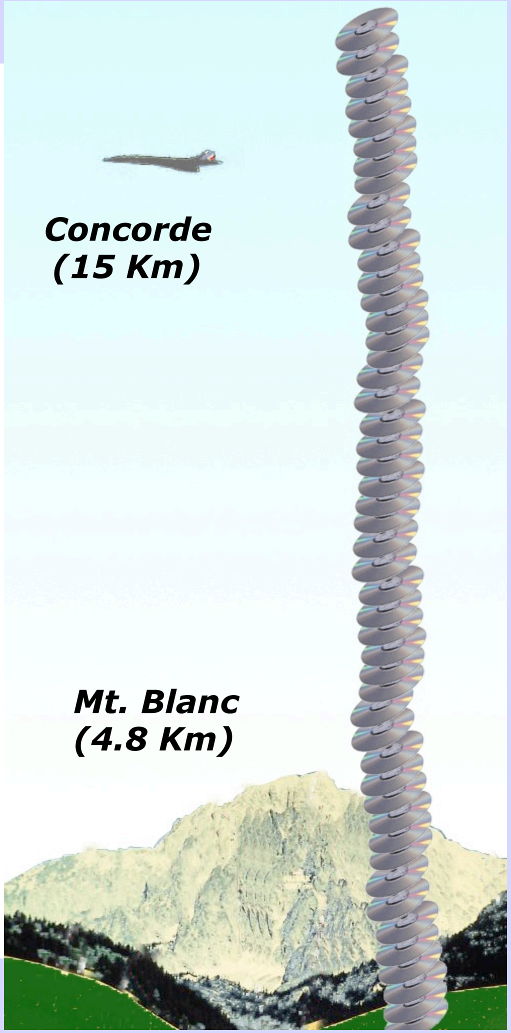




In collaboration with

University Hospital Geneva

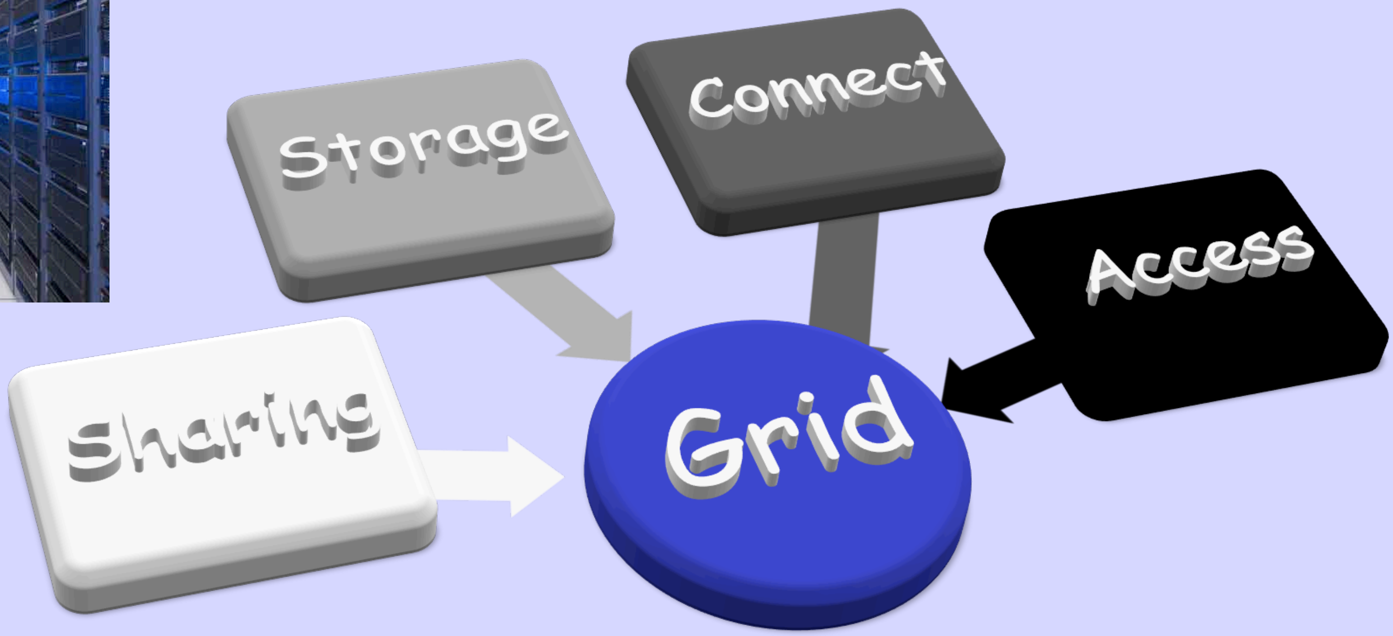
Computing for medical applications



www and grid

- WWW: sharing information
- GRID: sharing computing power

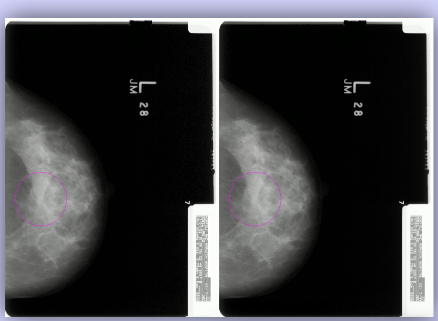
The Grid

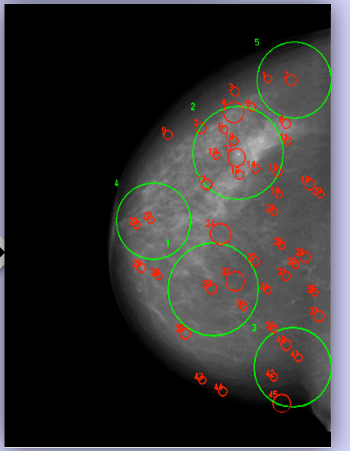


Data and Resources

Mammogrid – a grid mammography database

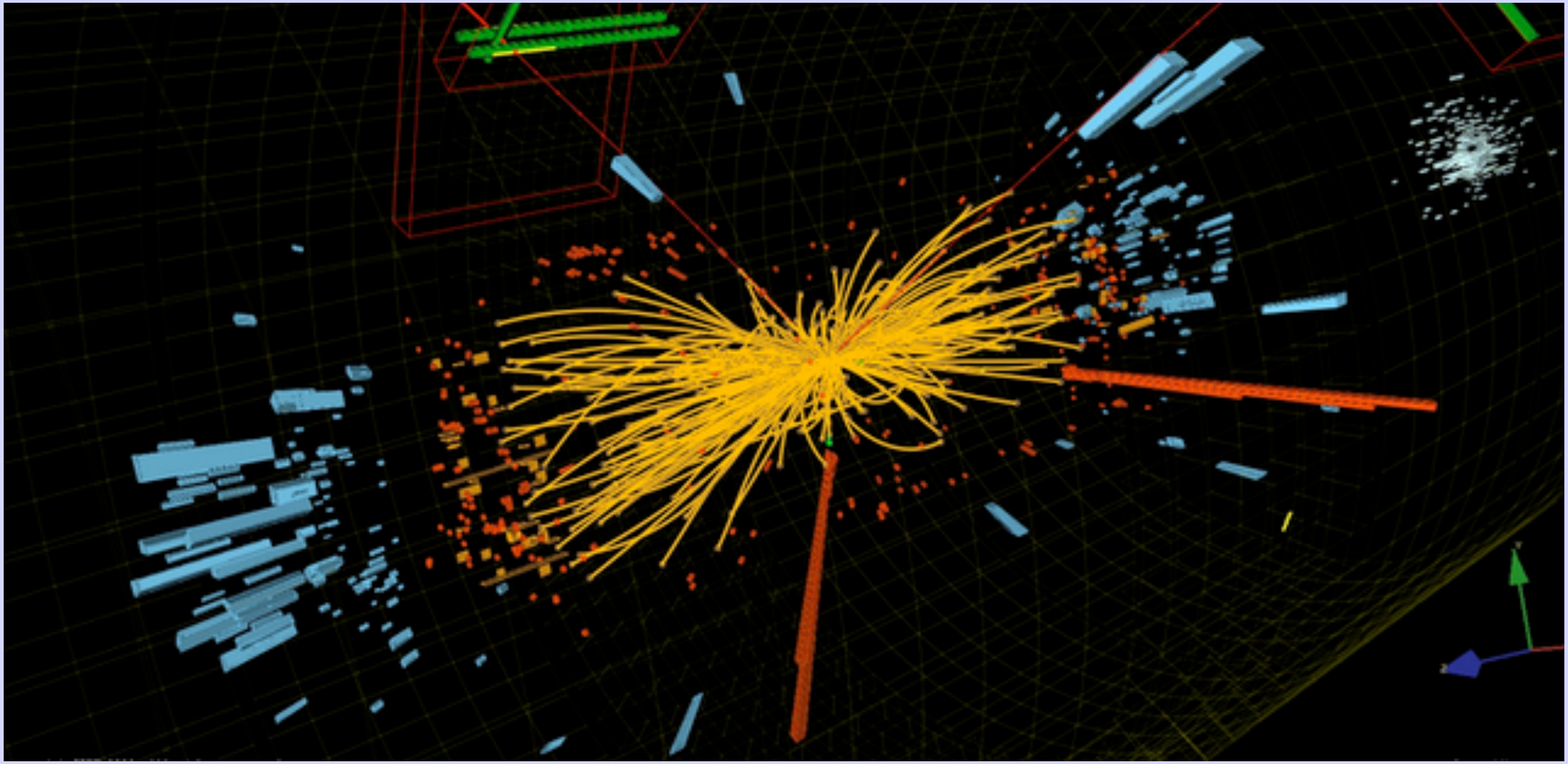
- Second Opinion
- Cancer Screening
- Education and Training
- Reference Database / Repository



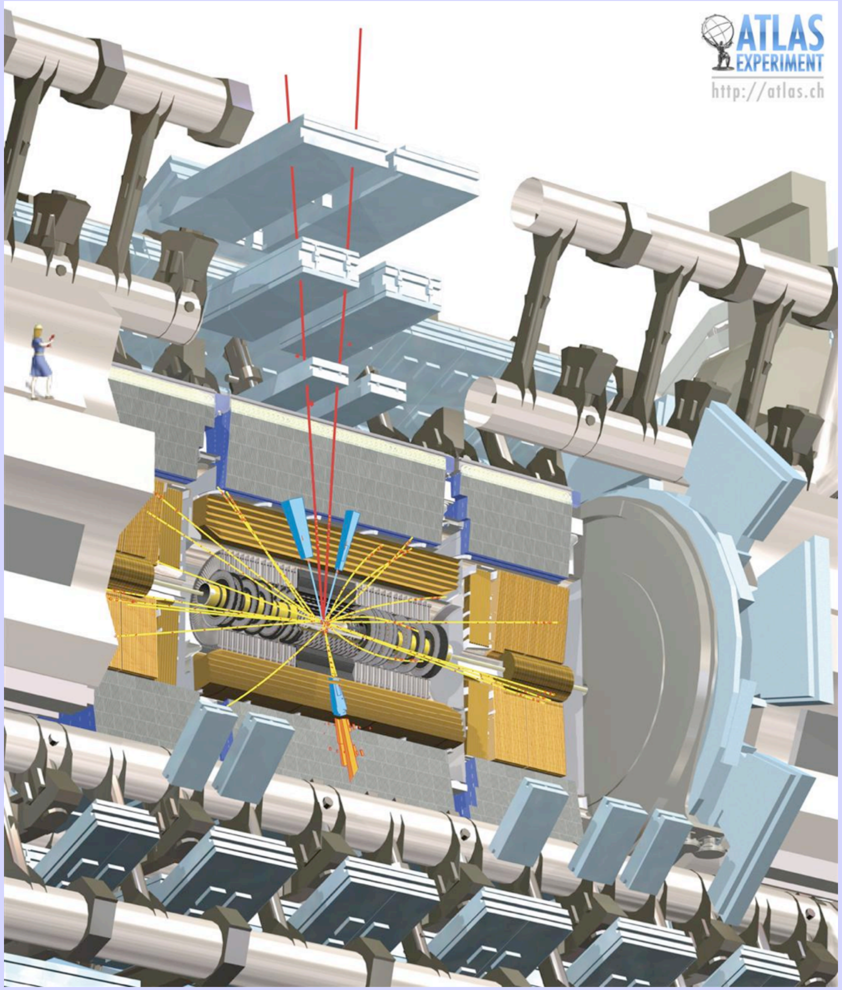


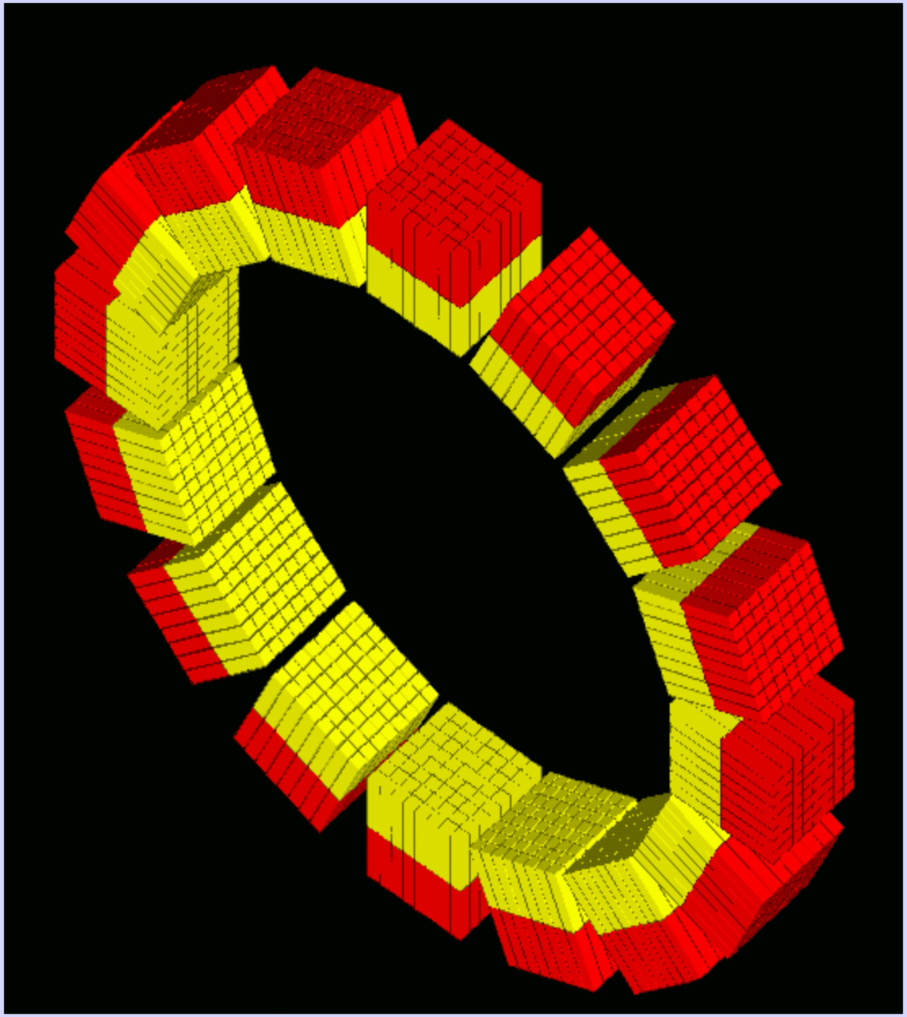
From: David MANSET, CEO MAAT France, www.maat-g.com

Simulation



Simulation





https://cds.cern.ch/record/1611721

References

- **cern.ch/crystalclear**
- **cern.ch/enlight**
- **cern.ch/medipix**
- **cern.ch/twiki/bin/view/AXIALPET**
- cern.ch/medaustron
- cern.ch/fluka/heart/rh.html
- www.fluka.org/fluka.php
- cern.ch/wwwasd/geant
- cern.ch/wwwasd/geant/tutorial/tutstart.html