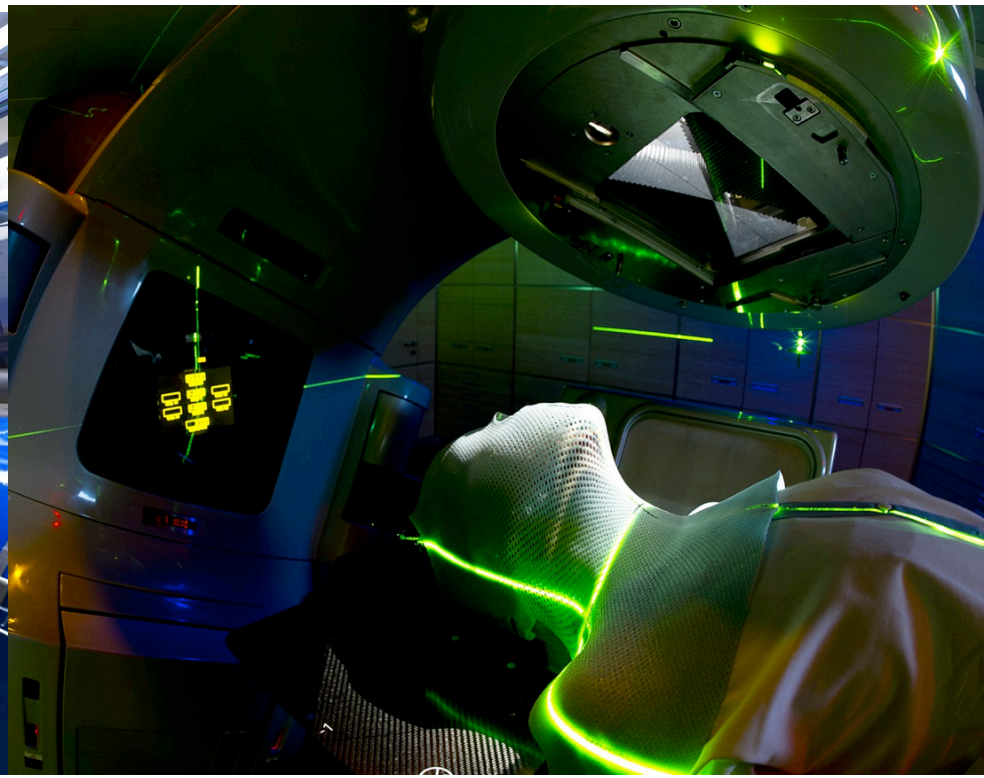
CERN and Medical Applications

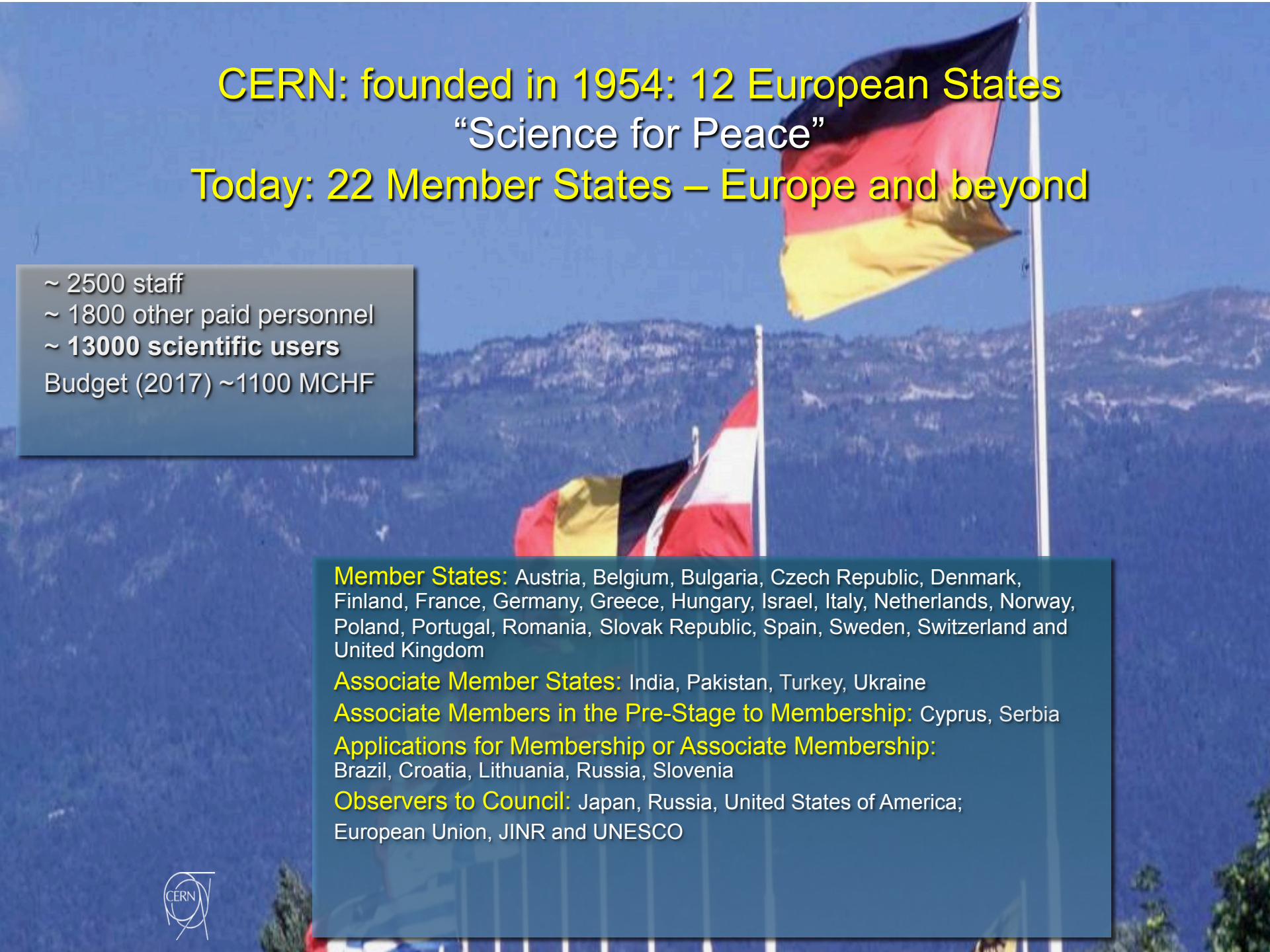


Manjit Dosanjh, CERN, 28 August 2017

Δημόσια Ομιλία στα πλαίσια του Διεθνούς Συνεδρίου
Public talk at Great Arsenali on the occasion of International Workshop
Ions for Cancer Therapy, Space Research and Material Science

CERN: founded in 1954: 12 European States
"Science for Peace"
Today: 22 Member States – Europe and beyond

~ 2500 staff
~ 1800 other paid personnel
~ 13000 scientific users
Budget (2017) ~1100 MCHF



Member States: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Spain, Sweden, Switzerland and United Kingdom

Associate Member States: India, Pakistan, Turkey, Ukraine

Associate Members in the Pre-Stage to Membership: Cyprus, Serbia

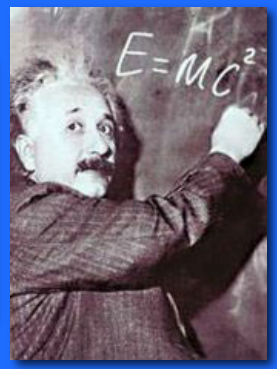
Applications for Membership or Associate Membership: Brazil, Croatia, Lithuania, Russia, Slovenia

Observers to Council: Japan, Russia, United States of America; European Union, JINR and UNESCO

The Mission of CERN

- **Push back** the frontiers of knowledge

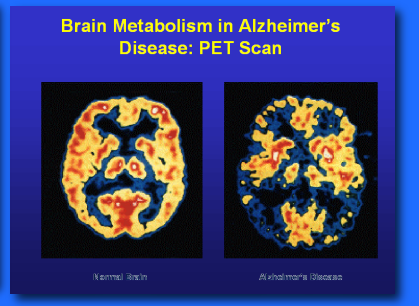
  E.g. the secrets of the Big Bang …what was the matter like within the first moments of the Universe's existence?



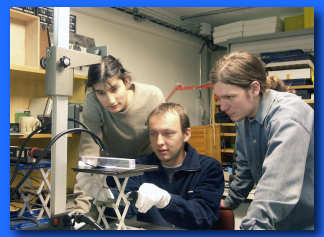
- **Develop** new technologies for accelerators and detectors

  Information technology - the Web and the GRID

  Medicine - diagnosis and therapy



- **Train** scientists and engineers of tomorrow



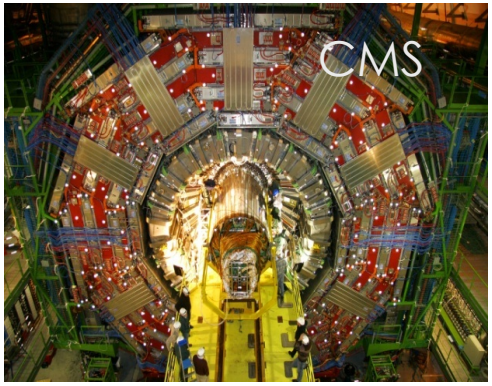
- **Unite** people from different countries and cultures

Particle Physics and innovation

Interfacing between fundamental science and key technological developments

Technologies and Innovation

Accelerating particles beams

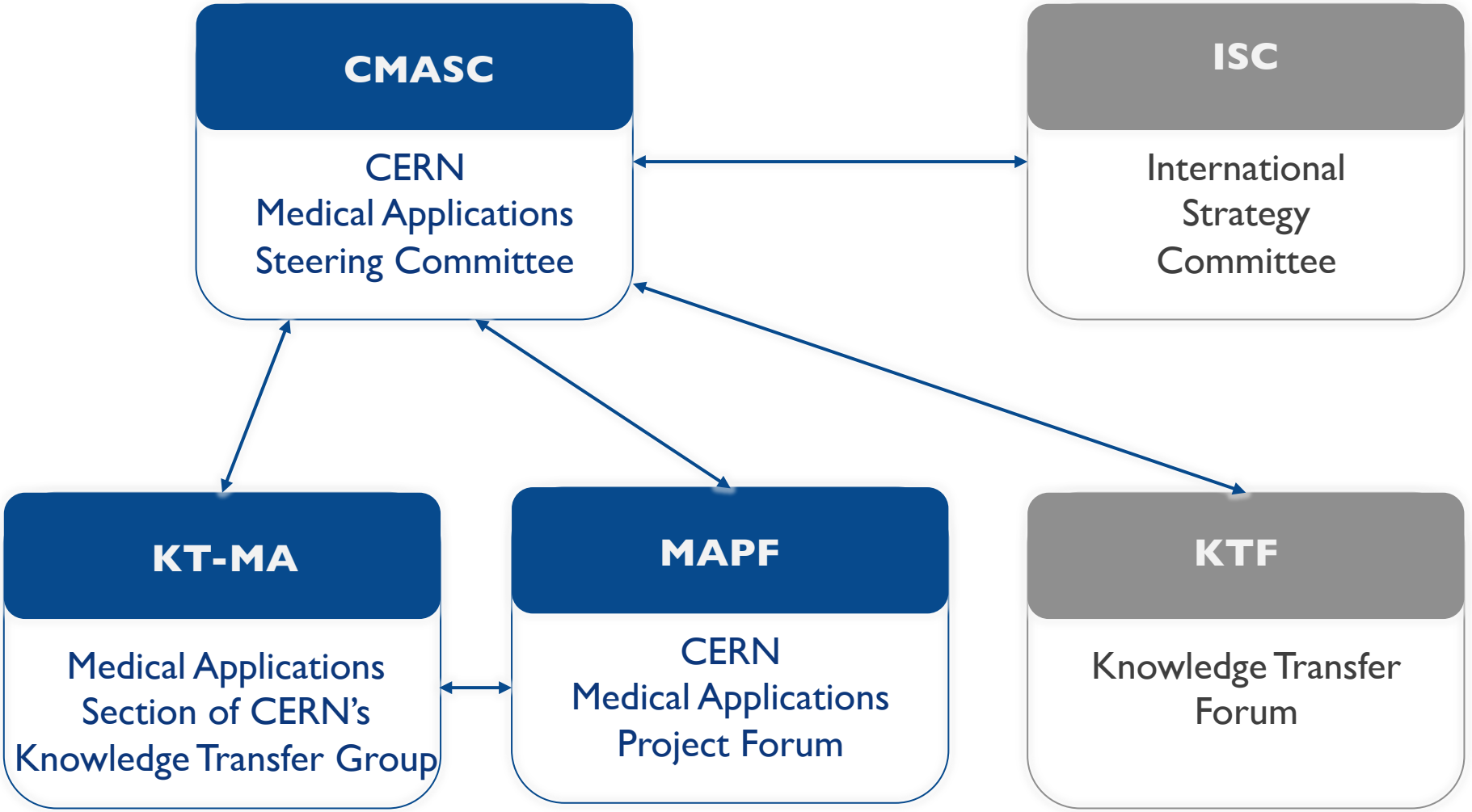


Detecting particles

Large-scale computing (Grid)

Blue: CERN internal bodies
Grey: external bodies

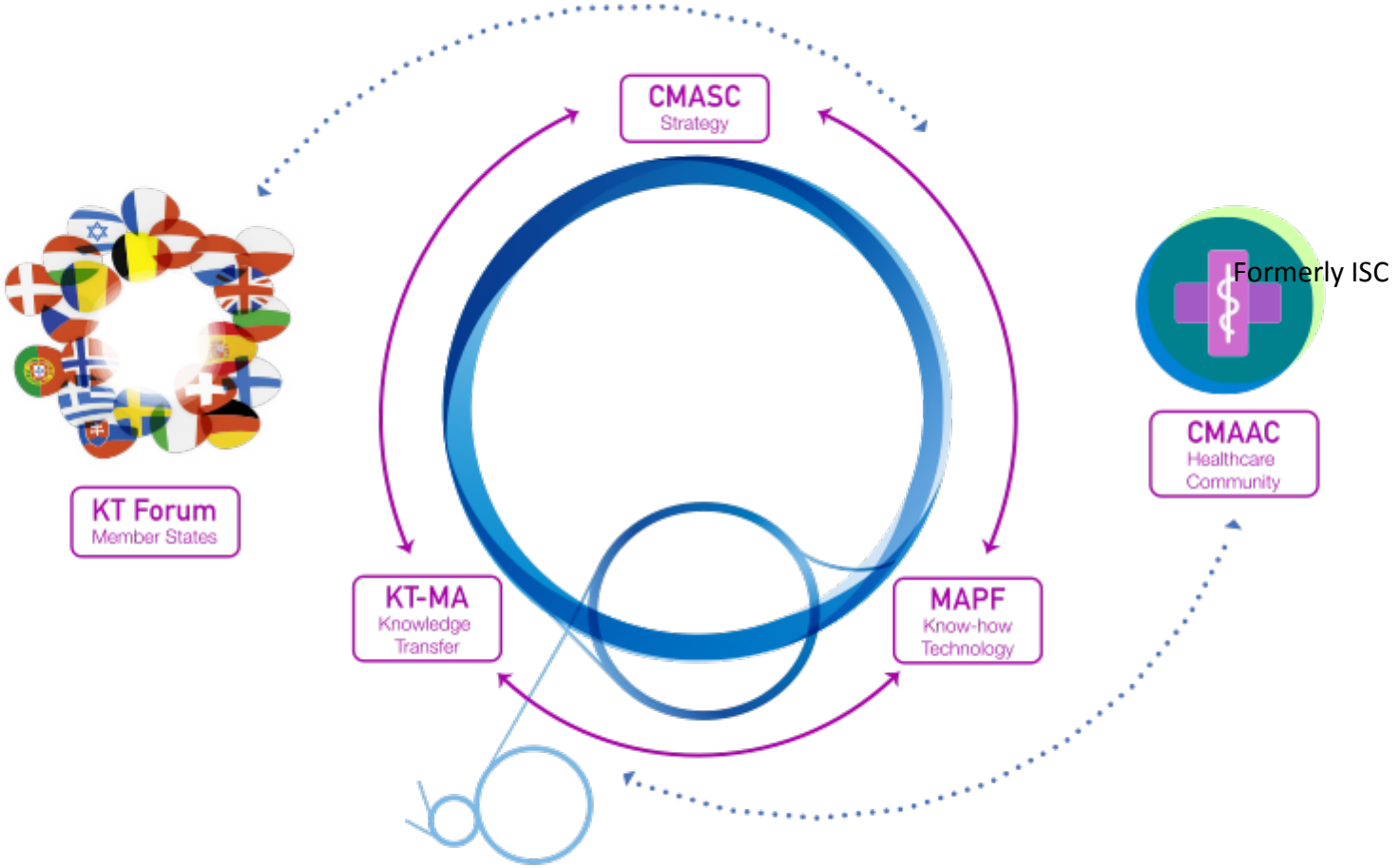
CERM Medical Applications-1



1n 2016, CMA was re-structured with well defined approval procedures and guidelines

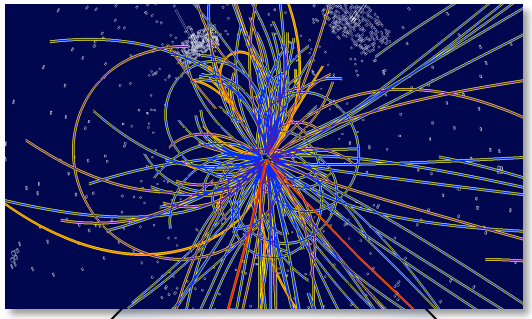
CERN Medical Applications - 2

The current structure and the Strategy document for medical application was formally approved in June 2017 Council



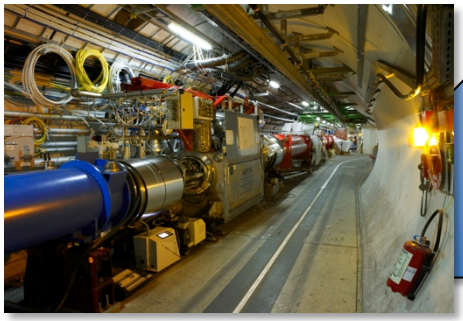
KT-MA = CERN Knowledge Transfer Group, Medical Applications Section
MAPF = Medical Applications Project Forum
CMASC = CERN Medical Applications Steering Committee
CMAAC = CERN Medical Applications Advisory Committee

CERN and Physics Technologies and innovation



Detecting particles

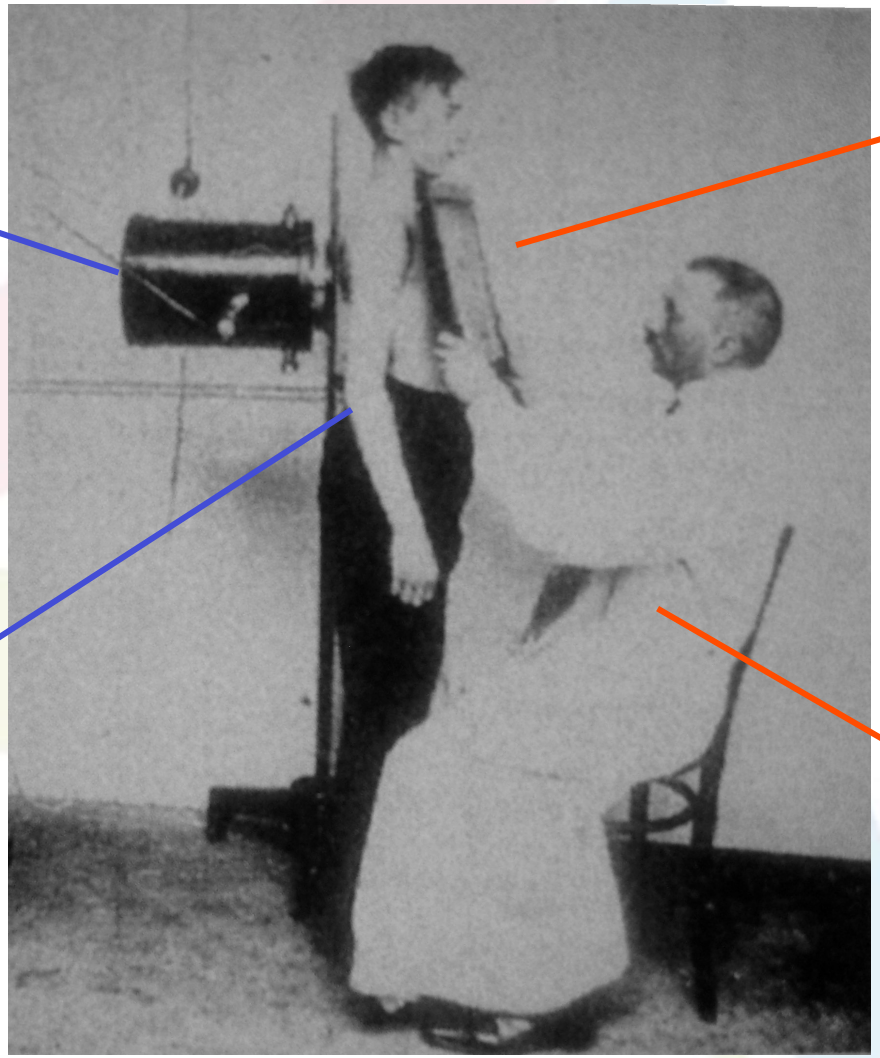
Accelerating particle beams



Higgs

Large-scale computing (Grid)

X-ray systems



X-ray source

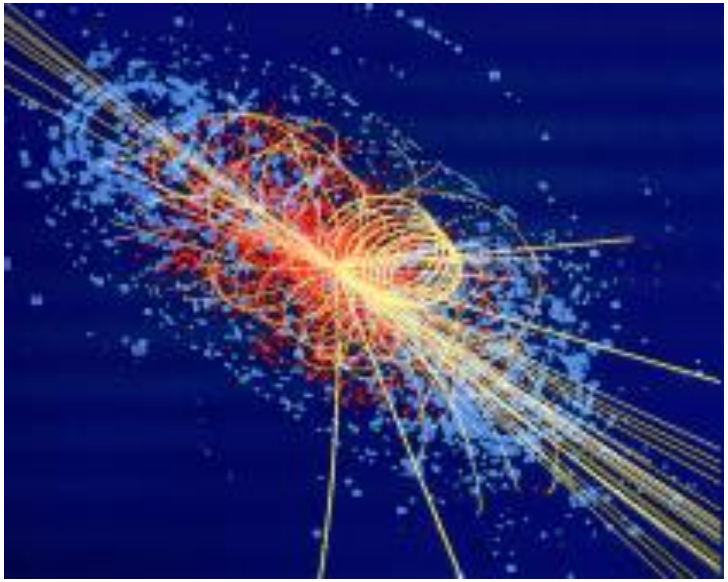
Detector

Object

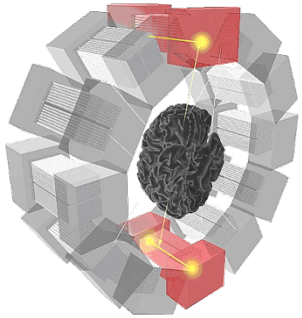
Pattern Recognition System

No treatment without detection!

Particle Detection

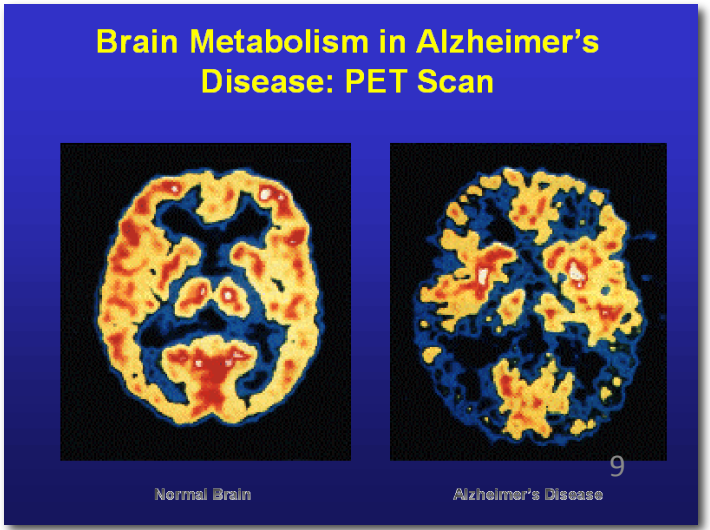


Imaging



PET Scanner

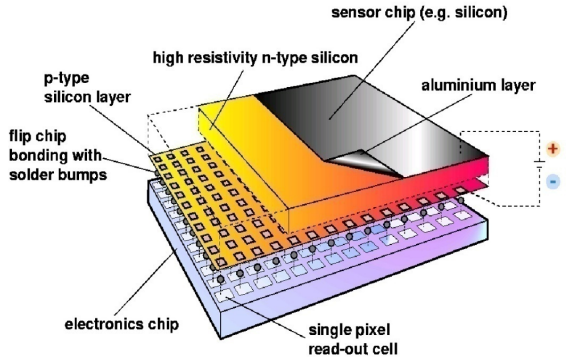
Breast imaging
(ClearPEM)



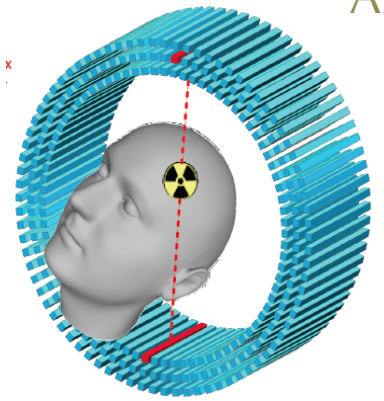
CERN is contributing to imaging for decades

CERN-coordinated international collaborative projects

MEDIPIX

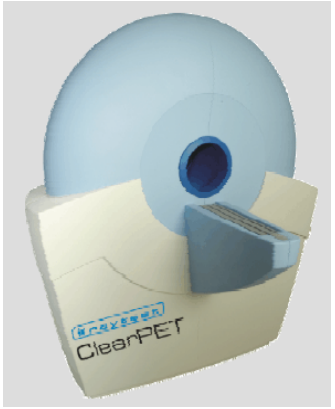


AXPET



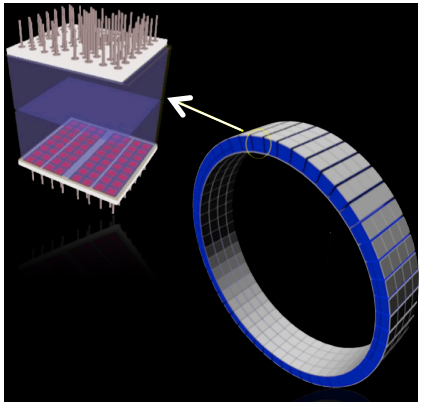
Crystal Clear projects

Courtesy of Paul Lecoq



ClearPET

ClearPEM & ClearPEM-Sonic



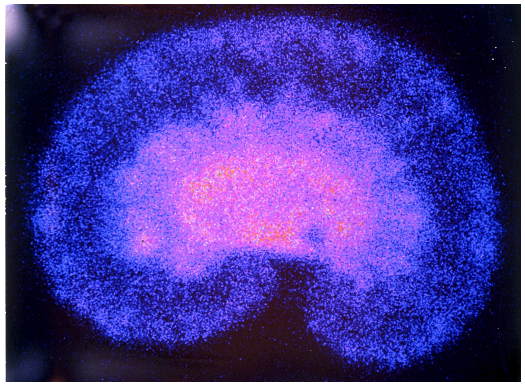
BrainPET

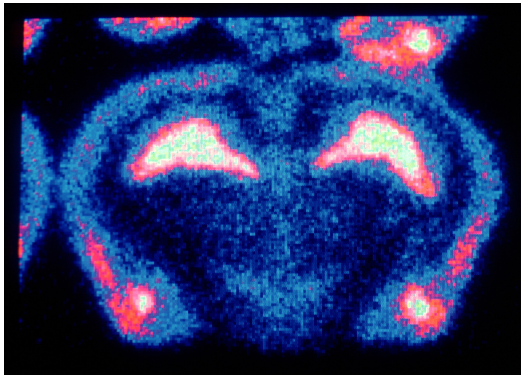
Low dose X-Ray Imaging

1968

Physics Nobel Prize 1992

Georges Charpak





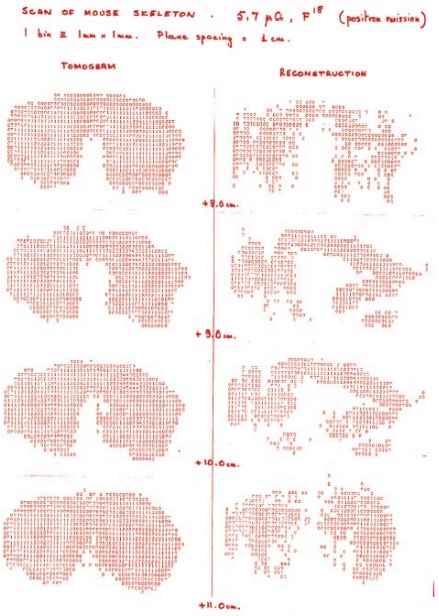
Low dose X-ray image of rat brain and kidney the use of MWPC

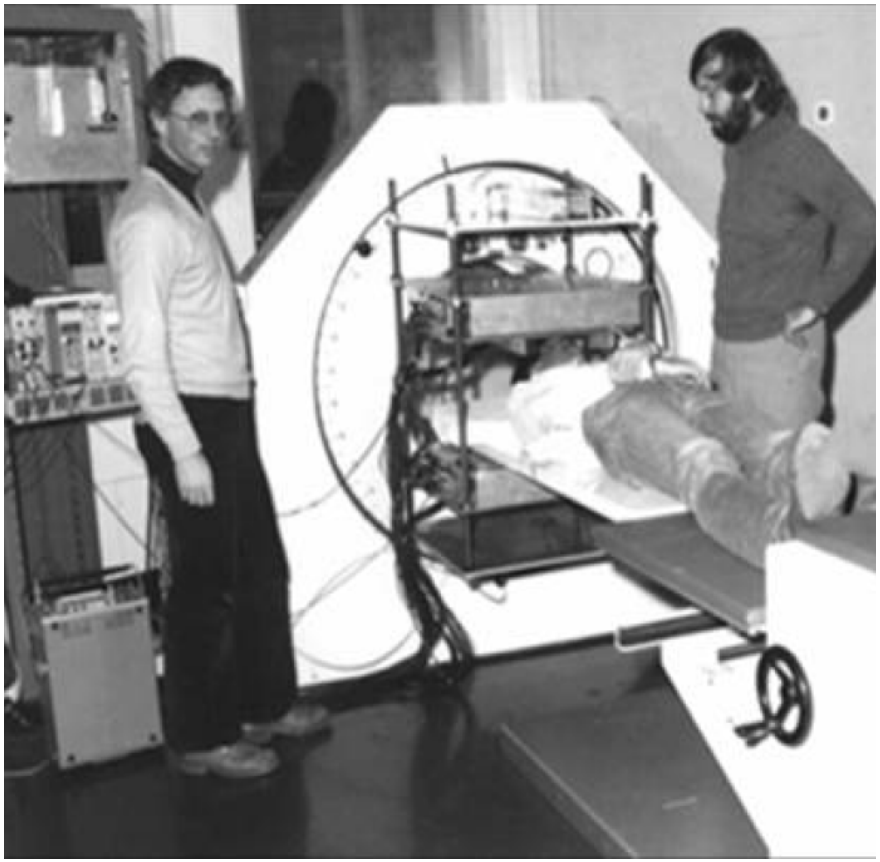
PET Imaging activities at CERN

1977

Alan Jeavons and David Townsend built and used in Geneva Hospital

a PET system based on high-density avalanche gas chambers
HIDACs





Crystal Clear Collaboration and PET Imaging

Photos: Crystal Clear Collaboration

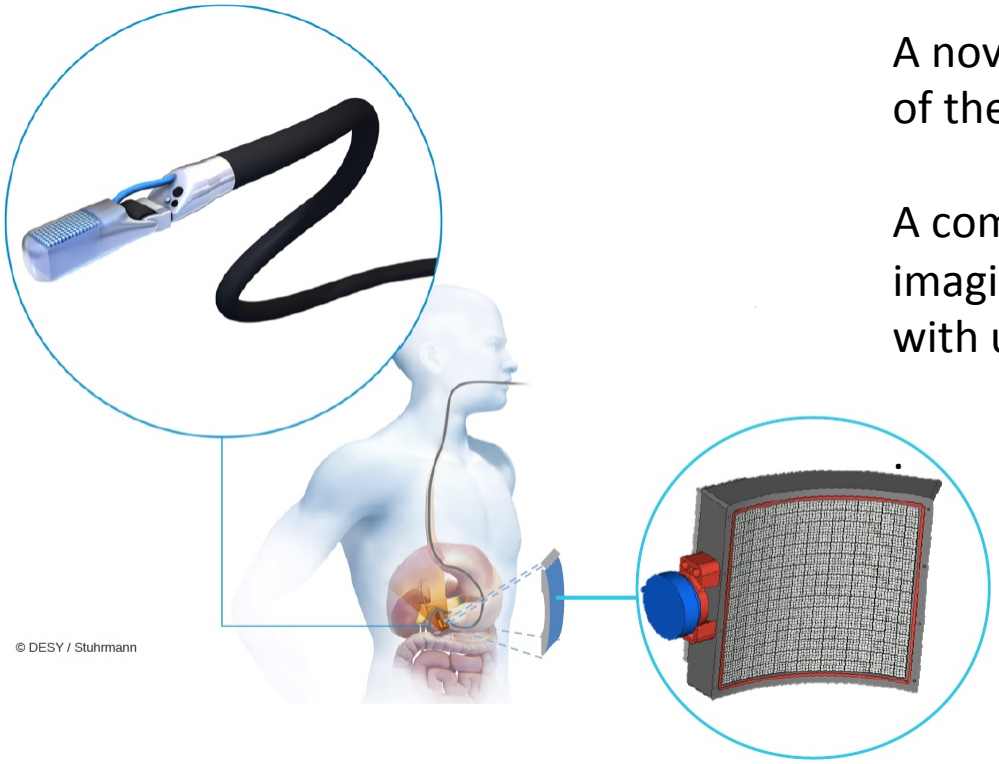
ClearPEM

Photos: Crystal Clear Cololaboration

Dedicated PET for mammography: Crystal Clear Collaboration

Endo TOFPET-US

a novel multimodal tool for endoscopy and positron emission tomography



A novel imaging system for endoscopic exams of the pancreas or the prostate.

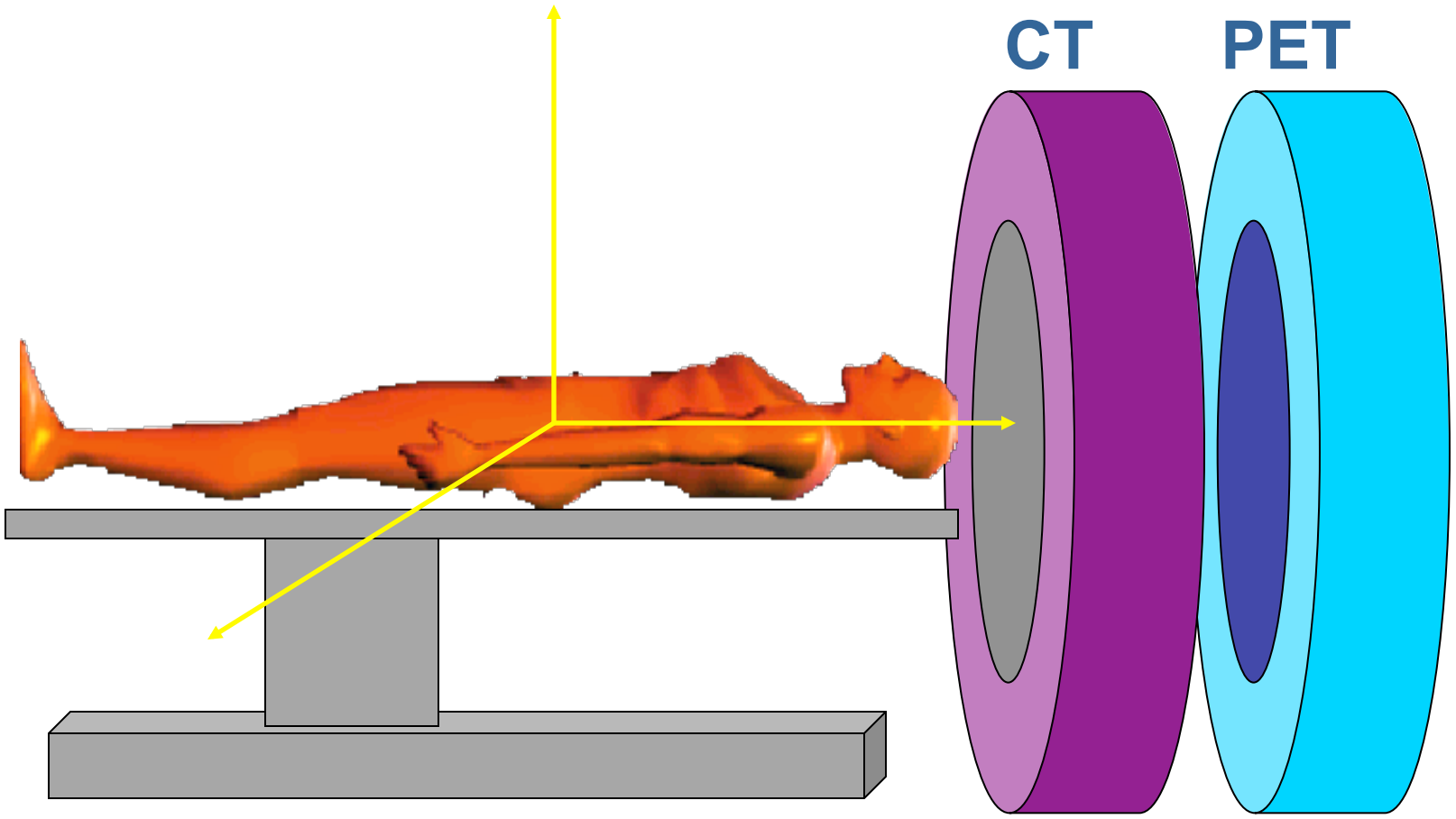
A combination of high resolution metabolic imaging with TOFPET and anatomical imaging with ultrasound.

Endo = Endoscopic
TOF =Time of Flight PET
US = Ultrasound

Courtesy of Paul Lecoq, : Crystal Clear Collaboration

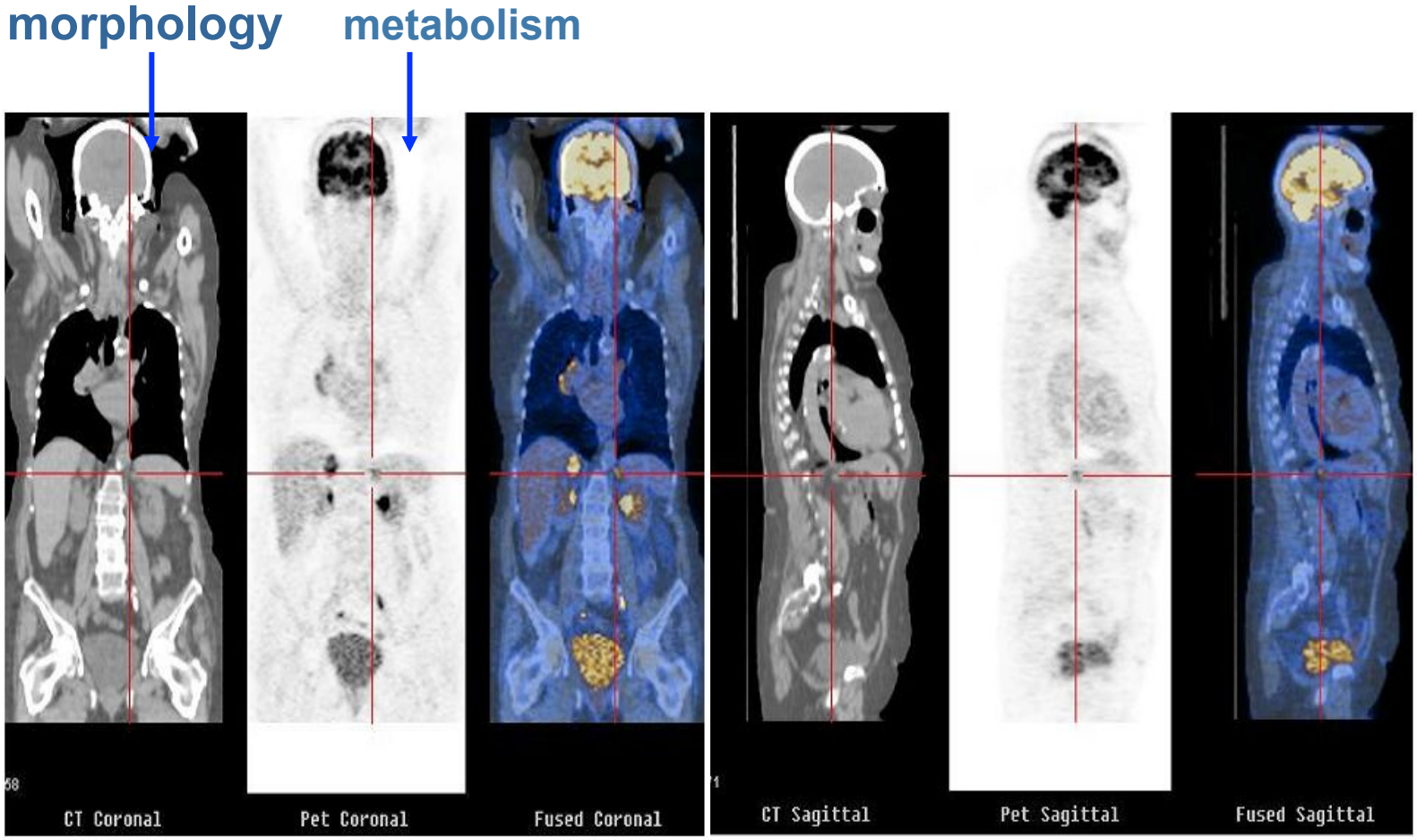
Multimodality Imaging and concept of PET-CT

David Townsend



Multimodality imaging: CT with PET

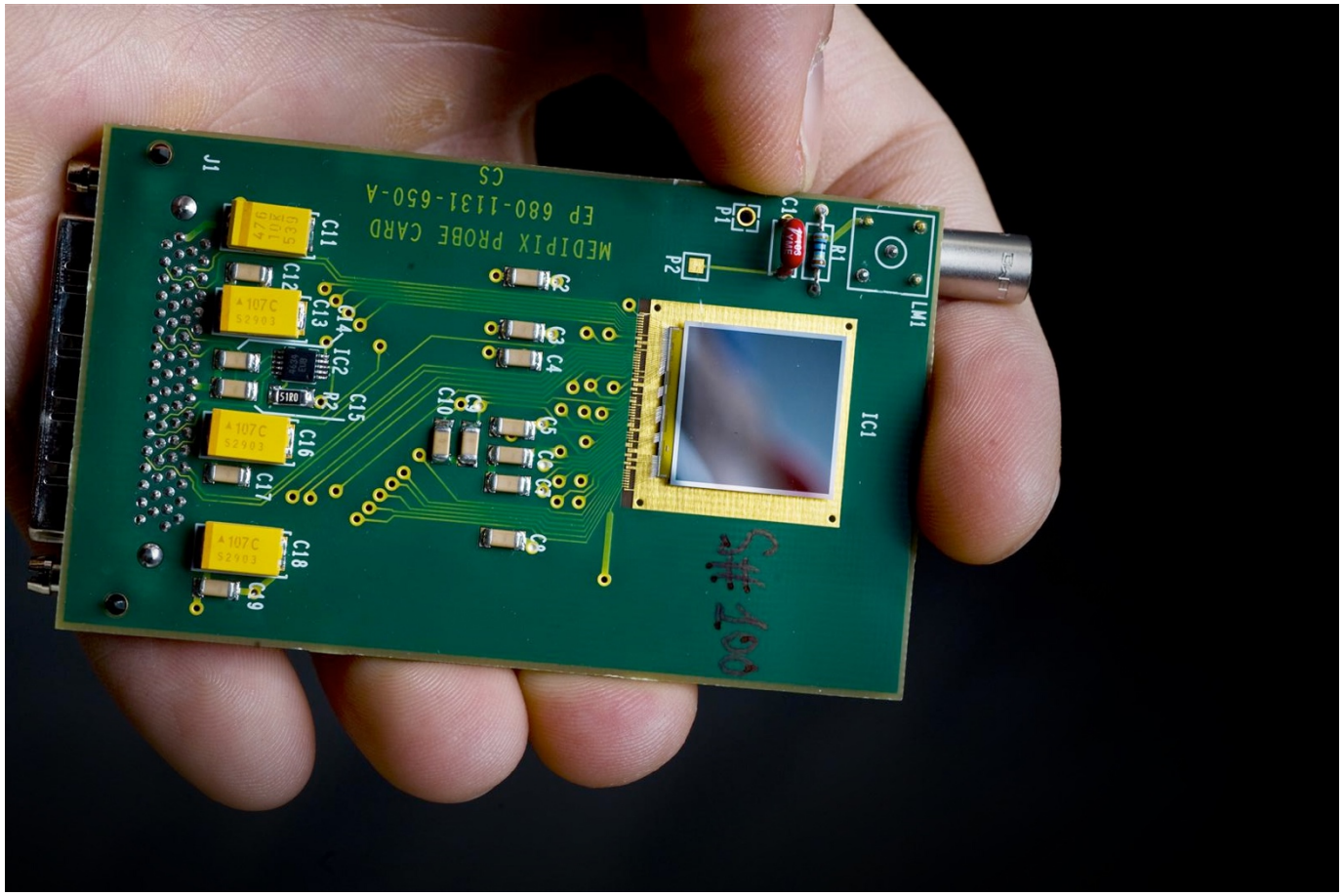
Combining anatomic and functional imaging



David Townsend, Former CERN Physicist

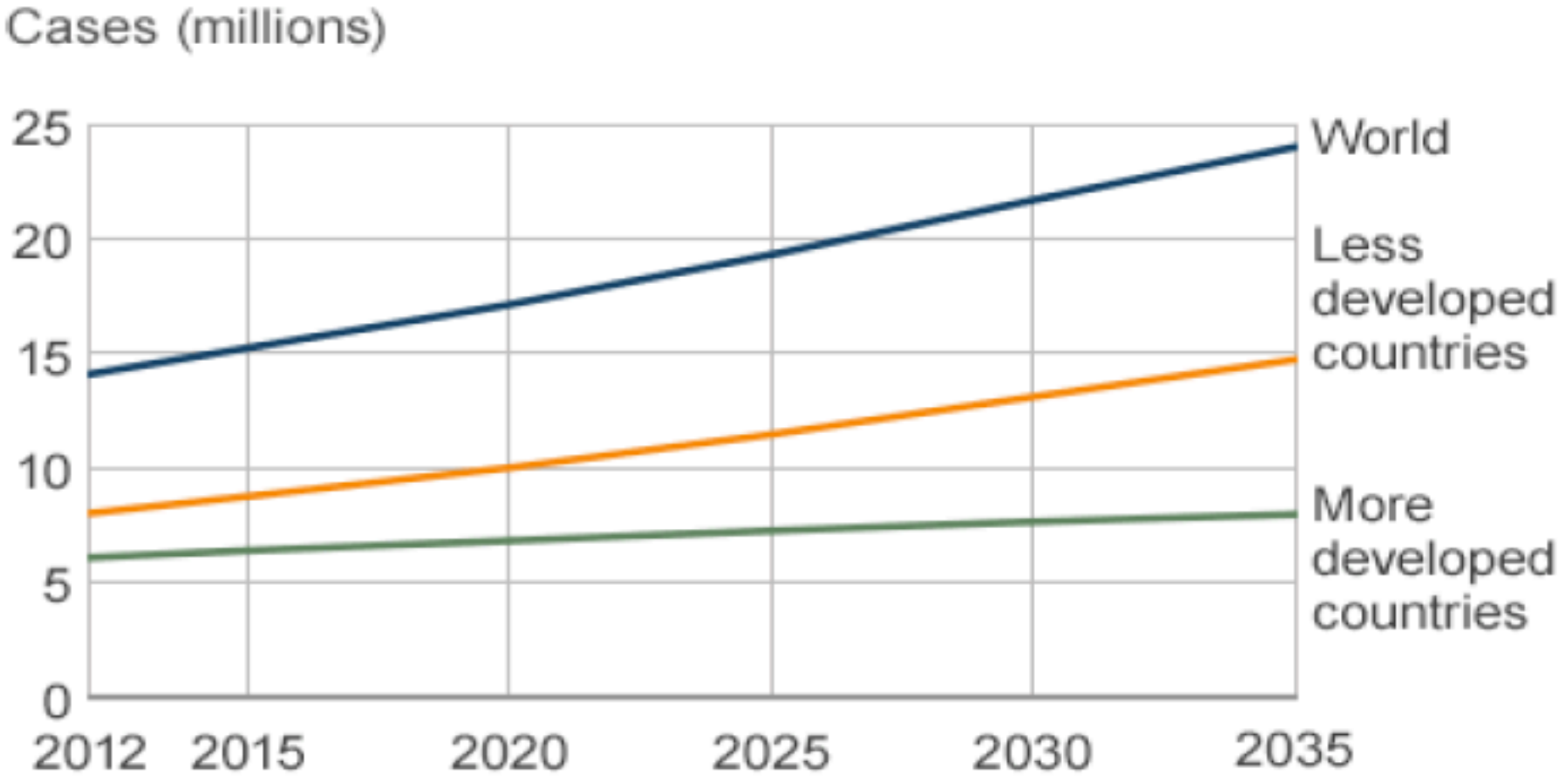
CERN and X-Ray Imaging

Design of high-performance hybrid pixel detectors (Medipix family)



Talk by Michael Campbell

Predicted Global Cancer Cases



Source: WHO GloboCan

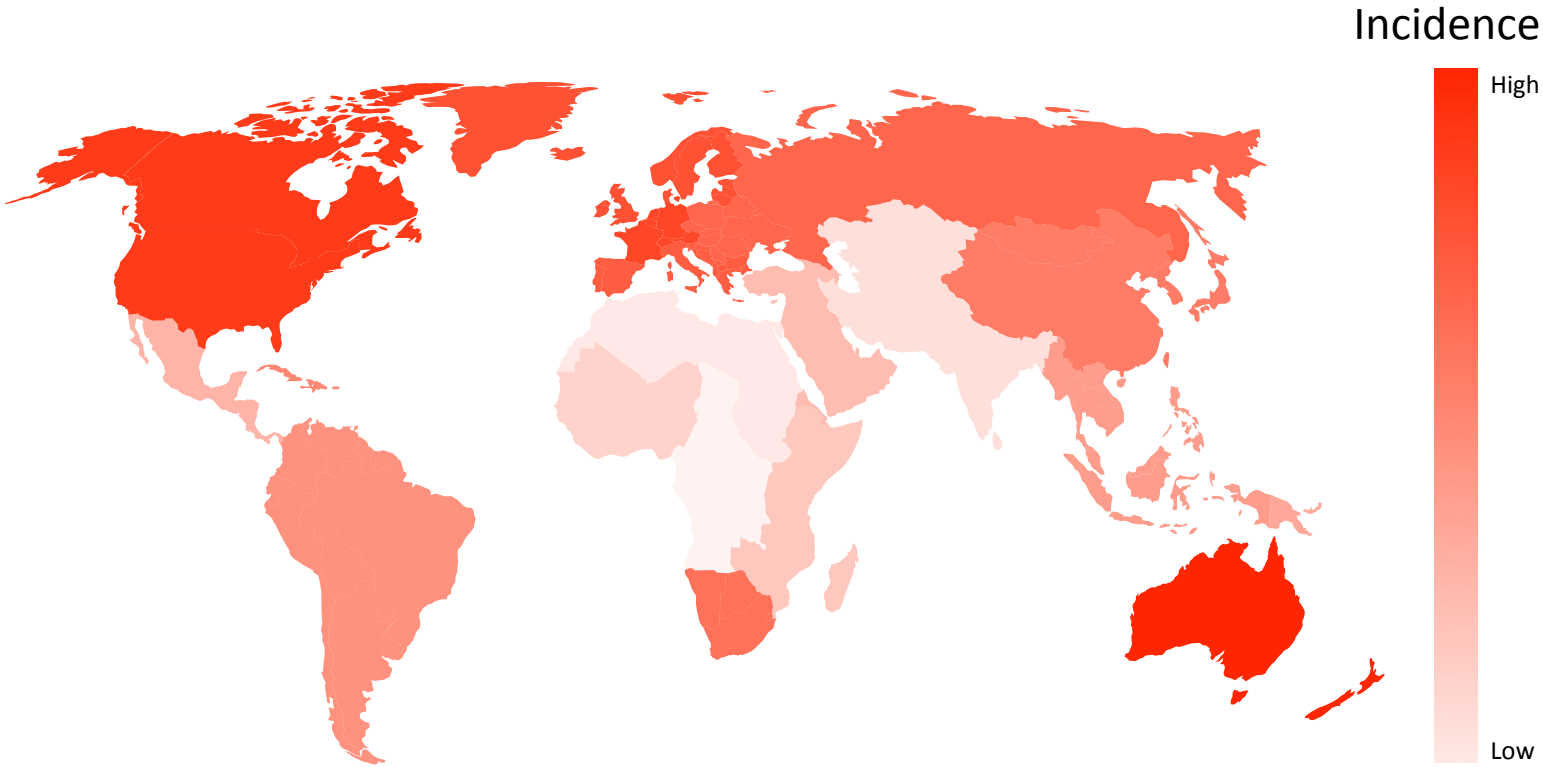
Why is cancer important?

Cancer, increasing huge global mortality, which has an Astronomical Cost

A leading cause of death worldwide

25m new cancer cases by 2030

$286bn, the global economic cost of new cancer cases in 2009

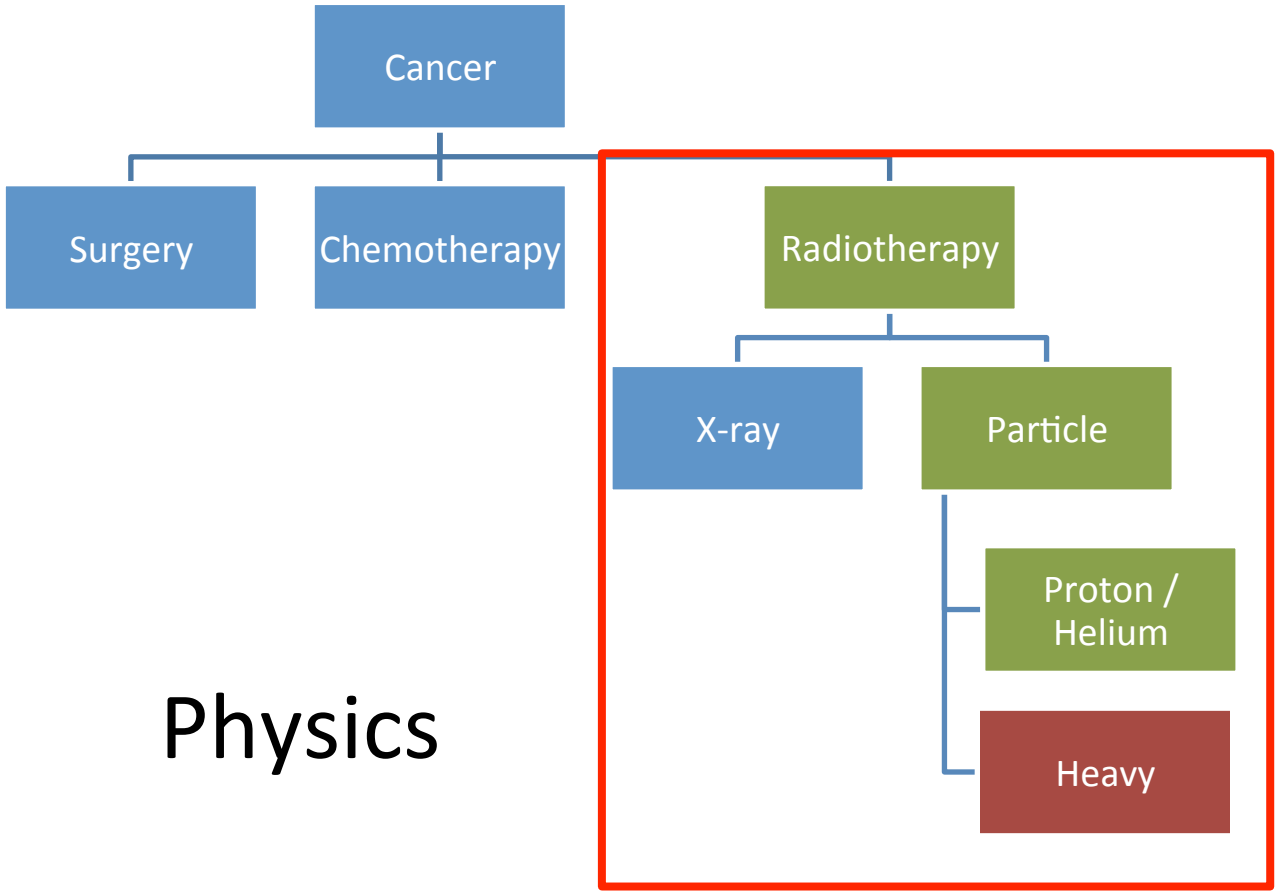


Cure from cancer achieved for only 45% of patients

8m people likely to die as a result of cancer p.a.

1. *Alone or in combination with other modalities*
2. *By 1934 Coutard had developed a protracted, fractionated process that remains the basis for current radiation therapy*
3. *GLOBOCAN 2008, Cancer incidence and Mortality Worldwide. IARC, 2010 (http://globocan.iarc.fr) http://info.cancerresearchuk.org/cancerstats/*

Cancer treatment



Physics

The Challenge of Treatment

Ideally one needs to treat:

- The tumour
- The whole tumour
- And nothing BUT the tumour”

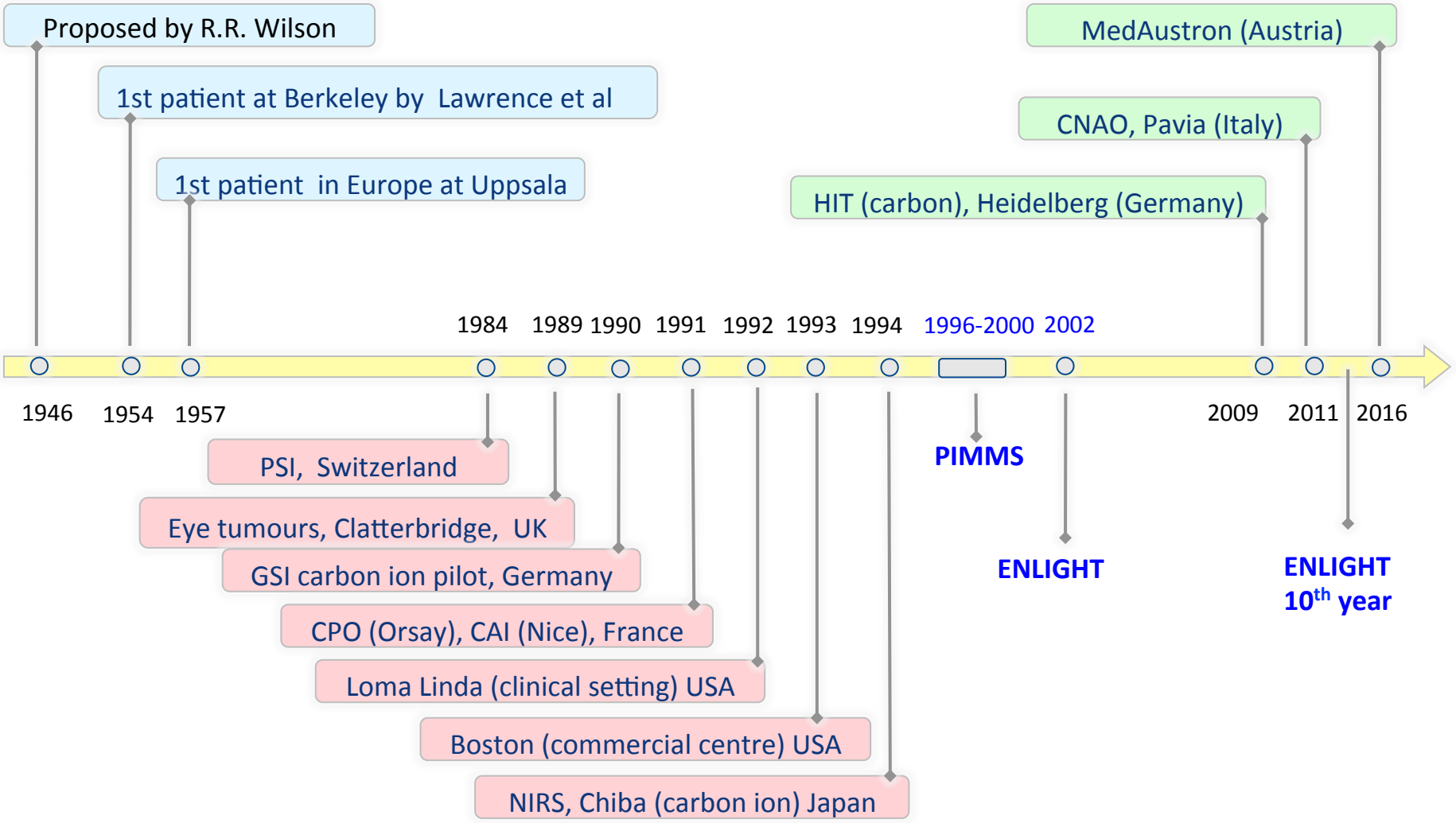
Radiotherapy has two equally important goals to destroy the tumour and protect the surrounding normal tissue. Therefore “seeing” in order to know where and precise “delivery” to make sure it goes where it should are key.

Improving Cancer Outcome

Earlier diagnosis, better tumour control, fewer side-effects

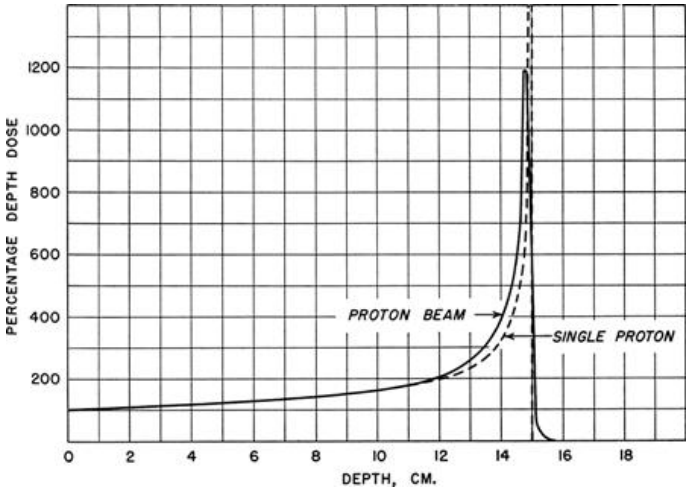
- Imaging: accuracy, multimodality, real-time, organ motion
- Accelerator technologies: higher dose, more localised, real time targeting
- Data: analysis, image fusion/reconstruction, treatment planning, sharing, screening, follow-up patient ….
- Biology: basic research, fractionation, radio-resistance, radio-sensitization

Particle therapy: a short history

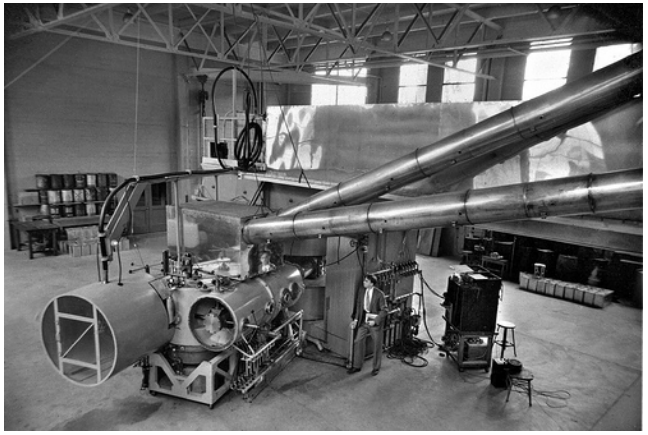


1932 - E. Lawrence
First cyclotron

1946 – proton therapy proposed by R. Wilson

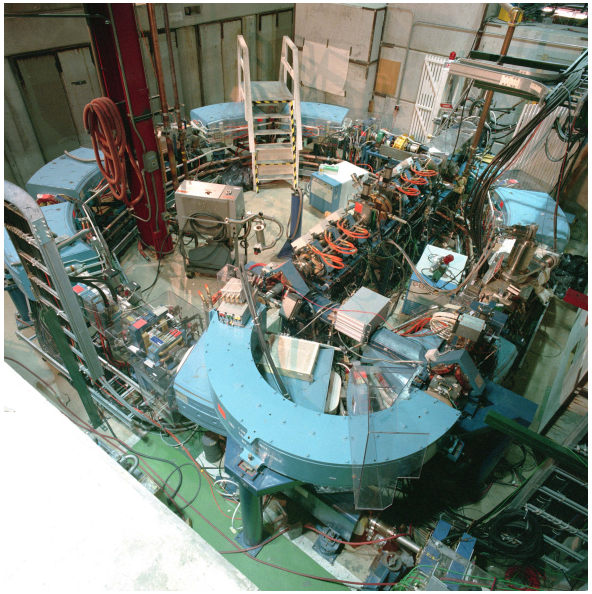


1954 – Berkeley treats the first patient



From physics……

1993- Loma Linda
USA (proton)



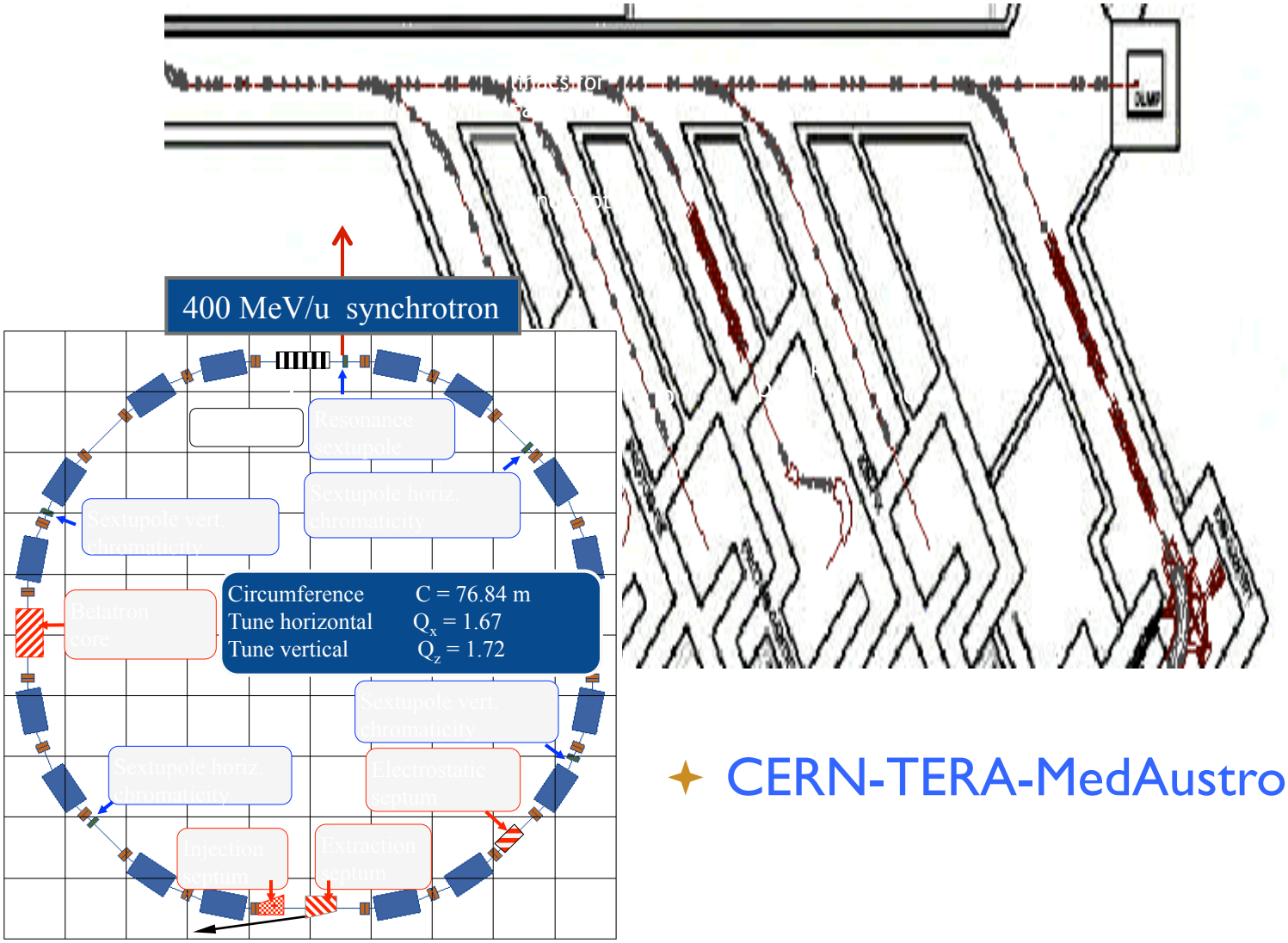
First dedicated clinical facility

1994 – HIMAC
Japan (carbon)

1997 – GSI
Germany (carbon)

.....to clinics

PIMMS at CERN (1996-2000)



- CERN-TERA-MedAustron

ENLIGHT is 15 years young!

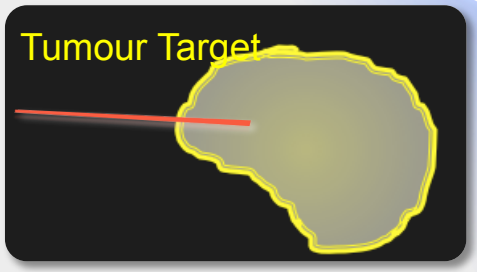
- ENLIGHT was launched in February 2002 at CERN in this very room
- Idea germinated in 2001 in MedAustron meeting where PIMMS was presented

Organisers: Manjit Dosanjh & Hans Hoffmann

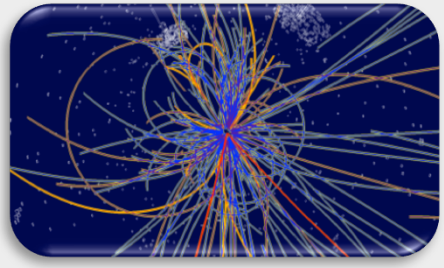
4th Pillar Catalysing & facilitating collaboration

Accelerating particle beams

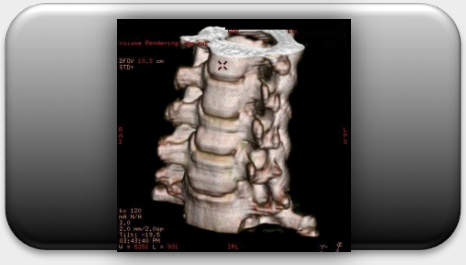
Radiation Therapy



Detecting particles



Medical imaging

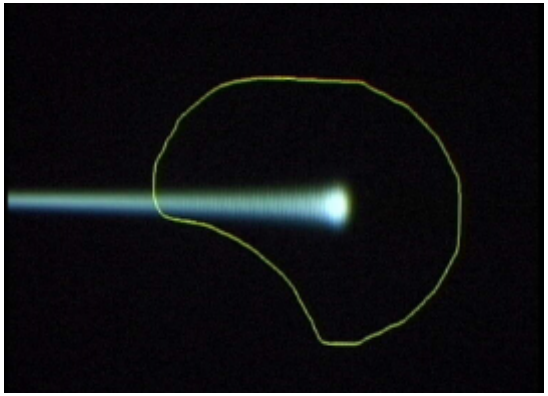


Large scale **computing** (Grid)

Grid computing for medical data management and analysis

ENLIGHT: Importing Physics collaboration philosophy into a medical environment

- Create common multidisciplinary platform
- Cancer treatment
- Identify challenges
- Share knowledge
- Share best practices
- Harmonise data
- Provide training, education
- Innovate to improve
- Lobbying for funding

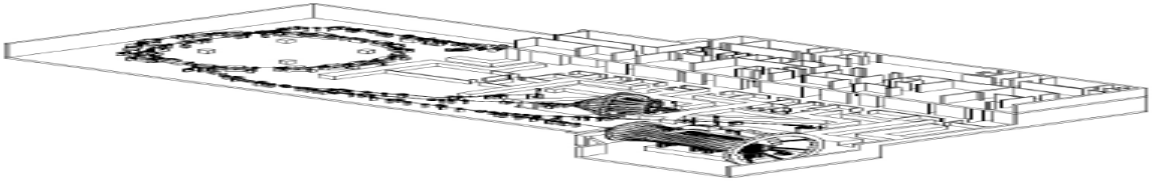


Particle therapy centres in Europe - 2002

Source: PTCOG, October 2015

Accelerator Technologies

PIMMS 2000 (coordinated by CERN) has led to:



TERA Fondazione per Adroterapia Oncologica → fondazione CNAO

Treatment centre in Pavia, Italy.

First patient treated with in 2011

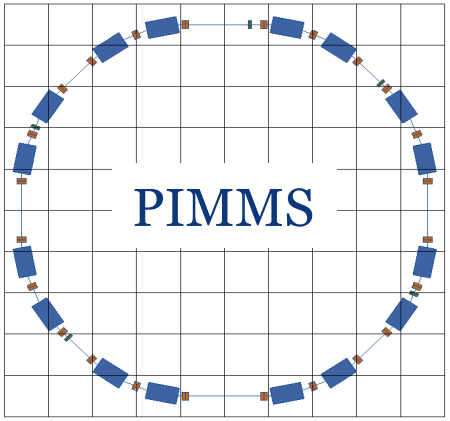
ebg MedAustron

Treatment centre in Wiener Neustadt, Austria, foundation stone in 2011, installation moved to MedAustron at beginning of 2012, first patient treated in 2016

PIMMS study at CERN (1996-2000)

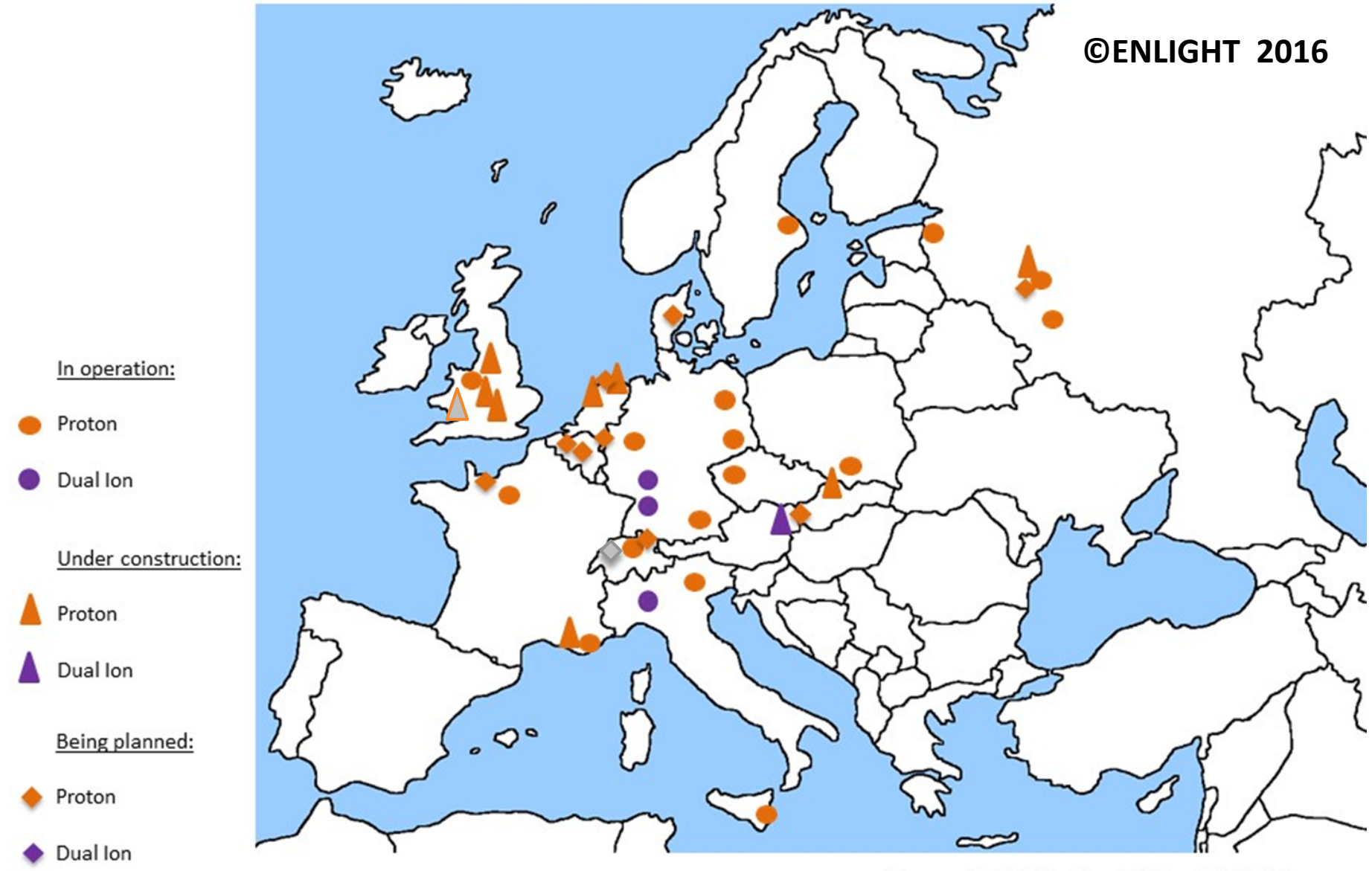
Treatment, CNAO, Italy 2012

1996-2000
PIMMS
study

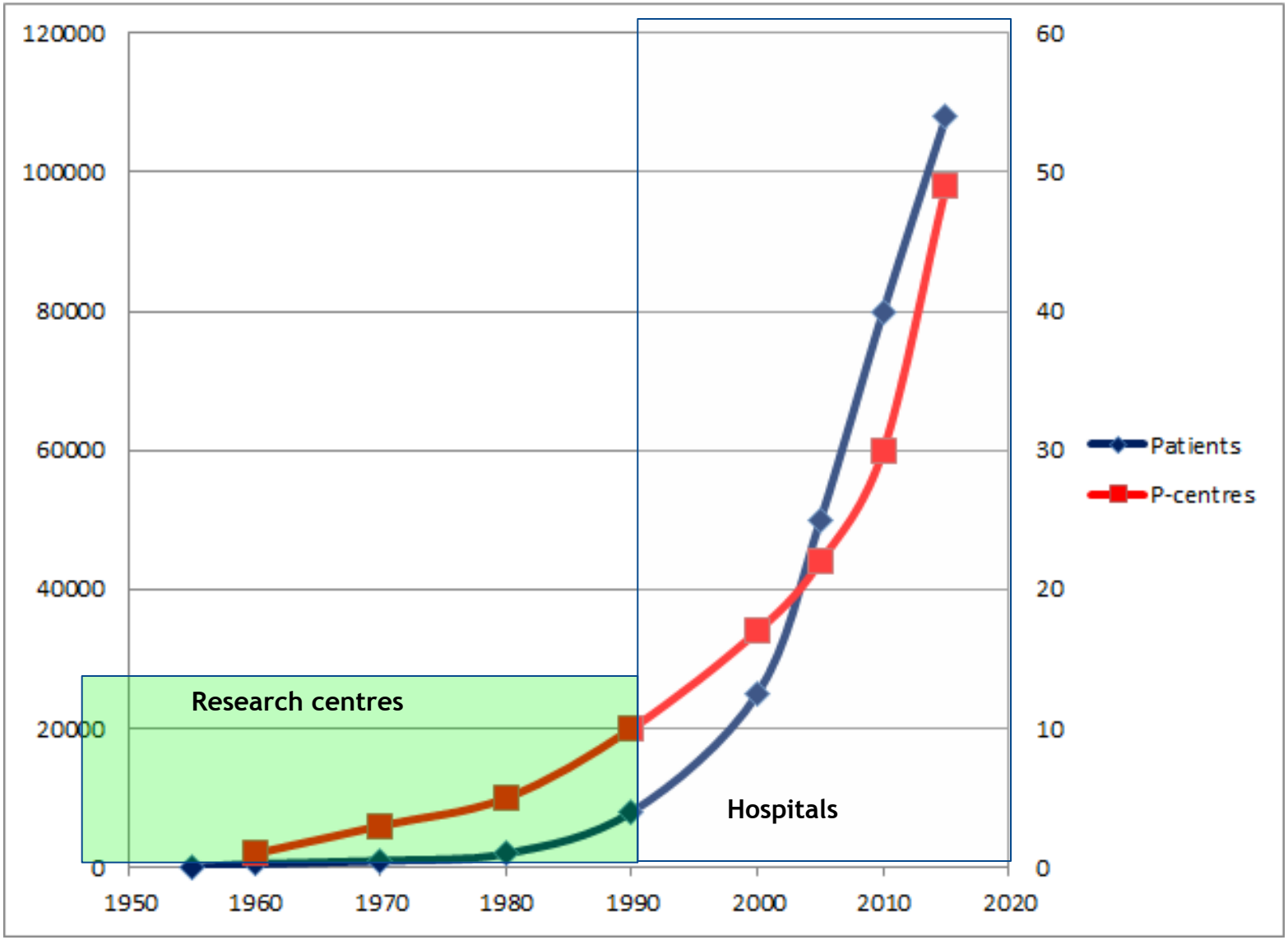


MedAustron, Austria 2016

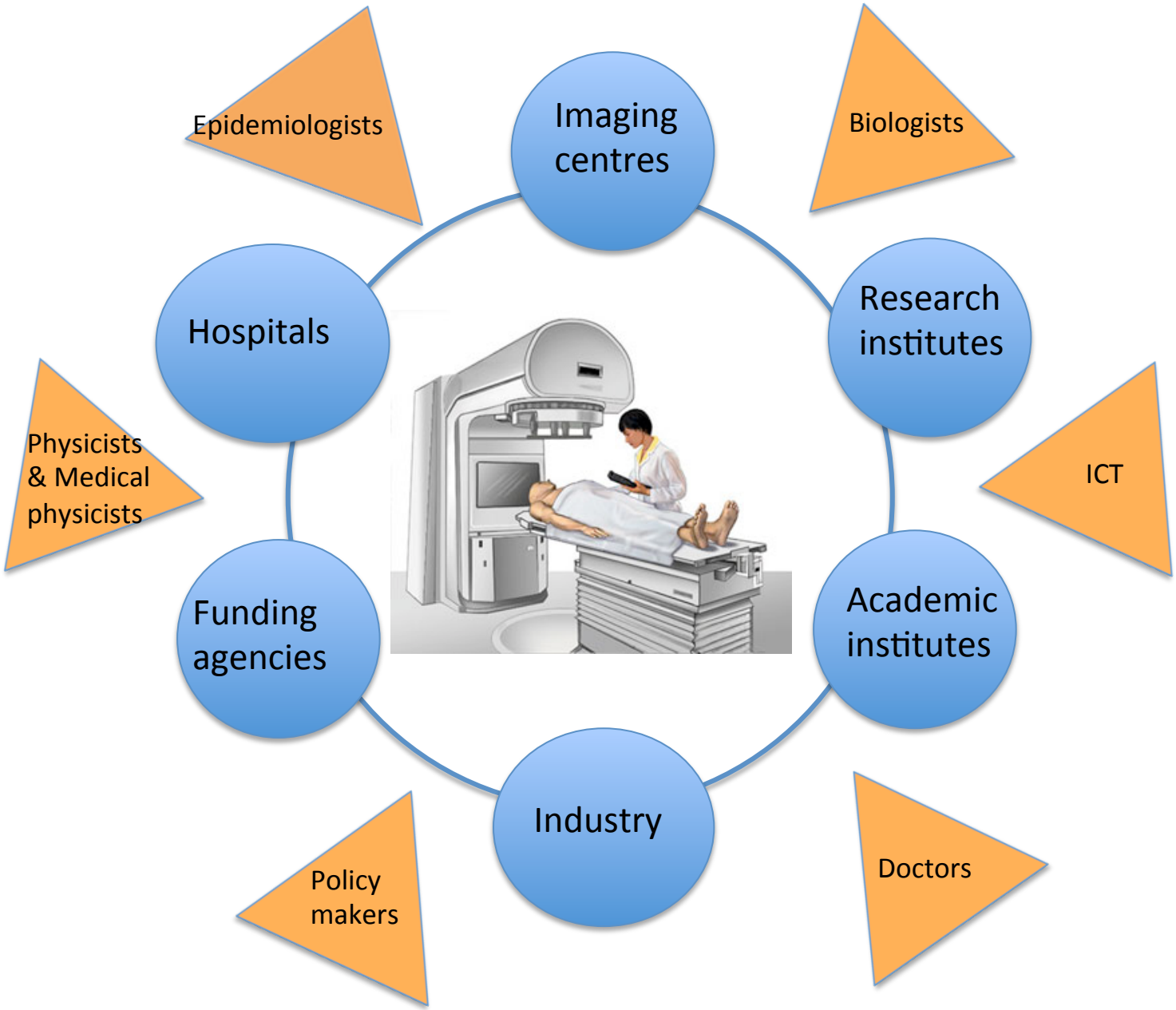
Particle therapy centres in Europe - 2016



[Data from www.ptcog.ch]

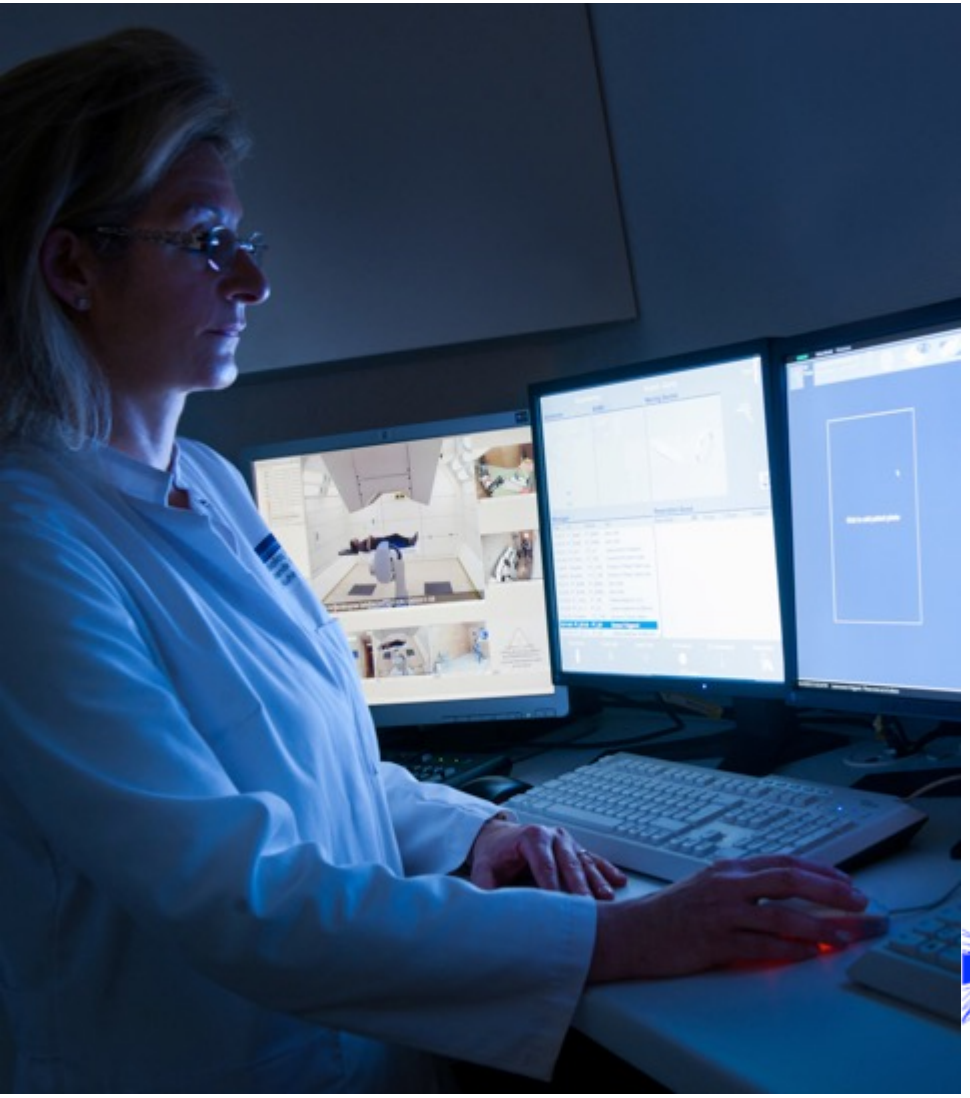


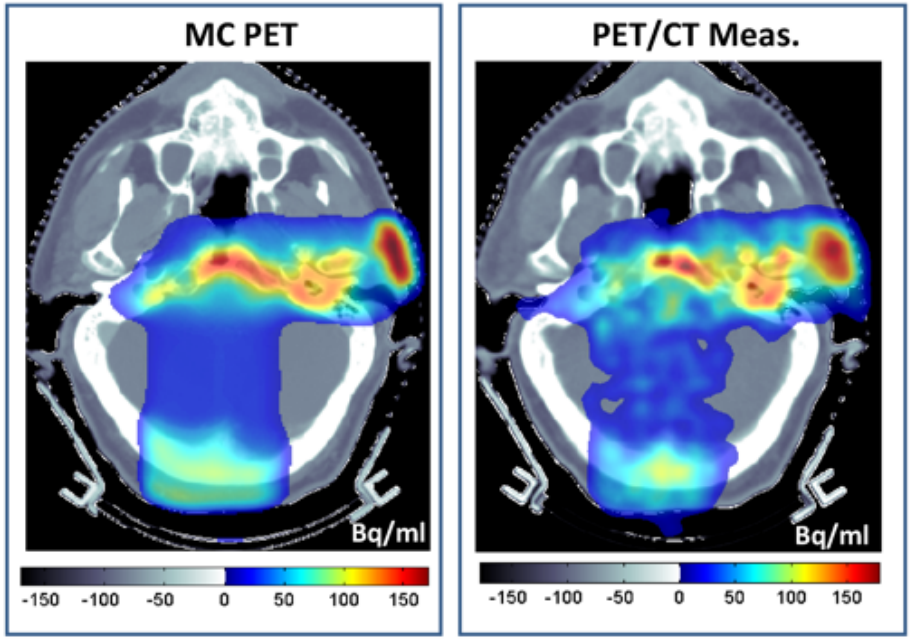
ENLIGHT is a open collaborative network

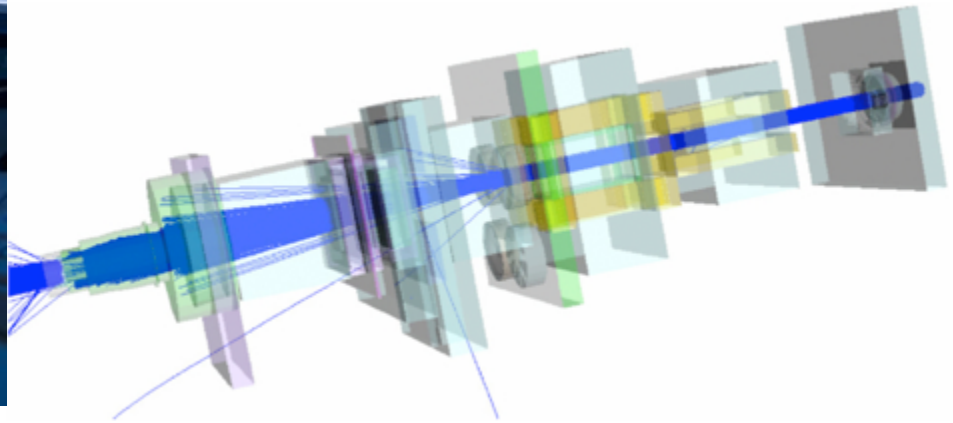


Other Current Activities @ CERN

Simulations for hadron therapy

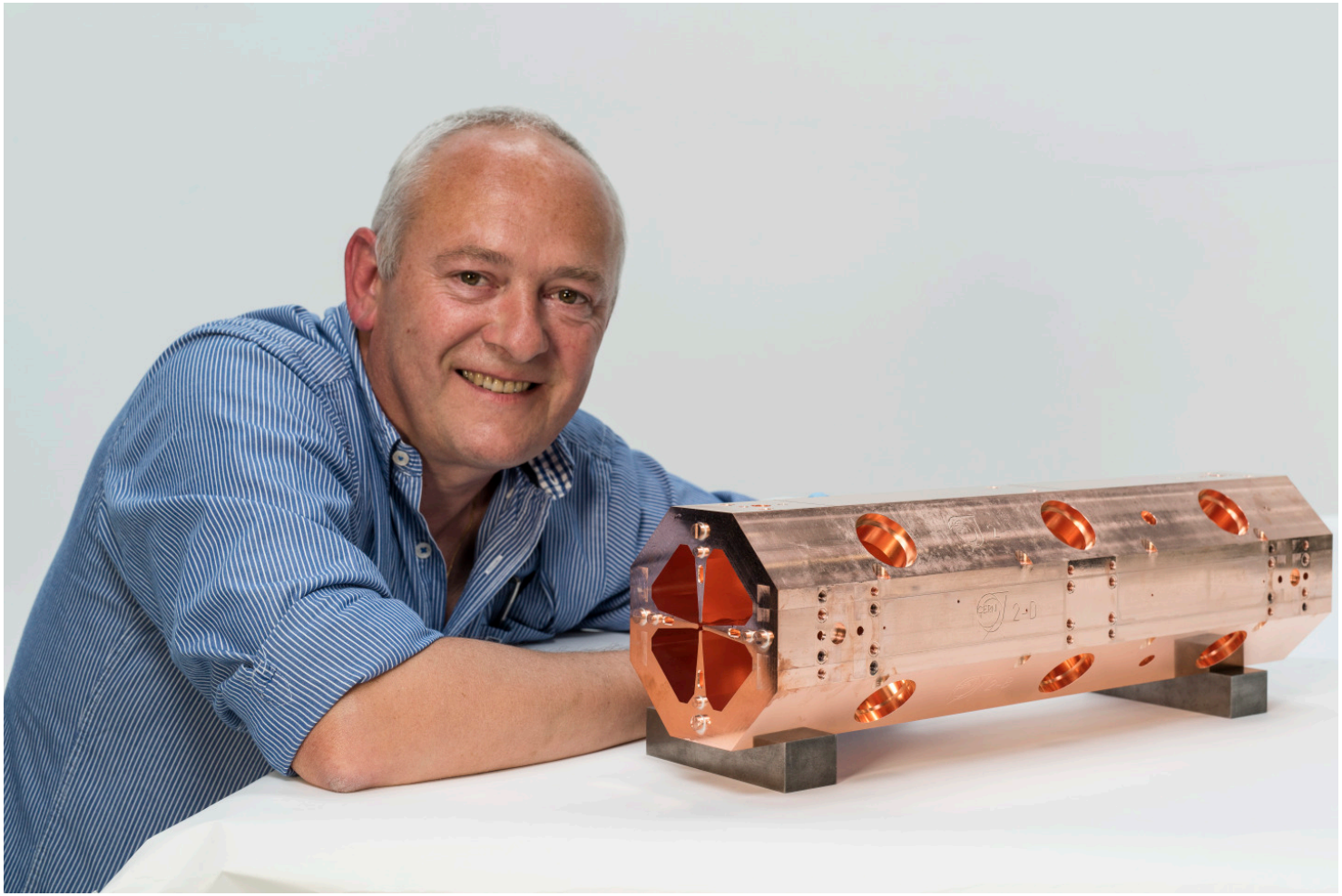






Wioletta Kozolowska will speak on Wednesday

The miniature linear accelerator



The miniature linear accelerator

A new high-frequency RFQ

Compact, lightweight, low beam loss
2.5 MeV/m (vs <1 MeV/m)

First application: proton therapy
(commercialised through CERN's spin-off A.D.A.M. S.A.)

Potential applications: on-site radioisotope production, alpha-particle radiotherapy, analysis of archeological materials, radiobiology

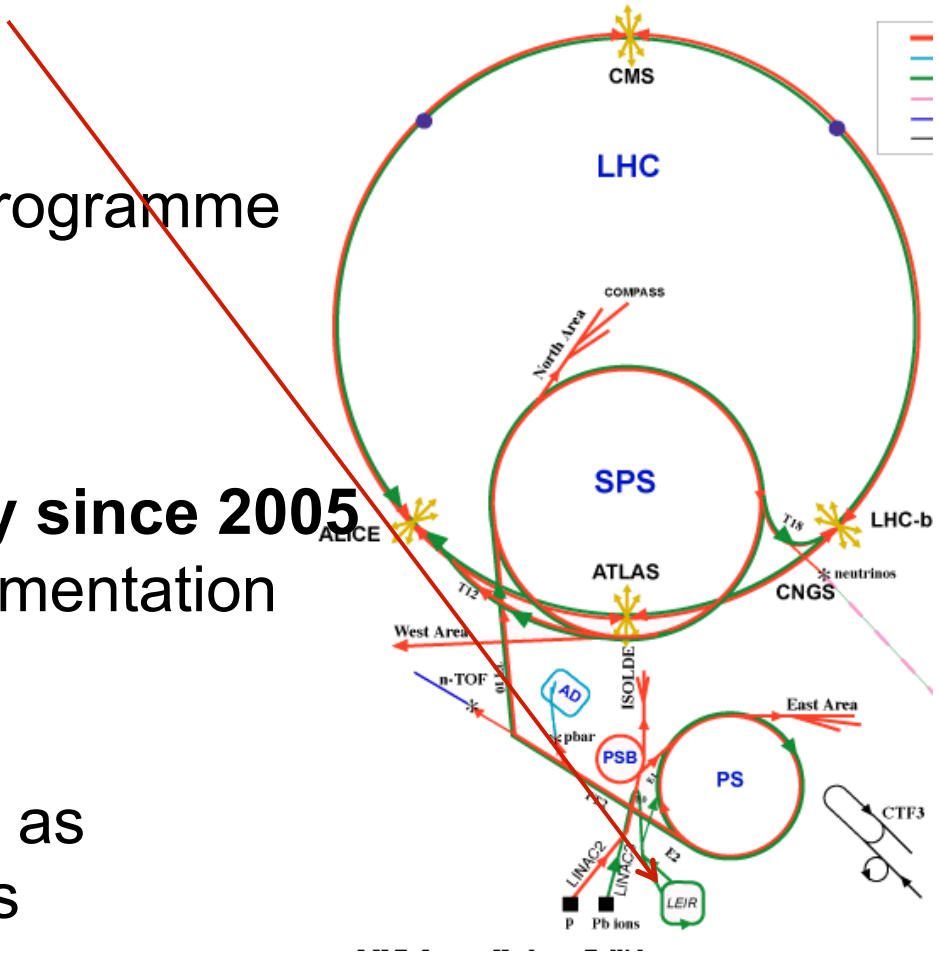
LEIR for biomedical research

LEIR (Low Energy Ion Ring)

- part of LHC injection chain
- accumulator for LHC ion programme (lead ions)

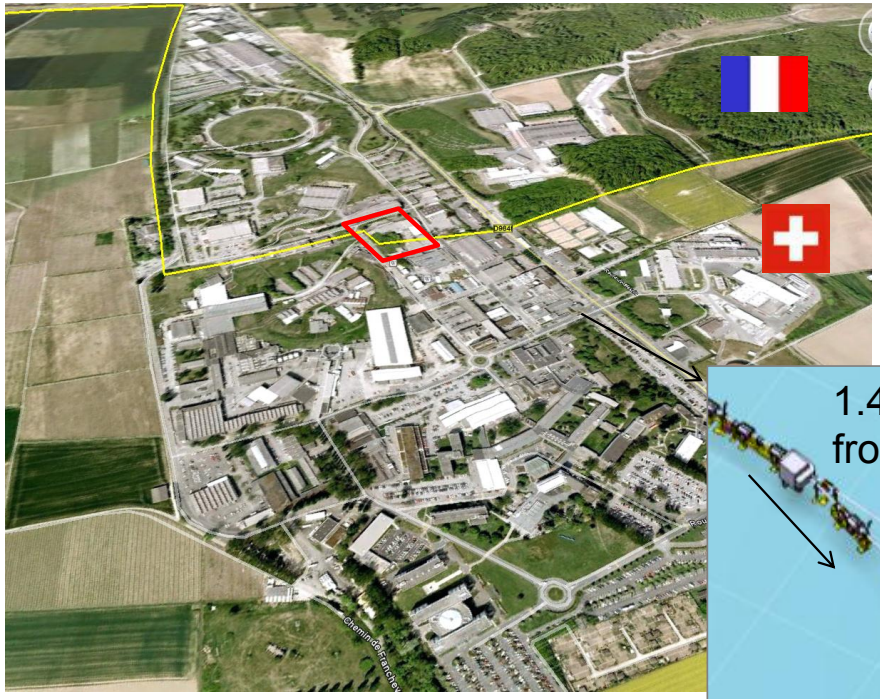
Discussions to **establish facility since 2005**

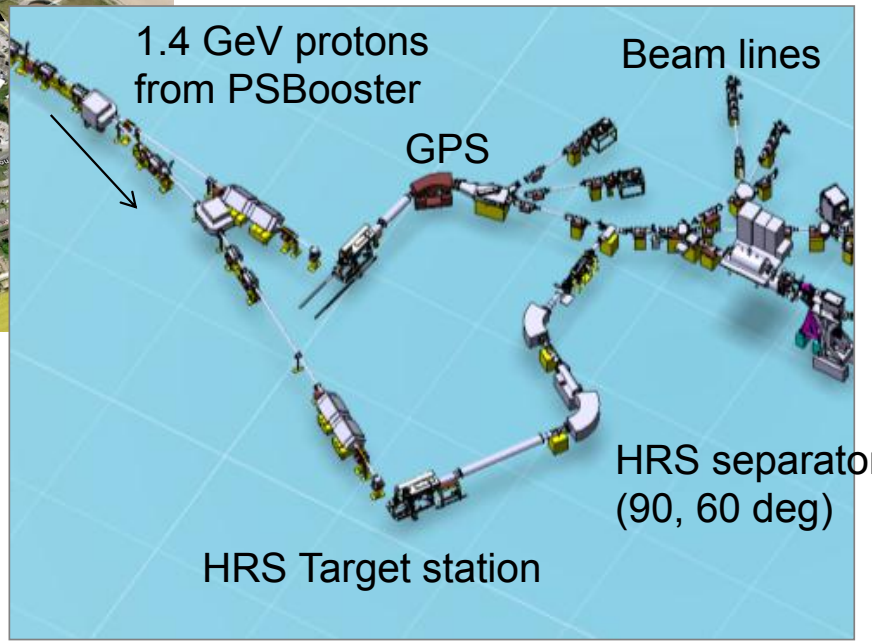
- Test-bed for medical instrumentation
- Diagnostics and dosimetry
- radiobiology
- basic physics studies such as fragmentation of ion beams



Maurizio Vretener will address this

The Isolde facility at CERN





MEDICIS: MEDical Isotopes Collected from ISolde

Production of radioisotopes for research

Started as KT Fund project:
shuttle robot to transport irradiated targets

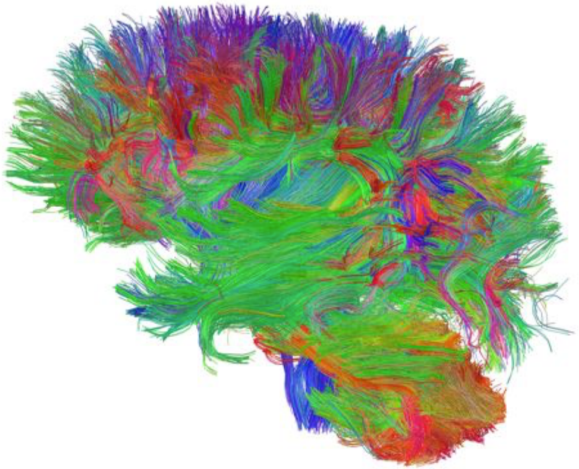
During LS1, the building was adapted

An international collaboration will operate the facility with CERN

Big Data for health

BioDynaMo — The Biology Dynamic Modeller

- Platform for high-performance simulations of biological dynamics
- Involves detailed physical interactions in biological tissue
- Highly optimised and parallelised code
- To be run on hybrid (multi-core, manycore) cloud environments
  - Cortical column: 10k neurons - brain cancer
  - Cortical sheet: 10m neurons - epilepsy
  - Cortex: 100m - 10bn neurons - schizophrenia



The GeneROOT Project

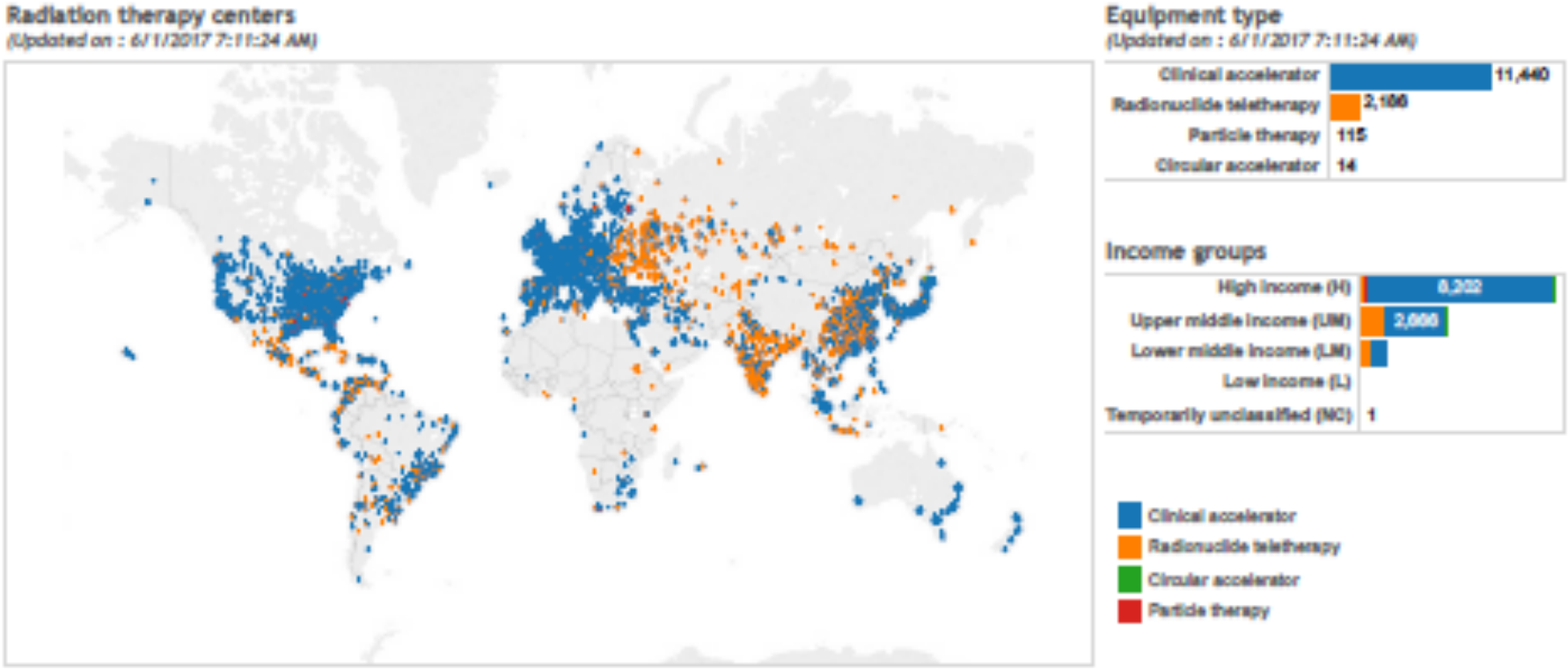
CERNopenlab

- Based on data from the TwinsUK project, the biggest UK adult twin registry (more than 11000 twins, 300 TB genomics data)
  - Formal interface: King's College London
  - Behind KCL: entire consortium working on Twins UK (~ 50 institutes)
- Evaluate if the optimised ROOT file format and analysis features are more efficient for this type of studies than BAM and standard genomic analysis tools
- Evaluate Seagate Kinetics key/value storage facility for this type of cases

CERN KING'S College LONDON SEAGATE EMBL-EBI

Global Challenge: how to go from no radiotherapy to high quality radiotherapy globally: Challenging Environments

World wide radiotherapy coverage



Countries	RT centers	Equipment	Linac	Radionuclide Therapy	Circular Accelerator	Particle Therapy
139	7041	13755	11440	2186	14	115

Reality in numbers……

- No radiotherapy in 36 countries
- HIC have over 60% of all teletherapy machines and 16% of the world population
- LIC and LMIC have less than 10% of teletherapy machines which serve 50% of the world

Needs by 2035 in LMIC

Globally 15 million (2015) to 25 million in (2035):

- 12,600 megavolt-class treatment machines
- 30,000 radiation oncologists
- 22,000 medical physicists
- 80,000 radiation technologists

Many thanks

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E. Blakely, LBNL, USA

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KT at CERN, BioLEIR

Medipx, Crytal Clear, Fluka, GEANT

ICEC and IAEA for developing country and global data