Cancer and Particle Therapy

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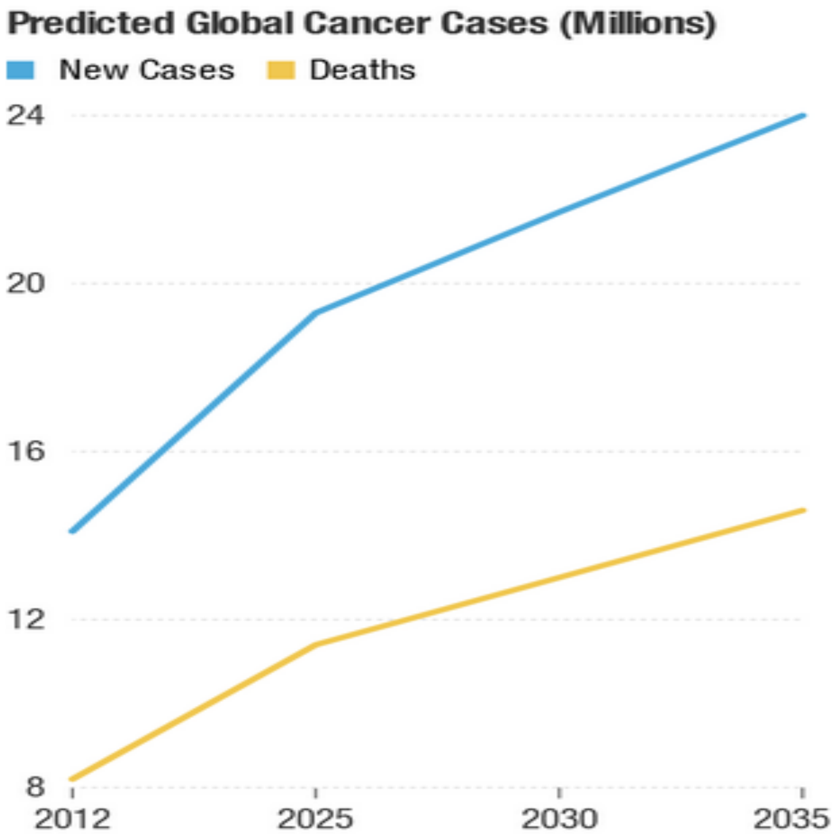
ENLIGHT Coordinator

Cancer is growing global challenge

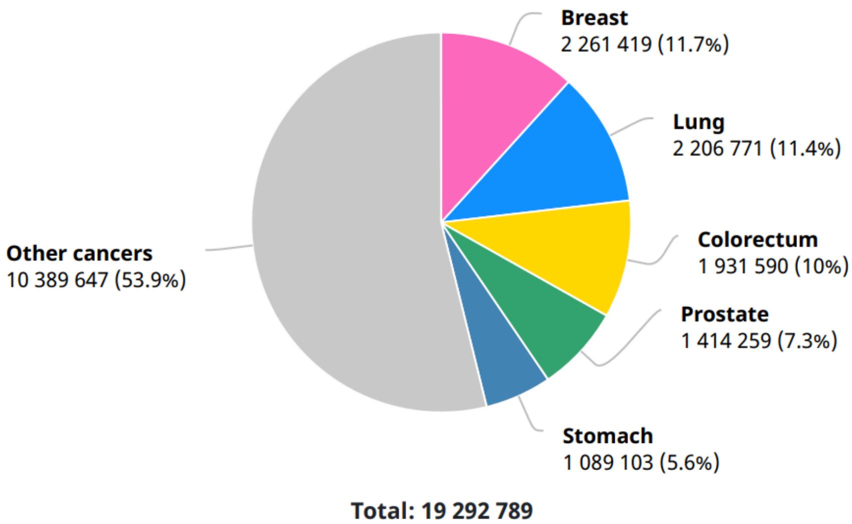
- Globally **18** million new cases per year diagnosed and **9.6** million deaths in **2018**
- This will increase to **27.5** million new cases per year and **16.3** million deaths by **2040**
- **70% of these deaths** will occur in low-and-middle-income countries (LMICs)



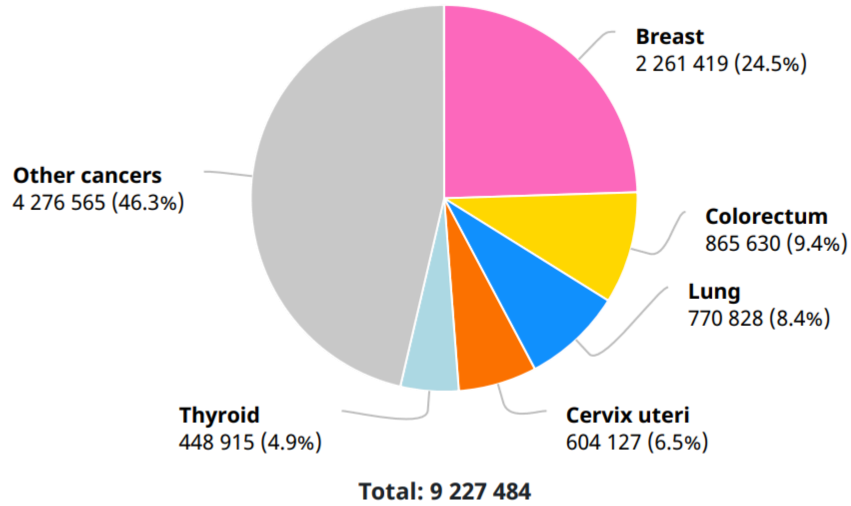
Radiation therapy is a key tool for treatment for over 50% patients

GLOBOCAN 2020

Number of new cases in 2020, both sexes, all ages



Number of new cases in 2020, females, all ages



Every year, 2 million women worldwide are diagnosed with breast or cervical cancer:

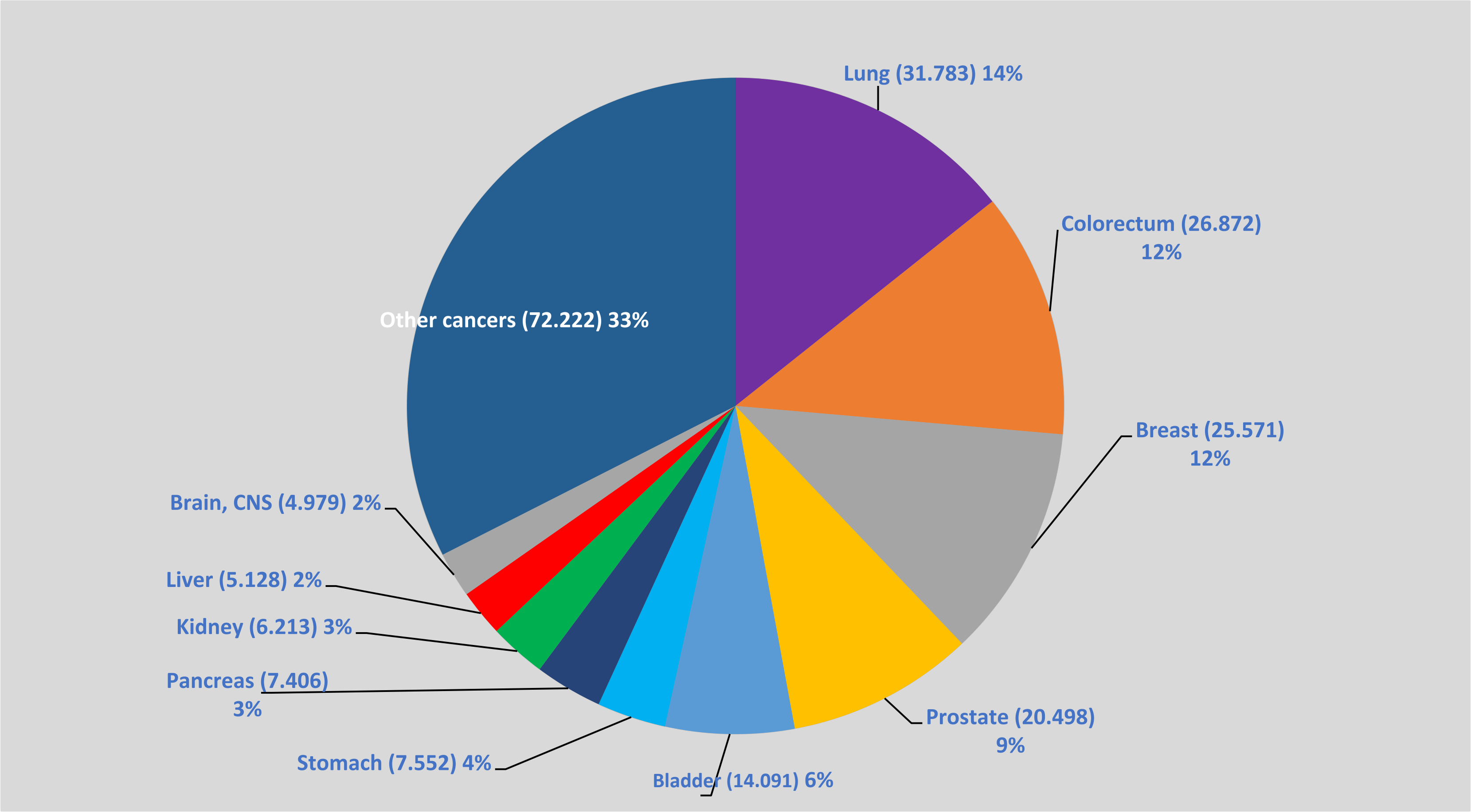
- 7 of 10 breast cancer deaths occur in low-middle income countries
- 9 of 10 cervical cancer deaths occur in low-middle income countries

SDG Goals and Maternal mortality: These breast and cervical cancer deaths also have a huge impact on child mortality, for every 100 women about 14-20 children die

Estimating child mortality associated with maternal mortality from breast and cervical cancer

Raymond B. Mailhot Vega, MD, MPH[1,2]; Onyinye D. Balogun, MD[3]; Omar F. Ishaq, MD[1]; Freddie Bray, MD[4]; Ophira Ginsburg, MD[5]; and Silvia C. Formenti, MD[3]

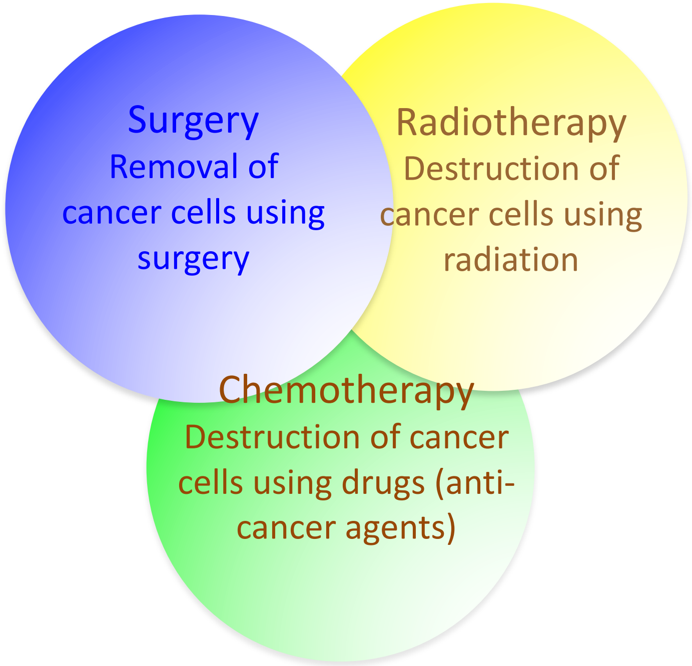
Estimated cancer incidence in absolute numbers in SEE region by cancer type, All ages, Both sexes (2018)



Cancer

- Tumour: why?
  - Abnormal growth of cells
  - Uncontrolled growth, can spread → cancer
  - Age related?

- Treatment: how?
  - Surgery
  - Radiation
  - Chemotherapy



The Challenge of Treatment

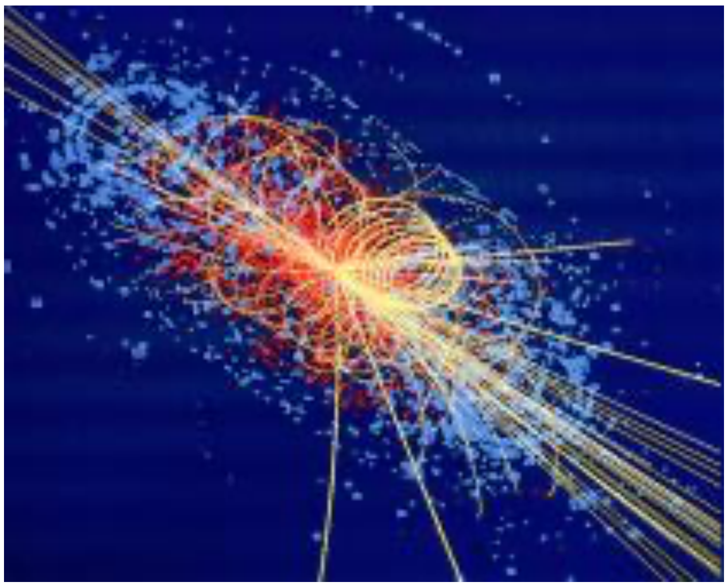
Ideally one needs to treat:

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

Treatment has two important goals to kill 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.

No treatment without detection!

Particle Detection



Imaging

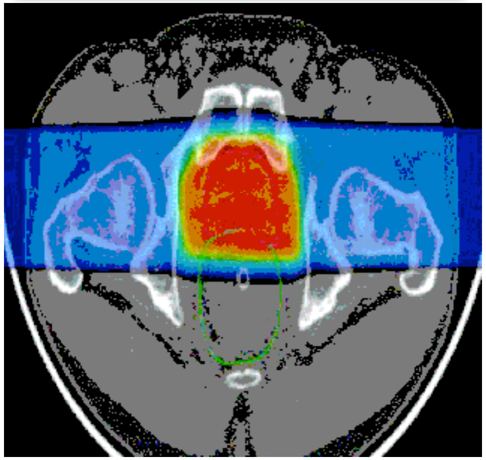
X-ray, CT, PET, MRI

Art of seeing………

Treatment options

Surgery

Radiotherapy



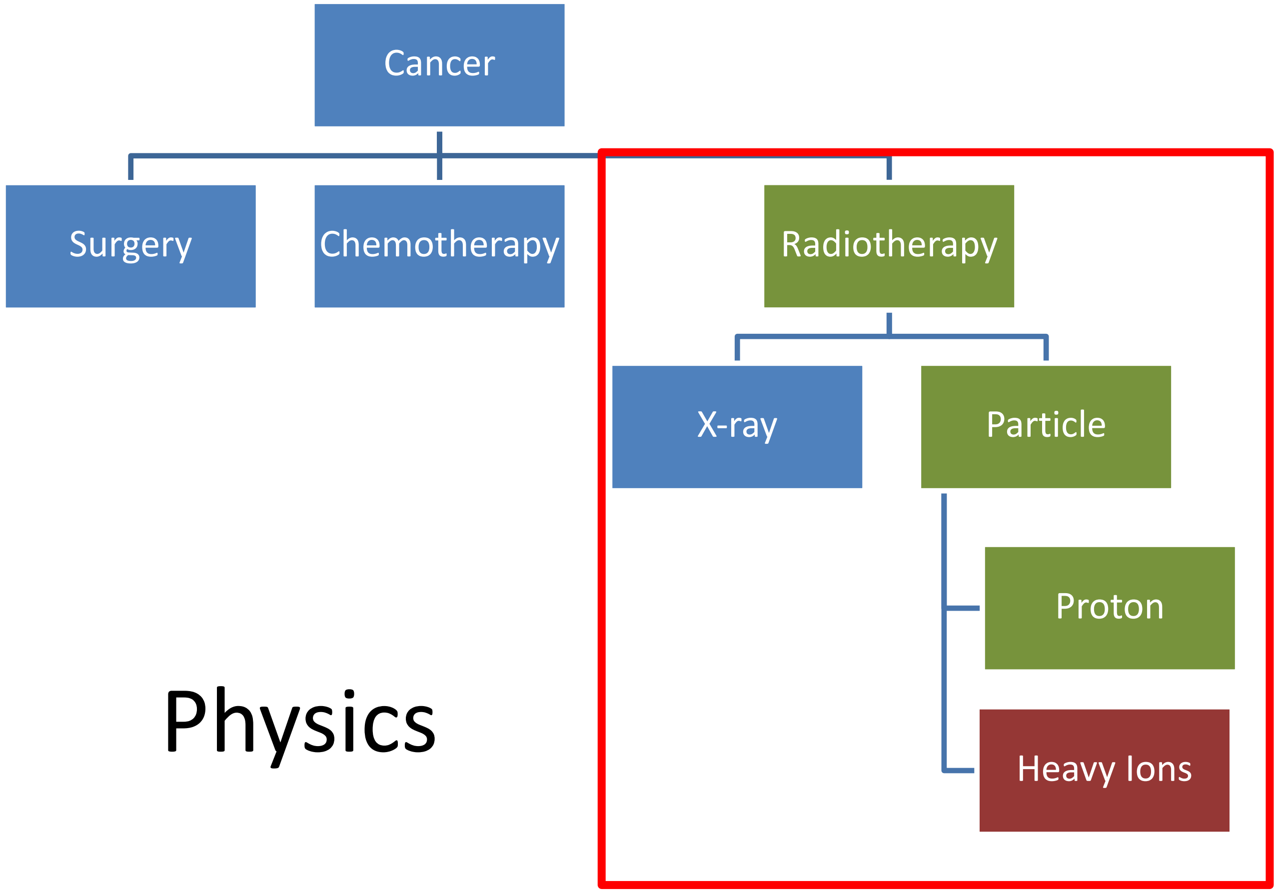
X-ray, IMRT, Brachytherapy, Hadrontherapy

Chemotherapy (+ others)

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

AIM:
Survival, Quality of life

Cancer treatment options



Physics

Radiotherapy in 21st Century

3 "Cs" of Radiation

Cure (about 50% cancer cases are cured)

Conservative (non-invasive, fewer side effects)

Cheap (about 10% of total cost of cancer on radiation)

(J.P.Gérard)

- About 50% patients are treated with RT
- No substitute for RT in the near future
- No of patients is increasing

Radiation Therapy Today

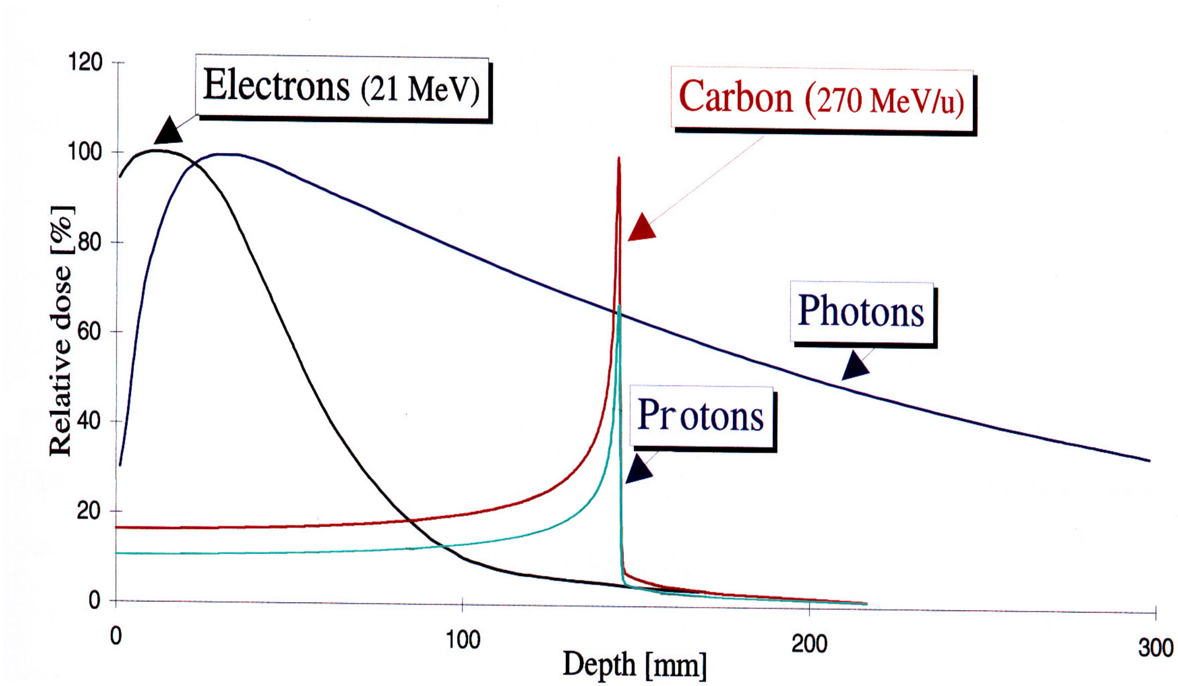
- Key radiation therapy delivery systems
  - Cobalt 60 machines
  - Linear accelerators (Linacs)
  - Brachytherapy
  - Image-guided radiotherapy (IGRT); MR-guided etc.
  - Particle therapy (proton and carbon, other ions)
  - FLASH therapy

Aims of Radiotherapy:

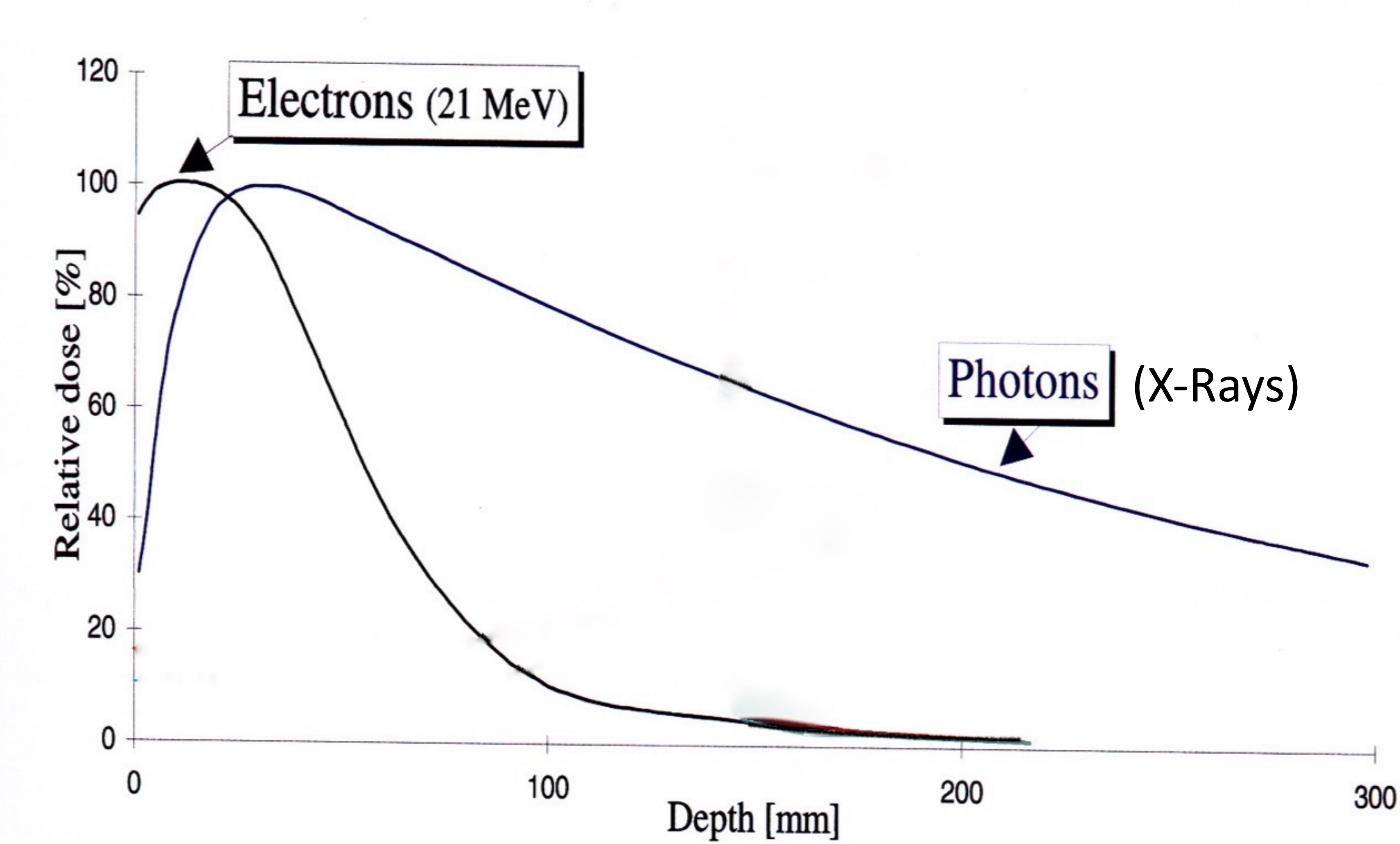
- Irradiate tumour with sufficient dose to **stop cancer growth**
- **Avoid complications** and **minimise** damage to surrounding tissue

Current radiotherapy methods:

- MV photons
- 5 - 25 MeV electrons
- 50 - 300 MeV/u hadrons

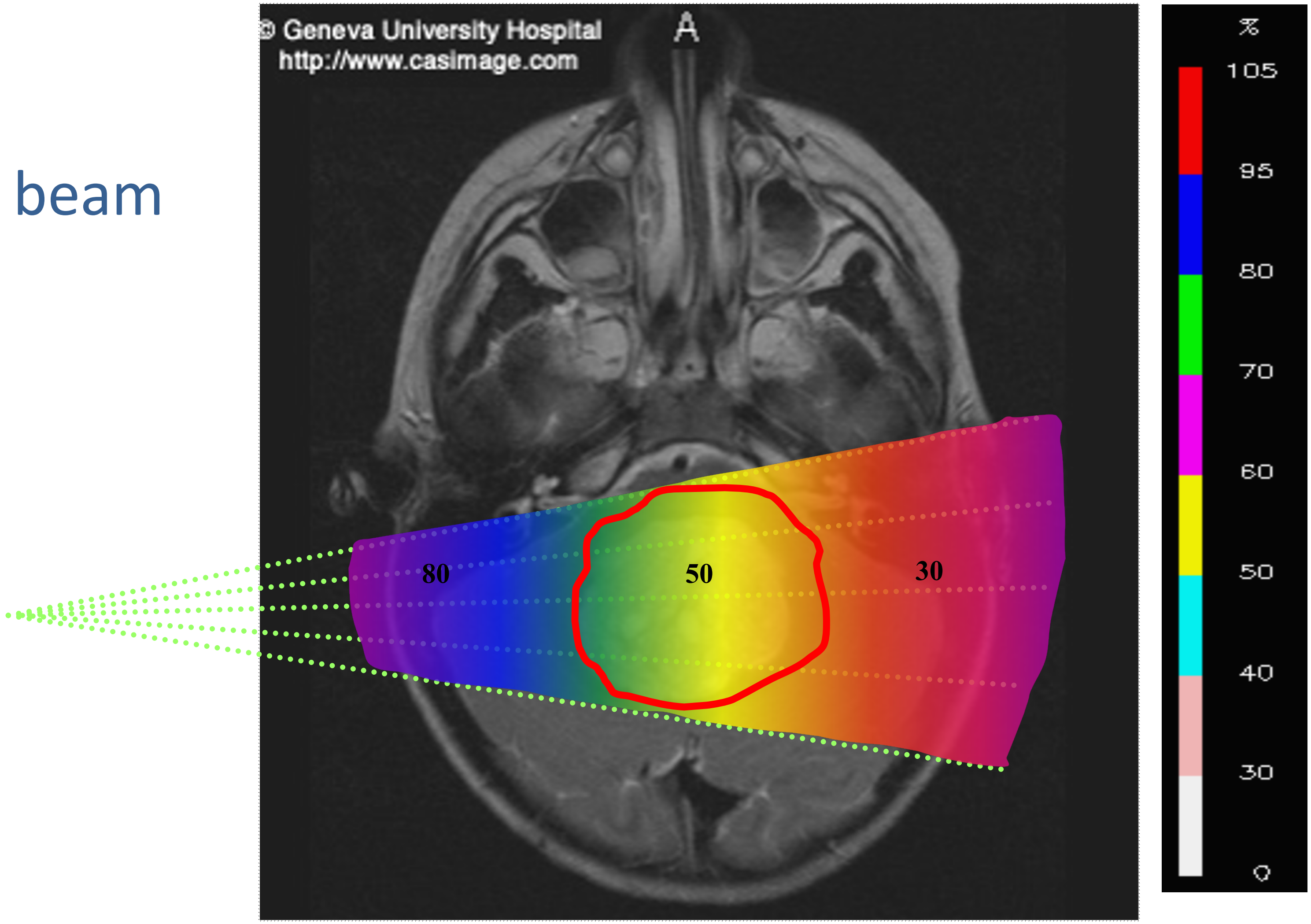


Radiation therapy



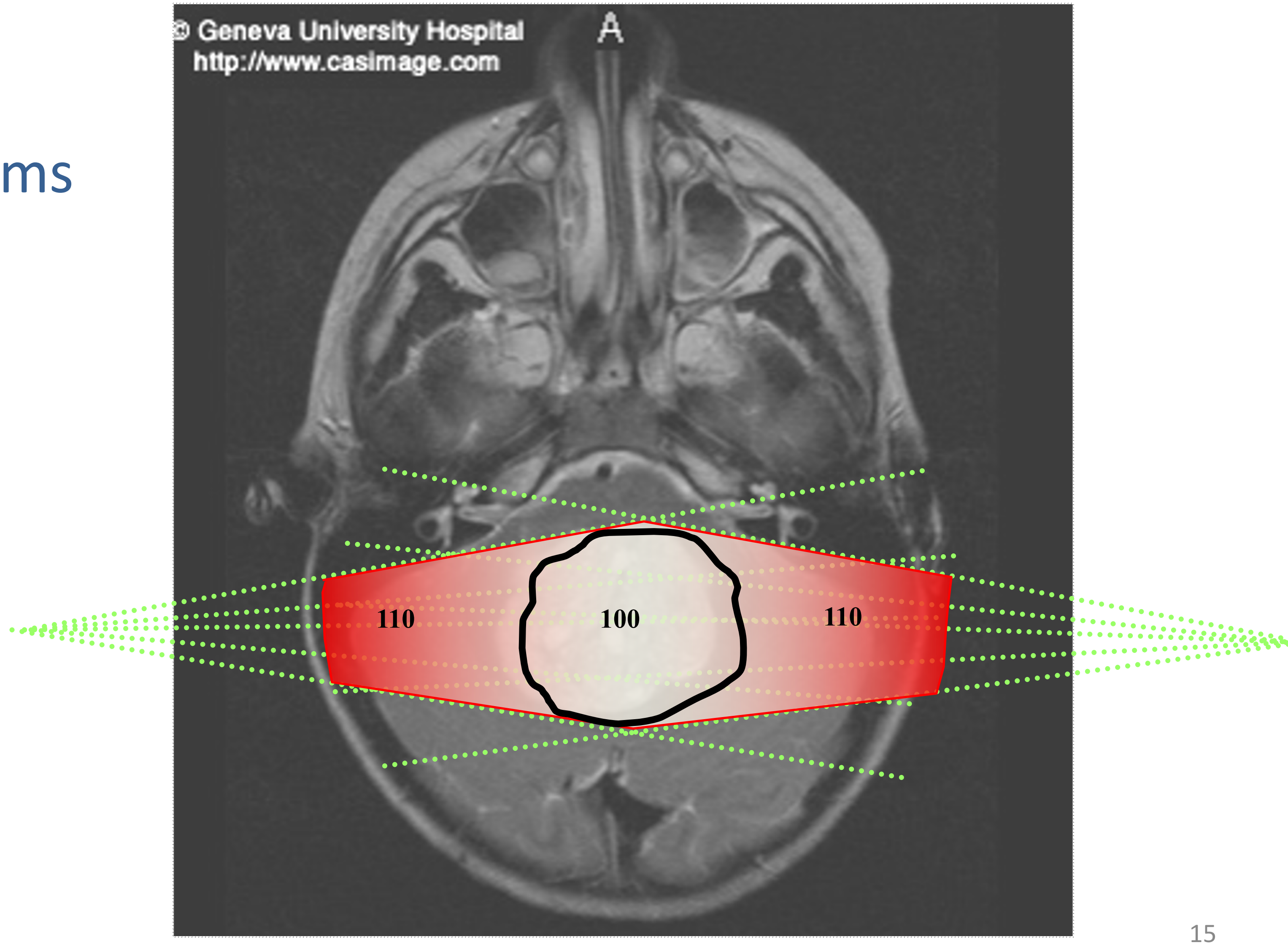
Classical Radiotherapy with X-rays

single beam

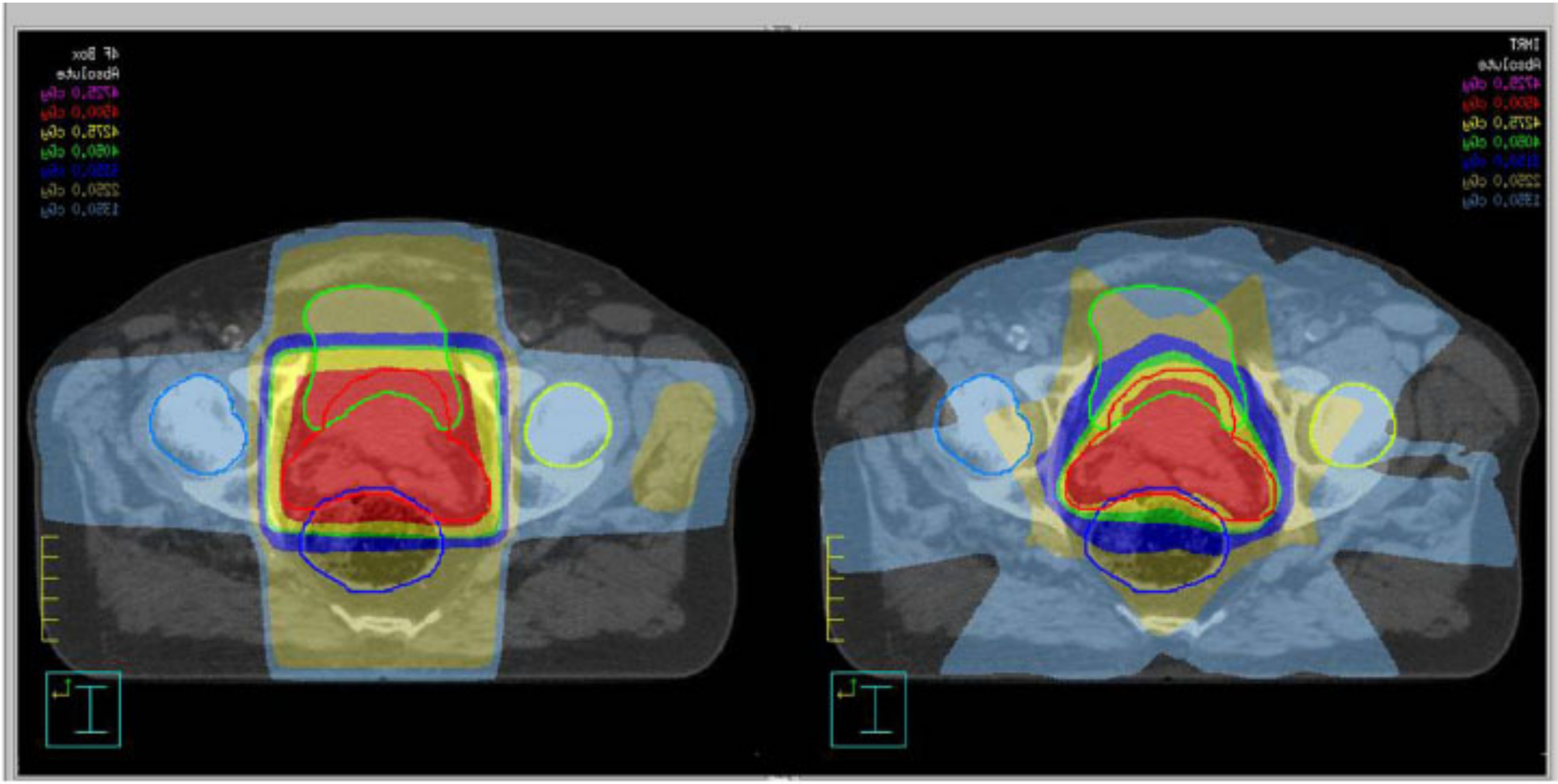


Radiotherapy with X-rays

two beams



Improved Delivery

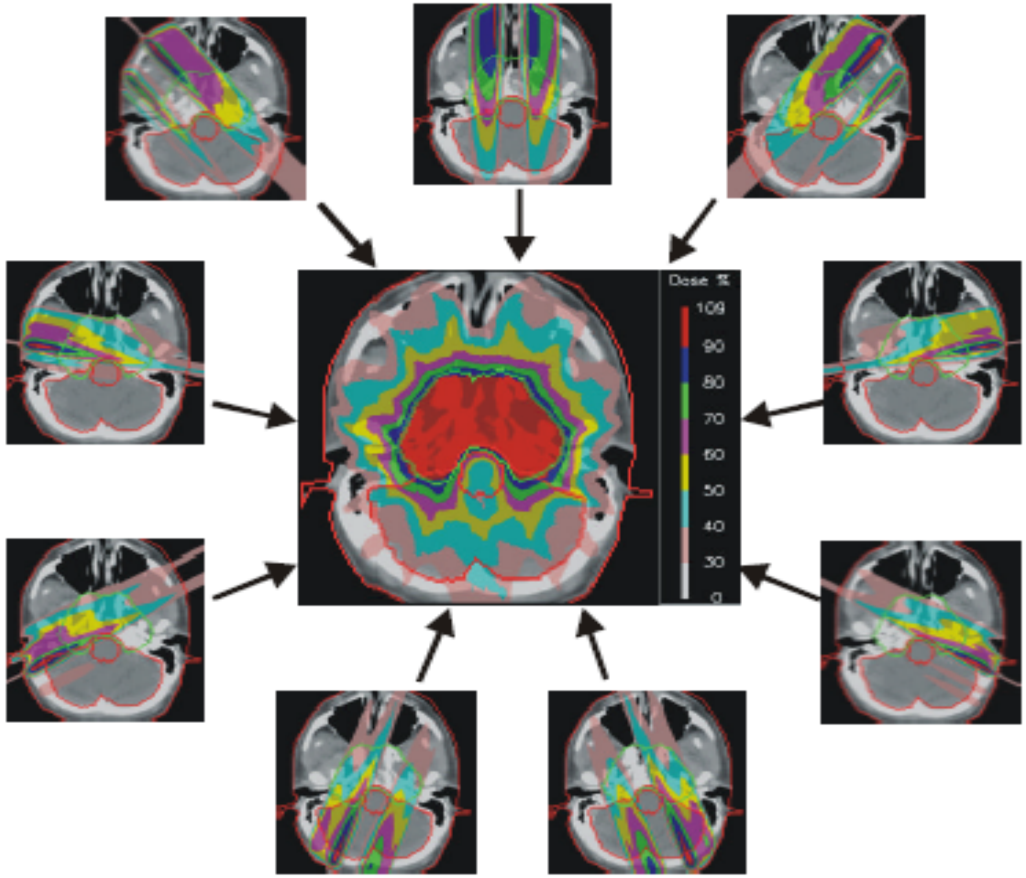


1990s: 4 constant intensity fields

Current state of RT: Intensity Modulated Radiotherapy (IMRT) – Multiple converging field with planar (2D) intensity variations

Intensity Modulated Radiation Therapy

9 NON-UNIFORM FIELDS



RSI

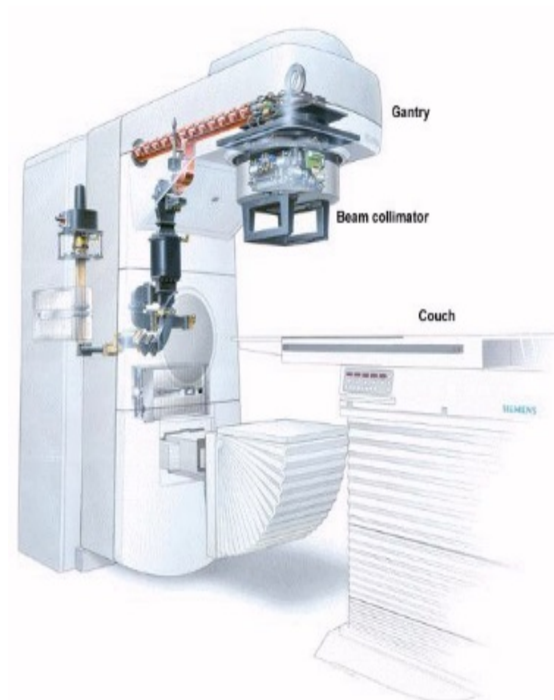
60-75 grays (joule/kg) given in 30-35 fractions (6-7weeks)

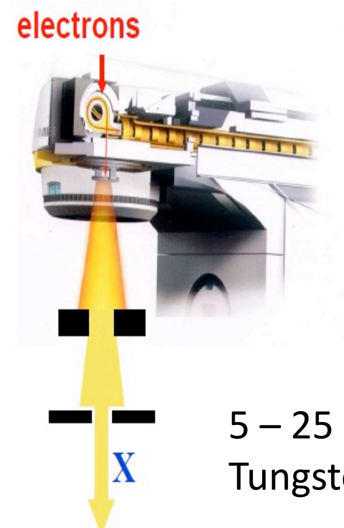
to allow healthy tissues to repair:

90% of the tumours are <u>radiosensitive</u>

The most widespread accelerator

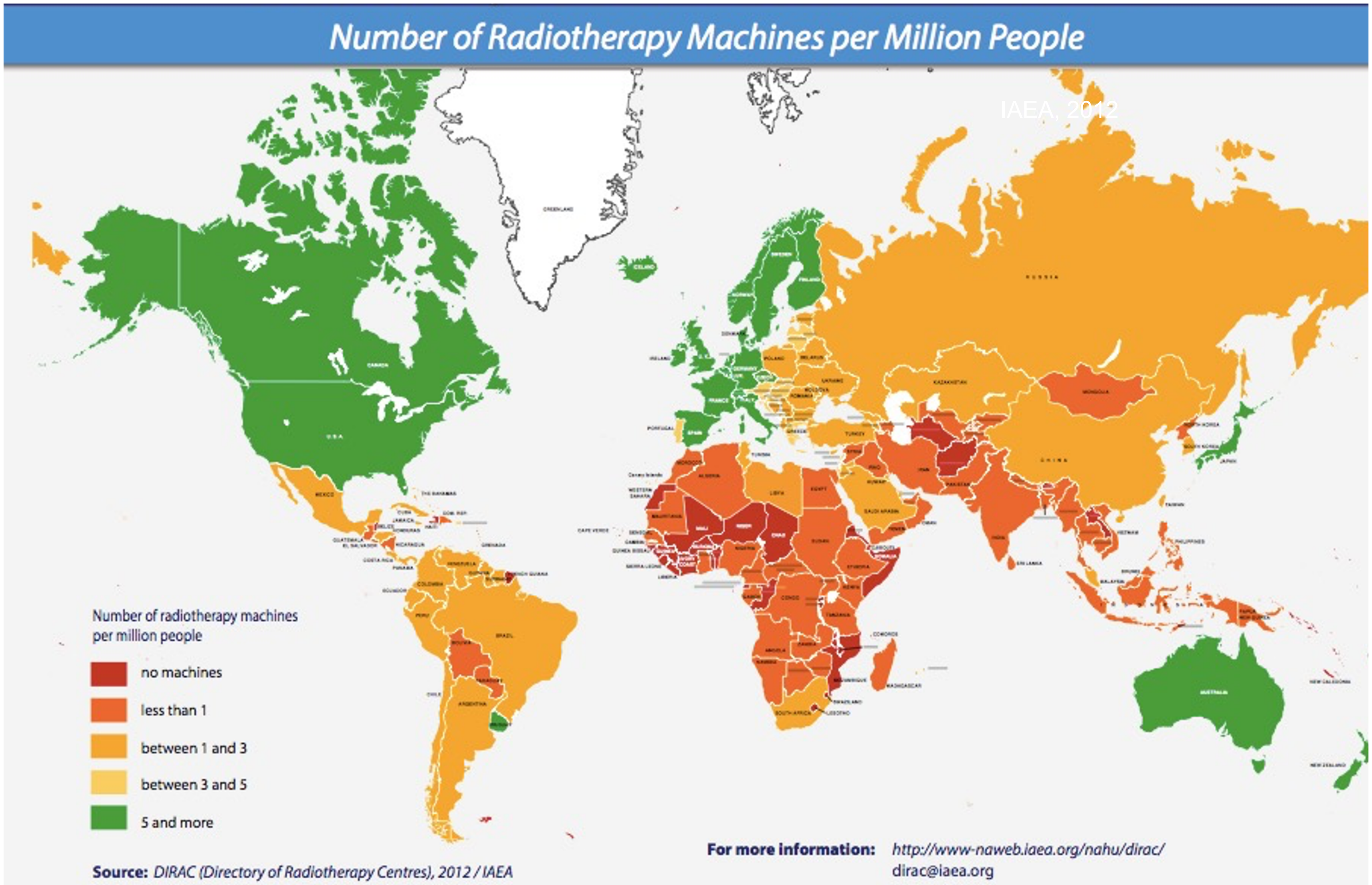
Electron Linac (linear accelerator) for radiotherapy (X-ray treatment of cancer)





5 – 25 MeV
Tungsten target

Cancer and Linac-based Radiotherapy Treatment

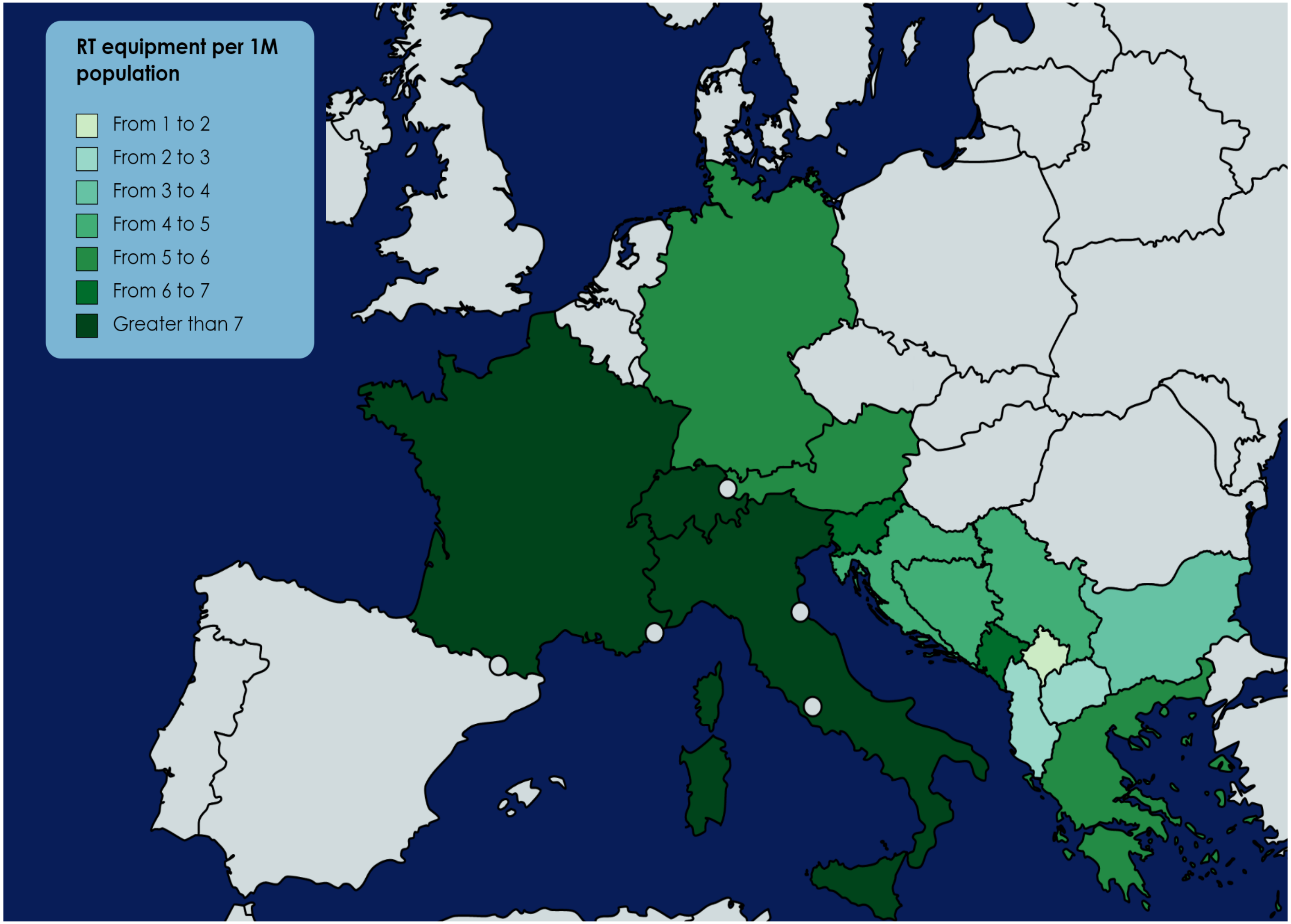


CERN

International Cancer Expert Corps
Partnering to transform global cancer care

UNIVERSITY OF OXFORD

RT machines per Million Inhabitants

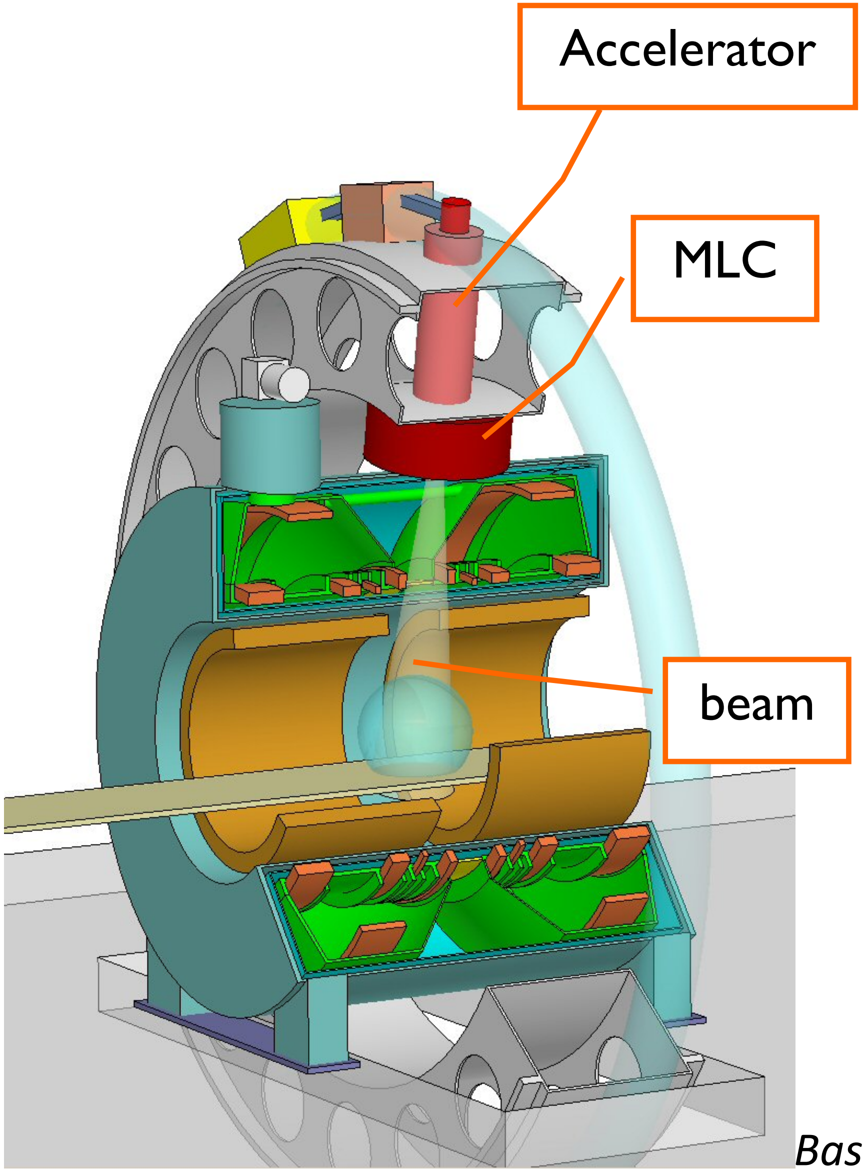


Advances in Radiation Therapy

In the past two decades due to:

- improvements in imaging modalities, multimodality
- technology, powerful computers and software and delivery systems have enabled:
  - Intensity Modulated Radiotherapy (IMRT),
  - Image Guided Radiotherapy (IGRT),
  - Volumetric Arc Therapy (VMAT) and
  - Stereotactic Body Radiotherapy (SBRT)
  - MRI-guided Linac therapy
- Is Hadron/Particle Therapy the future?

Concept of MRI guided accelerator



Seeing what you treat at the moment of treatment

Bringing certainty in the actual treatment

Bas Raaymakers, Utrecht, UMC, ENLIGHT

Utrecht solution: Integrating a Philips MRI scanner with a Elekta radiotherapy accelerator

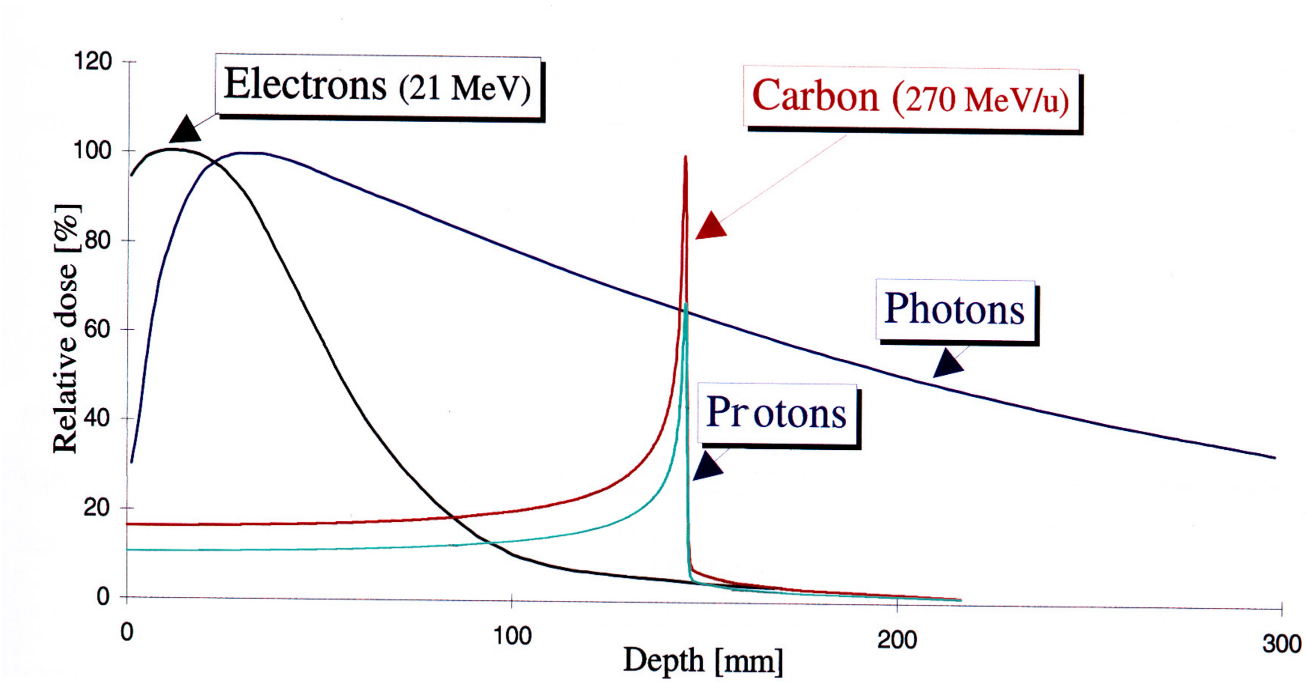
1.5T 70 cm bore Philips Ingenia

Lagendijk and Bakker, MRI guided radiotherapy - A MRI based linear accelerator
Radiotherapy and Oncology Volume 56, Supplement 1, September 2000, 220

Why Hadron Therapy?

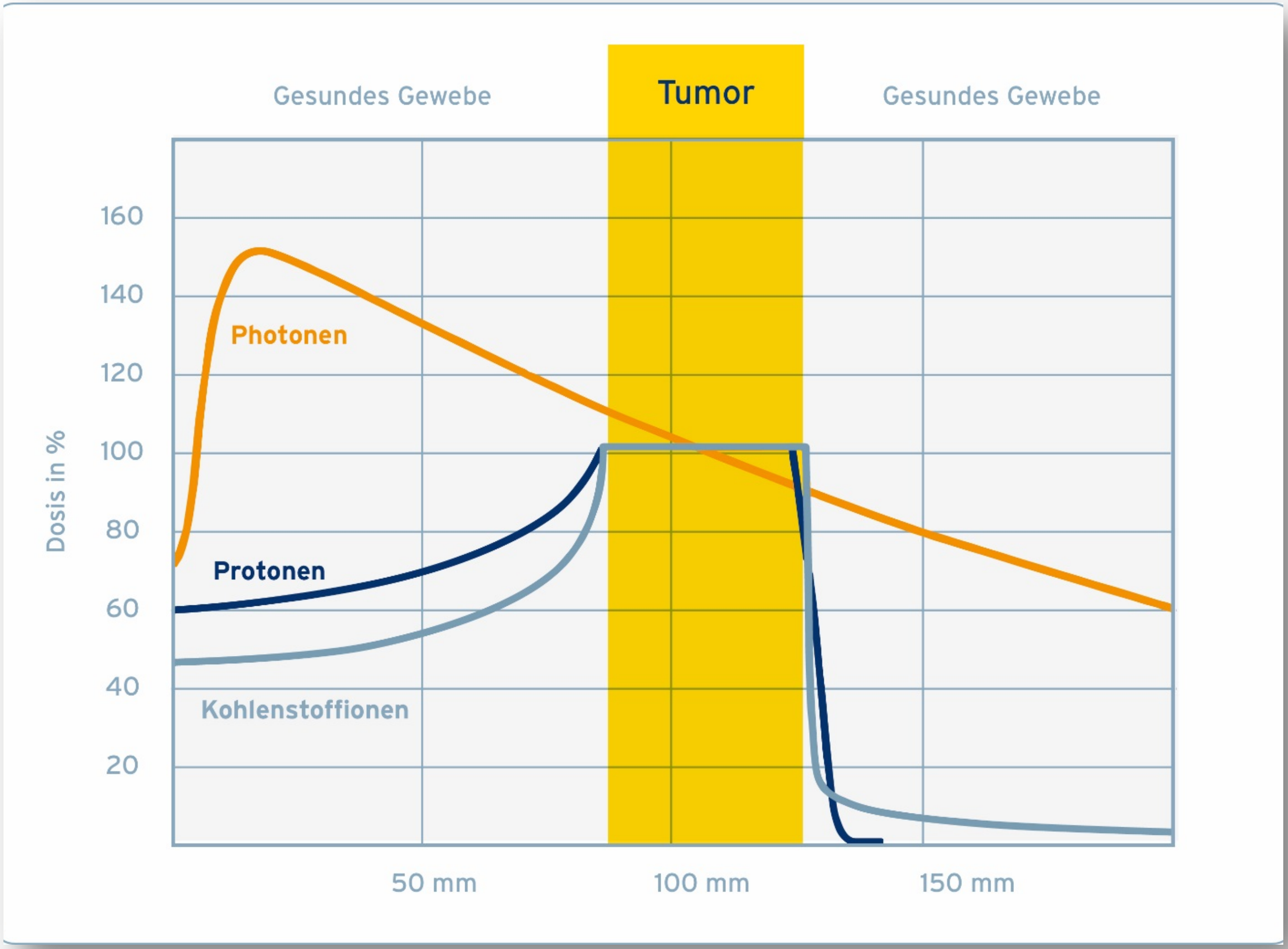
In 1946 Robert Wilson:

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



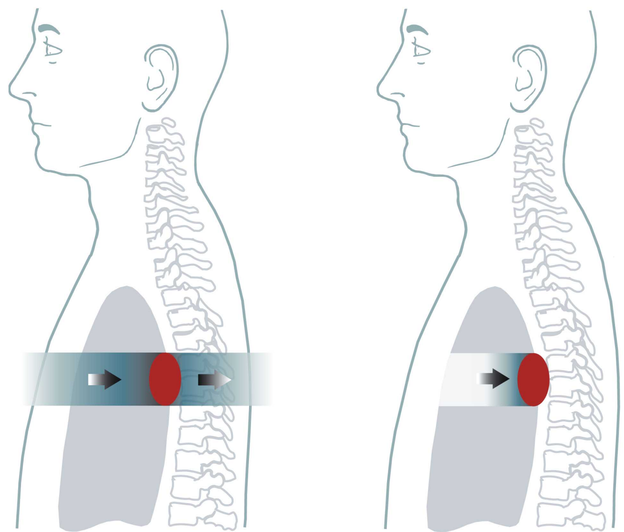
Depth in the body (mm)

Hadron Therapy

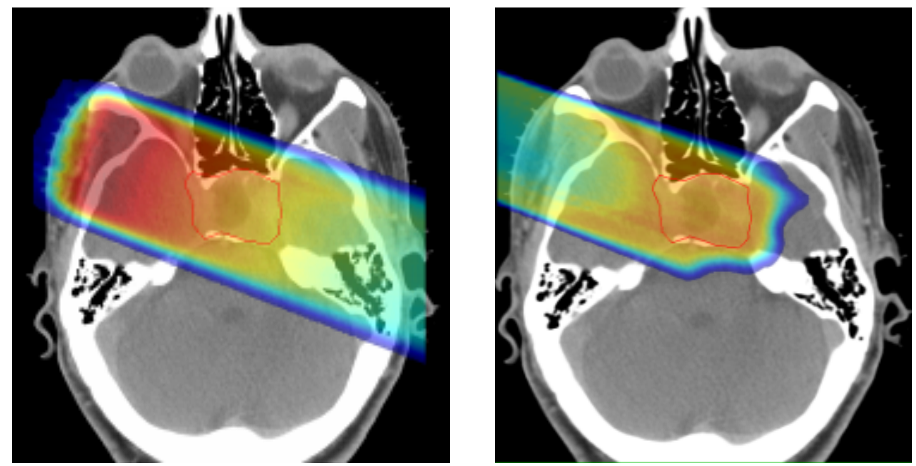


Why hadron therapy?

Image courtesy MedAustron

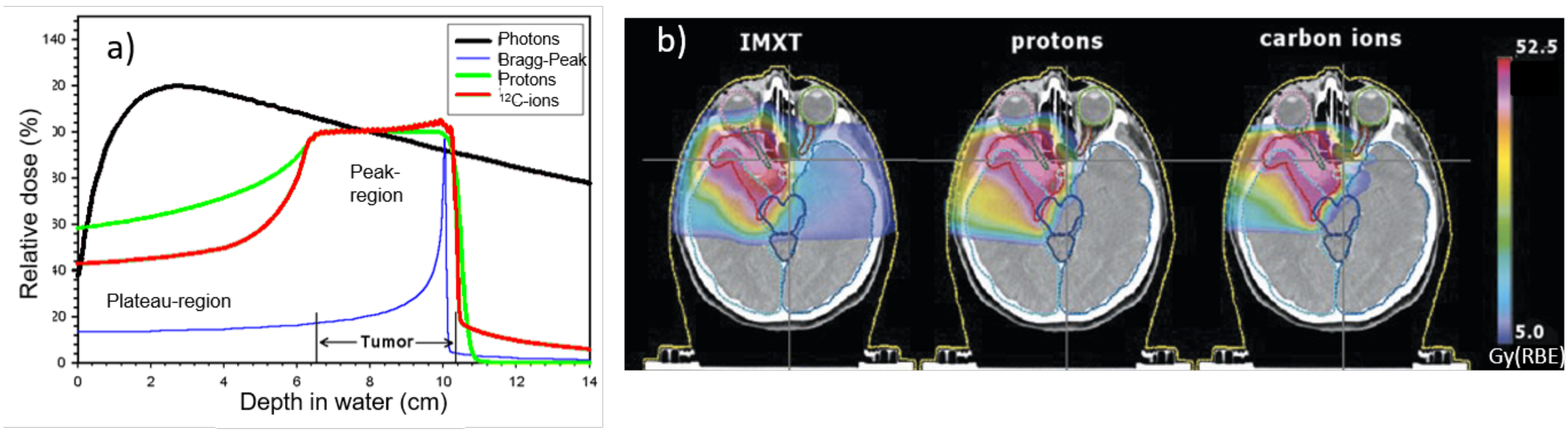


Conventional: X-Rays Ion Radiation



Spares normal healthy tissue

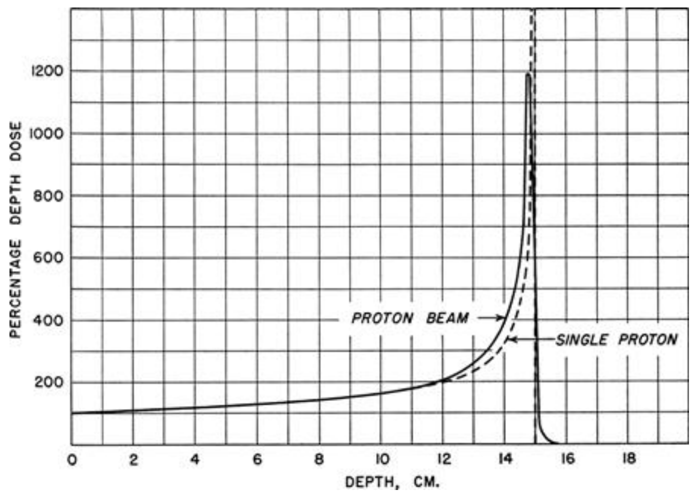
Why Particle/Hadron Therapy?



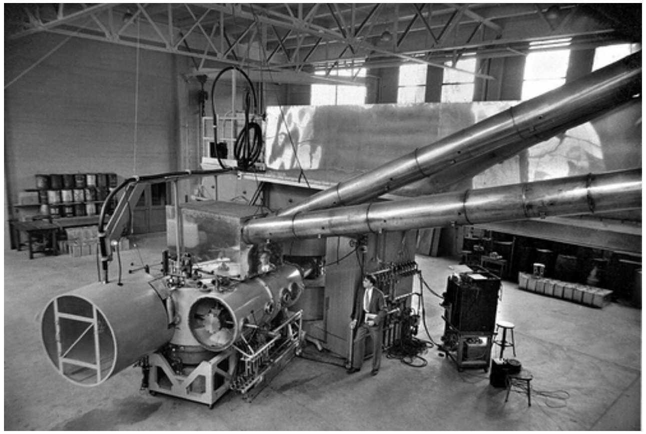
Depth dose profiles in water (a) and treatment plans (b) comparing photons, delivered with the most advanced intensity modulation RT (IMXT), and state-of-the-art scanned protons and ^{12}C ions, showing the increased tumour-dose conformity of ion therapy due to the characteristic Bragg peak (a).

1932 - E. Lawrence
First cyclotron

1946 – proton therapy
proposed by R. Wilson

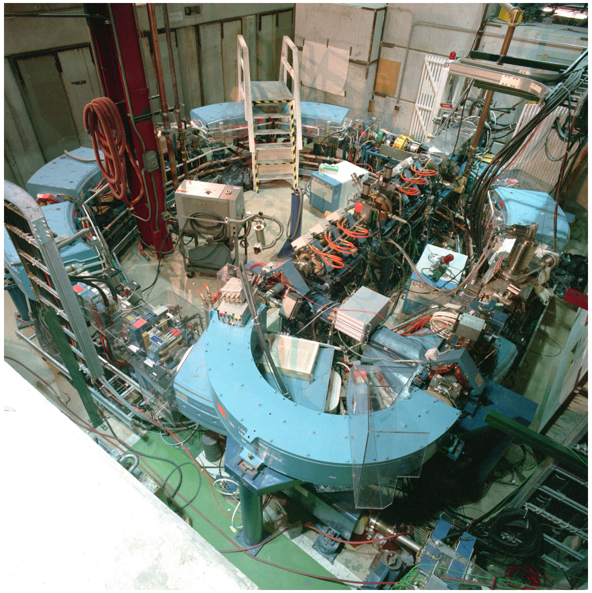


1954 – Berkeley treats
the first patient



From physics……..

1993- Loma Linda USA (proton)



First dedicated clinical facility

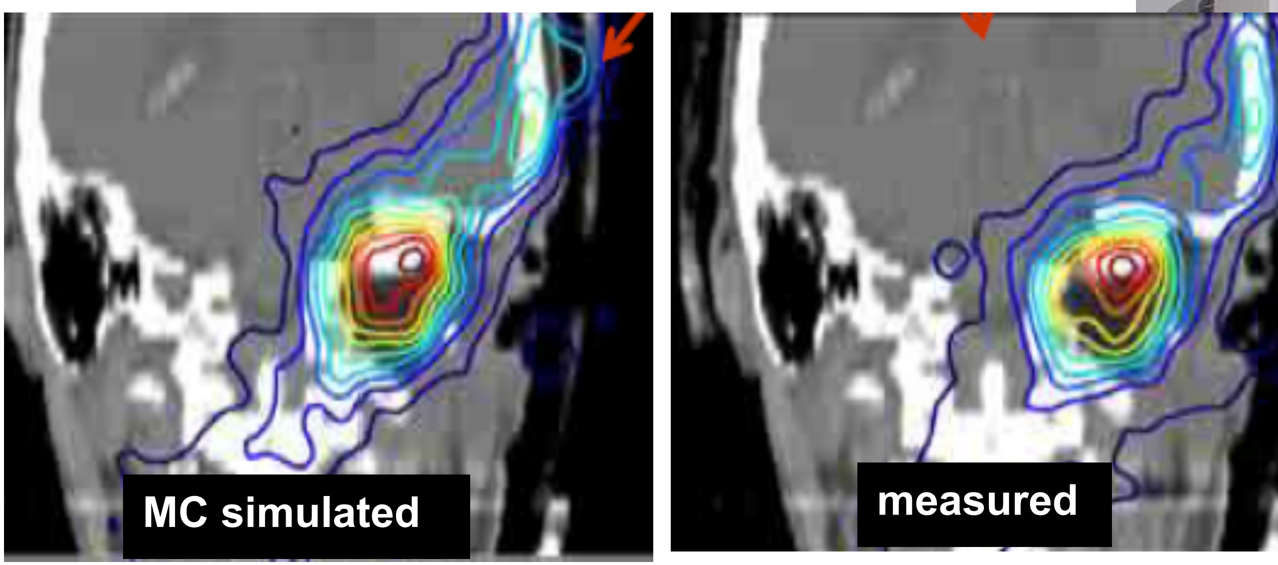
1994 – HIMAC/NIRS Japan (carbon)

1997 – GSI Germany (carbon)

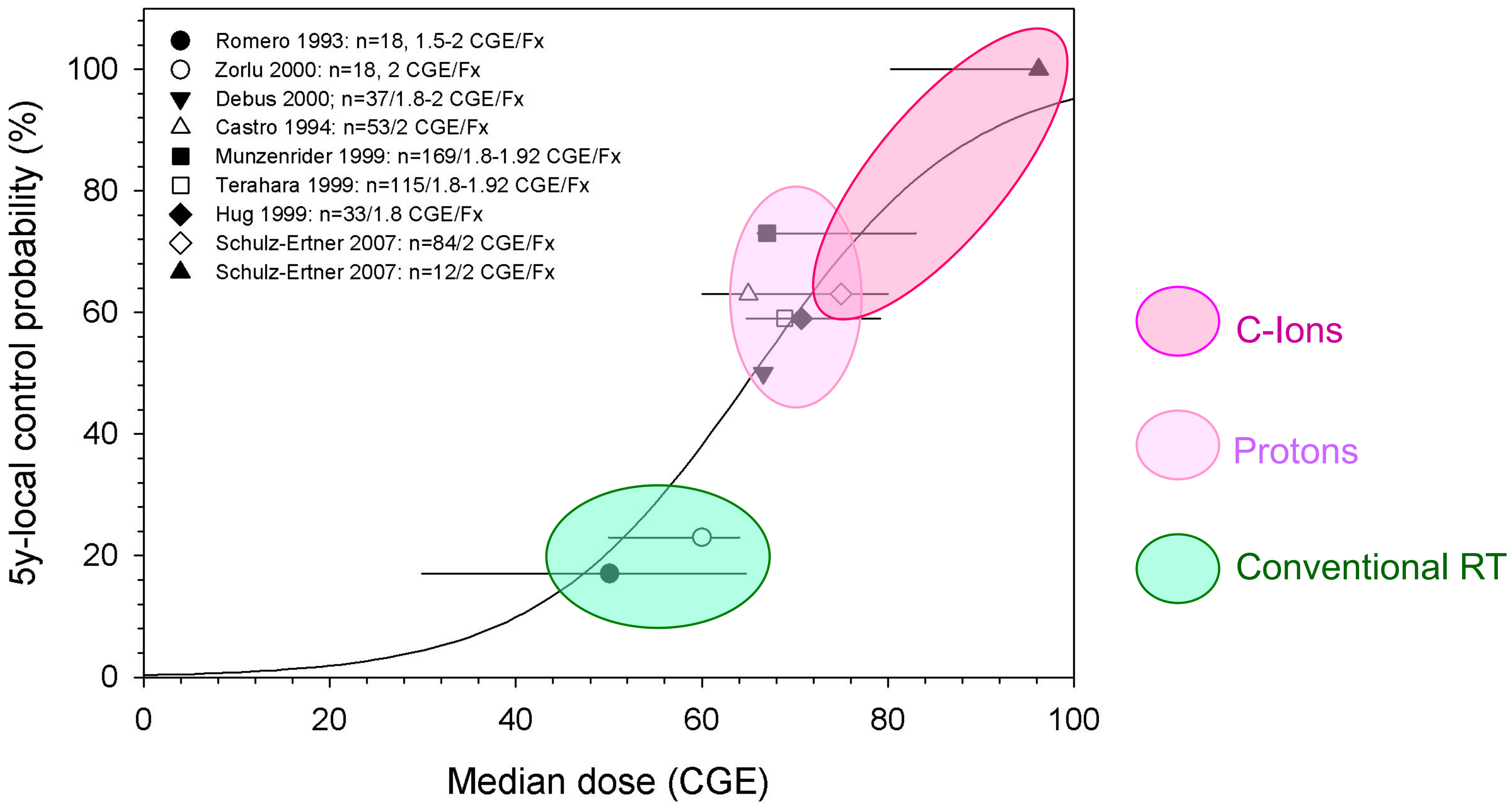
Three crucial years for PT……..to clinics

Real-time monitoring

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

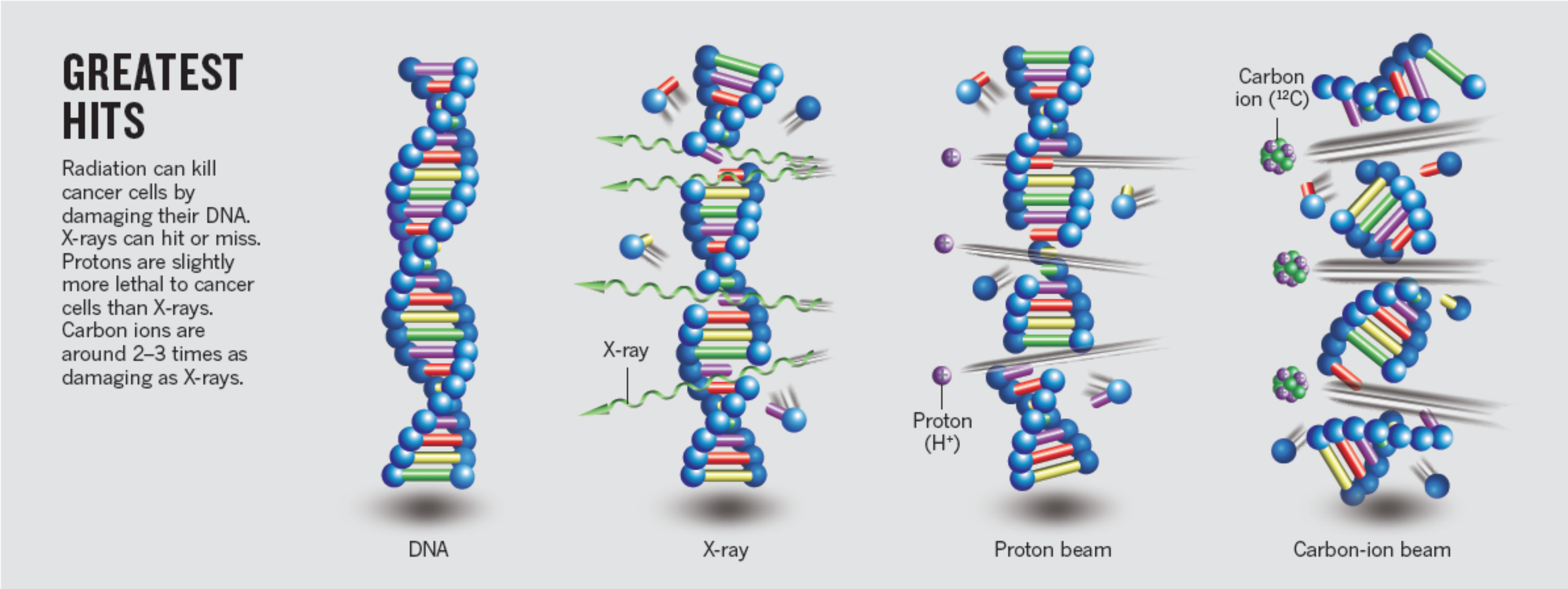


Tumour Control Rate: Chordomas



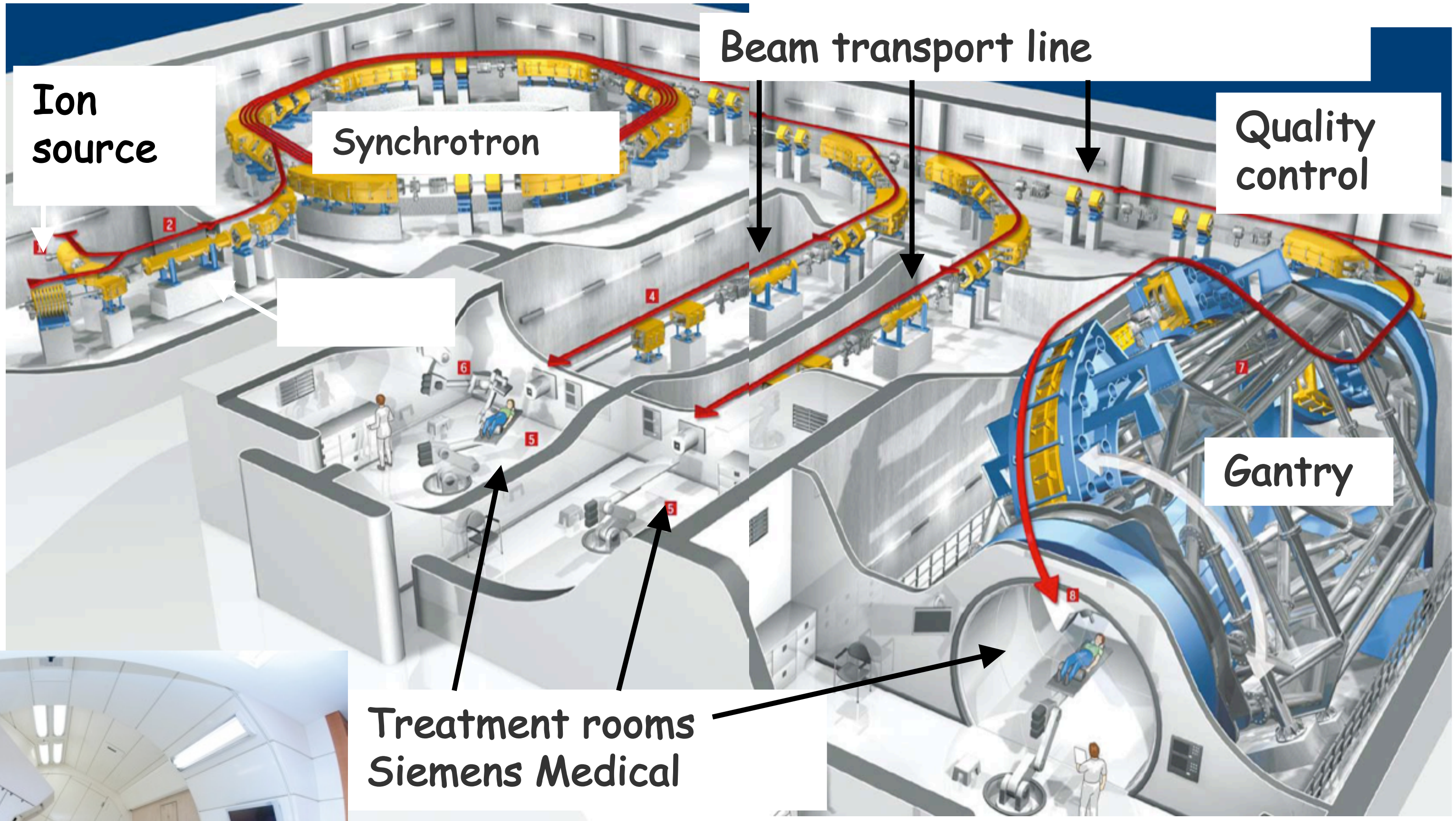
Schulz-Ertner, IJROBP 2007

DNA X-rays Protons Carbon ions



Marx, Nature, 2014

HIT - Heidelberg



Carbon facilities in Europe: first was HIT in Heidelberg – started treating patients in 2009

Facilities in operation in Europe 2002

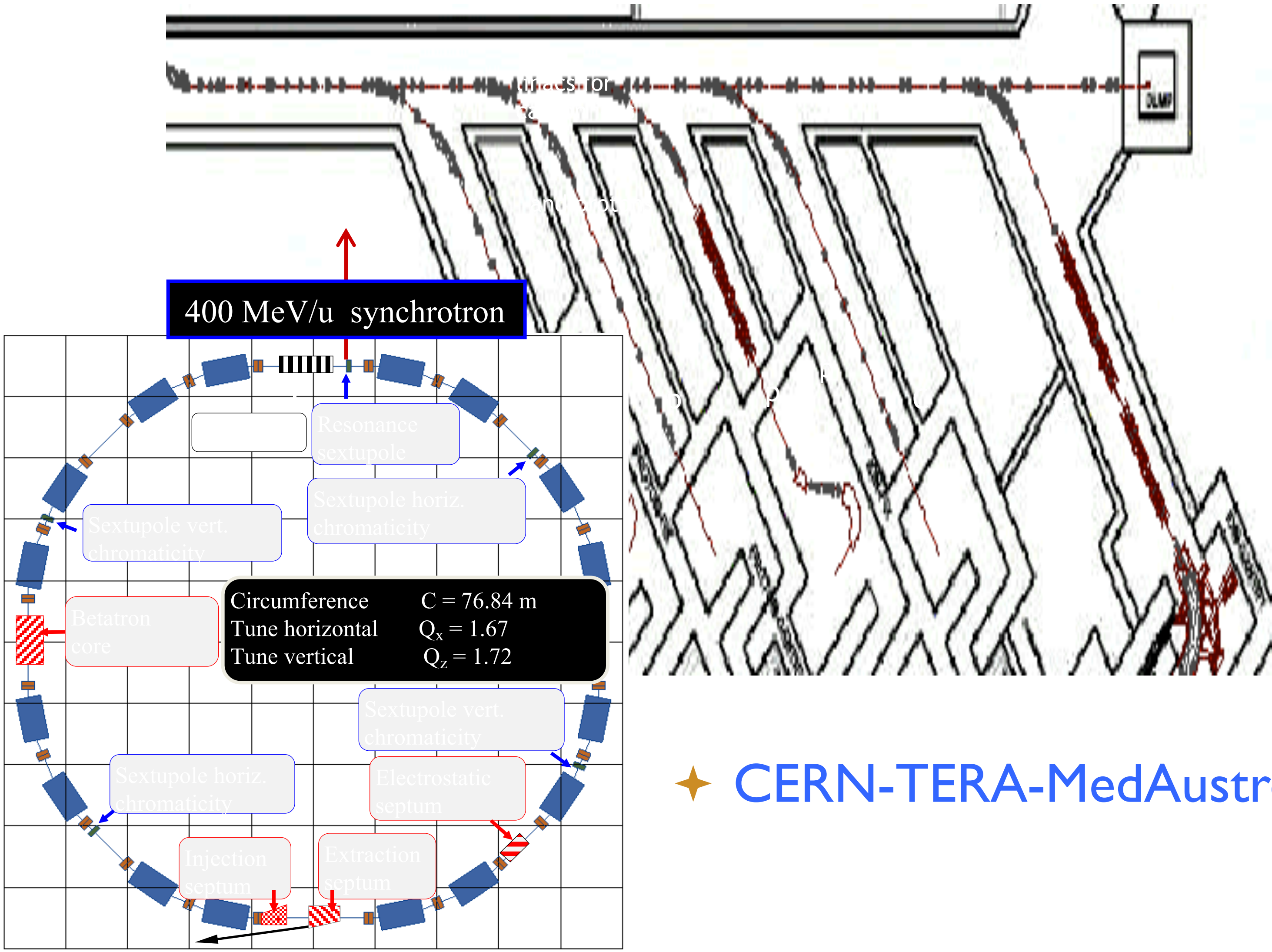
P centres

C-ion centres

Dual-ion centres

Source: PTCOG

PIMMS at CERN (1996-2000)



- CERN-TERA-MedAustron

2001

The beginnings of ENLIGHT

- The idea germinated in 2001 after ESTRO- Med-AUSTRON meeting
- In October 2001 the proposal for a Thematic Network was submitted to EC
- ENLIGHT was launched In February 2002 at CERN
- Funded: 1 million Euros in 2002

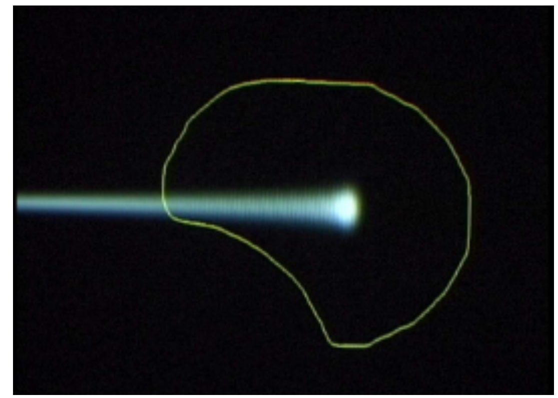
Driving Force:
Ugo Amaldi
Jean Pierre Gerard
Germane Heeren

Organisation:
Hans Hoffmann
Manjit Dosanjh

ENLIGHT

European Network for Light Ion Hadron Therapy

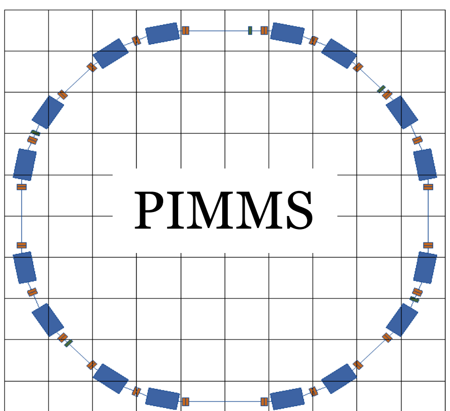
- Launched at CERN in 2002, following PIMMS study
- Common **multidisciplinary platform**
- Cancer treatment
- Identify **challenges**
- Share **knowledge** and best practices
- Harmonise data
- Provide **training**, education
- **Innovate** to improve
- Lobby for funding



PIMMS study at CERN (1996-2000)

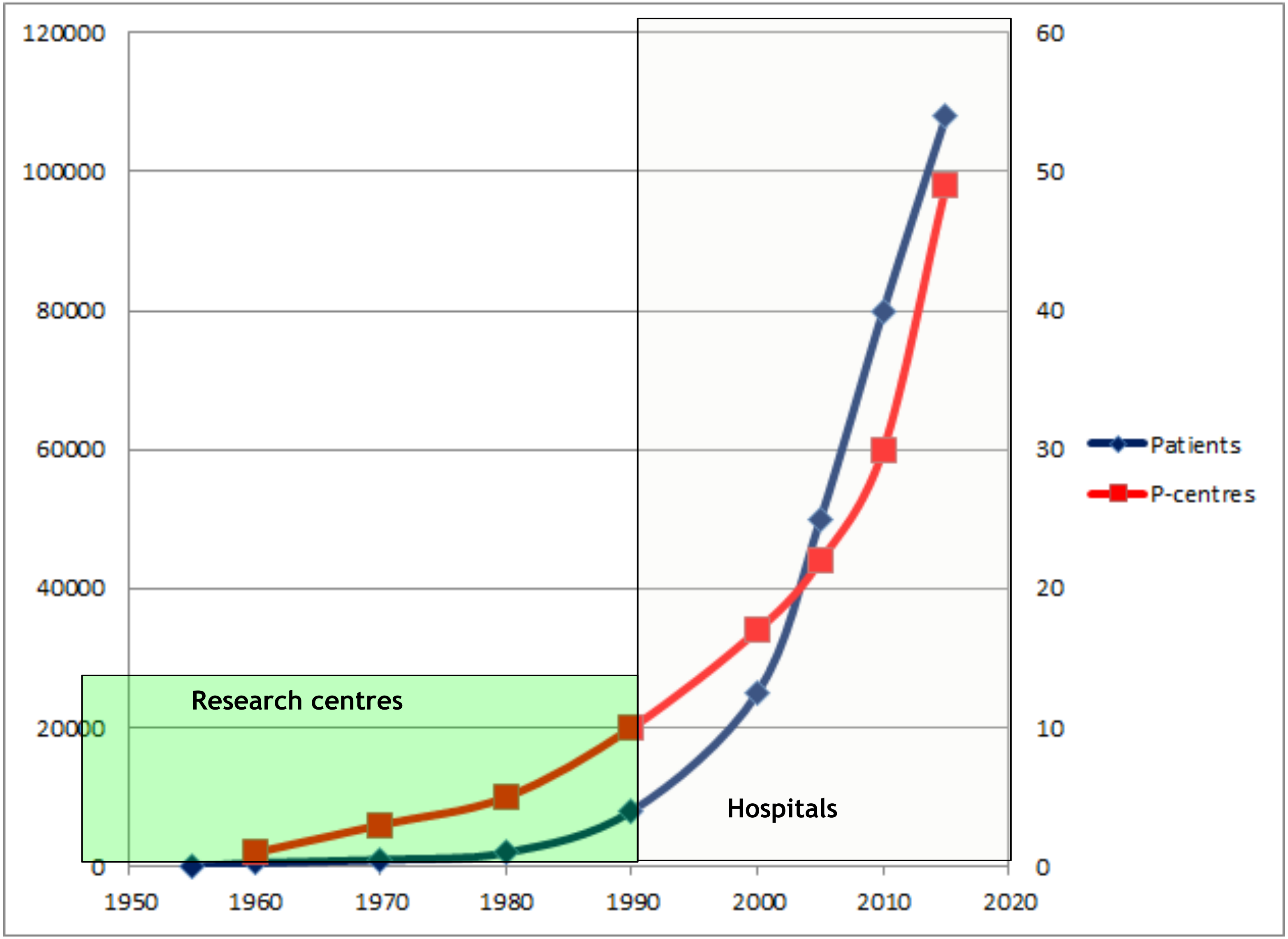
Treatment , CNAO, Italy
2011

1996-2000
PIMMS study

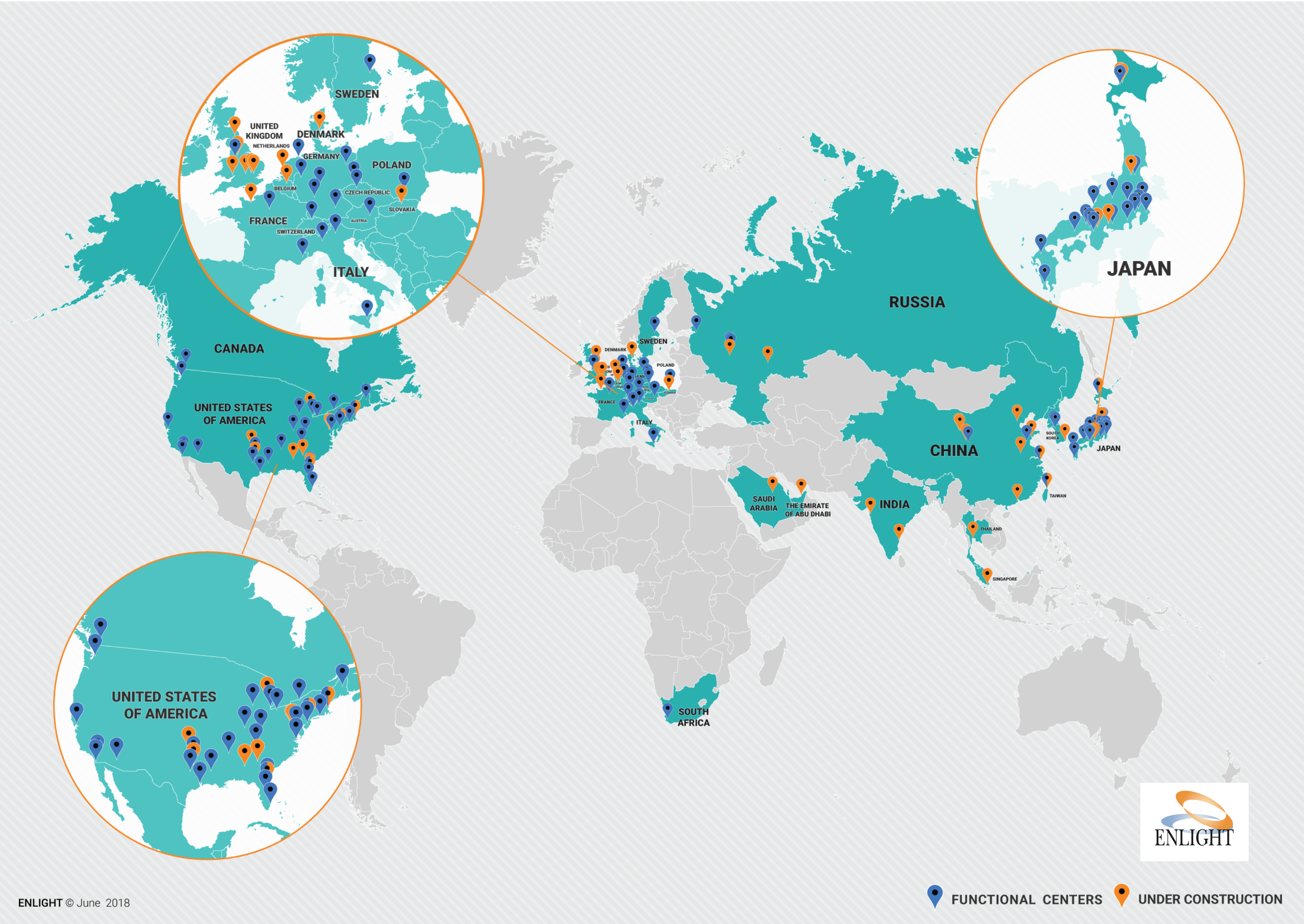


MedAustron, Austria 2016

[Data from www.ptcog.ch]



Facilities in operation in Europe 2020


SWEDEN
UNITED KINGDOM
DENMARK
NETHERLANDS
GERMANY
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BELGIUM
CZECH REPUBLIC
SLOVAKIA
FRANCE
AUSTRIA
SWITZERLAND
ITALY
JAPAN
RUSSIA
CANADA
UNITED STATES OF AMERICA
CHINA
SOUTH KOREA
TAIWAN
SAUDI ARABIA
THE EMIRATE OF ABU DHABI
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SINGAPORE
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UNITED STATES OF AMERICA
ENLIGHT
FUNCTIONAL CENTERS
UNDER CONSTRUCTION
ENLIGHT © June 2018

What do we need in the future?

- Treat the tumour and only the tumour

    ⇒Even if the tumour is moving

- Cheap
- Small: Fit into every large hospital ?

New collaboration project started for a future improved facility in SEE region (CERN, GSI, CNAO, HIT, SEE, ……….)

CERN: Beyond PIMMS to NIMMS

A new accelerator design


Ideas and technologies for a next-generation facility for medical research and therapy with ions

Requirements of the ion therapy community, expressed at the Archamps Workshop, June 2018

1. Concentrate on heavy ions (Carbon but also Helium, Oxygen, etc.) because proton therapy is now commercial (4 companies offer turn-key facilities) while ions have higher potential for treatment but lower diffusion.

2. A next generation ion research and therapy accelerator must have:

- ❑ Lower cost, compared to present;
- ❑ Reduced footprint;
- ❑ Lower running costs;
- ❑ Faster dose delivery with higher beam intensity or pulse rate;
- ❑ A rotating ion gantry;
- ❑ Operation with multiple ions (for therapy and research).

An innovative design:

- Can attract a wide support from the scientific community;
- Can increase the exchange SEE-WE and inside SEE thanks to stronger collaboration on scientific and technical issues;
- Can bring modern high technology to the region, with new opportunities for local industry and scientific institutions.

+ Specific requirements for SEEIIST:

- ❑ Easy Industrialization
- ❑ Reliability
- ❑ Simple operation
- ❑ Reduced risk
- ❑ Acceptable time to development

SEEIIST Architectural Design

Where it all started.....

Thank you for listening