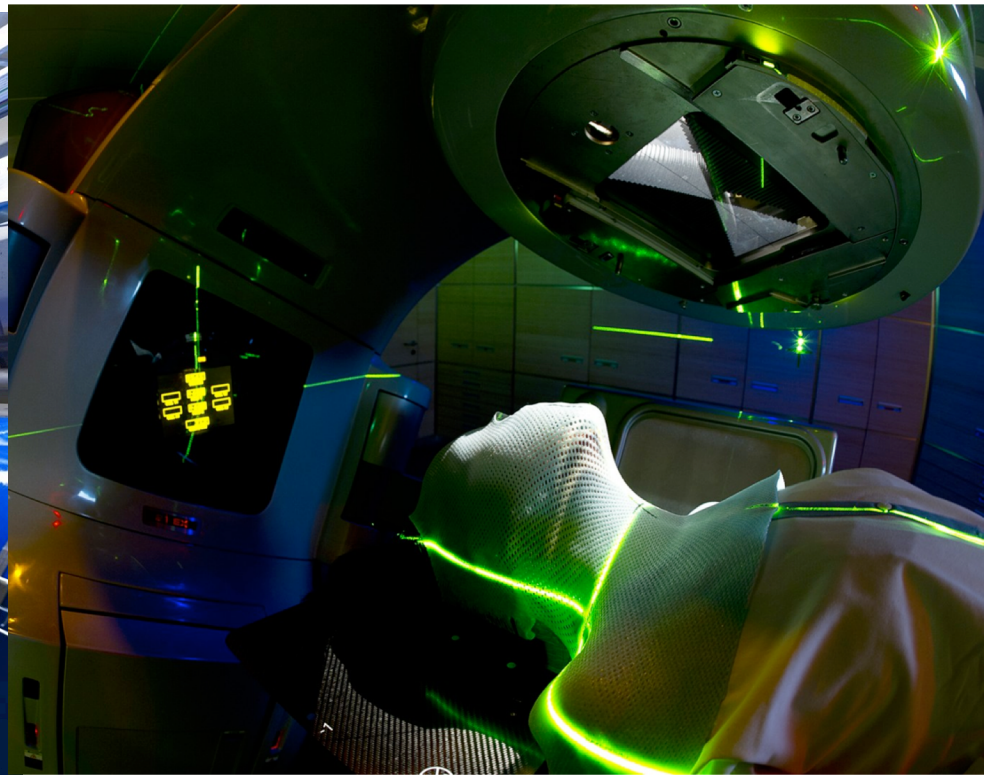
From physics to medical applications



Manjit Dosanjh

Manjit.Dosanjh@cern.ch

CERN Founded: September 1954

The first meeting of the provisional CERN Council
Key people: Sir Ben Lockspeiser, Edoardo Amaldi, Felix Bloch, Leew Kowarski, Cornelis Bakker, and Niels Bohr

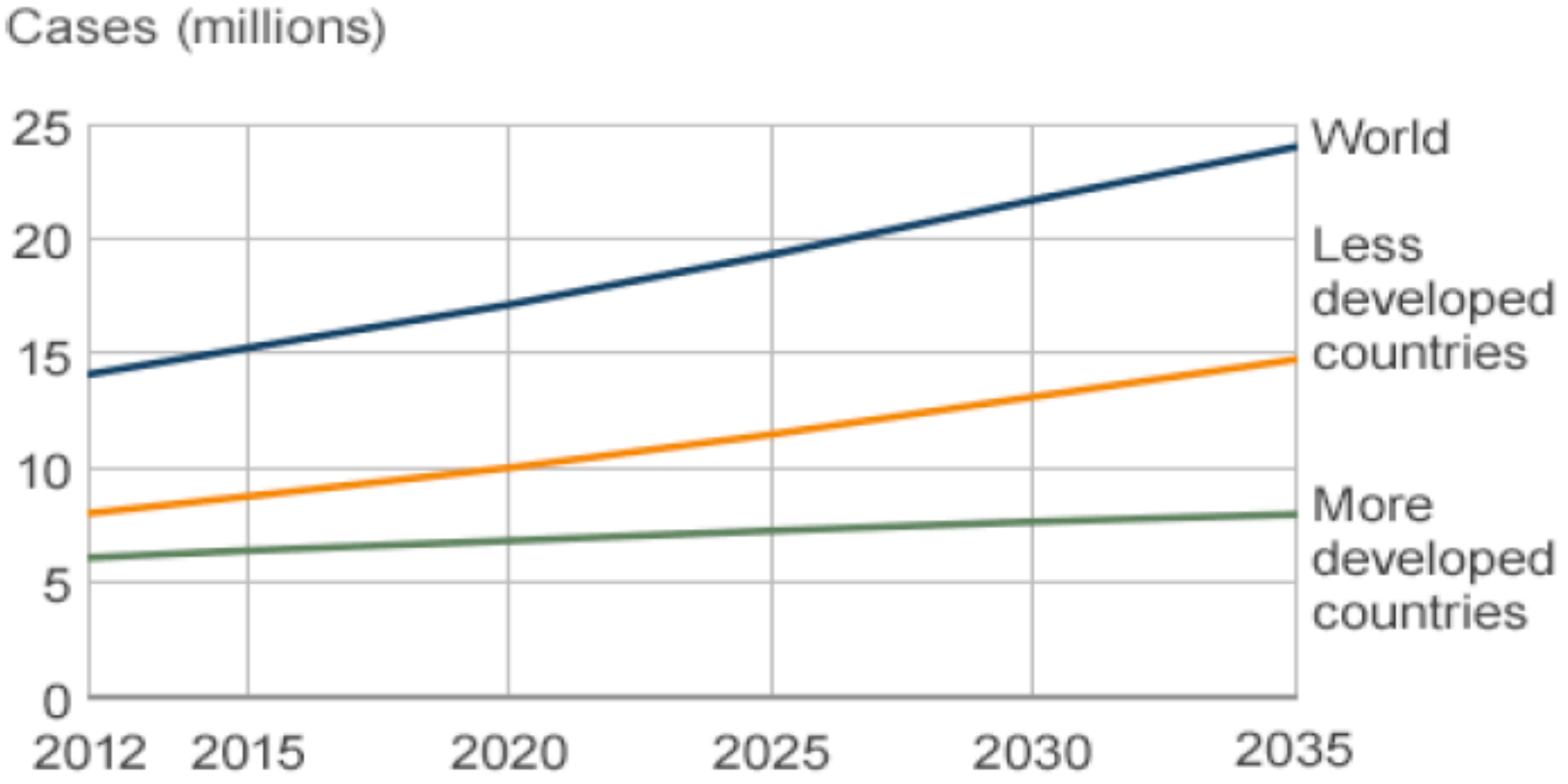
E. Lawrence
First cyclotron

Lawrence brothers
Physicist and Doctor

Sept 1954 – Berkeley
Treats first patient

Importance of collaboration…….

Predicted Global Cancer Cases



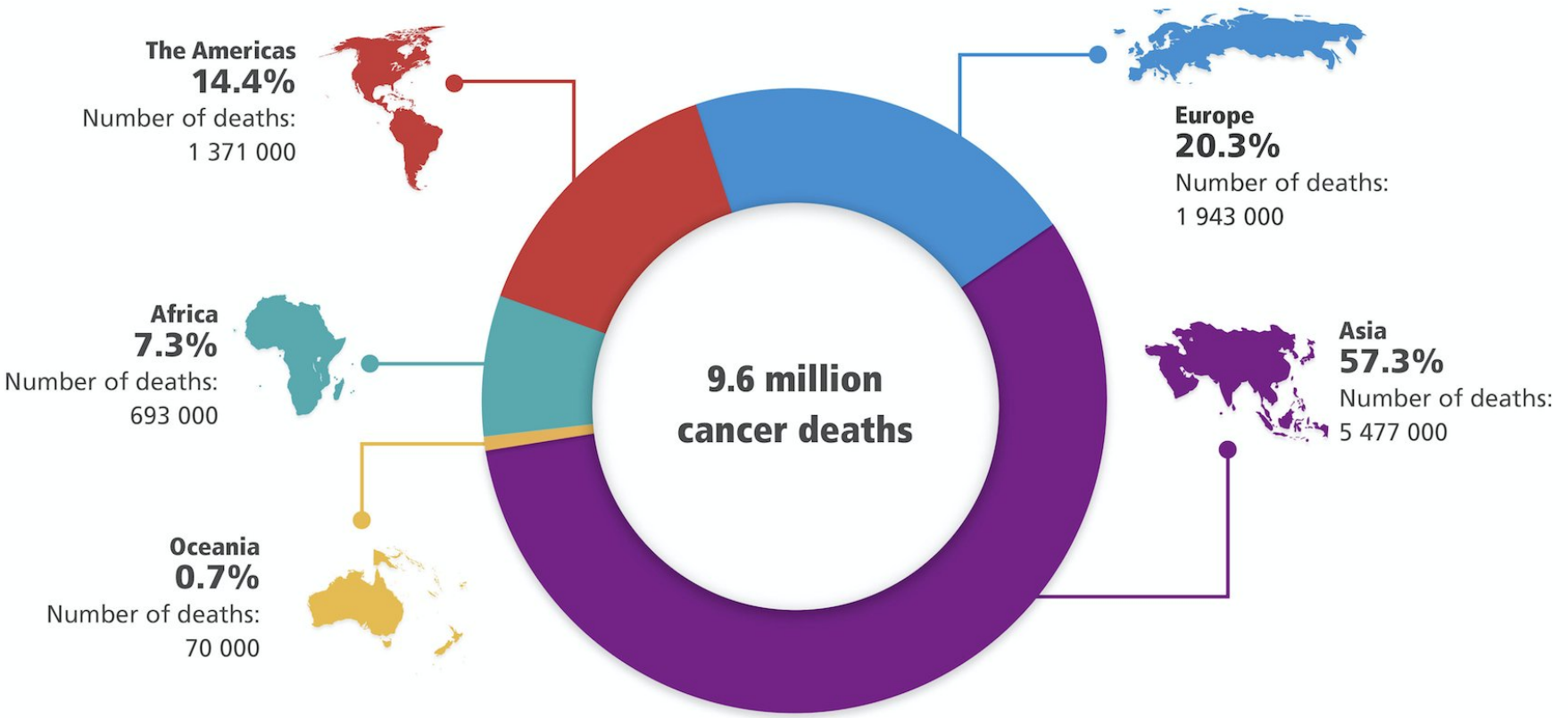
Source: WHO GloboCan

Cancer: growing global challenge

It is a large and a growing societal challenge:

- Nearly **18** million globally in **2018**
- This number will increase to **25** million in **2030**
- People living with cancer **44** million
- Currently around **9.6 million deaths** will go to **13** millions

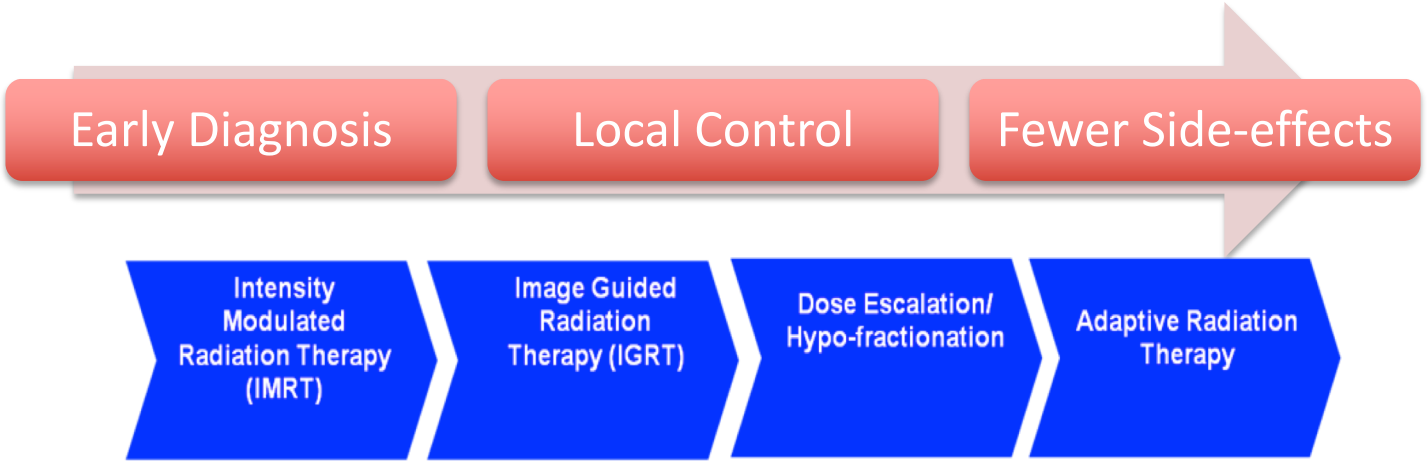
Global cancer mortality



Estimated number of deaths, both sexes, all cancers including non-melanoma skin cancer, for all ages, worldwide

Data source: GLOBOCAN 2018
Available at Global Cancer Observatory (http://gco.iarc.fr/)

Improving Cancer Outcomes: how?



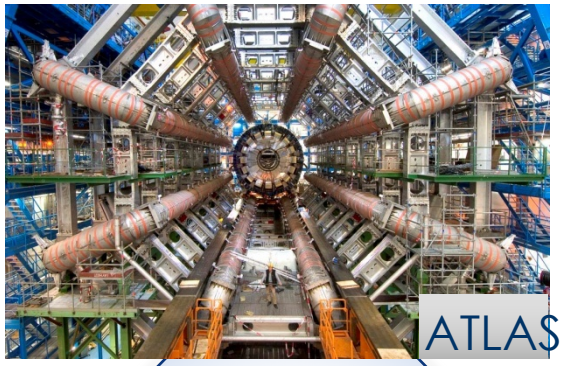
- New Technologies
- Advanced radiotherapy
- Radiobiology, Biology, Clinical
- Multi-disciplinary collaboration

Improving Cancer Outcomes: how?

Although cancer is a common condition, each patient is different and each tumour is individual which changes with time

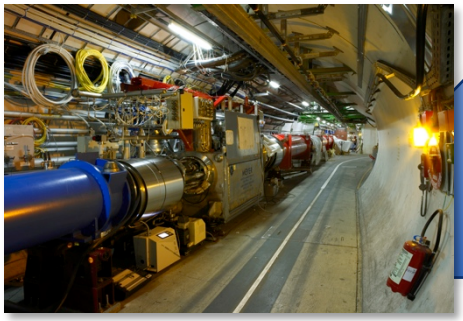
- **Personalised** approach
- Large patients data to understand the key drivers of the disease
- Need **Patient specific** treatment

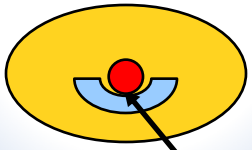
Physics technologies for cancer



Detecting particles

Accelerating particle beams



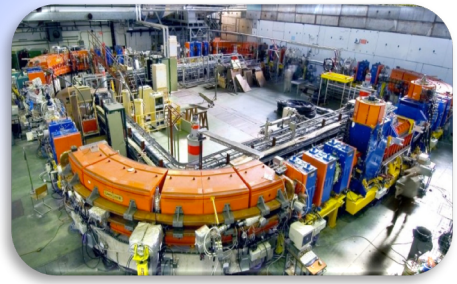


CANCER

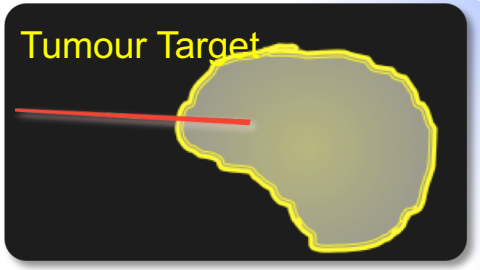
Large-scale computing (Grid)

4th Pillar Catalysing & facilitating collaboration

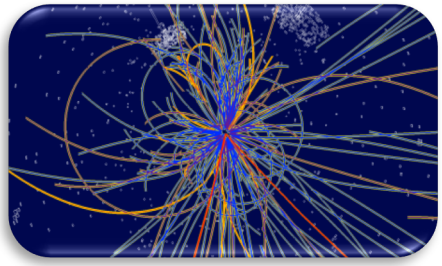
Accelerating particle beams



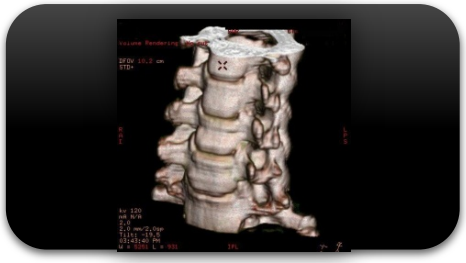
Particle Therapy



Detecting particles



Medical imaging

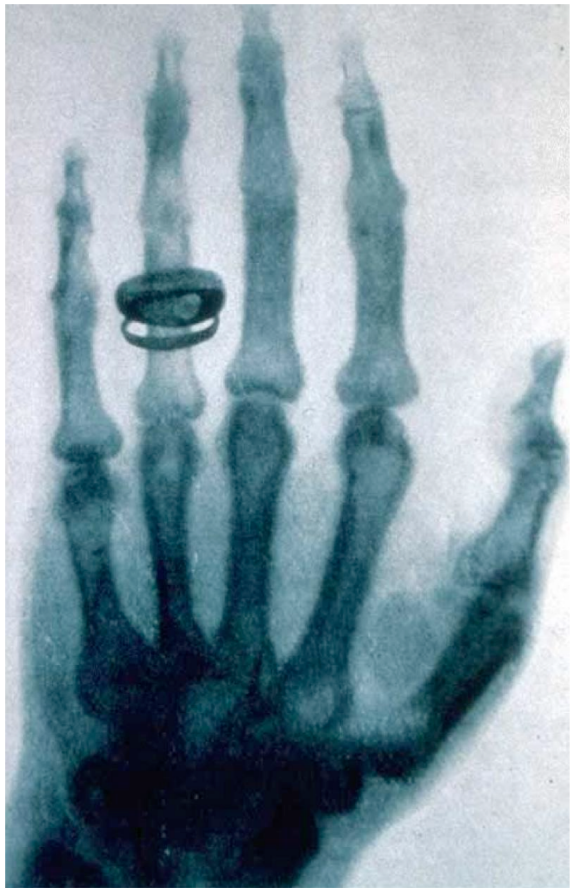


Large scale **computing** (Grid)

Grid computing for medical data management and analysis

No treatment without detection

The beginning



X-rays 1895

Manjit Dosanjh, November 2019

Cancer: ideal situation

Ideal cancer treatment would be to eliminate all tumour cells without affecting any normal cells

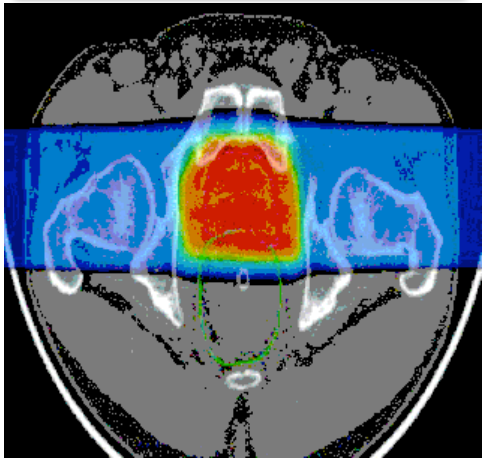
Physics : 100% of the dose on target
0% of the dose in surrounding healthy tissues or critical organs

Biology : differential effect
kill 100% of cancer cells "protect" normal cells

Treatment

Surgery

Radiotherapy



X-ray, IMRT, Brachytherapy, Hadrontherapy

Chemotherapy (+ others)

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

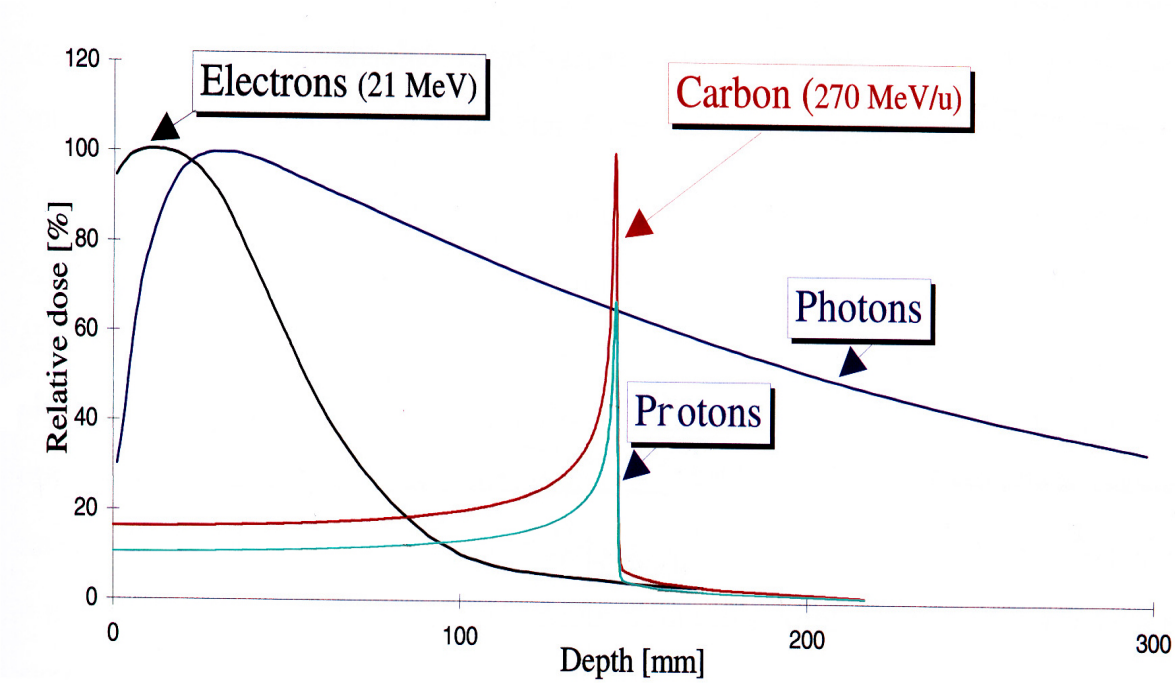
AIM:
Survival, Quality of life

Aims of Radiotherapy:

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

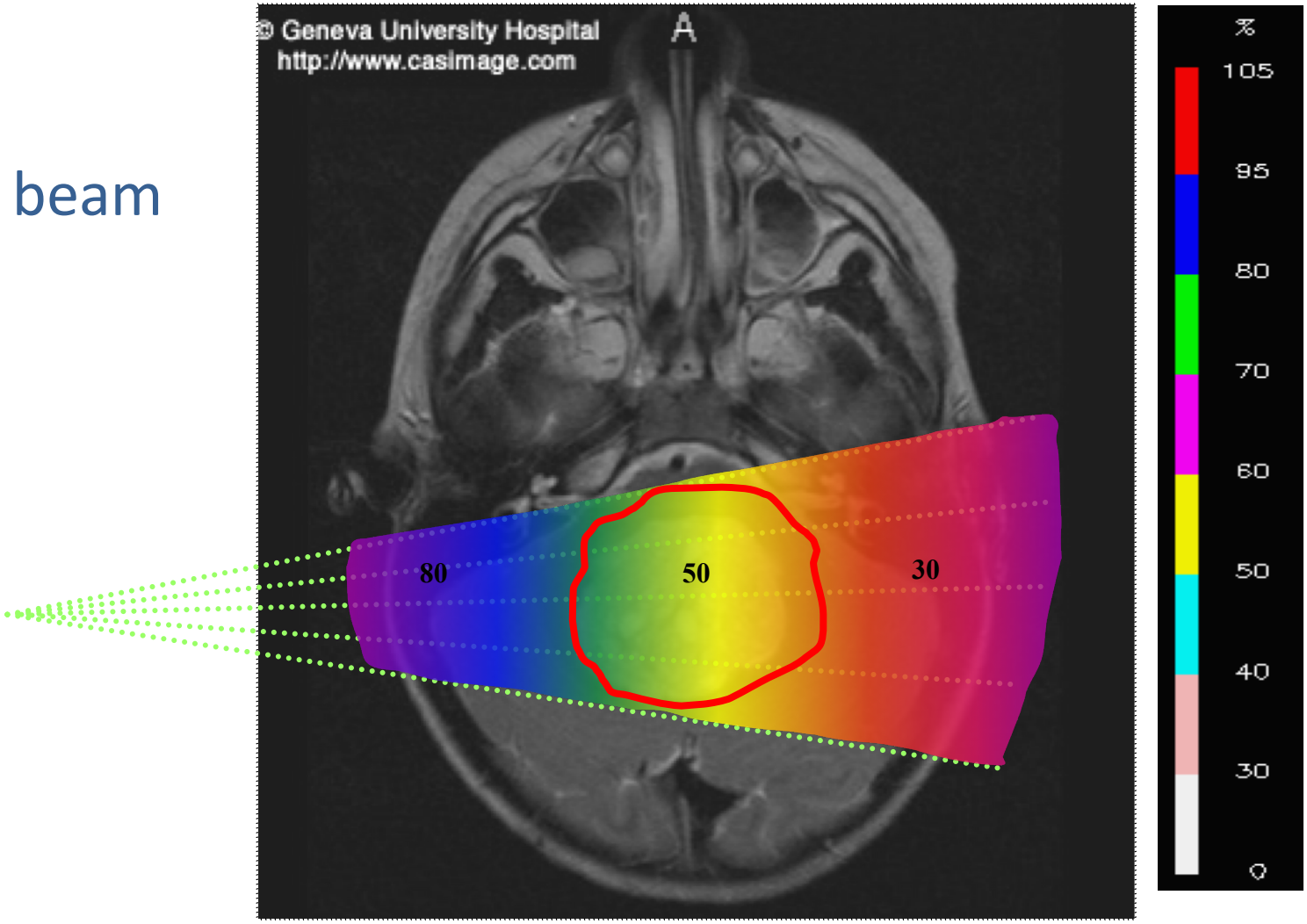
Current radiotherapy methods:

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

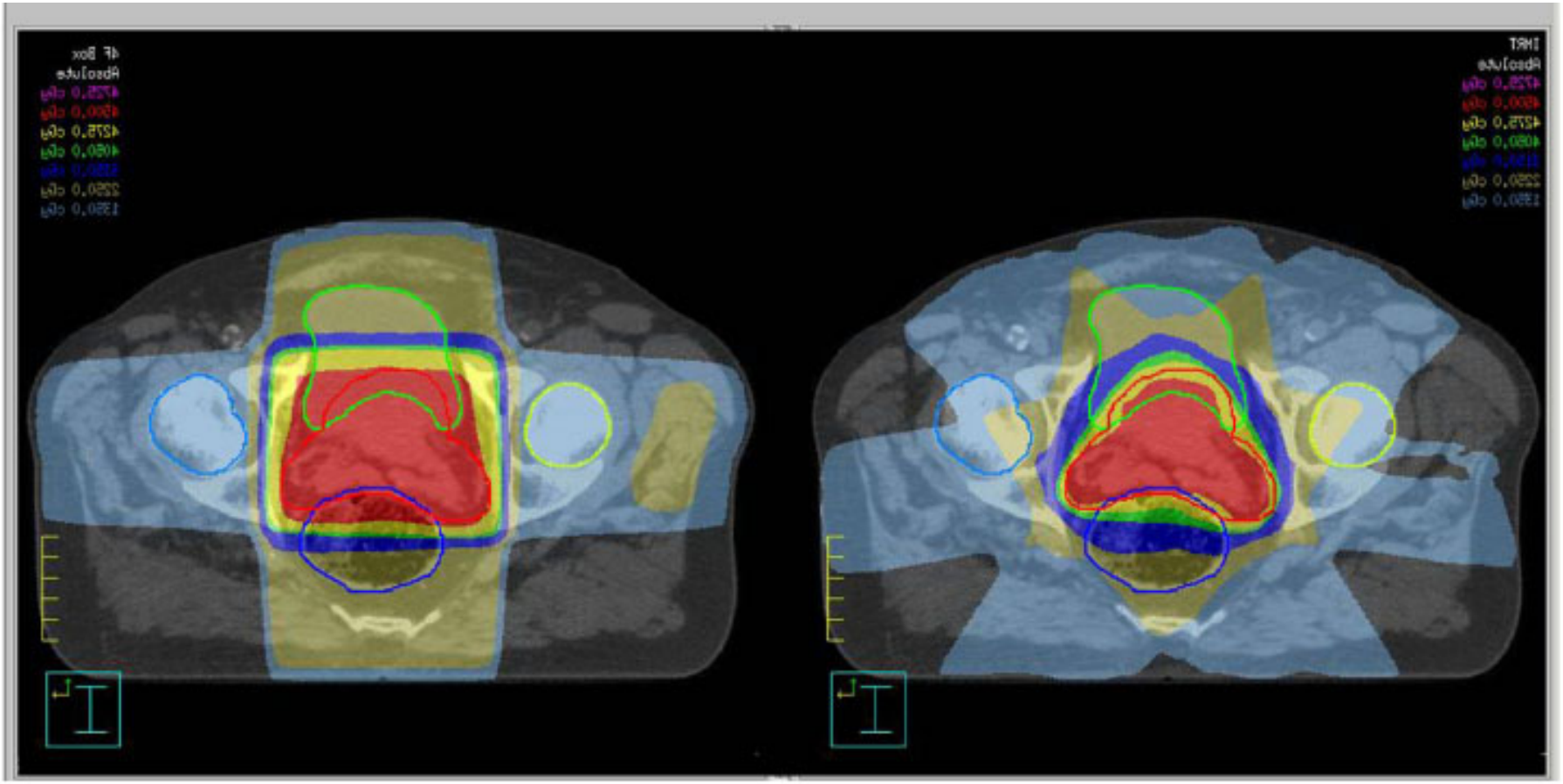


Classical Radiotherapy with X-rays

single beam



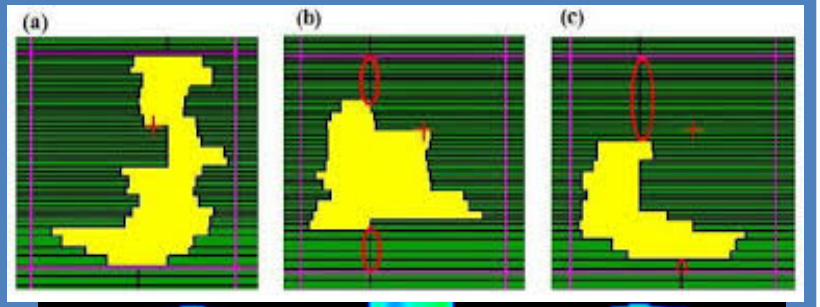
Improved Treatment

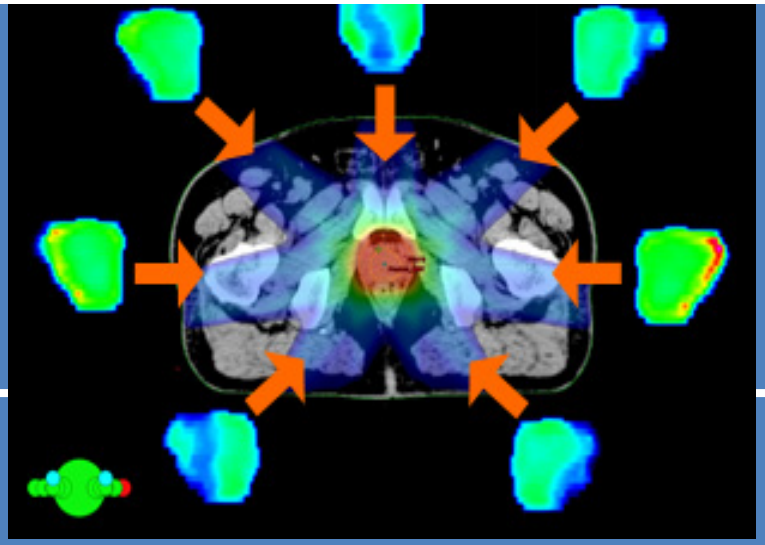


1990s: 4 constant intensity fields

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

Current state of the art X-ray Therapy





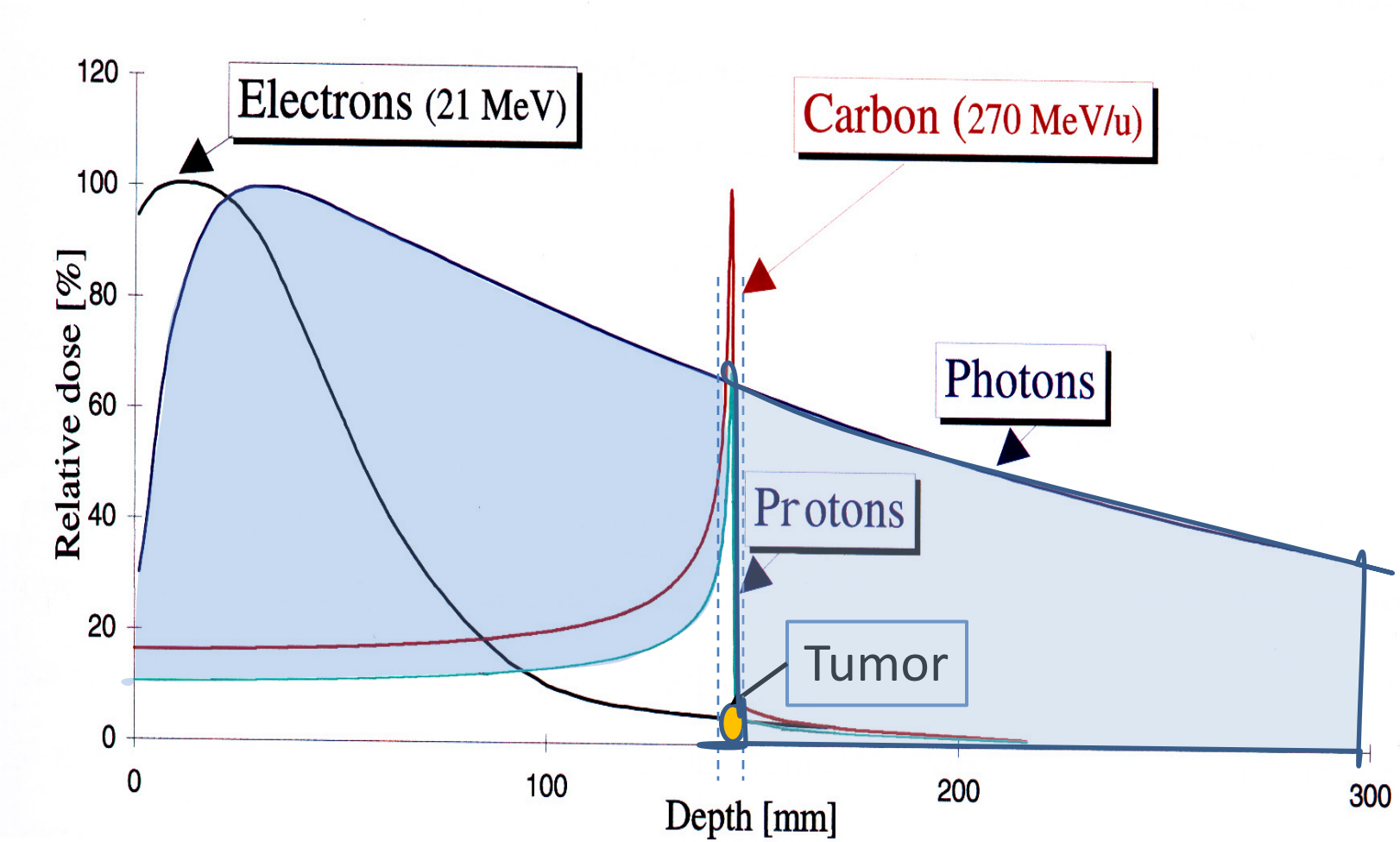
Advances in Radiation Therapy

In the past two decades due to:

- improvements in imaging modalities,
- powerful computers and software and delivery systems have enabled:
  - Intensity Modulated Radiotherapy (IMRT),
  - Image Guided Radiotherapy (IGRT),
  - Volumetric Arc Therapy (VMAT)
- Biological, molecular and clinical advances
- Is Hadron/Particle Therapy the future?

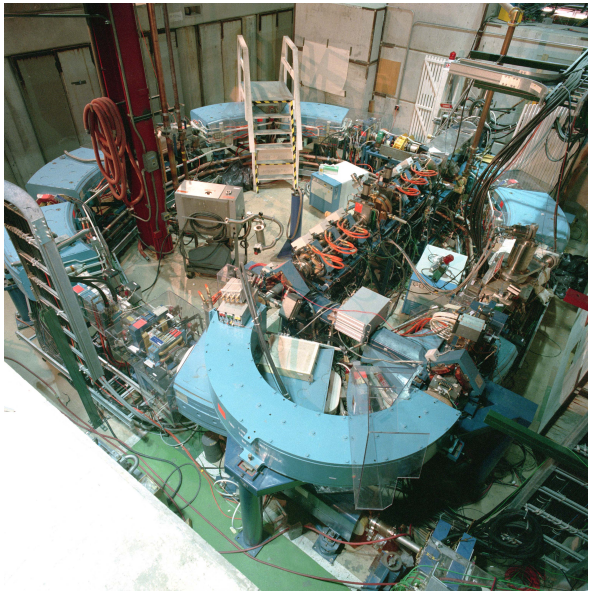
Back ot first patient in September 1954

Photons vs. electrons, hadrons



Depth in the body (mm)

1993- Loma Linda
USA (proton)



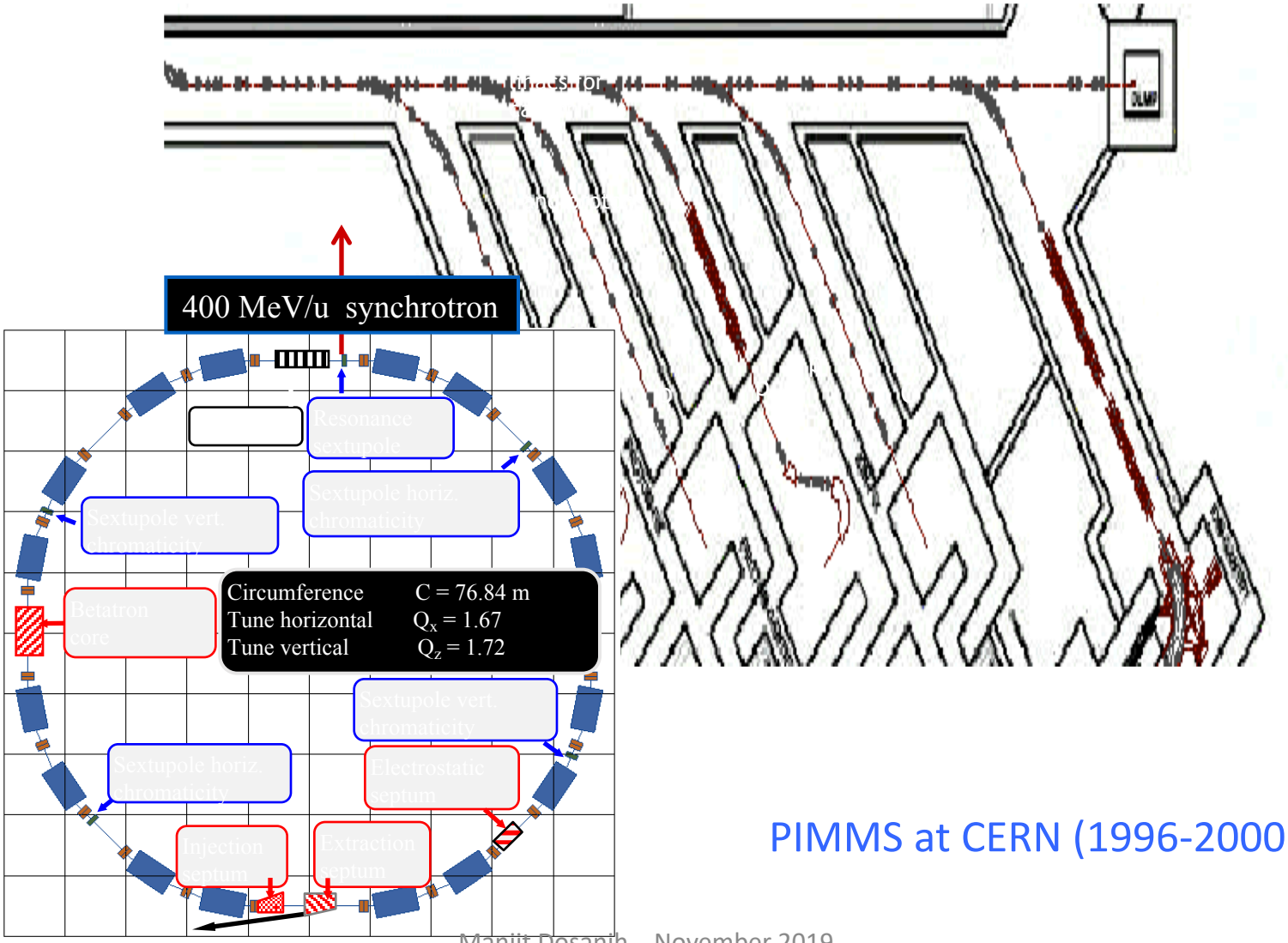
First dedicated clinical facility

1994 – HIMAC
Japan (carbon)

1997 – GSI
Germany (carbon)

.....to clinics

Converting studies into reality



PIMMS at CERN (1996-2000)

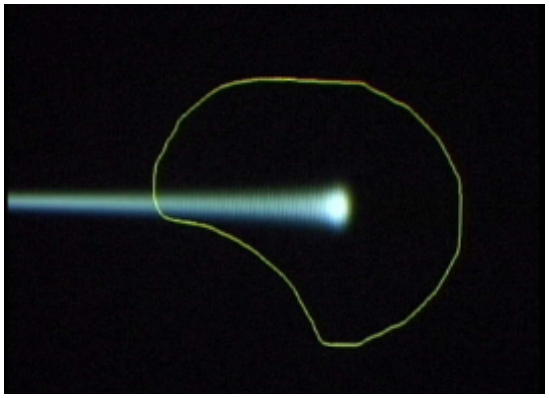
ENLIGHT established 17 years

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

Organisers: Manjit Dosanjh & Hans Hoffmann

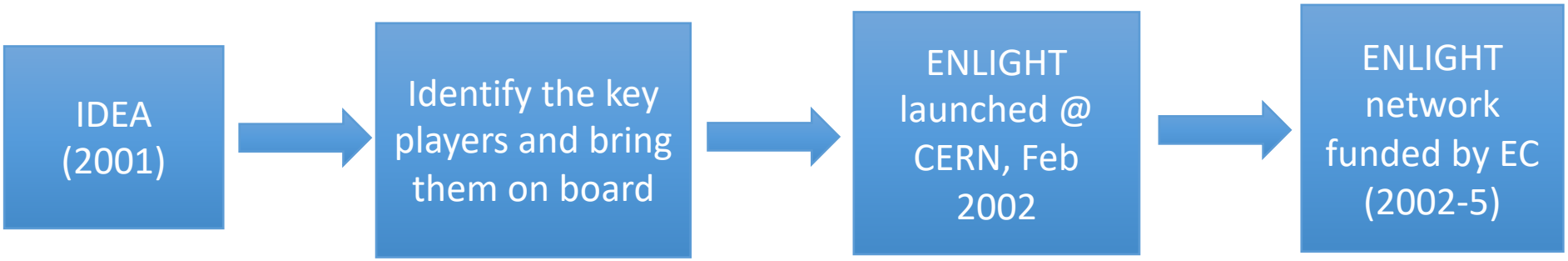
ENLIGHT was established to ……

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



Leveraging Physics collaboration philosophy into a multidisciplinary medical environment

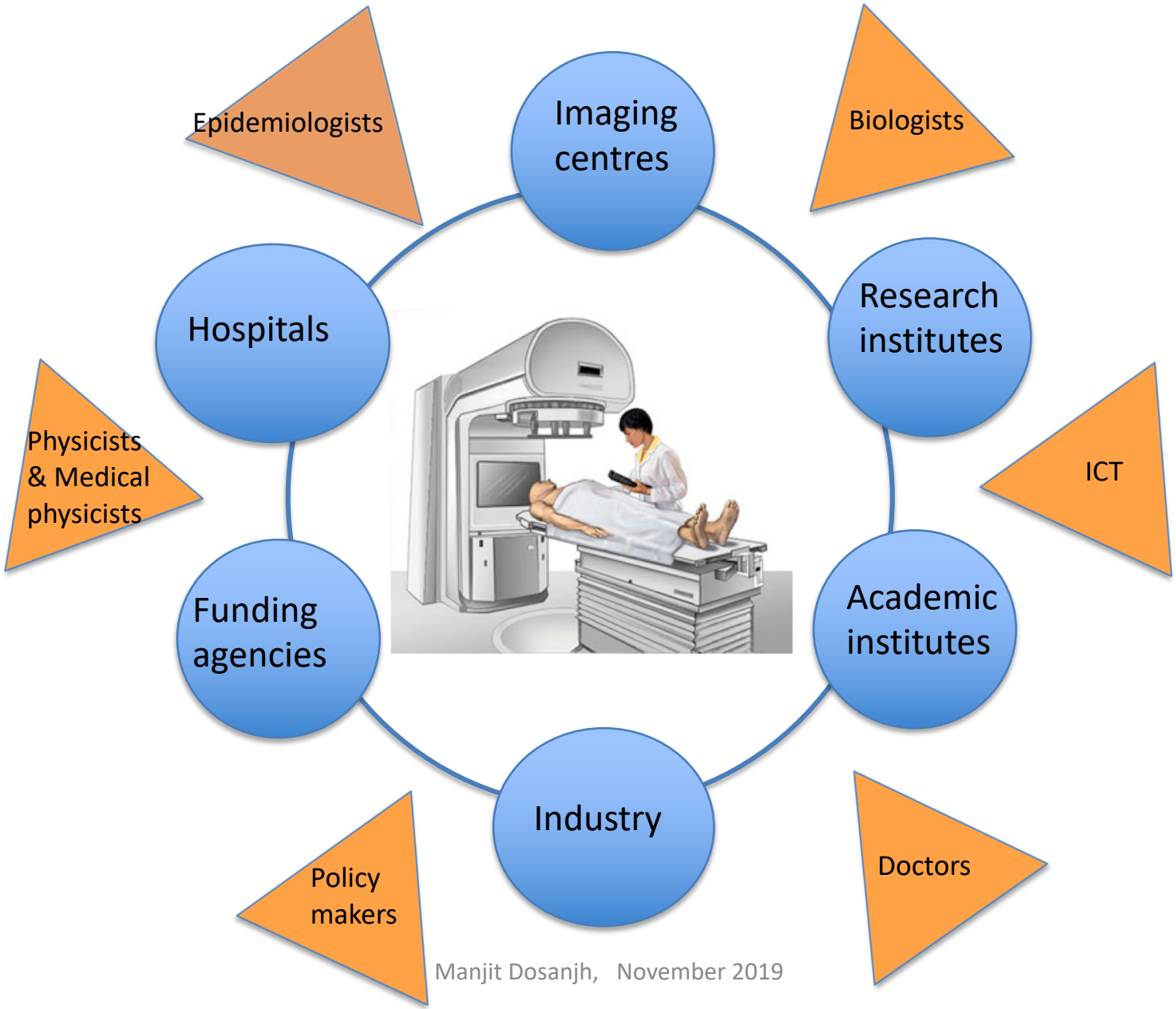
Build a collaborative multidisciplinary network



European Network for Light Ion Hadron Therapy

Since 2005, no more EC funds for the ENLIGHT but the collaboration continued at the request of the partners

Importance of collaboration



EU funded projects

- Marie Curie Initial Training Network
- 12 institutions
- 29 trainees

2008-2012

- Infrastructures for hadron therapy
- 20 institutions

2009-2013

- R&D on medical imaging for hadron therapy
- 16 institutions

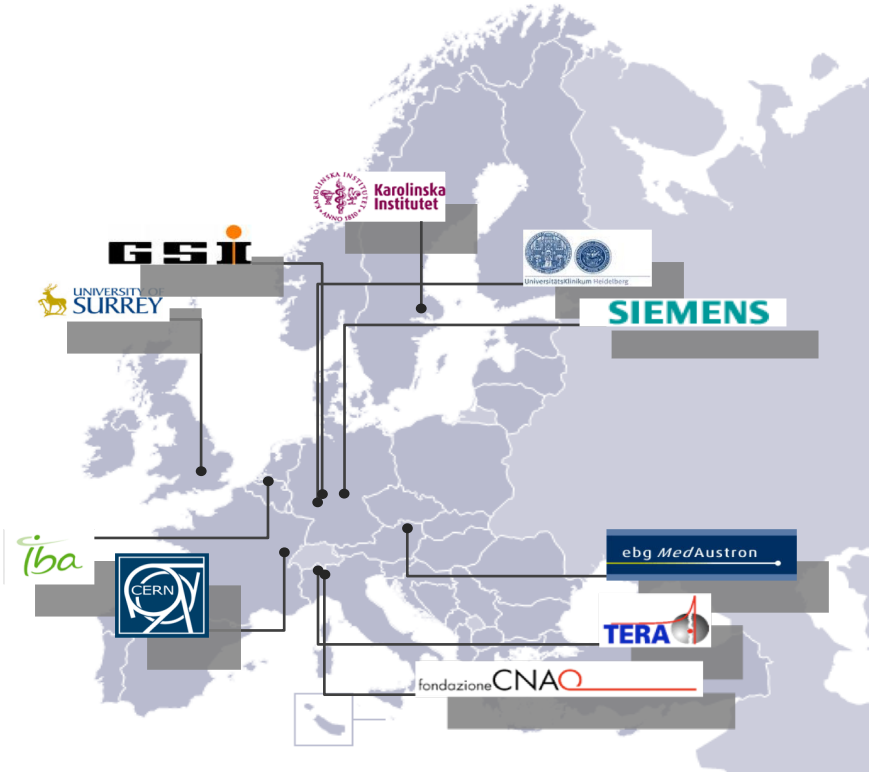
2010-2014

- Marie Curie ITN
- 12 institutions
- 16 trainees

2011-2015

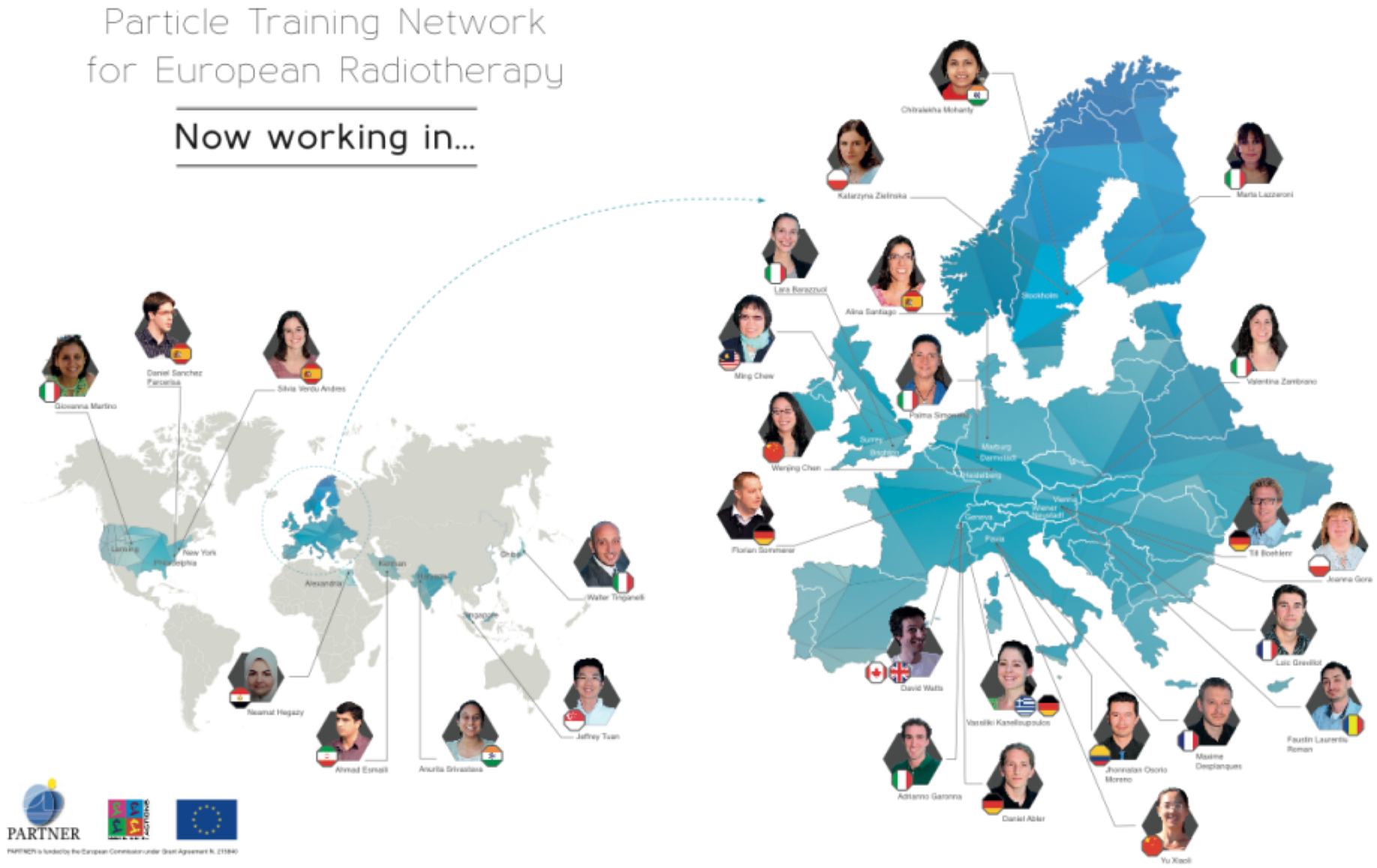
PARTNER – a success story

- Particle Training Network for European Hadrontherapy
- 10 academic institutes, research centres, 2 leading companies
- 29 young researchers



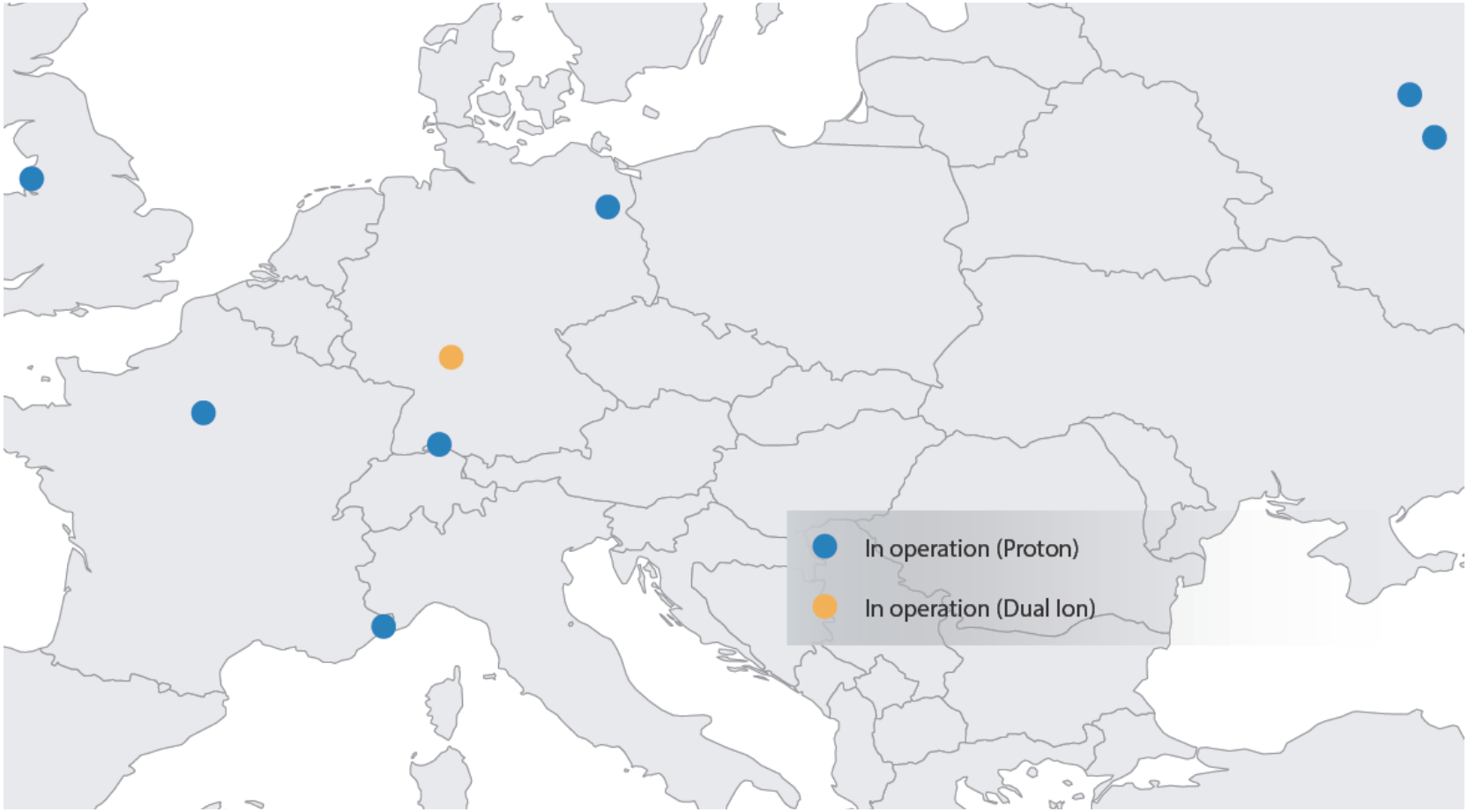
Outcome :

- Now working around the World
- 7 at Medaustron
- Open access PARTNER-JRR



Manjit Dosanjh, CMASC

Particle Therapy Centres in Europe 2002- start of ENLIGHT

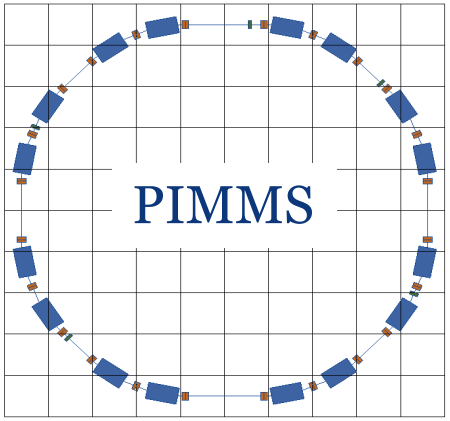


Outcomes of a successful collaboration:

PIMMS has led to:

Treatment , CNAO, Italy 2011

1996-2000 PIMMS study

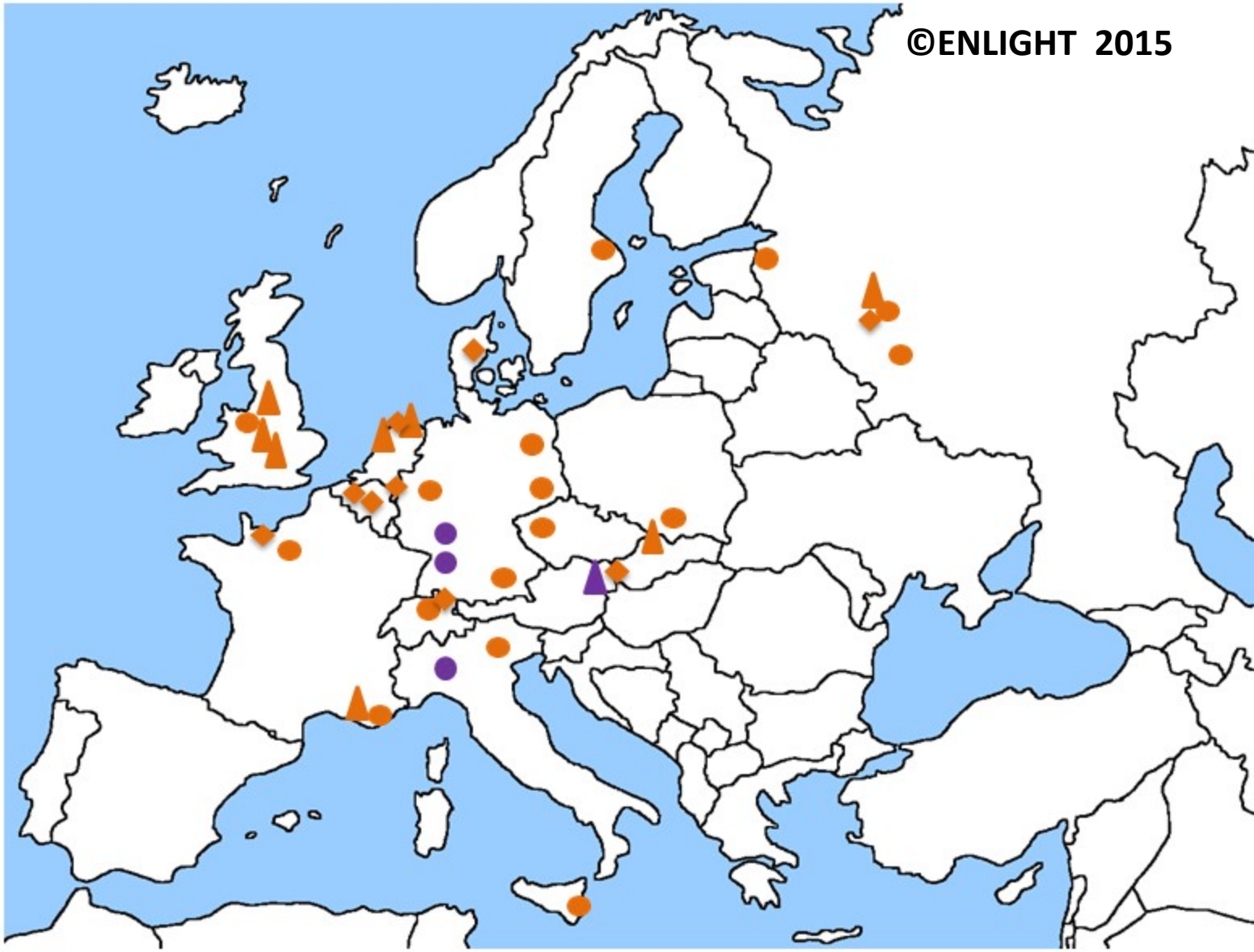


MedAustron, Austria 2017

ENLIGHT network (> 30 countries, >1000 people)

Manjit Dosanjh, November 2019

Particle therapy centres in Europe - 2015



Source: PTCOG, October 2015 and ENLIGHT

Collaborations need to evolve

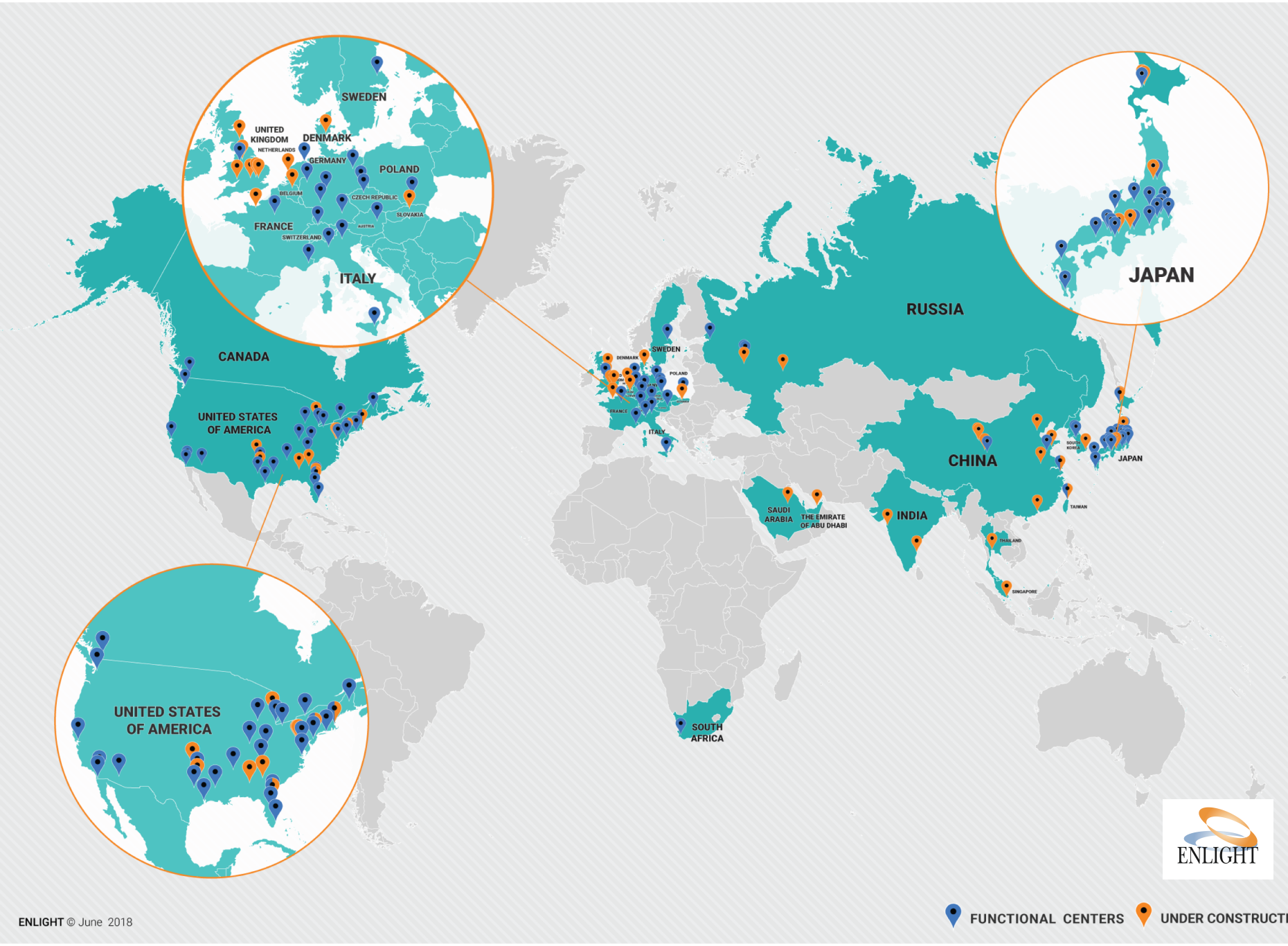
Much had changed since 2002: many centres, community was established, more than 600 members for over 20 countries, much had been done…

- Did we still need **ENLIGHT**?
- If yes, what sort of **ENLIGHT** did we need?

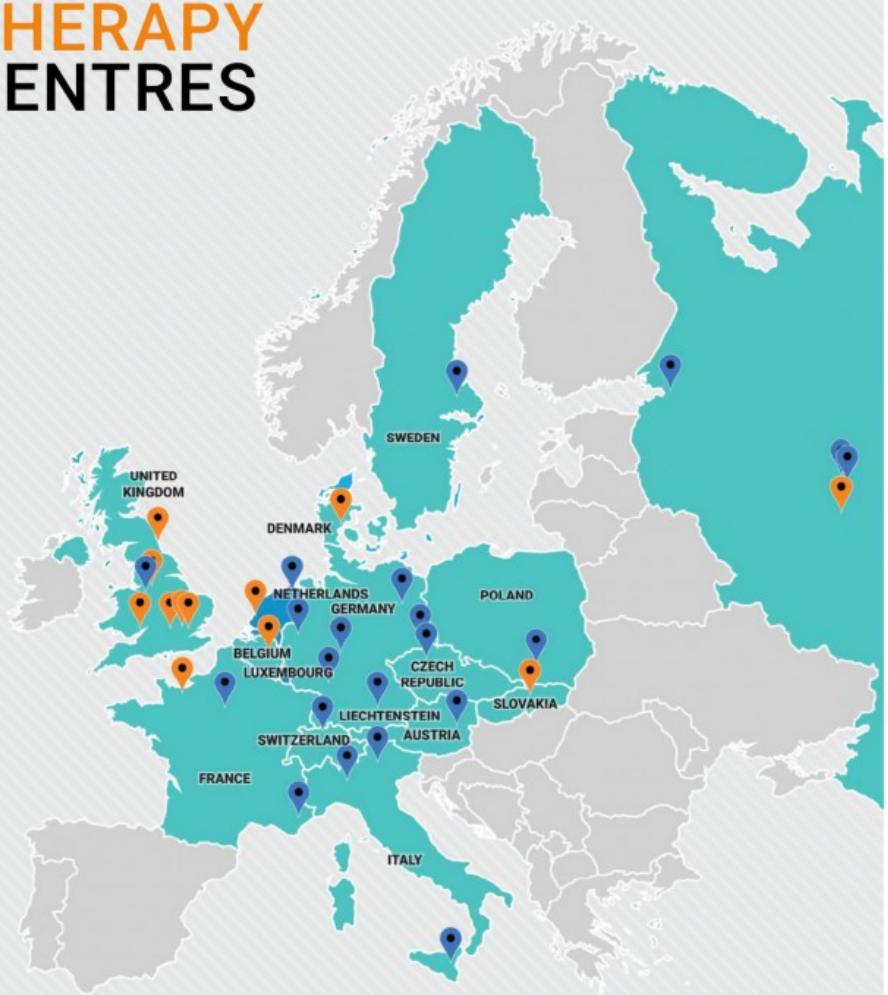
ENLIGHT

Krakow Meeting 2015 a turning point… new challenges

- Establish the ENLIGHT network as a non-profit network/foundation to make it sustainable since it is considered an important instrument and needs to be maintained
- Play a key role in the education of the young generation in this rapidly growing field of particle therapy
- Help to fully exploit the advantage of hadron therapy: more research, better tools, clinical trials, extend collaboration
- Advise partners who want to have access to HT



PARTICLE THERAPY CENTRES



ENLIGHT

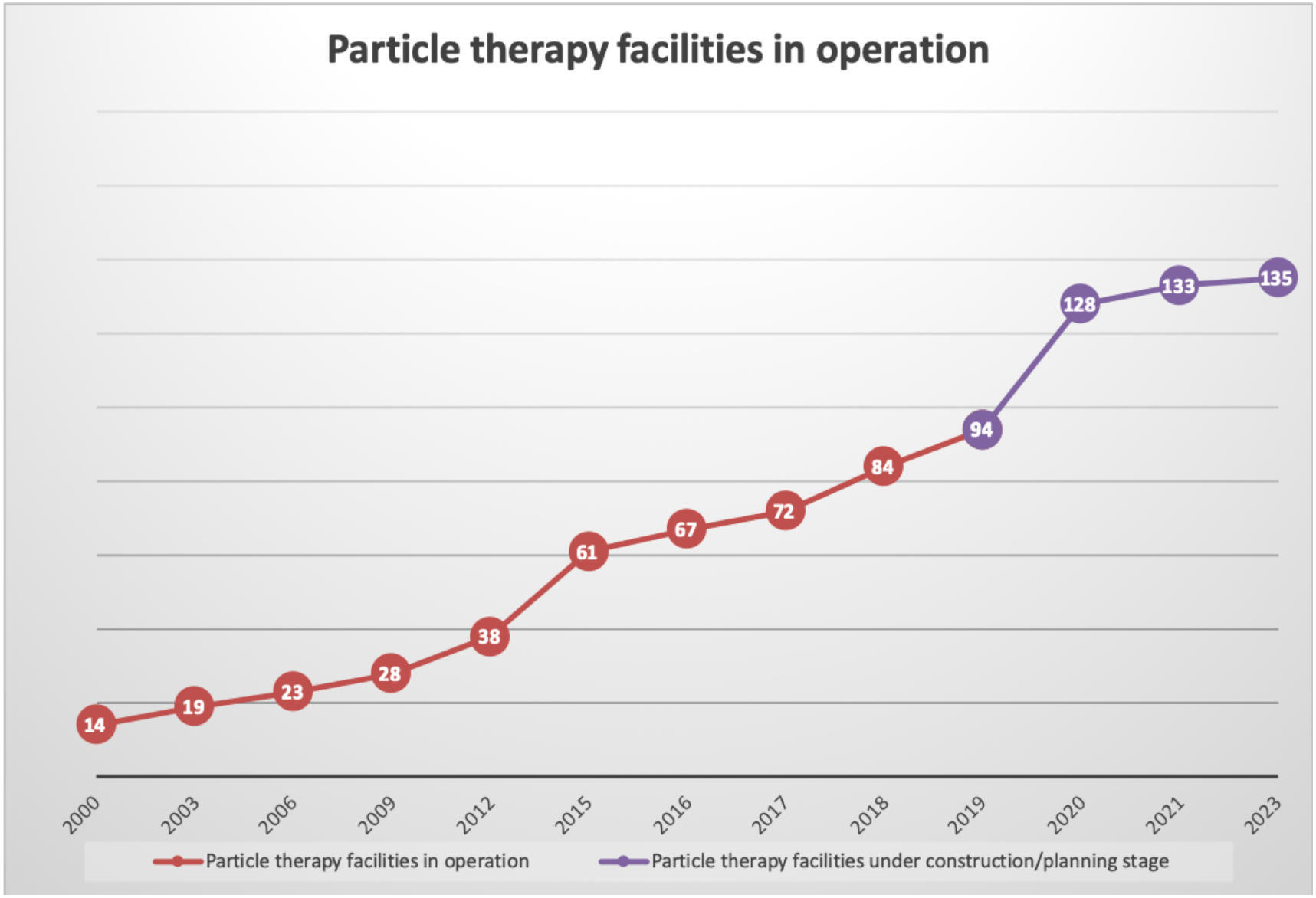
FUNCTIONAL CENTRES UNDER CONSTRUCTION

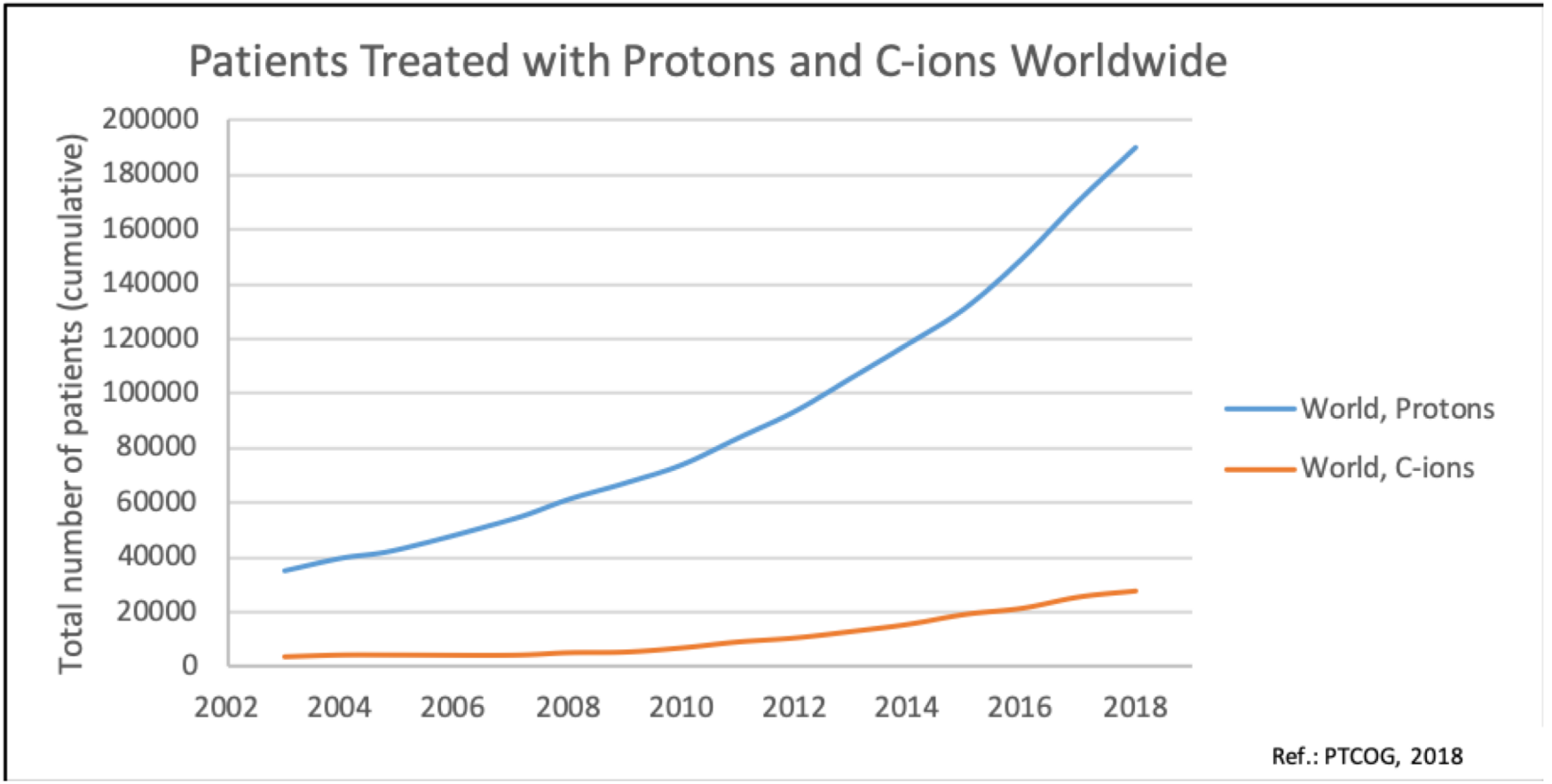
PARTICLE THERAPY CENTRES

ENLIGHT

UNCTIONAL CENTRES UNDER CONSTRUCTION

ENLIGHT © June 2018


Particle therapy facilities in operation
14
19
23
28
38
61
67
72
84
94
128
133
135
2000
2003
2006
2009
2012
2015
2016
2017
2018
2019
2020
2021
2023
Particle therapy facilities in operation
Particle therapy facilities under construction/planning stage


Patients Treated with Protons and C-ions Worldwide
Total number of patients (cumulative)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
2002
2004
2006
2008
2010
2012
2014
2016
2018
World, Protons
World, C-ions
Ref.: PTCOG, 2018

ENLIGHT

- ***Annual meeting***, open, free
- Latest developments in the field
- Oral presentation for winning posters
- Networking
- Collaboration
- Exchanges
- Education and training at CERN
- Sharing and building bridges
- Raising awareness at international level
- Special day dedicated to training
- Biannual Magazine – ***Highlights***
- **@ENLIGHTNETWORK**

ENLIGHT

Linked in Groups

www.cern.ch/enlight

2010

An outcome of ENLIGHT: Physics for Health in Europe

PHE + ICTR

ICTR-2010
Jacques Bernier

ICTR-PHE 2012

A conference that brings together the International Conference on Translational Research in Radio-Oncology and Physics for Health in Europe

ICTR-PHE 2014

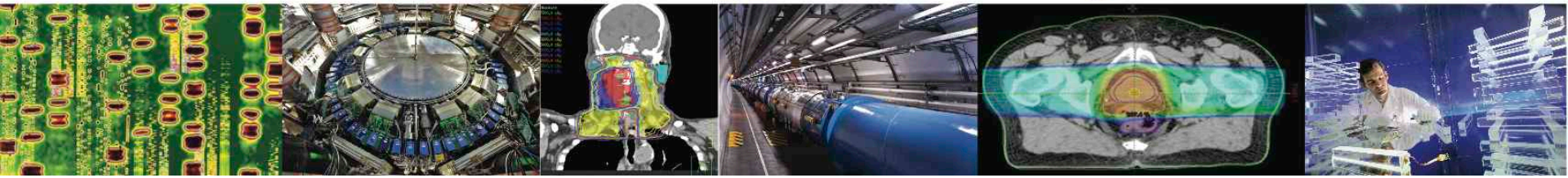
ICTR-PHE 2016

INTERNATIONAL CONFERENCE ON TRANSLATIONAL RESEARCH
IN RADIATION ONCOLOGY | PHYSICS FOR HEALTH IN EUROPE

February 15 – 19, 2016 CICG, Geneva, Switzerland

ICTR-PHE 2016

Uniting physics, biology and medicine for better healthcare

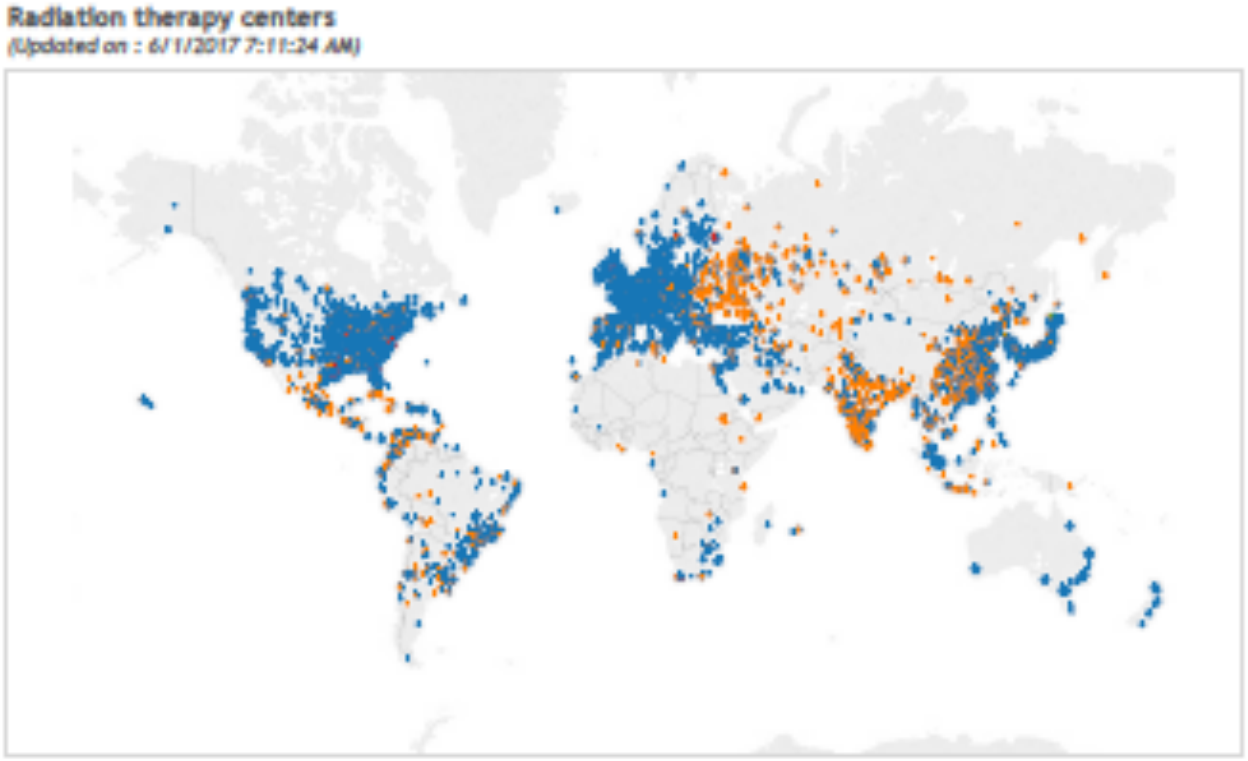


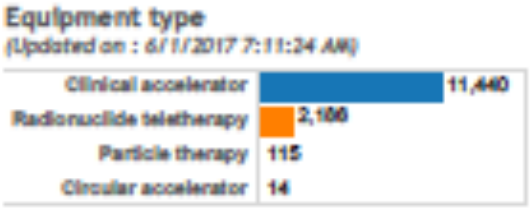
The conference became a unique event because:

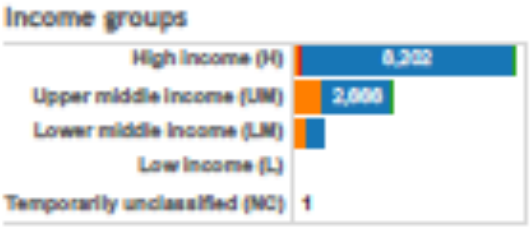
- To **make the path from lab to bed as efficiently as possible** by bringing together all diverse people, technologies, approaches,…
- It featured **discussions and presentations at the highest level**: all the latest research topics (personalised medicine, radiomics big data) are presented by eminent experts
- Allowed **cross dissemination**. Two-way thing: visibility to young researchers + education by information sharing

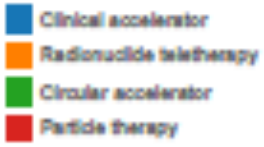
Collaboration for development……

World wide radiotherapy coverage





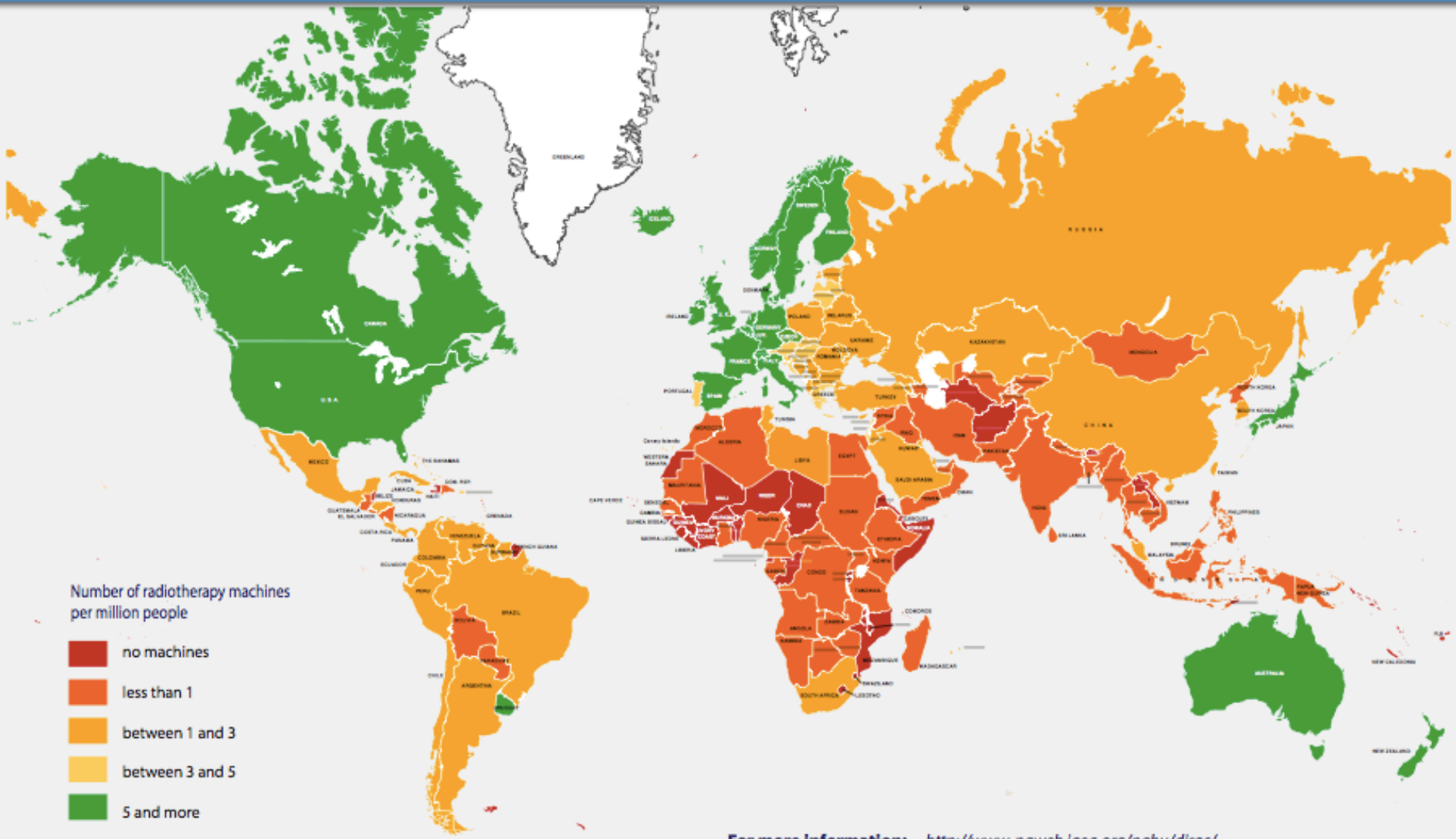




Countries	RT centers	Equipment	Linac	Radionuclide Therapy	Circular Accelerator	Particle Therapy
139	7041	13755	11440	2186	14	115

Availability of **RADIATION THERAPY**

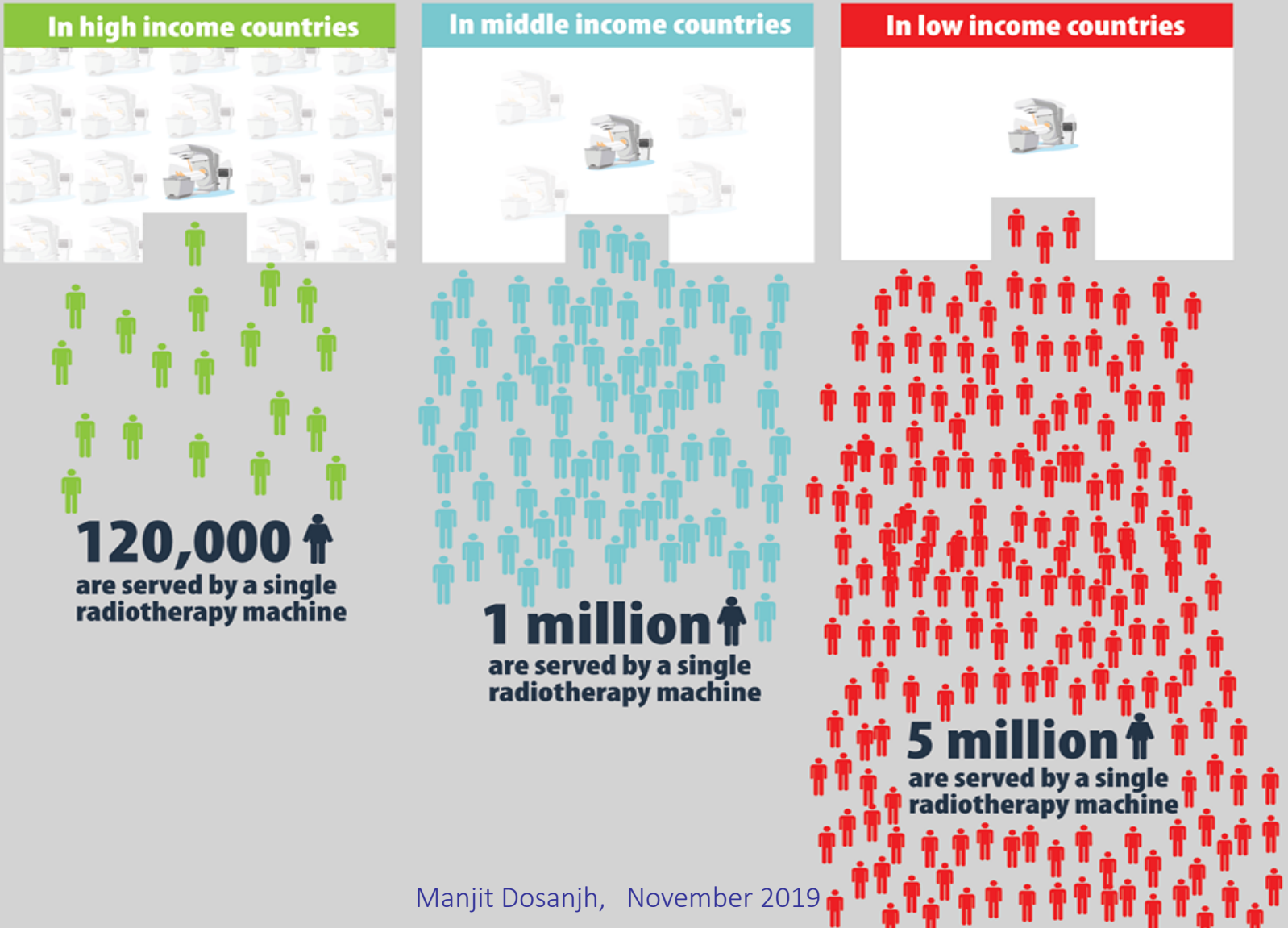
Number of Radiotherapy Machines per Million People 2012



Source: *DIRAC (Directory of Radiotherapy Centres), 2012 / IAEA*

For more information: *http://www-naweb.iaea.org/nahu/dirac/*
dirac@iaea.org

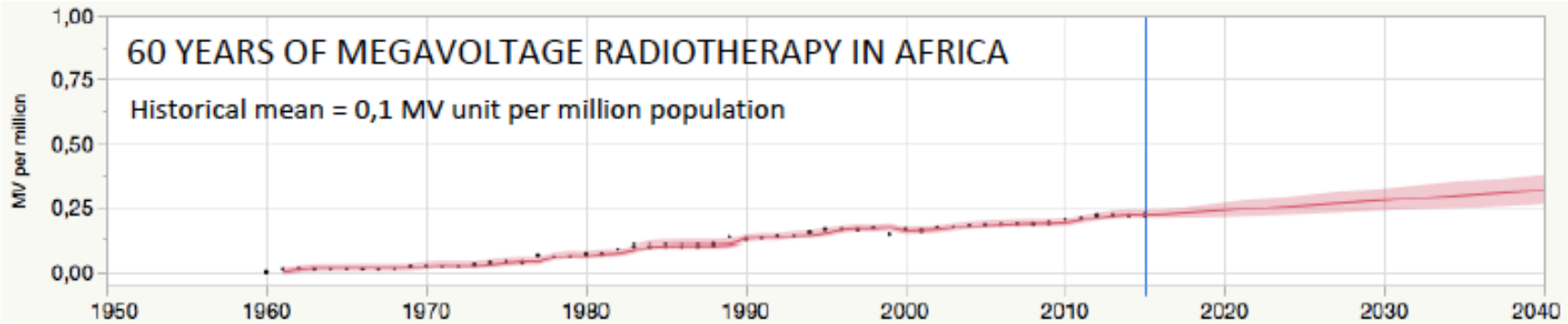
Radiotherapy in Cancer Care



RADIOTHERAPY IN AFRICA

21 countries with RT in 1995

23 countries with RT in 2017



Medical LINACs for challenging environments

- Design Characteristics of a Novel Linear Accelerator for Challenging Environments, November 2016, CERN
  - Understanding the problem
  - Oncologists, medical physicists, accelerator physicists
  - Botswana, Ghana, Kenya, Nigeria, Tanzania, Zambia……
- Bridging the Gap Workshop, October 2017, CERN
- Burying the Complexity Workshop, March 2018, Manchester
- Accelerating the Future Workshop, March 2019, Gaborone

Courtesy D. Townsend

Meeting in Botswana: March 2019

Understanding problem together with discussion, agreed strategy

Manjit Dosanjh, November 2019

Improving Access to Radiation Therapy Globally

PROJECT STELLA

Smart **T**echnologies to **E**xtend **L**ives with **L**inear **A**ccelerators

Collaboration

Government-funded Institutes and Departments

- European Organization for Nuclear Research (CERN)
- UK Science Technology and Facilities Council (STFC) and its Daresbury Laboratory
- Cockcroft Institute, UK
- US Department of Energy (DOE) and the National Nuclear Security Administration (NNSA)
- National Space and Aeronautical Administration (NASA)
- International Atomic Energy Agency (IAEA)
- U.S. National Cancer Institute

Universities and Teaching Hospitals

- University of Oxford
- University of Bristol
- Kings College (London)
- University of Toronto
- Weill Cornell Medical Center
- University of Pennsylvania Abramson Cancer Center
- University of Botswana
- National Hospital Abuja
- Kenyatta National Hospital
- University of Dar es Salaam, Ocean Road Cancer Institute

Lower-and-Middle Income Country Cancer Representatives

- Nigeria
- Botswana
- Ghana
- Kenya
- Tanzania
- Zimbawe
- Zambia

NGOs

- International Cancer Expert Corps
- Medical Physics for World Benefit (MPWB)
- African Centre for Science and International Security (AFRICSIS)

Hospital Management
(upper income countries)

Radiation Oncologists

Healthcare Technology Experts

Accelerator Physicists

Medical Physicists

Technology Manufacturing

Scientists and Engineers

Health System Innovators

Collaboration for Peace & Development

Manjit Dosanjh, November 2019

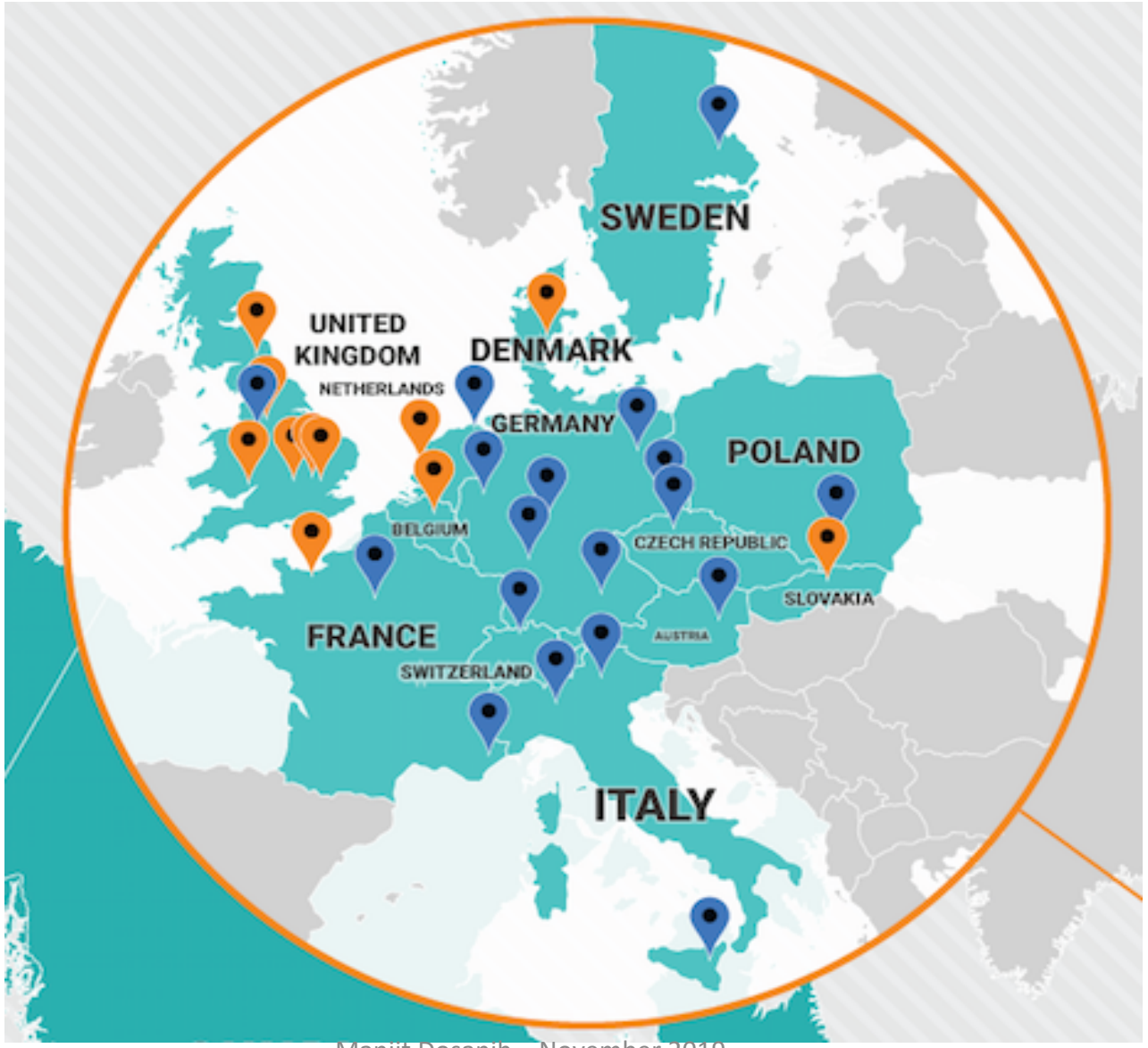
South-East European International Institute for Sustainable Technologies (SEEIIST) in the spirit of 'Science for Peace'

Prof. Herwig Schopper, former Director General of CERN

Dr. Sanja Damjanovic, Minister of Science of Montenegro

positive reception by a number of organizations and institutions

The need for SEEIIST?



Candidate Members for the South-East European International Institute for Sustainable Technologies

Republic of Albania

Bosnia and Herzegovina

Republic of Bulgaria

Republic of Croatia

Hellenic Republic

Kosovo*

FYR of Macedonia

Montenegro

Republic of Serbia

Republic of Slovenia

SEEIIST

Bridges across SEE countries and disciplines (medicine, physics, detectors and radiobiology)

- To mitigate tensions between countries in the region
- Bringing people from different countries to work together
- Capacitance building and slow down brain-drain
- Address a global health challenge be tackling cancer

Why and how ?

- Fosters international collaboration in a common research area
- Reduce fragmentation of research efforts/investment
- Train future European task force and increase the number of specialists
- Accelerate implementation of the research into clinical settings throughout Europe
- Cement links with industrial partners, healthcare policy makers and other key stakeholders for benefit of patients

Forum on New International Research Facilities in South East Europe, ICTP, Trieste 25-26 January 2018

What do we need in the future?

- Treat the tumour and only the tumour
  - ⇒ Control and monitor the ideal dose to the tumour
  - ⇒ Minimal collateral radiation “outside” the tumour
  - ⇒Minimal radiation to nearby critical organs
  - ➢ Patient specific solution
- Be affordable
  - ✓ Capital cost ?
  - ✓Operating costs ?
  - ✓Increased number of treated patients per year ?
  - ✓Universal access
- Compact: Fit into every large hospital ?

- Improve patient through-put
- Increase effectiveness
- Decrease cost

Collaboration is Key

Thank you to ENLIGHT

Manjit Dosanjh, November 2019