

Current status of hadron therapy

Manjit Dosanjh, CERN/ENLIGHT
Stellenbosch, 21 August 2010

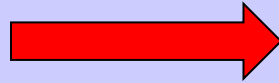
The Problem

Cancer Incidence

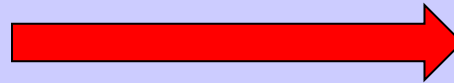
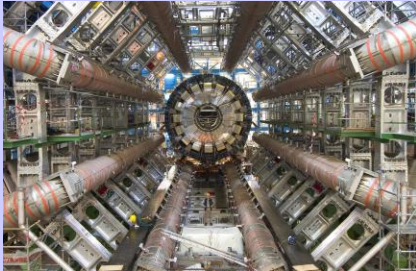
- Every year millions of new cases globally
- The number of patients needing treatment is increasing in the years to come
- The main cause of death between the ages of 45 and 65 in Europe, Canada and the US
- Second most common cause of death in Europe, Canada, US

Medical Applications

Particle beams for **cancer treatment**



Detector technologies for **medical imaging**



Computing for **medical data management and analysis**



Treatment Options...

Primary tumour

Metastasis

Surgery

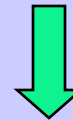
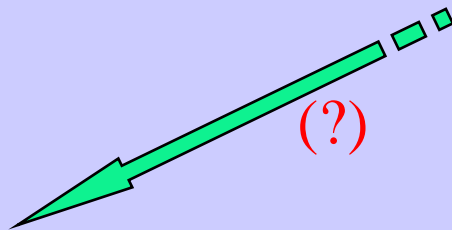
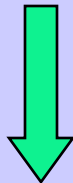
Radiotherapy

Other treatments
Hormones; Chemotherapy;
Immunotherapy; Cell therapy;
Genetic treatments...



X-ray, IMRT
Hadron therapy

Novel specific targets
(genetics..)



Local control



Survival
Quality of life

Three 'Cs' Radiotherapy

- **Cheap:** the least expensive cancer treatment method (around 5% of total cost)
- **Cure:** Good cure rate (30-40%)
- **Conservative:** generally non-invasive, fewer side effects

Cancer: ideal situation

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

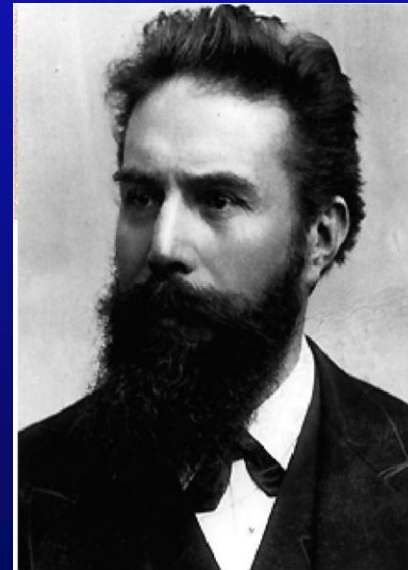
Physics : 100% of the dose on target
0% of the dose in surrounding healthy tissues or critical organs

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

X-Rays, the fastest technology transfer

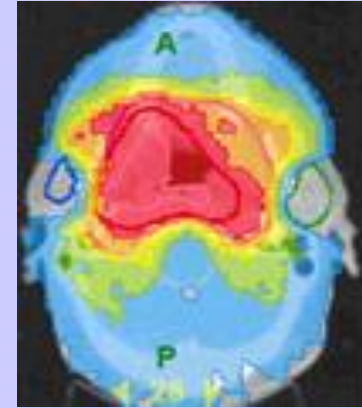


- On November 8, 1895 Röntgen discovered X-Rays
- On November 22, 1895 he takes the first image of his wife's hand



Röntgen received the first Nobel prize in physics in 1901

110 years after discovery of radioactivity.....

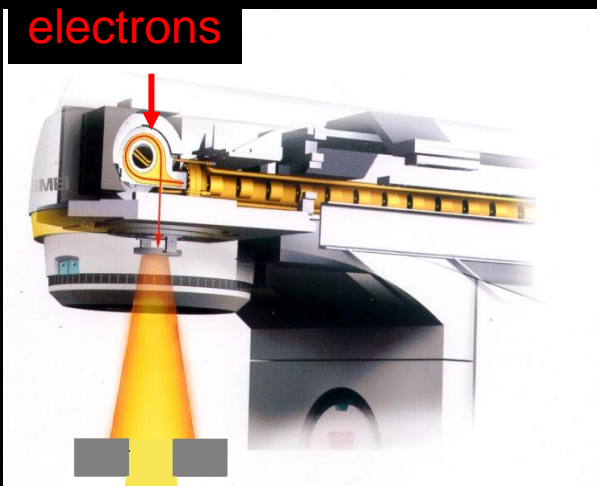


From 50 to 65% of cancer patients receive RT

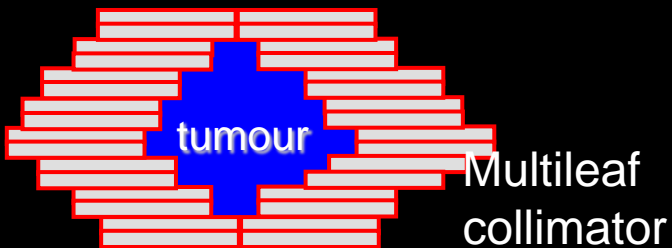


'Conventional' radiotherapy: linear accelerators dominate

Courtesy of Elekta

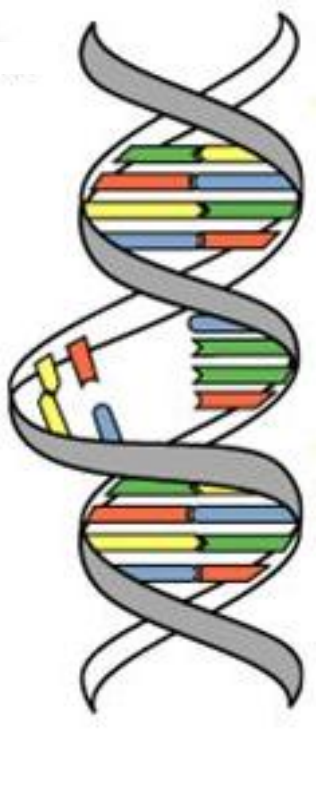


Linac for electrons
@3 GHz
5-20 MeV



20 000 patients per year every
10 million inhabitants
1 linac every <250,000 inhabitants

Radiotherapy in the 21st Century



- RT is the least expensive cancer treatment method
- RT is the most effective
- 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 still fail locally after RT

(Acta Oncol, Suppl:6-7, 1996)

•

How to overcome failures?

- Physics & treatment technology: dose escalation
- Imaging: MRI, PET, image registration
- Biology: altered fractionation, radiosensitization

Raymond Miralbell, HUG



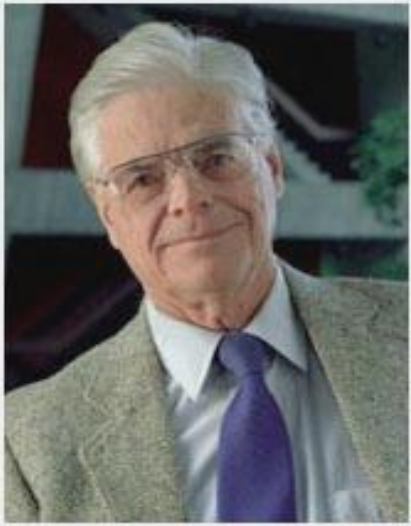
How to overcome failures?

- Physics & treatment technology: dose escalation
- Imaging: MRI, PET, image registration
- Biology: altered fractionation, radiosensitization

Raymond Miralbell, HUG



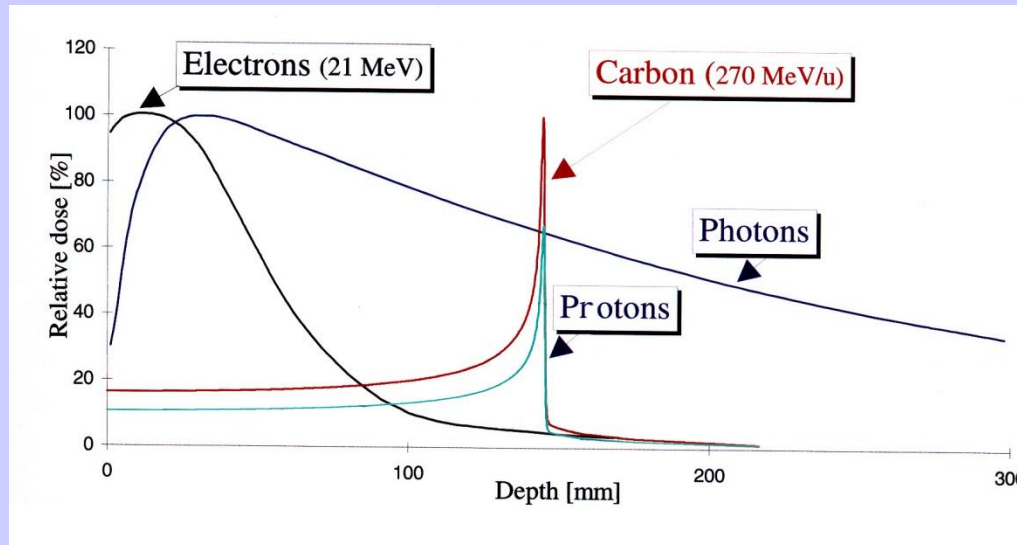
Hadrontherapy: all started in 1946



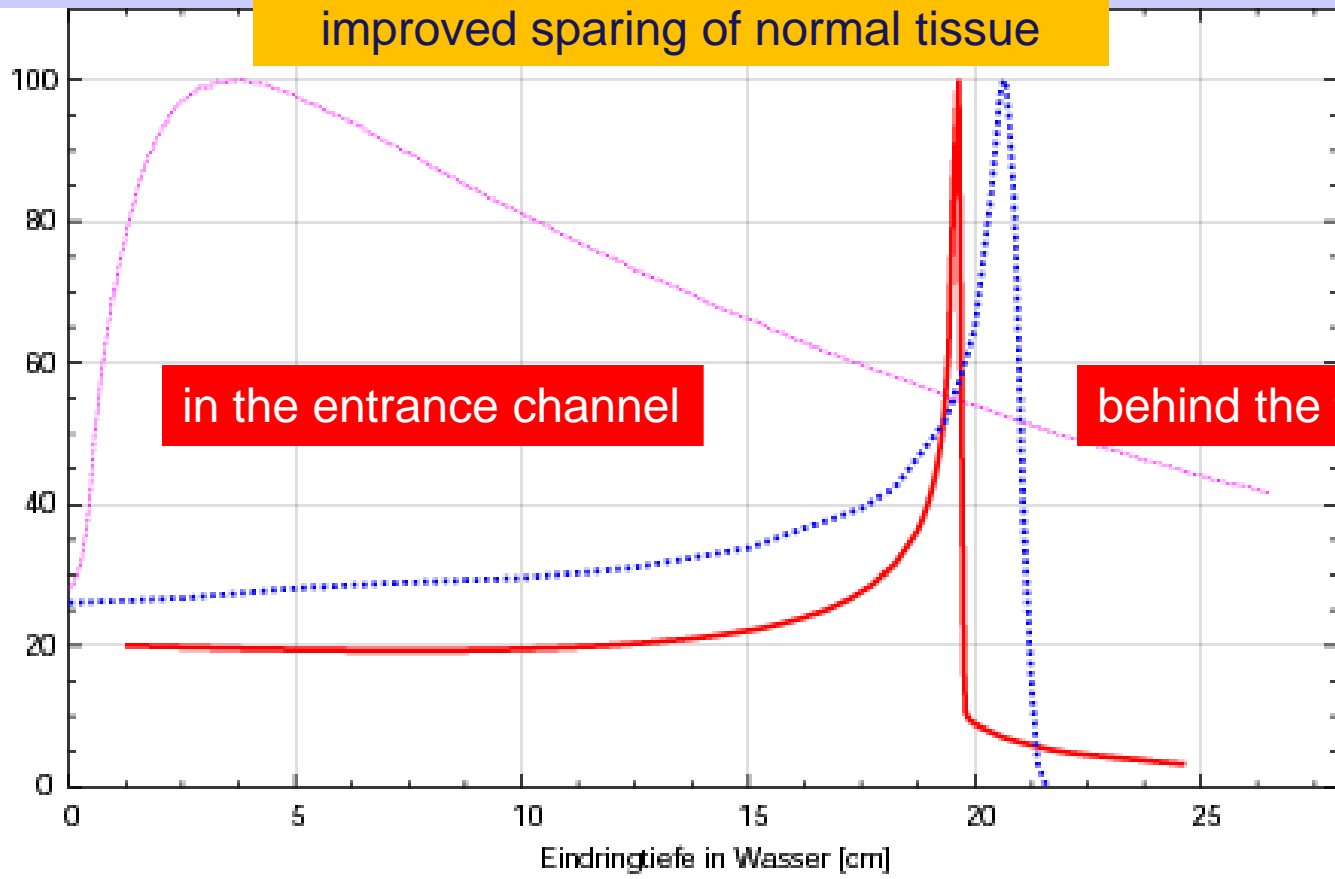
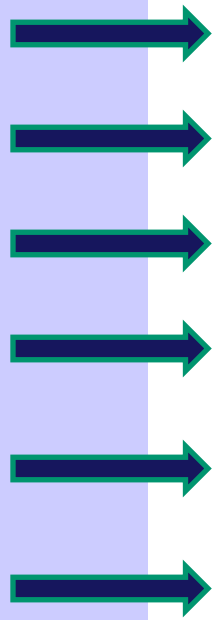
Founder and first director of Fermilab

Robert Wilson:

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



Due to the physical selectivity
improved sparing of normal tissue

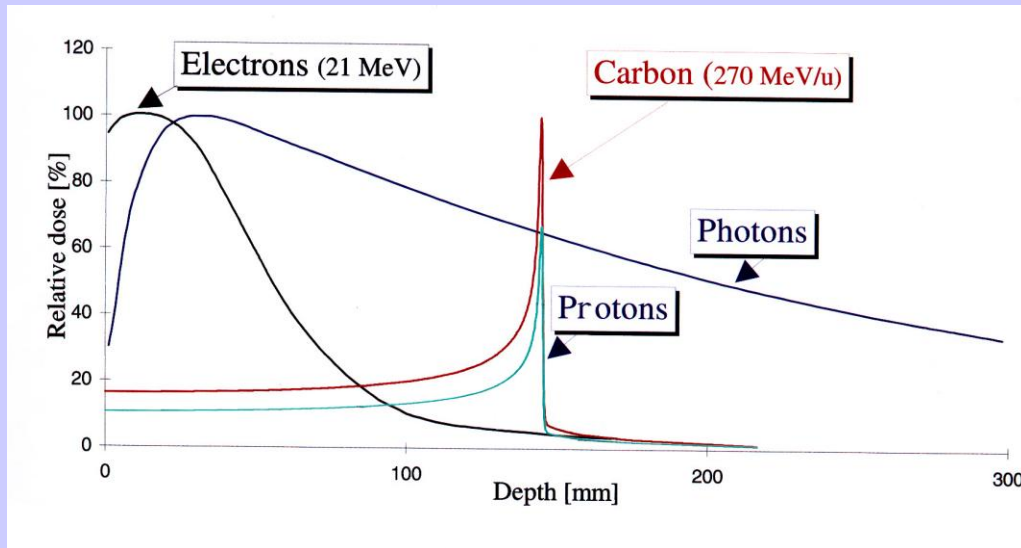


in the entrance channel

behind the tumor

Photonen 25 MV Protonen 176 MeV
Kohlenstoffionen 330 MeV

Hadrontherapy vs. radiotherapy



- Tumours close to critical organs
- Tumours in children
- Radio-resistant tumours

Photons and Electrons

- Physical dose high near surface
- DNA damage easily repaired
- Biological effect lower
- Need presence of oxygen
- Effect not localised

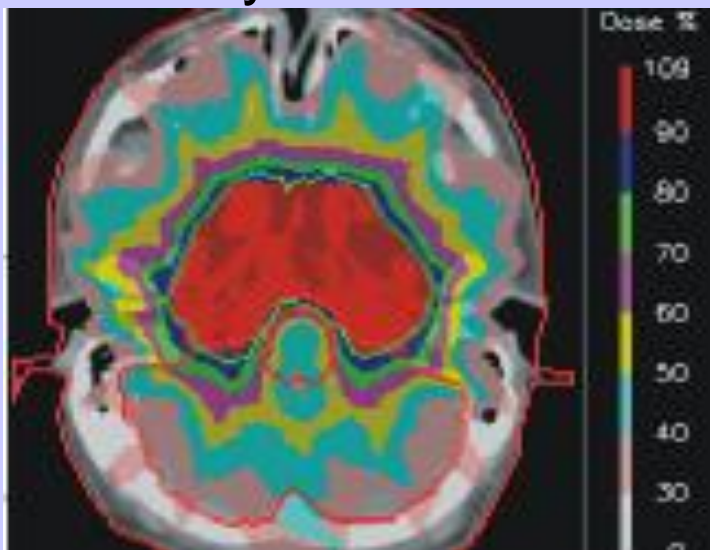
vs.

Hadrons

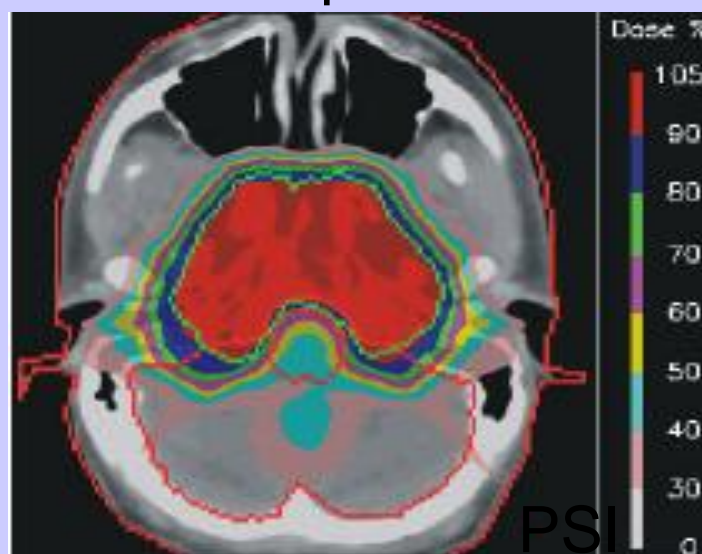
- Dose highest at Bragg Peak
- DNA damage not repaired
- Biological effect high
- Do not need oxygen
- Effect is localised

Protons are quantitatively better than X-rays

9 X-ray fields



4 proton fields



A better dose distribution allows an increase in the tumour dose: typically if the dose increases from 60 Gy to 72 Gy the tumour “control rate” at 5 years passes from 50% to 65%

Proton therapy in children and young adults

Reduced treatment volume

=

Reduced late side effects

=

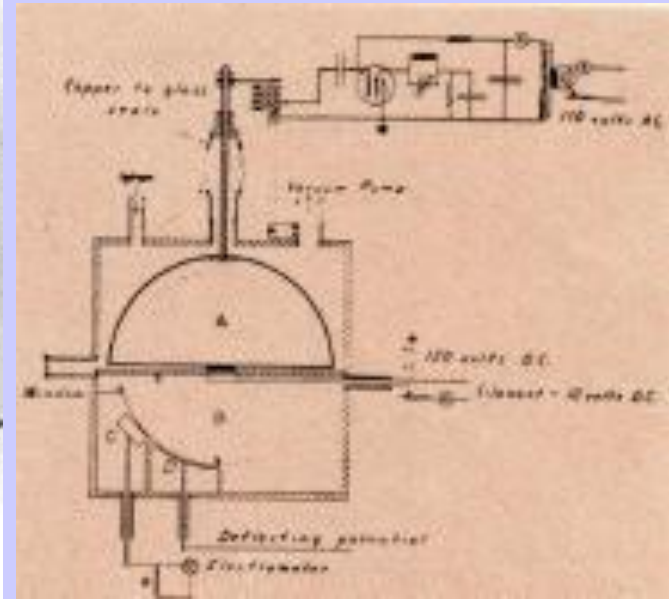
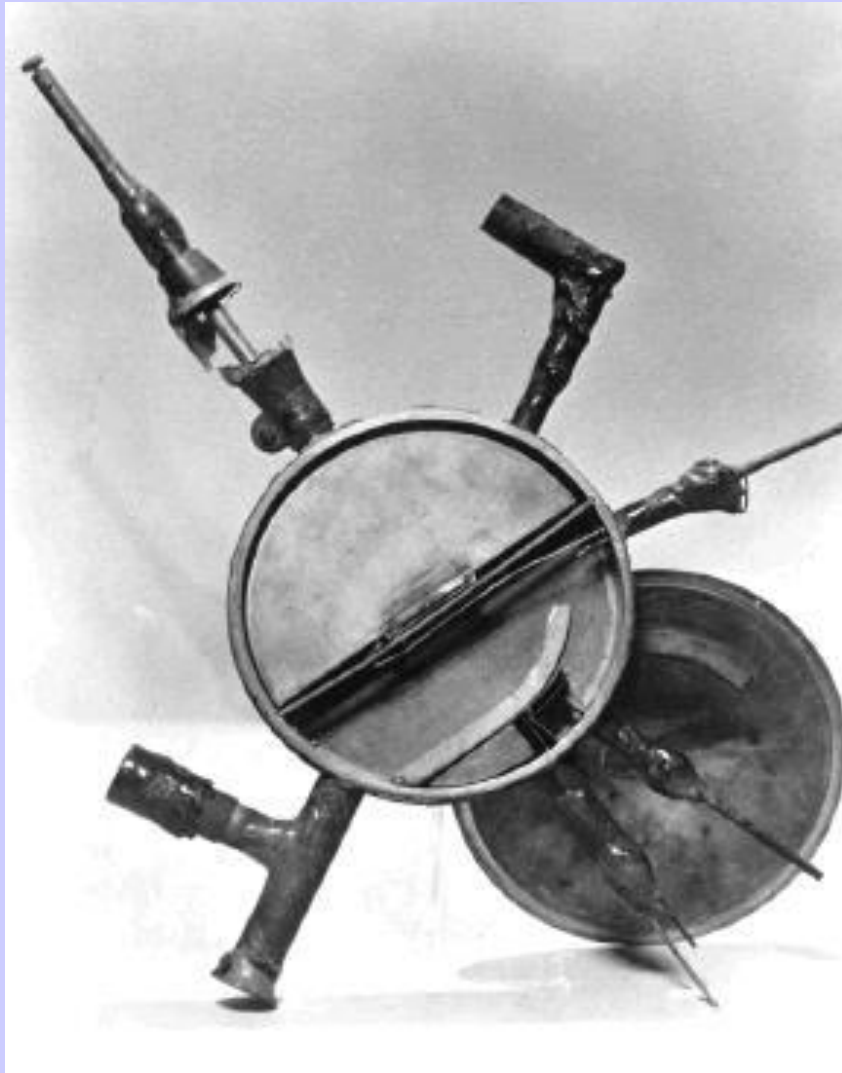
Reduced risk of second malignancies

Ernest Orlando Lawrence



*Ernest Lawrence
came to Berkeley
from Yale as
associate professor
of physics in 1928.*

The First Successful Cyclotron.....



*The first successful
cyclotron constructed
by Lawrence and M. S.
Livingston (1930).*

12 cm in diameter.

184-Inch Cyclotron



*The first beam,
November 1, 1947.*

1945



Protontherapy in Europe

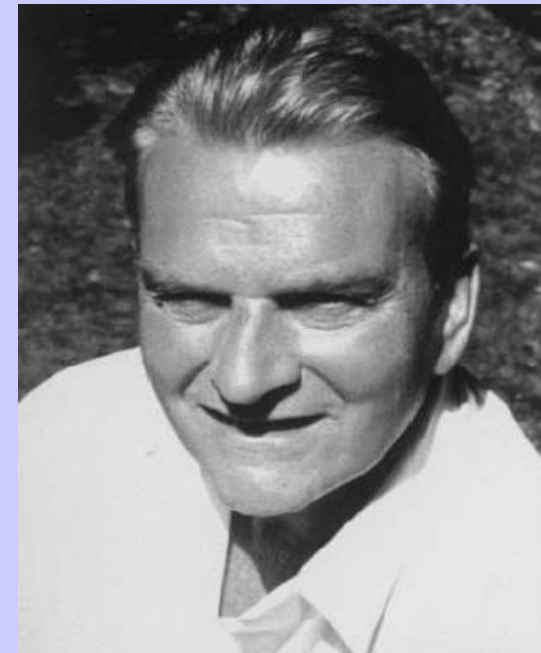
Börje Larsson at Uppsala

**“On the Application of a 185 MeV
Proton Beam to Experimental
Cancer Therapy and Neurosurgery”**

Doctoral dissertation - 1962



The modified synchrocyclotron



(1931-1998)

1943 - Harvard



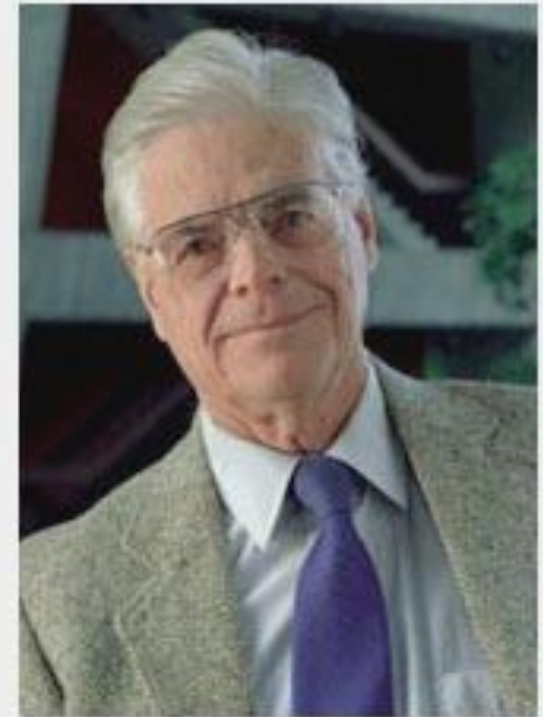
Protontherapy

Hymer Friendell Bob Wilson Percy Bridgeman

1946 R.R. Wilson proposes the use of Bragg Peak

1954 First irradiations in Berkeley

1961 New Harvard cyclotron irradiates patients



Founder and first director of Fermilab - 1990

184-Inch Cyclotron and Hadron Therapy

1956 - 1986

Hadron Therapy

Clinical Trials

1500 patients treated



Closure of the 184-Inch, 1986.

Milestones of Hadron therapy

1991 — First hospital based *Proton* facility
Loma Linda University Medical Center, CA, USA



360° Gantry



Milestones of hadron therapy

Start of carbon ion therapy

1994 in Japan/Chiba

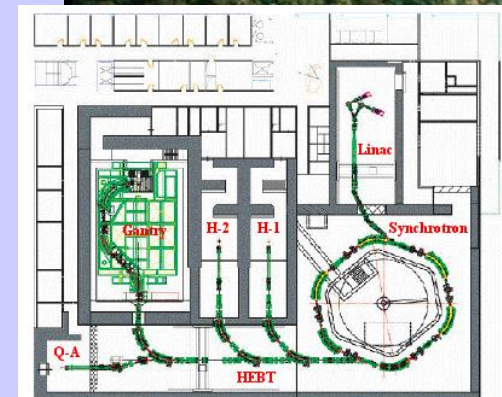
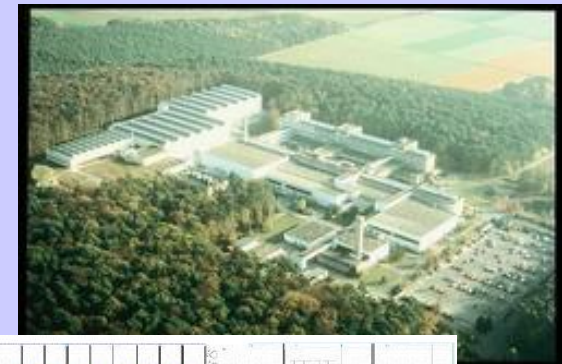
Heavy Ion Medical Accelerator
(HIMAC)

National Institute of
Radiological Sciences (NIRS)



1997 in Germany/Darmstadt

GSI (Gesellschaft für
Schwerionenforschung)



The Darmstadt GSI 'pilot project'
(1997-2009)



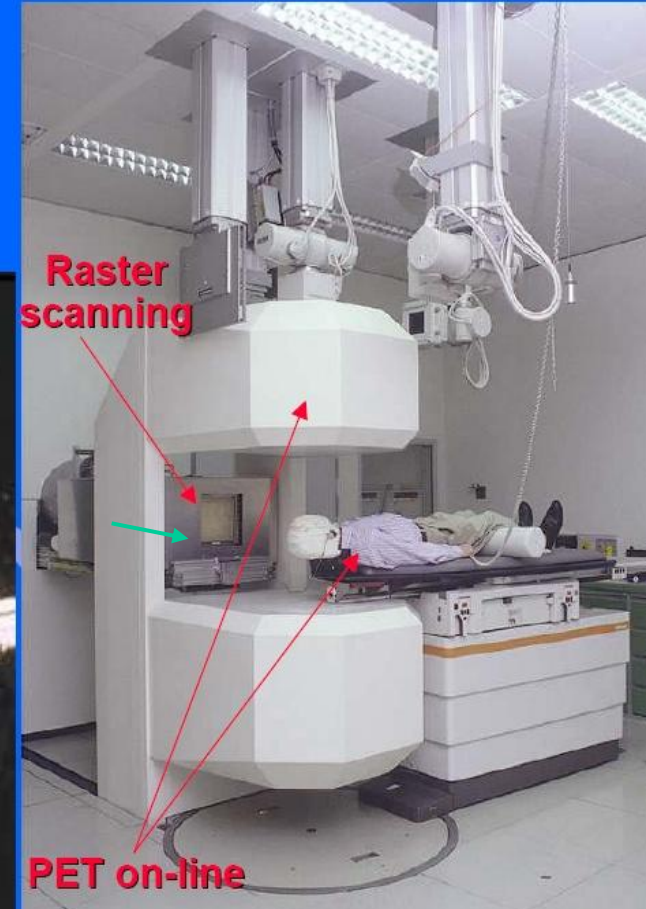
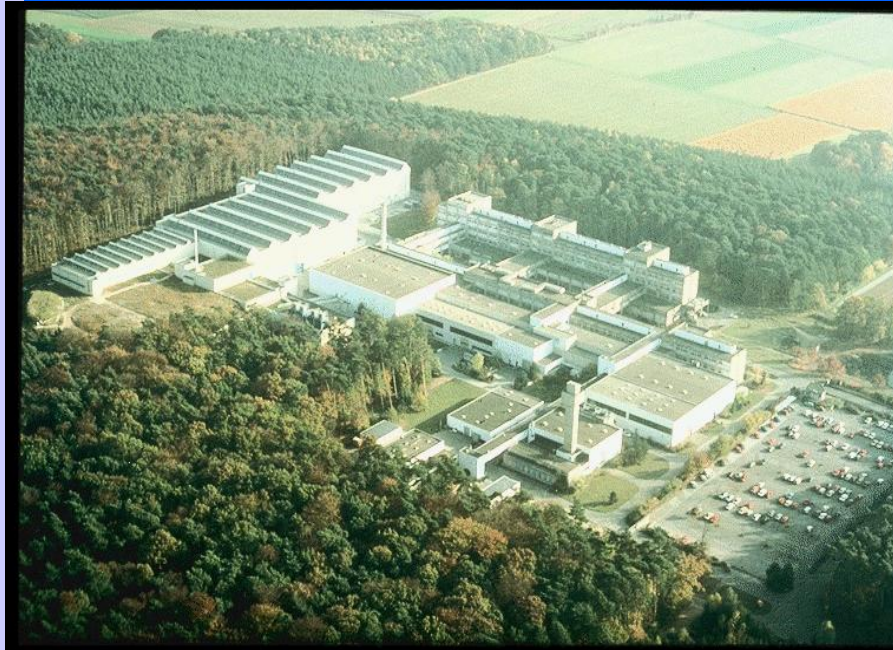
G. Kraft

G. Kraft

450 patients treated
with carbon ions
J. Debus (Heidelberg Univ.)



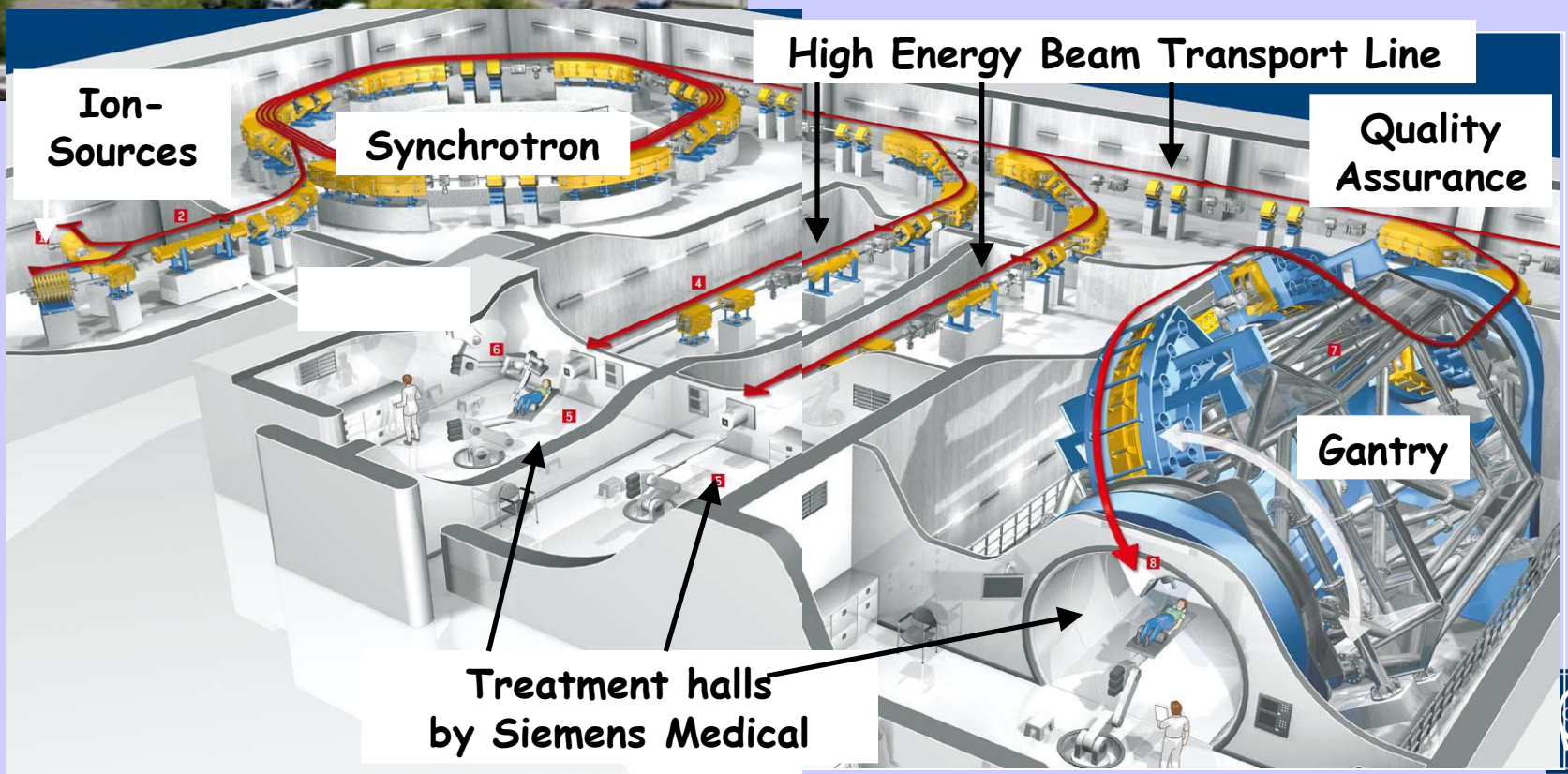
J. Debus



HIT - HEIDELBERG

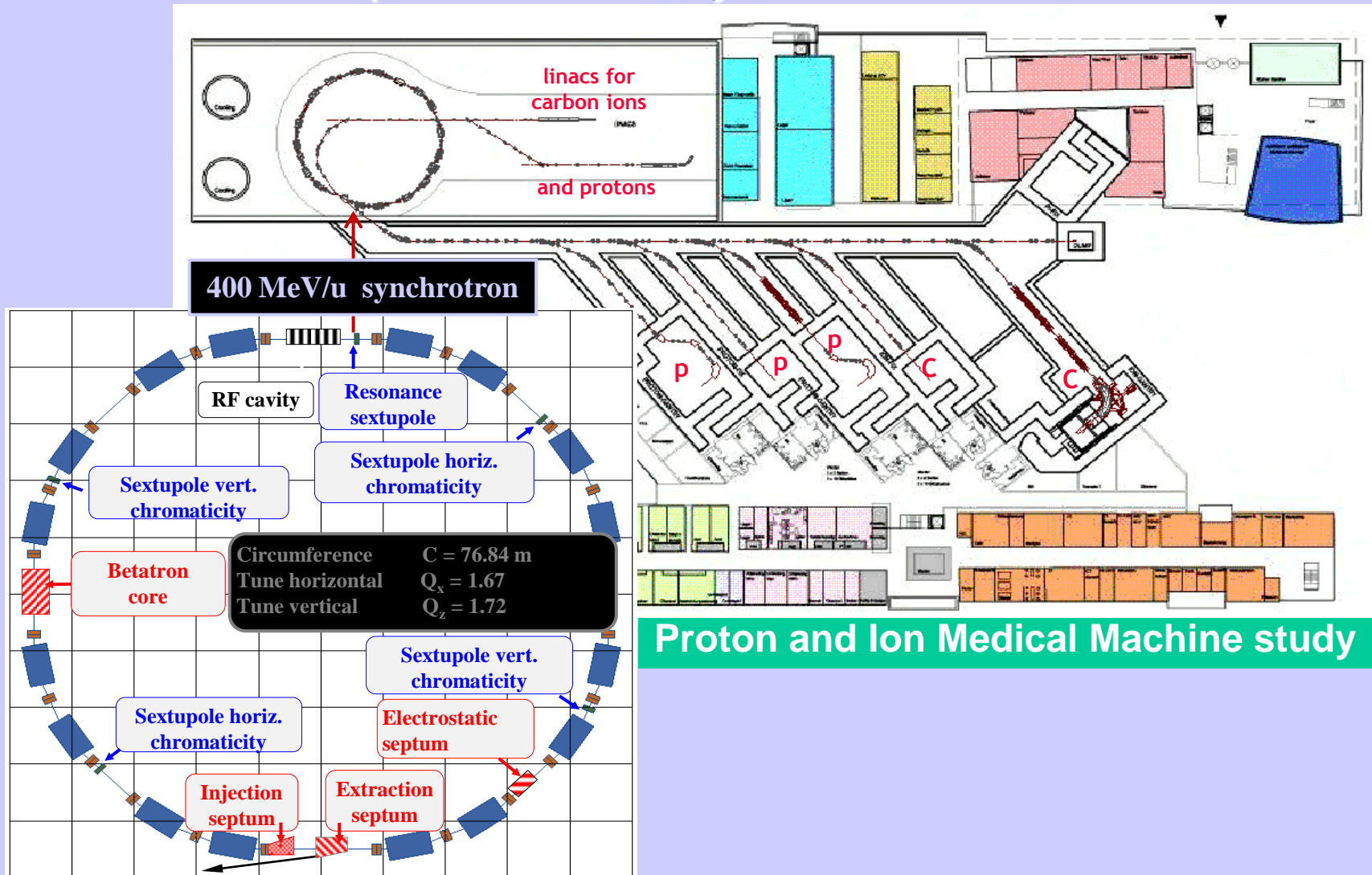
First beam extracted in 2007

First patient: Nov 2009



PIMMS at CERN in 1996 - 2000

CERN-TERA-MedAustron-Oncologie 2000 Collaboration
for optimized medical synchrotron



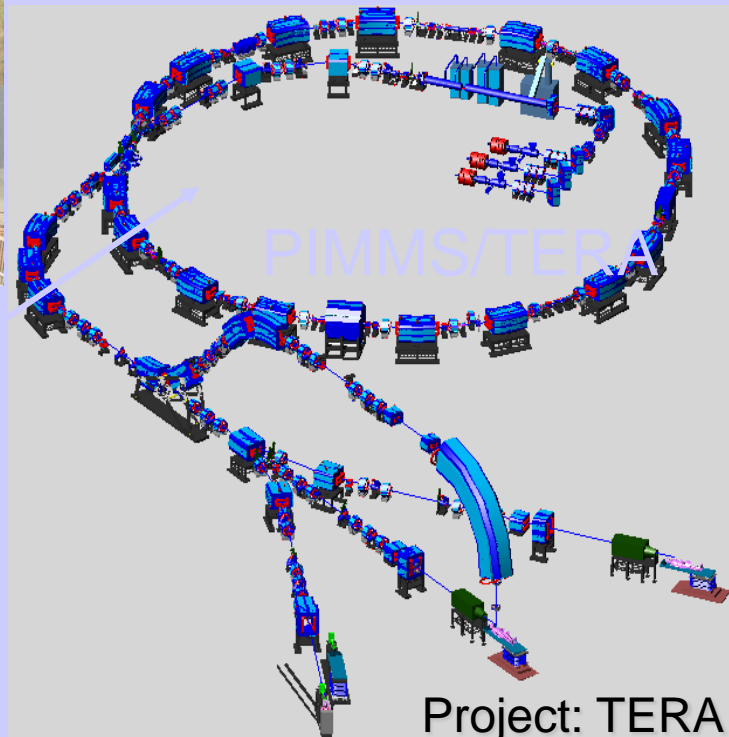
The CNAO Italian national centre designed by TERA

Project: Calvi –TEKNE



Main source of 90 MEuro:
Italian Health Ministry

CNAO Foundation constructs and manages
INFN is co-responsible for the construction



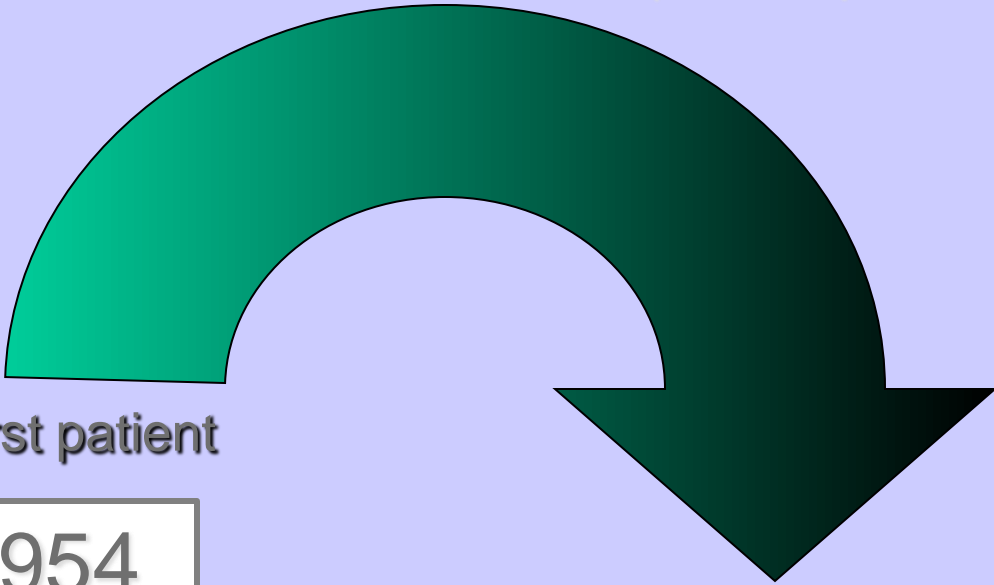
Project: TERA

A company is negotiating with CNAO a license for PIMMS/TERA

Hadrontherapy history ...

...in 1997

22,000 patients since the beginning
(18,300 protons)



First patient

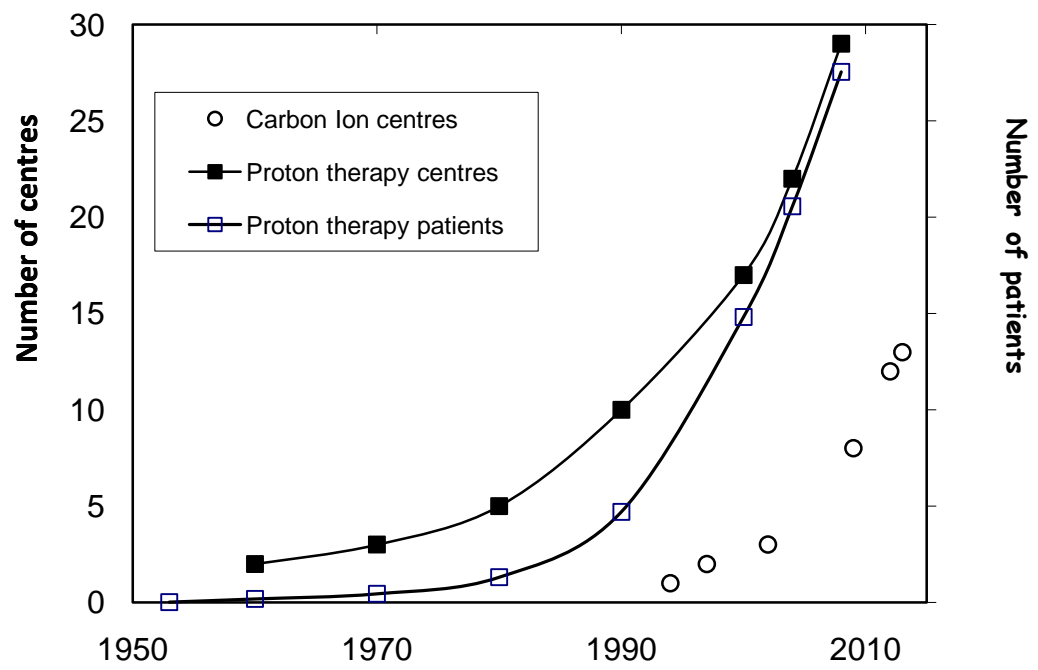
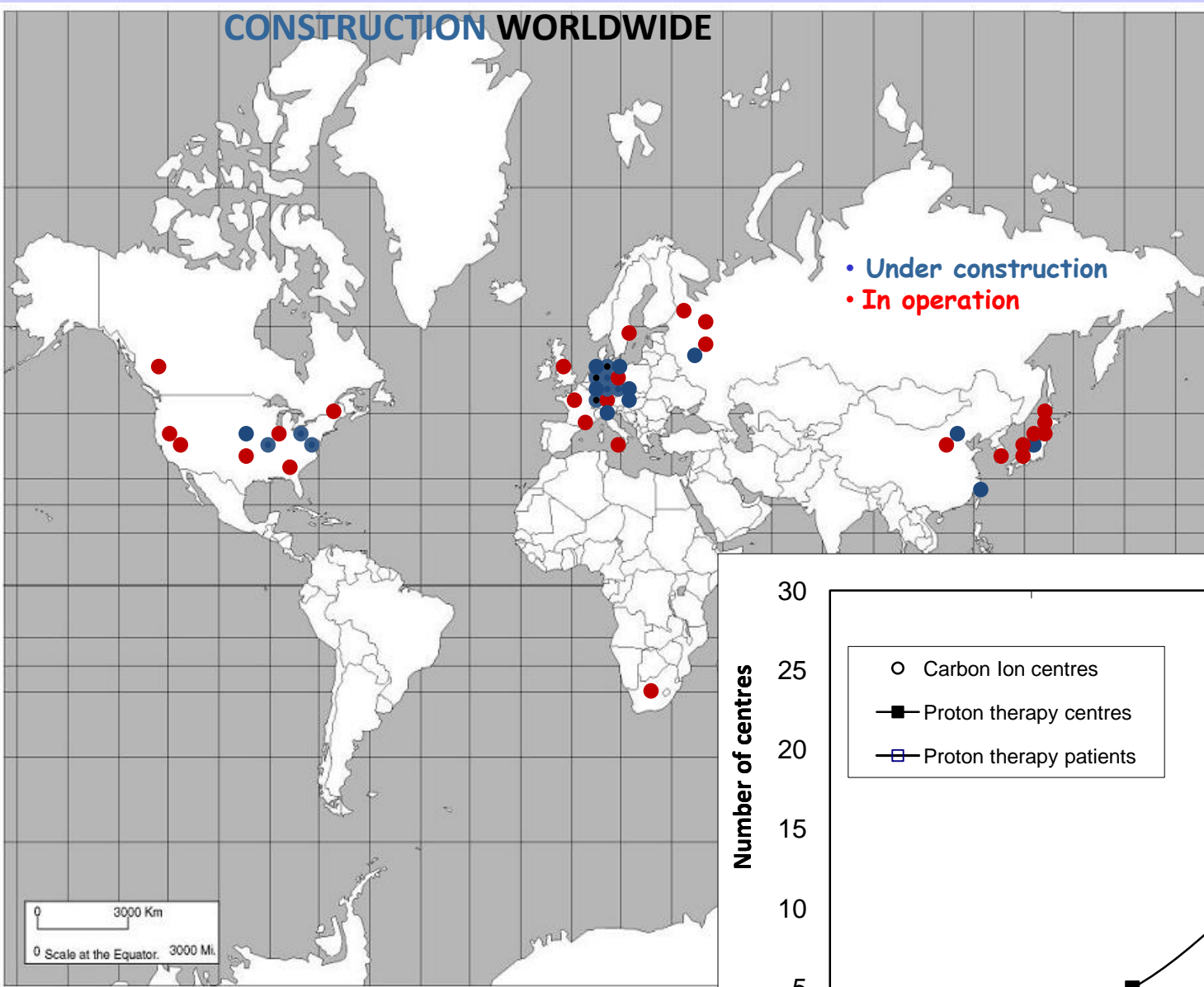
1954
Berkeley

Today

60,000 patients
(55,000 protons,
5000 carbon ions)



HADRON THERAPY CENTRES **IN OPERATION** AND **UNDER CONSTRUCTION** WORLDWIDE



Hadron Therapy Challenge

Multidisciplinary and cutting-edge technologies:

- Clinical Studies
- Radiobiology
- Treatment planning for Intensity Modulated Particle Therapy
- Adaptive ion therapy and treating of moving organs
- Novel in-beam PET systems
- Feasibility study for innovative gantry designs
- Improved gantry design
-



ENLIGHT

Hadrontherapy complex undertaking, therefore ENLIGHT was established to

- Create common multidisciplinary platform
- Share knowledge
- Share best practices
- Harmonise data
- Provide training, education
- Identify challenges
- Innovate



ENLIGHT++ in 2010

- ENLIGHT provides a multidisciplinary European collaboration amongst partners interested in hadrontherapy
- ENLIGHT acts as a platform for defining research needs
- Developing projects and securing funding and collaboration
- ENLIGHT is a useful resource for other communities interested in hadron therapy

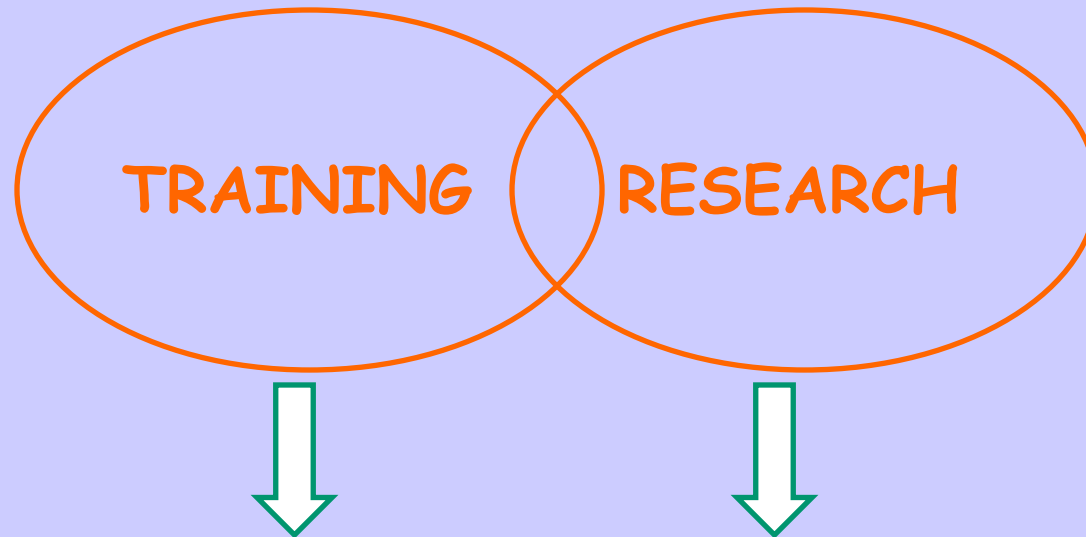


What are the community needs?

- Trained people in the new multidisciplinary field
- Access to the facilities and beam time for research
- Better Imaging, organ-motion
- Treatment planning,
- Information sharing and networking
- Improving present technologies/facilities
- Funding

THE PARTNER PROJECT

PARticle Training Network for European Radiotherapy



Young Researchers
→ Future Leaders
in Ion Therapy

Clinical
Biological
Technical
(Instrumentation)

Key details for PARTNER

✓ Contribution from European Commission: **5.6 M€**

- ✓ 25 young researchers
- ✓ PARTNER wide training in all collaborating institutes
- ✓ 20 training workshops in hadron therapy for all young researchers
- ✓ Ten Institutes & 2 companies

www.cern.ch/partner

ULICE

Union of Light Ion Centres in Europe

Coordinator Prof Orecchia of CNAO, Italy



- **Joint Research Activities**

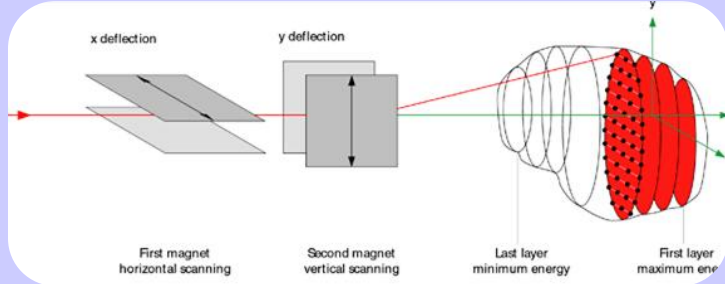
- **Networking Activities**

- **Transnational Access**

JRA: Improving the performance of facilities



Coordinator Professor PÖTTER , Vienna



- Develop methods to match the volume treated by **active scanning particle beams** to the target volume

- Identify tumours** that need the superior physical selectivity provided by ion beams



- Develop/investigate a new carbon ion gantry design



- Develop novel treatment planning for ion radiotherapy



Transnational Access: Providing access to existing facilities

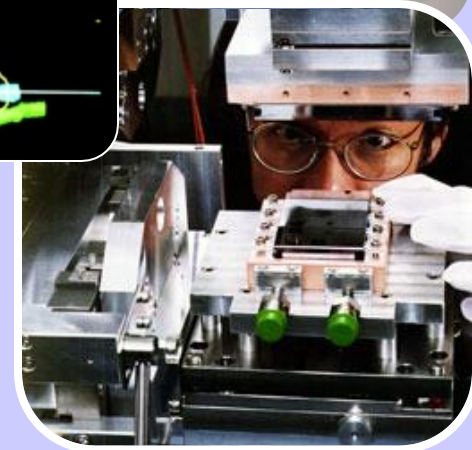
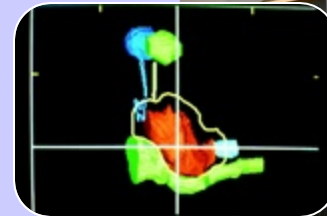
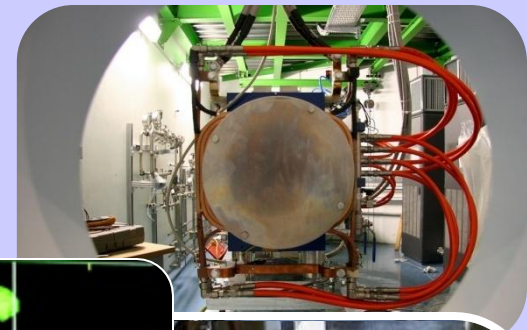


Coordinator: Professor Debus , Heidelberg, HIT



- Provide **beam-time for external researchers through clinical trial programmes** aimed at improving different technical aspects of the facilities.

- Provide **beam-time through 'open requests'** from external researchers for **radiobiological and physics experiments.**



Networking Activities: Communication and dissemination



Coordinator Professor Dosanjh, CERN

- Communication and dissemination for promoting hadron-therapy research facilities to end-users

- Recommendations for further improvement and investments of the current and future Hadron Research Infrastructures

- Development and spreading of Europe wide common protocols standardizing operational procedures to facilitate access to hadron-therapy facilities and inter-comparison of results

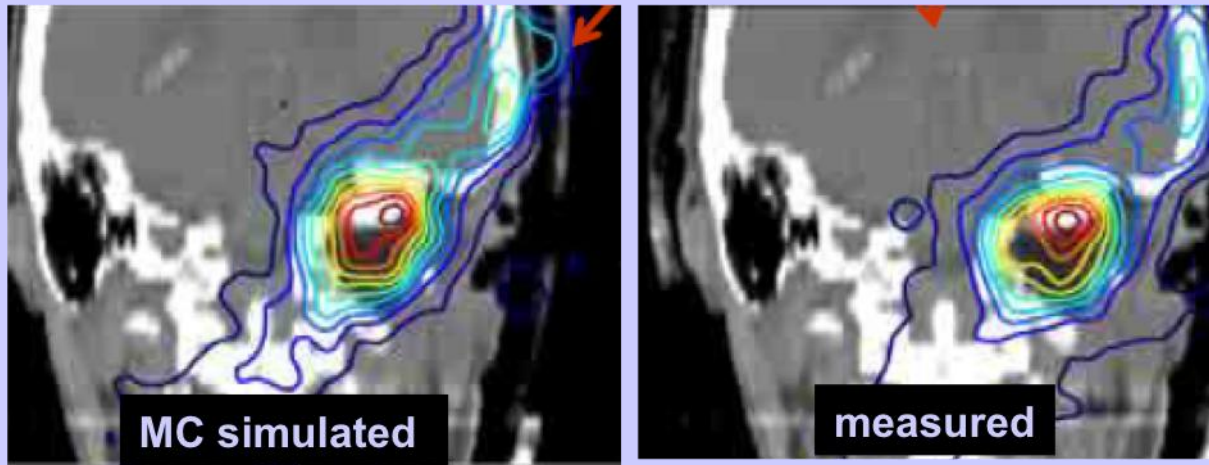




ENVISION

European Novel imaging systems for in vivo monitoring for ion beam therapy

ENVISION



In beam-PET imaging during irradiation helps to monitor in-vivo the actual dose delivery

- ENVISION aims at:
 - Enhancing the dose conformation to the cancer volume
 - Improving the treatment of moving organs



Quality assurance!

ENVISION



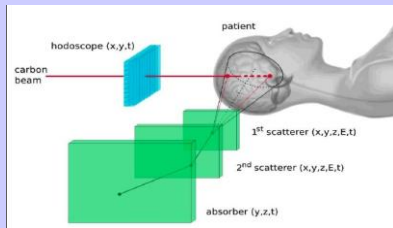
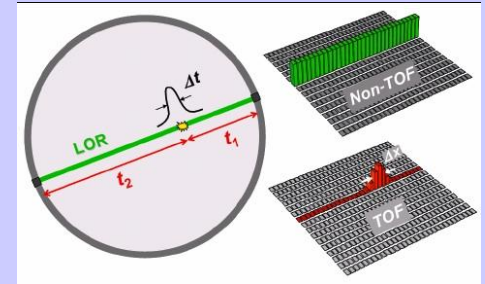
POLITECNICO
DI MILANO

- Project funded for 6M Euros
- Started February 1st, 2010
- Coordinated by CERN



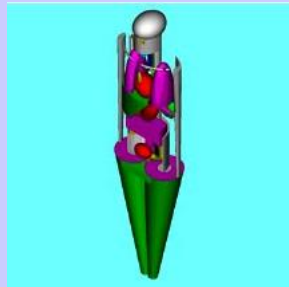
ENVISION

- Improve the quality of in-beam PET images through time-of-flight measurement



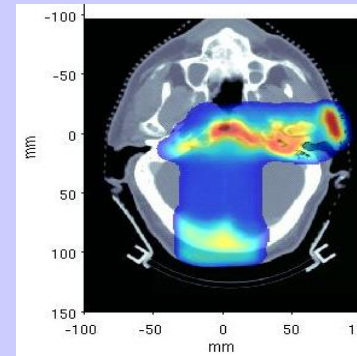
- In-beam dose monitoring with prompt single particles (photons and protons)

- In-vivo dosimetry and moving organs



- The combination of in-vivo dosimetry, treatment planning and clinical relevance

- Monte-Carlo simulation of in-vivo dosimetry



ENTERVISION

Marie-Curie ITN focussed on imaging

Just funded and will start soon.....

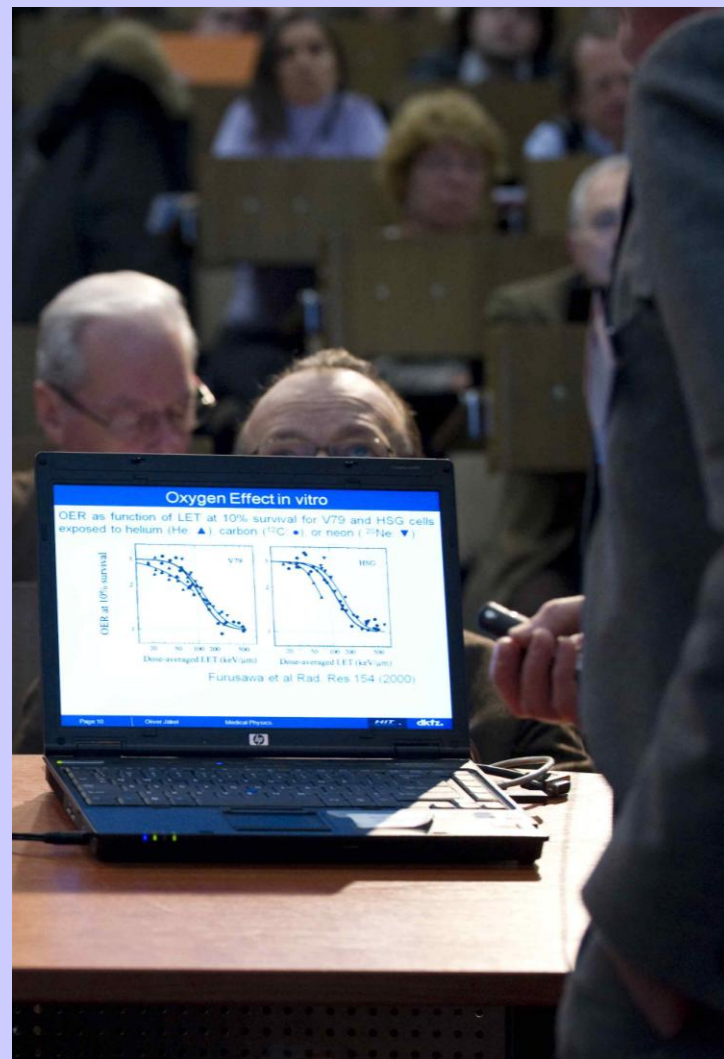
Physics for Health Workshop

Motivation

- review the progress in the domain of physics applications for health
- identify the most promising areas for further developments
- explore synergies between physics and physics spin-offs
- catalyse dialogue between doctors, physicists, medical physicists.....

Future

- Develop a roadmap to foster physics applications in the fields of medicine and life sciences
- Next workshop in 2012



Specific Initiatives requested from CERN

- Coordinate design study for compact and low cost particle therapy (similar to PIMMS)
- Irradiation Facility: infrastructure for fragmentation studies, detector development and radiobiology.....
- New isotopes for R&D...Isolde and other facilities through out Europe