GIORNATA INTERNAZIONALE DELLA FISICA MEDICA

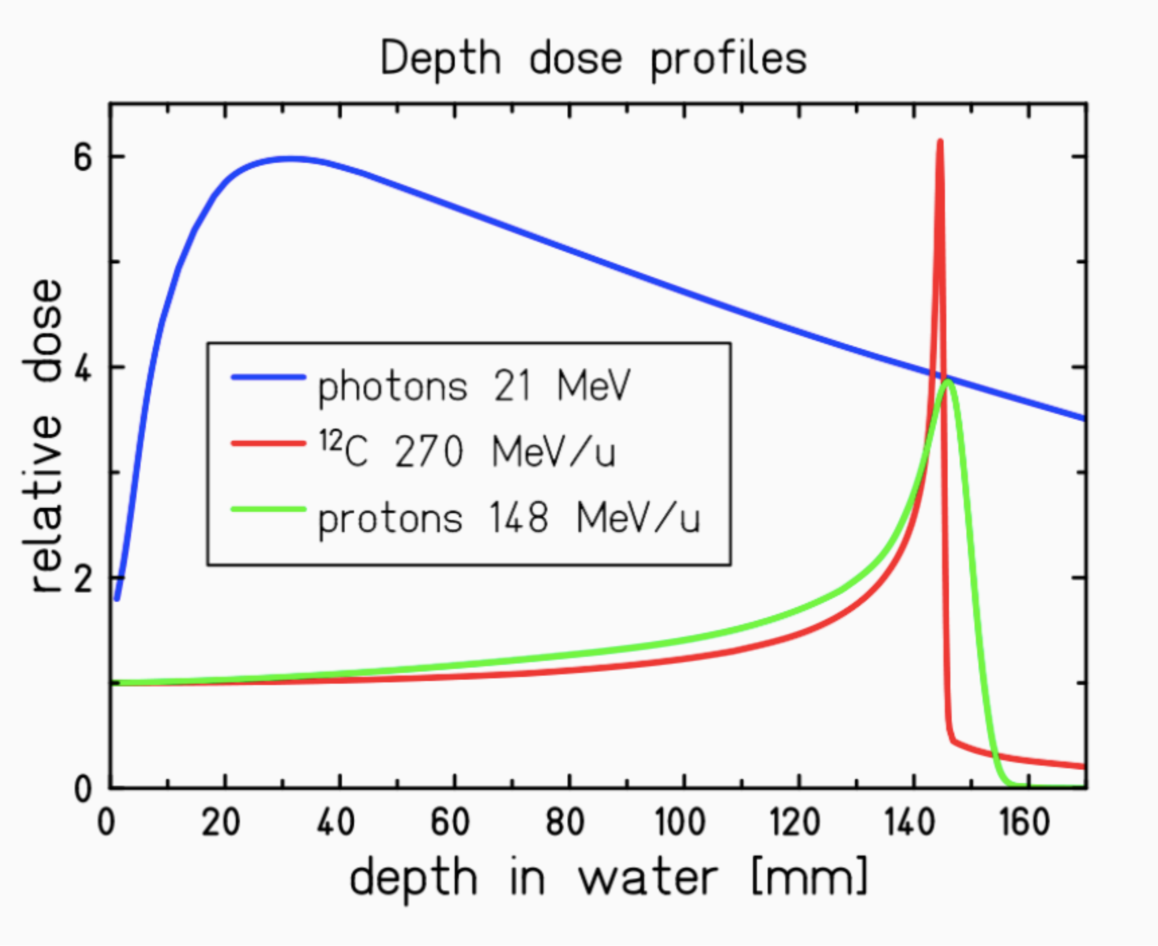
La tecnologia della protonterapia in ambito clinico

Federica Cattani
Unità di Fisica Sanitaria
Istituto Europeo di Oncologia - Milano

IEO
Istituto Europeo di Oncologia

Why do we use protons?

Physical advantages of protons

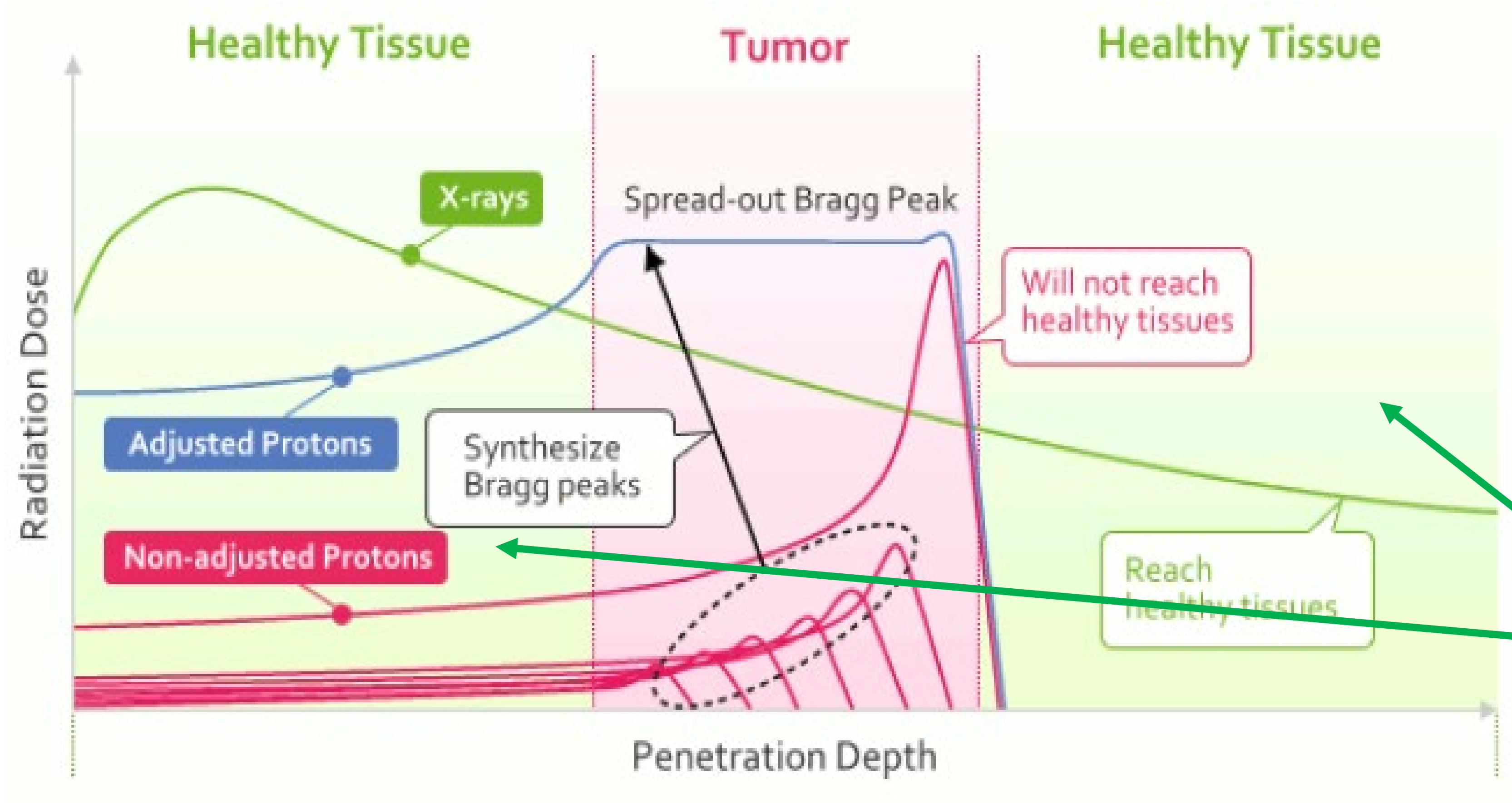


The main reason for using protons in radiotherapy is their favorable depth dose profile «Bragg peak»

X-rays: Steep built-up; exponential attenuation of fluence

Particles: Bragg maximum; slowing down to stop

Depth dose distribution of particle beams



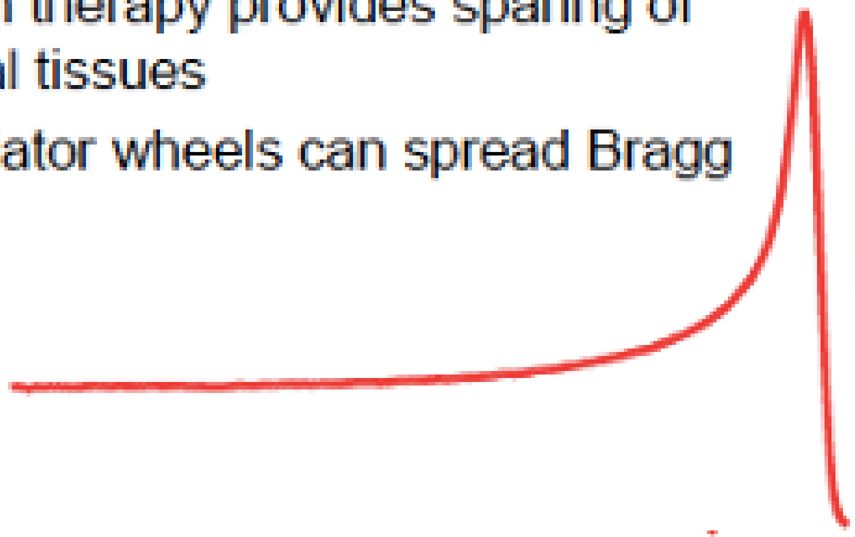
Superposition of Bragg peaks with various energies and different weights

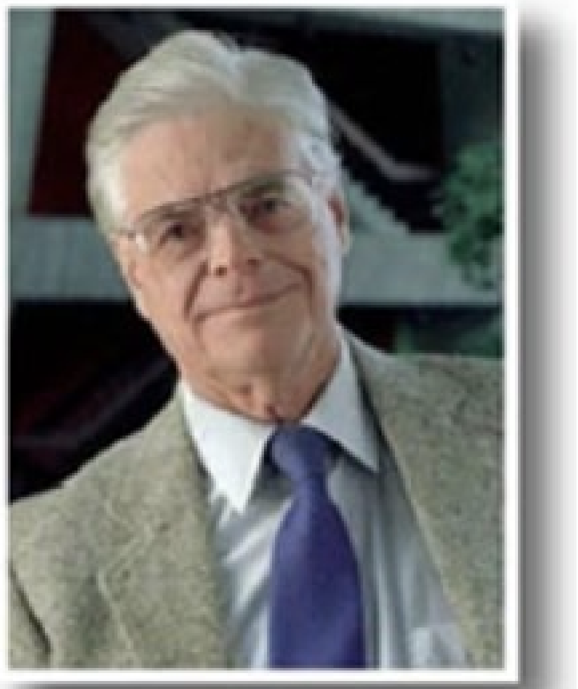
Significant reduction of integral dose in normal tissue

Source: http://w3.ai-hosp.or.jp/assets/images/fl/ptc/what_03.png

1946: Robert Wilson (1914-2000) physicist at Harvard

- Protons can be used clinically
- Accelerators are available
- Maximum radiation dose can be placed into the tumor
- Proton therapy provides sparing of normal tissues
- Modulator wheels can spread Bragg peak





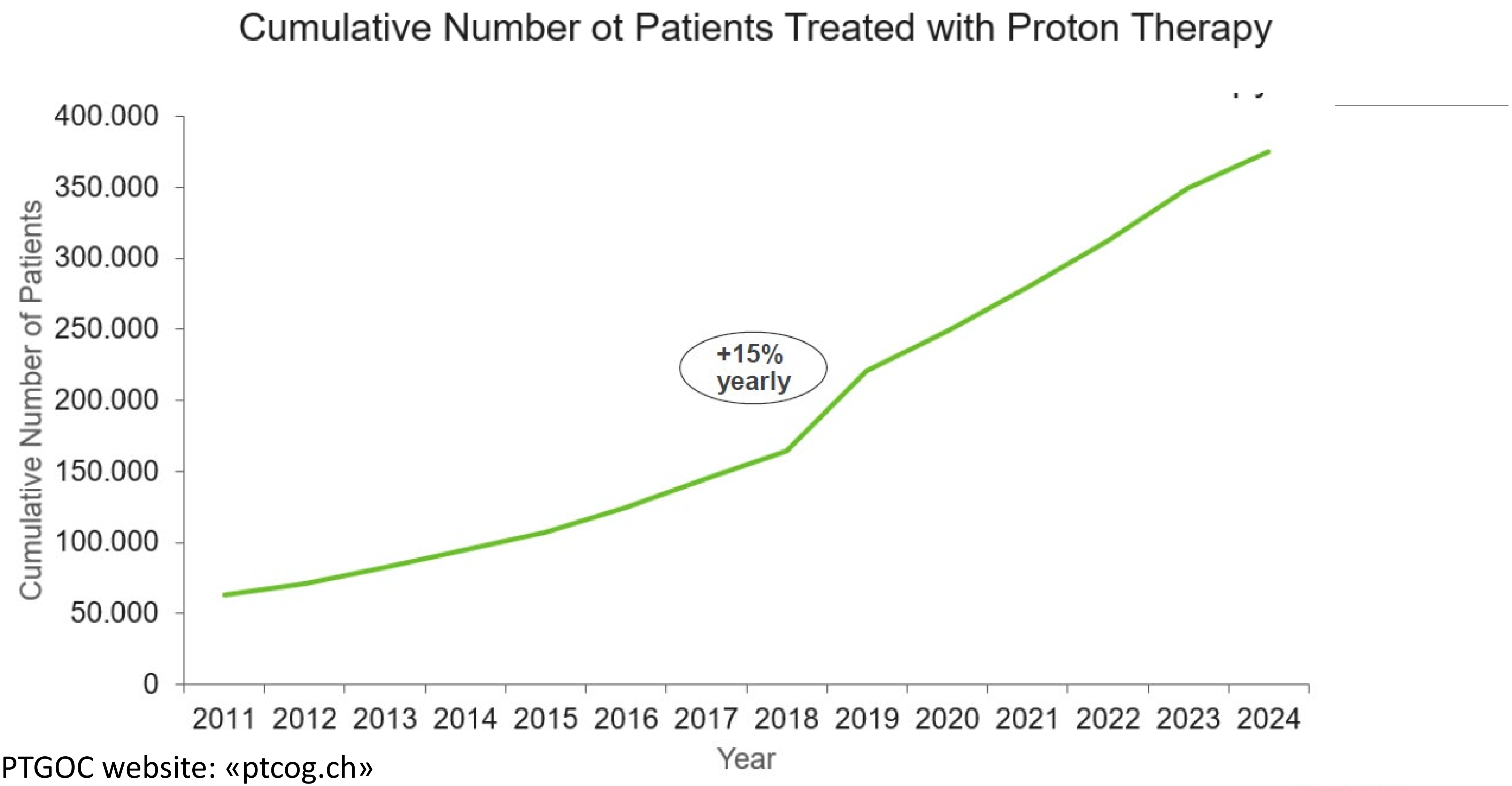
Robert Wilson

*Wilson, R.R. (1946). "Radiological use of fast protons," Radiology 47, 487.

Facilities in operation worlwide
with proton (orange) and carbon ions (violet)

PTGOC website: «ptcog.ch»

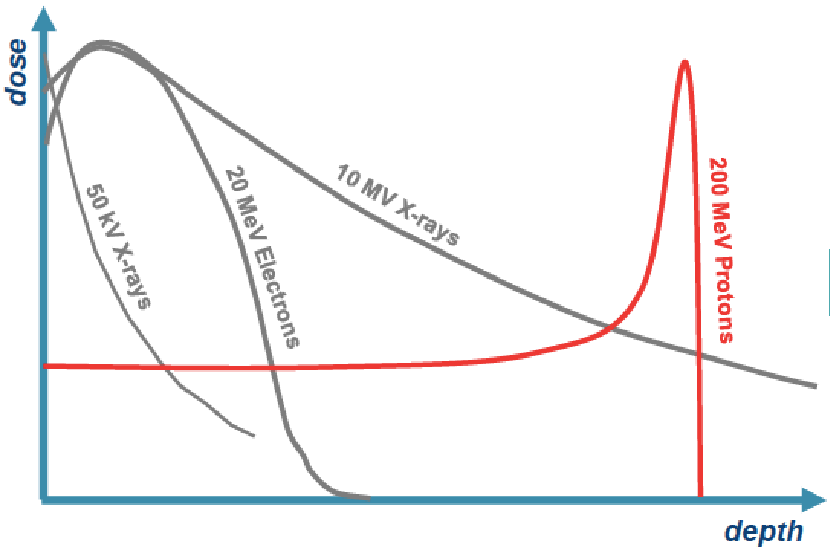
Rising numbers of PT centers in the world



PTGOC website: «ptcog.ch»

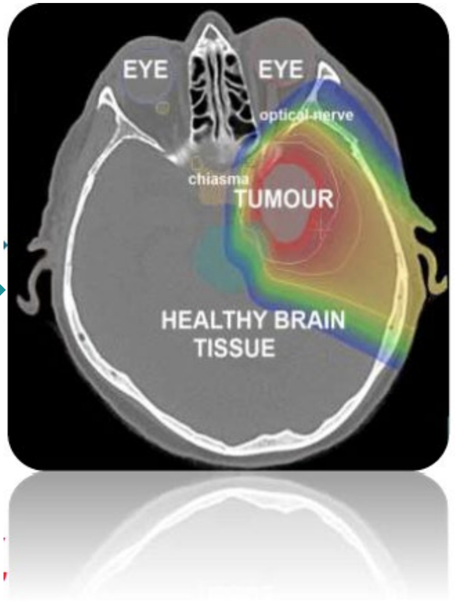
From radiation physics to a clinical radiotherapy treatment modality

«Theoretical advantage»



«TECHNOLOGY is KEY»

«Clinical solution»

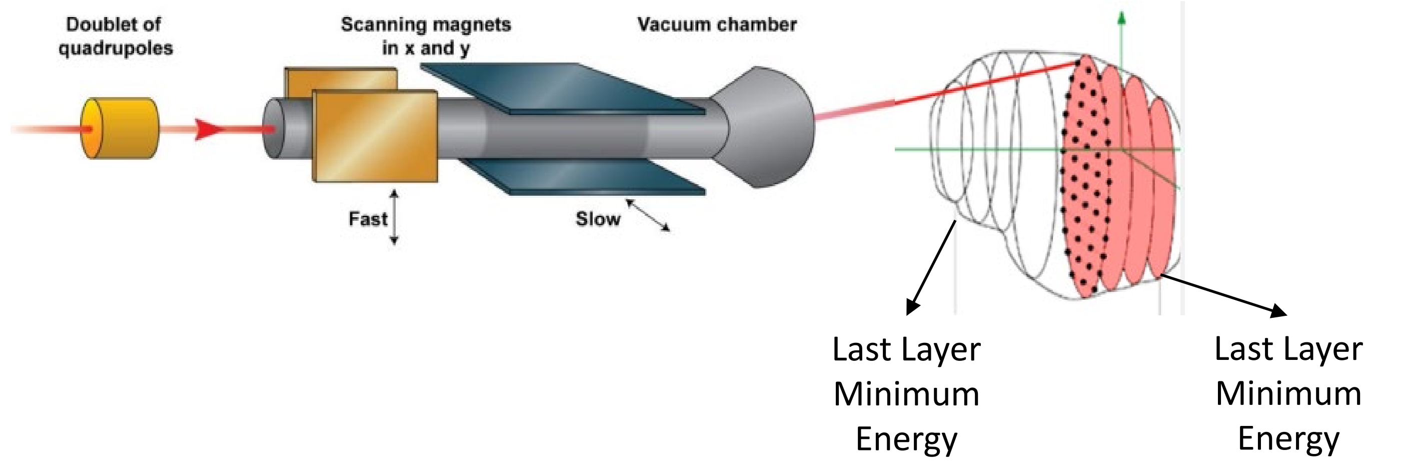


A whole range of technologies is necessary to fully unleash the potential of proton therapy in the clinic

Topics

Delivery technology

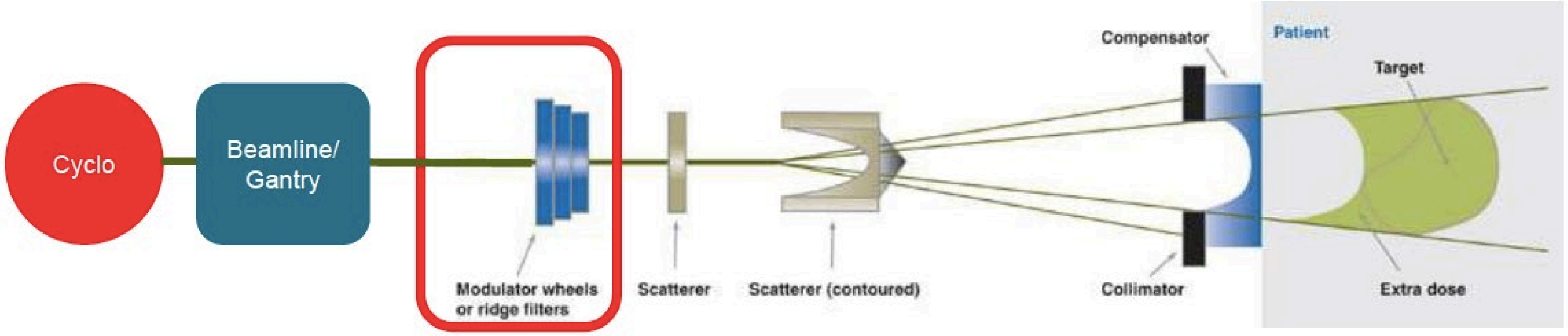
Compact layout systems



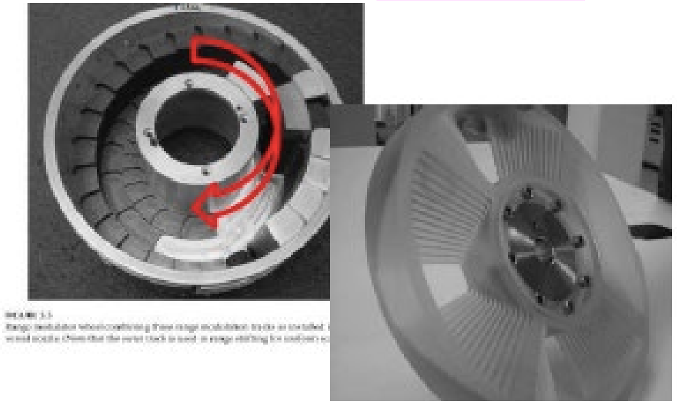
Delivery technology

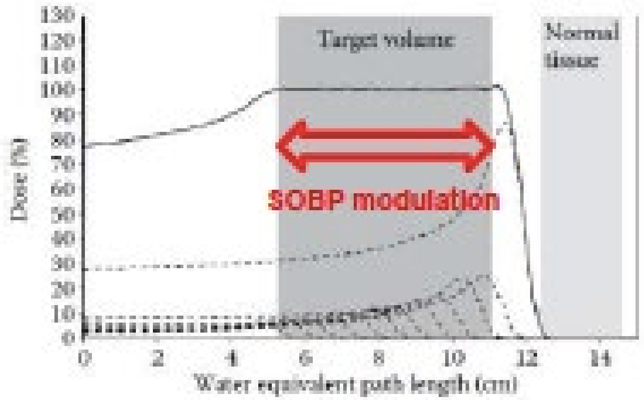
Passive scattering (PS) nozzle

«Generating high dose plateau in depth»



Modulator





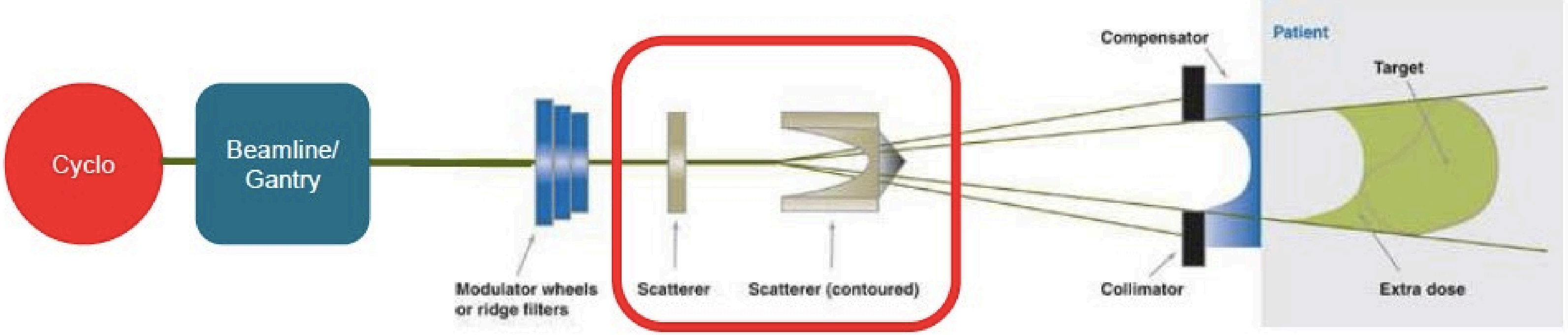
- Create from a Bragg peak single energy proton beam, a Spread Out Bragg Peak (SOBP) covering a volume in depth
- SOBP is a weighted sum of Bragg peak

- **Range modulator wheels rotate at high frequencies and «scan» the Bragg peak fast in depth to create a SOBP**

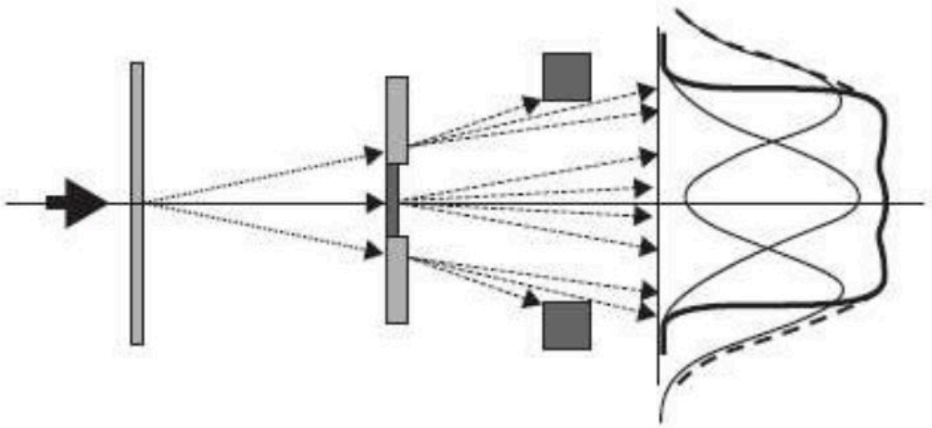
Delivery technology

Passive scattering (PS) nozzle

«Generating wide beam»



Scatterer



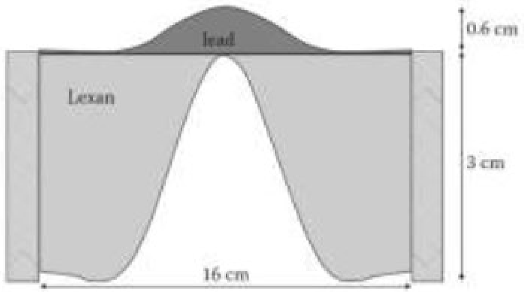


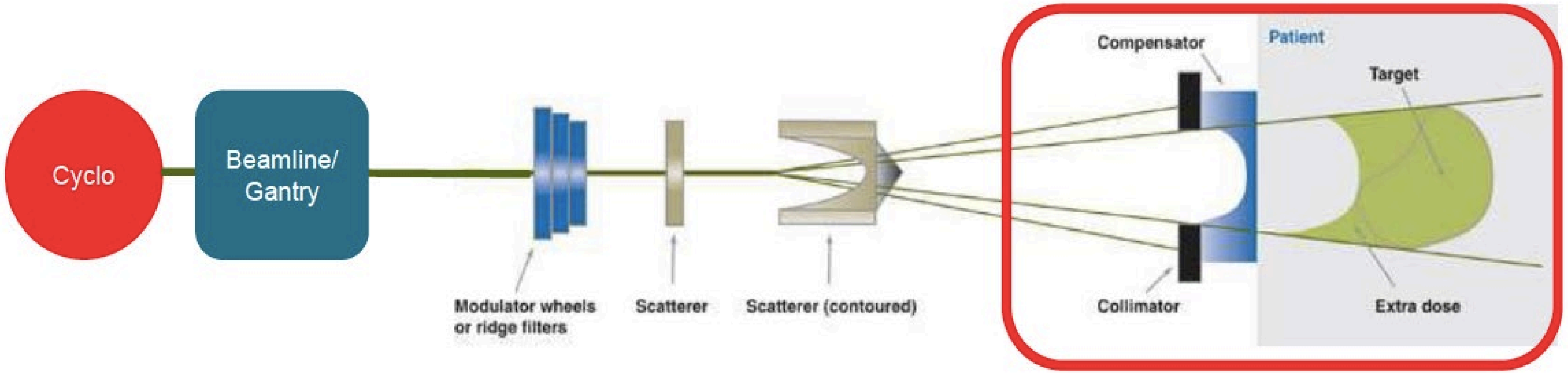
FIGURE 5.2
Schematic cross section of an energy-compensated contoured scatterer in the IBA universal nozzle.

- Create from a 3 mm diameter single energy proton beam a **wide beam with homogenous intensity** (similar to linac system for photons)
- Multiple scatterers in a cascade, homogenous or costructed from a combination of rings of high-Z and low-Z materials to refocus as many protons as possible into the field aperture

Delivery technology

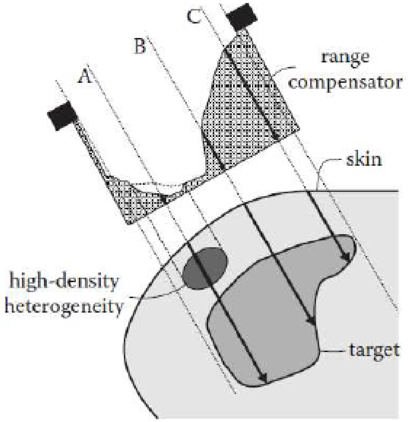
Passive scattering (PS) nozzle

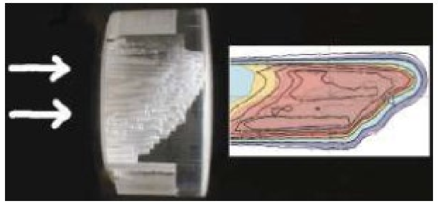
«Customize distal edge and shape of the beam»

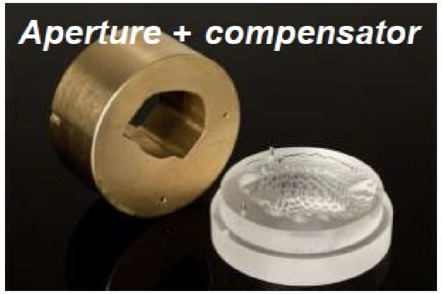


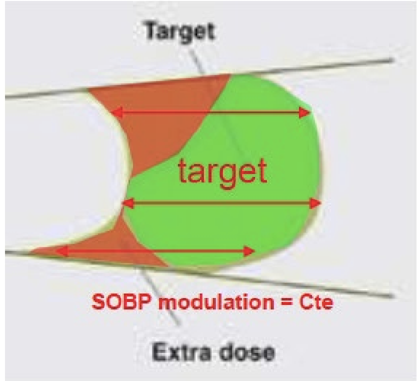
Compensator and collimator

Patient-specific **apertures** and **range compensators** are used to shape the beam and distal edge depth of the SOBP to the target volume contours



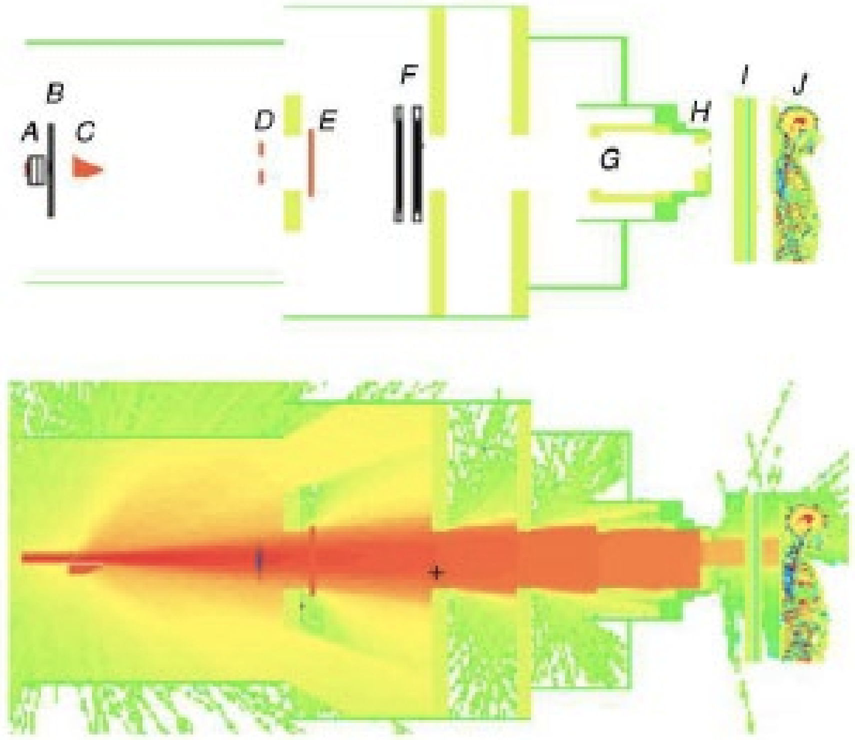






Delivery technology

Passive scattering (PS) nozzle



Stray radiation in PS

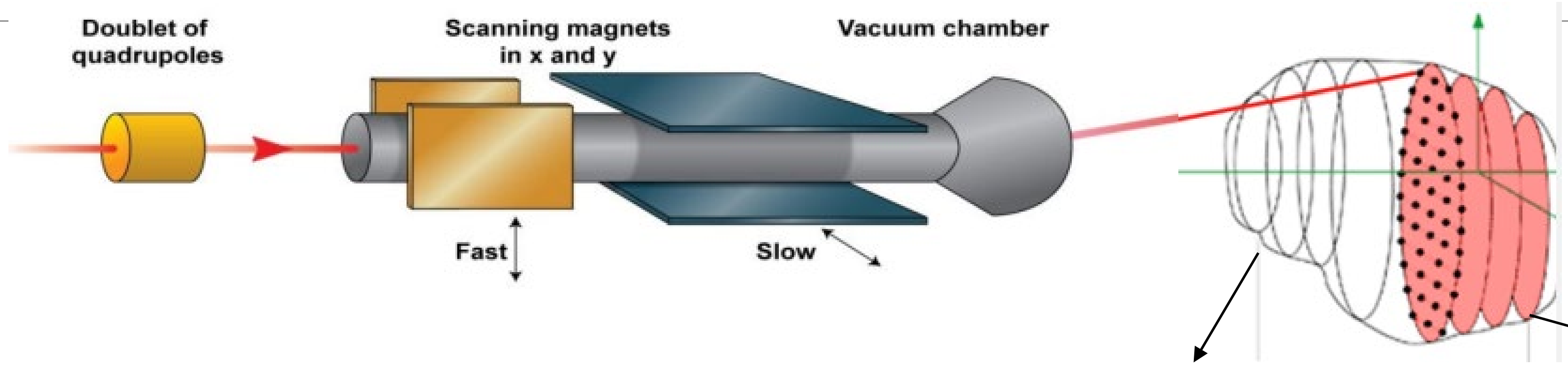
- Interactions of the proton beam with **components of the PS delivery system**, primarily in the nozzle generate secondary radiation
- Interactions of the proton beam **with the patient** generate secondary ratiation
- **Backscatter** from treatment vault walls

- These secondary radiation sources cause a **total body neutron dose bath** to patient during PT delivery
- Some concerns about secondary cancer induction (Hall 2006): «Passive modulation results in **doses distance from the field edge that are 10 times higher than those characteristic of IMRT with X-rays**»

IEO Istituto Europeo di Oncologia

Delivery technology

Pencil Beam Scanning (PBS)



Last Layer Minimum Energy

Last Layer Minimum Energy

- ✓ **Point by point irradiation with a pencil beam of few mm width**
- ✓ **No individual collimators and compensators required**
- ✓ **Good 3D dose conformity**
- ✓ **“Flexible”**
- ✓ **Low neutron dose**

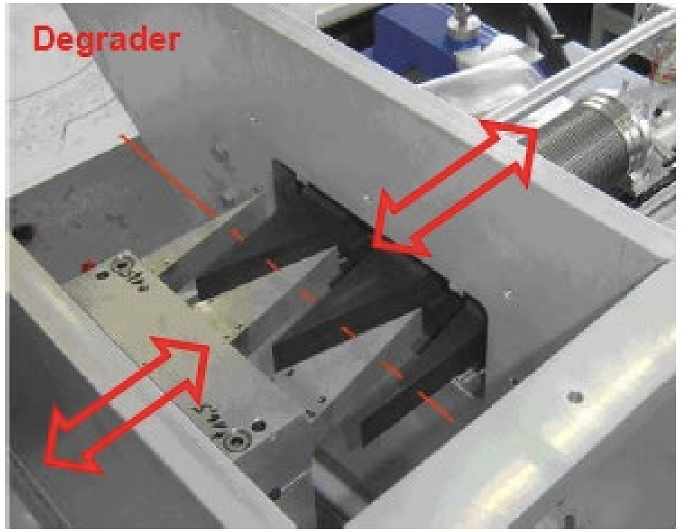
Target volume is subdivided into several slice, each related to a specific particle range

Typically 30-50 energies, 20000-50000 beams spots

Delivery technology

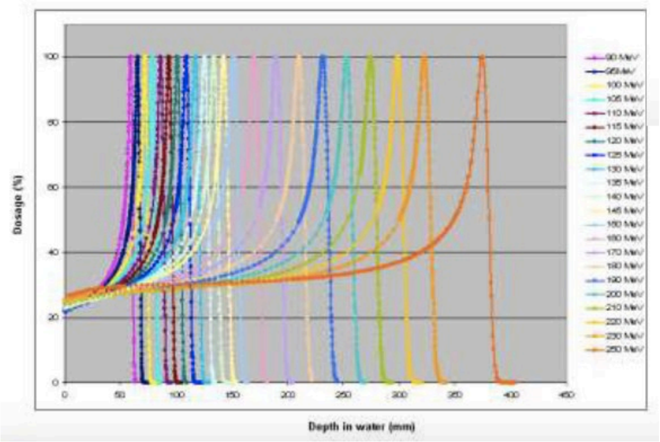
Pencil Beam Scanning (PBS)

Energy selection system (ESS)



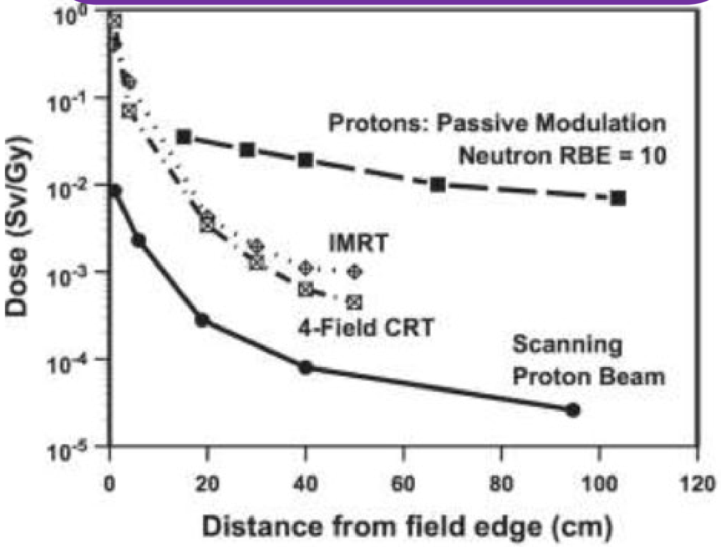
Layer/Energy switching using degraders

- Cyclotron produces single energy (~250 MeV)
- Degrader to select lower proton beam energy



Secondary neutrons mainly generated in the patient. Contribution of nozzle negligable

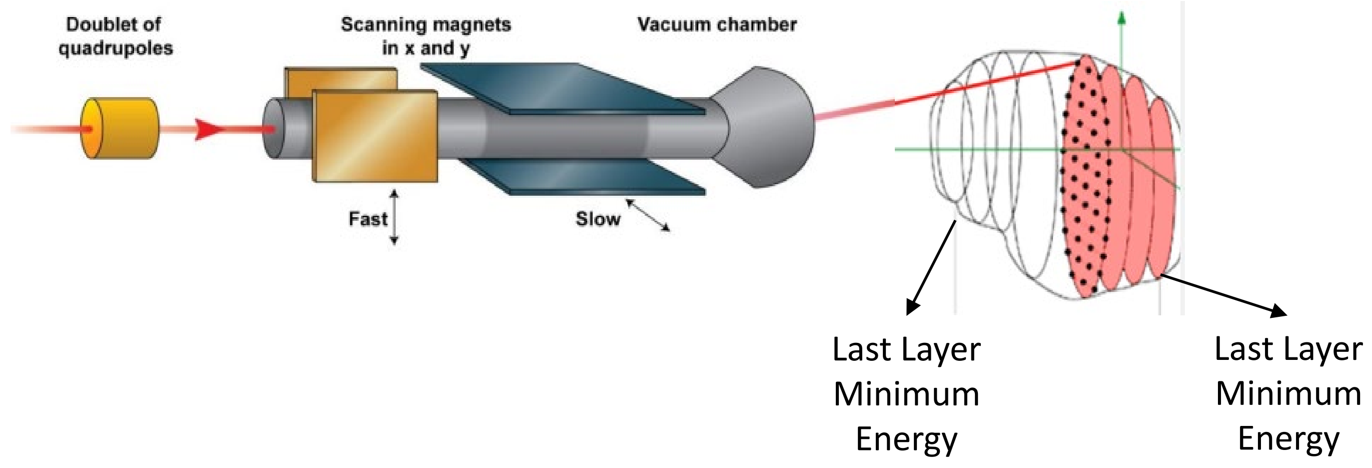
Less out-of-field dose



ESS is an important source of seconday radiation, however usually located at large distance from the patient, behind shielding

Topics

Delivery technology



Compact layout systems

Compact layout systems

History of Proton Therapy (PT) facilities

PT facilities evolves from being…

A by-product

NUCLEAR PHYSICS RESEARCH FACILITY

PT

Compact layout systems

History of Proton Therapy (PT) facilities

PT facilities evolves from being…

A by-product → **Dedicated stand-alone facility**

NUCLEAR PHYSICS RESEARCH FACILITY

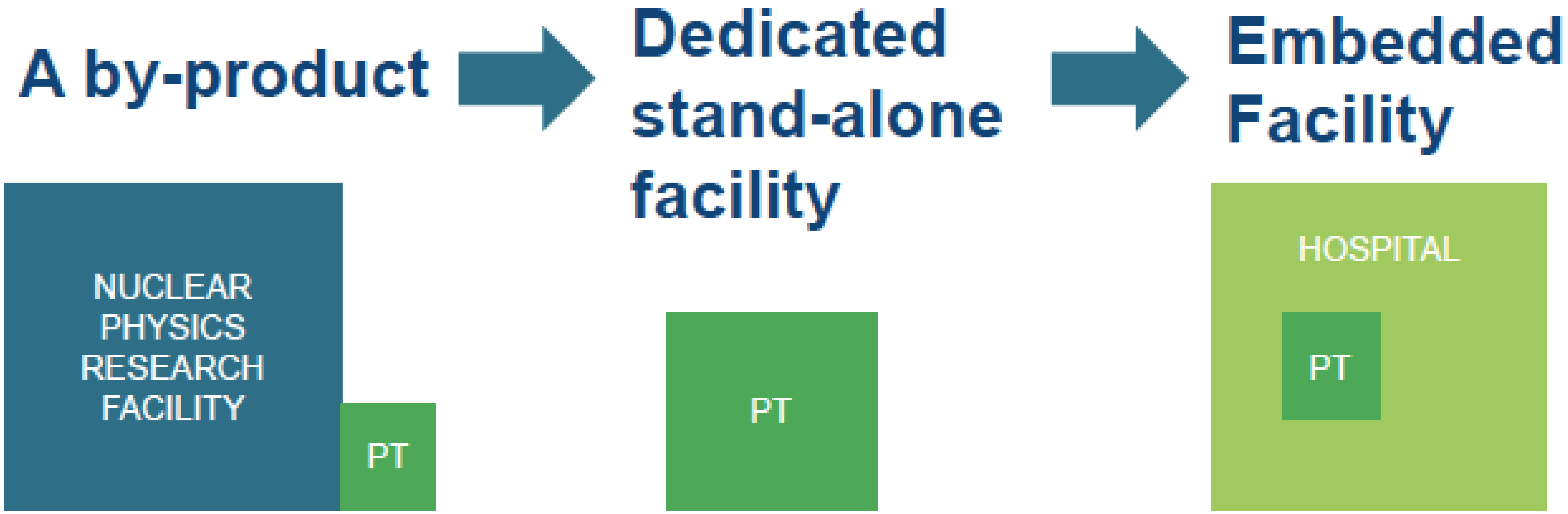
PT

PT

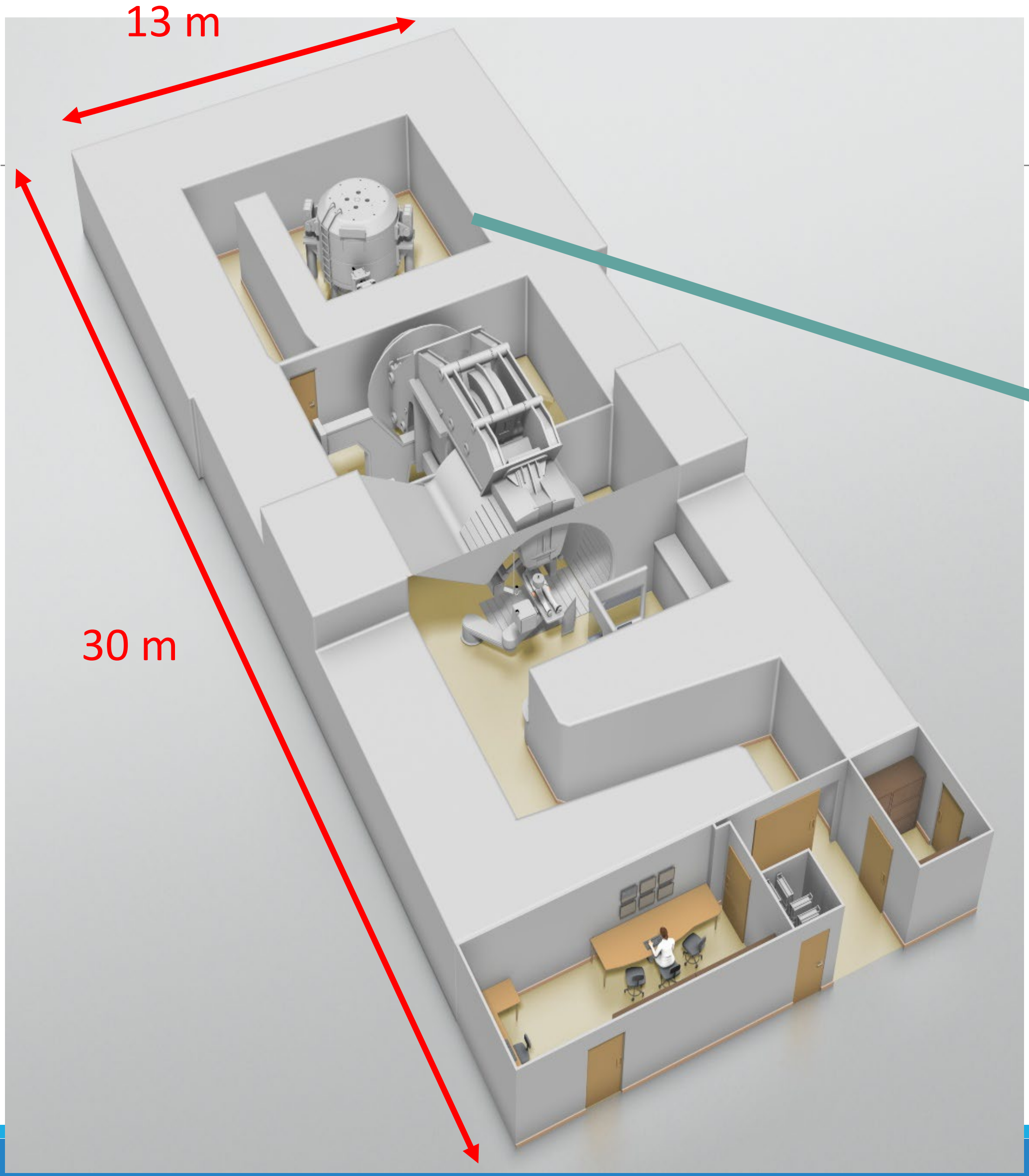
Compact layout systems

History of Proton Therapy (PT) facilities

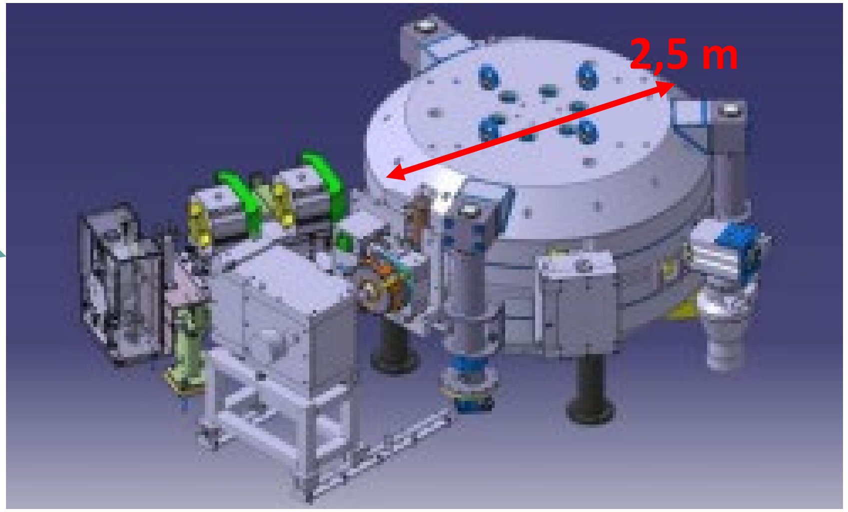
PT facilities evolves from being…



Compact Single Protontherapy Room



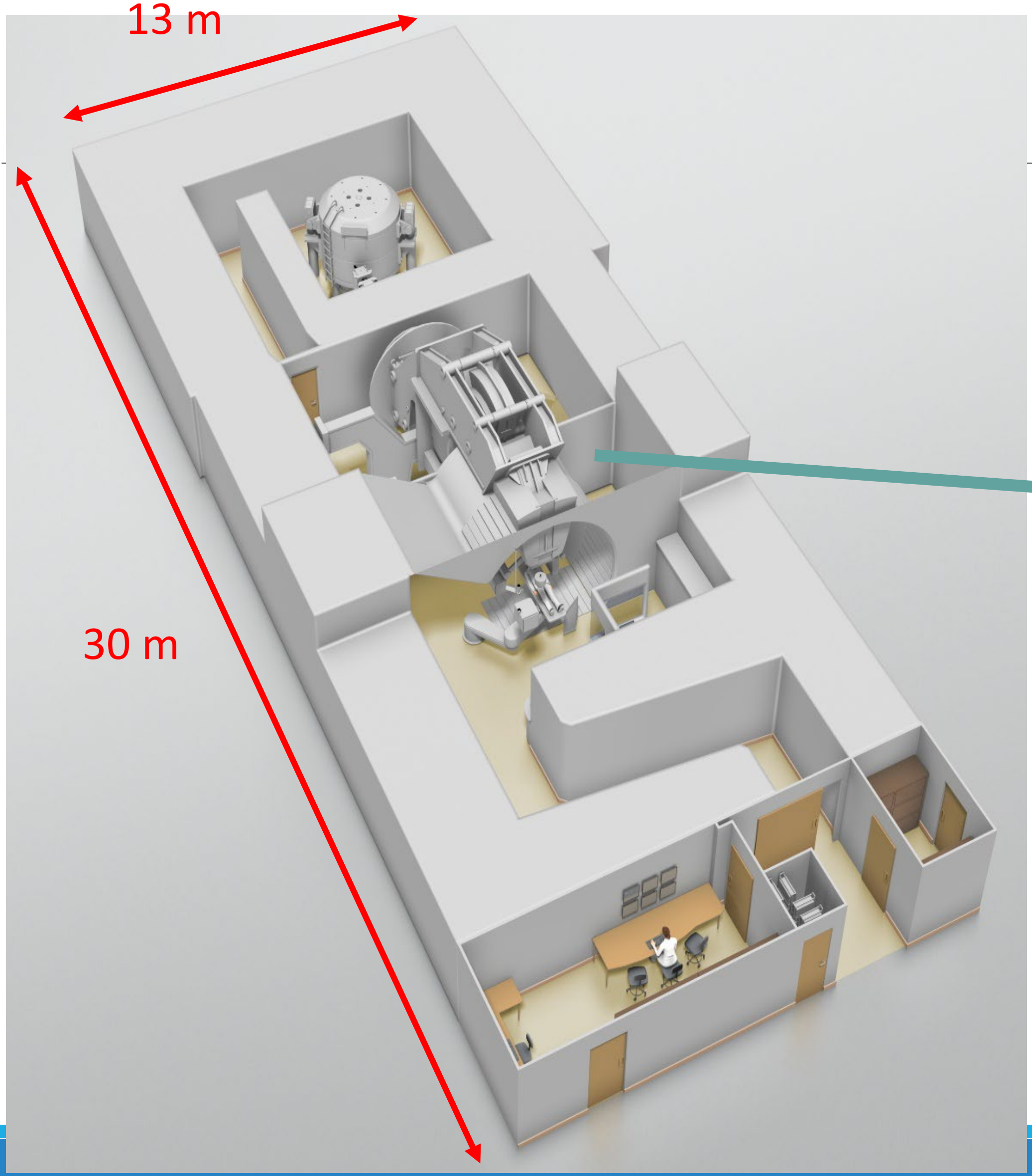
Proteus® ONE



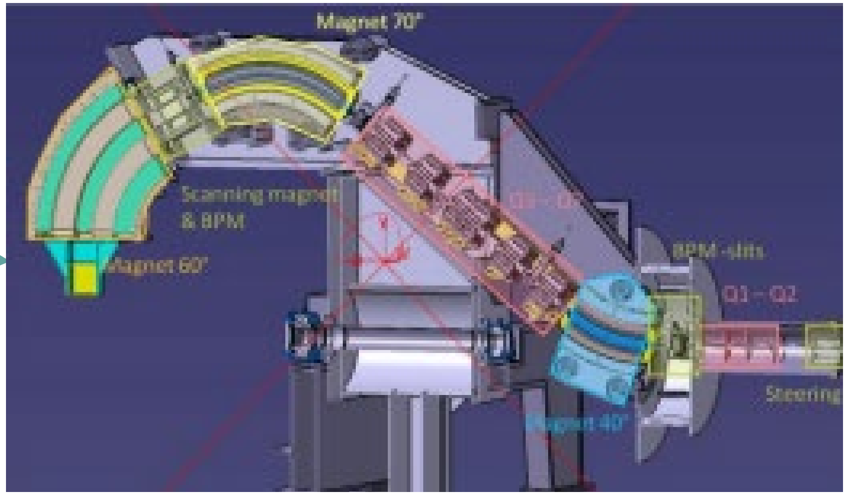
IBA S2C2 superconducting synchrocyclotron

for producing the energetic proton beam

Compact Single Protontherapy Room

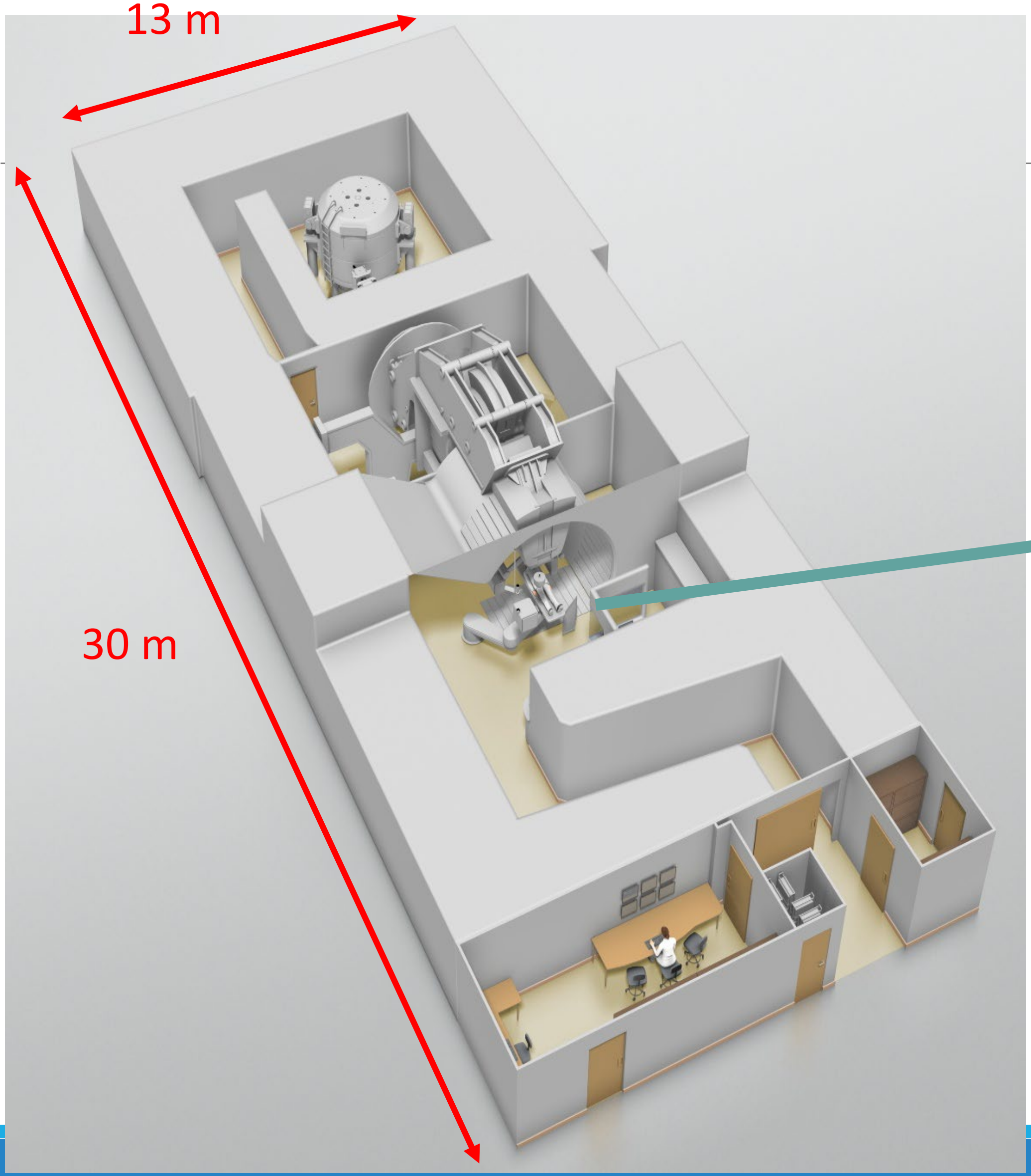


Proteus® ONE



Rotating gantry to set the beam at the right angle

Compact Single Protontherapy Room



Proteus® ONE

CLINICAL TREATMENT ROOM

Compact gantry with 220° rotation

Field size 20x24 cm^2 (scanning range)

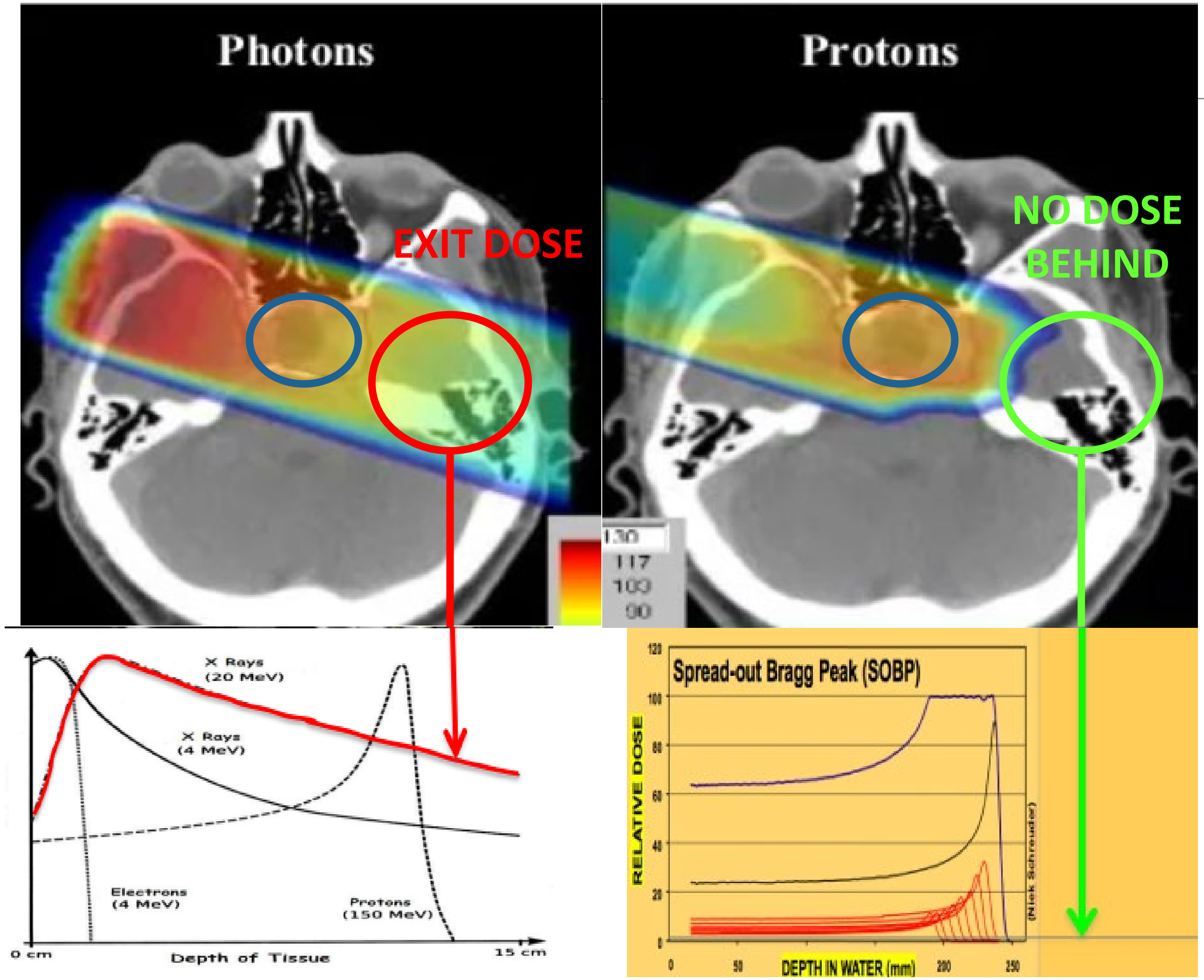
Protontherapy center in Milan (embedded)

PT embedded in existing radiation oncology clinic

- **Smaller facility truly integrated** in existing radiation oncology and hospital enviroment
- **Commercial compact systems** with one o two treatment rooms
- **Proton beam only**
- **Pencil beam scanning (PBS) only**
- **Sharing treatment preparation imaging equipment and clinical workflow** with conventional radiation oncology and hospital
- **Clinically oriented staff, shared but PT trained staff from XT clinic,** with limited technical staff to run the facility

PT seen as an additional modality, rather an separate facility

Proton vs. Photon Therapy



What is the benefit of proton therapy?

Less integral dose → **Reduction of toxicity**

Higher target dose → **Improvement of local control**

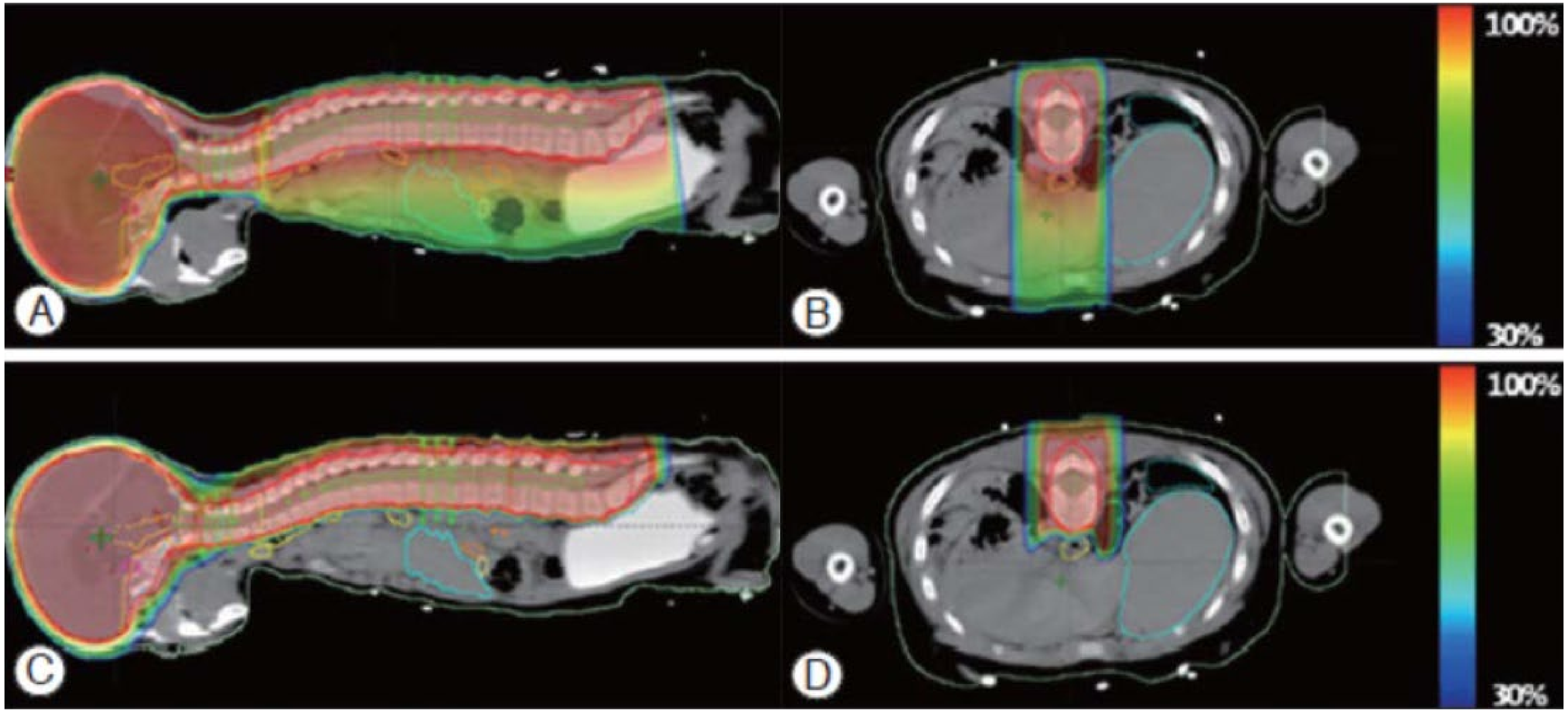
Proton vs. Photon Therapy

Craniospinal irradiation

Review Article

Understanding the Treatment Strategies of Intracranial Germ Cell Tumors : Focusing on Radiotherapy

Joo-Young Kim, M.D., Ph.D., Jeonghoon Park, Ph.D.
Proton Therapy Center, Research Institute and Hospital, National Cancer Center, Goyang, Korea



3D conformal radiation therapy

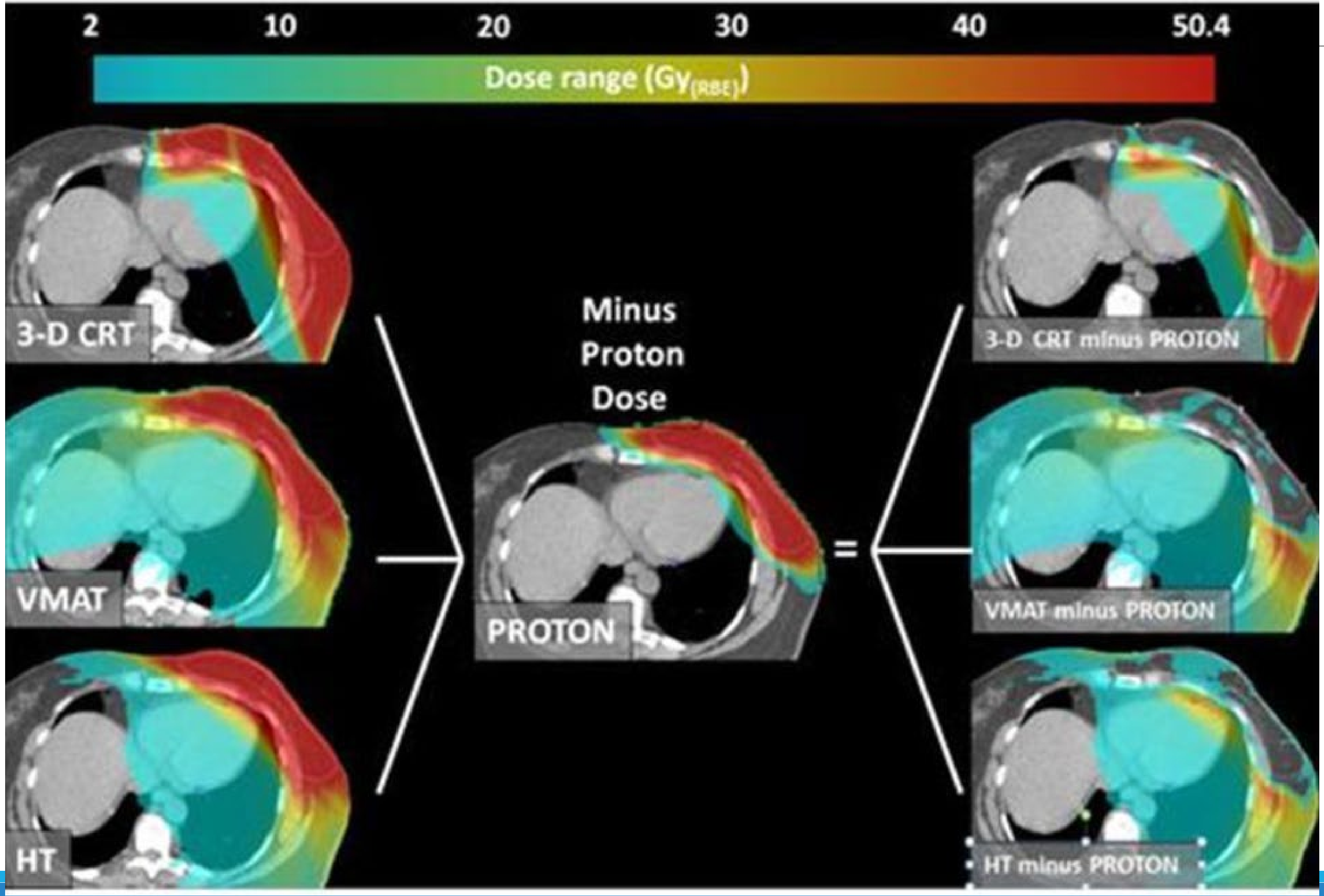
Proton

Finite range of protons reduces dose to dose reduction in heart, lung, intestine, mediastinum

Proton vs. Photon Therapy

Breast cancer

Fagundes, Hug et al. ASTRO 2013



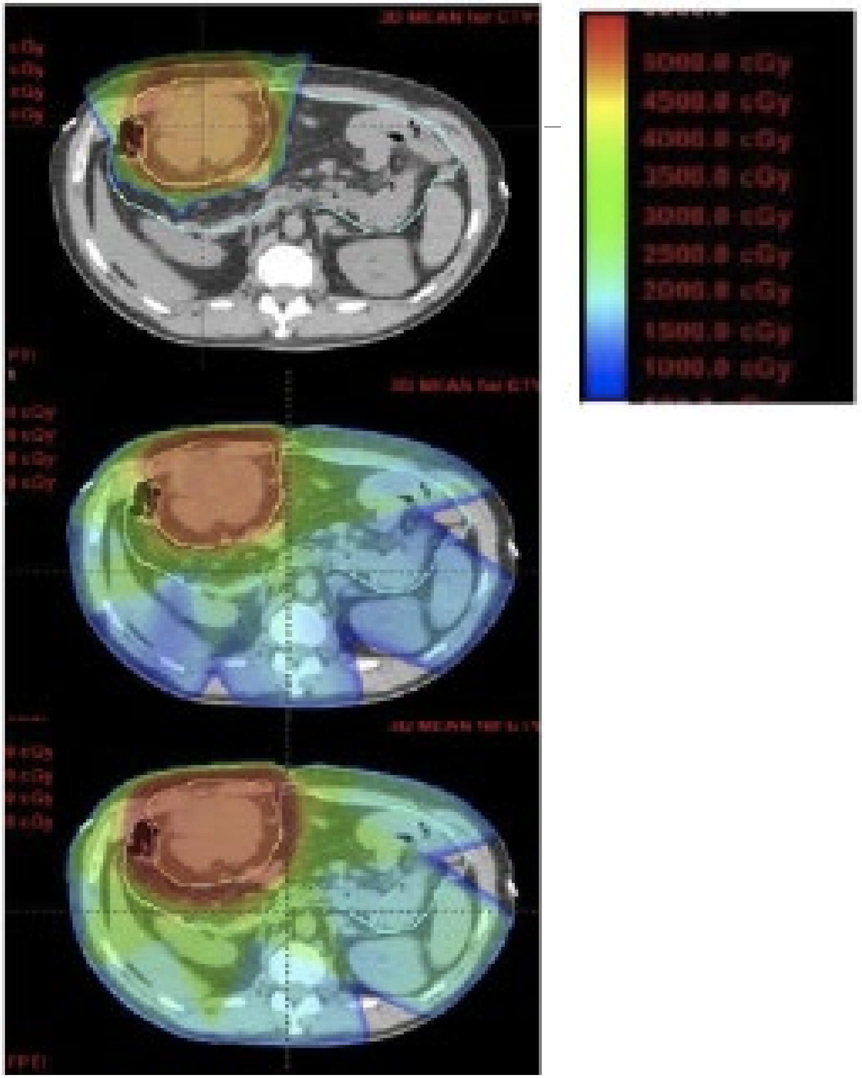
3D conformal Radiation Therapy

Volumetric Arc Therapy - VMAT

Tomotherapy

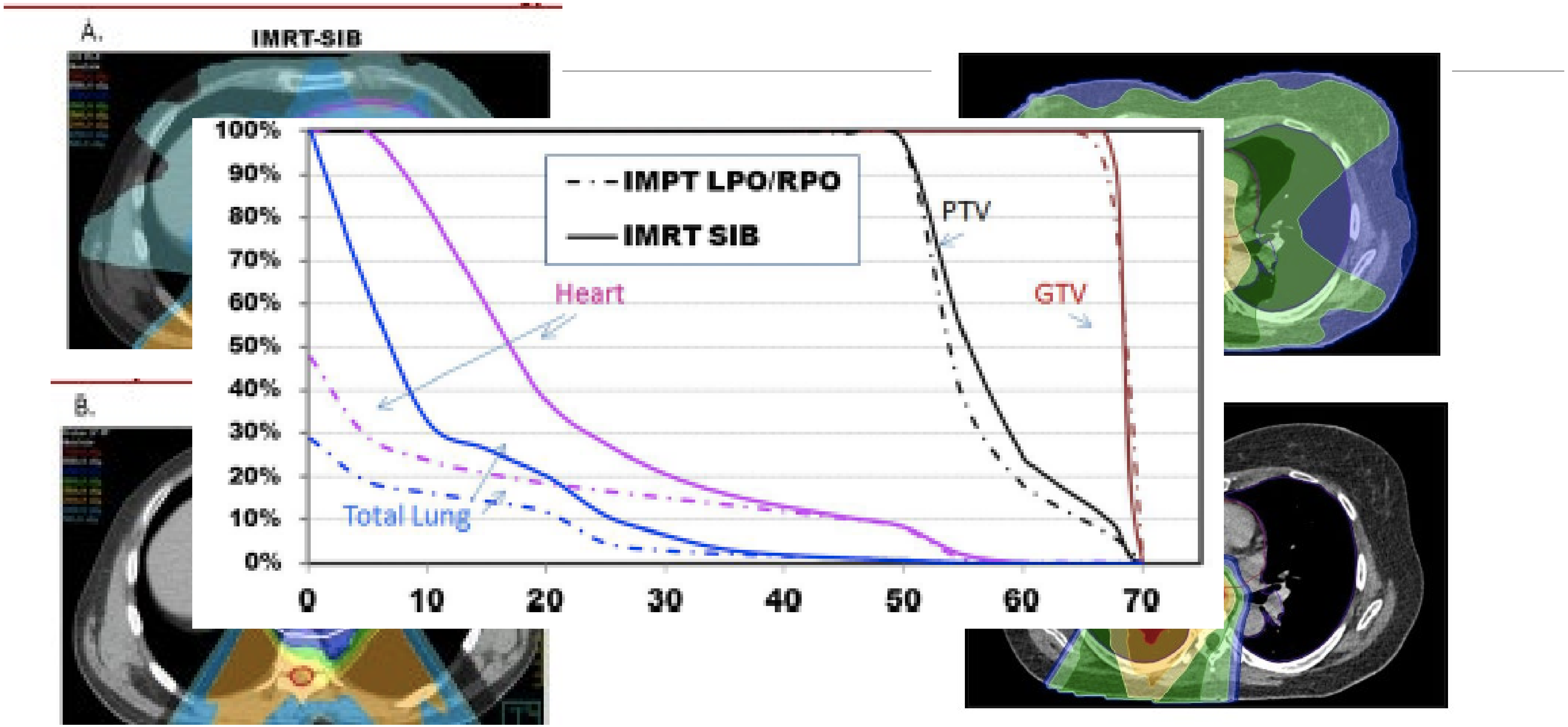
Proton vs. Photon Therapy

- PT is highly conformal
- Few fields needed
- Small irradiated volume



Swanson et al., IJROBP 83, 1549-57, 2012

Proton vs. Photon Therapy




Thank you!
BEST SOLUTION
FOR
INDIVIDUAL PATIENTS
PHOTONS
AND
PROTONS
imgflip.com