Radiobiological Effectiveness of Protons: Development of a new radiobiology beam line for the study of proton RBE at low energies.

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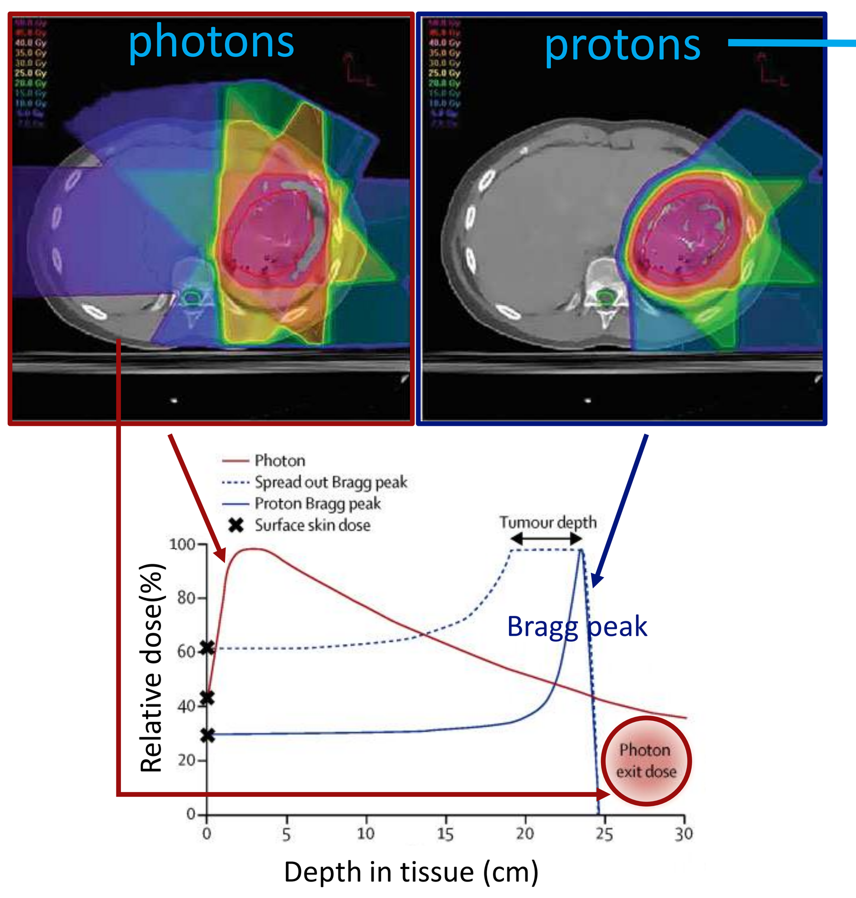
1. Introduction

The discovery of X-rays by Wilhelm C. Röntgen (Nobel prize in Physics, 1901) and of natural radioactivity by Antoine H. Becquerel and Marie and Pierre Curie (Nobel prize in Physics, 1903) at the end of the 19th century, lead almost immediately to the use of **ionizing radiation** in medicine, and to the birth of medical physics. Marie Sklodowska Curie, in particular, gave a huge contribution to the development of this field, being one of the first scientists to think about and conduct the first studies on the treatment of cancer using radioactive substances. That was the beginning or radiation therapy.

Radiation Therapy: Radiation kills living cells by damaging their DNA. The successful use of radiation in cancer treatment is based on the ability to direct radiation **dose** to the tumour, sparing the surrounding healthy tissue. Radiation is usually delivered externally with **linear accelerators**, being photons and electrons the ionizing particles most commonly used. More Recently, radiation therapy with proton beams has become available in clinics, gaining an increasing interest in the medical community for its excellent clinical results and higher .

A See Glossary

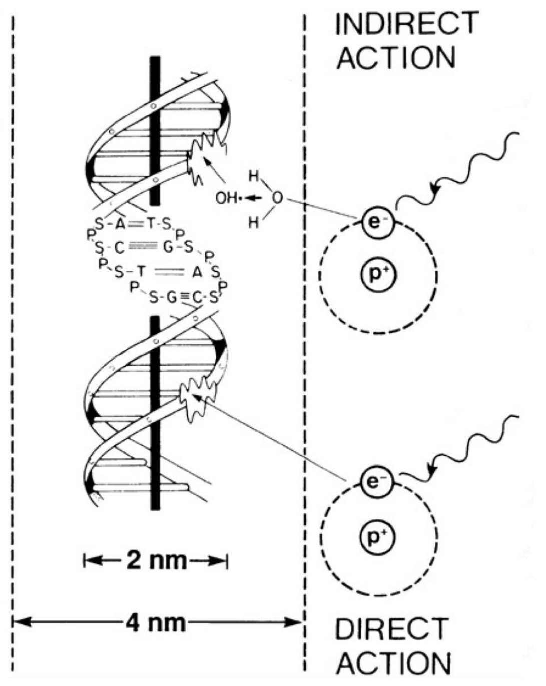
2. Photons vs Protons



ADVANTAGES OF PROTONS
- Optimal radiation dose delivered, targeting the tumour with high precision.
- **Minimal exit dose.**
- Reduced overall toxicity.
- Reduced probability and/or severity of side effects.
- Especially appropriate for cancers with limited treatment options.
- Indicated for the treatment of **pediatric tumors.**

Is there any physical quantity that we can use to compare the different effectiveness of photons and protons in killing cancer cells?

Biological Effect of Radiation



Photons:
1. Mostly indirect action.
2. Small density of energy depositions, "damage", along track.

Protons:
1. Direct action more probable.
2. Increased density of energy depositions along track

Relative Biological Effectiveness (RBE)

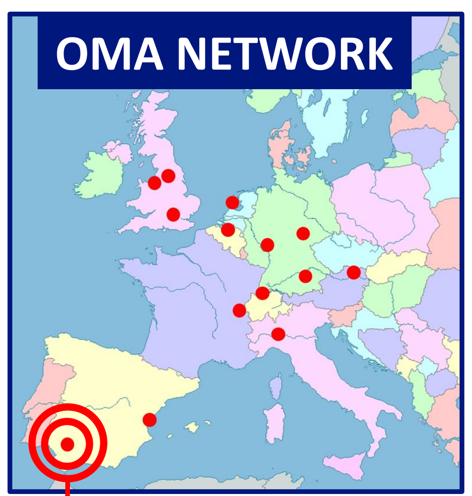
"Ratio between the absorbed dose of a reference radiation (photons, D_X) and the dose of the radiation of interest (protons, D_P) that causes the same amount of biological damage"

$$RBE = \left.\frac{D_X}{D_P}\right|_{same\ damage}$$

Nowadays a uniform RBE of 1.1 is assumed almost universally for the purposes of proton therapy treatment. However, there is evidence that the **RBE** is variable along the course of the proton depth in tissue as it loses its energy, and that it **increases at the very end of the depth-dose curve** [3], in correspondence to the Bragg peak.

Studies of RBE at low proton energies (<20MeV) are necessary to optimize treatment plans.

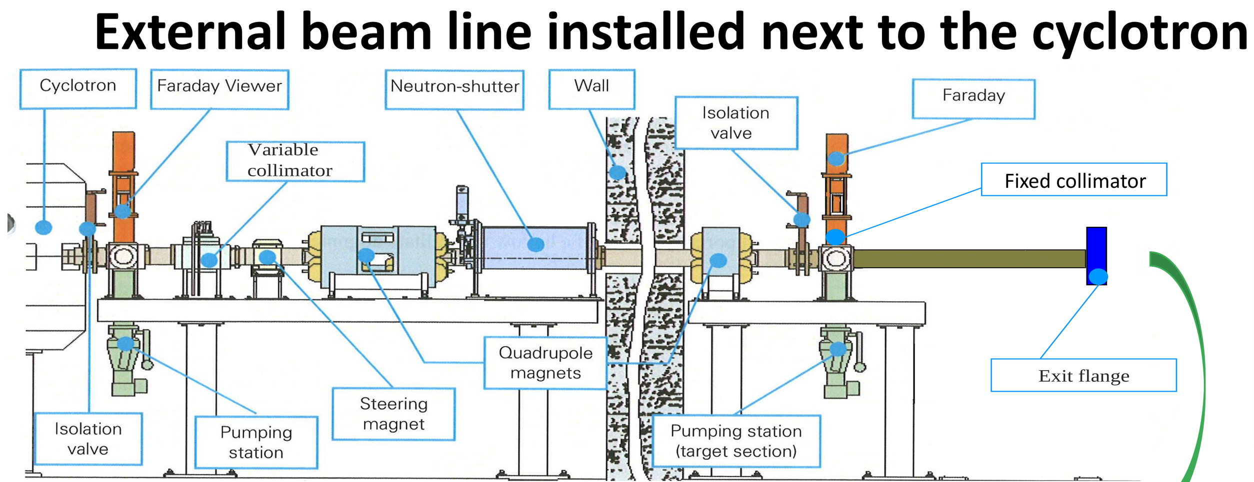
3. Experimental Setup



Optimization of Medical Accelerators (OMA) is an European Training Network which joins universities, research centers and ion beam treatment facilities with industry partners to provide interdisciplinary training to 15 fellows located all over Europe. The network addresses the challenges in treatment facility design and optimization, numerical simulations for the development of advanced treatment schemes, and in beam imaging and treatment monitoring.

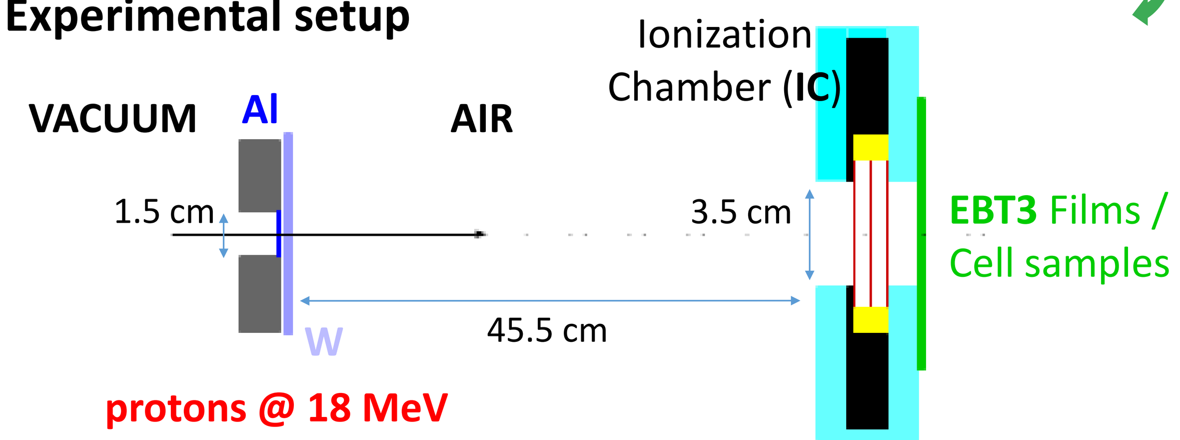
CNA, National Centre of Accelerators in Seville.
Proton beams facilities:
- 3MV Tandem Accelerator
- 18 MeV proton **cyclotron**

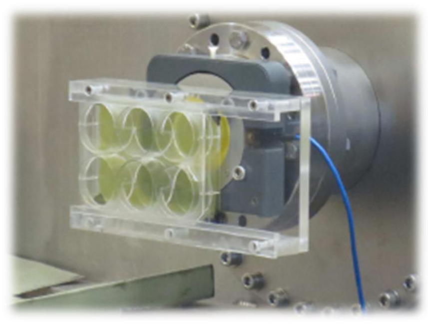
External beam line installed next to the cyclotron bunker @CNA



Ionization Chamber

Experimental setup



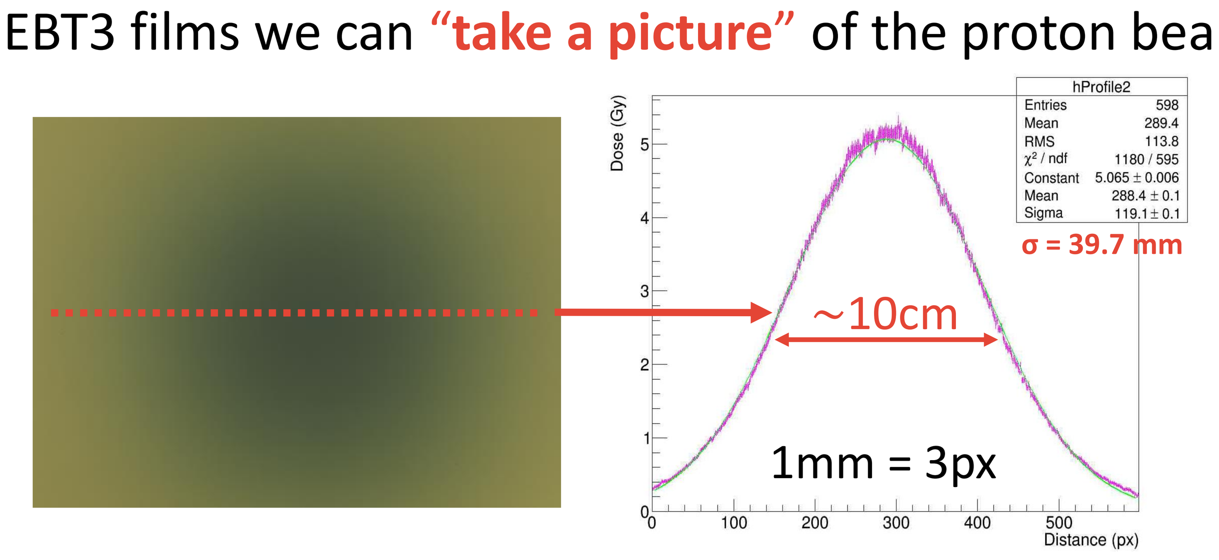


Sample Holder

4. Results

What do we need for the irradiation of biological samples?
1. Homogeneous dose in an area of 3.5 cm of diameter (dimension of Petri dishes for cell culture).
2. Uniform beam energy in the same area.
3. Low beam intensity (~pA) to control irradiation time.

With EBT3 films we can **"take a picture"** of the proton beam:



Under exposure to radiation, EBT3 films exhibit a **darkening correlated to the dose** deposited in their sensitive layer.

Glossary

Ionizing radiation: radiation that carries enough energy to liberate electrons from atoms or molecules, therefore ionizing matter.
Dose: mean energy imparted to matter per unit mass by ionizing radiation.
Linear Accelerator: machine which accelerates particles along a linear path.
Cyclotron: machine which accelerates particles along a spiral path.

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