Introduction – PTMC 8 Mars 2021

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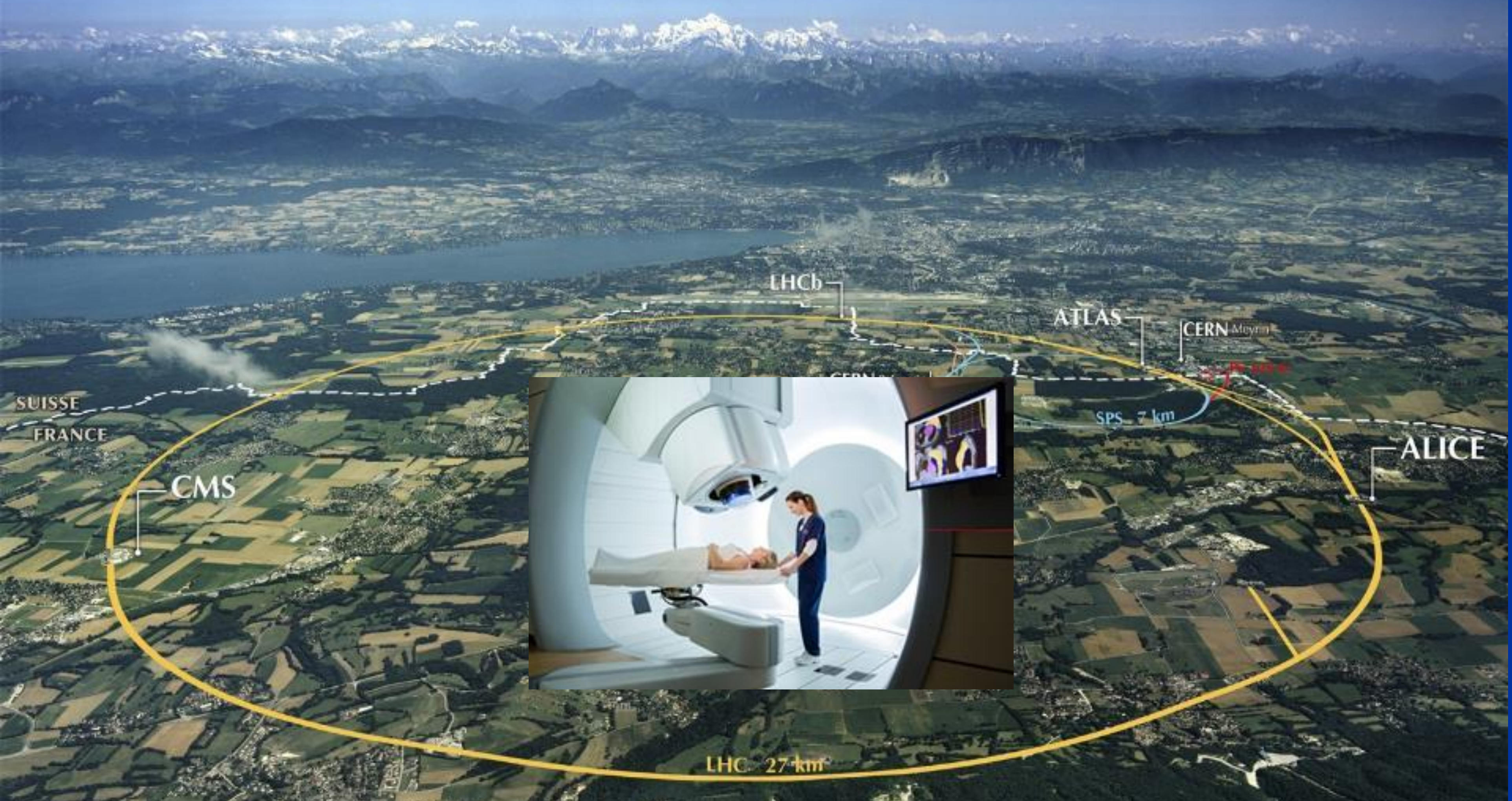
CERN ATS/DO



Le CERN, les accélérateurs de particules, et le traitement du cancer avec les accélérateurs

CERN: founded in 1954: 12 European States

“Science for Peace”

Today: 23 Member States

Employees: ~2 700 staff, 800 fellows
Associates: ~12 400 users, 1 300 other

The Mission of CERN

❑Push back the frontiers of knowledge

E.g. the secrets of the Big Bang …what was the matter like within the first moments of the Universe’s existence?

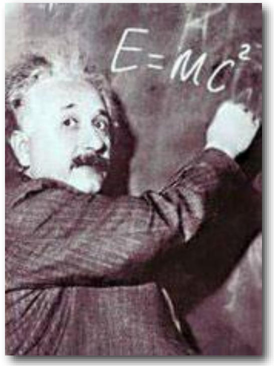
❑Develop new technologies for accelerators and detectors

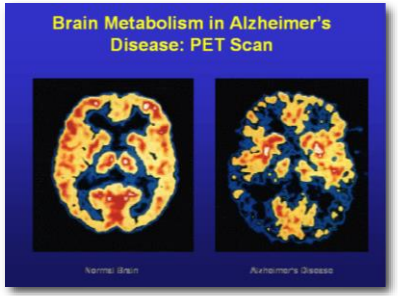
Information technology - the Web and the GRID

Medicine - diagnosis and therapy

❑Train scientists and engineers of tomorrow

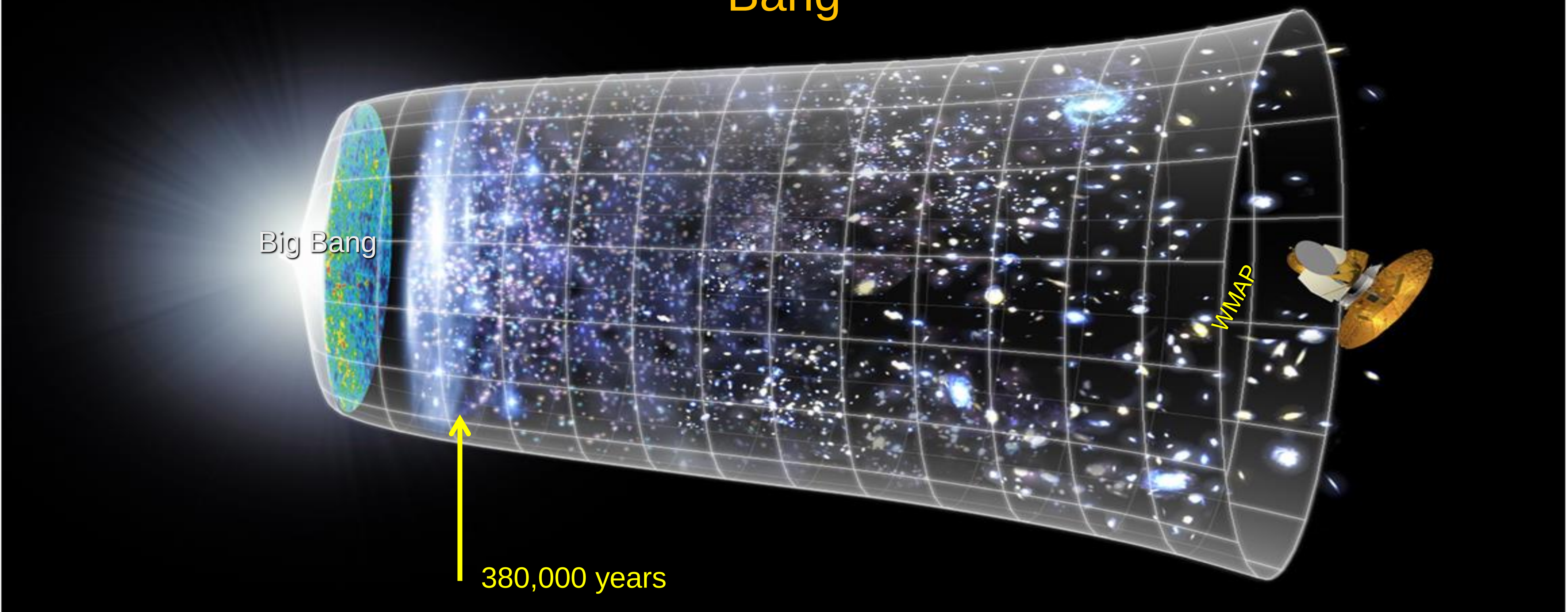
❑Unite people from different countries and cultures





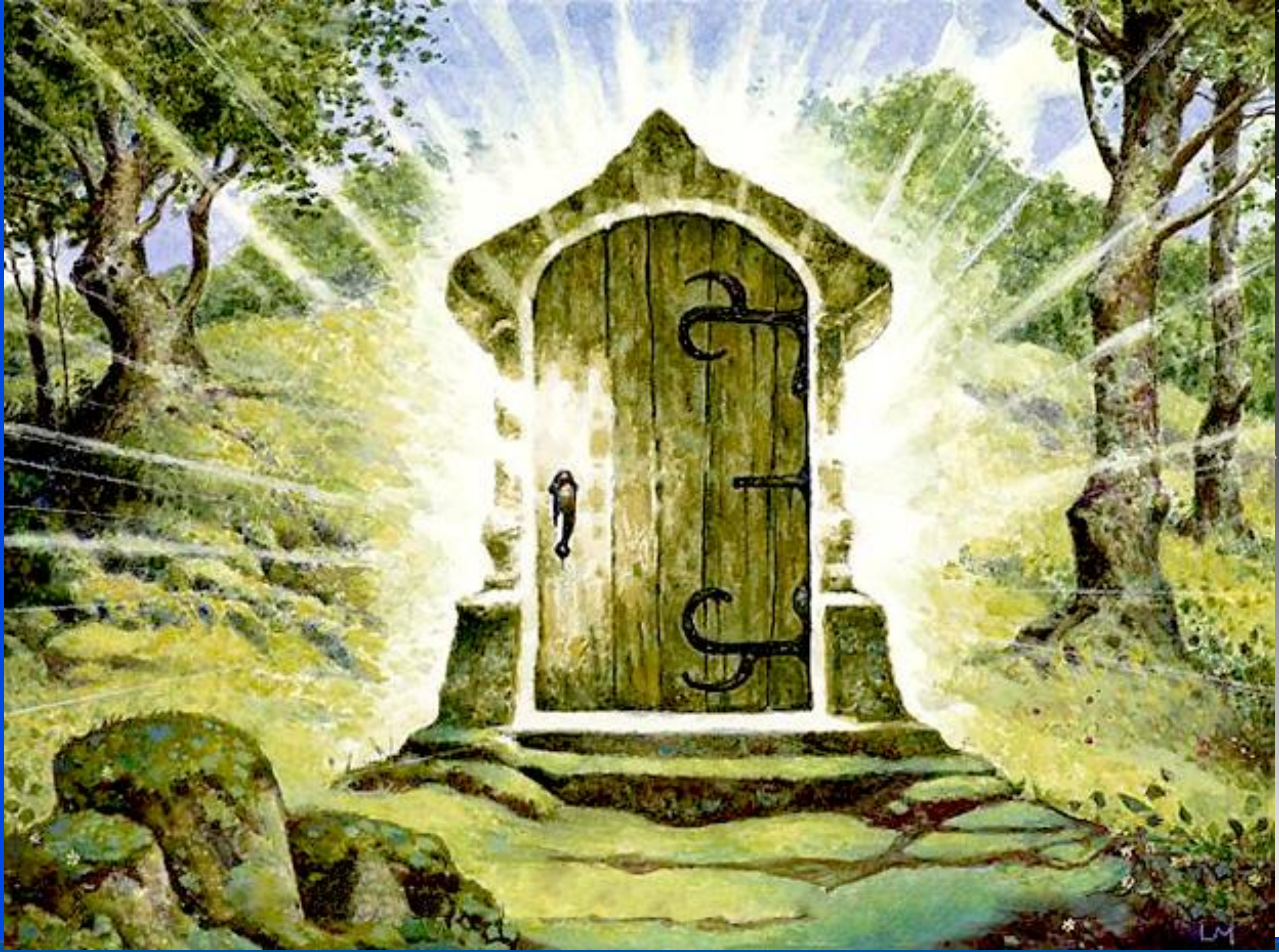
Our Scientific Challenge:

to understand the very first moments of our Universe after the Big Bang



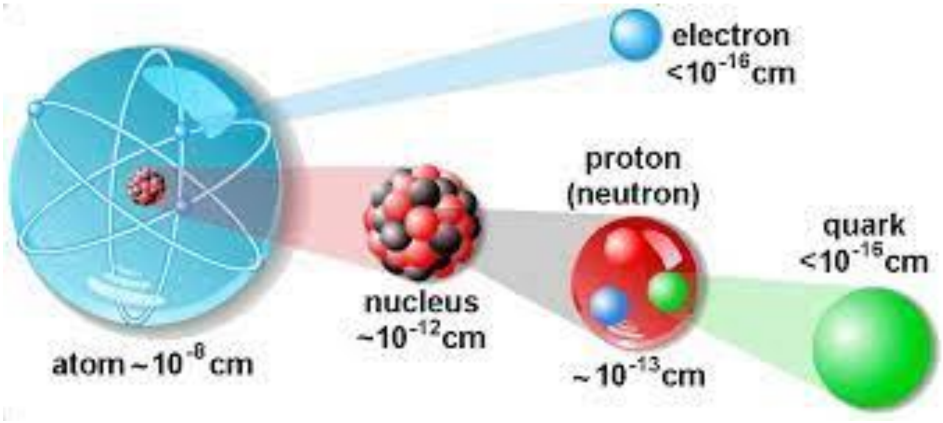

LHCb
ATLAS
CMS
LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
ALICE
CMS
ALICE
LHC ring:
27 km circumference
CERN

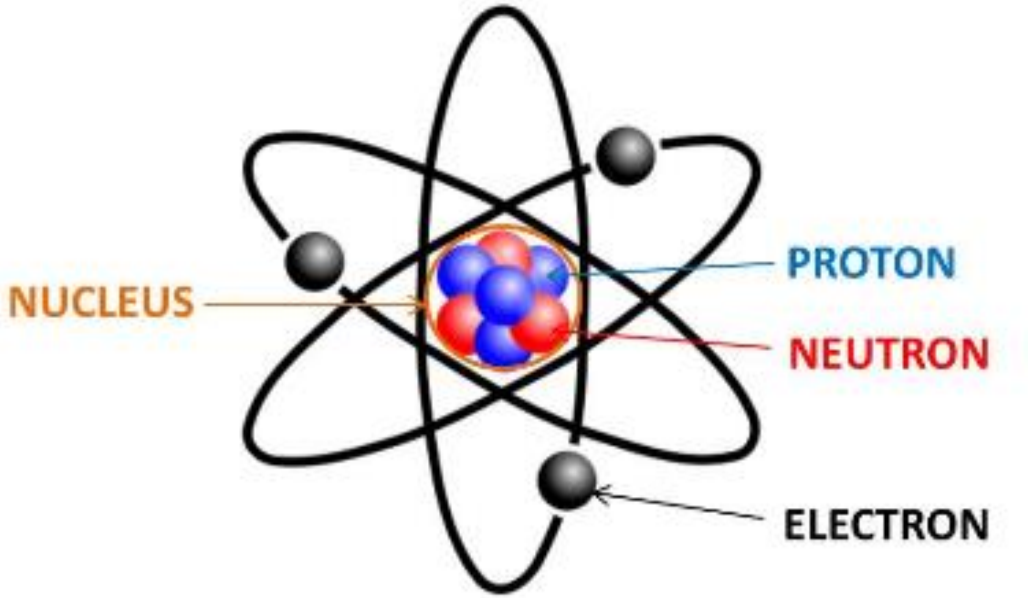
Particle accelerators are our door to access the subatomic dimension… and exploit the atom and its components



Where do we find the particles?

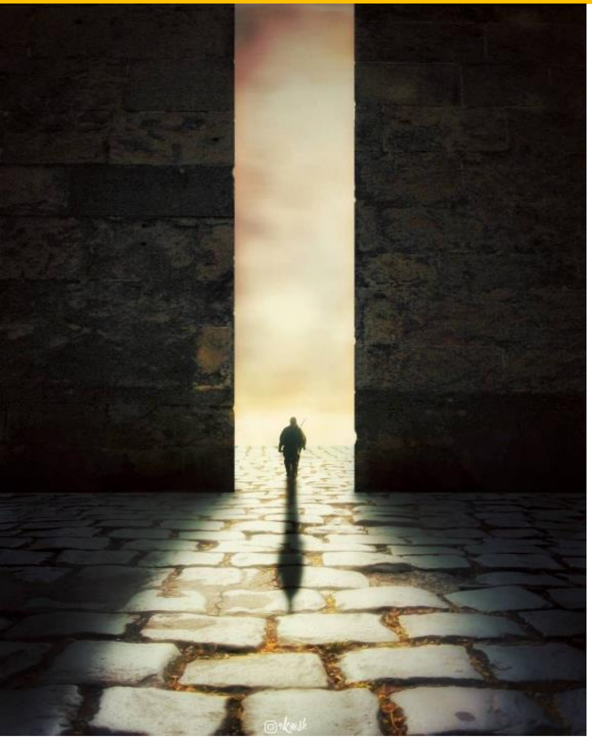
Inside the atoms!



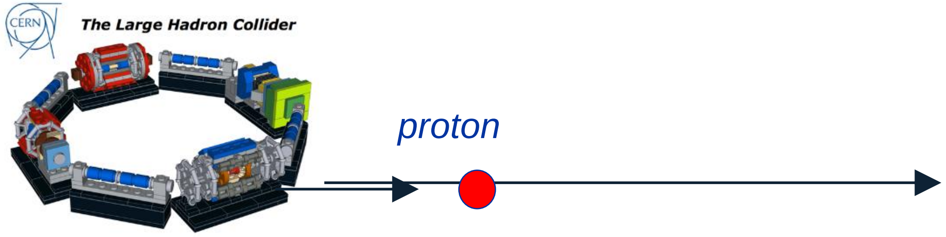


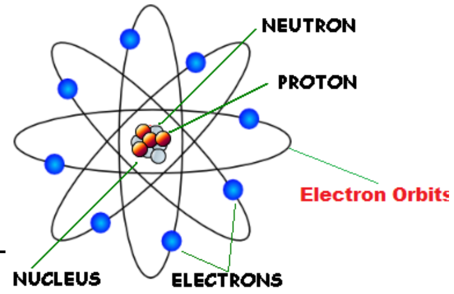
We can use electrons (very light) or protons (1836 times heavier).
For the **Large Hadron Collider**, we prefer the heavier protons

Accelerators: our key to enter the subatomic world



When we extract particles from an atom (protons, electrons) and we accelerate them we concentrate **enormous amounts of energy in tiny volumes**





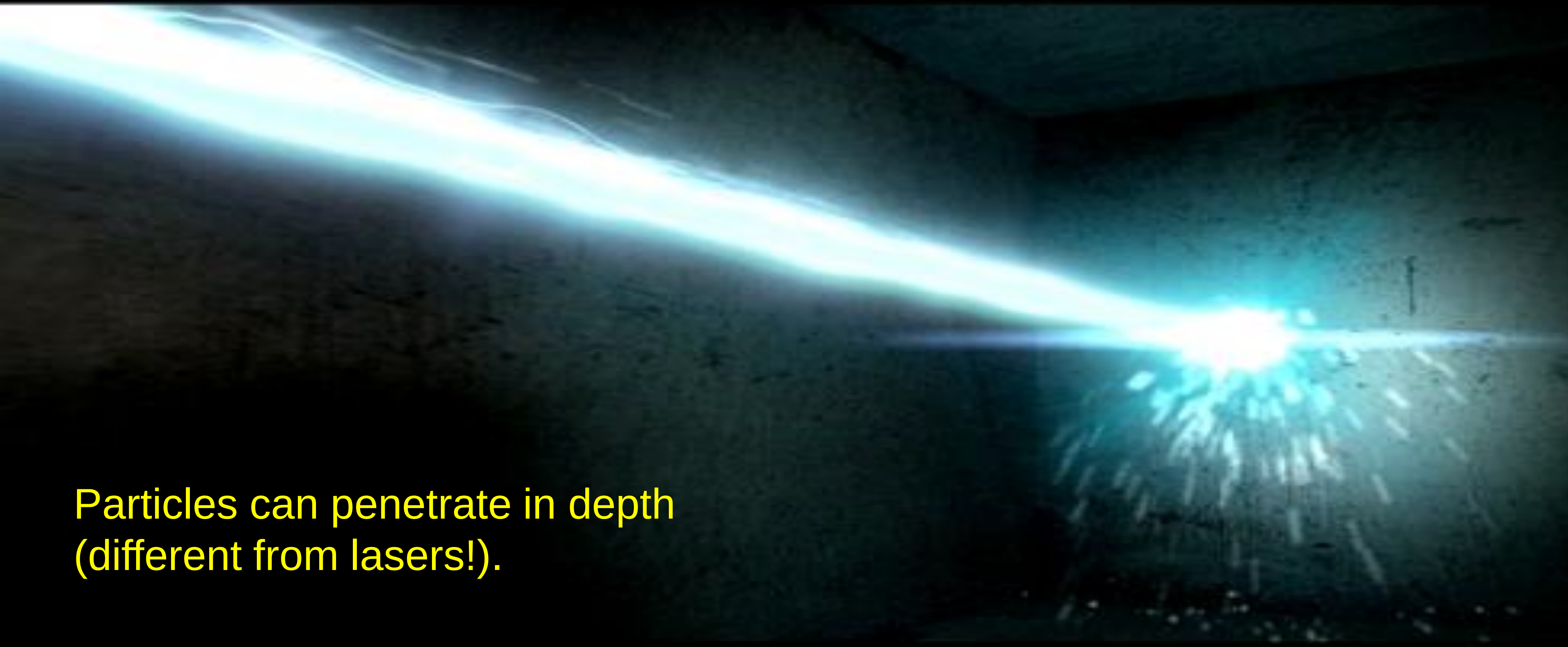
	Proton out of LHC	150g Yoghurt	TGV train
	•		
Energy	1.1 10^{-6} J	5 10^{5} J	3.6 10^{8} J
Energy density	5.3 10^{38} J/m^3	3.3 10^{9} J/m^3	1.5 10^{11} J/m^3
Type of energy	Kinetic Subatomic scale	Chemical Macroscopic scale	Kinetic Macroscopic scale
Energy full LHC beam	3.6 10^{8} J		

Where will this energy go? An accelerated particle sent towards an atom will:

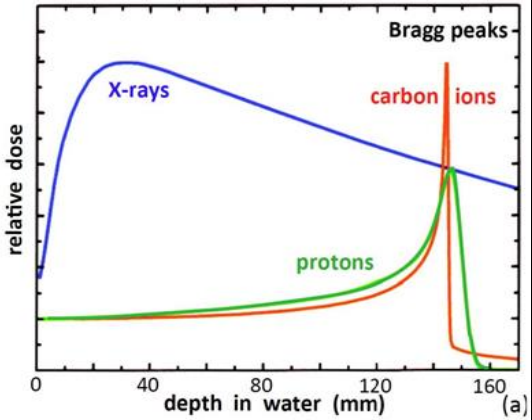
1. Deliver some **energy to the electrons**.
2. Deliver some **energy to the nucleus**

Accelerators can precisely deliver energy

A «beam» of accelerated particles is like a small "knife" penetrating into the matter



A particle beam can deliver energy to a very precisely defined area, interacting with the electrons and with the nucleus.



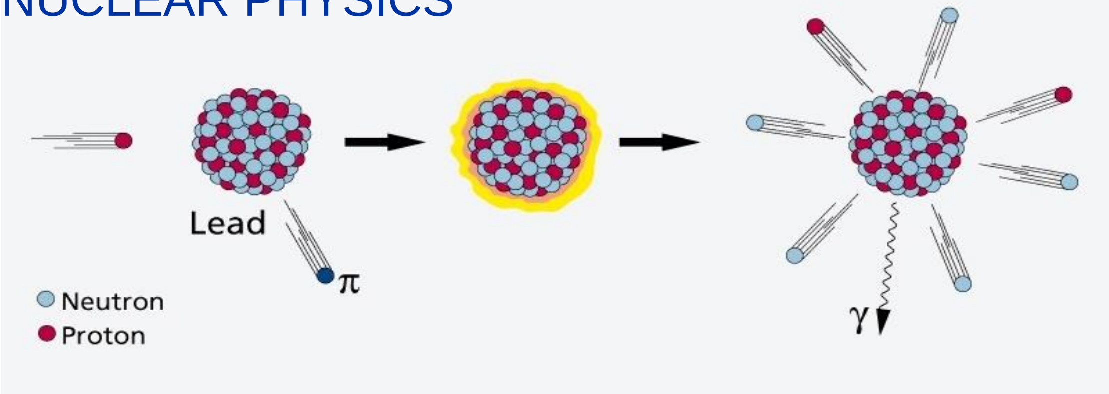
Particles can penetrate in depth
(different from lasers!).

Particle beams are used in medical and industrial applications,
e.g. to cure cancer, delivering their energy at a well-defined depth inside the body (Bragg peak)

Accelerators can modify the nuclei and create new particles

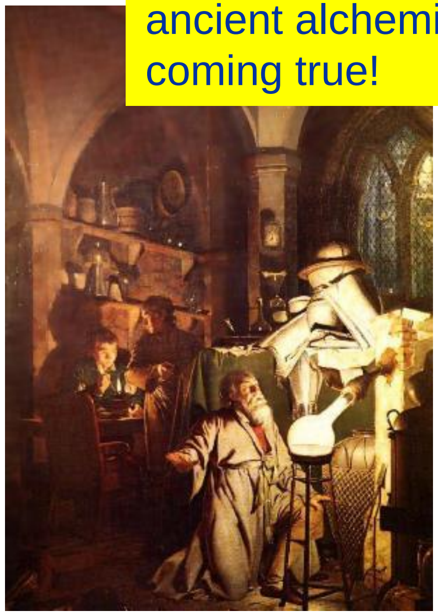
If the energy is sufficiently high, the particles in the beam transfer energy to the nucleus and its components (and are then scattered, reflected or absorbed).

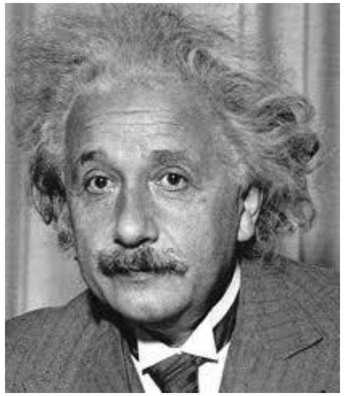
NUCLEAR PHYSICS



Particles in the beam can break and modify the nucleus (and then generate new elements and transform the matter!)

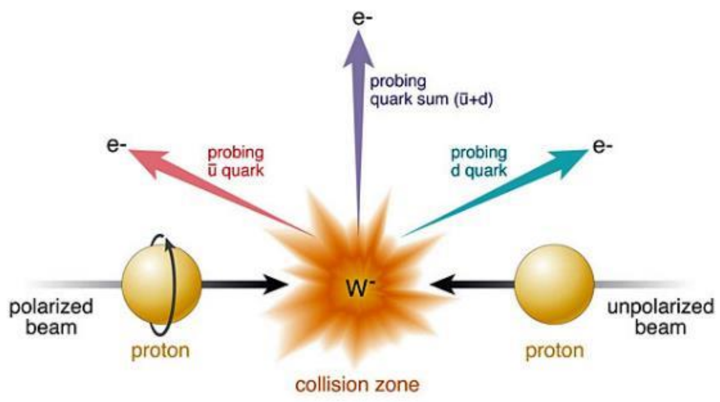
It's the dream of the ancient alchemists coming true!



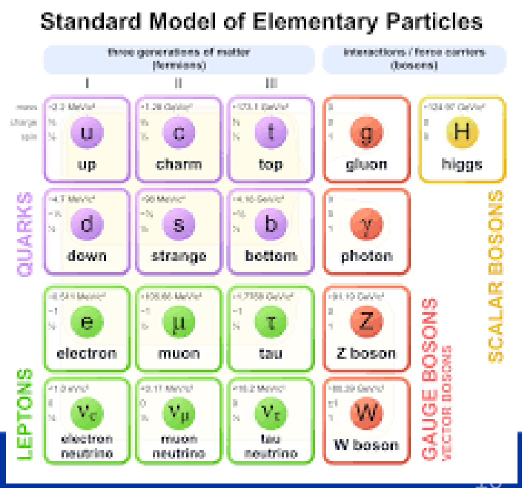


$E = m c^2$

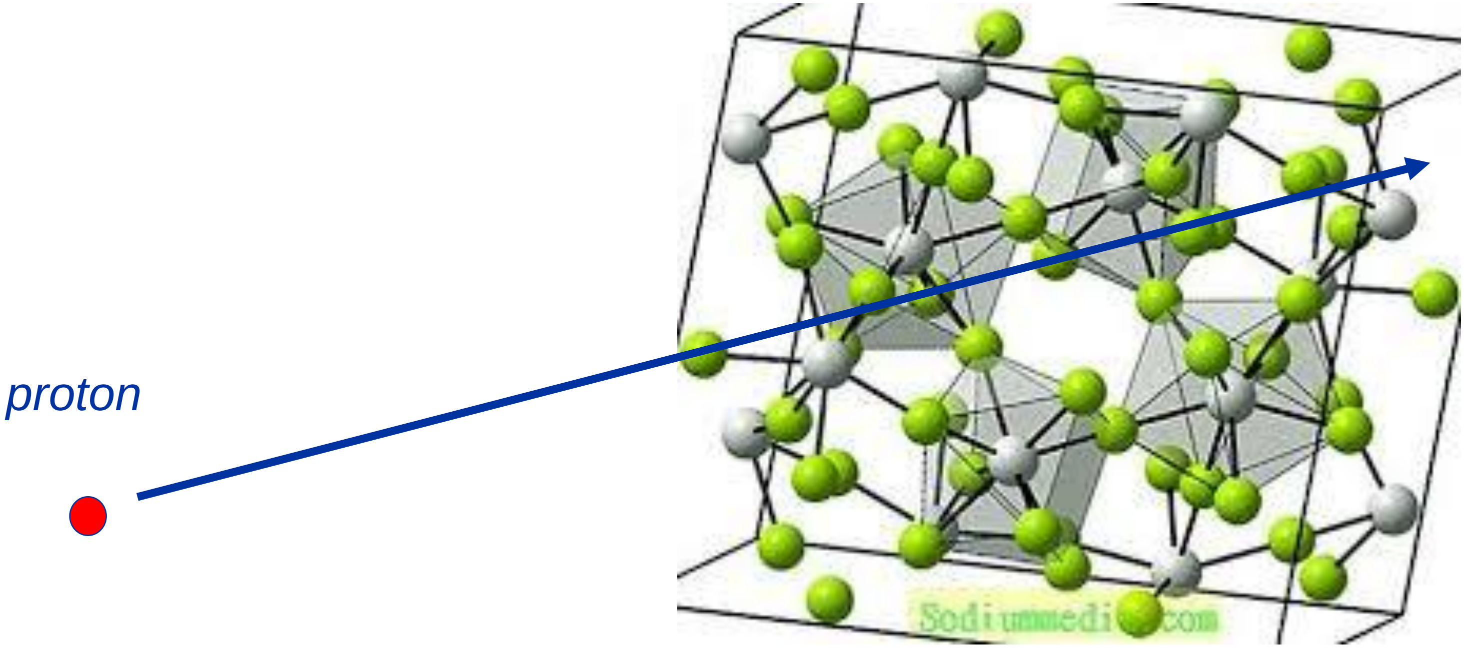
PARTICLE PHYSICS

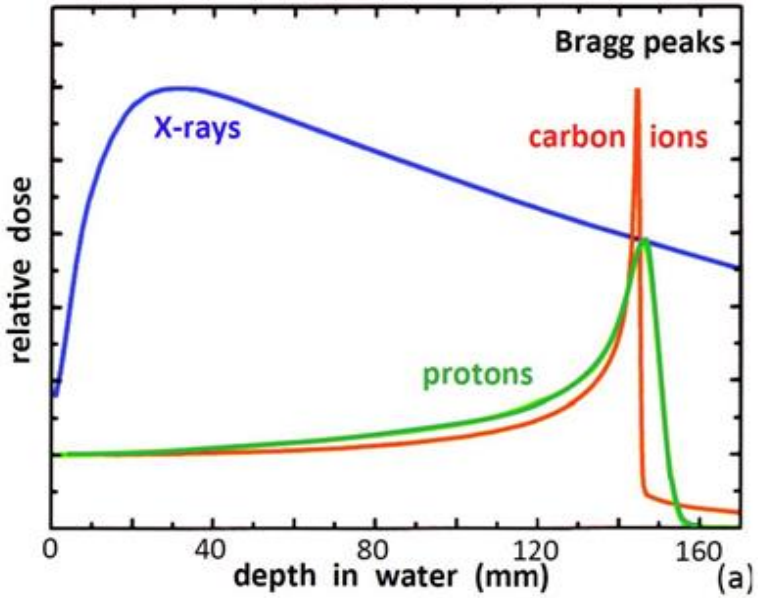


In the collisions can be generated new particles.



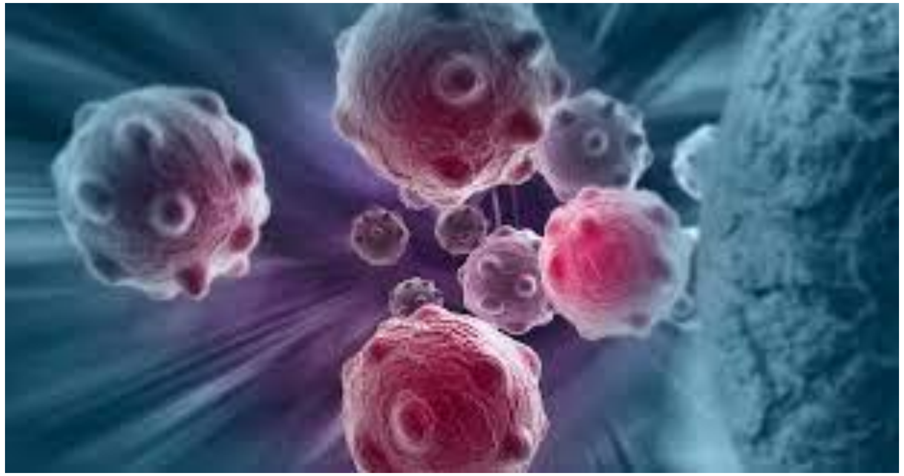
A particle beam in the matter



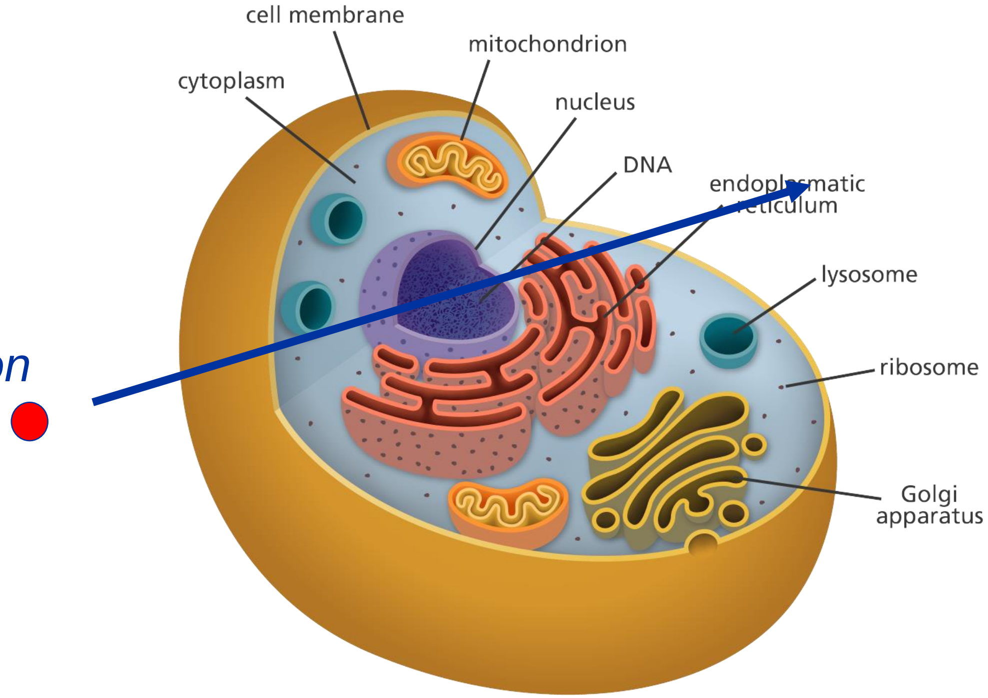


A particle loses energy very slowly, until the time spent next to an atom becomes short enough to let it lose large fractions of its energy, and then the particle stops.

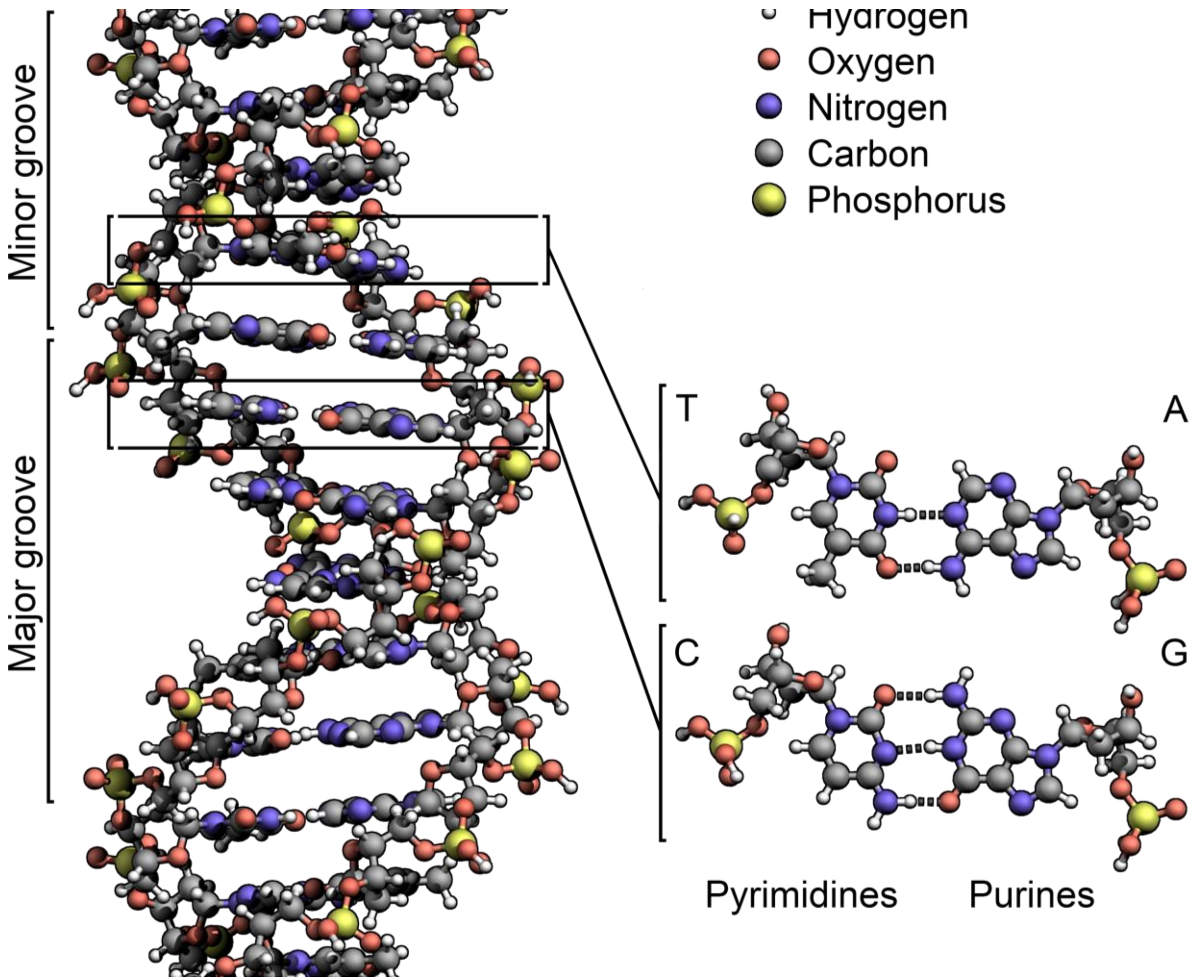
A particle beams in human cells

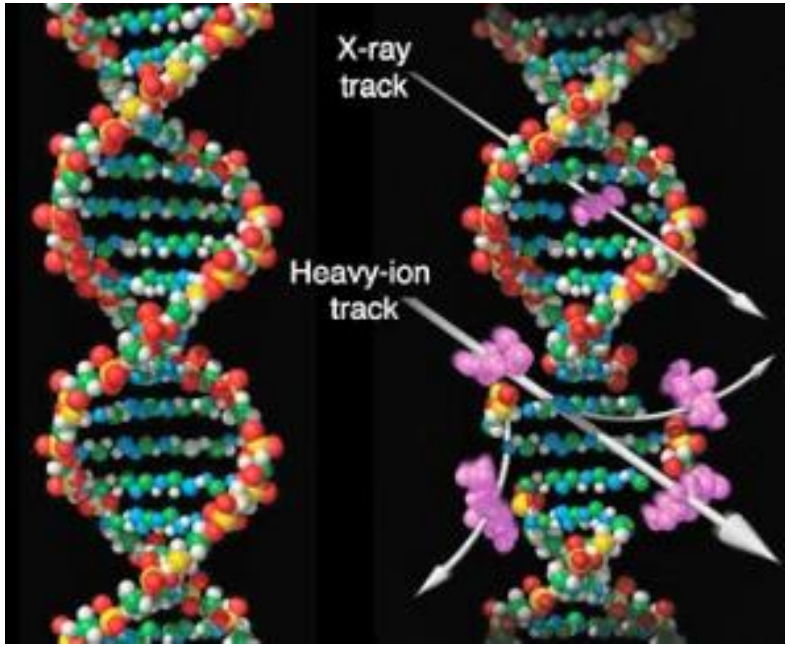


proton

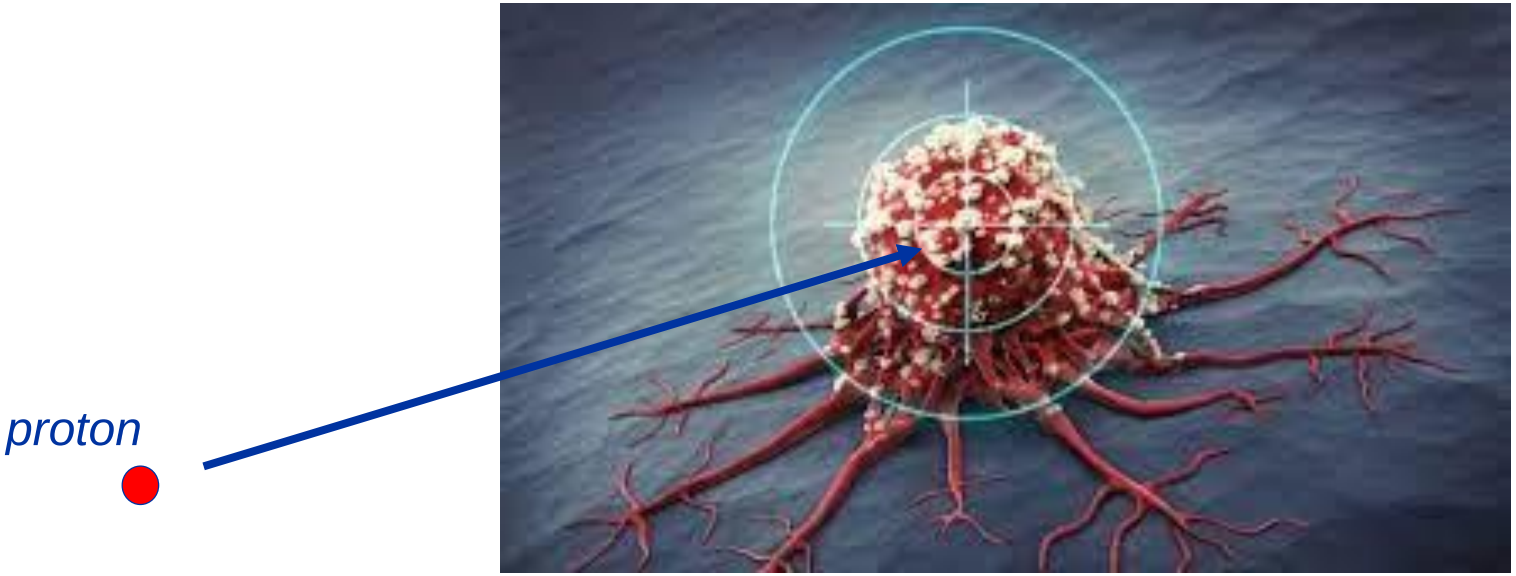


A particle beam can break the DNA and kill a cell



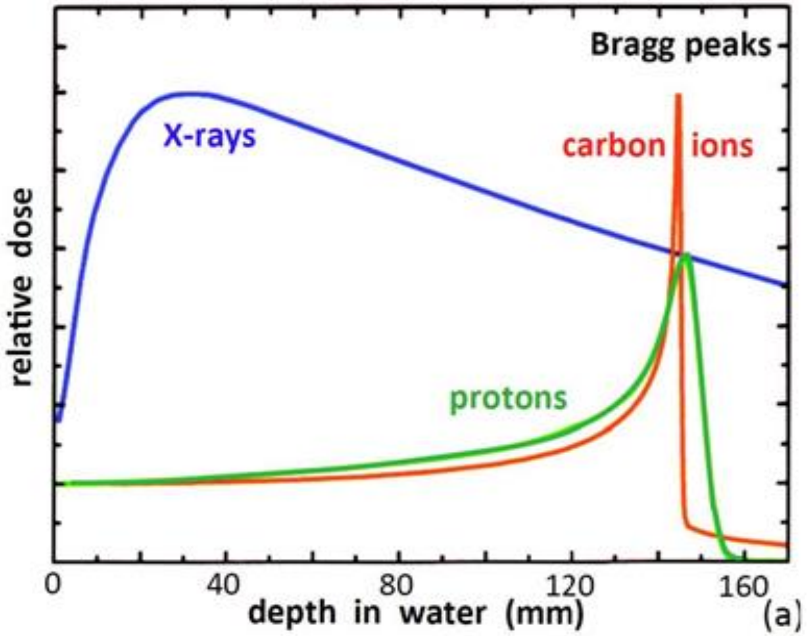


And if the cell has the cancer? Killed!



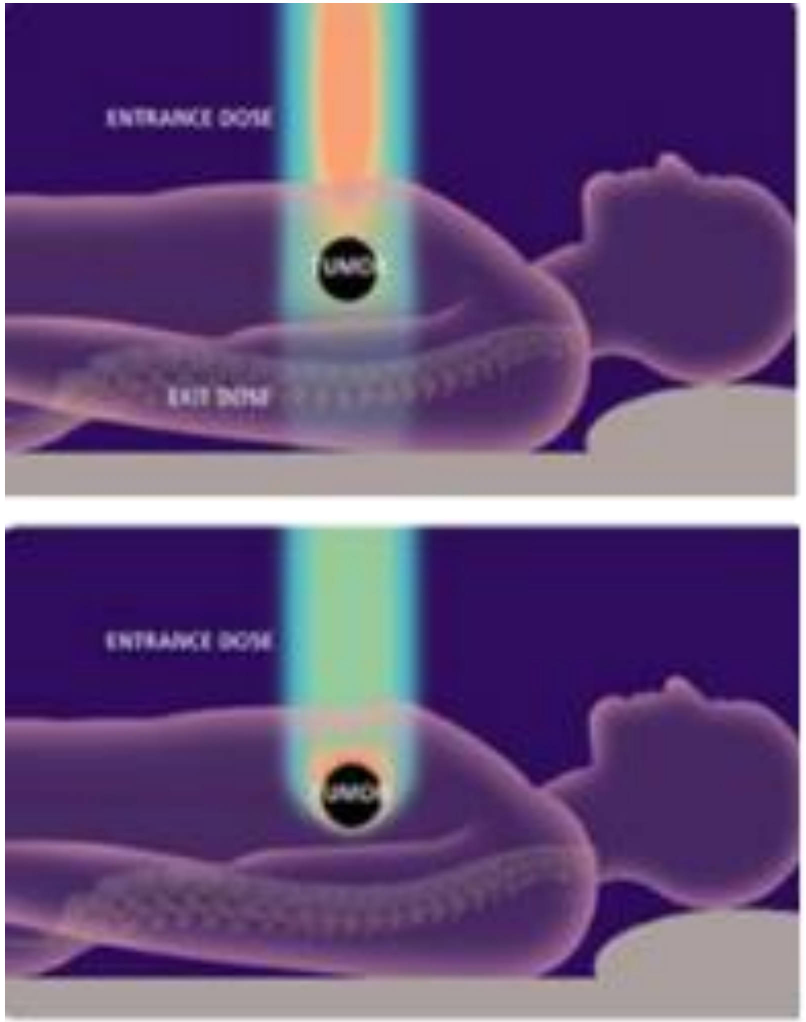
Hadron therapy (protons or ions)

The Bragg peak



Different from X-rays or electrons, protons (and ions) deposit their energy at a given depth inside the tissues, **minimising dose to the organs close to the tumour,** sparing nearby organs.

Required energy for full-body penetration: 230 MeV protons, 450 MeV/u C-ions.

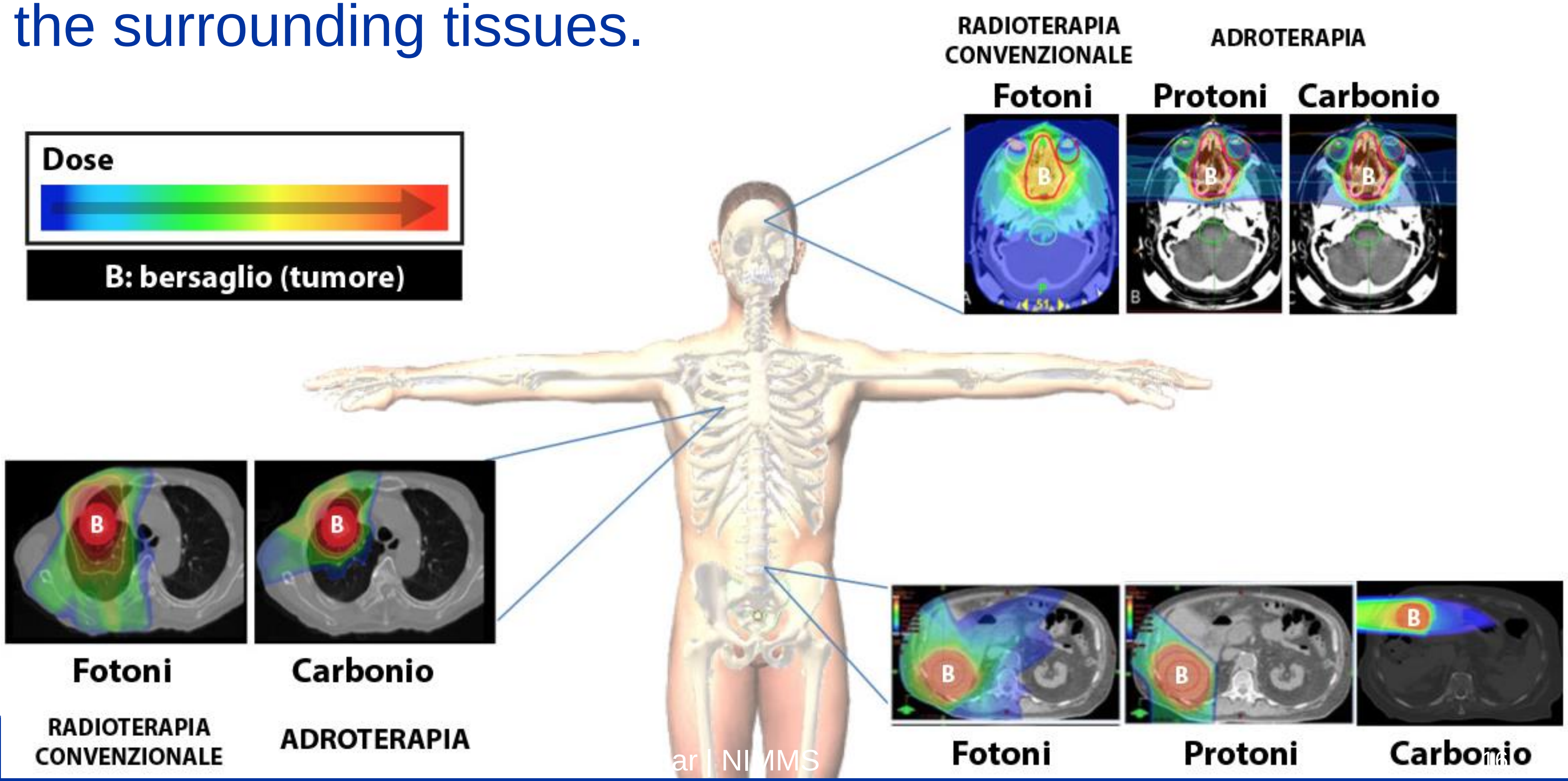


22,000 patients/year (2018) treated with particle beams, 25,000,000 patients/year with X-rays.

Accelerators for particle therapy

Particle beams realise an old human dream, of “bloodless surgery”: curing the internal part of the body without opening it.

We need to build very precise accelerators that can send the particles ONLY on the cancer and do not damage the surrounding tissues.



Accelerator option #2: the advanced RT synchrotron

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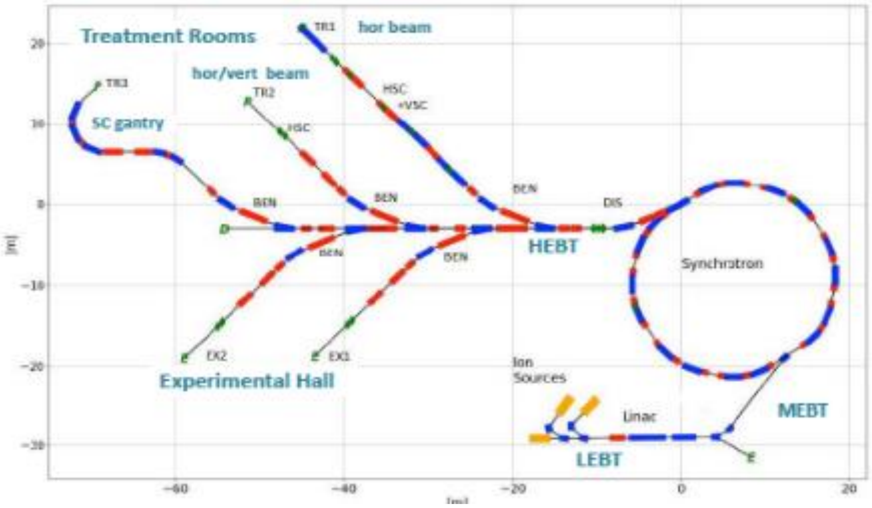
U. Amaldi, TERA
A. Avdic, A. Ibrahimovic, U. Sarajevo
X. Zhang, U. Melbourne
M. Vretenar, CERN

Starting point: the PIMMS design

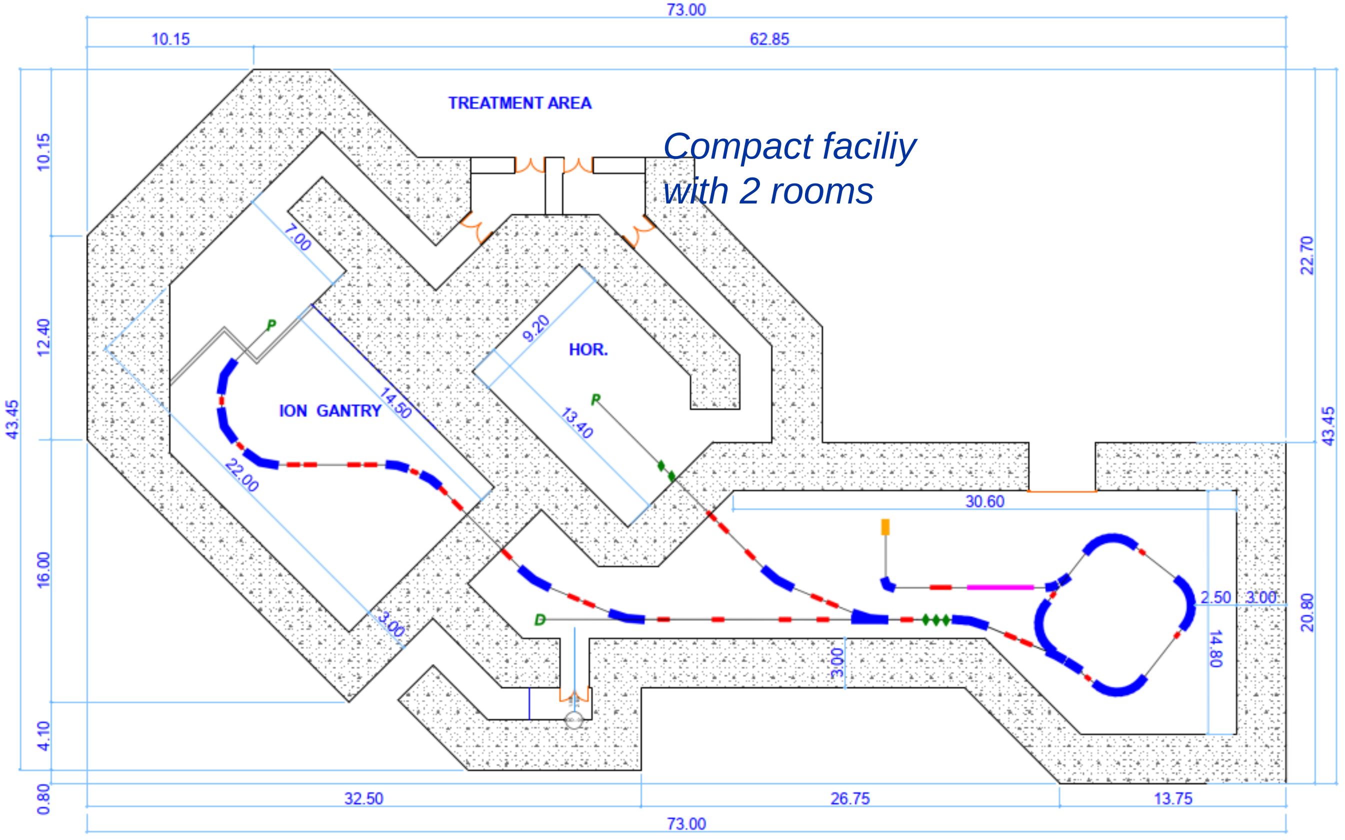
Improvements:

- Higher beam intensity for faster treatment ($2x10^{10}$, 20 times higher)
- Multiple energy extraction (multiple flat-tops)
- Additional fast extraction for FLASH operation
- Redesigned linac at higher frequency, for lower cost and parallel isotope production
- Multiple particles: p, He, C, O
- Optimised layout of beam transport, for both research and therapy

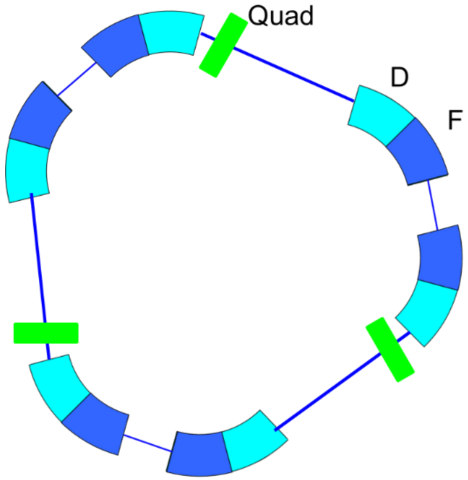


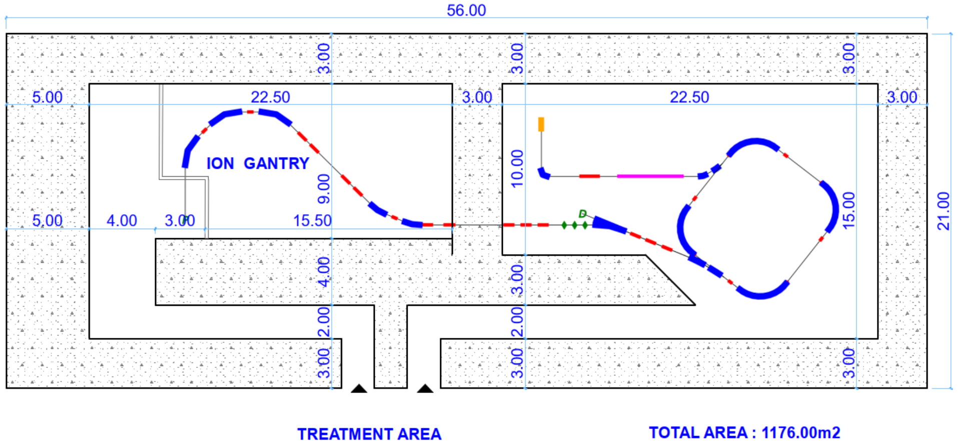
Injection/Acceleration	Unit					
Particle after stripping		p	$^{4}He^{2+}$	$^{12}C^{6+}$	$^{16}O^{8+}$	$^{36}Ar^{16+}$
Energy	MeV/u	7				
Magnetic rigidity at injection	Tm	0.38	0.76	0.76	0.76	0.86
Extraction energy range (**)	MeV/u	60 – 250 (1000)	60 – 250 (430)	100 - 430	100 - 430	200 – 350
Magnetic rigidity at highest energy (for therapy)	Tm	2.42	4.85	6.62	6.62	6.62
Maximum nominal field	T	1.5				
Maximum number of particles per cycle		$2.6 \cdot 10^{11}$	$8.2 \cdot 10^{10}$	$2 \cdot 10^{10}$	$1.4 \cdot 10^{10}$	$5 \cdot 10^{9}$
Ramp-up rate	Tm/s	<10				
Ramp-down time of magnets	s	1				
Spill ripple, intensity ratio I_{max}/I_{mean} (average on 1 ms)		< 1.5				
Slow extraction spill duration with multi-energy	s	0.1 – 60				
Fast extraction	s	$< 0.3\ 10^{-6}$				

A small superconducting synchrotron for ion therapy



Compact faciliy with 2 rooms





A compact single-room ion therapy facility in about 1,000 m²

Layout of the complete SEEIIST-type facility

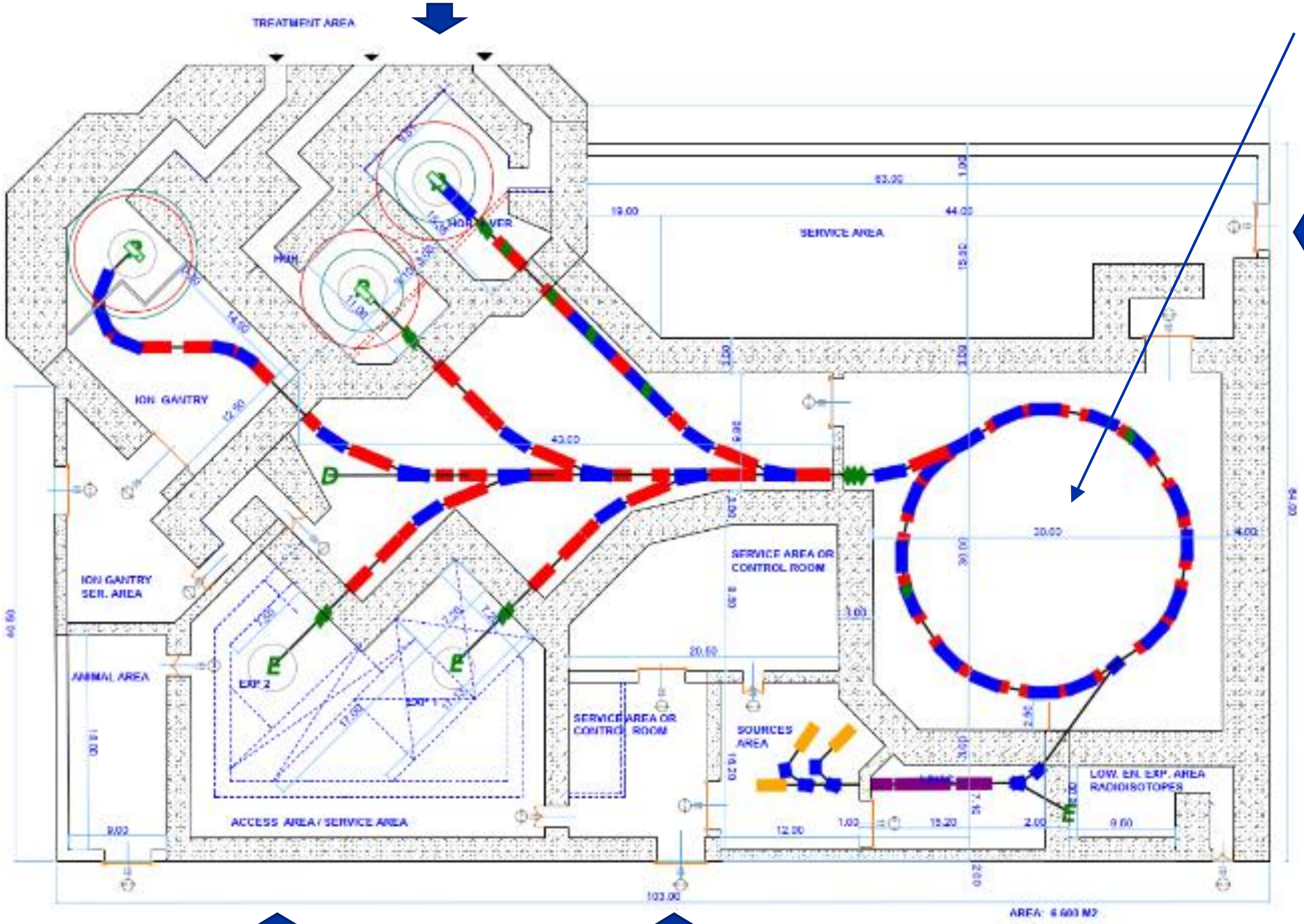
All team, with P. Foka, GSI and D. Kaprinis, Kaprinis Architects

Research and Therapy Facility

(50% daily beam time for research, 50% for therapy)

Total 6,600 m^2

Access for therapy



The synchrotron can be replaced by an SC version if R&D successful

Equipment room and access to synchrotron

Target for isotope production

Access for animal testing

Reconfigurable experimental room

Access to experimental room and linac

A new medical centre for cancer therapy with ions

Thank you for your attention

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