DE LA RECHERCHE À L'INDUSTRIE

Rewriting Nuclear Physics textbooks

one more step forward

Pisa (Italy), July 22nd – 26th, 2019

Program

- Nicolas Alamanos (IRFU-CEA-Saclay): Introduction to modern Nuclear Physics.
- Shawn Bishop (TUM, Munich): Reach for the stars by digging in the dirt.
- Luciano Canton (INFN, Padova) - Andrea Fontana (INFN-Pavia): Nuclear Physics applied to the production of Innovative Radio-Pharmaceuticals.
- G.A.P Cirrone (INFN-LNS, Catania): Hadron therapy: from the conventional approach to laser-driven applications.
- Maria Elena Fedi (INFN-LABEC, Firenze): How a small accelerator can be useful for interdisciplinary applications. Part II: cultural heritage studies.
- Paolo Finocchiaro (INFN-LNS, Catania): From nuclear physics to applications: new detectors for radioactive waste monitoring.
- Andreas Knecht (PSI, Zurich): Study of nuclear properties with muonic atoms.
- Franco Lucarelli (LABEC, Firenze): How a small accelerator can be useful for interdisciplinary applications. Part I: the study of air pollution.
- Miguel Marques (LPC, Caen): The extremes of neutron richness.
- Sandra Moretto (Padova University): Neutron Technique in civil security applications.
- Nicholas van der Meulen (PSI, Zurich): Radionuclides for nuclear medicine: the triumphs and challenges.
- Oliver Zimmer (ILL, Grenoble): Pedestrian neutrons - tool and object for fundamental physics.

Friday afternoon 26th July, visit to LABEC, Florence

Local Organizing Committee

Ignazio Bombaci, University of Pisa
Angela Bonaccorso, INFN - Pisa (co-chair)
Giovanni Casini, INFN - Firenze (co-chair)
Maria Agnese Ciocci, University of Pisa
Alejandro Kievsky, INFN - Pisa
Domenico Logoteta, University of Pisa
Laura Elisa Marcucci, University of Pisa
Valeria Rosso, University of Pisa
Michele Viviani, INFN - Pisa

SUMMER SCHOOL UNIVERSITÀ DI PISA

INFN PISA Istituto Nazionale di Fisica Nucleare Sezione di Pisa

EPJ.org your physics journal

Irfu

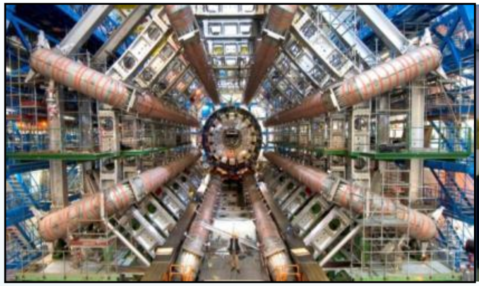
Lucia Lilli and Claudia Tofani, INFN, Pisa (Secretaries)

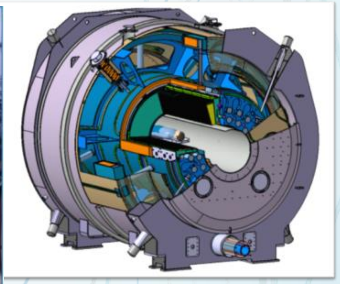
www.cea.fr

DE LA RECHERCHE À L'INDUSTRIE

Rewriting Nuclear Physics Textbooks: one more step forward

Part 2. Medical and Societal Applications





Medical applications :

Using radiations for imaging

Producing radioisotopes for medical treatment

Using radiations for therapy - the hadron-therapy

Societal applications :

Cultural heritage – Archeometry and

Study of air pollution.

Neutron technique in civil Security Application

Wilhelm Conrad Röntgen - The discovery of the "X-rays" and the beginning of "Imaging"

A little bit of history : November 8, 1895, Röntgen was studying the phenomena accompanying the passage of an electric current through a gas of extremely low pressure. He found that, if the discharge tube is enclosed in a sealed thick black carton, to exclude all light, and if he worked in a dark room, a paper plate covered on one side with barium platinocyanide, placed in the path of the rays, become fluorescent even when it was as far as two meters from the discharge tube.

Wilhelm Conrad Röntgen - The discovery of the "X-rays" and the beginning of "Imaging"

Nearly two weeks after his discovery, he immobilized for some moments his wife Anna Bertha's hand in the path of the rays over a photographic plate. After development he observed an image of the hand.

This was the first "Röntgenogram" ever taken.

A little bit of history

The discovery of Röntgen quickly spread around the world. In France, Antoine Béclère, a renowned pediatrician and clinician, has realized immediately the possible applications in medicine. He created in 1897, the first radiology laboratory in an hospital.

Between the 4th and 23rd July 1896, Victor Despeignes, a French district physician, has performed the first anticancer radiotherapy that has been validated by undeniable publications and practical facts. https://doi.org/10.1016/j.canrad.2013.01.012

A little bit of history

During the First World War, Marie Curie with her daughter Irene, and Antoine Béclère, designed eighteen mobile surgical units, "radiological ambulances“ nick-named the "*Petites Curies*".

The first to suggest the use of proton beams for radiation therapy, in 1946, is Robert Wilson, an accelerator pioneer. The leading center was the Lawrence Berkeley National Laboratory (LBNL). These pioneering studies lead to a collaboration between the LBNL and the Massachusetts General Hospital in order to develop the proton therapy in the USA.

Part 2. Medical and Societal Applications

Medical applications :

Using radiations for imaging

Producing radioisotopes for medical treatment

Using radiations for therapy - the hadron-therapy

Societal applications :

Cultural heritage – Archeometry and

Study of air pollution.

Neutron technique in civil Security Application

Using radiations for imaging

The first medical application of X-rays represents one of the most obvious benefit of nuclear physics in medicine.

Today, medical imaging combines different techniques used to obtain anatomical information; such as bone displacement, the condition of organs or the presence of tumors.

NuPECC Nuclear Physics for Medicine

Using radiations for imaging

i) The Magnetic resonance imaging (MRI).

Is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body. MRI does not involve X-rays or the use of ionizing radiation.

ii) The Positron emission tomography (PET).

NuPECC Nuclear Physics for Medicine

Magnetic Resonance Imaging (MRI).

Is based on the fact that the spin of nuclei into a magnetic field is aligned either into the direction of the magnetic field either into the opposite direction. The total magnetization of a sample is the difference of the number of nuclei between each spin direction. This difference is proportional to the applied field: the larger the field, bigger the magnetization, the more accurate the quality of the information.

Magnetic Resonance Imaging (MRI).

To perform a study, the person is positioned within an MRI scanner that forms a strong magnetic field around the area to be imaged.

An oscillating magnetic field is temporarily applied to the patient at the appropriate resonance frequency. The excited hydrogen atoms emit a radio frequency signal, which can be measured.

Imaging - MRI with 11.75 Tesla fields

Visualize the human brain at an unprecedented resolution:

(~100 μ).

- Magnetic field: 11.75 T,
- Current : 1483 A,
- Aperture: 90 cm,
- Weight : 132 tones.

MRI has proven to be a highly versatile imaging technique. However, the sustained increase in demand for MRI devices in hospitals lead to concerns about “cost effectiveness”.

Imaging - MRI with 11.75 Tesla fields

L'aimant du futur IRM Iseult à 11,7 teslas installé à NeuroSpin (CEA Paris-Saclay) a atteint un champ magnétique de 11,70 teslas au cours des tests réalisés le 18 juillet 2019.

Using radiations for imaging

i) The Magnetic resonance imaging (MRI).

Is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body. MRI does not involve X-rays or the use of ionizing radiation.

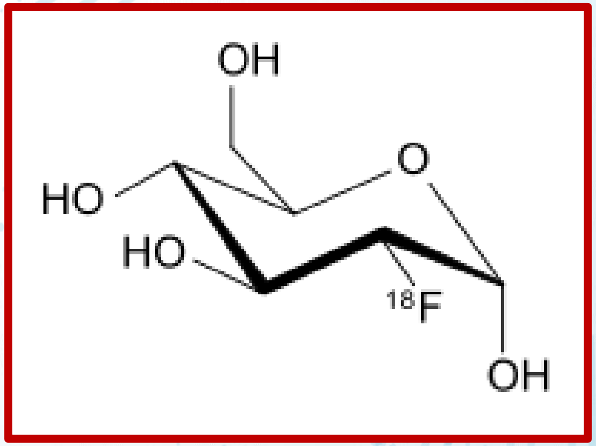
ii) The Positron emission tomography (PET).

NuPECC Nuclear Physics for Medicine

Imaging - Positron emission tomography (PET) and radio-isotopes

Cells to live, function and reproduced need energy in the form of glucose. Cancer cells require a lot of energy, and therefore have a very high glucose consumption.

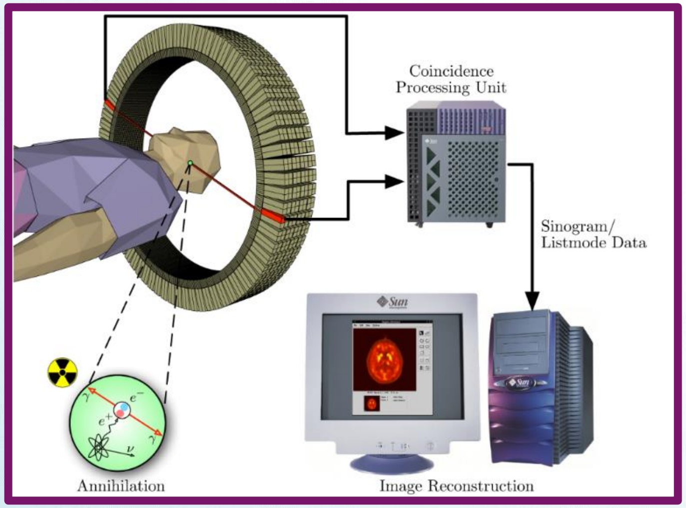
(PET) consists in administrating intravenously to the patient a marked molecule with a radioactive isotope of a relatively short lifetime. One of the most popular molecules is the *radioactive glucose*, labelled Fluor-18. It is an hydroxyl group (HO) where an ^{16}O is replaced by a nucleus of ^{18}F.



Imaging - Positron emission tomography (PET) and radio-isotopes

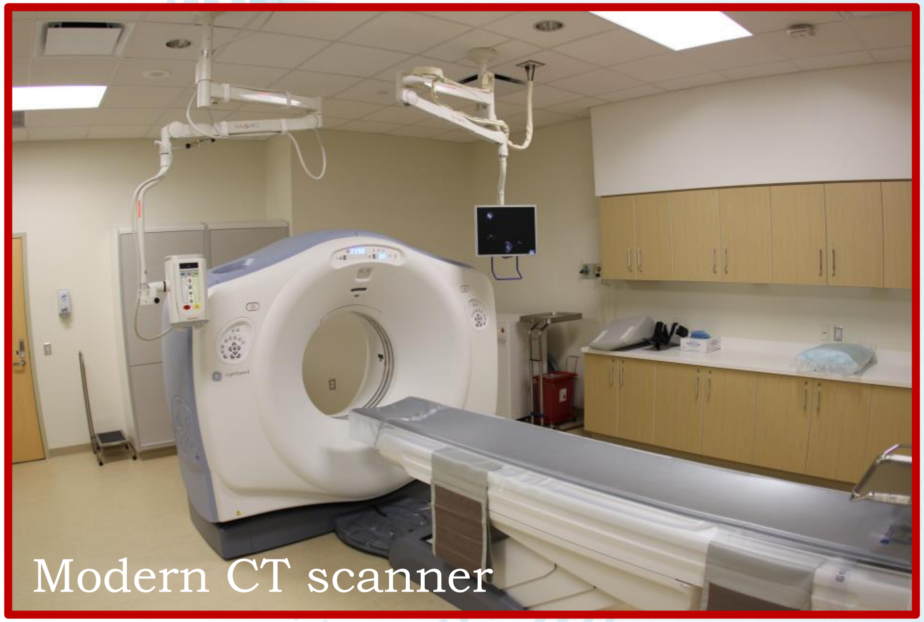
The ^{18}F is unstable and decreases by positron emission. The positron is immediately captured by an electron. The two particles annihilate each other. Their masses being 511 keV their annihilations is followed by the emission of two photons of 511 keV each.

The annihilation takes place very close to ^{18}F.



Imaging - Positron emission tomography (PET) and radio-isotopes

~50 radionuclides are commonly produced for medical purposes. Among them the most commonly used radionuclides are ^{18}F, or ^{11}C, ^{13}N, ^{123}I or ^{67}Ga… ^{99}Mo/^{99m}Tc…



Modern CT scanner

These short-lived isotopes require for their production *cyclotrons, reactors and dedicated nuclear physics techniques* .

Outlook - Using radiations for imaging

A century ago, the living body, like most of the material world, was opaque. Then Wilhelm Roentgen captured an X-ray image of his wife's finger – her wedding ring 'floating' around a white bone – and our vision changed for ever.

The large majority of PET scanner installed in hospitals are hybrid system where a PET detector is combined with an X-ray Computer Tomography (CT).

……. *Makes use of computer-processed combinations of many X-rays measurements taken from different angles to produce cross-sectional images of specific areas of a scanned object…….*

PET/CT is a technical evolution that has led to a medical revolution.

Part 2. Medical and Societal Applications

Medical applications :

Using radiations for imaging

Producing radioisotopes for medical treatment

Using radiations for therapy - the hadron-therapy

Societal applications :

Cultural heritage – Archeometry and

Study of air pollution.

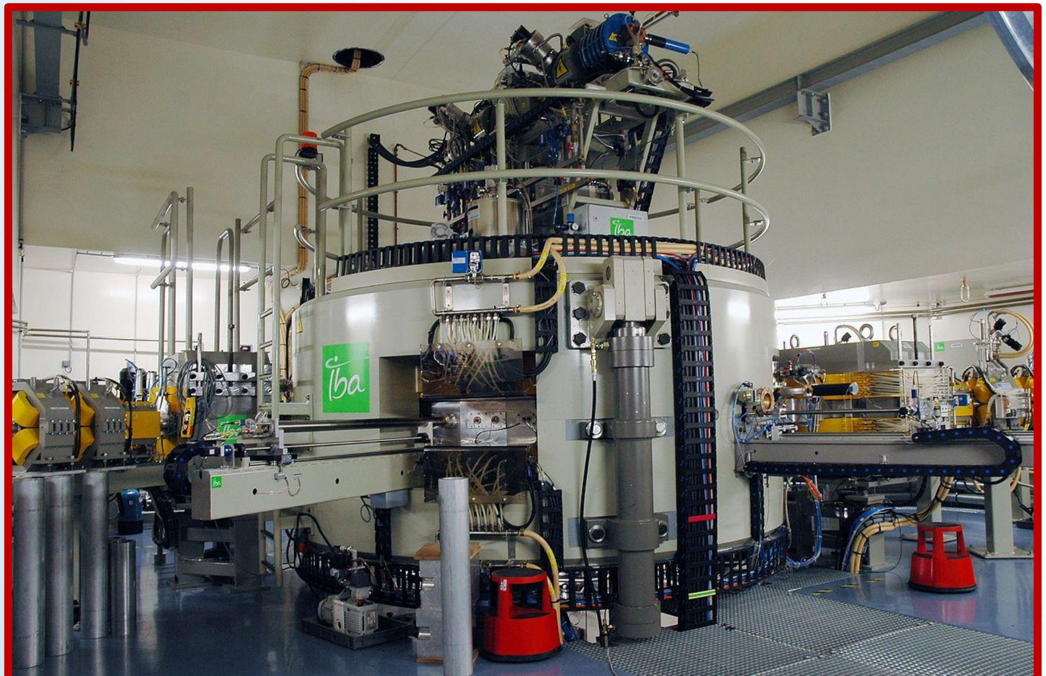
Neutron technique in civil Security Application

Producing radioisotopes for medical treatment

Today, about 950 cyclotrons are used worldwide to produce radionuclides. Among these cyclotrons, 350 are dedicated to the manufacture of radionuclides for PET imaging.

ARRONAX: Accélérateur pour la recherche en radiochimie et oncologie à Nantes-Atlantique

Is a cyclotron of high energy (70 MeV) and high intensity (750 µA)



Inaugurated in 2008 it is expected to be specialized in the production of :

β+ emitters (Cancérologie)

^{64}Cu, ^{44}Sc, ^{68}Ge, ^{82}Sr

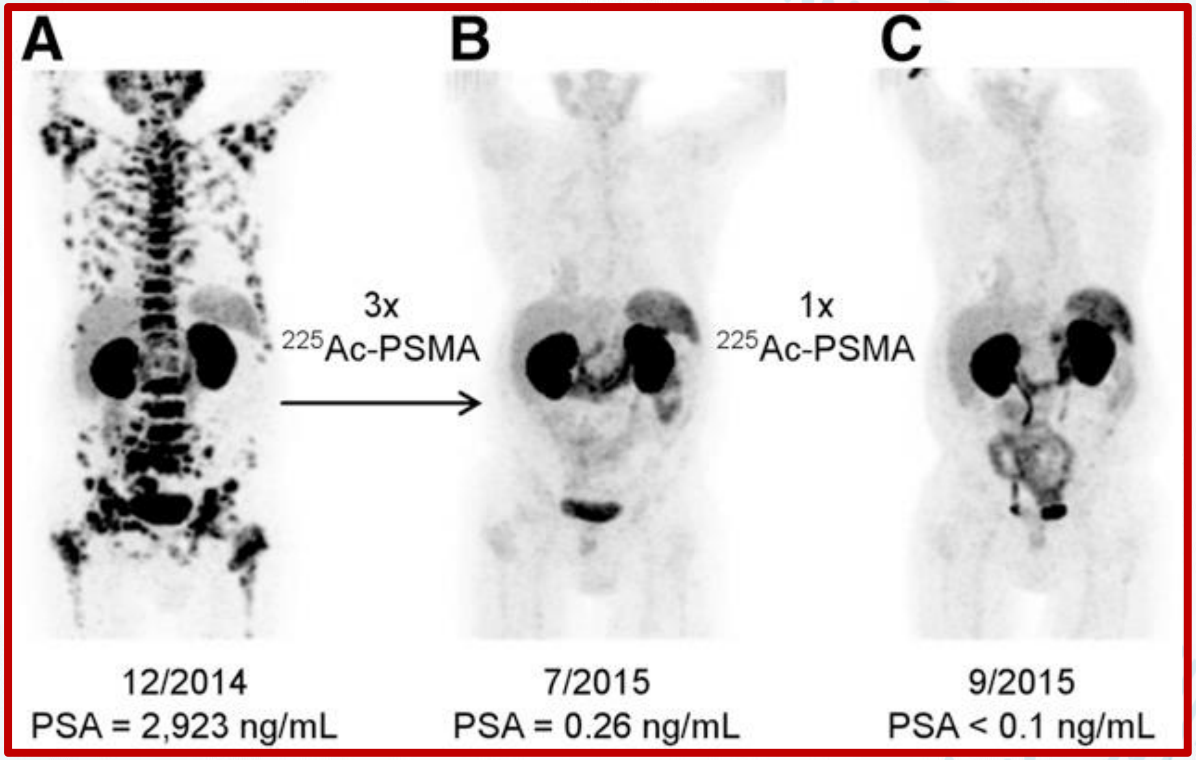
β- emitters

^{67}Cu, ^{47}Sc, ^{166}Ho

α emitters (immunothérapie)

^{211}At

^{225}Ac α-Radiation Therapy of Metastatic Castration-Resistant Prostate Cancer



PET/CT scans. The patient was treated with 3 cycles of ^{225}Ac at bimonthly intervals. (^{225}Ac actinium has a half-life of 19 days)

Clemens Kratochwil et al., J Nucl Med 2016; 57:1941–1944

Producing radioisotopes for medical treatment

Another radioisotope broadly used is the ^{99}Mo/^{99m}Tc. Technetium-99m itself is used in more than 80% of diagnostic nuclear imaging procedures, with over 30,000 scans performed with this isotope in the United States each day and global consumption exceeding 40 million scans per year.

Radioisotopes : ^{82}Sr/^{82}Rb and ^{99}Mo/^{99m}Tc

^{99}Mo/^{99m}Tc : In 2013 only eight research reactors were involved in the large scale production (>95% of world supply) of ^{99}Mo. Today two of them were shutdown. Others are expected to stop irradiating targets for ^{99}Mo production within the decade. These supply shortages also raised interest in alternative production routes of ^{99}Mo and ^{99m}Tc.

…. Cyclotron type "methods" stands as an invaluable tool for the production of both ^{99m}Tc. They become attractive to combat the impending shortage of ^{99m}Tc due to aging reactors and to produce these radioisotopes with higher specific activities.

Radioisotopes – Outlook

There are currently more than 12 million medical procedures per year in Europe (diagnosis and therapy) using radioisotopes, or more than 30,000 procedures per day. About 90% of the radioisotopes are used for diagnostic purposes and 10% for therapy. “theranostics”, where radioisotopes are used simultaneously for imaging and treatment.

The use of radionuclides for diagnostic purposes is a mature field in nuclear medicine. The main problem is the shortage of ^{99}Mo/^{99m}Tc (emitting a 140 keV photon with a half-life of approximately 6 hrs).

New facilities are necessary to ensure a regular supply of these important radioisotopes.

Lecture by: Luciano Canton

Luciano Canton: Nuclear Physics applied to the production of Innovative Radio-Pharmaceuticals.

…….The lecture will introduce the basic concepts related to radionuclide production at cyclotrons for radiopharmaceuticals application. The main goal is to find efficient production routes of novel radiopharmaceuticals (theranostics, multi-modal imaging, etc), with special considerations about purity and yields……

Nicholas van der Meulen: Radionuclides for nuclear medicine: the triumphs and challenges

Terbium is a unique element, as it provides a quadruplet of radionuclides suited for diagnostics and therapy in nuclear medicine. Much success has been gained from the PSI-ISOLDE collaboration, with the collection and purification of ^{149}Tb (α-emitter, T1/2 = 4.1 h), used for preclinical therapy studies and PET imaging, and ^{152}Tb (β+-emitter, T1/2 = 17.5 h), for preclinical and clinical PET imaging, respectively……

Part 2. Medical and Societal Applications

Medical applications :

Using radiations for imaging

Producing radioisotopes for medical treatment

Using radiations for therapy - the hadron-therapy

Societal applications :

Cultural heritage – Archeometry and

Study of air pollution.

Neutron technique in civil Security Application

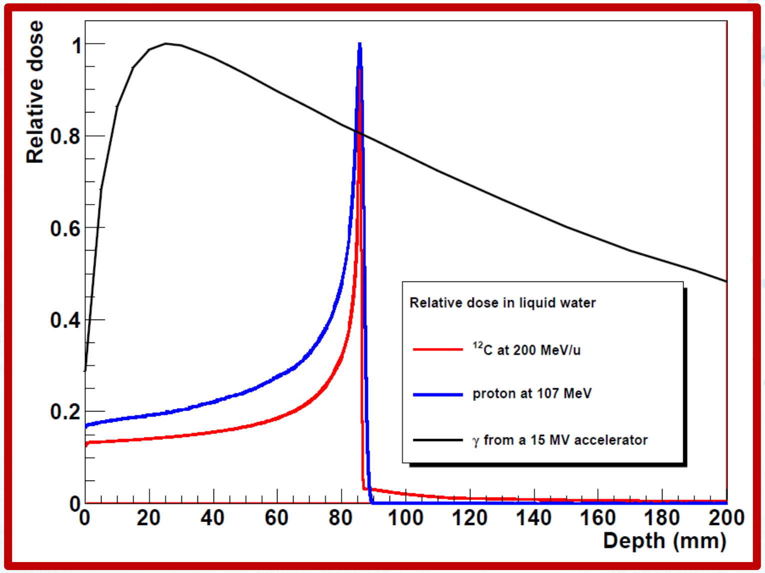
Radiation Therapy

Radiation therapy is the medical use of ionizing radiation to treat cancer. Today, cancer is among the highest cause of death in developed countries and its treatment presents a real challenge.

In conventional radiation therapy, beams of X rays (high energy photons) or hadrons are produced and then delivered to the patient to destroy tumor cells. Using crossing beams from many angles, radiation oncologists irradiate the tumor target while trying to spare the surrounding normal tissues. Inevitably some radiation dose is always deposited in the healthy tissues.

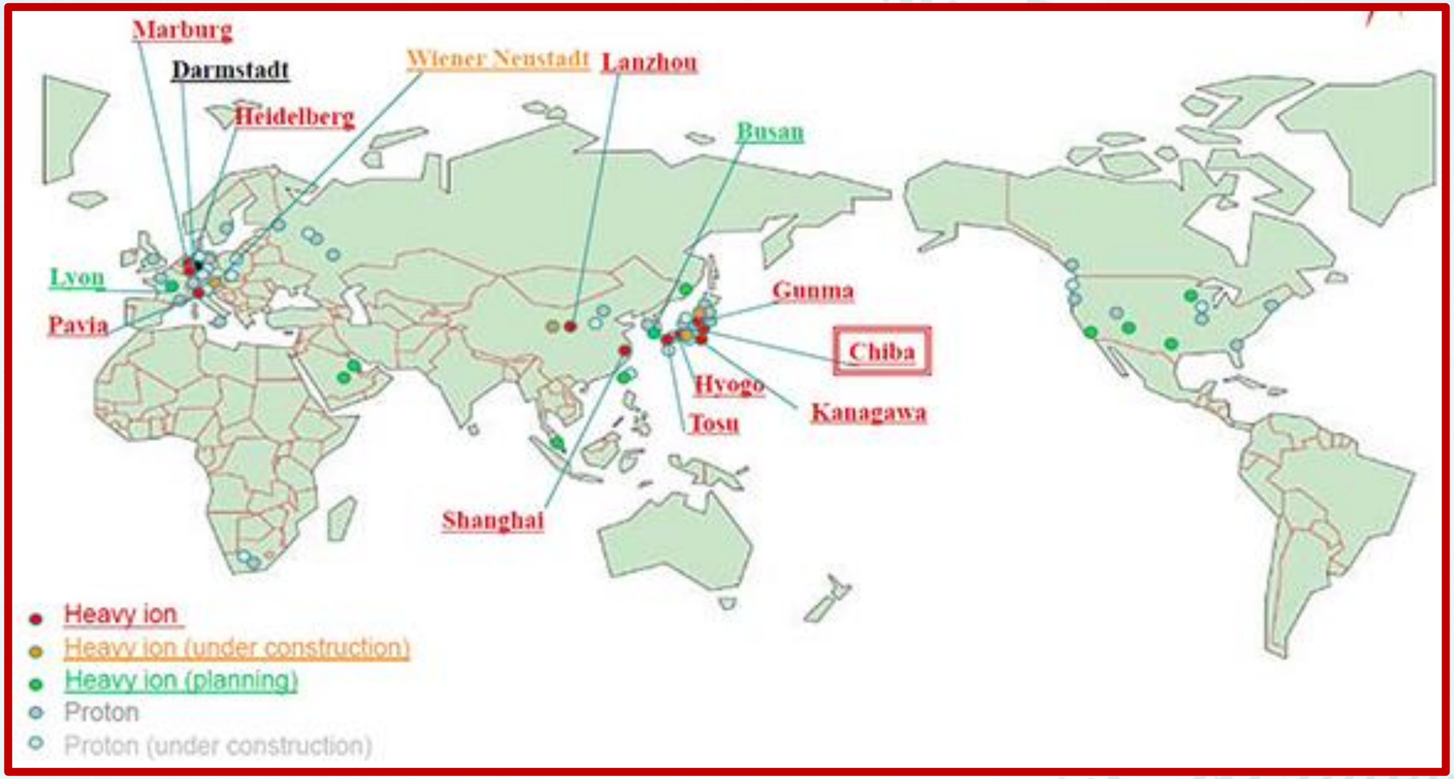
Why Hadron-therapy

The hadron-therapy uses light charged particles beams to irradiate tumors. These beams present a ballistic advantage with a maximum energy deposition at the end of the path (ie Bragg peak).



Evolution of the relative dose with respect to the penetration depth in water for different particles.

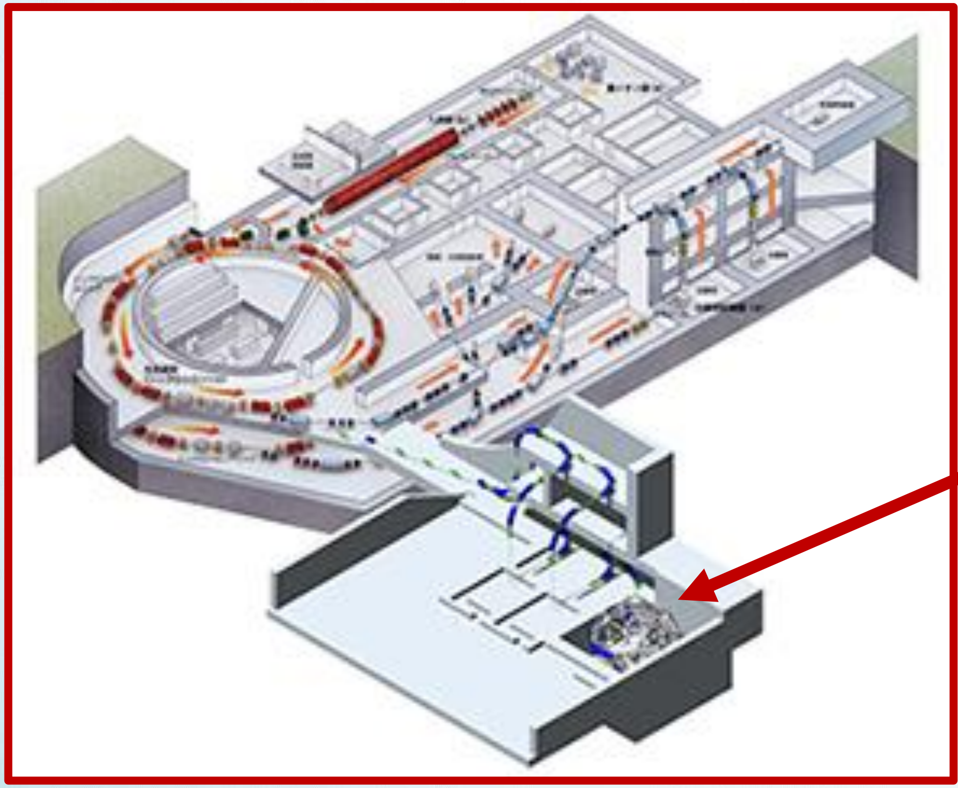
Hadron-therapy

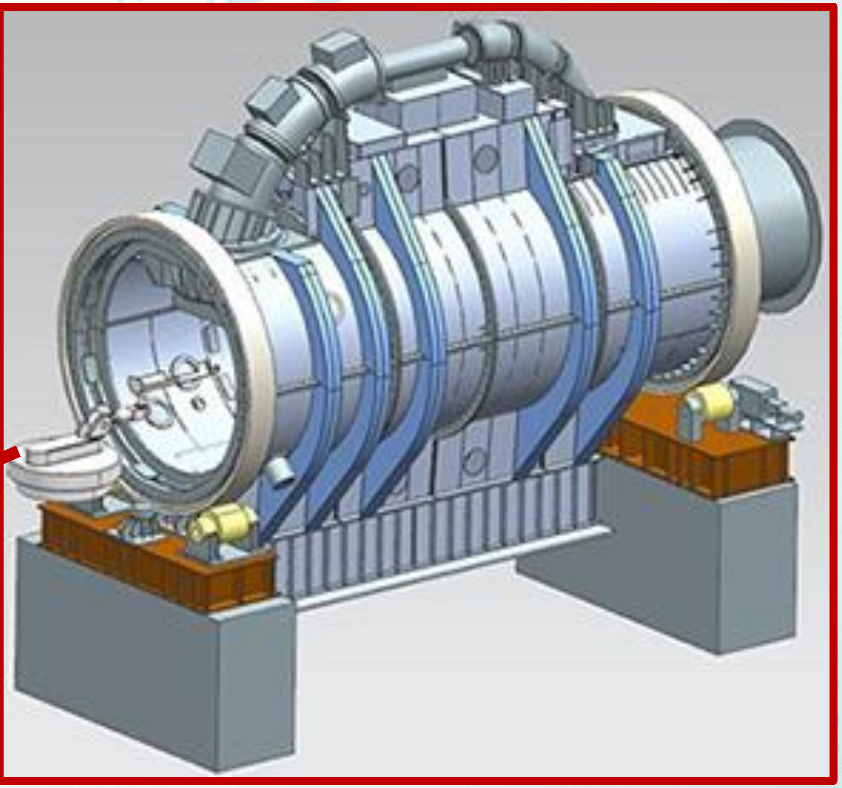


At the end of 2017, there are 63 centers worldwide for cancer treatment with protons (52 centers) or carbon ions (11 centers). This field benefits from the very strong interface between physics, biology and medicine.

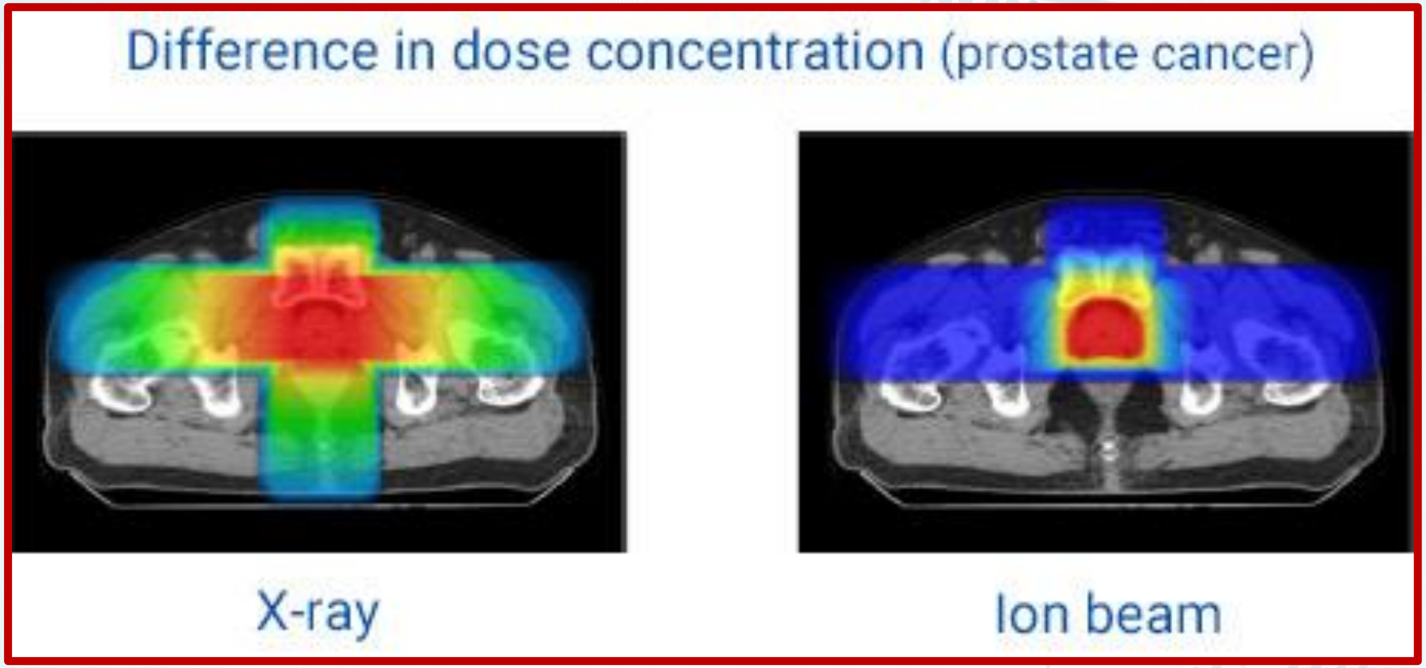
The Heavy- Ion Medical Accelerator in Chiba (HIMAC)

HIMAC complex consists of a three ion sources, one linac, two synchrotron rings, and three treatment rooms. The new treatment facility has also three treatment rooms.





Advantages of Hadron-therapy



Yamagata University Hospital is establishing a heavy ion cancer therapy center, with treatment starting in 2020. http://www1.id.yamagata-u.ac.jp/MIDINFO/en/hit/

Advantages of Hadron-therapy

The carbon therapy has grown up only very recently. The leading country is Japan where the first treatment center in Chiba was build in 1994. The HIMAC (Heavy- Ion Medical Accelerator in Chiba) facility has treated around 10000 patients.

Advantages of Hadron-therapy

1) Carbon ion beams have physical properties enabling to concentrate radiation damage intensively on the cancer site.
2) It's biologically more effective in killing cancer cells.
3) The treatment period is shorter than other radiotherapy.

Un outlook - Hadron-therapy

In our laboratories we have the knowledge to build high field magnets and heavy ion accelerators.

The next challenge is to find ways to get them out from our laboratories - build equipment that are cheap and simple to use – in order to make their use democratic, that is, possible for every citizen.

Lecture by: Pablo Cirrone

Pablo Cirrone: Hadron-therapy: from the conventional to the laser-driven approach.

Charged particle acceleration using ultra-intense and ultra- short laser pulses has gathered a strong interest in the scientific community and it is now one of the most attractive topics in the relativistic laser-plasma interaction research. Indeed, it could represent the future of particle acceleration and open new scenarios in multidisciplinary fields, in particular, medical applications….

Lecture by: Paolo Finocchiaro

Paolo Finocchiaro: From nuclear physics to applications: new detectors for radioactive waste monitoring

Nuclear physics experiments are always in need of more and more advanced detection systems. During the last fifteen years new technological developments have come out with many improvements in terms of performance and compactness of detector materials, transducers, electronics, computing and data transmission. In light of these achievements some applications previously prohibitive because of size and cost are now feasible........

Medical applications :

Using radiations for imaging

Producing radioisotopes for medical treatment

Using radiations for therapy - the hadron-therapy

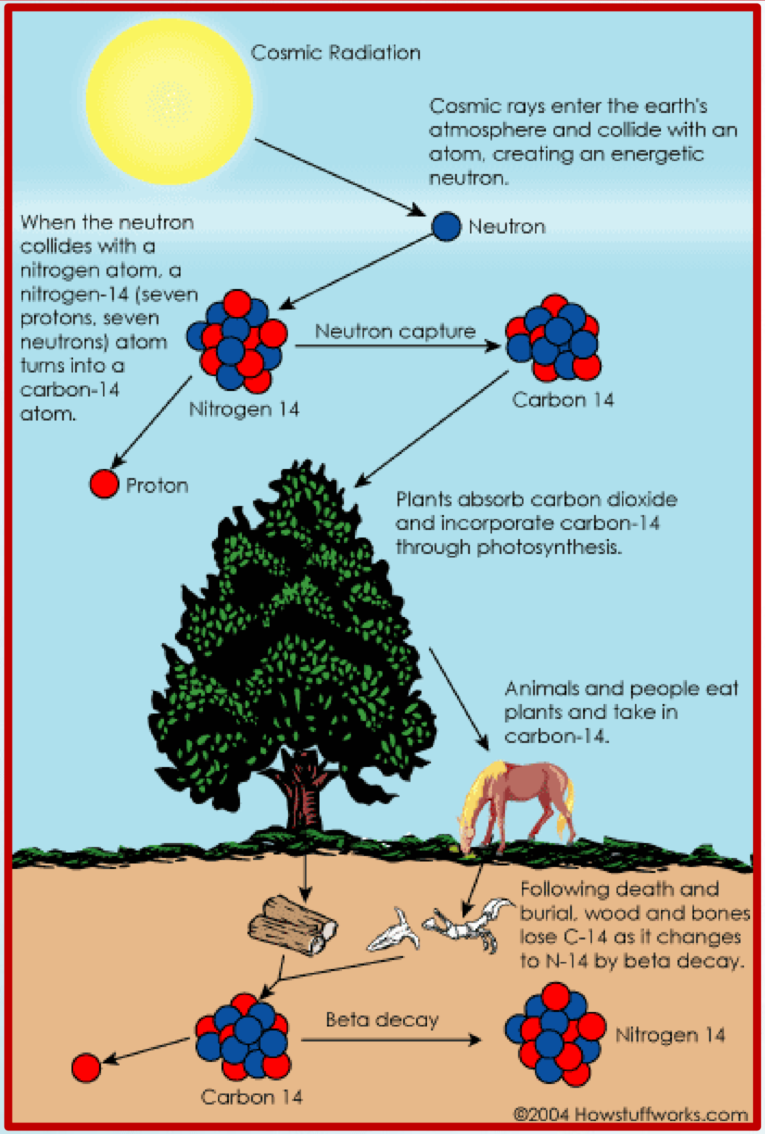
Societal applications :

Cultural heritage – Archeometry and

Study of air pollution.

Neutron technique in civil Security Application

The ^{14}C method is a great contribution of Nuclear Physics to Archaeology



…. A cosmic rays collide with atoms creating energetic neutrons. The neutrons collide with nitrogen atoms creating ^{14}C via the reaction ($n+^{14}N \rightarrow p+^{14}C$).

Carbon-14 is radioactive, with a half-life of about 5,700 years.

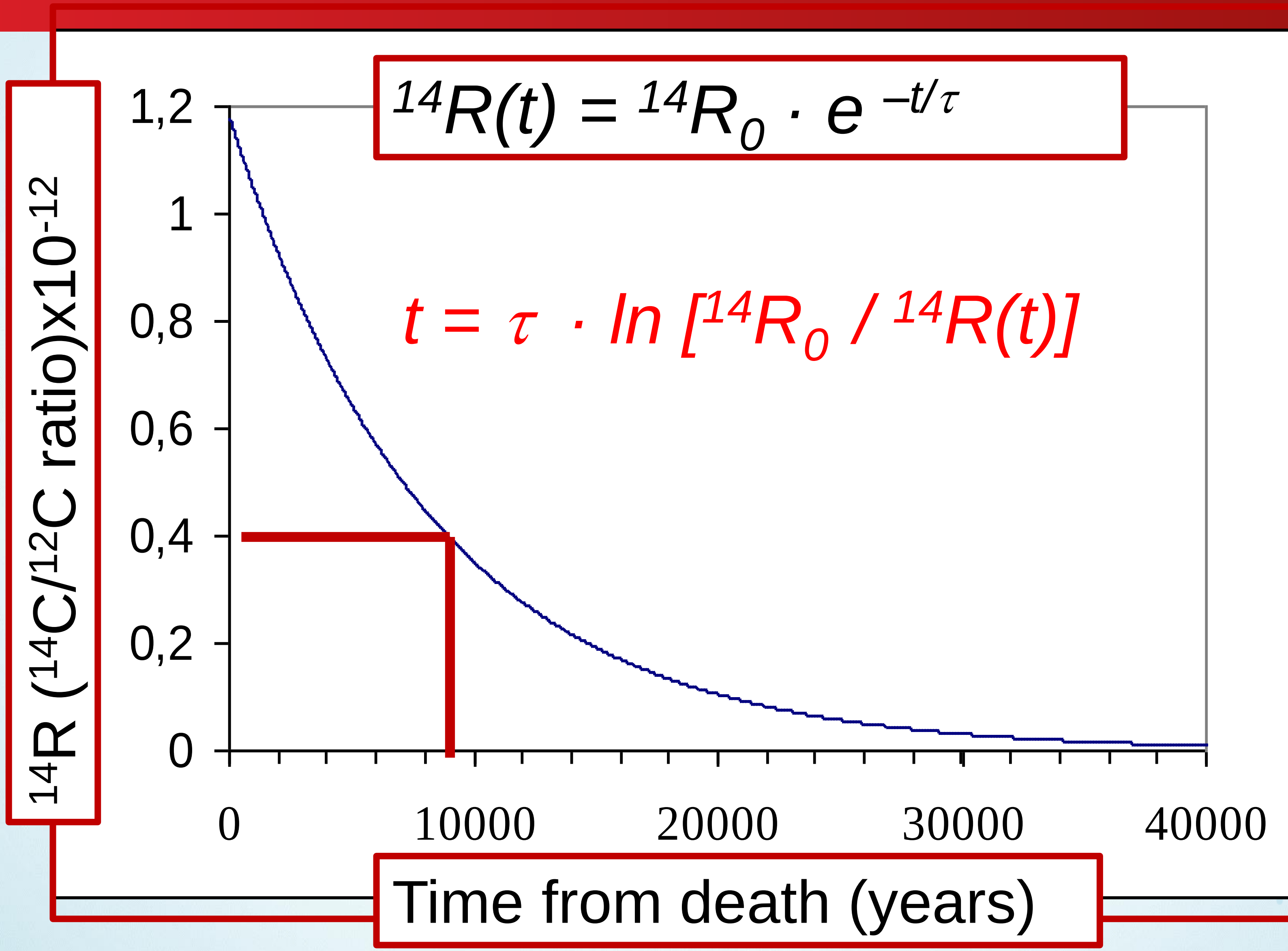
The ^{14}C method is a great contribution of Nuclear Physics to Archaeology

The carbon-14 atoms combine with oxygen to form carbon dioxide, which plants absorb naturally and incorporate into plant fibers by photosynthesis. Animals and people eat plants and take in carbon-14 as well. The ratio of normal carbon (carbon-12) to carbon-14 in the air and in all living things at any given time is nearly constant.

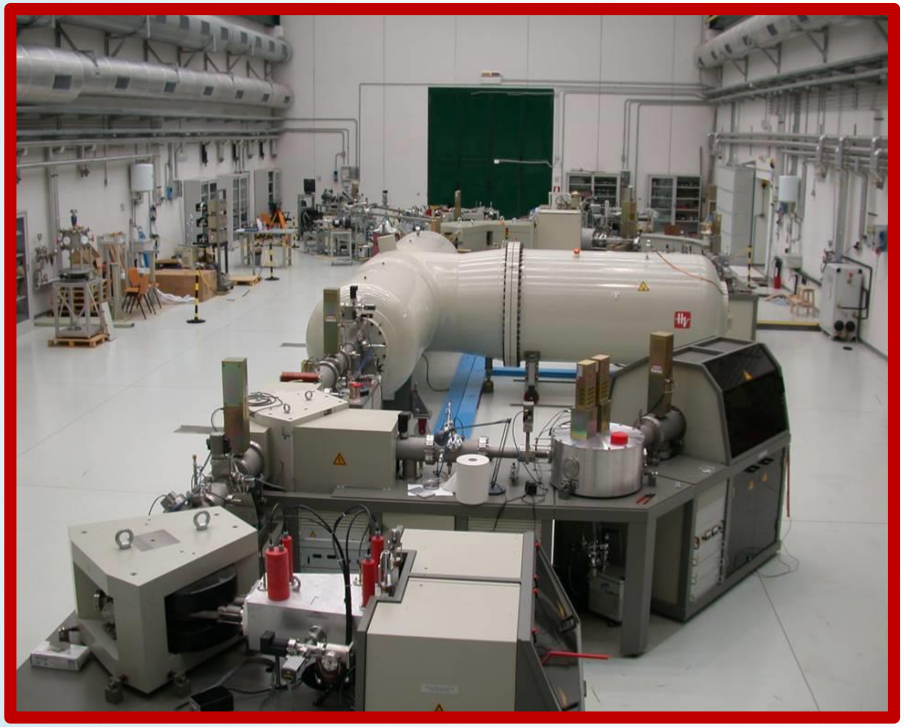
The carbon-14 atoms are always decaying, but they are being replaced by new carbon-14 atoms at a constant rate.

At this moment, your body has a certain percentage of carbon-14 atoms in it, and all living plants and animals have the same percentage.

The ^{14}C method



Accelerator mass spectrometry (AMS)



Laboratory of Nuclear Techniques
for Environment and Cultural Heritage

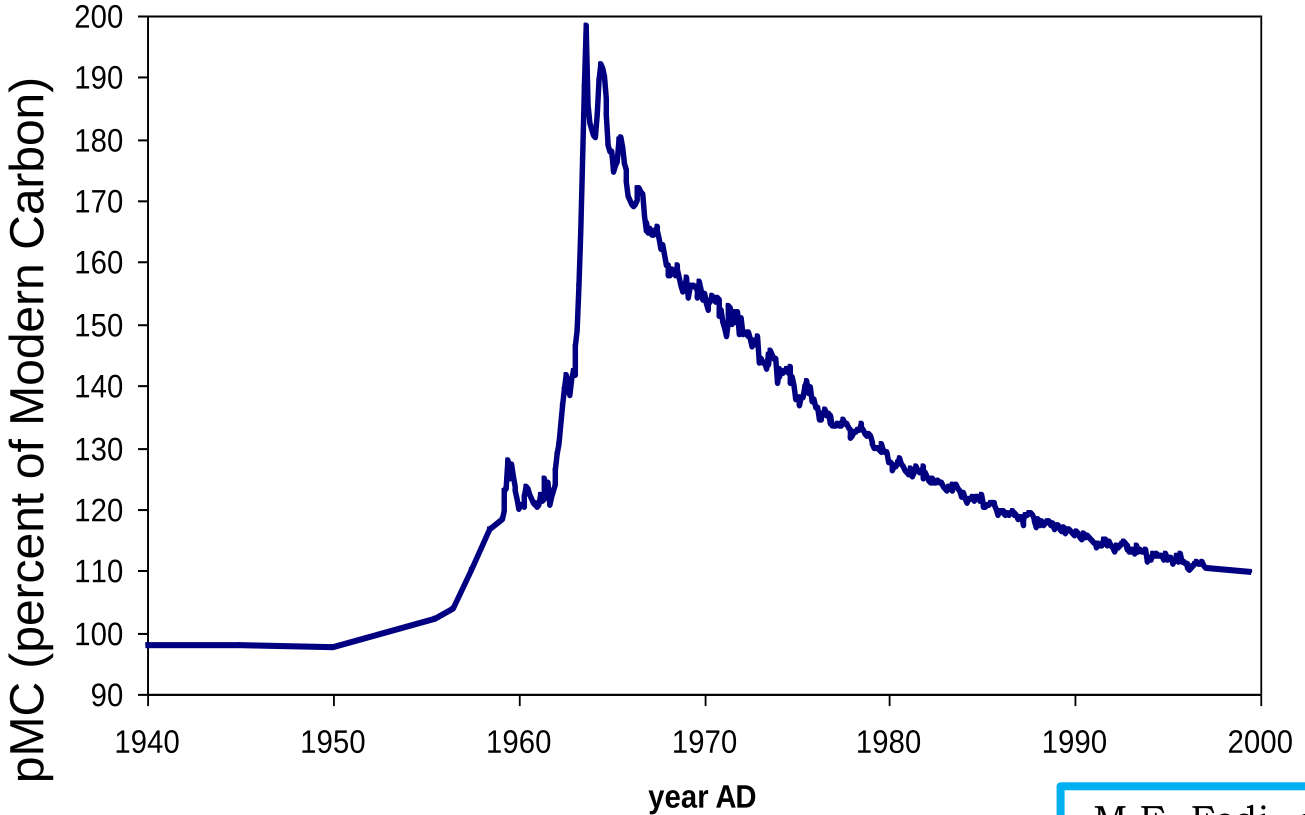
The ions are accelerated before mass analysis. The special strength of AMS is its power to separate a rare isotope from an abundant neighboring mass ("abundance sensitivity", e.g. ^{14}C from ^{12}C).

It makes possible the detection of naturally occurring, long-lived radio-isotopes such as ^{10}Be, ^{36}Cl, ^{26}Al and ^{14}C.

Their typical isotopic abundancies ranges from 10^{-12} to 10^{-18}.

The traditional ^{14}C dating apply to old (or very old!) objects but not only

Exploiting the effect of nuclear explosions in atmosphere during the cold war



M.E. Fedi, *et al*, *Nucl.Instr.&Meth. B* 294 (2013), 662

The traditional ^{14}C dating apply to old (or very old!) objects but not only

L. Caforio, et al, Eur. Phys. J. Plus (2014) 129: 6

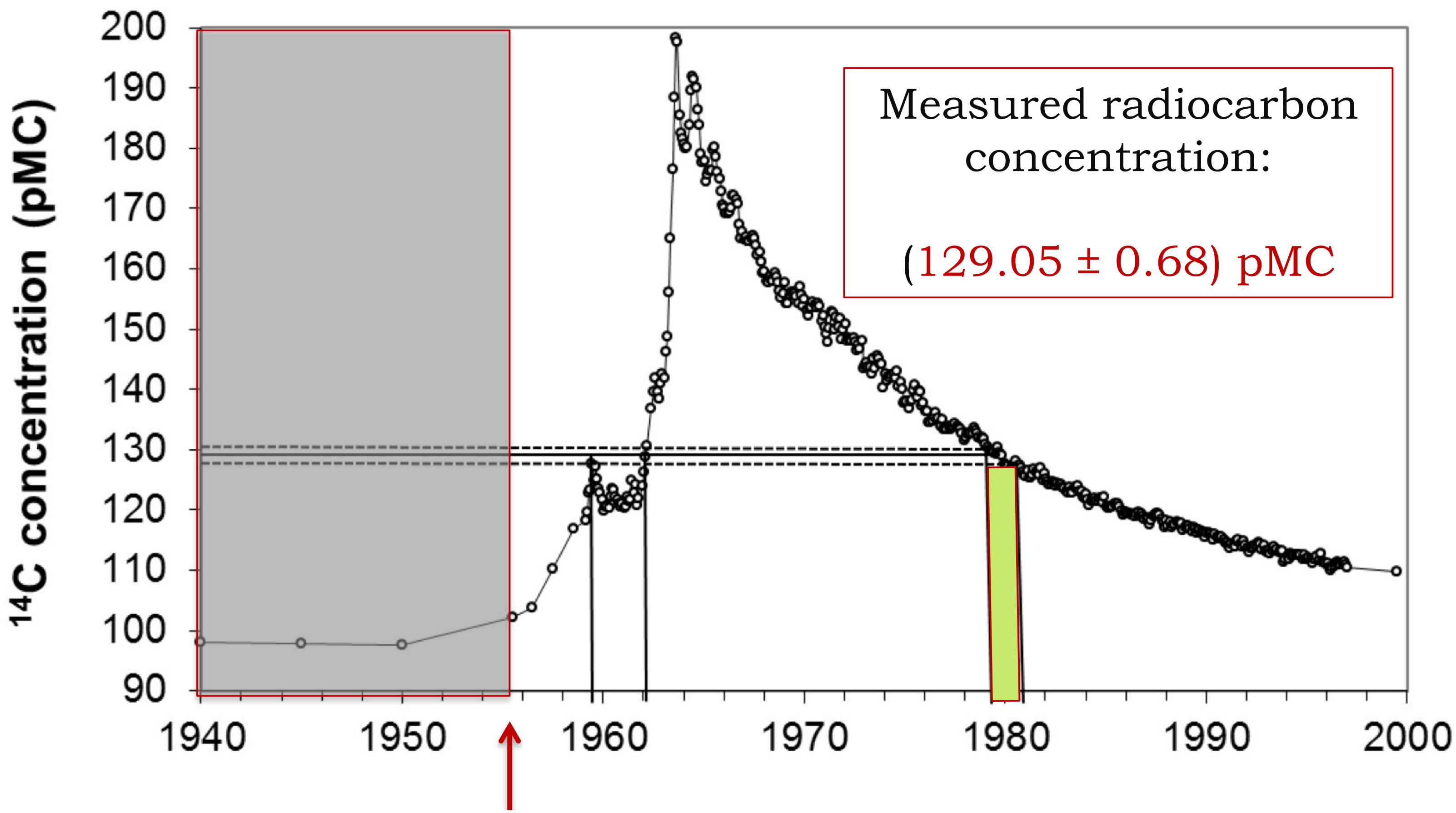
Fernand Léger, (Contraste de Formes)

allegedly painted in 1913-14

Bought by Peggy Guggenheim in the late 1960s

never on display to public because of early suspicions to be a forgery

The canvas was produced using cotton plants cut out in 1959, or 1962, or 1979-80



Léger's death → the painting is a fake

Archeometry Outlook

The Accuracy and precision in radiocarbon (^{14}C) dating depend on several factors affecting the main steps of the dating process, from the selection of the samples to their preparation and measurement involving a systematic evaluating of anomalies potentially introduced during each stage of the process and trying to minimize uncertainties.

C Scirè Calabrisotto, …, M.E. Fedi, *et al*, Radiocarbon, Vol 59, 2017,

The archeometric methods are at the crossroad of several scientific fields. Supported by sophisticated technologies, refine our vision of the Cultural Heritage world. This results into a renew interest in analytical pipelines, data management and preservation plan for cultural remains.

Lecture by: Mariaelena Fedi

Maria Elena Fedi: How a small accelerator can be useful for interdisciplinary applications. Cultural heritage studies.

Archaeometry, i.e. that discipline where science and modern technology are employed to examine archaeological remains, and in general Cultural Heritage, has become so far an important support for archaeologists, restorers and all operators in humanities. …… Nuclear physics, and in particular low voltage electrostatic accelerators, can allow us to solve such questions. In the lecture, we will discuss how Accelerator Mass Spectrometry (AMS) through the measurement of radiocarbon concentration and Ion Beam Analysis (IBA)

Part 2. Medical and Societal Applications

Medical applications :

Using radiations for imaging

Producing radioisotopes for medical treatment

Using radiations for therapy - the hadron-therapy

Societal applications :

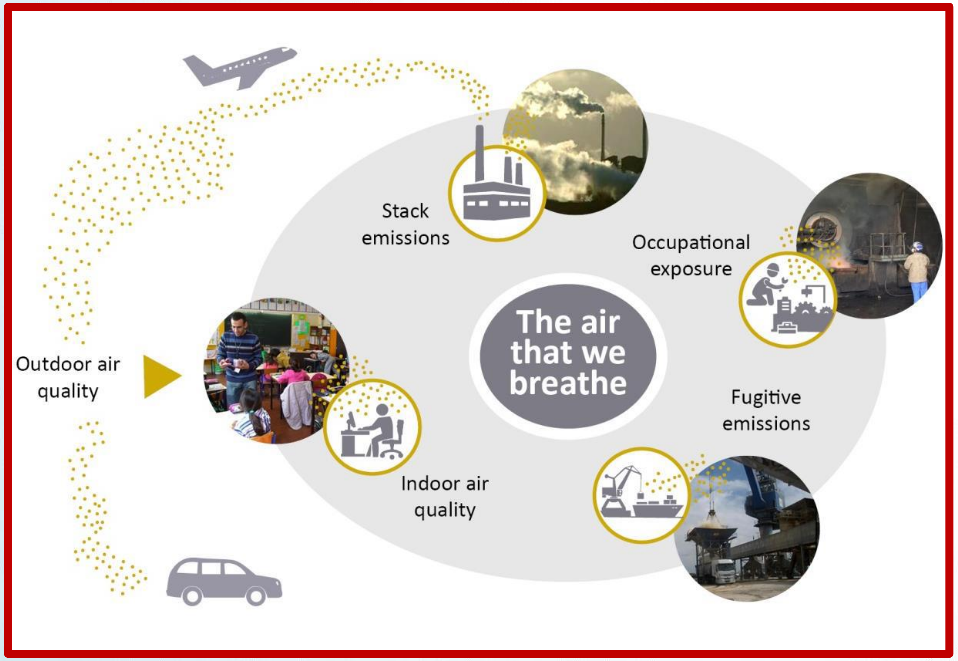
Cultural heritage – Archeometry and

Study of air pollution.

Neutron technique in civil Security Application

The study of air pollution.

The air that we breath



No matter where we are, indoors at home, school, work,…, the air that we breathe carries airborne particulate matter (APM) (*small particles with a diameter of less than 2.5 μm suspended in the air*) from a variety of sources.

Careful analysis of the APM granulometry and chemical composition can be used to "fingerprint" each source.

The study of air pollution - example France.

Air pollution is responsible for 48,000 deaths each year in France. It is the third leading cause of death in France, after tobacco (78,000 deaths) and alcohol (49,000 deaths).

At the origin of 9% of annual deaths in France, fine particles with a diameter of less than 2.5 micrometers – penetrate deep into the respiratory system and cause many pathologies - cause a loss of life expectancy, which can exceed two years in the most polluted cities

The study of air pollution

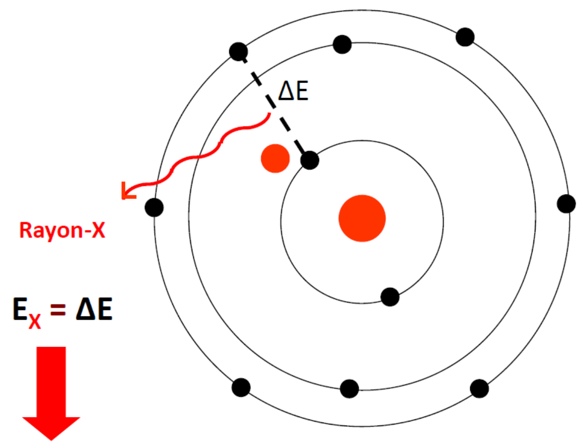
Particle Induced X-ray Emission (PIXE) and Neutron Activation Analysis (NAA) are very often used in air quality studies, due to their high sensitivity to metals and many other elements of interest, from 0.1 ng/m3 (nanogram per cubic meter of air) in favorable cases to 1000 ng/m3, and due to their ease of use.

The study of air pollution - PIXE

Particle Induced X-ray Emission: (PIXE), is sensitive (*to elements from Si to U*) in concentrations at ppm level (part per million).

PIXE belongs to the group of techniques known as Ion Beam Analysis. Beam of ions, normally protons, excites the atoms of the sample, leading to the emission of X-rays which are characteristic of each element.

PIXE: *Particle Induced X-Ray Emission*

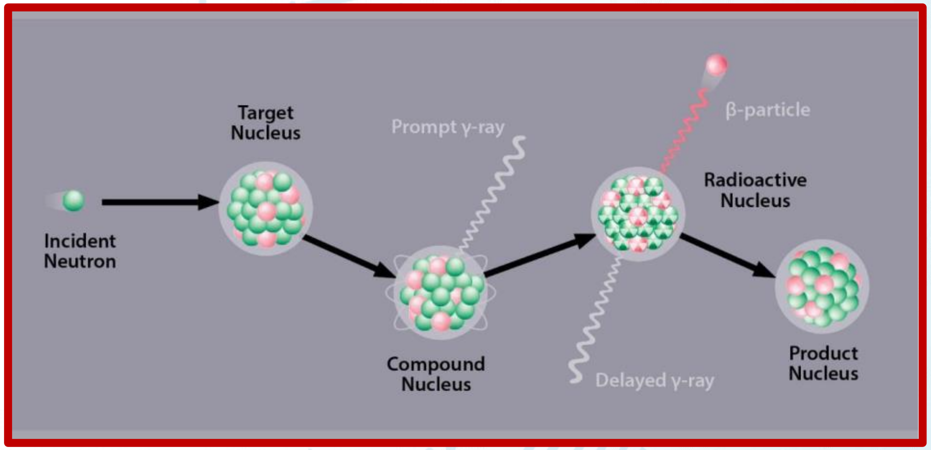


L'énergie des rayons-X est caraqueristique de l'élément.

Varying the energy of the protons, we can probe different depths of the sample.

The study of air pollution

Neutron Activation Analysis : (NAA) is a nuclear analytical technique capable of determining (*depending on the element and on the sample*), concentrations as low as (typically) 1 nanogram to 1 microgram per gram of sample.



Lecture by: Franco Lucarelli

Franco Lucarelli: How a small accelerator can be useful for interdisciplinary applications.

There is an increasing concern in European citizens about the problems related to the high levels of Particulate matter (PM) in our cities, which affects human health. Aerosol also affects climate change, directly by scattering and absorption of solar radiation and indirectly by impacting on cloud processes. In environmental sciences, Nuclear Physics plays an important role through the measurement of the elemental composition of the aerosol, in particular with PIXE, Particle Induced X-Ray Emission …

A better knowledge of the aerosol composition helps to identify its sources.

Medical applications :

Using radiations for imaging

Producing radioisotopes for medical treatment

Using radiations for therapy - the hadron-therapy

Societal applications :

Cultural heritage – Archeometry and

Study of air pollution.

Neutron technique in civil Security Application

Neutron technique in civil Security Application

The effectiveness of the custom clearance calls for the balance between two trade-related constrains: *Fluidity and security.*

Until recently only a small fraction of the containers was scanned with X-rays . The X-ray measurements are not able, some times, to solve doubts about the possibility of illicit trafficking, so that unloading and physical inspections are required, with additional costs and time delays.

In case of suspect cargos, the reconciliation between fluidity and security can be achieved implementing new technologies as the neutron based scanning systems as integral part of the custom inspection methodology.

The EURopean Illicit TRAfficking Countermeasures Kit (EURITRACK) inspection system

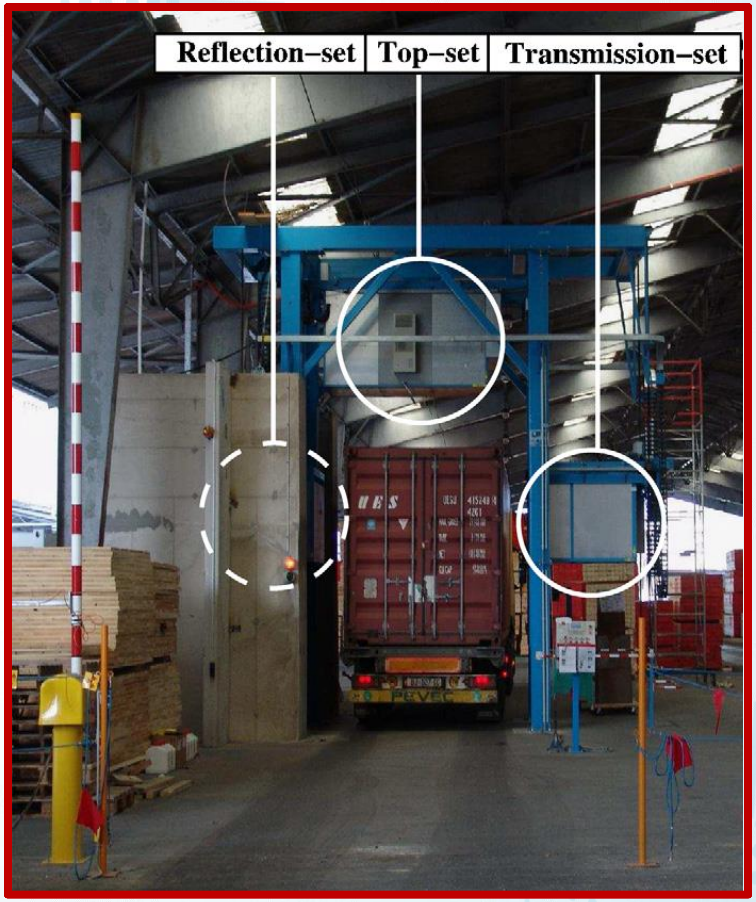
Explosives are identified by means of fast neutron interrogation given their peculiar carbon-to-oxygen (C/O) and carbon-to-nitrogen (C/N) chemical ratios

In the d+t->α+n fusion reaction, a 14MeV neutron and an alpha particle are emitted almost back to back.

Reflection-set: the neutron generator, the associated particle detector, ….

Top-set: Shielded γ-ray detectors

Transmission-set: Shielded γ-ray detectors and a liquid scintillator,….



The C-BORD helping customs to inspect containerized freight

Within the framework of the C-BORD project, a new generation container inspection system is foreseen, combining advanced X-ray techniques capable of locating objects inside a large volume (cargo container) at a high rate, as well as additional techniques more sensitive to specific substances, such as advanced passive detection technologies, a tagged neutron inspection system, photo-fission technology and artificial sniffing. The data generated by the five technologies is collated in a single graphic user interface for customs decision-making.

This project has received funding from the European Union's Horizon 2020 research and innovation programme. With a budget of 11.8M€, involves 18 partners from nine countries.

Lecture by: Sandra Moretto

Sandra Moretto: Civil Security Application using neutrons.

Non-destructive analysis (NDA) of materials is a well-known technique applied in several fields of bulk material analysis. It is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage. In particular, we will focus on neutron based technique, like PGNAA (Prompt Gamma Neutron Activation Analysis), PFNA (Pulsed Fast Neutron Analysis), PFTNA (Pulsed Fast/Thermal Neutron Analysis), API (Associated Particle Imaging), FNGT (fast neutron and gamma transmission).

Rewriting nuclear physics text books: one more step forward

Similarly to the previous editions, the aim of the 2019 summer-school "Rewriting nuclear physics text books" is to introduce the best students to Nuclear Physics.

Nuclear Physics is a highly mature scientific field with many open scientific questions, some of them will be discussed in this school, and several experimental installations are under construction around the world.

One of the concerns for each scientist is how the technological know-how can help the society? And this question, of paramount importance, is also among the questions which will be addressed during this week.

DE LA RECHERCHE À L'INDUSTRIE

www.cea.fr

Thank you