

Experimental techniques in high-energy nuclear and particle physics

“Dottorato di Ricerca in Ingegneria dell’Informazione”

LECTURE 11.

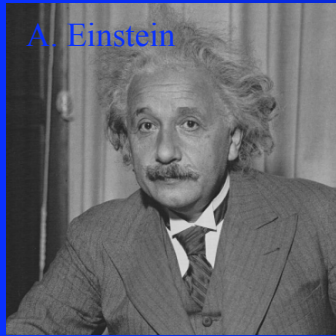
Prof. Rino Castaldi

INFN-Pisa

rino.castaldi@pi.infn.it

But what research in elementary particles, and its accelerators and detectors have to do with everyday life?

Fundamental research has always been a driving force for innovation

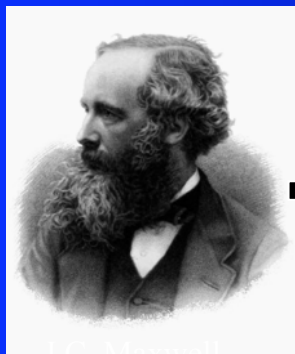


Relativity

100%
SCIENCE



For GPS to work, we have to take into account the correction due to time dilation. Otherwise, there would be a position error of around 10m after just 5 minutes of travel-time!



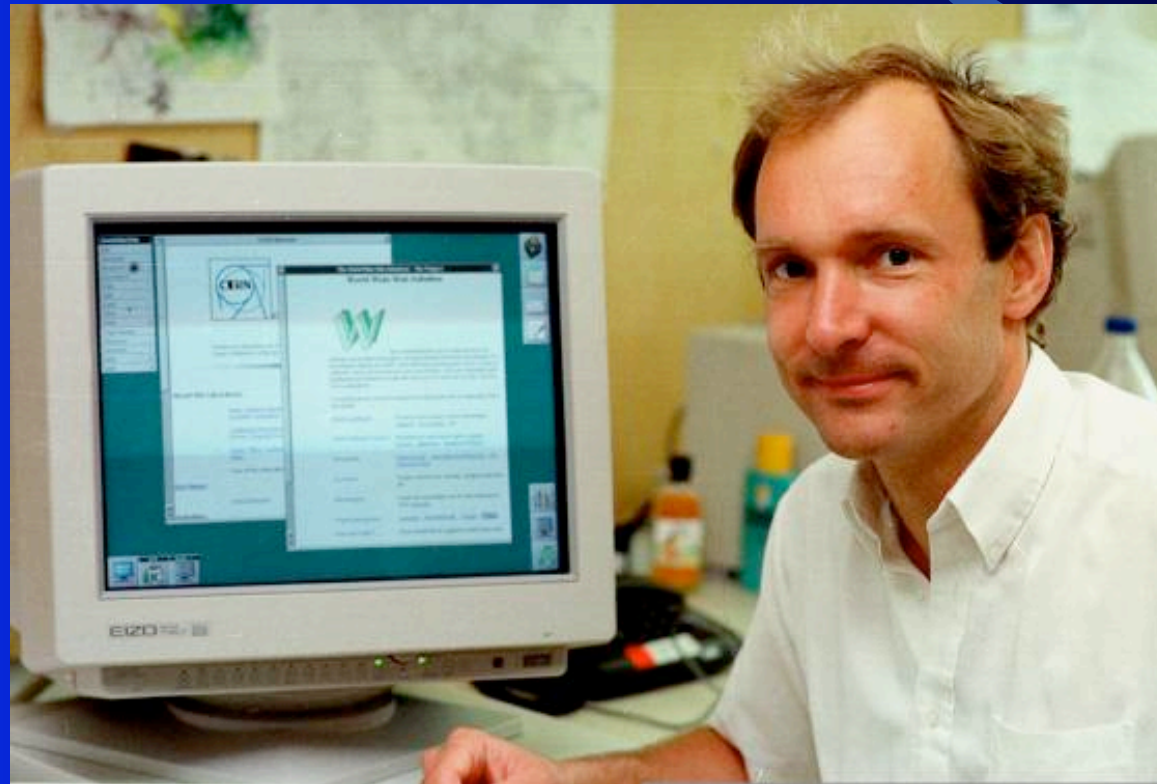
Electromagnetism

100%
SCIENCE



Telephones use electromagnetic waves to communicate

Other spinoffs include... **WWW**
>20 years old!



Accelerators: developed in physics labs & used in hospitals



Courtesy of IBA

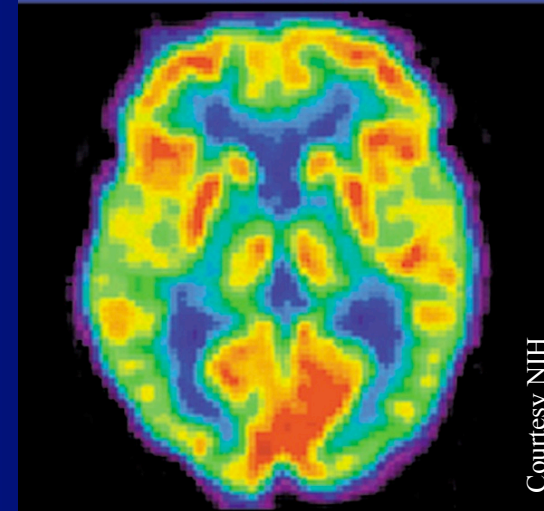
Around 9000 of the 17000 accelerators operating in the World today are used for medicine.

Hadron therapy is a growing method of treating tumours

Detectors: developed in physics labs & used for medical imaging



PET (Positron Emission Tomography) uses antimatter (positrons).



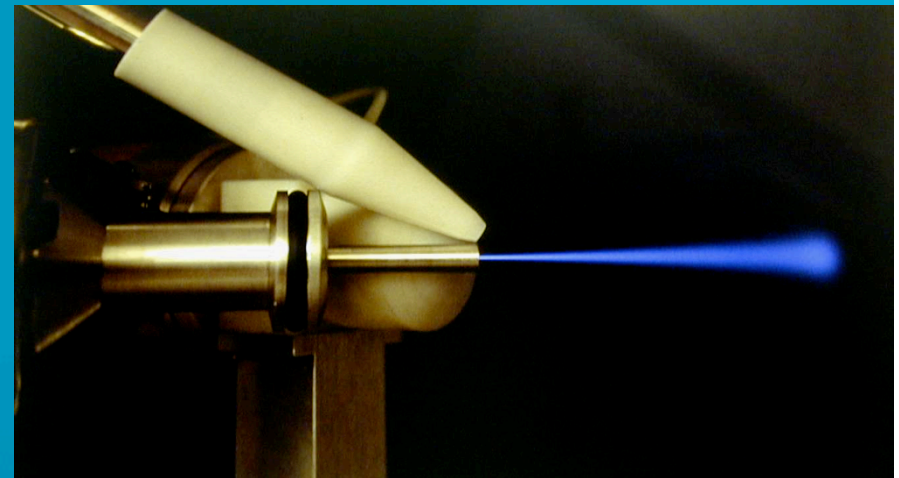
Courtesy NIH

Particle Accelerators in Art & Archaeology

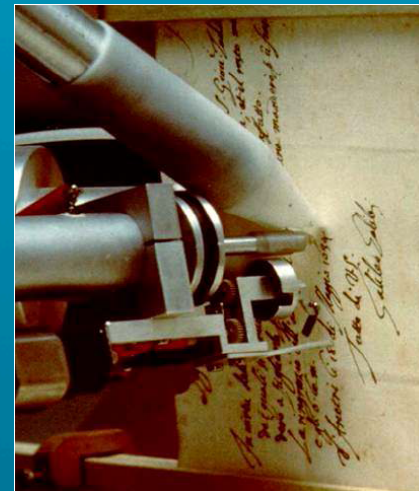
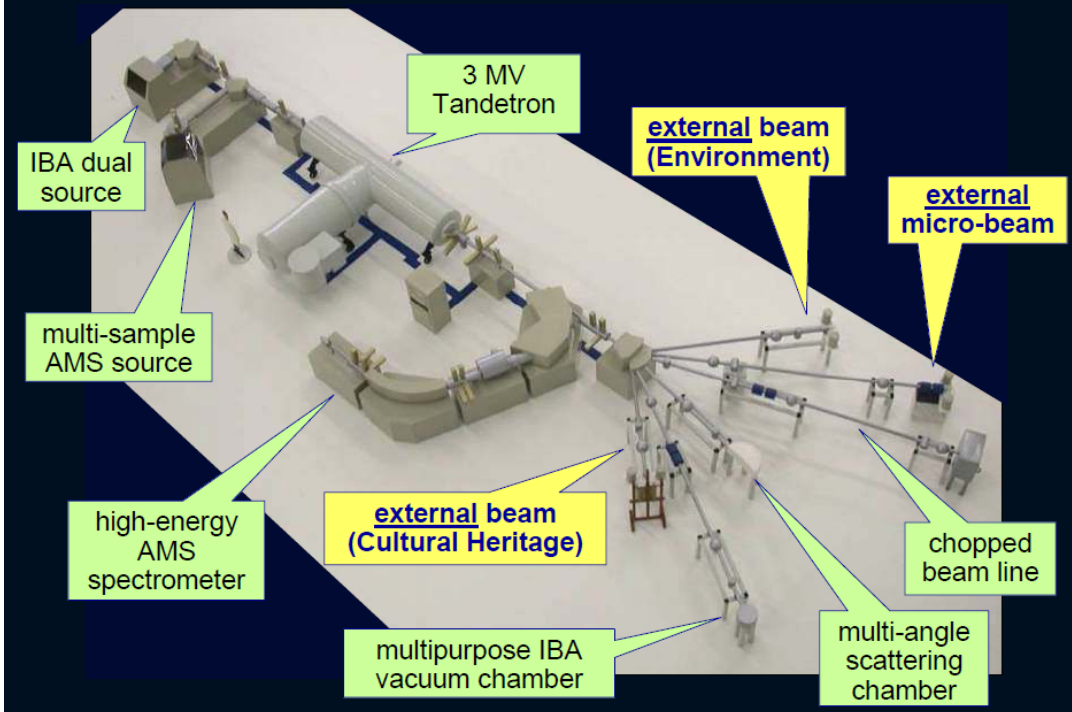


Pier Andrea Mandò

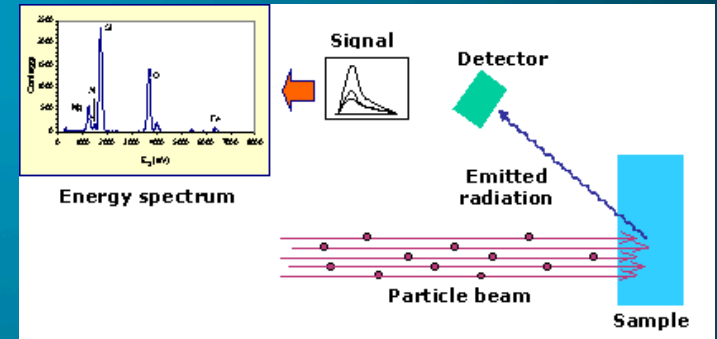
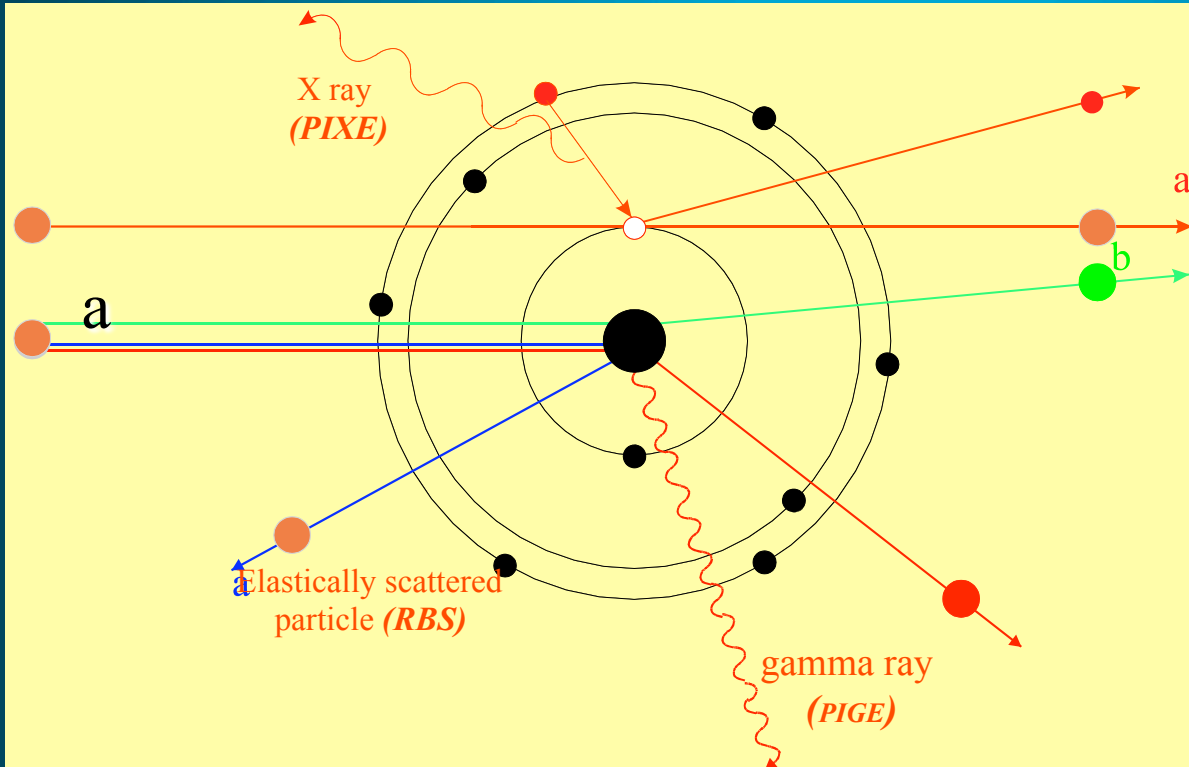
e-mail mando@fi.infn.it



La facility del Tandetron al LABEC



Ion Beam Analysis



Radiation to be detected
(X rays, γ , particles)

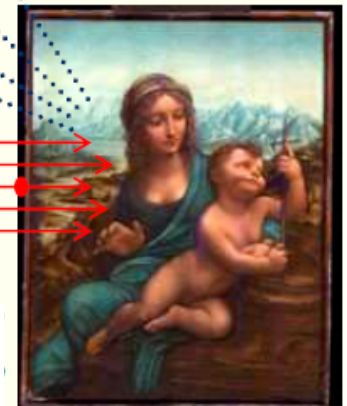
Powerful techniques for the compositional analysis of any material

Based on the emission of characteristic radiation, which is induced by accelerated particles, which bombard the material to be analysed :

X rays (PIXE), γ rays (PIGE), scattered particles (RBS),

Proton beam

Object under study





A letter of Galileo during PIXE analysis with the external beam at the Florence accelerator

Analysis of documents of historical interest

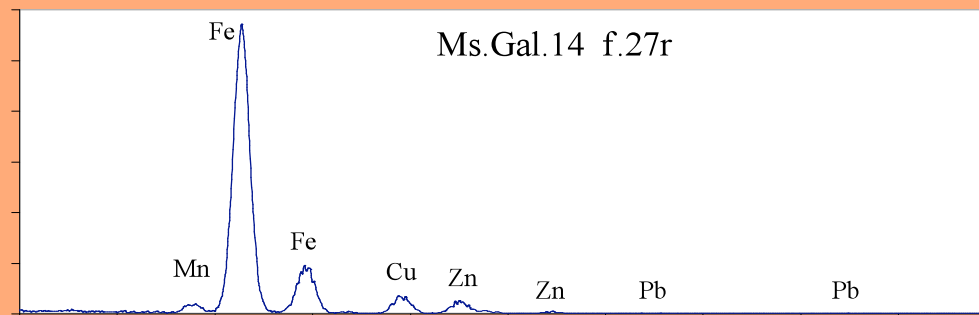
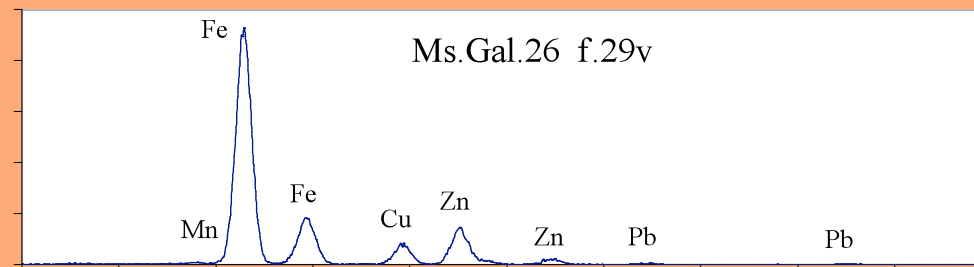
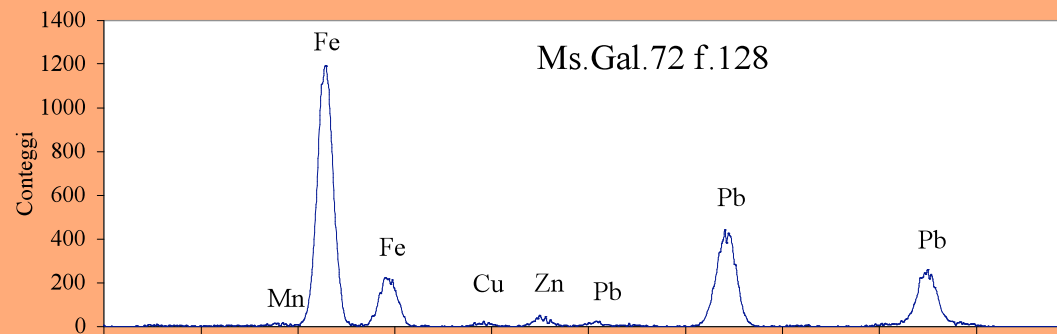
(INFN FI, Bibl.Naz. FI, MPI Berlin)

PIXE measurements to quantitatively determine ancient inks composition

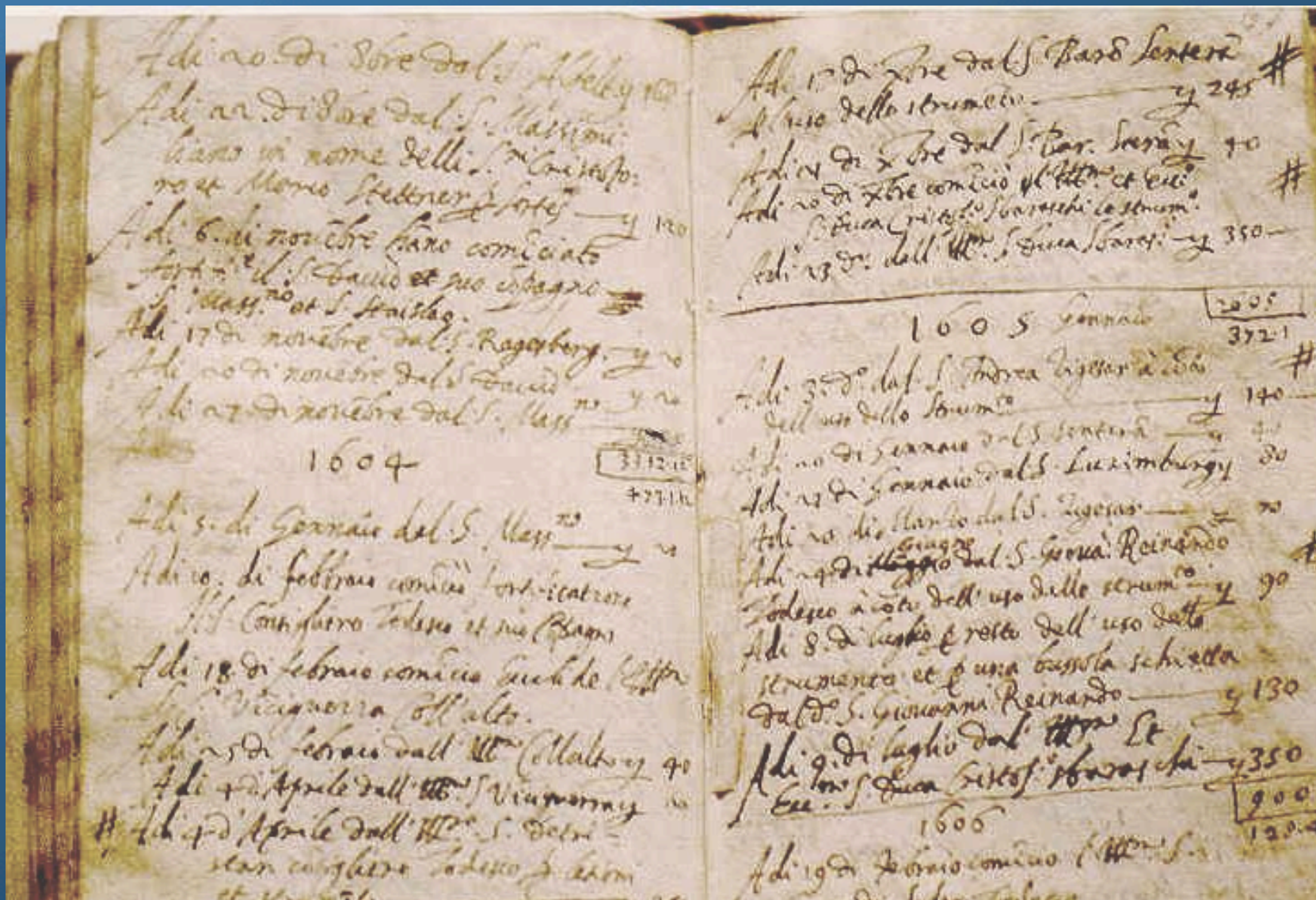
Important contribution to the chronological reconstruction of Galileo's hand-written notes about motion

Comparison of ink composition in the notes (which are not dated) with that in dated documents (letters, etc.)

Discriminating between different inks with PIXE



A precious database of dated inks: the “agenda” of Galileo (Ms. Gal.26)





Analysis of paintings on wood on canvas

*Understanding the
“secrets” of painting
techniques of famous artists
and/or reconstructing the
history of a specific painting
(possibility to be a forgery,
previous restorations, etc.)*

*PIXE, differential PIXE and PIGE
analysis of the*

Madonna dei Fusi, by Leonardo

*Universal Leonardo Project,
coordinated by OPD Firenze*



PIXE analysis of the “Ritratto di fanciullo” by Luca Della Robbia – before restoration at the Opificio delle Pietre Dure in Florence

Analysis of ceramics

Collaboration Louvre – Opificio Pietre Dure – INFN Genova, Firenze, LNS

Production techniques of the glazed terracottas by the Della Robbia’s

Characterisation of the schools of Andrea, Luca, their sons and imitators

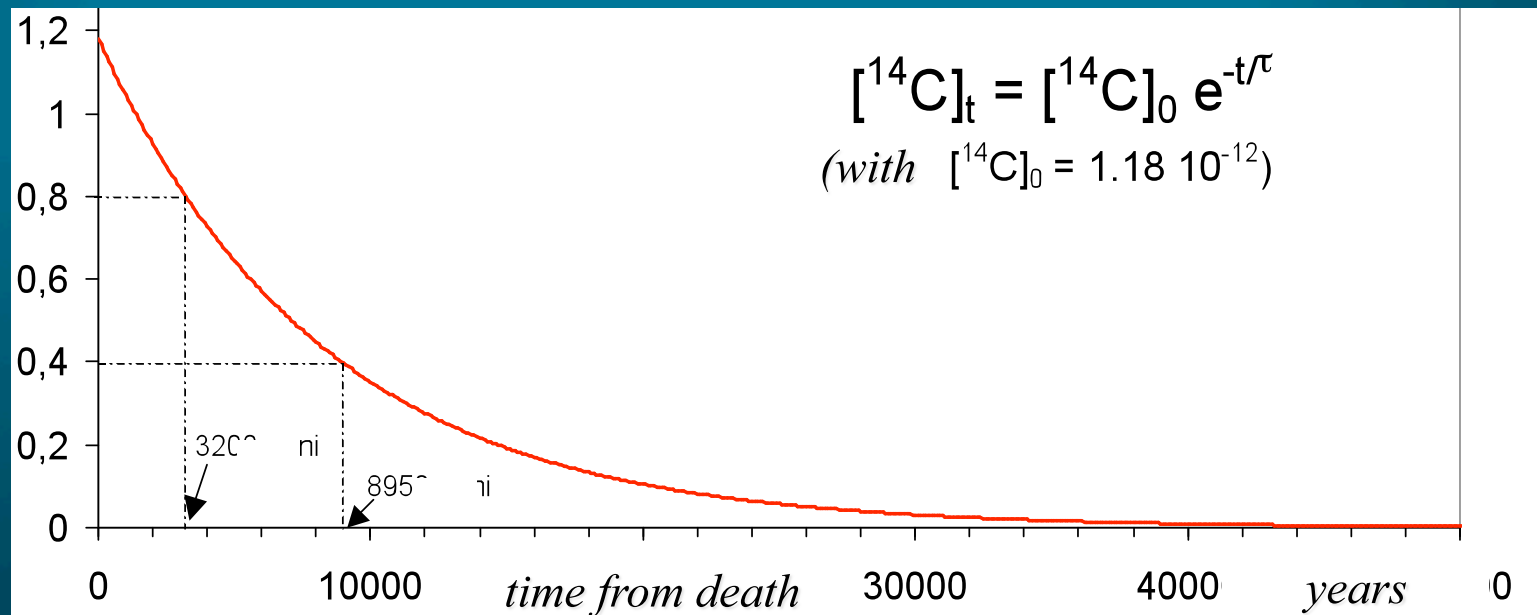
Changes in the raw materials employed, correlated with time, have been pointed out

Accelerator Mass Spectrometry (AMS)

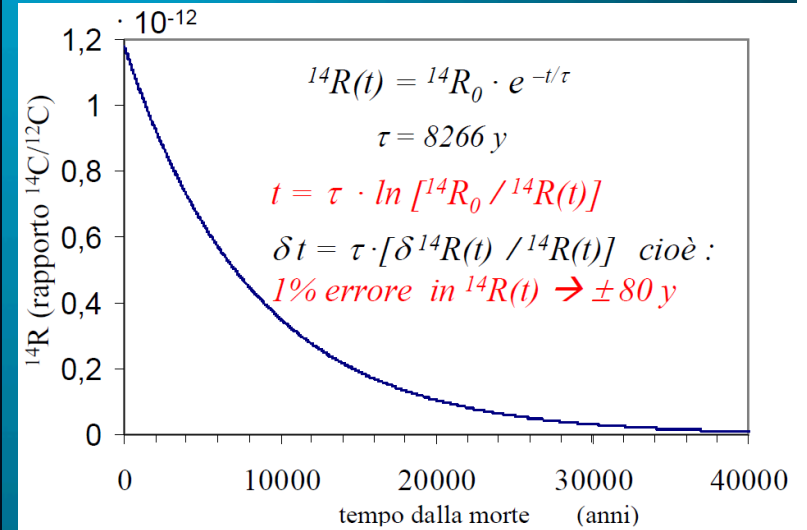
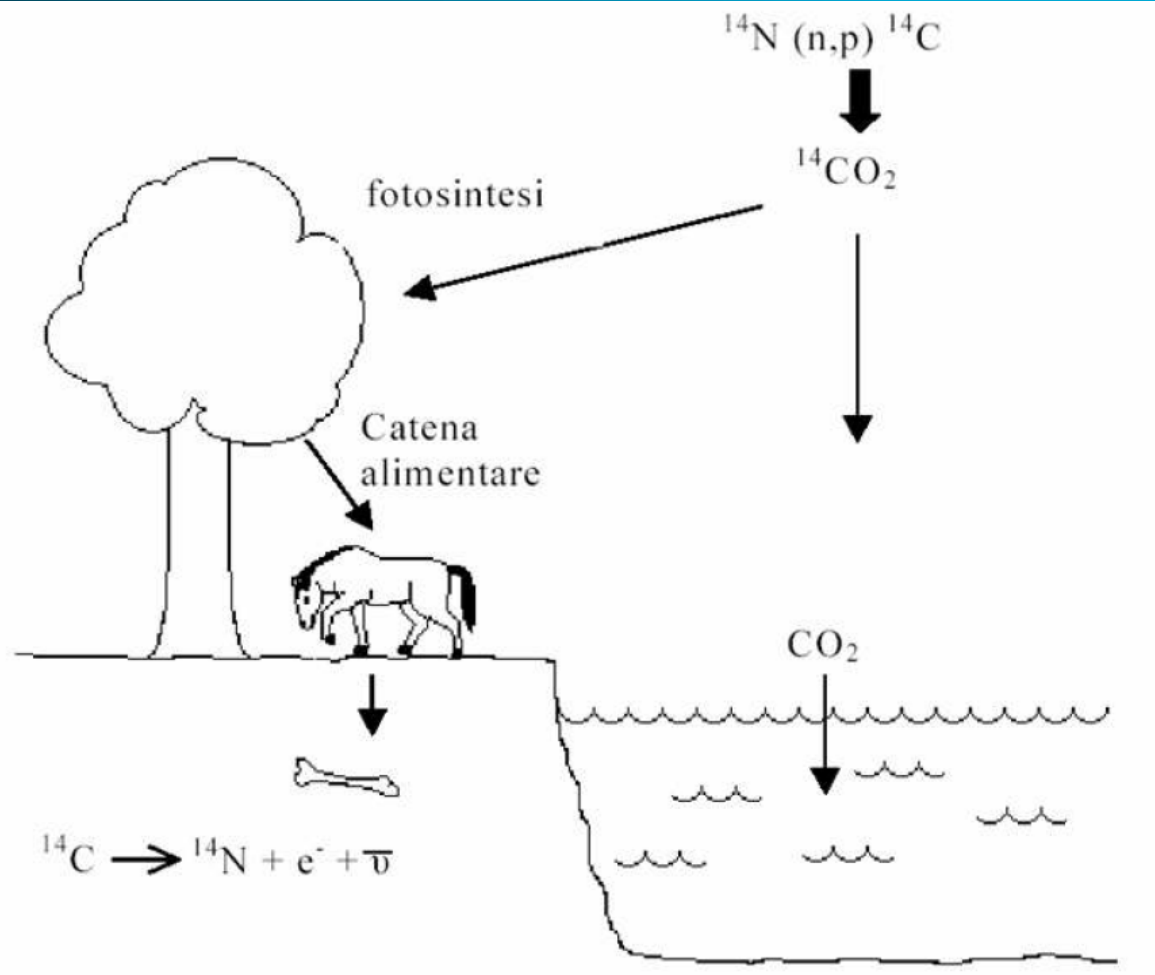
- *a very sophisticated technique which detects rare isotopes*
 - *extraordinary sensitivity*
 - *measurement of ^{10}Be , ^{14}C , ^{26}Al , ^{129}I and other radioisotopes of archaeological, geological, environmental interest*

^{14}C dating principle

- ^{14}C is a radioactive isotope ($T_{1/2} = 5730 \text{ y}$)
- Its decay is compensated by a continuous production in the troposphere due to cosmic rays
- An equilibrium concentration of ^{14}C is established ($\sim 1.2 \cdot 10^{-12}$) in atmosphere and in all living organisms
- When an organism dies, its ^{14}C concentration starts to decrease with the law of radioactive decay



^{14}C dating principle



How ^{14}C can be measured

$$|dN/dt| = \lambda N$$

β -counting

mass spectrometry

large sample masses (10÷100 g)
and long counting times (hours or
even days) needed

“standard” mass spectrometry is
not sufficiently sensitive

Accelerator Mass Spectrometry

Ultra-high sensitivity (10^{-15})

→ dating range up to 50000 years

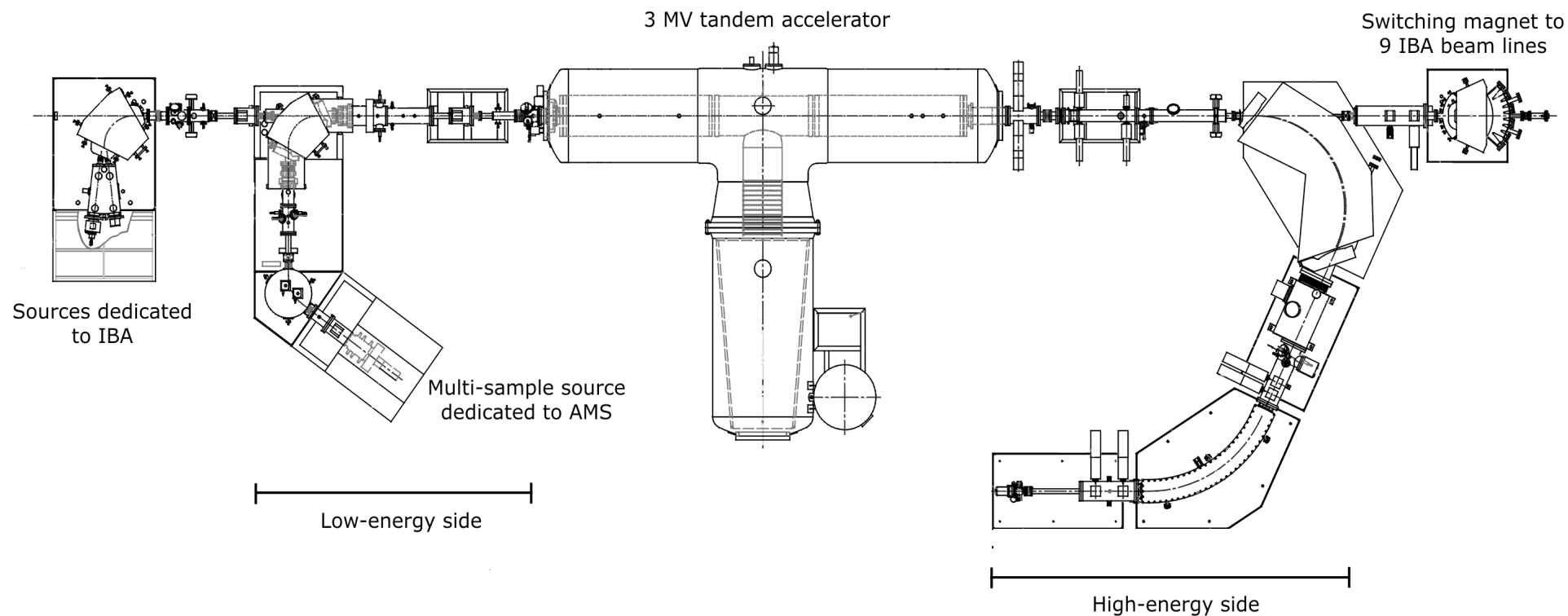
→ mass of a sample needed for dating ≤ 1 mg

Accelerator Mass Spectrometry (AMS)

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^{14}C measurement with AMS

Stripping at HV terminal
(eliminates interference
of ^{13}CH , $^{12}\text{CH}_2$)



Negative ion source
(eliminates interference
of ^{14}N)

Final analysis of high energy ions
(removes residual interferences)

A Franciscan relic: the frock from Cortona



front side



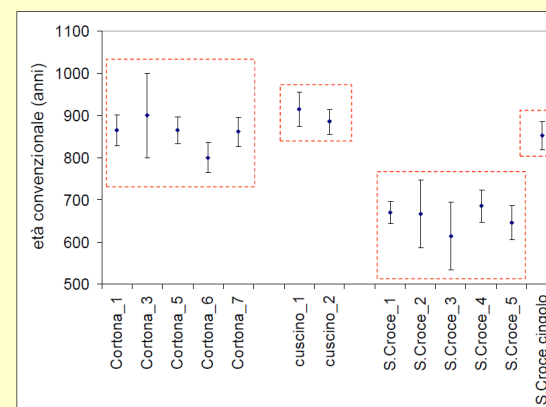
back side

Following tradition, worn by the Saint while passing away

Also dated two fragments from the pillow, on which tradition tells St. Francis was leaning his head while passing away



Results



The S.Croce frock in Florence

For comparison, we were also asked to date another frock, kept in the church of S.Croce in Florence: it was also assumed to have belonged to St. Francis



davanti

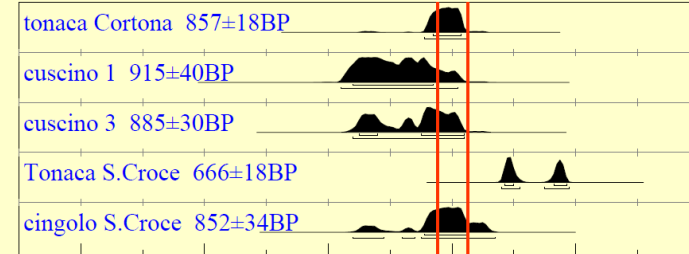
SFF3



dietro

A sample was also picked up from the rope belt assumed to be associated with the frock (sample SFF6)

Atmospheric data from Reimer et al (2004); OxCal v3.10 Bronk Ramsey (2005); cub r:5 sd:12 prob usp[chron]



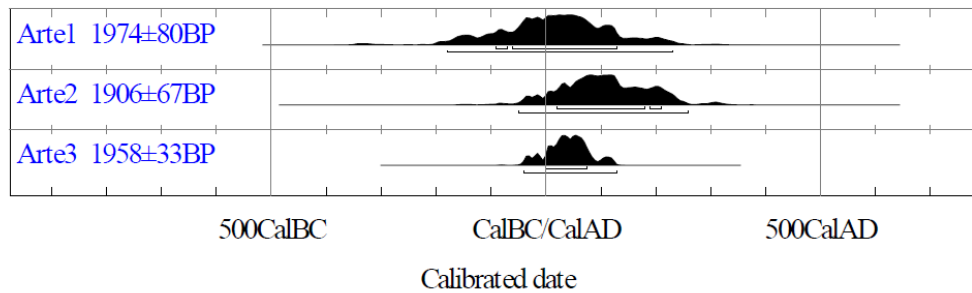
600CalAD 800CalAD 1000CalAD 1200CalAD 1400CalAD 1600CalAD

Calibrated date

Dating the "Arthemidorus papyrus"



Atmospheric data from Reimer et al (2004); OxCal v3.10 Bronk Ransey (2005); cub r5 sd:12 prob usp[chron]



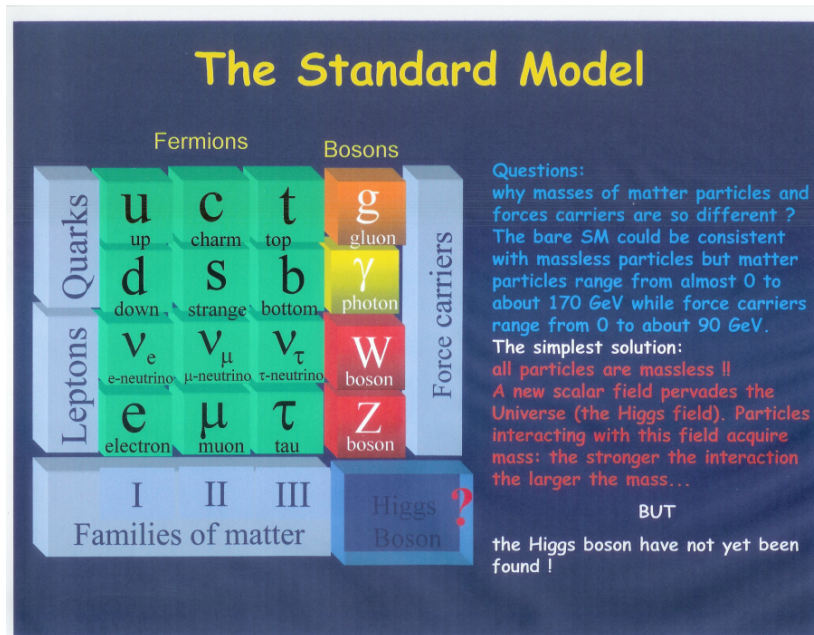
Calendar date of the papyrus

between 15 AD and 85 AD (1σ confid. level)

between 40 BC and 130 AD (2σ confid. level)

Conclusions

Basic research on elementary particle physics is trying to answer fundamental questions about how the Universe works



The Standard Model is one of the most successful theories tested so far but many questions are still without an answer.

- * What is the origin of the mass of quarks, leptons and force carriers ?
- * Why matter is made of fermions and force carriers of bosons ?
- * What is the dark matter (and dark energy), which pervades the Universe ?
- * Why our World is made with matter and how the antimatter disappeared ?
- * Why the interactions are so different in strenght and why Gravity cannot be included in our SM theory?
- * Are quarks and leptons fundamental particles or have they internal structures ?

We believe that the answer to some of these questions is probably hidden in the so far unexplored TeV region which will become accessible with the CERN Large Hadron Collider (LHC)

This basic research requires the use of cutting-edge technologies and instrumentation and therefore stimulates advances in technology which may have big impact on the everyday life.