

# *LABEC, Florence*

*Laboratory of Nuclear Techniques for  
Environment and Cultural Heritage*



# In Florence....



long standing tradition with **PIXE**  
(and **IBA** in general) applied to **Cultural Heritage**



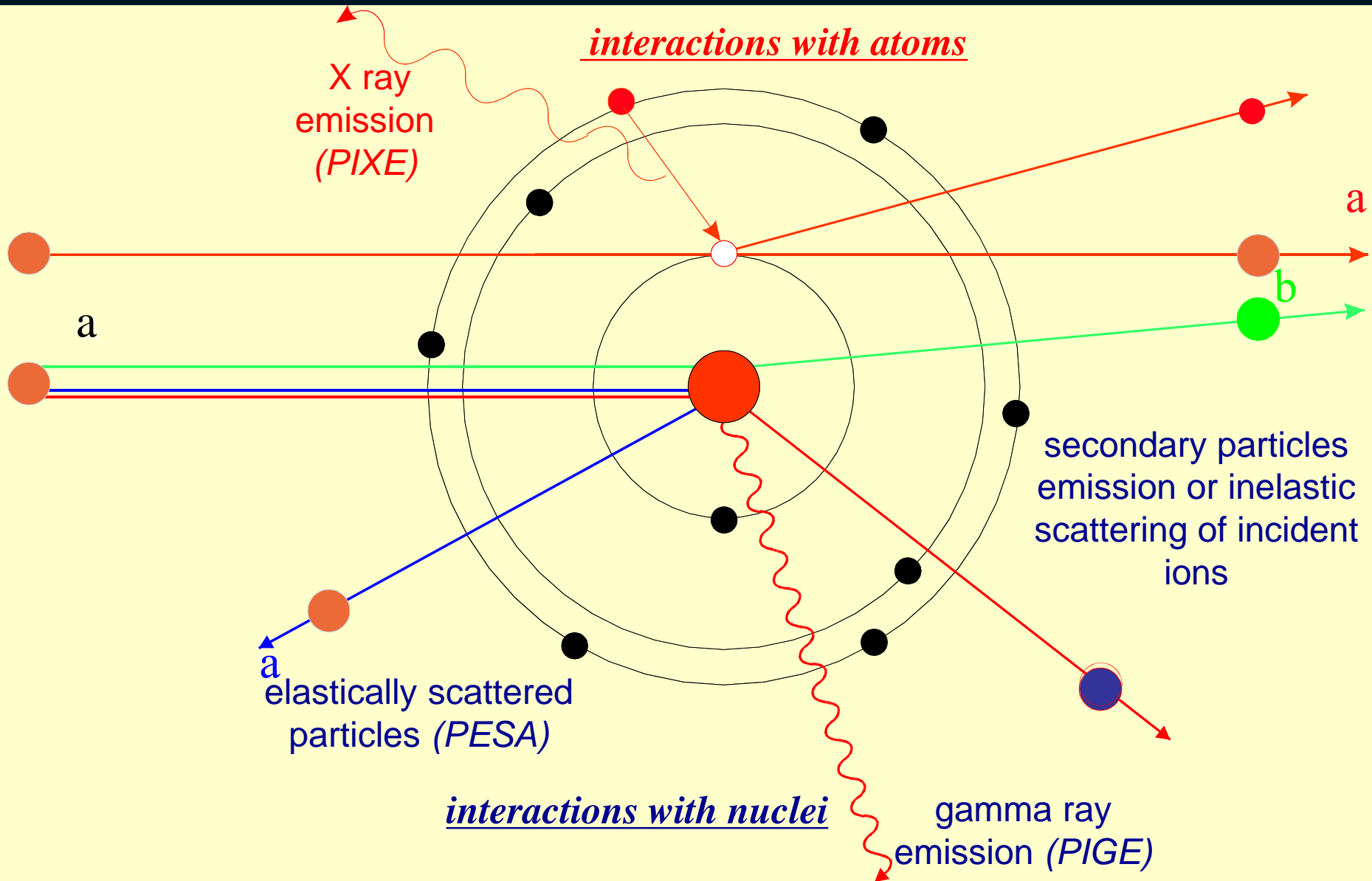
This applied physics activity started during the Eighties with an old 3 MV Van de Graaff single-ended accelerator

Until then, basic nuclear physics activities had been still carried out with this accelerator

Since the mid 1980's its "research goals" were changed to applications of Ion Beam Analysis, IBA (mostly Particle-Induced X ray Emission, PIXE)



# Particle – atom/nucleus interactions





# 2002-2003

*move of the Physics Department and INFN  
Unit to a new campus*

- *INFN and University create a new lab*
- *new 3 MV Tandetron, designed from the beginning to perform Accelerator Mass Spectrometry (AMS) besides IBA*
- *the new laboratory, LABEC, is operational  
in May 2004*



**INFN**  
**LABEC**

Laboratorio di Tecniche Nucleari  
per i Beni Culturali - Firenze

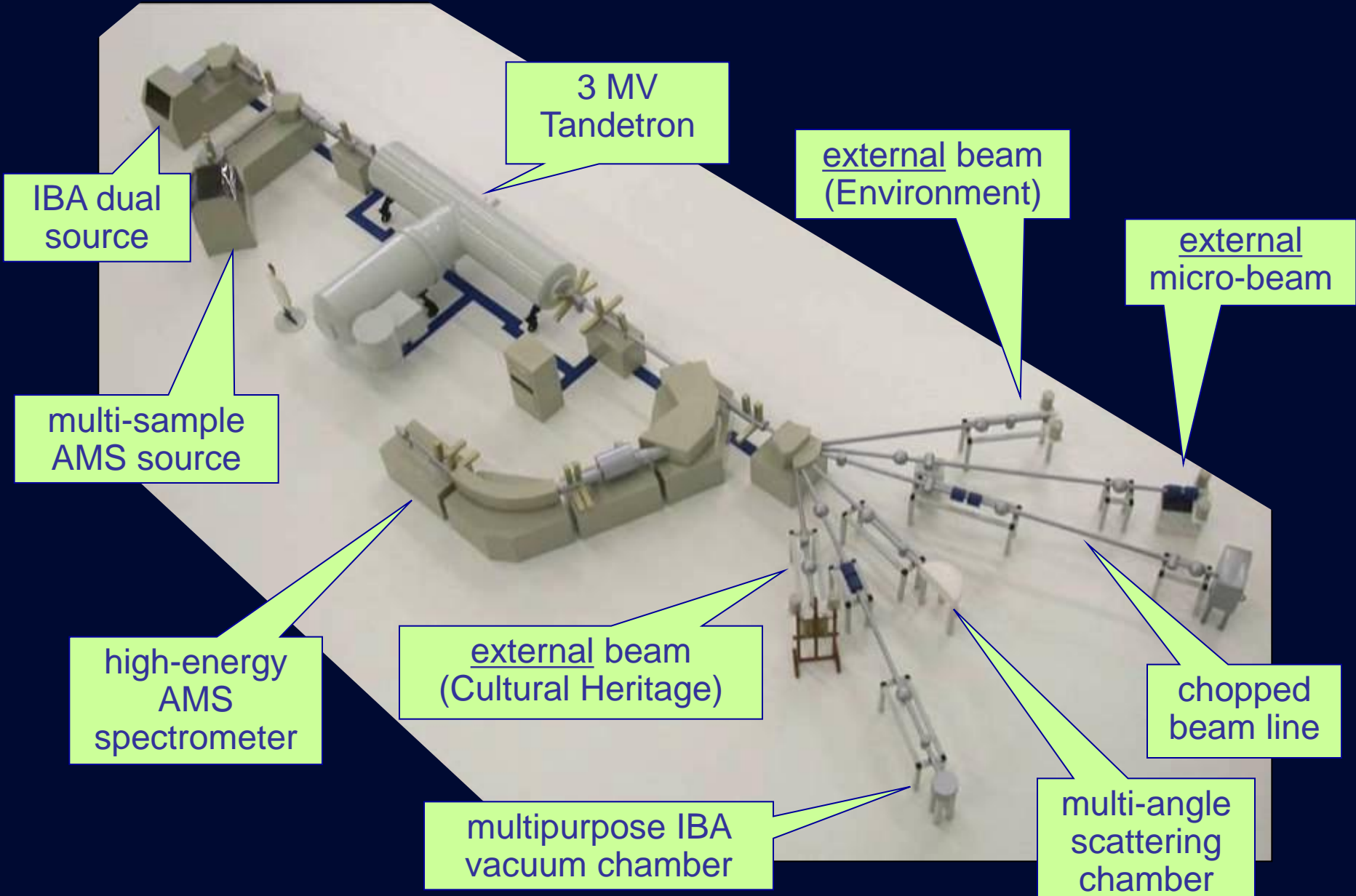


**Polo  
Scientifico**  
UNIVERSITA' DEGLI  
STUDI DI FIRENZE

*<http://labec.fi.infn.it>*



# The Tandetron facility at LABEC



# Activities at LABEC

technological developments (electronics and process automation, data acquisition systems, detection setups, further beamlines)

methodological developments (test of new ideas for application procedures)

measurements in the framework of both:

interdisciplinary research projects in collaboration with other Institutions (CNR, Cultural Heritage safeguard Institutions, Environmental Protection Agencies, IAEA) and University Departments other than Physics Dpts

“internal” collaborations supporting other nuclear physics groups (detector tests, radiation damage measurements, etc.)

# LABEC personnel

Franco Lucarelli (head of the lab)

+ 6 physicists and 1 technician  
permanent staff

+ 5 to 8 PhD students or post-docs

# Beam time

25-30% AMS

30% IBA for environmental problems

30-35% IBA for Cultural Heritage and  
other applications

10% other

# AMS at LABEC

The low-energy and high-energy AMS lines are equipped with the necessary hardware to implement the measurement of  $^{14}\text{C}$ ,  $^{10}\text{Be}$ ,  $^{26}\text{Al}$  and  $^{129}\text{I}$

however so far, at LABEC AMS only for  $^{14}\text{C}$   
 $^{14}\text{C}$ , in turn, mainly for dating purposes

*~ 400 samples/year*

*Standard precision < 0.5%*  
*(< 0.3% when required)*

*Overall background: ~ 55000 y equivalent*



Etruscan site diggings in Southern Tuscany

River sediments – the Abak Creek layers in Ethiopia



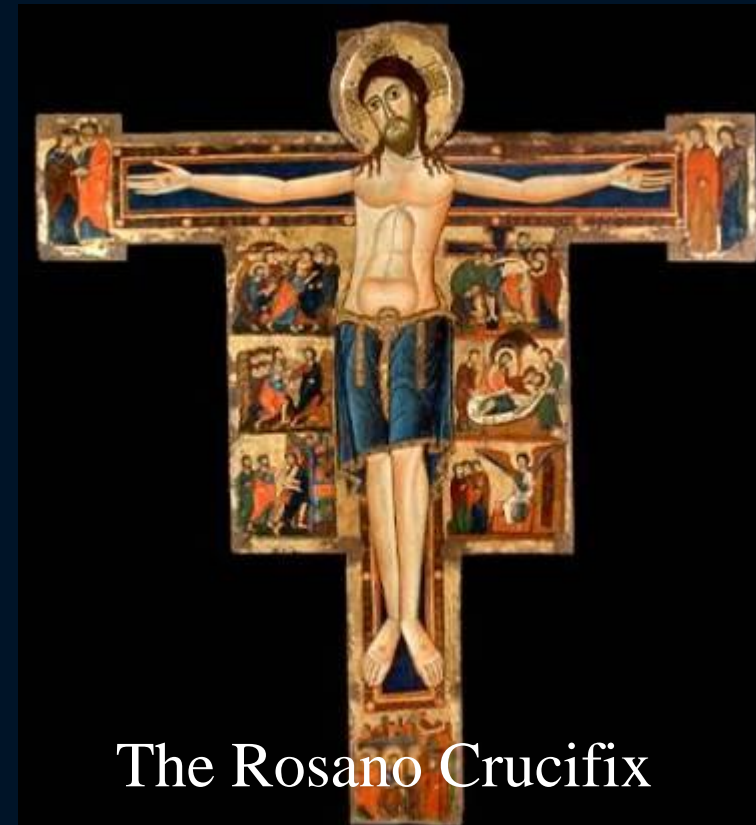
Archaeological diggings in downtown Florence (Palazzo Vecchio and surroundings)



# Artemidorus papyrus



The frame of a triptyc by Ambrogio Lorenzetti

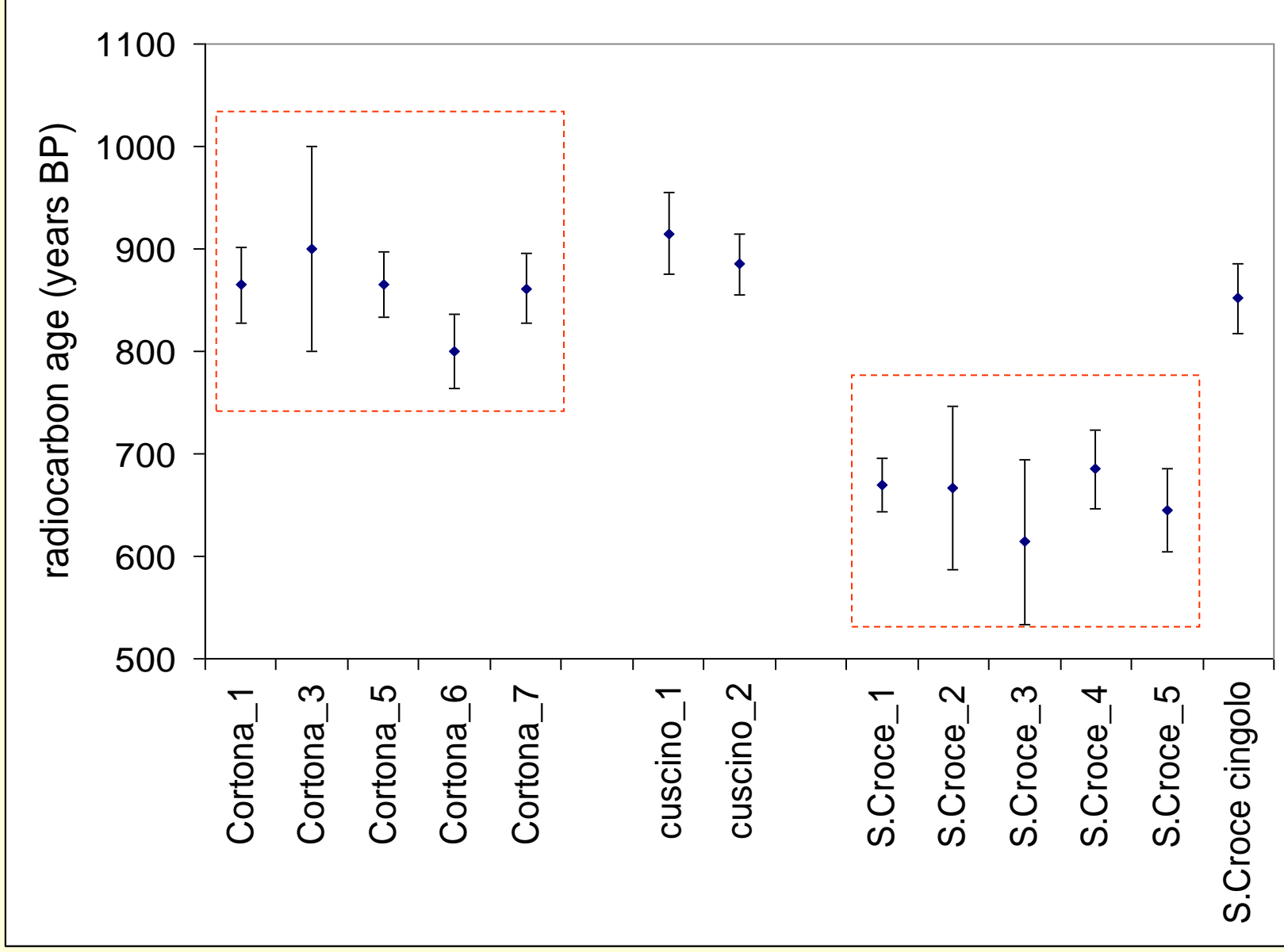


The Rosano Crucifix

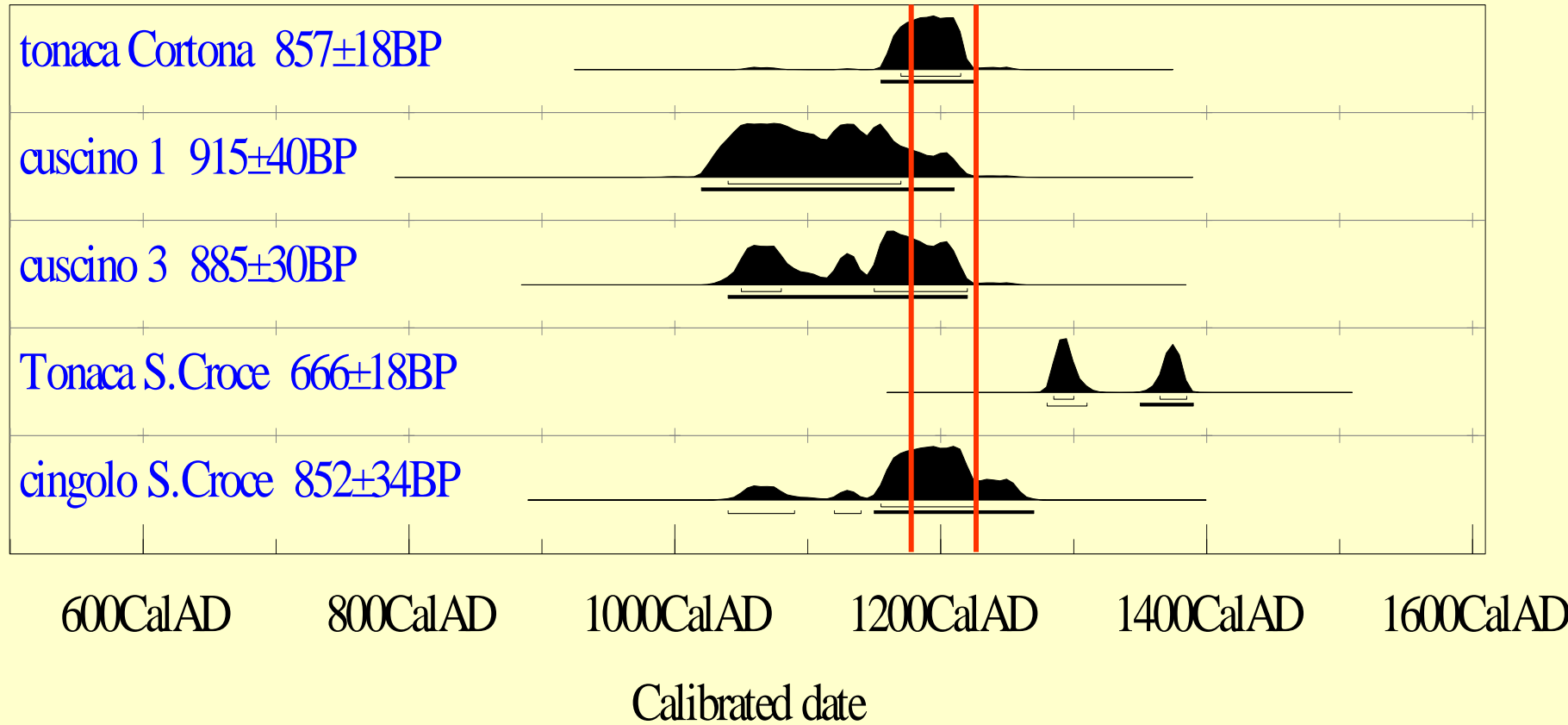
# St. Francis' relics in Cortona and Florence



# Results

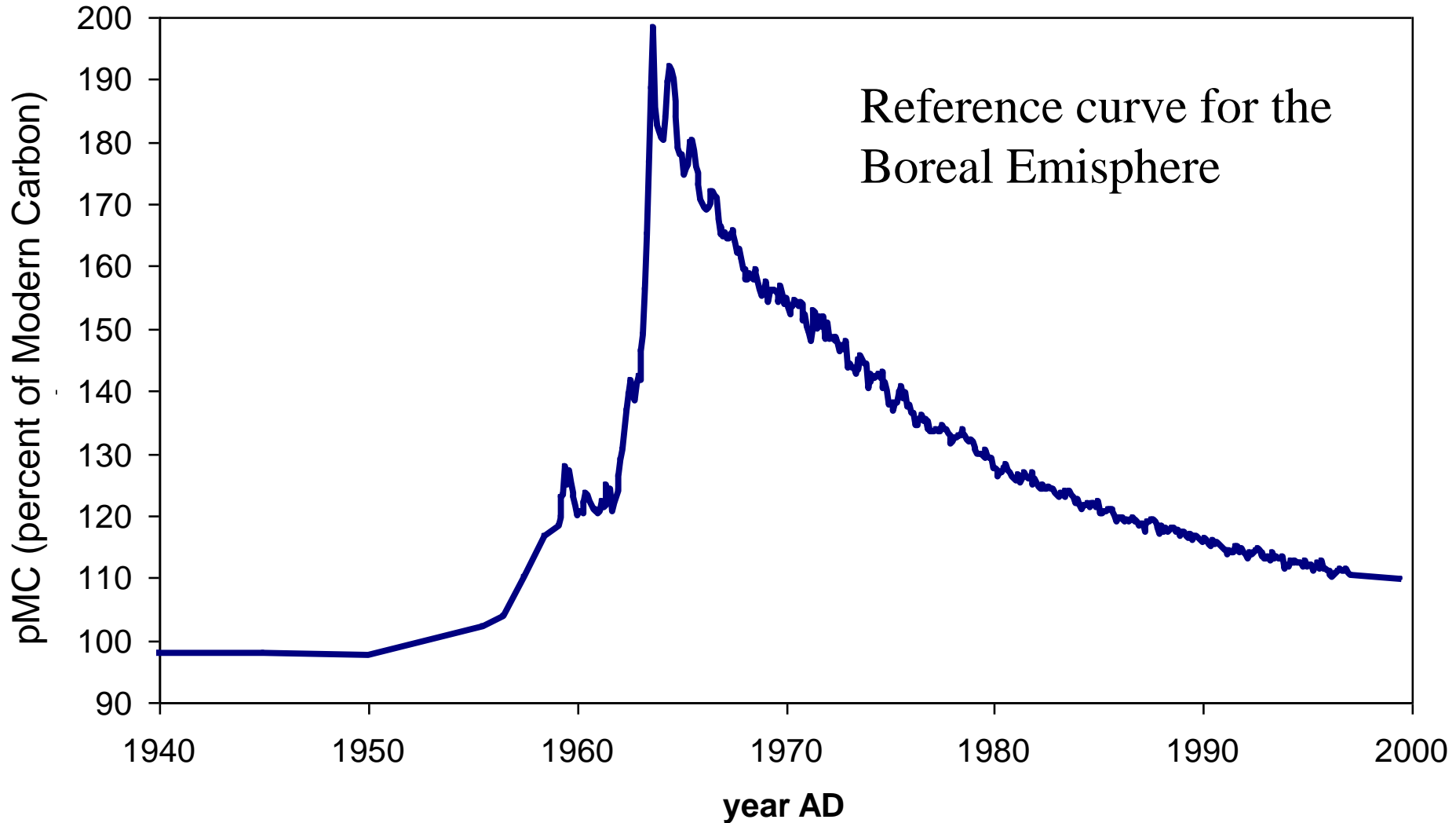


Atmospheric data from Reimer et al (2004);OxCal v3.10 Bronk Ramsey (2005); cub r:5 sd:12 prob usp[chron]





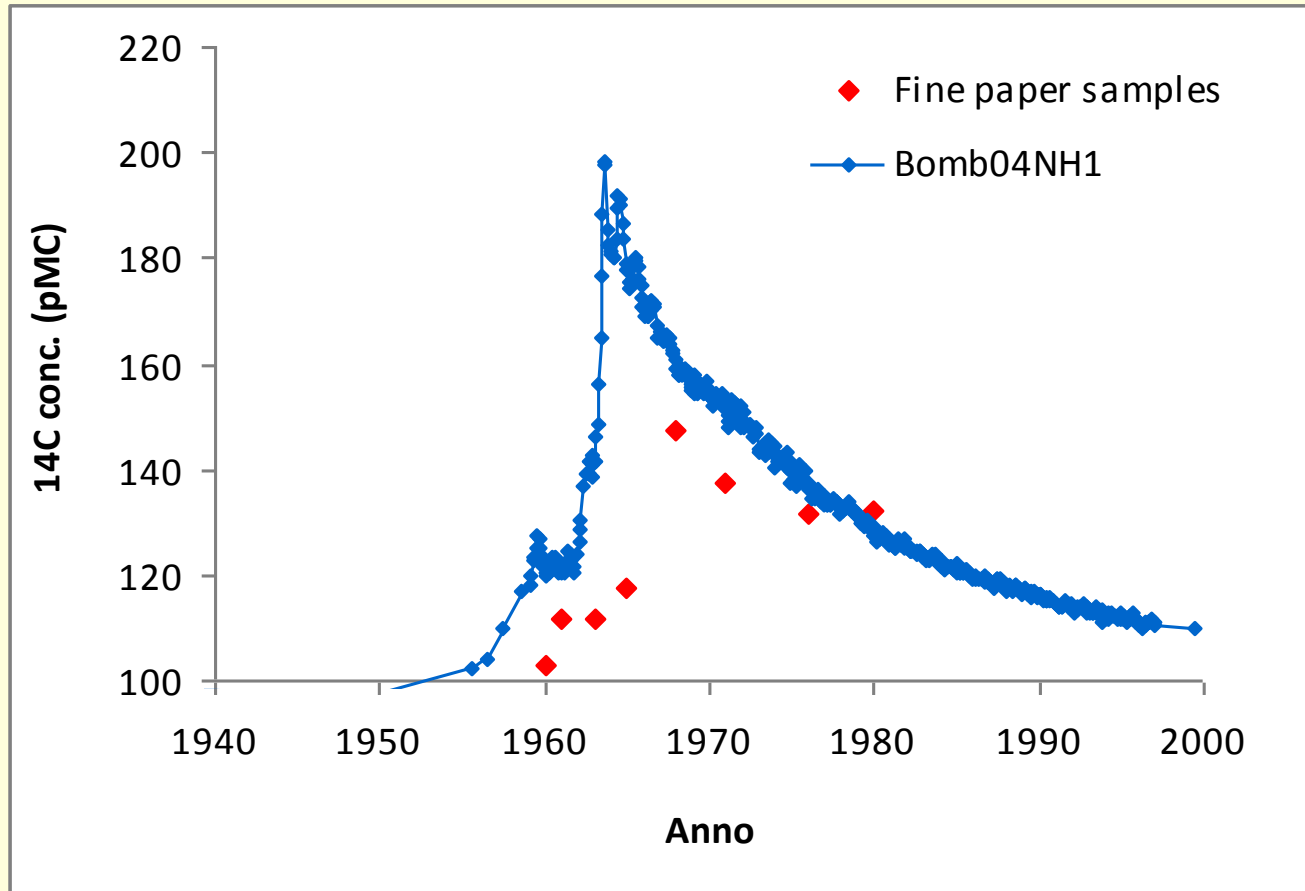
# *Exploiting the effect of nuclear explosions in atmosphere during the cold war*



Many interesting applications in forensics  
and biology,

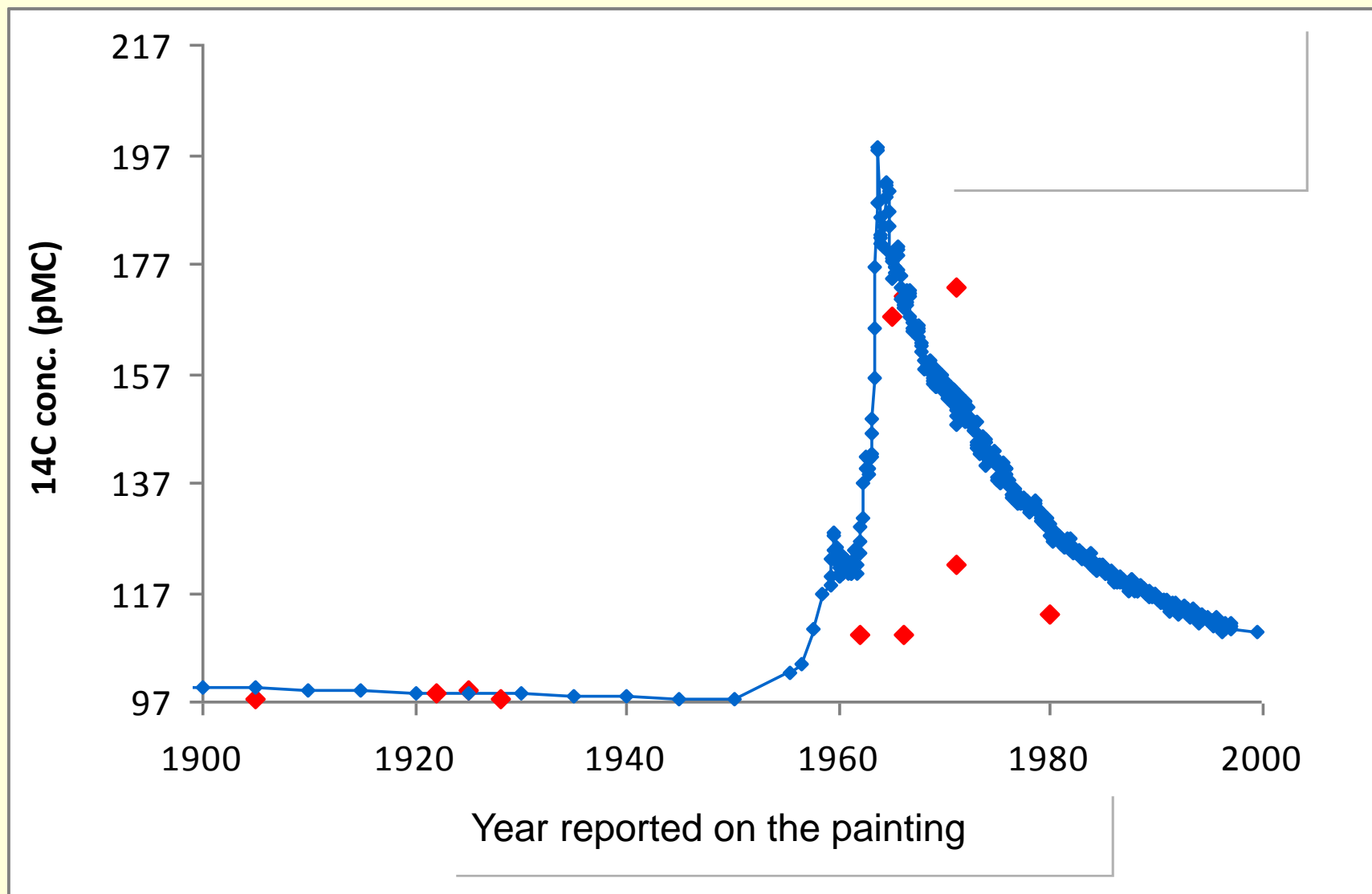
but these rapid variations can also be  
used to discover recent fakes of  
contemporary art e.g. from the first  
half of the XX century

# Samples of fine paper produced in different years



The date found must be compatible with at least one date prior to production

# Canvas samples from dated paintings





But...if the painting support is only compatible with a later period...

A canvas sample from a painting initially attributed to Fernand Léger

# Atmospheric aerosols

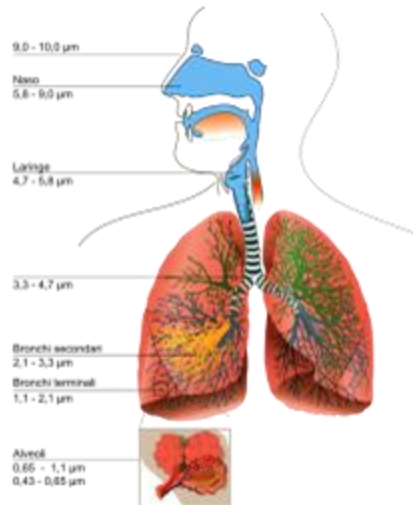
Solid or liquid particles with a diameter from  $10^{-3}$  to  $10^2 \mu\text{m}$

- natural or anthropogenic sources
- primary or secondary origin

## Impact on the environment



## Impact on human health



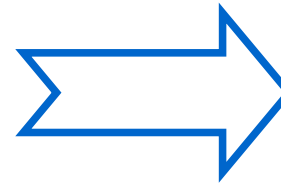
## Impact on cultural heritage



# What do we need to study aerosols

Many good data concerning:

- PM concentration and composition
- size distribution
- optical properties
- time and space evolution



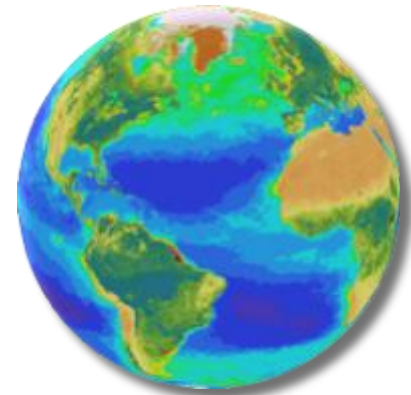
Quantification and identification of PM emissions sources

**OUTPUT**

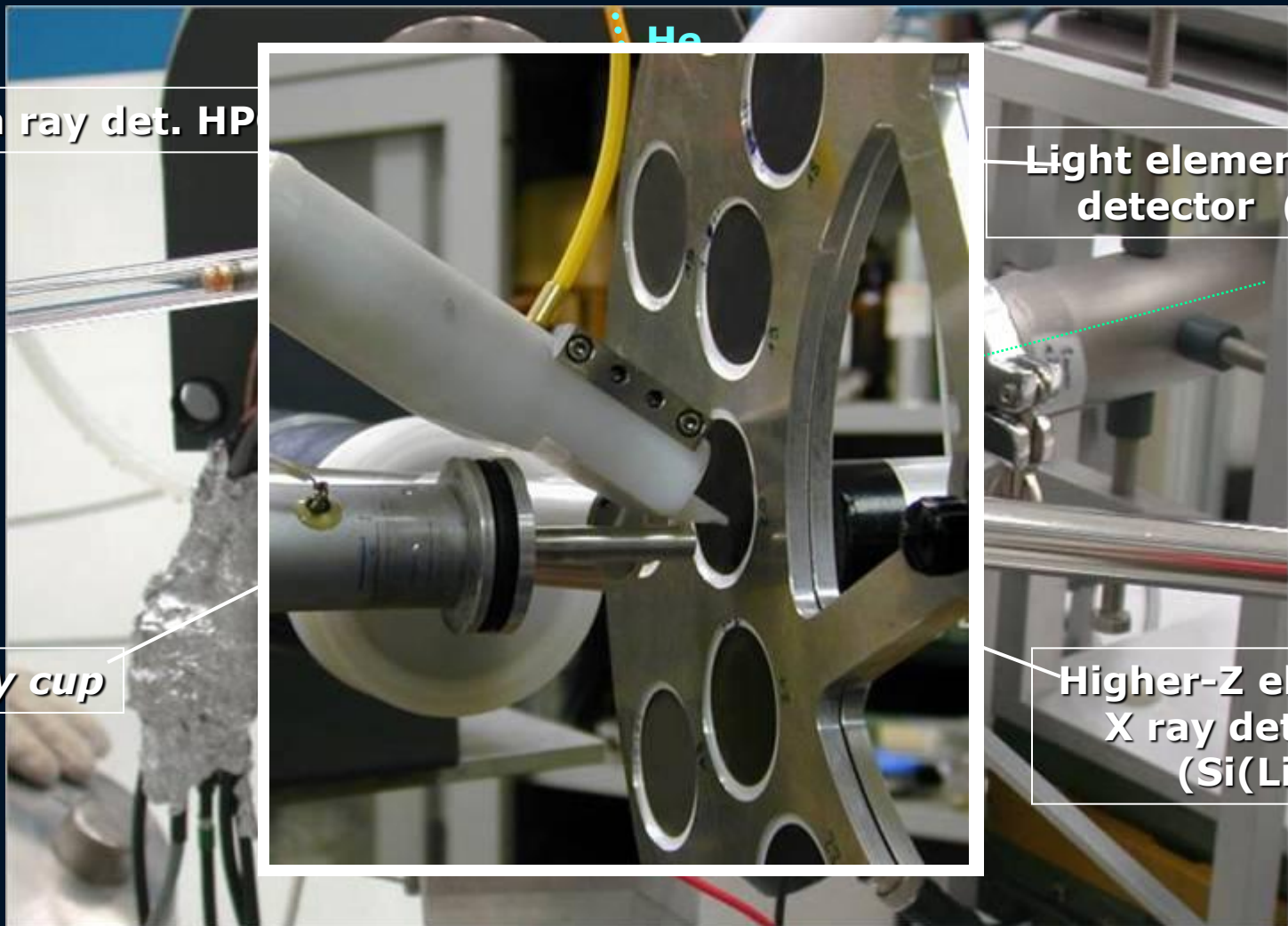


Contribution to pollution abatement policies to improve air quality

Contribution to climate models to assess the role of atmospheric aerosols in radiative forcing



# PIXE-PIGE external set-up at LABEC for aerosol composition measurements



**Gamma ray det. HP**

**Faraday cup**

**Light elements X ray detector (SDD)**

**Higher-Z elements X ray detector (Si(Li))**

# LABEC aerosol group research projects

## Local impact:

- Study of PM10, PM2.5 and PM1 in Tuscany (**PATOS, PATOS 2**) and in major Italian towns, Barcelona, Sevilla, Elche, Alicante, London, Japan

## Global impact:

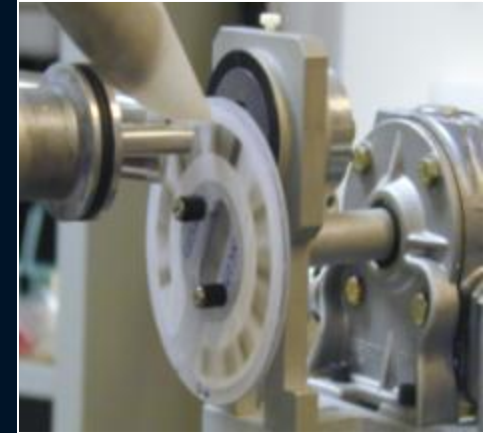
- **EPICA** - *European Project for Ice Coring in Antarctica*
- **TALDICE** - *TALos Dome Ice CorE*
- **ANDRILL** - *Antarctic Geological Drilling*
- **AMMA** - *African Monsoon Multidisciplinary Analysis*
- **MAIL** - *Marine Aerosol in the Island of Lampedusa*
- **DIRIGIBILE ITALIA** (multidisciplinary study of climate change in Arctic region)

## Environmental monitoring at cultural heritage sites

## Indoor pollution/Personal exposure:

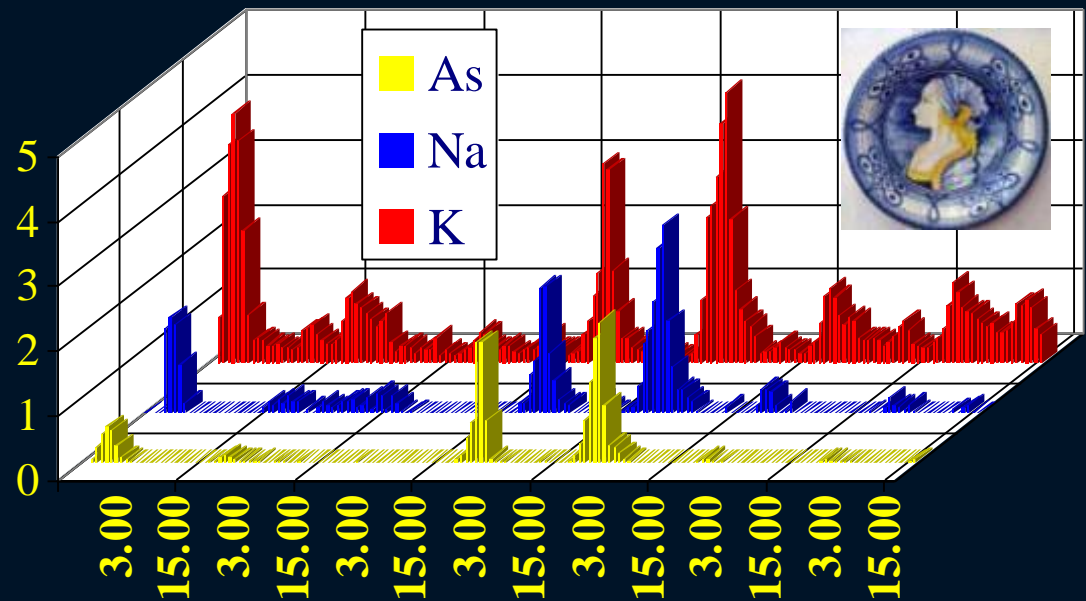
- **HEARTS** - *Health Effects And Risks of Transport Systems*

# Continuous streaker sampler

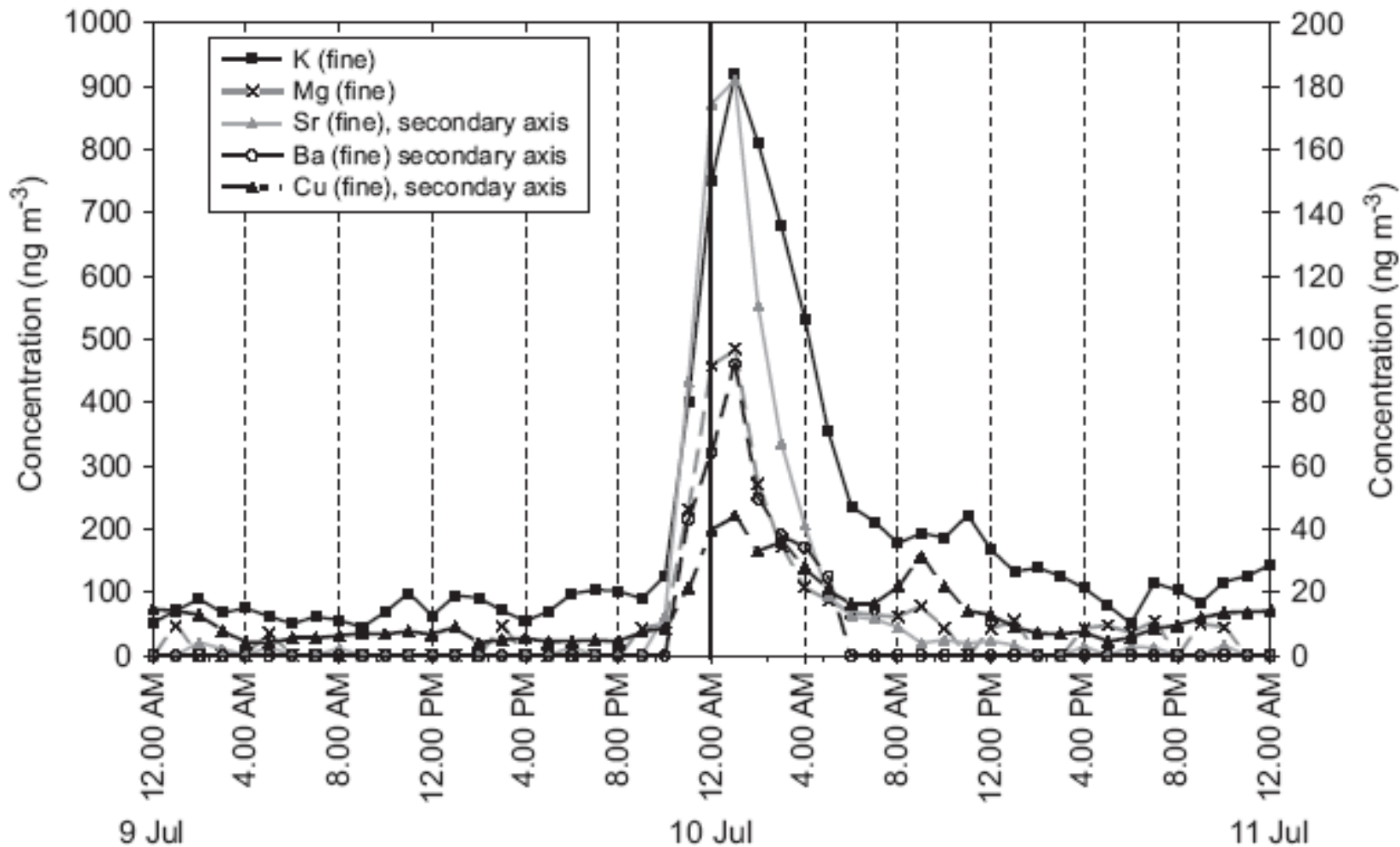


## Montelupo Fiorentino: artistic glass industry

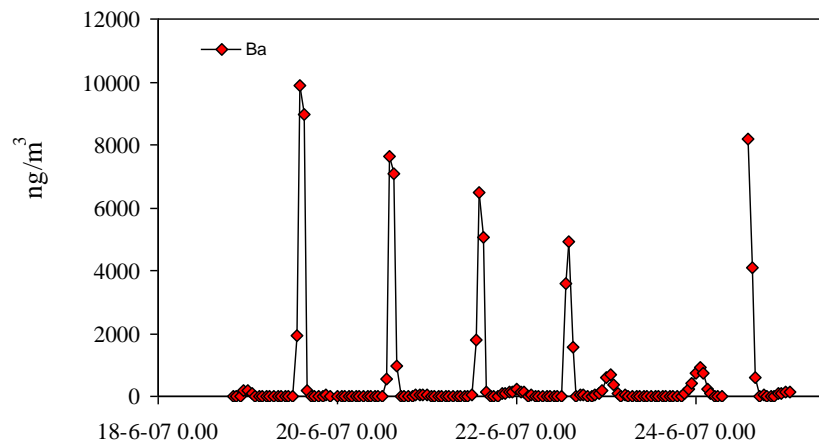
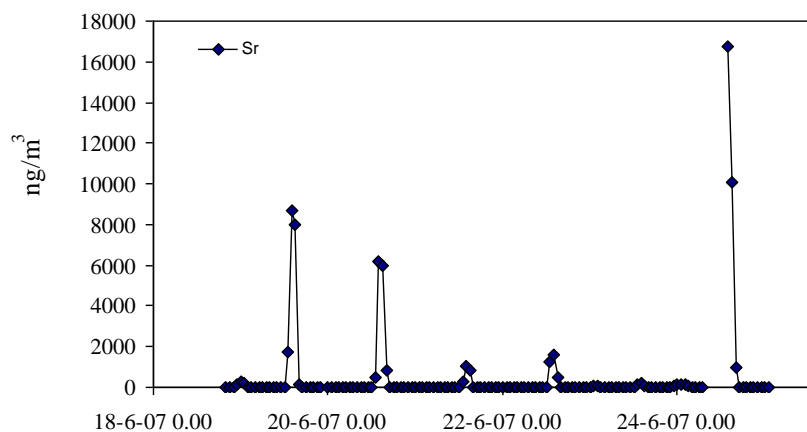
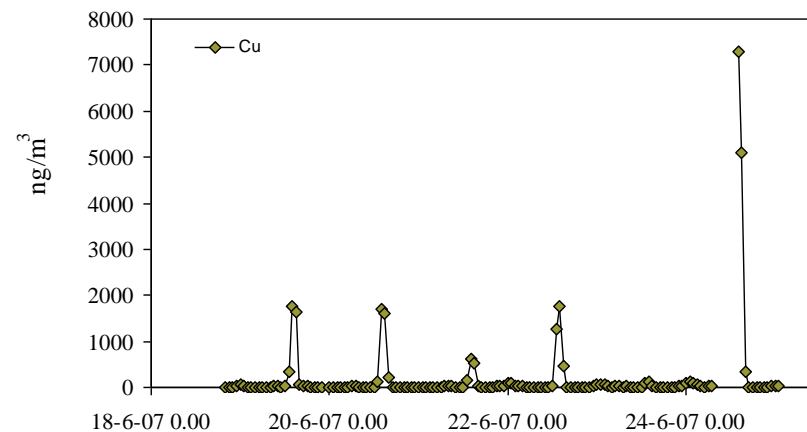
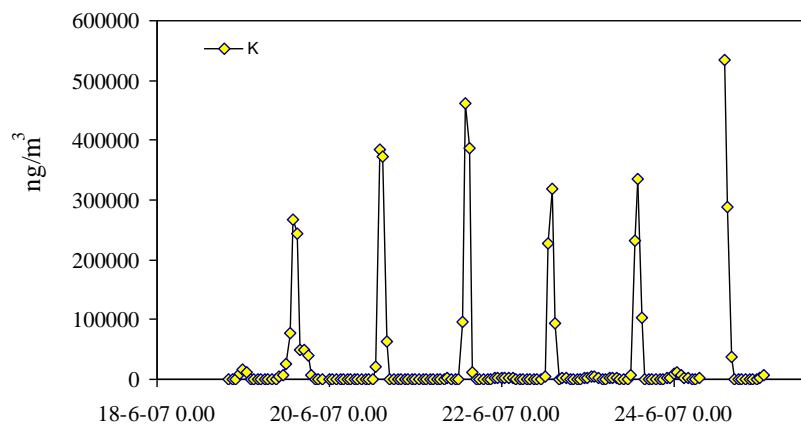
- Identification of emissions from industries
- Traffic emissions
- also natural sources are identified (e.g. marine aerosol, Saharan dust transport, etc.)



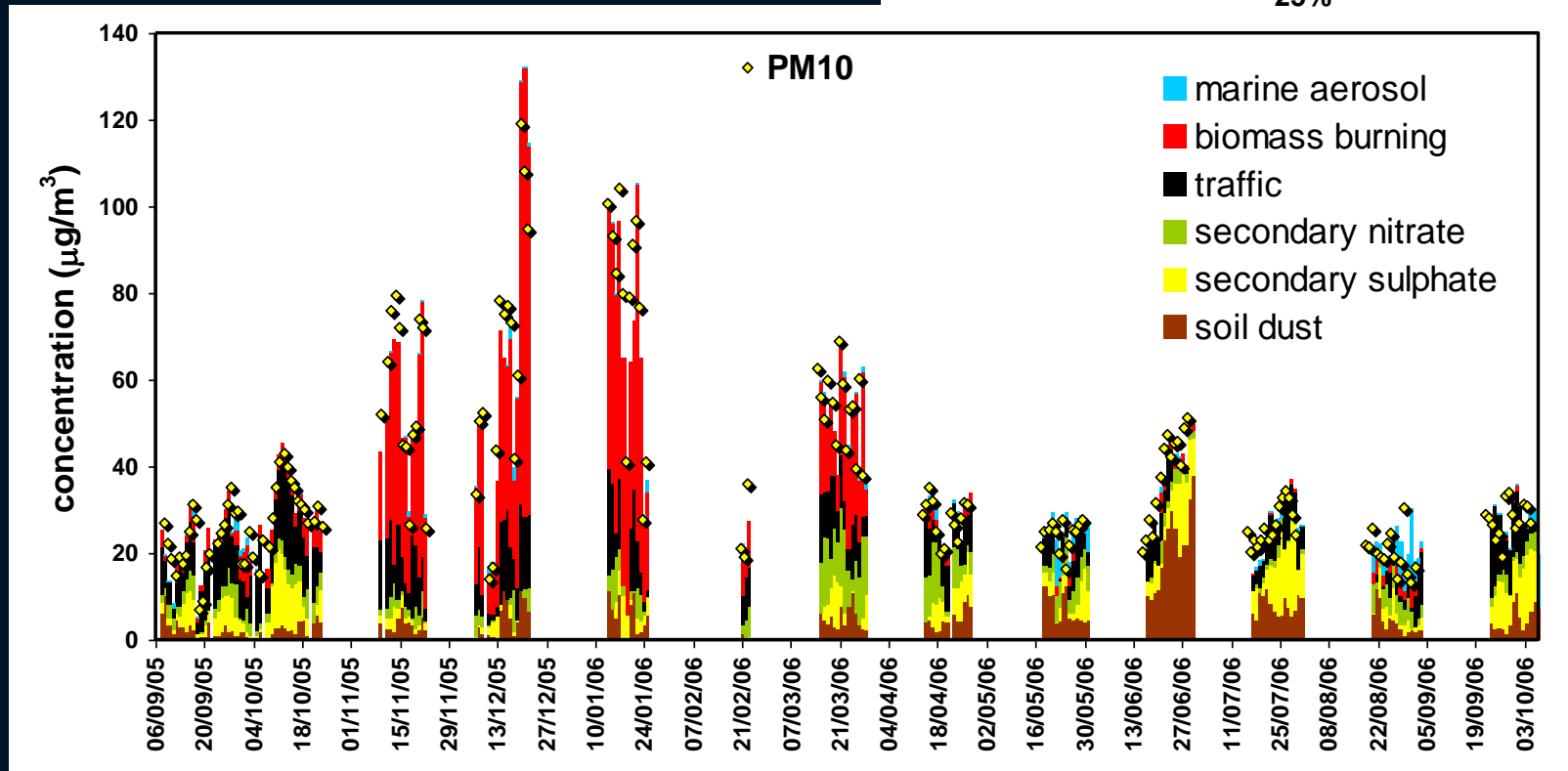
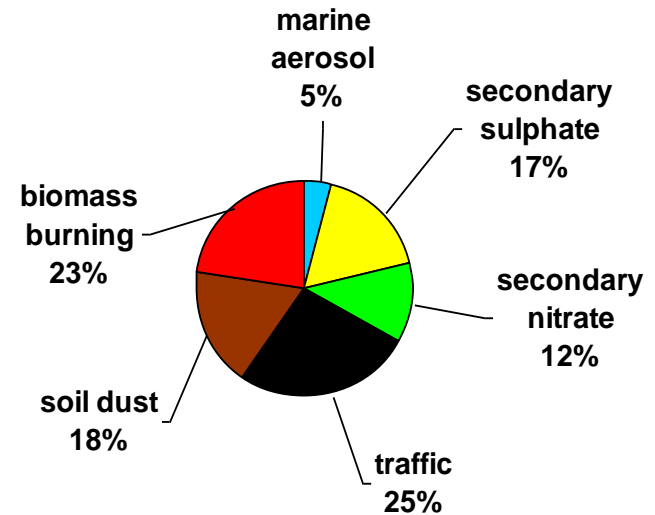
# July 9-10, 2006: fireworks to celebrate Italian soccer team winning at the World Championship



# Las Hogueras (Alicante, Spain)



# Identification of pollution sources through multivariate statistical models



Daily samples, Capannori (Lucca), 2005-2006

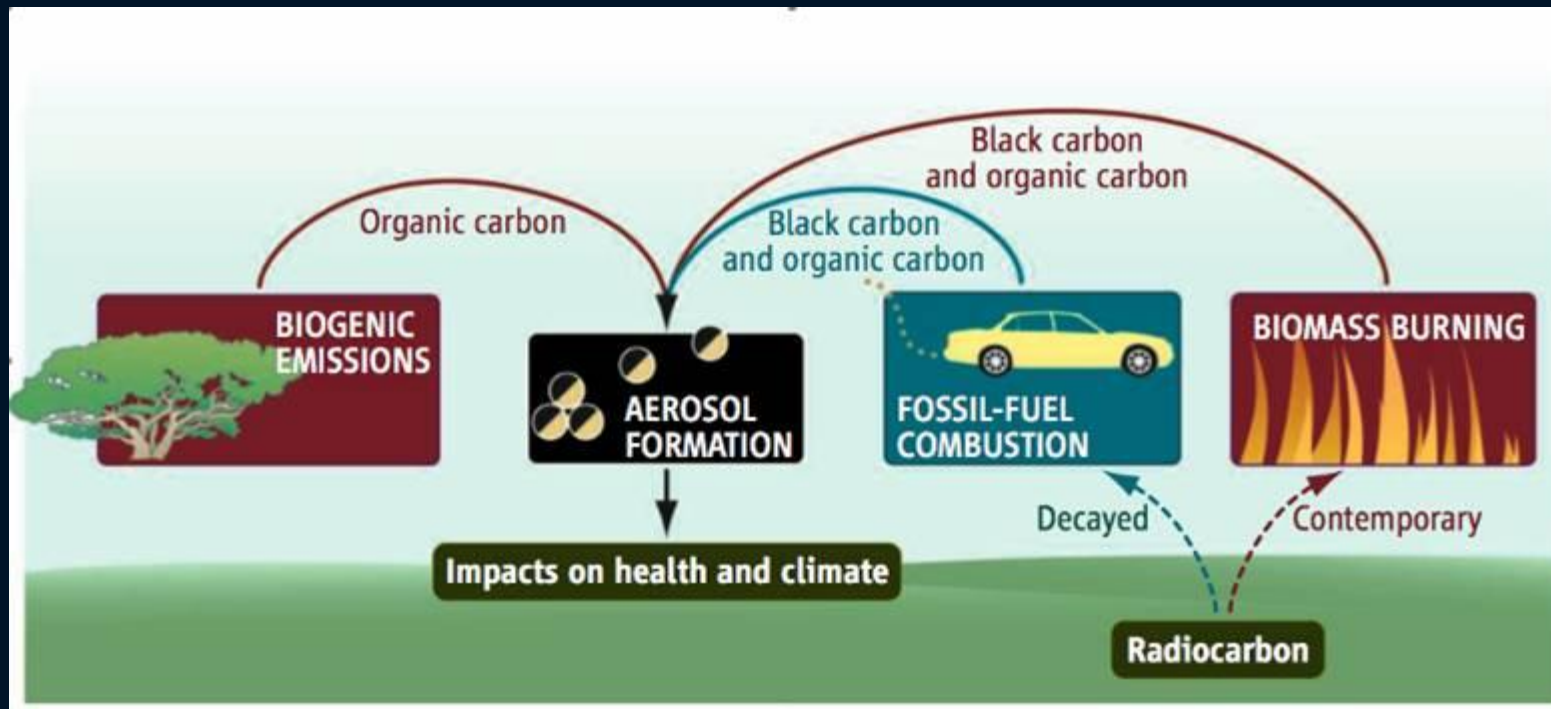
# AMS $^{14}\text{C}$ measurements in aerosols

$^{14}\text{C}$  fraction with respect to modern carbon:

~ 0 in the aerosols produced by fossil fuels

~ 1 in the aerosol of biogenic origin or from biomass burning

→ Marker of pollution from fossil fuels burning



from: S. Szidat, Science 323 (2009), 470

The image is a composite. On the left side, there is a close-up, slightly angled view of a man's face. He has a serious expression and is wearing a red garment. On the right side, there is a detailed view of a microscope, showing the eyepiece, objective lenses, and part of the base. The background is dark. Overlaid on the center of the image is the title text in a white, italicized serif font.

*Ion Beam Analysis techniques  
for Cultural Heritage*

# Material analysis in Archaeometry

## Why?

- Specific information on single artworks
- More general information on historical trends, sources of supply, trade exchange routes in the past,....



Art historians, archaeologists, historians of science and technology,....

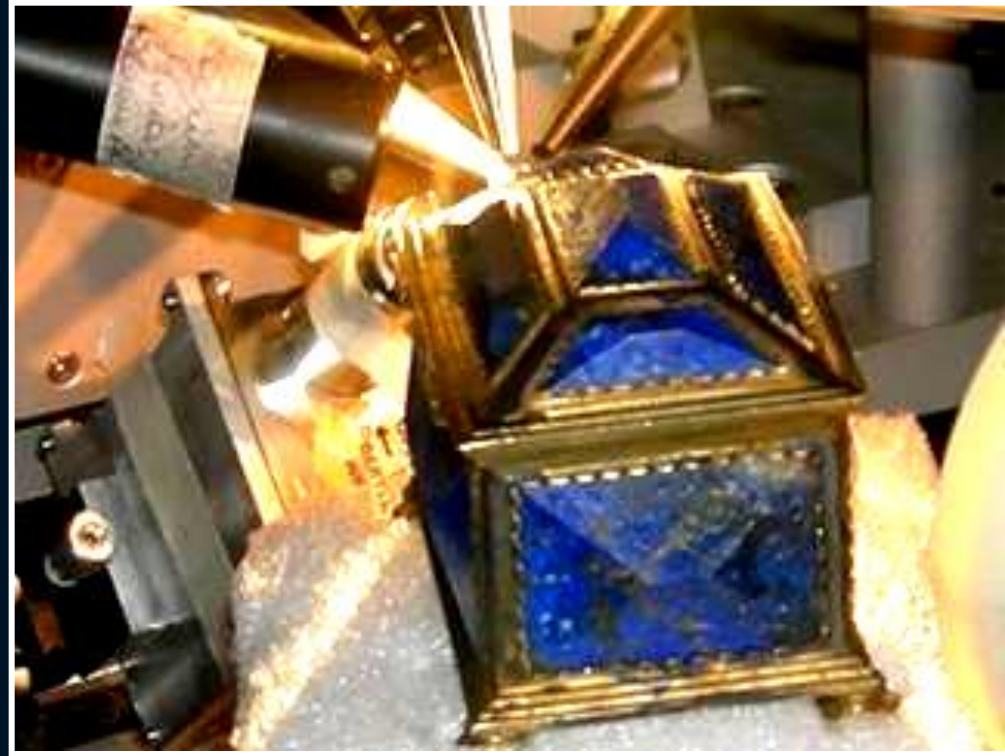
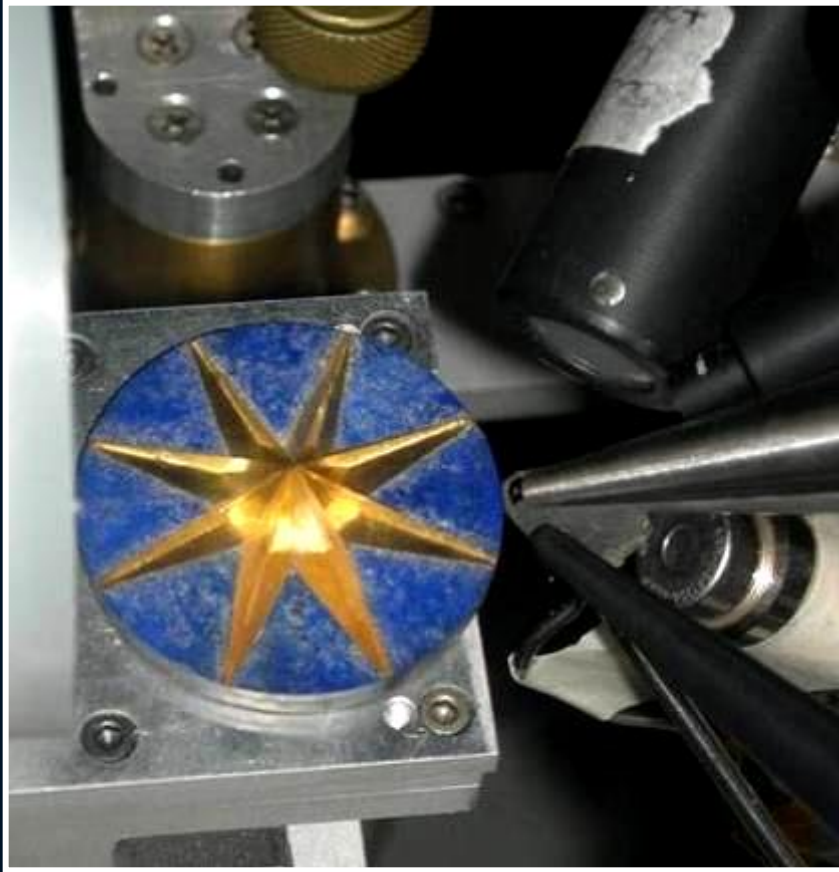
- Detection of degradation
- Having knowledge of the original materials, in order to choose the techniques and materials for a conservative intervention



Conservators and restorers

*Using external beam set-ups  
we can investigate  
in a totally non-destructive way  
the complete quantitative  
composition of any kind of artwork*

*Analysis of semiprecious stone manufacts,*



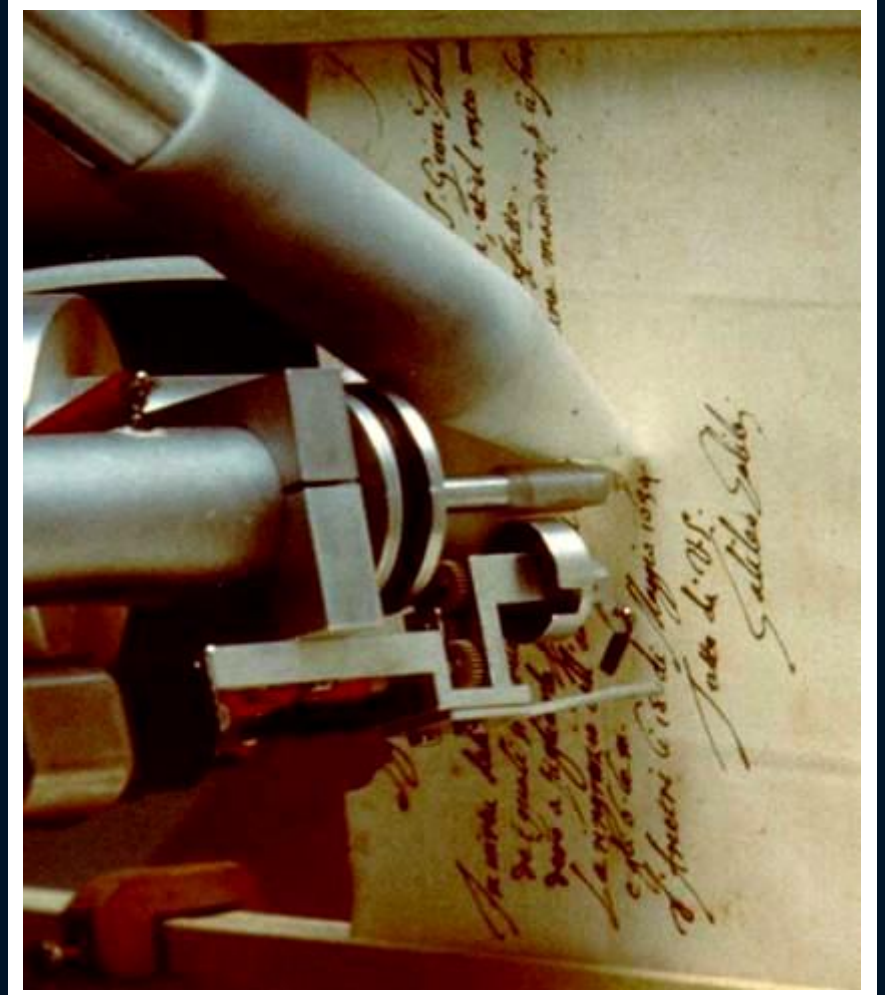
*“Disc with star”, and jewel case, from “Collezione Medicea di Pietre Ornamentali”, Natural History Museum, Florence*

*...ancient illuminated manuscripts,*



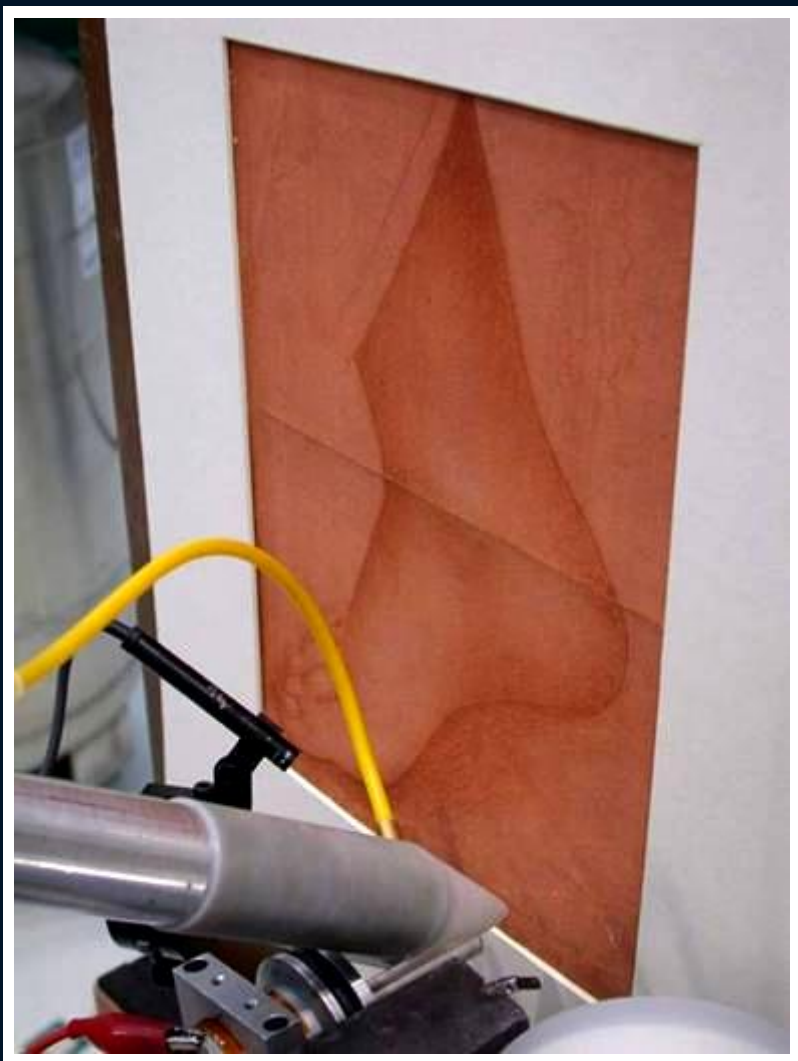
*External-beam PIXE analysis of the frontispiece of Pl.16,22 (XV century, Biblioteca Laurenziana in Florence)*

*...historical documents,*



*Inks in Galileo's manuscripts (Florence National Library) analysed by external PIXE*

*...drawings,*



*PIXE-PIGE analysis of a drawing on prepared paper, by Leonardo or his school*



*PIXE-PIGE analysis of a drawing on prepared paper, school of Verona, XVI cent.*

*...ancient embroideries,*



*Micro-PIXE and -PIGE analysis of gold threads of a Renaissance embroidery based on a cartoon by Raffaellino del Garbo*

*...early photographs*

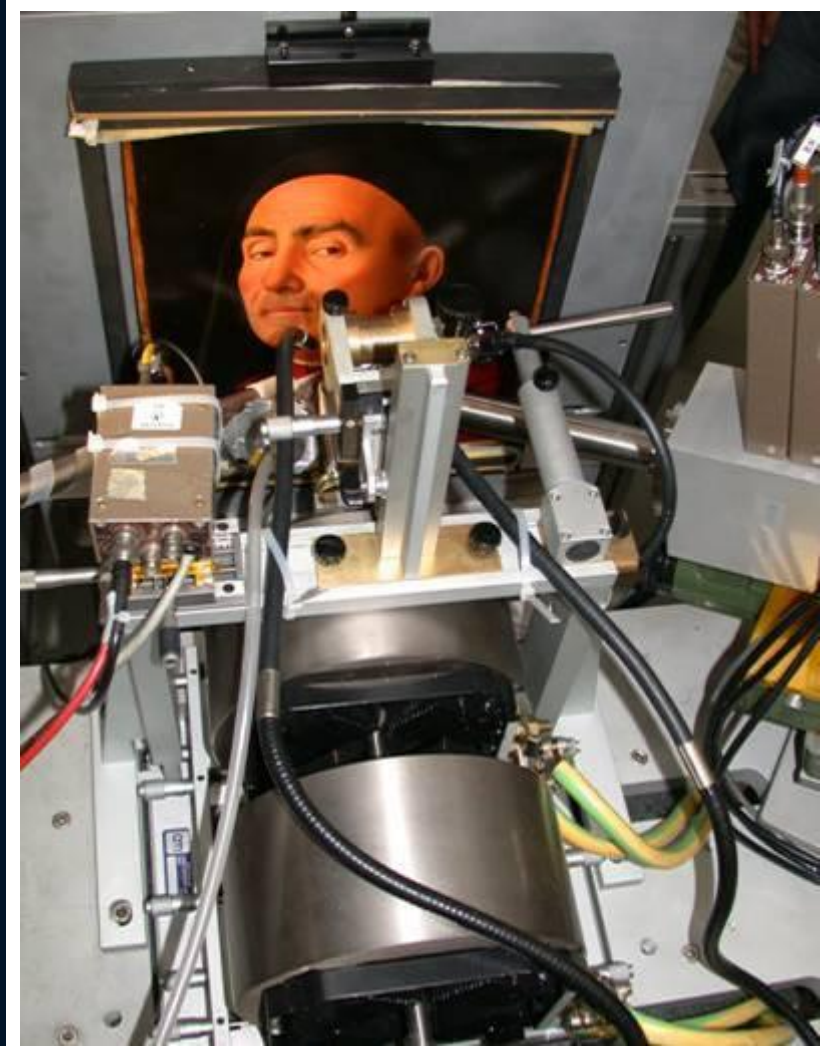


*PIXE-PIGE analysis of a print on metal plate of the XIX century*

*...paintings on wood or canvas*



*Differential PIXE and PIGE analysis of the  
Madonna dei Fusi by Leonardo*



*Micro-PIXE and -PIGE analysis of the  
"Ritratto Trivulzio" by Antonello da Messina*



*Giorgio Vasari*

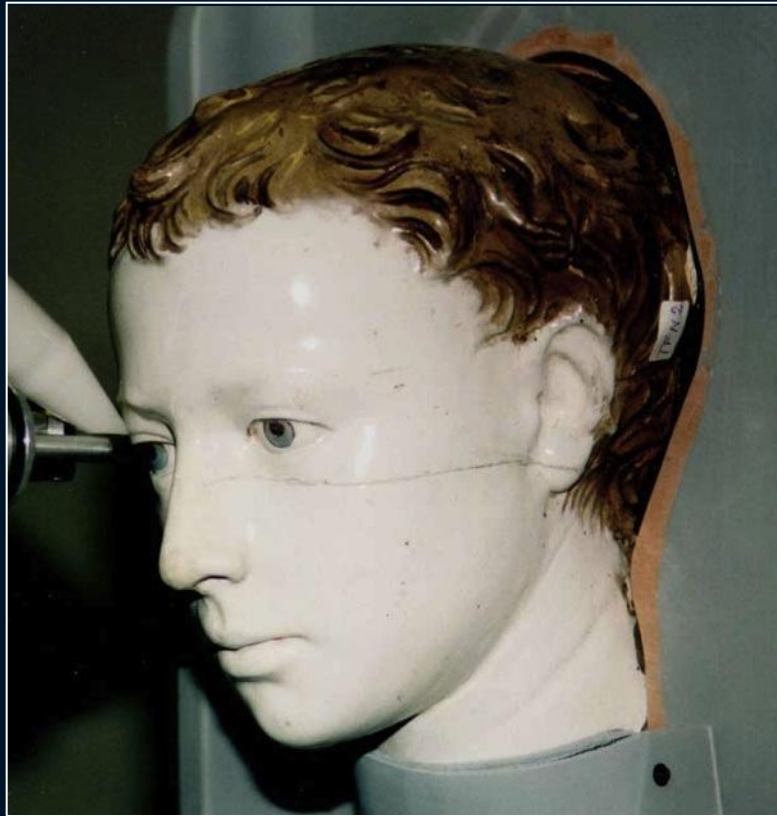
*Tavoletta with S.Lucia, from Pala  
Albergotti, Arezzo*



*Andrea Mantegna*

*Madonna col Bambino, oil on canvas,  
Accademia Carrara di Bergamo*

*...glazed terracottas,*



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

*...metal manufactures*



*PIXE and PESA analysis of some gilded  
chalices from the Museum of Casa Siviero,  
Florence*







# Two dedicated external beamlines

beam size defined by collimation  
( $\varnothing$  0.2  $\div$  1 mm)

strong focusing system,  
quadrupole doublet ( $\varnothing$  8  $\div$  10  $\mu\text{m}$ )



# External scanning microbeam line

< 10  $\mu\text{m}$  beam size on target

magnetic scan of areas  
within the window  
aperture

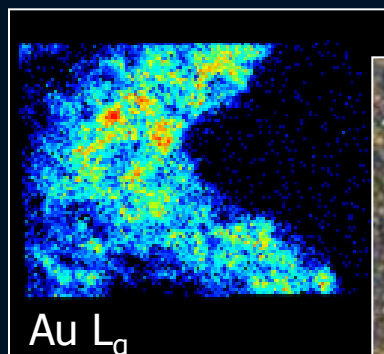
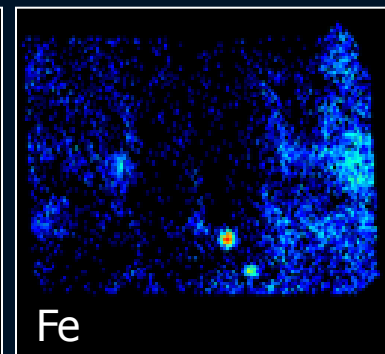
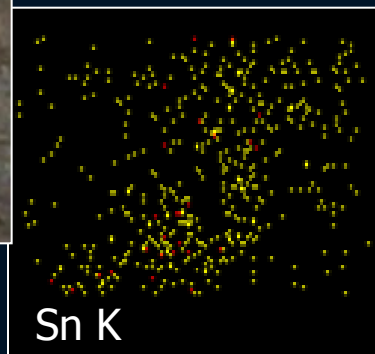
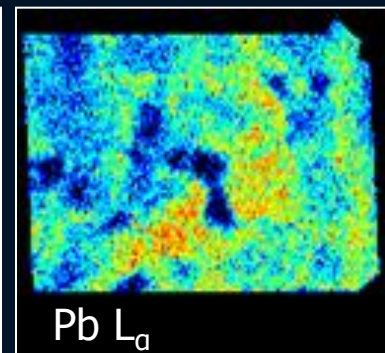
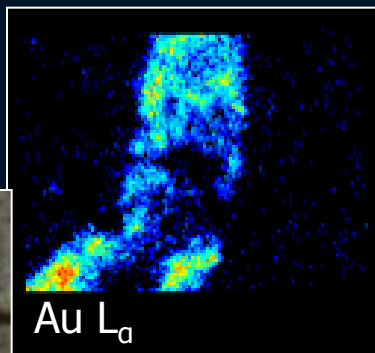
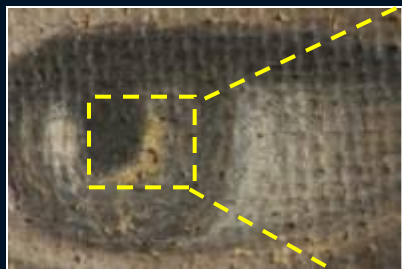
list-mode (E,x,y) DAQ

includes detection systems  
for PIXE, PIGE,  
backward and forward  
particle scattering,  
ion induced luminescence (IBIL)

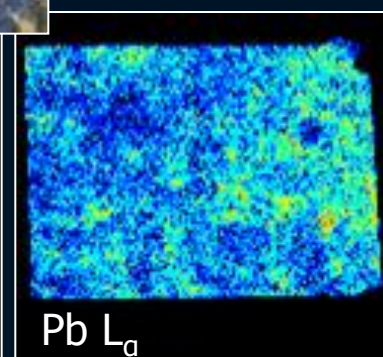
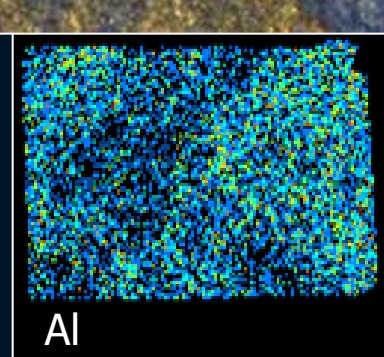
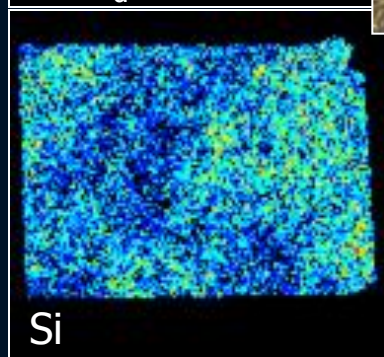


# Elemental mapping

## The eye of the Virgin



## The veil



Andrea Mantegna

Madonna col Bambino, oil on canvas, Bergamo

# External microbeam line

full control of beam currents from a few nA down to  
ultra low (hundreds of particles/sec)

higher beam intensities →

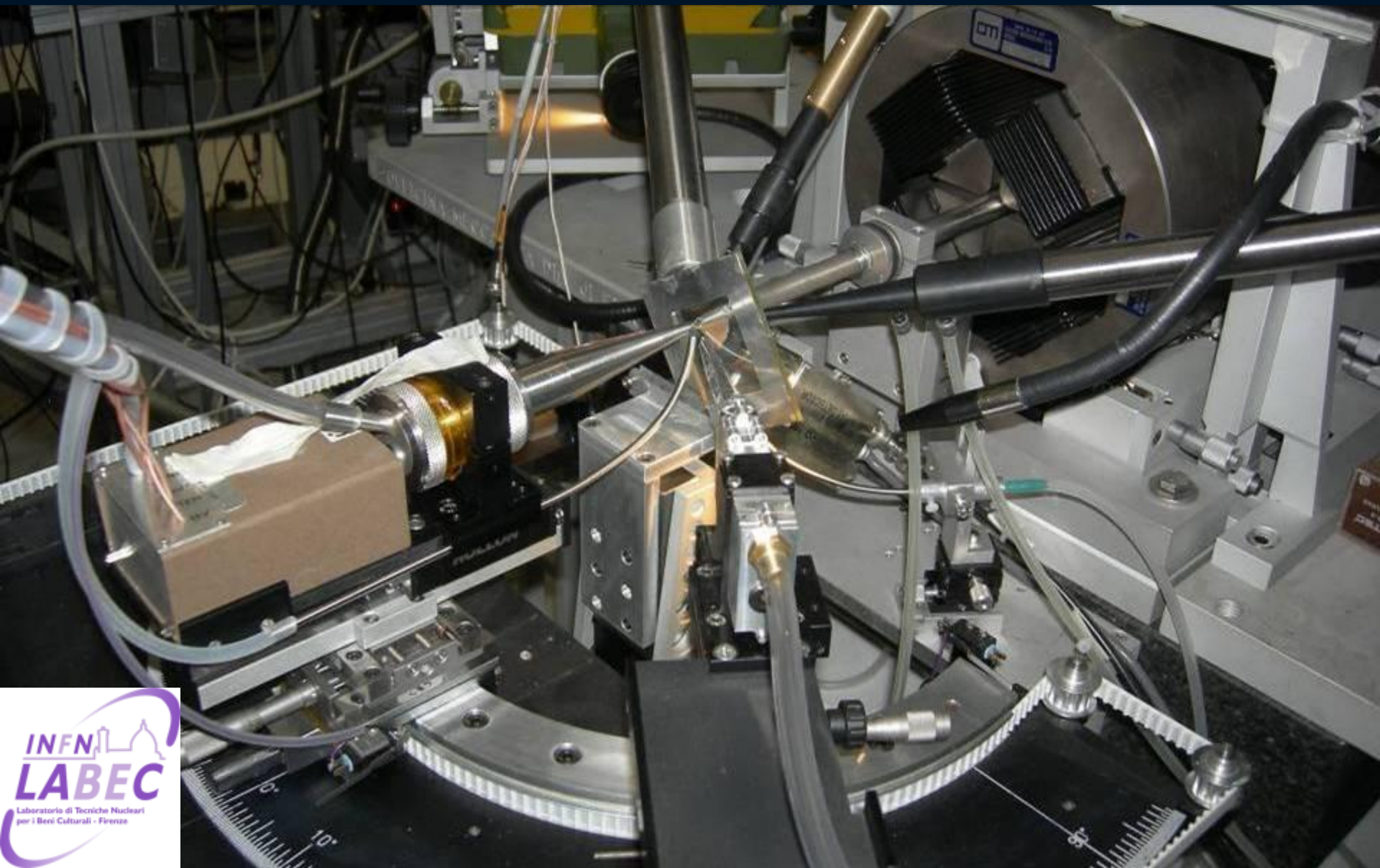
✓ elemental PIXE –PIGE maps also for trace elements (of  
great interest e.g. for geologists)

ultra-low currents →

✓ possibility of scanning transmission ion microscopy  
(STIM)

✓ tests of detectors response as a function of position  
(through IBICC, ion beam induced charge collection)

# External STIM set-up



# STIM of a thin copper grid

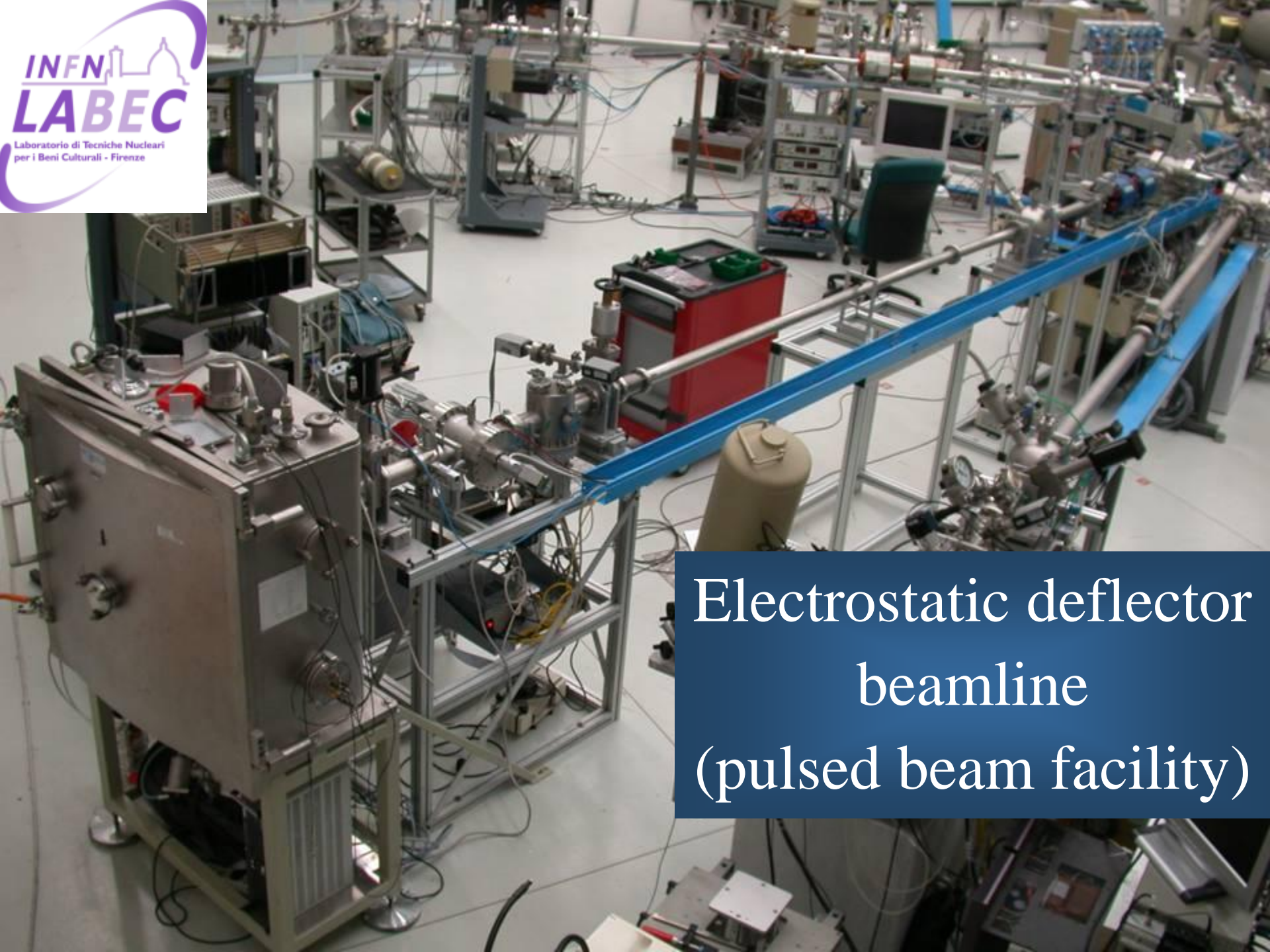


map of higher-energy  
transmitted protons

map of lower-energy  
transmitted protons

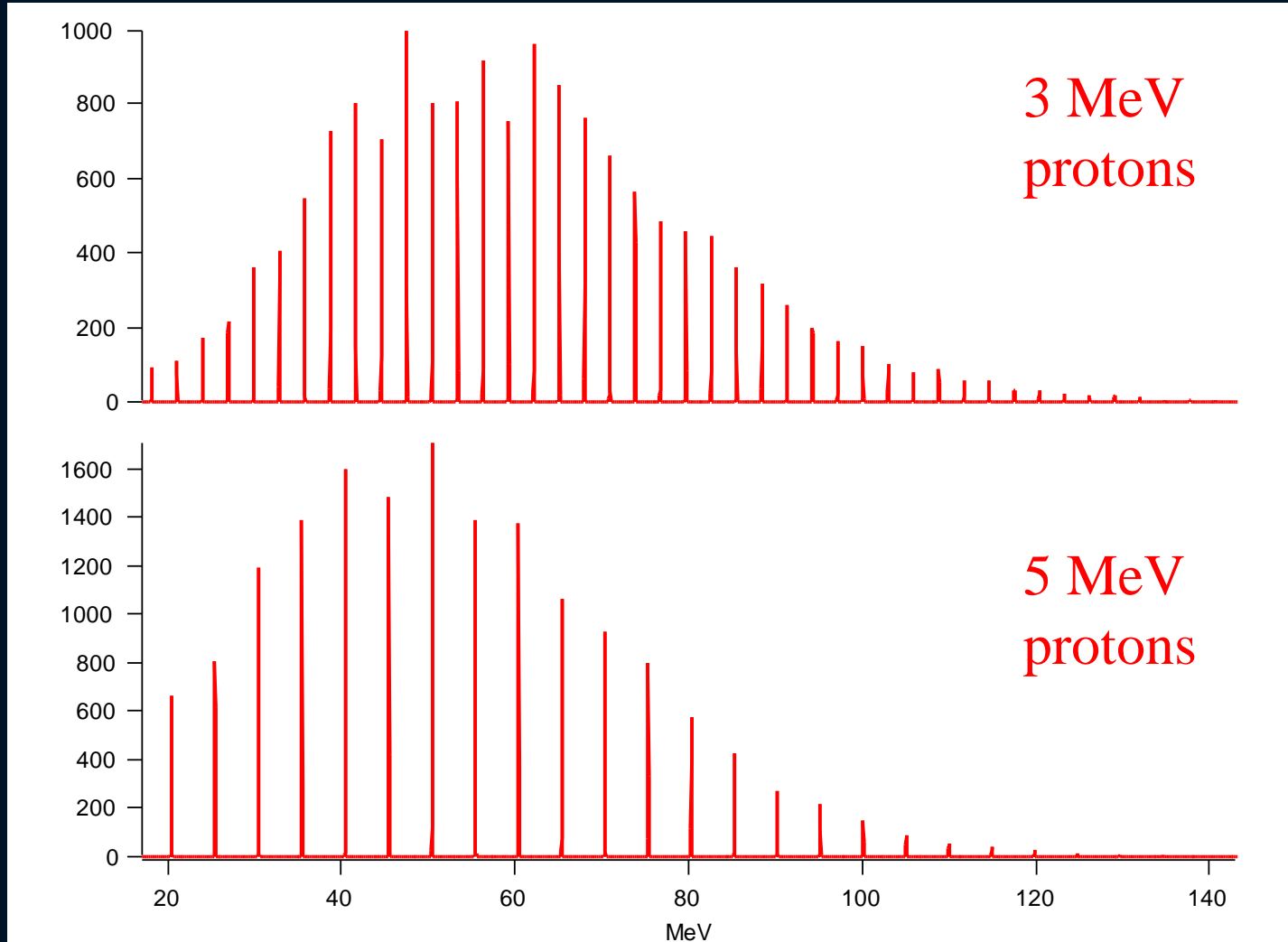
# Another achievement, exploiting IBMM (Ion Beam Modification of Materials)

Ion lithography (with protons or even heavier ions) through beam-induced alteration of material properties (optical, electrical, etc.) on selected zones “drawn” by the microbeam scan (material properties are selectively altered in depth thanks to the Bragg peak)



Electrostatic deflector  
beamline  
(pulsed beam facility)

*Beam bunches with different particle multiplicity can be delivered directly to a detector for response tests to particles*

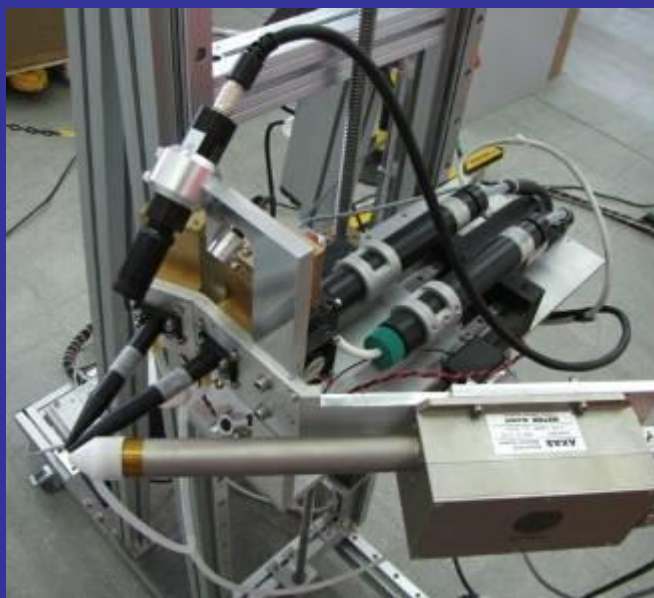


Not only accelerator-based  
techniques at LABEC

Developed an innovative XRF  
transportable system

for certain aspects, approaching the performance of  
IBA techniques

# The transportable XRF spectrometer



Measurement head

- independent PS for the two tubes
- data acquisition, He flow, X-Y-Z displacement and video camera are remotely controlled (via Ethernet) by the same computer

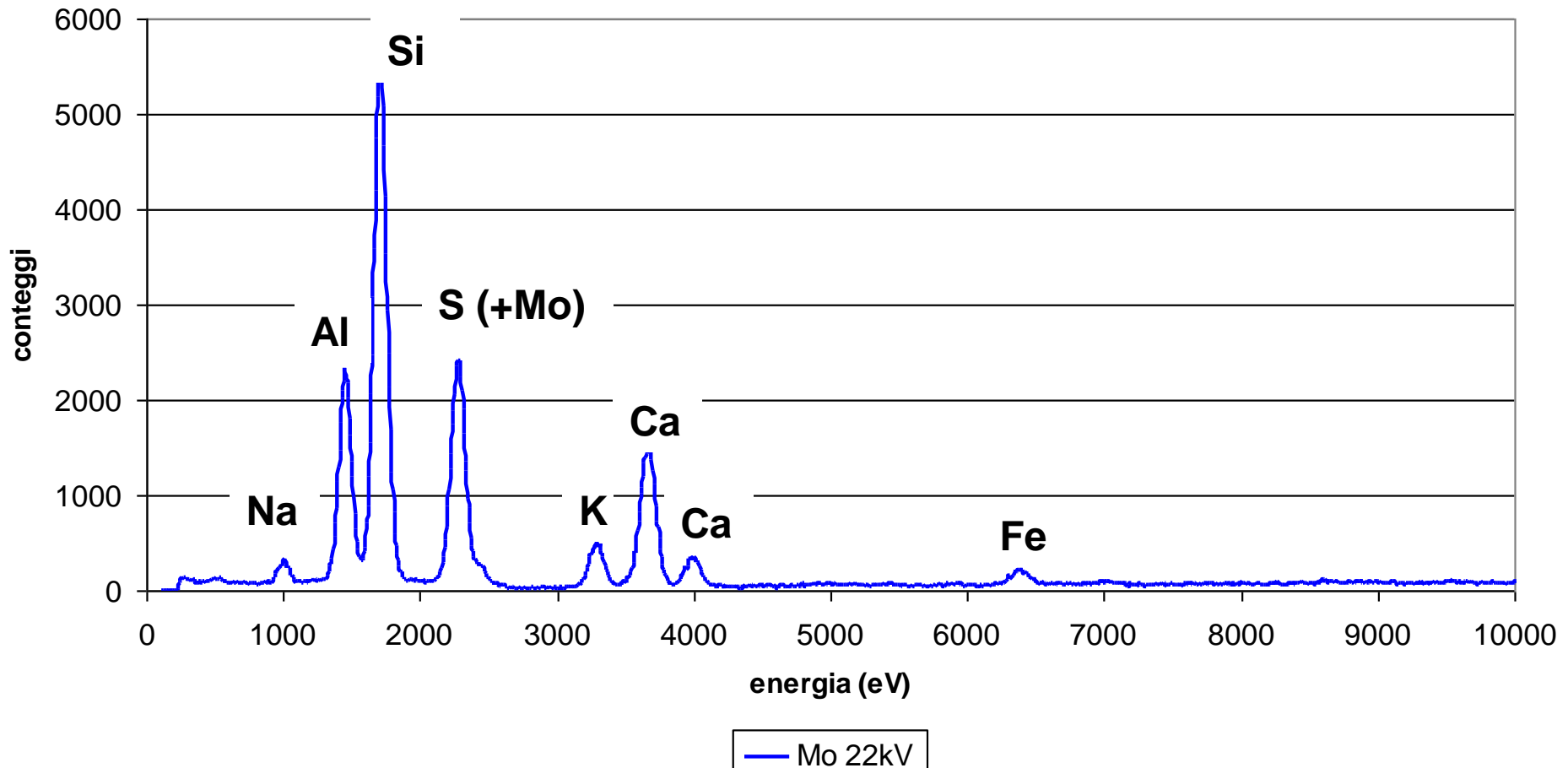
Controller



- **2 X ray tubes** (30 kV max, 1 mA max) with two different anodes (typically **Mo e Ti**; W if needed)
- interchangeable collimators; **typical beam diameter 0.5 mm**
- SDD detector (active area 10 mm<sup>2</sup>, 450 μm thickness, FWHM 139 eV @ 5.9 keV)
- **helium flow** in front of both tubes and detector
- 2 laser beams for accurate positioning

# Using this portable XRF....

ultramarine blue layer

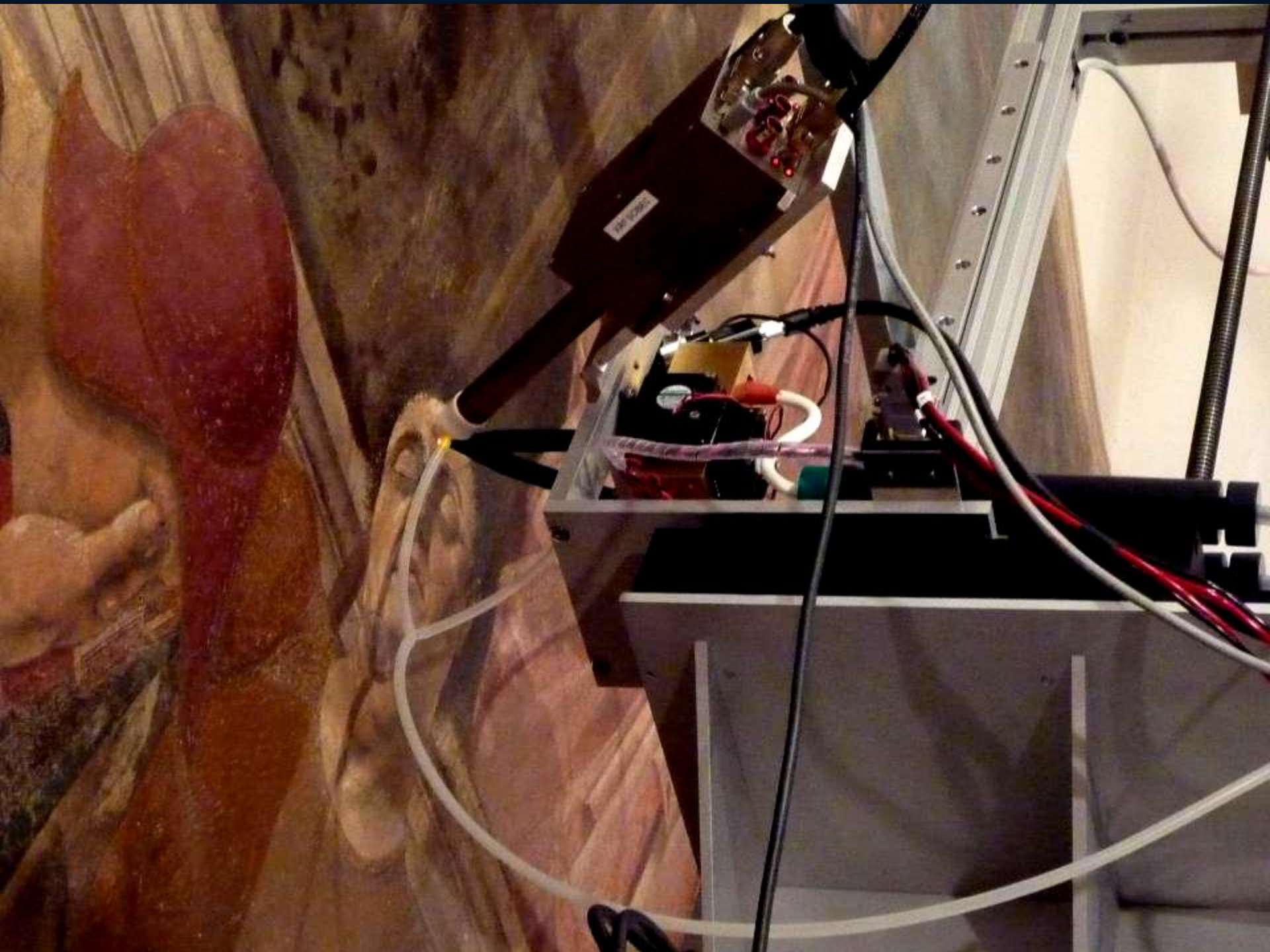




*Affresco della  
Resurrezione*

Piero della Francesca

Sansepolcro,  
Museo Civico



# *Crucifix by* Maestro di Figline

Santa Croce



*Santa Croce, Cappella Bardi –  
cycle of frescoes by Giotto*



*Madonna del Granduca*

**Raffaello**  
**Galleria Palatina**



# *La Chimera di Arezzo*

Museo Archeologico  
Firenze



Beato Angelico, *Crocifissione Capitolare*, San Marco, Firenze



*Thank you for your  
attention!*



# Nuclear Physics News International

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**FEATURING:**  
**Laboratory Portrait INFN-LABEC—  
Nuclear Techniques for Cultural Heritage  
and Environmental Applications**

*Vol. 19 Issue 1  
(2009), 5*

**FEATURING:**  
**Laboratory Portrait INFN-LABEC—  
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