Applicazioni di Fisica Nucleare

P.A. Mandò @ **RICCI90 SYMPOSIUM**
to celebrate Renato Angelo RICCI's 90th birthday

July 4 - 5, 2017, Laboratori Nazionali di Legnaro

The topic is so vast that I could hardly give something more than a list…

Let alone (we are in Italy) all what is connected to nuclear energy…

by the way, I wouldn’t be the proper guy to talk about that

The applications of nuclear-based methodologies to Medicine are innumerable (both to diagnostics and to therapy)

They are probably the best known, also to common people

(although not always is the connection to Nuclear Physics perceived)

Just to give an idea, about 50% of the accelerators in the world are used for medical purposes:

either for (mostly indirect) irradiation in radiotherapy, or for radioisotopes production used in both selective therapies and (mostly) as tracers for diagnostic techniques

Not to mention the huge contribution of X ray techniques for diagnostic imaging, which started very early after the discovery of X rays, with the standard radiographies, until the modern systems, which thanks to the progress in detection techniques allow for an important reduction in the delivered dose to the patient (even in the 3D tomographies, also relying on fast computer algorithms for image reconstruction)

Once again, I'm not the right person to talk about medical applications, as well as about applications in radiobiology, which are widely performed usign ion beams form the accelerators here in Legnaro, at the highest world standards.

I will instead briefly focus on something I'm more familiar with, which is perhaps less considered but can also be "socially" important among the applications of Nuclear Physics

ENVIRONMENTAL APPLICATIONS

Nuclear Physics to help Environment?

Oh my God!

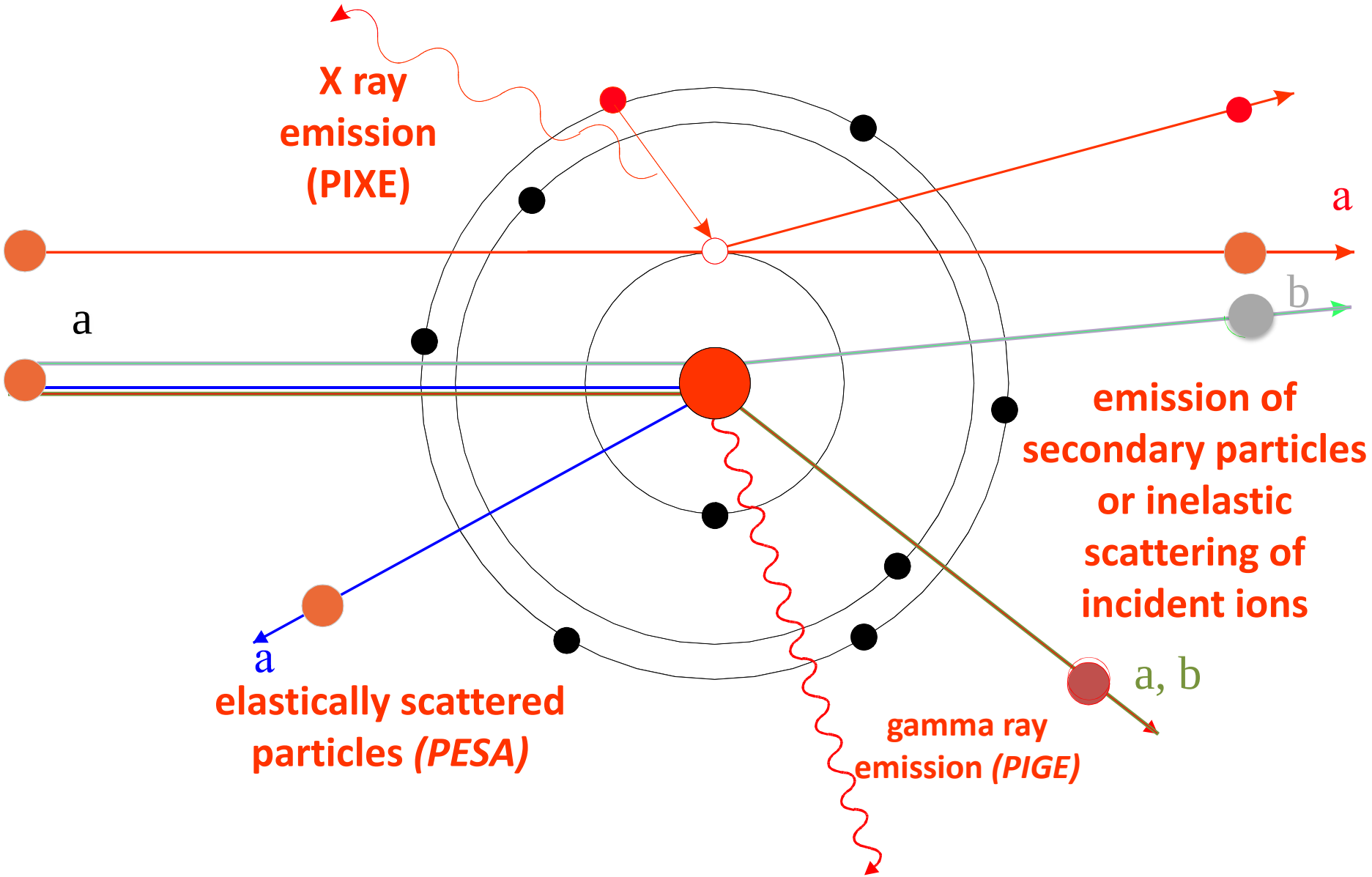
Certain kinds of (ignorant) people would be scandalised, considering this statement a heresy, a contradiction in terms…

I'm sorry, they are wrong!

For instance, the analysis of PM composition using ion beams is among the most powerful tools to detect the sources of air pollution and quantify their relative importance ("source apportionment").

A complete elemental analysis can be achieved exploiting the various beam interactions with atoms and nuclei of a target where the PM has been deposited using proper sampling techniques

Ion Beam Analysis (IBA)



And it is evident that the composition of PM - not only its mass per unit volume of air, as measured in the common monitoring stations of the environmental protection agencies - is crucial, not only for evaluating the health impact, but to determine where pollution comes from

The composition of aerosol (= PM) is also important, as is the CO_2 abundance) to determine the “radiative balance”, i.e. the main factor affecting

GLOBAL CLIMATE CHANGES

Ion Beam Analysis, thanks to the very high cross sections in particular of PIXE (hundreds or even up to more than one thousand barns for the detection of many elements) allows one to achieve sensitivities down to ng/m^3 of air (well below the risk levels) in measurements lasting one minute or less

Thus, tens of thousands measurements can be done on filters-deposited PM of various grain-size (PM_{10}, $PM_{2.5}$, PM_{1}, etc.) and correlations with other factors, such as meteorological parameters, or vehicular traffic, of the presence of given kinds of industries, can be soundly established

Facts, not hypotheses (often biased by preconceptions), to decide the most appropriate mitigation policies

Especially important (and unique available tool) is Ion Beam Analysis for the measurement of very small mass samples, such as those collected during short time lapses (one hour or less), or in remote areas)

This allows one to get e.g. a high resolution in the determination of the time trends of PM in atmosphere, thus pointing out also acute short episodes of pollution, and allowing for a correlation with fast-changing external parameters

What is needed to study aerosols (PM)

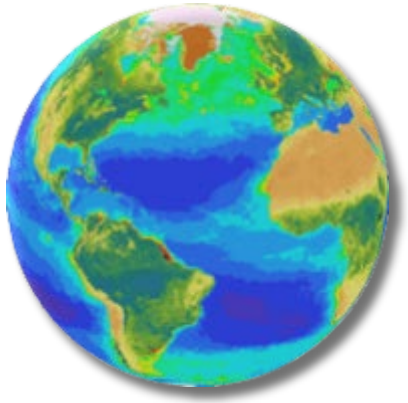
A wealth of data concerning:

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

Identification and quantification of PM emission sources

Contribution to strategies of pollution abatement to improve air quality

Contribution to climatic models to evaluate the role of atmospheric aerosol in the “radiative forcing”



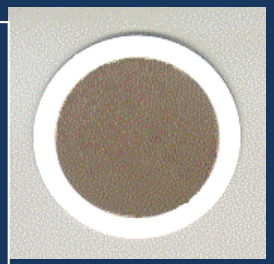
Measurements of “daily” samples

Sequential Samplers

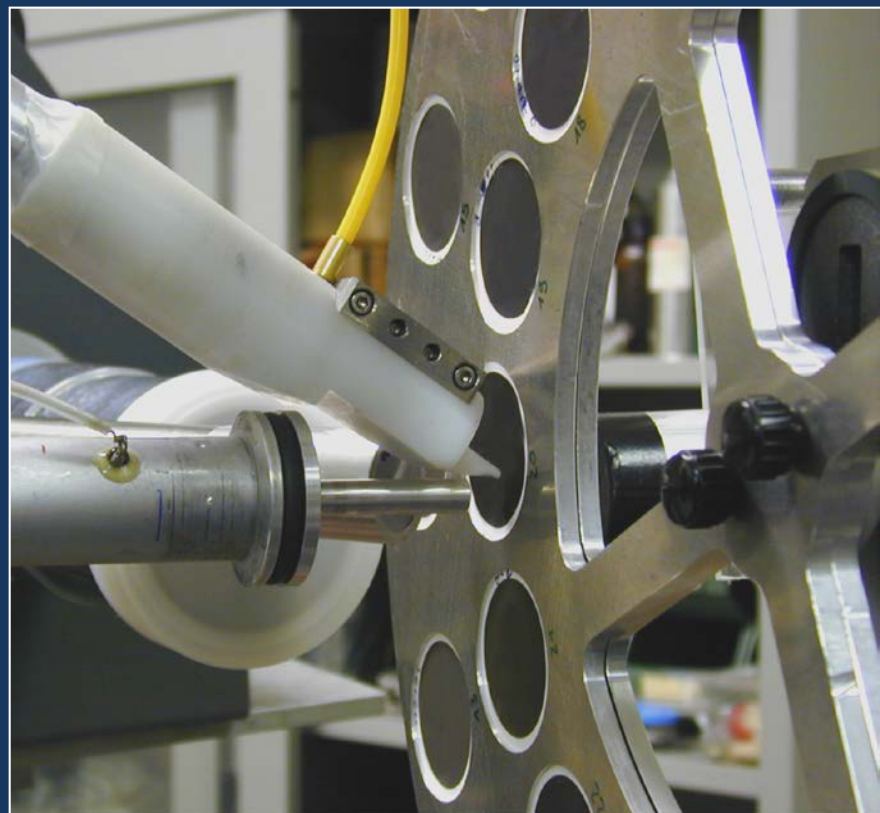
PM_1

$PM_{2.5}$

PM_{10}



- Multiple sample-holder
- Beam scan on the filter to average over the whole collection area



Measurements of “hourly” samples

Continuous sampler (“streaker”)

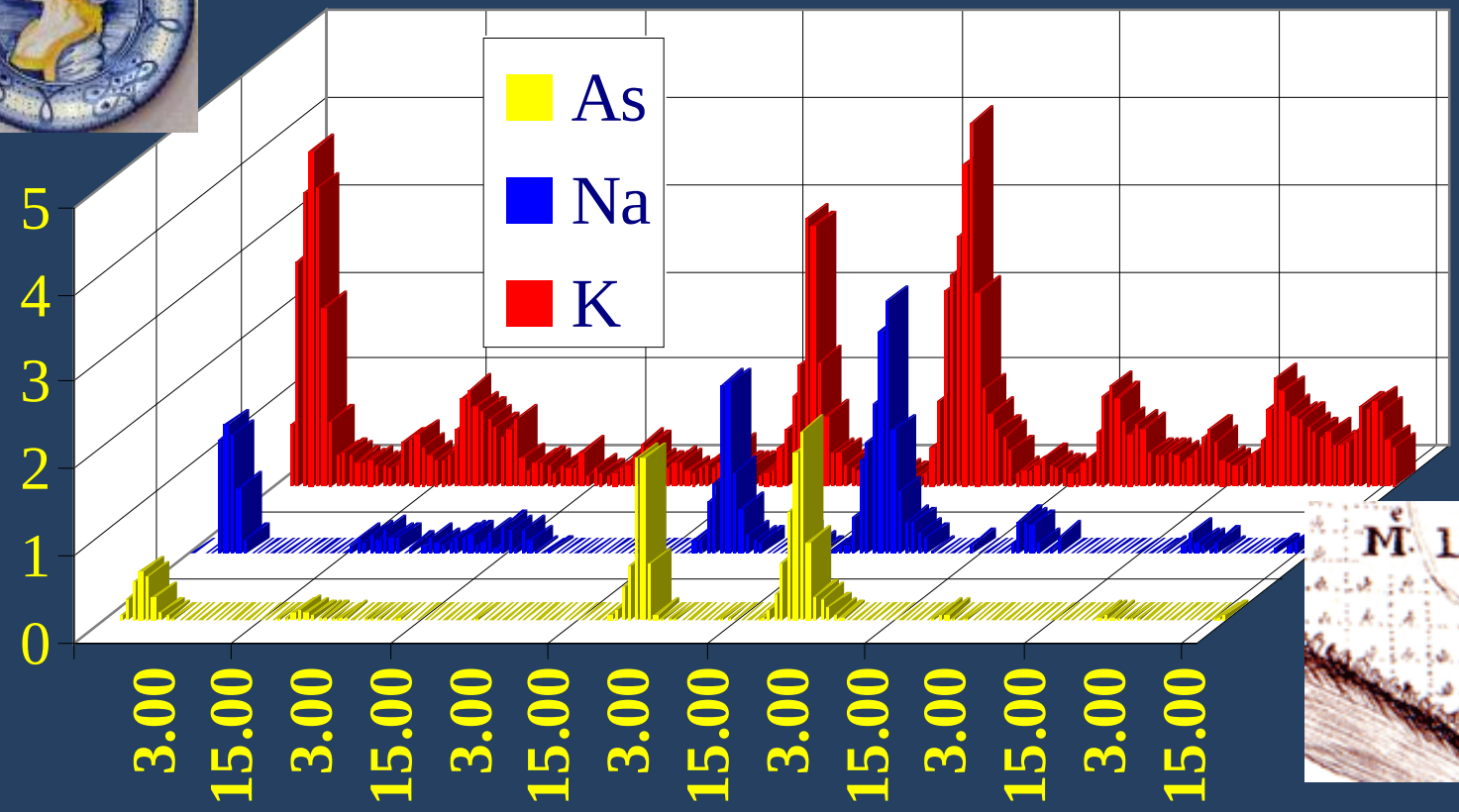
100 mm

- Kapton foils
- Nuclepore

Beam size: 1 mm x 2 mm, corresponding to the impact area of one hour sampling

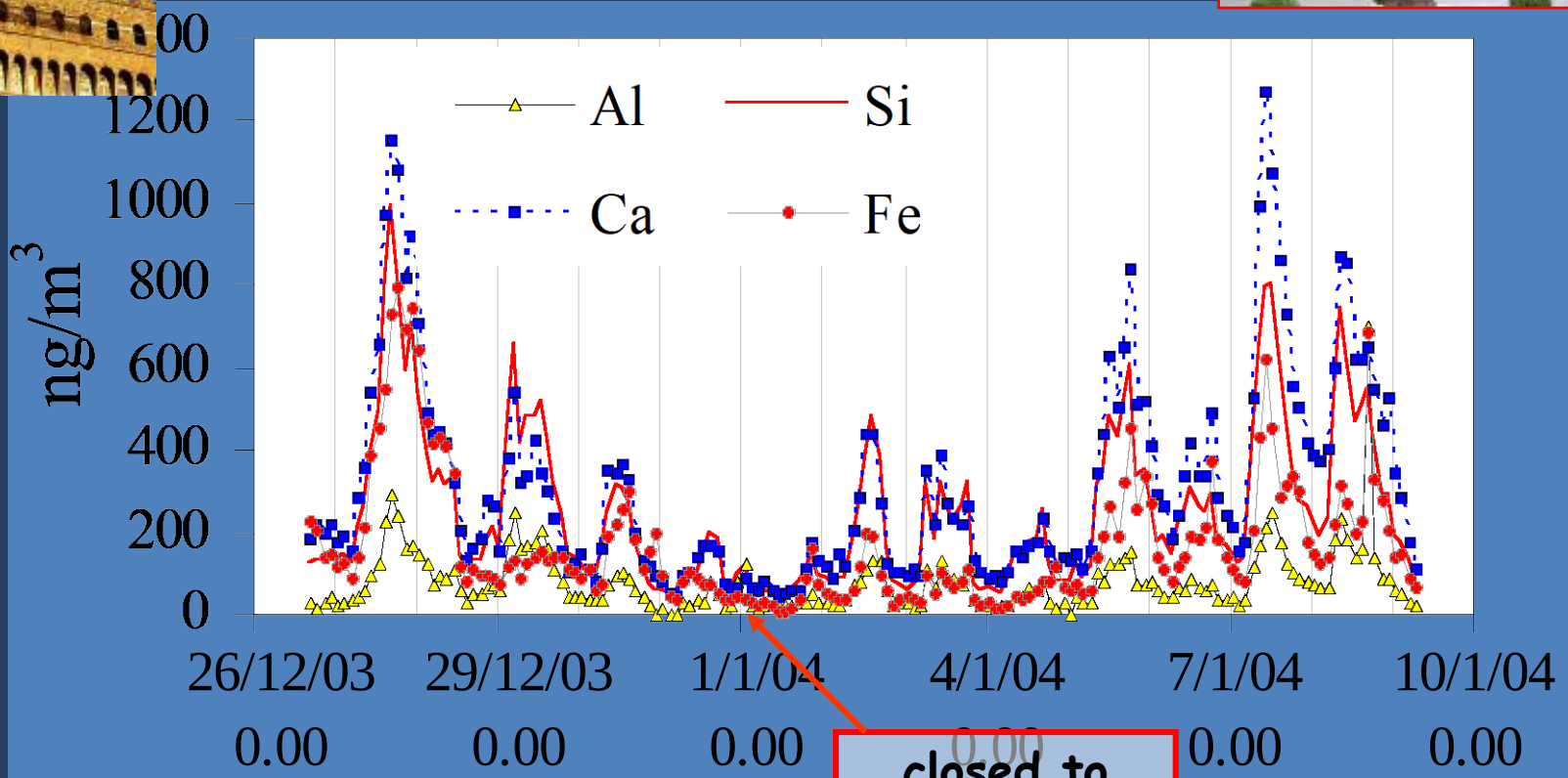
Industrial emissions

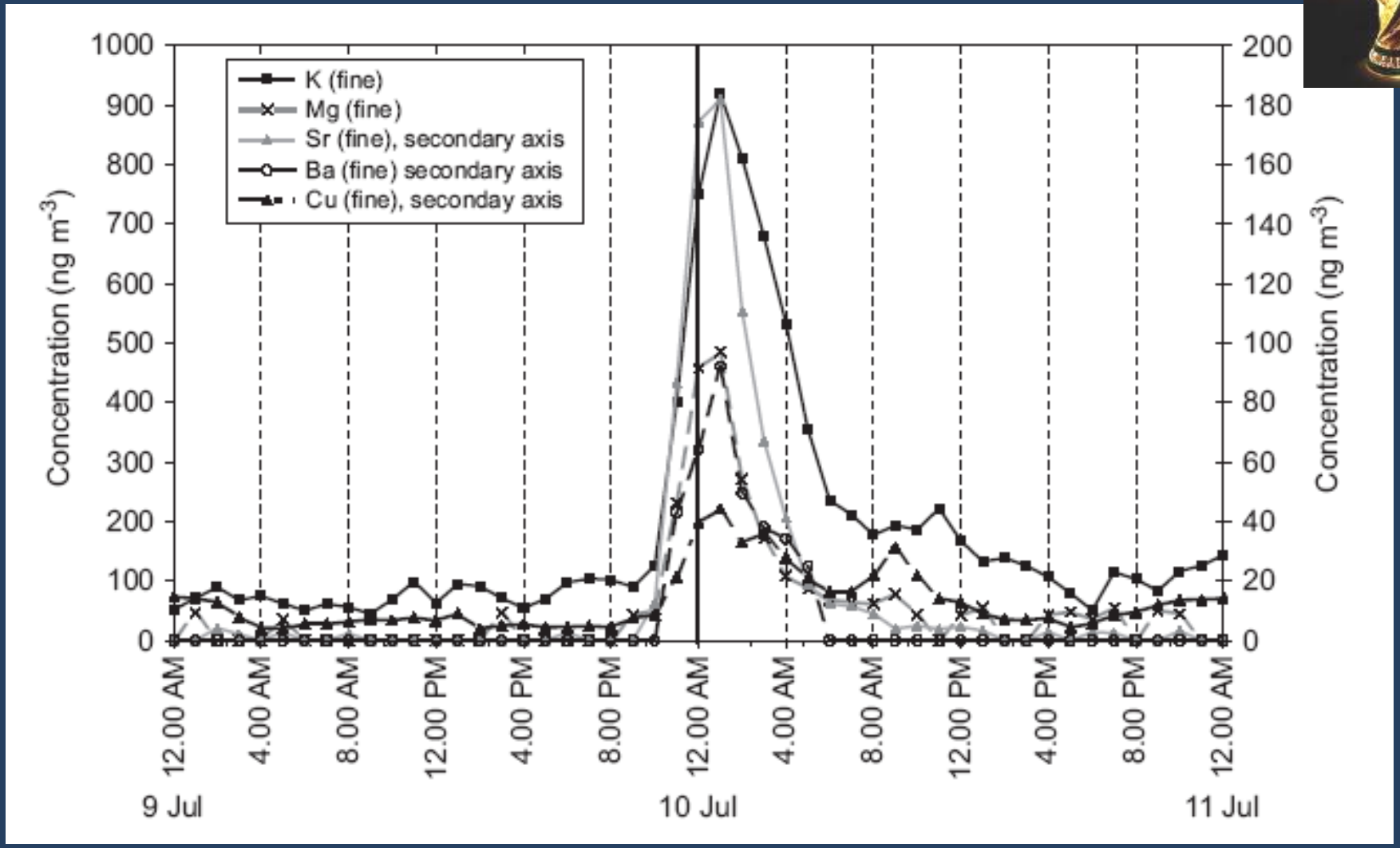
Industrial emissions at Montelupo Fiorentino: artistic glass and ceramics production



Impact of tourists on Cultural Heritage

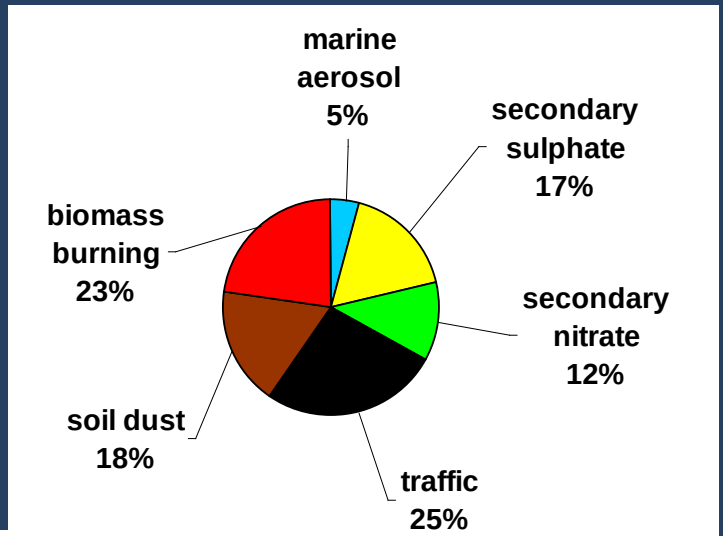
Cortile del Michelozzo (Palazzo Vecchio)

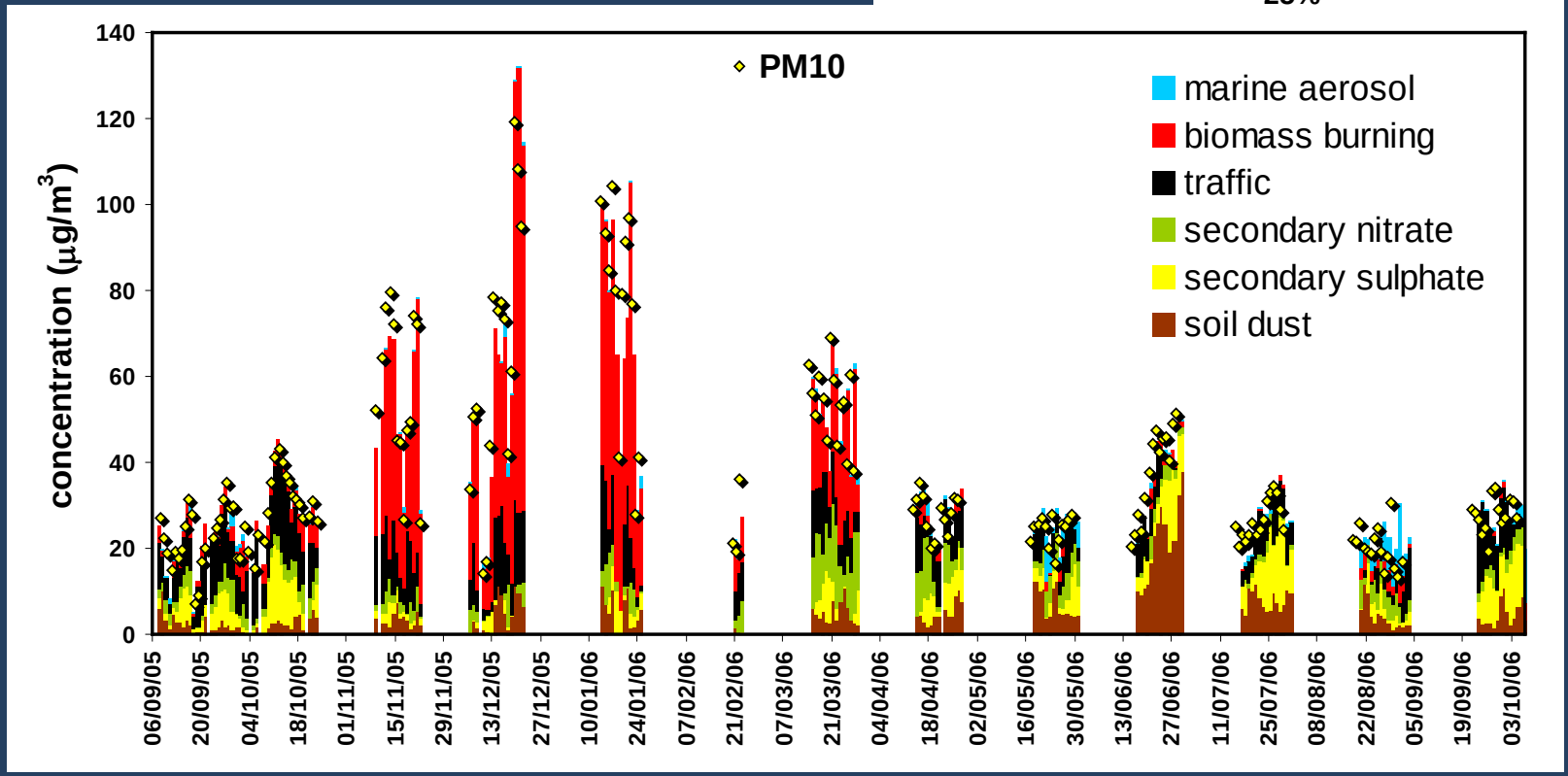




July 9-10, 2006: fireworks to celebrate Italian soccer team victory at the World Championship

Identification of pollution sources through multivariate statistical models





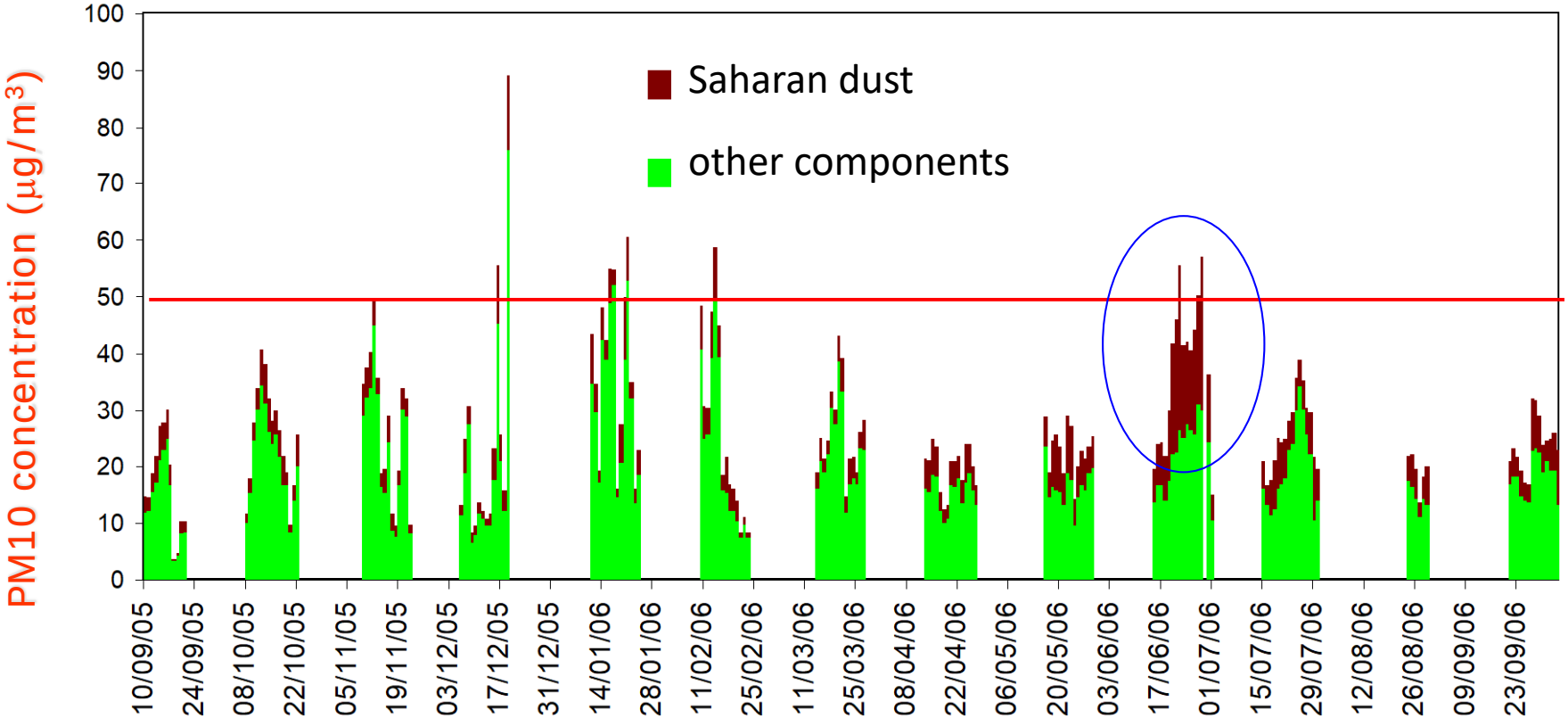
Daily samples, Capannori (Lucca), 2005-2006

Saharan dust

important contribution in the Mediterranean area

one should distinguish its contribution from the one of other pollution sources (also for legal regulations!)

Contribution to exceeding the limits of PM_{10}



Indeed, Saharan dust was sometimes the cause for exceeding the limit in June. However, other events of limit exceeding are due to other sources

Also important in PM analysis are ^{14}C measurements!

The carbon component is a large fraction of aerosols

Schematically, it can have a “natural” or a “bad”, man-induced component (e.g. combustion of fossil fuels)

The latter has zero ^{14}C, the former has the ^{14}C concentration characteristic of the living organisms

Therefore, the radiocarbon concentration in aerosols is an indirect measurement of the fraction of the “bad” anthropogenic component of carbon

The other field I'll briefly touch are the applications to Cultural Heritage.

C.H. is also apparently quite distant from Nuclear Physics, which has however by now conquered an important and widely acknowledged role in C.H.- related problems

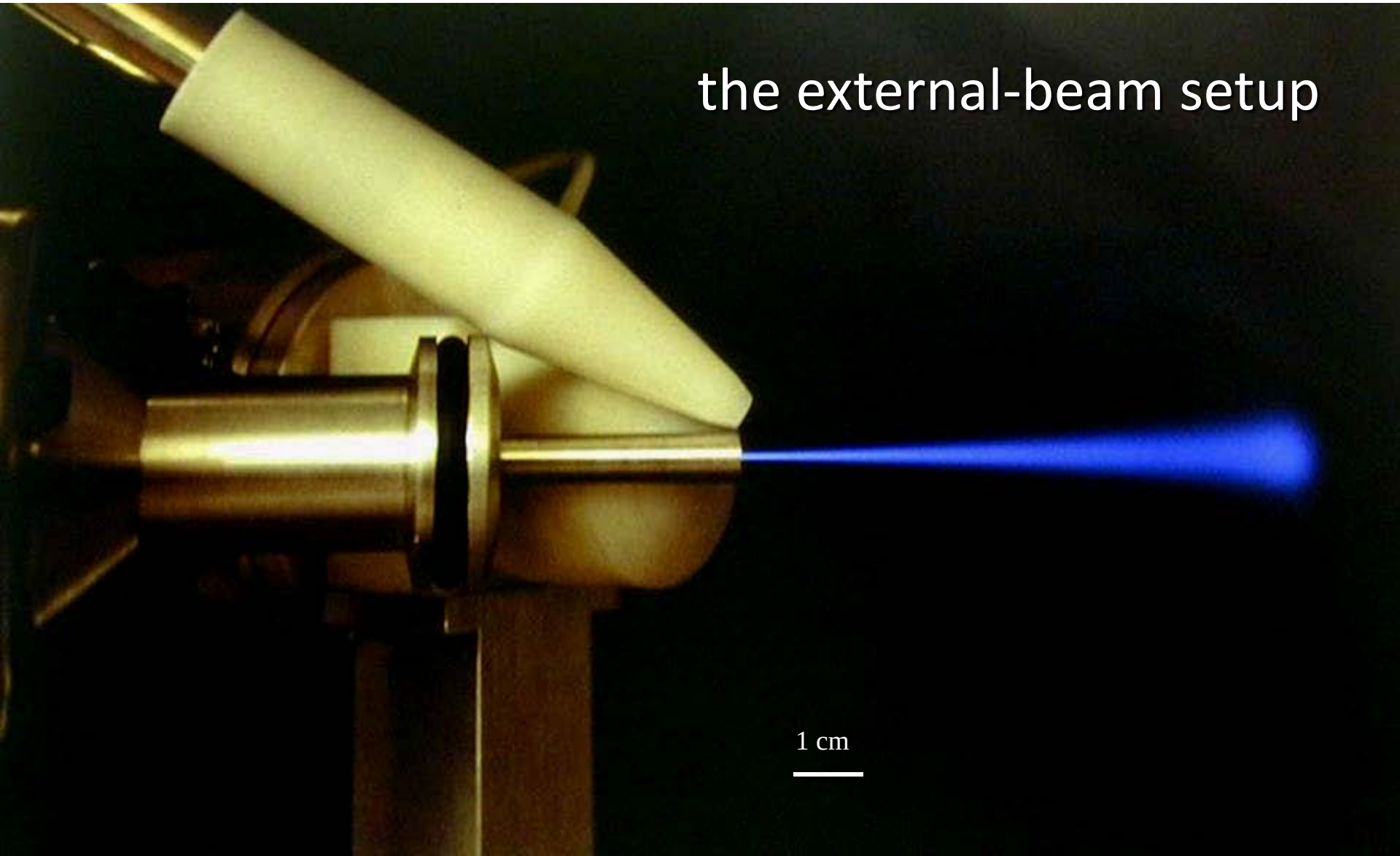
Once again, Ion Beam Analysis

Why material analysis for C.H.?

great importance for:

- attribution and authentication
- understanding technological skills in the past
- learning about materials used in a given period and production area, proving e.g. trade exchanges from other areas, if the detected materials are known to be locally unavailable
- detecting deterioration processes
- deciding for appropriate restoration techniques and materials

An essential feature to perform IBA for C.H.



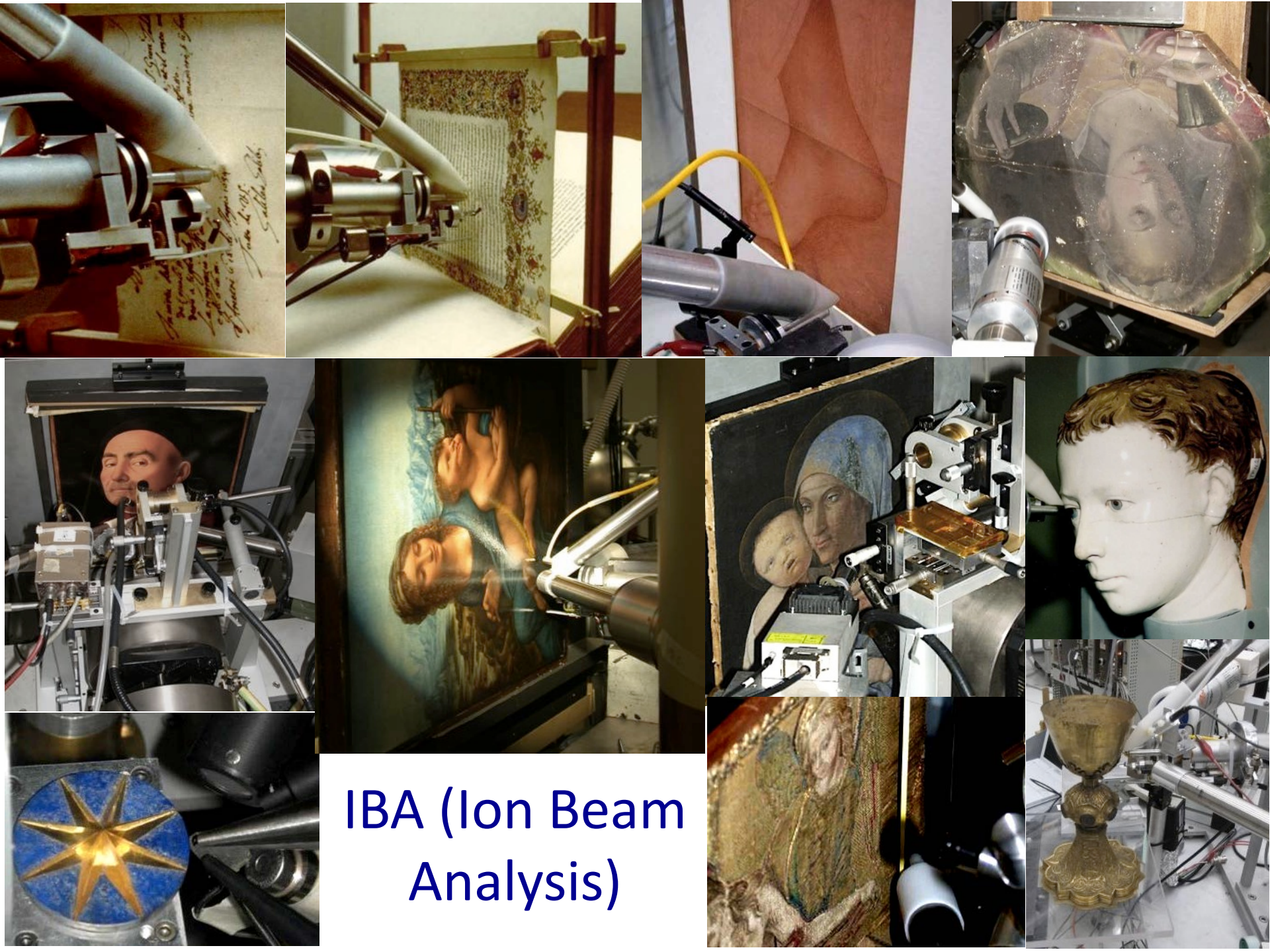
Using external beam set-ups

one can investigate

with no damage whatsoever

the quantitative composition of

a large variety of artworks



IBA (Ion Beam Analysis)

Radiocarbon

The role of ^{14}C measurements for C.H.

Most important method for
dating all materials of organic origin

Therefore:

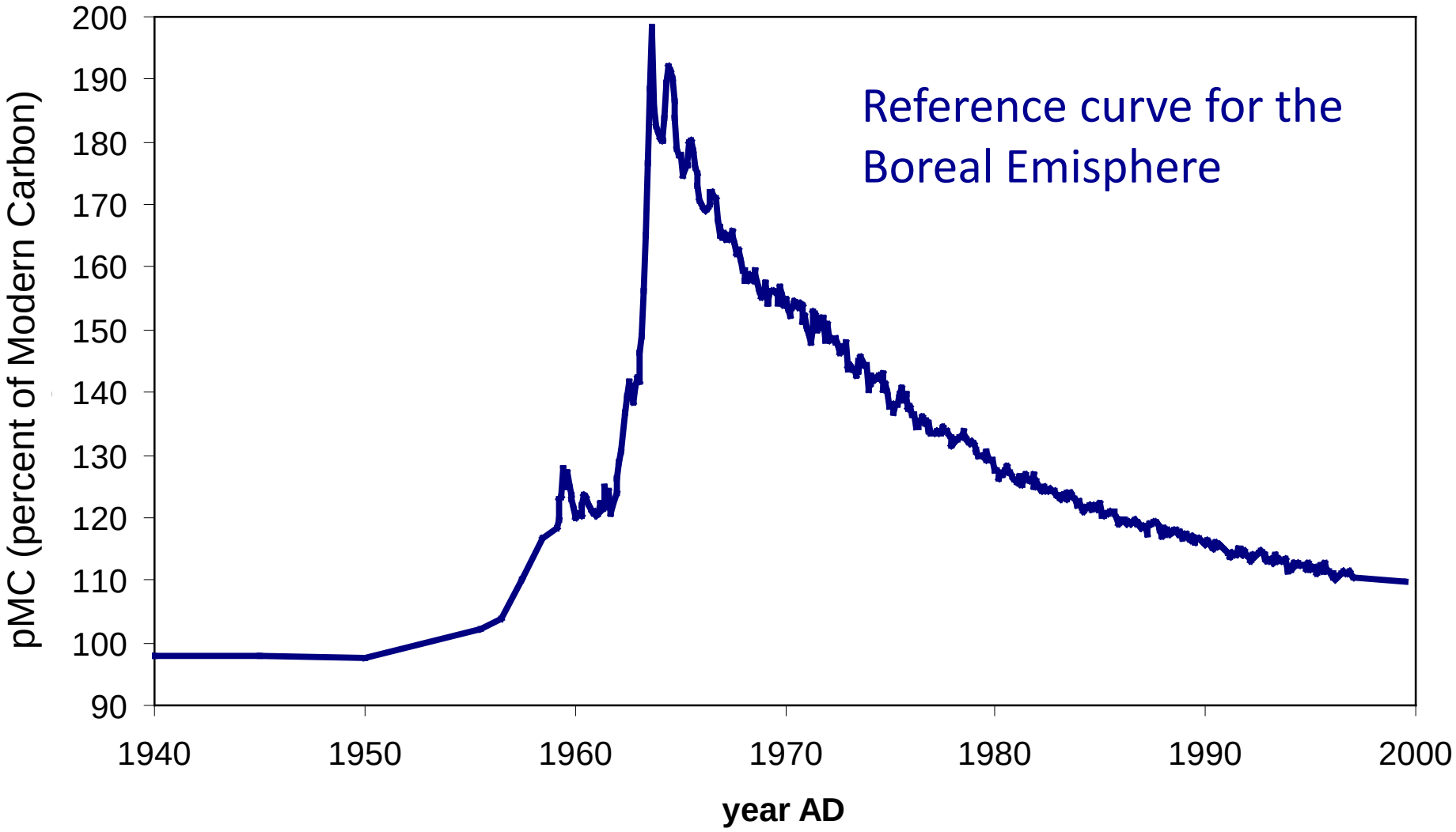
absolute chronological reconstruction of archaeological sequences

authentications of works of art

compatibility of alleged relics with their attribution

But something good may even come from the “bad” nuclear applications…

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



Many interesting applications in forensics and biology,

but these large variations of ^{14}C concentration during the past 60 years might also be exploited to discover recent fakes of contemporary art, claimed instead to have been produced during e.g. the first half of the XX century

When you measure the radiocarbon concentration of a painting support, you obtain a *terminus post quem* for the creation of the painting

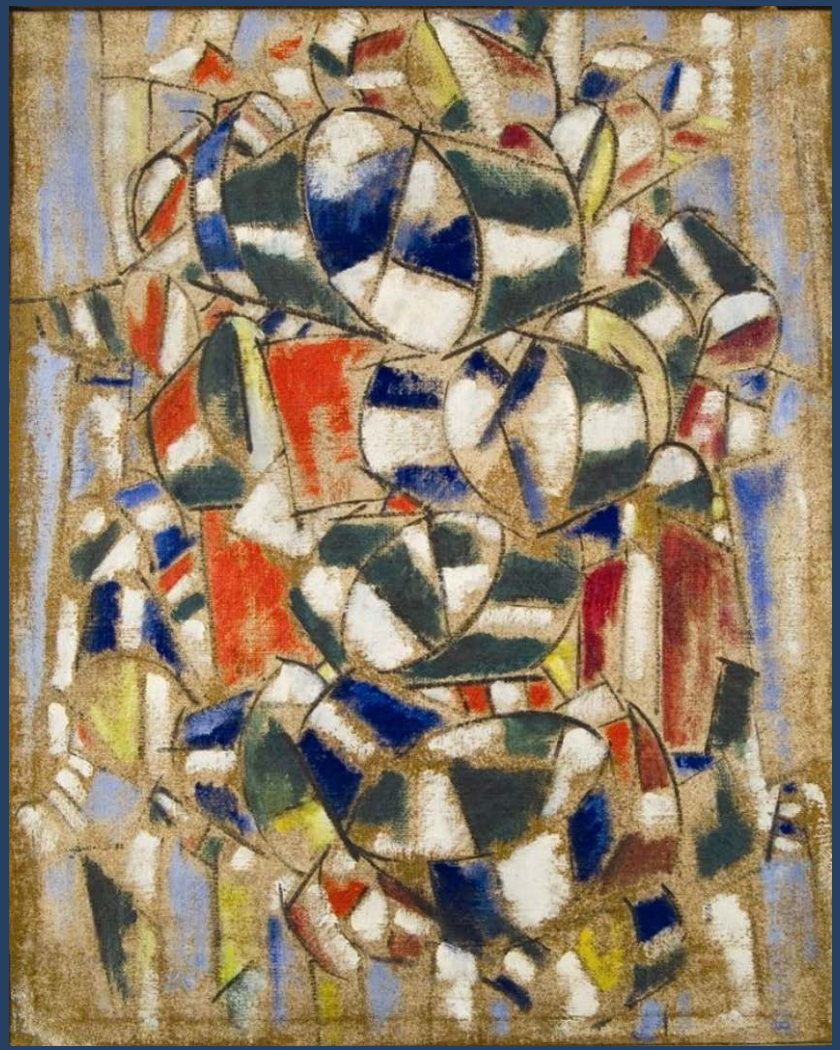
So, even when the date of the support matches the alleged date of painting, one can't positively confirm its authentivity; one can of course only declare "compatibility"

However, when the support happens to definitely come from a more recent period than the alleged date of painting, one is in the presence of

an unquestionable evidence of forgery!

Discovering forgeries of modern art by the ^{14}C Bomb Peak

L. Caforio, *et al,* Eur. Phys. J. Plus (2014) 129: 6
in collaboration with the Peggy Guggenheim Foundation, Venice



Fernand Léger, Contraste de Formes

oil on canvas, 92x73 cm

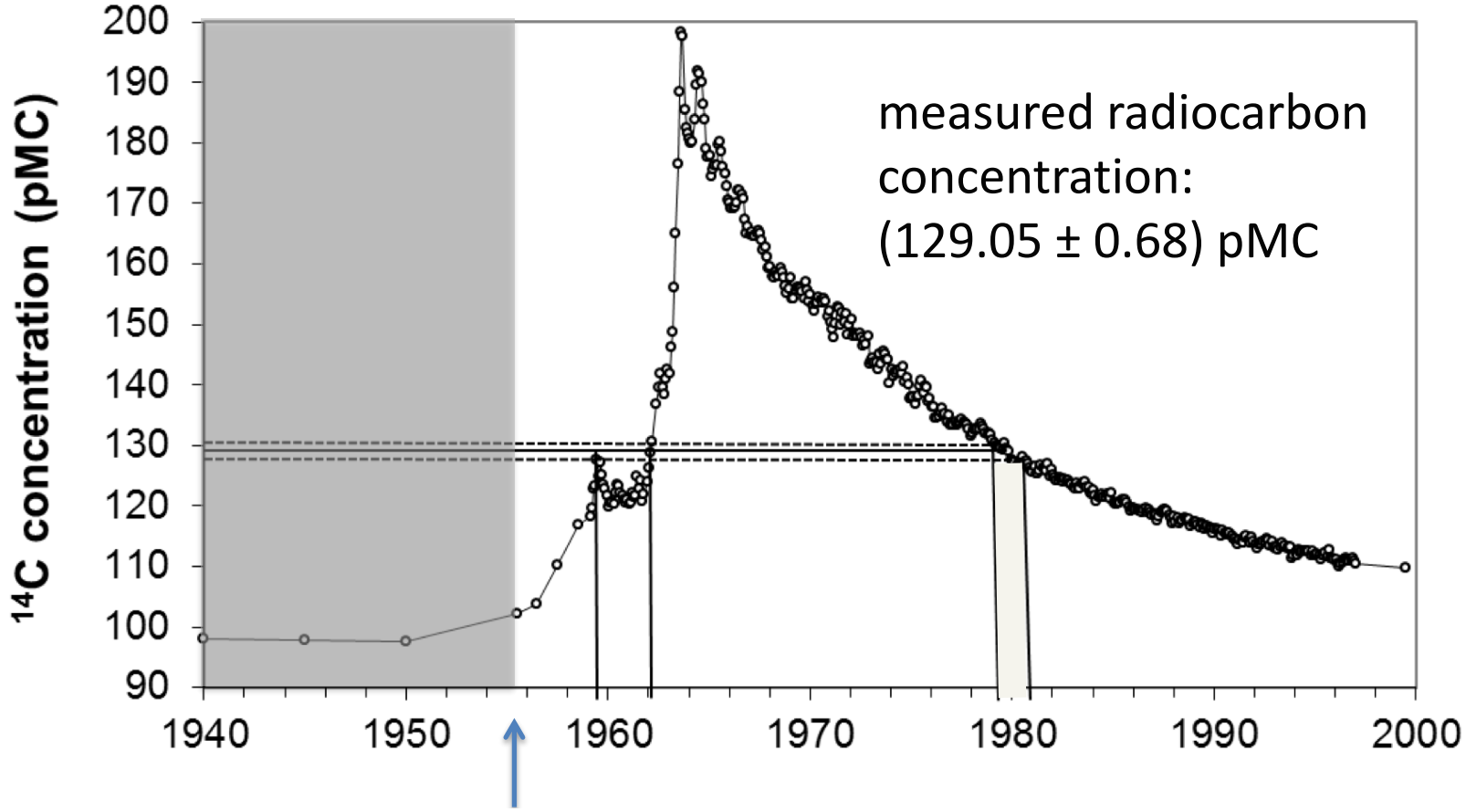
allegedly painted in 1913-14

bought by Peggy Guggenheim in the late 1960s

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

(remarkable example of fair behaviour)

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



Léger's death → the painting is a fake

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Spare slides

PIXE – Very large production cross sections!