INFN
CHNet
Istituto Nazionale di Fisica Nucleare
Cultural Heritage Network

X-ray and Neutron tomography for Cultural Heritage

Maria Pia Morigi

Bologna, 4 February 2021

Outline

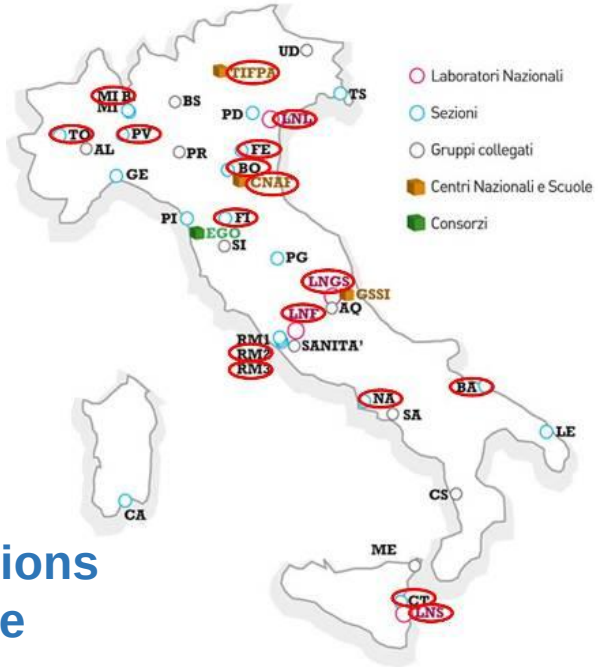
- INFN-CHNet: mission, structure and activities

- Activities of Bologna unit within INFN-CHNet
  - Research
  - Education
  - Third party services

- CHNET_NICHE

INFN – CHNet: the mission

Born to **coordinate the cultural heritage activities of INFN facilities**
Formalized in 2017

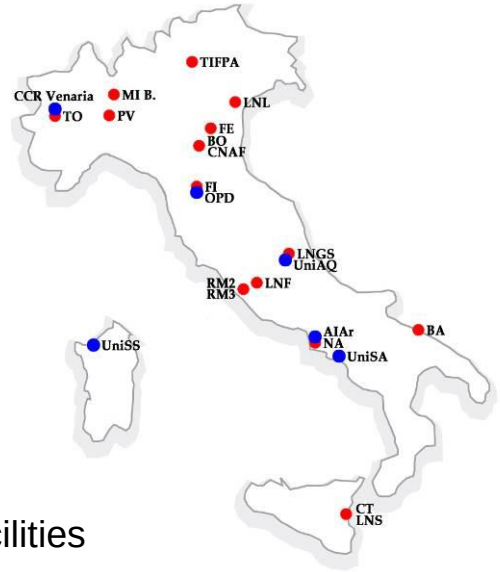


MISSION:

- Common **R&D** lines and activities
- **Sharing funds** from the Institute and projects
- **Technology & knowledge transfer**
- **Answering** the issues of the Italian **public Institutions** devoted to the preservation of the **Cultural Heritage**
- **Expanding the network worldwide**
- Interacting with other National Institutions for the creation of an **Italian hub for Cultural Heritage**

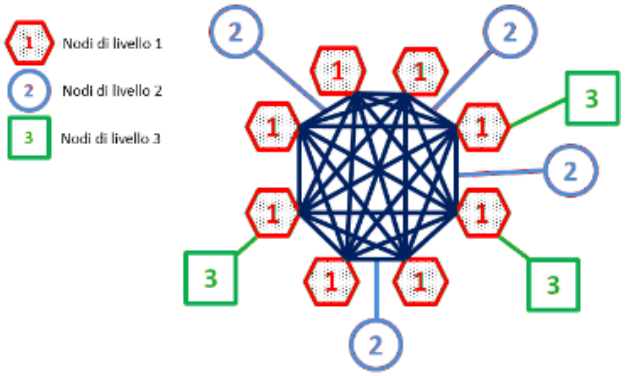
The structure

CHNet has opened to external partners in order to fulfill its mission



1st level nodes:
Laboratories in INFN facilities

2nd level nodes:
Universities, Restoration Centres, Associations with complementary competencies



3rd level nodes:
Foreign research centres/Universities outside Europe.
- Each 3rd level node is bound to a 1st level node
- Each 3rd level node is encouraged to create a local network with different competencies in its own country → Global Research Infrastructure

The infrastructure

Fixed Labs

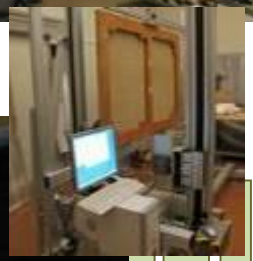
TL dating

X-ray imaging

Mass Spectrometry

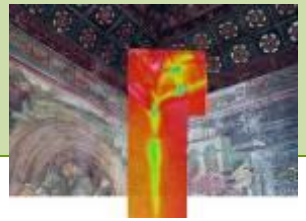
Medium-large scale facilities (IBA, ^{14}C, ...)

X-ray imaging



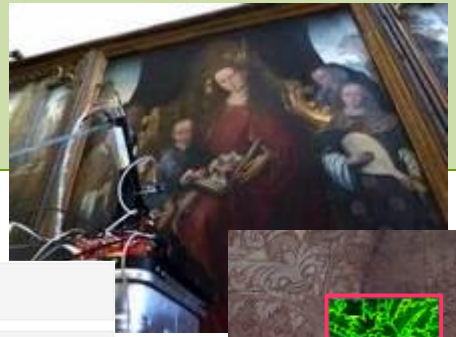
Mobile Labs

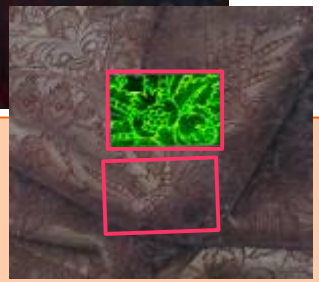
Thermography



XRD

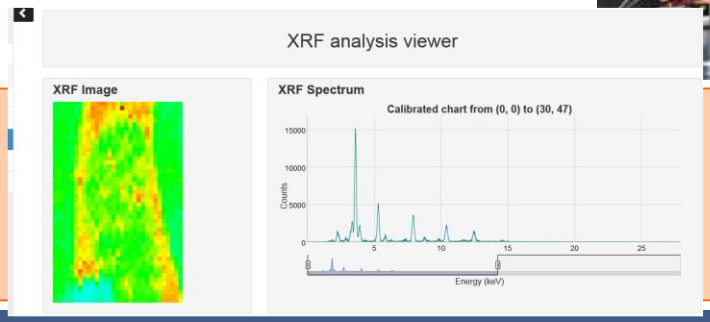
XRF





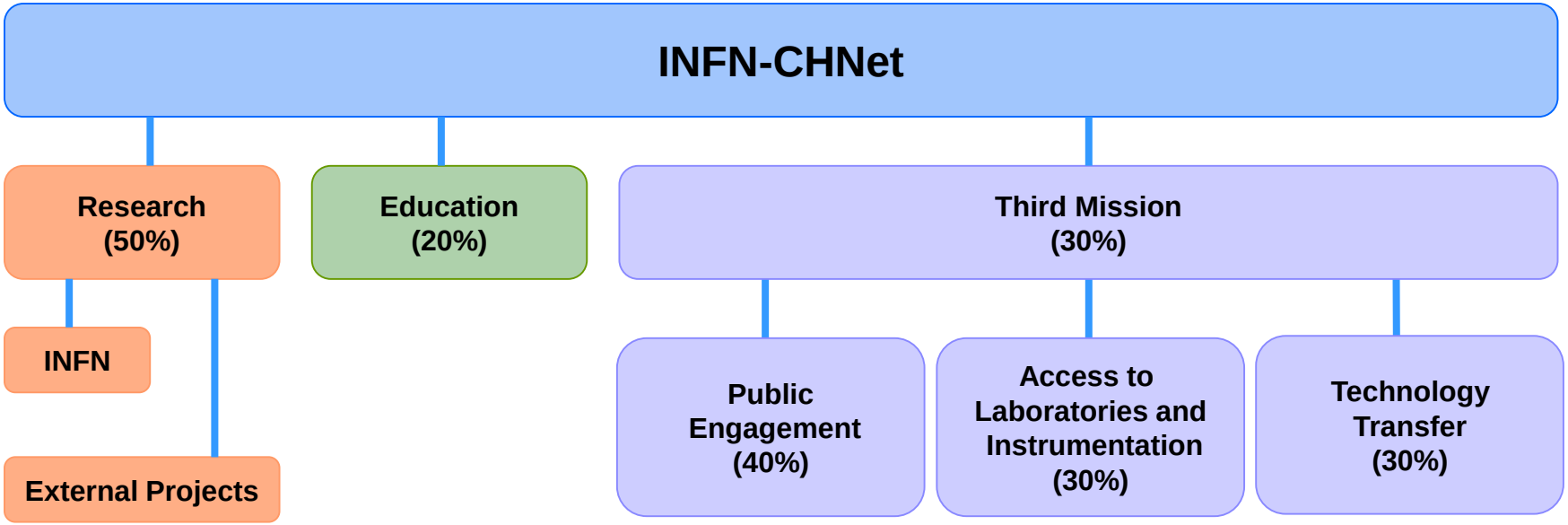
Digital Labs

Web tools for data fruition



Data Storage and fruition

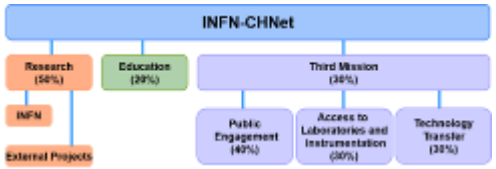
The activities

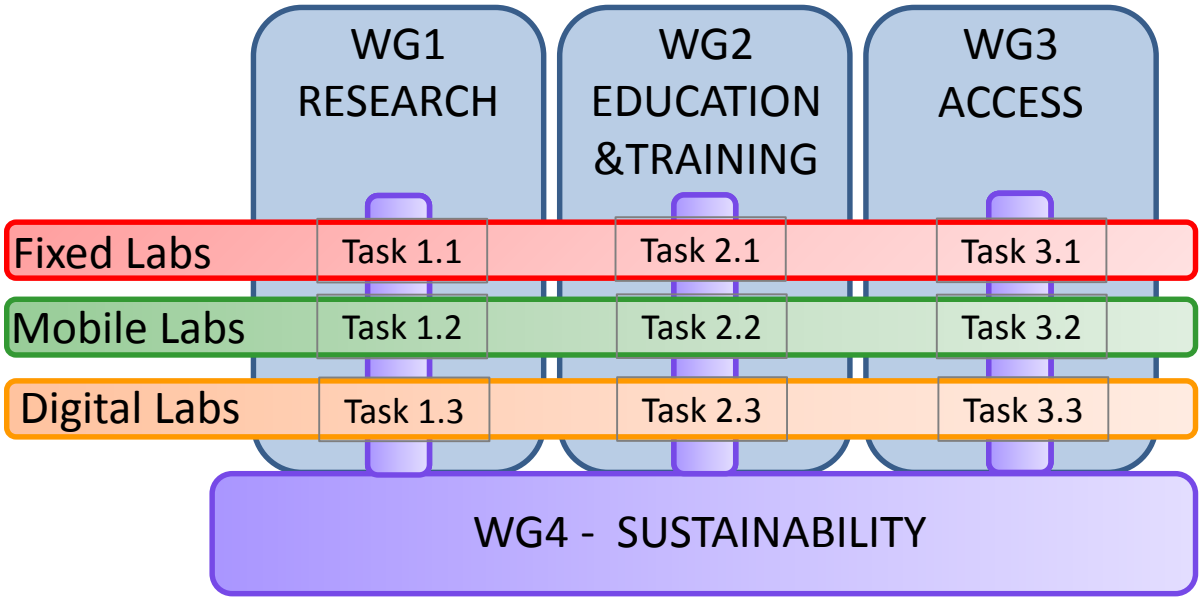


The governance

Three Working Groups following the Network activities

CHNet working groups





Research Infrastructure → Fixed, mobile and digital laboratories

A Working Group supporting the activities of the others

CHNet node in Bologna: expertise and activities

X-ray Imaging Group

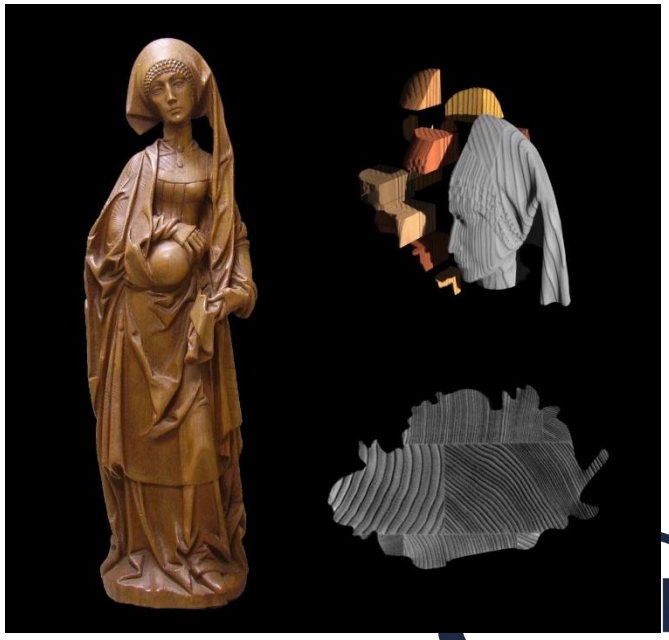
Maria Pia Morigi; Matteo Bettuzzi; Rosa Brancaccio; Fauzia Albertin

EXPERTISE: Development of acquisition systems for X-ray Computed Tomography for diagnostic investigations, both in the laboratory and on-site, on works of art and archaeological finds of different materials and sizes.

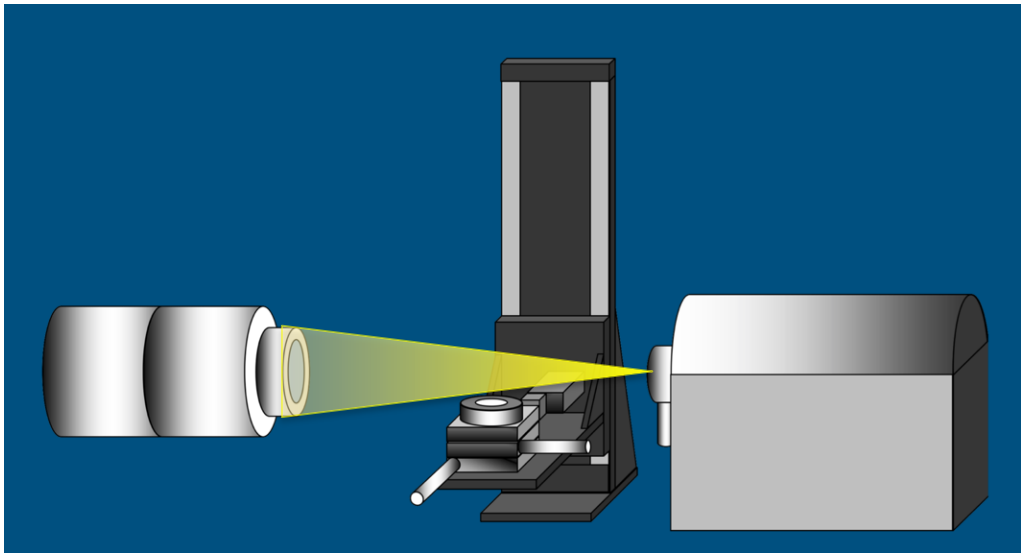
X-ray Computed Tomography (CT) is a powerful non-destructive technique, capable of displaying in a 3D way the internal structure of the investigated objects.

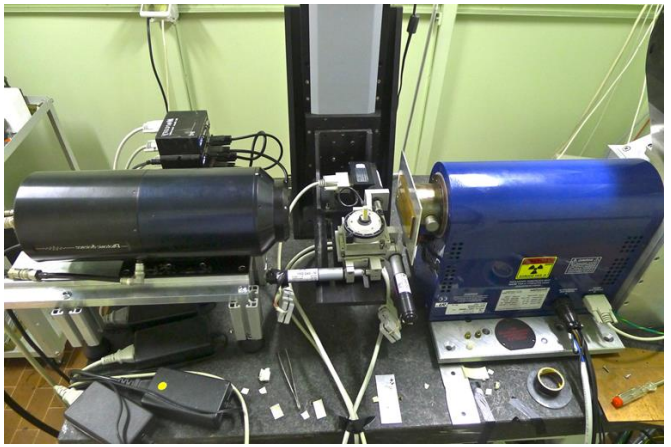
Thanks to this feature, it is currently playing an increasingly important role in the field of Cultural Heritage diagnostics.

The aim of the tomographic survey of an artefact is to obtain information on its construction technique and conservation status, both for knowledge and for setting-up a proper restoration.



Micro-CT system





CCD Camera

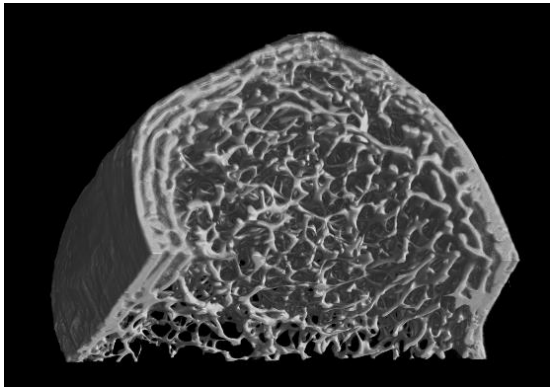
Photonic Science camera

- CCD + FO plate + CsI(Tl)
- 3.6 x 2.4 cm^2
- 4008 x 2672 pixel
- 9 µm pixel

Microfocus X-ray tube

KEVEX PXS10

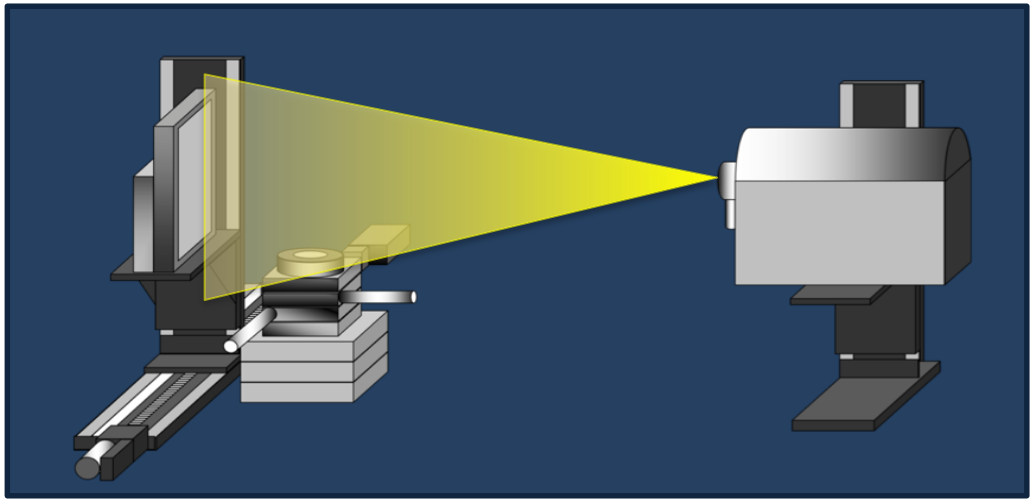
- 45-130 kV
- 0.5 mA
- 53° beam angle
- 7-100 µm focal spot



Trabecular microstructure of a child bone from the Anthropology Museum of UNIBO (voxel size: 10 µm).

Very high spatial resolution – voxel size < 10 µm

CT system for medium-size objects



Flat panel

VARIAN PS2520D

- Solid State Detector + CsI:Tl scintillator
- 19.5 x 24.5 cm^2
- 1536 x 1920 pixel
- 127 µm pixel

Microfocus X-ray tube

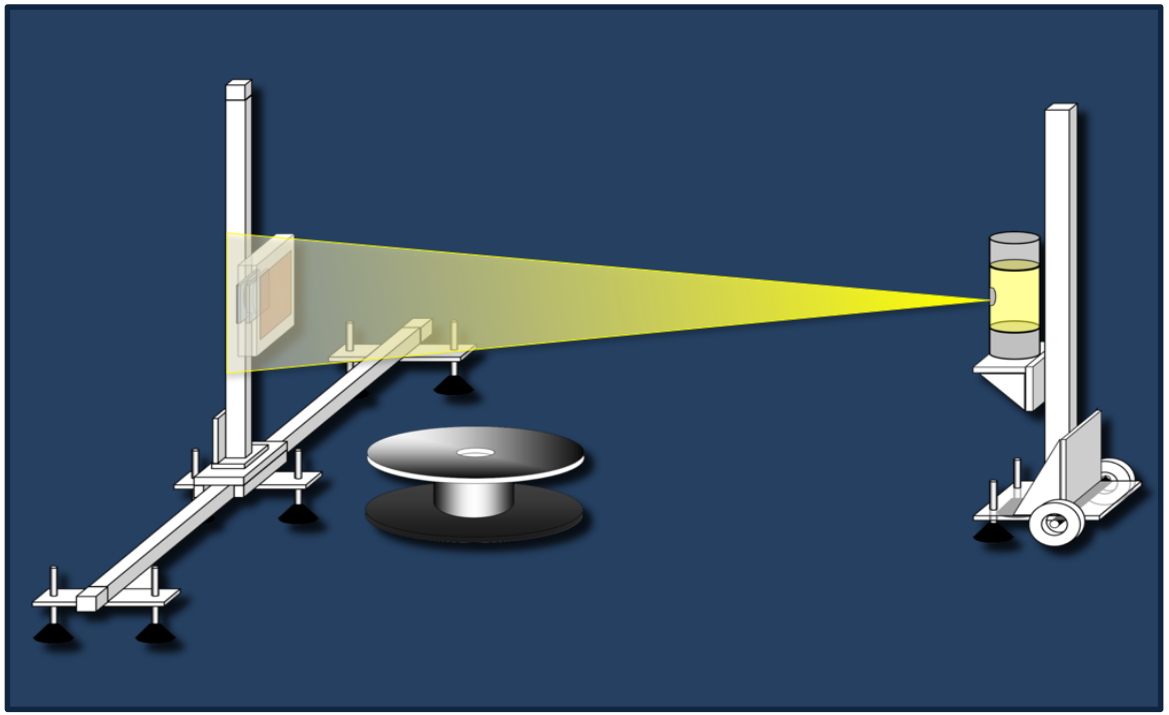
KEVEX PXS10

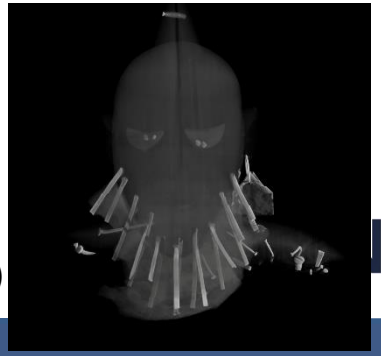
- Tungsten anode
- 5-130 kV
- 0.5 mA
- 53° beam angle
- 7-100 µm focal spot

Japanese theatre mask (ICR - Rome).

High spatial resolution – voxel size ≈ 50 -100 µm

CT system for large-size objects





African wooden statue
(Pigorini Museum –Rome)

X-ray detector

HAMAMATSU C10900D
- Solid State Detector + CsI:Tl scintillator
- 12 x 12 cm^2
- 1216 x 1232 pixel
- 100 µm pixel

X-ray tube

YXLON SMART EVO 200D
- 30-200 kV
- 0.5 – 6 mA
- 750 W
- 1 mm focal spot

Education: Training Camps

One-week Summer Schools on non-destructive in-situ Diagnostic techniques on Cultural Heritage, organisation led by INFN

Target: bachelor or master degree graduated in science or humanities applied to cultural heritage, and restorers

- Publication of a call
- Selection of about **20-30 participants**
- Laboratories **in small groups** (5-6 p) on selected artworks, with different techniques and together with researchers of ENEA, INFN, CNR and restorers of OPD

A fee is required to cover only part of the accommodation cost; the rest is covered by the MIUR

Multidisciplinary, small groups
Hands on instrumentation and artworks

Education: Training Camps

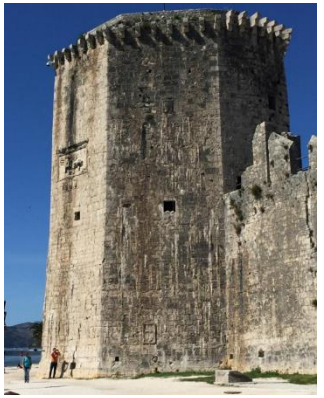
SANSEPOLCRO (AR) 2014

L'AQUILA 2015

SIRACUSA 2016

ALGHERO (SS) 2017

GIOIA DEL COLLE (BA) 2018



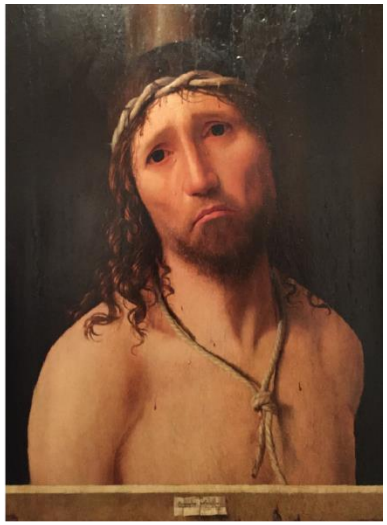
TROGIR 2019

INFN CHNet
Istituto Nazionale di Fisica Nucleare
Cultural Heritage Network

Third Mission: Access to Laboratories and Instrumentation

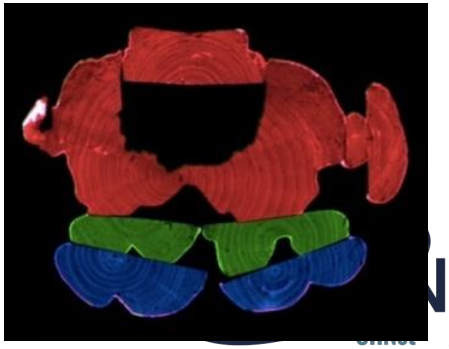
E-RIHS.it
EUROPEAN RESEARCH INFRASTRUCTURE FOR HERITAGE SCIENCE

Annual calls for access to Laboratories and Instrumentation



ECCEHOMO PROJECT

STA.VE. PROJECT

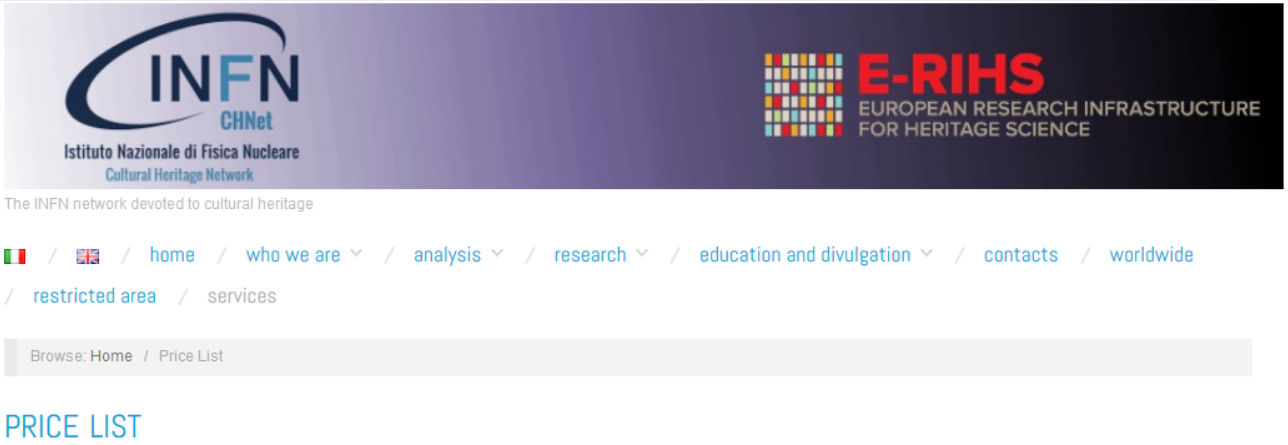


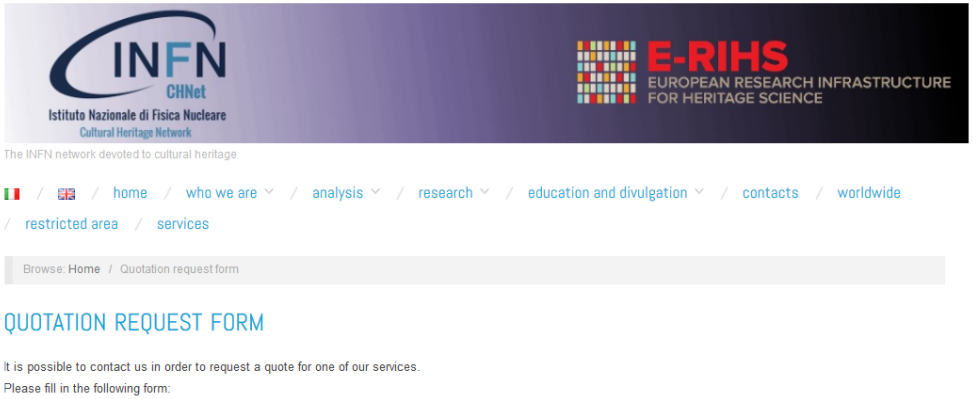
Third Mission: third party services

A common price list available online

~ 15 different techniques

~ 10 involved nodes





A quotation request form available online

The requests are received by the Access WG and sent to the proper CHNet node

INFN CNTT writes down the contract

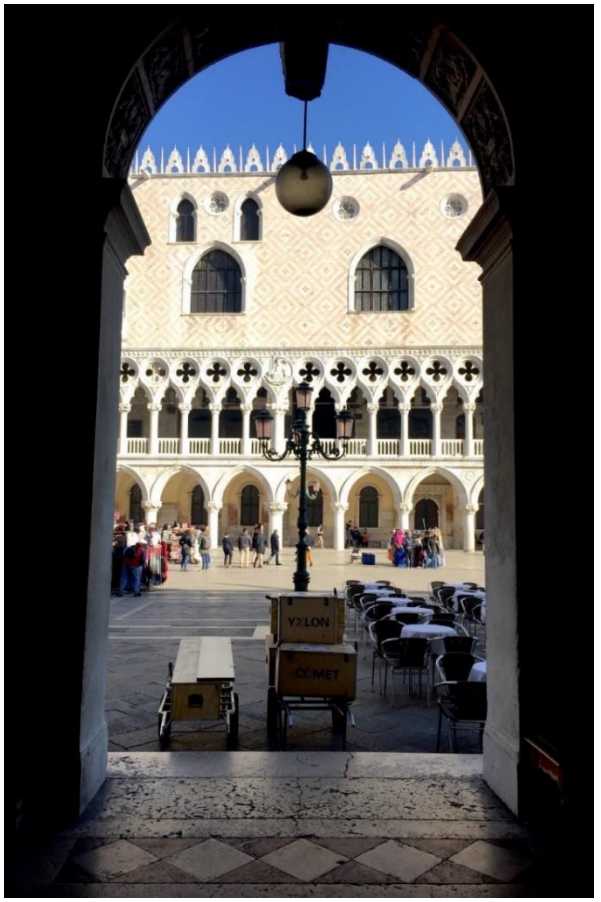
After the activitiy is performed, funds are shared between the CHNet network and the involved INFN structures

Third Mission: third party services

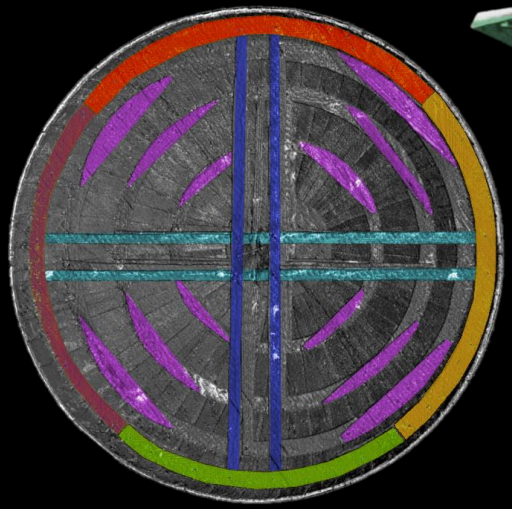
In situ CT analysis of a celestal globe by Vincenzo Coronelli (Marciana Library – Venice)

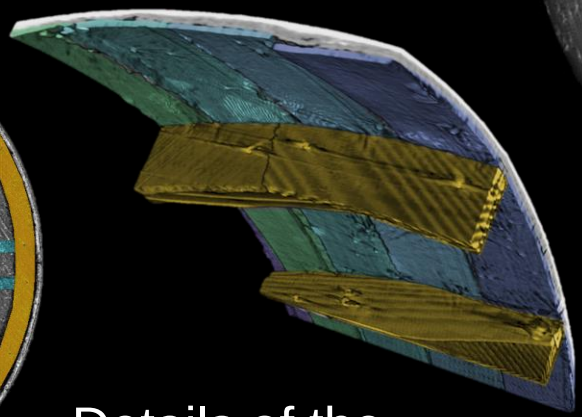
Third Mission: third party services

Transfer of equipment on-site

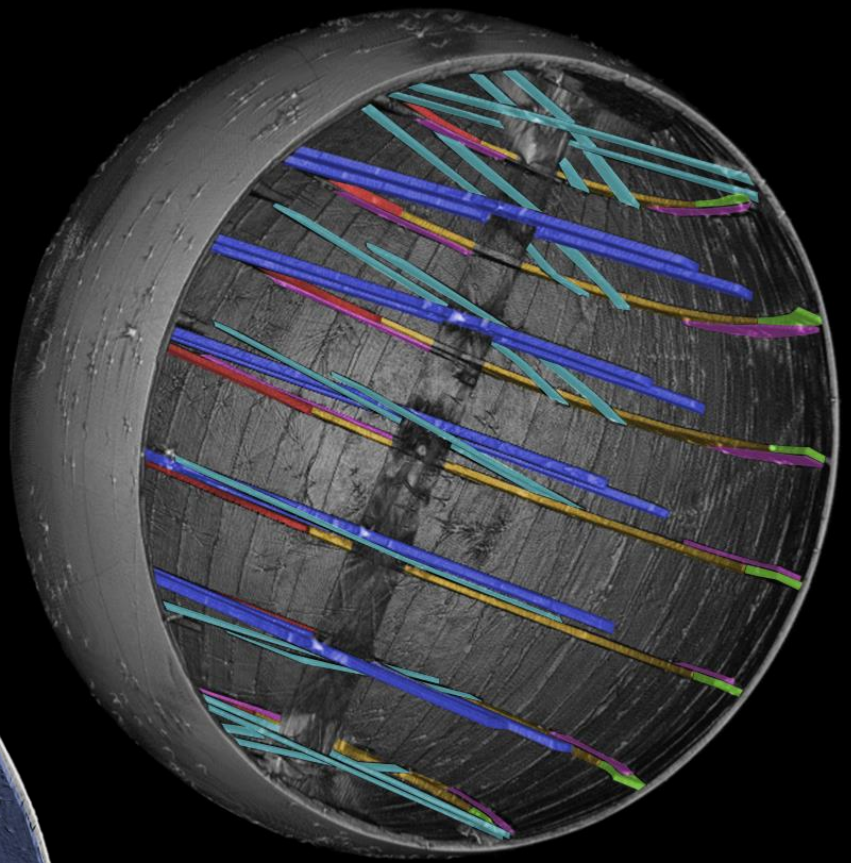


Third Mission: third party services





Details of the
inner structure



3D rendering

RESEARCH: CHNet_NICHE

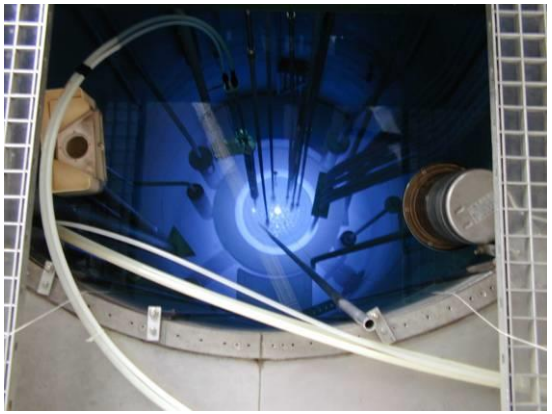
CHNet_NICHE

Neutron Imaging: non-destructive technique for morphological information, complementary to other more usual techniques (IBA, XRF, X-Ray Tomography, ...)

- **Goal**: **development and optimisation of a system for imaging and tomography with thermal neutrons at the TRIGA Mark II reactor of the LENA Lab in Pavia.**

- Take advantage of the TRIGA beamline used for PGNAA in the framework of the CHNet_TANDEM experiment, in order to realise the **first Italian facility of neutron radiography and tomography devoted to cultural heritage** applications, to be used also by external users.

- Integrating the new facility with the other instrumentation of the CHNet network

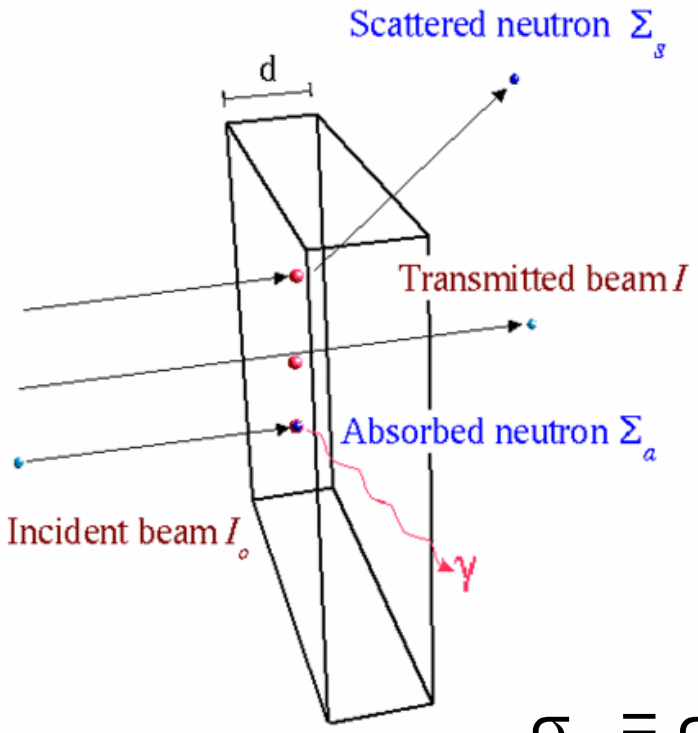


CHNet_NICHE

The radiographic method

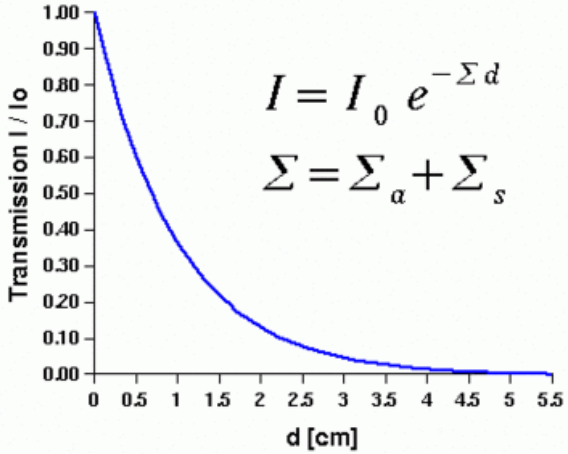
Narrow Beam Attenuation

$$I = I_o e^{-\Sigma d}$$



$\sigma_{tot} = \sigma_{sc} + \sigma_{ass}$

Exponential Attenuation Law



$$I = I_0 e^{-\Sigma d}$$

$$\Sigma = \Sigma_a + \Sigma_s$$

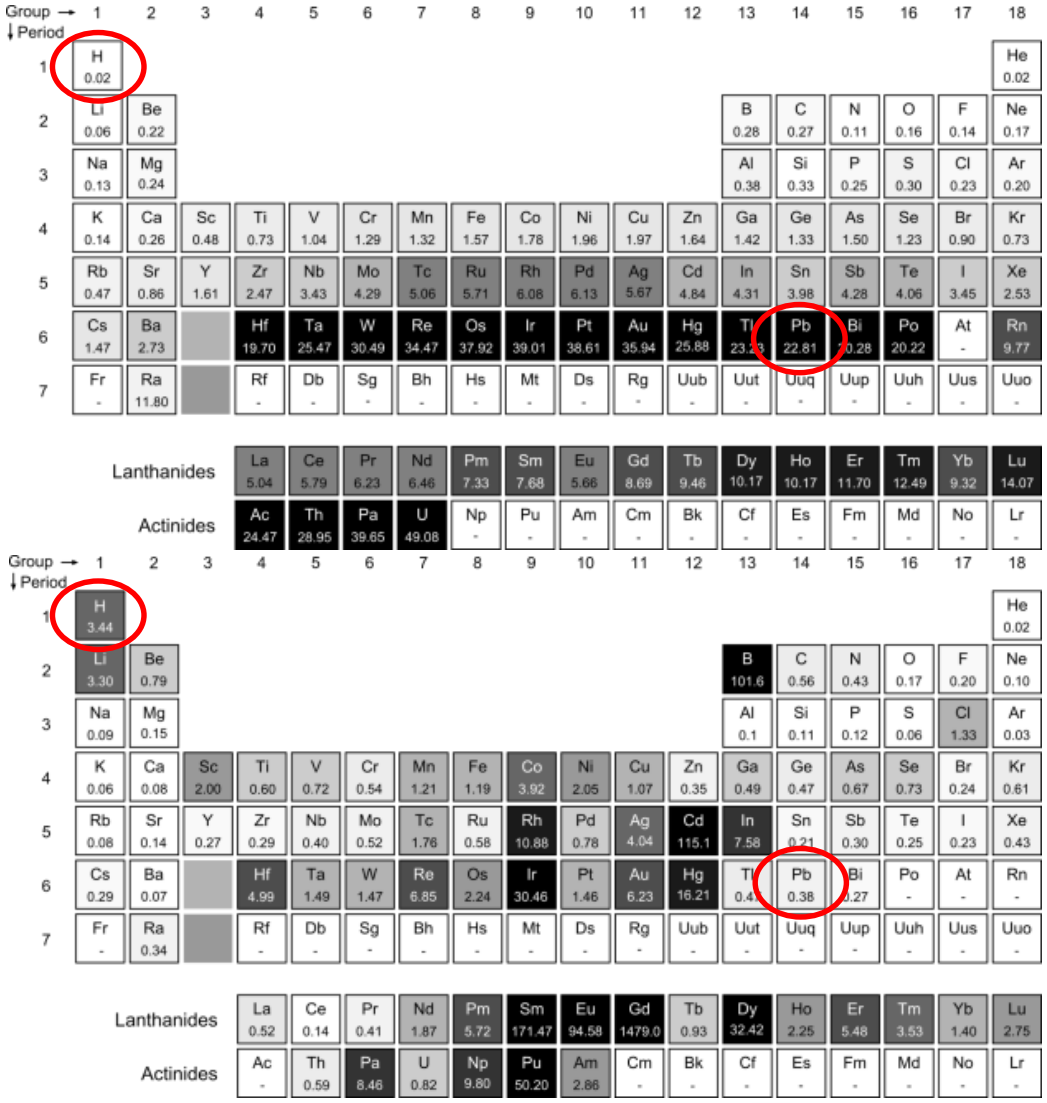
Macroscopic Cross Section Σ

$$\Sigma = N\sigma \quad [cm^{-1}]$$

$$N = \frac{\rho}{A} N_A \quad [cm^{-3}]$$

N := number density $[cm^{-3}]$
ρ := material density $[g\,cm^{-3}]$
A := atomic weight $[g\,mol^{-1}]$
N_A := Avogadro number $6.022\,10^{23}\,[mol^{-1}]$

CHNet_NICHE



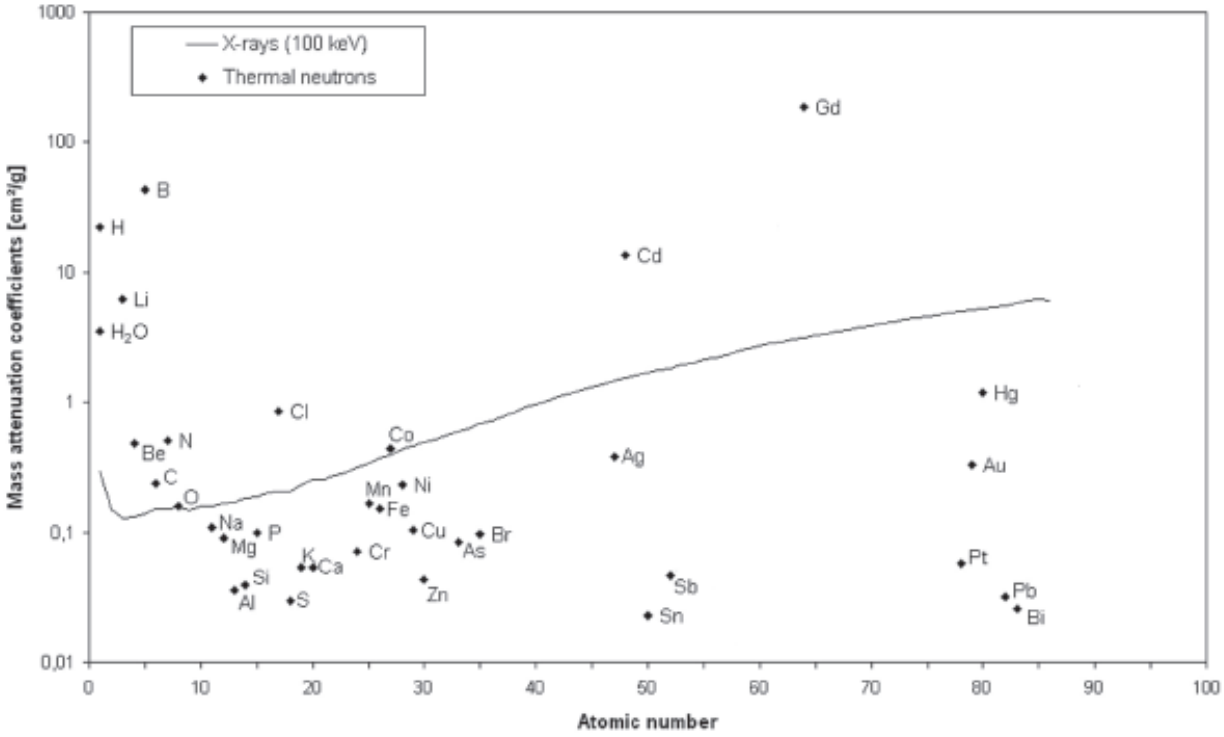
X-Rays and neutrons: different interactions with matter

First table: X-ray attenuation coefficient (energy 150 KeV) in gray scale for all the elements.

Second table: macroscopic cross section for thermal neutrons.

CHNet_NICHE

Neutronigraphy is not equivalent to conventional radiography; in fact, for X-rays, fixed their energy, the absorption coefficient is a regular function of the **atomic number Z** of the investigated medium. The absorption coefficient for neutrons, on the other hand, is not simply linked to the atomic number, nor to the mass number of the different nuclides, but it also varies with the energy of neutrons in an irregular way.



Mass attenuation coefficients for thermal neutrons and X-rays (100 keV) as a function of the atomic number.

CHNet_NICHE

Buddha Shakyamuni (XIV - XV century)

X-rays

Neutrons

Why neutrons:

-Higher penetration and contrast between nearby elements in metals

-High sensitivity to hydrogen (organic materials)

Source: Lehmann, E.H., Hartmann, S. and Speidel, M.O. (2010), investigation of the content of ancient tibetan metallic buddha statues by means of neutron imaging methods. Archaeometry, 52: 416-428.

CHNet_NICHE

Neutron imaging

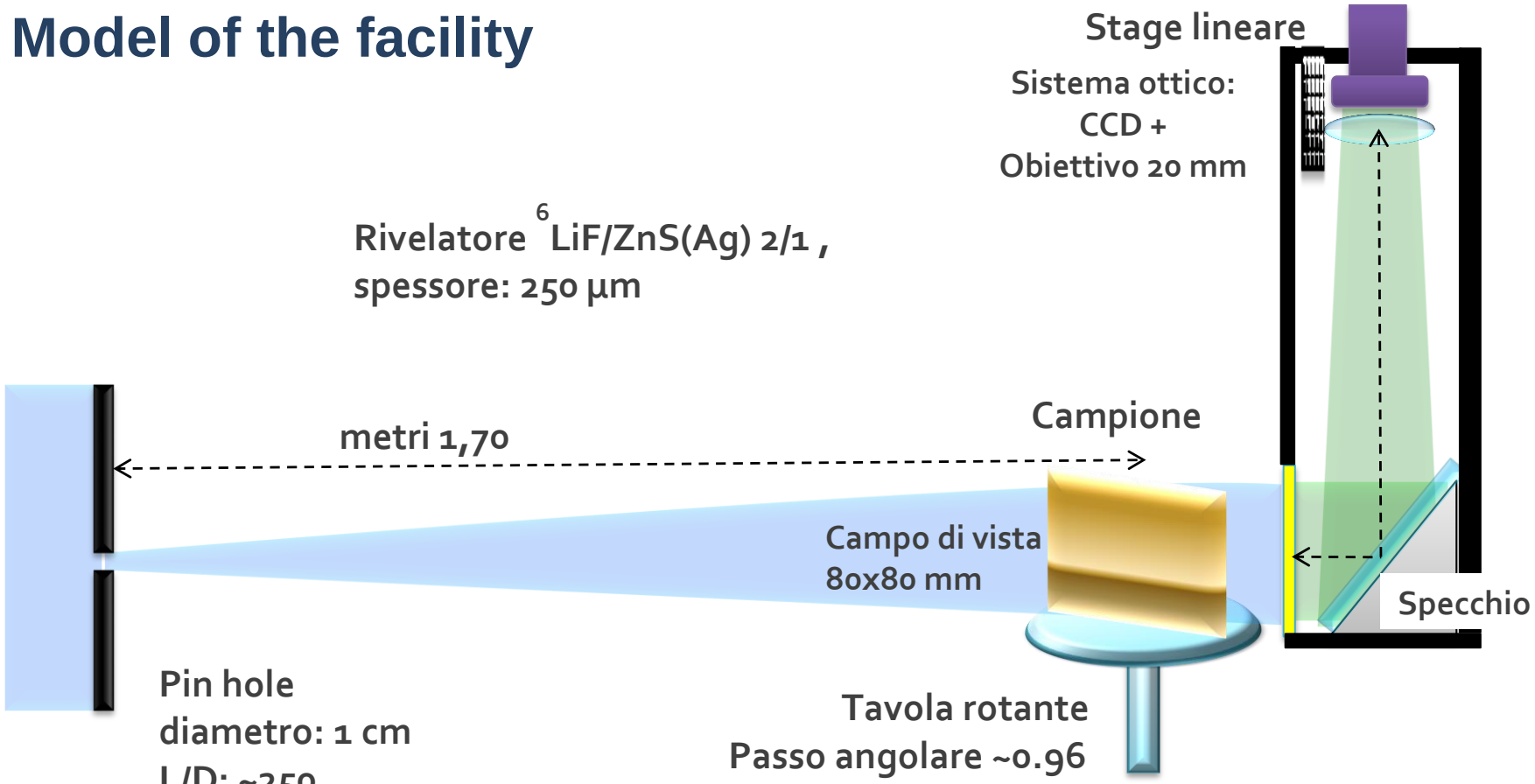
Radiography

Tomographic slice

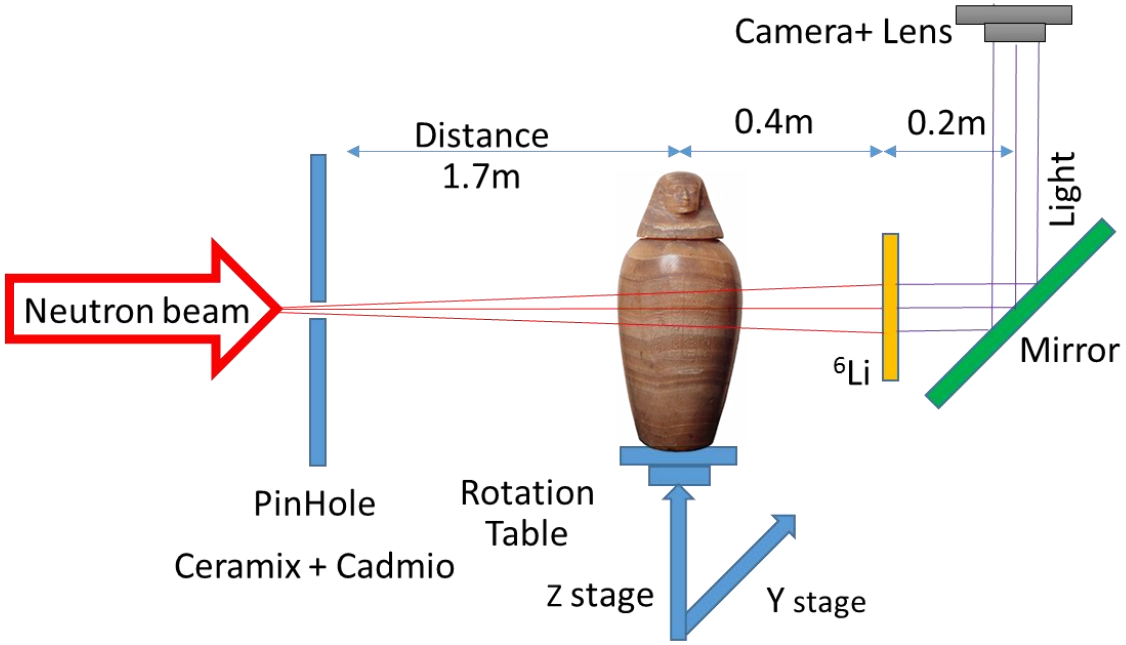
Volume rendering

CHNet_NICHE

Model of the facility



CHNet_NICHE



Variable geometry in order to obtain the best illumination and the best resolution.

CHNet_NICHE

Milestone 1 (month 6): simulations and development of a preliminary measurement system at LENA (FI and PV)

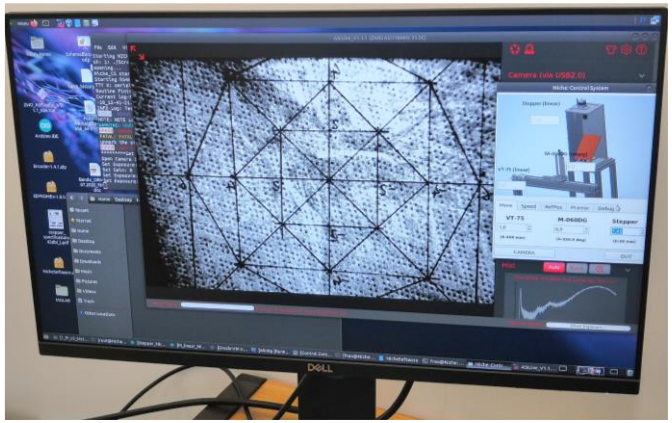
Milestone 2 (month 12): experimental tests (FI, TO, PV, BO) and optimization of the measurement system; preliminary characterization of the new facility (spatial resolution, dynamic range, etc.). First application on test objects.

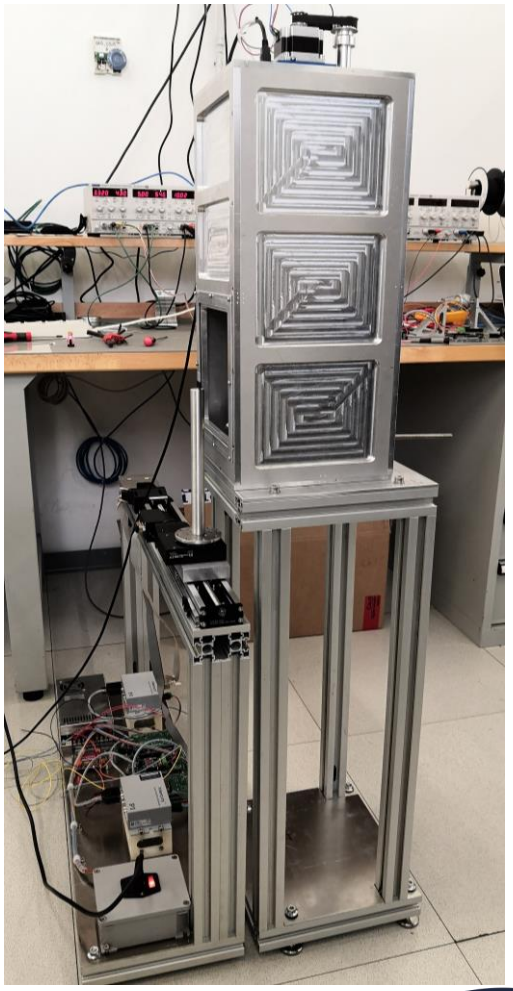
Milestone 3 (month 18): realization of the beam limiter and completion of the measurement point with shields and motorization (FI, MIB, PV). Definition of empirical laws for attenuation in the new geometry (FI, TO, BO).

Milestone 4 (month 24): application to case studies of interest, digital data processing and comparison with X-ray tomography (FI, TO, BO).

CHNet_NICHE

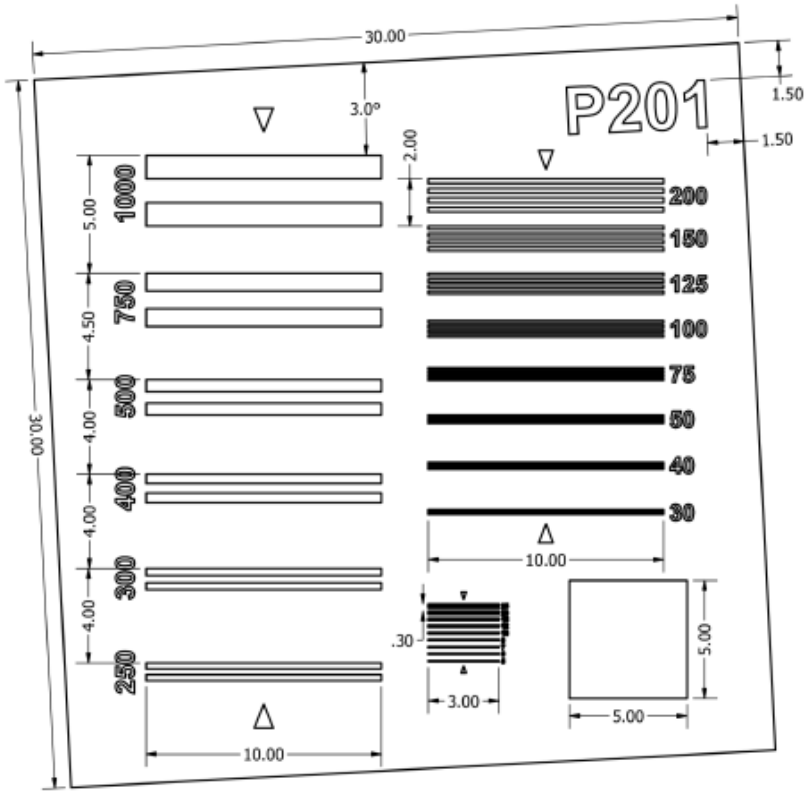
Activity 2020: development of detector





CHNet_NICHE

Test object



Line pair gauge

Thank you!

https://chnet.infn.it

Maria Pia Morigi
morigi@bo.infn.it
mariapia.morigi@unibo.it