The ANET Compact Neutron Collimator

Advanced Neutron Technologies

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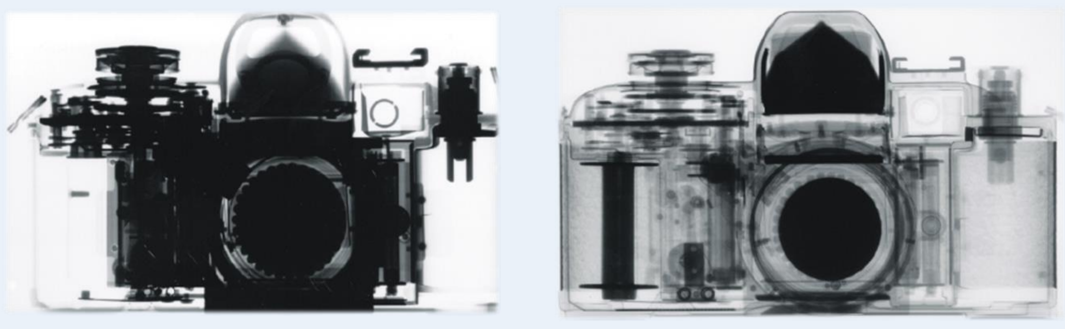
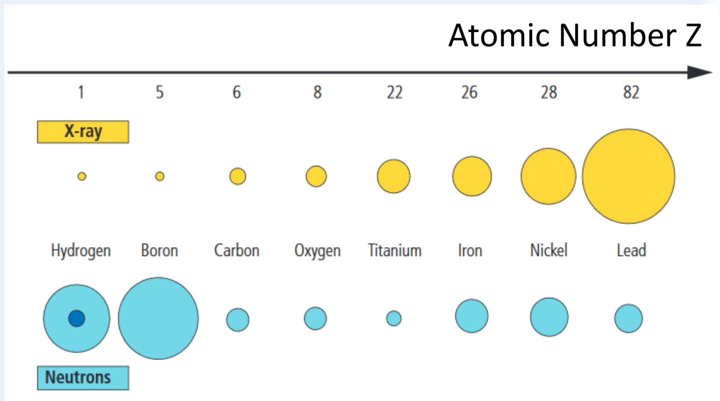
INFN

NEUTRON IMAGING



X-ray (left) and neutron (right) radiography of a camera.



X-ray (yellow) and neutron (blue) cross sections at increasing Z.

Neutron imaging allows to get information which is complementary to the X-ray imaging. As imaging probes, the neutrons:

- are very sensitive to some light elements like H, Li, B, where X-rays do not provide a good contrast;
- easily penetrate thick layers of Pb, Fe, Cu where standard X-ray fail;
- have a distribution of attenuation coefficients which is independent from the atomic number;
- can distinguish between isotopes of the same element.

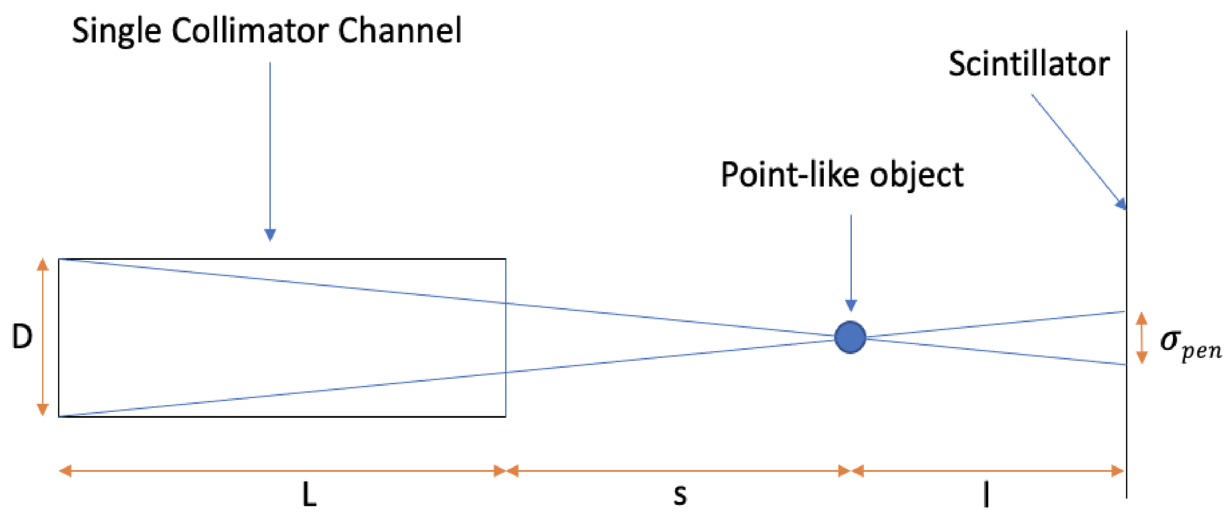
FIGURES OF MERIT

Physical quantities useful to characterize the imaging system:

Collimation power:

$$\frac{L}{D} = \frac{length}{diameter}$$

Intrinsic quality of the collimation



Divergence:

$$\theta_{div} = \arctan\left(\frac{1}{L/D}\right)$$

Penumbra:

$$\sigma_{pen} = \frac{lD}{L+s}$$

Resolution:

$$\sigma_{tot} = \sqrt{{\sigma_{pen}}^2 + {\sigma_{det}}^2}$$

ANET MEASUREMENT RESULTS

The collimator has been tested at the LENA reactor in Pavia (Italy) and at the BOA neutron line at the Paul Scherrer Institute in Zurig (Swiss).
A significant improvement in the beam quality has been appreciated.

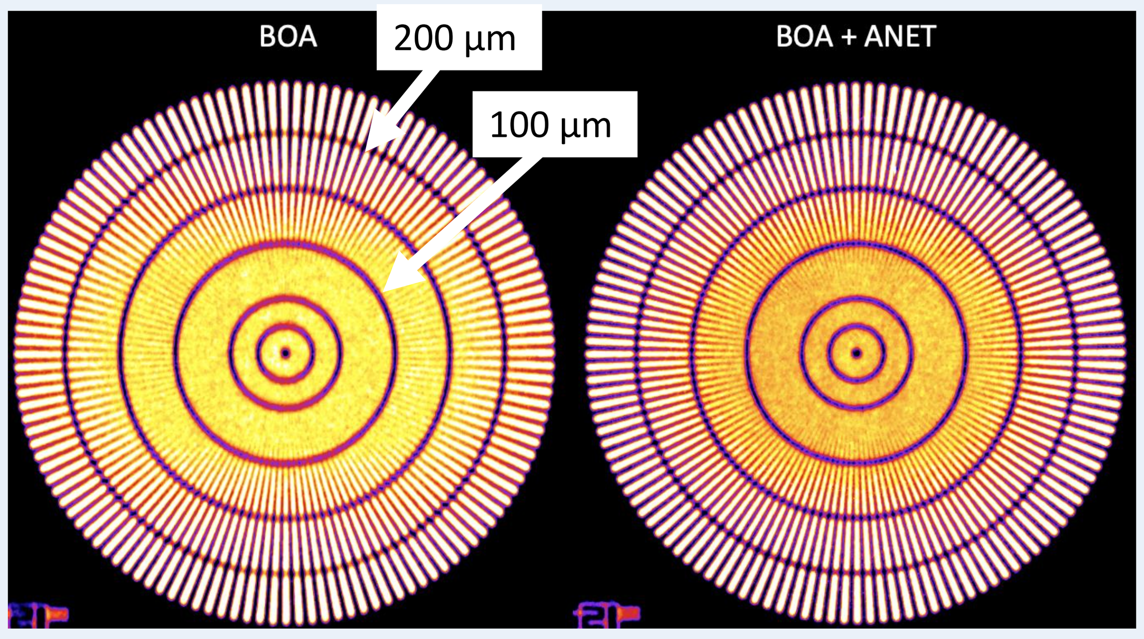
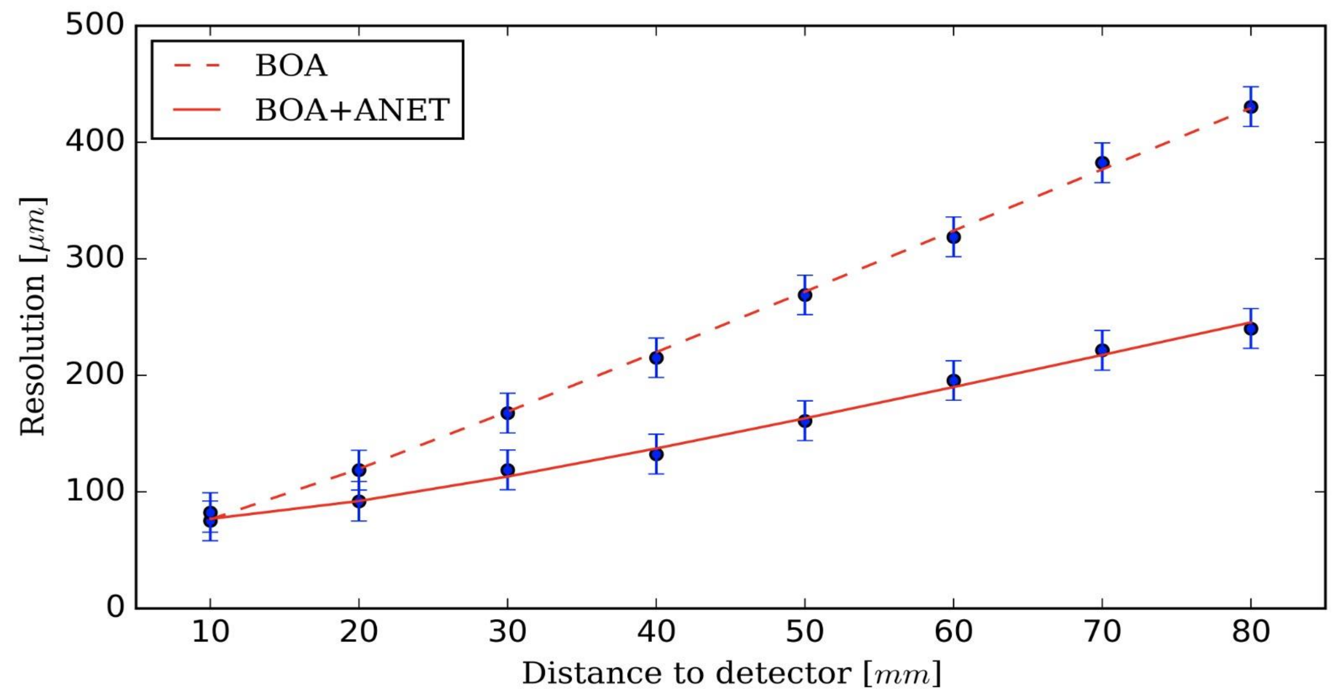


Image of a ***Siemens Star*** *used to measured the resolution of the beam at BOA without (left) and with (right) the ANET collimator inserted in the beam. The more lines are visible the better is the resolution.*

The system resolution has been measured positioning a Siemens Star at different distances from the scintillator (by varying l and s) and its value has been evaluated through a mathematical method. The improvement of x,y divergence and of the resolution values when including the ANET CNC is mighty.

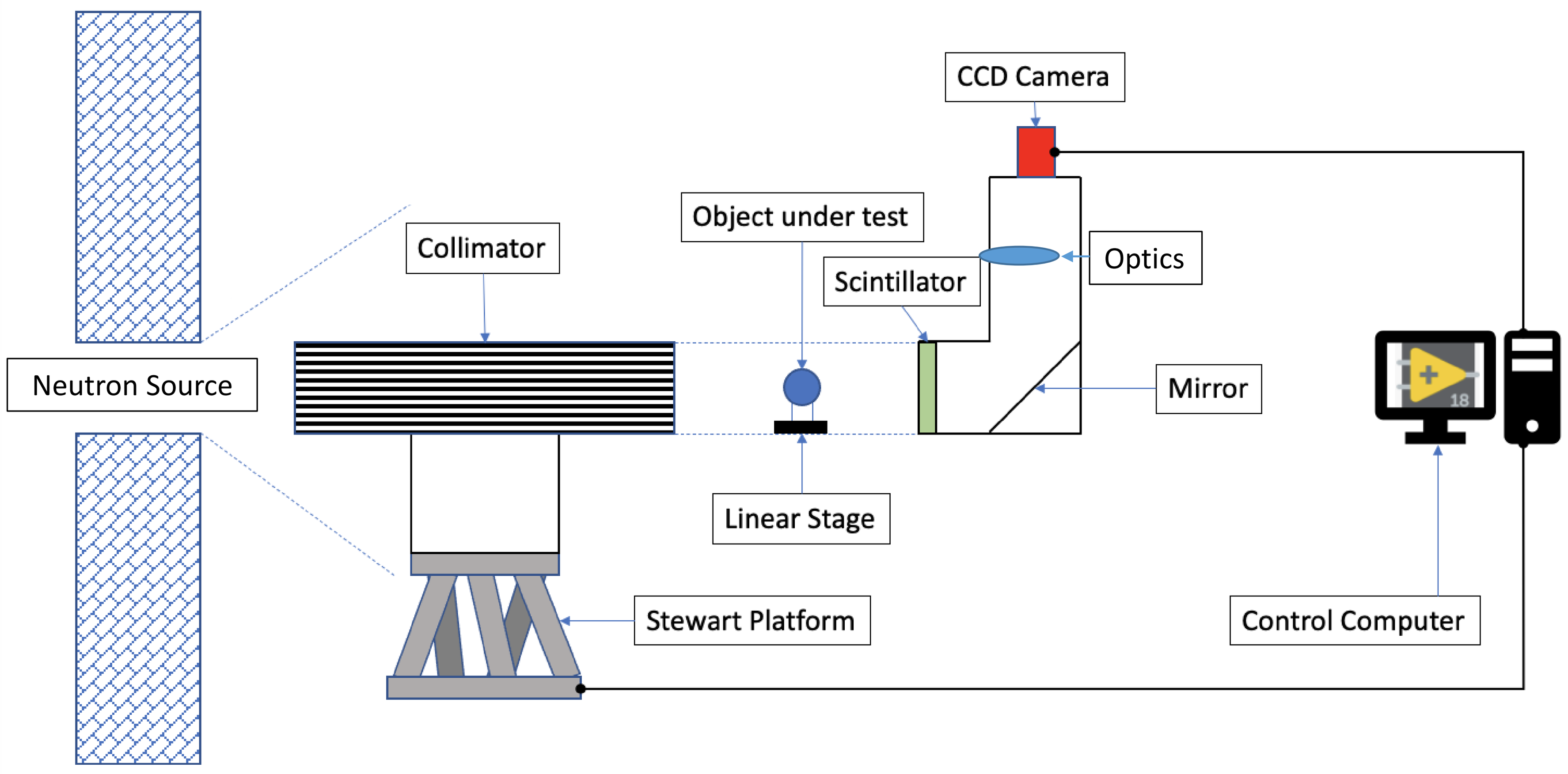


Resolution at different distances of the sample from the scintillator at BOA neutron beam with and without the ANET CNC.

PUBLICATIONS

[1] PCT Patent n. PCT/IB2021/053856 Collimatore
[2] Bedogni, R., et al. (2021). "Design of a novel compact neutron collimator". Journal of Instrumentation,16.08, P08055
[3] Oriol Sans-Planell et al. "First results with the ANET Compact Thermal Neutron Collimator". Journal of Instrumentation 16.11 (2021), P11025.

NEUTRON IMAGING SETUP

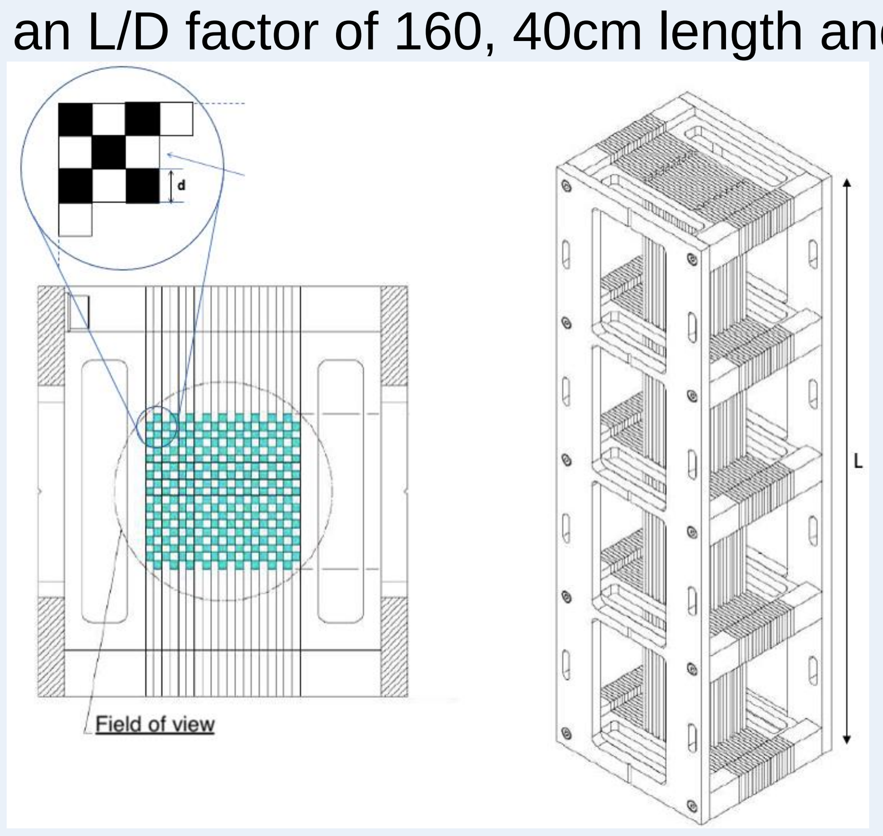


A neutron imaging setup comprehends the neutron source, a collimation system and a detector collecting the neutrons which pass through the object under test. In this case a CCD camera coupled to a LiF scintillator is used as neutron detector.

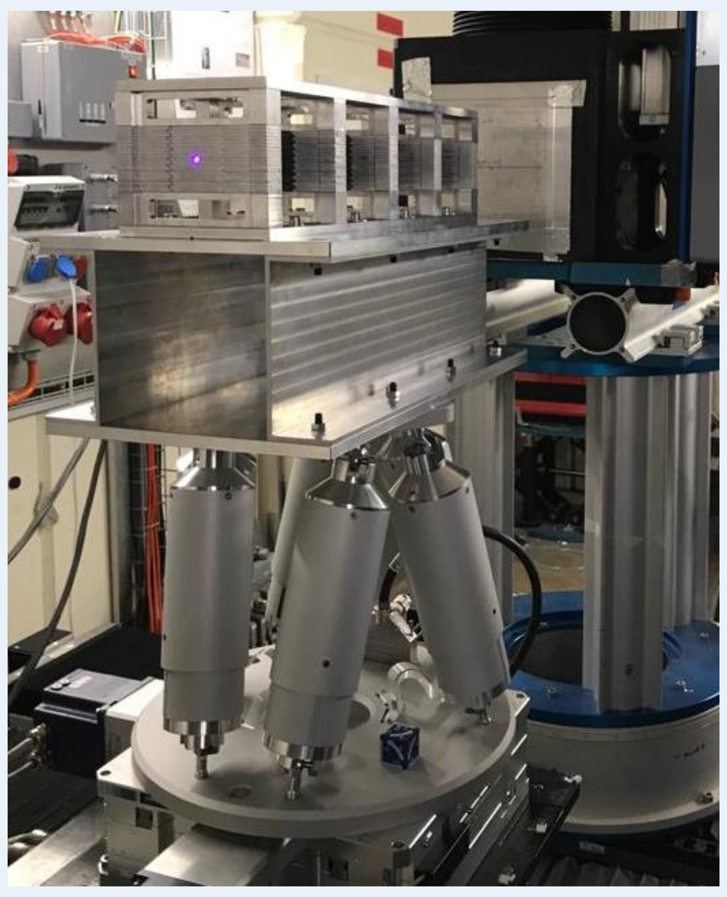
A collimation system is necessary because neutron imaging requires parallel extended beam implying extended sources (loss of collimation) or very long distances from a point source (loss of intensity).

THE ANET COLLIMATOR

It is a **compact multichannel collimator** with a chessboard-like structure, alternating B_4C and air channels. It geometrically selects the neutrons on a certain direction and eliminates the rest. Its scalable structures allows to decouple the L/D factor from the F.O.V. The first collimator prototype has an L/D factor of 160, 40cm length and 5x5cm^2 FOV.

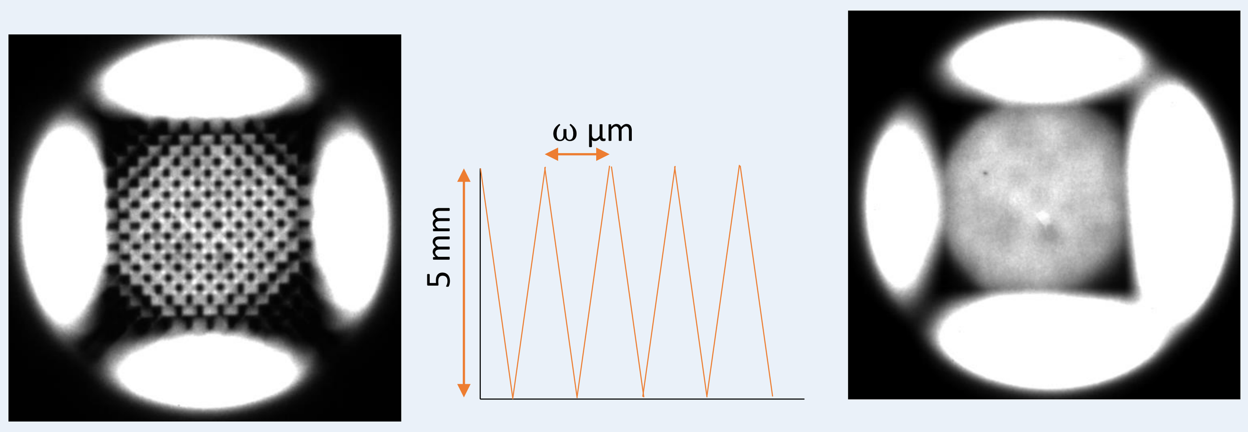


Cross sectional and prospective view of the structure of ANET collimator.



Picture of the ANET collimator prototype suited at the BOA neutron beam (PSI).

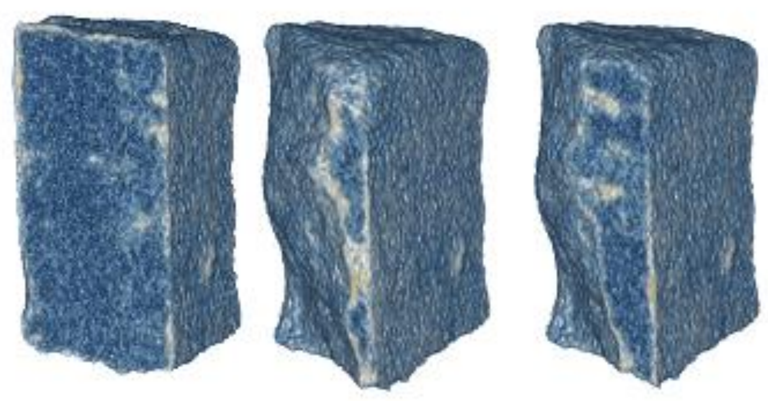
By moving the collimator following a dynamic continuous pattern in a 5x5mm^2 squared area throughout a single long exposure, the chessboard structure disappears, leaving a smooth image.



Static (left) and dynamic (right) acquisition of a white beam at the LENA reactor. In the middle the path followed by the collimator by means of the Stewart platform.

TOMOGRAPHY

Tomographies are obtained by adding a rotary stage on the sample and moving the collimator in a continuous cycle. 375 projections with an integration time of 140s were set in order to guarantee a reasonable image quality and the compatibility with the dynamic pattern.



(Up) Afghan lapis lazuli. It is assumed to be mainly composed by lazurite, pyrite and calcite. The Pyrite is very distinct w.r.t the other two phases.

Dane iron fibula (circa X century d.C.). Red areas show a higher attenuation w.r.t green areas and are associated with hydrogen-rich mineral phases, which implies an advanced corrosion stage.