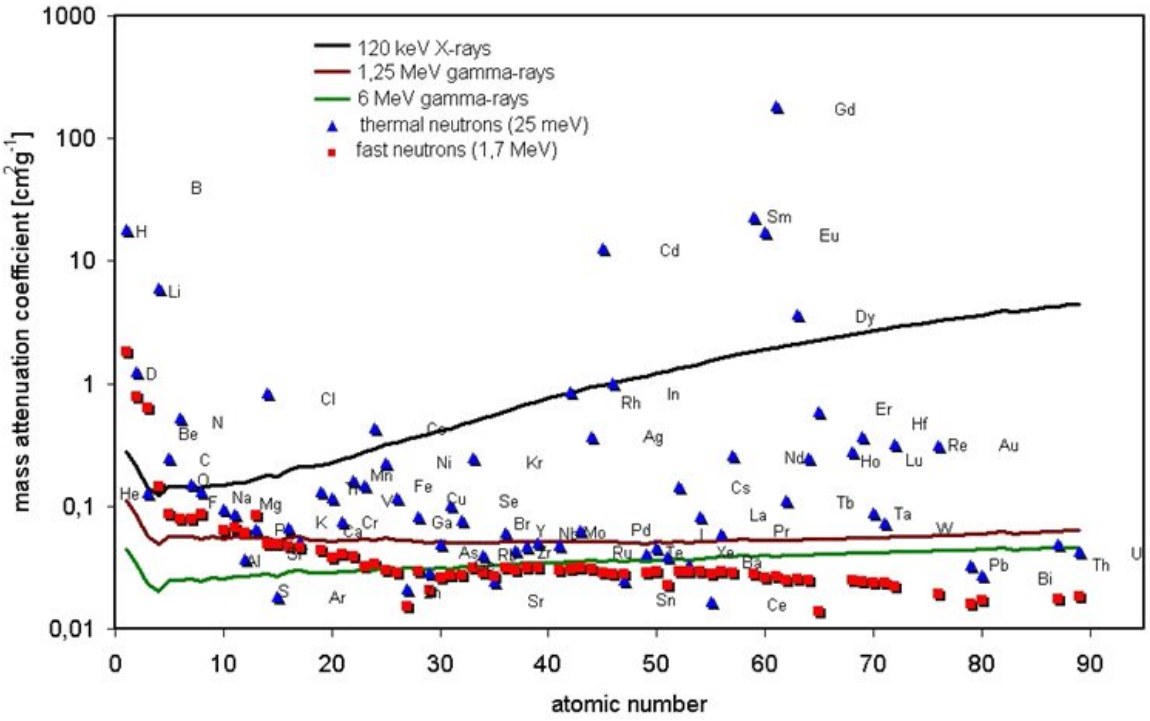
Neutron Imaging (NI) with cold, thermal and fast fission neutrons

What is possible with NI? – Complementary method to X-ray imaging with good penetration for most methods and good contrast for many light elements, especially hydrogen and organic materials.

The instrument ANTARES delivers cold neutrons, NECTAR delivers fast fission neutrons, or can switch to thermal neutrons (slightly higher penetration than cold neutrons, but also slightly less contrast).



Mass attenuation coefficient for 125 keV X-rays, 1.25 MeV gamma rays, 6 MeV gamma rays, for thermal and for fast fission neutrons. While the cross section rises monotonously with atomic number, it decreases for fast fission neutrons, and shows no obvious regularity for thermal neutrons, often giving large contrast between neighboring atoms and isotopes.

- Good penetration of metals, large contrast for hydrogen, liquids and organic materials
- Radiography, Computed Tomography and Phase Contrast Imaging possible like with X-rays, but with longer measurement times and resolution limited to a few tens of micrometers.
- Examination of combined metal and organic materials – metal relics with bones and tissues inside, wooden statues (fast neutrons) with layers of glue and steel support structures
- Contrast on many elements in geological samples, also on bone in chalk rock
- Phase identification in steels and other methods by Bragg Edge Scanning (Cold neutrons)

Samples: Size 0.5 cm to 1m if hollow.
Penetration limits for cold and thermal neutrons: 4-5 cm of steel, 5-10 cm of rock, 20 cm Aluminium, 5 cm of steel, 1 cm of water or plastic,
for fast fission neutrons: 10 cm of steel, 5-20 cm of rock, 20 – 40 cm Aluminium, 10 cm of steel, 10 cm of water or plastic.

- Neutrons do NOT break chemical bonds, possible remains of DNA are not affected.

- Samples are activated for limited time and may not be cleared immediately after the measurement – must be stored for some time after CT measurement (days to , rarely, a few weeks)
- Current resolution limit : 10 um for cold neutrons, 500 um for fast fission neutrons

Measurement time ~2 s to 120 s per radiography, depending on size, 2h -12h per computed tomography.

Applications in Geology/ Archaeology / cultural heritage (examples):

- Grains in volcanic drill cores
- Organic materials in relics or amphorae.
- Fossils in chalk rock or ferrous rock
- Complementary to X-rays: If X-rays do not work, there is an 80% chance that it will work with neutrons!