Commissioning And Perspectives Of The New Moderator For Thermal Neutrons At CNA HiSPANoS

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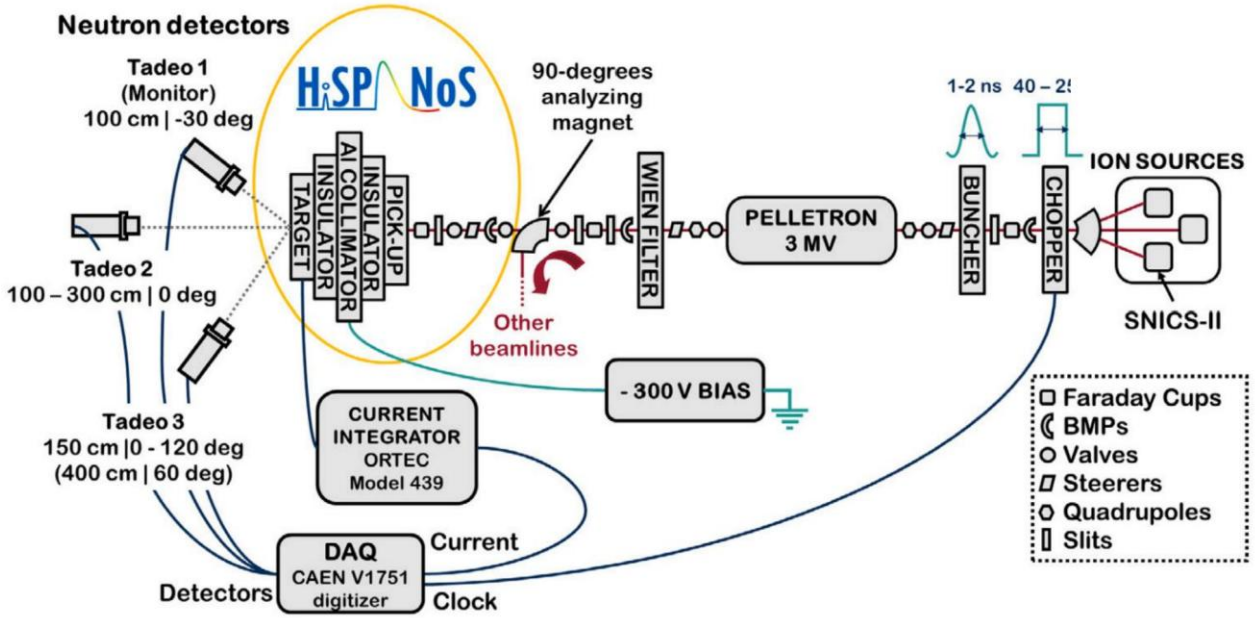
The CNA HiSPANoS facility

Accelerator-driven Neutron Source

Beams of ^{1}H, ^{2}H & ^{4}He

- **Continuous** (up to 5 μA)
- **Pulsed (ToF)** (1-2 ns pulses)



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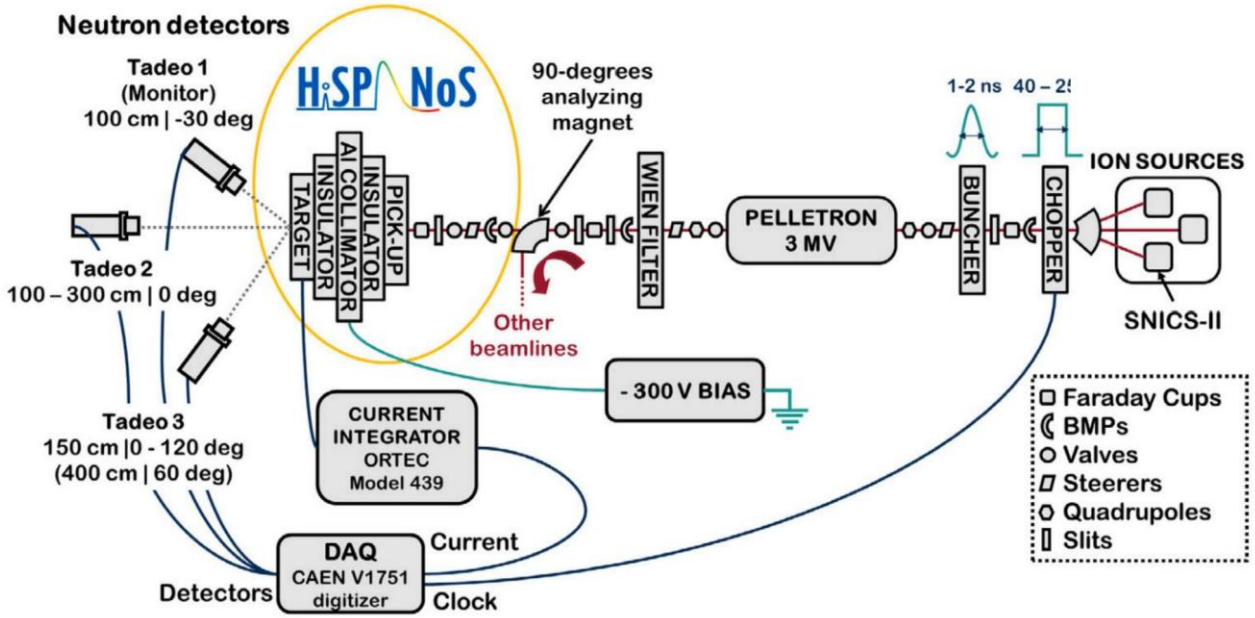
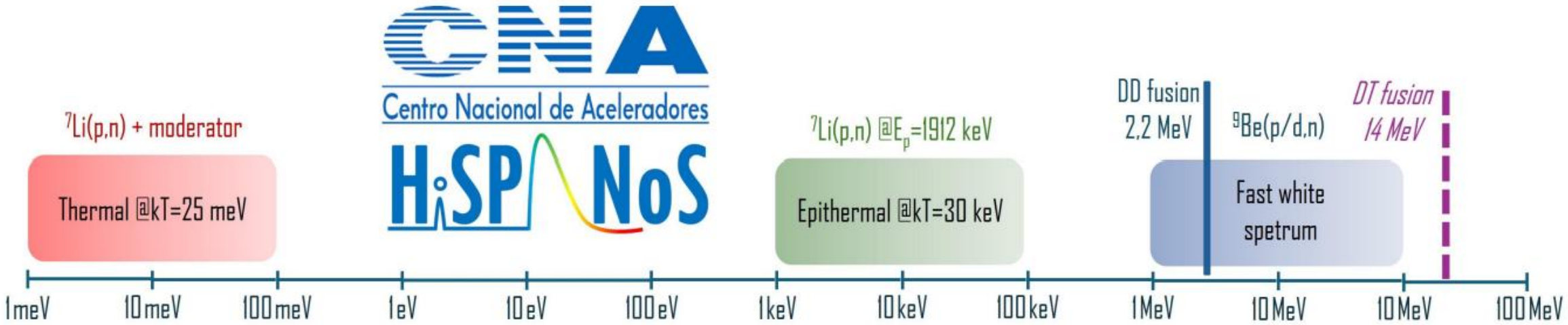


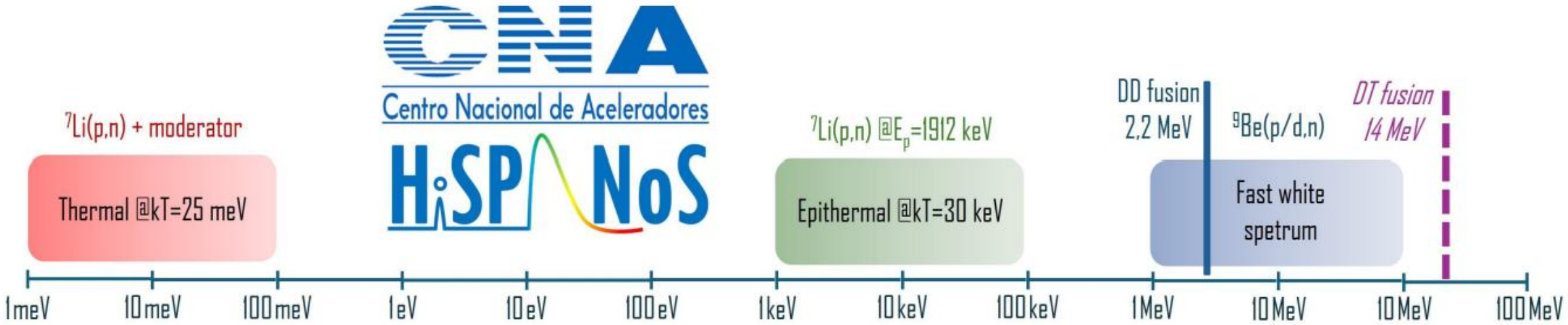
The CNA HiSPANoS facility

Neutron energy ranges



The CNA HiSPANoS facility

Neutron energy ranges

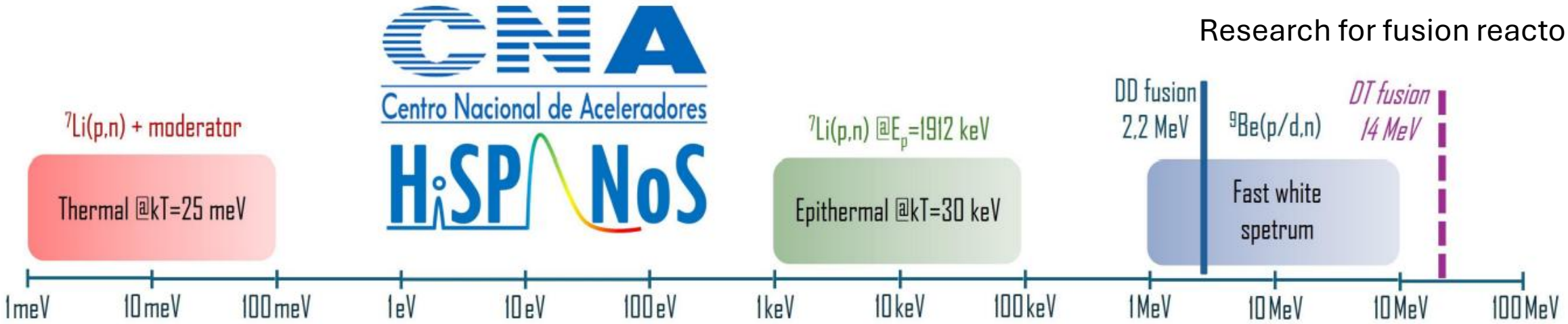


Epithermal:

Maxwellian distribution
Stellar Nucleosynthesis

The CNA HiSPANoS facility

Neutron energy ranges



Future: D-T fusion

Research for fusion reactors

Epithermal:

Maxwellian distribution
Stellar Nucleosynthesis

Fast:

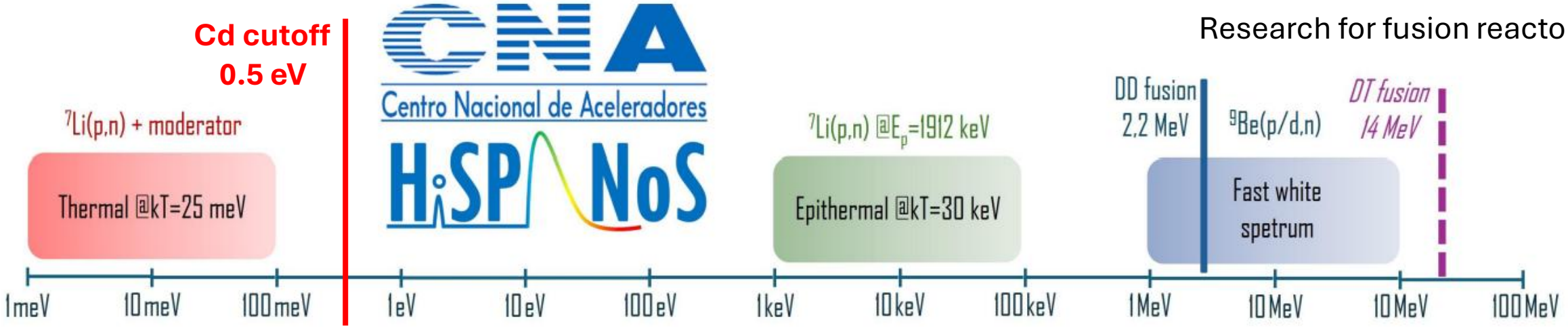
Detector characterization
Electronics and materials
Inelastic reactions

The CNA HiSPANoS facility

Neutron energy ranges

Future: D-T fusion

Research for fusion reactors



Thermal:

In thermal equilibrium with the medium
High cross sections, few channels

THIS WORK

Epithermal:

Maxwellian distribution
Stellar Nucleosynthesis

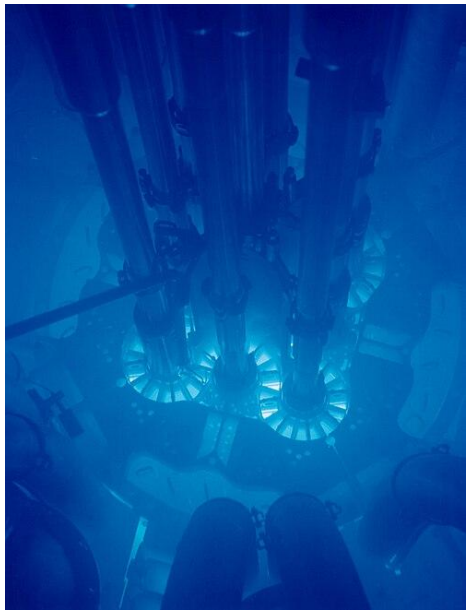
Fast:

Detector characterization
Electronics and materials
Inelastic reactions

Thermal neutron Production

Nuclear Fission: Reactors

$^{235}U(n_{th},f)$ Initial neutrons: **Fast ~MeV**



Moderator: Large volumes of water, graphite or heavy water.

-Very high neutron flux
-High maintanence, expensive

Accelerator based reactions

$^{7}Li/^{9}Be$ (d,n) Spallation

NPL termal pile (6 m^3 of graphite)

Very high neutron yields

Initial Neutrons: **Fast ~MeV**

Moderator: Graphite piles, heavy water

- Low-medium neutron flux
- Easier to maintain
- Dedicated beam lines

Thermal neutron Production

Nuclear Fission: Reactors

$^{235}U(n_{th},f)$

expensive

Accelerator based reactions

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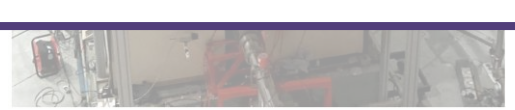


NPL termal pile (6 m^3 of graphite)

Fast neutrons are hard to moderate

Many interactions with the medium are required to reach thermal equilibrium

Compact moderator ⟷ **Epithermal Neutrons**

Design & Commissioning @ HiSPANoS

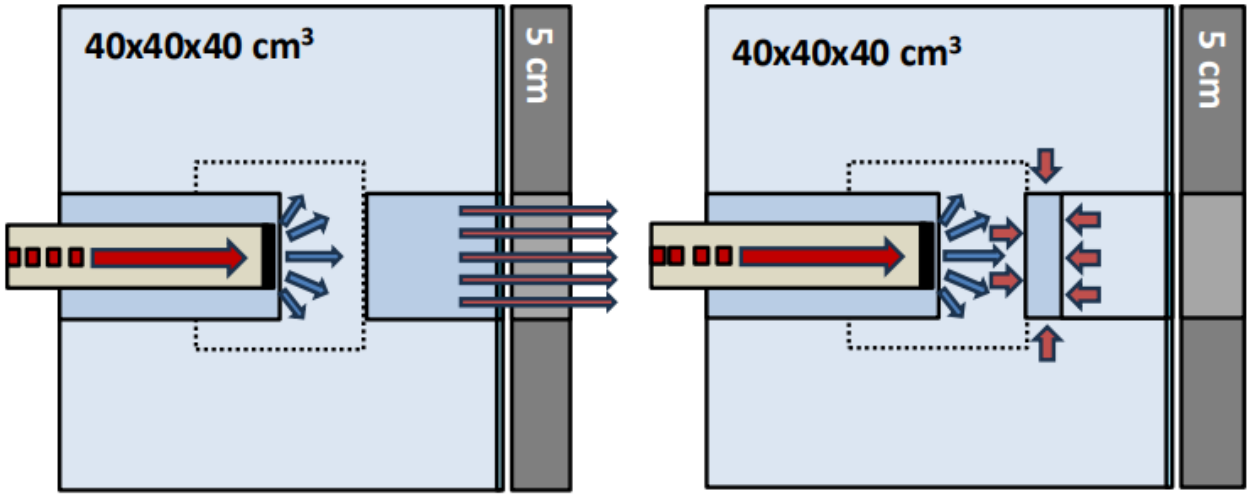
Moderator design:

Neutron Source:

^{7}Li(p,n) | 0.3 MeV $\phi_n \downarrow$ | 2 MeV $\phi_n \uparrow$

Geometry:

Polyethylene moderator
Lead shielding for γ-rays
Cadmium collimator



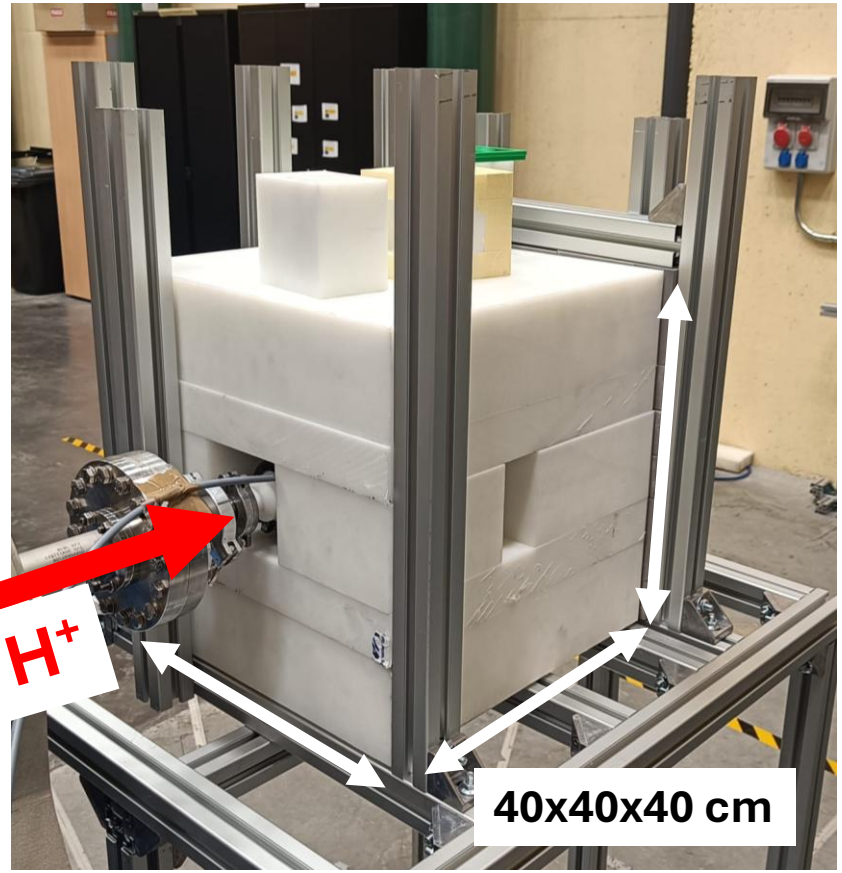
Beam Field

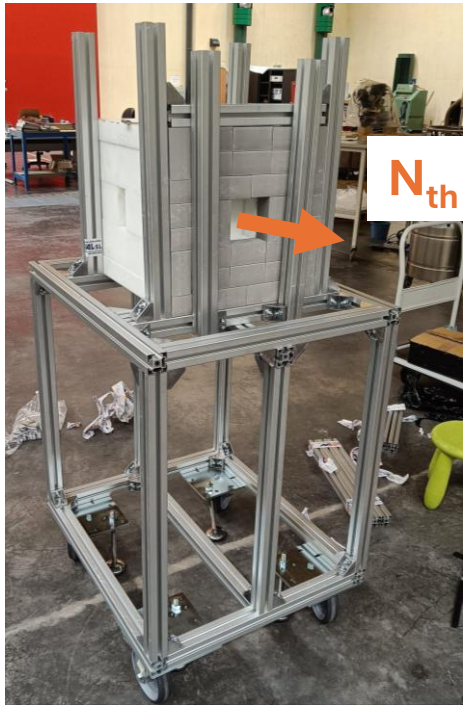
Compact & versatile:

- **Thermal neutron purity up to 98%** (fraction of neutrons below 0.5 eV)
- **Neutron flux: Field** $> 10^{7}$ **n/cm²/μC** **Beam at 50cm** $> 10^{4}$ **n/cm²/μC**

Design & Commissioning @ HiSPANoS

Moderator built and installed @ CNA HiSPANoS





Easy to install and handle: < 200 kg

Design & Commissioning @ HiSPANoS

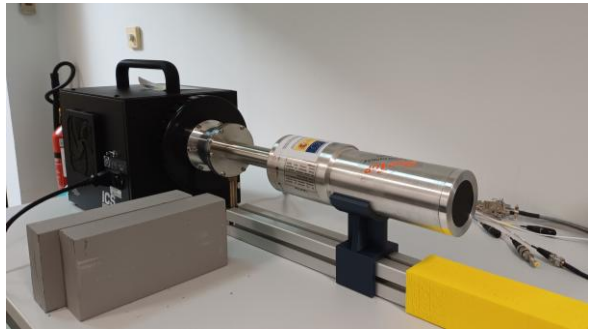
Commissioning: Gold activation

Gold foils irradiated with and without a Cd filter with termal neutrons for each configuration.

$$\phi_{th} \propto A_{total} - A_{fast}$$

$^{197}Au(n,\gamma)^{198}Au$
($t_{1/2}$=2.7d)
$\sigma(n_{th},\gamma)$ = 98.7 barn

Activity obtained via γ spectroscopy with a HPGe detector

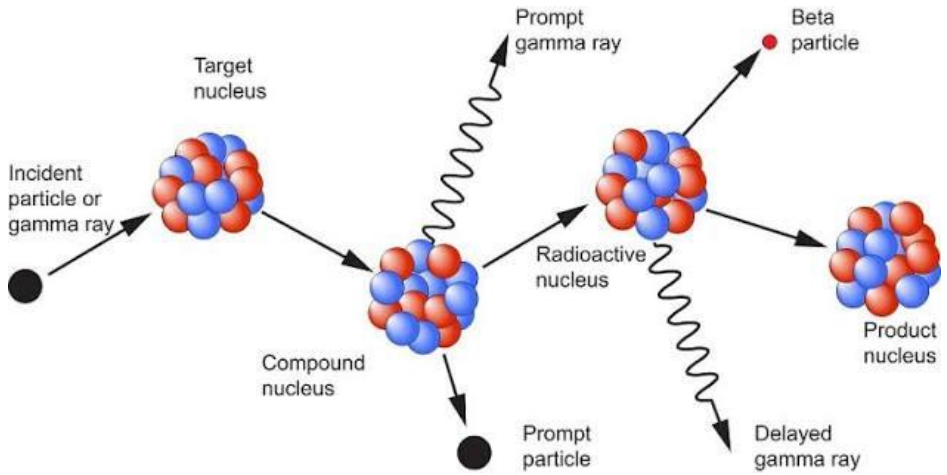


		Proton Beam	MC Simulations		Activation Measurements
Operational MODE		Energy (keV)	ϕ_{th}/ϕ	ϕ_{th} (n/cm²/μC)	Exp./ Sim.
FIELD	High Th. Purity	2250	0.90	$1.6 \cdot 10^6$	**1.06**
		2250	0.98	$6 \cdot 10^4$	**1.06**
	High flux	4000	0.8	$1.6 \cdot 10^7$	**0.72**
BEAM @ 50 cm	High flux	4000	0.4	$2 \cdot 10^4$	**0.72**

First Experiments

Neutron Activation Analysis (NAA)

Thermal Neutron capture activates some isotopes in the sample. Gamma Spectroscopy is used to identify them.



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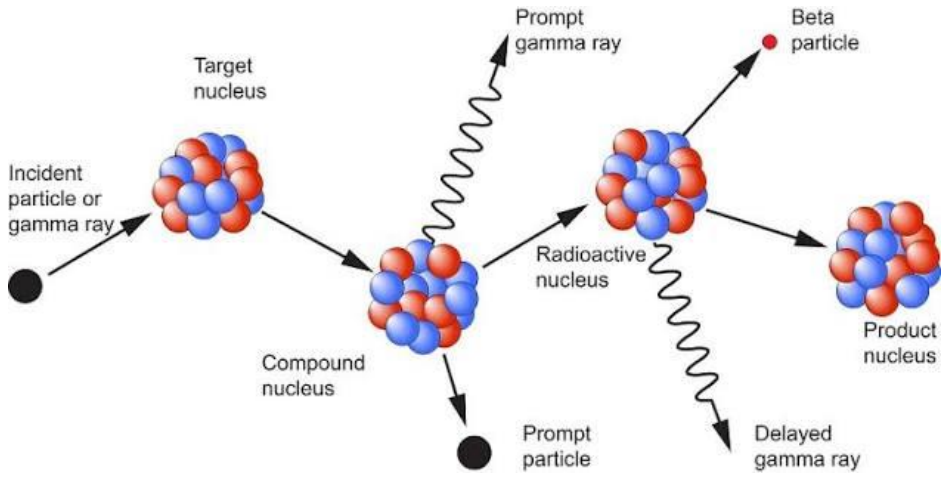
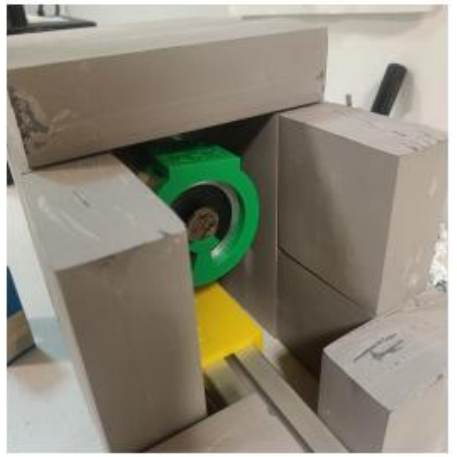


Non-destructive technique to measure the composition of samples. Valuable in many fields such as Archaeology:

Roman Coin



High-efficiency: 5 mm

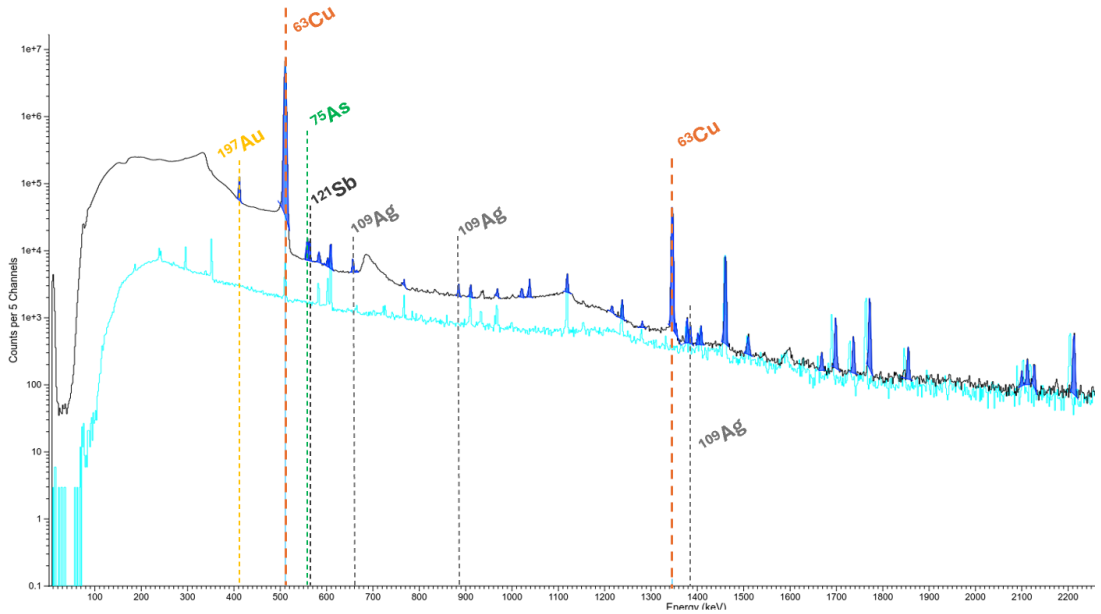
In collaboration with **Prof. Miguel Ángel Respaldiza**

First Experiments

Neutron Activation Analysis (NAA)

Photopeak lines are identified and linked to activated isotopes

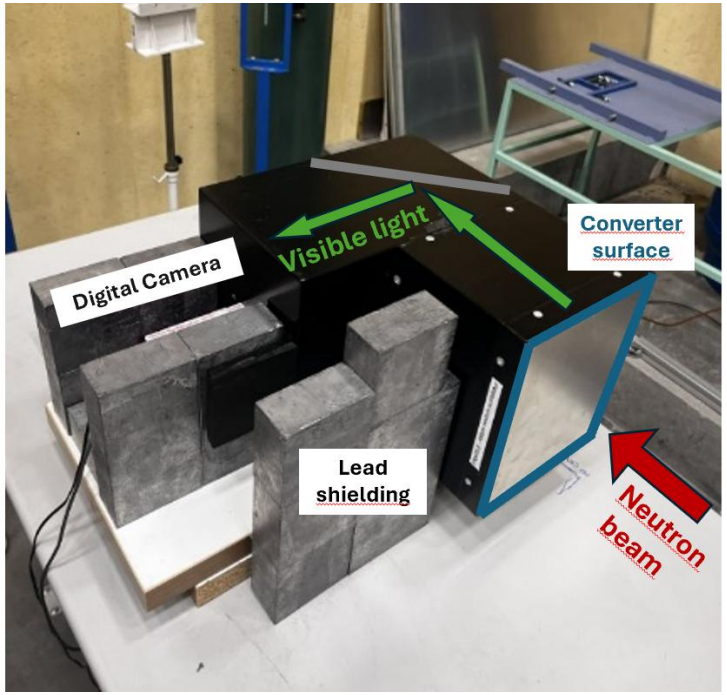
$$^{A}X_{Z}(n,\gamma)\ ^{A+1}X_{Z}$$



- 5 min Irradiation + 10 min HPGe
  - $^{65}Cu(n,\gamma)^{66}Cu$ ($t_{1/2}$=5.1min)
  - $^{107}Ag(n,\gamma)^{108}Ag$ ($t_{1/2}$=2.4min)
- 3 hour irradiation + 78 h HPGe
  - $^{63}Cu(n,\gamma)^{64}Cu$ ($t_{1/2}$=12.8h)
  - $^{75}As(n,\gamma)^{76}As$ ($t_{1/2}$=26.4h)
  - $^{109}Ag(n,\gamma)^{110m}Ag$ ($t_{1/2}$=250d)
  - $^{197}Au(n,\gamma)^{198}Au$ (t=2.7d)
  - $^{121}Sb(n,\gamma)^{122}Sb$ (t=2.7d)

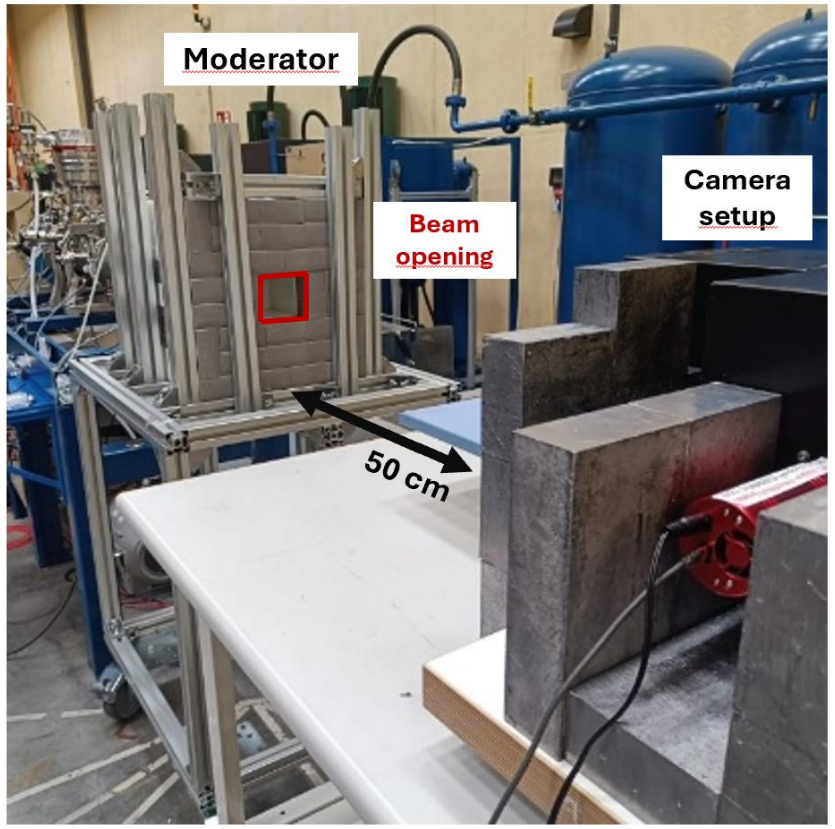
First Experiments

Neutron Imaging



Similar to an X-ray, "shadows" of samples are cast on a radiosensitive surface. Neutrons and X-rays have very different contrast on each material

With a collimated th. neutron beam an image can be formed on the ^{10}B converter sheet.
Camera from *Neutron Optics*



First Experiments

Neutron Imaging

Images of test samples were taken to test contrast, focus and resolution of the setup

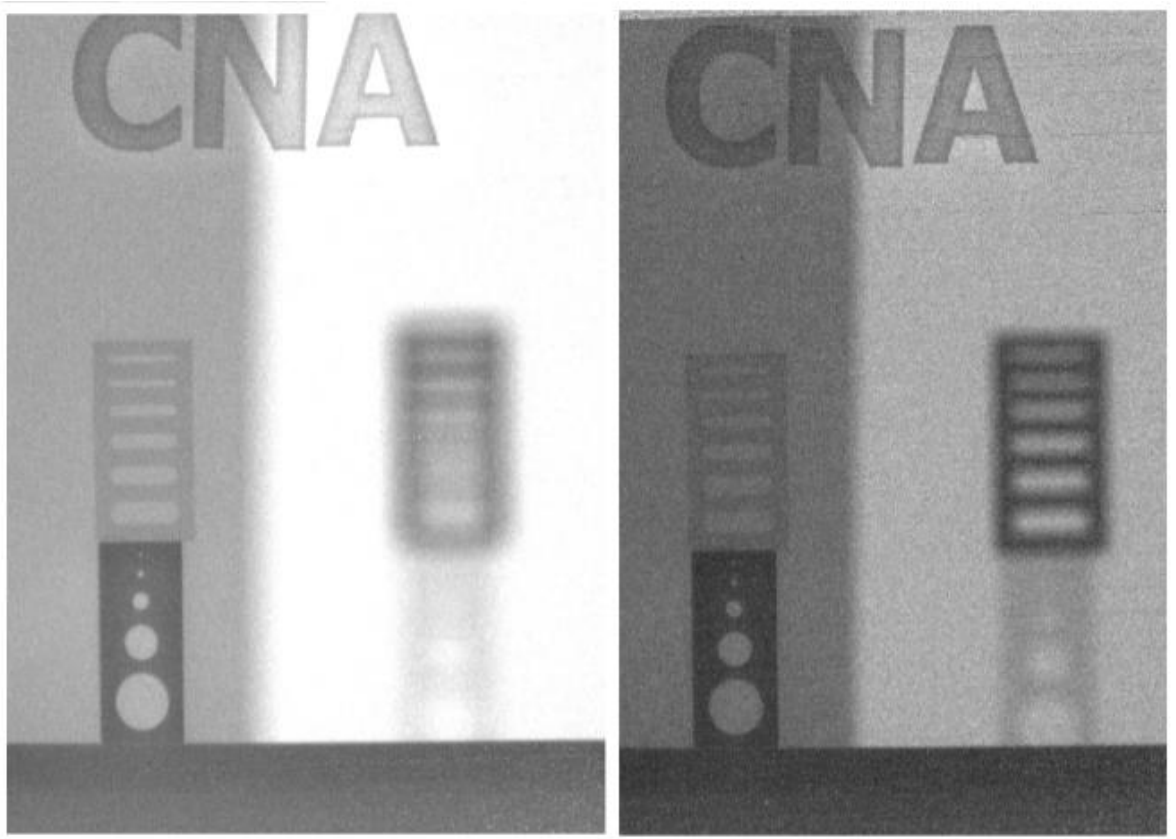
PE and Teflon pieces were irradiated and a 2cm wide lead plate covering half of them

First Experiments

Neutron Imaging

Two images of the same setup using different collimators: 10cm (left) and 5cm (right)

A reduction in the beam opening increases resolution significantly, at the cost of beam intensity.



Collimator: 10cm 5cm

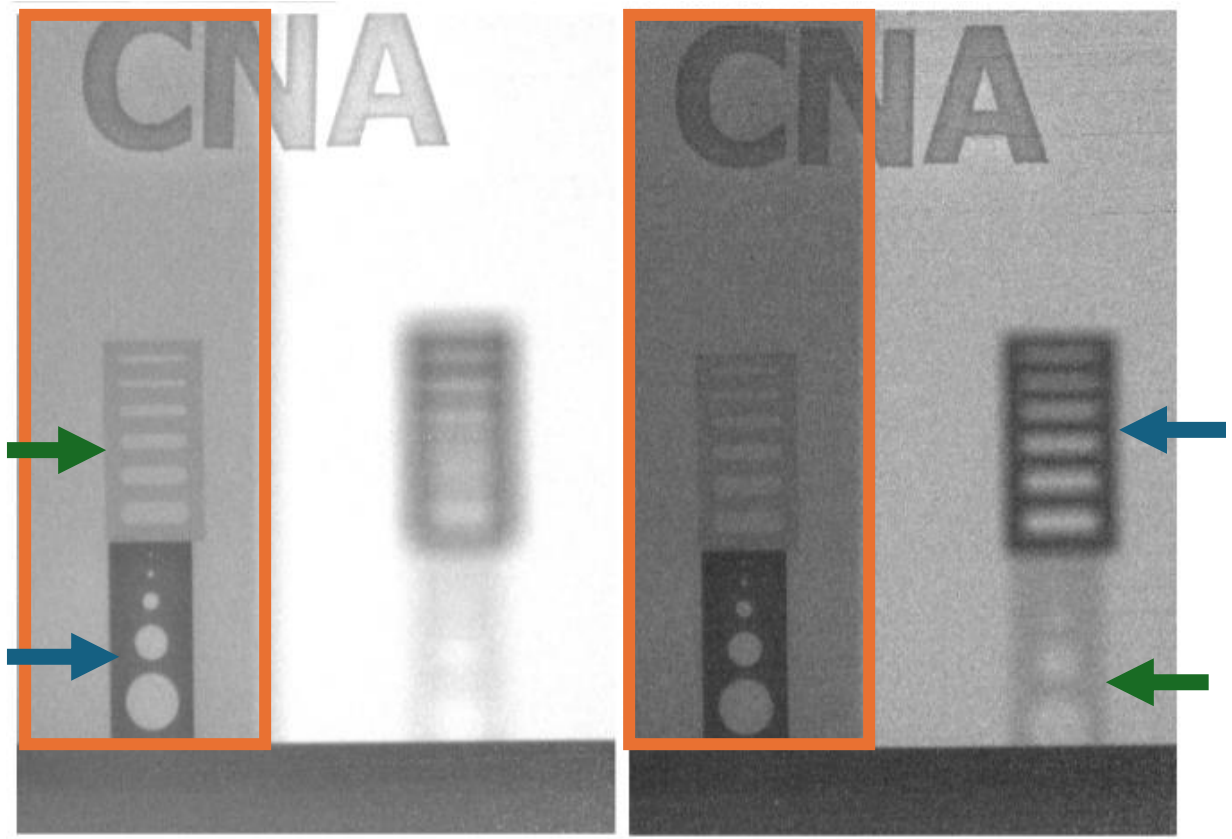
First Experiments

Neutron Imaging

Two images of the same setup using different collimators: 10cm (left) and 5cm (right)

A reduction in the beam opening increases resolution significantly, at the cost of beam intensity.

High contrast on H-rich materials (**PE**), low on **lead** and **teflon.**



Collimator: 10cm 5cm

Conclussions & outlook

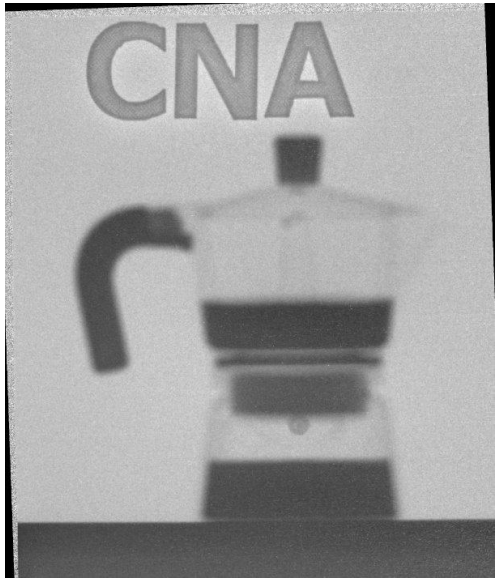
Compact and versatile moderator @ CNA HiSPANoS

- Designed
- Installed and Tested

High intensity thermal neutron fields **10^8·n/cm^2/s**
and beams **10^5·n/cm^2/s** availeable for science & industry.

First experiments show promising results

- NAA and Neutrography are being explored further
- New techniques are on their way!
  Prompt Gamma Activation Analysis (PGAA)



Thank you for your attention!!

Acknowledgements

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