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Measurement of the $^{27}Al(\alpha,n)^{30}P$ thick-target yields and differential cross-sections using the miniBELEN neutron detector at CMAM

By Nil Mont Geli
On behalf of the MANY collaboration

Institut de Tècniques Energètiques – Universitat Politècnica de Catalunya (INTE - UPC))
Institute of Energy Technologies – Technical University of Catalonia

MANY

The **MANY (Measurement of Alpha Neuntron Yields)** collaboration: recently formed, it is a collaboration between several institutions in Spain aiming to carried out measurements of (α,n) reaction cross-sections, production yields and neutron energy spectra.

“*most of the available experimental data was measured decades ago, is incomplete and/or the uncertainties in the cross sections and neutron emission spectra are rather large. Furthermore, the evaluated libraries are incomplete or based on evaluations that are now outdated*” INDC(NDS)-0836 tehcnical meeting report (November 2021)

Physical motivation:

- Nuclear astrophysics: source of neutrons for the s-process, “ligth” r-process.
- Rare-event experiments (dark matter, neutrinos, etc.): neutron-induced background in underground laboratories.
- Non-destrutice assays for spent fuel management and nonproliferation.
- Nuclear technologies: fission and fusion reactors, neutron-induced background in particle accelerators.

MANY

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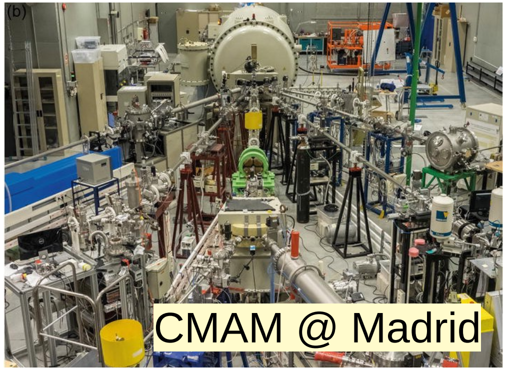
Measurement of Alpha Neutron Yields and spectra (MANY)

- Workshop at CIEMAT (Madrid): November 2019.
- First measurements: March 2021.
- Aluminium campaing at CMAM (comissioning): Dec. 2021 – Jun. 2023)



Talk by C. Guerrero (3-Oct, 09:45)

MANY

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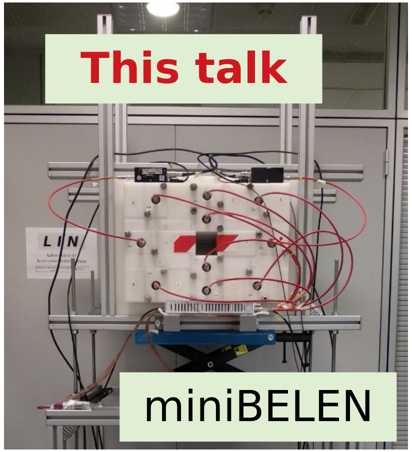
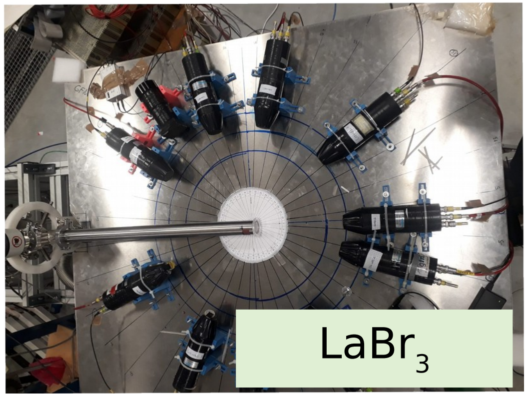


UPC/IFIC

Talk by A. Pérez de Rada
(2-Oct, 16:15)

CIEMAT

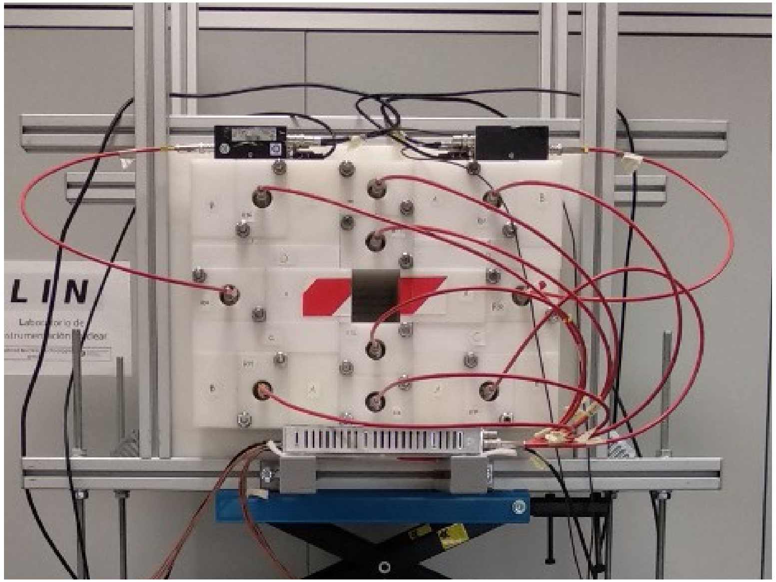


UCM

miniBELEN

Main characteristics

- Long counter tehcnique: thermal neutrons counters (^{3}He) + moderator (hihg density polyethylene).
- Detection efficiency nearly independent from the neutron energy (**<u>flat response</u>**) up to 8/10 MeV.
- Modular moderator.



N. Mont-Geli *et al.*, EPJ Web of Conferences (2023)

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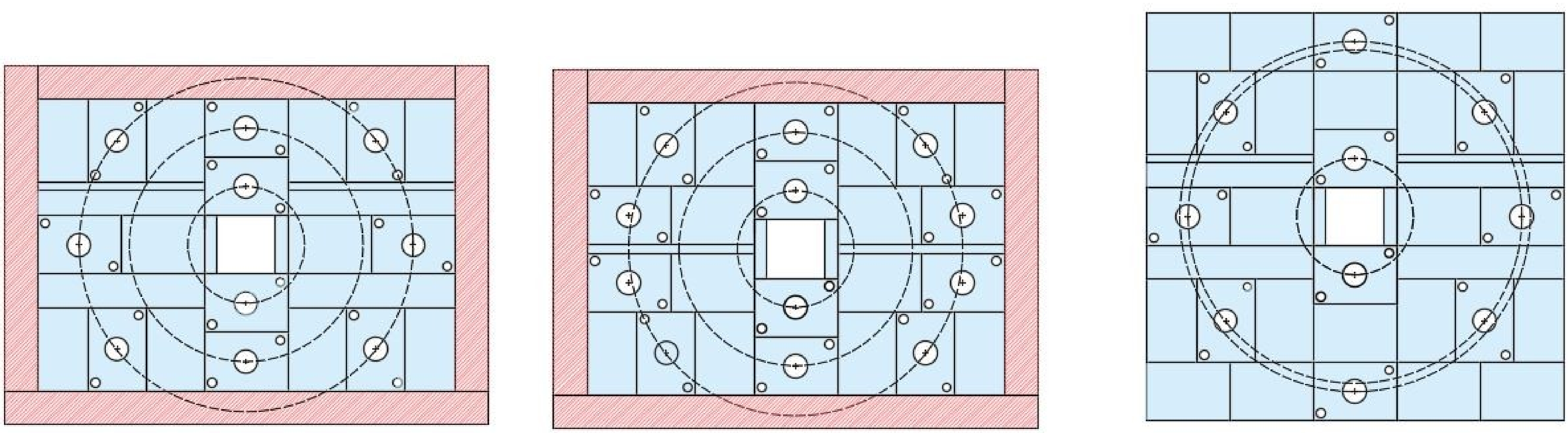
Three configurations:



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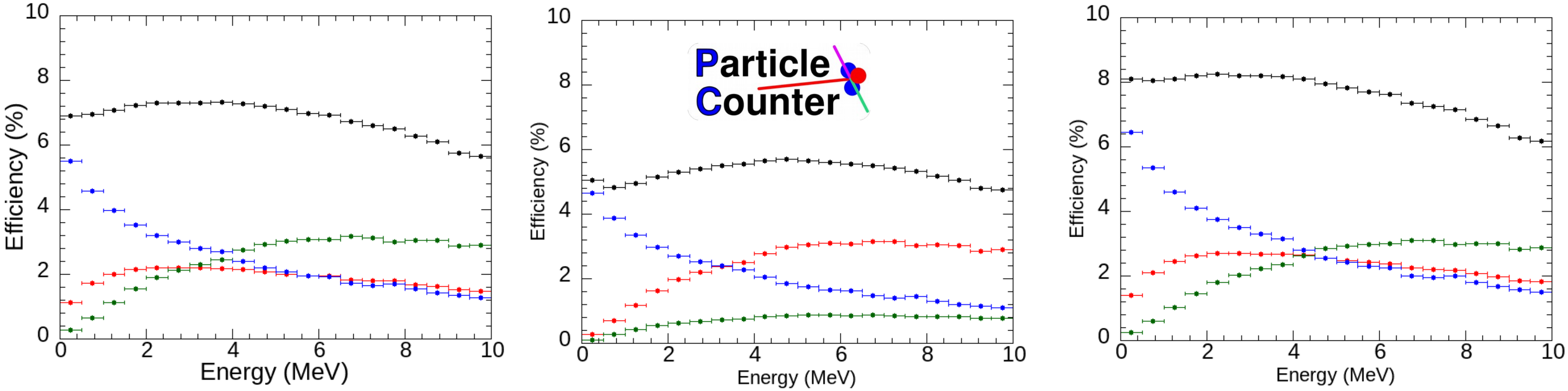
Three configurations:

www.particlecounter.net



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miniBELEN-10A

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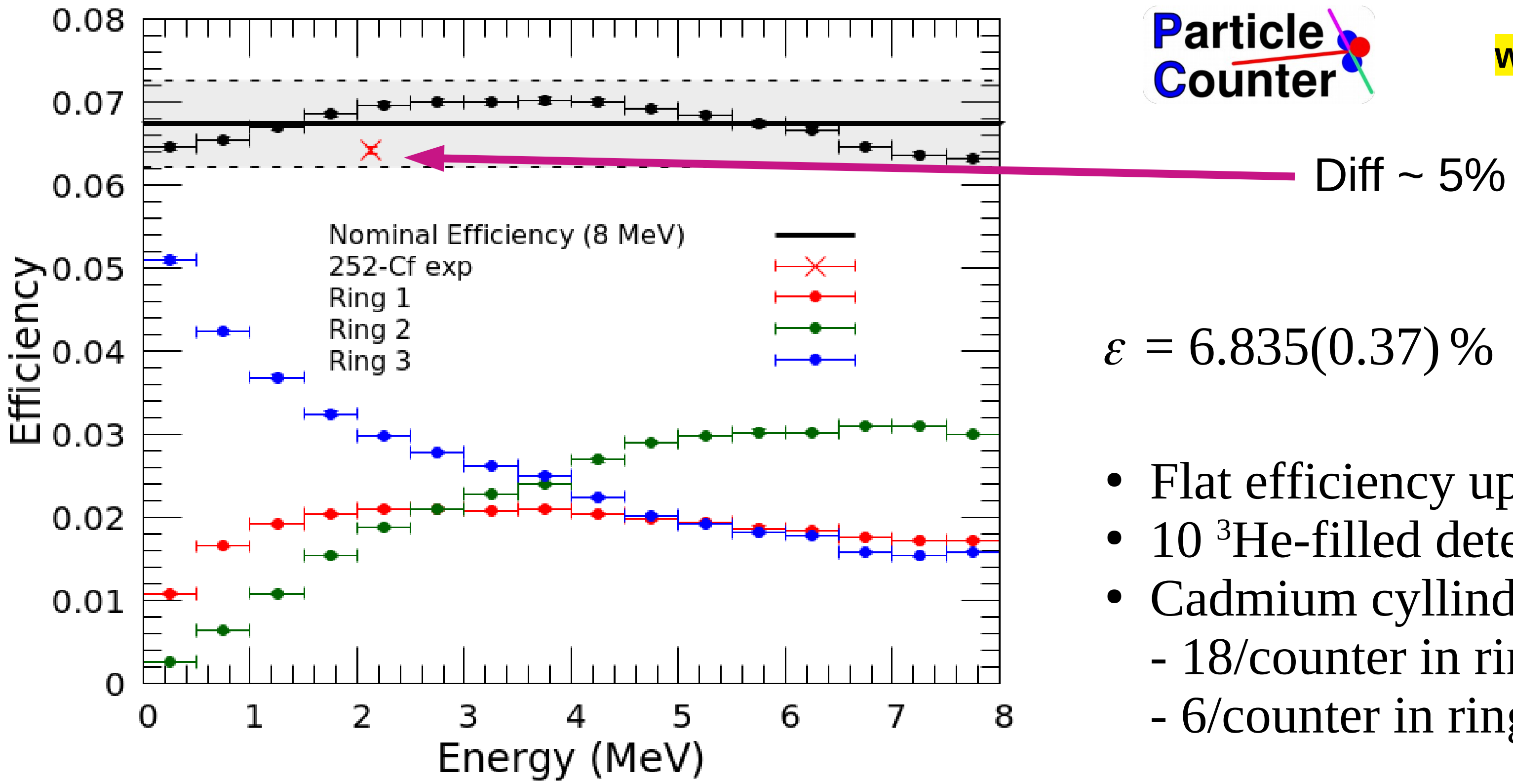

www.particlecounter.net

$$\varepsilon = 6.835(0.37)\,\% \qquad \delta\varepsilon = \frac{\varepsilon_{max} - \varepsilon_{min}}{2}$$

- Flat efficiency up to 8 MeV.
- 10 ^{3}He-filled detectors.
- Cadmium cyllinders:
  - 18/counter in ring 1 (60% coverage).
  - 6/counter in ring 2 (20% coverage).

$^{27}Al(\alpha,n)^{30}P$

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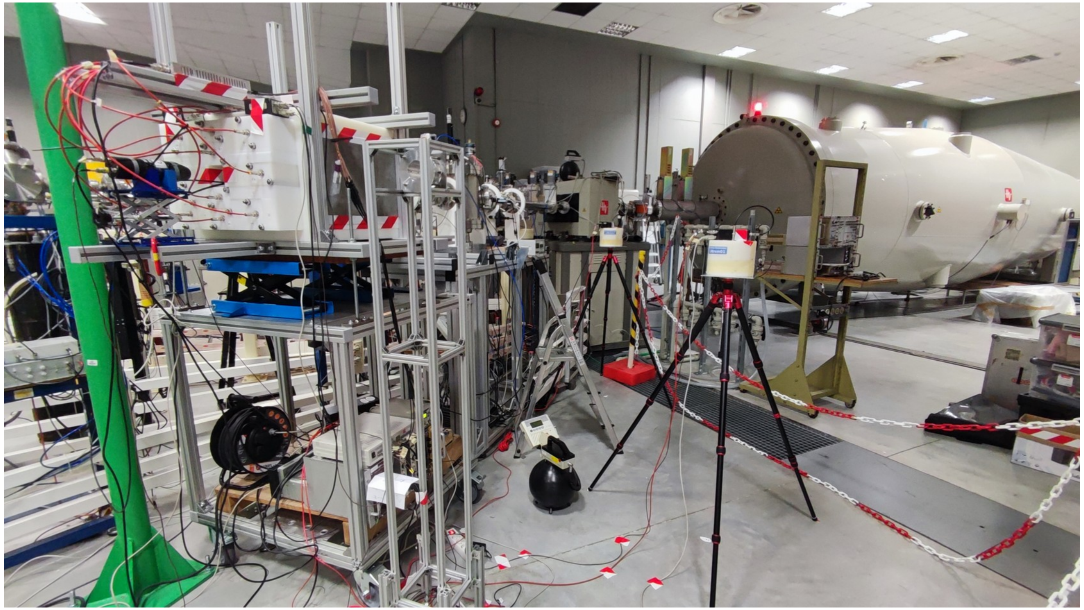
Centro de Micro-Análisis de Materiales (CMAM, Madrid)

- 5 MV Tandem accelerator. Beam particles: ^{4}He (q = +2).



Physical interests:

- **<u>Comissioning</u>**
- Nuclear astrophysics
- Nuclear reactors
- Underground laboratories.
- Management of spent fuel.

$^{27}Al(\alpha,n)^{30}P$

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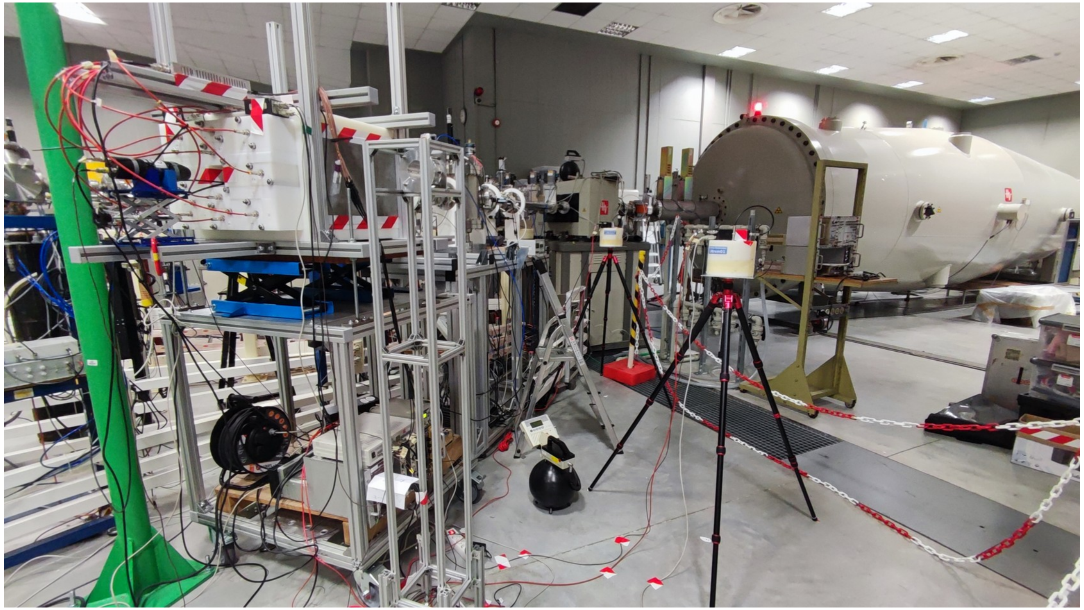

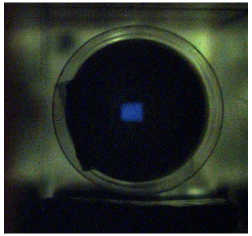

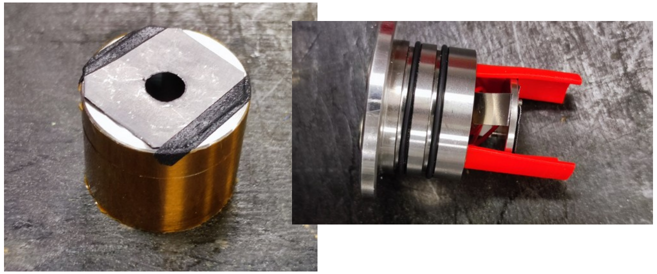

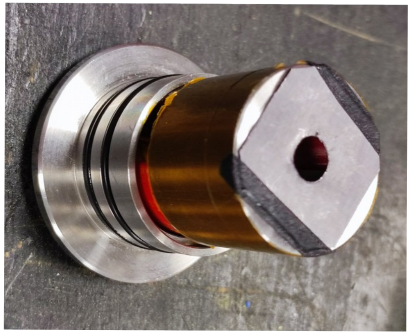

$^{27}Al(\alpha,n)^{30}P$

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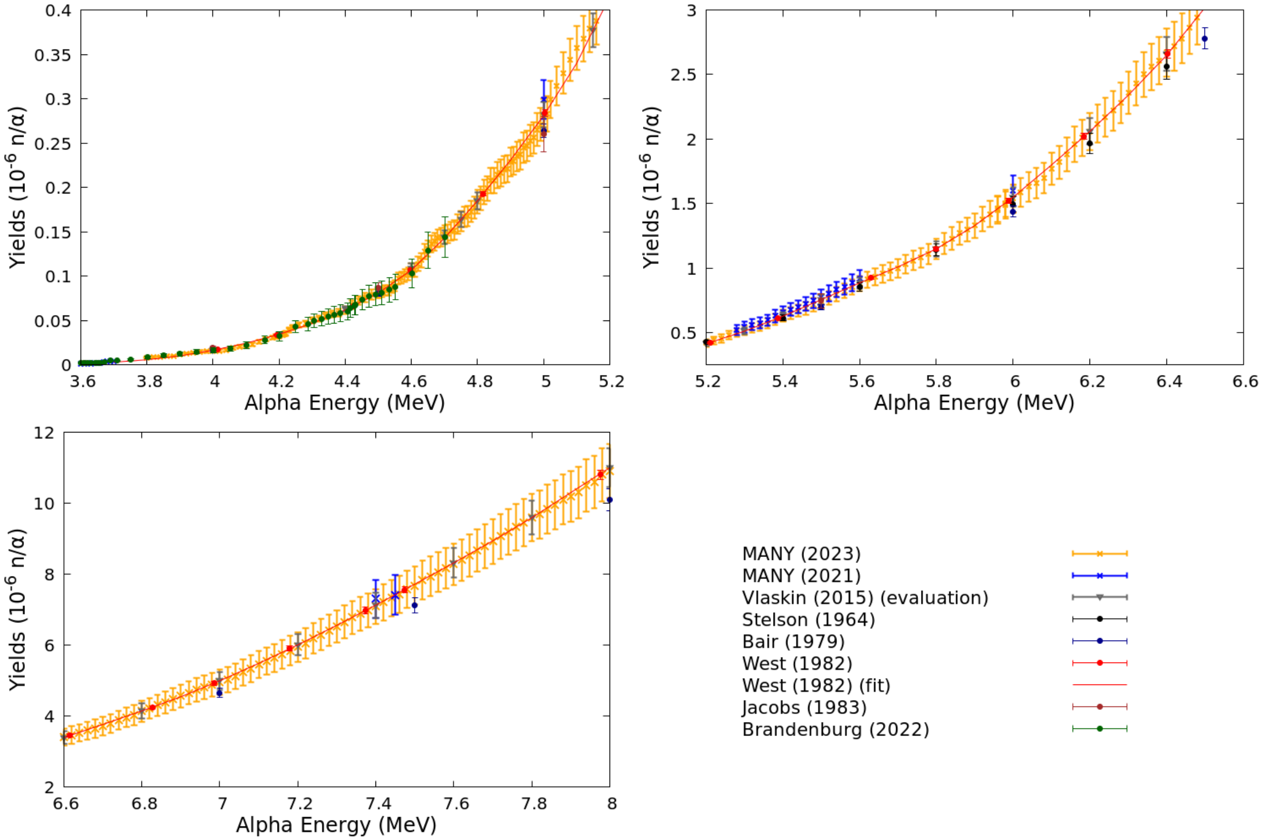
Neutron yields

$$Y = \frac{R}{I \cdot \varepsilon}$$

- Y = neutron yield
- R = miniBELEN neutron rate
- I = beam current (particles/s)
- ε = miniBELEN neutron efficiency

Background estimations using a dummy natural tantalum target (threshold ~ 10 MeV)



$^{27}Al(\alpha,n)^{30}P$ measurement

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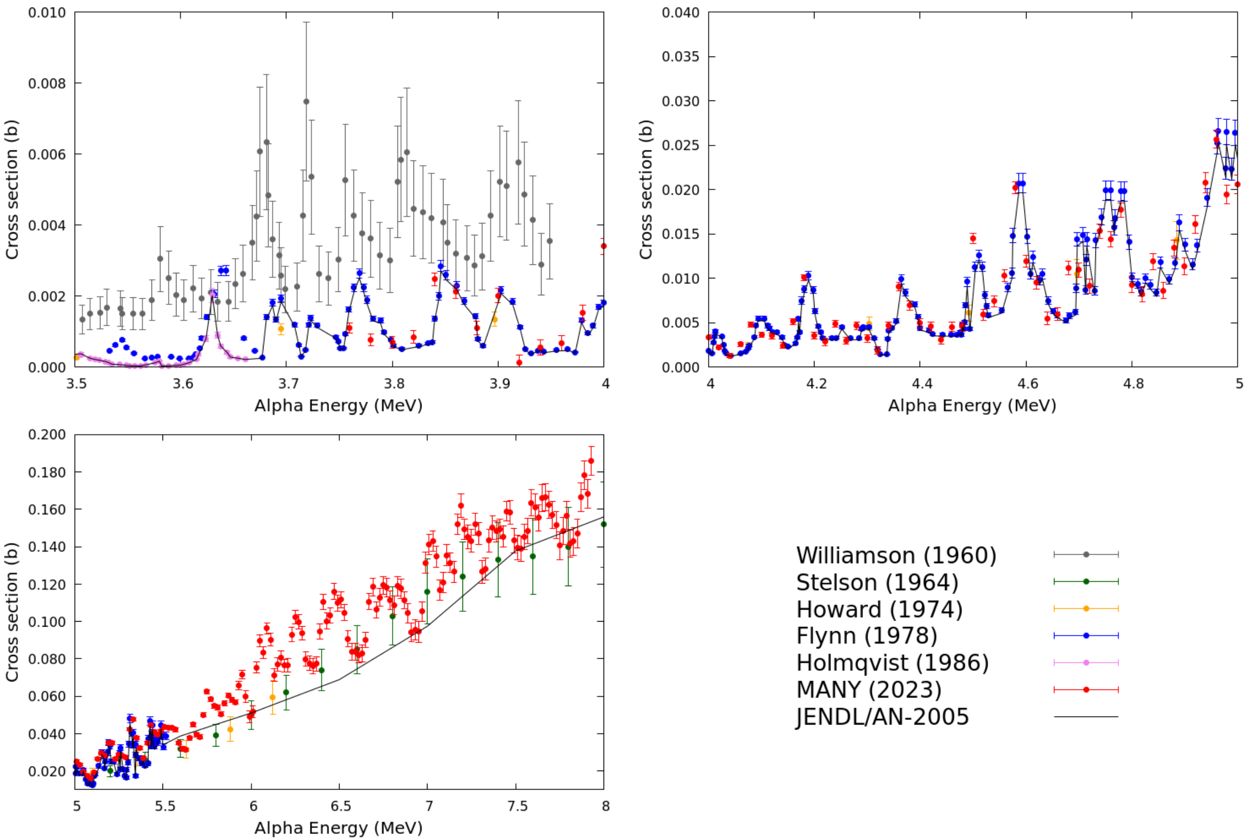
Cross-sections

$$\sigma(E_b) = \frac{N_A}{A_t} \frac{Y(E_1) - Y(E_2)}{E_1 - E_2} \cdot \frac{dE}{dx}$$

σ = cross-section
N_A = Avogadro number
A_t = target density
dE/dX = stopping power
Y = neutron yield
E = beam energy

50 keV in respect of Flynn data



$^{27}Al(\alpha,n)^{30}P$ measurement

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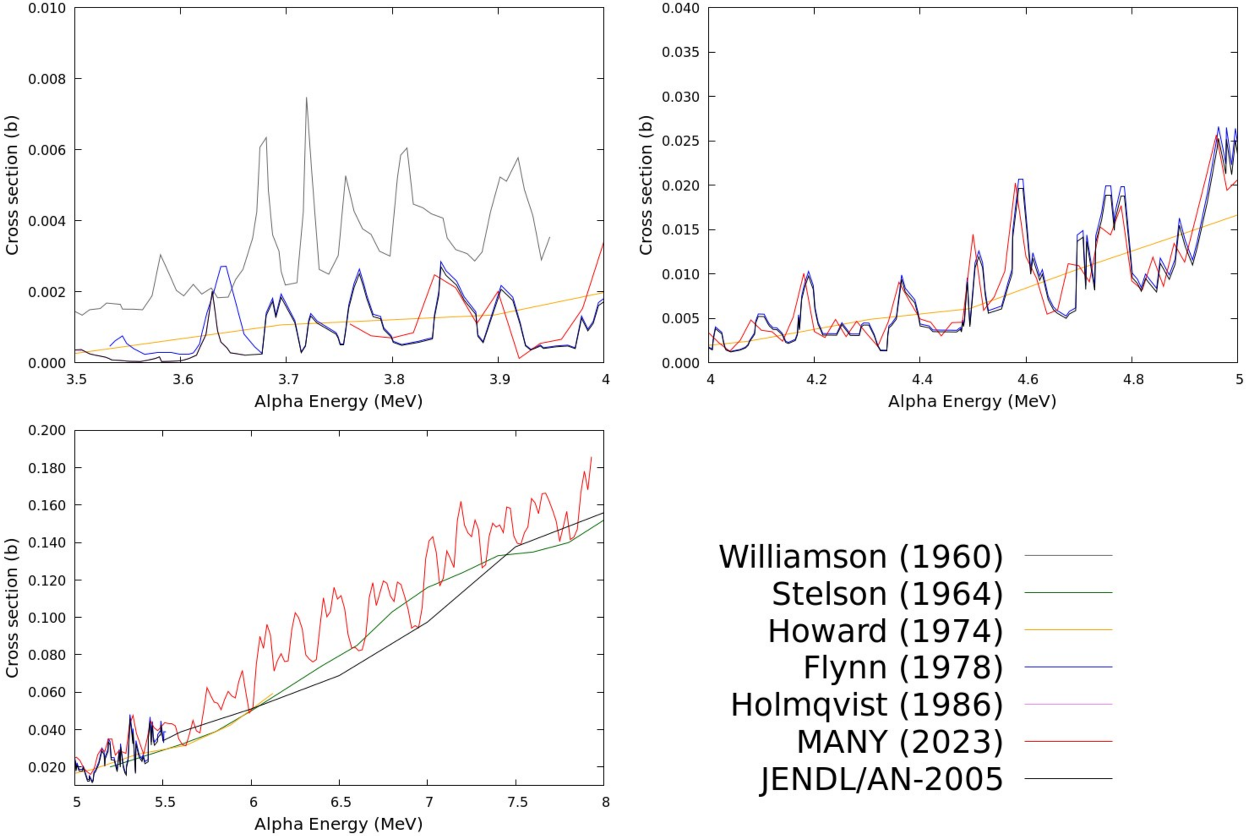

Summary and remarks

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- miniBELEN: a modular neutron counter with a nearly flat response for (α,n) reactions.

- Experimental characterization of the detector using ^{252}Cf neutron sources and the well-known $^{27}Al(\alpha,n)^{30}P$ reaction.

- Determination of the $^{27}Al(\alpha,n)^{30}P$ reaction cross sections using differential thick-target yields measurements.

NEXT STEPS

- Short term: complete the $^{27}Al(\alpha,n)^{30}P$ at low energies (near the reaction threshold).

- Long term: to be decided.

List of collaborators

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INTE-UPC: *N* Mont-Geli, *M* Pallàs, *G* Cortés, *F* Calviño, *A* De Blas and *R* Garcia.

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CMAM – UAM: *S* Viñals and *G* García.

IEM – CSIC: A Perea, *M J G* Borge, *J A* Briz and *O* Tengblad.

CIEMAT: *V* Alcayne, *D* Cano-Ott, *E M* González-Romero, *T* Martínez, *A* Pérez de Rada, *V* Pesudo, *J* Plaza, *A* Sánchez, *R* Santorelli, and *D* Villamarín.

CNA – US: *B* Fernández, *J* Gómez-Camacho, *C* Guerrero and *J M* Quesada

Acknowledgements

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Backup slides

miniBELEN

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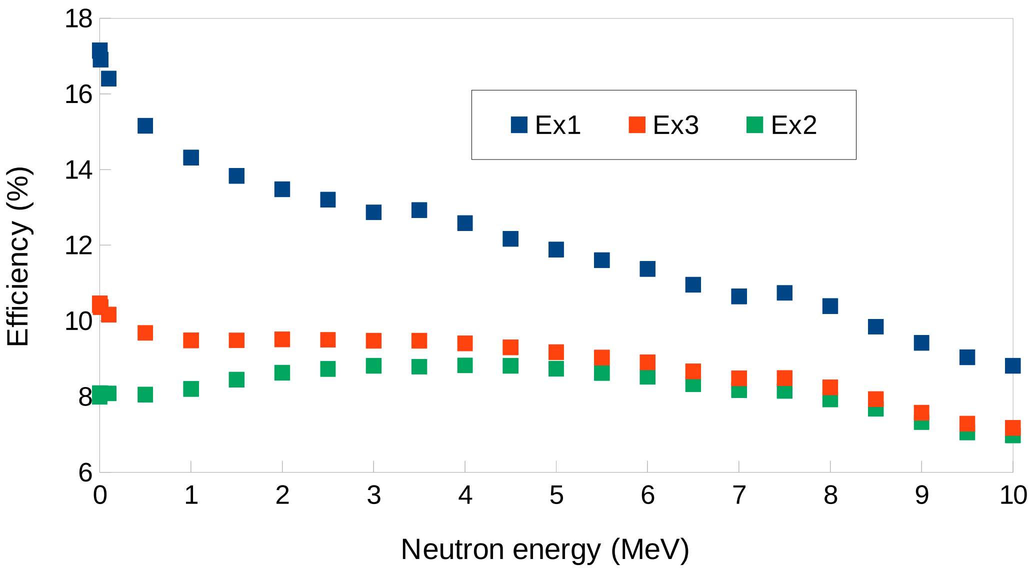
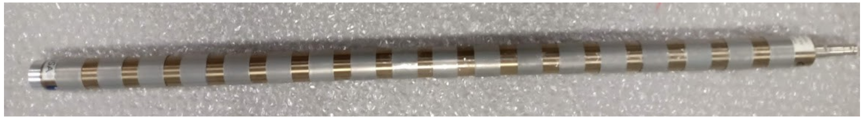
Composition method

- Use of cadmium to obtain a flat response.



Ex1: $f_1 = f_2 = f_3 = 1$
Ex2: $f_1 = 0.6,\ f_2 = 0.8,\ f_3 = 1$
Ex3: $f_1 = 0.45,\ f_2 = 0.95,\ f_3 = 1$

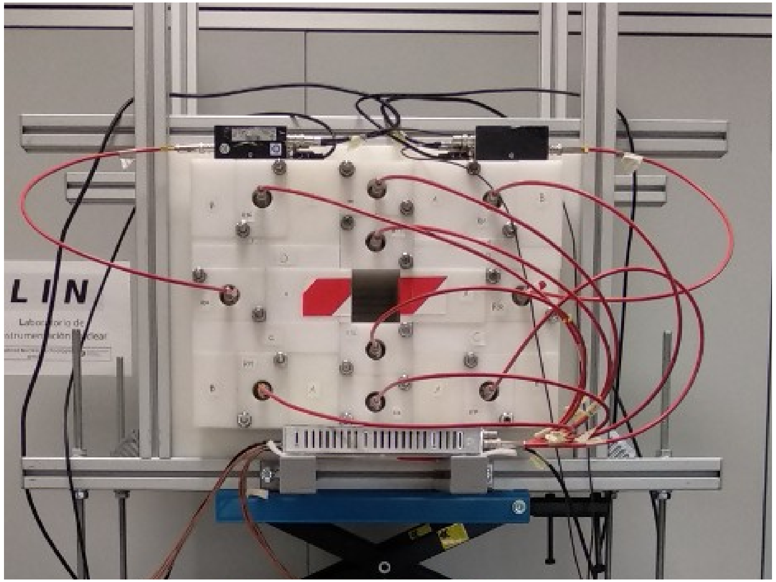
$$\varepsilon(E) = \sum_{i=1}^{3} \varepsilon_i(E) = \sum_{i=1}^{3} f_i(E) \cdot \varepsilon_i(E)$$



miniBELEN

Design constraints

- Long counter tehcnique: thermal neutrons counters (^3He) + moderator (hihg density polyethylene).
- Detection efficiency nearly independent from the neutron energy (flat response) up to 8/10 MeV.
- Modular moderator.



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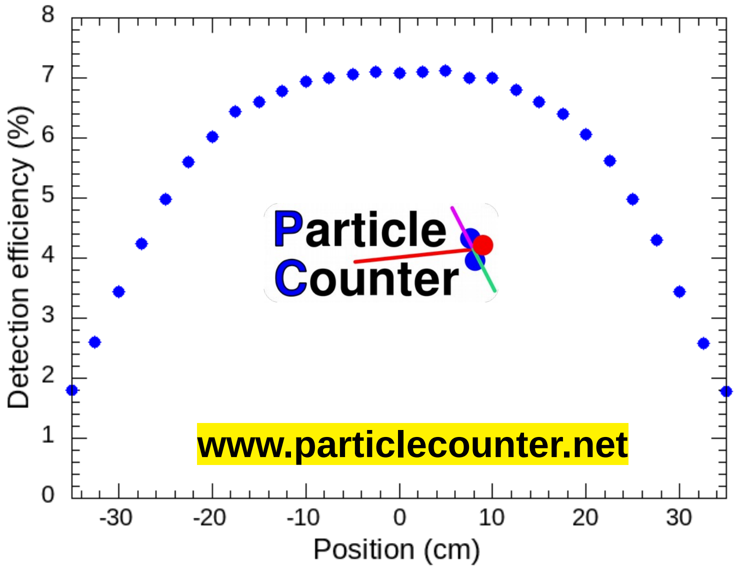
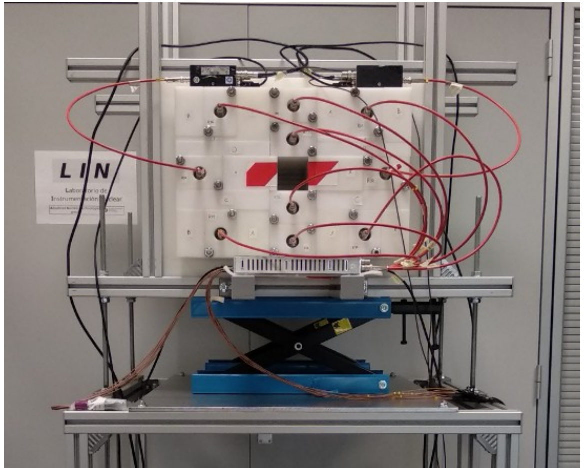
miniBELEN-10A (modular neutron counter):

- ^{3}He-filled proportional counter + HDPE.
- Flat response up to 8/10 MeV.





$^{27}Al(\alpha,n)^{30}P$

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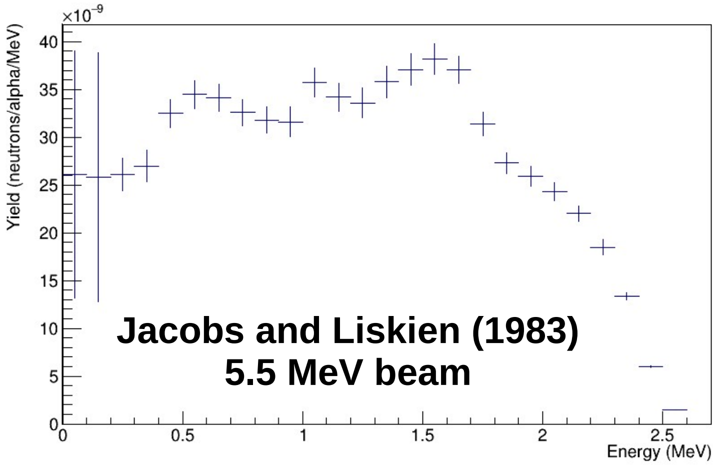
Bench-marking of the efficiency calculation using the $^{27}Al(\alpha,n)$ reactions

$$Eff_{Ri} = \int \varepsilon_i(E)S(E)\,dE$$

$$Q = \frac{Rate_i / Rate_j}{Eff_{Ri} / Eff_{Rj}}$$



Q (R1/R2)	Error	Q (R1/R3)	Error	Q (R2/R3)	Error
0.93	0.04	0.93	0.04	1.03	0.02

$^{27}Al(\alpha,n)^{30}P$ measurement

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Cross-sections (p,n)

Flynn data on (p,n) reactions also present a 50 keV with other data in the literature