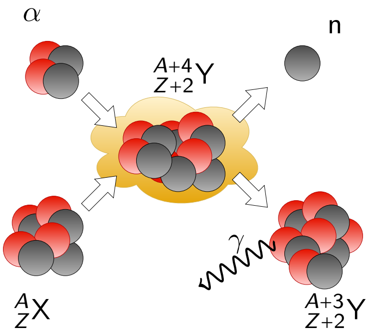
New equipment and methodologies for (α,n) measurements within MANY at CNA HiSPANoS

Gabriel Auñón, Begoña Fernández, Carlos Guerrero
& the MANY Collaboration

Centro Nacional de Aceleradores (CNA)
University of Seville (US)

XVII CPAN Days, November 19th – 21st 2025

Relevance of (α, n) reactions



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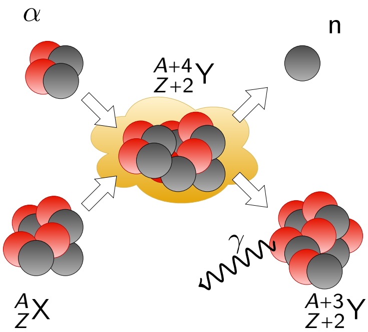

- (α,n) reactions play a crucial role in:
  - Nuclear astrophysics (0-15 MeV)
  - Nuclear fusion (0-3.5 MeV)
  - Nuclear fission (0-9 MeV)
  - Nuclear physics/reactions/ structure
  - Background in underground dark matter experiments (0-9 MeV)

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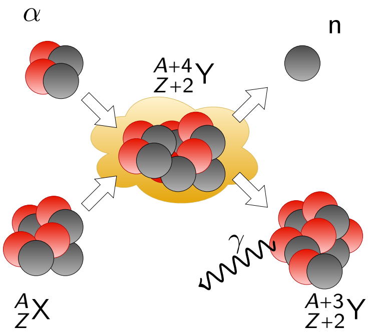

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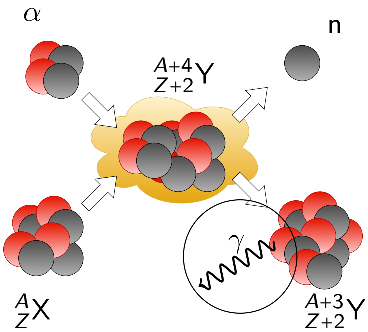

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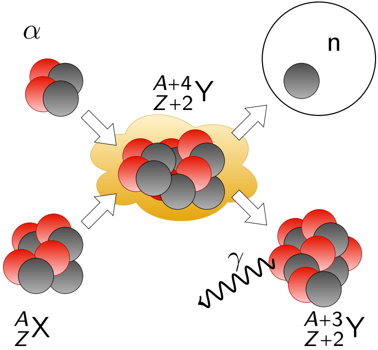

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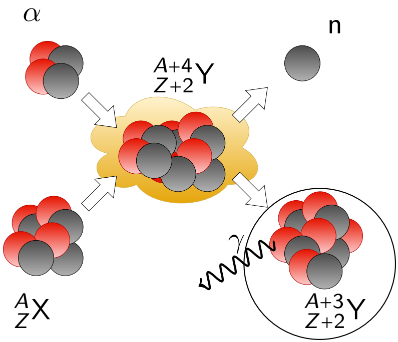

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- Experimental techniques depend on what particles are detected:
  - γ radiation (PGAA)
  - Neutrons (neutron ToF, neutron counting)
  - Product nuclei (activation)

The MANY Collaboration

Two Spanish facilities

Infraestructuras Científicas y Técnicas Singulares

UPC

Universidad de Sevilla

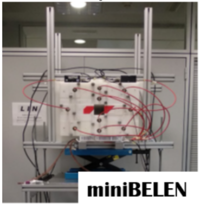
IFIC
Institut de Física Corpuscular

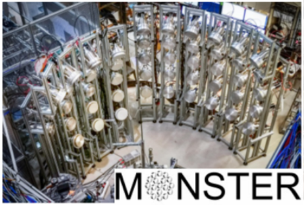
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

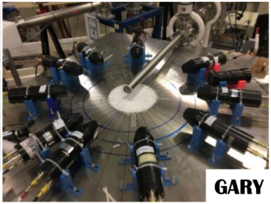
Universidad Complutense Madrid

IEM
Instituto de Estructura de la Materia

Three Spanish detectors







MANY = **M**easurement of **A**lpha-**N**eutron **Y**ields

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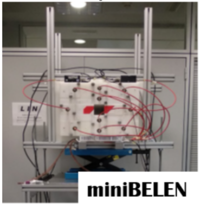
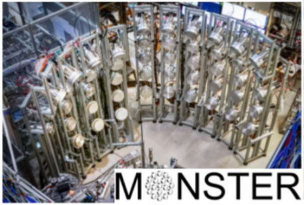
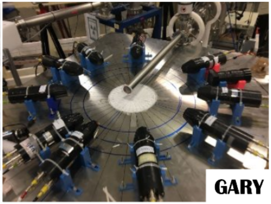
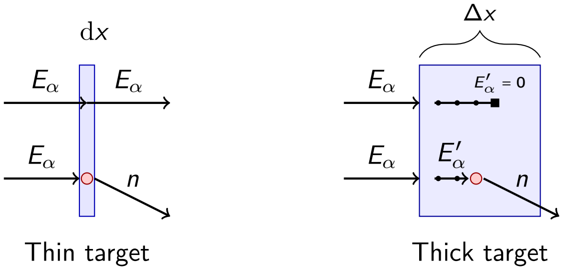






See Daniel Soler & José Llanes' talks for more details.

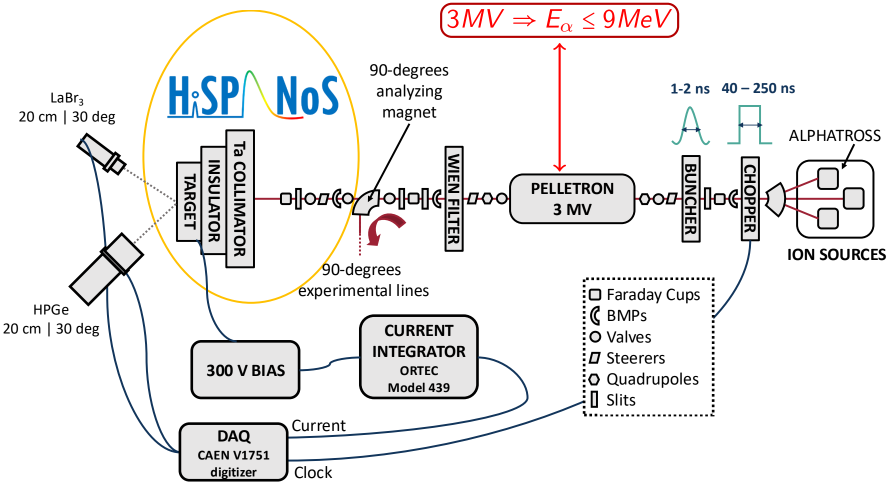
Cross-section vs Thick Target Yield



$$TTY(E_\alpha) = \int_0^{E_\alpha} \frac{\sigma(E')}{-\left(\frac{1}{\rho}\frac{\mathrm{d}E'}{\mathrm{d}x}\right)} \mathrm{d}E'$$

$$\sigma(E) = -\frac{1}{\rho}\frac{\mathrm{d}E}{\mathrm{d}x}\frac{\mathrm{d}\mathrm{TTY}(E)}{\mathrm{d}E}$$

The HiSPANoS facility at CNA



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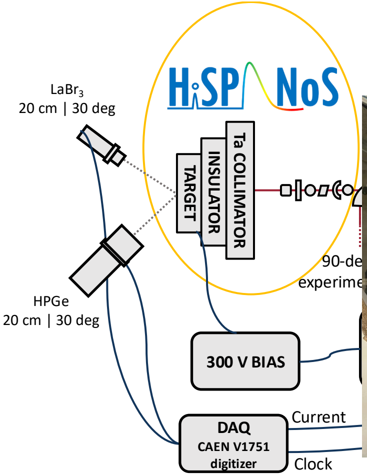

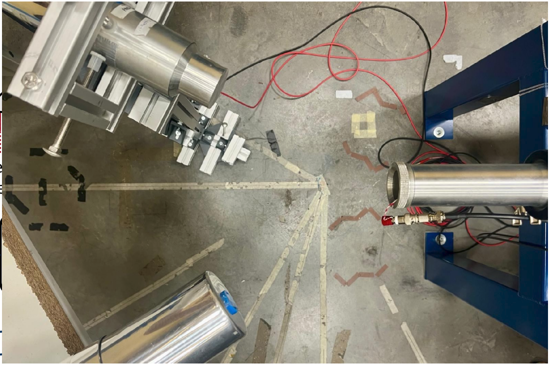

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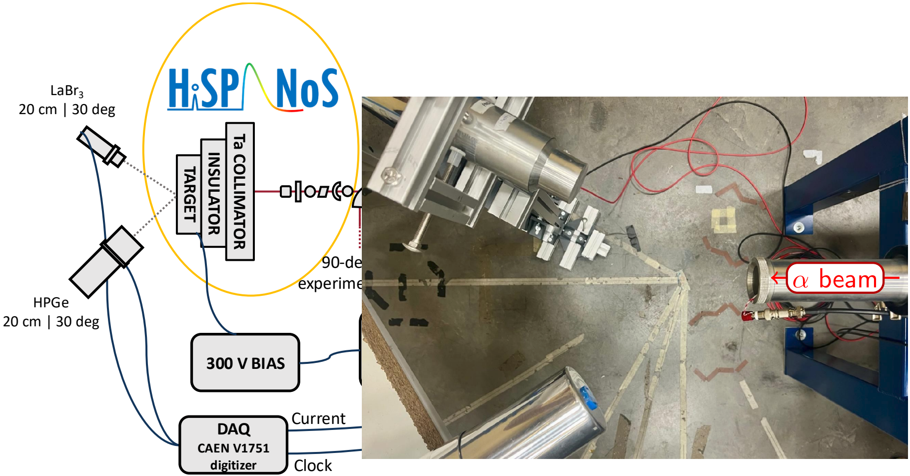

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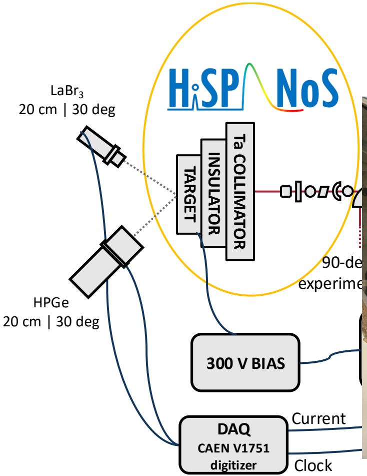

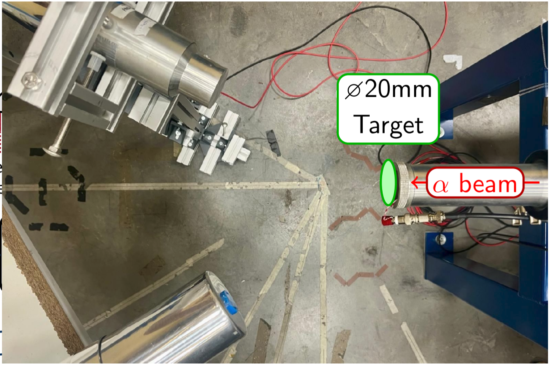

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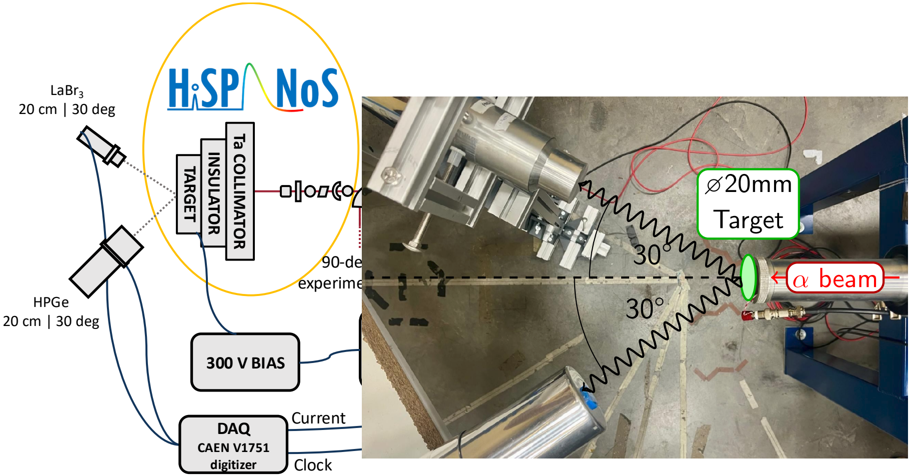
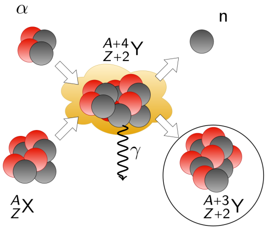
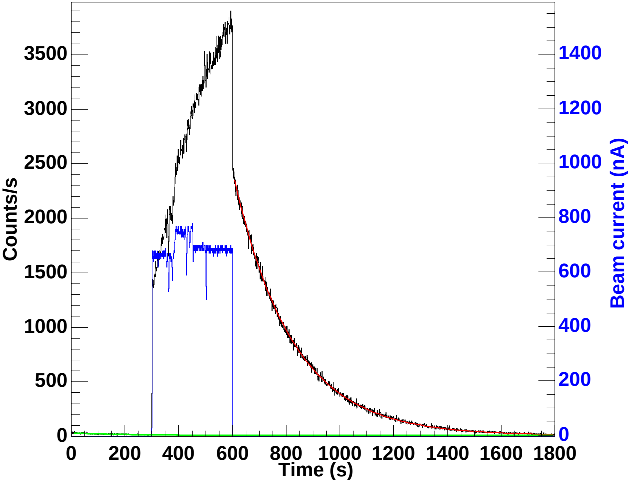


The activation technique



$$TTY = \frac{N_{decays}}{N_\alpha} =$$

$$= \frac{C_{EOI}}{I_\gamma \varepsilon} \frac{\Delta t}{1 - e^{-\lambda \Delta t}} \frac{1}{I_\alpha \Delta t}$$



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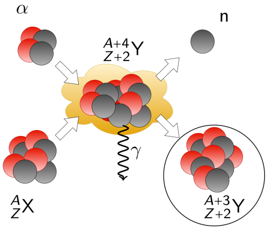

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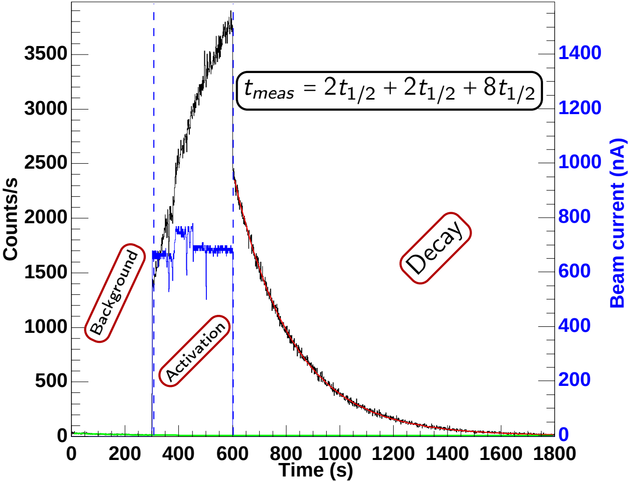
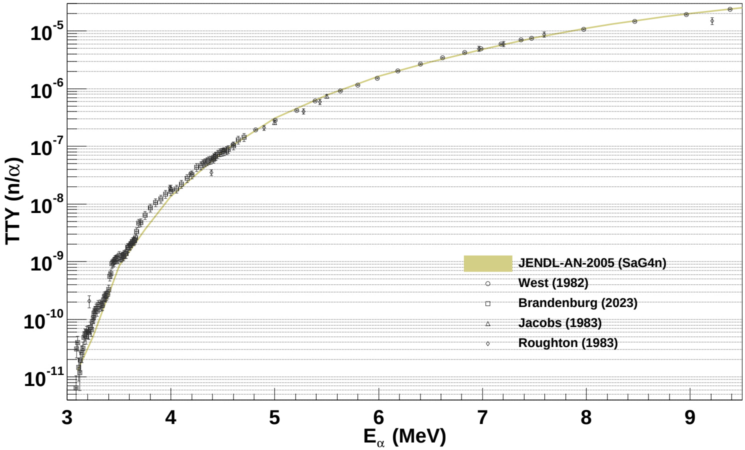


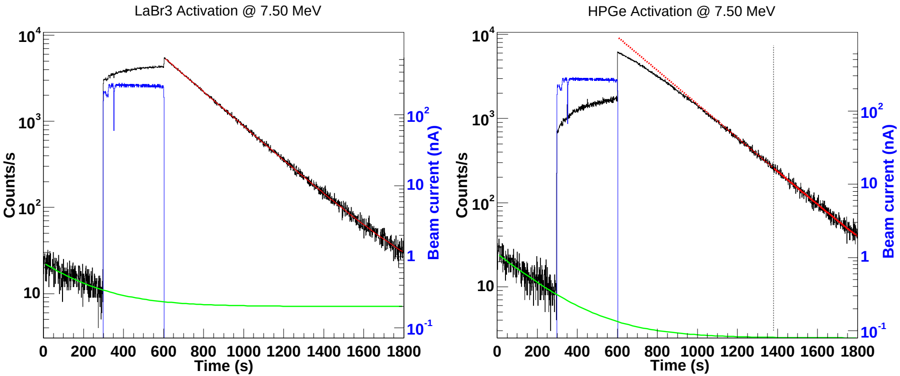
State of the art: ^{27}Al

- ^{27}Al(α,n)^{30}P is well known, and has been measured with miniBELEN, MONSTER & GARY. We use it as a benchmark for our methodology.



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

- $E_{th} = 3.014$ MeV; Energy range: 3.5 - 9 MeV
- 511 keV from ^{30}P (β^+, $t_{1/2}$ = 150 s).
- HPGe has a higher efficiency, but it has a lower cps limit.



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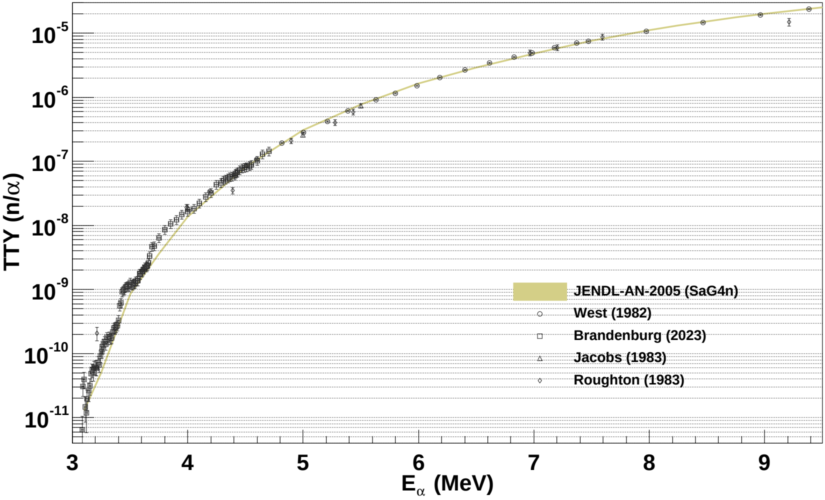
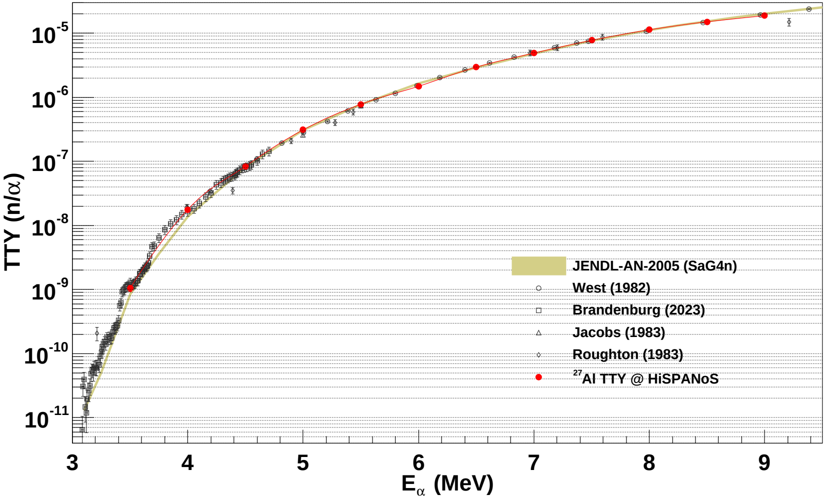


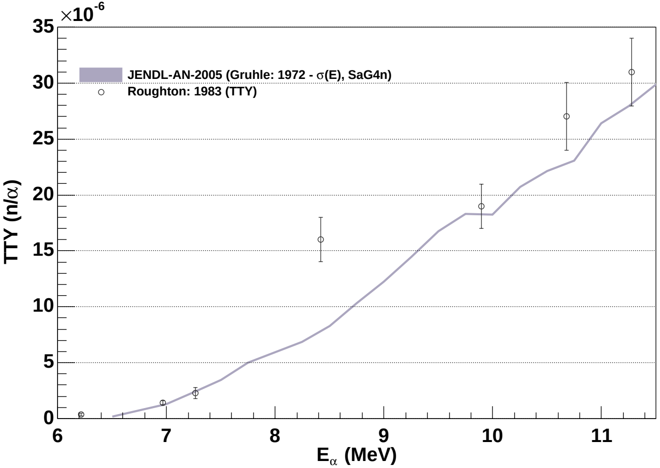
TTY for $^{27}Al(\alpha,n)^{30}P$

$$\epsilon_{syst} = 4\%(\varepsilon, \Delta t, I_\alpha) \qquad TTY = \frac{C_{EOI}}{I_\gamma \varepsilon} \frac{\Delta t}{1 - e^{-\lambda \Delta t}} \frac{1}{I_\alpha \Delta t}$$



State of the art: ^{14}N

- $^{14}N(\alpha,n)^{17}F$ yield has only been measured twice, and it is important for (α, n) induced background, often used as inert buffer gas and present in some plastics.



TTY for $^{14}N(\alpha,n)^{17}F$

- $^{14}N(\alpha,n)^{17}F$, gaseous target?

TTY for $^{14}N(\alpha,n)^{17}F$

- $^{14}N(\alpha,n)^{17}F$, ~~gaseous target~~, measured indirectly in an AlN compound target.
  - Solid target.
  - It is non conductive.
  - The chosen alloy allows simultaneous measurement of ^{27}Al and ^{14}N, enabling a current-independent normalization.

TTY for ^{14}N(α,n)^{17}F

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$$TTY(^{14}N) = \frac{C^{N}_{EOI}}{I^{N}_{\gamma}\varepsilon}\frac{\Delta t}{1-e^{-\lambda_N \Delta t}}\frac{1}{I_\alpha \Delta t}$$

$$TTY(^{27}Al) = \frac{C^{Al}_{EOI}}{I^{Al}_{\gamma}\varepsilon}\frac{\Delta t}{1-e^{-\lambda_{Al} \Delta t}}\frac{1}{I_\alpha \Delta t}$$

TTY for $^{14}N(\alpha,n)^{17}F$

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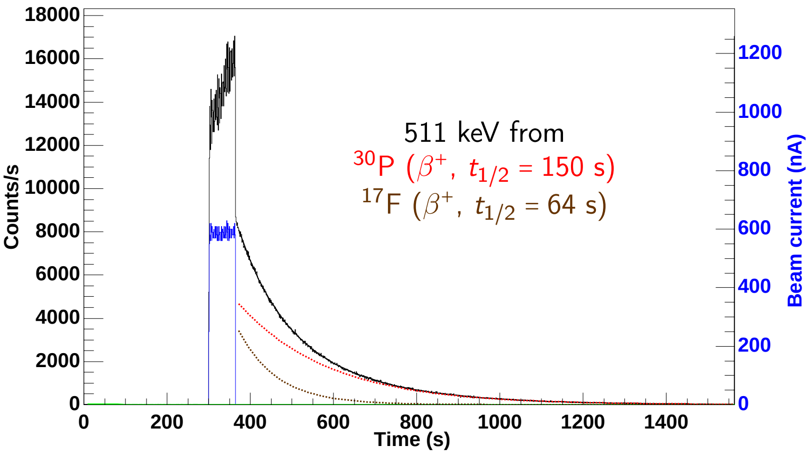
$$\left.\begin{aligned} TTY(^{14}N) &= \frac{C^N_{EOI}}{I^N_\gamma \cancel{\epsilon}} \frac{\cancel{\Delta t}}{1-e^{-\lambda_N \Delta t}} \cancel{\frac{1}{I_\alpha \Delta t}} \\ TTY(^{27}Al) &= \frac{C^{Al}_{EOI}}{I^{Al}_\gamma \cancel{\epsilon}} \frac{\cancel{\Delta t}}{1-e^{-\lambda_{Al} \Delta t}} \cancel{\frac{1}{I_\alpha \Delta t}} \end{aligned}\right\} \Rightarrow TTY(^{14}N) = TTY(^{27}Al) \frac{\frac{C^N_{EOI}}{I^N_\gamma (1-e^{-\lambda_N \Delta t})}}{\frac{C^{Al}_{EOI}}{I^{Al}_\gamma (1-e^{-\lambda_{Al} \Delta t})}}$$

TTY for $^{14}N(\alpha,n)^{17}F$

- $E_{th} = 6.055$ MeV; Energy range: 6.5 - 9 MeV
- HPGe cannot be used due to high count rate.

LaBr3 Activation @ 9.00 MeV



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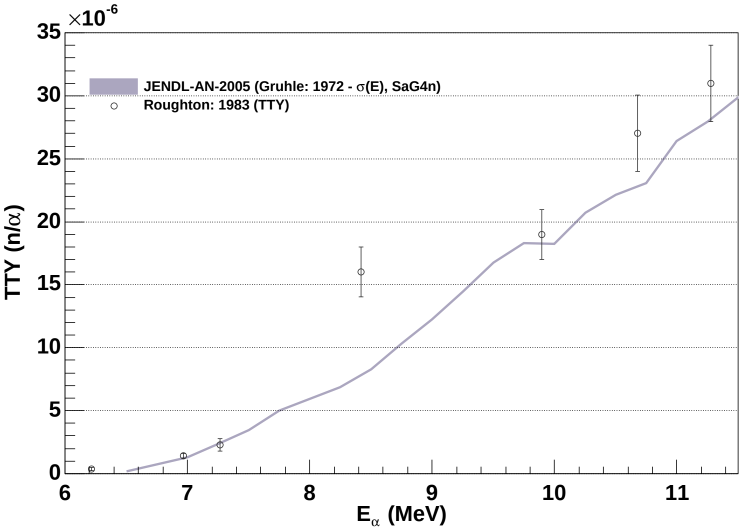

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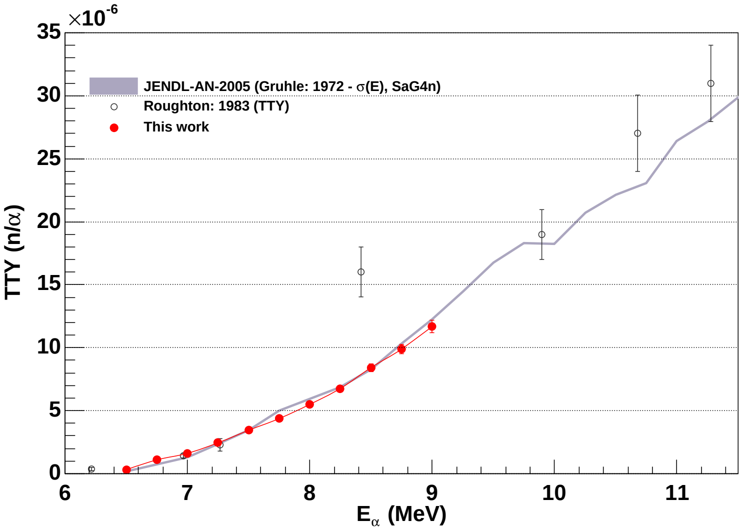
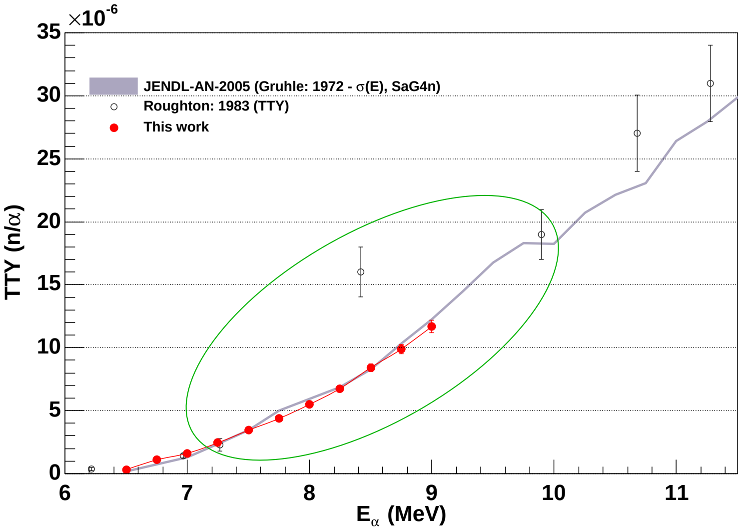
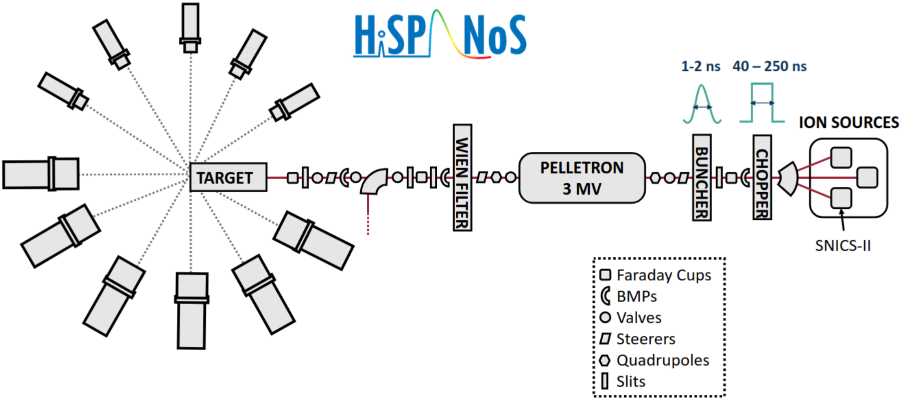


TTY for $^{14}N(\alpha,n)^{17}F$



Upgrade plans



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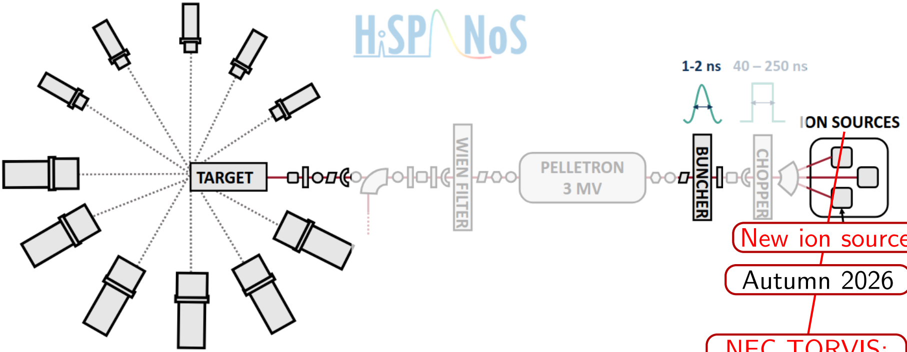
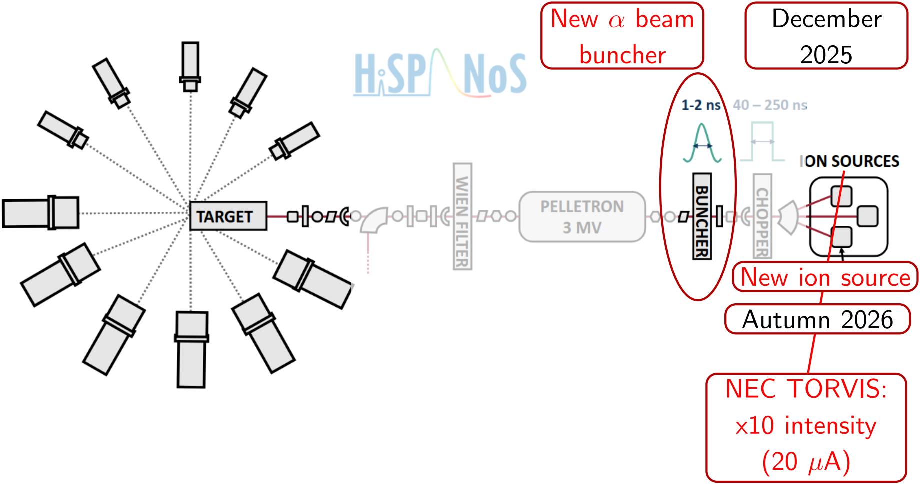


New ion source

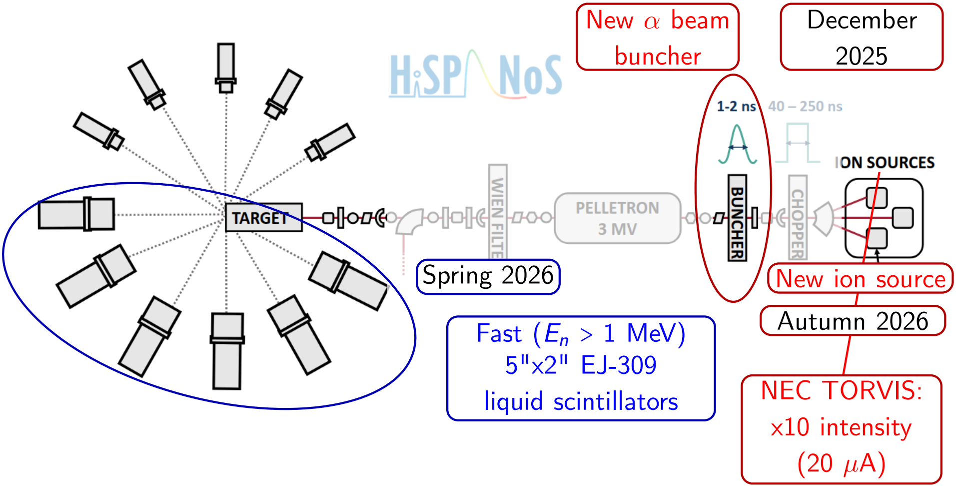
Autumn 2026

NEC TORVIS:
x10 intensity
(20 μA)

Upgrade plans



Upgrade plans



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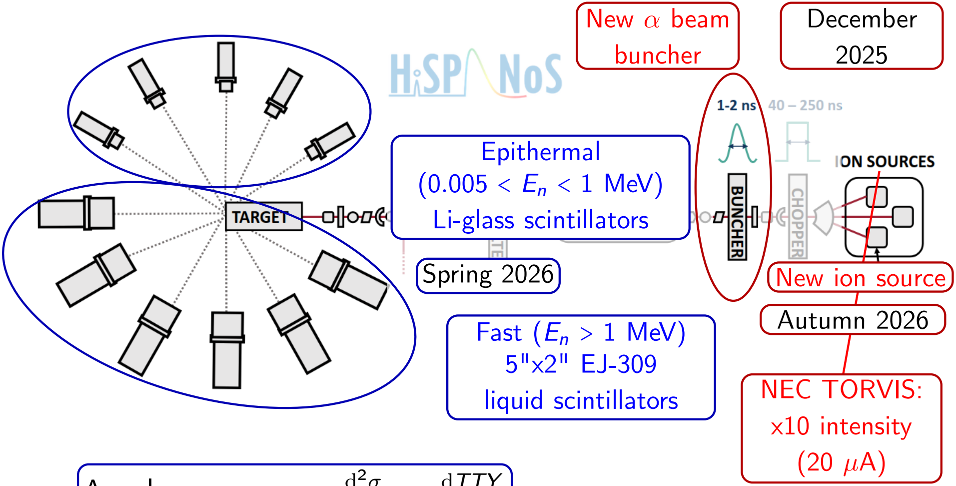

Angular coverage $\rightarrow \frac{d^2\sigma}{dE d\Omega}$ or $\frac{d\,TTY}{d\Omega}$

Summary and outlook

- **Activation:**
  - ^{27}Al: good agreement with literature validates our methodology.
  - ^{14}N:
    - Good agreement with cross-sectional data (JENDL)
    - We confirm the discrepancy with Roughton *et al.*
    - Usage of compound targets:
      – Solves gaseous target complications.
      – Enables TTY ratio to a reference.
  - Next measurements: ^{48}Ti & ^{76}Ge (nuclear fusion)*
- **(α,n) ToF improvements @ HiSPANoS:**
  - New ion source (20 μA)
  - New beam buncher (<2ns pulse width)
  - New array of fast and epithermal detectors (EJ-309 + Li-glass)
  - First measurements: ^{27}Al & ^{9}Be (within APRENDE)*

*Complete list of isotopes: *Review of Neutron Yield from (α,n) Reactions: Data, Methods, and Prospects.* Santorelli, R. *et al.*

Thank you for your attention!

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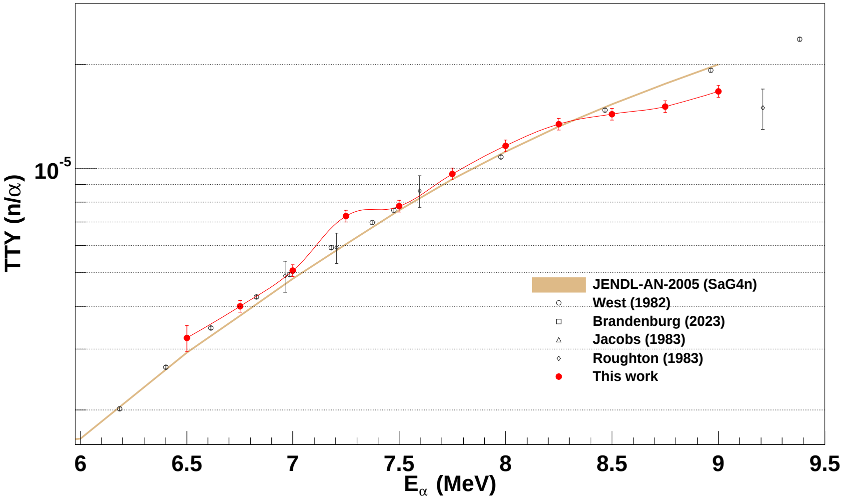
* *Contact: gaunon@us.es*

Backup slides

Extra - Current lecture in AlN target

- Since AlN is an insulator → current measurements are not reliable.



Extra - TENDL vs JENDL for $^{14}N(\alpha,n)^{17}F$