Upgrades at CNA HiSPANoS for continuous and pulsed (α,n) measurements within MANY

Gabriel Auñón-Fernández[1], Begoña Fernández[1,2], Carlos Guerrero[1,2]
& the MANY Collaboration

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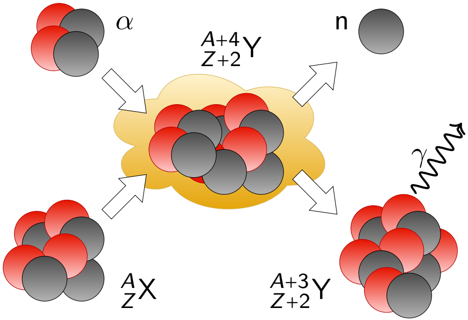
[2]University of Seville (US)

XL Bienal RSEF, July 20^{th}-24^{th} 2026

Relevance of (α, n) reactions



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

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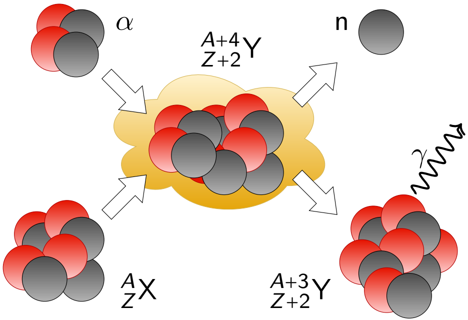

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  - γ radiation (PGAA)
  - Neutrons (TOF, neutron counting)
  - Product nuclei (activation)

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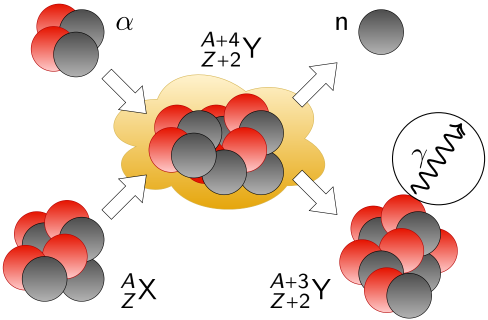

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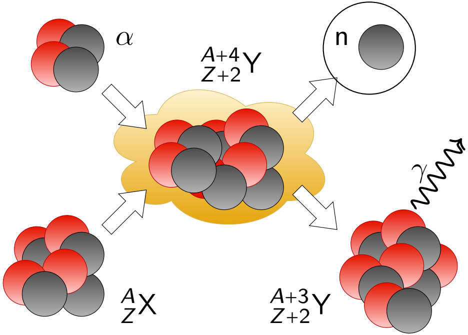

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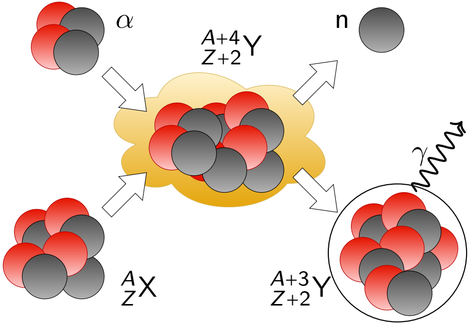
Relevance of (α, n) reactions



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  - γ radiation (PGAA)
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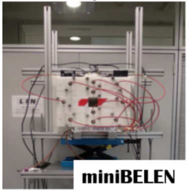
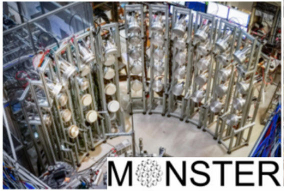
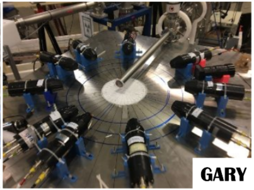
The MANY Collaboration

Two Spanish facilities

Three Spanish detectors

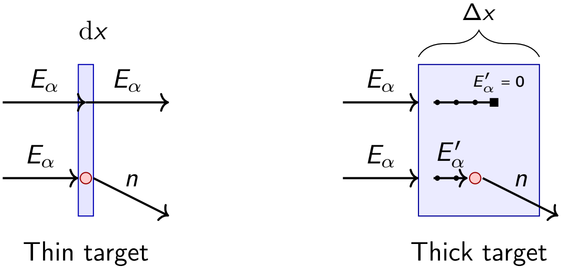






MANY = **M**easurement of **A**lpha-**N**eutron **Y**ields

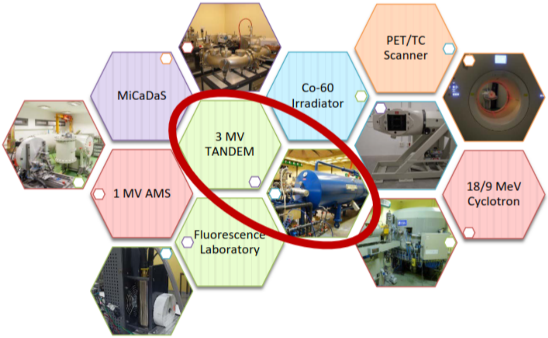
Cross-section vs Thick Target Yield



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

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

Multidisciplinary research center open to external users



Centro Nacional de Aceleradores (CNA) and the HiSPANoS facility

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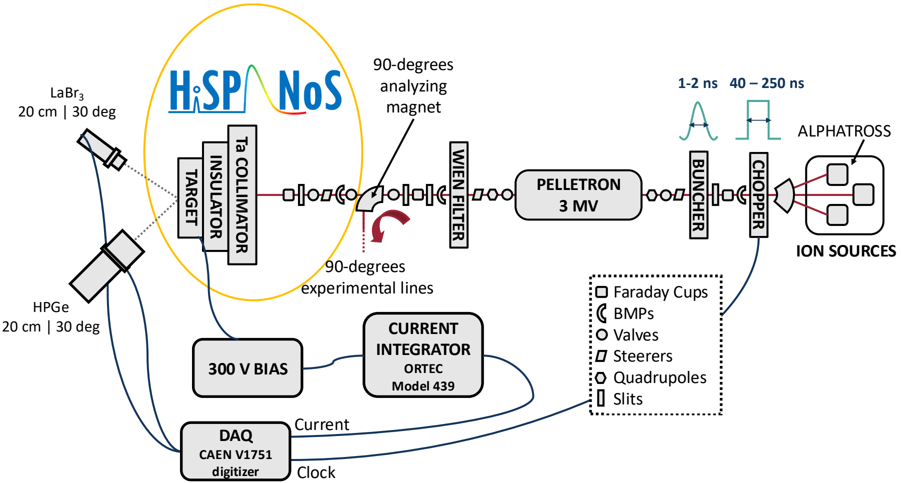


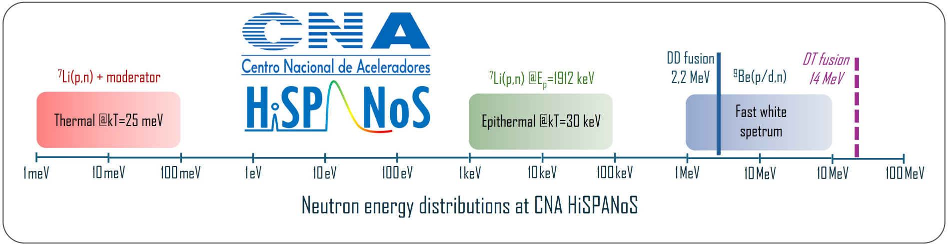
Figure based on the work of M.A.Millán-Callado

HiSPANoS overview [1]

- 1st accelerator-based neutron source in Spain
- H^+, D^+: Several tens of μA up to 6 MeV
- α: Nominal 2 μA up to 9 MeV

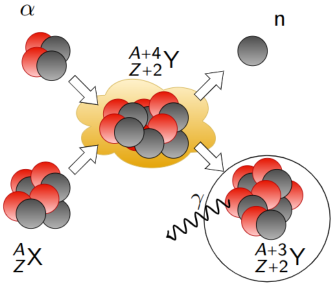
Operating modes

- Continuous mode since 2013
- Pulsed mode (H^+ & D^+) since 2018 (<2 ns pulses, up to 2 MHz)

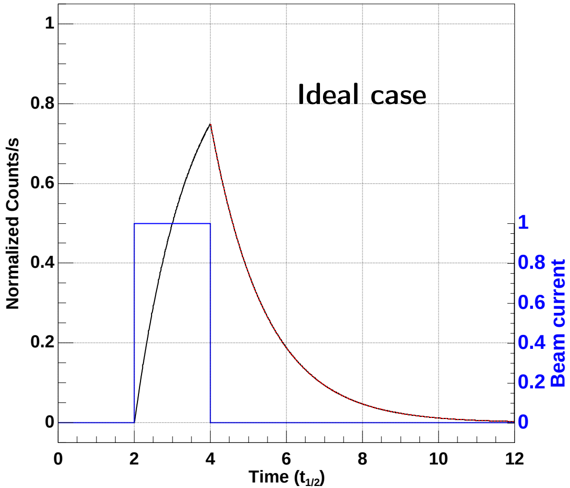


[1] M.A. Millán-Callado, et al.,Radiation Physics and Chemistry 217 (2024) 111464.

Activation measurements at HiSPANoS



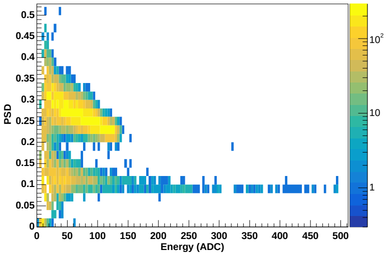
$$TTY = \frac{N_{decays}}{N_\alpha} = \frac{C_{EOI}}{I_\gamma \varepsilon} \frac{\Delta t}{1 - e^{-\lambda \Delta t}} \frac{1}{I_\alpha \Delta t}$$

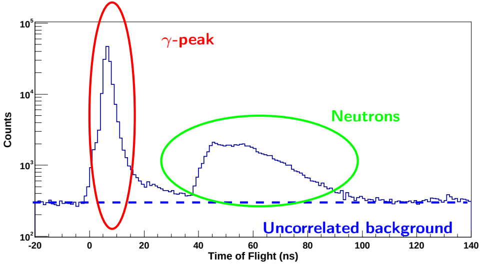


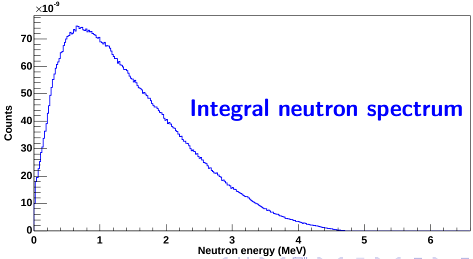
Time of Flight measurements at HiSPANoS

- Neutron-γ discrimination with Pulse Shape Discrimination (PSD)
- **Issue: α beam not properly pulsed**

PSD Selection

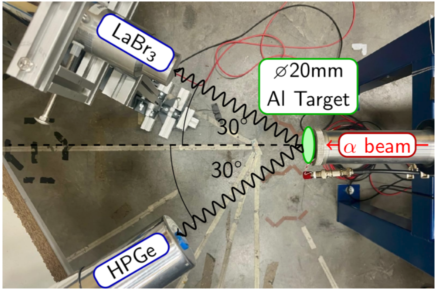


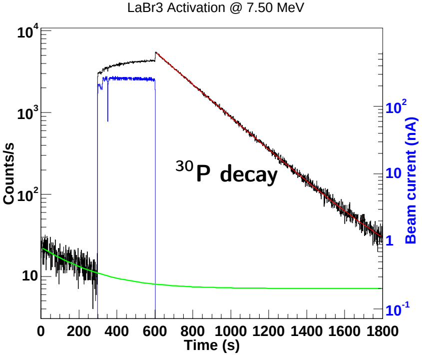




Benchmarking: the ^{27}Al(α,n)^{30}P reaction

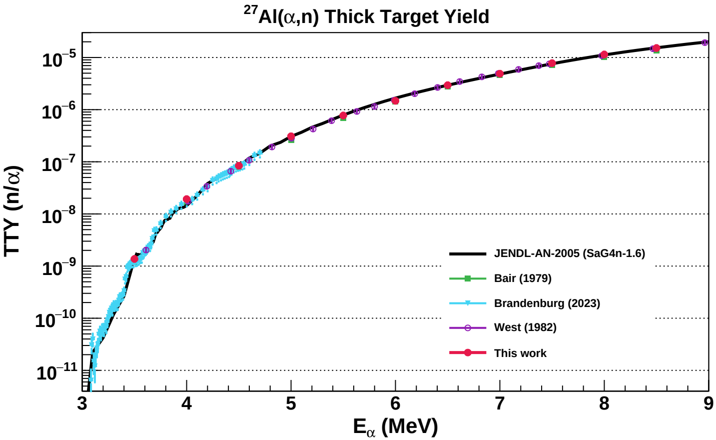
- ^{30}P (β^+, $t_{1/2}$ = 150 s)
- E_{th} = 3.014 MeV
- Energy range: 3.5 - 9.0 MeV
- TTY value is obtained from both $LaBr_3$ and HPGe detectors, with consistent results





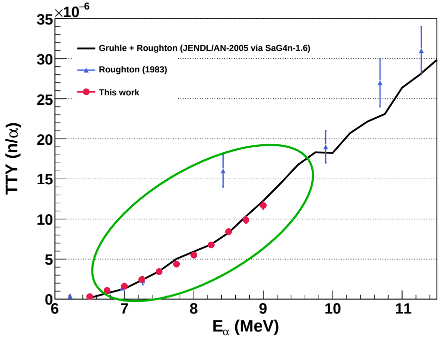
Benchmarking: the ^{27}Al(α,n)^{30}P reaction

- The thick-target yield is well known, and has been measured with miniBELEN, MONSTER & GARY
- $\sigma_{syst} \simeq 4\%(\varepsilon, \Delta t, I_\alpha)$
- ΔTTY $\leq$ 3% (4.5-9.0 MeV)

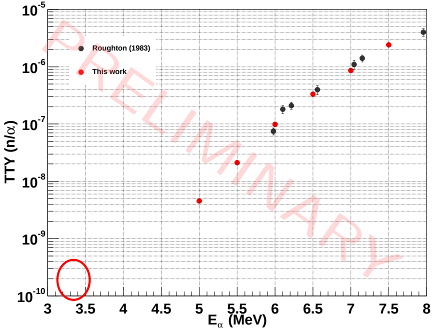


Other activation reactions

- ^{14}N
  - Present as inert buffer gas and in plastics
  - Only two existing datasets: one σ measurement and one TTY measurement
  - Gas element → solid compound target



- ^{48}Ti
  - Potential tool for measuring alpha particle losses
  - Needed TTY with $E_\alpha < 3.5$ MeV, but only measured at $E_\alpha > 6$ MeV



1 Motivation

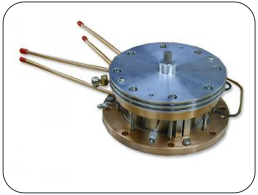
2 Current results

3 New upgrades
- Beam current
- Pulsing system
- Detection capabilities

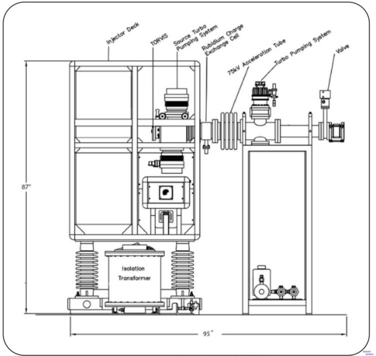
4 Conclusions

Upgrade I — Beam current

- Current: NEC Alphatross delivers **up to 2 μA**
- Upcoming: **NEC TORVIS** will deliver **up to 20 μA**
- Shorter irradition time, access to very low (α,n) cross-sections, more stability and easier maintenance
- Arrival in **Fall 2026**, commissioning in **early 2027**

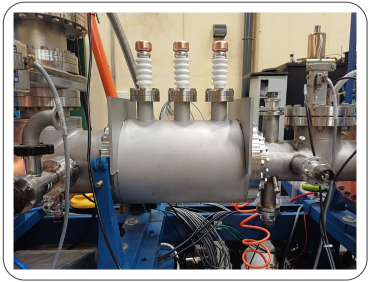


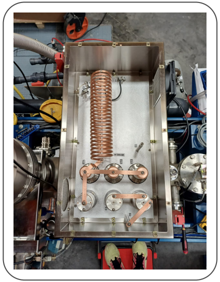
Toroidal Ion Source

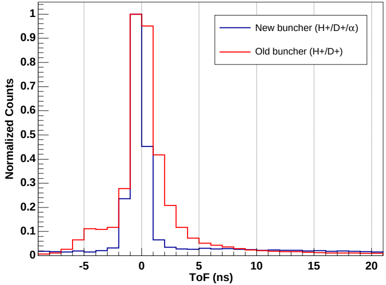


Upgrade II — α-optimized Buncher

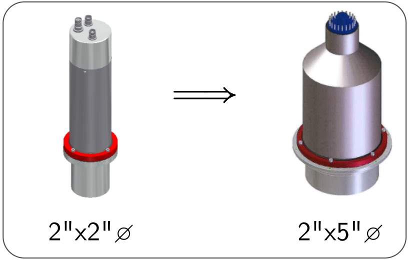
- The previous buncher was not designed for α particles, leading to a poor pulse shape
- We aim to improve the time structure for α while maintaining good performance for H^+ and D^+



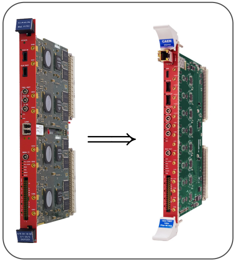




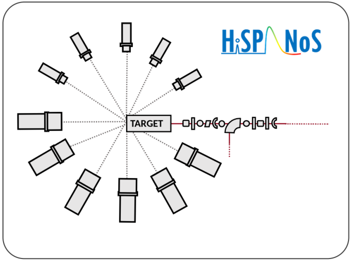
- 6 new EJ-309 detectors (2"x5"⌀)
- New CAEN VX2751 digitizer @ 1 GS/s



Efficiency x6.25

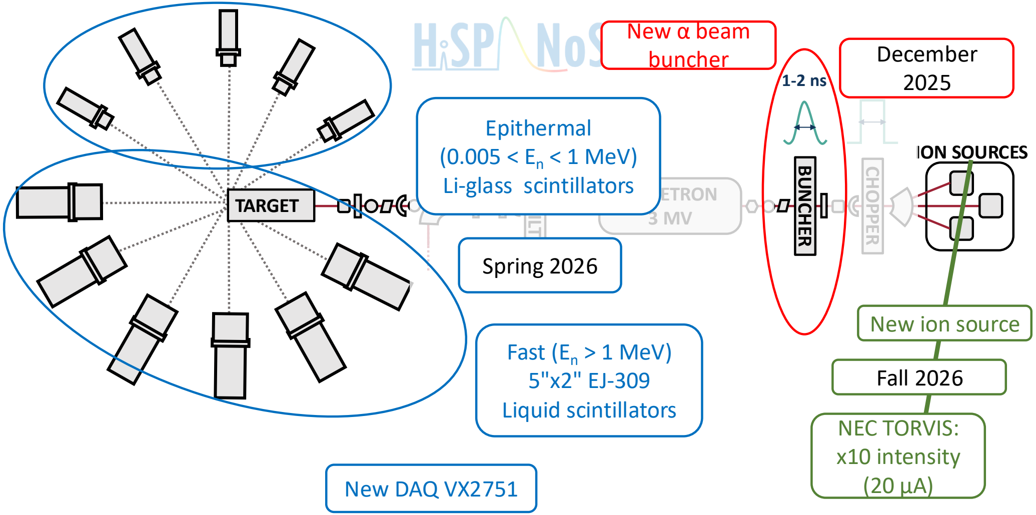


10→14 bits
8→16 channels



Fast & epithermal neutron detectors array

Upgrades



New α beam buncher
December 2025
1-2 ns
BUNCHER
ION SOURCES
TARGET
Epithermal
(0.005 < E_n < 1 MeV)
Li-glass scintillators
Spring 2026
Fast (E_n > 1 MeV)
5"x2" EJ-309
Liquid scintillators
New DAQ VX2751
New ion source
Fall 2026
NEC TORVIS:
x10 intensity
(20 µA)

Summary and outlook

- **Activation:**
  - ^{27}Al: good agreement with literature validates our methodology
  - ^{14}N:
    - Solved discrepancy between experimental data & JENDL evaluation
    - Successful usage of compound target measurements relative to a reference, avoiding gaseous target complications
  - ^{48}Ti: successful measurements of TTY values down to 5 MeV, and irradiation at lower energies pending on TORVIS arrival
- **Plans for Time of flight:**
  - Improved α pulse shape (new buncher)
  - Better statistics (new ion source & new array of fast and epithermal detectors)
  - First measurements: ^{27}Al and ^{9}Be within EC APRENDE

HiSPANoS aims to be a reference facility for (α,n) measurements in the 3-9 MeV range

Thank you for your attention!

G. Auñón-Fernández*, B. Fernández & C. Guerrero
& the MANY Collaboration

This work has been funded by the Ministerio de Ciencia, Innovación y Universidades under grants EQC2024-008842-P, PID2021-123879OB-C21 and PID2024-155965OB-I00. This project has received funding from the European Union's Horizon Euratom Research and Training Programme under grant agreement No 101164596 (APRENDE).

* *Contact: gaunon@us.es*

Backup slides

Backup - IAEA monitor reactions

Monitor reactions are the common language for comparing beam current, energy, and yield

Radiation Physics and Chemistry
Volume 190, January 2022, 109759

Production yields at the distal fall-off of the β^+ emitters ^{11}C and ^{13}N for in-vivo range verification in proton therapy

Teresa Rodríguez-González [a b], Carlos Guerrero [a b 1], María del Carmen Jiménez-Ramos [b], Jorge Lerendegui-Marco [a], María de los Ángeles Millán-Callado [a b], Ángel Parrado [b], Joaquín Gómez [a b], Jose Manuel Quesada [a]

Research article Get rights and content ↗

Production of ^{11}C, ^{13}N and ^{15}O in proton-induced nuclear reactions up to 200 MeV

T. Rodríguez-González [a b], C. Guerrero [a b], C.M. Bäcker [c d e f], J. Bauer [g], C. Bäumer [h d e f i], S. Brons [g], W. Jentzen [e f j], M.C. Jiménez-Ramos [b] [k], M.Á. Millán-Callado [a b], C. Schömers [g], B. Timmermann [d e f i l], J.M. Quesada [a], R. Capote [m] Show more

^{63}Cu(p,n)^{63}Zn as monitor reaction

The (α, n) community still lacks a single universally accepted monitor reaction

Alpha-particles

- ^{27}Al(α,x)^{22}Na
- ^{27}Al(α,x)^{24}Na
- ^{27}Al(α,x)^{28}Mg
- ^{nat}Ti(α,x)^{51}Cr
- ^{nat}Ni(α,x)^{57}Co
- ^{nat}Ni(α,x)^{57}Ni
- ^{nat}Ni(α,x)^{60}Cu
- ^{nat}Ni(α,x)^{61}Cu
- ^{nat}Ni(α,x)^{62}Zn
- ^{nat}Ni(α,x)^{63}Zn
- ^{nat}Ni(α,x)^{65}Zn
- ^{nat}Cu(α,x)^{65}Zn
- ^{nat}Cu(α,x)^{66}Ga
- ^{nat}Cu(α,x)^{67}Ga
- ^{nat}Mo(α,x)^{96}Tc
- ^{nat}Mo(α,x)^{95}Ru
- ^{nat}Mo(α,x)^{97}Ru
- ^{197}Au(α,x)^{196}Au
- ^{197}Au(α,x)^{199}Tl
- ^{197}Au(α,x)^{200}Tl

Backup - Other activation reactions

Journal of Physics G: Nuclear and Particle Physics

TOPICAL REVIEW • OPEN ACCESS

Review of neutron yield from (α, n) reactions: data, methods, and prospects

D Cano-Ott, S Cebrián, P Dimitriou, M Gromov, M Harańczyk, A Kish, H Kluck, V A Kudryavtsev, I Lazanu, V Lozza Show full author list

Published 27 February 2026 • © 2026 The Author(s). Published by IOP Publishing Ltd
Journal of Physics G: Nuclear and Particle Physics, Volume 53, Number 2
Citation D Cano-Ott *et al* 2026 *J. Phys. G: Nucl. Part. Phys.* **53** 023001
DOI 10.1088/1361-6471/adeffa

ELSEVIER
Fusion Engineering and Design
Volume 86, Issues 6–8, October 2011, Pages 1298-1301

Fusion alpha loss diagnostic for ITER using activation technique

G. Bonheure [a], M. Hult [b], R. González de Orduña [b], P. Vermaercke [c], A. Murari [d], S. Popovichev [e], J. Mlynar [f]

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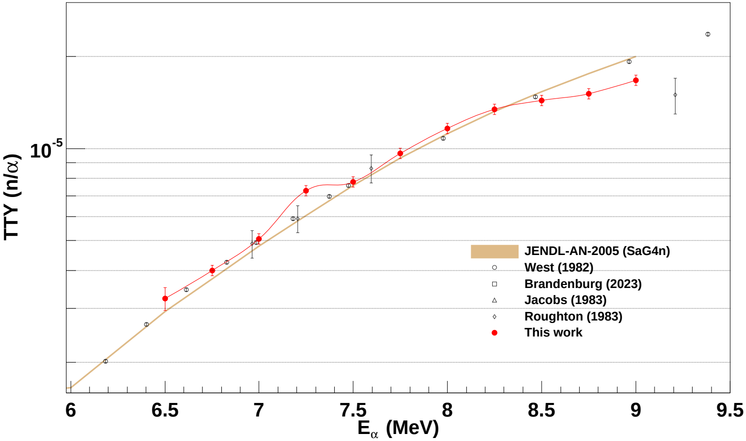
https://doi.org/10.1016/j.fusengdes.2011.03.007 Get rights and content

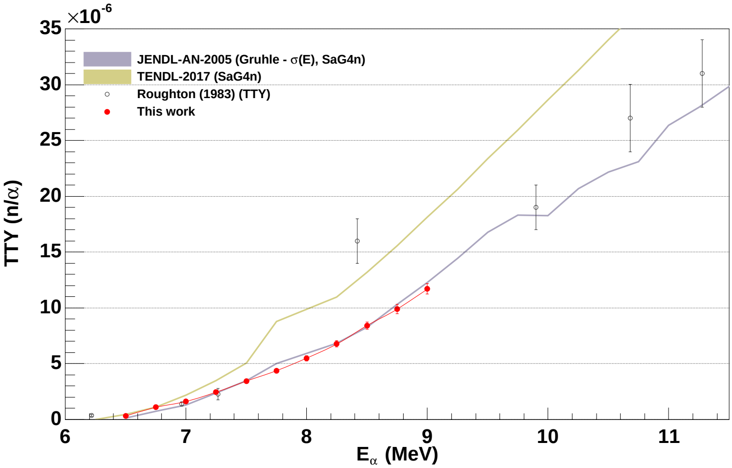
We wanted to identify the most useful candidate reactions according to data needs and feasibility

- ^{14}N
  - Present as inert buffer gas and in plastics
  - Only two existing datasets: one σ measurement and one TTY measurement
  - Gas element
- ^{48}Ti
  - Potential tool for measuring alpha particle losses
  - Needed TTY with $E_\alpha < 3.5$ MeV, but only measured at $E_\alpha > 6$ MeV

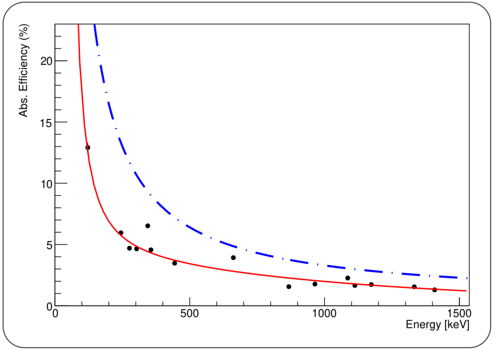
- Since AlN is an insulator → current measurements are not reliable.



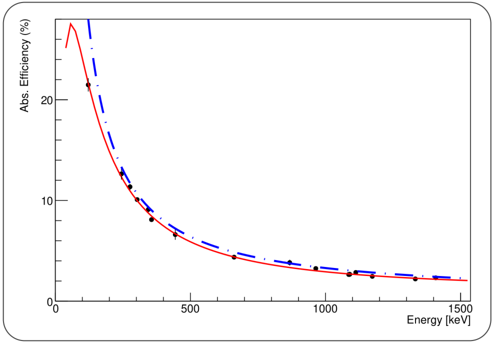
Backup - TENDL vs JENDL for $^{14}N(\alpha,n)^{17}F$



Backup - HPGe efficiency calibration



Non-corrected contact measurements with ^{152}Eu, ^{133}Ba, ^{137}Cs and ^{60}Co sources.



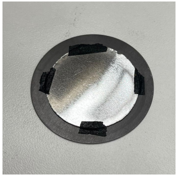
Effective branching ratio obtained from the contact measurements

Backup - The $^{14}N(\alpha,n)^{17}F$ reaction: a compound target approach

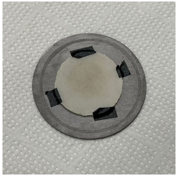
- ^{14}N, gaseous target?

Backup - The ^{14}N(α,n)^{17}F reaction: a compound target approach

- ^{14}N, ~~gaseous target~~, measured indirectly in an AlN compound target.
  - Solid target, easy to handle
  - It is a ceramic, so it's insulator
  - The chosen alloy allows simultaneous measurement of ^{27}Al and ^{14}N, enabling a current-independent normalization



Pure Al target



AlN target

Backup - The ^{14}N(α,n)^{17}F reaction: a compound target approach

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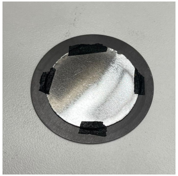
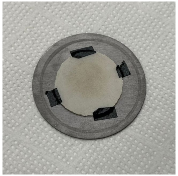


Pure Al target

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

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



AlN target

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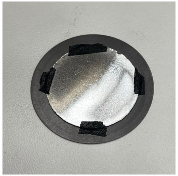
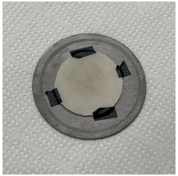


Pure Al target

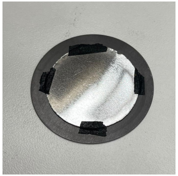
$$TTY(^{14}N) = \frac{C^{N}_{EOI}}{I^{N}_{\gamma}\varepsilon} \frac{\Delta t}{1-e^{-\lambda_N \Delta t}} \frac{1}{I_\alpha \Delta t}$$

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



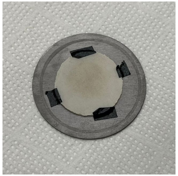
AlN target

- ^{14}N, ~~gaseous target~~, measured indirectly in an AlN compound target.
  - Solid target, easy to handle
  - It is a ceramic, so it's insulator
  - The chosen alloy allows simultaneous measurement of ^{27}Al and ^{14}N, enabling a current-independent normalization



Pure Al target

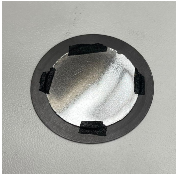
$$\left.\begin{aligned} TTY(^{14}N) &= \frac{C^N_{EOI}}{I^N_\gamma \cancel{\epsilon}} \frac{\cancel{\Delta t}}{1-e^{-\lambda_N \Delta t}} \cancel{\frac{1}{I_\alpha \Delta t}} \\ TTY(^{27}Al) &= \frac{C^{Al}_{EOI}}{I^{Al}_\gamma \cancel{\epsilon}} \frac{\cancel{\Delta t}}{1-e^{-\lambda_{Al} \Delta t}}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



AlN target

Backup - The ^{14}N(α,n)^{17}F reaction: a compound target approach

- ^{14}N, ~~gaseous target~~, measured indirectly in an AlN compound target.
  - Solid target, easy to handle
  - It is a ceramic, so it's insulator
  - The chosen alloy allows simultaneous measurement of ^{27}Al and ^{14}N, enabling a current-independent normalization

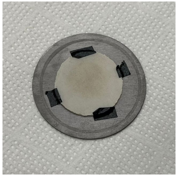


Pure Al target

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

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

$$\Rightarrow TTY(^{14}N) = TTY(^{27}Al) \frac{\frac{C^{N}_{EOI}}{I^{N}_{\gamma}(1-e^{-\lambda_N \Delta t})}}{\frac{C^{Al}_{EOI}}{I^{Al}_{\gamma}(1-e^{-\lambda_{Al} \Delta t})}}$$

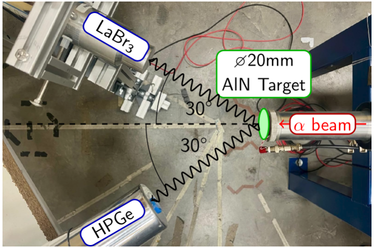


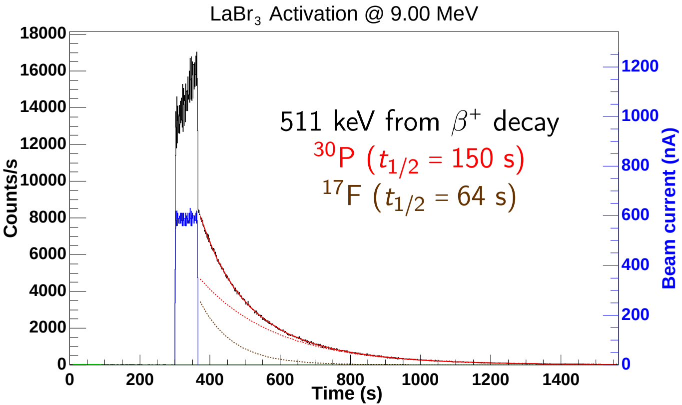
AlN target

Best example of why it's important to have a monitor reaction!

Backup - The $^{14}N(\alpha,n)^{17}F$ reaction: a compound target approach

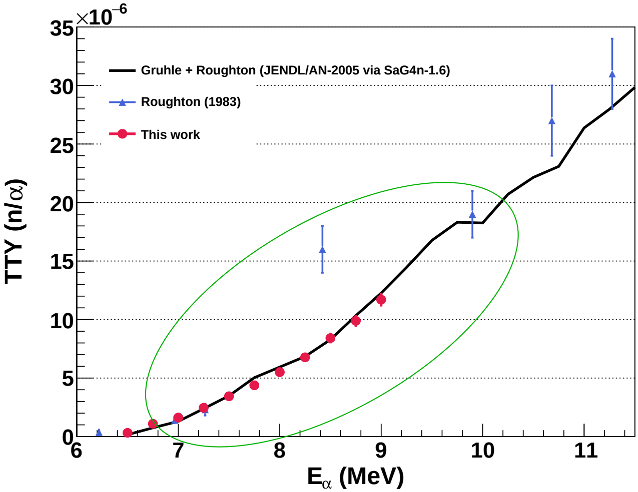
- ^{17}F (β^+, $t_{1/2}$ = 64 s)
- $E_{th} = 6.055$ MeV
- Energy range: 6.5 - 9 MeV
- Same setup as for ^{27}Al
- HPGe detector cannot be used





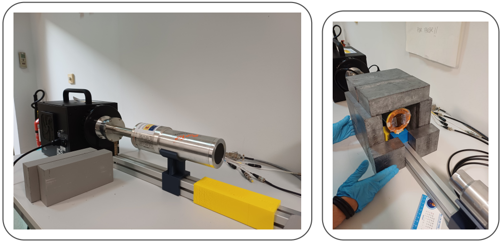
Only feasible by activation!

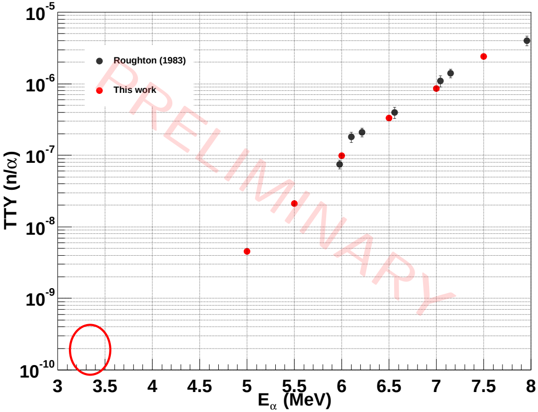
Backup - The $^{14}N(\alpha,n)^{17}F$ reaction: a compound target approach



Backup - The $^{48}Ti(\alpha,n)^{51}Cr$ reaction (ongoing)

- ^{51}Cr (ε, $t_{1/2}$ = 27.7 days)
- $E_{th} = 2.892$ MeV
- We aim to measure the TTY at 3.5 MeV





1 month of nonstop irradiation needed!

Backup - The MANY Collaboration

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