PHY3004W Laboratory
Neutron activation of ^{27}Al

(also known as Half-Life)

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Neutrons

… are subatomic particles comprised of quarks (udd) and are present in all atomic nuclei (except ^1H).

… are stable within atomic nuclei, but when free, β^- decay to $p, e, \bar{\nu_e}$ with a mean lifetime ~15 minutes

Charge	0
Mass	1.675 x 10^{-27} kg
Spin	+1/2
Magnetic moment	-1.91 μ_n

… play a key role in nuclear reactions, fission, fusion, and neutron activation

… are used in applications like neutron imaging, materials analysis, and medical therapy

Where do the neutrons come from?

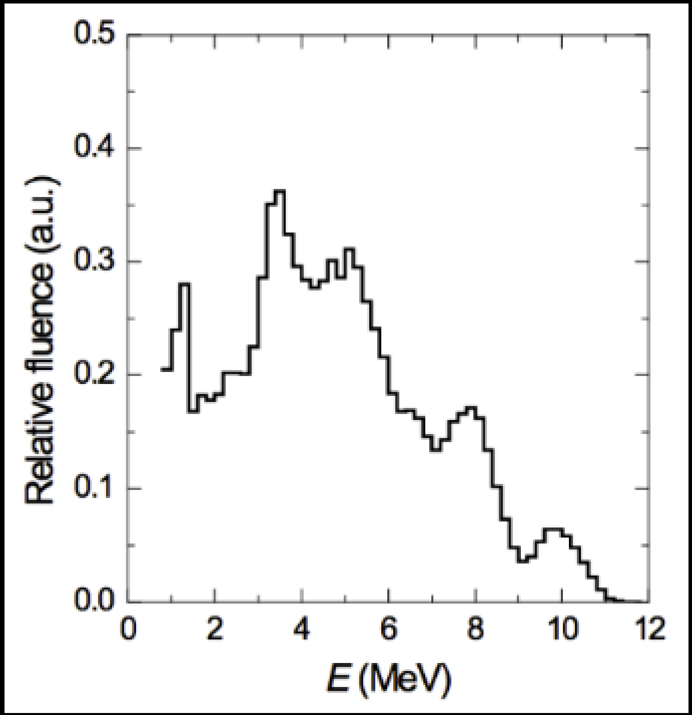
$^{241}Am \rightarrow {}^{237}Np + \alpha \quad (t_{½} = 433 \text{ years})$

Author: M. S. Basunia   Citation: Nuclear Data Sheets 107, 3323 (2006)

Parent Nucleus	Parent E(level)	Parent Jπ	Parent $T_{1/2}$	Decay Mode	GS-GS Q-value (keV)	Daughter Nucleus	Decay Scheme	ENSDF file
$^{241}_{95}Am$	0.0	5/2−	432.6 y 6	α: 100 %	5637.82 12	$^{237}_{93}Np$		

$^{9}Be + \alpha \rightarrow {}^{13}C^* \rightarrow {}^{12}C^* + n \rightarrow {}^{12}C + \gamma\ (4.43 \text{ MeV})$

$^{9}Be(\alpha,n)^{12}C^*$



See *Neutron Radiation From AmBe* for more information

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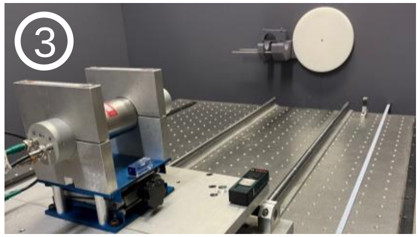

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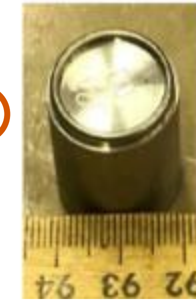
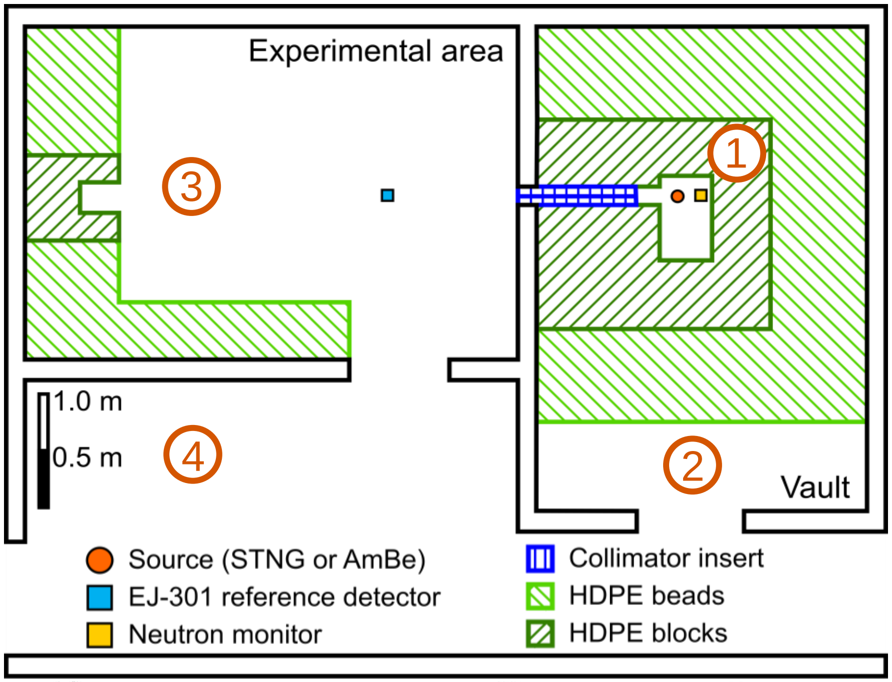
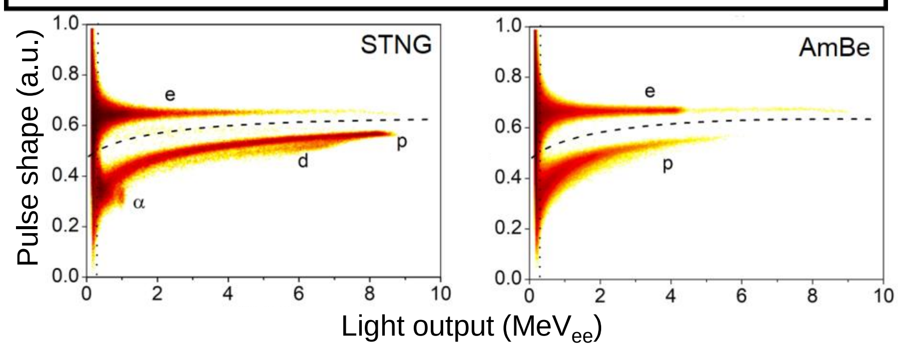


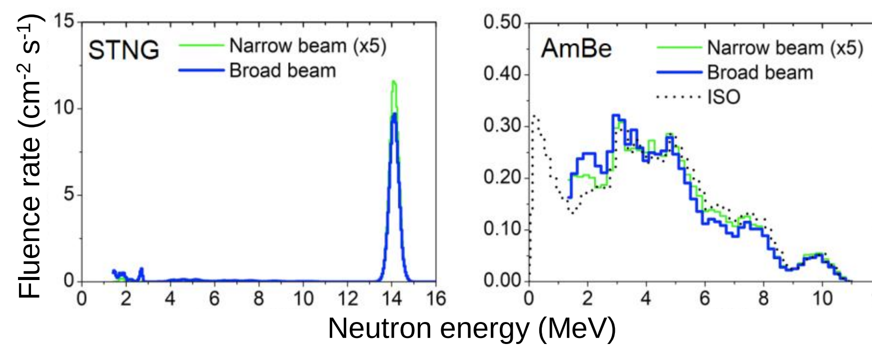
MP 320 sealed tube neutron generator

Americium-beryllium (220 GBq)



	STNG	**AmBe**
Reaction	^{3}H(^{2}H, **n**)^{4}He	^{9}Be(α, **n**)^{12}C + γ
Neutron energy (MeV)	14.103(85)	<11.0 MeV
Emission rate (s^{-1})	10^{8}	10^{7}
$\phi_{>1.5\ \mathrm{MeV}}$ [narrow] (cm^{-2} s^{-1})	24.2(47)	1.350(84)
$\phi_{>1.5\ \mathrm{MeV}}$ [broad] (cm^{-2} s^{-1})	102(12)	6.745(35)

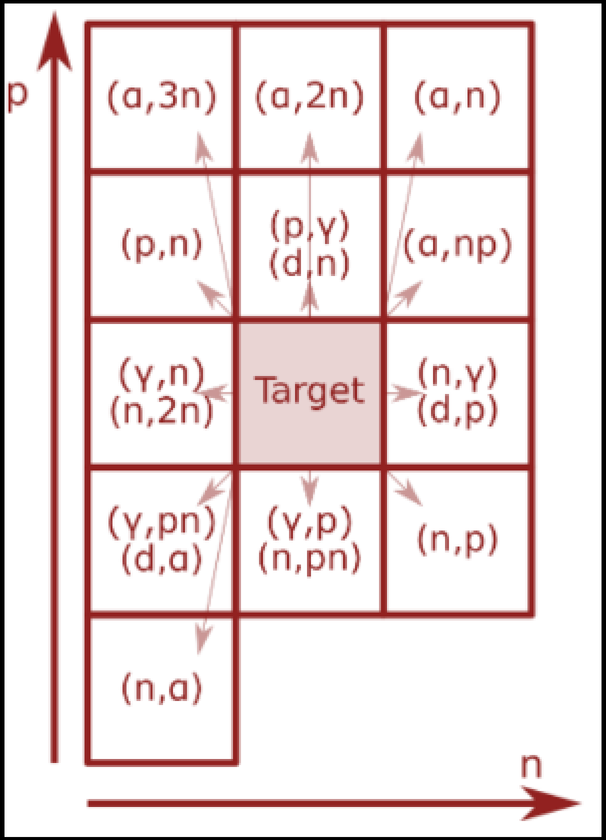




Tanya Hutton & Andy Buffler, “Characterisation of neutron fields at the n-lab, a fast neutron facility at the University of Cape Town”, *ARI* **206** (2024) 111196

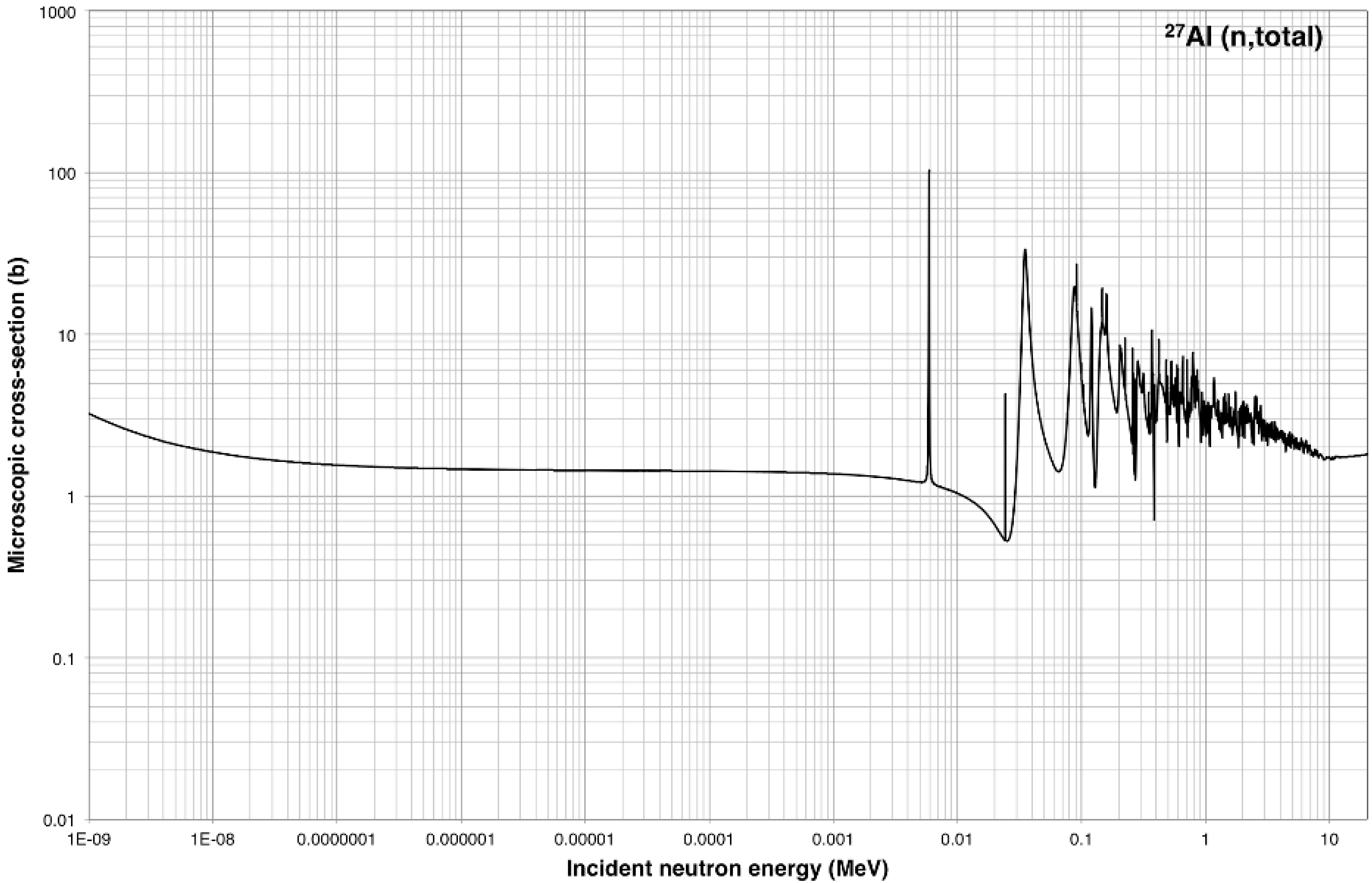
How do neutrons interact?

- No Coulomb barrier
- Stochastic process
- Characterise interaction probability by the microscopic cross-section, σ
  - Units of barns, 1 b = 10^{-24} cm^2
- σ is dependent on energy and interaction type

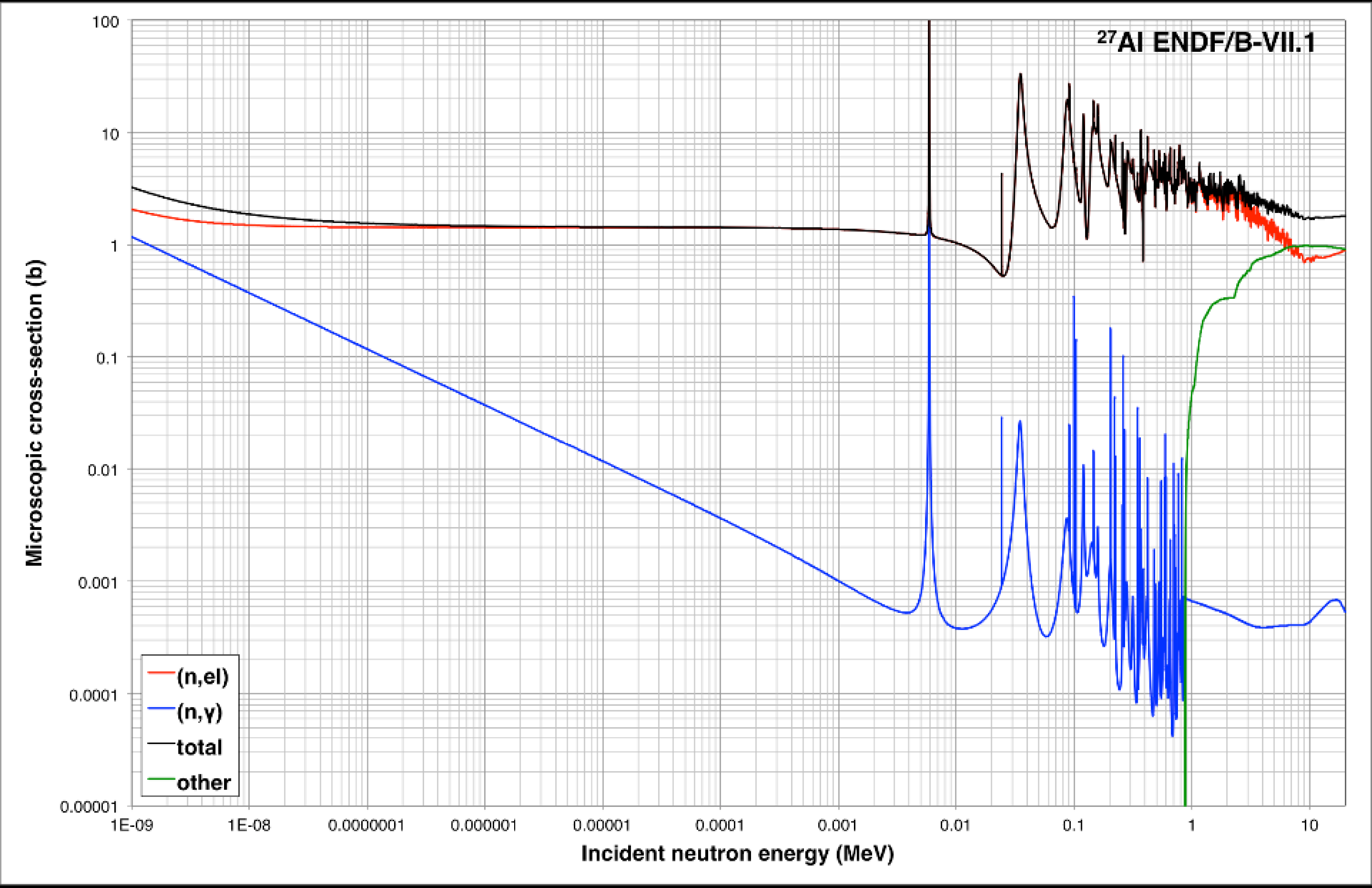


Notation for nuclear reactions:
$^{x}A(a,b)^{y}B$

^{x}A: target nucleus
a: incoming projectile
b: ejected particle
^{y}B: product nucleus



^{27}Al (n,total)
Microscopic cross-section (b)
1000
100
10
1
0.1
0.01
1E-09
1E-08
0.0000001
0.000001
0.00001
0.0001
0.001
0.01
0.1
1
10
Incident neutron energy (MeV)



^{27}Al ENDF/B-VII.1
Microscopic cross-section (b)
Incident neutron energy (MeV)
100
10
1
0.1
0.01
0.001
0.0001
0.00001
1E-09
1E-08
0.0000001
0.000001
0.00001
0.0001
0.001
0.01
0.1
1
10
(n,el)
(n,γ)
total
other

Using the water of the goldfish fountain of his Institute, Enrico Fermi established for the first time, in the afternoon of 22 October 1934, the crucial role of hydrogenous substances on neutron induced radioactivity, thus opening the way to the use of slow neutrons in nuclear fission chain reactions.

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Physics in Perspective

Check for updates

Enrico Fermi's Discovery of Neutron-Induced Artificial Radioactivity: A Case of "Emanation" from "Divine Providence"

Francesco Guerra, Matteo Leone and Nadia Robotti*

https://www.eps.org/page/distinction_sitesFF

Enrico Fermi
Facts

Photo from the Nobel Foundation archive.

Enrico Fermi
The Nobel Prize in Physics 1938

Born: 29 September 1901, Rome, Italy

Died: 28 November 1954, Chicago, IL, USA

Affiliation at the time of the award: Rome University, Rome, Italy

Prize motivation: "for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons"

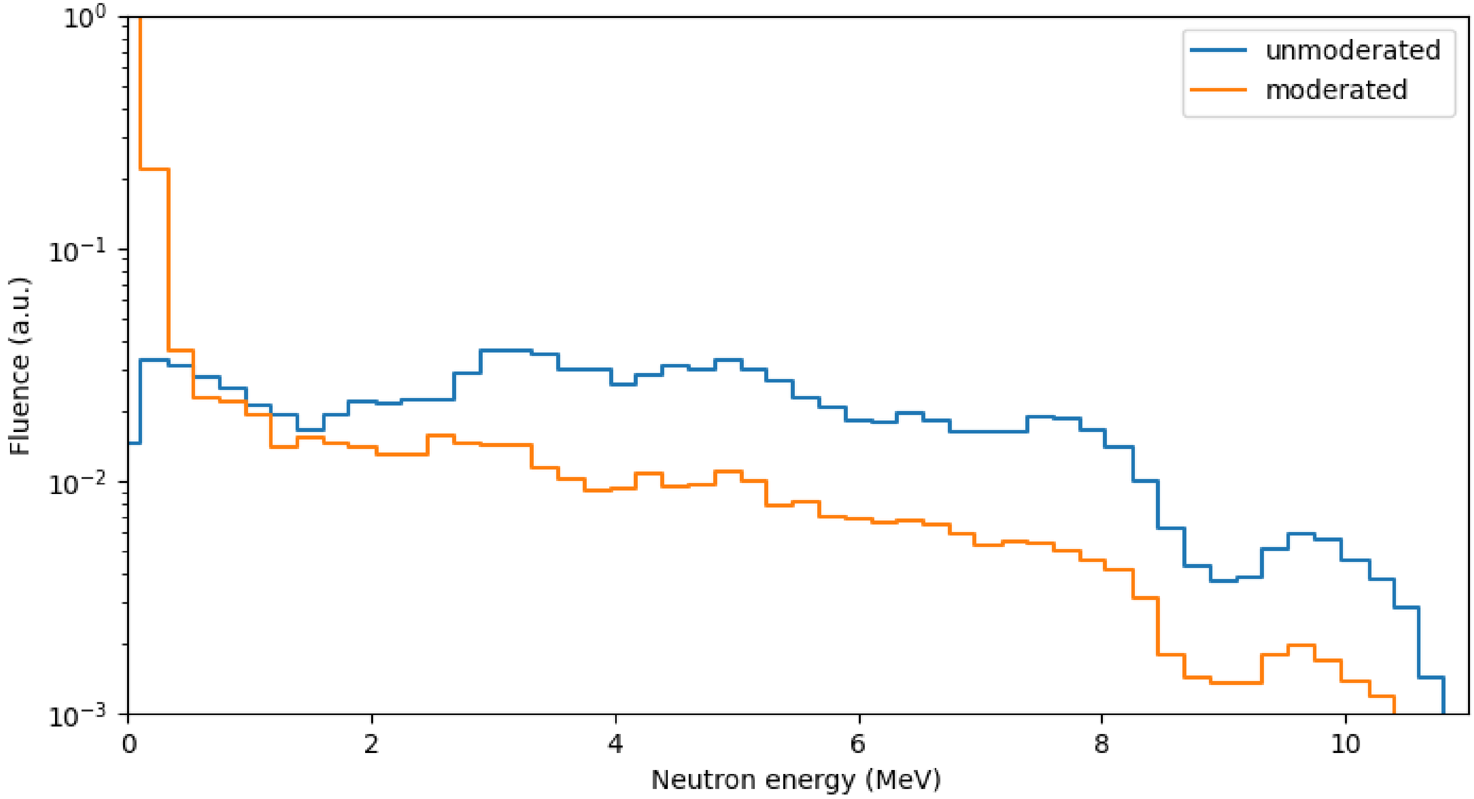
Prize share: 1/1

Enrico Fermi – Facts. NobelPrize.org. Nobel Prize Outreach AB 2023. Mon. 24 Jul 2023.

How do we slow down neutrons?

- The process of slowing down neutrons is called moderation
- To slow down, energy must be removed
- Classical/Newtonian kinematics
  - Elastic scatter
  - Conserve energy and momentum

$$E' = E\left(\frac{A-1}{A+1}\right)^2$$

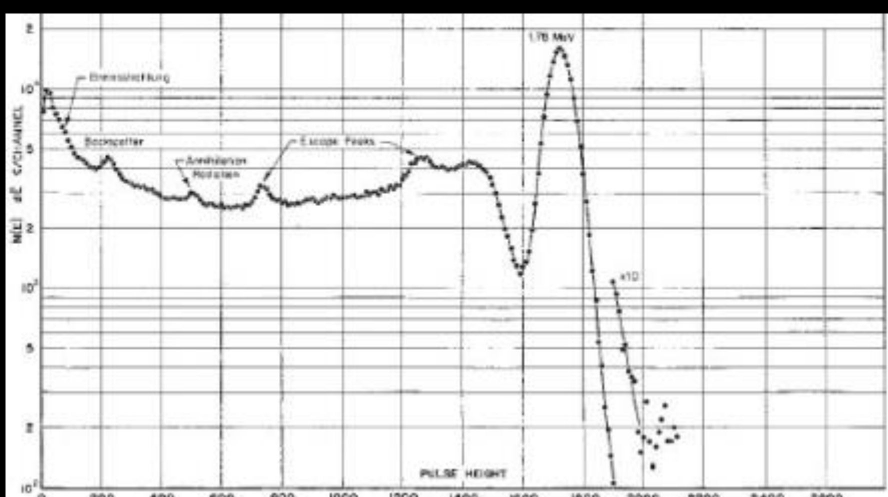


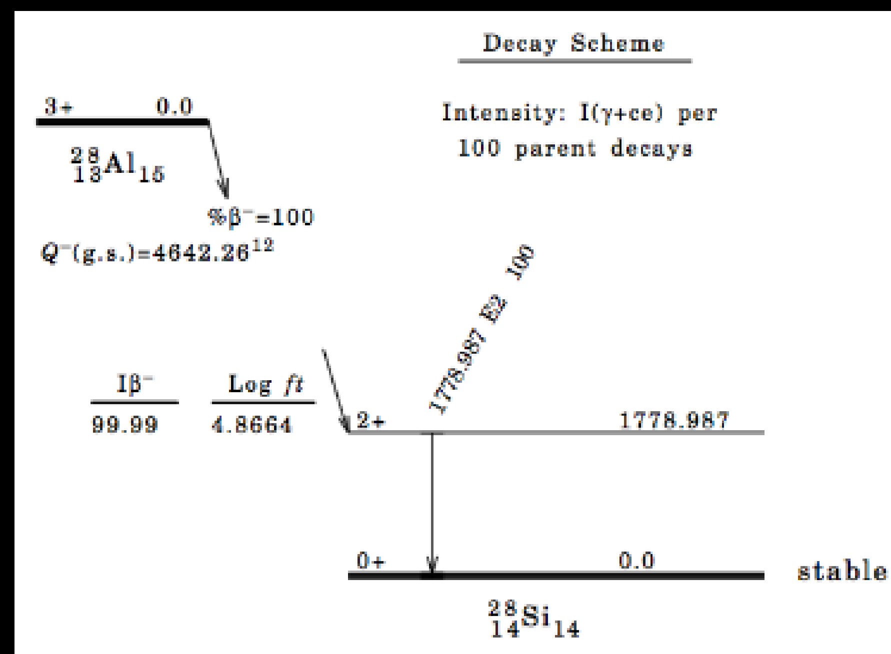
unmoderated
moderated
Fluence (a.u.)
Neutron energy (MeV)
10^0
10^{-1}
10^{-2}
10^{-3}
0
2
4
6
8
10

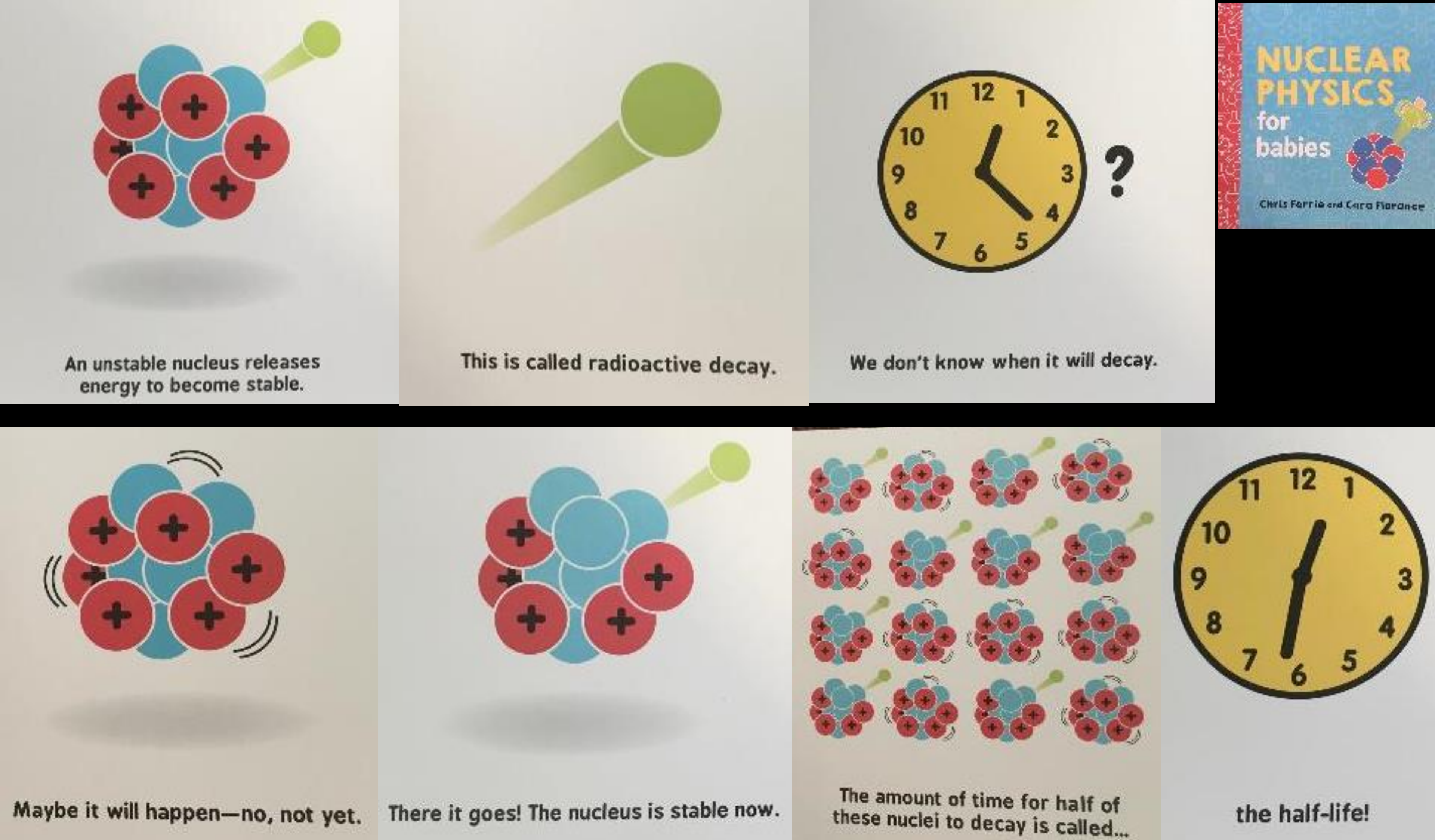
Production and decay of ^{28}Al

$$^{27}\mathrm{Al} + \mathrm{n} \rightarrow {}^{28}\mathrm{Al}^{*} \rightarrow {}^{28}\mathrm{Al} + \gamma$$

$$^{28}\mathrm{Al} \rightarrow {}^{28}\mathrm{Si} + \beta^{-} + \gamma + \bar{\nu}_e$$







$$\frac{dN}{dt} = -\lambda N \qquad N(t) = N_0 \exp -\lambda t \qquad t_{1/2} = \frac{\ln 2}{\lambda}$$