Experimental neutron capture data of ^{58}Ni from the CERN n_TOF facility

Petar Žugec
Department of Physics, Faculty of Science, University of Zagreb

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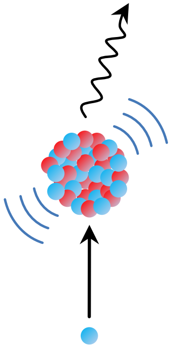
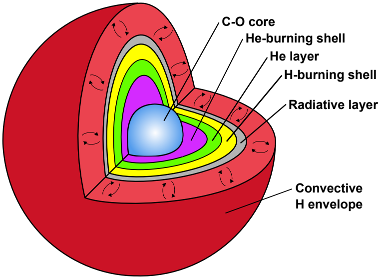
Overview

- Motivation
- n_TOF facility
- Measurements and simulations
- Final results

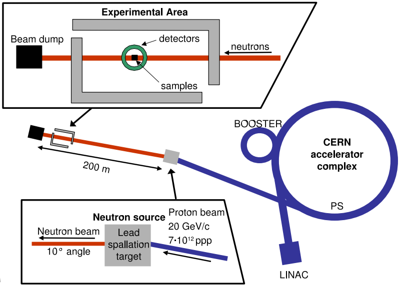


Motivation

- fundamental research in nuclear physics
- astrophysical implications
  - modeling the stellar nucleosynthesis (*s*-process)
- technological concerns
  - ^{58}Ni as a constituent material in nuclear technologies



n_TOF facility: neutron production



Spallation target:

- Pb block (1.3 t)

Proton source:

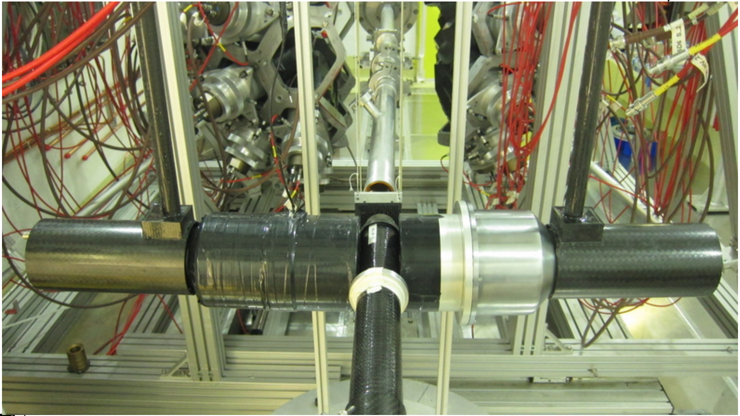
- PS (Proton Synchrotron) accelerator
- proton energy: 20 GeV
- pulse mode: $\Delta t = n \cdot (1.2\,\mathrm{s})$
- $7 \cdot 10^{12}$ protons per pulse
- every proton → 300 neutrons

Moderation:

- Pb block + layer of (borated) water
- E_n = 10 meV – 10 GeV

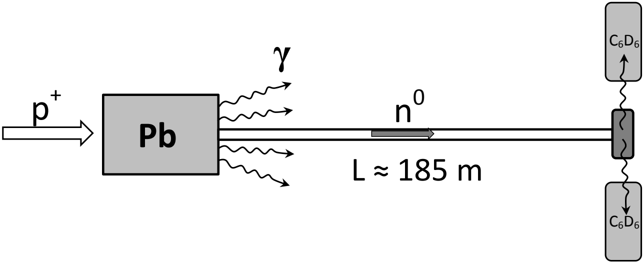
C. Guerrero et al., Eur. Phys. J. A 49, 27 (2013)

C_6D_6 detectors



R. Plag et al., Nucl. Instrum. Methods A 496, 425 (2003)

Time of flight technique



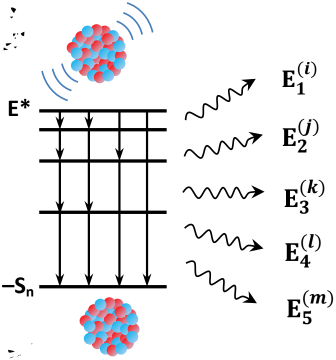
$$E_n = m_n c^2 \left(\frac{1}{\sqrt{1 - \left(\frac{L}{c\Delta t}\right)^2}} - 1 \right)$$

Goals and challenges

Goals:
- to calculate the capture yield
- to extract the cross section

Challenges:
- detection efficiency
- scattered neutrons

Detection efficiency



Efficiency for detecting a cascade C by a detector of **low** detection efficiency:

$$\varepsilon_\mathrm{C} \approx \sum_i \varepsilon_i^{(\mathrm{C})}$$

If $\varepsilon_i^{(\mathrm{C})} \propto E_i^{(\mathrm{C})}$ then:

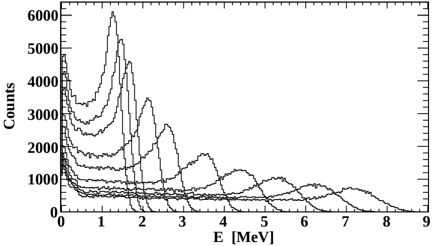
$$\varepsilon_\mathrm{C} \propto \sum_i E_i^{(\mathrm{C})} = E_\mathrm{tot}$$

where:

$$E_\mathrm{tot} = S_n + E^* \neq f(\mathrm{C})$$

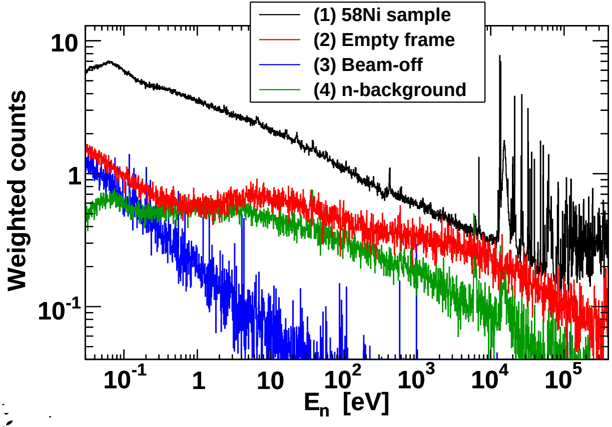
Pulse height weighting technique

$$\boldsymbol{W(E)} \quad \Rightarrow \quad \boldsymbol{\varepsilon_i^{(\mathrm{K})} = \alpha E_i^{(\mathrm{K})}}$$

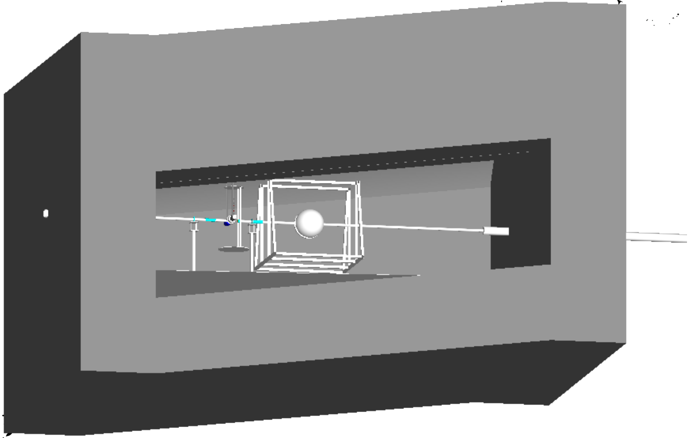


$$\sum_j \left[\int W(E') R(j;E') \mathrm{d}E' - \alpha E_\gamma(j) \right]^2 = \mathrm{min.}$$

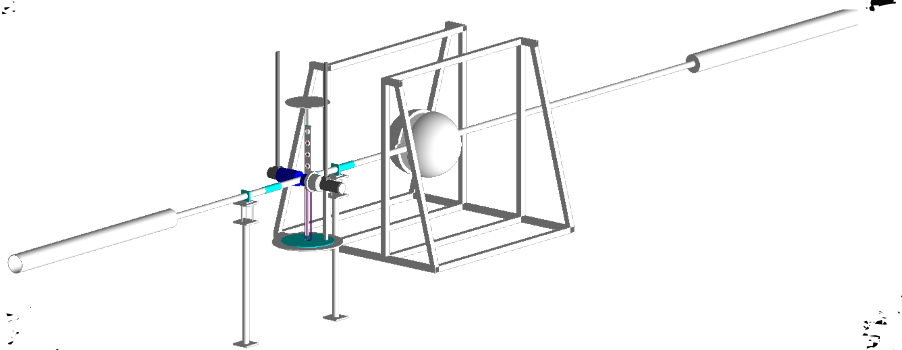
Weighted counts



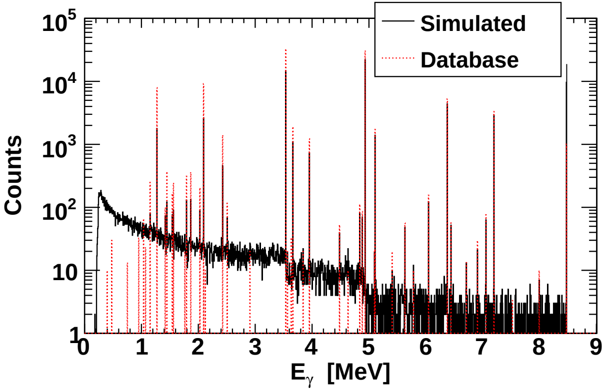
GEANT4 simulation of the neutron background



GEANT4 simulation of the neutron background

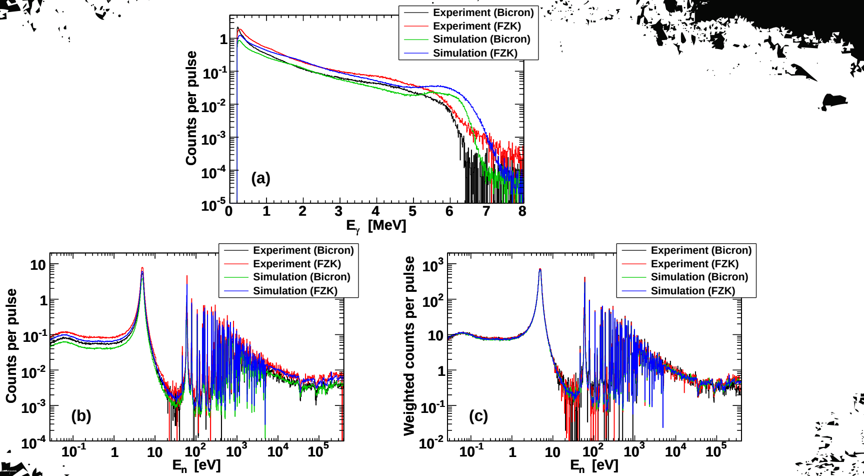


γ-ray cascades (example: ^{28}Si)



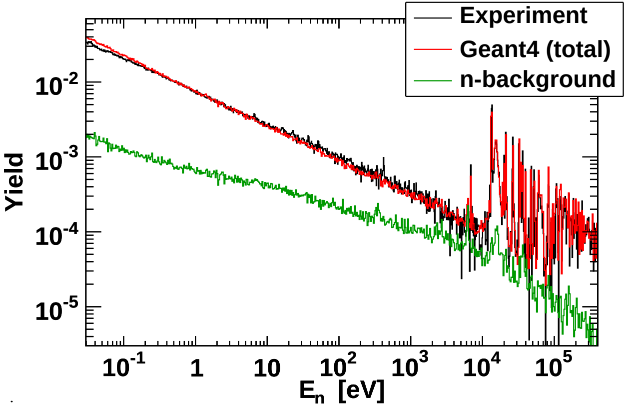
P. Žugec et al., Nucl. Instrum. Methods A 760, 57 (2014)

γ-ray cascades (^{197}Au case)



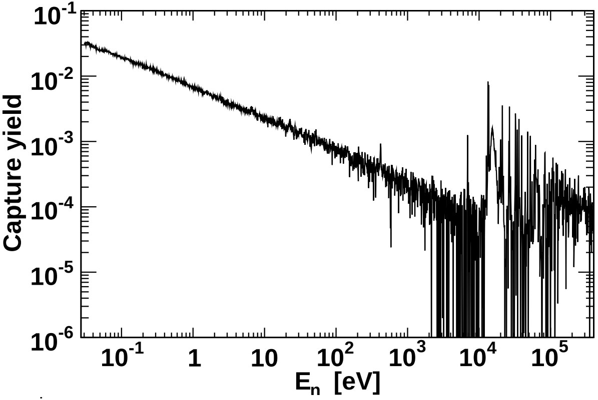
P. Žugec et al., Nucl. Instrum. Methods A 760, 57 (2014)

Experiment vs. simulation

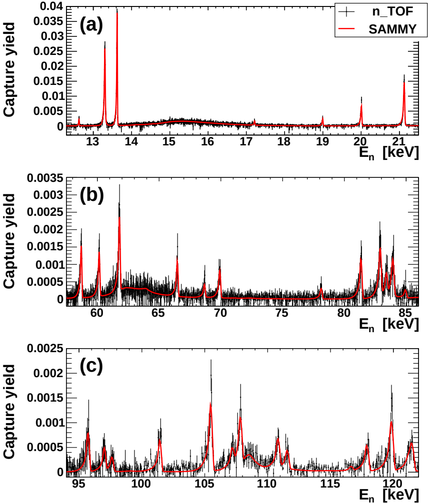


P. Žugec et al., Nucl. Instrum. Methods A 760, 57 (2014)

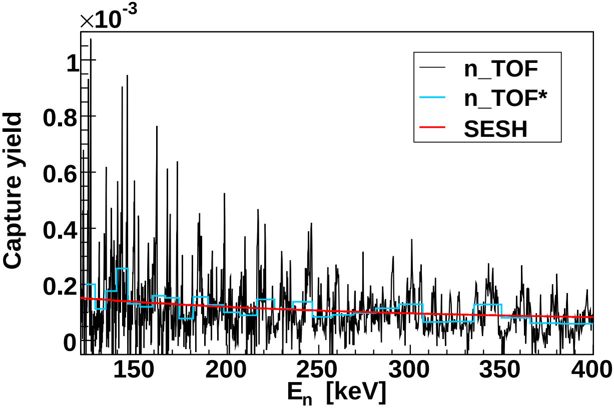
^{58}Ni capture yield



Resolved resonance region (<122 keV; SAMMY)

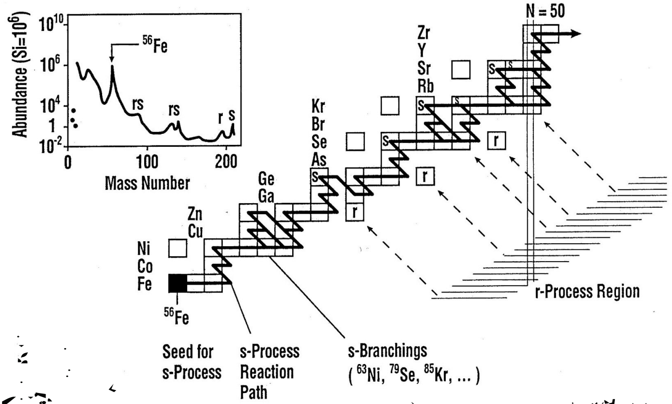


Unresolved resonance region (>122 keV; SESH)



Maxwellian averaged cross sections (MACS)

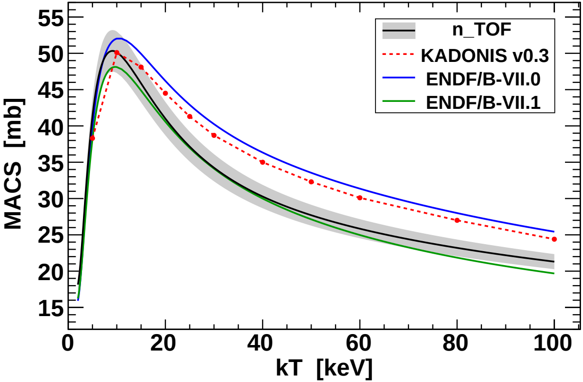
$$\langle\sigma\rangle_{kT} = \frac{2}{\sqrt{\pi}} \cdot \frac{1}{(kT)^2} \int_0^\infty \sigma(E_n) E_n e^{-E_n/kT} \mathrm{d}E_n$$



Maxwellian averaged cross sections (MACS)

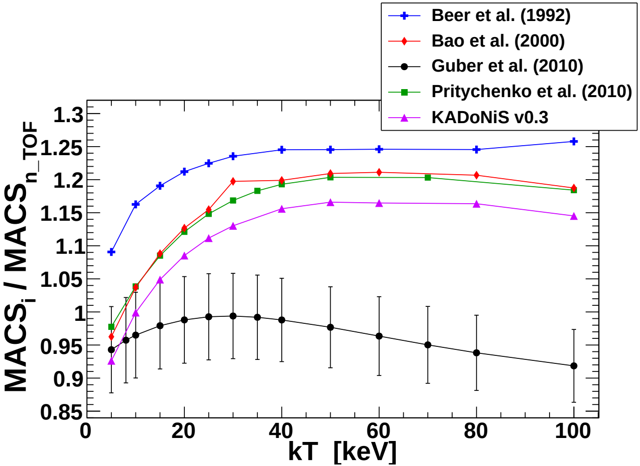
12% lower MACS at 30 keV

60% more ^{58}Ni in 25$M_\odot$ stars



P. Žugec et al., Phys. Rev. C 89, 014605 (2014)

Maxwellian averaged cross sections (MACS)



P. Žugec et al., Phys. Rev. C 89, 014605 (2014)

Thank you for listening!