Experimental Astrophysics

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

INTC-P-381

Neutron capture cross sections of ^{70,72,73,74,76}Ge at n_TOF EAR-1

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23rd October 2013

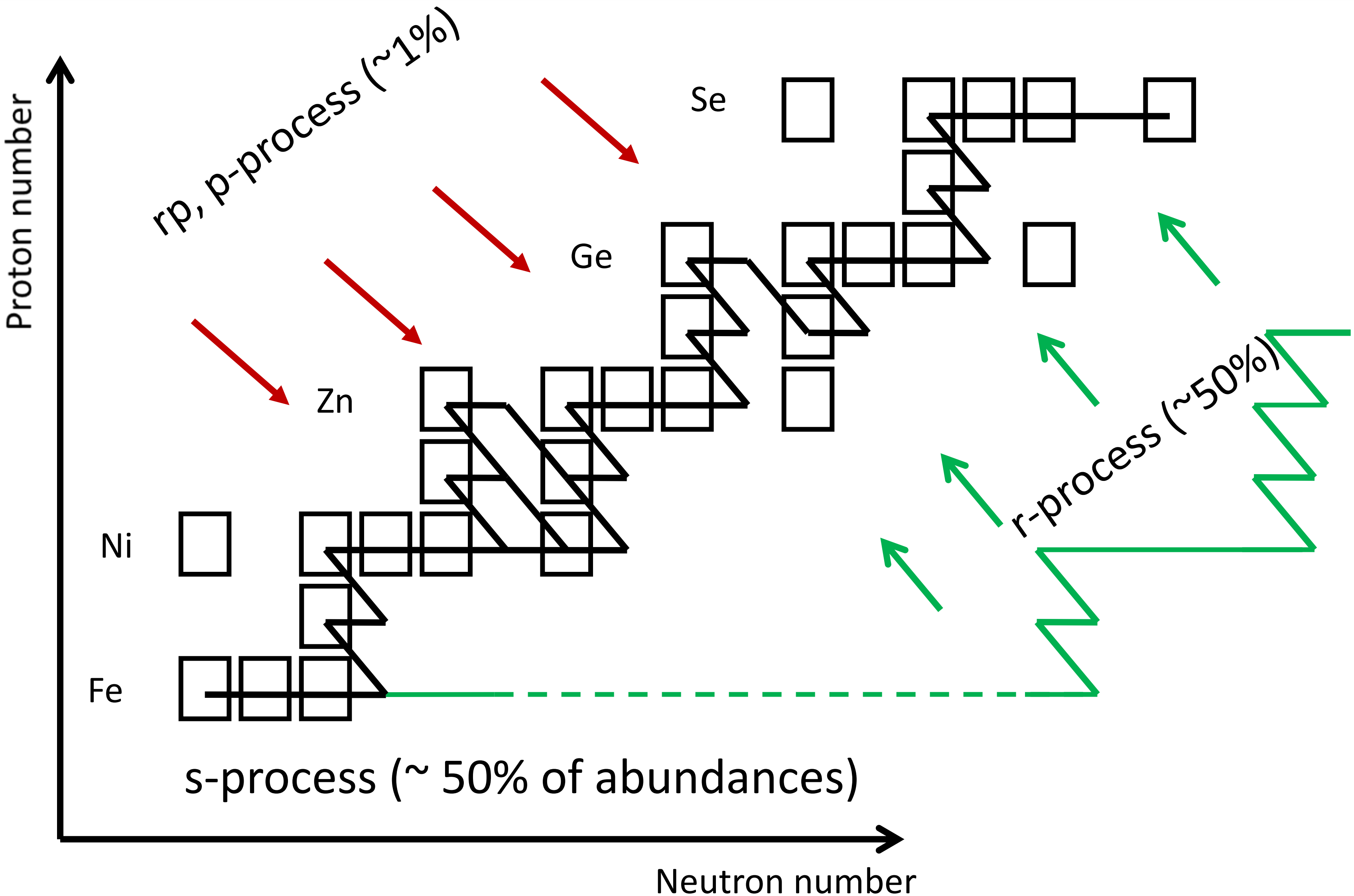
INTC Meeting,CERN

Adolf Messer Stiftung

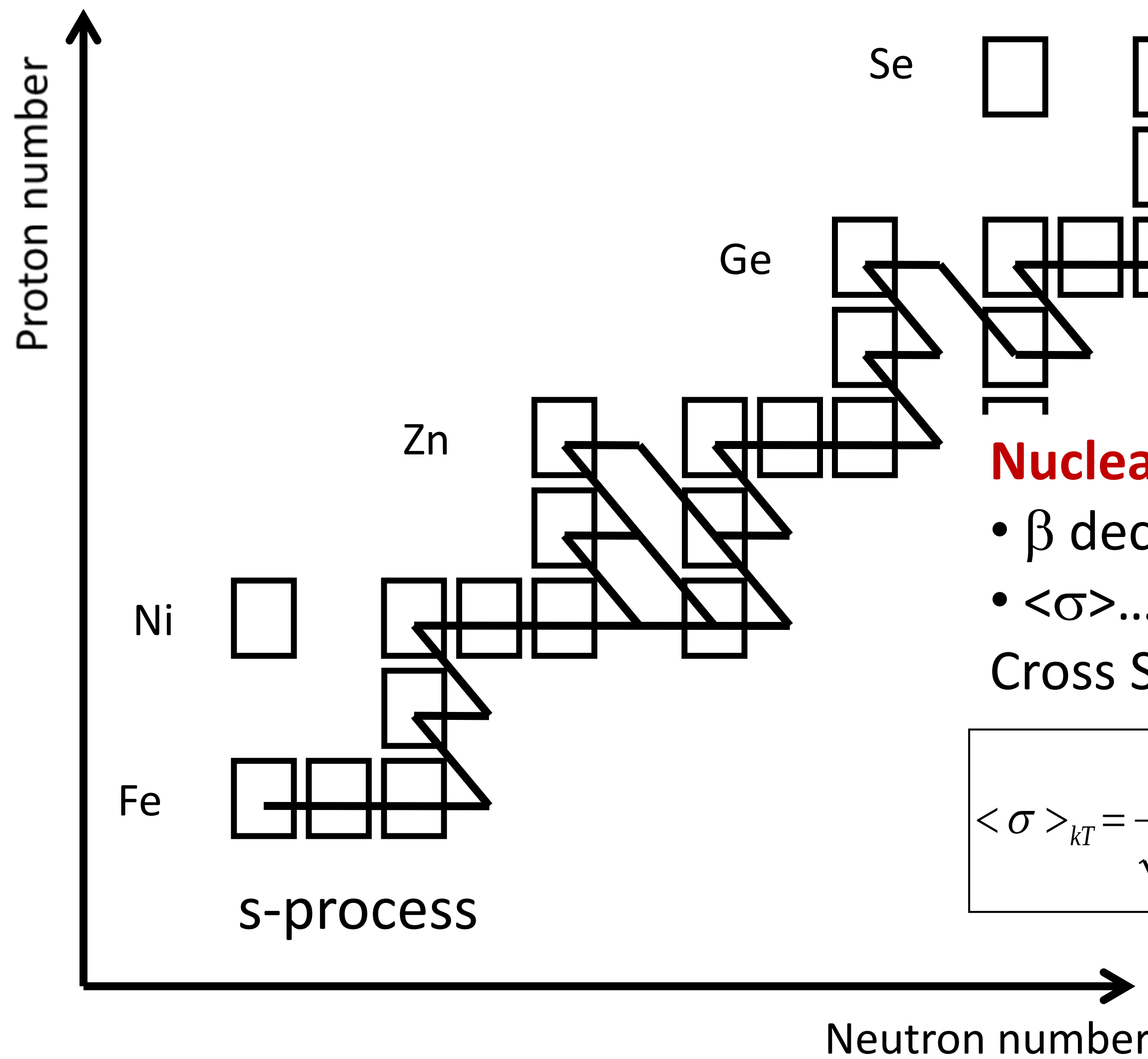
n_TOF

Bundesministerium für Bildung und Forschung

Nucleosynthesis above Fe



s process

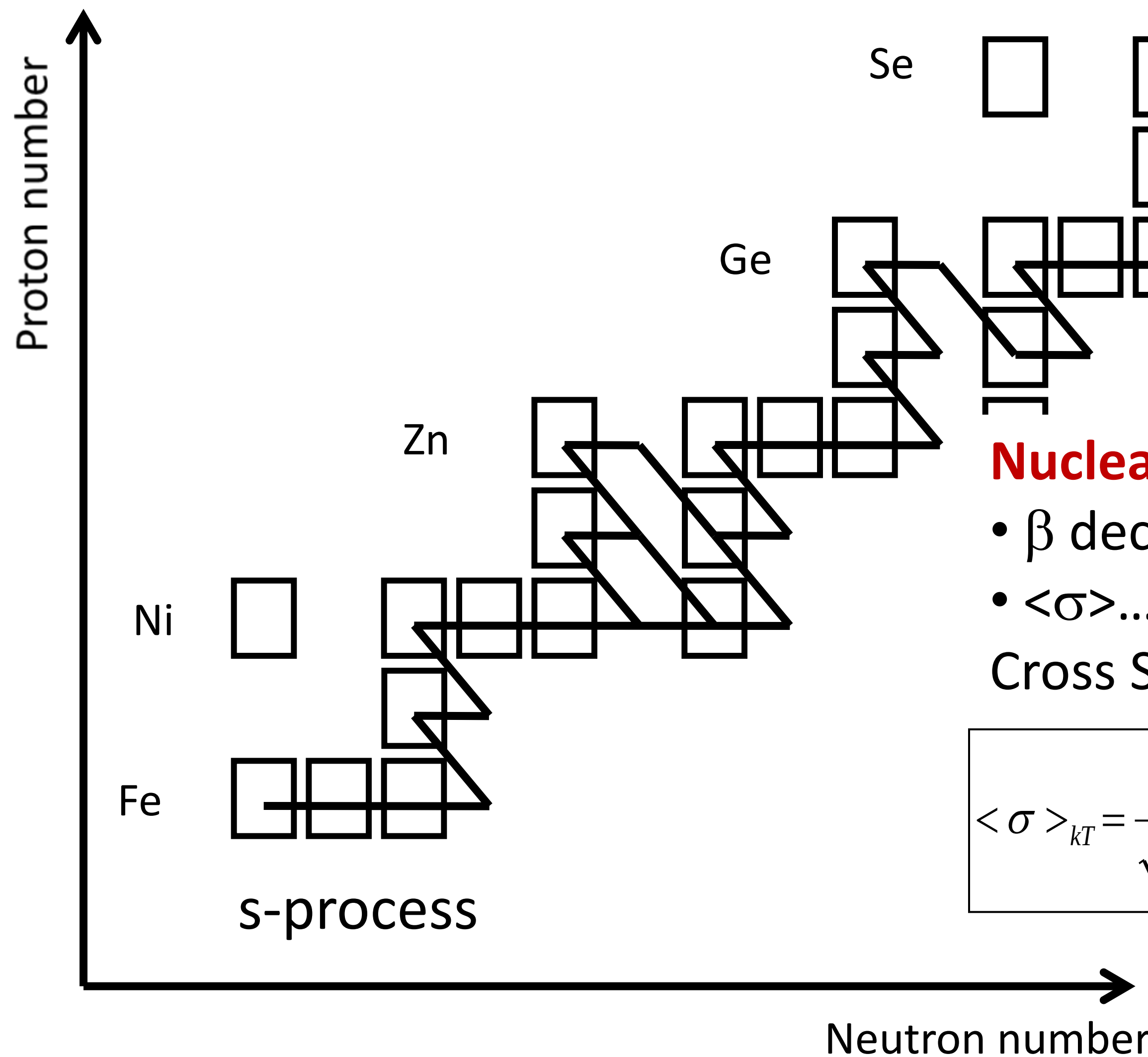


Nuclear Physics Input:

- β decay half lives
- <σ>…. Maxwellian Averaged Cross Section MACS

$$<\sigma>_{kT} = \frac{2}{\sqrt{\pi}} \frac{\int \sigma(E_n) E_n \exp(-E_n / kT) dE_n}{\int E_n \exp(-E_n / kT) dE_n}$$

s process



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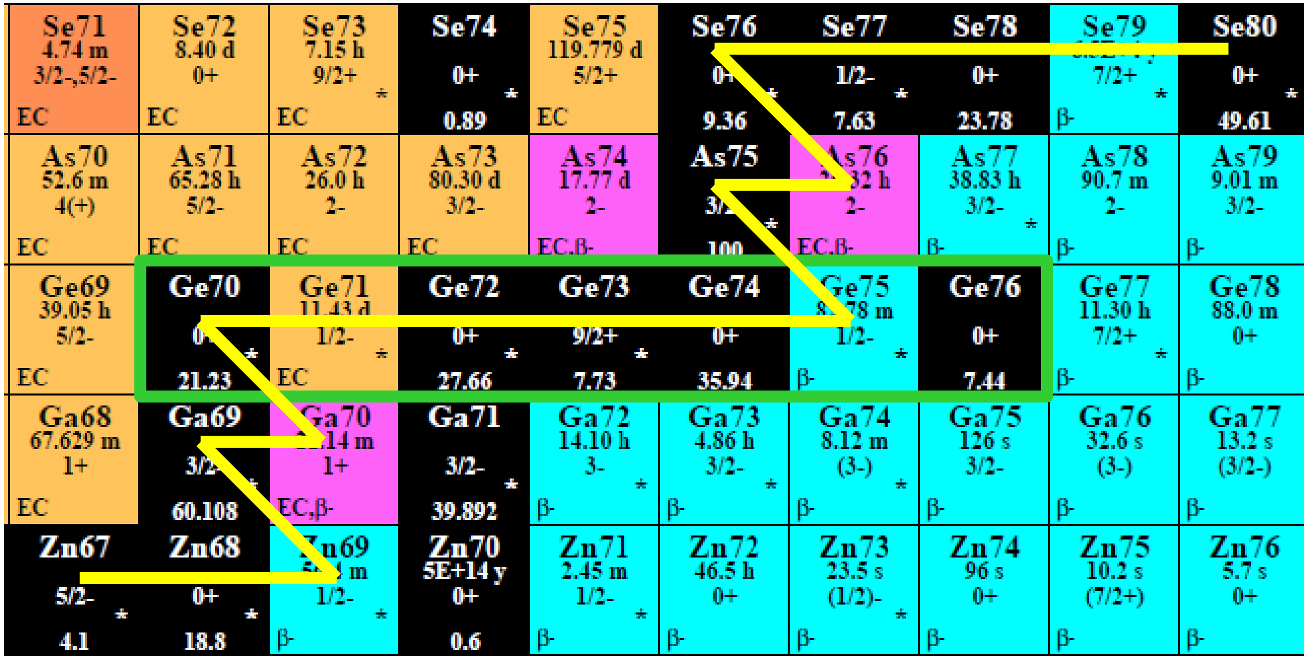
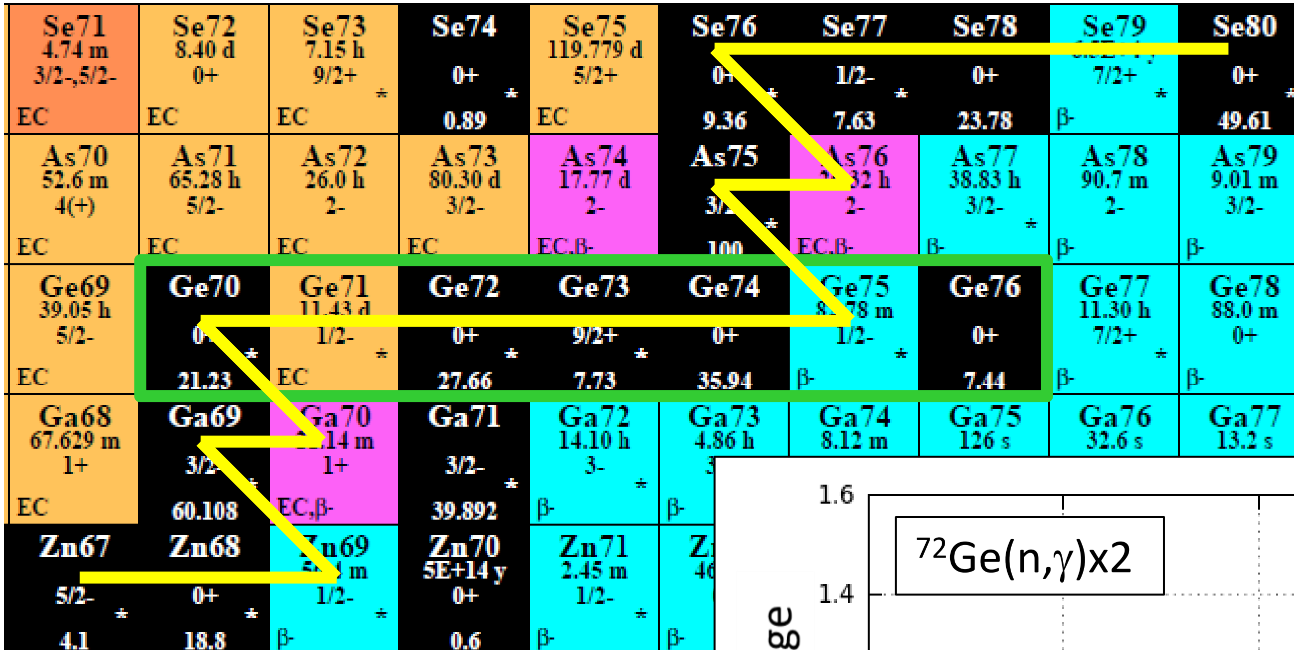
kT=8 – 90 keV

s process


Se71 4.74 m 3/2-,5/2- EC
Se72 8.40 d 0+ EC
Se73 7.15 h 9/2+ EC
Se74 0+ 0.89
Se75 119.779 d 5/2+ EC
Se76 9.36
Se77 1/2- 7.63
Se78 0+ 23.78
Se79 7/2+ β-
Se80 0+ 49.61
As70 52.6 m 4(+) EC
As71 65.28 h 5/2- EC
As72 26.0 h 2- EC
As73 80.30 d 3/2- EC
As74 17.77 d 2- EC,β-
As75 100
2- EC,β-
As77 38.83 h 3/2- β-
As78 90.7 m 2- β-
As79 9.01 m 3/2- β-
Ge69 39.05 h 5/2- EC
Ge70 21.23
Ge71 1/2- EC
Ge72 0+ 27.66
Ge73 9/2+ 7.73
Ge74 0+ 35.94
1/2- β-
Ge76 0+ 7.44
Ge77 11.30 h 7/2+ β-
Ge78 88.0 m 0+ β-
Ga68 67.629 m 1+ EC
Ga69 60.108
1+ EC,β-
Ga71 3/2- 39.892
Ga72 14.10 h 3- β-
Ga73 4.86 h 3/2- β-
Ga74 8.12 m (3-) β-
Ga75 126 s 3/2- β-
Ga76 32.6 s (3-) β-
Ga77 13.2 s (3/2-) β-
Zn67 5/2- 4.1
Zn68 0+ 18.8
1/2- β-
Zn70 5E+14 y 0+ 0.6
Zn71 2.45 m 1/2- β-
Zn72 46.5 h 0+ β-
Zn73 23.5 s (1/2)- β-
Zn74 96 s 0+ β-
Zn75 10.2 s (7/2+) β-
Zn76 5.7 s 0+ β-

s process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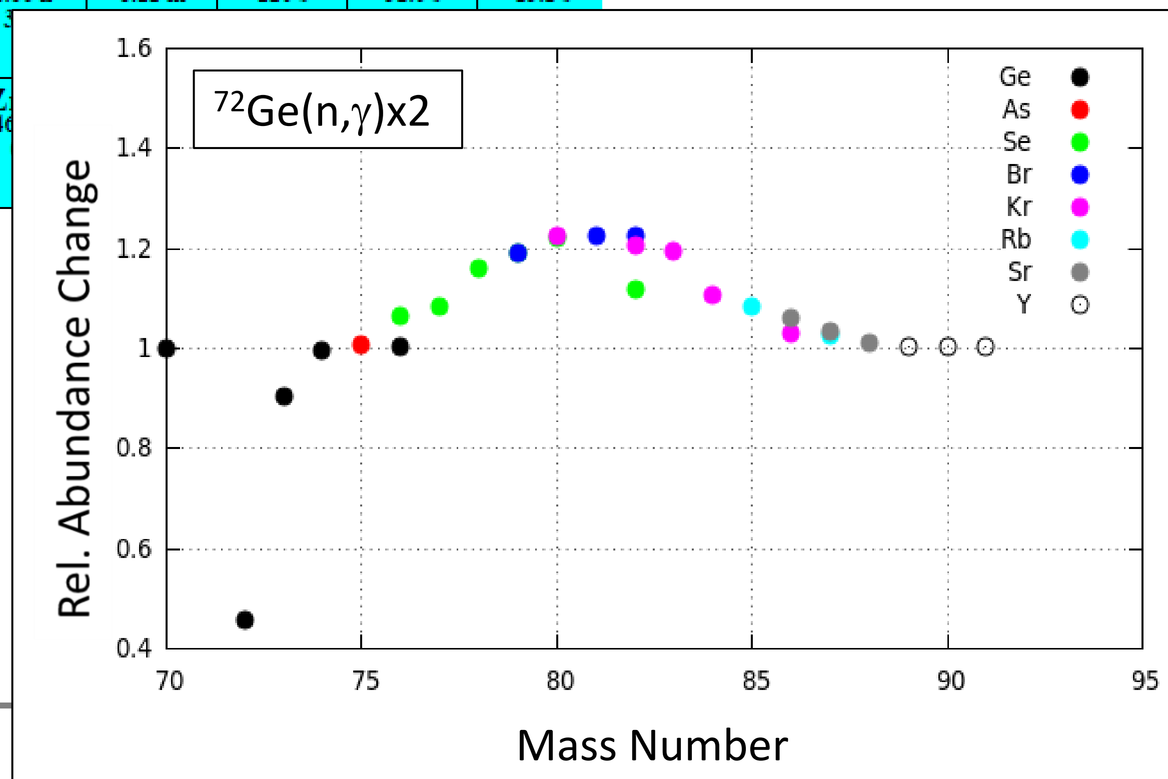
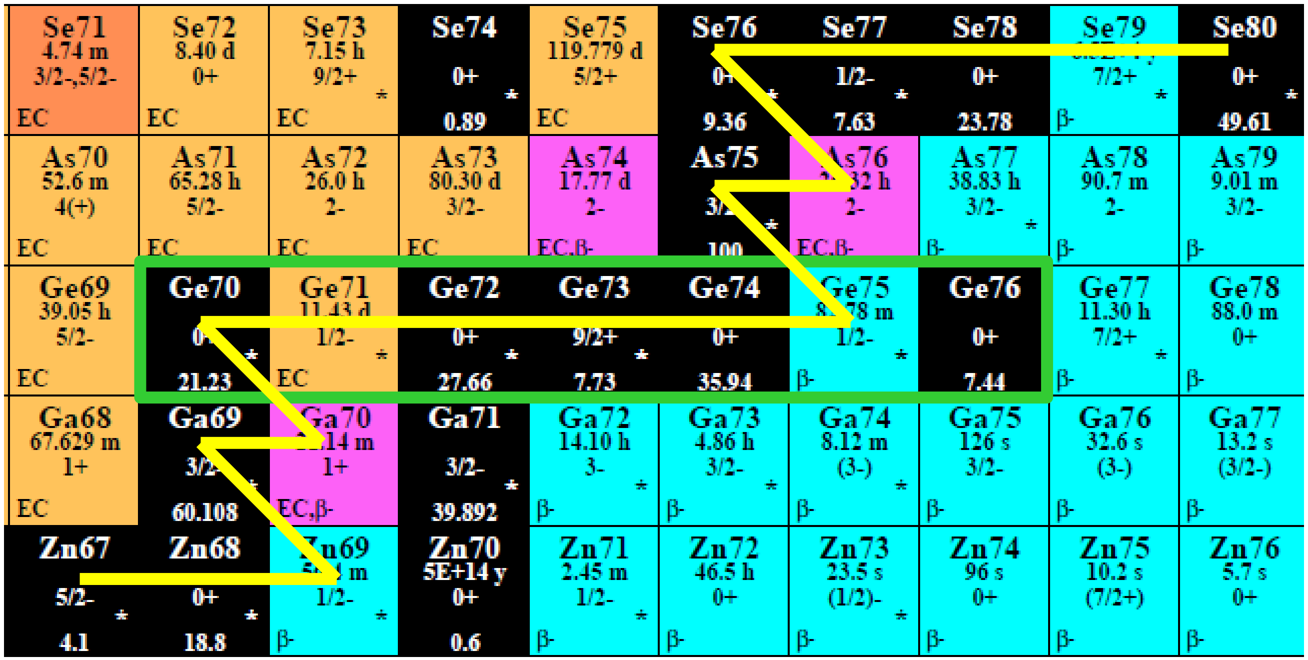

^{72}Ge(n,γ)x2
Rel. Abundance Change
Mass Number
Ge
As
Se
Br
Kr
Rb
Sr
Y
0.4
0.6
0.8
1
1.2
1.4
1.6
70
75
80
85
90
95

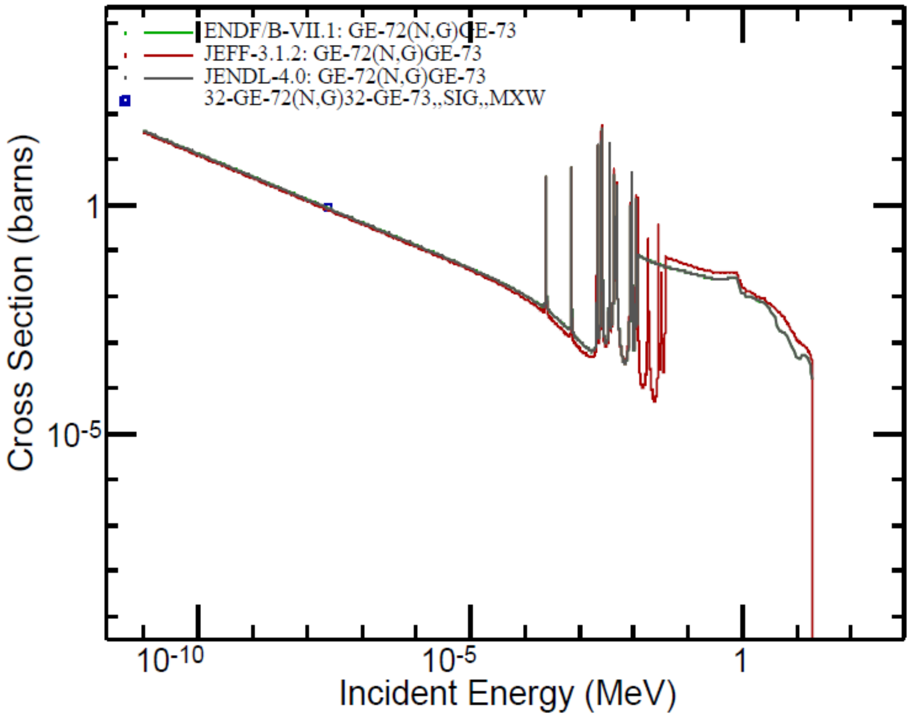
Motivation



Neutron capture cross sections of Ge crucial for

- understanding elemental abundances from Ge to Sr
- Low background experiments:
  - GERDA (neutrinoless double β decay of ^{76}Ge)
  - Dark matter experiments, e.g. CDMS-II (Ge detectors)

Available Data



Good et al (1966):

Γ_n for E_n<40 keV

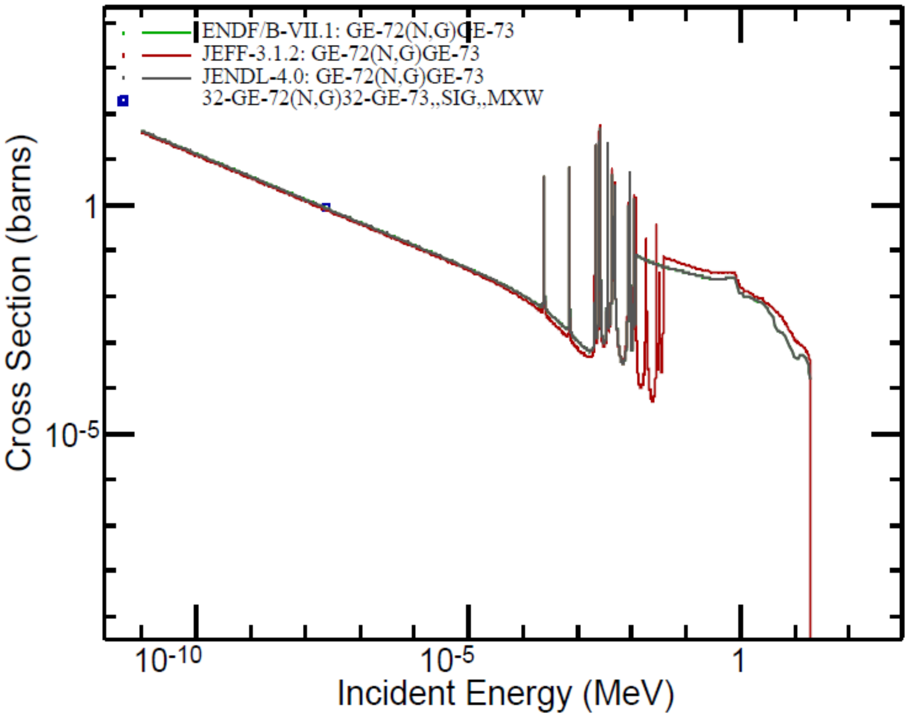
Maletski et al (1968):

Γ_n for E_n<30 keV

Γ_γ for E_n<4 keV

^{72}Ge(n,γ)

Available Data



Good et al (1966):
Γ_n for E_n<40 keV

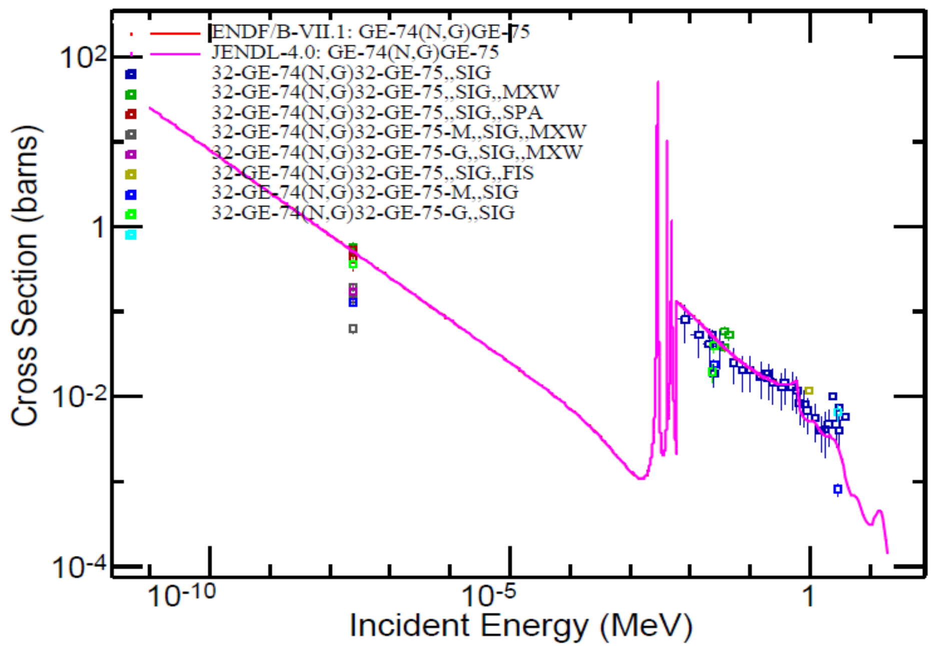
Maletski et al (1968):
Γ_n for E_n<30 keV
Γ_γ for E_n<4 keV

^{72}Ge(n,γ)

^{74}Ge(n,γ)

Good et al (1966):
Γ_n for E_n<22 keV

Maletski et al (1968):
Γ_n for E_n<60 keV
Γ_γ for E_n<3 keV



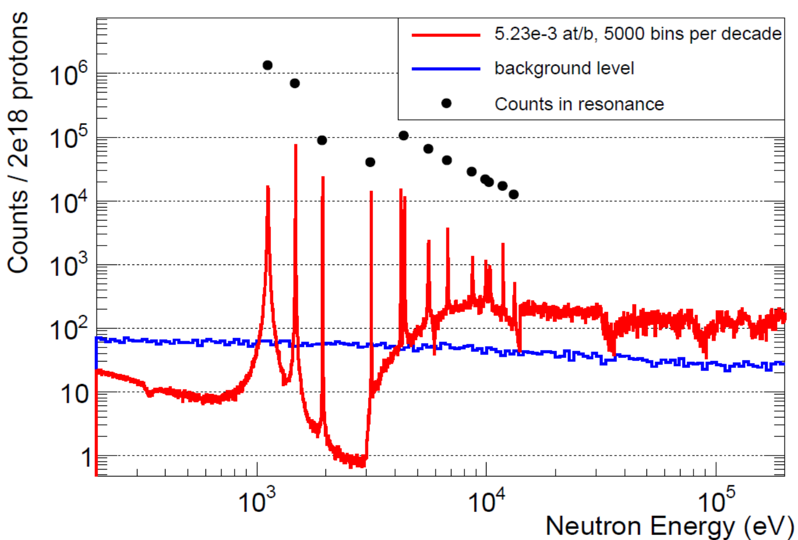
Experimental Setup

- n_TOF EAR-1 – high neutron energy resolution, high neutron flux
- C_6D_6 Detection system – low neutron sensitivity
- Samples: enriched GeO_2 pellets from ISOFLEX prepared at PSI, cylindrical form, 2 cm diameter

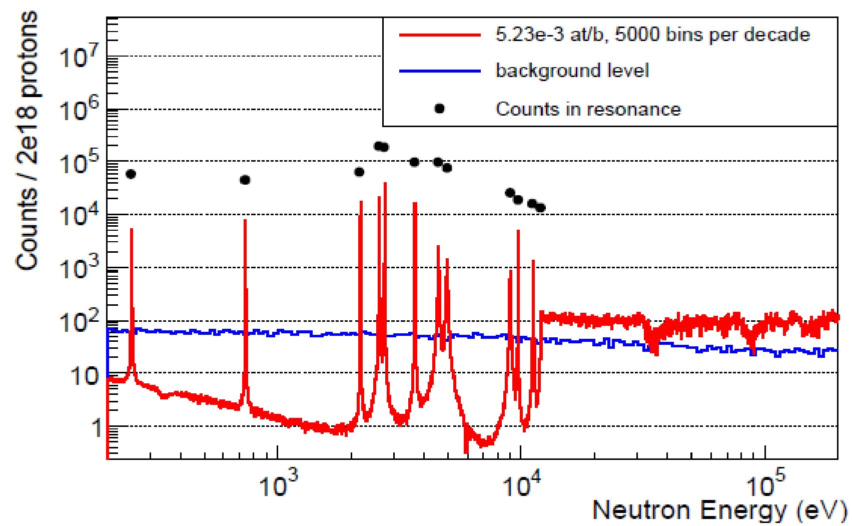
Sample	Mass (g)	Purity (%)	Thickness (at/b)
^{70}Ge	2	95.3	5.23×10^{-3}
^{72}Ge	2	98.2	5.23×10^{-3}
^{73}Ge	2	95.5	5.02×10^{-3}
^{74}Ge	2	99.8	5.18×10^{-3}
^{76}Ge	2	99.9	5.04×10^{-3}
^{nat}Ge	2		5.1×10^{-3}
Au			
C			
Empty Frame			

Countrate Estimate

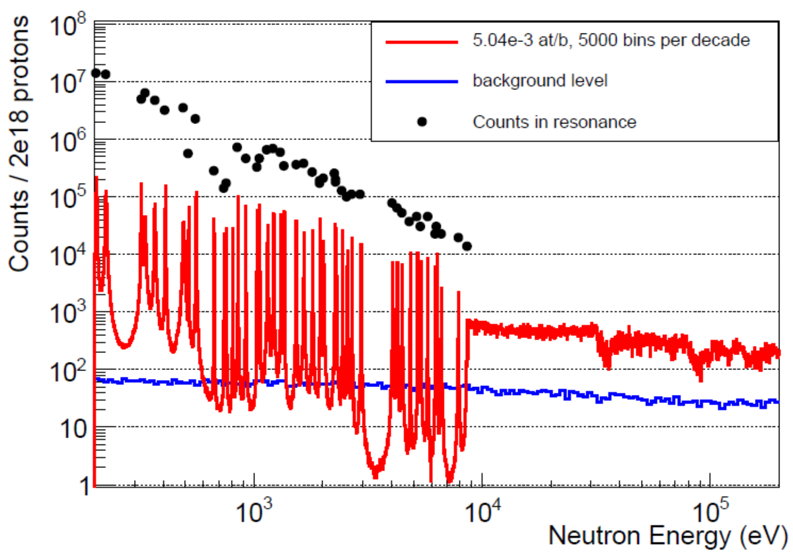
^{70}Ge



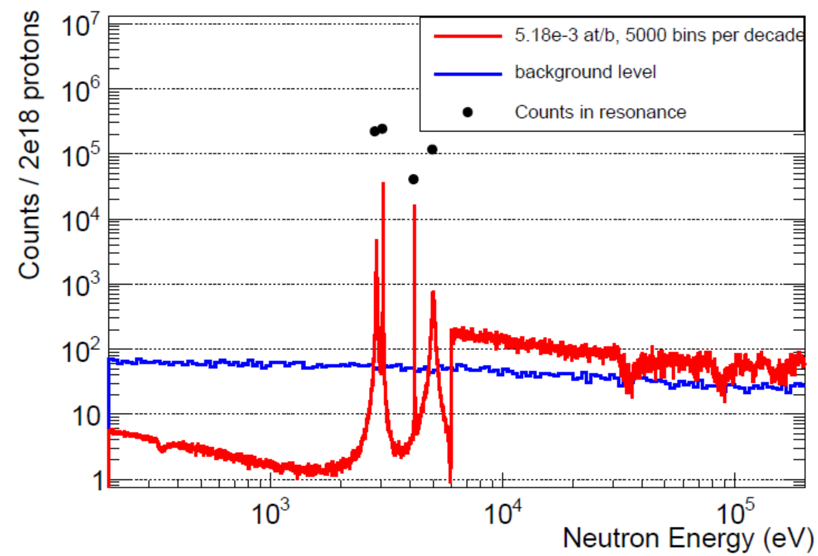
^{72}Ge



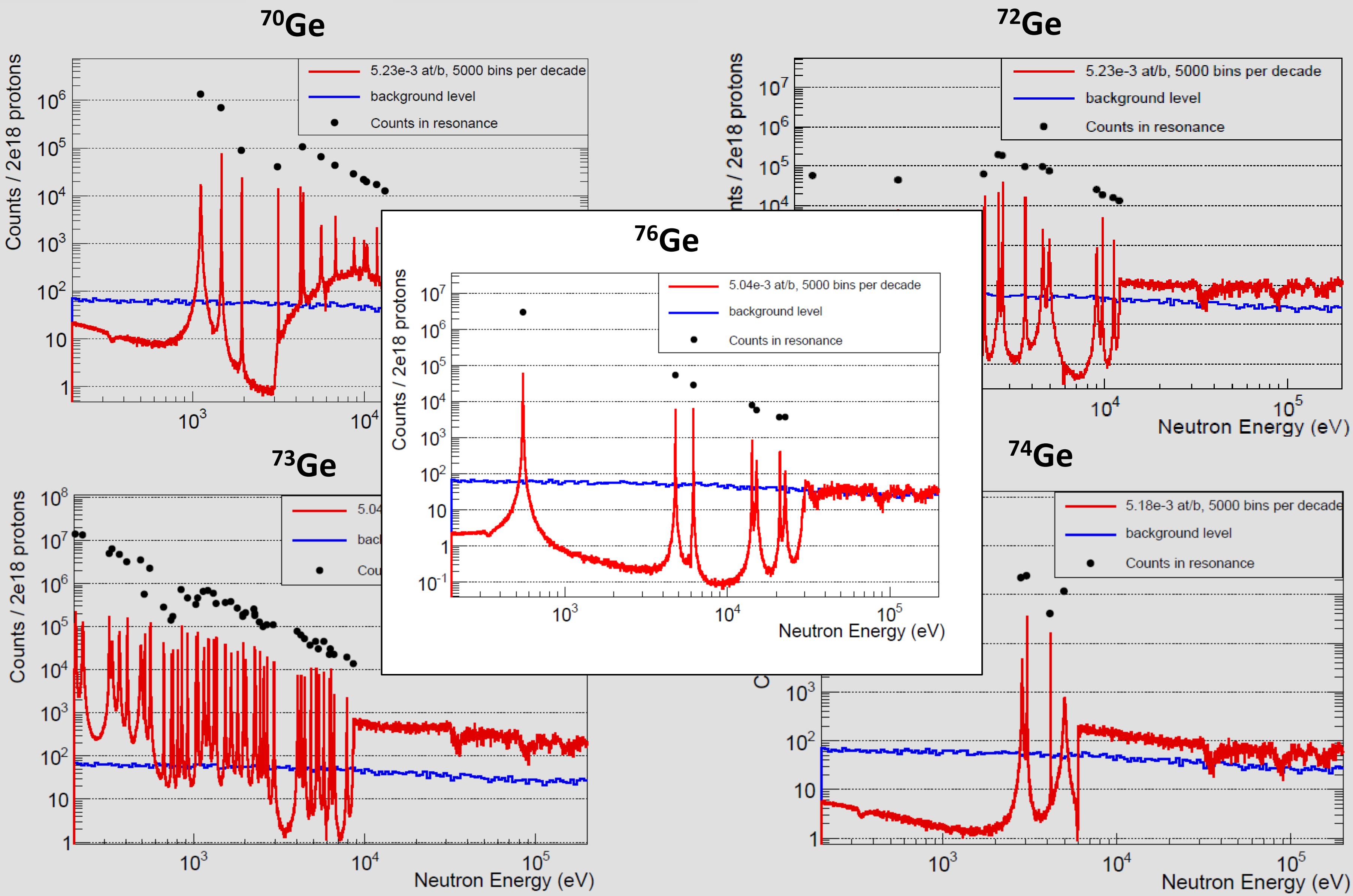
^{73}Ge



^{74}Ge



Countrate Estimate



Beam Time Request

- n_TOF EAR-1 – high neutron energy resolution, high neutron flux
- C_6D_6 Detection system – low neutron sensitivity
- Samples: enriched GeO_2 pellets from ISOFLEX prepared at PSI, cylindrical form, 2 cm diameter

Sample	Mass (g)	Purity (%)	Thickness (at/b)	No. of Protons ($\times 10^{18}$)
^{70}Ge	2	95.3	5.23×10^{-3}	2.0
^{72}Ge	2	98.2	5.23×10^{-3}	2.0
^{73}Ge	2	95.5	5.02×10^{-3}	2.0
^{74}Ge	2	99.8	5.18×10^{-3}	2.0
^{76}Ge	2	99.9	5.04×10^{-3}	2.0
^{nat}Ge	2		5.1×10^{-3}	0.5
Au				0.4
C				0.1
Empty Frame				1.0
Total				**12.0**

Summary

- (n,γ) cross sections on Ge isotopes are crucial for understanding s process nucleosynthesis and are important for estimating backgrounds in dark matter and double β decay experiments
- Few experimental data on Ge in the keV neutron energy region

Goal:

- measure cross section and analyze resonances from thermal up to about 200 keV
- MACSs from 10-100 keV with uncertainties <5%

Measurement:

- enriched GeO_2 samples of 2 g
- Measurement at n_TOF EAR-1 - high neutron energy resolution, high neutron flux
- C_6D_6 capture setup - low neutron sensitivity

- **12×10^{18}** protons on target, split over 2 experimental campaigns

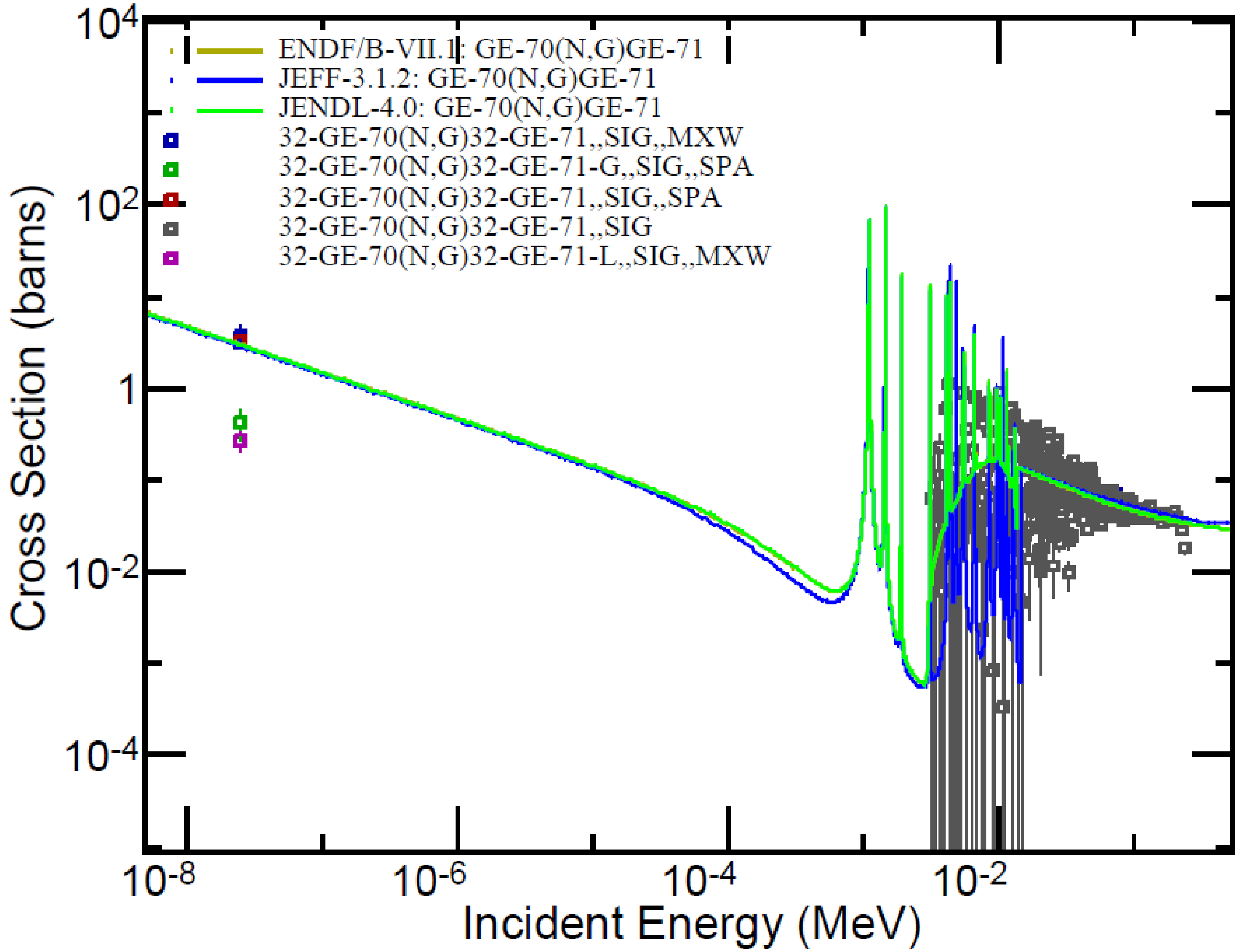
Additional Slides

Experimental Data

^{70}Ge(n,γ)

Good et al (1966):
Γ_n for E_n<40 keV

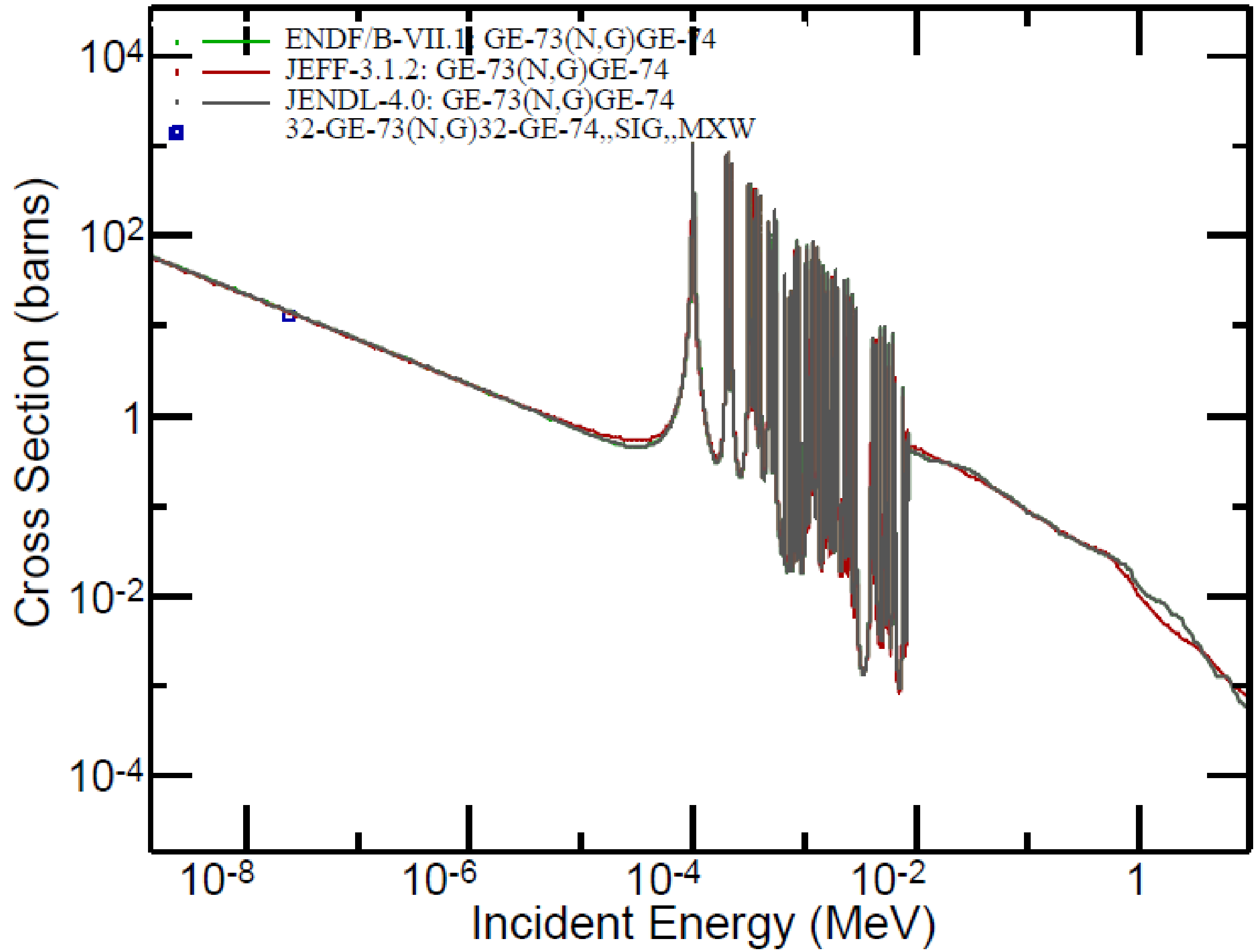
Maletski et al (1968):
Γ_n for E_n<30 keV
Γ_γ for E_n<4.5 keV



Experimental Data

^{73}Ge(n,γ)

Maletski et al (1968):
Γ_n for E_n<9 keV
Γ_γ for E_n<2 keV

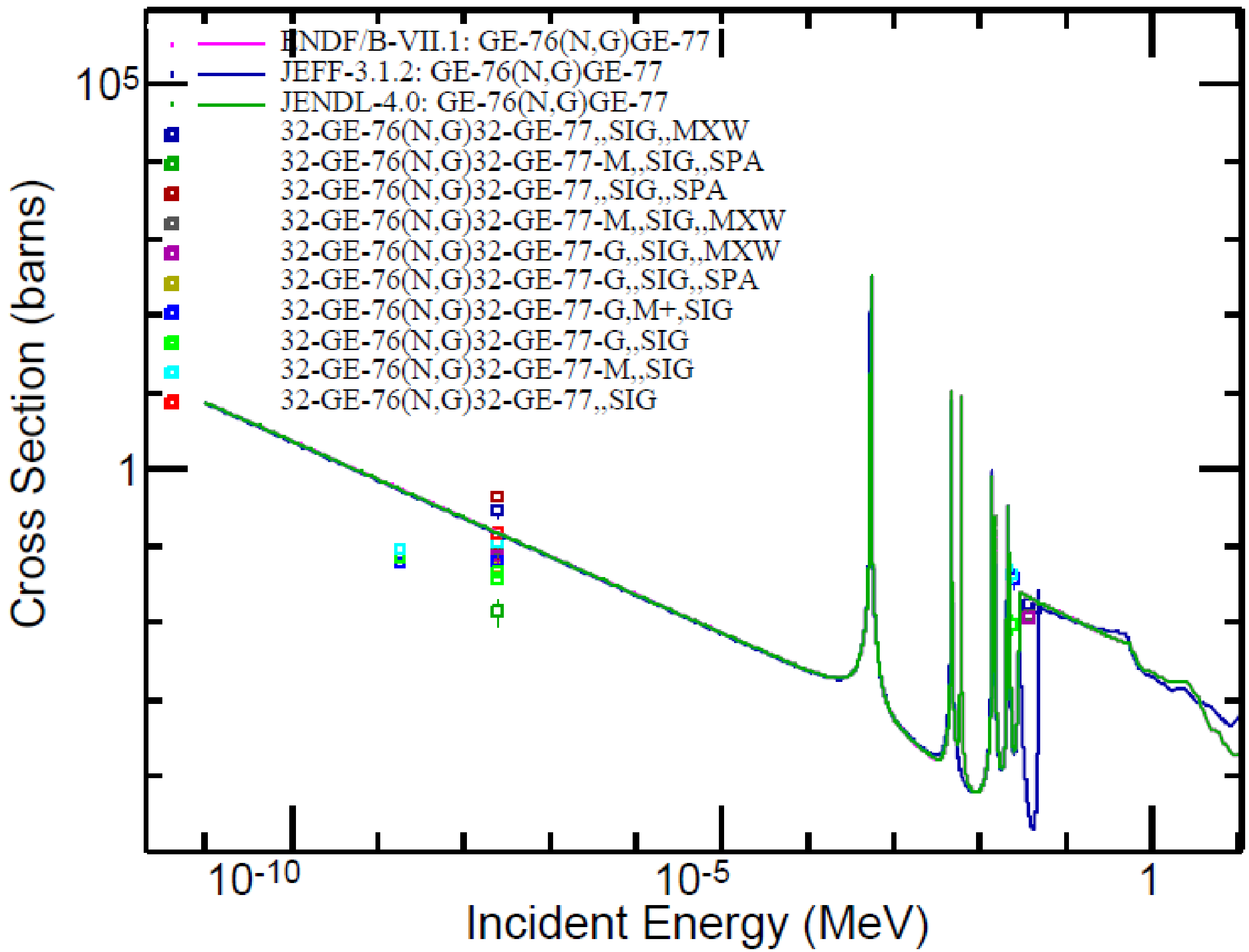


Experimental Data

^{76}Ge(n,γ)

Good et al (1966):
Γ_n for E_n<30 keV

Maletski et al (1968):
Γ_n for E_n<50 keV
Γ_γ for E_n<5 keV



Neutron scattering