Neutron capture cross section measurement of the s process branch point ^{63}Ni at n_TOF/CERN

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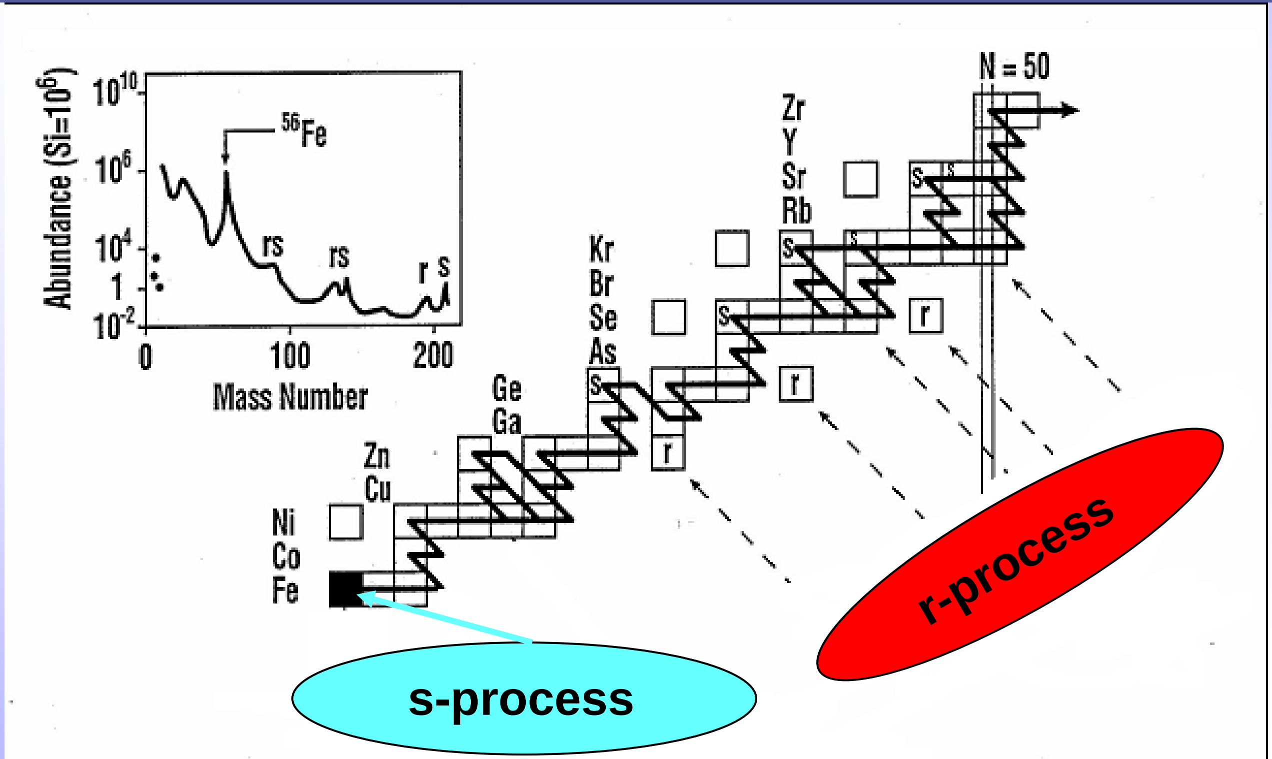
On behalf of the n_TOF collaboration

20. September 2011

Santa Tecla

Nucleosynthesis of heavy elements



rapid neutron capture

•explosive scenarios (supernovae)

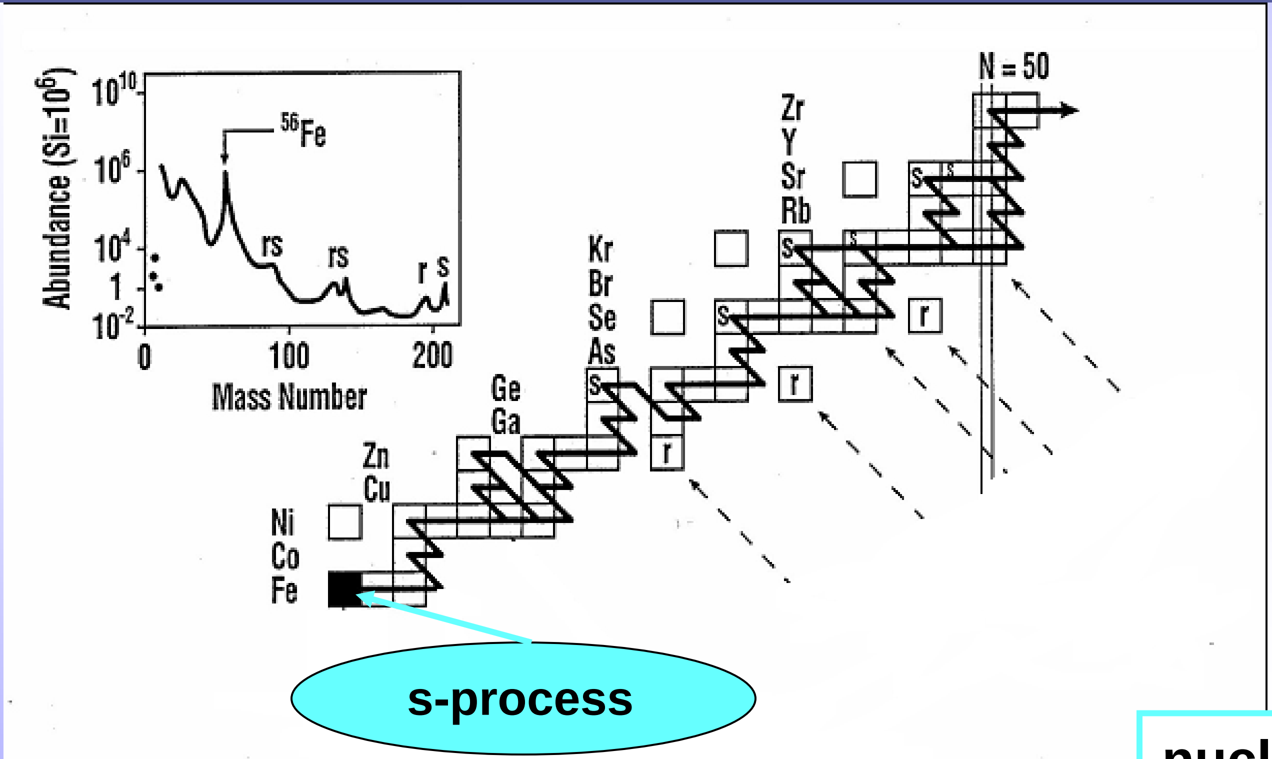
- $\tau_{n,\gamma}$ (10^{-3}s) < $t_{1/2}$
- N_n~10^{21} cm^{-3}

slow neutron capture

•AGB stars, massive stars

- $\tau_{n,\gamma}$ (~100 yr) > $t_{1/2}$
- N_n~10^8 cm^{-3}

Nucleosynthesis of heavy elements



slow neutron capture

- AGB stars, massive stars
- $\tau_{n,\gamma}$ (~100 yr) > $t_{1/2}$
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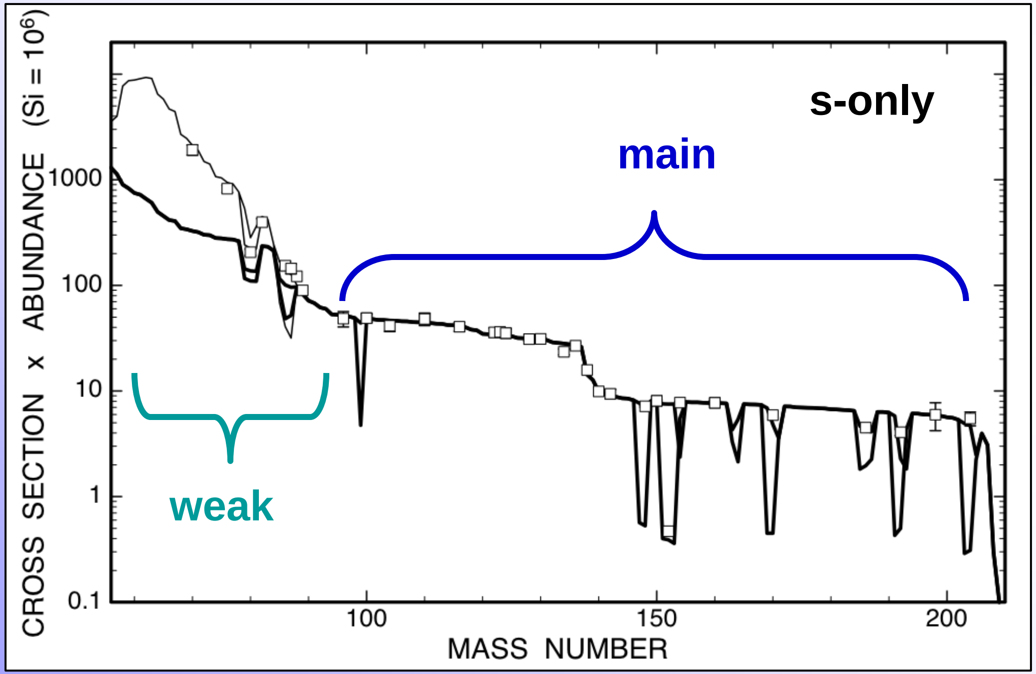
nuclear physics input:

- β decay rates
- stellar (n,γ) cross section

(Maxwellian Averaged Cross Section MACS)

s-process components

- **main (A>90): $N_s\langle\sigma\rangle$ = constant**
- **weak (A<90): no flow equilibrium**



F. Käppeler (1999)

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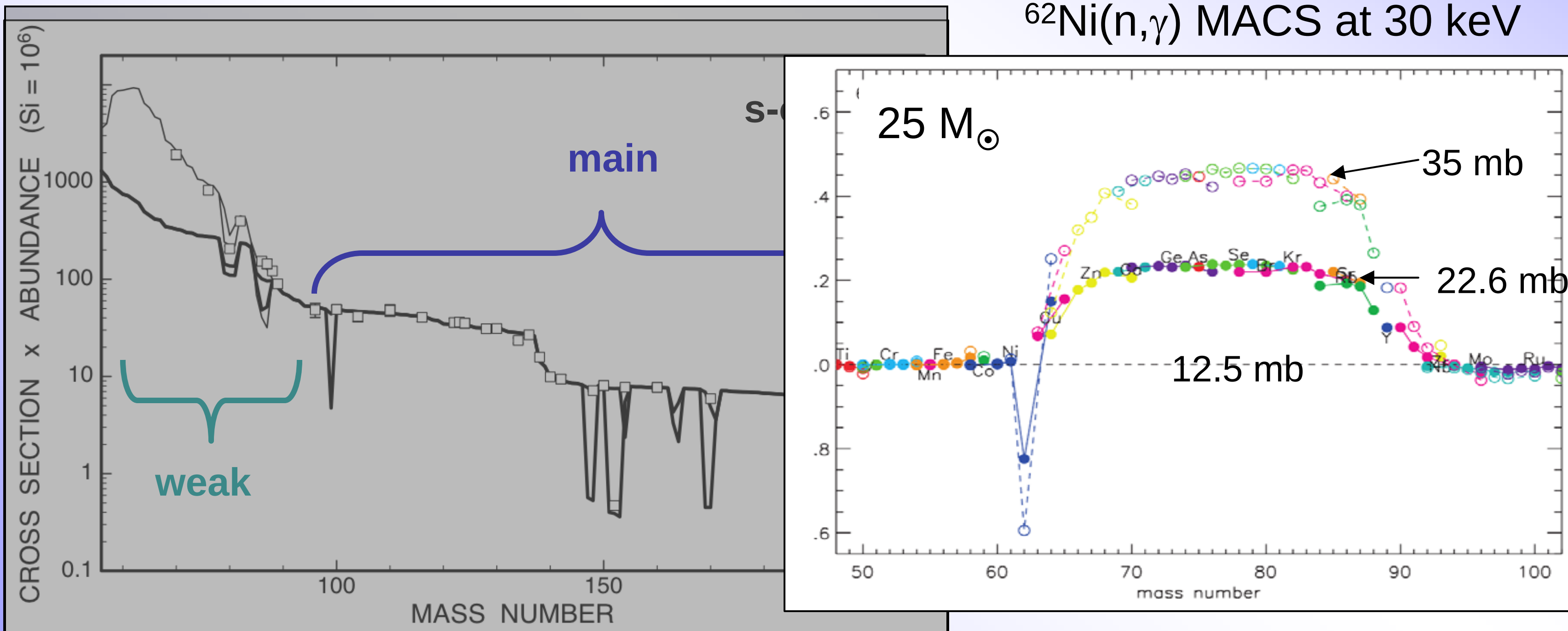
$^{62}Ni(n,\gamma)$ MACS at 30 keV



F. Käppeler (1999)

Nassar et al. (2005)

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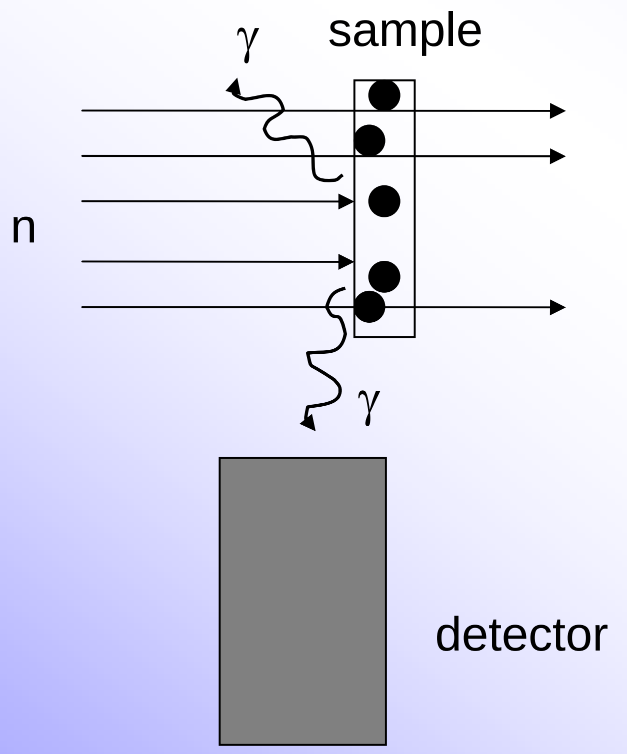
The time-of-flight technique



$^{63}Ni + n \rightarrow {}^{64}Ni^* \rightarrow {}^{64}Ni + \gamma$

Extract cross-section by determining **reaction-yield Y_R (E_n)**:

$$Y_R = \frac{C - B}{\varepsilon \cdot f \cdot \Phi}$$

C....count-rate

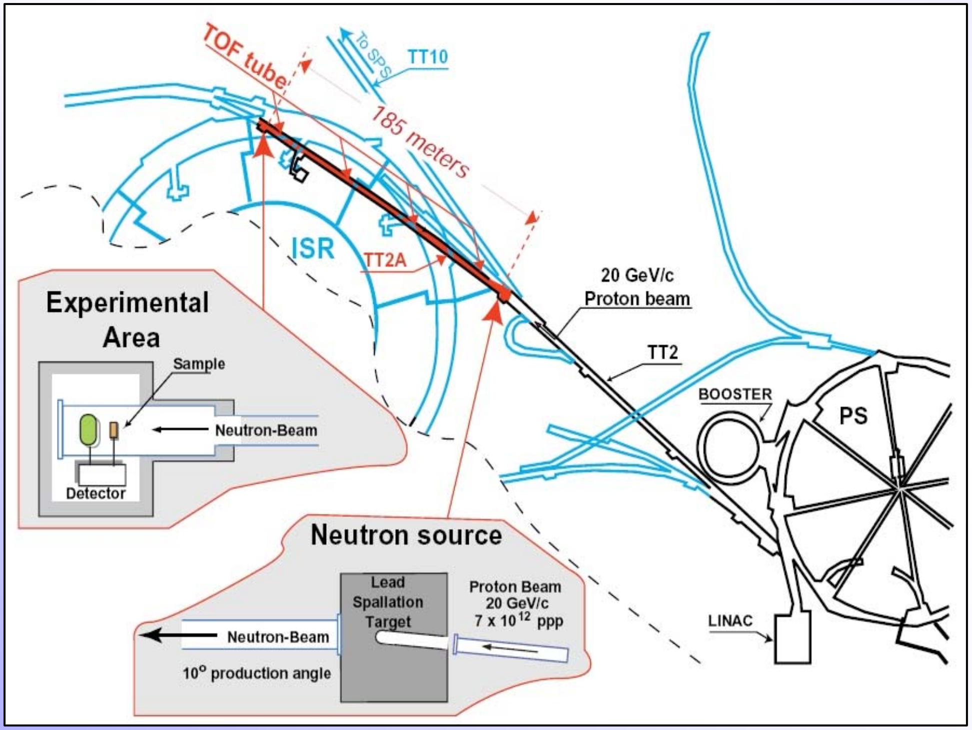
ε.....efficiency

f.....sample size corrections

Φ....neutron flux

B....background

The n_TOF/CERN facility

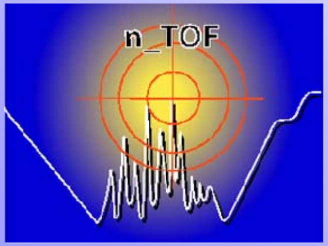


spallation neutron source

- 20 GeV/c protons on Pb-target
- water as moderator and coolant
- pulse width: 7 ns
- intensity: 7 $\cdot 10^{12}$ protons per pulse

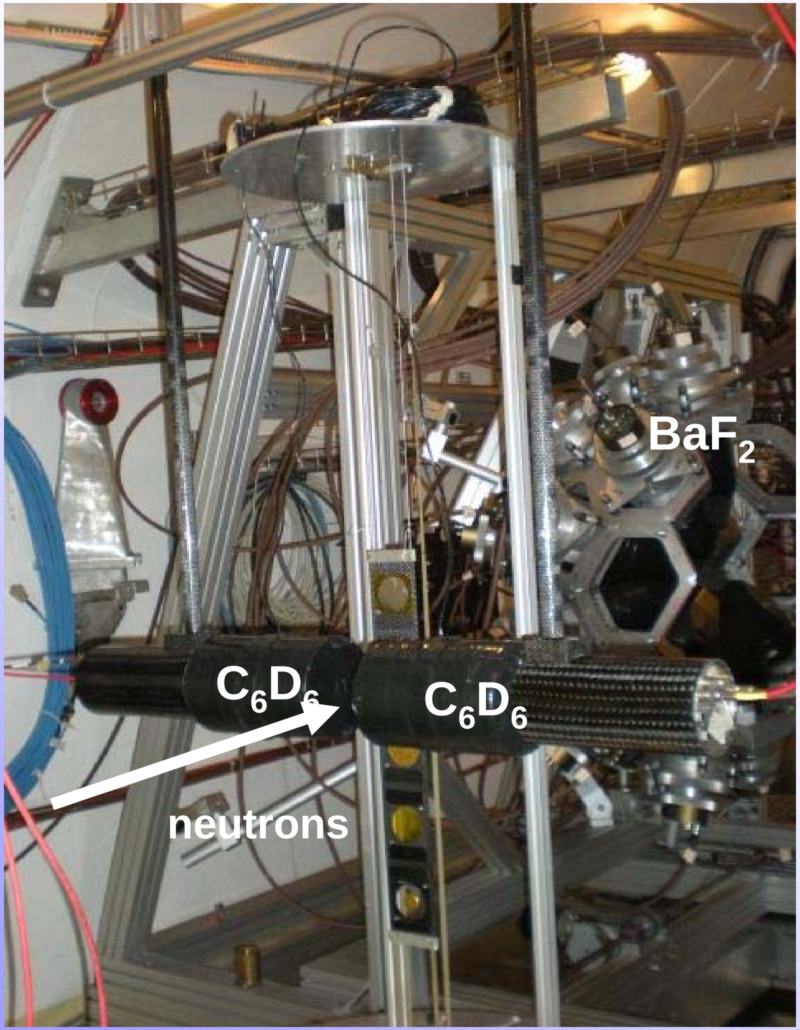
→ 1.2×10^6 neutrons/pulse @ 185 m

- flight path: 185 m
- neutron energy: 10^{-3}-10^{10} eV
- beam size at capture setup: Ø~4 cm
- energy resolution $\Delta E/E$:
  3×10^{-4} @ 1 eV – 4.2×10^{-3} @ 1 MeV



www.cern.ch/ntof

The n_TOF/CERN facility



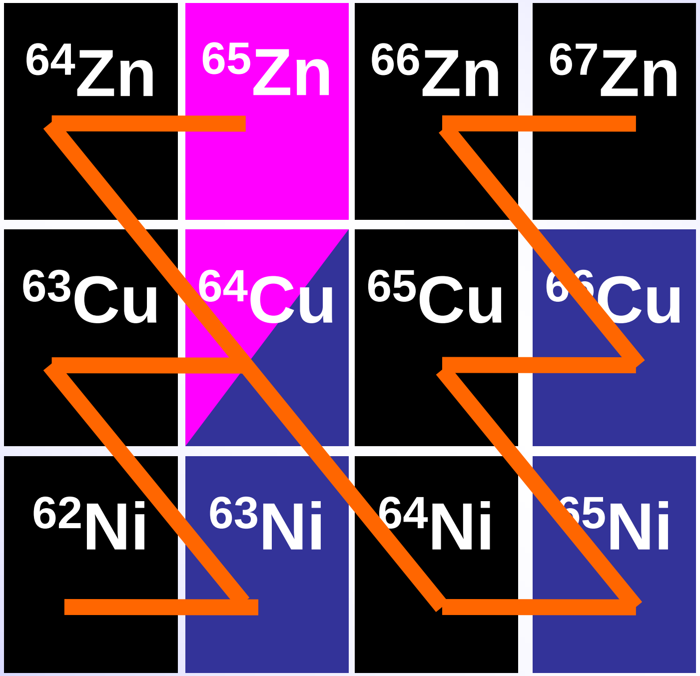
2 setups for capture measurements:

• BaF_2 total absorption calorimeter
40 crystals in 4π geometry

• **two C_6D_6 detectors**
optimized for low neutron sensitivity ($\varepsilon_n/\varepsilon_\gamma < 4 \cdot 10^{-5}$)
detection of at most one γ ray per cascade

^{63}Ni(n,γ): Motivation

- $t_{1/2}$(terr)=100.1 y, $t_{1/2}$(90 keV)= 0.4 y



core He burning, kT=25 keV, N_n~10^6 cm^{-3}

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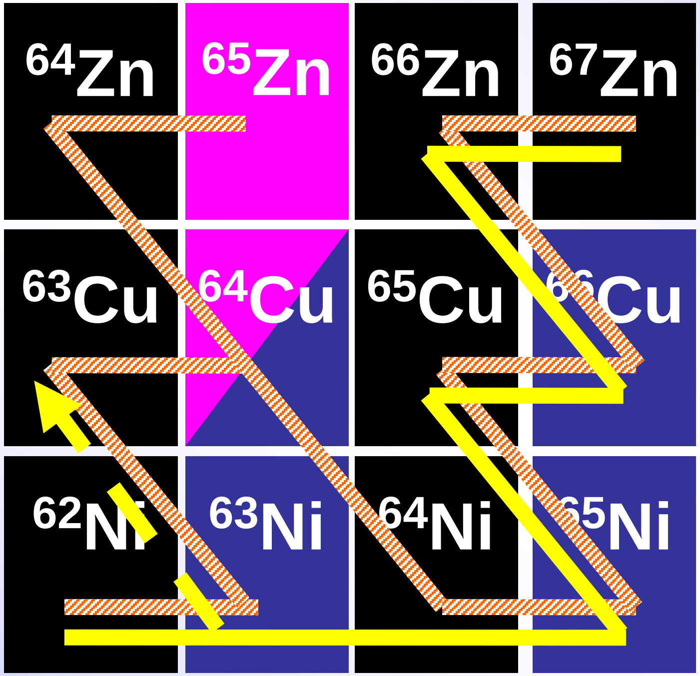

core He burning, kT=25 keV, N_n~10^6 cm^{-3}

C shell burning, kT=90 keV, N_n~10^{11} cm^{-3}

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$^{63}Ni(n,\gamma)$: Motivation

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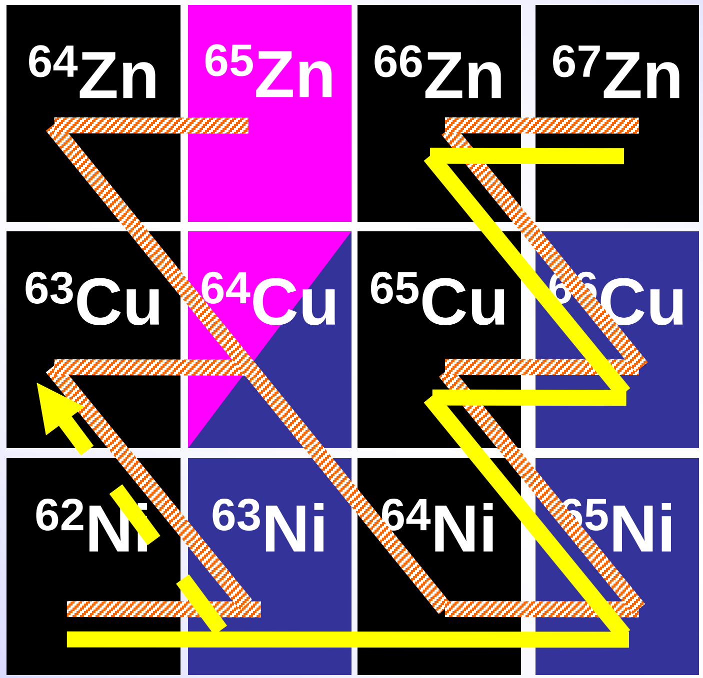
^{63}Ni MACS crucial for expected ^{63}Cu abundances !!

Pignatari et al. (2010)



core He burning, kT=25 keV, $N_n \sim 10^6$ cm^{-3}

C shell burning, kT=90 keV, $N_n \sim 10^{11}$ cm^{-3}

$^{63}Ni(n,\gamma)$ at n_TOF

- $t_{1/2}$=100.1 yr
- no cross section data above thermal energies
- MACS at stellar energies relies on extrapolations or calculations

- MACS at 30 keV:

KADoNiS:	31± 6 mb
TENDL(2009):	68.9 mb

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- MACS at 30 keV:

KADoNiS:	31± 6 mb
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A. Mengoni:	90.8 mb

- Measurement of $^{63}Ni(n,\gamma)$ at n_TOF (C. Lederer, C. Massimi, et al., INTC/P-283, 2010)

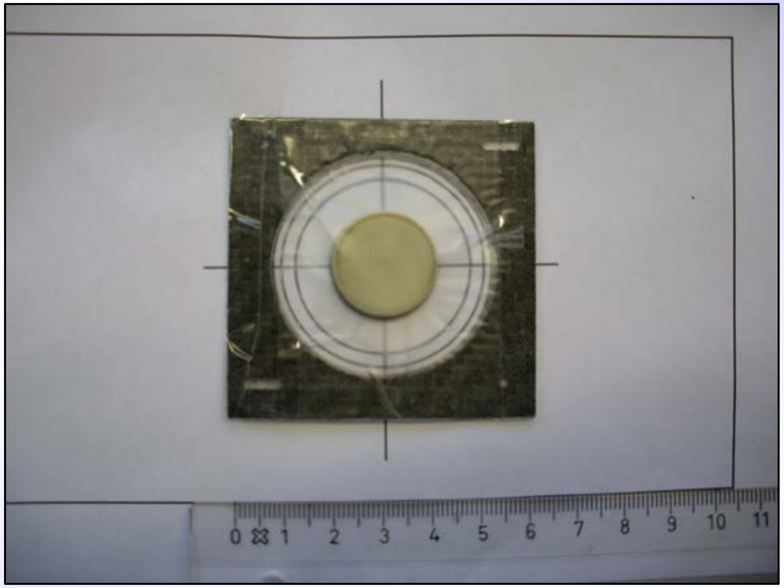
^{63}Ni sample

Original material (TU Munich, *G. Korschinek, T. Faestermann*):

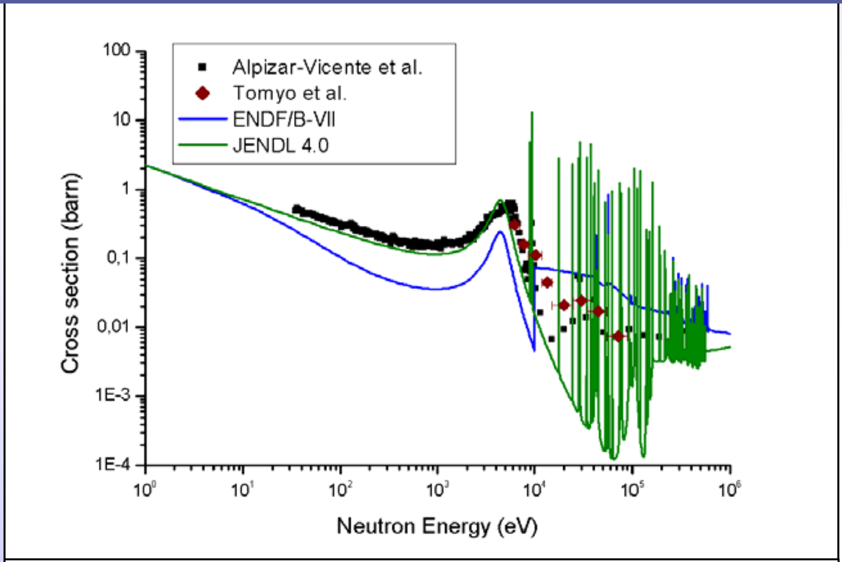
- ^{62}Ni sample irradiated in thermal reactor (in 1984 and 1992)
- total mass: 1002 mg
- enrichment in ^{63}Ni: ~13 % (= 131.8 mg)
- contaminants: ~15.4 mg ^{63}Cu

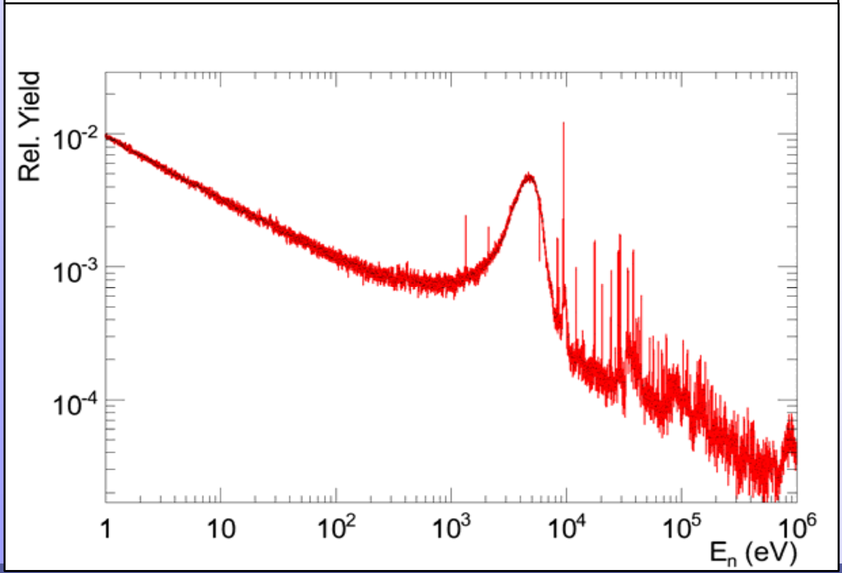
After chemical separation at PSI (*D. Schumann*):

- NiO powder, 1156 mg
- ^{63}Ni/^{62}Ni=0.134 (=108.4 mg)
- Container: PEEK ($C_{20}H_{12}O_3$)
- <0.01 mg ^{63}Cu



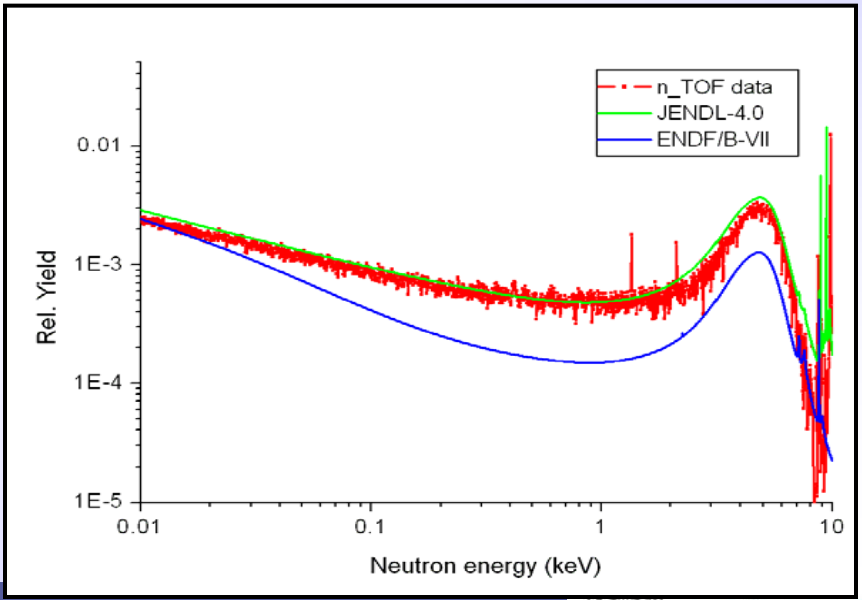
$^{62}Ni(n,\gamma)$ – n_TOF 2009



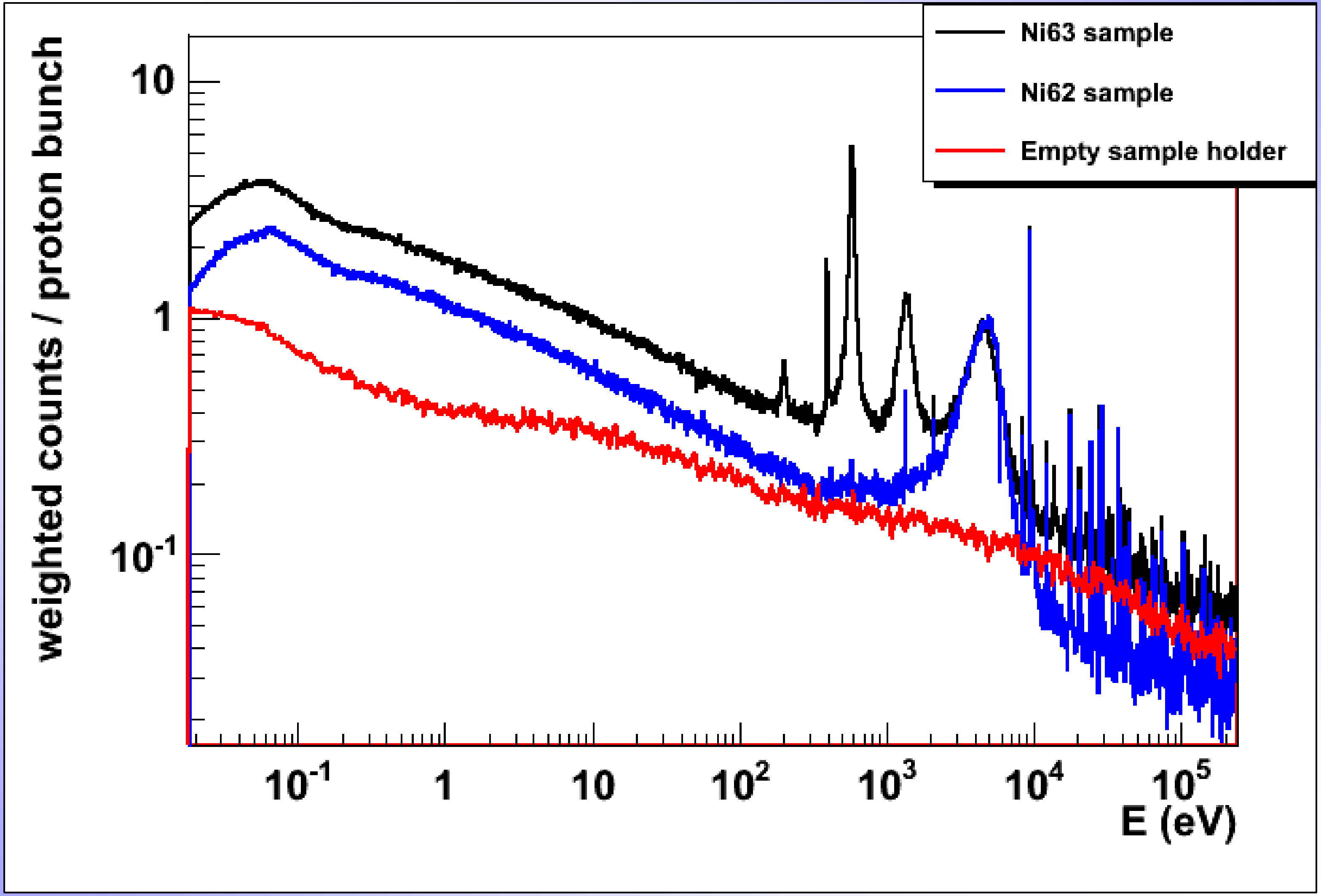


previous measurements compared to evaluations

Preliminary results n_TOF:



^{63}Ni(n,γ) – first results from n_TOF (2011)



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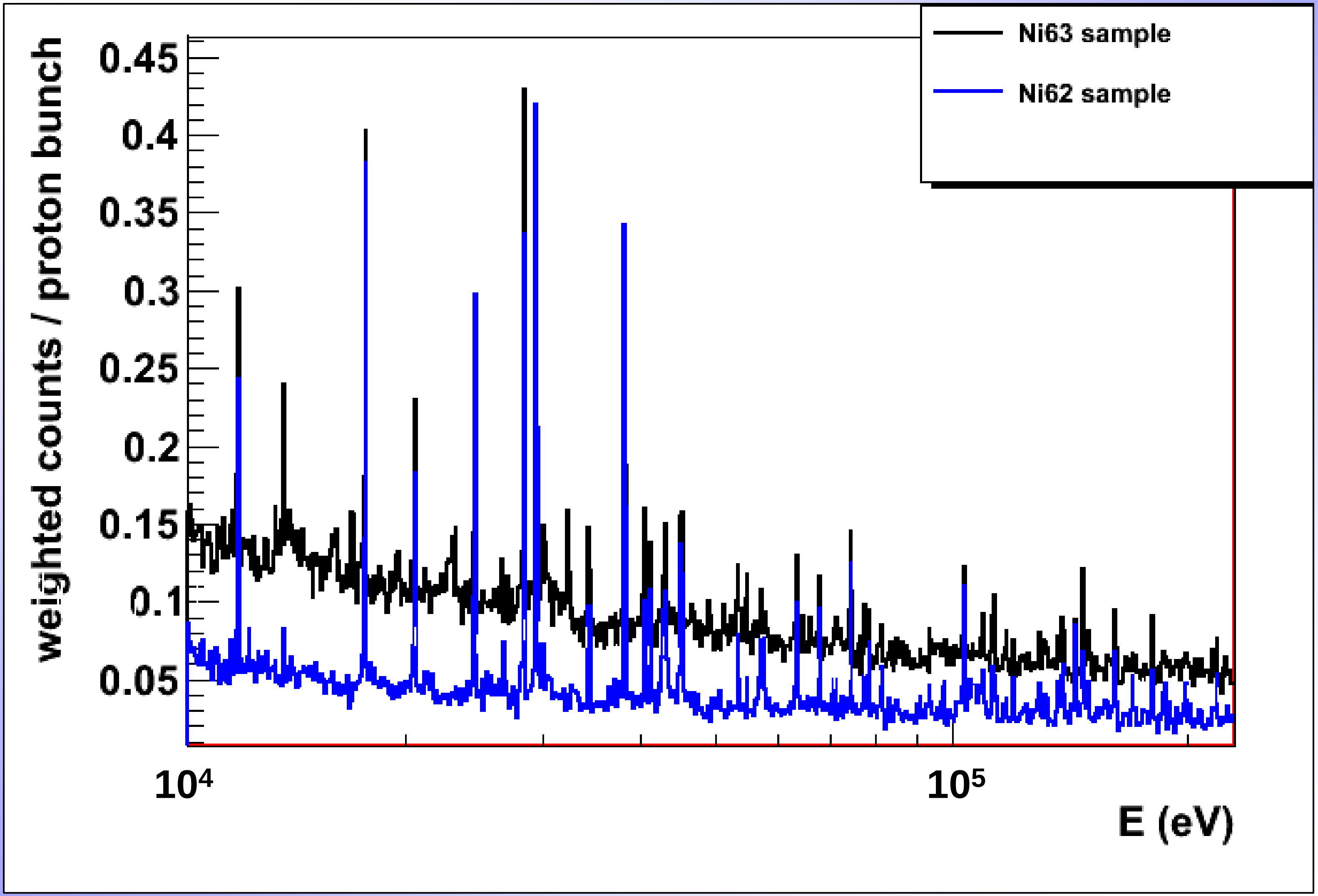

Summary

- (n,γ) cross sections over wide energy range (few – hundreds keV) are needed as input for s-process studies
- measurement campaign at n_TOF for improving data on Fe/Ni cross sections (^{54,56,57}Fe, ^{58,62}Ni analysis underway)
- measurement of unstable ^{63}Ni(n,γ) at n_TOF sucessfully finished 2011, data analysis underway
- new n_TOF programmes of astrophysical interest coming forward, e.g. (n,α) (see talk by *C Weiß*) and (n,p) (collaboration with *PJ Woods, University of Edinburgh*) reactions

THANK YOU FOR YOUR ATTENTION