Nuclear reactions in ^{60}Fe production and destruction

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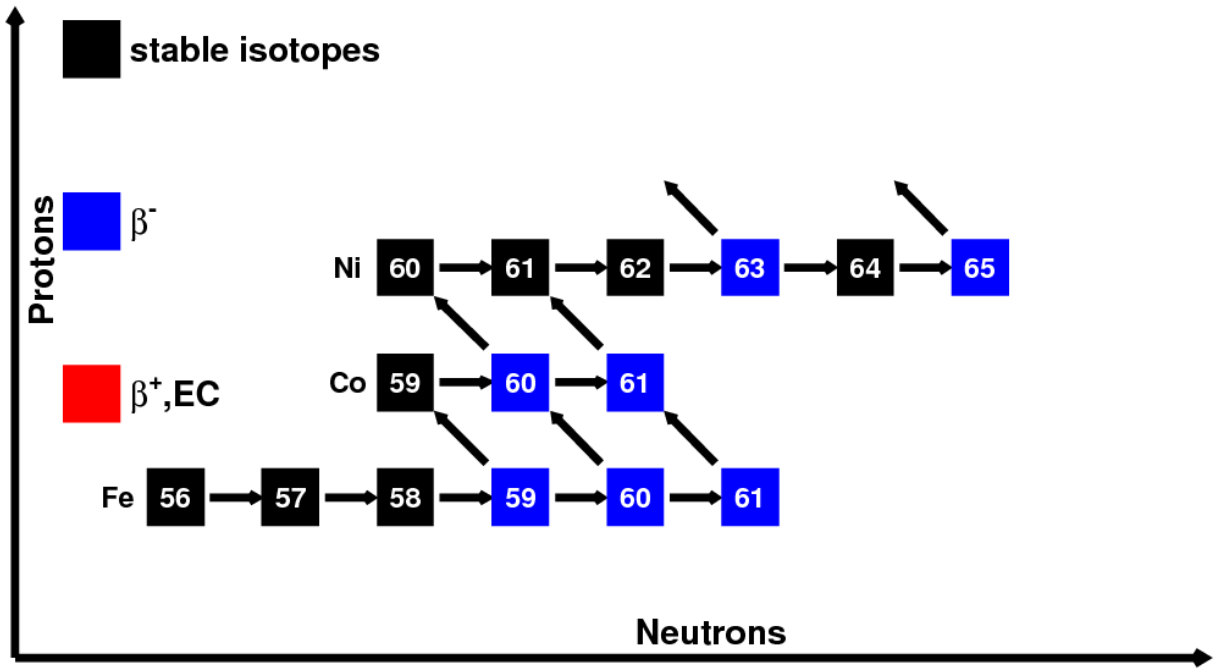
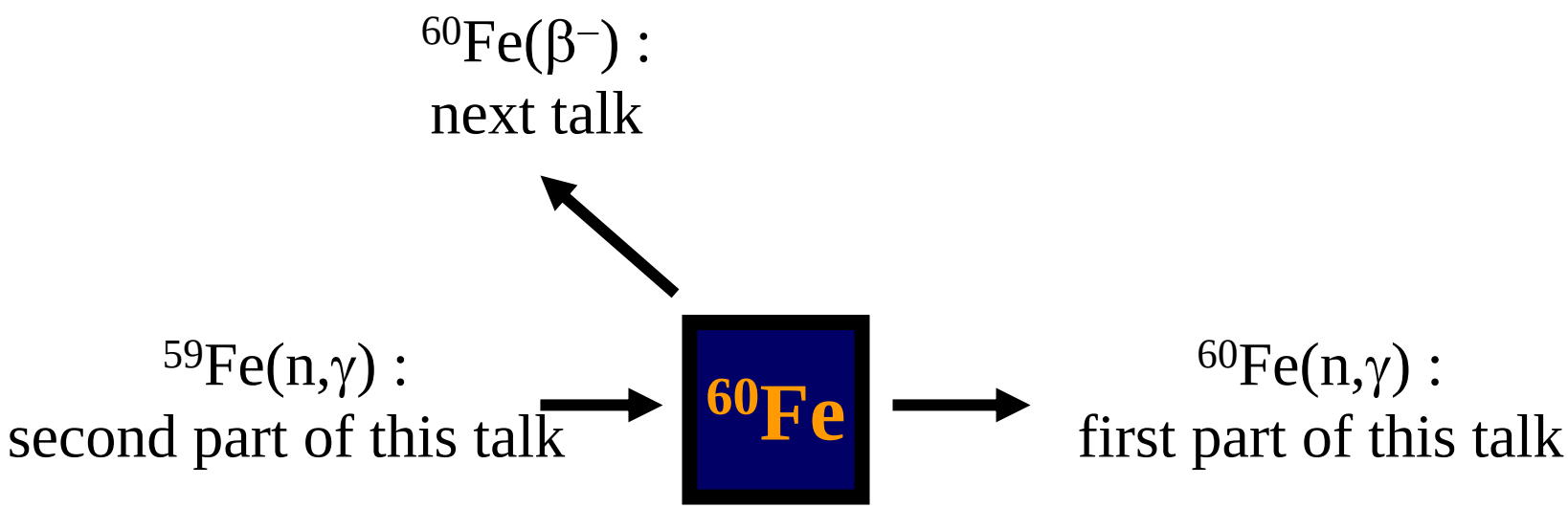
Research Day of "Universe Cluster" RA-G:
Nuclear Astrophysics with ^{60}Fe
Garching, 15. July 2008

^{60}Fe in stars

- Weak s-process component
- During C-shell burning in massive stars



Production and Destruction of ^{60}Fe



^{60}Fe - sample

- 7.8 10^{15} atoms **^{60}Fe** (0.78 µg) ($t_{1/2}$ = 1.5(3) Ma)
- Retrieved from proton-irradiated copper beam stop (PSI)
- carrier: ^{nat}Fe, C
- active impurities:
  - ^{55}Fe ($t_{1/2}$ = 2.7 y)
  - ^{60}Co (ingrowth)
- 6 mm diameter

activation only (presently) feasible method

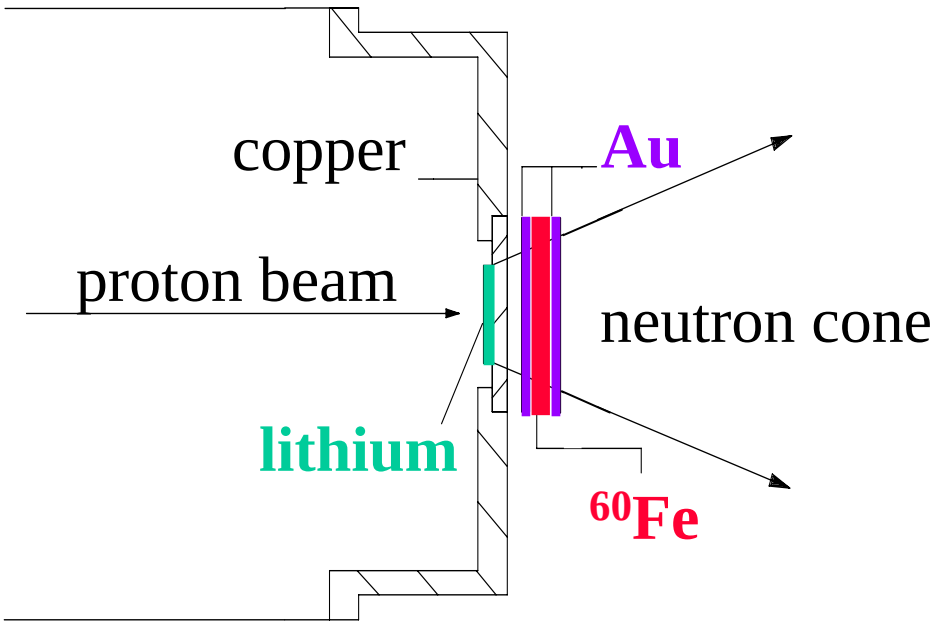
Activation Method

^{60}Fe sample irradiated 40 times for 15 min, then activity counted for 10 min

^{60}Fe(n,γ)^{61}Fe reaction detected via **^{61}Fe(β$^-$)^{61}Co** decay ($t_{1/2}$=6.0 min)

Determination of neutron flux via

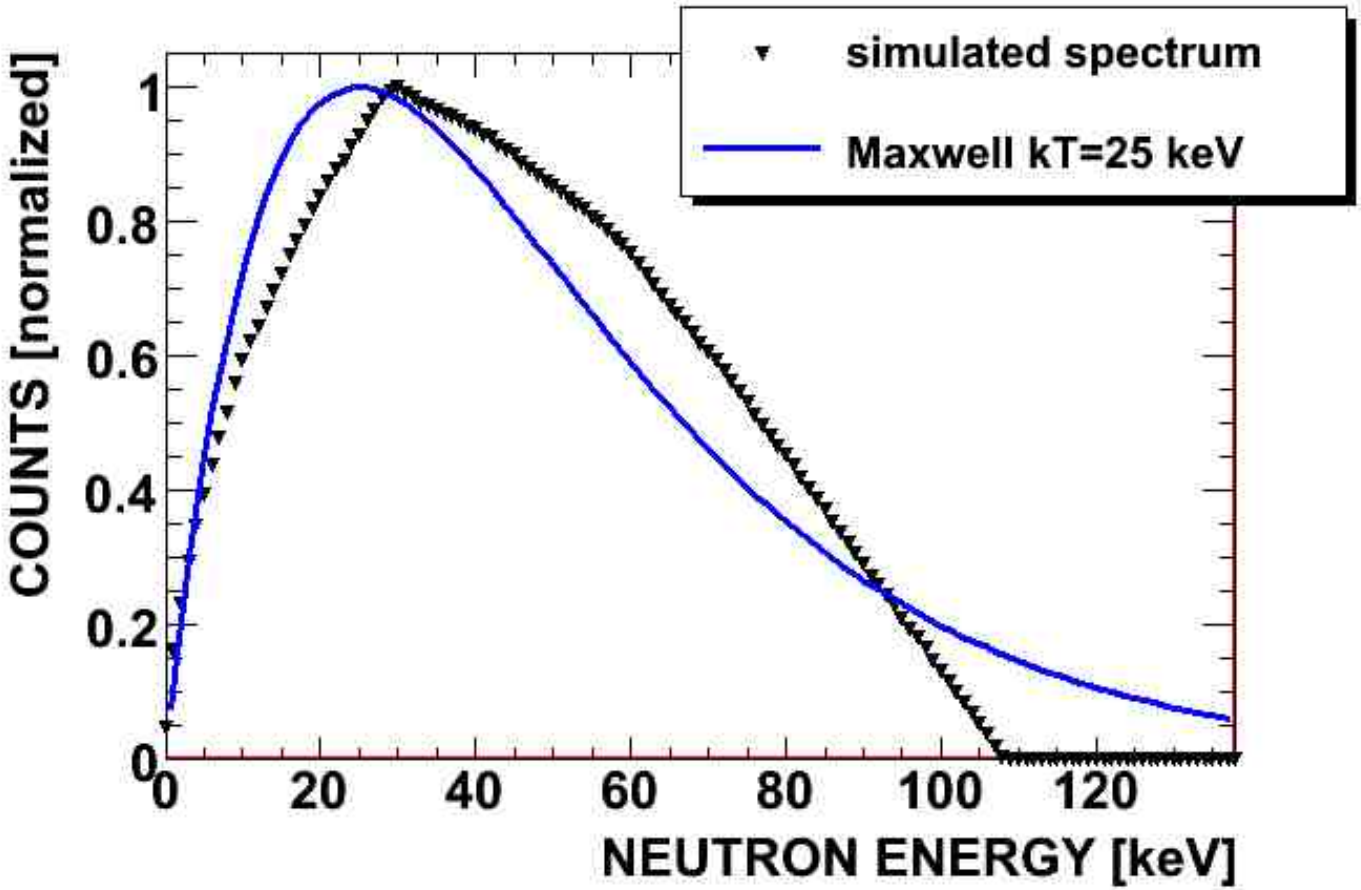
^{197}Au(n,γ)^{198}Au



Neutron source:

^{7}Li(p,n)^{7}Be

Neutron spectrum

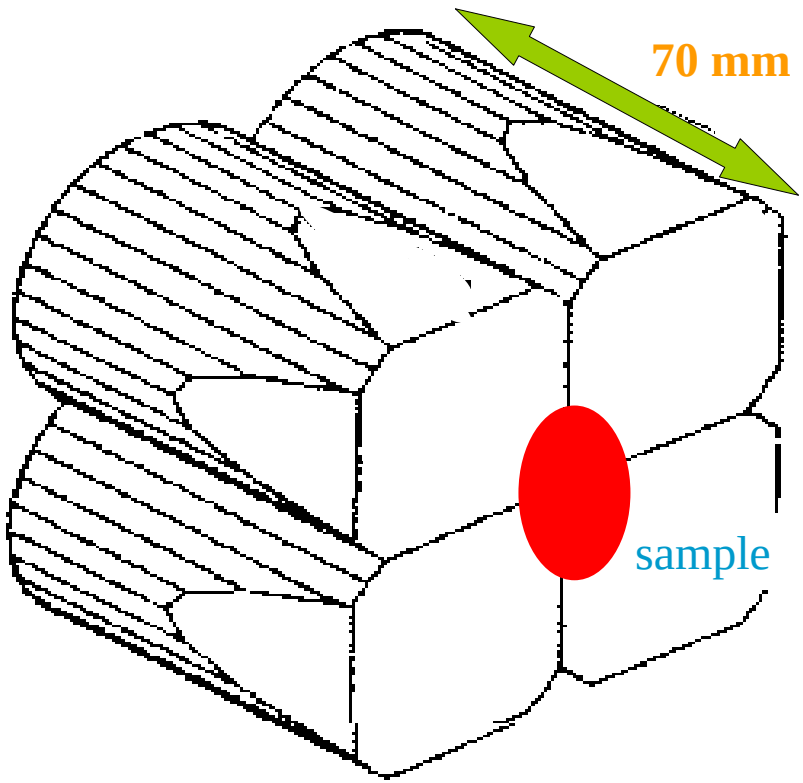


Quasi-Maxwellian averaged distribution:

kT = **25 keV**

E_{max} = **110 keV**

γ-detection



2 Ge-Clovers, face to face

Efficiency @ 1115 keV:

single crystal:

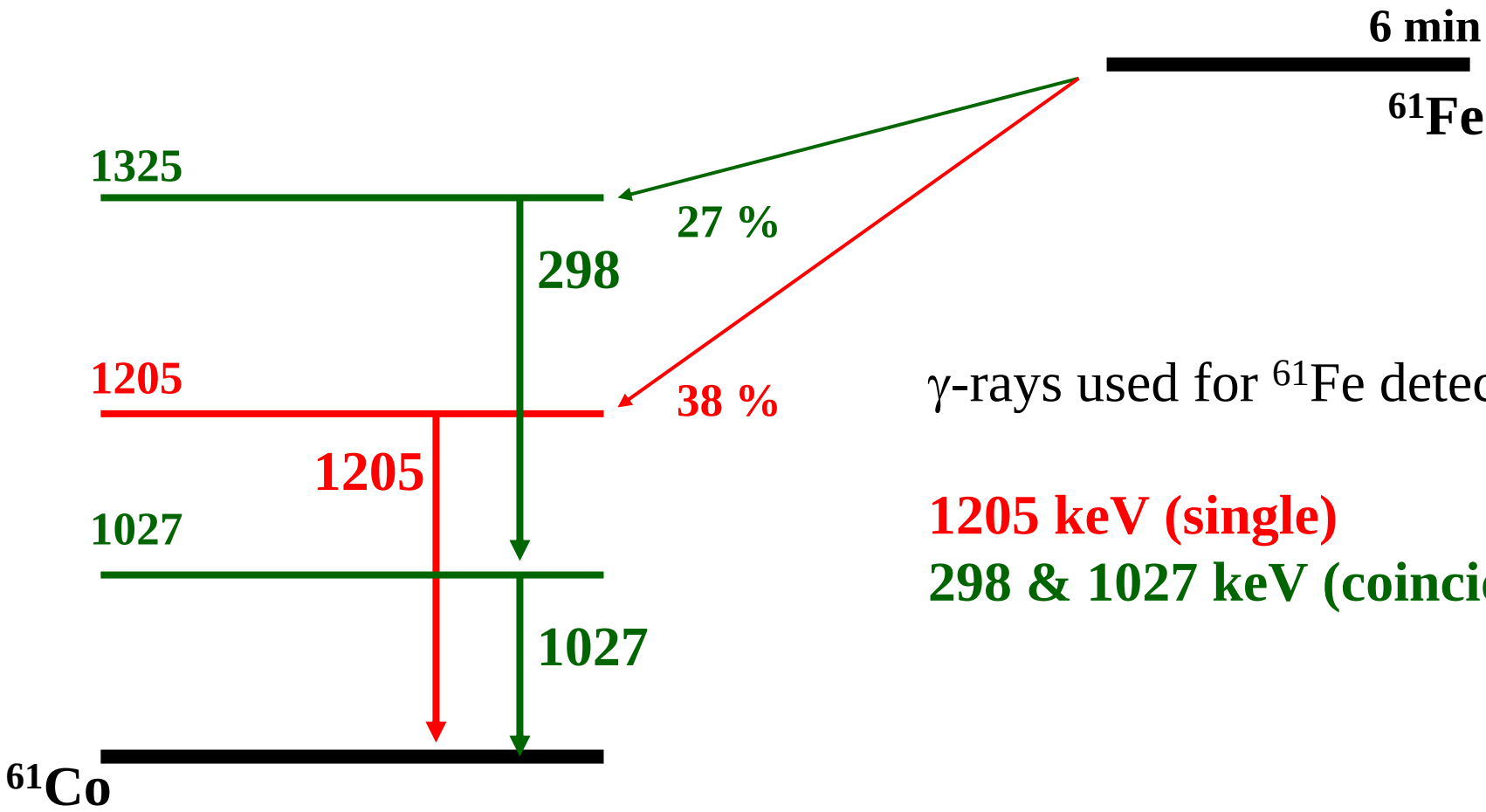
ε_{tot} = 11 %

ε_{peak} = 1.1 %

addback:

ε_{peak} = 15 %

^{61}Fe decay



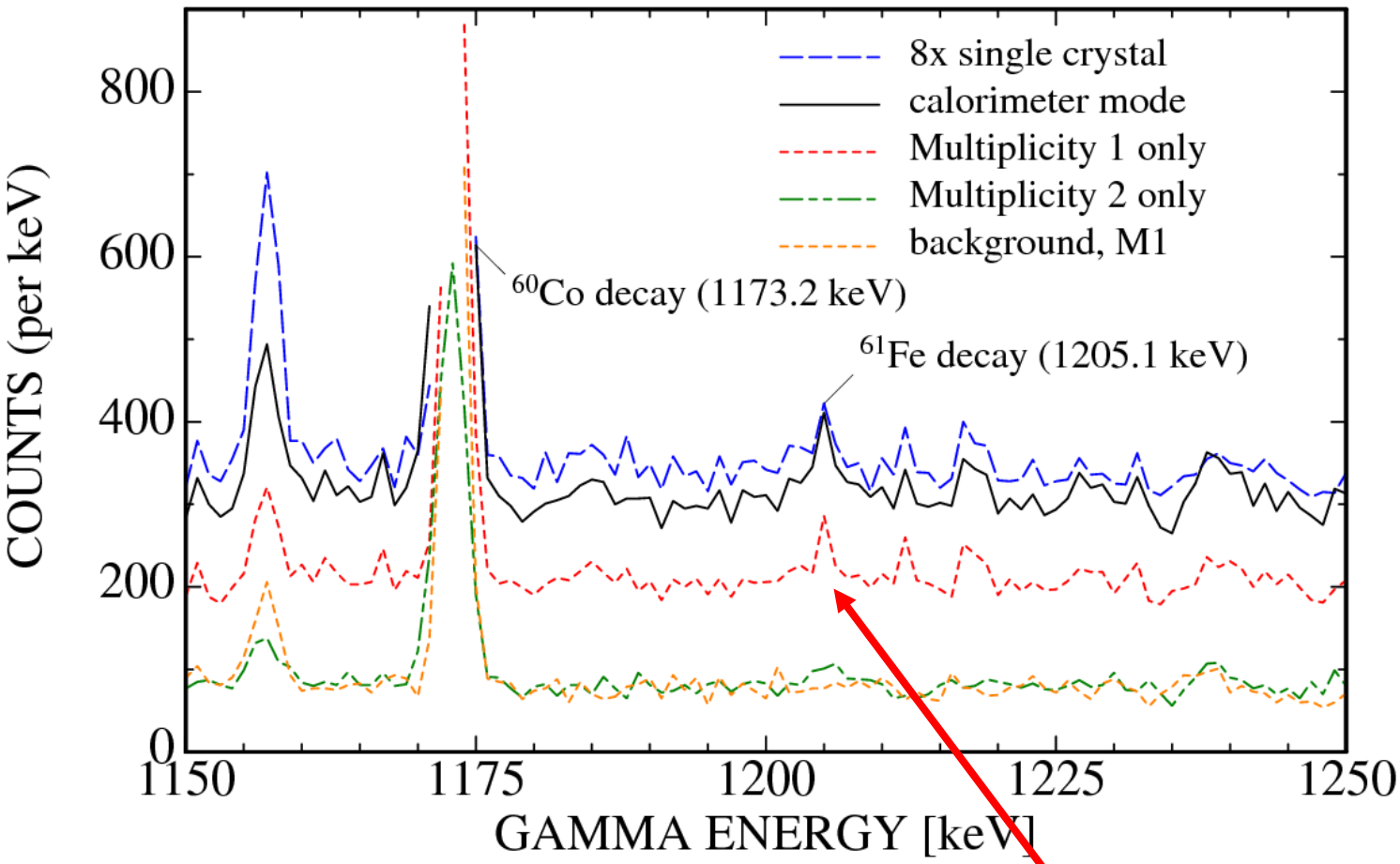
γ-rays used for ^{61}Fe detection:

1205 keV (single)

298 & 1027 keV (coincidence)

Single spectra

$^{60}Fe(n,\gamma)$

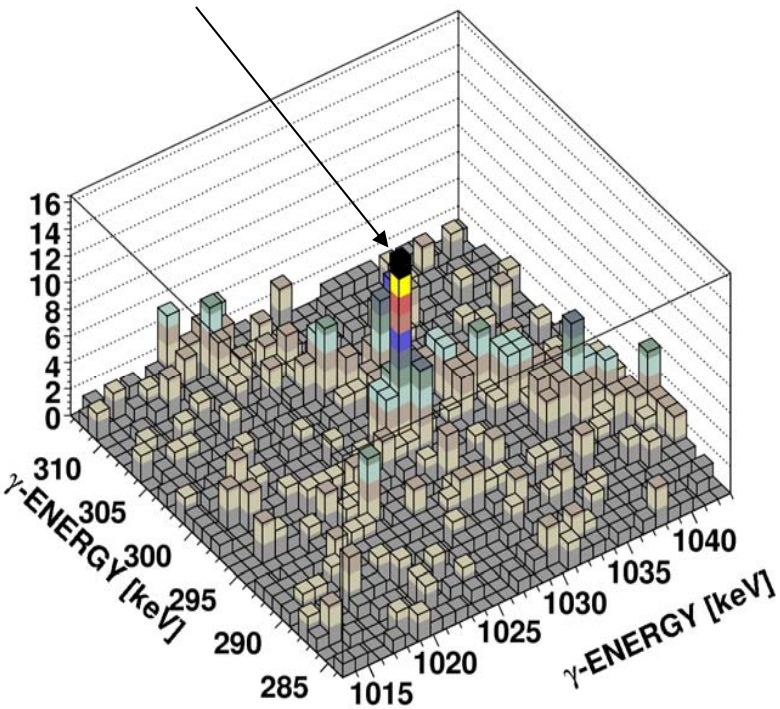


1205 keV (single)

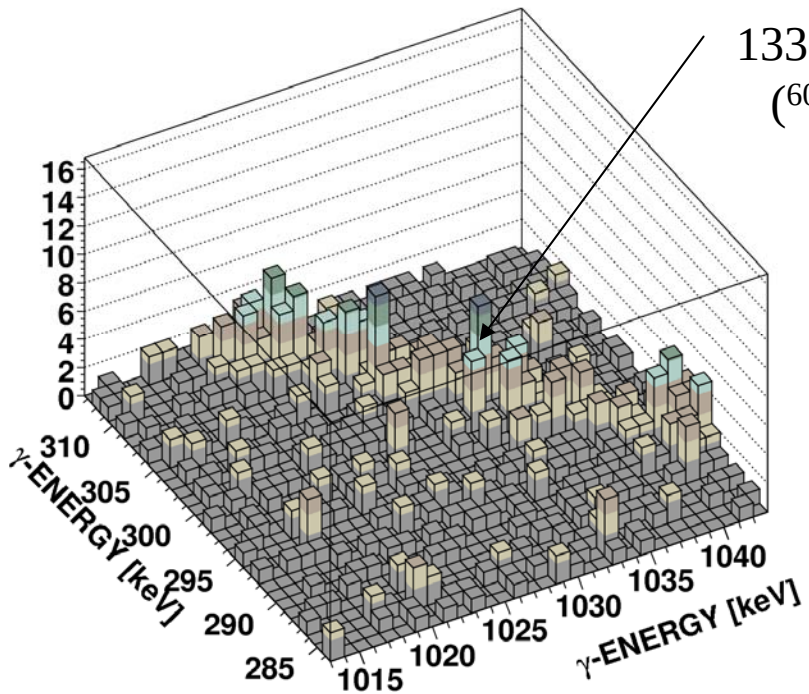
Coincidences: 298 & 1027 keV

- almost no background
- significantly reduced counts

^{61}Fe



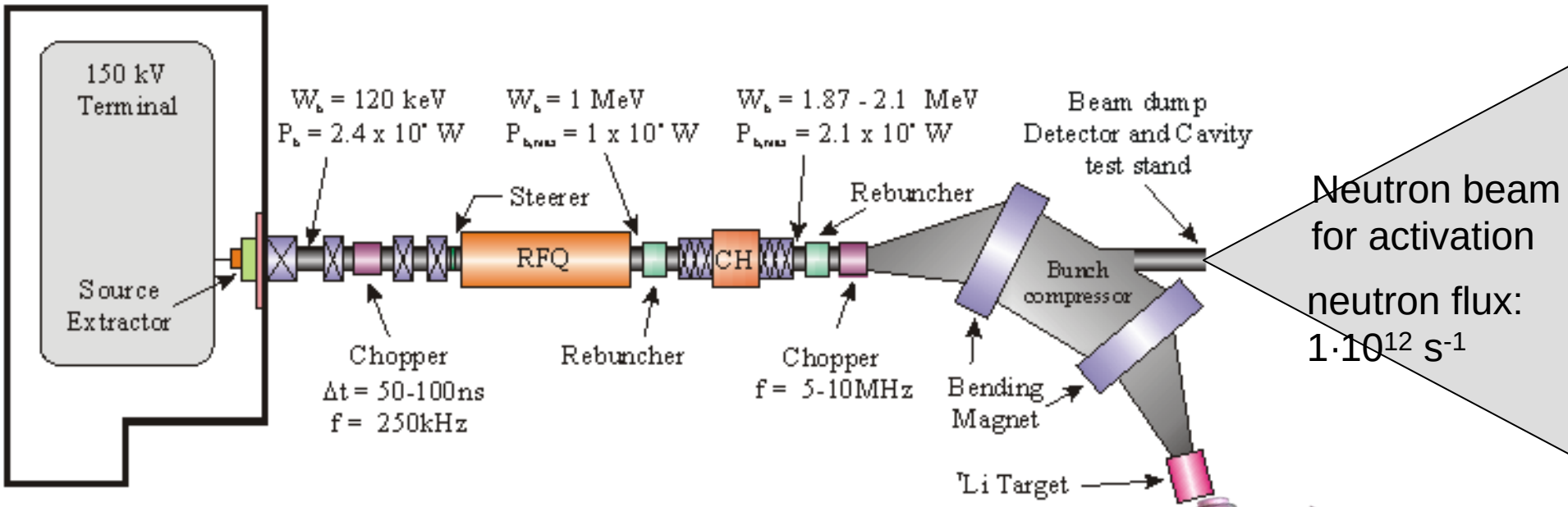
Sample background only



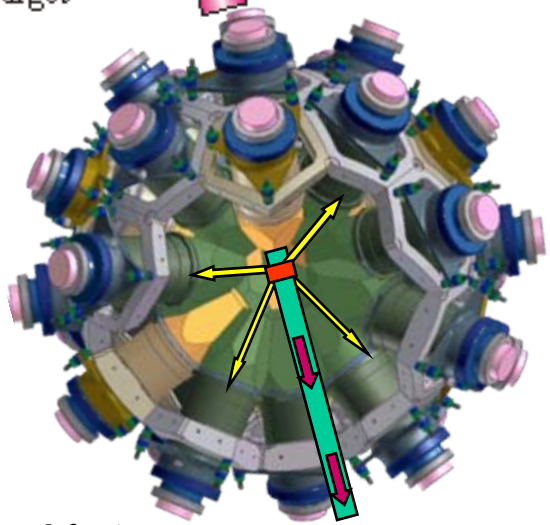
Results

- **10.2 (2.9^{sys}) (1.4^{stat}) mb for experimental spectrum**
- **Extrapolation to Maxwellian spectra necessarily based on theoretical energy dependence**

The Frankfurt neutron source at the Stern-Gerlach-Zentrum (FRANZ)

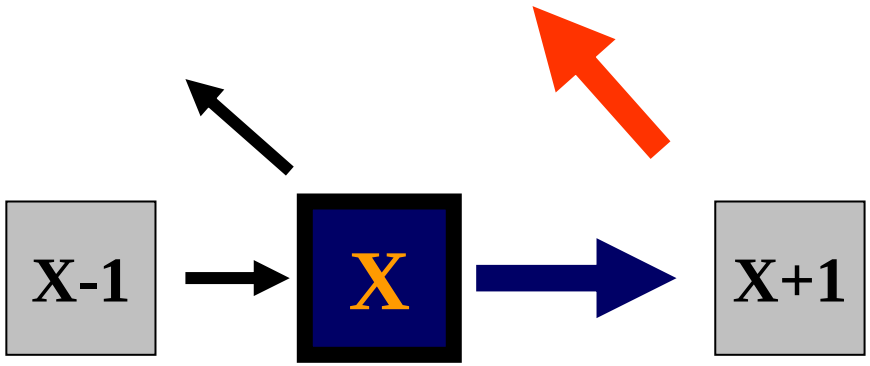


2 mA proton beam
250 kHz
< 1ns pulse width
neutron flux: $4 \cdot 10^7$ s^{-1} cm^{-2}



Design by Prof. Ratzinger, Prof. Schempp, O. Meusel and P. C. Chau

Double neutron capture

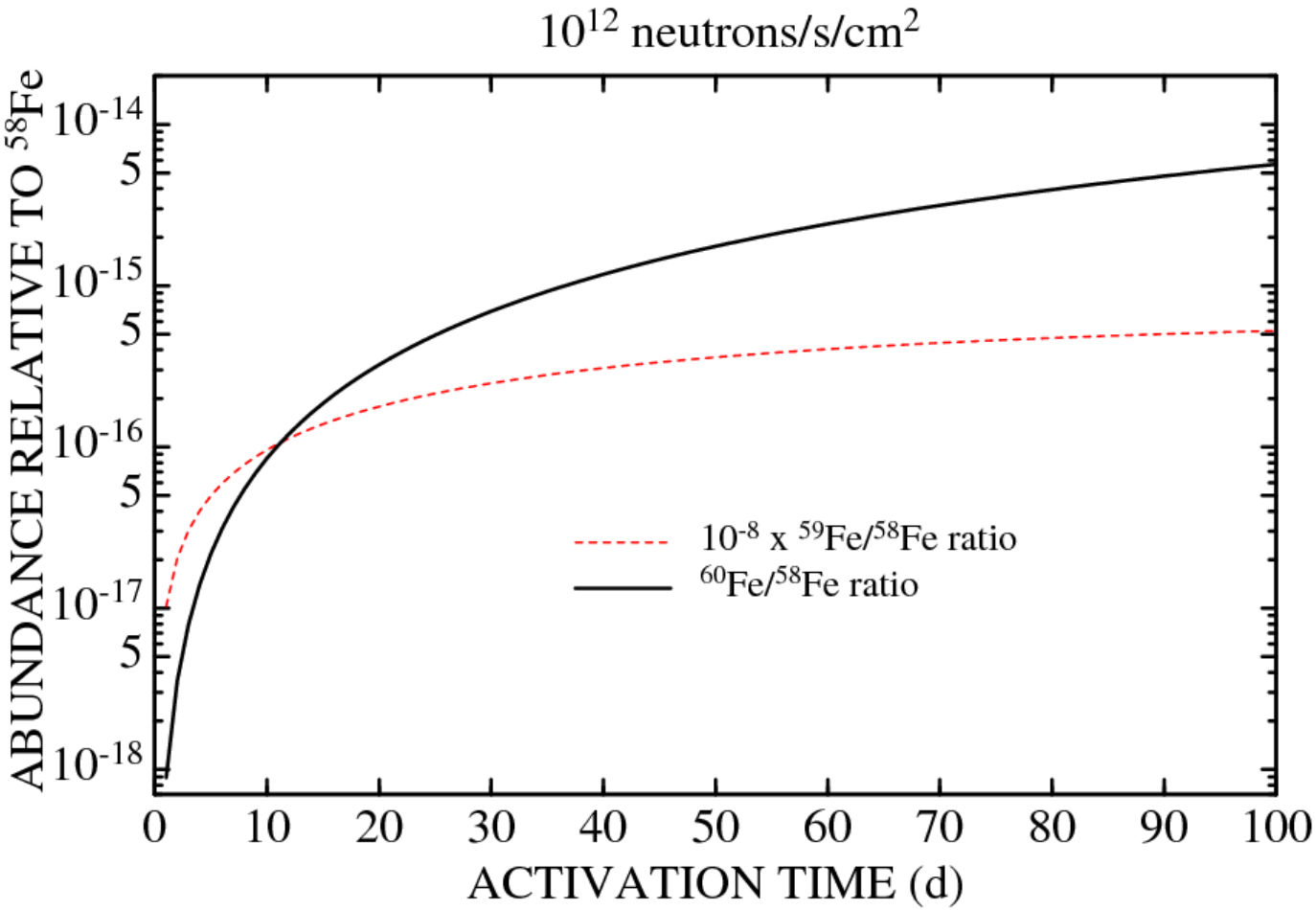


$t_{1/2}$ ~ 1..100 d

- produce the sample “on the fly”
- 10^{12} n/s/cm^2 @ 25 keV ~ 5 10^3 n/cm^3

^{59}Fe(n,γ) at FRANZ ($t_{1/2}$=45 d)

- activate ^{58}Fe, wait for 2nd neutron capture
- measure ^{60}Fe/^{58}Fe ratio via AMS



Summary

- Neutron capture cross section of ^{60}Fe measured
- Determining uncertainty from half-life
- Direct measurement of ^{59}Fe(n,γ) on the horizon