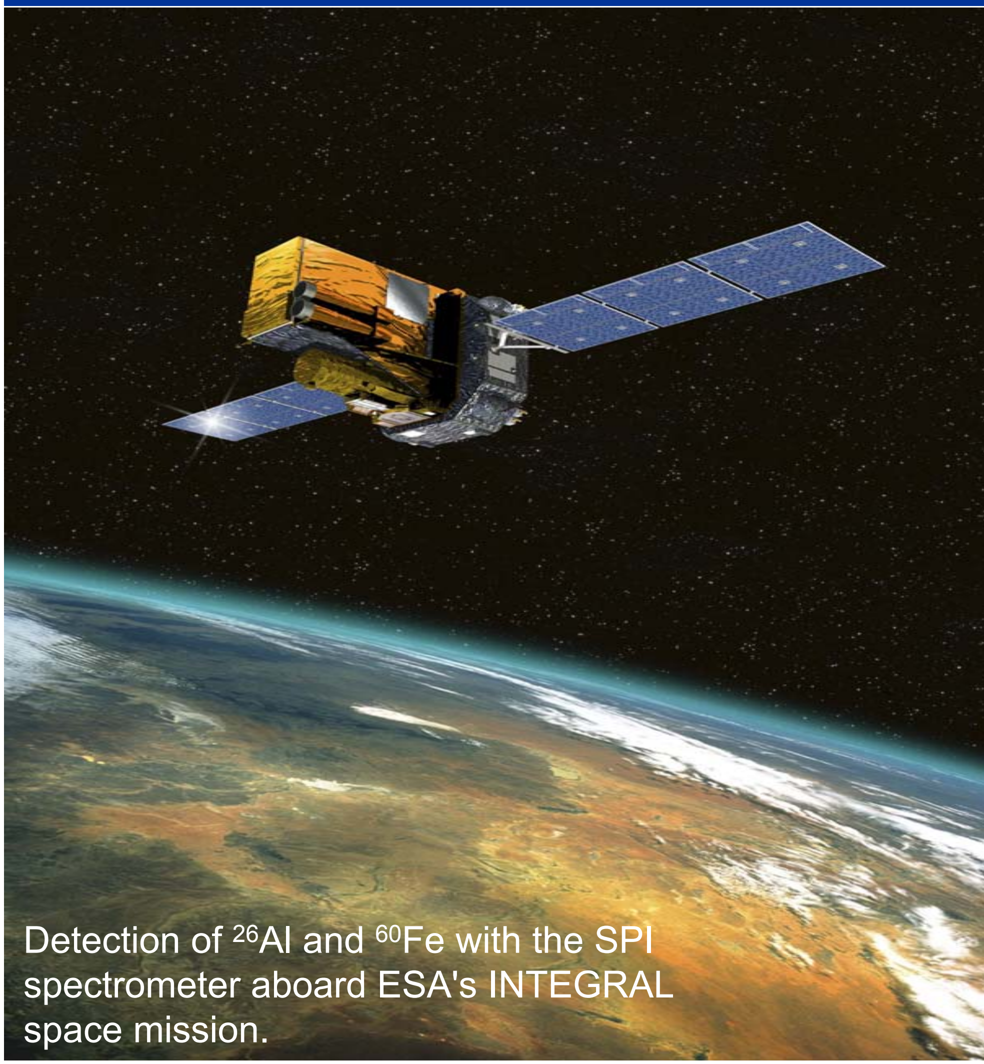
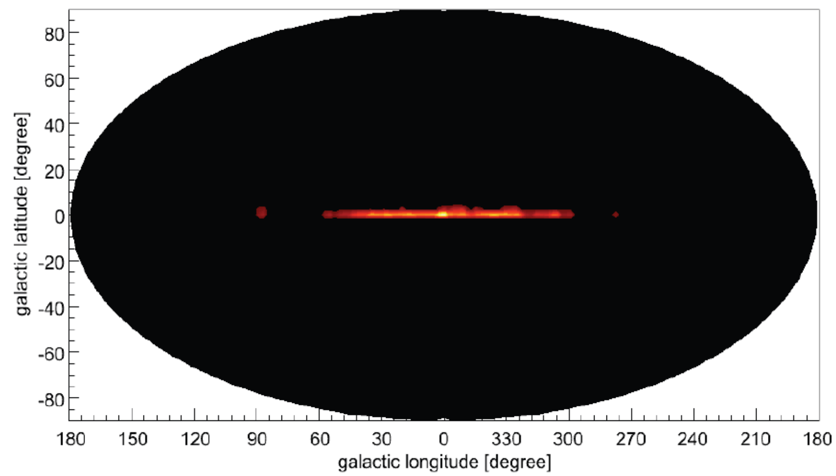
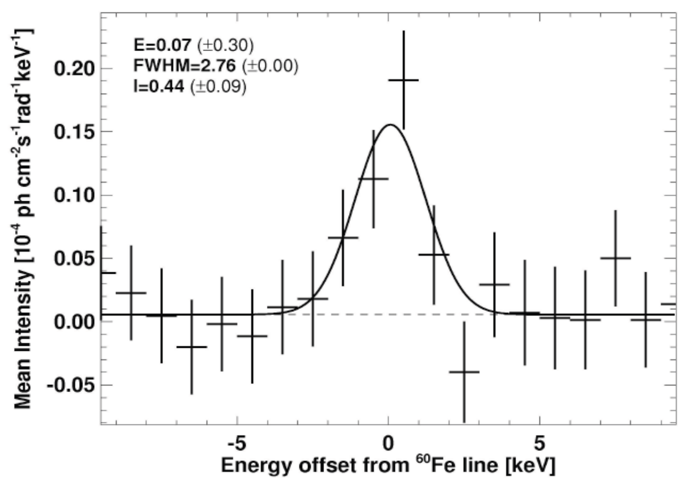
Spokesperson: Michael Wiescher
GSI contact: Michael Heil

Measurement of $^{59}Fe(n,\gamma)^{60}Fe$ using the Coulomb Dissociation Method



Detection of ^{26}Al and ^{60}Fe with the SPI spectrometer aboard ESA's INTEGRAL space mission.





Motivation

The observation of radioactive isotopes such as ^{18}F, ^{22}Na, ^{26}Al, ^{44}Ti, and ^{60}Fe in our galaxy is a direct measurement of stellar nucleosynthesis products.

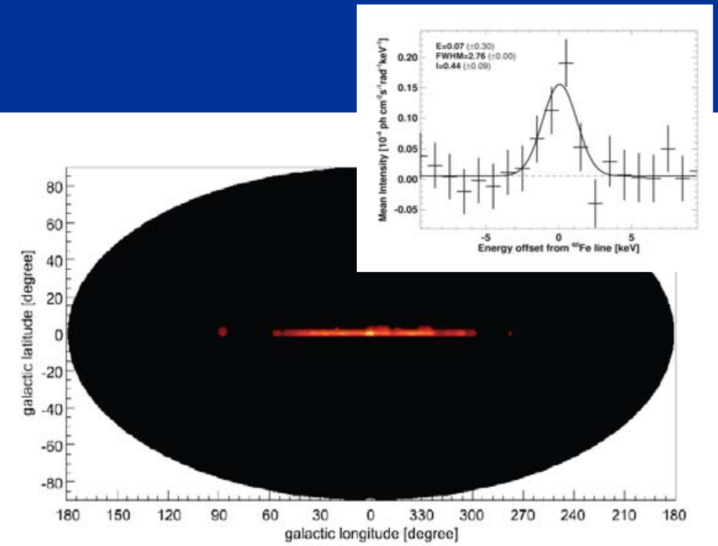
- The measured ratio of ^{60}Fe and ^{26}Al allows to test the complex models of massive-star nucleosynthesis.

Provided we know about the nuclear reaction rates for production and destruction of these isotopes we will get information on:

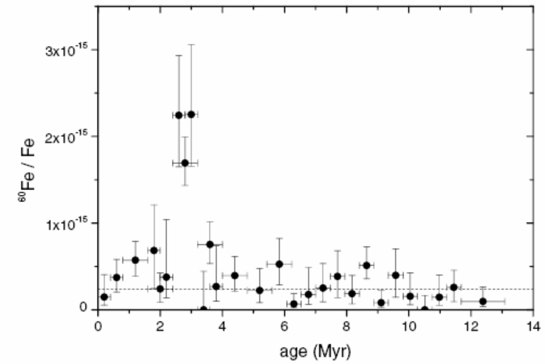
  - temperature
  - density
  - convection zones

inside stars and their

  - frequency.



Detection of ^{60}Fe with the SPI spectrometer aboard ESA's INTEGRAL space mission.



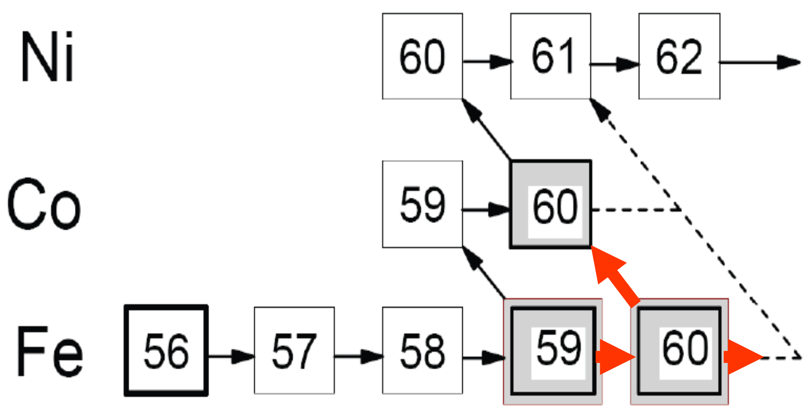
Detection of ^{60}Fe in layers of a Deep-Sea manganese crust with AMS gives evidence for a nearby SN 2.8 Myr ago at a distance of a few 10 pc.

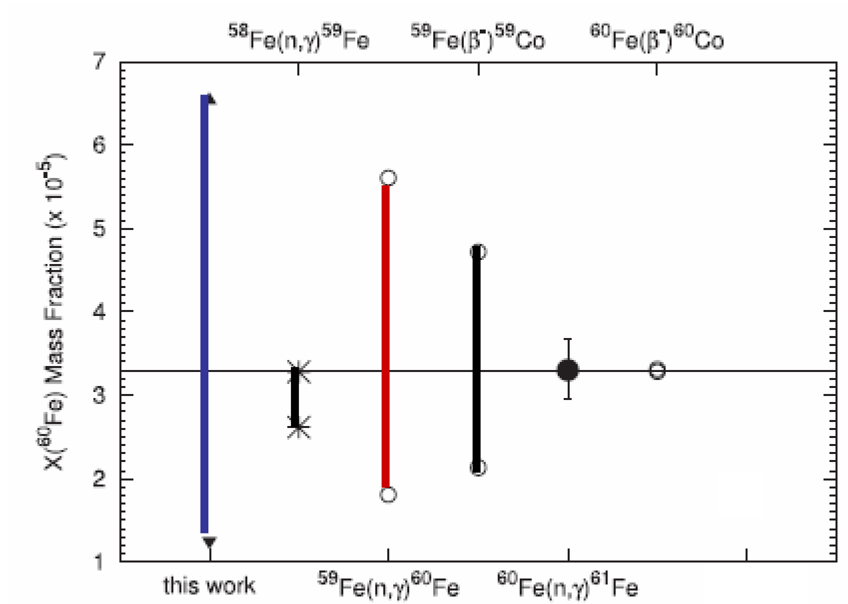
Production of ^{60}Fe in massive stars

^{60}Fe is produced in massive pre-supernovae stars by neutron capture reactions.

Requirement: We need to know the production and destruction mechanism of ^{60}Fe:

- Production by ^{59}Fe(n,γ)^{60}Fe
- Destruction by ^{60}Fe(n,γ)^{61}Fe, ß-decays, ^{60}Fe(γ,n)^{59}Fe

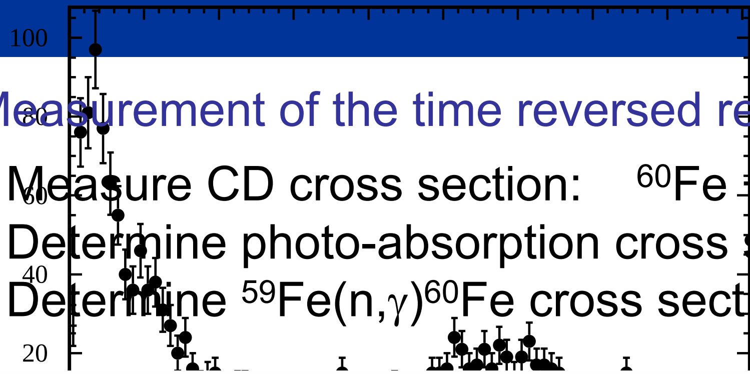




Production of ^{60}Fe depends most strongly on ^{59}Fe(n,γ)^{60}Fe

Direct laboratory investigation of the ^{59}Fe(n,γ)^{60}Fe not possible because of the relatively short lifetime of ^{59}Fe isotope ($T_{1/2}$=44.5 d).

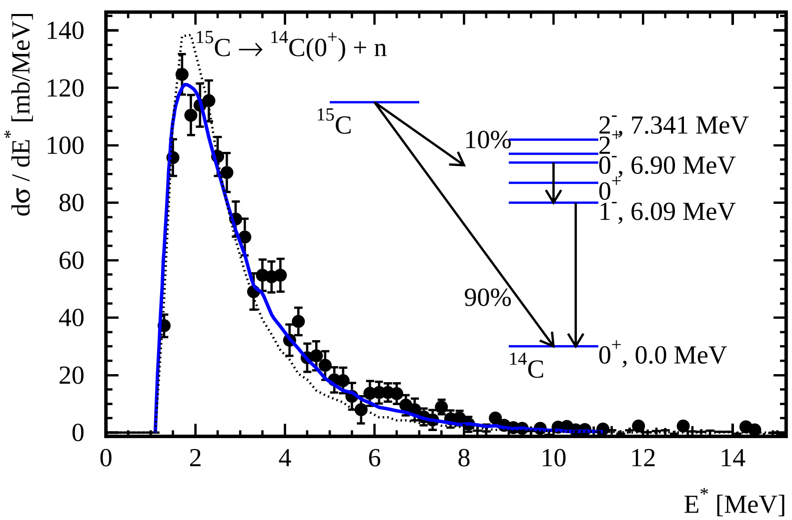
Experimental method

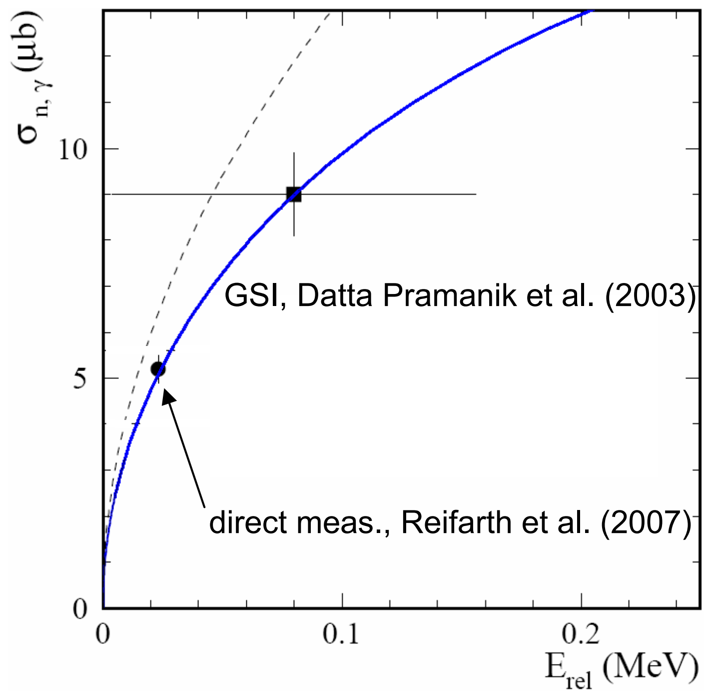


Measurement of the time reversed reaction using Coulomb breakup:

- Measure CD cross section: $^{60}Fe + ^{208}Pb \rightarrow ^{59}Fe + n + ^{208}Pb$ (CD)
- Determine photo-absorption cross section $\sigma_{(\gamma,n)}$
- Determine $^{59}Fe(n,\gamma)^{60}Fe$ cross section with detailed balance.

$$\sigma_{n,\gamma}(E_{\mathrm{rel}}) = \frac{(2j_a+1)}{(2j_b+1)(2j_n+1)} \frac{1}{\mu c^2} \frac{E_\gamma^2}{E_{\mathrm{rel}}} \sigma_{\gamma,n}$$

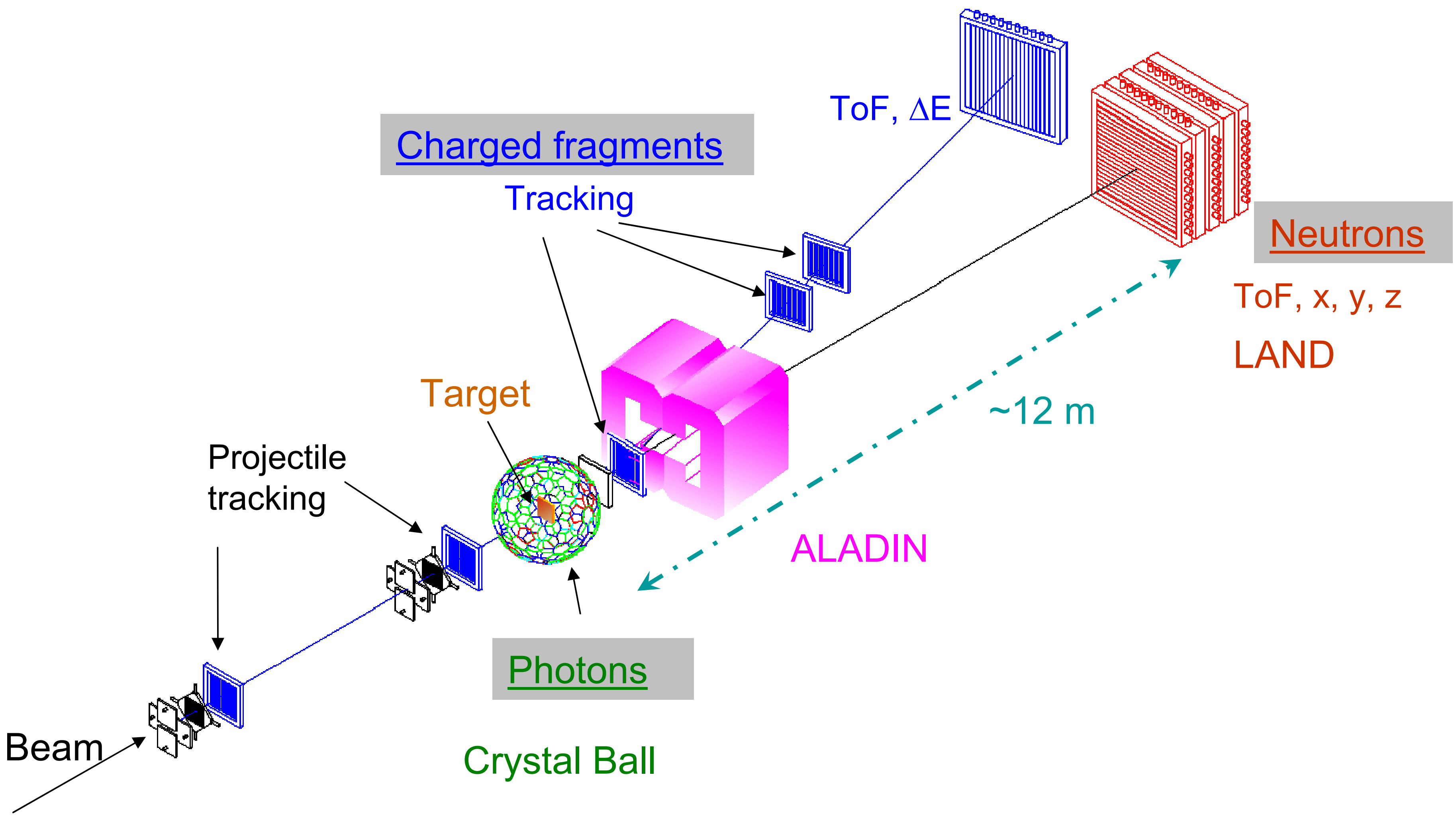




$^{60}Fe(\gamma,n)^{59}Fe$ is more complex and may require substantial corrections for γ-cascade patterns. Therefore, we propose to study also $^{59}Fe(\gamma,n)^{58}Fe$ and compare it to the (n,γ) measurements.

Experimental setup

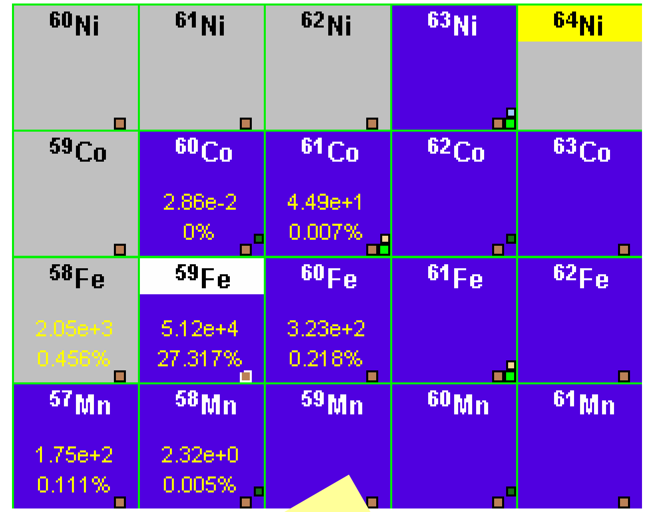
Standard ALADIN/LAND setup:



FRS settings

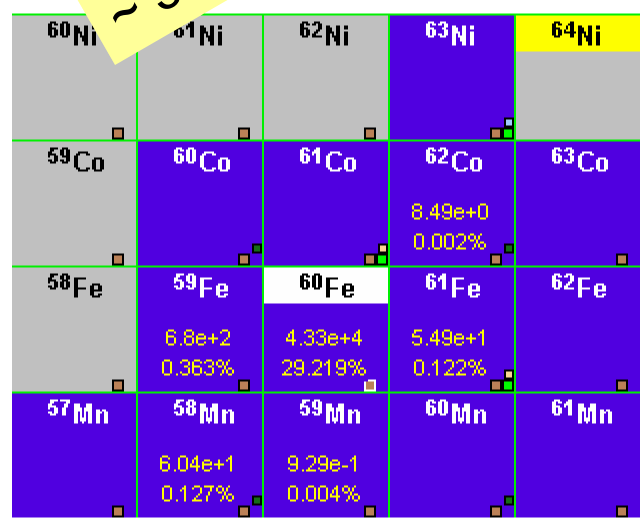
Primary beam: ^{64}Ni at 660 AMeV (1E8 pps)
Target: 2513 mg/cm2
S2: 3.250 mm
Wedge: 2000 mg/cm2 Al
S8: 1 mm
Beam energy on target 535 AMeV (Bρ=8.56 Tm)

~ 2-5E7 pps



~ 50000 1/s

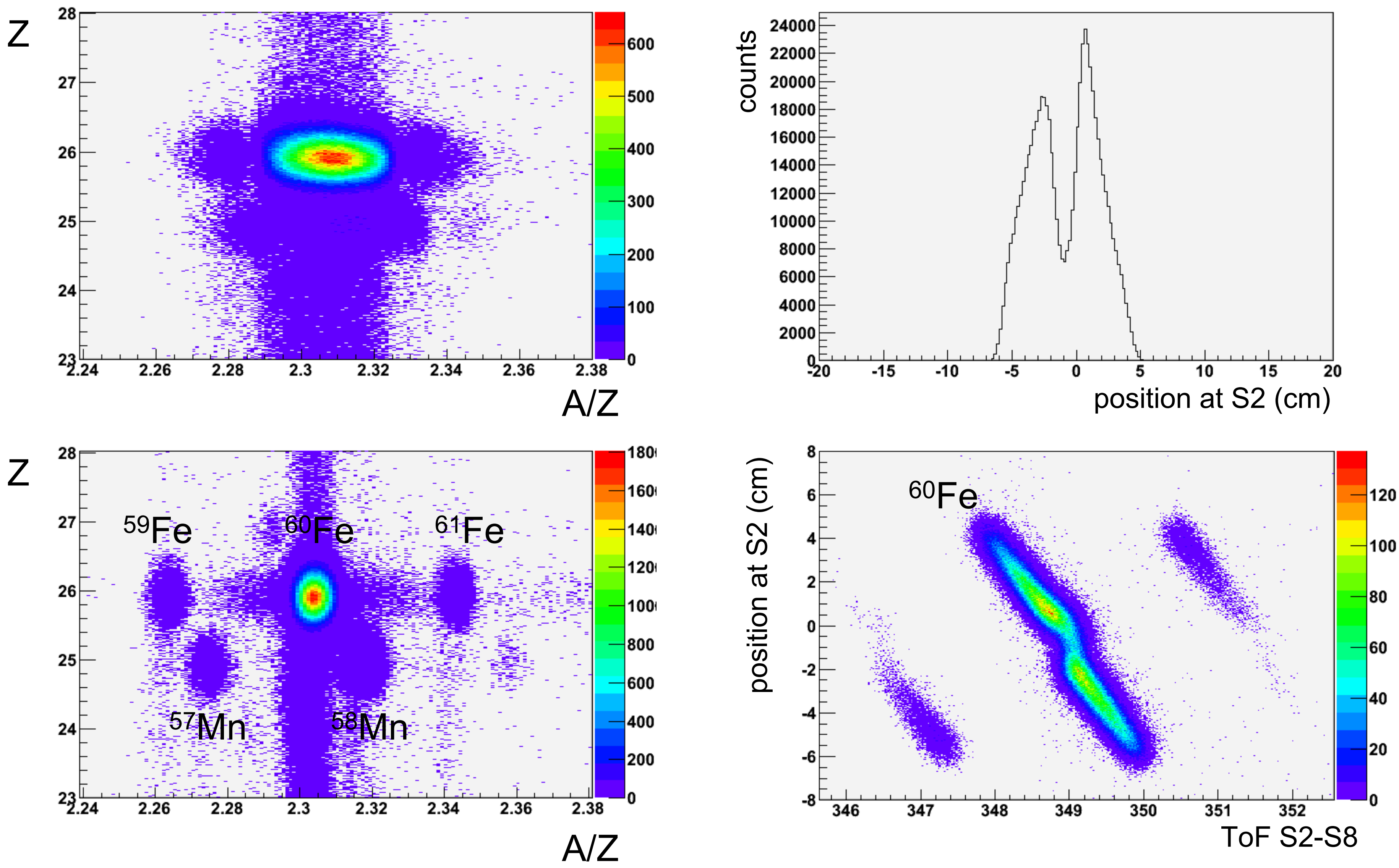
Important: Slits at S1: ± 35
Slits at S8: ± 20

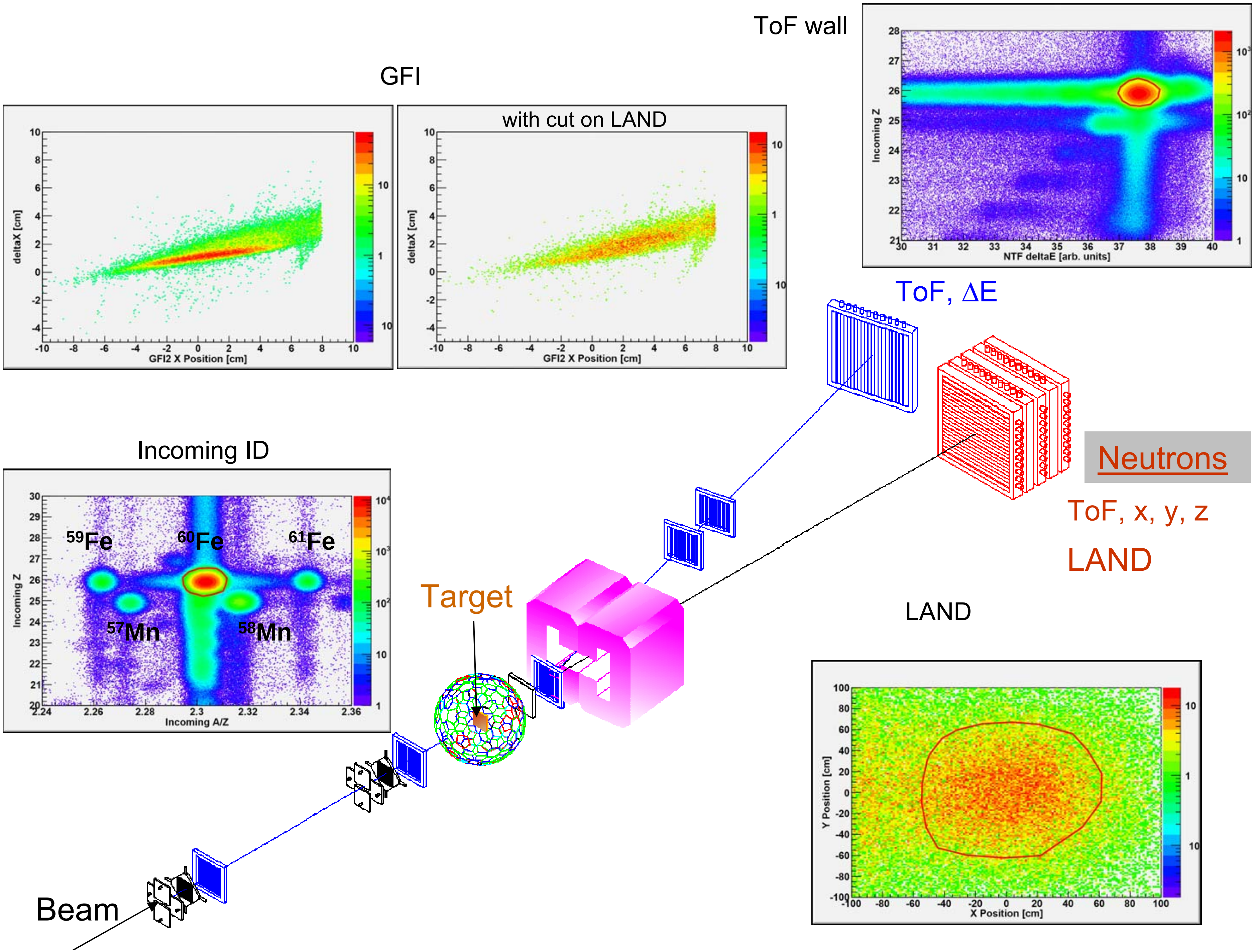


Count rate on S2 should be less than 1MHz in order to use S2 scintillator for position determination.

0.3-0.7 MHz

particle ID with position correction of S2





ToF wall
GFI
with cut on LAND
Incoming ID
59Fe
60Fe
61Fe
57Mn
58Mn
ToF, ΔE
Neutrons
ToF, x, y, z
LAND
Target
LAND
Beam
deltaX [cm]
GFI2 X Position [cm]
Incoming Z
NTF deltaE [arb. units]
Incoming A/Z
Y Position [cm]
X Position [cm]

Summary

- Successful experiment performed!
- This experiment will provide detailed information about the $^{60}Fe(\gamma,n)^{59}Fe$ dissociation cross section
- This experiment will provide detailed information about the strength of the ground state transition of the $^{59}Fe(n,\gamma)^{60}Fe$ capture reaction
- This experiment is part of a larger experimental effort:
  - $^{60}Fe(n,\gamma)^{61}Fe$ activation measurement at FZ Karlsruhe
  - ^{60}Fe half-life measurements at NSCL
  - The γ-decay of the unbound states in ^{60}Fe will be measured in a separate study using photo-excitation techniques at the DALINAC facility at the TU Darmstadt or the HIγS Facility at TUNL Duke University in collaboration with local groups
- PhD students: Tanja Heftrich and Ethan Uberseder