Development of multi-detector systems for radiation measurements at Simon Fraser University

Melanie Gascoine

Simon Fraser University
Department of Chemistry

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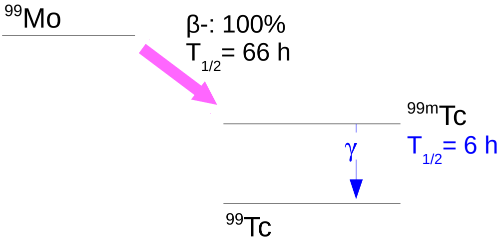
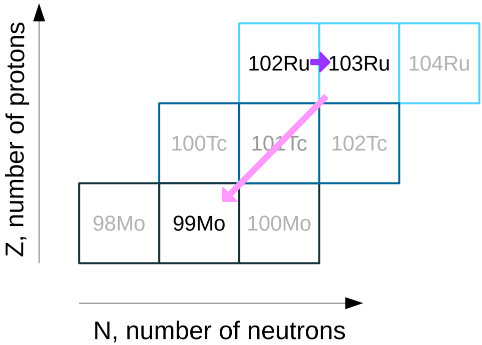
Production of ^{99}Mo

- ^{99}Mo is an isotope of interest because it decays to ^{99m}Tc, the most widely used radioisotope in medical diagnostic procedures



- Most commonly produced using thermal neutrons (∼25 meV) in nuclear reactors via fission reactions

- Production of ^{99}Mo via ^{102}Ru(n, α)^{99}Mo reaction
- Reaction is induced by the absorption of fast neutrons ($\sim$14.1 MeV)
- Irradiation of ^{nat}Ru with fast neutrons from neutron generator resulting in α emission to produce ^{99}Mo
- Separation of ^{99}Mo from target following irradiation

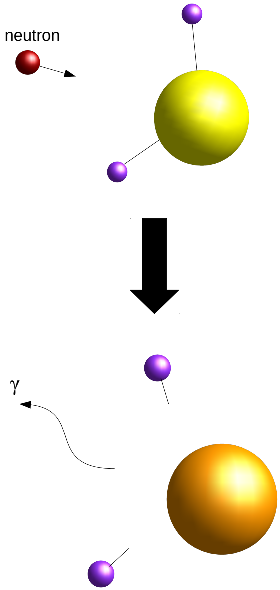


Neutron Generator facility

- Thermo scientific P-385 deuterium-tritium neutron generator
- $^2H + ^3H \rightarrow n + ^4He$
- Emits neutrons of energy 14.1 MeV with a nominal flux of 3×10^8 neutrons/second.

Szilard Chalmers reaction

- Discovered in 1934
- Thermal neutrons to induce an (n,γ) reaction
- Upon the emission of a gamma ray, the nucleus recoils with sufficient energy to break the intermolecular forces holding the molecule together
- This also occurs during the emission of α or β particles, or during the absorption of nucleons (protons and neutrons)

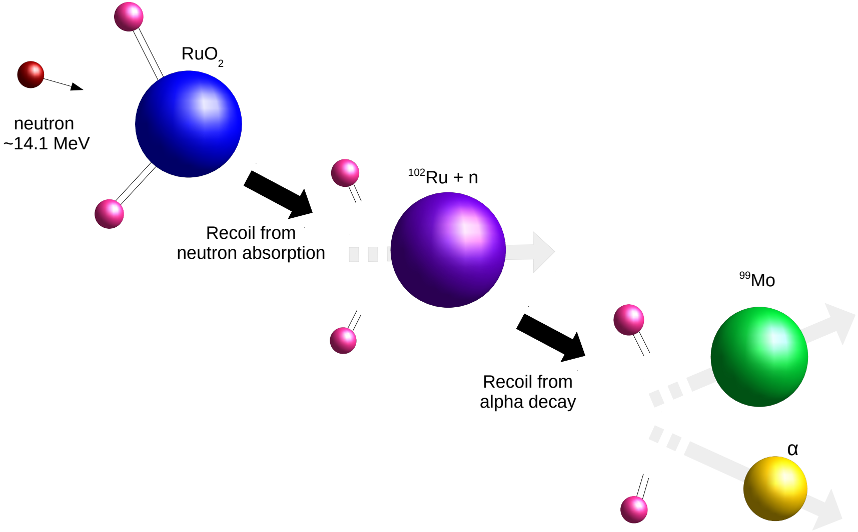


L. Szilard, T.A. Chalmers, Nature **134**, 462 (1934)

Project comparison to Szilard Chalmers reaction

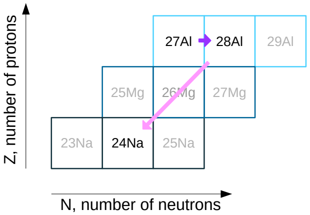
	Szilard Chalmers	**Production of ^{99}Mo**
Reaction	(n, γ)	(n, α)
Neutron energy	25 meV	14.1 MeV
Neutron Flux	high	low
Recoil energy	low	high
Final product	Chemically the same	Chemically different

Nuclear recoil

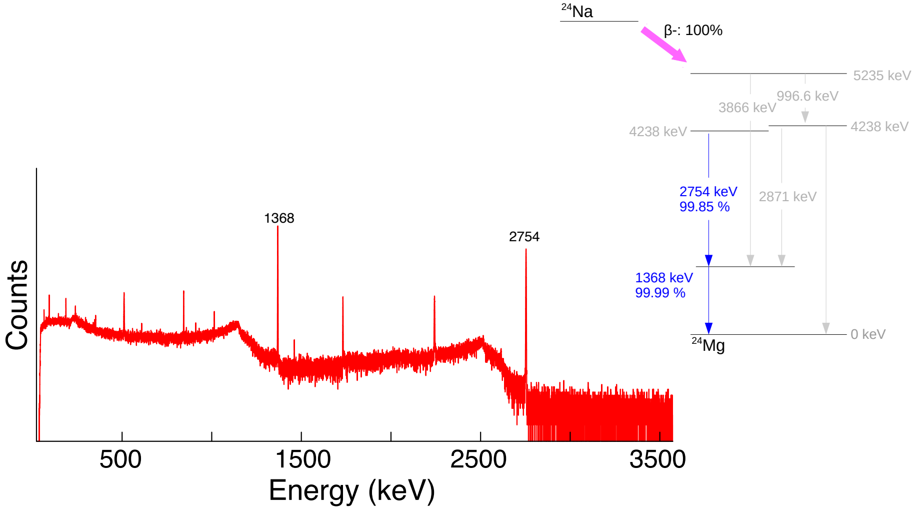


Recoil of product into solution

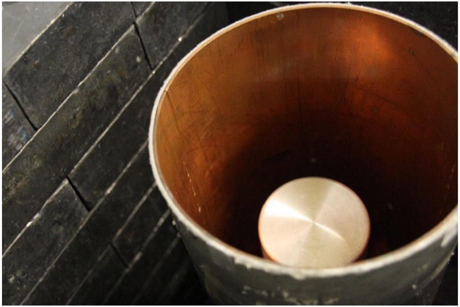
- $^{27}Al(n, \alpha)^{24}Na$ undergoes same reaction as $^{102}Ru(n, \alpha)^{99}Mo$
- ^{27}Al has been used in preliminary studies to quantify the effects of nuclear recoil

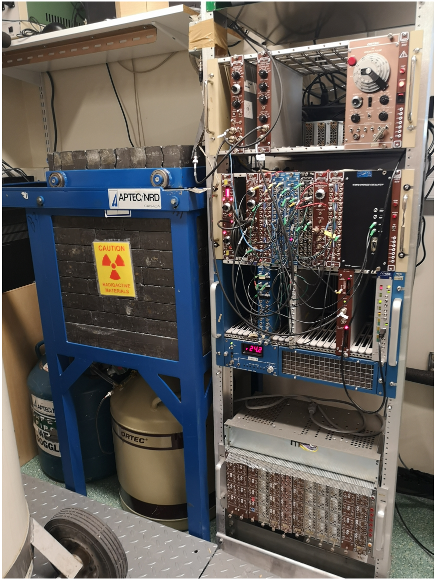


Quantifying results - Gamma ray spectroscopy



GEARS

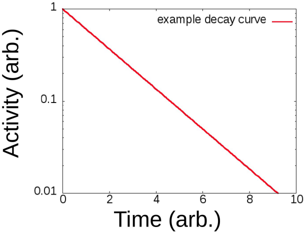




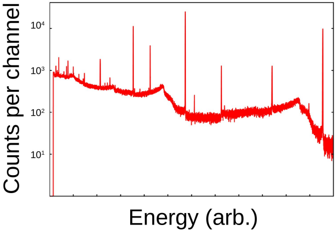
- High Purity Germanium (HPGe) operates at liquid nitrogen temperatures (<100 K)
- Passive shielding in lead box
- Data acquisition includes timing information

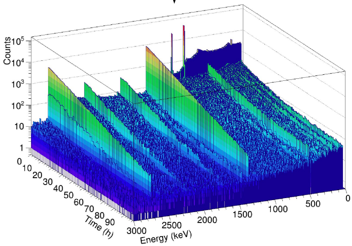
Time resolved spectroscopy

Timing Response



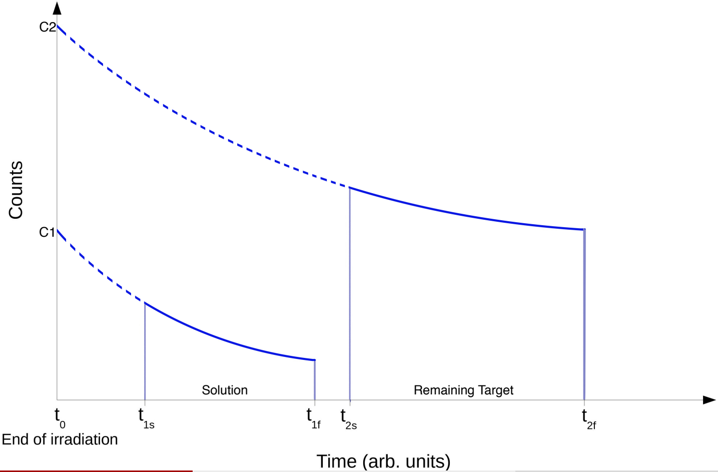
Energy Response





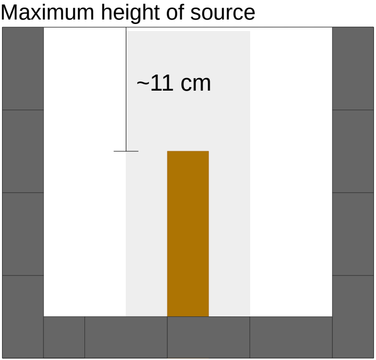
Aluminum experiment

- Irradiated 7.4 g of Aluminum oxide powder for 1 h. Activity at the end of irradiation was 15.4 kBq
- Recoil and centrifugation gave separation factor of 8%

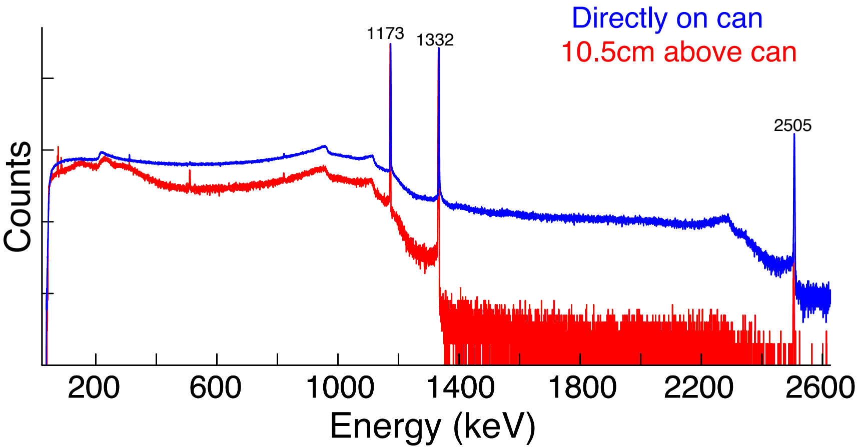


Developing another detection system

- Multiple detectors for simultaneous measurements.
- Longer detection time improves counting statistics and accuracy
- Unable to improve detector sensitivity of GEARS
- Source position and size is limited within GEARS



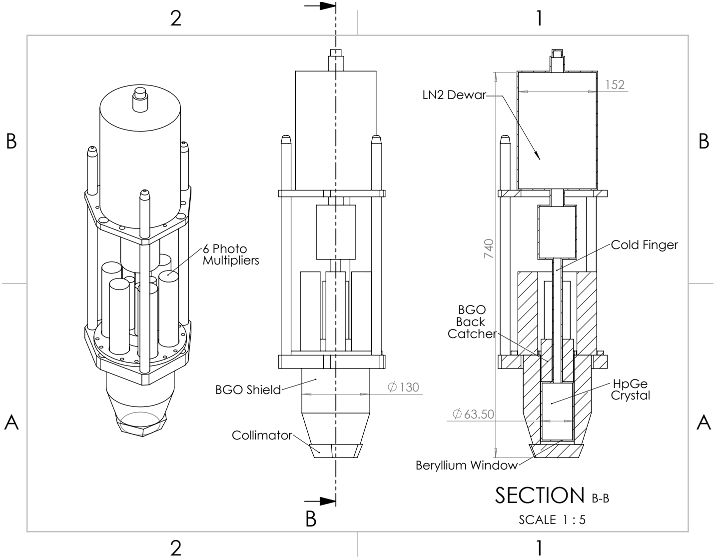
60Co in two positions



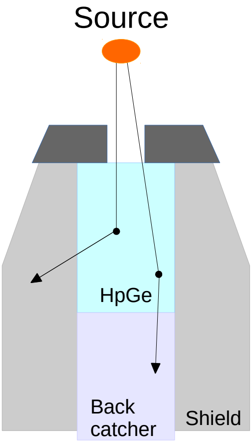
Compton suppressed spectrometer (CSS)

- HpGe detector
- BGO shield optically coupled to 6 photomultipliers
- 2 BGO back catchers
- Allows for active shielding of partial energy deposits
- Reduce background at low energies to improve detection limit at energy lower than a few 100 keV

Compton suppressed spectrometer



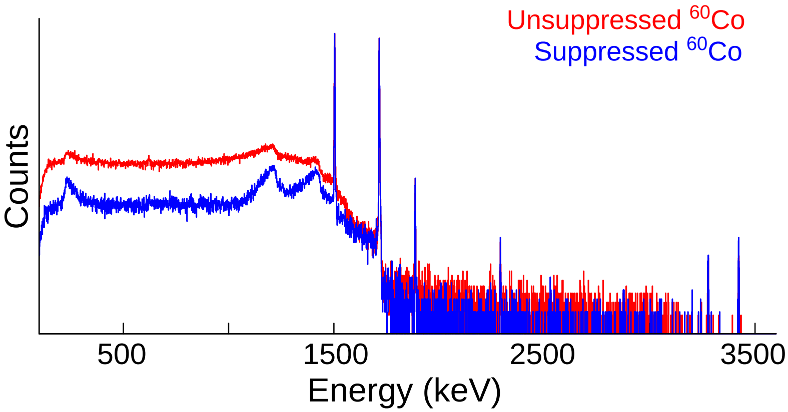
Active Shielding - time coincidence method



- Partial energy deposits are detected by the HPGe, as well as either shield or back catchers
- Time coincidence occurs when multiple signals are registered at the same time
- Signals in the HPGe that are in time coincidence with signals in either the shield or back catcher are rejected

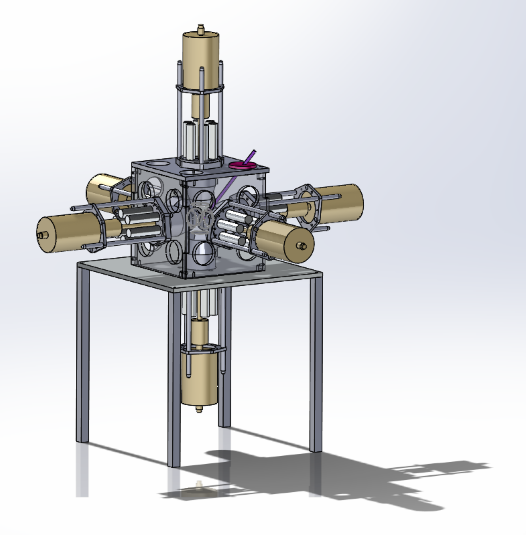
CSS table

CSS table - suppressed vs. unsuppressed spectra



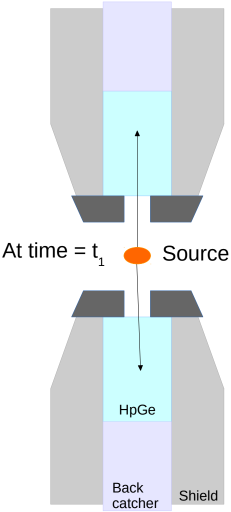
CSS table

Building up the CSS Cube



- 6 CSS's with source position in the center
- Full coverage on 6 sides will improve sensitivity while increasing signal to noise ratio
- Can use time coincidence method for detection as well as active shielding

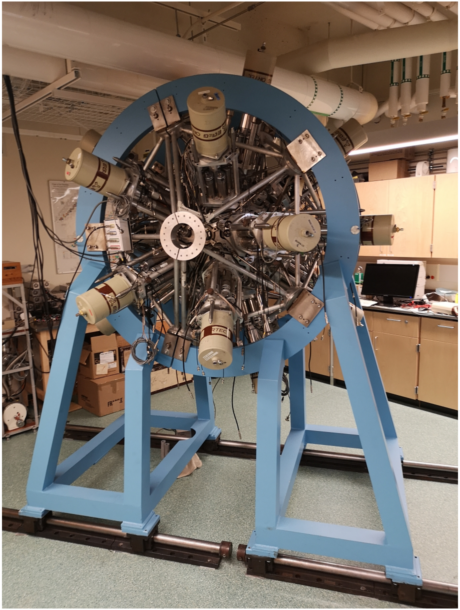
Multi detector systems - time coincidence



- Coincidence occurs when gamma rays are detected at the same time in separate spectrometers
- Signals in coincidence are accepted, those that are not get rejected

8π at SFU

- 21 HPGe detectors (20-30% efficiency)
- 20 BGO shields
- 21 pairs of BGO back-catchers
- 21 CSS: high resolution low efficiency outer layer
- BGO Ball: high efficiency low resolution inner layer
- 4π coverage from CSS + 4π coverage from BGO ball



Future work

- Time coincidence method in multi detector system allows for the detection of very weak signals
- Explore different reactions; as the number of nucleons increases, the reaction yield decreases
- Higher sensitivity will allow for the observation of weaker signals that are produced in lower yield reactions

Acknowledgements

Collaborators

K. Starosta, E.J. Williams, A. Redey, K. Van Wieren, F. Wu

SFU machine shop

SFU electronics shop