Development of multi-detector systems for gamma-ray coincidence measurements

Melanie Gascoine

Simon Fraser University
Department of Chemistry

WNPPC 2020, Banff, AB
February 14 2020

NSERC CRSNG

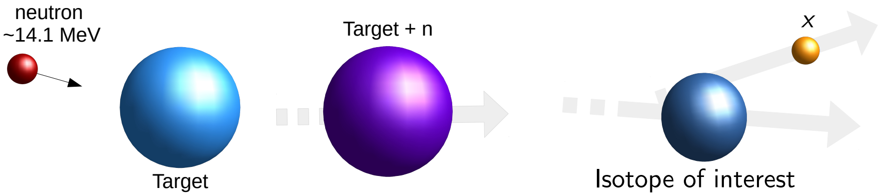
SFU SIMON FRASER UNIVERSITY
ENGAGING THE WORLD

CINP ICPN Canadian Institute of Nuclear Physics
Institut canadien de physique nucléaire

Production of radioactive sources via neutron irradiation

- Thermo Fisher Scientific P-385 deuterium-tritium neutron generator
- $^{2}H + ^{3}H \rightarrow n + ^{4}He$
- Emits neutrons of energy 14.1 MeV at 3×10^{8} neutrons/second.

Production of radioactive sources via neutron irradiation



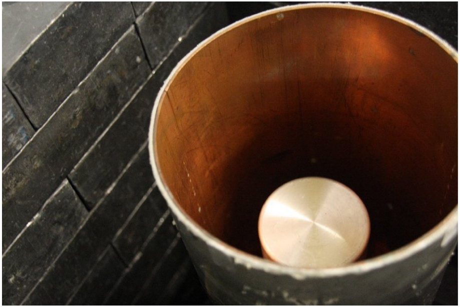
- Induce (n, x) reactions to produce isotopes of interest
- Analyze reaction products using γ-ray spectroscopy

Experimental program

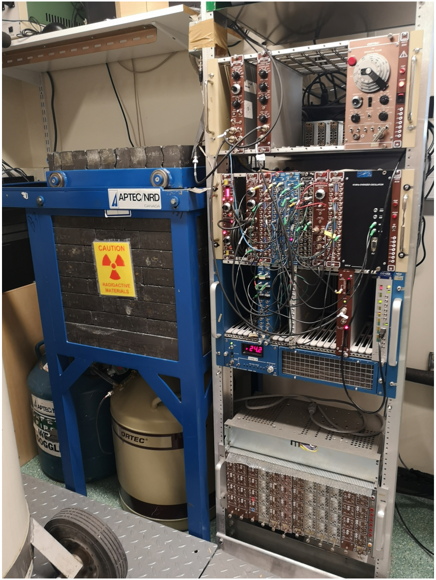
- Isotope production
  - Neutron generator as a source of nuclear reactants
- Neutron activation analysis
  - Elemental analysis
- Nuclear structure studies
  - Characterization of unknown excited states
- Environmental radioactivity monitoring
  - Fukishima Daichii fallout since 2011

γ-ray spectroscopy is an analytical technique used for all above components of the experimental program.

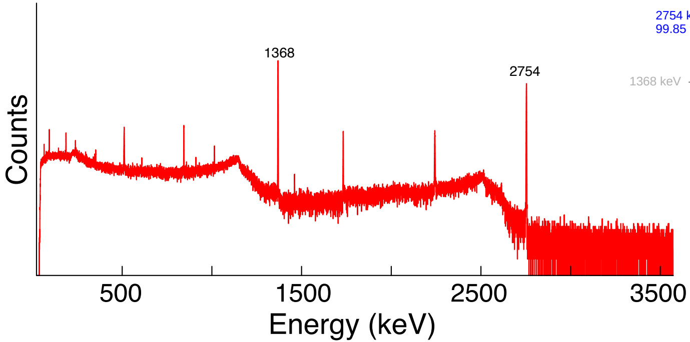
GEARS

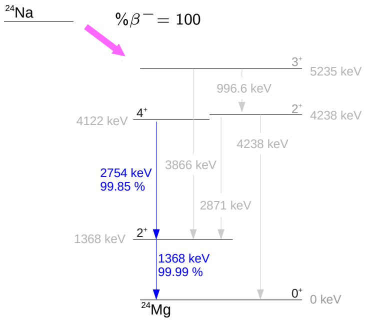


- High Purity Germanium (HPGe) operates at liquid nitrogen temperatures (<100 K)
- Passive shielding in lead box
- Data acquisition includes timing information



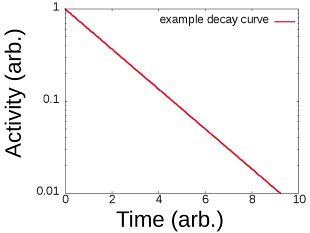
Quantifying results - Gamma ray spectroscopy



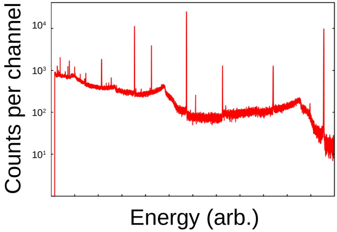


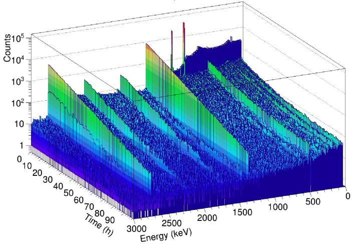
Time resolved spectroscopy

Timing Response



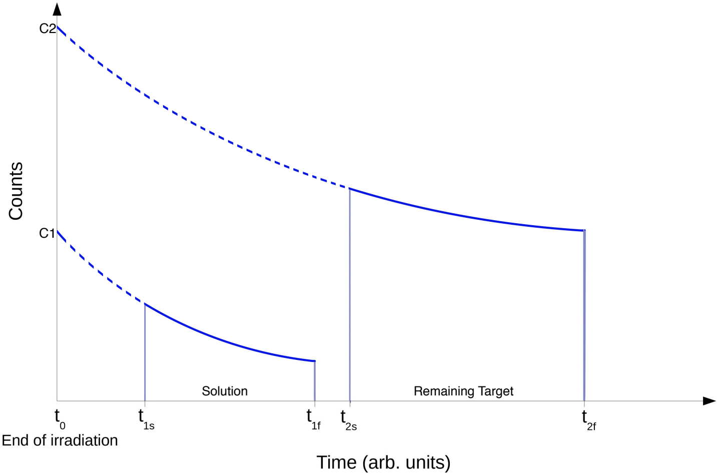
Energy Response





Time resolved spectroscopy

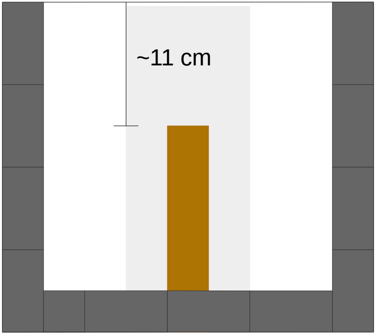
$$\text{Activity} \propto counts = C(t) = C_i e^{-\frac{ln(2)}{t_{1/2}} t}, \quad i = 1, 2$$



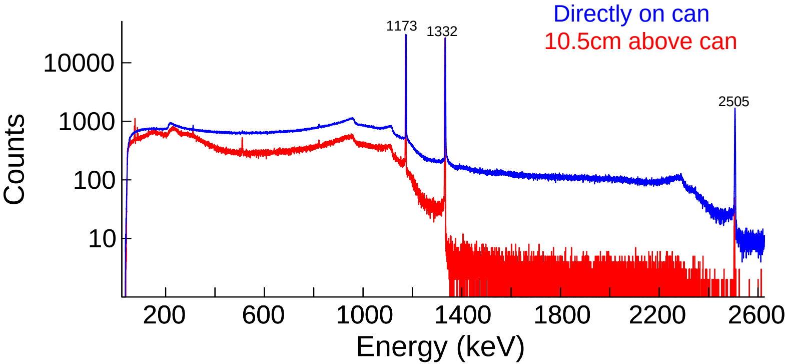
Developing an improved detection system

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

Maximum height of source



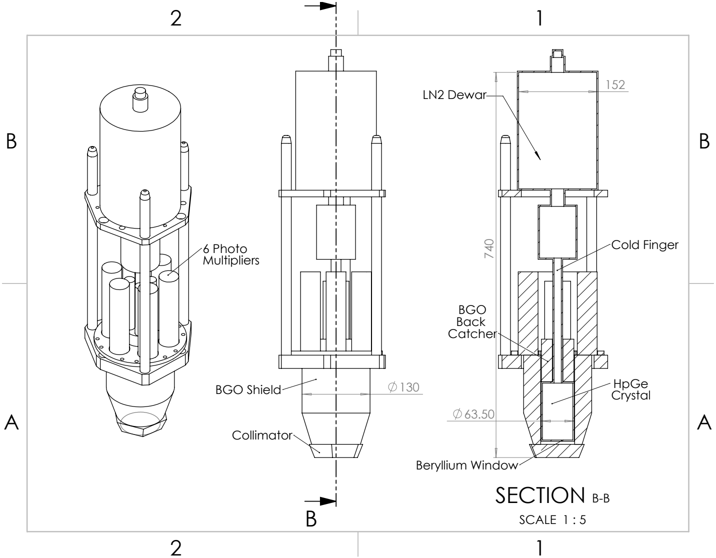
^{60}Co in two positions



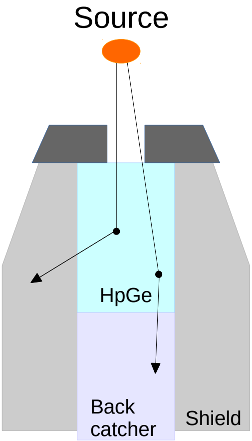
Compton suppressed spectrometer (CSS)

- HPGe detector
- Bismuth Germanium Oxide (BGO) shield optically coupled to 6 photomultipliers
- 2 BGO back catchers
- Allows for active shielding of partial energy deposits
- Reduce background and improves detection sensitivity at low energies

Compton suppressed spectrometer

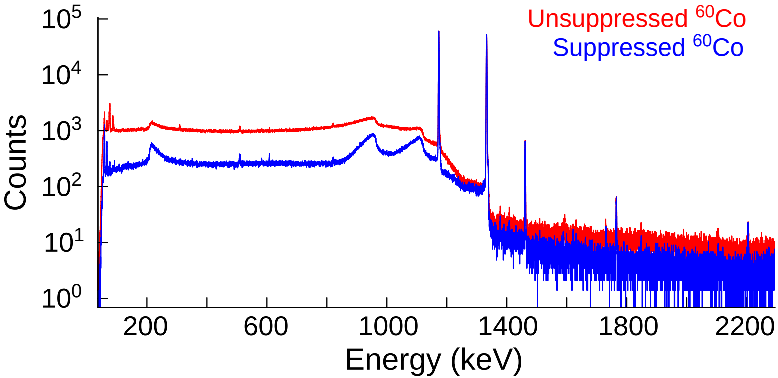


Time coincidence method - active shielding

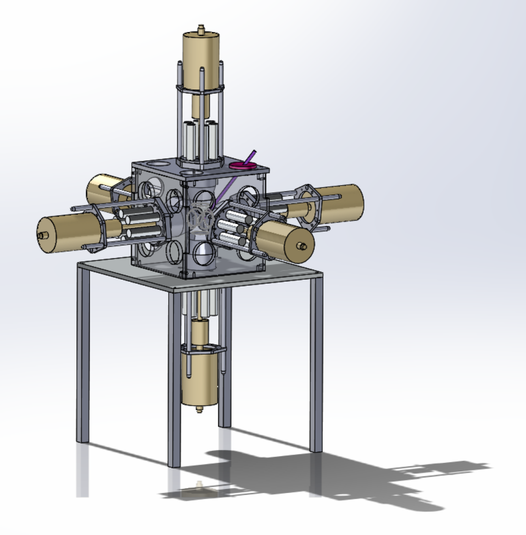


- Partial energy deposits are detected by the HPGe, as well as either shield or back catchers
- Time coincidence occurs when multiple signals are registered at the same time
- Signals in the HPGe that are in time co-incidence with signals in either the shield or back catcher are rejected

^{60}Co - suppressed vs. unsuppressed spectra

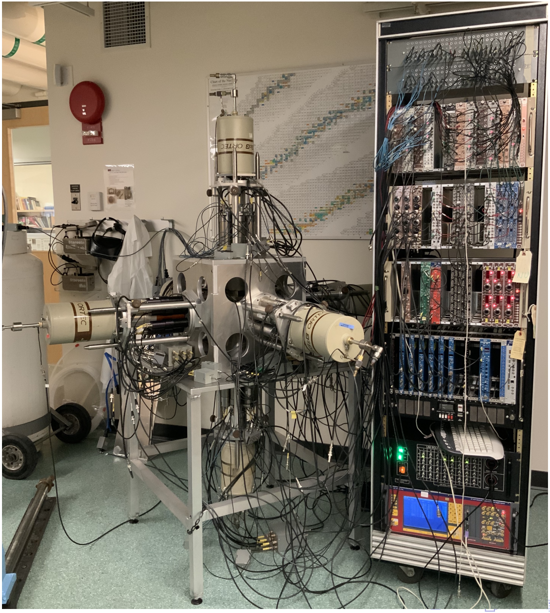


Building up the CSS Cube

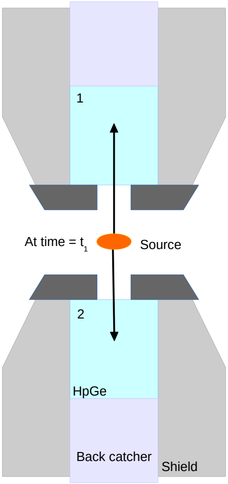


- 6 CSS's with source position in the center
- Coverage on 6 sides will improve sensitivity while increasing signal to noise ratio
- Can use time coincidence method for detection as well as active shielding

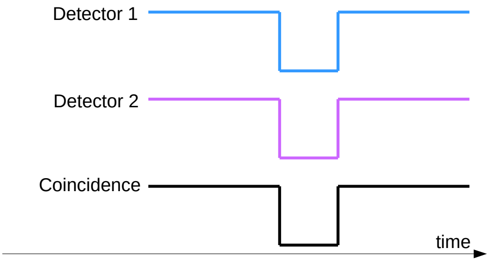
CUBE



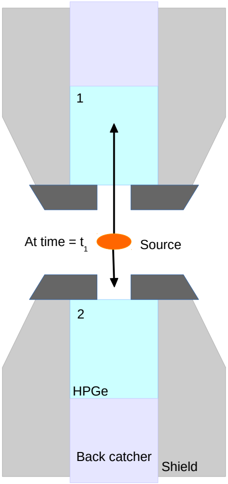
Multi detector systems - time coincidence



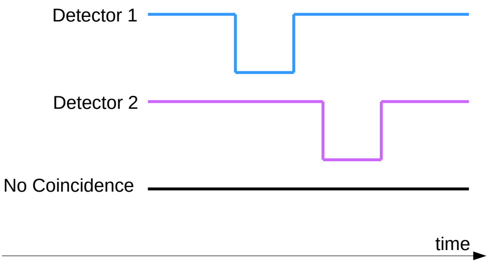
- Coincidence occurs for gamma rays detected at the same time in separate components of the spectrometer
- Signals in coincidence are accepted, those that are not get rejected



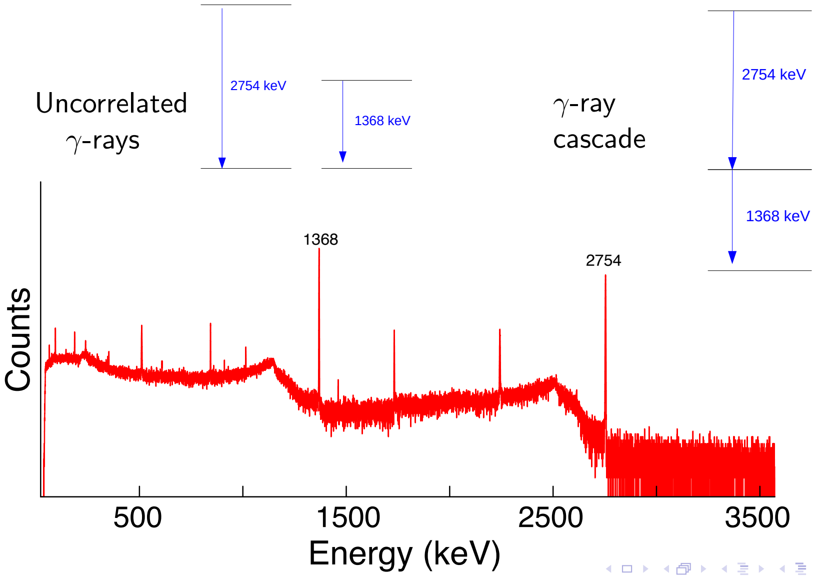
Multi detector systems - time coincidence



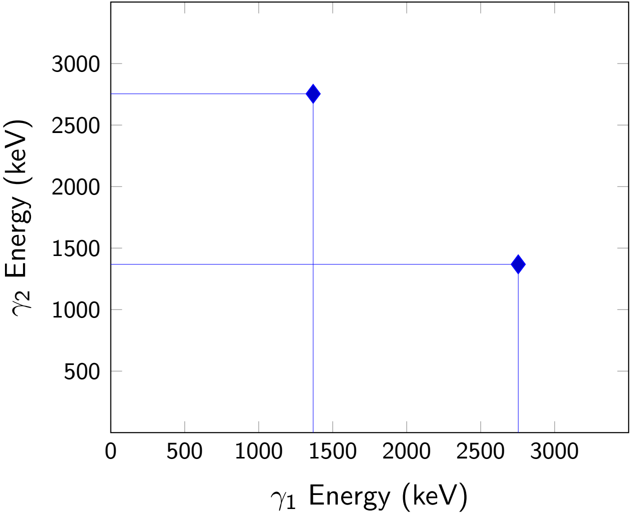
- Coincidence occurs for gamma rays detected at the same time in separate components of the spectrometer
- Signals in coincidence are accepted, those that are not get rejected



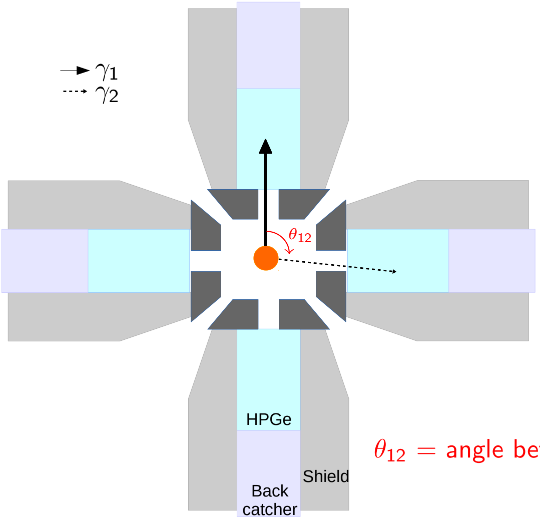
2-D spectroscopy



2-D spectroscopy



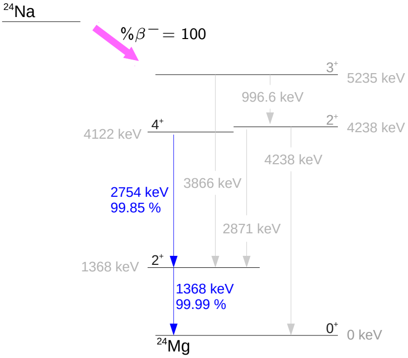
Angular correlation measurements



θ_{12} = angle between γ_1 and γ_2

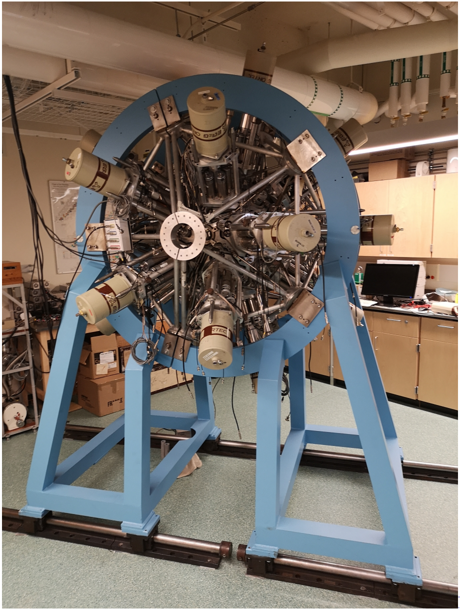
Angular correlation measurements

- For a newly observed γ-ray cascade
- Examine angular distribution of the number of events vs. θ_{12}
- Compare resulting plot to simulations to determine the multipolarity of γ-rays
- Use conservation of angular momentum to determine spin and parity of unknown excited states



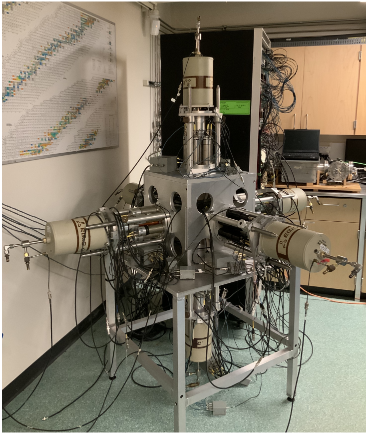
Rebuilding the 8π at SFU

- 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



Summary

- γ-ray spectroscopy is a necessary analytical tool for nuclear science
- Development of multi-detector systems significantly improves detection capabilities in γ-ray measurements
- This broadens the scope and provides new opportunities for fundamental and applied nuclear science at SFU



Acknowledgements

Collaborators

K. Starosta, E.J. Williams, A. Redey, K. Van Wieren, F. Wu, S. Srivastava, M. Martin

SFU machine shop

SFU electronics shop

NSERC CRSNG

SFU SIMON FRASER UNIVERSITY
ENGAGING THE WORLD

CINP ICPN
Canadian Institute of Nuclear Physics
Institut canadien de physique nucléaire