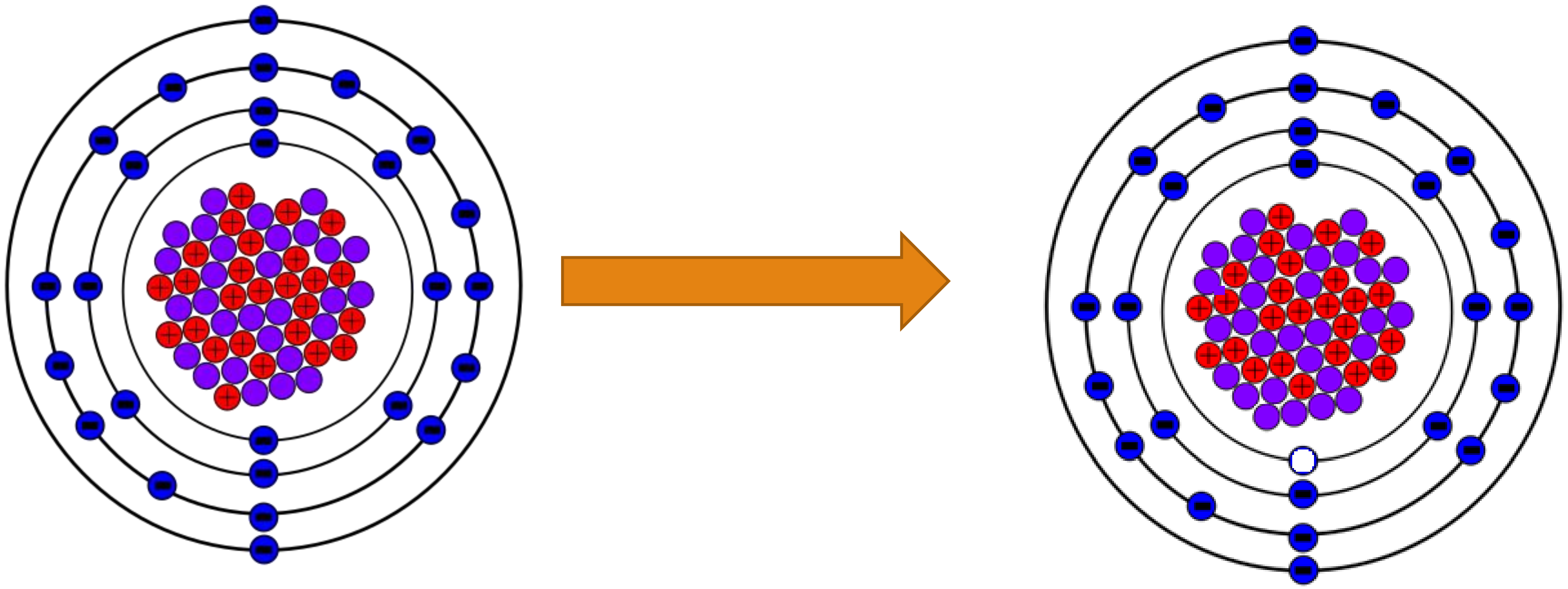
Study of Deexcitation Intensities to the K-Shell in Iron 55

ERIC HELGEMO

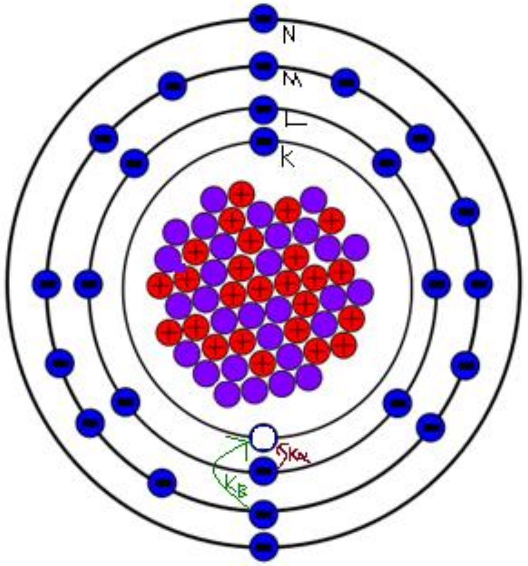
The Physics: Electron Capture



Fe55 Mn55

The Physics: Deexcitation Intensities

Transition Type	Value	Error
$K\alpha_1$	16.2% ± 0.7	± 4.3%
$K\alpha_2$	8.2% ± 0.4	± 4.9%
$K\beta_1$	1.89% ± 0.09	± 4.8%
$K\beta_3$	0.96% ± 0.05	± 5.2%
Emission Ratio	8.6 ± 0.8	± 9.3%



Dataset #1:

Author: Huo Junde Citation: Nuclear Data Sheets 109, 787 (2008)

Parent Nucleus	Parent E(level)	Parent Jπ	Parent $T_{1/2}$	Decay Mode	GS-GS Q-value (keV)	Daughter Nucleus		
$^{55}_{26}Fe$	0.0	3/2-	2.744 y 9	ε: 100 %	231.21 18	$^{55}_{25}Mn$	Decay Scheme	ENSDF file

Electrons:

	Energy (keV)	Intensity (%)	Dose (MeV/Bq-s)
Auger L	0.61	139.9 % 14	8.53E-4 8
Auger K	5.19	60.1 % 8	0.00312 4

Gamma and X-ray radiation:

	Energy (keV)	Intensity (%)	Dose (MeV/Bq-s)
XR l	0.64	0.66 % 10	4.2E-6 6
XR kα2	5.888	8.2 % 4	4.85E-4 21
XR kα1	5.899	16.2 % 7	9.6E-4 4
XR kβ1	6.49	1.89 % 9	1.23E-4 6
XR kβ3	6.49	0.96 % 5	6.3E-5 3
	126.0 1	1.280E-7 % 20	1.61E-10 3

Applications

- X-Ray Telescope Flux Calibrations
  - Error Reduction

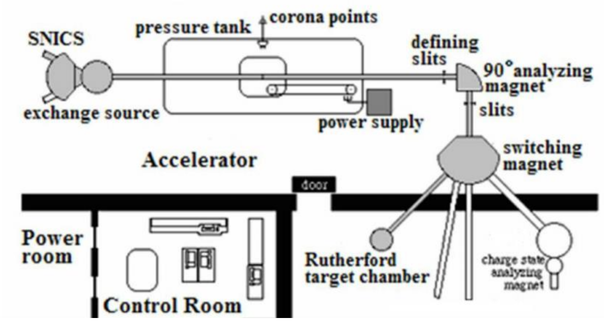
- Examples of experiments this error reduction applies to:
  - Verifying Hubble Constant Value
  - Improve accuracy for NICER measurements of neutron star radii
  - Test massive neutrinos as a source of cold dark mater that is causing of the disagreement between CMB measurements and measurements obtained through observing clusters of galaxies or just error in the measurements

Target Generation

- Foil
  - 98.7% Purity
  - 10 µm thick Mn layer
  - 125 µm thick polyester support layer

- Frame:
  - Calcium

Procedure: Getting a Fe55 Source



$$t = \frac{-1}{\lambda} ln\left(1 - \frac{A}{\Phi n \sigma}\right)$$

A = Activity of Fe55(in becquerel)

Φ = beam intensity (protons per second)

n = number of Mn55 targets per cm^2

σ = Mn55(p, n)Fe55 cross section

$\lambda = \frac{ln(2)}{T_{1/2}}$ where $T_{1/2}$ = 2.737 years is the half life of Fe55

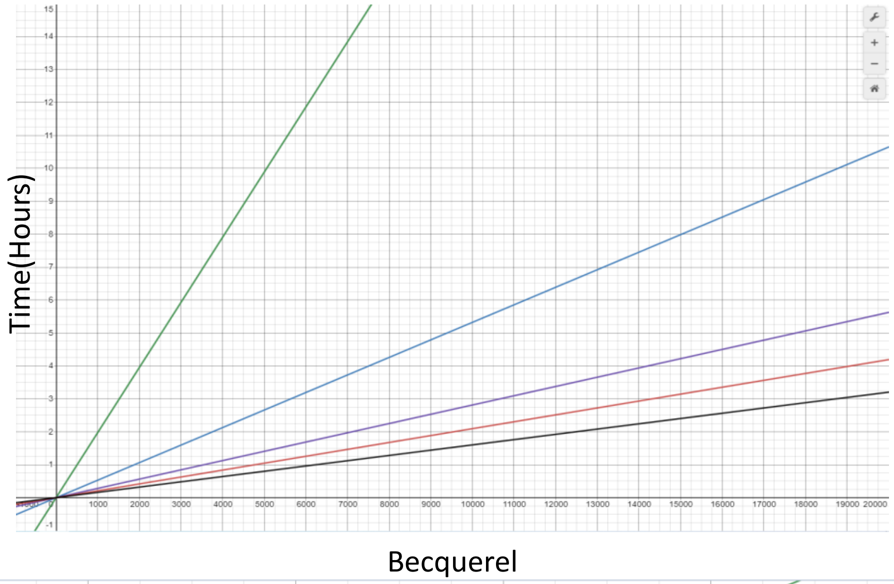
Green: 3 MeV

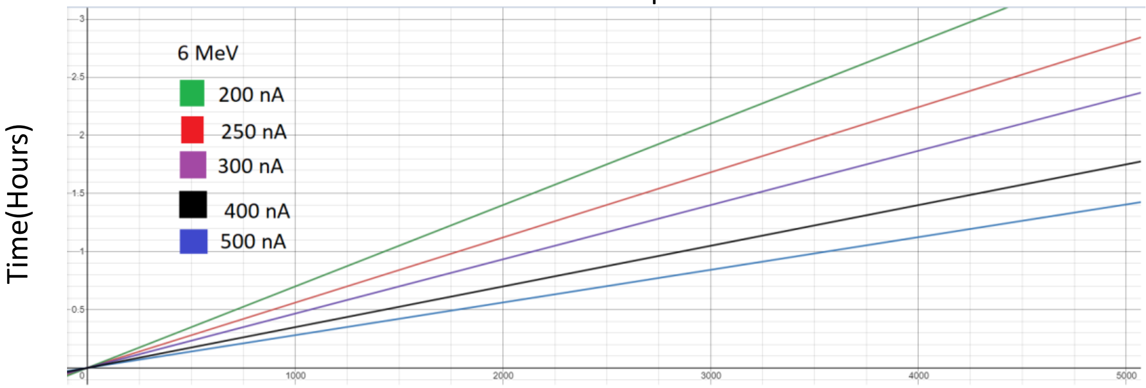
Blue: 4 MeV

Purple: 5 MeV

Red: 6 MeV

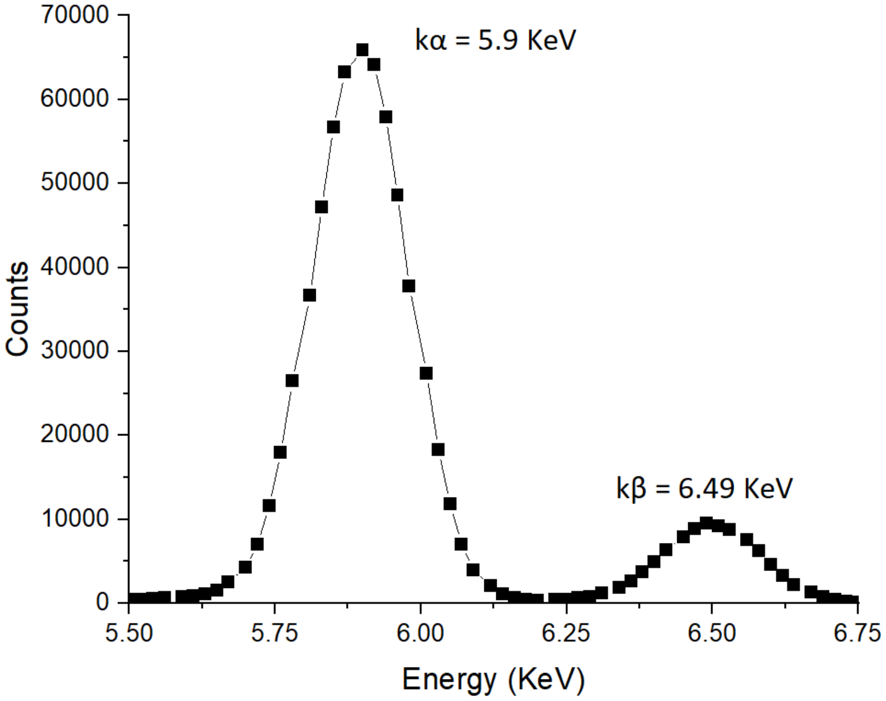
Black: 11 MeV

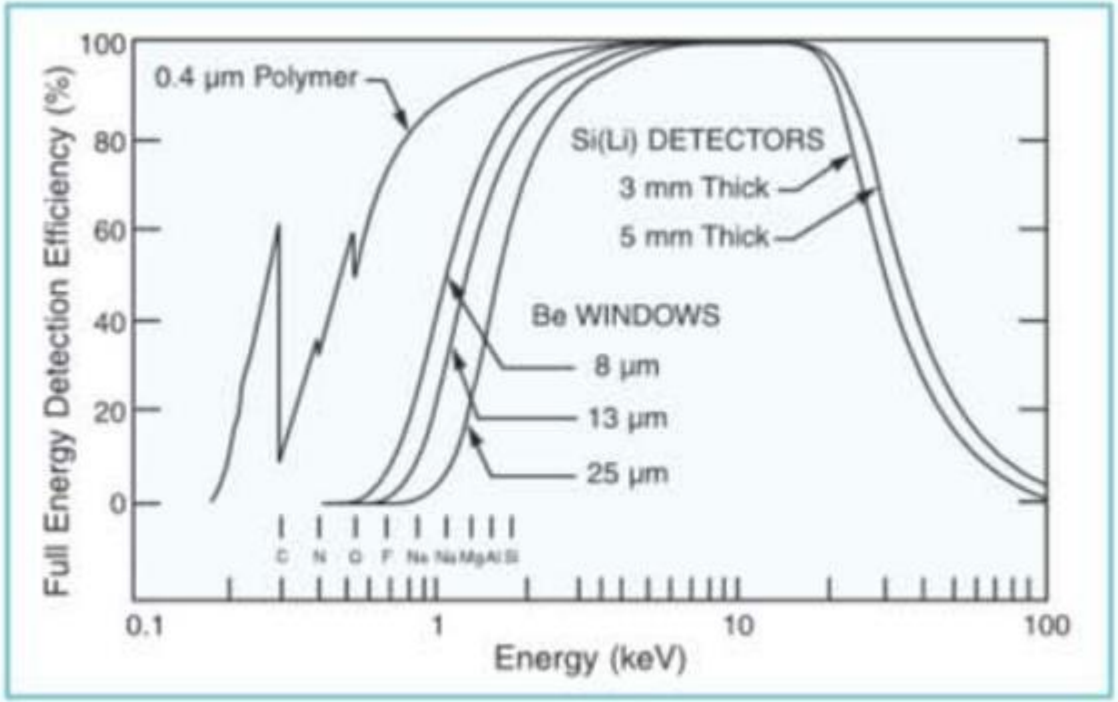




Procedure: Measurement/Analysis

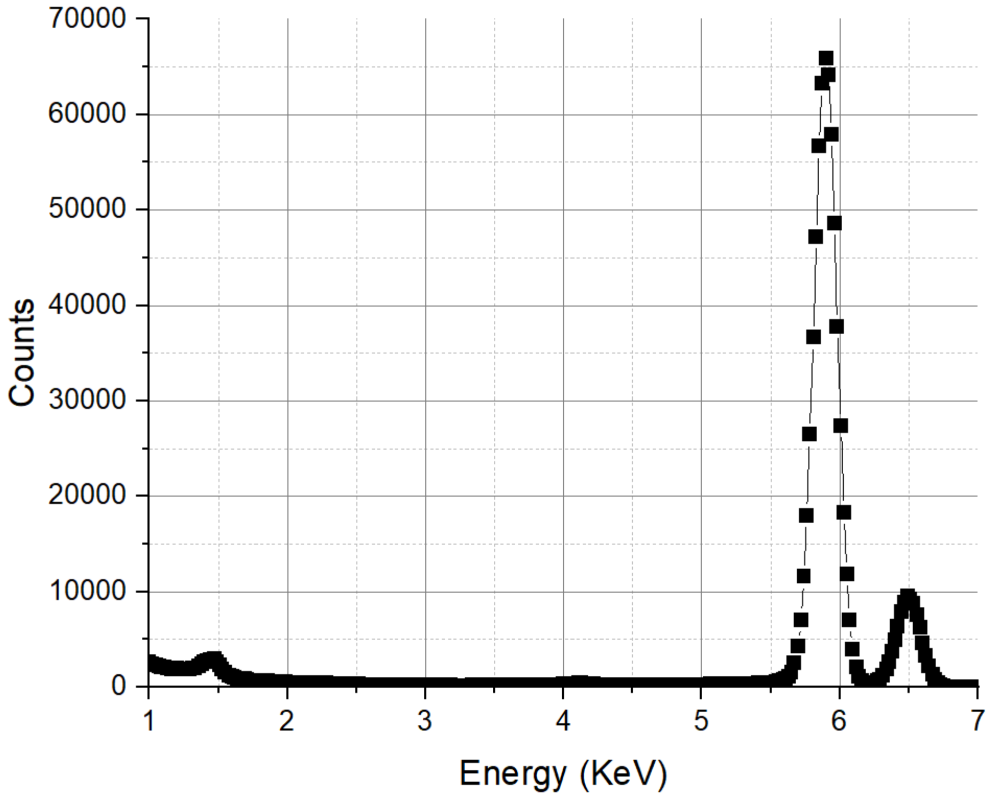
- Cosmic Radiation contributes to error
  - Active Shielding

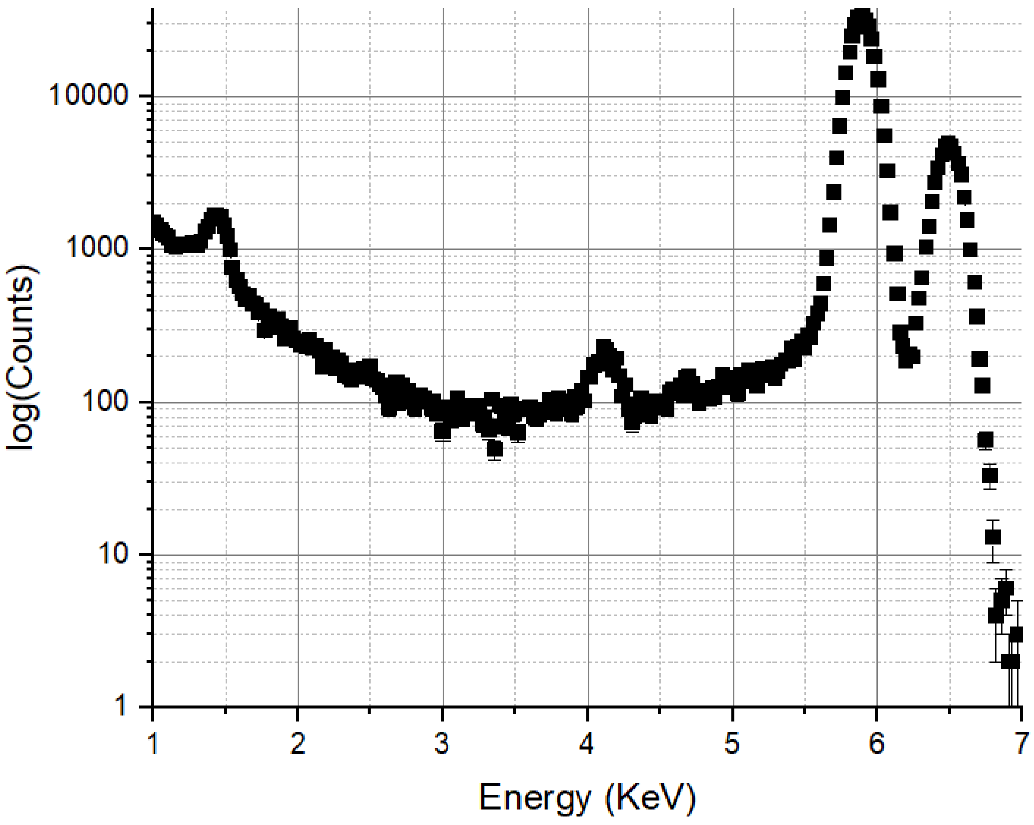




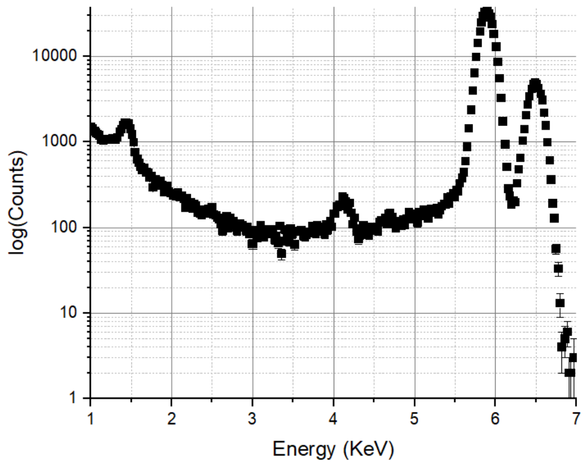
SiLi Detector Efficiency Curves (2017)

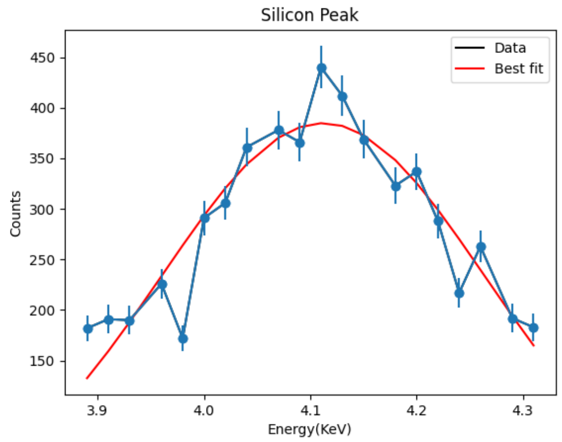
Total Spectrum



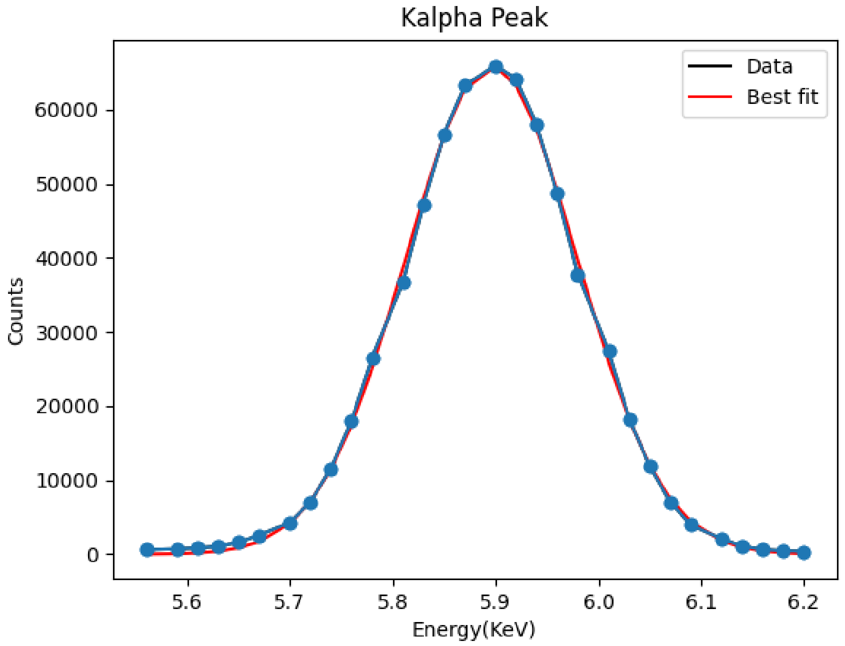


Regions of Interest

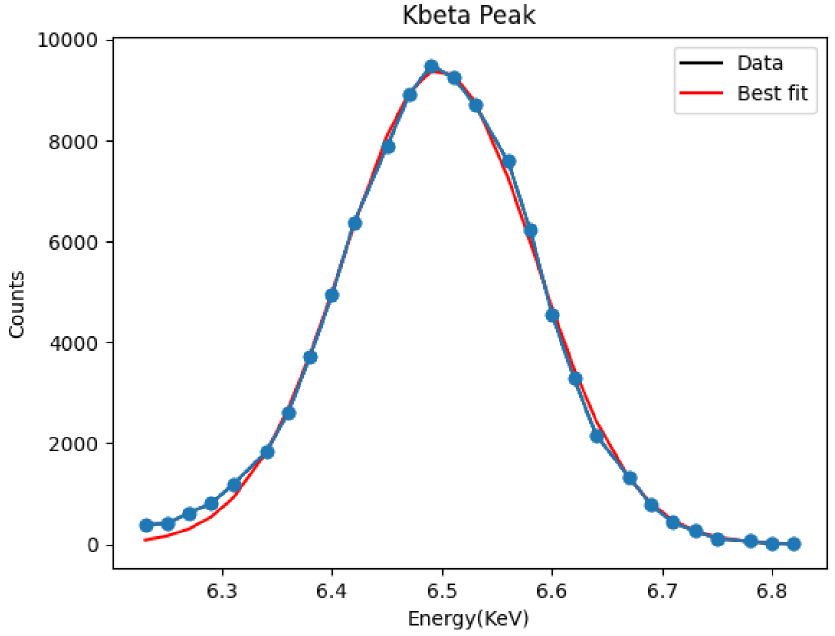




Peak Counts: 65909 ± 257
Total Counts: 626204 ± 791



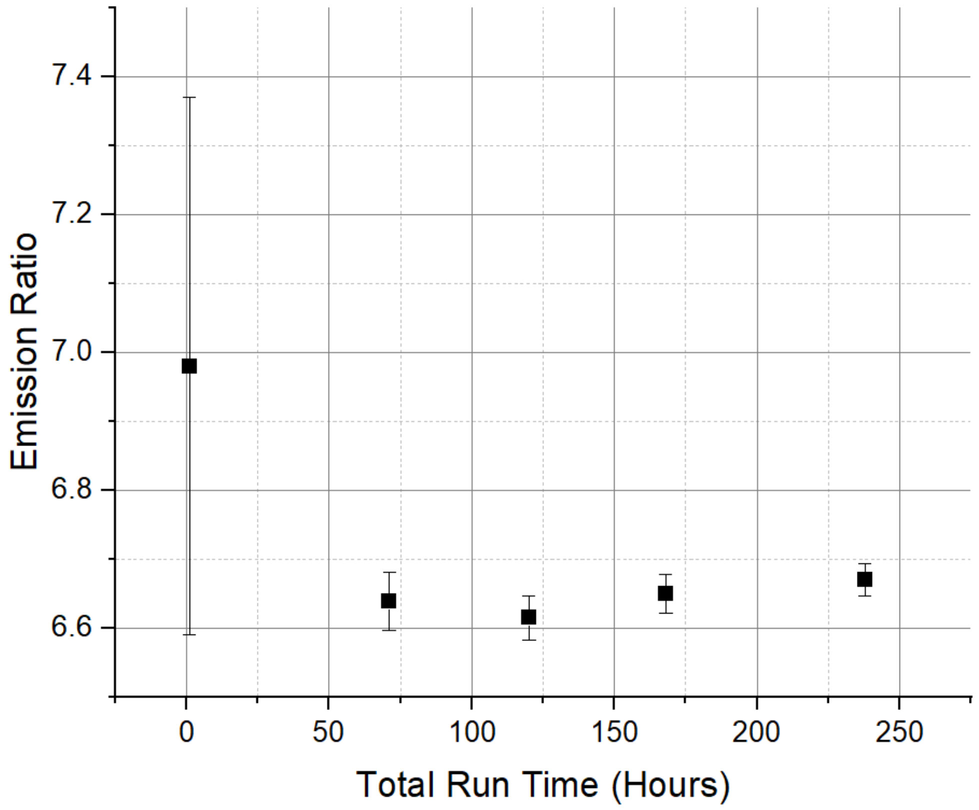
Peak Counts: 9490 ± 97
Total Counts: 93954 ± 307



Analysis: Emission Ratio

- Experiment's Emission Ratio: 6.67 ± 0.02
- Best known value (Junde, H. 2008): 8.6 ± 0.8

- Cause of discrepancy?
  - Not 55Mn(p, n)55Fe → 55Fe(p, n)55Co
    - Half-life of 55Co is 17.5 Hours
  - Not due to detector efficiency gradient
    - Detector efficiency difference Kα to Kβ << 15%
  - Not due to cosmic ray background



Future Study and Project Goals

- Short Term:
  - Determine source of discrepancy in emission ratio
  - Take background and subtract it
  - Generate a higher activity target
  - Get system to store measurements as function of time
- Long Term:
  - Apply for NASA funding to upscale project
  - Get a 100% efficient detector over the 5.6 – 6.8 KeV region
  - Get detector with thinner channel energies
  - Improve target isolation from background
  - Measure 55Fe source for years

References

Junde, H. (2008). Nuclear Data Sheets for A = 55. *Nuclear Data Sheets*, *109*(4), 787-942. https://doi.org/10.1016/j.nds.2008.03.001

SiLi Detectors for X-Ray Spectroscopy. (2017). Retrieved 12 December 2021, from http://www.canberra.com

Questions?