Neutron Activation Analysis of Titanium

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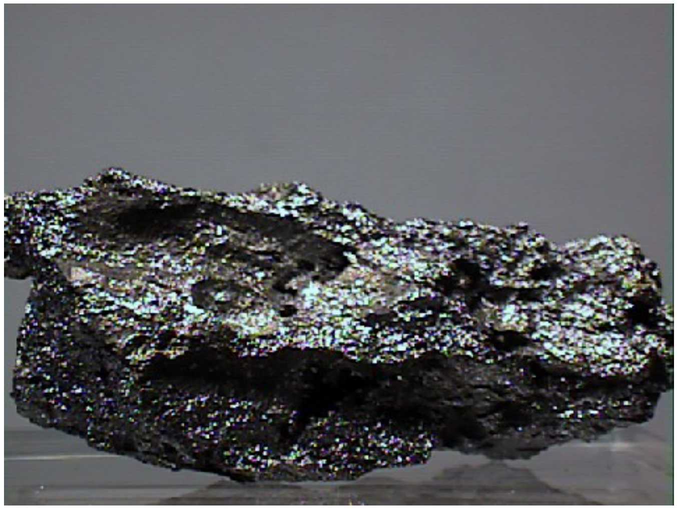
Material Properties

	Density (g/cc)	Tensile Strength (MPa)	Weldability
Titanium	4.5	434	yes
Stainless Steel	8.03	860	yes
Copper	8.94	220	no



Radiopurity

Material	Size	Uranium		Thorium		Potassium	
		ppb	mBq/kg	ppb	mBq/kg	ppm	mBq/kg
Titanium	3/8” Plate	< 0.2	< 2.5	< 0.4	< 1.6	< 0.2	< 6.2
Titanium	3/16” Plate	< 0.3	< 3.8	< 0.7	< 2.8	< 0.3	< 9.3
Titanium	3/16” Plate	< 0.03	< 0.4	< 0.2	< 0.8	< 0.05	< 1.6
S Steel 316L	3/4” Plate	0.07	0.9	0.71	2.9		1.8
S Steel 316L	1/4” Plate	0.17	2.1	0.57	2.3		3
S Steel 316L	1/8” Plate	< 0.03	< 0.4	0.84	3.4		5.1
Copper		< 1		< 1		< 0.001	
Copper		< 0.5		< 0.5		< 0.01	

Stainless Steel data from D. McKinsey
Copper data from UKDM collaboration

NAA Process

- Thermal Activation – signal

$$^{41}K + n_{th} \rightarrow {}^{42}K$$

$$\sigma_{\gamma} = 1.46b$$

$$^{42}K \rightarrow {}^{42}Ca + e^{-} + \gamma_{1524.73}$$

- Fast Activation - background

$$^{48}Ti + n_{fast} \rightarrow {}^{48}Sc$$

$$\sigma = 0.07b$$

$$^{48}Sc \rightarrow 48Ti + e^{-} + \gamma_{1037.6} + \gamma_{983.5}$$

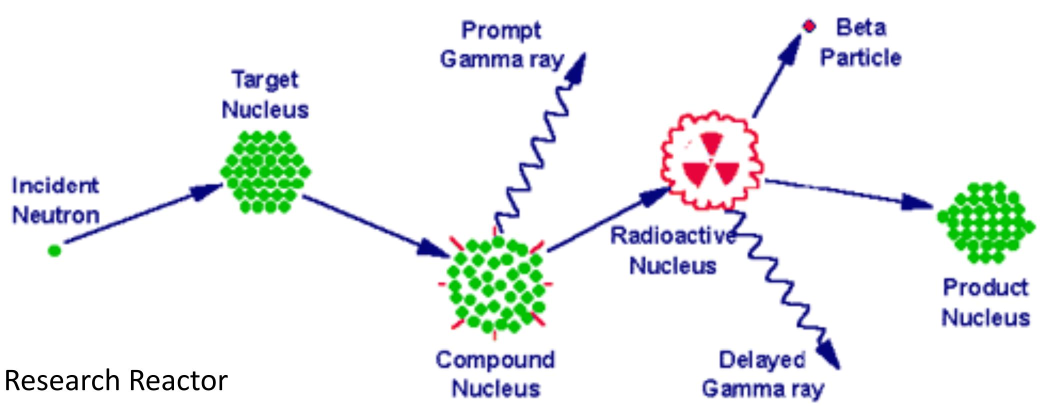
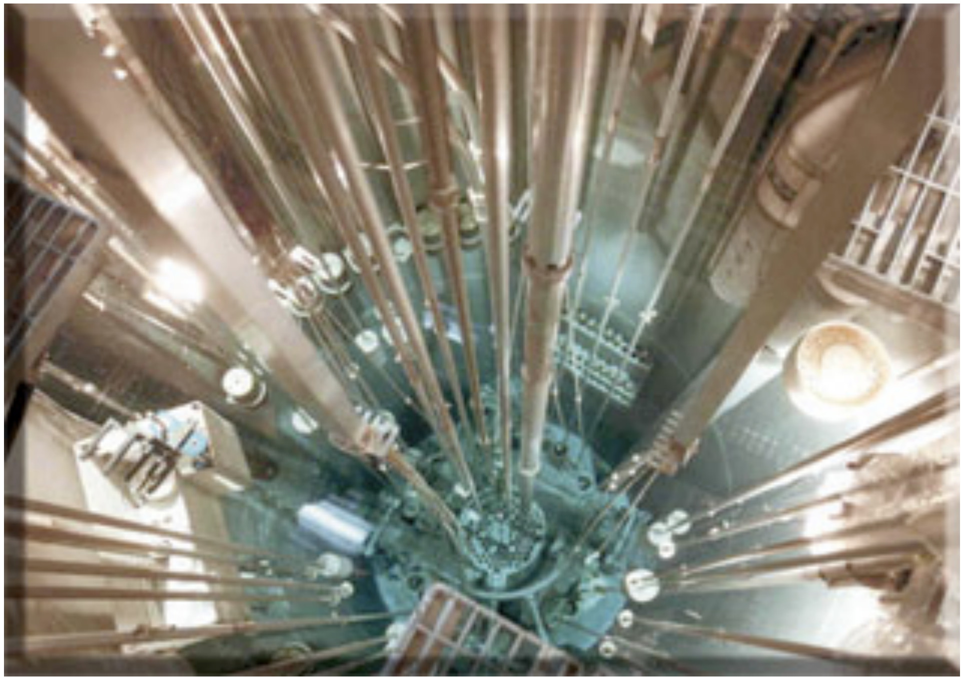


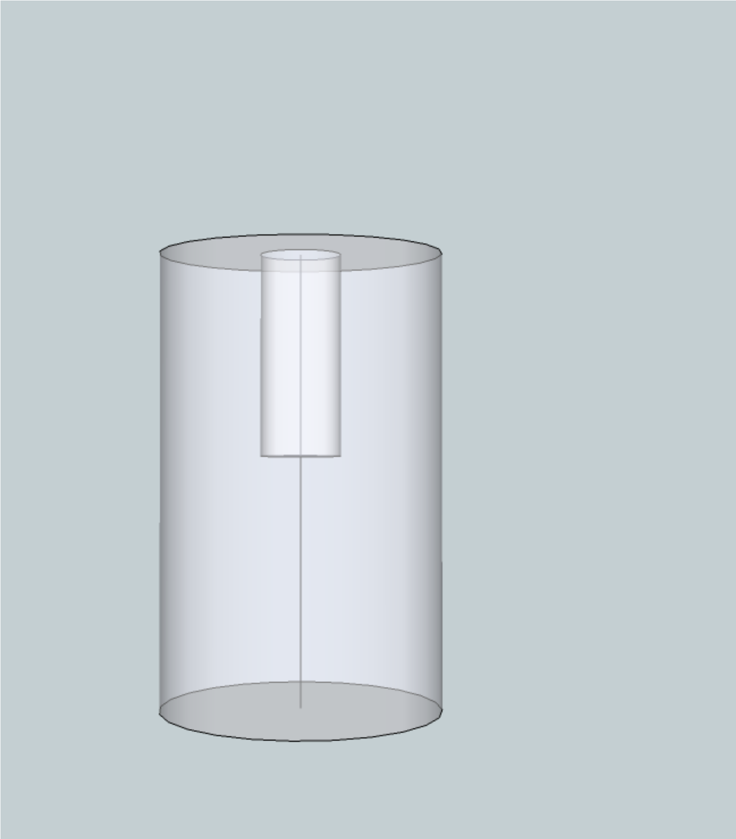
Diagram: University of Missouri Research Reactor

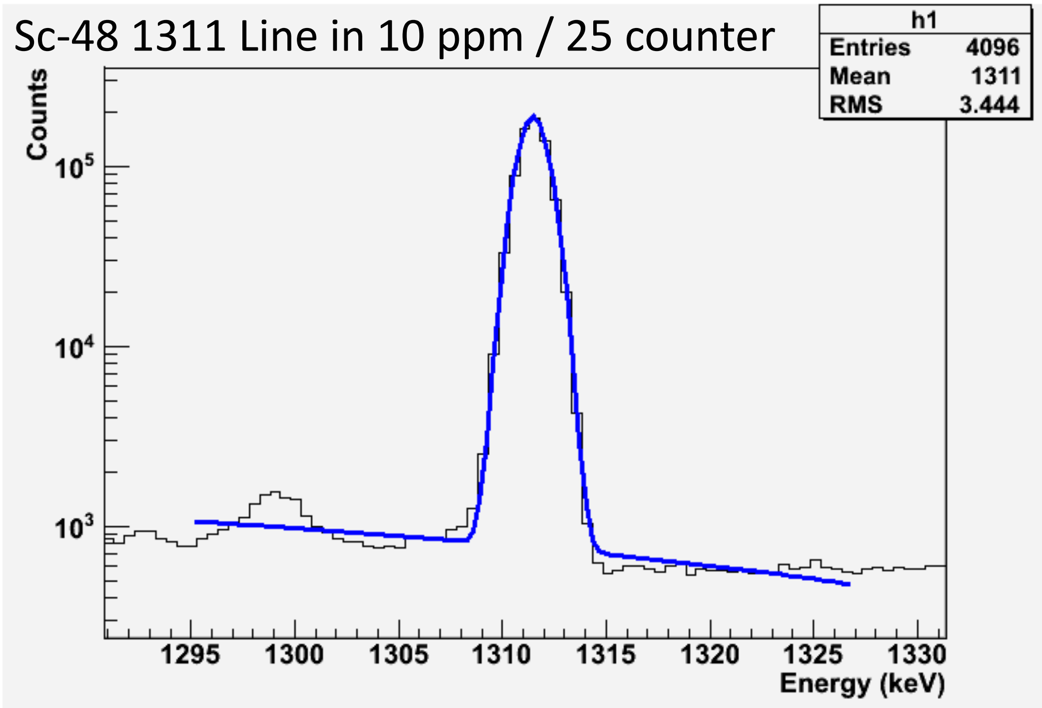
- TRIGA Mark II Reactor
- 2.3 MW max power, 1.5 MW typical
- 4 Canberra germanium counters



Potassium Calibration

- 4 x15 g titanium vial
  - <0.04 ppm intrinsic K
- Add potassium impurity
  - 0 ppm, 0.1 ppm, 10 ppm, 50 ppm
- Expose for 1 hour at 1.5 MW
- Count for 60000s livetime





Sample	Counter Efficiency	Area of 1311
50 ppm	8	7.15e4
10 ppm	25	3.52e5
0 ppm	50	7.03e5
0.1 ppm	99	1.16e6

Cross-check the counters using Sc-48 1311 line:
Ratio of area ~ ratio of efficiency

Compare 50 ppm to 10 ppm

$$\frac{3.52 \times 10^5}{7.15 \times 10^4} = 4.92 \text{ but } \frac{25}{8} = 3.13$$

Compare 0 ppm to 10 ppm

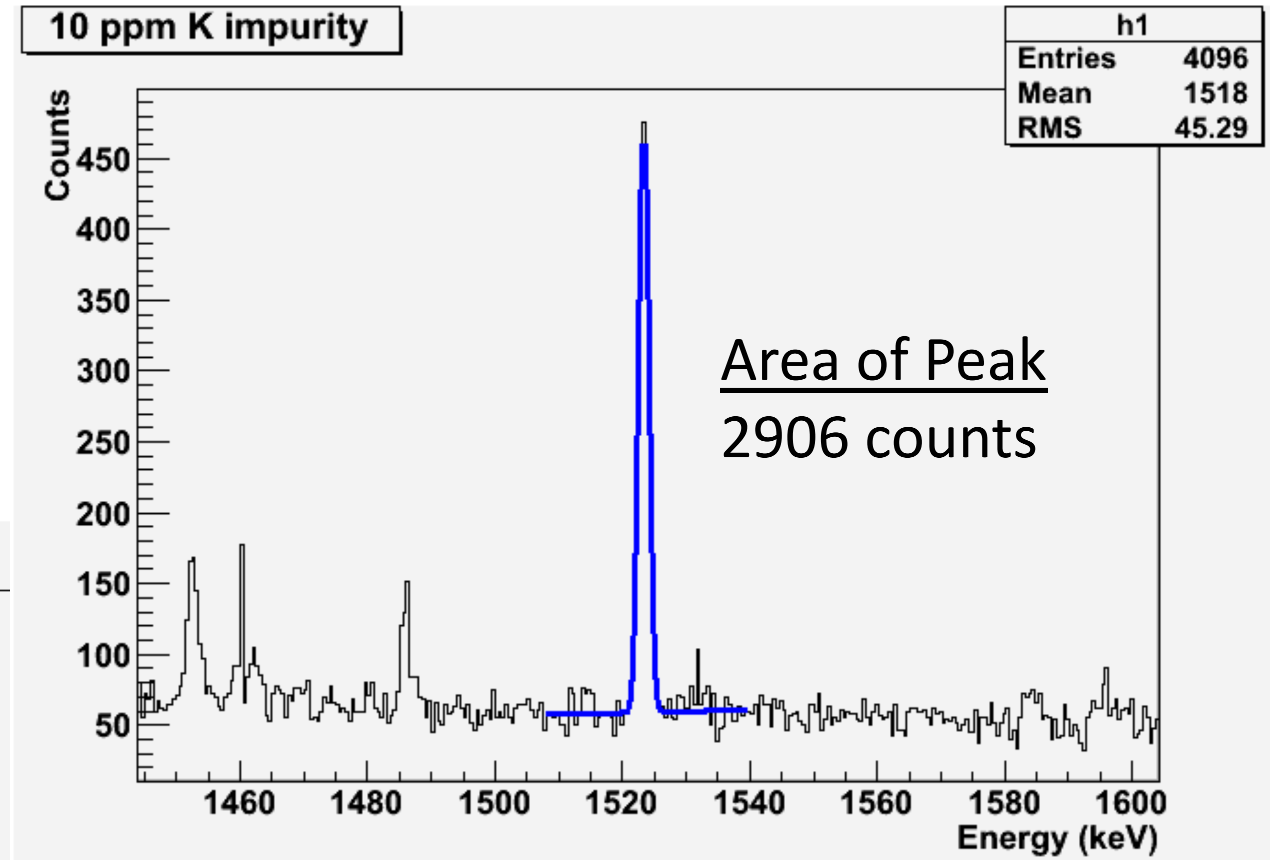
$$\frac{7.03 \times 10^5}{3.52 \times 10^5} = 1.99 \text{ and } \frac{50}{25} = 2$$

Compare 0.1 ppm to 0 ppm

$$\frac{1.16 \times 10^6}{3.52 \times 10^5} = 4.54 \text{ and } \frac{99}{25} = 3.96$$

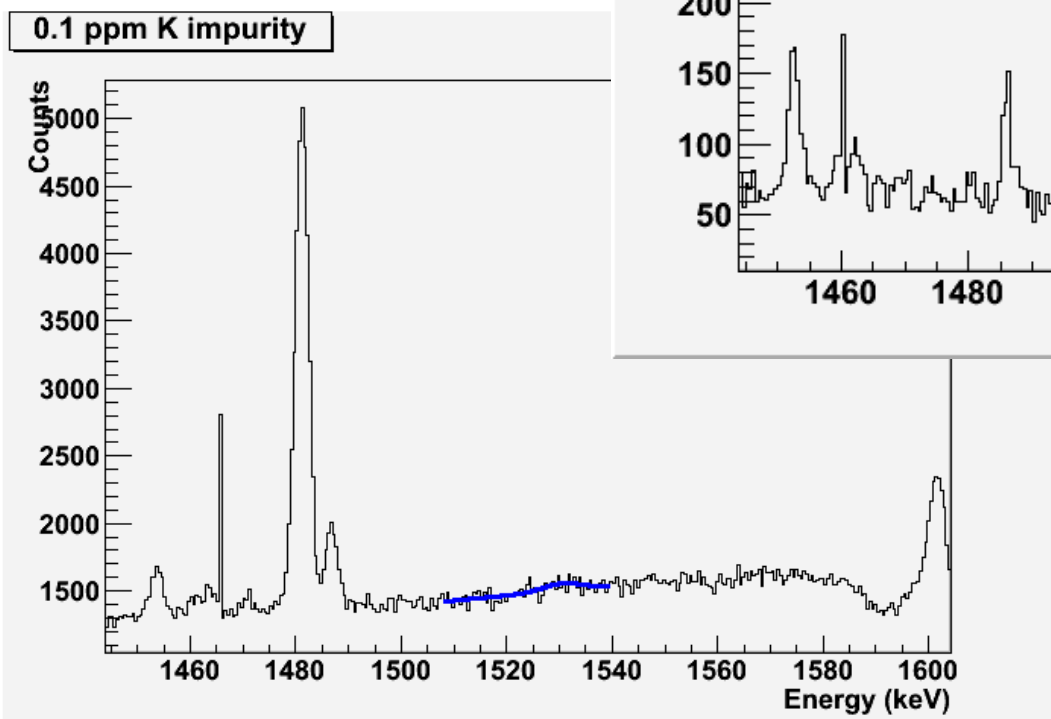
Something is wrong with the 8% counter
There is a 15% systematic error from 99 counter to others

Set 90% C.L. using 10 ppm and 0.1 ppm data



<u>Area of Peak</u>

2906 counts



<u>No Peak</u>

Set 90% C.L. using 10 ppm and 0.1 ppm data

$$Activity = \frac{counts}{livetime \times efficiency}$$

$$A_{10ppm} = \frac{2906 counts}{60000s \times .12\%} = 40.3 \text{ Bq}$$

$$A_{0.1ppm} = 0$$

Use square root of background as 1 sigma limit

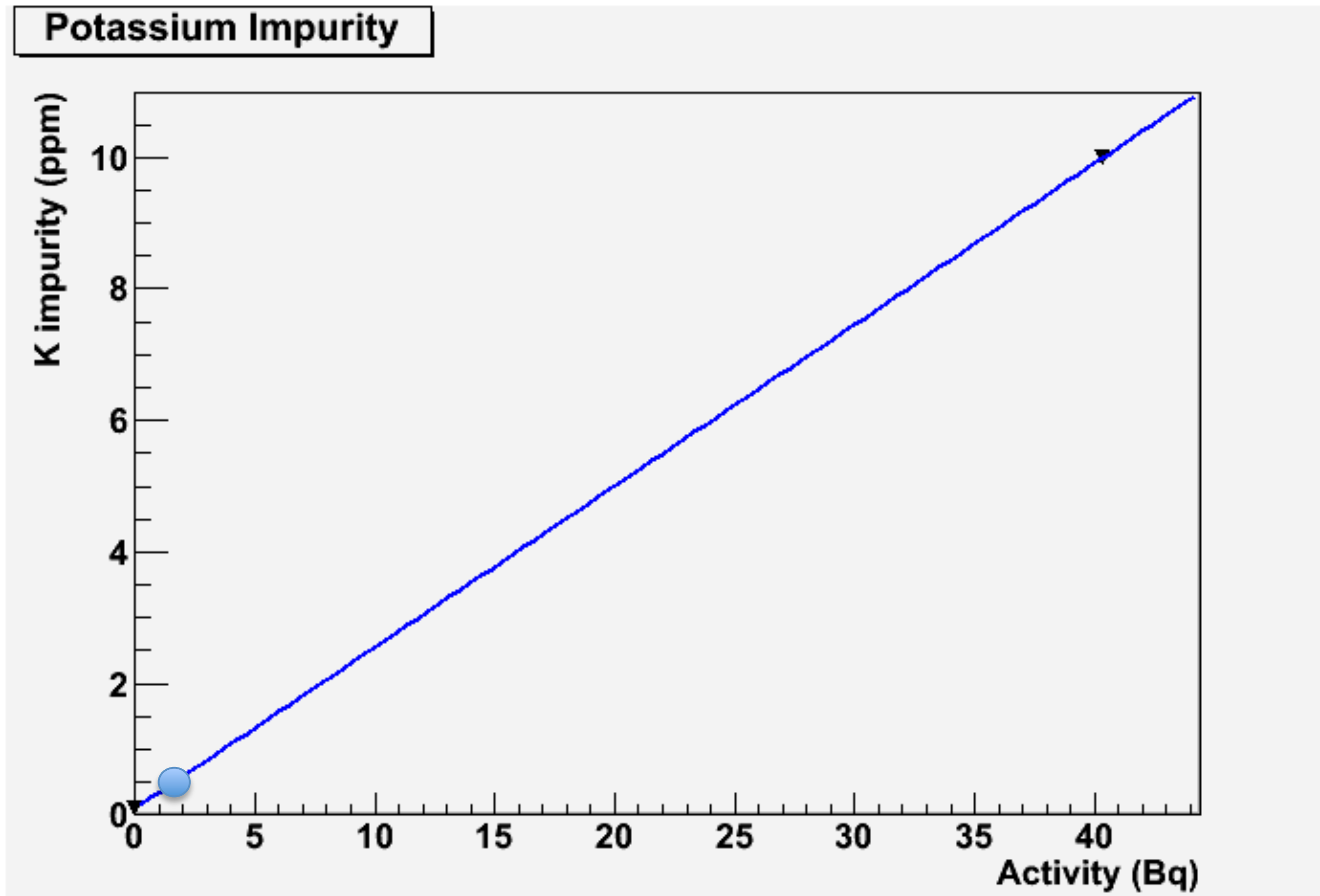
$$A_{limit} = \frac{\frac{90}{68}\sqrt{bkgrd}}{livetime \times efficiency}$$

There are 1264 events in the background in the region covered by the width of the 1524 peak if present

$$A_{limit} = \frac{\frac{90}{68}\sqrt{12614}}{60000s \times 0.65\%} = 0.3927 \text{ Bq}$$

Set 90% C.L. using 10 ppm and 0.1 ppm data

Fit a line to control points and use to limit ppm limit of sample



90% C.L. is < 0.22 ppm K impurity in this Ti sample

Summary

- This method puts limit at < 0.22 ppm
- Compare to < 0.02 ppm from direct counting
- Only took a day to do compared to weeks
- Fix the 50 ppm control point
- Add U and Th to mixture
- Measure other materials relevant to low background physics
- Reduce background rate using heavy water shielding

[redacted]