Restoration of Beam Port and Utilization as Gamma Irradiation and X ray Fluorescence Facility

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Introduction

- The KSU TRIGA Mk II reactor is equipped with four beam ports.
- Each beam port can be sealed with an inner and outer shield plug.
- The wooden outer plug became bound against the inside of the beam port in the piercing beam port.
  - Possibly due to swelling from water condensation or leak.
  - Incapacitated the beam port.
  - Tons of force couldn’t move plug.

Introduction

- A decision was made to remove the plug and restore the beam port as an experimental facility.
- Characteristics of piercing beam port[1]:

Diameter	8 inches
Neutron flux (500 kW)	8.5×10^8 n / cm^2 / s
Flux-avg. neutron energy	0.5 MeV
Gamma dose rate (500 kW)	45,000 R / h

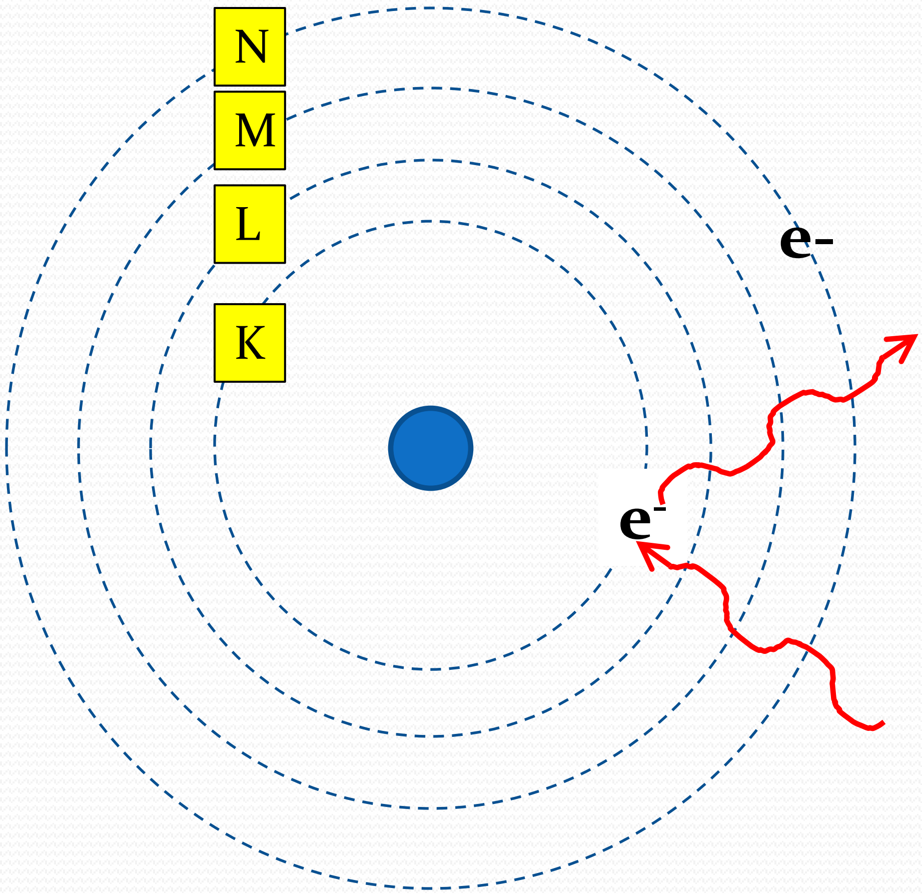
Introduction

- The high neutron energy makes shielding experiments difficult.
- KSU reactor facility does not have a gamma irradiator.
- Proposed beam port use:
  - Block as many neutron as possible with low-Z material (5% borated polyethylene).
  - Use beam port as gamma irradiation facility.
  - Plan "B": use gammas for x-ray fluorescence.

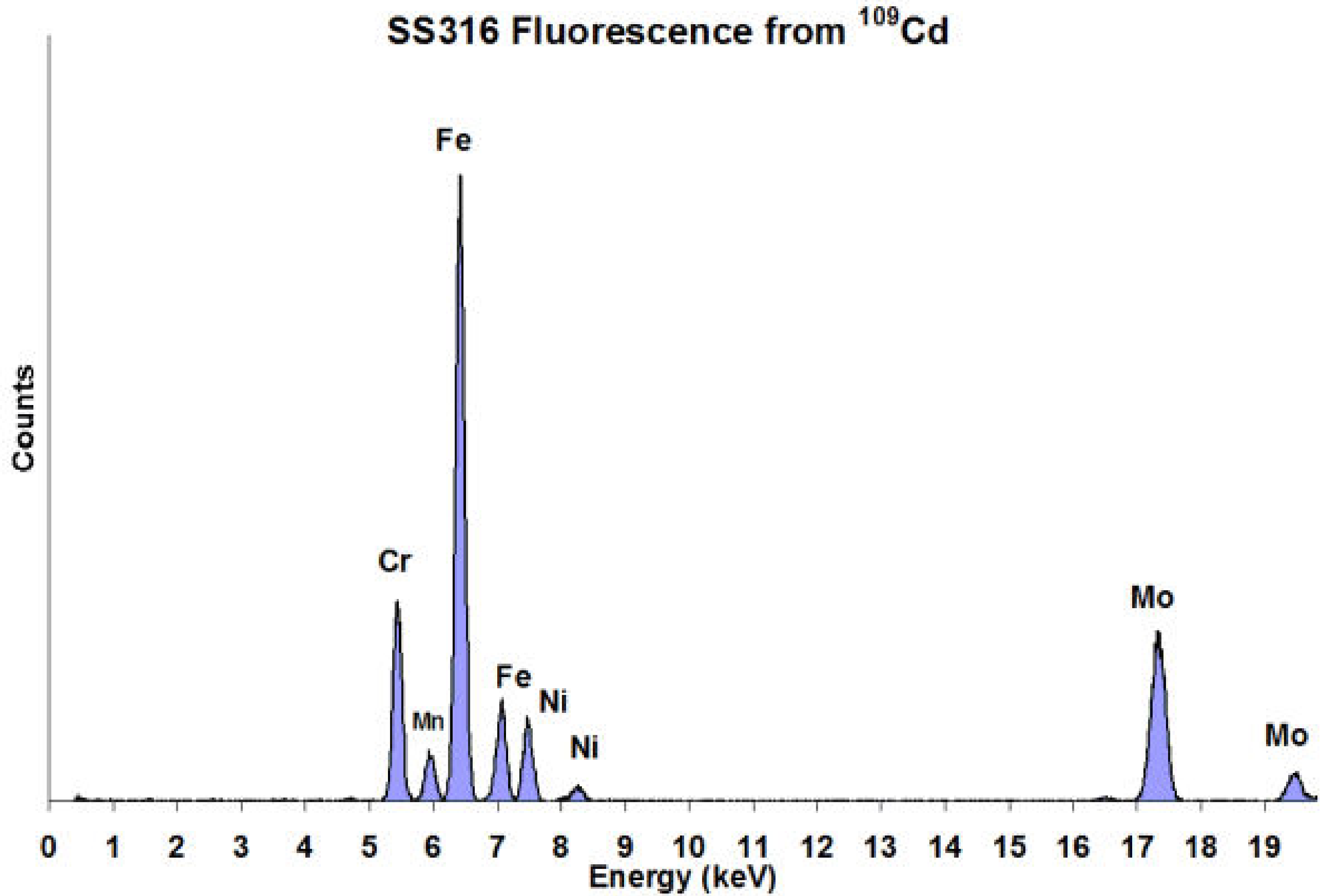
X-ray Fluorescence

- X-ray fluorescence results from an electron being excited to a higher shell by an incident gamma or x-ray
- Upon de-excitation, the atom emits an x-ray of characteristic energy
  - Typically 5 – 100 keV
- A CZT or CdTe detector can be used to perform surface spectroscopy
- Sample is not radioactive → technique is truly “non-destructive”

X-ray Fluorescence



X-ray Fluorescence



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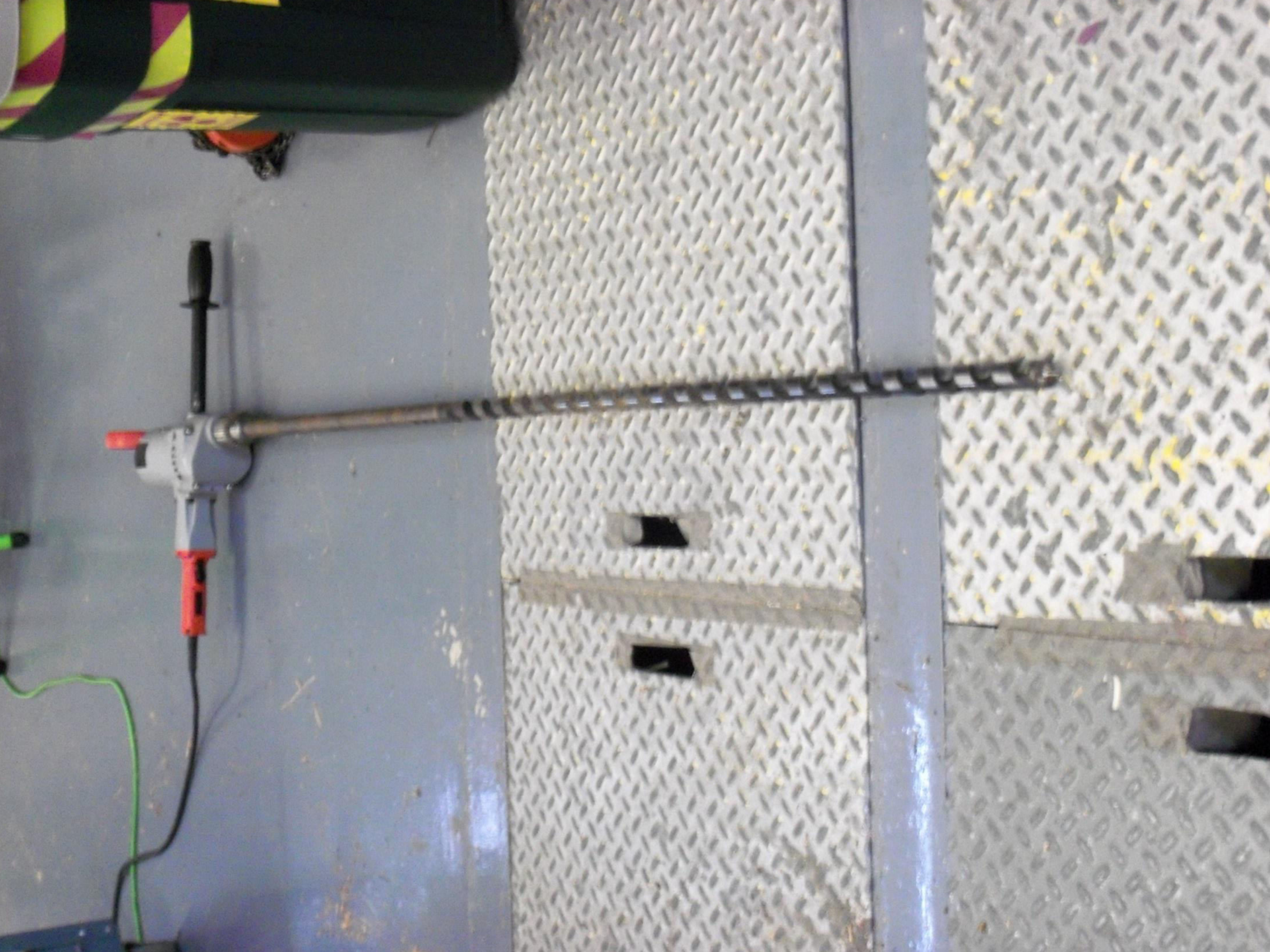
Extracting Plug

- Kansas Forestry Service recommendation:
  - Drill holes down length of plug;
  - Allow time to dry;
  - Mount bolt in drill holes, extract.
- End of plug had already been chipped away and holes were already drilled into the plug.
- It was clear that the plug could not be pulled out, and would need to be removed piecemeal.

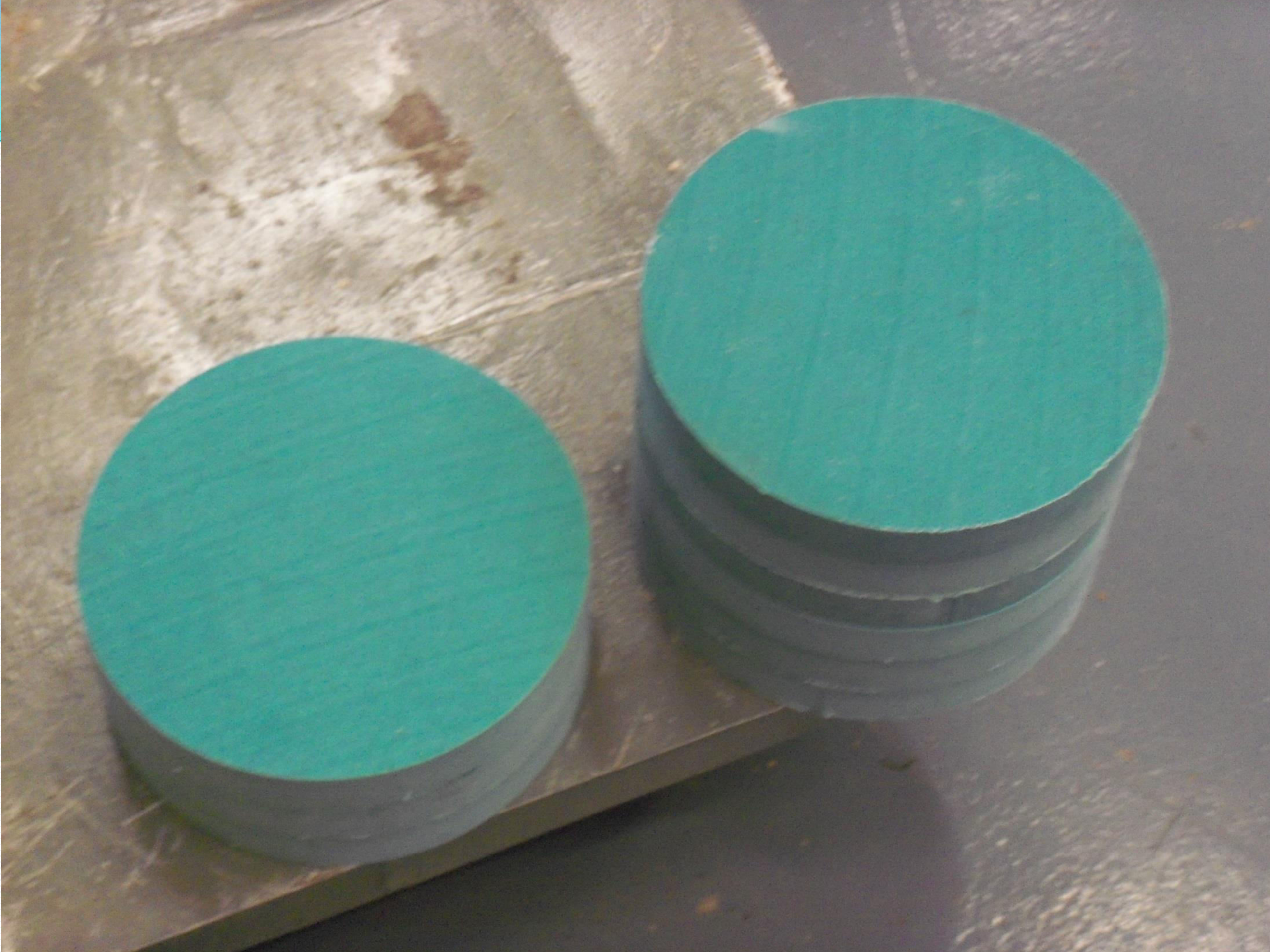
Tools Required:

- Milwaukee Super Hole Shooter drill (10 A, triple reduction gear, ¾” chuck)
- 48” long, 1 1/8” dia. drill bit
  - Tapered end to prevent seizing in damp wood
- 24” long drill bit extension
- Gas-powered pruning saw
- Pinch-point digging bar
- Sharpened flat-head digging bar



Inner Plug Removal

- After removing most of the wooden plug, we were able attach a threaded rod to inner plug.
  - 1 week, 3 people.
- Inner plug and last 8” of outer plug were removed by turning a nut against a ½” steel bracket.



Shielding

- 33 in. of 5% BPE
  - 7 sections
  - Two sections sealed with caulk
- Lead bricks stacked inside tube, leaving ~2" aperture in 6" shield
- 3" lead collimator with 1" aperture
- Concrete and lead outer shield
- Dose rates outside shield at full power <= 36 mrem / h

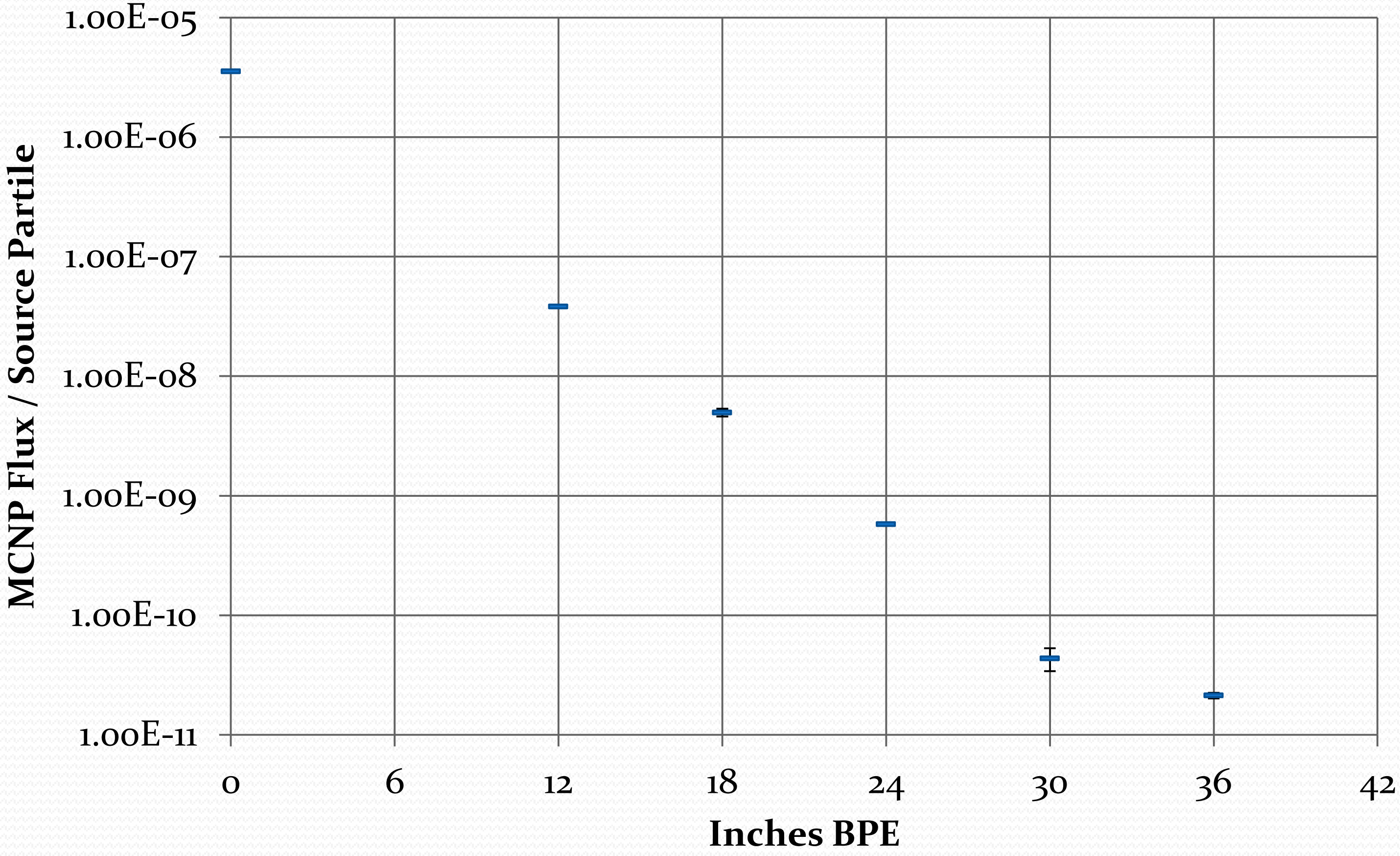
Results

- There are no apparent leaks in the beam port.
- None of the wood was radioactive (< 100 CPM above background using frisker).

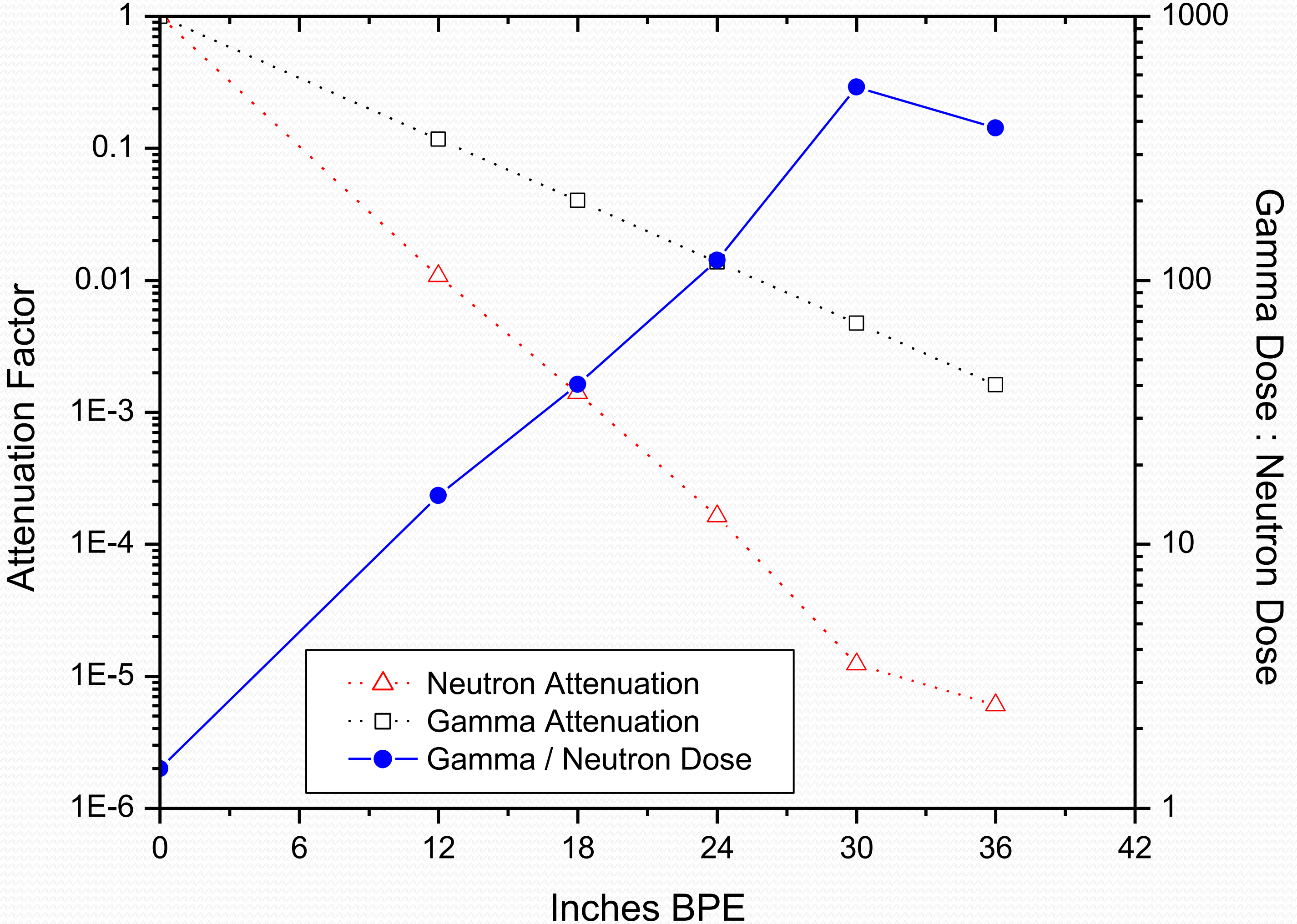
Results: Gamma Irradiation

- Assumptions:
  - Watt fission spectrum
  - Semi-infinite planar shield
  - Neutron dose proportional to flux
  - Insignificant secondary gamma dose
- BPE of sufficient thickness to block neutrons also significantly attenuates gamma rays.

Results: Gamma Irradiation

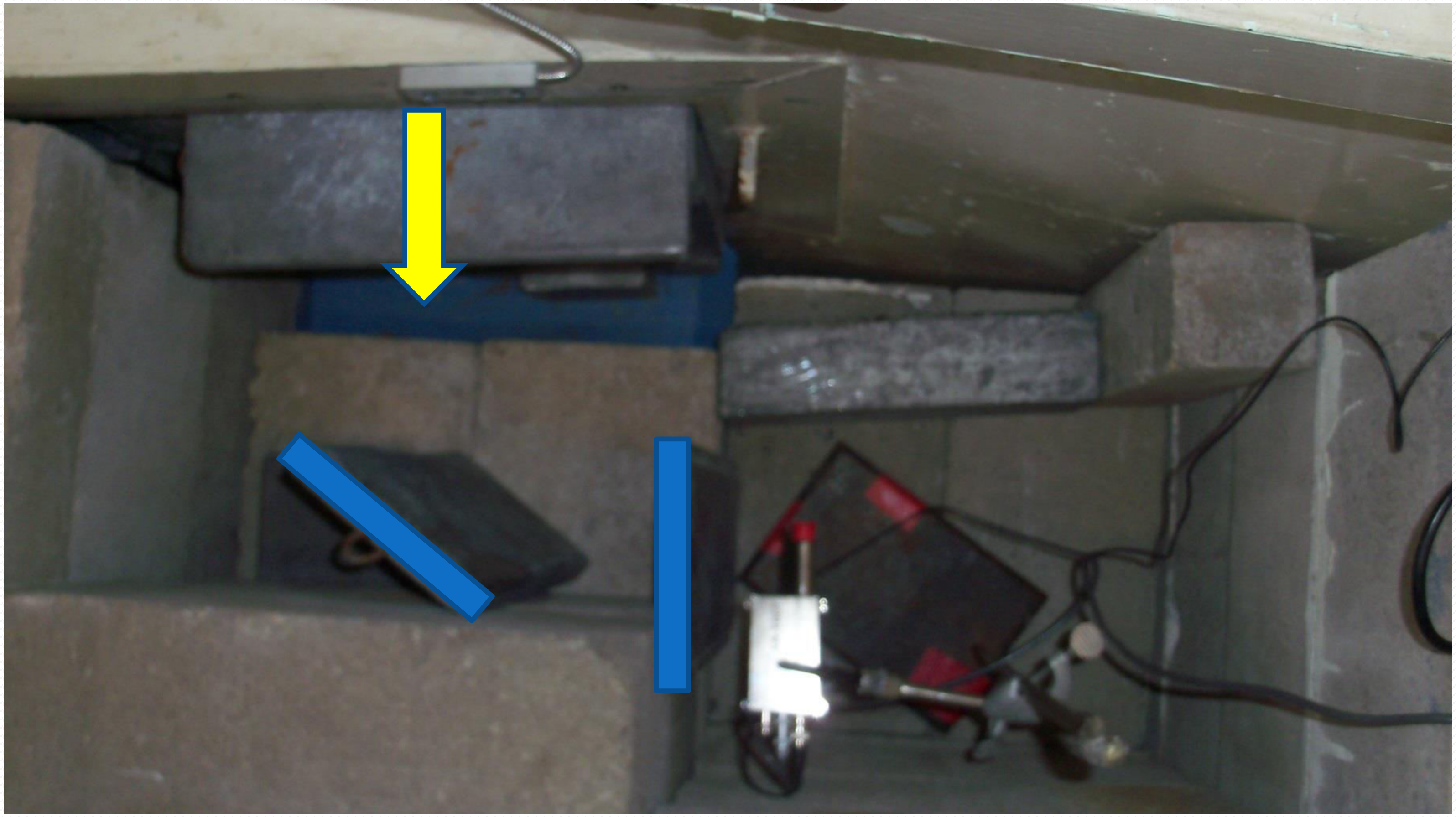


Results: Gamma Irradiation

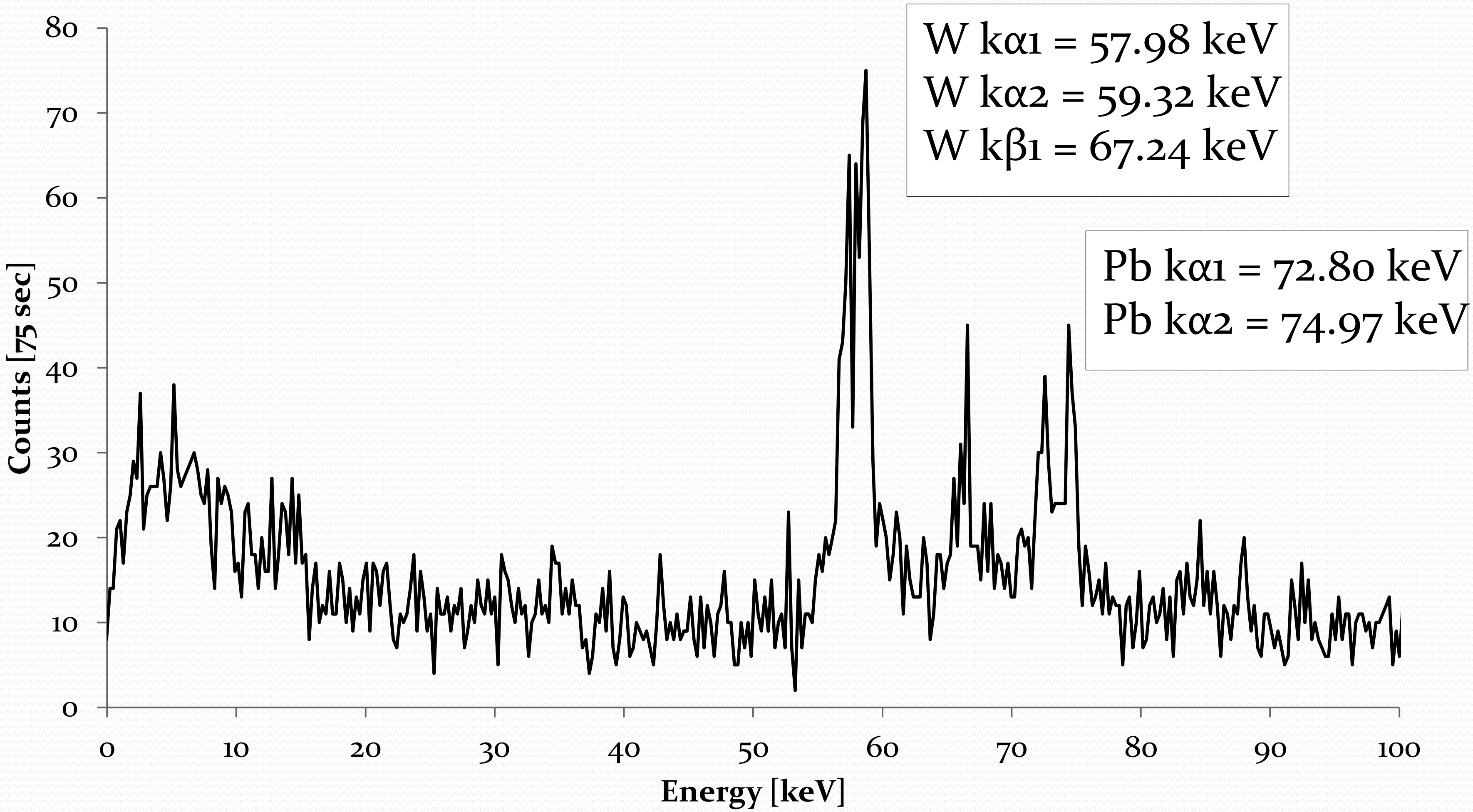


Results: XRF Facility

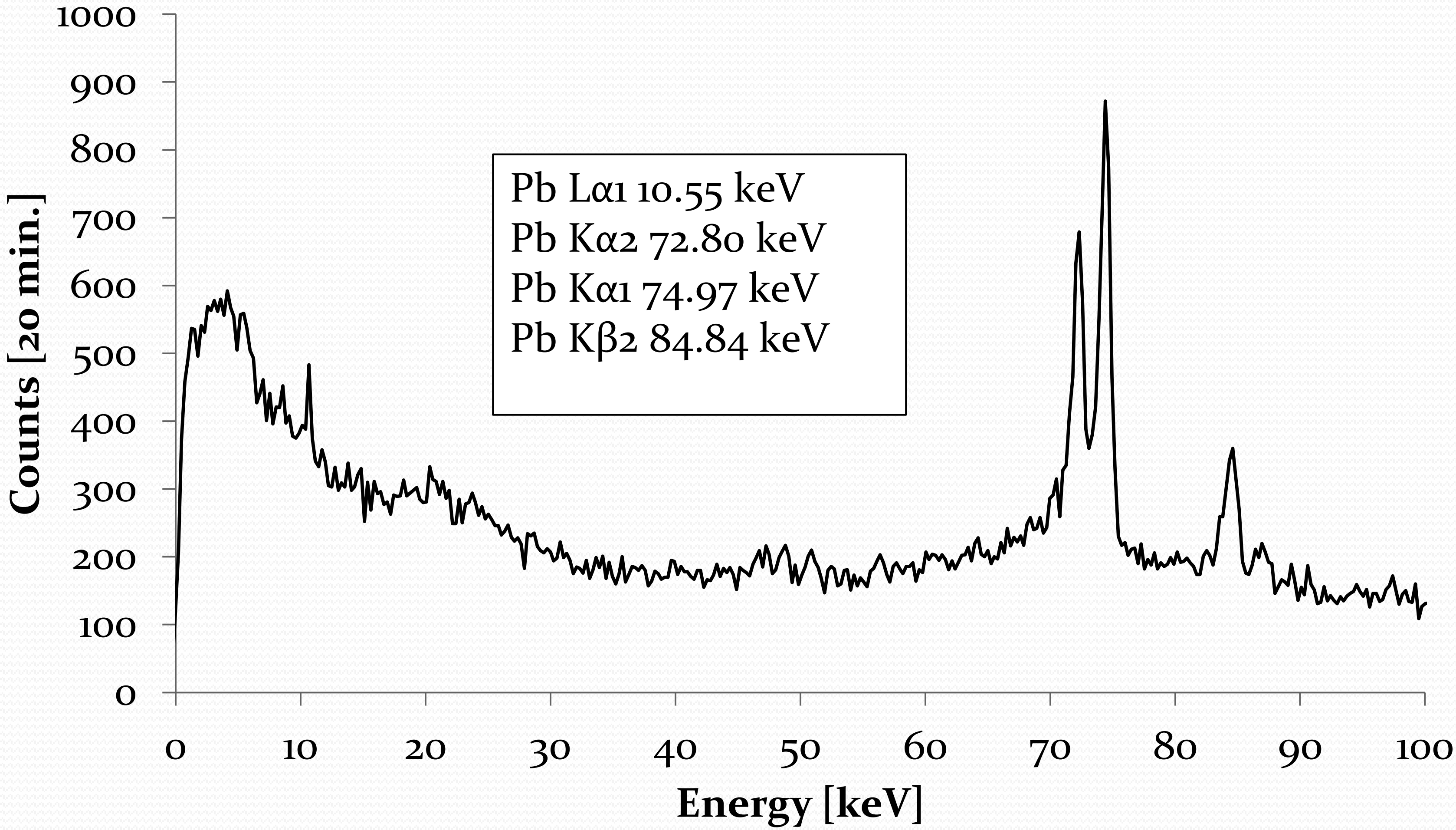
- The reactor can be used to produce fluorescence x-rays.
- The background is high due to scattered gammas.
- The system cannot outperform an x-ray tube or isotope.
- Use is restricted to classroom instruction or demonstration.



W / Pb Identification



Pb Identification



Going Forward

- XRF system is only useful for classroom / demonstration purposes.
- We are evaluating alternatives to BPE shielding to explore better ways of blocking neutrons but transmitting more gammas.
  - Enriched BPE
  - Higher-load BPE
  - Other boron compounds
  - Two-layer shield
- Moving shielding inward would improve gamma dose.
  - 72 megarads per hour of gammas at outer surface of core
- Placing sample after first 12” would result in neutron flux on the order of 10^6, gamma dose rate of 5000 rads / hr

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