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Fast Neutron Signatures for Uranium Hexafluoride Enrichment Measurements

Scott Kiff, Robert Cooper, Peter Marleau

Sandia National Laboratories, Livermore, CA

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Presentation Outline

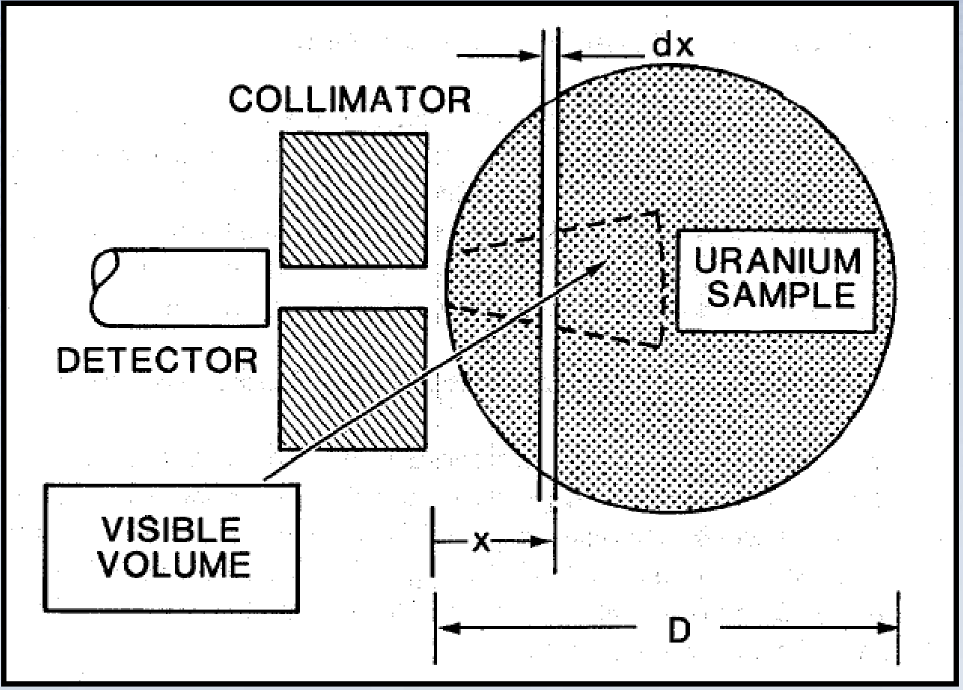
- Introduction to the problem
- Sandia's concept: imaging neutron spectrometers
- Initial calculations
- Discussion

What is the problem?

- Enriched uranium can be used to construct a nuclear weapon
- It is important to verify the enrichment of uranium as it exits the processing stream to detect material diversion efforts

Current technology is good, but…

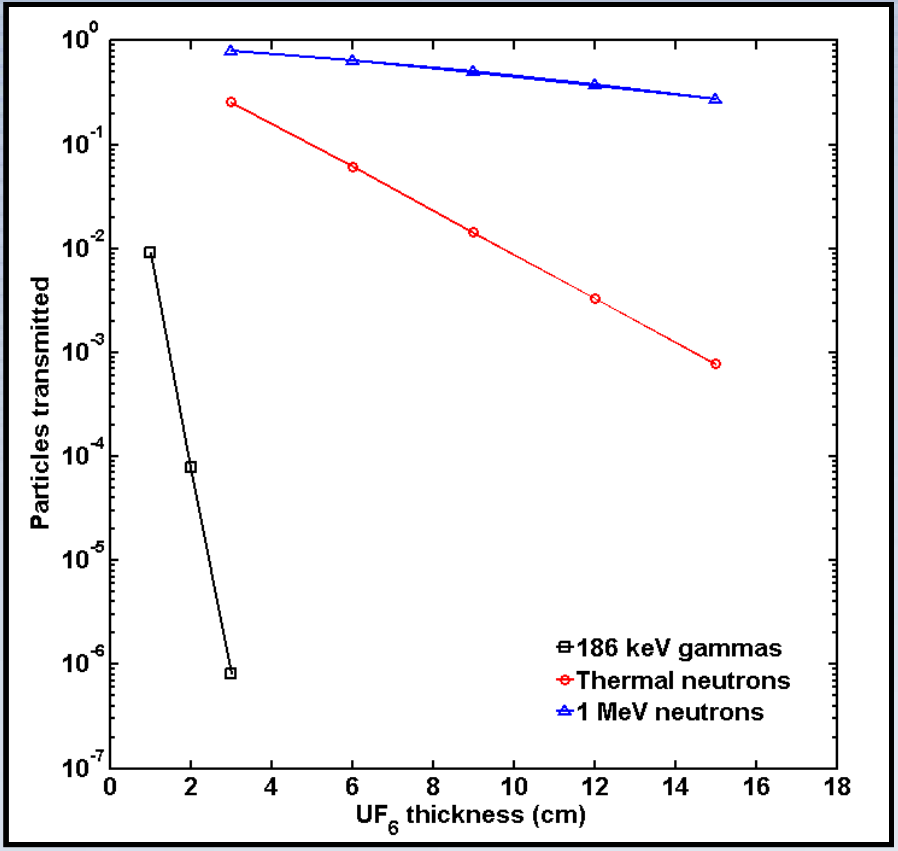
- **“Enrichment meter” measures gamma emissions from the uranium hexafluoride (UF_6)**
  - Gives local enrichment, not total mass
  - Sensitive to variations in container wall thickness
  - Not sensitive to material beyond outer skin of UF_6



The enrichment meter principle. From Reilly et al.,*Passive Nondestructive Assay of Nuclear Materials*, Fig. 7.3

Sandia's concept: directly measure fast neutron emissions

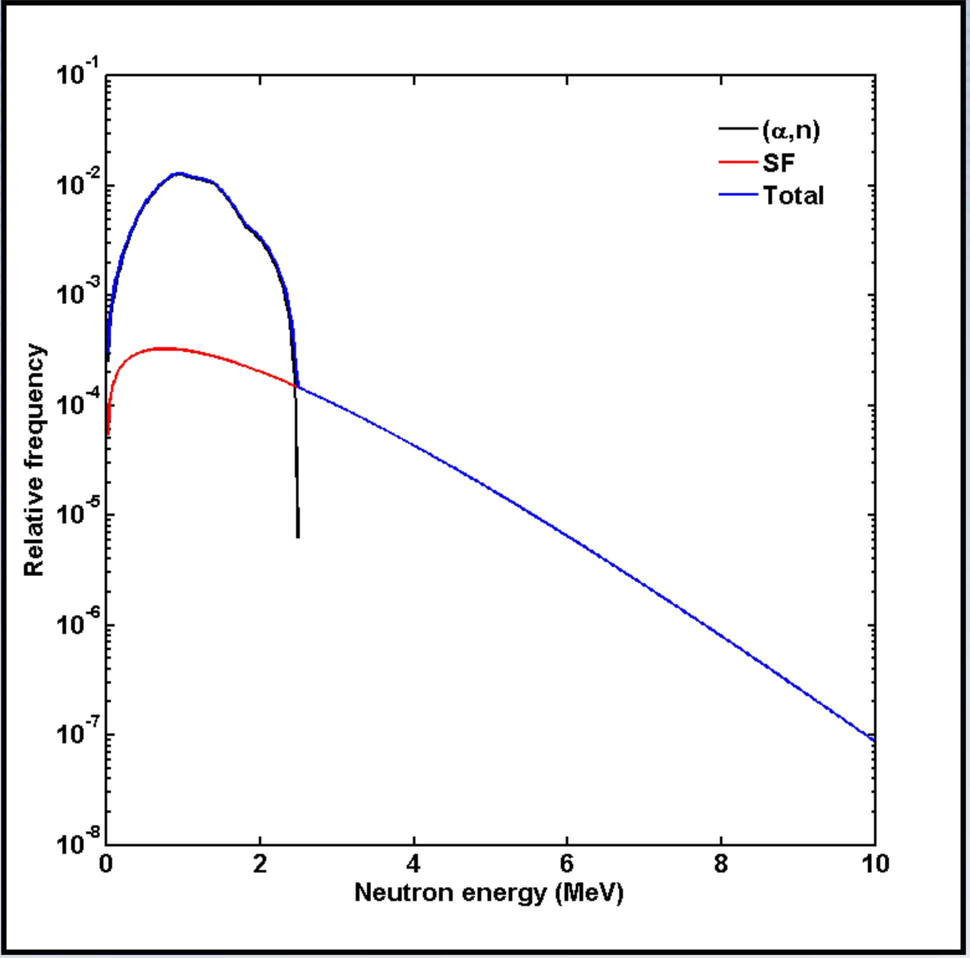
- Fast neutrons generated by independent processes within the UF_6 can provide an independent enrichment measurement that samples the entire UF_6 volume
- Neutron imaging of the UF_6 distribution detects unexpected UF_6 geometries and applies necessary corrections
- Sandia has developed expertise in neutron imaging and spectroscopy that will enable success



Transmission of particle beams through 5% enriched UF_6 (without container wall)

Neutron spectrometry can potentially be used to determine UF_6 enrichment and mass in a 30B

- **^{238}U: neutrons via spont. fission and (α,n) reaction on F atoms**
- **^{234}U: neutrons via (α,n) reaction on F atoms**
- **The two processes have measurably different energy spectra**
  - It should be possible to separate ^{234}U and ^{238}U contributions to the energy spectrum
  - Direct measurement of ^{234}U and ^{238}U masses
- **^{234}U content is proportional to ^{235}U content (proven by LANL for enrichment ≤ 5%)**

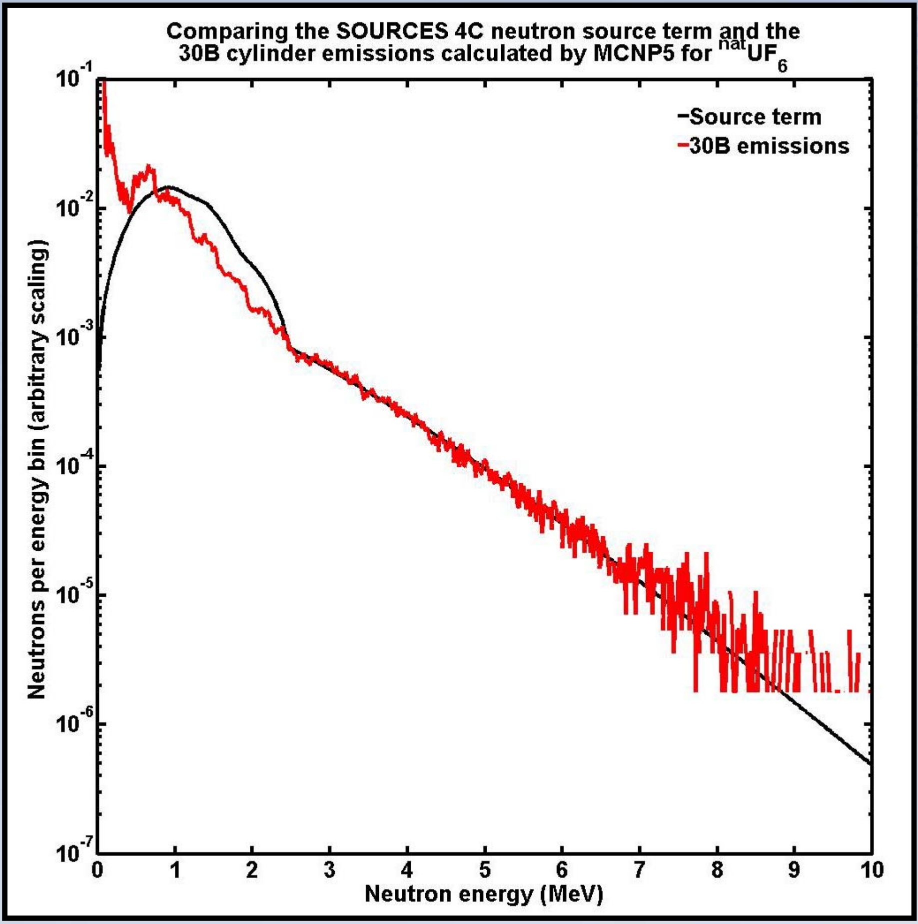


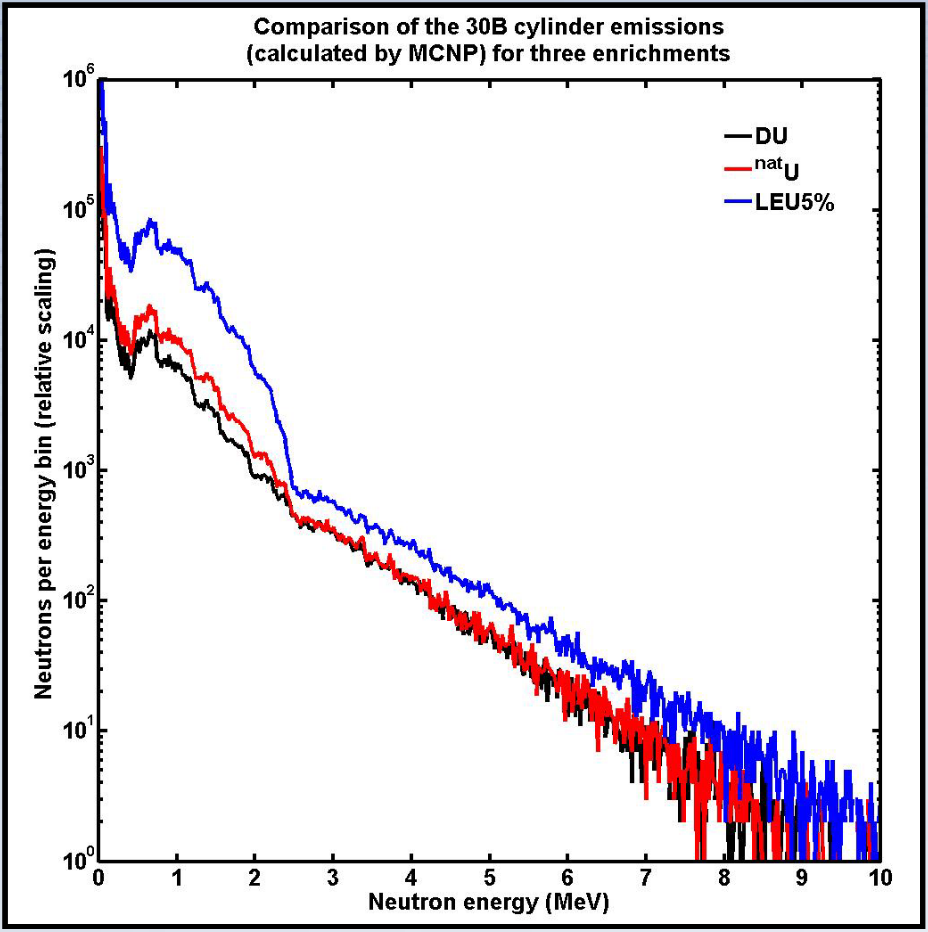
SOURCES4C calculation of neutron spectrum for 5% enriched UF_6

Calculations of the cylinder emissions imply manageable spectral perturbations

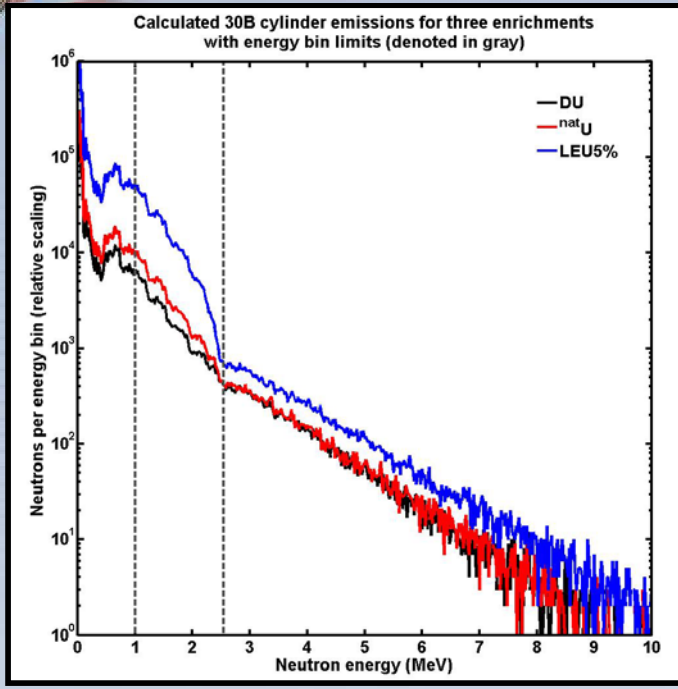
- **The source term is perturbed in a large mass of UF_6.**
  - Scattering
  - Induced fission
  - Absorption
- **A 30B cylinder was modeled in MCNP5.**
  - Enrichments: DU, ^{nat}U, 5% enriched ^{235}U
  - Maximum fill mass
- **Spectra appear to maintain enough structure for the measurement concept to work.**

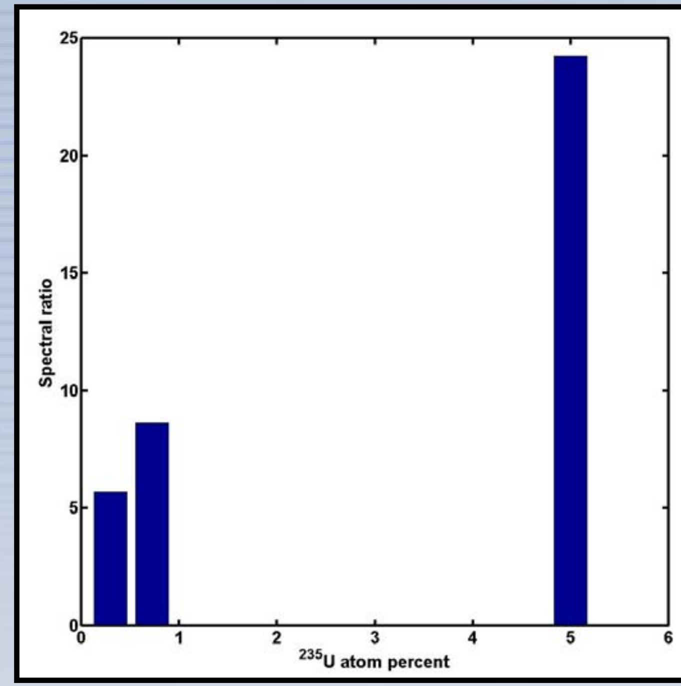
Results of the MCNP5 calculations





The enrichment can be inferred from the neutron energy spectrum

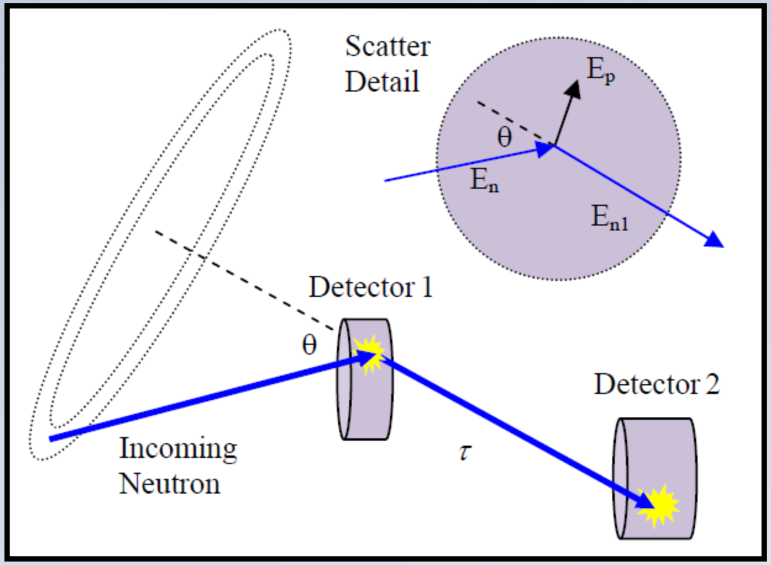


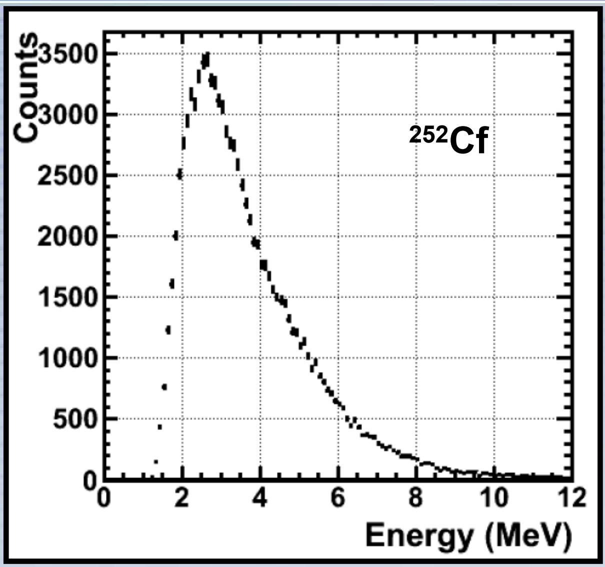


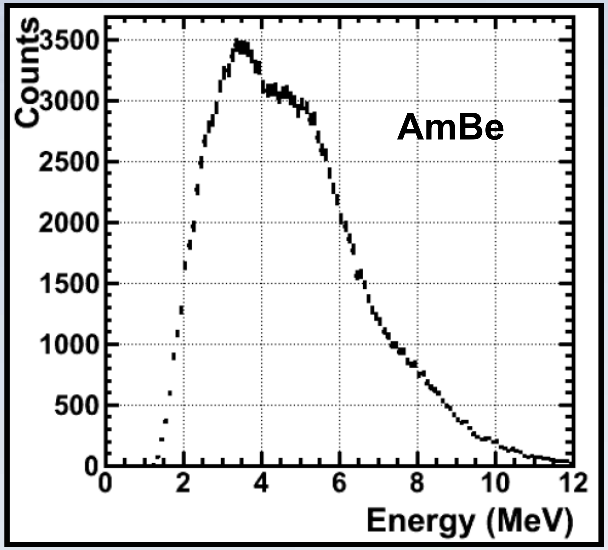
- **The ratio of neutrons in the (α,n) and S.F. regions is a function of enrichment**
  - Cut data at the end of the (α,n) spectrum (~2.54 MeV)
  - A realistic detector will have a detection threshold (choose 1 MeV)
- **For the simulated data, the ratio is a monotonic function of enrichment**

Neutron spectrometry measurements will be performed with the Neutron Scatter Camera

- **The Neutron Scatter Camera is a mature system developed at Sandia for large-area search**
  - Multi-element system
  - Liquid scintillator for n/γ discrimination
  - Imaging capabilities (interaction cell locations, measured energies)
  - Spectrometry (deposited energy, time-of-flight)







Discussion and Summary

- **We propose direct use of neutron signatures for UF_6 material accountancy**
  - Two physical processes create neutrons with different energy spectra
  - Simulations indicate enrichment can be extracted from emitted neutrons, even after full transport
- **Advantages:**
  - Spectrum shape/magnitude gives UF_6 enrichment/mass
  - Use of an imaging system (Neutron Scatter Camera) suppresses backgrounds from nearby cylinders, allows one to map material distribution within a cylinder (if important)
- **Next steps:**
  - Consider detector response
  - Try to collect actual data from 30B cylinders