

High-Resolution Gamma-Ray and Neutron Detectors For Nuclear Spectroscopy



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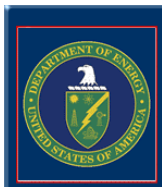
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Fisk University, TN, U.S.A.

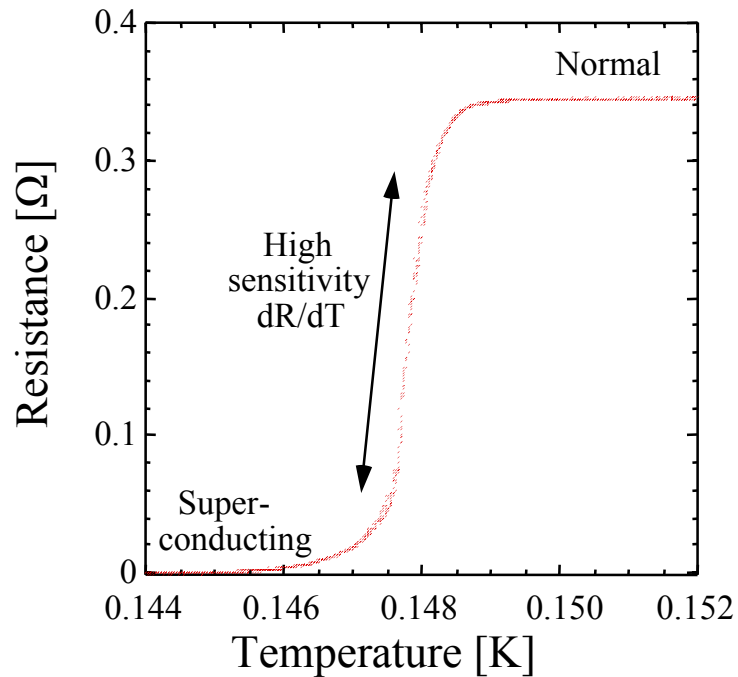
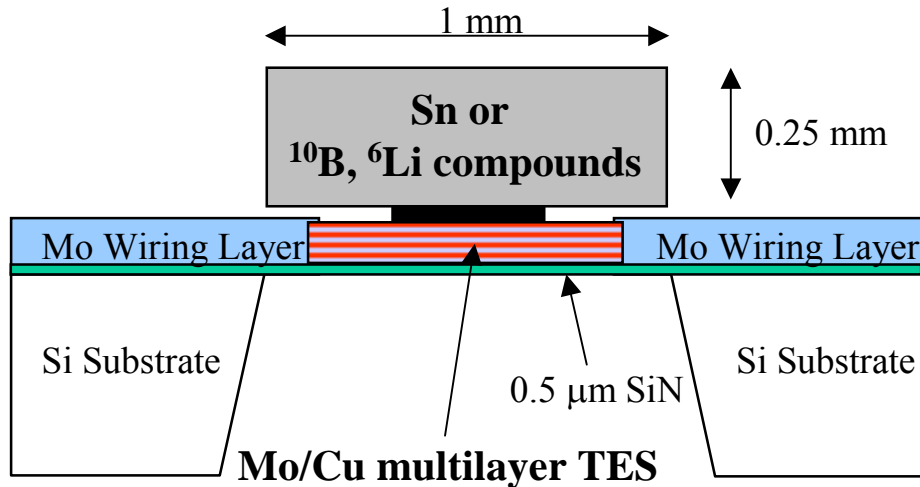
Z. W. Bell, V. E. Lamberti



Y-12 National Security Complex, TN, U.S.A.

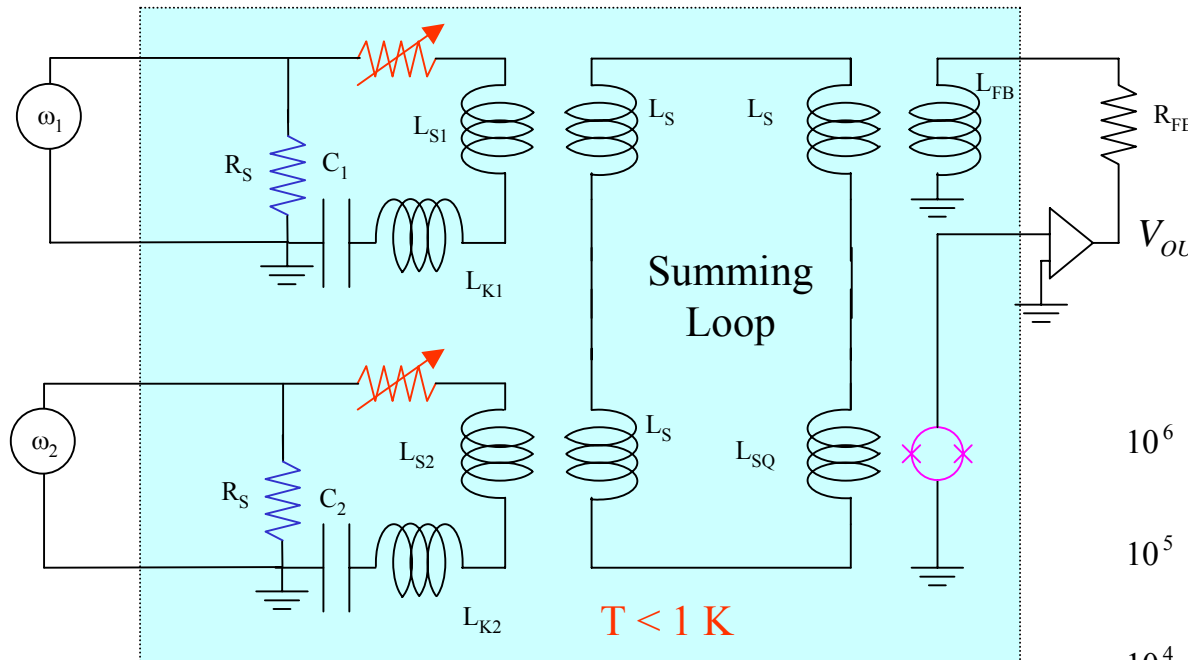


Composite Microcalorimeter Spectrometer

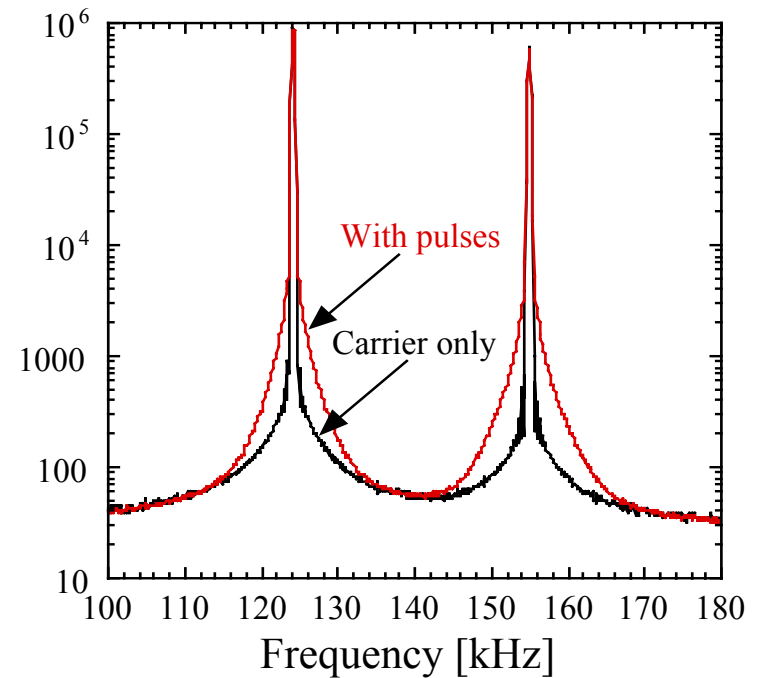


2 stage ADR
6-8 hours operation below T_c

Frequency-Domain Multiplexing



$$V_{OUT}(\omega) = \frac{A_1}{1 + (\omega - \omega_1)^2 \tau^2} + \frac{A_2}{1 + (\omega - \omega_2)^2 \tau^2}$$

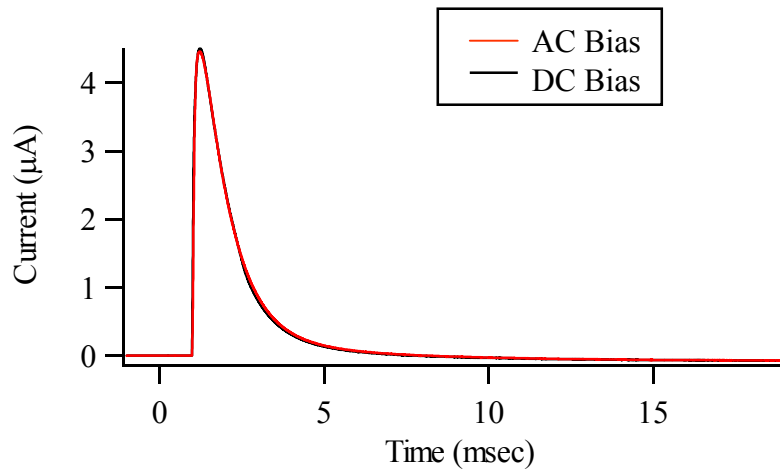


Sum signals from 2 sensors with summing loop
 Readout 2 sensors with one SQUID amplifier
 Demodulate output with lock-in amplifiers
 Scalable to n ⊗ 2

DC and AC Comparison

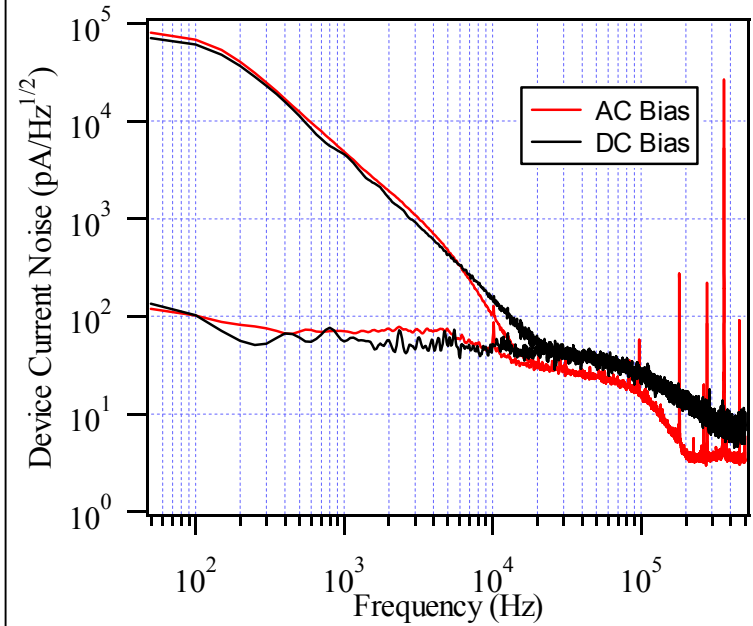


Current Pulse (Time)



DC and demodulated AC pulse shapes are identical

Current Pulse (Frequency)



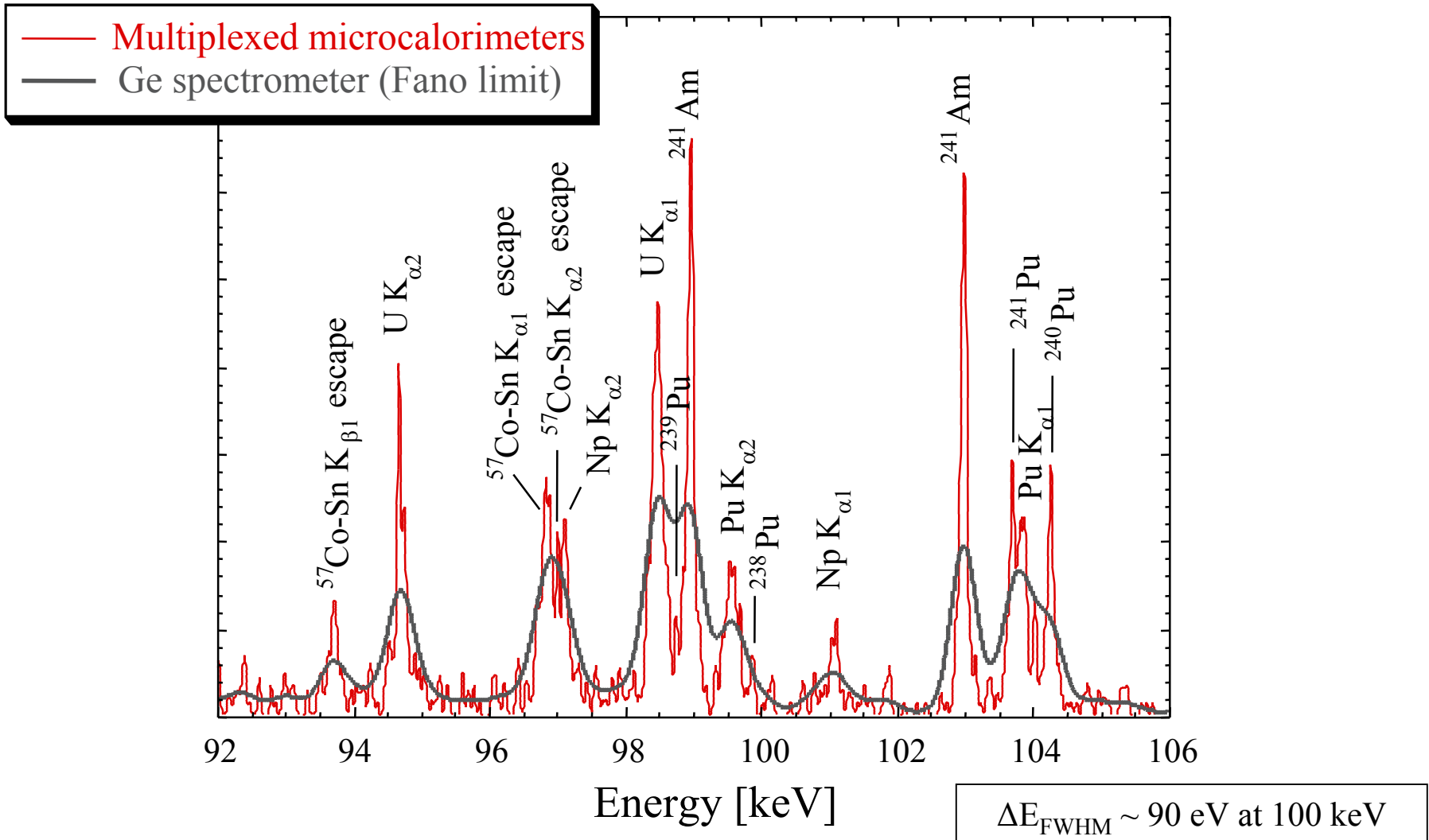
LC resonant circuit acts as a filter for AC Biased Data

Demonstrated $\Delta E_{FWHM} = 60$ eV at 60 keV for 2 multiplexed detectors, same as DC case

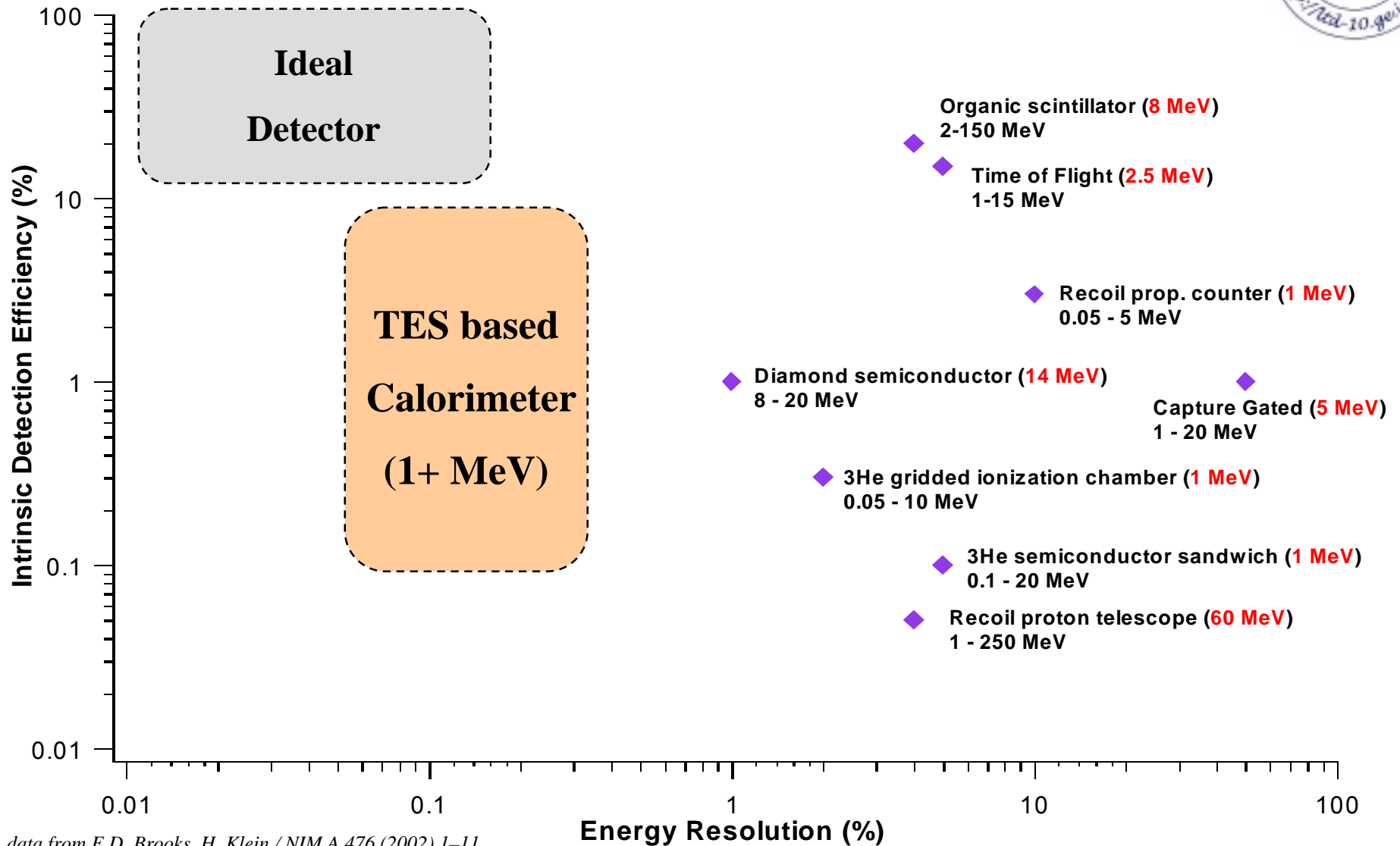
γ -ray Spectrum of a Mixed Pu Isotope Source



Determination of Pu Isotopes Abundances



Fast-Neutron Spectrometer

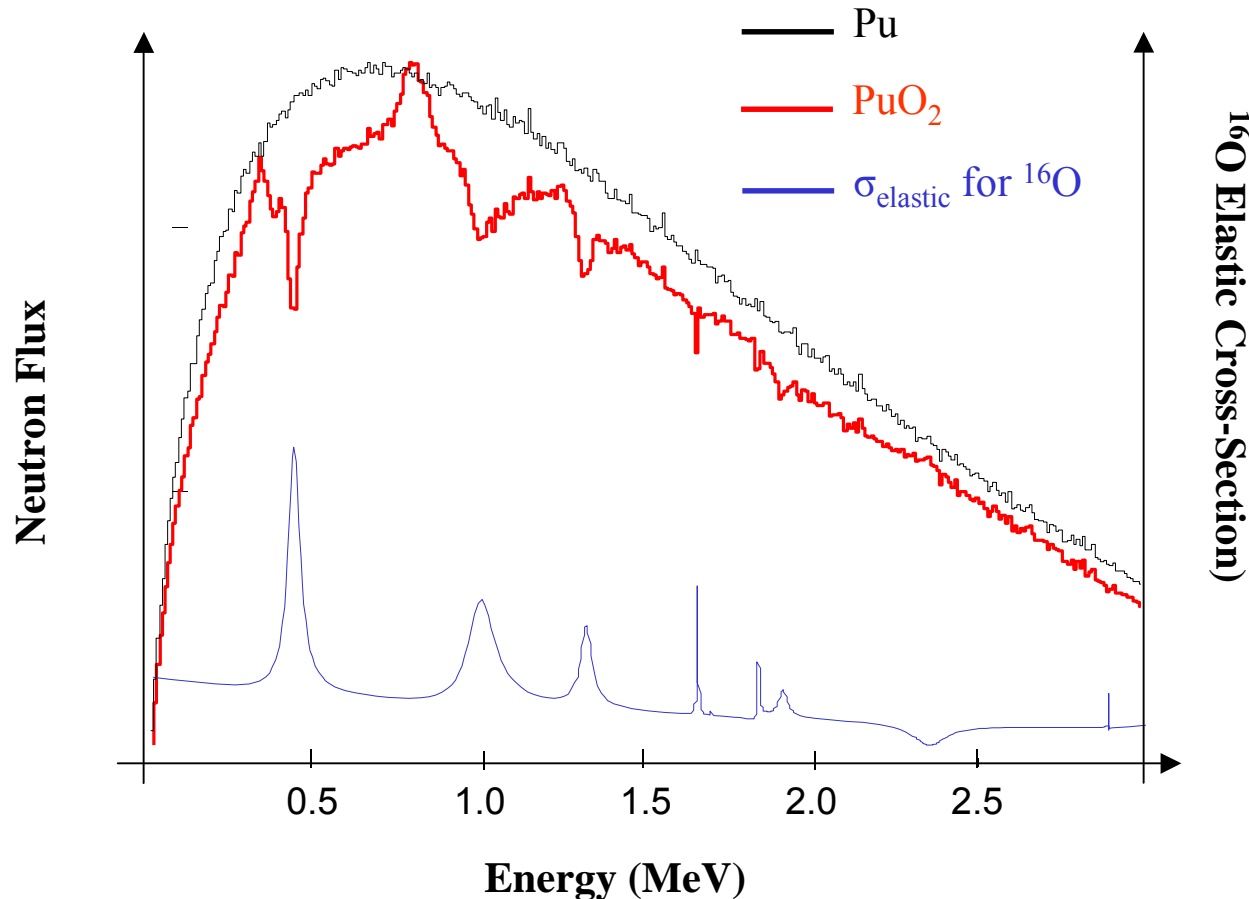


data from F.D. Brooks, H. Klein / NIM A 476 (2002) 1-11

Neutron Transmission Spectroscopy



MCNP simulation of the neutron emission spectrum from Pu and PuO₂



Active or passive interrogation for elemental composition analysis
Advantages: large penetration depth and nondestructive

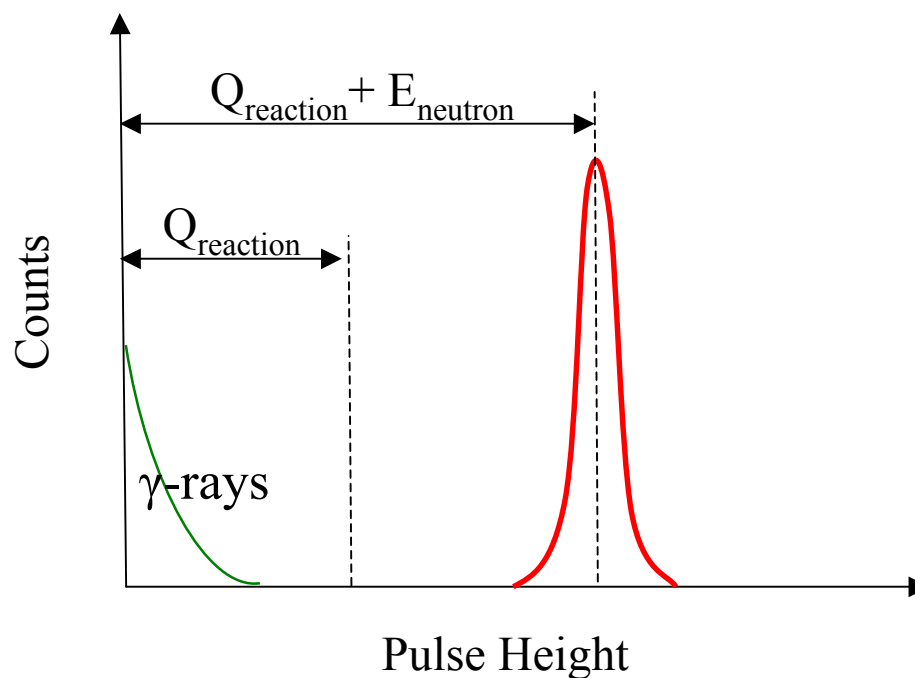
Neutron Detection Principle



- Choose absorber material with high (n,α) cross section
- After neutron capture:

Heavy charged particles are created and stopped in the absorber

$$E_{\text{deposited}} = Q_{\text{reaction}} + E_{\text{neutron}}$$

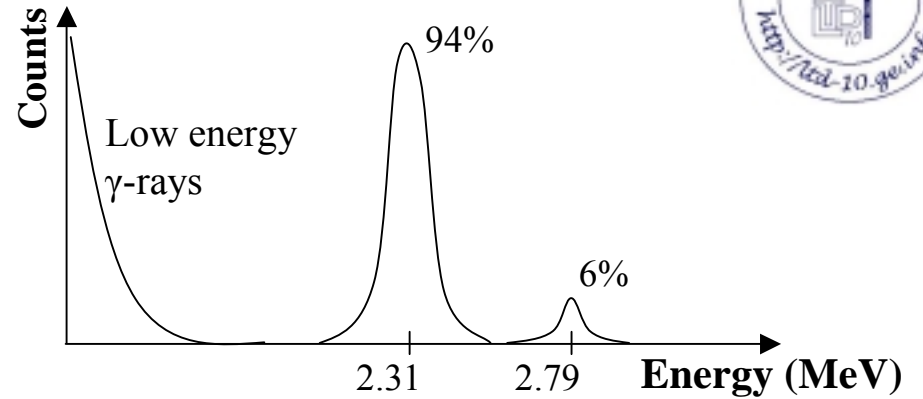
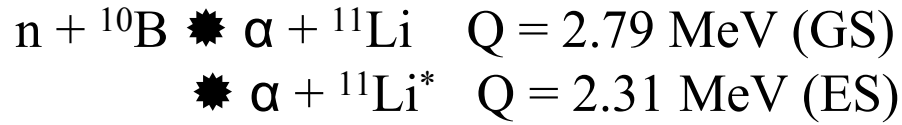


Photons with $E_{\gamma} < Q_{\text{reaction}}$ can be discriminated against neutrons

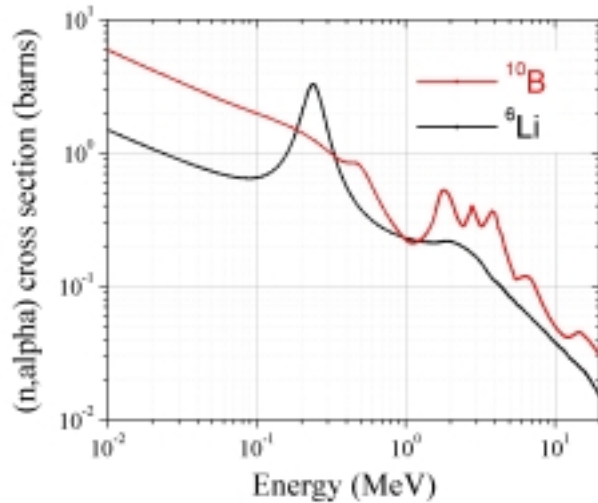
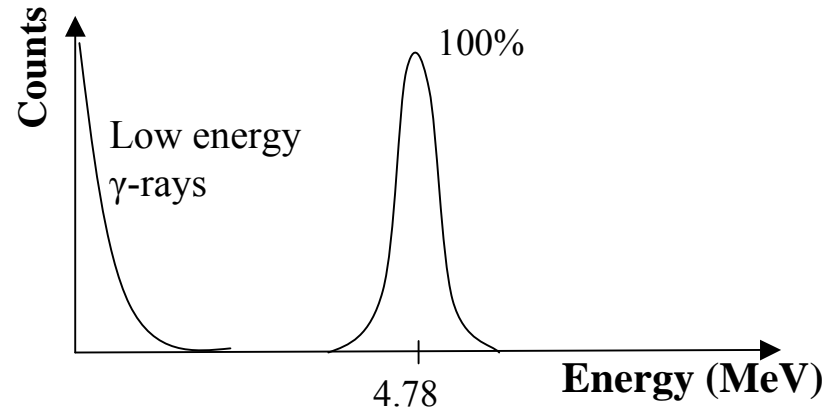
Neutron detection materials



^{10}B



^6Li



Expected spectrum for thermal neutrons

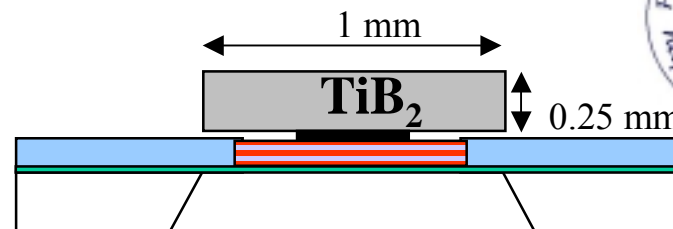
First neutron spectrum



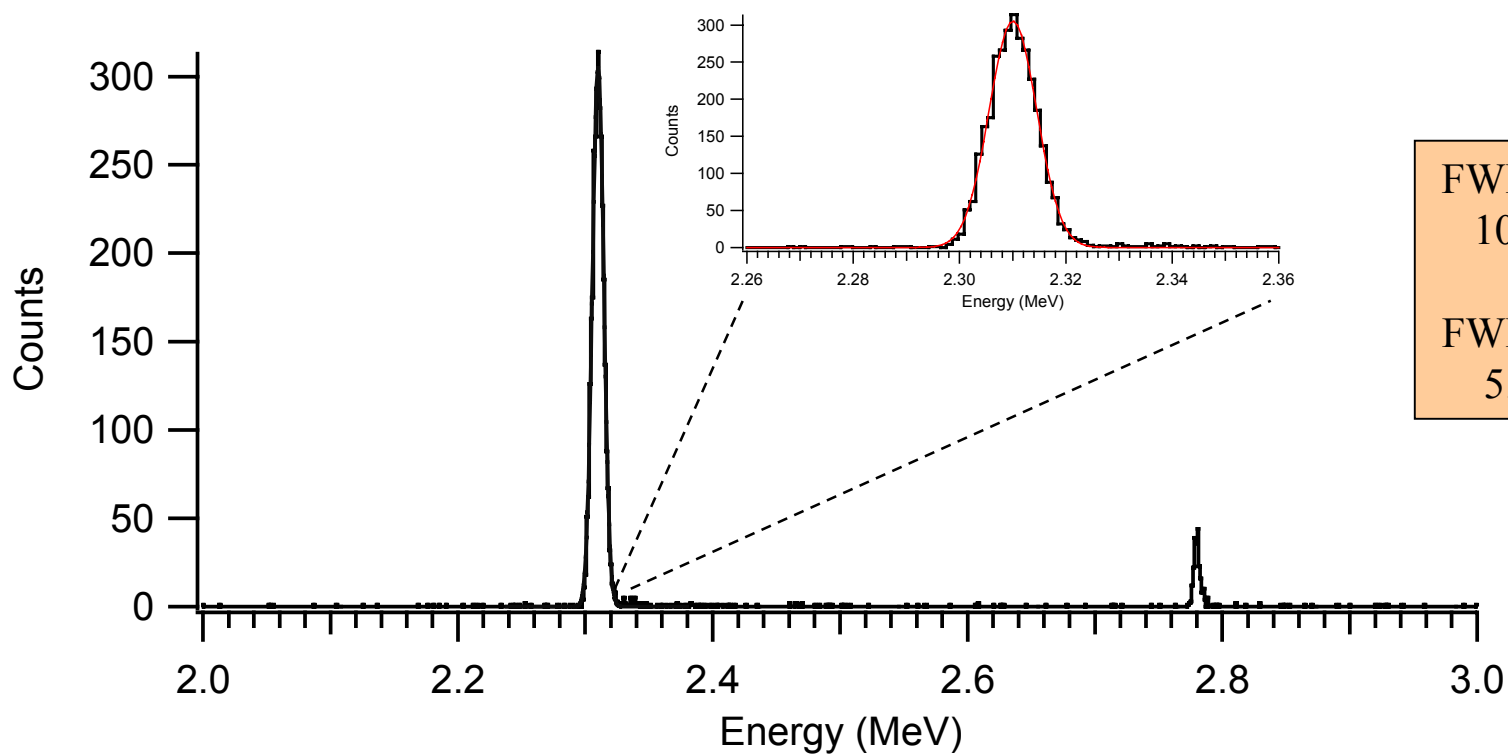
TiB₂ absorber for neutron detection:
large heat capacity per unit mass (metal)

$$C_{\text{absorber}} = 10 \text{ nJ/K}$$

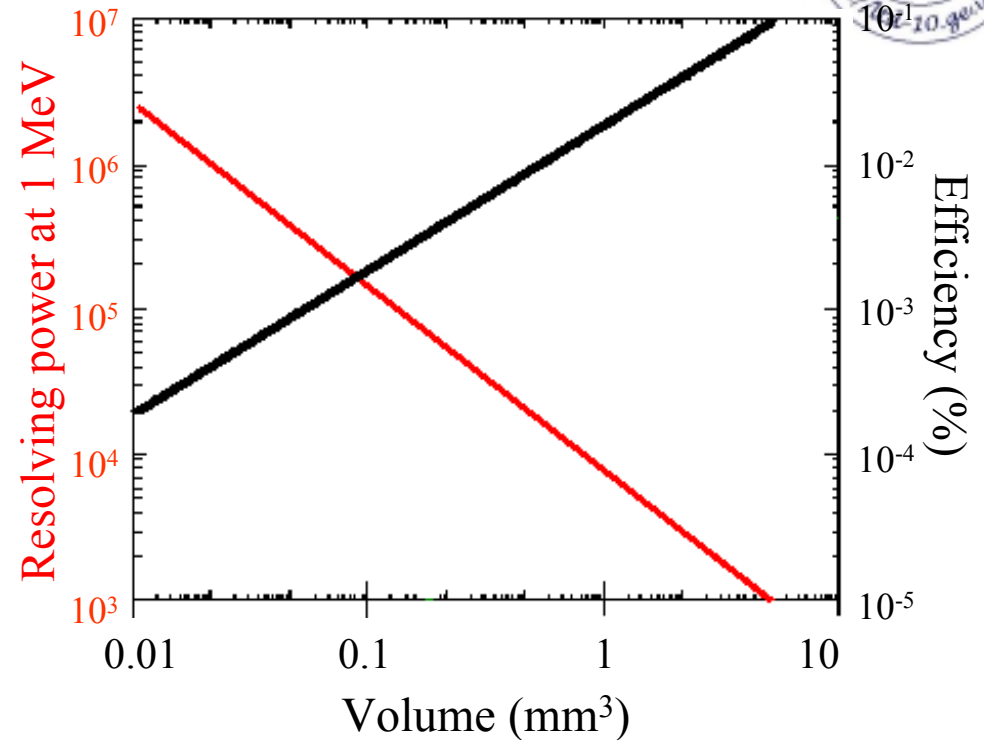
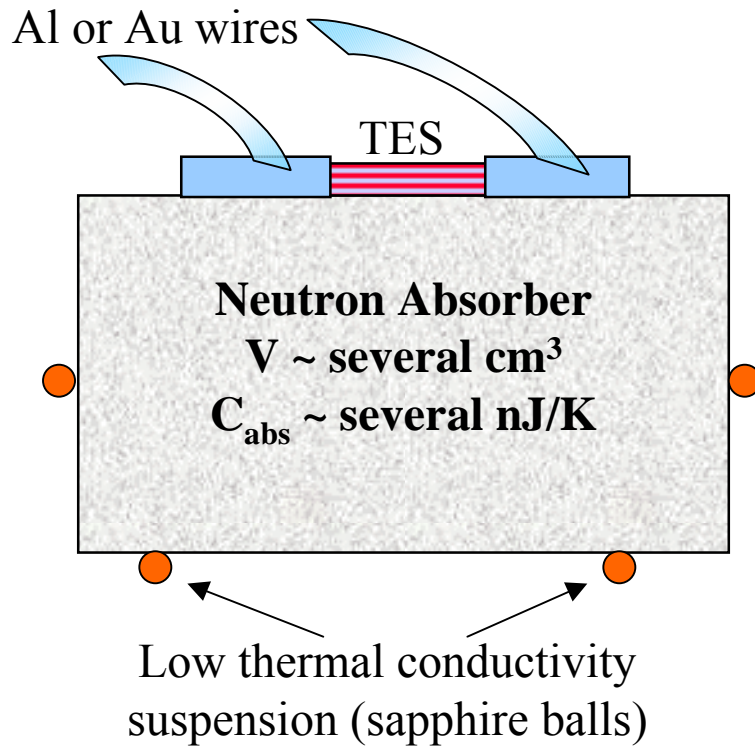
$$m_{\text{abs}} = 4 \text{ mg}$$



Thermal neutrons spectrum



Large absorber design



Size will be adjusted for particular application:

- Max. count rate capability limits maximum size of each individual pixel
- Source strength sets number of pixels to multiplex

Summary



High resolution γ spectroscopy with multiplexed detectors

✱0.1% FWHM energy resolution at 100 keV

High resolution neutron spectroscopy

✱0.2% FWHM energy resolution at 2.79 MeV