Monte Carlo Analysis of Energy Deposition in a Cryogenic Neutron Detector

Z. W. Bell, S. A. Pozzi

Oak Ridge National Laboratory, USA

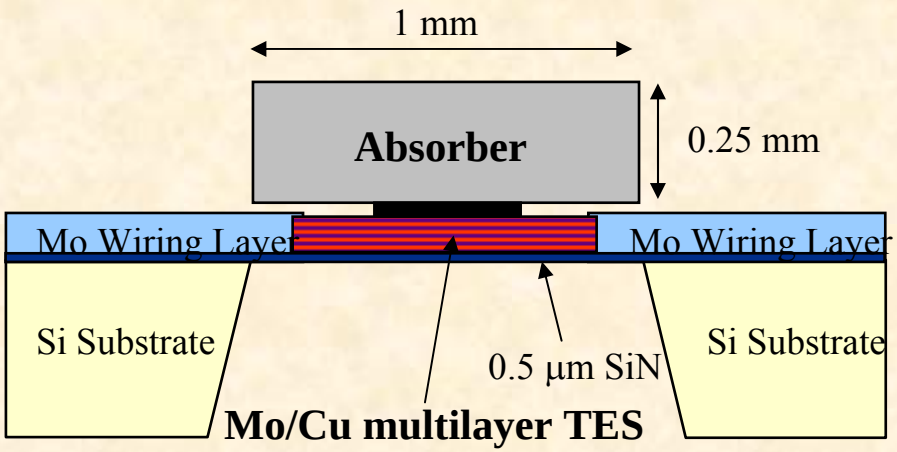
Enrico Padovani

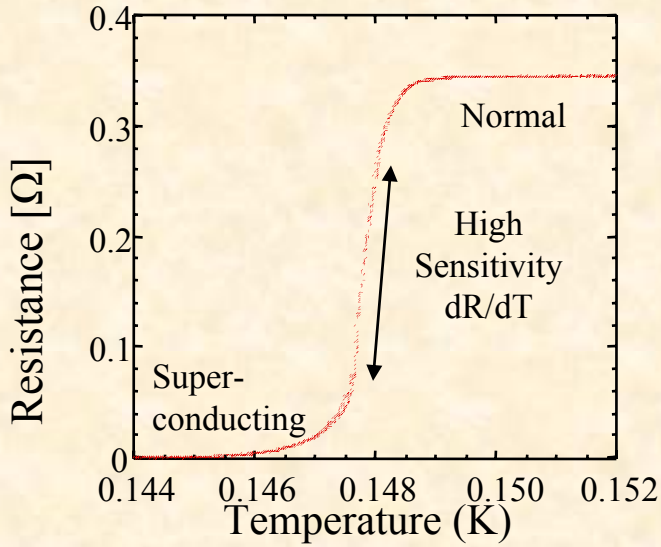
Polytechnic of Milan, Italy

Motivation

- Cryogenic neutron detection
  - Measurement of heat generated by neutron capture
  - Operates below 1 K
  - Uses superconducting, insulating, or semiconducting absorber
  - Promise of <20 keV resolution, independent of neutron energy
  - Detection demonstrated with ^{6}LiF and TiB_2 absorbers

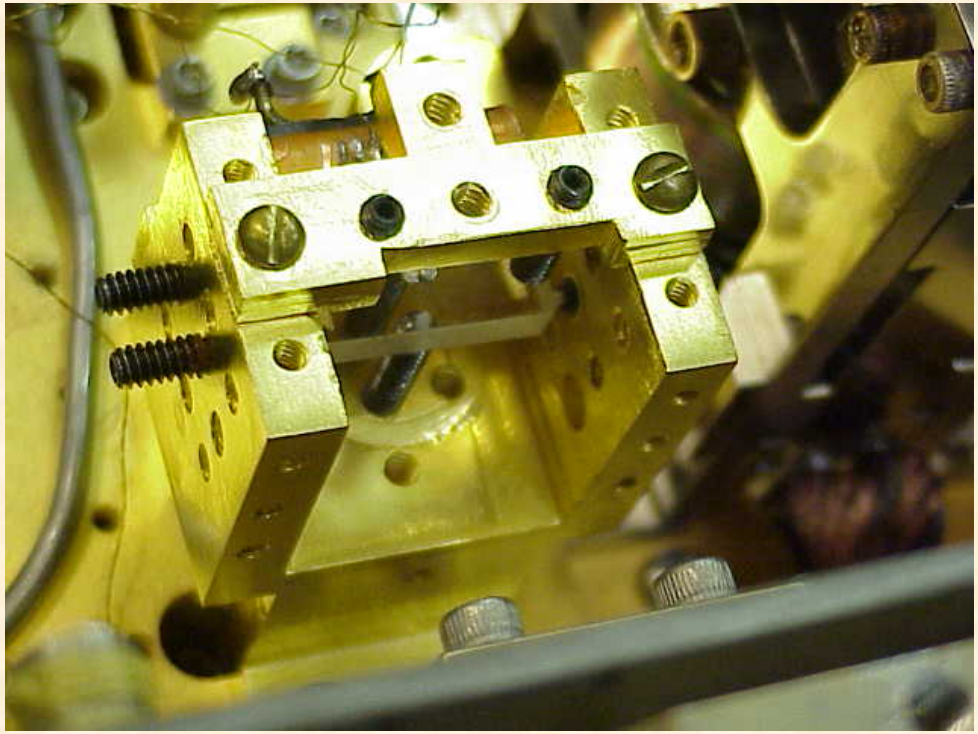
LLNL Design





Drawing and plot courtesy of S. Friedrich, LLNL

- Absorber glued to TES
- TES deposited onto Si_3N_4 membrane grown on Si substrate
- Thermal pulse in absorber diffuses through TES and Si_3N_4 to thermal ground
- Temperature excursion of ~0.2 mK, max
- This design works for gammas and **conducting** neutron absorbers

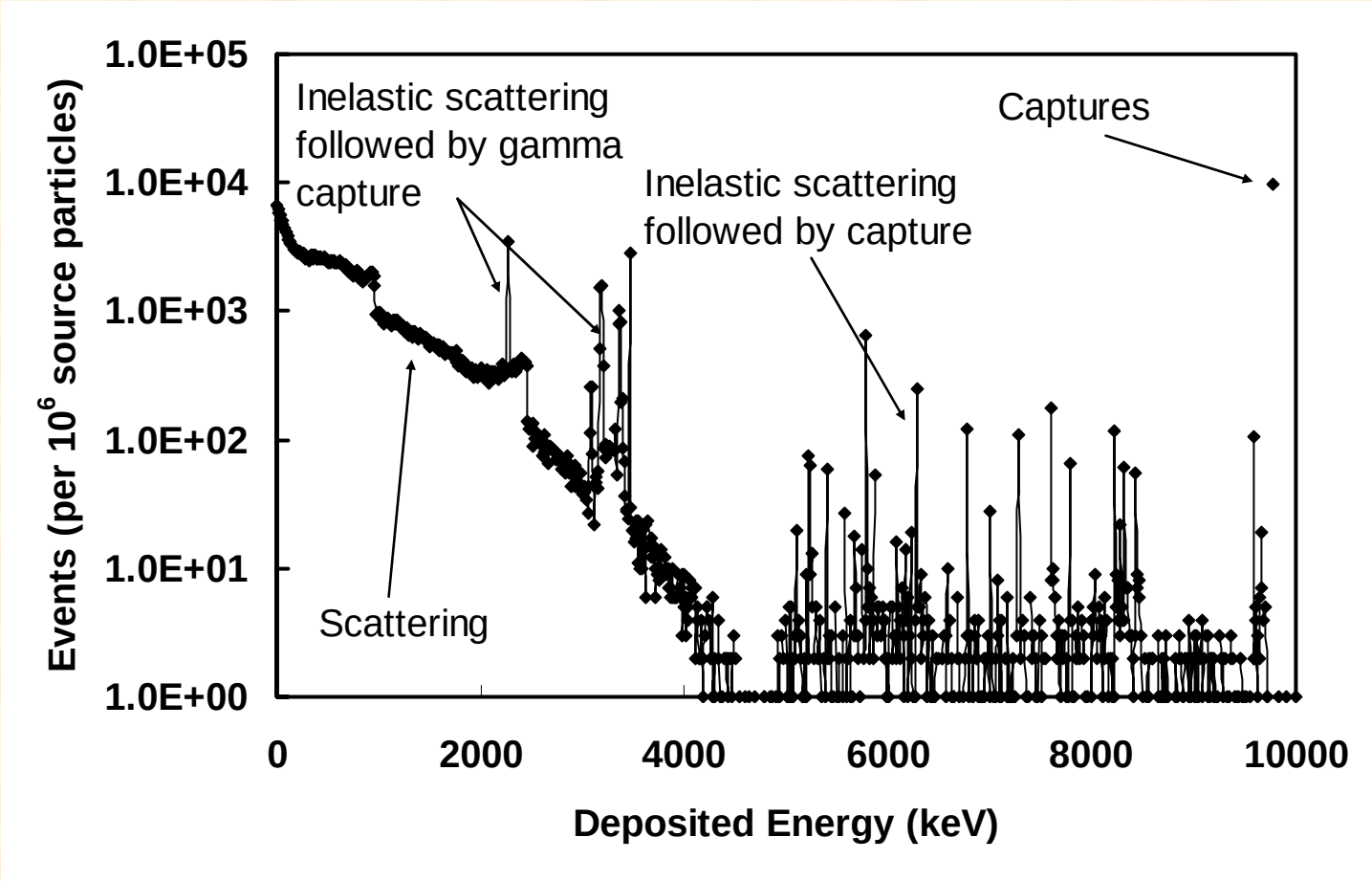


0.8 cm^3 ^{nat}LiF in holder

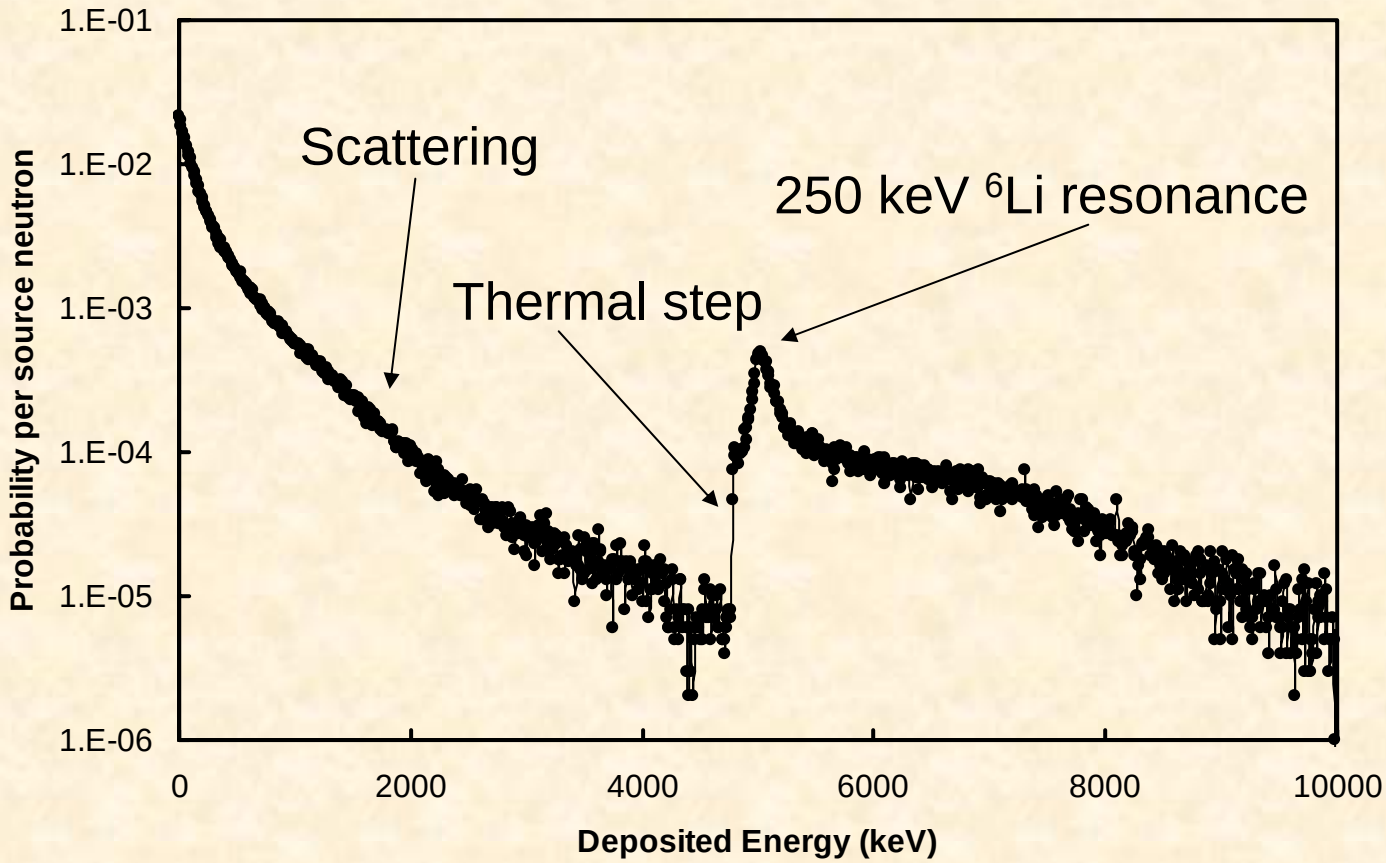
Photograph courtesy of I. D. Hau, LLNL

Motivation

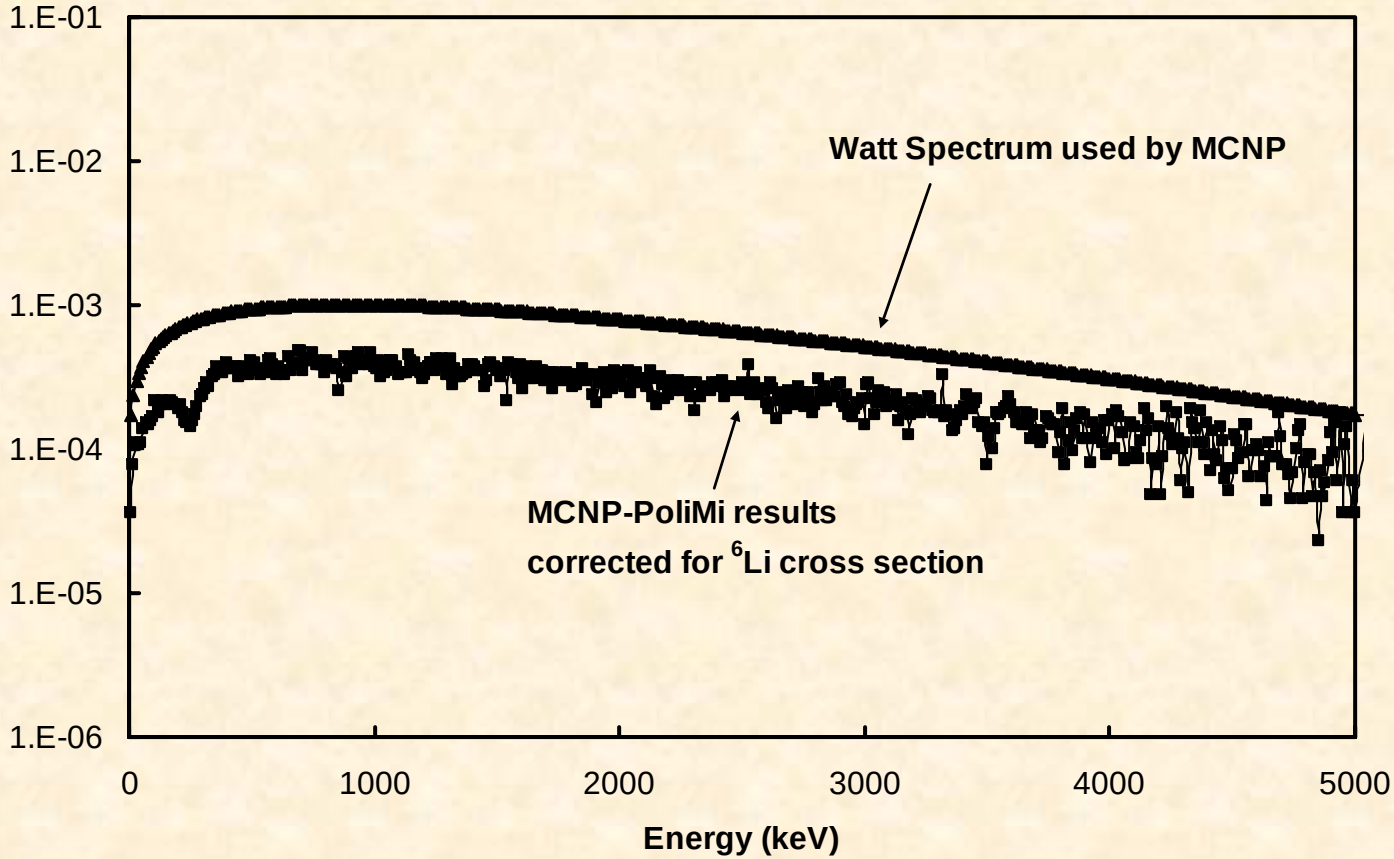
- But how do we extract neutron spectrum from measured spectrum?
  - Desire: E_n = simple function of E_{dep}
  - Capture: $E_{dep} = Q_c + E_n$
  - Scattering: usually below Q (energy of recoiling ion, energy from γ absorption/scattering)
  - Elastic Scattering + capture: $E_{dep} = Q_c + E_n$
  - Inelastic scattering + capture: $E_{dep} = Q_c + E_n - E_\gamma \rightarrow$ "Ghost spectra"
- Modeling with MCNP-PoliMi



Simulation of 5 MeV neutrons incident on 2-cm block of ^{6}LiF



Simulation of ^{252}Cf neutrons (Watt spectrum) incident on 2-cm block of ^{6}LiF



Recovered ^{252}Cf spectrum

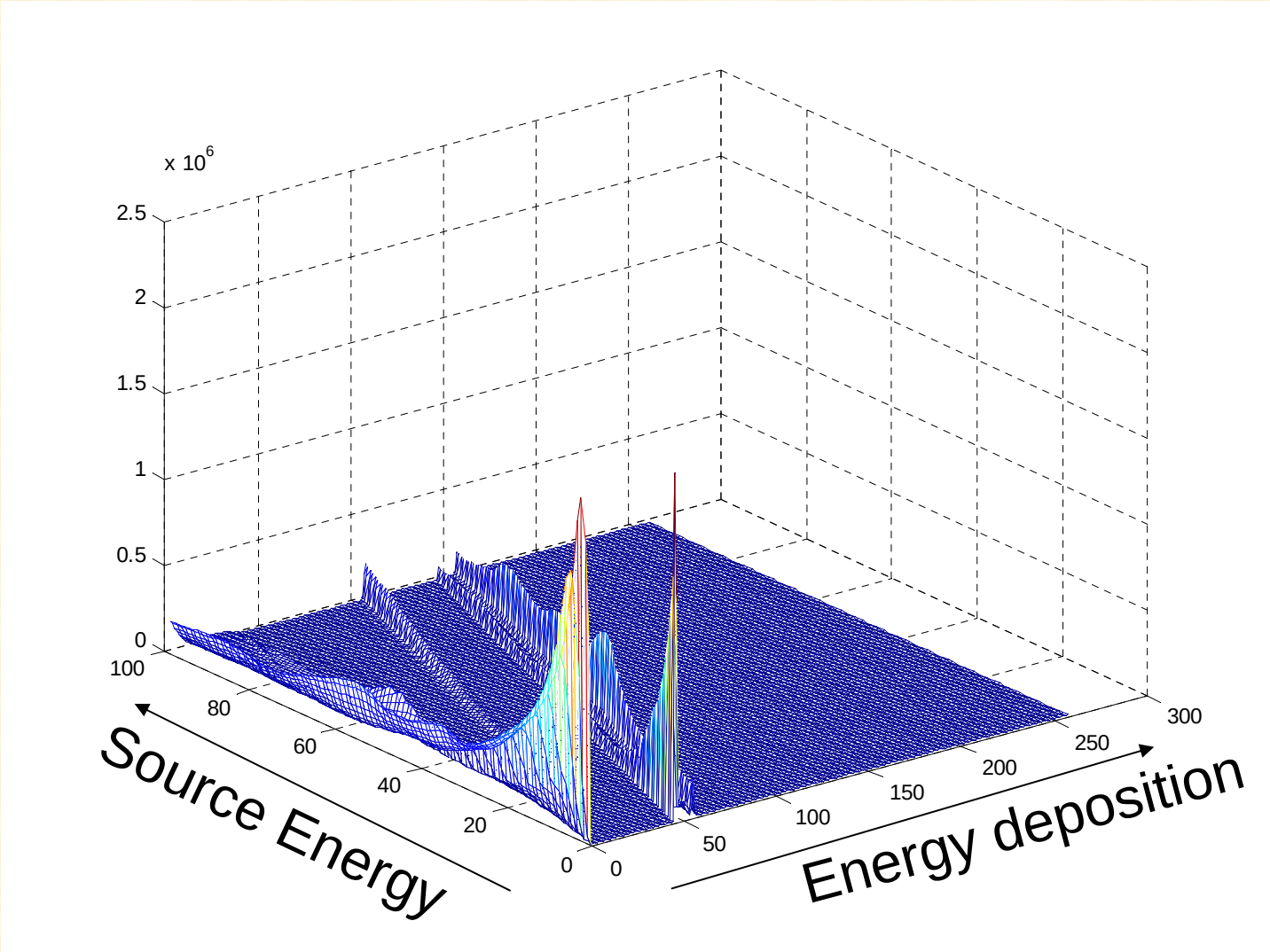
Simulation above thermal step scaled by ^{6}Li(n,α) cross section

Li Conclusions

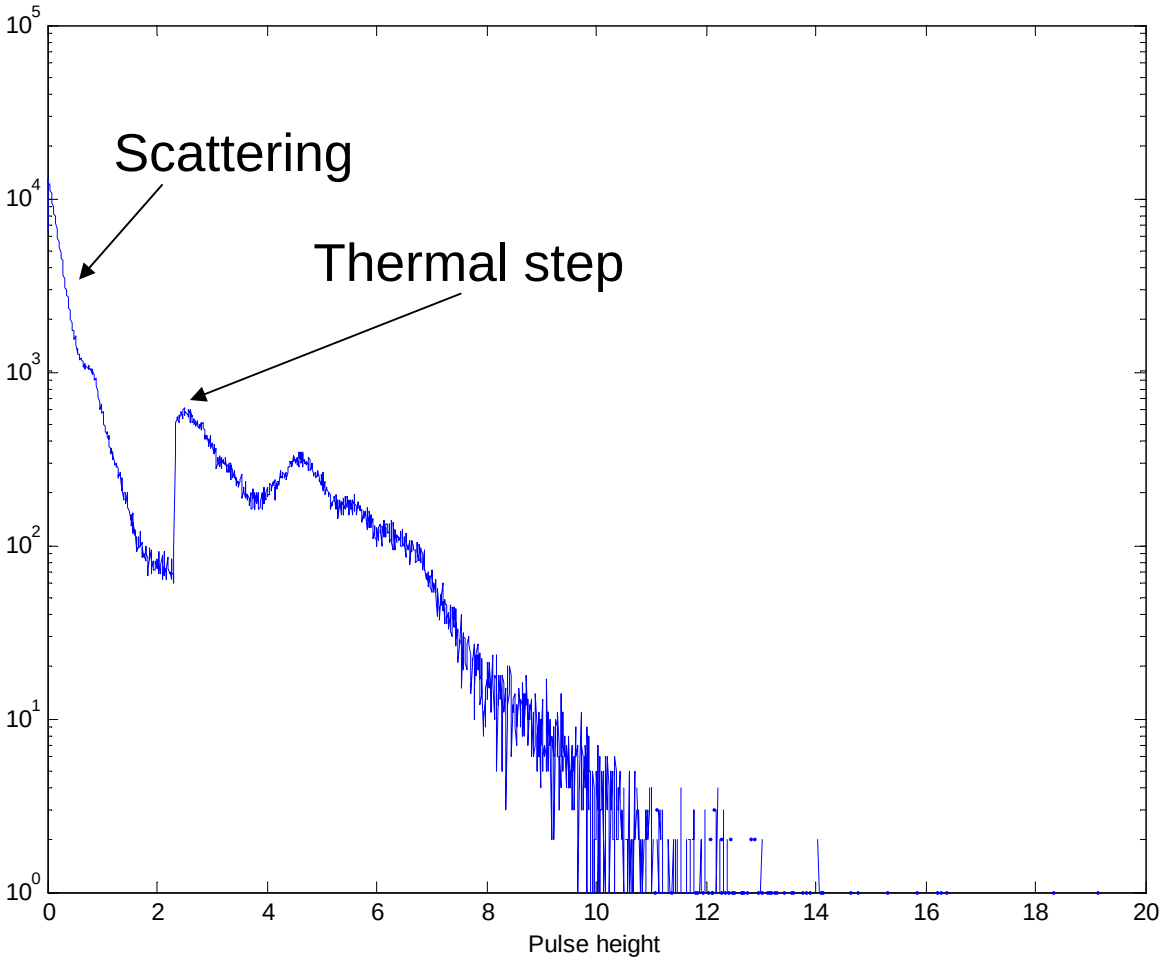
- For LiF, simple analysis works reasonably well because:
  - Only one capture reaction
  - High Q_c
  - Inelastic scattering leads to mostly low-energy gammas that are captured in 8 cm^3 block
  - "Ghost spectra" 1 – 2 orders of magnitude lower amplitude

What about Boron?

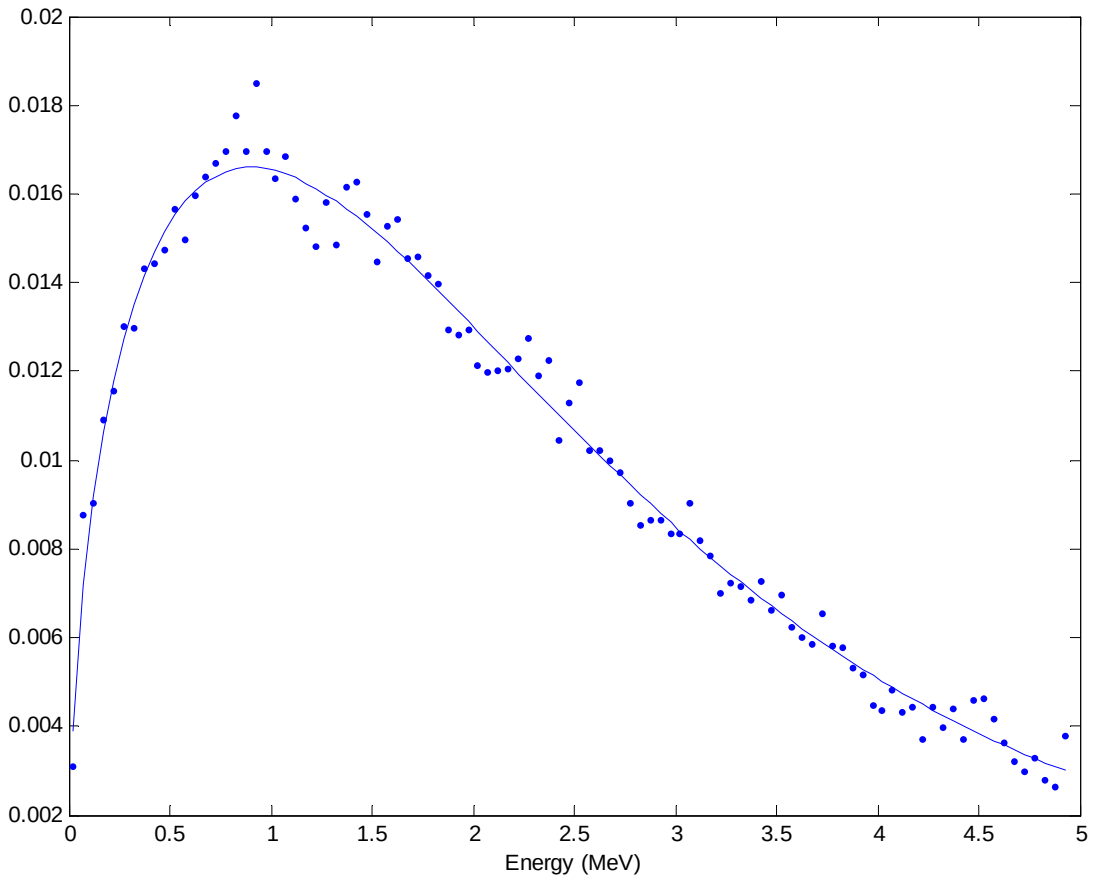
- More complicated:
  - Two capture reactions
  - Essentially bi-diagonal response matrix
  - Dominated by thermal response
  - Lower Q_c



^{10}B response matrix



Simulated ^{252}Cf spectrum on a 2-cm ^{10}B cube



Recovered ^{252}Cf spectrum

Full response matrix used, including scattering

B Conclusions

- For ^{10}B, simple analysis does not work reasonably well because:
  - Two capture reactions preclude simplest processing
    - Each E_n contributes to two energy bins
    - Bins must be aligned or subtractions are incomplete
    - Noise causes artifacts in the unfolding that propagate
  - $^{10}B(n, t+2\alpha)$ becomes important above 5 MeV
- Full response matrix is probably needed