Data Analysis of Neutron Capture Measurements on ^{75}As using DANCE or: What I did last summer.

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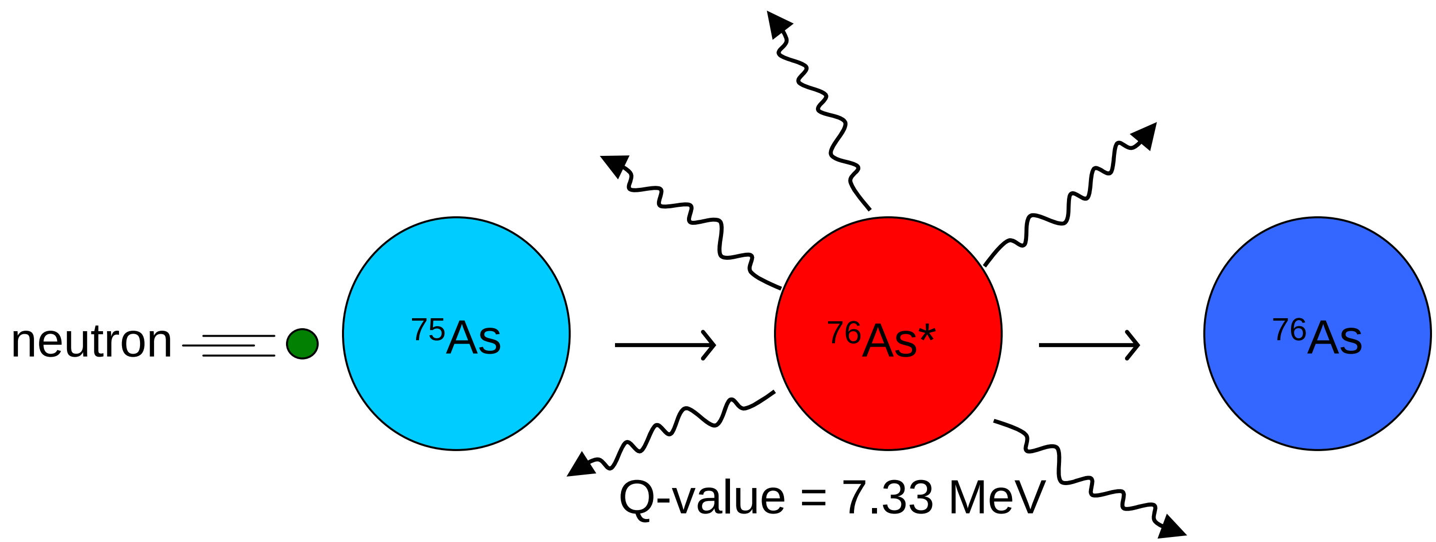
Outline

- What is neutron capture?
- Why study neutron capture of ^{75}As?
- Detector for Advanced Neutron Capture Experiments
- Data Analysis
  - Energy and time calibration
  - Background subtraction
  - Adjusting gates on data to maximize signal-to-noise
  - Calculation of DANCE efficiency
- Results

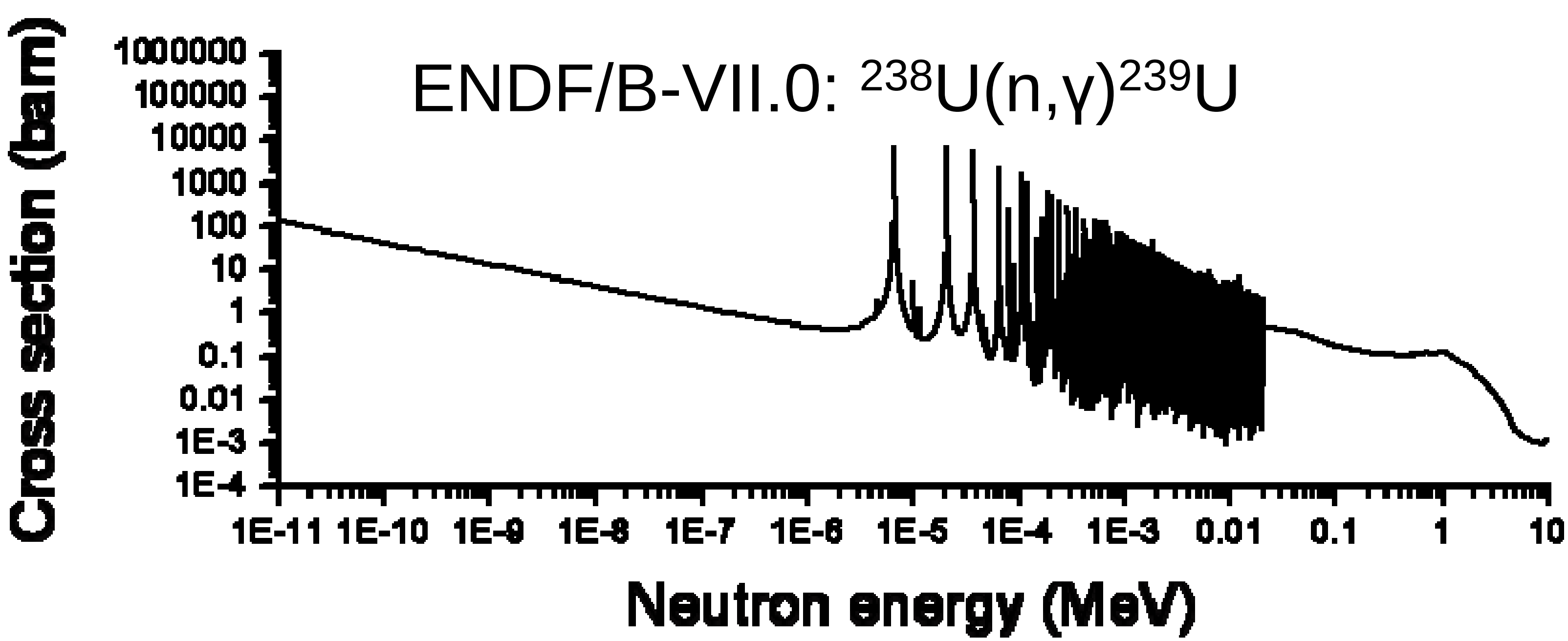
Neutron capture basics

- Nucleus picks up a neutron and forms an excited nuclear state with energy equal to the neutron separation energy (Q-value)
- Releases this energy by gamma ray emission
- Emits 3 – 7 gamma rays with total energy of ~5 – 8 MeV, depending on Q-value



Neutron capture basics (cont.)

- At low neutron energy, observe increasing cross section
- Observe resonances where cross section drastically increases (3 – 5 orders of magnitude)



Measuring cross section

Intensity of
bombarding neutrons

Number of ^{75}As atoms
being bombarded

Cross section

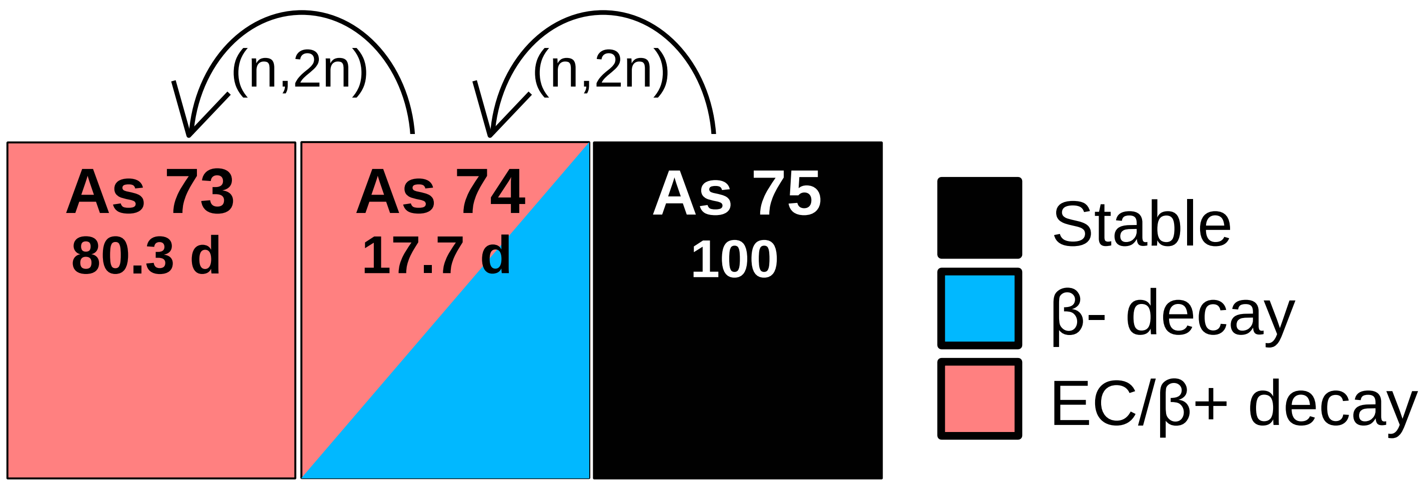
- Probability of neutron capture by ^{75}As
- measured in units of area (1 barn = 10^{-24} cm^2)

Gamma cascade event rate = $N \cdot I \cdot \sigma$

Goal of my work: To determine the total number of ^{75}As neutron-capture events!

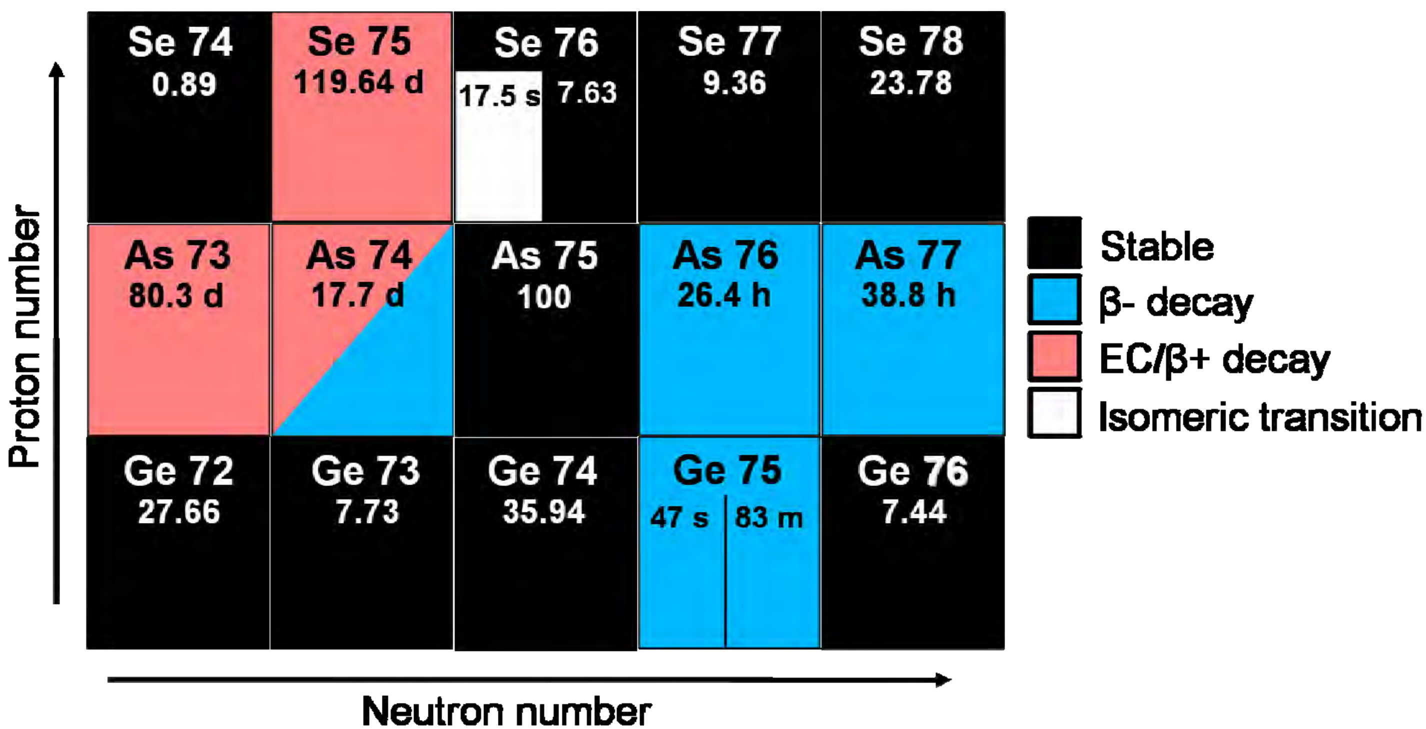
Why study neutron capture of ^{75}As?

- Stockpile Stewardship
  - ^{73}As/^{74}As ratio used as high energy (E_n > 10.2 MeV) neutron fluence monitor by testing program



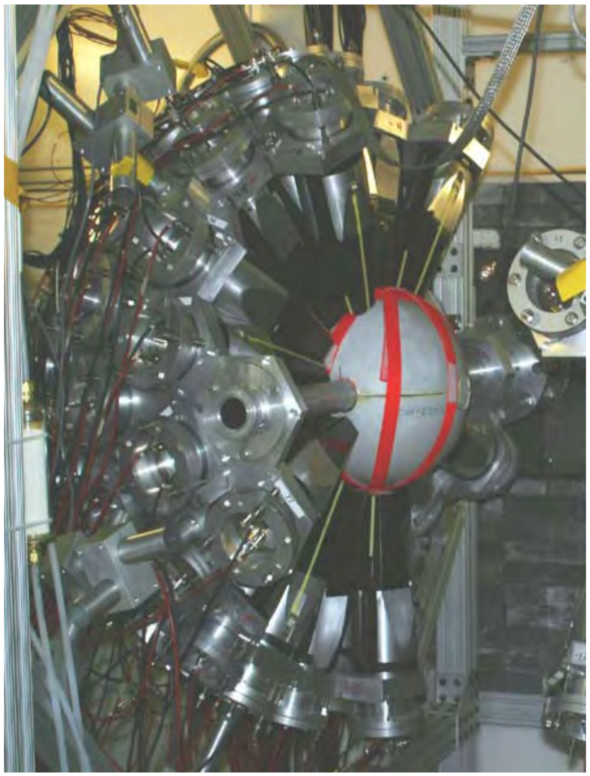
Something more about nuclear astrophysics?

- Nuclear astrophysics
  - Important to the slow-neutron-capture-process of stellar nucleosynthesis
    - Produces of ~1/2 of all elements heavier than iron
    - Occurs in relatively low neutron density and temperature stars



Detector for Advanced Neutron Capture Experiments (DANCE)

- DANCE is a highly segmented, high efficiency BaF_2 gamma ray detector array to measure neutron capture cross sections
- Neutrons produced through pulsed 800 MeV protons on a moderated tungsten spallation target



- Energy of neutron causing an event can be distinguished by time-of-flight between beam pulse and event time
- Measures neutron capture information as a function of neutron energy for milligram quantity targets of stable and radioactive (half-life >100 days, <1 Ci) targets
- Situated at the Los Alamos Neutron Science Center at Los Alamos National Laboratory

Data Analysis - Energy and time calibration

- Time calibration – essentially a neutron energy calibration

- Energy calibration done in two ways
  – Y-88 source (898 keV, 1836 keV)
  – Radium impurities in BaF_2 crystals (4.78 MeV alpha particles), distinguished from gammas by pulse shape

Data analysis - Background sources

- Scattered neutrons capturing in BaF_2 crystals

- Scattered photons coming from up beam line

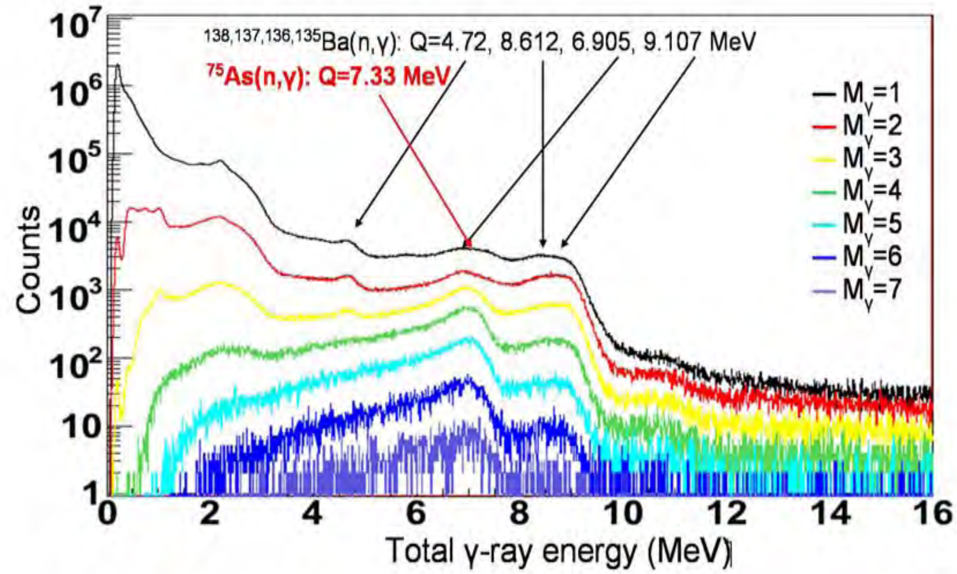
- Decay of naturally occuring radioisotopes

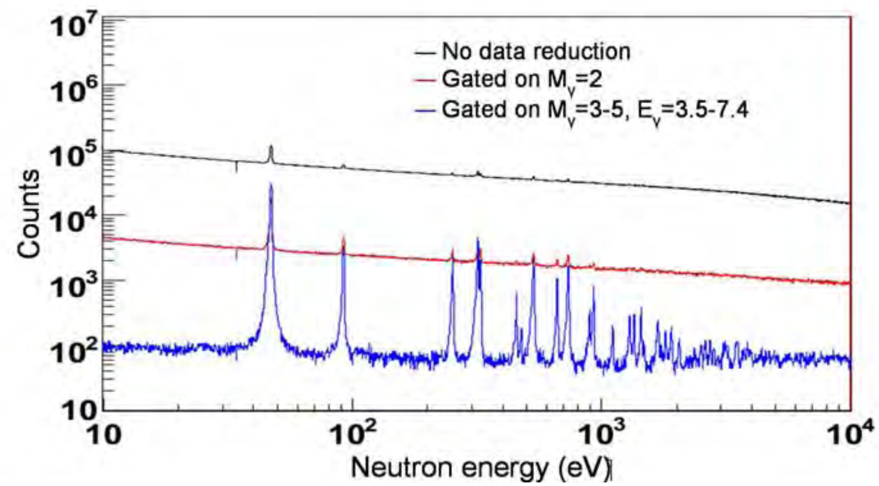
Data analysis - Background subtraction

- On- / Off-resonance analysis
  - Background contains exact experimental conditions as experiment
  - Only gives you background information at neutron energies of the resonances
- Analyze blank data
  - Allows you to calculate background at any neutron energy
  - No background from beam scattered in target

Data analysis - Improving signal-to-noise

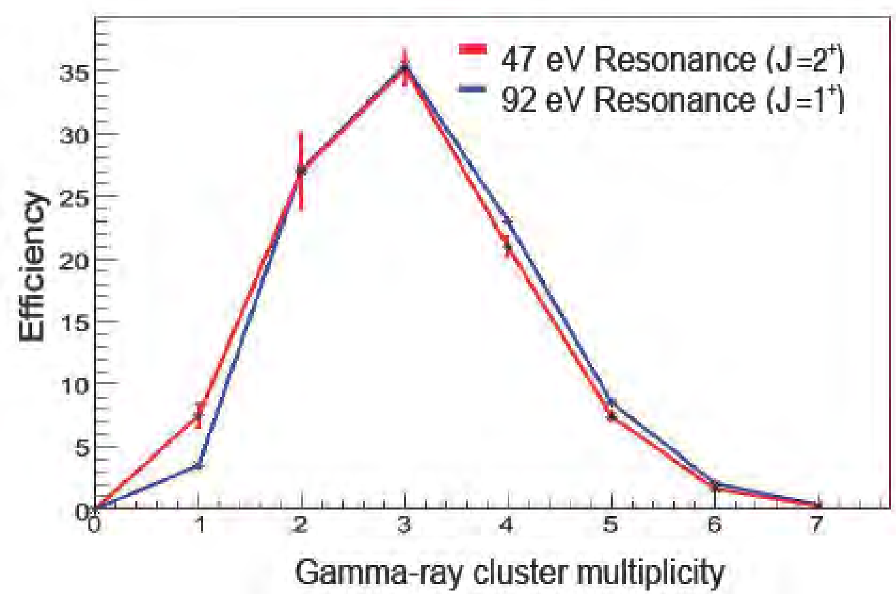
- Background is dependent on total gamma energy and multiplicity
  - Allows for a normalization of background to experimental data prior to subtraction
- Putting cuts on the total gamma ray energy and multiplicity gives better signal-to-noise ratio and smaller errors on end cross section value
  - Allows for the calculation of the optimal energy and multiplicity gate for the lowest error





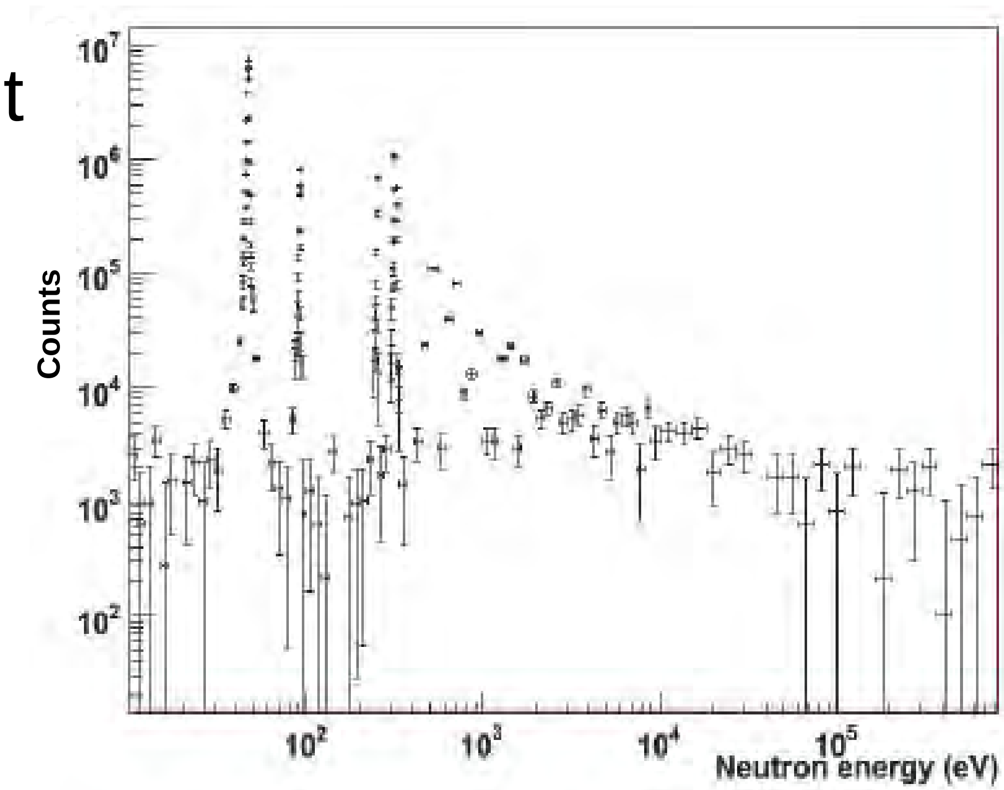
Data analysis – Examining the gamma ray distibution

- Different resonances correspond to different nuclear excitation levels
  - Therefore have a nuclear spin and parity
- Gamma ray emission is highly dependent on the spin and parity of the decaying state
- Thus, the gamma ray emission distribution ratio may be spin state dependent.



Data analysis - Selecting neutron energy bins

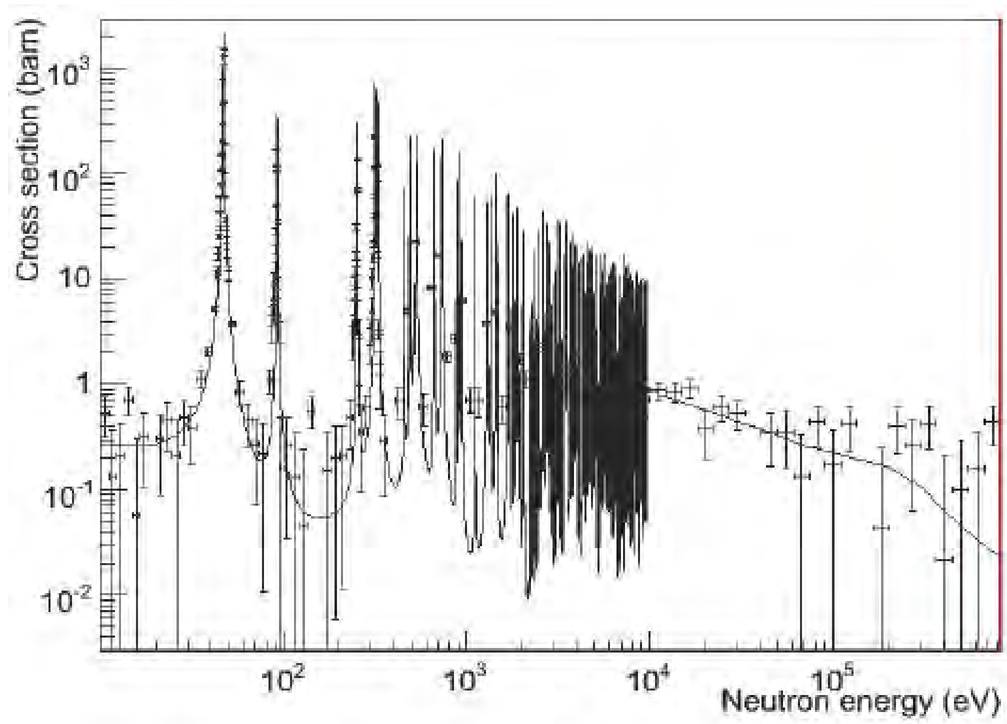
- Using the Ti-backing background subtraction, we can get net counts for all neutron energies
- Selection of neutron energy bins is important
  - Must be small enough to see energy dependent features
  - Must be large enough to have good statistics



Results

- Several steps were still necessary to get an actual cross section measurement
  - The ~700 μg ^{75}As target needed to be mass analyzed to get exact mass
  - The beam monitor data needed to be analyzed to get the beam intensity as a function of neutron energy

- However, can generate a normalized plot by:
  - Using empirical formula for beam flux
  - Normalizing data to literature data for the largest 47 eV resonance



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