The Chopper Efficiency:

Cd is used in the neutron chopper for the student experiment in the reactor. The isotope that does all the work is ^{113}Cd. Data on neutron cross sections are available from Brookhaven at `http://www.nndc.bnl.gov/sigma/`. (The Cd data are in the file `endf-6[80942].txt`.) The natural abundance of ^{113}Cd is about 12.2%, and the chopper is presumably made of natural Cd. I wanted an empirical numerical representation of the data for energies between 0.001 eV and 10 eV. Here is what I found that worked pretty well.

For low energies σ_T starts out as proportional to $1/\sqrt{E}$ and that works until the resonance at about 0.2 eV pops up. A Lorentzian works fairly well for the resonance except that it falls off a bit faster than the Lorentzian on the high energy side. I found empirically that having it fall off as $z^{-2.3}$ helped that.

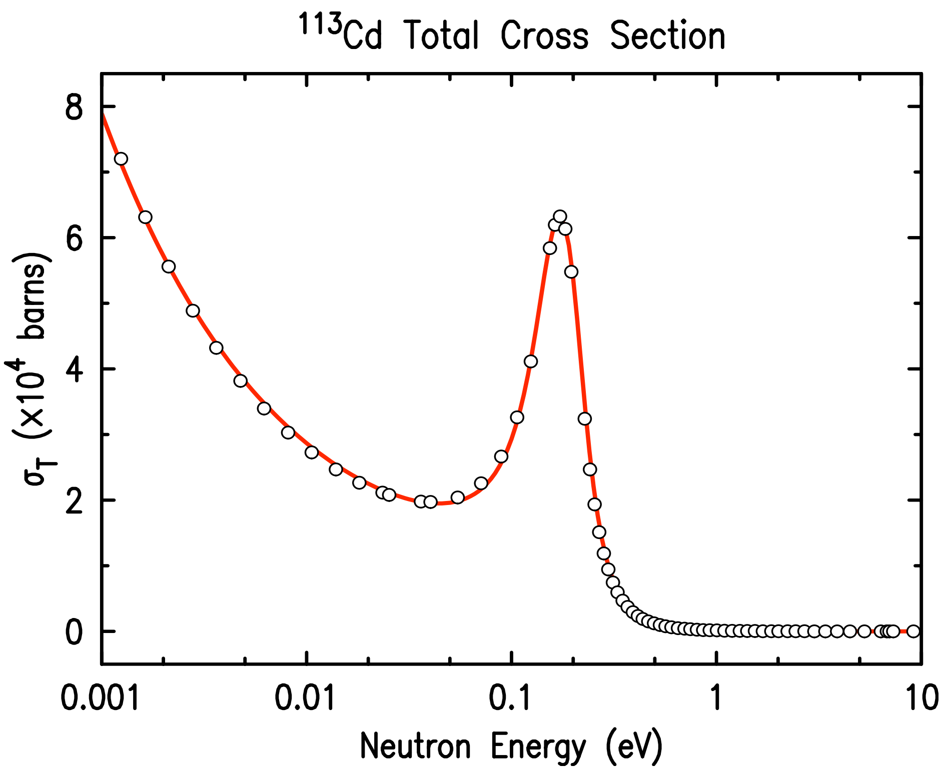
$\mathbf{0.001}\,\mathrm{eV} \leq \mathbf{E} \leq \mathbf{0.174}\,\mathrm{eV}$:

$$\sigma_T = \frac{2350}{\sqrt{E}} + \frac{57360}{1 + [(E - 0.174)/0.06]^{2.3}} + 4.5$$

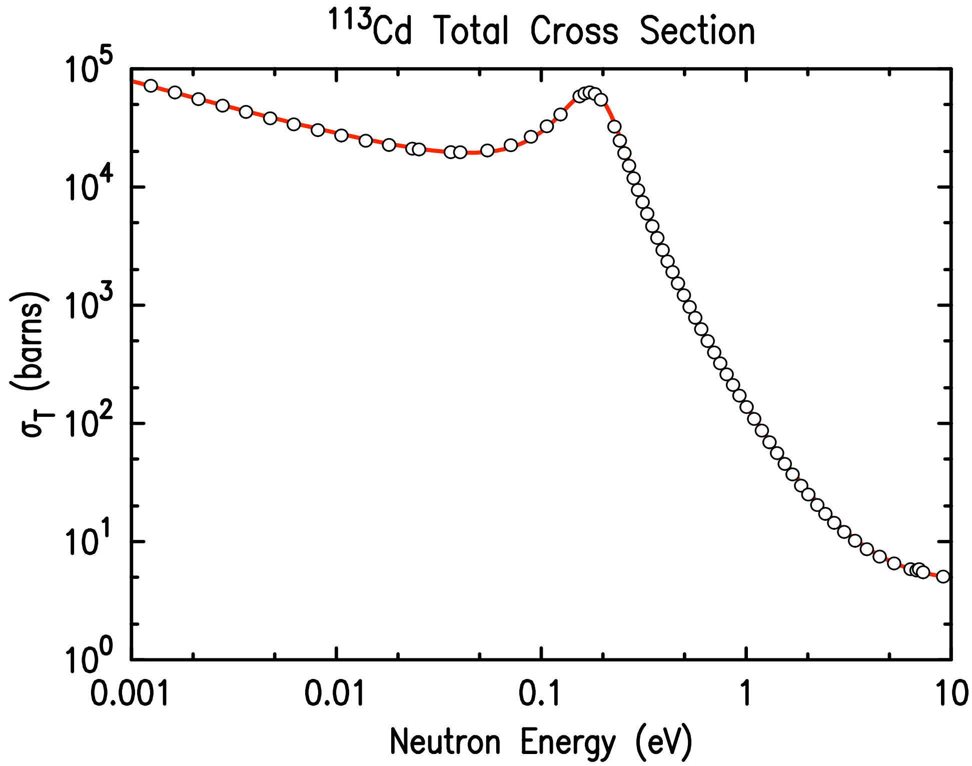
$\mathbf{0.174}\,\mathrm{eV} \leq \mathbf{E} \leq \mathbf{10}\,\mathrm{eV}$:

$$\sigma_T = 5634\, e^{-(E-0.174)} + \frac{57360}{1 + [(E - 0.174)/0.06]^{2.3}} + 4.5\,,$$

where E is in eV and σ_T is in barns ($10^{-24}\,\mathrm{cm}^2$). The purpose of the $e^{-(E-0.174)}$ term is to gracefully get rid of the $1/\sqrt{E}$ part and let the decay of the modified Lorentzian take over above the resonance. The background helps above about 2 eV and might have to be changed for $E > 10$ eV. Here is the Cd cross section; the red line is my empirical representation and the circles are the “data” from Brookhaven.



Here are the same data on a log-log plot.



The attenuation of neutrons by the Cd chopper will be proportional to $e^{-\mu x}$; here $\mu = \sigma_{\mathrm{T}}\, n_{\mathrm{Cd}}$ where n_{Cd} is the number of ^{113}Cd atoms per unit volume of the material and σ_{T} is expressed in appropriate units. The Cd chopper disk is 1 mm thick. The atomic weight of Cd is 112.411 gm/mole and the density is 8.564 gm/cm^3. This means $n_{\mathrm{Cd}} = 5.61 \times 10^{21}\,\mathrm{cm}^{-3}$ for ^{113}Cd in natural Cd. That in turn gives $\mu = 5.61 \times 10^{-3}\,\sigma_{\mathrm{T}}\,\mathrm{cm}^{-1}$ when σ_{T} is expressed in barns. Neutrons that are not chopped effectively are equally likely to be counted into any channel of the MCS. There are a lot of them (relatively), which is why doing measurements with the student spectrometer is like watching a movie with the lights on.

We might define a chopper efficiency $\eta(E) = 1 - e^{-n_{\mathrm{Cd}}\, x\, \sigma_{\mathrm{T}}(E)}$ which is the amplitude of the chopped neutron counts relative to the total neutron counts for neutrons of energy E incident on the chopper. For the student spectrometer this is $\eta(E) = 1 - \exp[-5.61 \times 10^{-4}\,\sigma_{\mathrm{T}}(E)]$ when σ is in barns. In terms of neutron speed, the Cd cross section is

440 m/s $\leq$ **v** $\leq$ **5800** m/s:

$$\sigma_T(v) = \frac{3.250 \times 10^7}{v} + \frac{57360}{1 + [8.713 \times 10^{-8}\, v^2 - 2.90]^{2.3}} + 4.5$$

5800 m/s $\leq$ **v** $\leq$ **4** $\times$ **10^4** m/s:

$$\sigma_T(v) = 6705\, e^{-5.228\times 10^{-9}\, v^2} + \frac{57360}{1 + [8.713 \times 10^{-8}\, v^2 - 2.90]^{2.3}} + 4.5\,,$$

You might find it interesting to calculate the chopper efficiency when $E = 0.025\,\mathrm{eV}$ and also use the chopper efficiency along with TOF data for $Z \simeq 48$ (from which you can determine how many epithermal neutrons are chopped compared to how many are not chopped) to say something about the energy spectrum of the epithermals; to do that, you will have to assume a model for the spectrum (i.e., Gaussian, thermal at a higher temperature, etc.). You might also use your data to estimate the relative sizes of the thermal and epithermal neutron fluxes.