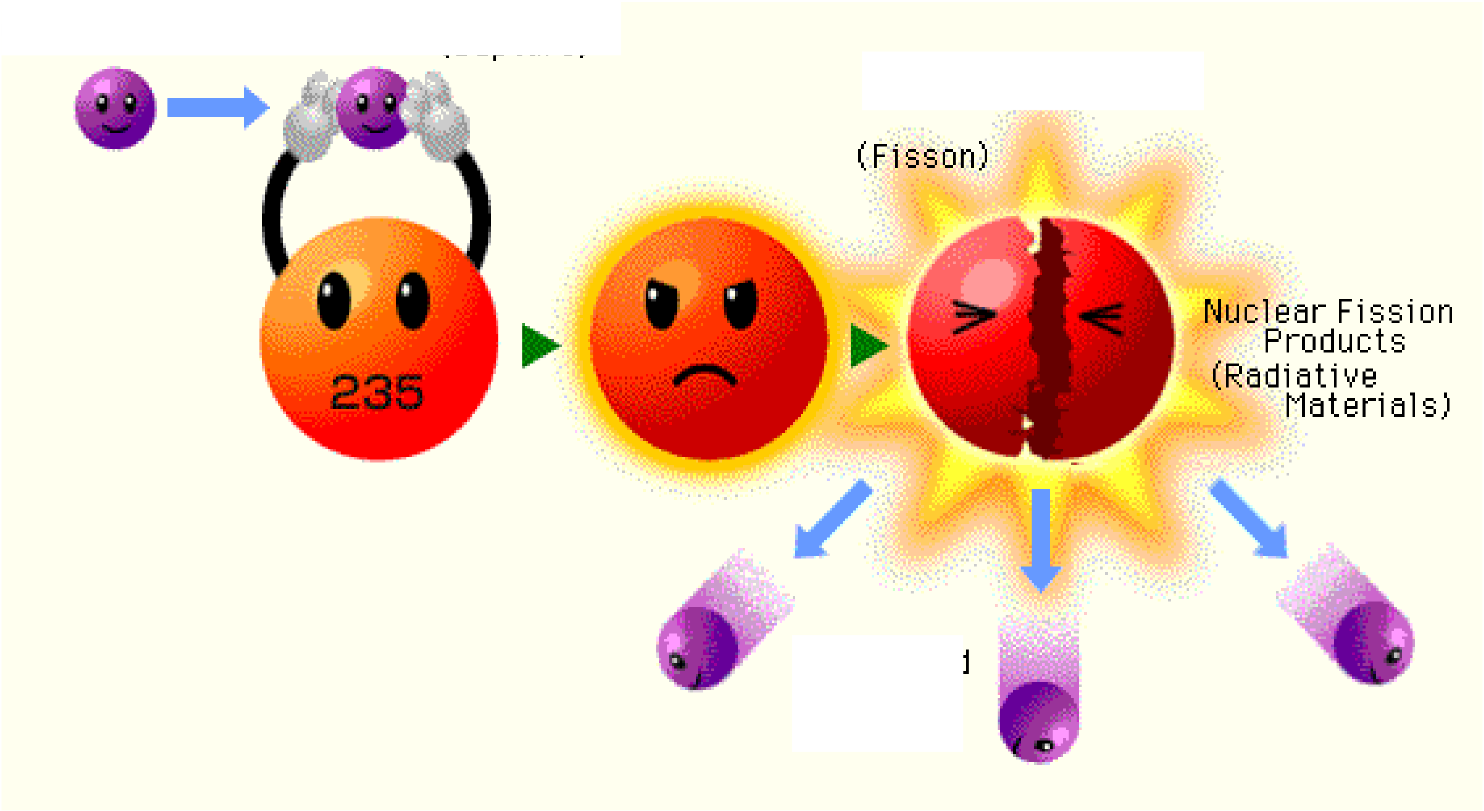
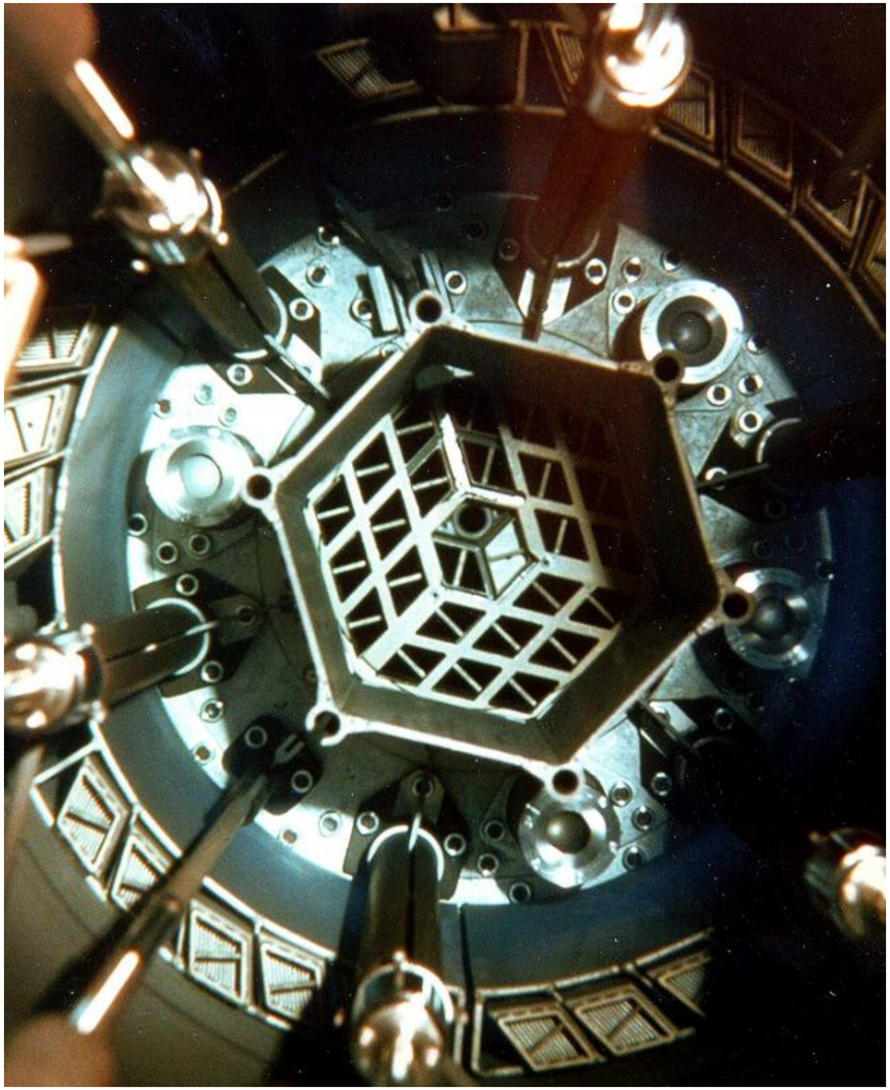
# Neutrons: Time of Flight




Rachel Bowens-Rubin

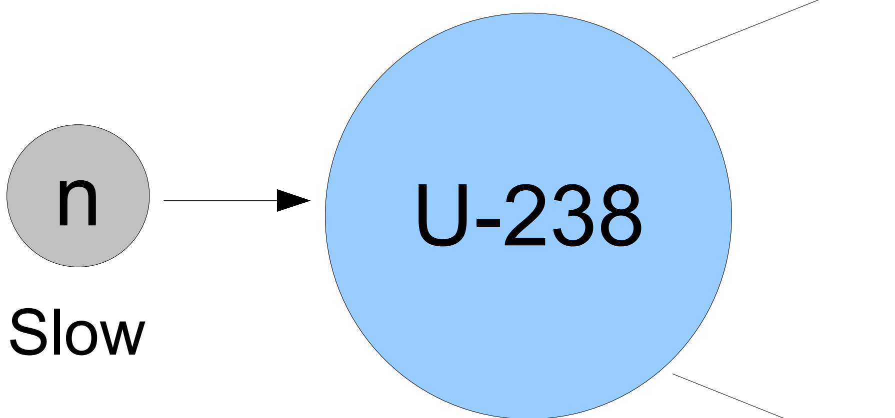
# Purpose

- Measure the velocity distribution of neutrons inside the reactor
  - Find the neutrons most probable velocity
- Calculate the neutron density and flux inside the reactor



MIT Nuclear Reactor Core

# How are Neutrons produced?




$${}^{87}_{35}Br + {}^{148}_{57}La + {}^{1}_{0}n$$

Fast

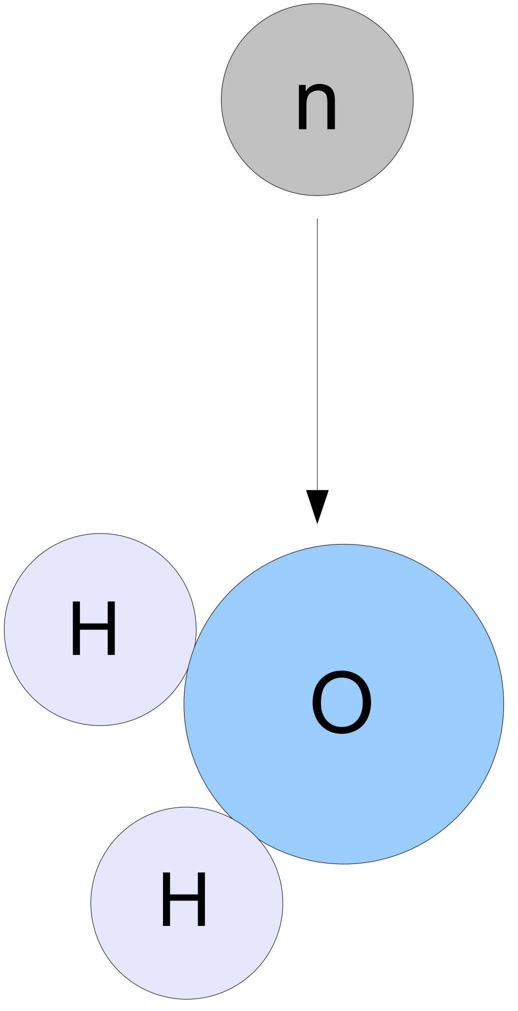
$${}^{94}_{36}Kr + {}^{139}_{56}Ba + 3{}^{1}_{0}n$$

Fast

Mass → Energy

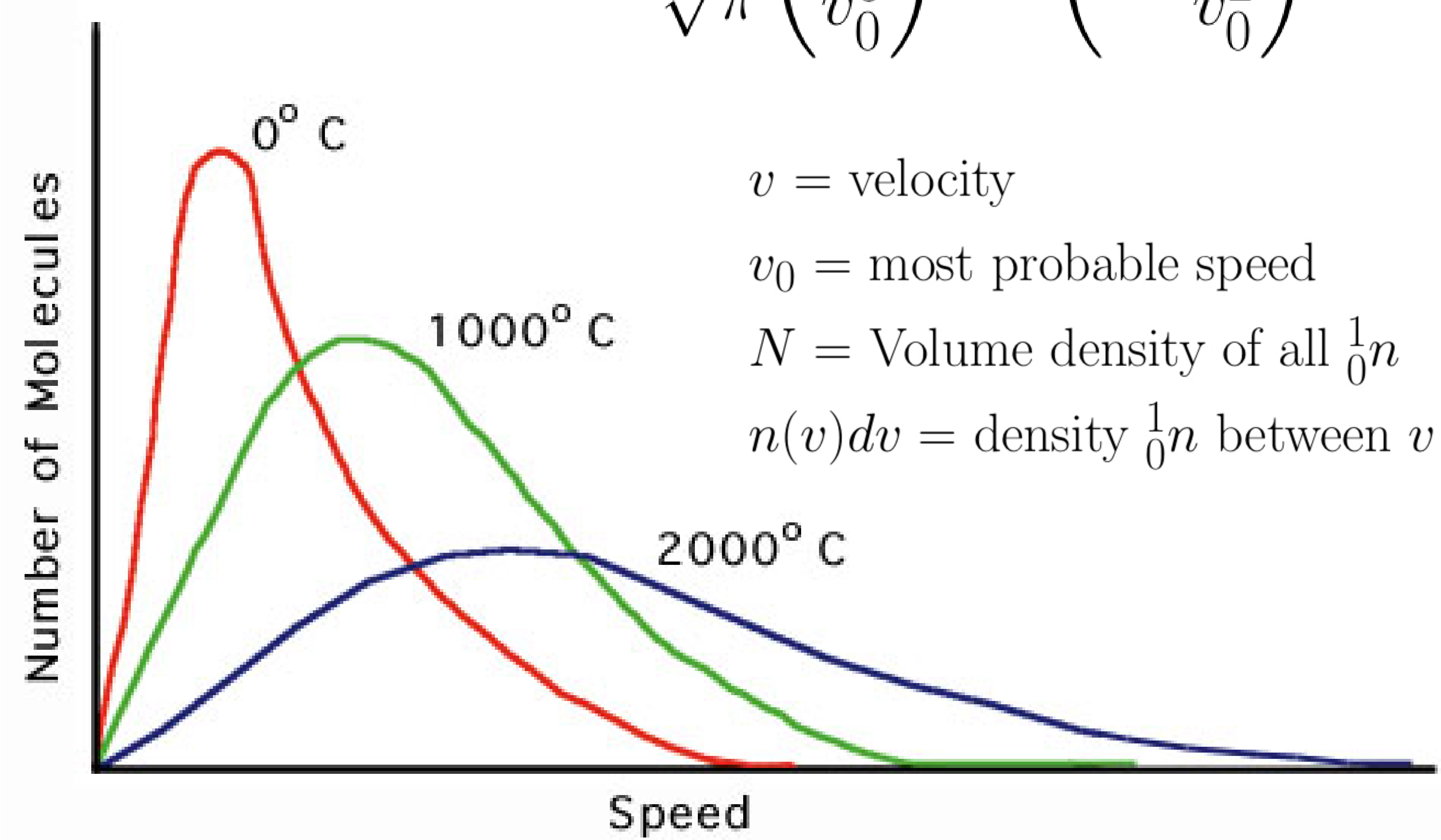
# Slowing the Neutrons

- U-238 only reacts with slow neutrons
- Moderator – slows down neutrons (water)
- Result: Velocity Distribution
- Thermal Equilibrium



# Maxwell-Boltzmann Distribution

$$n(v)dv = \frac{4N}{\sqrt{\pi}}\left(\frac{v^2}{v_0^3}\right)exp\left(-\frac{v^2}{v_0^2}\right)dv$$



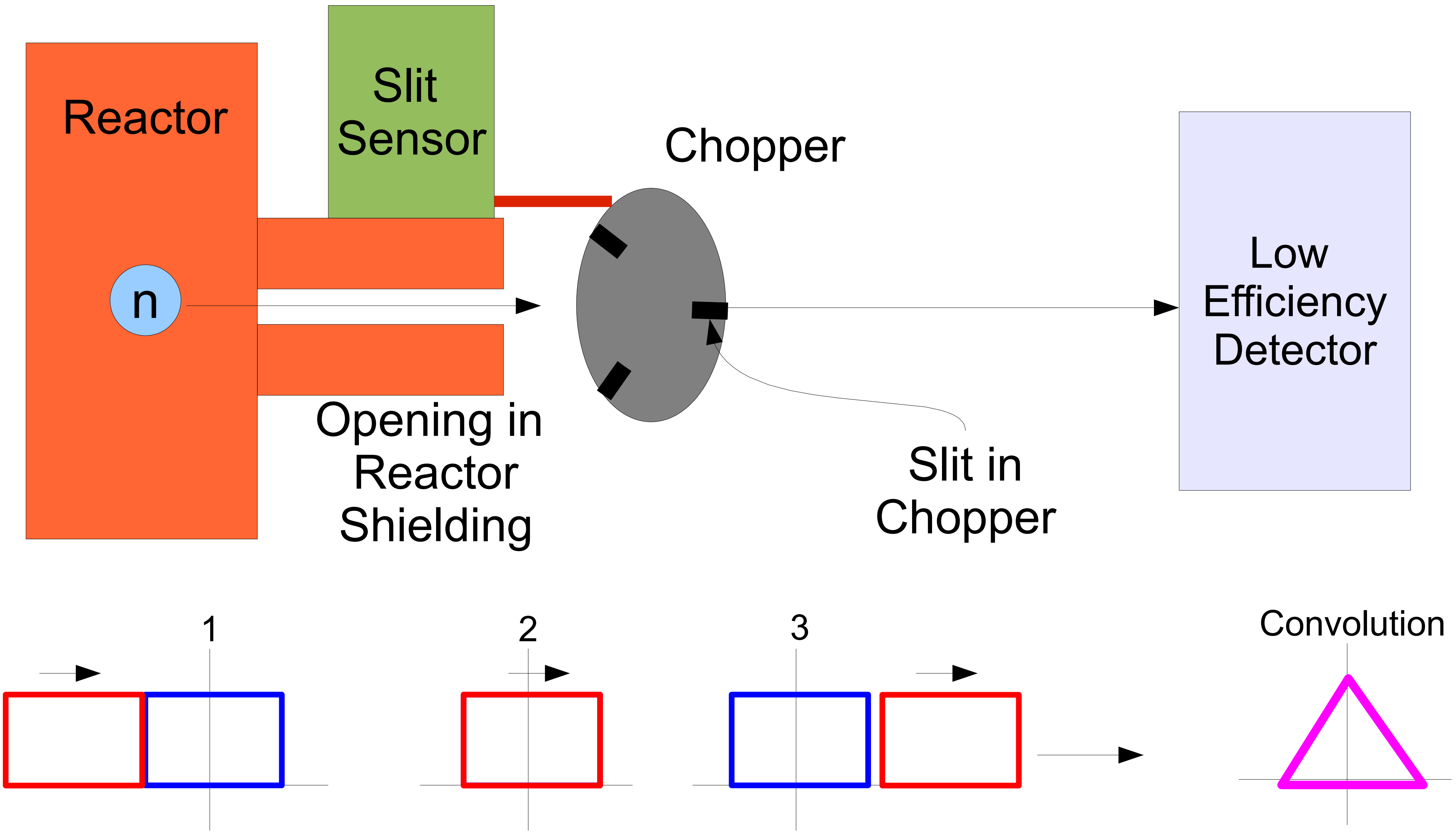

$v$ = velocity

$v_0$ = most probable speed

$N$ = Volume density of all $\frac{1}{0}n$

$n(v)dv$ = density $\frac{1}{0}n$ between $v$ and $v + dv$

# Overall Experimental Setup



# Low Efficiency Detector

- Made of $BF_3$

$$ {}_0^1n + {}_5^{10}B \rightarrow {}_3^7Li + {}_2^4He $$

- Efficiency follows 1/v

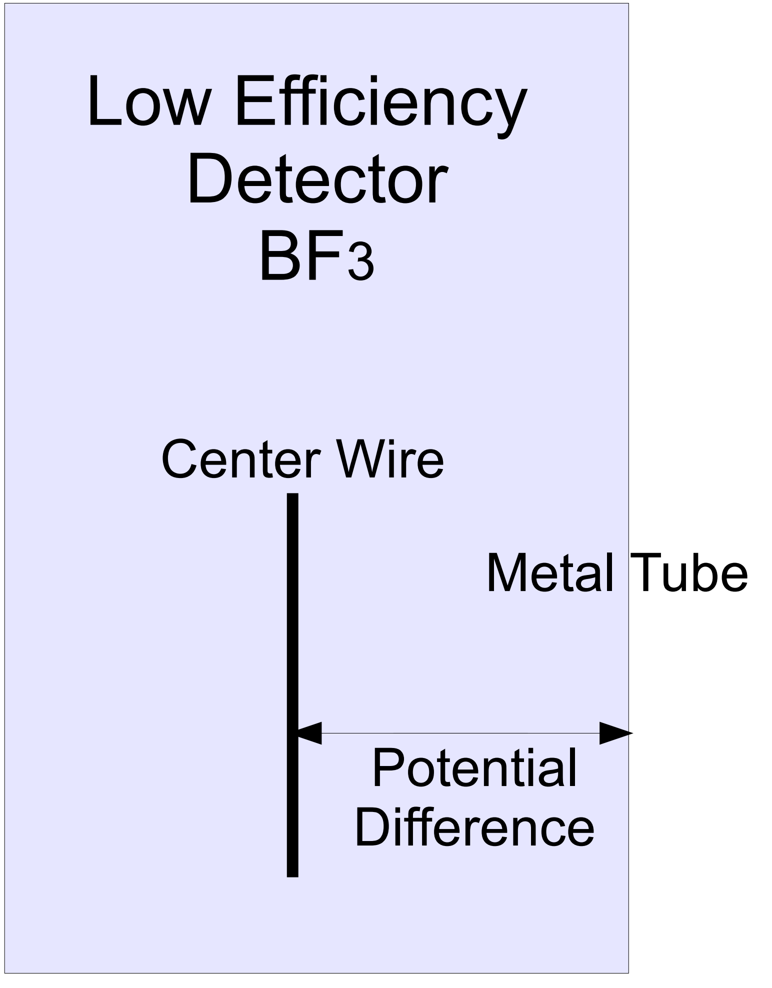
$$ j'(v)dv = Bv^2 exp\left( -\frac{v^2}{v_0^2} \right) dv $$

$v$ = velocity

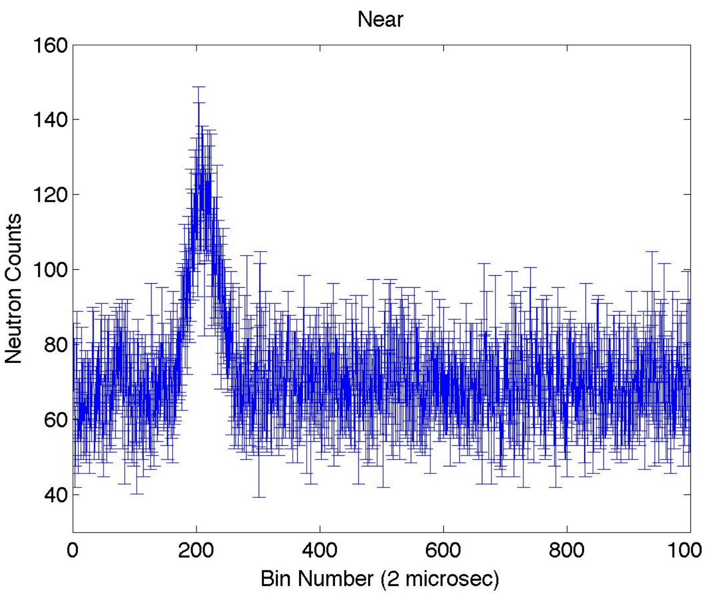
$v_0$ = most probable speed

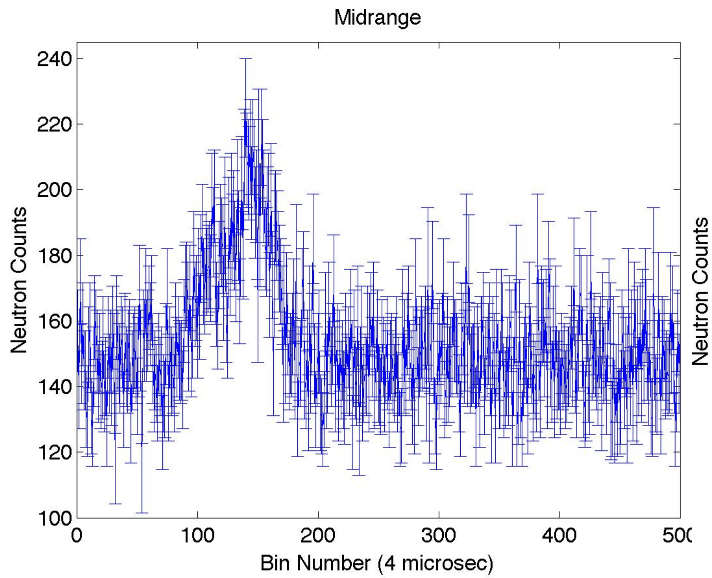
$B$ = constant

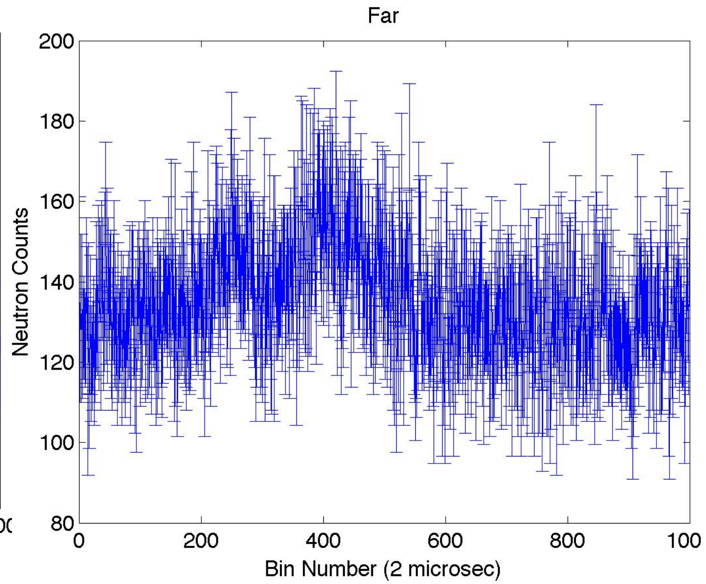
$j'(v)dv$ = detected density



# Data Collection




$$\sigma = \sqrt{counts}$$

$$v = \frac{l_{travel}}{t_d(m - n_0)}$$

$l_{travel}$= distance chopper to detector

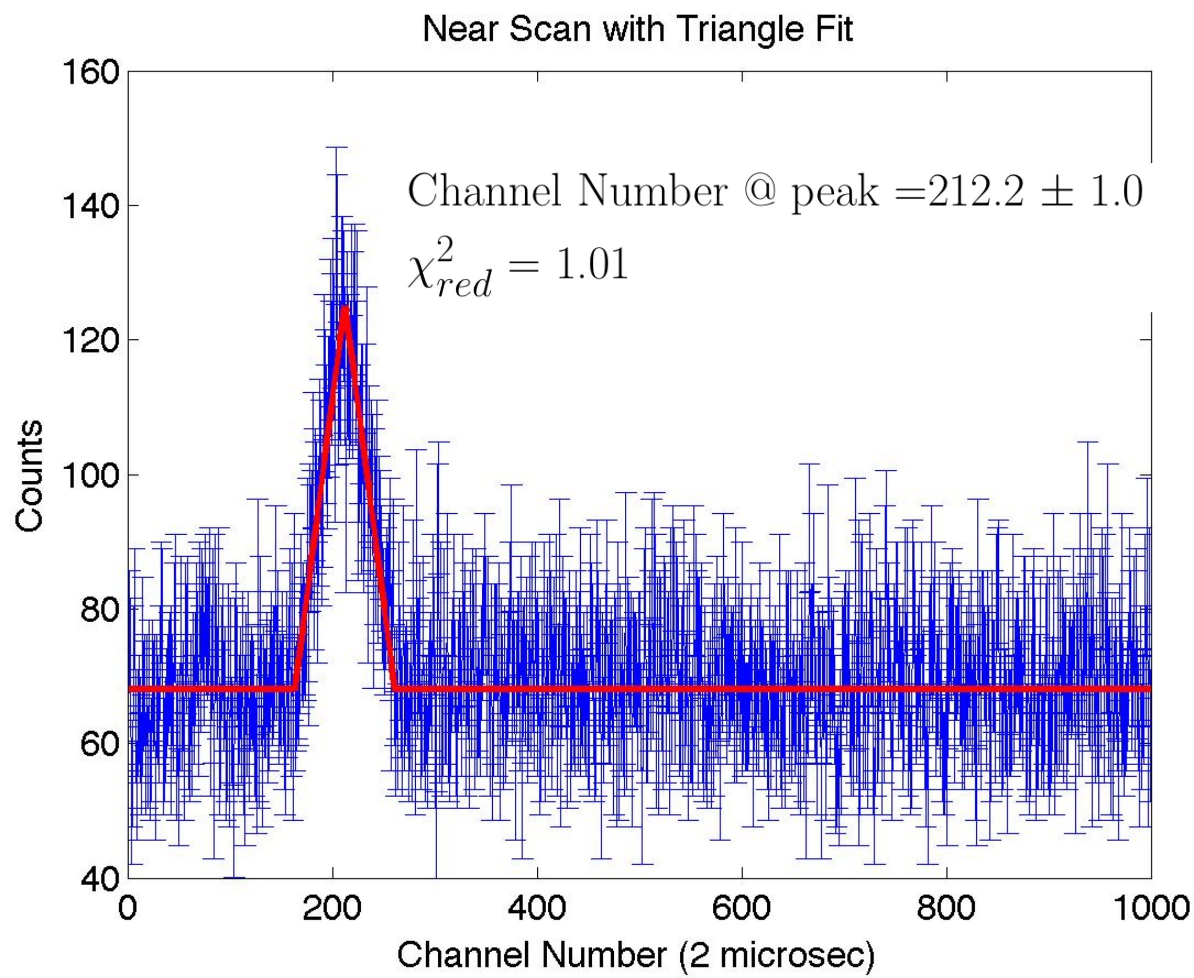
$t_d$= Dwell Time

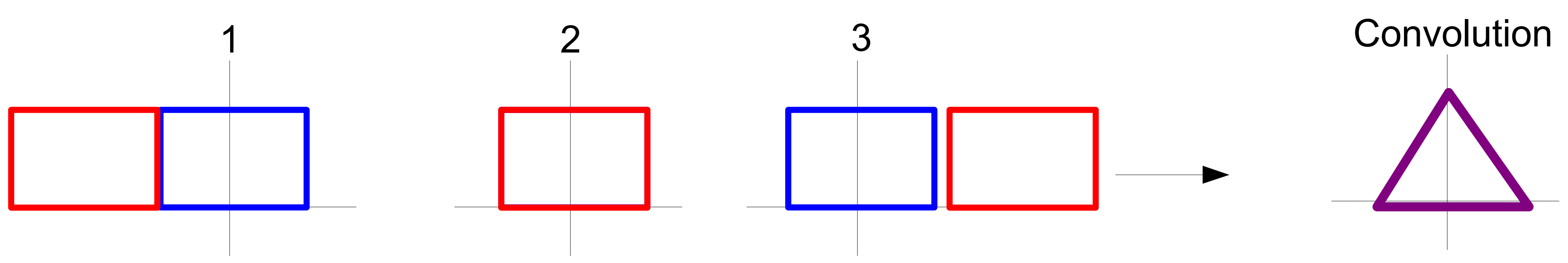
$m$ = Channel Number

$n_0$ = Channel Number with most probable v

# Near

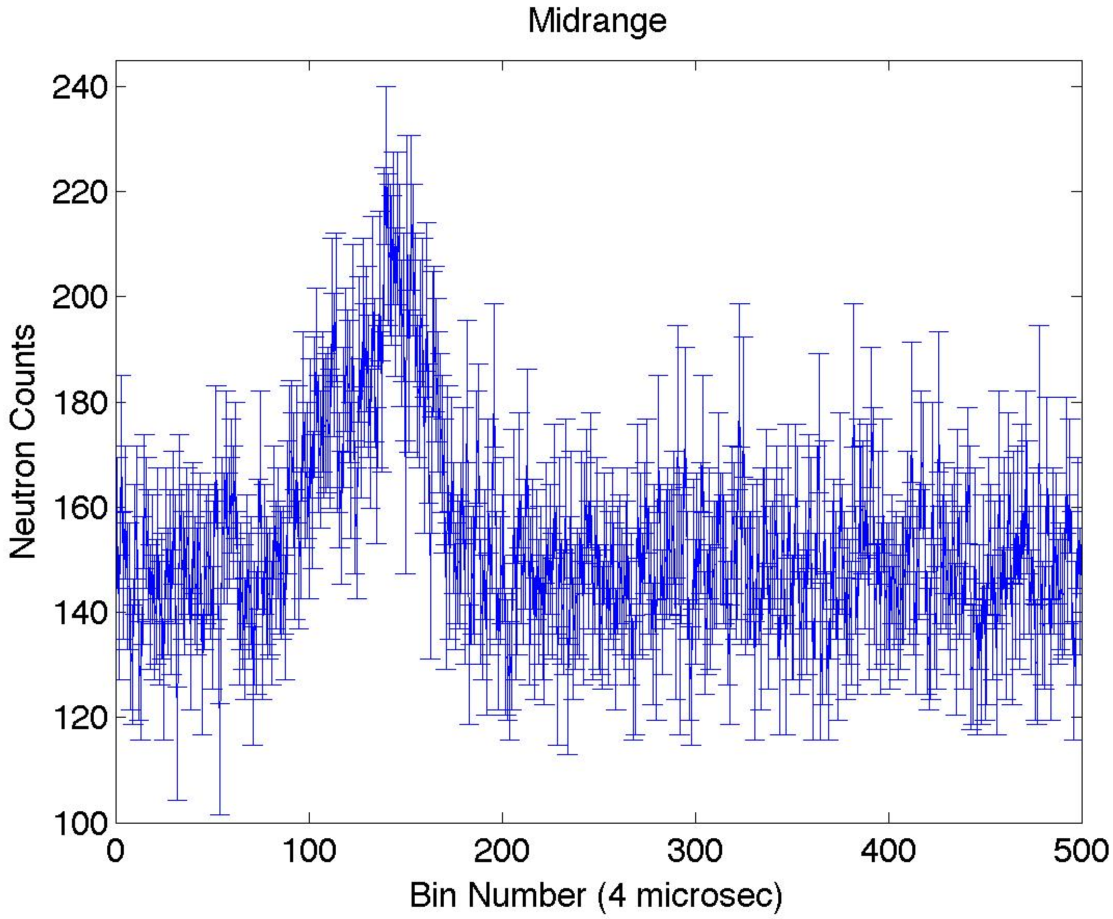
- Different velocities don't travel far enough to separate
- Convolution



# Midrange

- Wider than Near
- Combination of Triangle and Maxwell-Boltzmann



# Far

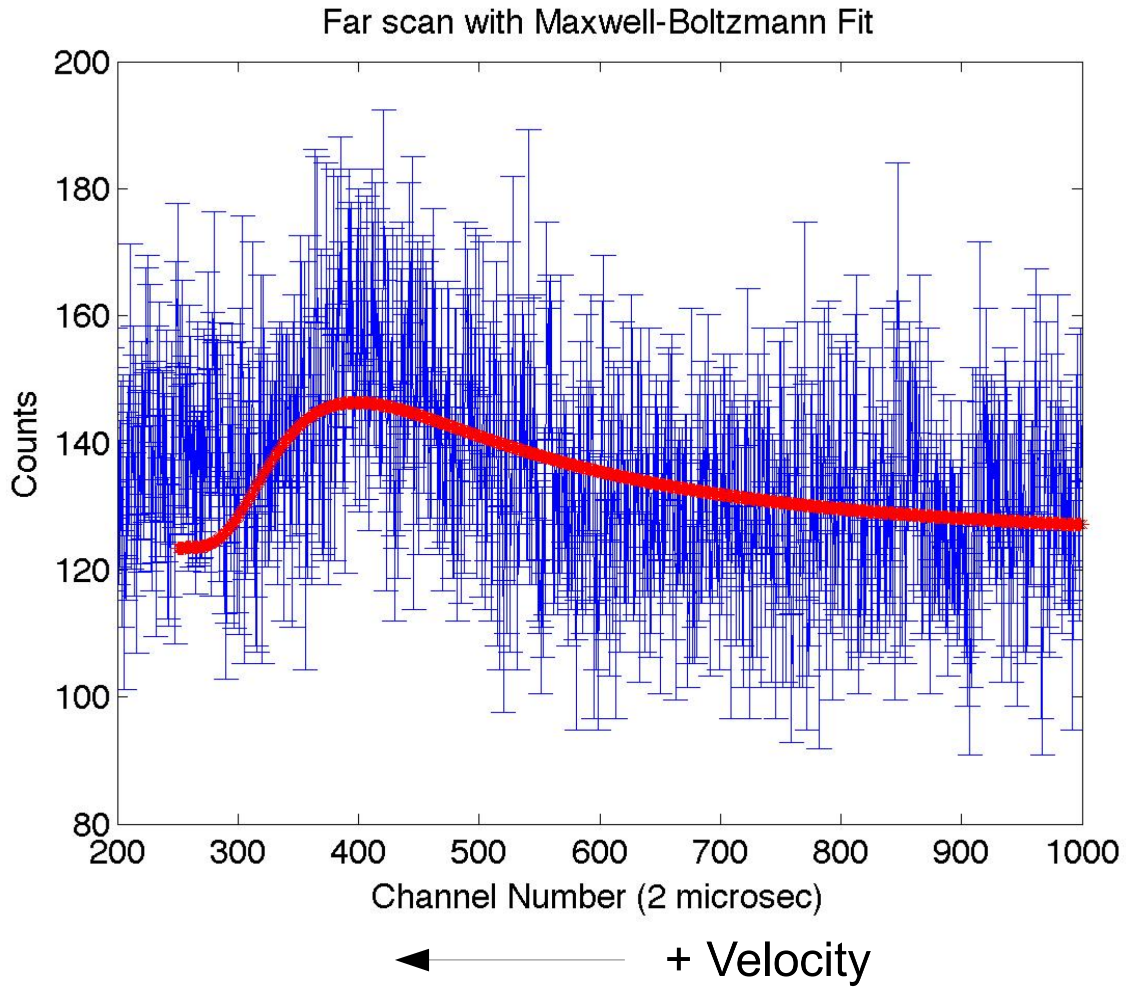
## Maxwell-Boltzmann

$$j'(v)dv = Bv^2 exp\left(-\frac{v^2}{v_0^2}\right)dv$$

$$v_0 = 3135 \pm 75$$

$$\chi^2_{red} = 1.18$$

$$T = \frac{1/2 m_n v_0^2}{k} = 596 \pm 29K$$

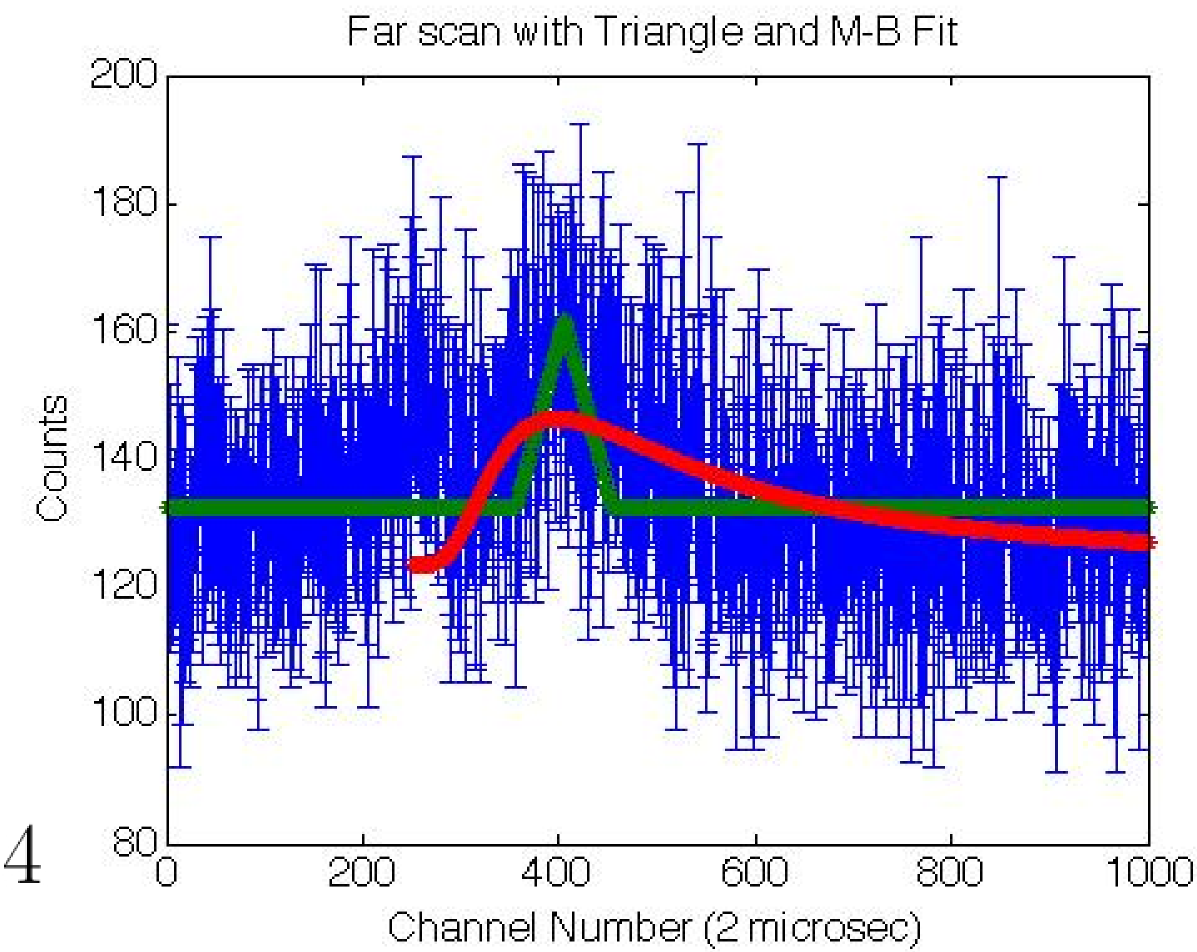


# Problems Fitting

- Graph is a minefield for gradsearch
- Triangle has lower Reduced Chi Square

M-B: $\chi^2_{red} = 1.18$

Triangle: $\chi^2_{red} = 1.14$



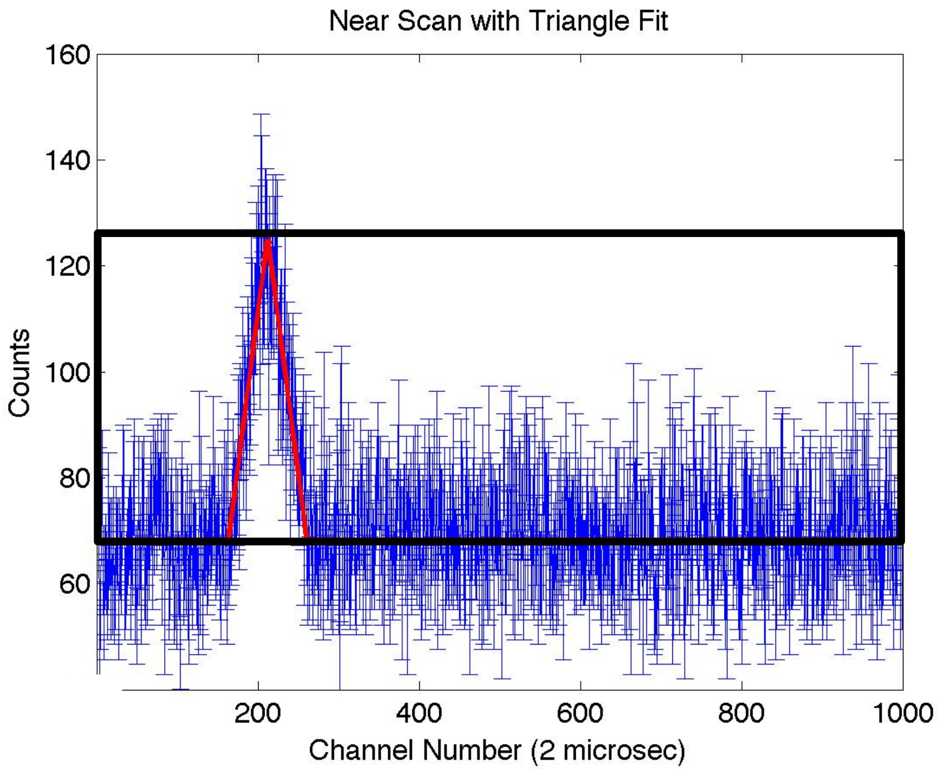
# Calculating Intensity

Use near scan data:

$$I = \frac{C_{tot}}{t_{tot}}$$

$$= \frac{(passlength)C_{peak} \times t_{tot}/t_d}{t_{tot}}$$

$$= (6.250 \pm 0.056) \times 10^8 \text{ counts/s}$$




$t_d = 2$ microsec

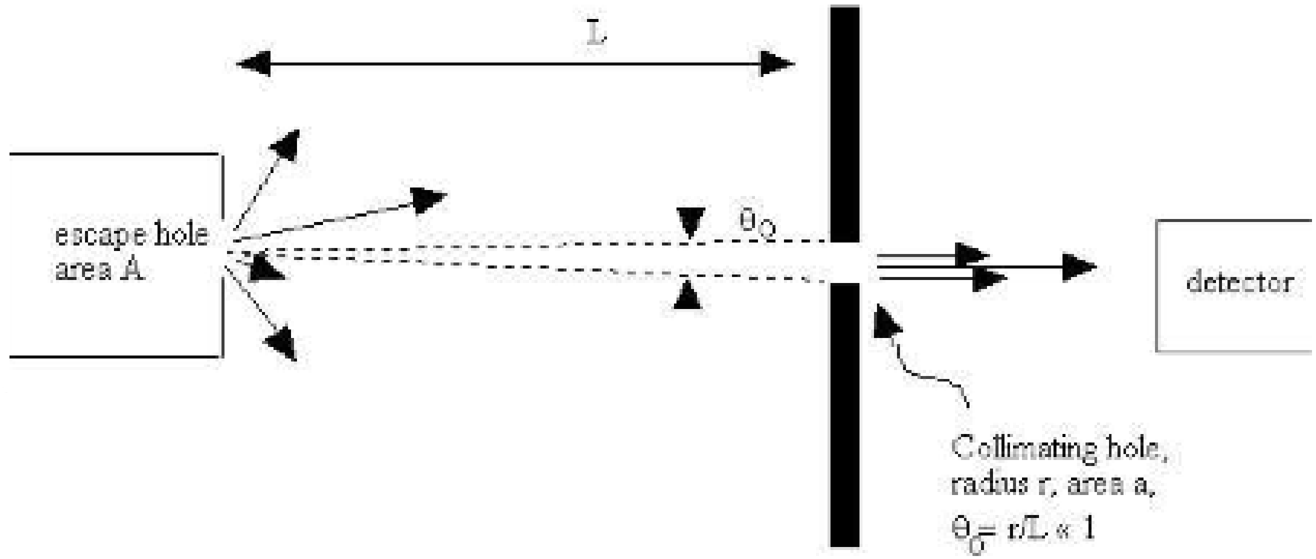
$passlength = 1000$ channels

$C_{peak} =$ Counts at peak

$C_{tot} =$ Total Counts if left unblocked

# Calculating Neutron Flux

$$I = A\frac{a}{4\pi L^2}nv_{avg}$$




$$\phi_{reactor} = nv_{avg} = (1.572 \pm 0.014) \times 10^{20}\frac{counts}{sm^2}$$

- If Maxwell-Boltzmann was reliable, could have calculated neutron density in the reactor using:

$$v_{avg} = \frac{2}{\sqrt{\pi}}v_0$$

# Summary

- Time of Flight measures were taken at 3 distances
- Near was represented by triangle (chi squ = 1.01)
- Far scan was inconclusive - fits multiple distributions

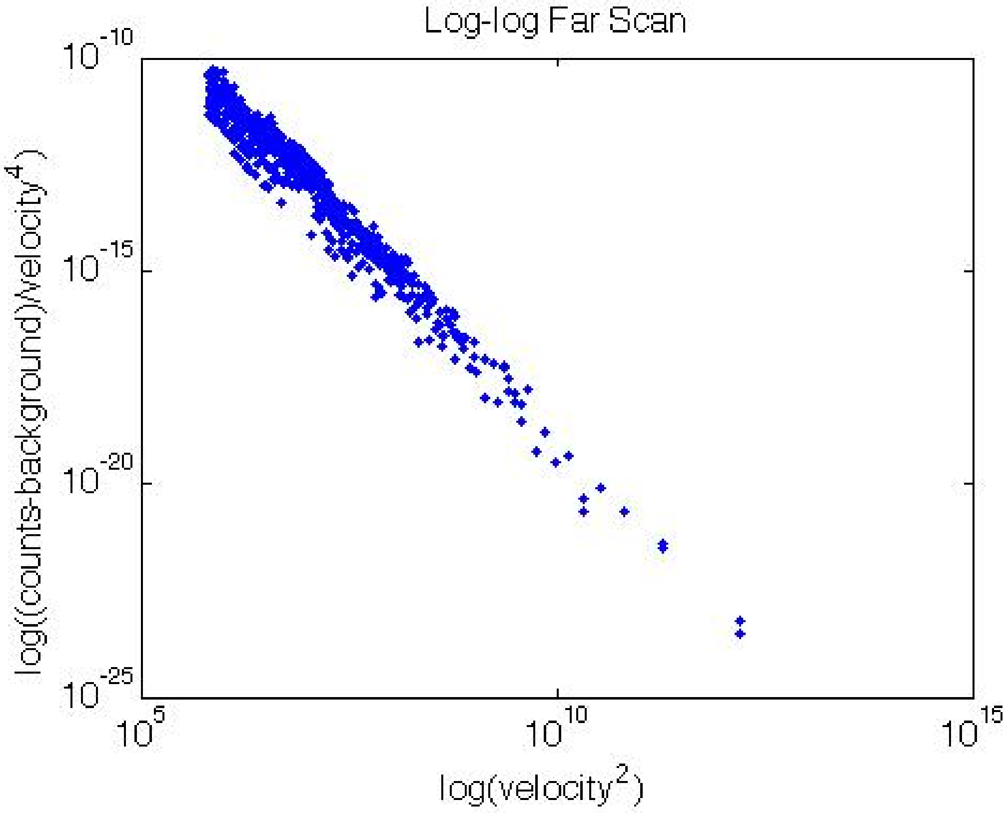
$$\mathrm{I} = (6.250 \pm 0.056) \times 10^8 \ \mathrm{counts/s}$$

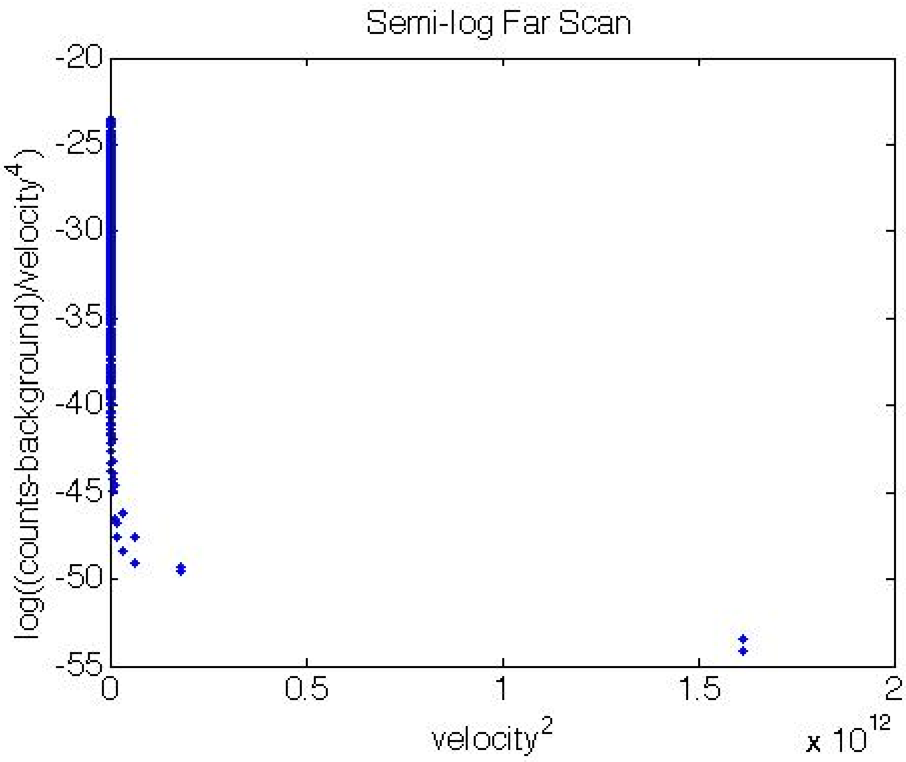
$$\phi_{reactor} = (1.572 \pm 0.014) \times 10^{20} \frac{counts}{sm^2}$$

# References


- MIT Physics Department, Junior lab written report notes (2005).
- Casiday, Rachel and Regina Frey. Department of Chemistry, Washington University. "Maxwell-Boltsmann," http://www.chemistry.wustl.edu/~edudev/LabTutorials/Airbags/airbags.html
- MIT. "The MIT Nuclear Reactor Lab," http://web.mit.edu/nrl/www/

# Log-Log Plot


Log-log Far Scan
log((counts-background)/velocity^4)
log(velocity^2)
10^-10
10^-15
10^-20
10^-25
10^5
10^10
10^15


Semi-log Far Scan
log((counts-background)/velocity^4)
velocity^2
x 10^12
-20
-25
-30
-35
-40
-45
-50
-55
0
0.5
1
1.5
2

# Outline:Notes to me

- Purpose of Experiment
- Theory:
  - Maxwell bolt
  - 
- Collecting Data: Exp setup, reactor equation
- Data Analysis: Fitting tri vs
- Interpretation of 3 graphs:triangle, max bolt, mix
  - 
- Sneak peak into finding galactic arms