# Updated Two vs Three Zone Studies

Do the changes to our Monte Carlo program affect any of our conclusions regarding the 2 vs 3 zone issue? (NO)

# Neutron Capture Time, Gd Concentration, and Acceptance

Using the neutron capture time to monitor Gd concentration and to estimate the change in acceptance due to changes in concentration (Josh and Ed's idea)

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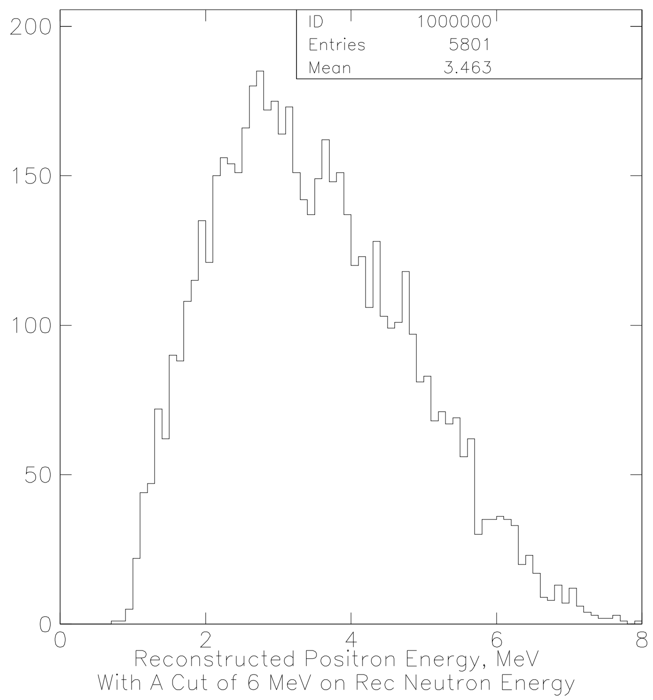
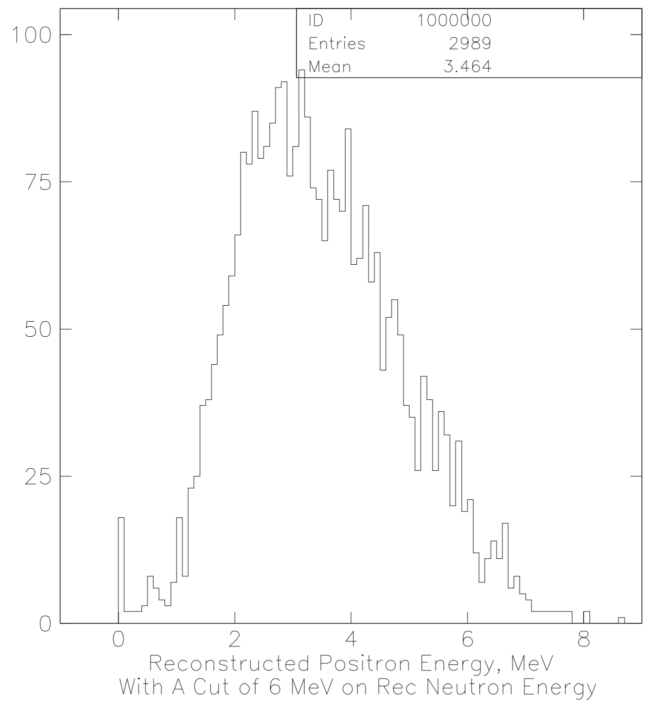
# Reconstructed Positron Energy Spectrum

## OLD

Positron energy cut at .5 MeV; Neutron cut at 6 MeV

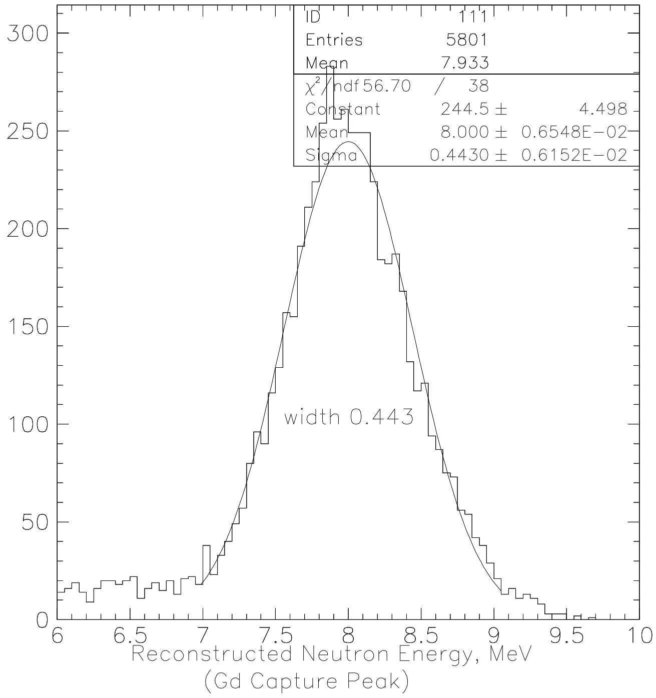



## NEW

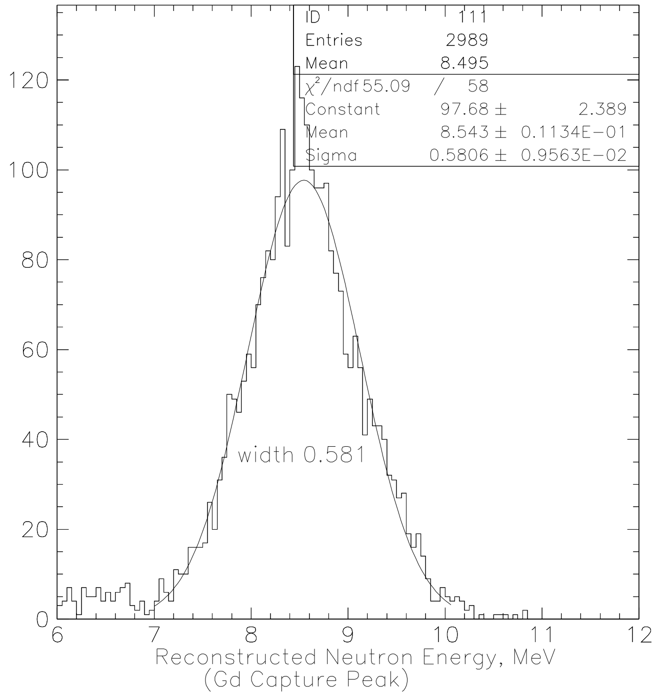


# Reconstructed Neutron Energy Spectrum

## OLD




## NEW



RECALL: looked at how varying the thickness of the gamma-catcher affected the systematic error associated with changes in the energy scale

A difference in the energy scale between the near and far detectors leads to different acceptances in the two detectors.

Parameters

Gd-loaded region radius fixed at 260 cm

overall detector radius fixed at 350 cm

gamma-catcher radius varies from 260 cm to 350 cm

Nominal Cuts

$$\text{Energy}_{\text{positron}} > .5\text{ MeV} \quad \text{and} \quad \text{Energy}_{\text{neutron}} > 6\text{ MeV}$$

To evaluate the impact of different energy scales in the two detectors, study how the acceptance changes as the energy cuts change.

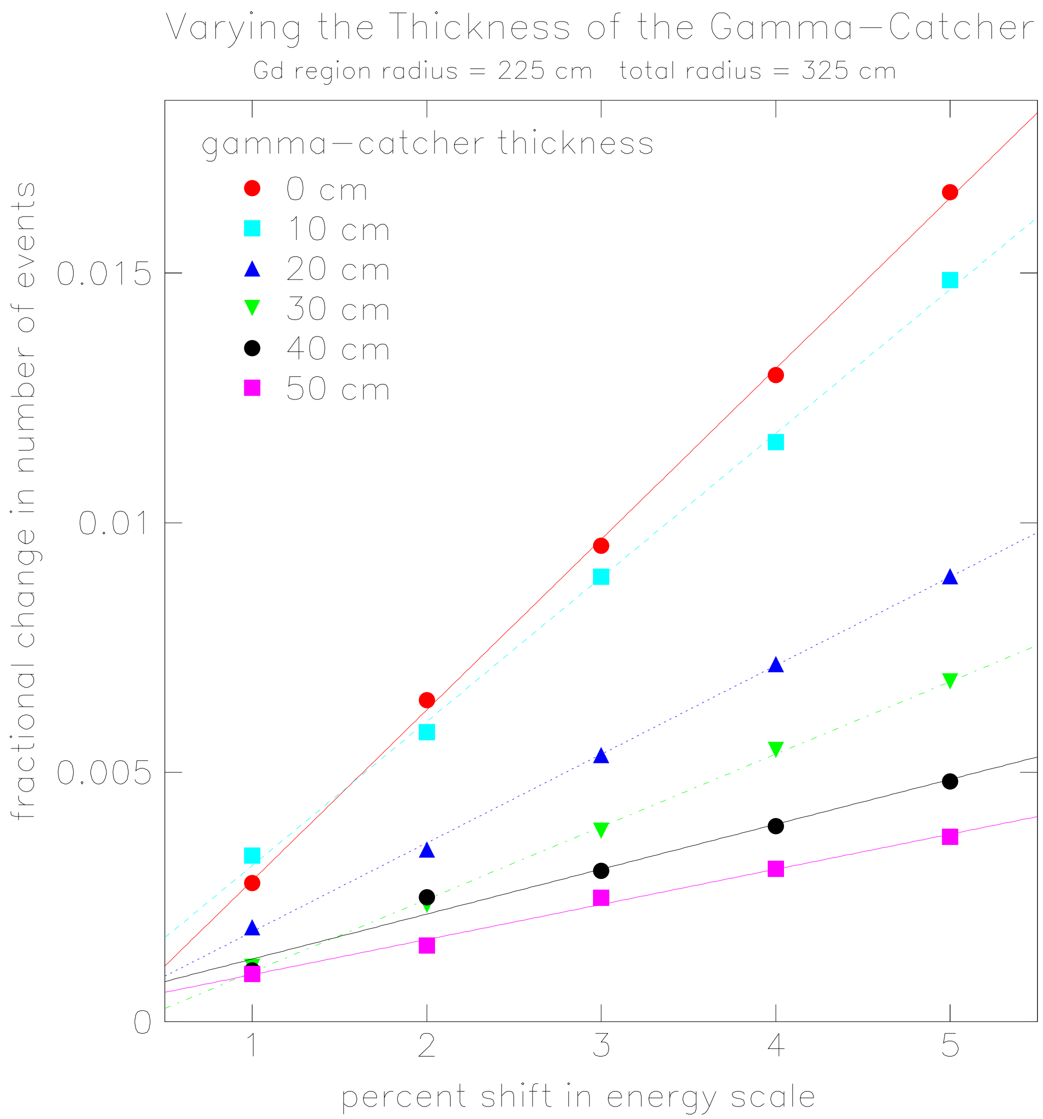
Vary the nominal cuts by 1,2,3,4,5 percent for each of the gamma-catcher thicknesses.

The fractional change in the number of events is calculated as

$$\frac{|\text{Number events nominal cuts} - \text{Number events shifted cuts}|}{\text{Number events nominal cuts}}$$

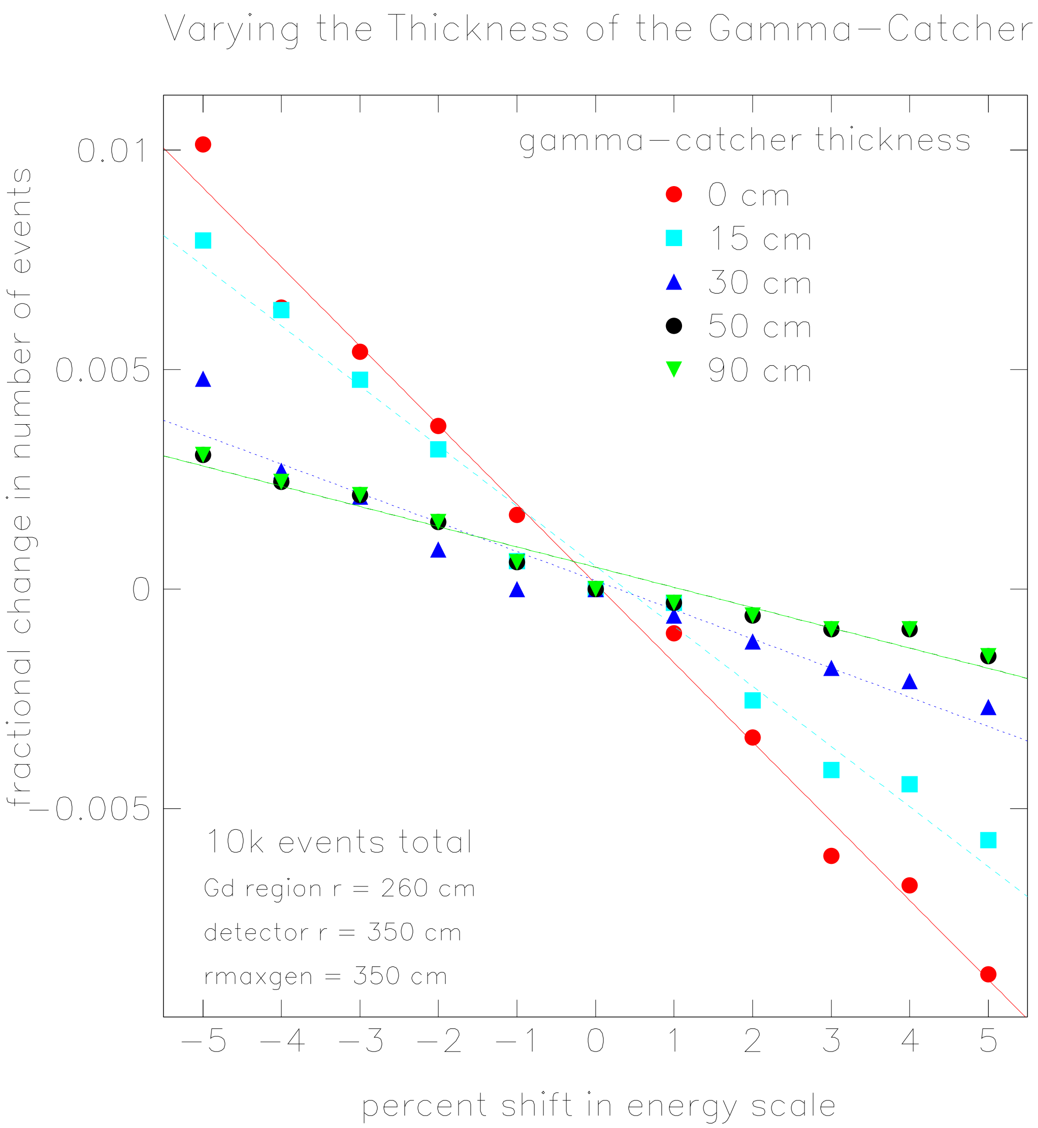
## Result of Old Study

note that different parameters were used previously




Once we know how well we can calibrate energy in the detectors, we can use a plot like this to relate the thickness of the gamma-catcher to a systematic uncertainty.

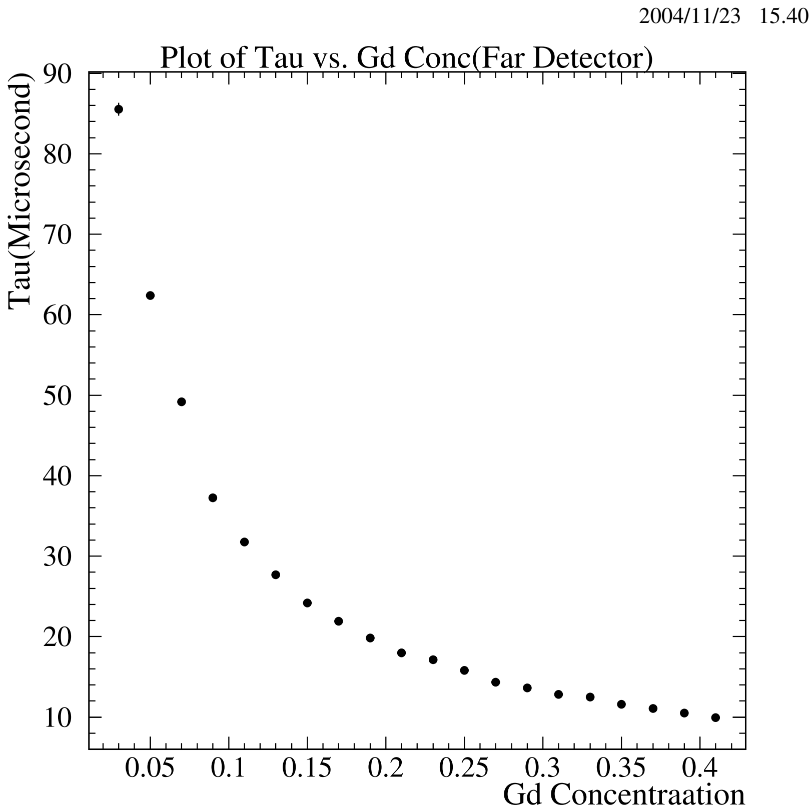
## New Results




- New ReactorFsim does not change our conclusions regarding the sensitivity to the energy scale
- Neutron capture peak widens $\rightarrow$ more run-time necessary to get enough events to determine location of peak to within particular uncertainty

# Neutron Capture Time vs Gadolinium Concentration

plot courtesy of Josh and Atiq

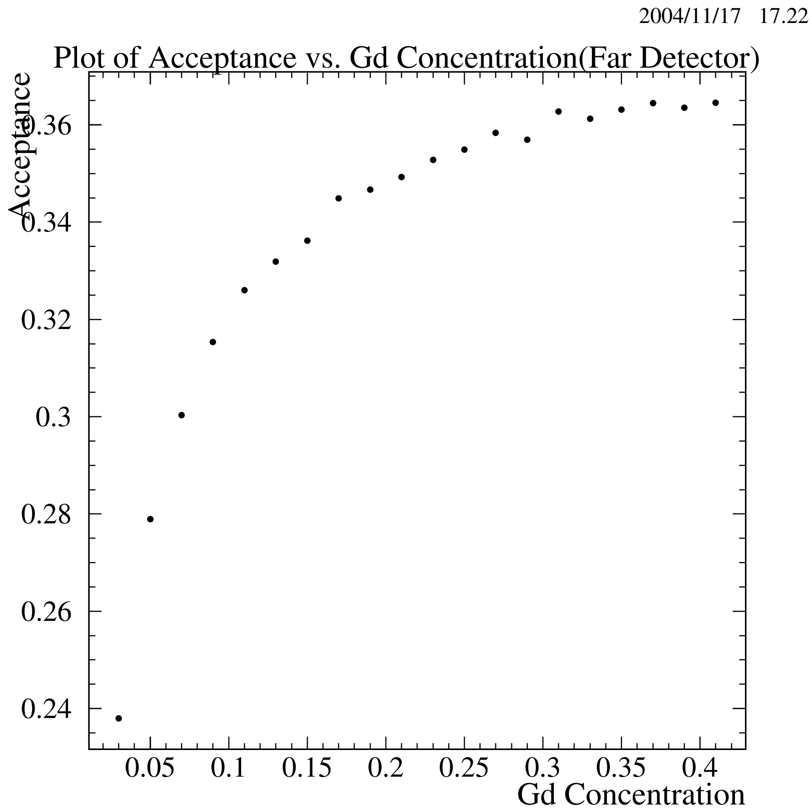



$\sim$1 month of running $\rightarrow$ can measure Gd concentration at the 2% level (based on Gd conc of 0.1%)

Note that filling detectors from same batch of Gd-LS $\rightarrow$ same concentration initially

## Acceptance vs Gd Concentration

plot courtesy of Josh and Atiq



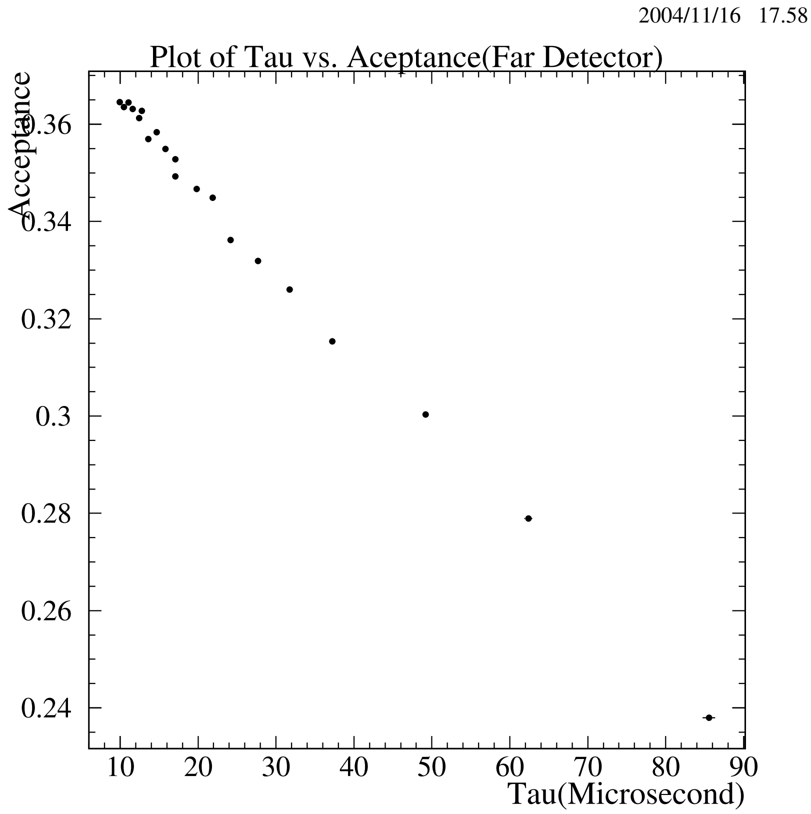

At concentrations around 0.1% or 0.2%, a change in concentration $\rightarrow$ change in acceptance.

For a concentration of 0.1%, a 2% uncertainty corresponds to a $\sim$0.4% uncertainty in the acceptance.

To improve the uncertainty in the concentration, (and therefore the uncertainty in acceptance), run for longer than a month.

# Acceptance vs Capture Time

plot courtesy of Josh and Atiq




Acceptance vs capture time is a straight line: measure capture time $\rightarrow$ know the acceptance.

If detectors have different Gd concentrations, we can use the neutron capture time directly to figure out how this affects the acceptance.

## Conclusions

- New physics in ReactorFsim does not alter the conclusions of previous 2 vs 3 zone studies.

- Most significant modification is multiple Compton scattering - adds to positron spectrum tail and widens peaks.

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- Can use neutron capture time to determine acceptance.

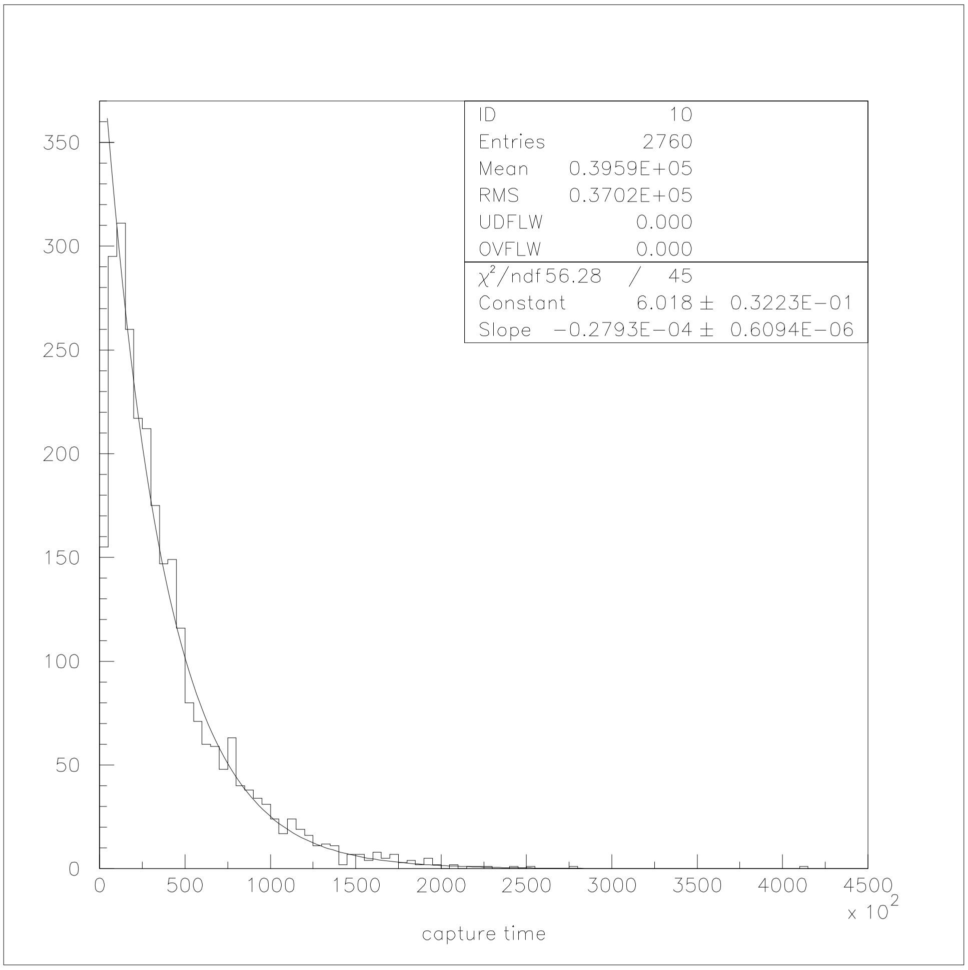
- Running for $\sim$1 month allows us to achieve a $\sim$0.4% uncertainty on changes in the acceptance due to changes in Gd concentration.

## Details of the Neutron $\tau$ - Gd Concentration - Acceptance Study

- For several Gd concentrations, generate 10k neutrino events
- Fit the capture time for each concentration to an exponential to get uncertainty in the half-life
- Relate uncertainty in the half-life to uncertainty in the concentration
- Uncertainty in the concentration $\rightarrow$ uncertainty in the number of events passing nominal cuts
- Small uncertainty in number of events passing cuts $\rightarrow$ smaller systematic error associated with uncertainty in Gd concentration

# Fitting the Neutron Capture Time to an Exponential

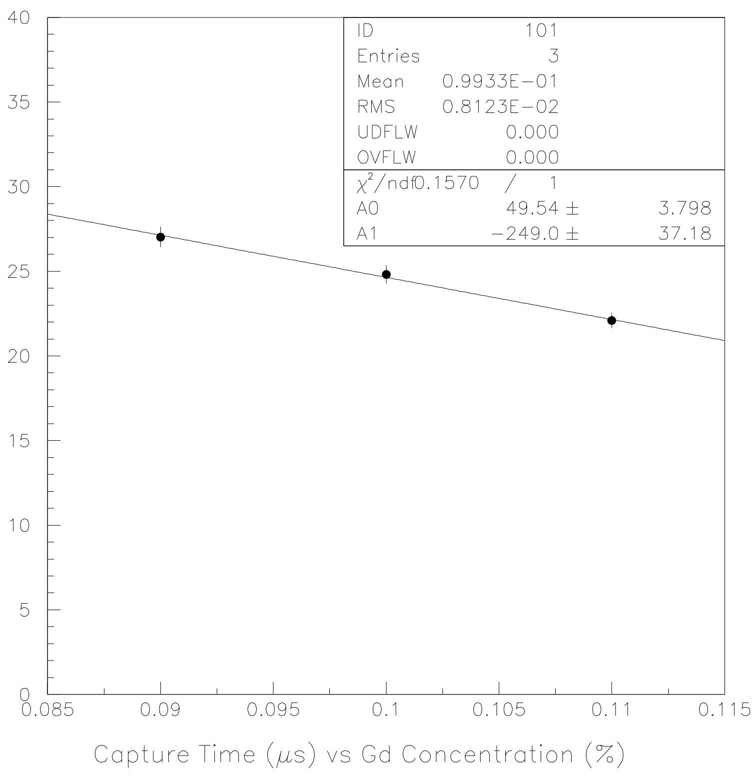
## An Example




Capture time (ns) of neutrons passing nominal cuts for Gd concentration of .10%. From the fit, the neutron half-life is calculated to be $24.8173 \pm .5415 \mu s$.

Focus on concentrations near .1% and .2%.

Plot capture time vs Gd concentration and fit to a line to determine the slope.



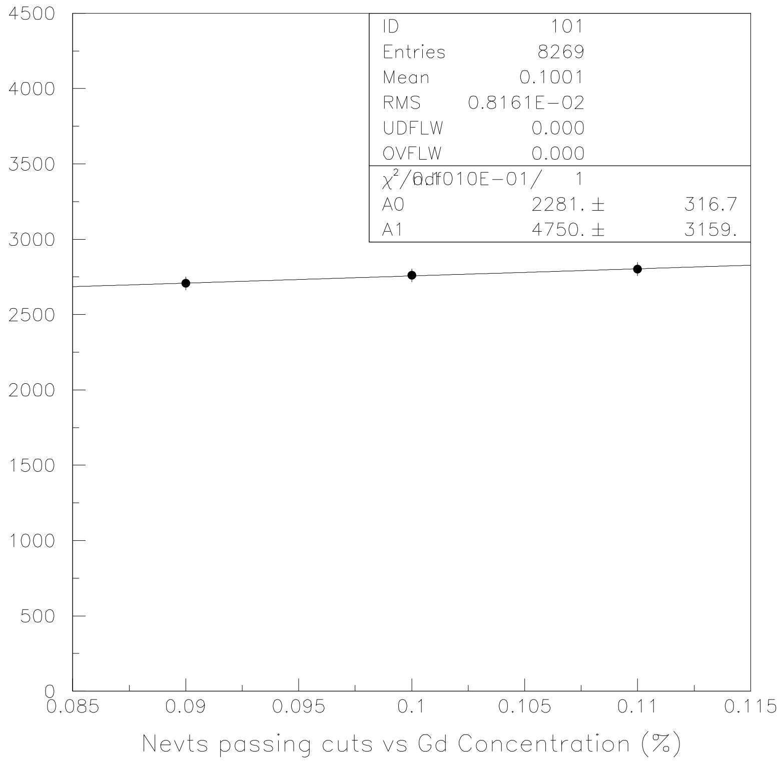

Slope: -249

$$\delta conc = \frac{\delta t}{slope} \tag{1}$$

so for concentrations near .1%

$$\delta conc = \frac{.5415\mu s}{249.0} = .0022\% \tag{2}$$

Plot the number of events passing the cuts vs Gd concentration




$$\delta N_{pass} = slope \times \delta conc. \tag{3}$$

If the concentration of .1% changes at the 2% level (the change that we could detect in about 1 month of running), the change in the number of events passing cuts would be about 10.5 events out of 2760. That is, in 1 month of running, you would have a 0.4% uncertainty on your acceptance due to possible changes in the Gd concentration.

## Study Conclusions

- Monitoring half-life of the neutron capture effectively monitors Gd concentration.

- If the Gd concentration changes by more than about 2% for a .1% Gd concentration ($\frac{.0022}{.10} = .02$) or by more than about 4% for a concentration of .2% ($\frac{.0075}{.20} = .04$), we will notice that change in the half-life of the neutron capture by taking data for about 1 month.

- For 0.1% concentration: based on the uncertainty in our knowledge of the Gd concentration if we run for ~1 month, we will have a $\frac{10.5}{2760} = 0.38\%$ error on how well we know the efficiency.

- For a Gd concentration of 0.2%, this error is $\frac{14.6}{2961} = 0.49\%$