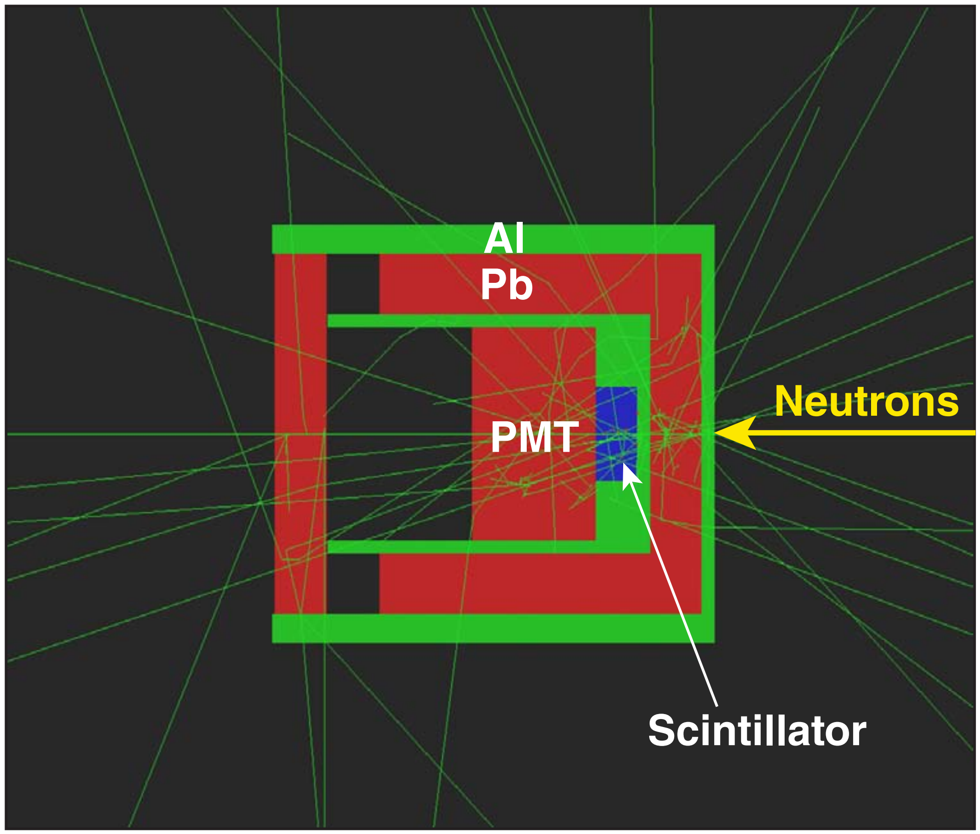
Monte Carlo Simulations of Neutron Scattering in Current-Mode Neutron Time-of-Flight (nTOF) Detectors



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Summary

Geant4 simulations were used to estimate the influence of neutron scattering on the nTOF signals

- Geant4 is a Monte Carlo transport code developed at CERN, which uses high-quality neutron cross sections from LBL
- A δ-function source of monoenergetic 2.45-MeV neutrons was used in these simulations
- Different levels of refinement of the detector geometric model produce significant differences in the neutron history
- The simulated time constants of the full NIF nTOF configuration, including a simplified PMT, are very close to the experimental values

Collaborators

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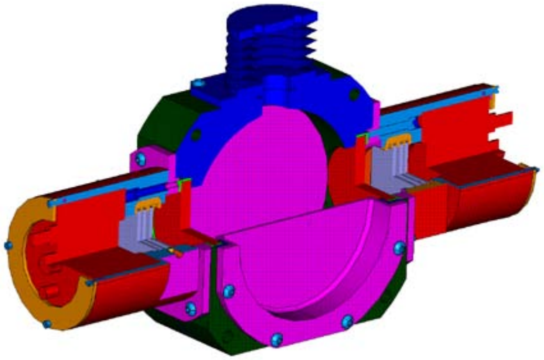
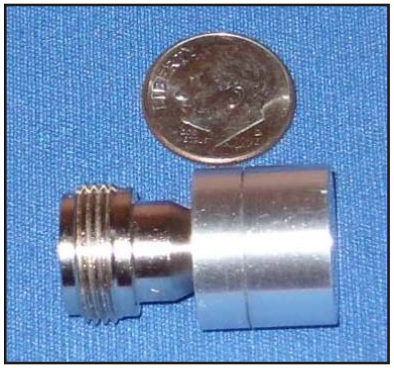
The NIF nTOF system consists of eight detectors with 18 channels based on three different techniques

- Plastic scintillator (BC-422 or BC-422Q) coupled with gated PMT or photodiode

- Oxygen-saturated liquid scintillator with gated PMT

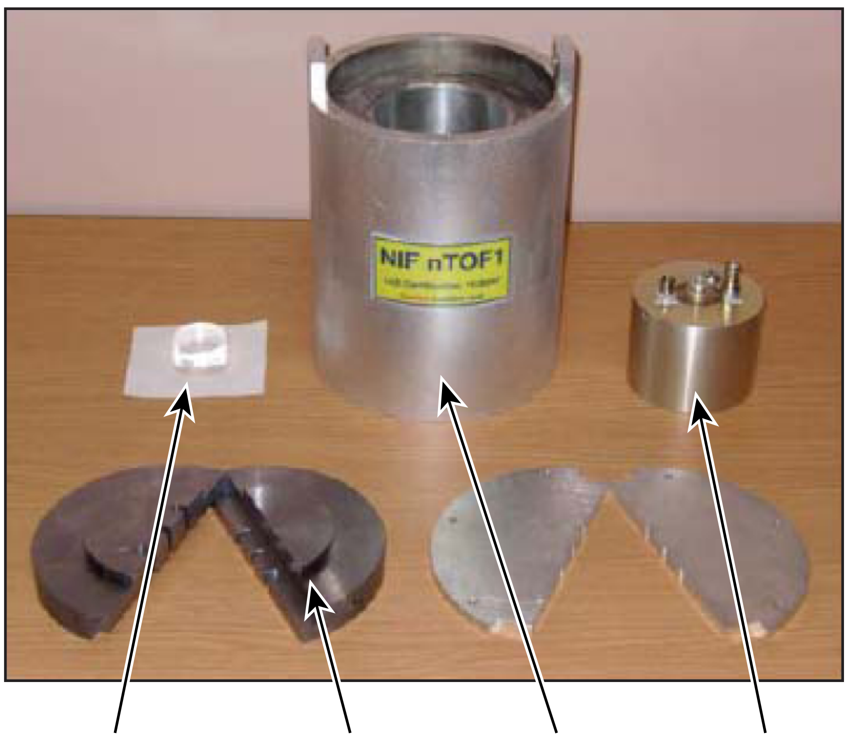


- Detectors based on chemical-vapor-deposition (CVD) diamonds

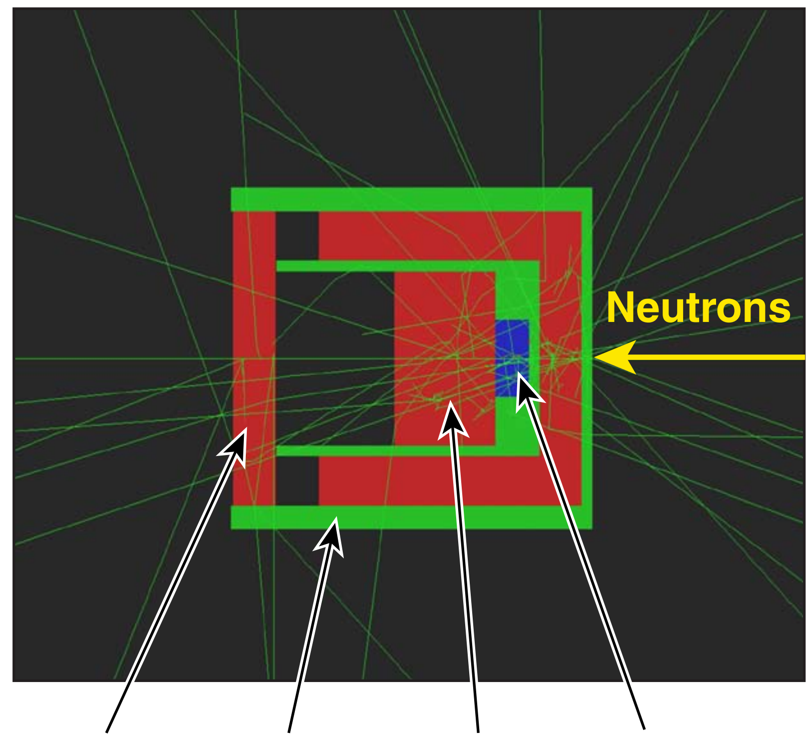


The system response of a neutron time-of-flight detector is strongly affected by neutron scattering

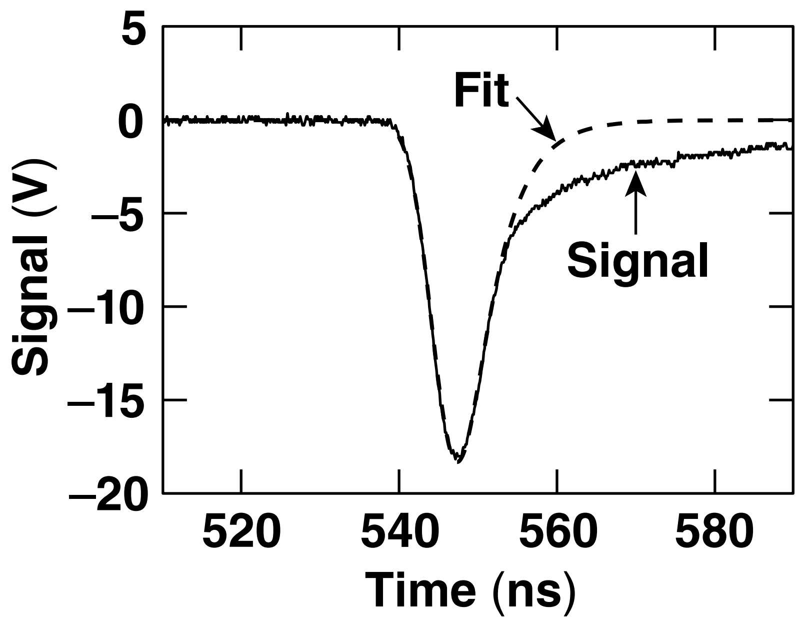
Detector parts



Monte Carlo simulation



On OMEGA, the best fit to the NIF nTOF detectors has a fall time of 4 ns and a system response of 1.5-ns FWHM



- Fit is a convolution of a Gaussian and an exponential decay:

$$\mathrm{Fit} = A_0 \exp\left[-\frac{(t-t_0)^2}{2\sigma^2}\right] \otimes \exp\left[-\frac{(t-t_0)}{\tau}\right]$$

- The full width at half max (FWHM) of the Gaussian is a combination of the ion temperature and system response:

$$\mathrm{FWHM} = \sqrt{\mathrm{FWHM}_t^2 + \mathrm{FWHM}_r^2}$$

Fit parameters: A_0 = –33 V, σ = 2.50 ns , τ = 4.00 ns
FWHM = 5.68 ns, FHWM_t = 5.48 ns, FWHM_r = 1.5 ns

The manufacturer's specification for the exponential decay time of the scintillator is ~1.3 ns.

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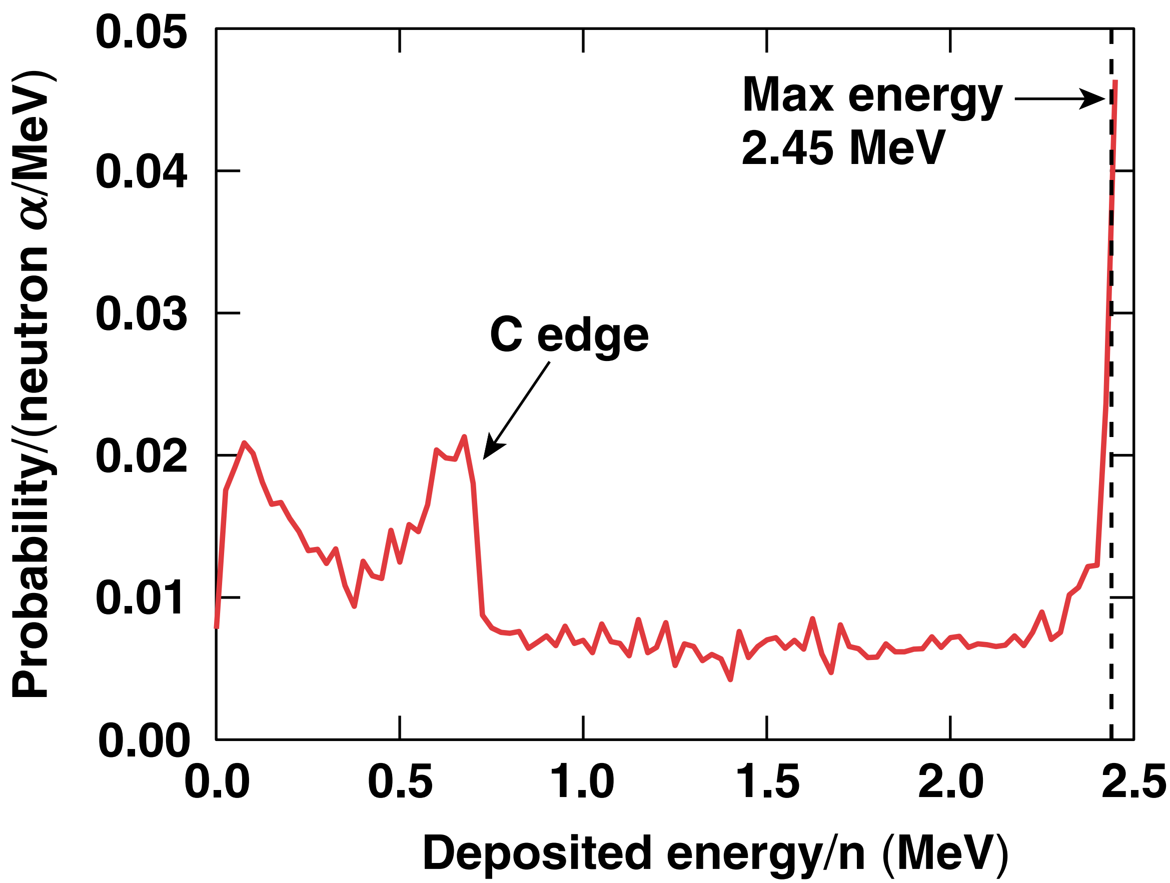
Geant4 simulations provide realistic neutron-interaction probabilities and energy-transfer functions

- Geant4 uses high-quality cross sections from LBL
- Simulations include the effects of shielding



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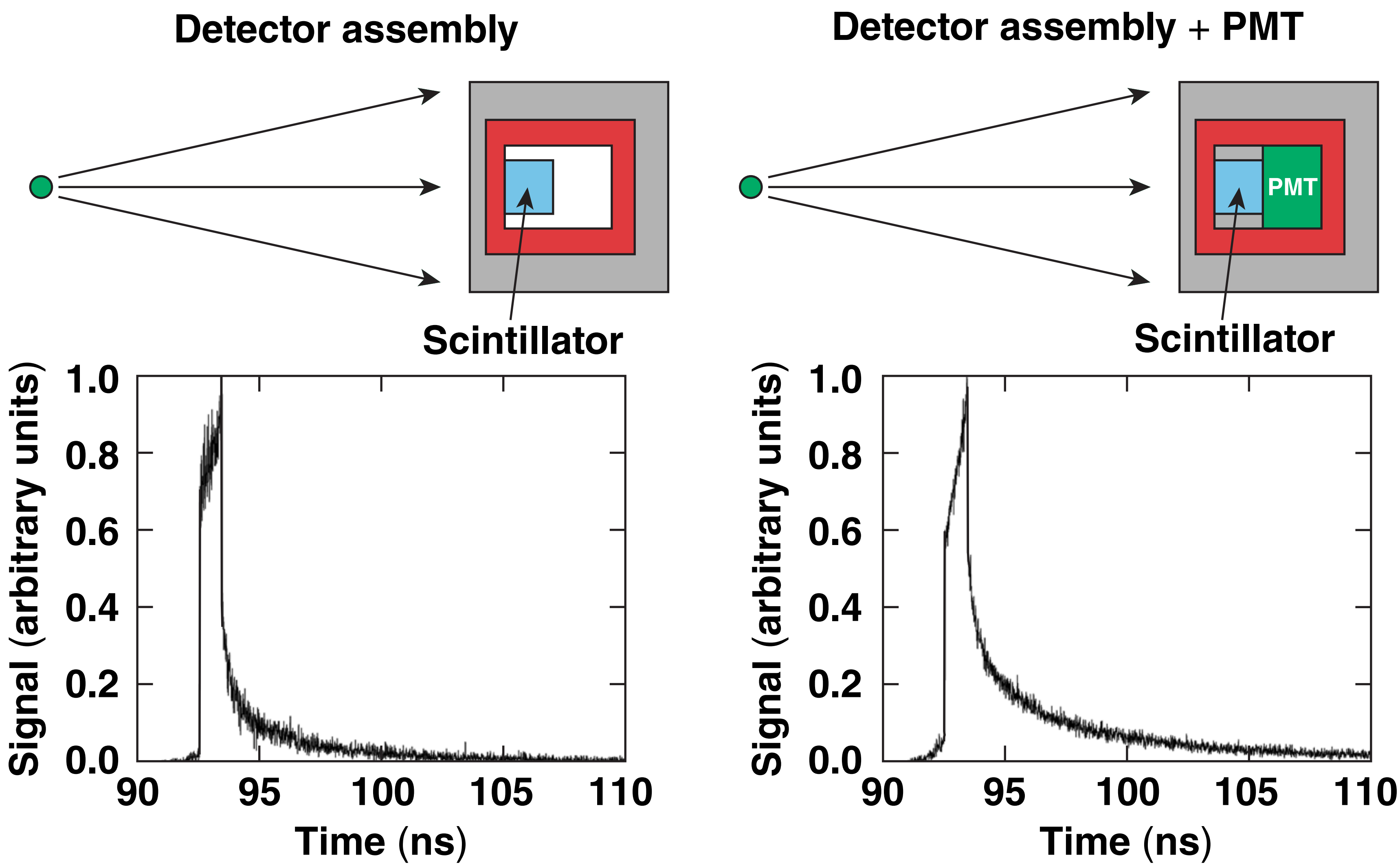
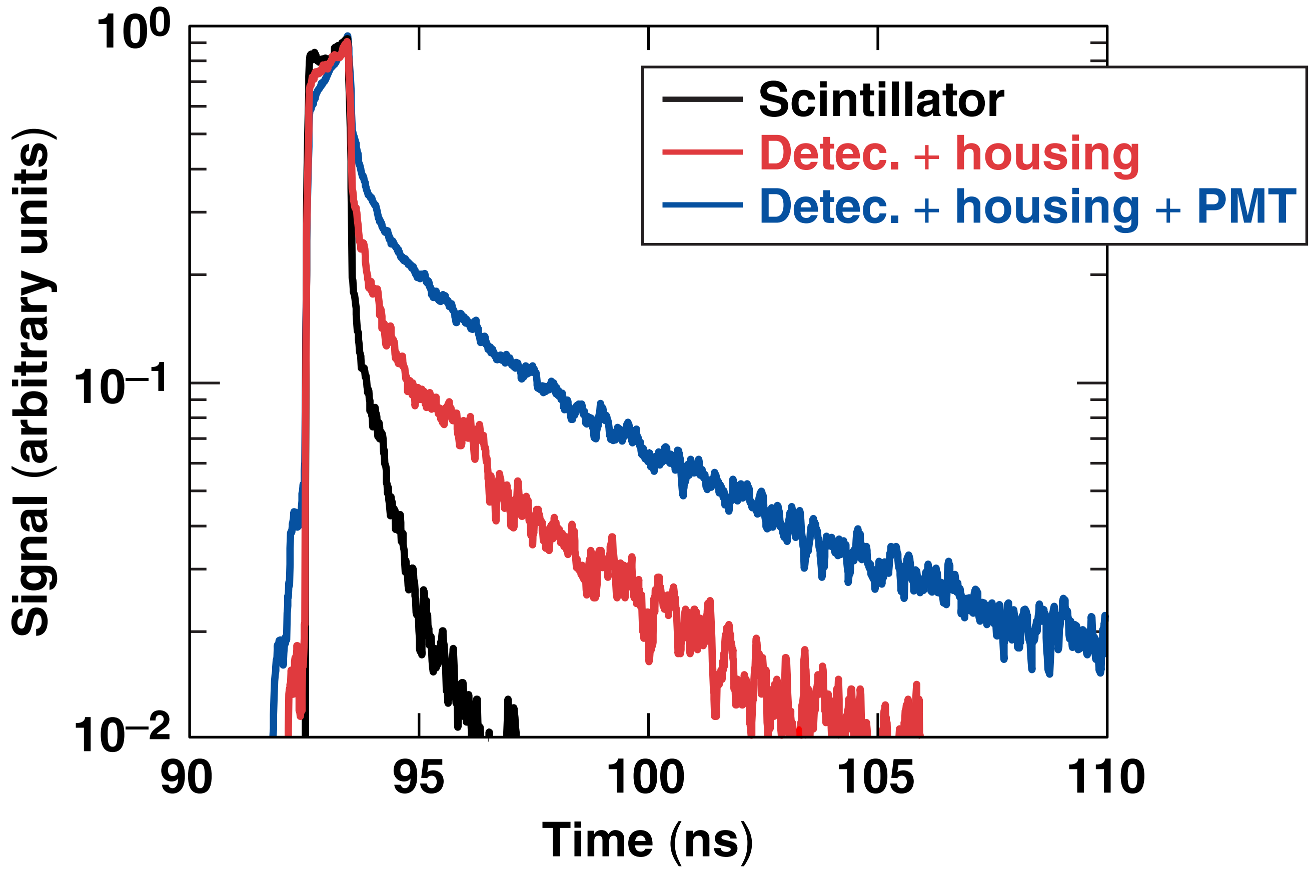
Different levels of refinement of the Monte Carlo model produce significant differences in the neutron history



E19503

Different levels of refinement of the Monte Carlo model produce significant differences in the neutron history



Data smoothed by 10-sample running average

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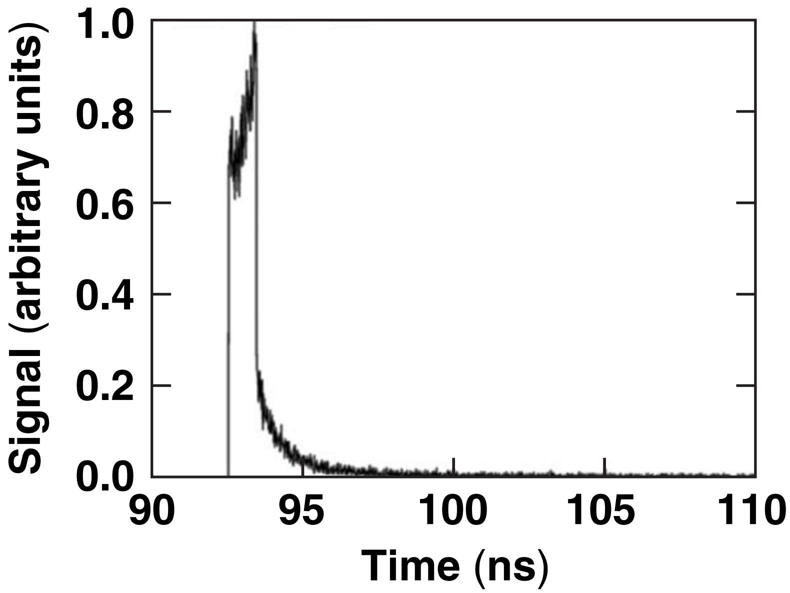
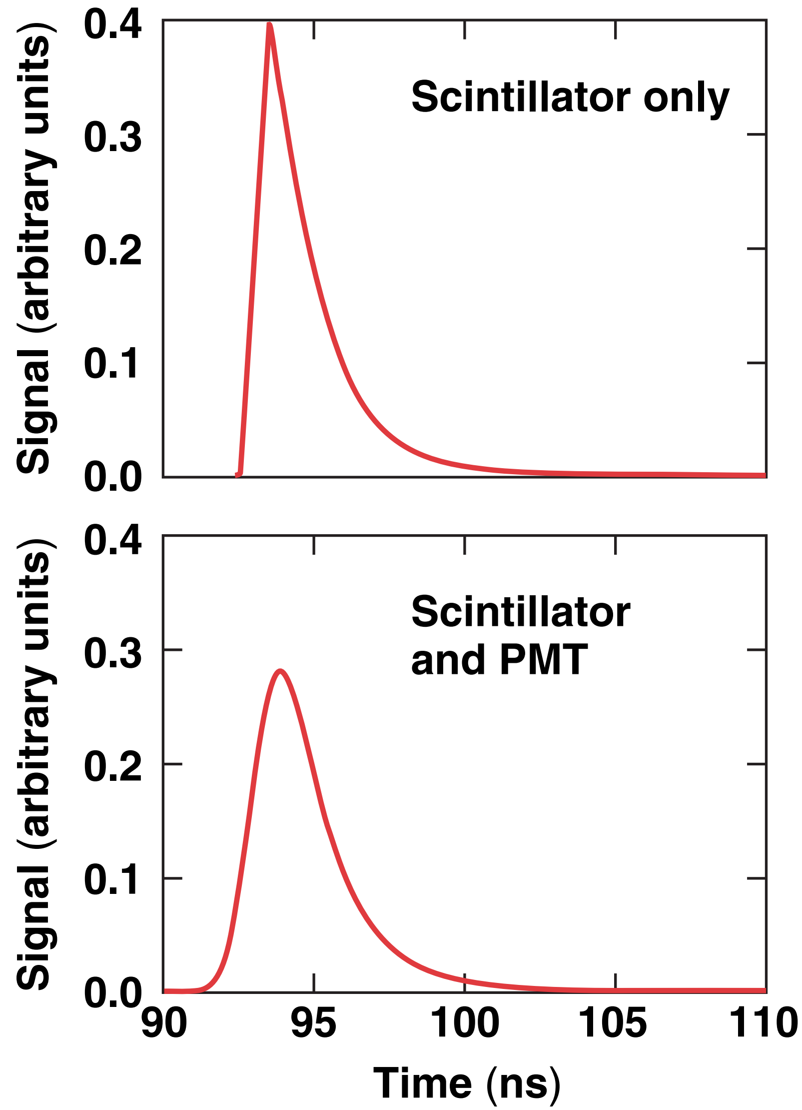
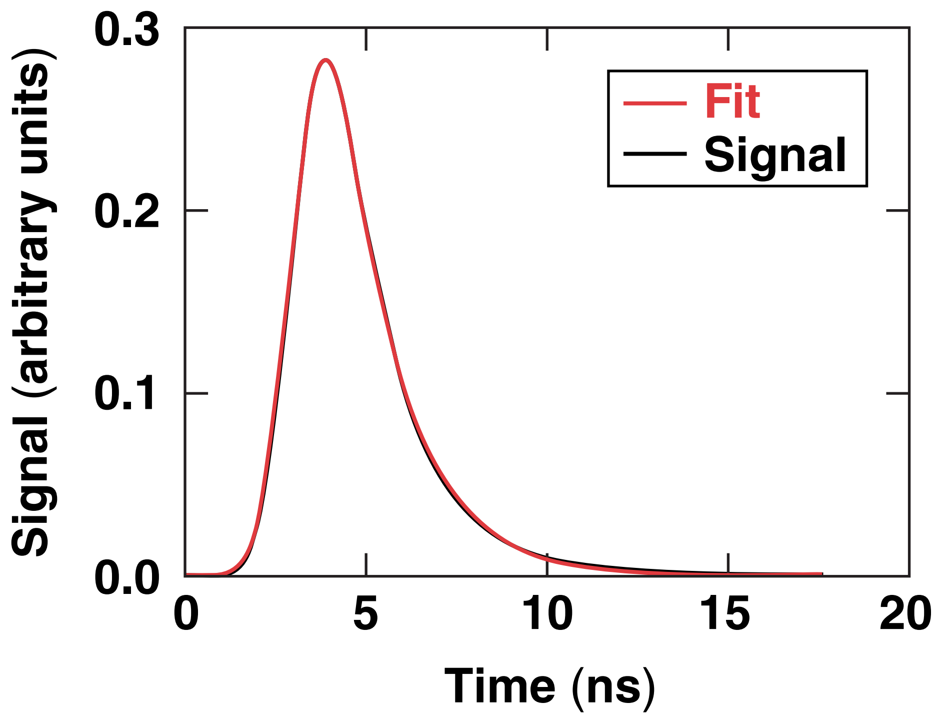
For further analysis the Geant4 data are convolved with the scintillator decay and the system response





- Exponential scintillator decay: 1.3 ns
- Gaussian system response: 1.5 ns
- Includes contributions from
  - PMT
  - scope
  - cable

A convolution of a Gaussian and an exponential decay is fit to the processed Geant4 data



Scintillator only
FWHM: 1.7 ns
Fall: 1.6 ns

$$m(t)=\frac{A}{2\tau}\exp\left[-\frac{(t-t_1)}{\tau}\right]\times\exp\left(\frac{\sigma^2}{2}\right)\left\{1+\mathrm{erf}\left[\frac{(t-t_1)-\sigma^2/\tau}{\sqrt{2\sigma^2}}\right]\right\}^*$$

*T. J. Murphy, R. E. Chrien, and K. A. Klare, Rev. Sci. Instrum 68, 610 (1997).

With all the major elements of the detector included, the calculated fall time is close to the measured 4 ns

- Three parameter fit: FWHM, signal, position (first approx.)
  - system response: 1.5 ns; scintillator fall: 1.3 ns

Configuration	FWHM (ns)	Fall (ns)	Error sum
Scintillator	1.67	1.54	0.01
Detector	1.60	2.59	0.05
Detector + PMT	1.64	4.20	0.12

- Three parameter fit: FWHM, signal, position (second approx.)
  - system response: 1.3 ns; scintillator fall: 1.3 ns

Configuration	FWHM (ns)	Fall (ns)	Error sum
Detector + PMT	1.50	4.17	0.13

Summary/Conclusions

Geant4 simulations were used to estimate the influence of neutron scattering on the nTOF signals

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