Neutron Spectra Measured with Time-of-Flight Detectors on the National Ignition Facility

Normalized spectrum $dY/dE$ (fraction/MeV)

Alcove Spec20

- N110618
- N110914

Energy (MeV)

Normalized spectrum $dY/dE$

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Summary

High-quality data from NIF Spec20 detectors make it possible for neutron spectra to be calculated from a deconvolution

- Instrument response function (IRF) determined from in-situ measurements
- Spec20 detectors probe NIF implosions from two different lines-of-sight
- Neutron spectra are calculated with an error analysis built into the deconvolution
NIF nTOF development has been done by a large team of collaborators

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Several nTOF detectors are distributed around the NIF target chamber.

- nTOF-20 alcove (116-316)
- nTOF-4.5 DT-Lo (64-309)
- nTOF-4.5 DT-Hi (64-330)
- nTOF-3.9 DSF (64-275)
- nTOF-4.5 BT (64-253)
- nTOF-20 equatorial (90-174)

Neutron down scatter is measured along four lines-of-sight.
DSR measurements sample $\rho R$ of large-opening angle cones about the diagnostic direction.

Neutrons scattered from tritium and deuterium.

**Instrument** – $(\theta, \phi)$
- 3.9 m DSF – (64, 275)
- MRS – (77, 324)
- Alcove Spec20 – (116, 316)
- Equator Spec20 – (90, 174)

The average of all DSR measurements represents the average target $\rho R$. 
Instrument response functions (IRF’s) are constructed with a dynamic range of $10^3$.

Instrument IRF is calculated from x-ray data, neutron propagation in scintillator calculated from MCNP, and exploding-pusher data.
Spec20 deconvolution uses a Wiener-filtered FFT technique

- Use signal-to-noise to determine number of points for FFT analysis (typically 4096)
- Use same number of points in data for leading and trailing noise windows
- FFT data, noise, and IRF
- Construct Wiener filter from power spectrum from IRF and noise using a Lagrangian multiplier
- Calculate deconvolved signal from inverse FFT of \((WF^* [\text{FFT(data)}/\text{FFT(IRF)}])\)
- Optimize Lagrangian multiplier by minimizing under- and overshoots in signal (subjective)
- Convert data to energy domain
- Calculate scalars DSF, \(T_{ion}\), yield
- Calculate energy spectrum with 50-keV resolution
Errors propagated throughout deconvolution analysis

- $\delta$ FFT from noise
- $\delta$ signal from $\delta$ FFT
- $\delta$ spectrum from $\delta$ signal
- $\sigma$ scalars
Exploding-pusher neutron spectra agree but may show a difference between 1.5- and 2.1-mm shells.
Convolution of DT peak with IRF shows scattered neutrons
Down-scattered neutrons are clearly seen in deconvolved spectra
THD spectra show the TT neutrons in both alcove and equator Spec20’s.

TT neutrons seen for energies <9.3 MeV
Summary/Conclusions

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Deconvolution of neutron spectra allow for a generalized DSR to be calculated.
Convolution of DT peak with IRF does not match layer shot data
Convolution of DT peak with IRF matches data from 1.6-mm exploding-pusher shell

Forward convolution of deconvolved model agrees with measured data.
Deconvolution of IRF enhances the signal to background in the DSR region

- Layered shot data shown as red line
- Exploding-pusher shot data shown as points; time > 14.9-ns data multiplied by 20 to show signal background
- $\text{DSR} \equiv Y_{10 \text{ to } 12}/Y_{13 \text{ to } 15}$
Two nTOF Spec20 detectors are installed on the NIF target chamber.

Design can accommodate an expansion chamber

Mounting holes on back of PMT mount

PMT 140
Gain $10^3$

Equator installation 20 m from tcc
Alcove installation 22 m from tcc

Off-the-shelf metal bellows

Fused-silica windows

Photek PMT 240
Gain $10^6$

Filter glass

4-in.-diam × 2-in.-thick aluminum cavity filled with xylene

nTOF Spec20 has been calibrated with DT and D$_2$ implosions on both OMEGA and the NIF.