Conceptual design of The Neutron Temporal Diagnostic (NTD) for Measuring DD or DT Burn Histories at the NIF

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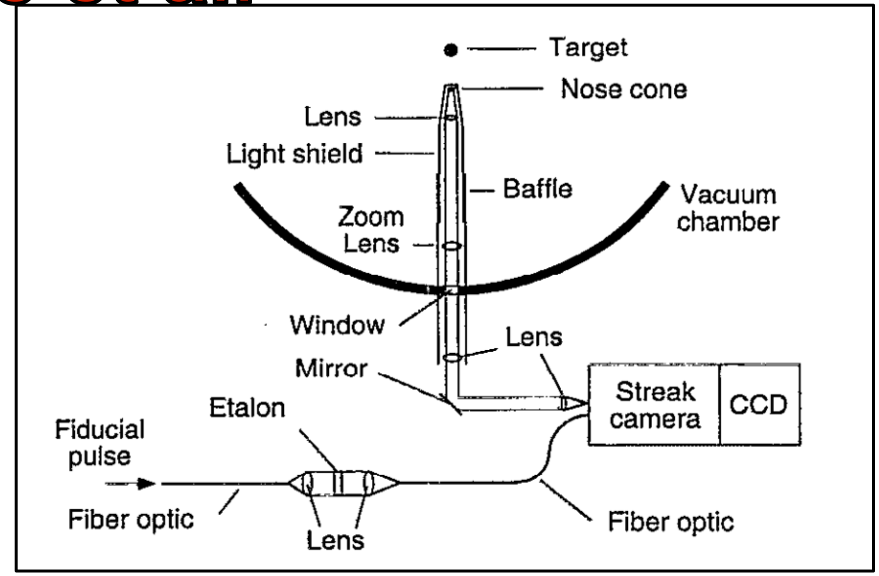
An NTD has been conceptually designed to measure DD or DT burn histories with a time-resolution of <30 ps at the NIF

- The front end of the NTD consists of a 100 micron thick, 5 mm diameter scintillator positioned 18 mm (DD) and 100 mm (DT) away from TCC.
- The NTD will compliment the existing GRH and future MRSt for measurement of DT-burn histories. It will also measure DD-burn histories.
- MCNPX was used to assess signal to background from NIF implosions
- For DD, on the basis of NVH implosion data and estimates of ambient backgrounds levels, burns widths and bang times can be determined with an accuracy of 45 ps and 30 ps respectively for yields greater than 5×10^{10}
- The NTD can also be used to measure burn widths and bang times of DT implosions with an accuracy of 45 ps and 30 ps for yields greater than 10^{13}

The scintillator-based NTD concept was defined and implemented on NOVA in the 90s by Lerche et al.

- Thin plastic scintillator produces light from neutrons which is transported to an optical streak camera outside the target chamber

- Photoelectrons are then streaked onto a CCD



*Retrieved from R. A. Lerche et al. RSI **66**, 933 (1995)*

Around 2000 a similar system was implemented on OMEGA by Stoeckl et al.

The time-resolution requirement of 30 ps sets strict restrictions on the NTD scintillator geometry and position

- Time dispersion creates an uncertainty that scales with T_{ion} and stand-off distance $\ell_{standoff}$
    - Max $\ell_{standoff}$ ~ 2 cm for 4keV DDn
    - Max $\ell_{standoff}$ ~ 12 cm for 4keV DTn

$$\Delta t_{dispersion} \propto \sqrt{T_{ion}}\,(\ell_{standoff}/E_{neutron})$$

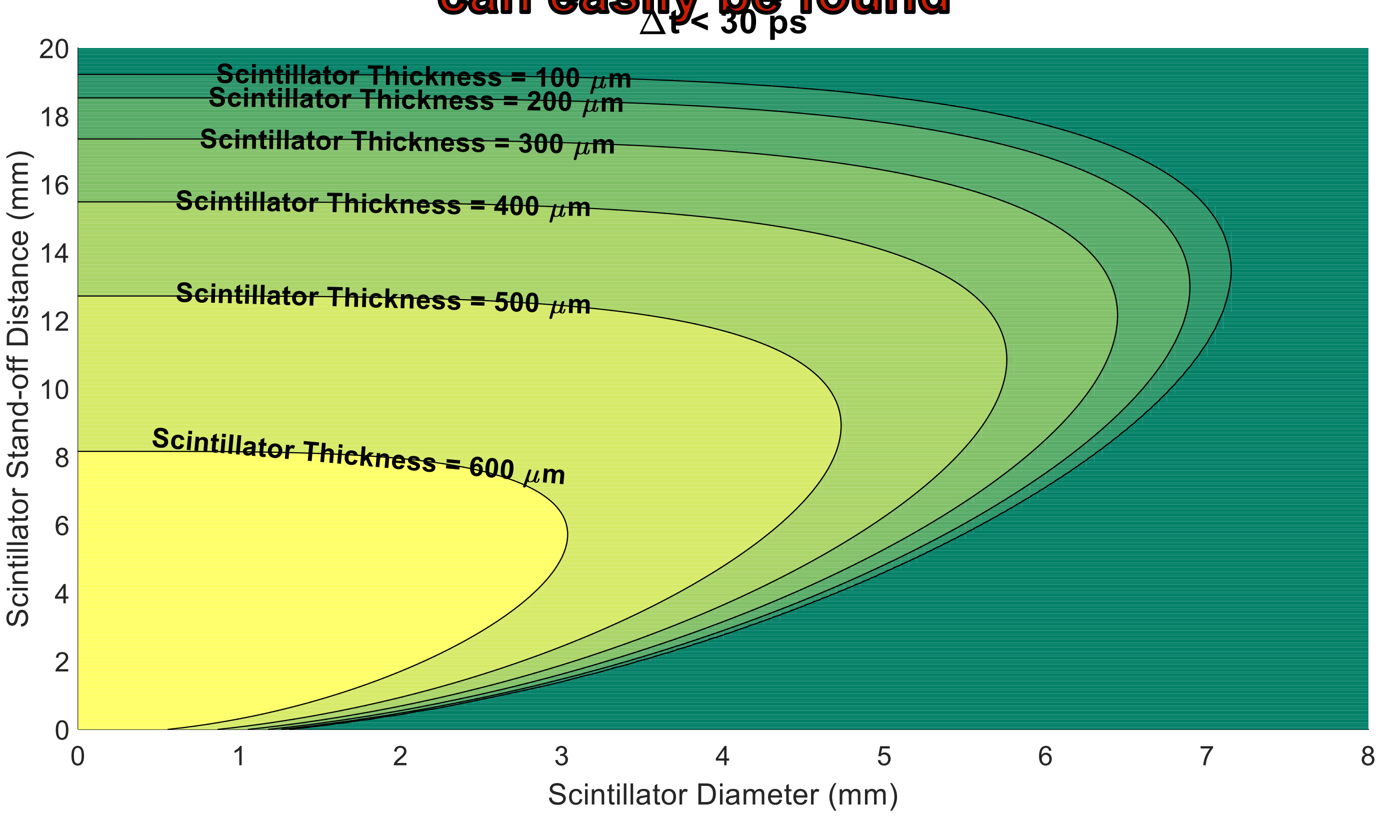
- The detector thickness w_{thick} creates an uncertainty in neutron-interaction time
    - Max w_{thick} ~ 650 microns for DDn
    - Max w_{thick} ~ 1500 microns for DTn

$$\Delta t_{thickness} \propto (w_{thick}/\sqrt{E_{neutron}})$$

- Detector diameter can contributes to the uncertainty in the interaction time if it's comparable to the standoff distance
    - Max d ~ 0.8 cm for DDn
    - Max d ~ 2.8 cm for DTn

$$\Delta t_{diameter} \propto (d/\ell_{standoff})(d/\sqrt{E_{neutron}})$$

Considering minimum stand-off distance and shielding space constraints, an optimal NTD design that meets the requirements for DD can easily be found



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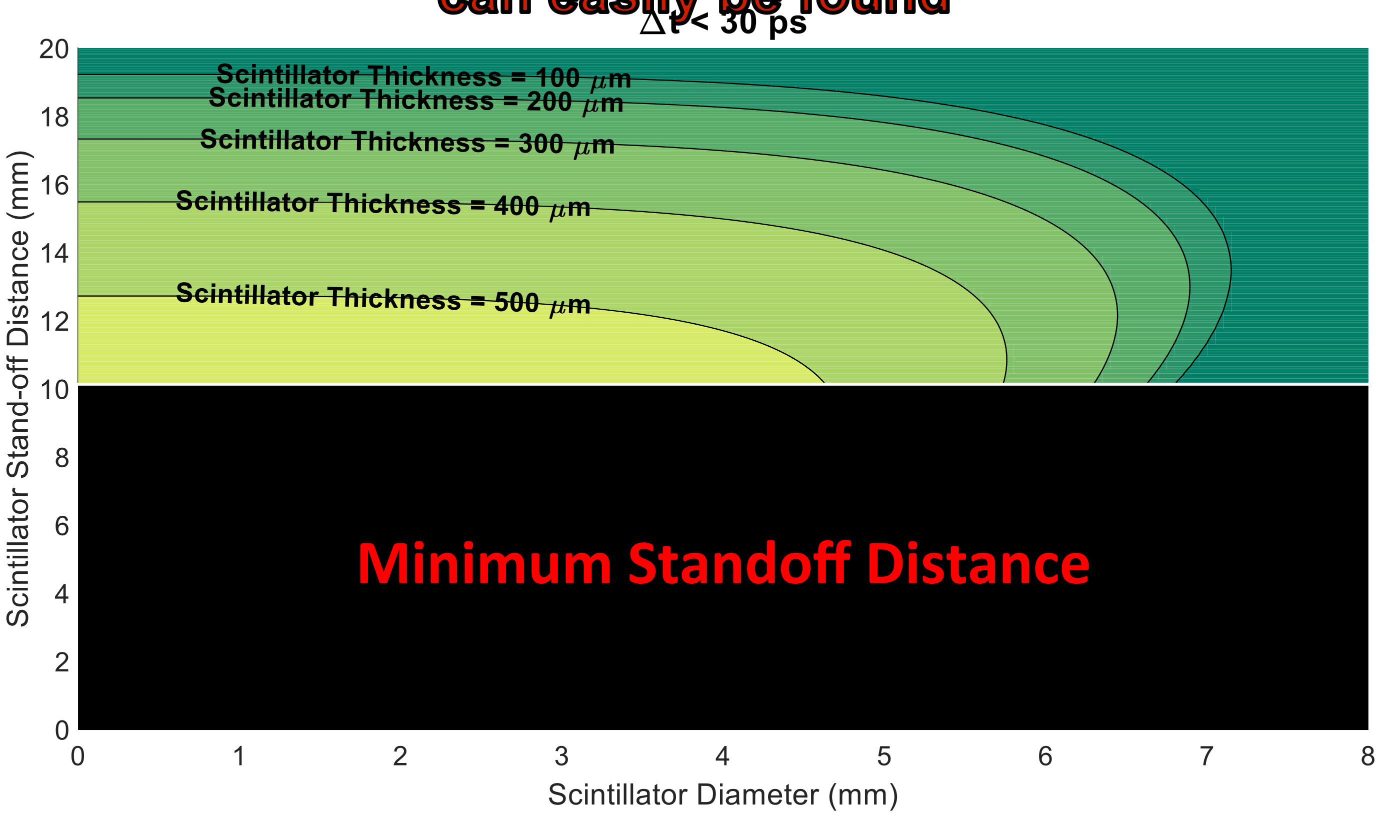

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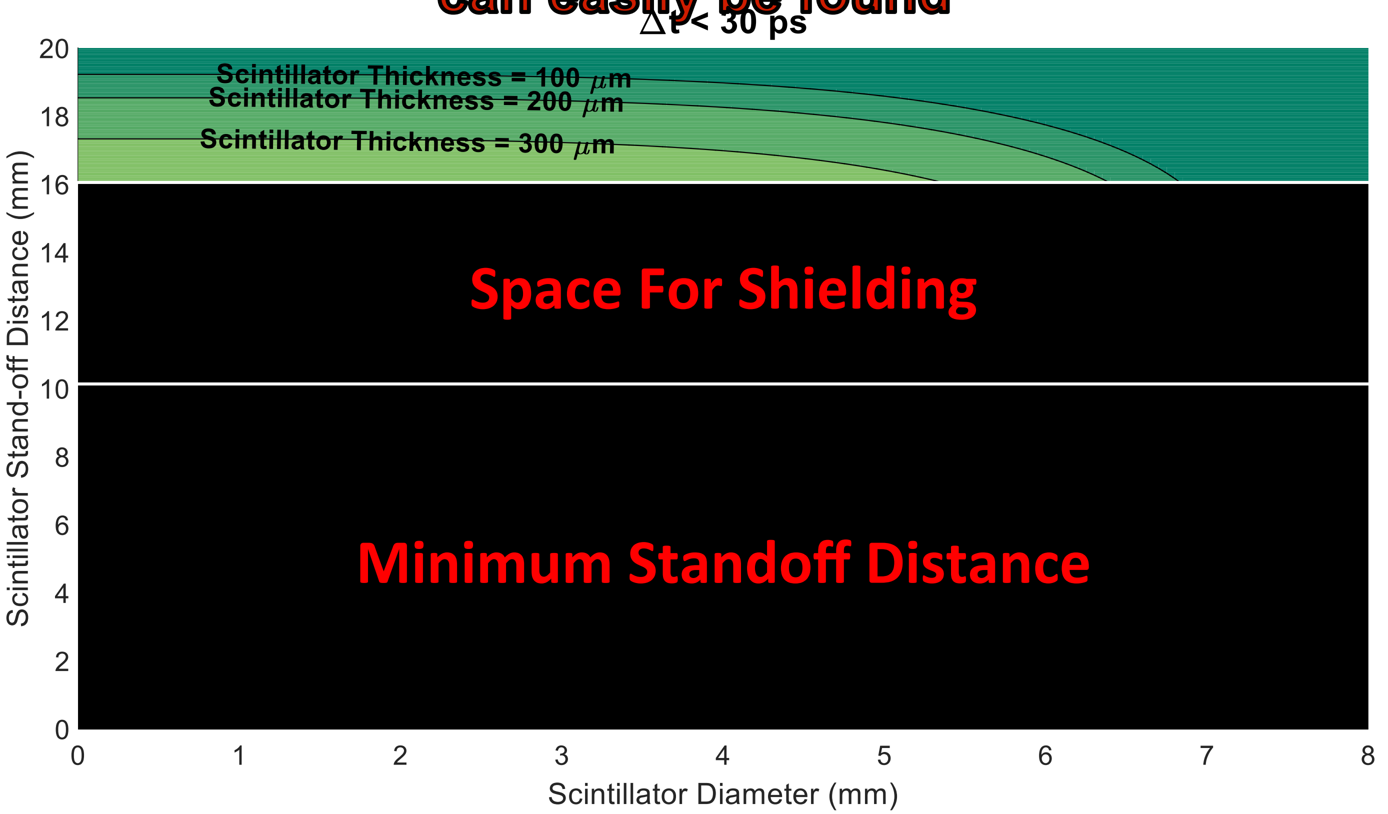

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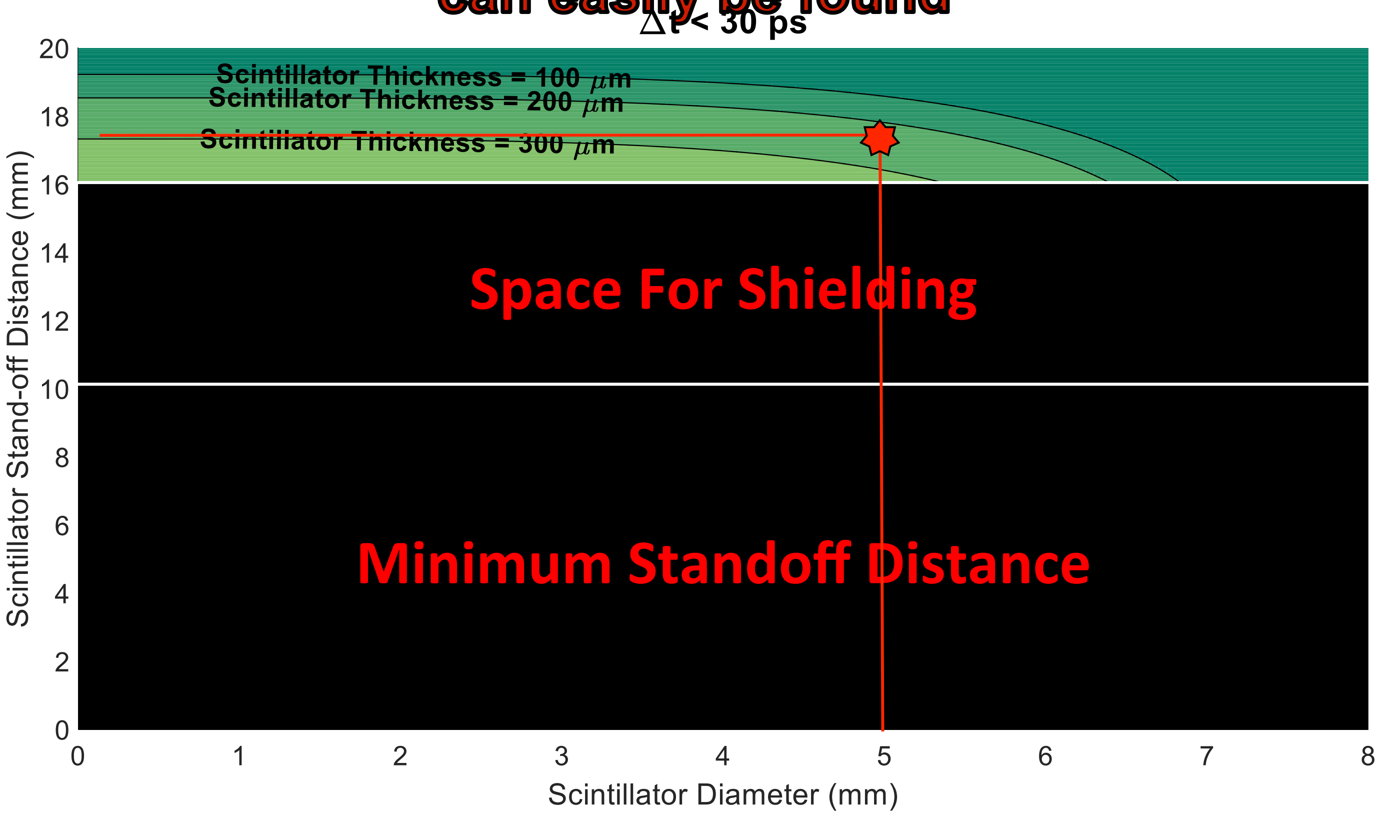
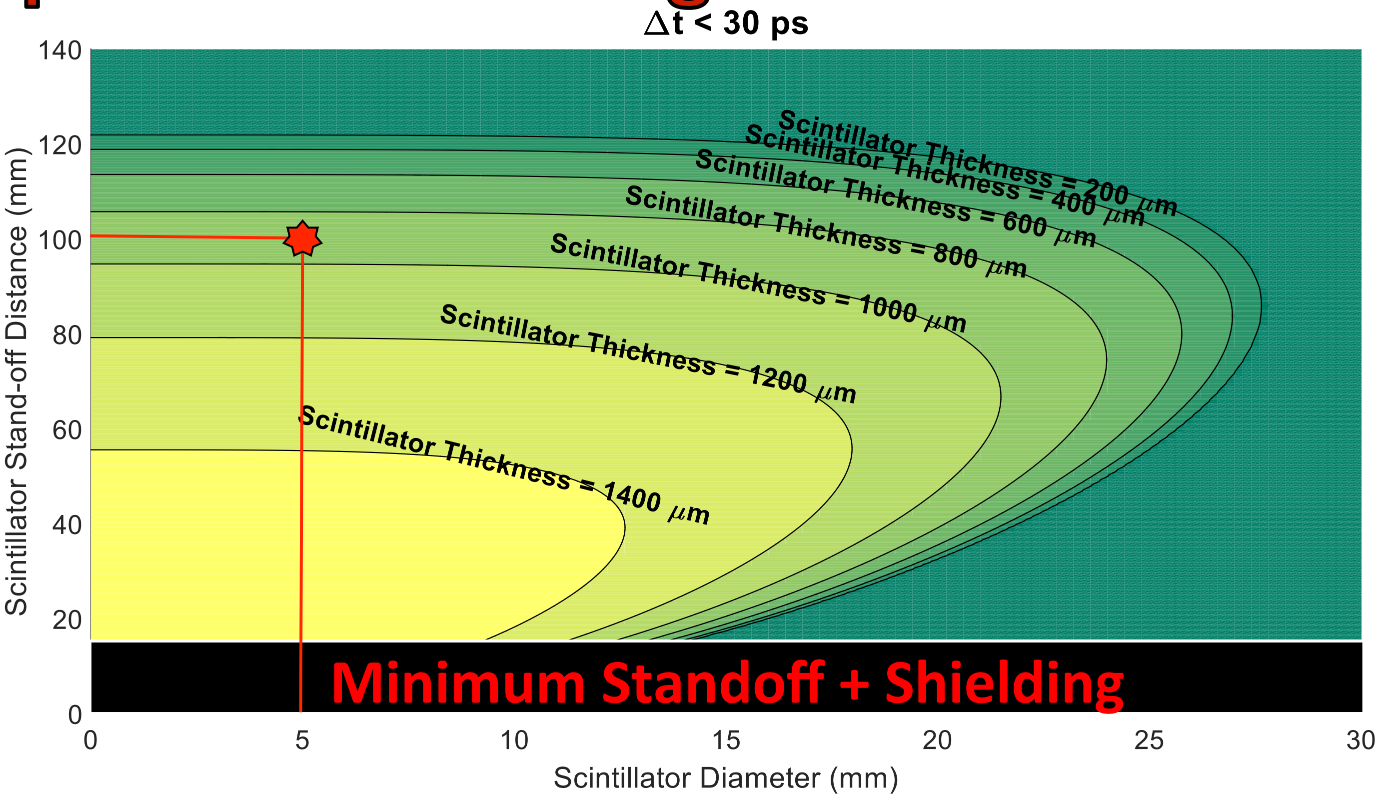
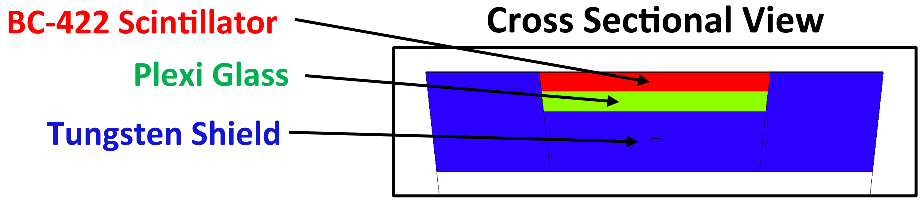


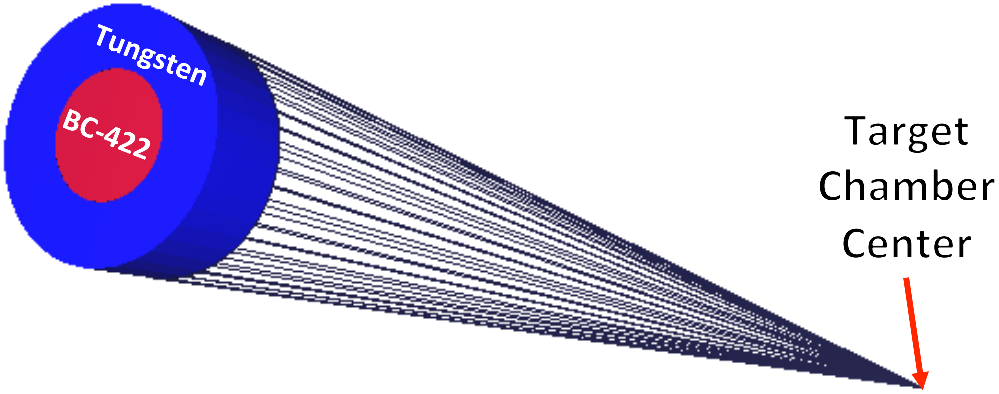
A similar procedure can be applied to find an optimal NTD design for DT neutrons



MCNPX was used to model the energy deposited in the scintillator by signal neutrons and direct x-ray background

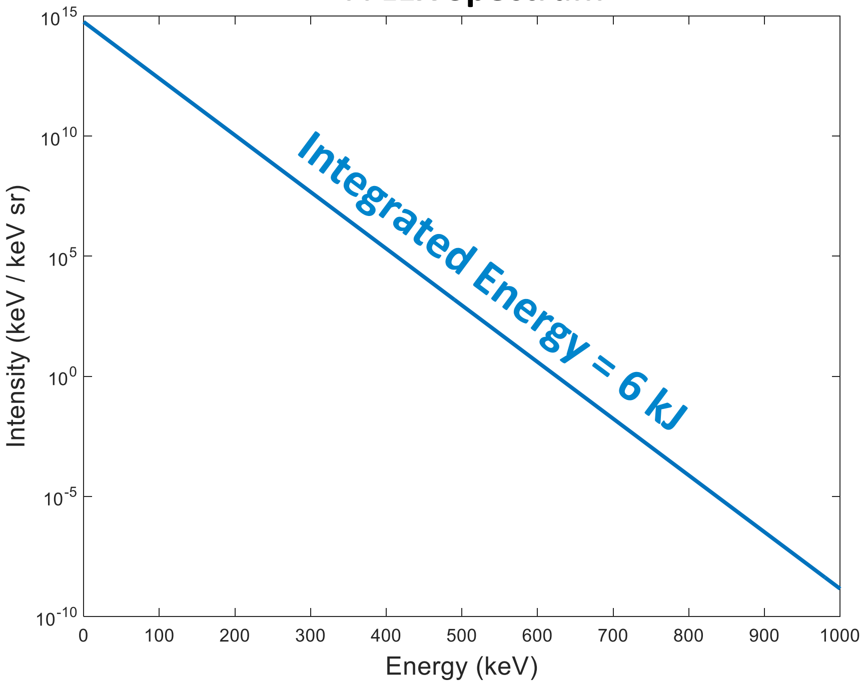
Cross Sectional View

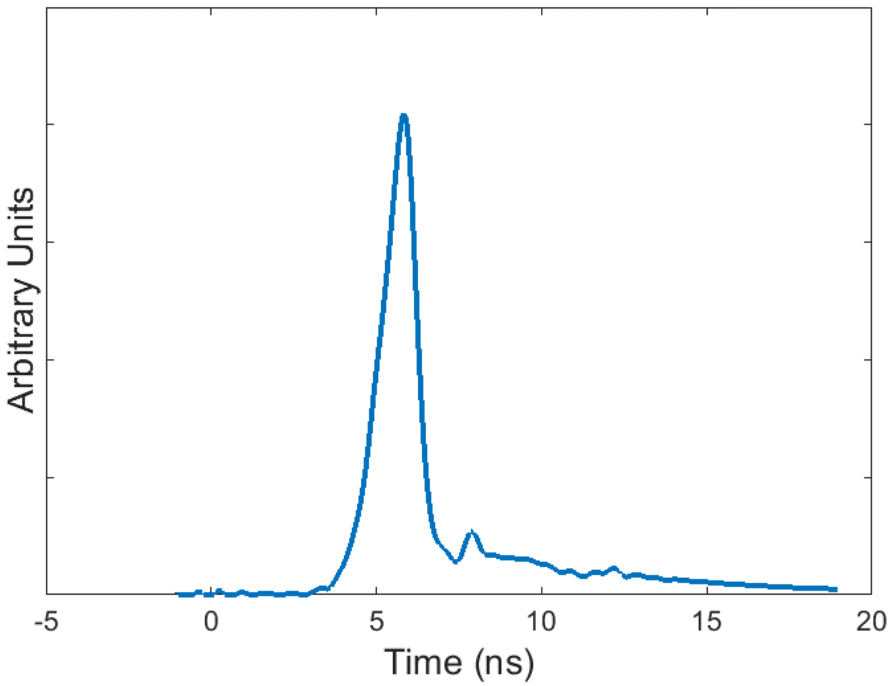




- A 4 keV DDn or DT neutron spectrum were used as input
- X-ray backgrounds determined from FFLEX and SPBT detectors for ‘representative’ NIF shots were also used as input

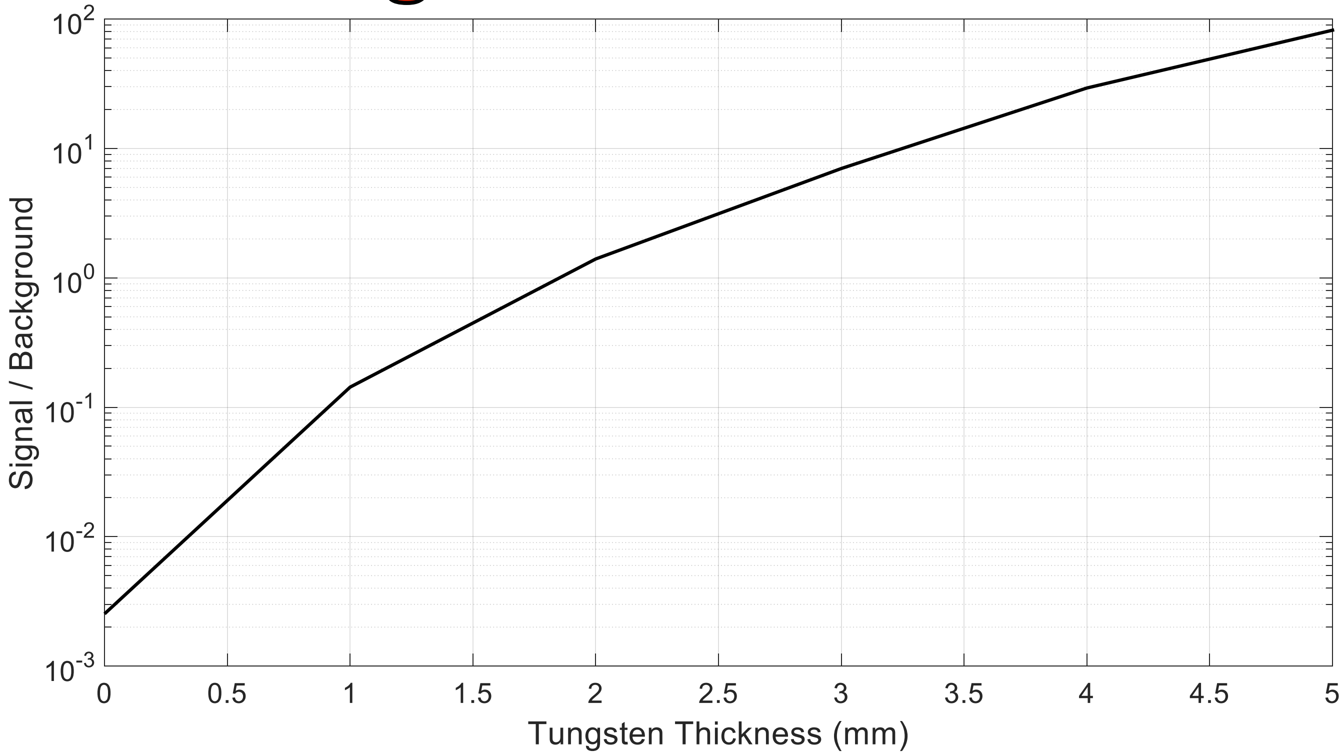
FFLEX and SPBT data from N130920 were used to simulate ‘typical’ x-ray background in NVH experiments


FFLEX Spectrum


SPBT Signal

Shielding is required to sufficiently reduce the x-ray background below the neutron signal

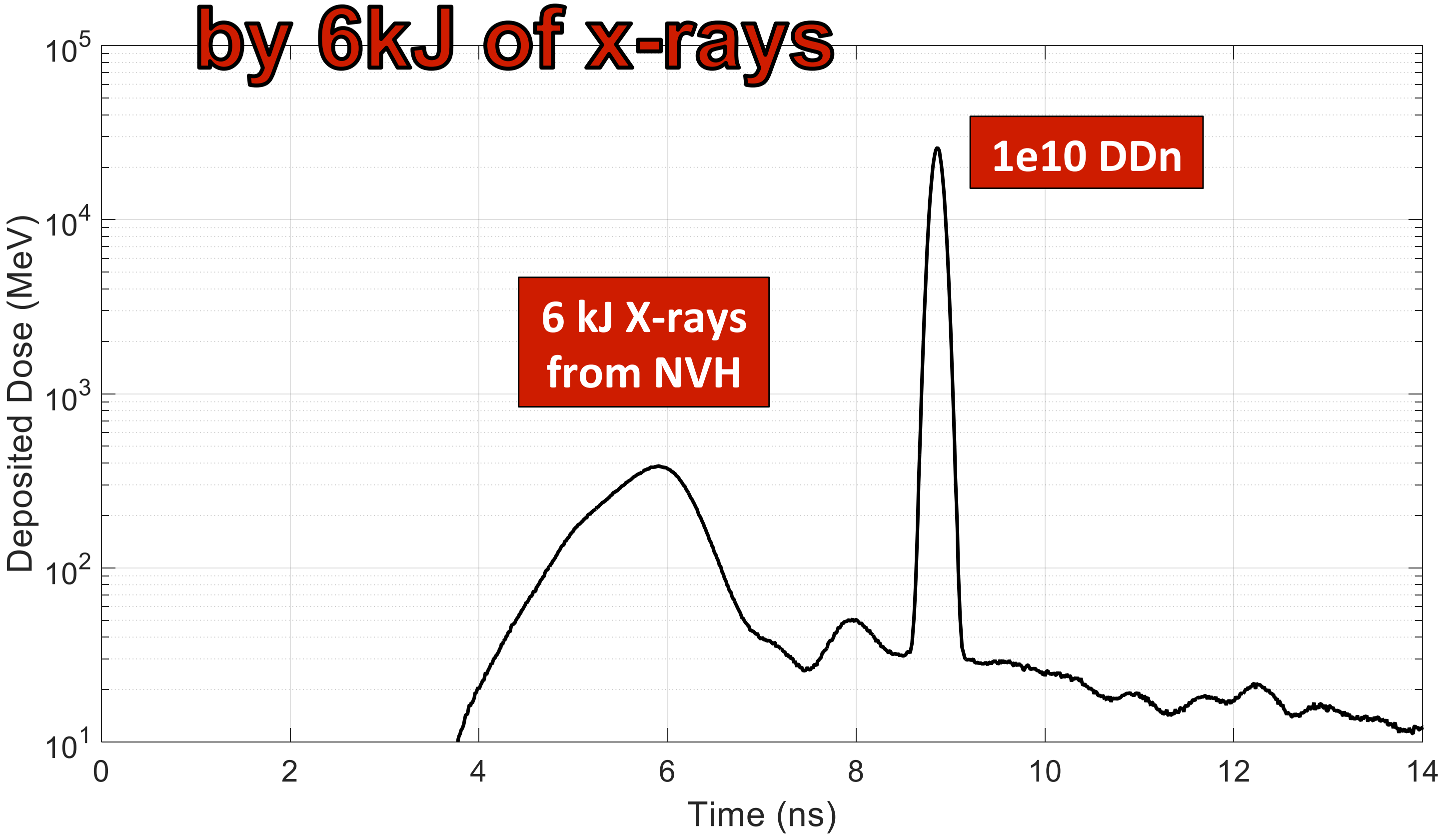
For the case of 5e10 DDn and a background of 6 kJ of NVH x-rays, S/B of ~7 can be achieved with 3mm of Tungsten



The energy deposited in the scintillator by $5\text{x}10^{10}$ DDn dominates the energy deposited by 6kJ of x-rays

NTD Dimensions

Thickness - 100 µm
TCC Distance - 18 mm
Diameter - 5 mm
W Shielding - 3 mm



6 kJ X-rays from NVH

1e10 DDn

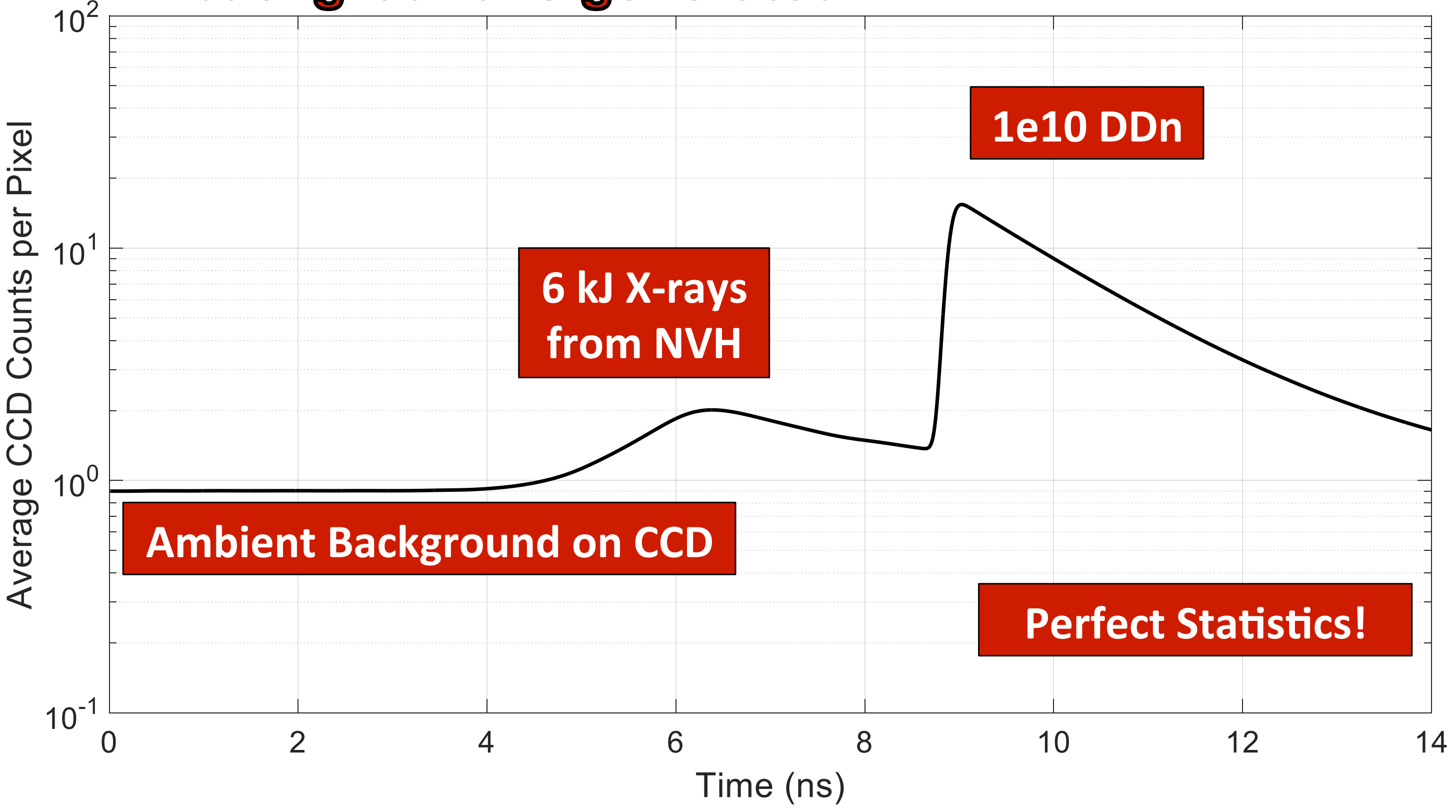
Considering the scintillator properties, signal chain inefficiencies, and ambient background on the CCD, synthetic CCD signal and background is generated

Assumed IRF

Rise Time = 25 ps
Fall Time = 1600 ps
Efficiency = 8400 photons / MeV

Signal Chain Inefficiencies

Collection Efficiency = 1.5 %
Surface Light Loss = 50 %
1:1 Signal Imaging = 5%
Photo Cathode Q.E. = 6%
Counts / Photoelectron = 3%



1e10 DDn

6 kJ X-rays from NVH

Ambient Background on CCD

Perfect Statistics!

Considering the scintillator properties, signal chain inefficiencies, and ambient background on the CCD, synthetic CCD signal and background is generated

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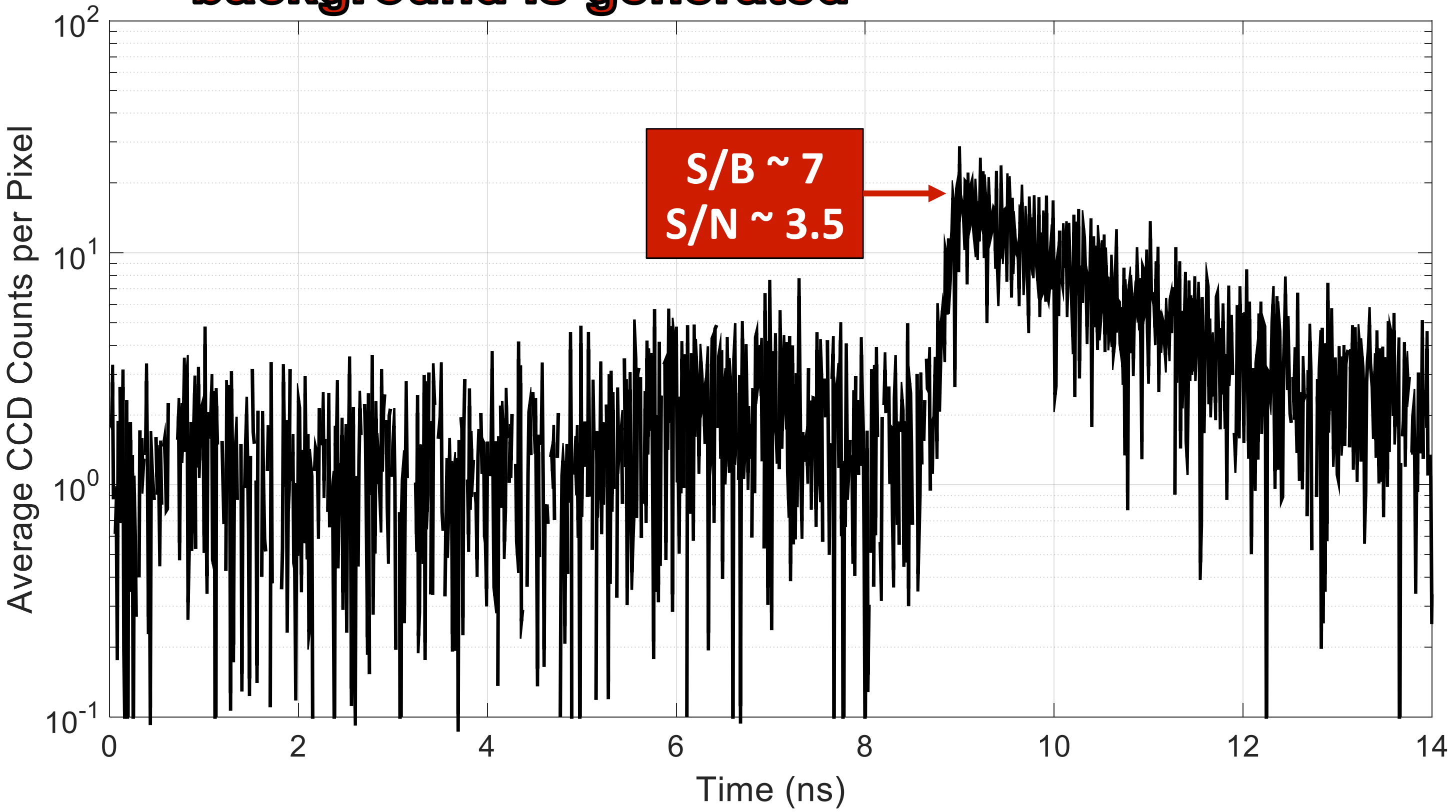
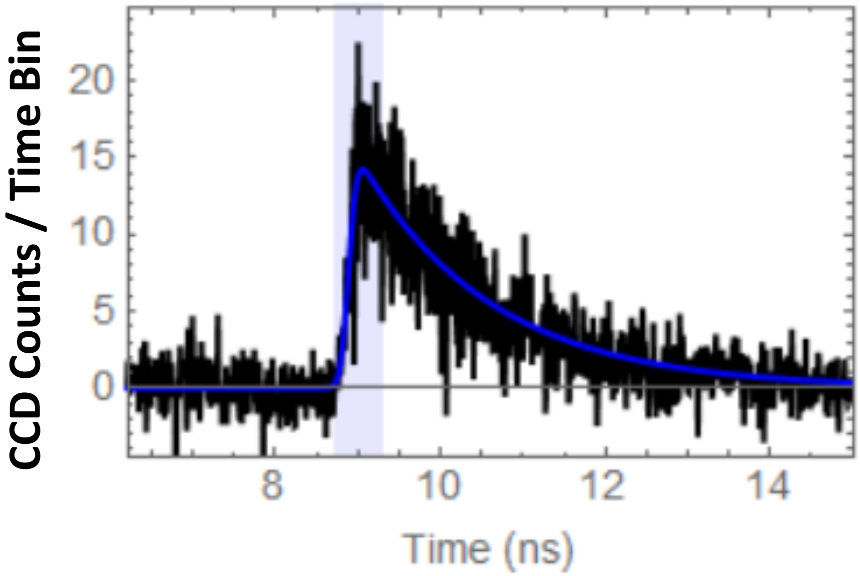


Bang time and burn width can be accurately determined from the signal in this low yield scenario



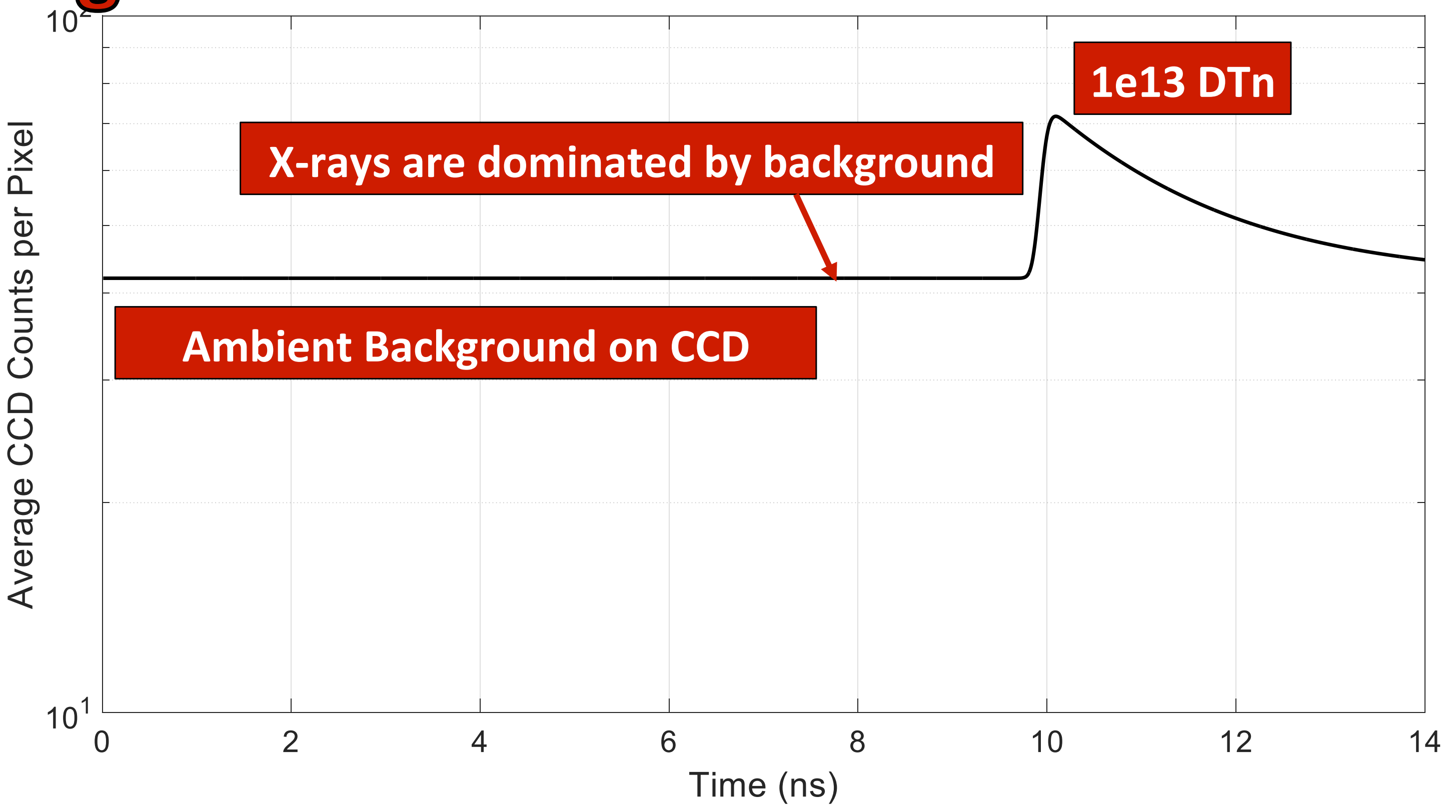
Forward Fit To Signal

Parameter	Modeled Value	Deconvolution Value
Bang Time (ps)	8000	
Burnwidth (ps)		

Same NTD design can easily be extended to DTn using a different standoff distance

NTD Dimensions

Thickness - 100 µm
TCC Distance - 100 mm
Diameter - 5 mm
W Shielding - 3 mm



1e13 DTn

X-rays are dominated by background

Ambient Background on CCD

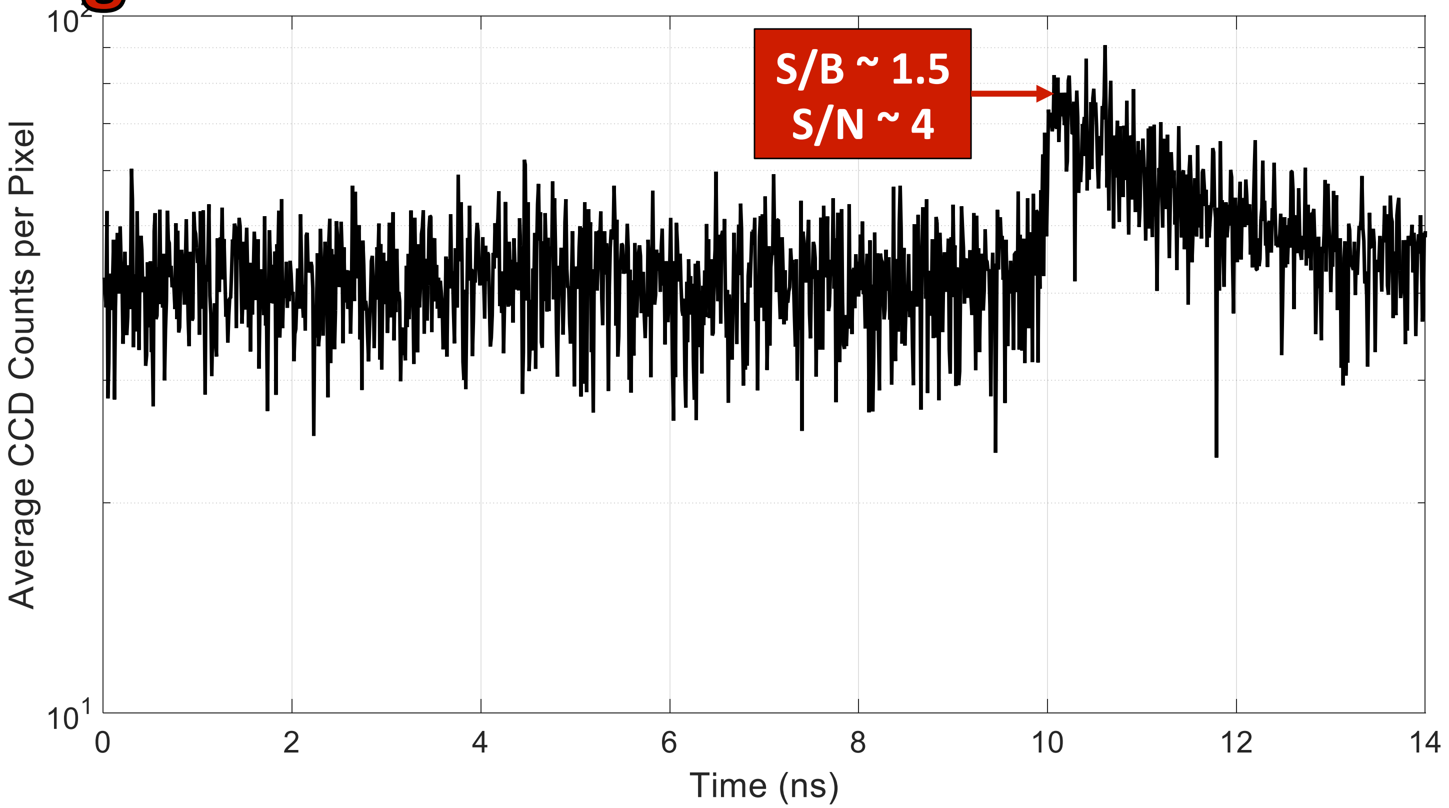
Same NTD design can easily be extended to DTn using a different standoff distance

Assumed IRF

Rise Time = 25 ps
Fall Time = 1600 ps
Efficiency = 8400 photons / MeV

Signal Chain Inefficiencies

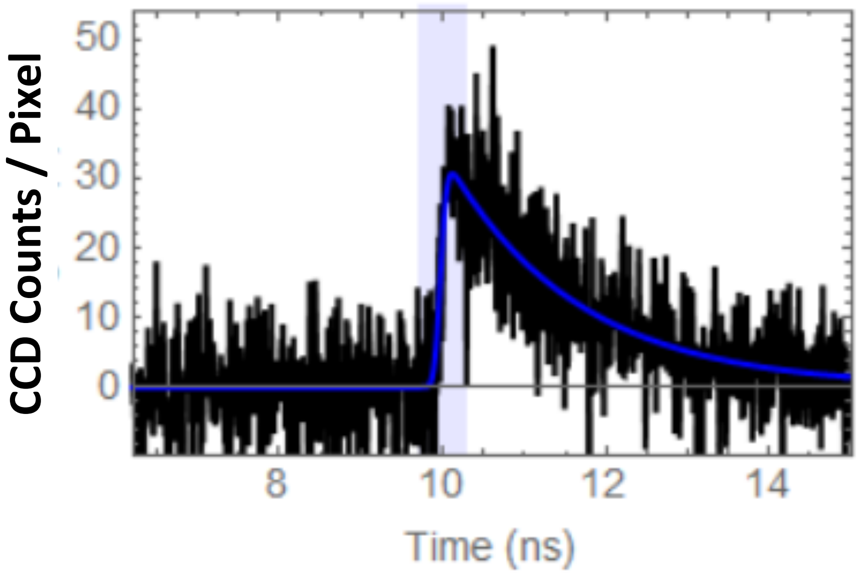
Collection Efficiency = 1.5 %
Surface Light Loss = 50 %
1:1 Signal Imaging = 5%
Photo Cathode Q.E. = 6%
Counts / Photoelectron = 0.5%



S/B ~ 1.5
S/N ~ 4

Bang time and burn width can be accurately determined from the signal in this low yield scenario

Forward Fit To Signal



Parameter	Modeled Value	Deconvolution Value
Bang Time (ps)		
Burnwidth (ps)		

Future Work

- The NTD system will have it's viability confirmed for PDD and GFH type implosion

- Uncertainties in the IRF's effect on inferred values will be explored

An NTD has been conceptually designed to measure DD or DT burn histories with a time-resolution of >30 ps at the NIF

- The front end of the NTD consists of a 100 micron thick, 5 mm diameter scintillator positioned 18 mm (DD) and 100 mm (DT) away from TCC.
- The NTD will compliment the existing GRH and future MRSt for measurement of DT-burn histories. It will also measure DD-burn histories.
- MCNPX was used to assess signal to background from NIF implosions
- For DD, on the basis of NVH implosion data and estimates of ambient backgrounds levels, both burns widths and bang times can be determined with an accuracy of 30 ps for yields greater than 10^{10}
- The NTD can also be used to measure both burn widths and bang times of DT implosions with an accuracy of 30 ps for yields greater than 10^{12}

Extra Slides

$5x10^{10}$ DTn response for an CCD located outside the target bay

Assumed IRF

Rise Time = 25 ps
Fall Time = 1600 ps
Efficiency = 8400 photons / MeV

Signal Chain Inefficiencies

Collection Efficiency = 1.5 %
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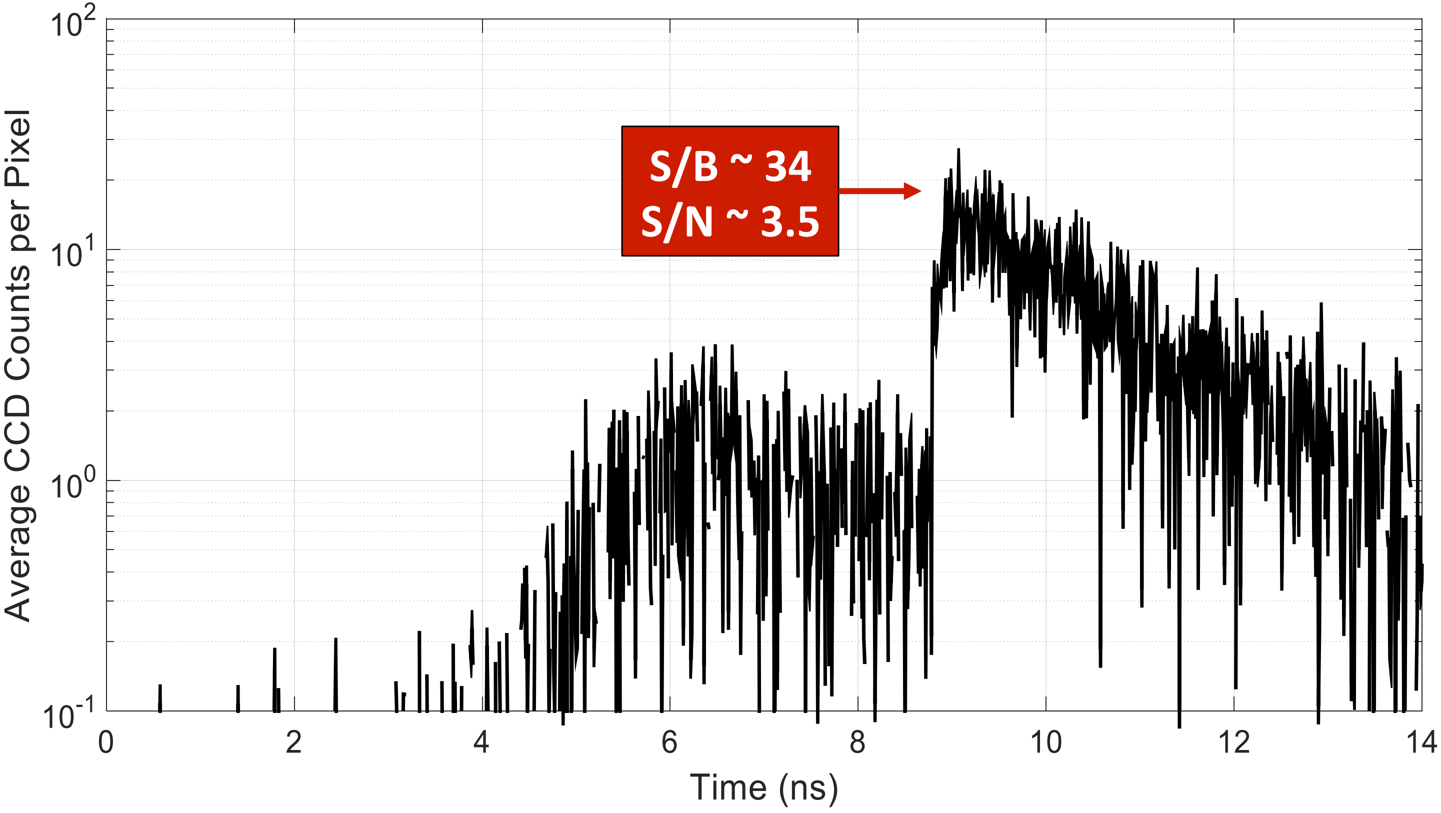


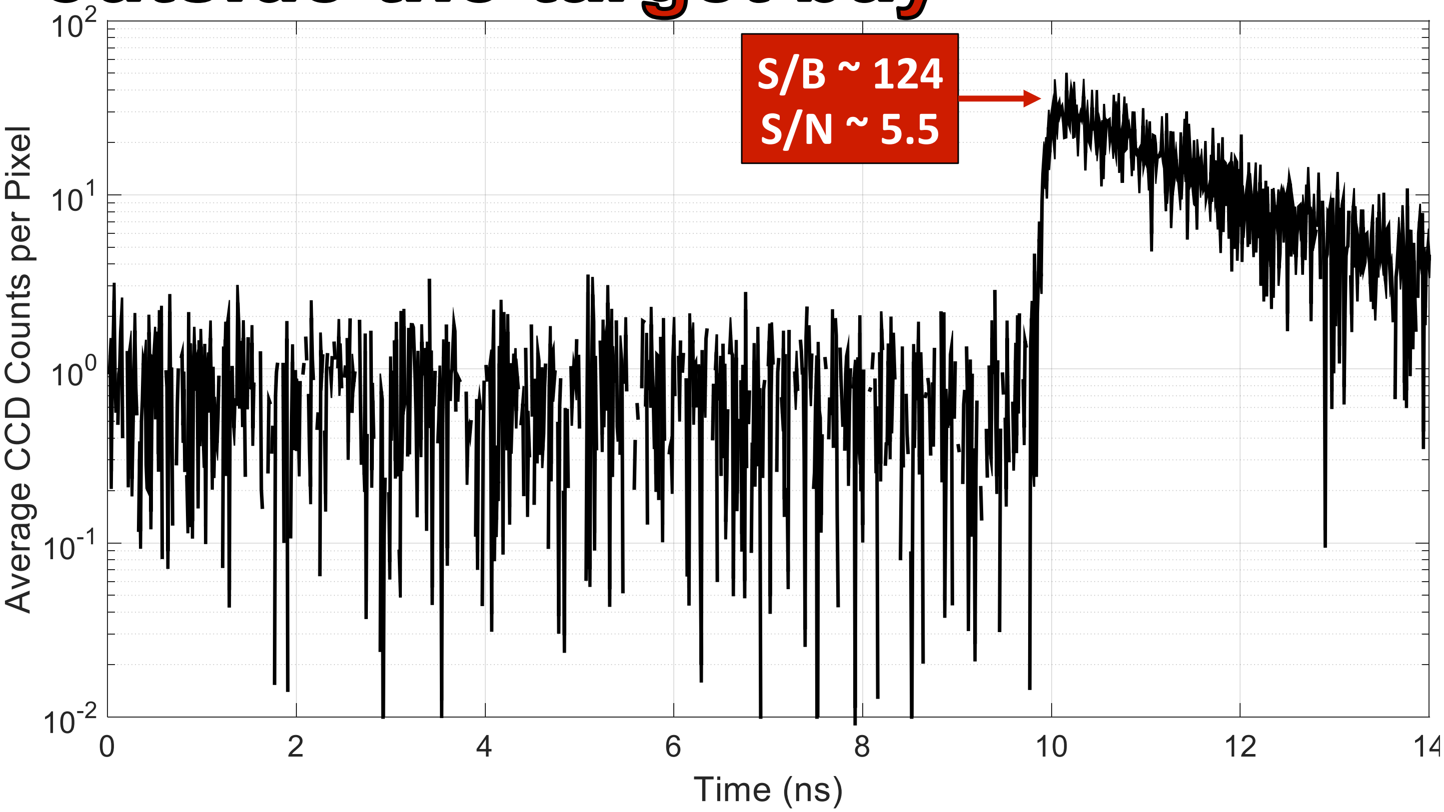
10^{13} DTn response for an CCD located outside the target bay

Assumed IRF

Rise Time = 25 ps
Fall Time = 1600 ps
Efficiency = 8400 photons / MeV

Signal Chain Inefficiencies

Collection Efficiency = 1.5 %
Surface Light Loss = 50 %
1:1 Signal Imaging = 5%
Photo Cathode Q.E. = 6%
Counts / Photoelectron = 0.5%


S/B ~ 124
S/N ~ 5.5