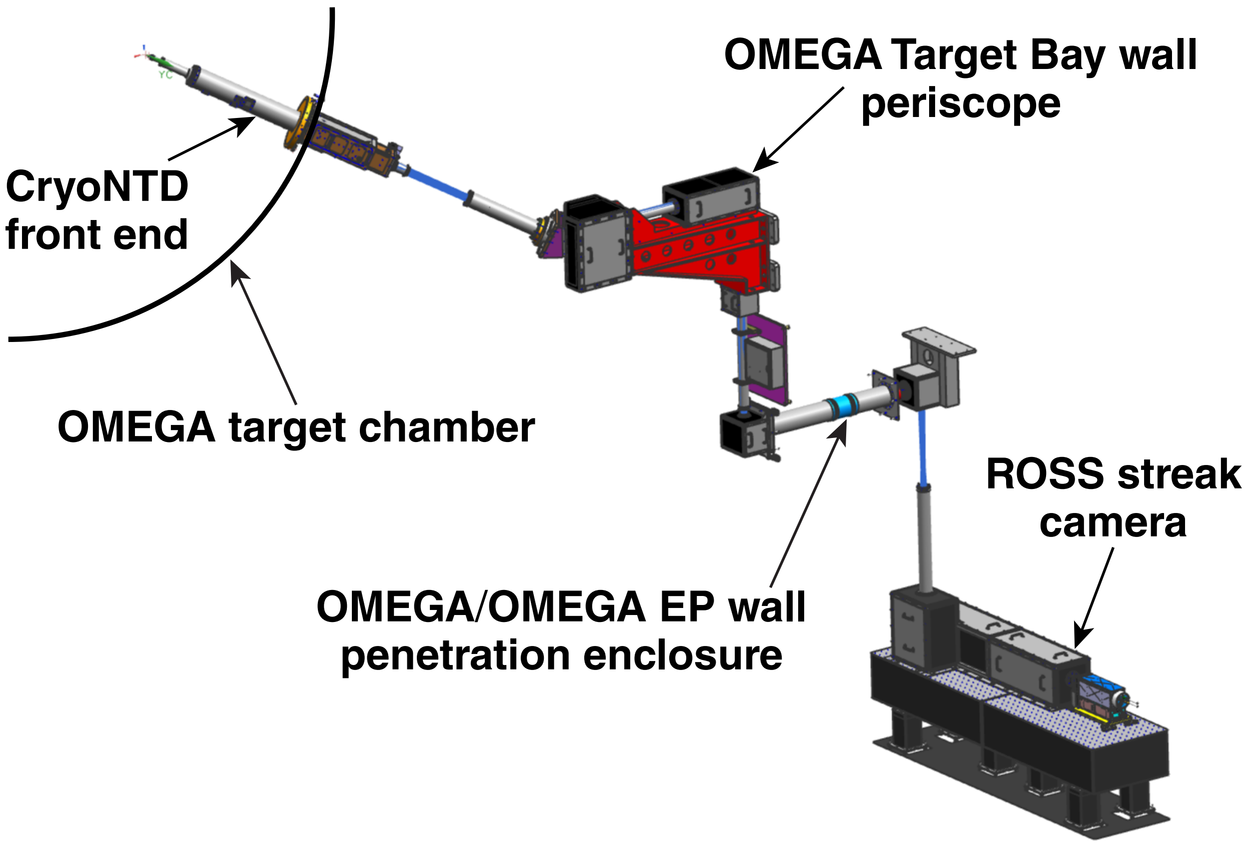
A Neutron Temporal Diagnostic for High-Performance DT Cryo Implosions on OMEGA



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Los Alamos National Laboratory
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Summary

A new neutron temporal diagnostic (NTD) has been built for high-yield DT cryo implosions on OMEGA

- The neutron background and the large scintillator standoff (20 cm) required to clear the cryo shroud severely limits the quality of the data on the previous NTD system on high-performance DT cryo implosions
- The cyroNTD diagnostic was installed in port P11 close to the equator of the target chamber, allowing the scintillator to be inserted to 9 cm
- The ROSS streak camera for the cyroNTD is located in the OMEGA EP plenum for $>100\times$ improvement in the neutron shielding
- A ~16-m-long relay system was designed to transport the light from the scintillator to the photocathode with $<$20-ps group velocity dispersion
- With the standard 3-ns sweep window, the system has a measured impulse response of 40$\pm$10 ps, which allows a 70-ps neutron pulse to be measured with 10% accuracy
- Preliminary measurements with the 1.5-ns sweep window show an impulse response of 25$\pm$10 ps, which allows a 50-ps neutron pulse to be measured with 10% accuracy

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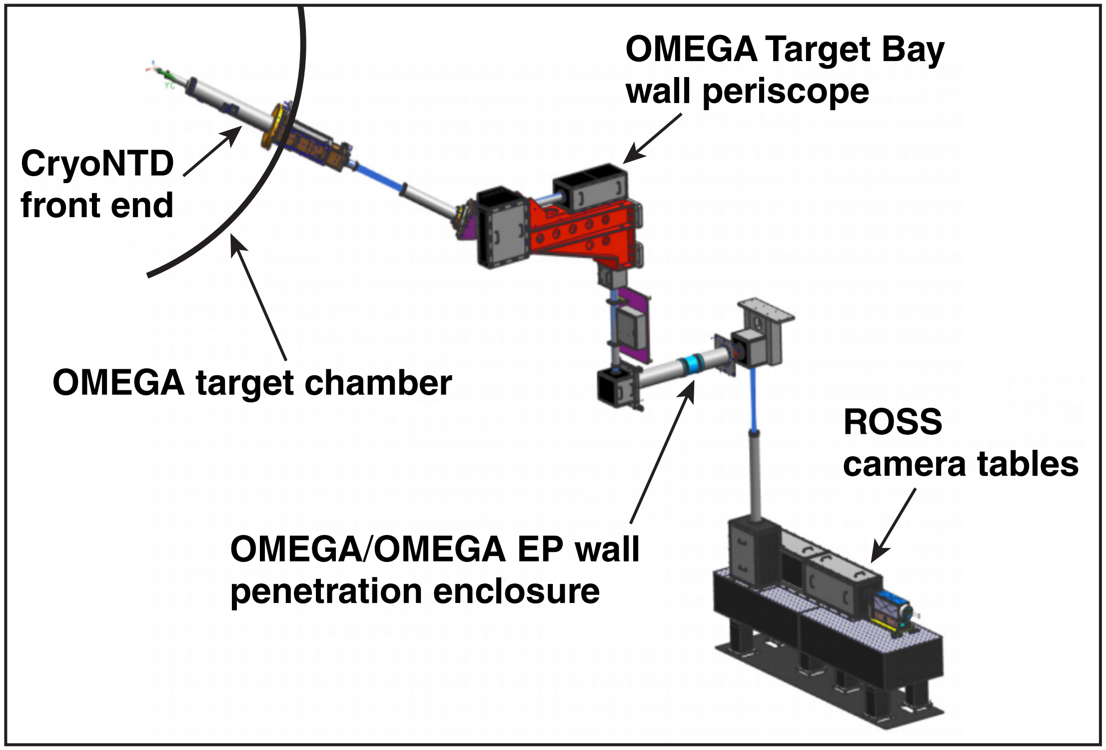
The P11-NTD delivers the instrument performance required to support the current and future LLE cryogenic campaign



Performance metric	Performance status
Minimum burnwidth	50 ps
Bang-time measurement accuracy	±50 ps
Detectable DD neutron-yield range	5×10^9 to 1×10^{13}
Detectable DT neutron-yield range	5×10^{10} to 1×10^{15}

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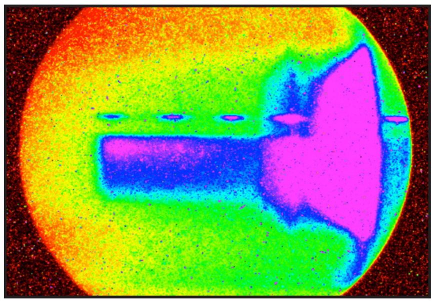
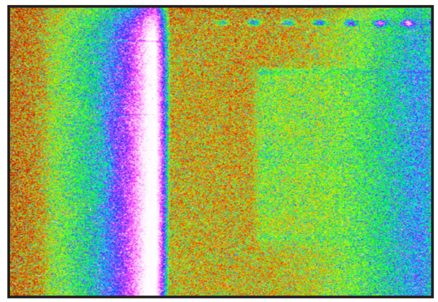
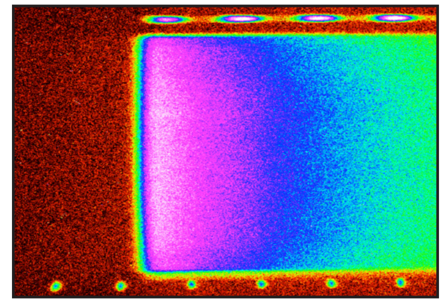
The P11-NTD provides superior data quality on high-yield implosions compared to previous NTD diagnostics

UR LLE

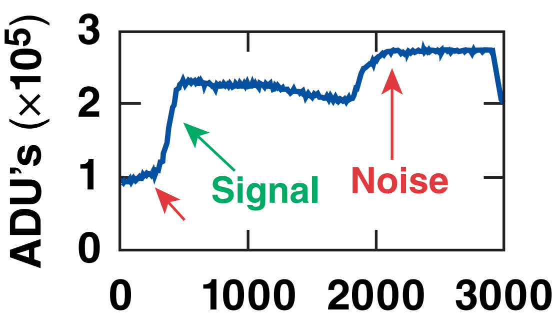
LLNL H5-NTD	LLE H5-NTD	LLE P11-NTD
Cryo shot 69515 DT yield: 2.95×10^{13}	Cryo shot 76358 DT yield: 2.61×10^{13}	Cryo shot 76358 DT yield: 2.61×10^{13}



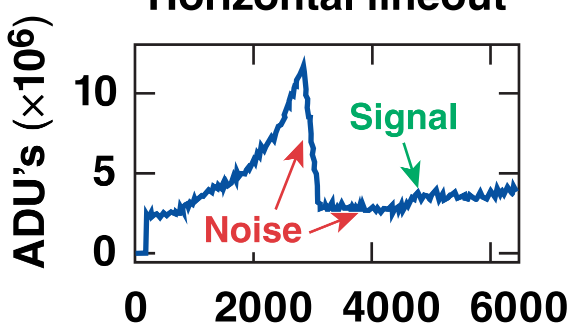




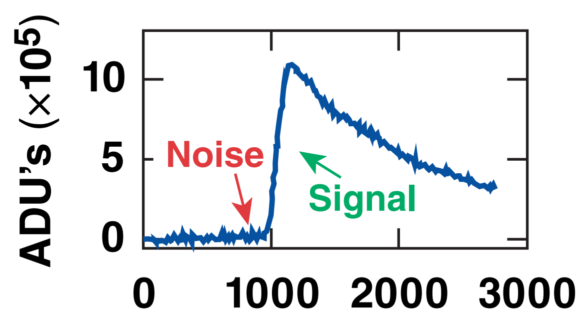
Horizontal lineout



Horizontal lineout



Horizontal lineout



Time (ps)

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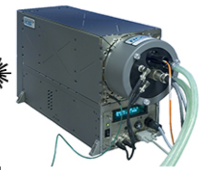
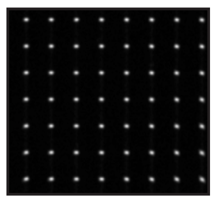
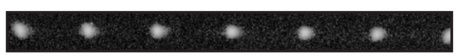
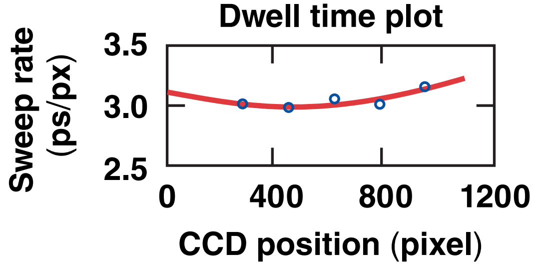
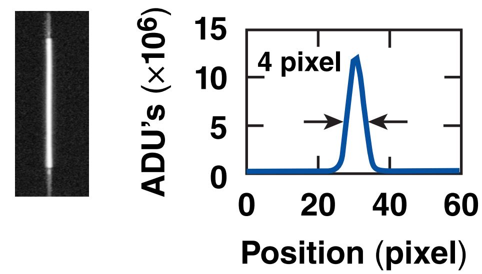
The P11-NTD leverages the power of the ROSS streak-camera platform to provide a well-characterized camera response

Rochester Optical Streak System ROSS



Sweep-time base calibration	
Streak-tube geometric distortion	Grid point array 
Ramp-driver sweep-speed profile	On-shot 2-GHz comb  

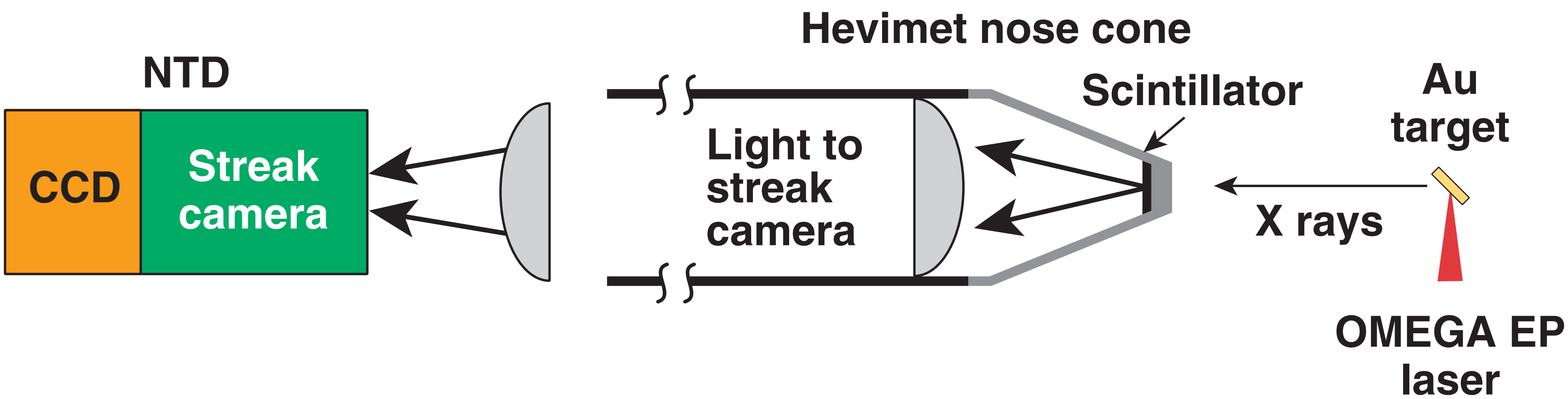
Time base corrected with 1% accuracy

Camera bandwidth characterization	
Cathode image focus time axis	Static line spread function 

Sweep speed (ns)	Temporal resolution (ps)
13	60
6	25
3 (nominal)	15
1.5	7

15-ps on-shot camera resolution

The impulse response of P11-NTD was measured using short laser pulses (10 ps) from OMEGA EP on an Au foil



- The high-intensity (>10^{17} W/cm^2) laser pulse generates hard x rays with energies >200 keV
- These x rays penetrate through the heviment shielded nose cone and generate light similar to the high-energy neutrons
- The temporal width of the x-ray pulse is of the order of the width of the laser pulse

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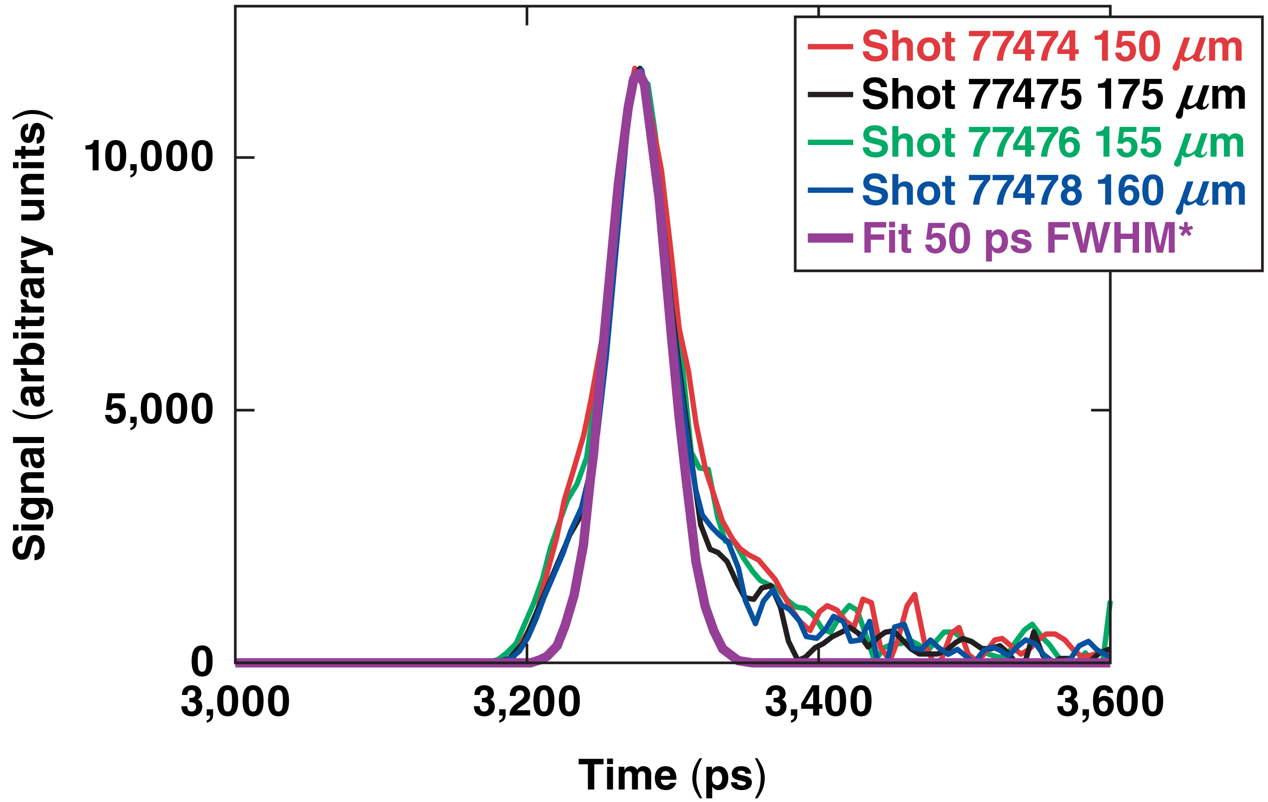
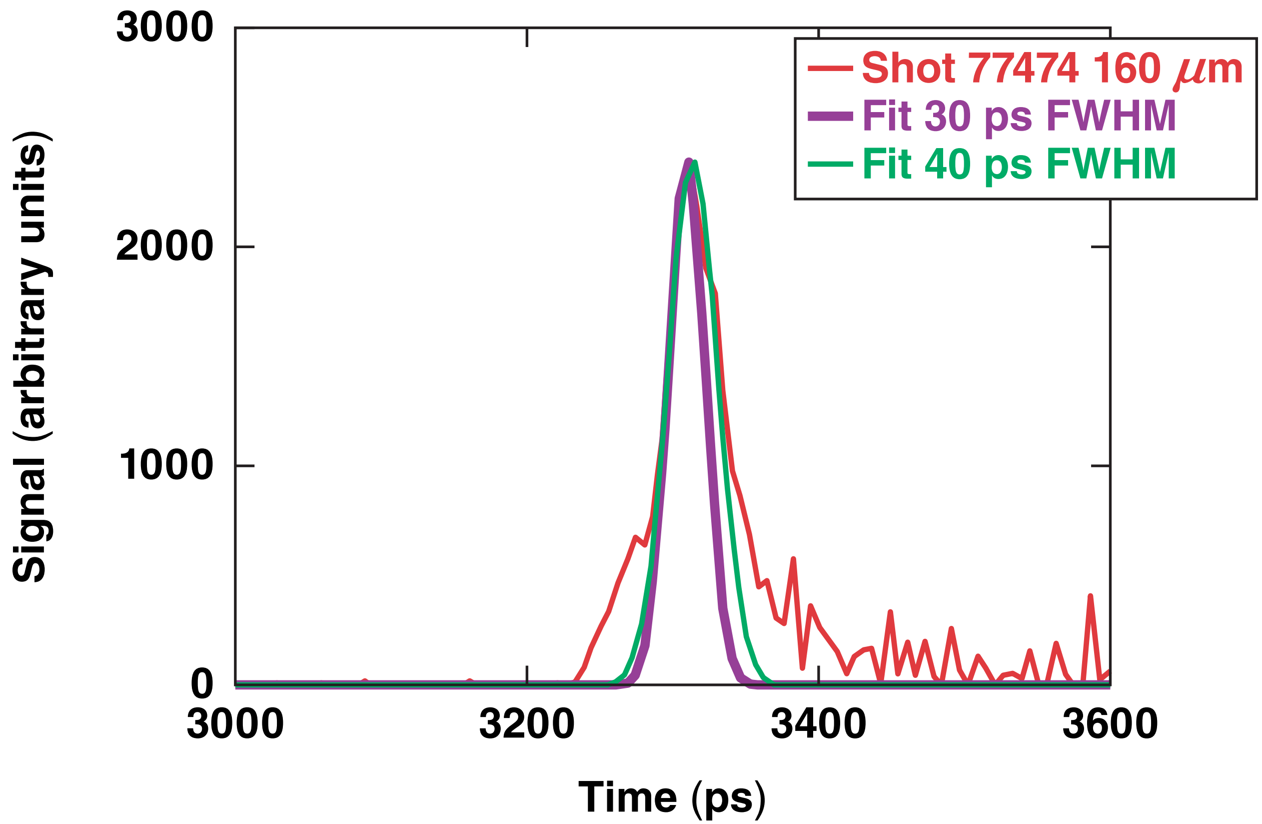
With the standard 3-ns sweep window, P11-NTD has a measured impulse response of 40±10 ps



- Using an intrinsic width of the x-ray signal, 25±10 ps, the measured width of ~50 ps deconvolves to an impulse response of 40±10 ps
- The absolute timing of P11-NTD is calibrated against NTD with an accuracy of ~50 ps

*FWHM: full width at half maximum

Preliminary measurements with a 1.5-ns sweep window show a shorter impulse response of 25±10 ps



- Using an intrinsic width of the x-ray signal, 25±10 ps, the measured width of 35±5 ps deconvolves to an impulse response of 25±10 ps

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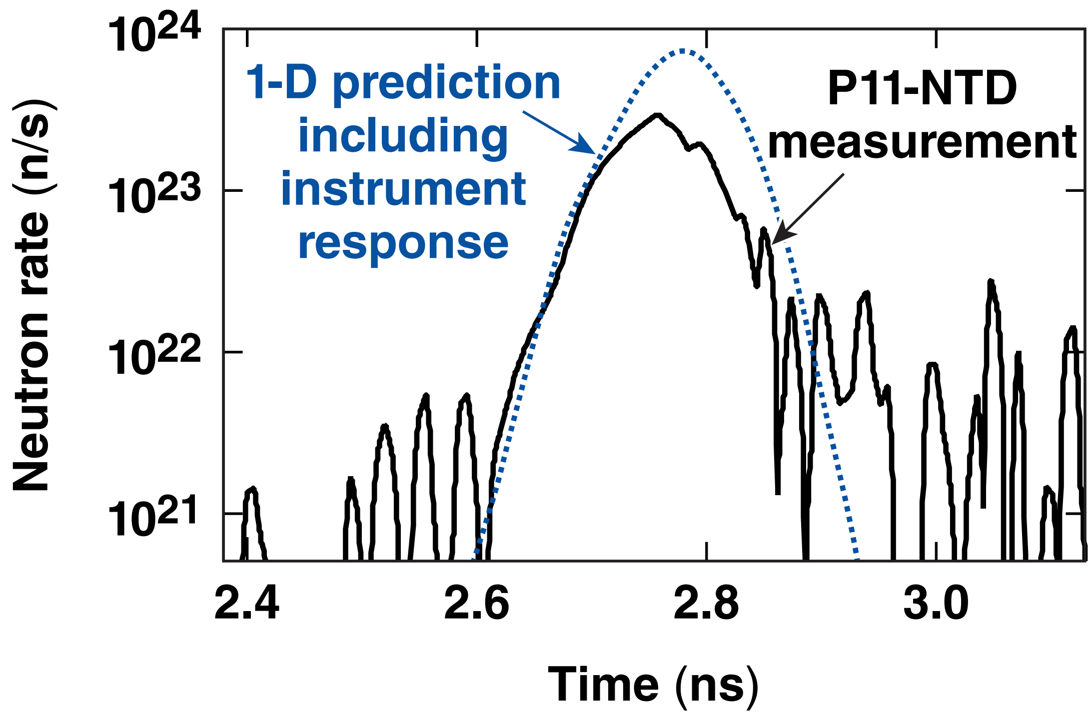
The new neutron temporal diagnostic provides an accurate measurement of the neutron production rate



- The NTD measurements show an earlier peak and burn truncation for the current cryo implosions

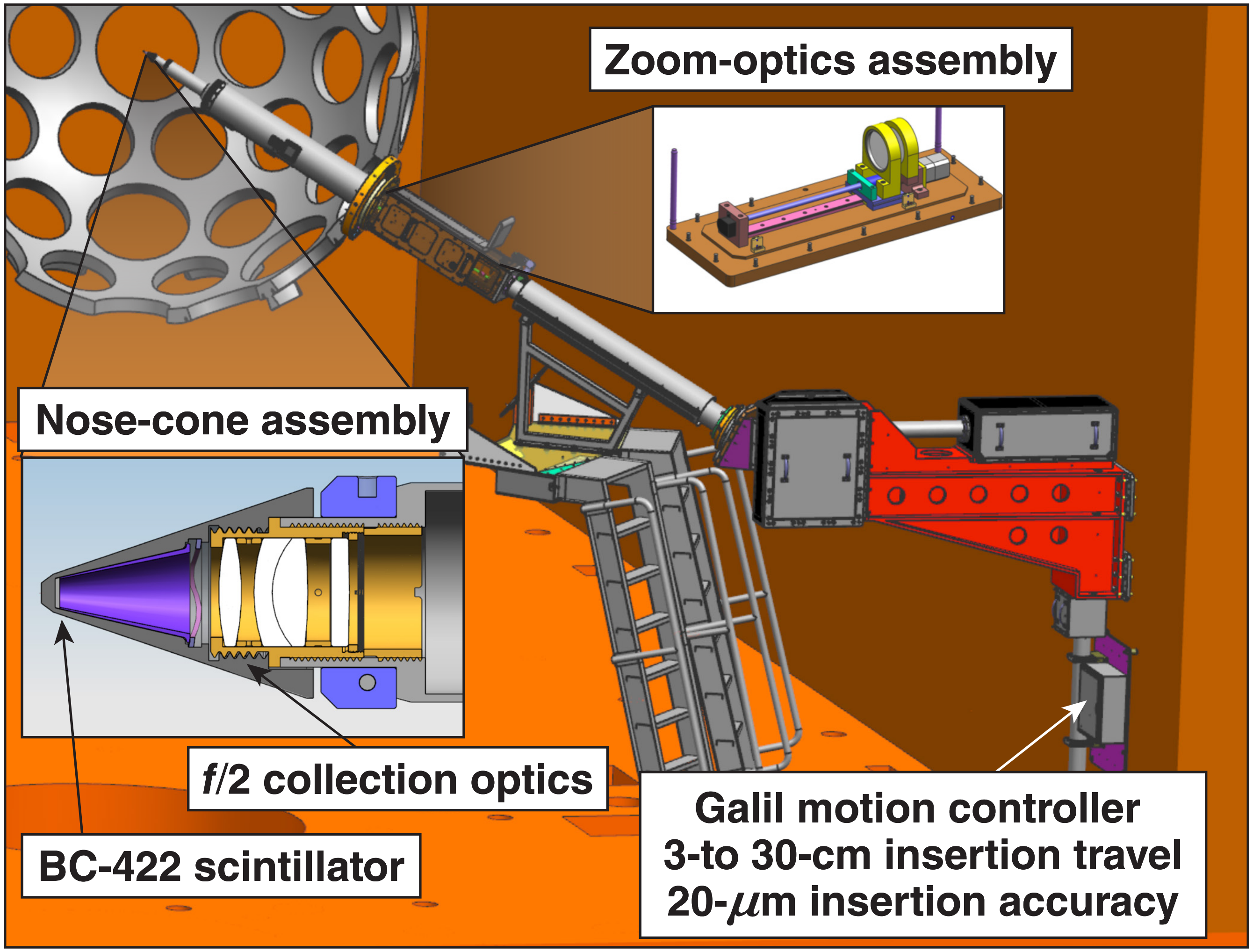
E23692d

It is conceptually quite simple to transfer the P11-NTD design for implementation on the NIF

- The ~$10^4\times$ larger yields on the NIF will require significantly more shielding
  - An additional 1 m of concrete or equivalent compared to P11-NTD is probably necessary
- An ~20-m-long optical relay system could transport the light outside the 2-m-thick bio-shield
- With a typical neutron production width of ~150 ps for sub-ignition experiments on the NIF, the time-resolution requirements would be relaxed compared to OMEGA
- The impulse response of a NIF-NTD could be calibrated *in-situ* using the NIF/ARC short-pulse capability
- A project has been established in Prof. Petrasso's group at MIT to evaluate designs for a NTD on the NIF (Brandon Lahmann, Ph.D. student)
- A NTD-like setup is being installed on LLE's short-pulse Multi-Terawatt (MTW) Laser System, which can be used to qualify new scintillator materials and calibration strategies

E24562

The OMEGA Target Bay section includes the scintillator-transport mechanism, zoom-optics assembly, and image-relay hardware



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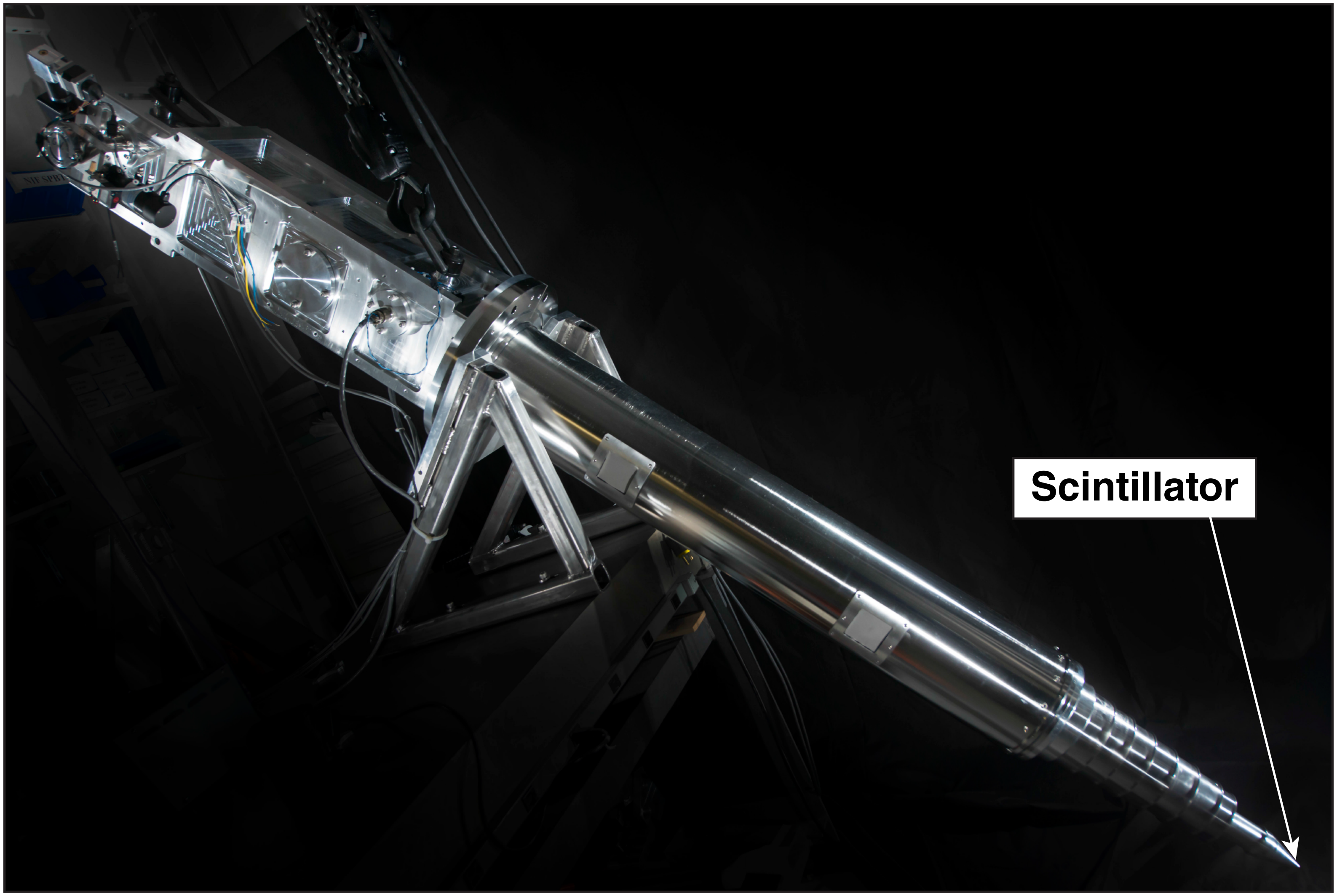
The scintillator is placed inside a telescoping mechanism re-entrant into the target chamber



E24500

The final image relay section includes focusing optics, a remote-controlled filter wheel, and the ROSS streak camera