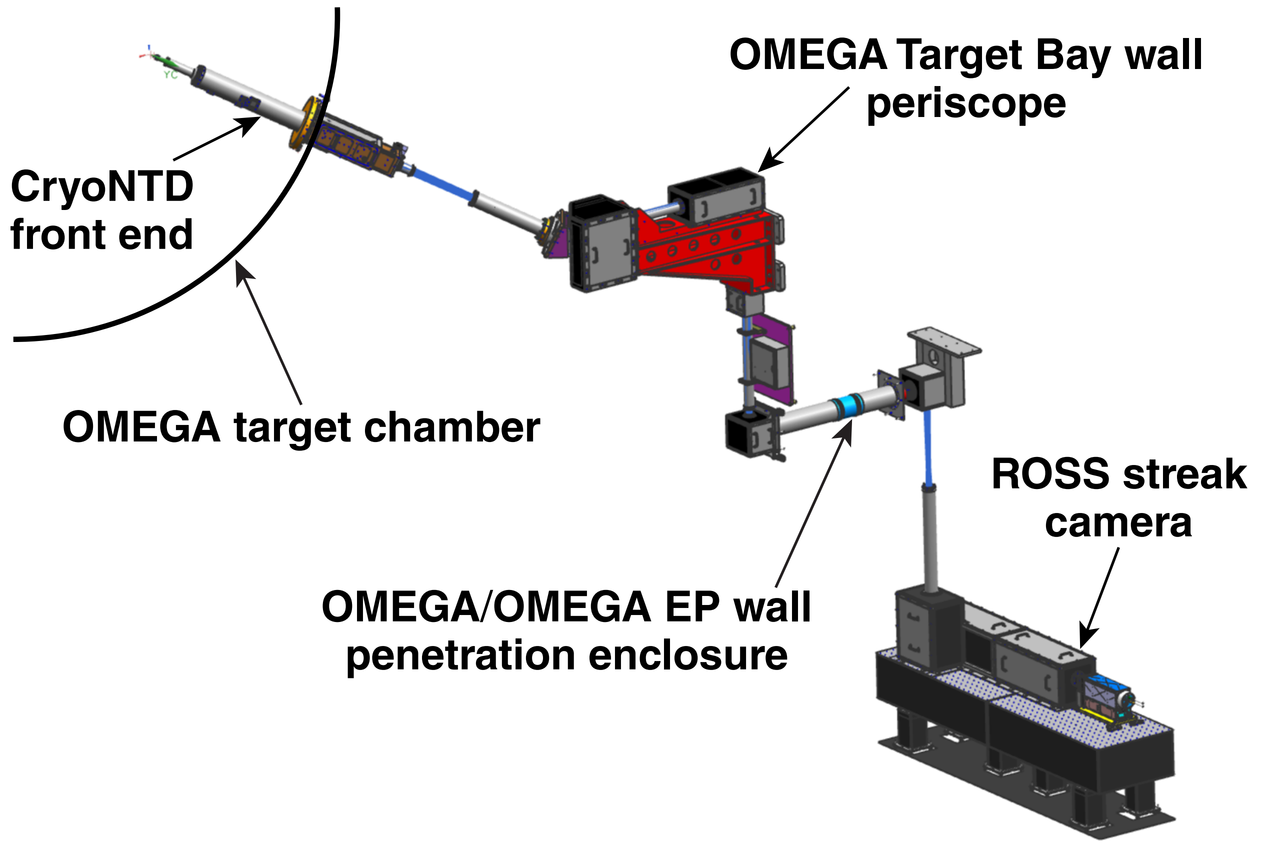
A Neutron Temporal Diagnostic for High-Performance DT Cryo Implosions on OMEGA



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Los Alamos National Laboratory
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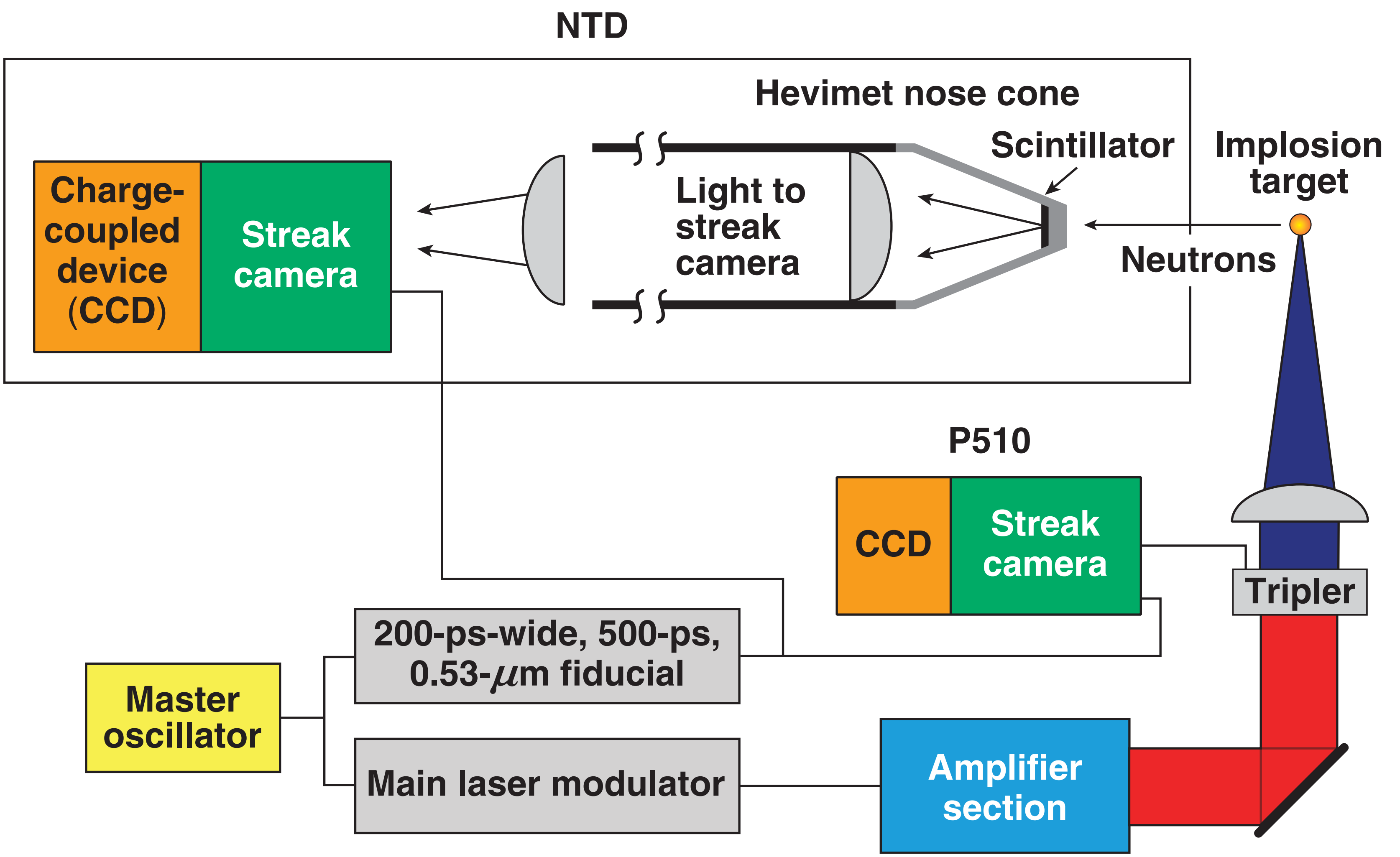
Summary

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× 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±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±10 ps, which allows a 50-ps neutron pulse to be measured with 10% accuracy

E24496

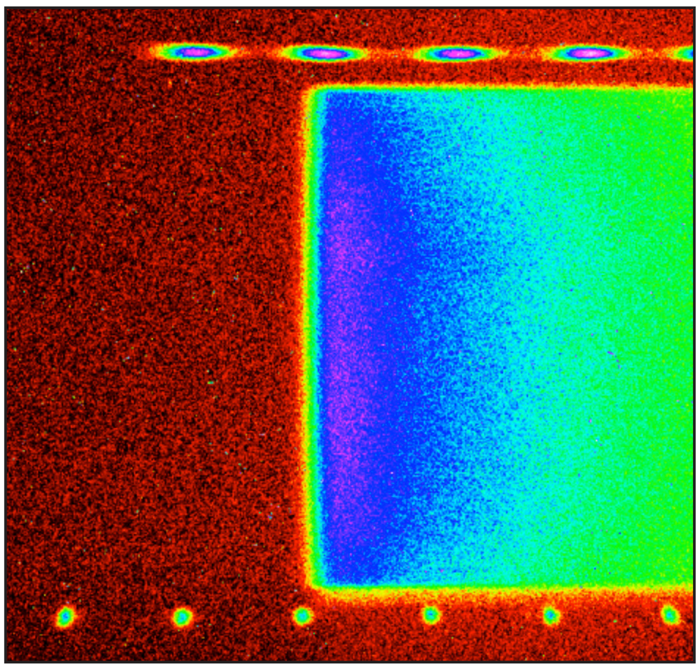
The NTD measures the neutron production rate and bang time



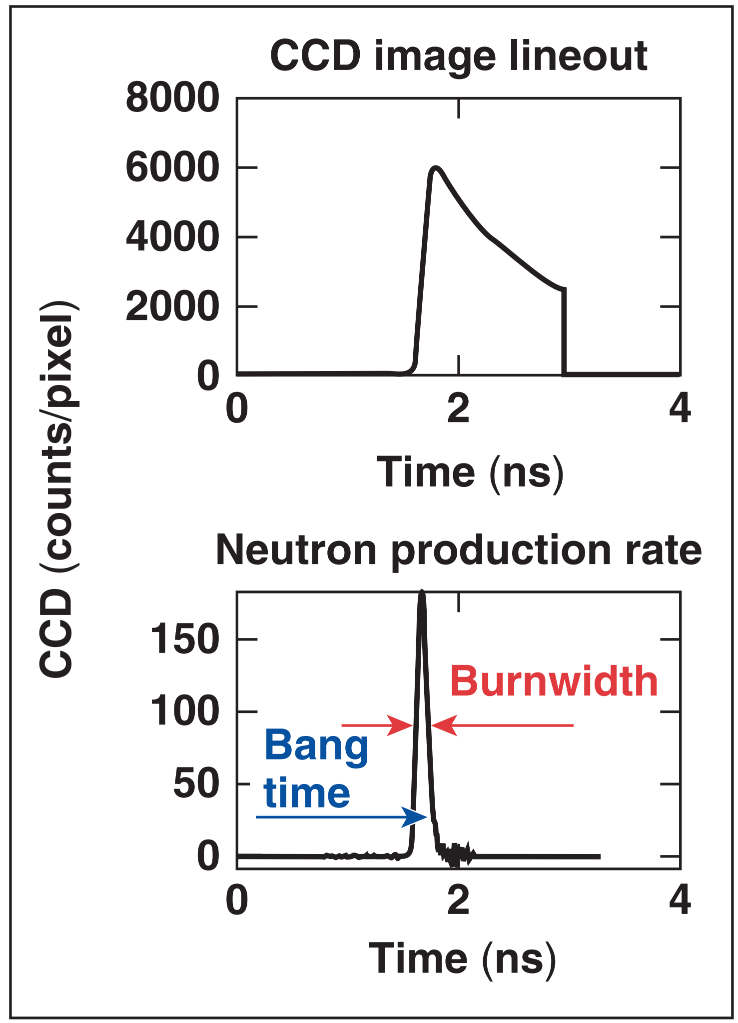
E23900a

The neutron production rate is inferred from the unfolded scintillator signal

CCD image

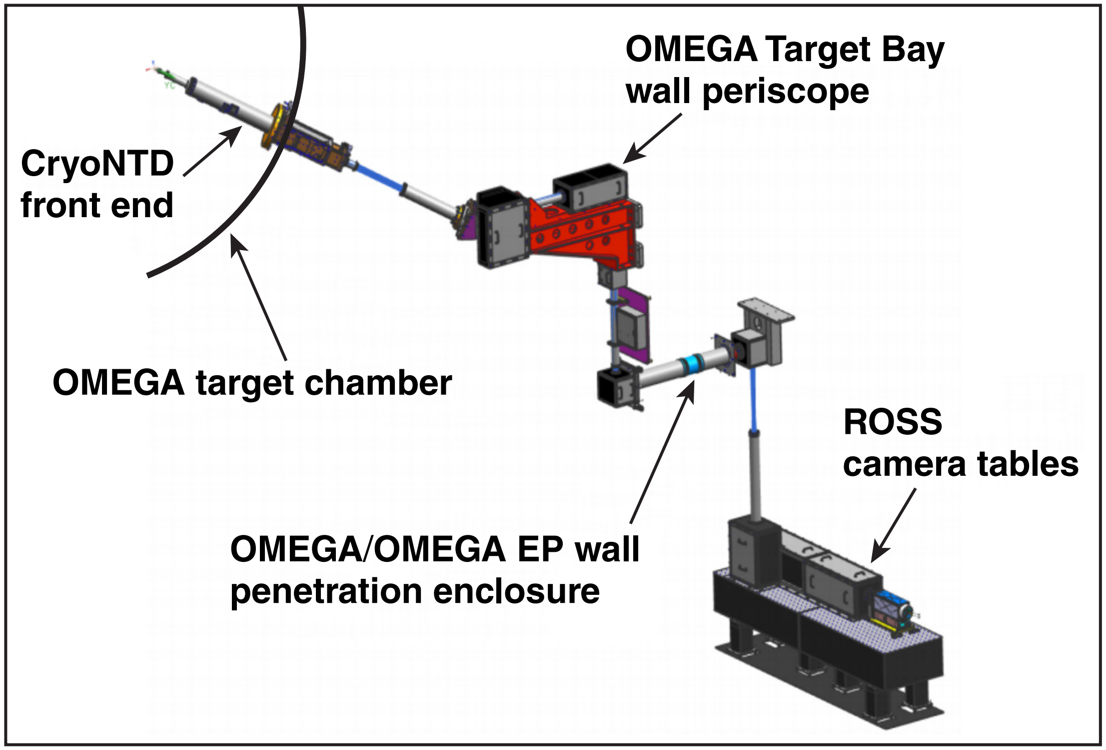


Data reduction



E23900b

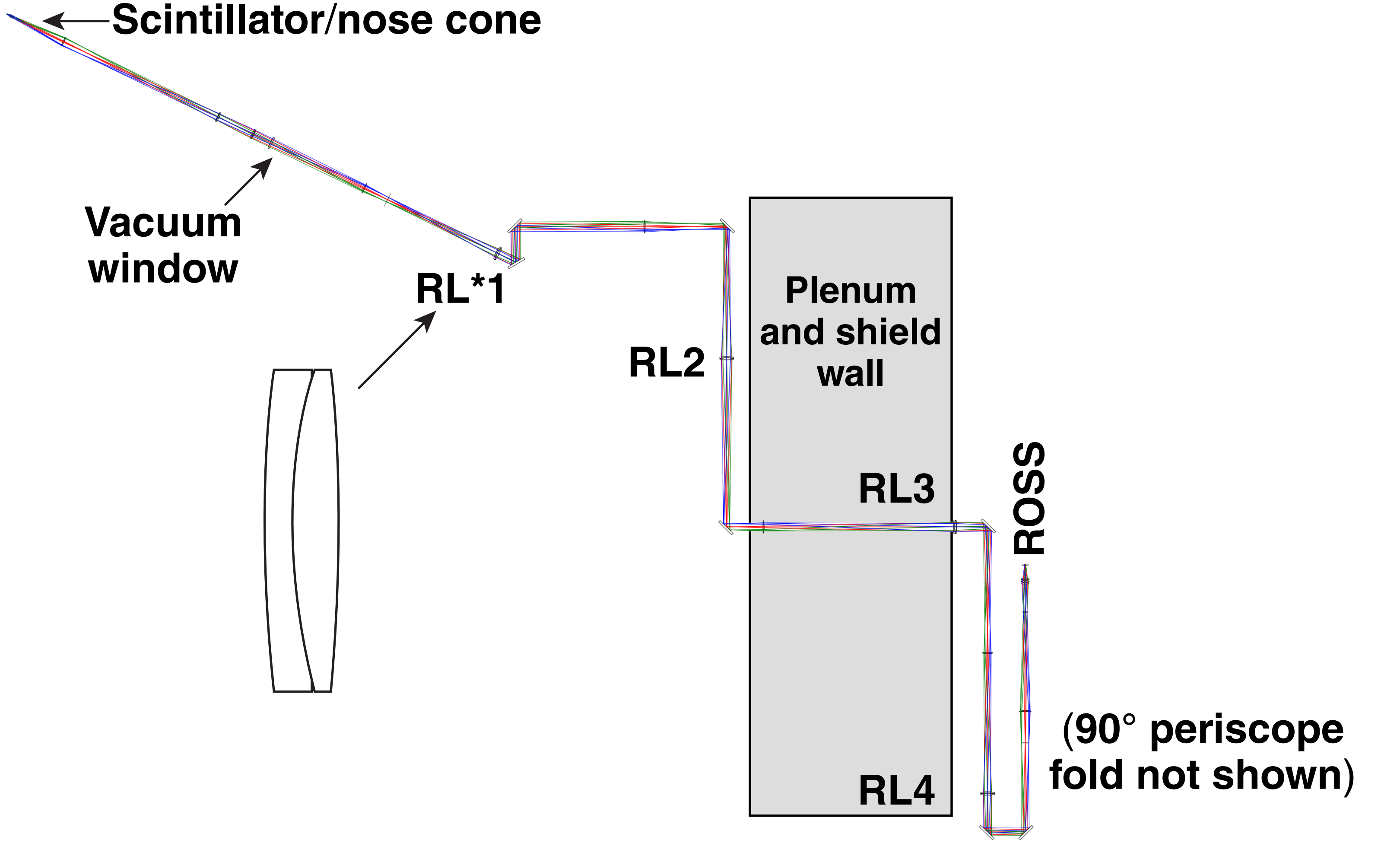
The P11-NTD delivers the instrument performance required to support the current and future LLE cryogenic campaign



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}

E23902a

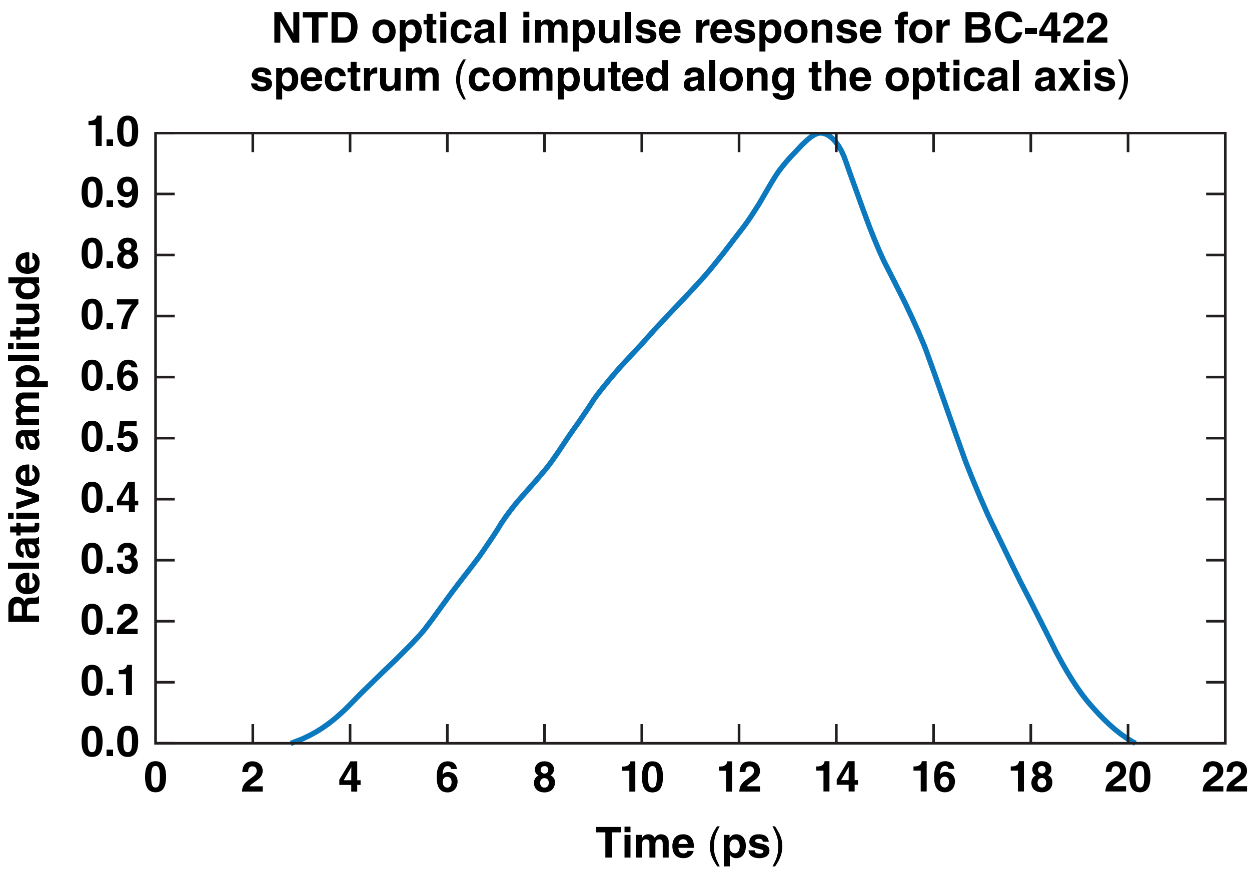
Cryo-NTD beam transport uses seven mirrors and four relay stages to cover 16.2 m from the scintillator to the ROSS



E24498

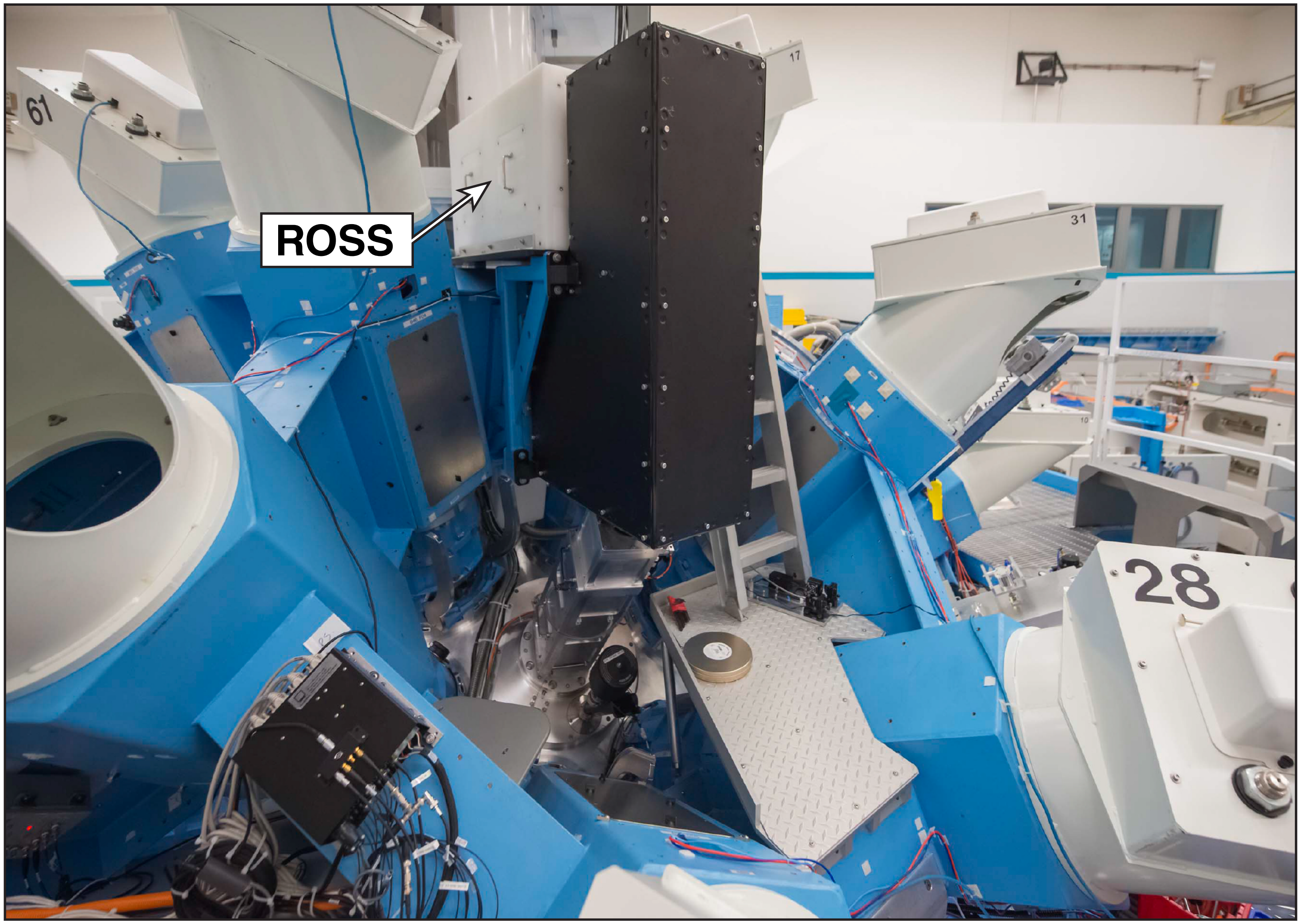
*RL: relay lens

Group velocity dispersion is less than 20 ps over a 340- to 500-nm bandwidth



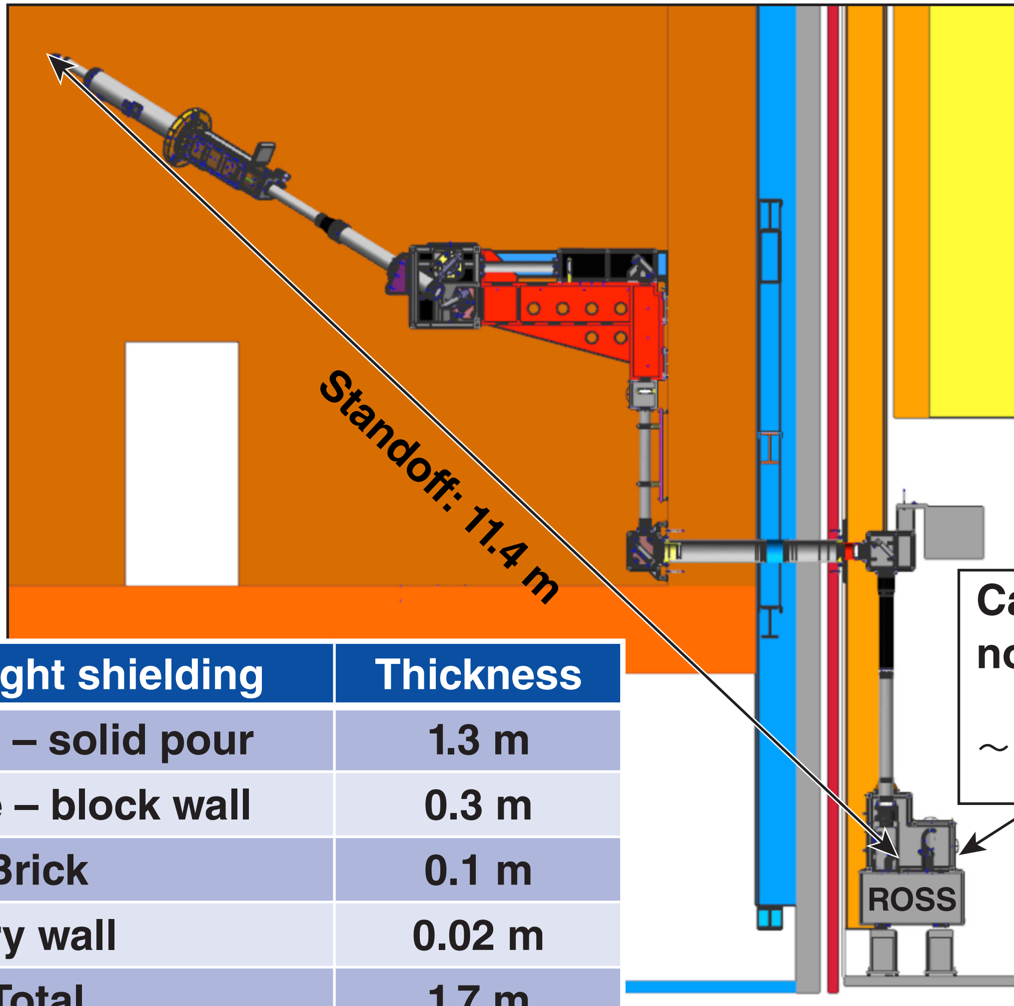
E24499

The ROSS streak camera of the H5 NTD is placed close to the target chamber in a 10-cm-thick CH shield



E24497

Neutron noise was minimized by placing the streak camera ~11 m from the target with ~170 cm of shielding



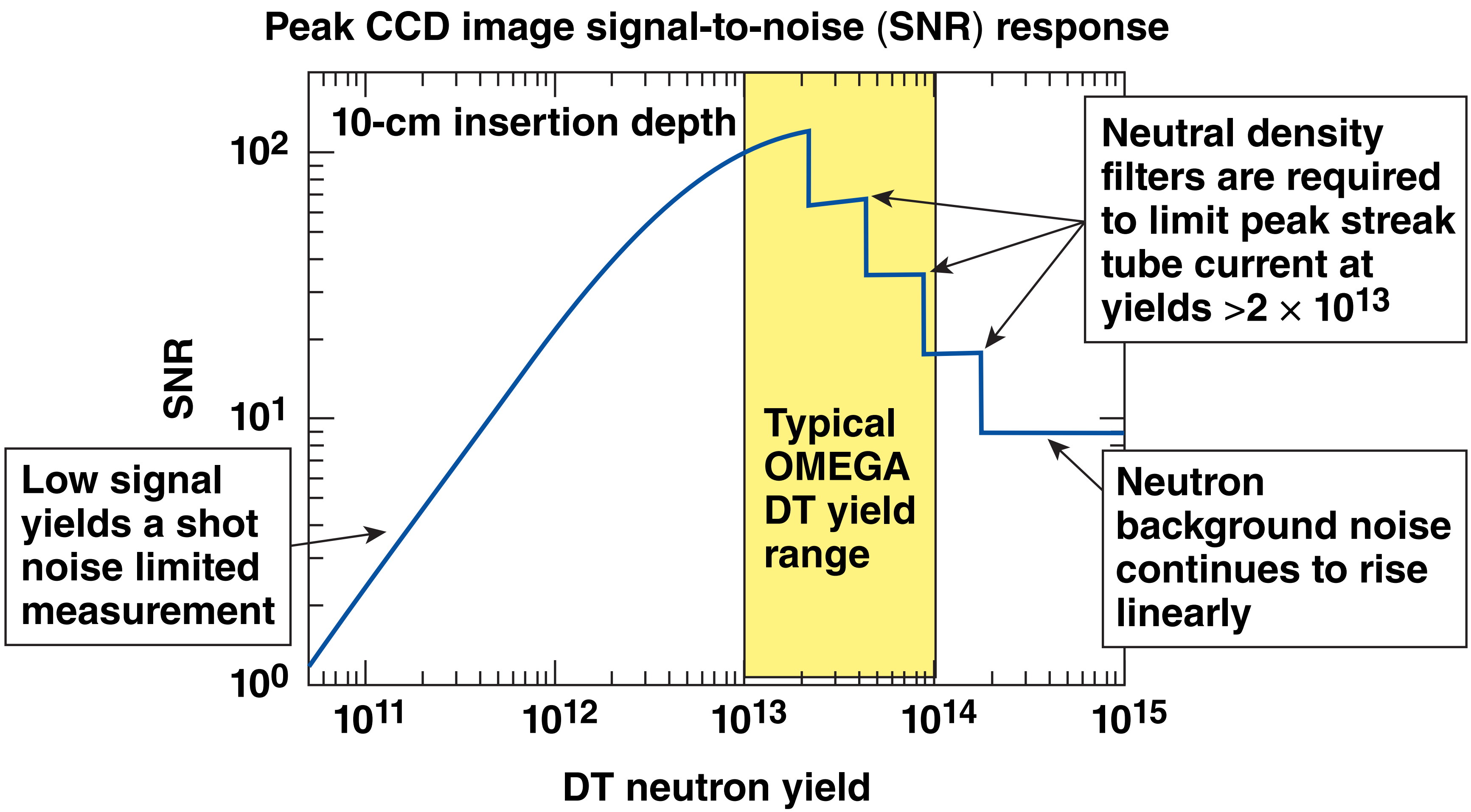
Line-of-sight shielding	Thickness
Concrete – solid pour	1.3 m
Concrete – block wall	0.3 m
Brick	0.1 m
Dry wall	0.02 m
Total	1.7 m

Camera DT neutron noise sensitivity:

$$\sim 1 \times 10^{-12} \frac{\text{ADU}}{n_{\text{DT}} \times \text{pixel}}$$

E23905a

The P11-NTD maintains excellent CCD image signal-to-noise ratios throughout the typical OMEGA DT neutron yield range



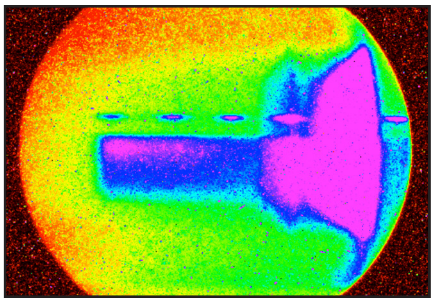
E23919

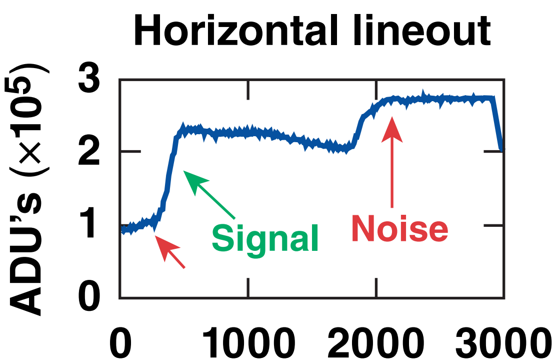
The P11-NTD provides superior data quality on high-yield implosions compared to previous NTD diagnostics

UR LLE

LLNL H5-NTD

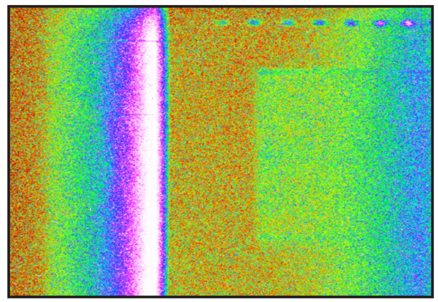
Cryo shot 69515
DT yield: 2.95 × 10^{13}

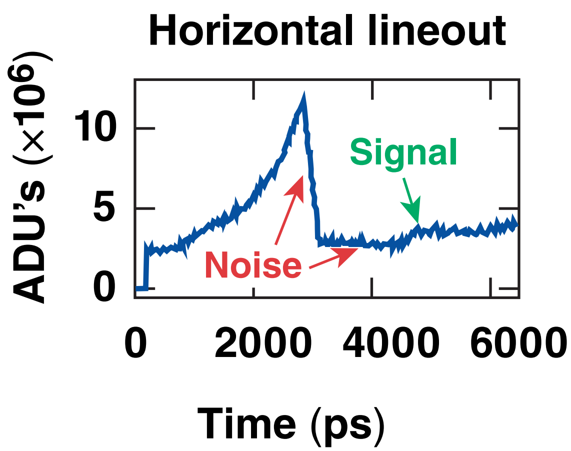




LLE H5-NTD

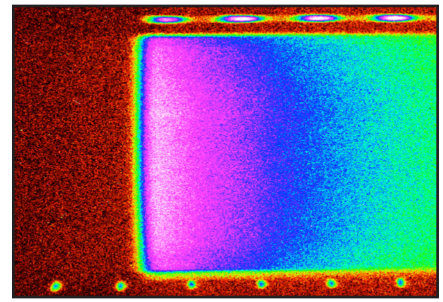
Cryo shot 76358
DT yield: 2.61 × 10^{13}

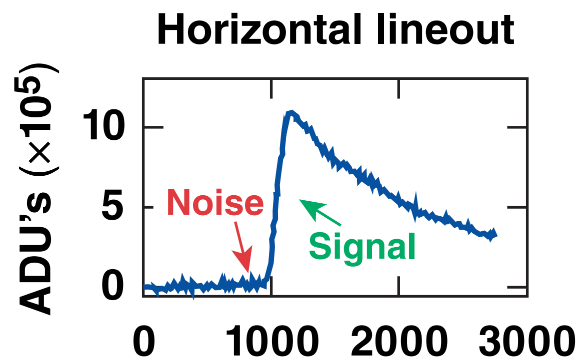




LLE P11-NTD

Cryo shot 76358
DT yield: 2.61 × 10^{13}

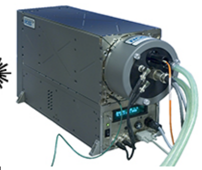




The P11-NTD leverages the power of the ROSS streak-camera platform to provide a well-characterized camera response

UR LLE

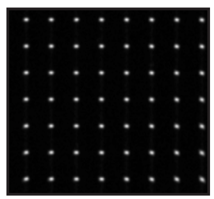
Rochester Optical Streak System ROSS



Sweep-time base calibration

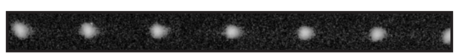
Streak-tube geometric distortion

Grid point array

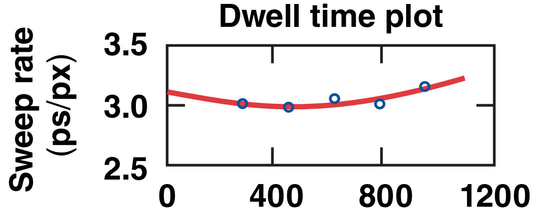


Ramp-driver sweep-speed profile

On-shot 2-GHz comb



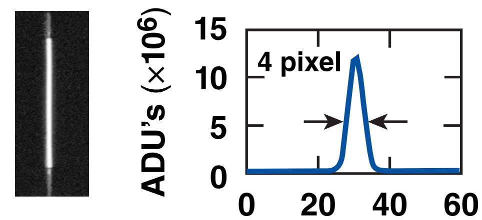
Dwell time plot



Camera bandwidth characterization

Cathode image focus time axis

Static line spread function



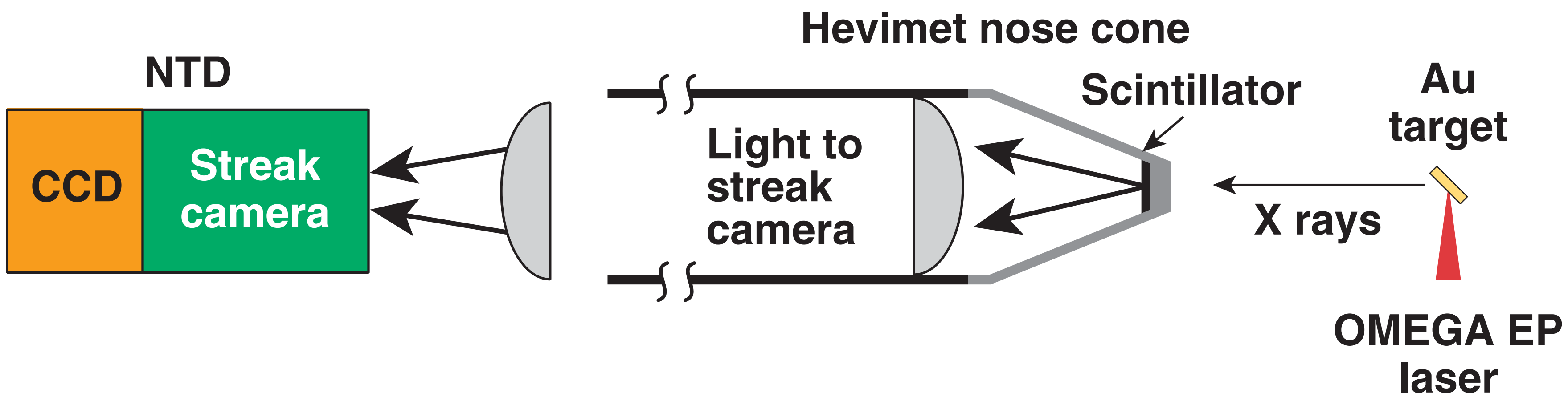
Sweep speed (ns)	Temporal resolution (ps)
13	60
6	25
3 (nominal)	15
1.5	7

Time base corrected with 1% accuracy

15-ps on-shot camera resolution

E23907

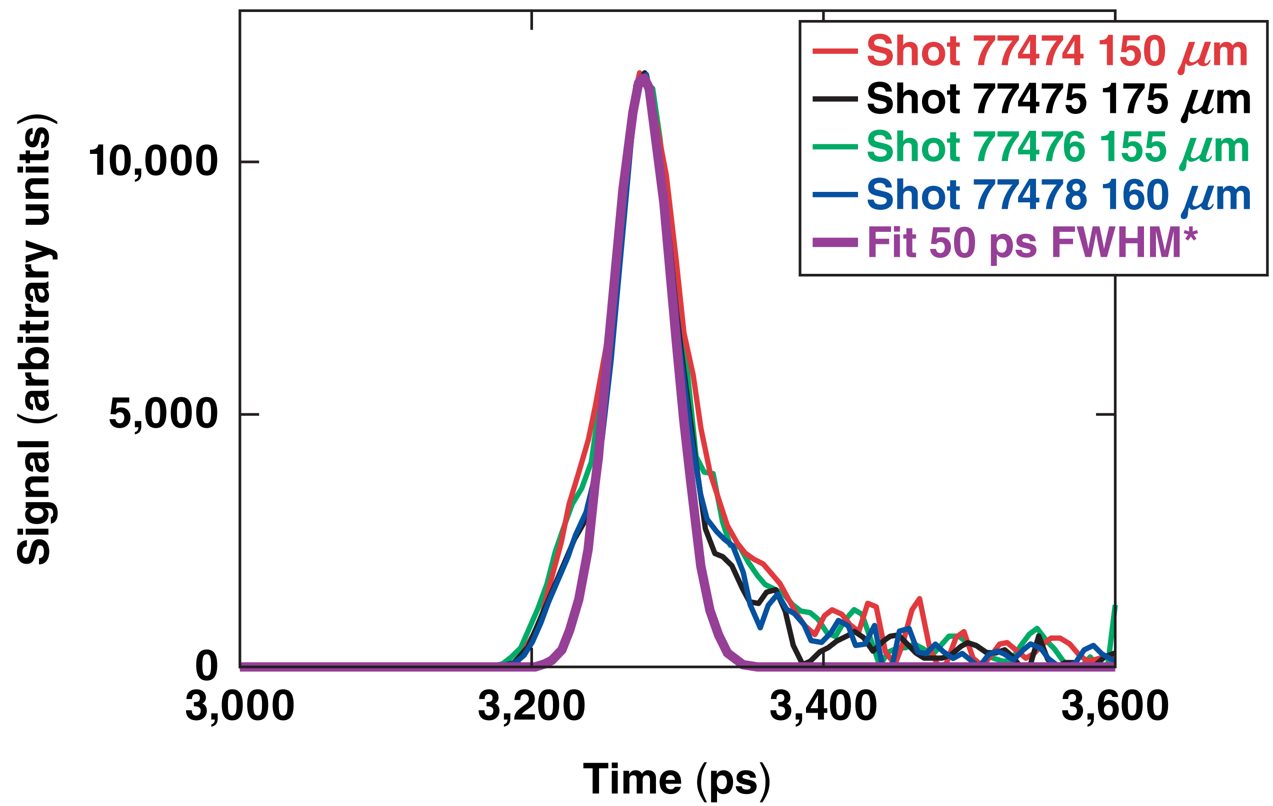
The impulse response of P11-NTD was measured using short laser pulses (10 ps) from OMEGA EP on an Au foil



- 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

E9262a

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

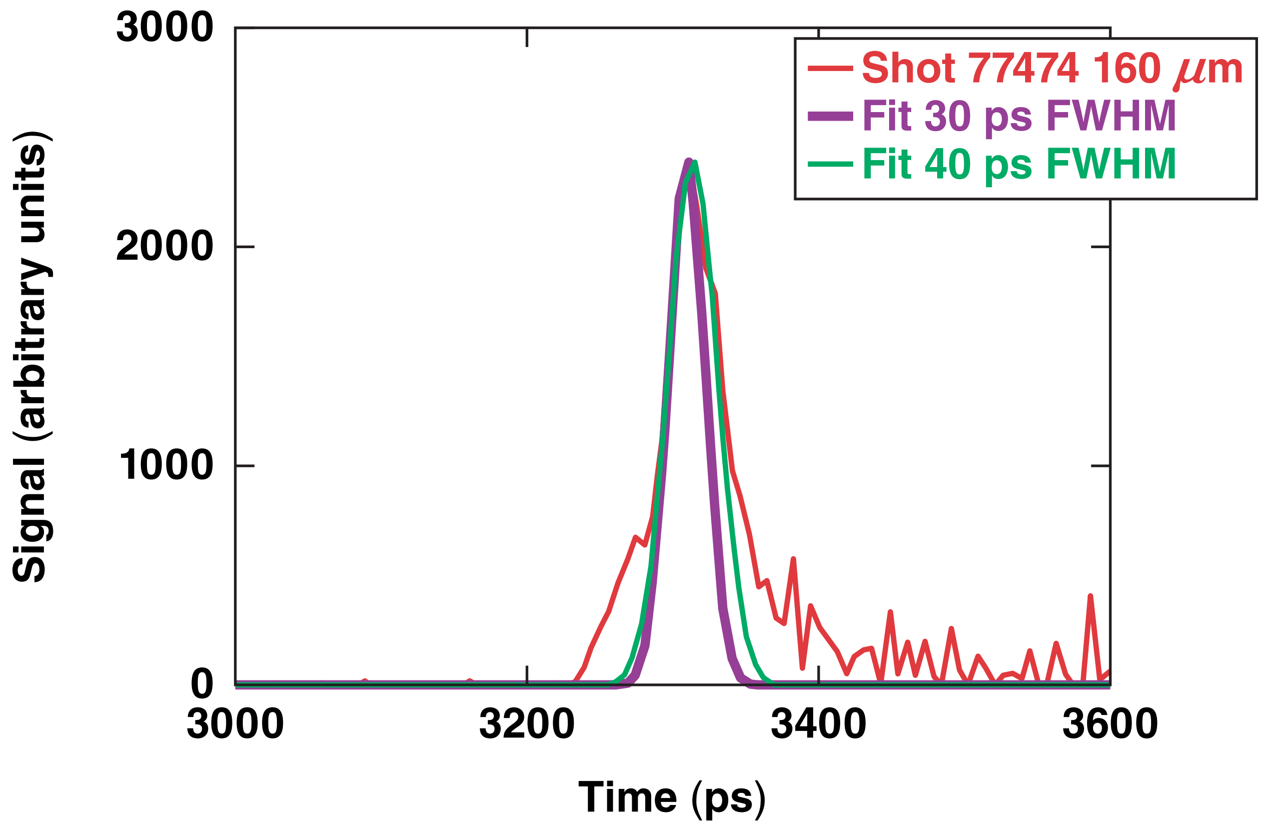


- Using an intrinsic width of the x-ray signal, 25±10 ps, the measured width of ~50 ps deconvolves to an impulse response of 40±10 ps
- The absolute timing of P11-NTD is calibrated against NTD with an accuracy of ~50 ps

*FWHM: full width at half maximum

E24385

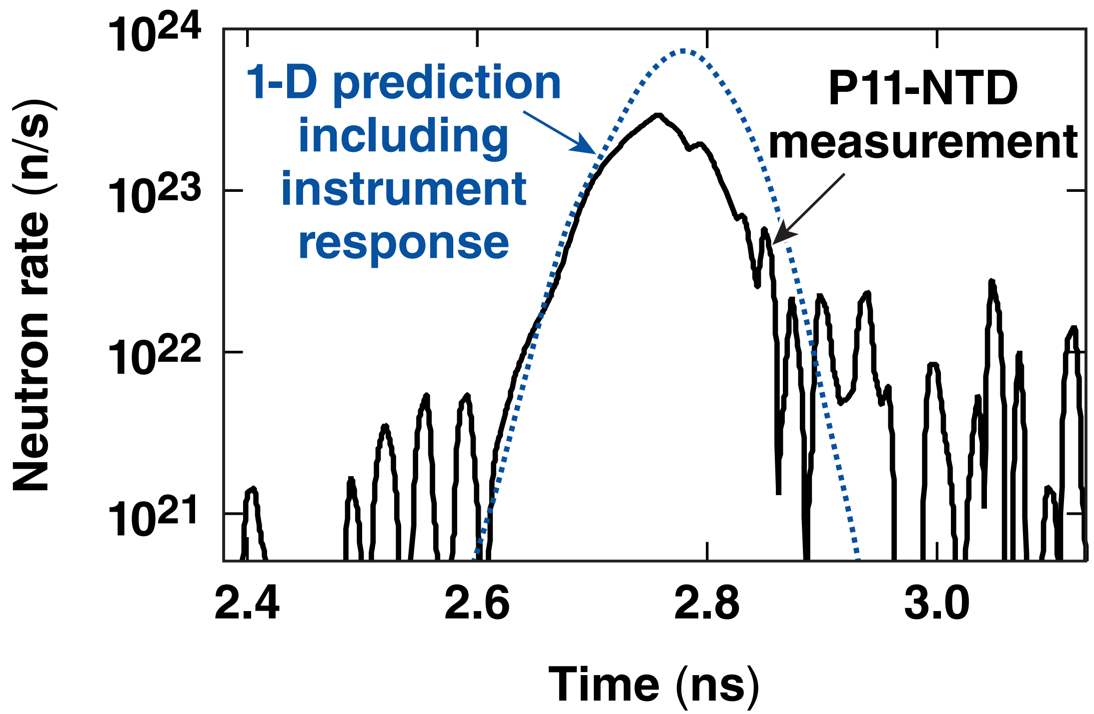
Preliminary measurements with a 1.5-ns sweep window show a shorter impulse response of 25±10 ps



- 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

E24386

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



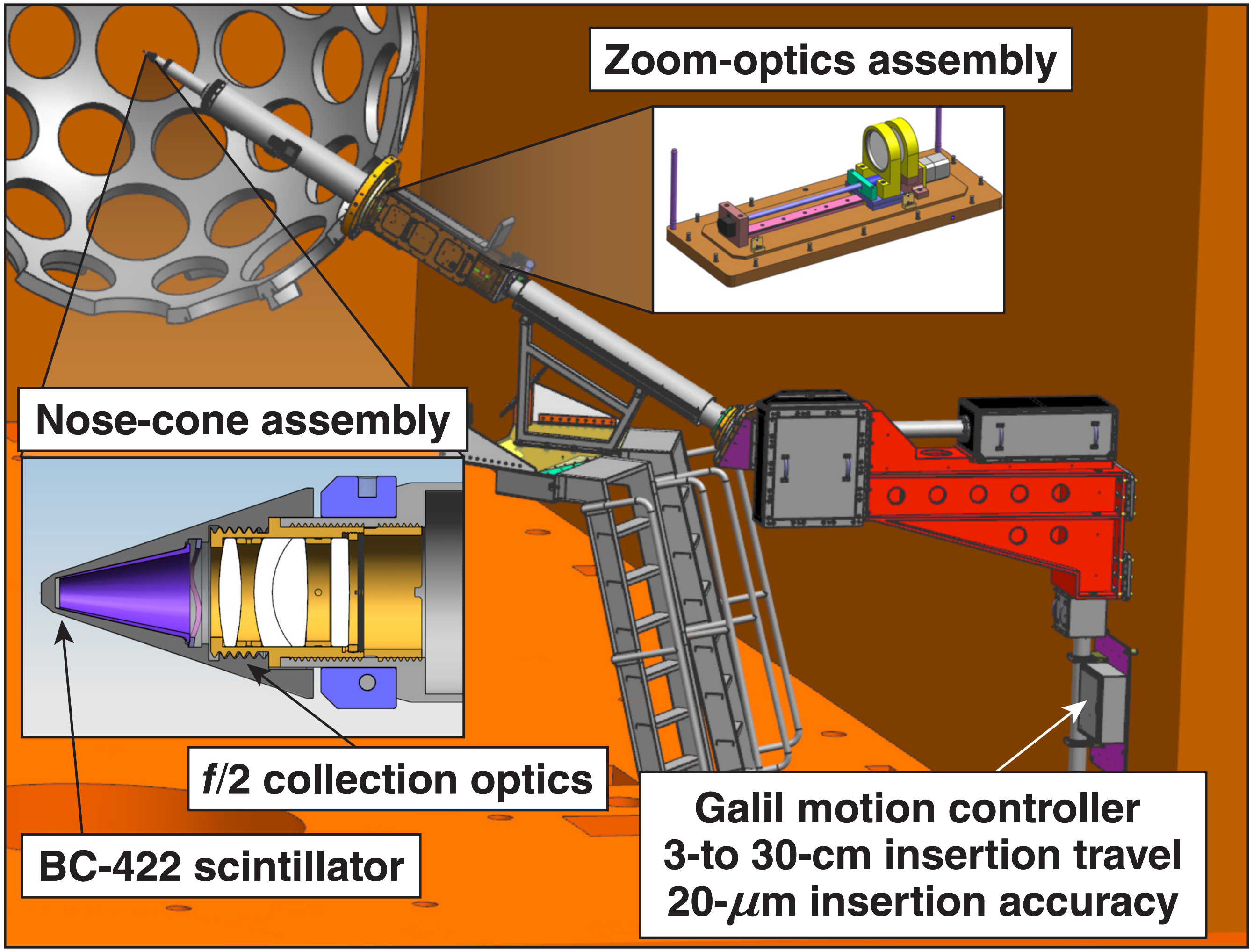
- The NTD measurements show an earlier peak and burn truncation for the current cryo implosions

E23692d

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

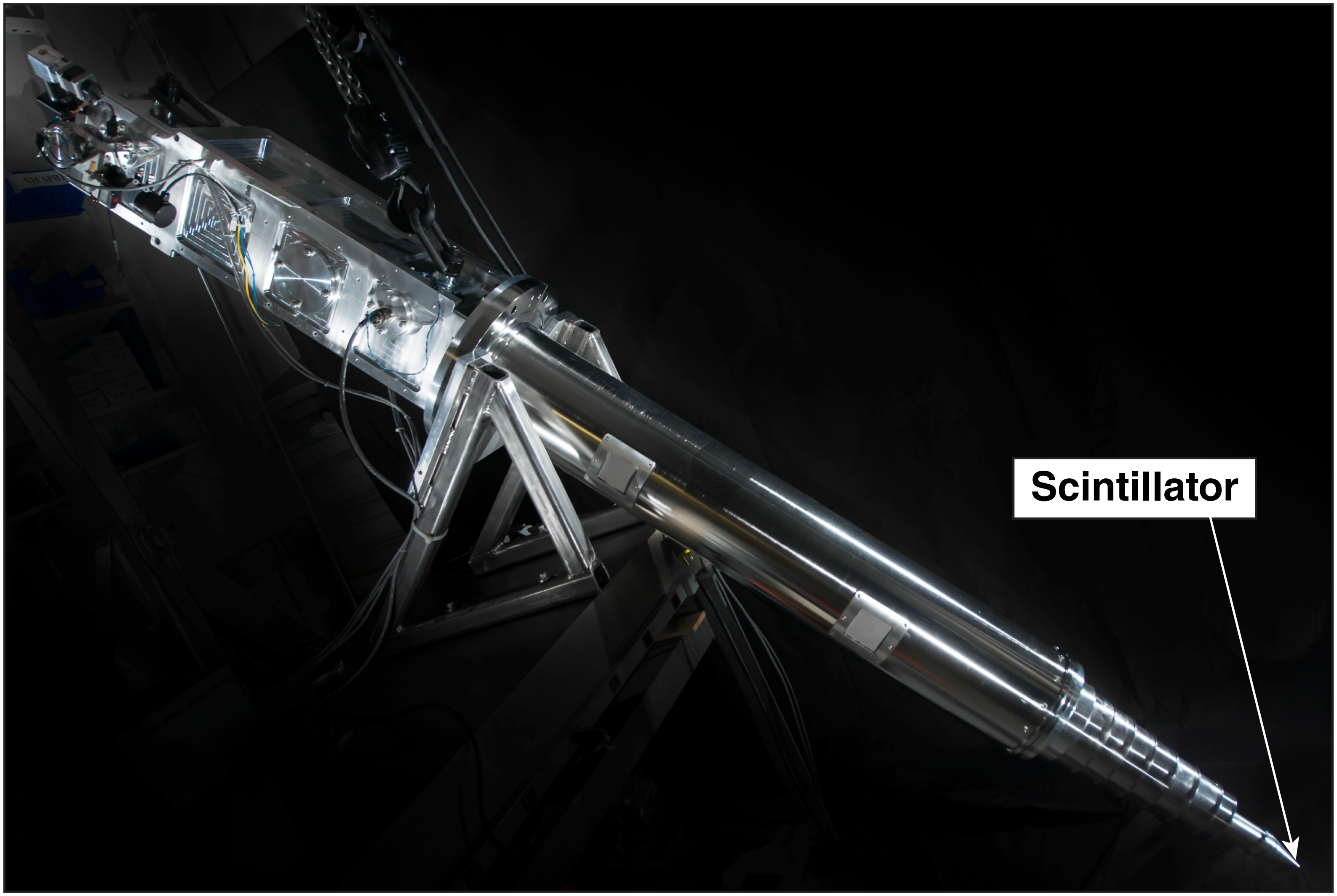
- The ~$10^4\times$ larger yields on the NIF will require significantly more shielding
  - An additional 1 m of concrete or equivalent compared to P11-NTD is probably necessary
- An ~20-m-long optical relay system could transport the light outside the 2-m-thick bio-shield
- With a typical neutron production 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

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



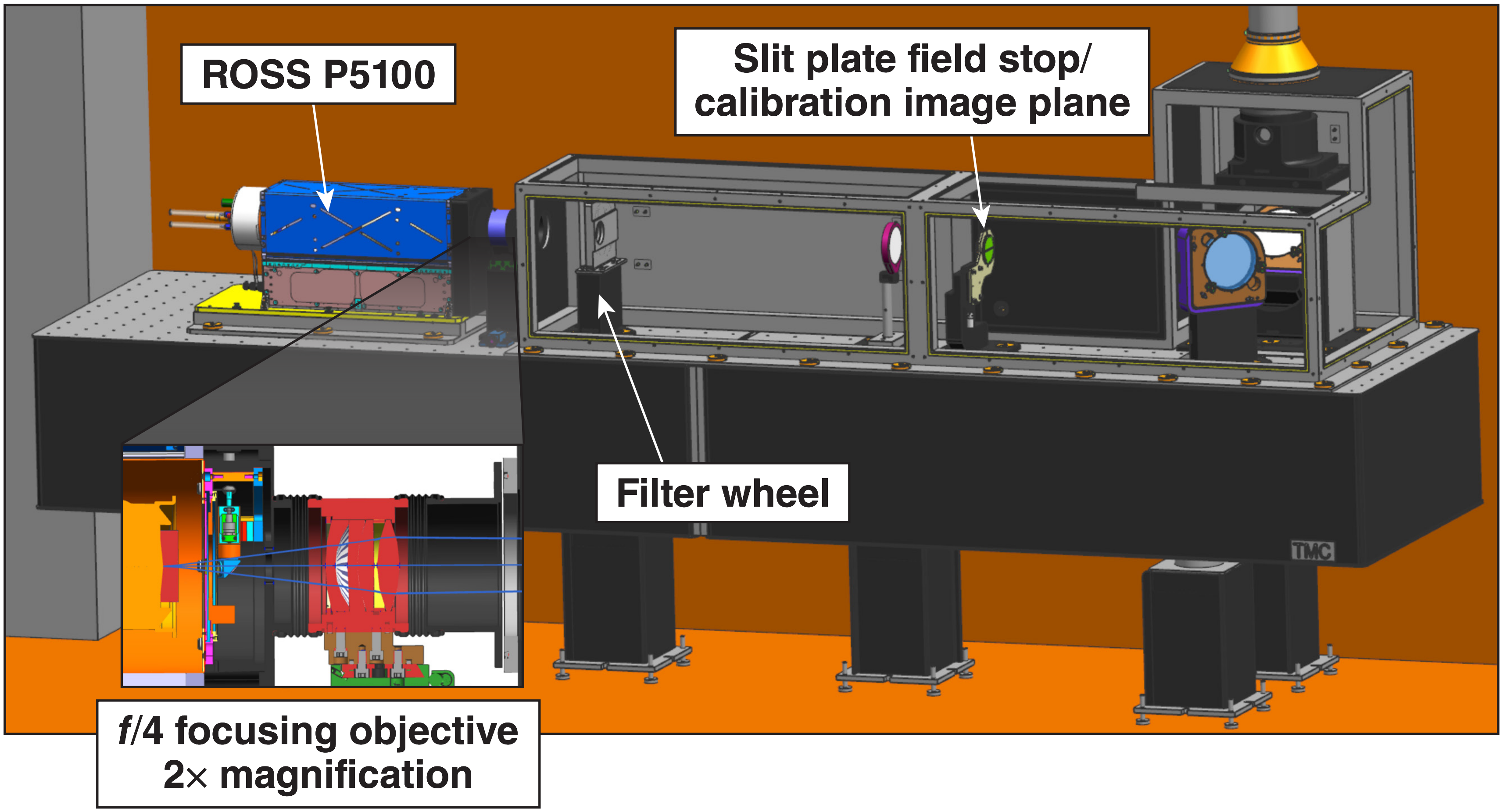
E23903

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



E23904