Neutron-Induced Background in CCD Detectors

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We report on measurements of the neutron-induced background levels in the CCD detectors that are replacing film as the recording medium in many ICF diagnostics. This background degrades the SNR of the recorded signals and, for the highest yield shots, comprises a substantial fraction of the pixel's full well capacity. We discuss the spectrum of the deposited energy per pixel, its time history, and the efficacy of shielding. On OMEGA we have had to move our most-sensitive streak camera diagnostics over 16 m from the target chamber's center, behind a 2-m (line of sight)-thick concrete shield wall, to make meaningful measurements at 1.0×10^{13} DT neutron yields. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority.

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Abstract

We report on measurements of the neutron-induced background levels in the CCD detectors that are replacing film as the recording medium in many ICF diagnostics. This background degrades the SNR of the recorded signals and for the highest-yield shots comprises a substantial fraction of the pixel's full well capacity.* We discuss the spectrum of the deposited energy per pixel, its time history and the efficacy of shielding. On OMEGA we have had to move our most-sensitive streak camera diagnostics over 16 m from the target chamber center, behind a 2-m (line of sight)-thick concrete shield wall, to make meaningful measurements at 1.0×10^{13} DT neutron yields.

*R. A. Lerche, Rev. Sci. Instrum. 68, 628 (1997).

Data recorded with CCD-based diagnostics is compromised by the neutron-induced background

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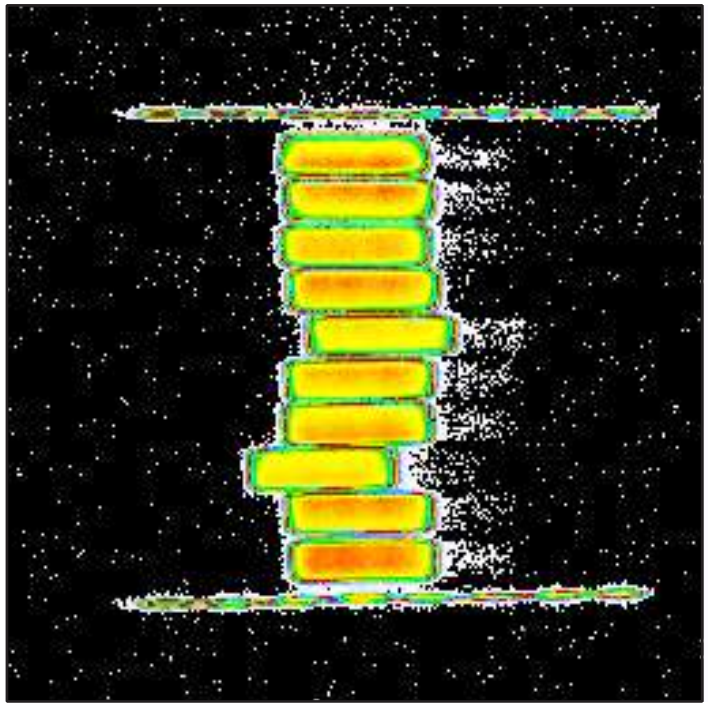
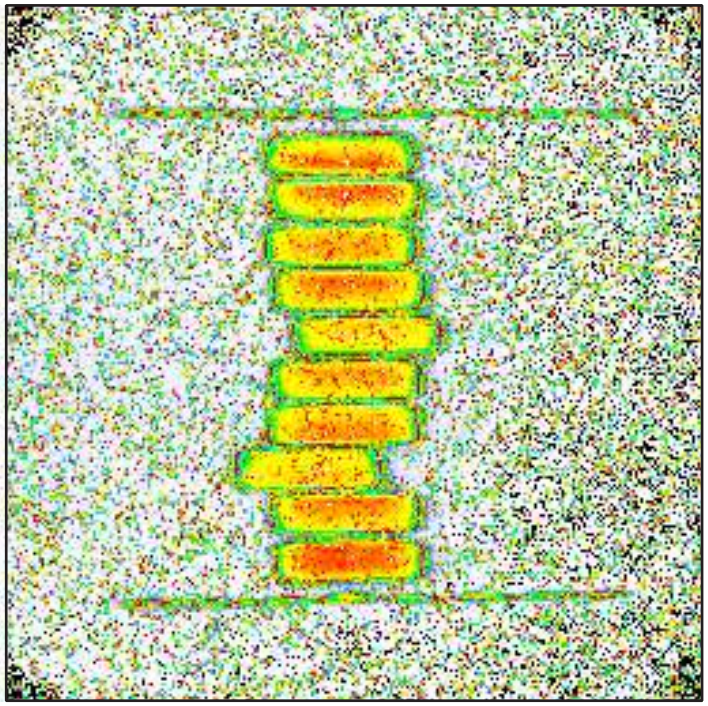
Shot 17627



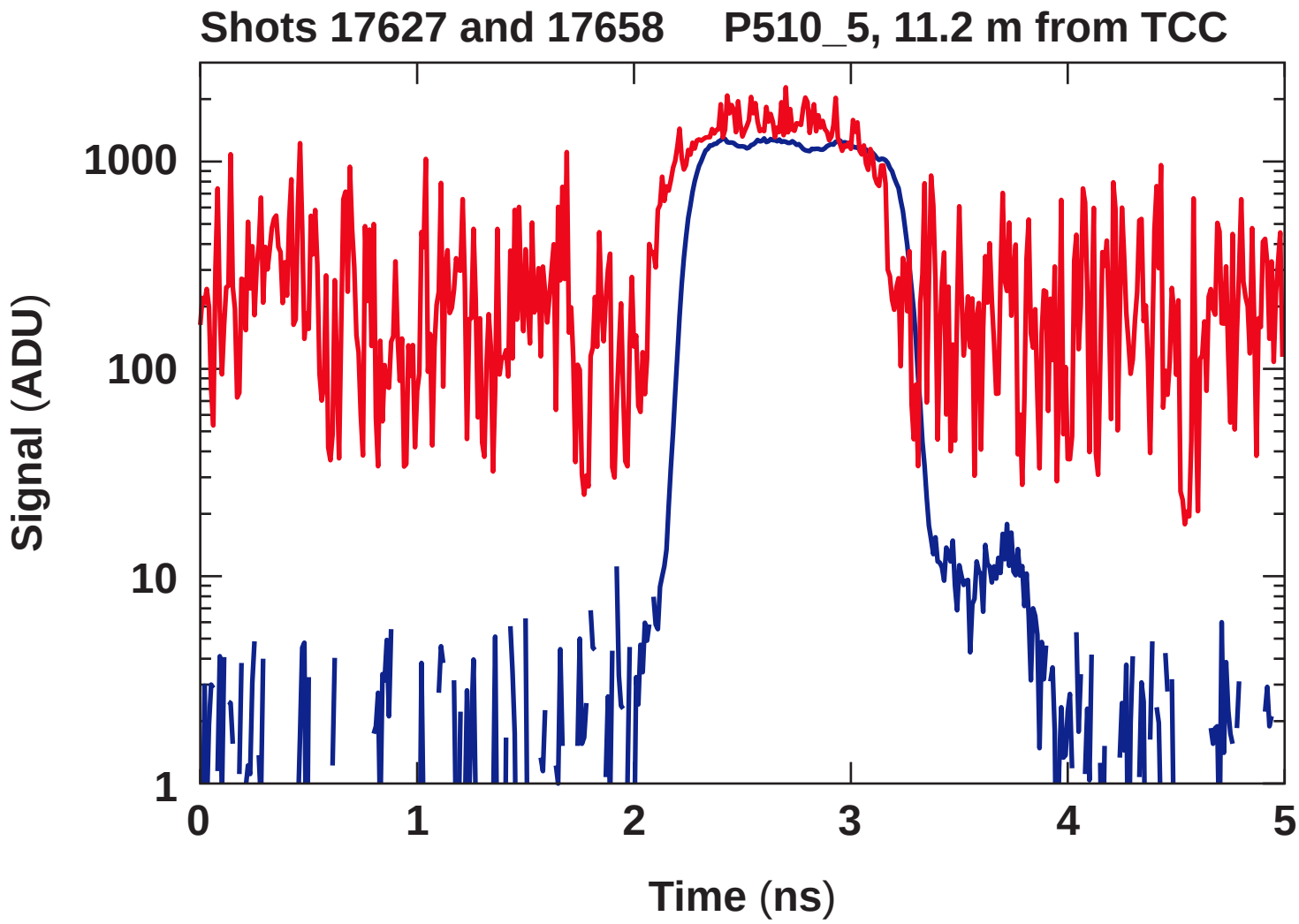
P510_5. 11.2 m from target chamber center

Shot 17658



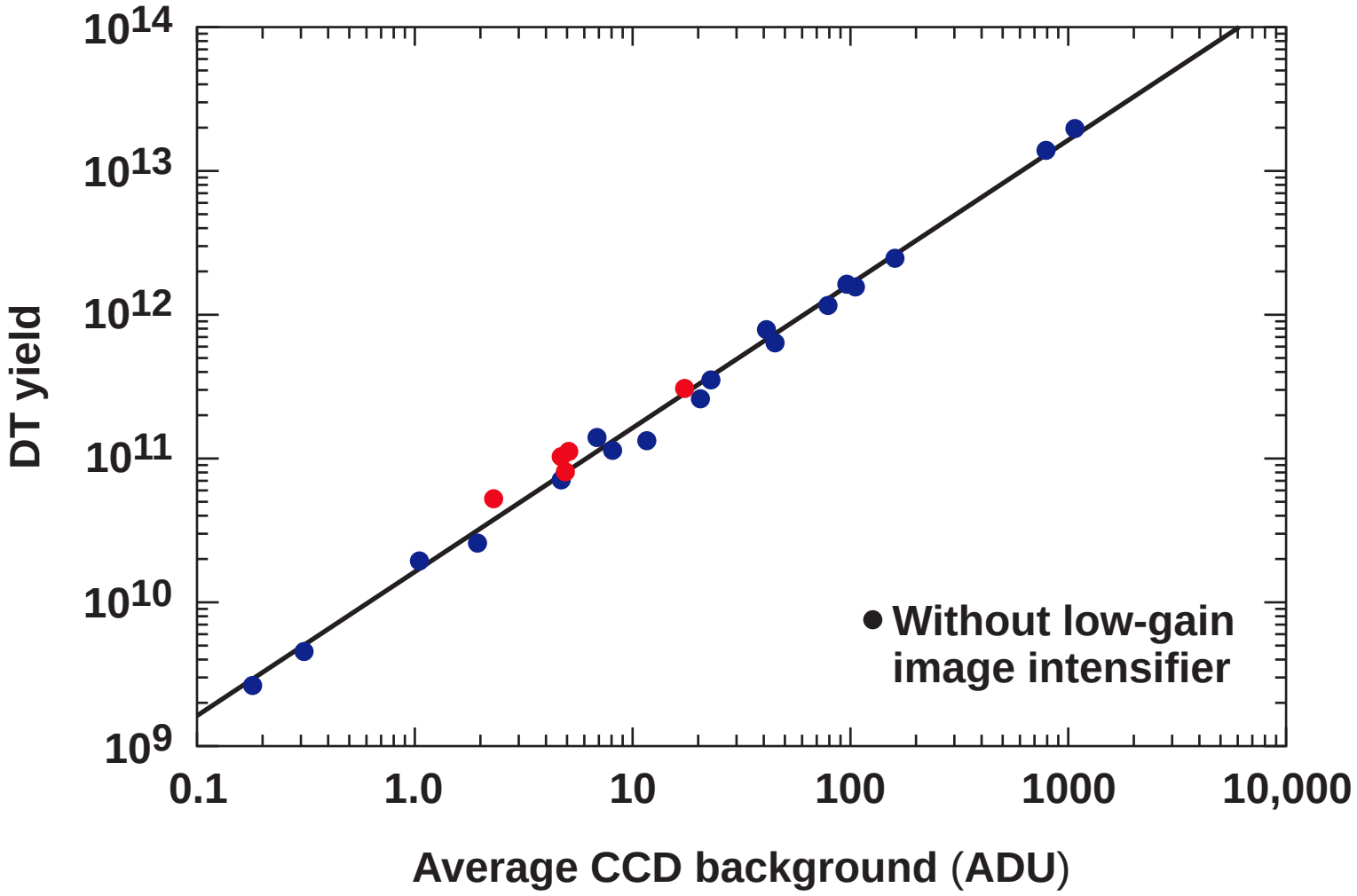
10^{13} neutrons

The peak signal-to-noise ratio for pulse-shape measurements decreases from 100 to 5 due to the neutron-induced background for DT yields of 10^{13}



E10091

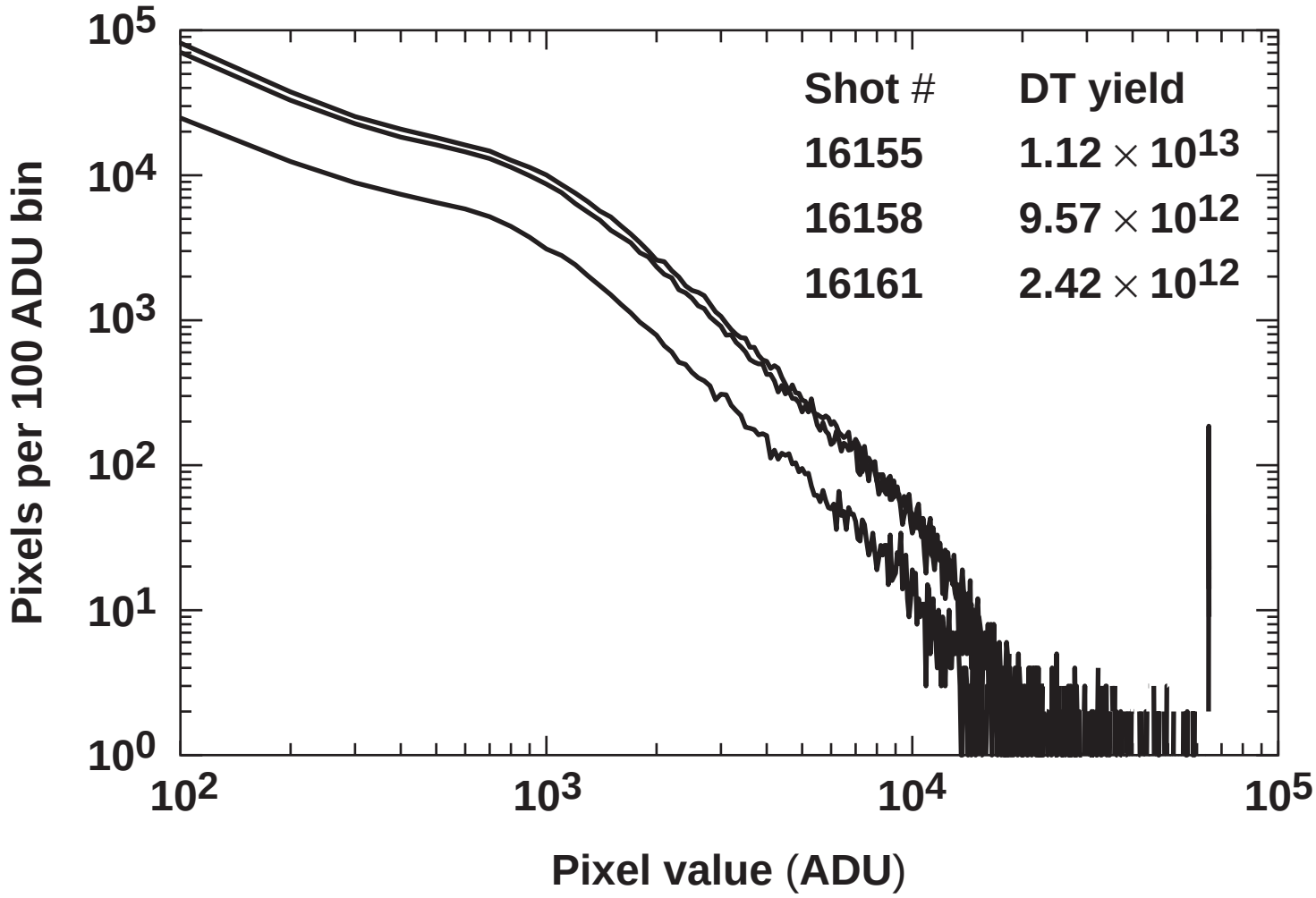
The average CCD background level is proportional to the DT neutron yield



E10092

TEK 512 CCD at 2.2 m, 4.9 electrons/ADU

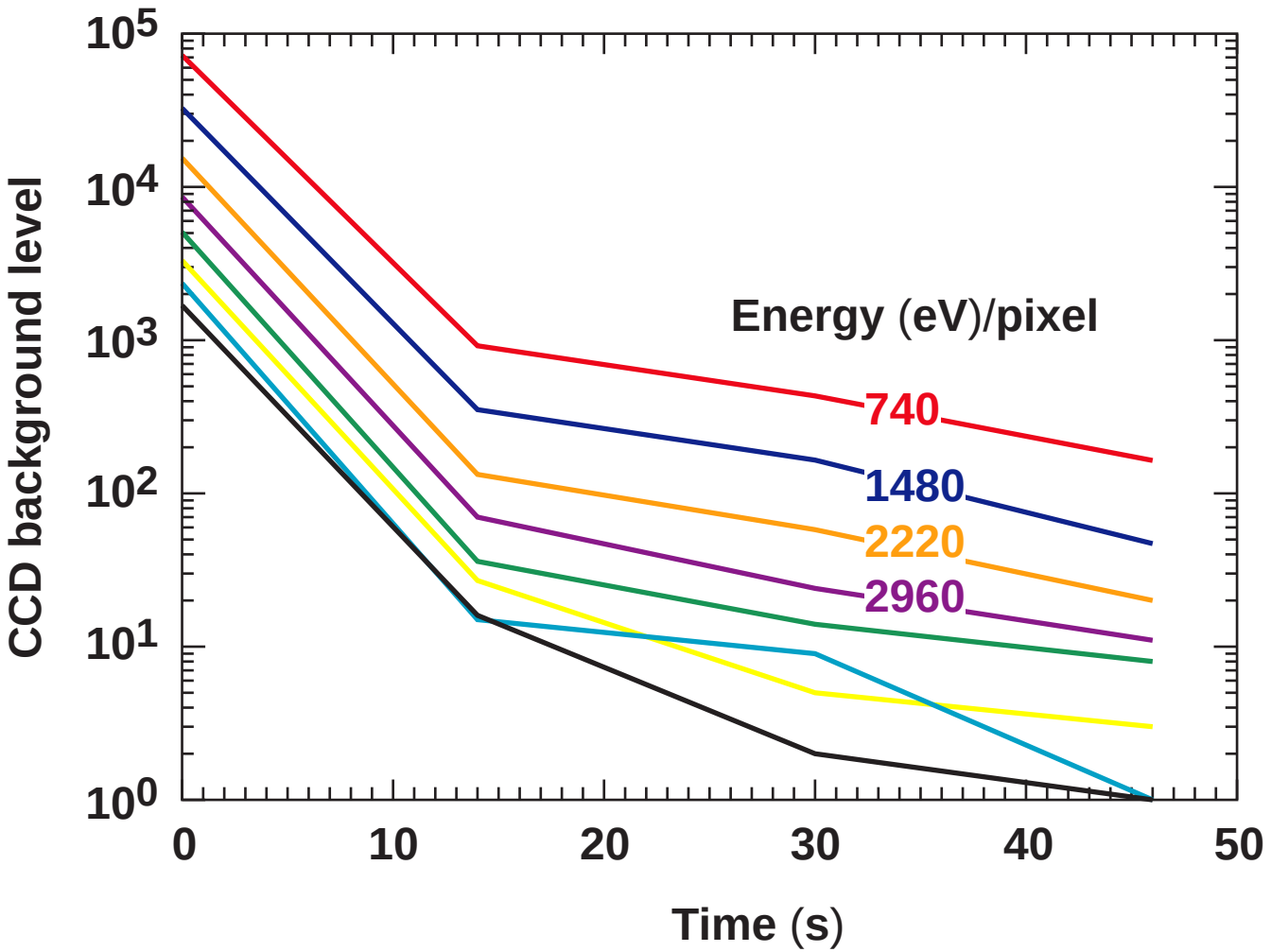
The bulk of the deposited energy/pixel spectrum is at low energies, with a small number of saturated pixels



E10093

SITe 1024 (#C2200 on the floor at 7.62 m) 4.5 eV/ADU

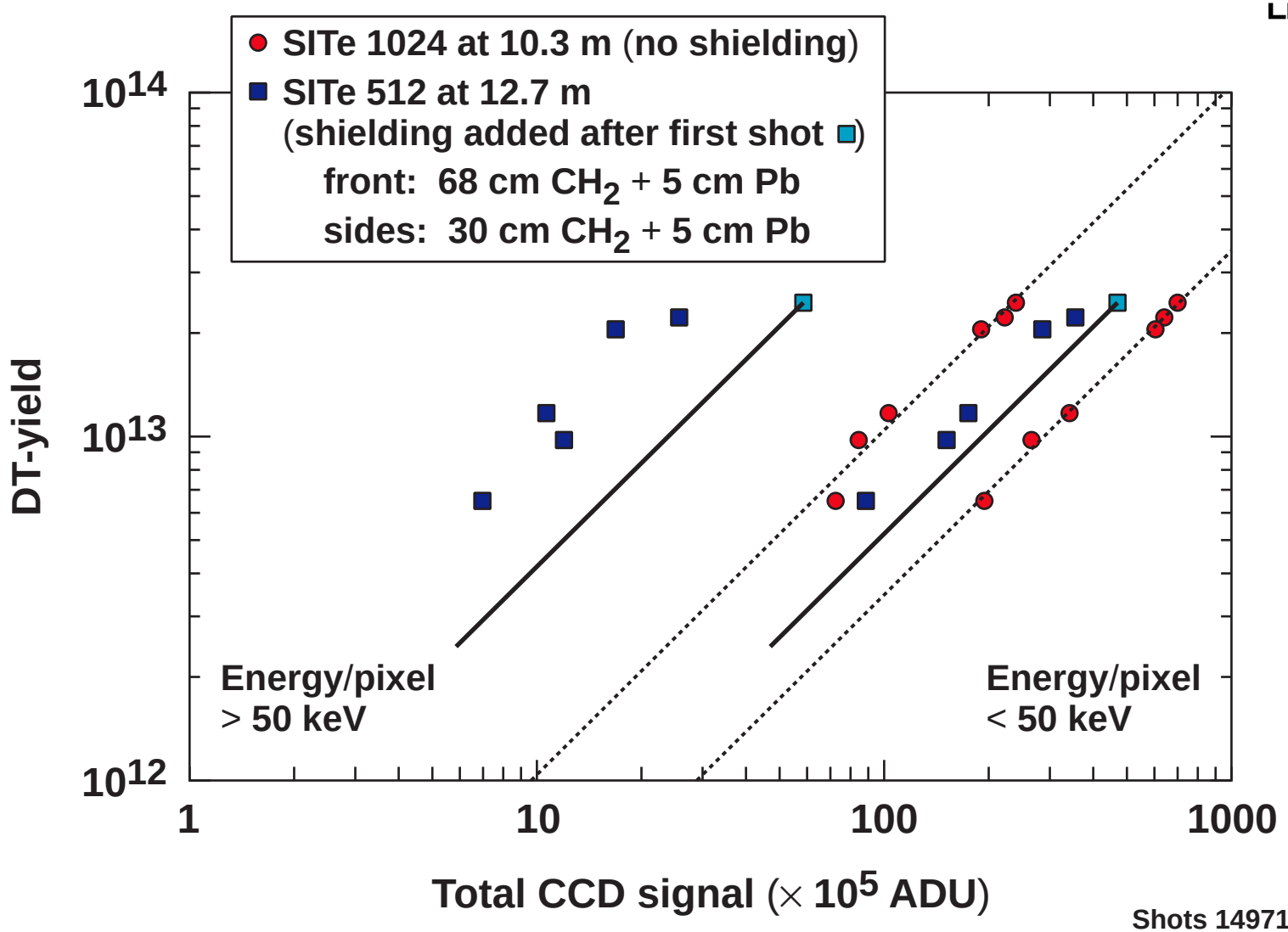
A sequence of CCD dark frames taken after the target shot shows that the prompt background level is followed by the decay of the activation products with a 13-s half-life



E10094

Shot 16155 DT-yield = 1.1×10^{13}

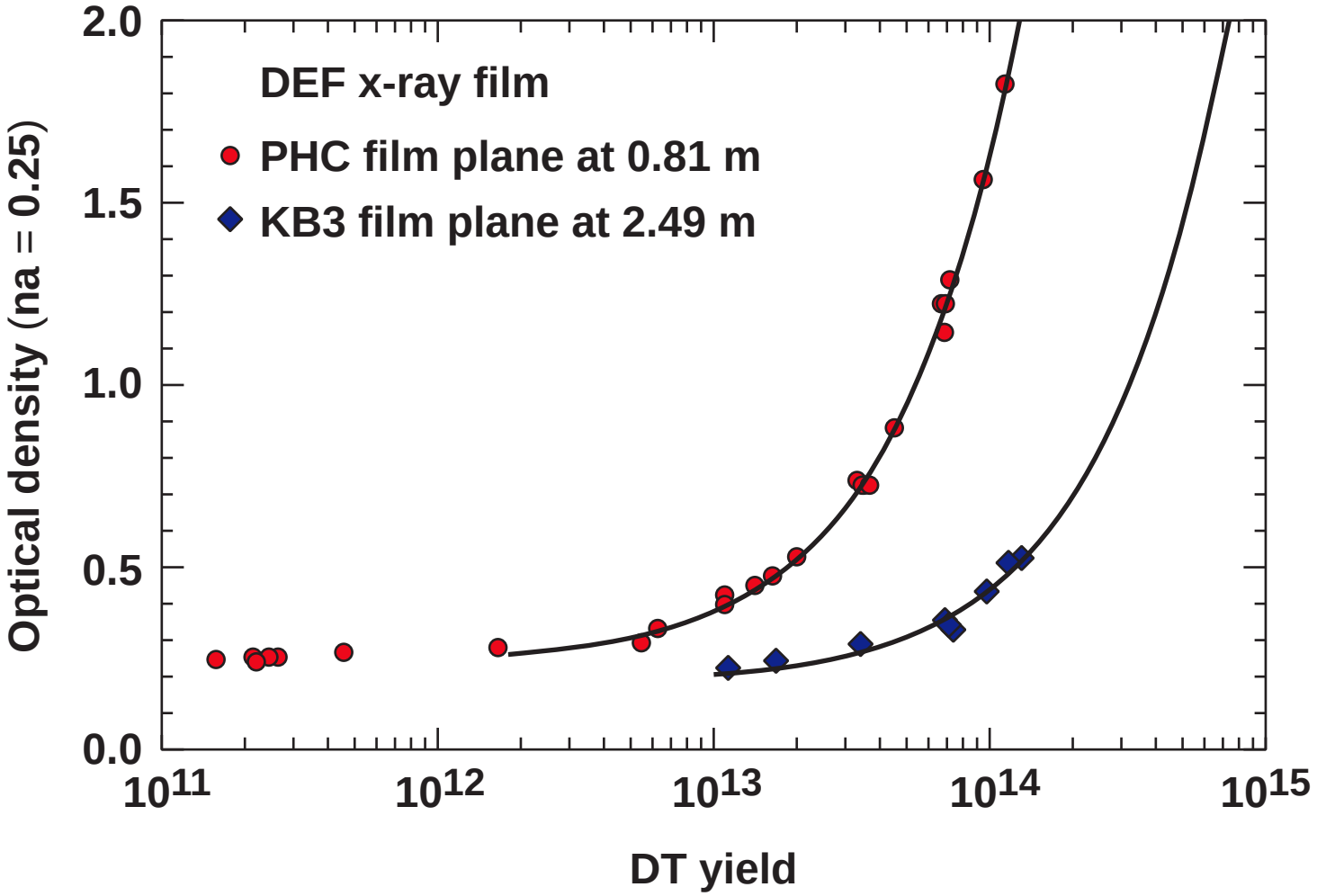
Shielding along the direct line of sight attenuates the high end of the deposited energy/pixel spectrum, but has negligible effect on the average background level



E10095

Shots 14971–14979

Film-based recording systems are compromised by increased fog levels on high-yield target shots



DEF film D-LogE curve for E_x = 6 keV
Normalization: 1.0 photon/μm^2 at 1.8×10^{14} and 10^{15}

Summary

Lots and lots of shielding will be required to protect diagnostics on high-yield neutron shots

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- Data recorded with CCD cameras located inside the NIF target bay will be overwhelmed by the neutron-induced background and rendered useless (SNR < 1) for DT yields > 10^{15}. DD neutron-induced backgrounds are comparable; they are actually 2 to 3× larger near the shield wall and the floor.
- Neutron shielding along the direct line of sight to the target can be used to attenuate the high end of the deposited energy per pixel spectrum, but it is only marginally effective in reducing the average background levels. Most of the noise is caused by down-scattered neutrons and gammas, which come from all directions. Even the decay of the activation of any materials in the target bay is problematic for time-integrating recording systems.
- The 75-cm-thick concrete shield wall around the OMEGA target bay attenuates the CCD background level by 8×.
- The fall-back position of film-based diagnostics also suffers from enhanced background levels, reaching film saturation for DT yields > 10^{16}; less if they are used in conjunction with an image intensifier.