Effects of Pre-Ionization on Current Distribution in a Gas-Puff Z-Pinch

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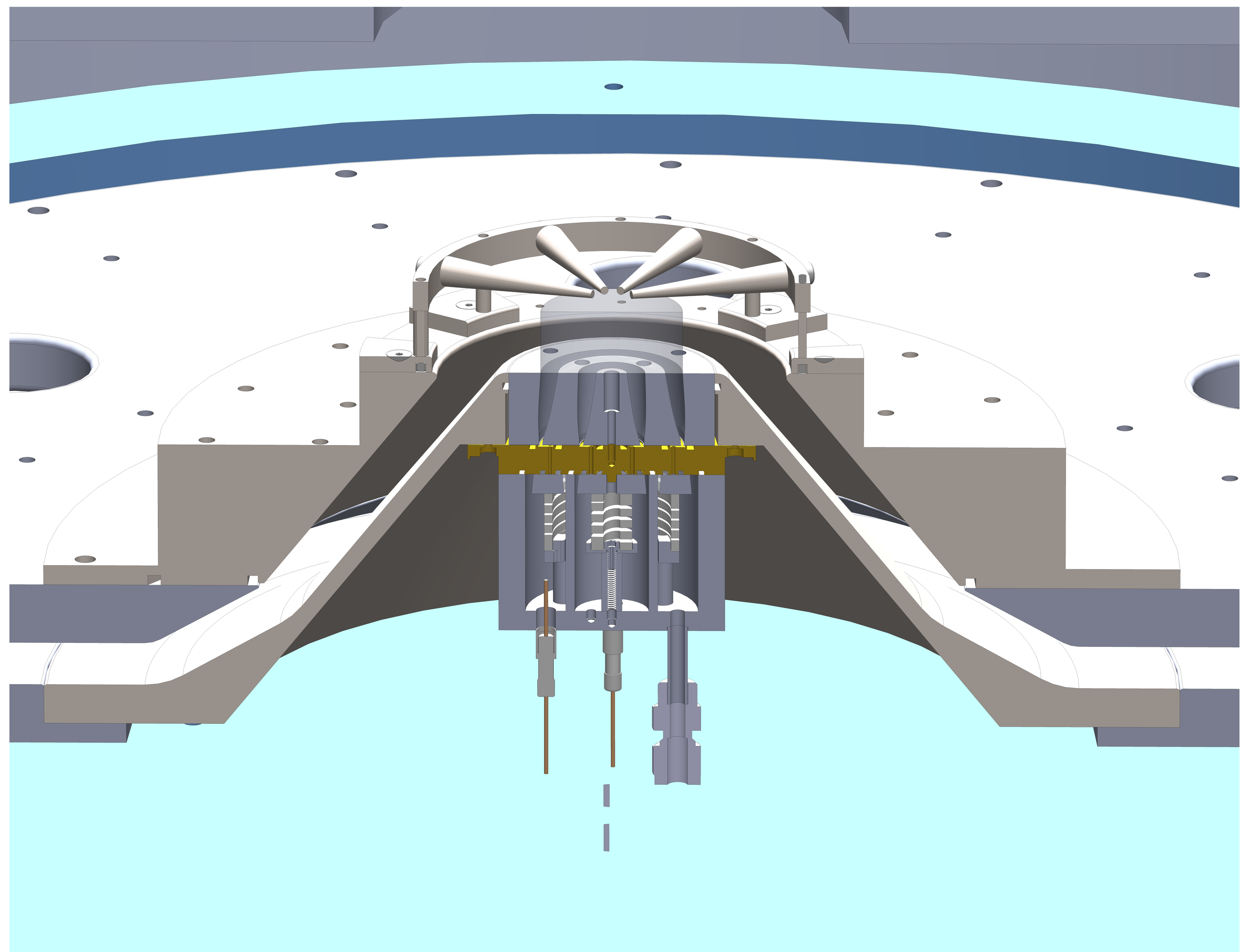
Motivating a Gas-Puff Z-Pinch

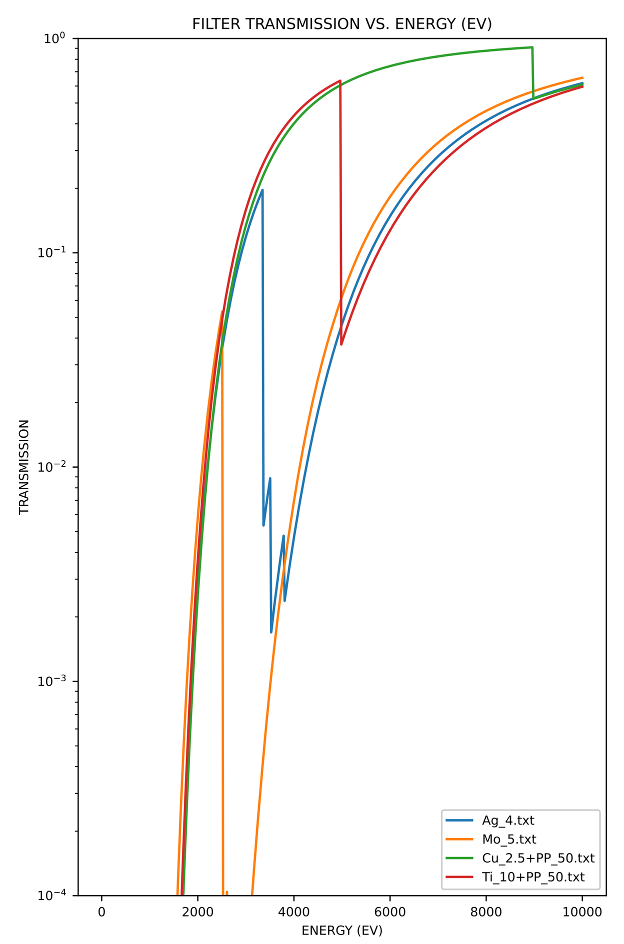
UNIVERSITY-SCALE z-pinch experiments, such as gas-puff z-pinches, can inform the high-value experiments conducted at Sandia. A gas puff z-pinch requires gas to be puffed into the region between two electrodes, which is then pulsed with a high voltage [1]. The gas is ionized and compressed as the current flows across the electrodes, allowing for a systematic study of pinch phenomena including fusion reactions. The initial ionization condition of the gas is poorly understood [2]. Additionally, how the initial condition affect micro-pinch instabilities, which in turn affect fusion yields, is also poorly understood.

Experimental Setup

A MULTI-SHELL implosion was modeled using ballistic trajectories given by an inward Lorentz force that results from a current distribution in the z-direction. Various geometries and shell densities were tested to determine the optimal implosion parameters for a MAIZE-like current. The optimal design was modeled, manufactured, and integrated onto MAIZE.

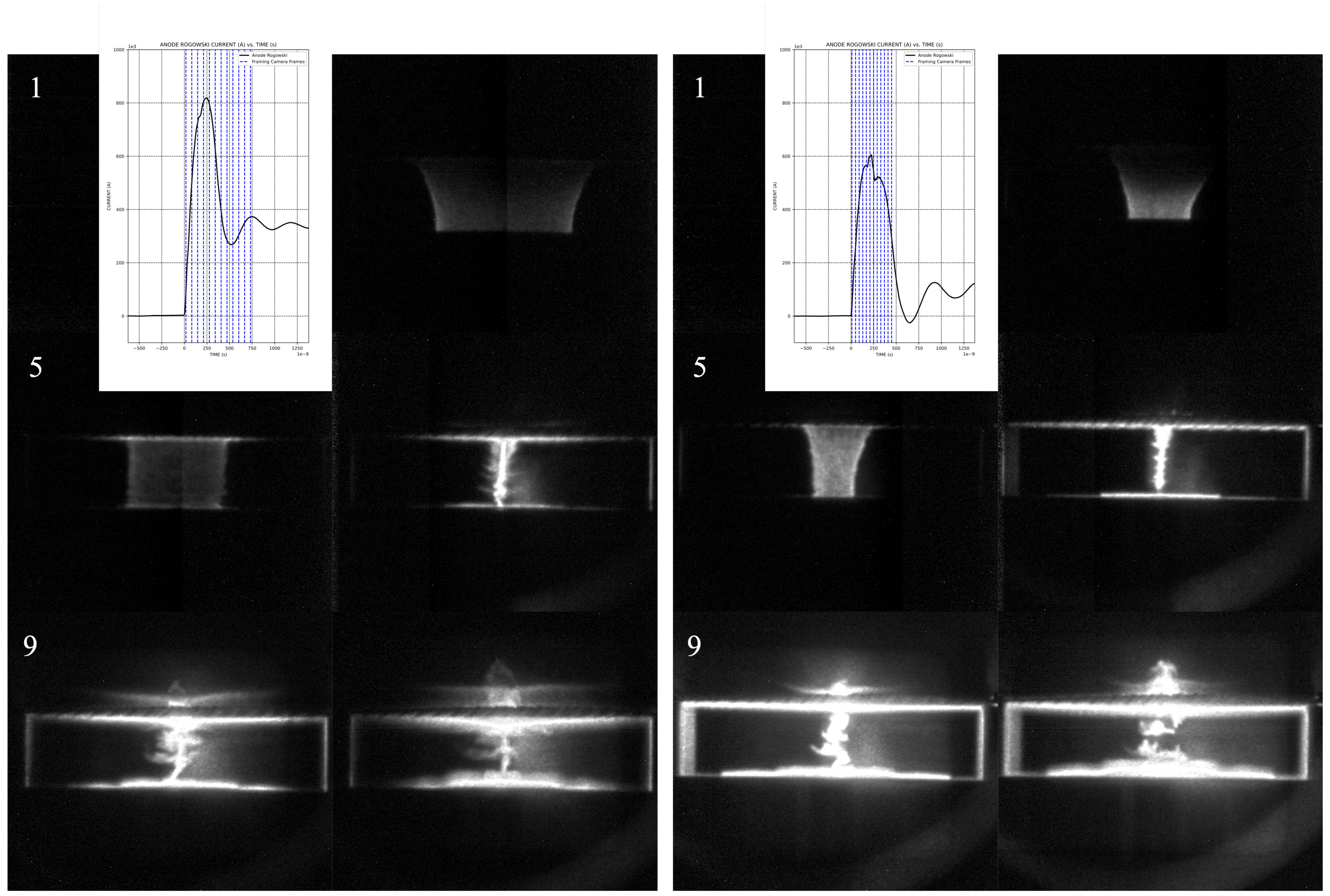


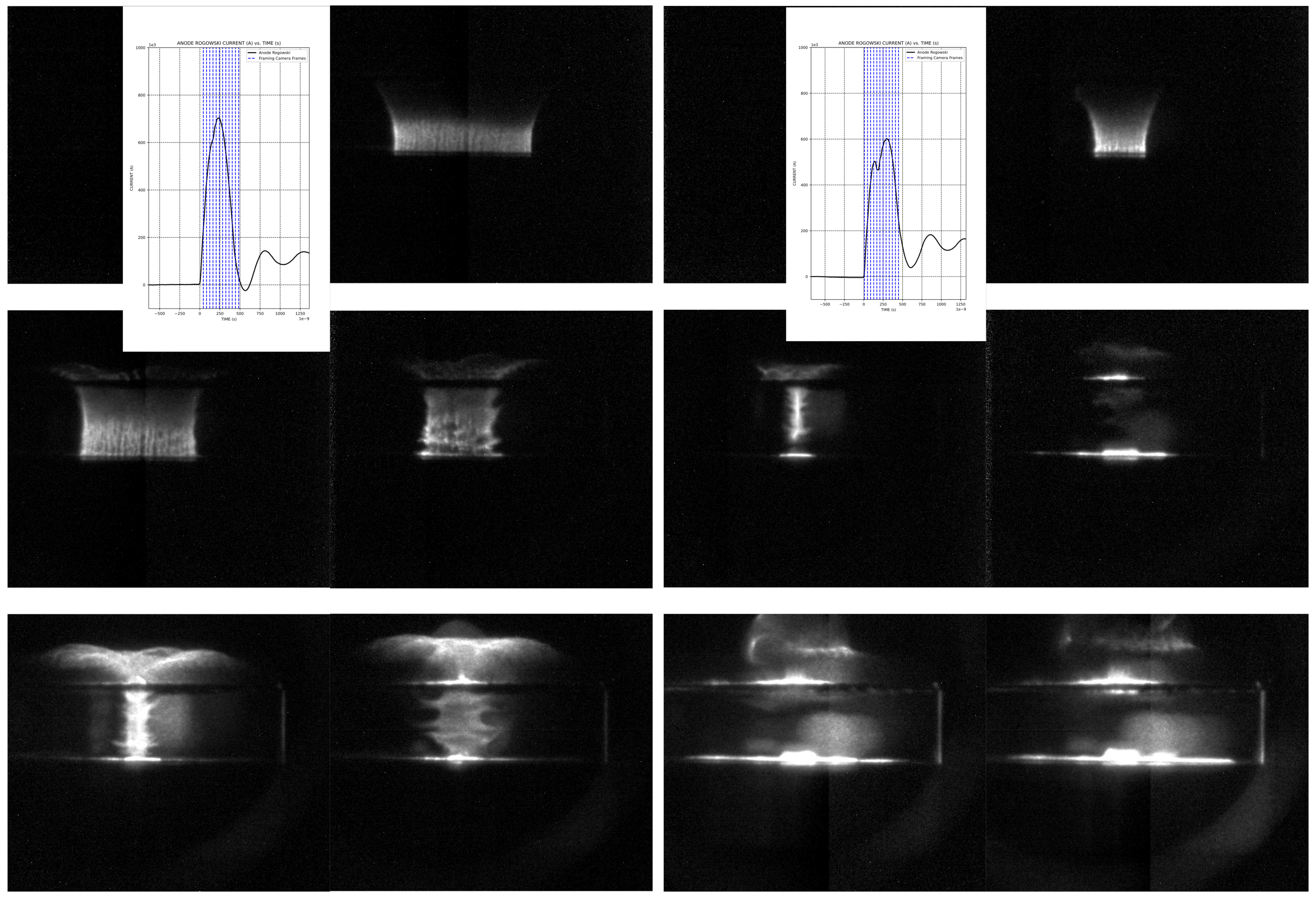
IN ADDITION TO cameras for imaging and a bolometer to characterize total x-ray yields, we developed and installed diagnostics to characterize initial gas distribution using an interferometer, x-ray spectra using Ross filter pairs, and total neutron yields using bubble detectors.



Experimental Results

ARGON AND DEUTERIUM was pinched on MAIZE, separately in the inner and outer shells of the gas-puff hardware in order to examine the implosion dynamics of each. The pinches are captured on the 12-frames of a fast-framing camera and the current traces are acquired using a Rogowski coil mounted on the anode. We see the progression of an implosion, which results in the formation of a stagnant pinch column in addition to various plasma instabilities, which need to be analyzed.





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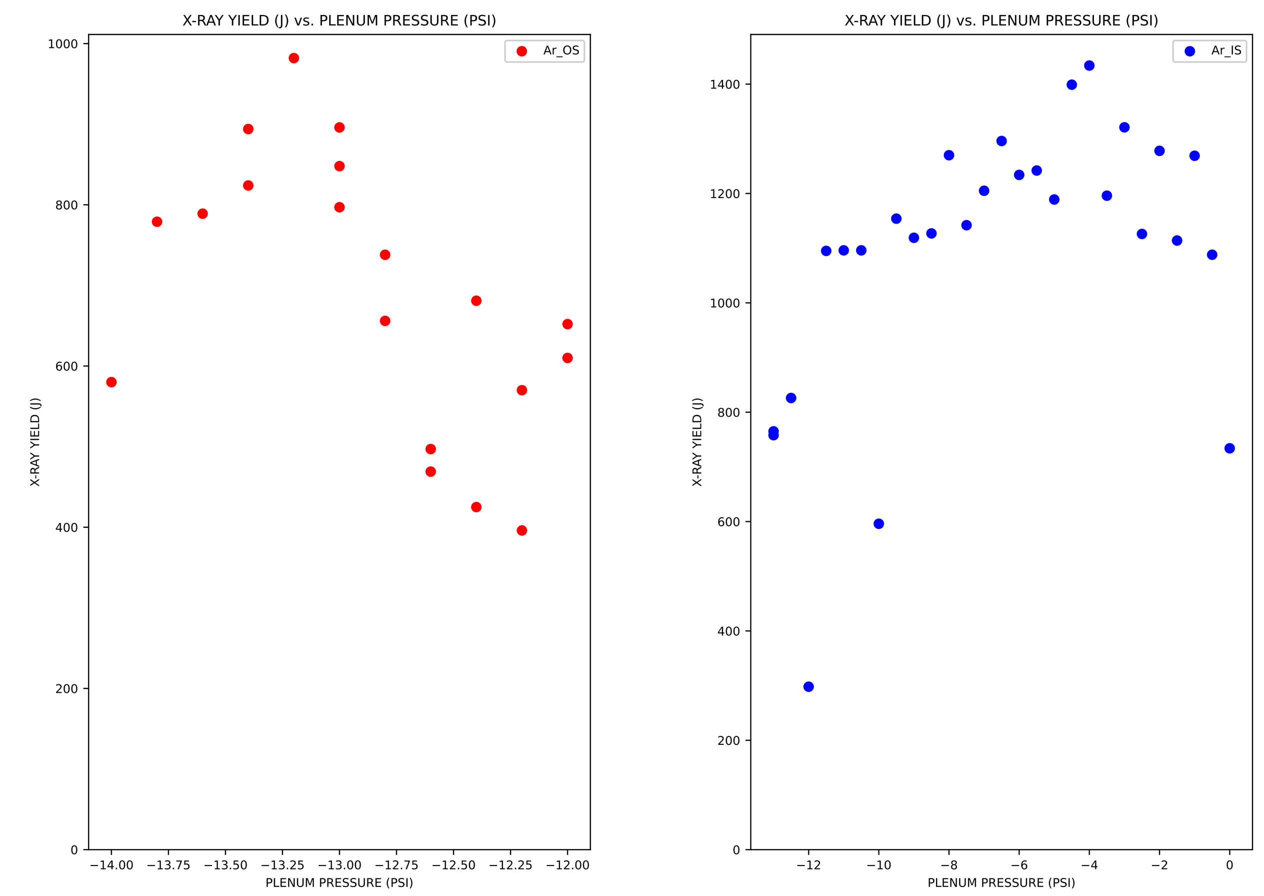
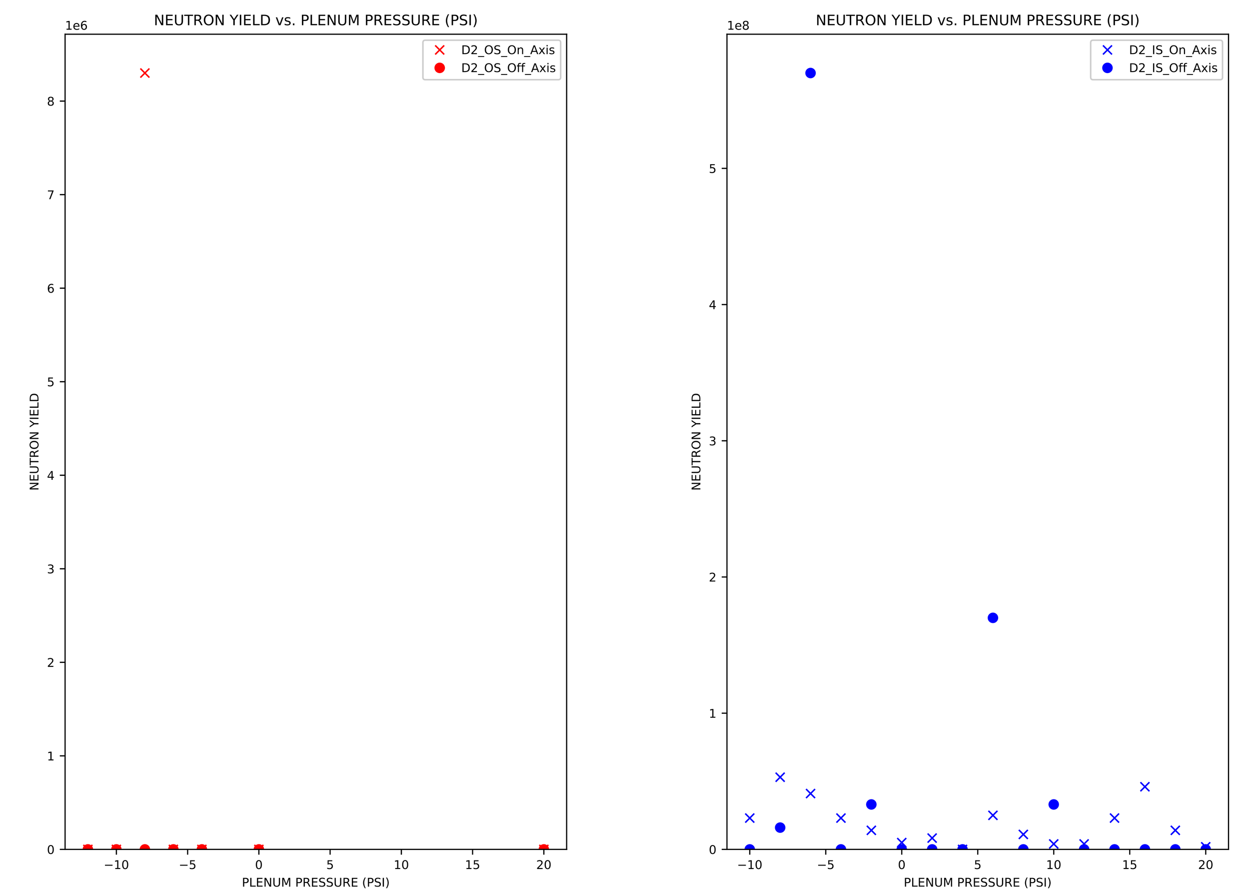
X-Ray Output Optimization Results

SWEEPING THROUGH the various mass densities of argon in the load for each of the shells gives the optimum density for implosion on MAIZE. Crucially, we see a record 25% wall-plug efficiency with 1.4-kJ of x-ray energy output with stored electrical energy of 5.7-kJ for a specific set of parameters.



Neutron Output Optimization Results

SWEEPING THROUGH the various mass densities of deuterium in the load for each of the shells gives the optimum density for implosion on MAIZE. We see that the inner shell is a far more productive neutron source than the outer shell.



References

1. M. Krishnan, "The Dense Plasma Focus: A Versatile Dense Pinch for Diverse Applications", IEEE Trans. Plasma Sci. 40, 3189 (2012).
2. J. Giuliani, "A Review of the Gas-Puff Z-Pinch as an X-Ray and Neutron Source", IEEE Trans. Plasma Sci. 43, 2385 (2015).