# Extending Experimental and Diagnostics Capabilities on the 1-MA, 100ns MAIZE Pulsed Power Facility

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## Experimental Capabilities Motivation

University-scale z-pinch experiments can inform high-value experiments conducted at Sandia National Laboratories. A Dense Plasma Focus (DPF), gas puff z-pinch, and a hybrid of the two are such types of z-pinches [1]. Specifically, they involve plasma compression resulting in a significant number of fusion reactions. The fusion reactions result from micro-pinch instabilities, regions of extremely high pressure and temperature within the plasma and they are poorly understood. Hybrid systems allow for gas to be puffed into a DPF leading to long-lasting shear-flow stabilized compressions that allow for a systematic study of micro-pinch phenomena. The experimental design is based on simulations run using the Lee model [2], which we recoded in Python. Additional simulations will be carried out using PERSEUS, an extended magnetohydrodynamics code. These simulations will lay the foundations for experimentation on MAIZE.

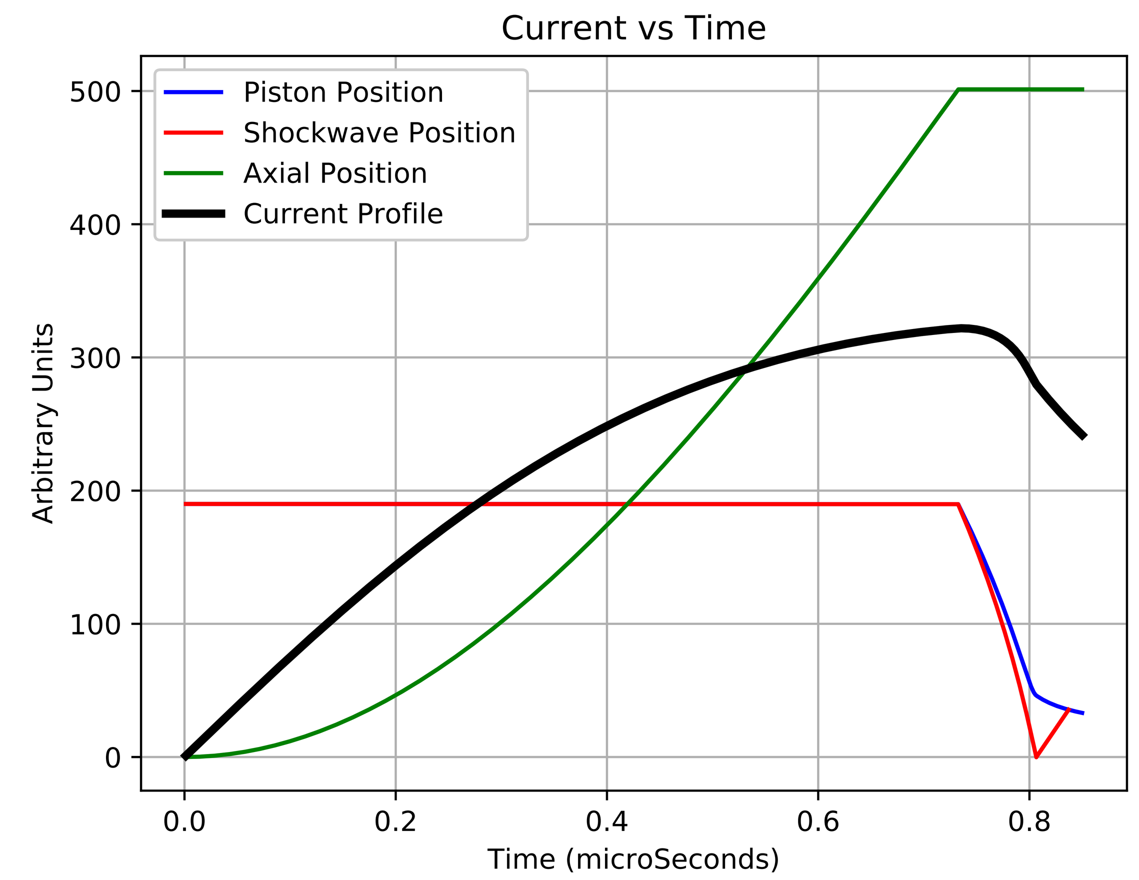
## Goals

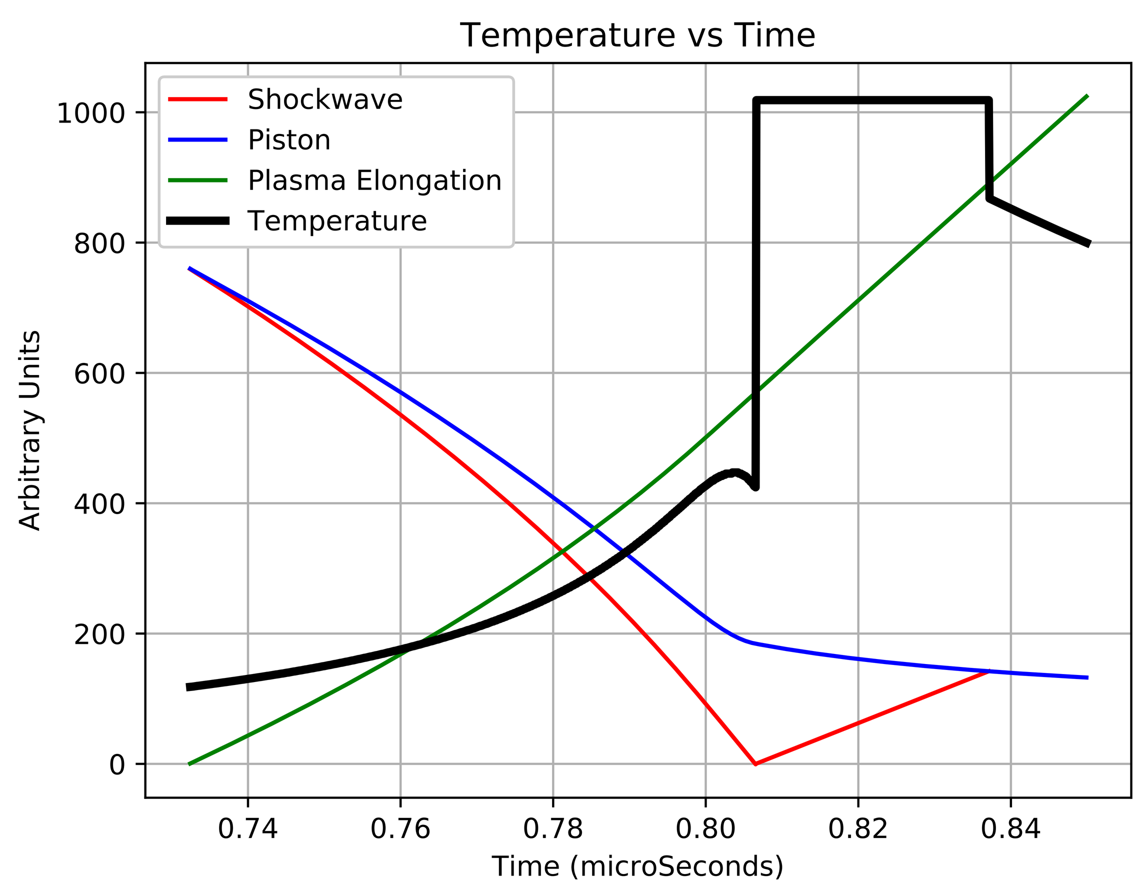
We are developing neutron producing z-pinch capabilities at the University of Michigan for integration into the 1-MA, 100-ns MAIZE pulsed power facility. To this end, our goals are broadly characterized as follows.

1. Simulate the DPF using the Lee model and revamp the Lee model platform.
2. Determine a point design using the 1D results of the Lee model.
3. Carry out additional simulations using the 2D and 3D extended magnetohydrodynamics code, PERSEUS.

## 1. The Lee Model Revamped

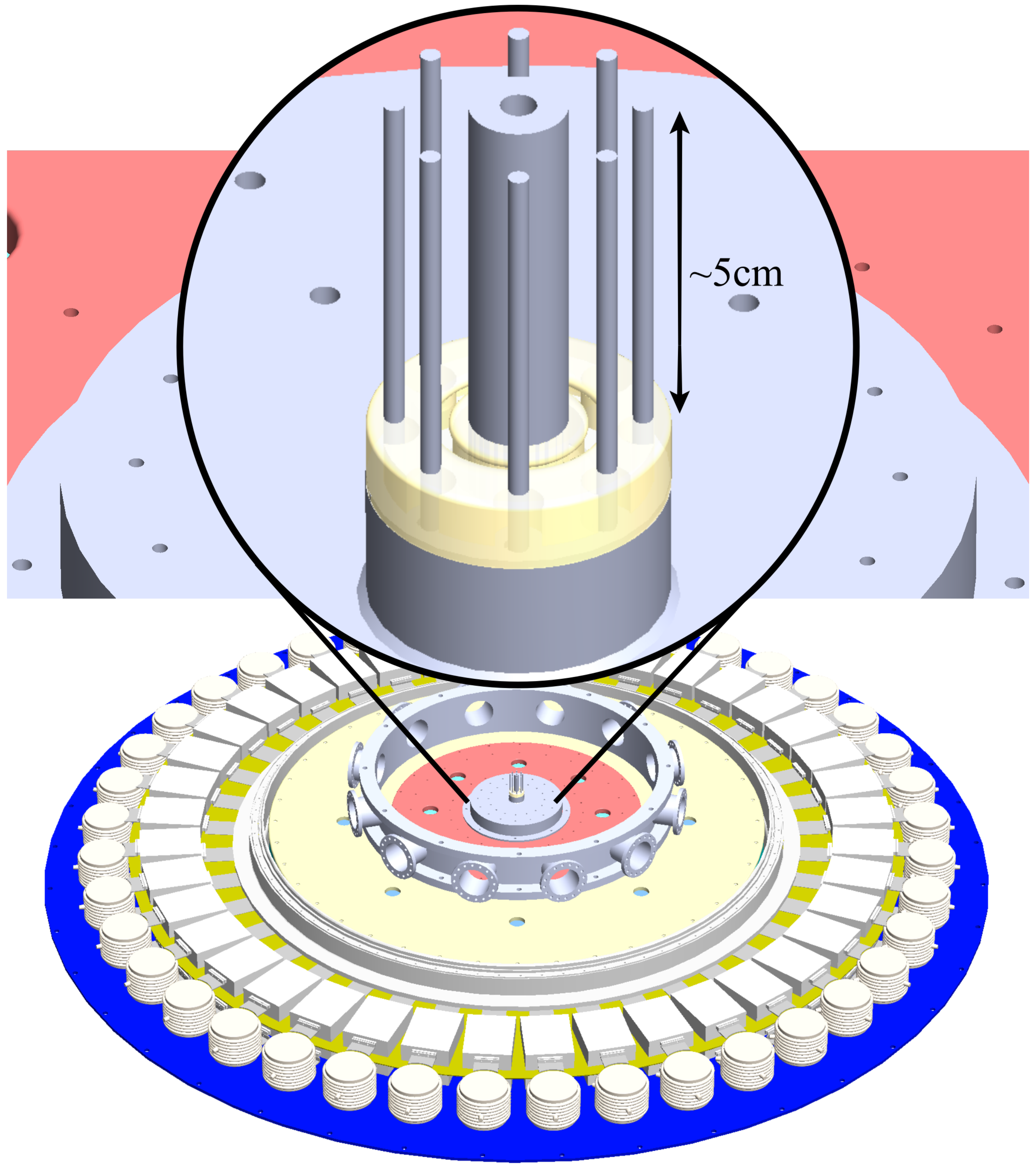
The original model was written as a Microsoft Excel macro using Visual Basic. In order to modernize the platform and to better understand the model for use in DPF construction, we recoded the Lee model in Python (see images below).




## 2. Design Process

DPF parameters were determined by the Python code and validated by Lee's original Microsoft Excel macro. These provided the benchmark for a point design. See image for the hybrid DPF/gas-puff load on MAIZE.




## 3. Extended Magnetohydrodynamics (PERSEUS)

Treating the two-fluid model in the Generalized Ohm's law formulation as a relaxation system allows for efficient numerical computation of plasma fluids [3]. We intend to simulate the DPF with PERSEUS to visualize instability structures. This information will determine the future trajectory of the project, in terms of design parameters amongst other considerations.

## Future Work

We intend to further develop the python version of the Lee model to account for various electrode geometries as well as a variety of fuels including Argon and Neon. Higher fidelity simulations will be carried out using PERSEUS. After construction of the hybrid pinch system and a subsequent set up of various diagnostics– such as laser induced fluorescence, x-ray spectroscopy, and neutron spectroscopy– actual experiments will be carried out on MAIZE.

## References

1. M. Krishnan, "The Dense Plasma Focus: A Versatile Dense Pinch for Diverse Applications", IEEE Trans. Plasma Sci. 40, 3189 (2012).
2. S. Lee, S. H. Saw, A. E. Abdou, and H. Torreblanca, "Characterizing plasma focus devices-role of the static inductance-instability phase fitted by anomalous resistances", J. Fusion Energy 30, 277 (2011).
3. C. E. Seyler and M. R. Martin, "Relaxation model for extended magnetohydrodynamics: Comparison to magnetohydrodynamics for dense Z-pinches", Phys. Plasmas 18, 012703 (2011).

## Diagnostics Capabilities Motivation

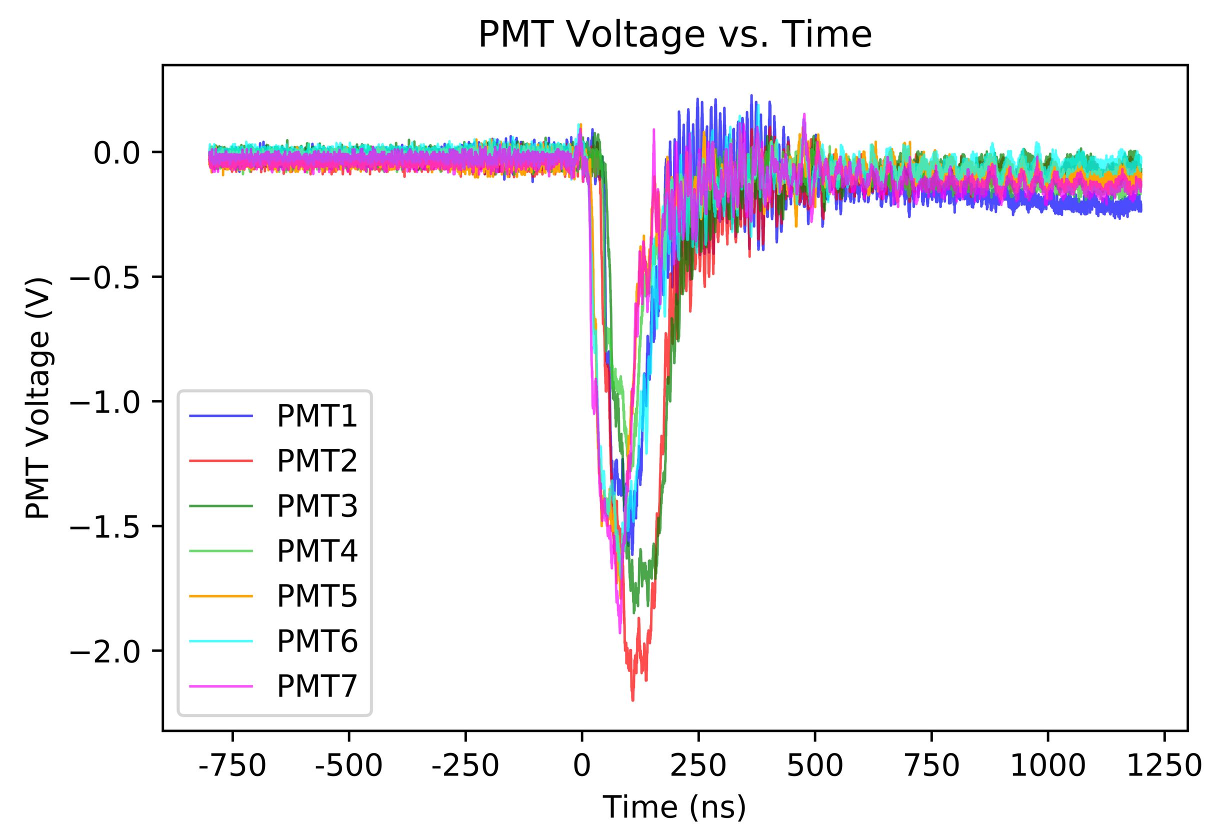
Maize consists of a set of 40 capacitor-switch-capacitor "bricks". Discharging each of the capacitors in a brick is carried out by the breakdown of a spark-gap switch, a process that results in emission of light. Monitoring this output light provides information on switch performance– whether a switch fired early or in phase with the other switches. However, examination of 40 switches during each shot with a dedicated photomultiplier tube (PMT) and oscilloscope channel is a resource-intensive process and can be made more efficient.

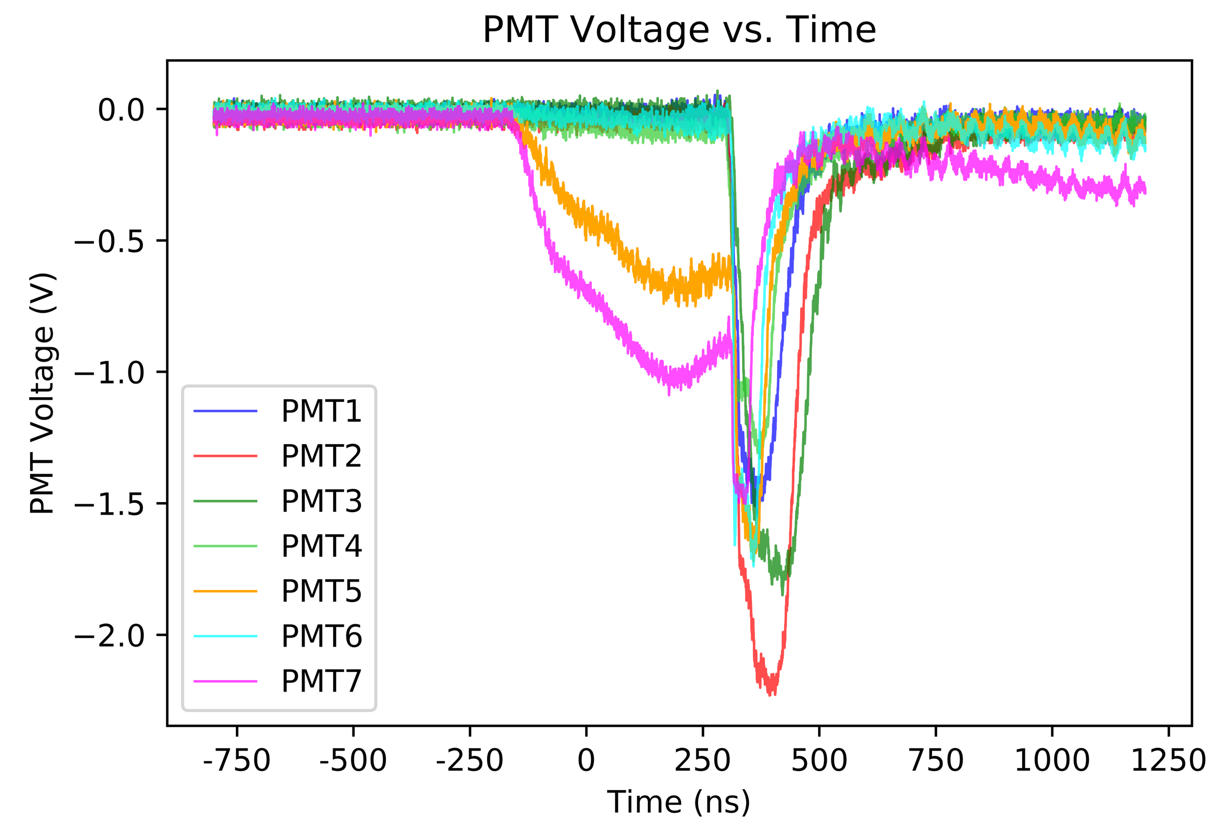
## Goals

If the only information required is the pre-fire of a switch, a circuit can be set up that reduces a PMT to a single computer bit. With such a circuit, six PMTs can uniquely identify a single pre-firing switch out of 40 (specifically, $\log_2 40$ PMTs).

## Results

The graphs show a shot with all switches firing in phase with each other and another shot with a switch pre-firing.




## Future Work

More information about switch performance can be derived by considering the amplitudes of the PMT traces. This may allow multiple pre-fires and late fires to be uniquely identified. Machine learning algorithms can be developed to determine poor switch performance based on more complicated PMT traces that would result from LTDs with more switches and/or LTDs with current shaping capabilities.

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