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Nuclear Engineer

Flash Neutron Radiography

A High Flux Transient Neutron Beam for Flash Neutron Radiography of Highly Dynamic Processes at the Transient Reactor Test Facility

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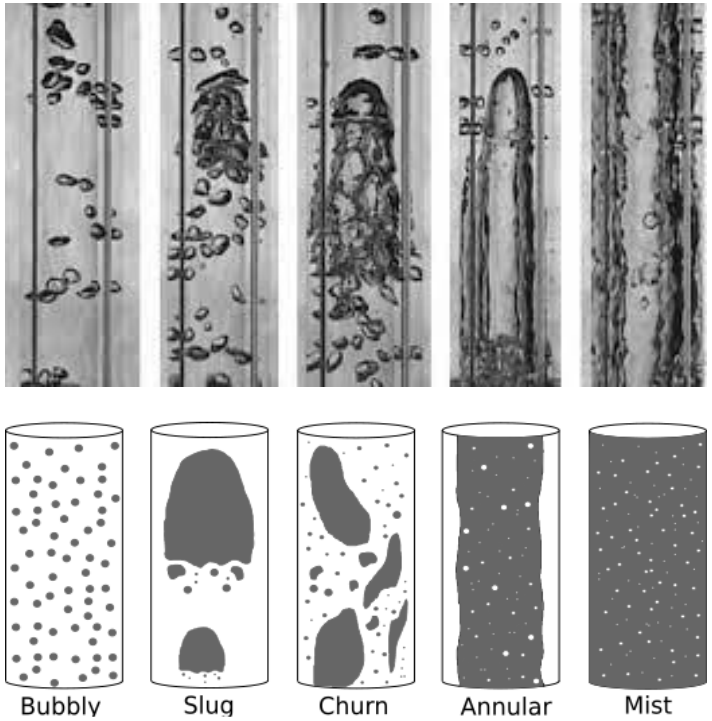
Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy

Idaho National Laboratory

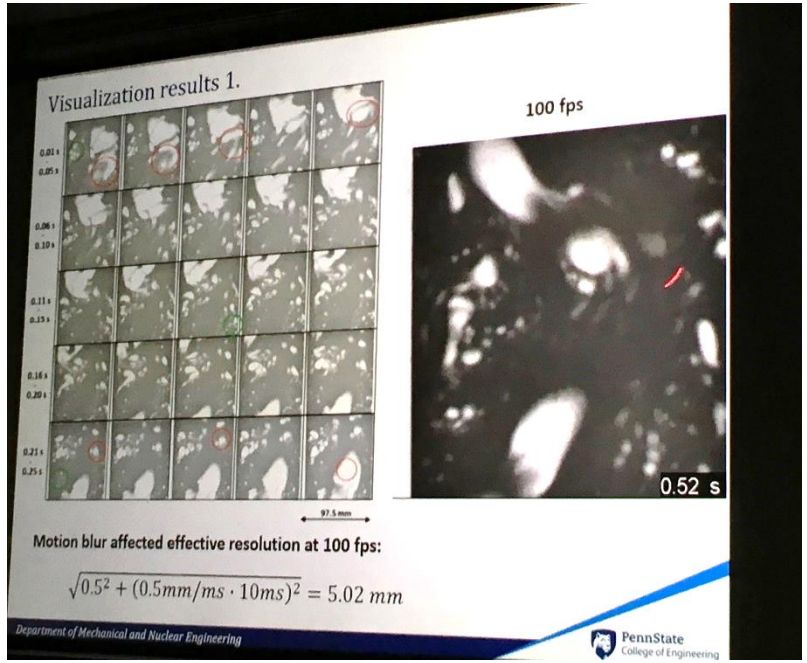
Meaningful Science Question

- What is the mechanistic behavior of liquid-vapor interactions at high pressures and temperatures like those in a nuclear power plant?
- We have yet to observe this behavior.
  - Too extreme for typical viewing methods
  - Too low contrast for X-ray imaging

PWR (15.4 MPa and 340ºC)

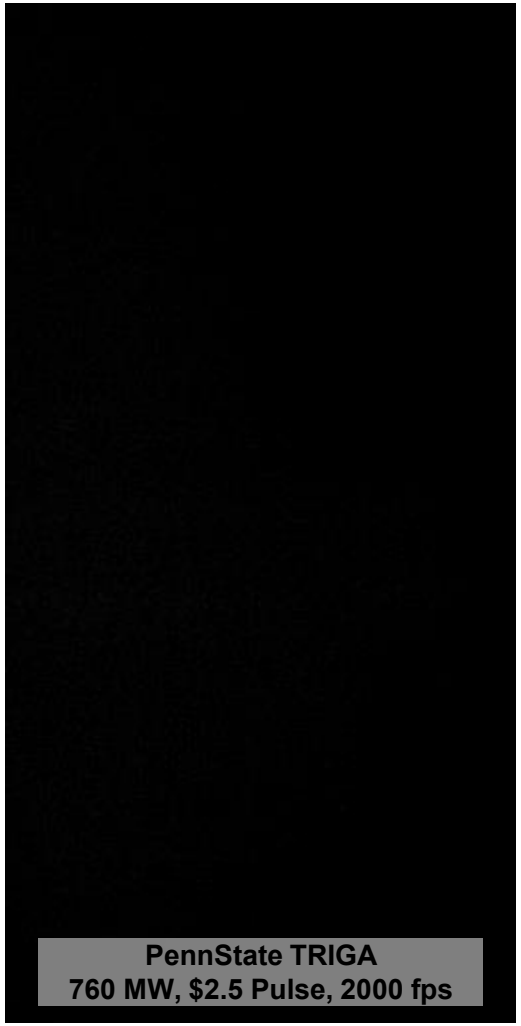


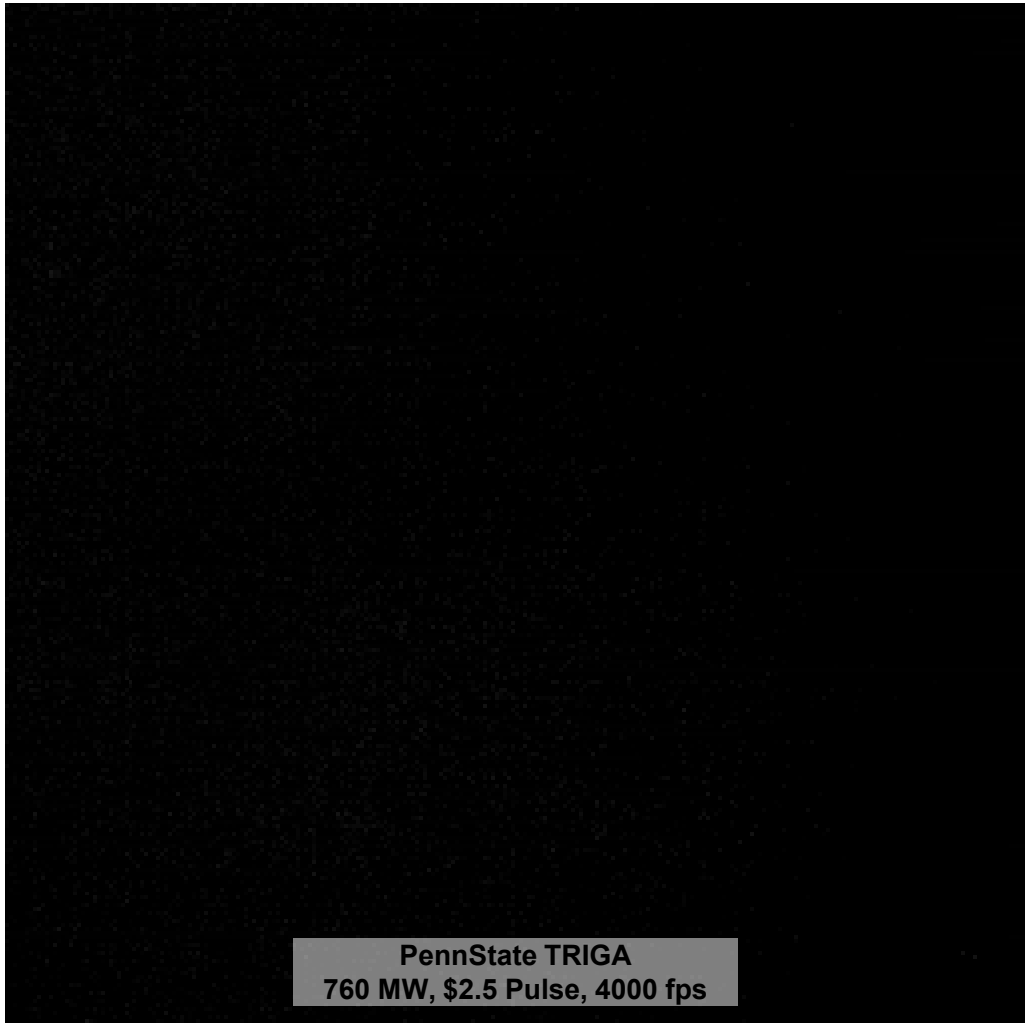
WCNR-11 in Sydney Australia, 2018

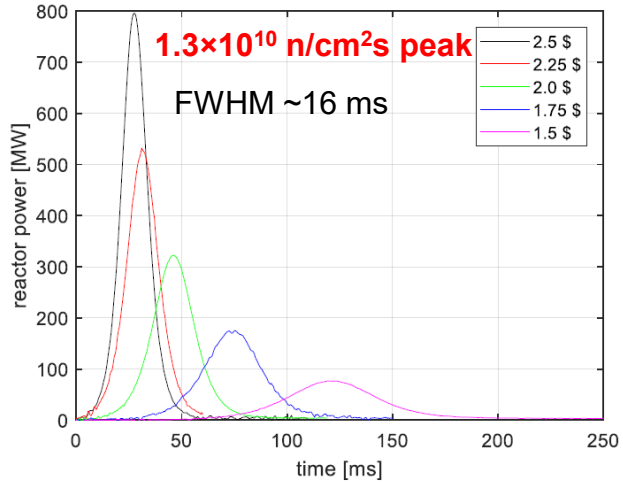


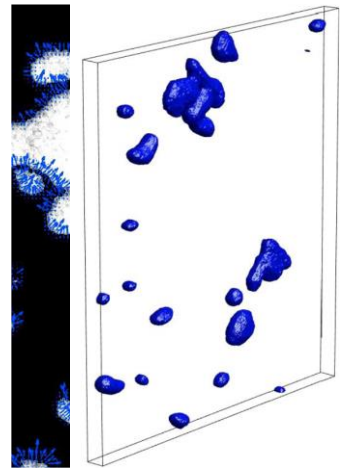
Lani, C. and Zboray, R. (2020) “Development of a high frame rate neutron imaging method for two-phase flows.” Nuclear Instruments and Methods, A 954, 161707
Zboray, R. and P. Trtik, P. (2019) “In-depth analysis of high-speed, cold neutron imaging of air-water two-phase flows.” Flow Measurement and Instrumentation 66, 182-189

Flash Neutron Radiography – Previous Work









FOV = 70 mm square, 130 μm/pixel, L/D~150, $\Phi_{peak}=3.25\times10^{6}$ $cm^{-2}s^{-1}$/frame

Lani, C. and Zboray, R. (2020) “Development of a high frame rate neutron imaging method for two-phase flows.” Nuclear Instruments and Methods, A 954, 161707
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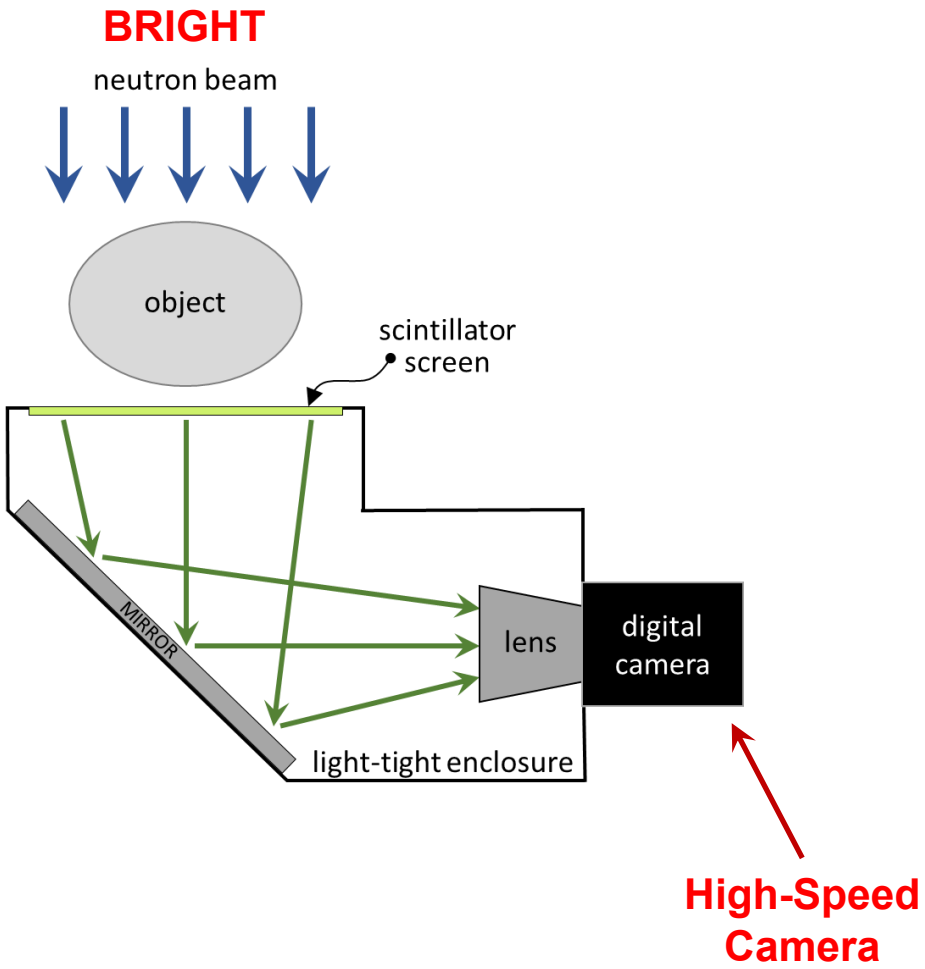
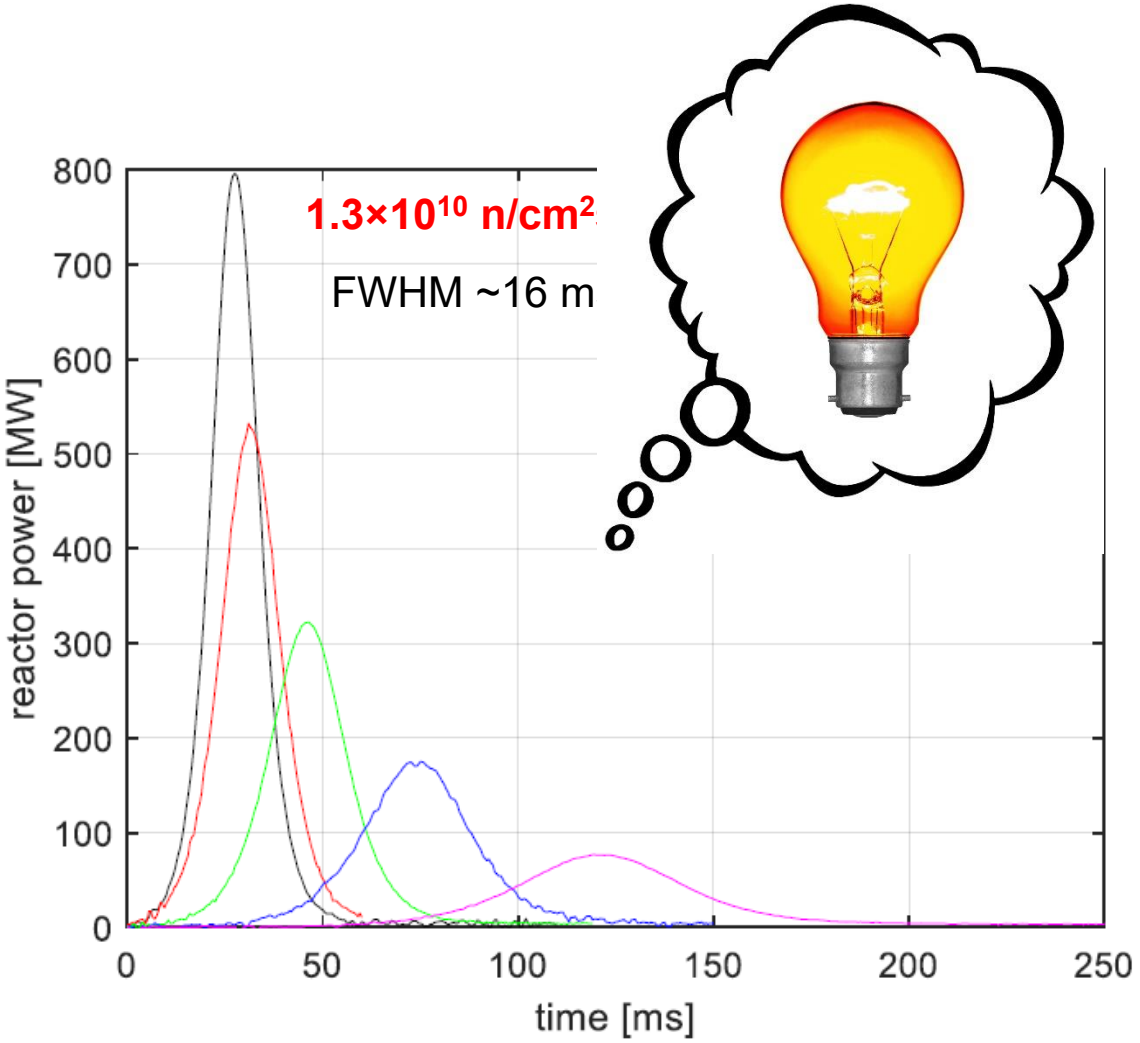
Flash Neutron Radiography

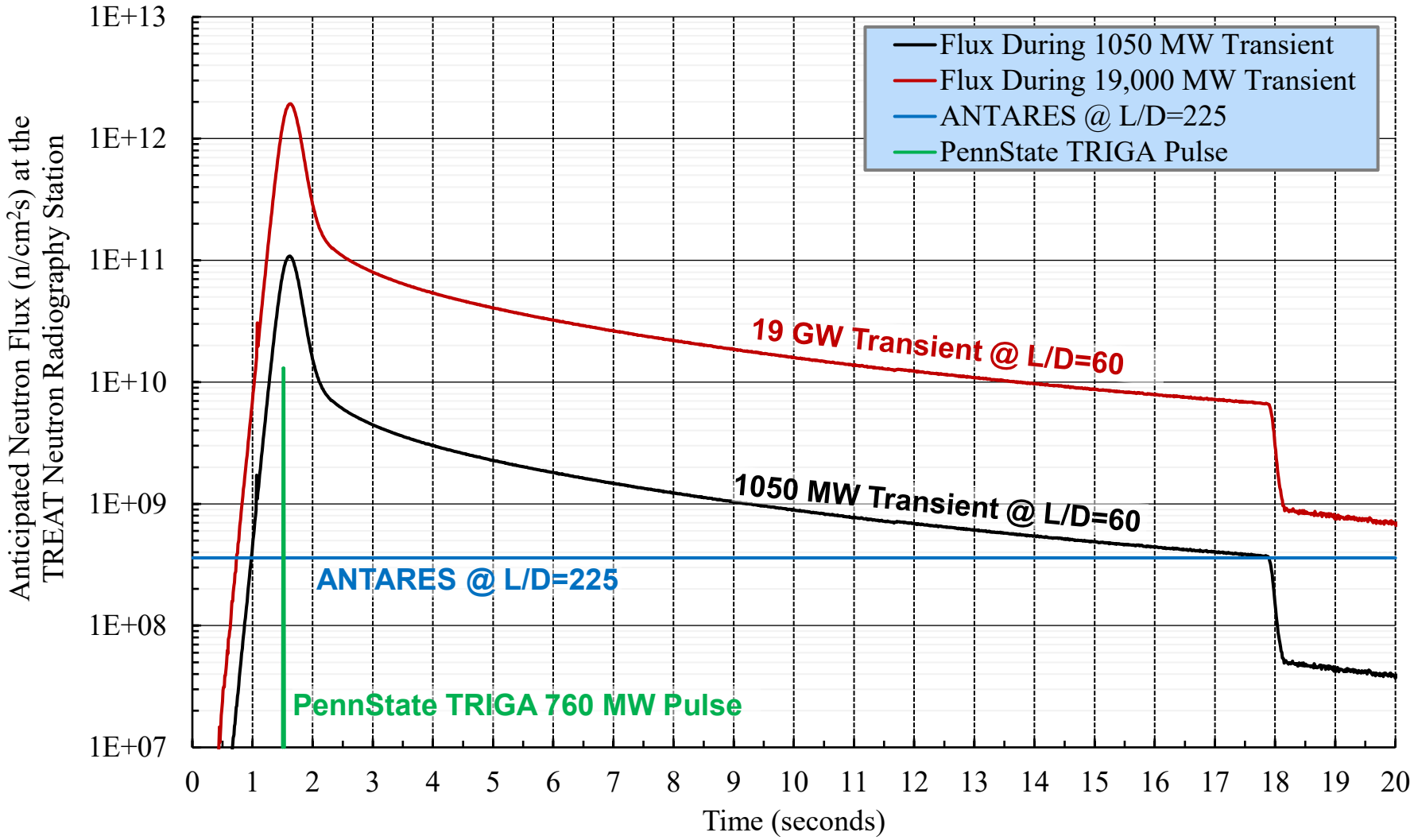
TREAT



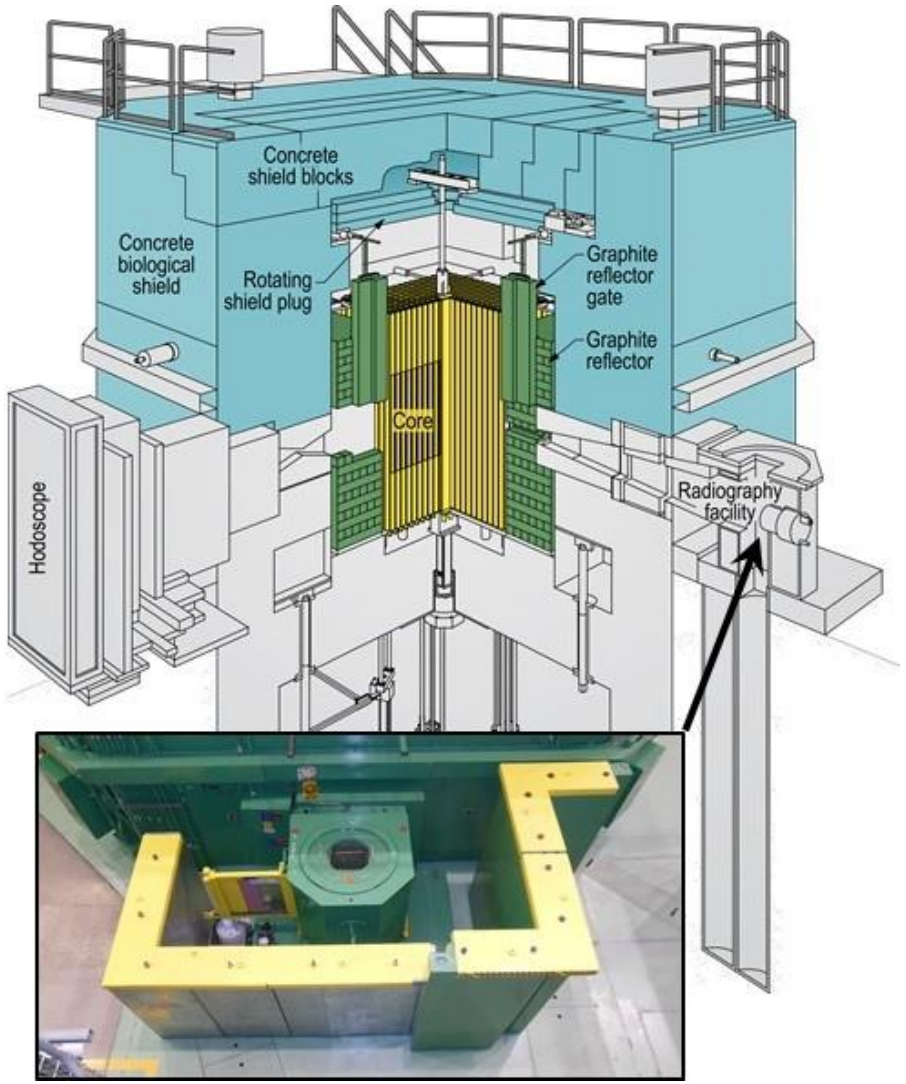


3. Lani, C. and Zboray, R. (2018) “Development of a high frame rate neutron imaging method for two-phase flows.” Nuclear Instruments and Methods, A. In press.
4. Lerche, M., Tremsin, A.S. and Schillinger, B. (2015). “Bright Flash Neutron Radiography at the McClellan Nuclear Research Reactor.” Physics Proceedia 69, 299-303.

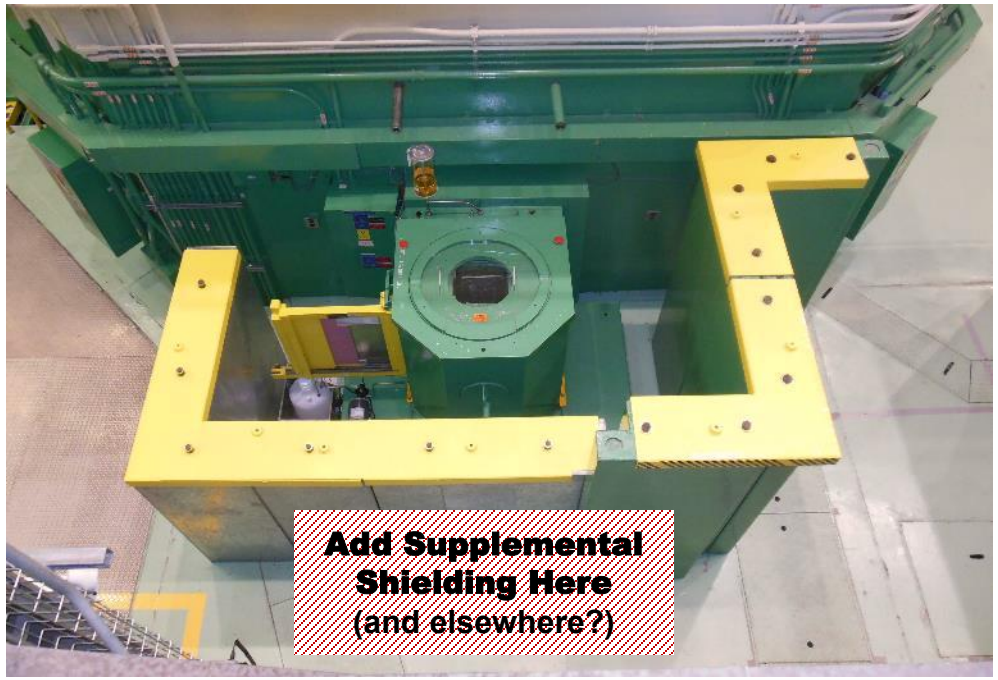
TREAT has the brightest imaging beam in the world!



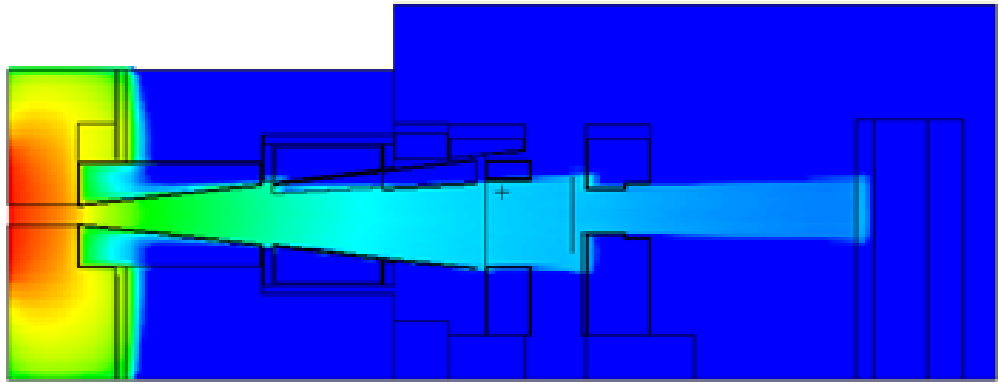
Install a Flash Radiography behind the TREAT NR Station

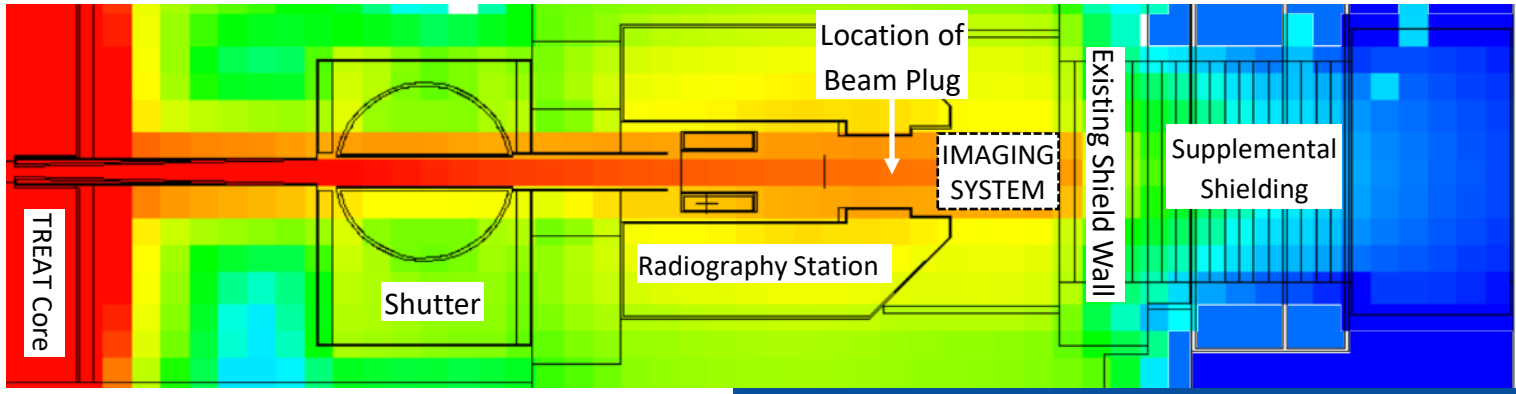


Shutter Open During a Transient – Radiation Shielding Mods

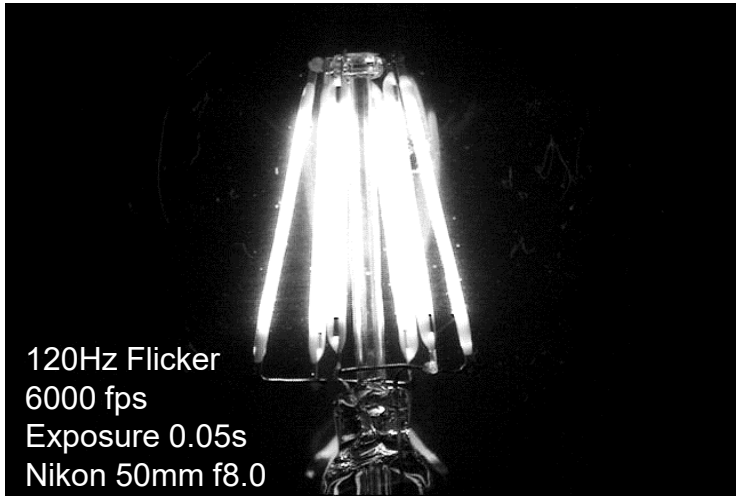


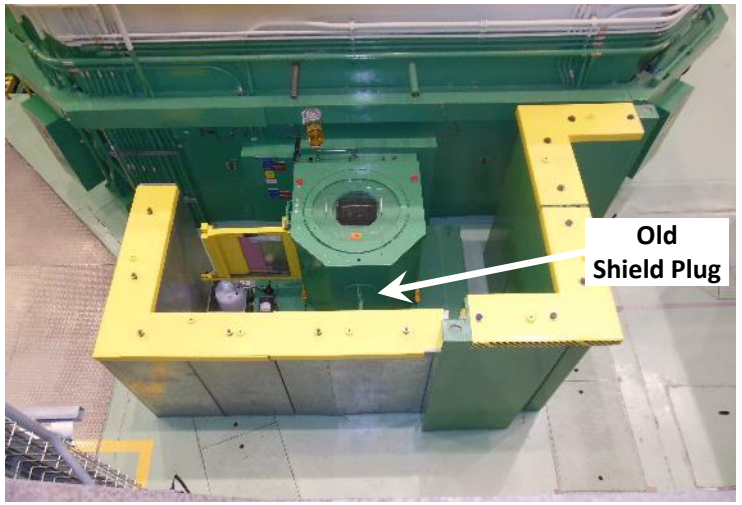
Radiation shielding calculations using MCNP



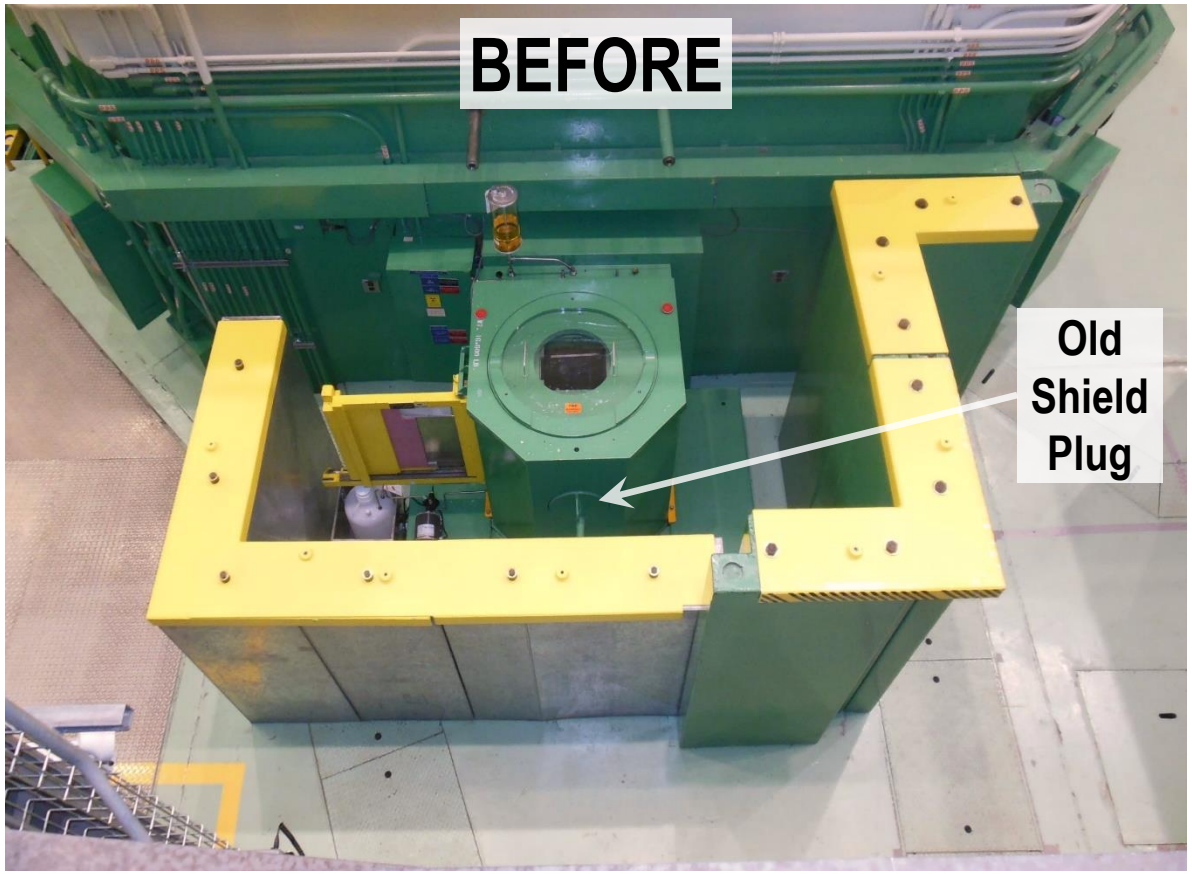


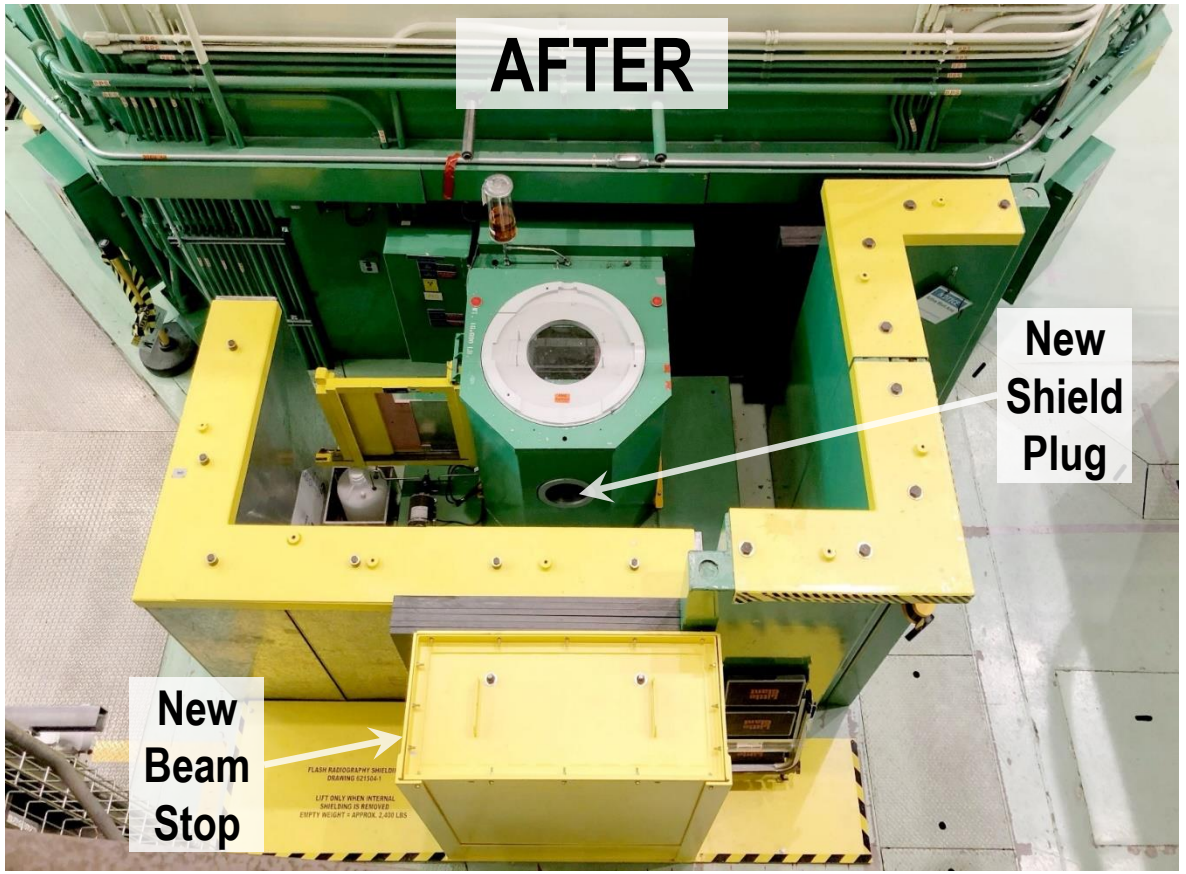
Developing the Hardware



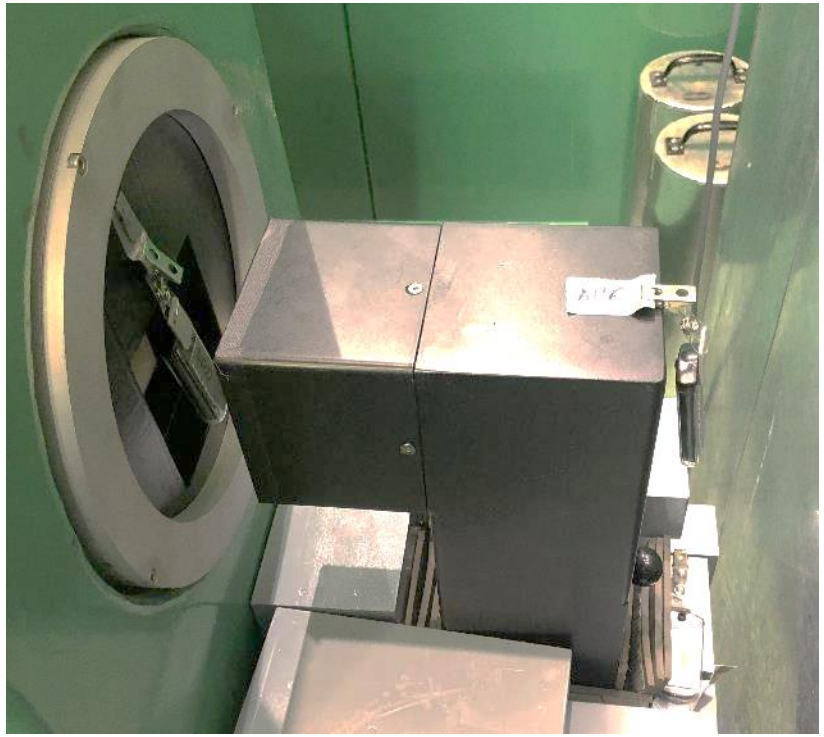


Supplemental Shielding

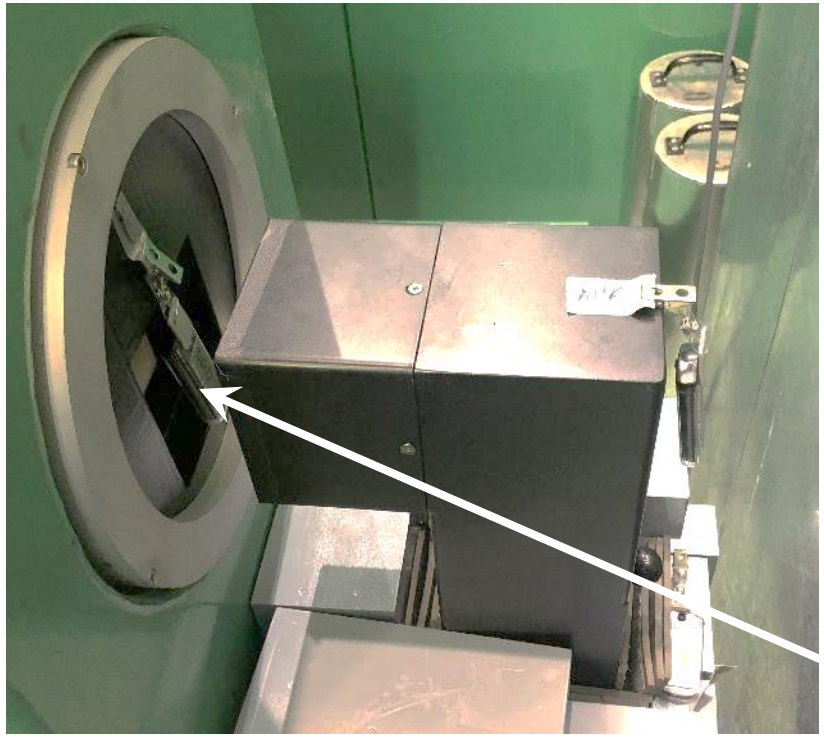




First Measurement – *Just in Time for ITMNR-9*



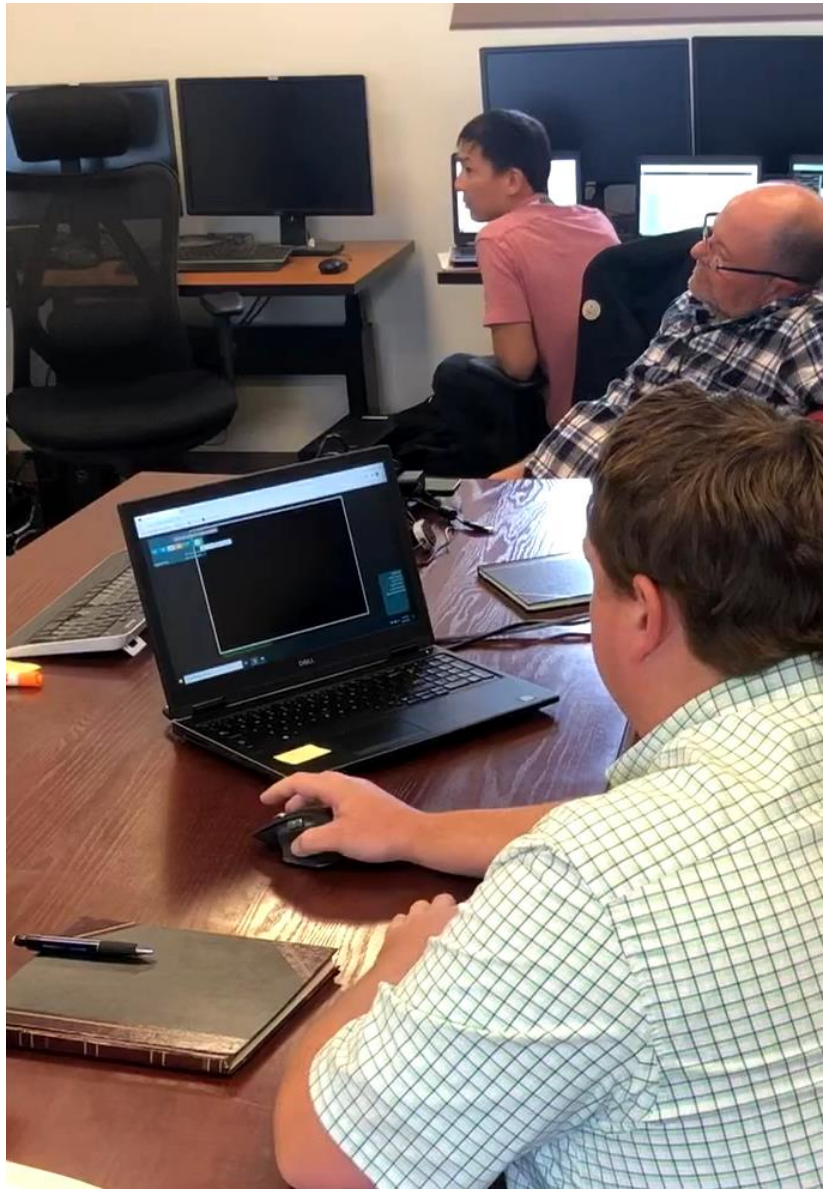
First Measurement – *Just in Time for ITMNR-9*

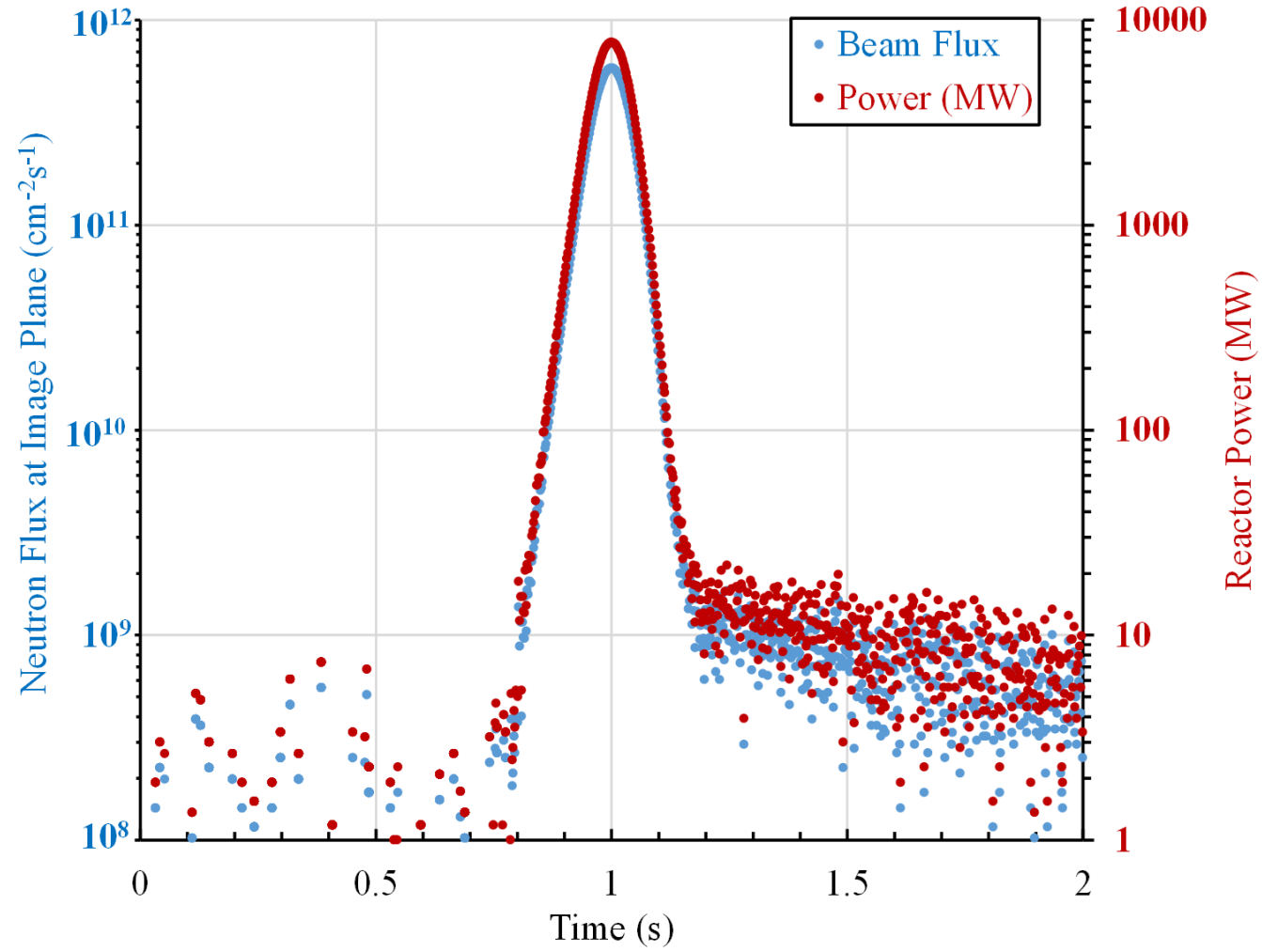


First measurement:

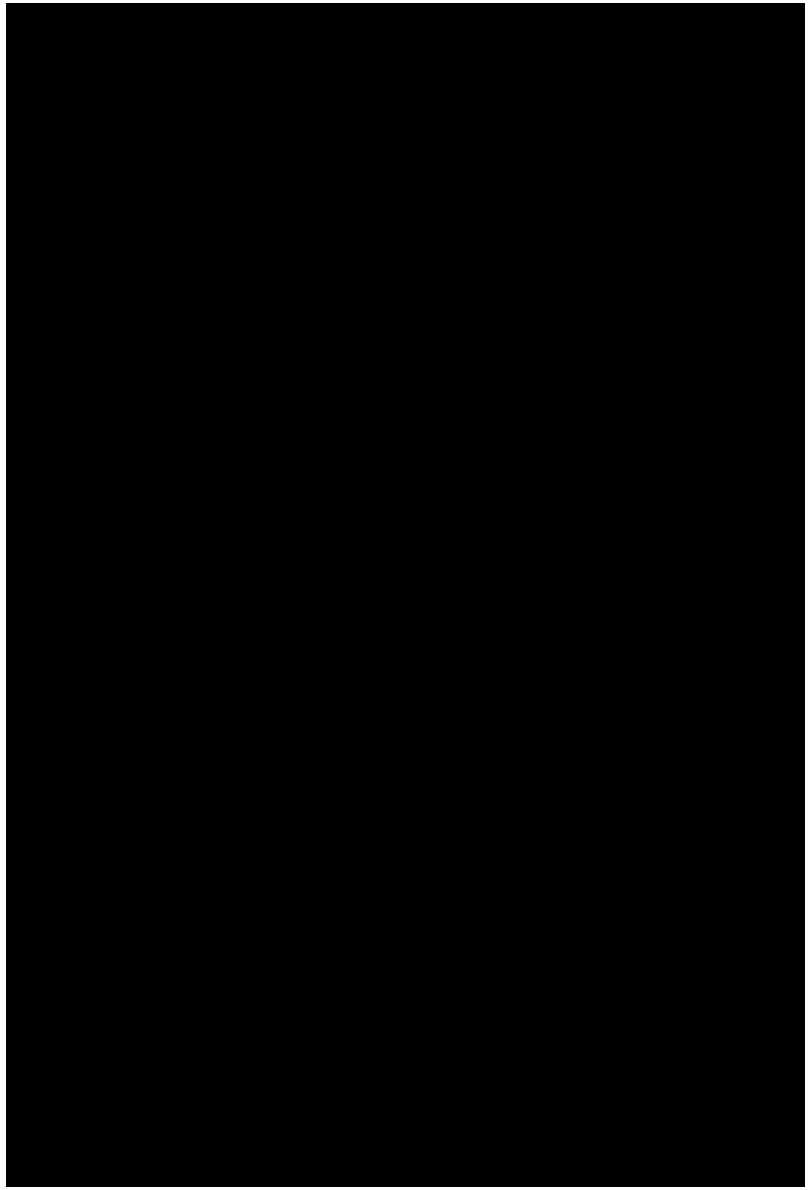
- Camera parameters set to highest sensitivity
- Low frame rate (100 fps)
- Success = Saturation

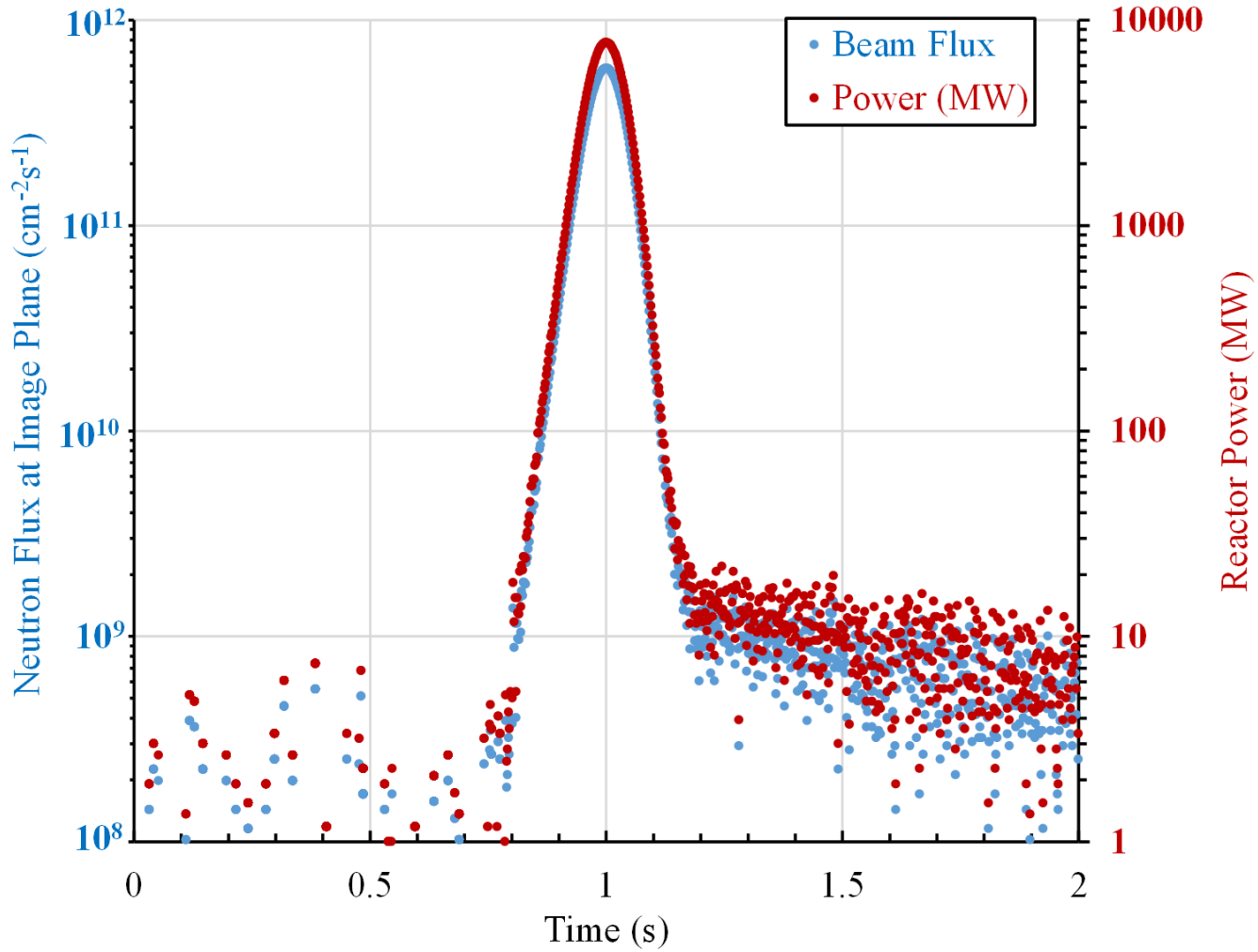
First Measurement – Welcome to the Control Room





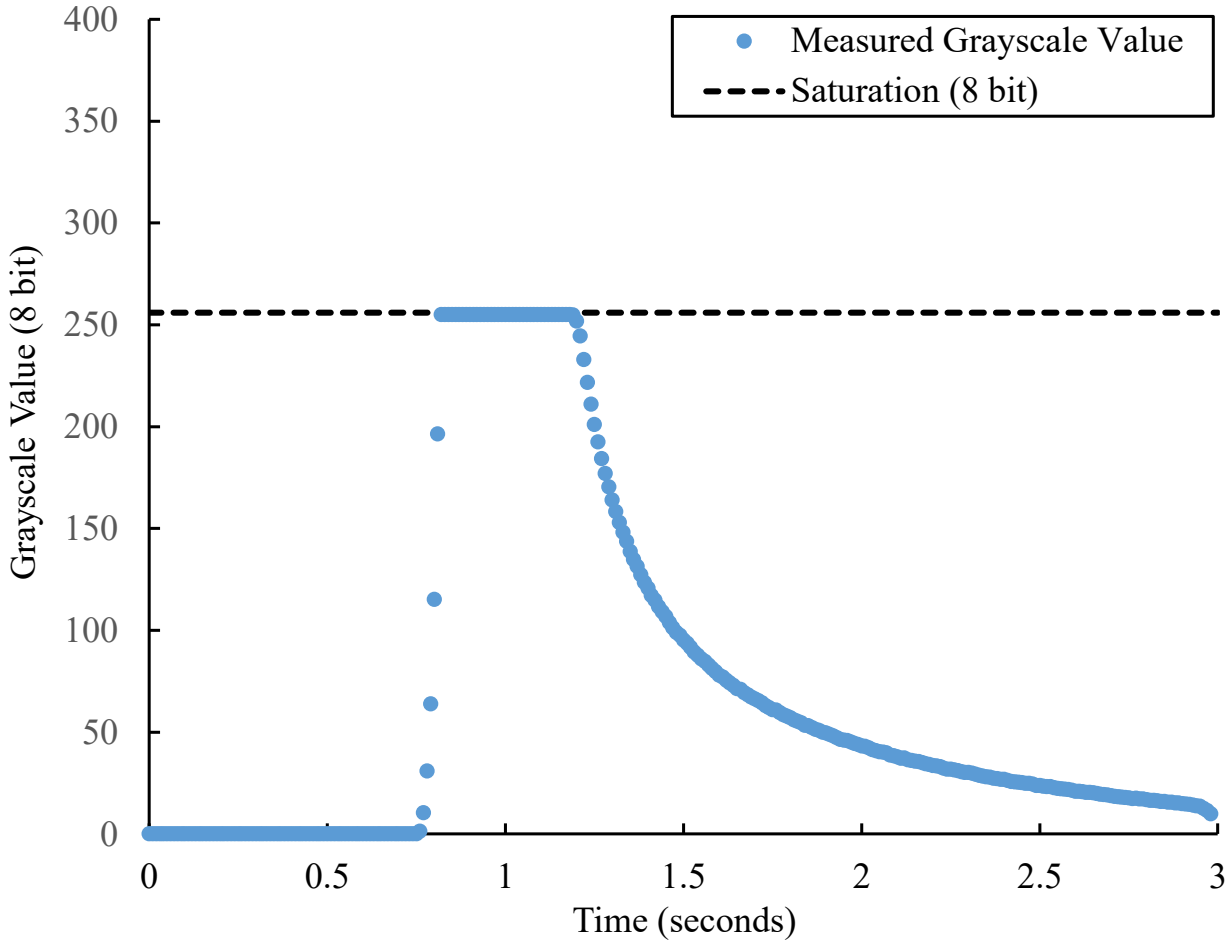
First Measurement – Results



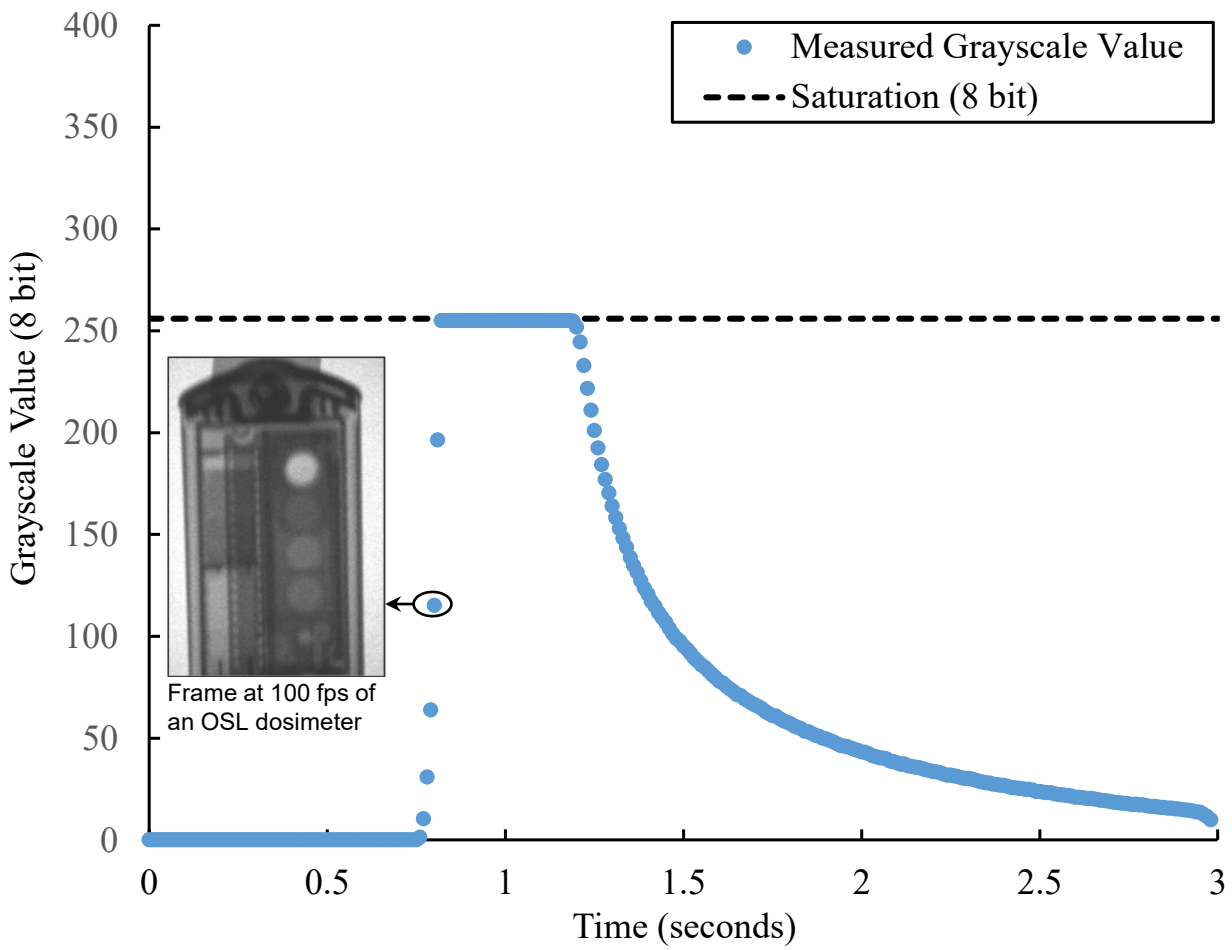


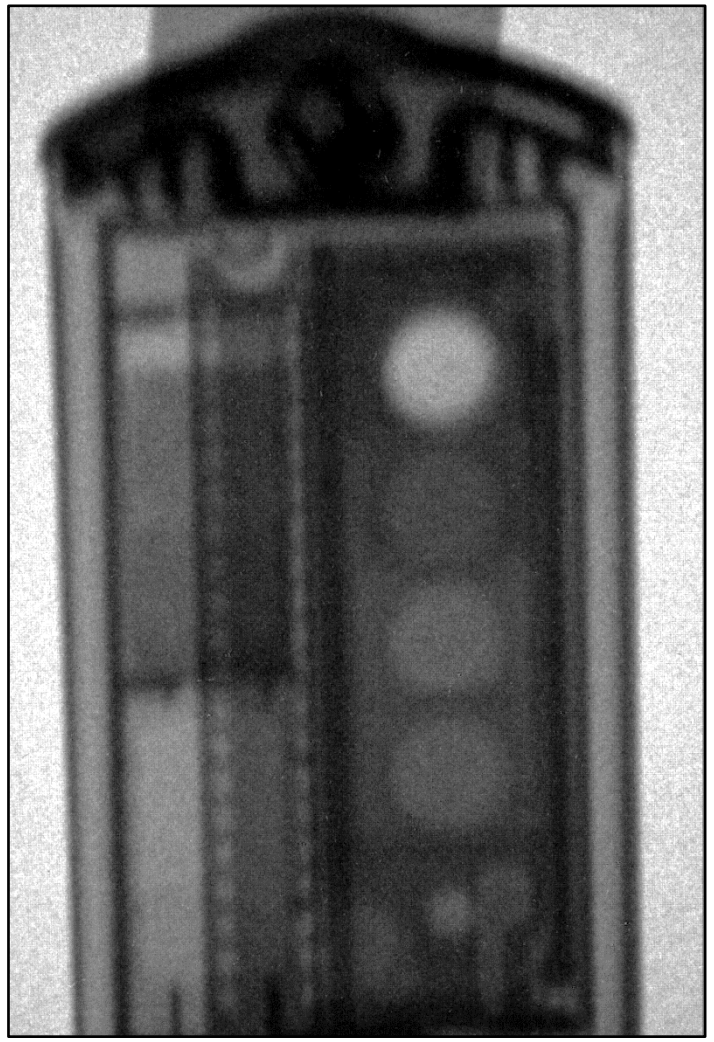
FOV = 62.5 mm × 42.2 mm
pixel size = 48.8 μm
L/D = 75

First Measurement – Results

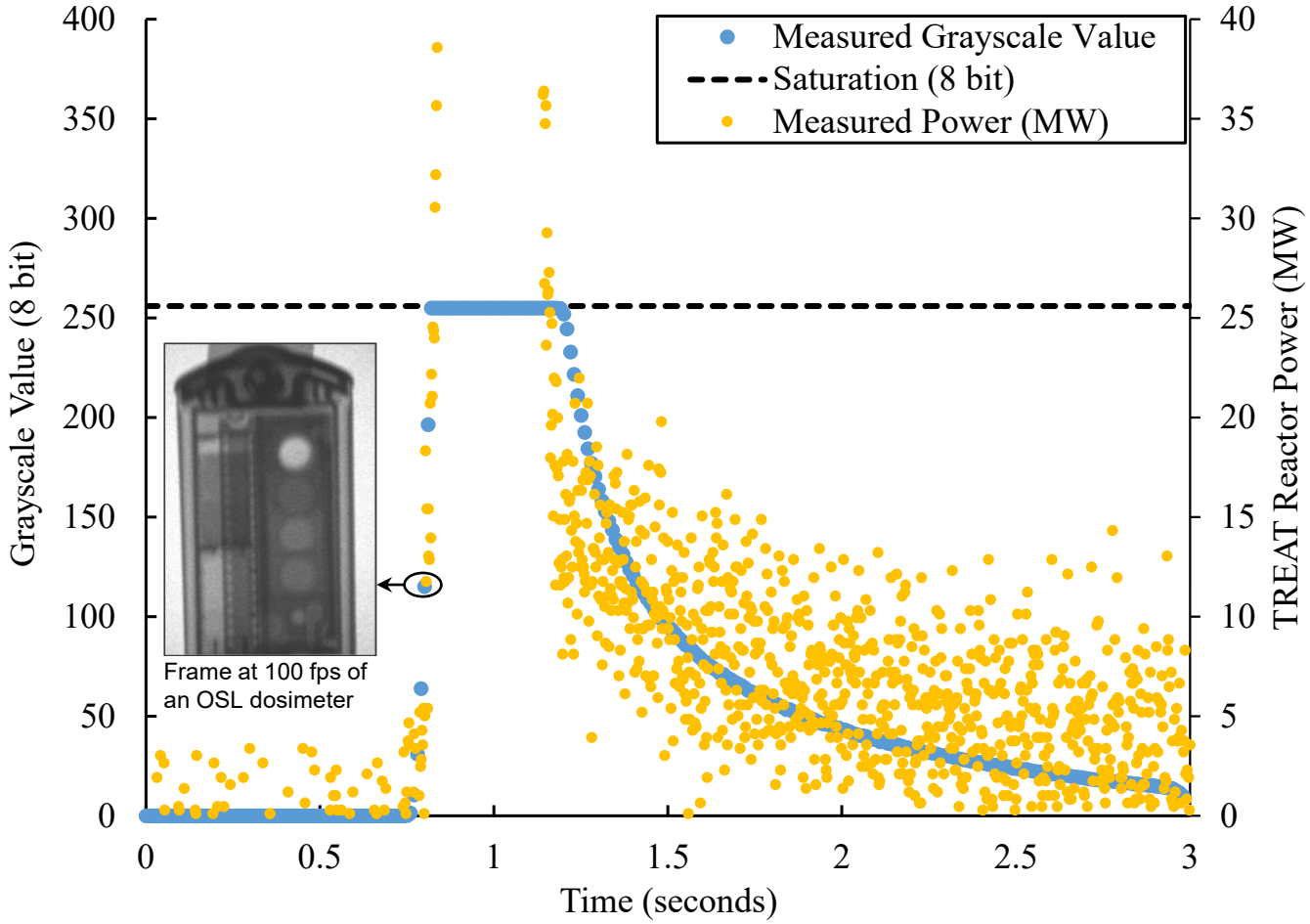


First Measurement – Results





First Measurement – Results



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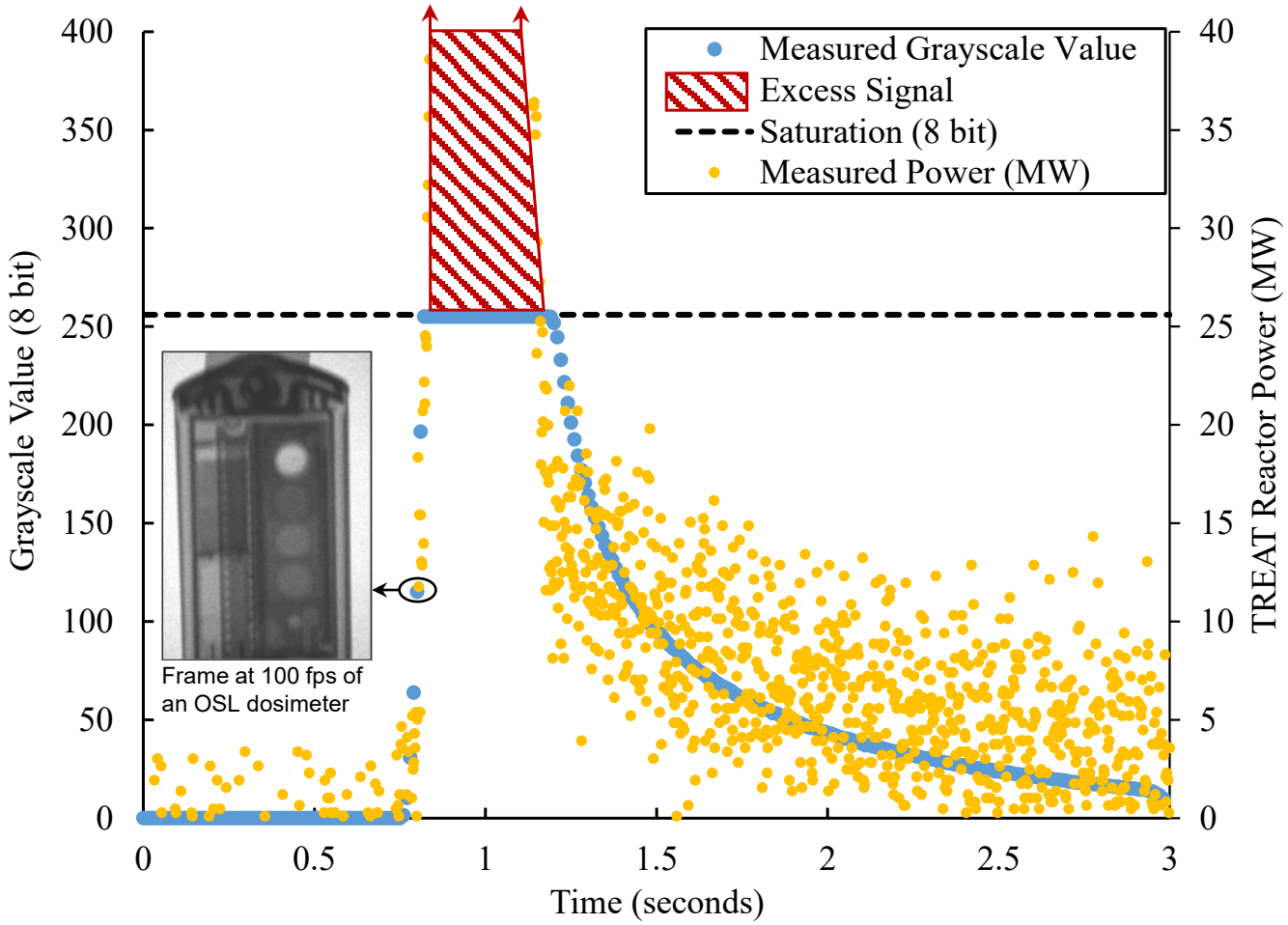
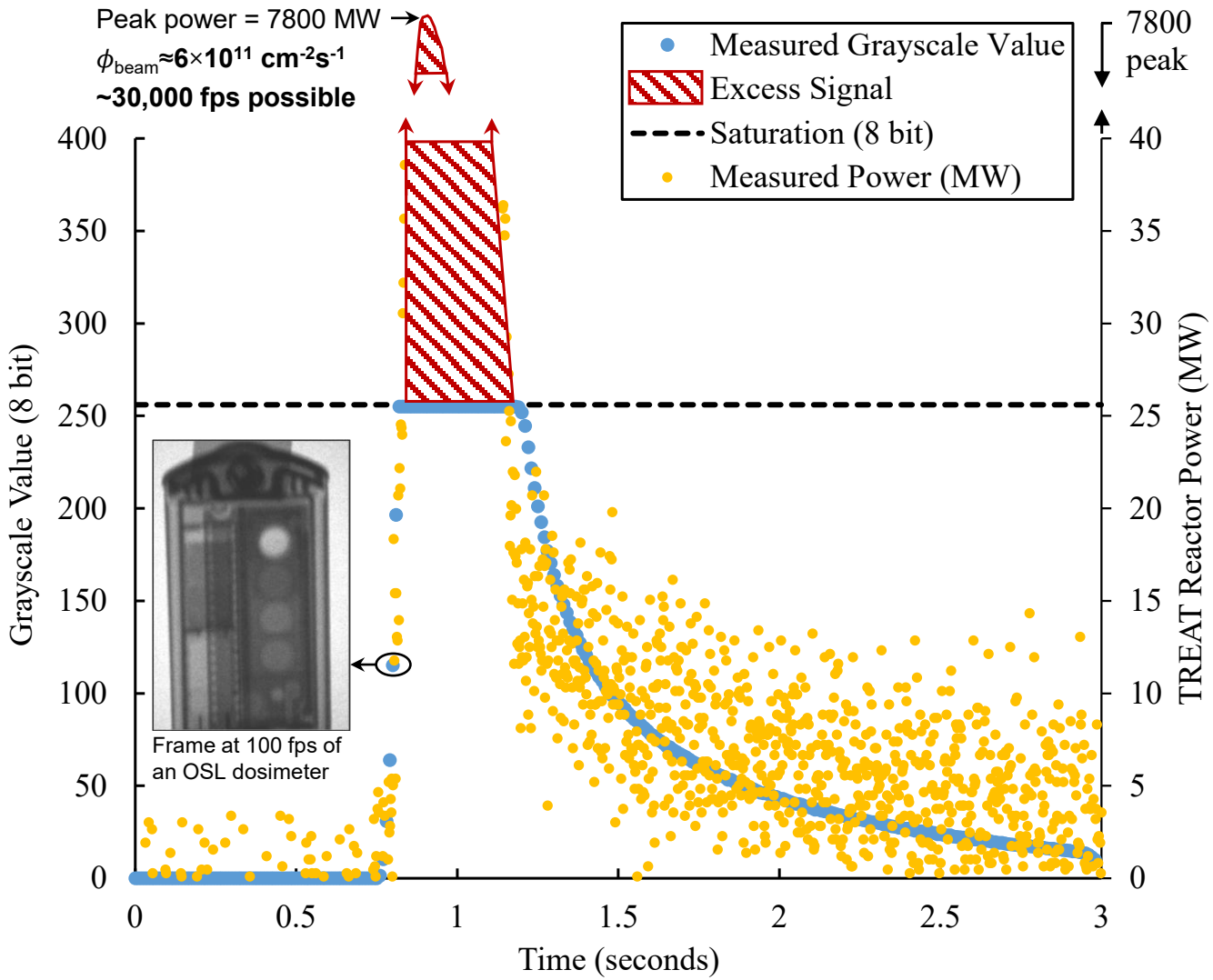
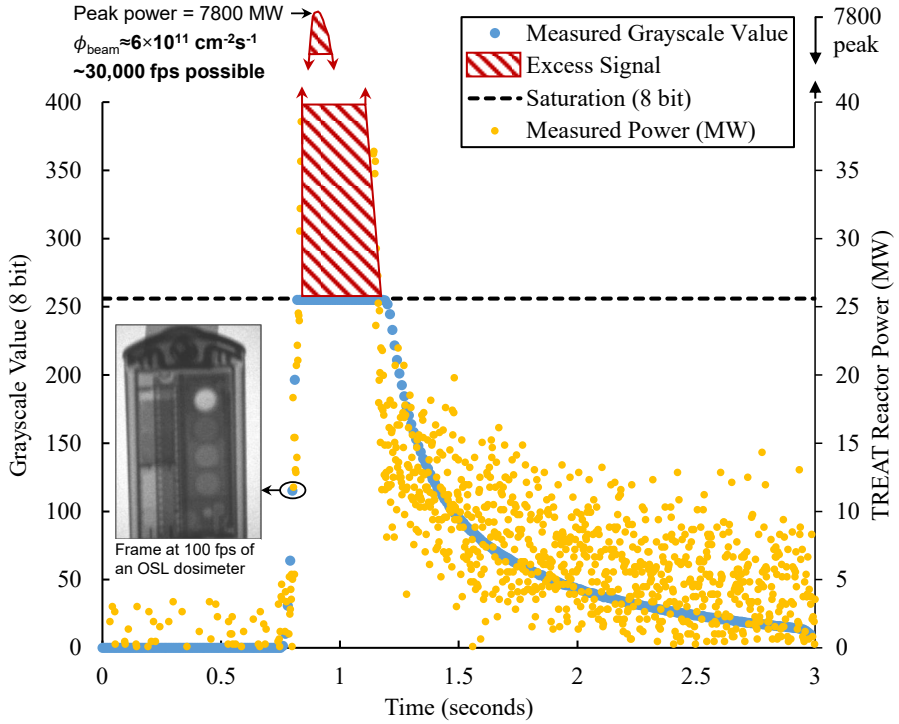


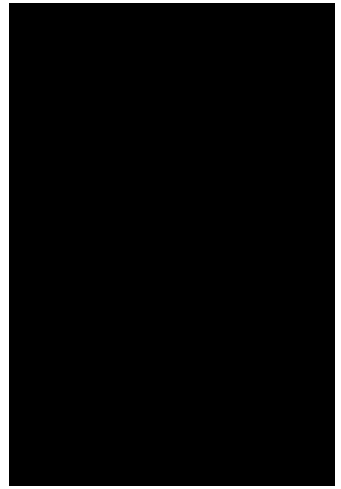
First Measurement – Results



Summary & Next Steps

- Acquired during a **7,800 MW** peak transient
- Neutron beam flux = 6.0×10^{11} $cm^{-2}s^{-1}$ at L/D=75
- Possible frame rate of ~30,000 fps
- Collaborating with university partners to study bubbly flow at PWR conditions.
- Subsequent measurements:
  - Higher frame rate to capture the full transient without saturation
  - Higher spatial resolution
  - Simple bubbly flow column to assess visibility of small bubbles
  - Two-phase flow experiment under PWR temperature and pressure





Idaho National Laboratory

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