



# An Autonomous Critical Data Extrapolator for the AGN-201m

December 2023

*Changing the World's Energy Future*

Jaden Sonny Palmer



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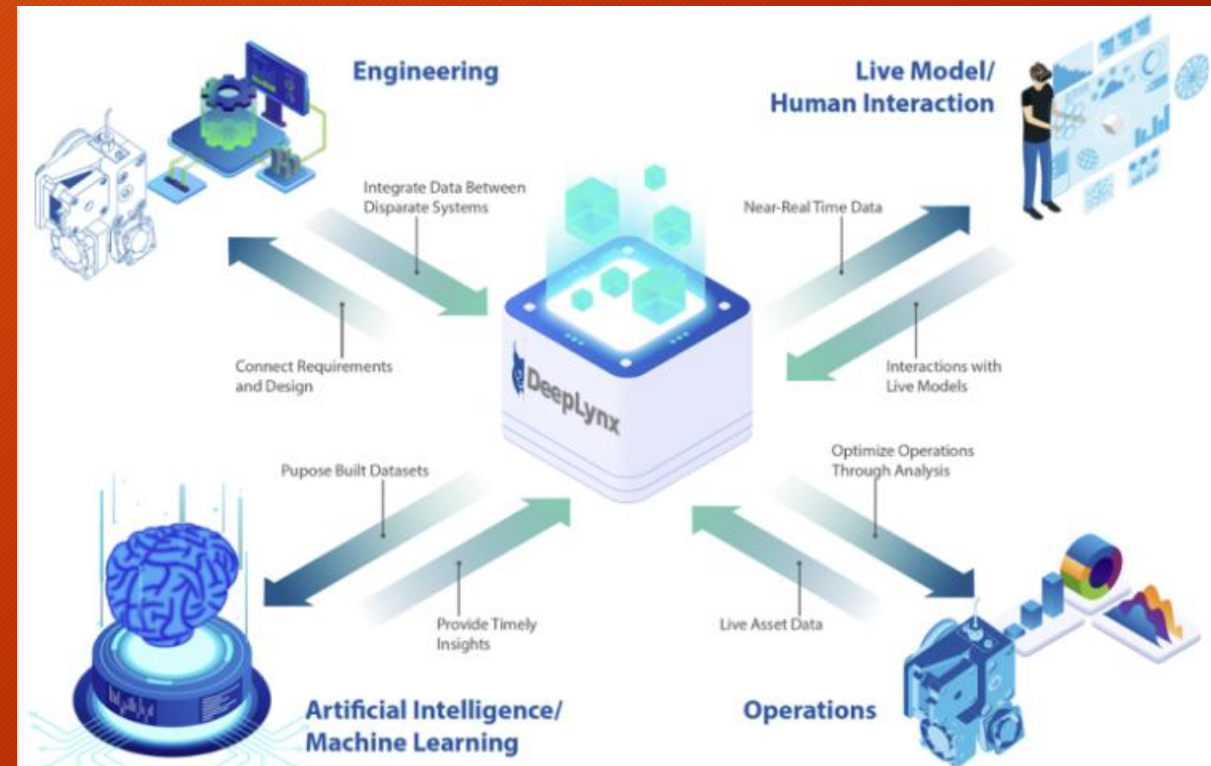
# An Autonomous Critical Data Extrapolator for the AGN-201m

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# Historical Research

**Digital Twin:** A virtual model capable of sufficiently describing a physical system (Nuclear Reactor).

- Development of a safe-guards digital twin to detect nuclear proliferation [1].
  - Real time anomaly detection to detect abnormal operation conditions
- No previous digital twins created for an operating nuclear reactor!

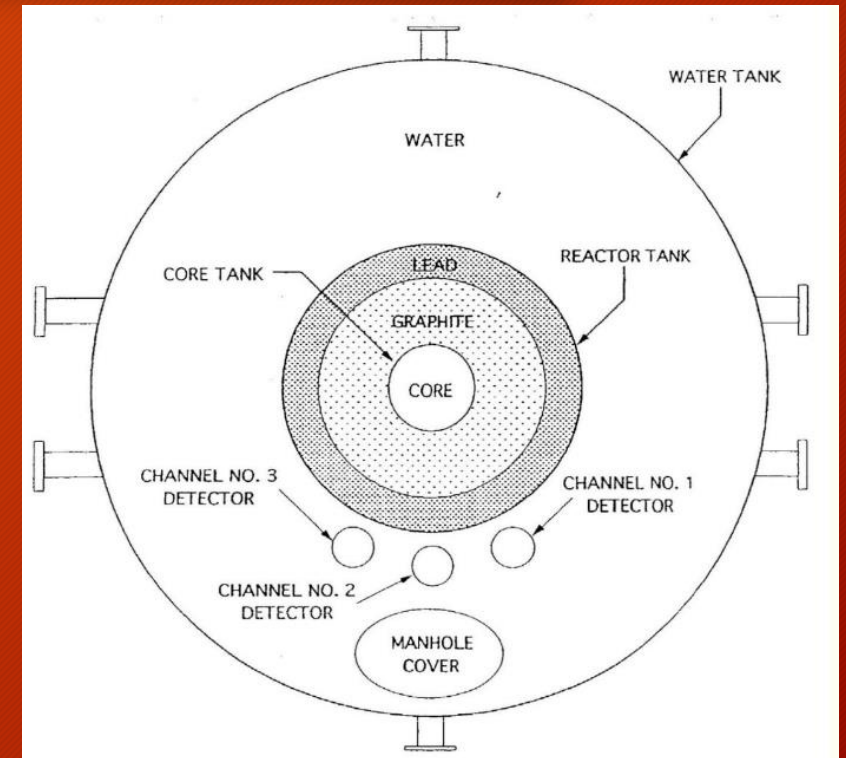


Credit: Stewart et al, *A digital twin of the AGN-201 reactor to simulate nuclear proliferation*

# AGN-201m Data Collection

## Four Main Sources of Data [2]:

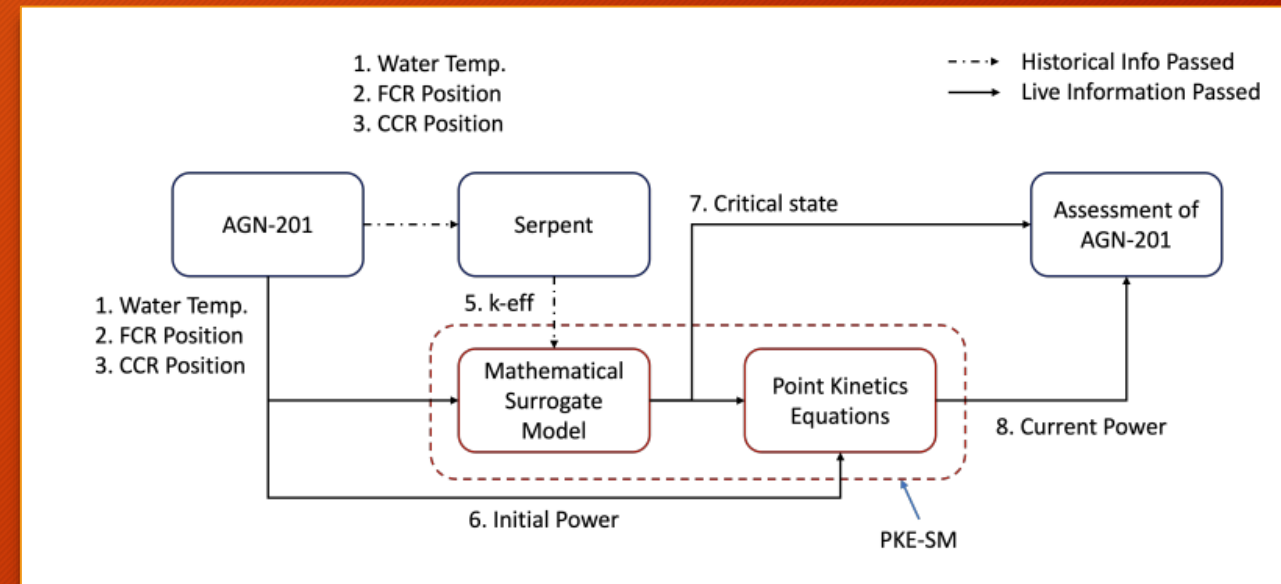
- Channel 2: Measures reactor power on a logarithmic scale & reactor period
- Channel 3: Measures reactor power on a linear scale
- Coarse Control Rod (CCR): Typically, at or near full insertion (25 cm)
- Fine Control Rod (FCR): Typically, adjusted until the reactor reaches criticality at desired power



Credit: Pope et. al. Idaho State University  
AGN-201 Low Power Teaching Reactor - An  
Overlooked Gem

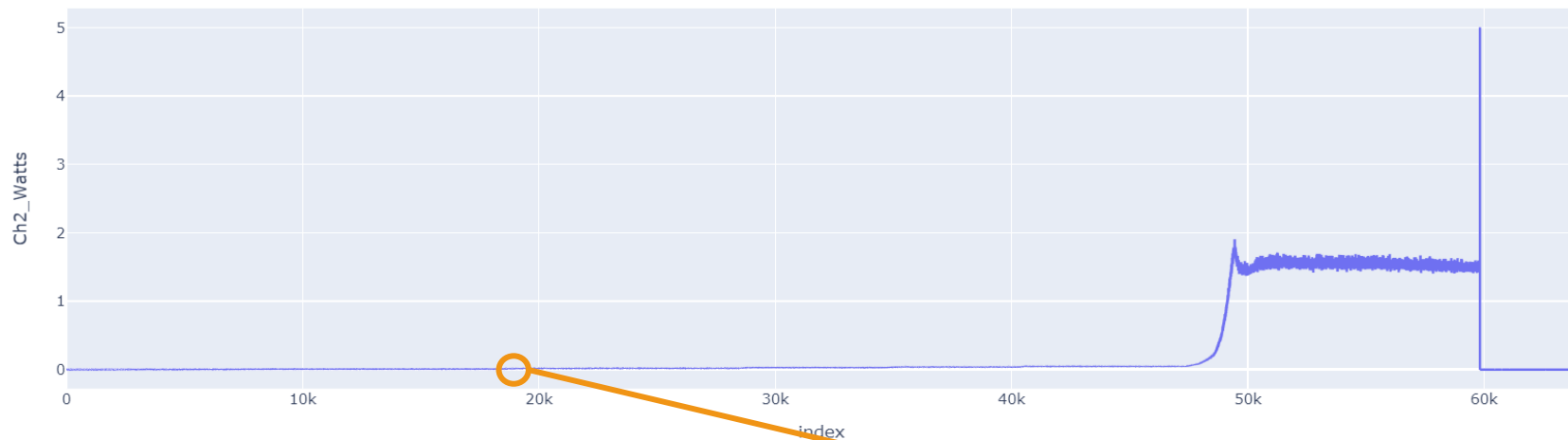
# AGN-201m Reactor Physics Model

- Water temperature, FCR, and CCR data is used in Serpent predict K-effective [3].
- Surrogate model will constantly in these variables to constantly determine K-effective
- First iteration of K-effective must be determined from critical data



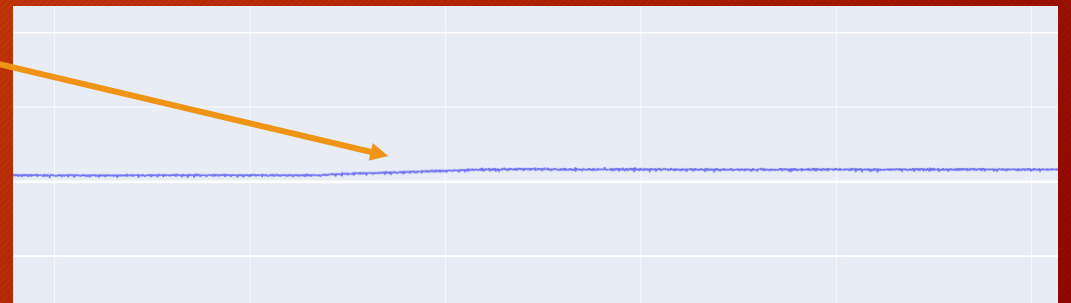
Credit: Stewart et al, *A digital twin of the AGN-201 reactor to simulate nuclear proliferation*

# Recognizing Reactor Startup



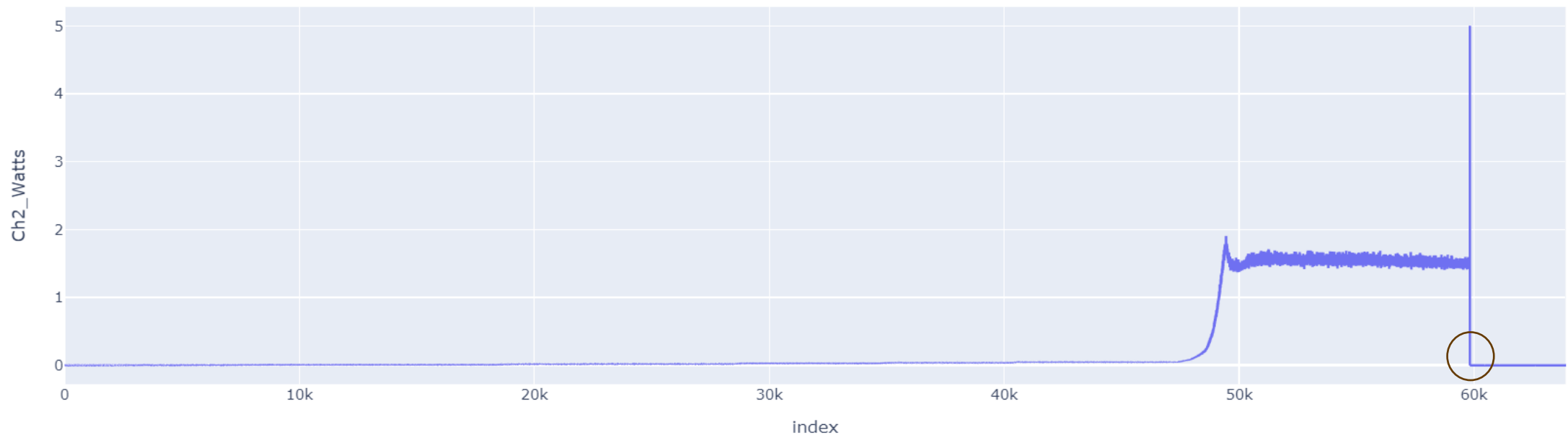
\* Slopes  
taken over 1  
second  
interval of  
data

- Detect initial increase in slope of power (Super-Critical)
- Detect stabilization of slope of power (Critical)
- General critical power  $\sim 10$  mW





# Recognizing Reactor Shutdown



Detect dropping of control rods out of the reactor:

- Fine Control Rod
- Coarse Control Rod

# Flow of Data Through Critical Extrapolator

All Data Before Super-Critical is Cut

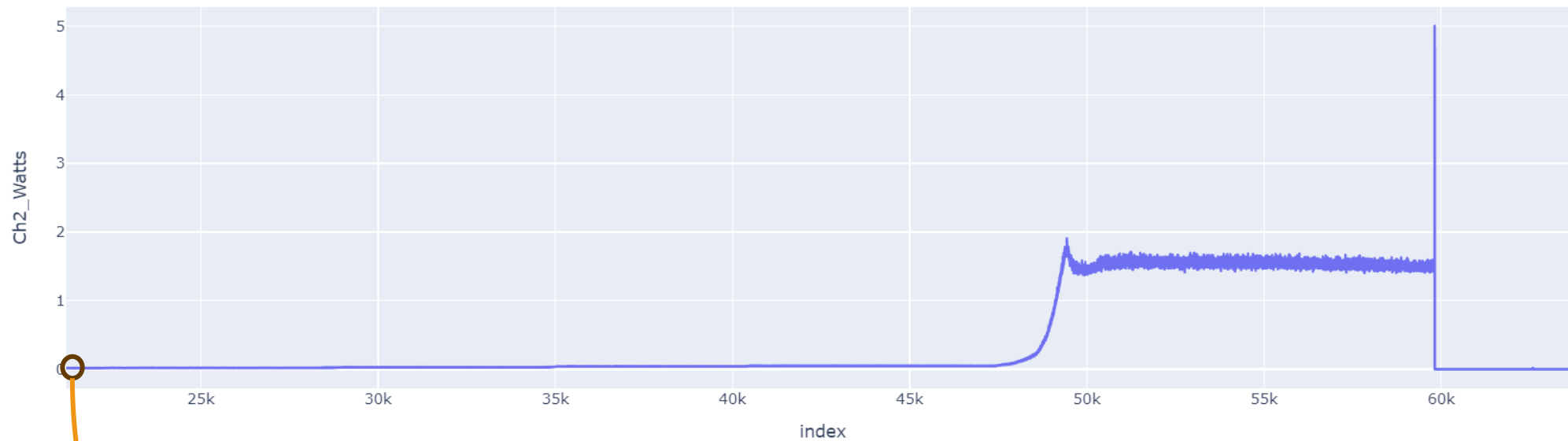
Data Before Critical Startup is Detected is Cut

Data After Shutdown is Cut



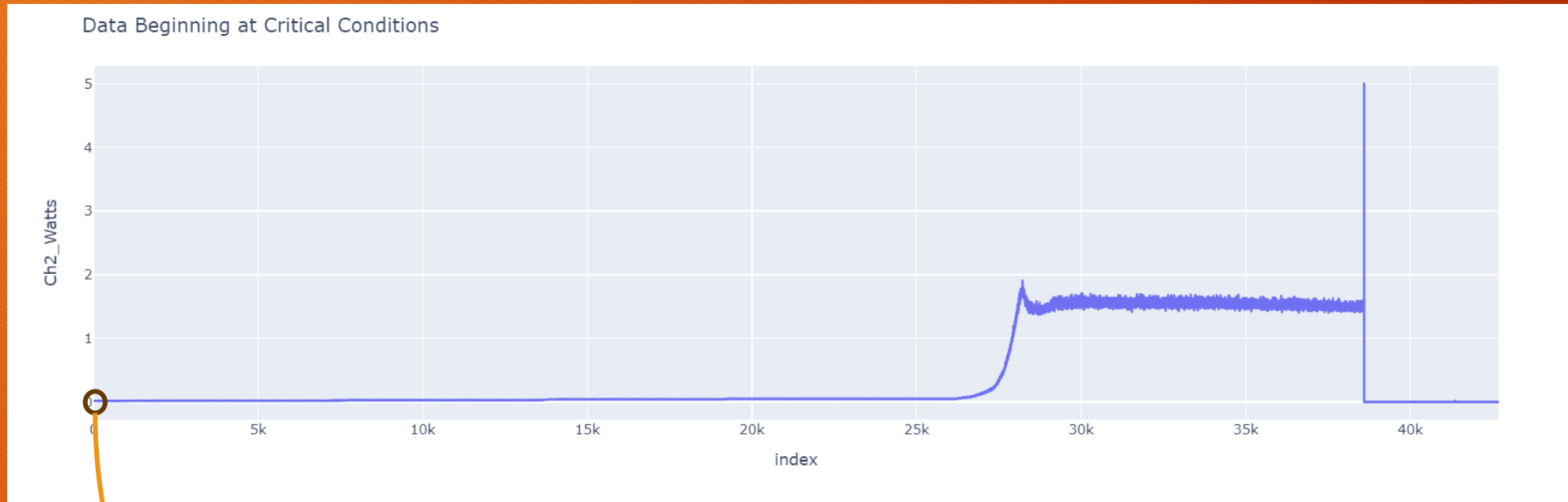
# Super-Critical Recognition

Data Beginning at Super-Critical Conditions



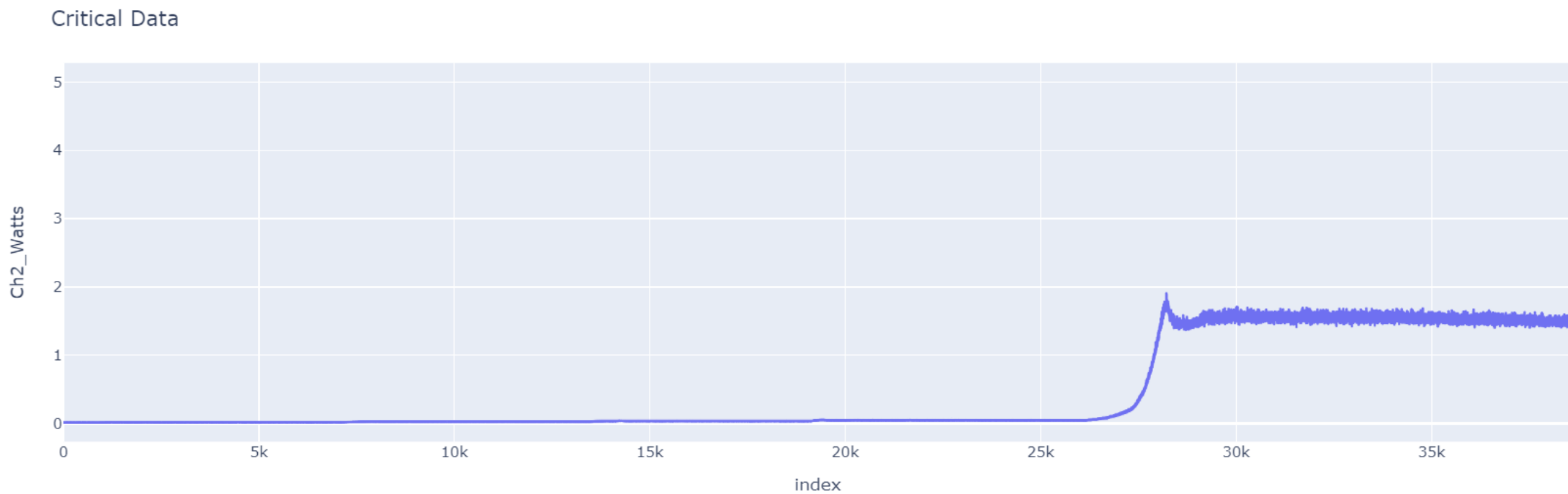
Power at point of cut: ~15.94 mW

# Critical Data Recognition



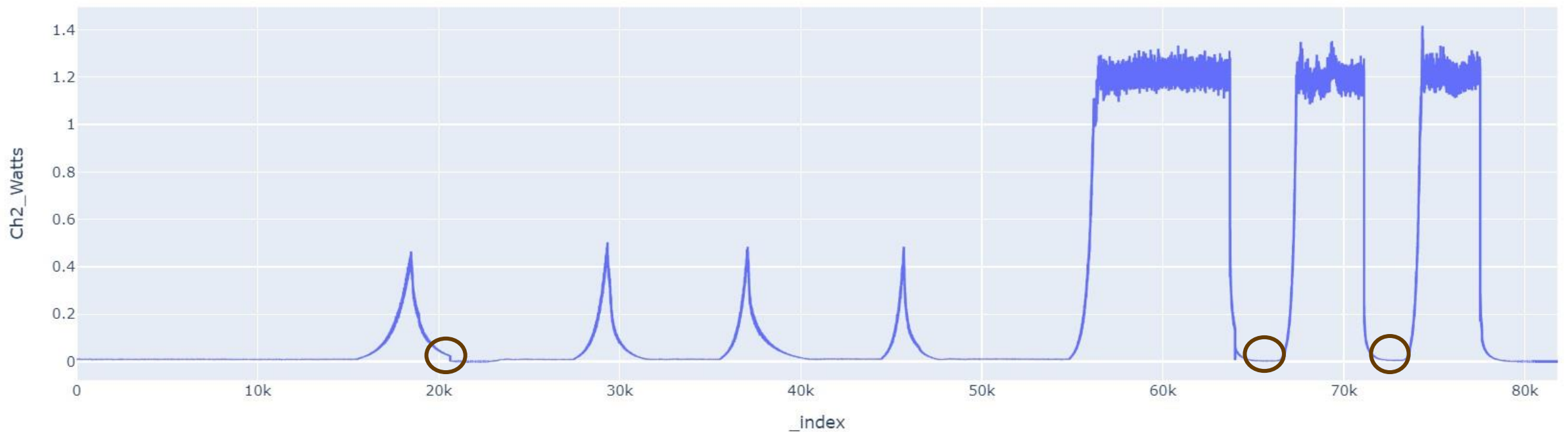
Power at point of cut: ~17.10 mW

# Shutdown Recognition (Final Dataset)



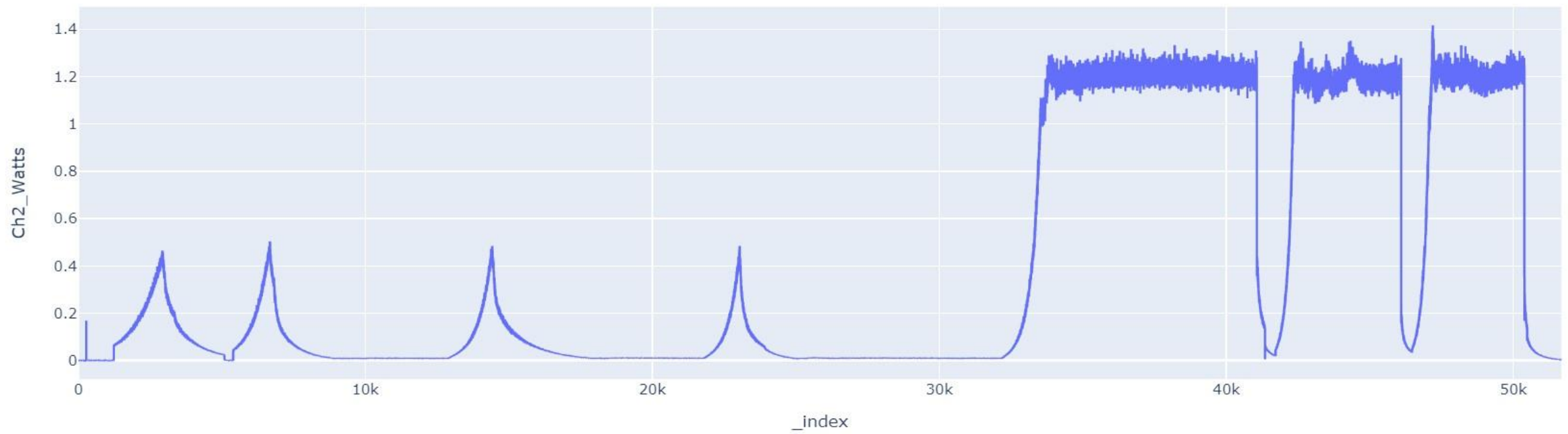
# Iterative Loop: Critical Data After Shutdown Recognition

Shutdown detected at multiple points after startup.



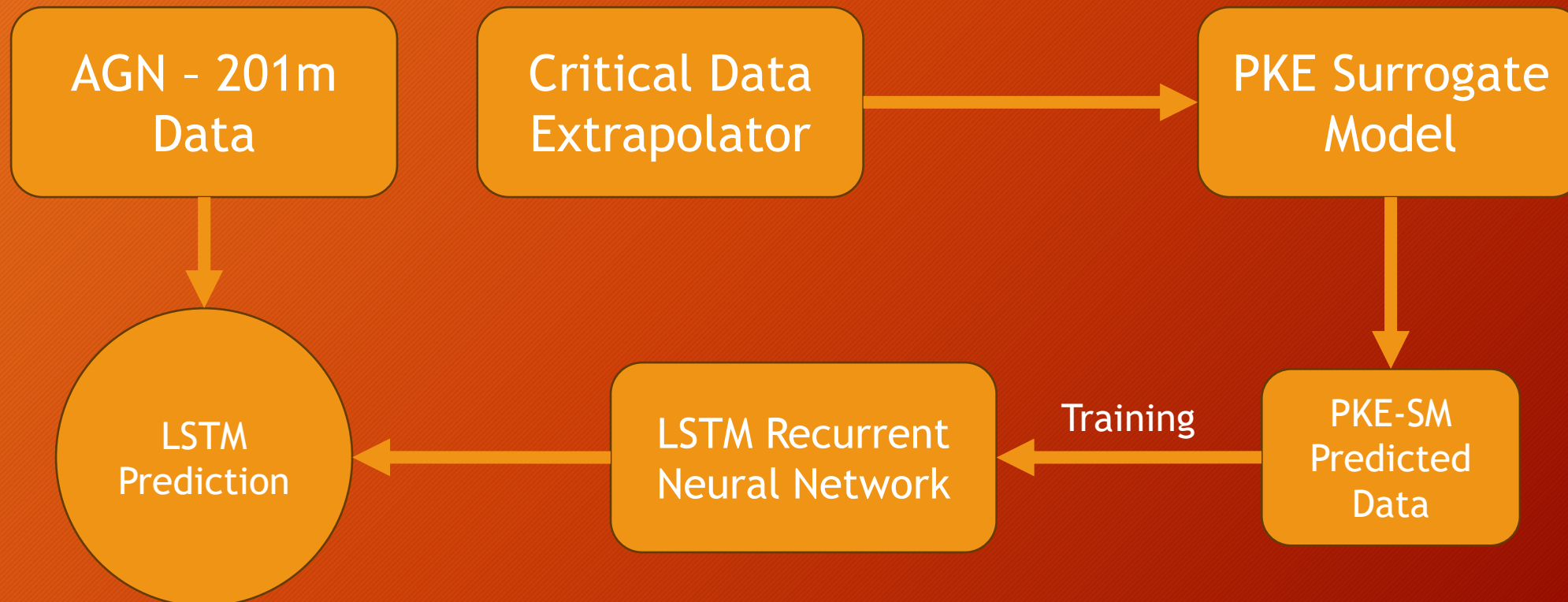
# Final Dataset

Data Beginning at Super-Critical Conditions



# Future Initiatives

- Executing the critical extrapolator live within the digital twin





# References

1. Ritter, C., Hays, R., Browning, J., Stewart, R., Bays, S., Reyes, G., Schanfein, M., Pluth, A., Sabharwall, P., Kunz, R., Shields, A., Koudelka, J., & Zohner, P. (2022). Digital twin to detect nuclear proliferation: A case study. *Journal of Energy Resources Technology*, 144(10). <https://doi.org/10.1115/1.4053979>
2. L. Pope, C., & Phoenix, W. (2022). Idaho State University AGN-201 low power teaching reactor: An overlooked gem. *Nuclear Reactors - Spacecraft Propulsion, Research Reactors, and Reactor Analysis Topics*. <https://doi.org/10.5772/intechopen.105799>
3. Stewart, R., Shields, A., Pope, C. L., Darrington, J., Wilsdon, K., Bays, S., Heaps, K., Ritter, C., Palmer, J., Trevino, E., Schanfein, M., Reyes, G., Scott, J., & Woodruff, N. (2023). *A Digital Twin of the AGN-201 Reactor to Simulate Nuclear Proliferation*.