INL/MIS-23-75763-Revision-0

An Autonomous Critical Data Extrapolator for the AGN-201m

December 2023

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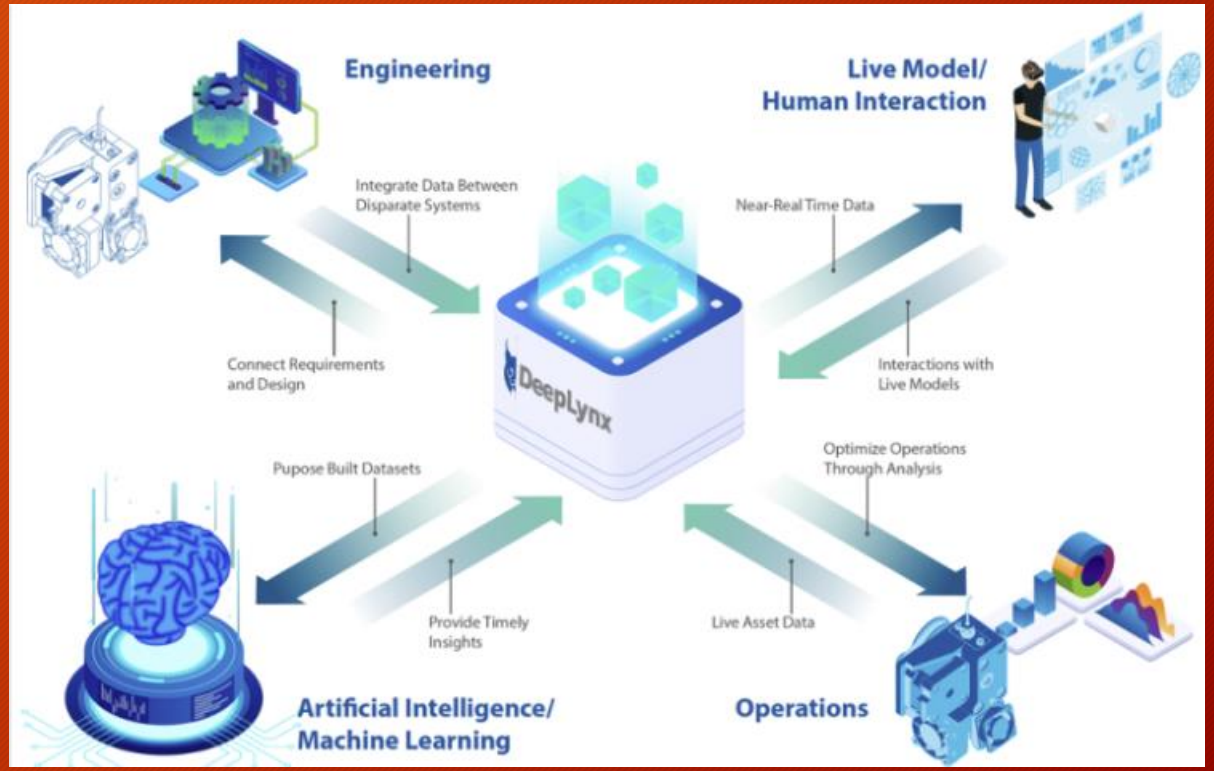
Historical Research

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!

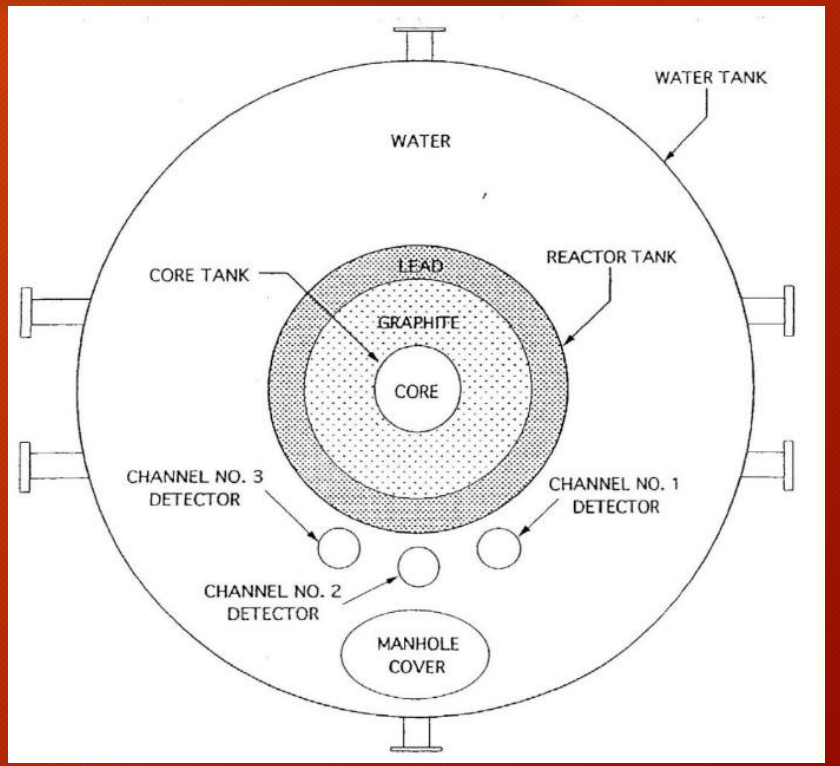


Credit: Stewart et al, *A digital twin of the AGN-201 reactor to simulate nuclear proliferation*

AGN-201m Data Collection

Four Main Sources of Data [2]:

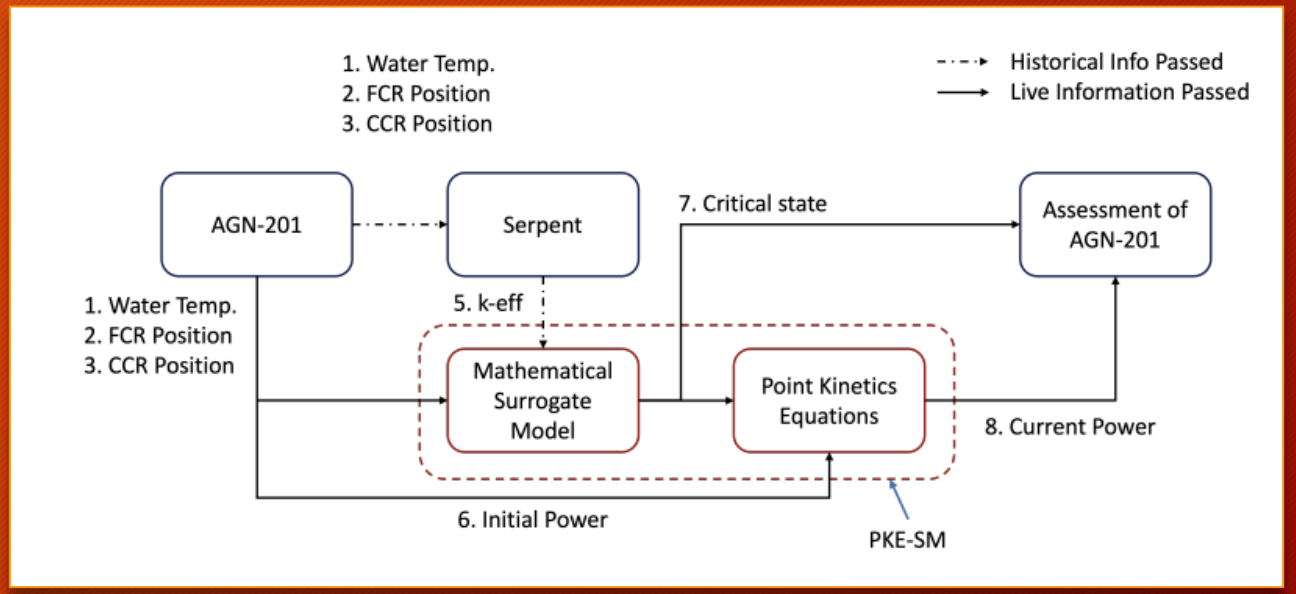
- Channel 2: Measures reactor power on a logarithmic scale & reactor period
- Channel 3: Measures reactor power on a linear scale
- Coarse Control Rod (CCR): Typically, at or near full insertion (25 cm)
- Fine Control Rod (FCR): Typically, adjusted until the reactor reaches criticality at desired power



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

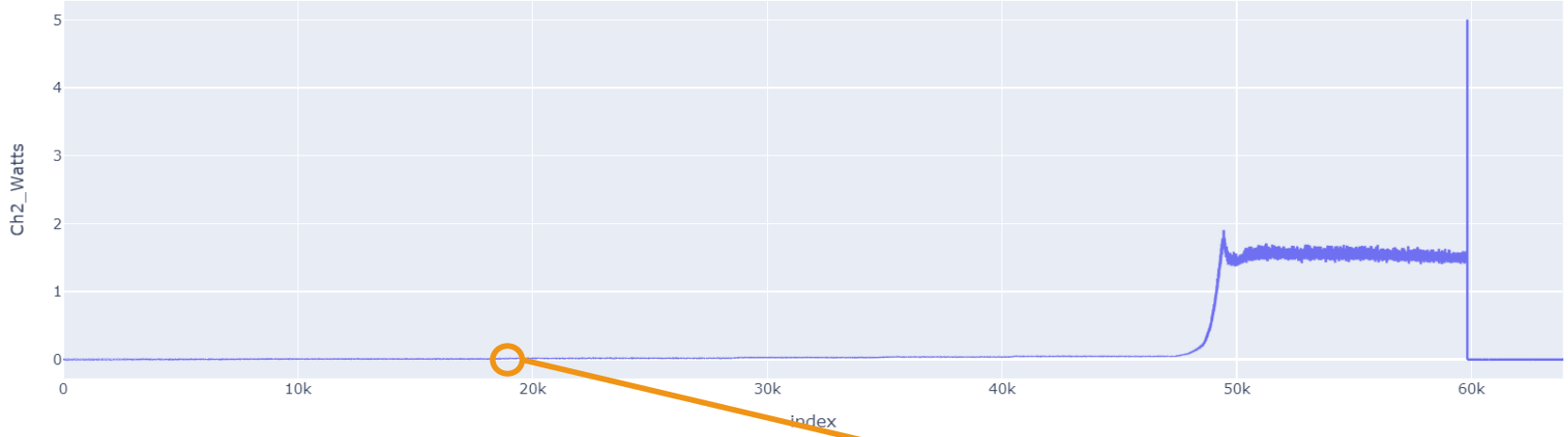
AGN-201m Reactor Physics Model

- 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

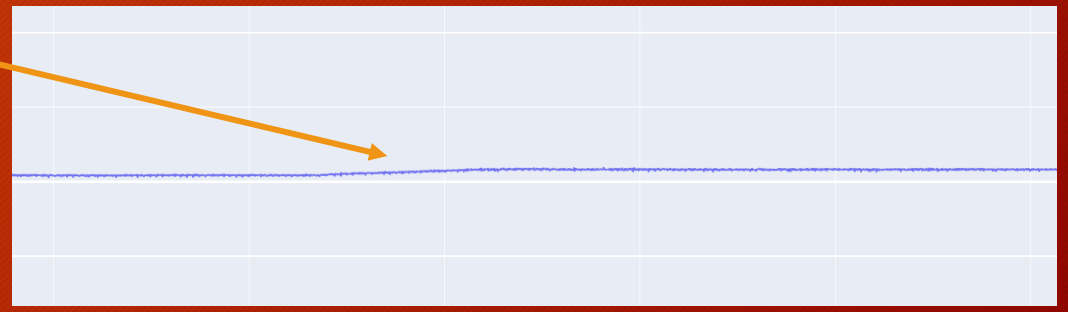


Credit: Stewart et al, *A digital twin of the AGN-201 reactor to simulate nuclear proliferation*

Recognizing Reactor Startup

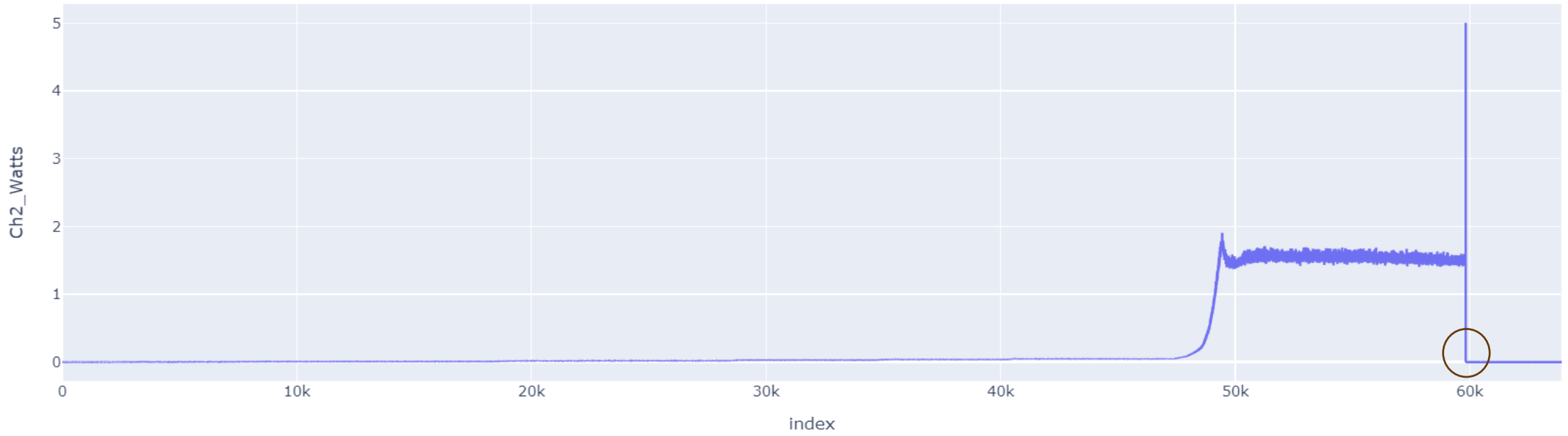


* Slopes taken over 1 second interval of data



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

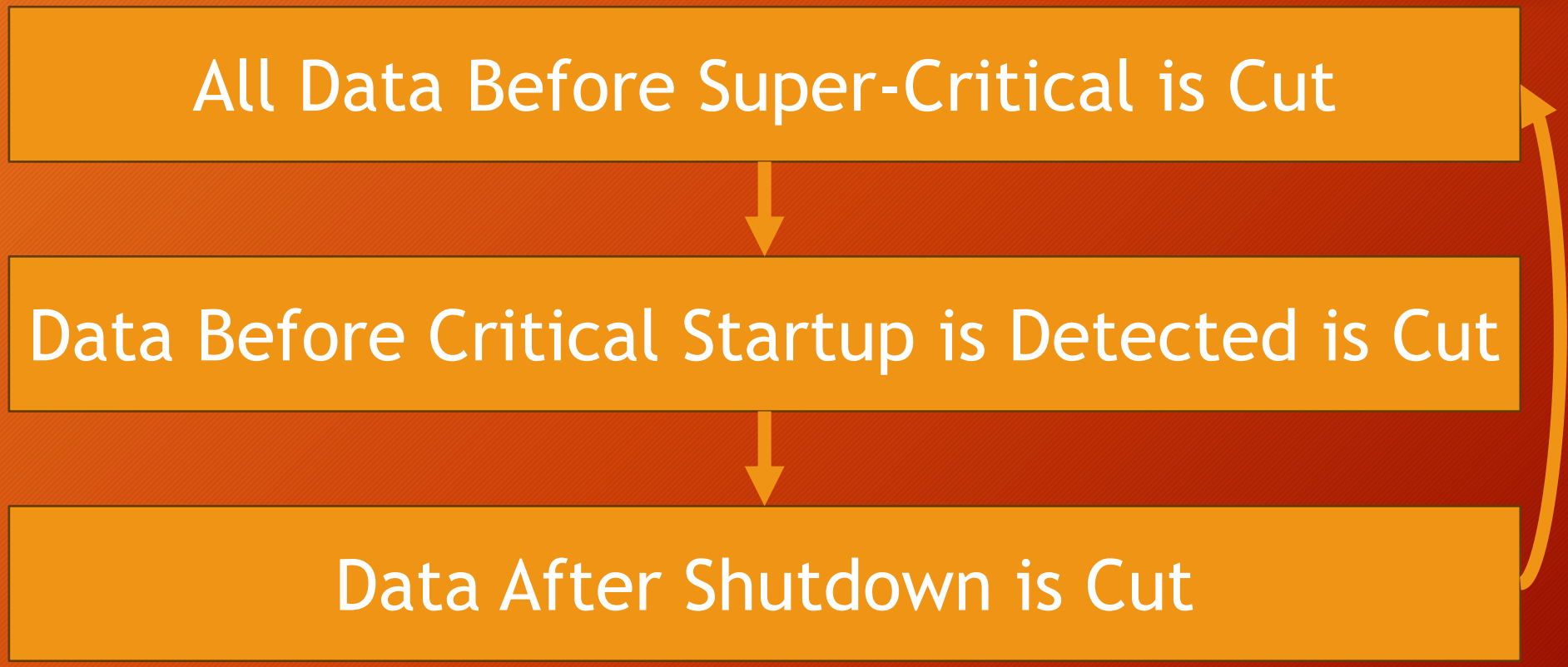
Recognizing Reactor Shutdown



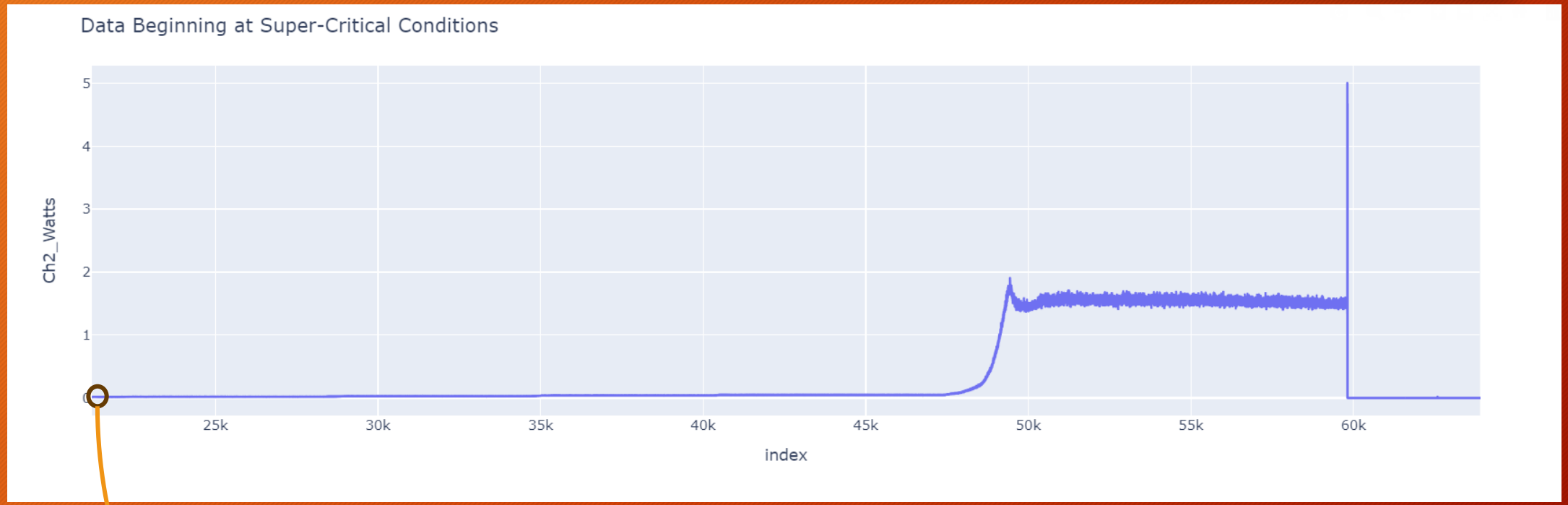
Detect dropping of control rods out of the reactor:

- Fine Control Rod
- Coarse Control Rod

Flow of Data Through Critical Extrapolator

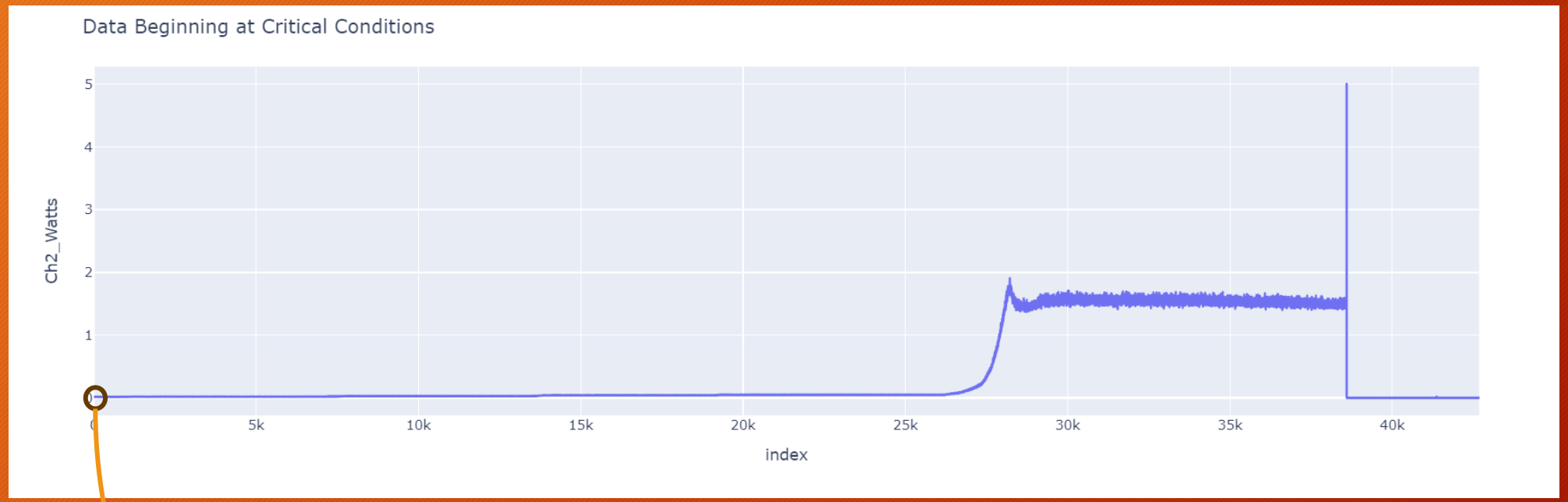


Super-Critical Recognition



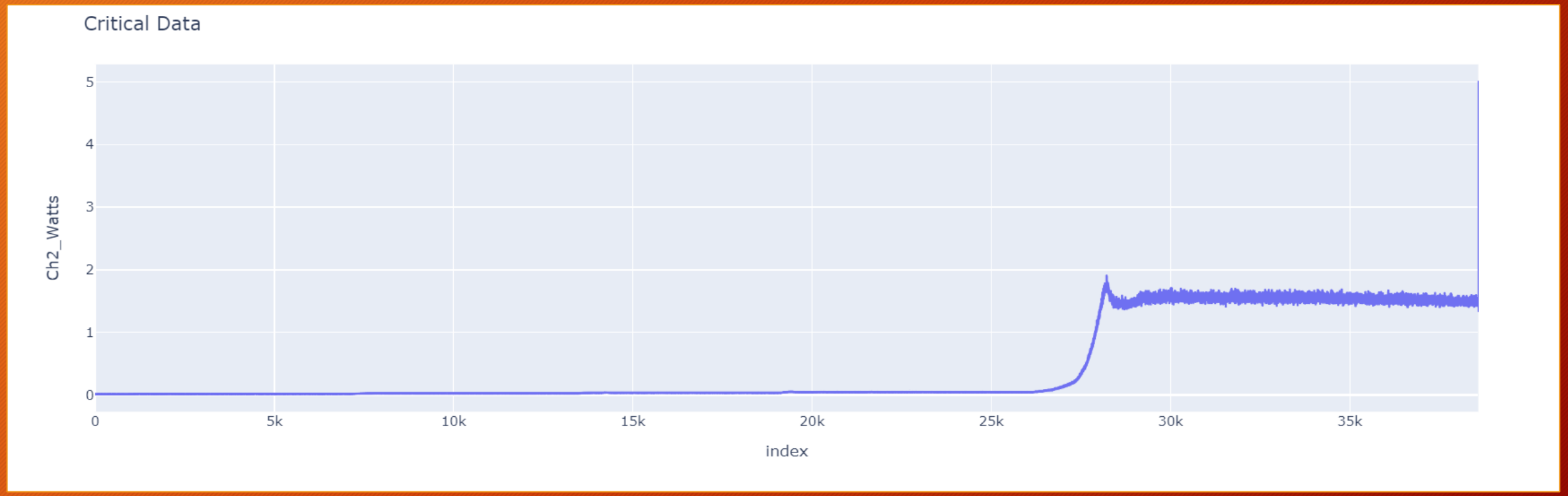
Power at point of cut: ~15.94 mW

Critical Data Recognition



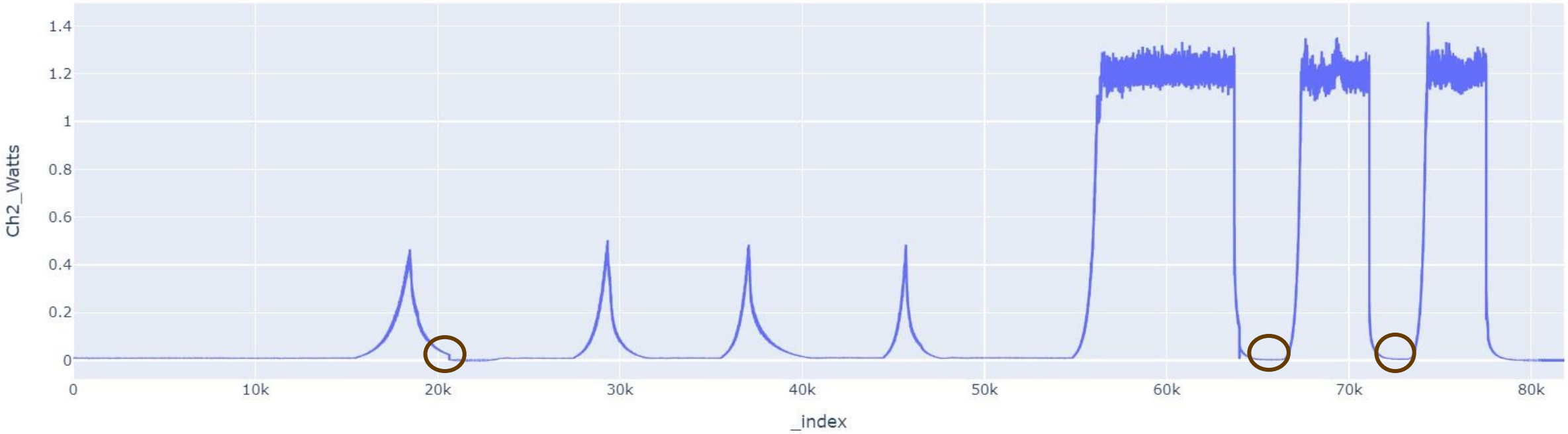
Power at point of cut: ~17.10 mW

Shutdown Recognition (Final Dataset)

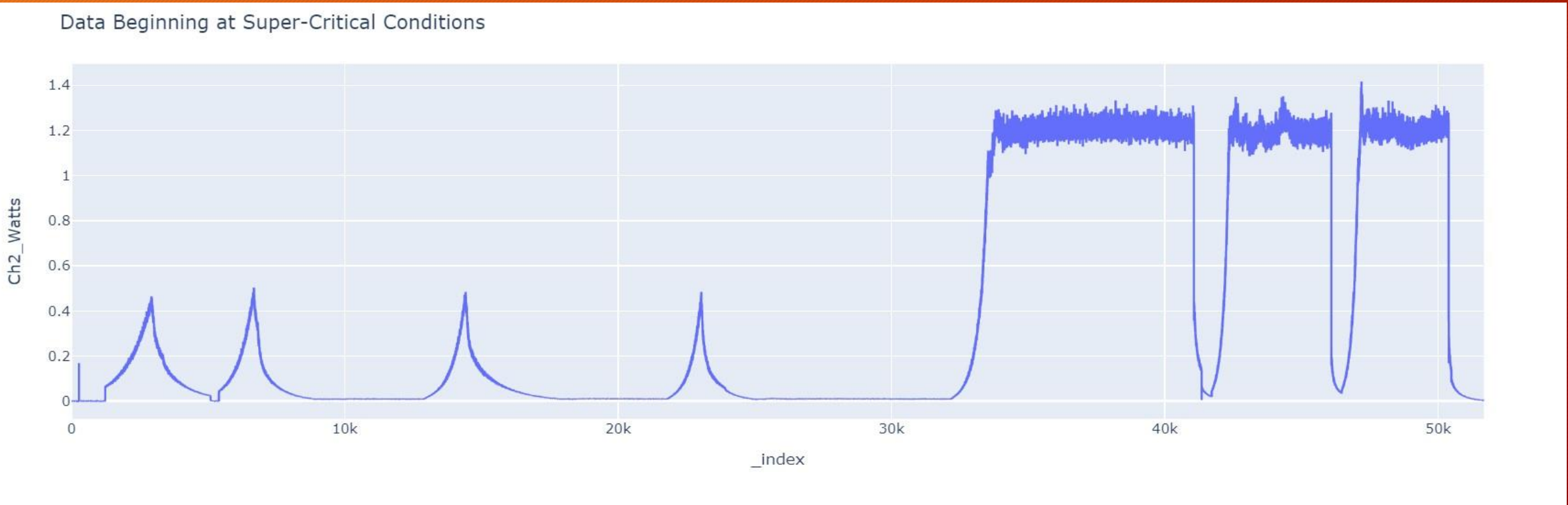


Iterative Loop: Critical Data After Shutdown Recognition

Shutdown detected at multiple points after startup.

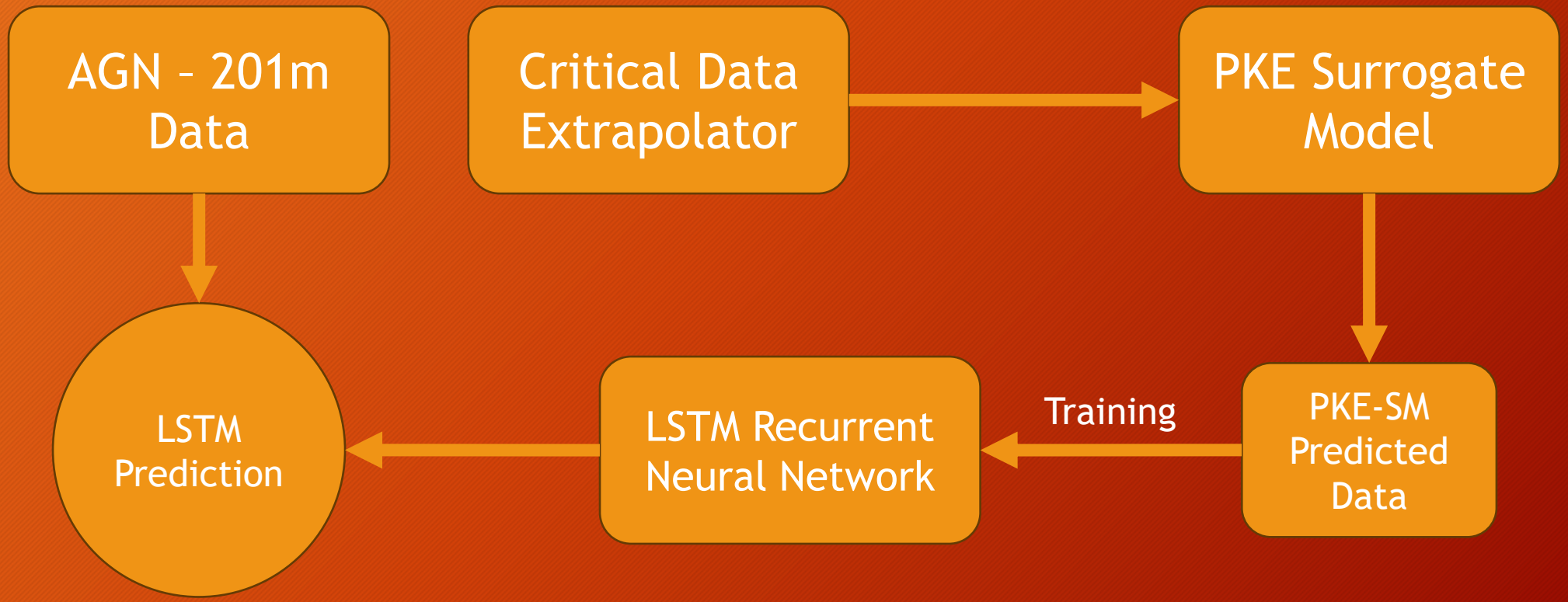


Final Dataset



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*.