Flexible Neutron Source Facility (FNS) at the University of Tennessee, Knoxville

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NSSC
NUCLEAR SCIENCE and SECURITY CONSORTIUM

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dnn TECH

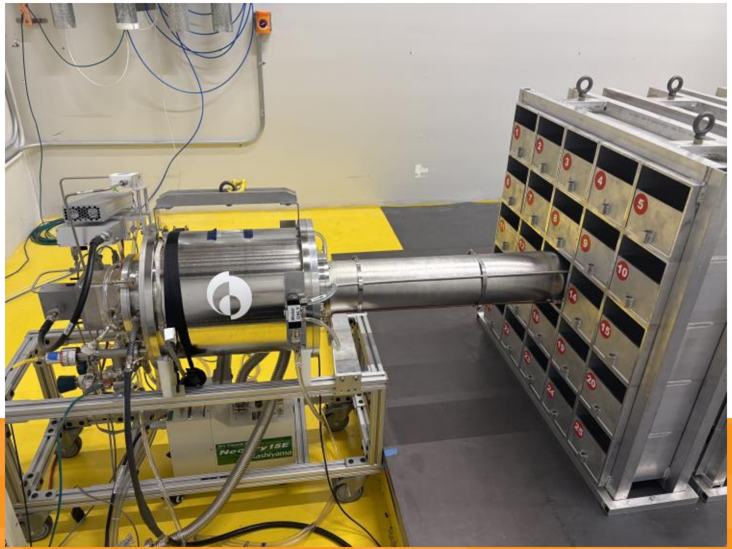
Flexible Neutron Source (FNS) Facility

- The development of this experimental facility has been underway for nearly 8 years and is **housed at the University of Tennessee** in a highly shielded vault within the new $129M engineering complex.
- **Highly Flexible Neutron Generator driven Subcritical Core designed to replicate the neutron spectrum of any fast reactor (Pb, Na, MSR), thermal reactor, or detonation by using artificial intelligence guided core design.**

The FNS subcritical facility Set-up

- **Source driven:** Deuterium-Deuterium (right) or Deuterium-Tritium generators
- **Highly Flexible:** 3 Aluminum assemblies (A, B & C).
  - 25 cassettes per assembly
  - Fuel: Uranium rods (shown below)
  - Additional Plate material: HDPE, Sodium, Stainless Steel and Aluminum, Lead, etc.
- **Near-term Upgrades:**
  - **9.9% LEU TRISO based Plates** *(budget approved as of 2026)*
  - **NSUF Facility**

DD Neutron Generator (above) Natural Uranium rods (below)

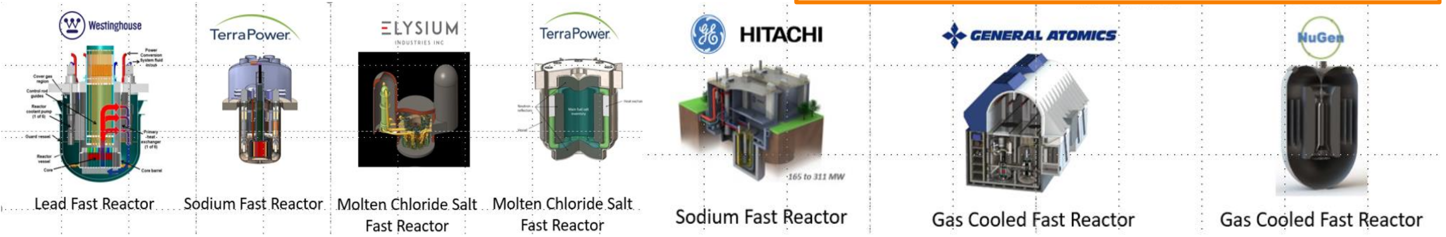


Flexible Neutron Source

- **FNS Application Opportunities:**
  - ➢ **Nuclear data uncertainty reduction to support**
    - **Advanced reactor designs**
    - **Nuclear safeguard and security applications**
  - ➢ HALEU benchmarking for transportation regulatory support
  - ➢ Neutron filter design studies for isotope production
  - ➢ **Neutron detector validation studies**
  - ➢ Nuclear criticality safety training
  - ➢ Digital twin devel. and validation
  - ➢ Synergistically work with larger benchmark testbed facility to support data production (e.g., NCERC)

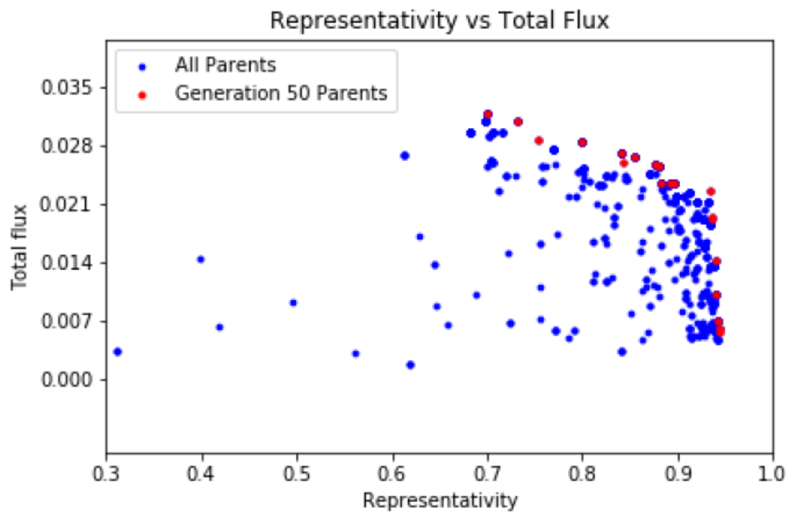
FNS at UTK as a Demonstration Facility

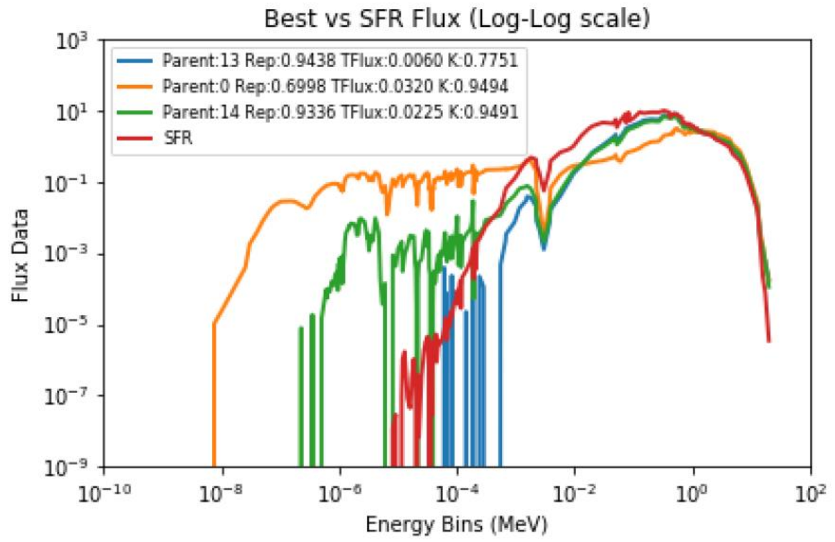
- ➢ Fast iteration time!
- Validate predicted optimal flux
- Match facility flux for design testing
- Obtain accurate specific data



AI-Design Spectrum Matching

- **Multi-objective Genetic Algorithm (NSGA-II) and Metaheuristic (E.g., *MultiGnowee*) applied to optimize 3D FNS core**
- **Dual performance objectives to maximize:**
  1. Spectrum Representativity
  2. Experimental Flux Level
- Result: Pareto front of solutions
  – Exemplify the trade-off between two objectives
- **Surrogate modelling, feature-extracting neural network (Convolutional neural network)**

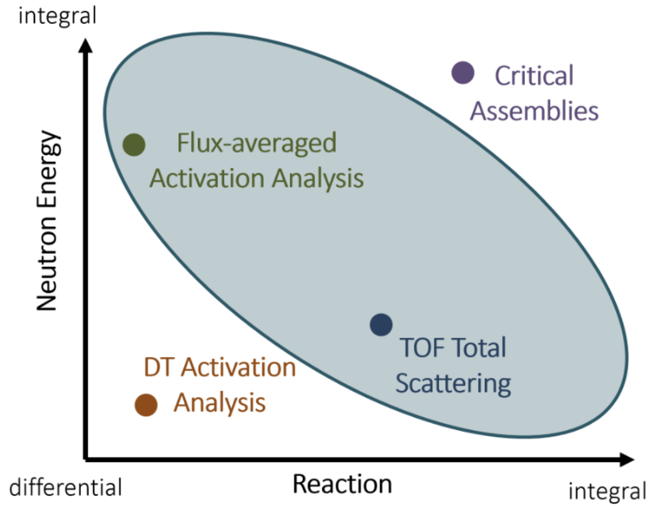


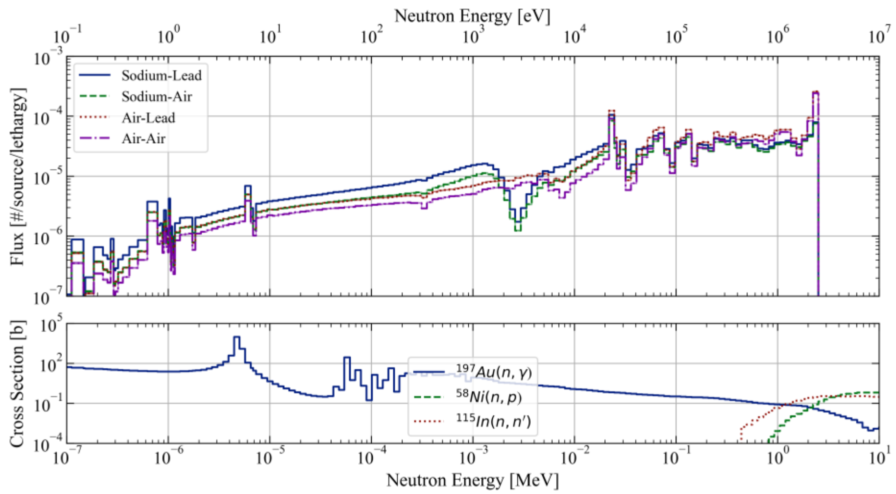


Representativity values up to 0.99 attained for 3D AI-based design.

Support Cross Section Data Needs

- **Produce a variety of neutron spectra with different combinations of sources, fuel, and other materials.**
- **Perform integral & quasi-integral data measurements*:**
  - Quasi-integral meas. follows differential experiment process of measuring background contributions to the signal
  - Setup of the full meas. deconstructed into various “partial” meas. without entire components
  - Individual meas. integral in energy and reaction
  - Full and background meas. reported together as highly-correlated experimental results

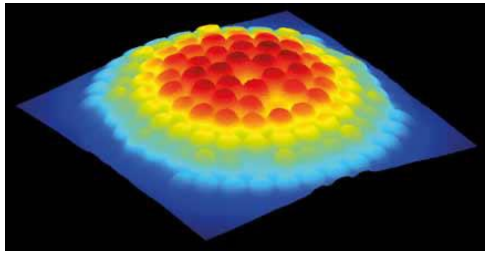




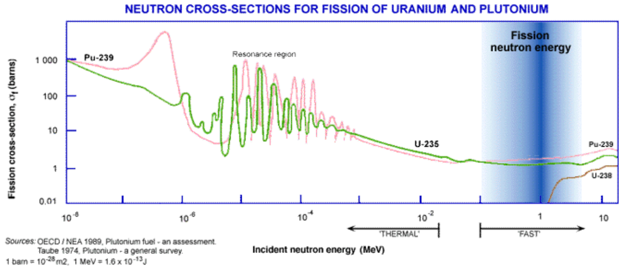
Lewis, A.M., Sobes, V., Williams, A. and Bogetic, S., 2025. Design of Quasi-Integral Experiments at the Flexible Neutron Source at the University of Tennessee. Nuclear Science and Engineering, pp.1-27.

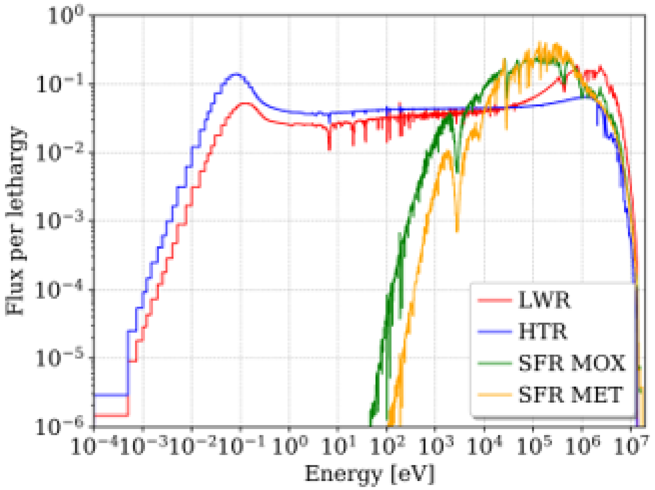
Application: Fast Reactor Cross Section Data Needs

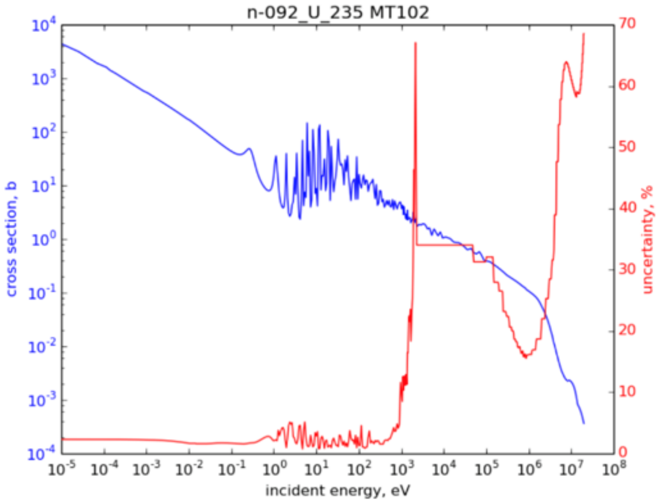
Next-generation (e.g., fast reactor) reactor design is strongly dependent on modeling & simulation



Modeling & simulation depends on nuclear data







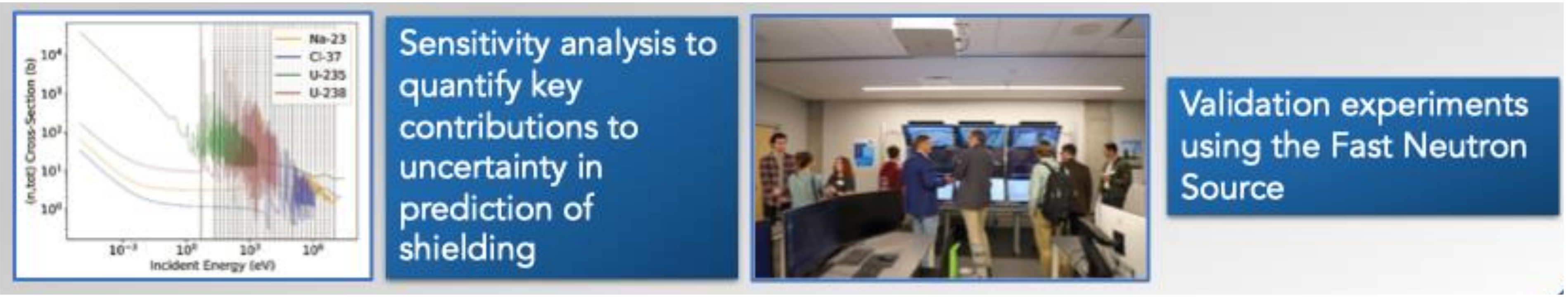
Sodium Plates from ZPPR Facility

Higher uncertainty in nuclear data results in more conservative designs making plants more expensive and less competitive

Room Length designed to perform TOF measurements

Application: Supporting Shielding Calculation

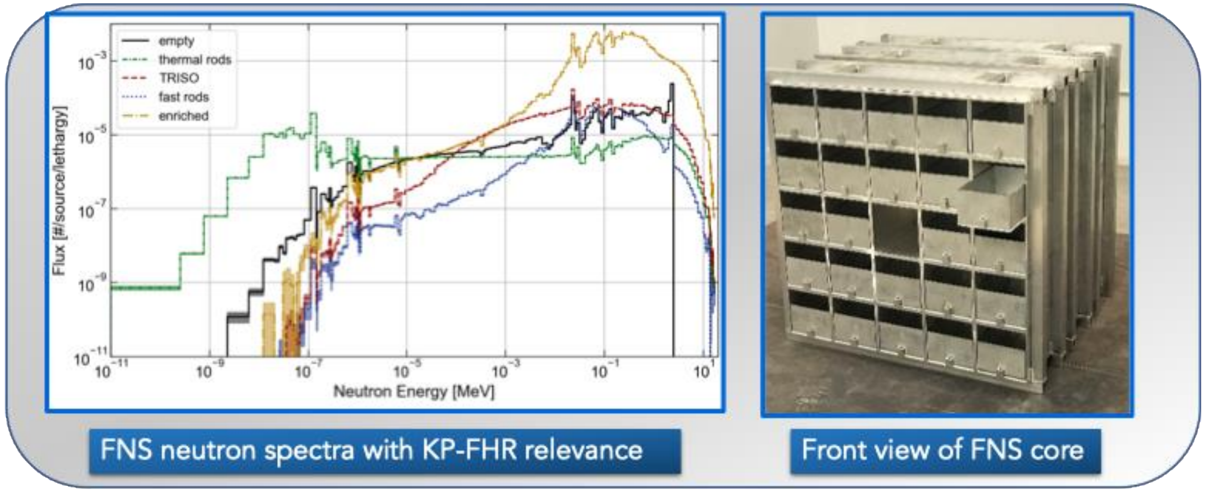
- **FNS experiments will be used to validate the shielding calculations**
  - ➢ **Reproducing neutron spectra that approximate key features of the KP (Kairos Power)-FHR environment.**



➢ **Emulate relevant irradiation geometries and boundary conditions.**

➢ **Validation deterministic and Monte Carlo neutronics** (e.g., Shift/SCALE and/or Serpent) **and angular characteristics of neutron leakage from the core and surrounding structures**.

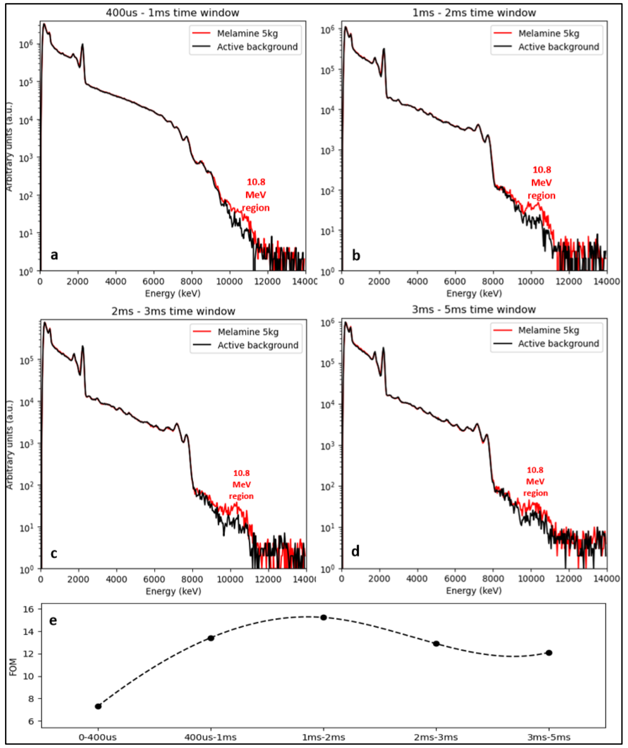
➢ Validation uncertainties associated with nuclear data, and modeling assumptions.

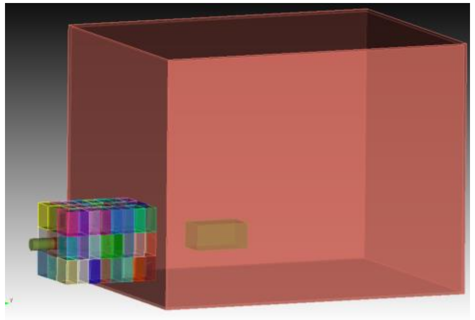


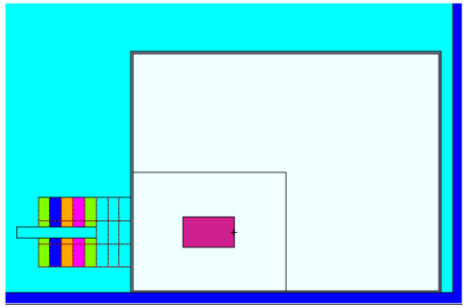
Application: Homeland Security Mission

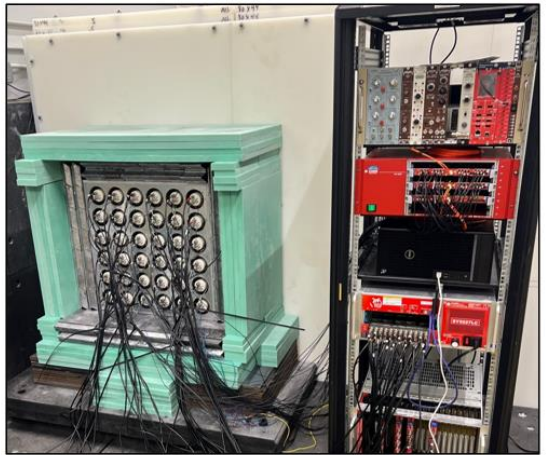
Active Interrogation for explosive and SNM Material

- Using DT/DD generators and Energy Tuning/ Beam Shaping Assemblies (e.g. Like ATHENA at NIF)









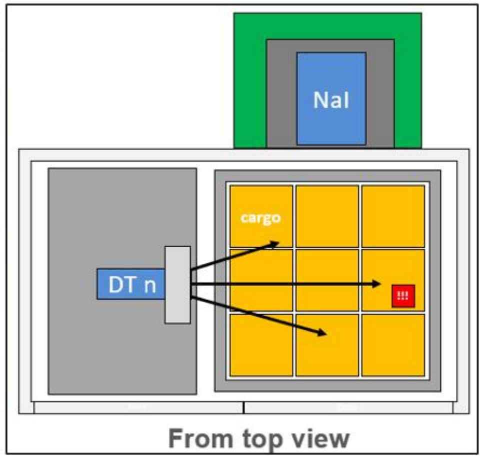


Image of the 6x6 NaI(Tl) detector array without the shielding on the back added (left), top-view of the orientation of the neutron source, cargo, and detector array.

K. Joshi, L. Drouet, S. Bogetic, X. Wen and J. Hayward "Time window optimization and effect of D-T generator pulse parameter changes on gamma spectra in a neutron interrogation system for contraband detection"

First Measurements ('25/early '26)

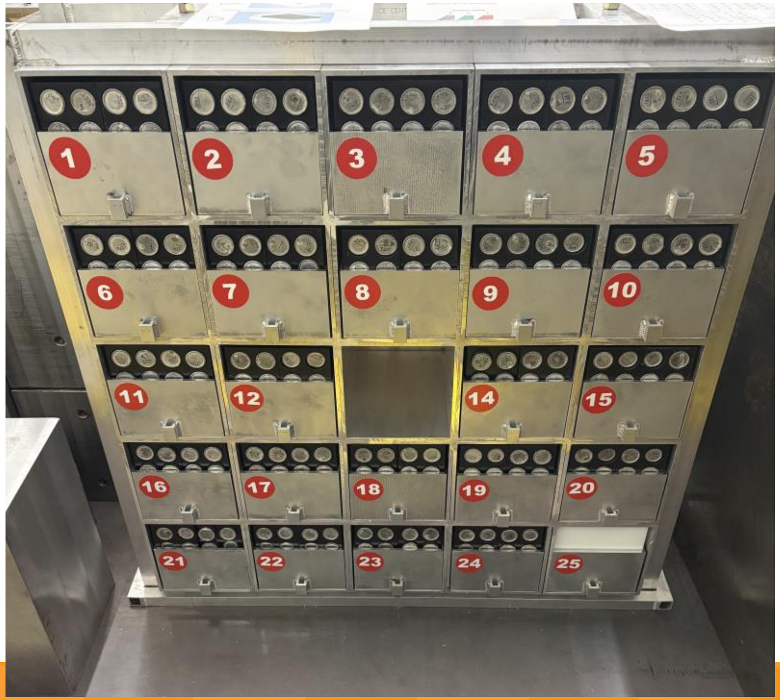
First Measurements Performed:

- Background Measurements (*empty*)
  - ➢ Empty, with cassettes, with cassettes with Poly holder
- Designed and optimized
- **Primary obj. :** Maximize k-eff and compare to MCNP/OpenMC model
- **Secondary obj.:** Minimize Uncertainties and Active Background on detectors
  - ➢ Explore opt. of material for various application

First Measurements (‘25/early ‘26)

- **Maximize k-eff with full Uranium Rods with Reflector and Shields and without**
  - k-eff validation (neutron and gamma noise measurements)
  - Neutron Spectra validation in target area
- **Achieve SFR-like Spectra in the target region using**

INL sodium plates



Thank you for the attention, Questions?