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Subcritical Experiment using U-7Mo LEU at KUCA facility

YOSHIYUKI TAKAHASHI, KOKI WAKABAYASHI, YASUNORI KITAMURA, **HIRONOBU UNESAKI,** TSUYOSHI MISAWA

INSTITUTE FOR INTEGRATED RADIATION AND NUCLEAR SCIENCE / GRADUATE SCHOOL OF ENERGY SCIENCE
KYOTO UNIVERSITY, JAPAN

KUCA HEU RETURN – ☑ completed

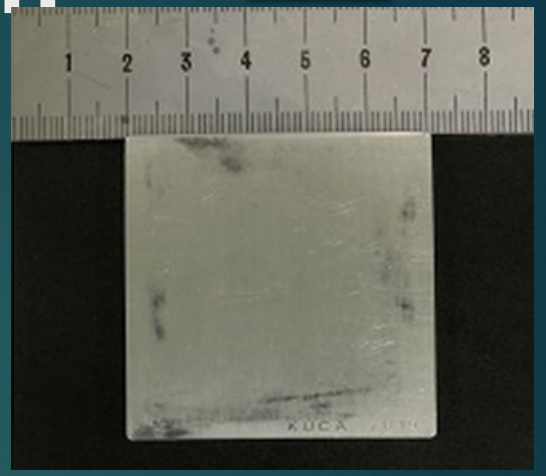
- About 15 years since first negotiation
- Formally announced @ 2016 Nuclear Safety Summitt
- Project “KRAKEN” initiated @ 2017
- Numerous challenges during COVID-19 pandemic
- Safely completed @ 2022 after multiple Cat II shipments
- Completion formally announced by NNSA and MEXT @ Aug 2022
- Total of 45kg of HEU, equivalent to > 10 critical cores @ KUCA
- KUCA now “HEU free”, facility under process to downgrade PP measures to Cat II
- Safeguards measures also downgraded (no monthly IIVs, etc.)

LEU Fuels Selected for KUCA conversion

- **Wet Core**
  - U_3Si_2 – Al dispersion type plate fuels, consistent with the technology used in the KUR and some JAEA research reactors in Japan, and many other research reactors globally

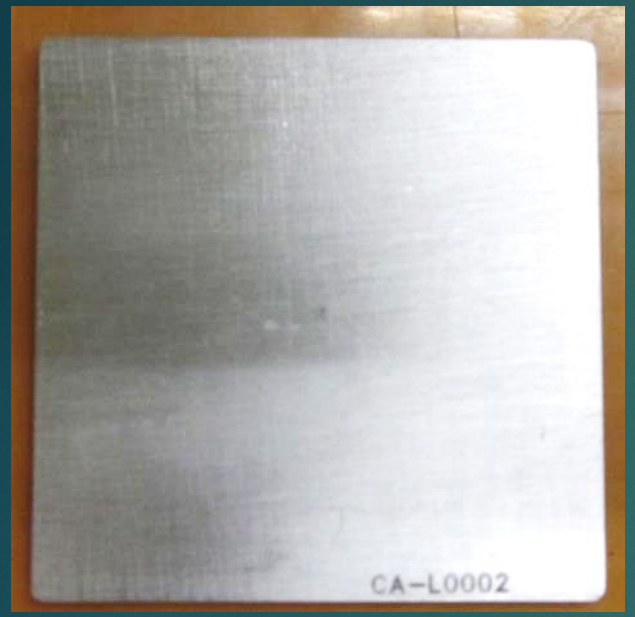
- **Dry Core**
  - U7Mo – Al dispersion type coupons, where higher density fuel was selected to support the broad range of experimental capabilities at KUCA dry core
  - Extensive R&D campaign for the specific coupons performed by the CERCA/US/KURNS team – fabrication technology confirmed and verified through fabrication of **LEU test sample coupons**

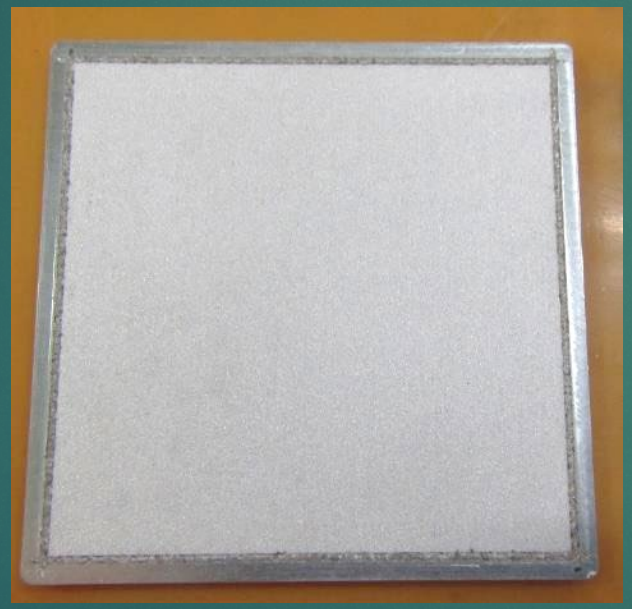
LEU subcritical experiment initiation



- Aimed to make best use of LEU sample (test) coupons developed by CERCA during the course of fuel technology development
- subcritical experiments using Natural Uranium + Polyethylene subcritical pile : commenced July 2022
- First batch of **LEU sample coupons** (10 coupons) received on 28 Sept 2022; loaded into subcritical pile on the same day
- First reactor physics experiment using U7Mo LEU fuel
- Measurement of subcriticality by neutron noise method, measurement of neutron flux distribution using optical fiber detectors hitherto executed

LEU sample (test) coupon





- Design and specification identical to KUCA LEU dry core coupon fuel

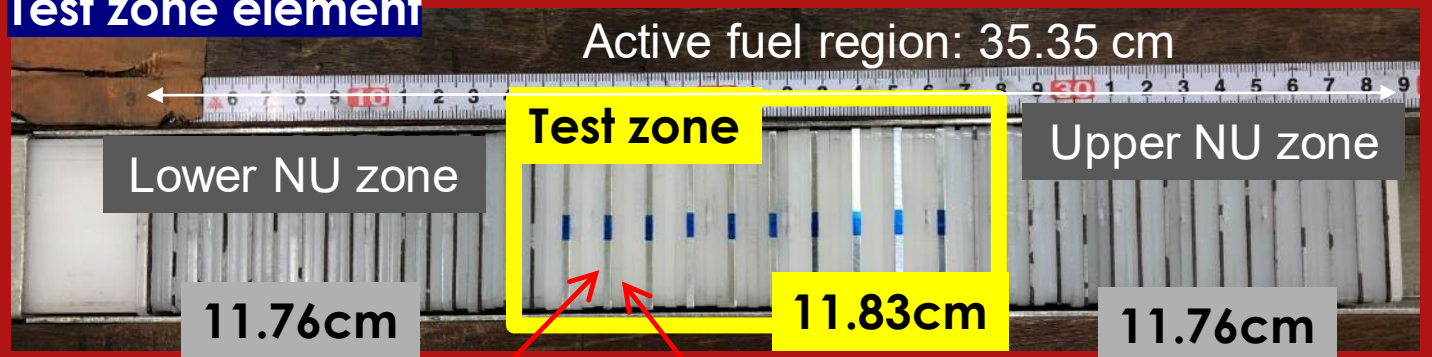
LEU subcritical experiment : subcritical pile

Natural uranium plate
1mmt

Polyethene plate
1/8” x 2

NU element

Test zone element

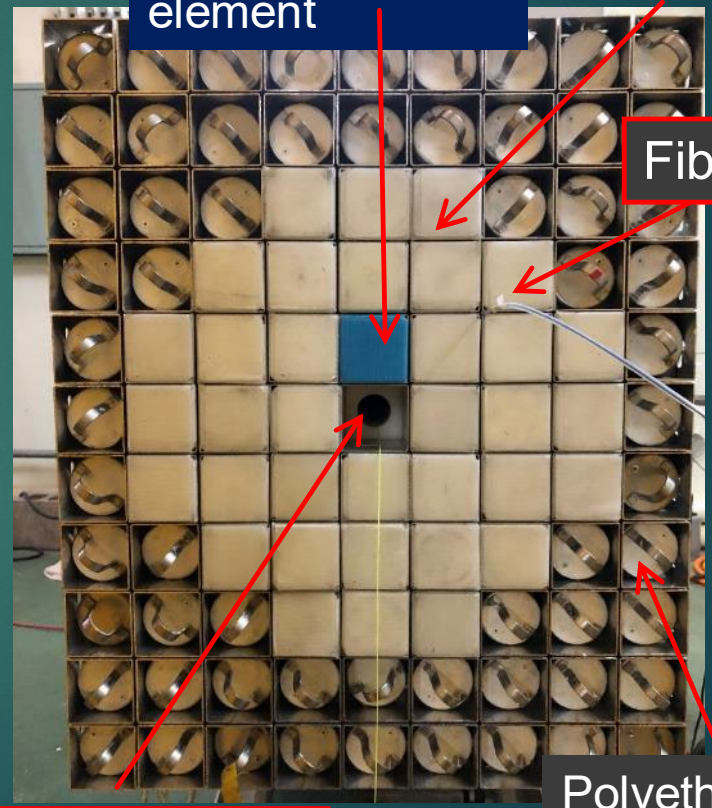


Al reference plate or
U-7Mo LEU test coupon

Polyethene plate
1/8” x 3

Test zone element

NU element



Fiber detector

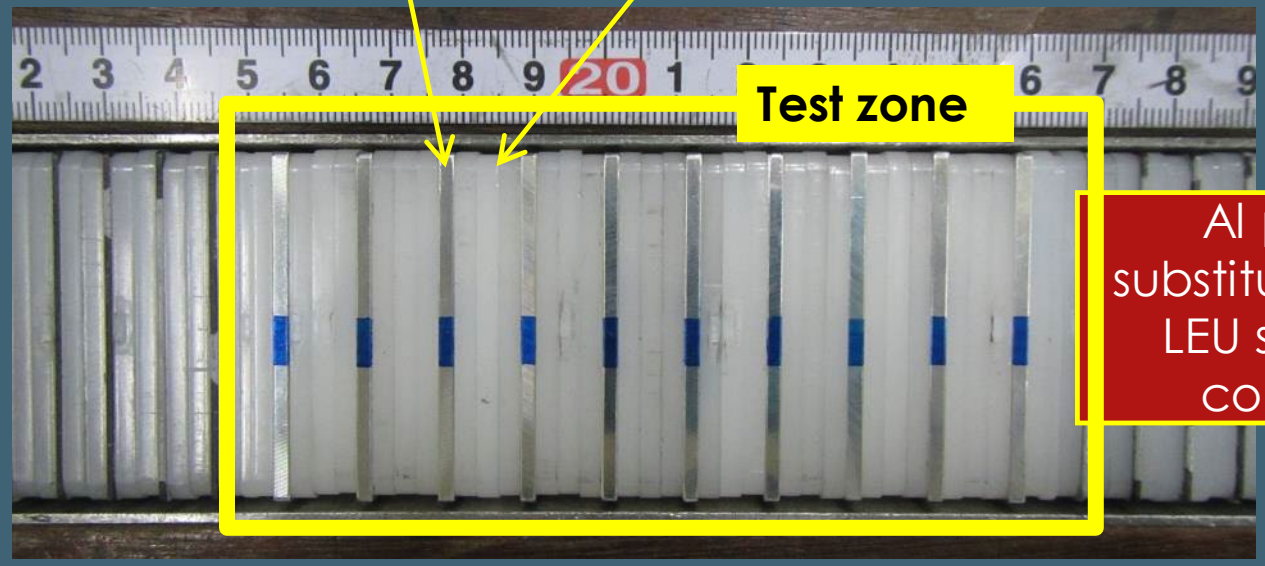
B-10 Detector

Polyethylene reflector

LEU subcritical experiment : LEU loading

Aluminum reference plate (dimension identical to LEU sample coupon)

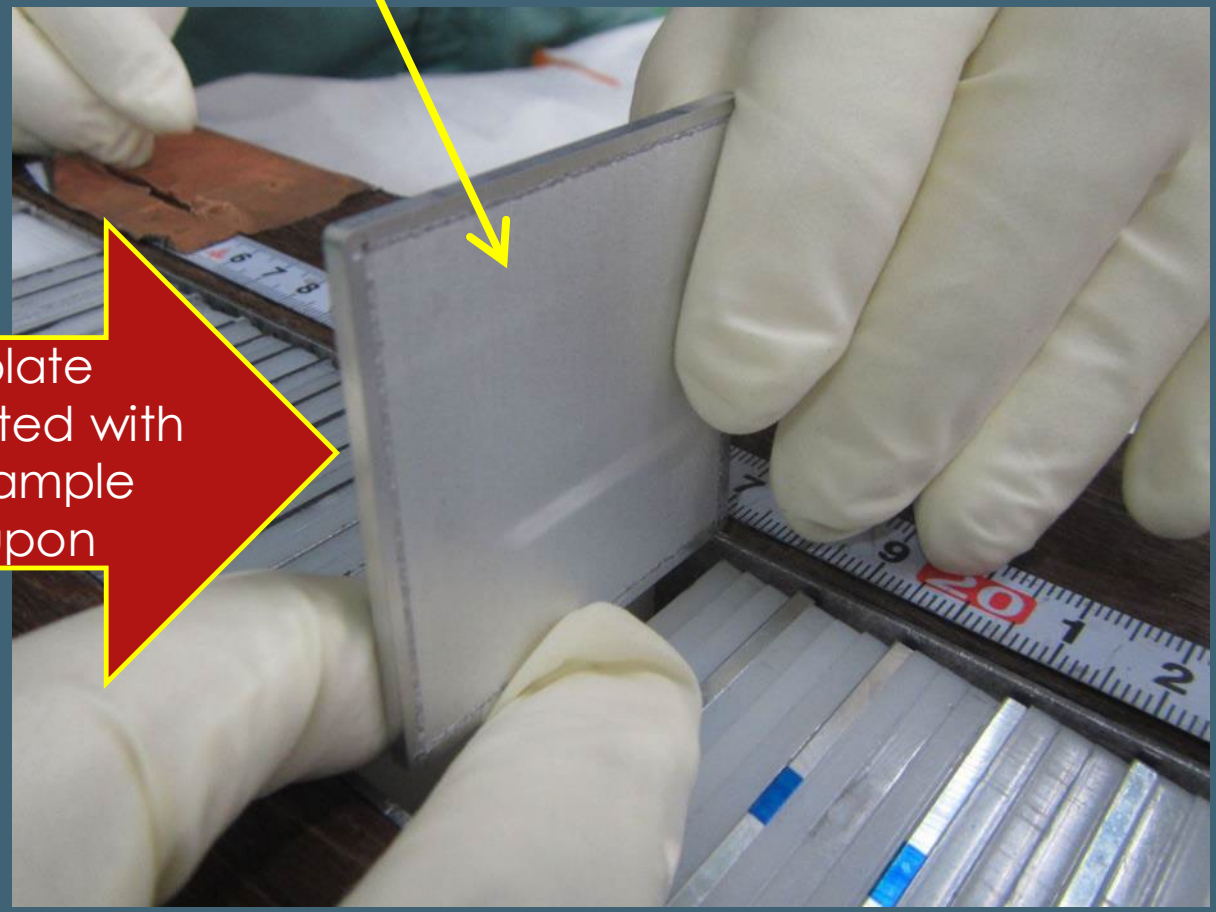
Polyethene plate



Test zone assembly

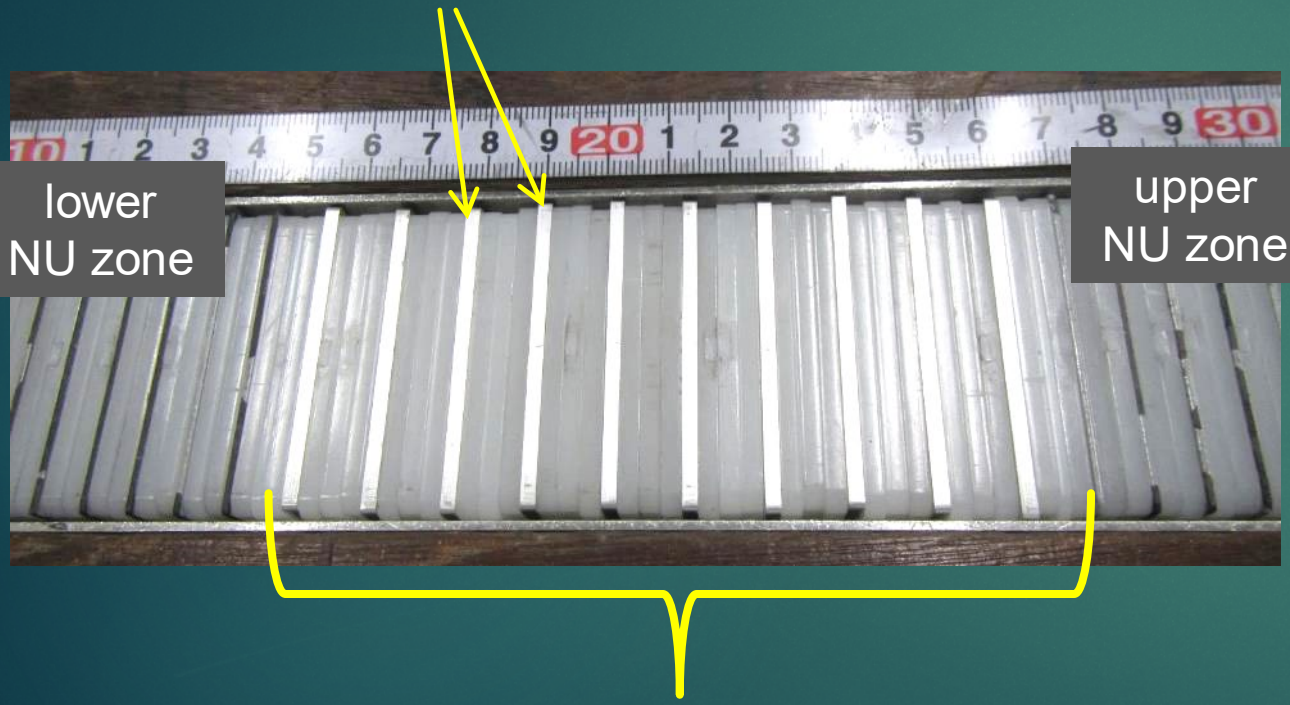
Al plate substituted with LEU sample coupon

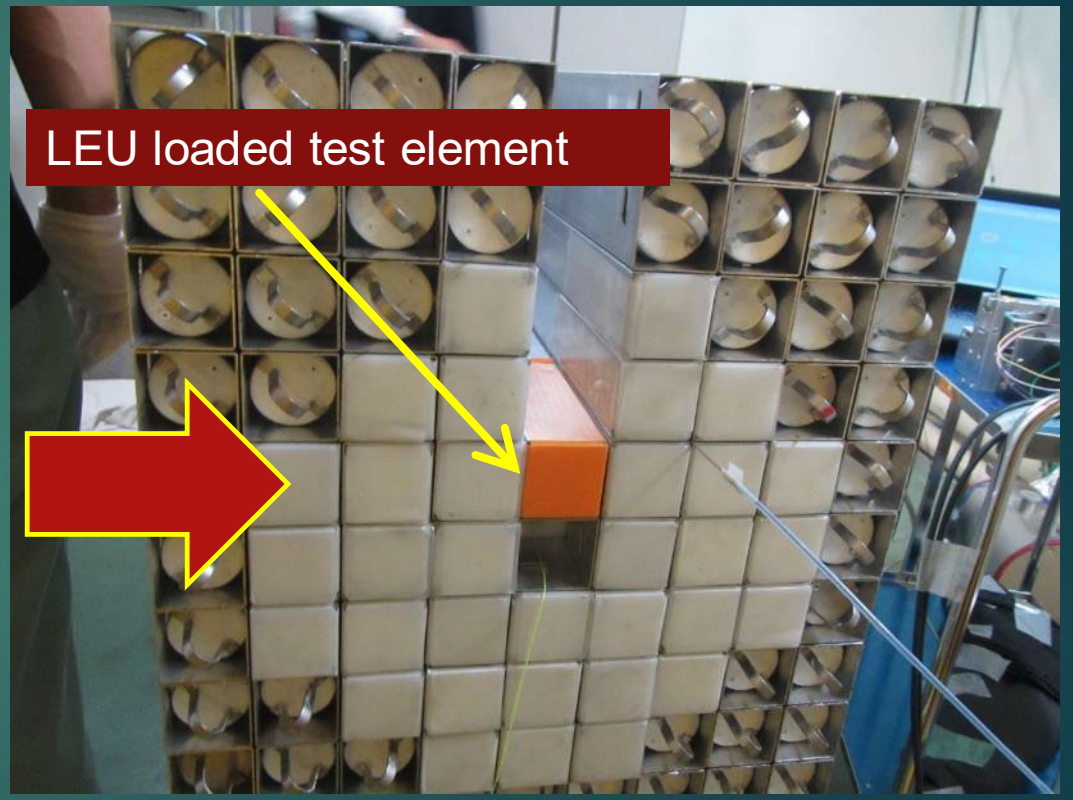
LEU sample coupon



LEU subcritical experiment : LEU loading

LEU sample coupons

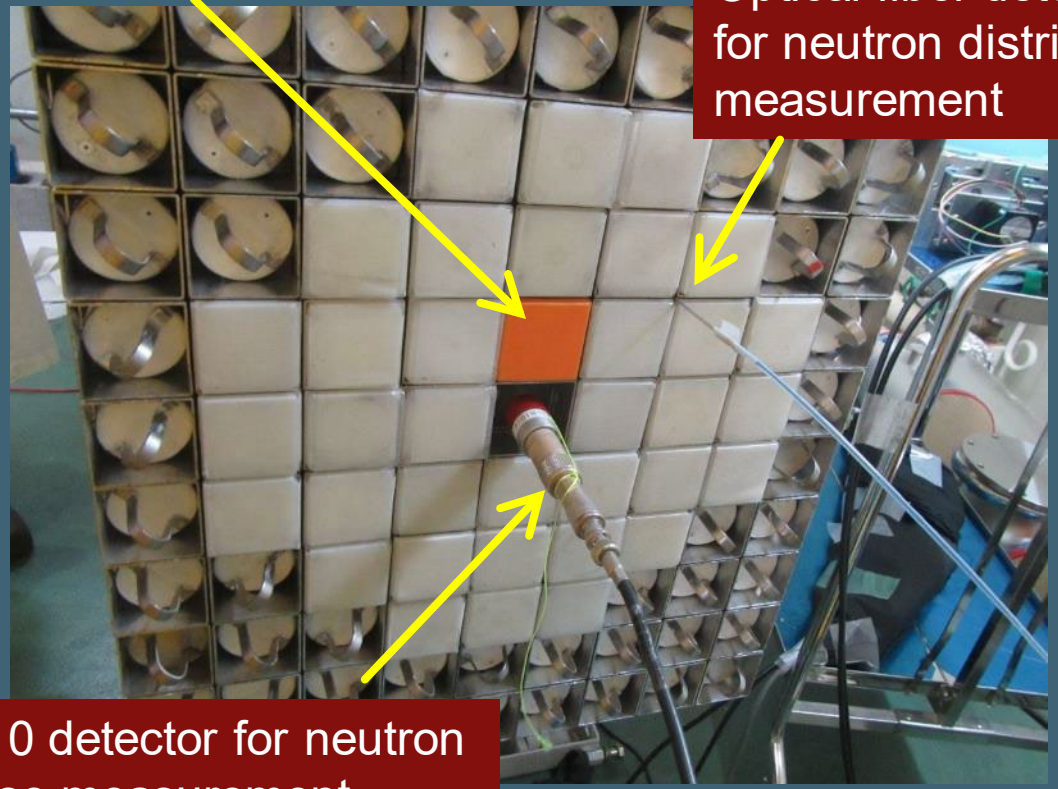




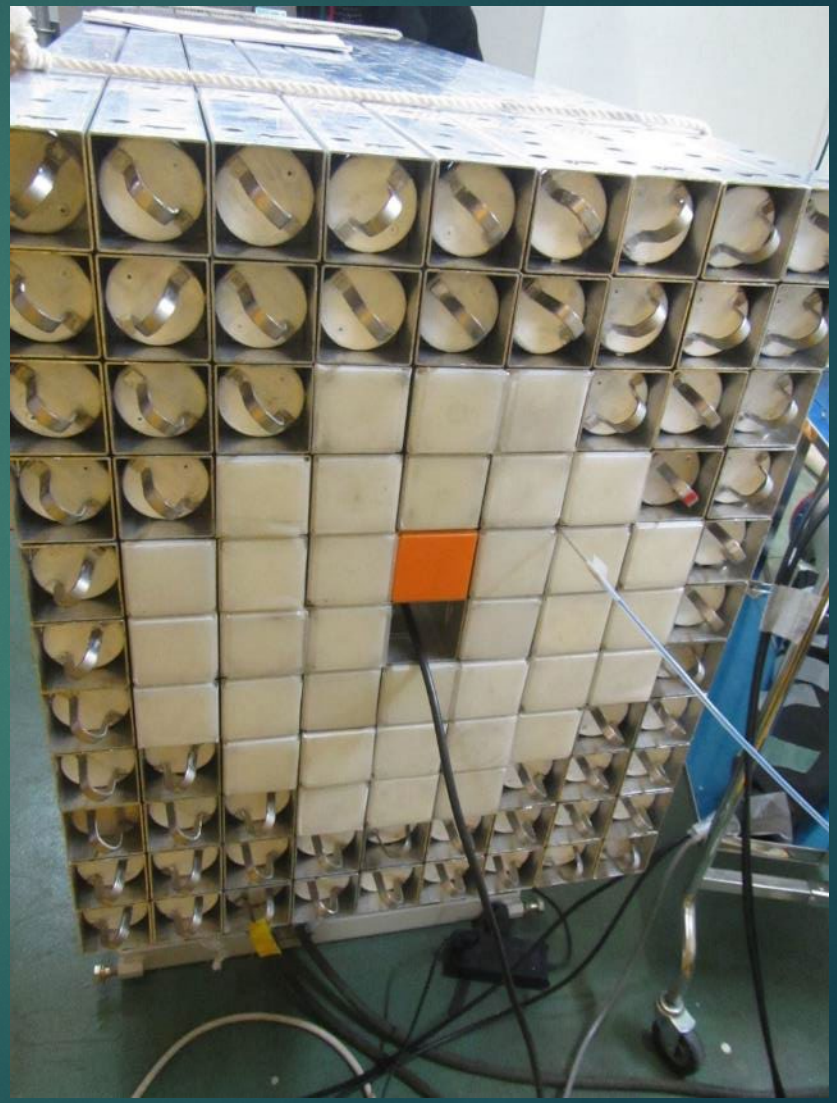
LEU subcritical experiment : Detector setup

LEU loaded test element

Optical fiber detector for neutron distribution measurement

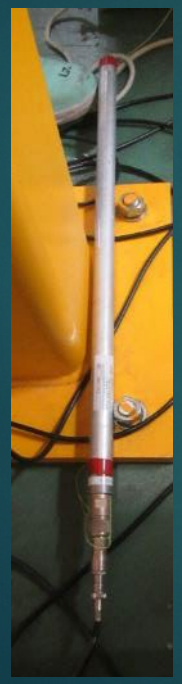


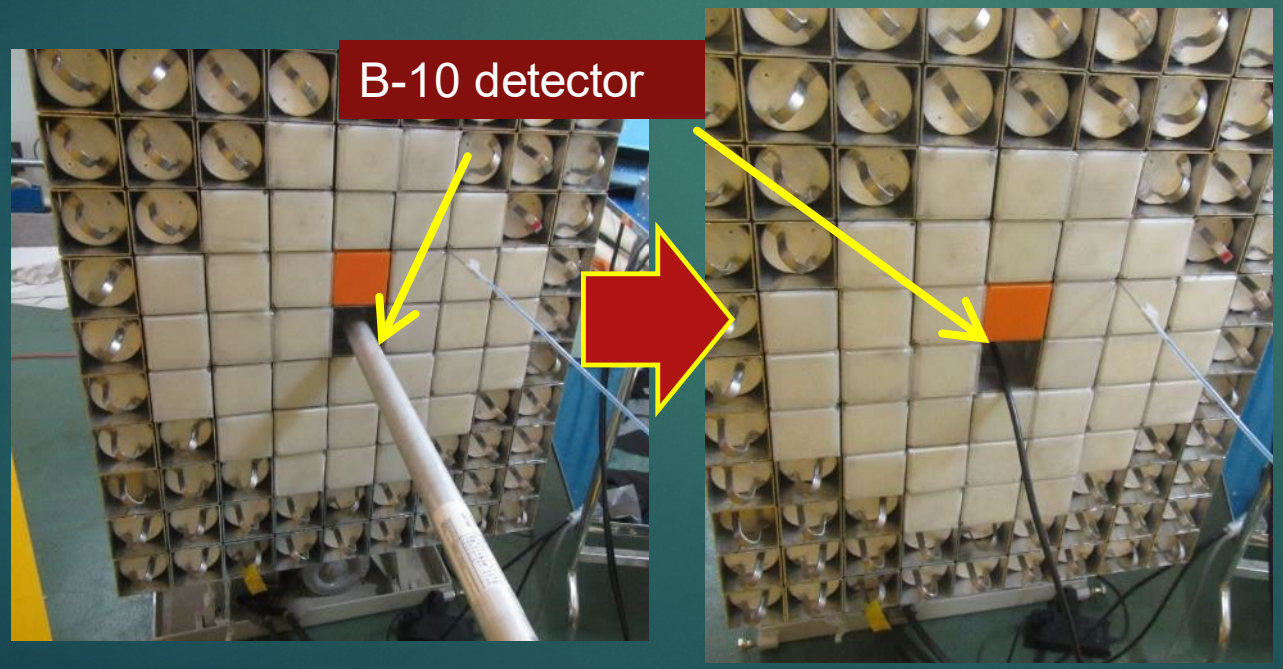
B-10 detector for neutron noise measurement



LEU subcritical experiment : neutron noise experiment

- B-10 detector + data accumulation system (neutron signal accumulated as time stamp data using MCA + time series data acquisition system)
- U-238 spontaneous fission neutron used as neutron source (e.g. no external neutron source)
- Time series of detector response (e.g. neutron detection) analyzed using Feynman-α method to obtain alpha (beta-over-lifetime) value



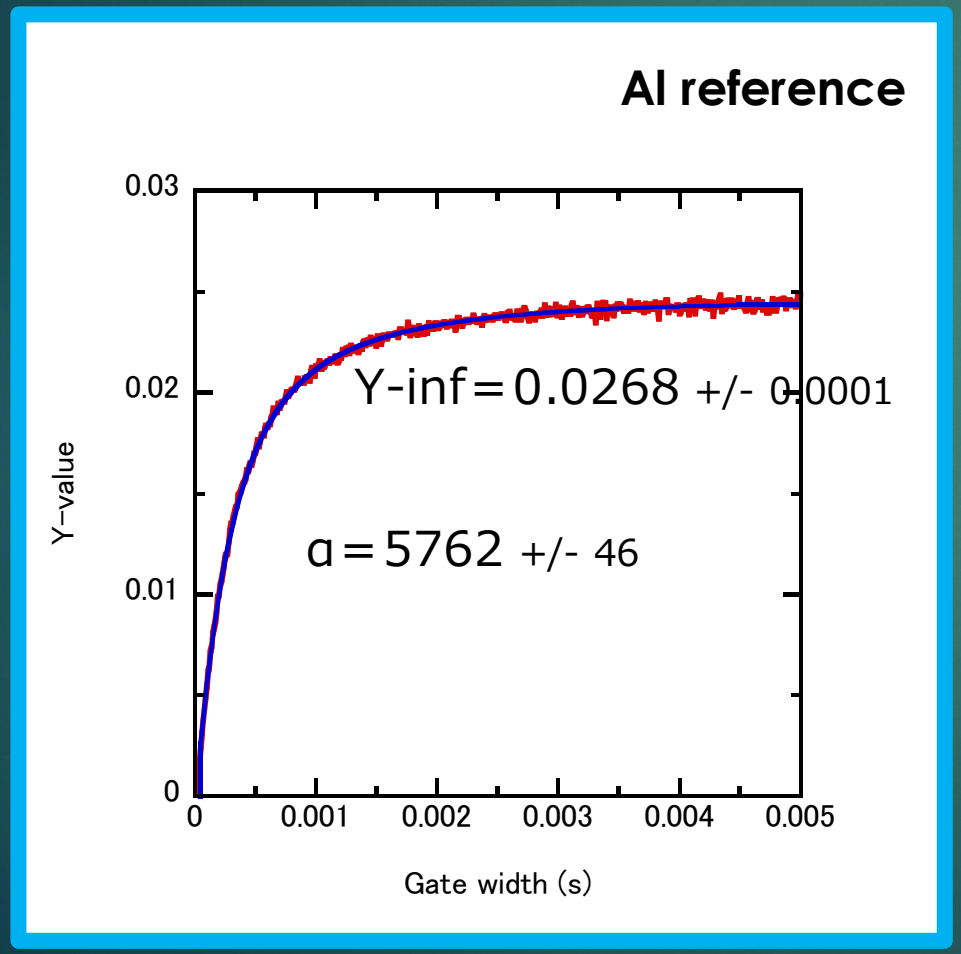


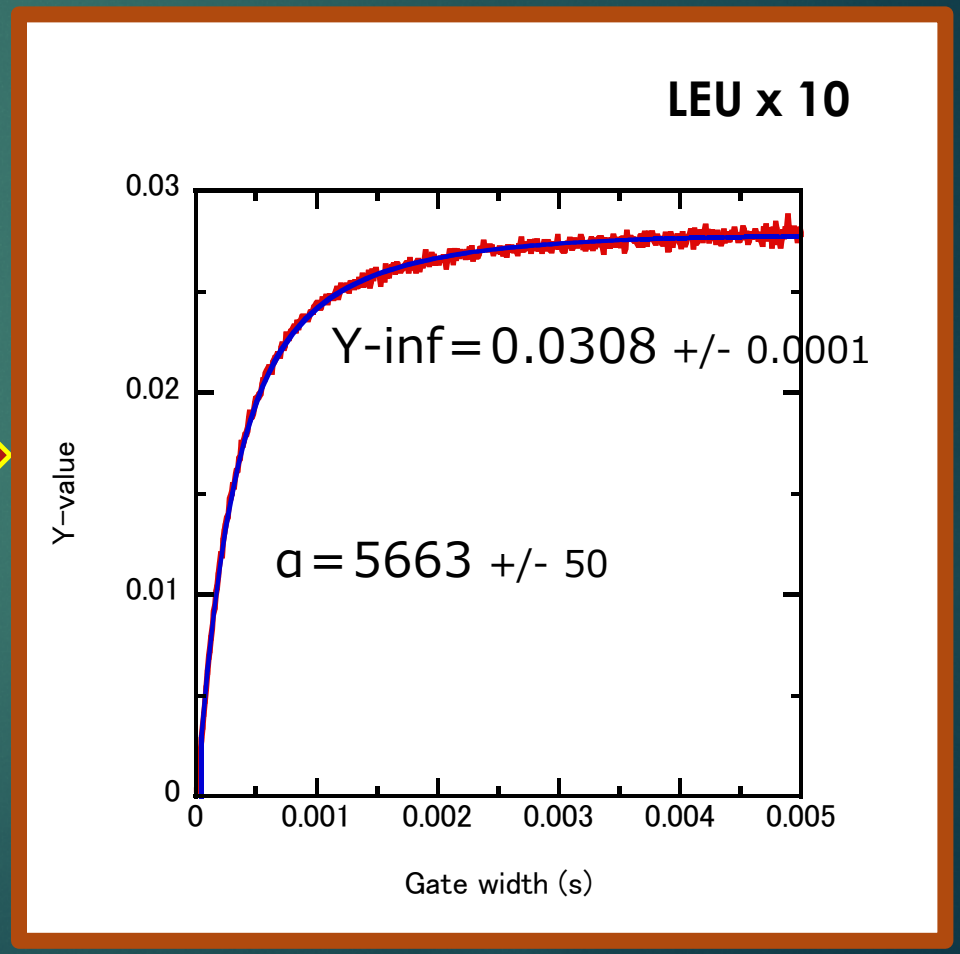
LEU subcritical experiment: neutron noise experiment

Two major indicator of subcriticality obtained through Feynman-a analysis:

a: increases with subcriticality (e.g. decreases when the multiplicity of system increases)

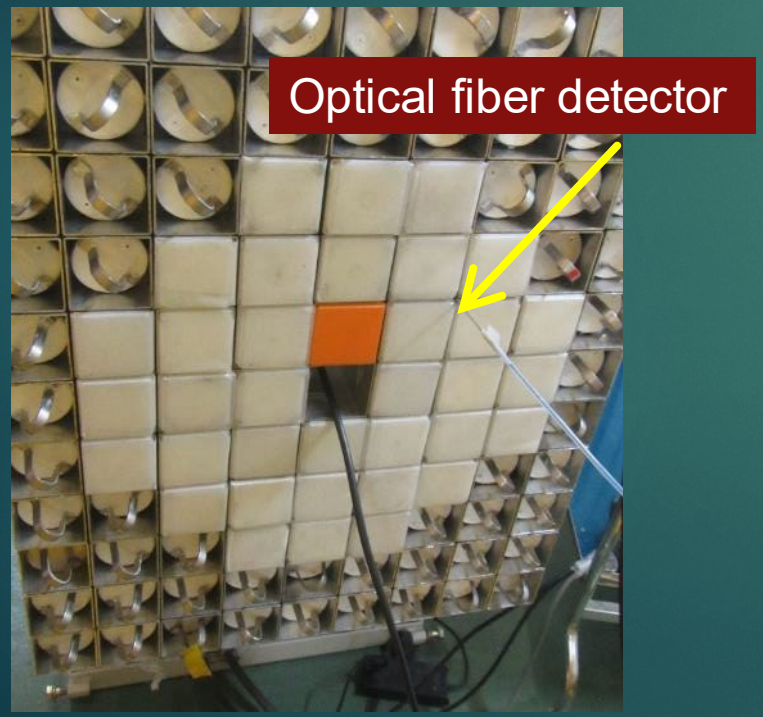
Y-inf: decreases with subcriticality (e.g. increases when the multiplicity of system increases)

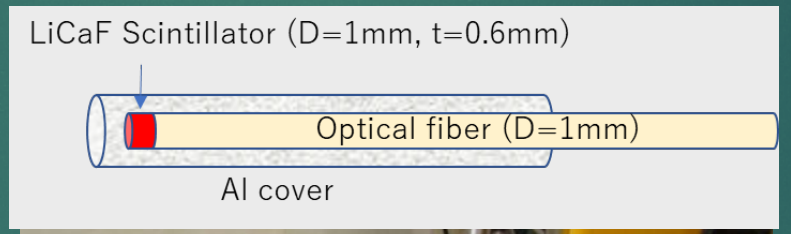


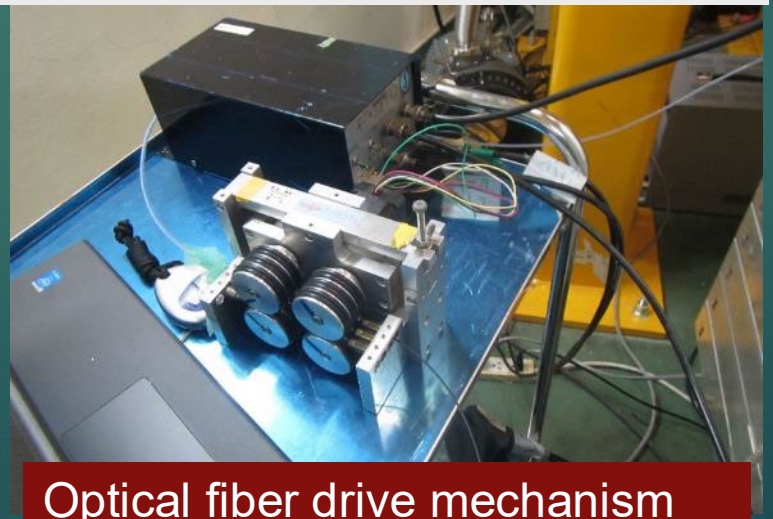


LEU subcritical experiment : optical fiber detector

- Small scintillator detector (LiCaF) attached to optical fiber tip – high spatial resolution
- Optical fiber mechanically driven to measure detector response traverse
- External neutron source (^{252}Cf) inserted @ core centre
- Detector response recorded as time stamp series data and analyzed to obtain special distribution

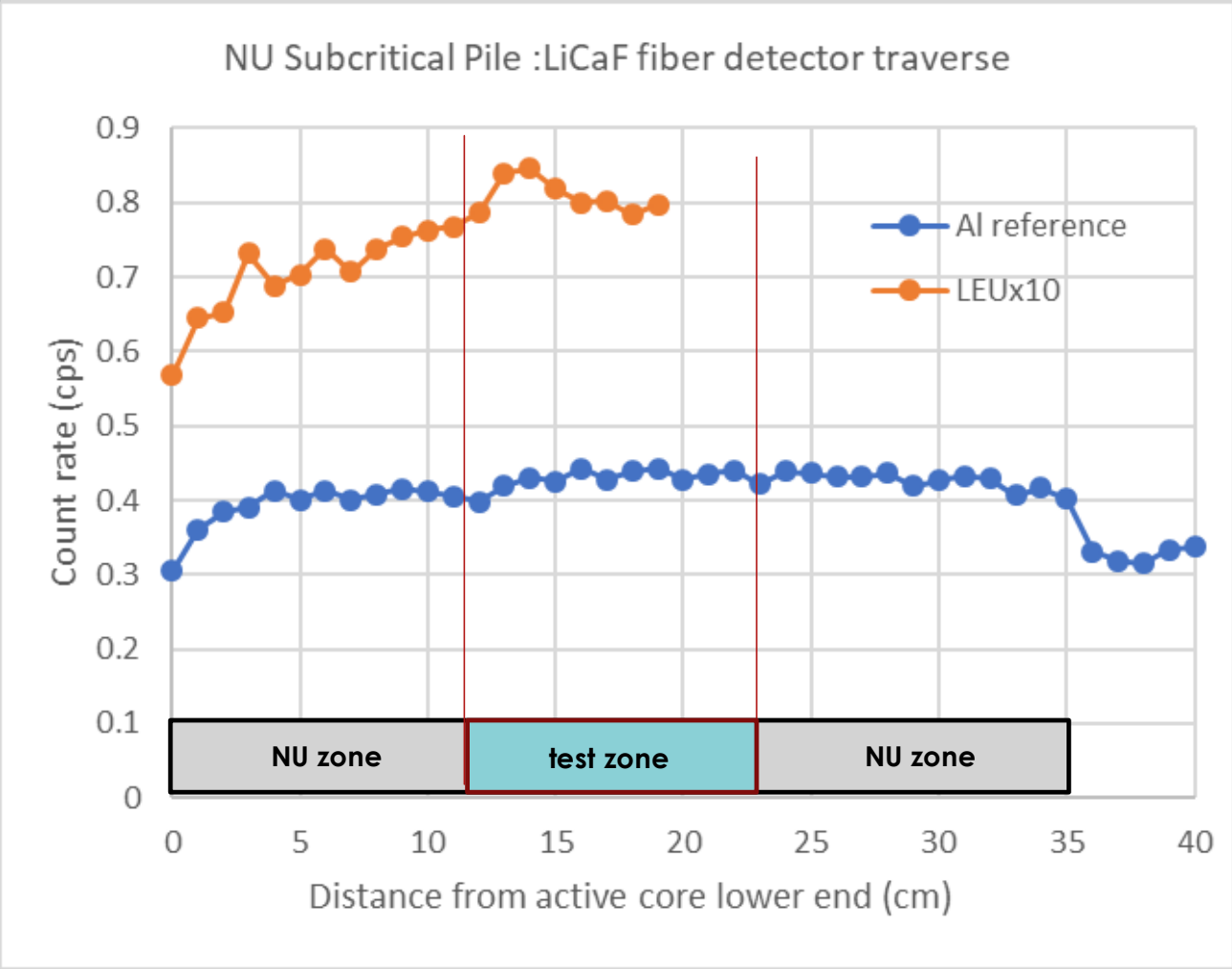


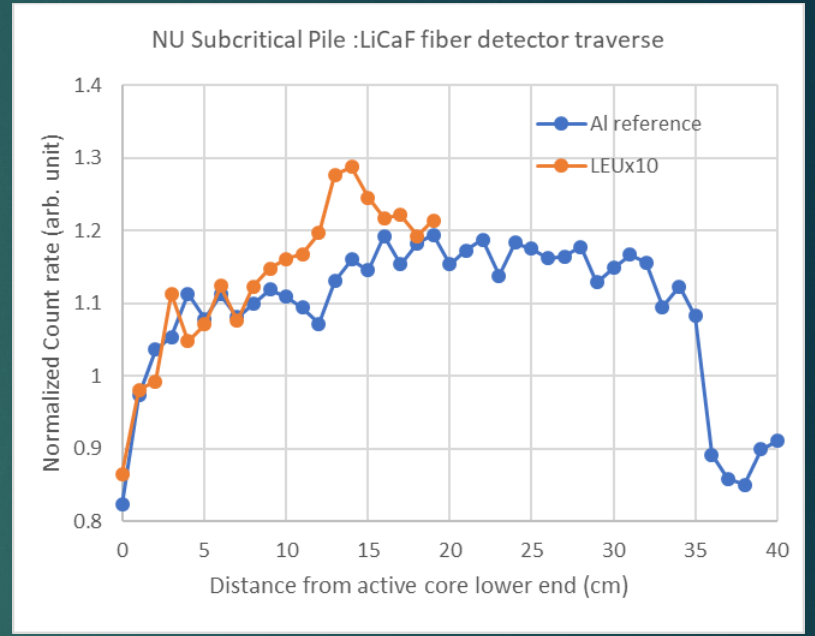



Optical fiber drive mechanism


Data acquisition system

LEU subcritical experiment : detector response traverse (Li-6 reaction rate distribution)

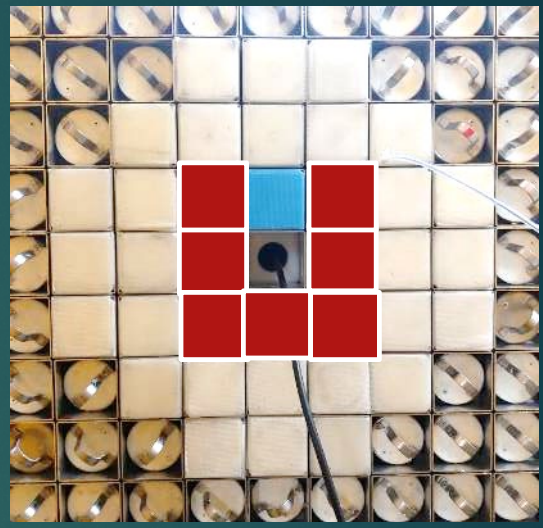




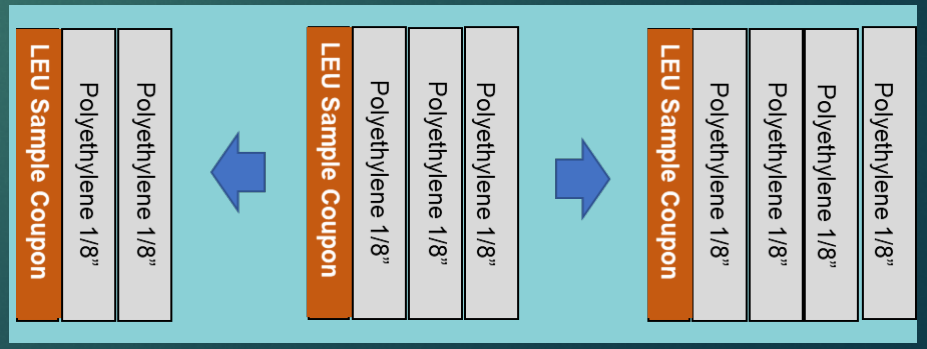
Normalized using average count rate of x=0 to 5 cm (lower end section of NU zone)

LEU subcritical experiment : forthcoming plan

- Rest of the LEU sample coupons to be received Oct - Nov 2022: final inventory = 100 sample coupons
- Subsequent modification of LEU test zone
  - Extension of test region (up to 8 test fuel assemblies)
  - H/U ratio variation by changing the combination of LEU and polyethylene plate in the LEU test zone
- Systematic measurement of subcriticality index by neutron noise method & neutron flux distribution using optical fiber detectors
- MCNP analysis for prediction accuracy evaluation



test regioin extension



LEU test zone variation

LEU subcritical experiment : academic significance

- **First reactor physics** experiment on U7Mo fuel
  - Subcriticality
  - Reaction rate
  - Neutron flux distribution

U-Mo fuel R&D : hitherto focused on fuel material science, fuel fabrication technology and in-core irradiation experiment & analysis for fuel integrity validation

- Expected contribution to
  - Reactor physics of next generation advanced reactors (including High-Assay Low-Enriched Uranium (HALEU) fuel system)
  - Reactor conversion science & technology

Thank you for your attention !