



PISTIL, A Reactivity Modulation Device to Probe the Transfer Function of Research Nuclear Reactor CROCUS

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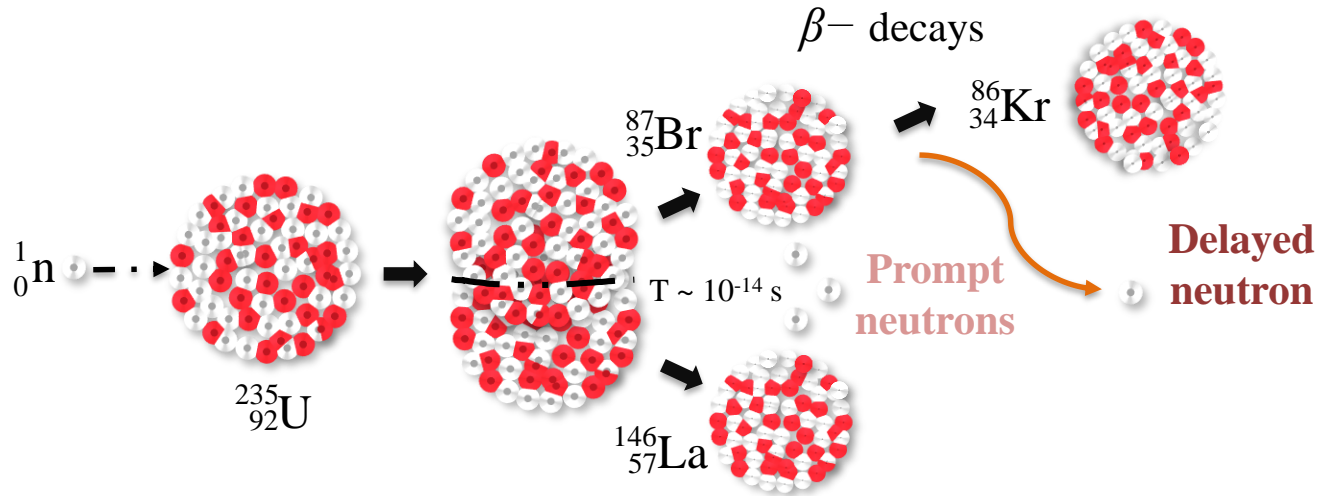
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Research institute on nuclear systems for low-carbon energy production

Criticality - Steady state of nuclear reactors

Absorption + Loss = Production

Capture Scattering Fission



Fission process

Importance of neutrons being delayed

Lifetime of neutrons in a PWR

Prompt $\sim 10^{-5}$ s

Prompt + Delayed ~ 8 s (average)

$\sim 0.7\%$ of the neutron population, yet crucial to reactivity (doubling time) estimates

Discrepancies between model and calculations

Improvements of delayed neutron data

Towards better reactivity estimate in reactor operation

Reduced safety margin in accident analysis

PISTIL, A reactivity modulation device to probe the transfer function of the research nuclear reactor CROCUS



EPFL

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ABSTRACT

The PISTIL device targets the determination of precursor abundances by reactivity modulation. We here present its design and testing in the CROCUS reactor at EPFL. It is capable of generating periodic modulations between 1 mHz

and 200 Hz. The modulation can either be continuous or following arbitrary a predefined motion profile. Thanks to the mechanical design, its reactivity worth and modulation amplitude are tunable.

MOTIVATIONS

IMPROVED REACTOR KINETIC PARAMETERS

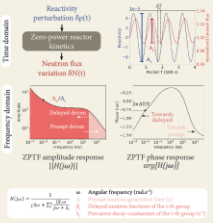
Uncertainty and bias reduction on delayed neutron parameters for better reactivity estimate to reactor operation and safety studies
 Towards improved knowledge of delayed neutron data and validation of calculation models

ZERO-POWER TRANSFER FUNCTION (ZPTF)

Reactor response to reactivity perturbations
 Frequency-dependent reactivity to delayed and prompt neutrons

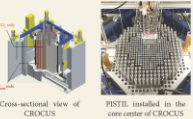
EXPERIMENTAL APPROACH

Development of a reactivity modulation device to generate controlled modulation covering frequency ranges of interest (~1 mHz to ~100 Hz)
 Mechanical qualification and reactivity calibration
 Fourier analysis of reactivity flux variations resulting from modulation



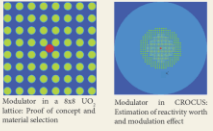
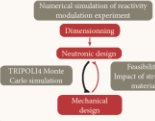
CROCUS REACTOR

Pool-type light water reactor
 Maximum power of 300 W
 Reactivity control by B₄C rods or spillover (in-core water level variation)
 Interlocked fuel zones of 1.806 wt% UO₂ lattice and 0.047 wt% ²³⁵U lattice
 Active core of 60 cm in diameter and 1 m in height
 PISTIL inserted in the core center



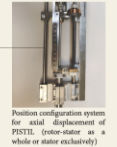
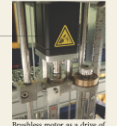
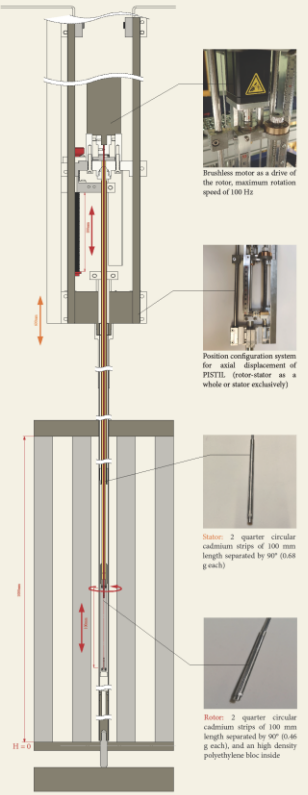
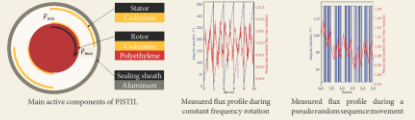
PERIODIC REACTIVITY INJECTION SYSTEM TRANSIENT INDUCED LOCALLY (PISTIL)

DESIGN METHODOLOGY



CHARACTERISTICS

- System of rotary (rotor) and stationary (stator) components
- Reactivity modulation through recovery and diversity in angular positions of rotor and stator cadmium elements
- 2.64d positional accuracy (1σ) for frequency doubling or modulation
- Configurable axial positioning
 - 600 mm range for the rotor-stator ensemble on reactivity tuning
 - 100 mm range for stator as modulation amplitude modulation
- Constant frequency operation or acquisition of predefined motion profile
- Asymptotic periodical calibration of the maximum modulation amplitude (rotor-stator at 550 mm water level)
 - 0.492 ± 0.002 ± (1SD) (B.V.L.)
 - 0.570 ± 0.002 ± (1SD) (B.V.L.)



CONCLUSION AND PERSPECTIVES
 PISTIL: a device allowing controlled and known in-core reactivity modulation for zero-power transfer function measurements
 Contribution to consistent and accurate kinetic parameter evaluation through experimental investigation
 First experimental campaign in CROCUS conducted from May to June 2021, modulation frequency ranging from 1.6 mHz to 200 Hz
 Second experimental campaign planned in Autumn 2021, benefiting from early analysis and using updated reactivity detection instrumentation

Zero-power reactor experiment

PISTIL

Installed in the center of CROCUS

Rotation with maximum speed of 100 Hz

Reactor transfer function measurement

See you at the poster stand!