Fuel Safety Analysis Capability Development in SÚRO

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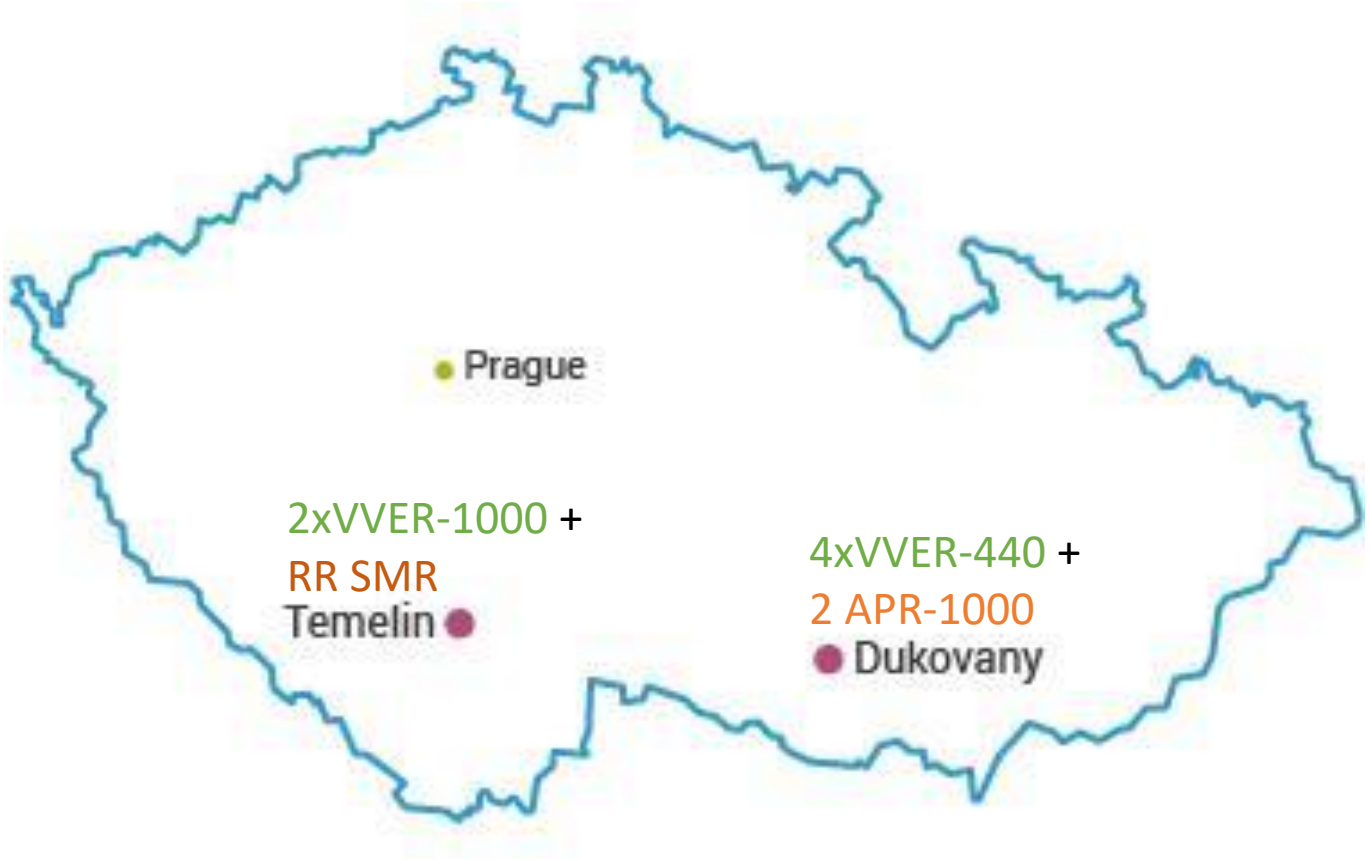
Outlook

1. SÚRO-TSO
2. Safety analyses in SÚRO
3. Fuel performance analysis methodology and capabilities
4. Results
5. Applications
6. Conclusions

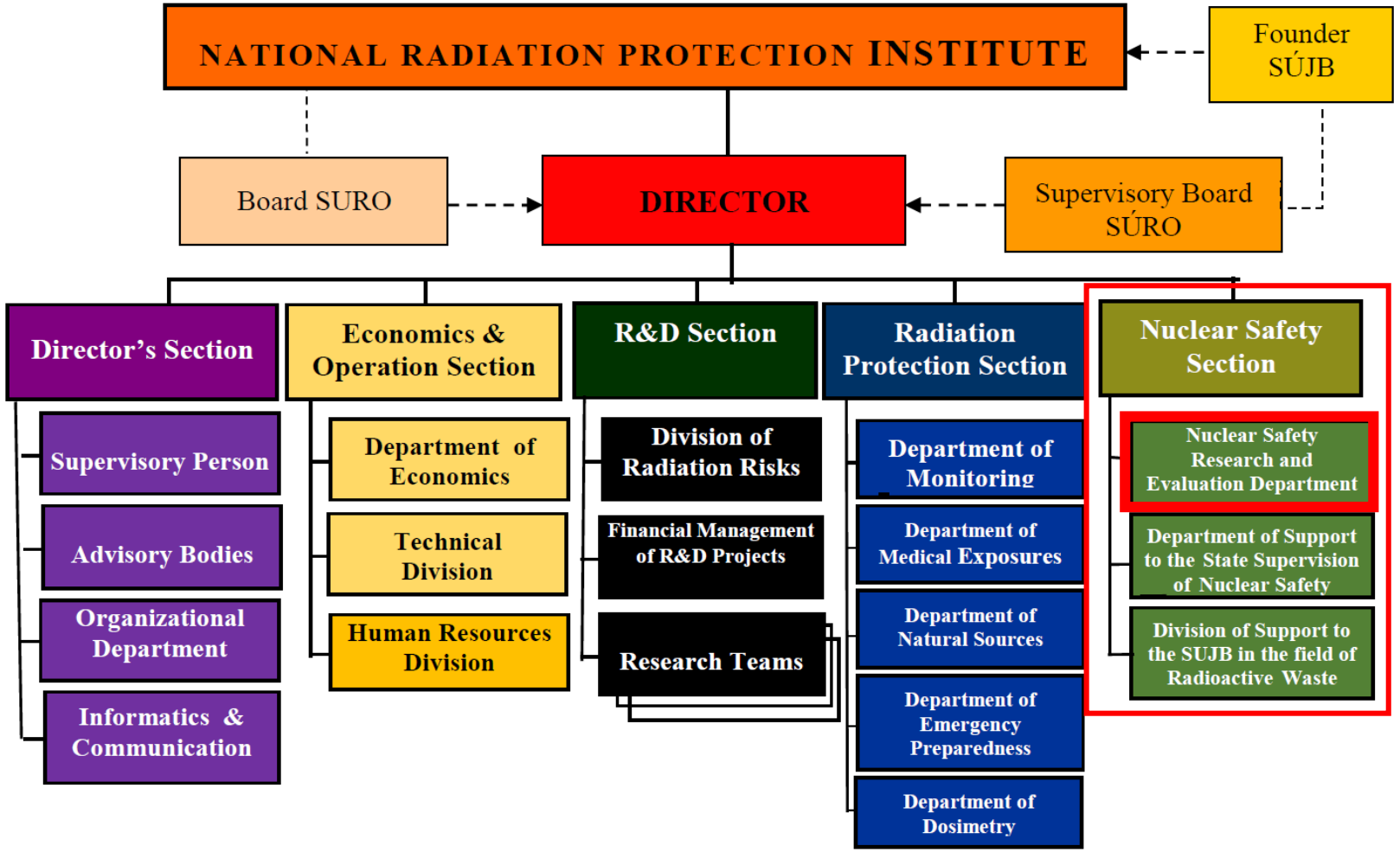
Nuclear power plants in Czechia



SÚRO: the Czech National Radiation Protection Institute (a.k.a. NRPI)

- founded by the State Office for Nuclear Safety (SÚJB)
- public research institute
- established in 1995 as the scientific and technical support organisation to SÚJB in the field of radiation protection
- from 1.1.2021 support extended to nuclear safety; relevant examples:
  - development of SÚJB guidelines
  - assessment of licensing documentation
  - confirmatory safety analyses
    - major development in fuel performance analyses since 1.1.2024

SÚRO-TSO


NATIONAL RADIATION PROTECTION INSTITUTE
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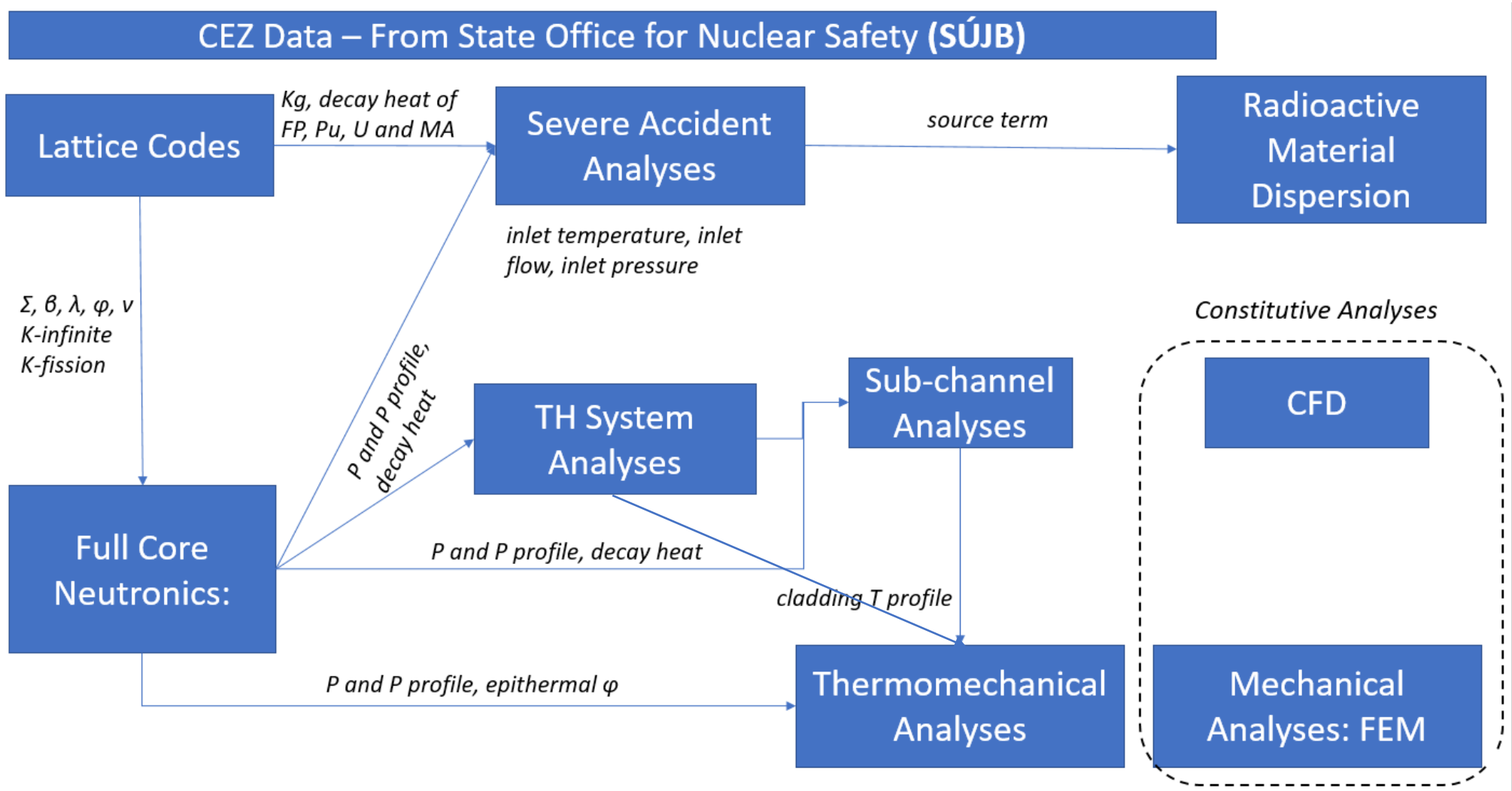
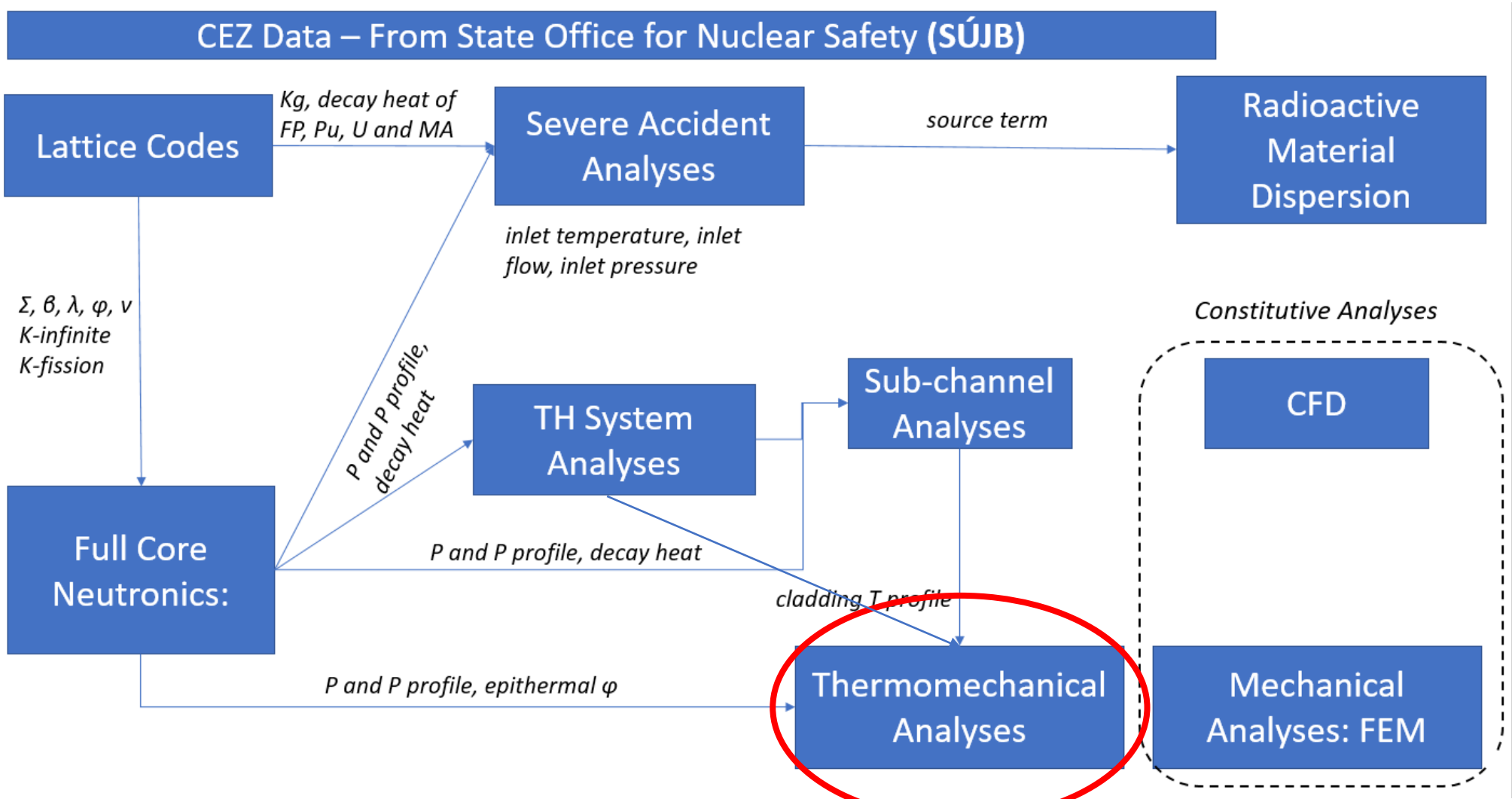
Board SURO
DIRECTOR
Supervisory Board SÚRO
Director's Section
Supervisory Person
Advisory Bodies
Organizational Department
Informatics & Communication
Economics & Operation Section
Department of Economics
Technical Division
Human Resources Division
R&D Section
Division of Radiation Risks
Financial Management of R&D Projects
Research Teams
Radiation Protection Section
Department of Monitoring
Department of Medical Exposures
Department of Natural Sources
Department of Emergency Preparedness
Department of Dosimetry
Nuclear Safety Section
Nuclear Safety Research and Evaluation Department
Department of Support to the State Supervision of Nuclear Safety
Division of Support to the SUJB in the field of Radioactive Waste

Deterministic safety analysis capabilities in SÚRO



Deterministic safety analysis capabilities in SÚRO



Fuel performance analysis

- Purpose:
  - on-demand analyses for SÚJB
- Code: TRANSURANUS (JRC Karlsruhe)
  - steady-state + transient
  - Russian correlations included in the code
  - Westinghouse proprietary correlations added → SÚRO proprietary version
  - can be further developed
- Input time series:
  - steady-state LHRs from the code ANDREA (ÚJV)
  - transient LHRs from the code PARCS (US NRC)
  - transient thermal-hydraulics from the codes TRACE (US NRC) or SubChanFlow (KIT)

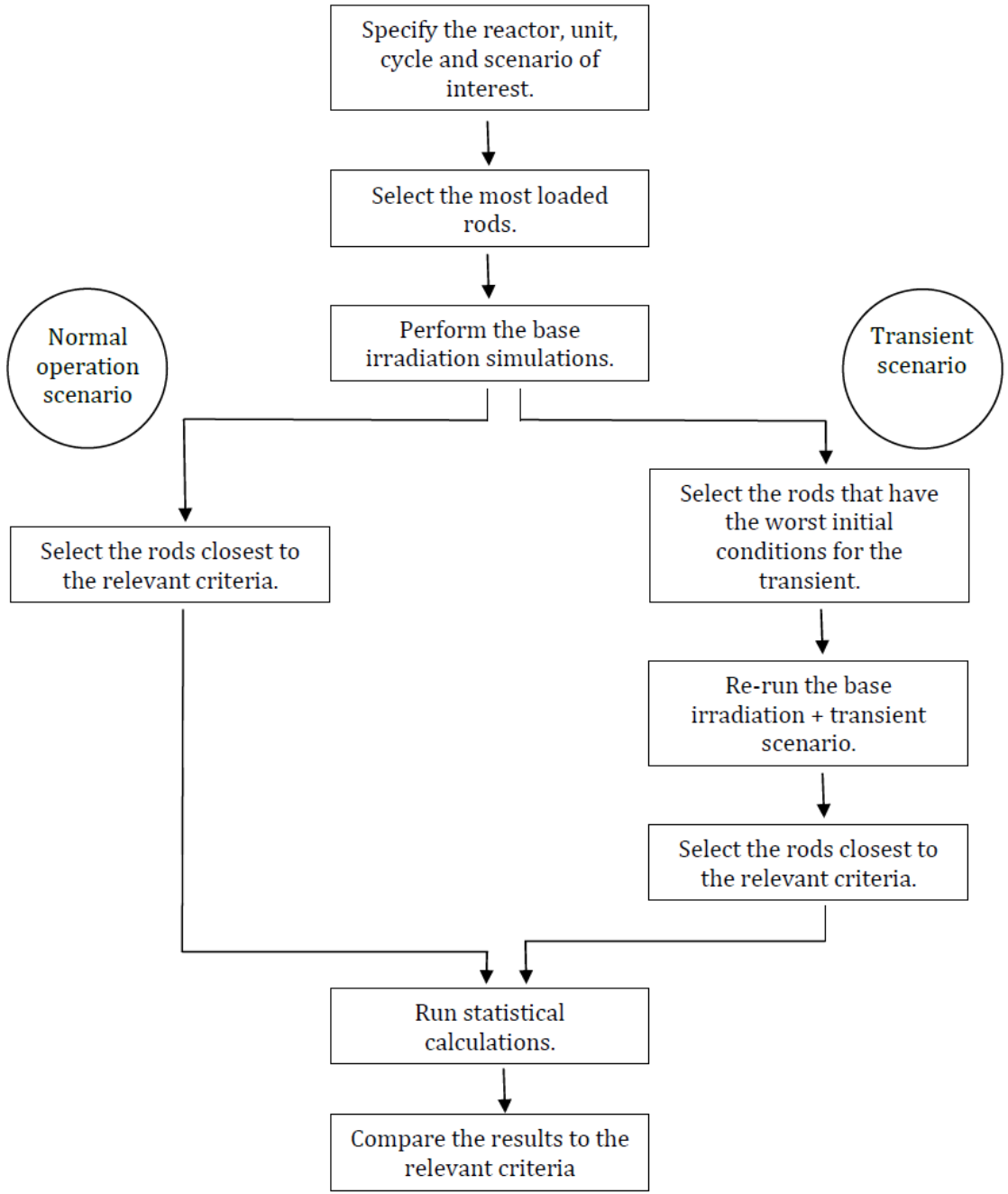
Fuel performance analysis methodology

- SÚJB specifies the analysis of interest (reactor, unit, cycle, scenario).
- Steady-state 'whole core' best-estimate analysis
  - select the most loaded rods (depending on the scenario) in each assembly in the core, this gives a conservative envelope of the whole core
    - highest local LHR
    - highest average LHR
    - highest change in LHR (if stresses are to be evaluated)
    - highest local burnup
    - highest average burnup

    at any moment during the lifetime, separately for UO_2 and UO_2+Gd_2O_3 rods
  - perform best-estimate analysis of the selected rods ('whole-core')
- Steady-state BEPU analysis
  - steady-state 'whole-core' best-estimate analysis as above
  - run statistical calculations for the rods closest to the relevant criteria

Fuel performance analysis methodology

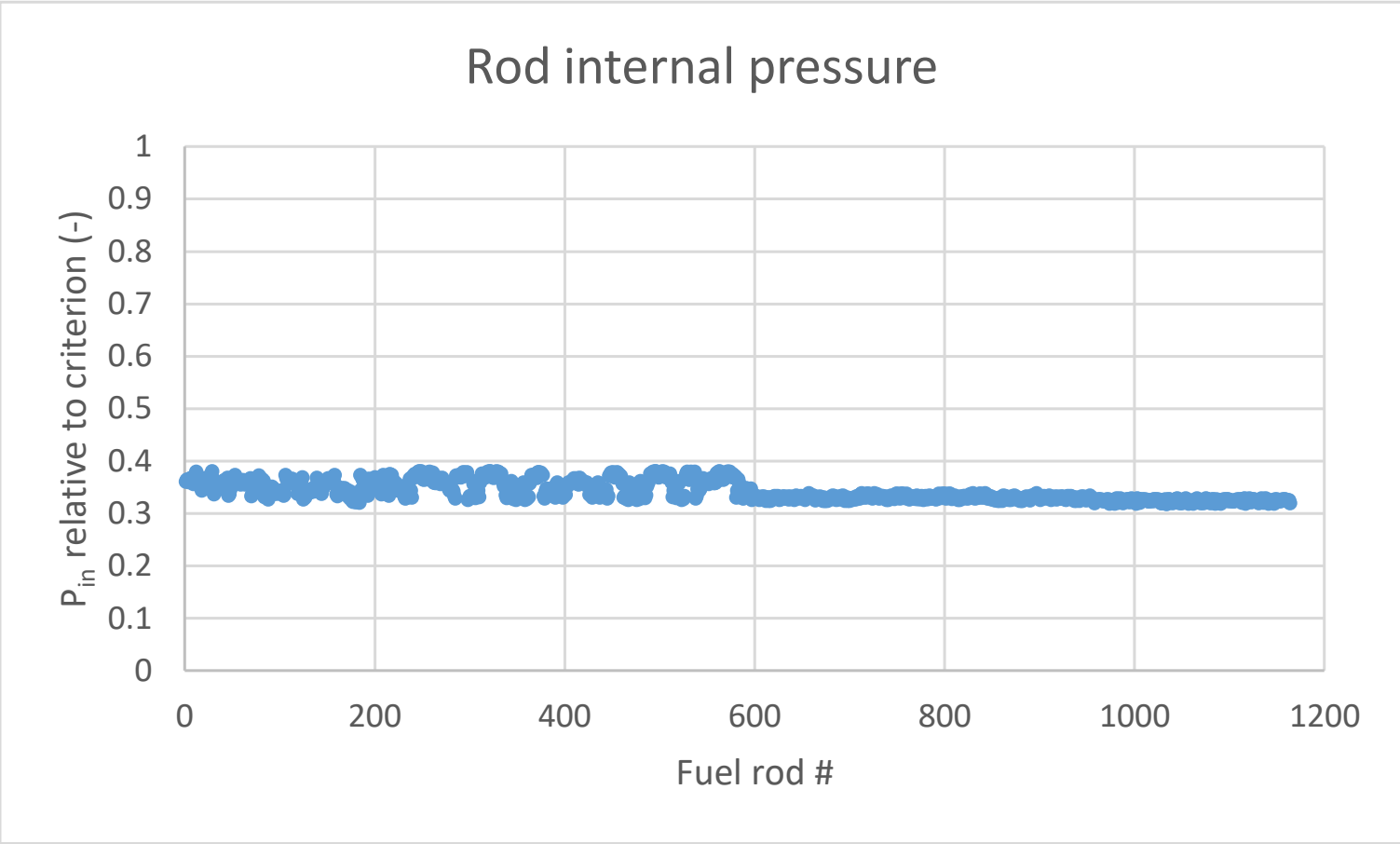
- Transient/accident analysis
  - steady-state ‘whole-core’ best-estimate analysis as above
  - select the rods with the worst initial conditions for the transient
  - perform the steady-state + transient simulation for the selected rods
  - run statistical calculations for the rods closest to the relevant criteria


Specify the reactor, unit, cycle and scenario of interest.
Select the most loaded rods.
Perform the base irradiation simulations.
Normal operation scenario
Transient scenario
Select the rods closest to the relevant criteria.
Select the rods that have the worst initial conditions for the transient.
Re-run the base irradiation + transient scenario.
Select the rods closest to the relevant criteria.
Run statistical calculations.
Compare the results to the relevant criteria

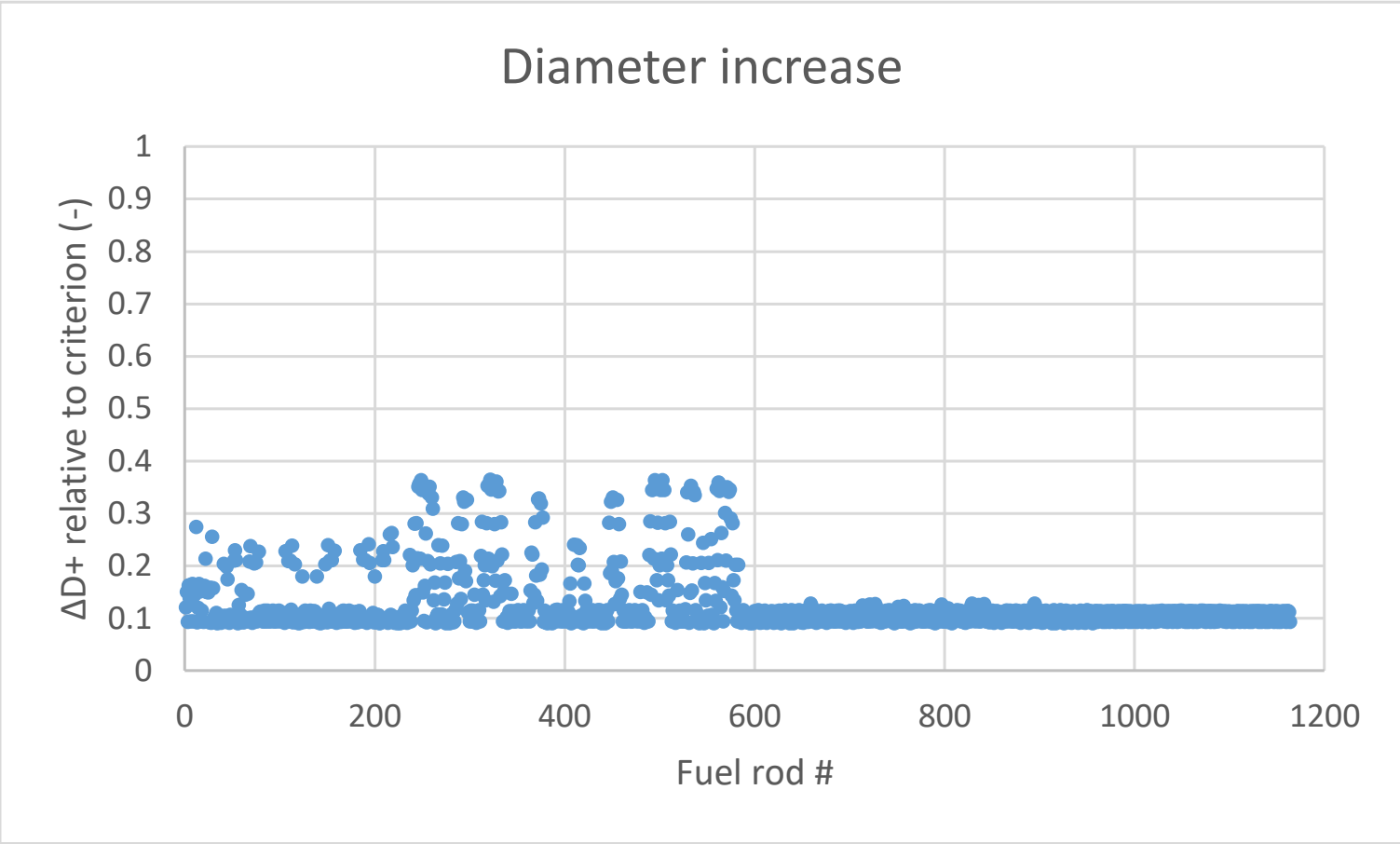
Fuel performance analysis capabilities

- Steady-state ‘whole-core’ analysis
  - for uniform core
  - for mixed core
- Statistical calculations
- LOCA analysis
- 3D problems

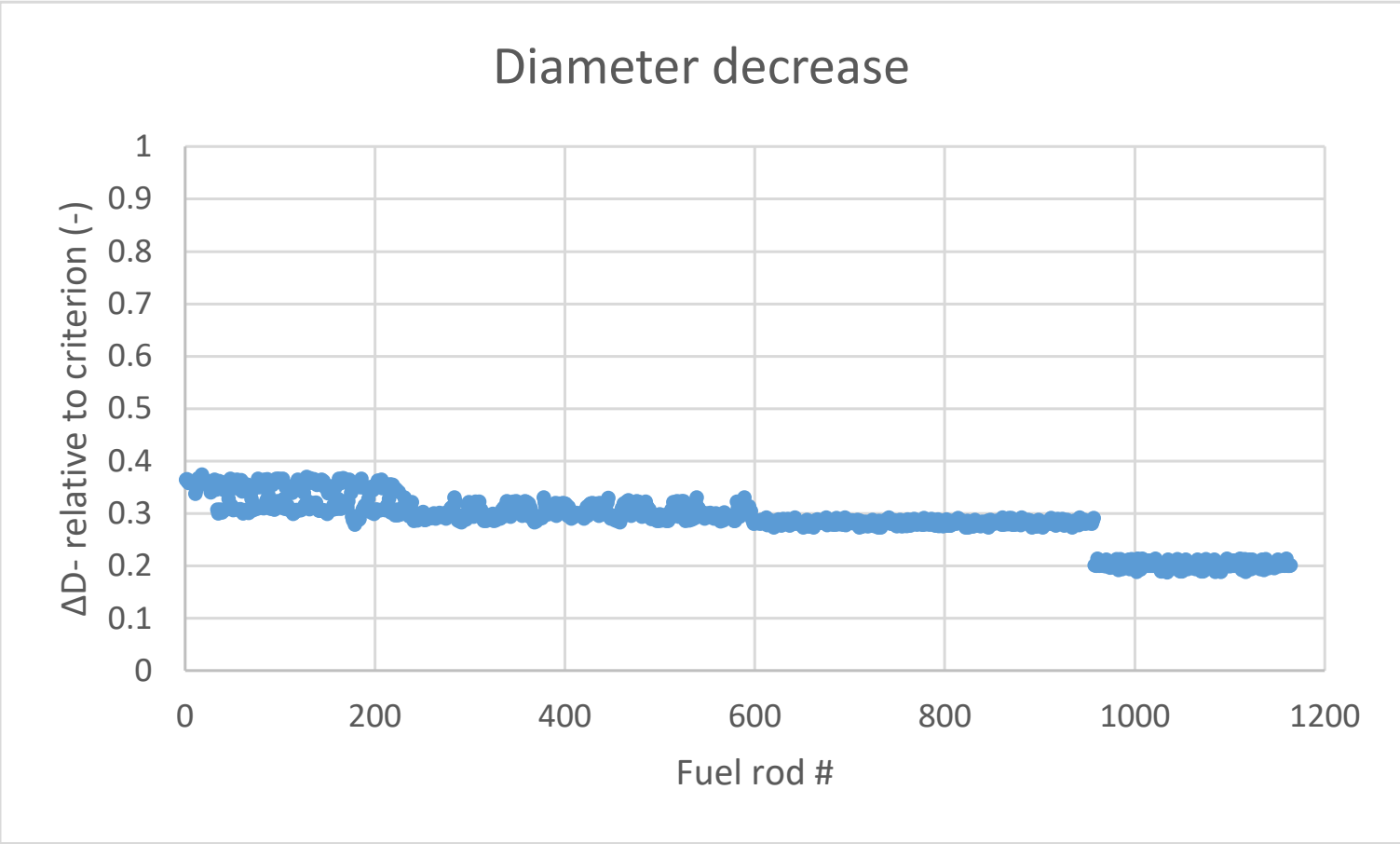
Results


Rod internal pressure
P_{in} relative to criterion (-)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
Fuel rod #

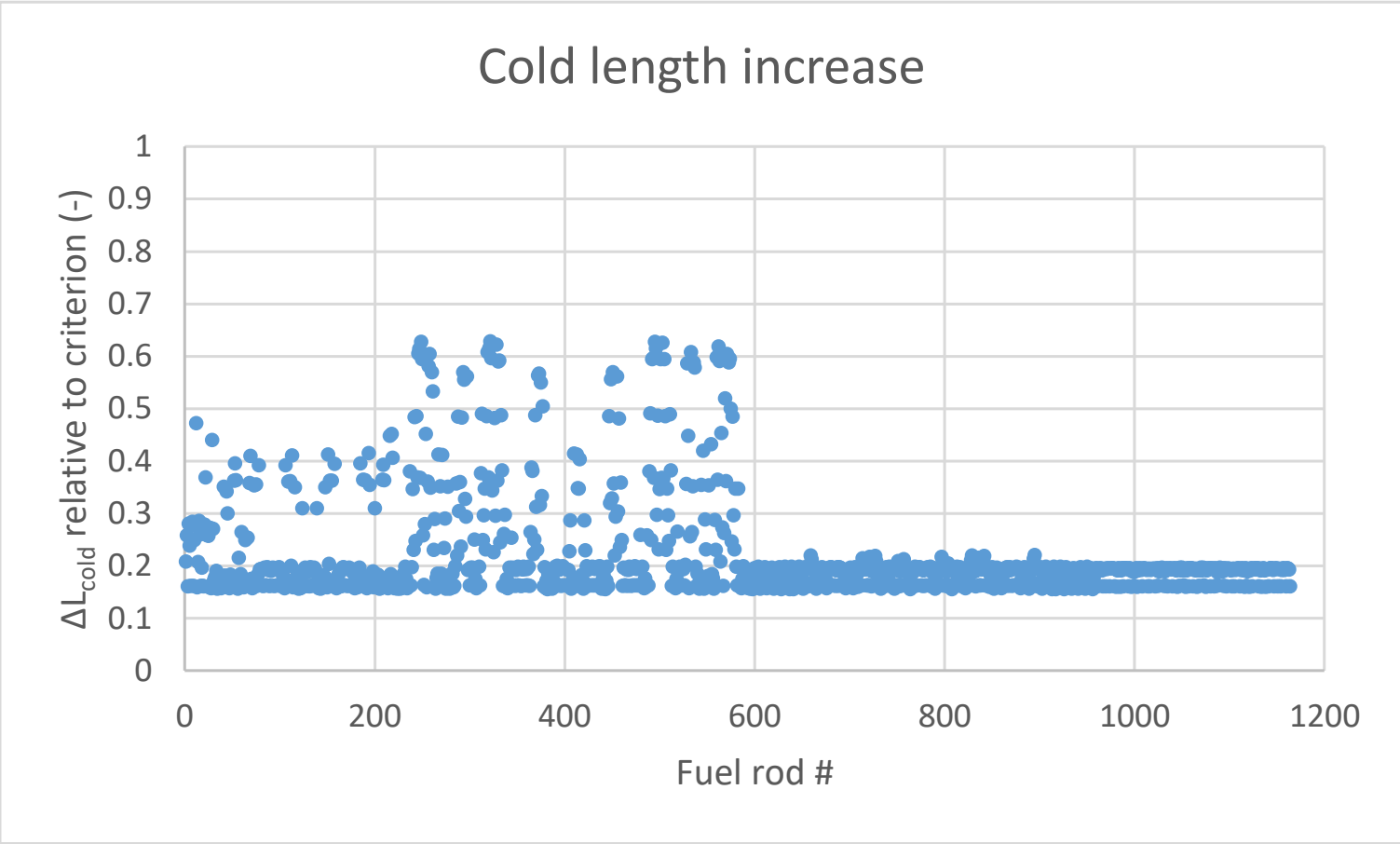
Results


Diameter increase
ΔD+ relative to criterion (-)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
Fuel rod #

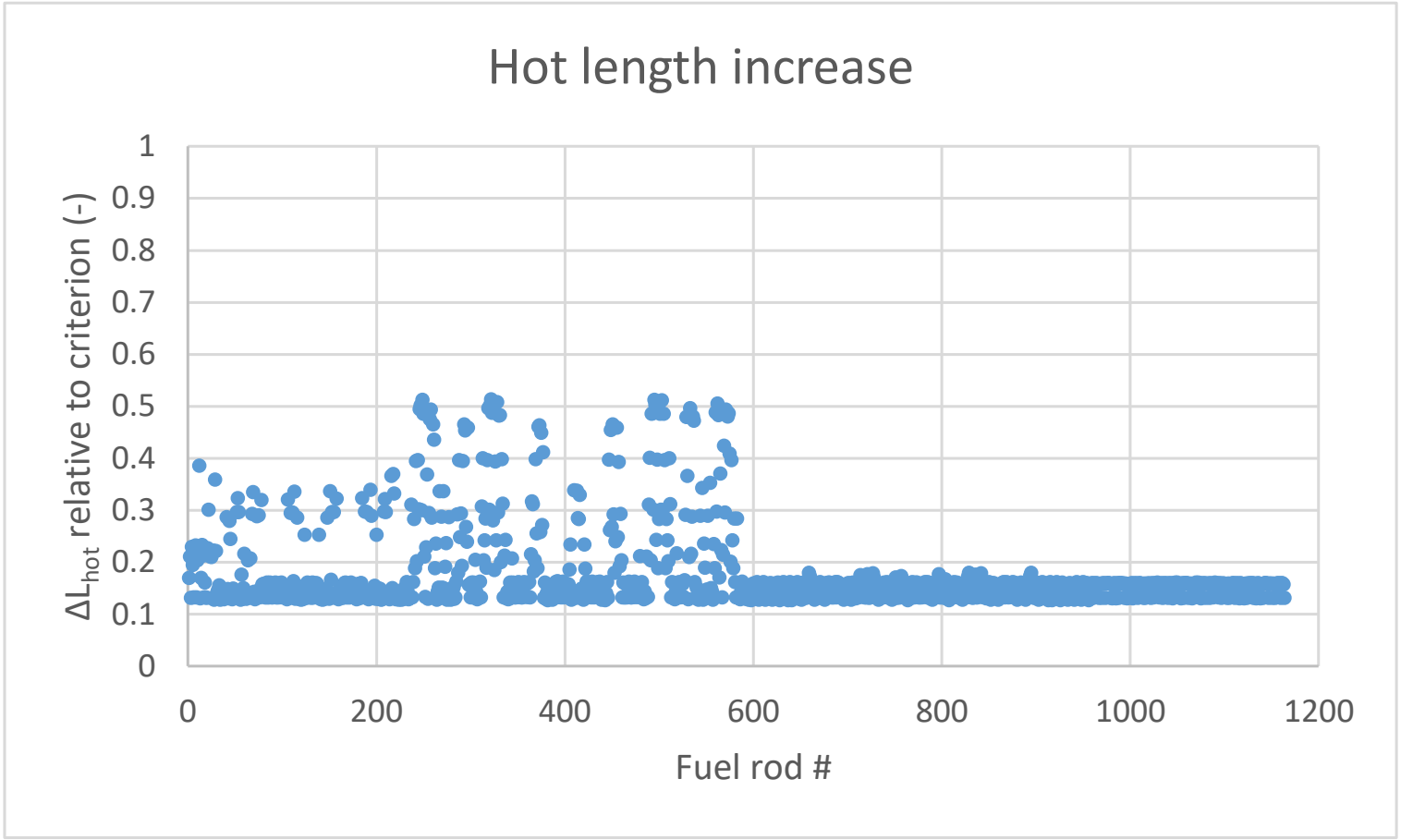
Results


Diameter decrease
ΔD- relative to criterion (-)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
Fuel rod #

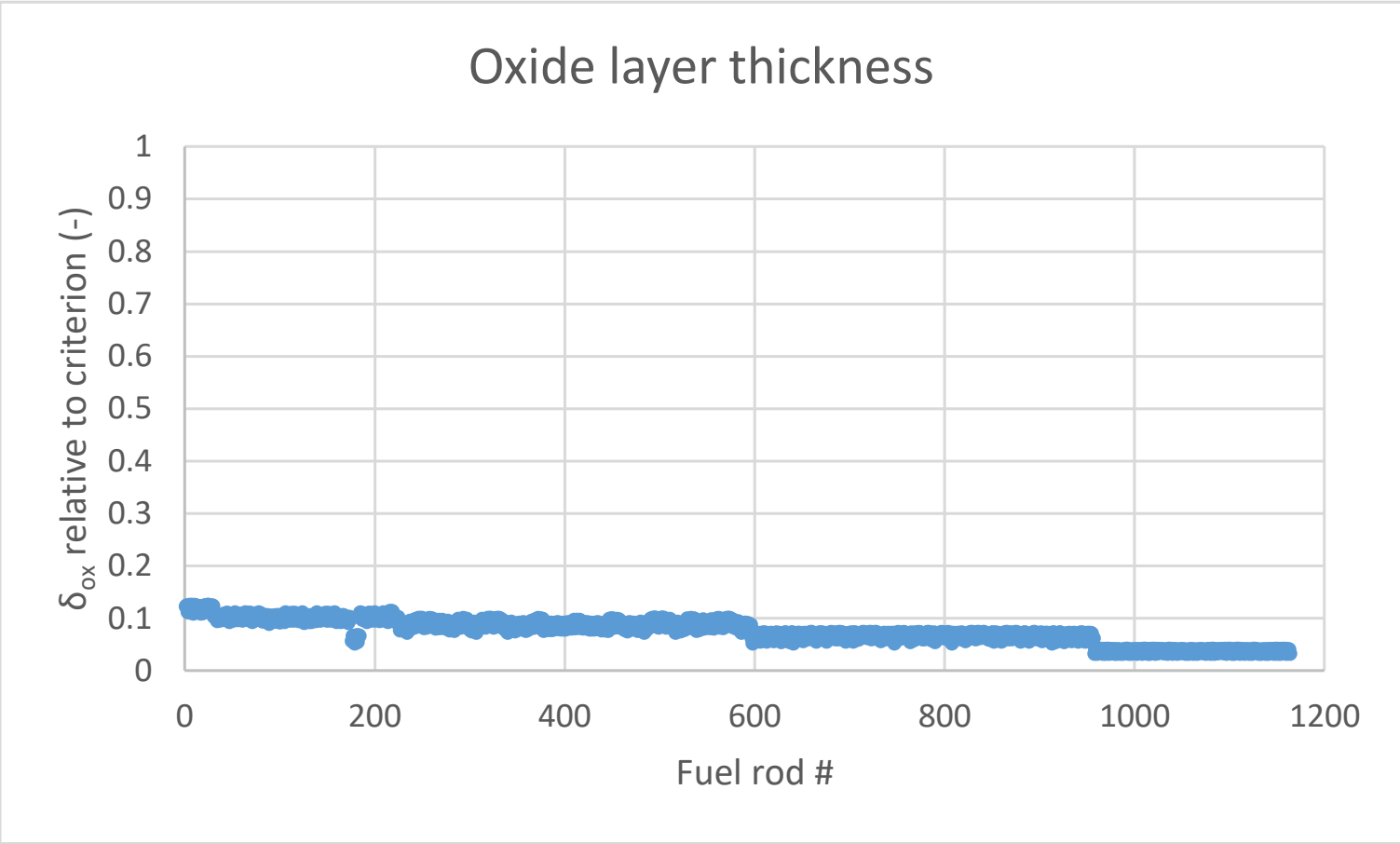
Results


Cold length increase
ΔL_{cold} relative to criterion (-)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
Fuel rod #

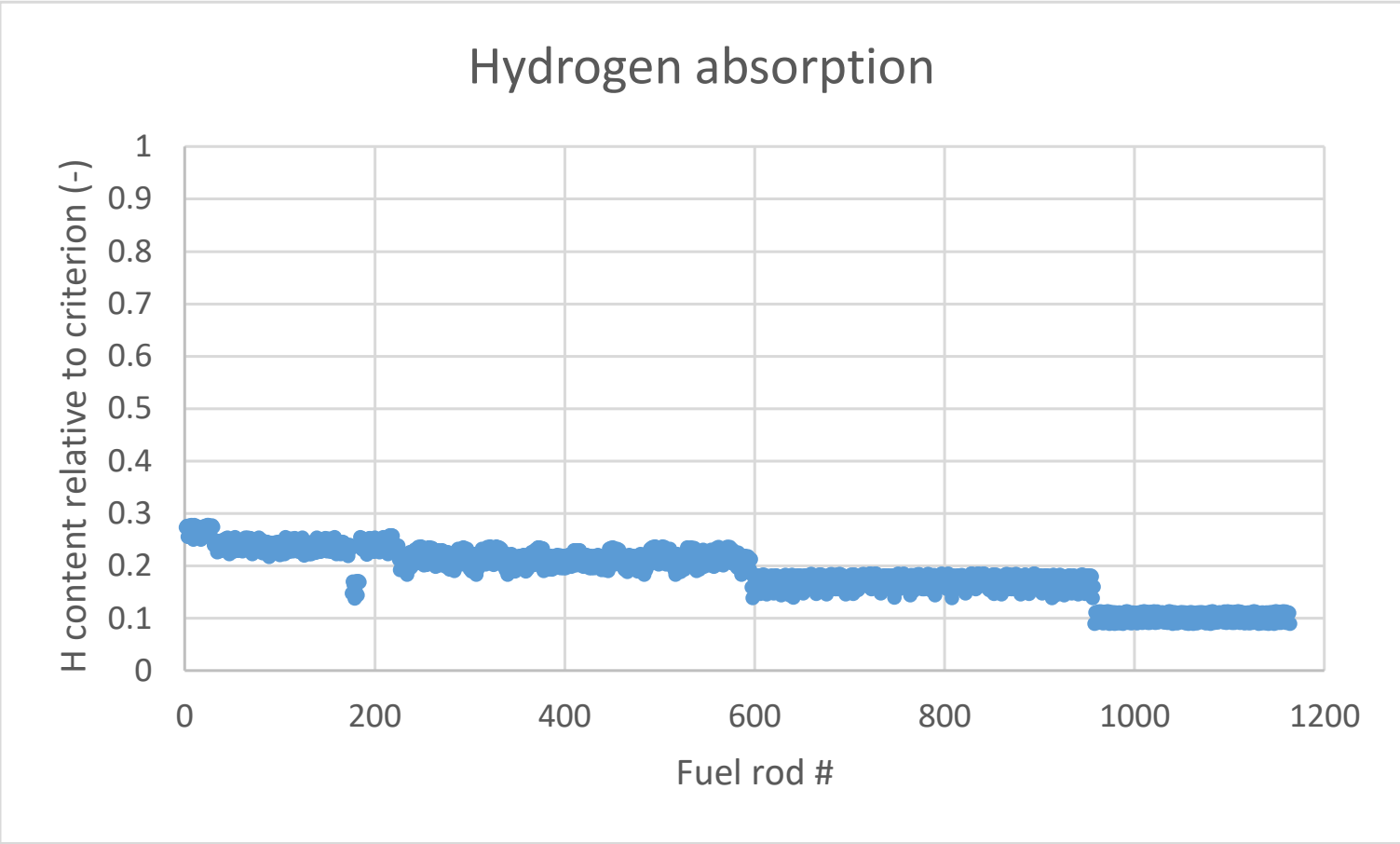
Results


Hot length increase
ΔL_hot relative to criterion (-)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
Fuel rod #

Results


Oxide layer thickness
δ_{ox} relative to criterion (-)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
Fuel rod #

Results


Hydrogen absorption
H content relative to criterion (-)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
Fuel rod #

Recent and near-term applications

Licensing analyses for

- 12-month → 18-month cycles transition in Temelín NPP with TVSA-T.Mod.2 fuel from TVEL
- New fuel: RWFA-T from Westinghouse in Temelín
- New fuel: NOVA E-6 from Westinghouse in Dukovany
- New APR-1000 units in Dukovany from KHNP
- New SMR in Temelín from Rolls-Royce
- …?

Conclusions

SÚRO is in the process of developing the capabilities necessary for the full-scope confirmatory analyses in the field of fuel performance.

The analyses are performed using the code TRANSURANUS.

The aim is to be able to do all the safety analyses independently.

The development of fuel performance analyses follows the developments in neutronics and thermal-hydraulics, but temporarily these input data can be provided by the licensee.

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Thank you for your attention!