Experiment is the ground truth.

The role of experimental facilities in the future of reactor physics simulation.



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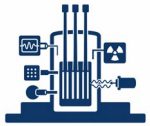
PHYSOR 2026 · Plenary: Vision and Future Directions of Reactor Physics

A paradox this plenary must name

Simulation rises. The infrastructure that validates it contracts.

Simulation capability ↑

- GPU Monte Carlo, continuous-energy fidelity
- Exascale multiphysics coupling
- AI/ML surrogates and digital twins
- Integrated platforms
- Physics based AI assisted



Experimental base ↓

- **Europe: 318 ➔ 30 research reactors 1960s ➔ 2026**
- Mean age ~ 60 years
- **USA: 65 ➔ 25 university RR**
- Generational loss of experimentalists

Source: TOURR (Towards Optimised Use of Research Reactors)

The validation gap

The simulation methods we use today are based on experiments and codes developed *45–50 years ago.*

How can we apply them to fundamentally new designs — fast-spectrum SMRs, molten-salt reactors, Gen-IV systems, fusion blankets — for which no validation data exists?

Extrapolation without validation is not prediction. It is assumption.

Why do we need experiments ?

Three categories. The gap in each is different.



Nuclear data

Differential and integral validation. Gaps for minor actinides, fast-spectrum materials, fusion-relevant nuclides.



Integral benchmarks

ICSBEP and IRPhEP coverage is thin for fast-spectrum, MSR, HTGR, and fusion blanket configurations.



Multiphysics

Neutronics–TH–fuel behavior- mechanics + full uncertainty. Almost non-existent for innovative reactors.

The V&V,UQ trap

AI and high-fidelity codes do not escape the experimental base. They amplify it.

1. **No modern integral benchmark** — *for your reactor concept or material*
2. **No quantified bias** — *nothing to measure the code against*
3. **No credible VVUQ** — *only procedural compliance*
4. **No licensing pathway** — *when the regulator pushes back*

AI is a multiplier on the data we have, not a cure for the data we don't.

A modern experiment is not a 1970s experiment

Same reactor, different deliverable.

Dimension	Legacy	What codes need now
Instrumentation	Point detectors, limited coverage	Distributed, time-resolved, multi-modal
Uncertainty	Often implicit, reconstructed later	Full uncertainty budget with the data
Geometry	Drawings, manual measurement	As-built CAD, digital twin of facility
Access	Reports, limited distribution	Open, machine-readable, FAIR data

Where we are — and where we must go

The gap is real. So is the opportunity.

Today

- Most graduates have never seen — let alone touched — a reactor
- Benchmarks built for reactors that already operated
- Experimental infrastructure ageing, “dying” and not replaced

How can one design a novel reactor without ever having seen one?

Tomorrow — by design

- Physics-based AI/ML for real-time, high-fidelity simulation
- “Real” digital twins for real-time diagnostics and control
- Immersive VR visualization and digital I&C
- Autonomous/automated control architectures

Three asks for this community

01

Treat experimental infrastructure as shared science.

Not national line items. A portfolio across OECD/NEA, Euratom, bilateral programs — the way ITER, ISS, and CERN are funded.

A research reactor is not a cost. It is investment. The Dutch PALLAS study ➔ 1-3 y ➔ 1–6 G€ saved per downstream commercial nuclear project through the engineers and expertise it trains. Build the reactor first. Build the power plant faster.

02

Make the experimental dependency visible in every paper.

Cite the integral benchmark your code was validated against. If there isn't one, say so.

03

Fund UQ-grade benchmarks before the current ones retire.

Recovery costs more than retention. The experimentalists are retiring.

You cannot validate a 2030 reactor *against a 1970 experiment.*

The vision for reactor physics is not only faster codes or smarter AI. It is the experimental foundation they stand on. We build that foundation together, or predictive credibility erodes regardless of how fast the simulation runs.

— but the foundation is already being built.

Action: VERONICA

Versatile European Reactor fOr Neutron Irradiation and nuClear reseArch

- One facility: ZPR + MPPR
- Zero-power-reactor: Education, training, benchmark experiments
- 10 MW multi-purpose core: Research, isotope production, neutron beam experiments, Multiphysics experiments
- Consortium model: EU and non-EU partners
- veronica.ijs.si

Why this model

- No field of science performs R&D without research infrastructure
- Zero-carbon society, SMRs, Gen-IV R&D, licensing ➔ all require experimental data
- Regional shared infrastructure: many countries, proportional funding

The research reactor of 2030

Not rebuilt from the past. Designed for the future.

Versatile

Adaptable spectrum, geometry, materials

Physics-based AI / ML

Surrogates trained on the facility's own measurements

Fully instrumented

State-of-the-art nuclear instrumentation — distributed, time-resolved, multi-modal

Digital twin + Immersive VR

Real-time diagnostics and sensor — remote experiment preparation and training

Digital I&C

Autonomous control architectures validated at zero power before deployment

Open benchmarks

Every campaign: uncertainty-quantified, machine-readable, FAIR-protocol benchmark

Thank you. Luka Snoj · JSI · luka.snoj@ijs.si

Europe built **318 research reactors. 30 are operating today.**

None of the 288 that closed were replaced.

The question is not whether we can afford these facilities.

It is whether we can afford *not* to have them.