



TWINTOK-IDA: An integrated validation and benchmarking Digital Twin framework



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with M2P2, CEA, IPP, EPFL teams

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Core idea: close the loop between simulations and measurements

- TWINTOK: simulated plasma → SD signals for validation of plasma simulations
- IDA/IDE: measured diagnostics → most probable profiles and equilibrium
- Together: set of signals from simulated and measured shots, compare them and locate the most consistent plasma state
- Issue/feature: various complexity of forward models

Forward models

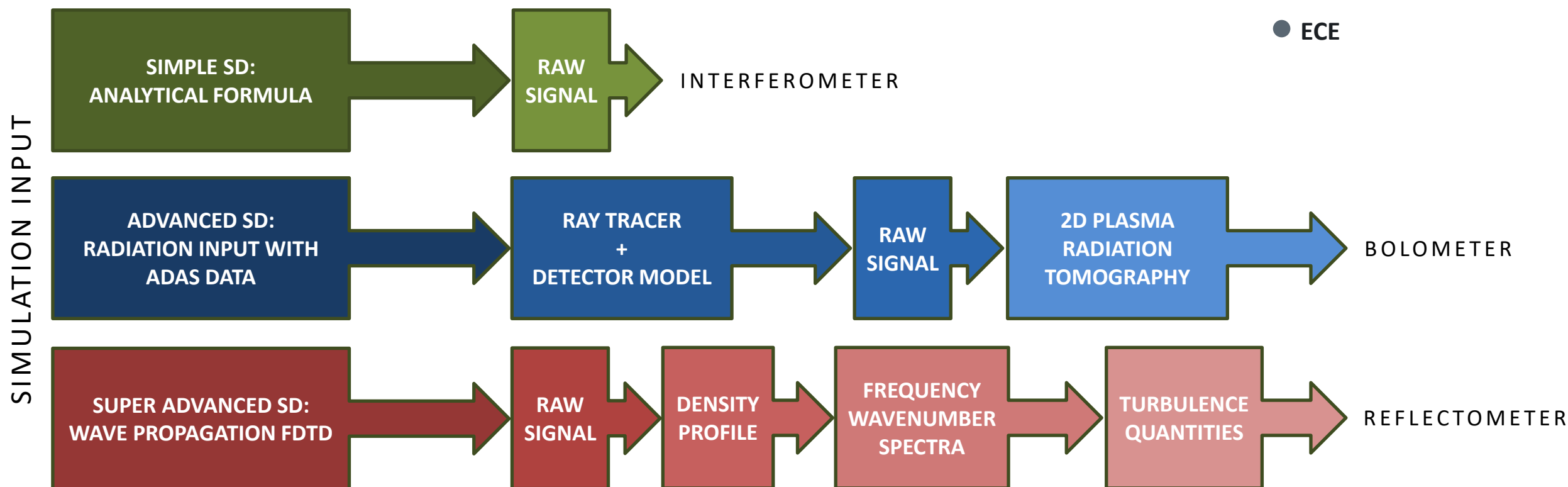
● Interferometry / TIP

● Visible + spectroscopy

● Bolometry

● Reflectometry / FeDoT

● ECE



Current TWINTOK workflow status: Jupyter notebook prototype

INPUT

3D machine geometry (CAD/IMAS),
diagnostic parameters (manual/IMAS),
multi-dimensional simulation data (h5/IMAS)

PLASMA
MODEL

Translates raw fluid grids into a fully
described, optically active plasma
state using OpenADAS atomic models

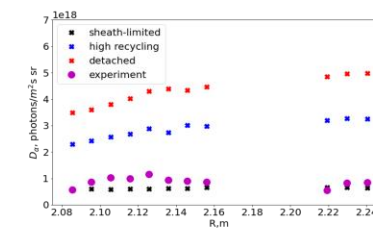
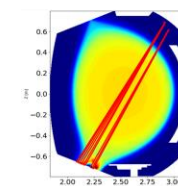
MODULAR SD

Cell-based command layer allowing
to deploy multiple synthetic
diagnostics on demand

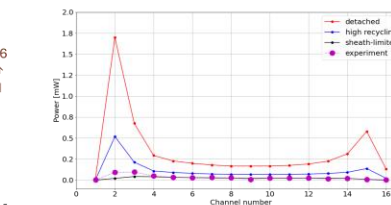
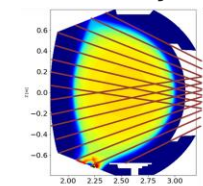
OUTPUT

Immediate visual
validation plots

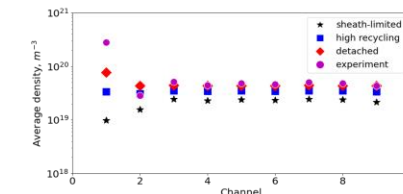
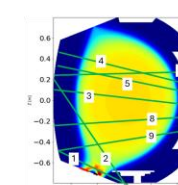
D α emission



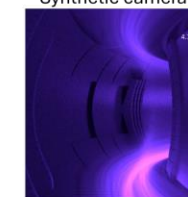
Bolometry



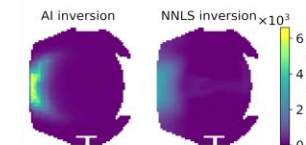
Interferometry



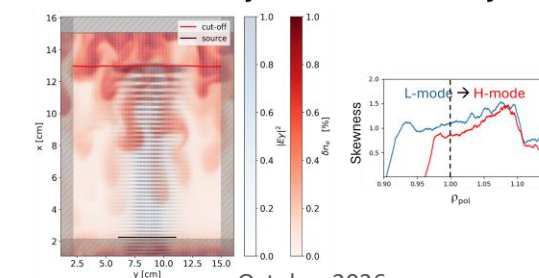
Visible emission
Synthetic camera



Tomographic analysis:
2D radiation map from bolometers signals



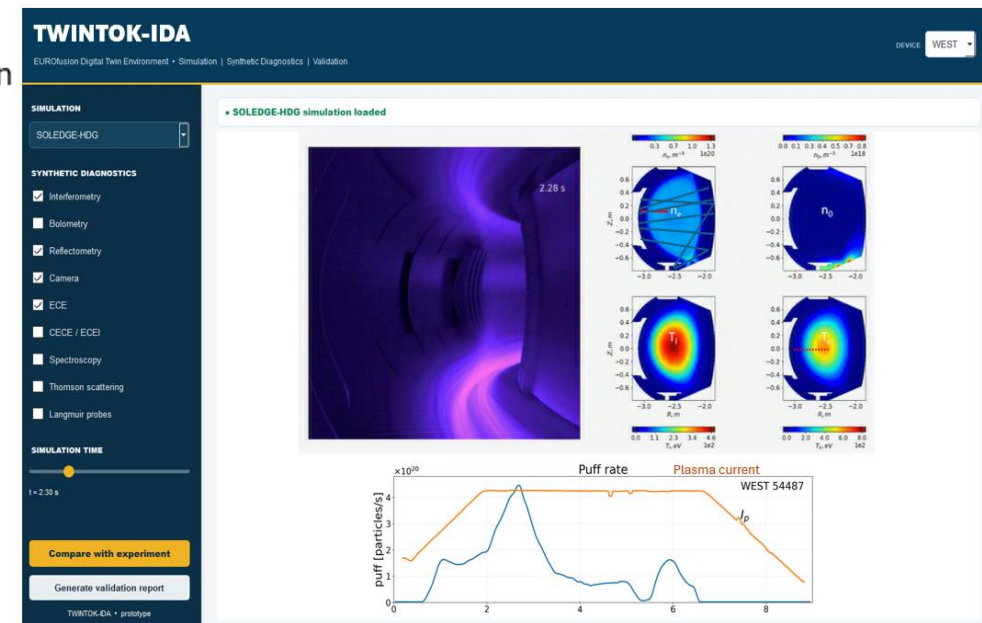
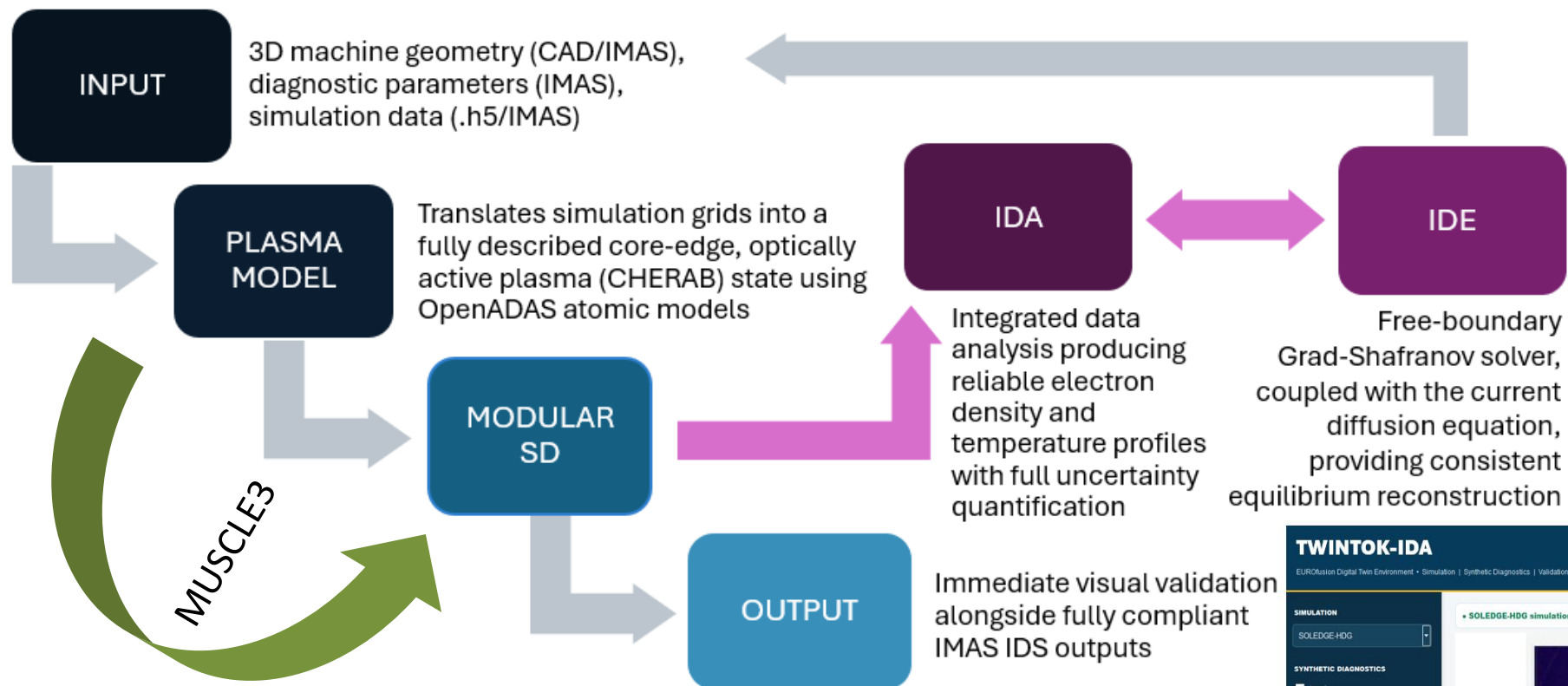
Turbulence analysis via reflectometry





- TWINTOK library — reusable forward models/synthetic diagnostics and analysis routines
- IDA + IDE — IMASified most probable profiles and consistent equilibrium
- Bayesian validation — quantitative comparison and scoring
- MUSCLE3 — coupling standalone codes and different simulation timescales

Towards the integrated TWINTOK-IDA validation workflow



Prototype release early 2027

- D1.1 — Extend and validate the synthetic diagnostic library inside TWINTOK/IMAS
- D1.2 — Deliver a beta Integrated Validation Service: run SDs and collect comparison metrics
- D1.3 — Deliver a beta interactive GUI with visual comparisons and automated reports
- D1.4 — Continue Python IDA transfer in the twin IMAS environment at WEST
- D1.5 — Add X-mode reflectometry to IDA and cross-check against other density diagnostics
- D1.6 — Develop IMAS-compatible IDE apply to WEST and benchmark against NICE equilibrium

- WP1 — Automate a broad SD library completed with standalone solvers through MUSCLE3
- WP2–WP3 — Infer the most probable profiles and equilibria with quantified uncertainties
- WP3 — Build a validation scoring system: Bayesian model support, residual maps and multi-metric comparison
- WP4 — Provide an operational visualization/reporting interface for WEST, TCV and any IMAS-compatible device

- WEST IR DT by M-H Aumeunier:
SOLEGE-HDG wall fluxes → MUSCLE3 thermal/IR placeholder → synthetic IR camera
- TCV data & visualization: Connect with C. Sommariva's DT
TWINTOK as a synthetic diagnostic/validation service inside a distributed visual platform
- Expand SDs through MUSCLE3 integration of existing forward models: IR, Langmuir probes, ECE...
- AI/UQ: separatrix and filament detection, surrogate acceleration, uncertainty propagation and discrepancy classification
- Community release: documented library, reproducible examples and beta GUI/reporting workflow