WEST data processing workflow and statistical analysis

DE LA RECHERCHE À L'INDUSTRIE

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J. Morales, H. Ancher, J.-F. Artaud, C. Bourdelle, R. Dumont, L. Fleury, F. Imbeaux, P. Maget, P. Maini, P. Manas, V. Ostuni and WEST team (west.cea.fr/WESTteam)

Introduction

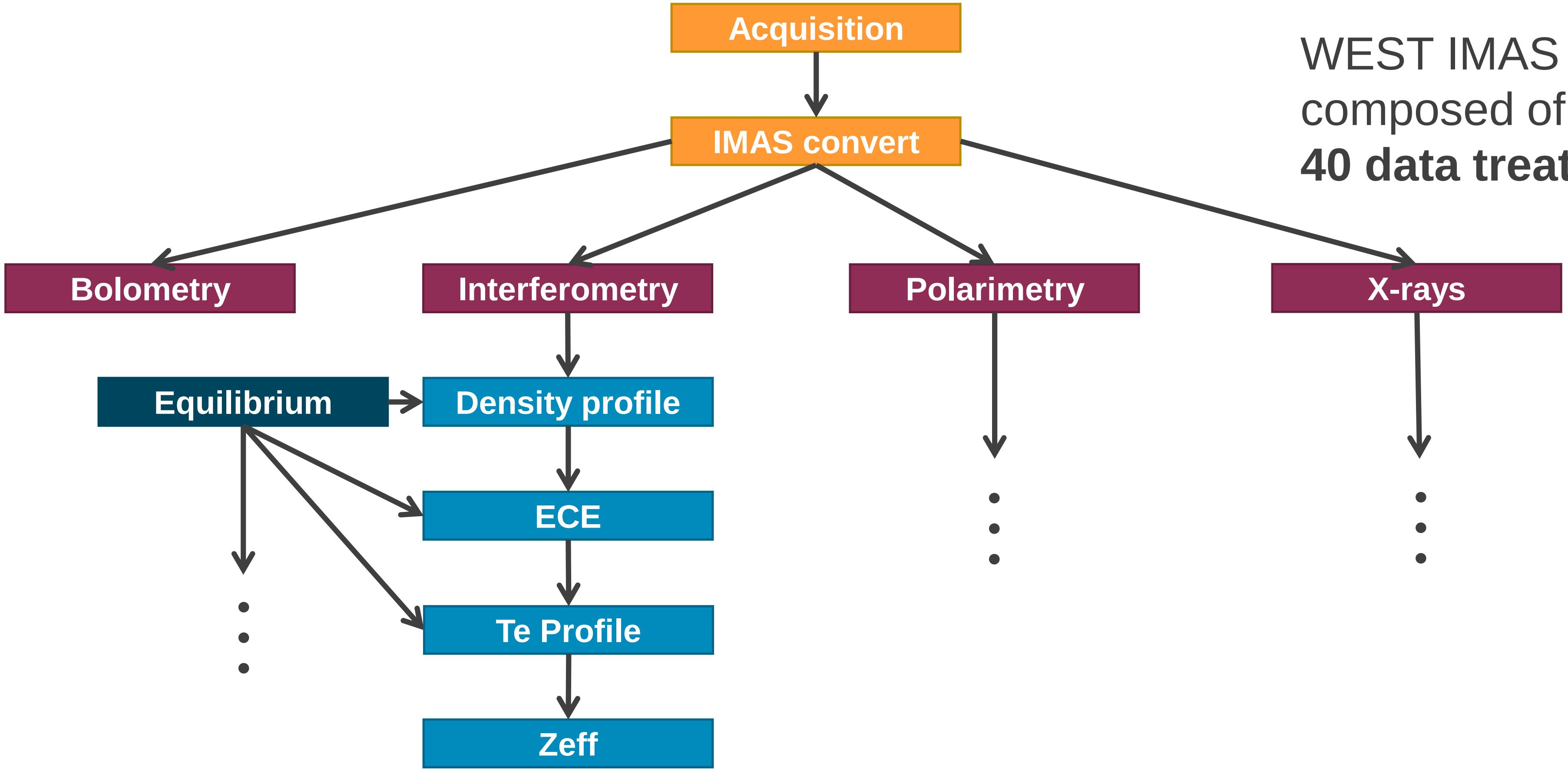
Leverage experimental data to answer:

- How to **better characterize** tokamak plasmas?
- How to **improve** tokamak **operation**?

To tackle these two questions, in this talk:

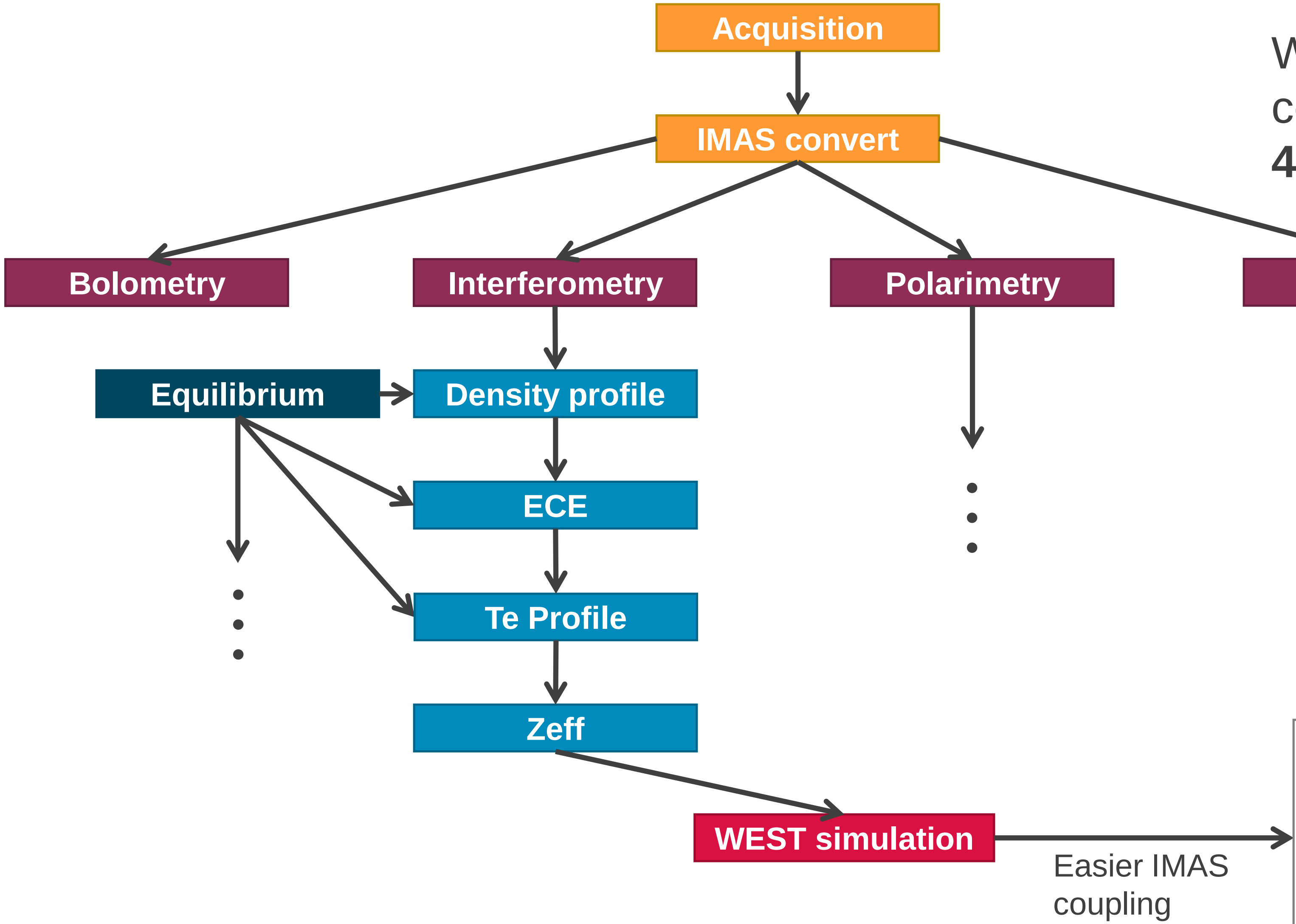
- **IMAS** data processing workflow in WEST tokamak
- Creation and statistical analysis of a database composed of:
  - ➢ Plasma quasi-steady states (plateaus)
  - ➢ Time evolving plasma quantities

WEST IMAS Data Processing Workflow



WEST IMAS workflow is composed of more than **40 data treatments**

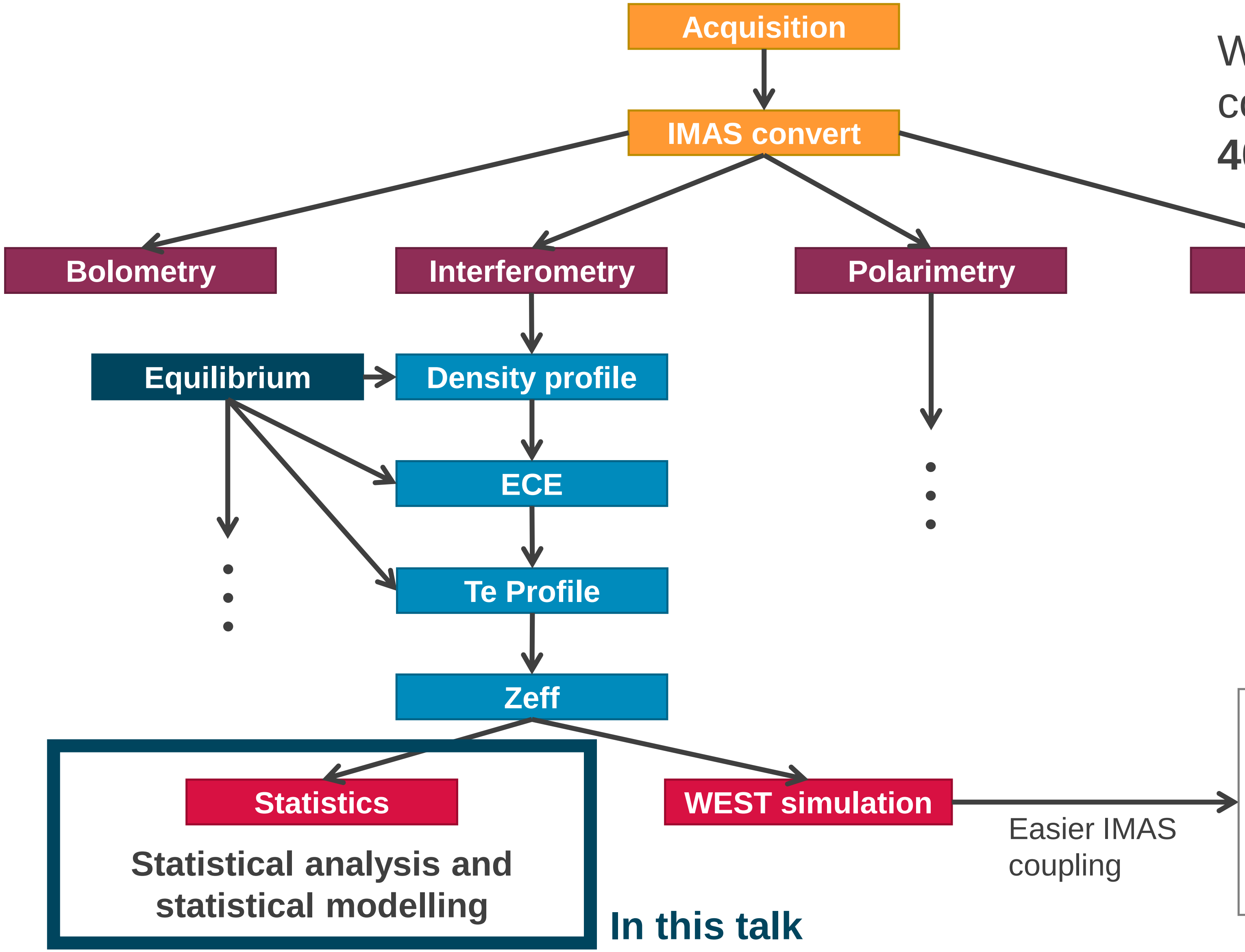
WEST IMAS Data Processing Workflow



WEST IMAS workflow is composed of more than **40 data treatments**

Simulation software:
- Heat and current drive (LH, ICRH)
- Integrated modelling (METIS, RAPTOR, HFPS, etc.)

WEST IMAS Data Processing Workflow



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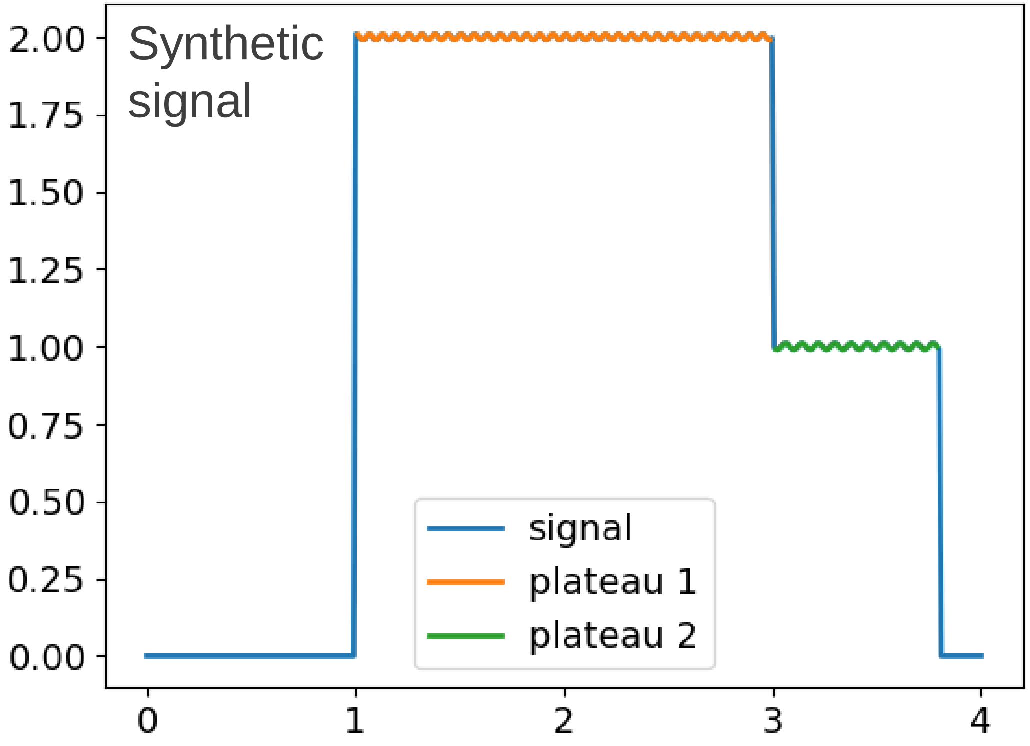
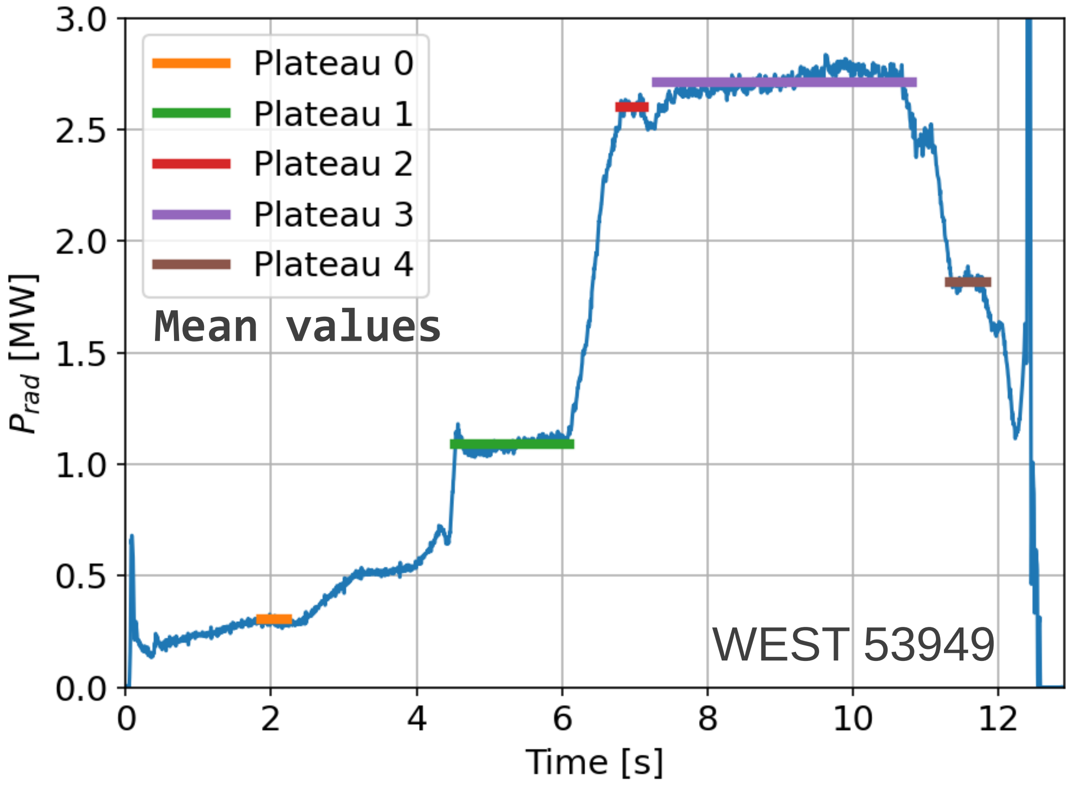
Simulation software:
- Heat and current drive (LH, ICRH)
- Integrated modelling (METIS, RAPTOR, HFPS, etc.)

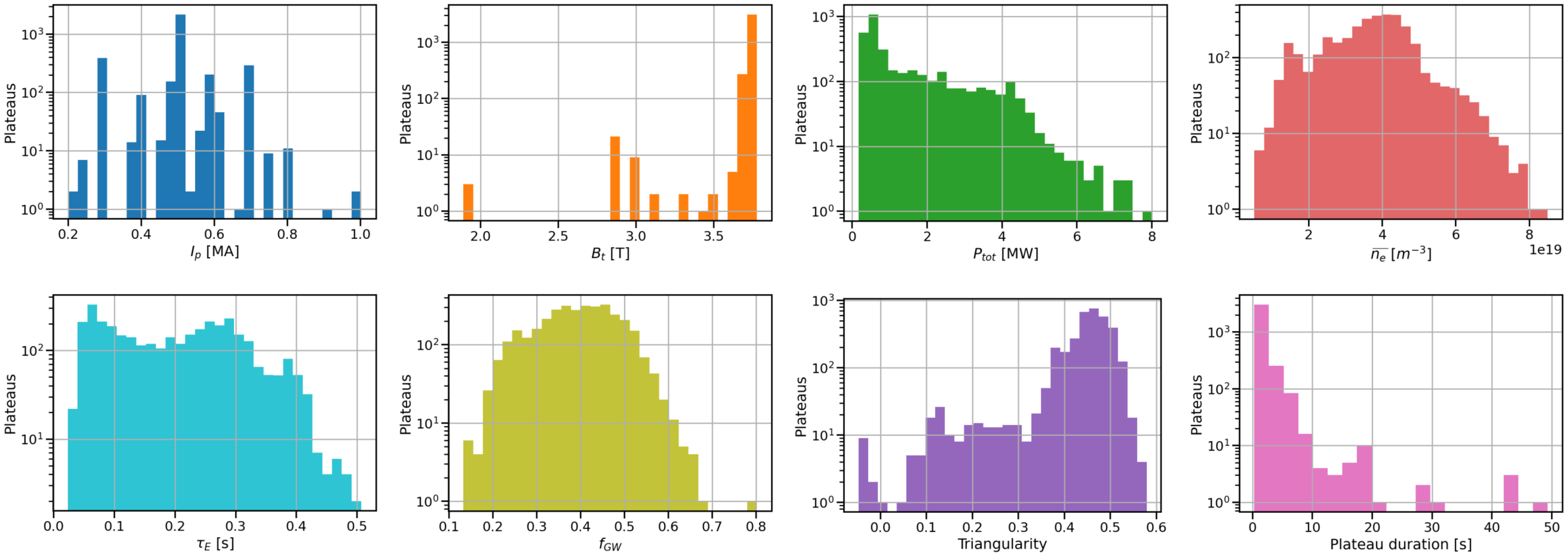
Quasi-steady states detection for statistics and classification

- Quasi-steady states are **detected automatically**, we avoid a bias that can appear when a human selection is made (from 2000 pulses: 6000 quasi-steady states for more than 700 quantities, as averaged temperatures, densities, equilibrium parameters, etc.)
- The definition of a steady state is explicitly given to the detection algorithm by the user, numerical code available at: github.com/jmoralesFusion/signal_plateau_recognition





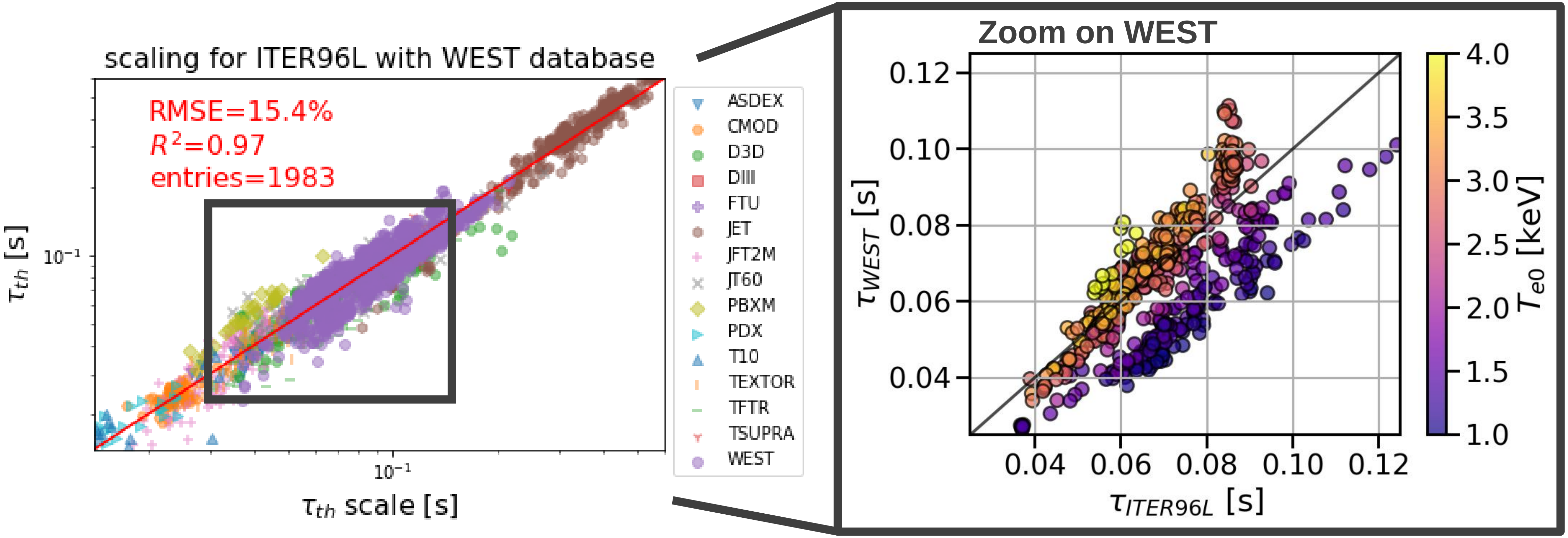
WEST quasi-steady states mean quantities example



Histogram data: mean quantities in identified plateaus of minimum 0.3s duration
WEST C4 and C5 campaigns (2019-2021)

Suited for <u>Integrated Data Analysis</u>: database includes more than 700 quantities, 6000 plateaus and continues to grow…

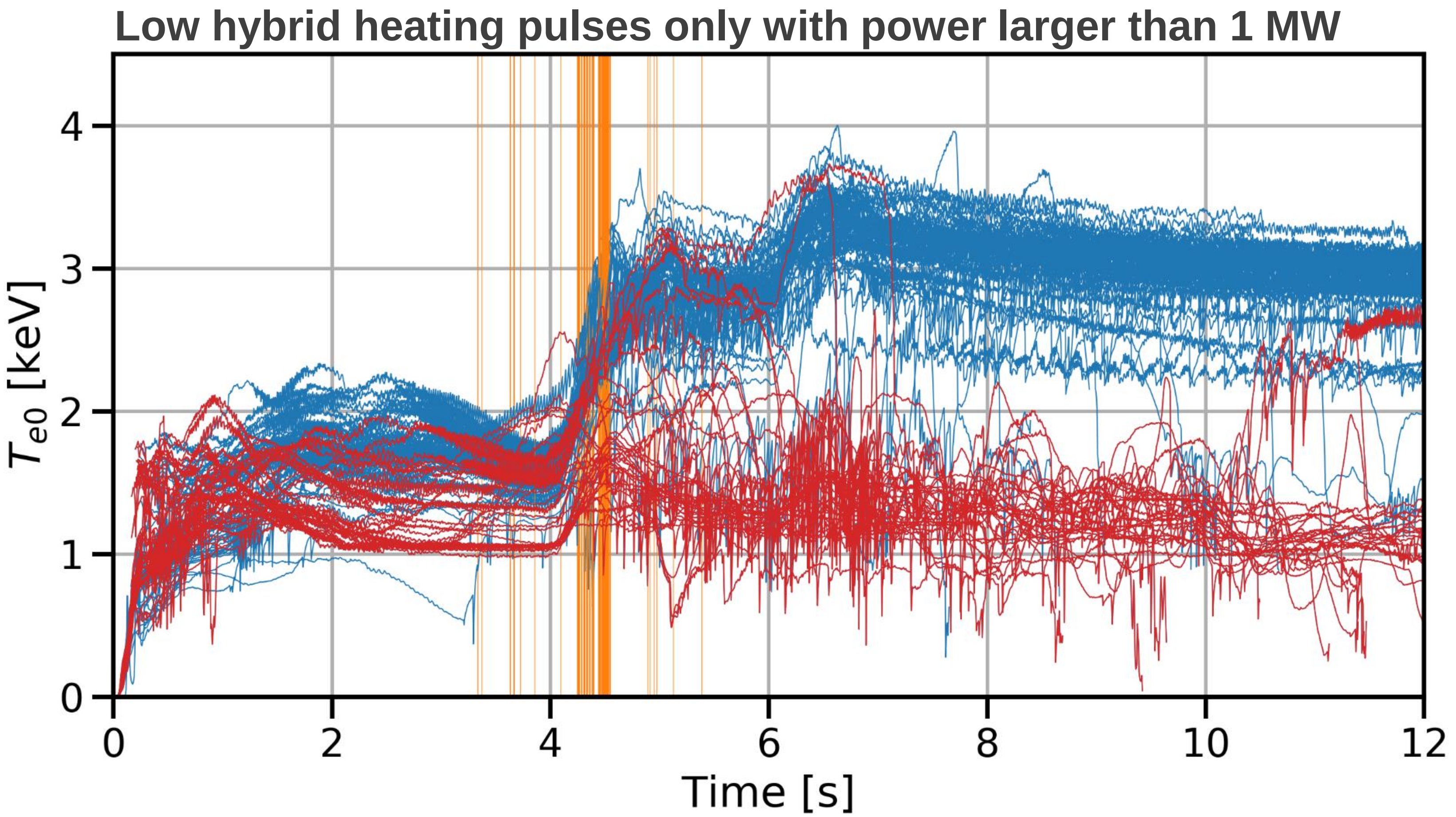
WEST confinement time analysis using quasi-steady states

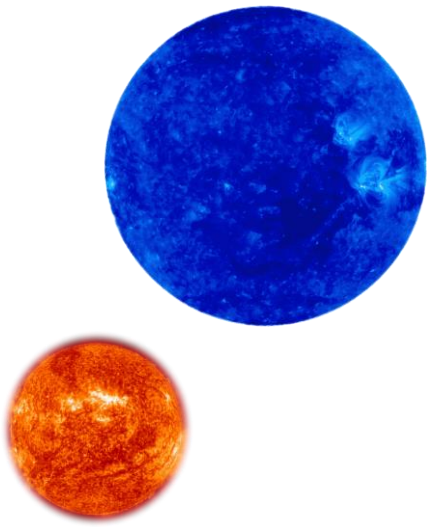


$$\tau_{ITER96L} = 0.023\, I_p^{0.96} B^{0.03} P^{-0.73} n_e^{0.4} M^{0.2} R^{1.83} \varepsilon^{-0.06} k^{0.64}$$ [Kaye, NF, 1997]

- Using **plateau averaged quantities** we find WEST confinement time in L mode **well aligned with ITER96L** scaling law [V. Ostuni, EU-US TTF, 2021]
- Interestingly in WEST **two confinement regimes** (clusters) are observed, they are strongly correlated with central electron temperature (T_{e0}), we call them **hot and cold T_{e0} branches**

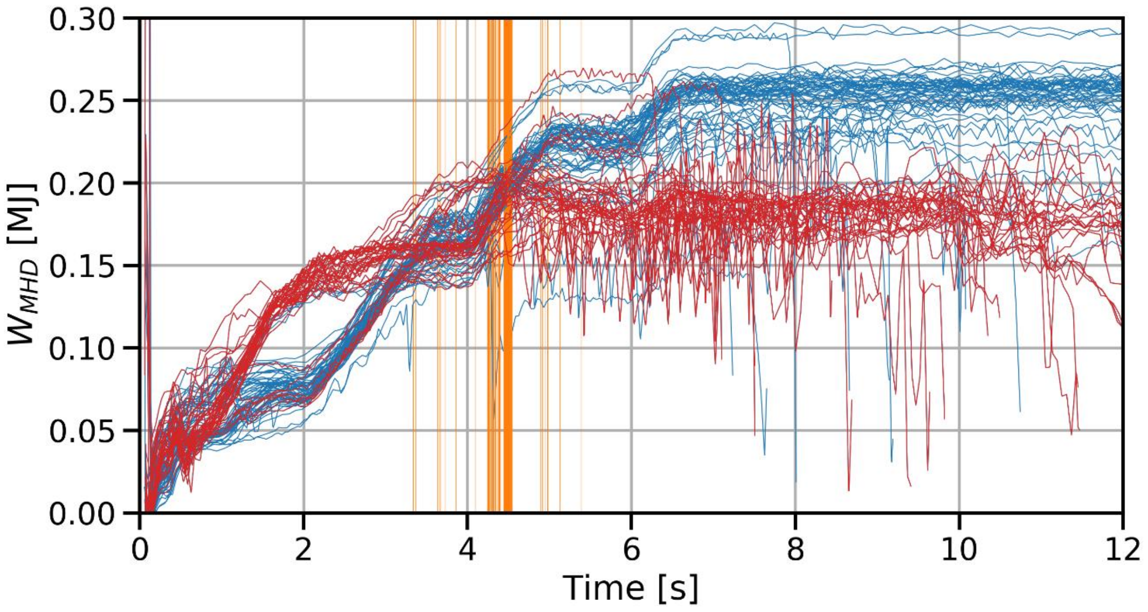
Time signals of hot and cold T_{e0} branches

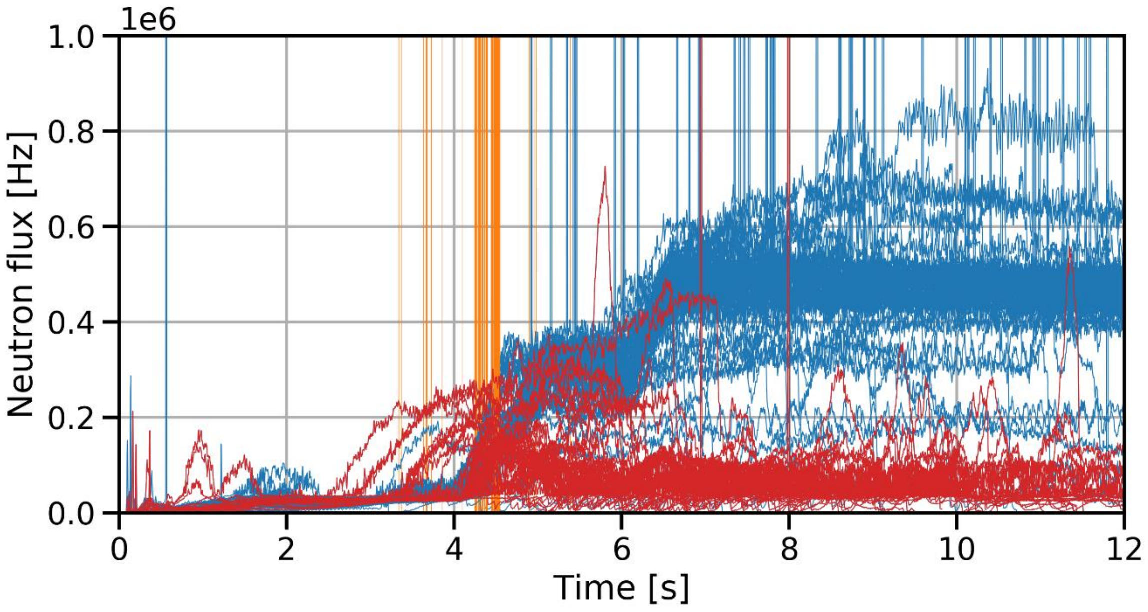




Vertical **orange** lines indicate times when **low hybrid power (*P_{LH}*)** crosses 1 MW (heating phase onset)

Hot T_{e0} correlates with high W_{MHD} and neutron flux

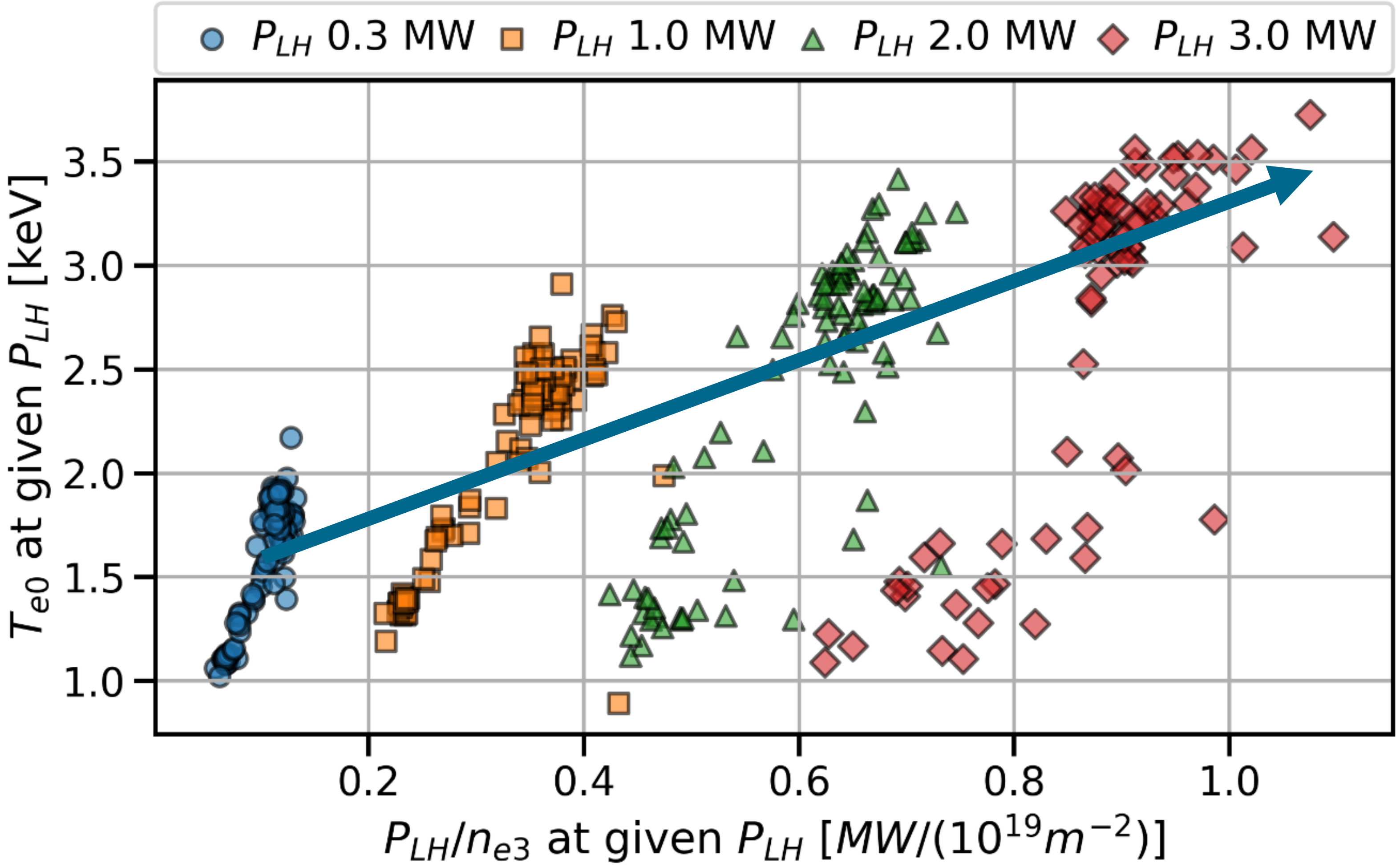




- **Improved plasma confinement** in the hot T_{e0} branch (high plasma energy and neutron flux)
- **<u>Question</u>: where is located the hot T_{e0} regime in WEST operational space?**

Identification of minimum low hybrid power over density, P_{LH} / n_{e3}

From time signals:

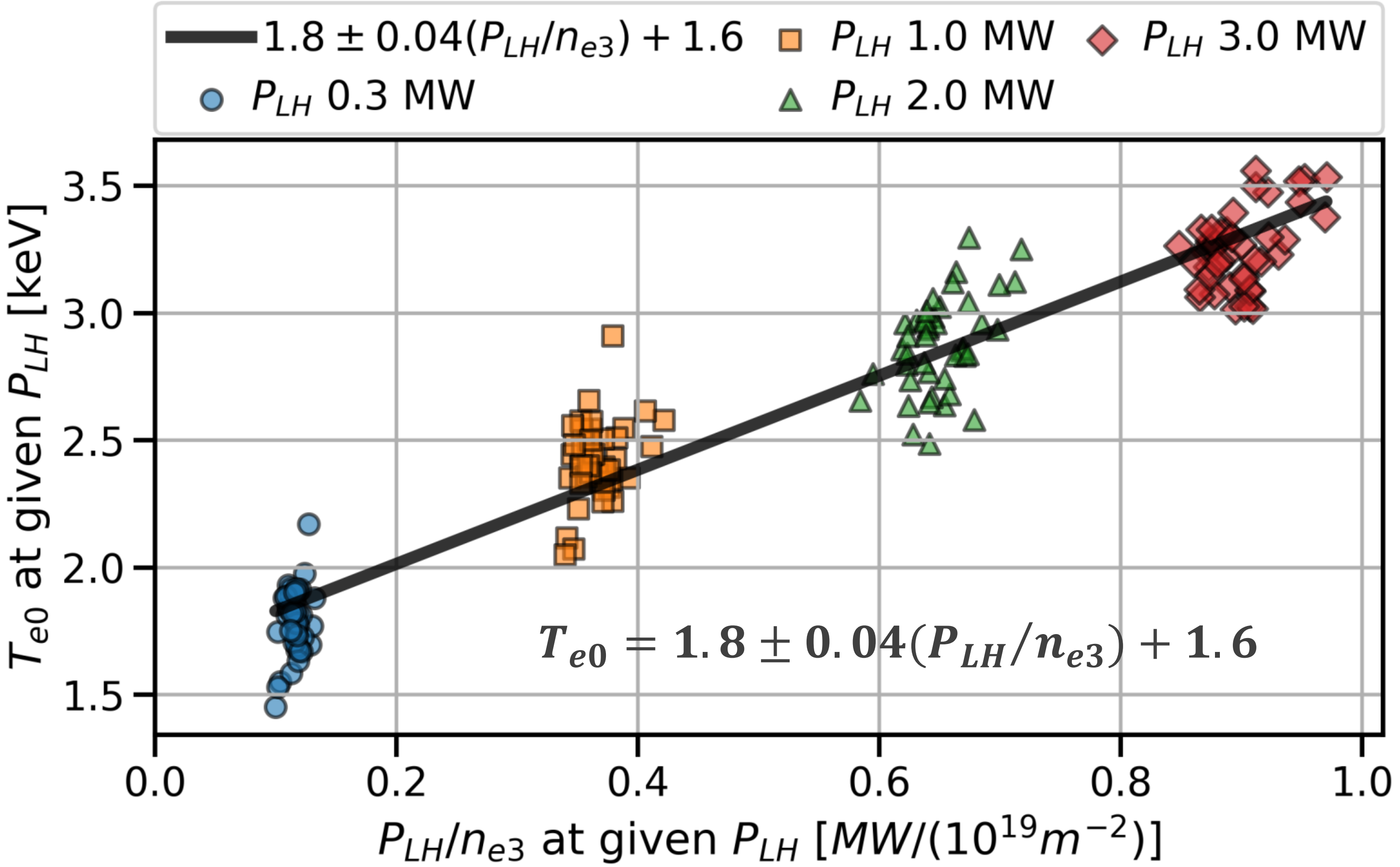


Desired initial heating phase trajectory to reach hot T_{e0} branch

P_{LH} = low hybrid power
n_{e3} = central line integrated density

Identification of minimum low hybrid power over density, P_{LH} / n_{e3}

From time signals:



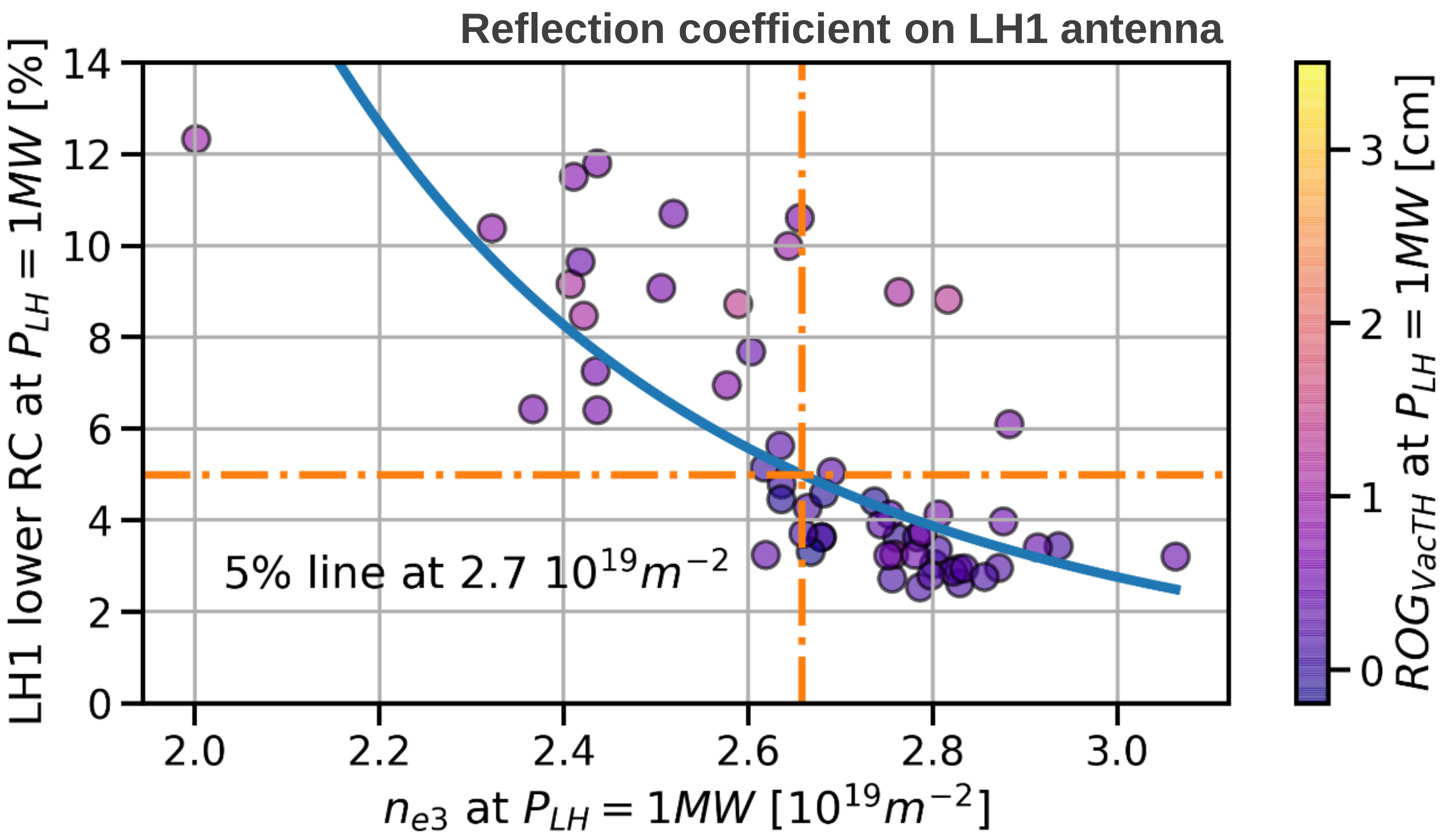
To get $T_{e0} > 3keV$:

$$\frac{P_{LH}}{n_{e3}} > 0.8\ [MW/10^{19}m^{-2}]$$

But also **need** to respect **minimal density constrained** by **maximum P_{LH} reflection coefficient (RC) on antenna (LH1)**

P_{LH} = low hybrid power
n_{e3} = central line integrated density

Minimum density using LH1 reflection coefficient constraint

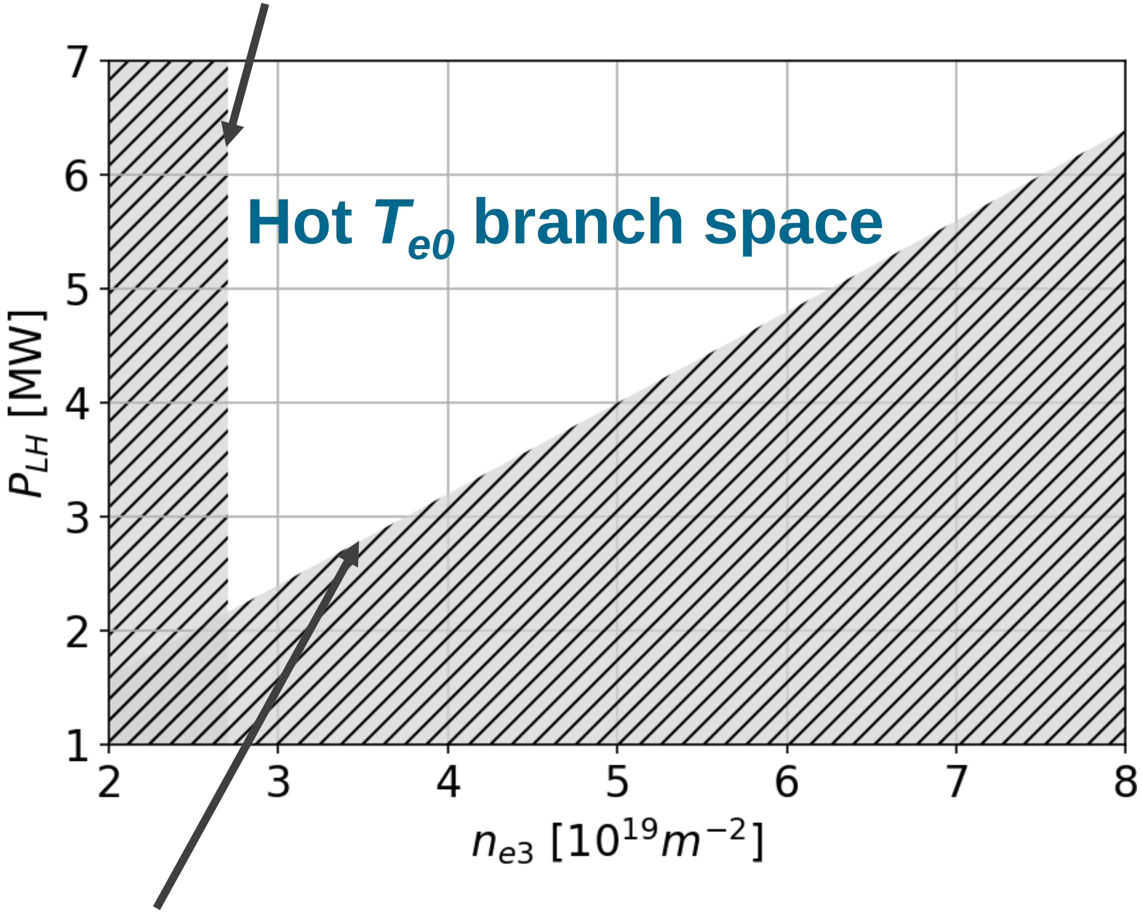


For ROG < 2cm, **to obtain RC < 5% we need:** $n_{e3} > 2.7\left[10^{19}m^{-2}\right]$

P_{LH} **= low hybrid power**
n_{e3} **= central line integrated density**

Identification of hot T_{e0} branch operational space

LH1 antenna reflection limit, $n_{e3} > 2.7\ [10^{19} m^{-2}]$



Cold T_{e0} branch limit, $\frac{P_{LH}}{n_{e3}} > 0.8\ [MW/10^{19} m^{-2}]$

P_{LH} = low hybrid power
n_{e3} = central line integrated density

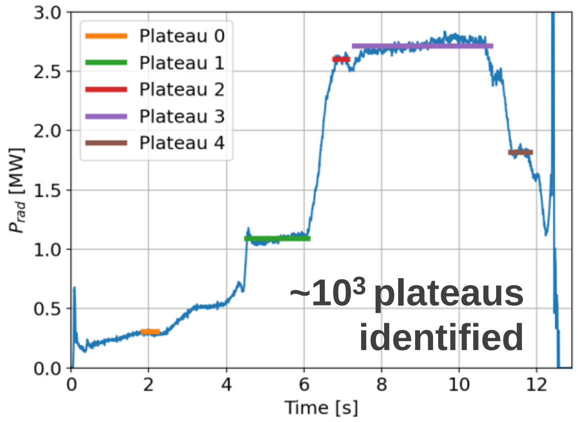
Summary

WEST IMAS data processing workflow → Quasi-steady states detection

WEST IMAS data processing workflow → Time signals

Quasi-steady states detection → Reduced database composed of **plateau statistics and time signals**

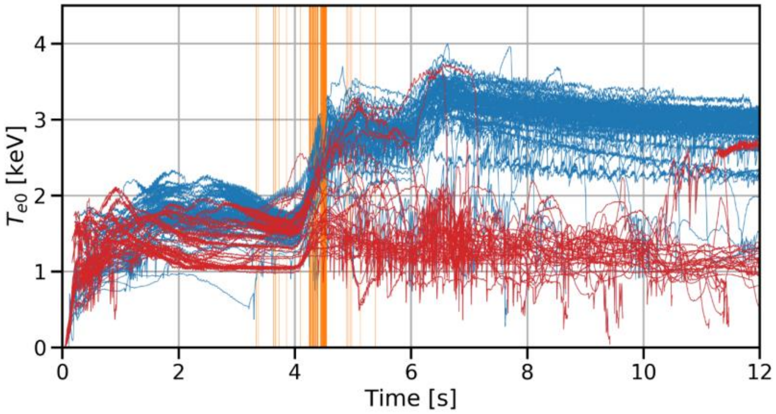
Time signals → Reduced database composed of **plateau statistics and time signals**

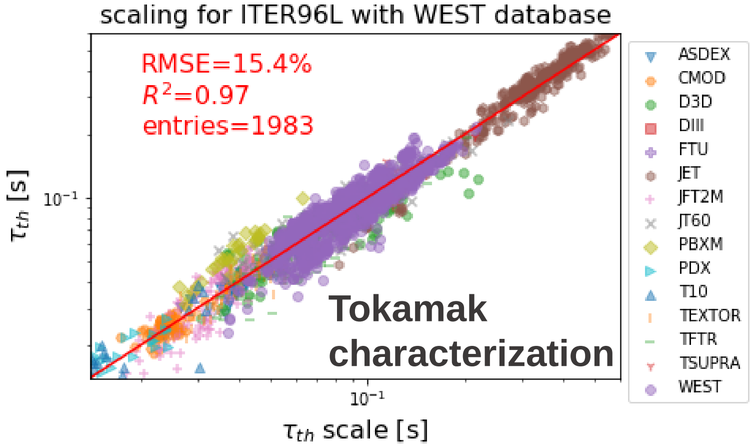


And more can be done:

- **Classifications**
- **Specific regressions**
- **Causal analysis…**

Analysis performed





Operational space identification