

Synthetic diagnostics for power exhaust and confinement studies

A. Medvedeva

special thanks to WEST, AUG, ITER teams and:

CEA:

N. Fedorszak
F. Clairet
C. Bottereau
P. Devynck
S. Hacquin
G. Dif-Pradalier
D. Vezinet

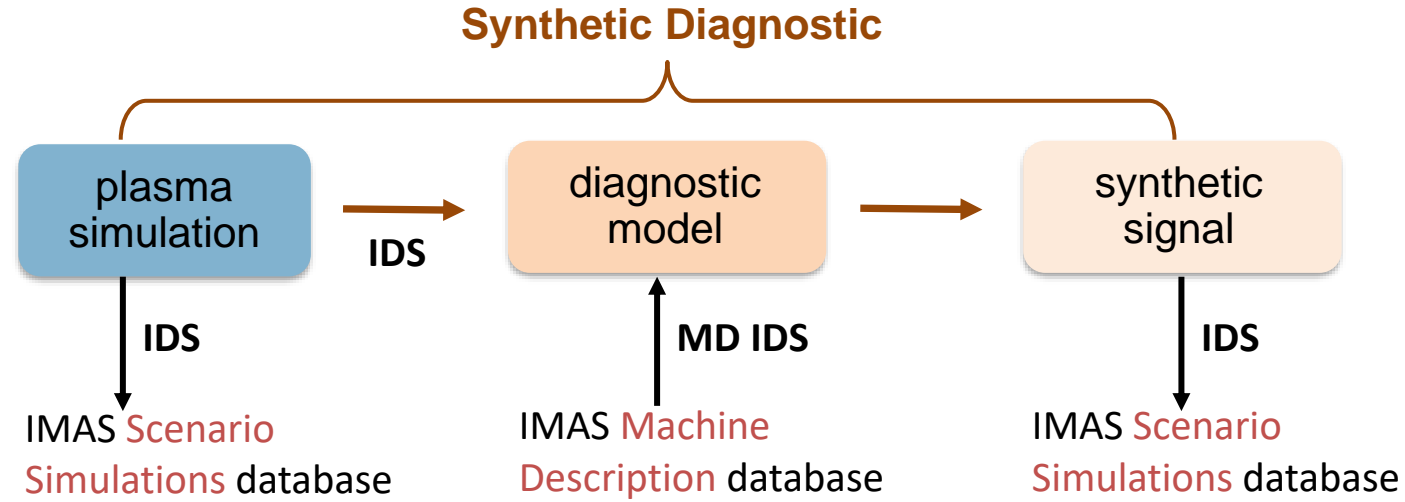
M2P2:

I. Kudashev
D. Zarzoso Fernandez
M. Scotto d'Abusco
S. Di Genova
E. Serre

ITER:

M. Schneider
S. Pinches
+
S. Denk
V. Neverov
R. Marcille
S. Heuraux

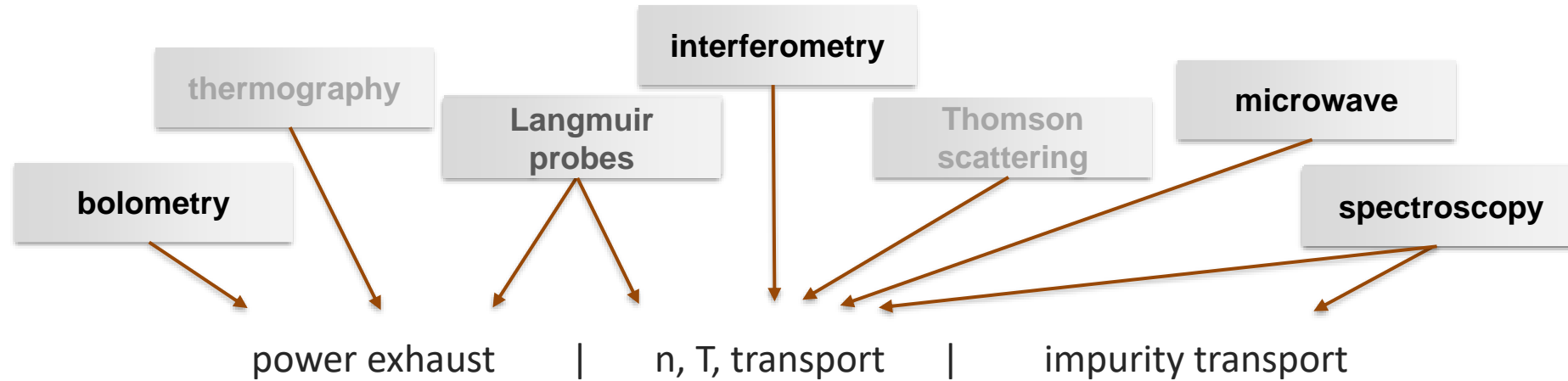




- Diagnostic's design in **IMAS Machine Description** database
- Plasma input from **IMAS Scenario Simulations** database
- Raw signals in **IDSs**
- Post-processing: tomography, profile reconstruction

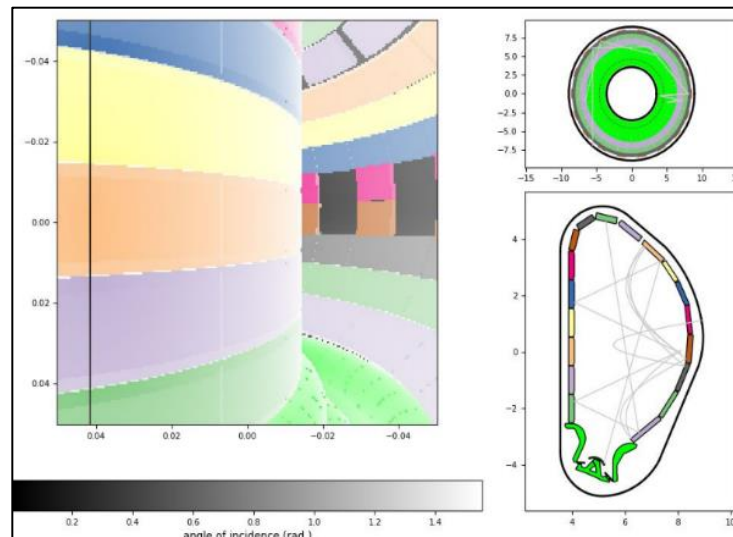
bolometer IDS

Full path name	Description	Data Type
▶ ids_properties	Interface Data Structure properties. This element identifies the node above as an IDS	structure
▶ channel(i1)	Set of channels (detector or pixel of a camera)	struct_array [max_size=500 (limited in MDS+ backend only)]
power_radiated_total(:)	Total radiated power reconstructed from bolometry data {dynamic} [W]	FLT_1D
power_radiated_total_error_upper(:)	Upper error for "power_radiated_total" {dynamic} [W]	FLT_1D
power_radiated_total_error_lower(:)	Lower error for "power_radiated_total" {dynamic} [W]	FLT_1D



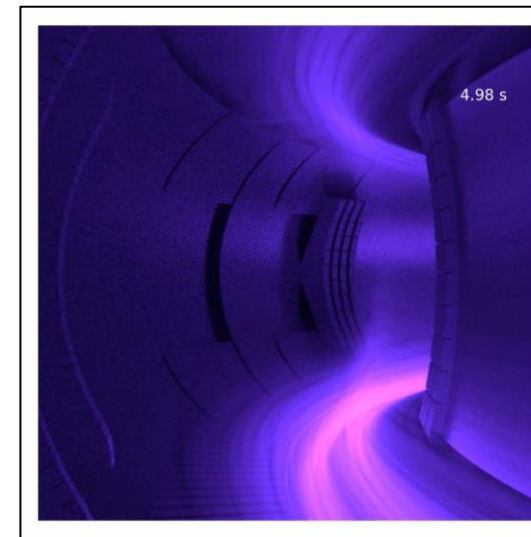
ToFu (Tomography for Fusion)

[D. Vezinet]

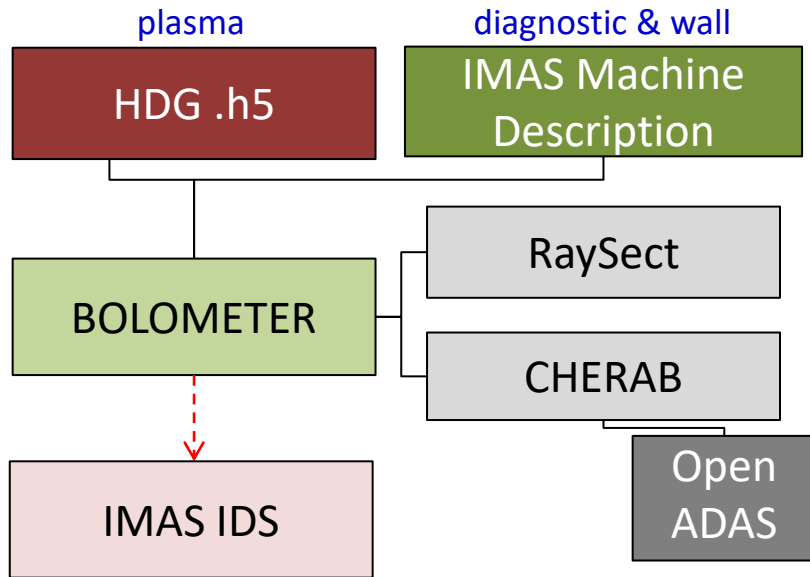


CHERAB + Raysect

[M. Carr, V. Neverov]

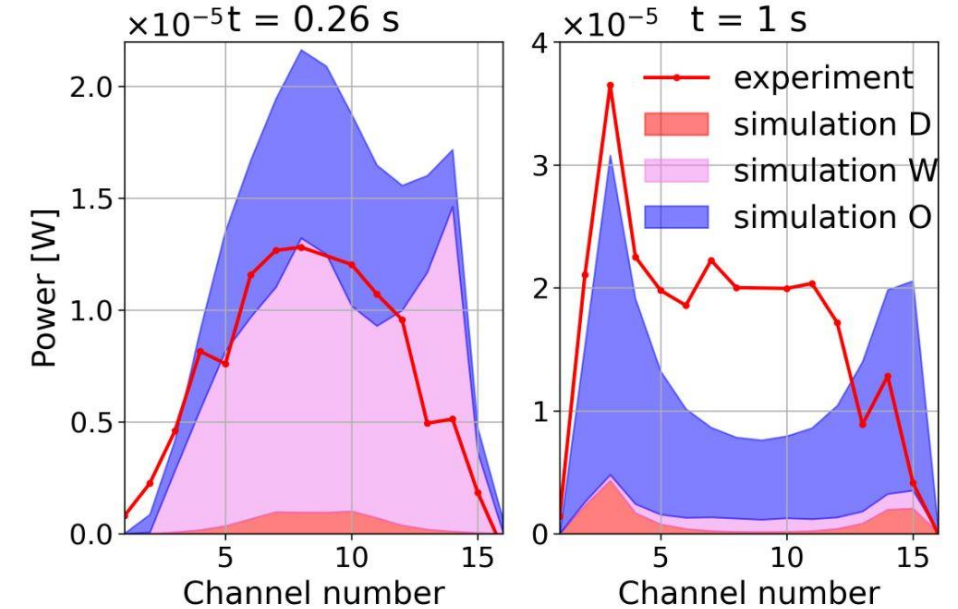
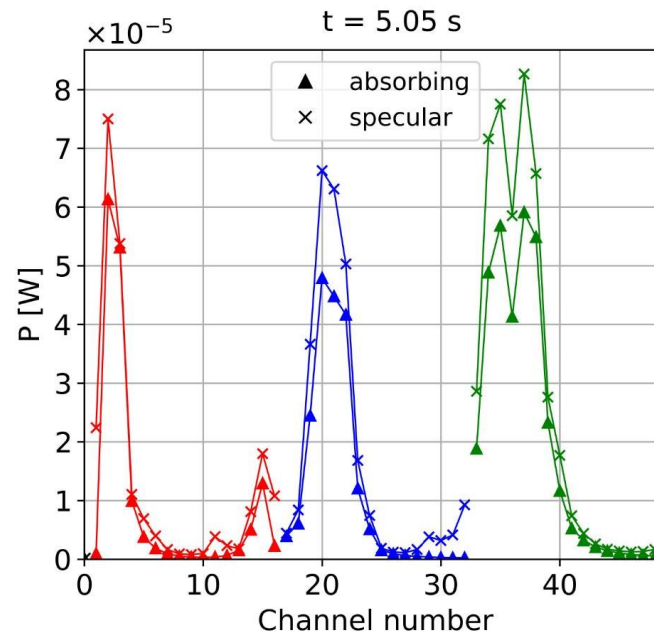
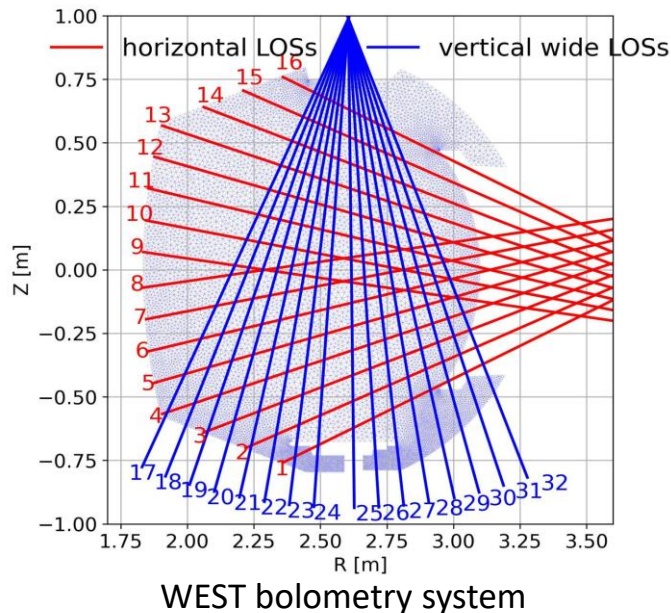


<https://www.raysect.org/>
<https://www.cherab.info/>
<https://open.adas.ac.uk/>
<https://tofuproject.github.io/>

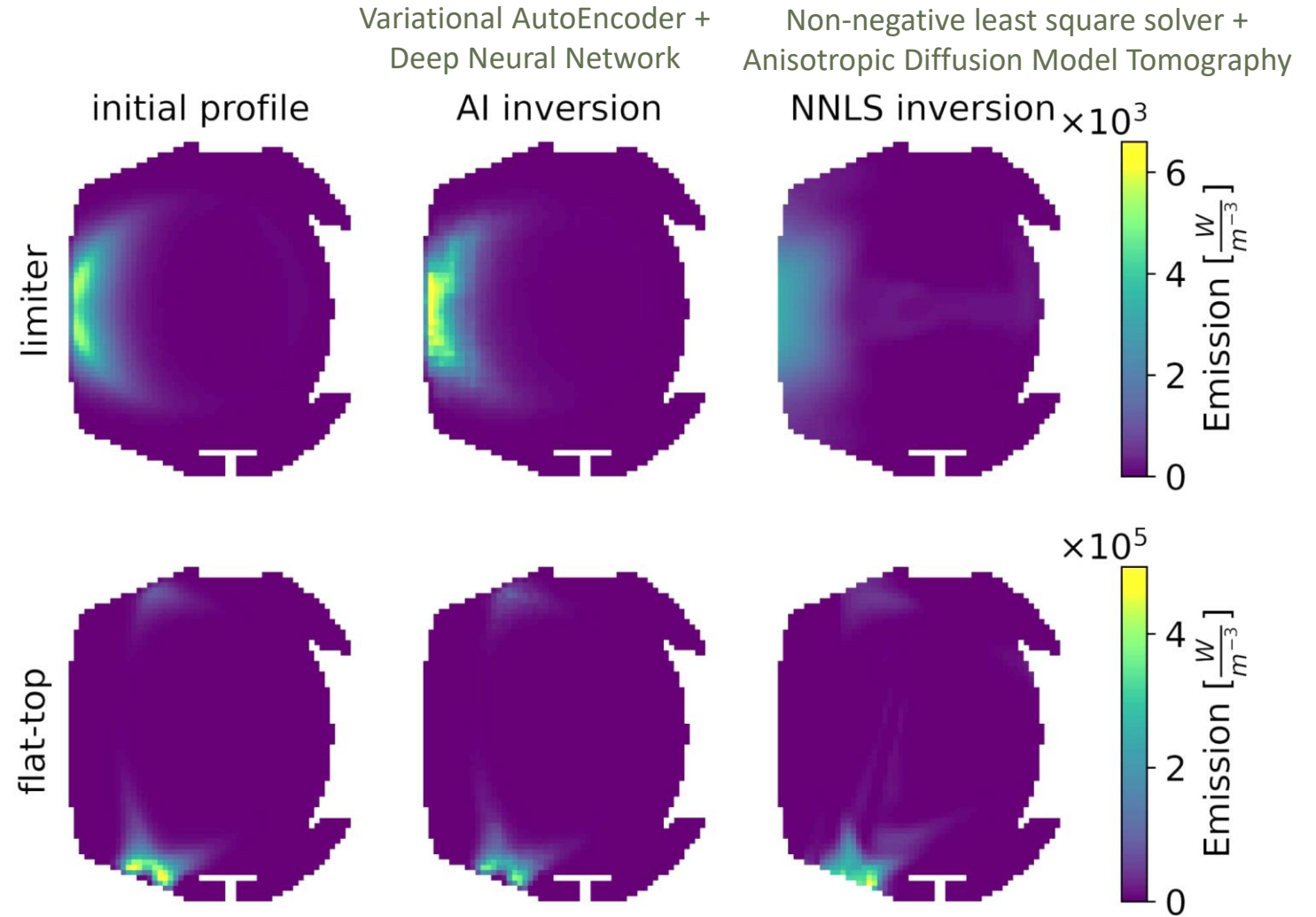


- Synthetic **pinhole camera** is located on an arbitrary position to nearly match existing one ($R, Z, \phi = 3.08 \text{ m}, -0.2 \text{ m}, -139.6^\circ$)
- All PFCs have the same surface model
- Simulation of **entire WEST discharge #54487** with **SOLEDGE-HDG**

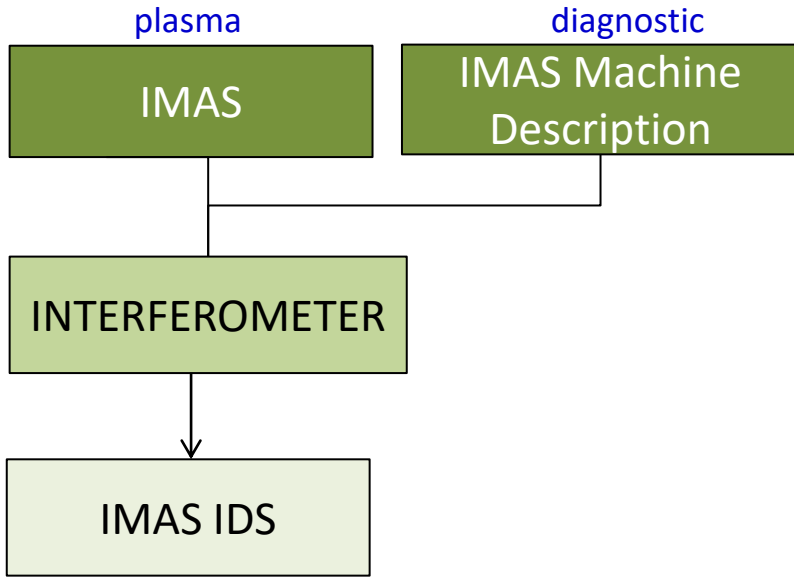
[Giorgiani Computers & Fluids 2014]
[Devynck J. Phys. Commun. 2021]
[d' Abusco NF 2022]
[Kudashev Applied Sciences 2022]



- Conventional tomography inversion
 - non-negative least squares solver
 - Anisotropic Diffusion Model Tomography matrix as a Tikhonov regularization matrix
- Neural network trained on snapshots of deuterium radiation from HDG simulated discharge
 - Variational autoencoder trained to reproduce 2D (64x64) radiation profiles passing through a bottleneck of latent space
 - DNN with 2 hidden layers of size 32 was trained to match 48 bolometer signals to 16 values in latent space



[Kudashev ICFDT6 Proc. 2022]



- Interferometer phase shift:

$$\Delta\phi = \frac{e^2\lambda}{4\pi\epsilon_0 m_e c^2} \int n_e \left(1 - \frac{3}{2} \frac{T_e}{m_e c^2}\right) dl = 2.82 \cdot 10^{-15} \lambda \cdot \int n_e dl$$

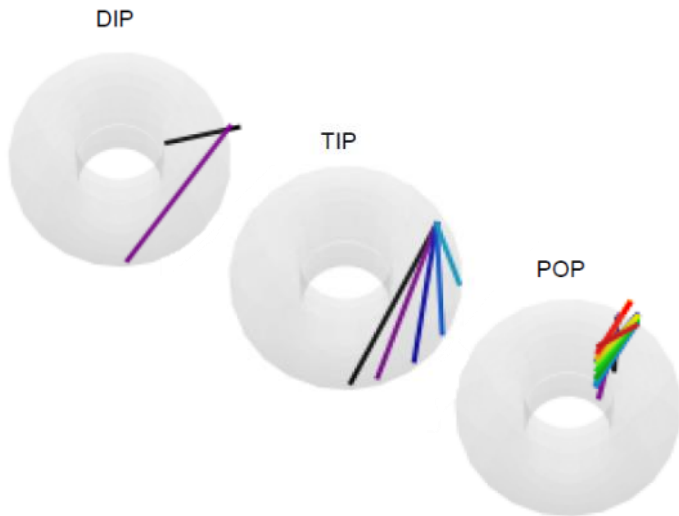
- Polarimeter Faraday angle:

$$\alpha = 5.24 \cdot 10^{-13} \lambda^2 \int \left(1 - \frac{2T_e}{m_e c^2}\right) n_e \vec{B} \cdot d\vec{l}$$

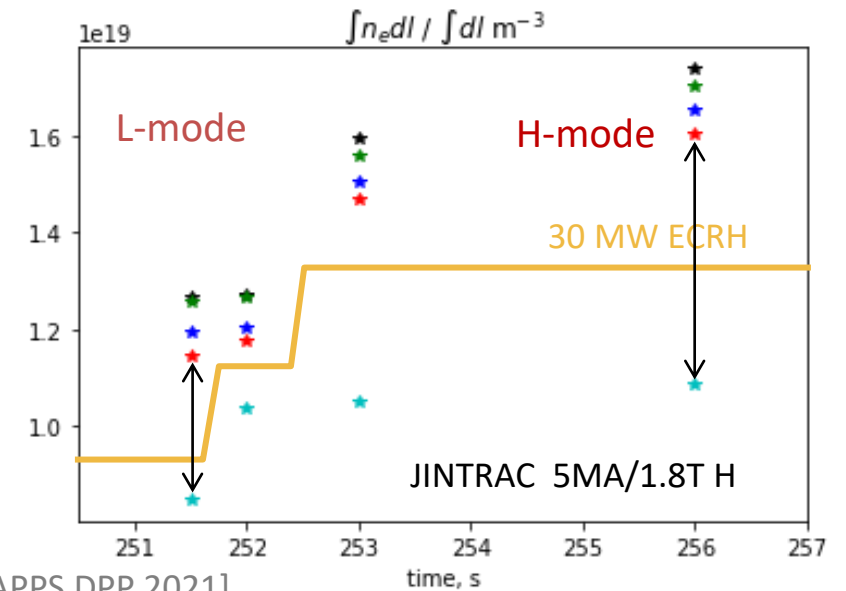
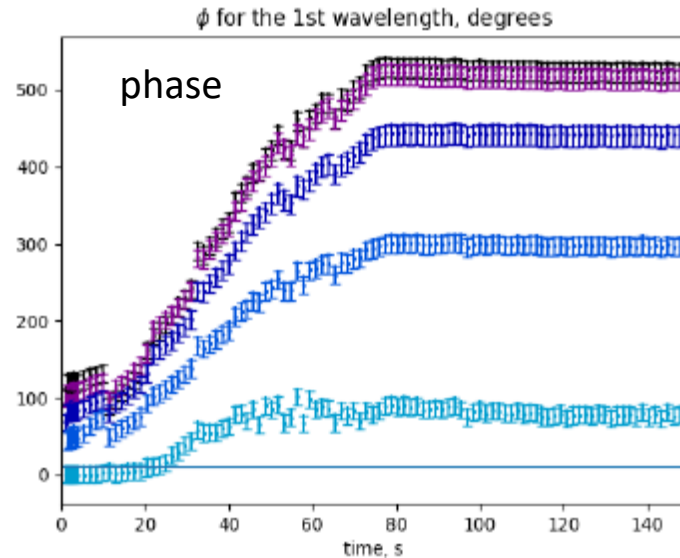
- Phase includes terms with electron temperature (A) and vibrational noise (B) (to be subtracted by 2-colours system)

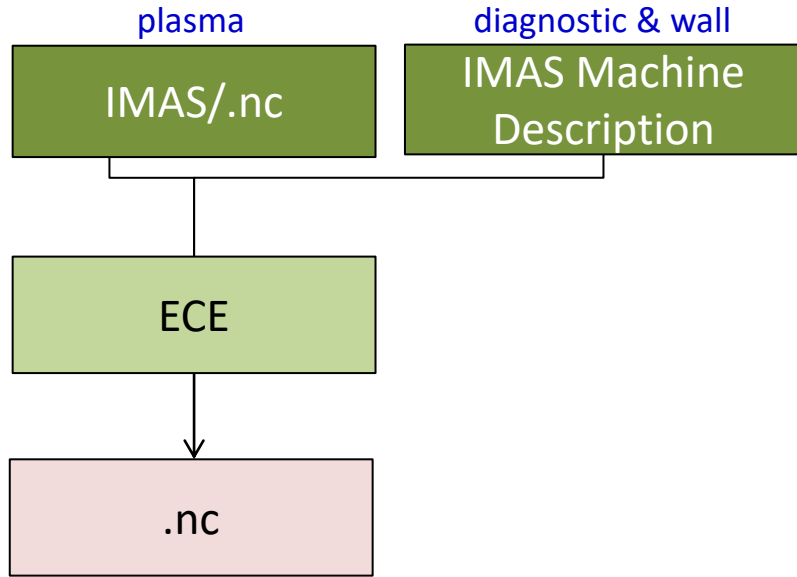
$$\Delta\phi = A\lambda + B/\lambda$$

- Applied for JINTRAC simulations (possible for any IMAS input)

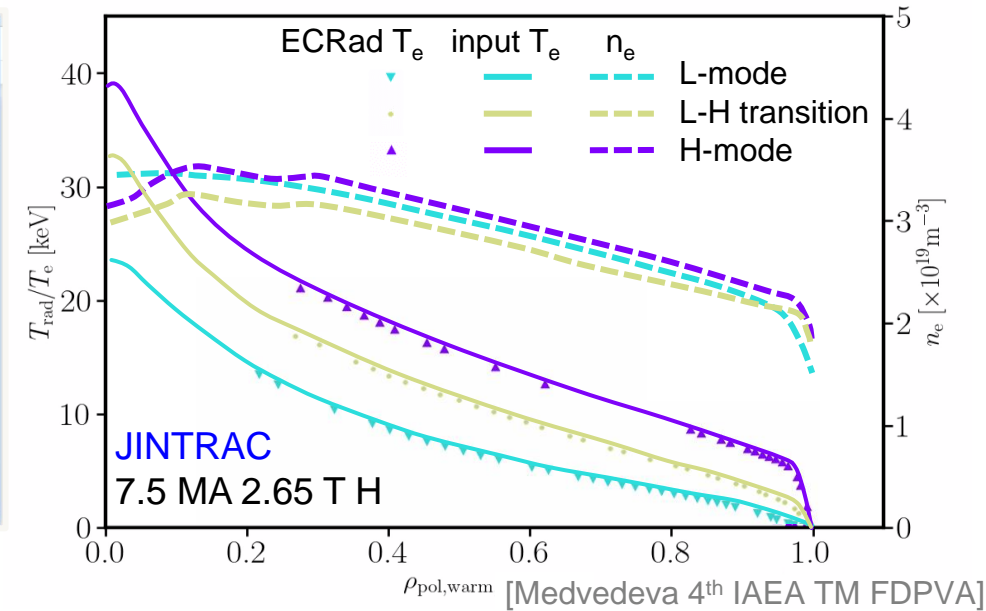
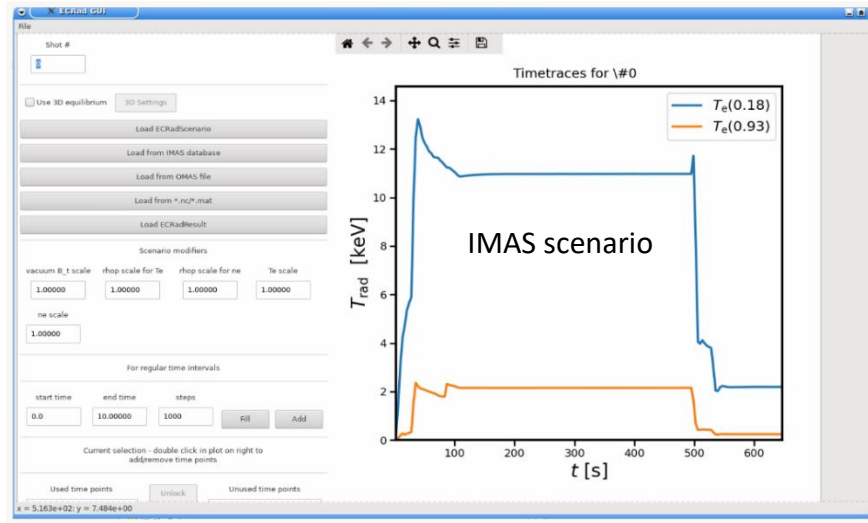
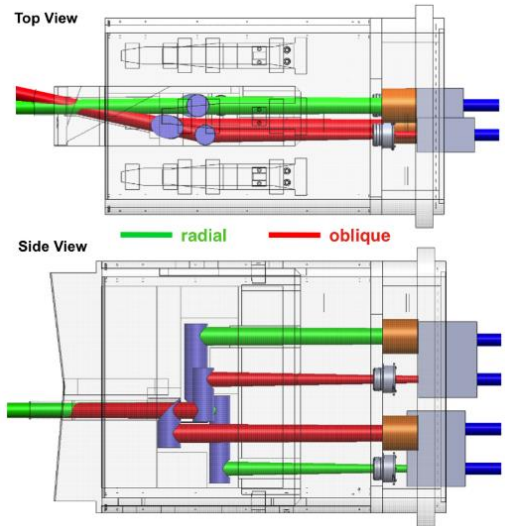


ITER interferometry/polarimetry system



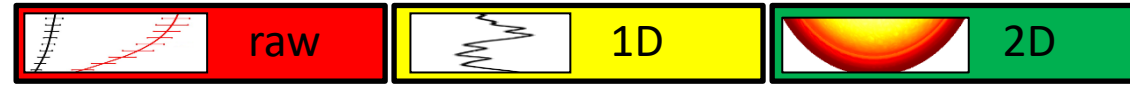
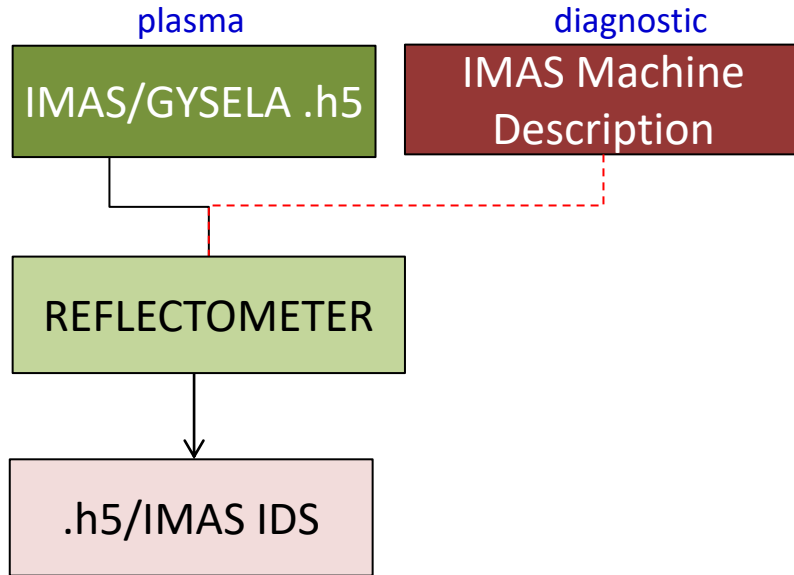


- **ECRad** synthetic diagnostic [Denk CPC 2020] is adapted to IMAS and reads ITER MD for radial and oblique ECE channels 123-353 GHz, O- and X-mode
- Reconstructs T_e profiles with position correction
- Ongoing work on its integration into the ITER SD workflow + other codes



ITER ECE front-end [Austin EPJ Web of Conf. 2012]

ECRad GUI interface

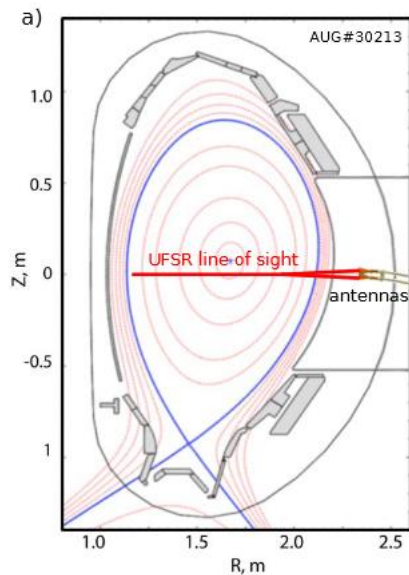


Finite Difference Time Domain 2D full wave code for wave propagation

[Yee 1966, Da Silva 2014, Medvedeva 15th IRW Proc. 2022]

- Computing
 - analytical WKB phase
 - 1D wave propagation
 - 2D wave propagation **FDTD-FW2D**

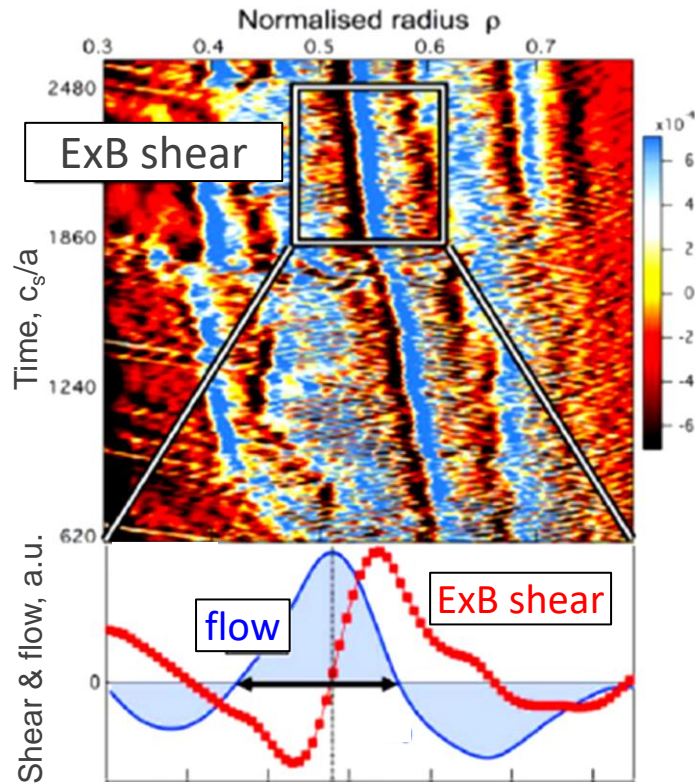
- Analysis
 - raw signal phase + amplitude in 2D
 - profiles by Bottollier-Curtet from phase signals
 - frequency and k-spectra
 - turbulence level
 - coherence



antenna, noise, filtering, O-mode, IMAS output, develop IDS

Ultra Fast Swept Reflectometer on AUG
[Medvedeva PhD thesis 2017]

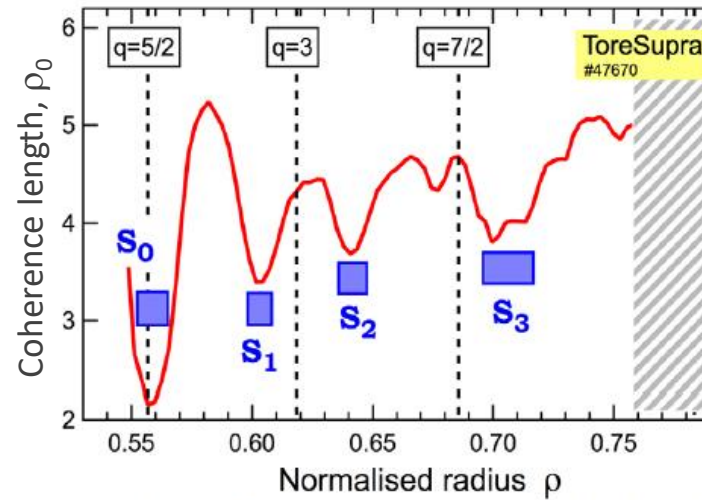
GYSELA simulation



Spontaneous organisation
of weak transport barriers: ExB staircase

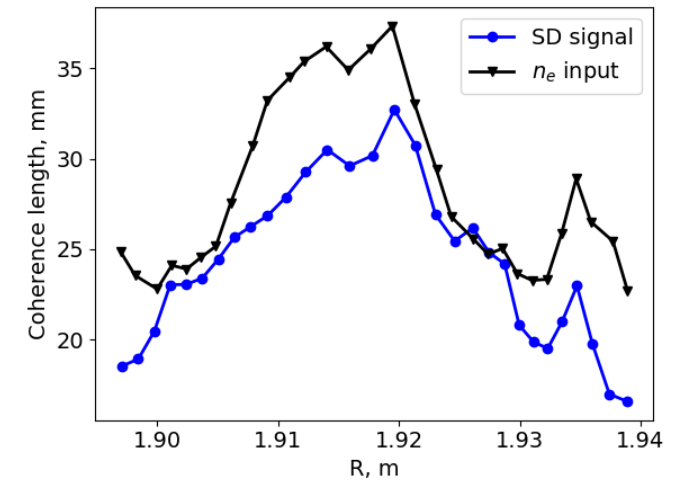
[Dif-Pradalier NF 2017]

UFSR measurement (Tore Supra)



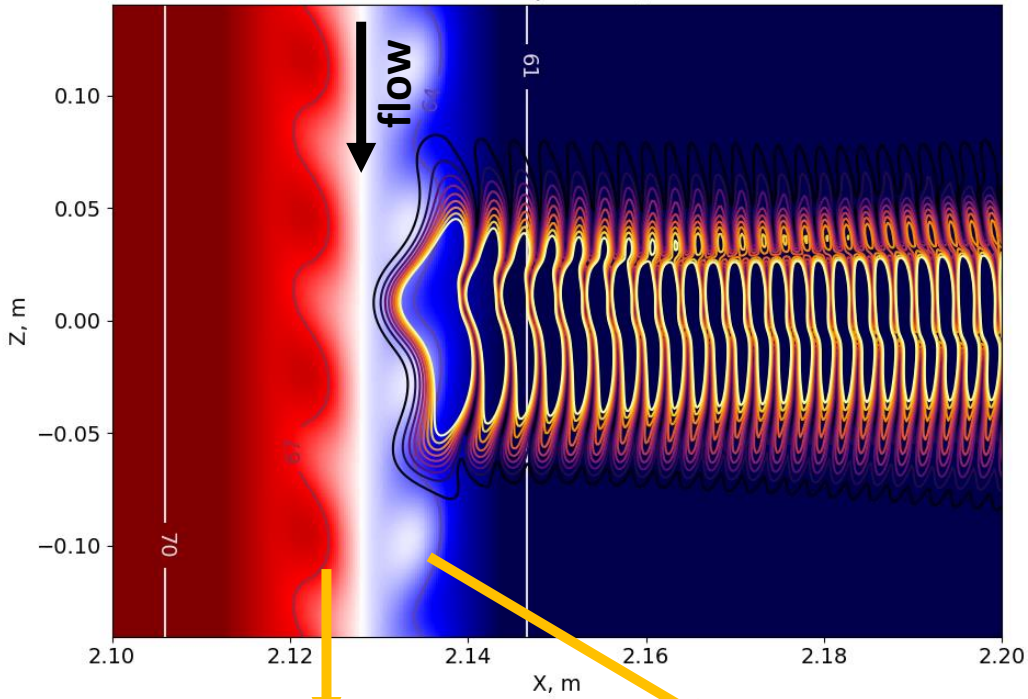
[Hornung NF 2017]

FeDoT synthetic diagnostic validation

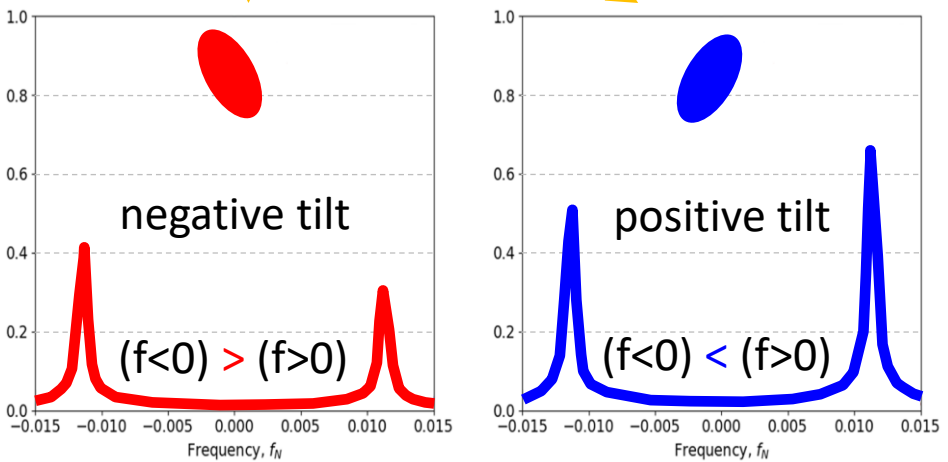
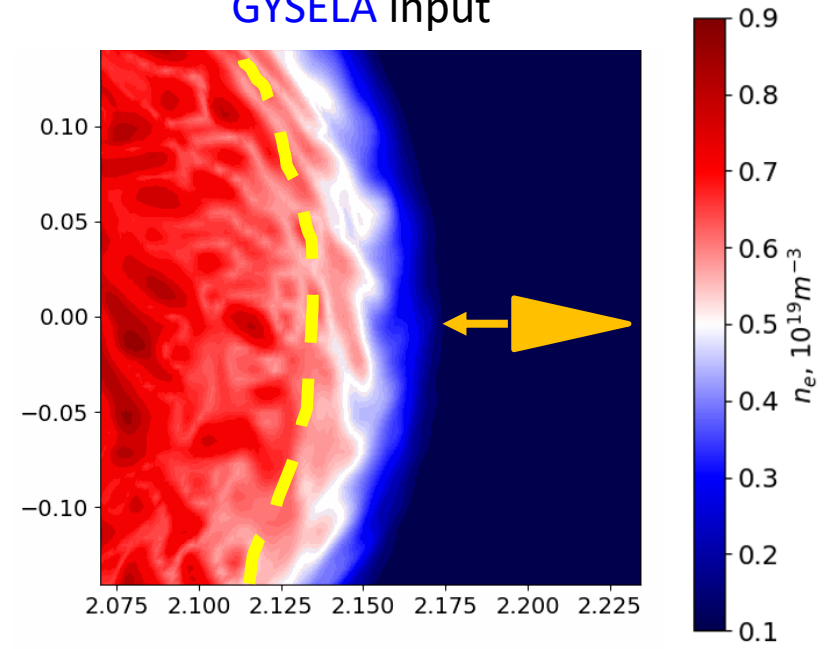


[Medvedeva 15th IRW Proc. 2022]

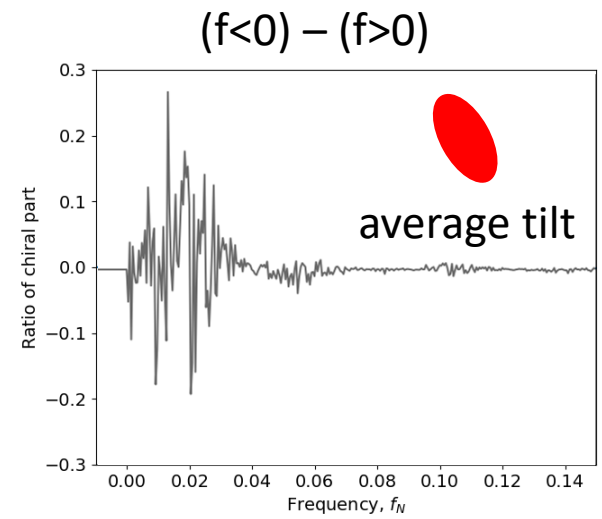
Tilt of turbulent structures causes signal's spectral asymmetry

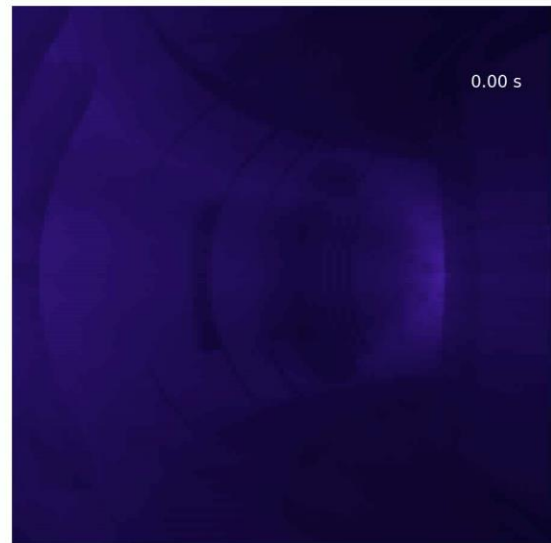
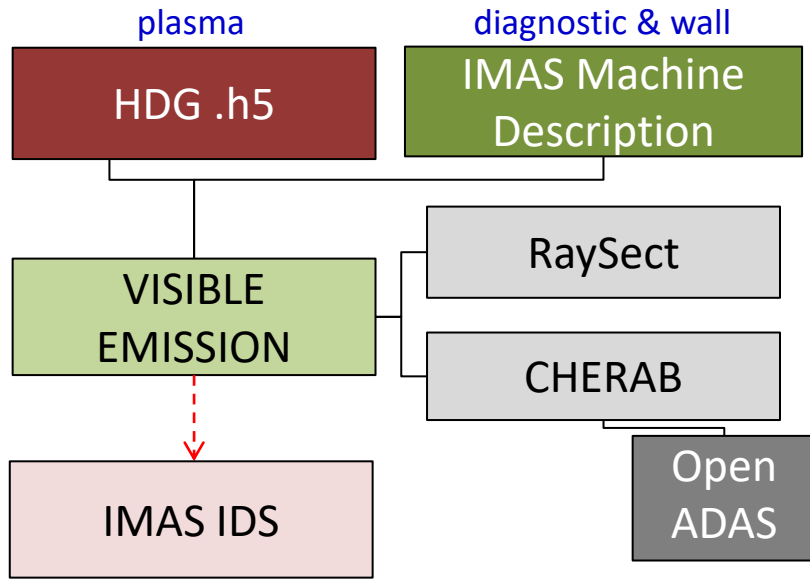


GYSELA input



signal frequency spectra





WEST synthetic visible camera

