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# TUNGSTEN GROSS EROSION AND PLASMA IMPURITY CONTAMINATION IN WEST PHASE I

## A statistical comparison of LH and ICRF-heated L-mode plasmas

### Goal:

- All-metal Magnetic Fusion devices prone to core contamination with high-Z impurities.
- This contribution documents experimentally the role of different categories of Plasma Facing Components (PFCs) in the core impurity contamination.

### Experimental procedure:

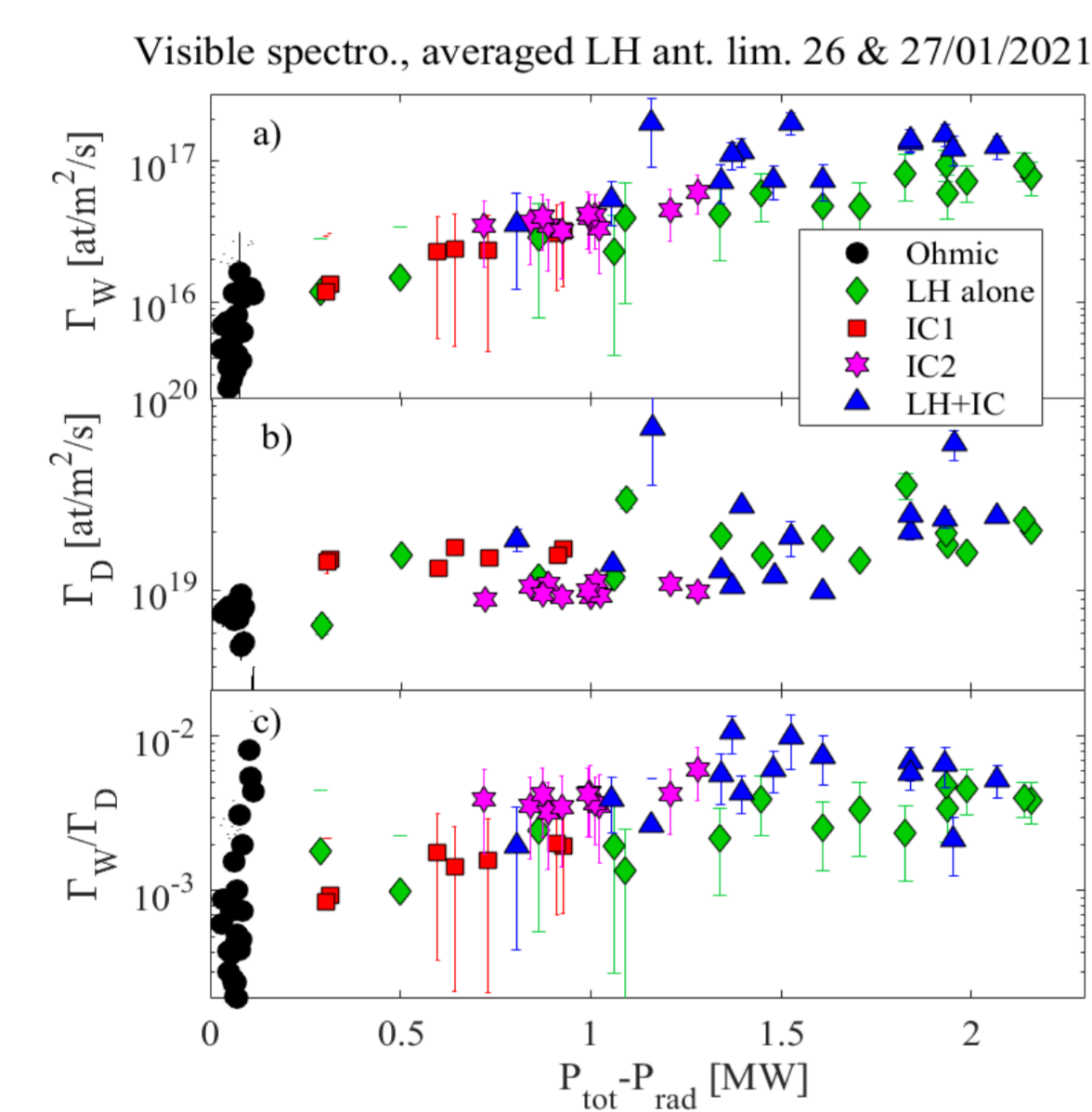
- Statistics over 2 experimental sessions at the end of WEST first operational phase.
- Change differently the W erosion on different PFC categories → scan heating power  $P_{tot}$  over similar L-mode plasmas ( $B_t, I_p, <n_e>$ ) with varying mix of LH and ICRF waves.
- Split data into 5 series ● ◆ ■ ★ ▲ depending on heating method and divertor state.
- Monitor gross W erosion using spectral lines W I ( $\lambda=400,9\text{nm}$ ) & D I ( $\lambda=434,1\text{nm}$ ) from visible spectroscopy on outboard LH and IC antenna limiters, as well as outer divertor.
- Look for correlation with core radiation properties and global plasma performance.

### Main findings:

- LH-only pulses** are consistent with earlier scans of  $P_{tot}$  → serve as **reference** pulses
- Compared to LH-only pulses at similar  $P_{tot}-P_{rad}$ , **enhanced gross W erosion on limiters of active IC antennas, correlated with RF voltage** feeding local IC antenna.
- In presence of ICRH, **reduced / suppressed W erosion near Outer Strike Point**.
- 2 divertor regimes** in IC-only discharges, associated with different radiation patterns.
- At first sight,  $P_{rad,bulk} \sim 45\% P_{tot}$  whatever the heating method. Closer look reveals  $\sim 25\%$  extra core radiation &  $\sim 10\%$  reduced energy content, when both ICRF-enhanced limiter W sources & divertor W sources are present. Compensation of opposite variations on limiter & divertor gross W sources ?

## Gross W sources from antenna limiters at the outer mid-plane

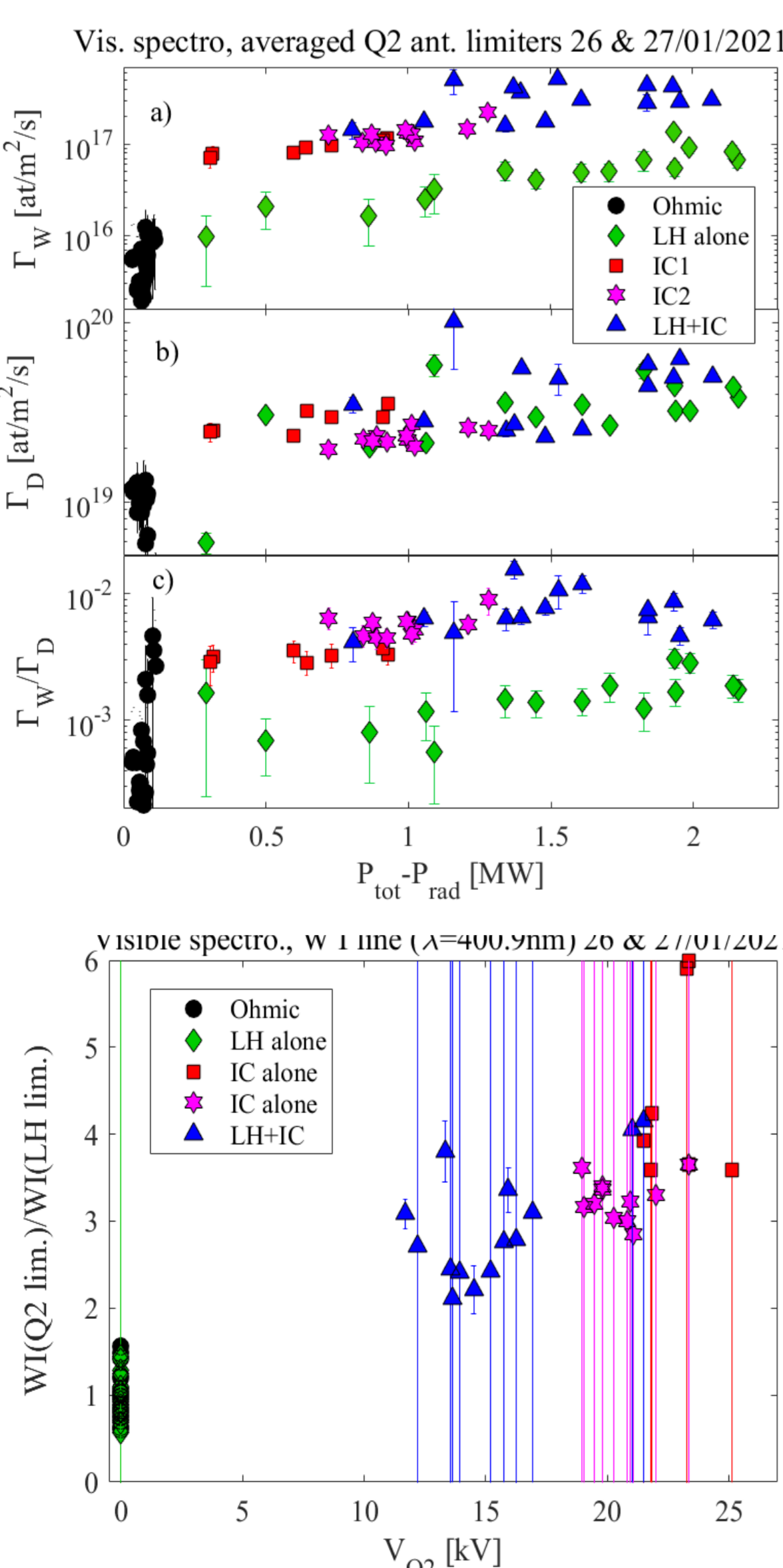
### LH antenna limiters



Proxy: W I line brightness ( $\lambda=400,9\text{nm}$ ) averaged over all LOSs on LH limiters

- Caveat: no systematic SOL  $T_e$  profiles in main chamber → single S/XB used over all database to convert brightness into particle fluxes.
- Some LH LOS magnetically connected to active IC antennas ?
- W I line brightness ↑ with  $P_{tot}-P_{rad}$
- Partly attributed to enhanced D I line brightness ( $\lambda=434,1\text{nm}$ ), averaged over LOS → proxy for particle flux onto limiters.
- Partly also to W I/D I ratio → proxy for effective sputtering yield.
- W I line brightness vs  $P_{tot}-P_{rad}$  is largely independent of heating method
- 2 regimes for D I line brightness ?

### ICRF antenna limiters

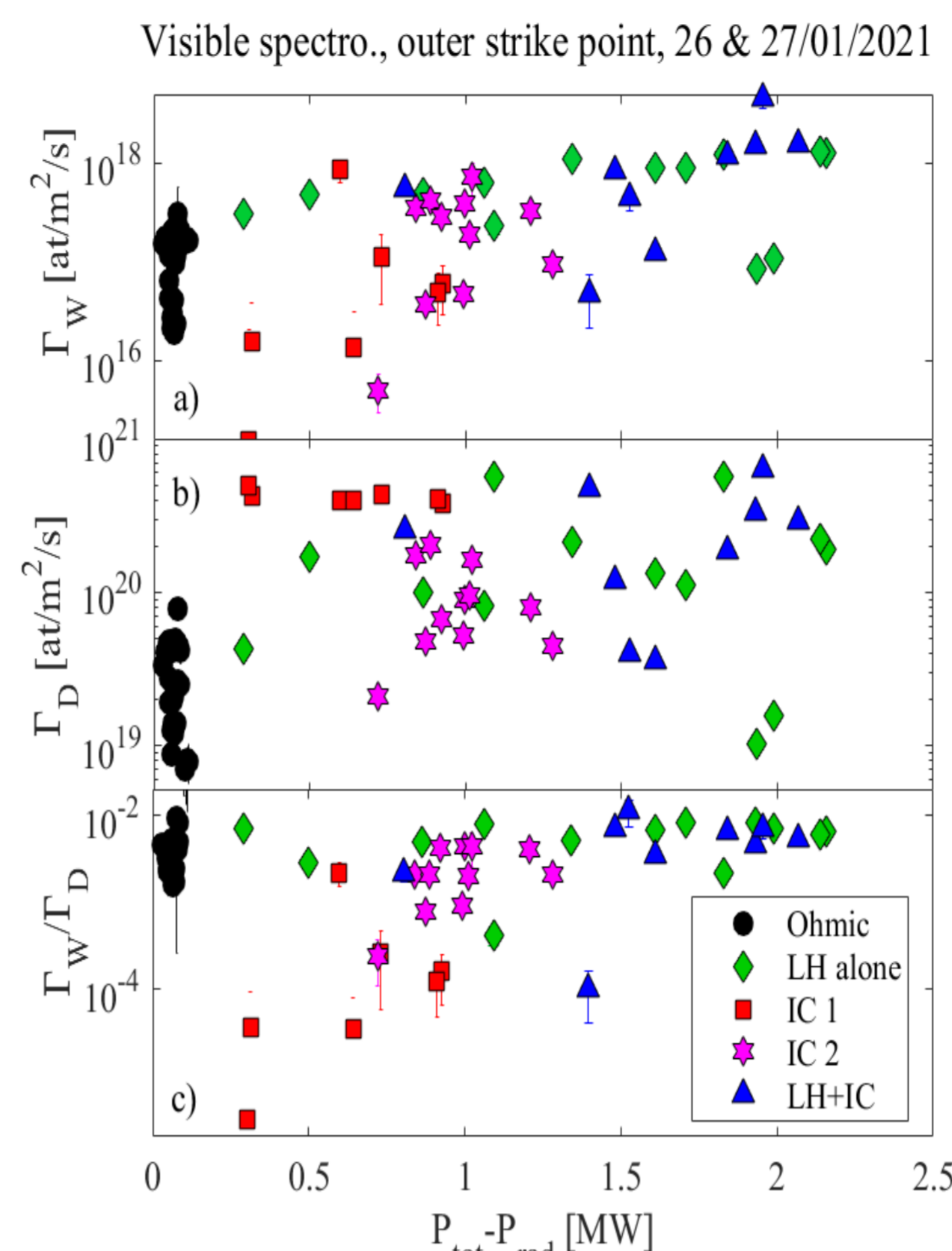


- Ohmic & LH-only phases: similar behaviour as LH grill limiters
- W I line brightness ↑ with  $P_{tot}-P_{rad}$
  - Partly associated with larger D I line brightness
  - Partly also with W I/D I ratio.
- At similar  $P_{tot}-P_{rad}$ , larger W I line brightness in the presence of ICRH
- ★ ▲ than on reference LH-only ◆
  - Mainly associated with larger W I/D I ratio.
  - Several regimes for D I line brightness on top?

Proxy for enhancement factor: ratio of averaged W I line brightness ( $\lambda=400,9\text{nm}$ ) IC lim./LH grill lim.

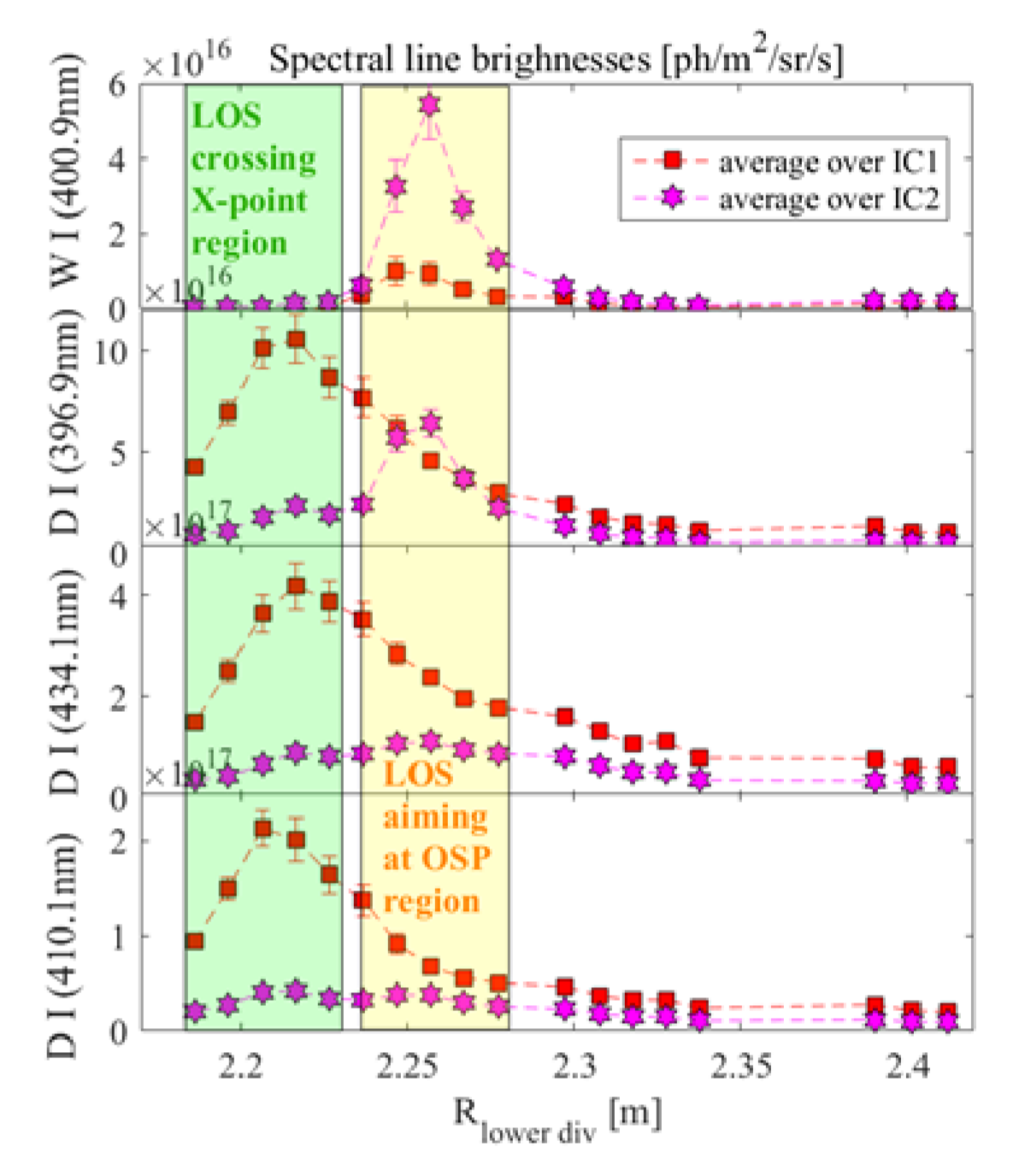
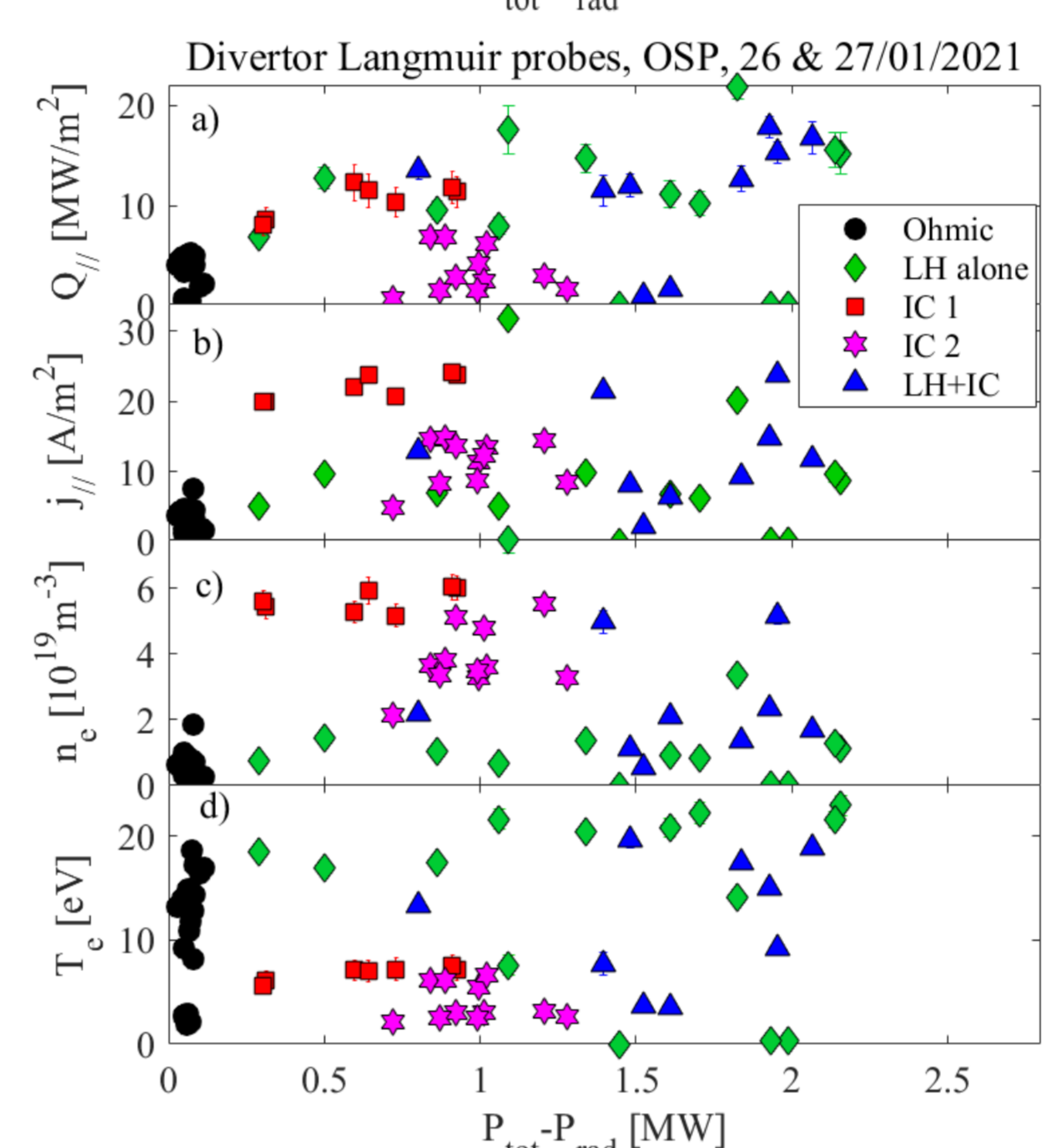
- Ratio close to 1 in ohmic & LH-only pulses
- Up to  $\times 3$  in the presence of ICRH
- ★ ▲ compared to LH-only series ◆
- Q2 ICRF antenna was always active in dipole phasing during reported ICRF pulses, sometimes with Q1.
- Correlated with RF voltage averaged over 4 feeding ports on antenna Q2
- Observation consistent with RF sheath rectification on active IC antennas.
- Factor 3 on 2 active IC antennas ⇔ number of ant. Limiters: 10 → 18 → +80% gross W erosion on limiters.

## Divertor regimes



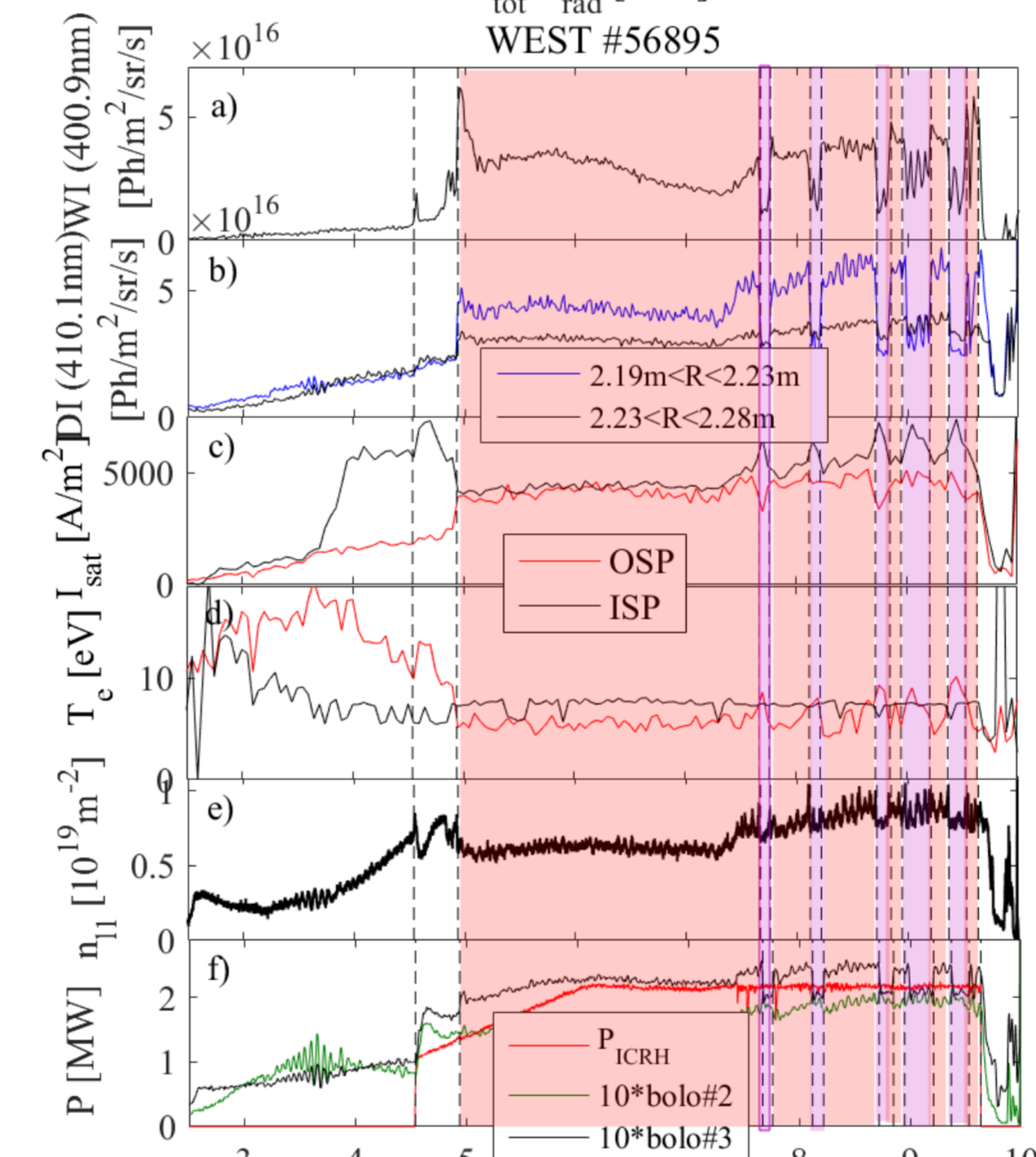
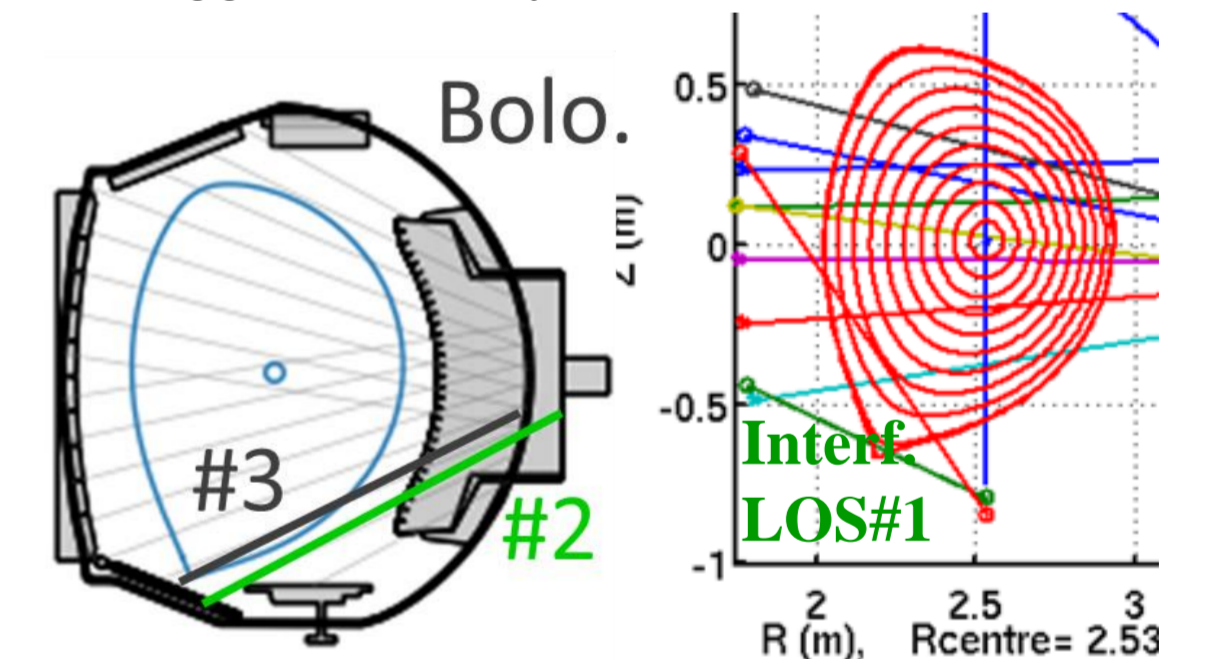
Visible spectroscopy: some series of points

- ★ ▲ are similar to LH-only ◆ trend
- for given  $P_{tot}-P_{rad}$
- Other points ■, mainly IC-alone
- W I line brightness below ohmic
- D I line brightness at Outer Strike Point (OSP) twice higher than LH-only ◆
- $P_{tot}-P_{rad}$  not the only relevant parameter?
- ICRF-only ■ vs LH-only ◆ discharges: different divertor plasma for similar  $P_{sep}$
- Lower  $T_e$  @ outer strike point
- Larger  $n_e$
- Div. probes: 2 IC-only regimes ■ vs ★
- Larger  $T_e$
- Larger  $n_e$
- Larger  $j_{||}$
- Similar qualitative trends at Inner SP
- D I radiation pattern changes with regime
- : Additional peak on visible spectro. LOS viewing X-point
- Also observed with other diagnostics
- Also observed in ohmic detachment

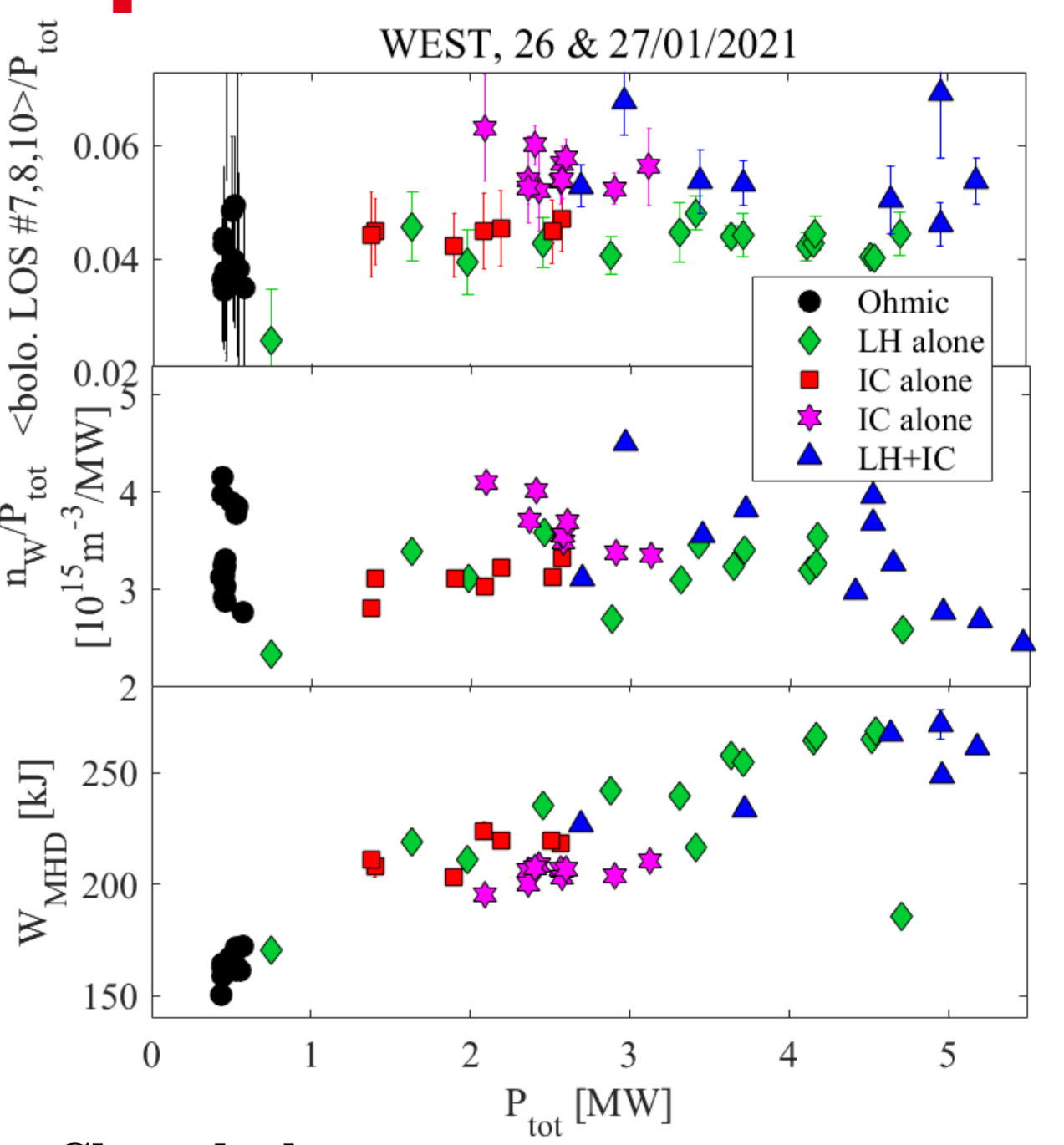
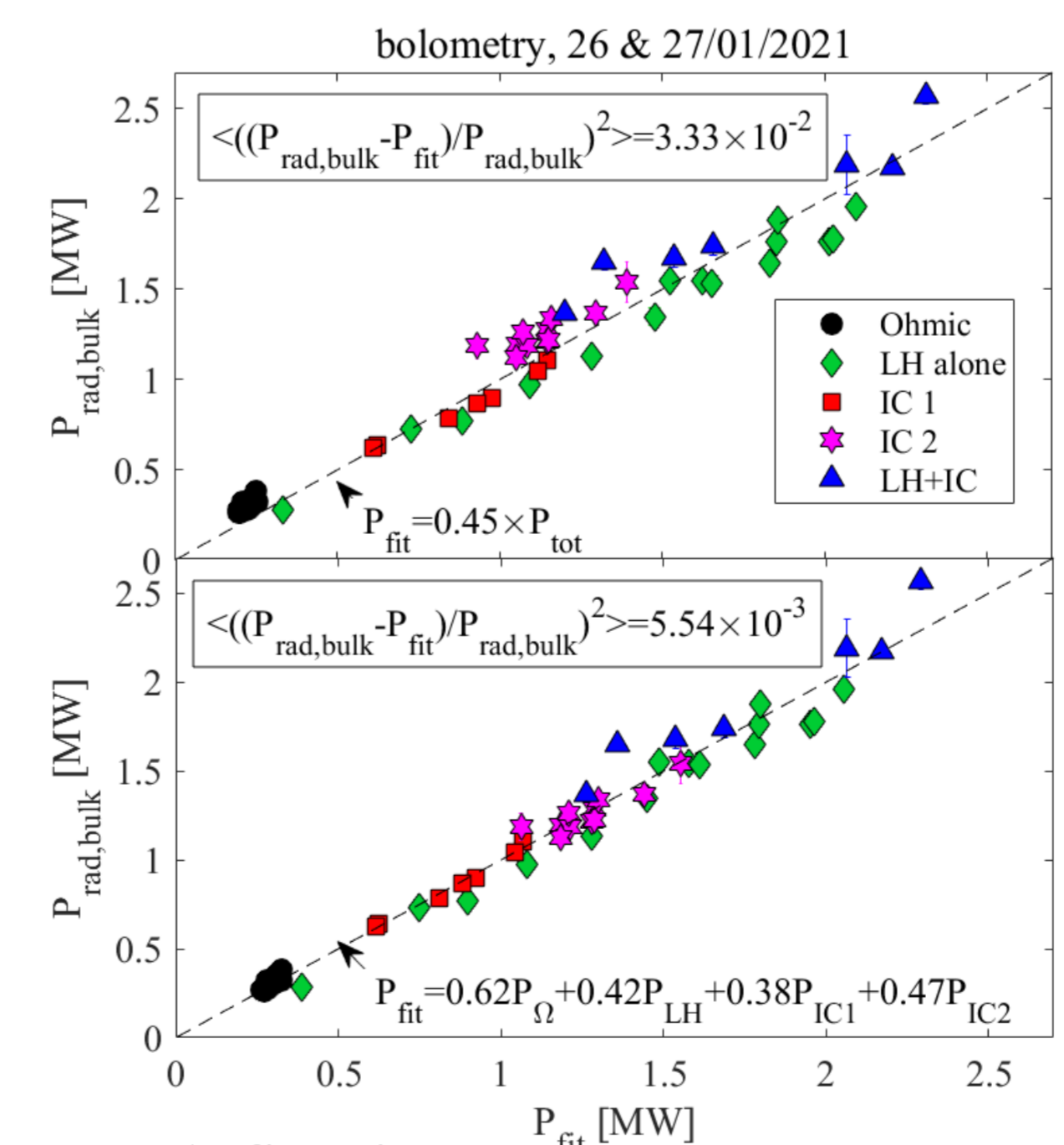


Multiple transitions between regimes within the same pulse on various signals

- Visible camera
- Visible spectroscopy
- Divertor probes
- bolo. LOS #2 (viewing outer strike point) & #3 (crossing X-point region)
- interferometer LOS #1 (inner div., Xpt)
- Delayed reaction at ICRF switch on.
- Trigger? Stability?



## Core radiation, estimated core W contamination & performance



- At first sight
- $P_{rad,bulk} \sim 45\% P_{tot}$  consistent with broader WEST database
  - Systematic deviations, correlated with point series (e.g. ★ ▲ above main trend)

- Closer look
- $\sim 25\%$  extra core radiation &  $\sim 10\%$  reduced energy content, when both ICRF-enhanced limiter sources & divertor sources are present ★ ▲

### Outlook for future WEST experiments:

- Role of other PFCs (baffle, upper divertor) ? → specific materials on these PFCs ?
- Better divertor coverage, poloidal asymmetries of  $P_{rad}$ ? → vertical bolometric LOS
- Exploit other plasma scenarios: controlled divertor recycling, add ECRH to heating mix