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# Double pulse laser-induced plasmas on W and Al for estimate of hydrogen-deuterium by ps-LIBS in tokamak-like conditions

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## CONTEXT & OBJECTIVES

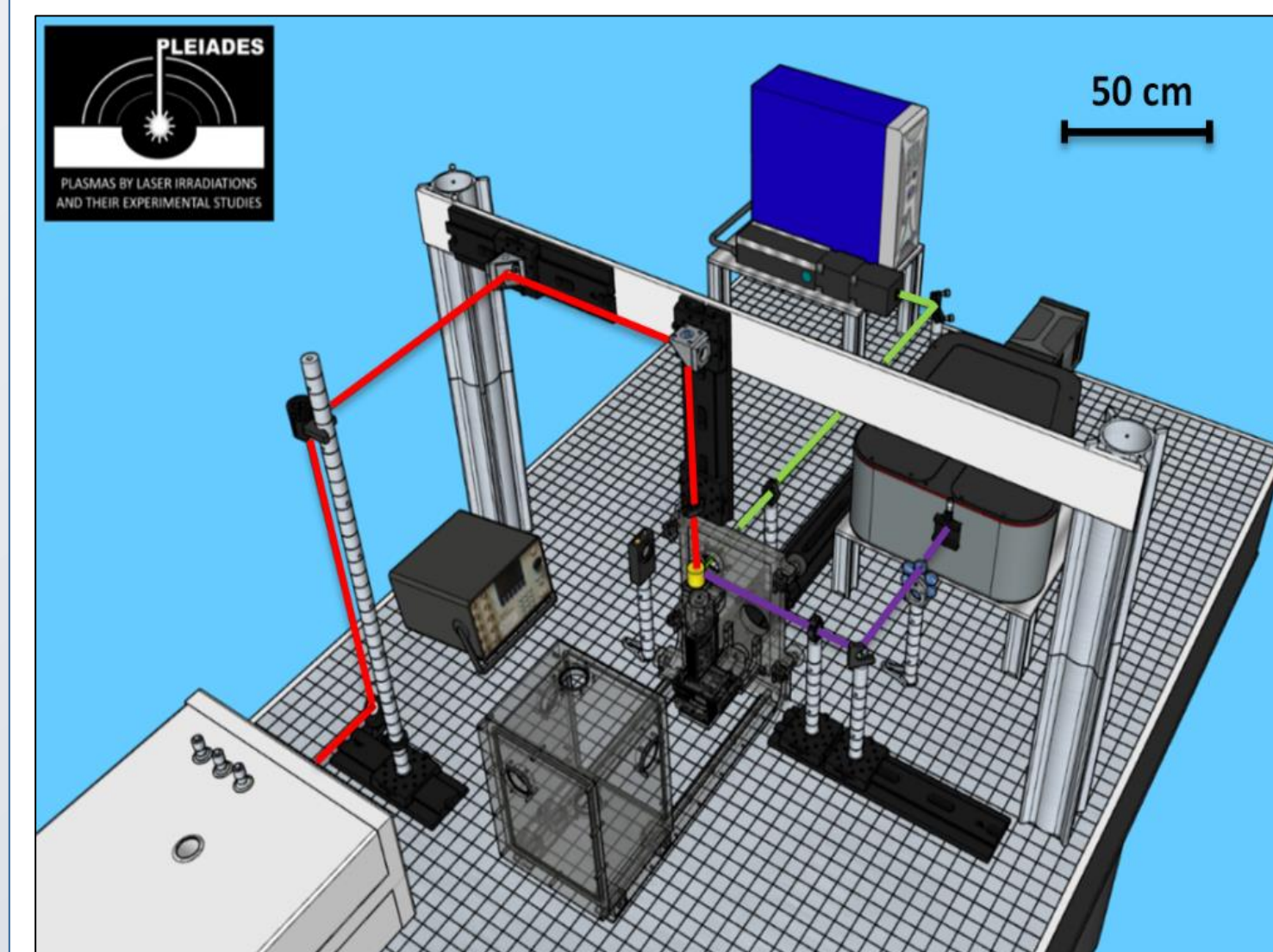
**Diagnostic technique LIBS (Laser-Induced Breakdown Spectroscopy)**

LIBS enables concentrations determination in a target using optical emission spectroscopy. For a target composed of elements in very low concentration or whose upper levels of usual transitions are at high energy (> 10 eV) the maximization of the output signal is mandatory. One efficient technique is to heat up the plasma with a second laser pulse shifted in time. This experimental process is called *double pulse (DP)*.

### Objectives

- Obtain an experimental setup accurately controlled in time and space
- Estimate the improvements in terms of output spectral radiance
- Quantify the electron density enhancement and the increase in number densities of weakly excited states

## EXPERIMENTAL SETUP

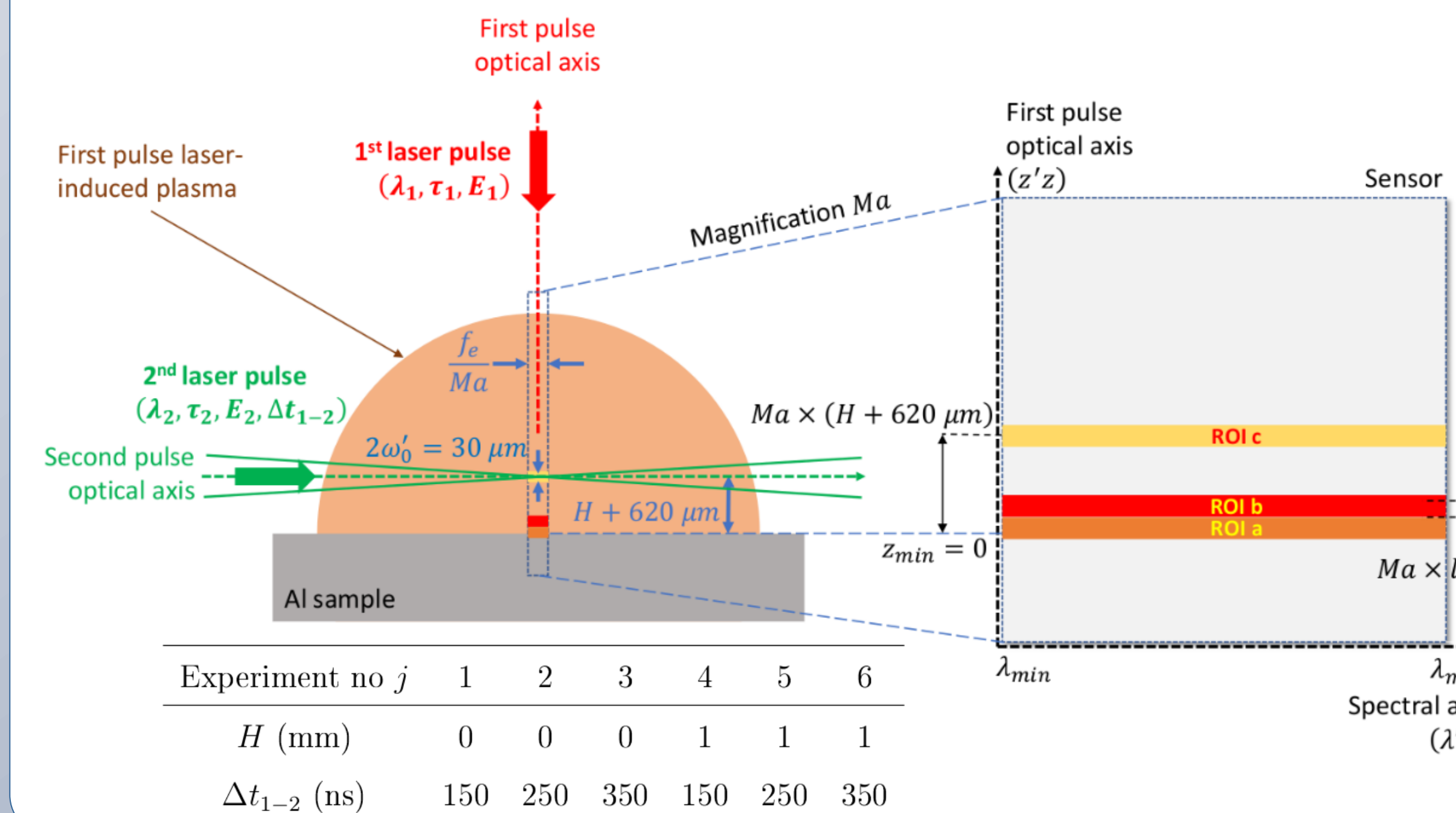


The **first pulse** ( $\tau_1, \lambda_1, E_1$ ) is focused on the target to produce a plasma. The **second pulse** ( $\tau_2, \lambda_2, E_2$ ) is focused in this plasma with a temporal shift of  $\Delta t_{1-2}$ . The **Heated plasma's** radiation is collected along a **third optical axis** to be analysed using a SCT-320 spectrometer.

### Laser sources

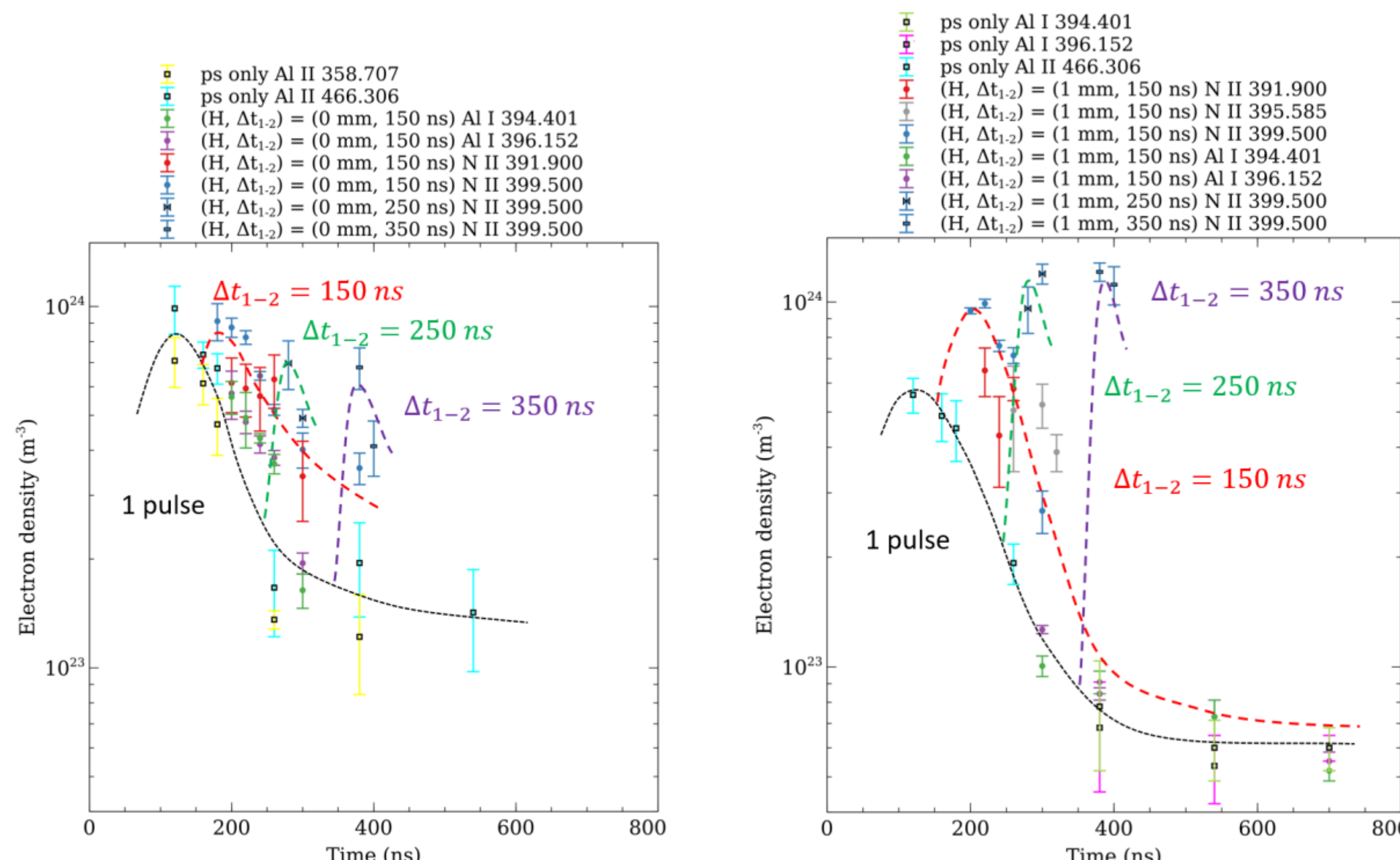
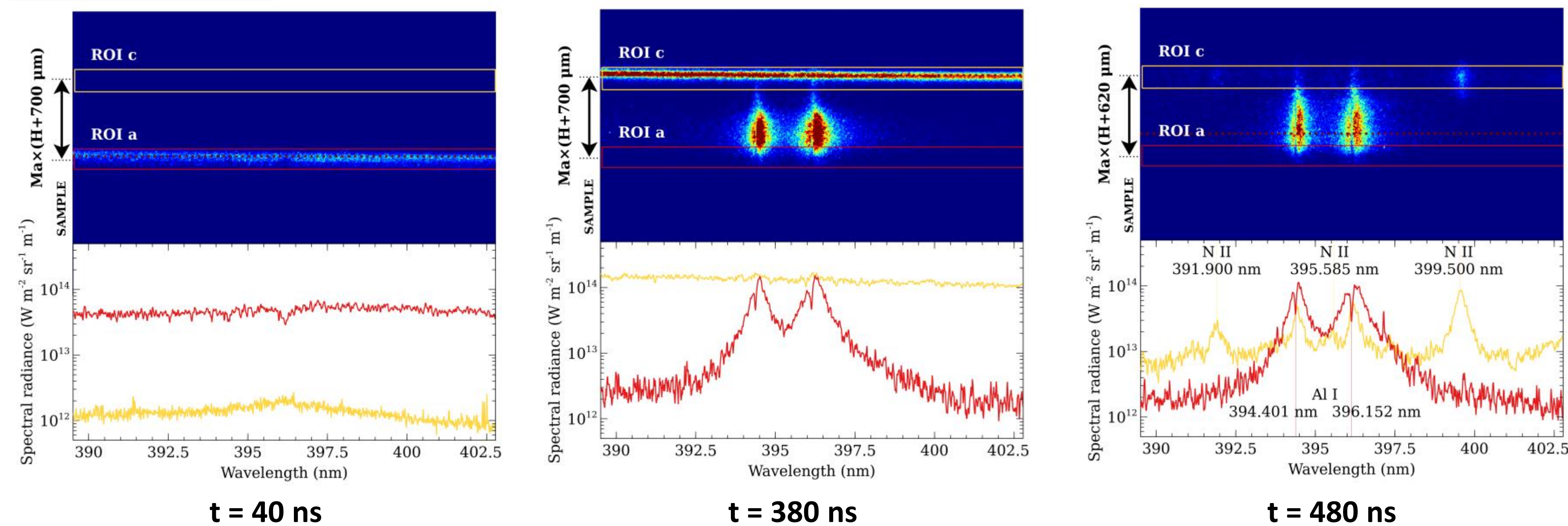
- EKSPLA PL-2251,  $\tau_1 = 30$  ps
- QUANTEL Q-SMART 450,  $\tau_2 = 5$  ns

## RELATIVE SENSOR/PLASMA ARRANGEMENT



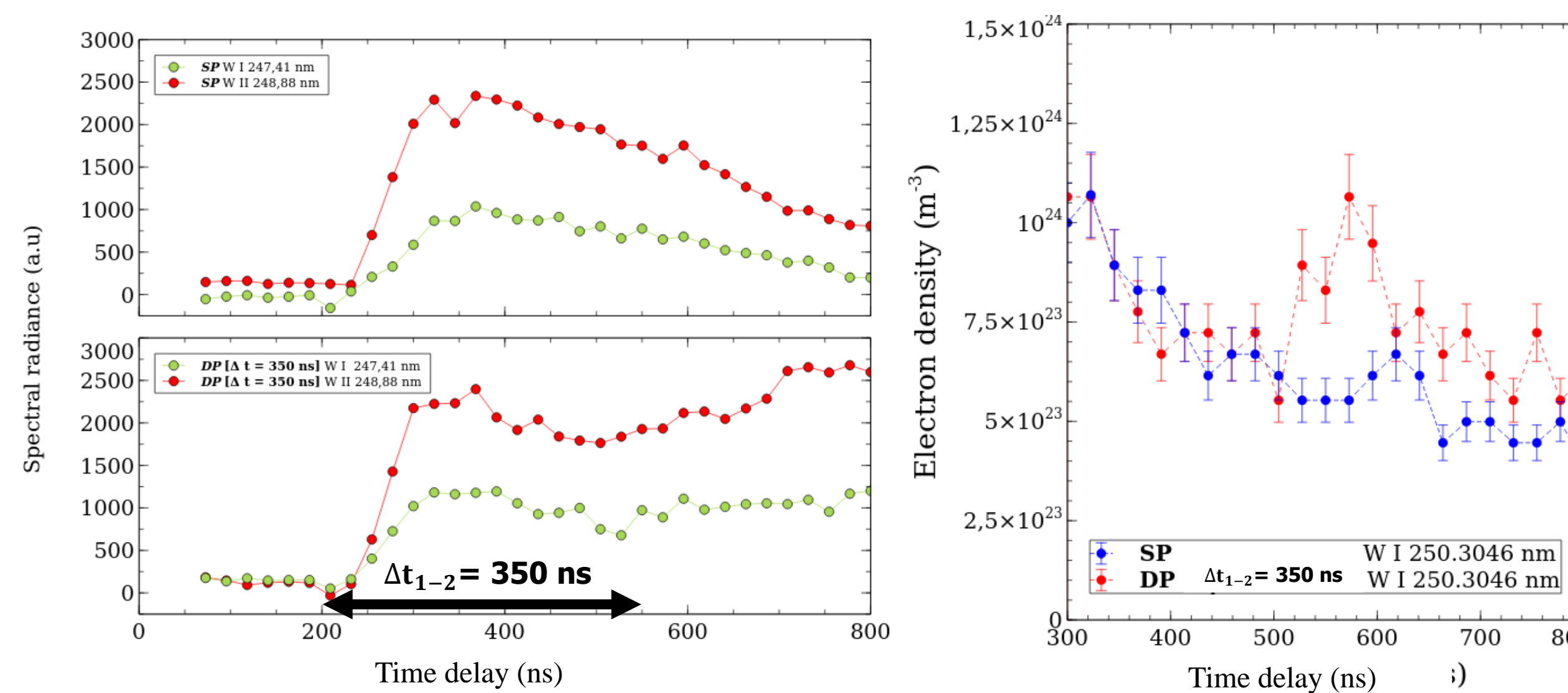
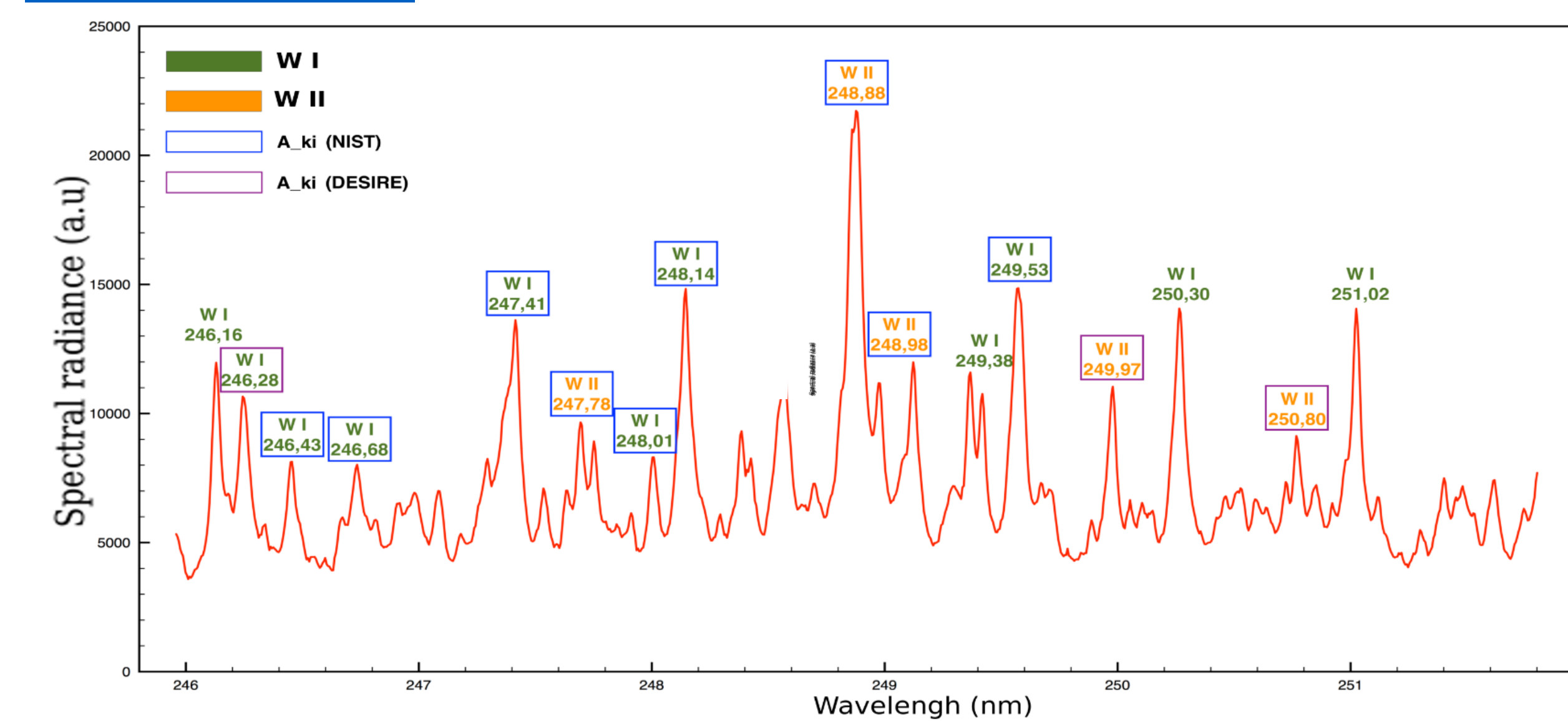
The **ps pulse** ( $\tau_1=30$  ps,  $\lambda_1=1064$  nm,  $E_1=20$  mJ) is focused on the sample using a lens of 125 mm focal length. The **ns pulse** ( $\tau_2=5$  ns,  $\lambda_2=532$  nm,  $E_2=15.2$  mJ) is delayed by  $\Delta t_{1-2}$  and is tangentially focused (with a lens of 150 mm focal length) in the plasma produced by the ps pulse at a distance  $H$  ( $=0$  or  $1$  mm) +  $0.62$  mm above the sample's surface.

## DP on AL targets



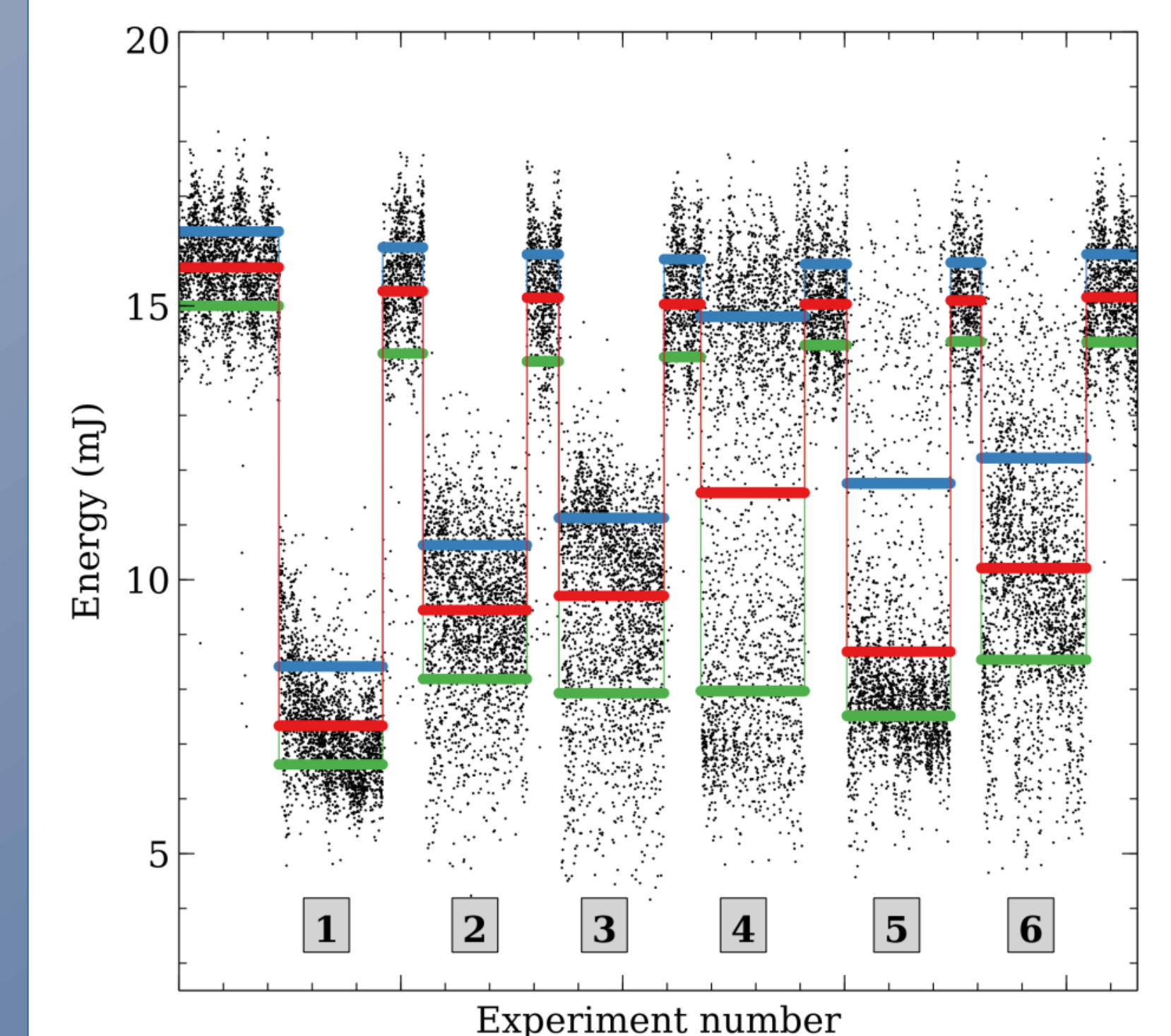
(a)  $H = 0$  mm. Experiments no 1 ( $\Delta t_{1-2} = 150$  ns), 2 ( $\Delta t_{1-2} = 250$  ns) and 3 ( $\Delta t_{1-2} = 350$  ns).  
(b)  $H = 1$  mm. Experiments no 4 ( $\Delta t_{1-2} = 150$  ns), 5 ( $\Delta t_{1-2} = 250$  ns) and 6 ( $\Delta t_{1-2} = 350$  ns).

## DP on W targets



- Electron density increase observed due to the absorption of the second laser pulse
- Many transitions observed in spectra, but few of them are well characterized in the usual database (about 7% of W I and W II on NIST)
- Dynamics similar to the one observed for Aluminum

## Laser attenuation for AL



- Maximum mean spectral absorptivity of 0.53

## DP on H-D-W targets

- Limit of observation of H or D in W: **0.5 % at.**

## PERSPECTIVES

- Study in collinear configuration (same optical axis for both pulses)
- Study in the VUV spectral range on the resonance lines of H and D

- Determination of the electron density based on the Stark broadening of numerous ionic and atomic lines

- Global recombination phase clearly observed without second pulse ( $t > 100$  ns)

- Re-ionization observed due to the second pulse absorption

- Similar values obtained for the maximum electron density resulting from the second pulse absorption whatever  $\Delta t_{1-2}$

⇒ **Saturation effect!**