

SUMTRAIC 2024

Spectroscopic measurements

during the transport barrier formation on GOLEM

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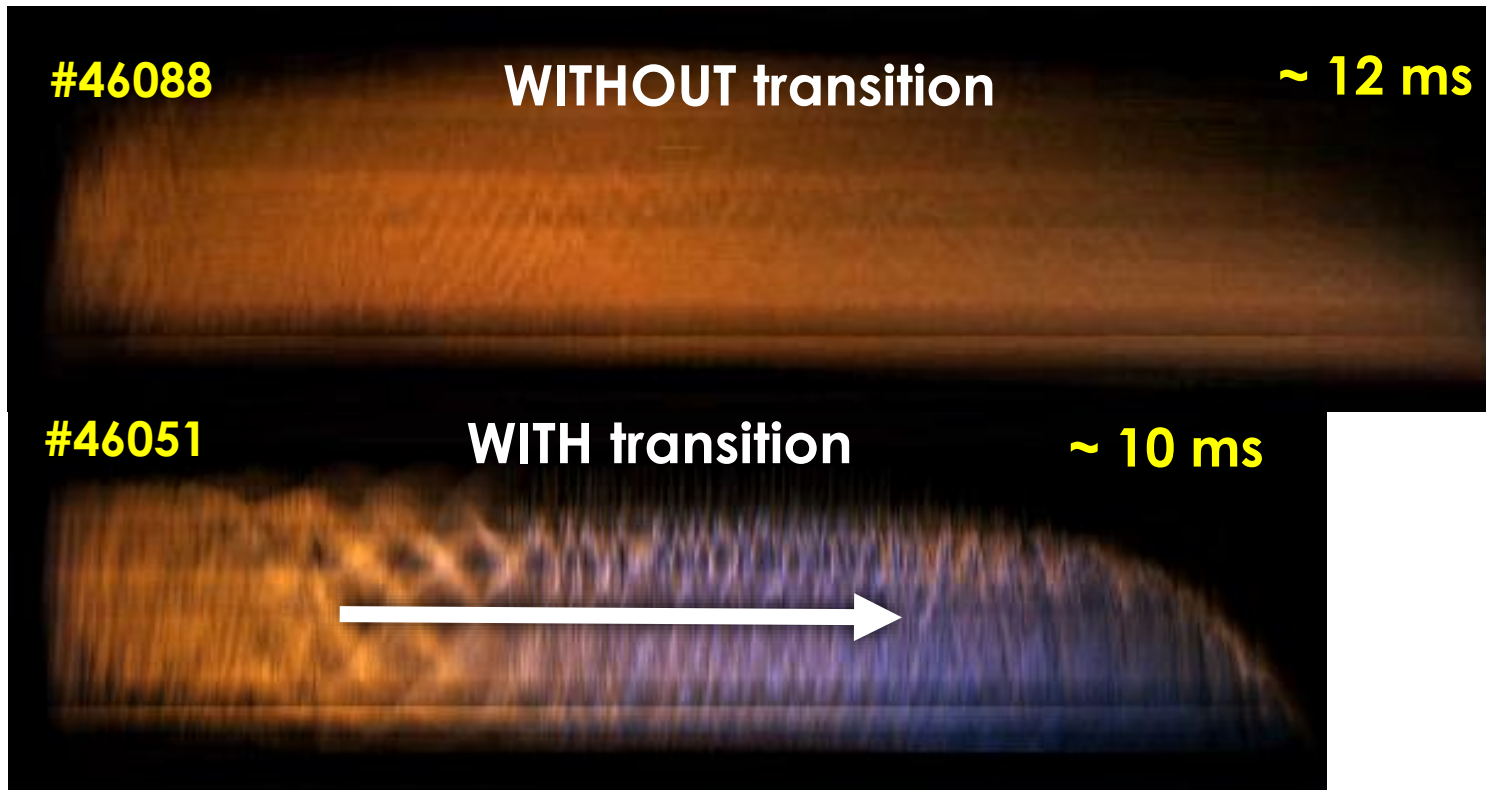
Affiliations:

1) Technical University of Athens (BsC/MsC)

2) Aristotle University of Thessaloniki (Bachelor student)

NEW REGIME ON THE GOLEM TOKAMAK ^[1]

CAMERA RECORDS

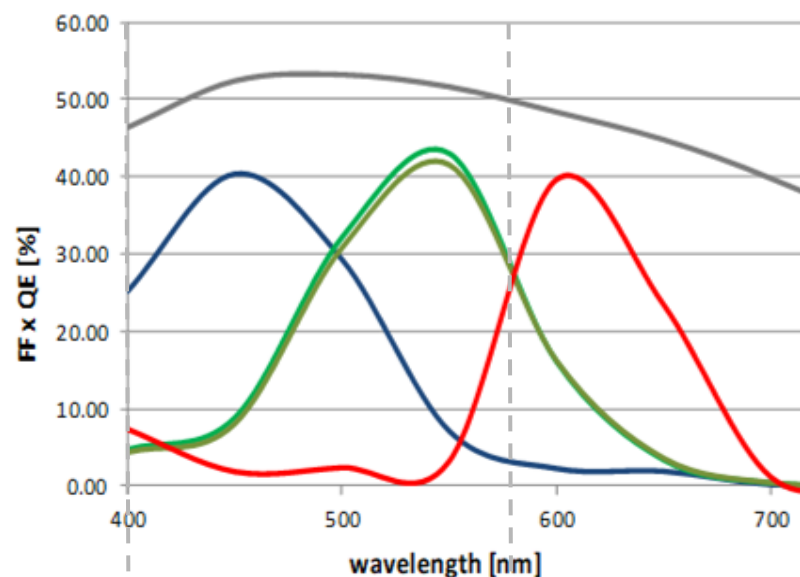


TASK:

**SPECTROSCOPIC
INTERPRETATION**

- Spontaneous transition
in He discharges
(see previous presentation)

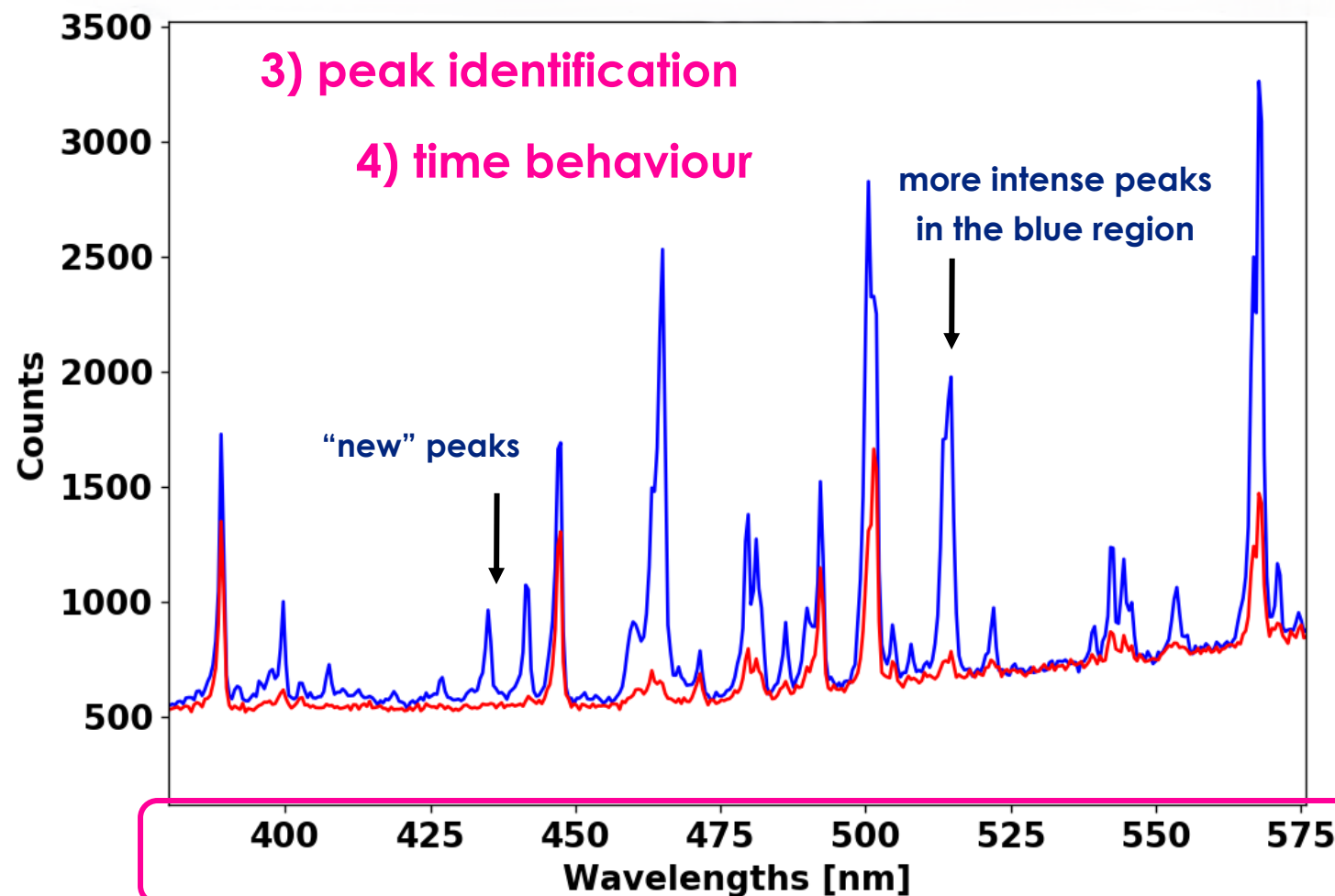
Camera Efficiency



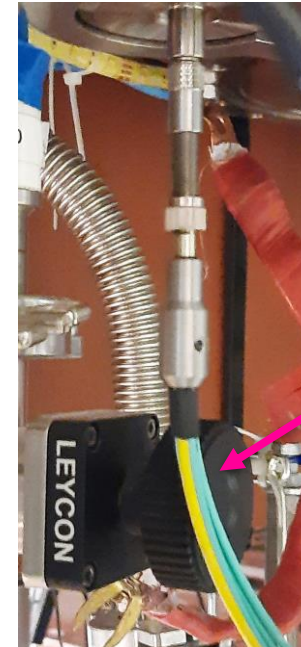
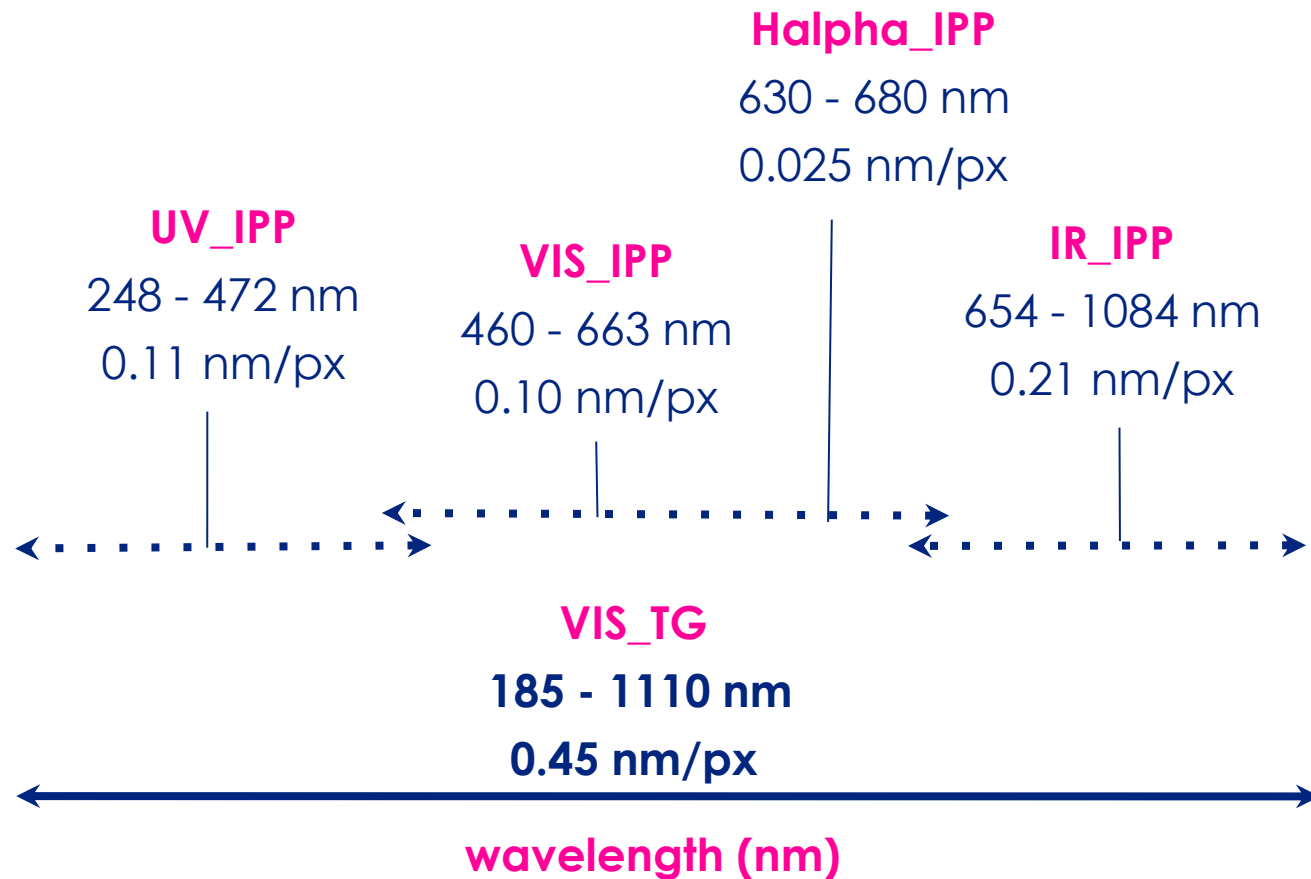
1) new optical set-up

2) spectral calibration

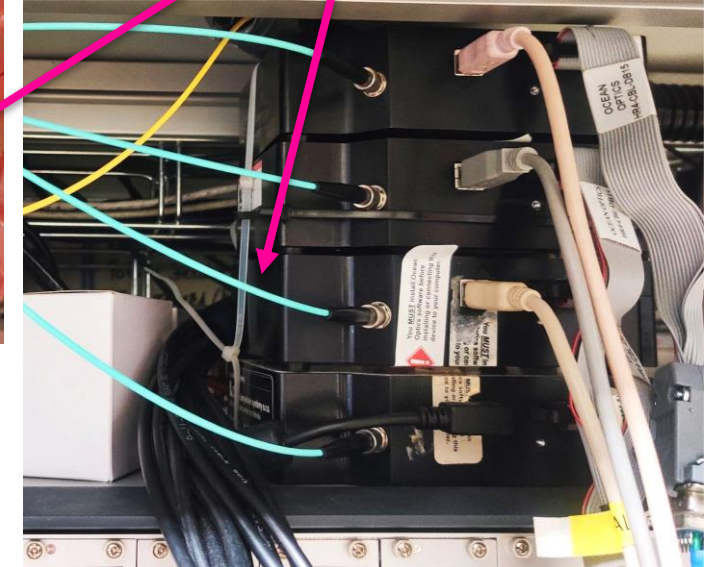
● #46088 [f5] (reference shot) ● #46051 [f4] (with the effect)



TOKAMAK \Rightarrow COLLECTION LENS \Rightarrow FEEDTHROUGH \Rightarrow FIBERS \Rightarrow 4 compact spectrometers

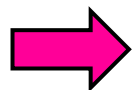


Optical Fiber Cable



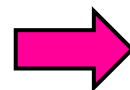
Calibration sources:

- Hg-2 (Hg + Ar)
- Ne-2 (Ne)



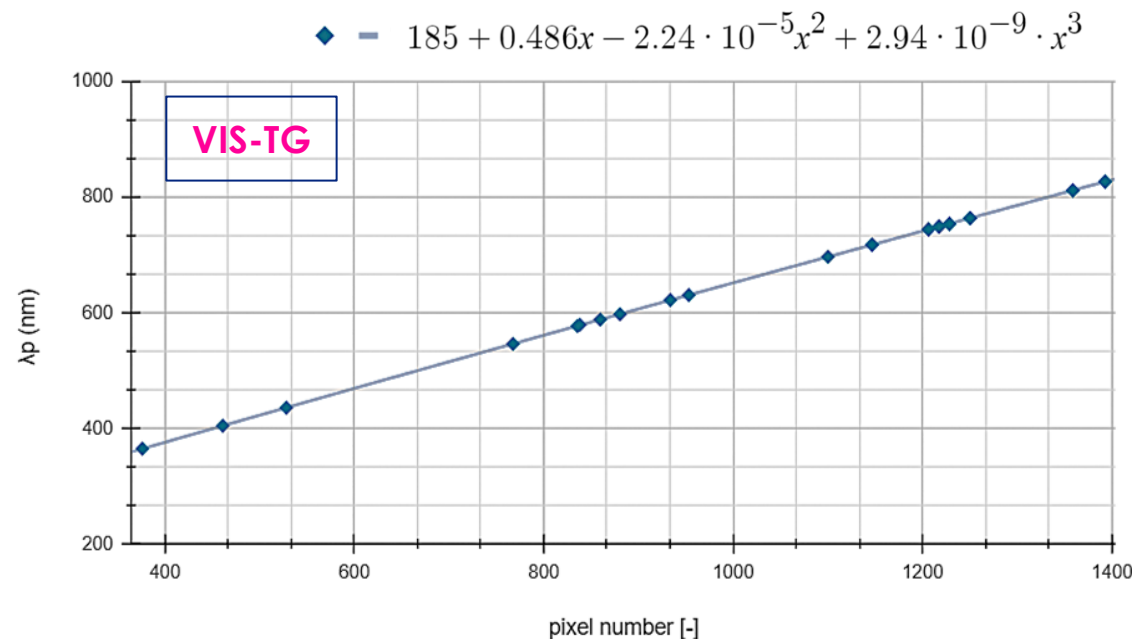
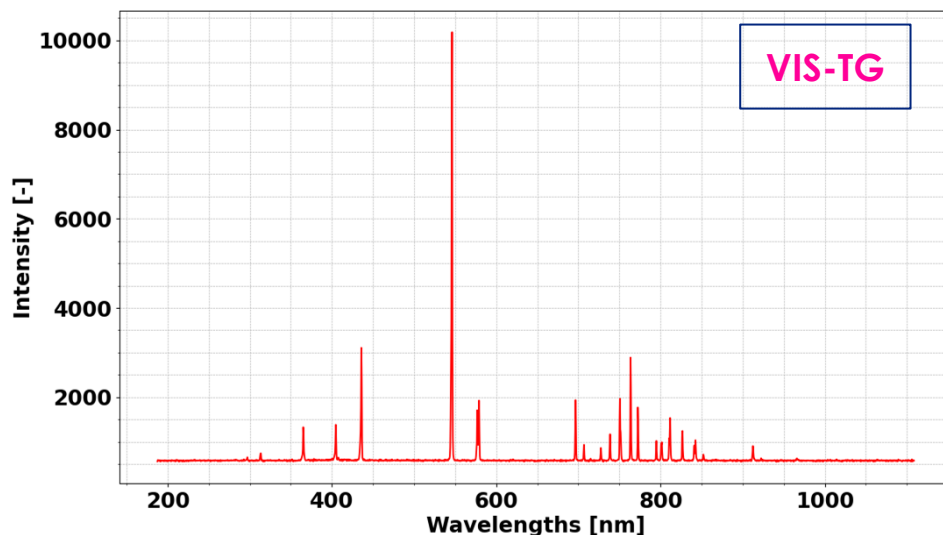
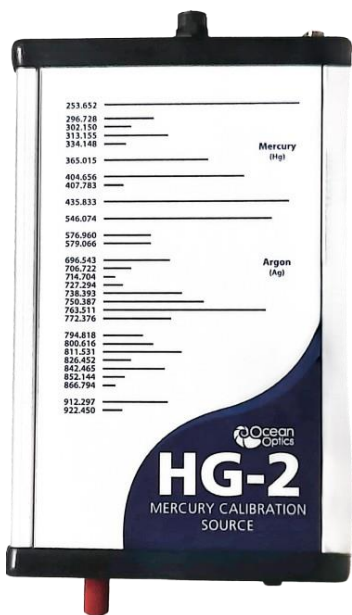
IN TOTAL:

- 2 measurements with exposure times (2 ms & 5 ms) respectively



Establish correct spectral axis for each spectrometer:

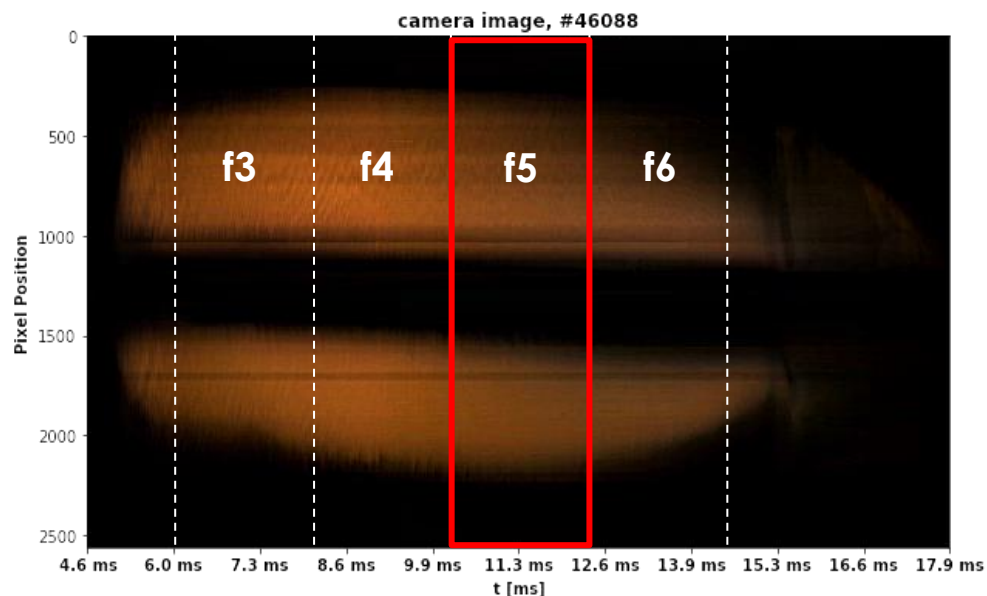
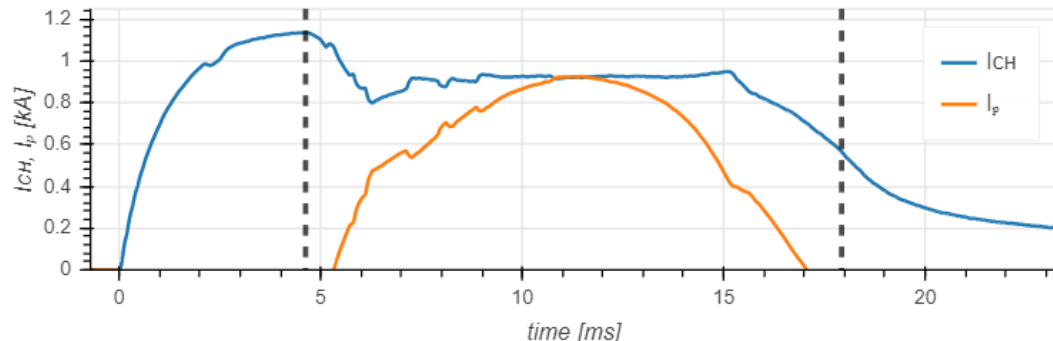
- identification of known spectral lines
- fit polynomial to identified spectrum



Main study

- **Before SUMTRAIC:** **No clear reasons** for the color change (probably probe position/probe erosion/impurities)
- **During SUMTRAIC:** Scan over probe position (group 1) - result: **No relevant dependence** of the effect on the probe position.
- **Observations:**
 - Possible dependence on **plasma parameters** e.g. input power (group 1).
 - **High intensity** of all observed spectral peaks, mainly in the **blue region**.
- **Method:** **Comparison** of the **reference shot #46088** (without effect and probes) spectra and other shots with the effect but with different probe positions, **shot #46051** and **shot #46042**.

Reference Shot #46088



* **Probe position:** 82 mm - outside the plasma

1) Select the important **frames** by comparing stronger and weaker plasma intensity regions. (e.g. f3 vs f5)-time evolution.

2) Focus mainly in **blue region** and investigate **time evolution** of the spectral lines.

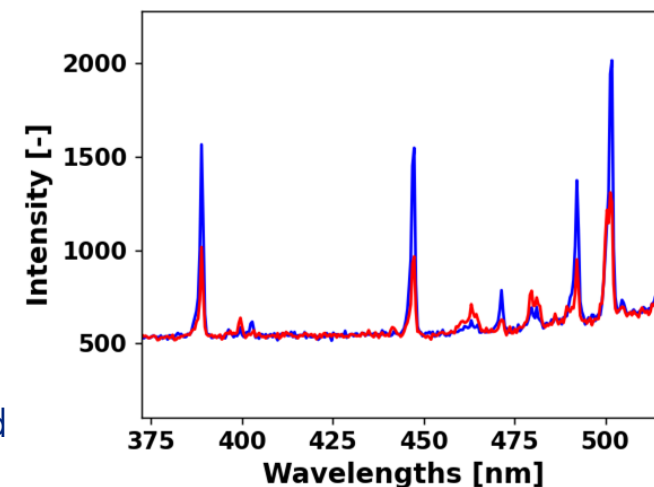
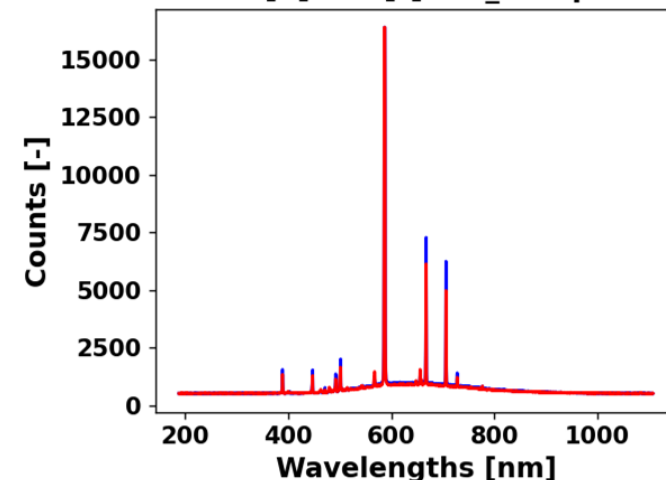
Notes:

each frame = **2 ms**

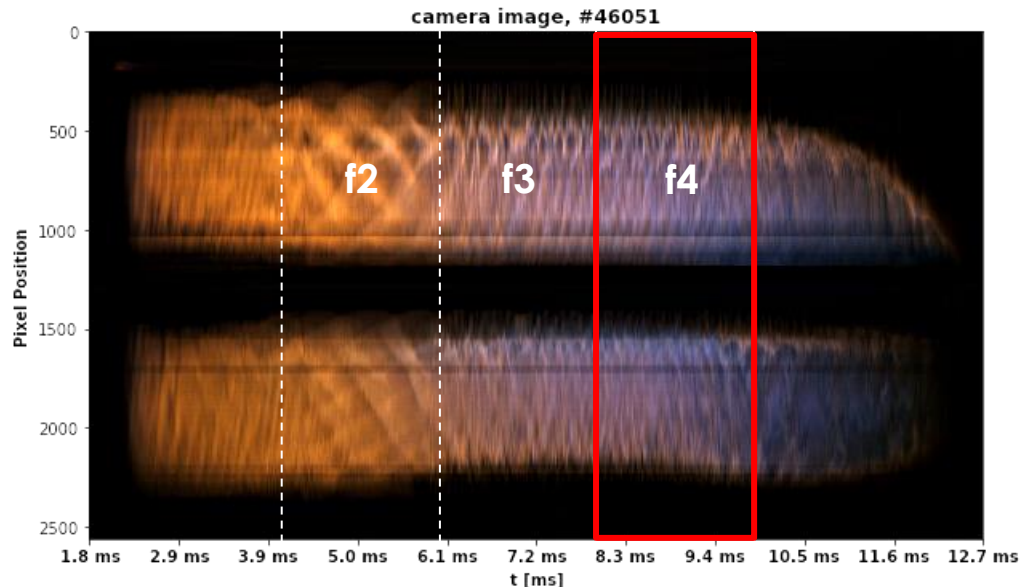
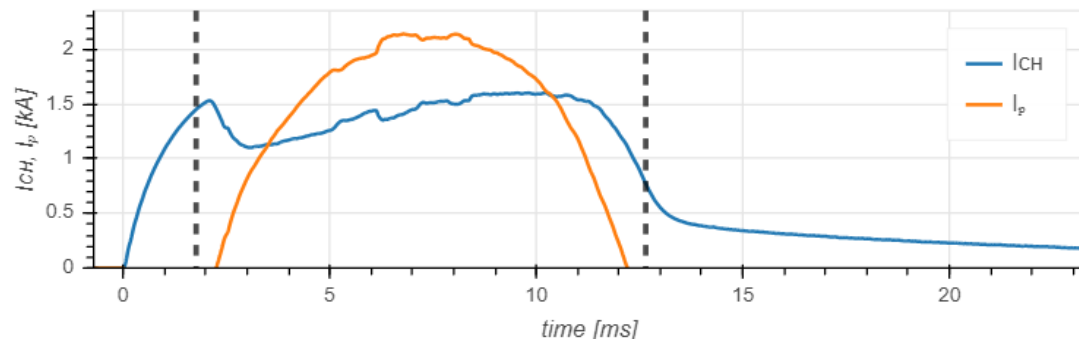
f5 = comparison frame (REF)

Only TG spectrometer shown - bad resolution but **higher sensitivity**.

Frame 3 [b] & 5 [r] VIS_TG Spectrum



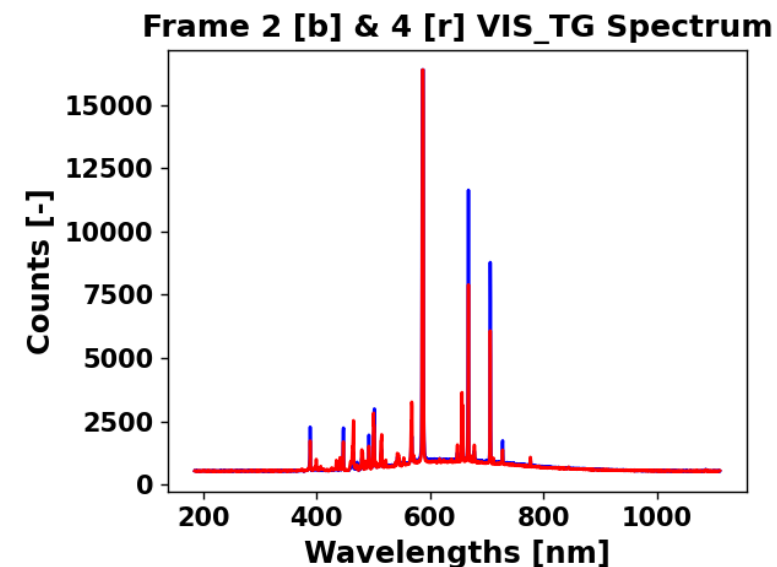
With effect: Shot #46051



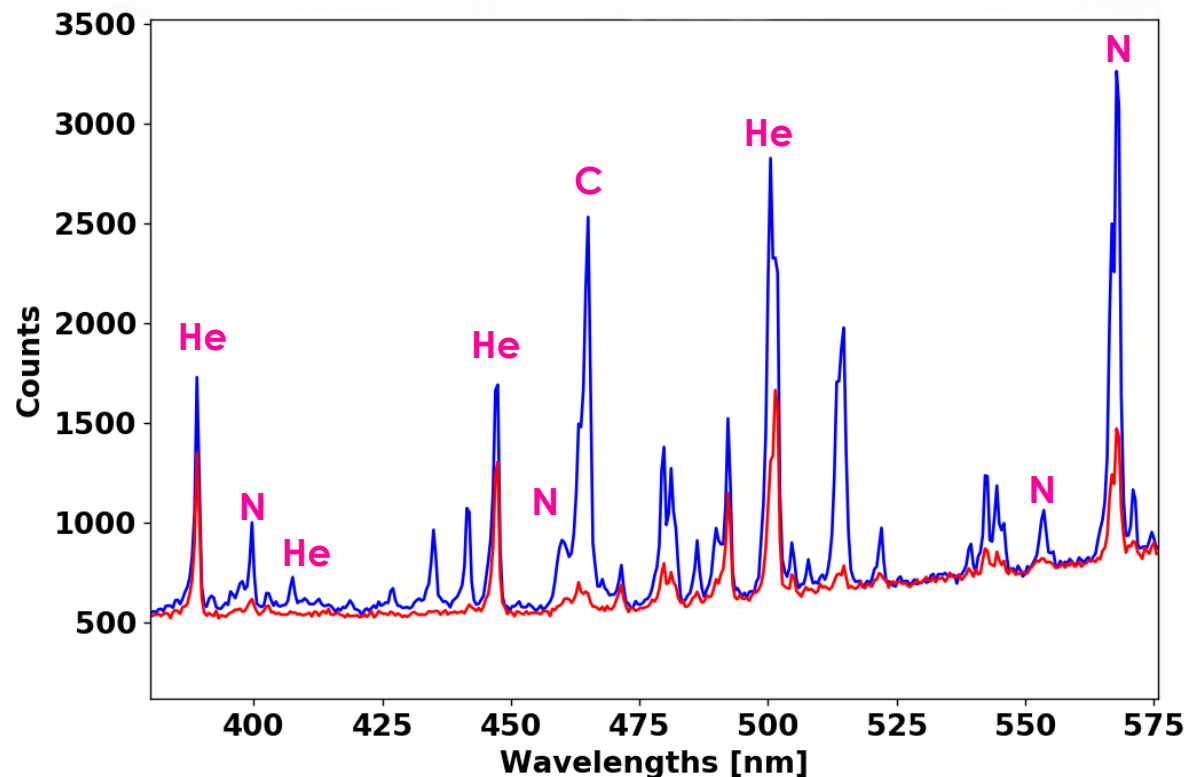
* **Probe position:** 54 mm - inside plasma

- 1) Investigate the important **frames** before and after effect appears. There is a time shift of the discharge - shift is approximately one frame.
- 2) Focus mainly in **blue region** and investigate **time evolution** of the spectral lines.

Notes:
 each frame = **2ms**
 f4 = comparison frame (EFF)



● #46088 [f5] (reference shot) ● #46051 [f4] (with the effect)

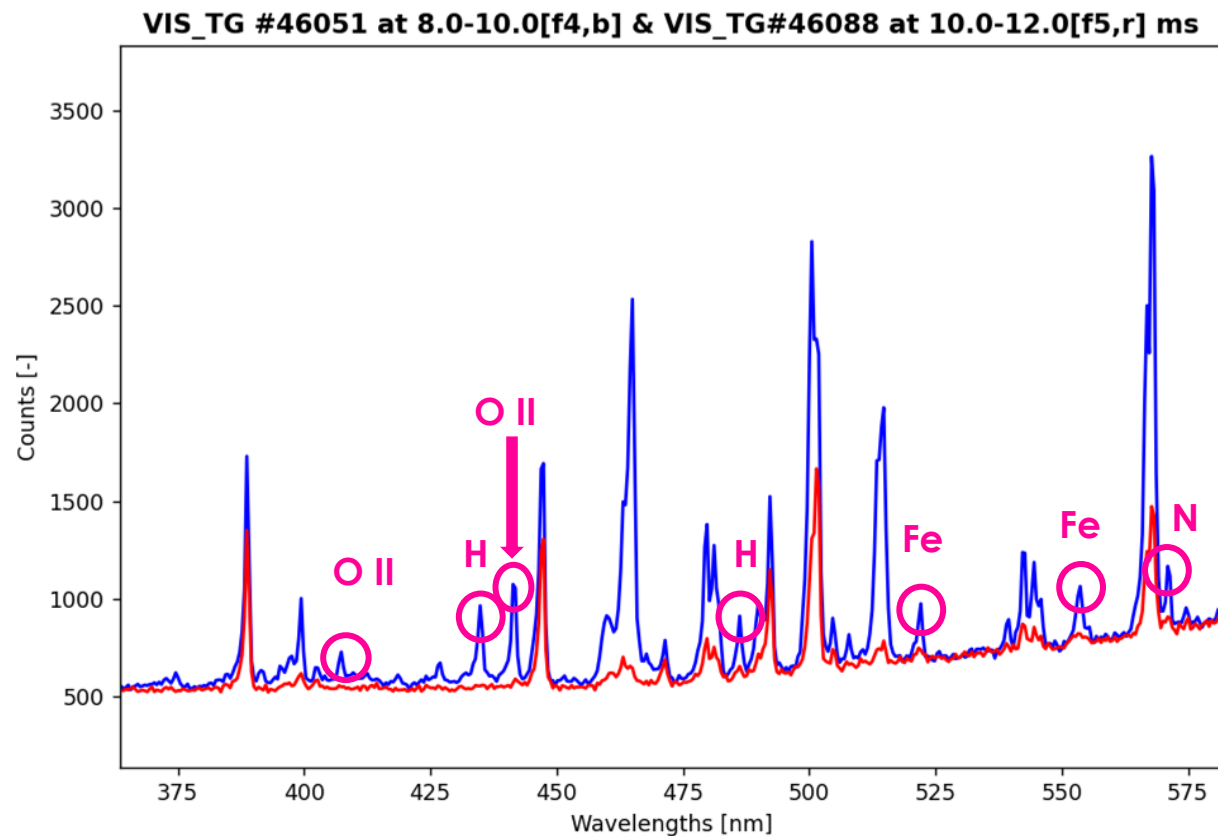


λ (nm) - NIST _[2]	CONFIRMED lines	#46088 (REF) (nm)	#46051 (EFF) (nm)
388.86	He I	389.89	388.63
399.5	N II	399.47	399.43
402.62	He I	402.68	402.67
447.15	He I	447.38	447.13
464.74	C II	463.1	464.94
501.57	He I	500.6	500.56
567.96	N II	567.9	567.9
657.8	C II	657.85	657.83
667.82	He I	667.71	667.72
706.52	He I	706.25	706.25
777.19	O I	777.0	777.0

Table 1

He I - N II - C II - O II: Lines verified from NIST_[2].

Also lines from infrared region are noted on the table 1, for future investigation.



λ (nm) - NIST	POSSIBLE lines	#46088 (REF, f5)	#46051 (EFF, f4)
407.59	O II	x	407.37
434.05	H	x	434.85
441.5	O II	x	441.58
434.05	H	x	434.85
486.13	H I	x	486.24
522.06	Fe III	x	522.06
553.48	Fe II	x	553.54
571.08	N II	x	571.23

Table 2

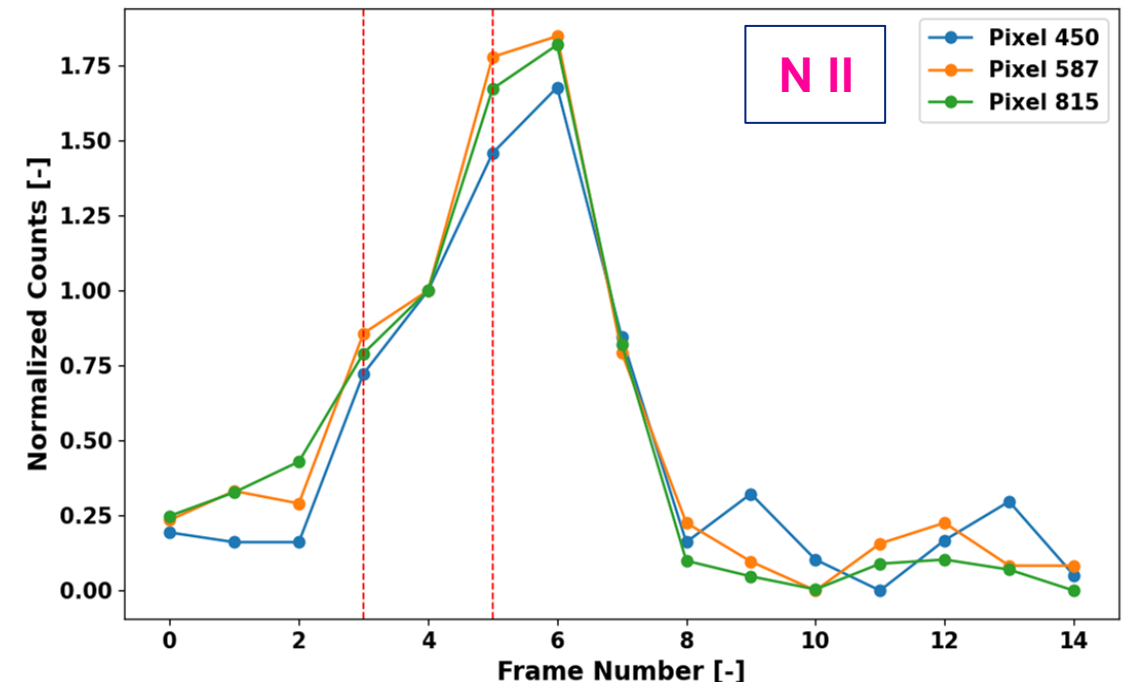
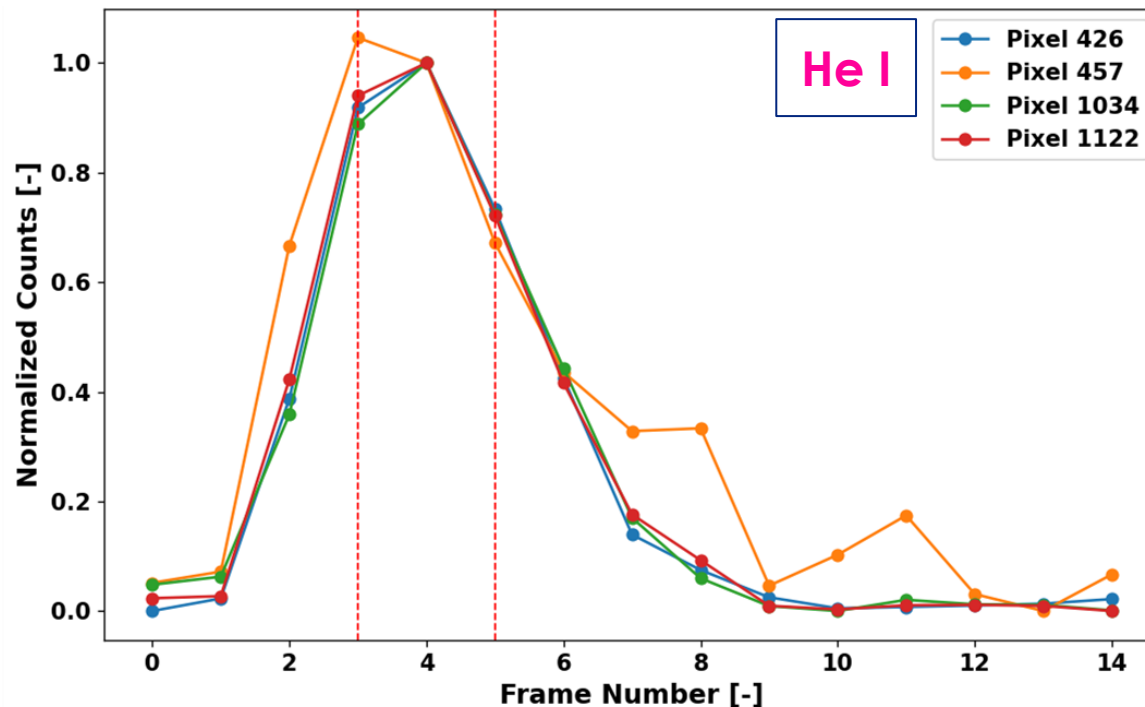
Notes:

- New peaks appear - impurities existence in plasma,
- Strong density and Intensity of peaks in blue region,
- **Further investigation needed.**

Time behavior during REF shot #46088

- **He I**: 30% decrease (e.g. 388.86 nm, 447.15 nm)
- **N II**: 40% increase (e.g. 399.5 nm, 501.06 nm)

Normalised on the 4th frame.

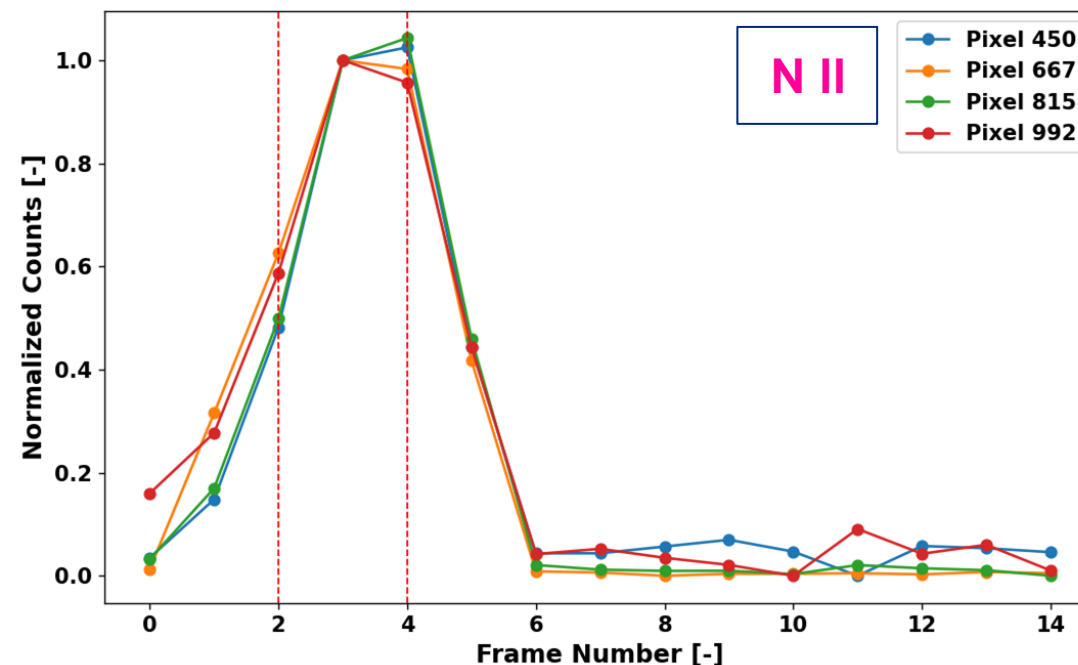
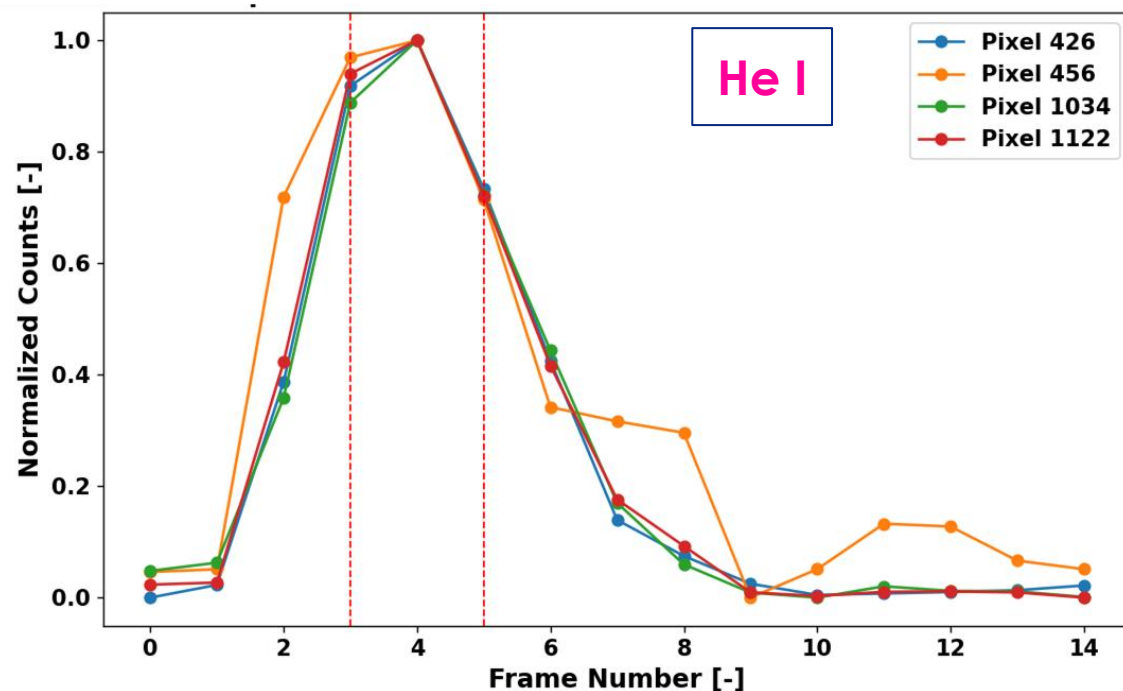


Time behavior during EFF shot #46051

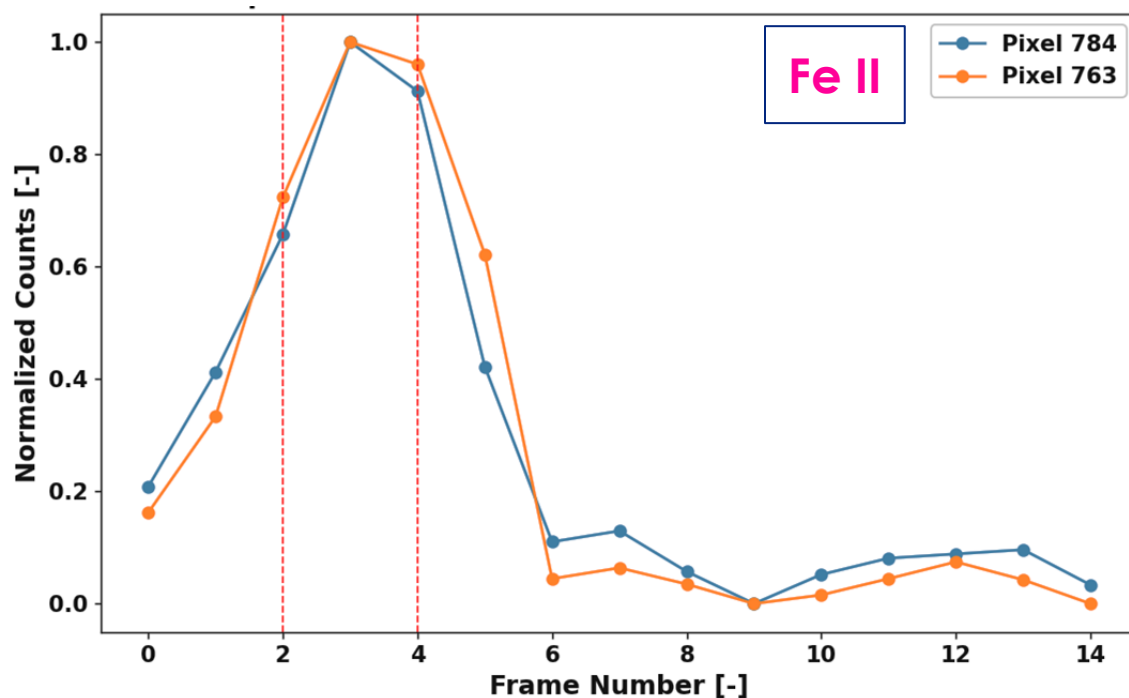
- **He I**: 30% decrease (e.g. 388.86 nm, 447.15 nm)
- **N II**: 40% increase (e.g. 399.5 nm, 501.06 nm)

Normalised on the 3rd frame.

Same behavior comparing to REF shot

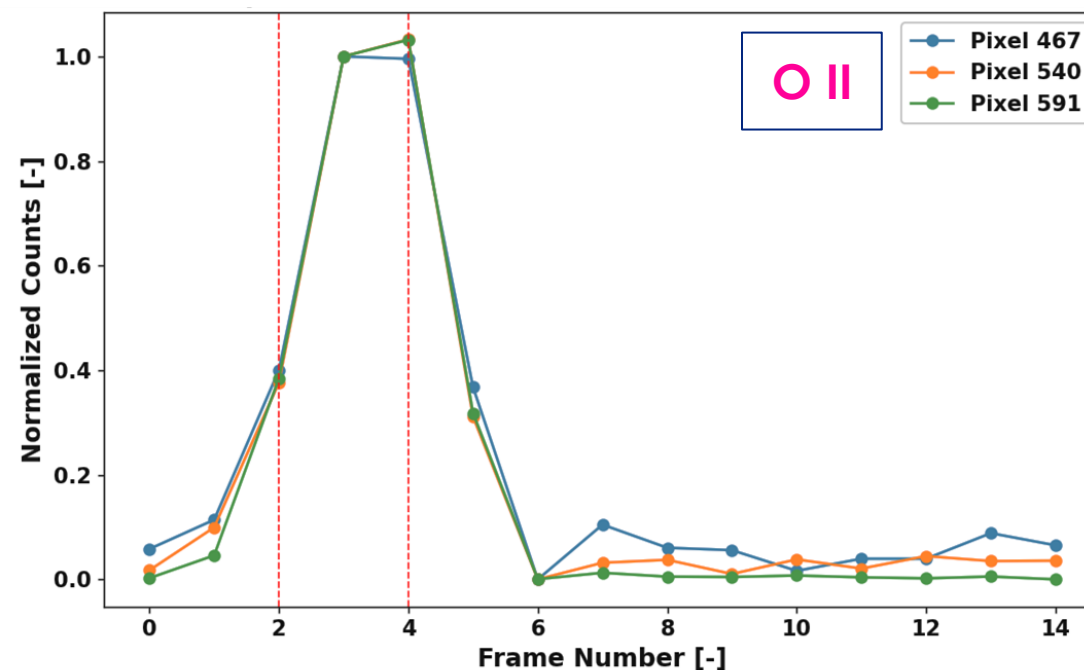


Time behavior during EFF shot #46051

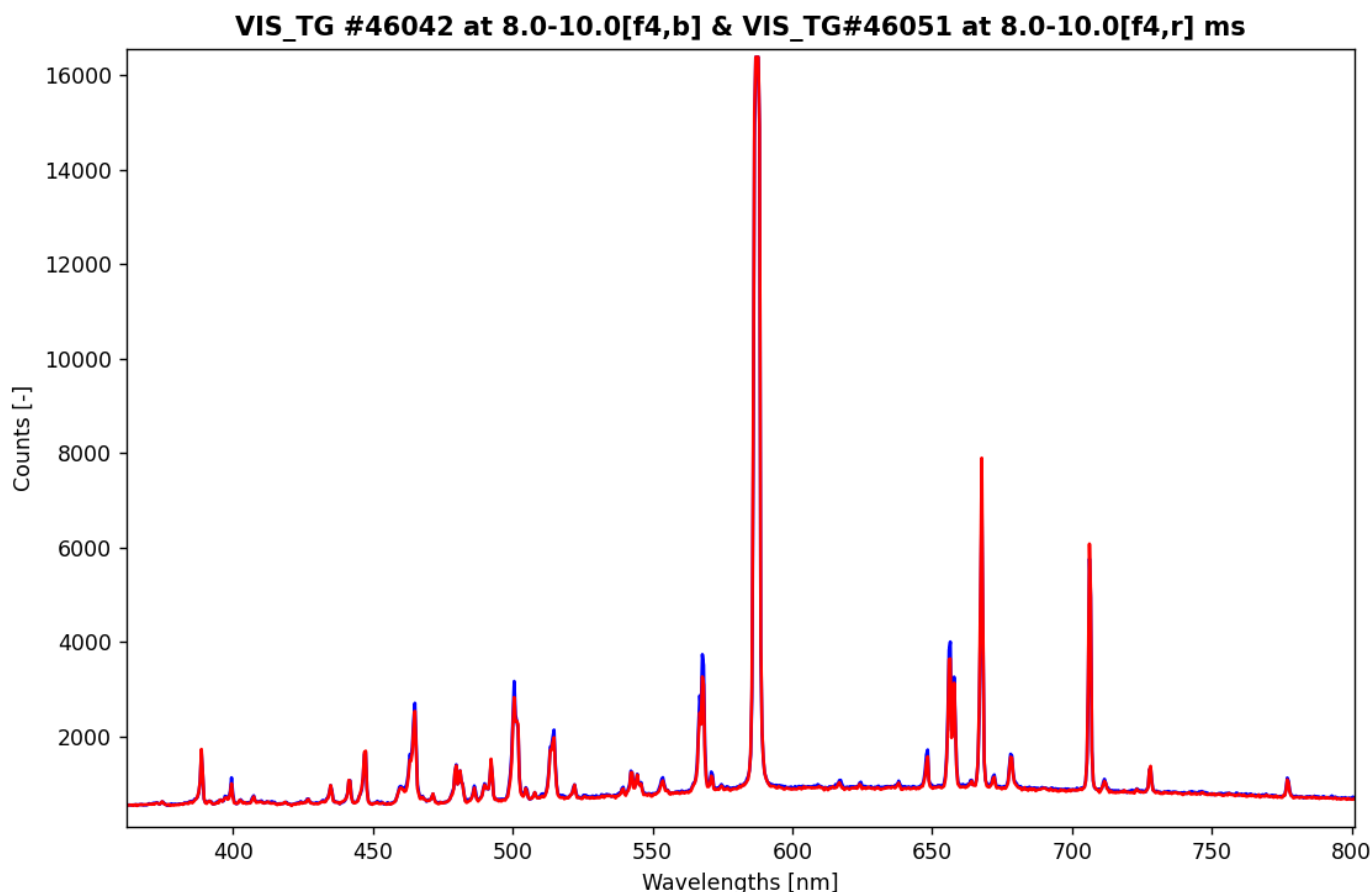


- **Fe II**: 20% increase (544.44 & 553.48 nm)
- **O II**: 60% increase (407.6, 464.9 & 441.5 nm)

The lines of those elements are not intense in REF shot (negligible).



Probe moved: shot #46042



- Similar behavior of the peaks is observed to be independent on the probe position.
- **Effect still exists** however it seems to be slightly more intense.

Spectral lines at shot-46042 **follow** the lines of the shot-46051 with effect.

Notes:

NO dependence on the probe position.

Tools are available for further investigation.

- New optical **set-up** prepared (of compact spectrometers at GOLEM tokamak)
 - 4 spectrometers used simultaneously
- **Calibrations** of the spectrometers performed
 - 2 calibration sources used (Hg & Ar | Ne)
 - 2 measurements (2 ms & 5 ms exposures) with 5 spectrometers/ 4 processed
 - Registration of the **wavelength** & **pixel number** for each peak → verification via Gaussian fitting
 - Polynomial fitting for establishing the calibrated spectral axis
- Measurements in the regime with the spontaneous transition in He discharges:
 - 5 spectrometers used stepwise (1 acceptable for temporal studies / others for line identification only)
 - Comparison of reference shot (**no effect** | **no probes**) **vs** investigated shots (**effect** | **different probe positions**)
 - **Identification of spectral lines** (using NIST database simulations)
 - Investigation of the **time behaviour** of particular lines - common patterns for He I lines...
 - **Blue color** explained from “new” intense peaks in the blue region
 - Automation tools for spectroscopic measurements have been prepared by our team for **future public use**.

Lots of data were collected but further analysis is definitely required!

References

- [1] P. Macha et al 2023 Nucl. Fusion 63 104003; <https://doi.org/10.1088/1741-4326/acf1af>
- [2] National Institute of Standards and Technology (NIST), "NIST Atomic Spectra Database," [Online].
Available: https://physics.nist.gov/PhysRefData/ASD/lines_form.html
- [3] Czech Technical University in Prague, "GOLEM Tokamak" [Online]. Available: <https://golem.fjfi.cvut.cz/>.
- [4] Czech Technical University in Prague, IPP, "Tokamak GOLEM - Shot database". <http://golem.fjfi.cvut.cz/shots/46088/>

