U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

# Characterization of boronized graphite in NSTX-U and its effect on plasma performance

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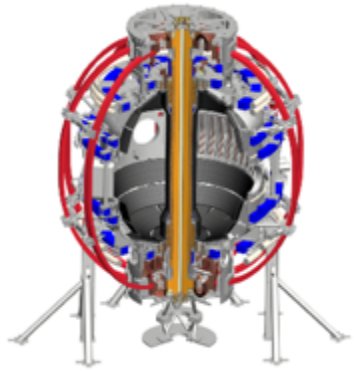
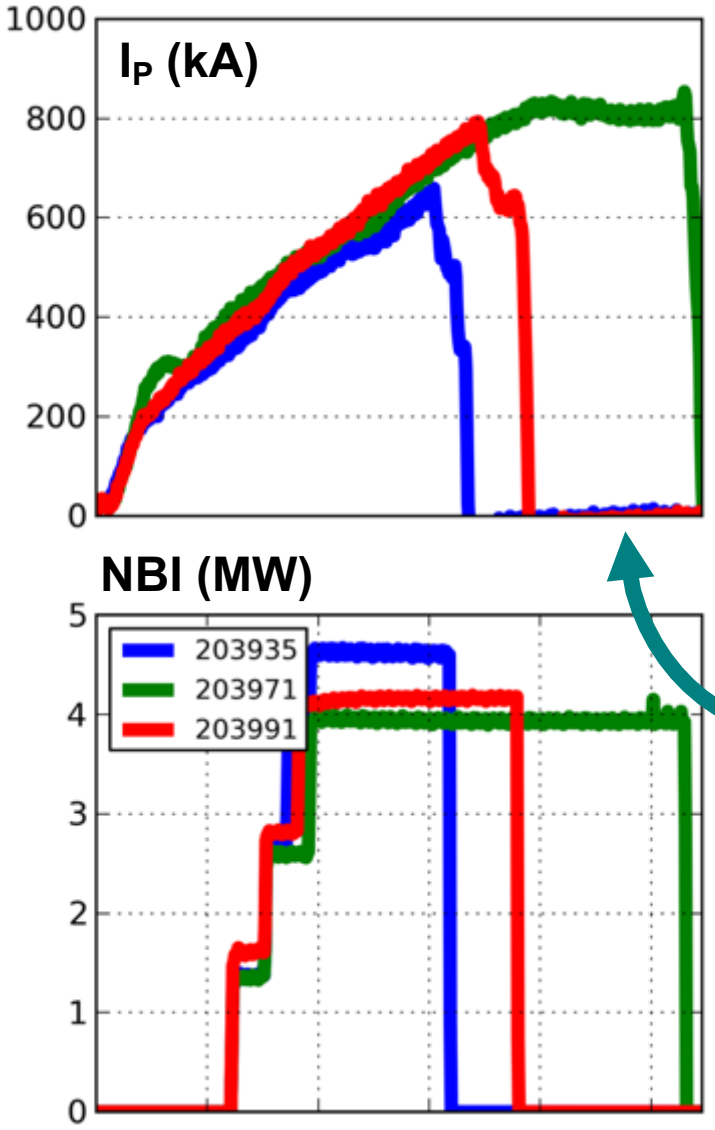
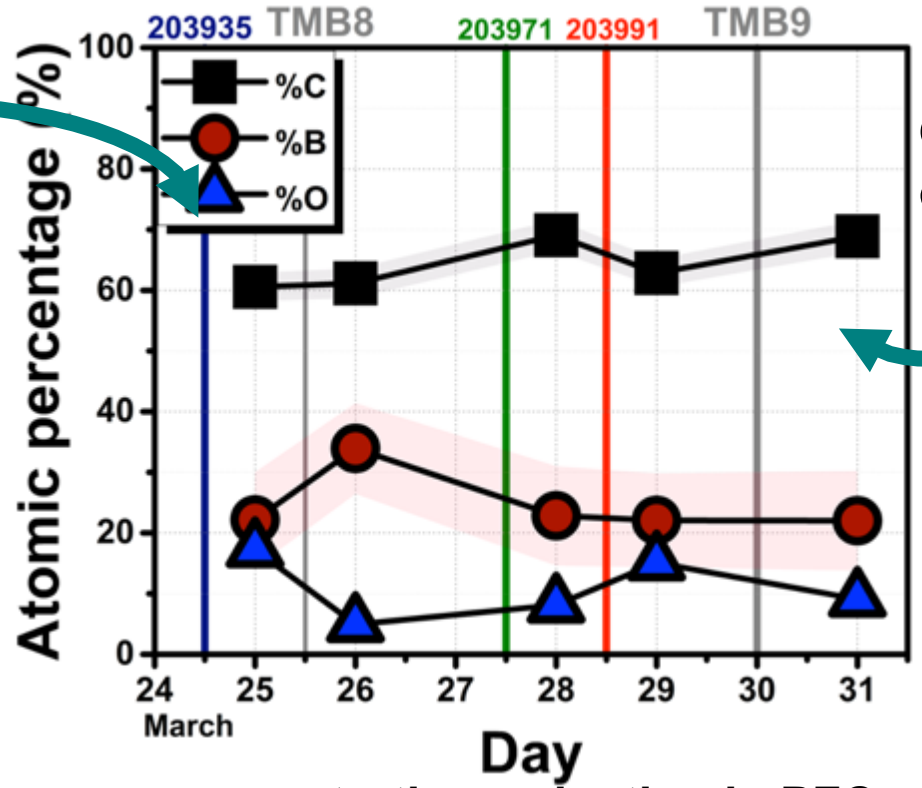


# Motivation – Oxygen retention




Low oxygen concentration following boronization

Improved plasma performance on similar scenarios



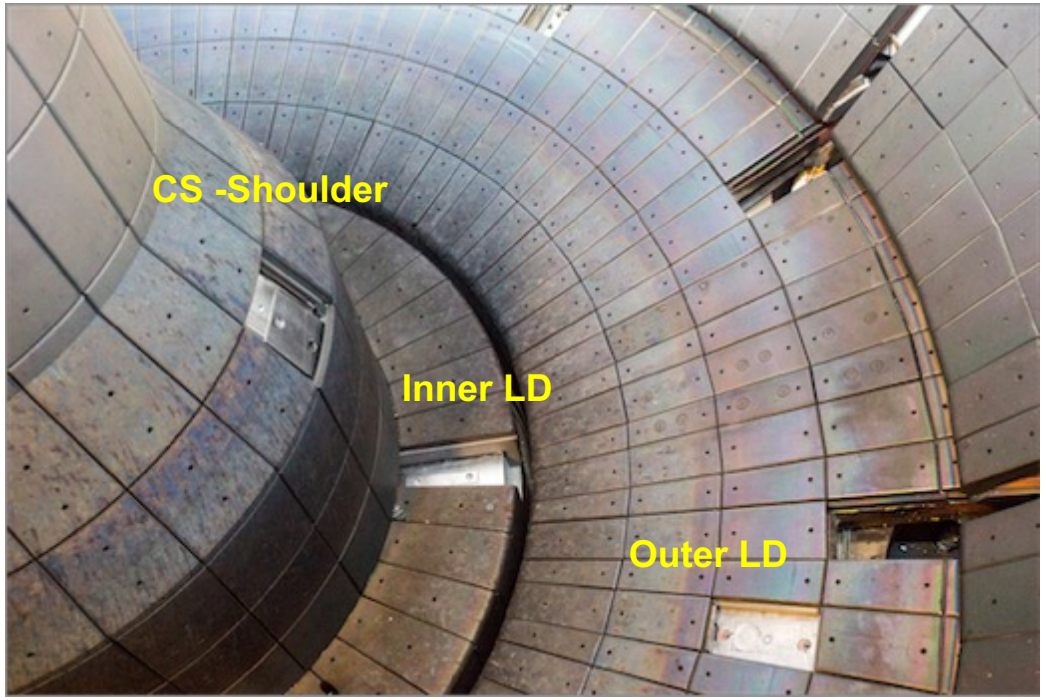

MAPP XPS data obtained at NSTX-U

Oxygen concentration reduction in PFCs with boronization improves performance.

**Further studies in the laboratory (*post-mortem and control*) to test this hypothesis**

# Samples made from NSTX-U tiles *(post-mortem)*

## Core samples





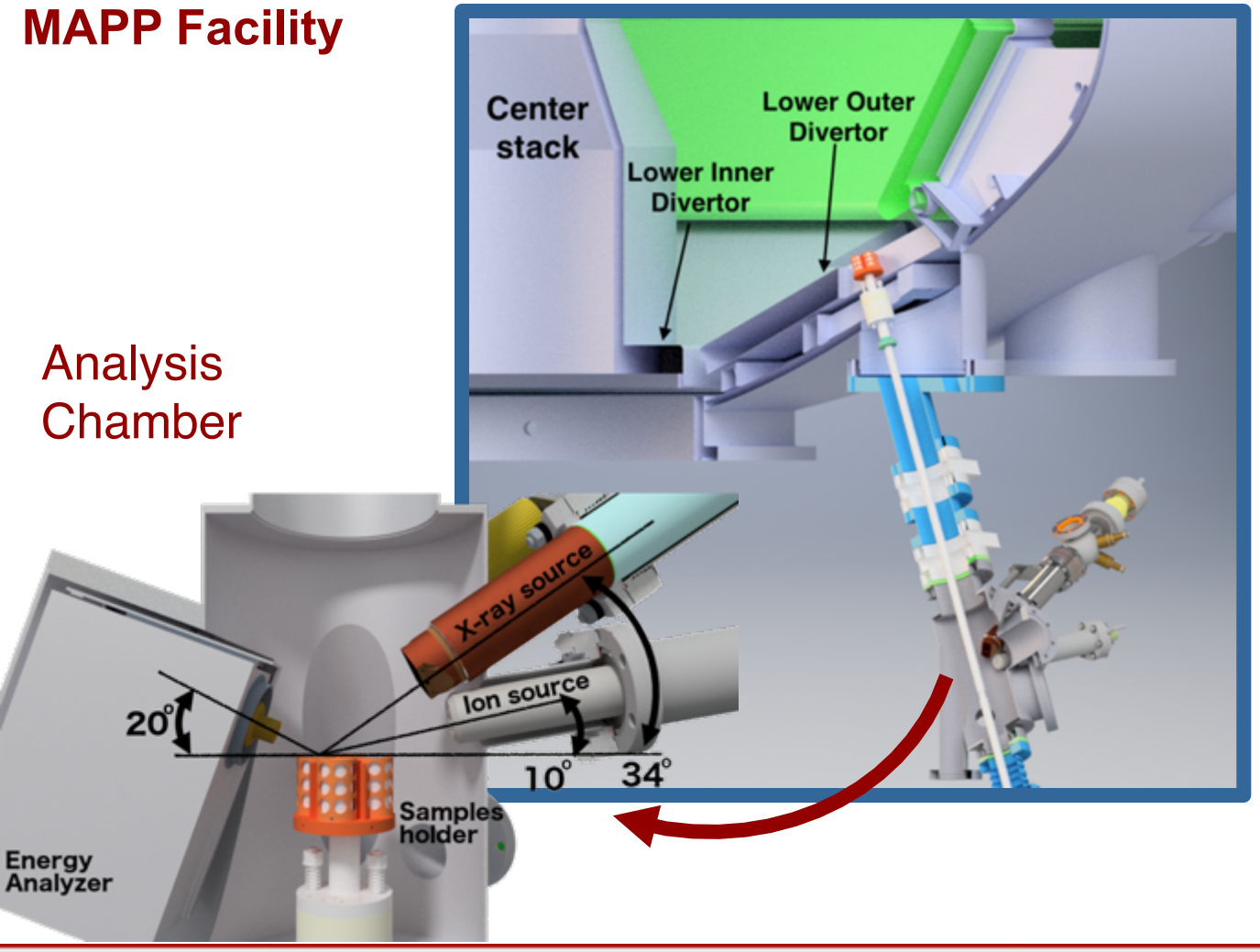
### Tiles location

- A18, Center Stack (CS) Shoulder
- B17, Inner Lower Divertor (ILD)
- C18, Outer Lower Divertor (OLD)

# Experimental methods

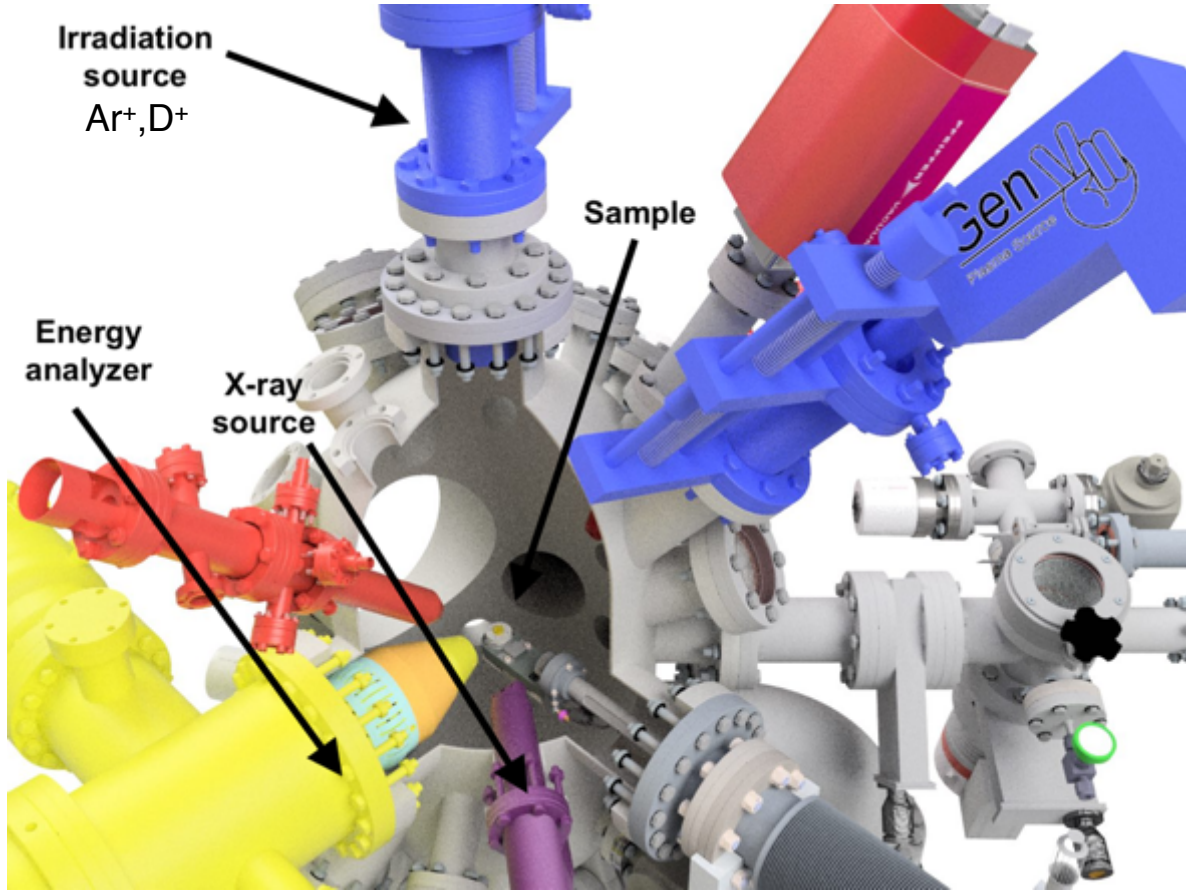
## Materials analysis in NSTX-U

### MAPP Facility



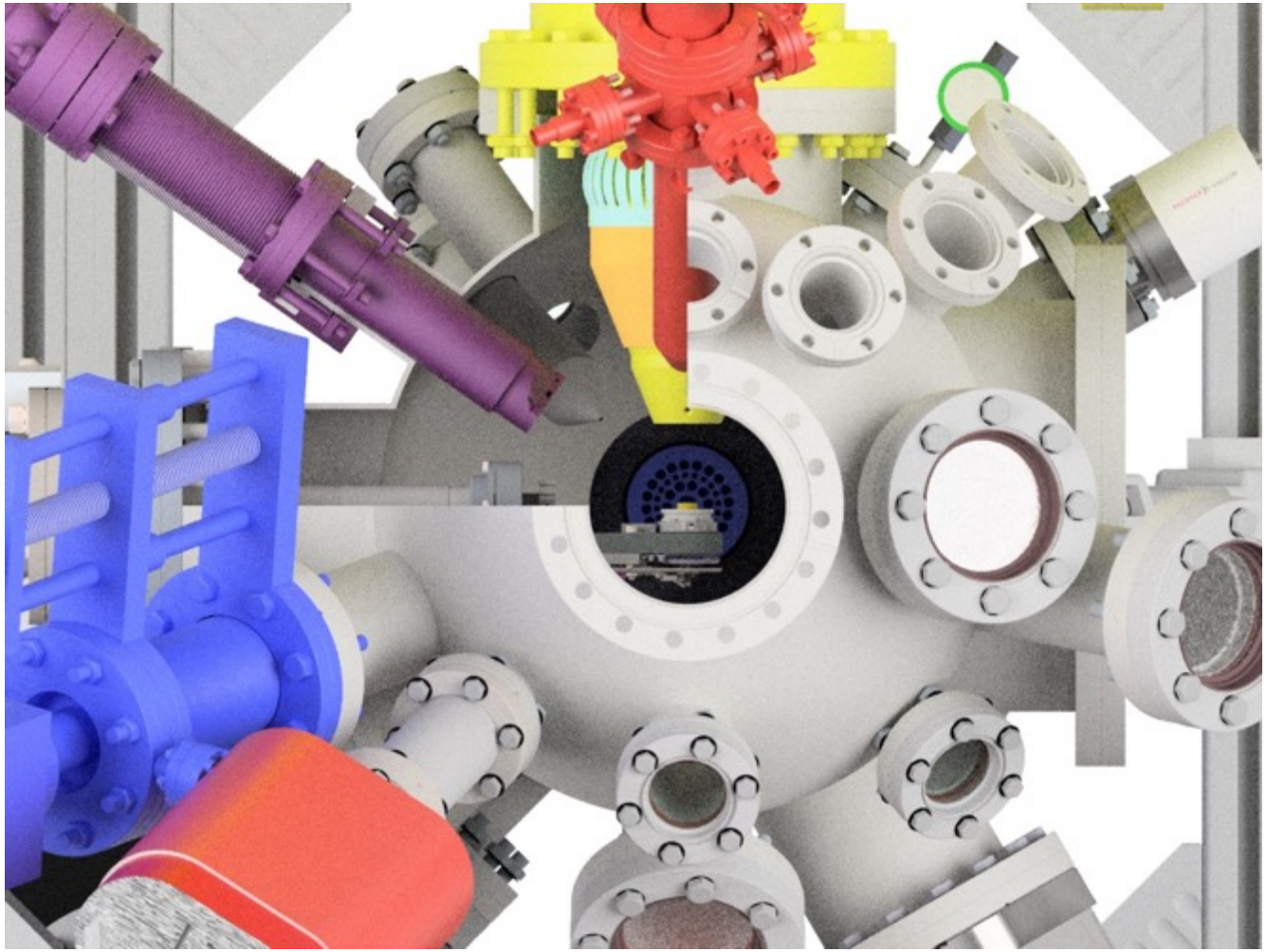

## *Post-mortem* and Controlled experiments at University of Illinois

### IGNIS Facility



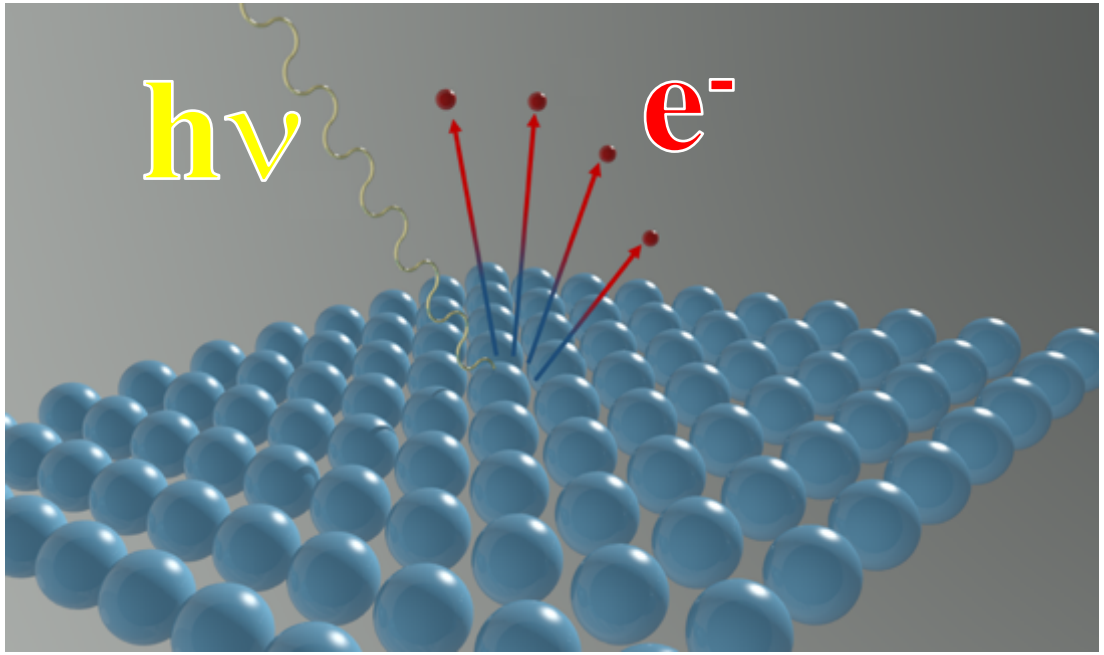
# Ion-Gas-Neutral Interactions with Surfaces (IGNIS) Facility

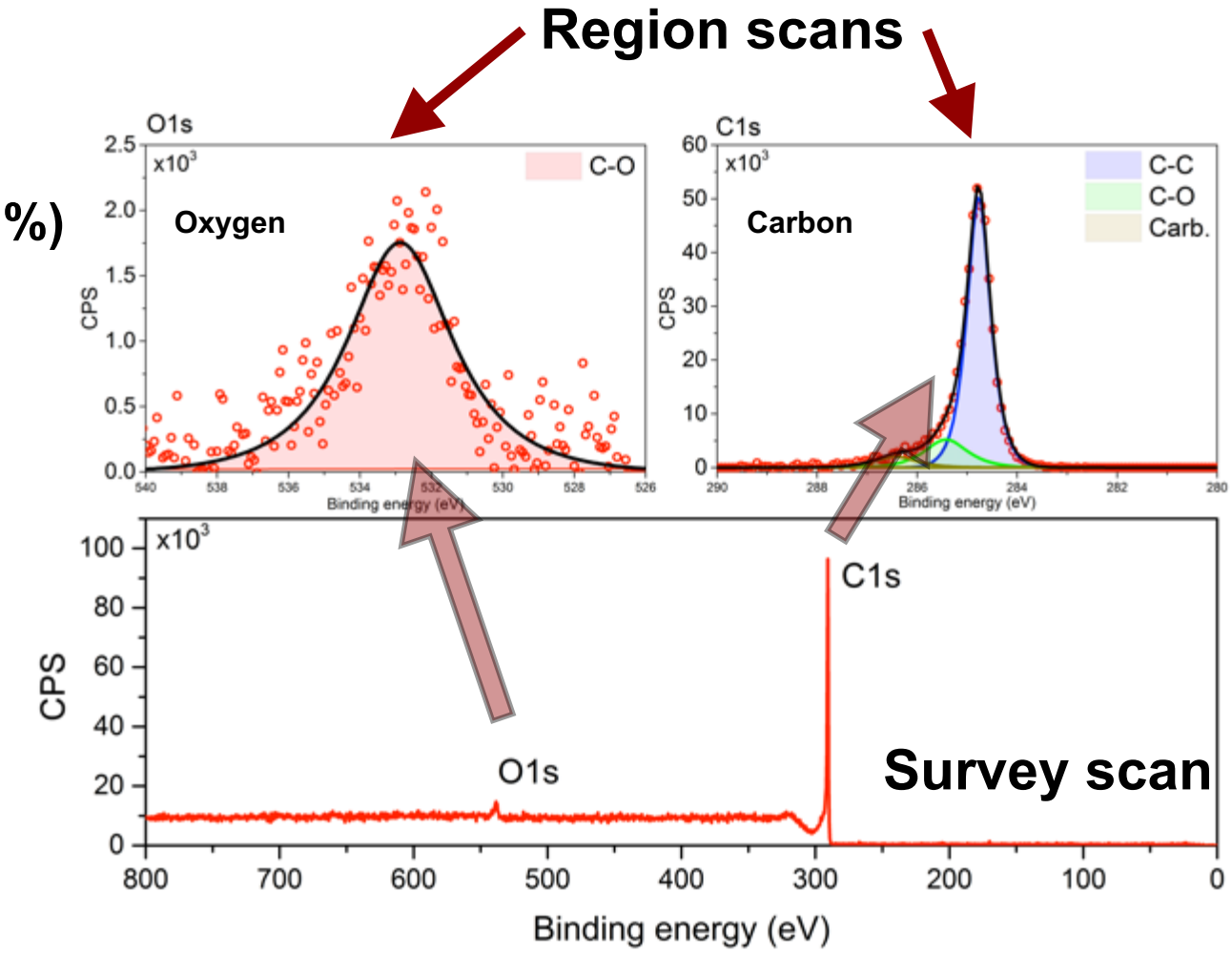
- **True *in-situ, in-operando* analysis of surfaces.**
- **Chemistry analysis (HR-XPS, HR-ISS) at NAP (UHV to 1 mTorr OP).**
- Wide experimental parameters space:
  - Temperature LN to 1000 $^{o}$C.
  - Plasma irradiations; noble and reactive gas (250 eV – 2 keV)



# Chemical identification of components via XPS

- Emission of photoelectrons under incident soft X-ray beam
- Probe top 1 – 10 nm of sample
- Elemental identification in survey scans
- Region scans allow quantitative analysis (at.%)

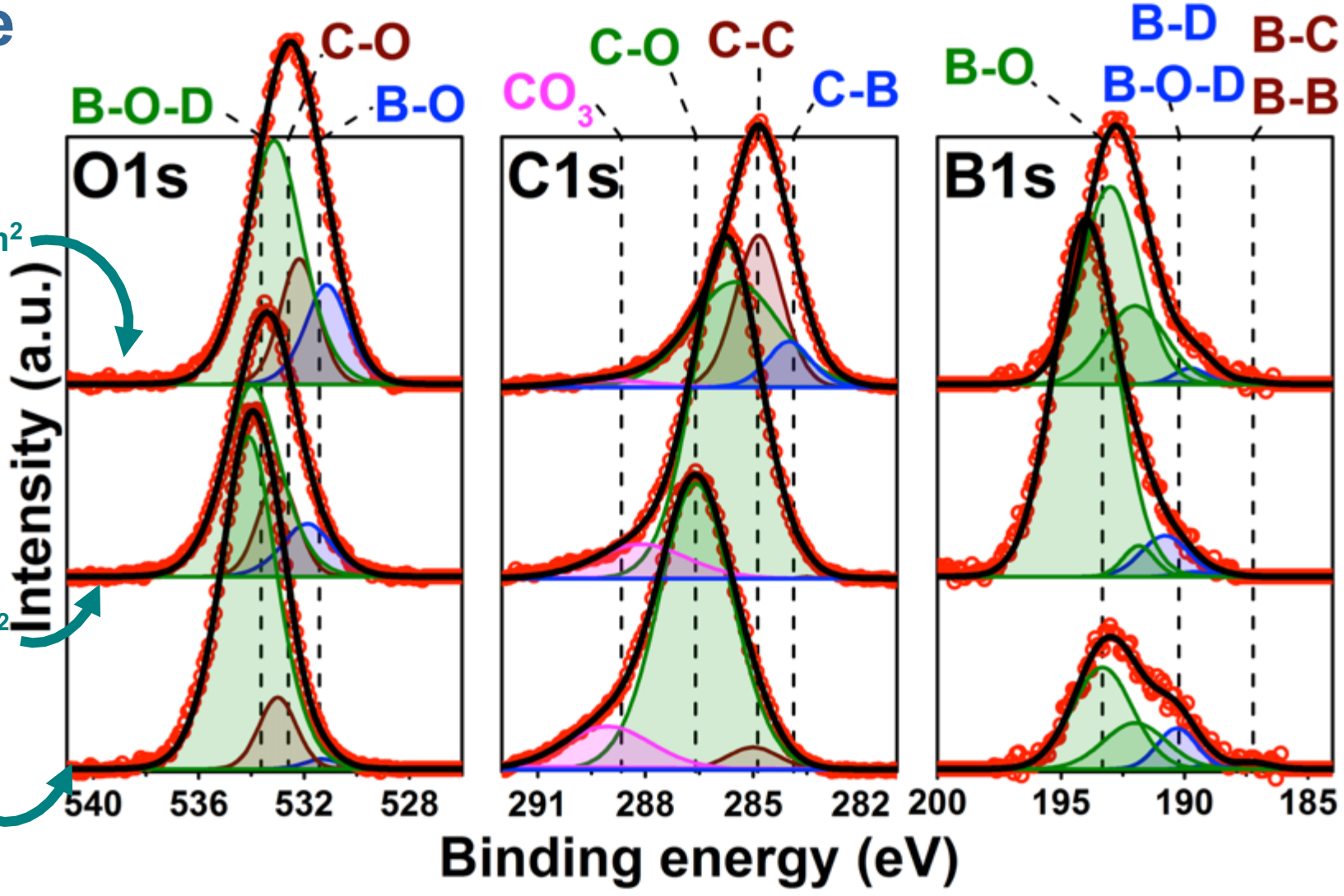


# XPS OLD sample – Highest oxygen and boron concentration at OSP region

## Core C18 – OLD sample

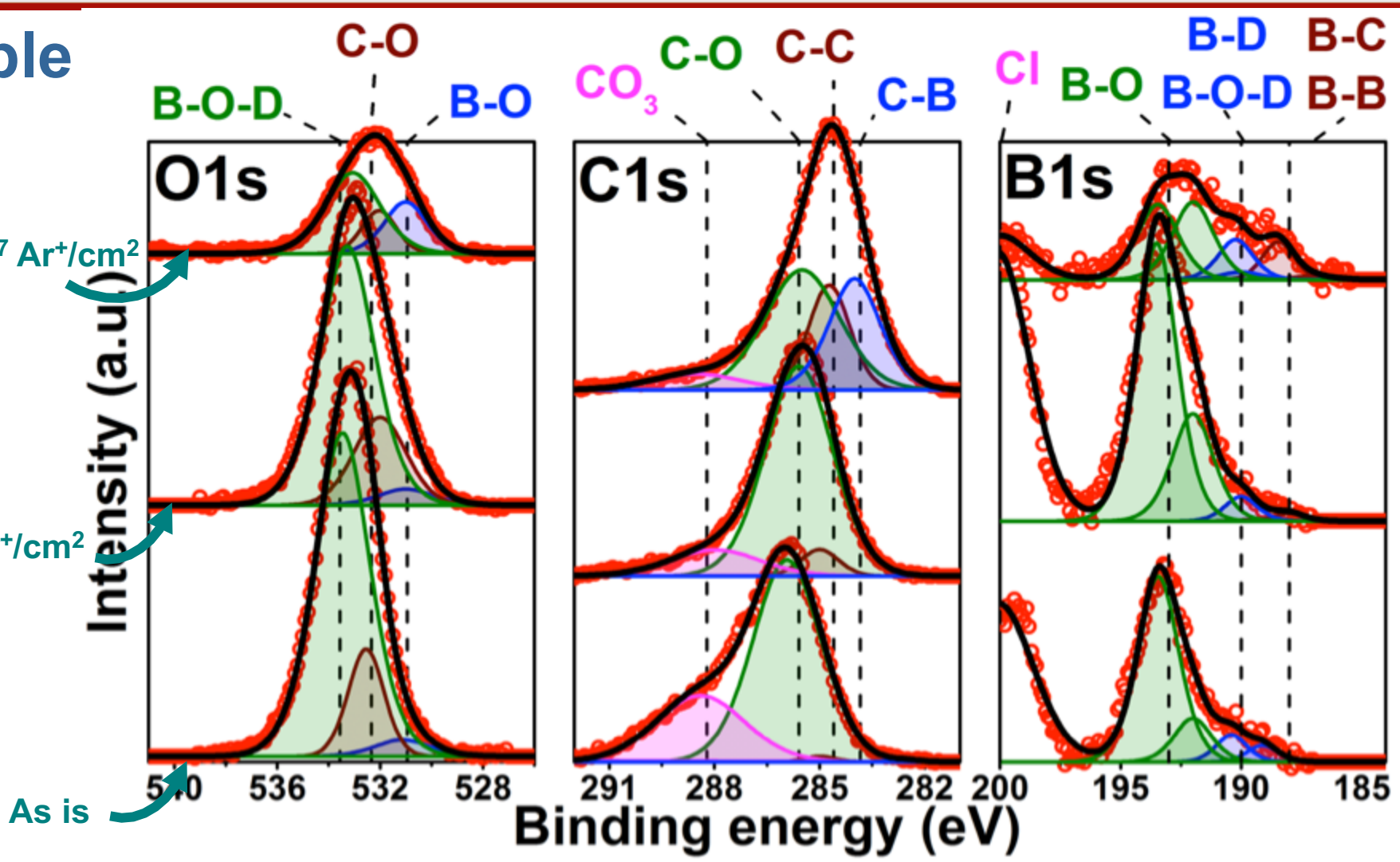
- High presence of oxides throughout the whole experiment
- **Highest boron concentration of all cores (~20%) in analyzed depth (~100 nm)**
- Also highest oxygen concentration in depth ( as much as 40%)



# XPS ILD sample – Evidence of presence of impurities on surfaces in PFR region

## Core B17 – ILD sample

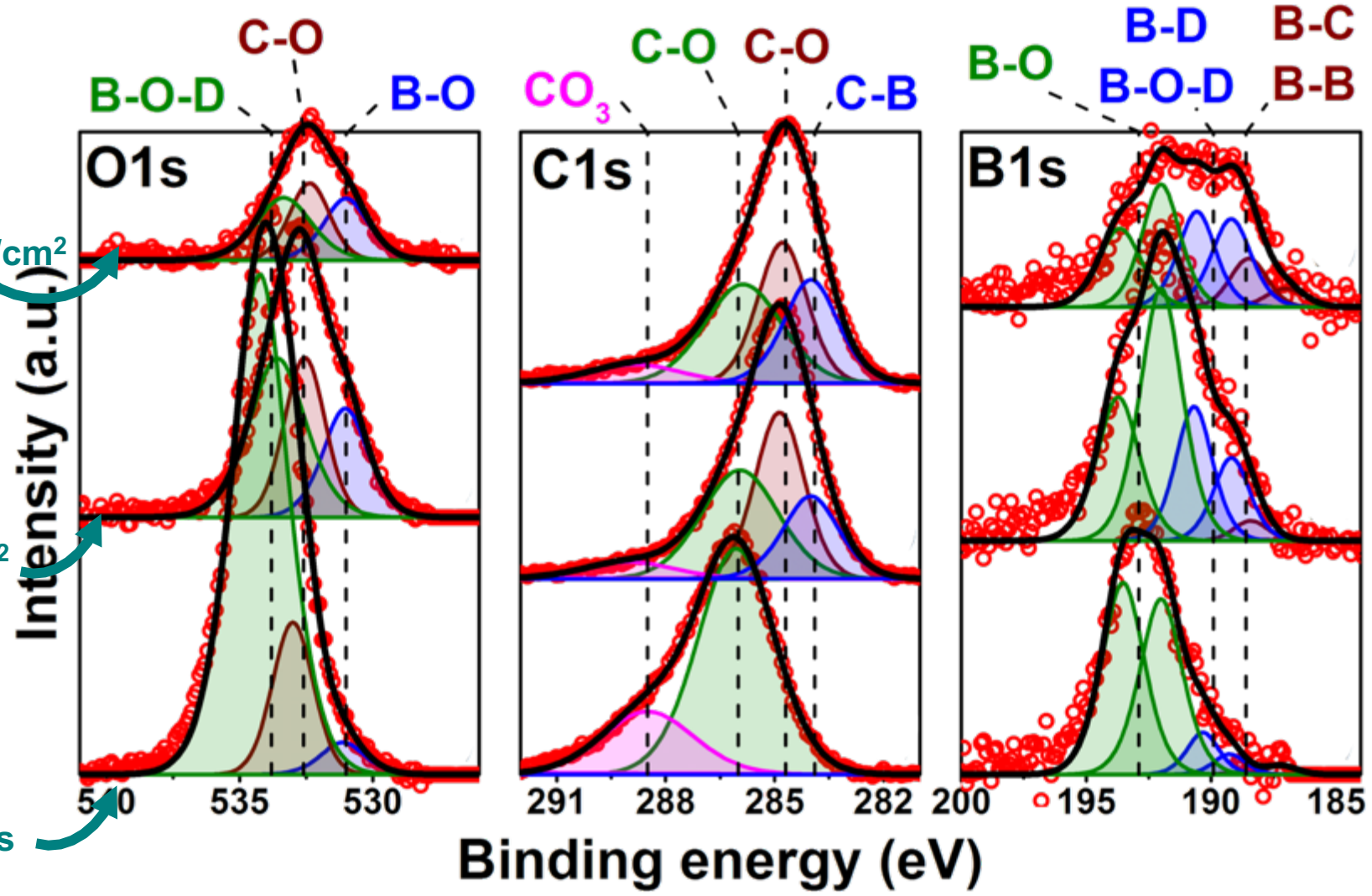
- High presence of oxides throughout the whole experiment
- Presence of a new XPS peak, attributed to Cl, possible NSTX-U impurity
- B-B and B-C (non-oxidized) states observable following $Ar^+$ irradiation



# XPS CS sample – Different chemistry in CS and LD

## Core A18 – CS Sample

- Initial high presence of oxides (lower concentration than other cores)
- B-B and B-C states visible after $Ar^+$
- **Post-cleaning state has the closest resemblance to post-boronized state from MAPP**

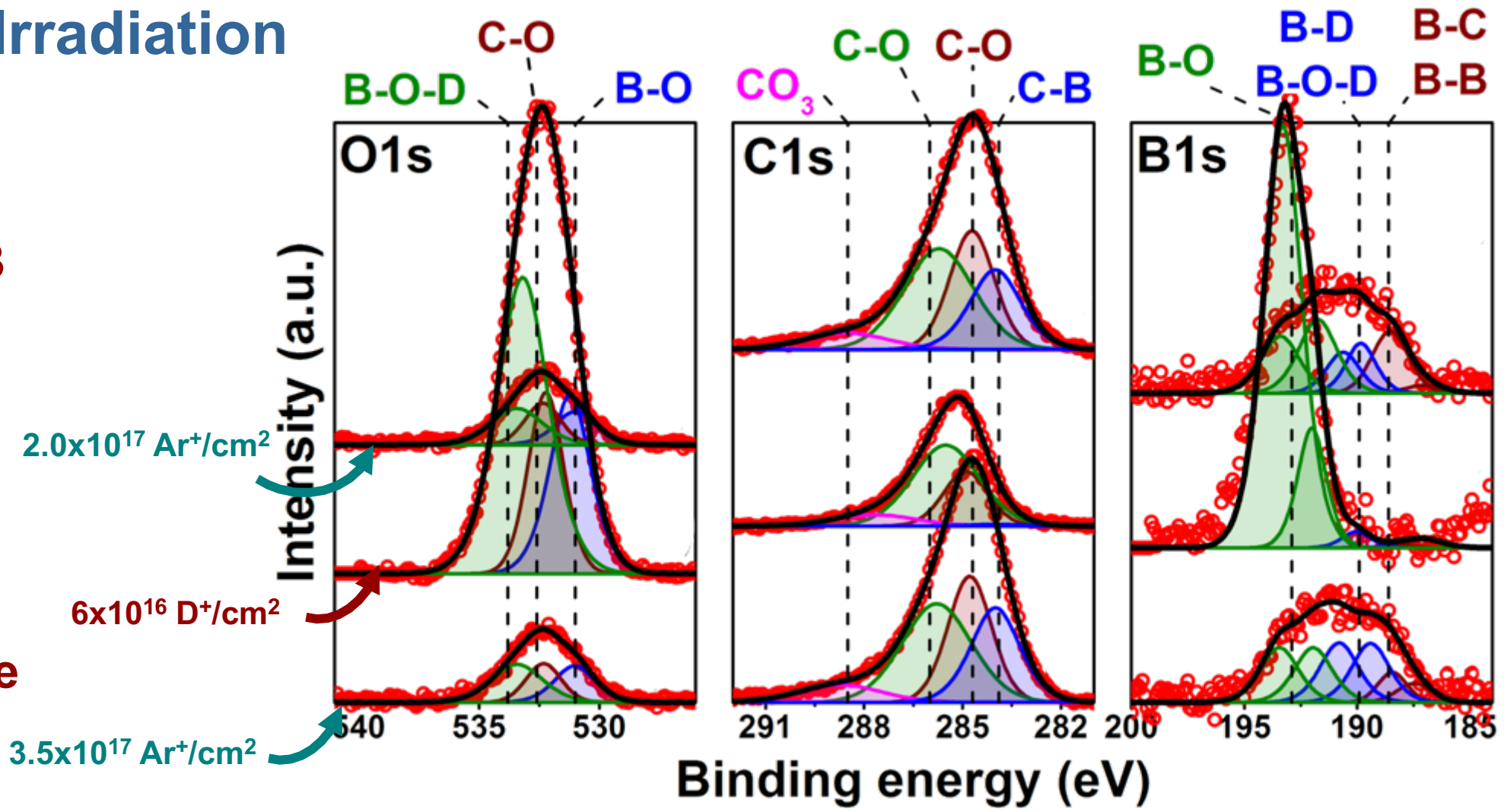


# XPS CS sample - $D^+$ Irradiation drives oxidation

## Core A18 – $D^+$ Irradiation

**Deuterium irradiation drives oxidation of the B coatings, the oxides can be *easily* removed with additional irradiation.**

**Similar to what we observed in NSTX-U with MAPP !!**



# Conclusions

- Samples manufactured from tiles extracted from NSTX-U were characterized *post-mortem* using XPS and ion beam etching

- The boron concentrations on the three samples were different, implying possible non-uniform deposition during boronization.

- **$D^+$ irradiation of clean *post-mortem* sample showed similar behavior to that observed in MAPP:**
  - **Deuterium ions driven oxidation**
  - Plasma ($Ar^+$) induced sputtering and oxides removal