U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

In-vacuo studies of boronization in NSTX-U and its relationship with plasma performance

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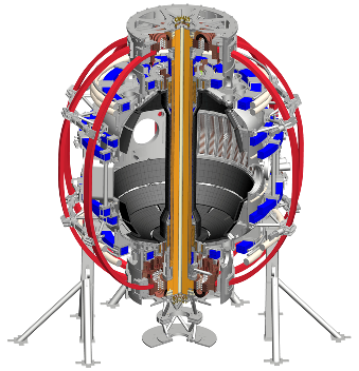
RSSEL

PPPL

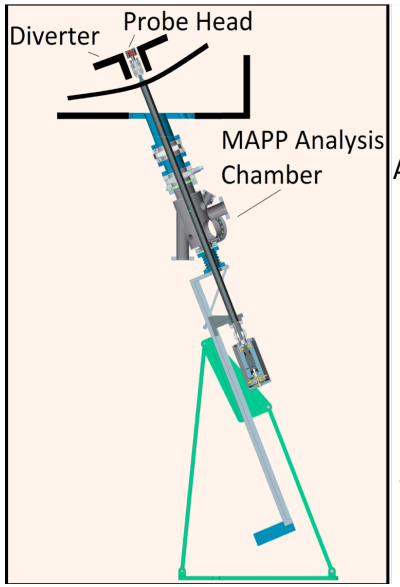


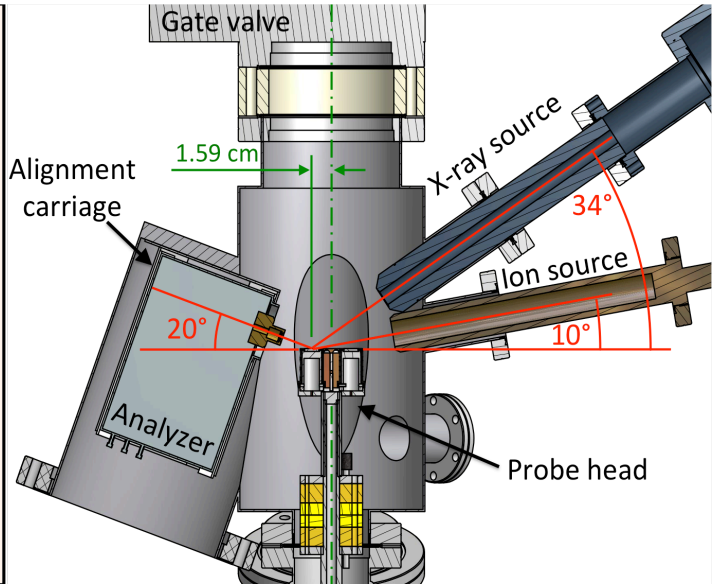
Novel PFC diagnostic - MAPP

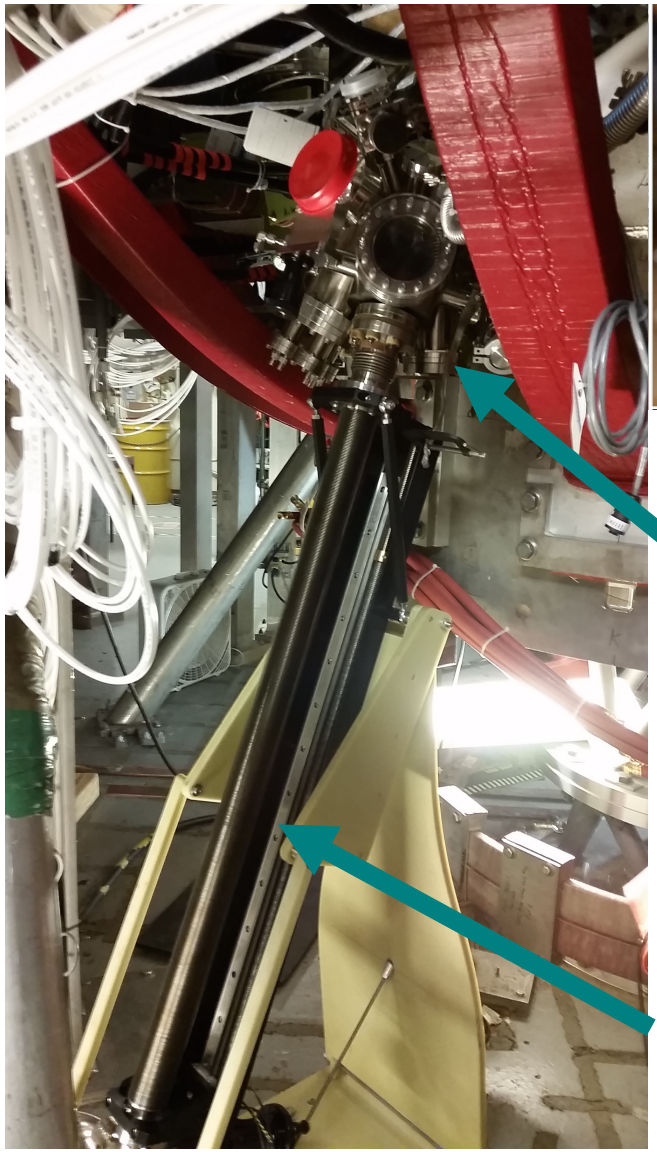
The Materials Analysis Particle Probe (MAPP) is a characterization facility for on-line diagnostic of samples exposed to fusion reactor plasmas in between discharges

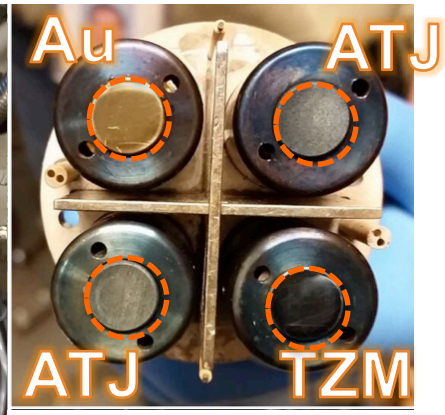
Analysis tools:

- Compact small diameter hemi-spherical energy analyzer
- Dual anode X- ray source
- 1 keV ion source
- 200°C UHV heaters
- Residual Gas Analyzer
- Langmuir probes







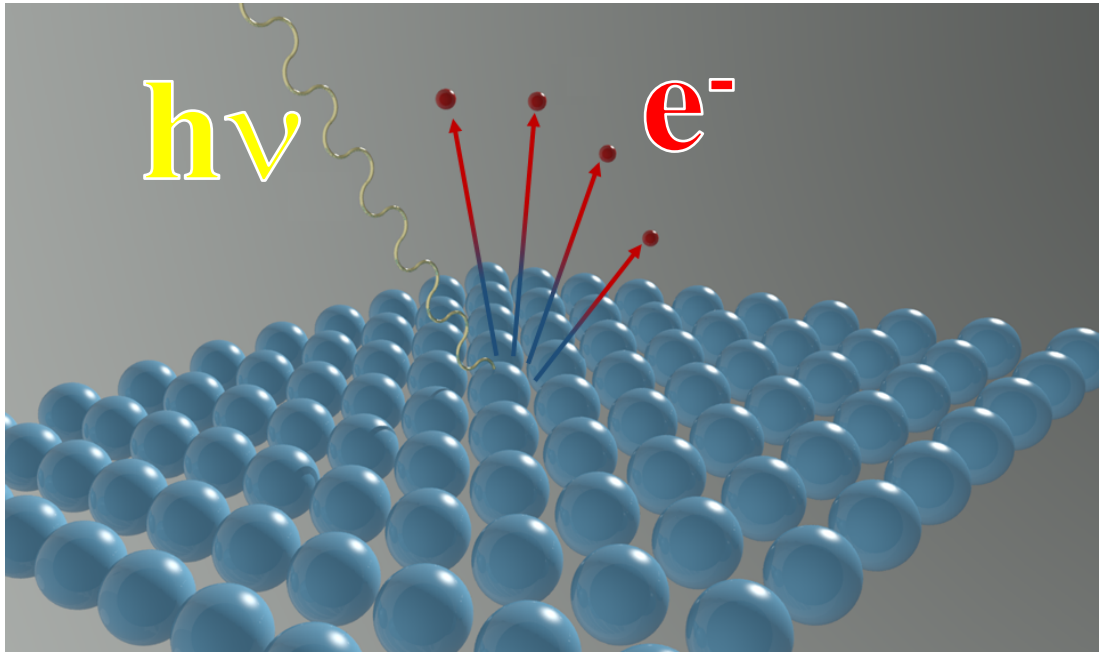


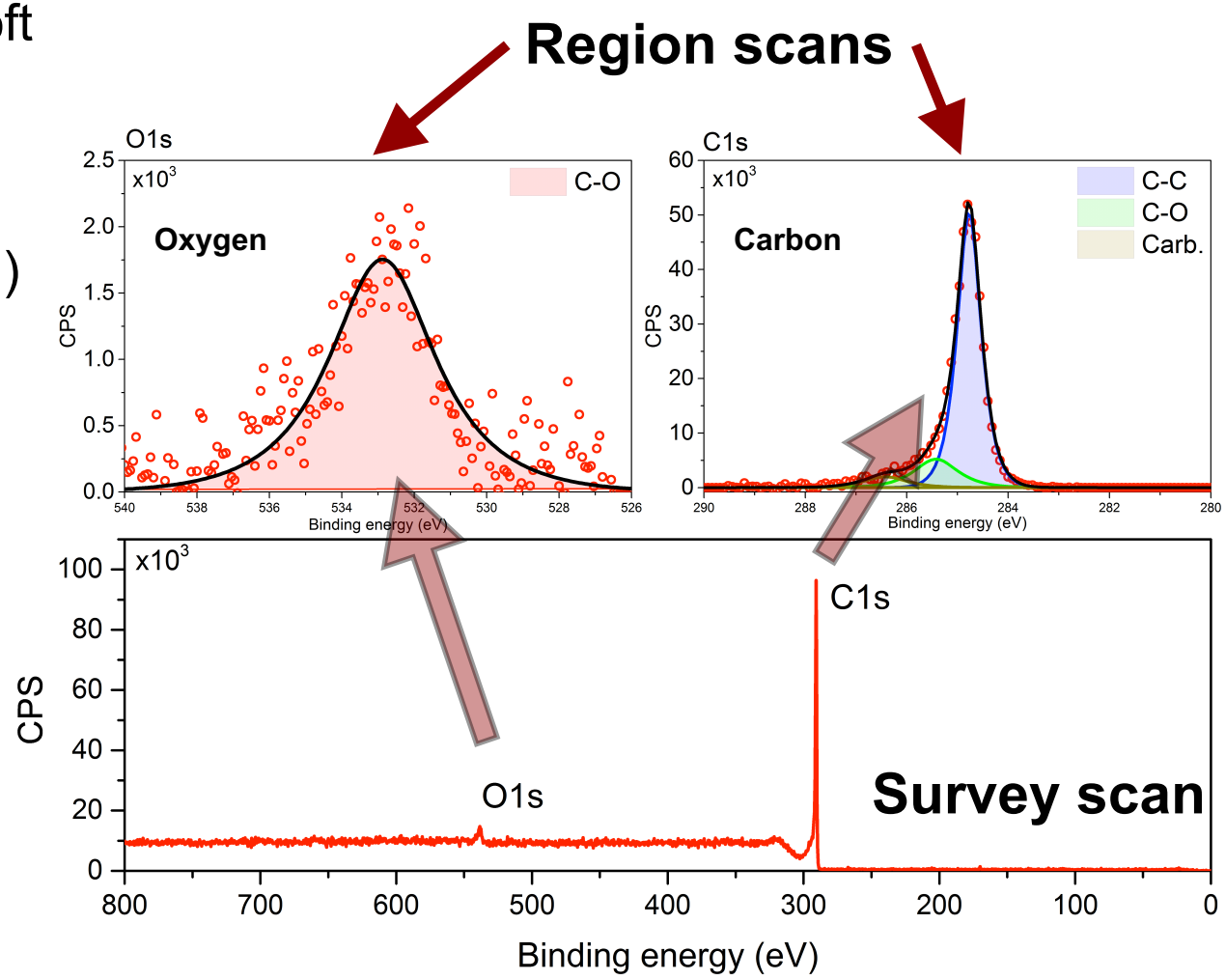
Analysis Chamber

Bellows drive for Inserting PFC in NSTX-U

Chemical identification of components via XPS

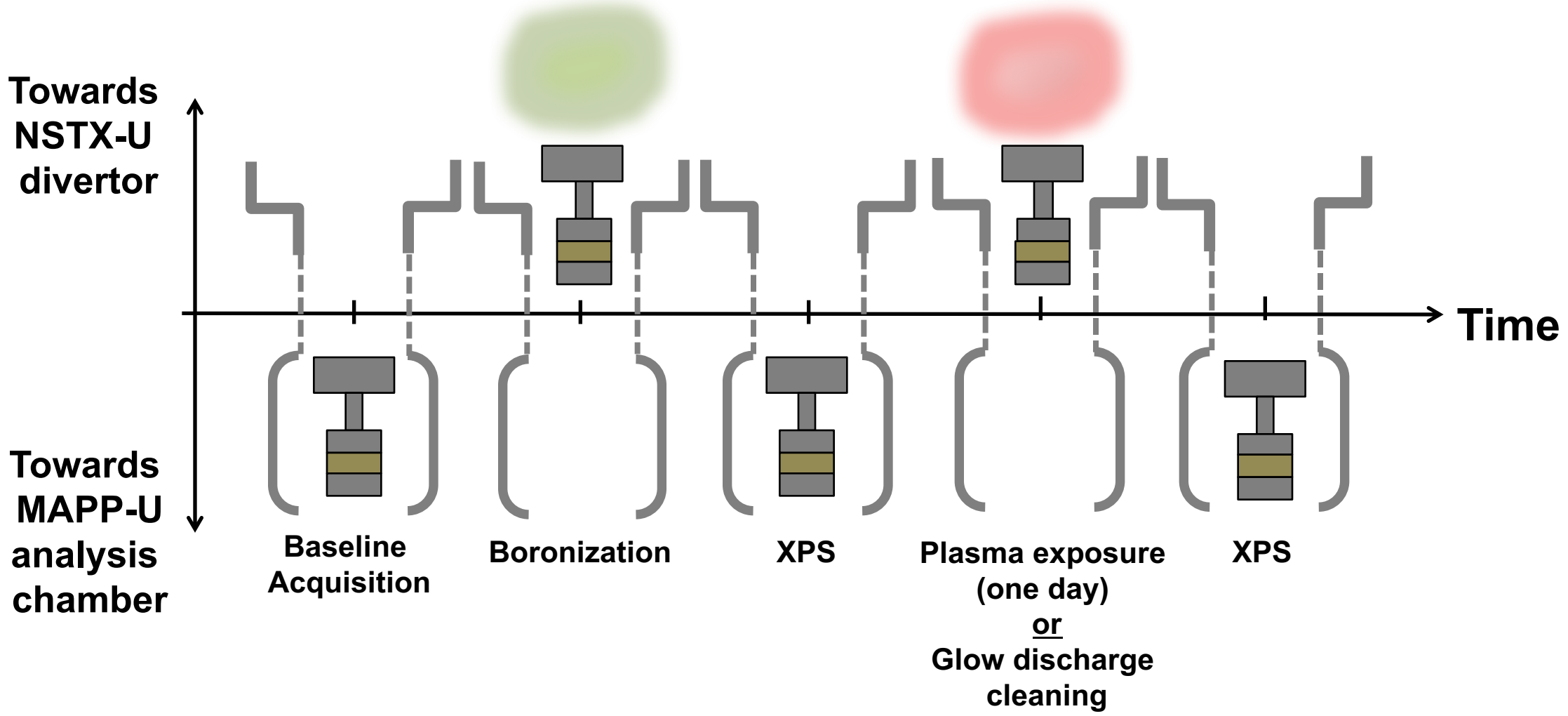
- Emission of photoelectrons under incident soft X-ray beam
- Probe top 10 – 20 nm of sample
- Elemental identification in survey scans
- Region scans allow quantitative analysis (at.%)





XPS data acquired between each day

- **#1_ATJ:**
  - Survey
  - B1s
  - O1s
  - C1s
- **#2_TZM:**
  - Survey
  - B1s
  - O1s
  - C1s
  - Mo3ds
- **#4_Au:**
  - Survey
  - B1s
  - O1s
  - C1s
  - Au4f



XPS data analysis

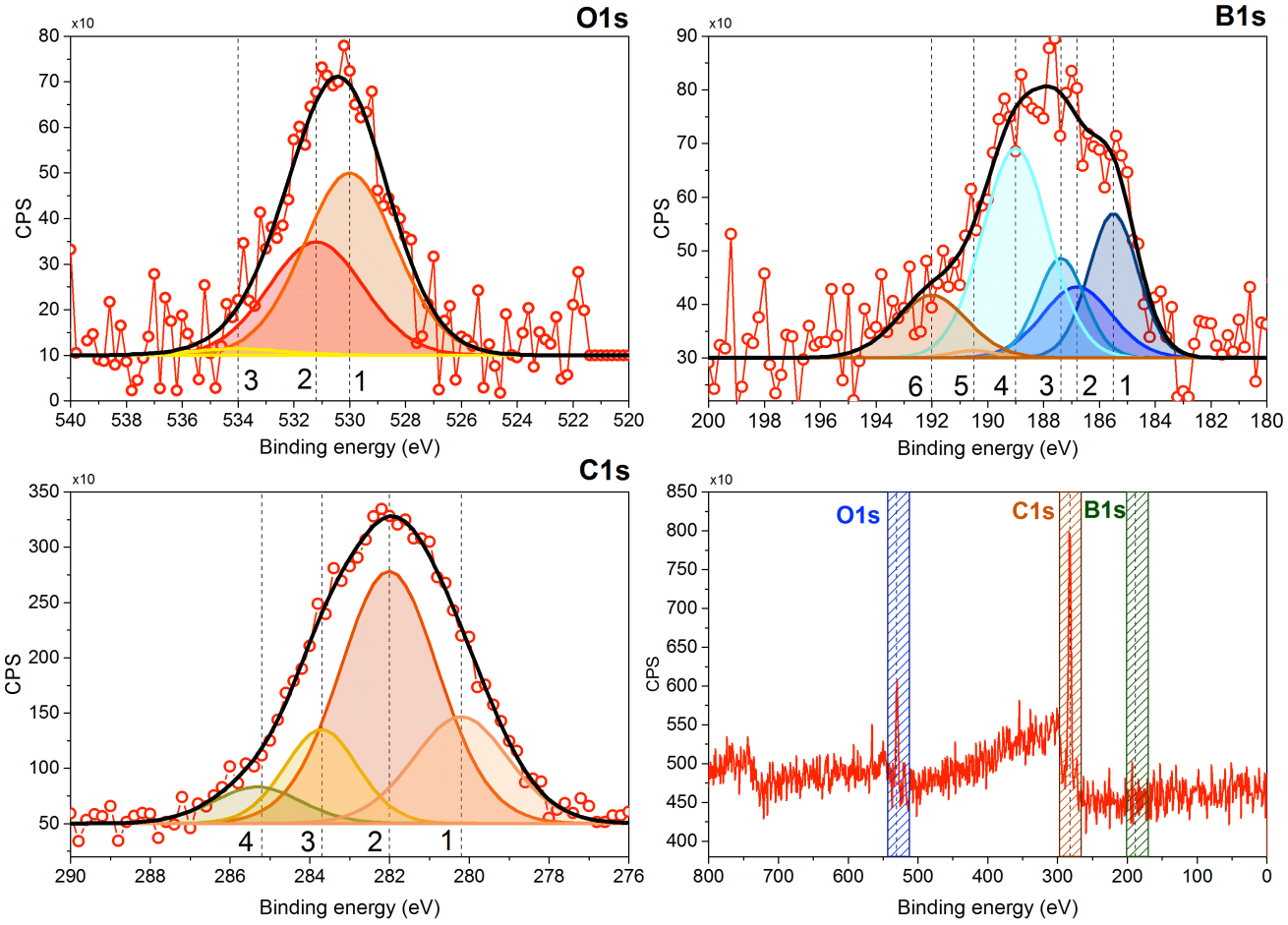
Deconvolution of peaks allows identification of chemical bonds

ID	Bond	Position (eV)	FWMH (eV)	Region
1	B-C	187.2	2.1	B1s
2	B-B	188.1	2.9	
3	B-D	189.1	2.0	
4	B-OD	190.2	2.8	
5	NSO	191.7	2.0	
6	B_2O_3	193.2	3.0	
1	B-C	282.7	2.9	C1s
2	C-C	284.5	2.2	
3	C-O, C-OD	288.9	2.6	
4	Carb.	285.2	2.8	
1	B-O	531.5	4.0	O1s
2	C-O, C-OD	532.7	3.9	
3	B-OD	533.9	4.0	

Source:

- Extensive literature review
- Baseline and reference measurements in laboratory (HR-XPS)

Deconvolution of XPS spectra of boronized ATJ sample (MAPP data in NSTX-U)[1]



[1] F. Bedoya, et al., Review of Scientific Instruments **87**, 11D403 (2016).

Effect of boronization on PFCs in NSTX-U

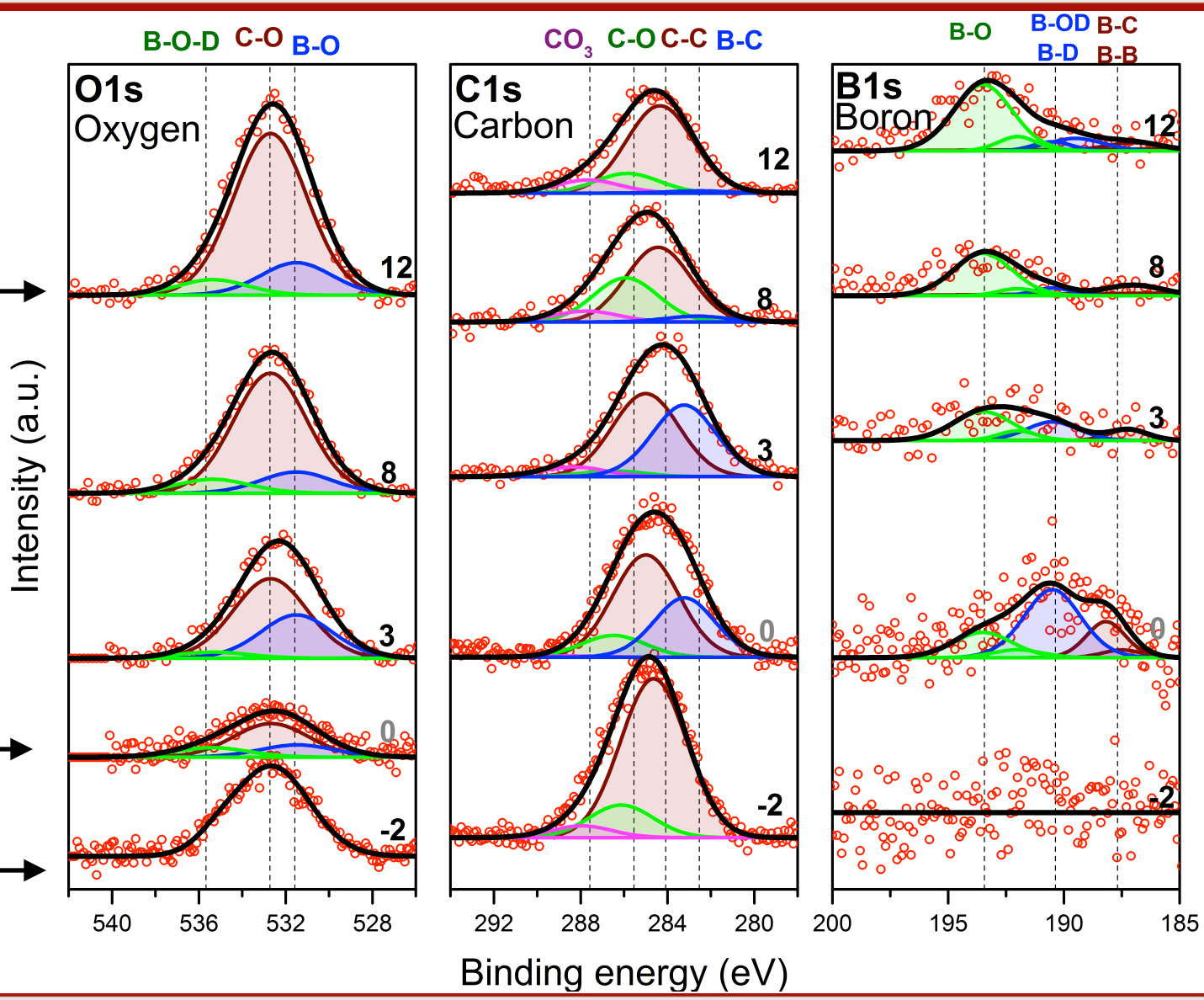
- **Boron oxidation due to plasma exposure measured with MAPP via XPS**

High oxygen % Low % of B in metallic state ← **3.** ATJ post boronization post plasma exposure →

Days after boronization
D⁺ fluence increasing

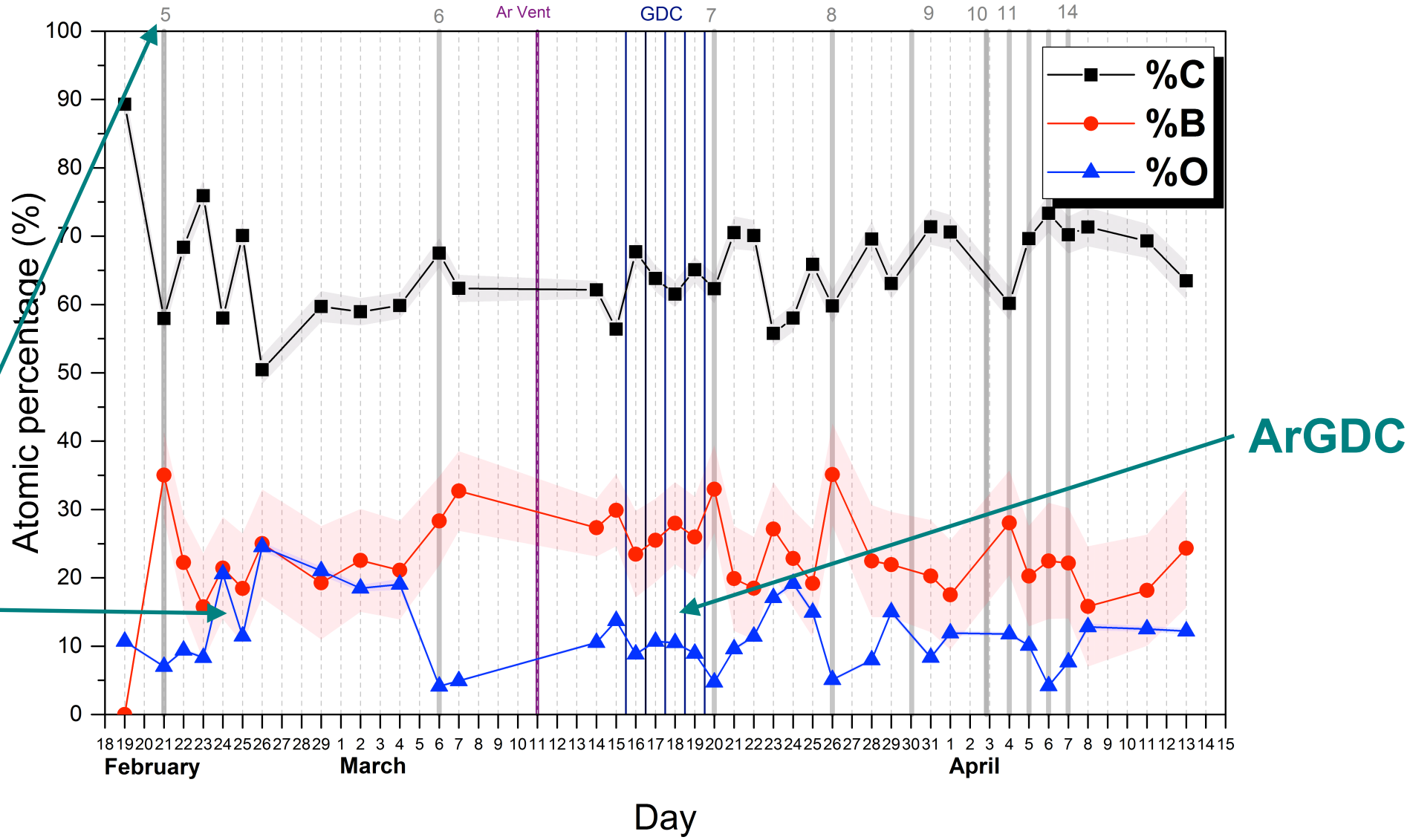
Low oxygen % High % of B in metallic state ← **2.** ATJ post boronization →

1. ATJ graphite →



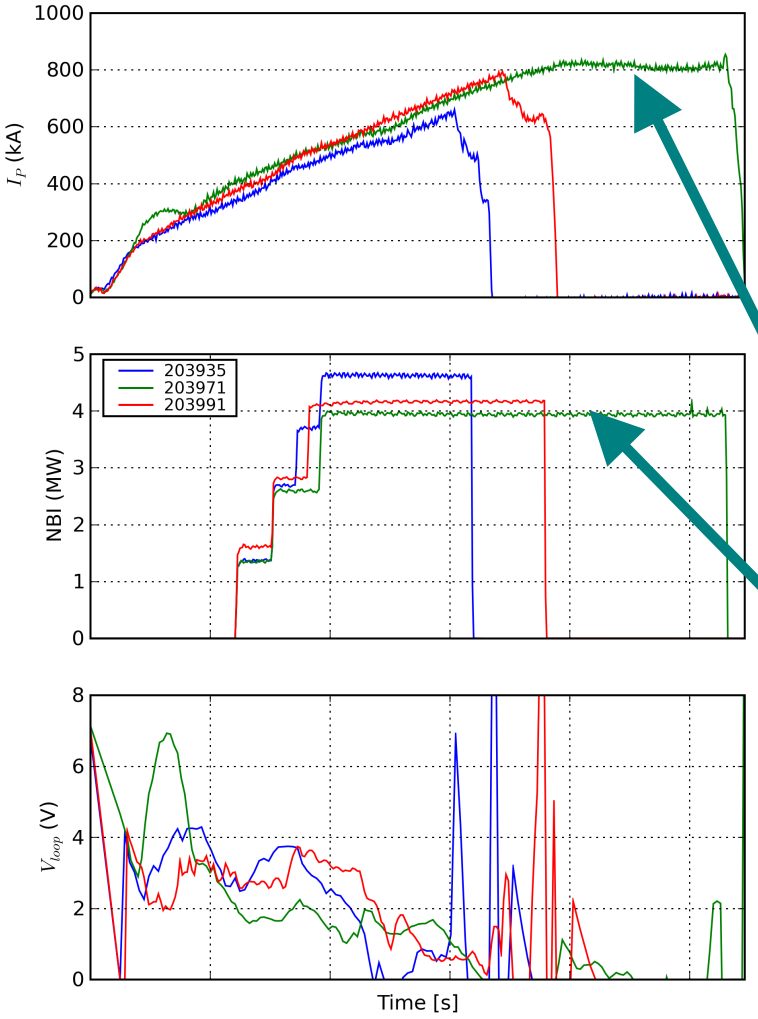
Daily evolution of atomic concentrations

Time resolution improved ~100 times compared with prior diagnostics



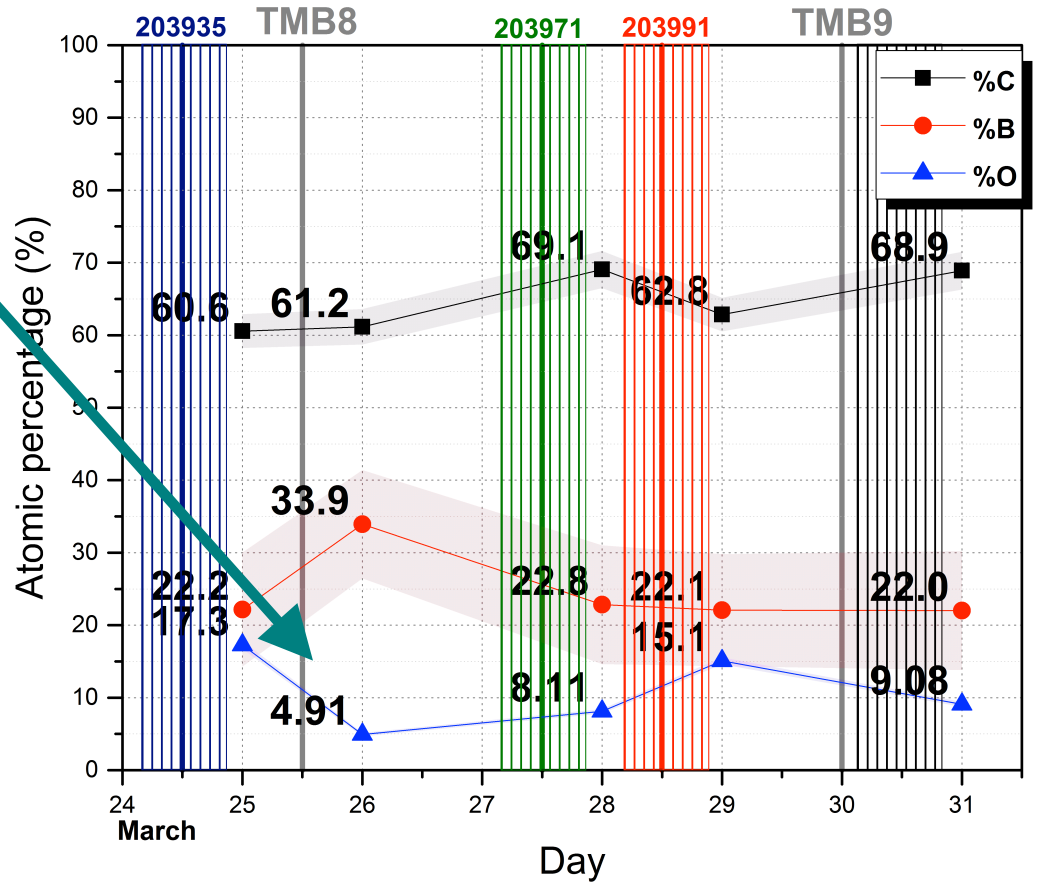
Boronization effect on plasma performance

- **Oxygen concentration reduction in PFCs with boronization seems to lead to improved performance**



Low oxygen concentration following boronization

Improved plasma performance on similar scenarios



Conclusions

- Successfully able to characterize the chemistry of PFC in NSTX-U and their evolution using the novel MAPP surface diagnostic.
- Oxidation has a relevant role behind the modifications on the PFC chemistry according to XPS.
- Results indicate that B coatings act as good gettering which could lead to a decrease in presence of impurities and better plasma performance.
- B coatings ”quickly” saturate with oxygen (depending on power and exposure), this in addition to erosion might be the reason of temporal improvements.