Irradiation studies of boron coatings on graphite samples from NSTX-U

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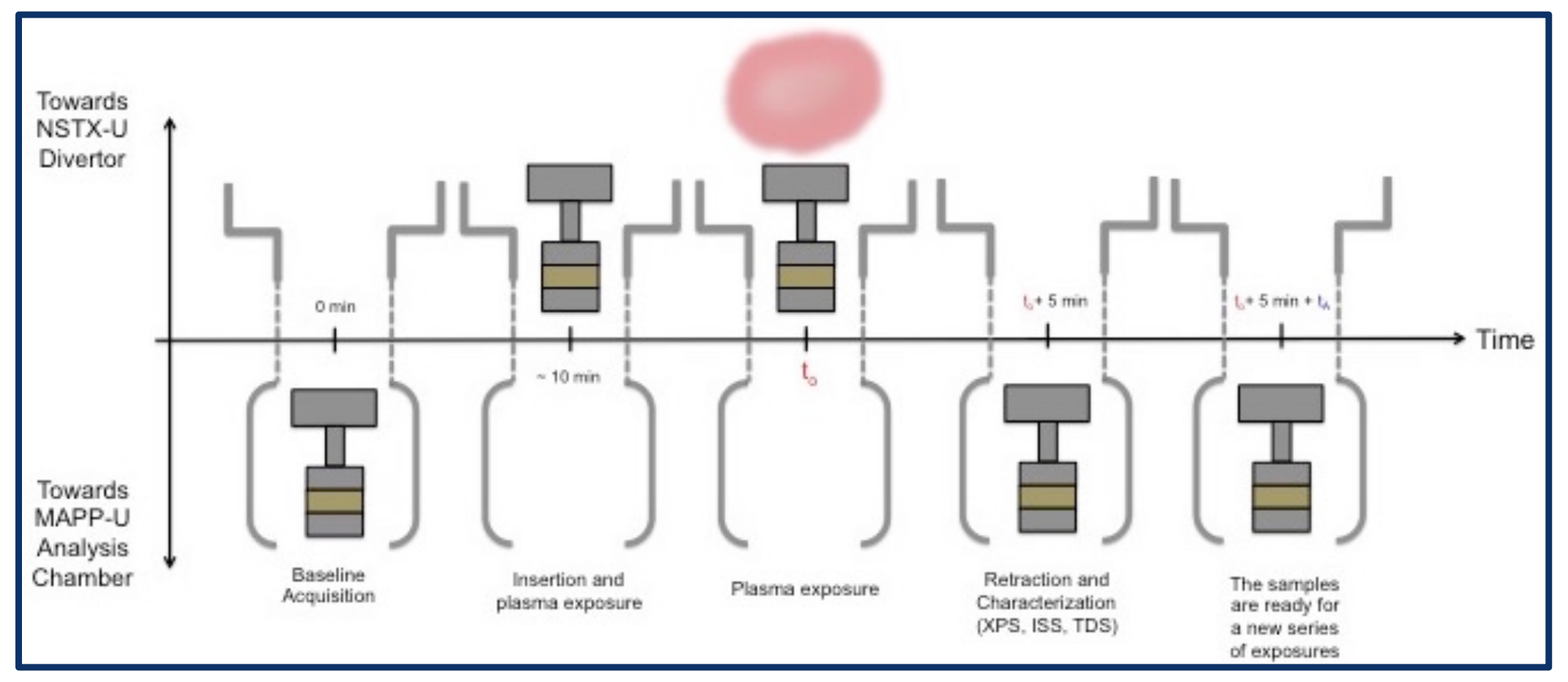
Introduction

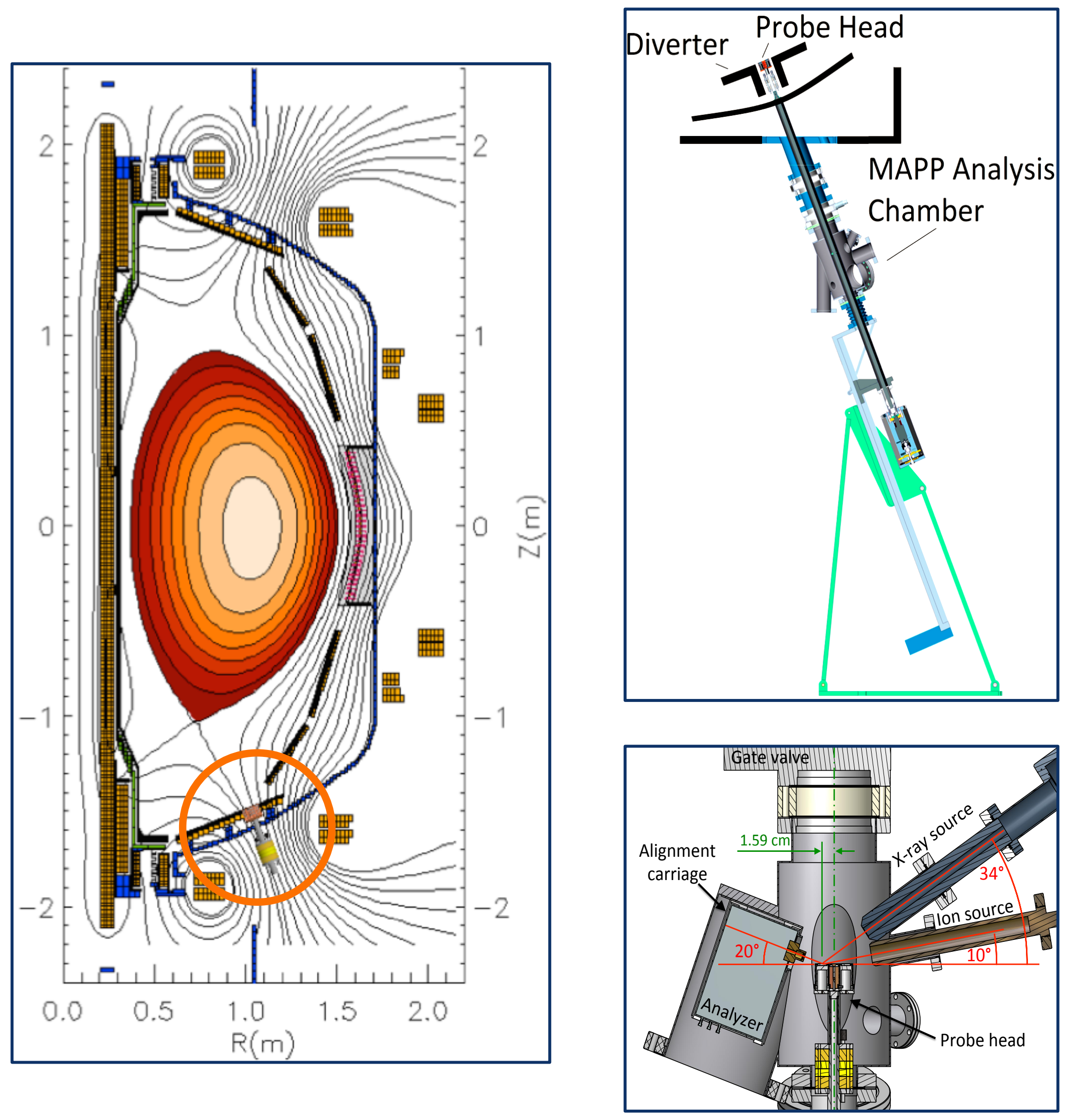
- MAPP is a materials characterization technique used in NSTX-U to study the evolution of the surface chemistry of the plasma-facing components.
- It has the capability of conducting X-ray Photoelectron Spectroscopy (XPS) *in vacuo.*
- The probe is not exposed to atmospheric conditions, and can take measurements on a day-to-day basis.



Schematic of the exposure sequence of MAPP

- Plasma-facing component conditioning is used to minimize the emission of impurities, fuel recycling, erosion, and redeposition.
- During the 2015-2016 NSTX-U experimental campaign, deuterated-trimethlyborane (d-TMB; $B(CD_3)_3$) was used to condition the PFCs.
- The next NSTX-U run will continue to feature a full graphite wall, and both boron and lithium will be used as PFC conditioning techniques. This will require new baseline XPS data for LI-B-C systems.
- Previous work by Taylor et al. [1] shows that oxygen plays a key role in deuterium retention in lithiated graphite surfaces.

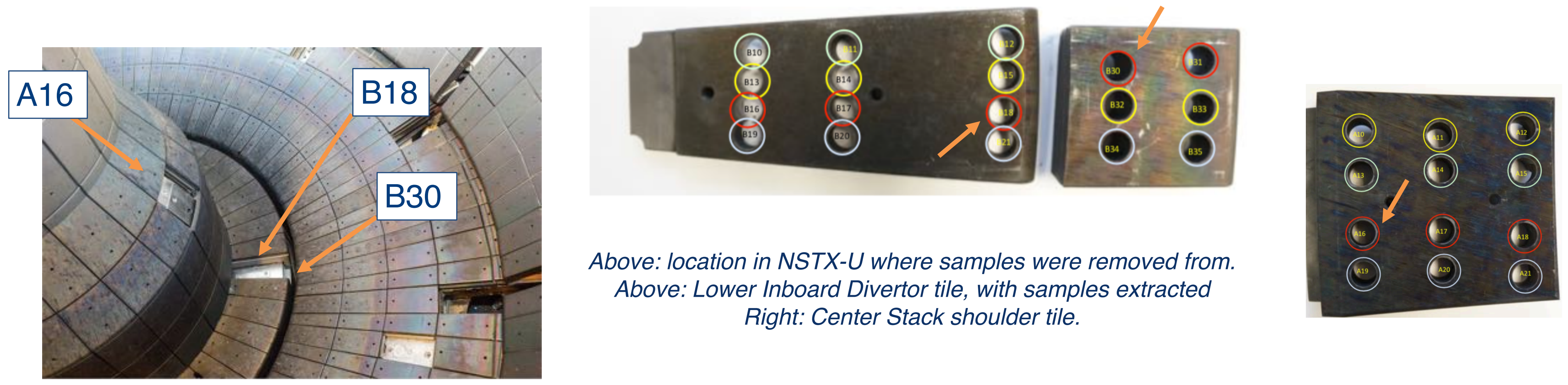
MAPP: The Materials Analysis and Particle Probe



Left: Cross section of NSTX-U Bay K. The probe is highlighted with the circle.
Upper right: MAPP probe and analysis chamber location with respect to the divertor.
Lower right: Detailed schematic of the MAPP analysis chamber and diagnostic tools.

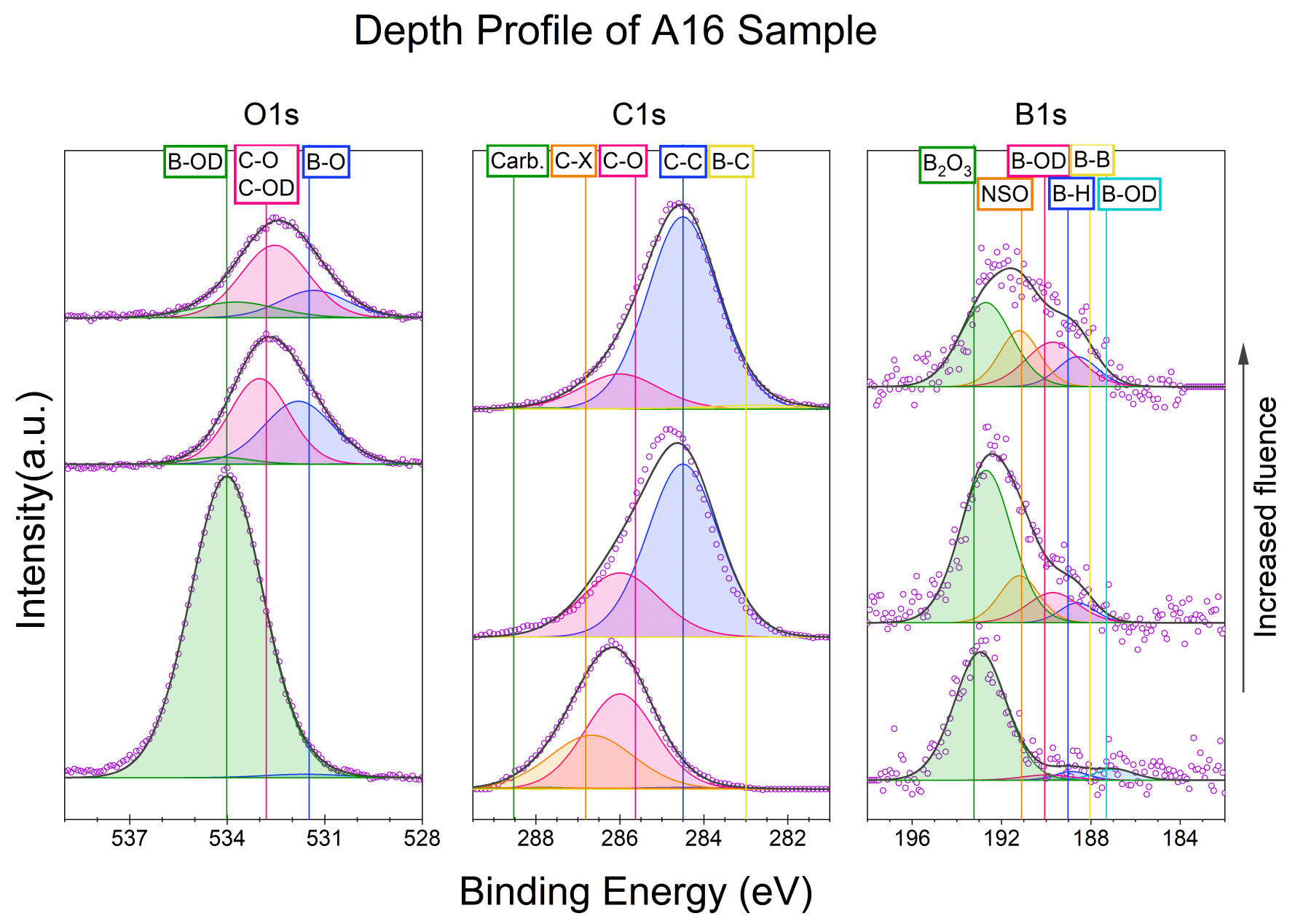
Depth Profile

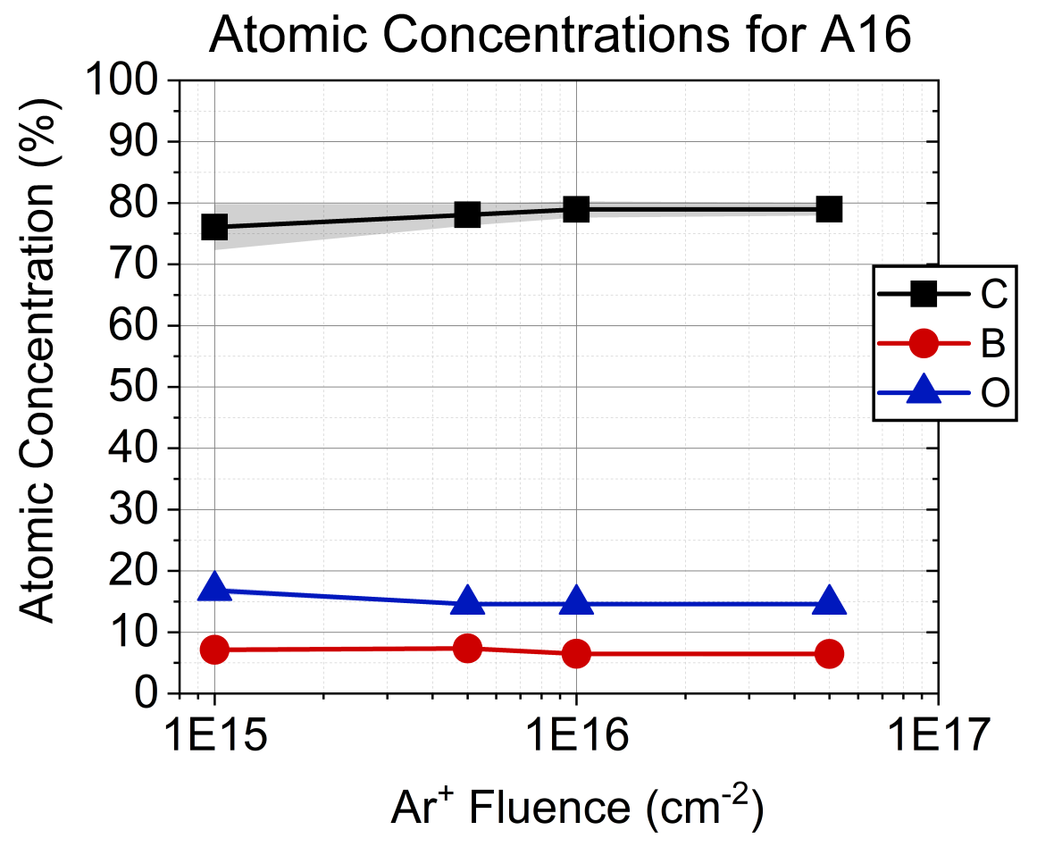
- Depth profile XPS was conducted in IGNIS of samples taken from various points in NSTX-U.
- The IGNIS facility at UIUC consists of a high vacuum chamber constructed for in-situ, in-operando surface modification and analysis using ion irradiation.
- Depth profile was conducted in-situ in IGNIS. 1 keV Ar ions at normal incident angle were used to sputter off layers of material, and XPS was used to characterize the layers.

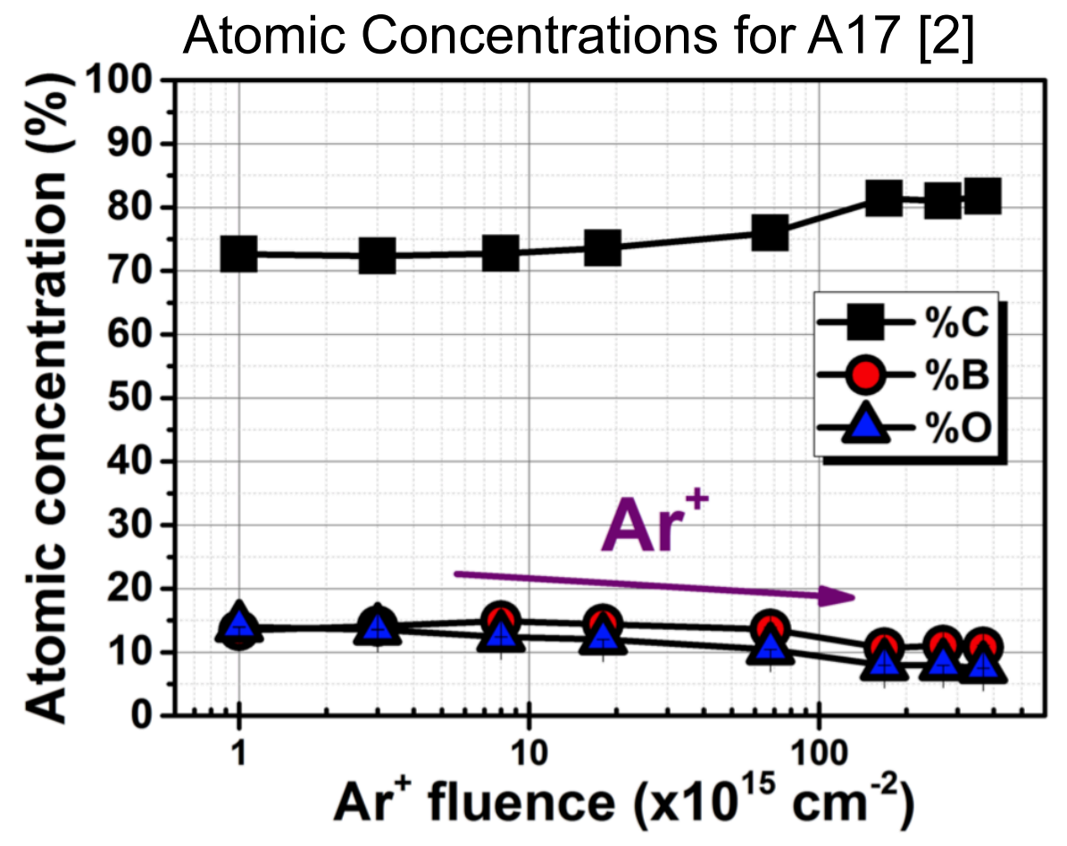


Above: location in NSTX-U where samples were removed from.
Above: Lower Inboard Divertor tile, with samples extracted
Right: Center Stack shoulder tile.

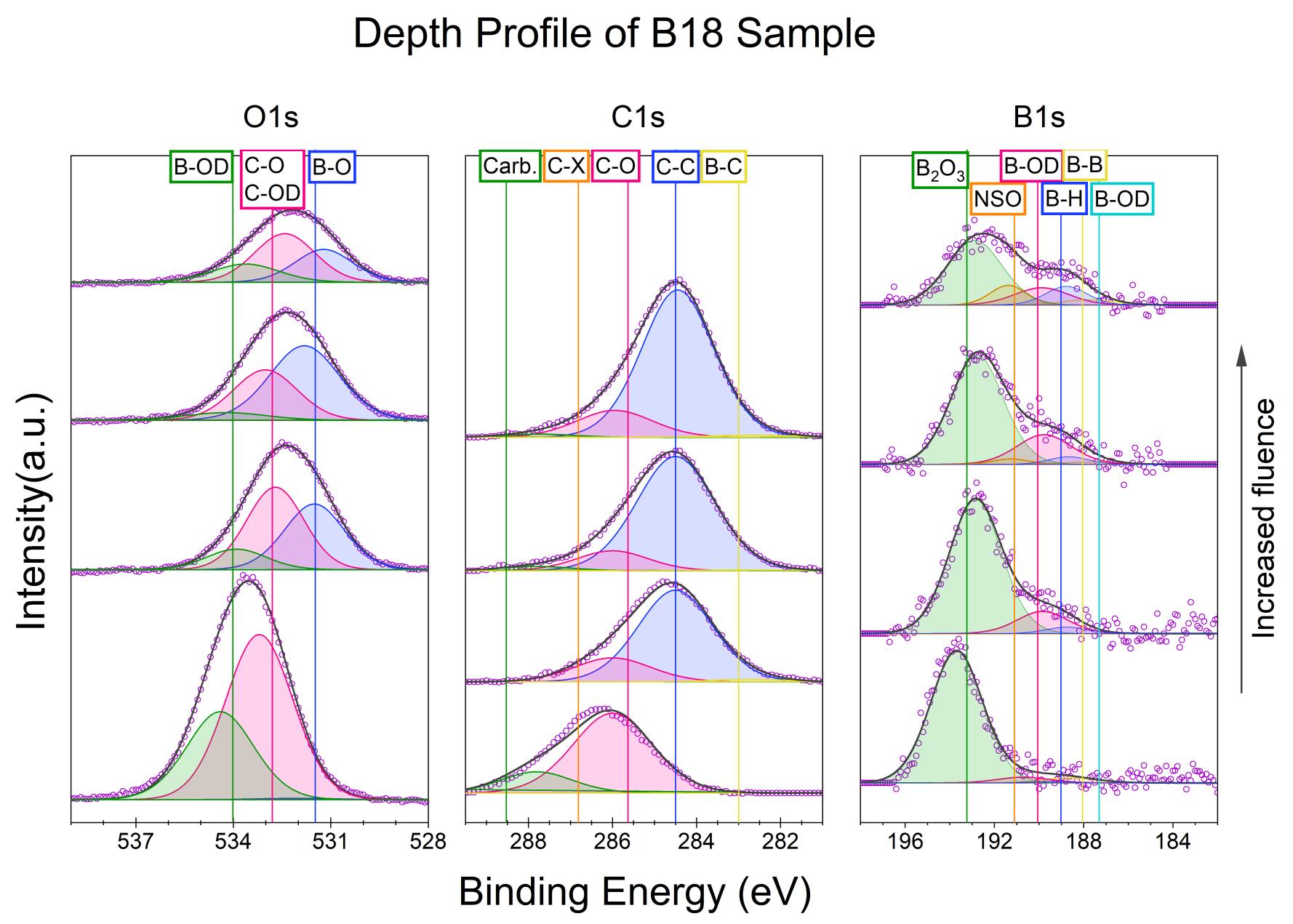
Sample A16 (Center Stack)

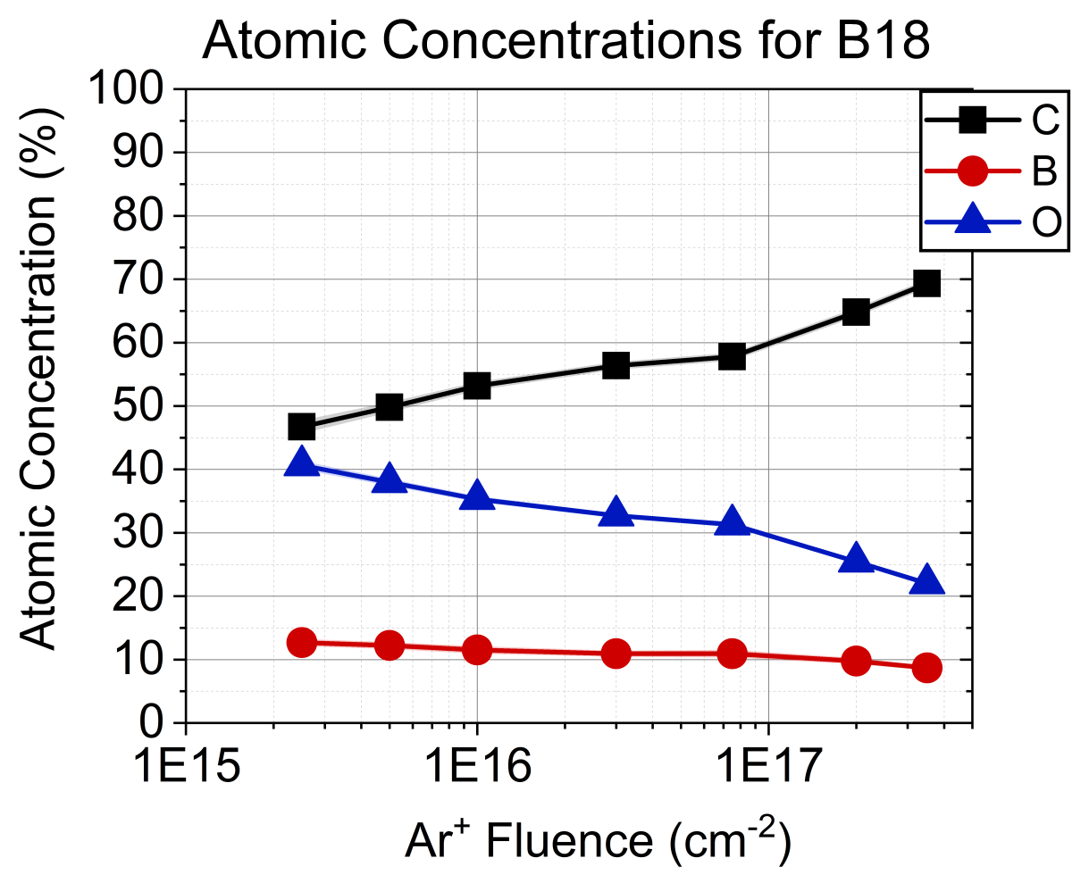


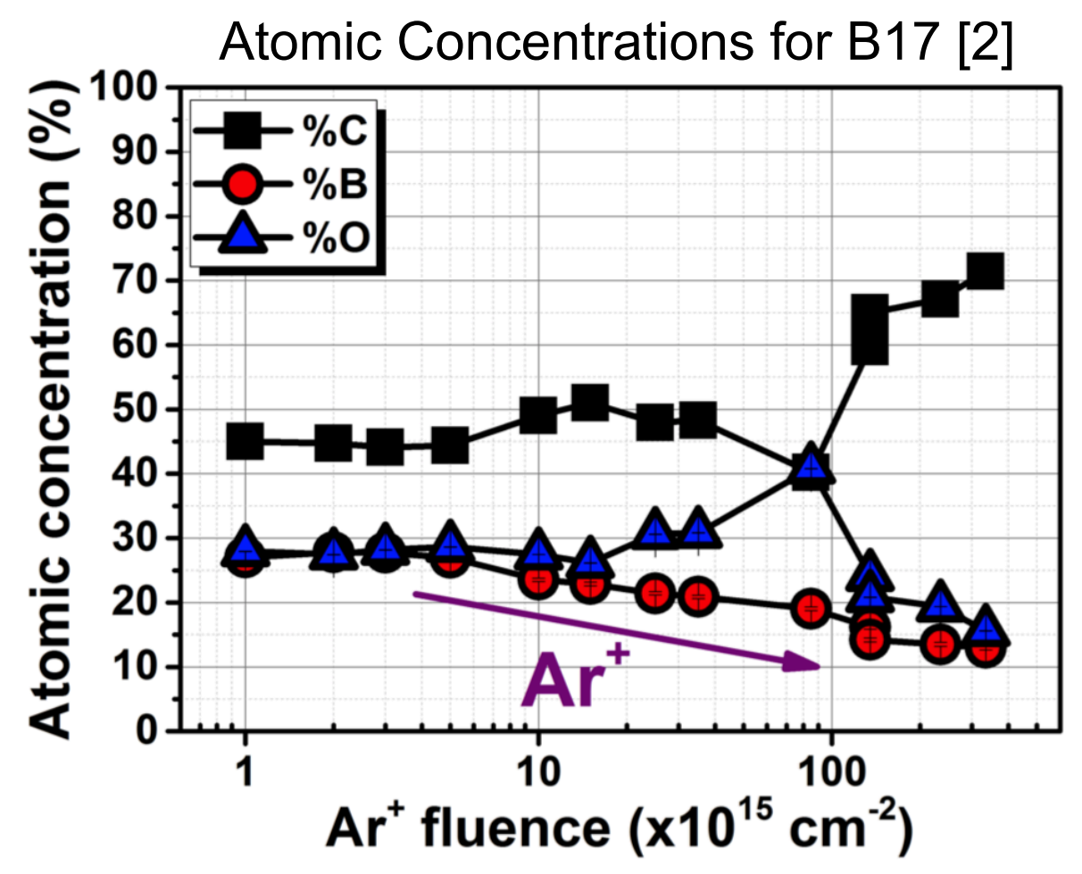




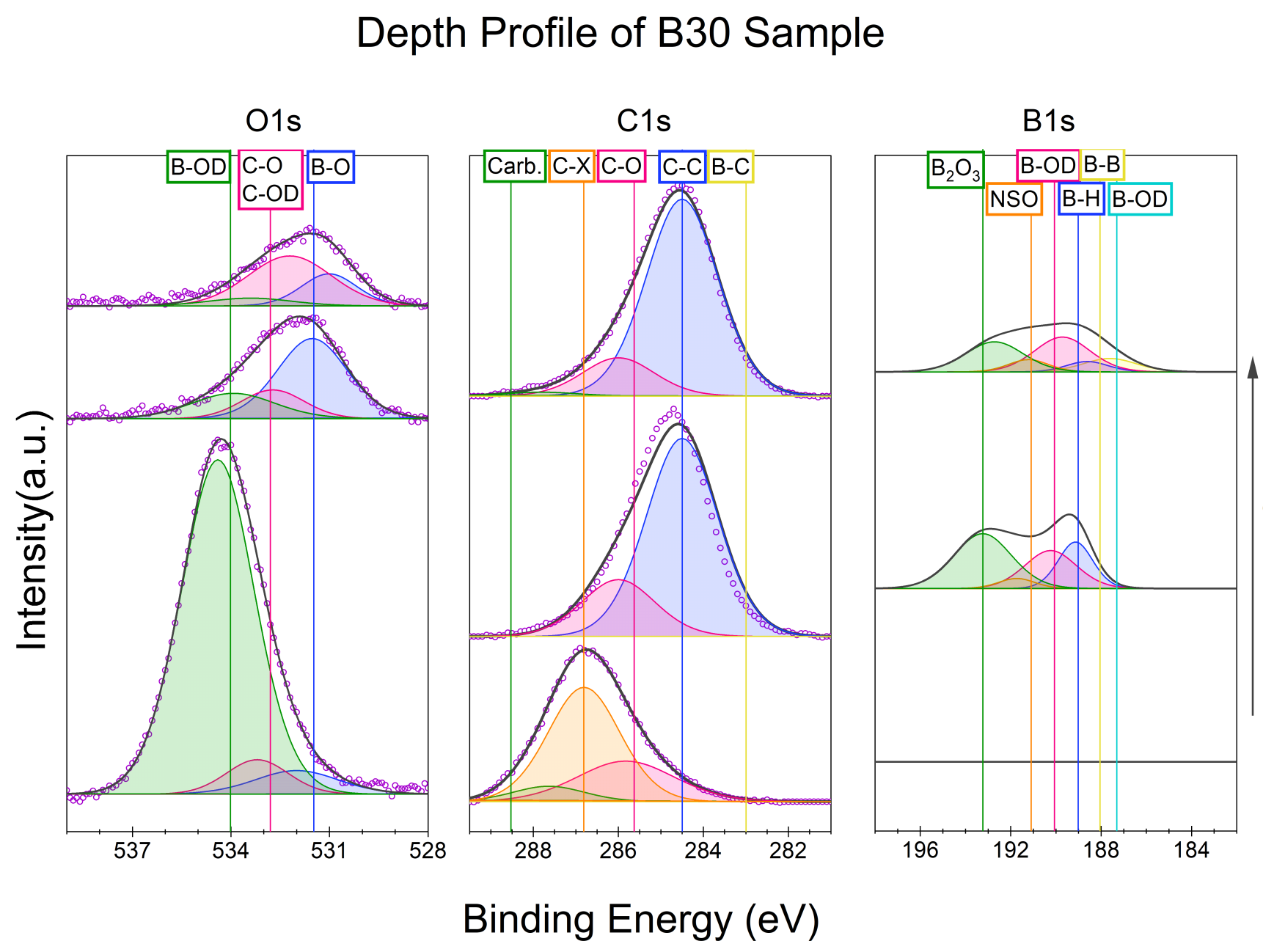
Sample B18 (Inner Divertor)

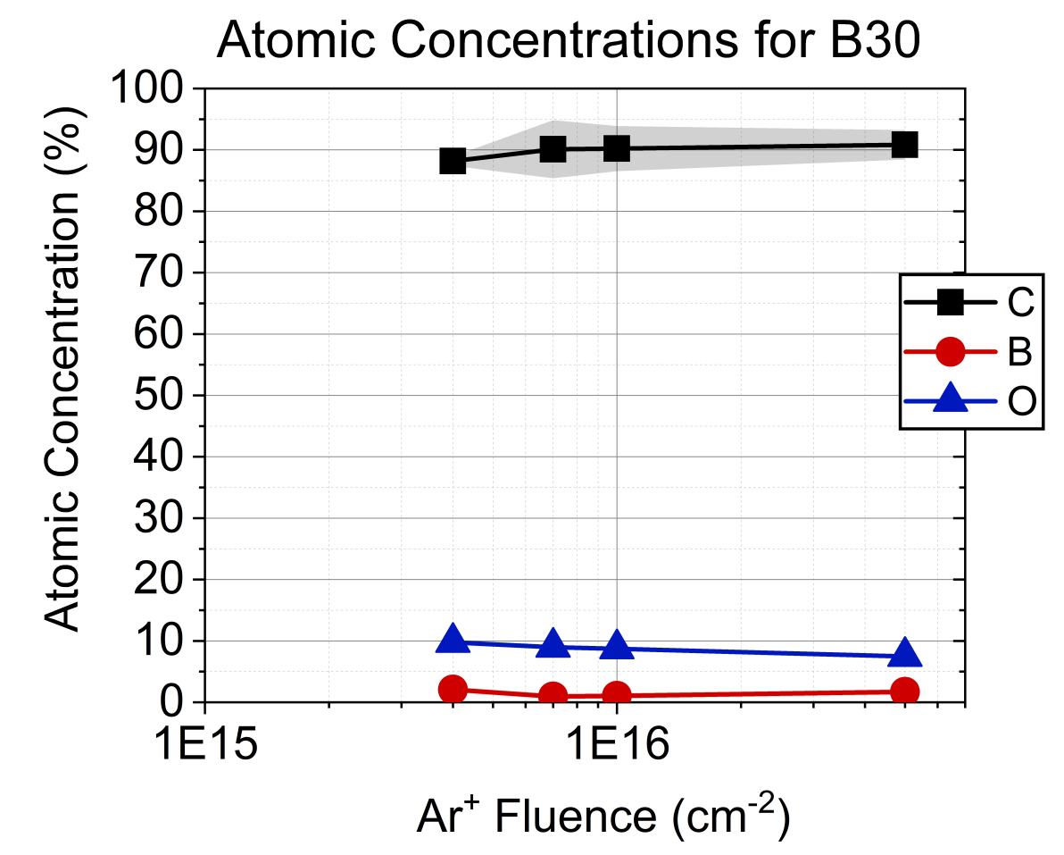






Sample B30 (Inner Divertor)





Comparison between samples

- Previous depth profiles were done on different samples from the same tiles: B17 (Lower Divertor) and A17 (Center Stack). [2].
- Samples A17 and A16 show similar atomic concentrations.
- B17 has much higher B concentration (~25%) than B18 (~12%), indicating a radial dependence.

XPS data fitting

- The XPS data obtained using MAPP gives information on the chemical composition of up to 10 nm of the surface of the samples.
- The samples were scanned in three regions (B1s, C1s and O1s).
- The data peaks were deconvoluted and fit according to the following constraints:
  - Position/Binding energy: obtained from previous controlled experiments [3].
  - FWHM of the spectral fits
  - Area relation between doublets
- Atomic concentrations are calculated taking into account the photoionization cross section of each element.

Future Work

- Further experiments will be carried out on the boronized graphite samples.
- Samples of varying boron concentration will be dosed with Li and then irradiated with D.
- In addition to providing insight into the surface processes of deuterium retention, these experiments will provide a baseline for MAPP measurements during the next NSTX-U campaign.
- Hardware upgrades to MAPP will allow for enhanced energy resolution, as well as additional techniques.

Summary

- With MAPP, PFC material evolution can be studied in ways not previously possible.
- Post-mortem analysis provides data for various radial points.
- The data shows differences in boron concentration, indicating shadowing during conditioning, sputtering, migration, or re-deposition during plasma operations.

Acknowledgments

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References

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