U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

In vacuo chemical characterization of PFCs in NSTX-U with MAPP

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Diagnostic research plans for FY2016-2018
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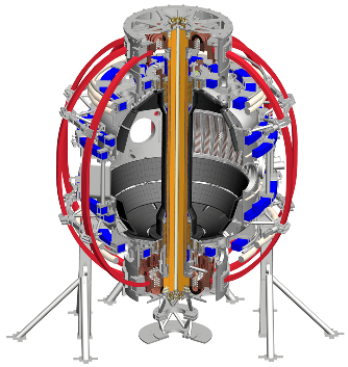
RSSEL

PPPL



MAPP Status update

- MAPP techniques:
  - X ray photoelectron spectroscopy (XPS)
    - Currently fully operational in remote and local modes
  - Thermal Desorption Spectroscopy (TDS)
    - Tested in LTX, however needs to resolve issue with RGAs (two RGAs broken in NSTX-U so far).
    - Sample heaters need conditioning and test in NSTX-U.
  - Ion Scattering Spectroscopy and Direct Recoils Spectroscopy
    - Ion source and gas manifold system installed and controlled remotely.
    - Ion source needs conditioning.
    - Need calibration and testing
  - Between shots analysis
    - Needs connectivity and wiring.

MAPP Status Update

- Currently XPS data collected in semi-remote mode i.e. manual insertion/retraction but remote control of XPS system is possible:
  - Monitoring chemistry of samples conditioned with boronizations and exposed to D+ plasmas.
- Several samples have been extracted from MAPP during the campaign for controlled laboratory experiments (collab. with B. Koel @ Princeton U.)
  - Boronized ATJ and TZM exposed to plasmas.
    - Post-mortem characterization with XPS-depth profile
  - Boronized ATJ and TZM unexposed to plasmas:
    - Controlled D+ irradiation in HR-XPS
    - Post-irradiation TDS

MAPP Methodology at NSTX-U

- XPS scans were collected after each boronization in bi-weekly and weekly modes, scans were collected after boronization and plasma operations in daily mode.
- XPS data collected every night after plasma operations.
- Data sets:

Installed in 10/15 will be removed at the end of the campaign

- #1_ATJ:
  - Survey
  - B1s
  - O1s
  - C1s

Installed in 2/16 and removed on 4/16 for off-line measurements

- #2_TZM:
  - Survey
  - B1s
  - O1s
  - C1s
  - Mo3ds
- #3_ATJ:
  - Survey
  - B1s
  - O1s
  - C1s

Binding energy calibration

- #4_Au:
  - Survey
  - B1s
  - O1s
  - C1s
  - Au4f

Acquisition time ~40 min per data set with optimized settings

MAPP Methodology

- Data analysis:
  - Define sets of peaks per region to be fitted:
    - References and QCMD simulations (collaboration with P. Krstic)
  - Define resolution (min in FWHM of peaks):
    - Theoretical resolution (~2.0 eV) and experimental (~3.5 eV)
  - Define delta BE between peaks to fit:
    - Laboratory high resolution XPS at Princeton University
    - References*
- **The goal is to develop the best set of constraints in each region to allow objective and unique fittings. Since MAPP's data is continuously generated to develop a standard data analysis routine is critical.**

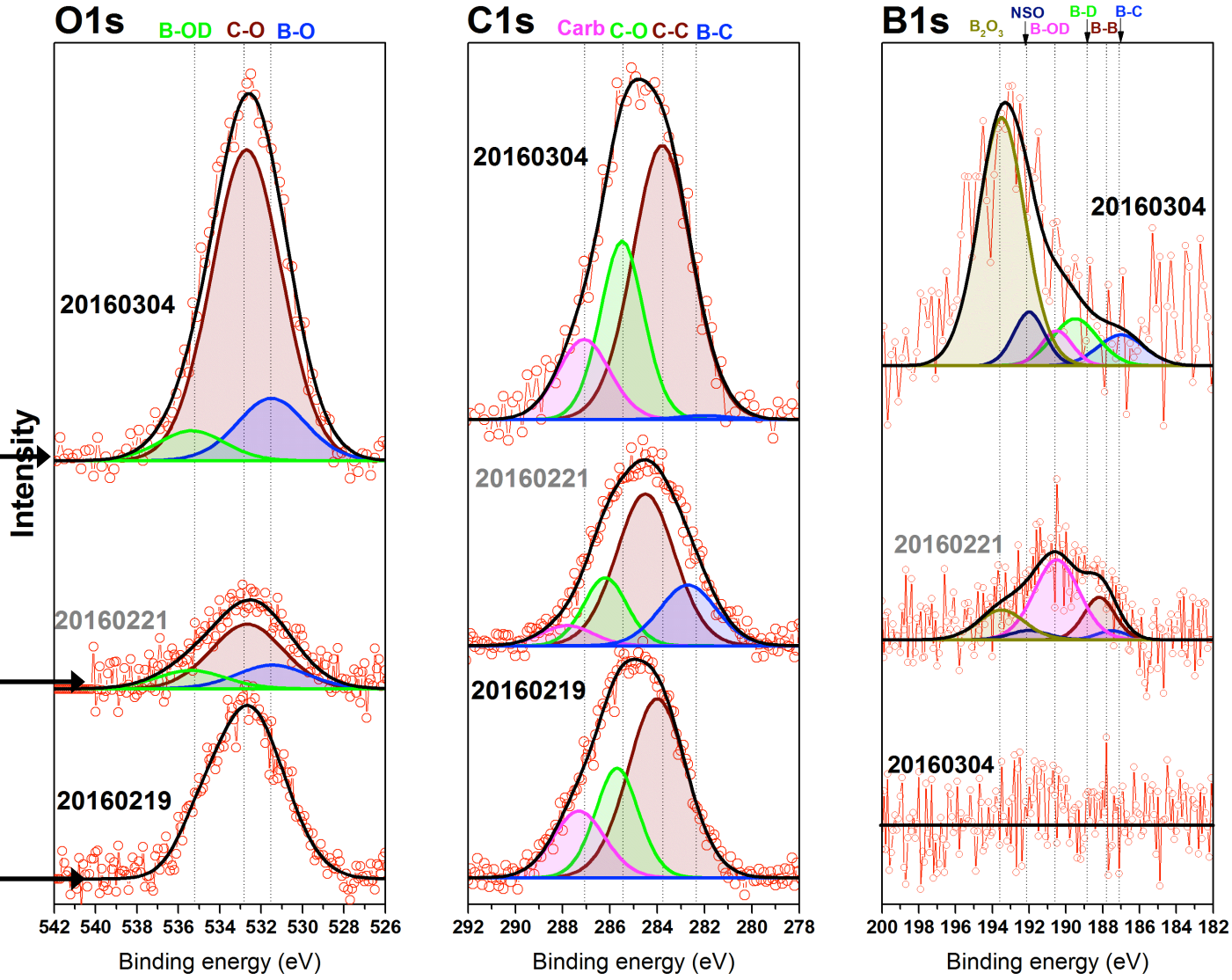
Evolution of surfaces

- Presence of B_4C after TMB
- Transition to B_2O_3 (exposure to plasma and residual gas e.g. H_2O)

Plasma operations

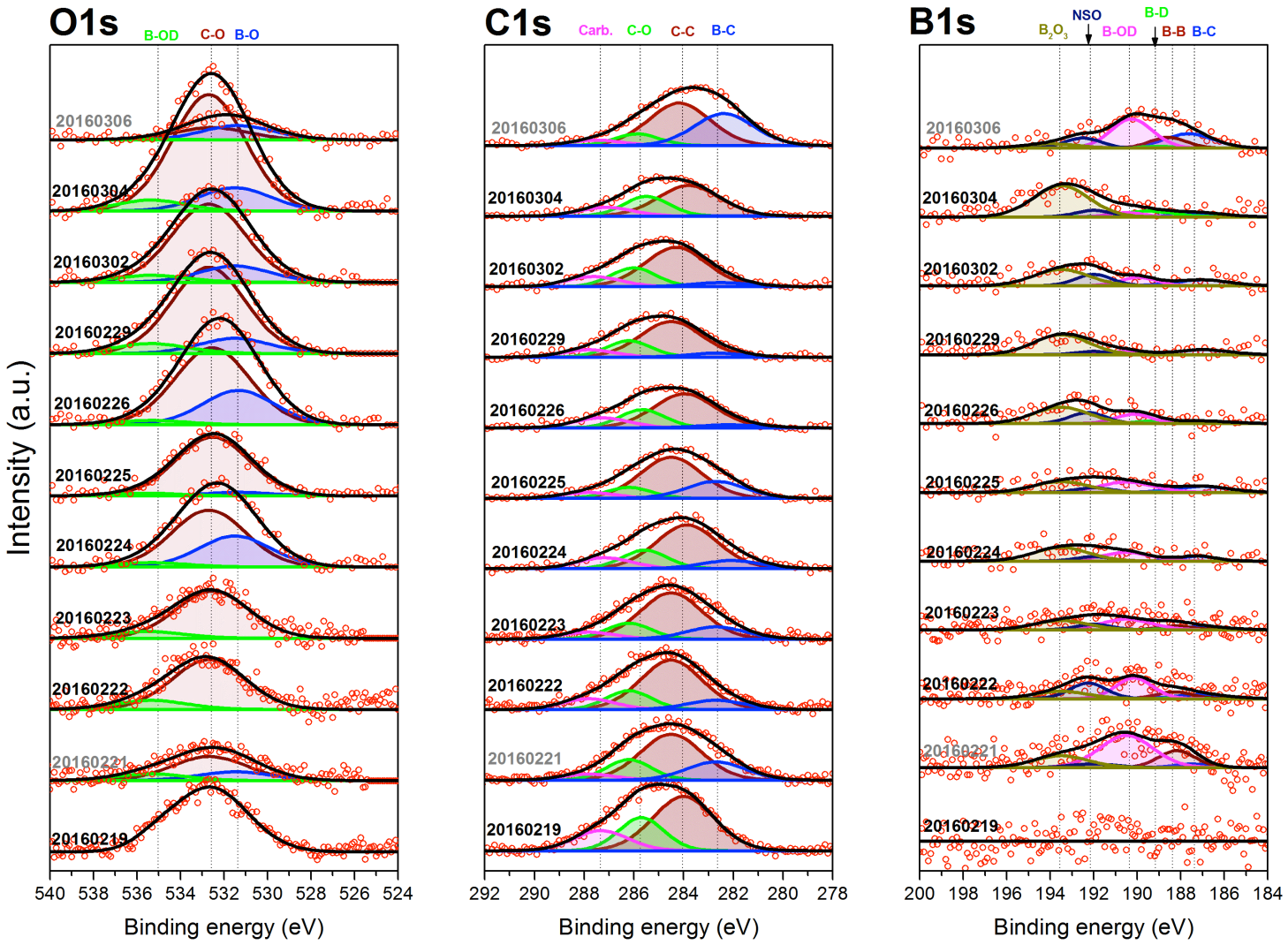
Boronization

ATJ Graphite



Transitions of surface chemistry

- Regions
  - Patterns:
    - Common features between boronizations
    - Evolution of components in each region
    - Oxidation
    - Sputtering

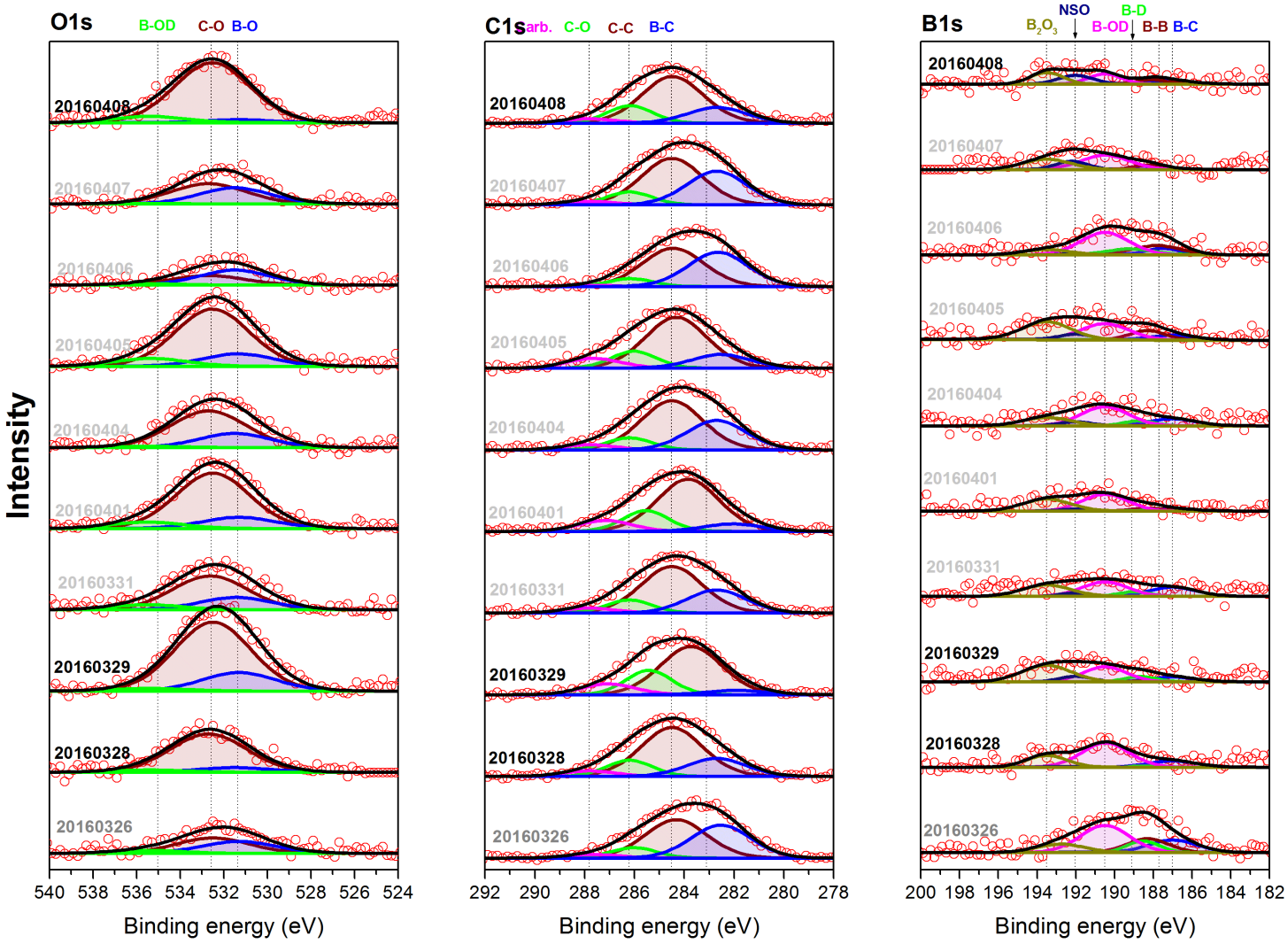


Surface transitions *smoothly* from carbide to oxide, additionally D+ erodes the coatings

* Gray font traces were collected ~30 min after boronization

Transitions of surface chemistry

- Regions$_{ATJ}$
  - Patterns:
    - Common features between boronizations
    - Evolution of components in each region
    - Oxidation
    - Sputtering
    - Effect of daily vs. weekly boronizations



The behavior seems to be the same in weekly vs. daily TMB, however small thickness accelerates the rate of erosion

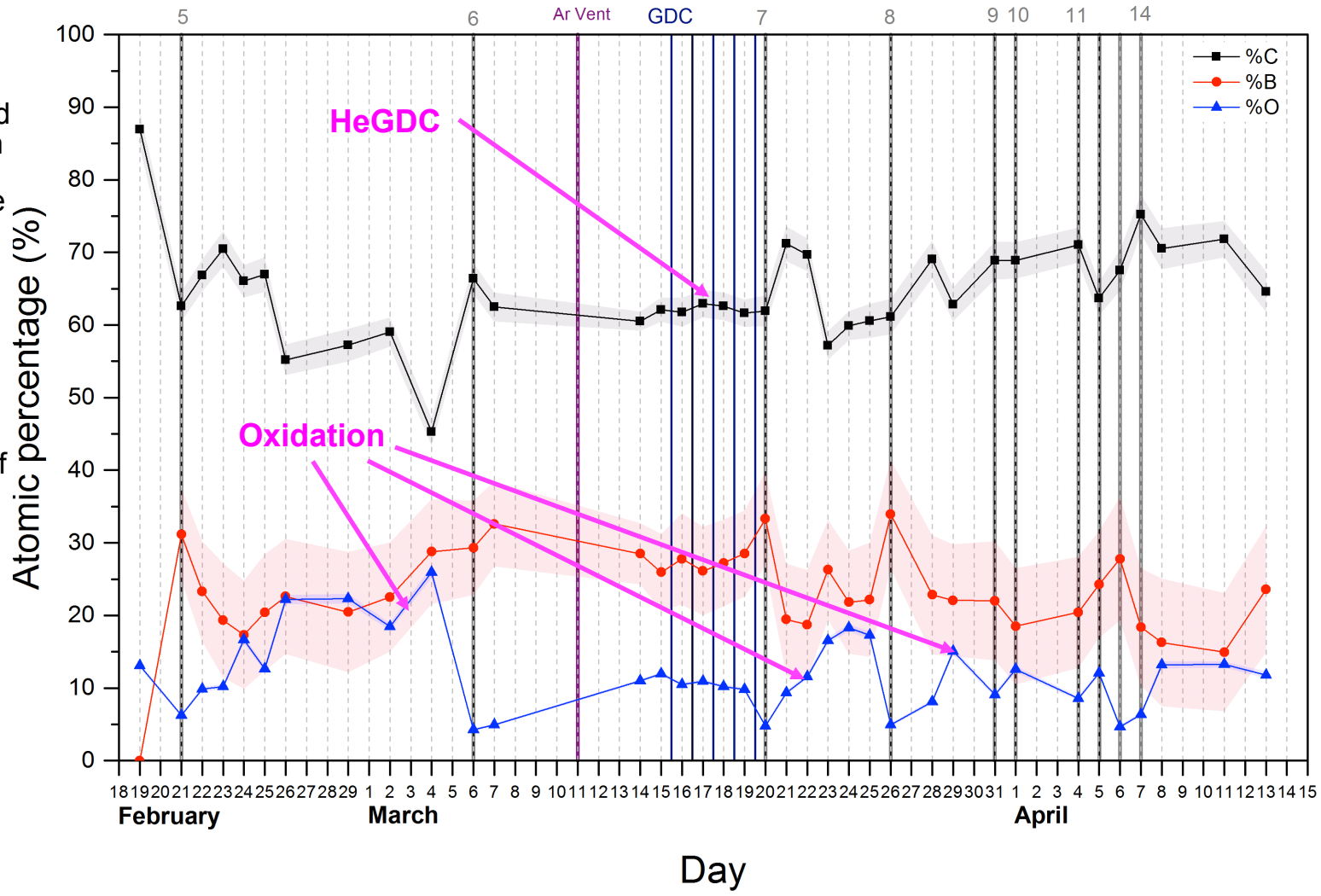
** Gray font traces were collected ~30 min after boronization and plasma exposure

Daily recorded concentration

- Atomic concentrations

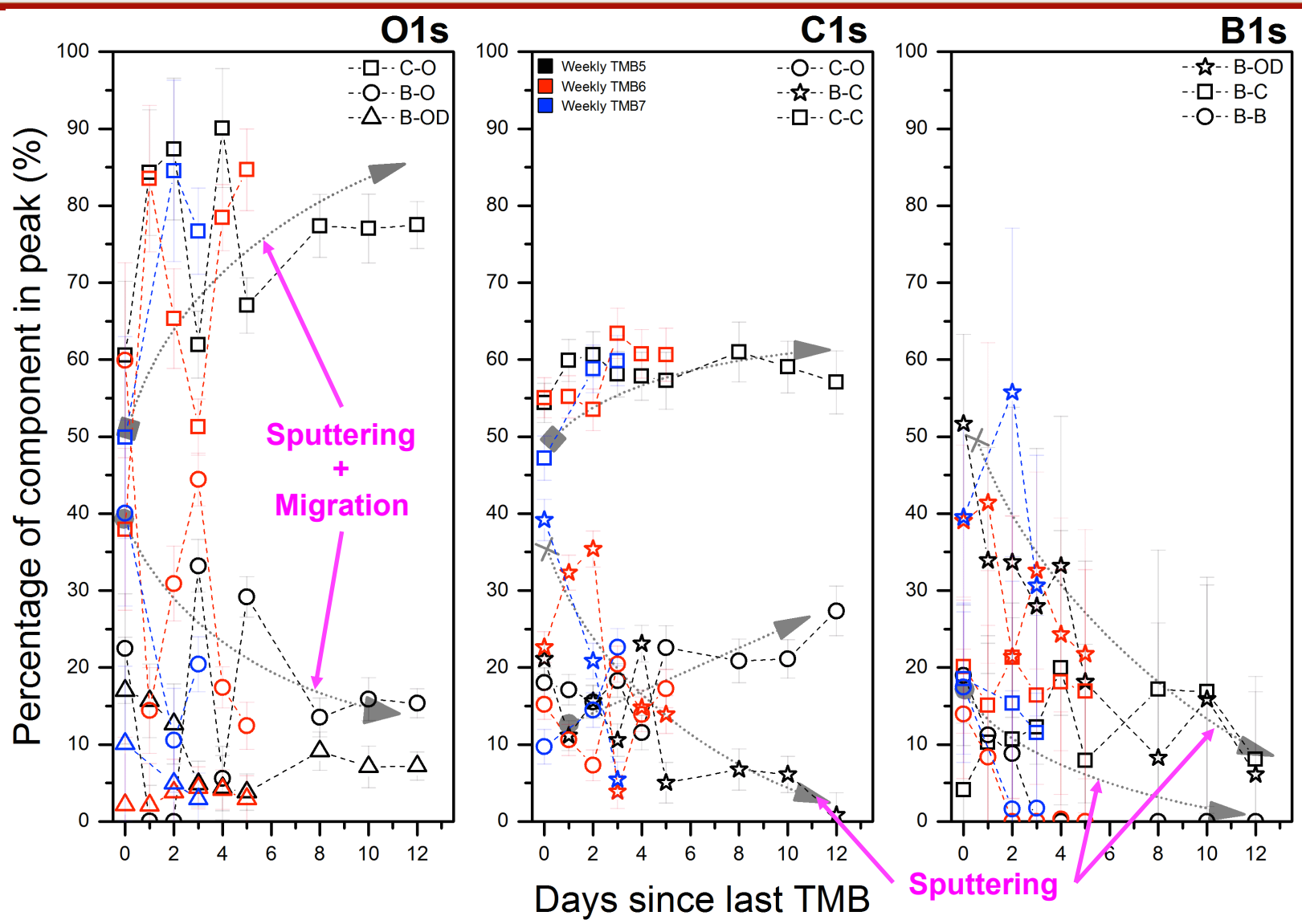
Day to day composition vs. campaign integrated data. The resolution improves by two orders of magnitude

Shot to shot will improve an additional order of magnitude



Analysis of compounds

Analysis of components provides ever more detail in the processes occurring at the surface.



Upcoming experiments and plans for 2015/2016 (FY16) campaign

- More and more boronizations. **Post-daily and pre plasmas XPS scans in daily boronization mode**
- Laboratory experiments with boronized samples
  - Boronized samples stored in C128 ready for off-line irradiations
- B to Li transition XP
- Li related measurements
- Ongoing efforts to set up remote insertion to enable in between shots analysis:
  - Probe drive motor cabling and control
  - Between shots pumping configuration
  - Interlock signals and TIVs sync

Long-term plans for FY17-18

- MAPP will be developed to be a routinely used PMI diagnostic able to support a growing base of users
  - **Our goal is to enable a user to also provide samples for in-vacuo testing and characterization**
  - Support with basic training for data analysis if needed
  - Shot-to-shot data acquisition optimized
- MAPP full diagnostic suite will be commissioned by FY17 campaign
  - Direct recoil spectroscopy for direct D surface concentration
  - TDS and LEISS optimization with support from Princeton and UIUC

Long-term plans for FY17-18

- Enhanced diagnostic suite in MAPP
  - Design of a backscattering low-energy ion scattering spectroscopy capability (to support Li-Mo and Li-W mixing experiments)
  - *In*-situ DC-QMB (dual-crysal quartz microbalance) compatible for high-temperature liquid-metal erosion and candidate solid PFC material erosion and re-deposition
  - hydrogen composition sensor to help quantify spectroscopic measurements at the MAPP surface. (collab. with R. Kolasinski)
- Integration of MAPP to OES measurements for multi-spatial diagnosis (collab. with V. Soukhanovskii and F. Scotti)