U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

Elemental and topographical imaging of microscopic variations in deposition on NSTX-U and DIII-D samples

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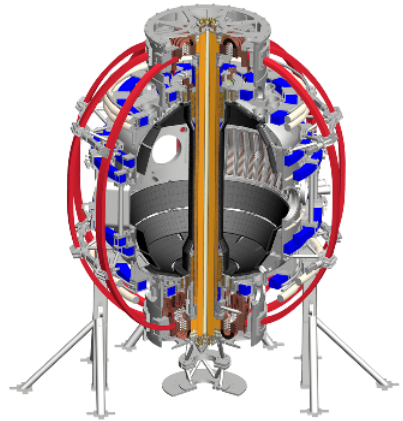
PPPL

Sandia National Laboratories

DIII-D NATIONAL FUSION FACILITY

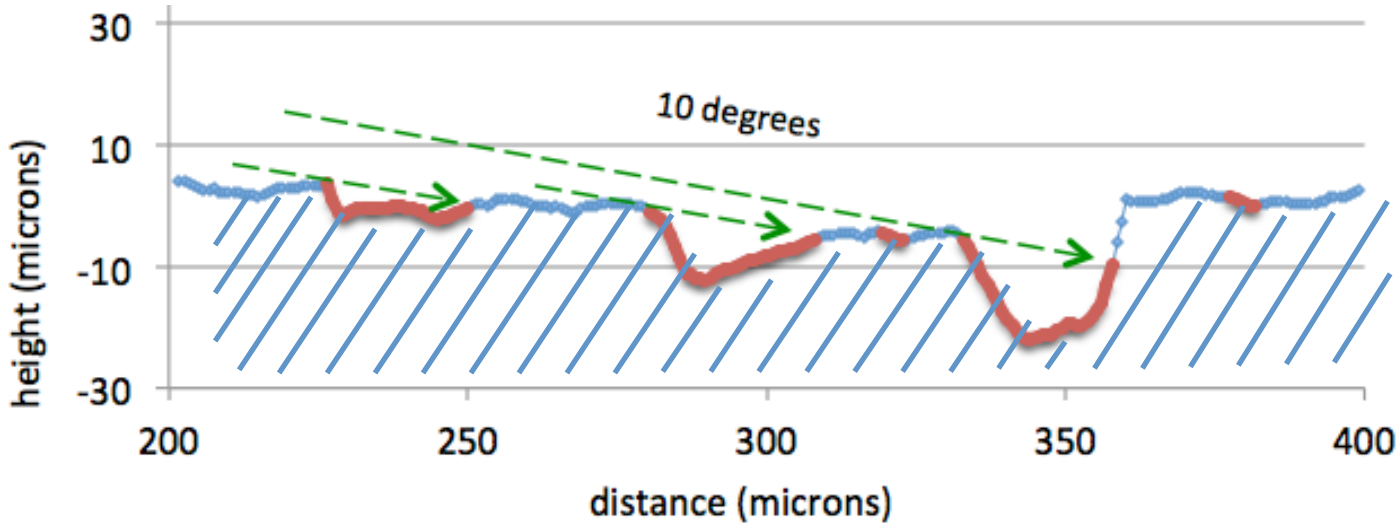
PRINCETON Chemical and Biological Engineering



Surface roughness can shadow incident ions.

- Erosion / deposition important for PFC lifetime, T retention and plasma contamination.
- Ion incidence angle can be close to surface due to magnetic pre-sheath*.
- Surface roughness then becomes a key factor in erosion and redeposition patterns.

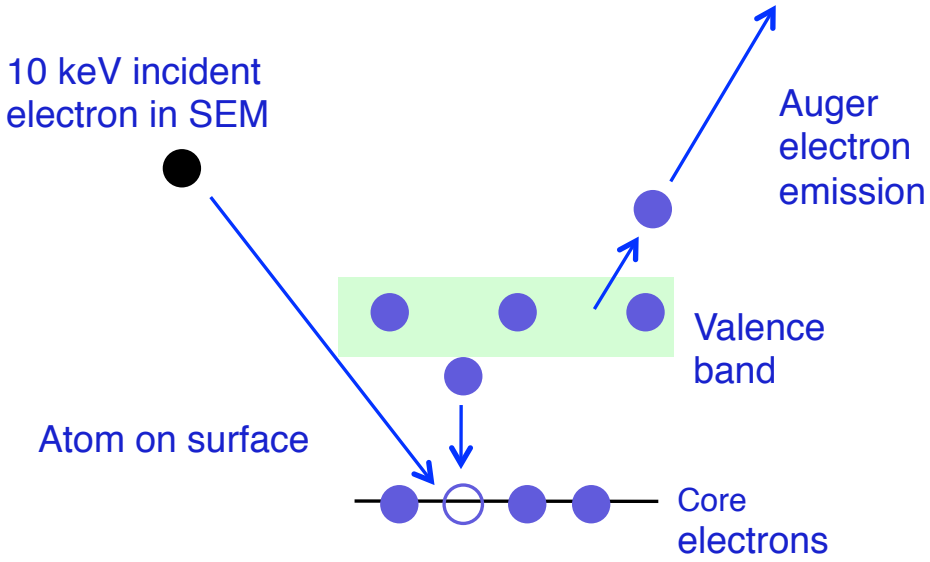
Lineout from 3D topographical image of NSTX-U upper divertor tile with arc tracks.
10 degree incident ions can form deposits on blue areas.
Re-eroded ions can deposit in red areas and be shadowed from further erosion.
So far no direct measurements of this.



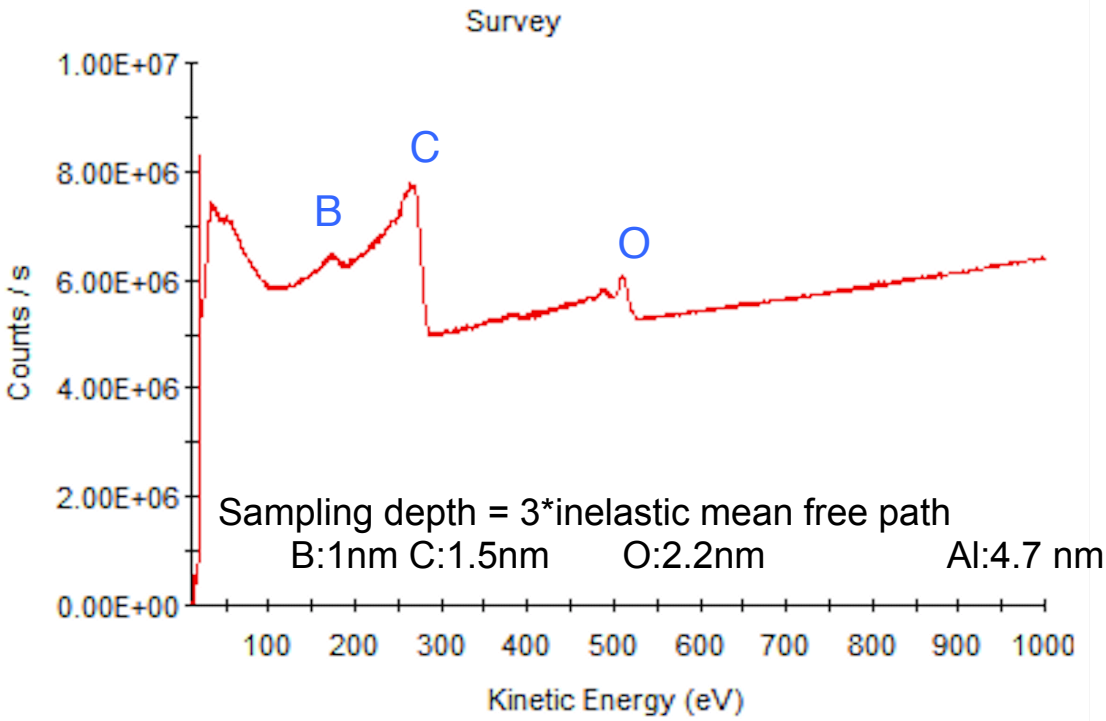
*Stangeby NF (2012)
Chrobak NME (2017)

Elemental imaging by Auger microprobe

Auger process



Secondary, backscattered, and Auger electron spectrum:

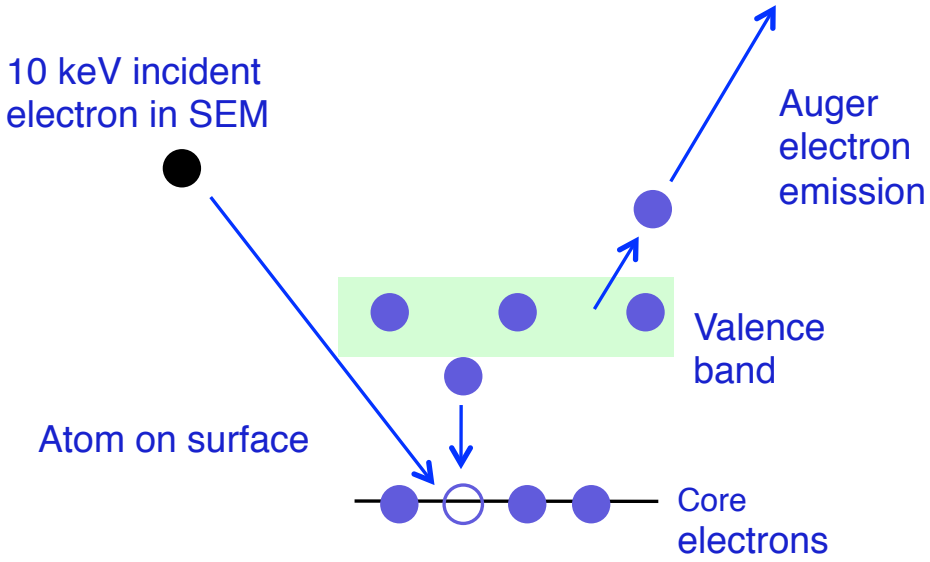


10 keV electron beam excites core electron
- atom relaxes via 2-electron transition
Auger electron energy is characteristic of element

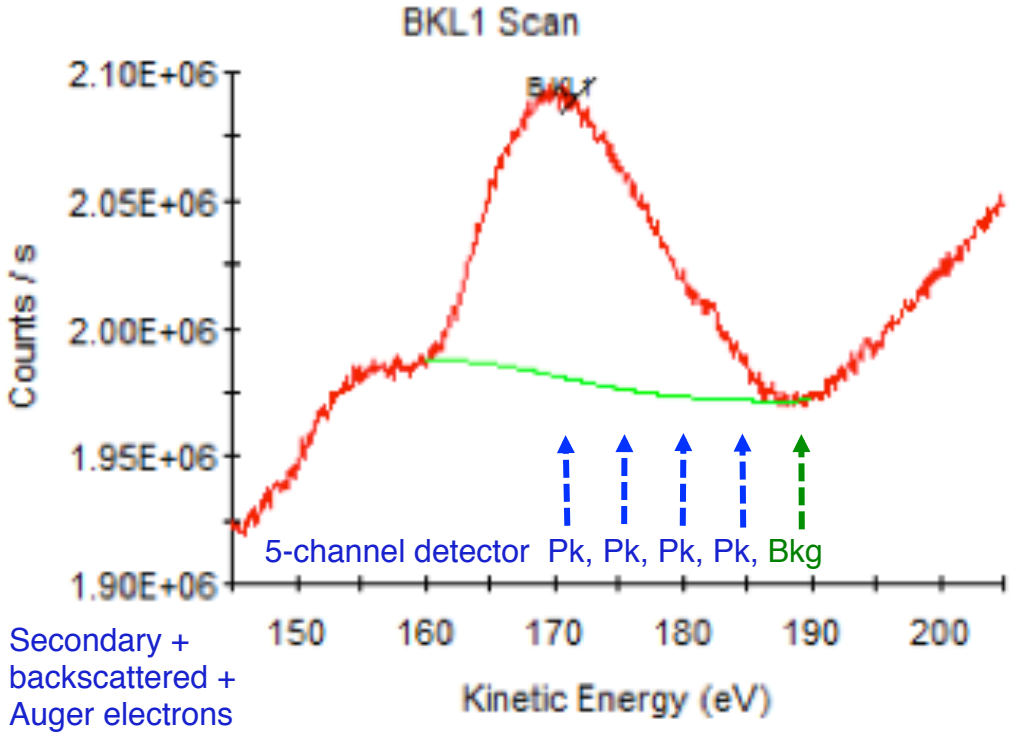
NSTX core sample C-15

Elemental imaging by Auger microprobe

Auger process



Boron Auger Line:



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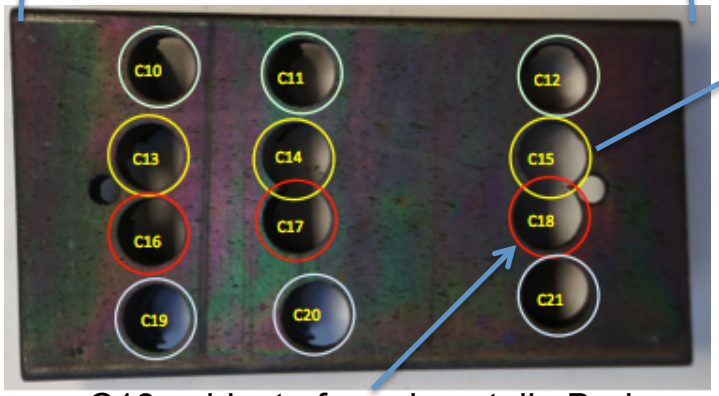
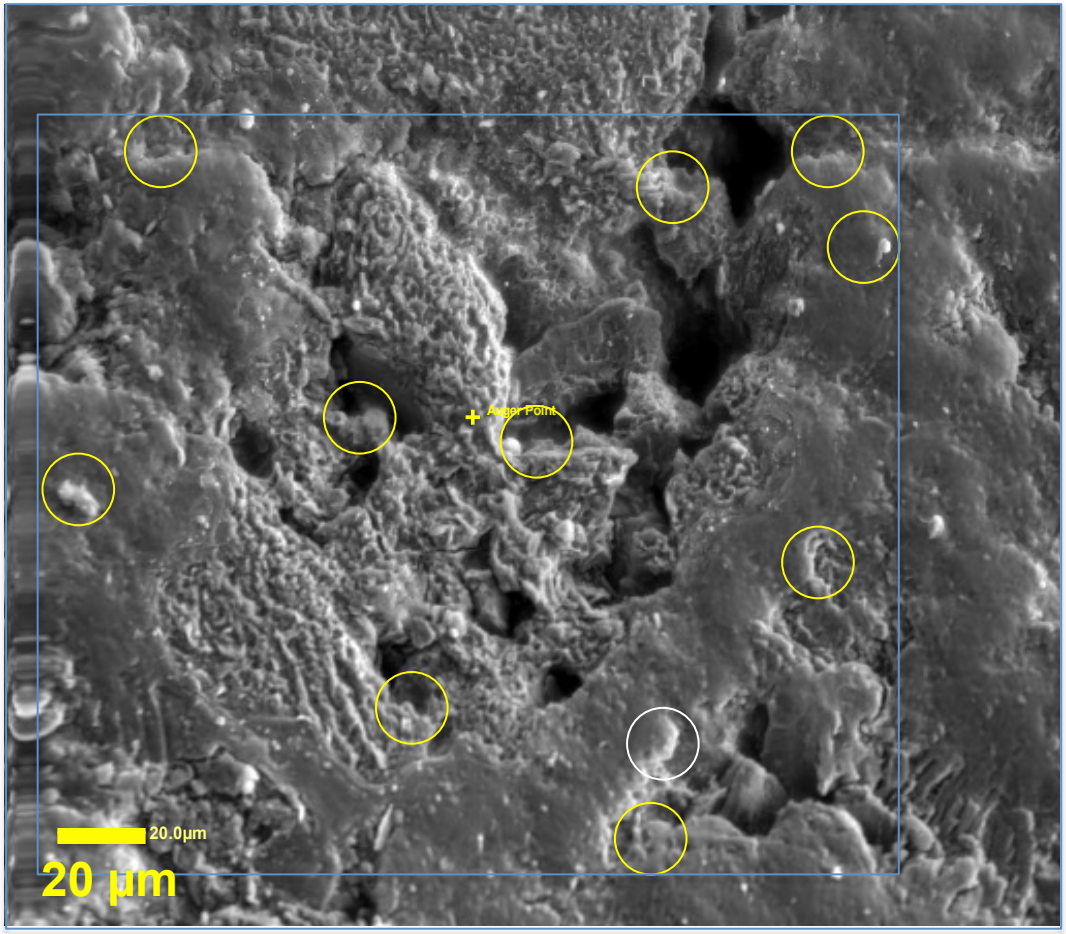
Auger electron energy is characteristic of element

Images calculated from (Pk-Bkg) / (Pk + Bkg)

NSTX-U: SEM image of tile core

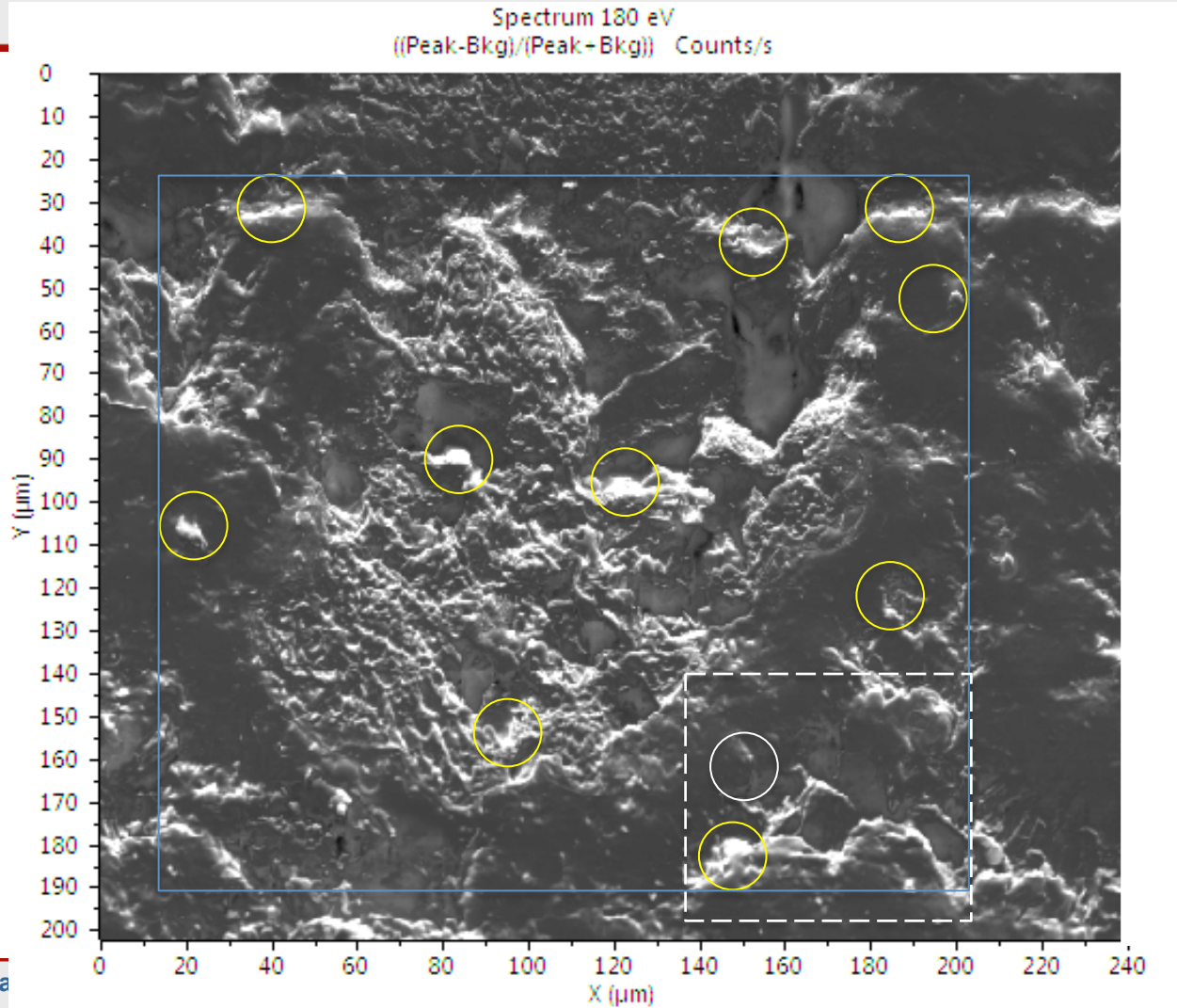


C18 subject of previous talk, Bedoya et al.,



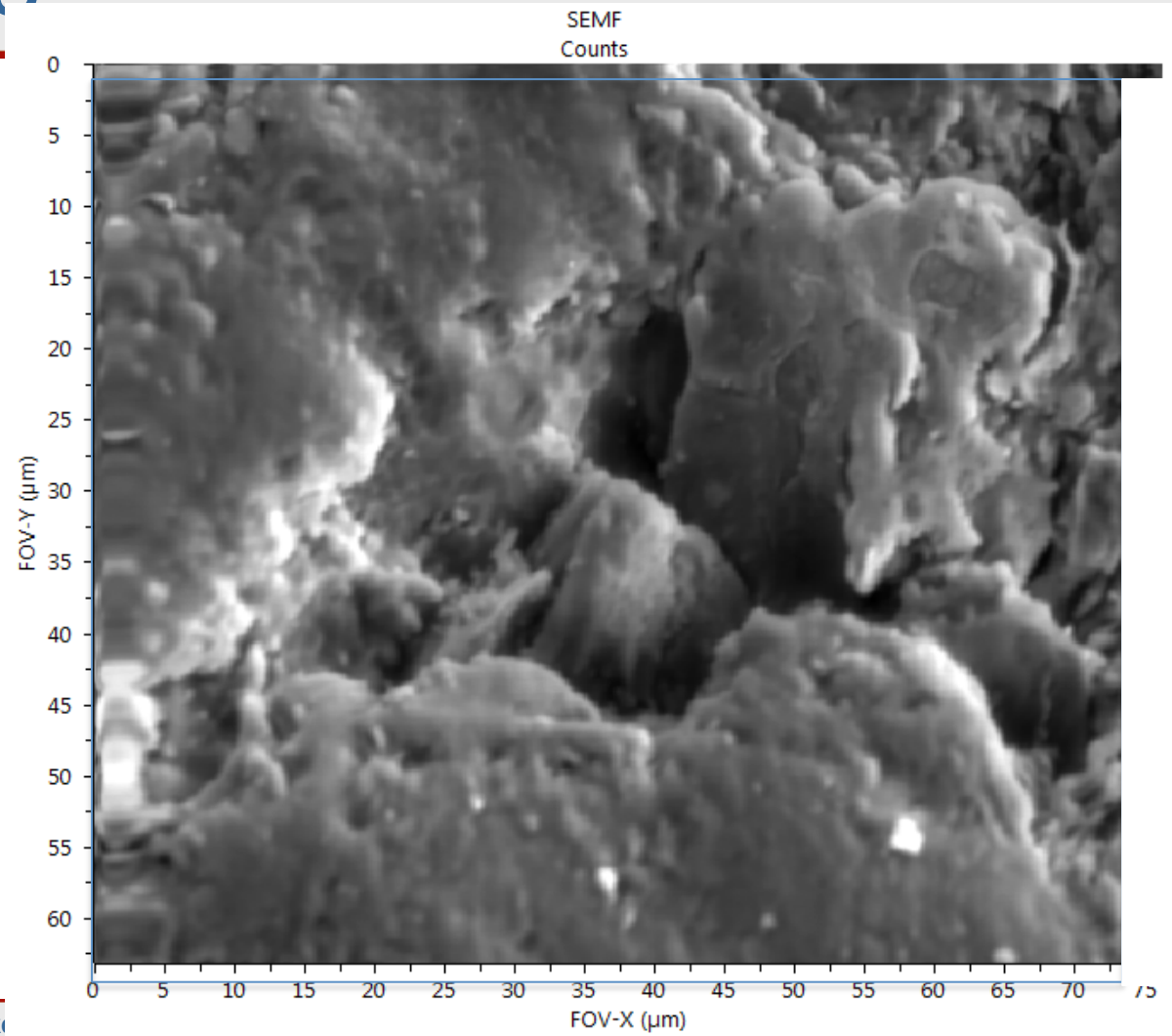
Auger image of boron 1

- Initial results, more analysis in progress.
- Auger line scans show low atomic concentration of boron ~ 4 – 9% at points measured.
- Appears to be higher B concentrations on North facing cliffs and little boron on South facing cliffs.
- Area in white square in next slides.
- ~3-day data acquistion.



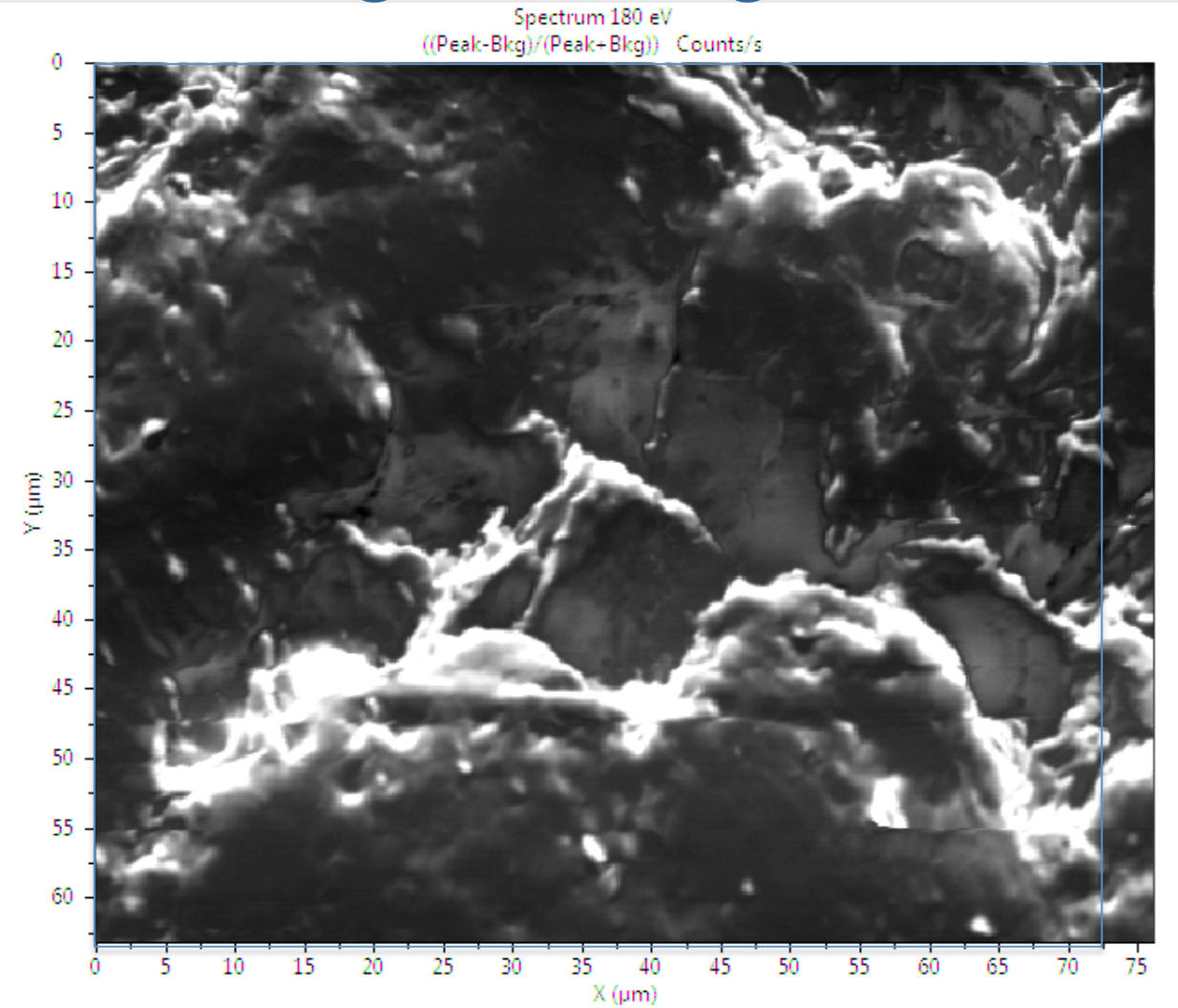
SEM higher magn

- Zoom in to white square in previous slide.



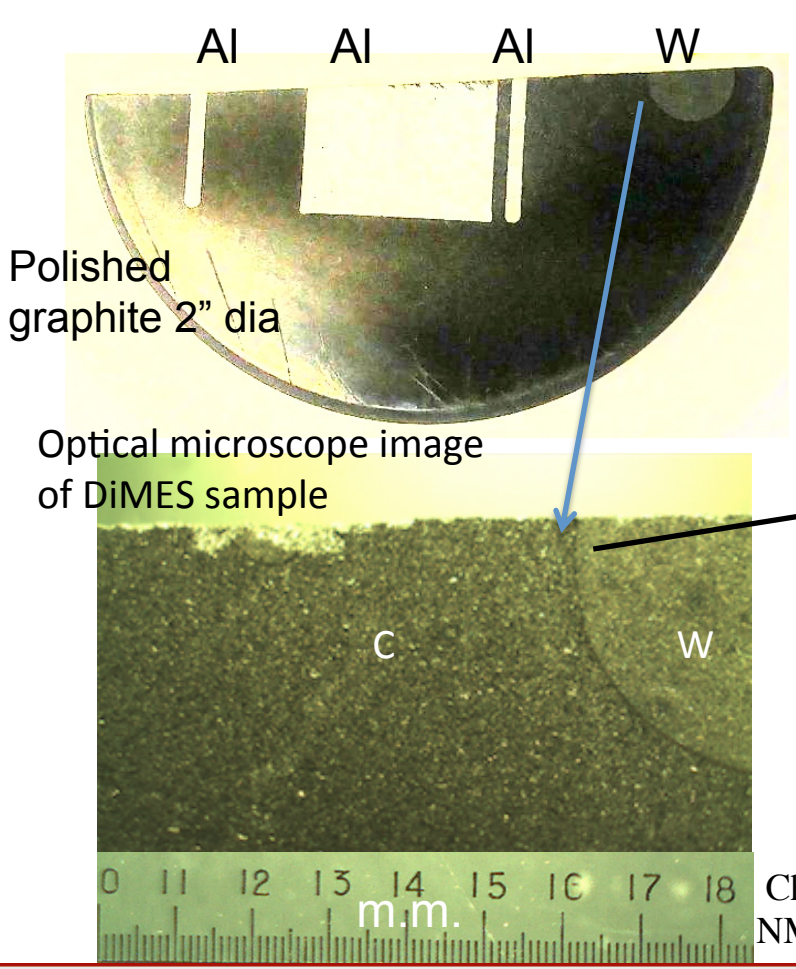
Auger image of boron higher magn

- Higher magnification image also shows higher B concentrations on ‘north’ facing cliffs and little boron on ‘south’ facing cliffs.
- More analysis planned.
- Topographical 3D mapping planned with Leica confocal microscope.

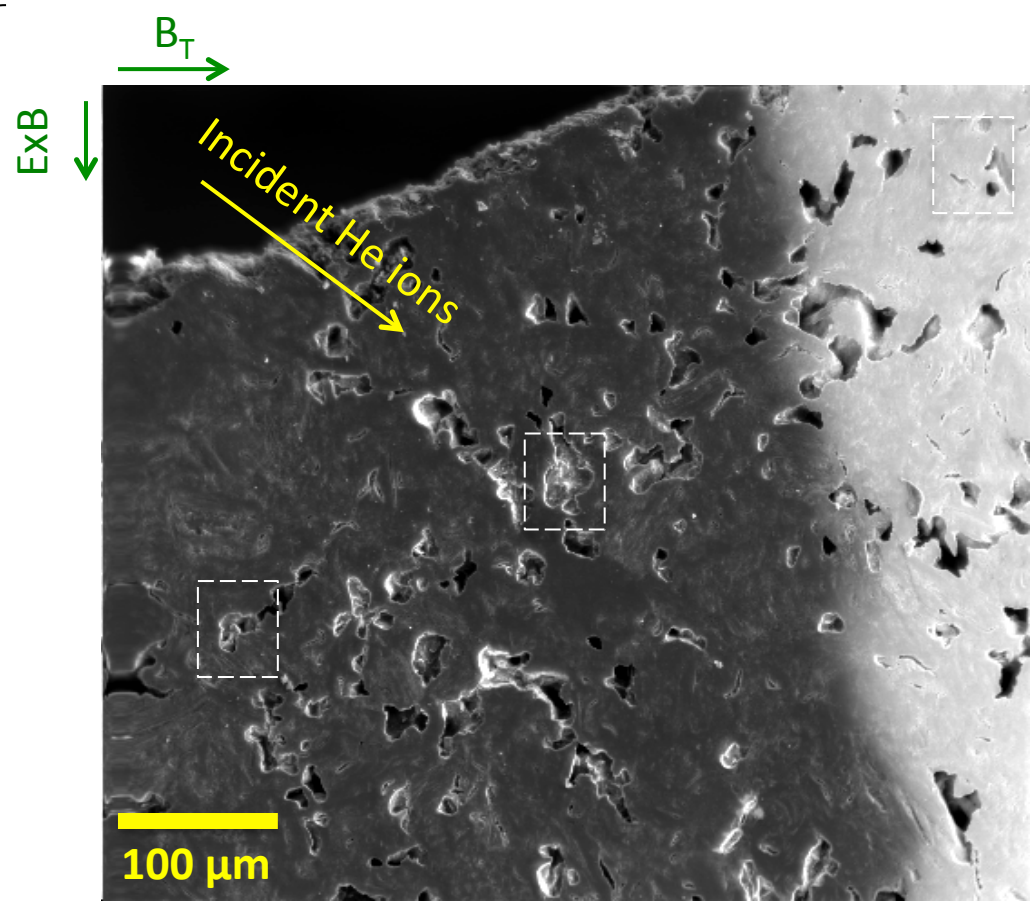


DiMES erosion study

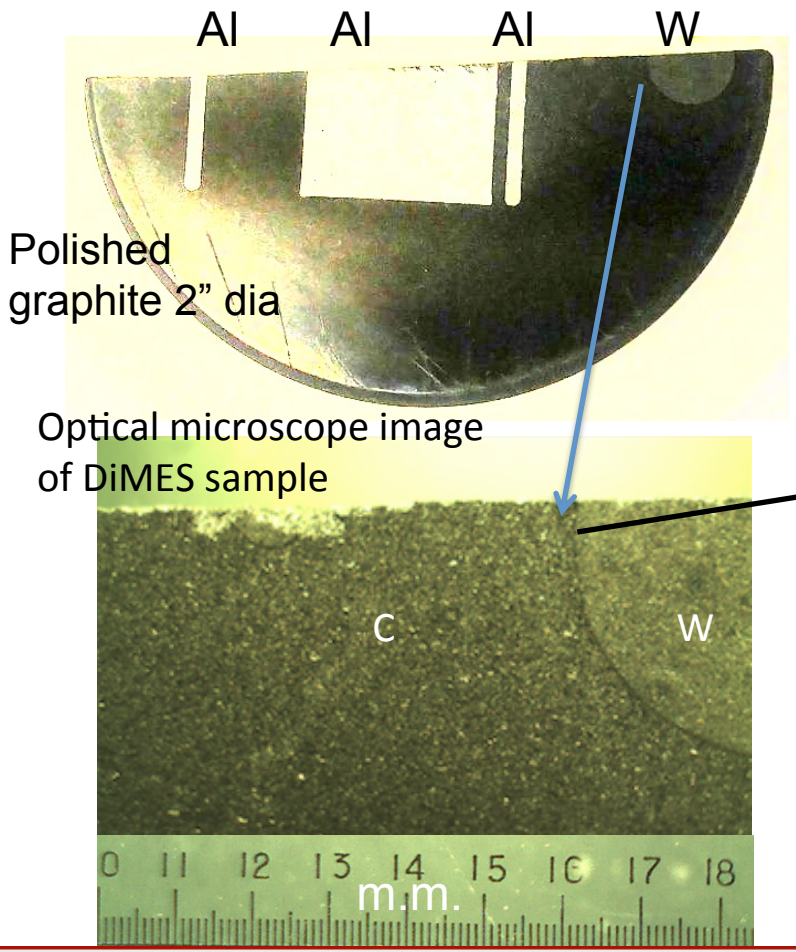
SEM image

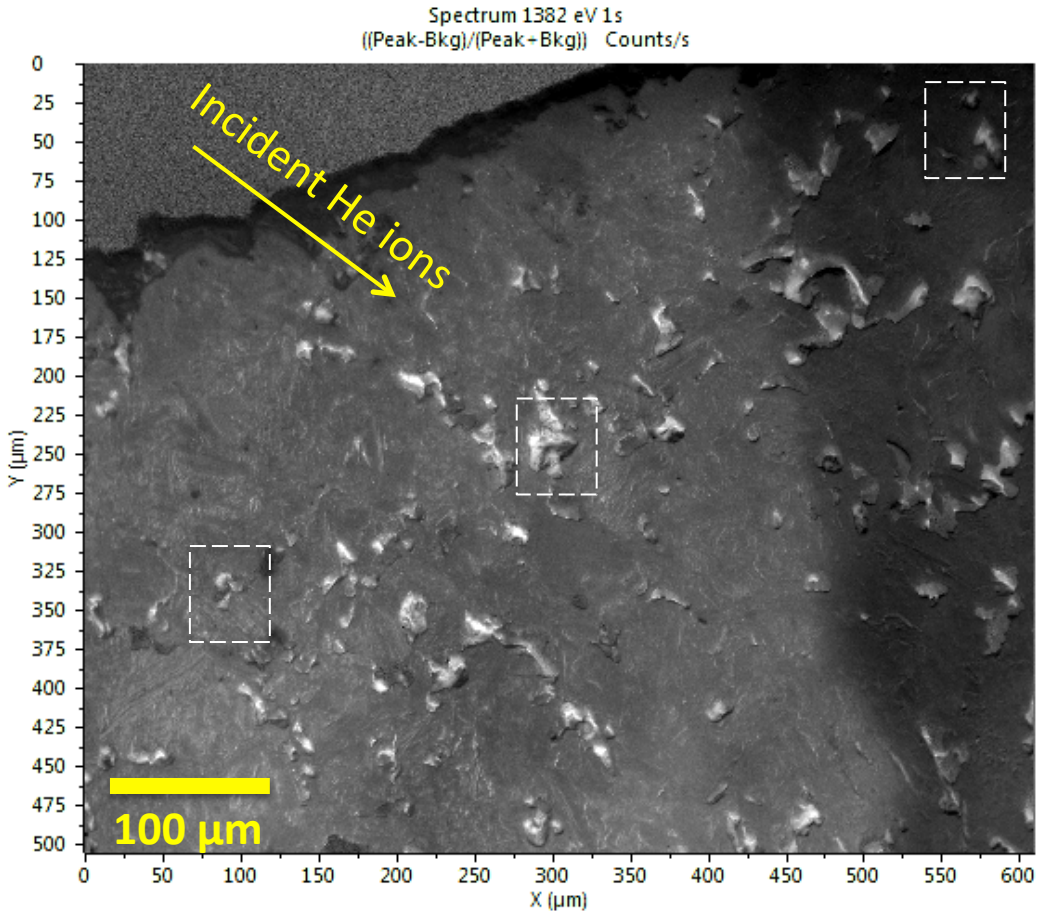


Chrobak
NME (2017)

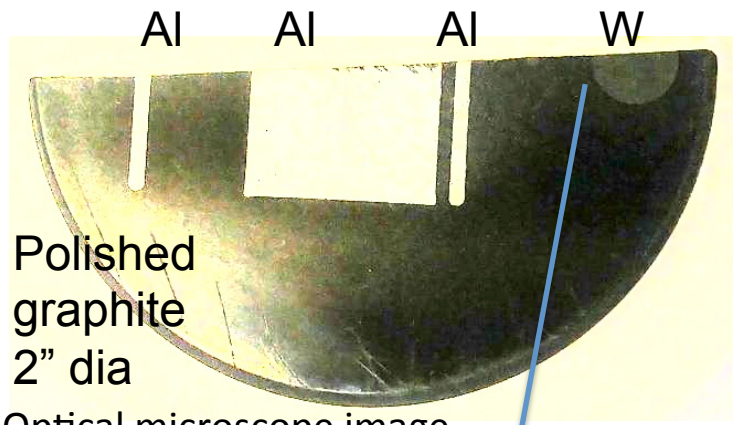


DiMES sample, Al Auger image

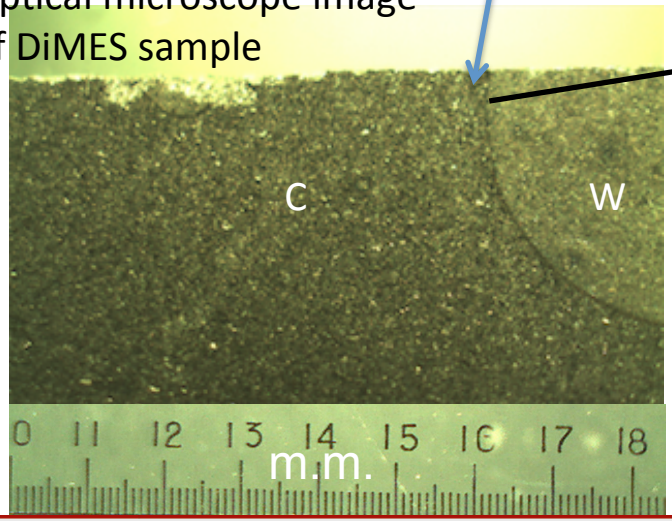


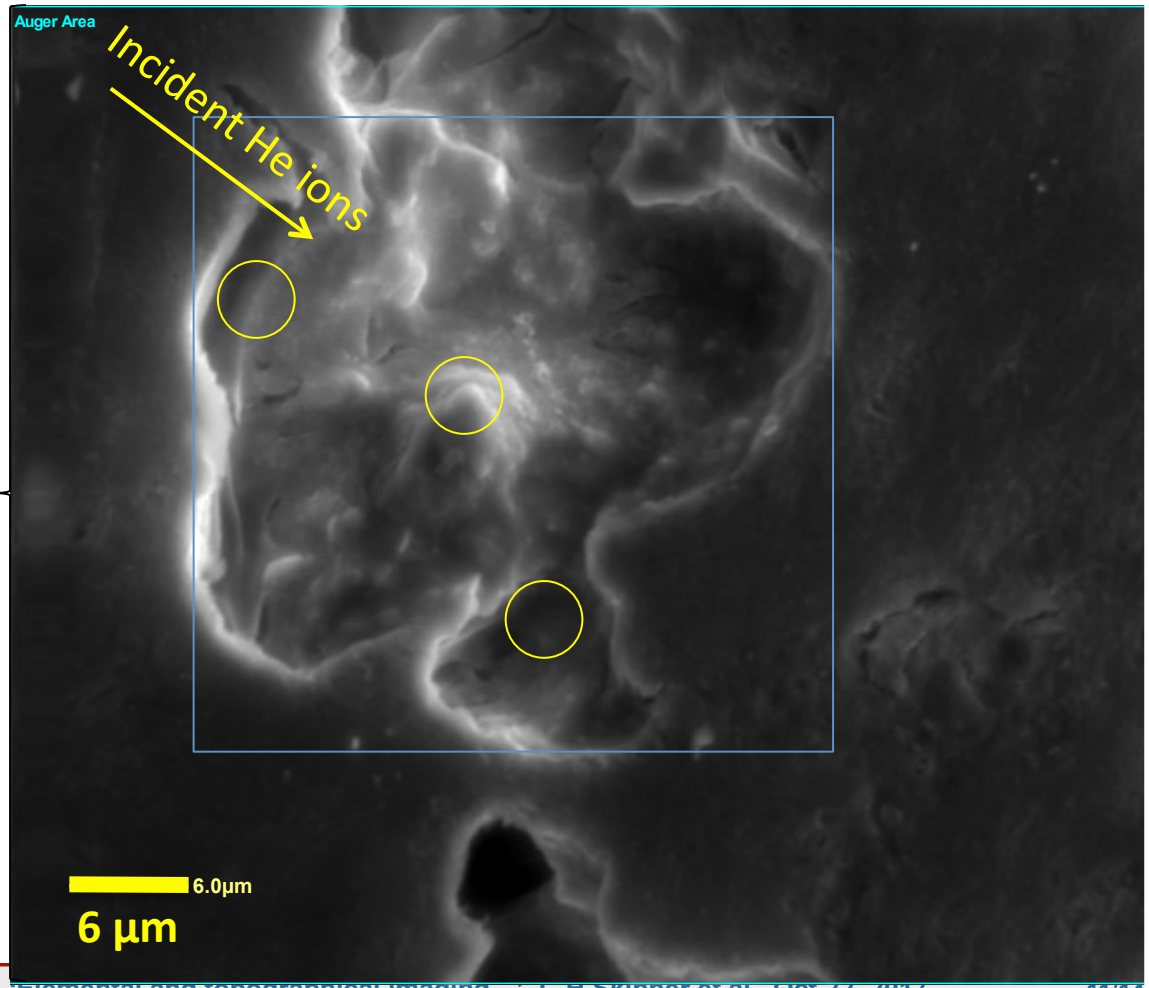


DiMES sample, SEM image of pore:



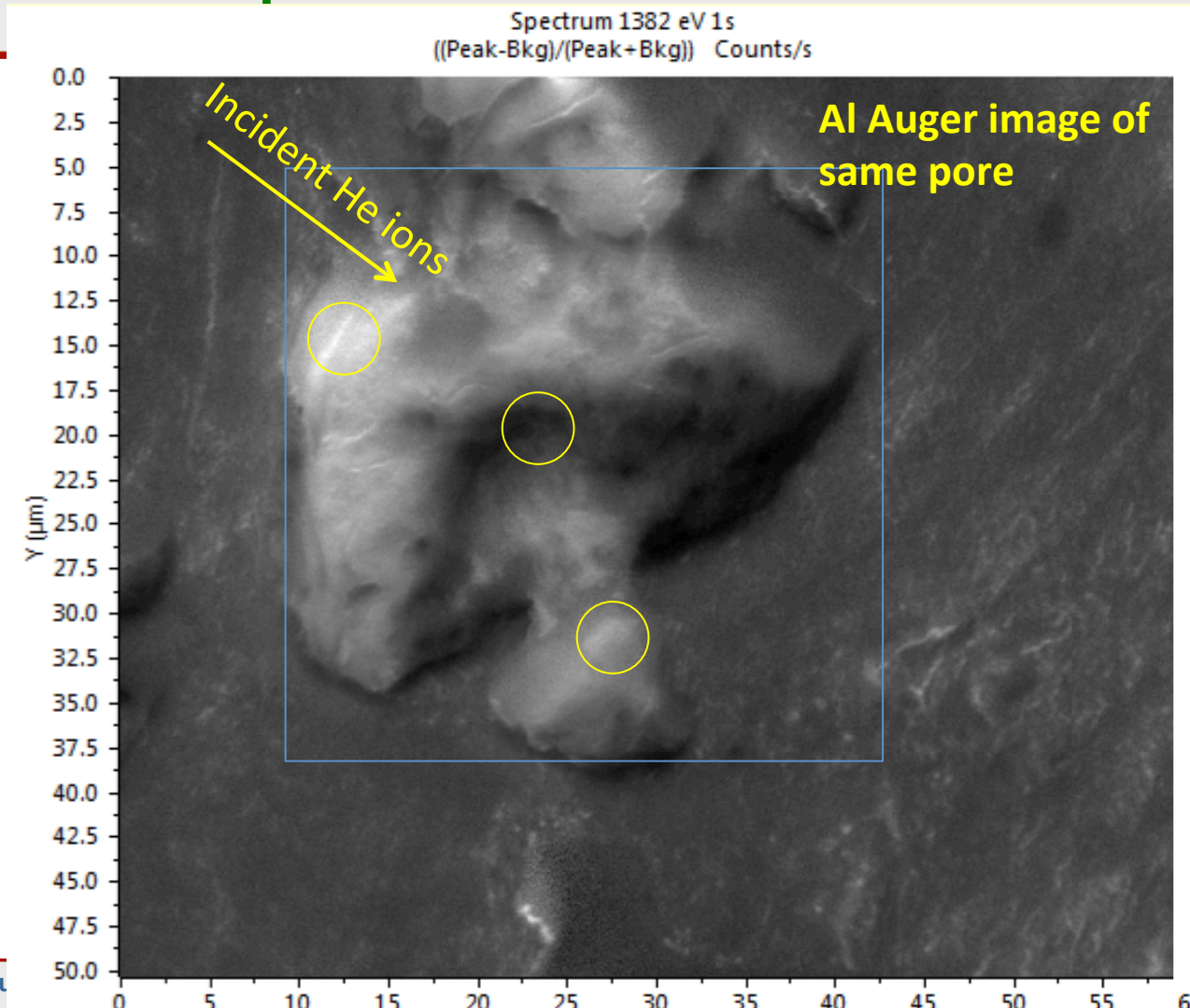
Optical microscope image of DiMES sample





Al Auger image of same pore

Microscopic features of surface affect erosion and redeposition.



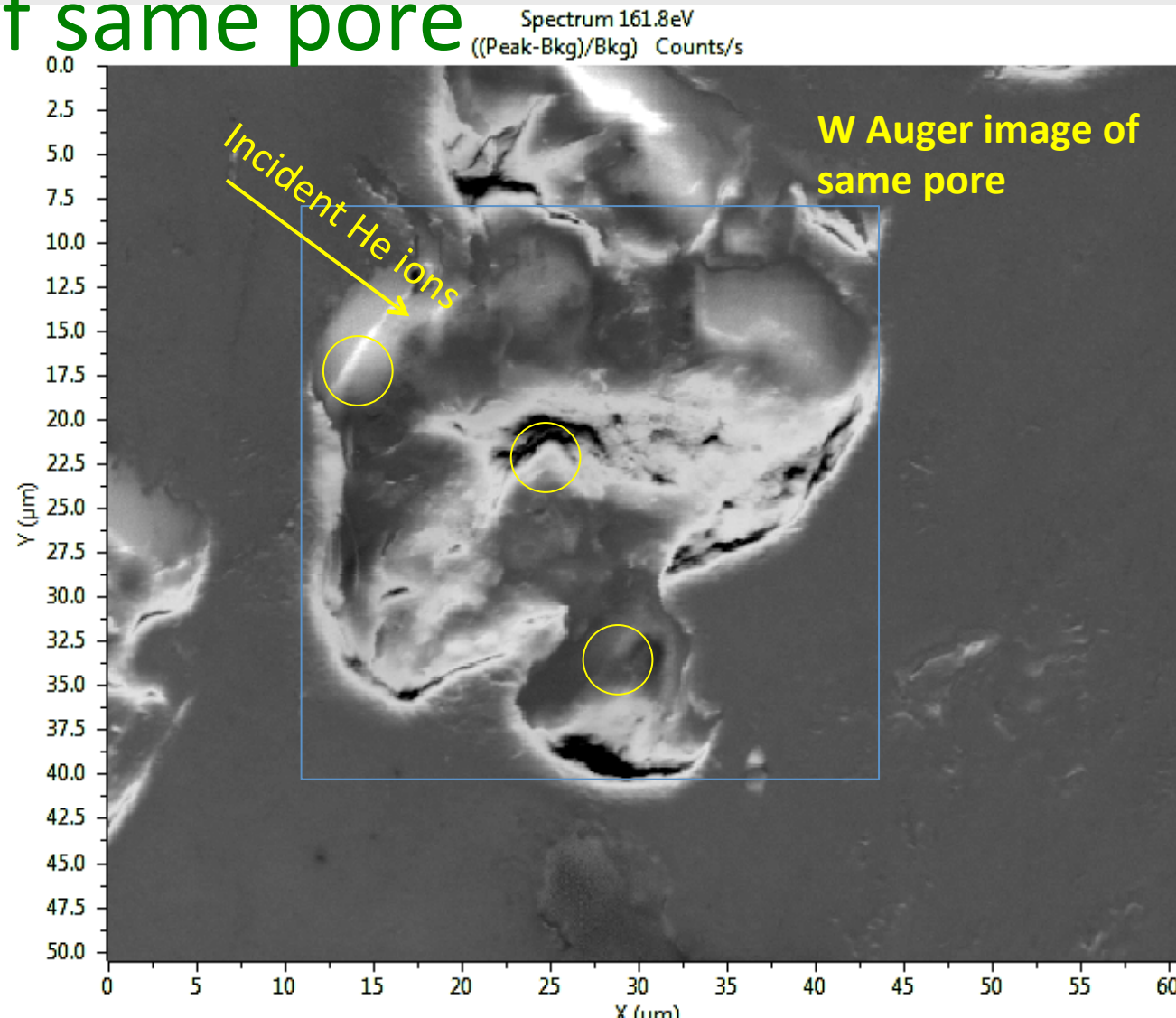
W Auger image of same pore

Most W eroded by incident C (not D) and promptly redeposited.

Conclude:

Direct measurement of how microscopic features of surface affect erosion and redeposition.

Surface topography needs to be taken into account in modeling erosion and redeposition on rough surfaces.



Conclusions:

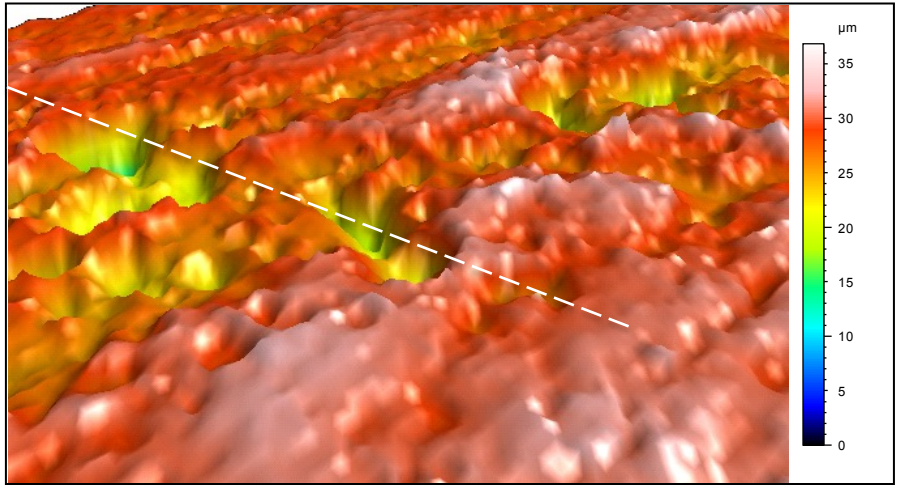
- Direct elemental mapping shows net deposition is inhomogeneous in NSTX-U and DiMES samples
- Surface morphology influences net deposition patterns
- Net deposition pattern is consistent with magnetic pre-sheath causing shallow angle incident ions and less erosion on shadowed areas.
- 3D topographical mapping planned to correlate topology to deposition patterns

Backups

Leica 3D images of NSTX-U tile:

NSTX-U upper divertor tile

3D image from Leica confocal microscope

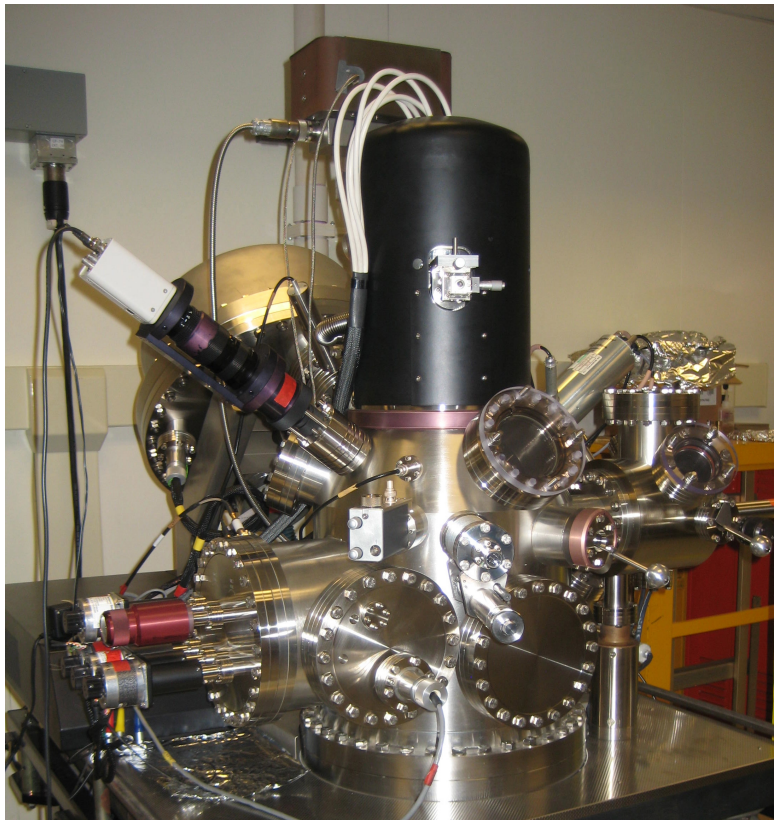


3D imaging of Auger areas planned when microscope is repaired.

Backups

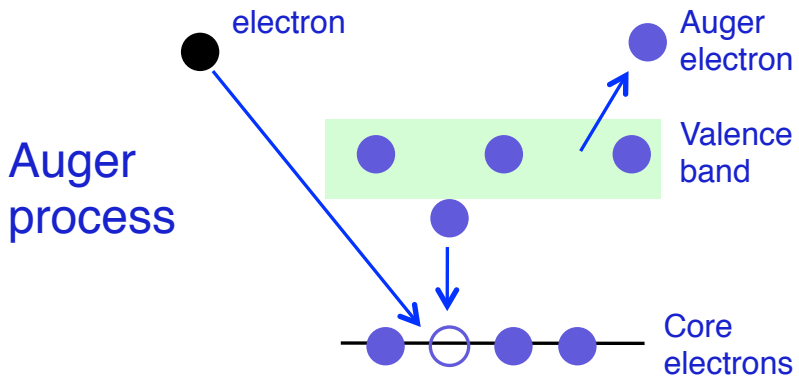
Scanning Auger Microprobe (SAM) combines:

- Secondary electron microscopy (SEM)
- Auger electron spectroscopy (AES) for 2D elemental mapping (SAM)
- Ion sputtering for surface cleaning and depth profiling

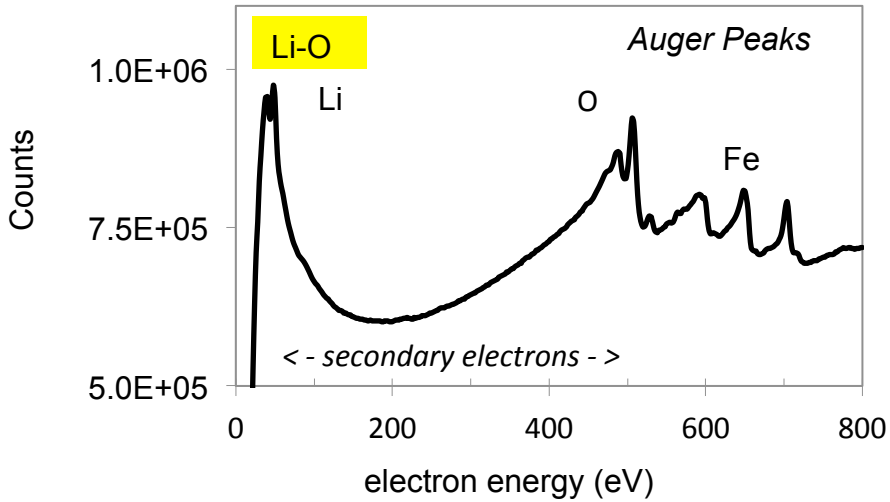


Backups

Cartoon of Auger process
From Skinner Lecture 2017a
Change to survey scan of NSTX-U sample



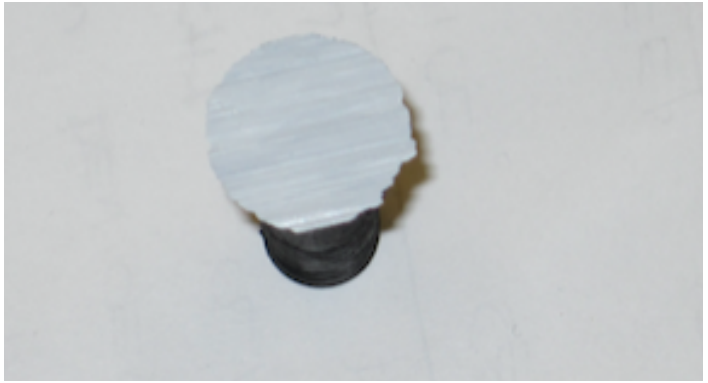
10 keV electron beam ejects core electron
- atom relaxes via 2-electron transition
Auger electron energy is characteristic of element



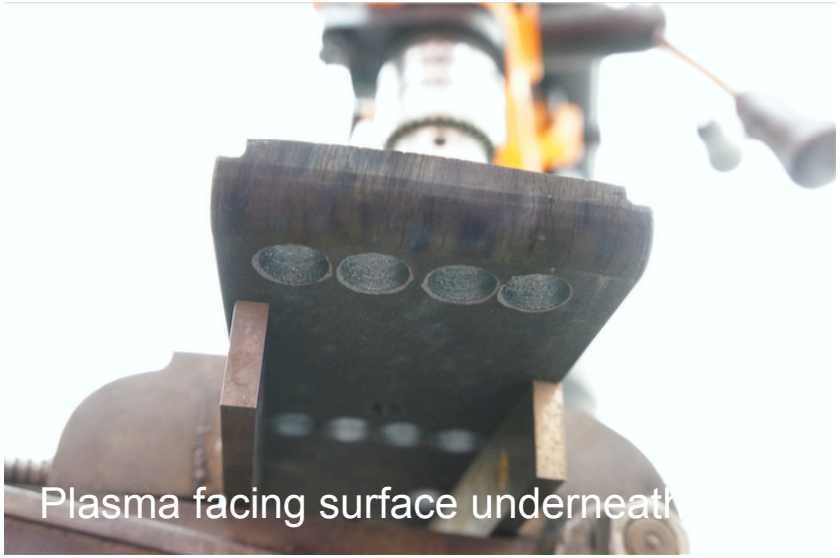
Li-O Auger electrons used to build an element specific image at SEM resolution

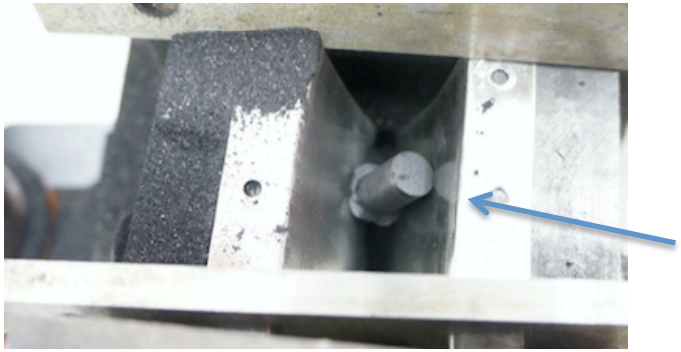
Backups

Precision, custom-made 3/8” i.d. core drill’



No dust evident on trial sample after coring

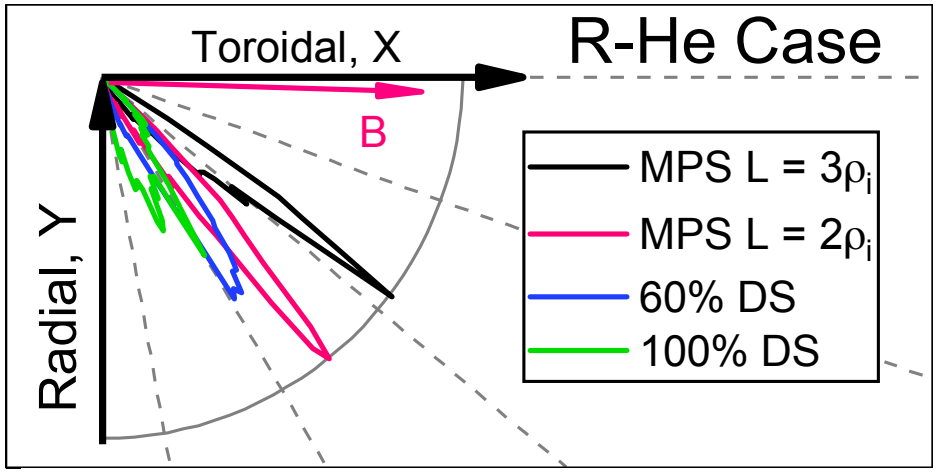


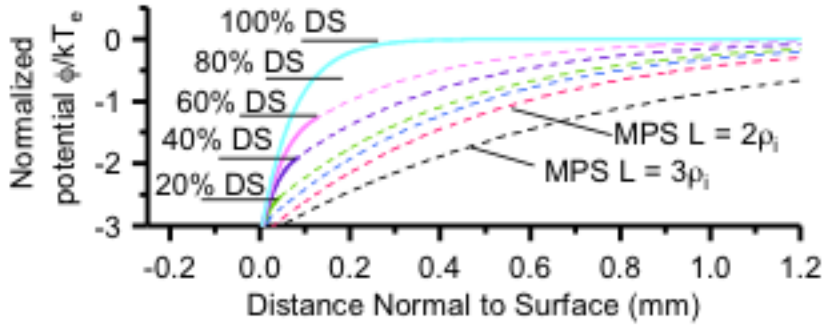


Core in 'catcher’

Incident Ion Angle Distribution

Chrobak





IAD For Case R-He with Varied Sheath