Initial results from XMP-108 'TMB sequencing'

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NSTX-U Physics Meeting
B318 PPPL
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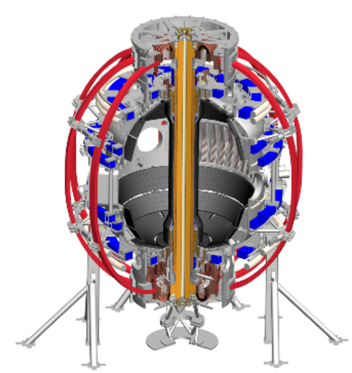


Motivation

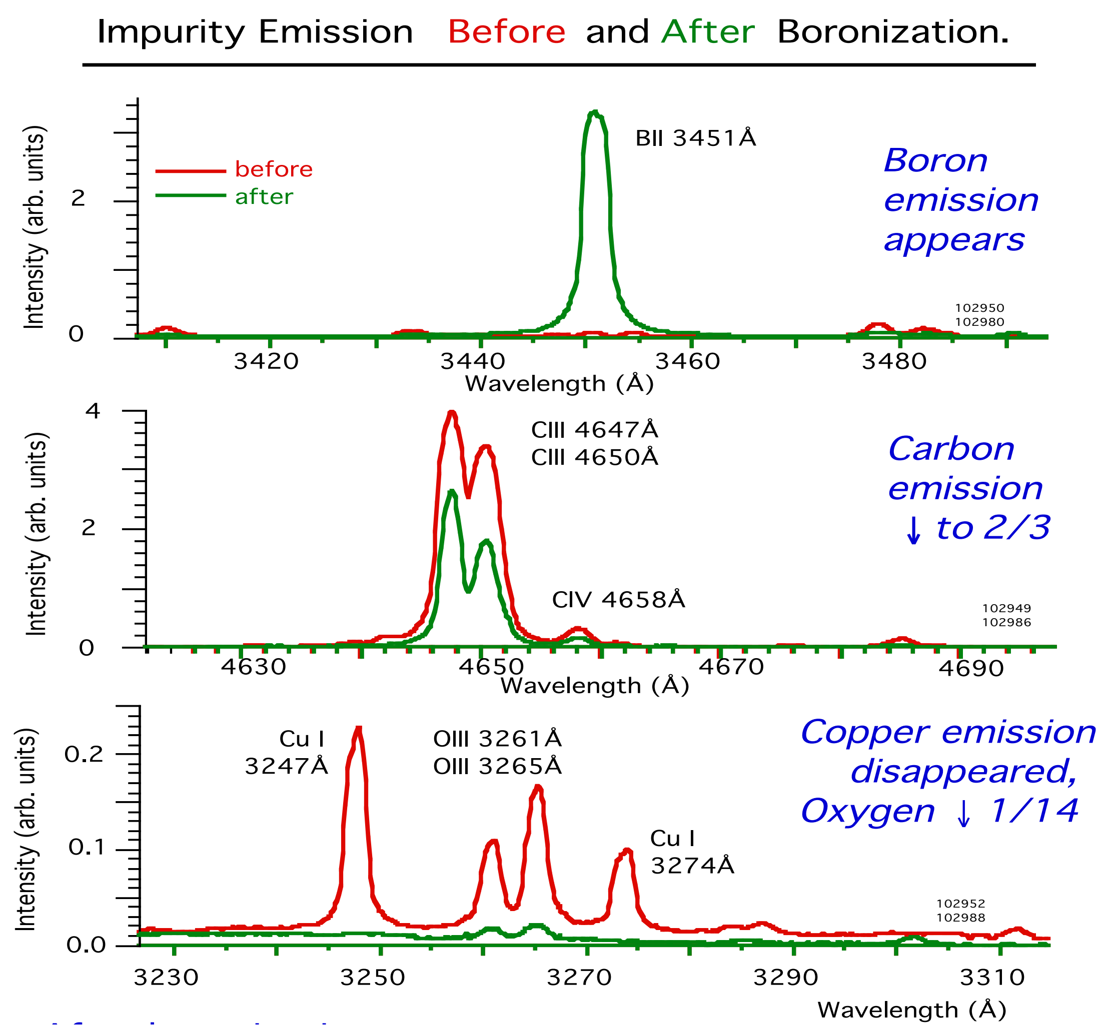
- Wall conditions have profound effect on plasma performance (e.g. JET-ILW; Kotschenreuther colloquium last week)
- Aim to advance the scientific understanding and optimization of wall conditioning by:
  - correlating in-vessel spatial coverage of conditioning species (boron or lithium) and their respective surface chemistries
  - to plasma performance.
- XMP-108 ‘TMB sequencing’ (this presentation)
- XP1505 ‘Optimizing Boronization’ coming later

Previously…

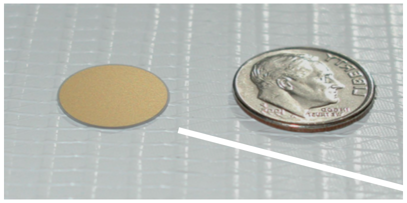
After 2002 boronization:

- D-alpha increased x2
- VB emission decreased to 1/3
- Energy confinement time increased by 30% - 70% (lower loop voltage).
- Ip flattop increased by 50-70%
- Access to H-mode plasmas after 3rd boronization.

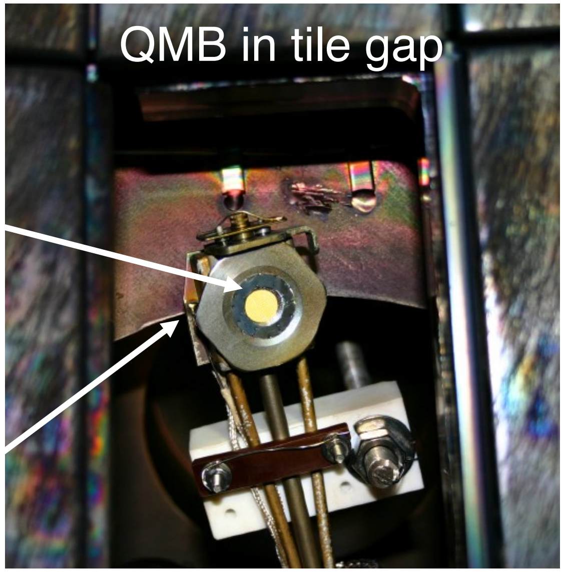
'Boronization in Ohmic plasmas'
[NF 42 (2002) 329]



Quartz Microbalance (QMB)



quartz crystal
coated with gold



thermo-couple

- Crystals oscillate near 6 MHz.
- $$\frac{\text{film mass}}{\text{crystal mass}} = \frac{\text{frequency change}}{\text{bare crystal frequency}}$$
- 81 Hz/µg/cm^2 or
  1.3 Hz per angstrom for 1.6 g/cm^3
- can measure frequency to < 1 Hz ,
- BUT….

2016 QMB locations:

Bay E top & F bottom,
7 cm 'behind' 7 cm wide gap
in outerboard divertor tiles

Bay B midplane ~10 cm outboard
of limiter

Data acquired continuously 24/7

CAVEATS:

- Crystal frequency is also temperature dependent and affected by light
  - temperature changes compensated.
  - average over 'glitches' from GDC light.
  - uncertainties ~ Å (~ 1 monolayer atomic scale)
  - GDC flux reduced in recess ?
  - outgassing of bake deposits ?

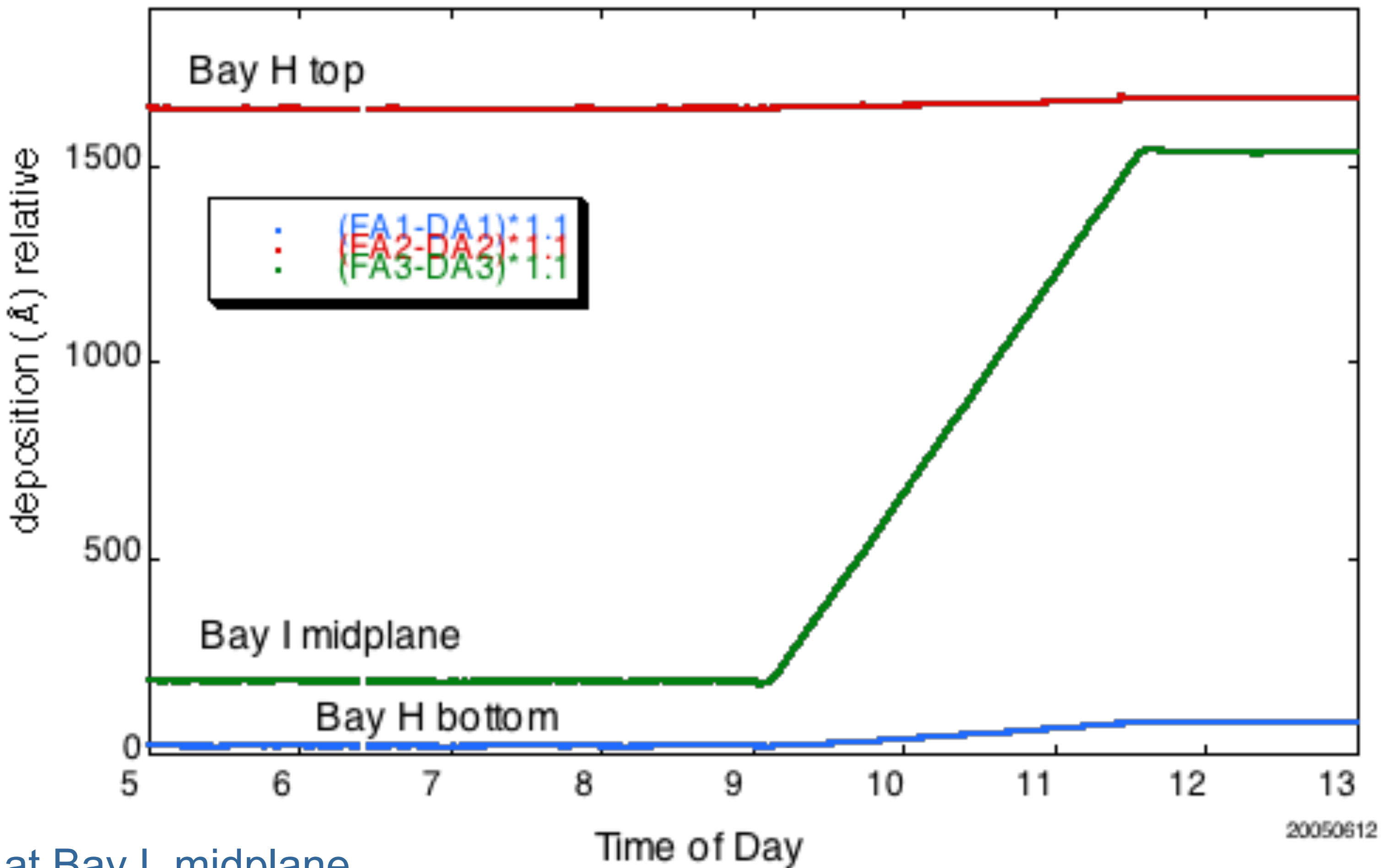
2005 Boron deposition highly non-uniform in NSTX

Totals:

Bay H top 62Å

Bay H bot. 27Å

Bay I mid 1367Å



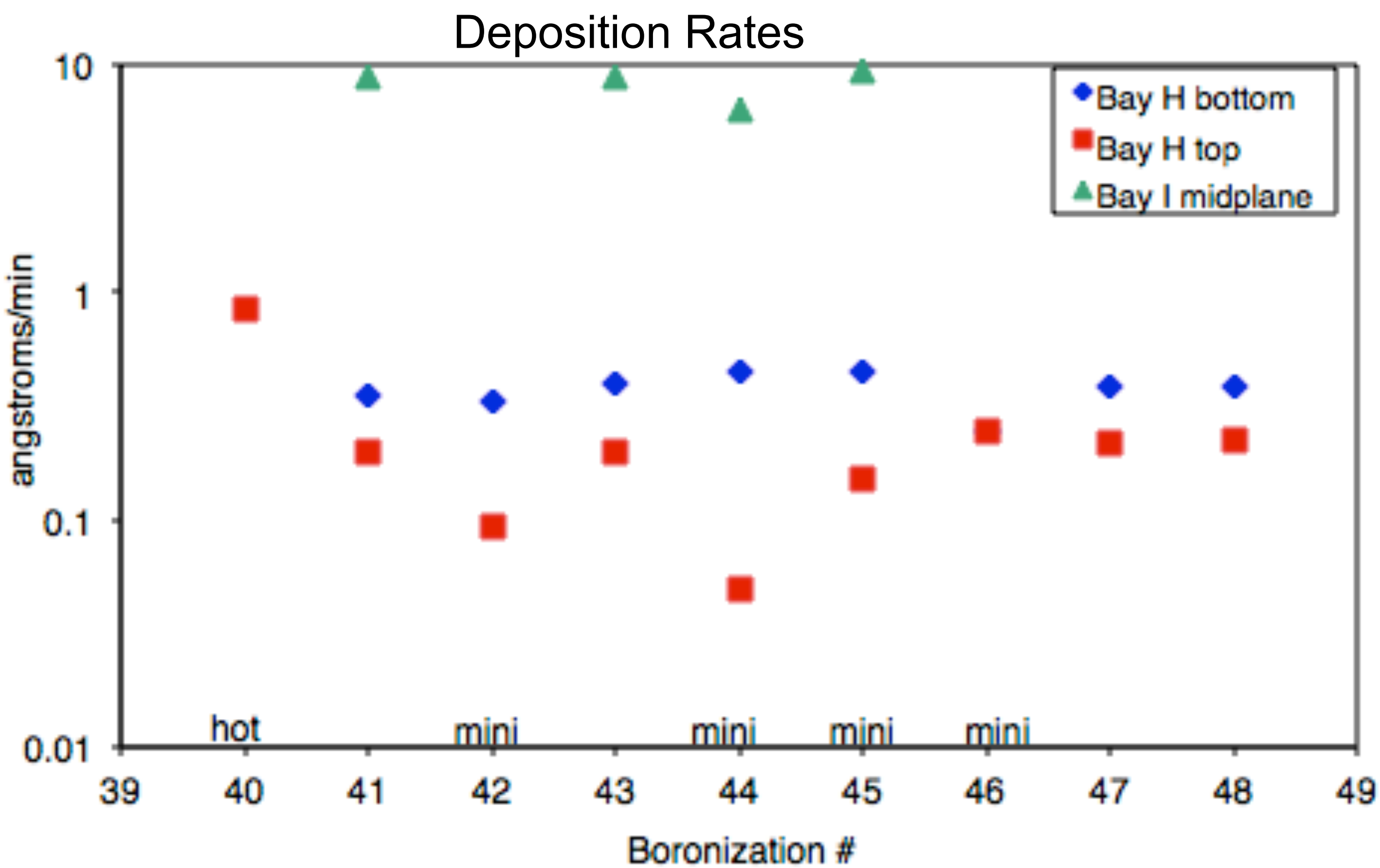
In 2005:

one dTMB inlet at Bay L midplane.

GDC electrodes Bay K and Bay G midplane

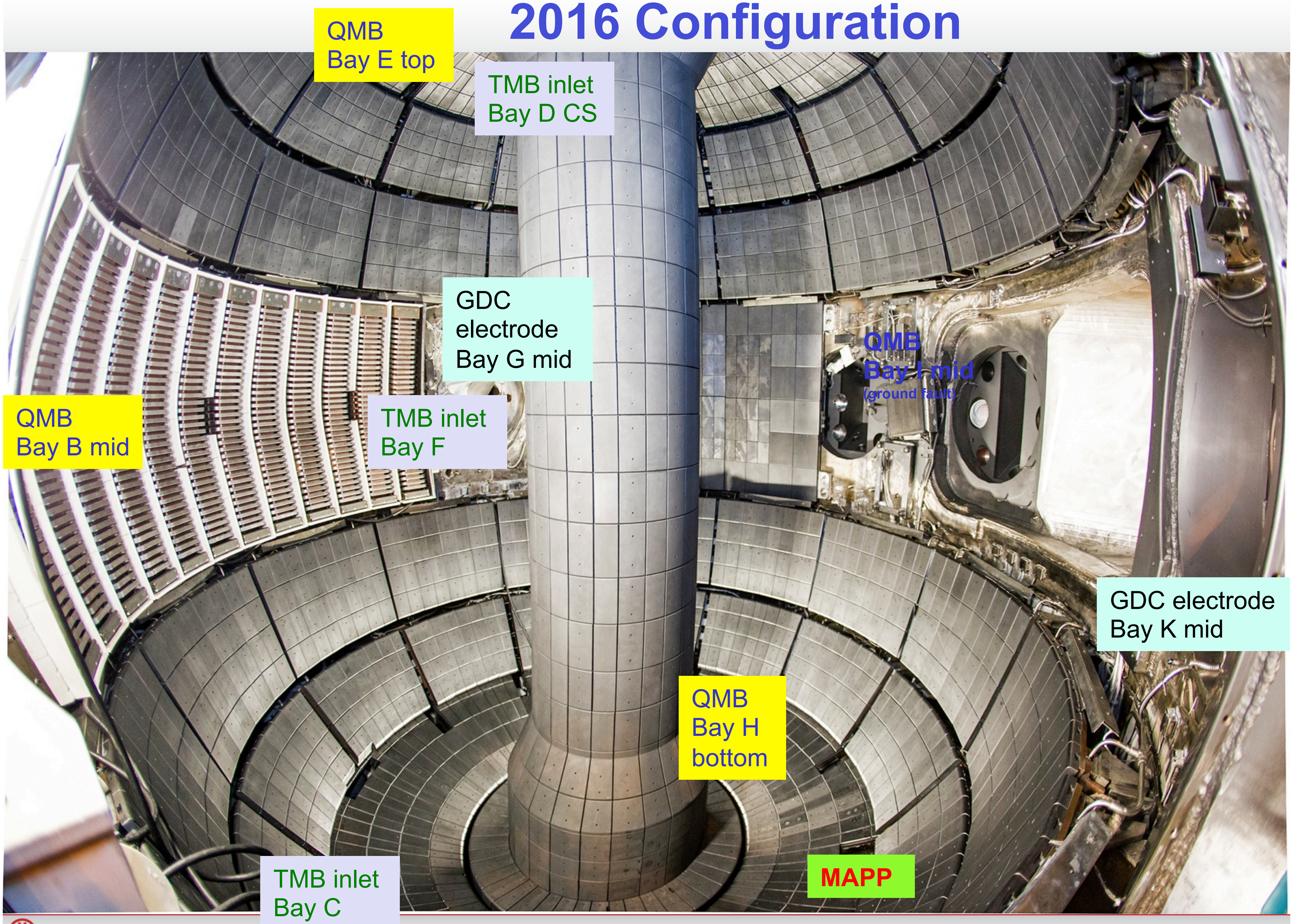
Å thickness based on density 1.6 g/cm^3

2005 deposition rates in NSTX



- Bay I midplane: 9 Å/min
- Bay H bottom: 0.36 Å/min (x25 lower)
- Bay H top: 0.19 Å/min (x47 lower)

2016 Configuration



XMP-108 Sequence:

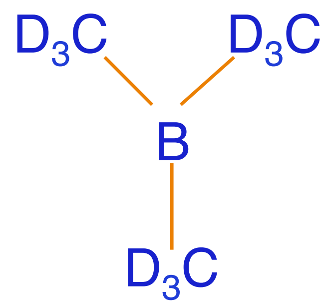
1st boronization, 4 Jan 2016

- 2 mtorr 5% dTMB 95% He GDC (41 min each)
  – 1.5 g d-TMB from Bay D upper CS injector
  – 1.5 g d-TMB from Bay F midplane injector
  – 1.5 g d-TMB from Bay C lower injector

- 4 mtorr 5% dTMB 95% He GDC (25 min each)
  – 1.5 g d-TMB from Bay D upper CS injector
  – 1.5 g d-TMB from Bay F midplane injector
  – 1.5 g d-TMB from Bay C lower injector

- 2 mtorr 100% He-GDC (2 h)

- MAPP XPS analysis before and after boronization, then after weeks plasmas.



deuterated tri-methyl boron

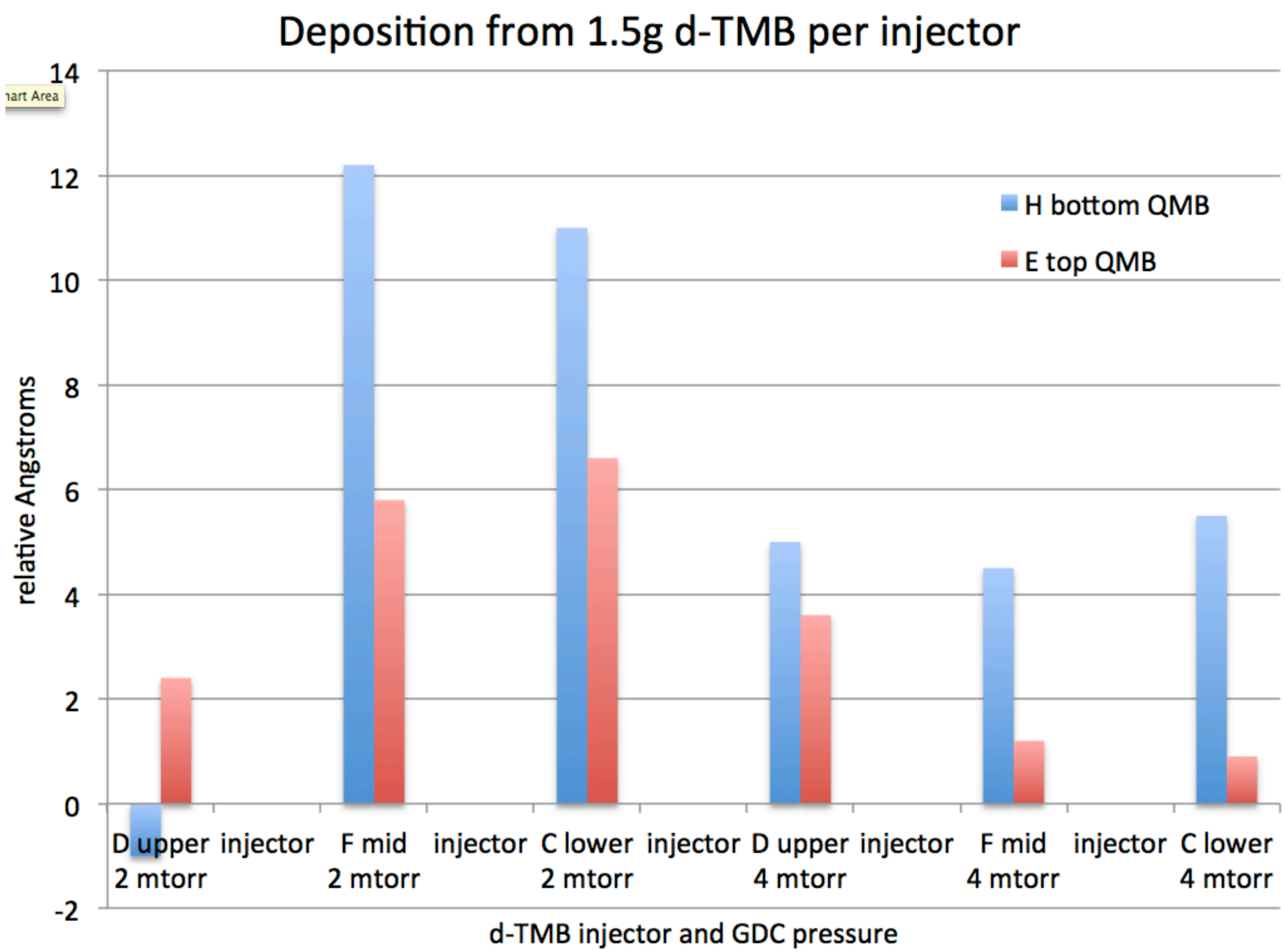
Deposition low on divertors

Results:

- Deposition not uniform

Calculation: 1.5g d-TMB spread uniformly over 40 m^2 = 233Å (@ 1.6g/cm^3)

- conclude d-TMB range < 2 m
- 2 mtorr GDC gives more uniform deposition
- Total deposition from GDC beginning to end:
  - H bottom 39 Å
  - E top 23 Å
  - B mid 292Å



- Bay B mid QMB signal affected strongly by GDC.
- Difference before and after whole sequence related to mass

QMB Summary

- B deposition still heavily weighted to midplane. Deposition on divertors 5-10x less than midplane
  - improved over 2005 value of x25 – x47 with only midplane d-TMB injection
  - GDC electrodes are at midplane.
  - reconsider moveable GDC probe at divertor ?
- More divertor deposition at 2 mtorr GDC pressure
  - presumably due to longer mean free path

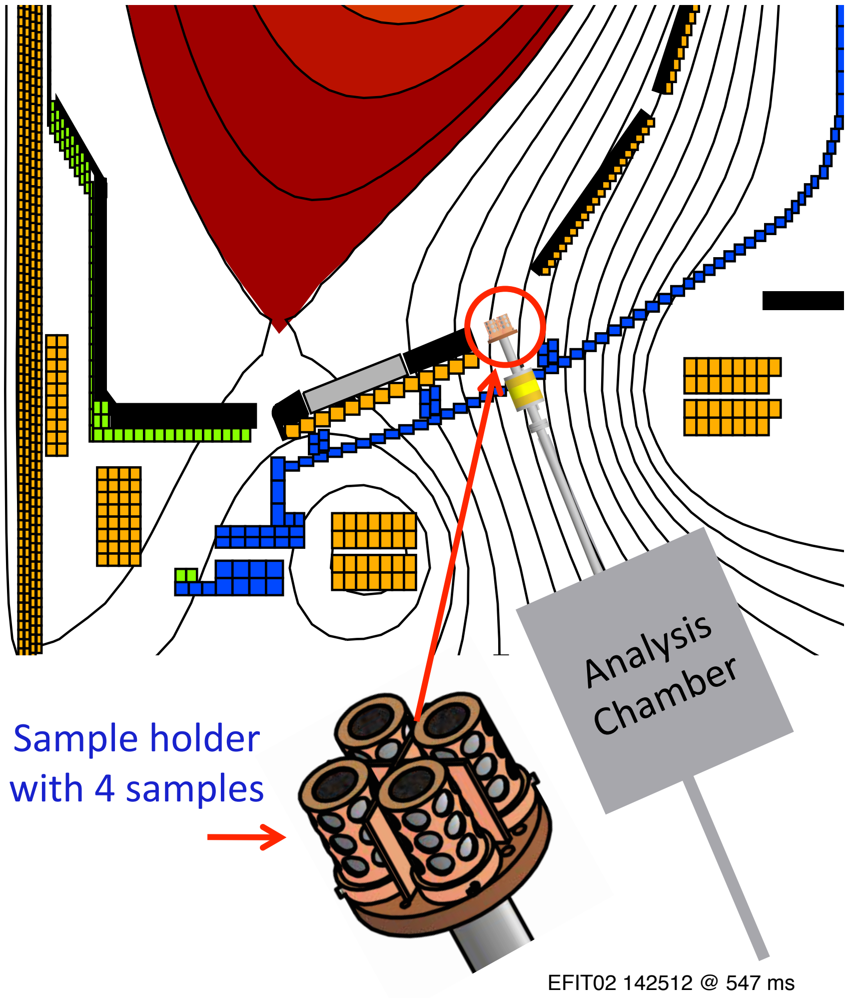
Proposal for tonight's boronization

- Run GDC at 2 mtorr only
- Operate F mid, C lower, D upper injectors separately (as before, but in different order to last week).
- Turn GDC off for 10 mins every 1.5 g d-TMB. (to remove effect of GDC light on Bay B mid QMB).
- Make all adjustments to GDC % power at beginning of each injection interval, then leave constant (to avoid 'glitches').

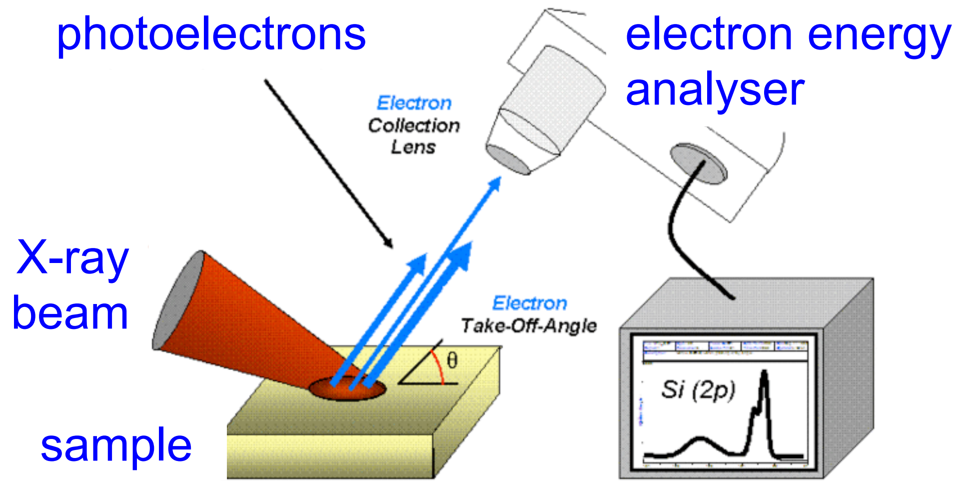
MAPP shows changes in surface chemistry

Materials Analysis Particle Probe (MAPP)

JP Allain, B Heim, F Bedoya, R Kaita et al…



X-ray Photoelectron Spectroscopy

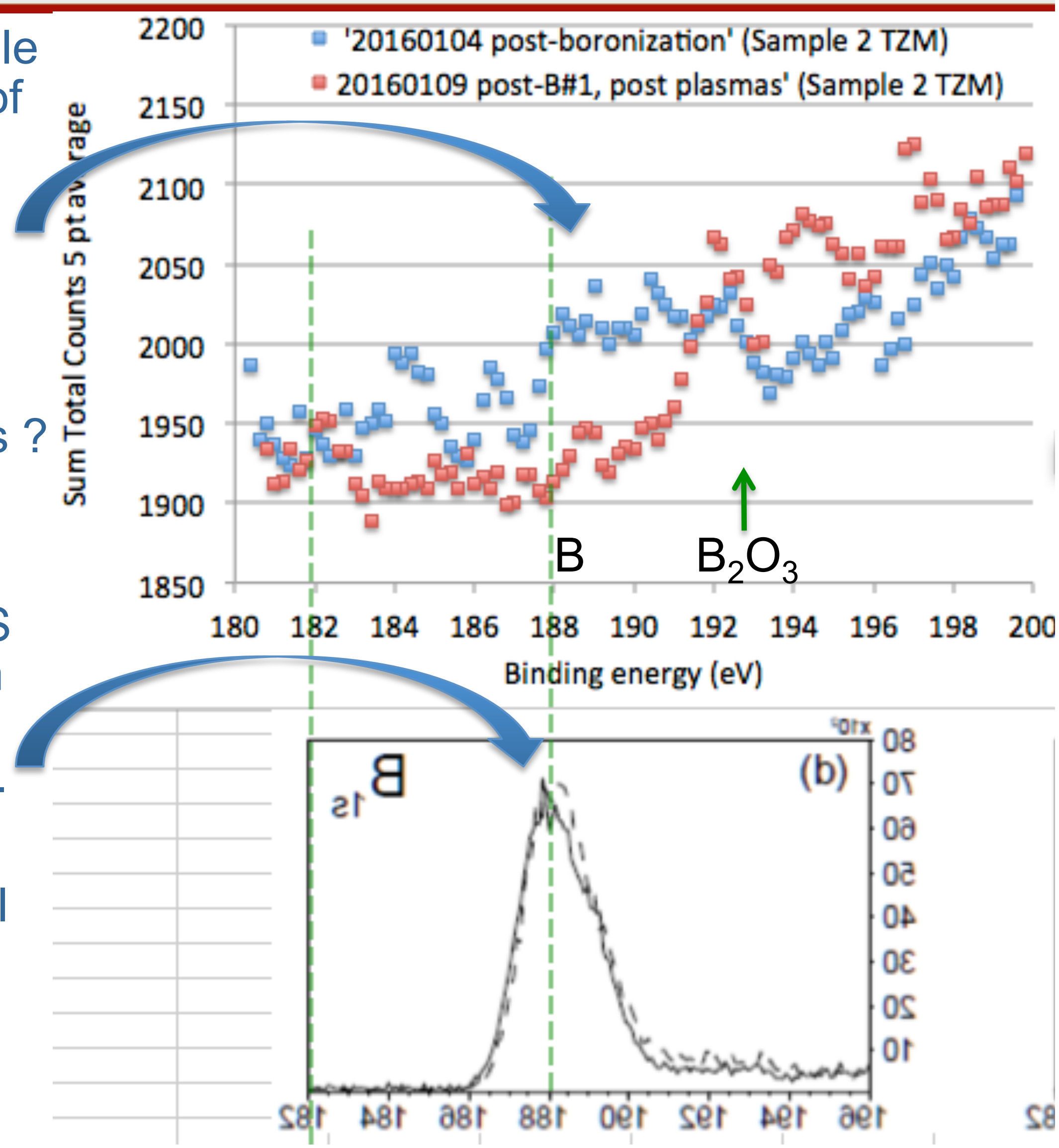


XPS spectrum shows elemental composition (and chemical shifts)

https://commons.wikimedia.org/wiki/File:System2.gif

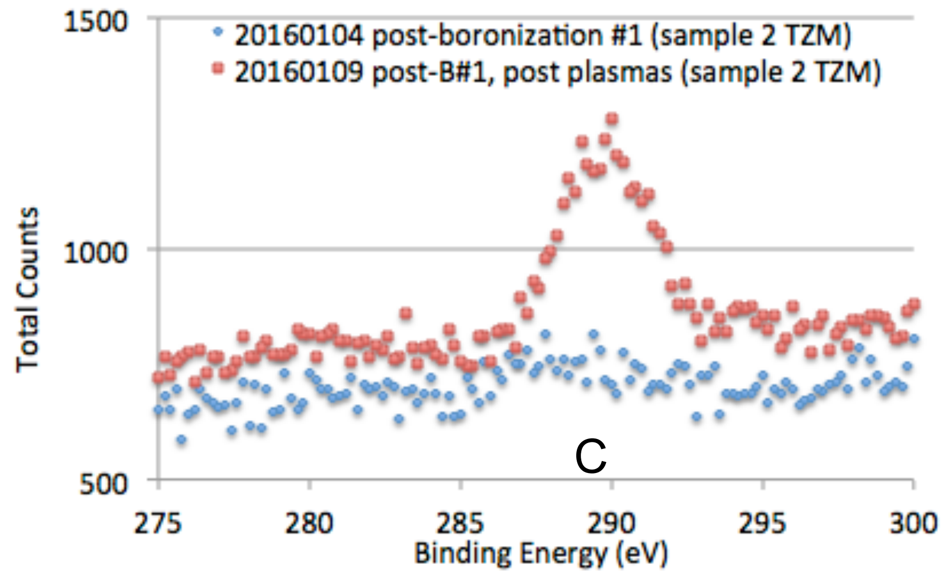
Preliminary XPS data - boron

- MAPP XPS spectrum of TZM sample after 1st boronization and after 4d of plasmas
- data limited by poor S/N
- hint of boron XPS line
  (XPS less sensitive for boron)
- B_2O_3 peak expected at 193 eV
- shift to Be-O after a weeks plasmas ?
- compare to high resolution HR-XPS spectrum of boronized sample from RFX, measured in Koel's lab on campus (Bilel Rais - Talk on 2 Feb).
- Plan to take MAPP samples to Koel lab for HR-XPS analysis in maintenance period.
- Also improve MAPP alignment

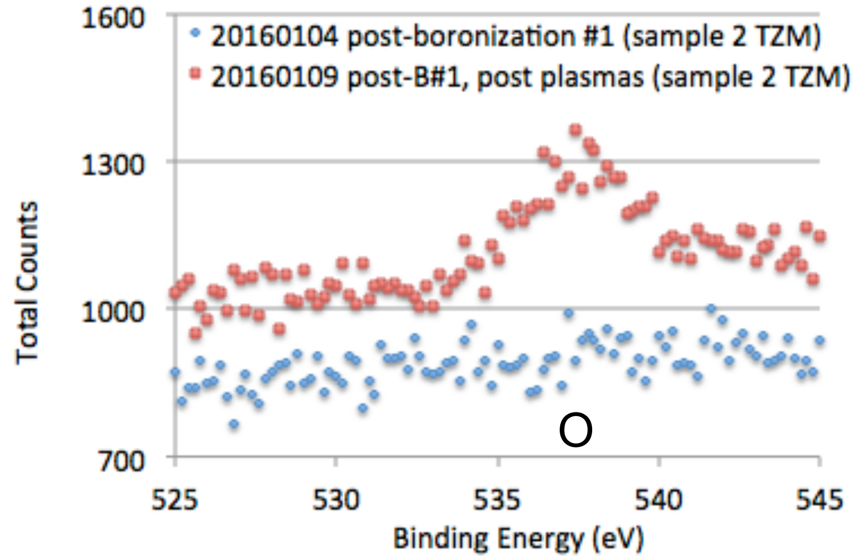


MAPP XPS evidence for carbon migration, and boron oxidation

- Carbon XPS spectrum of TZM sample after 1st boronization and after 4d of plasmas
- Evidence of carbon migration to TZM



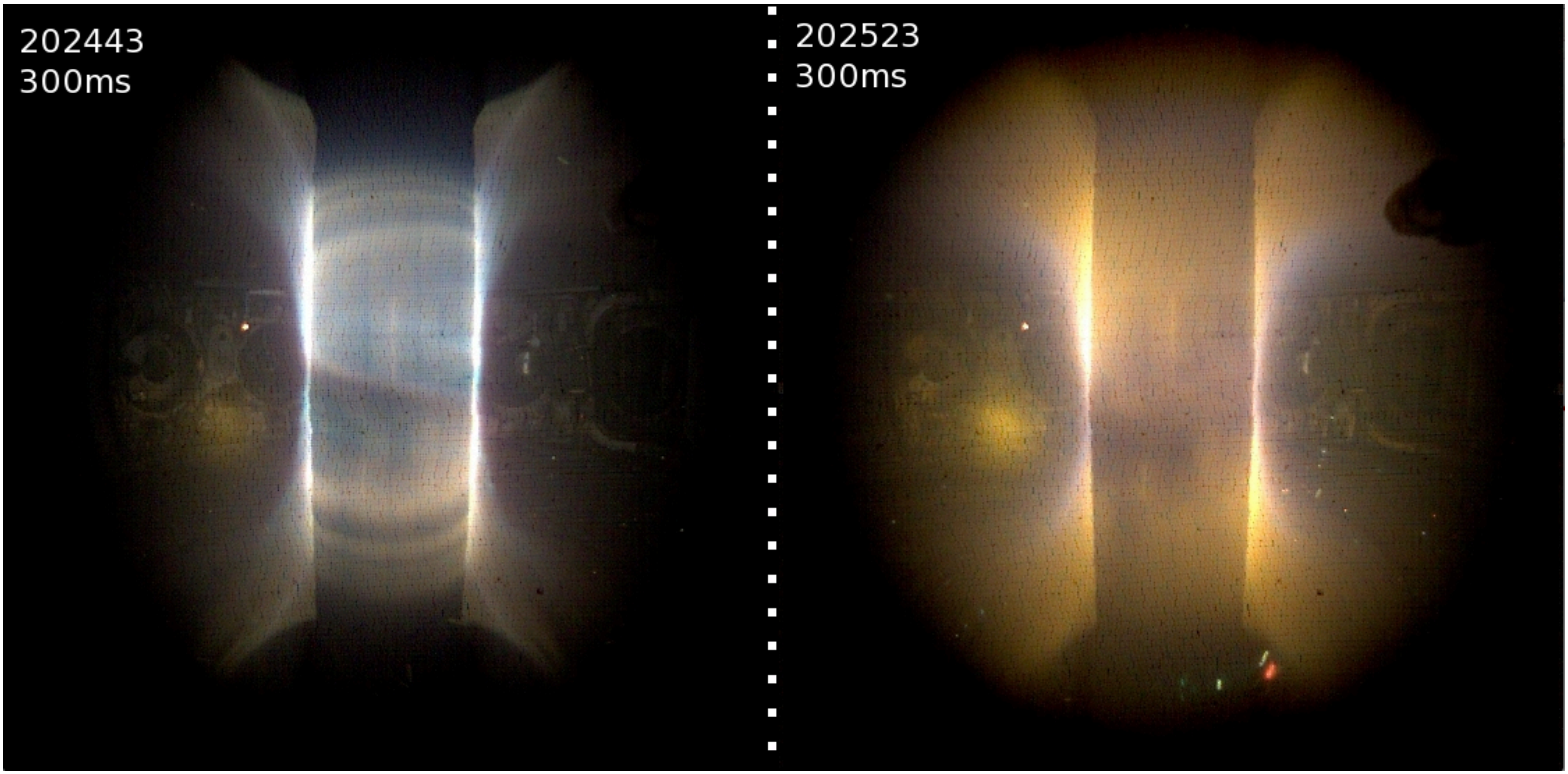
- Oxygen XPS spectrum of TZM sample after 1st boronization and after 4d of plasmas
- Evidence of boron oxidation after 4 d plasmas



Plasma TV

M. Jaworski

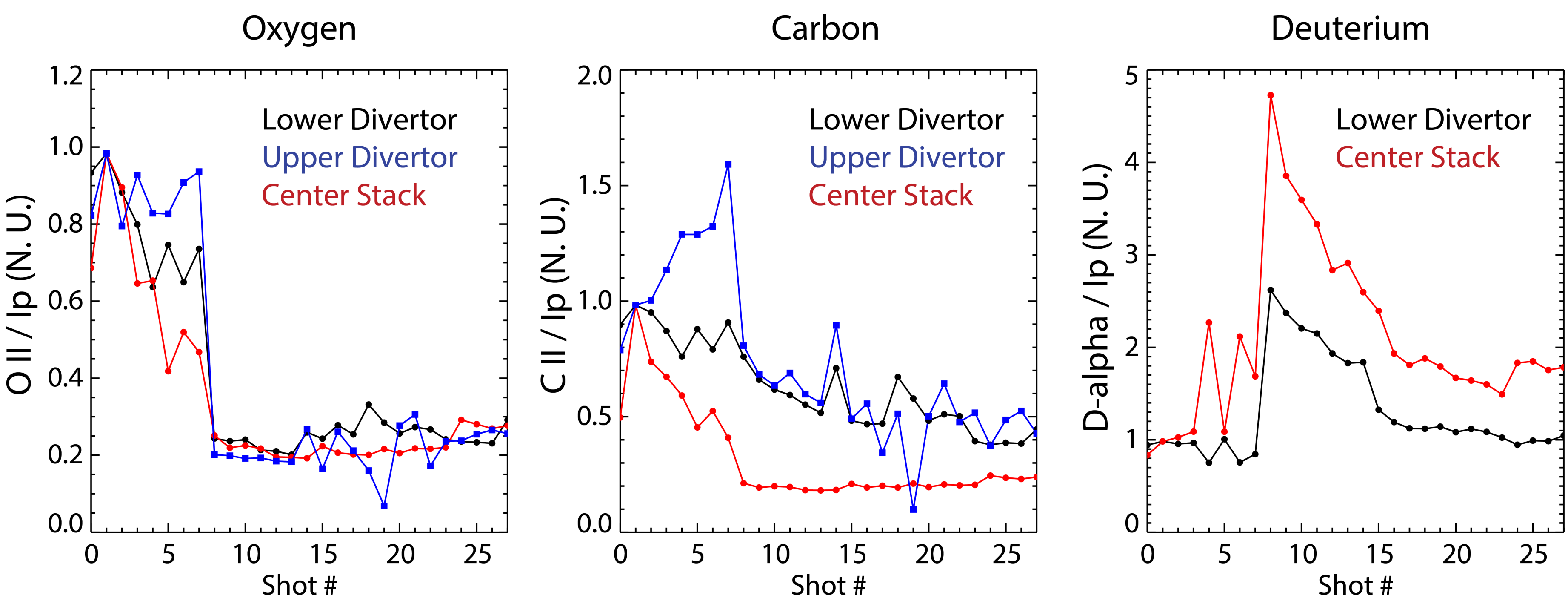
Before boronization 20160104 After boronization



Plasma TV (fcplayer miro4-18380), @ 300 ms, 0.4 ms exposure, Bay B midplane, no filters.

Oxygen reduction after boronization

- Inner wall limited discharges, deuterium pre-fill, LFS He fueling
- After boronization, reduction in O II (4416Å) from center stack, lower and upper divertors
- Some reduction in C II (5145Å) (boronization + variability due to discharge development?)
- No clear boron signature on filterscopes but boron lines observed on VIPS2 (3451Å, 4940Å, …)



F. Scotti, V.A. Soukhanovskii

Summary

QMB:

- QMB deposition on divertors 5-10x less than midplane
  - uniformity improved over 2005 values of x25 – x47 with only midplane d-TMB injection
  - more divertor deposition at 2 mtorr GDC pressure > presumably due to longer mean free path

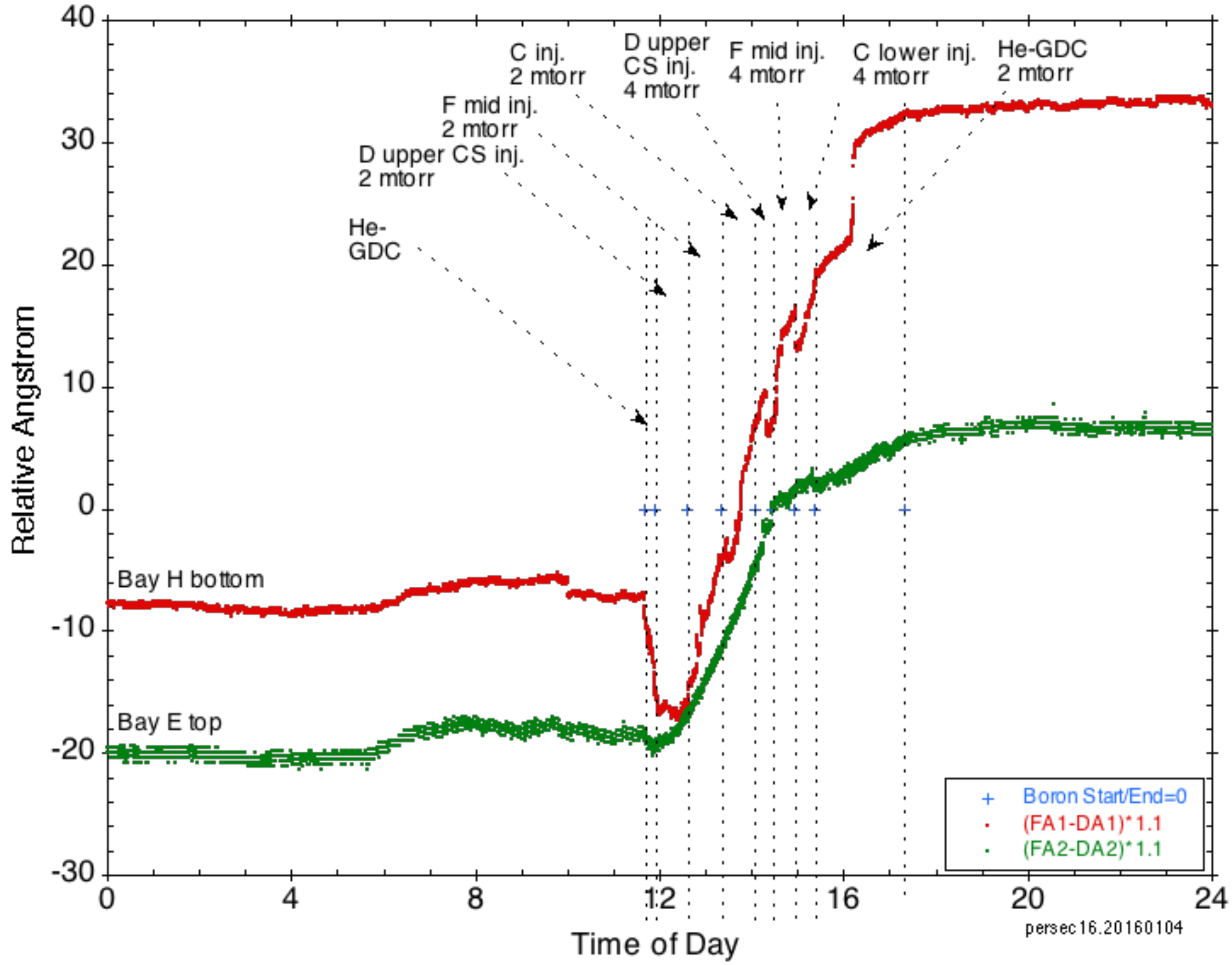
MAPP:

- Exciting first XPS data - reveals changes in NSTX-U surface chemistry !
- Opens window to correlate surface conditions with plasma performance

QMB details…

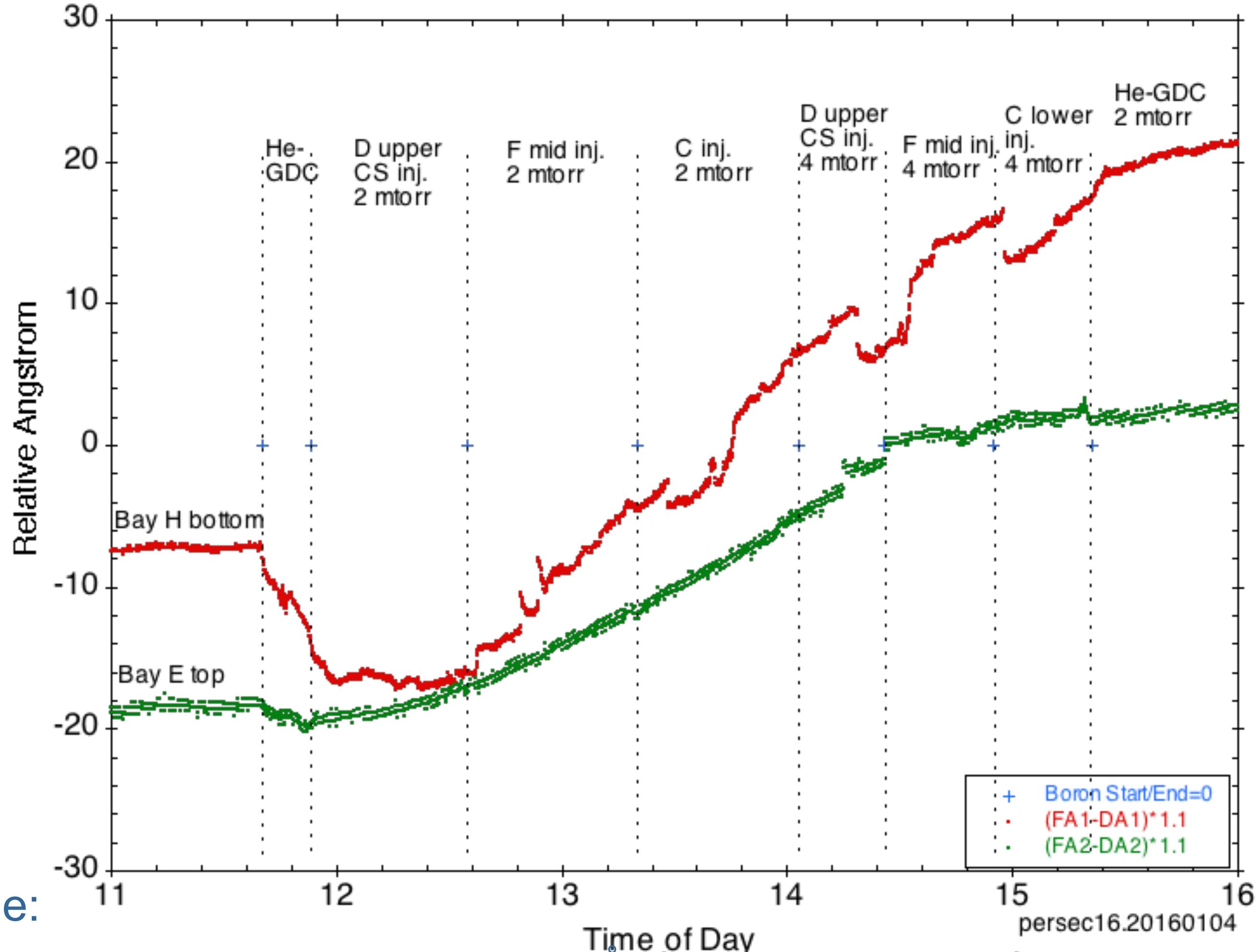
- QMB analysis in detail

Divertor deposition 20160104



'laminations' due to bit noise in TC measurement

D-TMB deposition on divertor

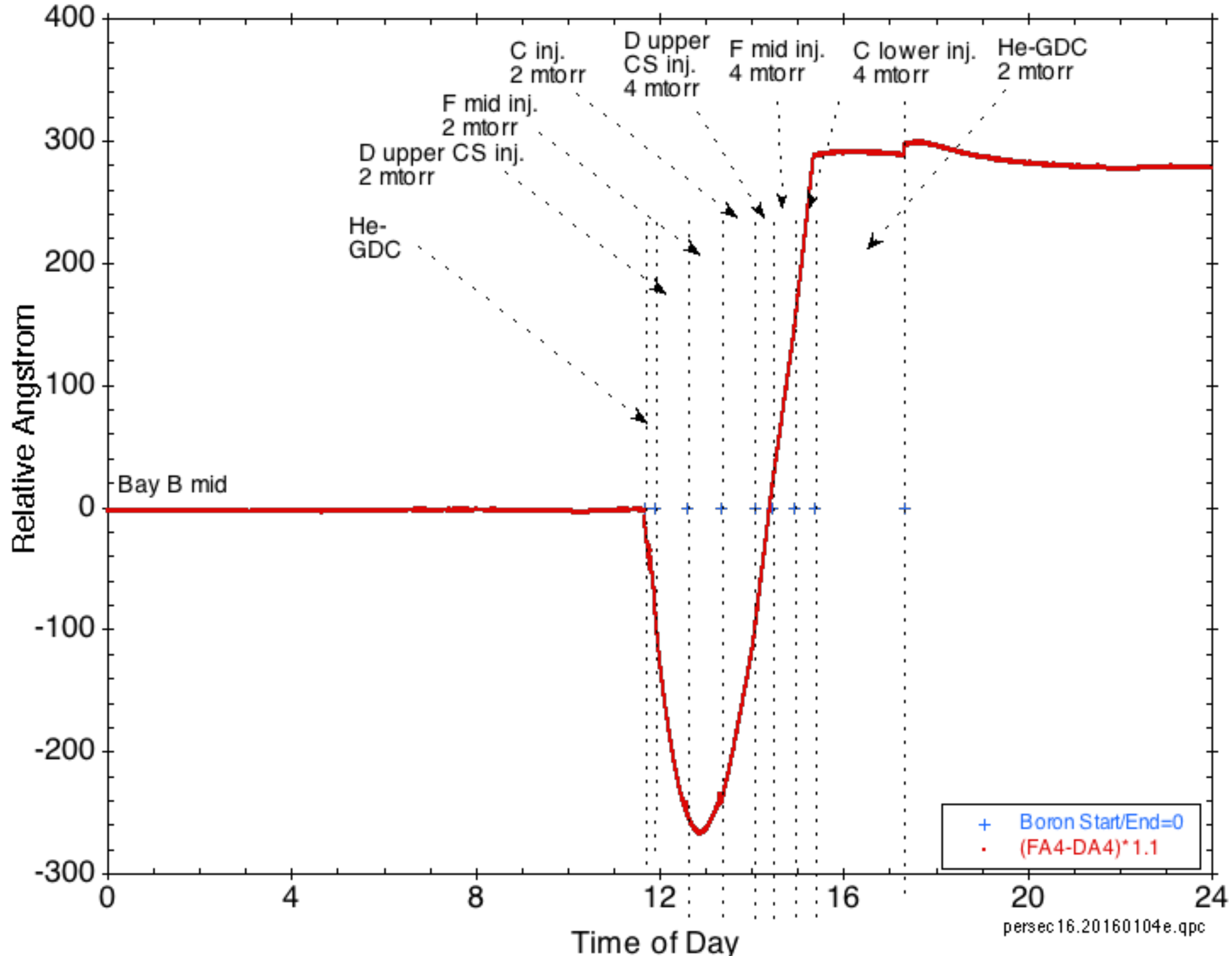


Conclude:

– Deposition low compared to ~1400 Å for 9 g d-TMB uniform coverage of 40 m^2

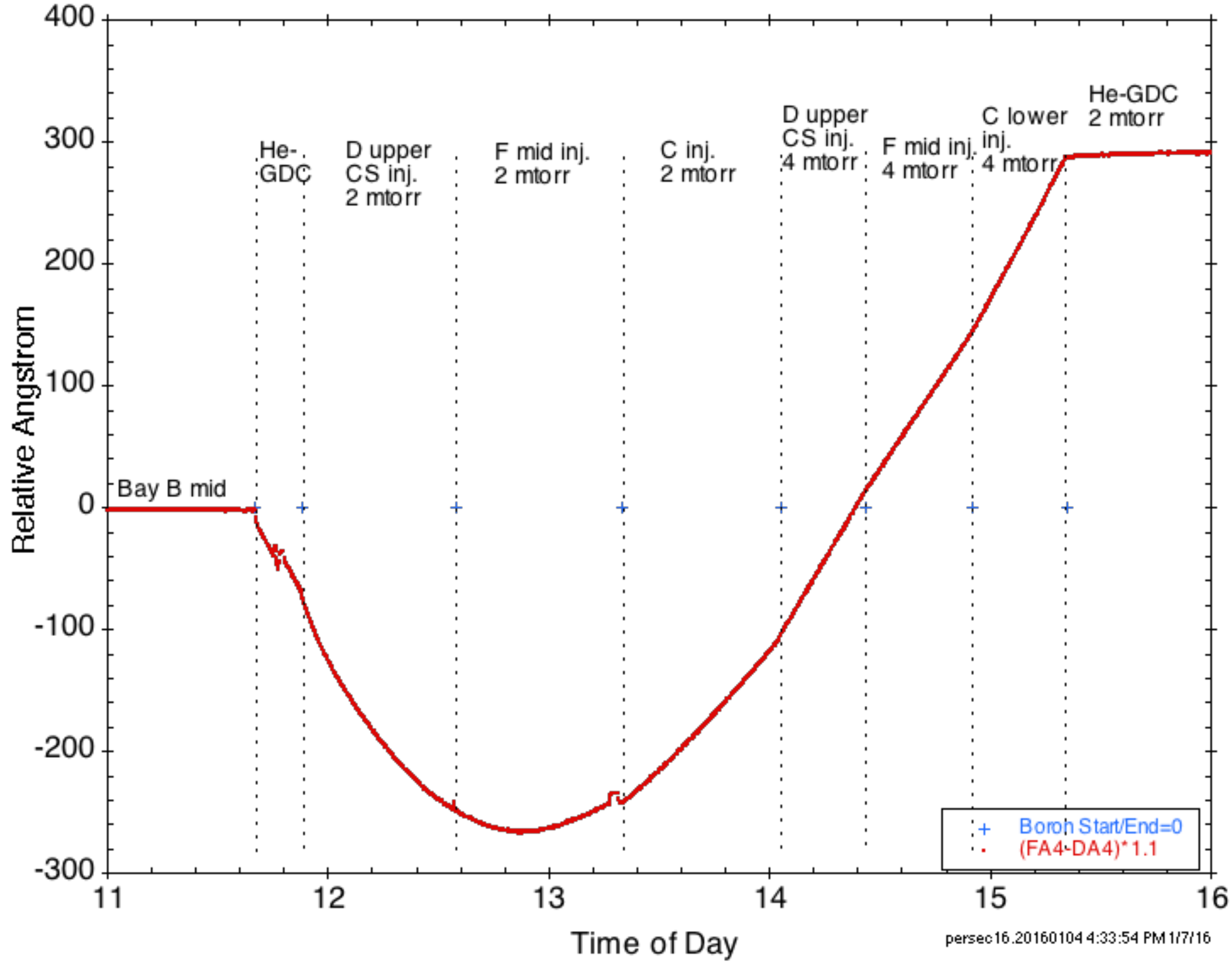
– More divertor deposition at 2 mtorr

D-TMB deposition at midplane



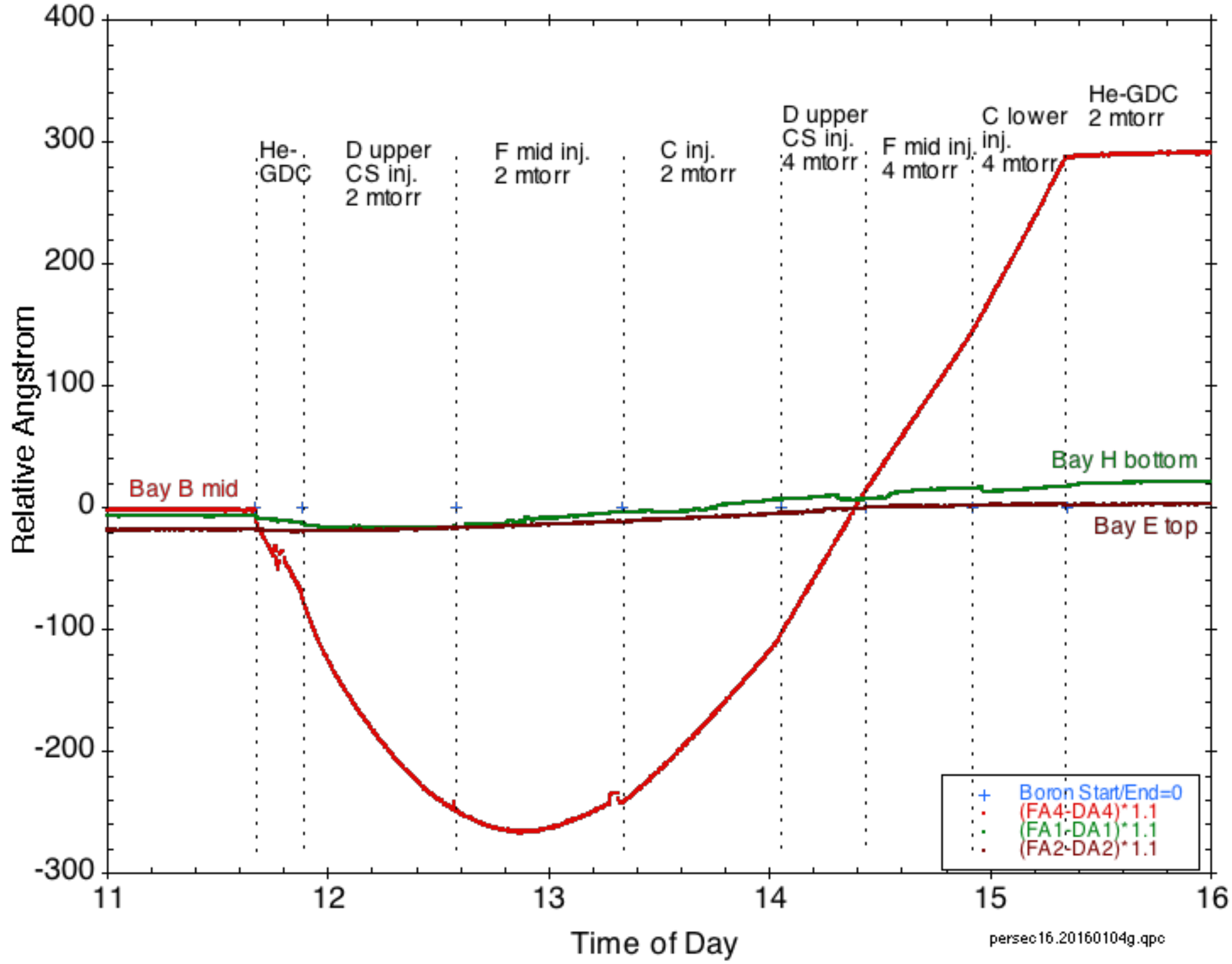
- Bay B mid QMB signal affected strongly by GDC.
- Total GDC end – GDC beginning = 292 Å

D-TMB deposition at midplane

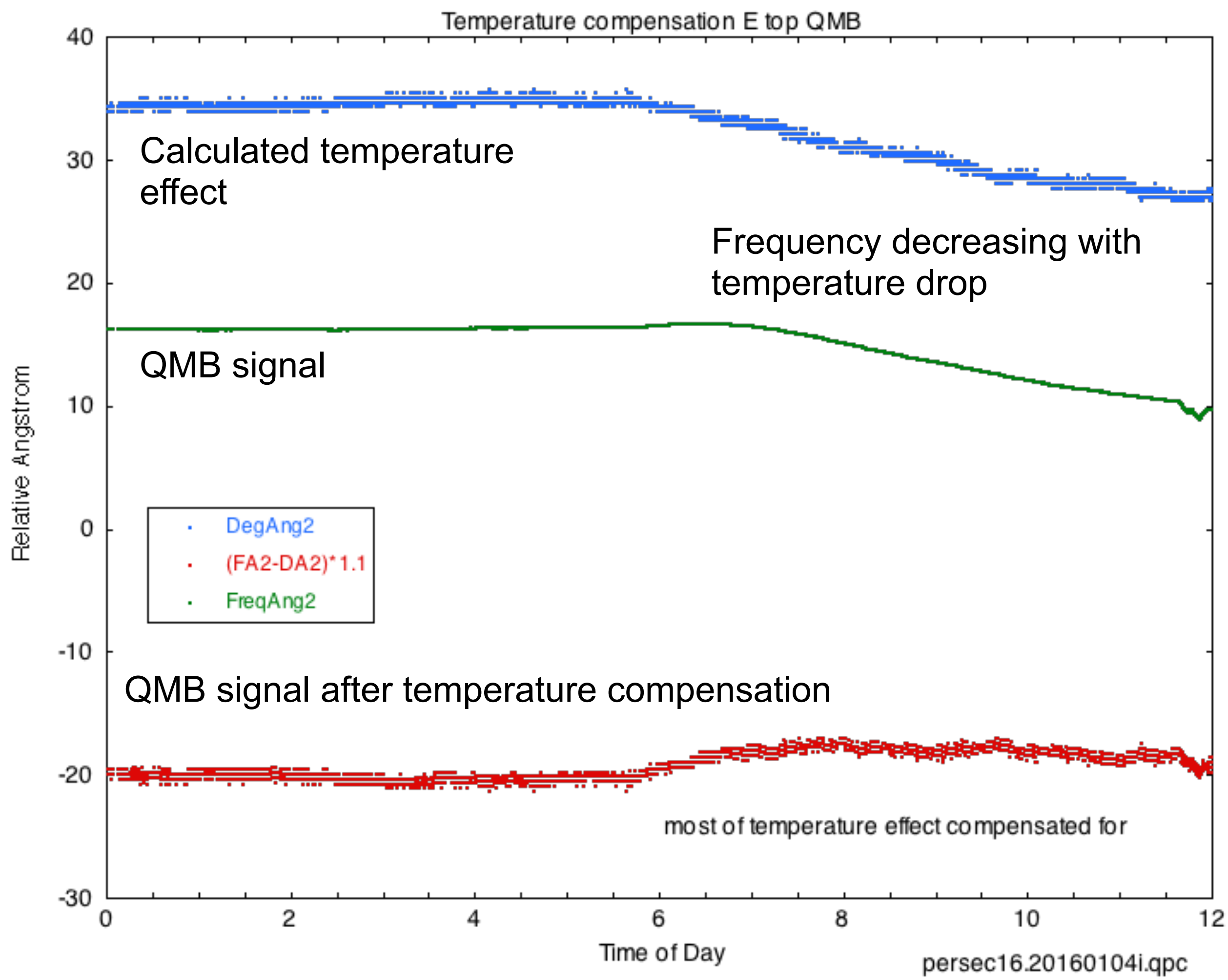


- Bay B mid QMB signal affected strongly by GDC light.
- Total GDC end – GDC beginning = 292 Å

All three QMBs



Temperature compensation E top QMB



Temperature compensation H bottom QMB