Surface reflectivity and carbon source studies with the Liquid Lithium Divertor in NSTX

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Princeton Plasma Physics Laboratory PPPL

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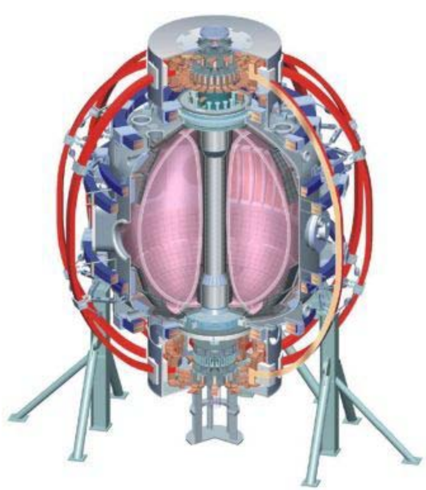

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NSTX and lithium wall conditioning

- Li-wall conditioning is routinely applied in NSTX by means of evaporators

- In 2010 a Liquid Lithium Divertor (LLD) was utilized to exploit enhanced pumping/reservoir capabilities of liquid lithium

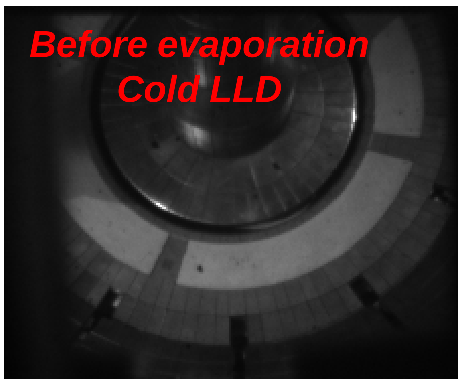
- Understanding surface conditions is a key to liquid Li exploitation
    - Necessity of having a clean Li surface
    - High reactivity of molten Li with vacuum residual gasses, D, sputtered C

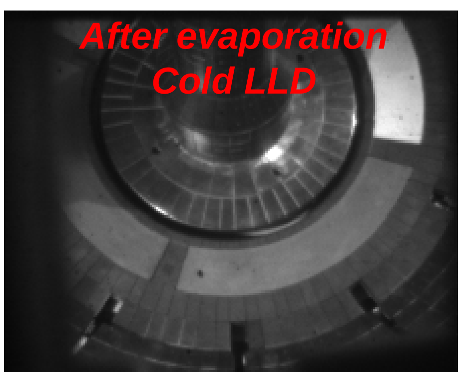
- In this talk divertor cameras were used to relate surface conditions to:
    - vacuum measurements and Li evaporation
        - surface diffuse reflectivity before/after evaporation – during heat-up
    - plasma interaction
        - local recycling on hot and cold LLD
    - surface contamination by sputtering from other PFCs
        - analysis of C influxes

Change in surface reflectivity observed following big evaporations

LLD experiments preceded by massive Li evaporations to fill hot LLD (~hours, ~days)
Unfiltered divertor cameras with same exposure, same illumination (vessel filaments)

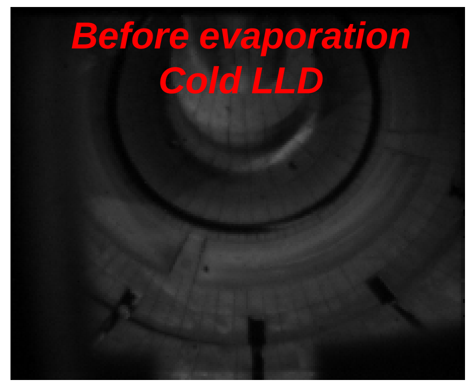
March 23 –
1st evaporation
Both LITERs
(12 g – 5% LLD fill)



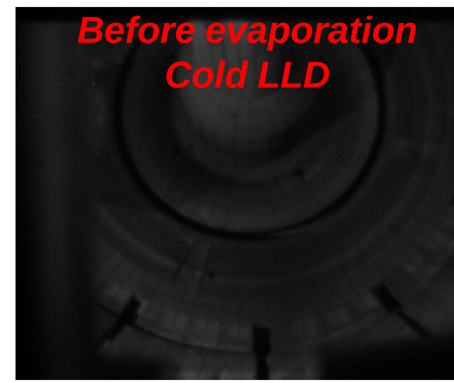


April 2nd
Exposure over weekend
No evaporation

August 8 –
Mega Evaporation
Both LITERs
(250 g -75h – 50% LLD)

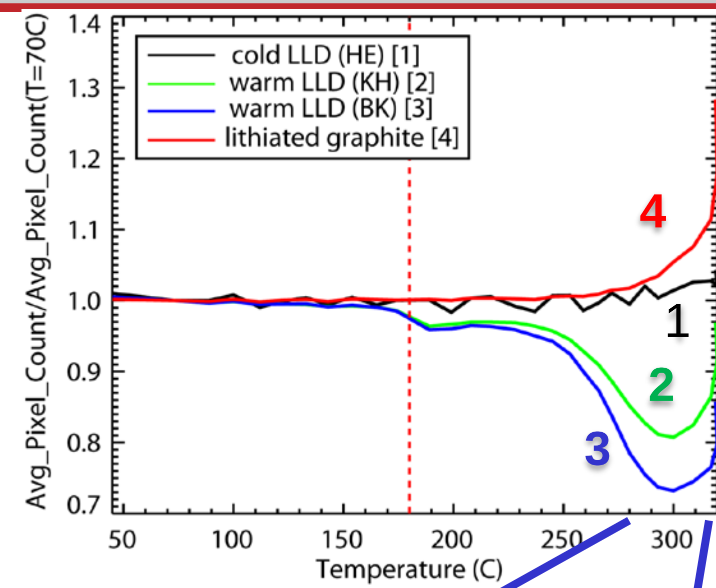


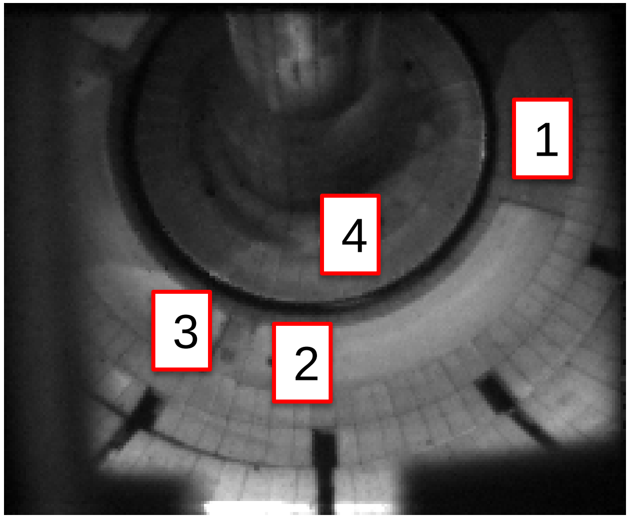
October 28 –
Last evaporation
One LITER (7 g)

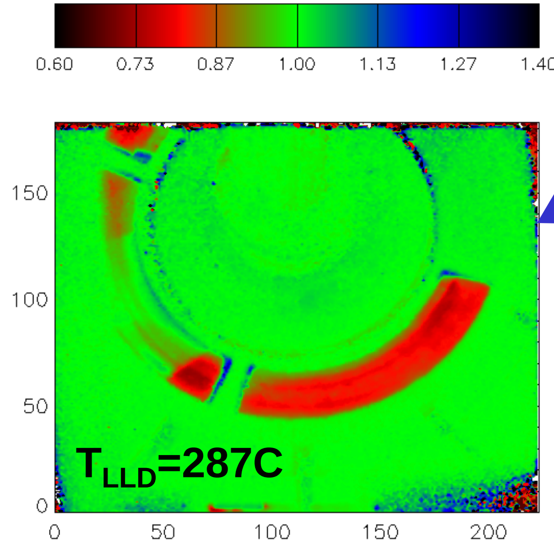


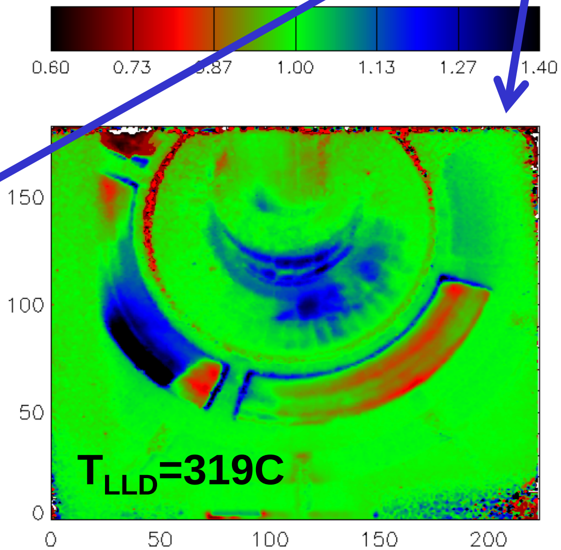
Surface diffuse reflectivity changes with LLD bulk temperature after Li melting point is achieved

- ~80 grams of Li deposited (5.5 g on LLD)
- Diffuse reflectivity of lower divertor PFCs monitored during LLD heat-up to 320C
- Relative reflectivity changes (ratio with respect to initial conditions at T_{LLD}=70C)



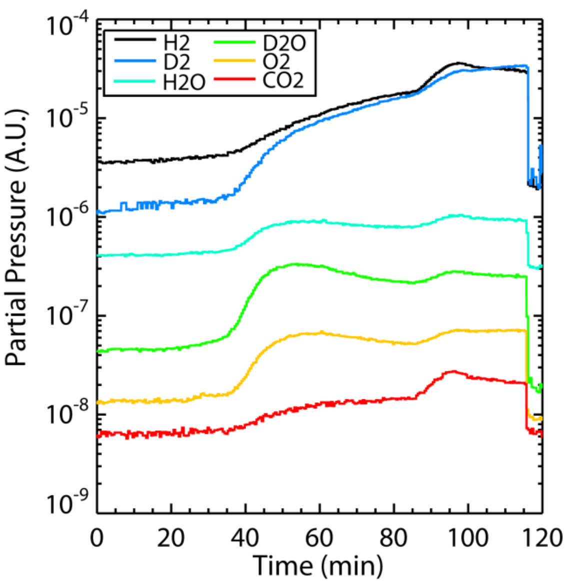


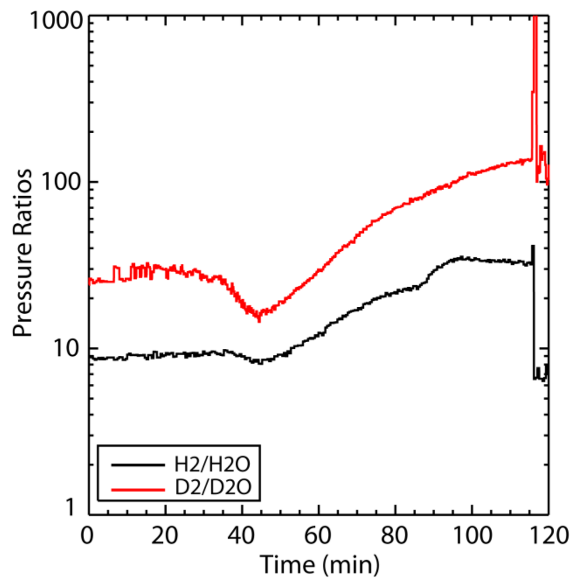


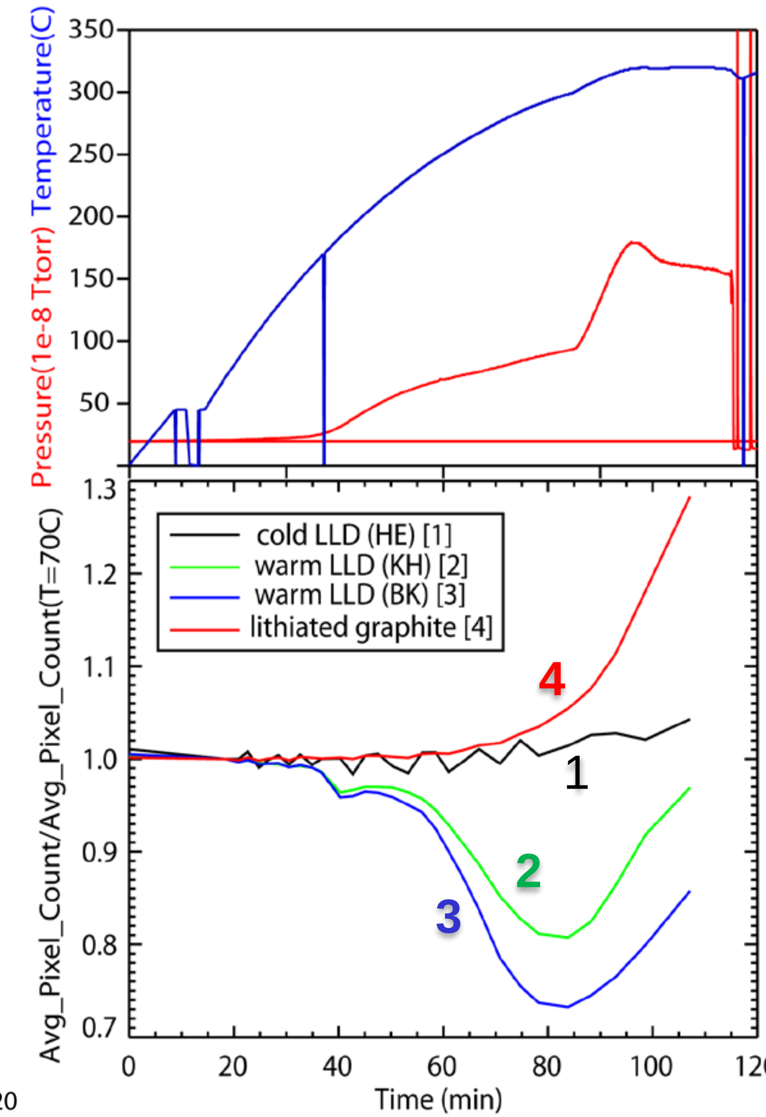


Reflectivity changes could be related to reaction of Li with vacuum residual gasses during LLD heating

- During LLD heat-up increase in vacuum base pressure over 1e-6 Torr
- Increase in reflectivity due to Li reactions with residual gasses?
- Surface segregation of impurities?
- Li+1/2 D_2 → LiD (white)
- Li+H_2O →LiOH (black) +1/2 H_2
- Li+1/2 O_2 → Li_2O (white)
- 2 Li+3/2 CO_2→ Li2CO_3 (white) +1/2 C







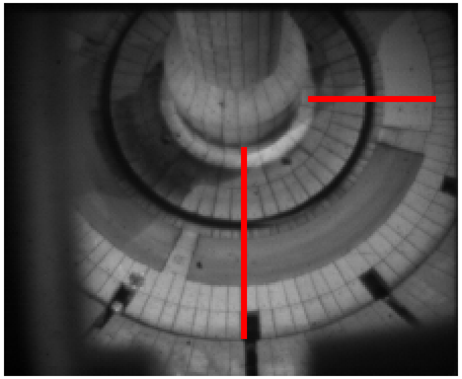
No apparent decrease in D-alpha emission on heated LLD as expected in case of reduced local recycling

- Divertor cameras give possibility of observing different LLD segments (heated vs. unheated)

- No decreased recycling observed on heated LLD with respect to solid Li coatings

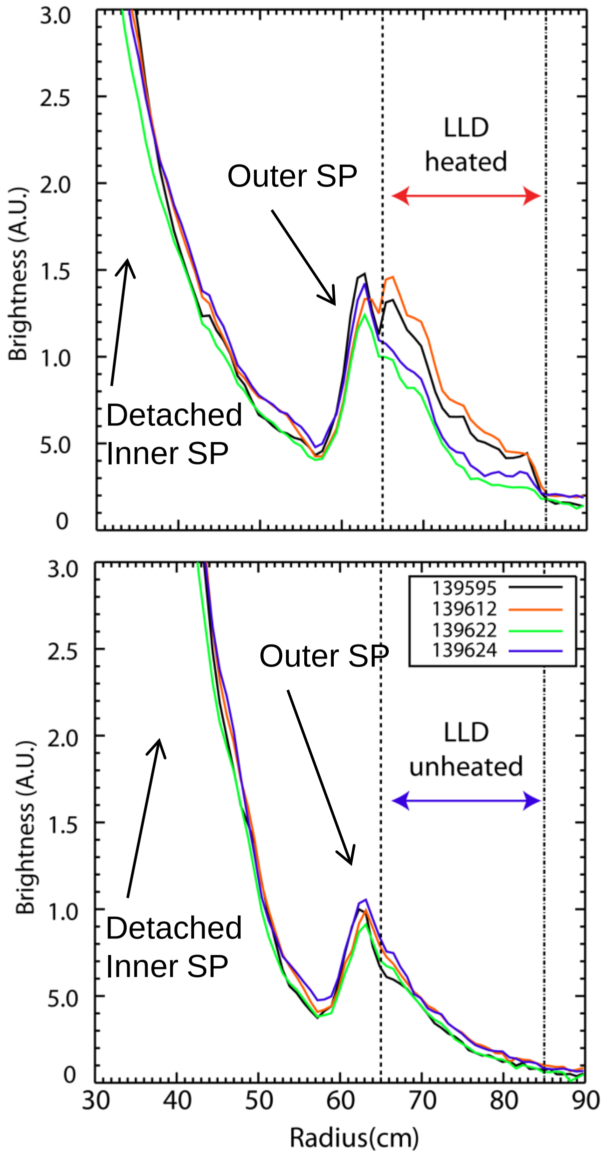
- Relatively smooth transition between graphite and LLD on cold LLD segment

- Increased D-alpha emission on hot LLD segment attributed to reflections



Cool-down sequence with 50% LLD fill

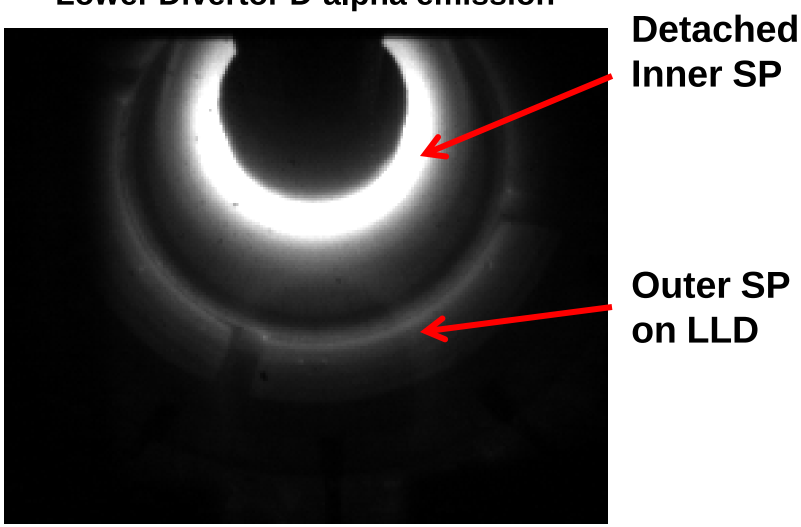
139595 T=220C w LITER
139612 T=217C w LITER
139622 T=100C w/o LITER
139624 T=110C w/o LITER

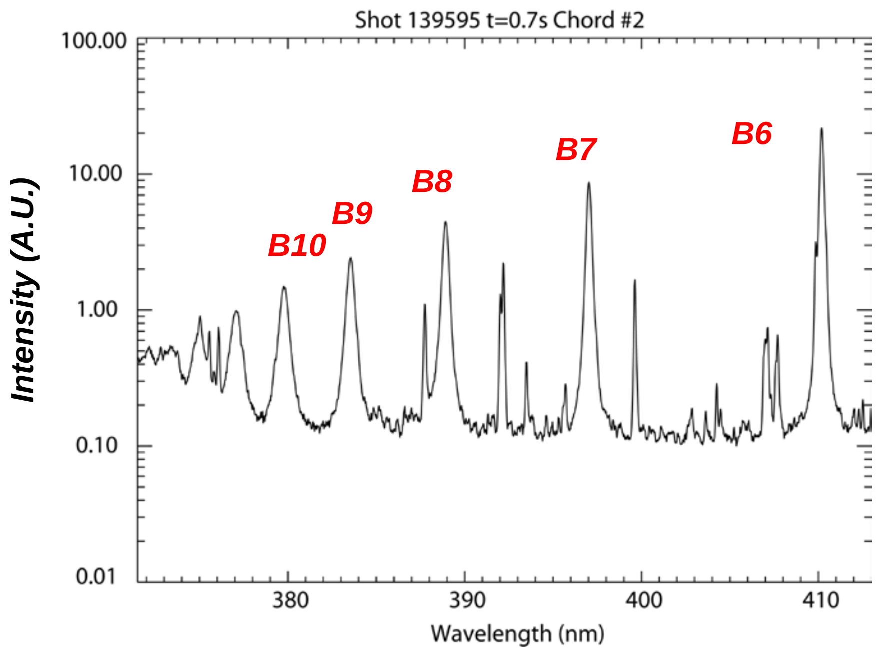


Detachment of inner divertor in NSTX discharges with OSP on LLD following big evaporations

- With solid Li coatings, typically the decreased recycling:
    - decreased divertor n_e and increased T_e → decreased recombination rate
    - caused ISP re-attachment
- However in LLD discharges, inner divertor detached
- Stark broadened high-n Balmer spectrum typical of high n_e recombining plasmas (e.g. n_e~$4X10^{20}m^{-3}$ from B10 Stark broadening , T_e<1.6eV)
- Suggests limited pumping of Li coatings

Lower Divertor D-alpha emission

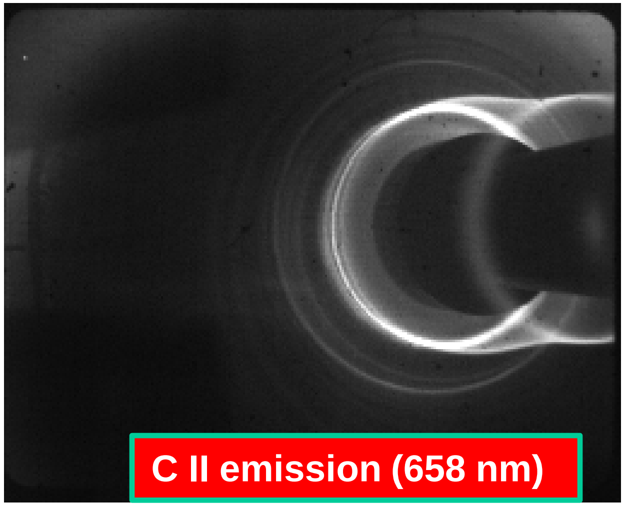




Impurity particle influxes are measured in NSTX by divertor fast cameras and divertor spectrometers

- Significant core carbon concentrations were observed in ELMy discharges with outer strike point on the LLD.
- Importance of understanding C sources in NSTX and the purity of Li on the LLD surface
- Divertor fast cameras are equipped with narrow band pass filters for impurity influx studies (e.g. CII, CIII, etc.).
- C influxes inferred from absolute brightness and ADAS S/XB coefficients based on the local n_e and T_e

$$\Gamma_i = \frac{S}{X\,B}\,\Gamma_{ph}$$

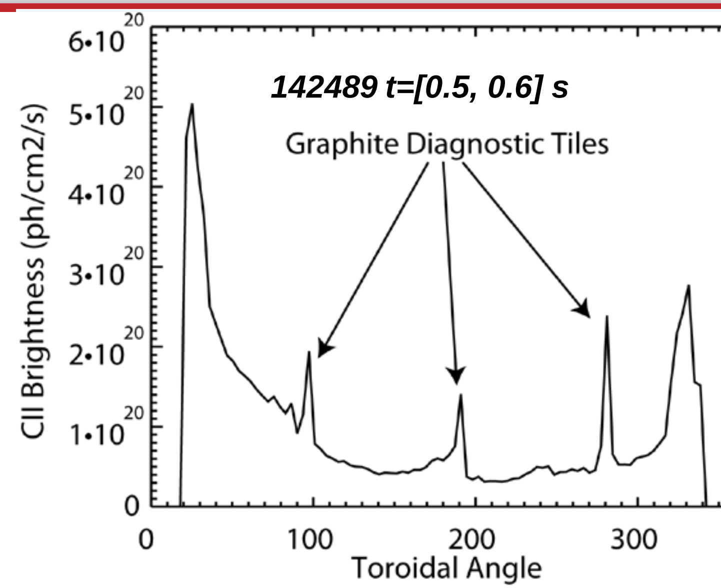


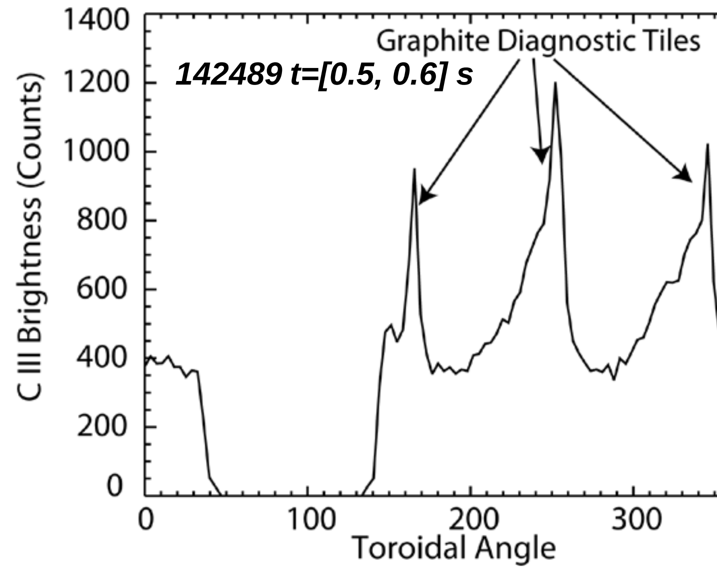
Analysis of carbon sources with outer strike point on the LLD complicated by presence of different PFCs

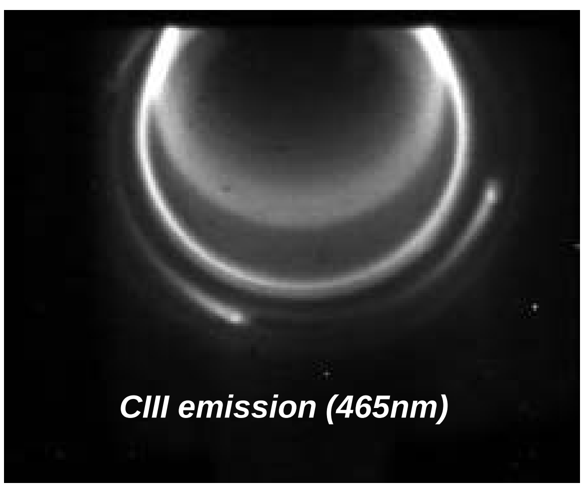
- Carbon sourced at diagnostic tile location and transported along magnetic field line

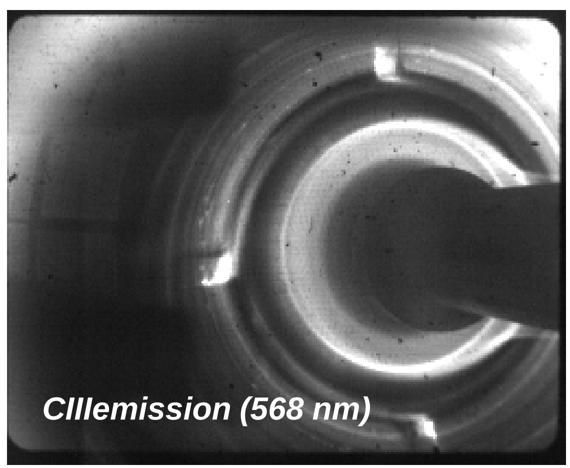
- This complicates determination of sputtered C from the LLD surface

- Work is ongoing in order to assess contamination of LLD surface with C sputtered from other PFCs



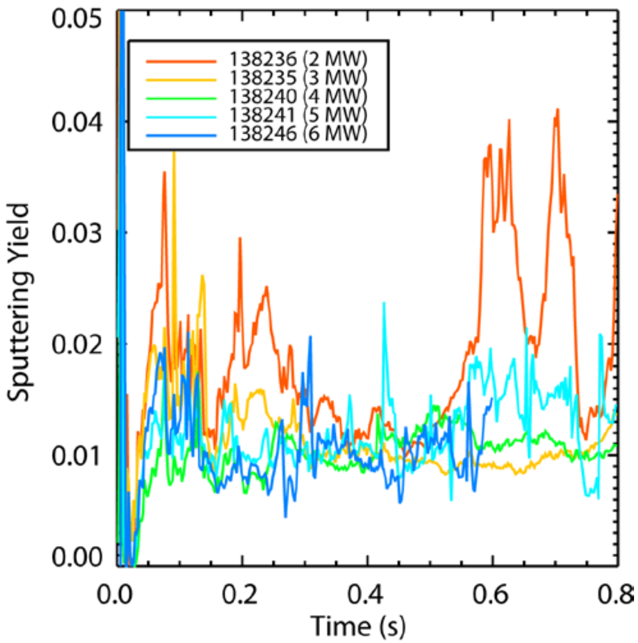



CIII emission (465nm)


CIIemission (568 nm)

Despite Li conditioning, lithiated graphite PFCs show sputtering yields consistent with C physical sputtering

- Besides sputtering from diagnostic tiles, sputtering from main wall and inboard divertor can contribute to LLD surface contamination
- Lithium layers at the inboard OSP region degrade due to sputtering - evaporation in high δ discharges
- Yield=Brightness [ph/m2/s]/Jsat[ion/m2/s]*S/XB [ion/ph]
- Assumptions for S/XB coefficients of Te~25eV, ne~3x10^{13}cm^{-3}
- Sputtering yield consistent with graphite physical sputtering



Summary

• In 2010, NSTX started experiments with liquid lithium divertor in order to exploit increased pumping and deuterium reservoir capabilities

• White-appearance of PFCs after evaporation suggested passivation of first layers of lithium coatings and motivated further investigation

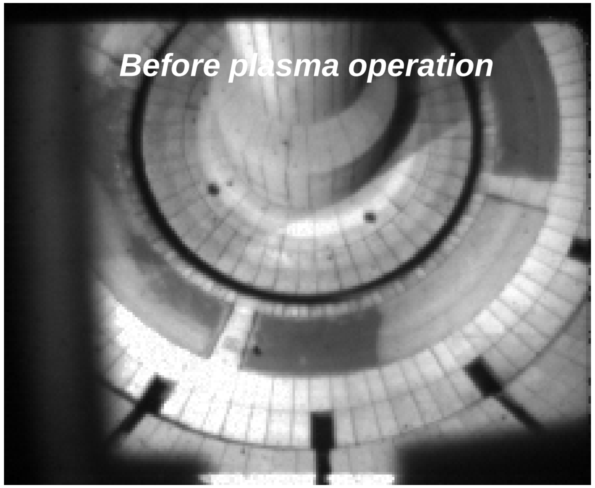
• No obvious further local recycling reduction was observed in the divertor after massive evaporations with respect to solid coatings

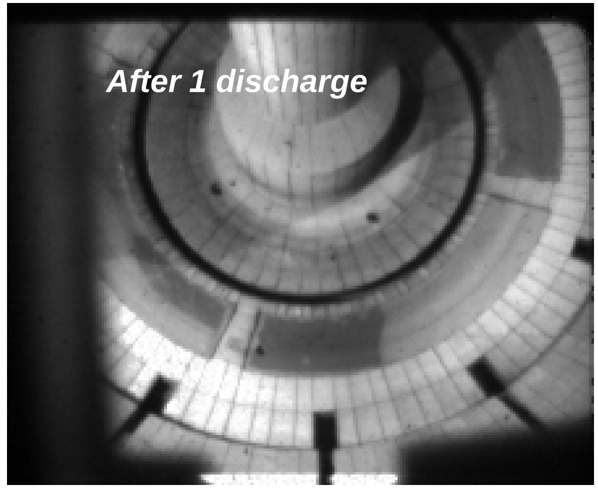
• Evidence of C on LLD due to sputtering from graphite PFCs

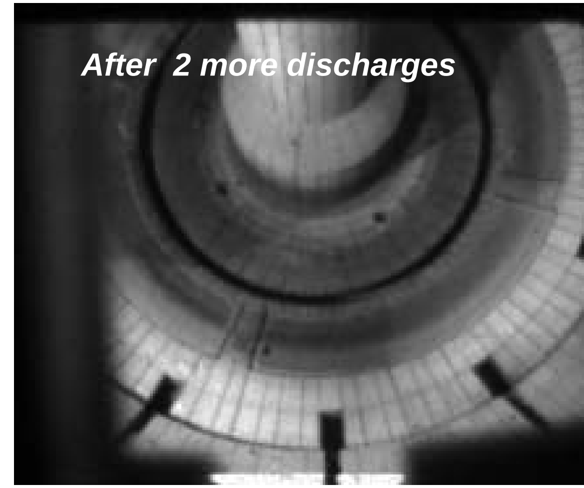
•Follow-up studies:

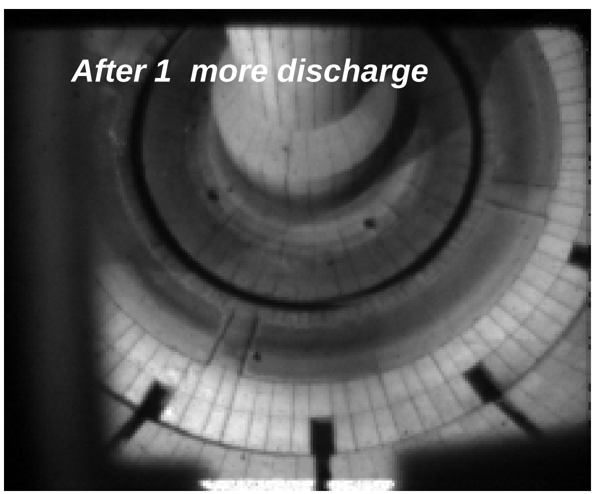
- Reflectivity studies in vacuum chamber with Li evaporator
- Investigate role of sputtered carbon on LLD for Li contamination and as impurity source

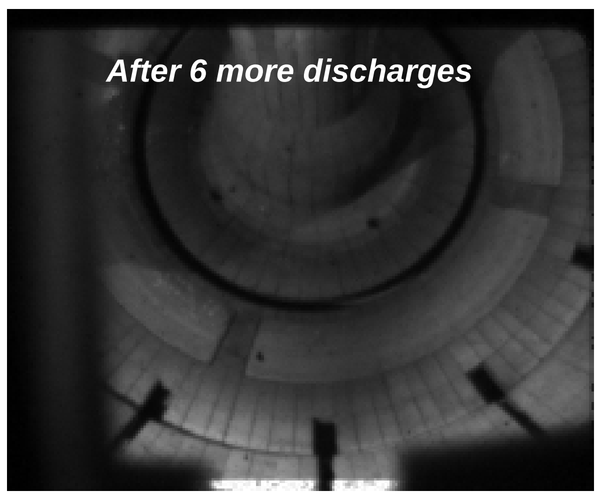
Sequence before, between and after discharges

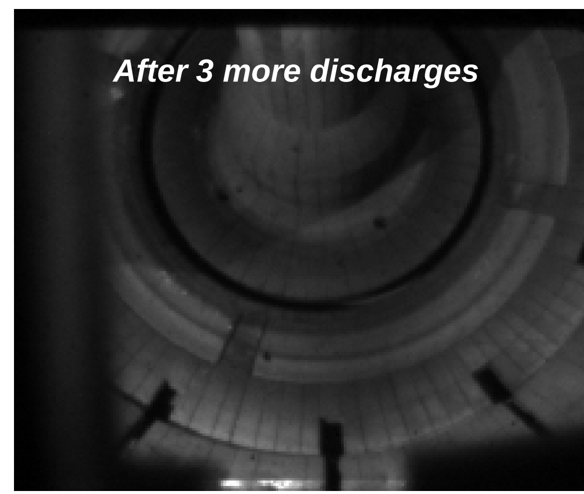




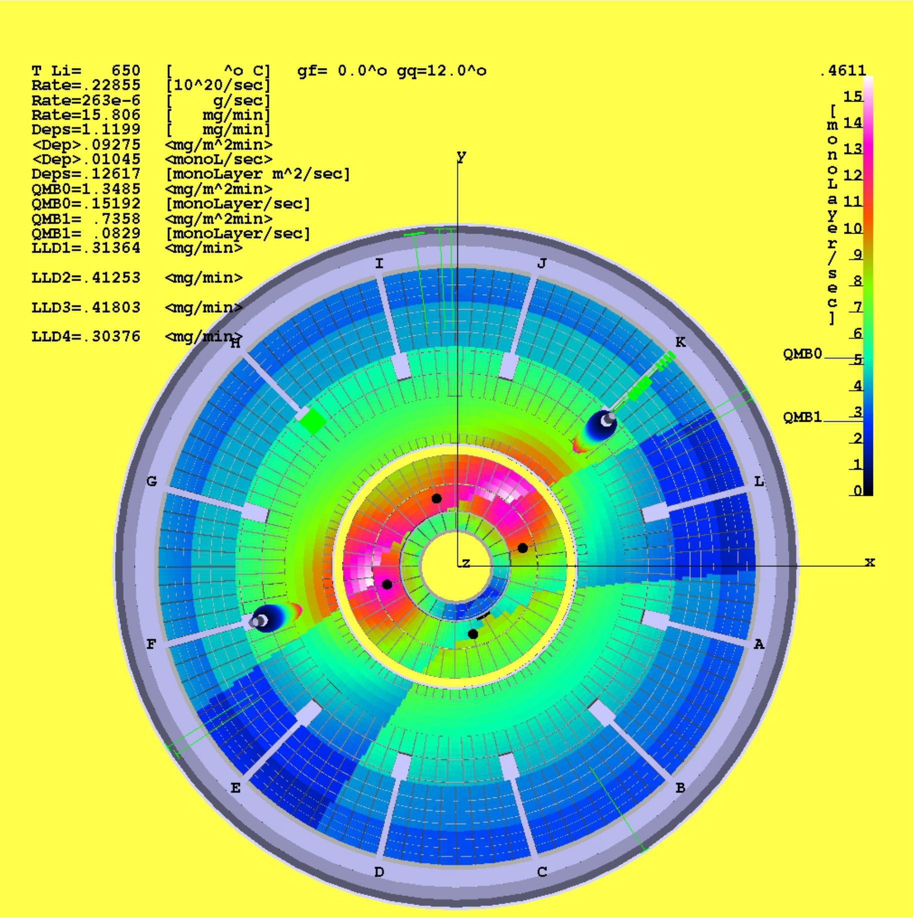






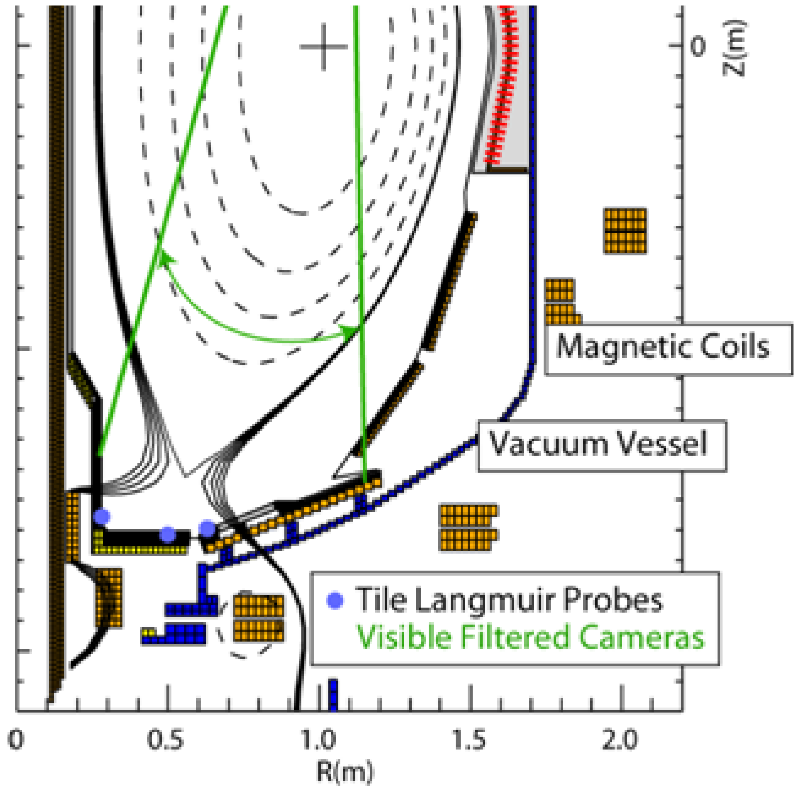


Calculations of Li deposition from double LITER evaporation

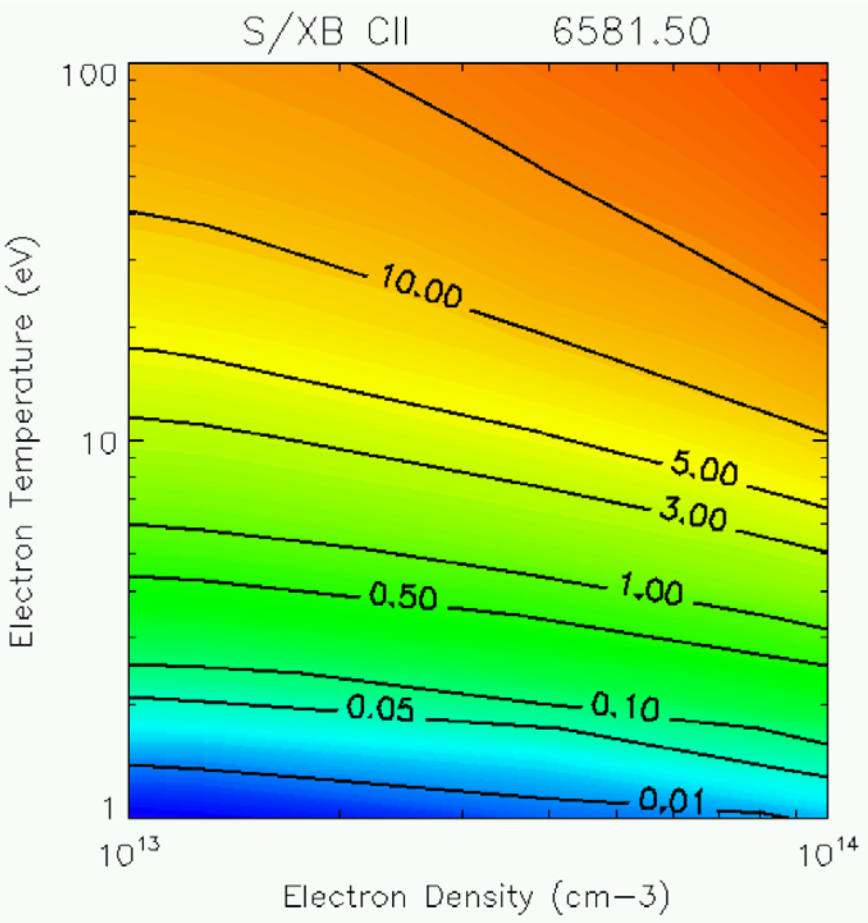


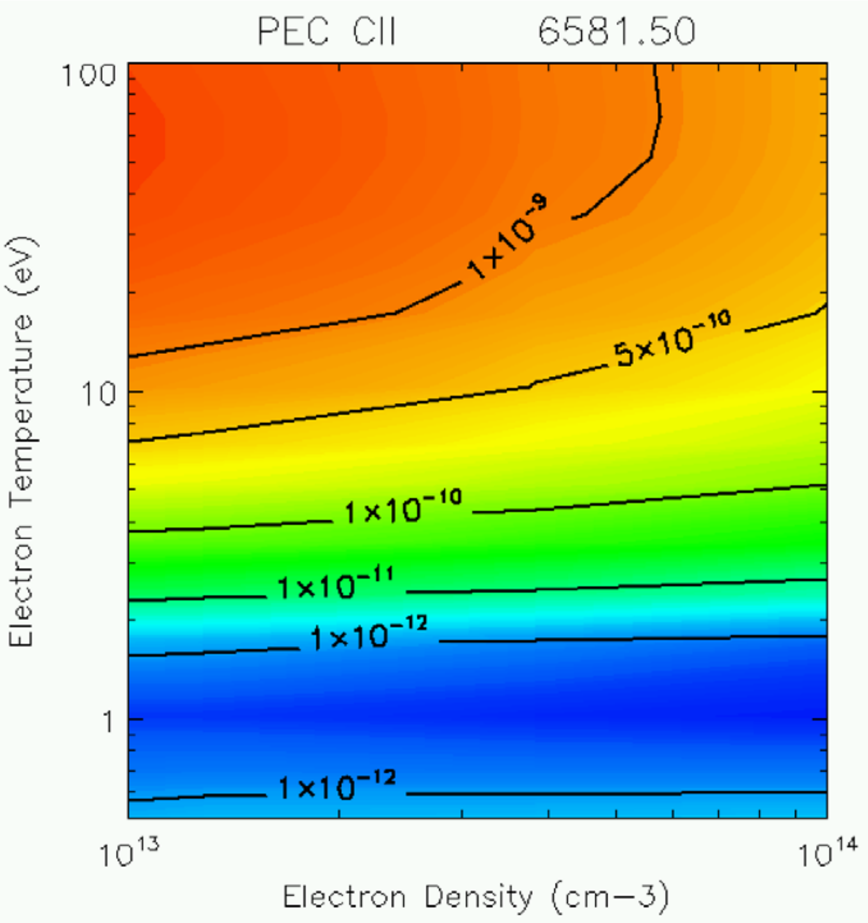
L. Zakharov

Divertor Diagnostics



PEC and SXB coefficients for CII





Open ADAS

SOURCES

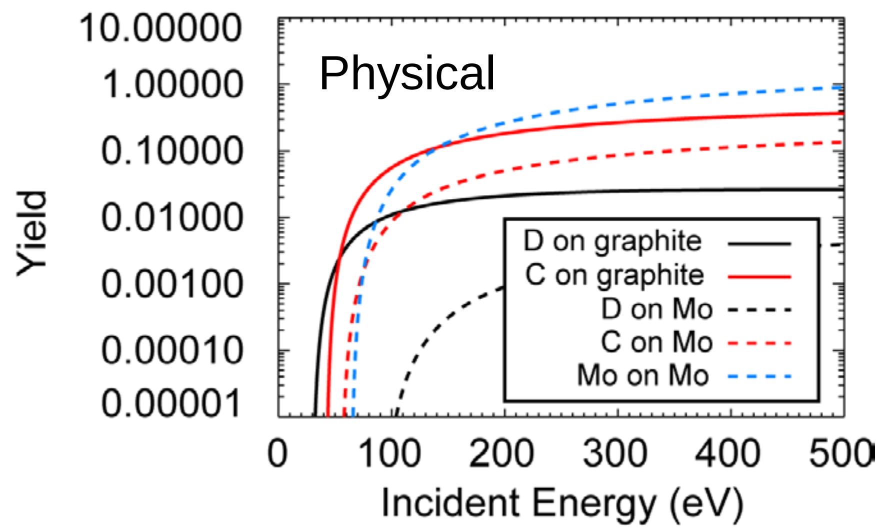
- Ion impact sputtering on divertor and main wall
- Fast charge exchange neutrals sputtering on the first wall

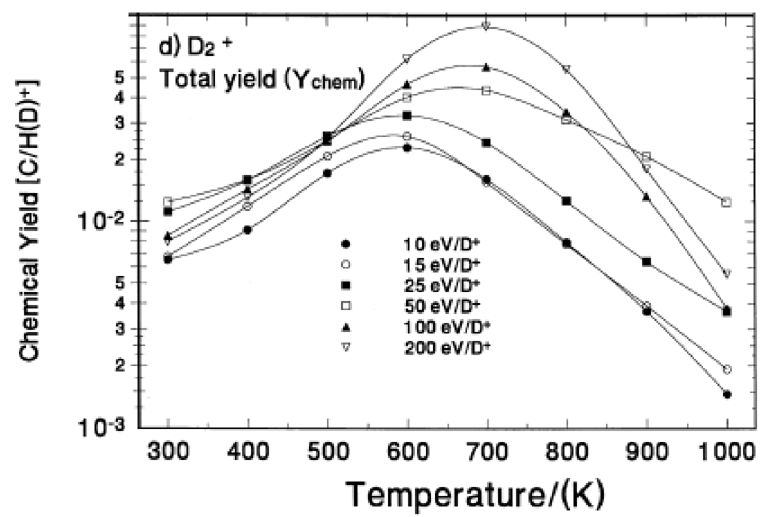
PROCESSES

- Physical Sputtering
- Chemical Sputtering

NSTX PLASMA FACING COMPONENTS

- ATJ graphite tiles on divertor
- ATJ and CFC tiles on center stack
- Molybdenum porous mesh on outer divertor (R=65-84 cm) since FY10
- Molybdenum tiles on outer row of inner divertor since FY11





B.V. Mech et al. J. Nucl. Mater. 255, 153–164 (1998).