THE EFFECT OF ION ENERGY AND SUBSTRATE TEMPERATURE ON DEUTERIUM TRAPPING IN TUNGSTEN

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NSTX PHYSICS MEETING
MONDAY DECEMBER 10 2012

OVERVIEW

- PROJECT SCOPE
- EXPERIMENTAL DESIGN AND EQUIPMENT
- RESULTS AND CONTRIBUTIONS
  - CONTAMINATION EFFECTS ON DEUTERIUM RETENTION
  - LOW ENERGY RETENTION
  - TEMPERATURE EFFECTS
  - FLUX DEPENDENCE

PROJECT SCOPE

- ☐ DEUTERIUM RETENTION IN TUNGSTEN
- ☐ EXTEND RETENTION DATA TO LOW ION ENERGY RANGE
- ☐ DEFINE RETENTION AS A FUNCTION OF ENERGY
- ☐ INVESTIGATE CONTAMINATION EFFECTS
- ☐ INVESTIGATE TEMPERATURE EFFECTS ON TRAPPING MECHANISMS
- ☐ INVESTIGATE EFFECT OF FLUX ON RETENTION
- ☐ RESULTS RELEVANT TO ITER HYDROGEN RETENTION ESTIMATES

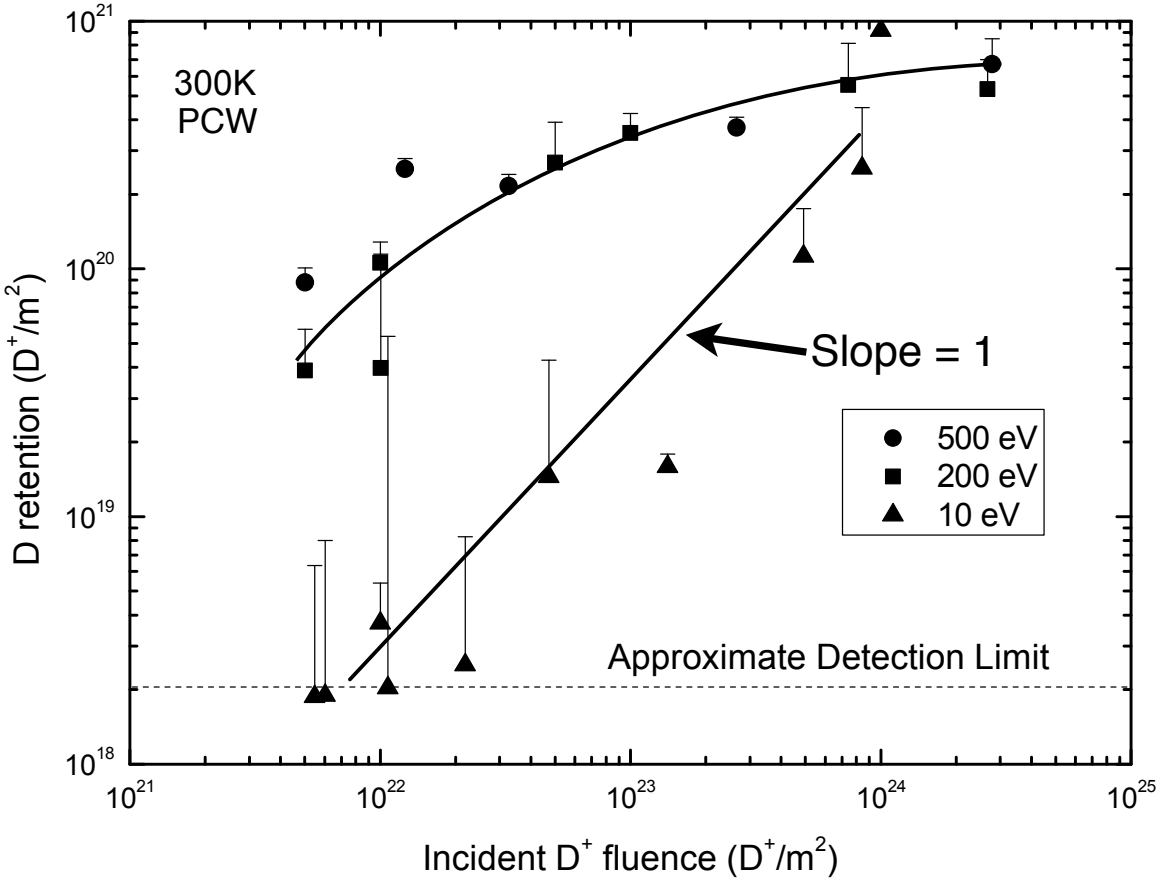
EXPERIMENTAL DESIGN

ION GUN AND MATERIAL

- LOW FLUX (~$7X10^{17}$ D^+/M^2S - $8X10^{18}$ D^+/M^2S) LOW ENERGY (AS LOW AS 10 EV/D^+)
- MASS ANALYZED - LOW CONTAMINANT
- ORDERS OF MAGNITUDE LOWER FLUX THAN ACCELERATORS (4-$7X10^{19}$ D^+/M^2S), PLASMA DEVICES (~$1X10^{22}$ D^+/M^2S) AND ITER FLUX PROJECTIONS (~$1X10^{24}$ D^+/M^2S)
- VERY STABLE CURRENT, 90 DAY EXPERIMENTS - TRACKED USING TIME-LAPSE PHOTOGRAPHY
- SCW (MOSCOW RARE METALS INSTITUTE) AND PCW (REMBAR CORP) SPECIMENS USED

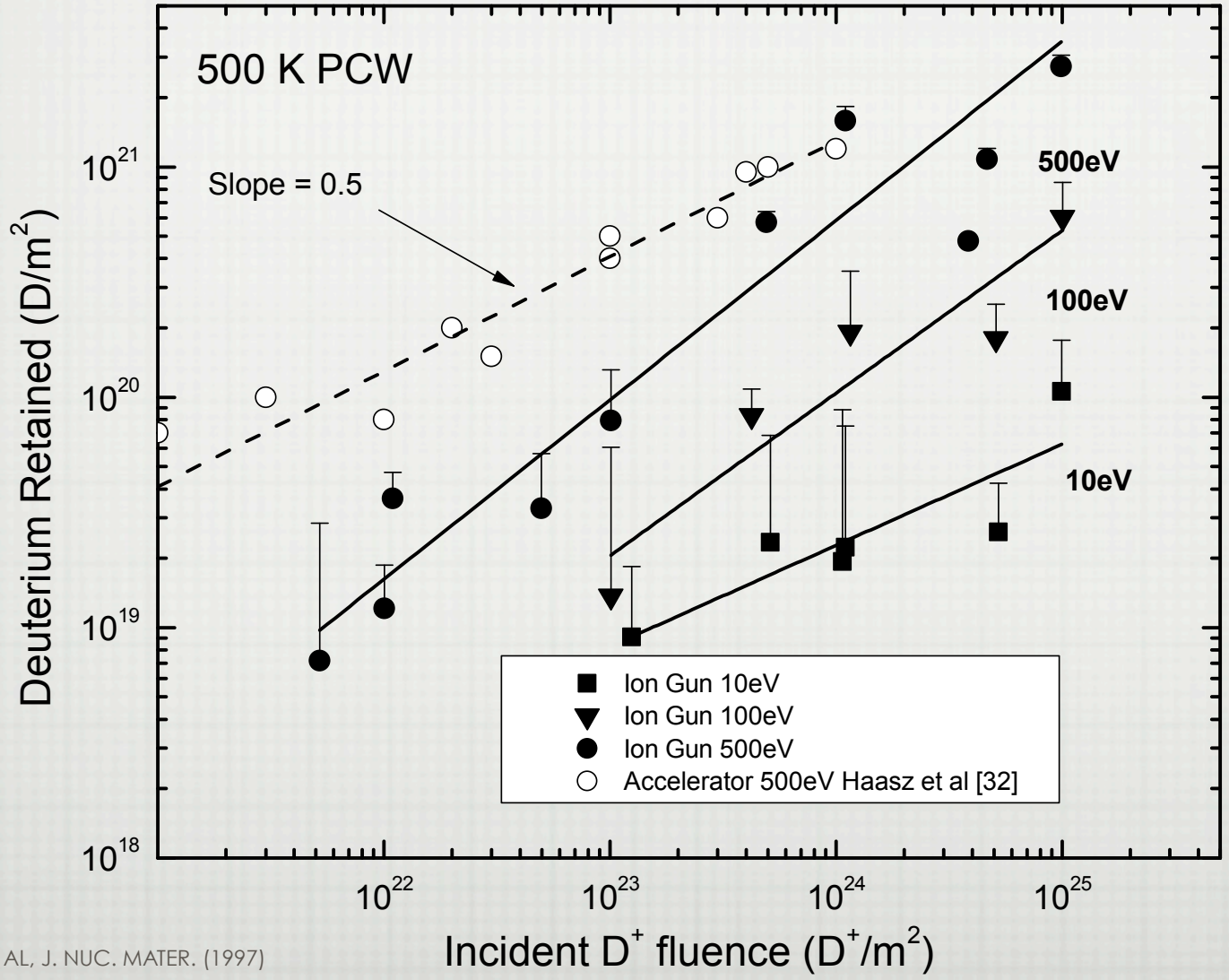
LOW ENERGY RETENTION

PCW



LOW ENERGY RETENTION

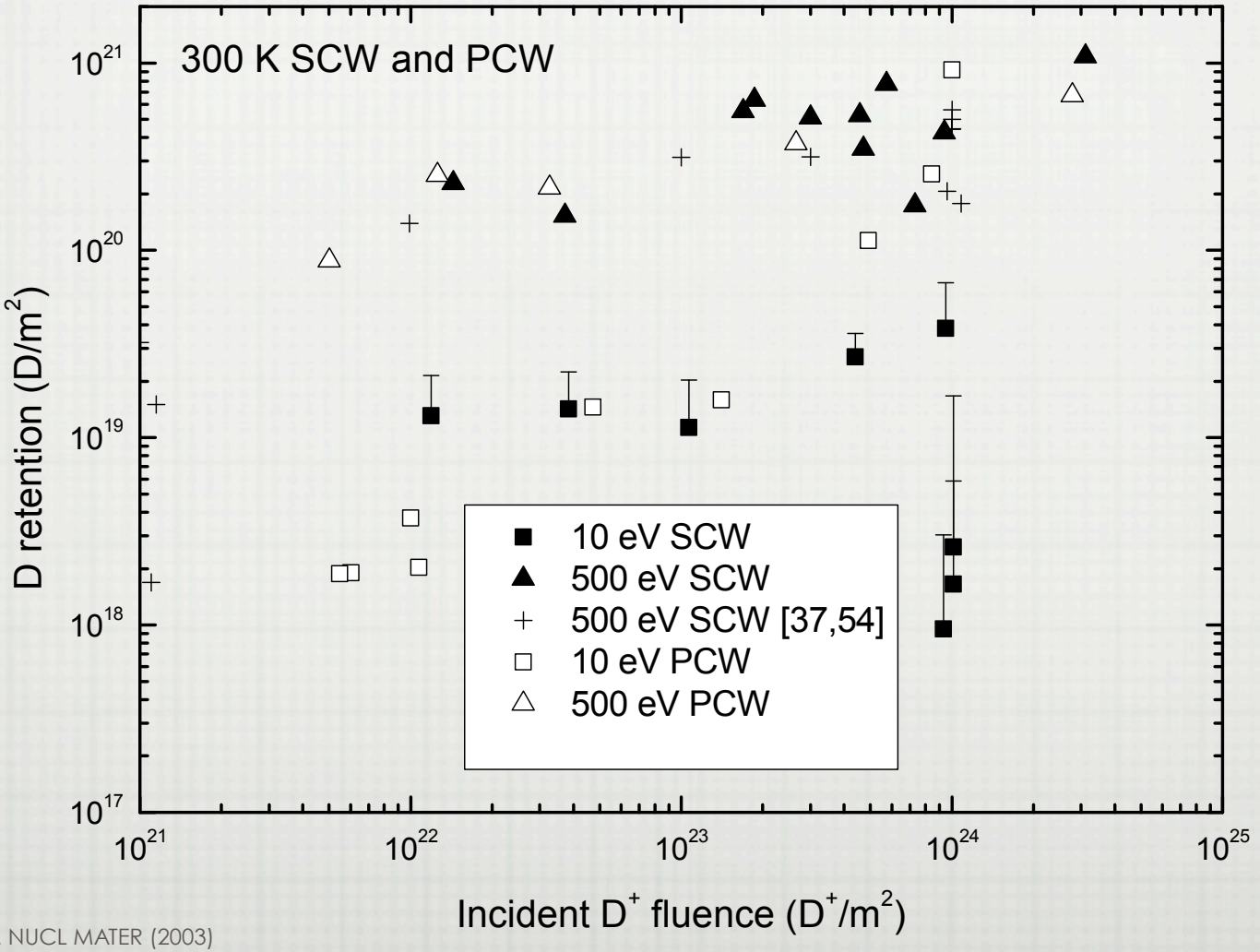
PCW



[32] HAASZ ET AL, J. NUC. MATER. (1997)

LOW ENERGY RETENTION

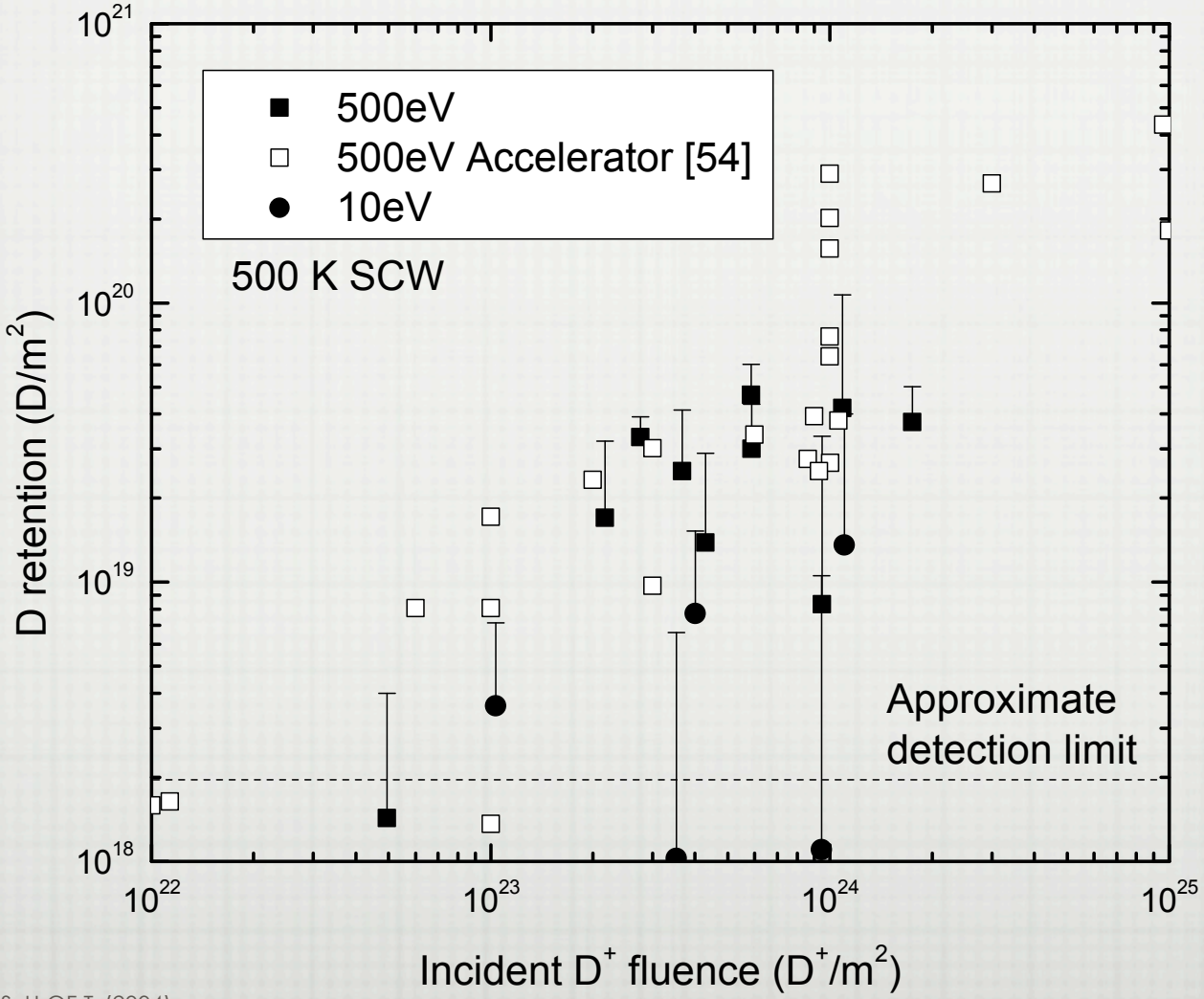
SCW



[37] POON ET AL, J. NUCL MATER (2003)
[54] POON, PH.D THESIS, U OF T, (2004)

LOW ENERGY RETENTION

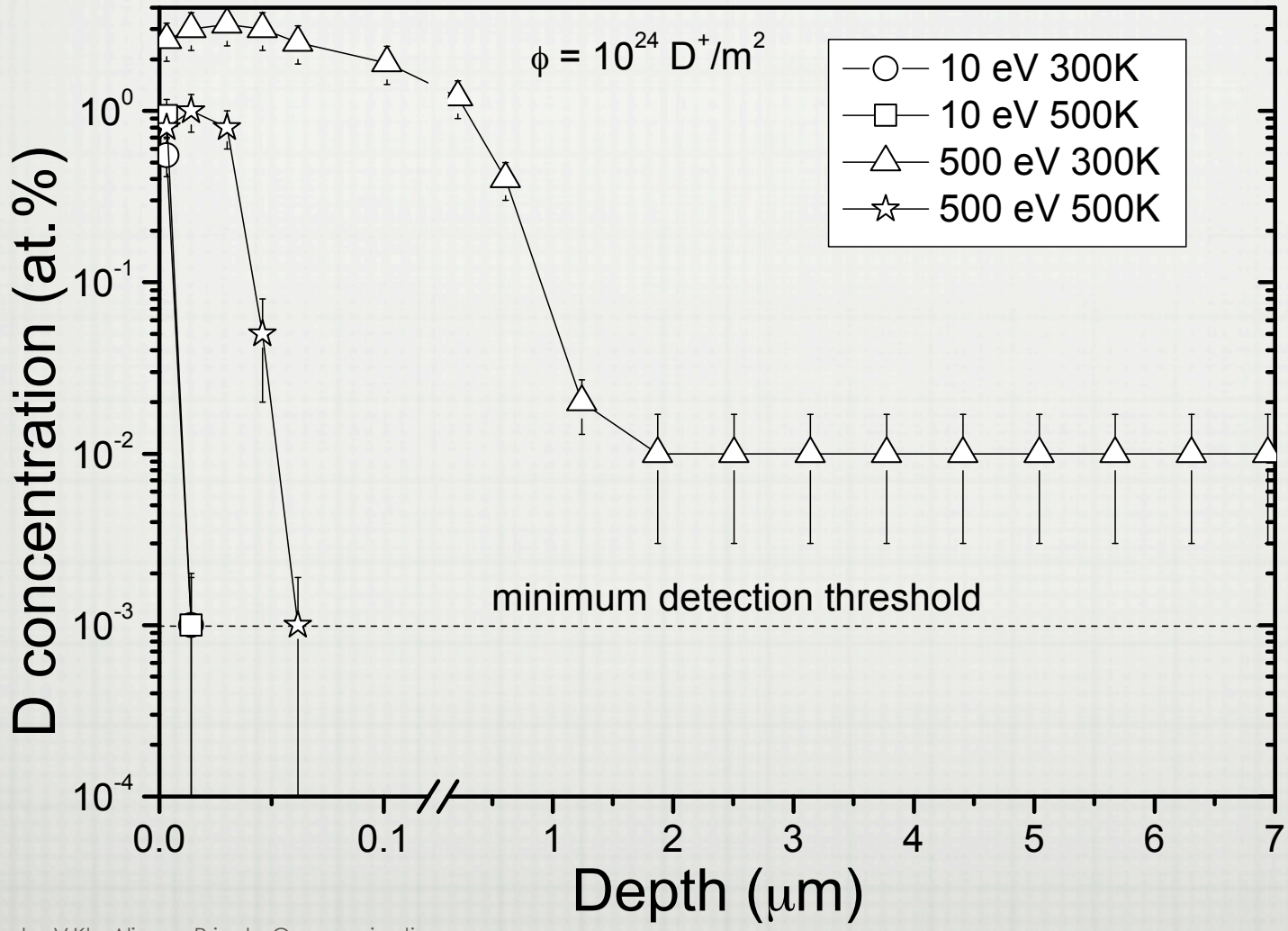
SCW



[54] POON, PH.D THESIS, U OF T, (2004)

LOW ENERGY RETENTION

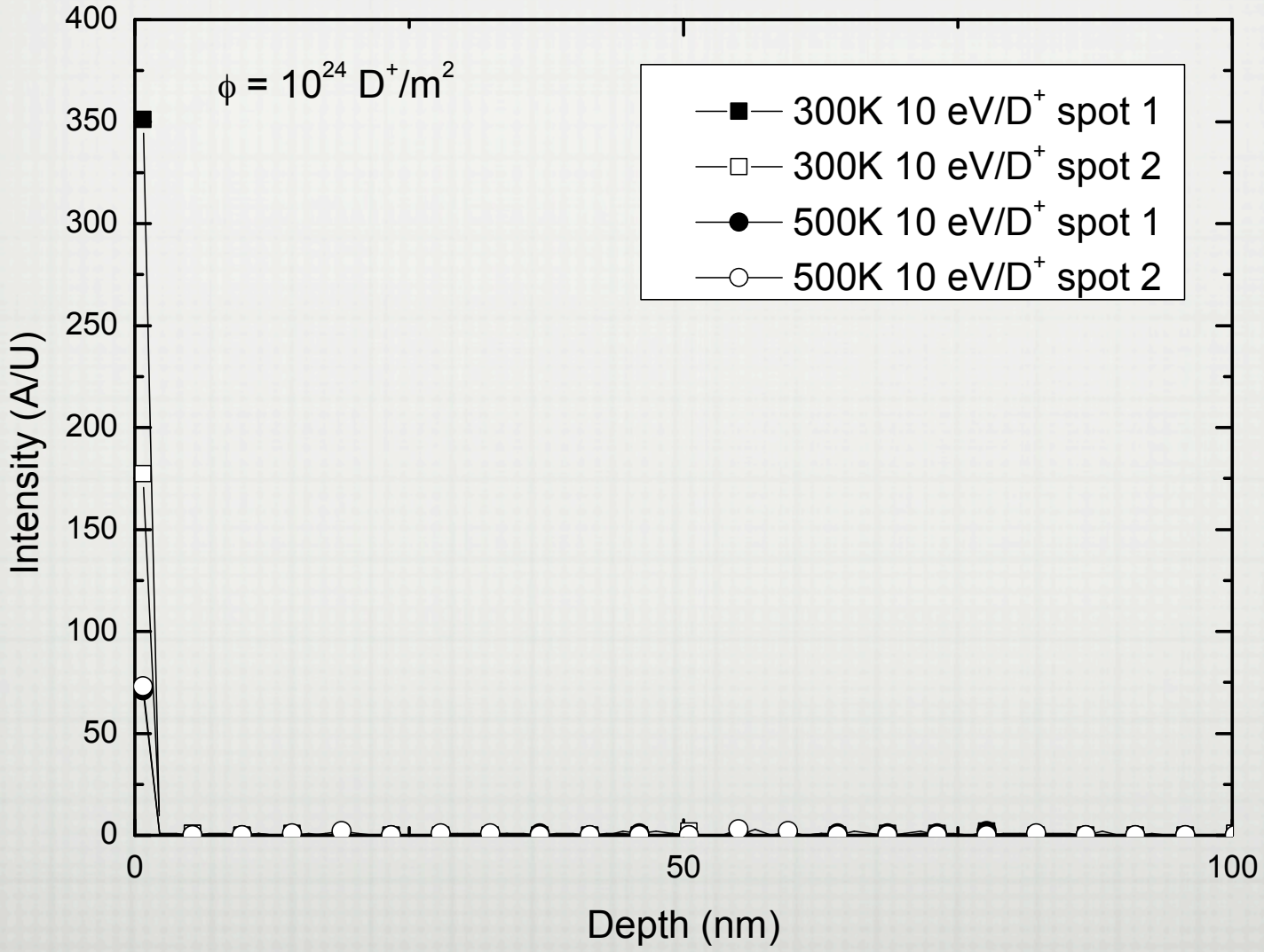
NRA DEUTERIUM DEPTH PROFILES



NRA profiles by V.Kh. Alimov, Private Communication (2011), Presented at PSI 20 in Aachen Germany May 2012

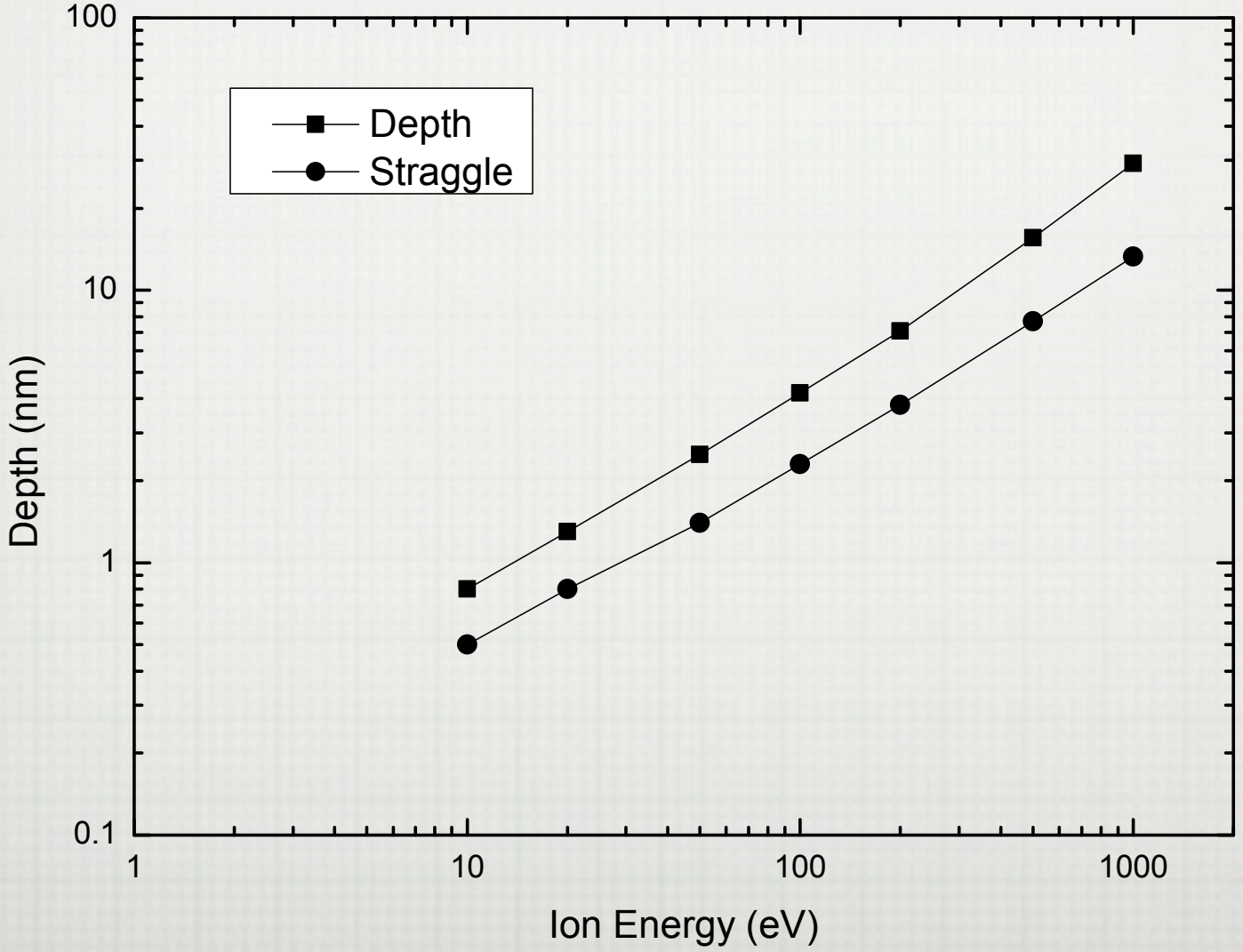
LOW ENERGY RETENTION

SIMS DEUTERIUM DEPTH PROFILES



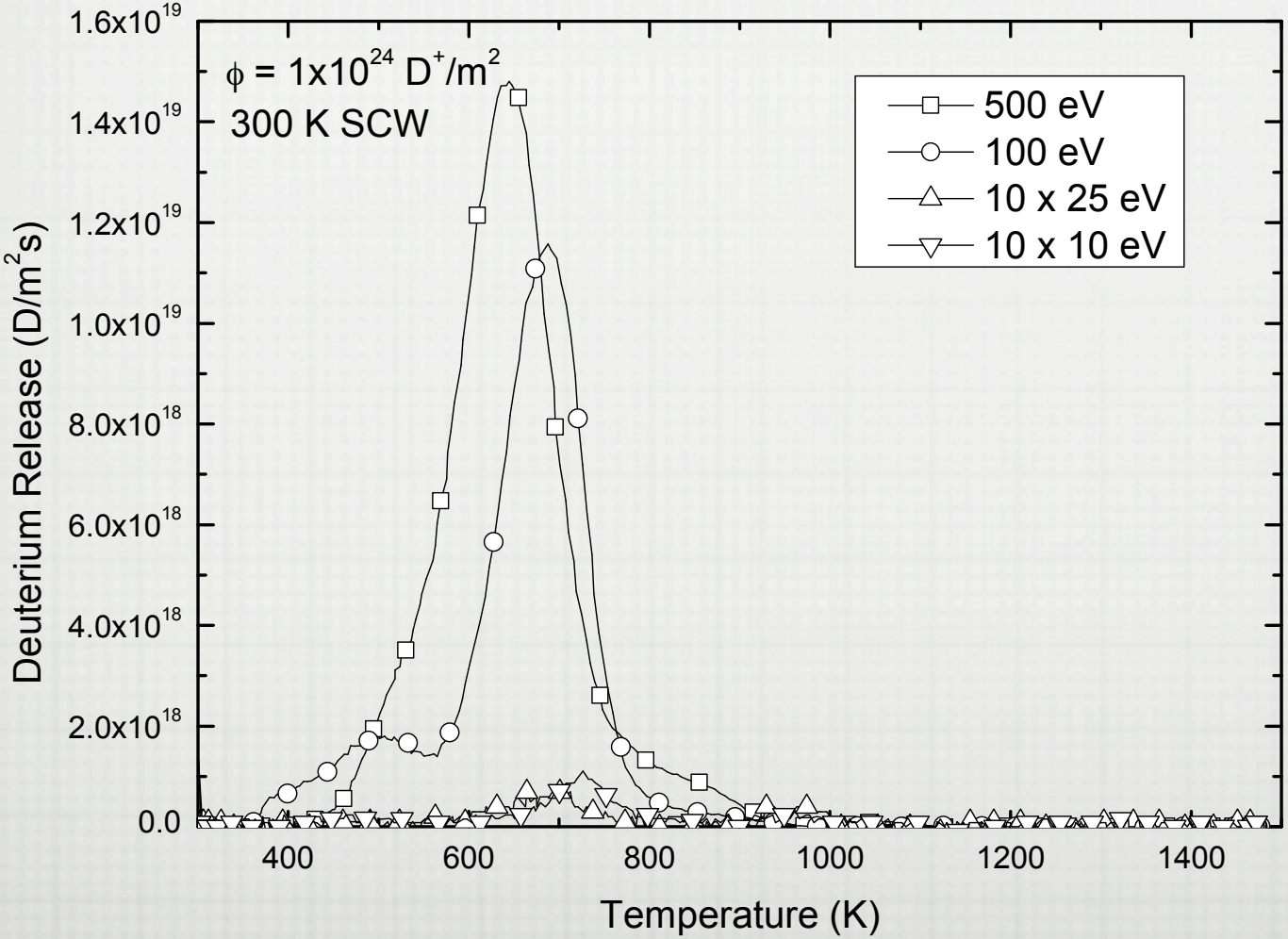
LOW ENERGY RETENTION

D PENETRATION DEPTHS (TRIM)



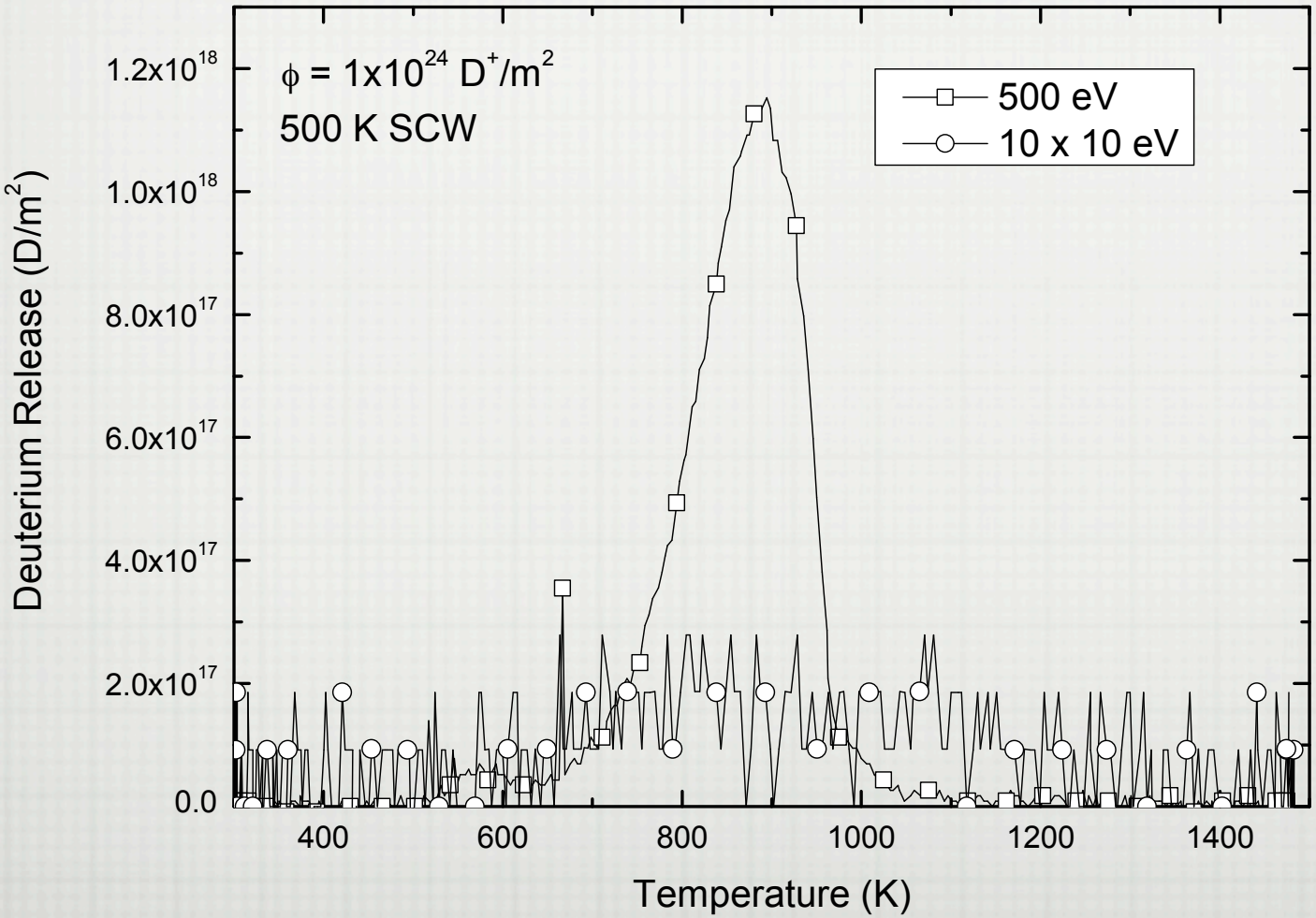
LOW ENERGY RETENTION

TDS SPECTRA



LOW ENERGY RETENTION

TDS SPECTRA



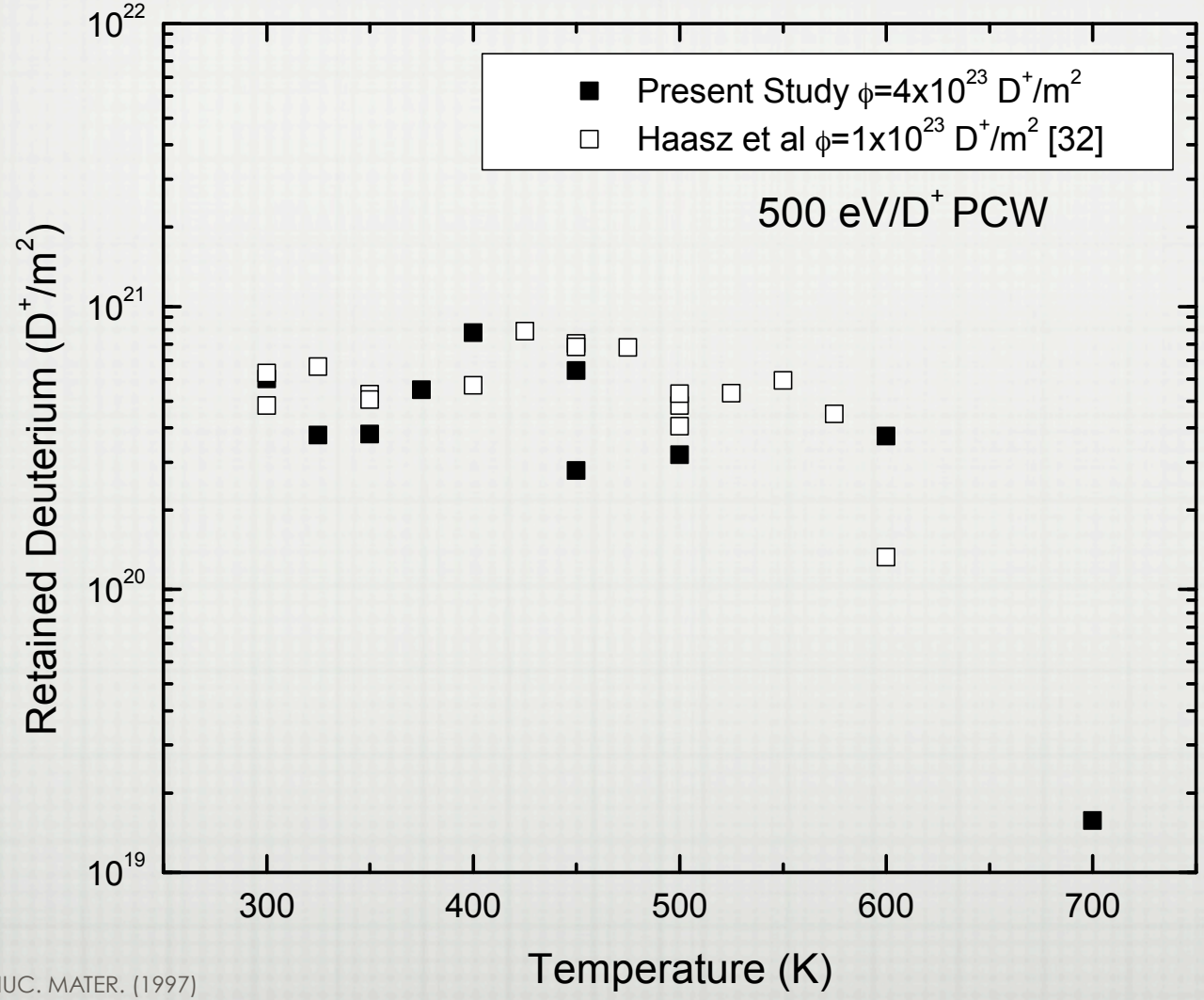
LOW ENERGY RETENTION

WHY LOWER RETENTION WITH LOWER ENERGY

- REDUCED RETENTION DUE TO SHALLOW IMPLANTATION DEPTH, NOT CHANGE IN TRAPPING MECHANISM
- PENETRATION DEPTH OF 10 EV D IONS: 8A, STRAGGLE 4A (CALCULATED WITH TRIM)
- SIGNIFICANT PORTION OF IMPLANTED DEUTERIUM IN FIRST MONOLAYER
- DIFFUSION TO SURFACE IN "SINGLE STEP"
- WIDE RANGE IN SCW RETENTION MEASUREMENTS COULD BE DUE TO INCONSISTENT SURFACE CONDITIONS

TEMPERATURE DEPENDENCE

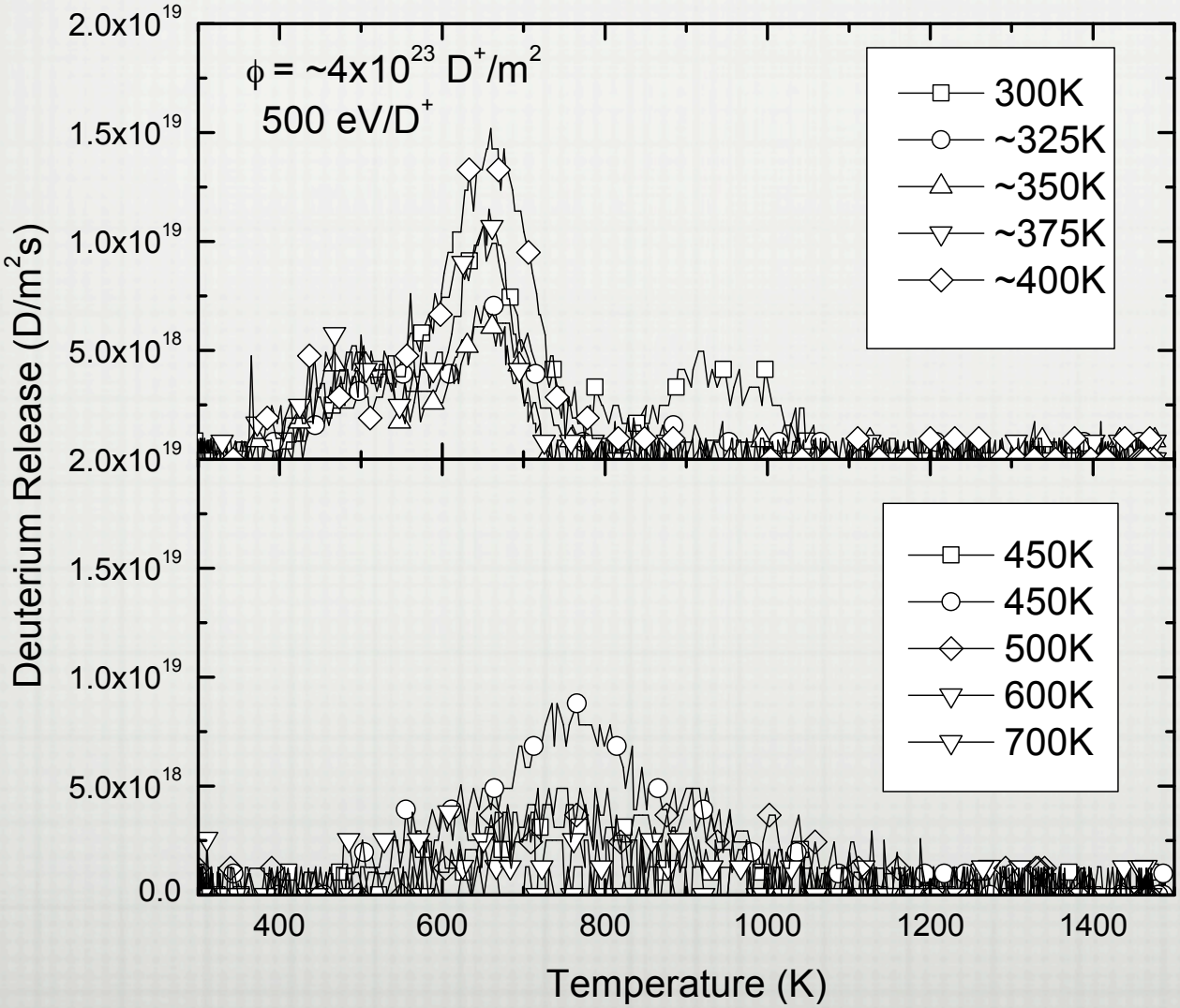
PCW



[32] HAASZ ET AL, J. NUC. MATER. (1997)

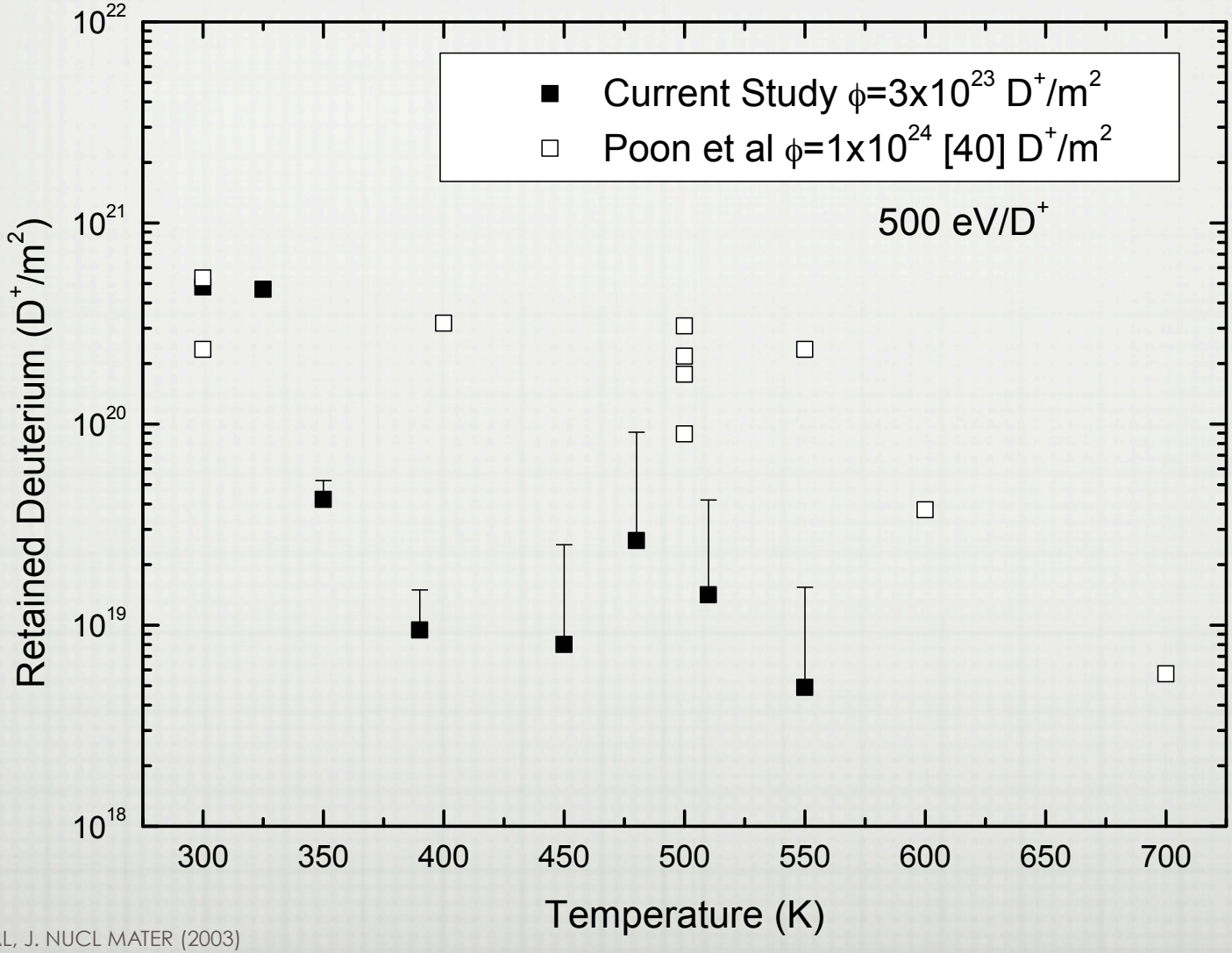
TEMPERATURE DEPENDENCE

TDS SPECTRA IN PCW



TEMPERATURE DEPENDENCE

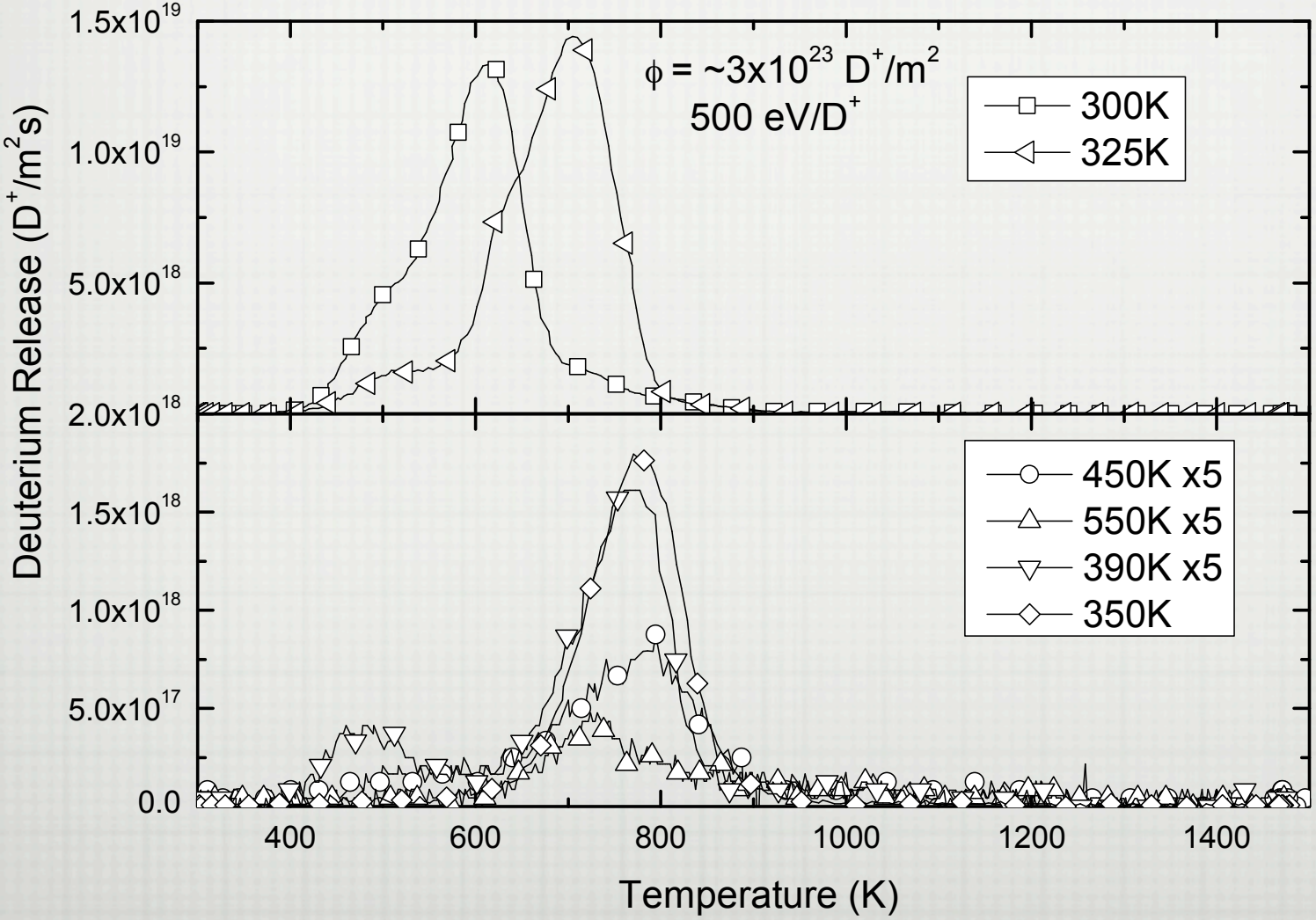
SCW



[40] POON ET AL, J. NUCL MATER (2003)

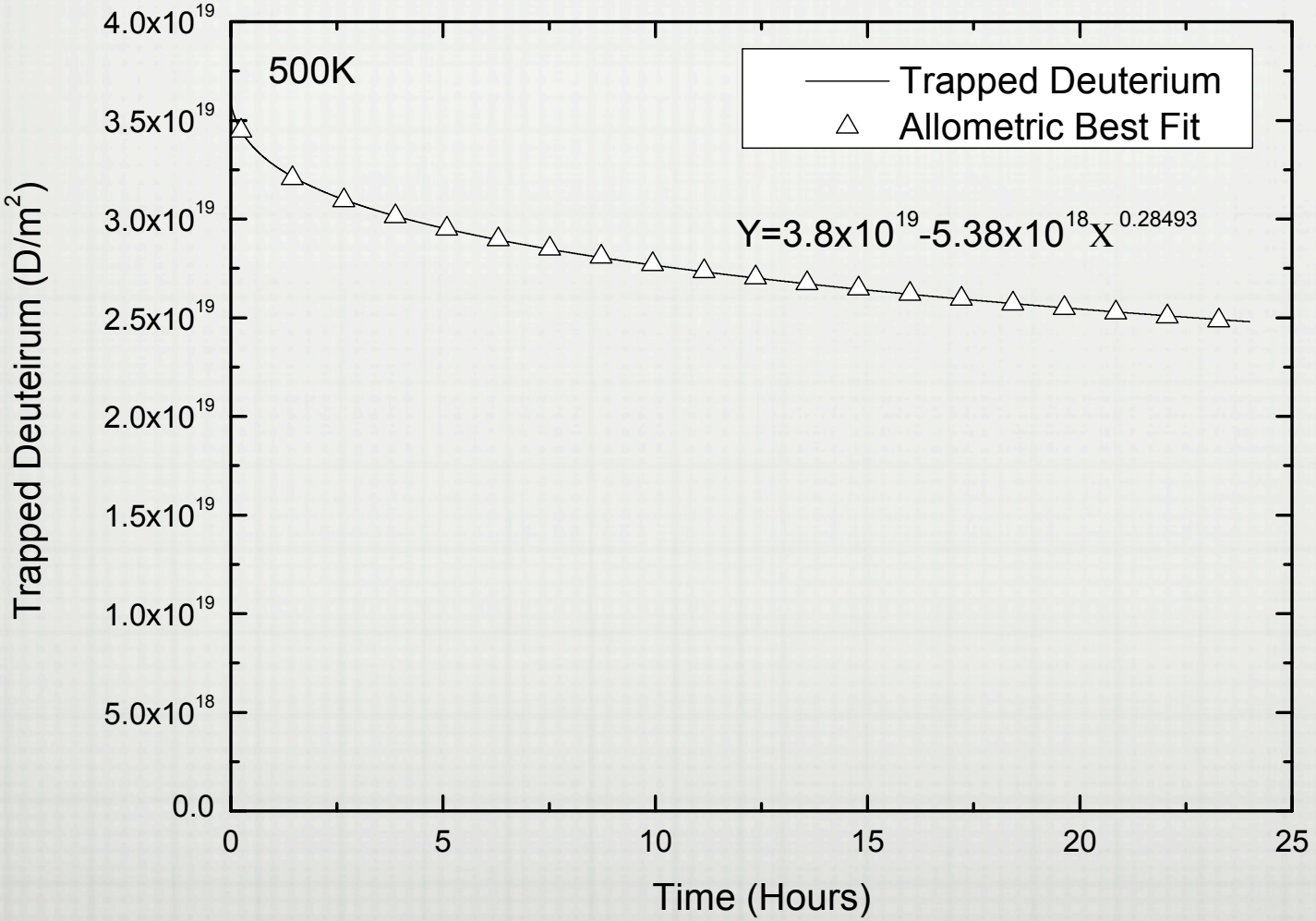
TEMPERATURE DEPENDENCE

TDS SPECTRA IN SCW

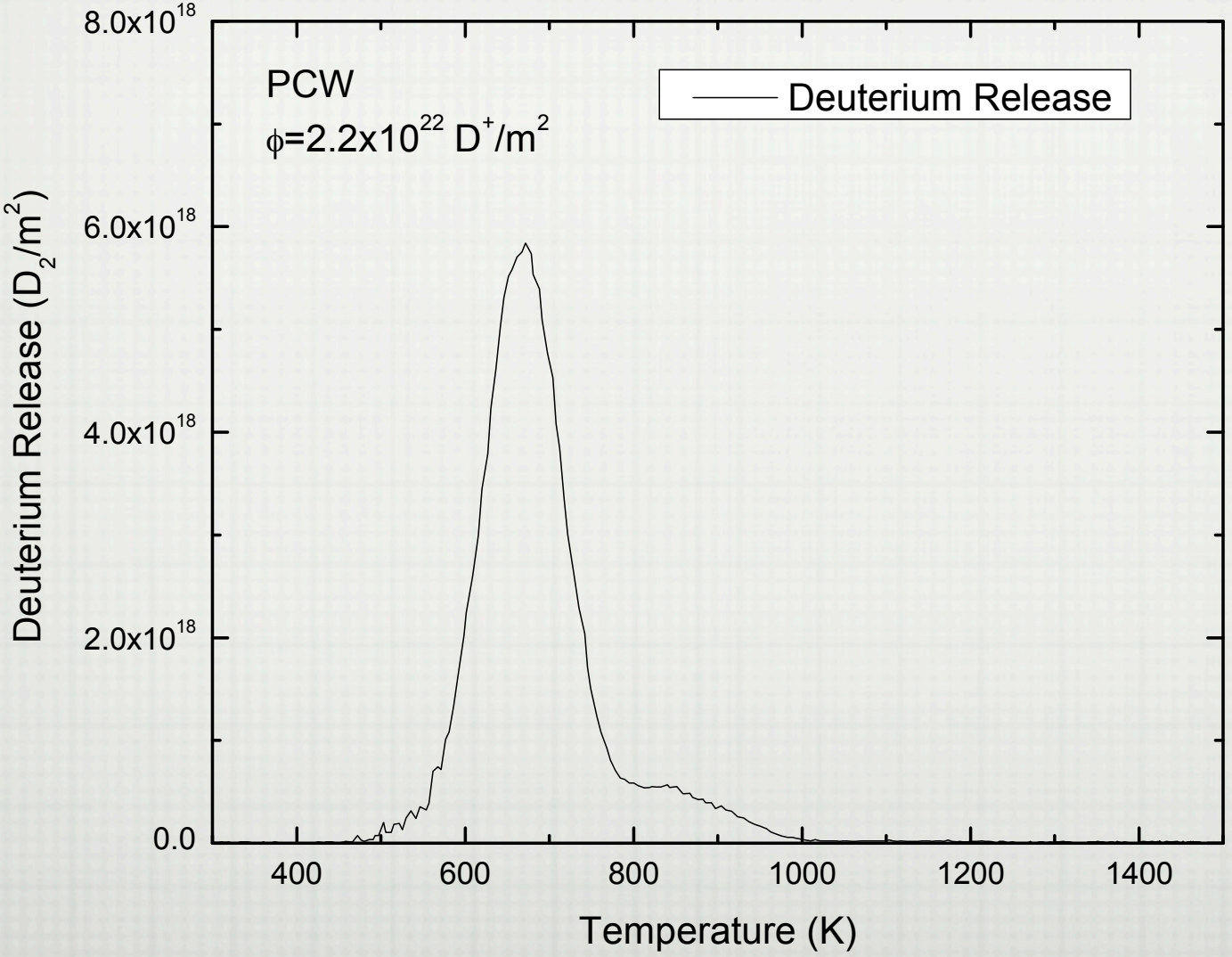


EXPLORING TRAP CREATION

TMAP ESTIMATES OF D RELEASE FROM 1.4 EV TRAPS

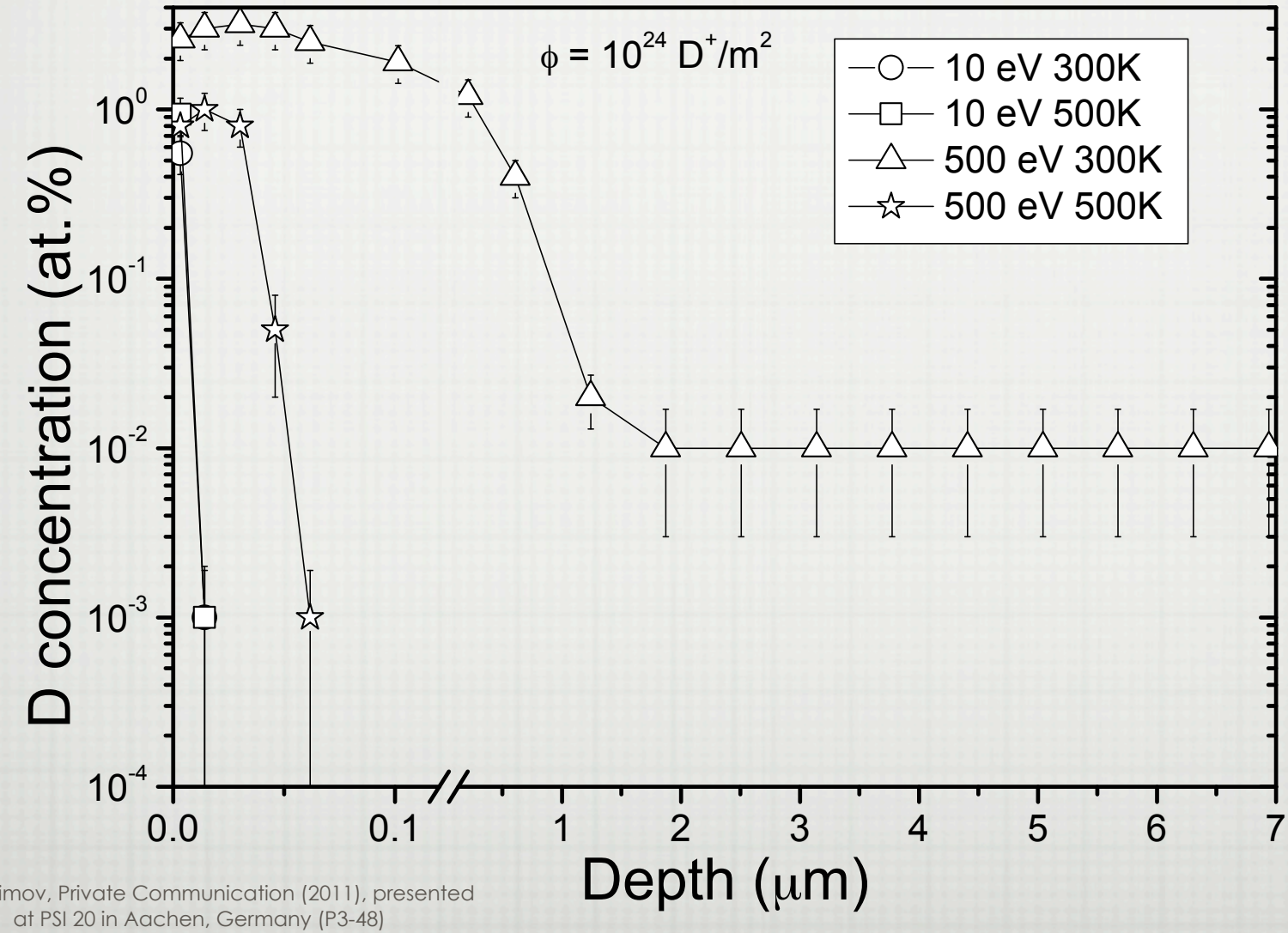


EXPLORING TRAP CREATION



DEUTERIUM DEPTH PROFILES

NRA



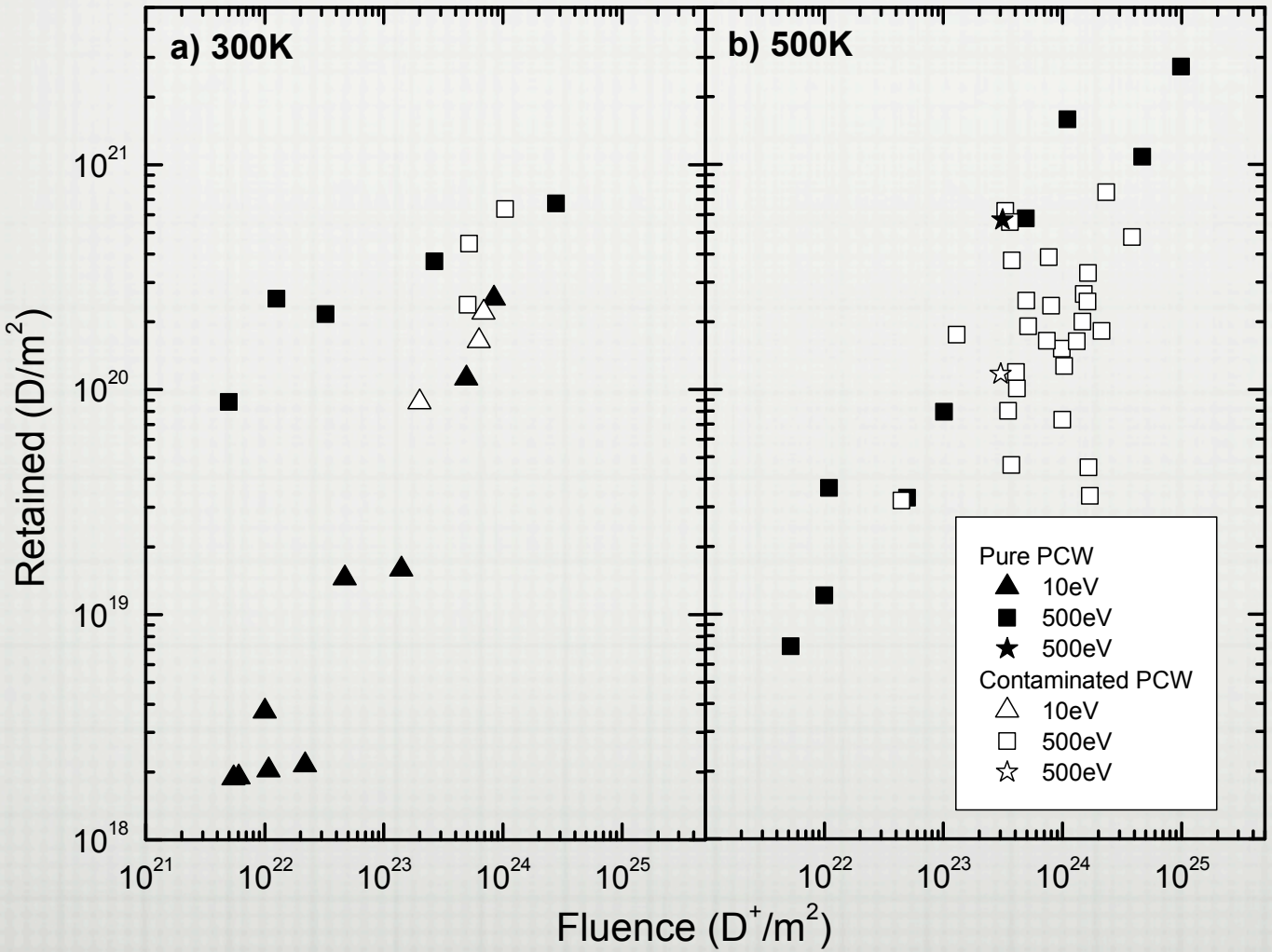
V.Kh. Alimov, Private Communication (2011), presented at PSI 20 in Aachen, Germany (P3-48)

TRAP CREATION MECHANISM

- MOBILE D-VACANCY COMPLEXES (1.3 EV) AT T>350K (SCW)
- ANNIHILATION FORMS STABLE NANOBUBBLES (2.1 EV)
- NANOBUBBLE FORMATION REQUIRES ONGOING IMPLANTATION
- BUBBLES CREATE DIFFUSION BARRIER
- ANNIHILATION OF 1.3 EV TRAPS EXPLAINS ABSENCE OF 600 K PEAK IN 500 K IRRADIATIONS
- FORMATION OF 2.1 EV TRAP EXPLAINS ABSENCE OF 800 K PEAK IN RT IRRADIATIONS

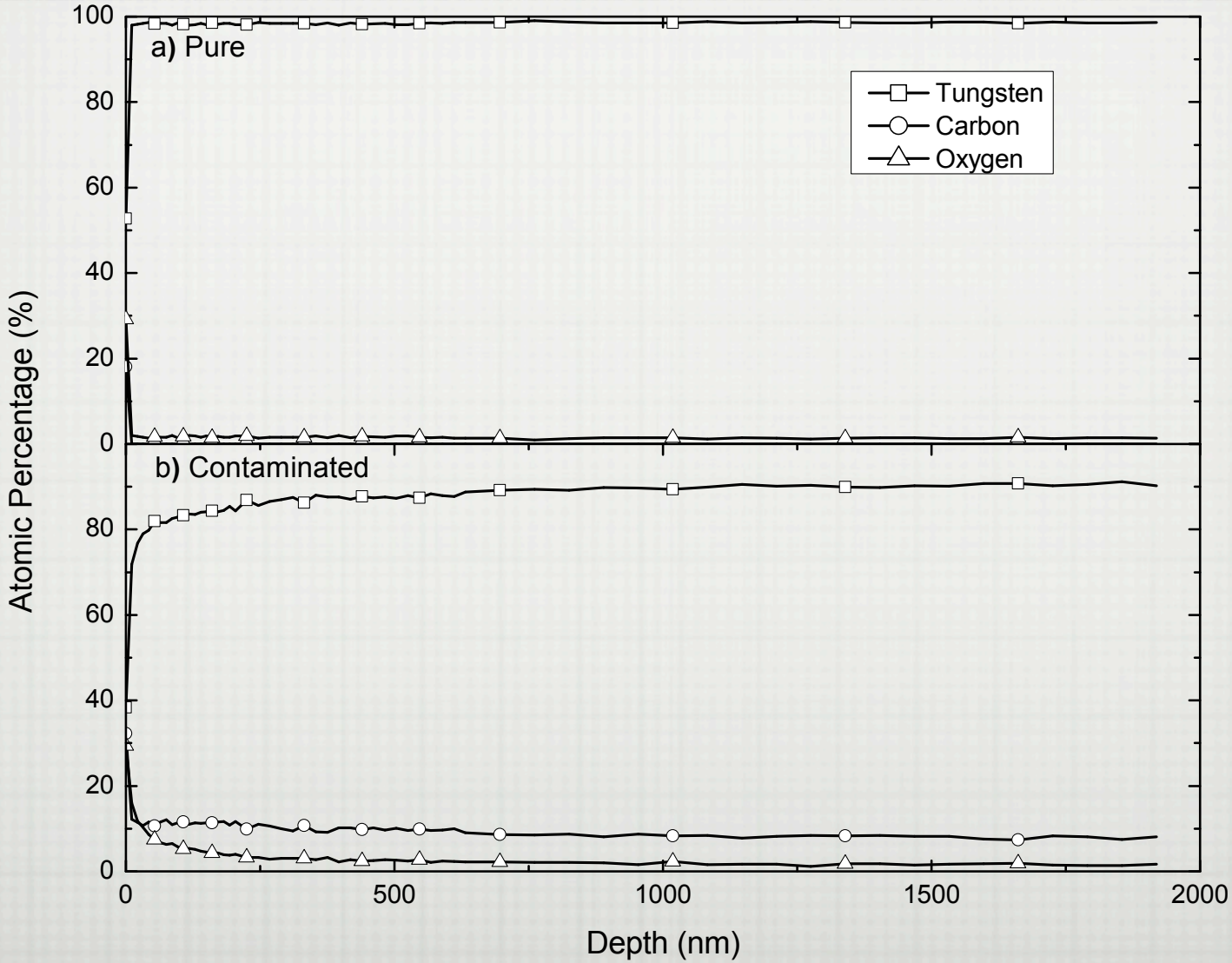
C AND O CONTAMINATION IN PCW FOILS

D RETENTION IN FOILS FROM DIFFERENT BATCHES



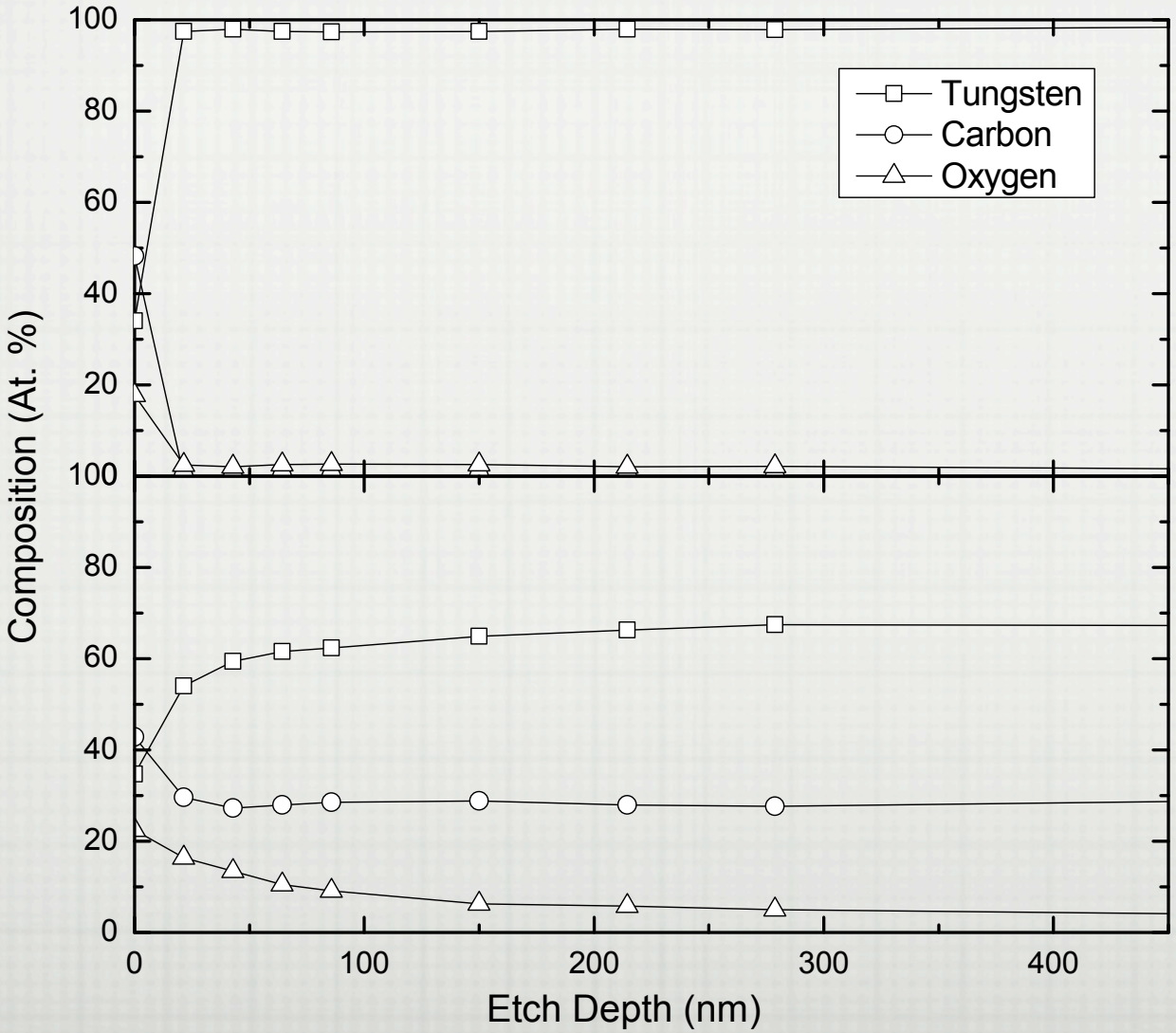
C AND O CONTAMINATION IN PCW FOILS

CHARACTERIZING THE PCW SPECIMENS



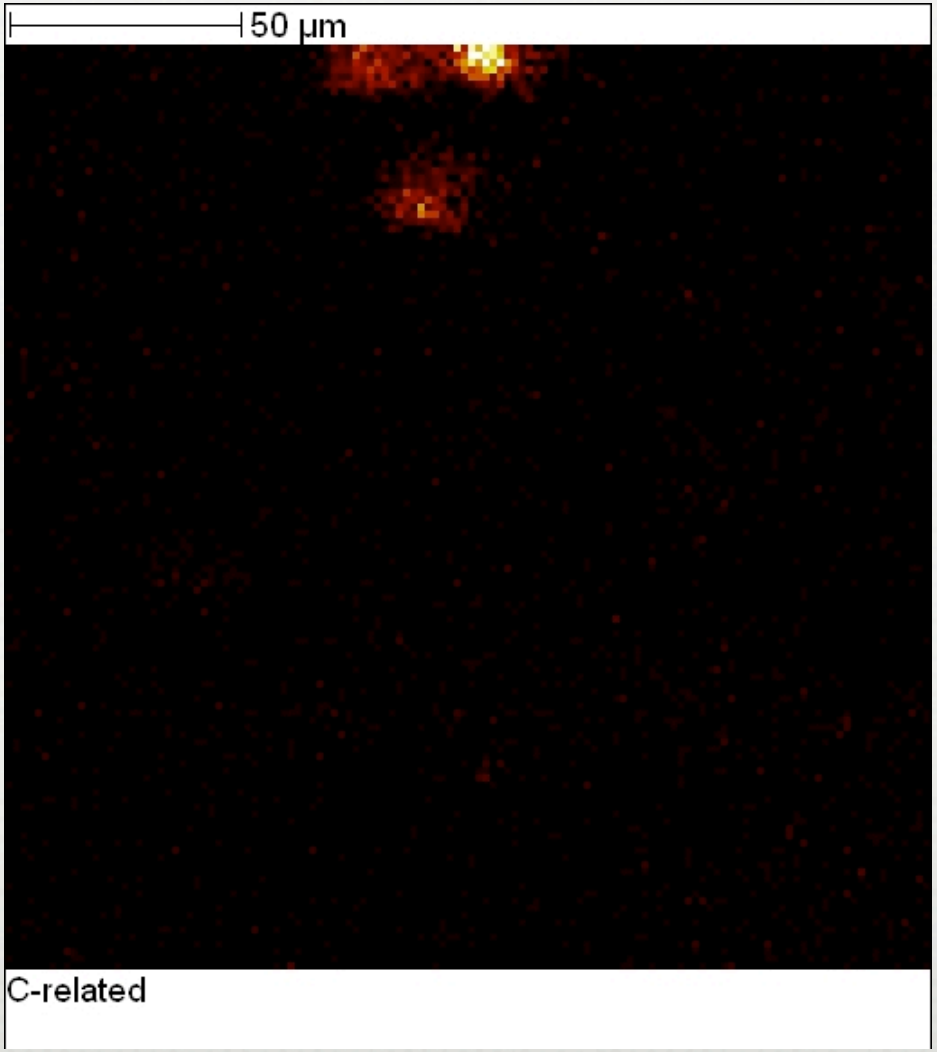
C AND O CONTAMINATION IN PCW FOILS

XPS ON SPOTS WITHIN A FEW MM



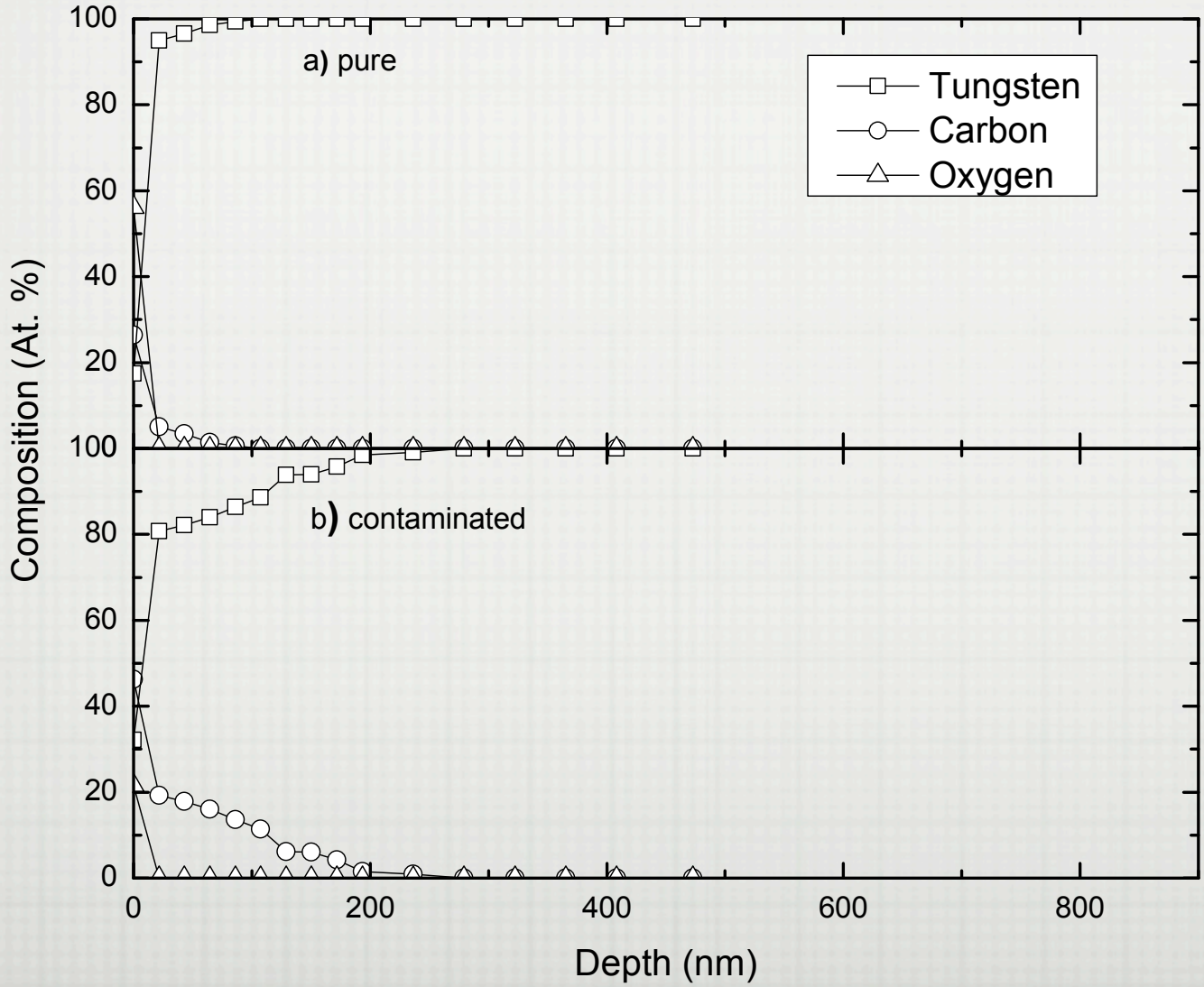
C AND O CONTAMINATION IN PCW FOILS

SIMS PROFILES OF CONTAMINATED PCW FOIL (C RELATED COUNTS)



C AND O CONTAMINATION IN PCW FOILS

XPS DEPTH PROFILES OF ★ RETENTION MEASUREMENTS



C AND O CONTAMINATION IN PCW FOILS

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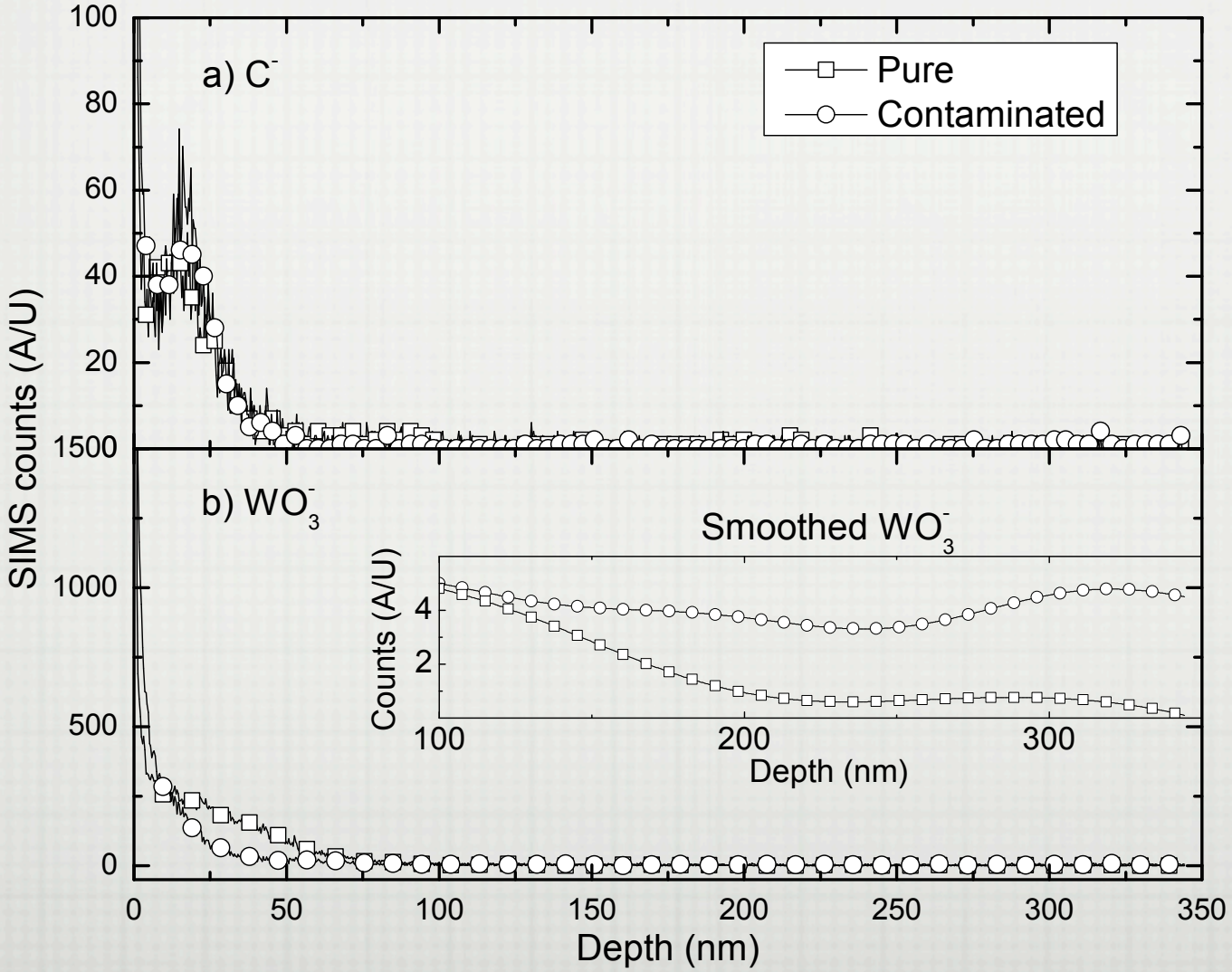
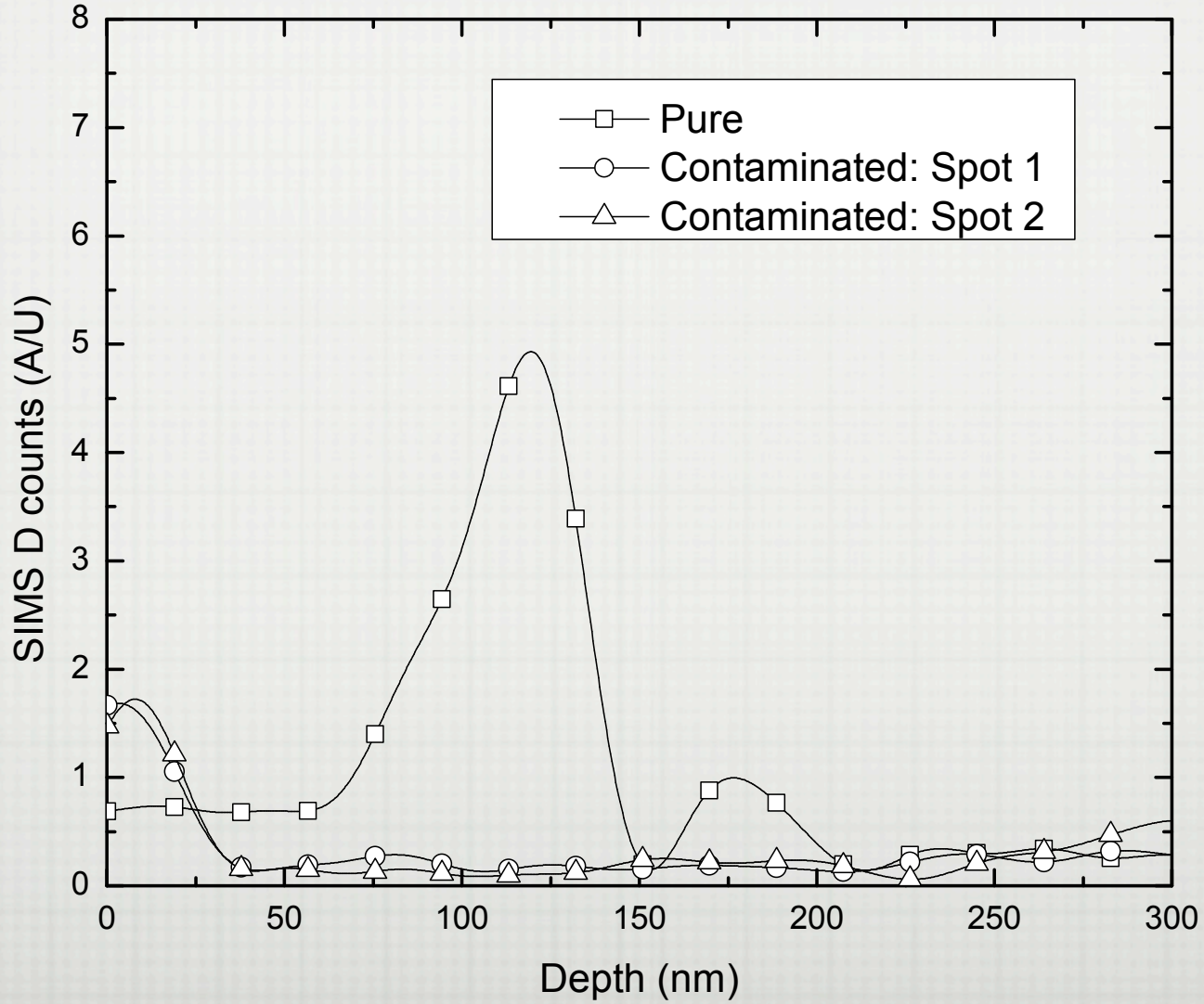


C AND O CONTAMINATION IN PCW FOILS

SIMS DEPTH PROFILES OF D IN PURE AND CONTAMINATED PCW FOILS



C AND O CONTAMINATION IN PCW FOILS
SUMMARY OF CONTAMINATION EFFECTS

- WIDE SPREAD IN RETENTION FOR 500 K IRRADIATIONS OF CONTAMINATED PCW
- CONTAMINATION IS NON-HOMOGENEOUS HIGH CONCENTRATION SPOTS
- NO DIFFERENCES OBSERVED IN D RETENTION IN 300 K PURE AND CONTAMINATED FOILS
- SIGNIFICANT, NON-UNIFORM CONTAMINATION FOUND IN SOME PCW SPECIMENS FROM "CONTAMINATED" BATCH
- CONTAMINATION SHOWN TO PREVENT DEUTERIUM DIFFUSION INTO BULK DESPITE HIGHLY LOCALIZED NATURE OF CONTAMINATION
- REDUCED RETENTION IN BULK RESULTS IN LOWER OVERALL RETENTION, EXPLAINS WHY 300 K EXPERIMENTS UNAFFECTED
- CONTAMINATED SPECIMENS SHOWED RESISTANCE TO BLISTER FORMATION WHEN IRRADIATED AT 500 K TO FLUENCES AS HIGH AS $3X10^{24}$ D^+/M^2

PUBLISHED CONTRIBUTIONS

- FIRST MASS ANALYZED STUDY OF LOW ENERGY/HIGH FLUENCE AND LOW FLUX DEUTERIUM IRRADIATION - PRESENTED PSI 19, J. NUCL. MATER. 415 (2011) S641
- CONTINUED STUDY OF LOW ENERGY DEUTERIUM IRRADIATION IN PCW AND SCW- PRESENTED AT PSI 20 P3-48 AND ACCEPTED FOR PUBLICATION IN J. NUCL. MATER. (2012)
- IN DEPTH STUDY OF CONTAMINATION EFFECTS ON DEUTERIUM RETENTION IN TUNGSTEN - J. NUCL. MATER. 427 (2012) 193
- PROPOSED MECHANISM FOR 2.1 EV TRAP CREATION IN SCW AND PCW - J. NUCL. MATER. 429 (2012) 48

THANK YOU VERY MUCH FOR YOUR ATTENTION

QUESTIONS?