Liquid-metal erosion and surface physics studies in IIAX

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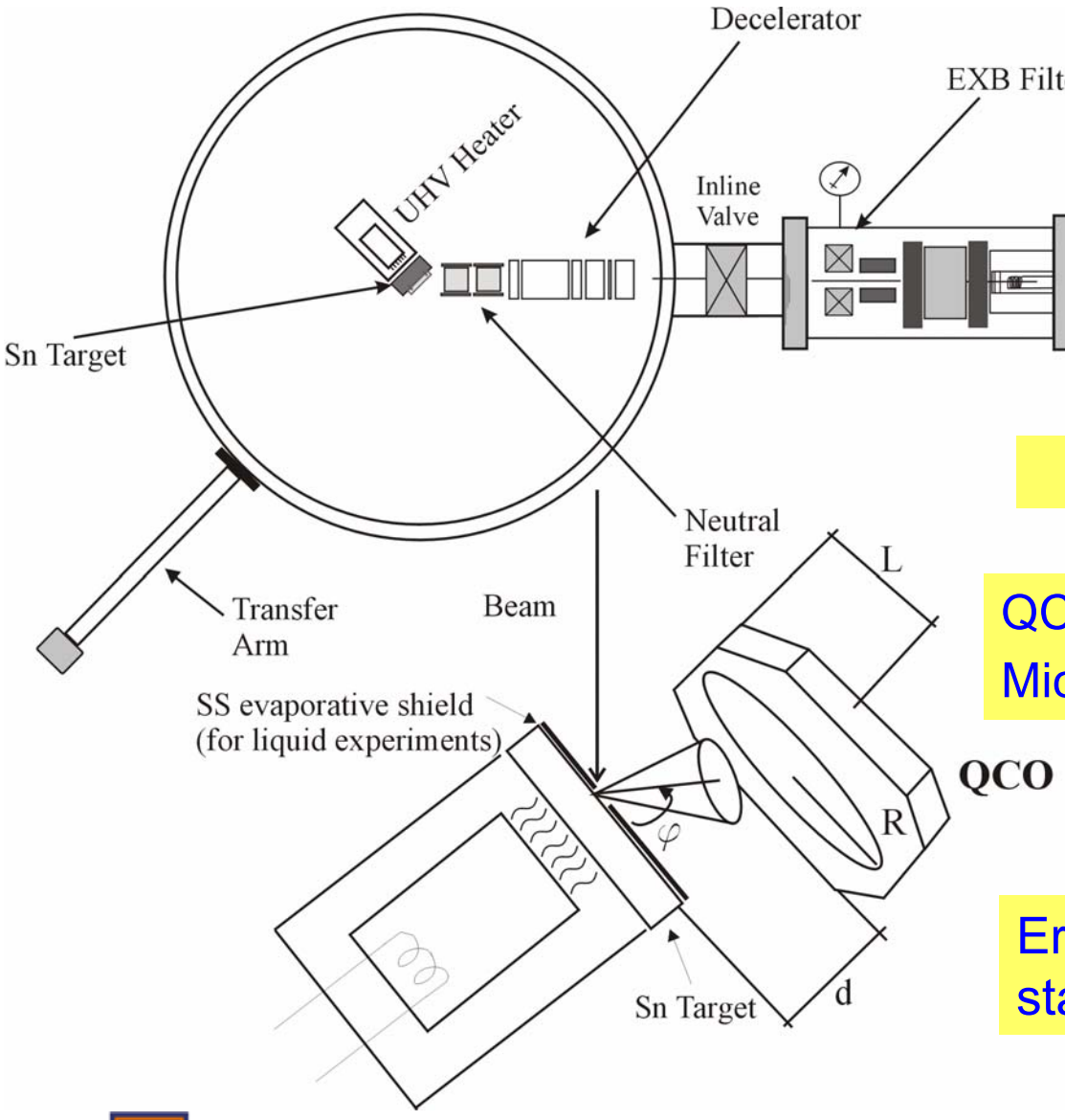
Outline of Talk

- Scope of liquid metal erosion work in IIAX
- Experimental setup of IIAX (Ion-surface Interaction Experiment)
- Measurements and modeling of solid and liquid tin
- Temperature-dependent erosion studies of liquid lithium
- Conclusions and Future Work

Scope of Experimental Work in IIAX

Liquid Lithium	Eo (eV) 200-1000	T (°C) 25-425	D-treated	Non D-treated
H^+	✓.	✓.	✓.	
D^+	✓.	✓.	✓.	✓.
He^+	✓.	✓.	✓.	✓.
Li^+	✓.	✓.	✓.	
Liquid Tin-lithium	**Eo (eV) 200-1000**	**T (°C) 25-425**	**D-treated**	**Non D-treated**
D^+	✓.	✓.	✓.	
He^+	✓.	✓.	✓.	✓.
Li^+	✓.		✓.	
Liquid Tin	**Eo (eV) 200-1000**	**T (°C) 25-425**	**D-treated**	**Non D-treated**
H^+	✓.	.		✓.
D^+	✓.	✓.		✓.
He^+	✓.	✓.		✓.



Colutron ion source for both Gaseous and metal species: H^+, D^+, He^+, and Li^+

$\Phi_{ion\ beam} \sim 10^{15} - 10^{18}$ ions/cm^2

$\Gamma_{ion\ beam} \geq 10^{14}$ ions/cm^2/sec

QCO (Quartz crystal oscillator Microbalance dual unit, ± 0.1 Å)

Erosion measurements on static liquid metals

J.P. Allain, M.D. Coventry, D.N. Ruzic, J. Nucl. Mater. Accepted (2002).
M.D. Coventry, J.P. Allain, D.N. Ruzic, J. Nucl. Mater accepted (2002).

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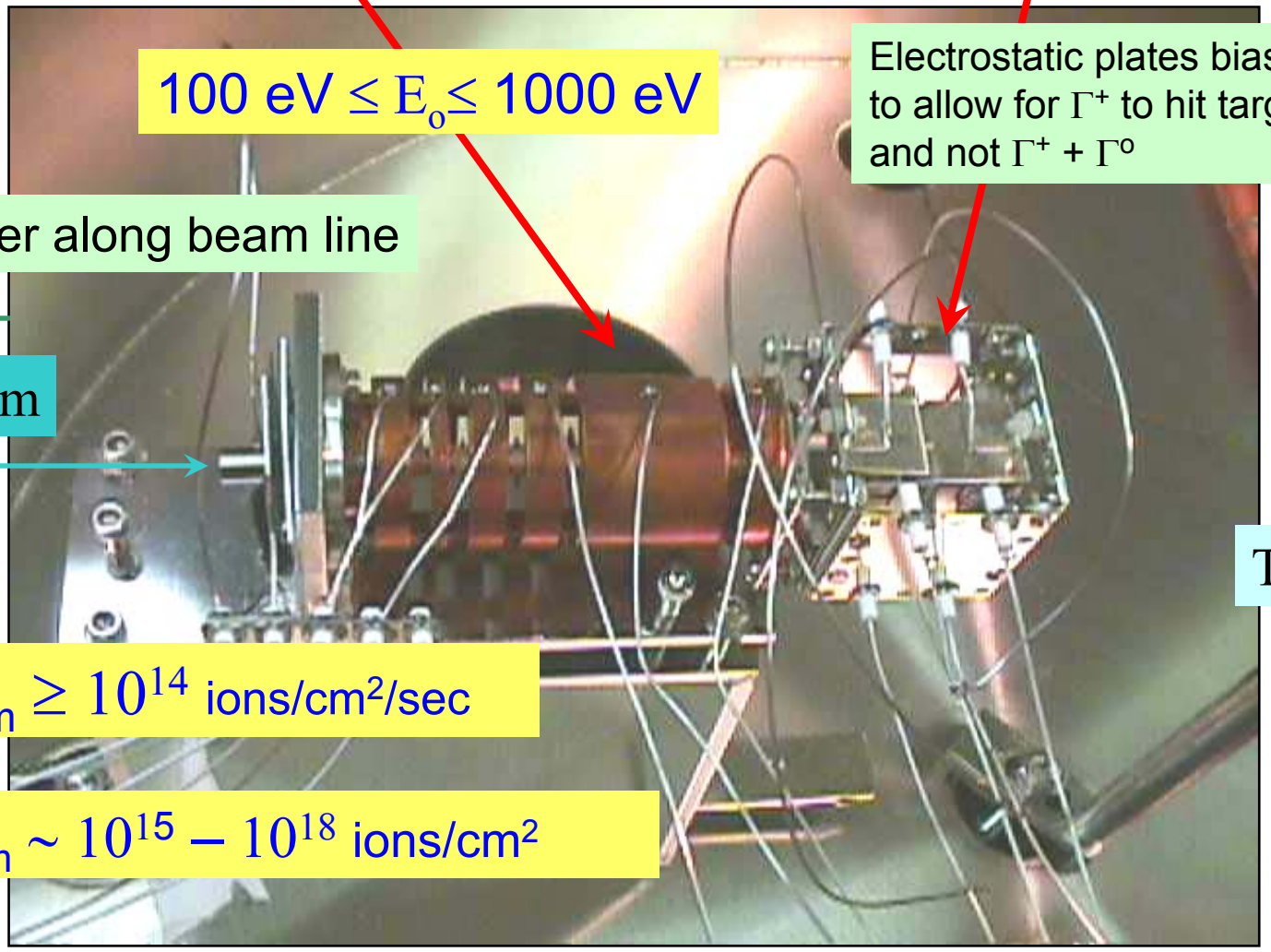
Decelerator and Neutral Filter



$100\ eV \leq E_o \leq 1000\ eV$

Electrostatic plates biased to allow for Γ^+ to hit target and not $\Gamma^+ + \Gamma^o$

E X B filter along beam line

Ion Beam

Target

$\Gamma_{ion\ beam} \geq 10^{14}$ ions/cm^2/sec

$\Phi_{ion\ beam} \sim 10^{15} - 10^{18}$ ions/cm^2

J.P. Allain, M.R. Hendricks and D.N. Ruzic, J. Nucl. Mater. 290-293 (2001) 180

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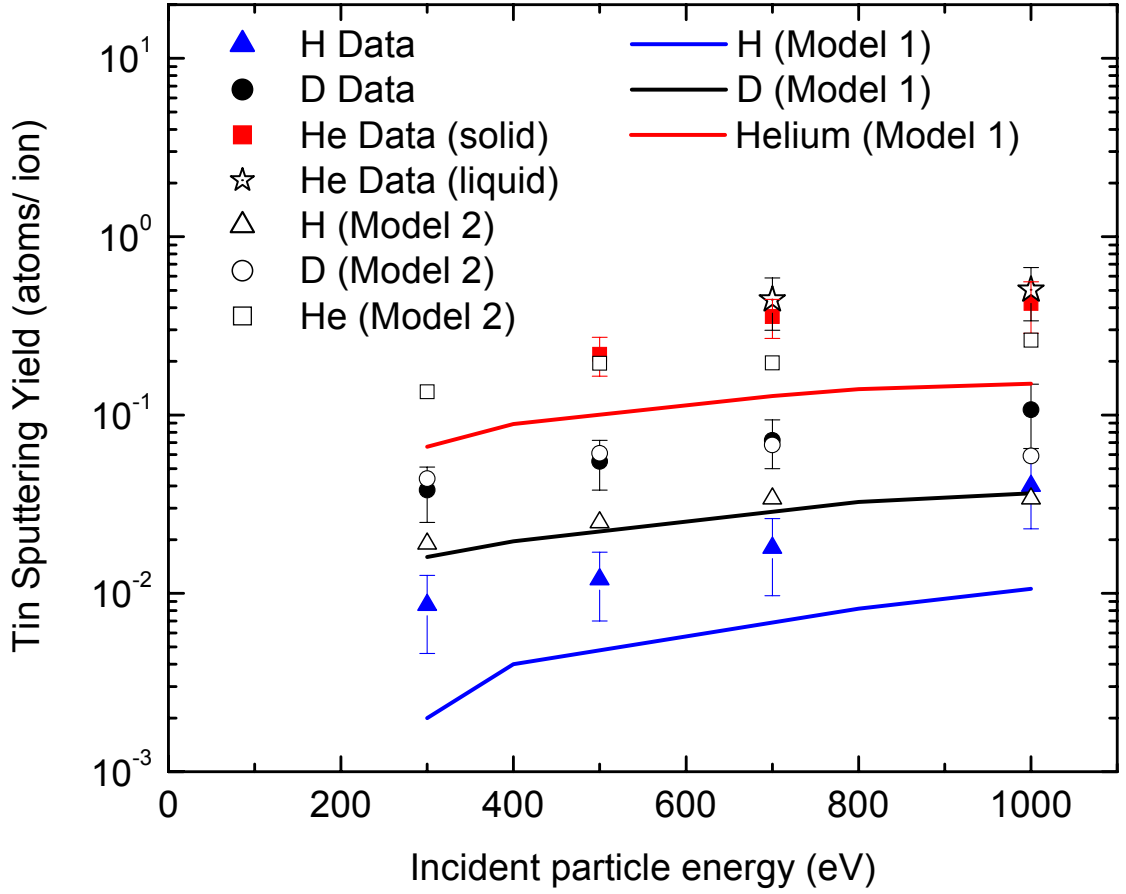
Tin erosion studies in IIAX



- Solid tin sputtering yield results showed enhanced erosion with the existence of an oxide coating consistent with tin-oxide behavior[1]

1. R. Kelly and E. Giani, Nuclear Instruments and Methods 209/210 (1983) 531.

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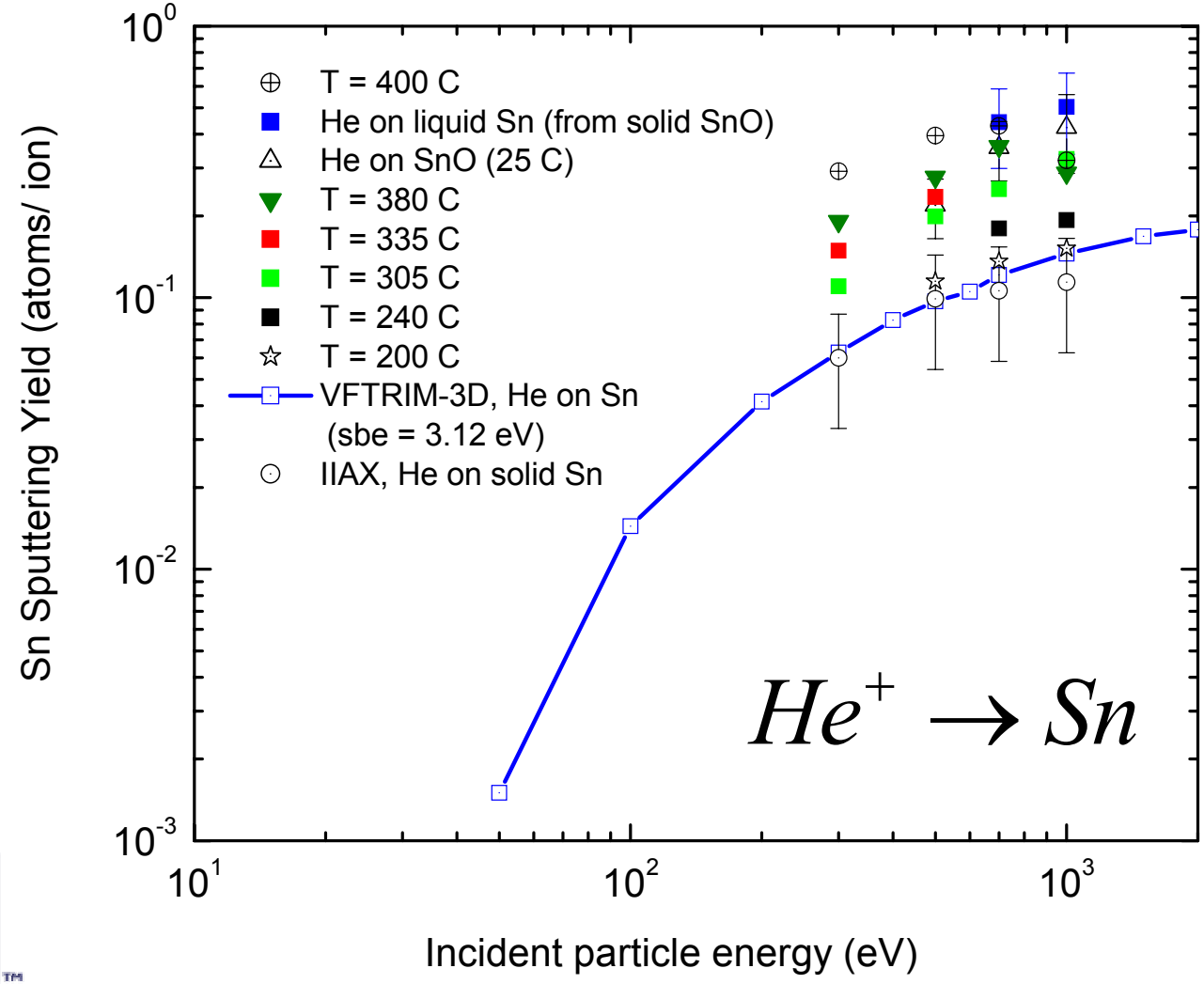
Sn sputtering vs incident particle energy by He^+ bombardment



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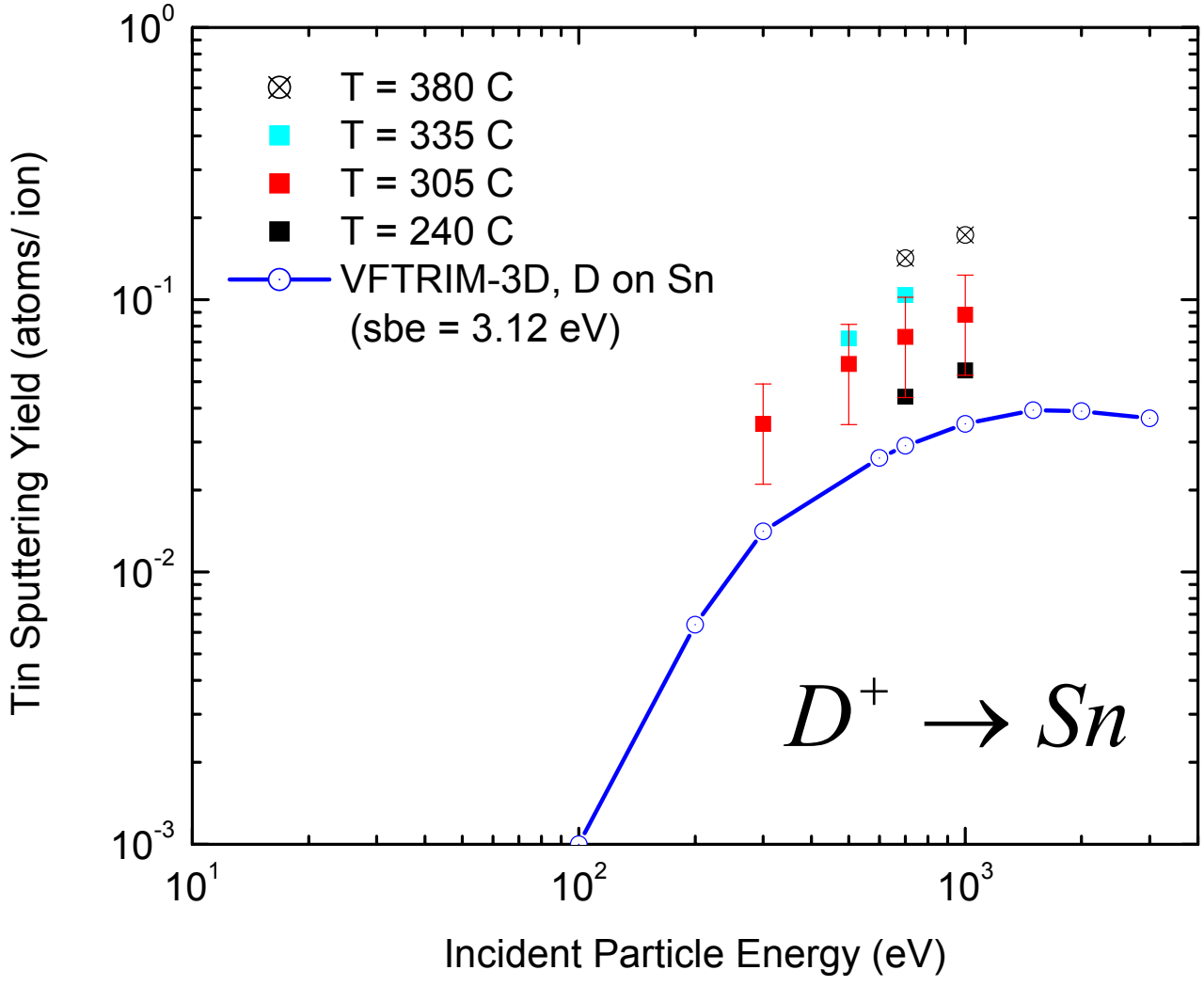
Sn sputtering vs incident particle energy by D^+ bombardment



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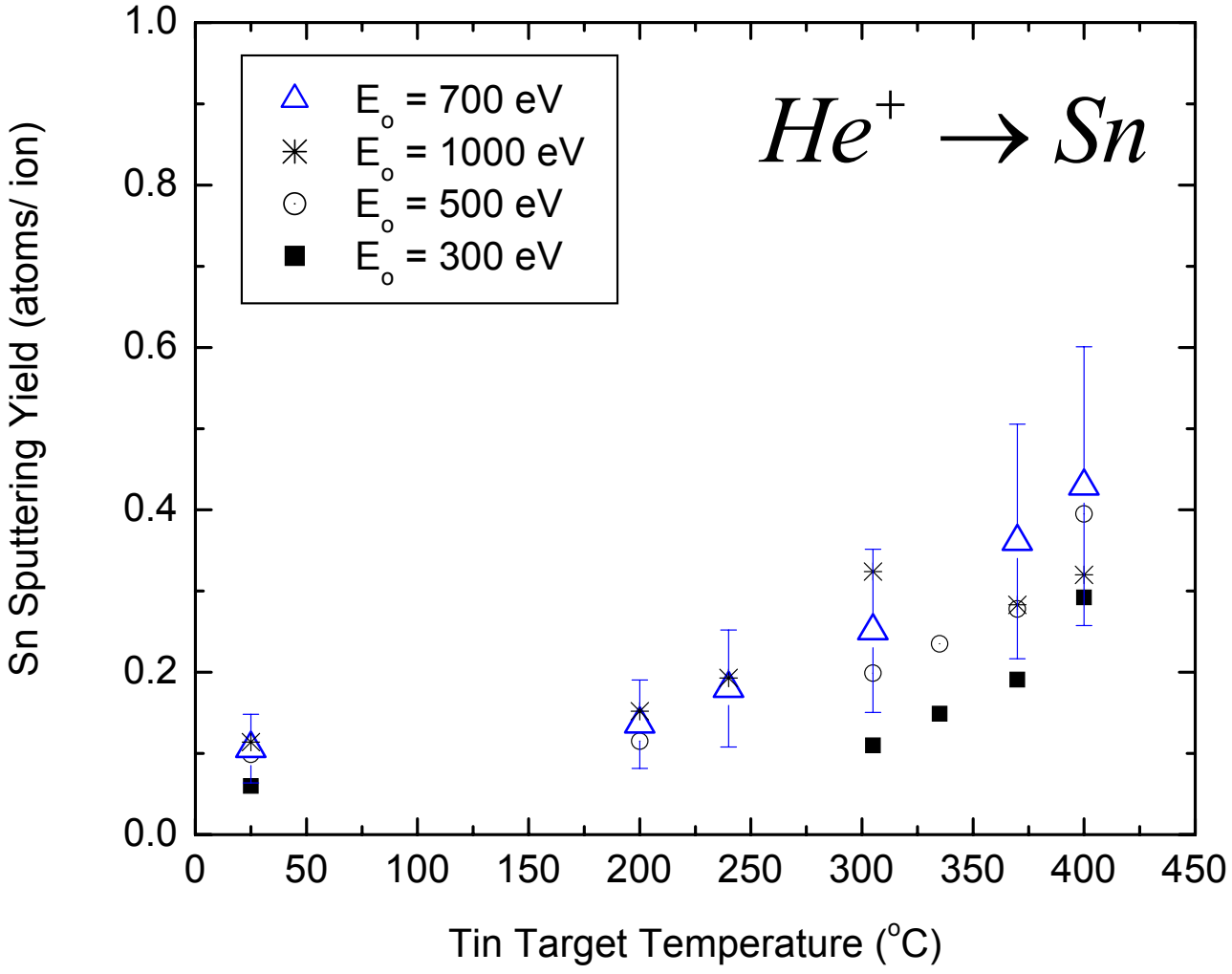
Tin sputtering dependence on temperature: He^+ on liquid Sn



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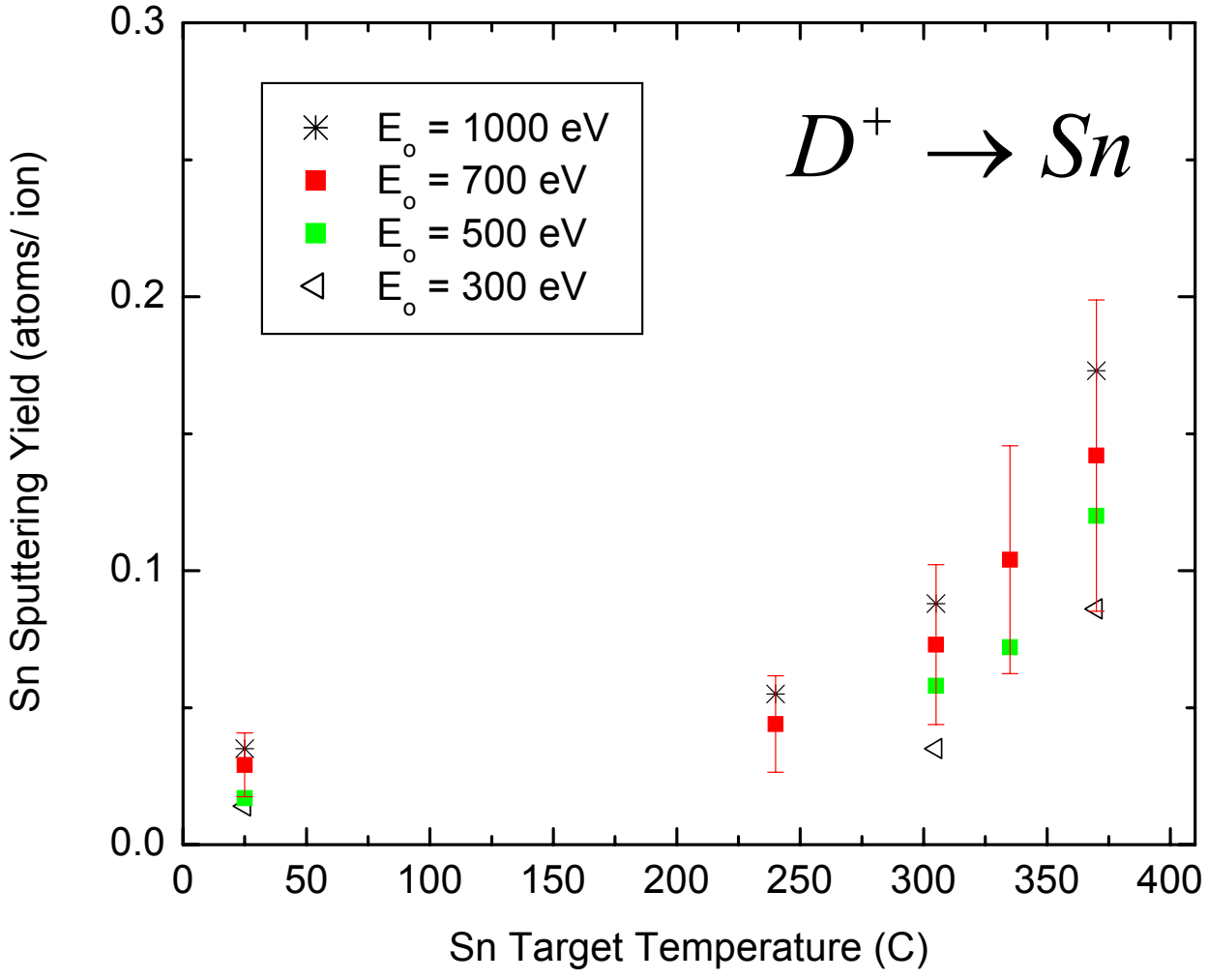
Tin sputtering dependence on temperature: D^+ on liquid Sn



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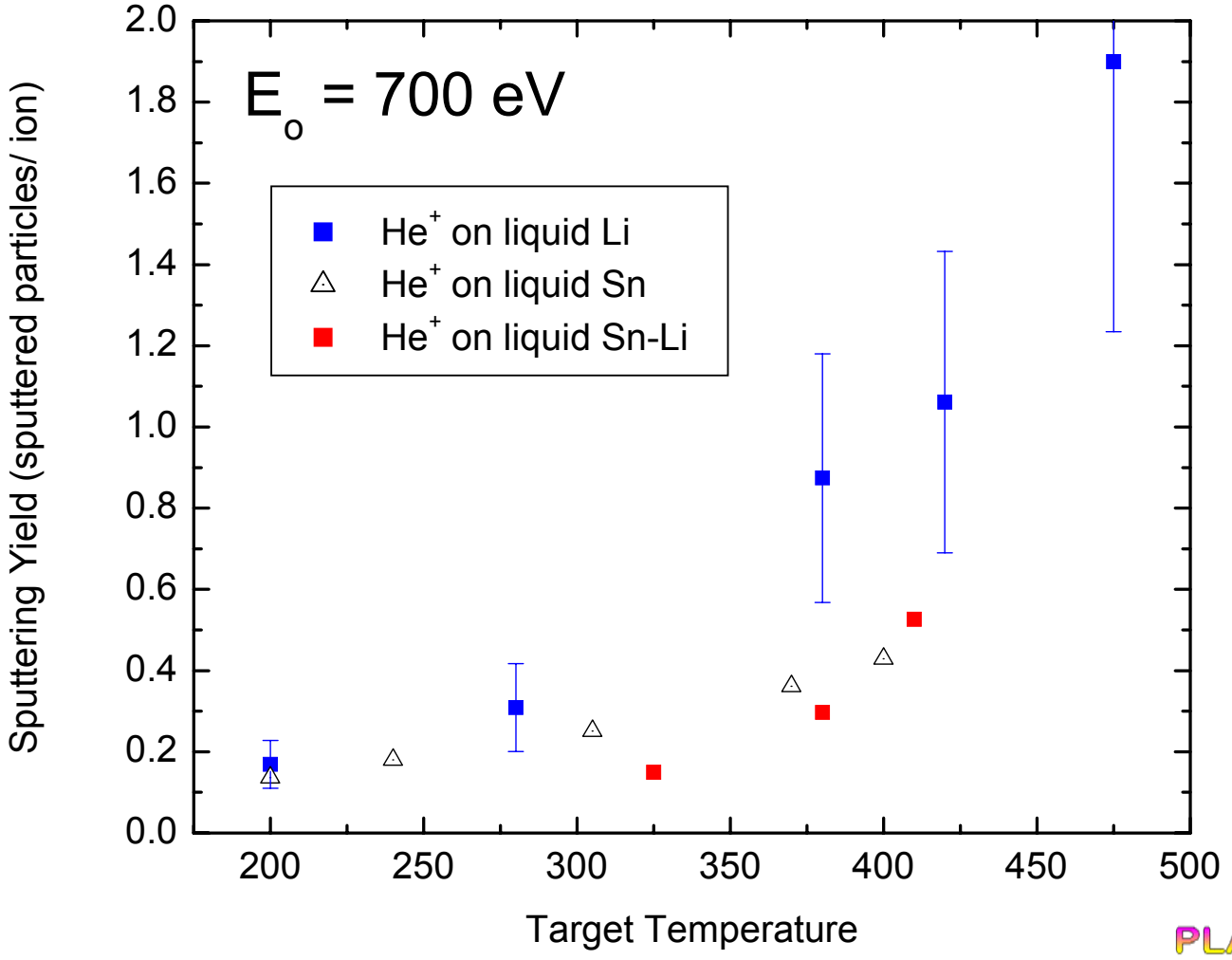
Comparison of Sn sputtering with SnLi and Lithium from He^+ bombardment



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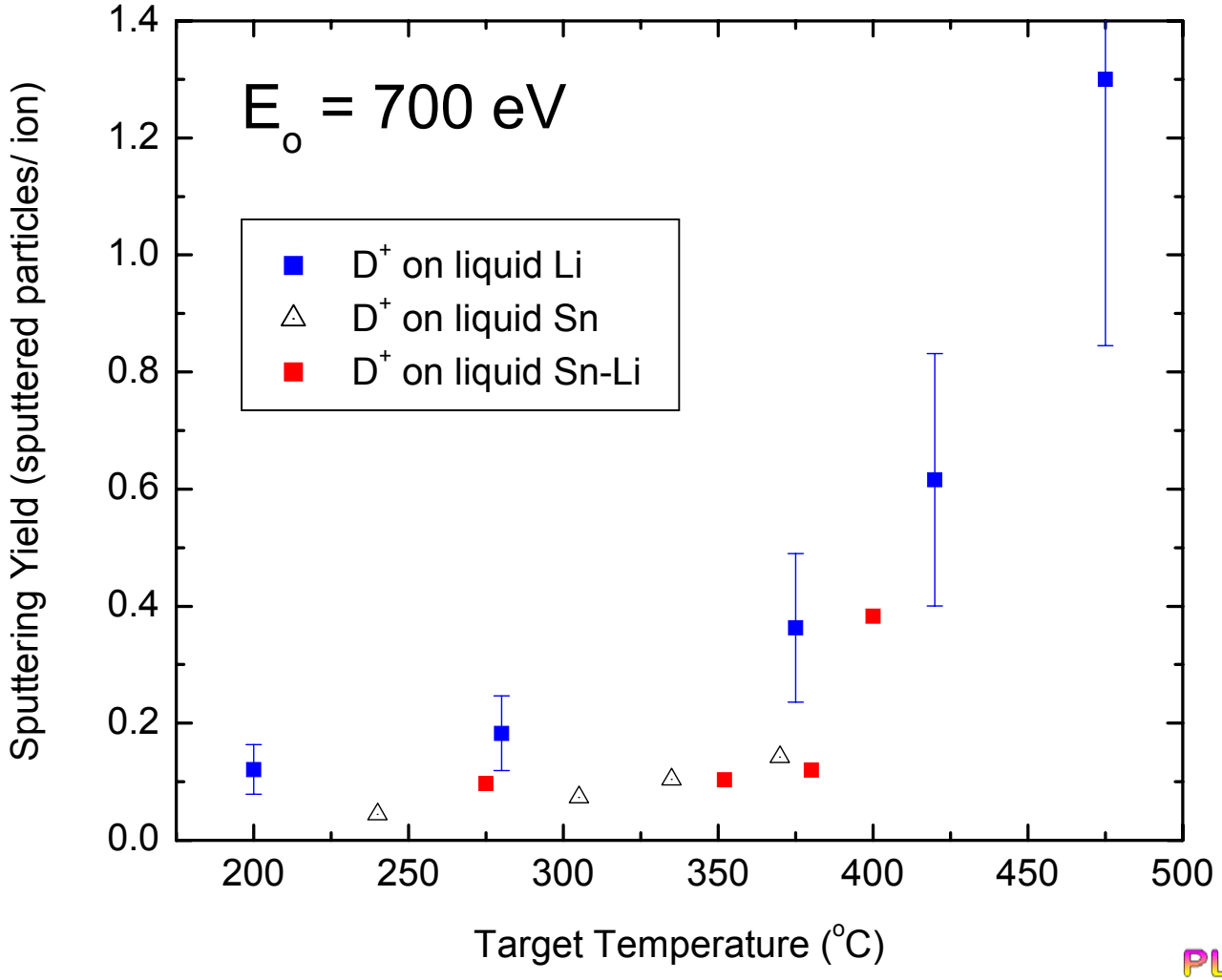
Comparison of Sn sputtering with SnLi and Lithium from D^+ bombardment



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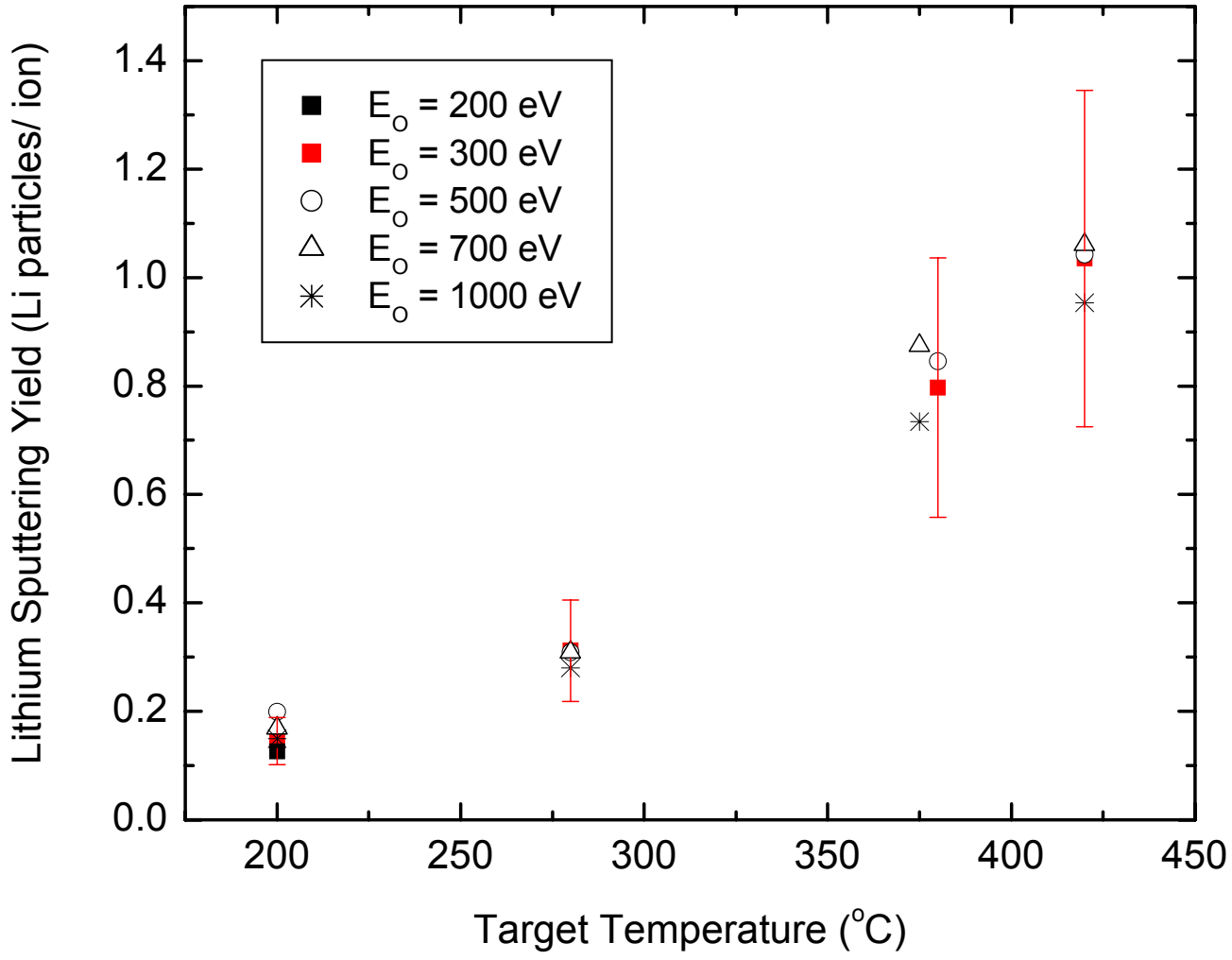
Lithium research at the UIUC

- Erosion of lithium from various surface conditions (i.e. deuterium coverage, variation in temperature)
- Secondary ion sputtered fraction from lithium and tin-lithium as a function of temperature and incident particle energy
  - Not a strong function at temps 200-400 °C and incident energies 200-1000 eV ($Y^+ \sim 0.65$)
- Currently developing models to understand erosion enhancement with target temperature

He^+ bombardment of liquid Li



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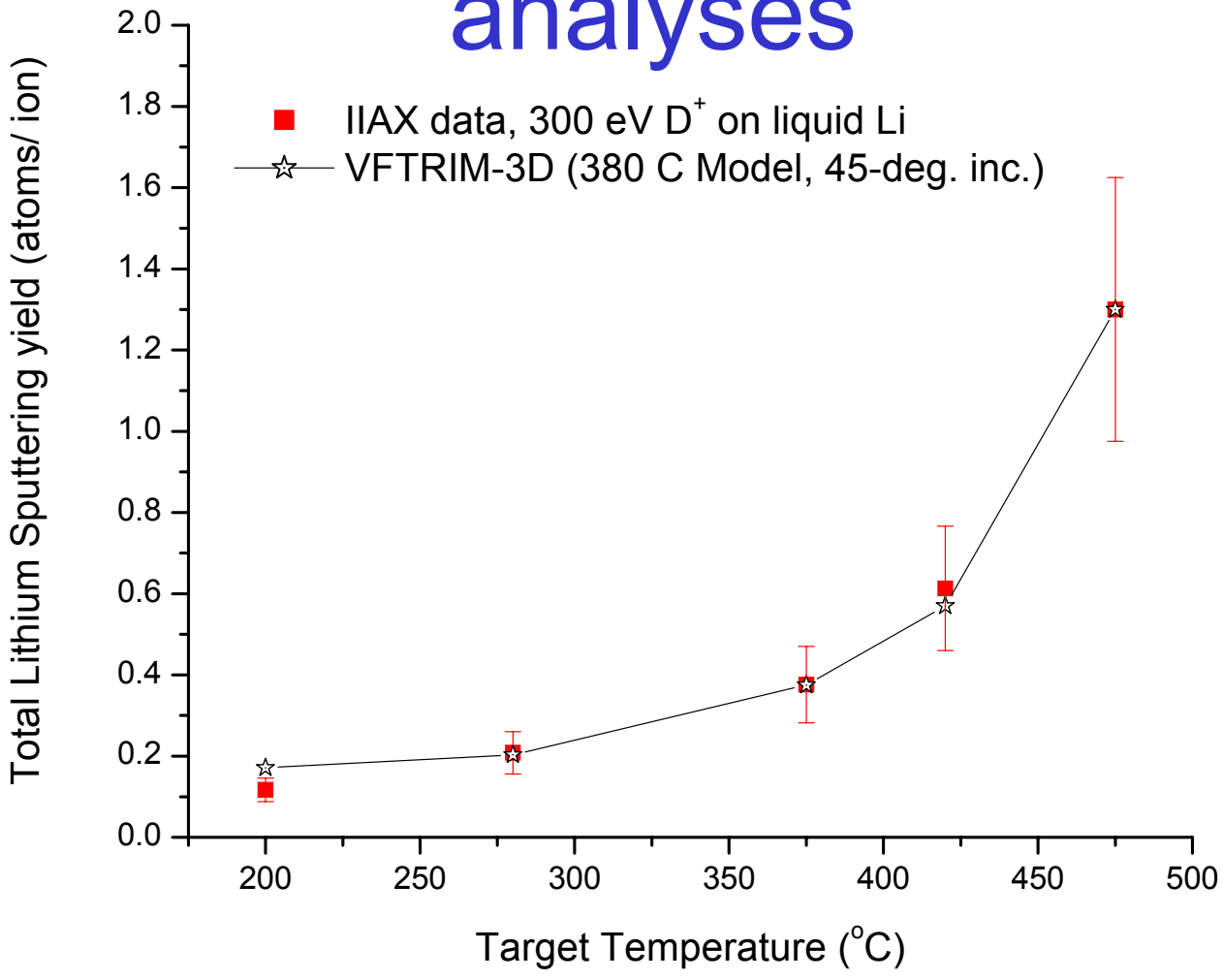
Modeling includes both Monte Carlo simulations and semi empirical analyses



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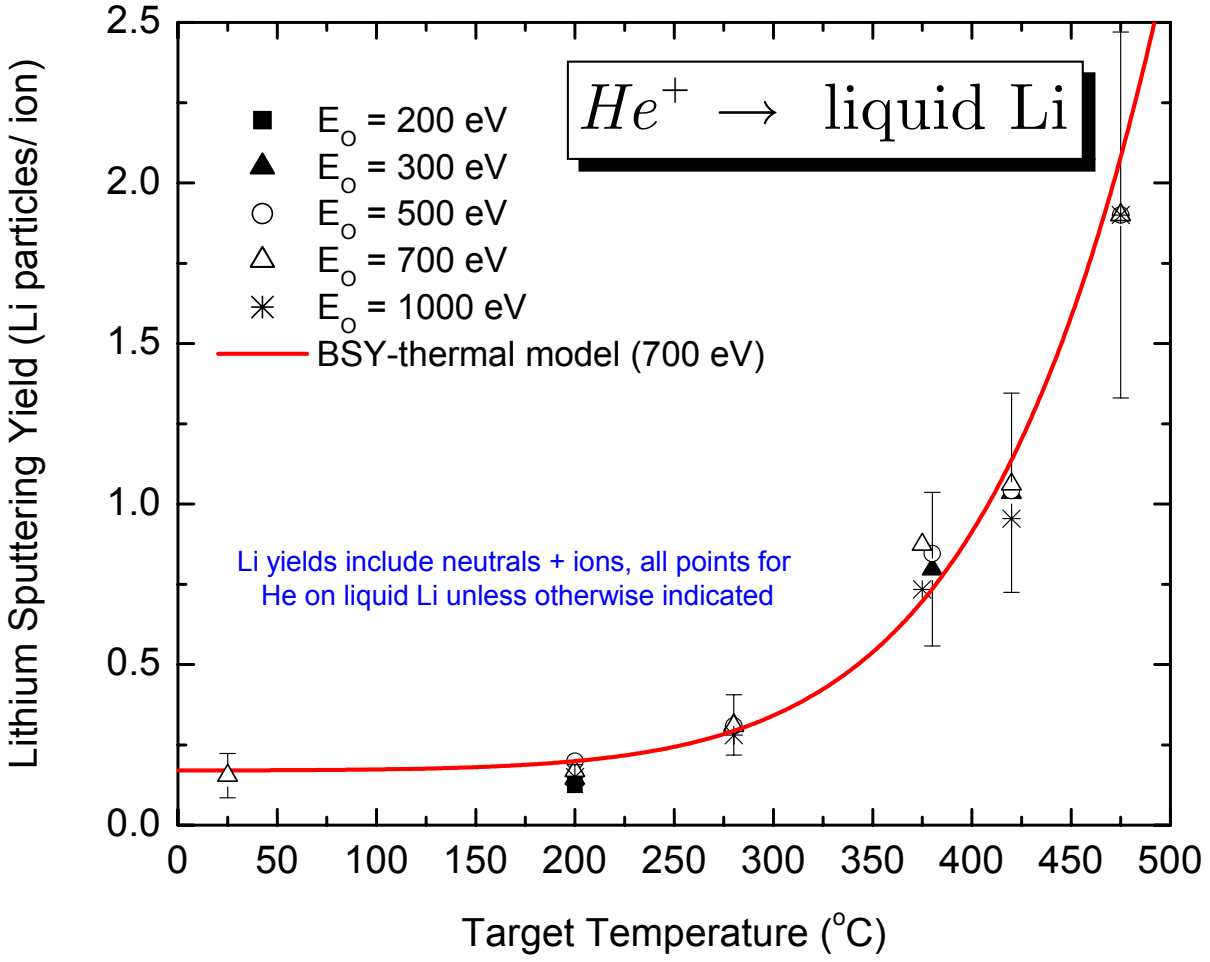
Liquid metal erosion studies in IIAX



- Bohdansky-Sigmund-Yamamura thermal Model is shown to predict the temperature-dependent data of IIAX quite well for bombardment cases of He^+ on liquid lithium. Cases for D^+ and Li^+ bombardment are currently being investigated as well as molecular dynamics studies.

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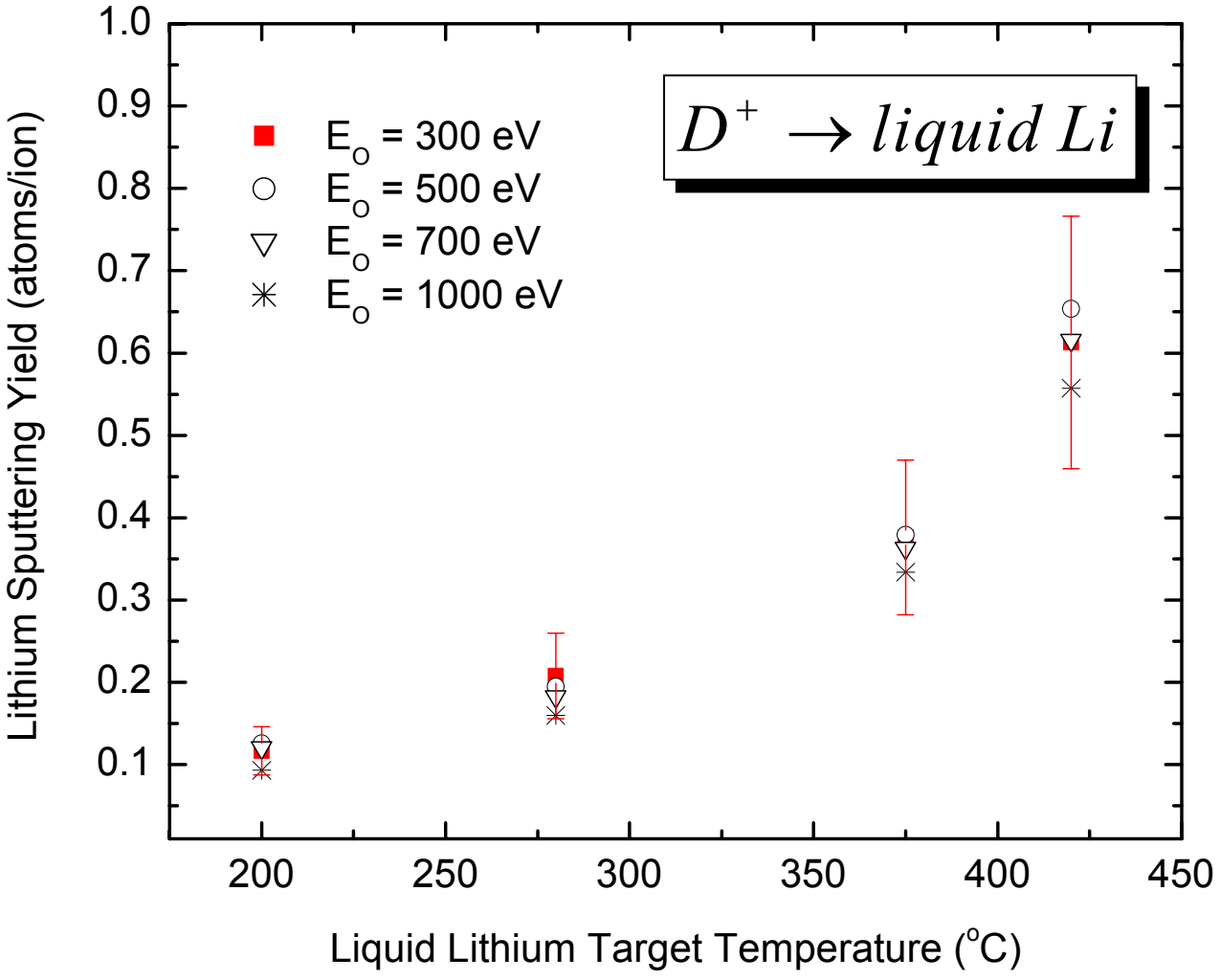
D^+ bombardment of liquid Li



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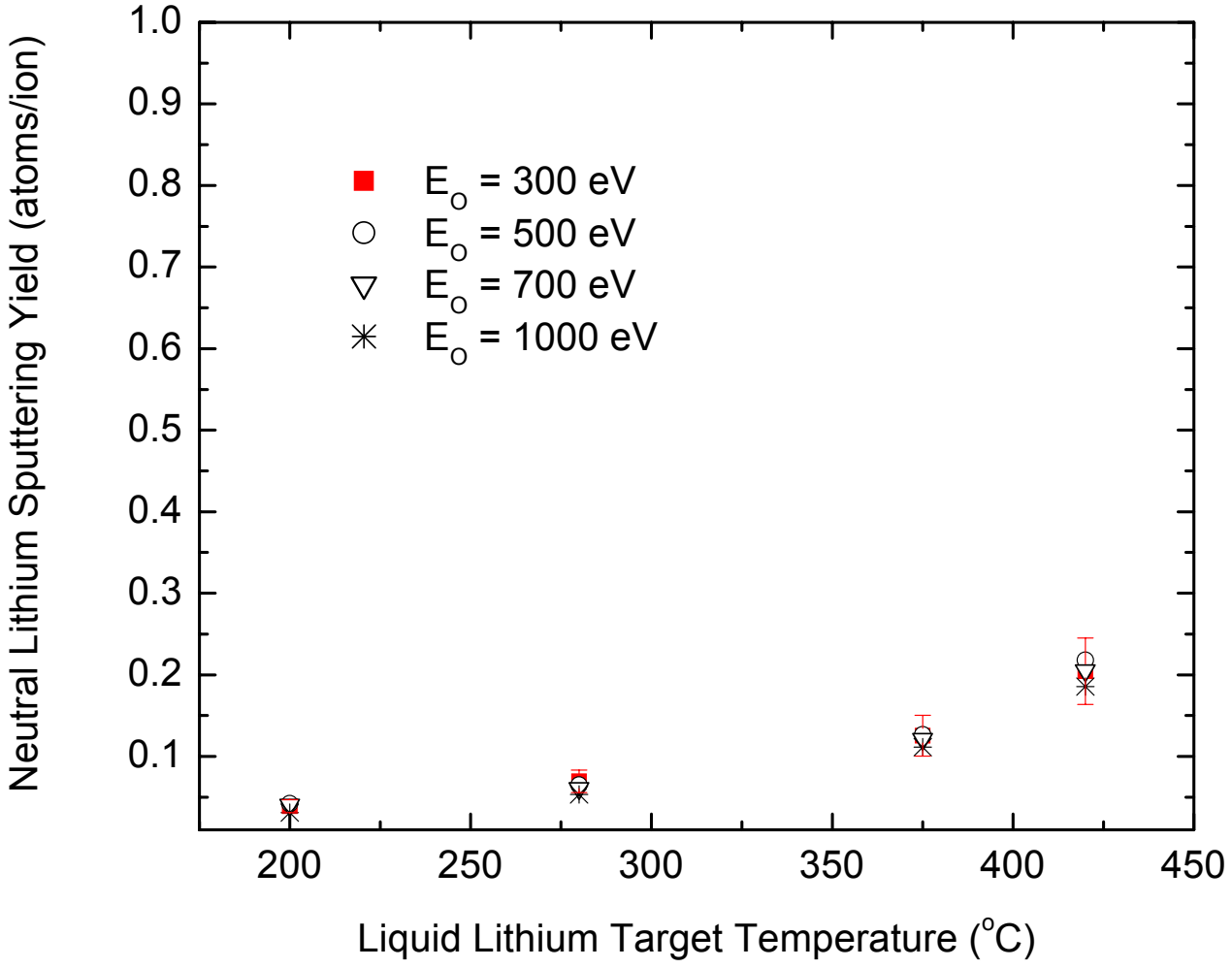
D^+ bombardment of liquid Li with sputtered neutrals yield only



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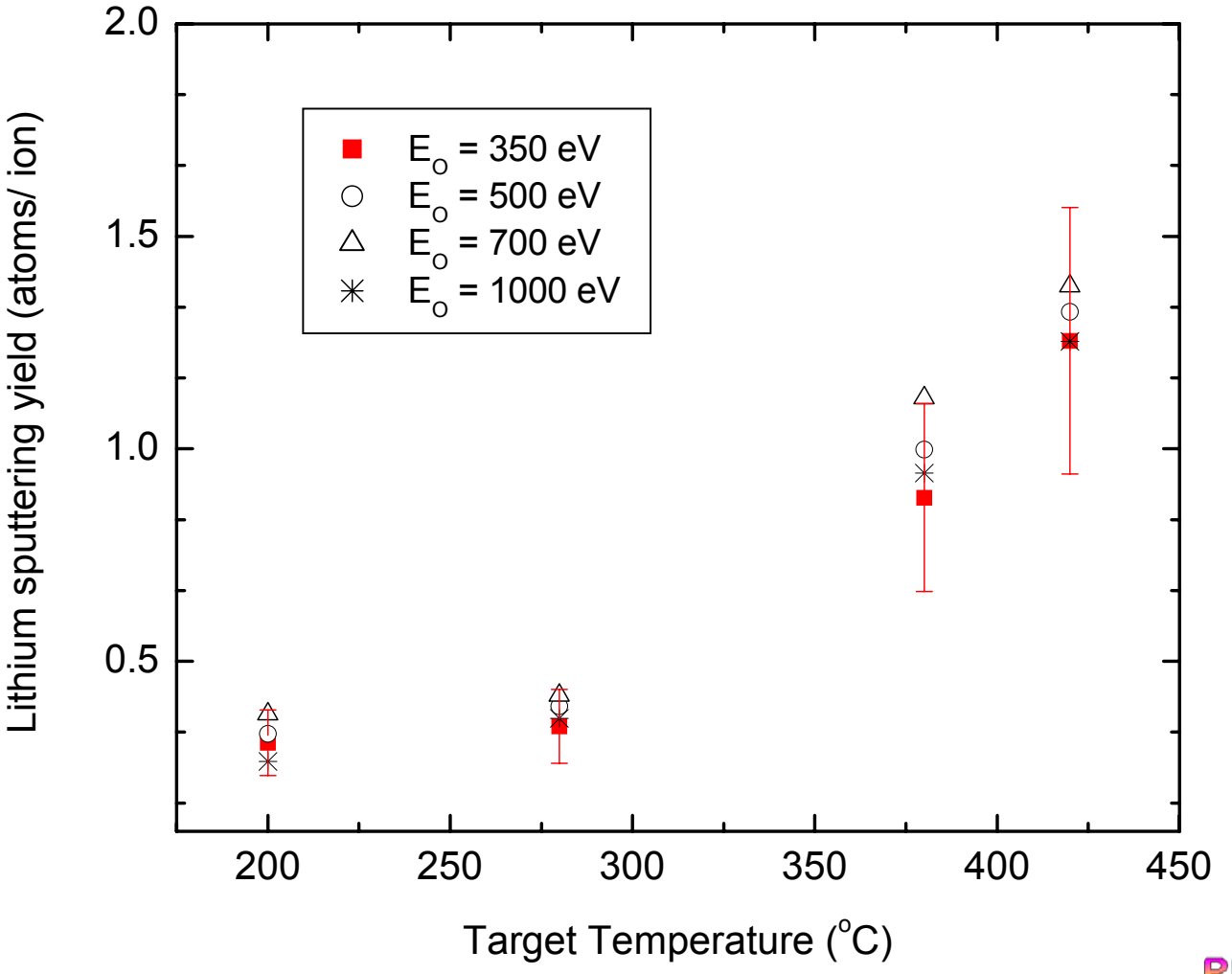
Li^+ bombardment of liquid Li (total: ions + neutrals)



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Conclusions

- Tin sputtering measurements in the solid phase shows enhancement in erosion if oxide coverage is present.
- Temperature dependent tin erosion shows signs of erosion enhancement, however there are signs of high sputtering threshold.
- Solid and liquid lithium sputtering yields measured in IIAX-UIUC show less-than unity self-sputtering yields.
- Temperature dependent measurements show lithium erosion enhancement for D, He and Li bombardment at 45-degree incidence.
- Further studies needed with molecular dynamics and semi-analytical models to study enhanced erosion phenomena.

Future Work Plan

- Continue study of temperature-enhanced erosion of liquid lithium and development of a self-consistent model using molecular dynamics and other simulation/analytical tools.
- Measurements of secondary ion sputtered fraction from solid and liquid tin surfaces.
- Continue study of Sn sputtering in solid and liquid phase under various surface conditions.
- Further study on bubble formation effects in liquid lithium sputtering and tin sputtering at oblique incidence.

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