Response of Tungsten to High Temperature Implantation of D^+ and He^+

R.F. Radel & G.L. Kulcinski

HAPL Meeting-NRL

March 3rd, 2005

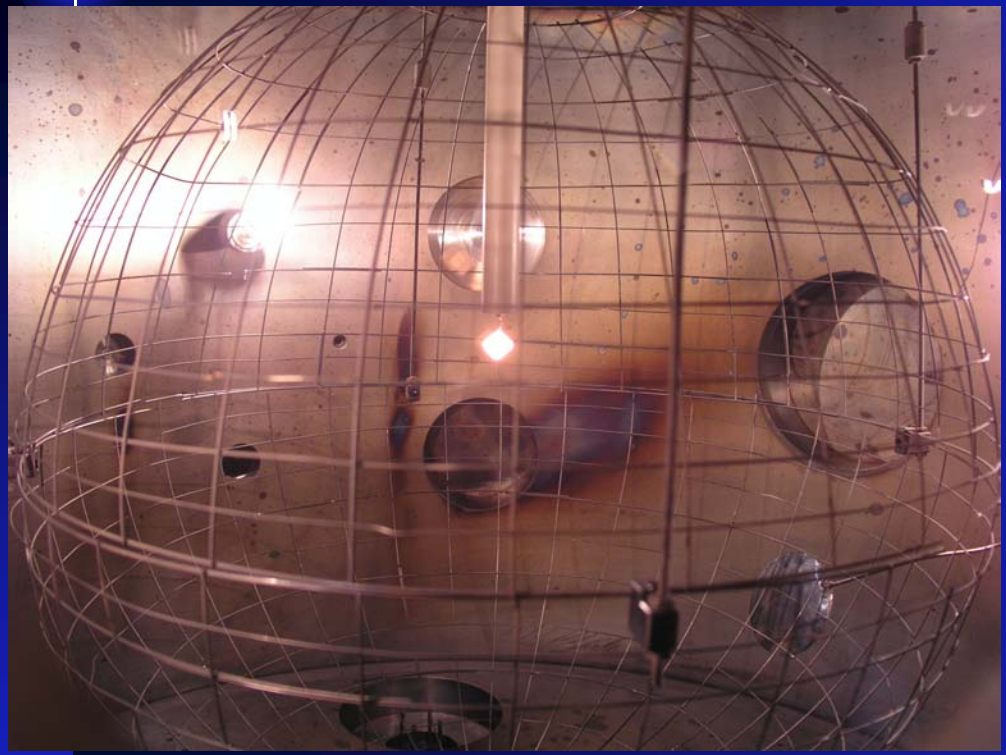
Fusion Technology Institute
University of Wisconsin-Madison

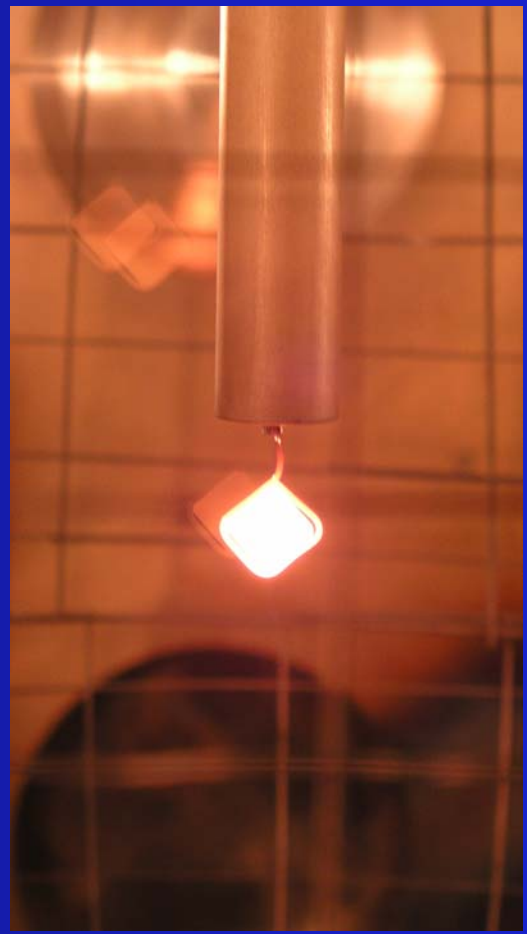
Objective of UW Study of Tungsten Coatings

To determine the effect of helium and deuterium implantation on the surface morphology of tungsten at high temperatures

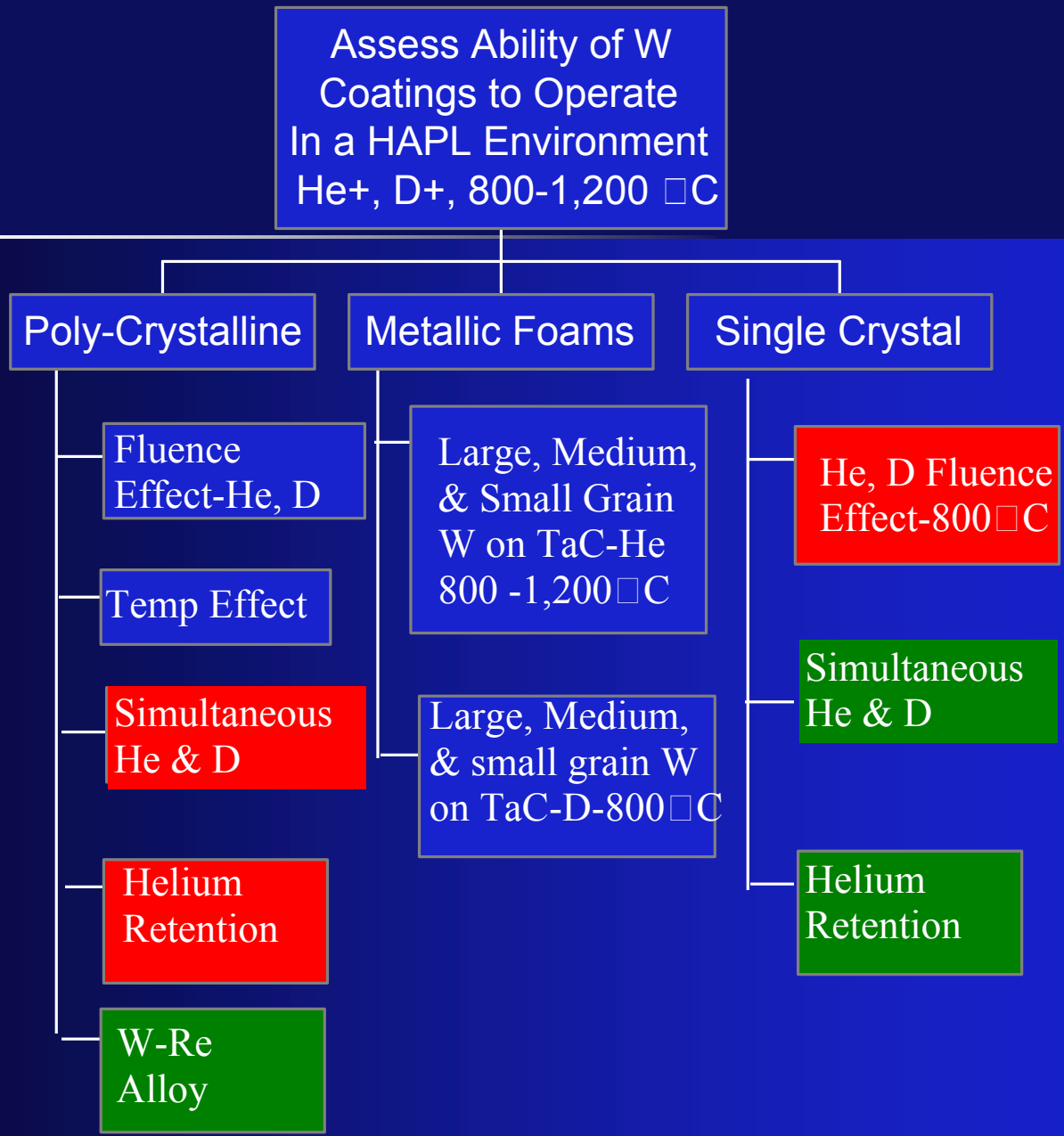
- **Why:** To evaluate whether tungsten will serve as a suitable material for the HAPL first wall
- **How:** Use IEC device to irradiate materials with He^+ and D^+ ions. Then use Scanning Electron Microscopy and Elastic Recoil Detection to determine morphology and retention rates of He and D.

UW IEC Chamber has Capability of High-Temperature Implantation at 10-100 kV

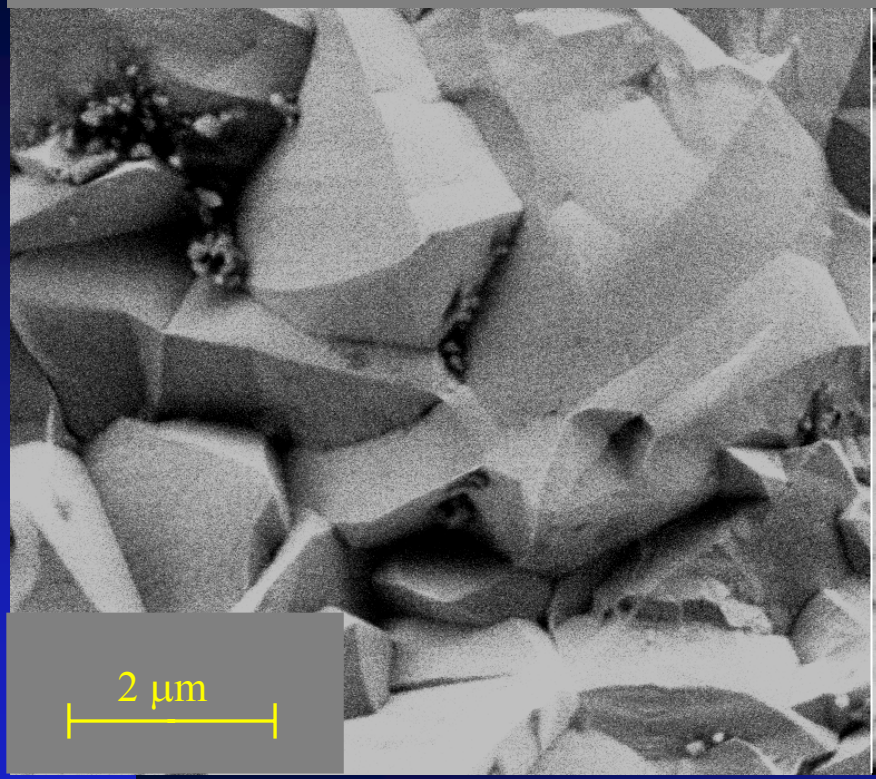


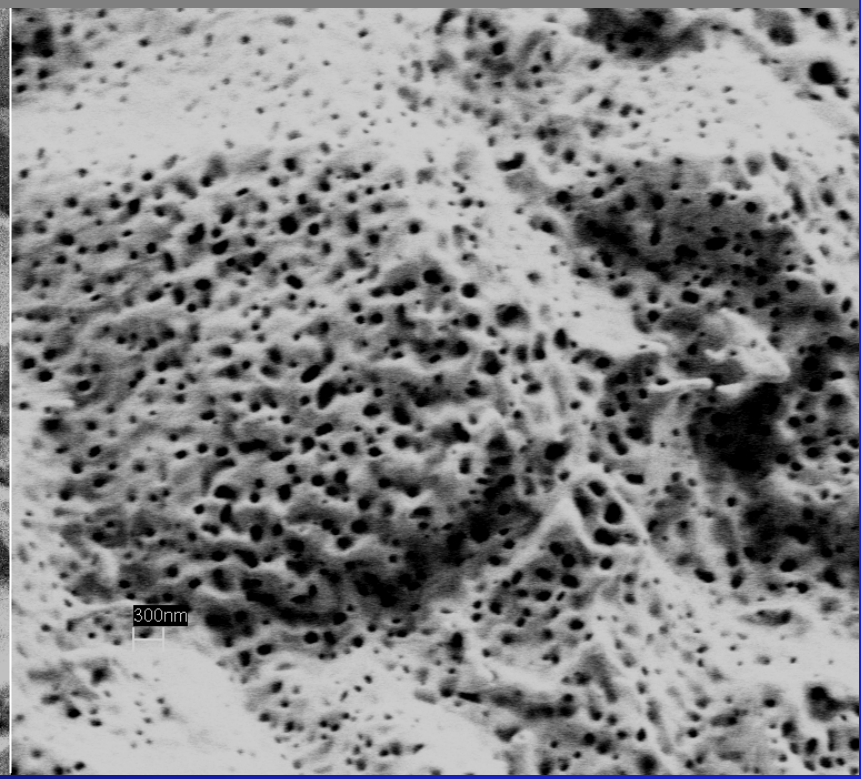


D^+, 20 kV, 5 mA
2 mtorr, 1100 °C


Assess Ability of W Coatings to Operate In a HAPL Environment He+, D+, 800-1,200 □C
Poly-Crystalline
Metallic Foams
Single Crystal
Fluence Effect-He, D
Temp Effect
Simultaneous He & D
Helium Retention
W-Re Alloy
Large, Medium, & Small Grain W on TaC-He 800 -1,200□C
Large, Medium, & small grain W on TaC-D-800□C
He, D Fluence Effect-800□C
Simultaneous He & D
Helium Retention

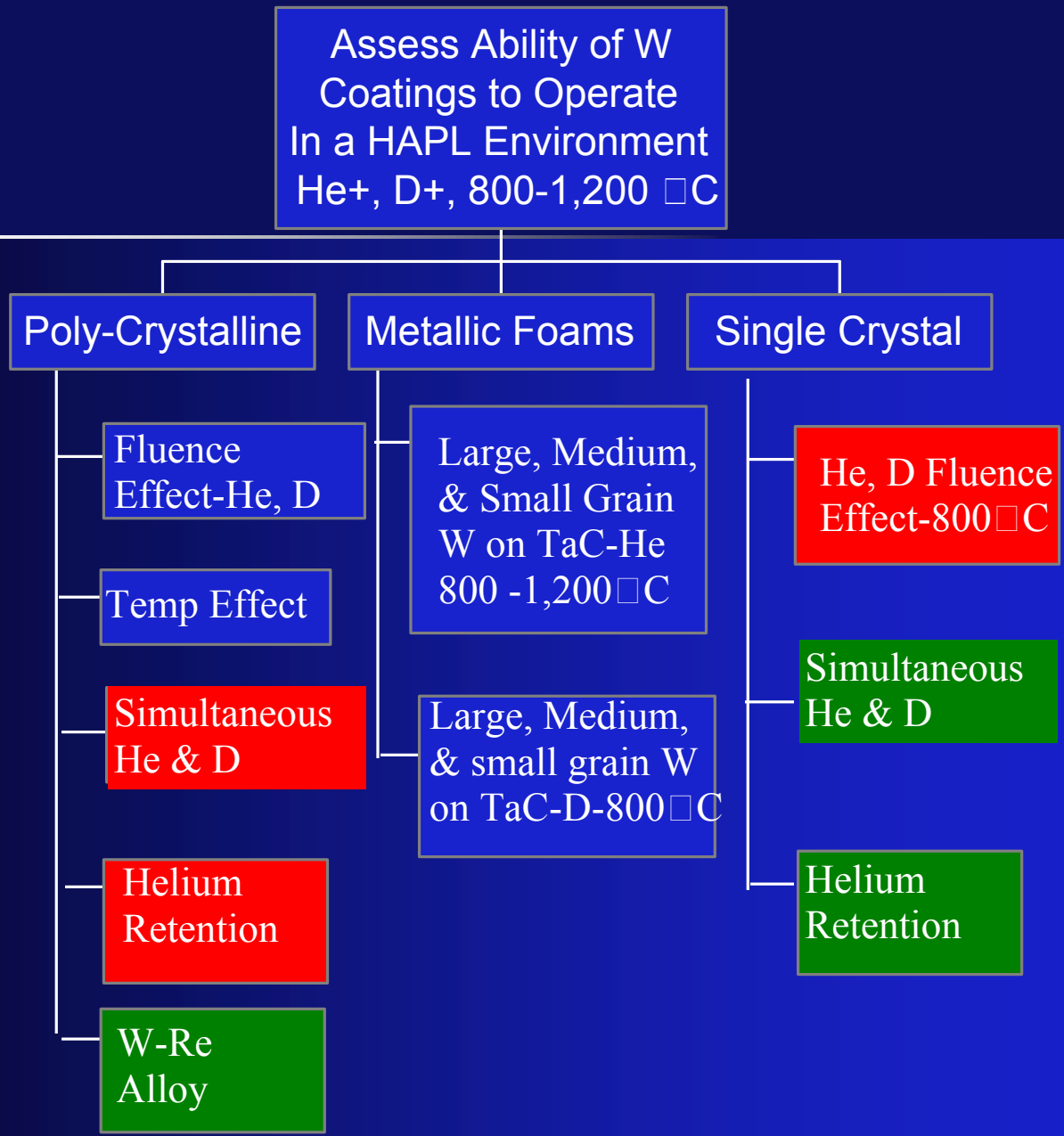
High Temperature He^+ Implantation Resulted in Porous Surface Structure in Large Grain W-coated TaC





Large Grain W-coated TaC Sample Irradiated at 800 °C with a $6x10^{17}$ He^+/cm^2 Fluence

Ref. HAPL Chamber Operation for ~8 hours

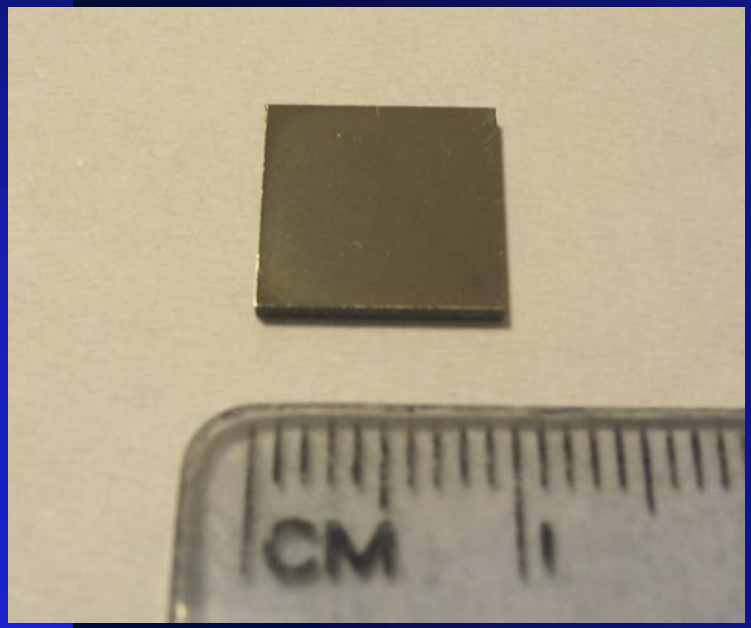

Assess Ability of W Coatings to Operate In a HAPL Environment He+, D+, 800-1,200 □C
Poly-Crystalline
Metallic Foams
Single Crystal
Fluence Effect-He, D
Temp Effect
Simultaneous He & D
Helium Retention
W-Re Alloy
Large, Medium, & Small Grain W on TaC-He 800 -1,200□C
Large, Medium, & small grain W on TaC-D-800□C
He, D Fluence Effect-800□C
Simultaneous He & D
Helium Retention

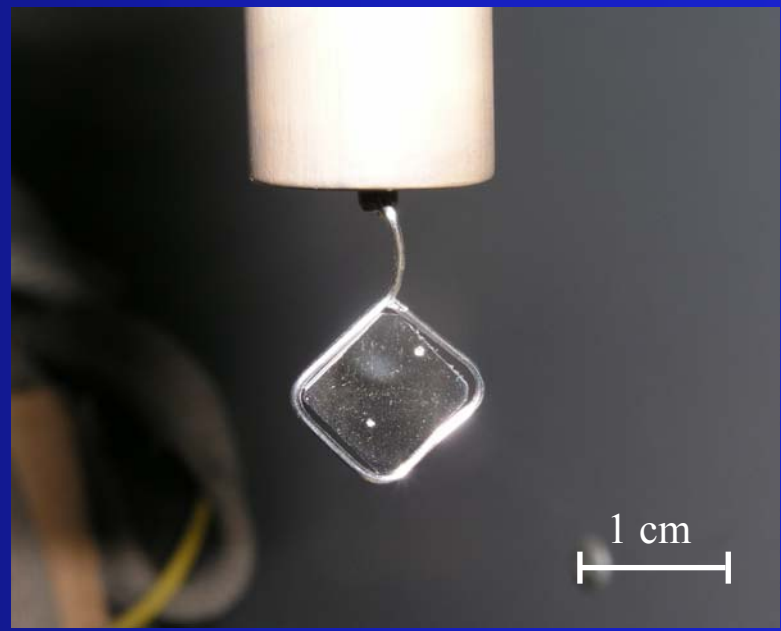
Progress Since the Last Meeting

- He^+ Fluence scans were performed on **polycrystalline** tungsten at 800 ºC
- He^+ Fluence scans were performed on **single crystal** tungsten at 800 ºC
- **Simultaneous** He^+ and D^+ Fluence scans were performed on polycrystalline tungsten at 800 ºC
- Elastic Recoil Detections was used to examine the **retention rates and depth profiles** of He^+ and D^+ in tungsten samples

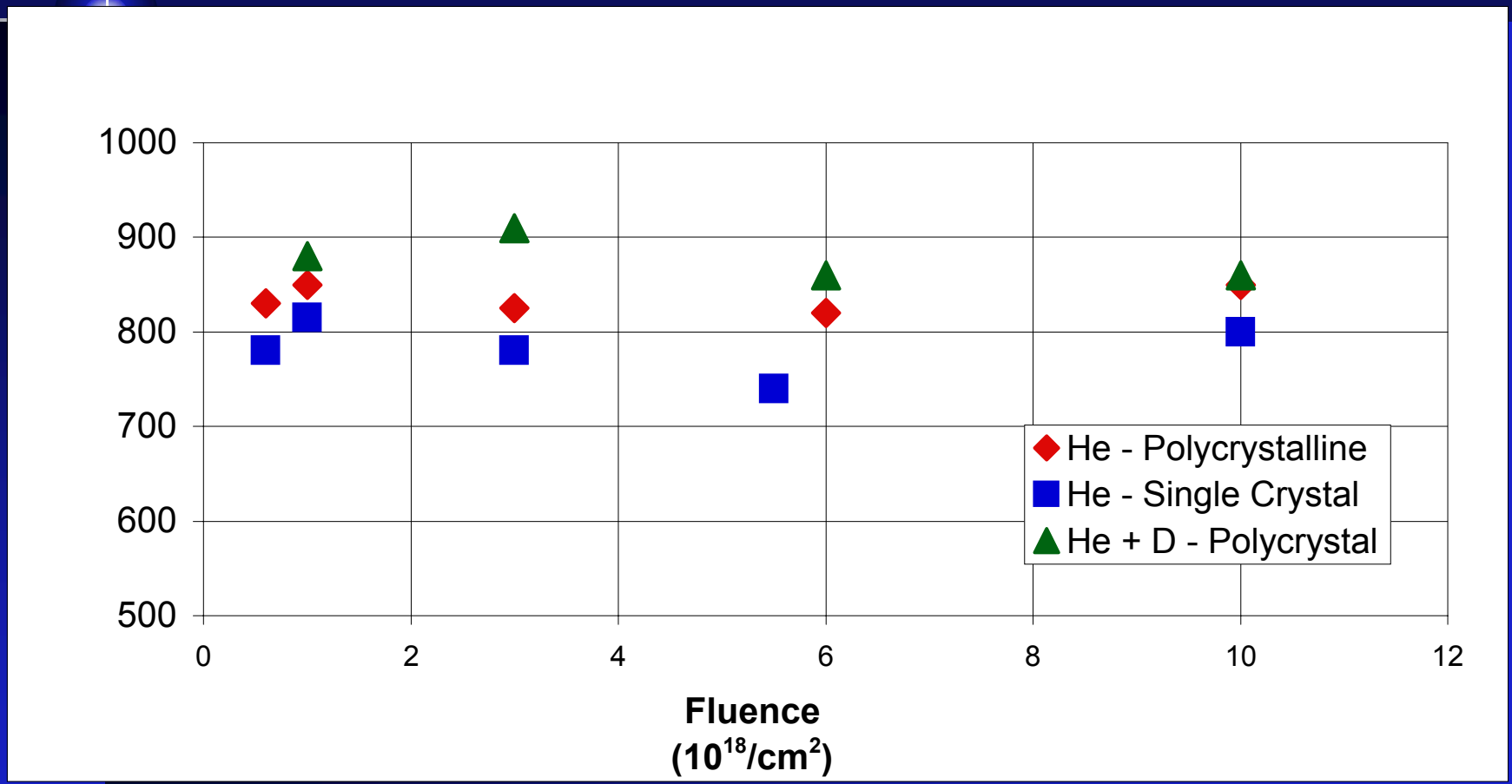
Two Types of Tungsten Samples Were Used for Irradiation Experiments

- Powder metallurgy or single crystal samples
- Obtained from Lance Snead, Oak Ridge
- Polished finish
- Spot-welded onto a W-Re wire loop





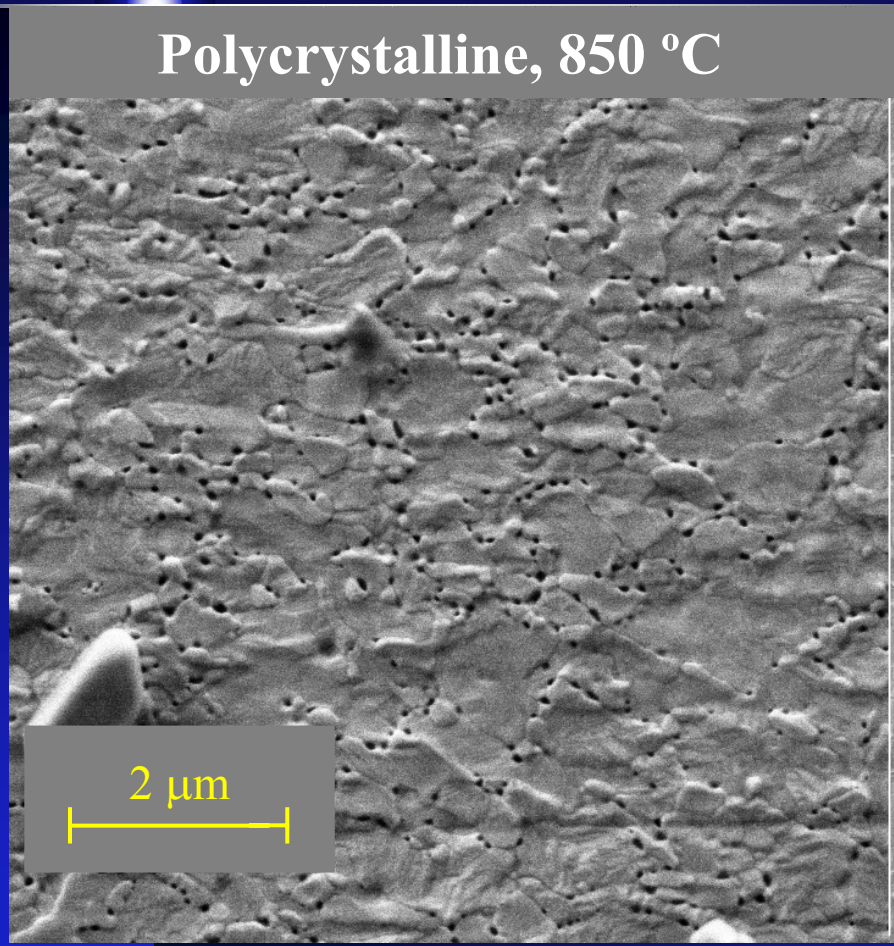
Experimental Conditions*



*All experiments were performed at 30 kV, 0.5 mTorr, $2\pm1\times10^{16}$ #/cm^{2}s

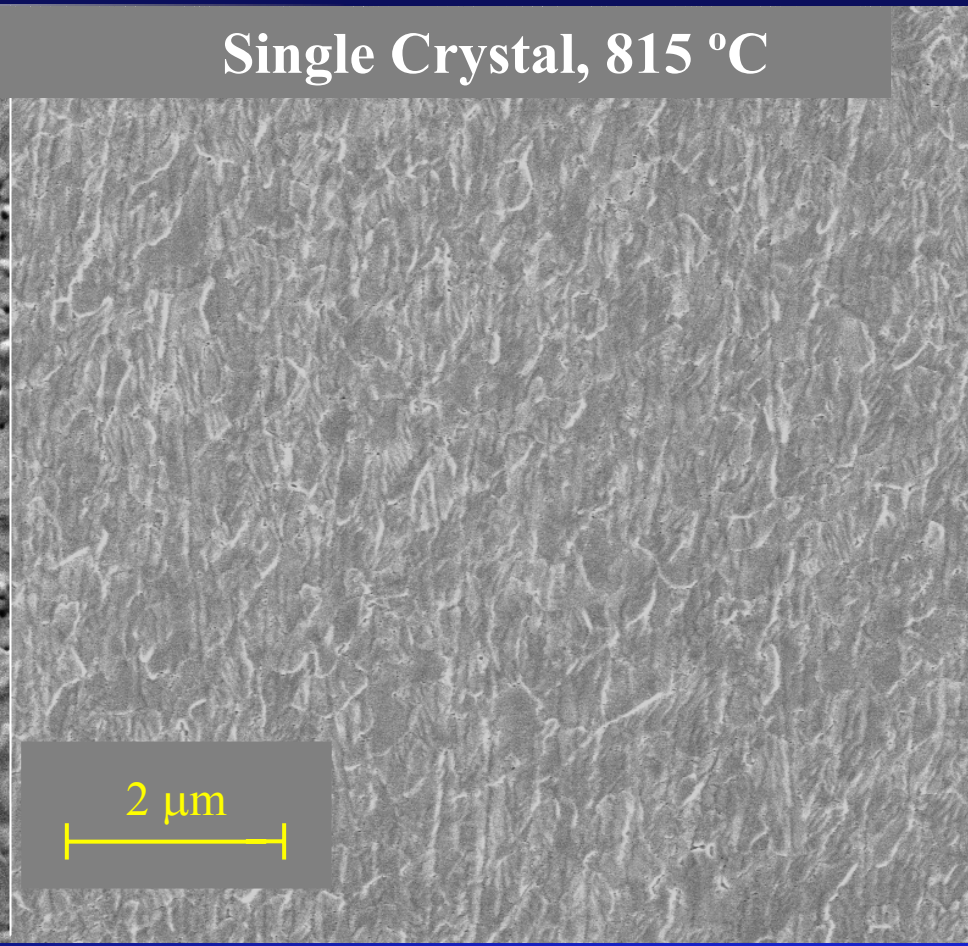
* Secondary Emission Coefficient of 2 was assumed for these experiments[9]

Threshold for He Pore Formation at 30 kV in Single Crystal Tungsten is Higher than Polycrystalline



Polycrystalline, 850 °C

9.4 x 10^8 pores/cm^2

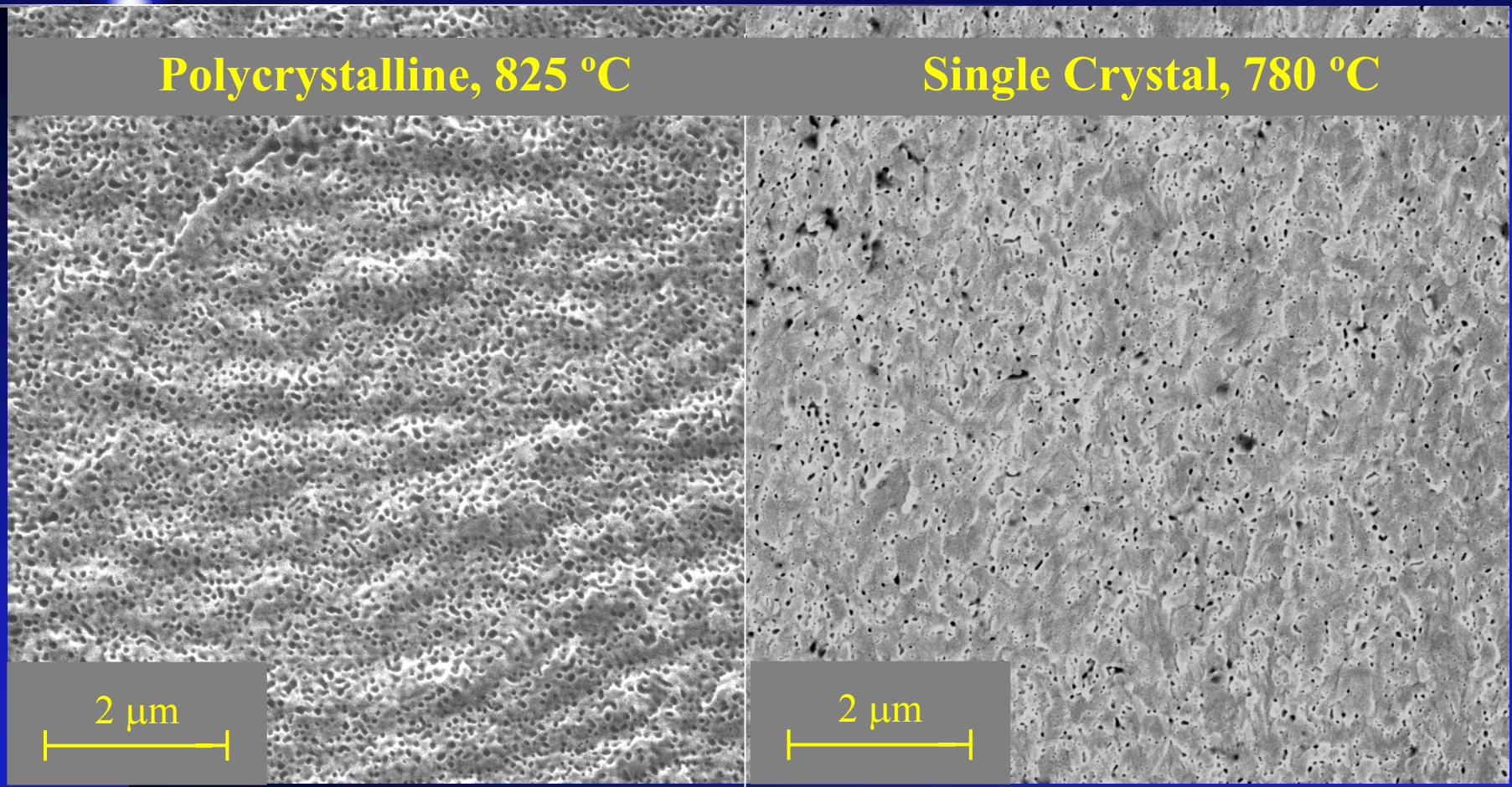


Single Crystal, 815 °C

<5 x 10^7 pores/cm^2

Tungsten Samples at 1x10^{18} He^+/cm^2

Single Crystal Tungsten Shows Reduced Pore Density (≈3X) at Higher Fluences

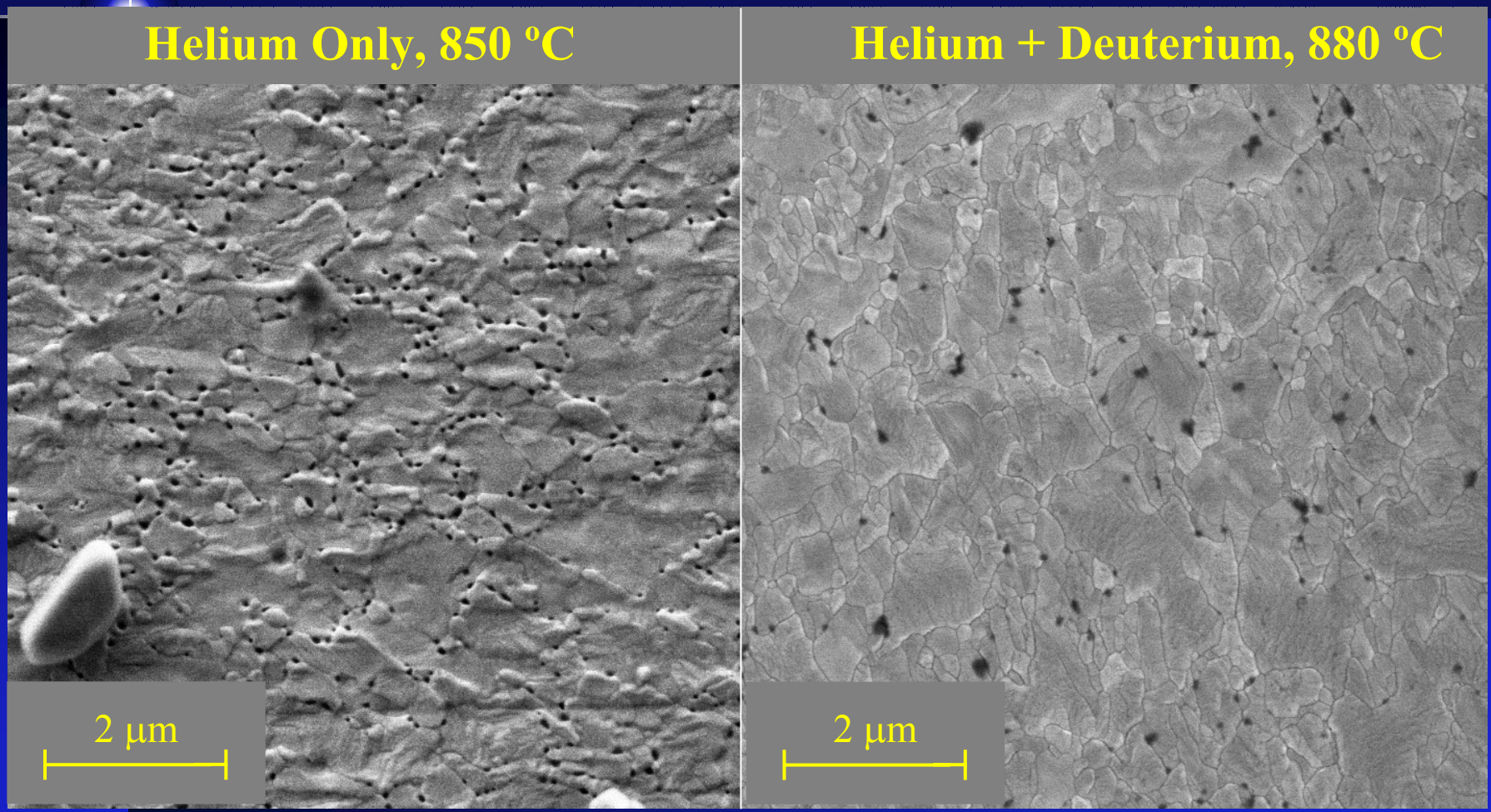


5.8×10^9 pores/cm^2

2.3×10^9 pores/cm^2

Tungsten Samples at 3×10^{18} He^+/cm^2

At Low Fluences, Simultaneous D^+ and He^+ Reduced Pore Density by a Factor of Four

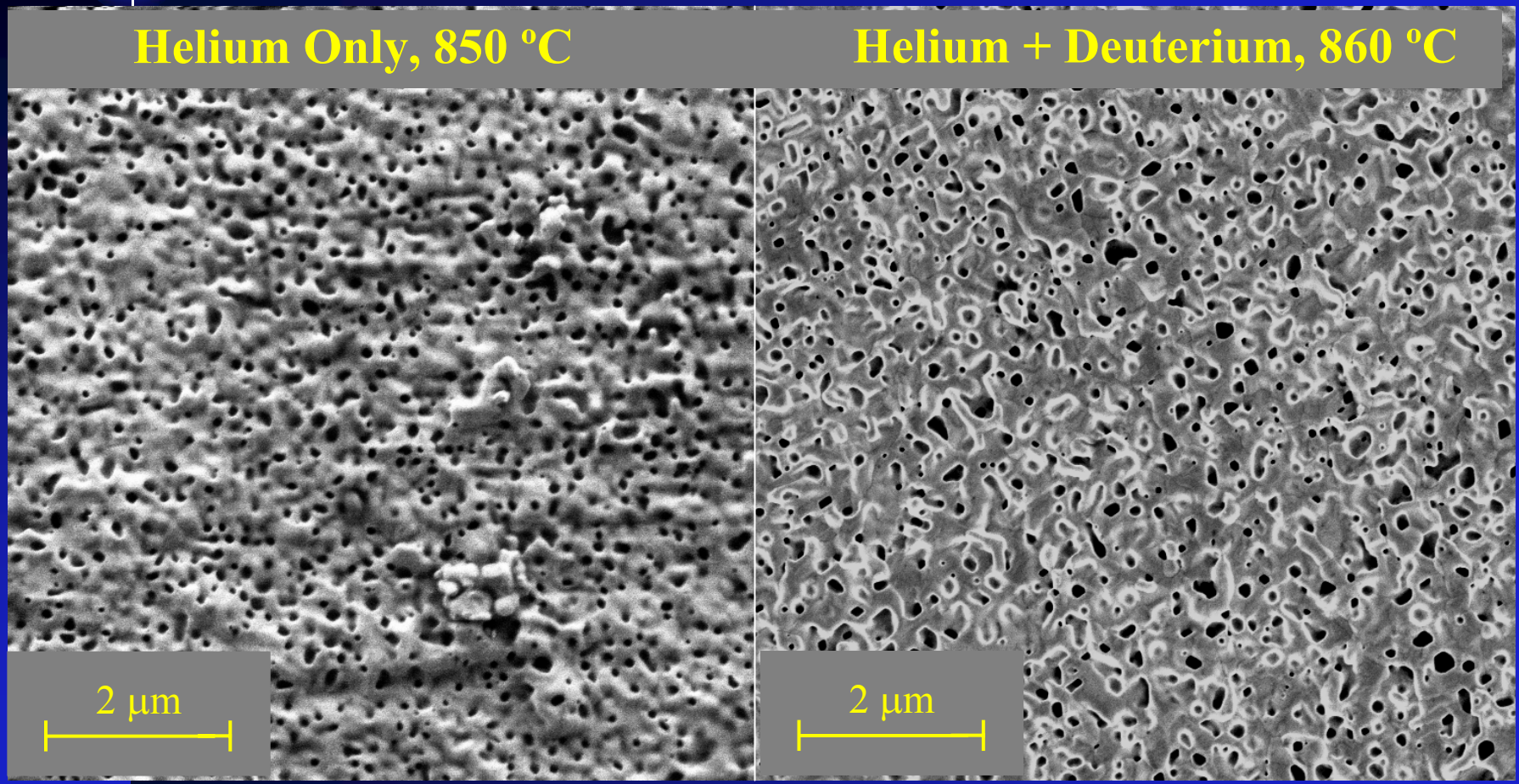


9.4×10^8 pores/cm^2

2.4×10^8 pores/cm^2

Polycrystalline Tungsten Samples at 1×10^{18} He^+/cm^2

Simultaneous D^+ and He^+ Has Little Effect on Pore Density in Polycrystalline W at Higher Fluences



5.9 x 10^9 pores/cm^2

4.1 x 10^9 pores/cm^2

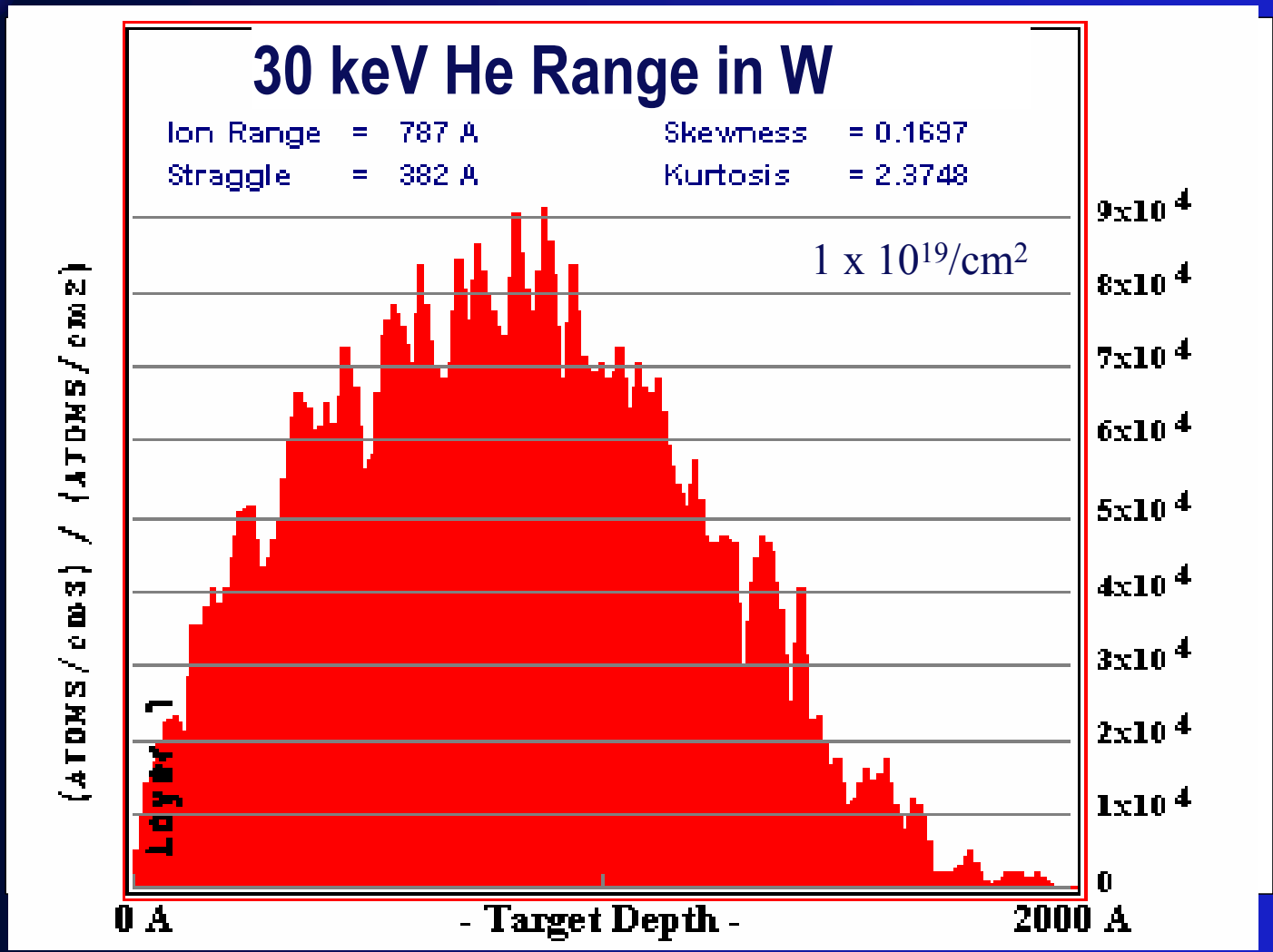
Tungsten Samples at 1x10^{19} He^+/cm^2

Elastic Recoil Detection (ERD) Analysis Was Used to Evaluate Helium Concentrations

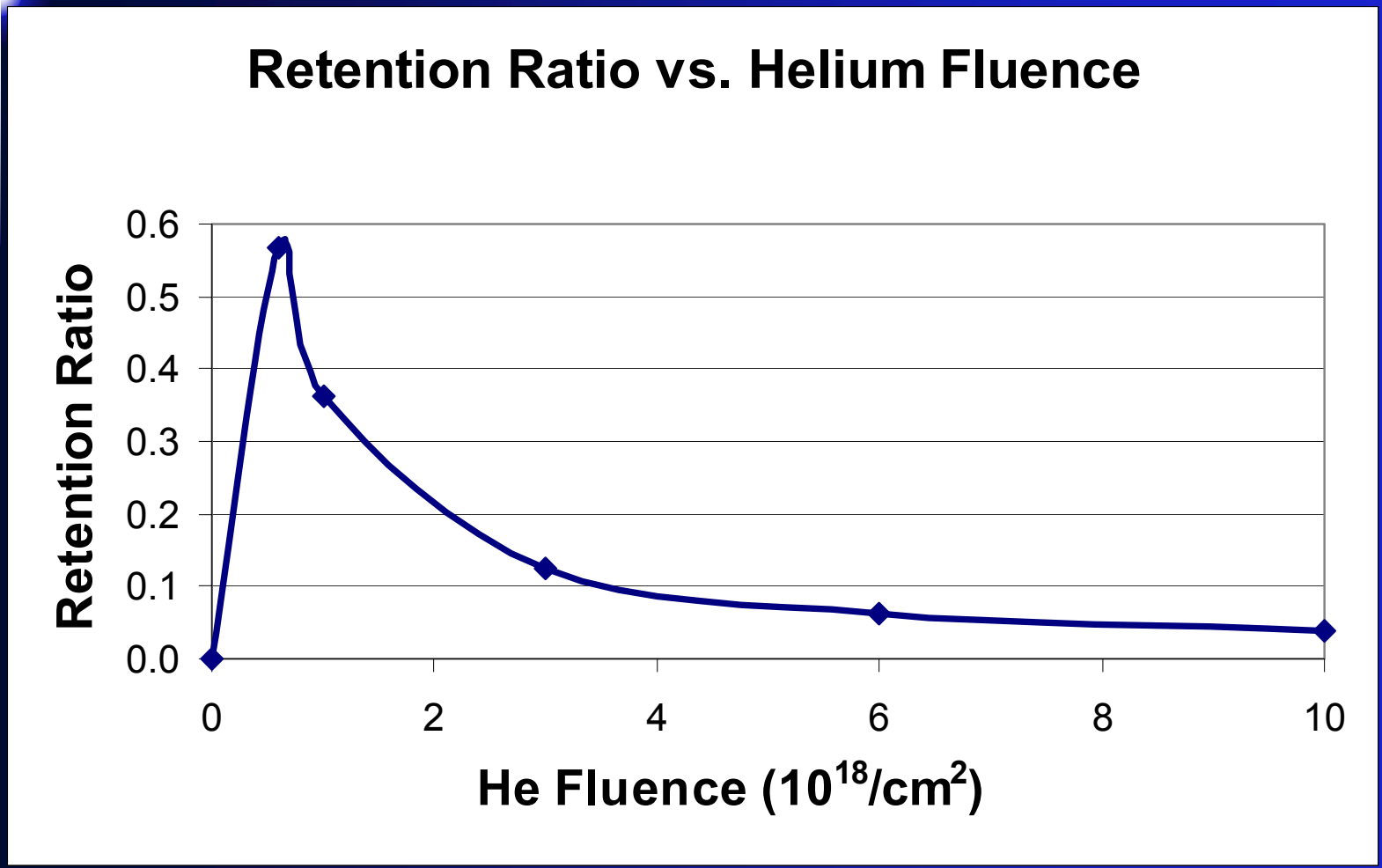
- UW-Madison Tandem Particle Accelerator

- 8 MeV (4^+) Oxygen Beam

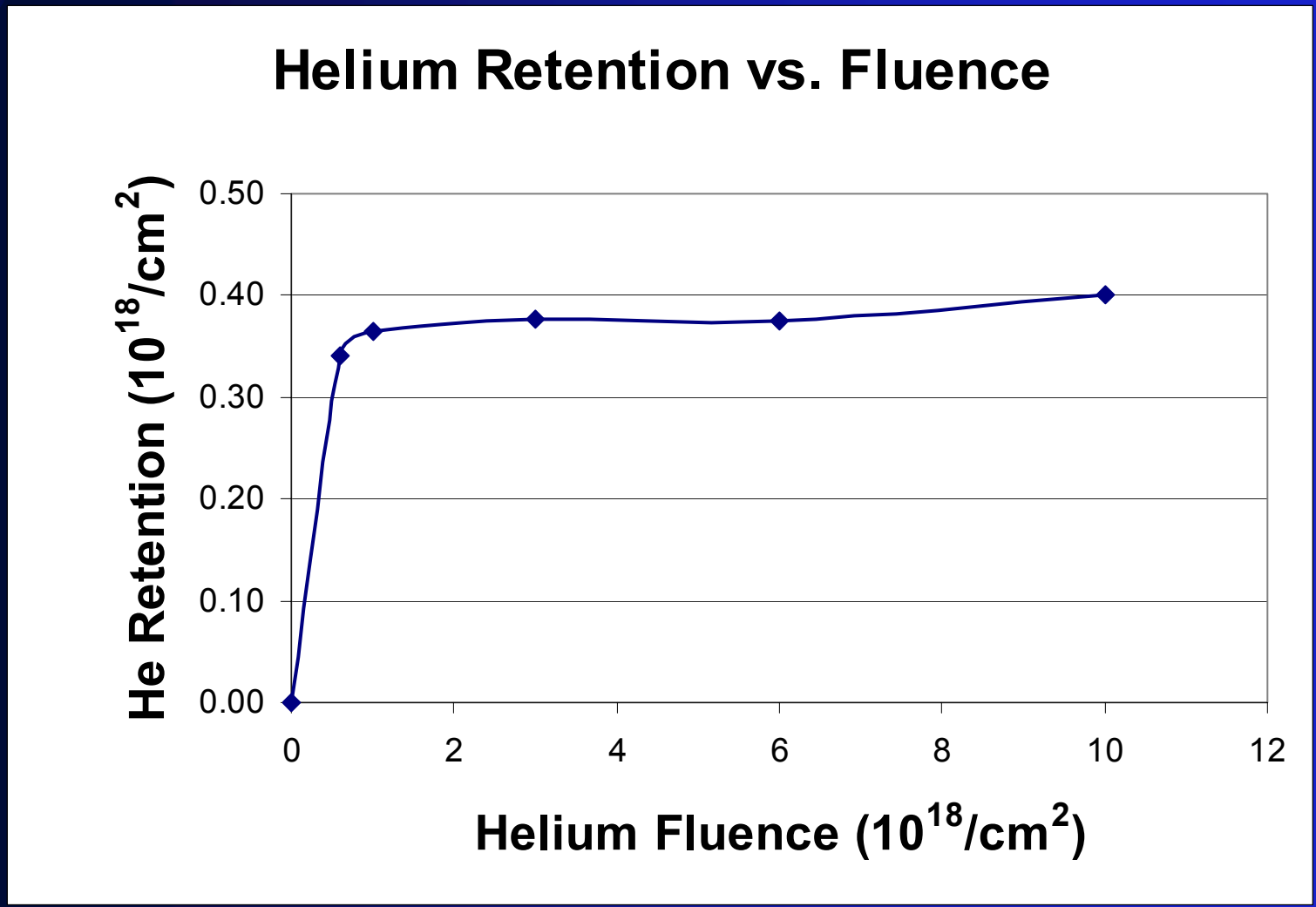
Initial Helium Retention Profile Qualitatively Fits TRIM Calculations



ERD Analysis Indicates That There May Be a Substantial Amount of □ He Recycle



ERD Analysis Indicates Saturated Amount of Helium Retention



Conclusions

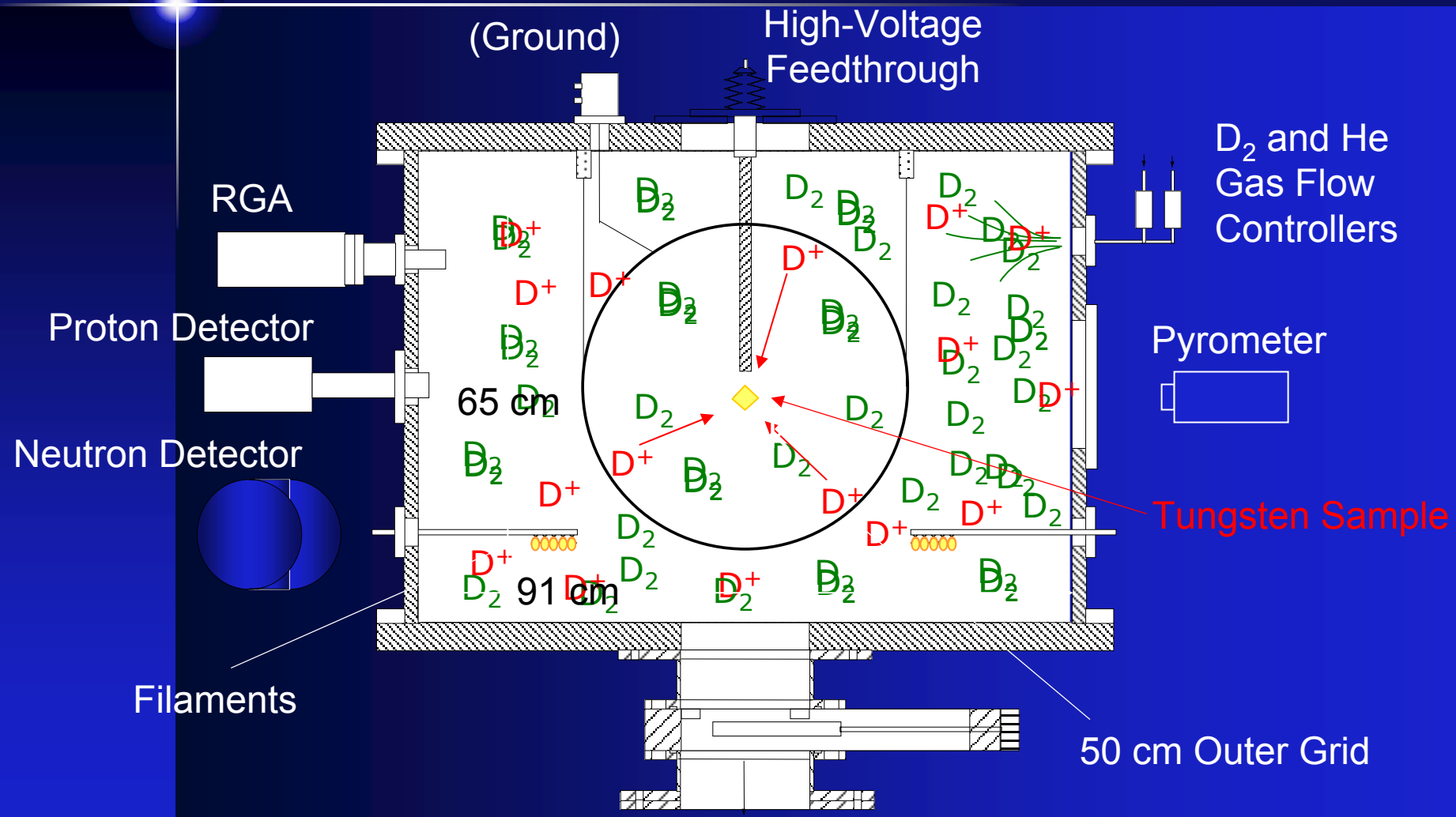
- Threshold for He pore formation in single crystal tungsten is higher than polycrystalline material.
- Single crystal tungsten shows reduced surface pore density at higher fluences (10^{18} – 10^{19} #/cm^2).
- Simultaneous D^+ and He^+ bombardment on polycrystalline tungsten reduced pore density by a factor of four at low fluences.
- At higher fluences, simultaneous D^+ and He^+ irradiation produced the same surface pore density as He^+ irradiation.
- Initial 30 keV helium retention profiles qualitatively fit TRIM calculations
- Elastic Recoil Detection analysis indicates saturated helium retention in polycrystalline tungsten

Future Work

- Examine effects of alloying tungsten samples with 25% rhenium in the 700 – 1200 ˚C range
- Evaluate deuterium retention rates and profiles using ERD analysis
- Determine helium retention rates and profiles in single crystal tungsten samples using ERD analysis

Questions?

IEC Device Provides Uniform Ion Fluence



World Record Steady State D^3He Fusion Reaction Rates Achieved in Wisconsin IEC Devices