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Electron Yield Measurements of Highly Insulating Granular Samples Related to Charging of Dusty Plasmas

Heather Allen
Utah State University, heather.allen@usu.edu

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By Heather Allen

Dust in Space

Ubiquitous

Solar radiation → Charged particles

- Air filtration, Astronaut health, Dust coatings on spacecraft affecting optical or mechanical function

Cosmic Dust – Messier 98 galaxy

Image Credit: ESA/Hubble & NASA, V Rubit et al.

Lunar Dust – Alan Bean Spacesuit

Image credit: **NASA TR-169-001**

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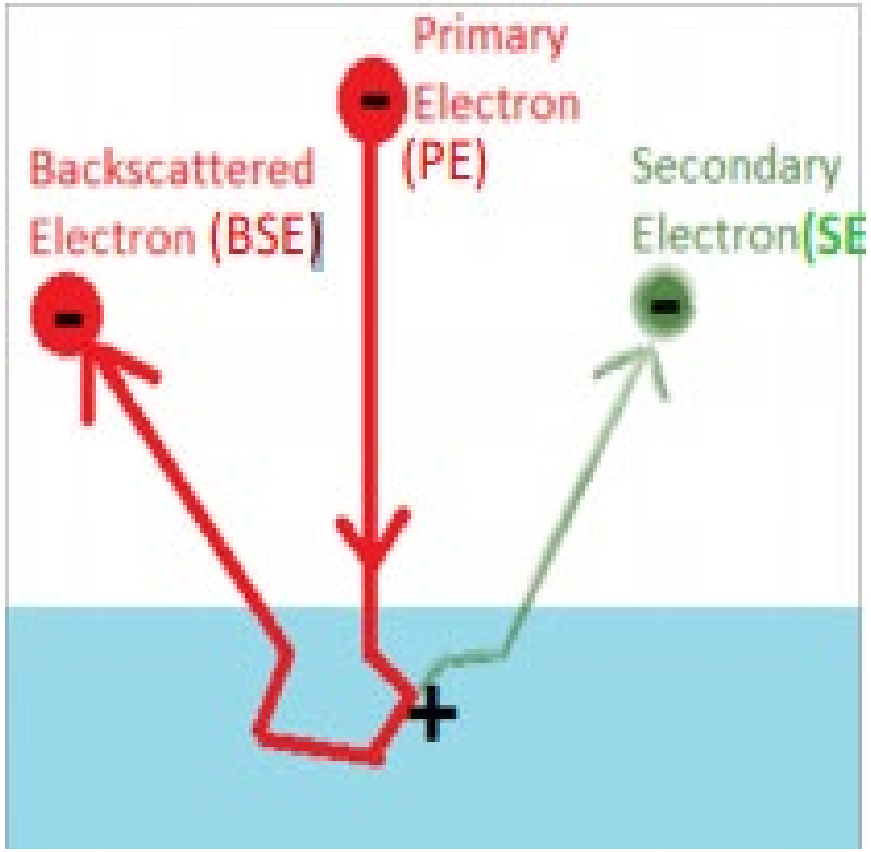
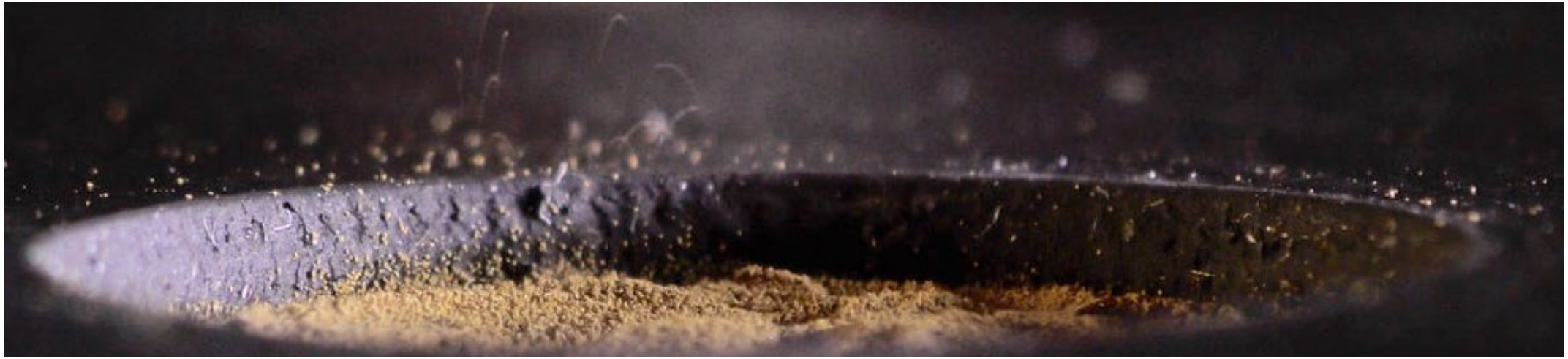
$$\text{Electron Yield (EY)} = \frac{Electrons\ Out}{Electrons\ In}$$



Experimental Complexities

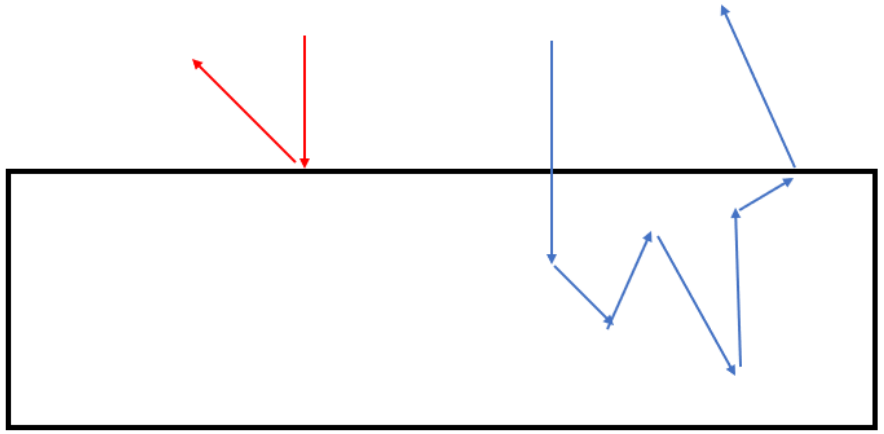
Lofting
Adhesion
Surface Roughness



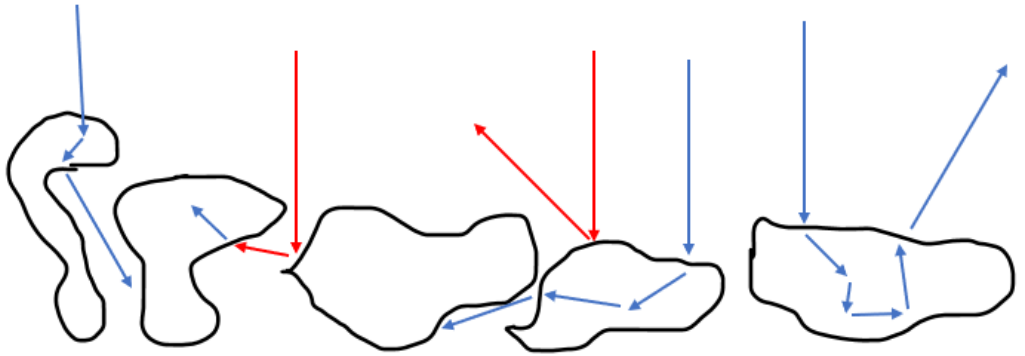
Surface Roughness

Backscattered Electron

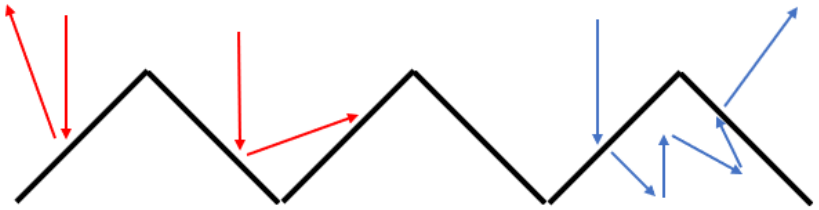
Secondary Electron



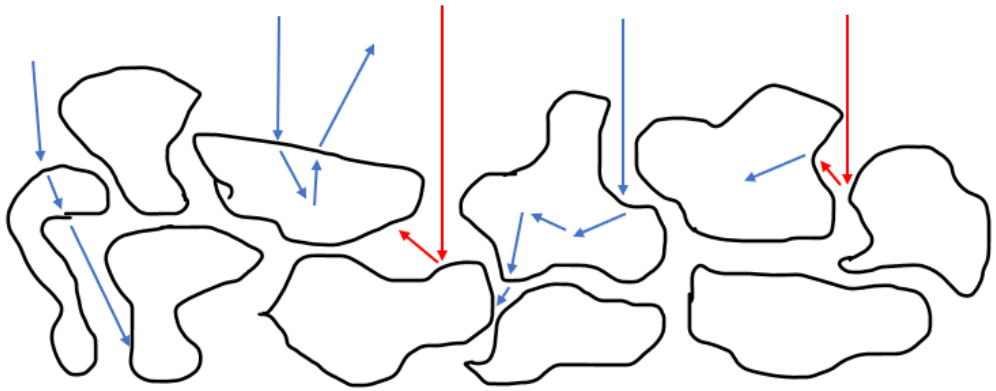
Atomically flat surface



Single Dust Layer

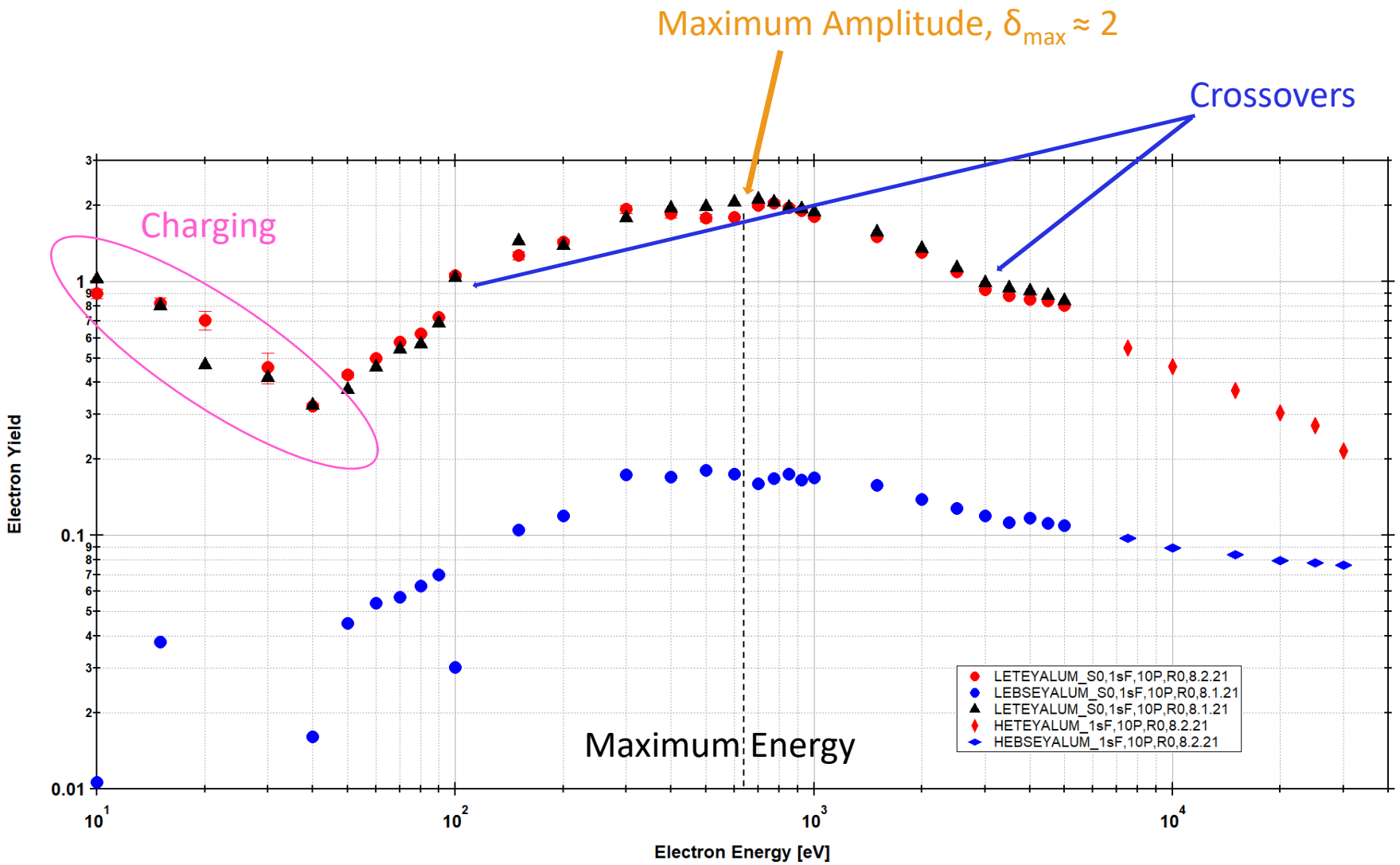


Rough surface



Double Dust Layer

Anatomy of a Graph



$\delta_1(E_1) = \delta_2(E_2) \equiv 1$

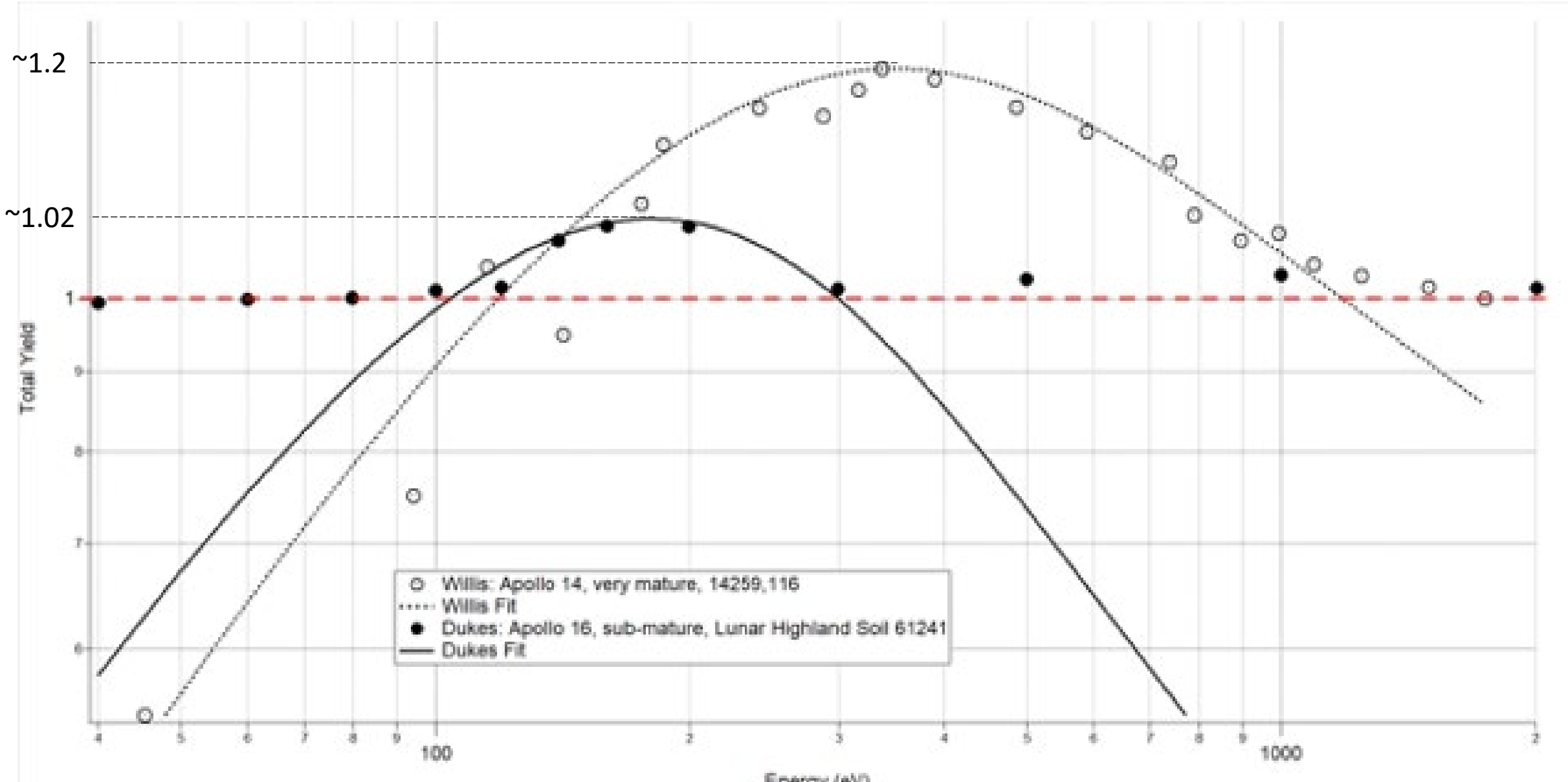
$E_1 \equiv$ First crossover energy

$E_2 \equiv$ Second crossover energy

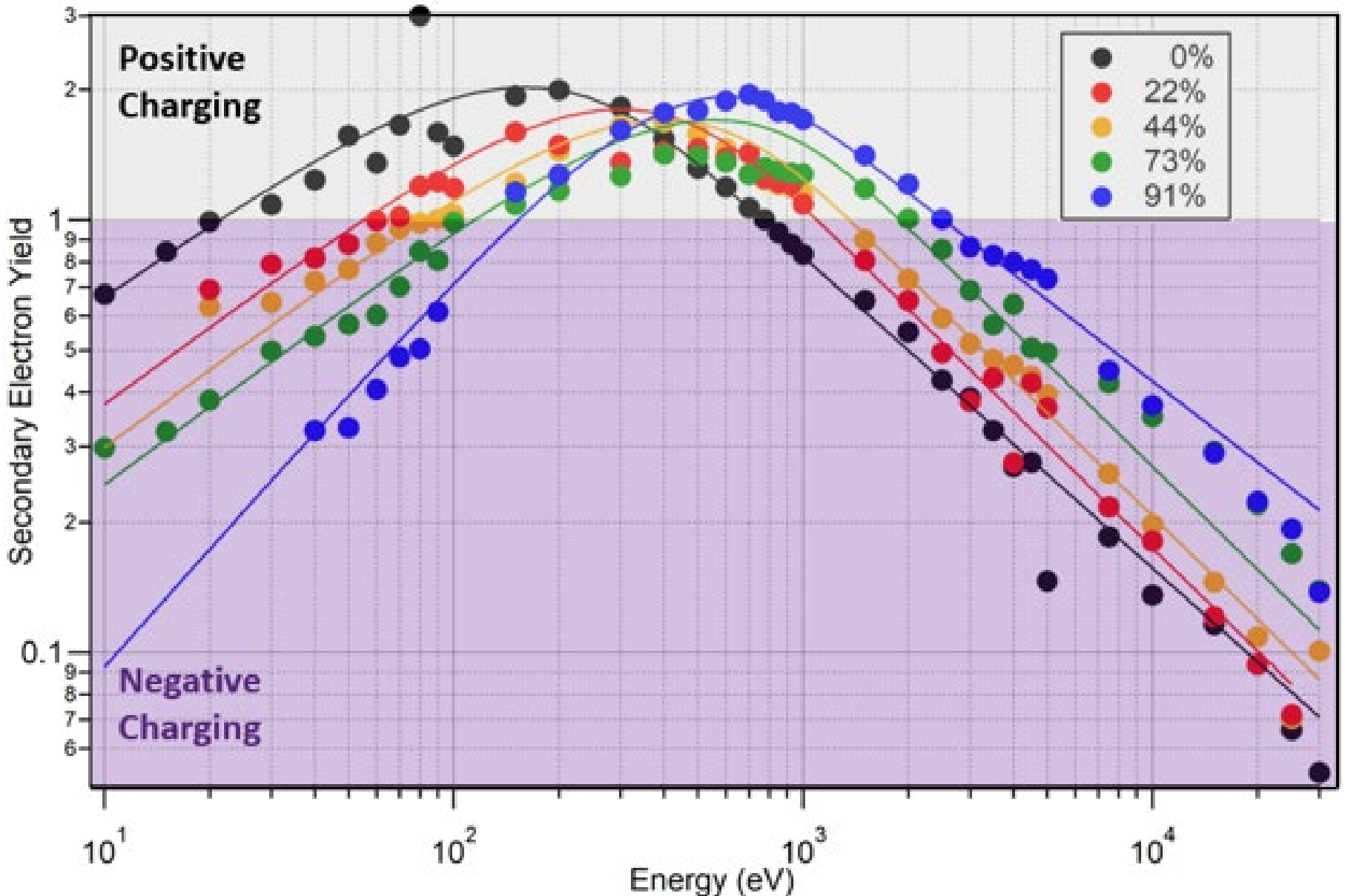
$\delta_{max} \equiv$ Maximum e^- yield

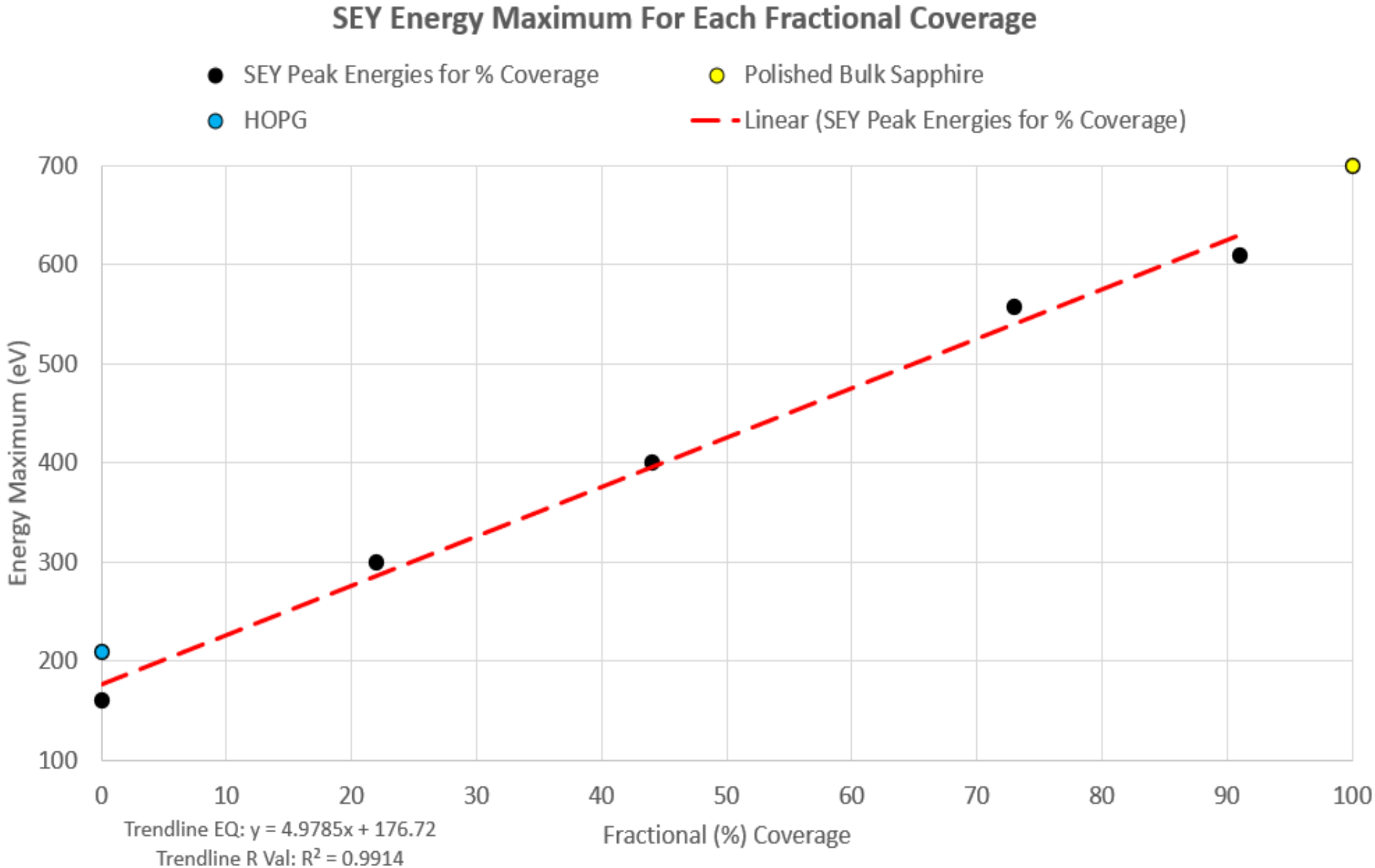
$E_{max} \equiv e^-$ energy at $\delta_{max}(E_{max})$

Previous Dust Data in Literature

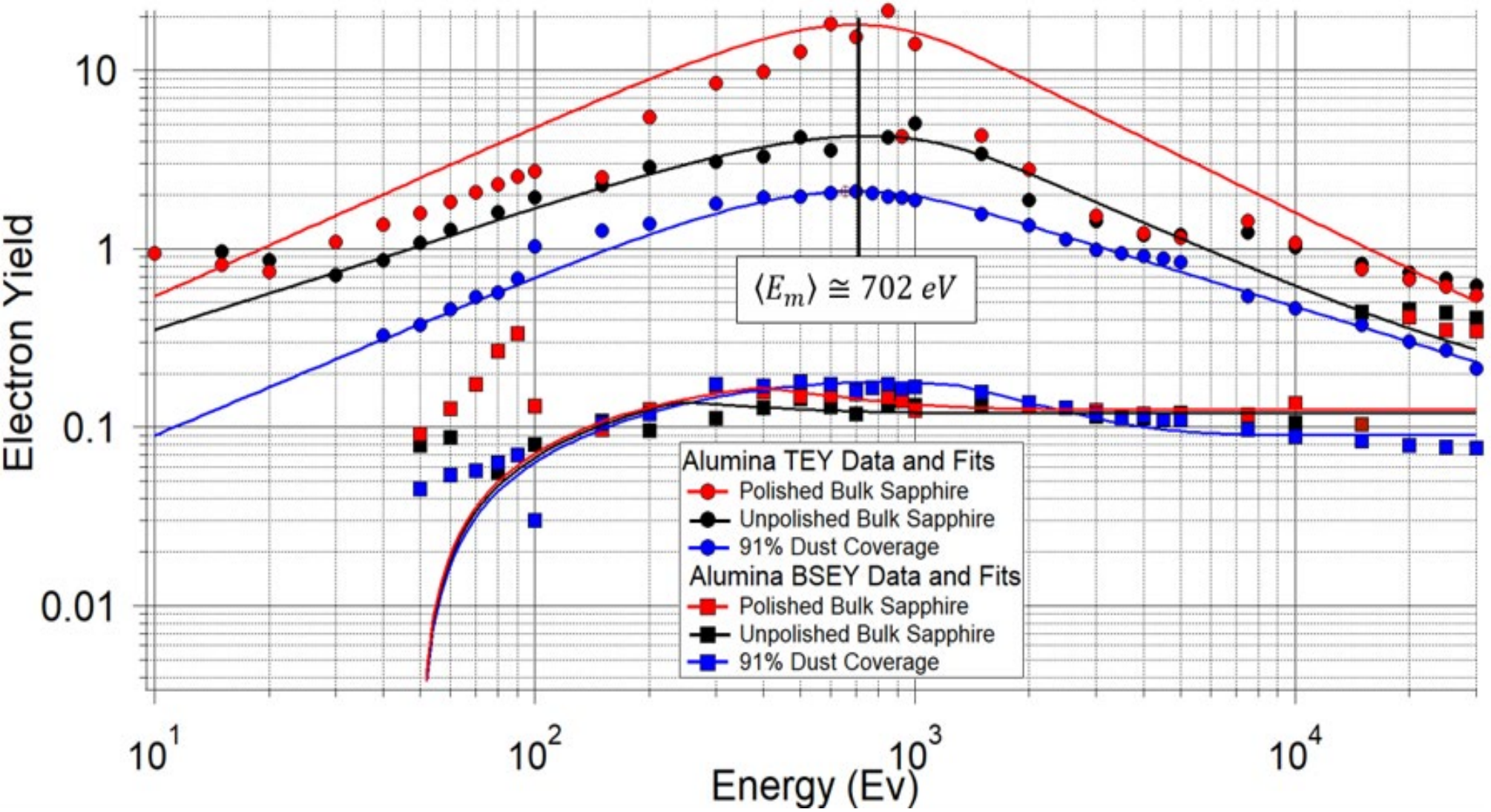


EY Dust Data - Coverages




SEY Energy Maximum For Each Fractional Coverage
SEY Peak Energies for % Coverage
Polished Bulk Sapphire
HOPG
Linear (SEY Peak Energies for % Coverage)
Energy Maximum (eV)
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
Fractional (%) Coverage
Trendline EQ: y = 4.9785x + 176.72
Trendline R Val: R² = 0.9914

Comparison Different Alumina Types

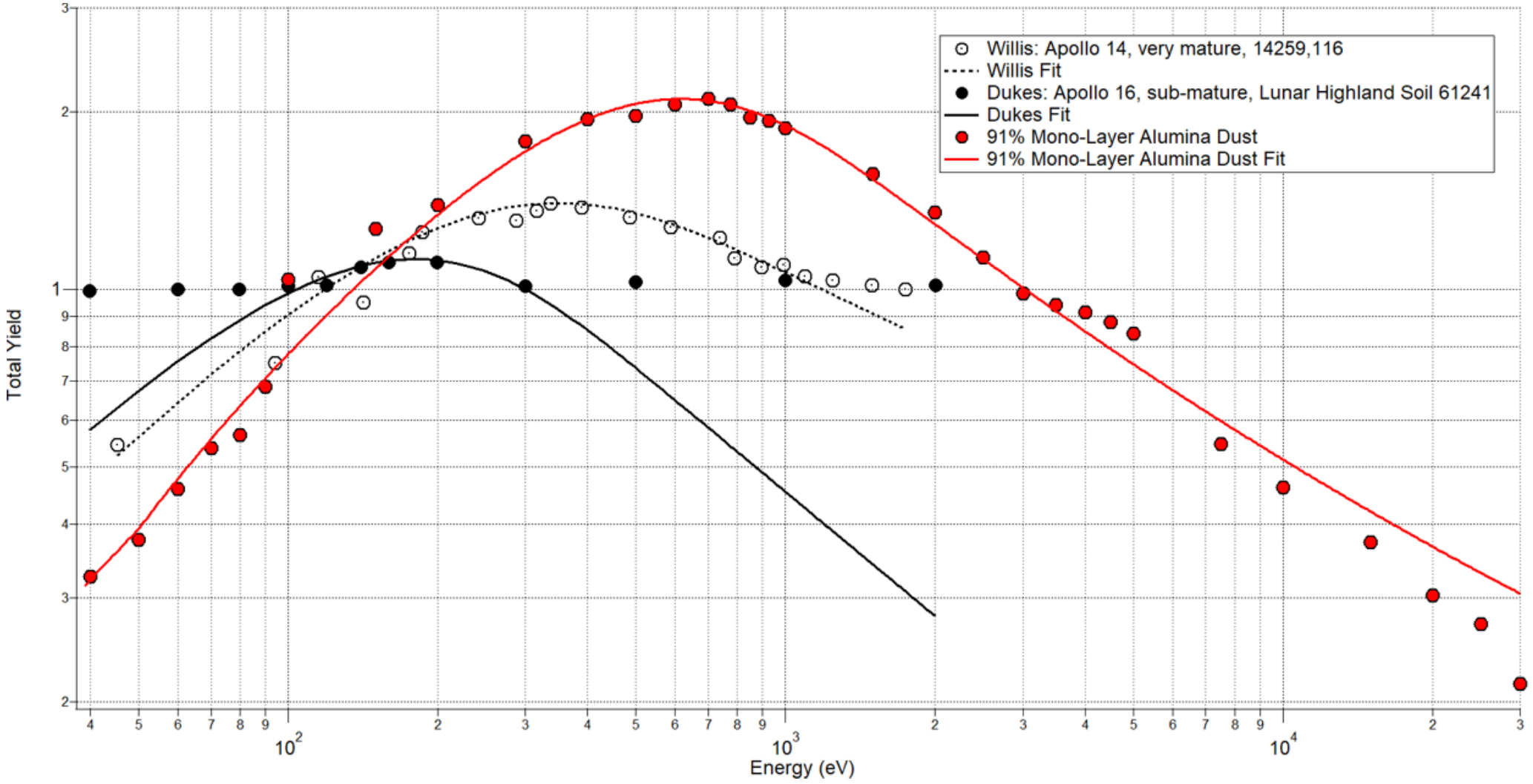


$\delta_{max} \approx 11$

$\delta_{max} \approx 4$

$\delta_{max} \approx 2$

91% Alumina Mono-Layer VS Lunar Dust Data



$\delta_{max} \approx 2$

$\delta_{max} \approx 1.5$

$\delta_{max} \approx 1.1$

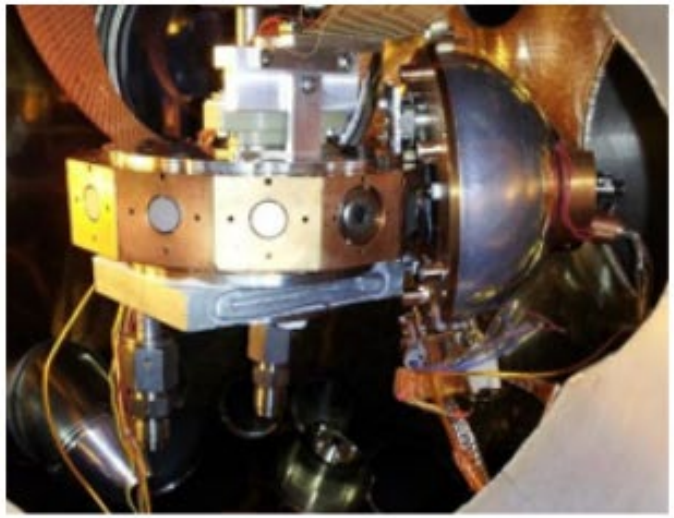
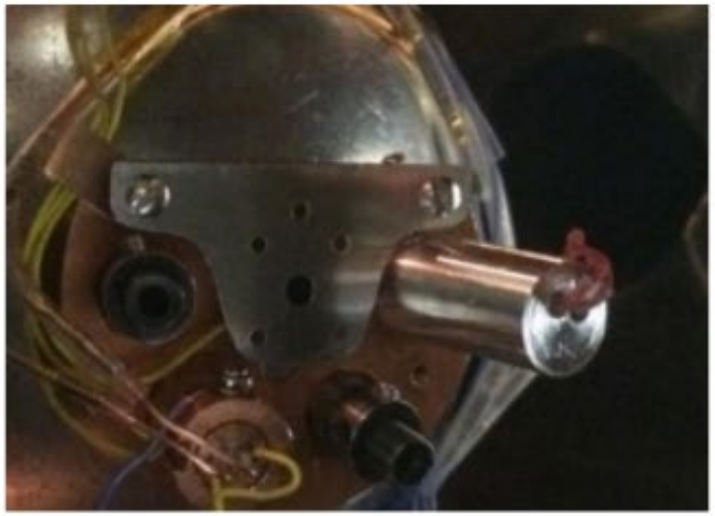
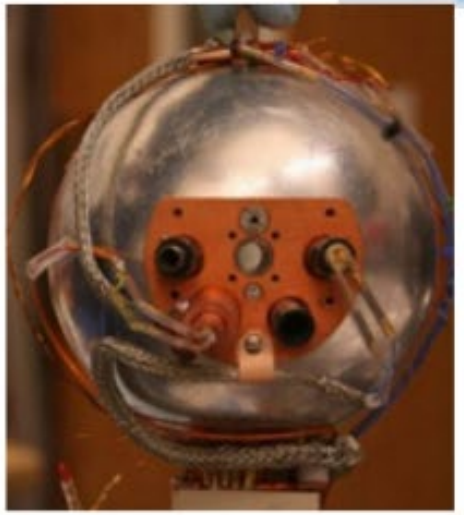
Conclusions

- EY dust data critical for myriad theory, modeling and engineering development
- Previous EY measurements were significantly affected by charging
- Accurate and precise EY data for highly-insulating, angular, rough, porous, homogeneous Al_2O_3 granular samples at USU
- Future Work: Collect EY on: Multilayer dust samples, Different dust materials and sizes. More quantitative analysis and modeling of surface roughness affects

Questions?

Supplemental 0: HGRFA

Hemispherical Grid Retarding Field Analyzer Electron Emission Detector

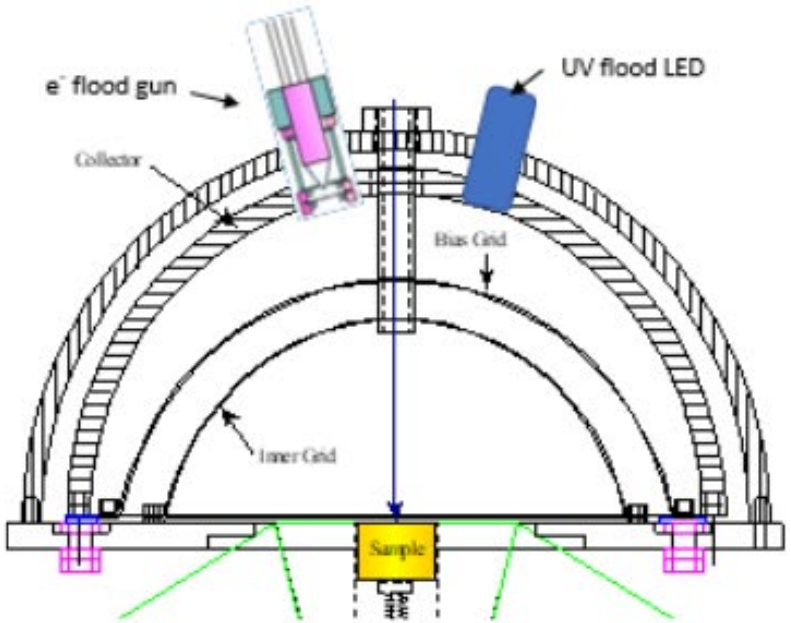





EY Instrumentation

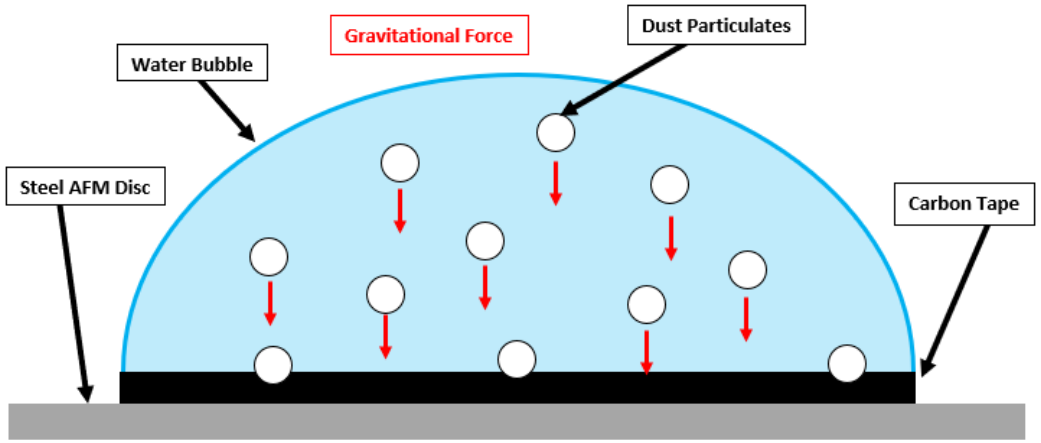
- 10 eV to 80 keV incident electrons
- fully enclosed HGRFA for emission electron energy discrimination.
- Precision absolute yield by measuring all currents
  - ~1-2% accuracy with conductors
  - ~2-5% accuracy with insulators
- *in situ* absolute calibration
- multiple sample stage
  - ~40 K < T < 400 K
  - reduced S/N

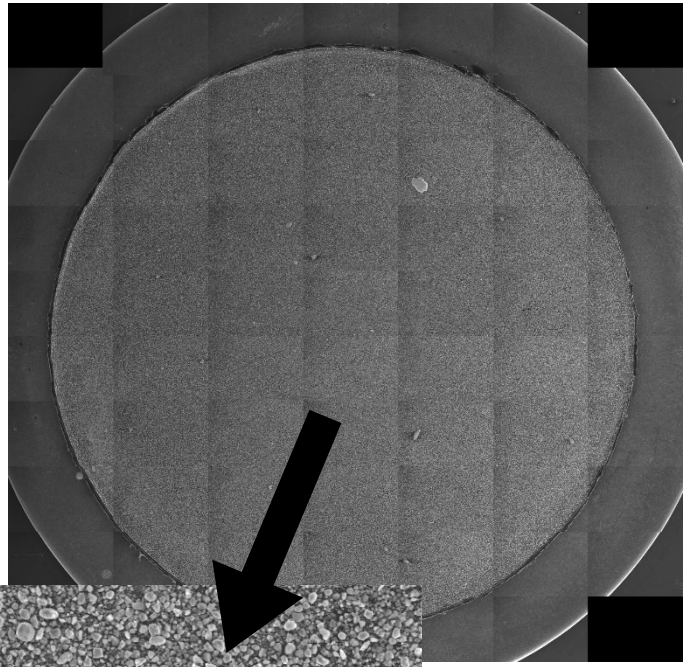
Enhanced Low Fluence Methods for Insulator Yields

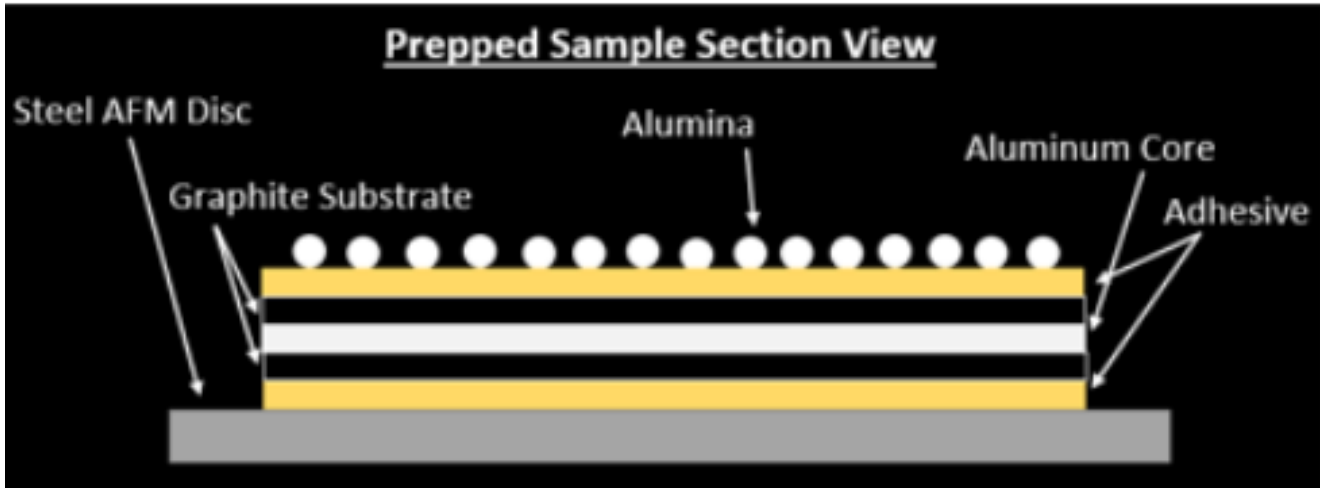
- low current (<1 nA-mm^{-2}), pulses (<4 μs) with <1000 e$^-$-mm^{-2}
- Point-wise yield method charge with <30 e$^-$-mm^{-2} per effective pulse
- neutralization with low energy (~5 eV) e$^-$ and UV and VUV and thermal dissipation
- *in situ* surface voltage probe

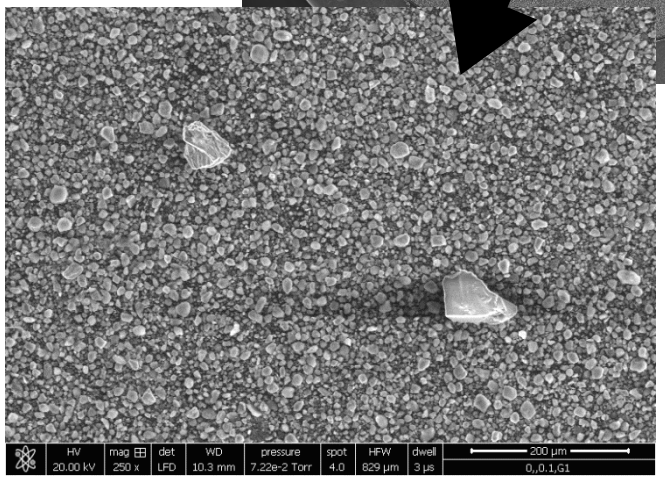


Supplemental 1: Sample Preparation

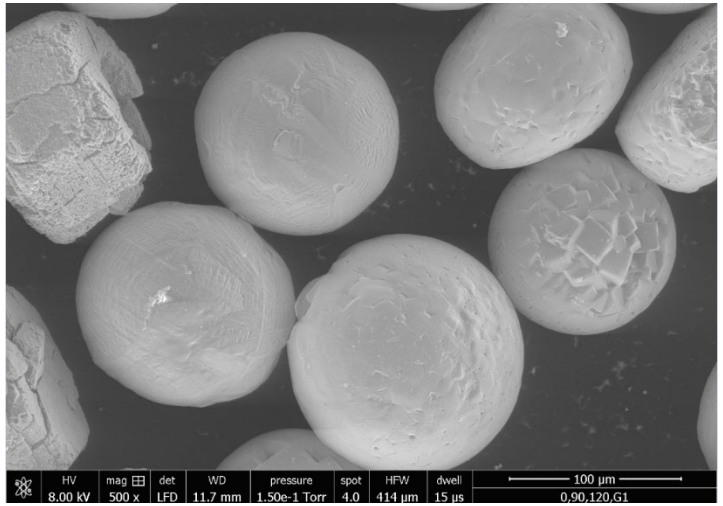




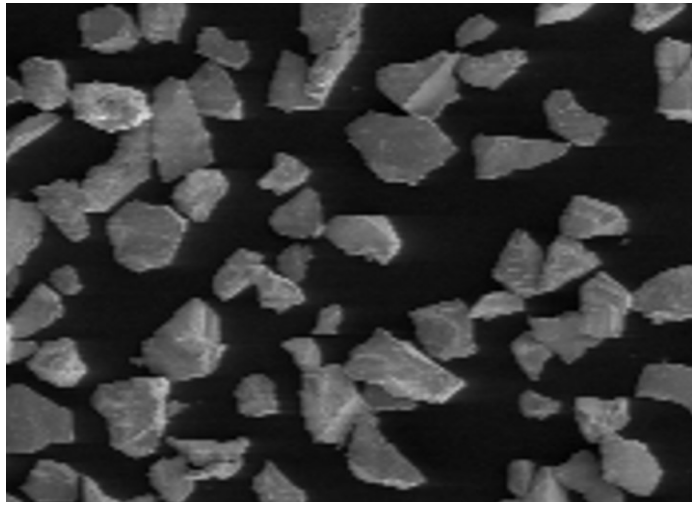




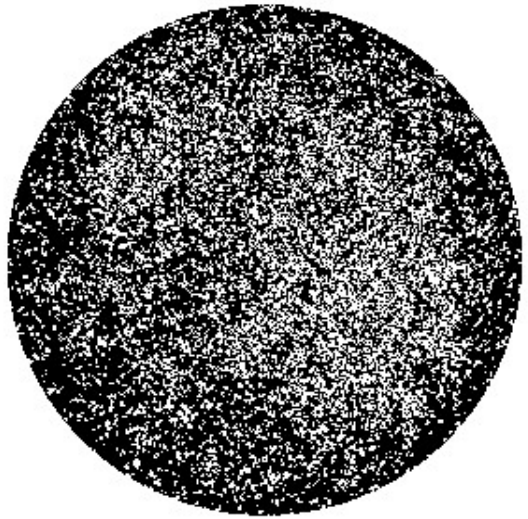
Supplemental 2: Sample Characterization

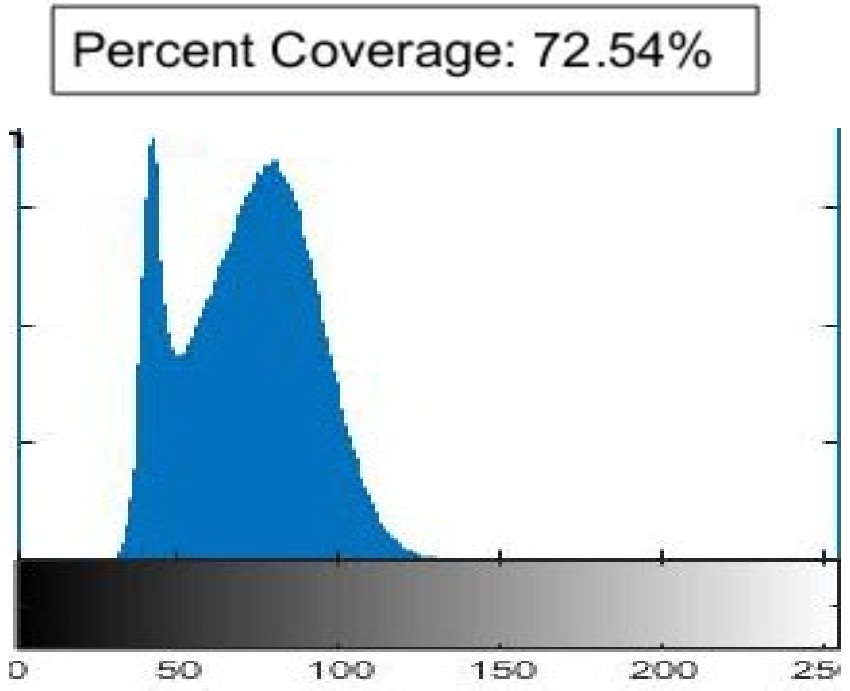


~100 microns



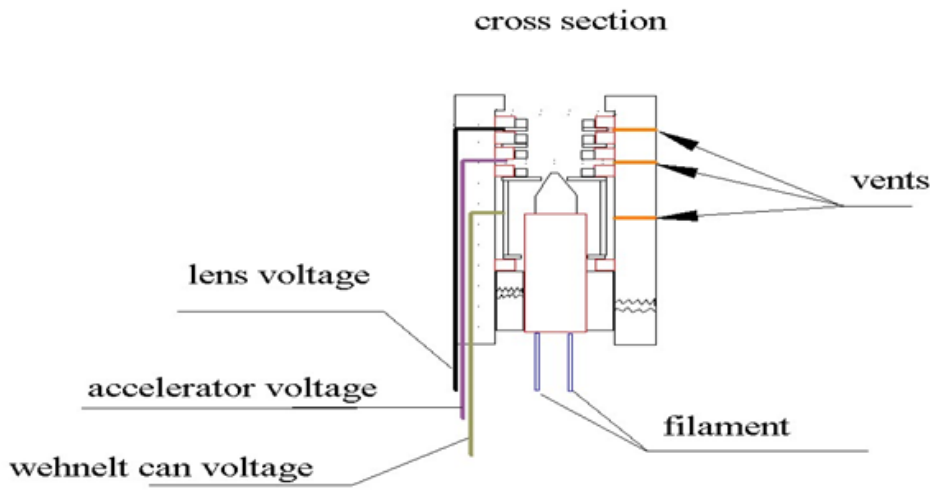
~60 microns

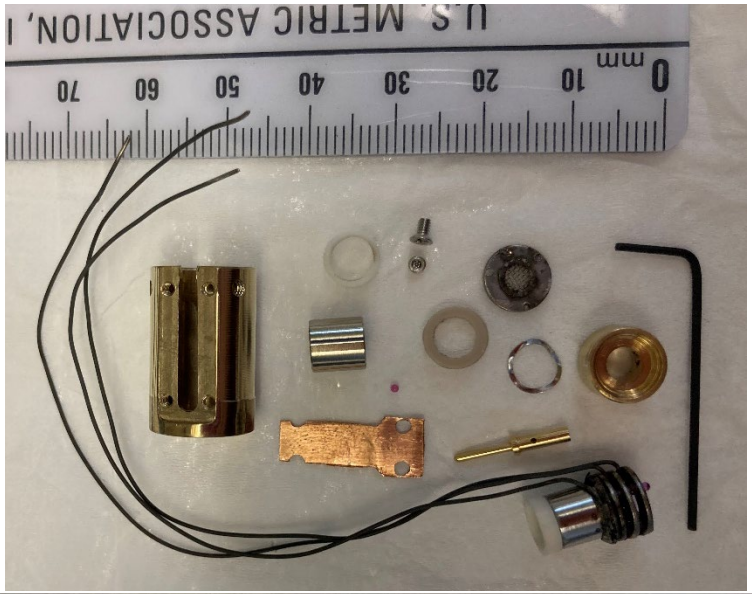


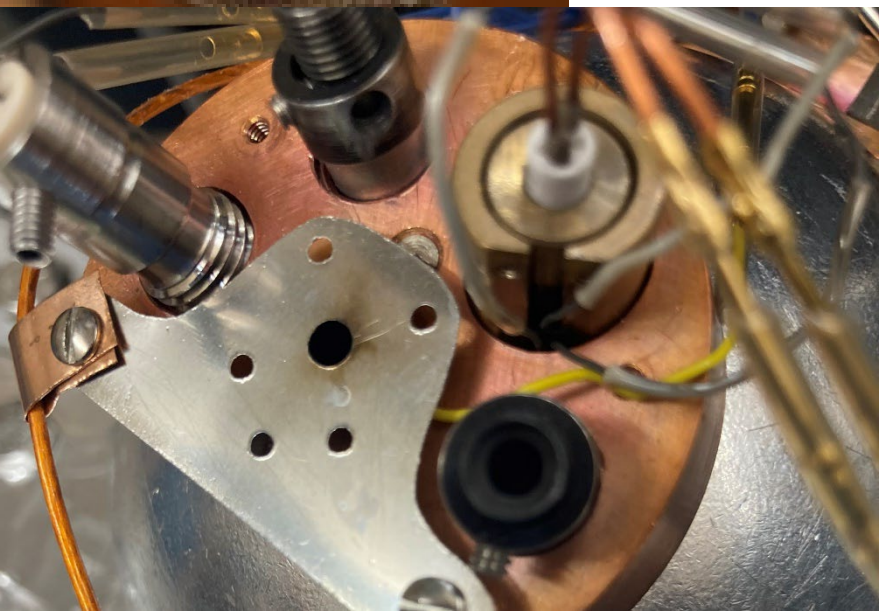


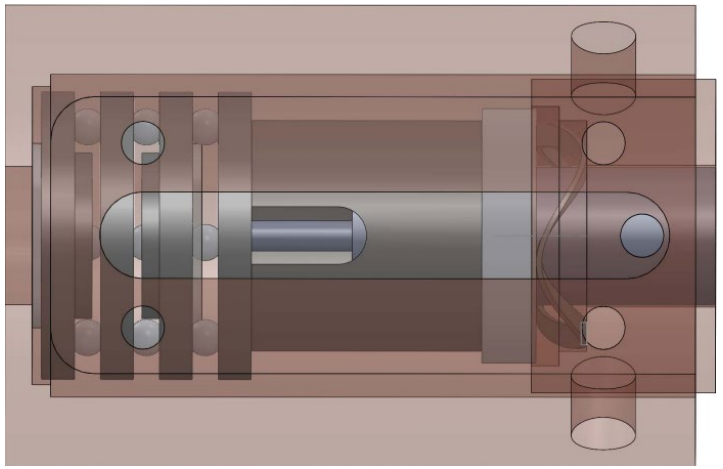
A sample was run through the analyzing program and the resulting histogram was produced. The first peak corresponds to the darker, adhesive substrate pixels and the second peak corresponds to the lighter, alumina pixels.

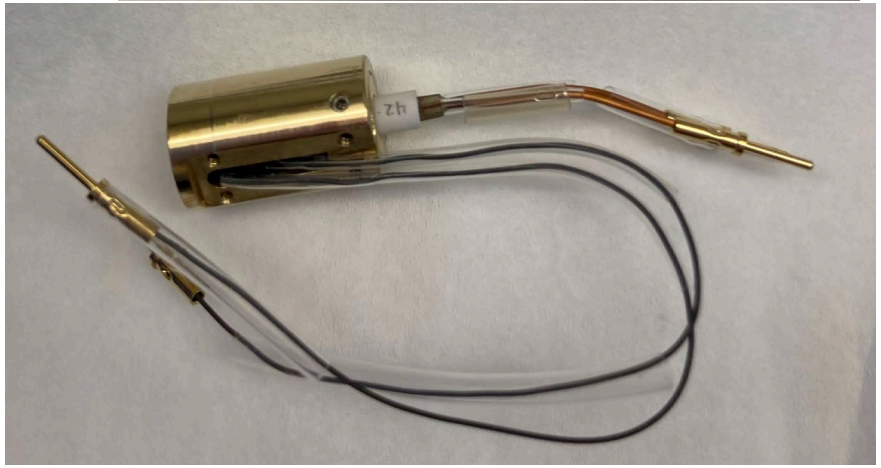
Supplemental 3: Flood Gun and Charge dissipation



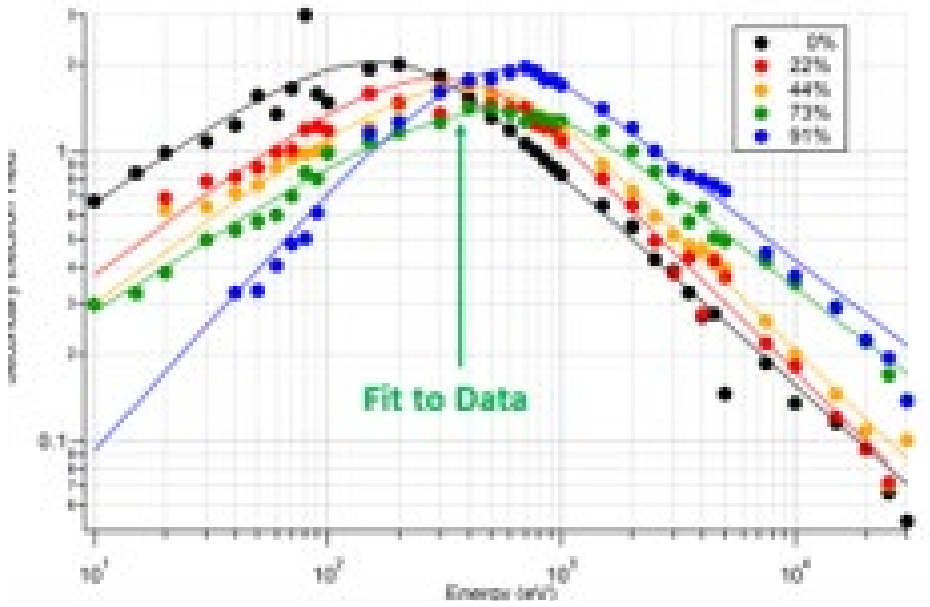


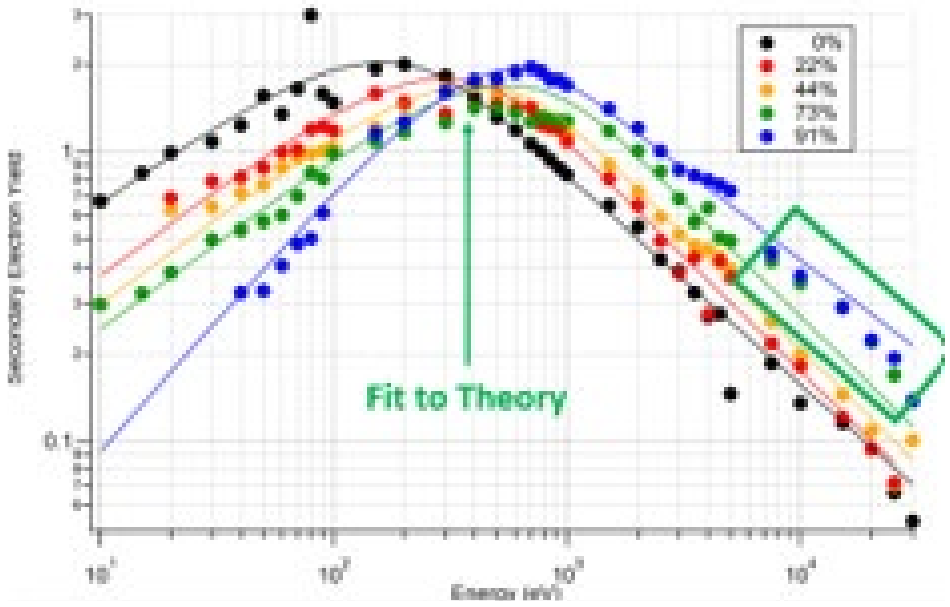




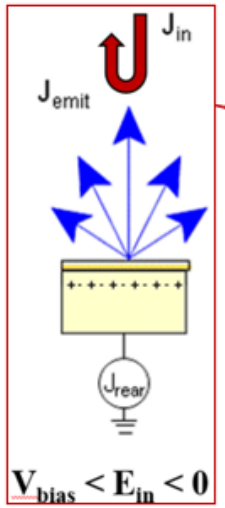


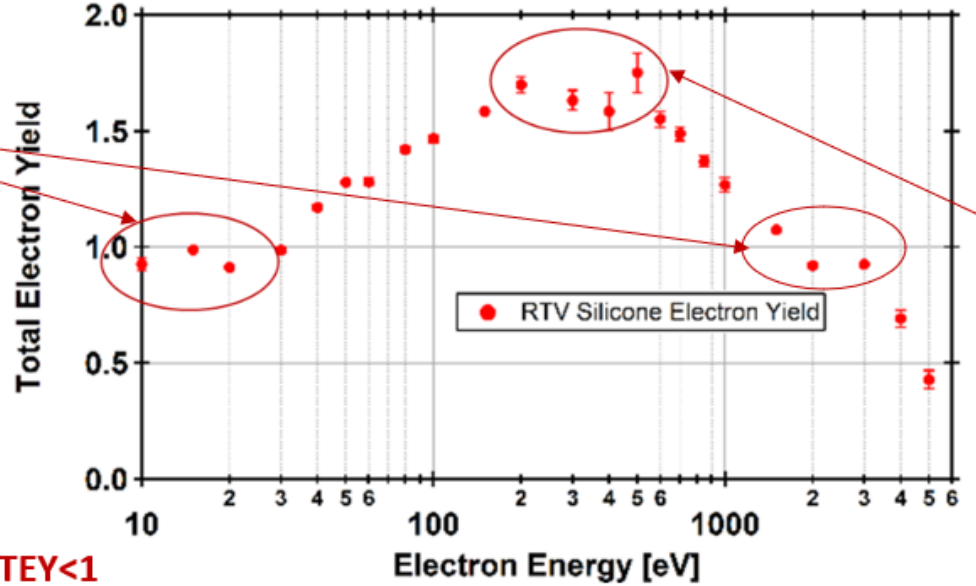
Supplemental 4: Coverages SEY fits

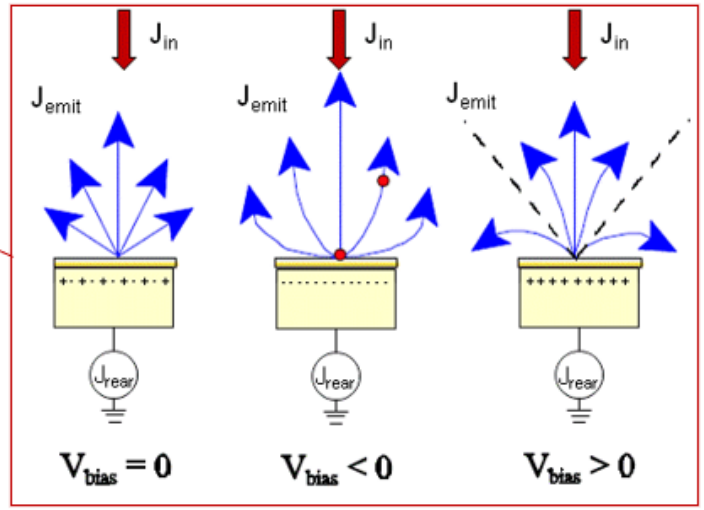




Supplemental 5: Electron Behavior

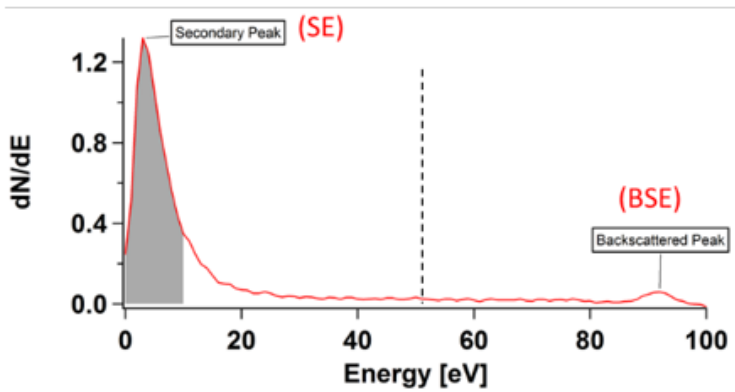


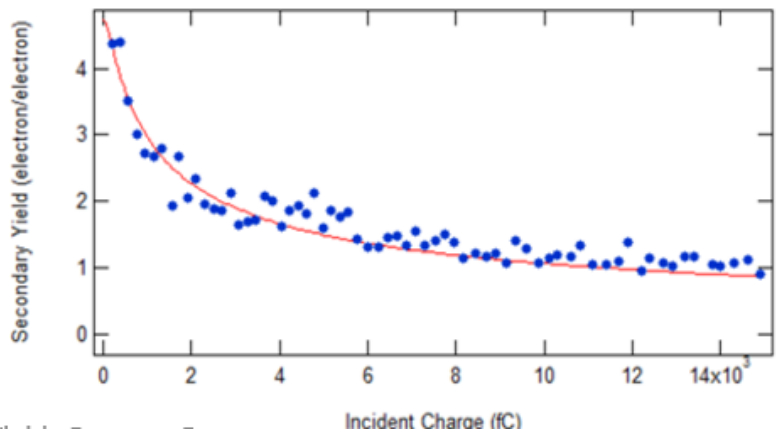




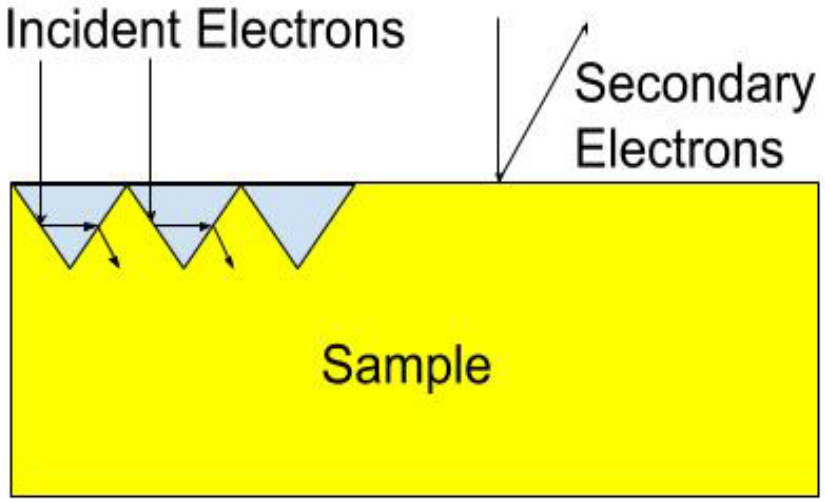
Negative charging suppresses TEY<1 through repulsion of incident electrons from negative surface

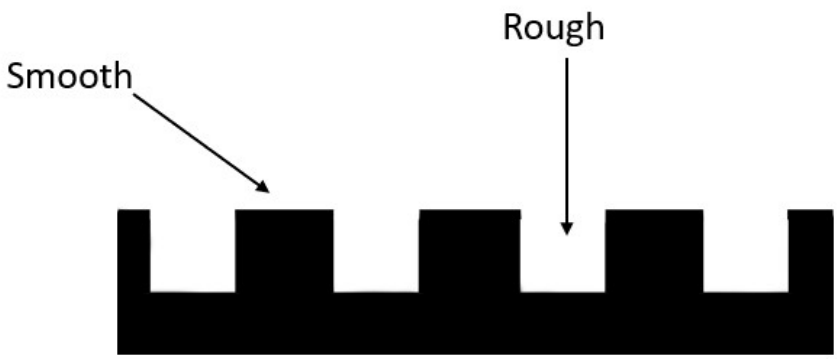
Positive charging suppresses TEY>1 through reattraction of low energy SEY to positive surface





Supplemental 6: Yield Patch Model





material surface with repeating square wells.