Measurements of Lunar Dust Chargi Properties by Electron Impact

M. M. Abbas[1], D. Tankosic[2], P. D. Craven[1],
T. A. Schneider[1], J. A. Vaughn[1], A. C. LeClair[1],
and J. F. Spann[1], and J. K. Norwood[1],

[1]NASA-Marshall Space Flight Center, Huntsville, AL
[2]USRA/NASA-Marshall Space Flight Center, Huntsville,

Dust Charging by Electron Impact

- The two dust charging processes by electron impact ar

(a) ***Sticking/Scattering of incident electrons*: Leads to discharging of positively charged grains, or charging of negatively charged grains.**

(b) *Secondary electron emissions (SEE):* Energetic electron penetrate a dust grain and lead to emission of excited secondary electrons, charging of positively charged dus grains to higher potentials, and discharging of negativel charged grains.

- **The SEE-yield (electrons ejected per electron incident) is function of: the incident electron energy, the grain size, potential, the grain material, and the flux density of the incident electrons.**

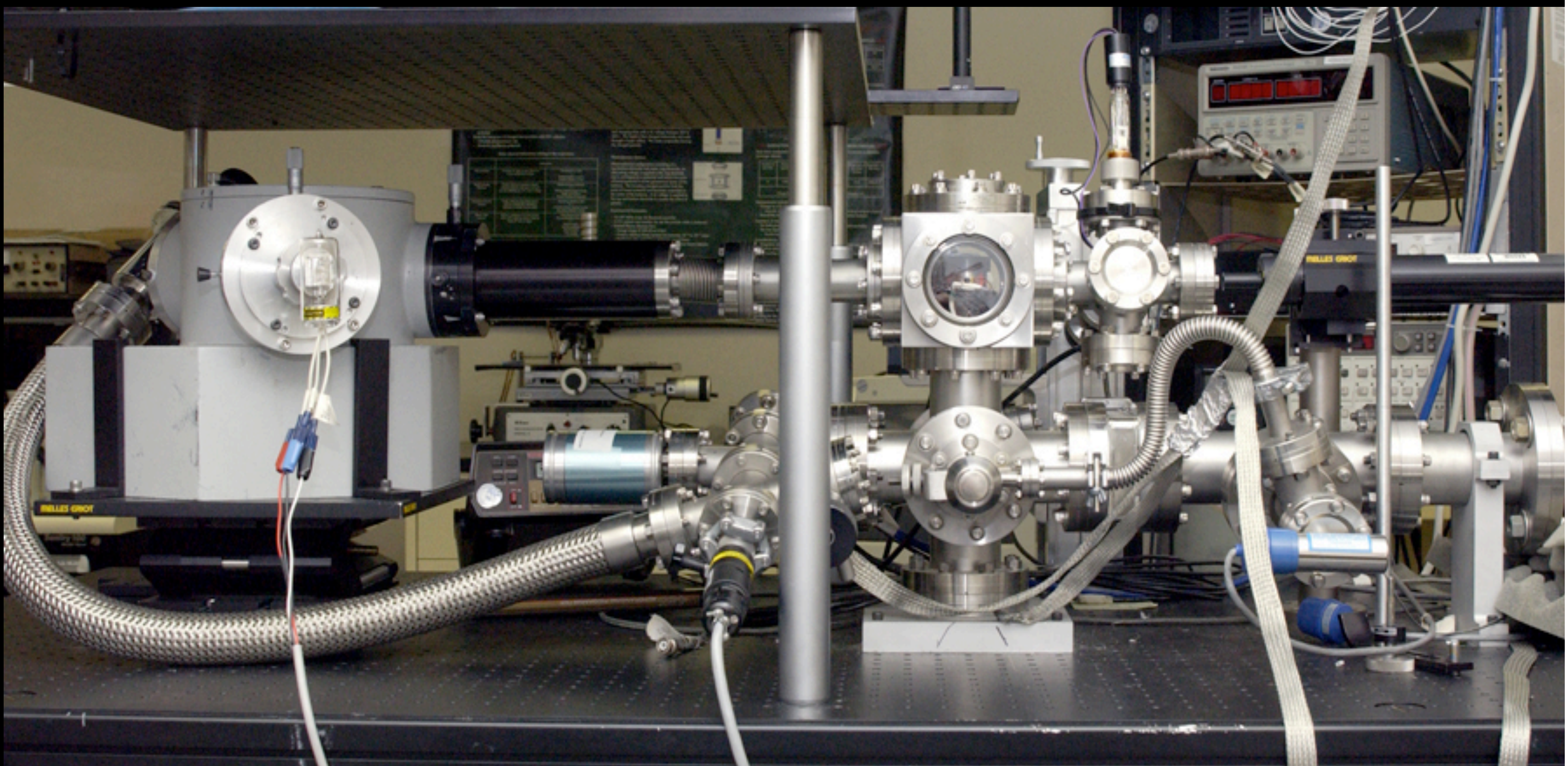
Charging Properties of Individual Dust Grai

- Charging properties of individual micron/submicron size dust grains are substantially different from those of bulk materials.

- No viable models for calculation of the charging properties of individual micron size dust grains are available. The photoelectric yields, and secondary electr emission yields, have to be obtained experimental method

- Laboratory measurements on charging of Apollo 11 & 17 dust grains by electron impact are reported here.

Laboratory Facility for Measurements of Chargin Properties of Individual Dust Grains: Electrodynamic Balance



Experimental Procedure

- **Positively or negatively charged particles of 0.1 - 15 µm size are injected into the trap and evacuated to pressures of ~ 10^{-4} - 10^{-5} torr**
- **Effective particle diameter is determined by viscous drag measurements at pressures of ~ 1 - 5 torr**
- **The levitated particle is exposed to an electron beam, and the particle charge is determined by measuring V_{DC} as a function of time by using:**

$$q(t) = g z_o m / 2 C_o V_{DC}(t)$$

where C_0 , z_0 are trap constants, m is the grain mass, and g is gravity.

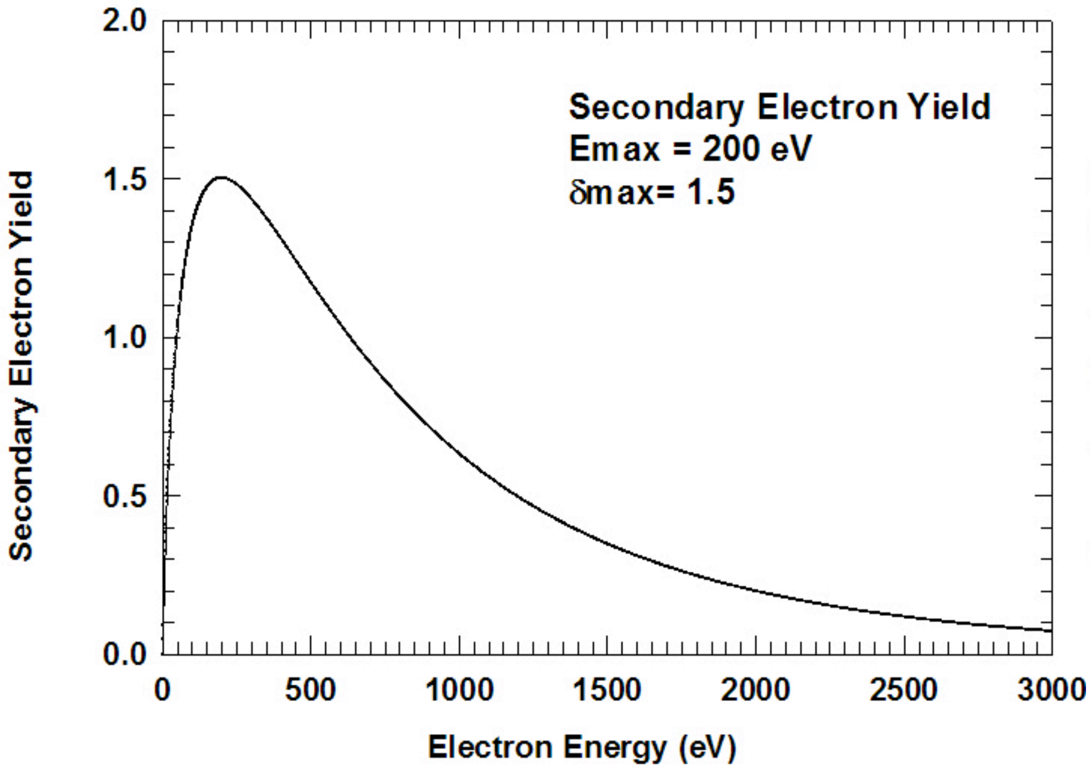
$\delta_{sec}(E) = 7.4\delta_M(E/E_M)\exp\left[-2(E/E_M)^2\right]$

Secondary Electron Yield for Bulk Materials

Sternglass Equation:

$$\delta_{sec}(E) = 7.4\delta_M(E/E_M)\exp\left[-2(E/E_M)^2\right]$$

where δ_M is the yield at maximum energy E_M



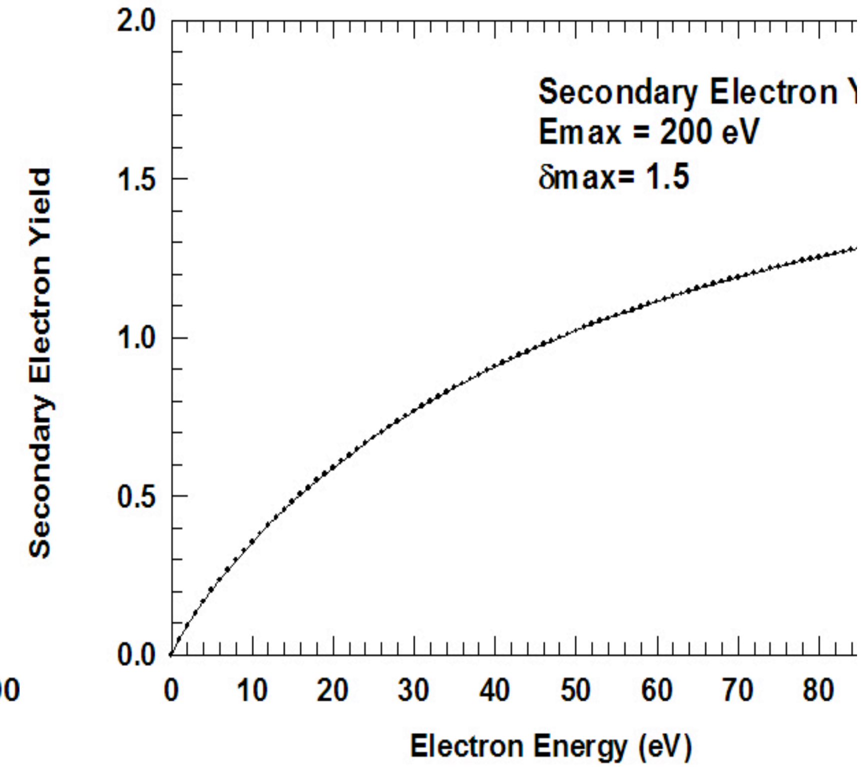


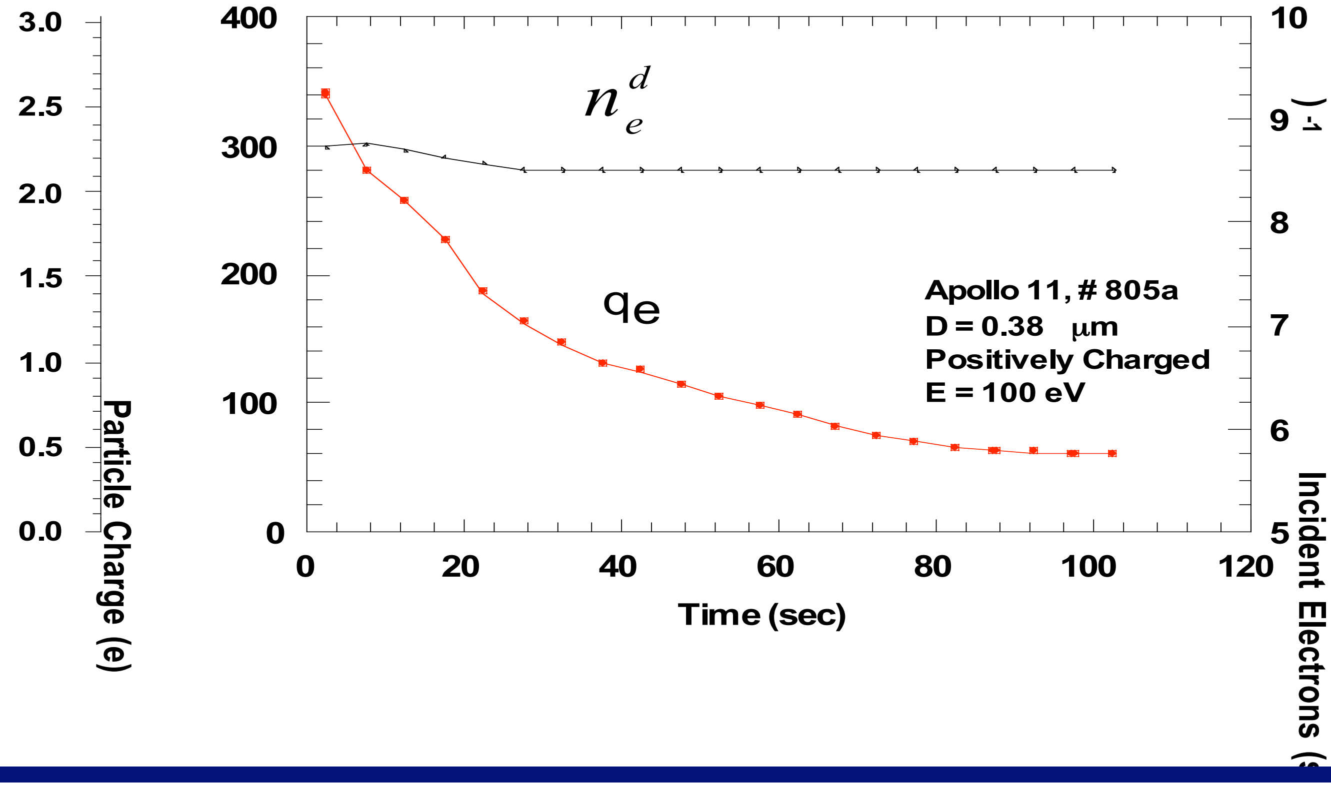
Table1. A listing of the Apollo 11 positively charged dust grains with measured response to the impact of low energy electrons

AP	part#	pol	D(μm)	E(ev)	qi(e)	qf(e)	Φ i(V)	Φf(V)	δi	δf	cha
11	804a	pos	0.29	100	100	44	1	[0.42]	0.25	1	dis
	804b	pos	0.29	10	100	300	1	3	5	3	c
11	766c	pos	0.29	25	40	500	0.2	4.8	20	2	c
11	794a	pos	0.34	25	155	50	1.3	0.4	0.25	0.75	d
	794b	pos	0.34	100	50	10	0.44	0.008	0.95	0.6	d
11	805a	pos	0.38	100	340	80	2.6	0.5	0.3	1	d
	805b	pos	0.38	10	80	420	1.5	3.5	3.6	1.55	c
11	834	pos	0.4	100	207	3000	5	21.6	3.6	1.3	c
11	807a	pos	0.57	10	1075	1700	0.5	7	5	4.8	c
	807b	pos	0.57	100	2400	200	12	1	0.005	1	d
11	767c	pos	0.56	100	700	100	3.5	0.5	0	1	d
11	783d	pos	1	25	2700	6285	38	15	11	3.8	c
11	837a	pos	1.4	100	5760	2095	12	4.5	0.2	1	d
11	786a	pos	2.1	25	10000	1800	13.6	2.4	0	1	d
11	784	pos	4	25	38000	5370	27	4			d
11	782	pos	4	25	45400	13500	35	9.25	0	1	d
11	785b	pos	6.55	25	16200	11000	6	4.4			dis

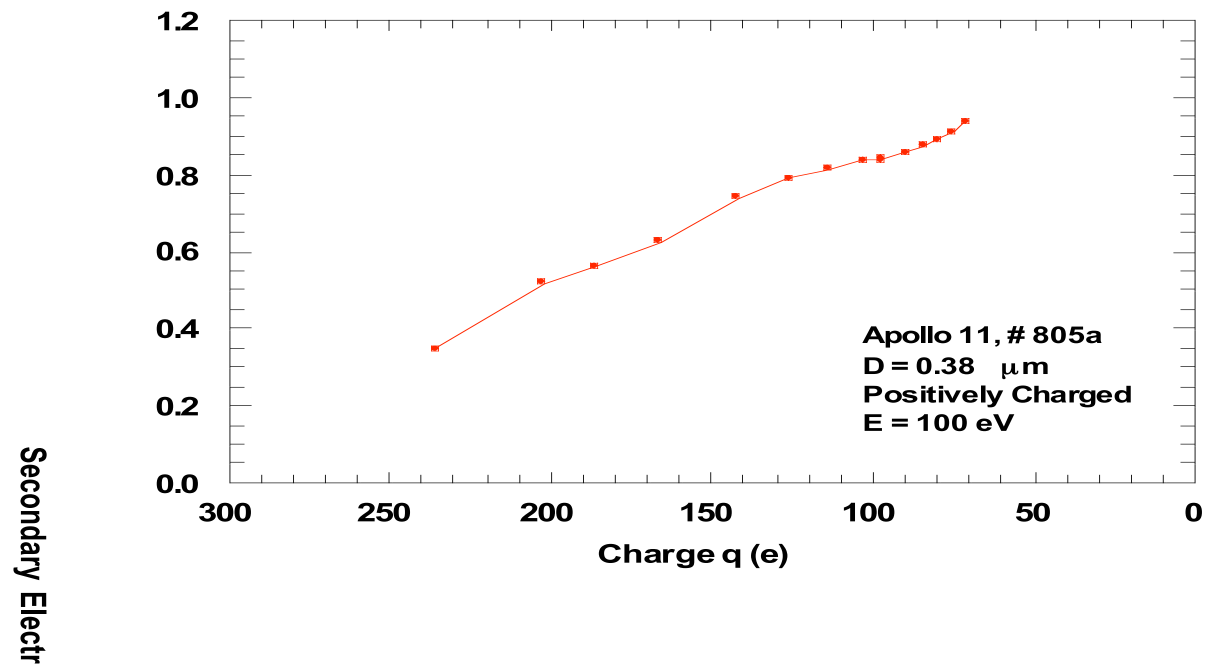
Table2. A listing of the Apollo 17 positively charged dust grains with measured response to the impact of low energy electrons

AP	part#	pol	D(μm)	E(ev)	qi(e)	qf(e)	Φi(V)	Φf(V)	δi	δf	char
17	780b	pos	0.35	100	80	24	0.62	[0.1]	0.1	0.9	d
	780d	pos	0.35	25	35	888	7.4	0.76	6	2	c
17	774a	pos	0.36	100	170	25	1.35	0.2	0	0.85	d
17	762b	pos	0.38	25	116	373	0.9	2.8	7	1.9	c
	762c	pos	0.38	100	302	14	2.3	[0.11]	0	1	d
17	779a	pos	0.45	100	390	42	2.5	[0.3]	0	1	d
	779b	pos	0.45	25	40	470	0.3	2.9	3.6	1.5	c
17	776	pos	0.8	100	1440	272	5.3	1			d
17	739	pos	1.9	25	4080	768	6.3	1.2	0.1	1	d
17	763a	pos	8.62	100	81500	22200	29	8	0	1	d

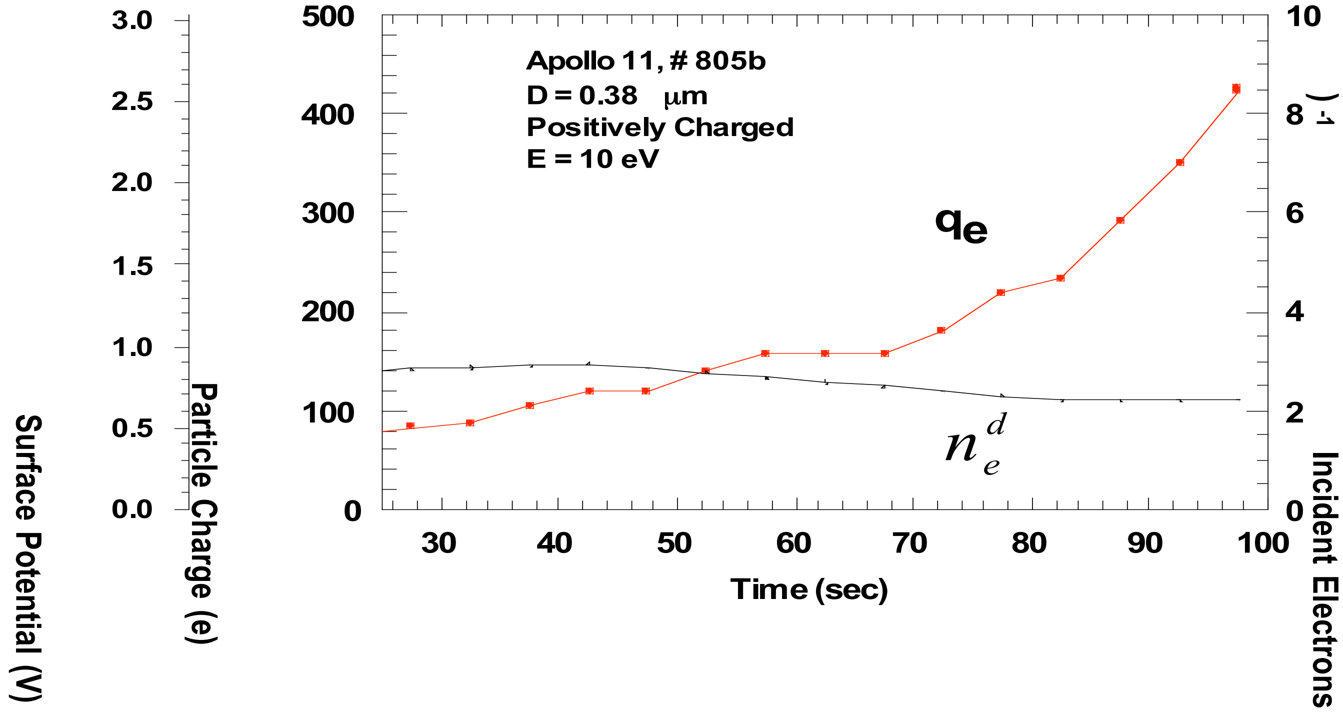
A positively charged 0.38 µm Apollo 11 dust grain Discharges with a 100 eV electron beam.



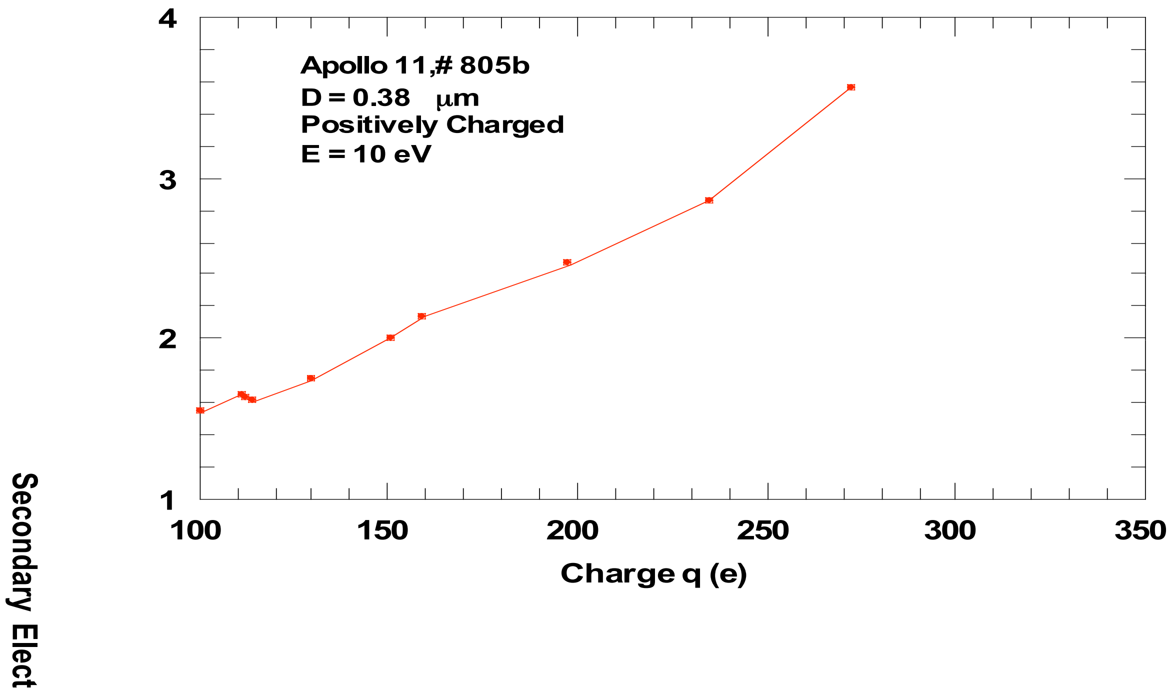
Calculated SEE Yield for discharging of the above particle.



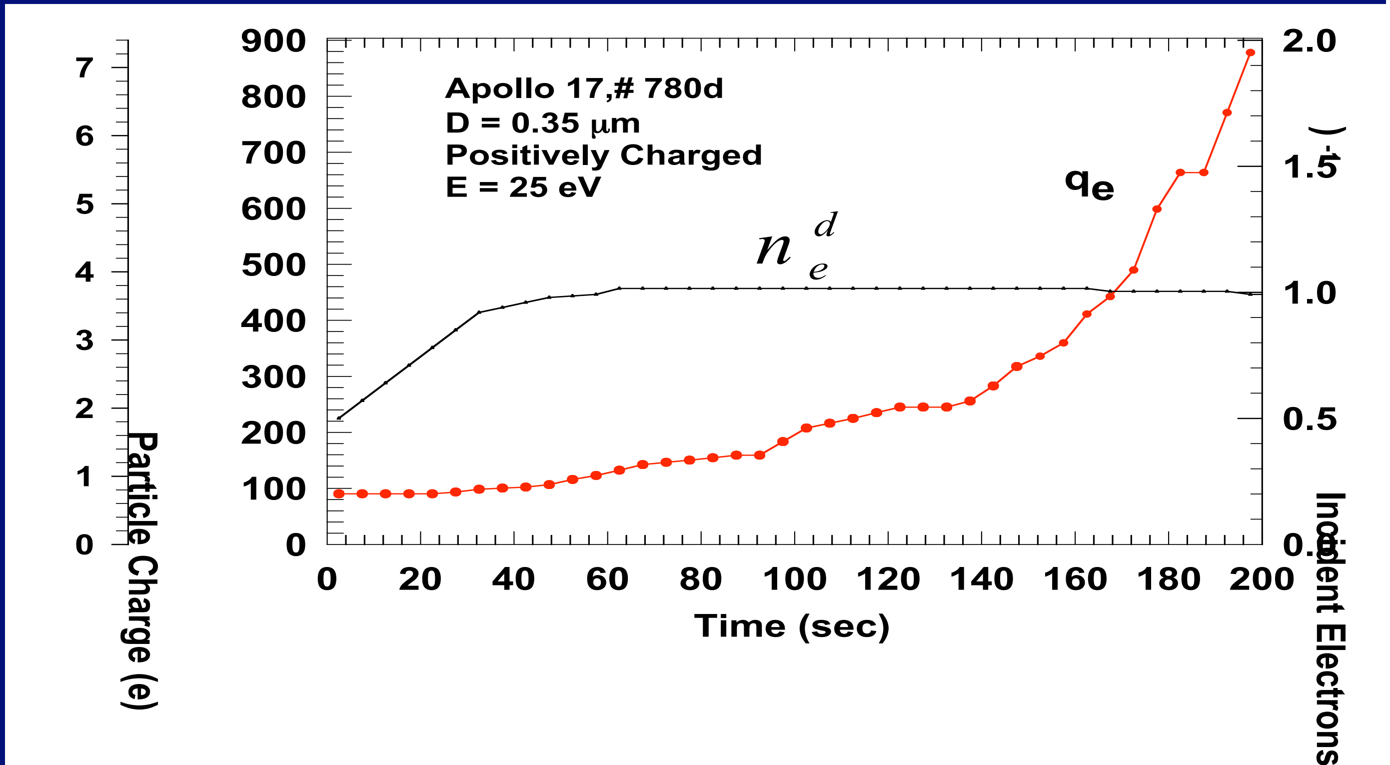
A positively charged 0.38 µm Apollo 11 dust grain Charges with a 10 eV electron beam.



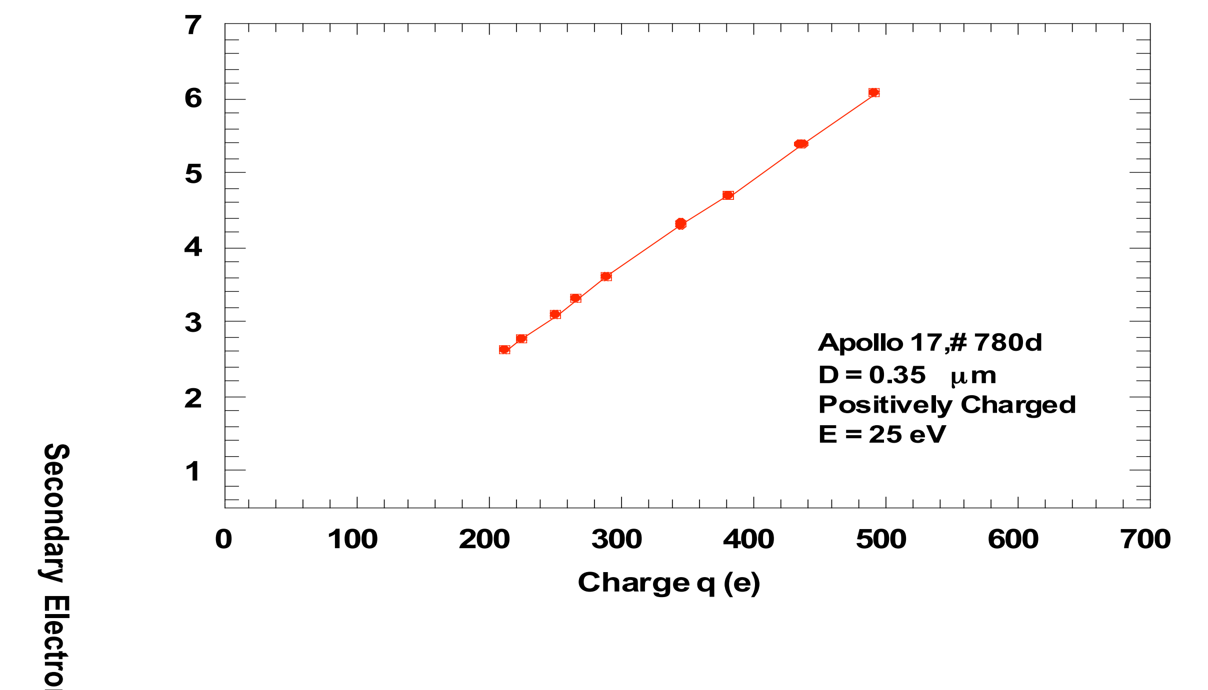
Calculated SEE Yield for charging of the above particle.



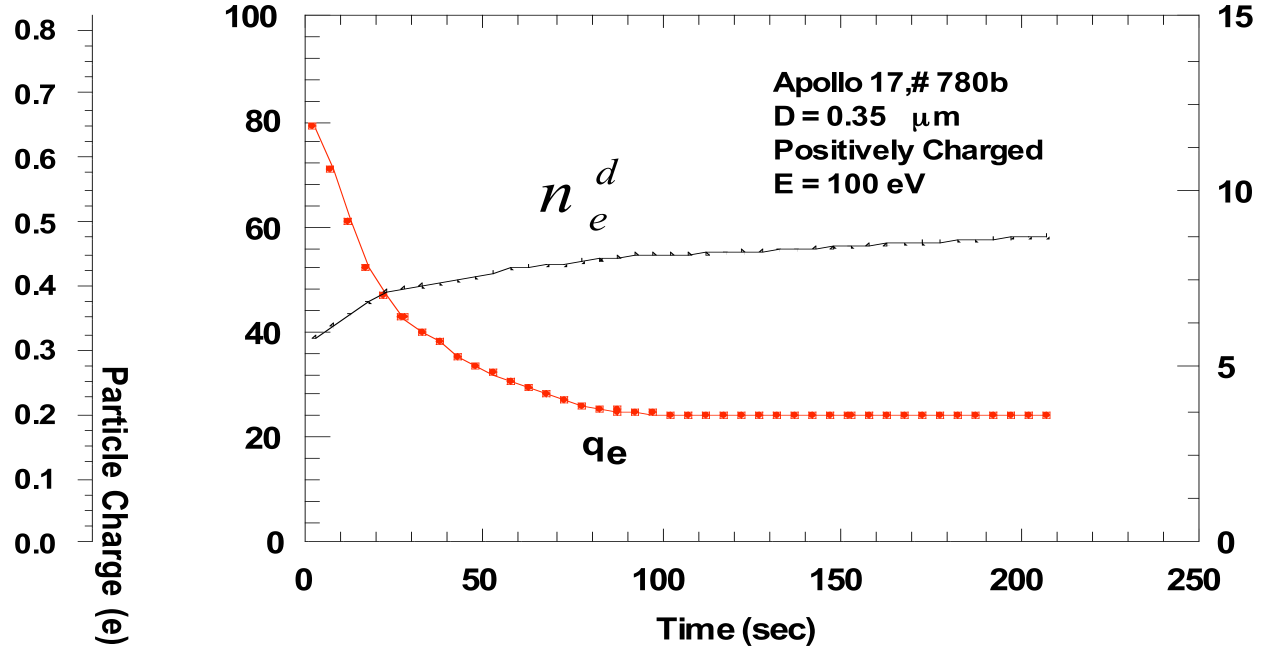
A **positively** charged **0.35 µm** Apollo 17 dust grain **<u>Charges</u> with a 25 eV** electron beam.



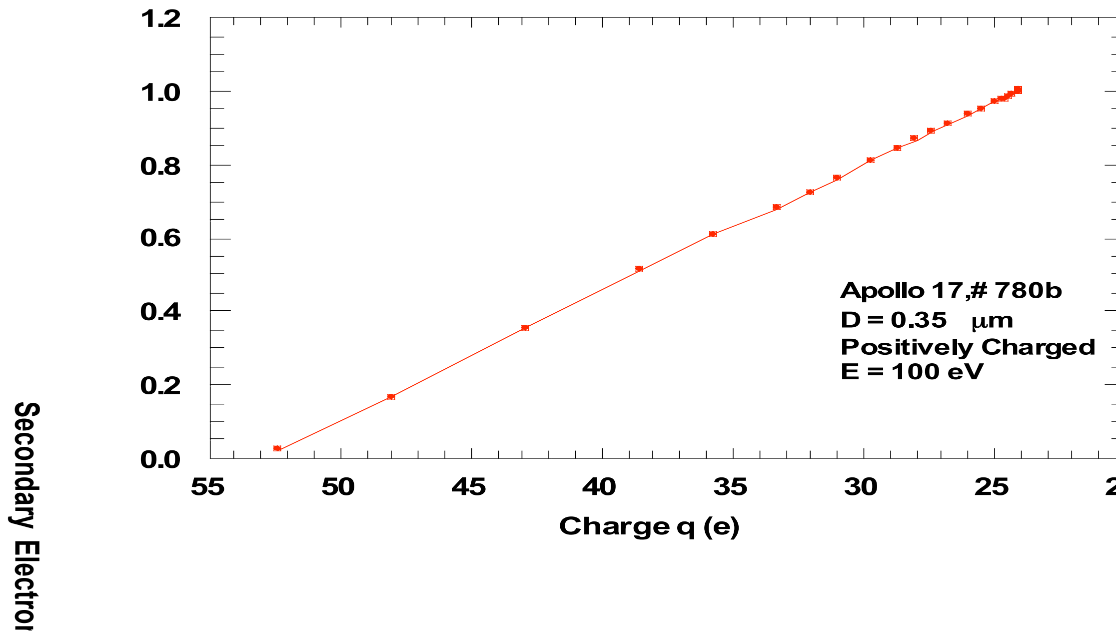
Calculated SEE Yield for charging of the above particle.



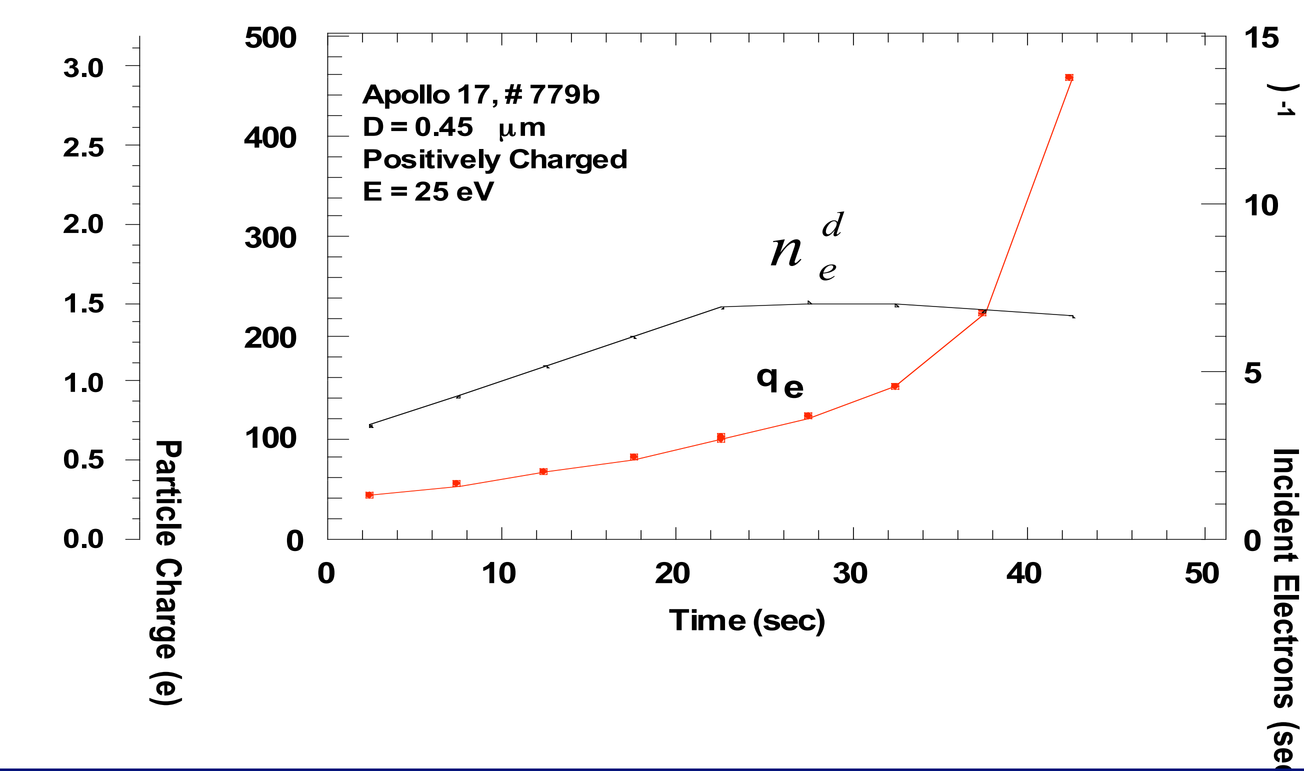
A positively charged 0.35 µm Apollo 17 dust grain Discharges with a 100 eV electron beam.



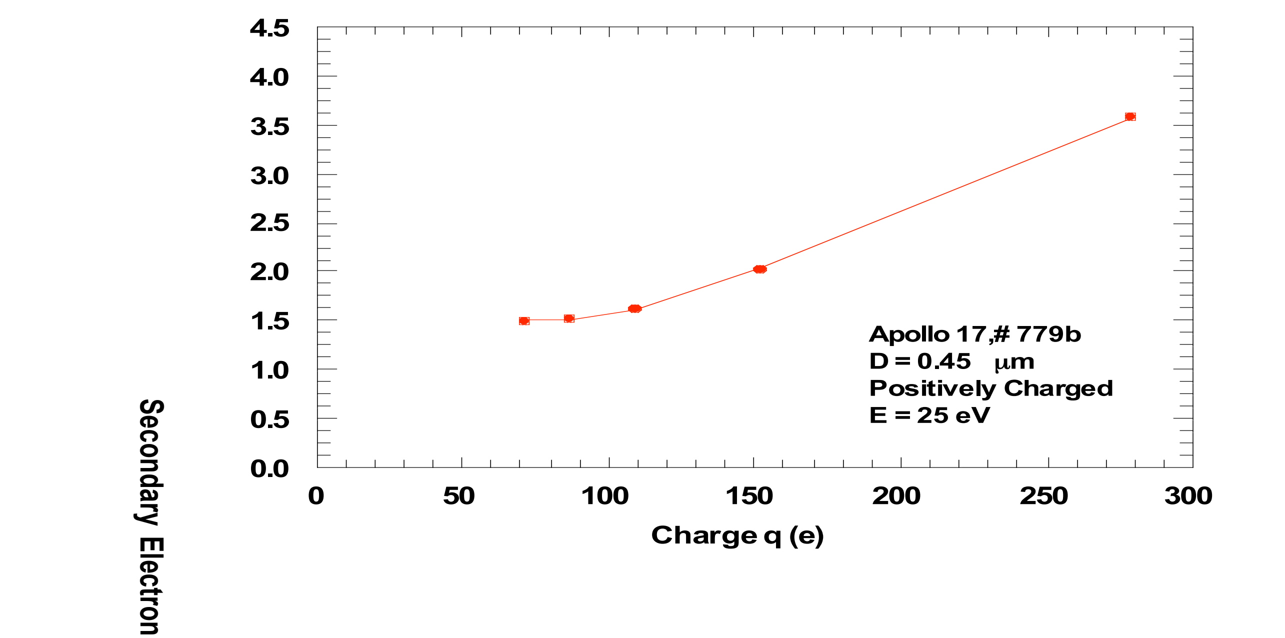
Calculated SEE Yield for discharging of the above particle.



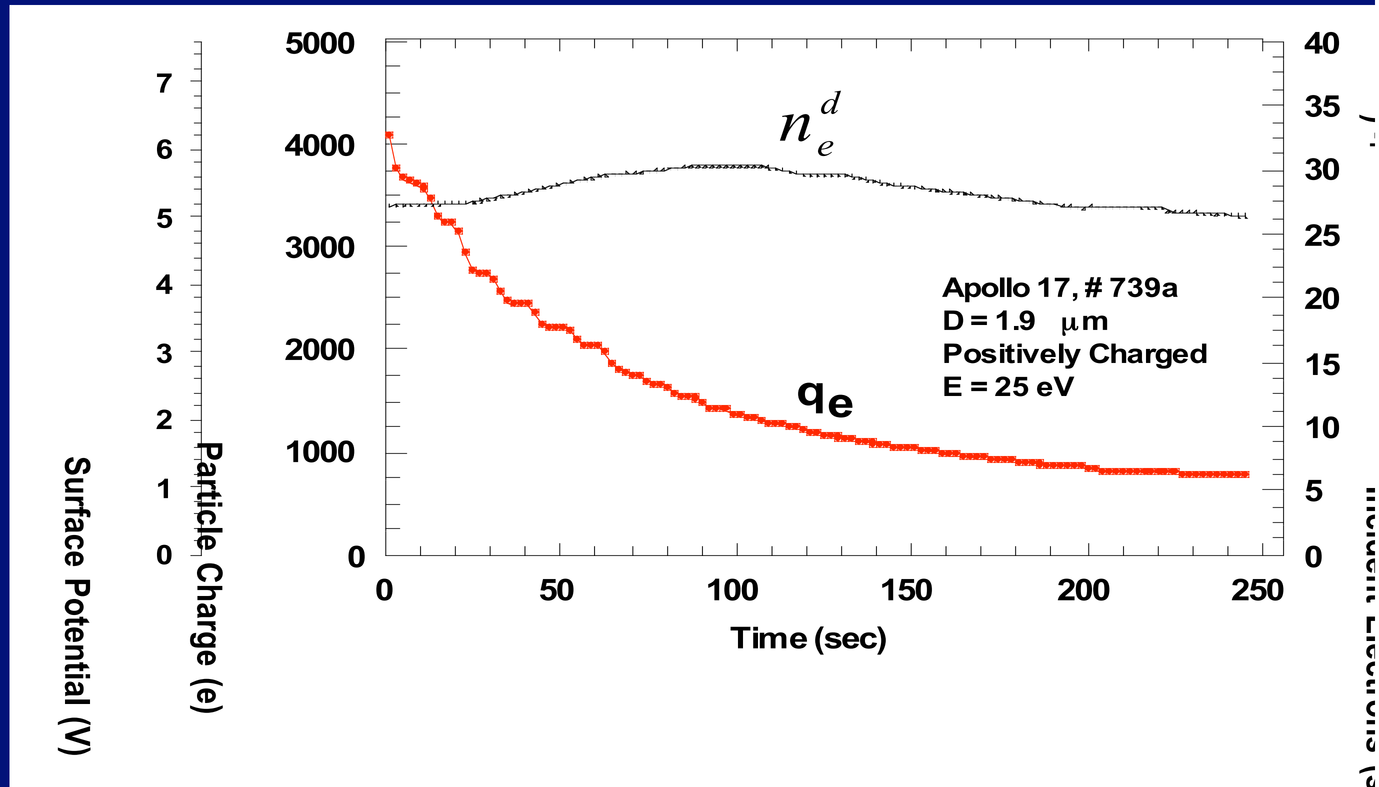
A positively charged 0.35 µm Apollo 17 dust grain Charges with a 25eV electron beam.



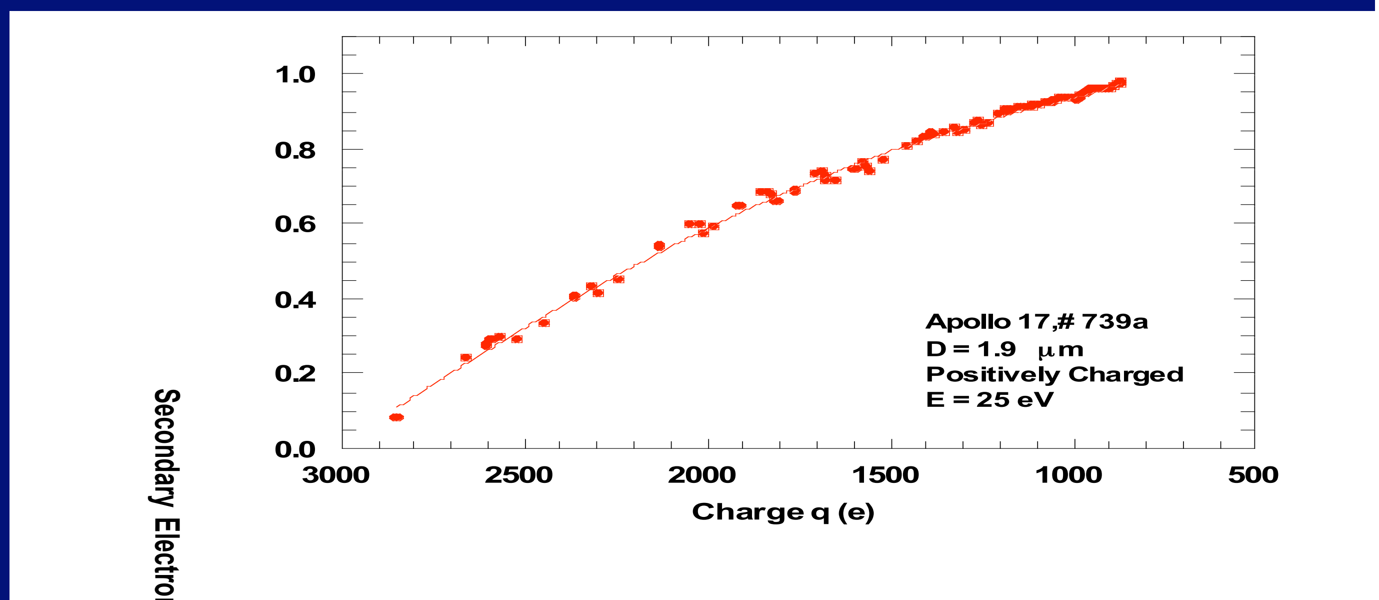
Calculated SEE Yield for charging of the above particle.



A positively charged 1.9µm Apollo 17 dust grain Discharges with a 25eV electron beam.



Calculated SEE Yield for discharging of the above particle.



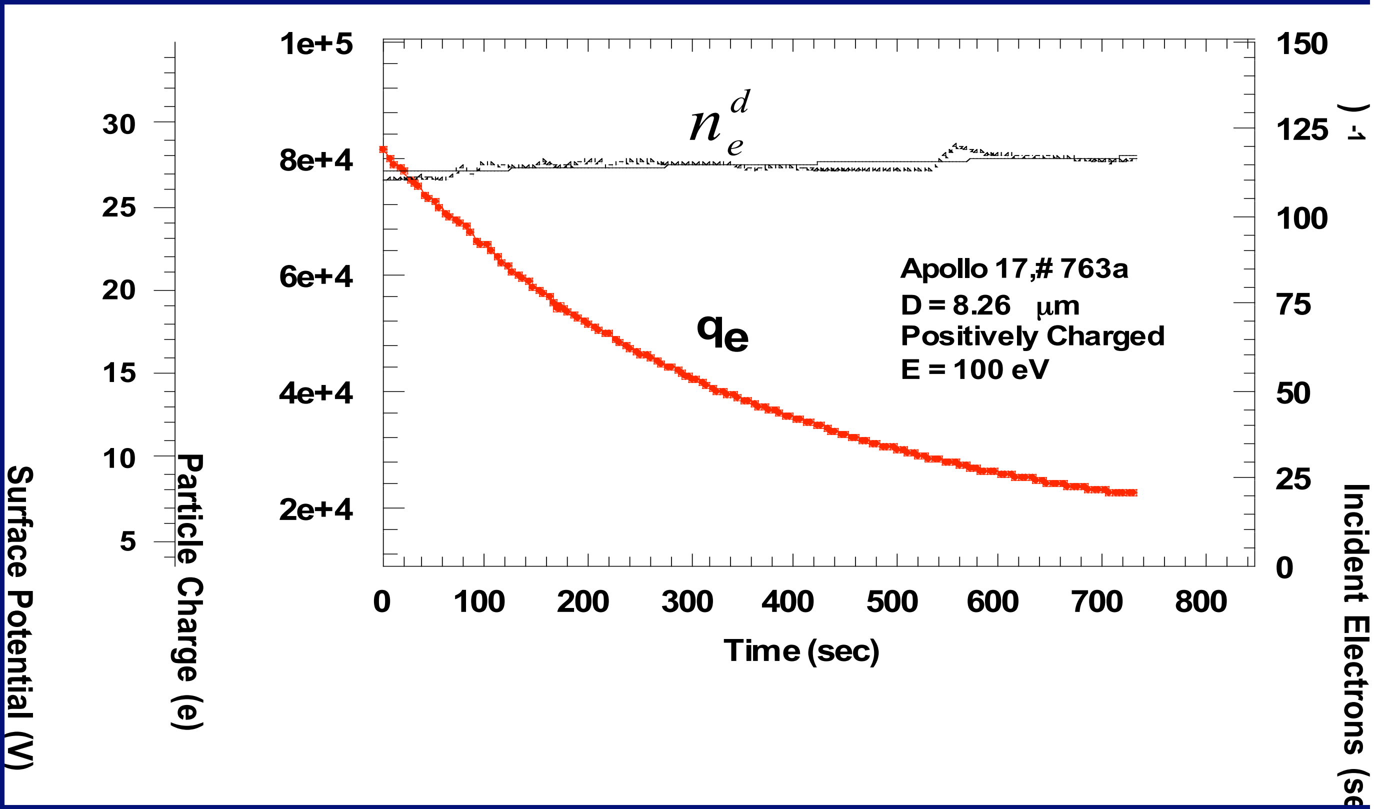
A **positively** charged

8.26 µm

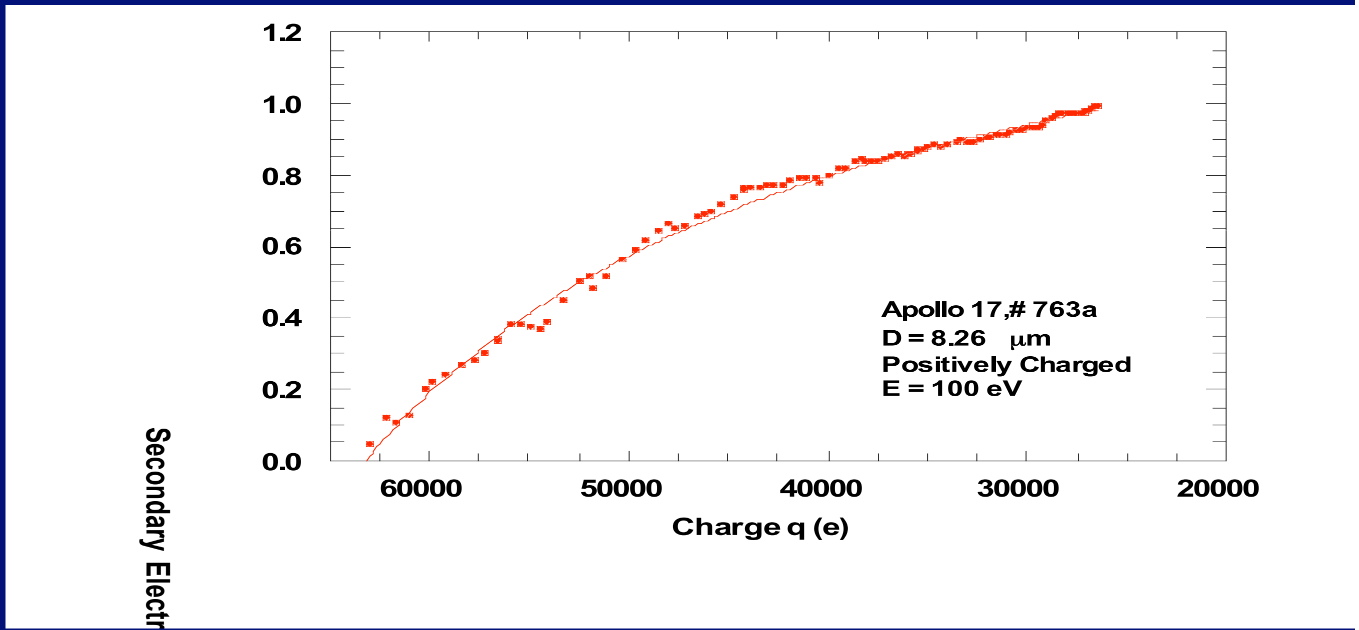
Apollo 17 dust grain

Discharges

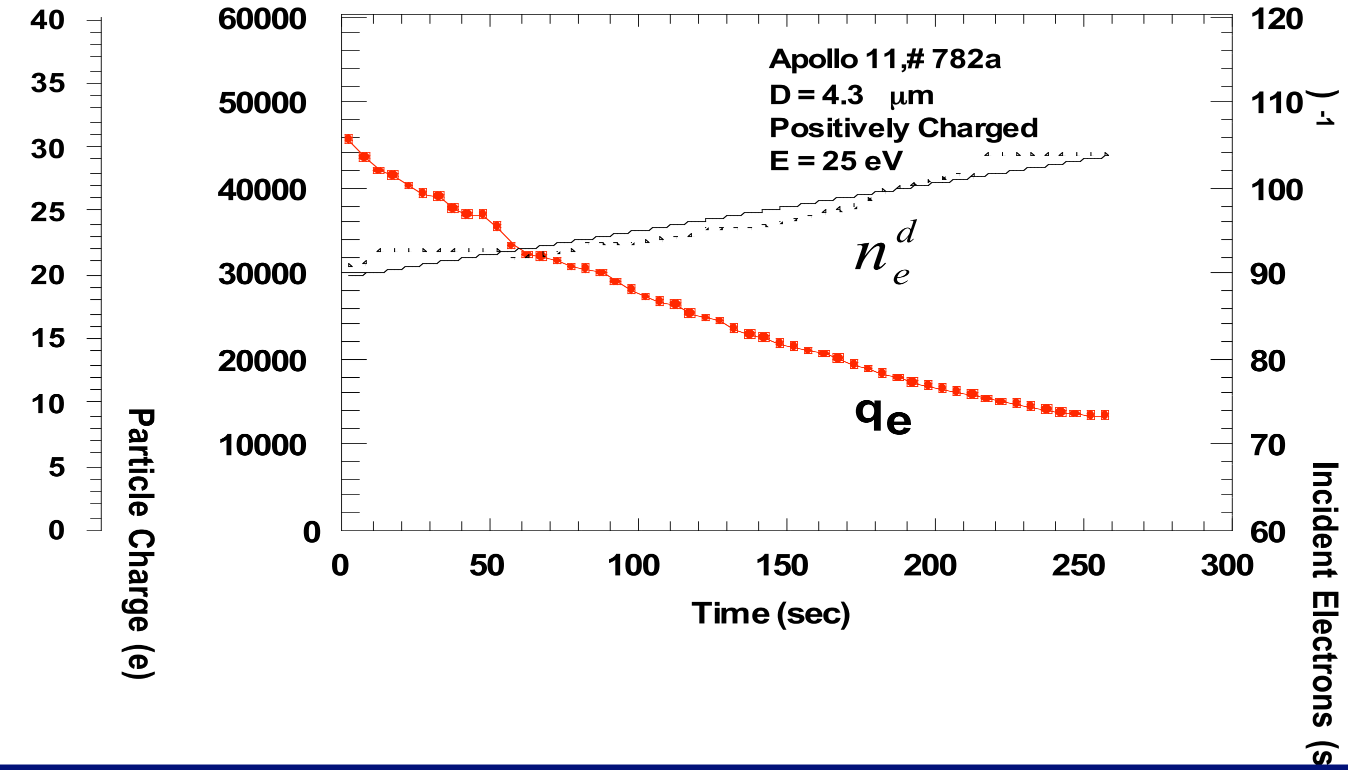
with a 100 eV electron beam.



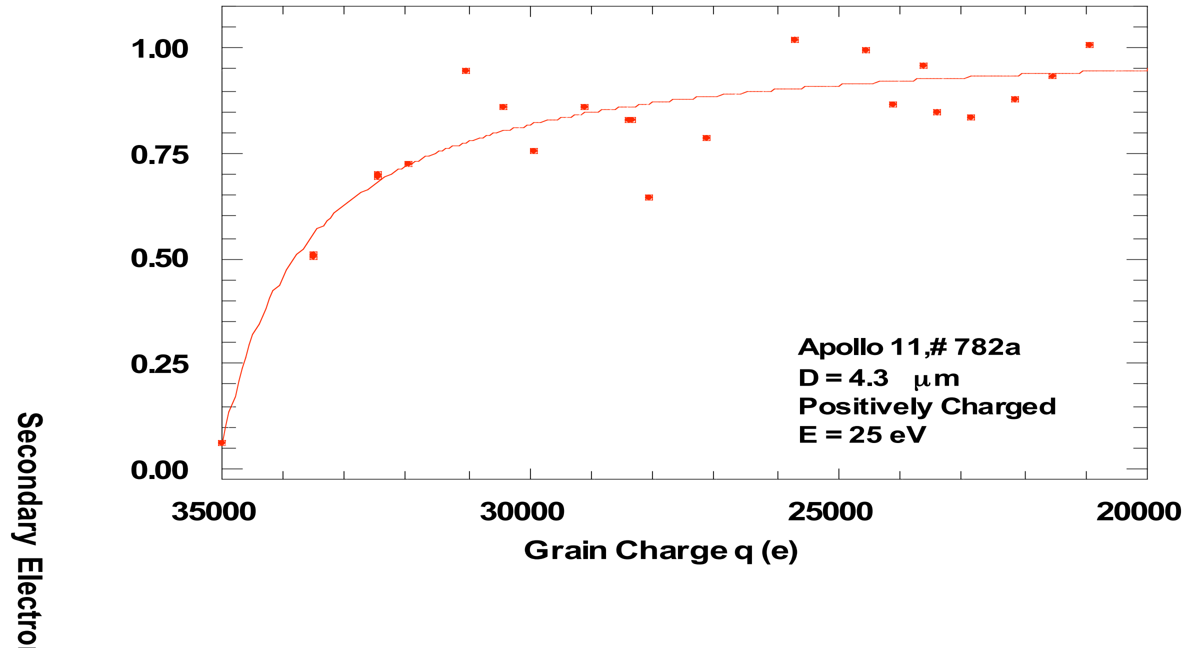
Calculated SEE Yield for discharging of the above particle.



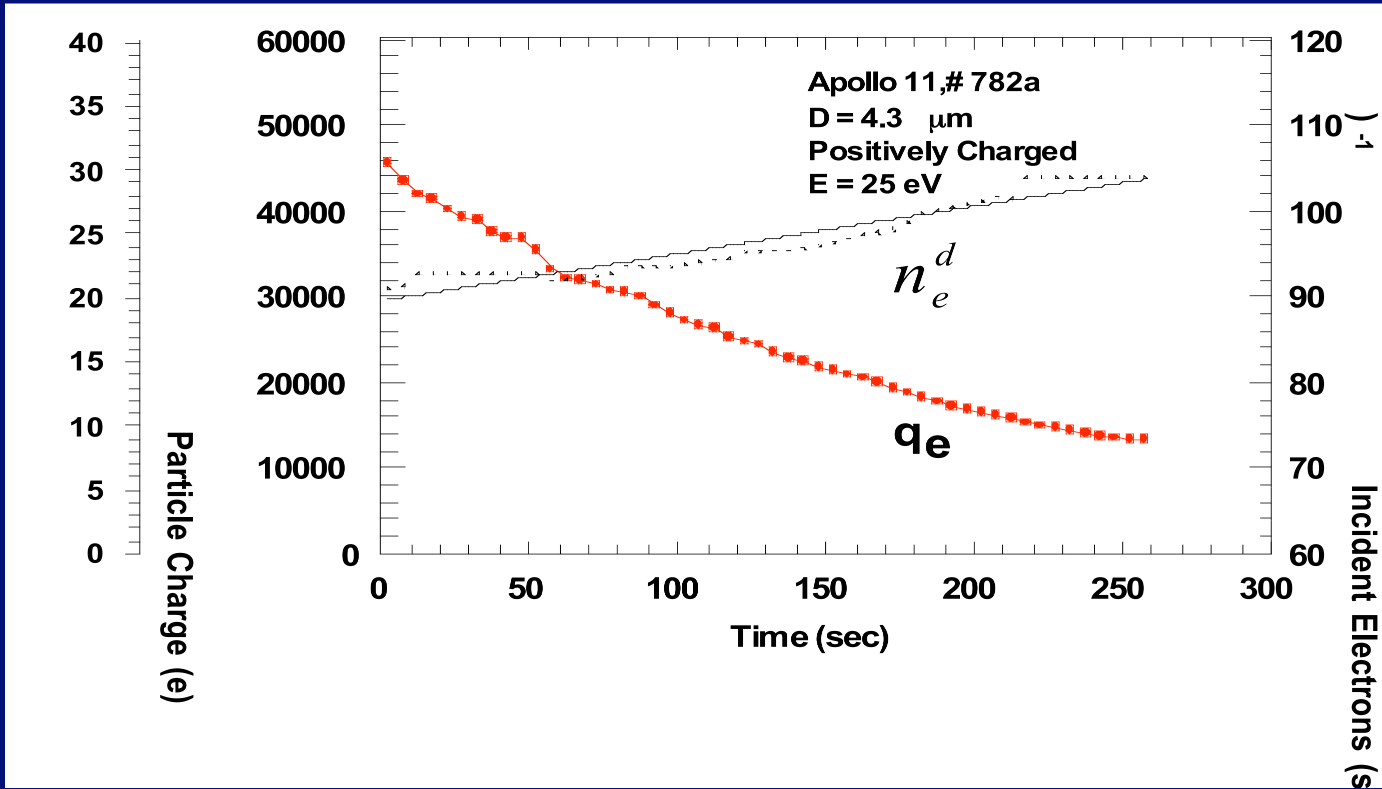
A positively charged 4.3 µm Apollo 11 dust grain <u>Discharges</u> with a 25 eV electron beam.



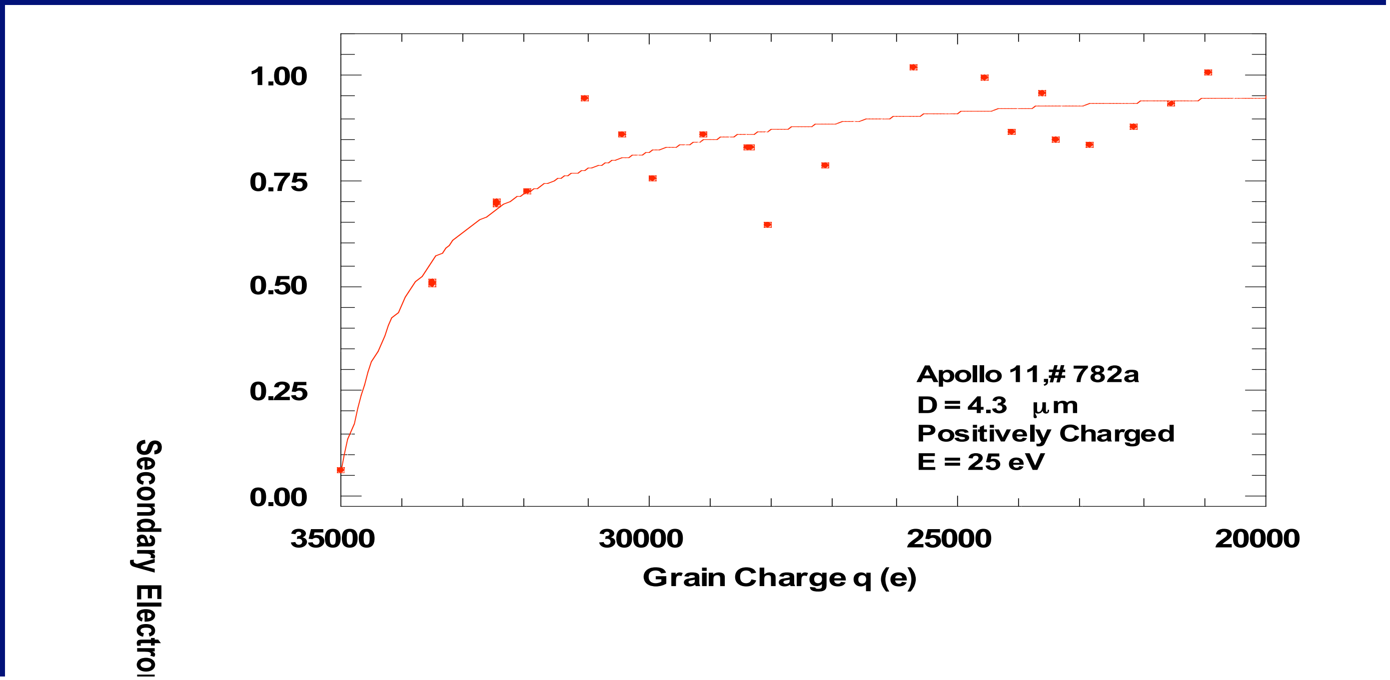
Calculated SEE Yield for charging of the above particle.



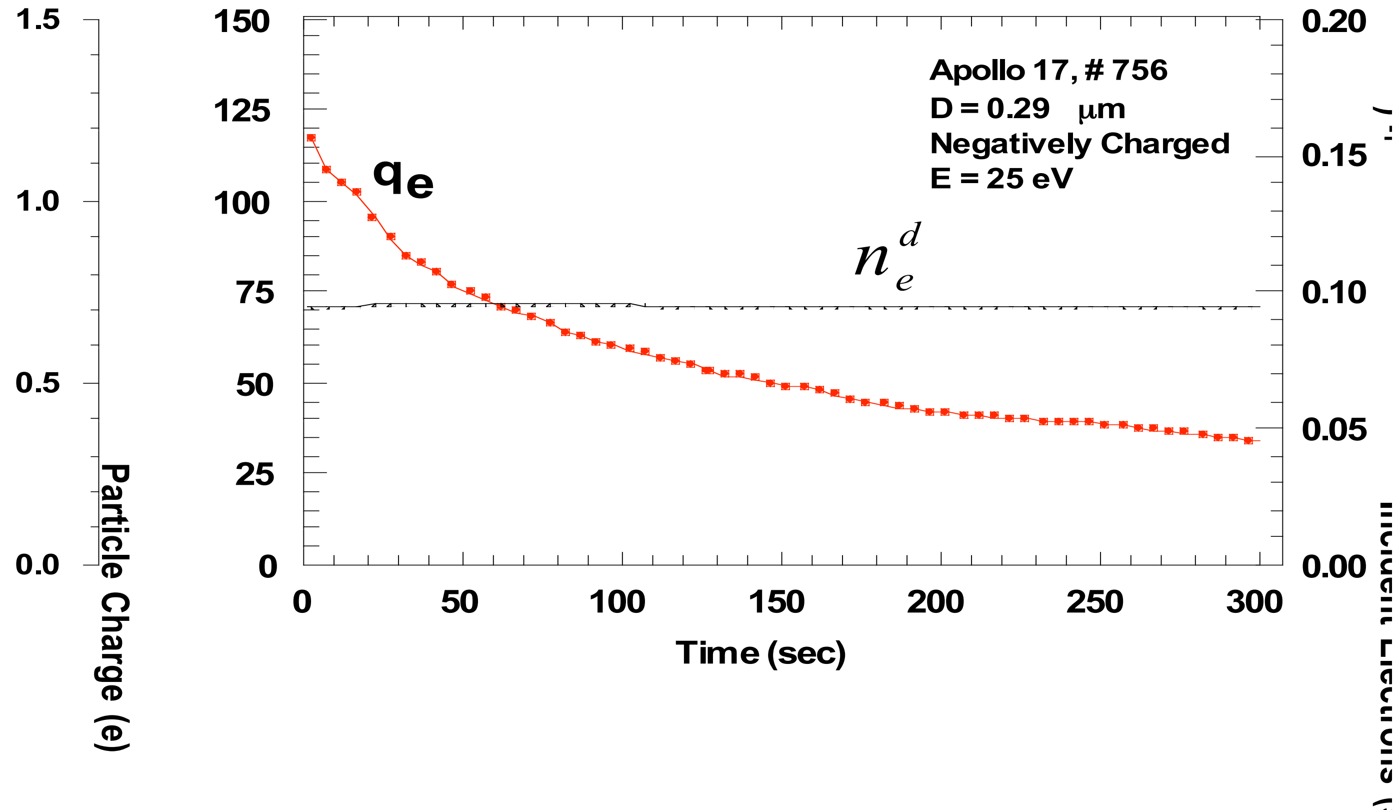
A positively charged 4.3 µm Apollo 11 dust grain <u>Discharges</u> with a 25 eV electron beam.



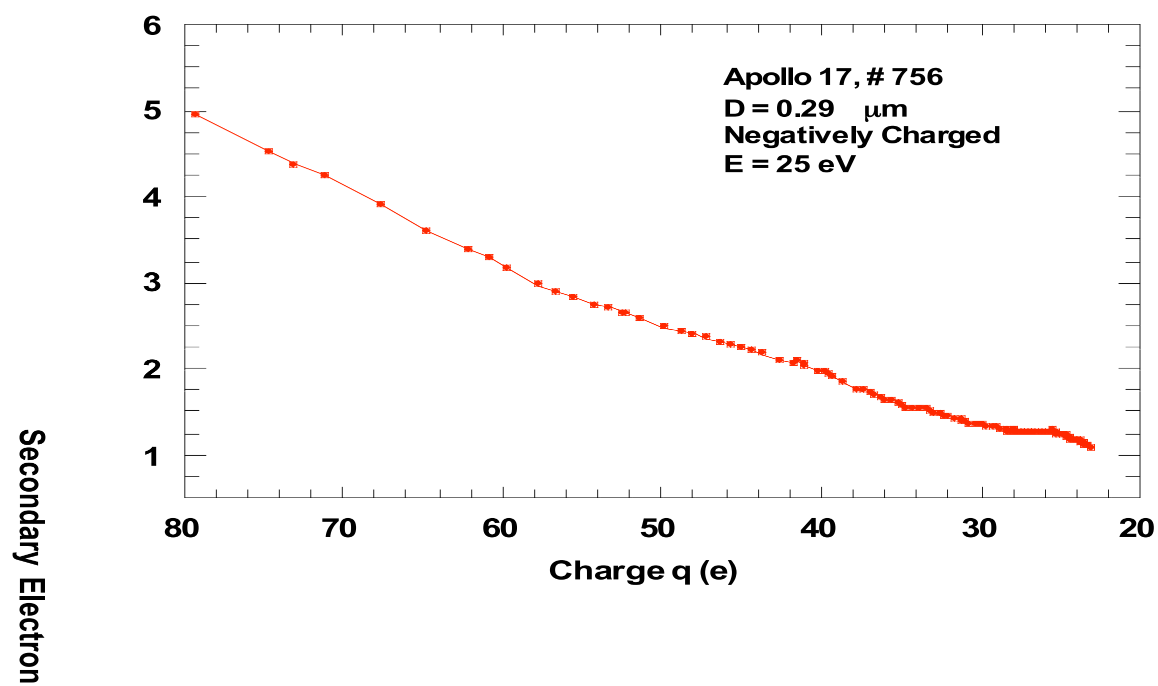
Calculated SEE Yield for charging of the above particle.



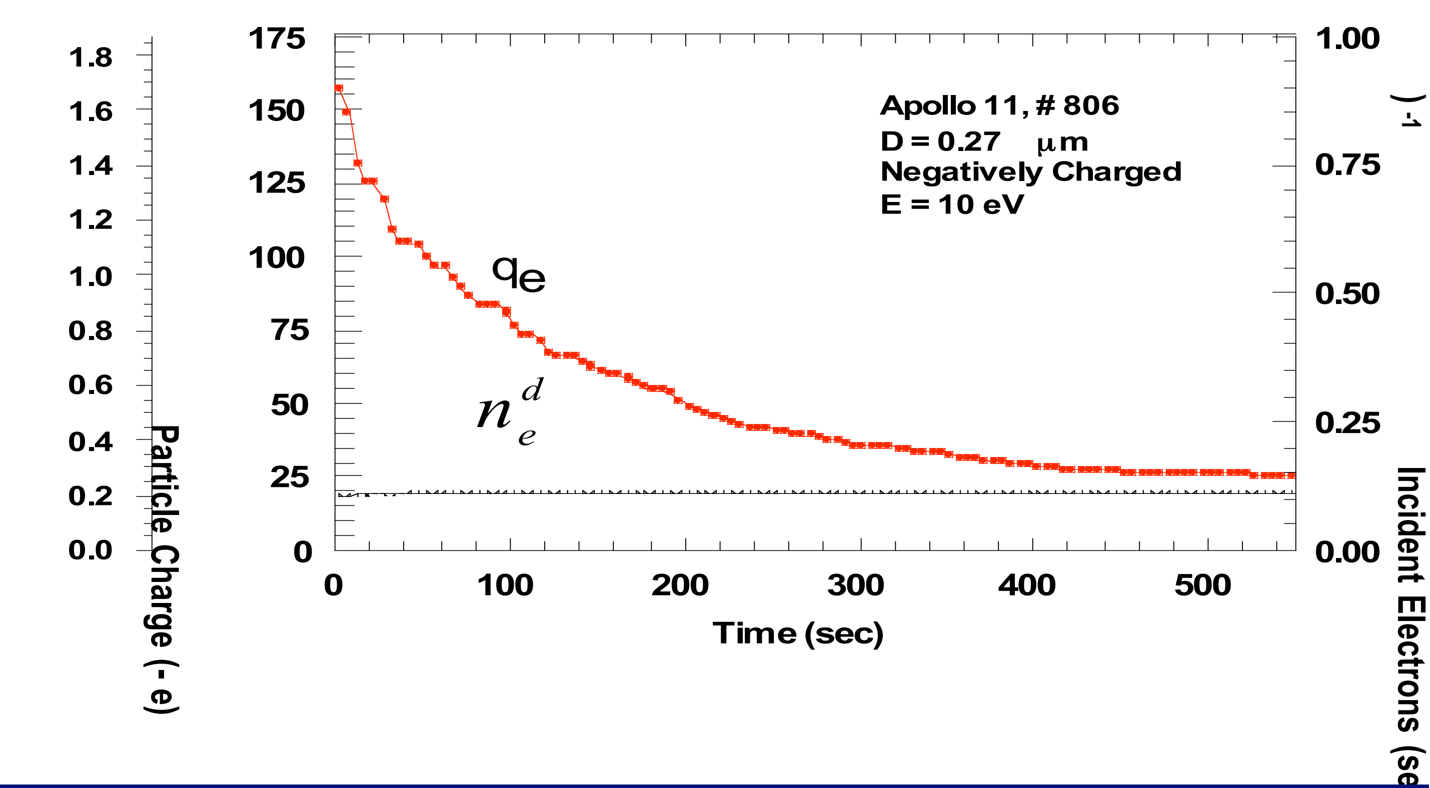
A **negatively charged 0.29 µm** Apollo 17 dust grain **Discharges** with a 25eV electron beam.



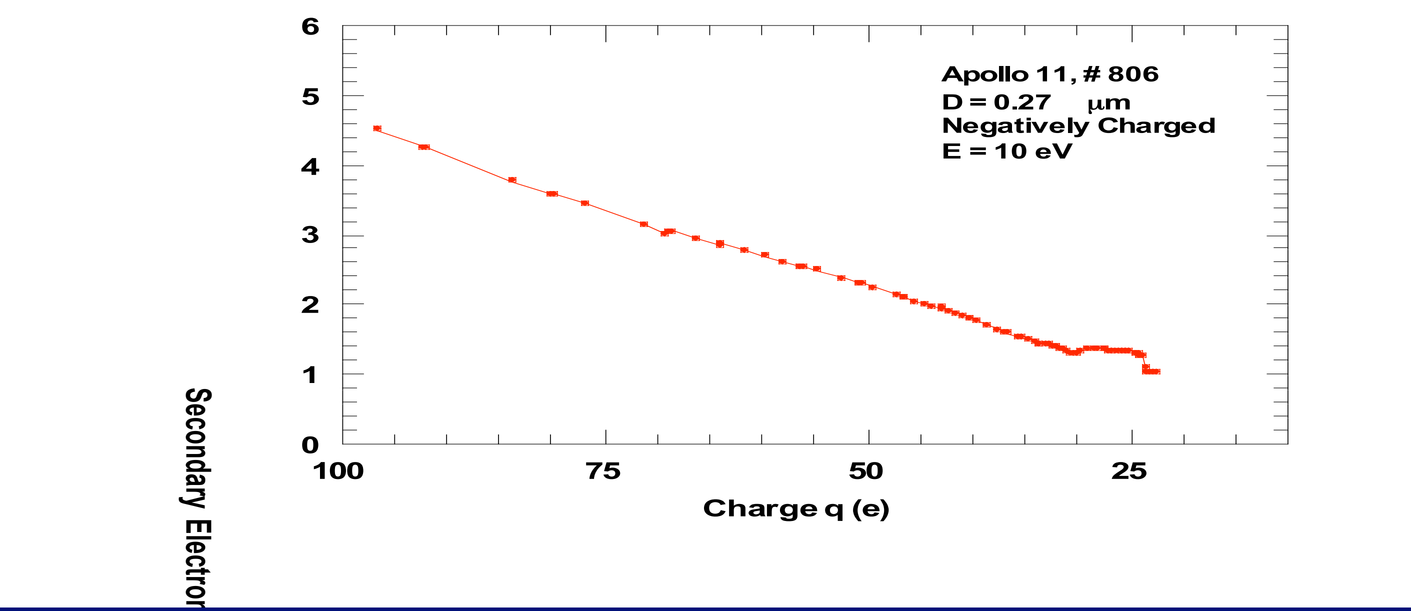
Calculated SEE Yield for discharging of the above particle.



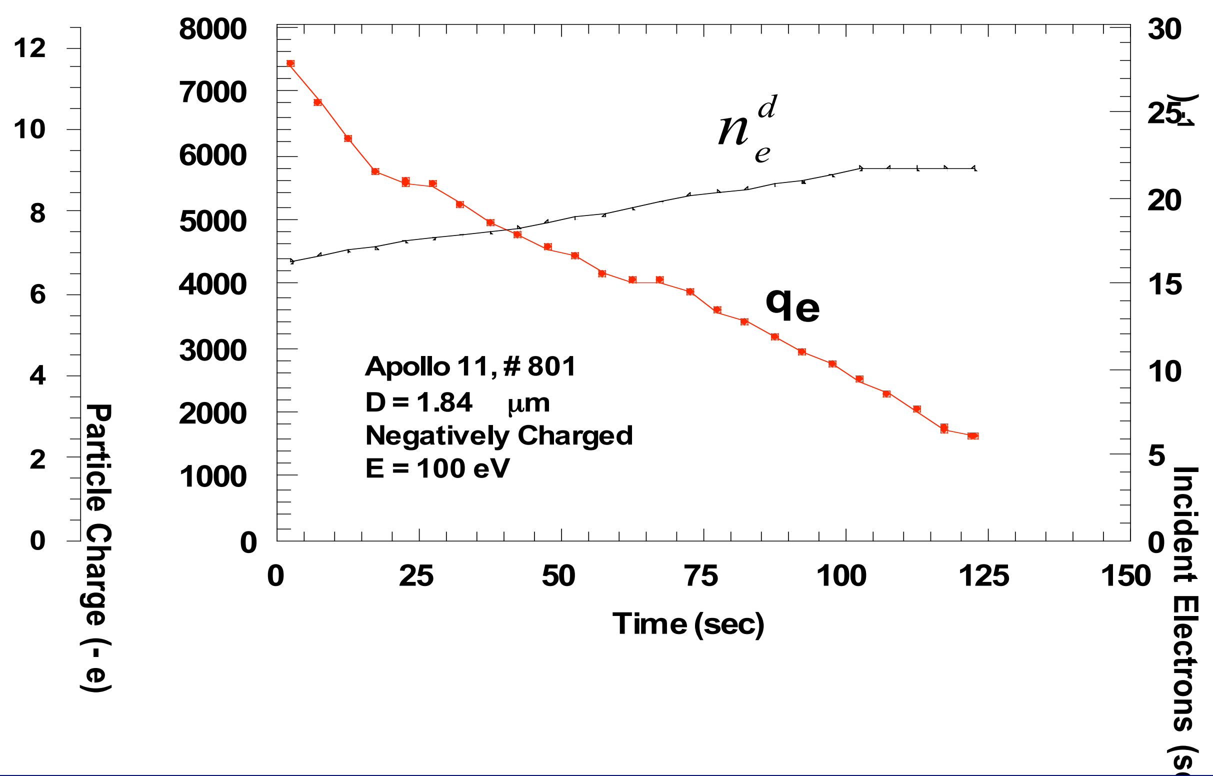
A negatively charged 0.27 µm Apollo 11 dust grain <u>Discharges</u> with a 10eV electron beam.



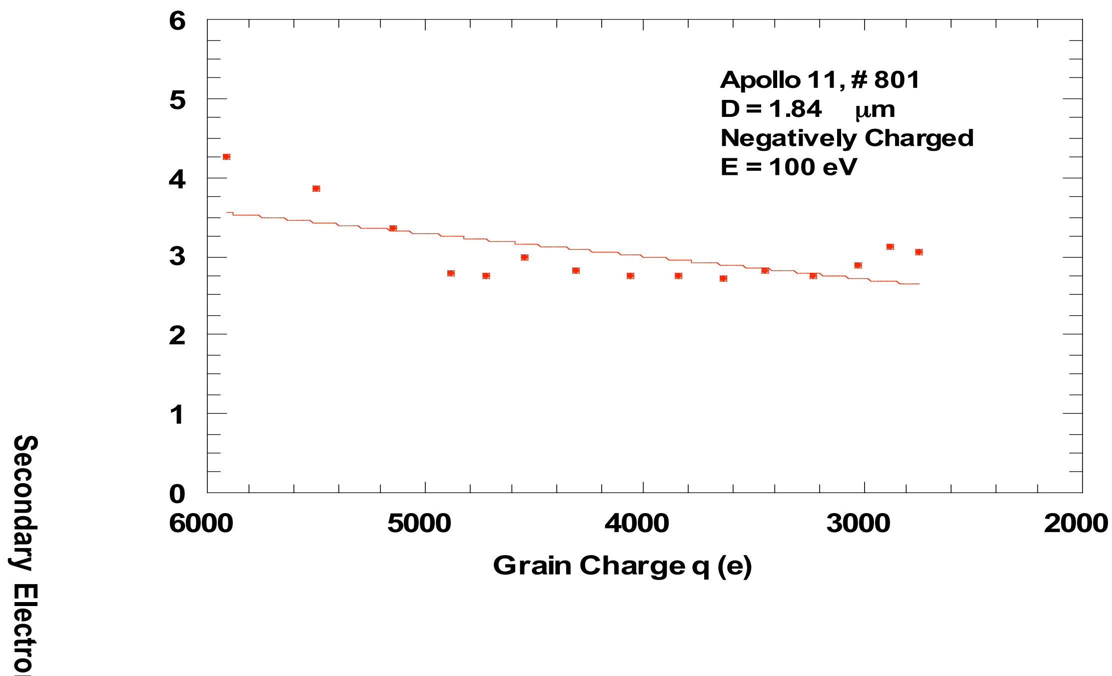
Calculated SEE Yield for discharging of the above particle.



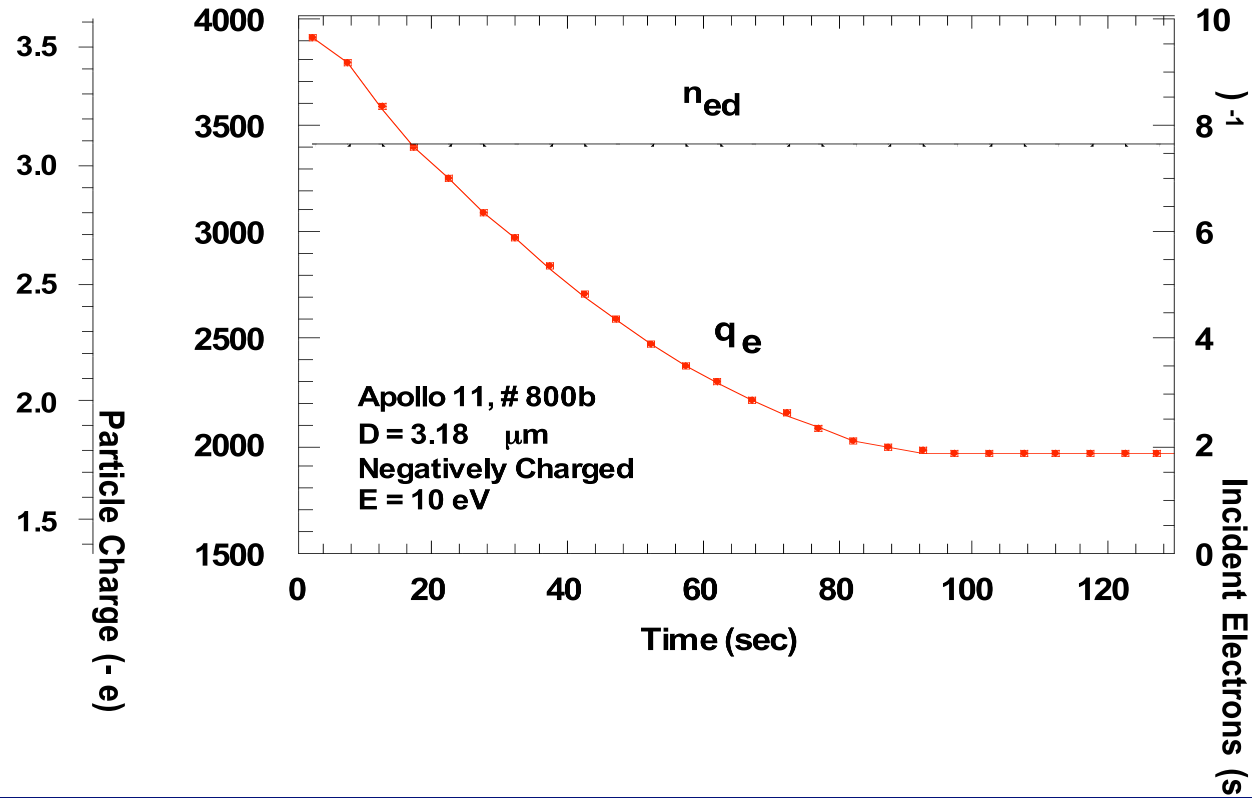
A negatively charged **1.84 µm** Apollo 11 dust grain **Discharges** with a 100eV electron beam.



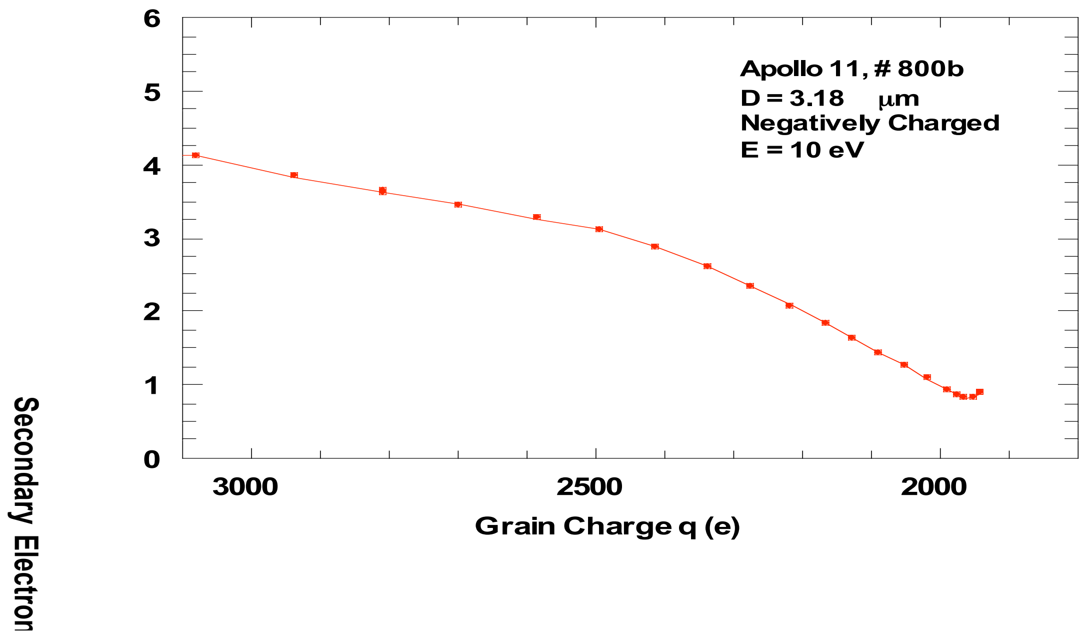
Calculated SEE Yield for discharging of the above particle.



A negatively charged 3.18µm Apollo 11 dust grain Discharges with a 10eV electron beam.



Calculated SEE Yield for discharging of the above particle.



Conclusions on SEE Measurements

General Conclusions:

- The measurements on Secondary Electron Emission on individual lunar dust grains by low energy electron impact are found to be at variance with the currently available model calculations and some measured values.

- Charging /Discharging processes and equilibrium potentials of small size dust grains depend on the initial particle conditions: **Particle Size, Polarity, Surface Potential**

Conclusions on SEE Measurements (contd.)

Positively Charged Particles

(1) Positively charged particles larger than a few micron in size, generally discharge at a rapid rate when exposed to 25 -200 eV electr beams, reaching equilibrium potentials.

(2) Submicron size positively charged particles at low surface potentials generally charge more positively to higher potentials when exposed to 10-25 eV electron beams, indicating the secondary electron emission process dominating the primary electron sticking.

(3) A surprising charging feature in the experiments is that positivel charged submicron size grains generally charge to higher values at lower electron energies of ~ 10 -25 eV, but discharge at 100 eV energi to lower equilibrium surface potentials.

Conclusions on SEE Measurements (contd.)

Negatively y Charged Particles

(1) Negatively charged particles exposed to 10-100 eV electron bea generally discharge to equilibrium potentials, with a balance between the secondary electron emission and the primary electron sticking. potentials.

Future Measurements

(1) More detailed data on charging properties of individual lunar dust grains need to be obtained.

(2) Measurements of the variability in the charging properties due variations of the grain composition and irregular configurations rem to be studied.

(3) Also, measurements of the effects extreme lunar temperature variations on the charging properties of lunar dust grains need to be made.