Electron Beam Regolith Separation (EBRS) System for Lunar In-Situ Resource Utilization

A. Cabra[1,2], X. Wang[1,2] and M. Horanyi[1,2]

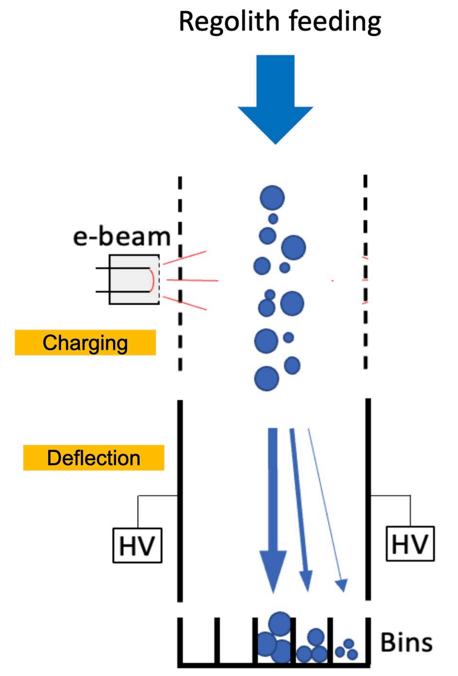
[1] NASA SSERVI's Institute for Modeling Plasma, Atmospheres, and Cosmic Dust (IMPACT), University of Colorado, Boulder, CO 80303;
[2] Laboratory for Atmospheric and Space Physics (LASP), University of Colorado, Boulder, CO 80303

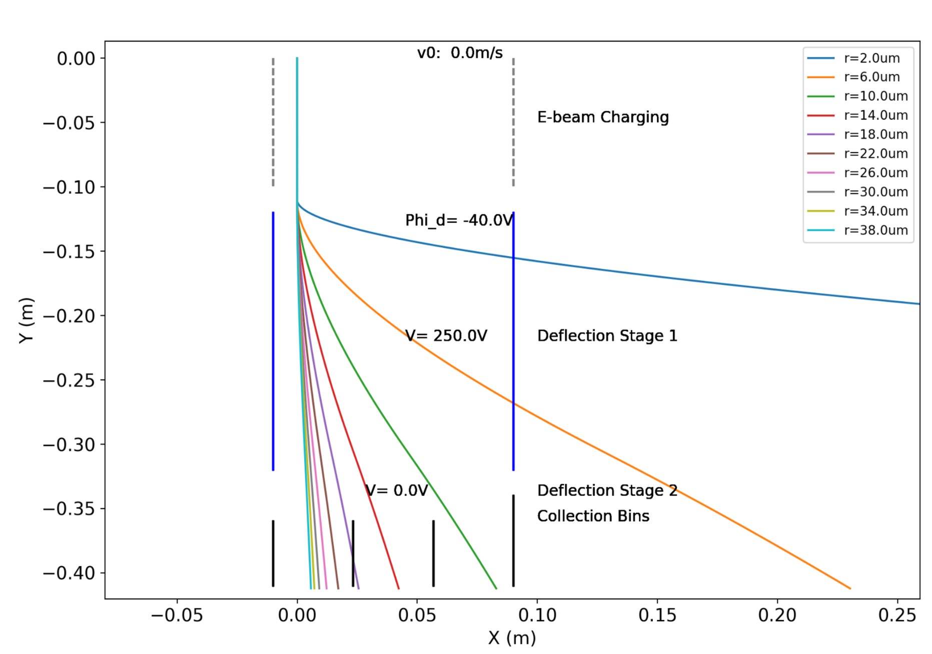
Introduction

In-Situ Resource Utilization (ISRU) is important for long-term, sustainable exploration on the lunar surface. Regolith separation by size is essential for methods like sintering and element extraction, where concentration often depends on dust size. Current technologies include electrostatic (e.g. triboelectric charging), magnetic based on material's magnetic suscepbility, and mechanical sieves [1]. However, these technologies have limitations including clogging, low throughput, and power dependencies. Here we present a new Electron-Beam Regolith Separation (EBRS) technology. EBRS utilizes an electron beam to charge dust particles in a well-controlled manner to separate them by size through electrostatic deflection. EBRS is intended to be a feasible mechanism for separating fine grains with high throughput.

Electron Beam Charging Theory

1. Charging with an electron beam in a controlled manner with the optimized beam energy and current.
2. Deflection by high-voltage (HV) electrodes, which depends on the charge-to-mass ratio that is related to the particle size.
3. Collection in separate bins at the bottom.

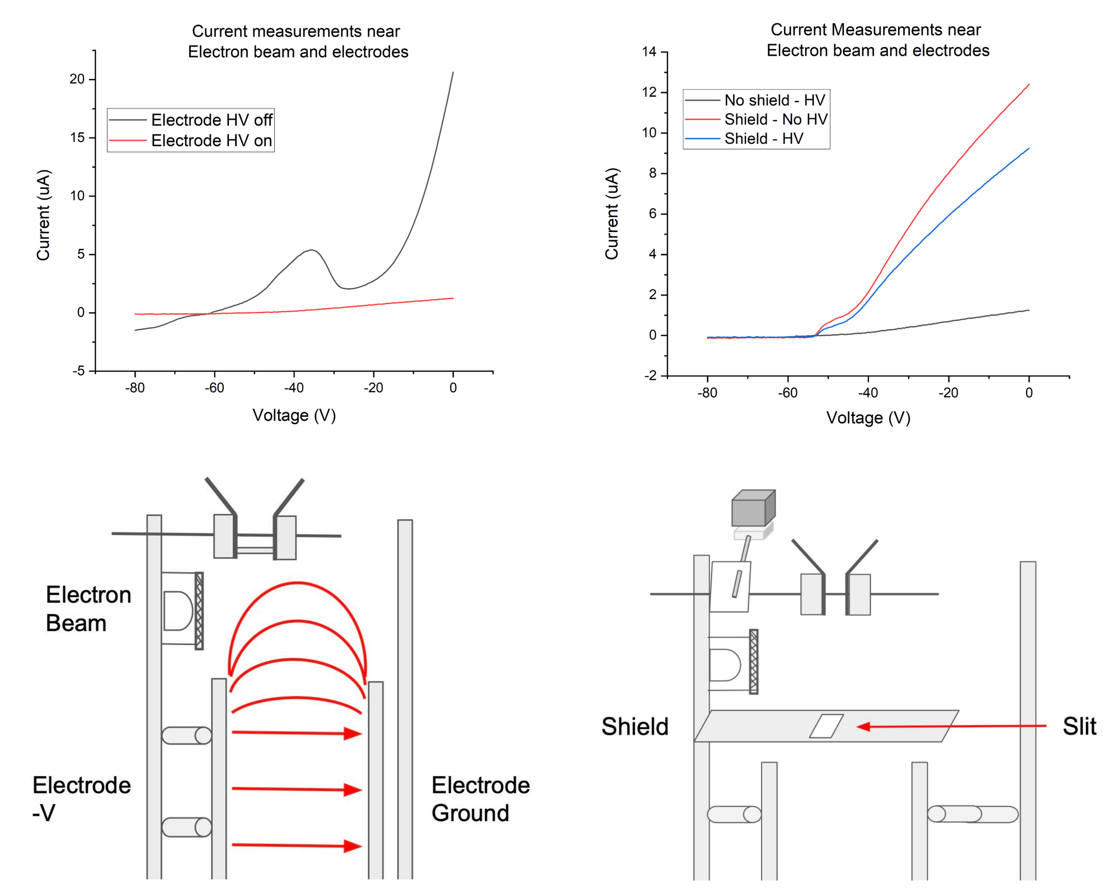




Testing and Results

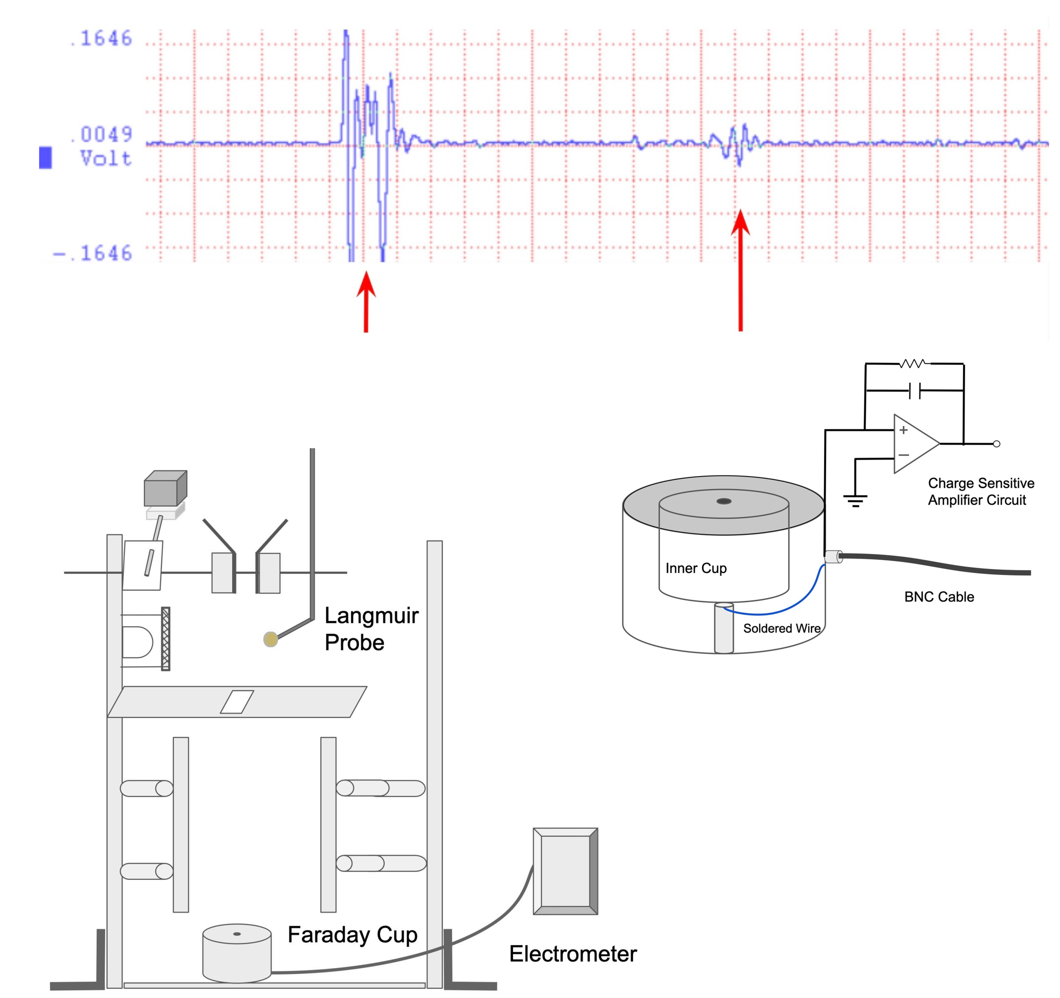
1. Electron Beam Characterization

- Langmuir probe characterizes beam energy and flux, and is charged to a floating potential that follows the beam energy
- Electric field interference from HV electrodes is minimized using a shield with a slit where dust falls through
- Expected separation not observed



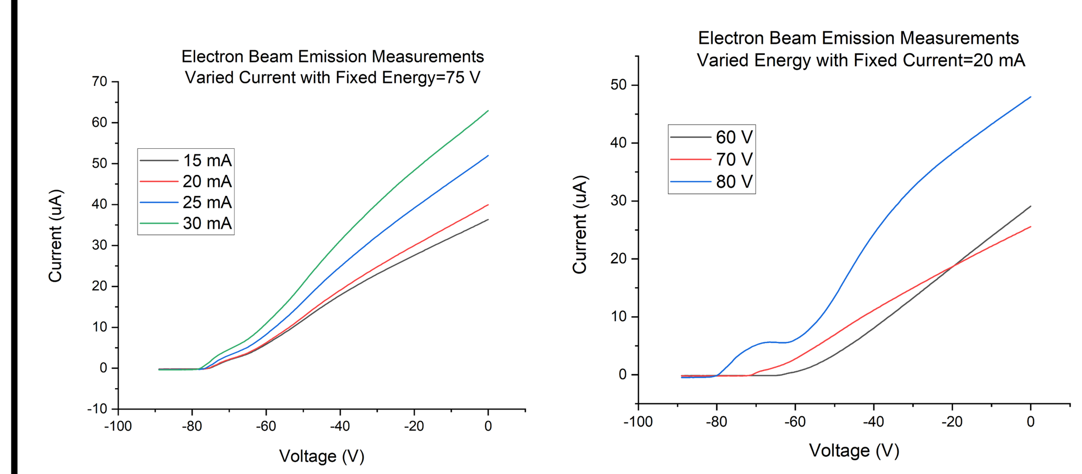
2. Faraday Cup Charge Measurements

- Clusters of dust particles
- Difficult to distinguish magnitude and polarity of a single dust particle

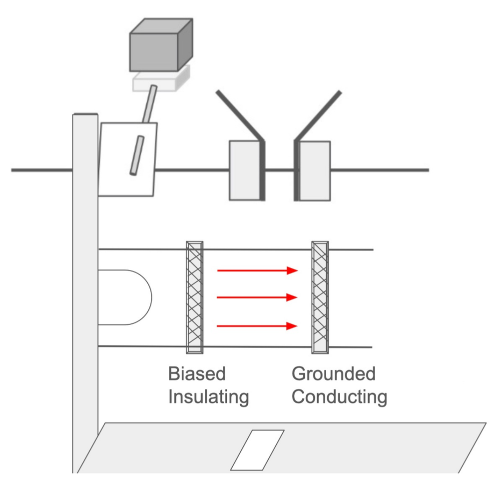


3. Space Charge Effects

- Beam energy determining factor for beam reaching dust particles
- Lower energy may experience space charge limit and lower flux

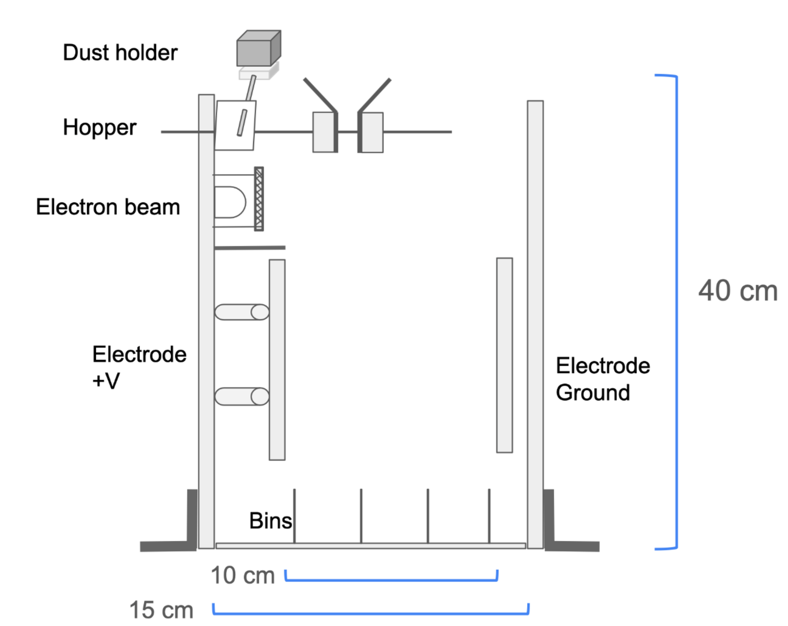


Two-Stage Electric Field Grid



Experimental Setup

- Tested in a vacuum chamber at 1e-5 Torr
- Electron beam energy: 40-60 V | current: 20 mA
- HV electrode: 500-1000 V
- Dust size: < 120 µm



Future Investigtations

- Attempt to isolate and detect individual particle drops for Faraday cup mreasurements
- Characterize the energy and current requirements to verify effective particle charging
- Re-examine dust sheet drops
- Scale up the system to process larger dust quantities for lunar mining and ISRU applications.
- Increase technology readiness level (TRL) through use of durable materials and testing in lunar-simulated environments.

References

[1] Rasera et al. (2020), PSS, 186, 104879;
[2] Wang et al. (2024), pending patent PCT/US25/1999