Laboratory experiment of the solar wind interaction with magnetic dipole fields on the lunar surface

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University of Colorado - Boulder

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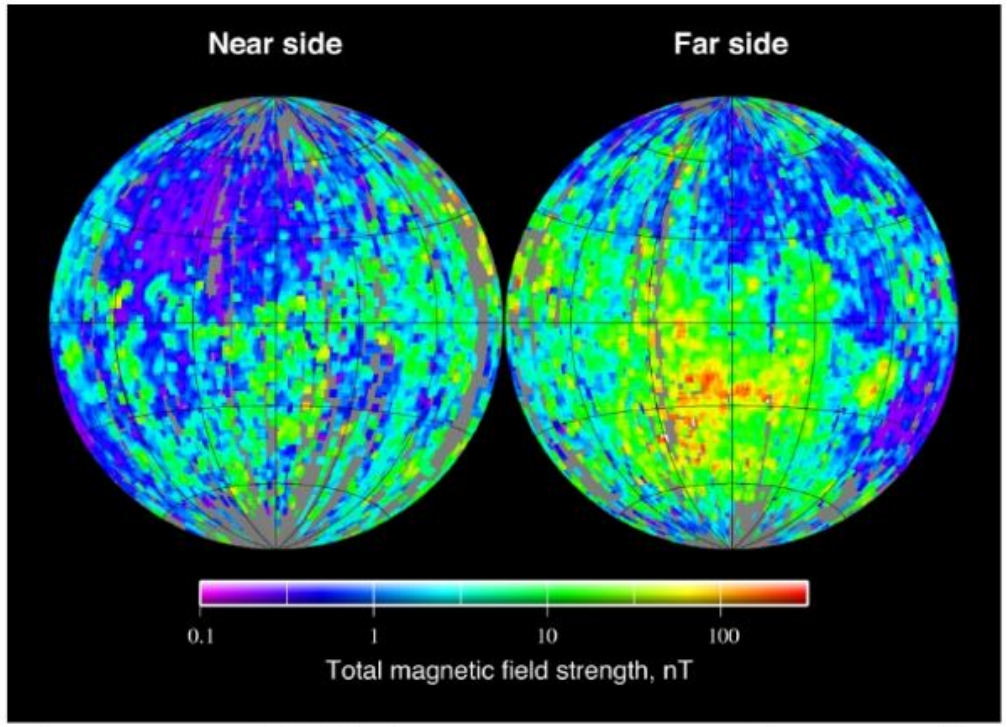
Lunar Magnetic Anomalies



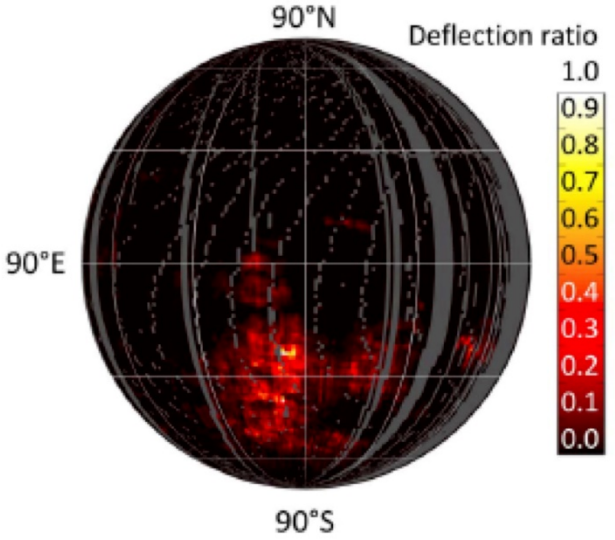
Surface magnetic fields by Lunar Prospector Electron Reflectometer (*from wikipedia*).

- Unlike Earth, the Moon has no global magnetic field.
- Crustal magnetic fields called “Lunar magnetic anomalies” are all over the surface.
- Magnetic field strength varies from tenth to hundreds nanoTesla.

Solar Wind Interaction with Magnetic Anomalies

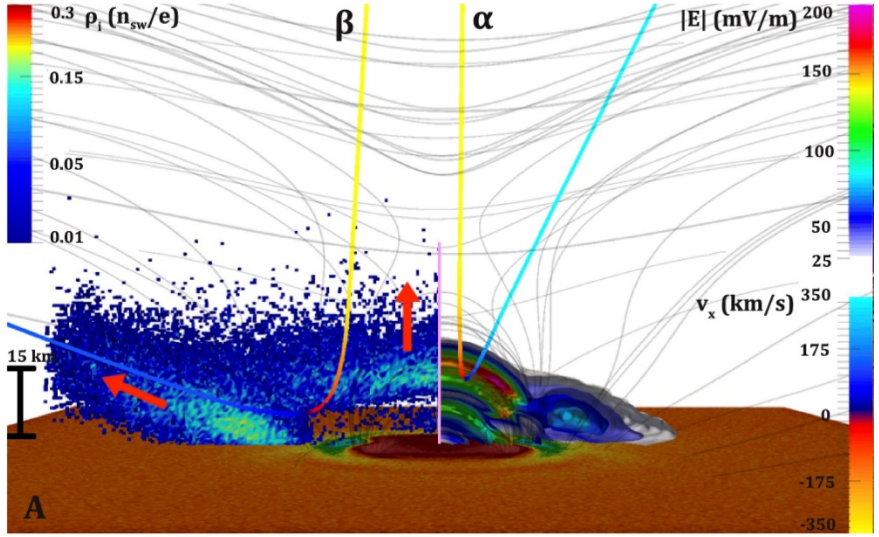
Solar wind ions are mainly reflected/deflected by electric fields created due to charge separation while electrons are magnetically reflected/deflected.

Observation



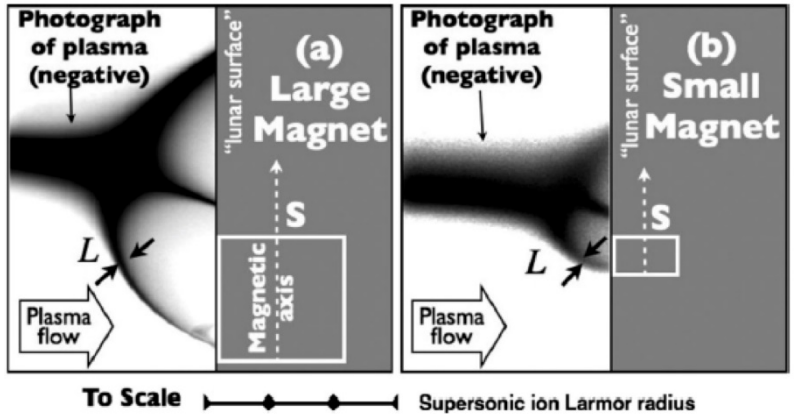
Lue et al., 2011

Simulation



Deca and Divin, 2016

Lab experiment



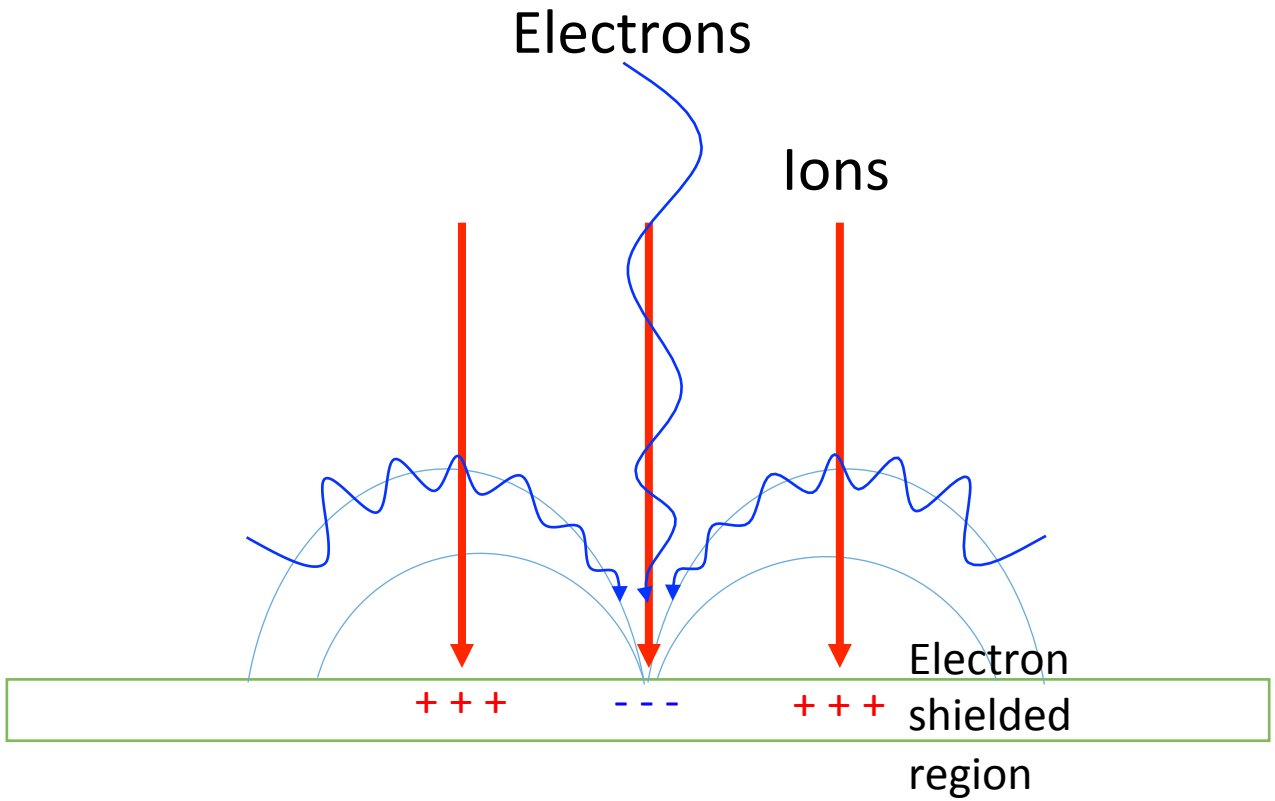
Bamford et al., 2012

Surface electric environment in magnetic anomaly regions

Significance

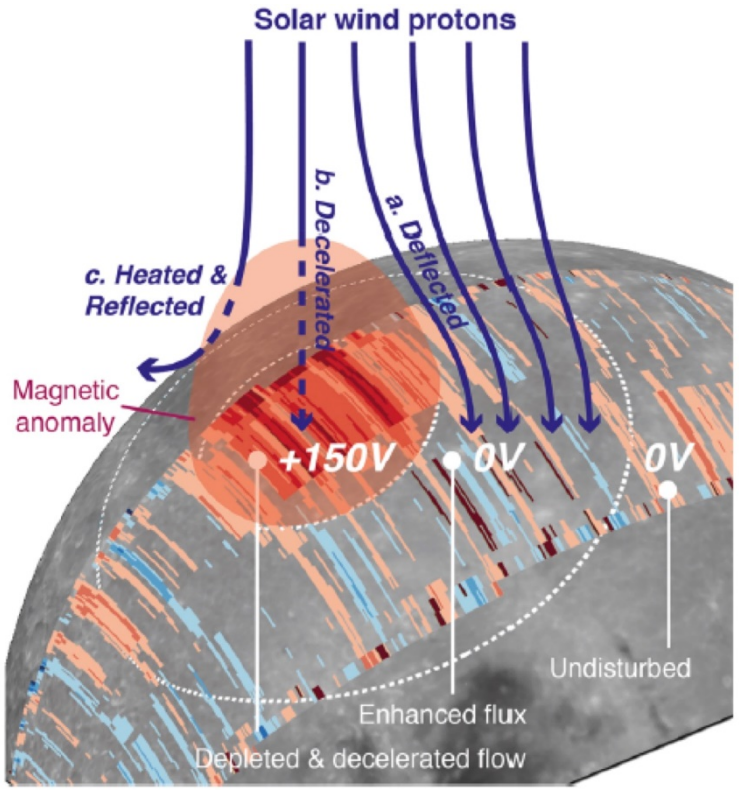
- Space weathering: How large are the energies of ions that bombard the surface in these regions?
- Electrostatic dust transport: How does dust get redistributed by the electric fields created in these regions?

A Basic Picture



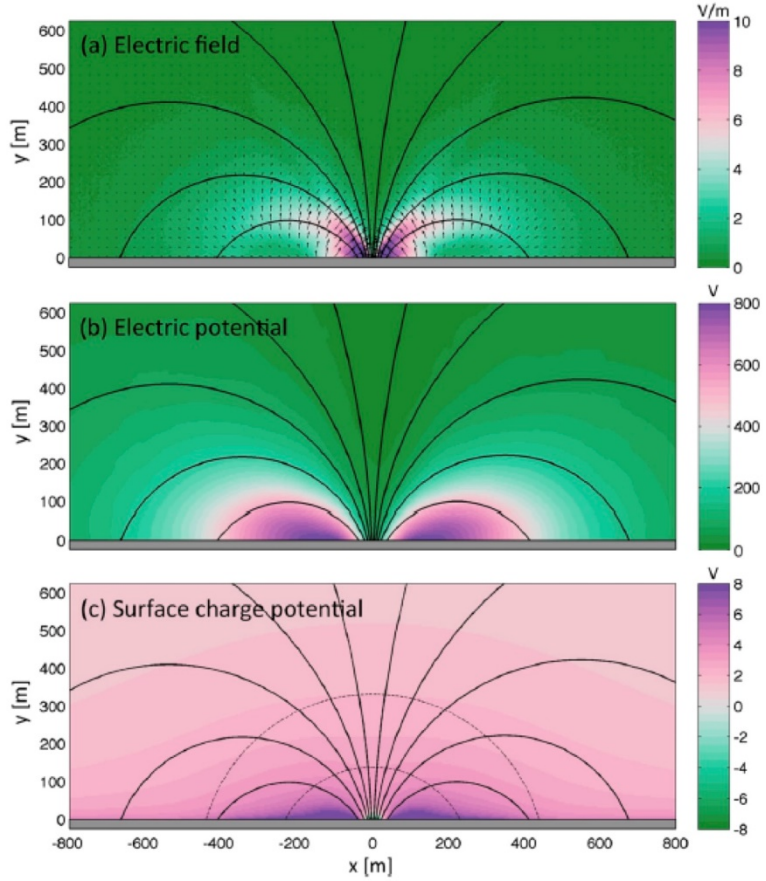
Observations and Simulations

Observation



Futaana et al., 2013

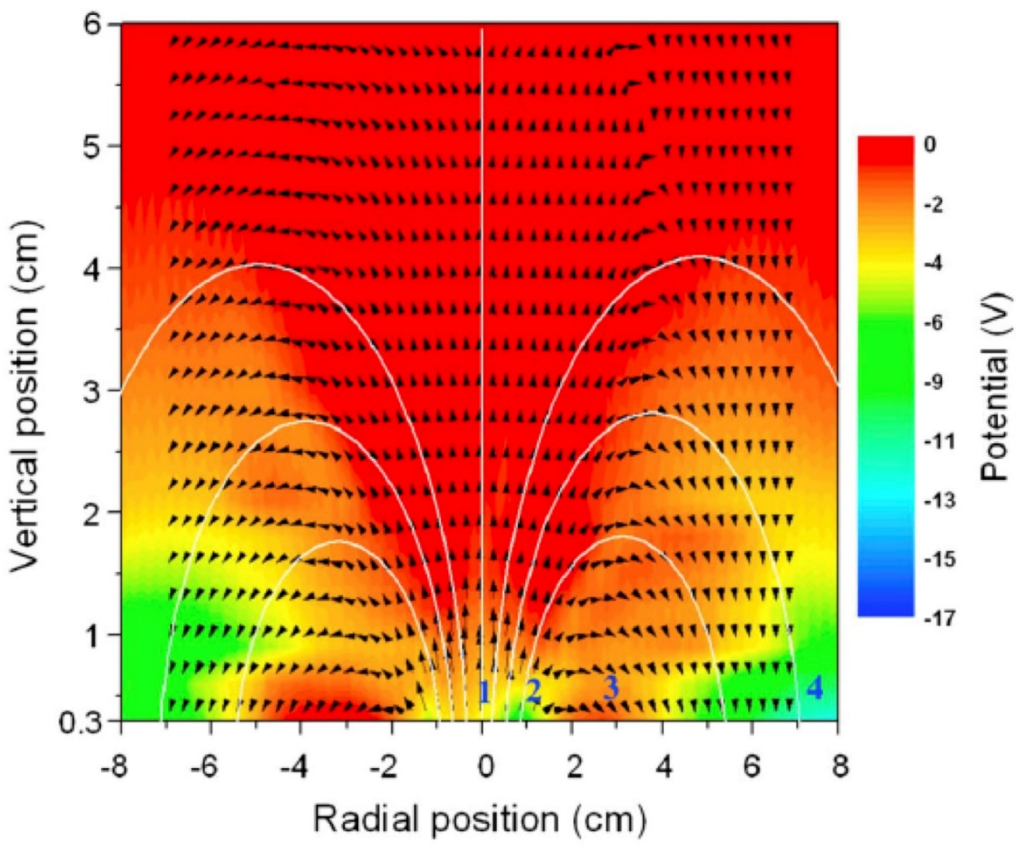
Simulation



Zimmerman et al., 2015

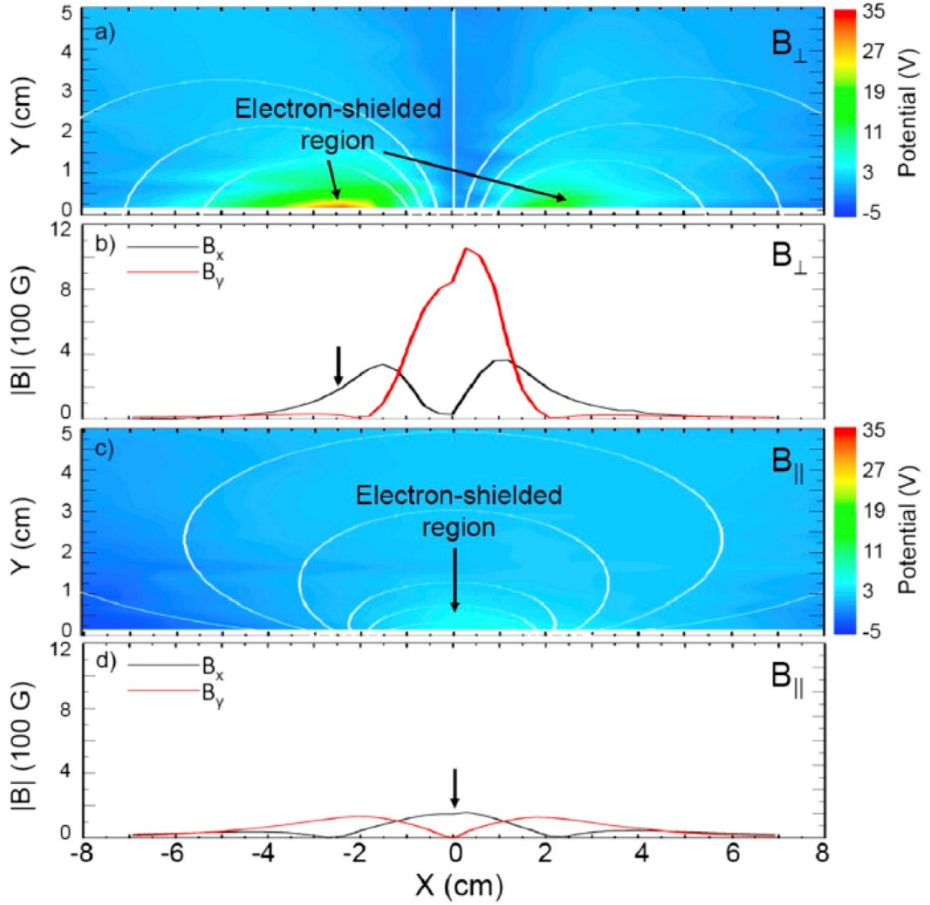
Laboratory Studies

Non-flowing plasma



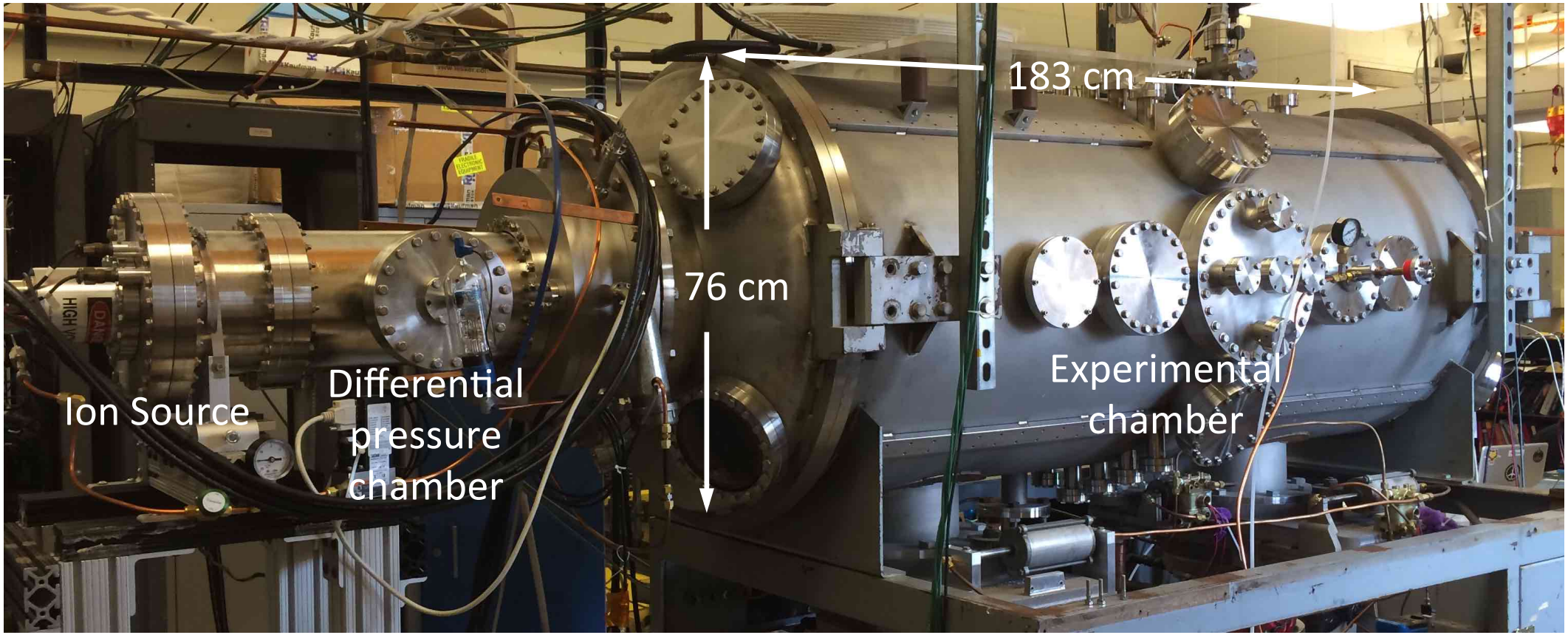
Wang et al., 2013

Flowing plasma (50 eV ions)



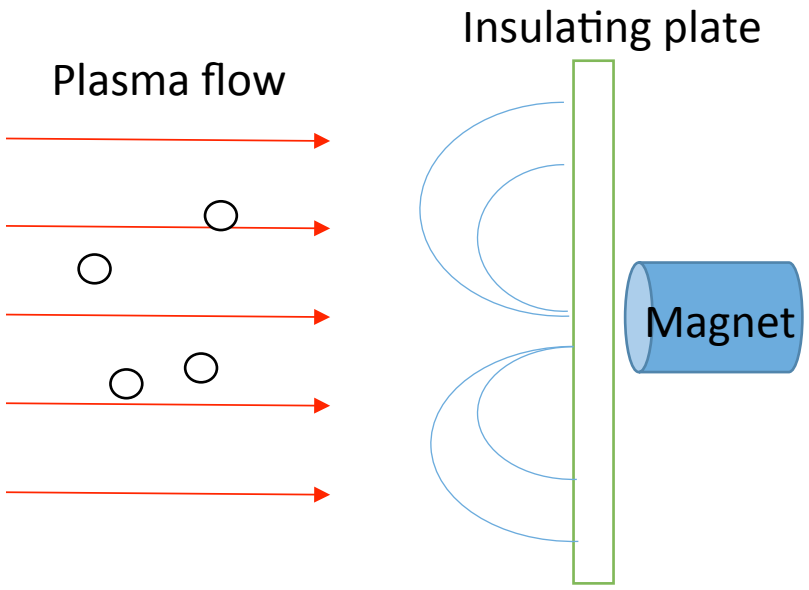
Howes et al., 2015

New Experiment with Laboratory Simulated Solar Wind



The Colorado Solar Wind Experiment (CSWE)

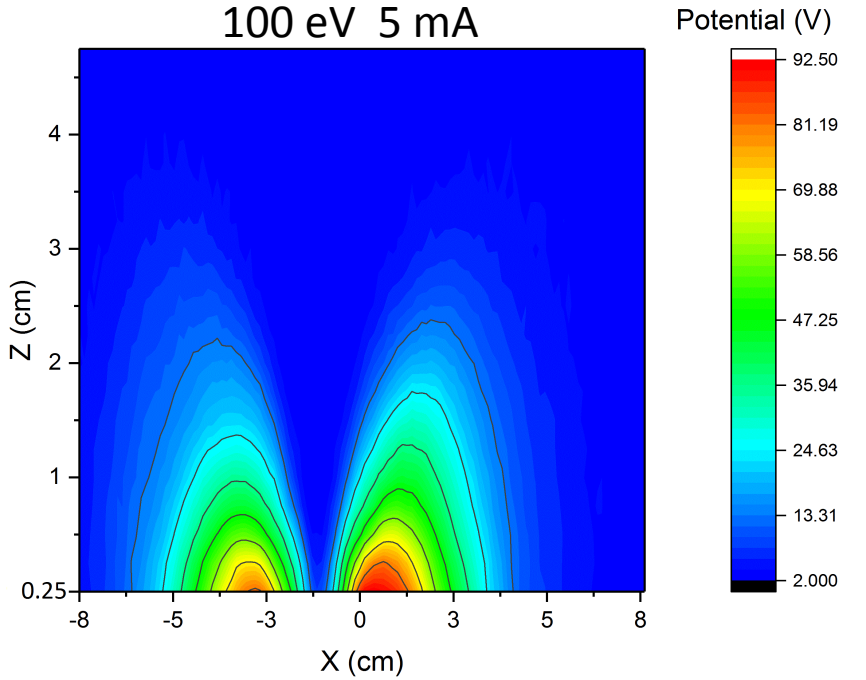
Experimental setup and parameters

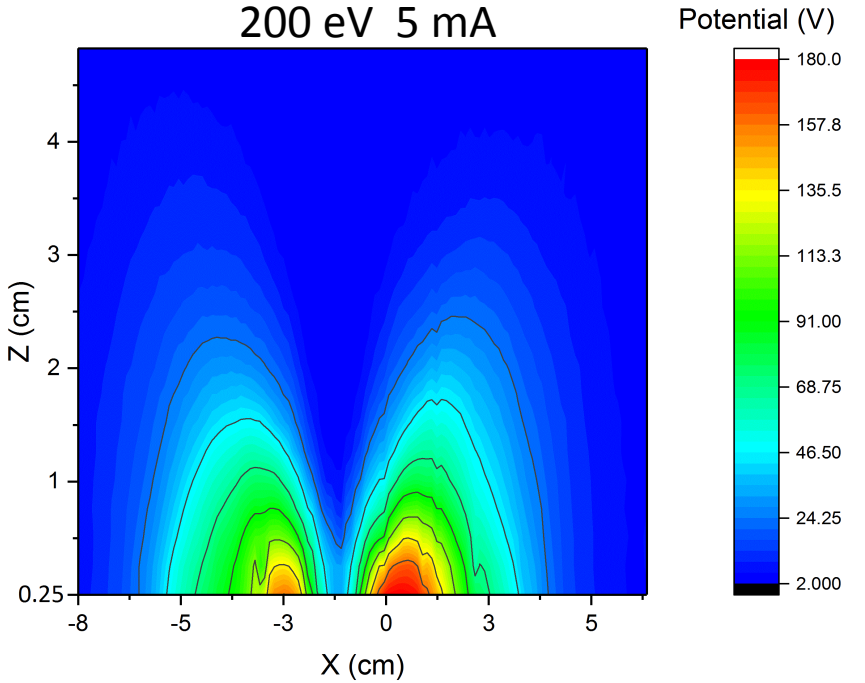


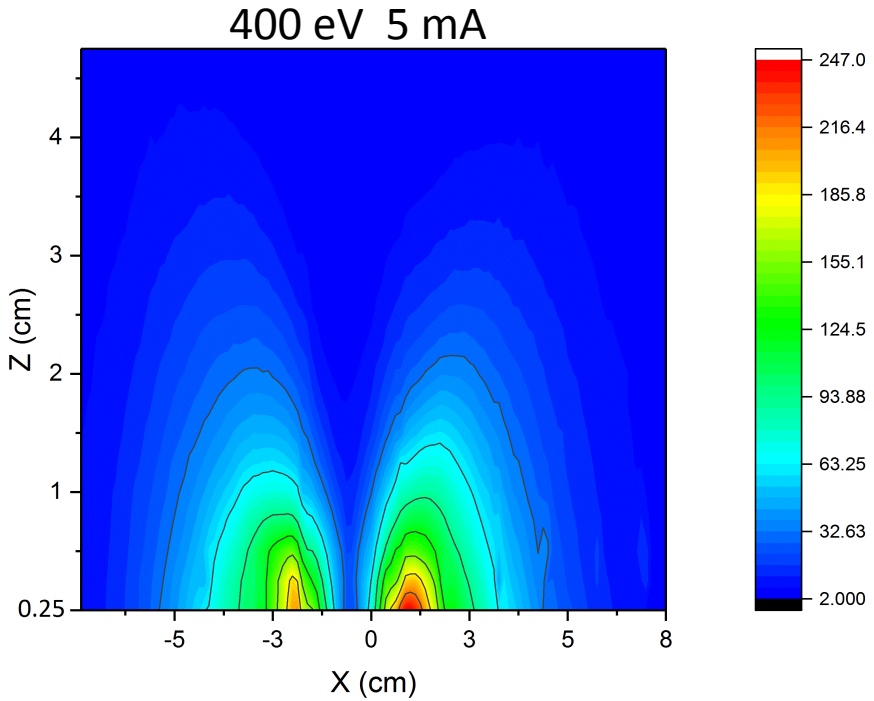
Parameter	Laboratory	Lunar case (Strong |B| region)
Ion species	N_2^+	H^+
Ion flow energy E_b (eV)	100 – 800	1000
Electron Temperature T_e (eV)	0.5 (cold), 10 (hot)	10
Ion Temperature T_i (eV)	14	10
Ion Mach number M	11	9
Electron gyro ratio (r_e / L)	< 1 (0.3 cm / 2 cm)	<< 1 (0.35 km / 30 km)
Ion gyro ratio (r_i / L)	>> 1 (250 – 720 cm / 2 cm)	> 1 (150 km / 30 km)
Electron Debye ratio (λ_{De} / L)	< 1 (0.2 cm / 2 cm)	<< 1 (0.01 km / 30 km)
Ion Debye ratio (λ_{Di} / L)	<1 to > 1 (1.4 – 6.5 cm / 2 cm)	<< 1 (0.1 km / 30 km)

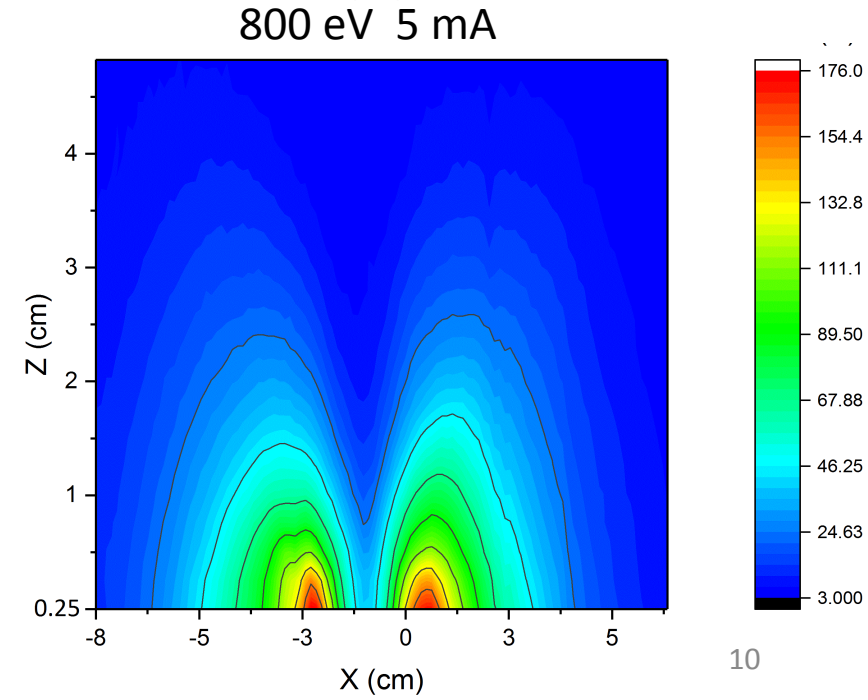
* The magnetic field strength 30 nT at 30 km altitude is used for the lunar case with strong magnetic anomalies [*Hood et al.*, 2001].

Surface Potential Results

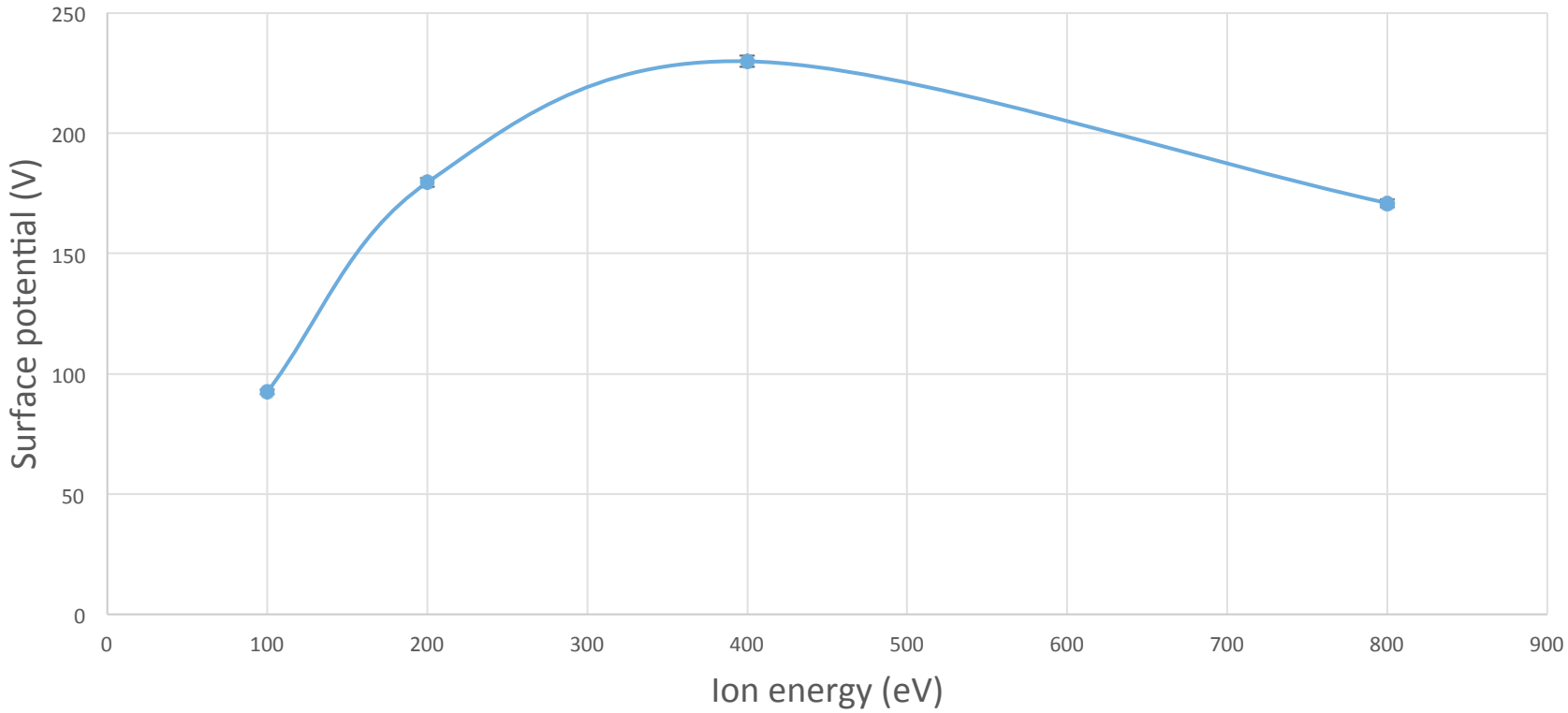








Surface potential in the electron shielded region vs. ion energy



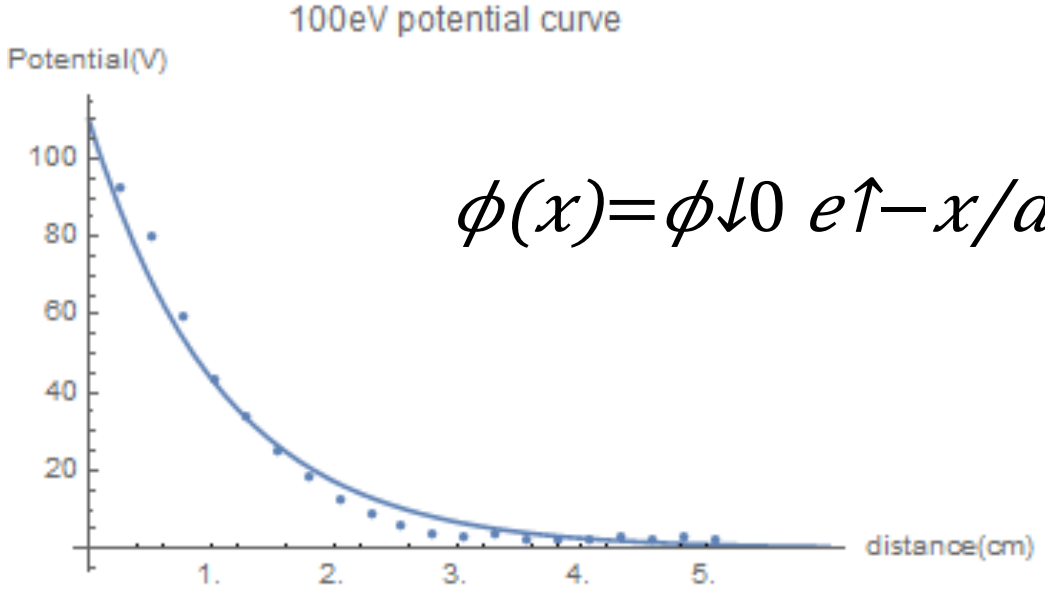
Question:

Why does the surface potential in the electron shielded region stop following the ion energy after 200 eV?

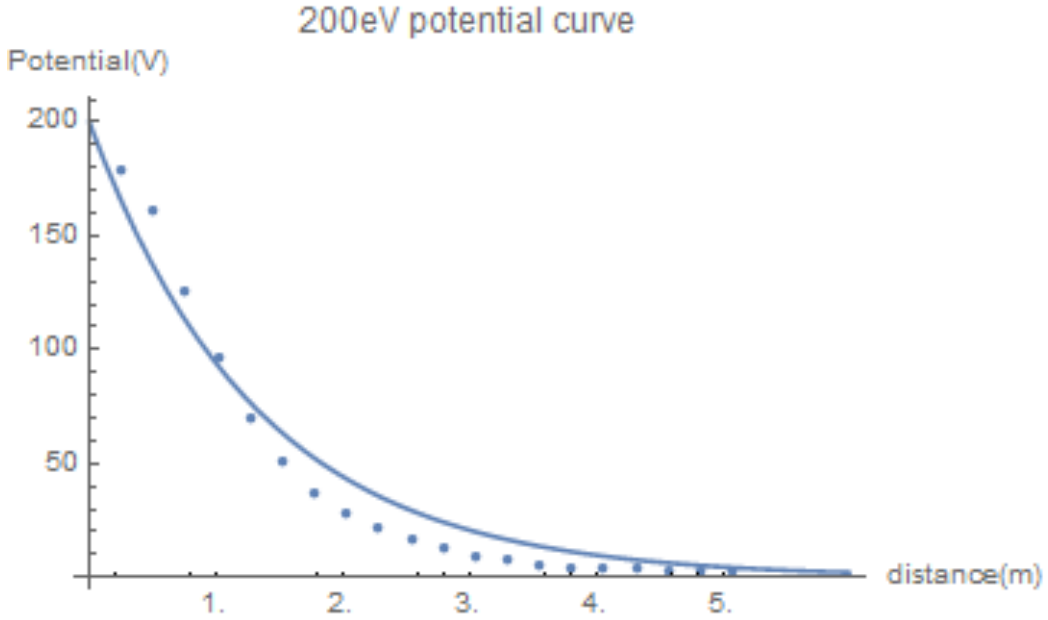
Possible explanation:

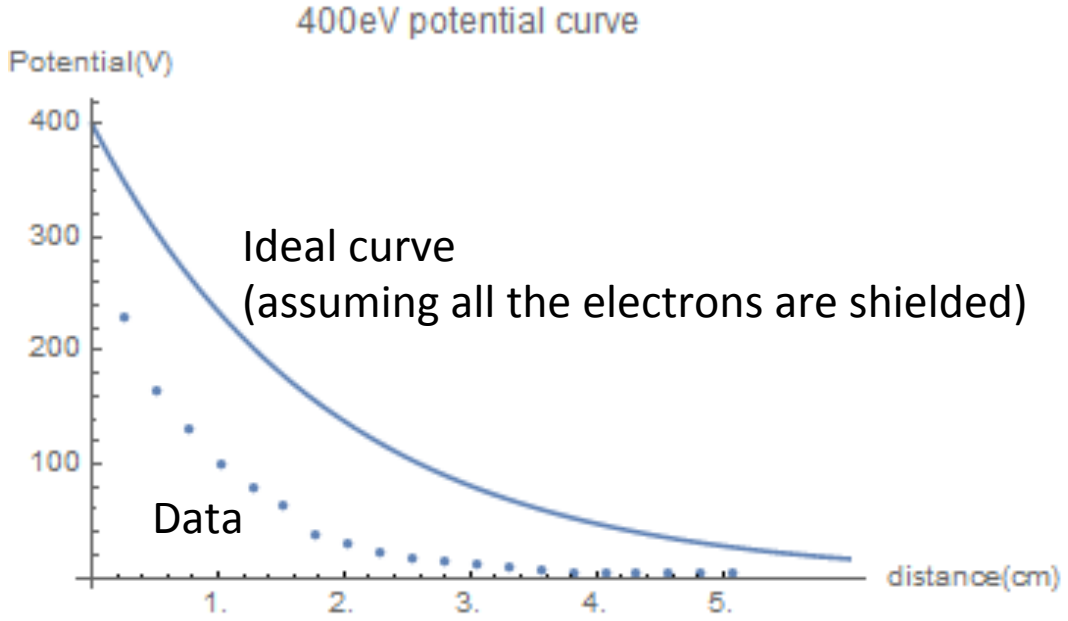
Electron dynamics are changed by large electric fields extended across the magnetic field region.

Preliminary Analysis to compare Electric force vs Lorentz force



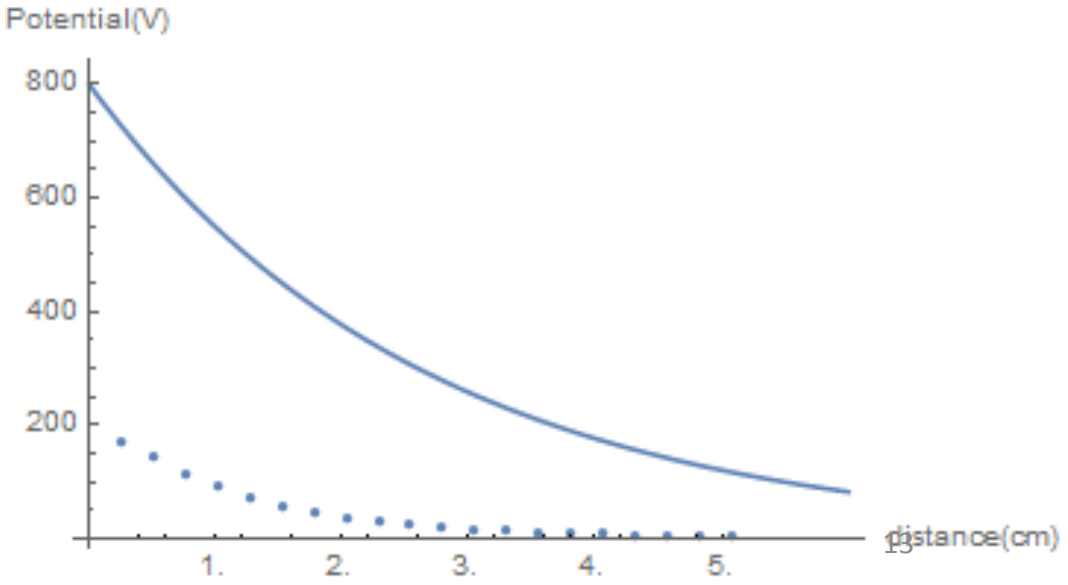
$$\phi(x)=\phi\downarrow 0\ e\uparrow -x/a\lambda\downarrow Di$$



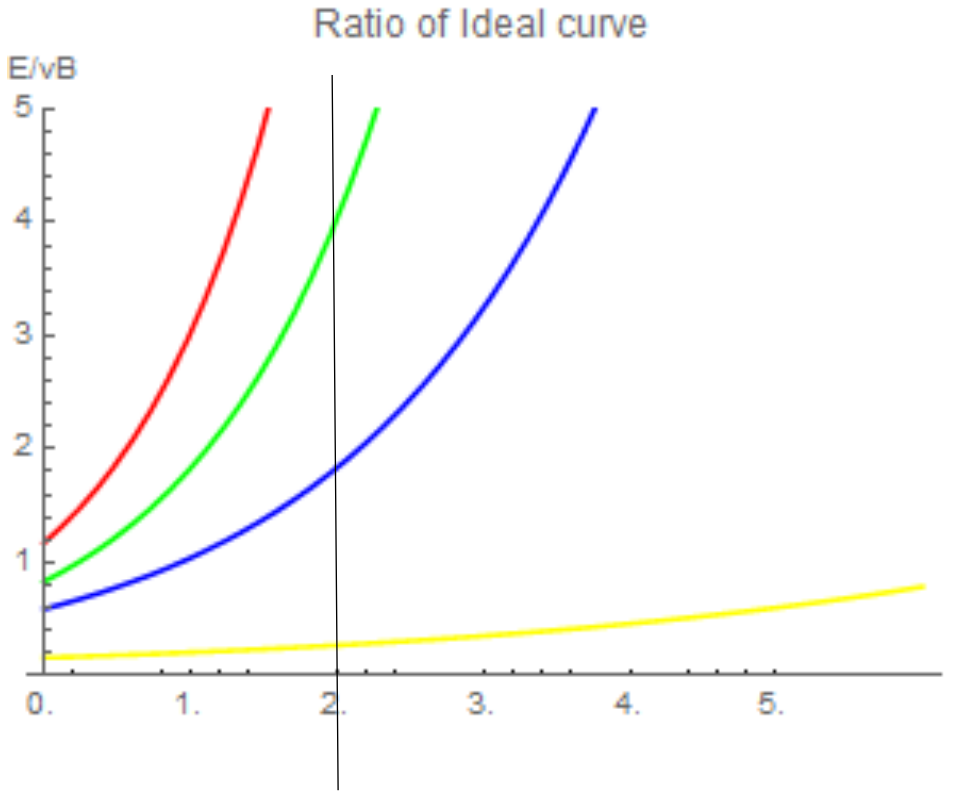


Ideal curve
(assuming all the electrons are shielded)

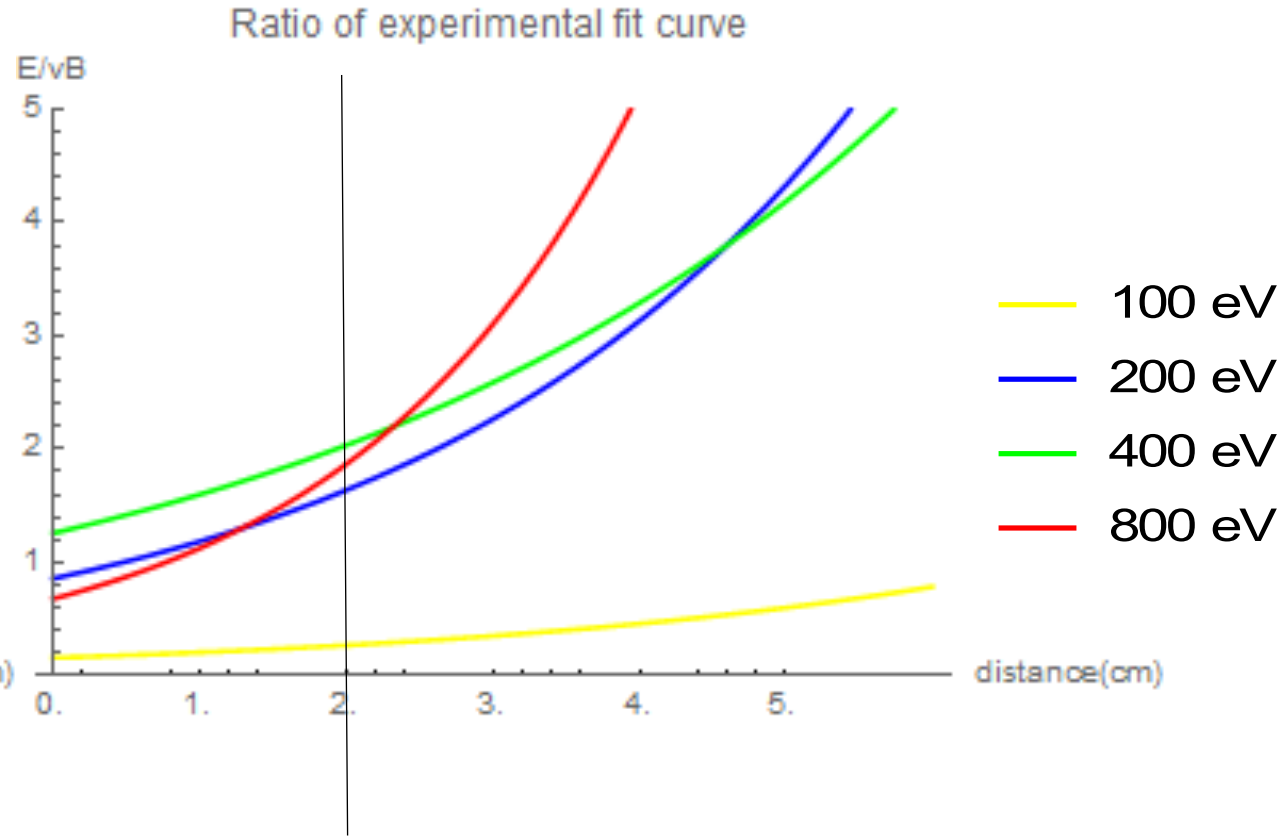
Data



Ratio of the electric force to Lorentz force

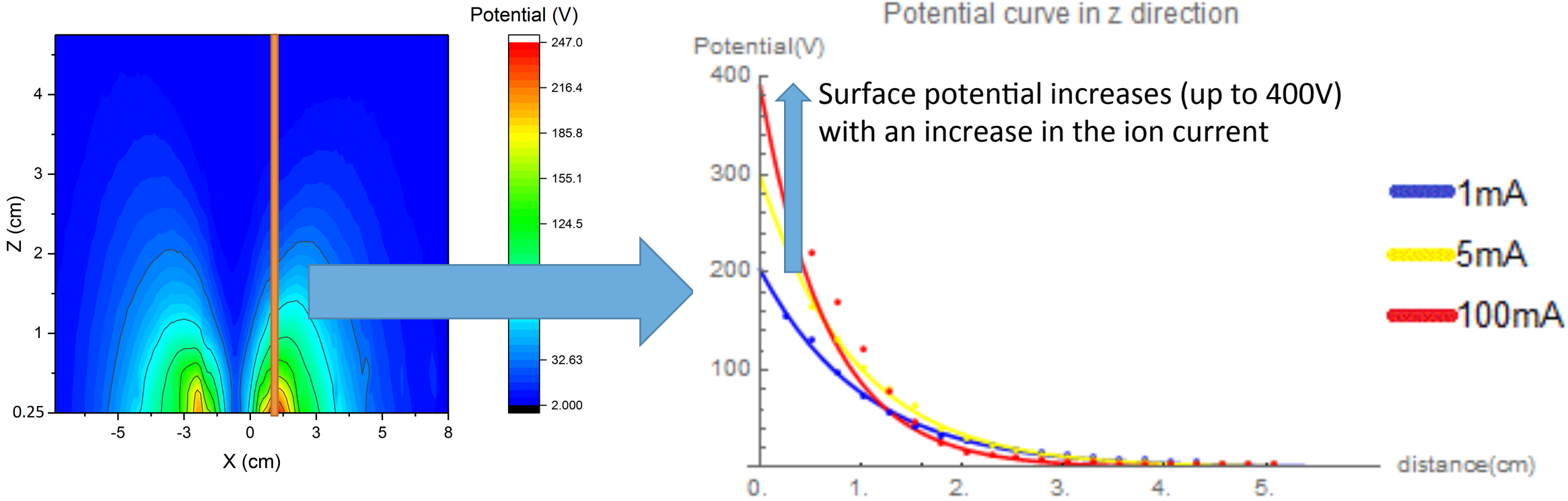


Force ratio much larger than 1 for the 400eV and 800eV ion energies



Force ratio around 1

Potential profiles for the 400 eV ion energy with different currents



Next To Do:

- Test particle simulation for the electron dynamics in response to the electric fields.
- Electron density measurement with a Langmuir probe.
- Examine any secondary electrons induced by the ions.

Thank you