# Light and Charge Measurements of Simulated Aluminum Micrometeoroids

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# Meteors in Earth and Space Science

- Atmospheric and Oceanic Effects
  - Deposit metals such as Fe, Na, K in upper atmosphere
    - Produces metal layers in atmosphere
    - Consequences for models of upper-atmospheric dynamics
    - Bio-available Fe filters down into the ocean

*Image from earthobservatory.nasa.gov*

*Image from apod.nasa.gov*

- Dust in the Solar System
  - Models of source bodies (comets and asteroids)
  - Meteoroid distribution in the near-Earth environment
    - Poses danger to spacecraft

# **Problem:** What is the total mass of cosmic dust entering Earth's atmosphere from space?

- Mass input estimates range from 5 to 270 metric tons/day (Plane, 2012)
- Most of this mass is in small particles that ablate in the mesosphere
  - Mass distribution peaks at $10^{-5}$ g
  - Radars are sensitive to $10^{-9}$ g - $10^{-3}$ g

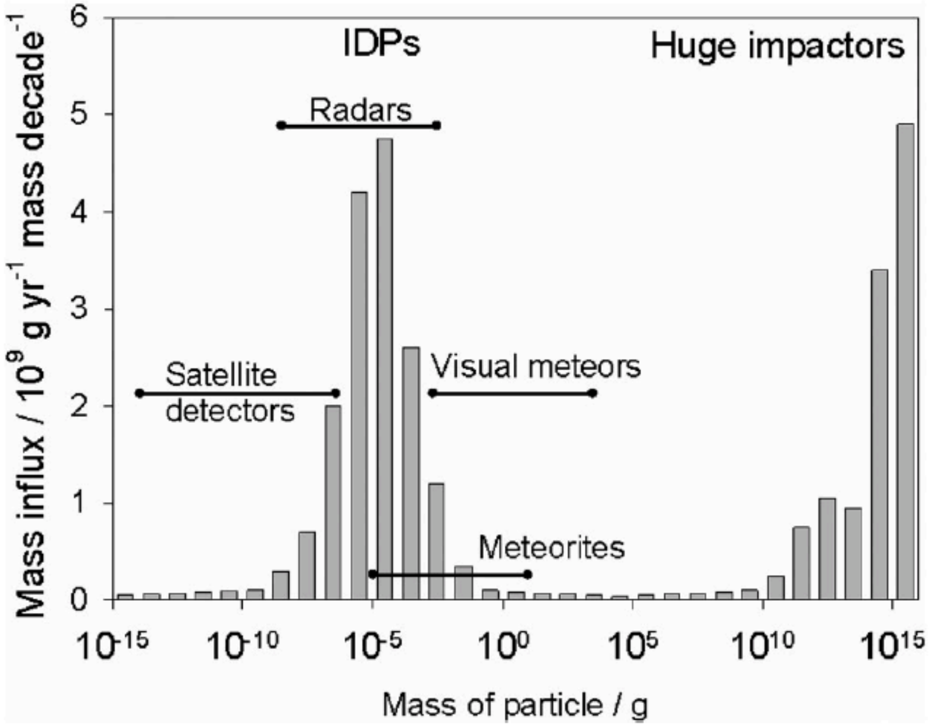



*Figure by Plane (2012)*

# Ablation Experiments

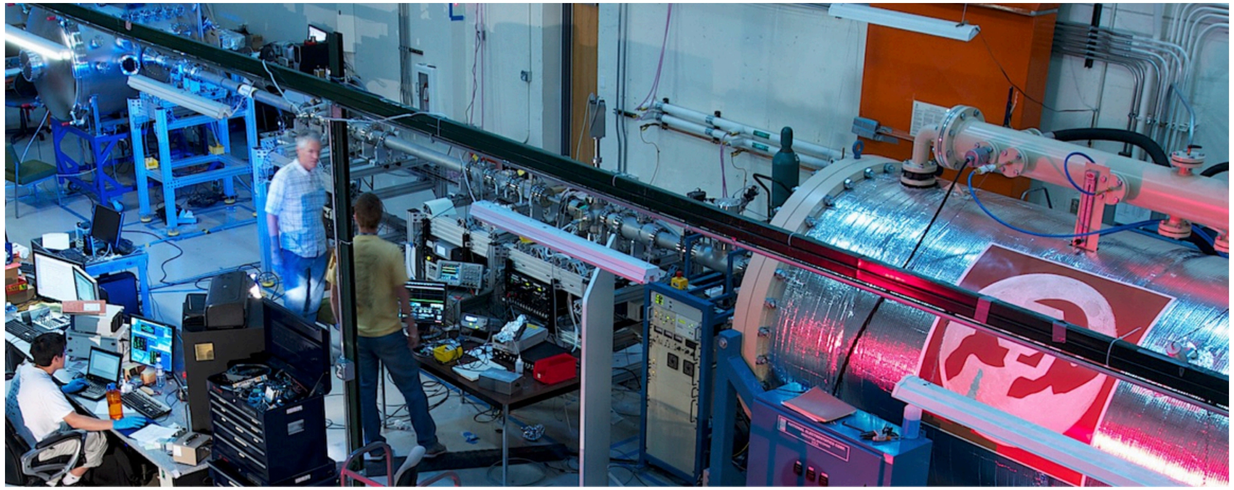


*Image from impact.colorado.edu*

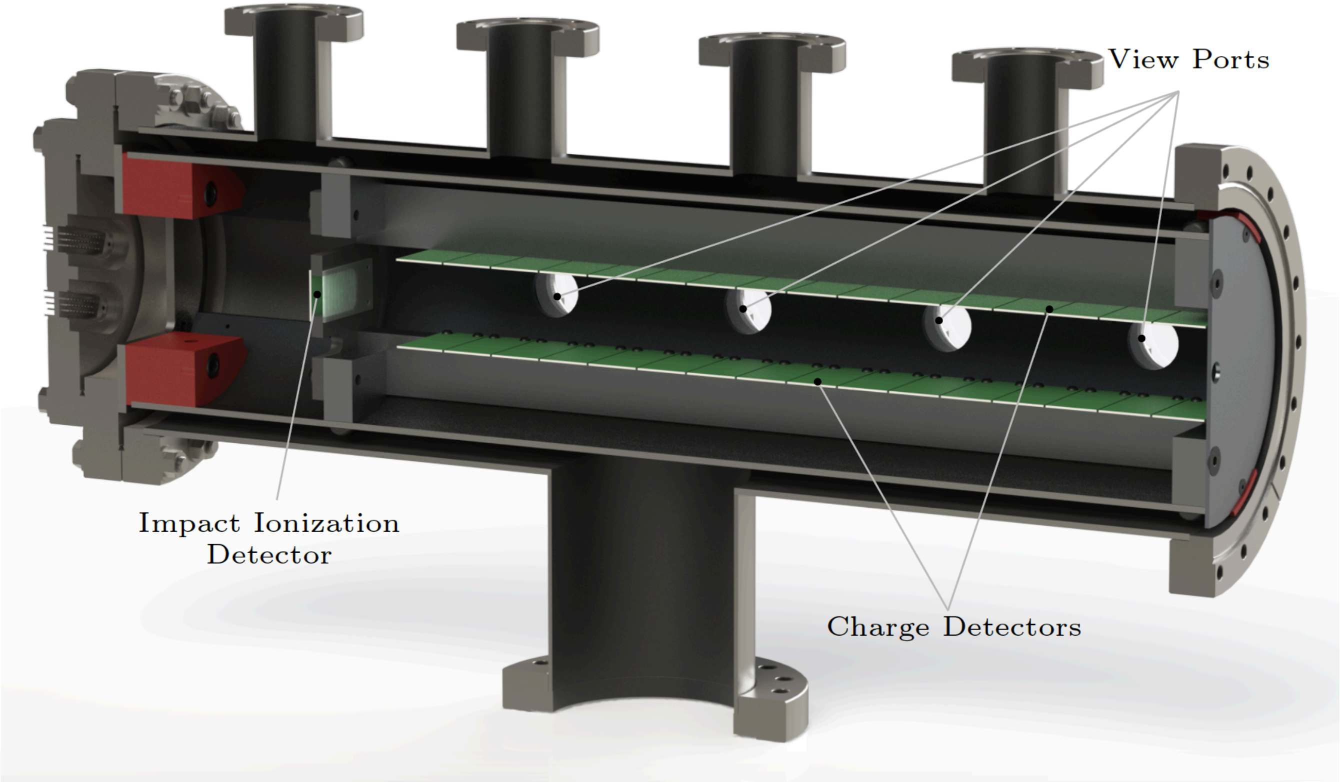



*Figure by J. Simolka (2013)*

**Particles shot into ablation chamber:**

*Speed:* 10-70 km/s

*Type:* Fe or Al

*Radius:* fraction of a micron

*Gas:* $N_2$, air, $O_2$, or $CO_2$ at p = 0.01 – 0.5 Torr

# Ionization Coefficient $\beta$

$$\beta = \text{number of electrons} / \text{number of ablated atoms} = (\Delta Q/e)/(\Delta m/m_{atom})$$

**Jones (1997):**

$$\beta_0 = \frac{\boldsymbol{c}(v-v_0)^2 v^{0.8}}{1+\boldsymbol{c}(v-v_0)^2 v^{0.8}}$$

$$\beta(v) = \beta_0(v) + \frac{(1-\beta_0(v))(1+\mu)^2}{2v^2\mu} \int_{v_0}^{v} \beta(v')v'\,dv'$$

# Past: Iron Ablation Experiments

- Charge measurements for Fe dust particles in $CO_2$, $O_2$, $N_2$, air

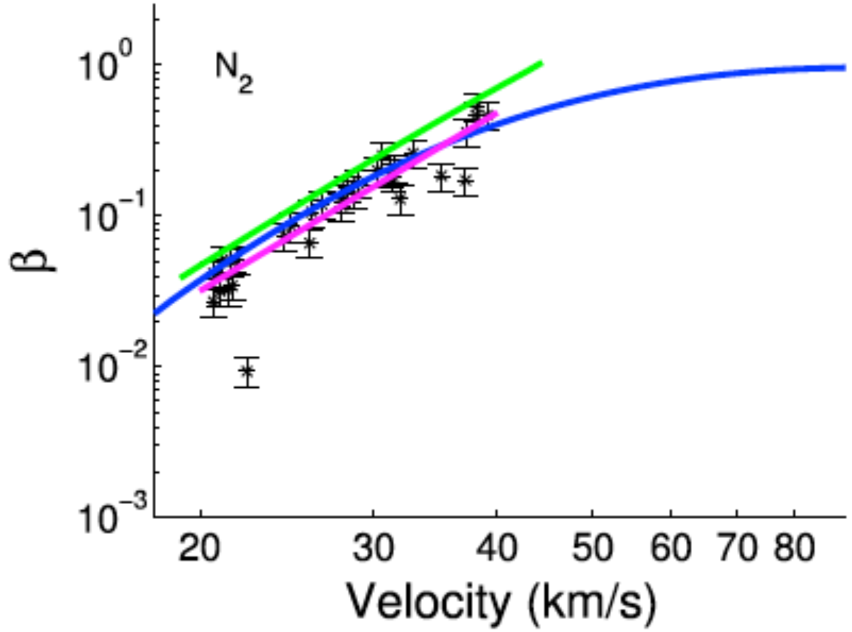
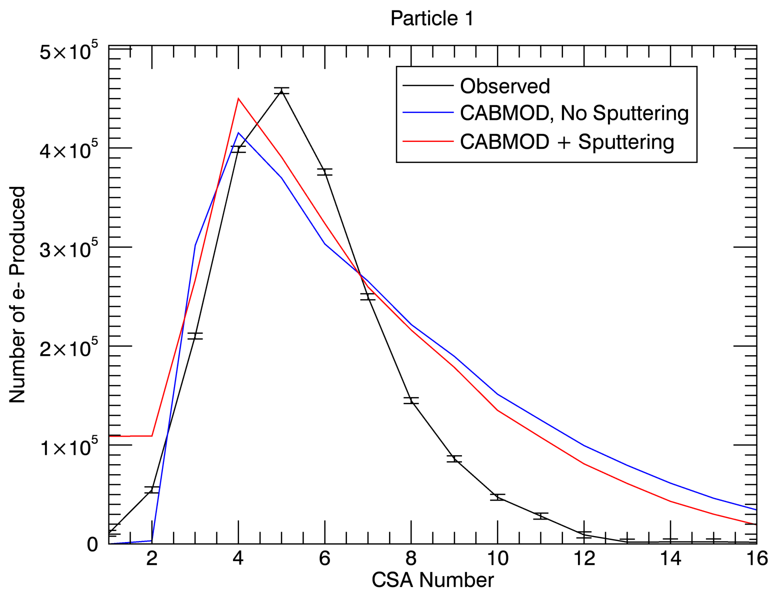
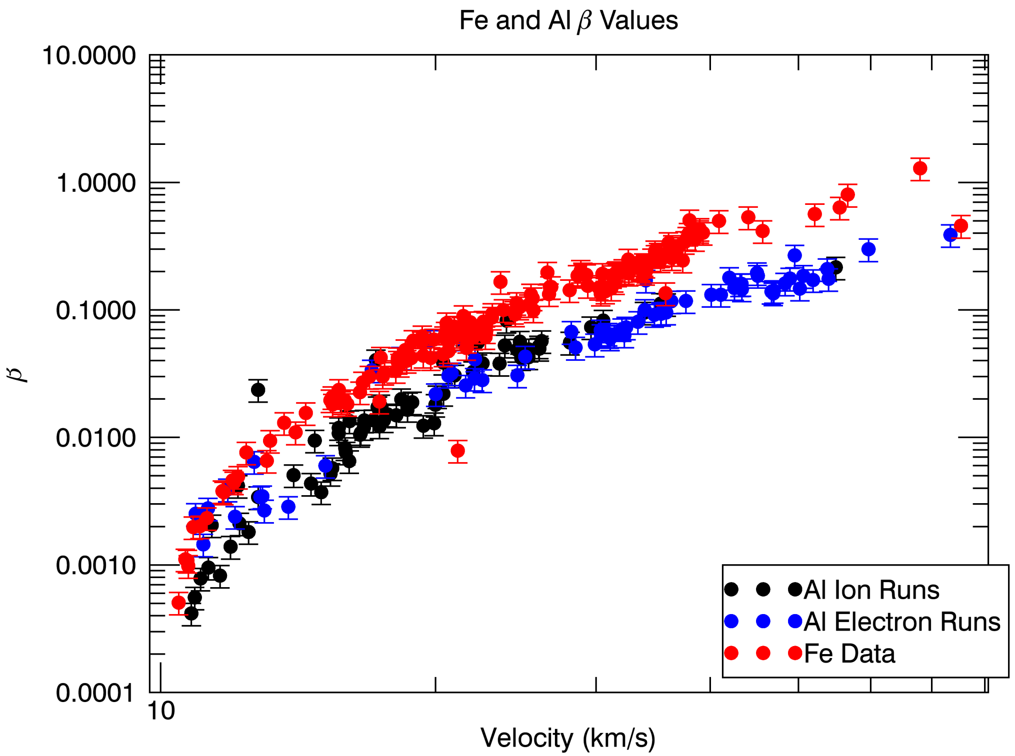


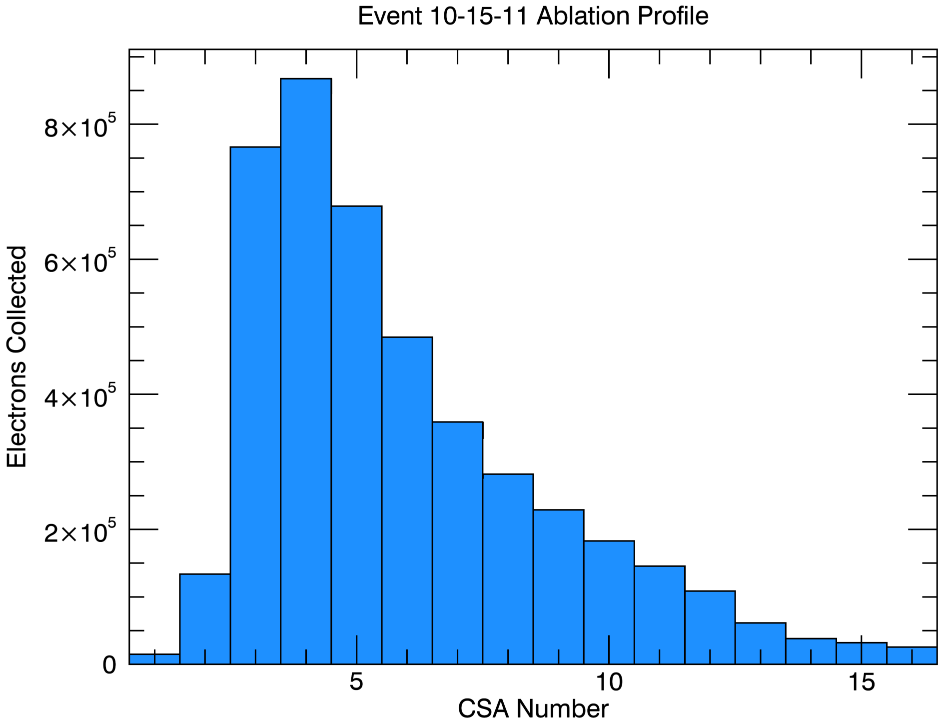

*Figure by Thomas, et al (2016)*



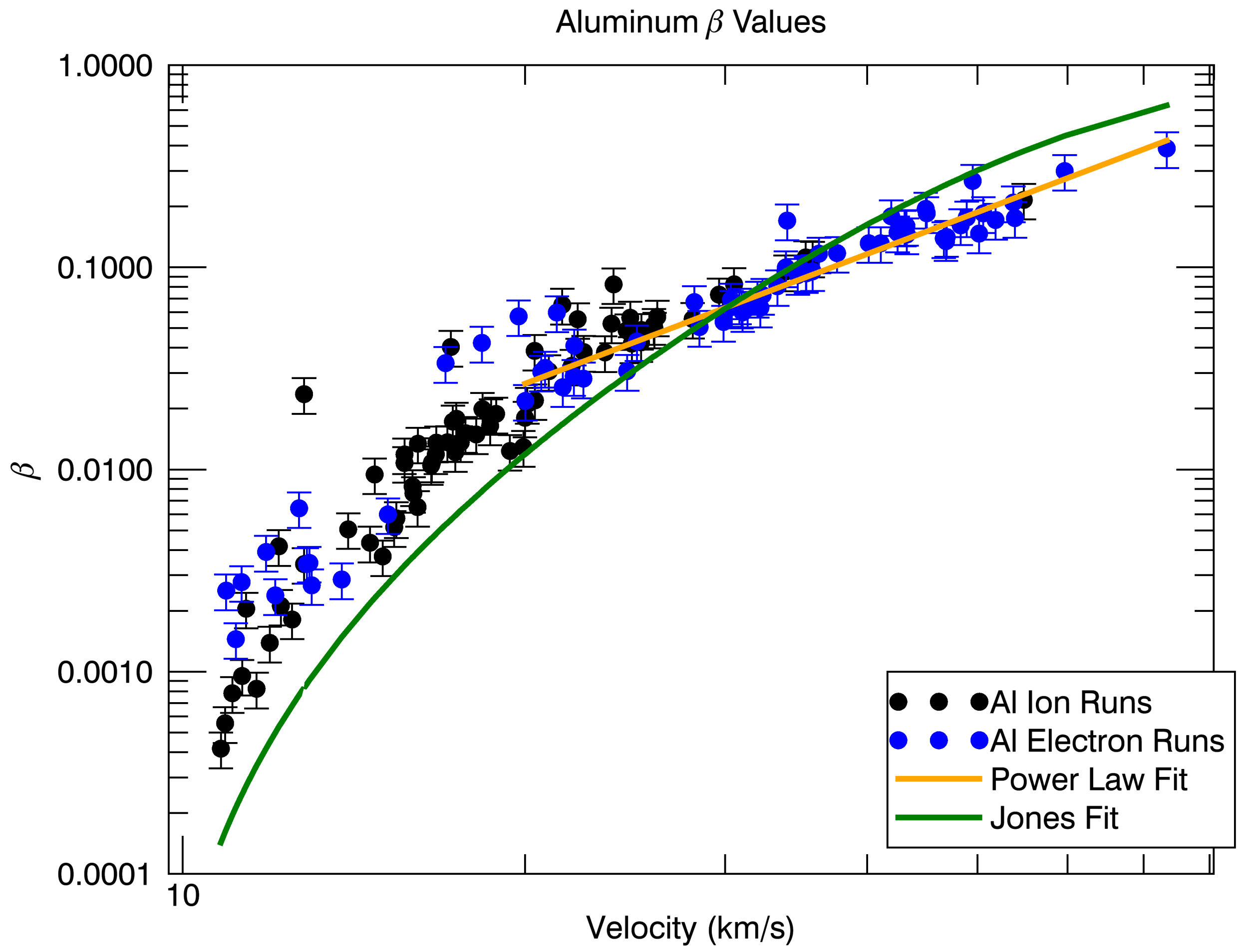
# Present: Aluminum Ablation Experiments

- Charge measurements for Al dust in air



# Aluminum Beta Results




Fit to Power Law gives:

$\beta = 4.491 \times 10^{-5}\, v^{2.131}$

Fit to Jones gives:

$c = 6.6911 \times 10^{-6}$

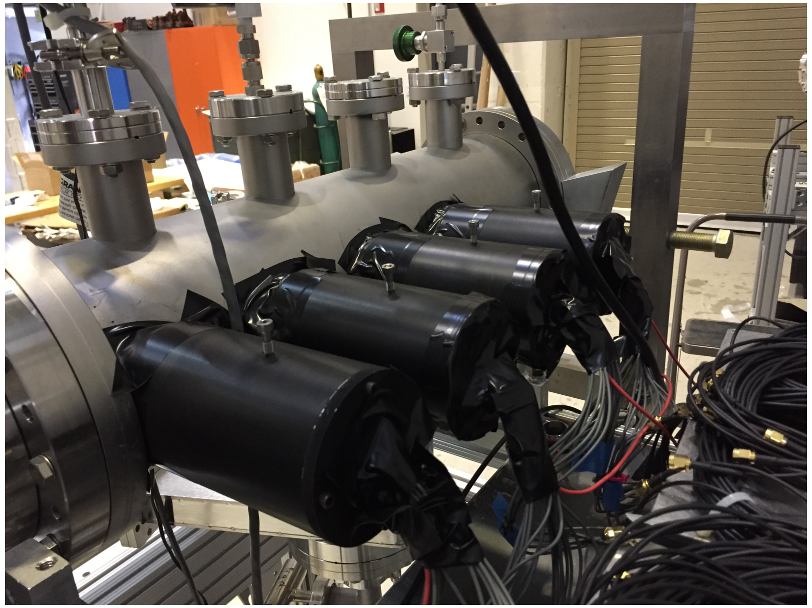
($c = 10.8320 \times 10^{-6}$ if neglect integral term)

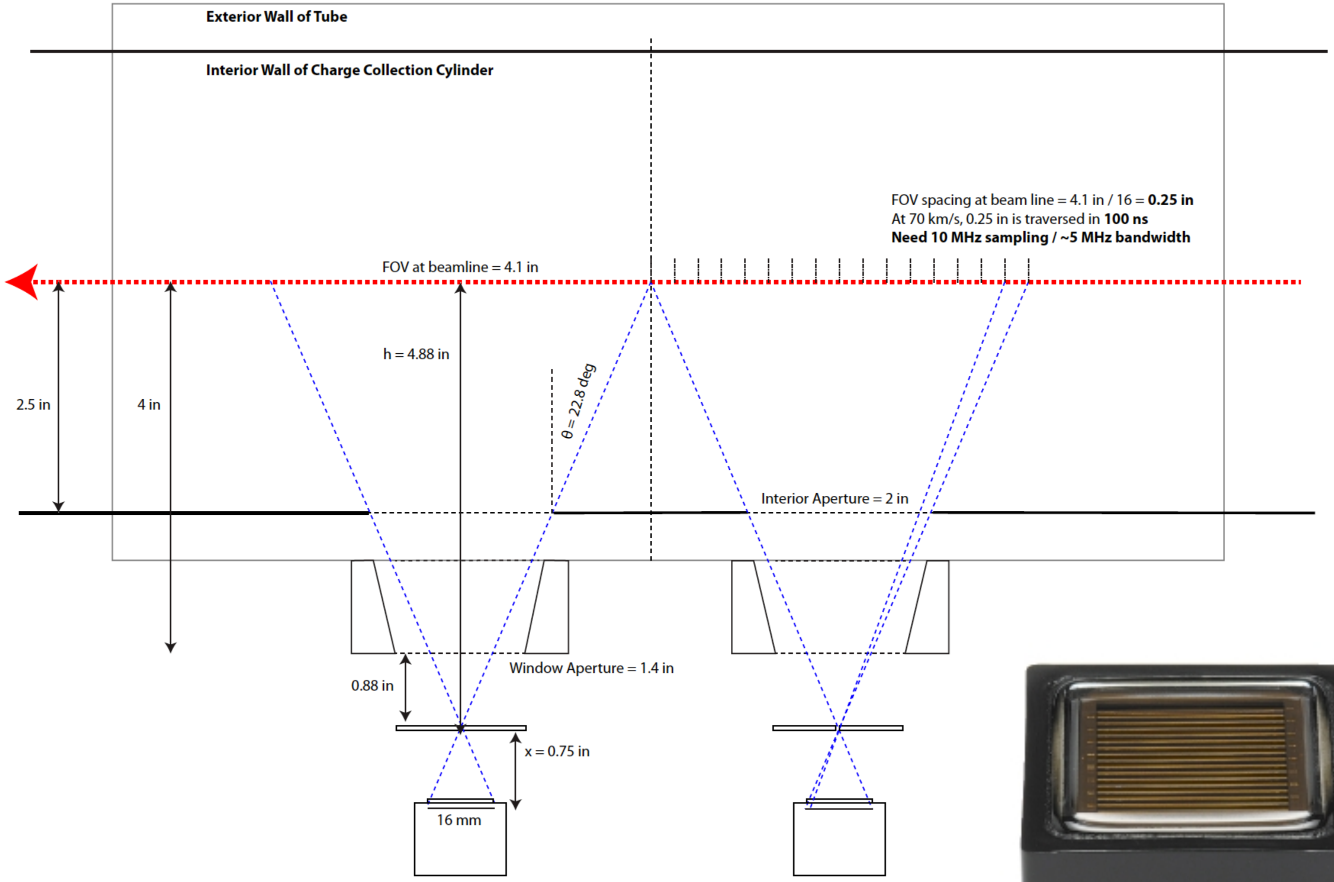
Threshold Velocity for Al:

$v_0 = 9.107$ km/s

# Light Measurements

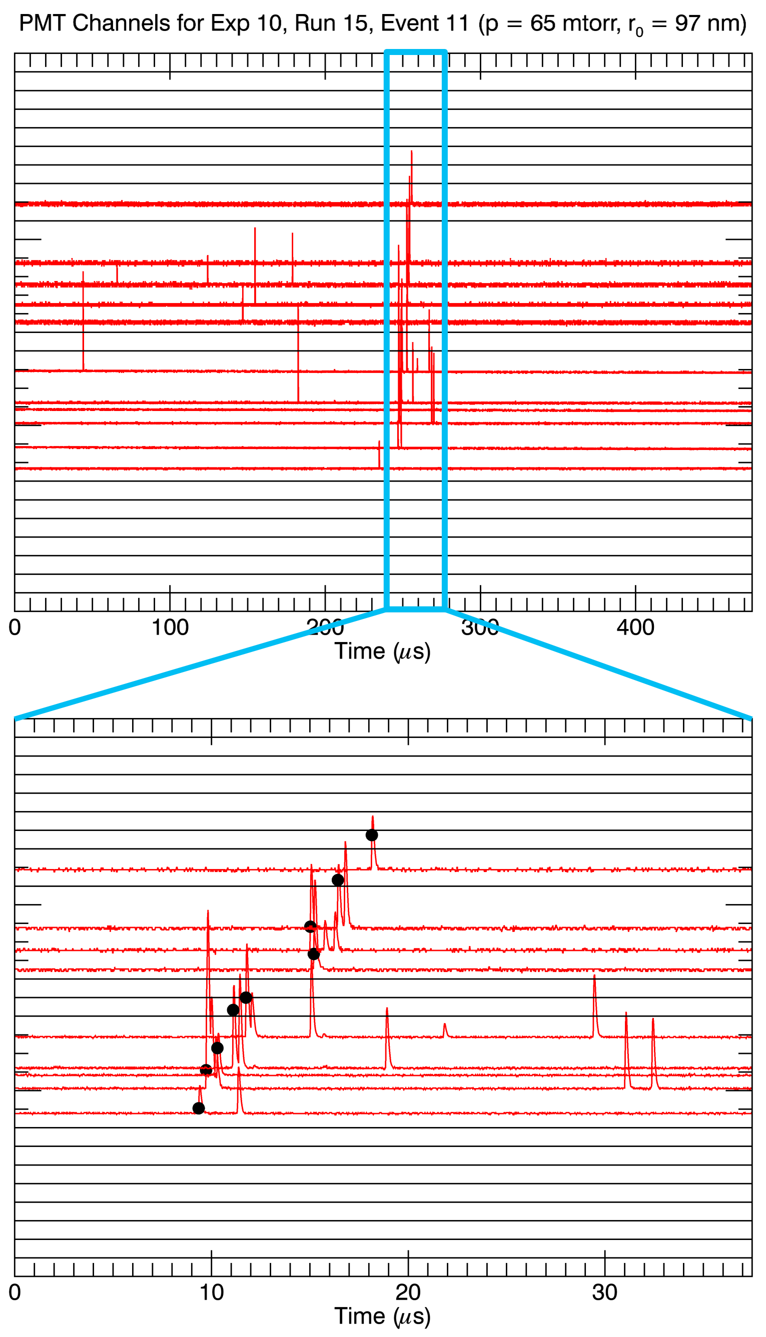
- Four 16-Channel PMT's

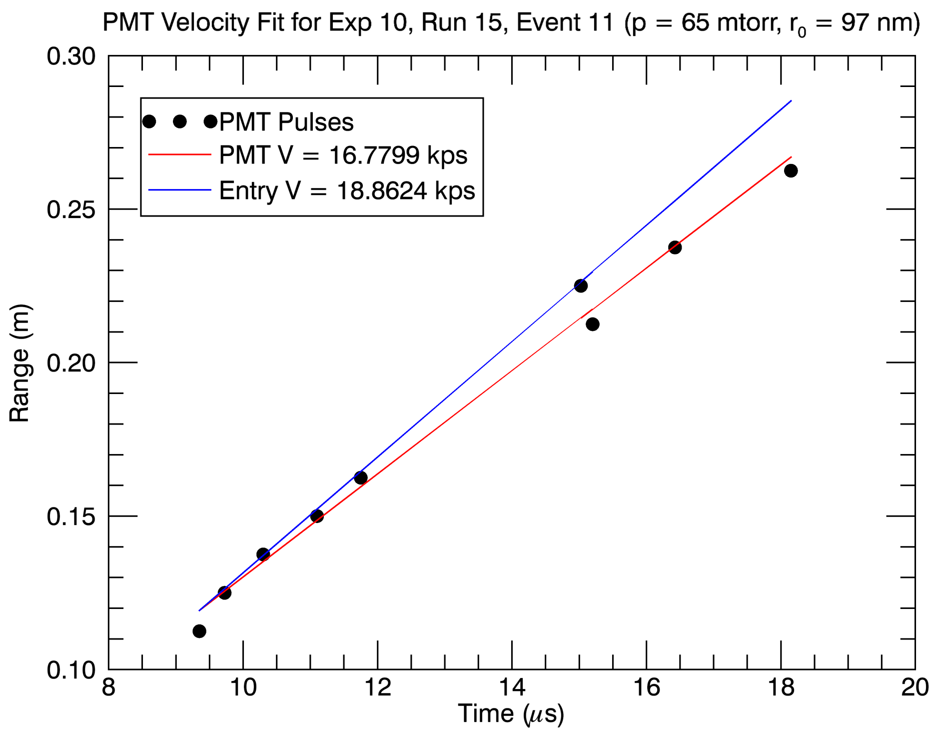


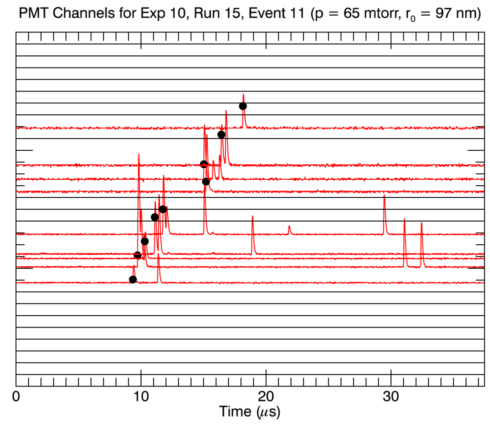


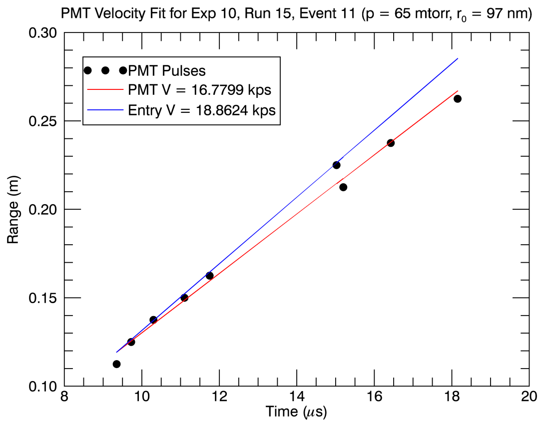

Hamamatsu R5900U-16-L20

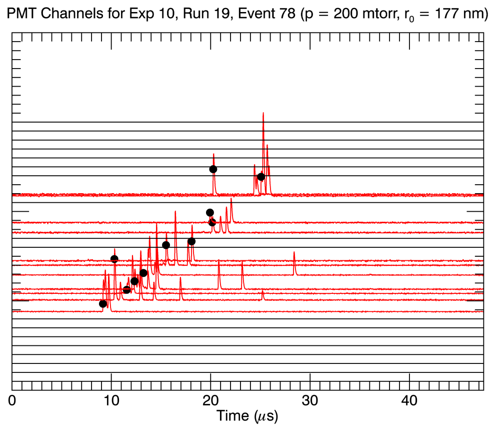
# Particle Tracking

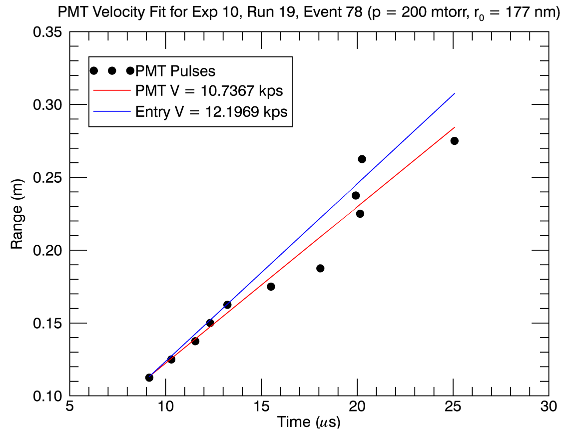


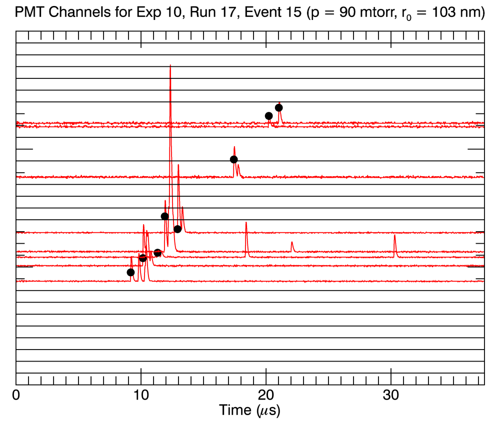



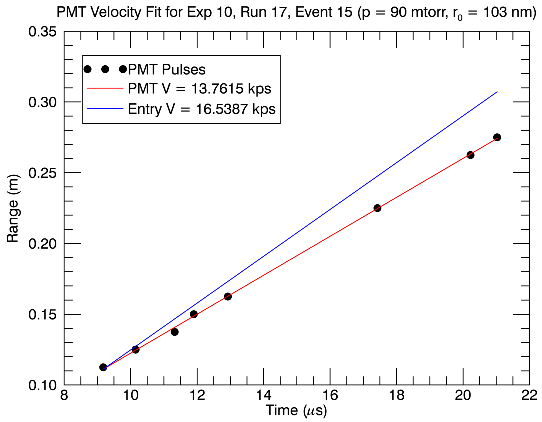

PMT Channels for Exp 10, Run 15, Event 11 (p = 65 mtorr, $r_0$ = 97 nm)
Time ($\mu$s)

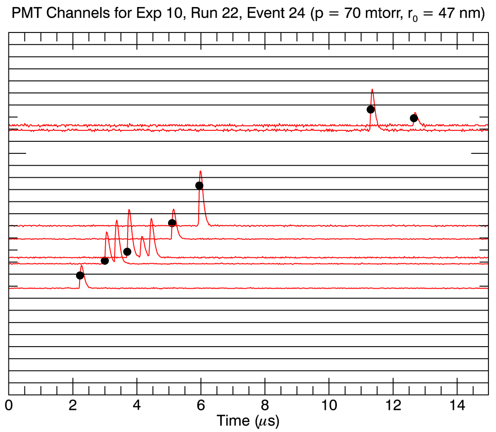

PMT Velocity Fit for Exp 10, Run 15, Event 11 (p = 65 mtorr, $r_0$ = 97 nm)
PMT Pulses
PMT V = 16.7799 kps
Entry V = 18.8624 kps
Range (m)
Time ($\mu$s)

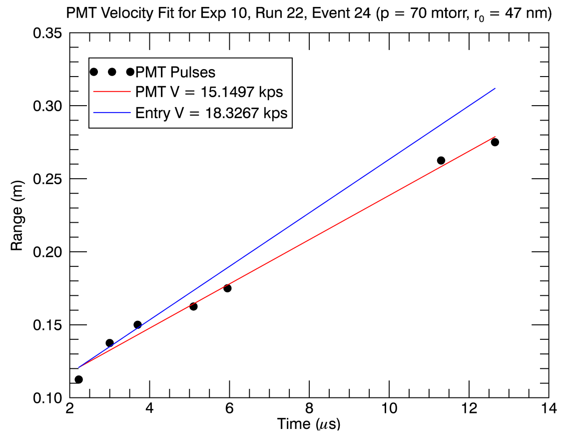

PMT Channels for Exp 10, Run 19, Event 78 (p = 200 mtorr, $r_0$ = 177 nm)
Time ($\mu$s)

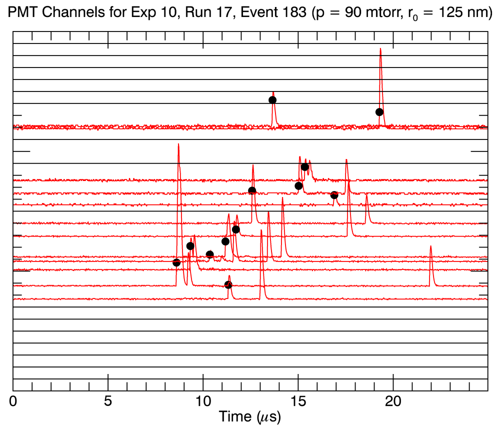

PMT Velocity Fit for Exp 10, Run 19, Event 78 (p = 200 mtorr, $r_0$ = 177 nm)
PMT Pulses
PMT V = 10.7367 kps
Entry V = 12.1969 kps
Range (m)
Time ($\mu$s)

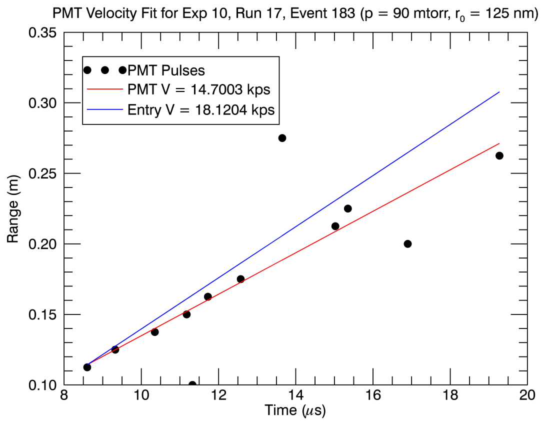

PMT Channels for Exp 10, Run 17, Event 15 (p = 90 mtorr, $r_0$ = 103 nm)
Time ($\mu$s)

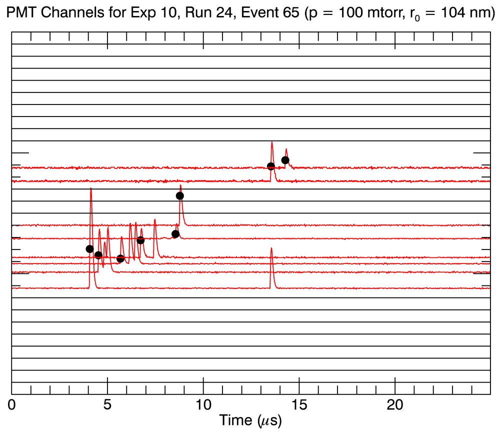

PMT Velocity Fit for Exp 10, Run 17, Event 15 (p = 90 mtorr, $r_0$ = 103 nm)
PMT Pulses
PMT V = 13.7615 kps
Entry V = 16.5387 kps
Range (m)
Time ($\mu$s)

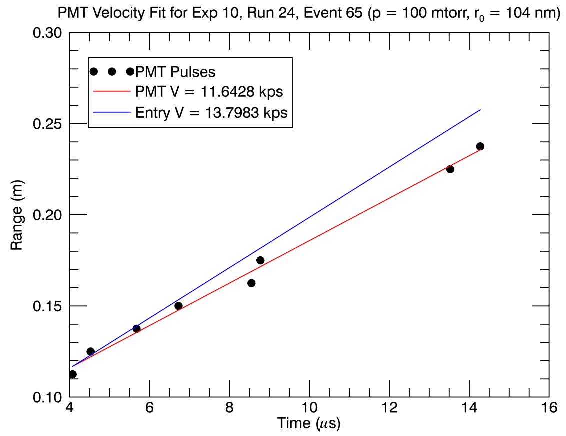

PMT Channels for Exp 10, Run 22, Event 24 (p = 70 mtorr, $r_0$ = 47 nm)
Time ($\mu$s)


PMT Velocity Fit for Exp 10, Run 22, Event 24 (p = 70 mtorr, $r_0$ = 47 nm)
PMT Pulses
PMT V = 15.1497 kps
Entry V = 18.3267 kps
Range (m)
Time ($\mu$s)


PMT Channels for Exp 10, Run 17, Event 183 (p = 90 mtorr, $r_0$ = 125 nm)
Time ($\mu$s)


PMT Velocity Fit for Exp 10, Run 17, Event 183 (p = 90 mtorr, $r_0$ = 125 nm)
PMT Pulses
PMT V = 14.7003 kps
Entry V = 18.1204 kps
Range (m)
Time ($\mu$s)

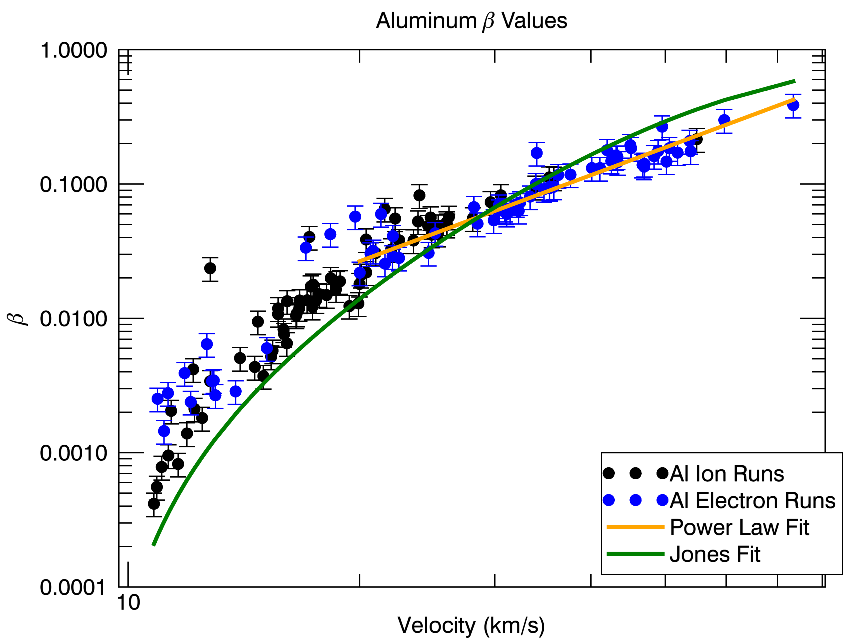

PMT Channels for Exp 10, Run 24, Event 65 (p = 100 mtorr, $r_0$ = 104 nm)
Time ($\mu$s)


PMT Velocity Fit for Exp 10, Run 24, Event 65 (p = 100 mtorr, $r_0$ = 104 nm)
PMT Pulses
PMT V = 11.6428 kps
Entry V = 13.7983 kps
Range (m)
Time ($\mu$s)

# Summary and Next Steps

- **Ablation Experiments with Aluminum**
  - Determined β for particles from 10.8 km/s to 73.4 km/s
  - Fit β to Power Law and Jones Curve
  - Tracked Particle using PMT's

- **Next Steps:**
  - Measure slowdown with a new pickup-tube detector
  - Model the ablation of Aluminum micrometeoroids



# References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- Plane, J.M.C., Cosmic Dust in the Earth's Atmosphere. *Chem. Soc. Rev.* 41, 6507-6518 (2012).
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- Vondrak, T., *et al,* A Chemical Model of Meteoric Ablation. *Atmos. Chem. Phys.* 8, 7015-7031 (2008).