Laboratory Micrometeoroid/Dust Ablation Studies

Evan Thomas[1*], Mihaly Horanyi[1], Diego Janches[2], Tobin L. Munsat[1], John M C Plane[3], Jonas Simolka[1], and Zoltan Sternovsky[1]

[1]University of Colorado, Boulder, CO, USA
[2]NASA/GSFC, Greenbelt, MD, USA
[3]University of Leeds, Leeds, LS2, UK
[*]evan.w.thomas@colorado.edu

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Introduction

- Every day, billions of micrometeoroids ablate in Earth's upper atmosphere.
  - The ablated materials affect a variety of phenomena:
    - Formation of layers of metal atoms and ions in the atmosphere
    - Nucleation of noctilucent clouds
    - Effects on stratospheric aerosols and O_3 chemistry
    - Informs us about the dust environment of the solar system

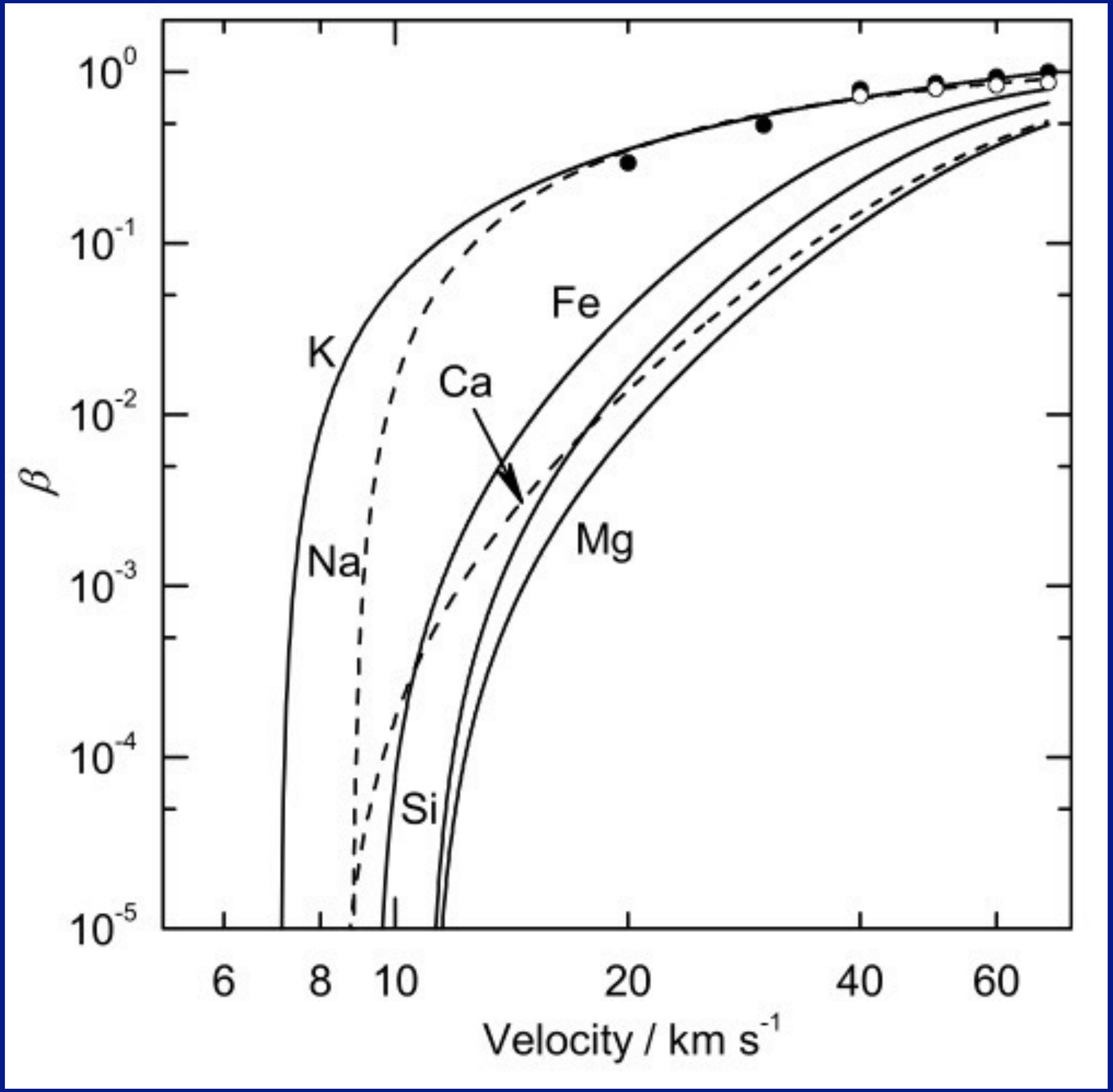
Introduction

- First laboratory measurements of the complete ablation process.
  - Spatial and temporal resolution
  - Extended measurements to relevant velocities.
  - First measurements address ionization efficiency (β)
- Long term goal is detailed validation of ablation models.

Meteors Ionize the Air

- The meteor collides with gas molecules and begins to heat.
  - Sputtering
- The meteor melts and the most volatile elements begin to evaporate.
  - Evaporated atoms collide with gas molecules and can form ion/electron pairs.
  - Amount of ionization given by β.
  - As meteor continues to heat, less volatile elements evaporate, etc.
- This process is modeled in meteor models, such as the Chemical Ablation Model (CABMOD, Vondrak et al. 2008).

Ionization (β) is Uncertain Quantity in Models



[Vondrak et al., 2008]

- Jones (1997) model of ionization coefficient is used in CABMOD.
- Very few measurements at low velocity.
- β is crucial for interpreting radar measurements of meteors.

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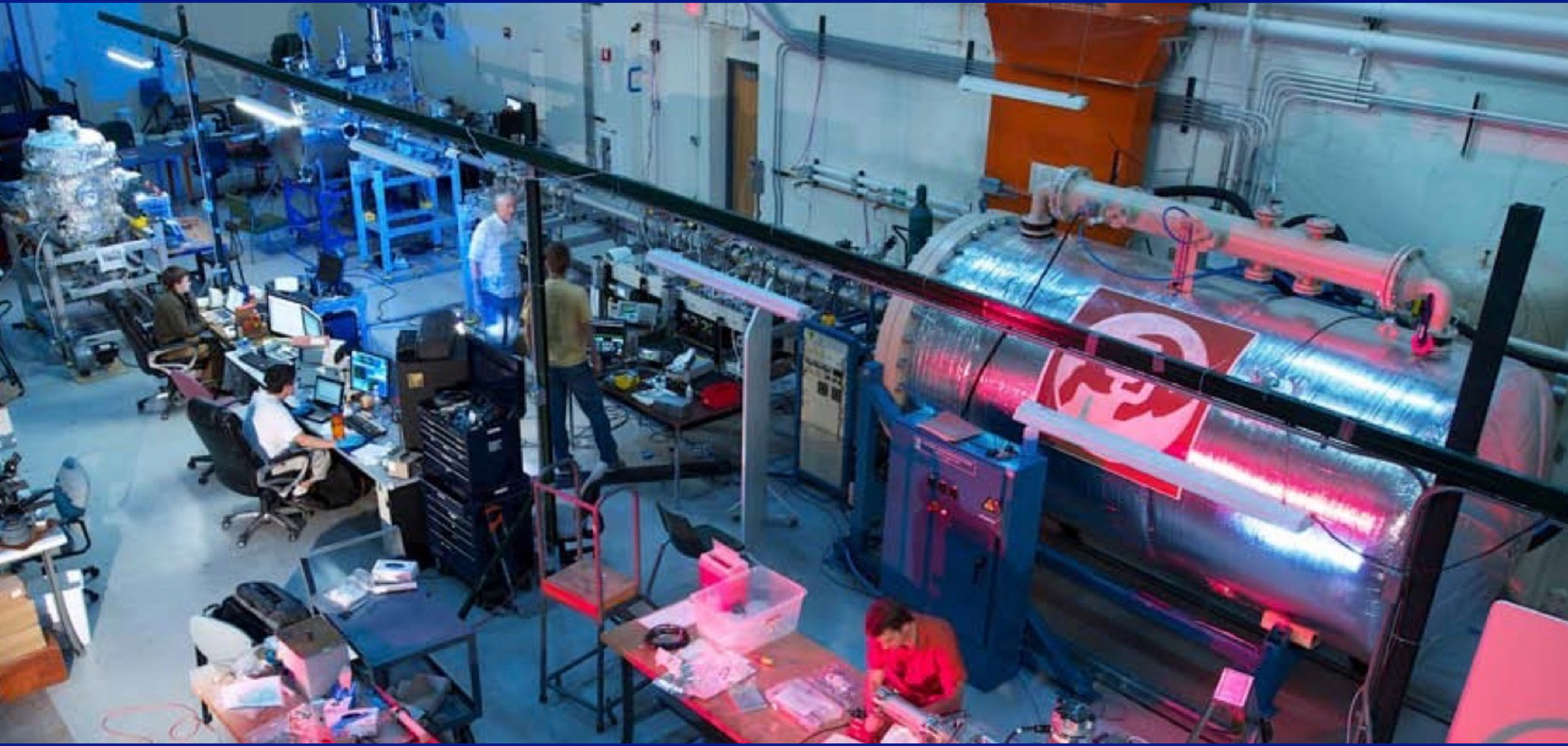
Experiment: Measure β

- Using a 3MV hypervelocity dust accelerator (Shu, 2012), we can simulate ablating micrometeoroids in the lab.
  - This experiment used micron and sub-micron sized iron particles.



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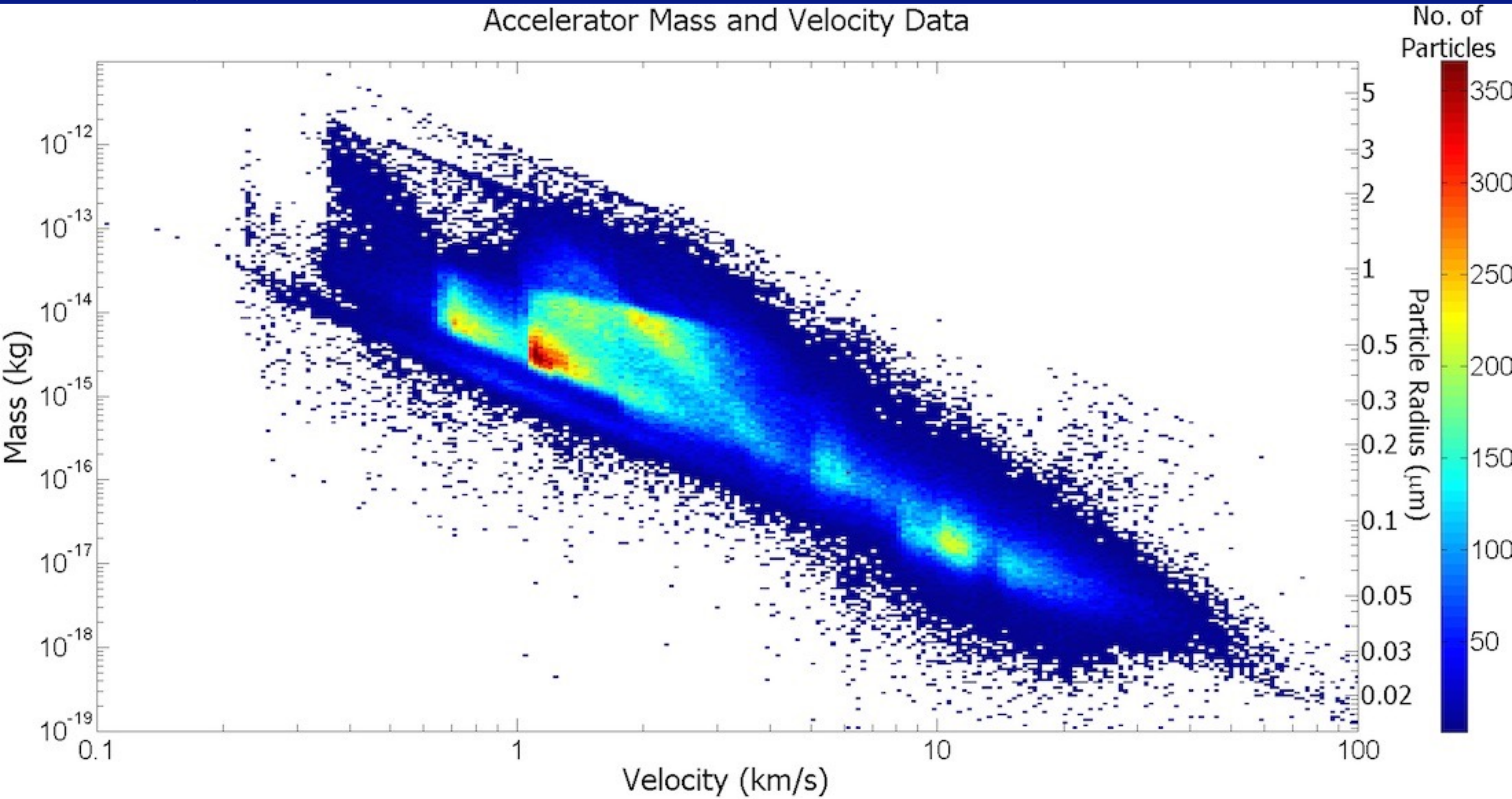

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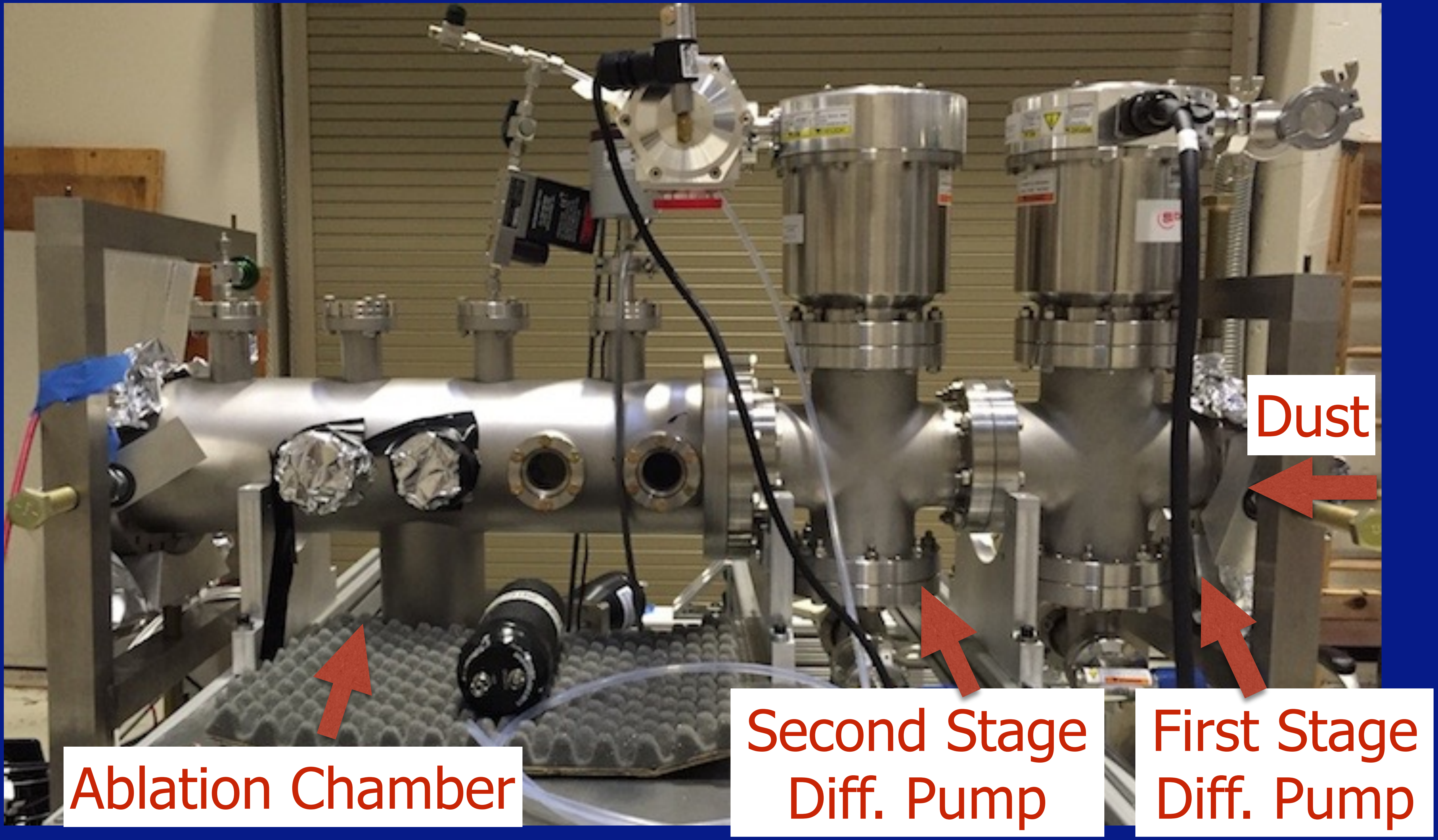
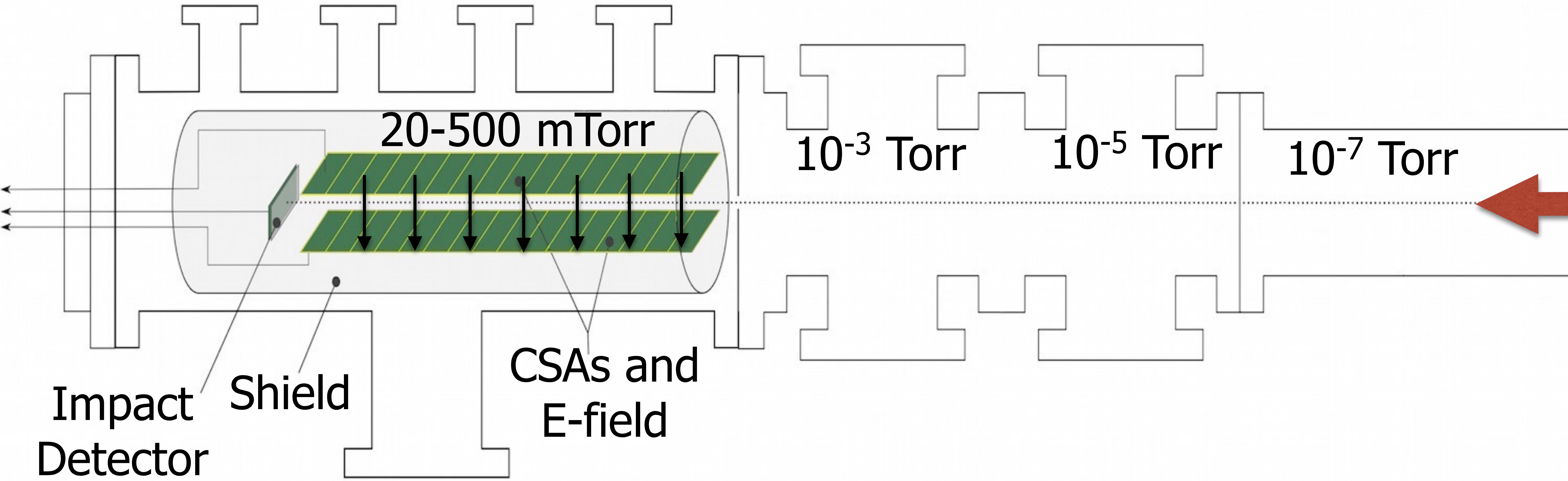
Experimental Apparatus



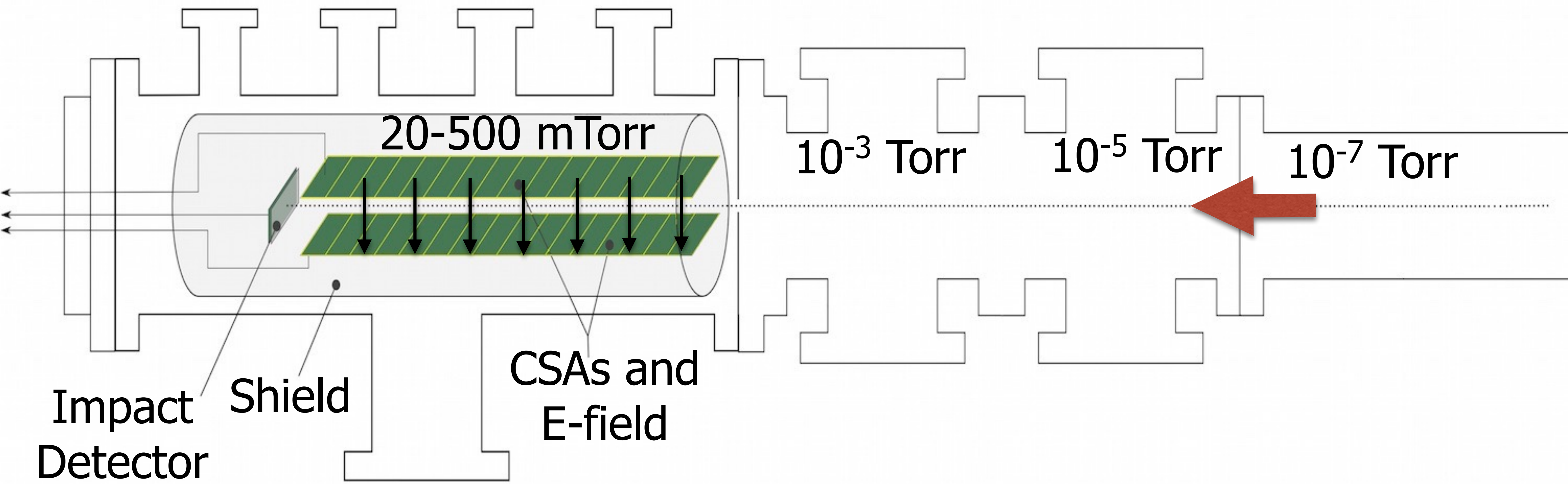
Experimental Apparatus

- The dust enters the experimental apparatus, shown below.



Experimental Apparatus

- The dust moves through two stages of differential pumping.



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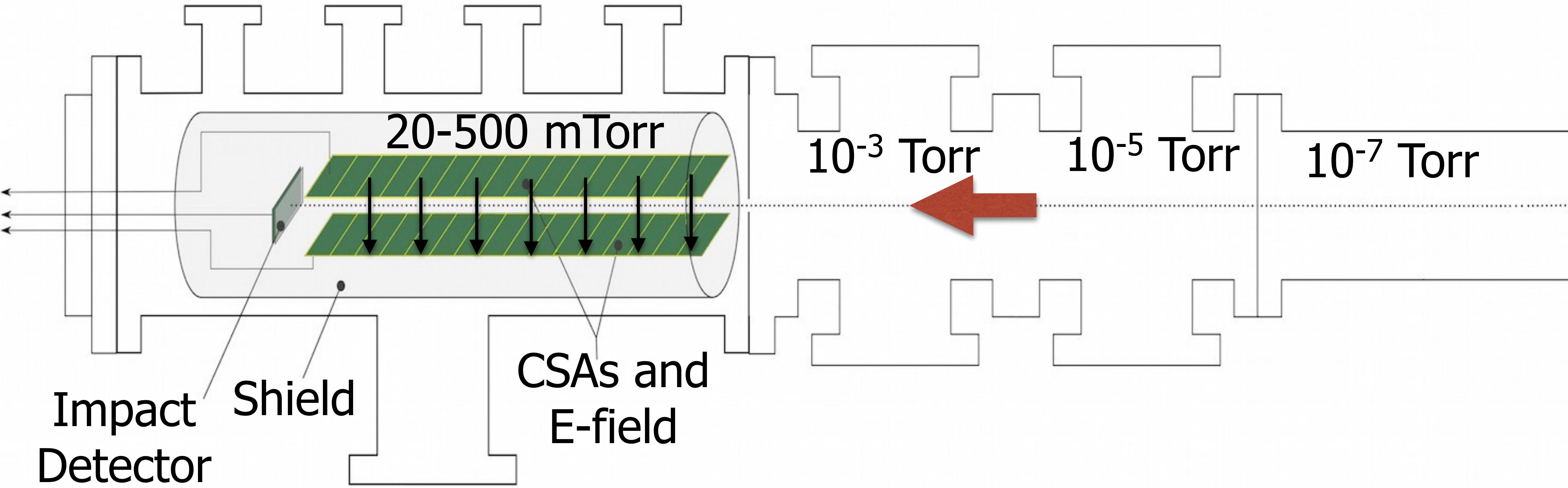
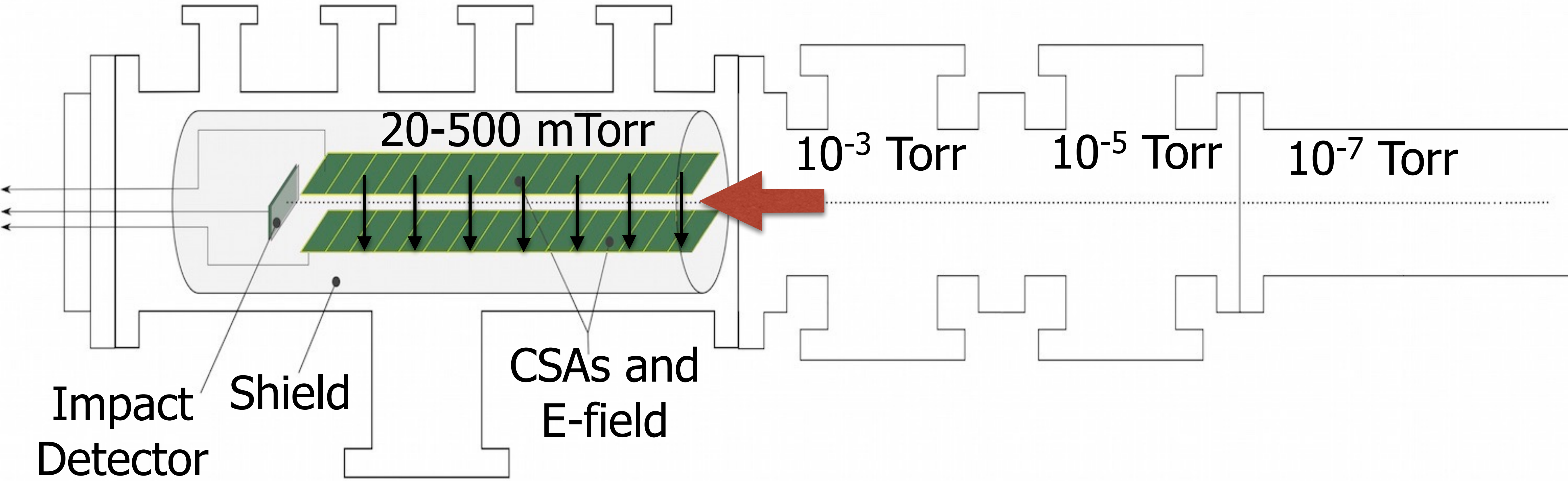


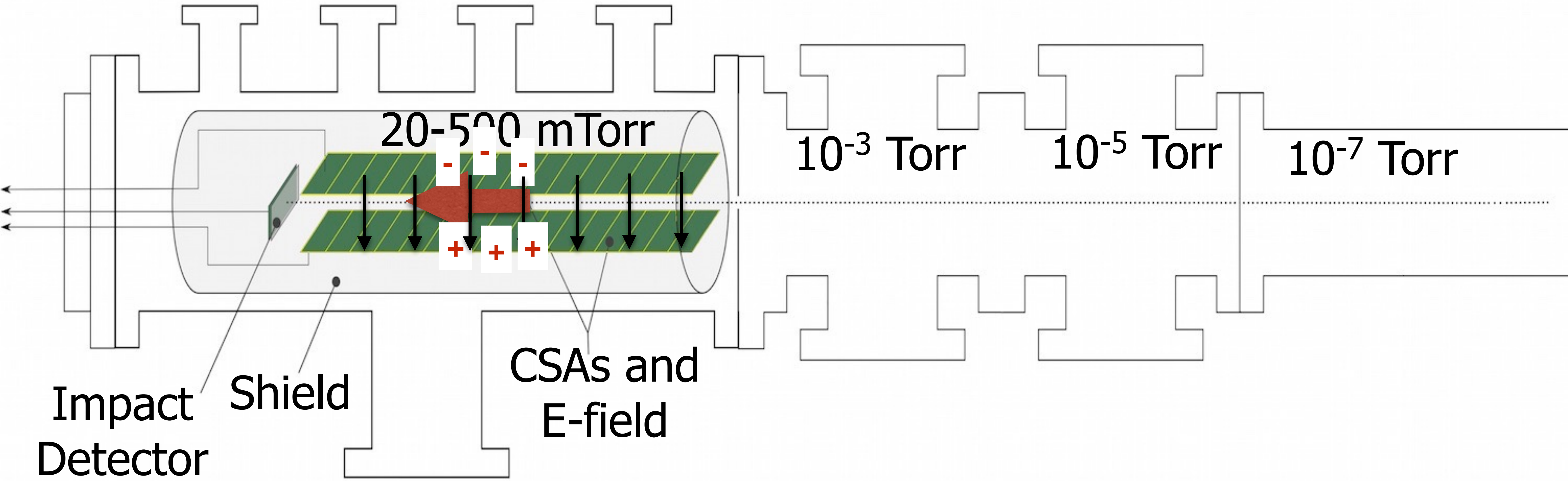
Experimental Apparatus

- The dust enters the ablation chamber with biased charge sensitive amplifiers (CSAs) above and below it.
  - The ablation gas used was N_2.



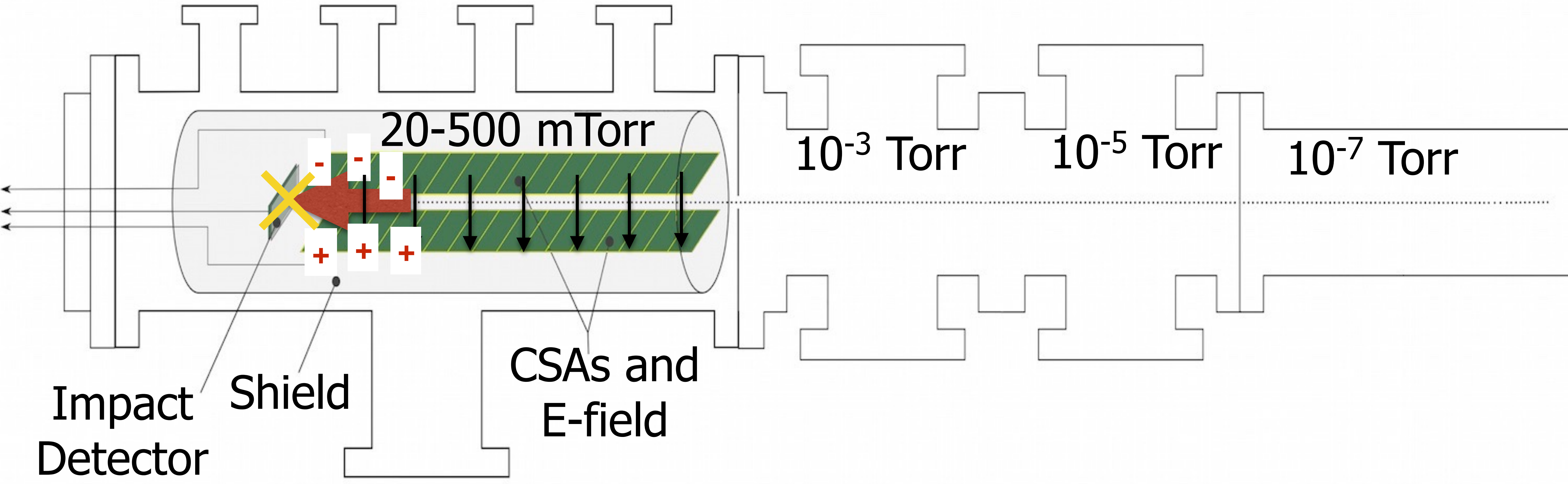
Experimental Apparatus

- Ions and electrons are collected separately on the top and bottom CSAs.

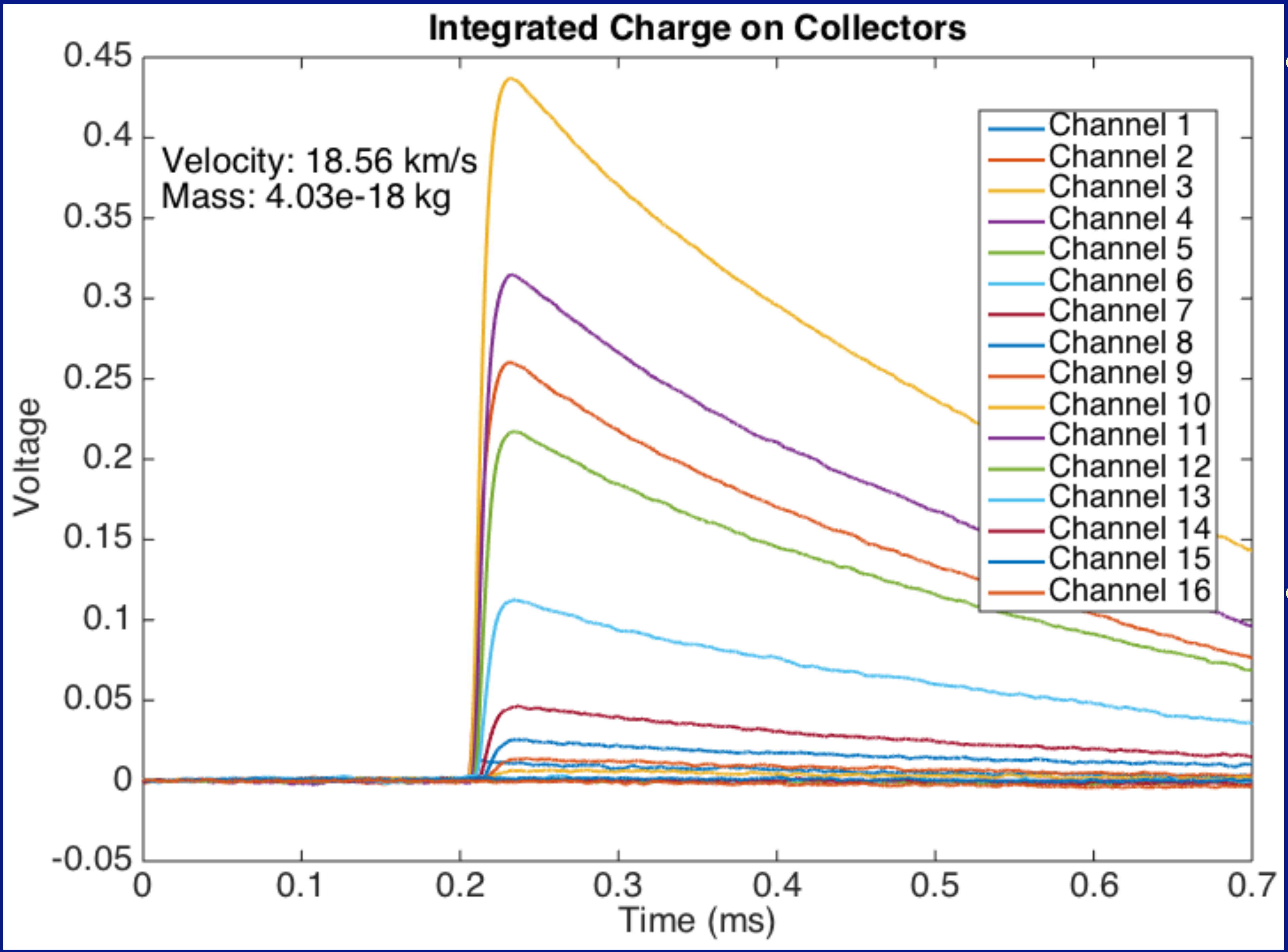


Experimental Apparatus

- If the particle survives, whatever is left of the particle strikes the impact detector.
  - We looked for particles with no impact signal.

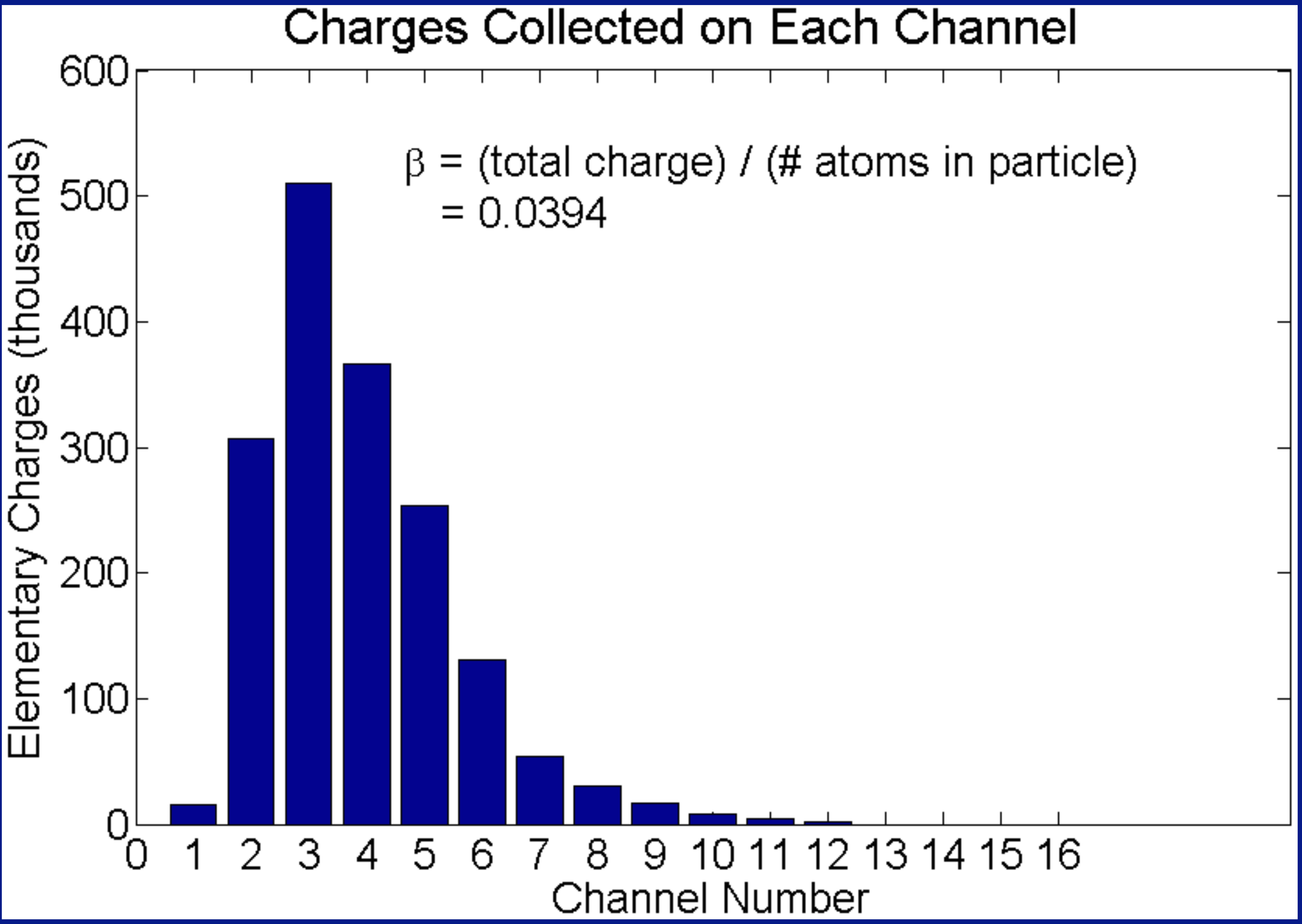


Signals Spatially/Temporally Separated



- Each CSA channel collects the charge which is produced near its collector.
- This results in temporally and spatially separated charge signals.

Charge Per Channel Shows Ablation Process



- The peak of each CSA signal gives the total charge for that channel.
- β is calculated by summing up all charge across 16 channels and dividing by the number of atoms in the particle.

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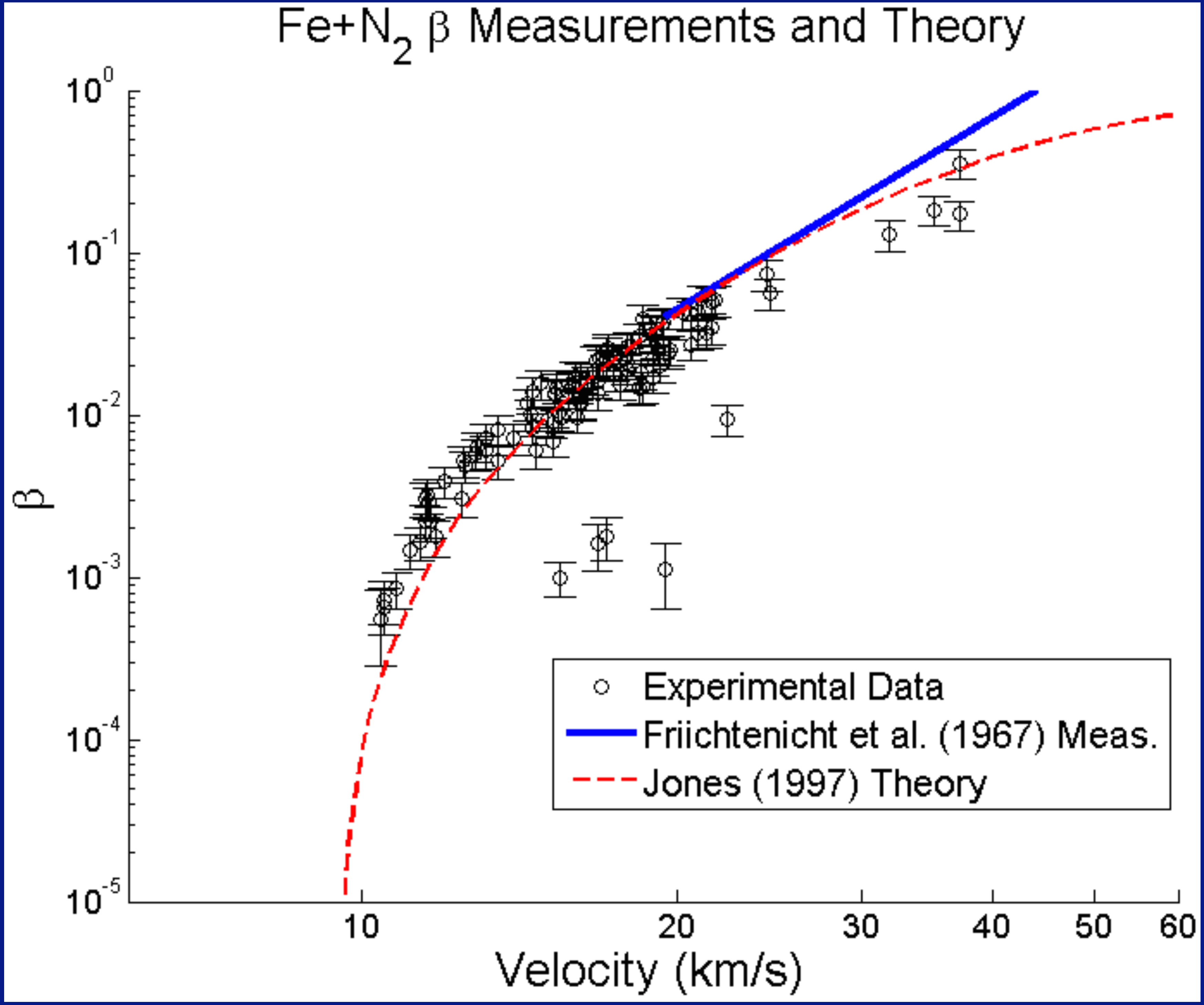
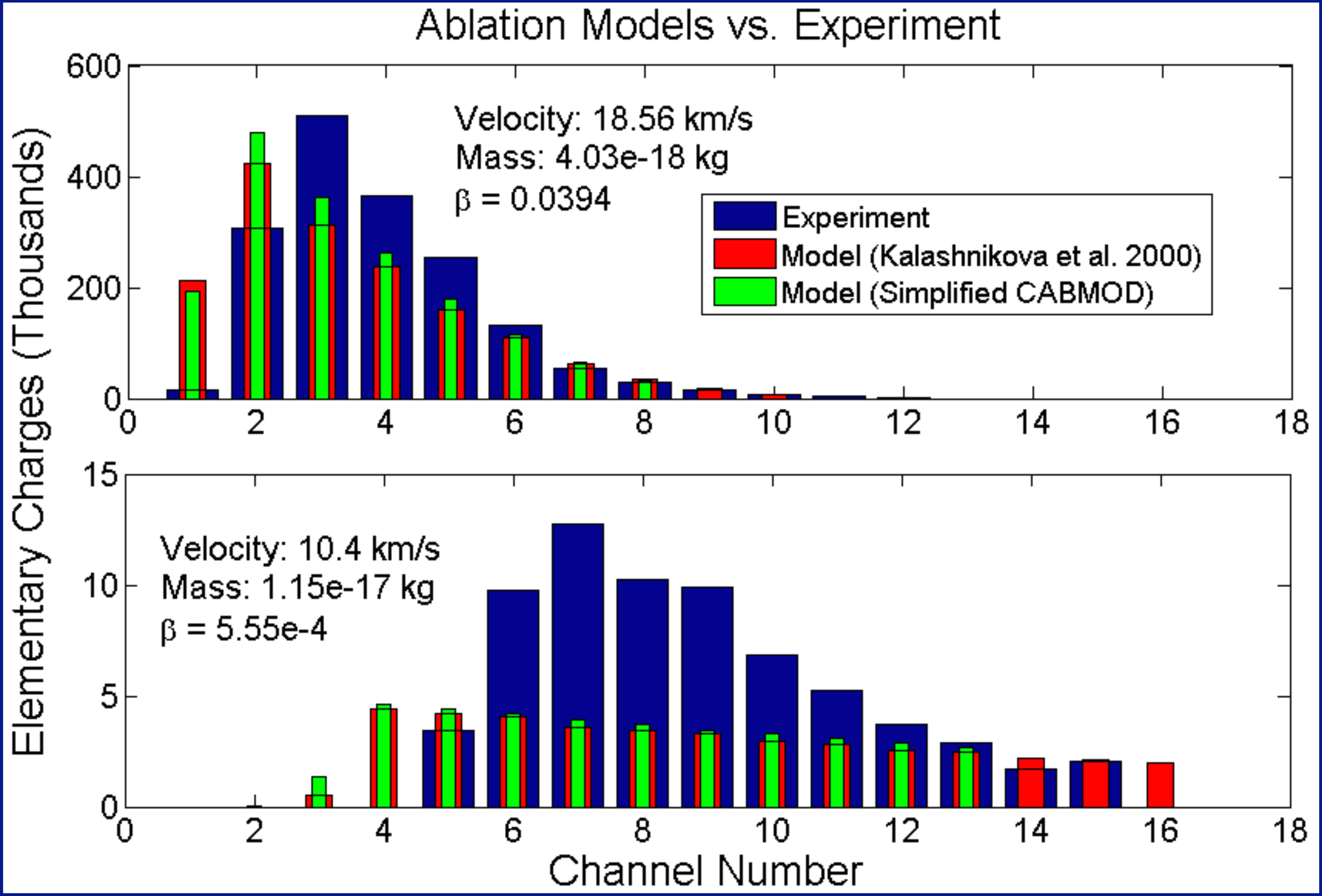
First Result: β Measurements Extended to Lower Velocities

- The experimental β(v) fits the Jones model for iron.
- First measurements below 20 km/s for $Fe+N_2$
- Data can also be used to verify ablation models



Compare Experiments to Ablation Models



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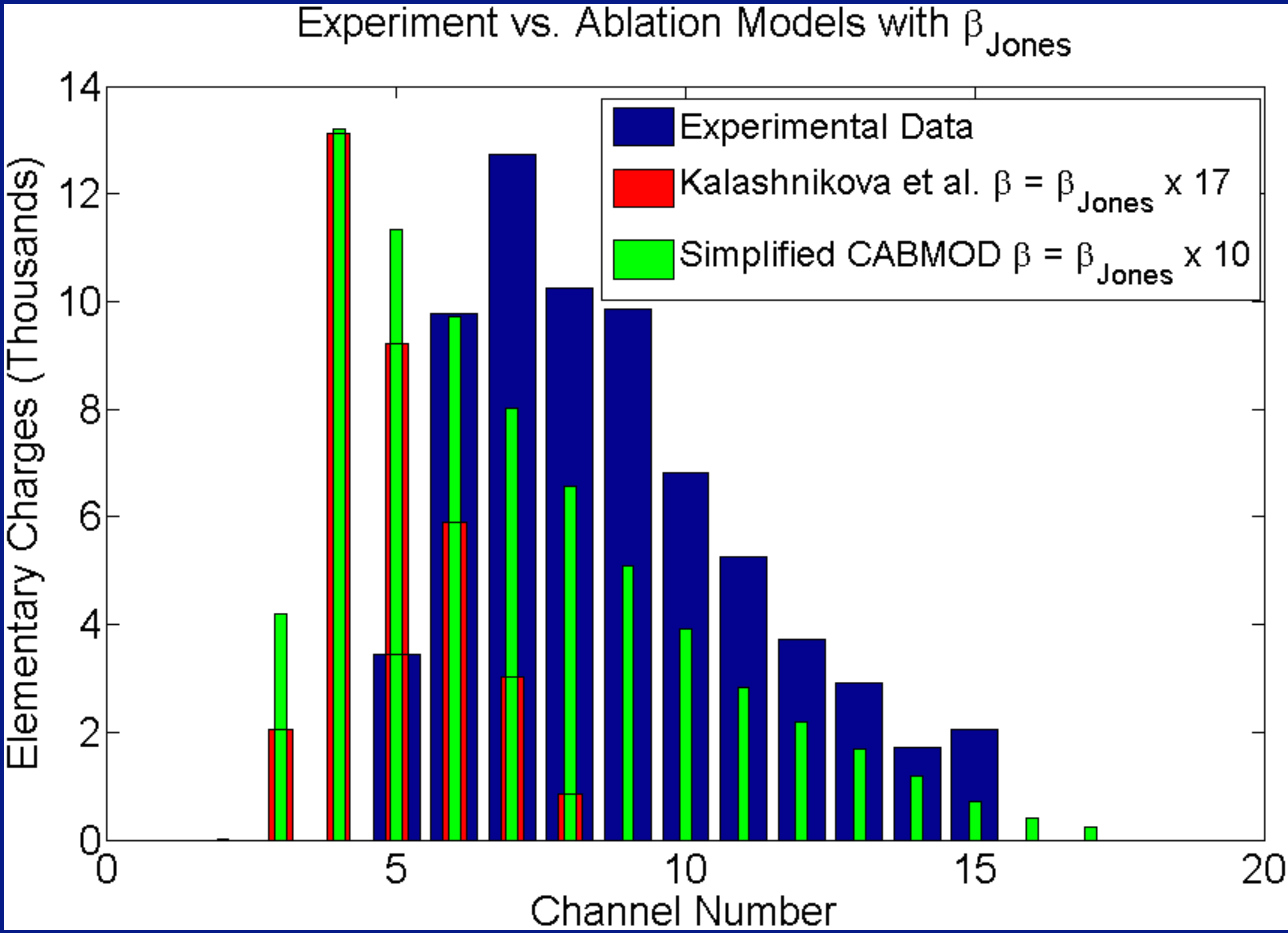
Slow Speeds Present Unique Challenges

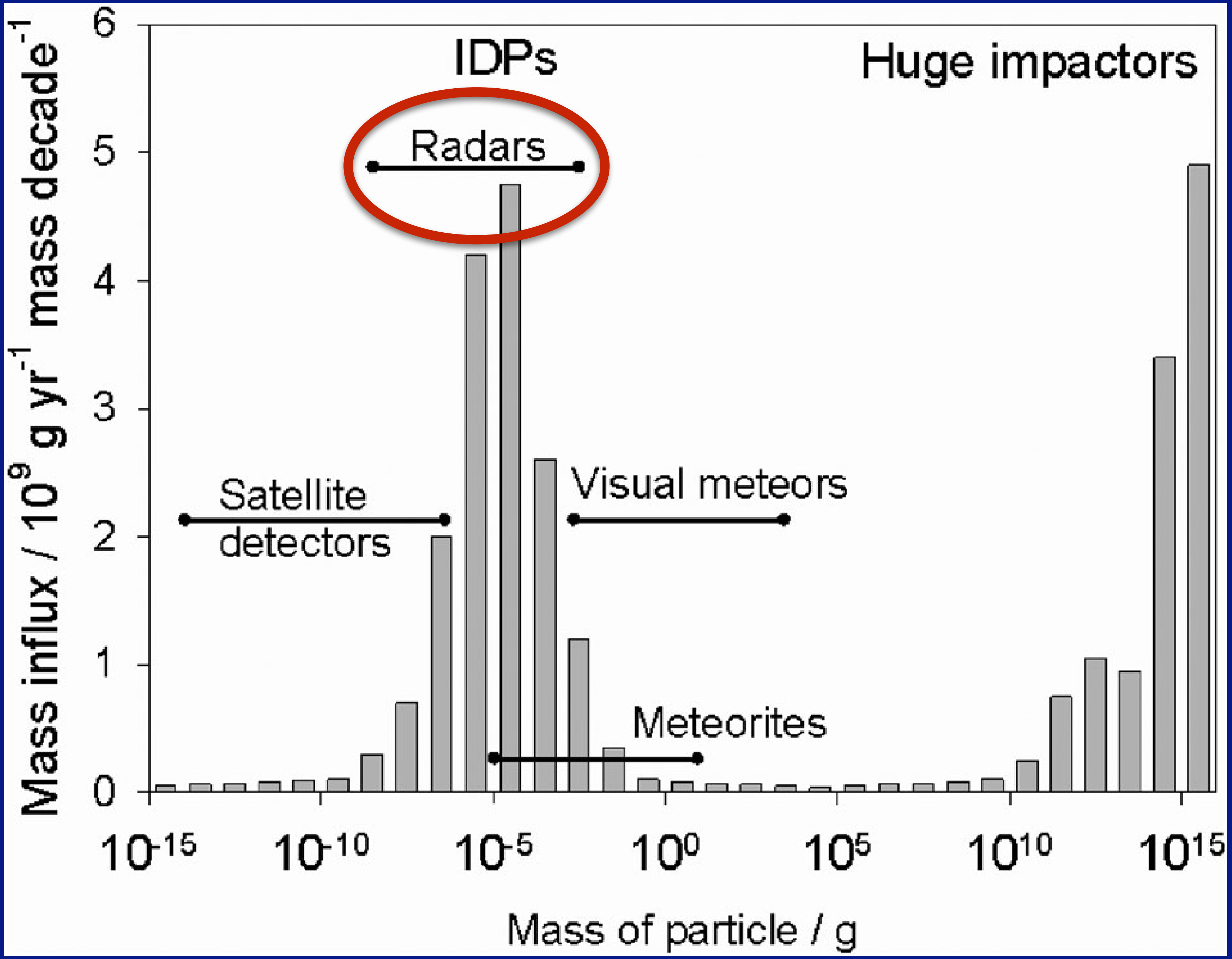
- Due to slowing of particle, used β(v) from Jones (1997)
- Jones theory apparently requires adjusting at slow speeds.



Conclusions & Future Work

- Our results corroborate the Jones model for iron particles at high speeds and suggest it may need adjustment at slow speeds.
- We have already run experiments with different gases (O_2, air, He, CO_2) and those results are coming soon.
- We plan to use different meteor analogs (like olivine) instead of just using iron.
  - Potentially observe differential ablation.
- Future measurements are planned of the luminous efficiency.
  - Useful for visual meteors.

Meteor Radars Sensitive in Most Important Mass Range



[Plane, 2012]

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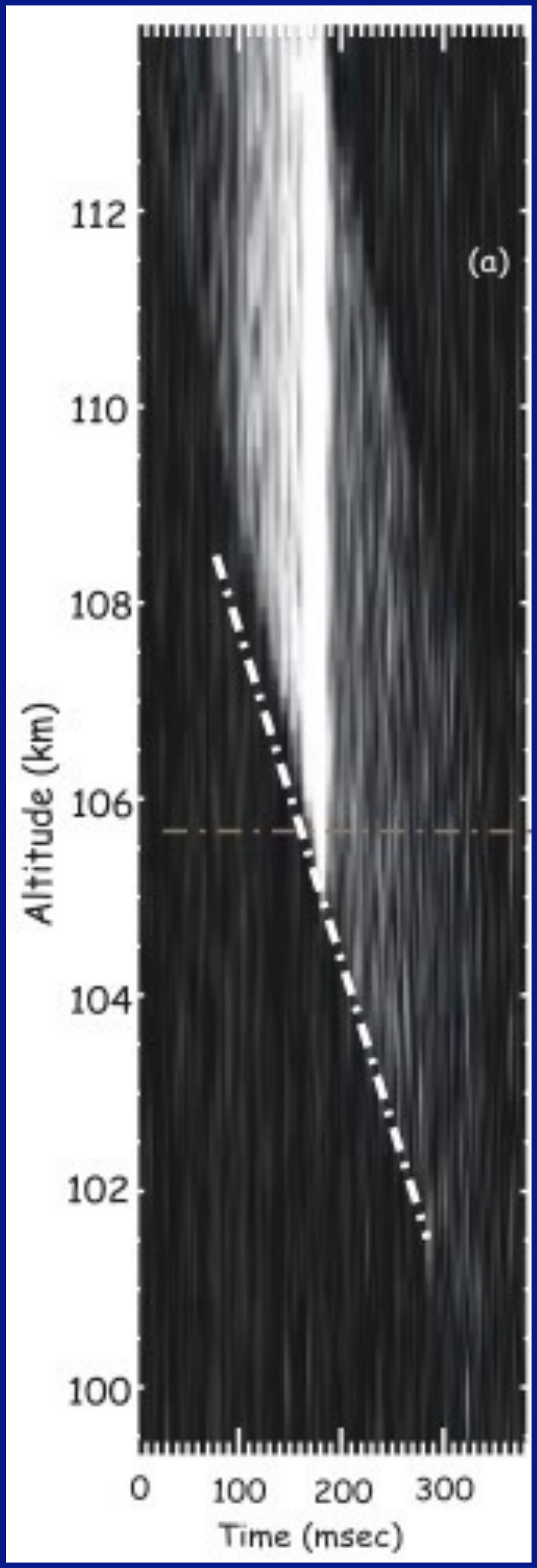
Radar Data Use Meteor Models

- Radar infers meteor characteristics from meteor plasma.



[Janches et al., 2009]

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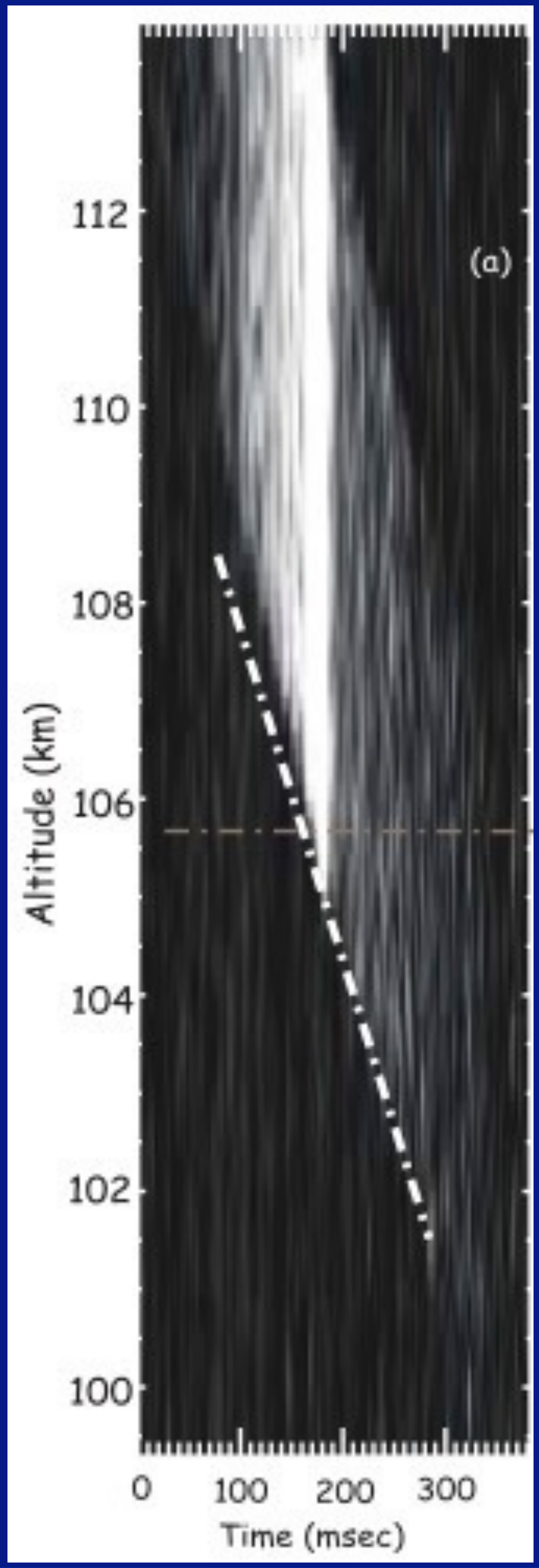

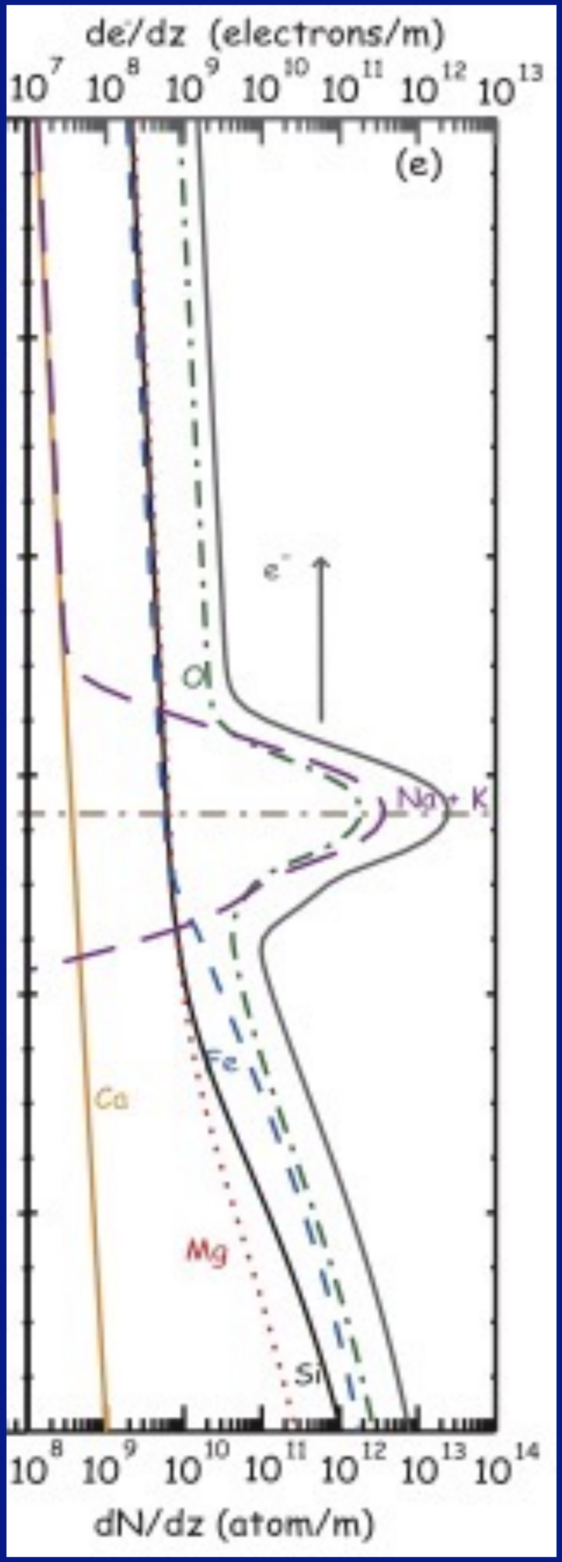

CABMOD