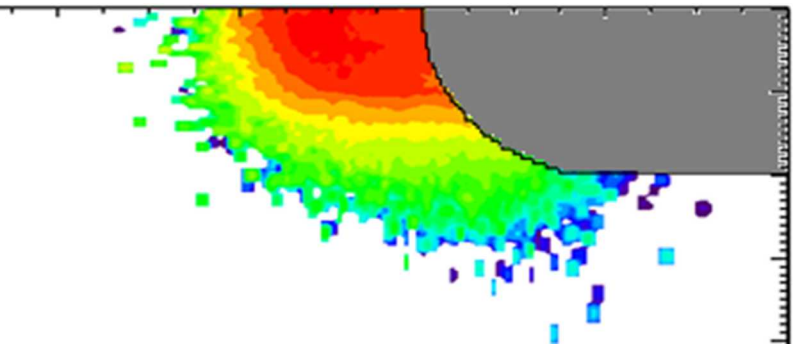
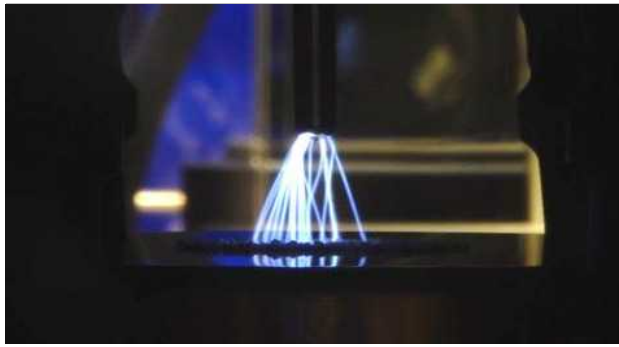
SAND2015-4583C

Exceptional service in the national interest

Sandia National Laboratories





Electrical Breakdown with Intervening Granular Materials

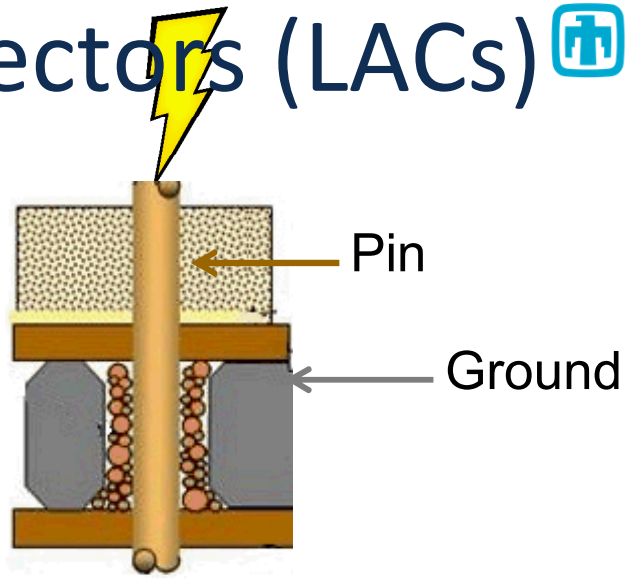
Kenneth Williamson, Laura Biedermann, Harry Hjalmarson, and Rebecca Coats

The 20th IEEE Pulsed Power Conference (PPC), May 31-June 4, 2015, Austin, Texas USA

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

Lightning Arrester Connectors (LACs)



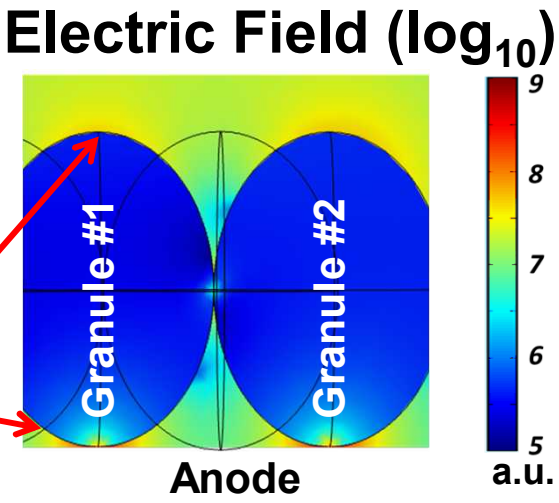
- A **LAC is a safety component** used in some weapon systems to ensure that transient voltage surges are safely redirected to ground.
  - Protection from lightning
- Some LACs rely on **dielectric stimulated arcing (DSA)** through a layer of high-permittivity granules.
  - A very effective, but not well understood mechanism
- Our mission is to ensure safe operation of LACs even in the most unlikely circumstance
  - A daunting parameter space for experiments
  - Requires the development of predictive simulation tools
- This motivates experiments to explore the fundamental processes of breakdown to develop the simulation tools.

Unique properties of rutile (TiO_2)

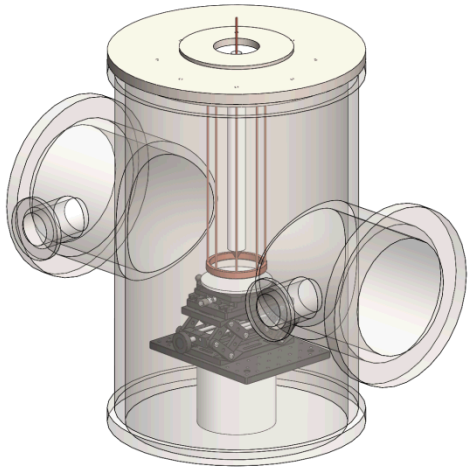
Sandia National Laboratories

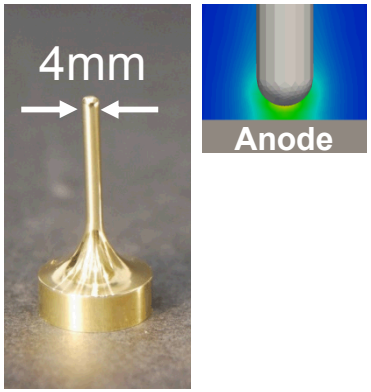
- Rutile is a white ceramic used to study DSA
  - Substantial reduction of breakdown voltage can be achieved when rutile bridges the air gap
  - Dielectric stimulated arc mechanism
  - Rutile relative permittivity ε ~ 100
  - Strong UV absorption
  - Inexpensive and environmentally friendly
- Crushed rutile granules sifted 200 – 300 µm diameter
  - Single layer on cathode
  - Minimal change to macroscopic electric field
  - Triple point enhancement
  - Exclude field inside dielectric

Crushed rutile granules



Experimental Setup

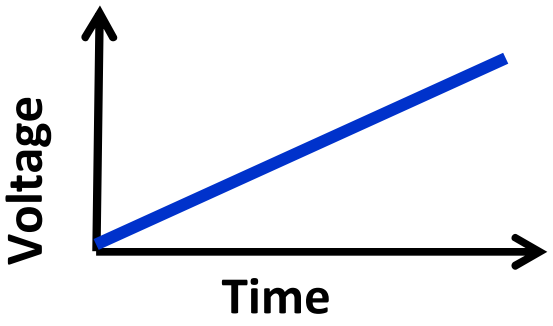




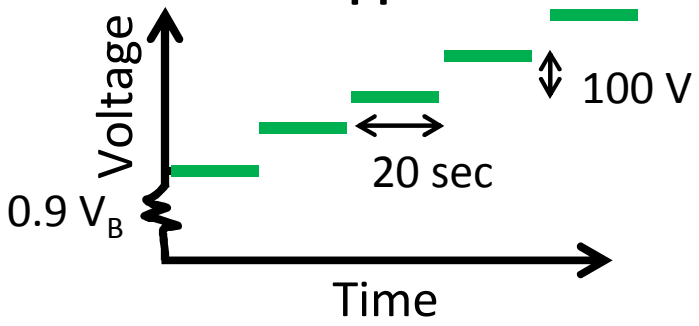
Rod Electrode

- Vacuum chamber
  - Dry air at 600 Torr
- Brass electrodes
  - 4 mm rounded rod to plane
  - Gaps less than 1 cm
- Open-shutter imaging and electrical diagnostics
- Optional UV LED (265 nm) illumination
- Voltage driver
  - Glassman power supply with arbitrary waveform generator

Ramped: 10 kV/s



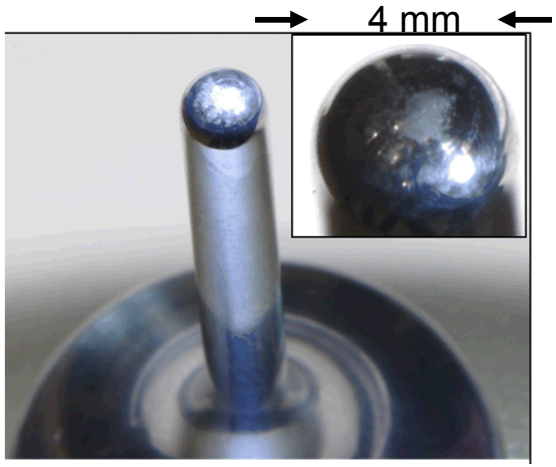
Stepped

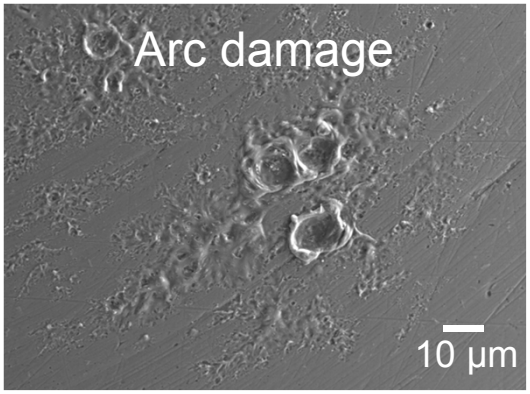


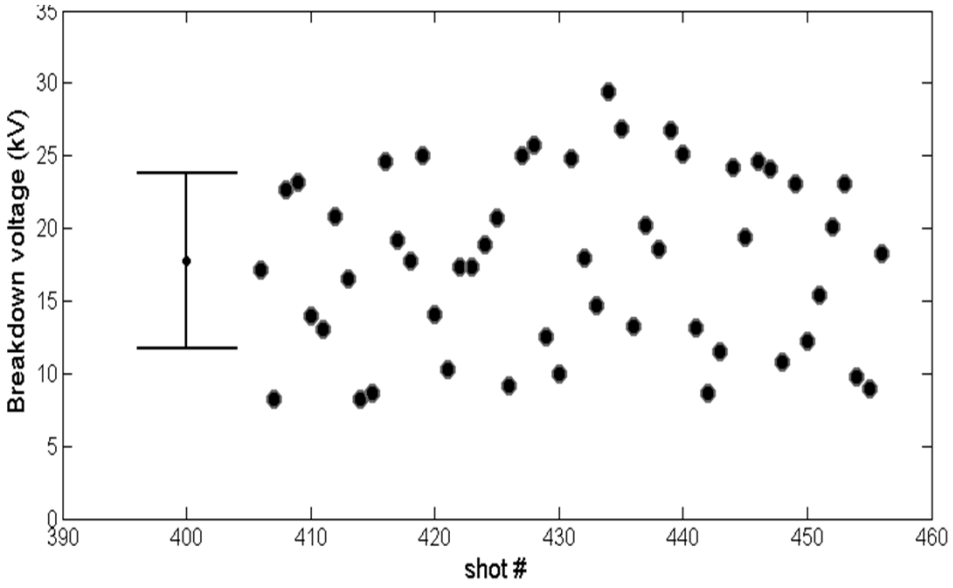
Reproducibility of Data

- Atmospheric DC breakdown in the several kV range is a difficult regime for reproducibility.
  - Goal is to produce reliable data for simulation development

- 50 shots on open aluminum electrodes at 10kV/s forms random distribution
  - Brass performs much better

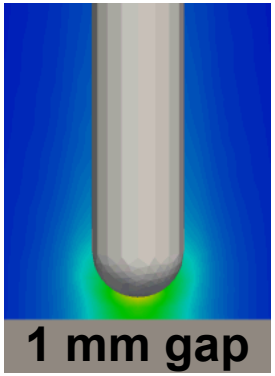


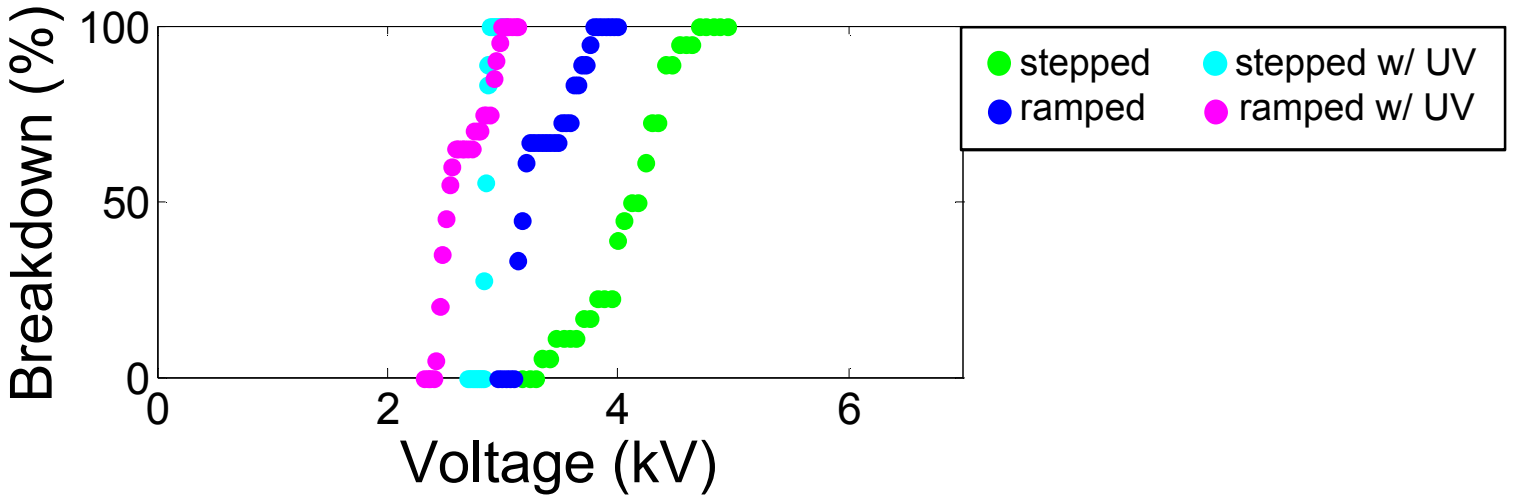




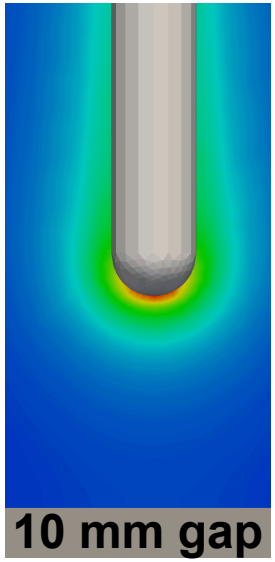
Voltage Profile Affects V_b

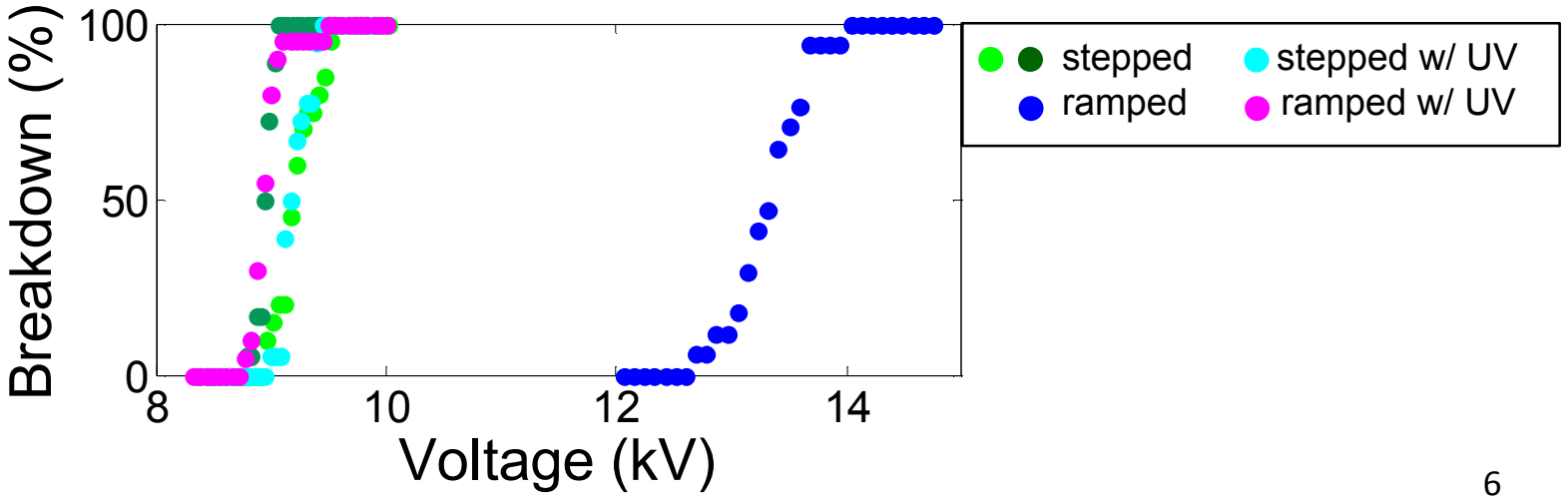
Townsend



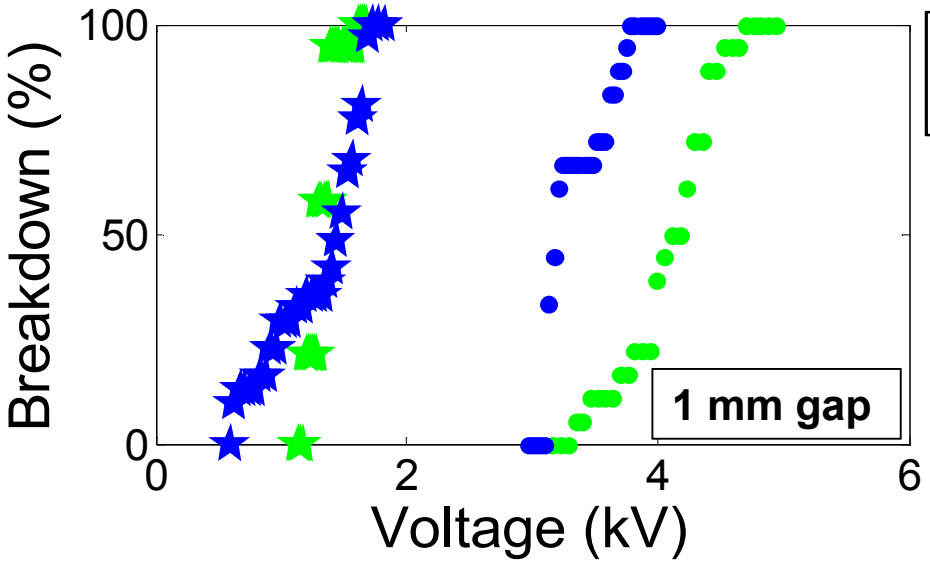


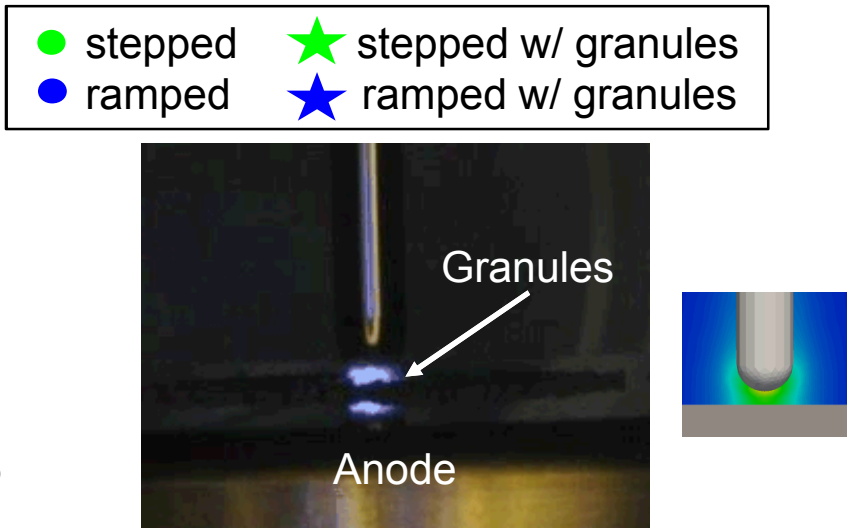
Streamer

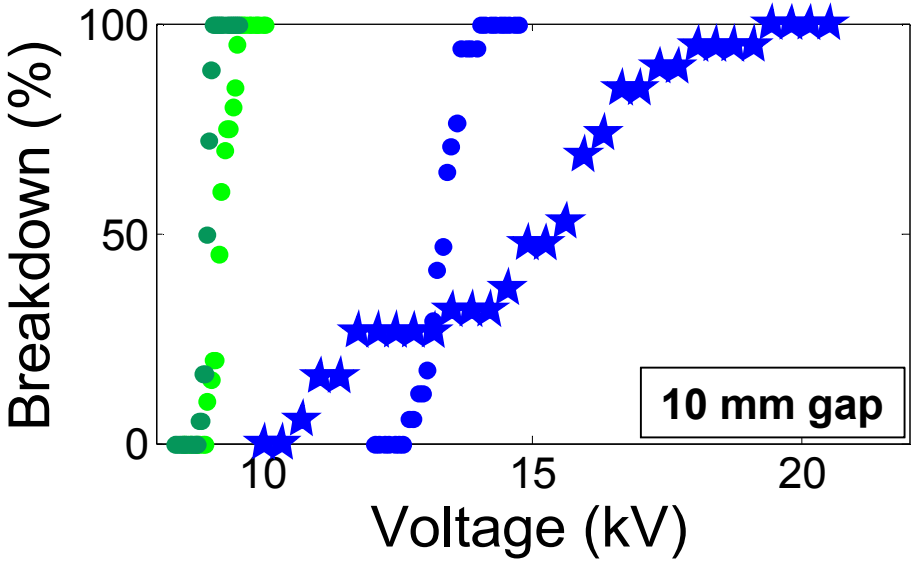


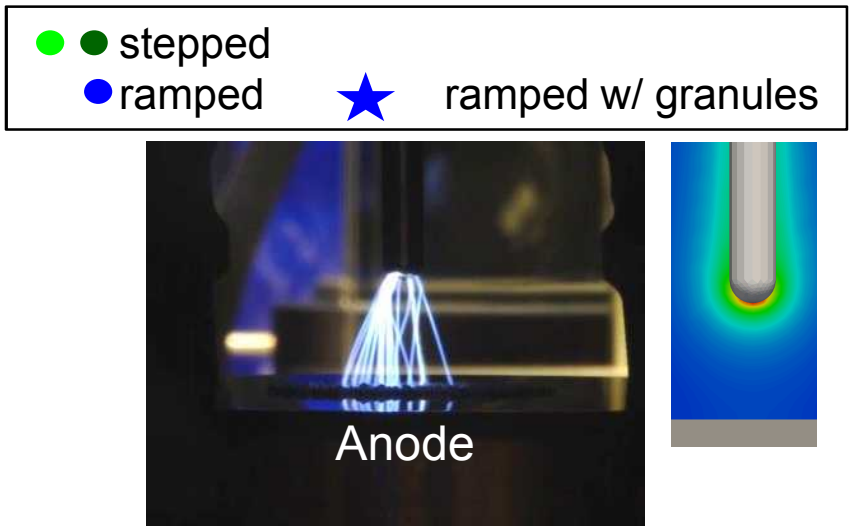


Rutile granules decrease Townsend V_b

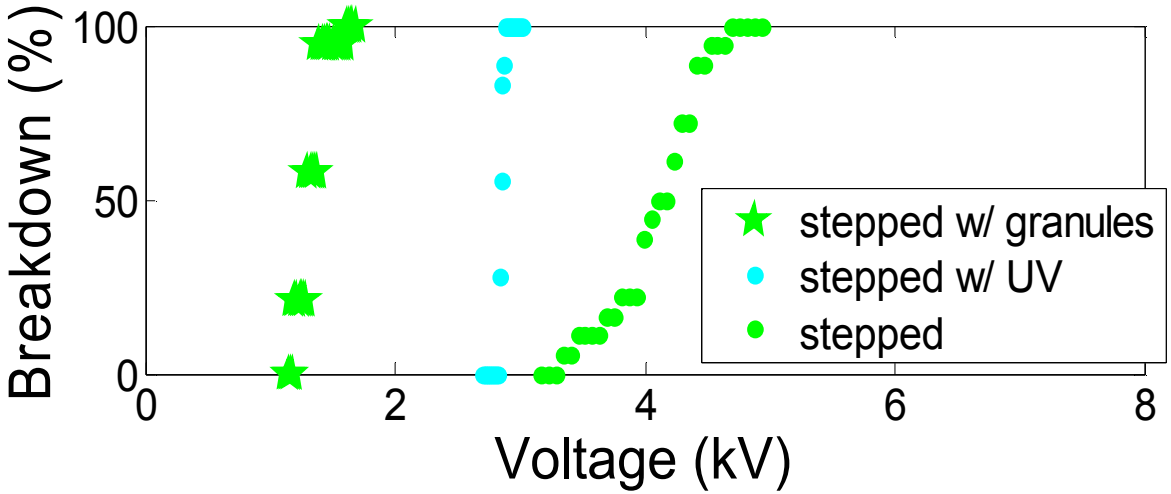


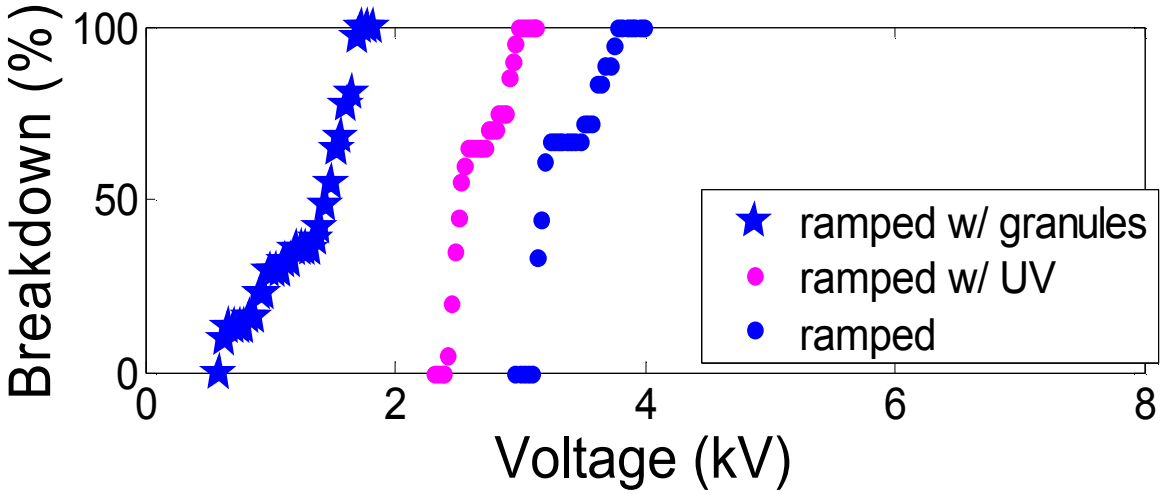






Rutile granules decrease V_b more than UV stimulation at 1 mm





- UV stimulation decreases V_b ~30%
  - Note that every 100 V is 20 s in the stepped profile
  - Significant decrease in standard deviation
- Rutile granules on the cathode decrease V_b by ~60% compared to empty gap
- At 1 mm ramped similar to stepped

Conclusions

- Ramping vs step-dwell lead to significantly different breakdown thresholds
  - More dramatic effect at larger gaps
- UV stimulation of these electrode gaps decreases V_B
  - Photon energy was greater than the work function of the electrodes
  - Enhanced space charge
- In the Townsend regime, granules reduce V_B more than UV
  - Expected due to field compression
  - Variance also decreased – good for LACs and safety
- In contrast, V_B and the variance increase in the streamer regime.
  - Even on the anode
  - Dielectrics may be charging up due to emission at triple points

Questions?

- Watch for:
  - Biedermann at 11am
  - Hjalmarson at noon
  - Moore 10am Wednesday