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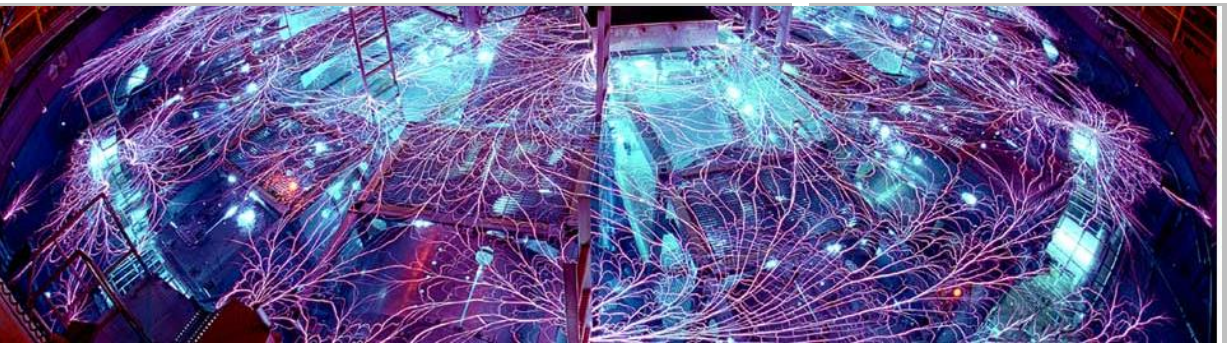
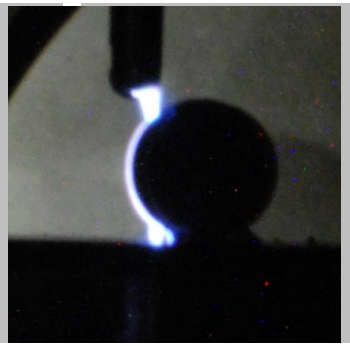
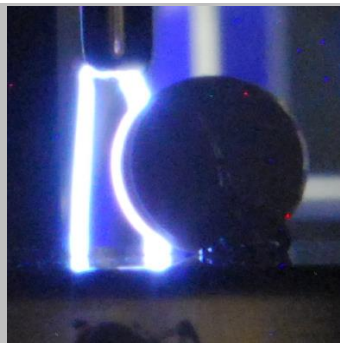

Dielectric-Directed Surface Flashover Under Atmospheric Conditions

Laura Biedermann, Kenneth Williamson, Harold Hjalmarson, Chris Moore, and Rebecca Coats

Sandia National Laboratories, Albuquerque, NM

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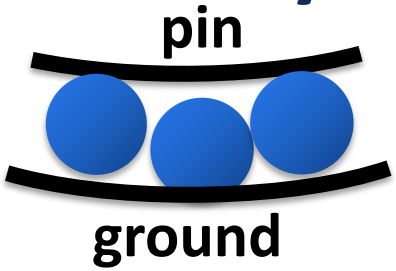
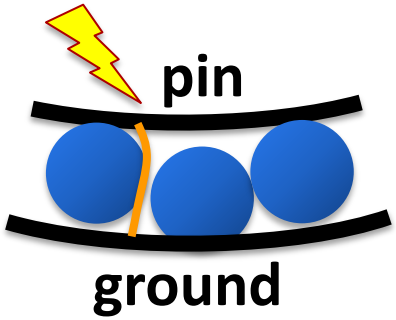
Lightning arrestor connectors rely on dielectric-directed surface flashover to protect high-consequence systems

Normal operation



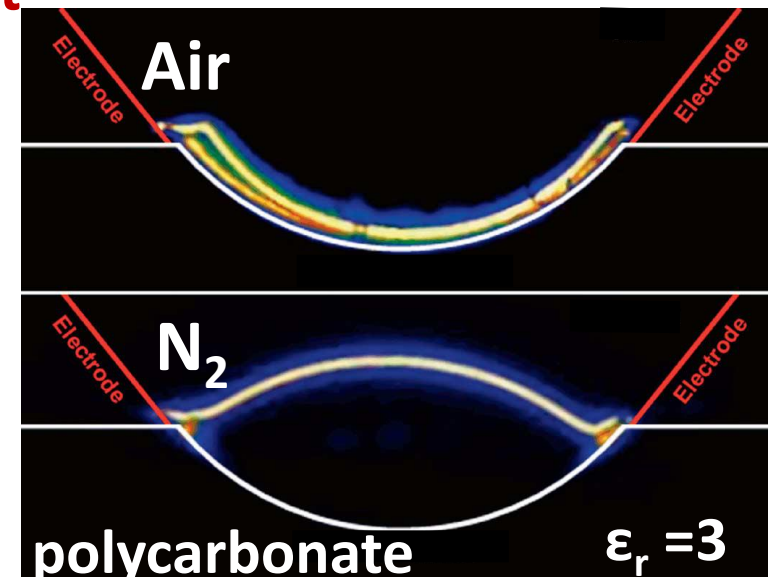
Lightning strike

Direct short to ground via reproducible atmospheric breakdown



Arc attachment

Arc over



Air

Al_2O_3 $\varepsilon_r \sim 10$

TiO_2 $\varepsilon_r \sim 100$

$BaTiO_3$ $\varepsilon_r \sim 10{,}000$

What processes drive arc attachment?

J. Krile *et al.*, IEEE Trans Plasma Phys. 33, 270-271 (2005)

E. Carleton and W. Huebner, IEEE Trans Dielect. Elect. Insul. 9, 253-262 (2002)

Surface flashover in atmospheric conditions

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photo-emission

$B + h\nu \rightarrow B + e^-$

excitation

$A + e^- \rightarrow A^* + e^-$

$A + h\nu \rightarrow A^*$

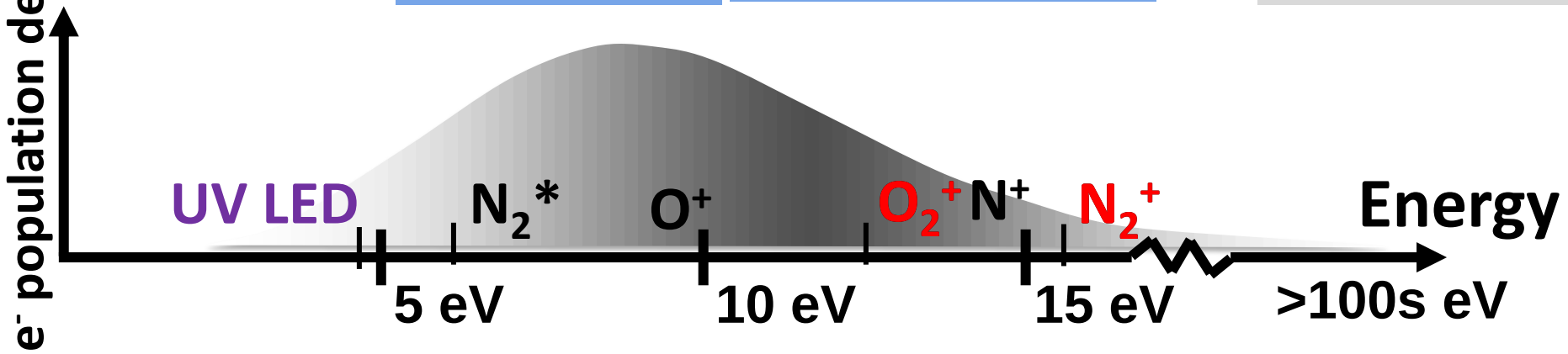
ionization

$A + e^- \rightarrow A^+ + e^- + e^-$

$A + h\nu \rightarrow A^+ + e^-$

secondary e⁻ emission

$B + e^- \rightarrow B^+ + e^- + e^-$



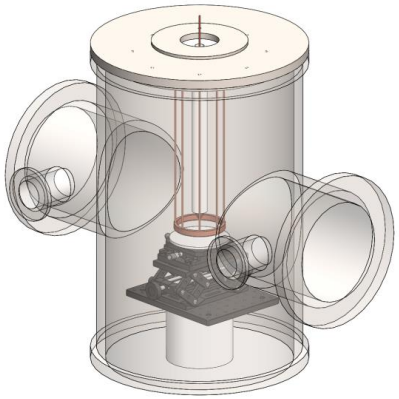
re-attachment $O_2 + e^- \rightarrow O_2^-$

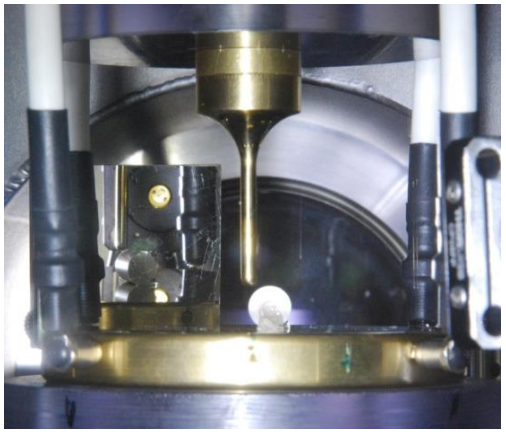
adsorption $B + e^- \rightarrow B^-$

gases (A)

dielectrics (B)

Reproducible measurements with controlled atmosphere and voltage profiles

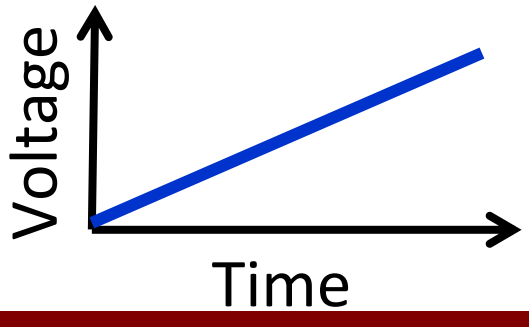




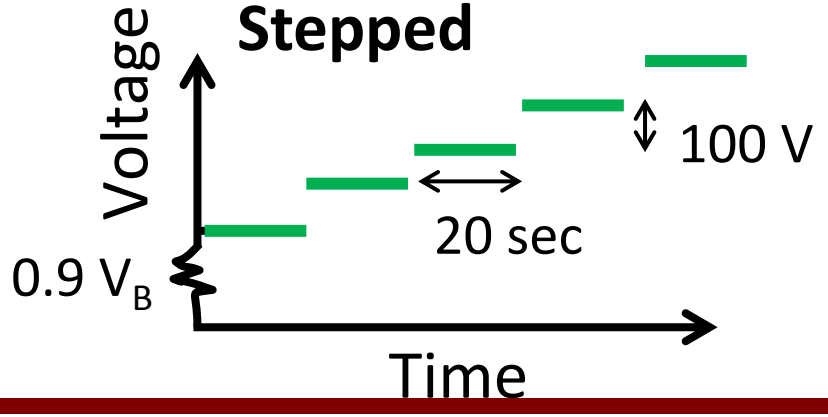
Brass electrodes
d_{gap} = 1-13 mm
600 Torr dry air
→ 80% lower V_B

Ensure initiating electron with voltage profile and/or UV irradiation (trio of 265-nm LEDs)

Ramped: 10 kV/s



Stepped



Sandia's elevation is 1660 m (5440 ft). Atmospheric pressure is 0.84 bar (630 Torr).

Controlled breakdown in streamer regime with stepped voltage or UV illumination

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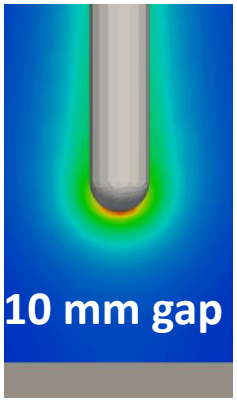
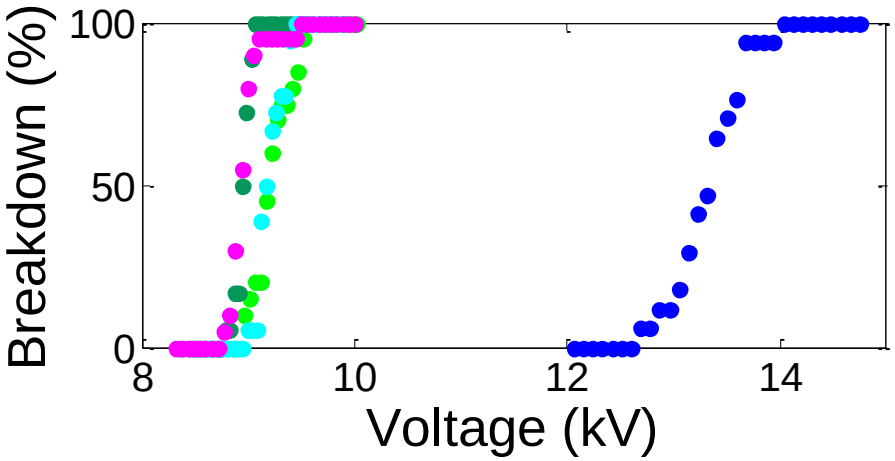
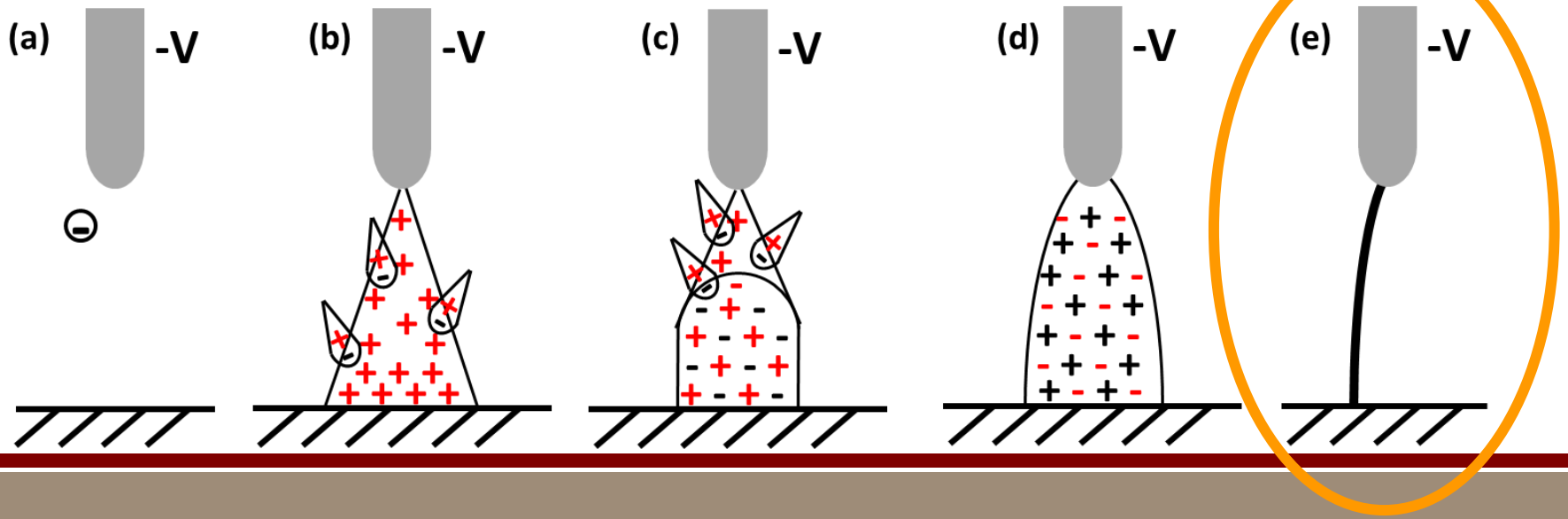




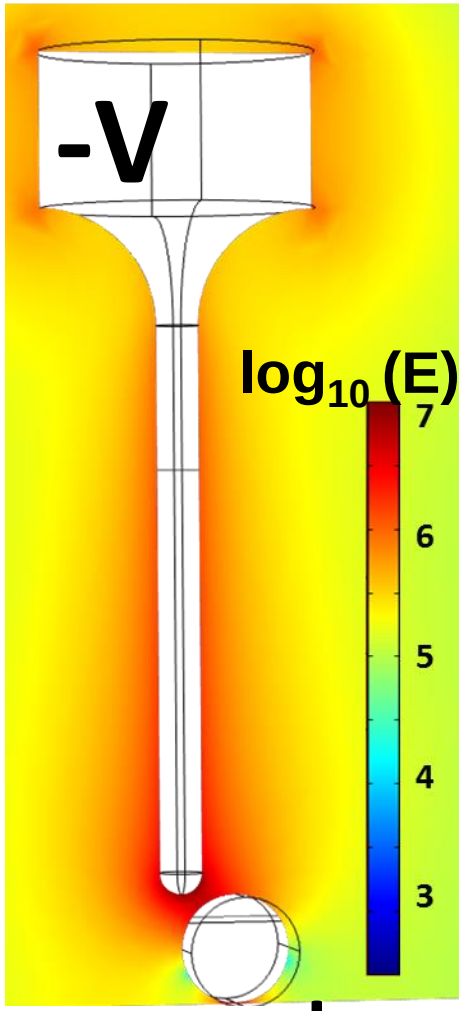
stepped
stepped w/ UV
ramped
ramped w/ UV

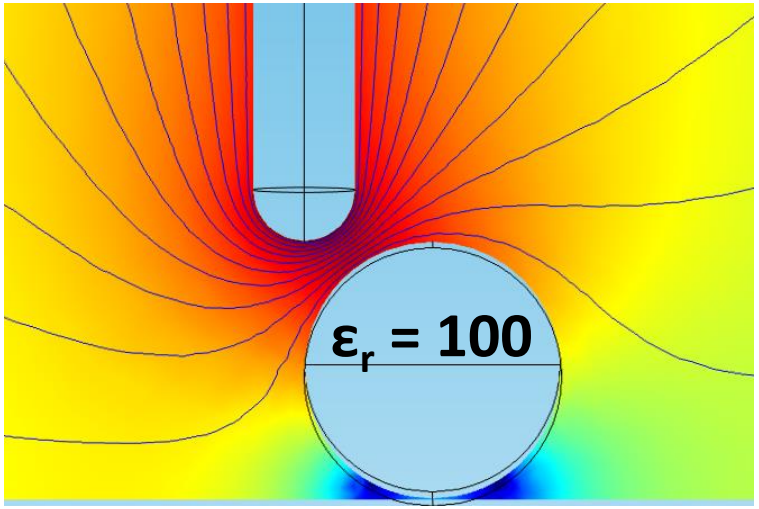
50 % overshoot for ramped voltage (●)

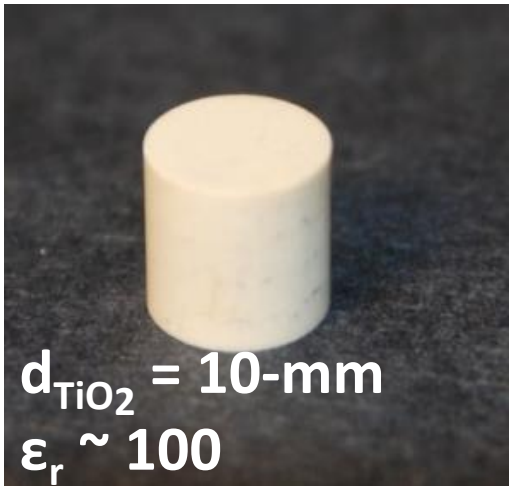
Avalanche to spark transition in an anode-directed streamer



What mechanisms control the surface flashover path and V_B?

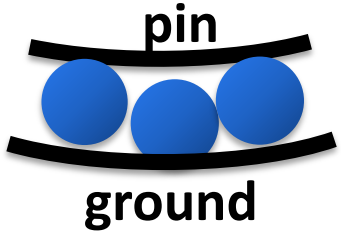




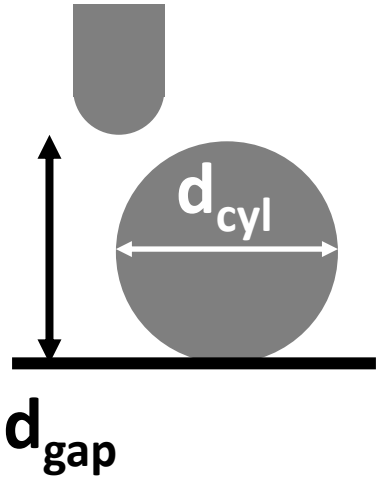


Dielectric cylinders

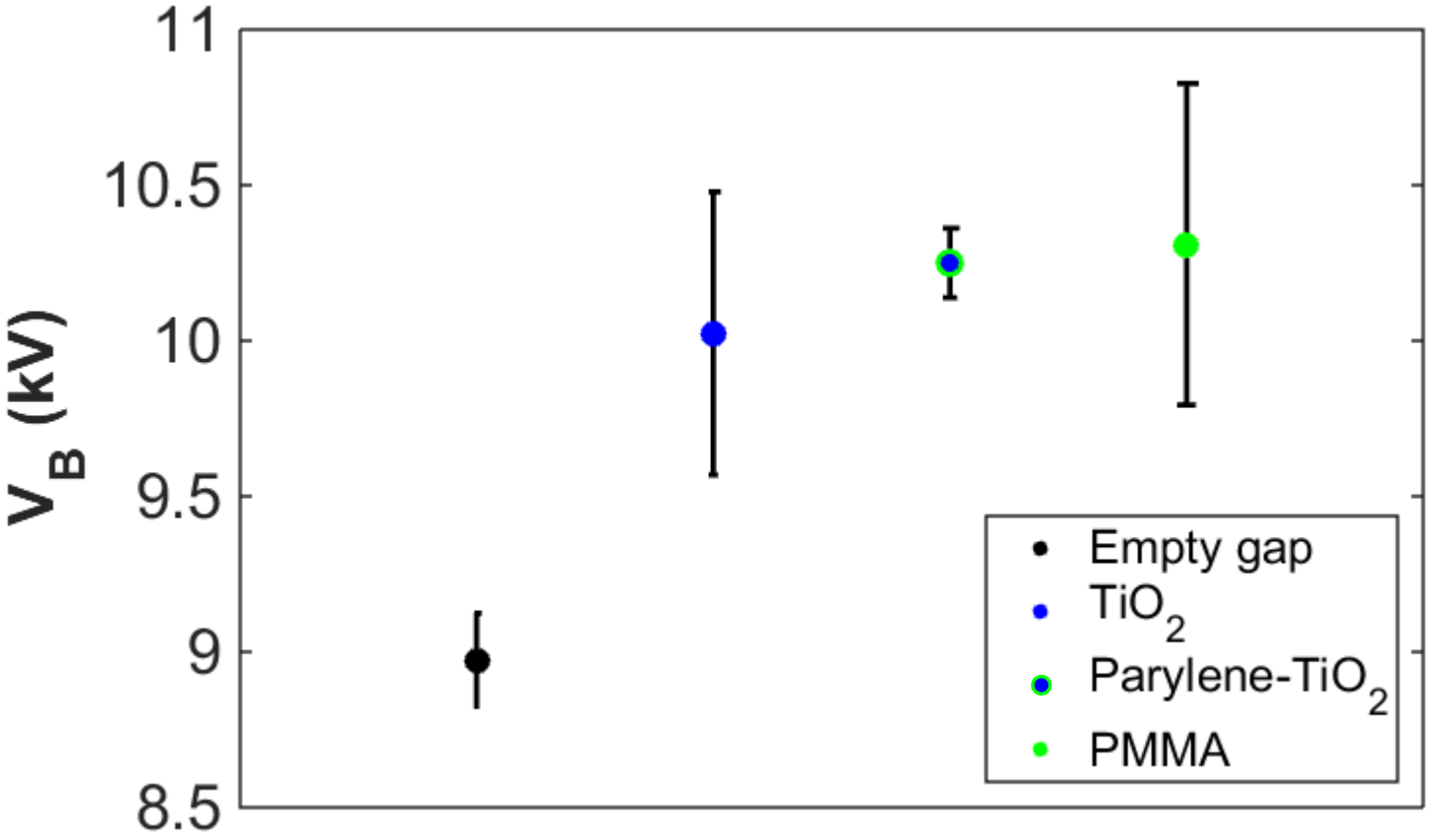
- **TiO_2** → representative of lightning arrestor connectors
- **Parylene-coated TiO_2** → remove TiO_2 surface effects
- **PMMA** → low-K dielectric



With dielectric cylinders, V_B increases slightly and variance increases significantly



d_{gap} = 10 mm
d_{cyl} = 10 mm



10 kV/s voltage rise with UV illumination

Dielectric permittivity dictates flashover path

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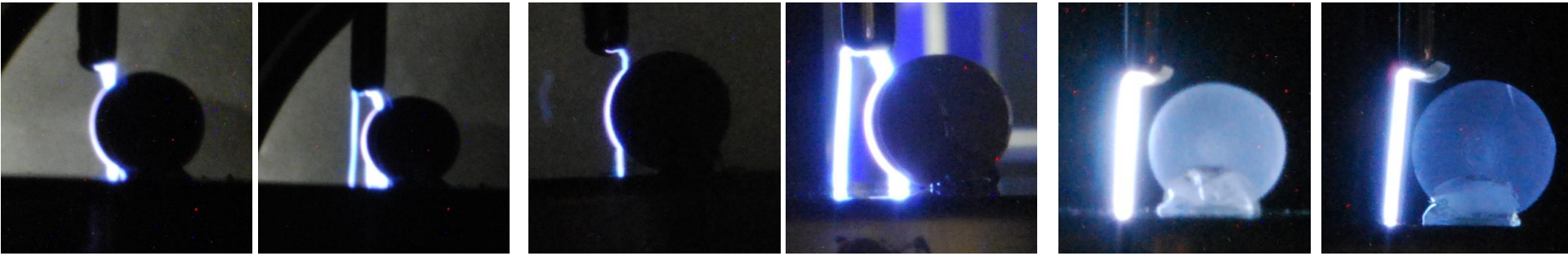
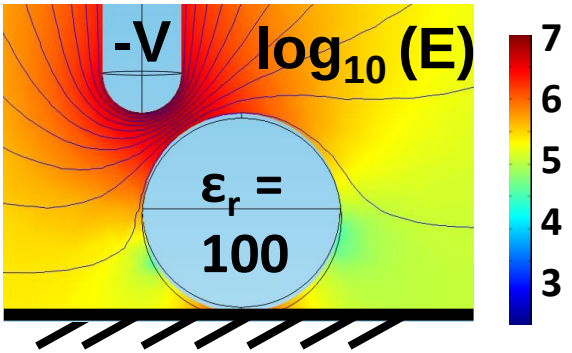
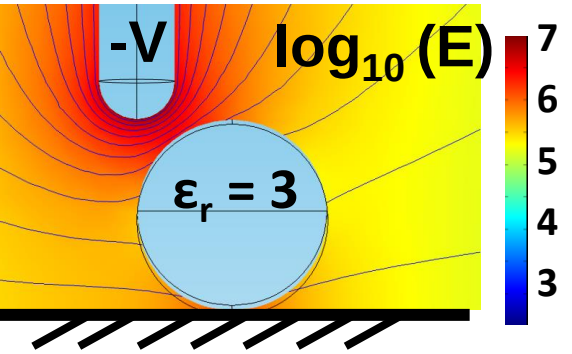
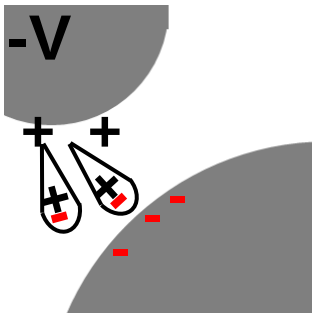
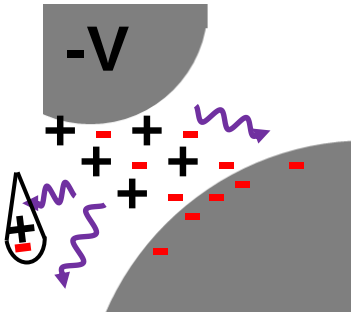
Bare TiO_2 | Parylene-coated TiO_2 | PMMA

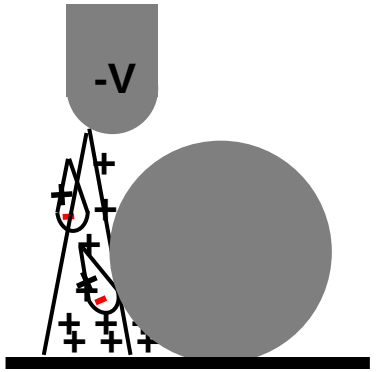


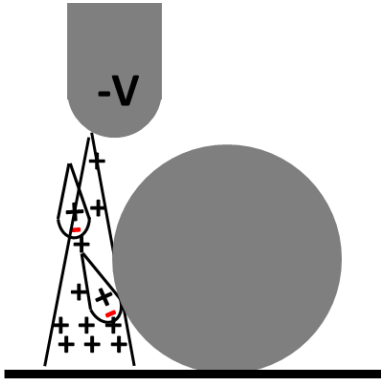


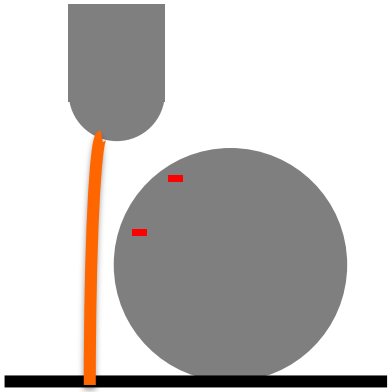






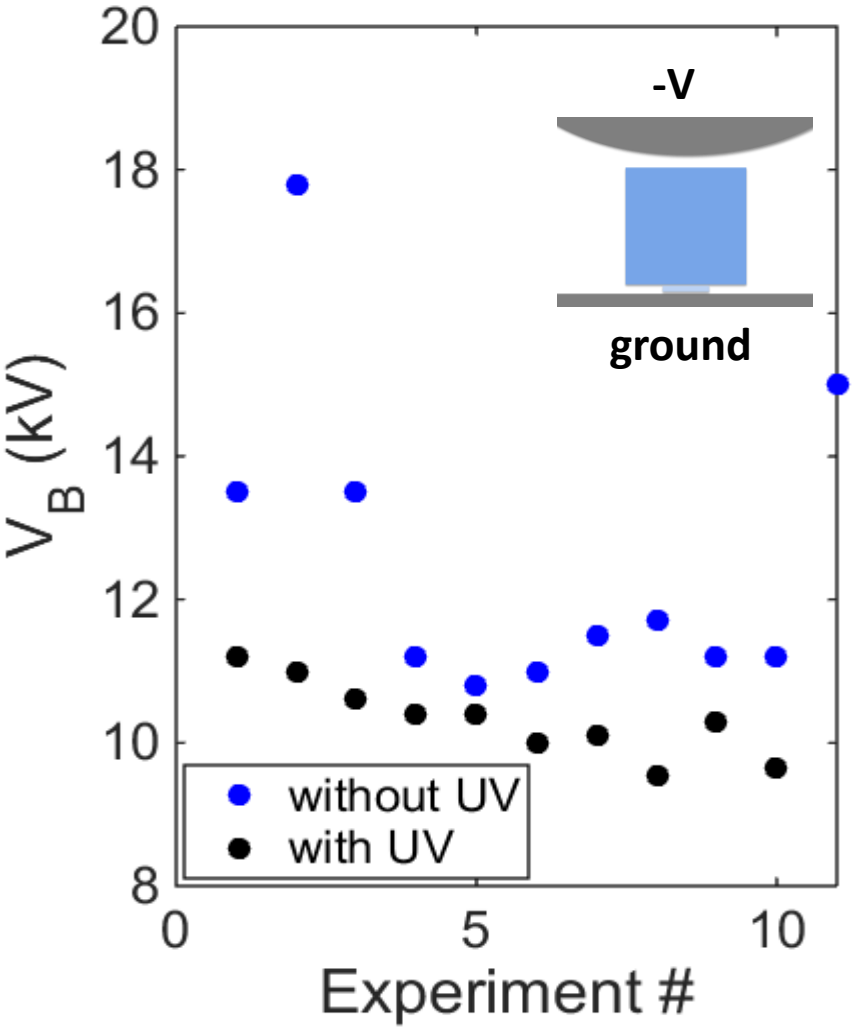


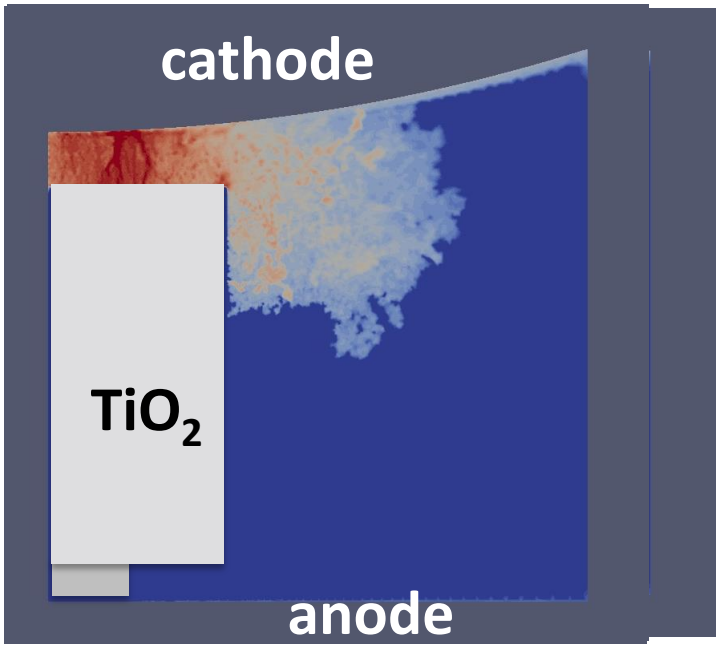


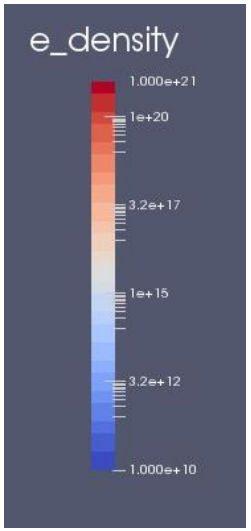


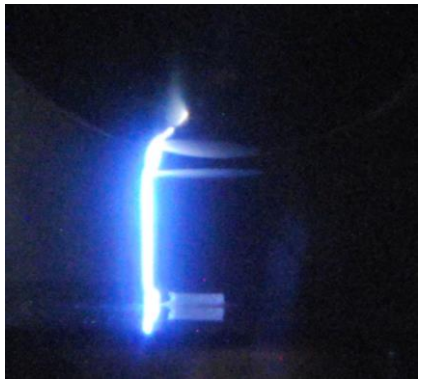
10-mm diameter gap

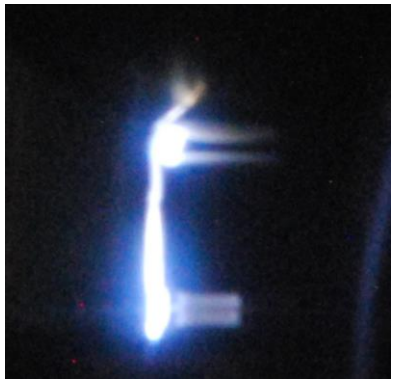
Axisymmetric cylinder placement lowers V_B











10 kV/s voltage rise

Conclusions

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UV-stimulated photoemission from electrodes is required to reduce variance in atmospheric breakdown experiments.

High-K dielectric cylinders enhance the electric field in the rod-cylinder gap, initiating breakdown in this sub-gap region.

Arc attachment to dielectric surfaces is driven by the dielectric permittivity; high-permittivity dielectrics exert a larger image force on the electrons within the streamer.

Axisymmetric geometry is being pursued to correlate models with data

Acknowledgements

Collaborators: Kenneth Williamson, Harold Hjalmarson, Chris Moore, and Rebecca Coats

Colleagues: Dan Sandoval, Ray Martinez, and Zach Wallace

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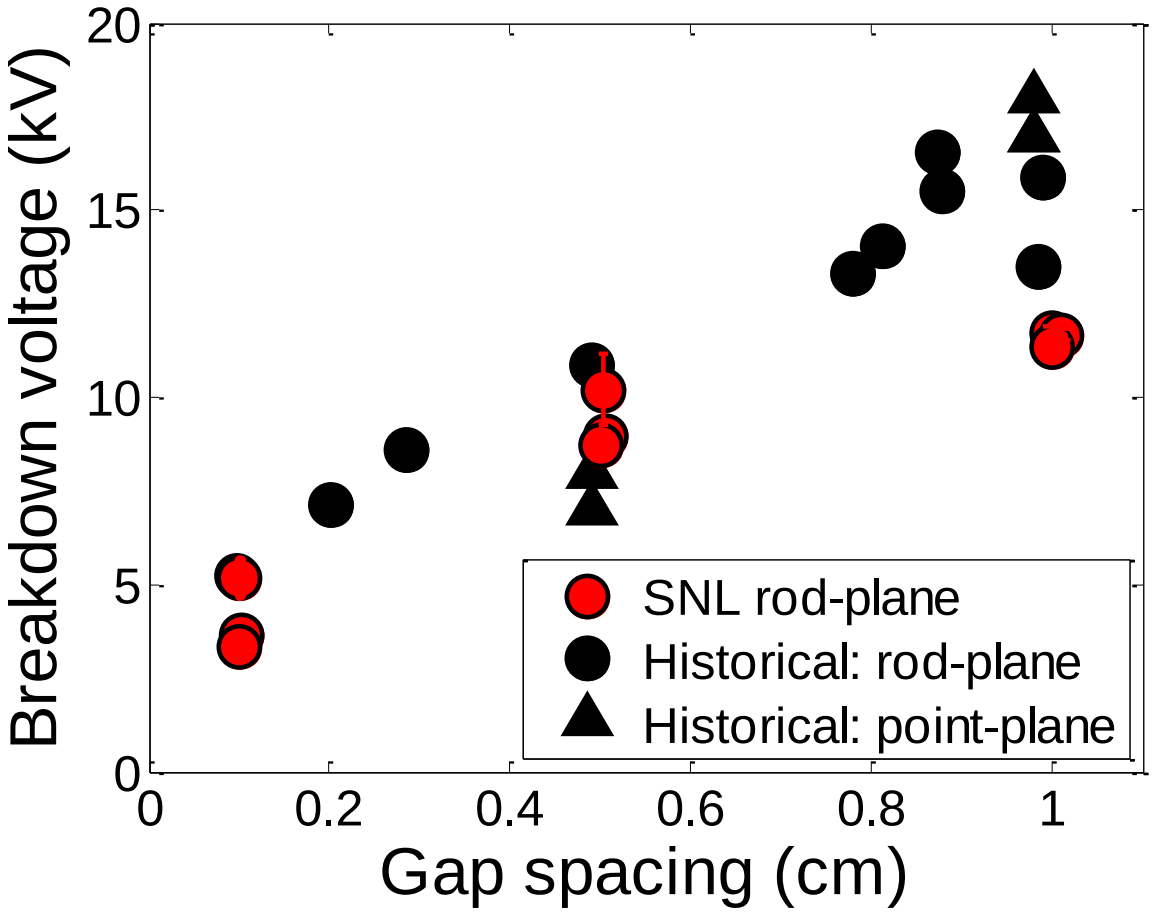
Atmospheric breakdown agrees with historical standards

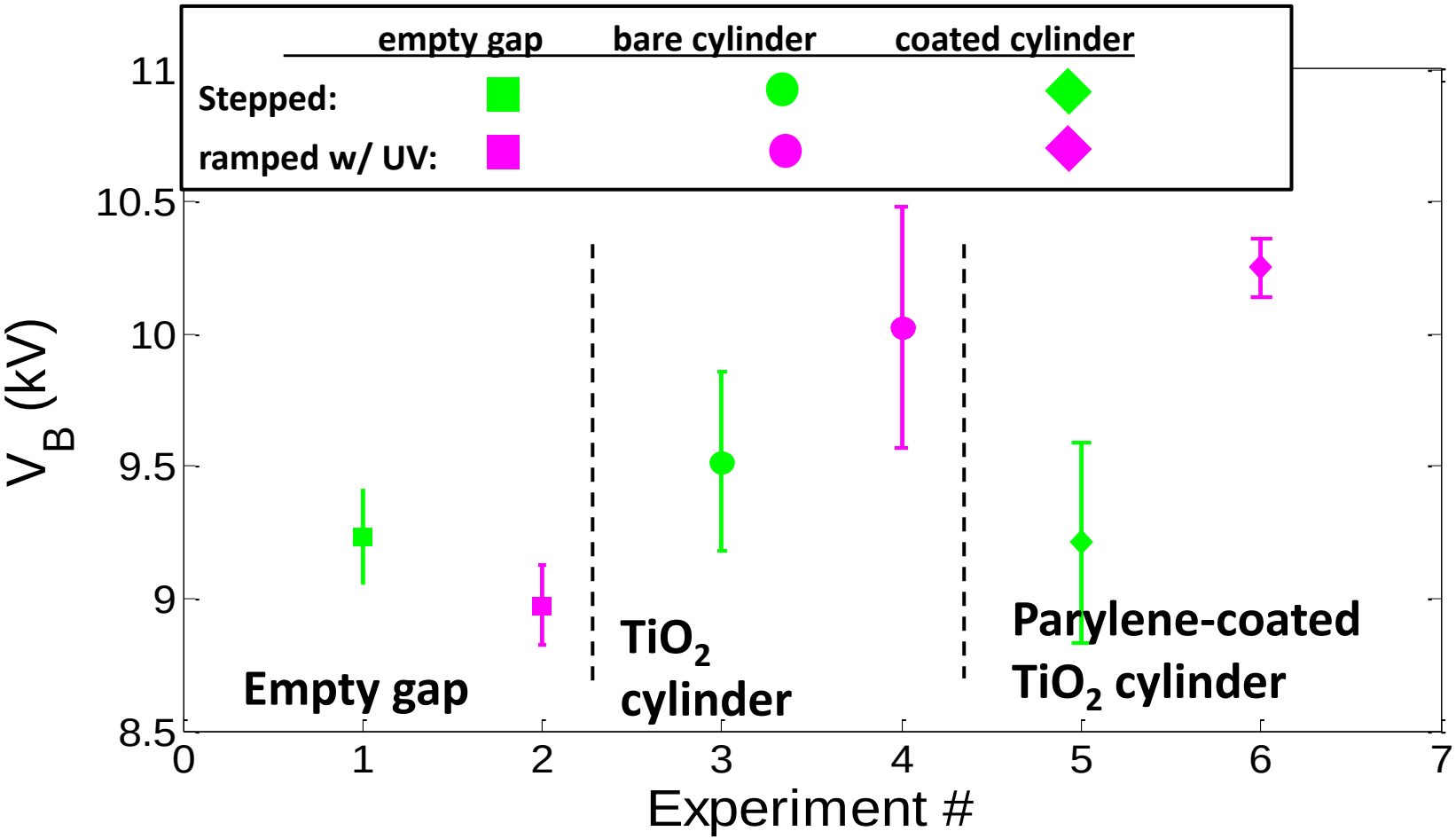


200 experiments; each dot is an average of 20-40 breakdown events

Error bars are smaller than most markers

For experiment details, see Ken Williamson *et al.*

With TiO_2 cylinder, VB increases slightly and variance increases significantly



Supplementary information: Same experiments with UV-illumination