2-23-2017

Using Quantile-Quantile Plots to Compare Experimental Apples and Oranges in Physics Labs

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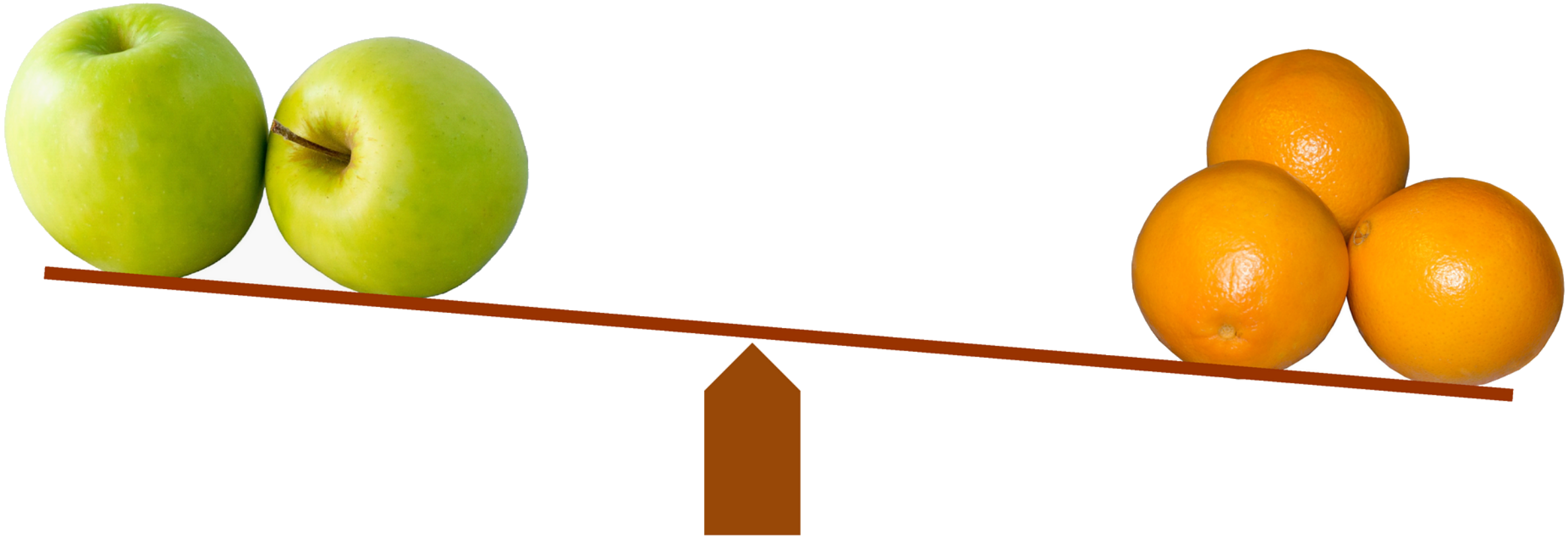
Comparing Experimental Apples and Orange with Quantile-Quantile Plots



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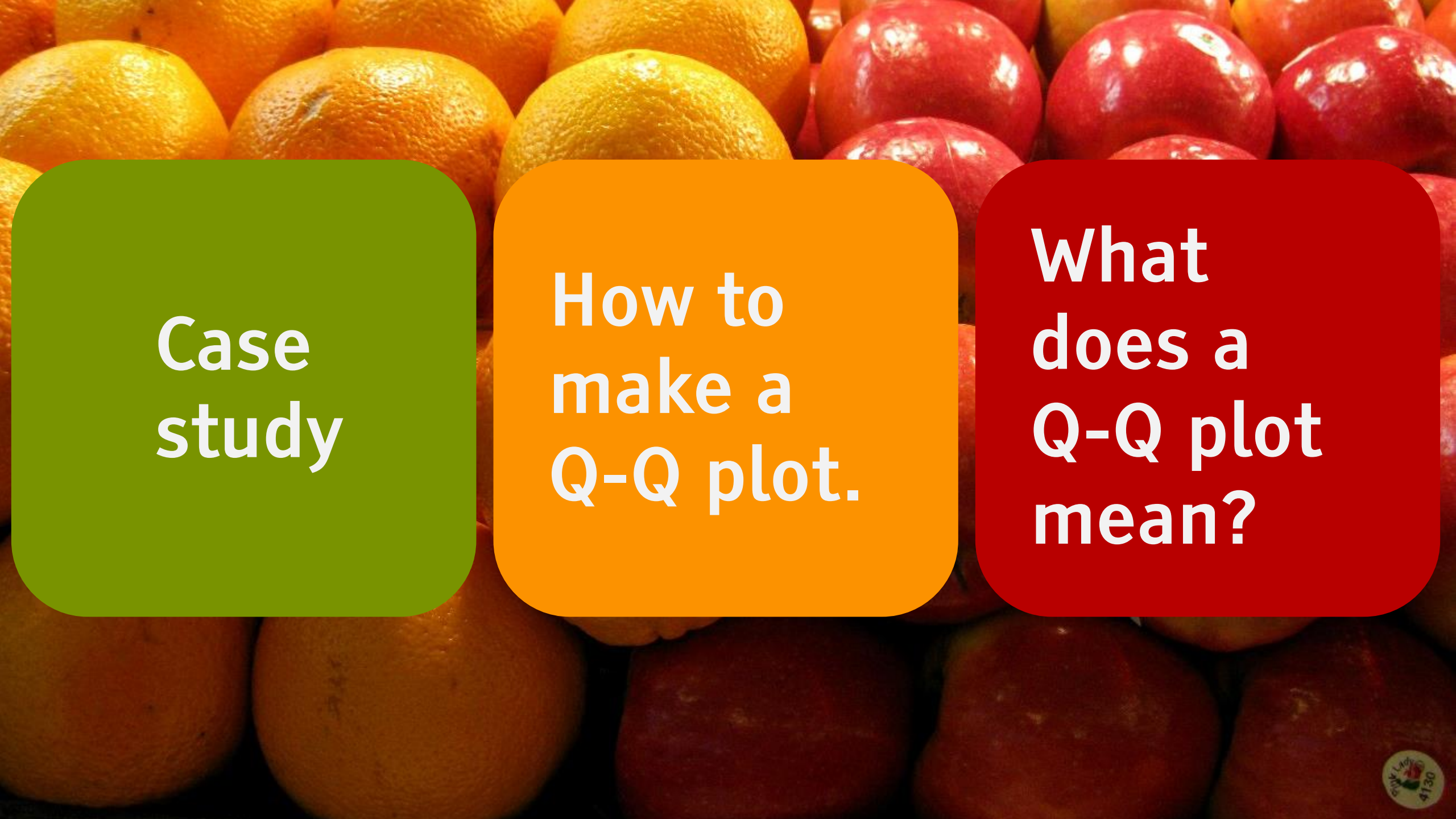
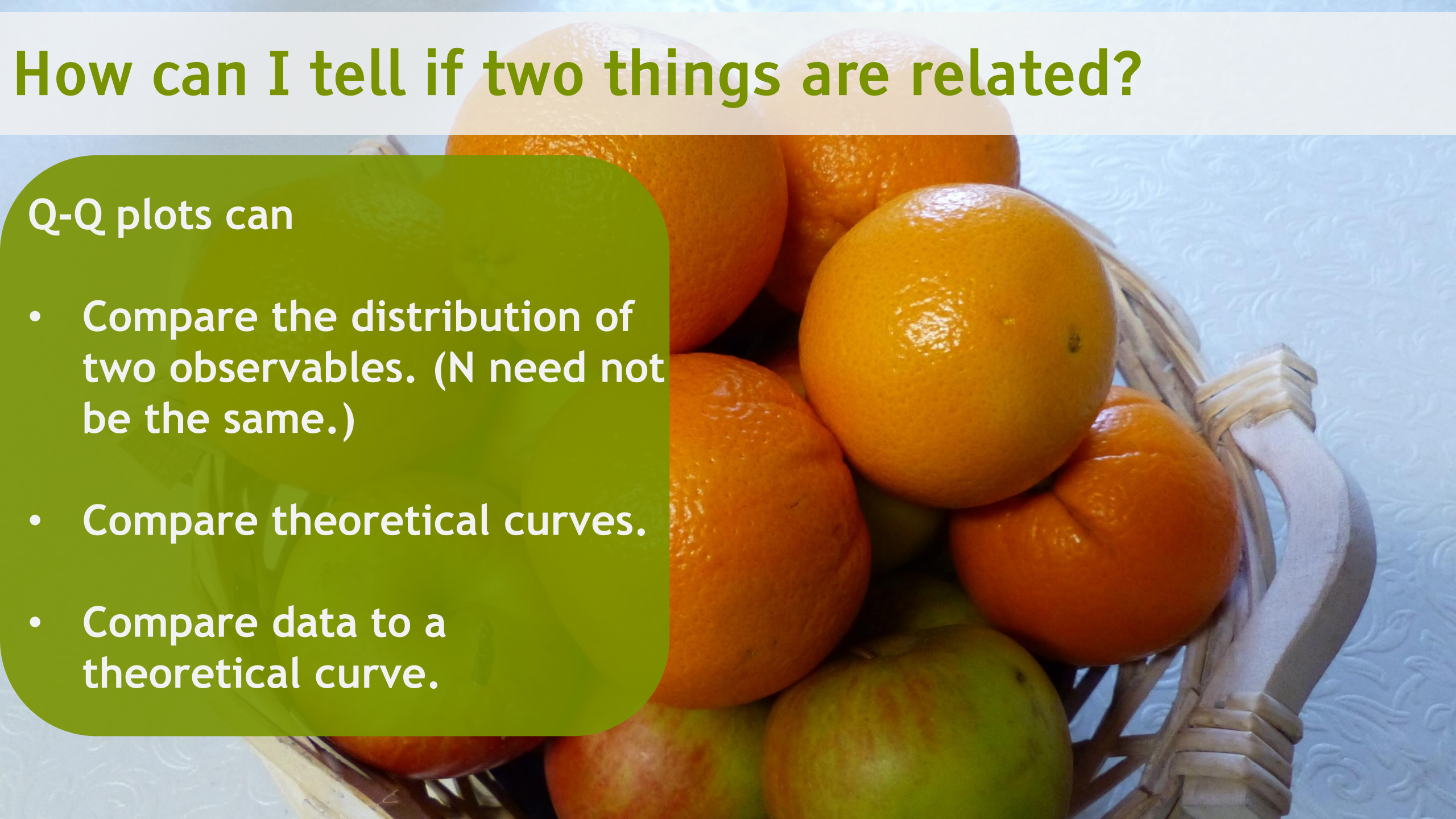
MATERIALS
PHYSICS GROUP

APS
physics
4CS
FOUR CORNERS SECTION


Case study
How to make a Q-Q plot.
What does a Q-Q plot mean?

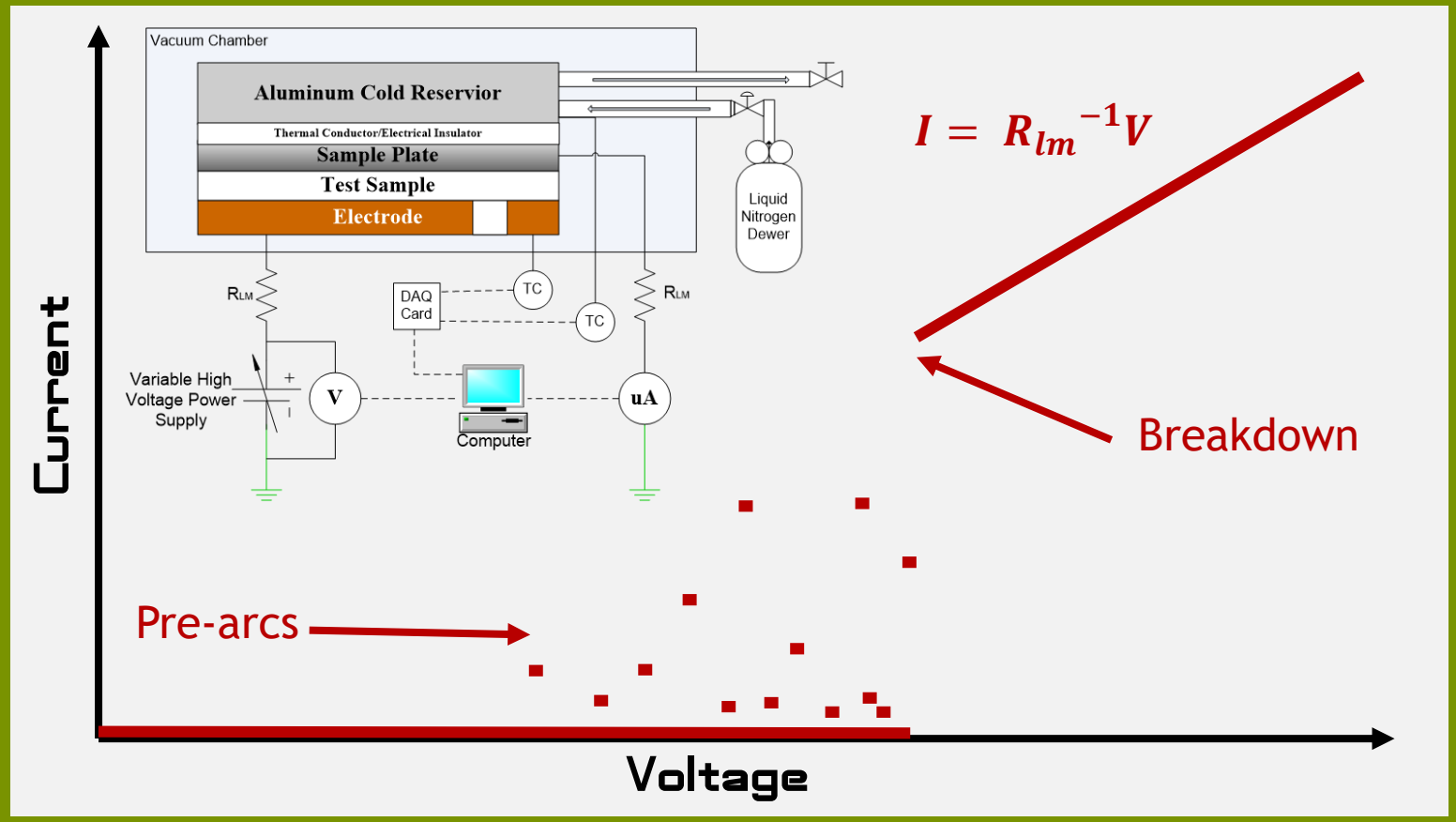
How can I tell if two things are related?



Q-Q plots can

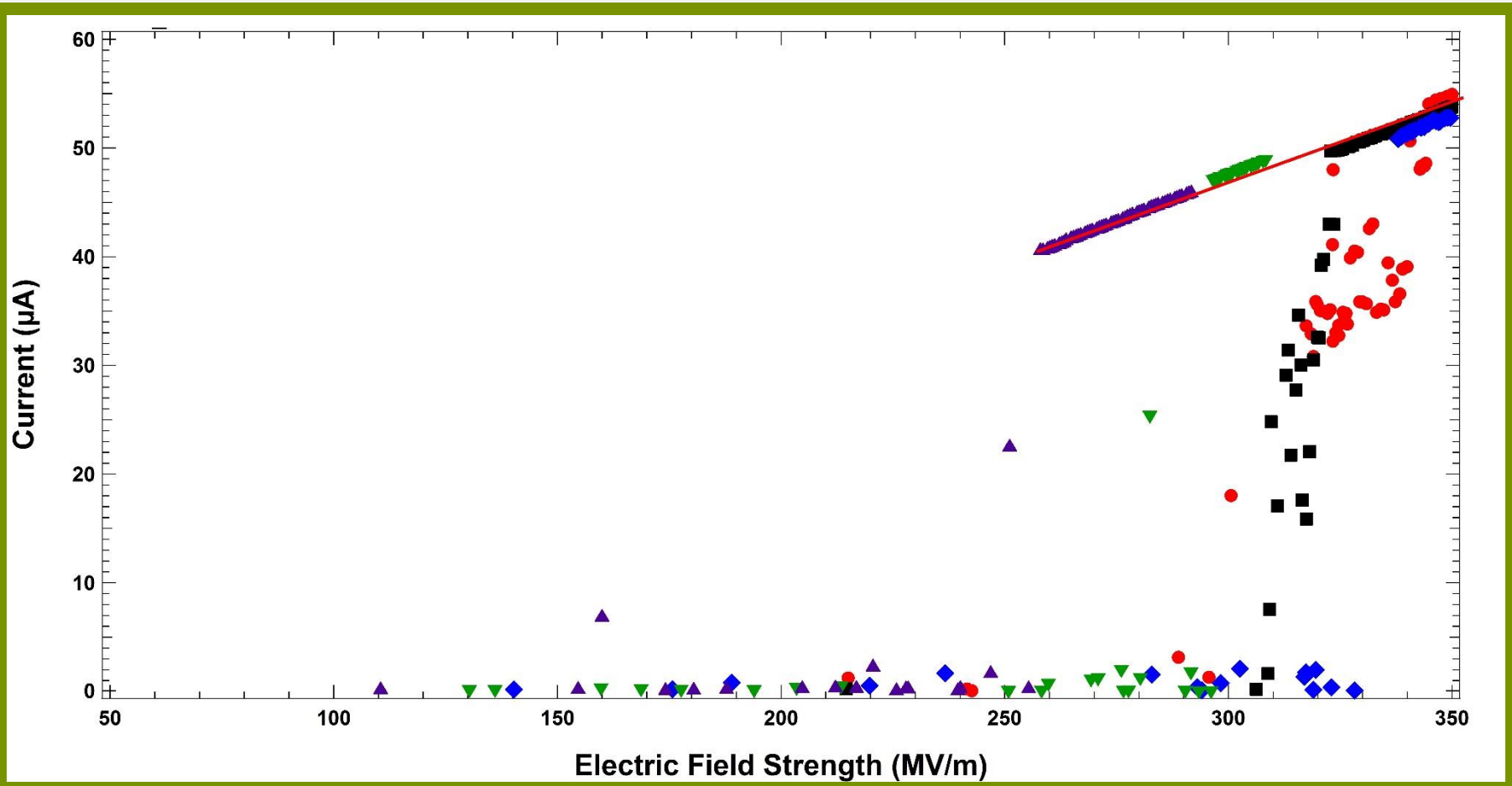
- Compare the distribution of two observables. (N need not be the same.)
- Compare theoretical curves.
- Compare data to a theoretical curve.

Case Study: Dielectric Breakdown Testing



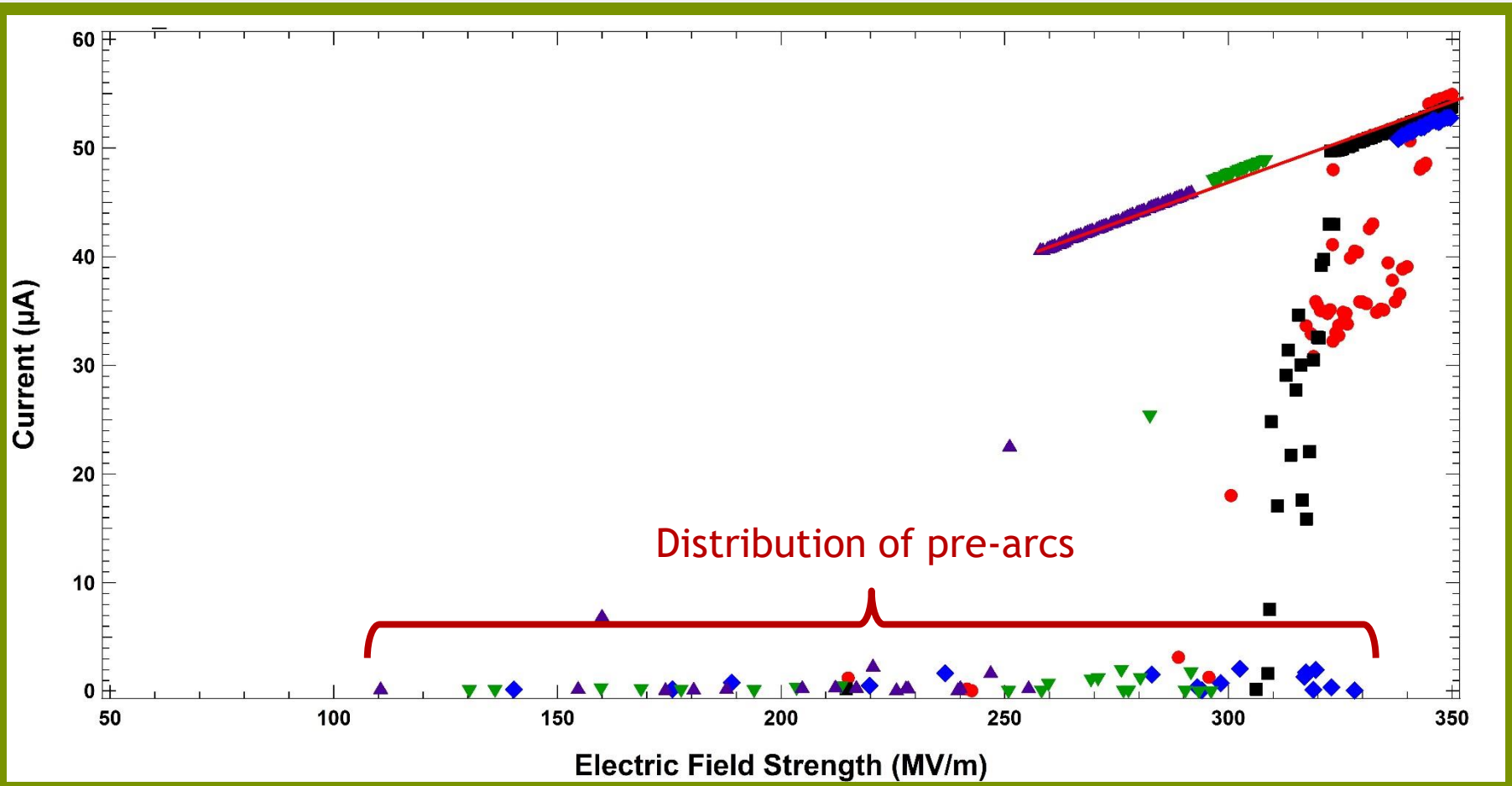
Voltage is increased across a dielectric sample in a parallel-plate capacitor and monitor the leakage current.

Case Study: Dielectric Breakdown Testing



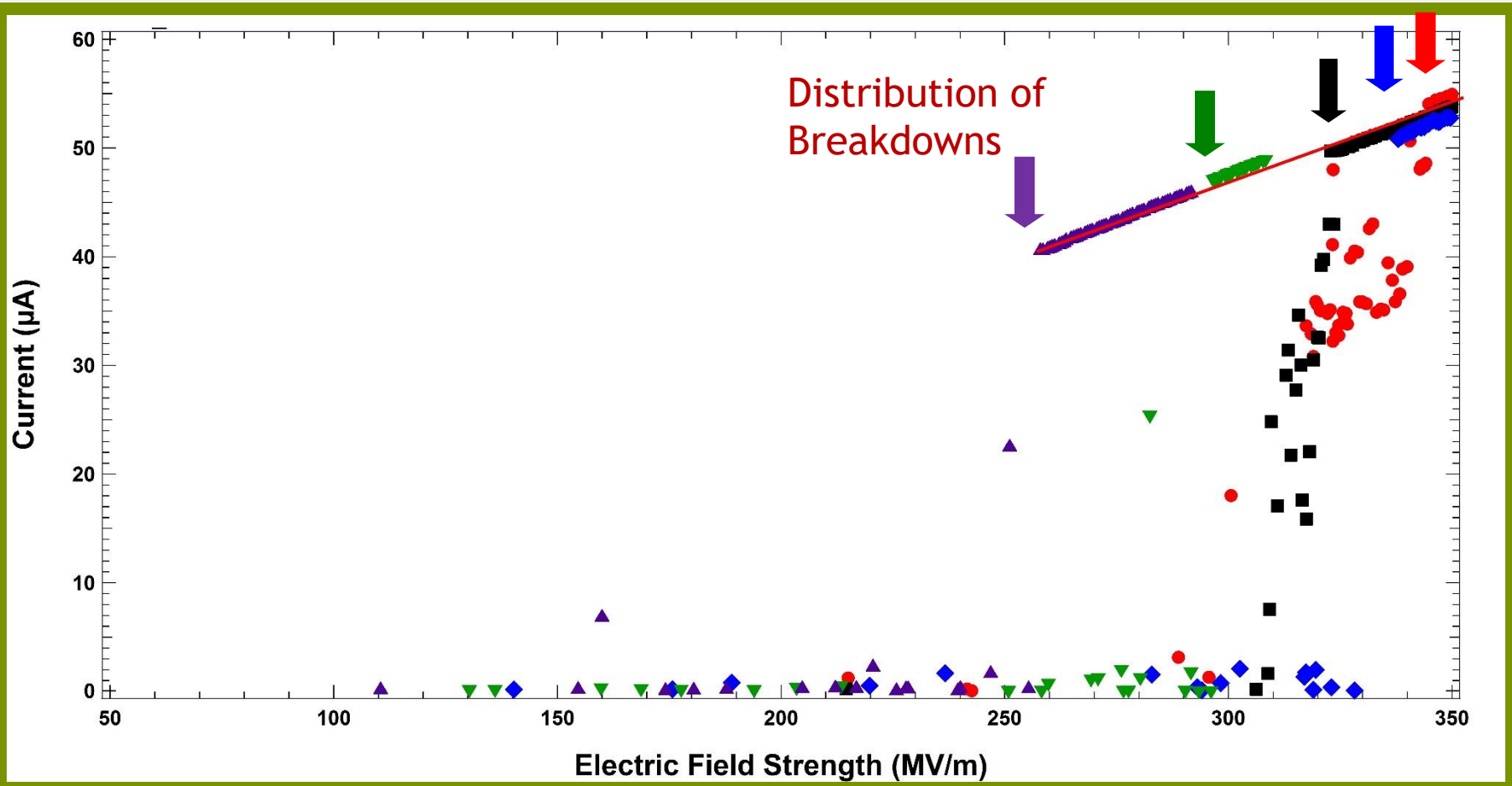
Plot of 5 voltage step-up to breakdown tests on LDPE.

Case Study: Dielectric Breakdown Testing



Plot of 5 voltage step-up to breakdown tests on LDPE.

Case Study: Dielectric Breakdown Testing



Plot of 5 voltage step-up to breakdown tests on LDPE.

Are pre-arcs related to the breakdowns?

Pre-arcing distributions

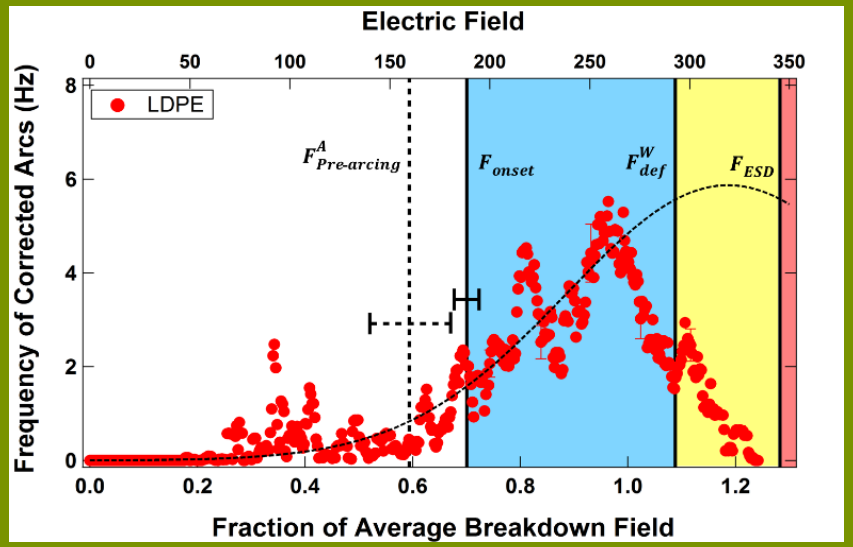
?

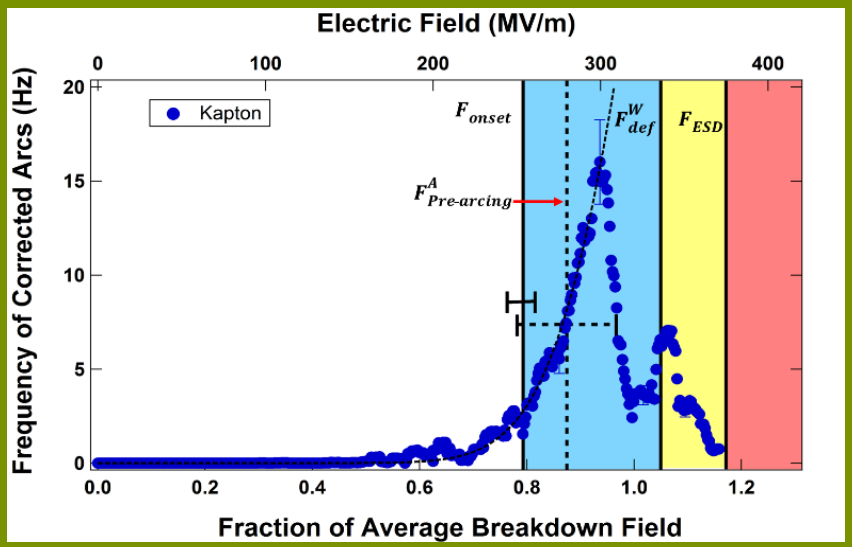
=

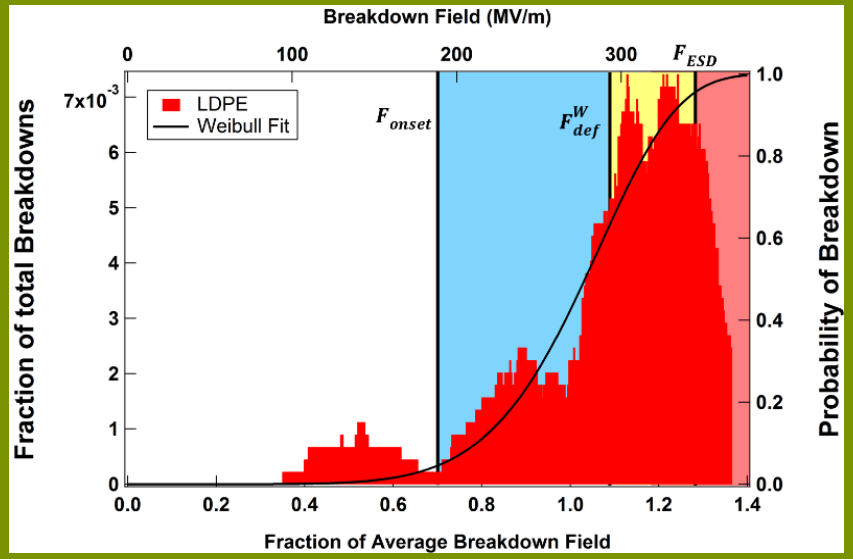
Breakdown distributions

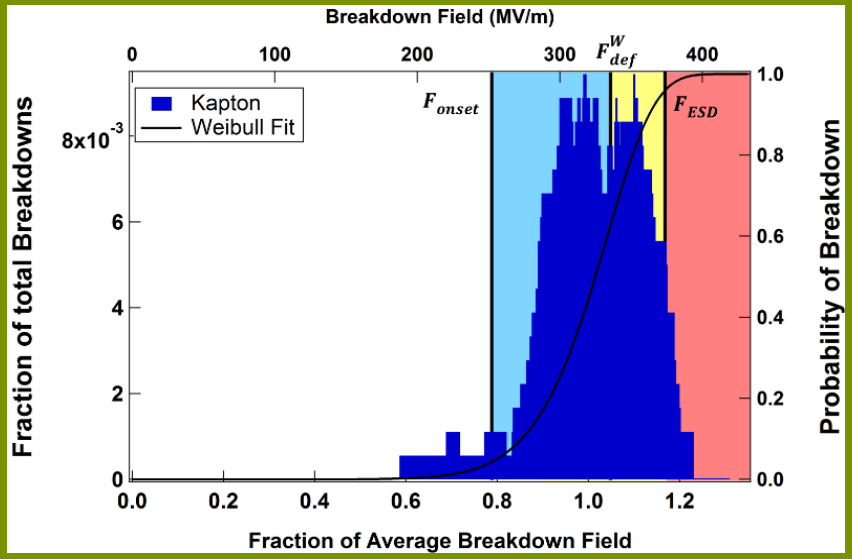
The reviewer for our last paper was not convinced.

A better method was needed.

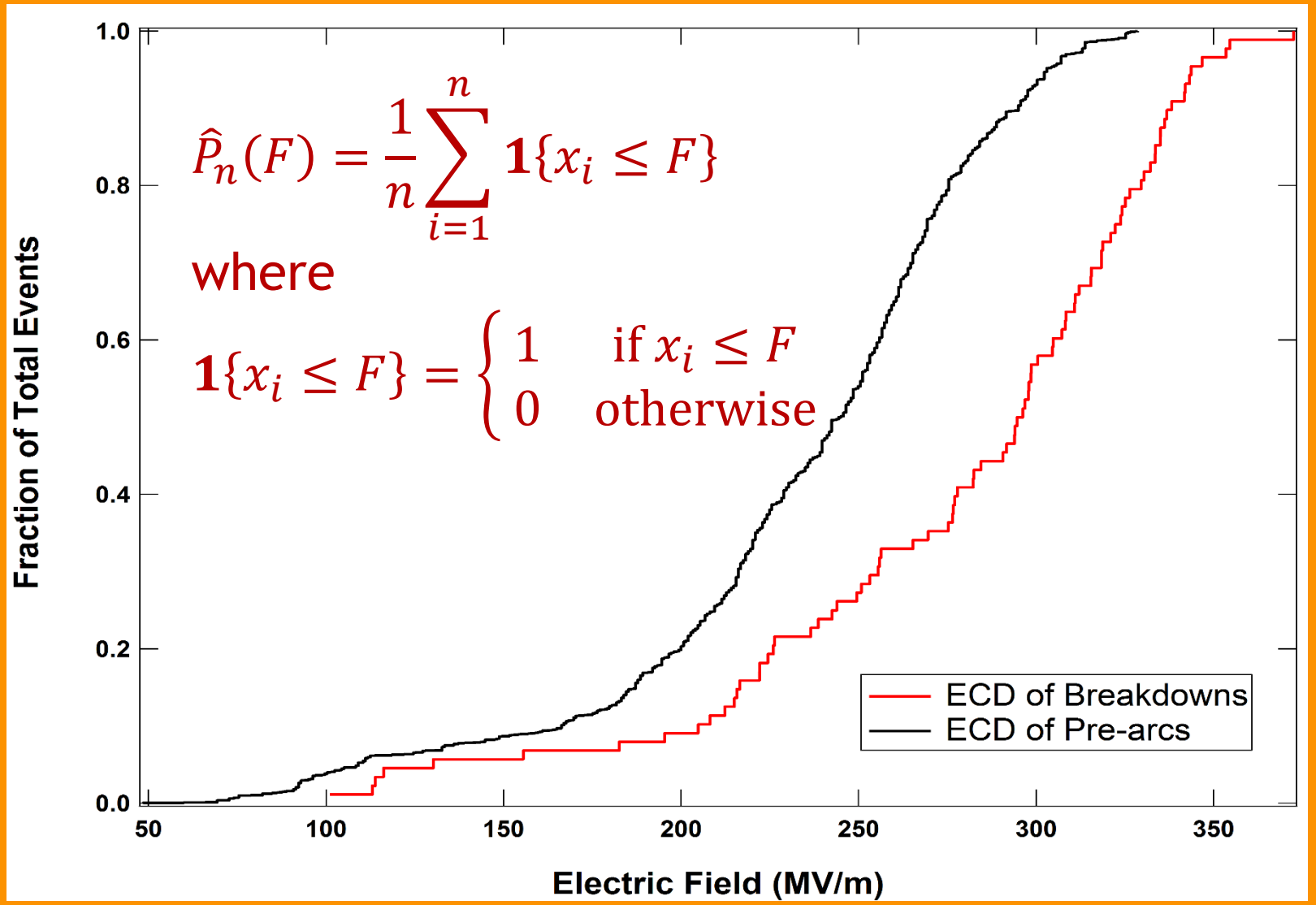




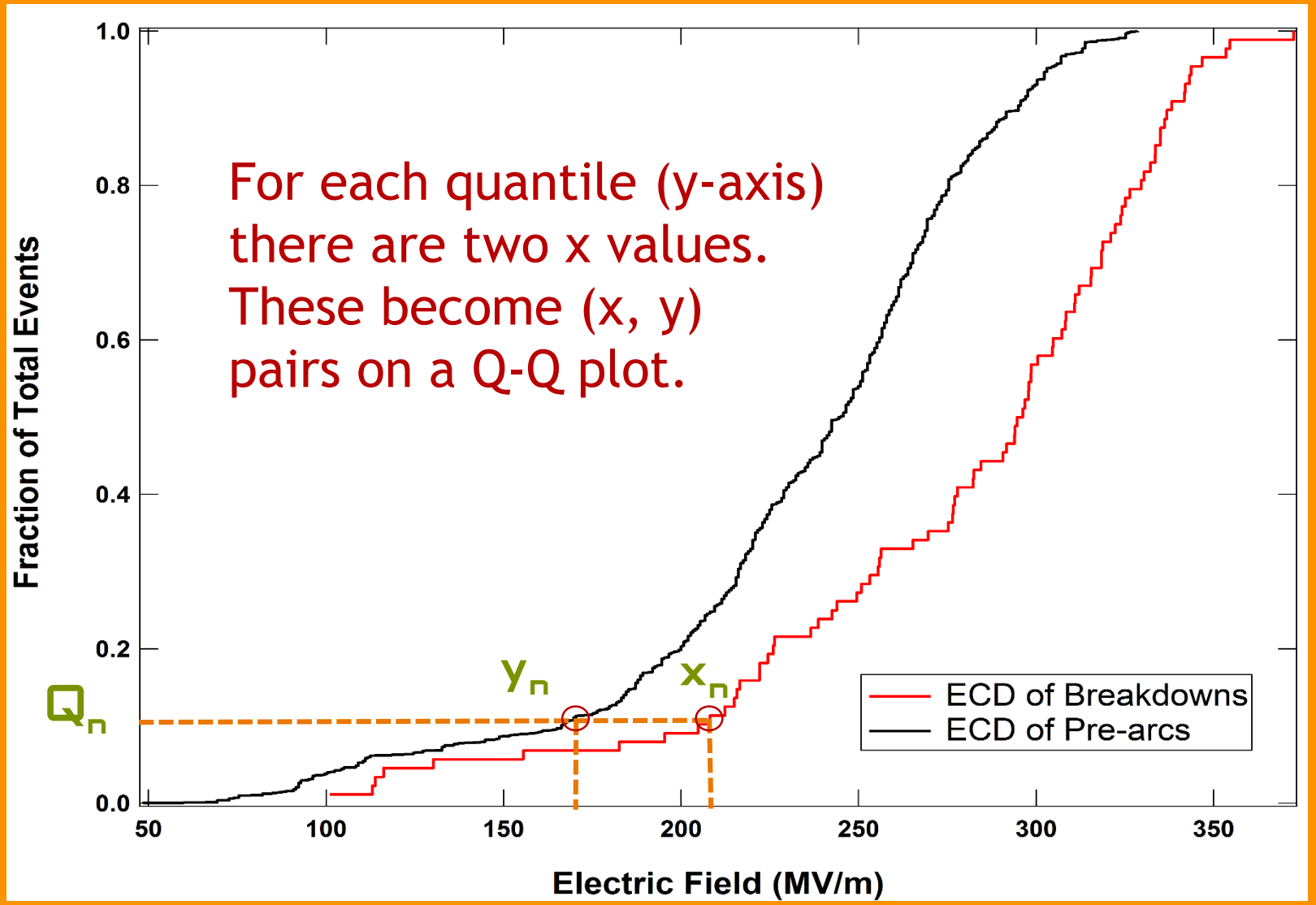




Step 1: Empirical Cumulative Distributions



Step 2: Match the quantiles.



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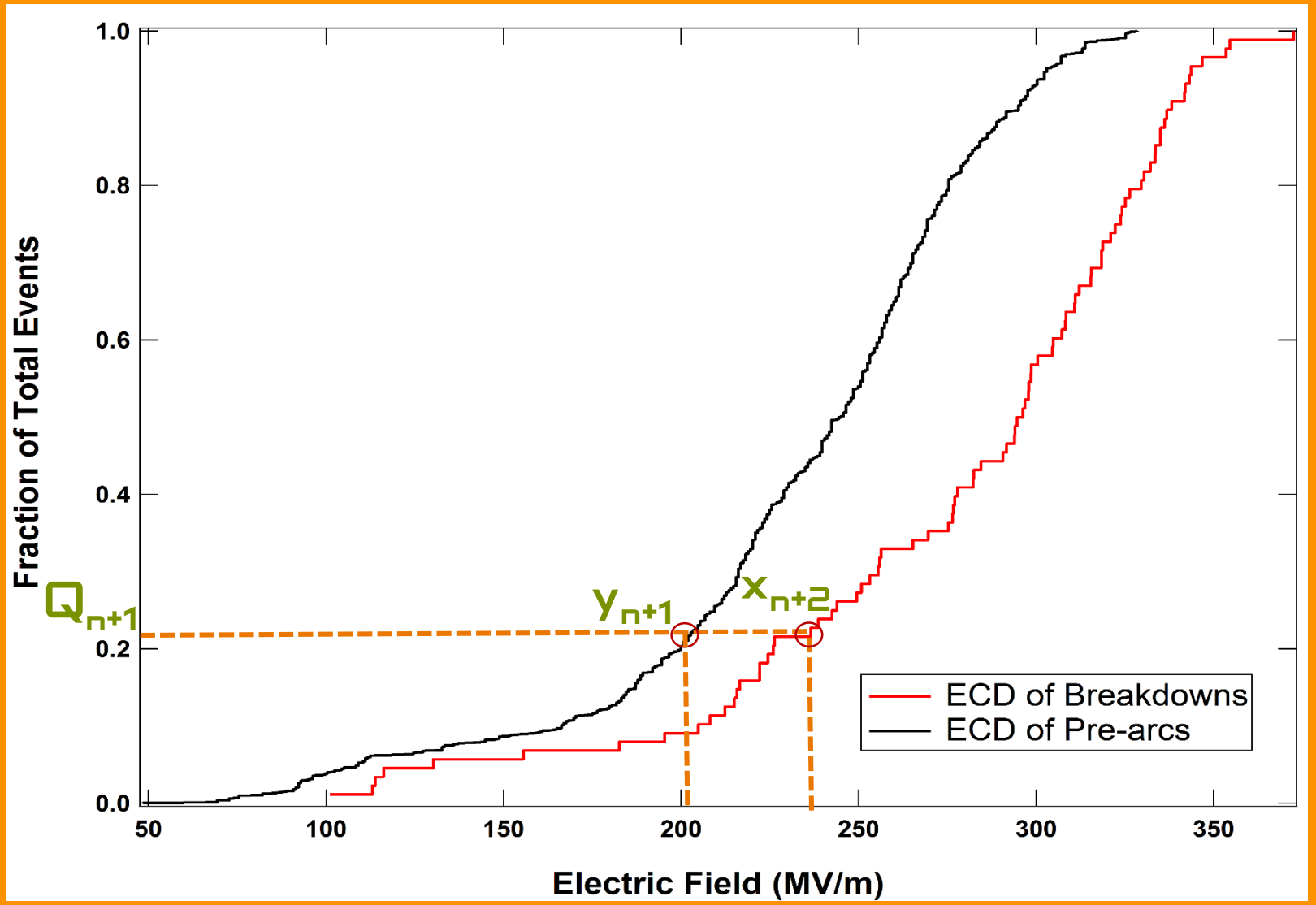

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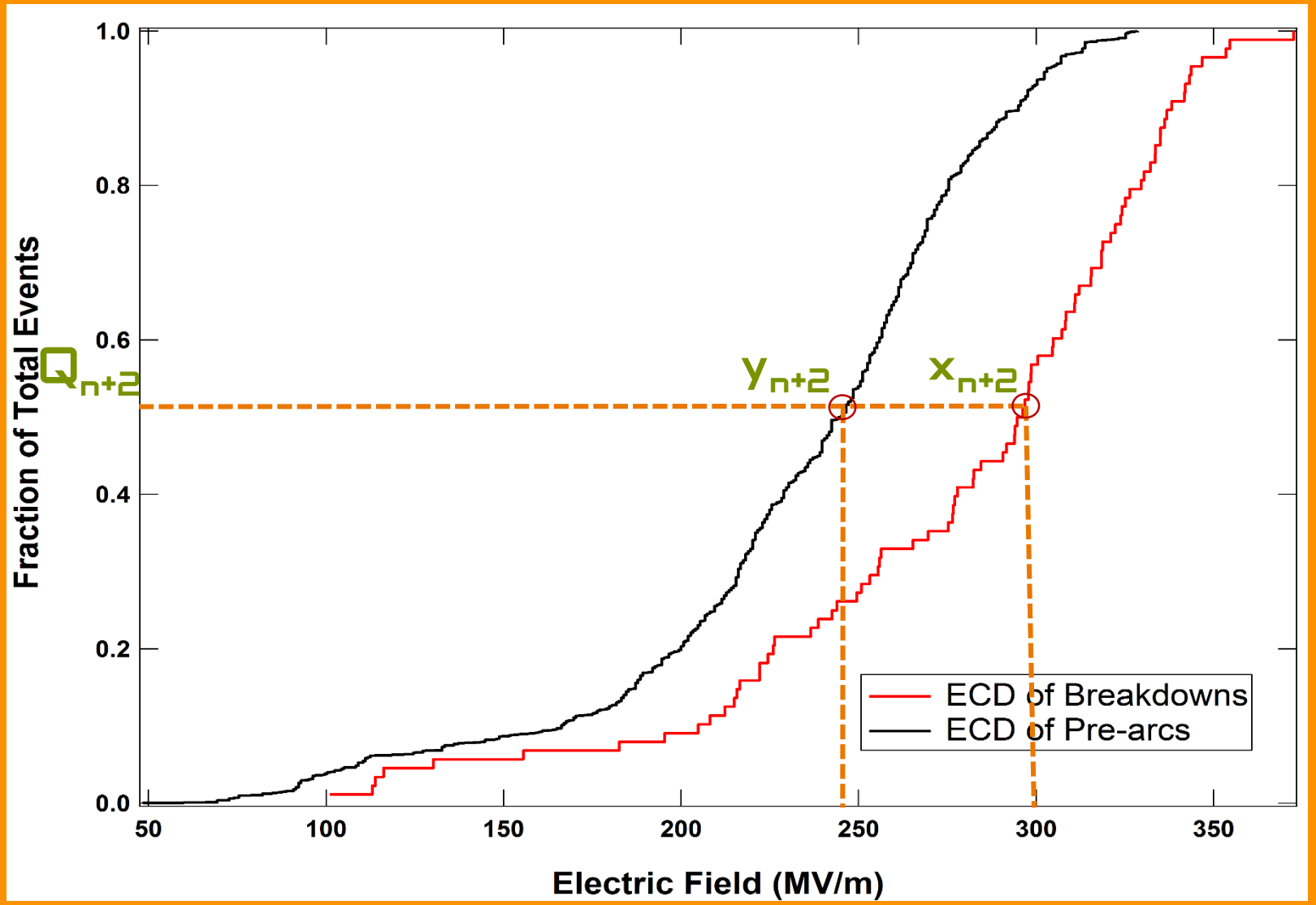

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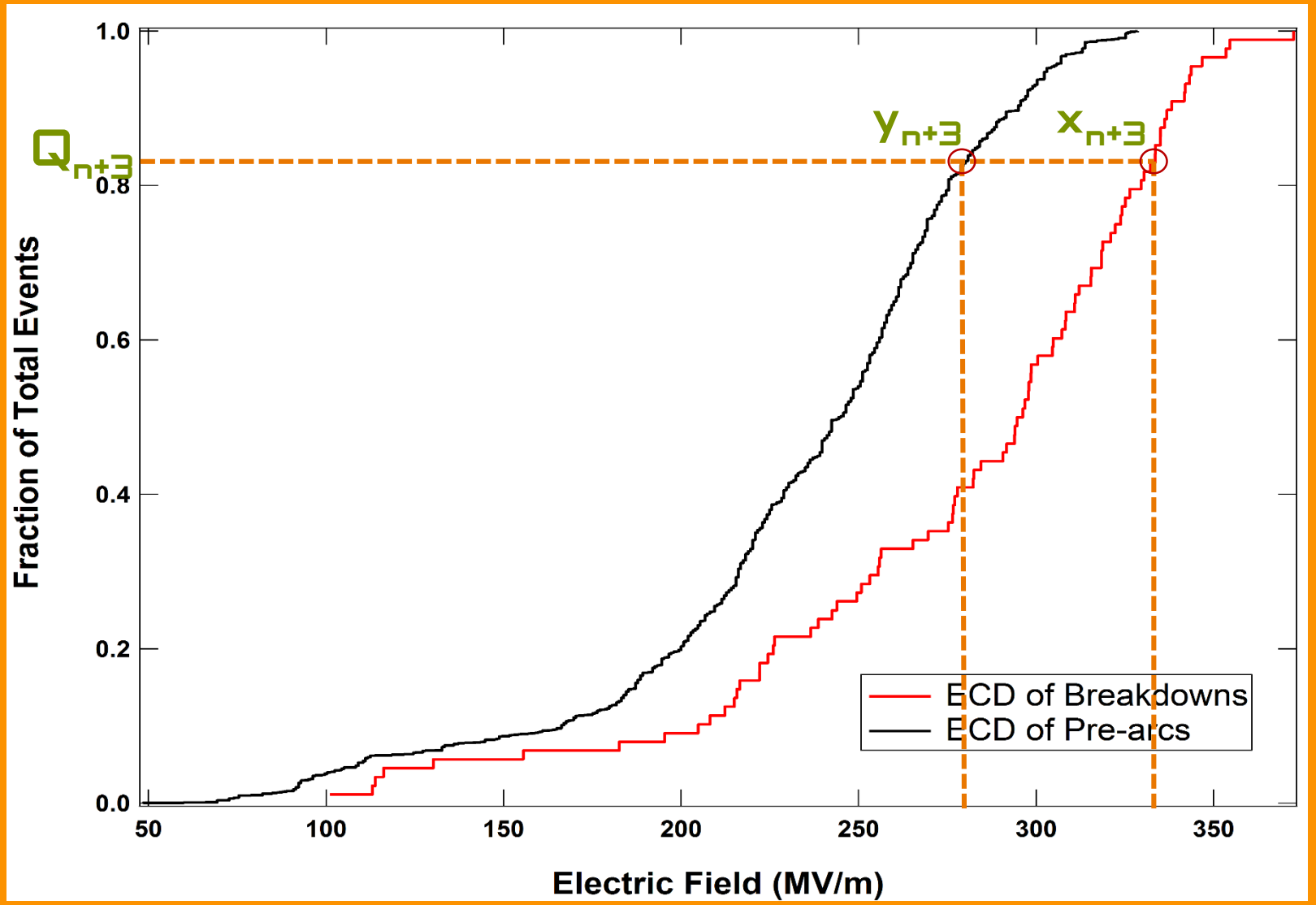
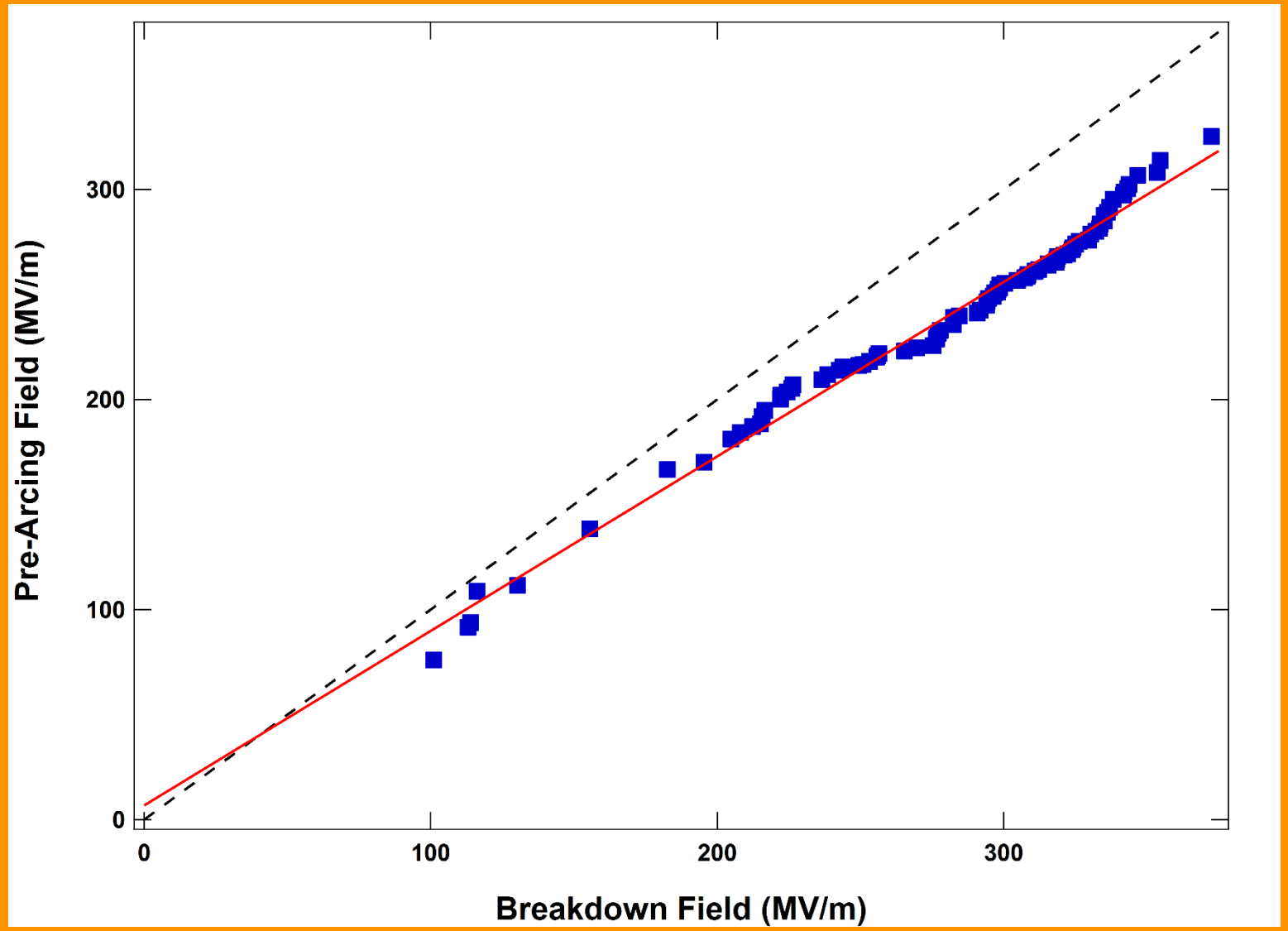


Step 3: Plot pairs and fit to a line.

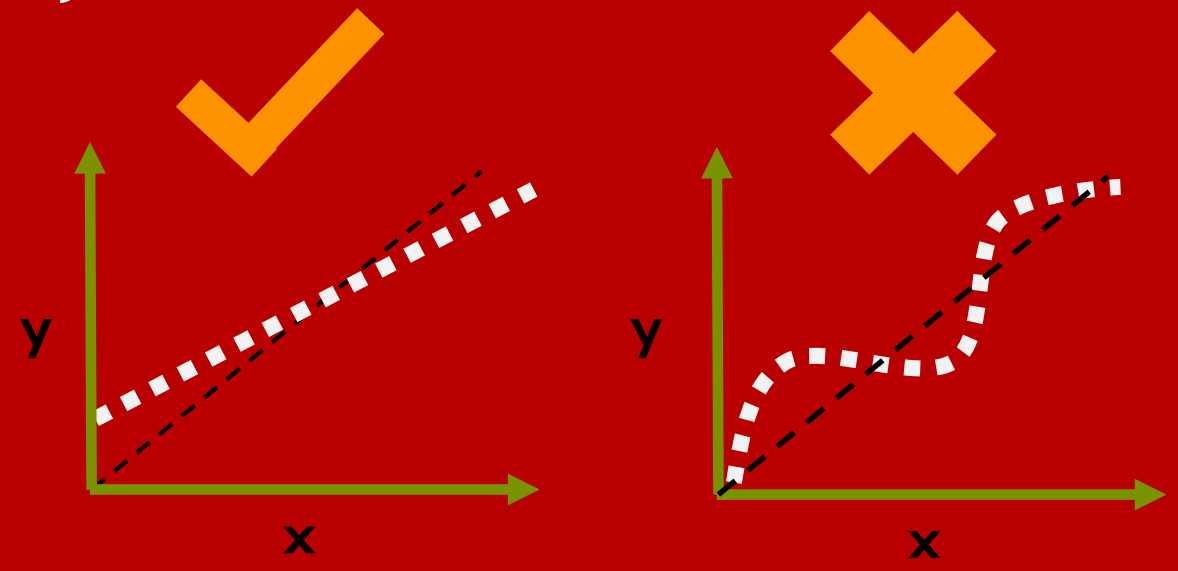


What does it mean?

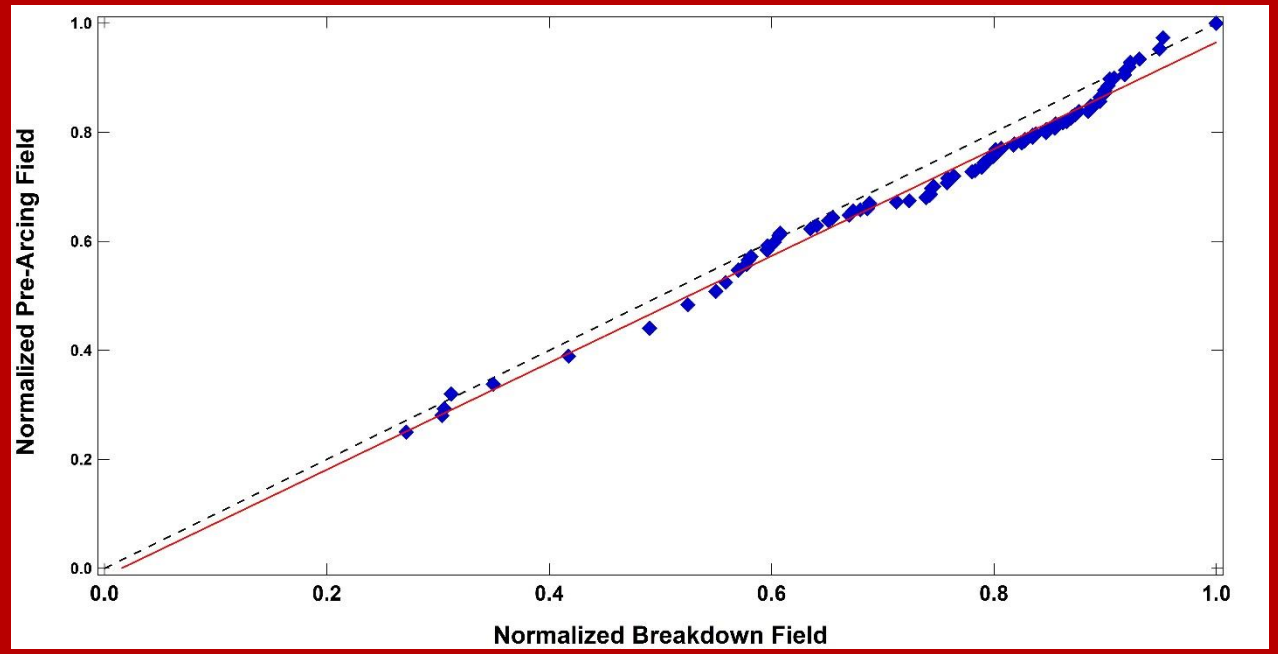
Quantile-Quantile plots compare the distributions of two observables.

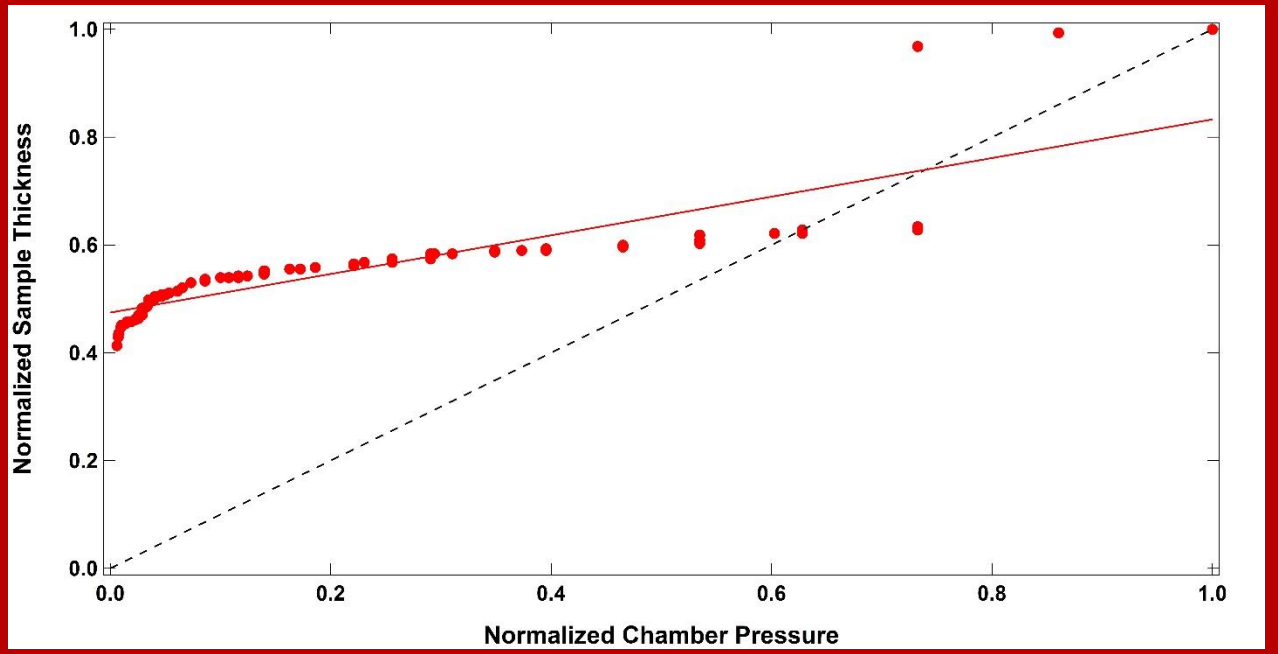
If the distributions are related the plot is a linear.

If the fields at each quantile are identical, points will lie on y=x.



Check the method.

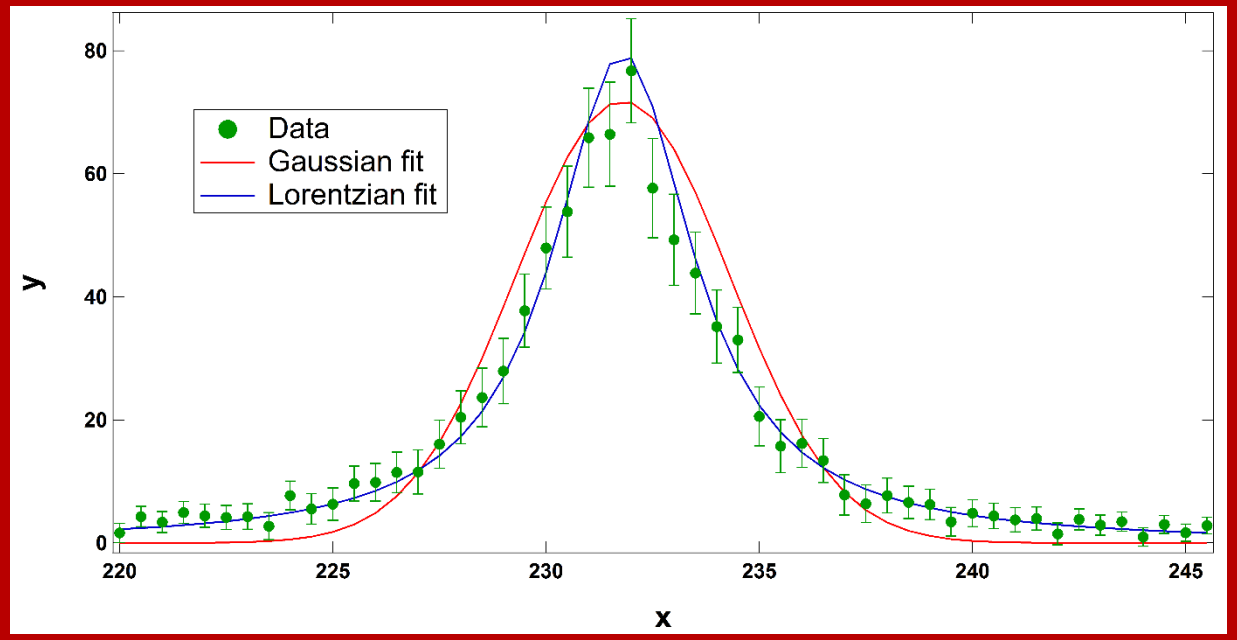


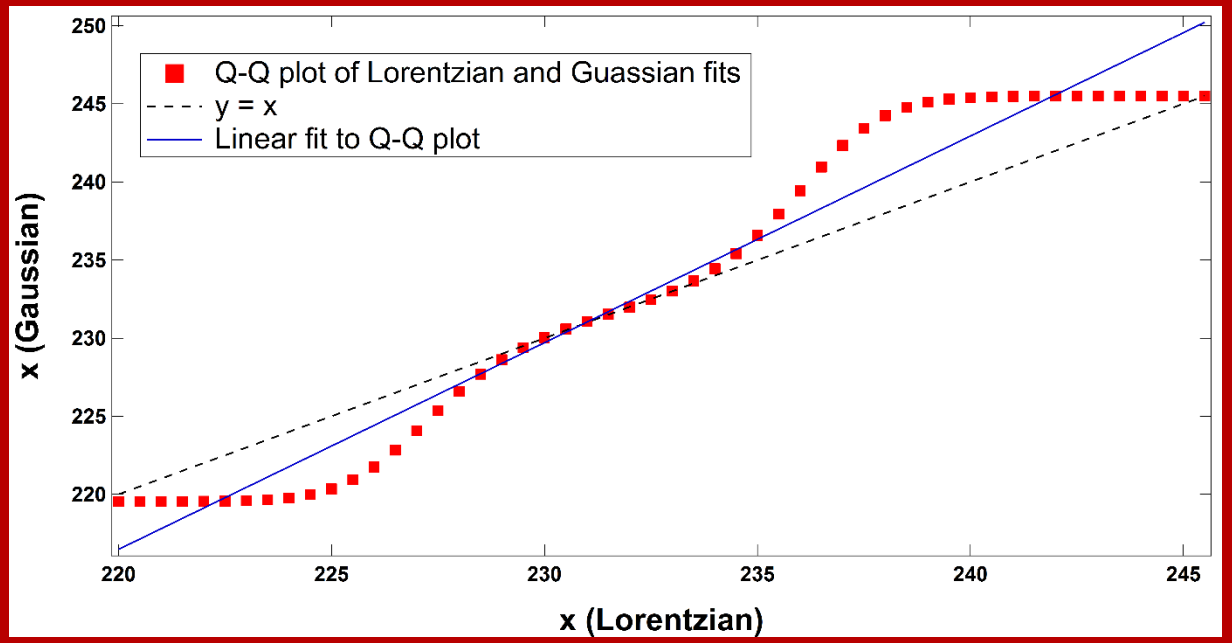


We see that pre-arcing correlates very well to breakdowns.

Sample thickness and chamber pressure do not—no surprise.

Additional Applications of Q-Q plots.

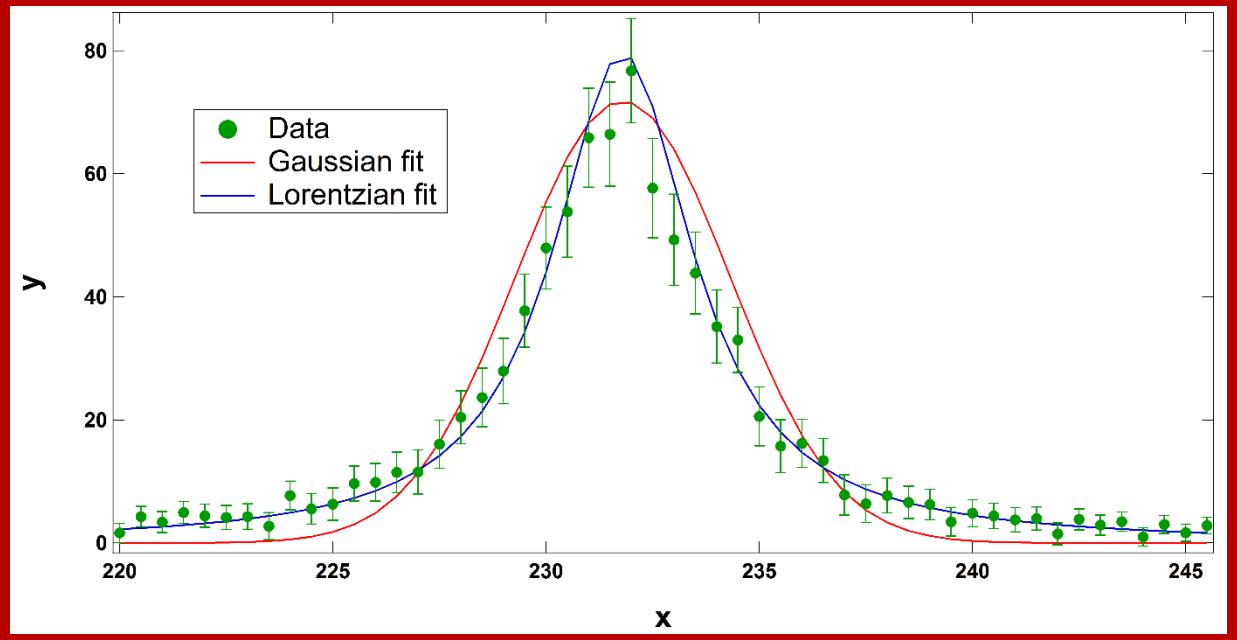


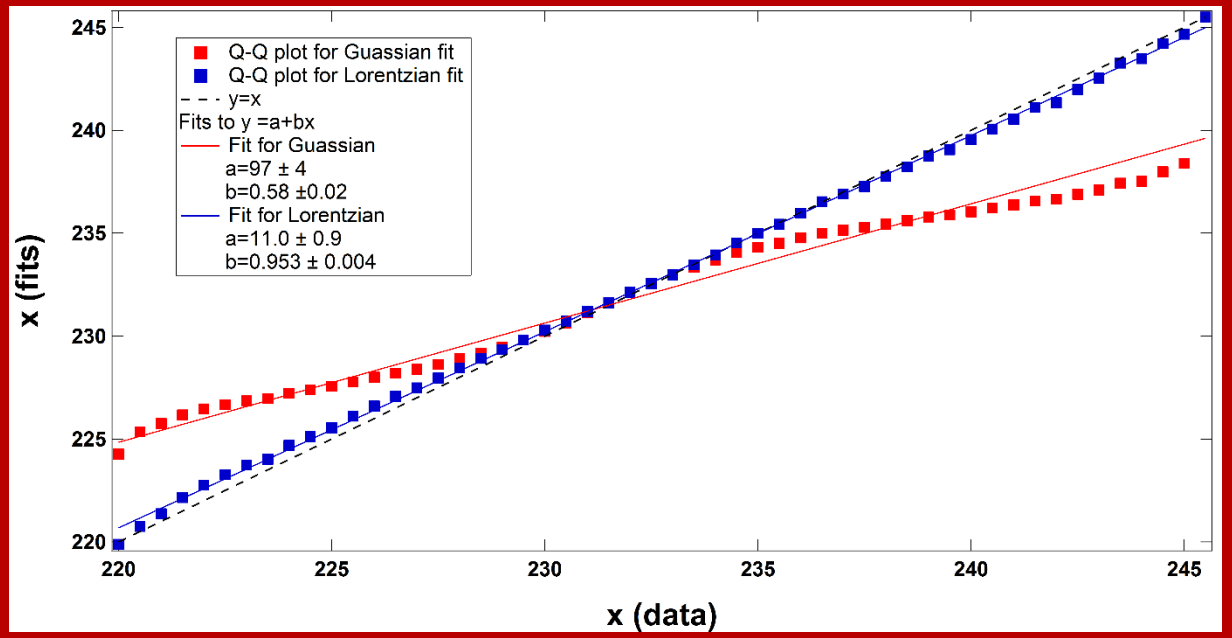


A Q-Q plot of the two fits shows that the two fits are significantly different.

Q-Q plots can compare mathematical functions.

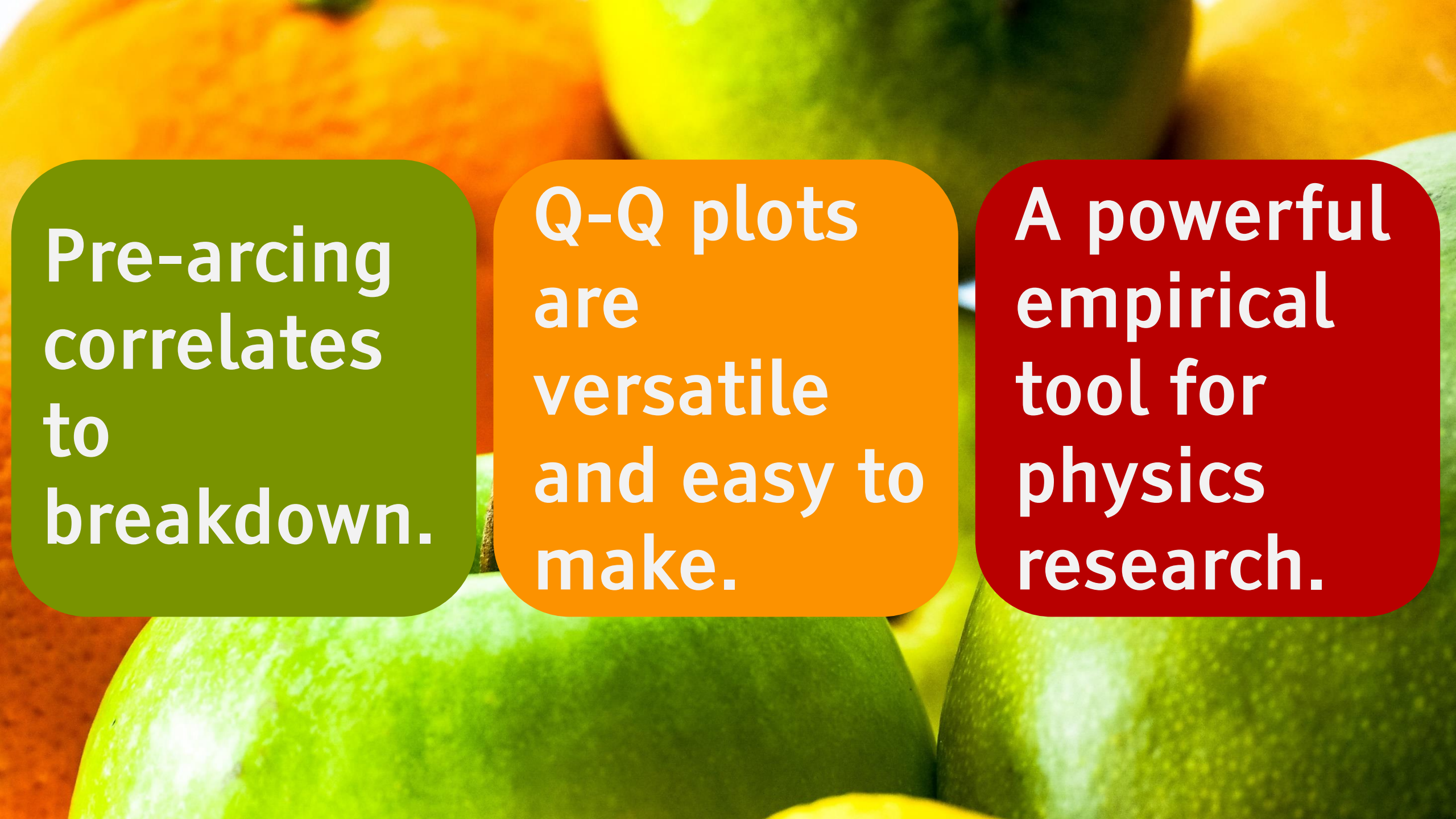
Additional Applications of Q-Q plots.





Q-Q plots comparing the two fits to the data show that the Lorentzian fit is better in this case.

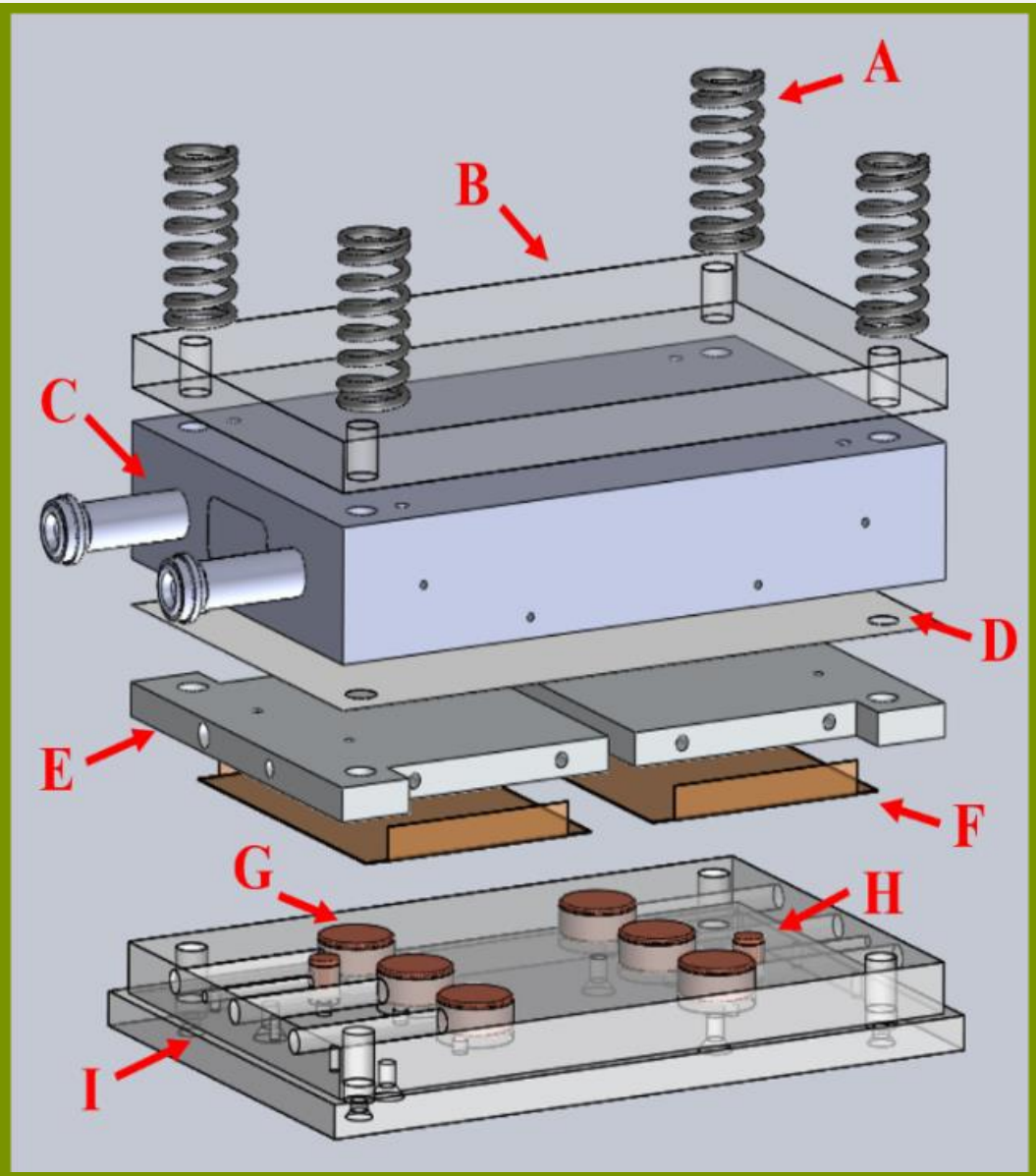
Q-Q plots can compare data to theoretical fits.


Pre-arcing correlates to breakdown.
Q-Q plots are versatile and easy to make.
A powerful empirical tool for physics research.

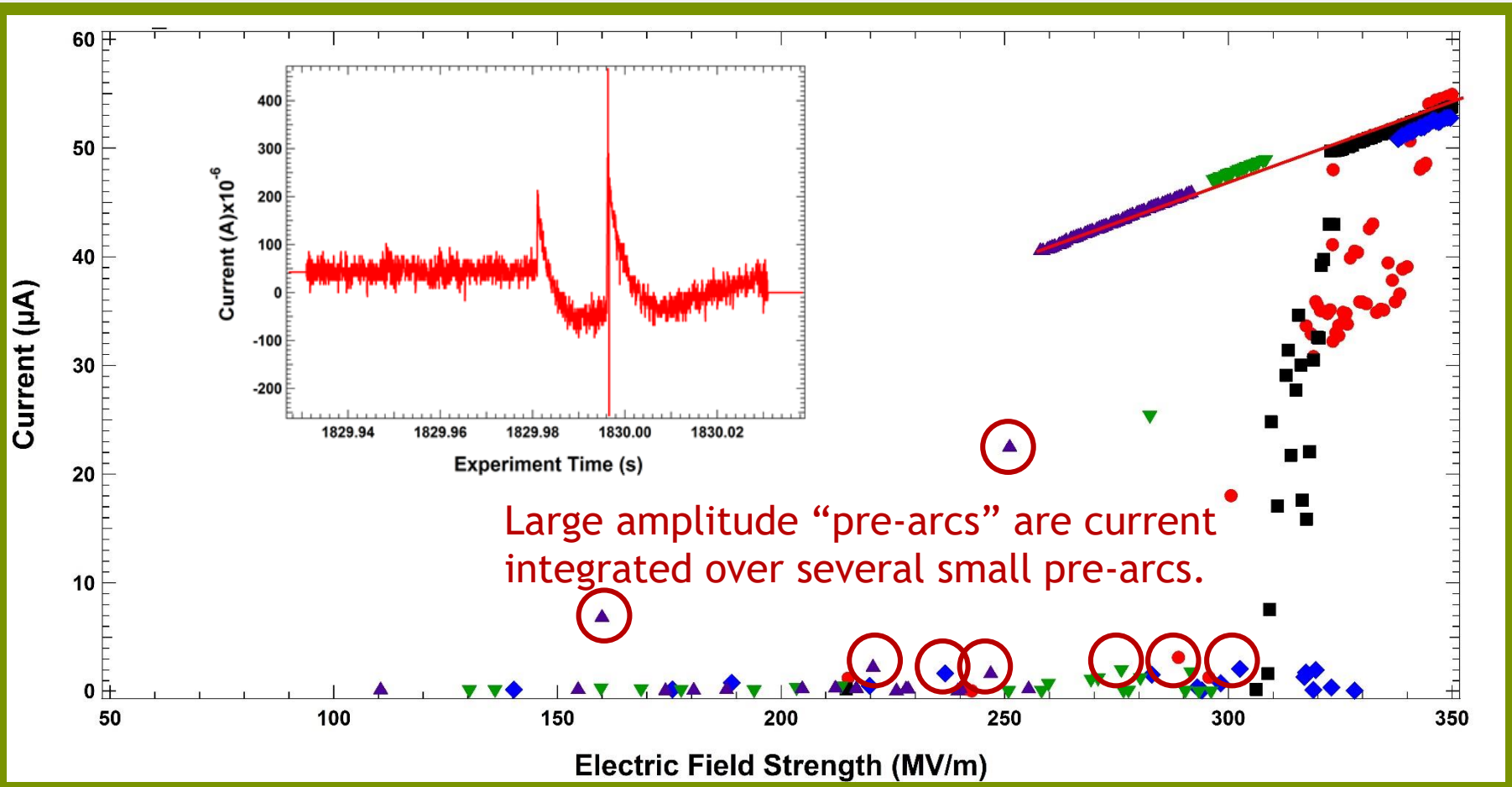
Case Study: Dielectric Breakdown Testing

ESD Test Assembly:

(A) Adjustable pressure springs,
(B) Insulating layer
(C) Cryogen reservoir,
(D) Thermally conductive, electrically isolating layer,
(E) Sample and mounting plate,
(F) Sample
(G) HV Cu electrode
(H) Cu thermocouple electrode,
(I) Insulating base.

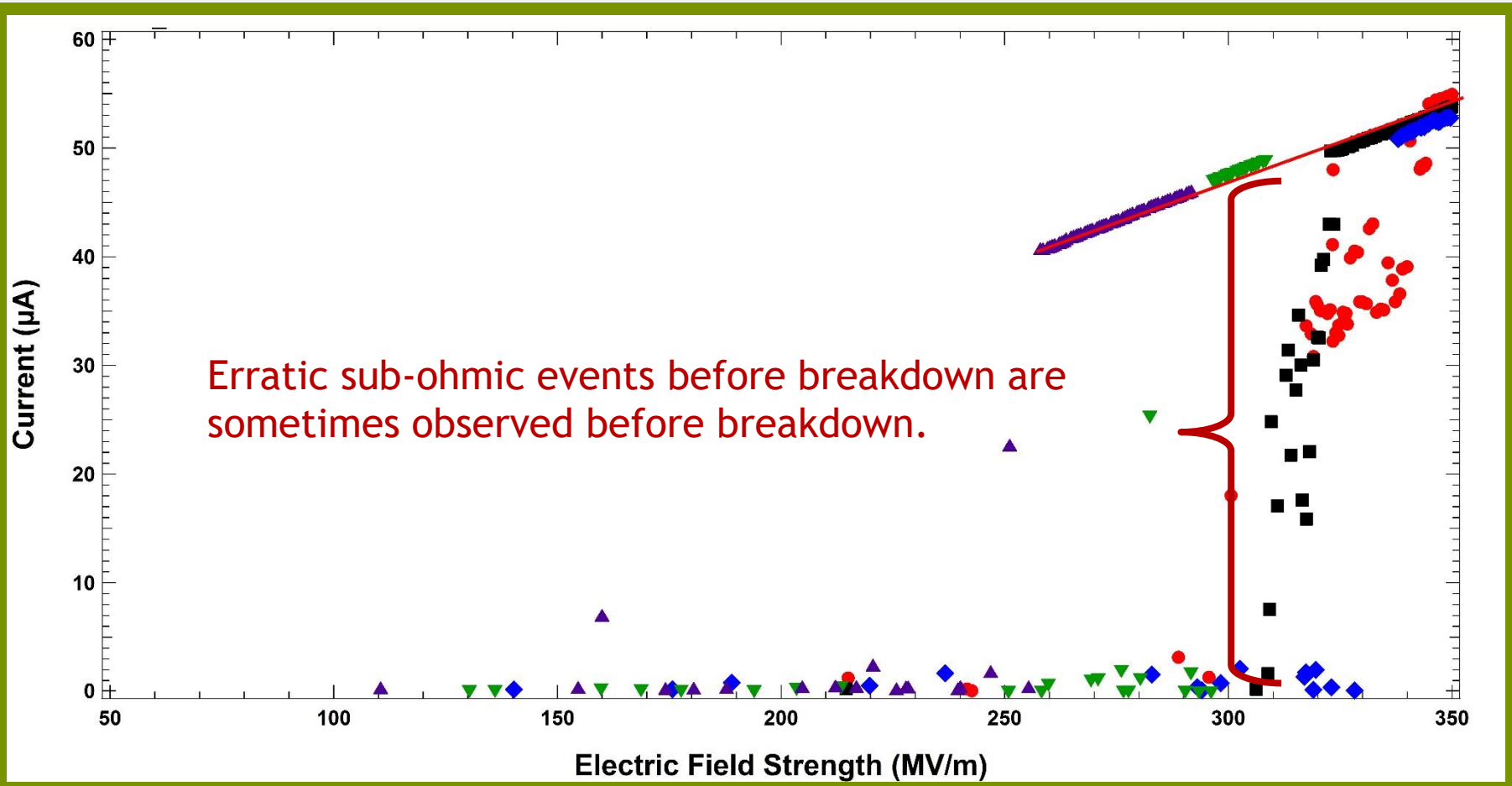


Case Study: Dielectric Breakdown Testing



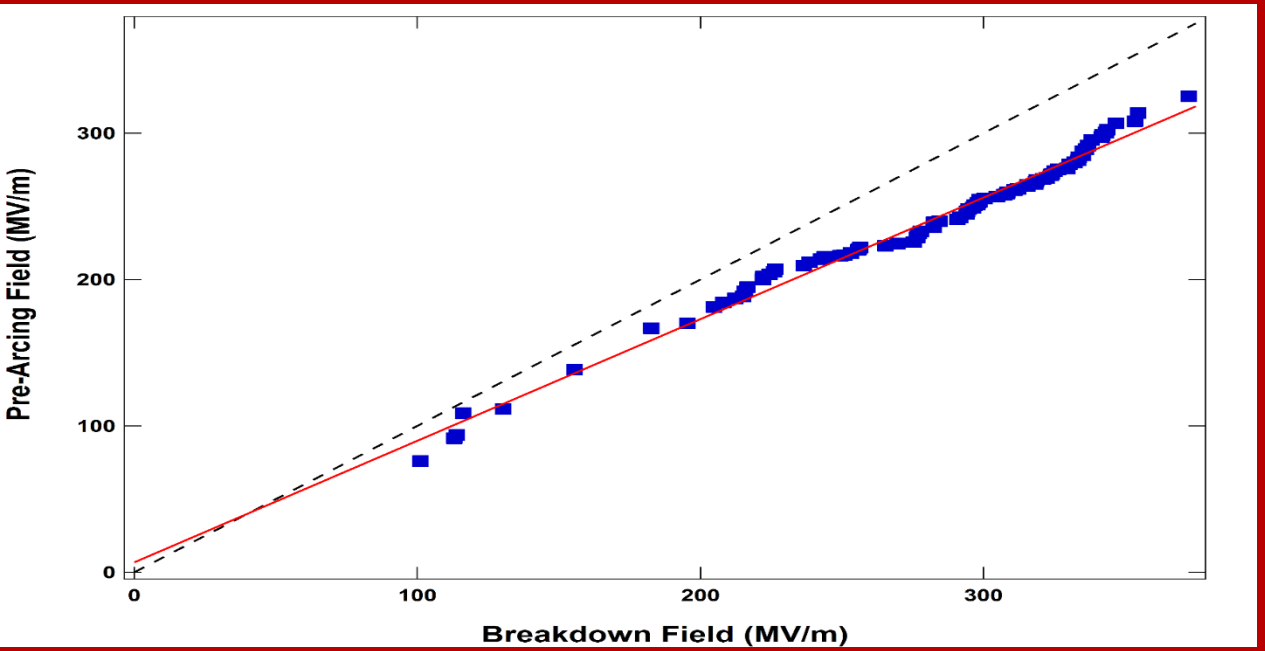
Plot of 5 voltage step-up to breakdown tests on LDPE.

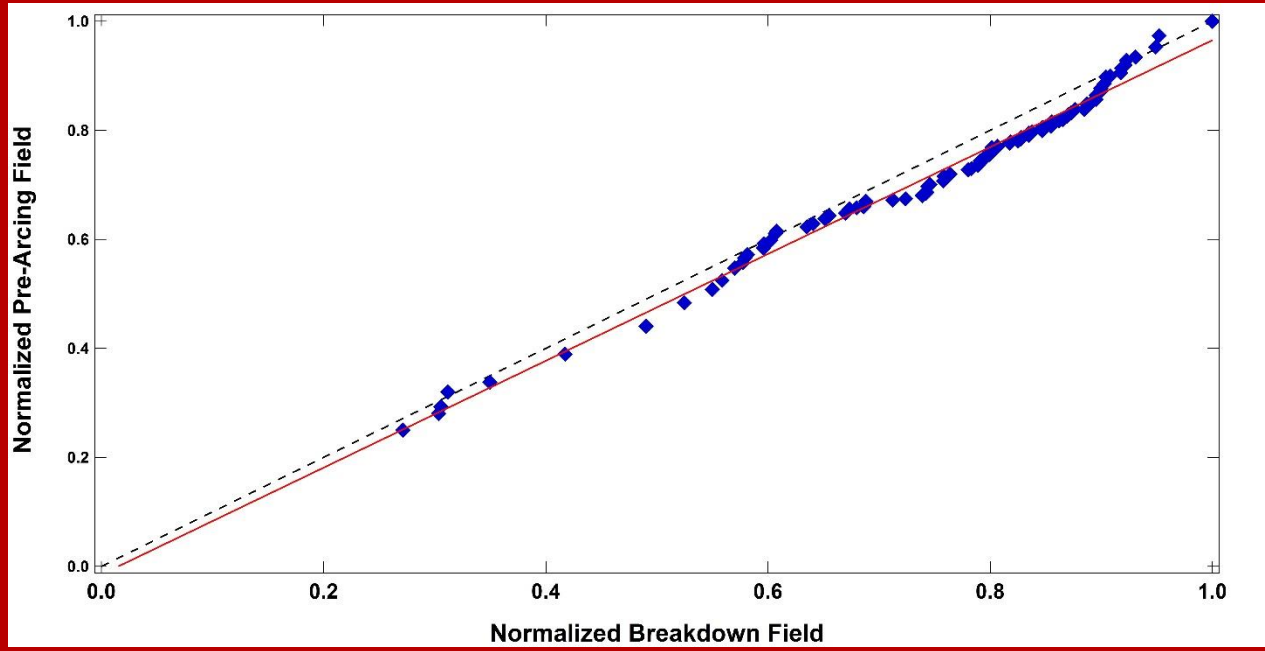
Case Study: Dielectric Breakdown Testing



Plot of 5 voltage step-up to breakdown tests on LDPE.

Effect of scaling on Q-Q plots.





Re-scaling the fields the fields brings in the Q-Q plot closer to y=x.