



Accelerating Battery Innovation and Validation Through 3D X-ray Inspection

Dr. Kevin Cedrone | Co-founder, Head of R&D

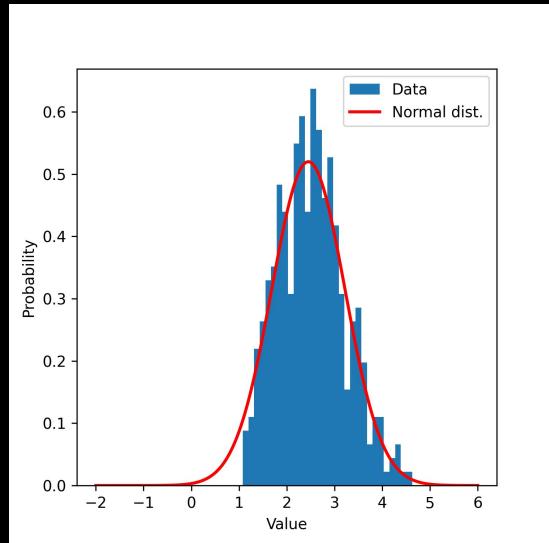
Goals for this talk



Highlight the uncertainty and risk of sampling



Explore what as few as 1,000 cell scans tell us



Establish the necessity of high volume X-ray CT

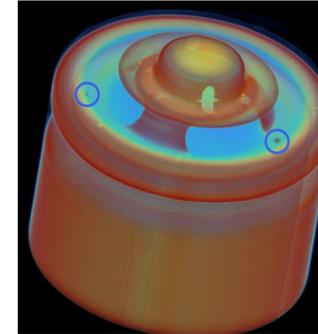
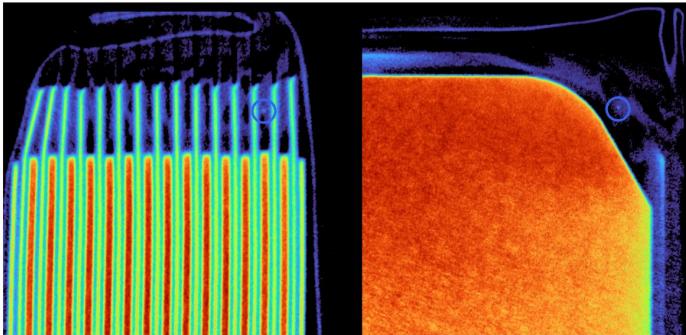
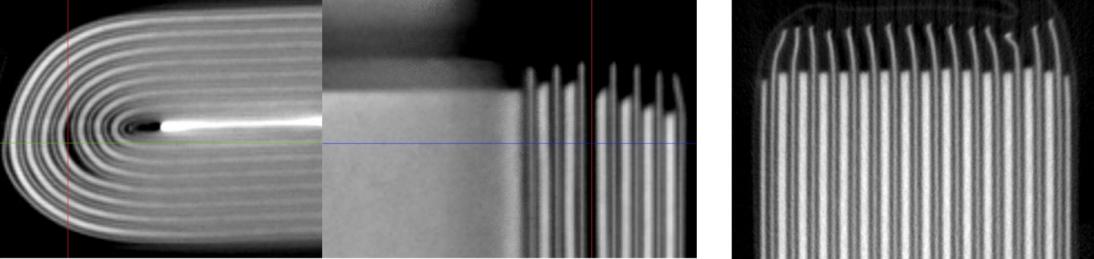


RICHARD FEYNMAN

NEIL ARMSTRONG

Cell defects and failure modes create weak links

Software Failure Mode and Effects Analysis (FMEA)									
Software Name		Model ID	Revision	Date	Date Completed				
ABC Application		000123	1.0	10/01/2000	05/05/2004				
Software System / Module									Approved By
User Authentication, Data Encryption, Session Management									
Brian Gorman (Software Engineer, DevSecOps) Quality Assurance Lead, Victoria Hanson (Cybersecurity Specialist)									
BRIEF DESCRIPTION OF THE ANALYSIS: This FMEA template is designed to help software development teams identify potential failure modes and their effects on the system. It includes columns for failure mode, severity, and detection, as well as a matrix for risk priority number (RPN) and action items.									
RPN Columns correspond to Risk Priority Number: 1 = Low risk or desired, 10 = High risk.									
Software FMEA Results									
Failure Component	Failure Mode	Effect of Failure	Severity	Detected	RPN	Prevention Actions	Detected Actions	Date Due	Date Completed
1. User Authentication	Malicious user attempting to gain unauthorized access.	Unauthorized access gained.	High	Yes	120	Implement stronger user authentication.	None	2023-01-01	2023-01-01
2. Data Encryption	Malicious user attempting to intercept and read encrypted data.	Encrypted data compromised.	Medium	Yes	30	Implement stronger encryption.	None	2023-01-01	2023-01-01
3. Session Management	Malicious user attempting to gain unauthorized access to user sessions.	Unauthorized access to user sessions.	Medium	Yes	140	Implement session timeout and logout.	None	2023-01-01	2023-01-01
4. API Management	Malicious user attempting to exploit API endpoints.	API endpoints compromised.	Medium	Yes	190	Implement strict API key management.	None	2023-01-01	2023-01-01
5. User Interface	Malicious user attempting to exploit user interface vulnerabilities.	User interface compromised.	Medium	Yes	80	Implement user input validation and sanitization.	None	2023-01-01	2023-01-01
6. Database	Malicious user attempting to exploit database vulnerabilities.	Database compromised.	Medium	Yes	160	Implement database encryption and regular audits.	None	2023-01-01	2023-01-01
7. File Management	Malicious user attempting to exploit file management vulnerabilities.	File management compromised.	Medium	Yes	180	Implement strict file permission and access controls.	None	2023-01-01	2023-01-01
8. Configuration Management	Malicious user attempting to exploit configuration management vulnerabilities.	Configuration management compromised.	Medium	Yes	90	Implement strict configuration management and auditing.	None	2023-01-01	2023-01-01
9. User Education	Malicious user attempting to exploit user education and training.	User education and training compromised.	Medium	Yes	100	Implement user education and training programs.	None	2023-01-01	2023-01-01



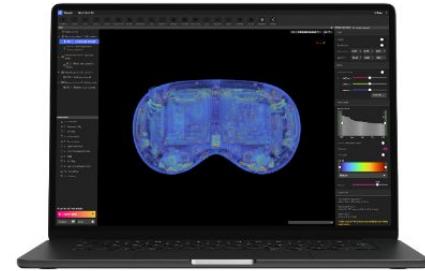
Lumafield makes hardware and software for industrial X-ray inspection



Neptune
Industrial CT scanner



Triton
Production-scale CT



Voyager
Analysis software

Lumafield Battery Quality Report

Murata 18650 Cell Quality Overview

Contact info@lumafield.com

lumafield.com/battery-report

Dataset Overview

Mean Values

Cell Type (mm)

Dimensions (mm)

Cell ID

Cell M093 Medium AOH representative

Cell M043 Minimum AOH representative

Measurements per Cell

Battery Quality Report | 25

Battery Quality Report | 18

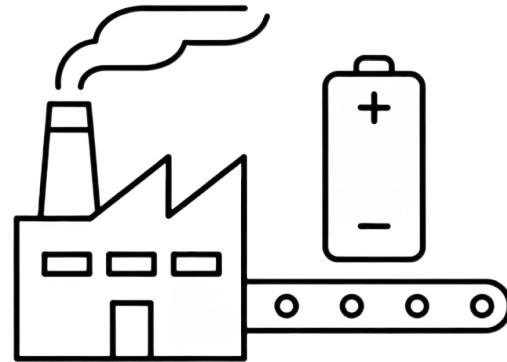
lumafield

Battery Quality Report

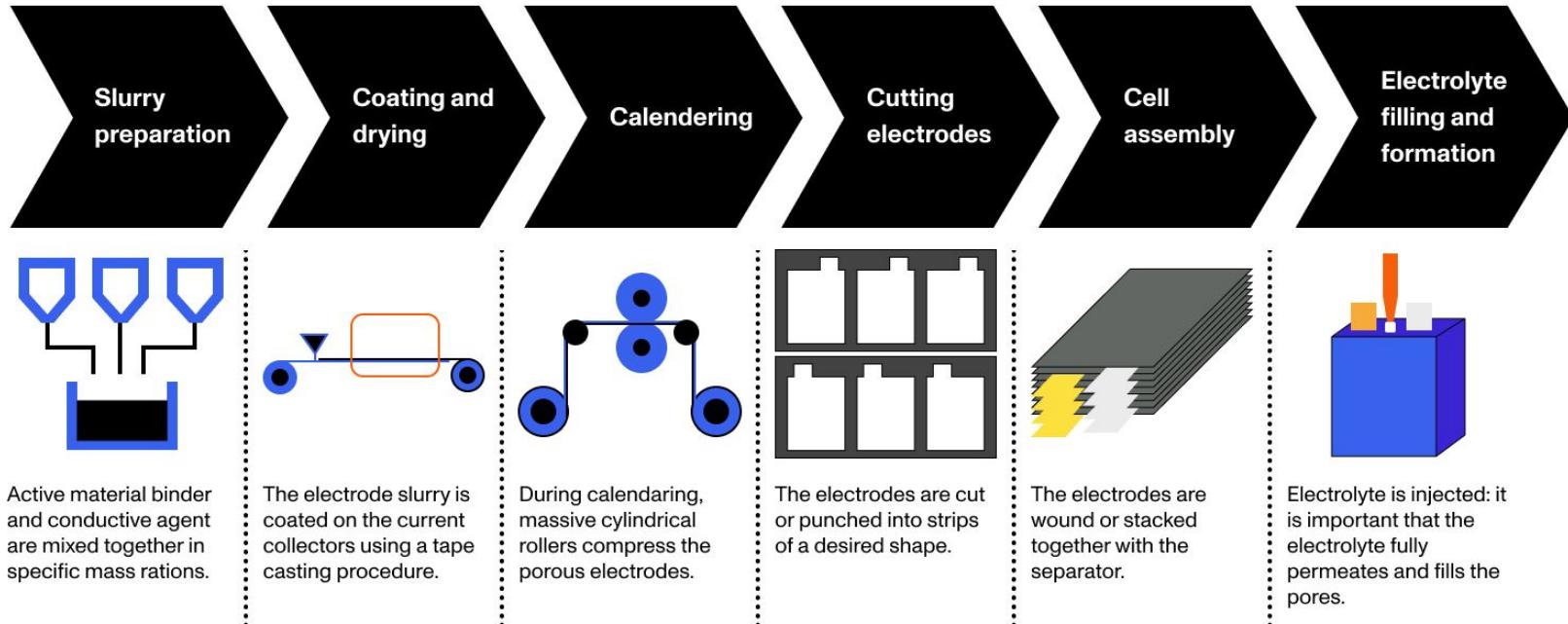
Using industrial X-ray CT to assess the hidden hazards in the lithium-ion battery supply chain

- Lumafield marketing material
- 1,054 scans of COTS 18650 cells
- Approx. 2 hours of UFCT scanning
- Thanks to automation, the data and analysis are accessible

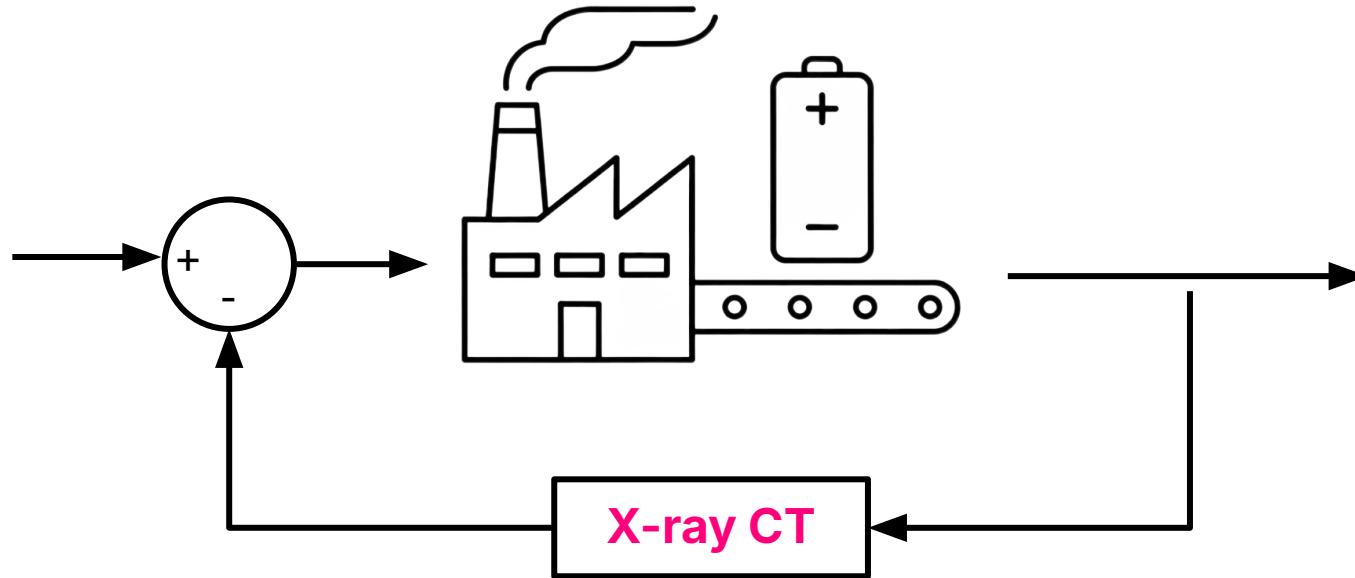
Battery inspection for manufacturers



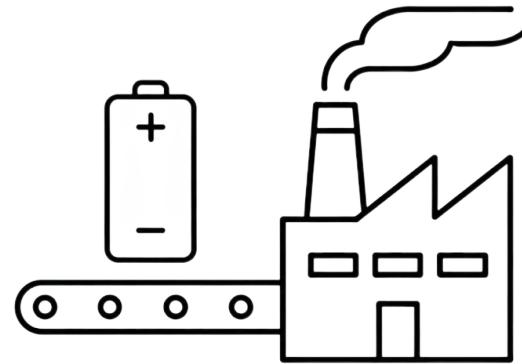
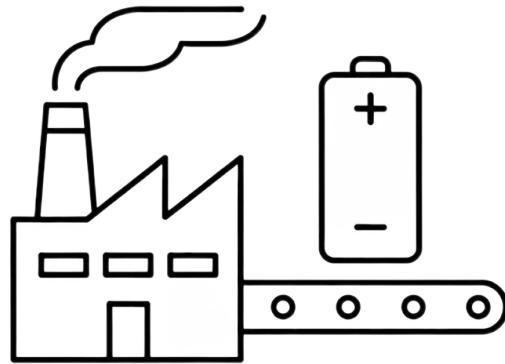
Battery inspection for manufacturers



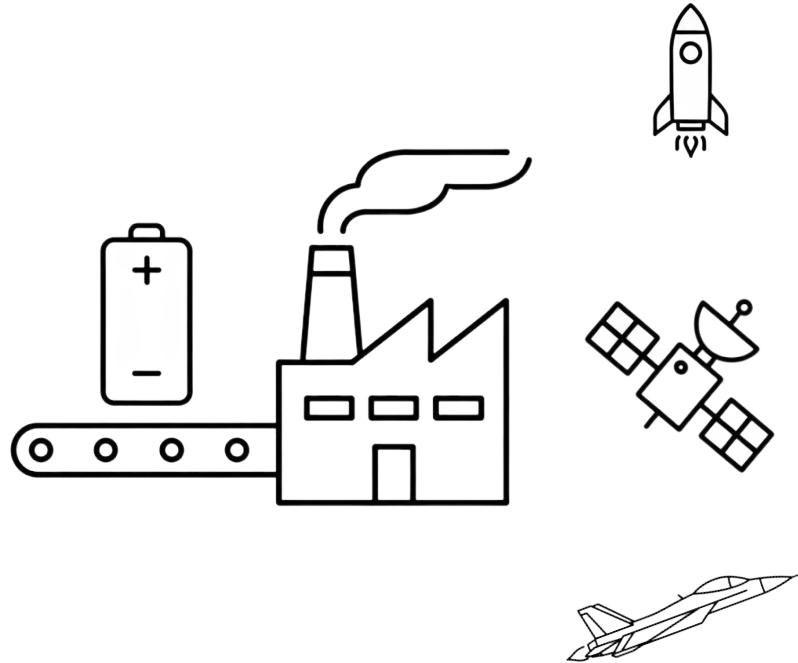
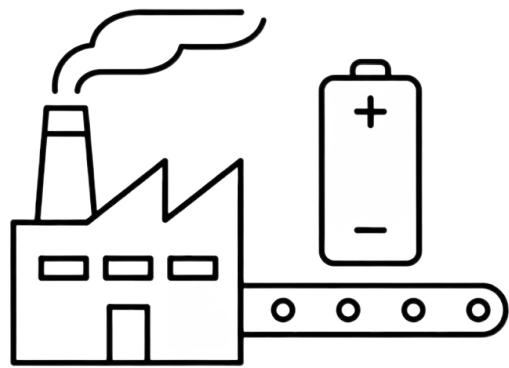
X-ray CT for closed-loop quality control

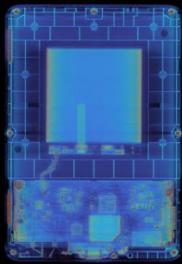


Cell manufacturing is only part of the picture

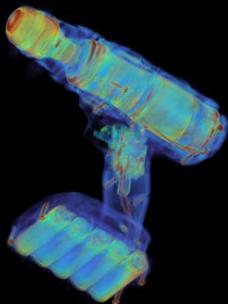


Integrators face significant risk and uncertainty

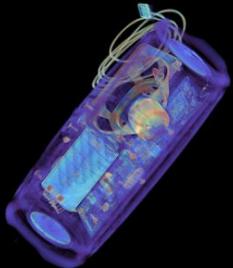




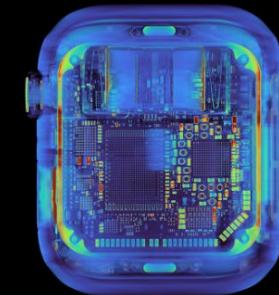
E-Reader



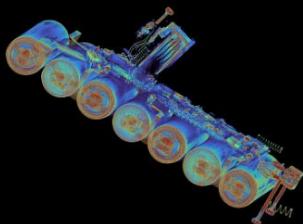
Cordless drill



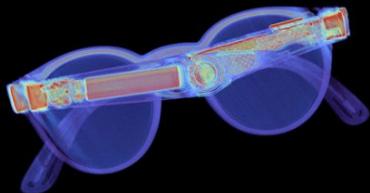
Bluetooth Speaker
Contains 3x 18650 cells



Smartwatch



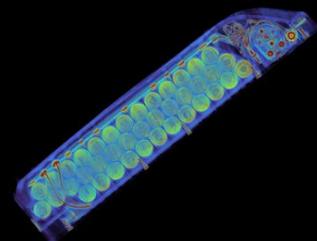
Cordless vacuum battery
Contains 7x 18650 cells



Smart glasses



Game controller



E-bike battery
Contains 39x 18650 cells

X-ray CT unlocks innovation
and validation for
manufacturers **and** integrators

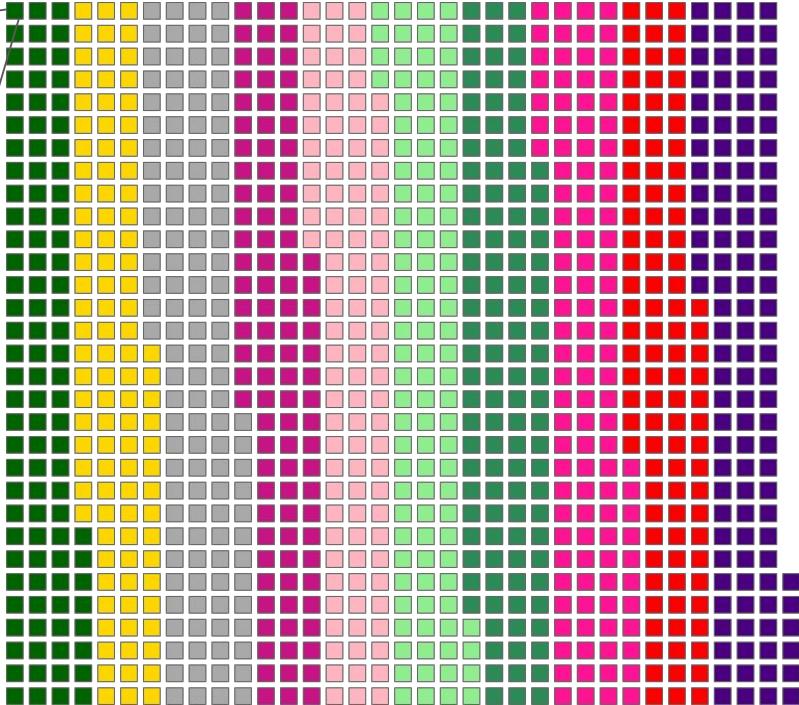
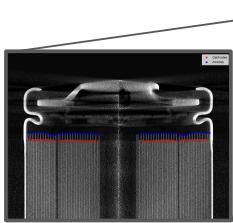
Let's look at 1,054 CT scans of COTS 18650 cells



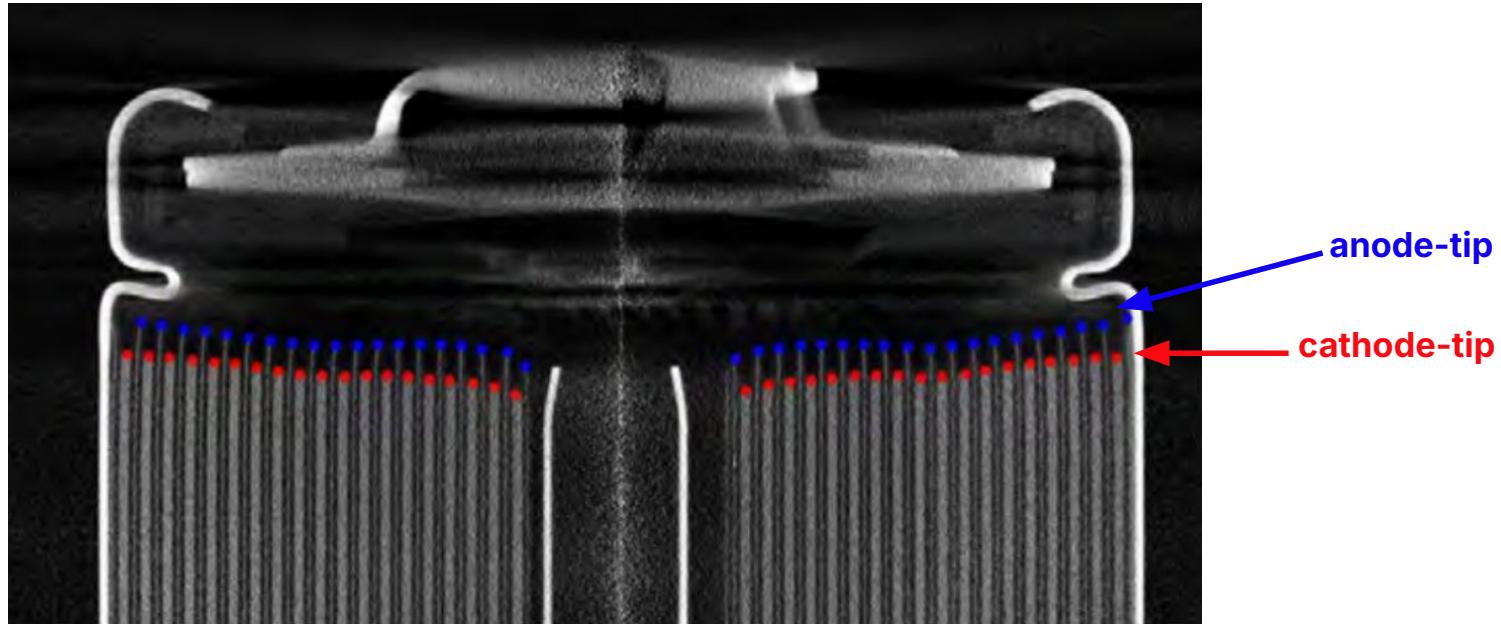
Murata Maxaeion Trustfire Efest SOOCOOL



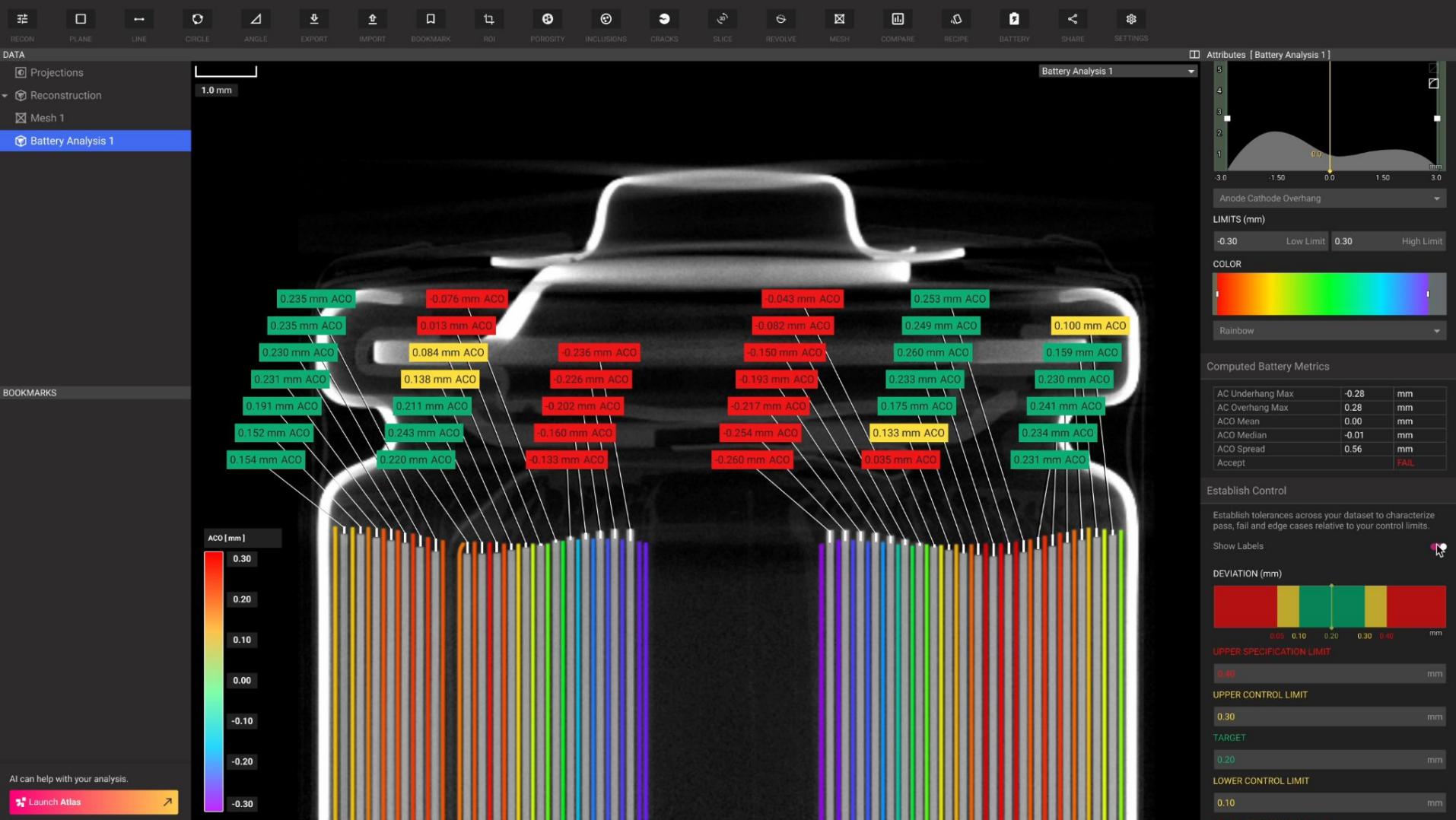
Panasonic Benkia Samsung Vapcell Treasurecase



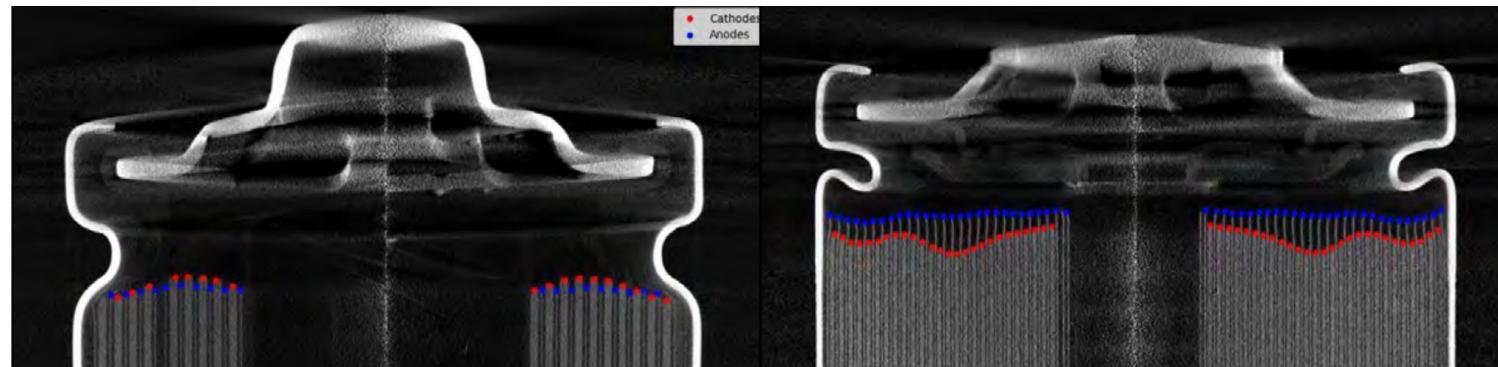
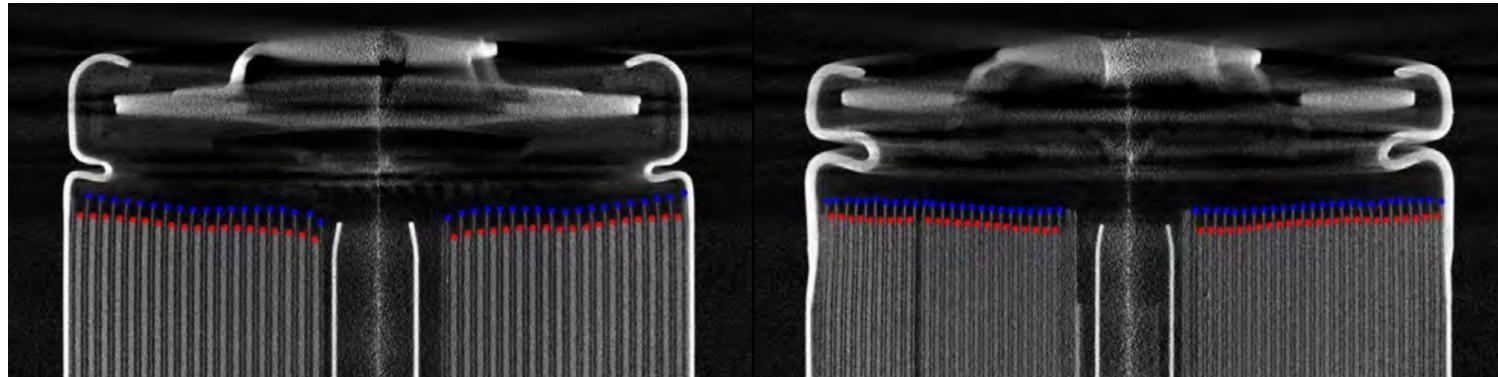
Let's focus on electrode alignment



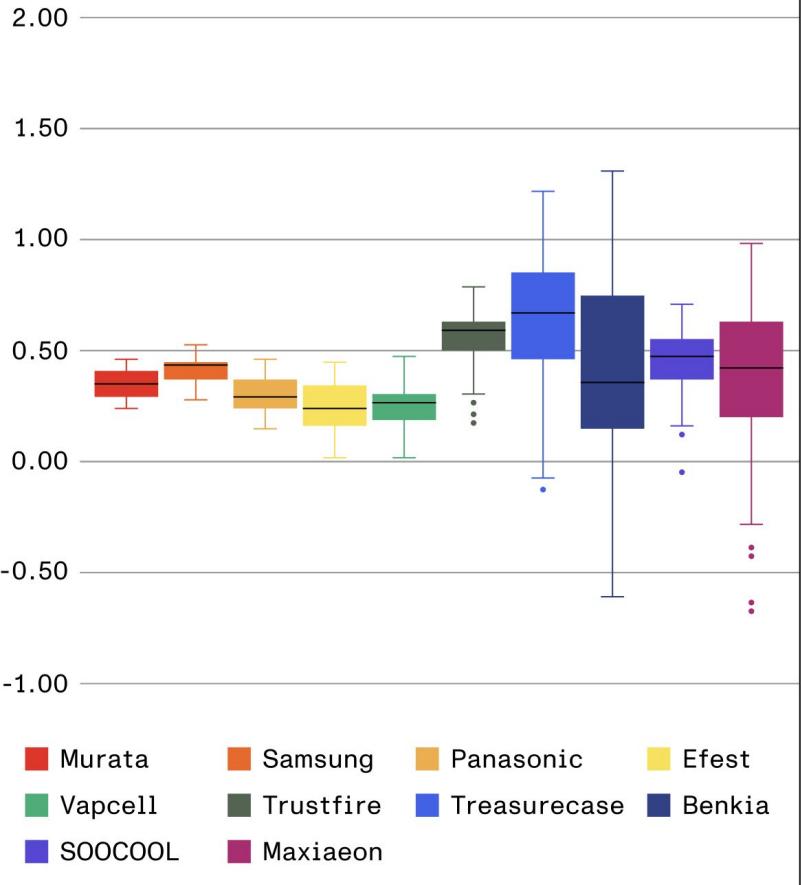
Anode overhang (AOH) Anode-cathode overhang (ACO)	$y_{\text{anode_i}} - y_{\text{cathode_i}}$
Cathode Edge Alignment	$y_{\text{cathode_max}} - y_{\text{cathode_min}}$



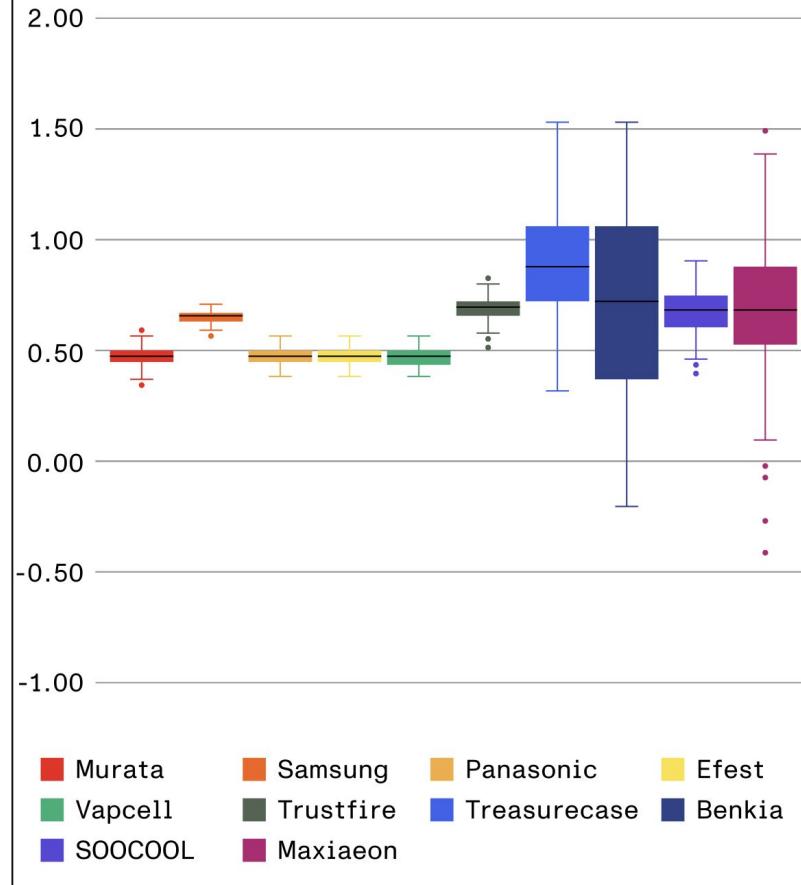
Electrode alignment varies wildly



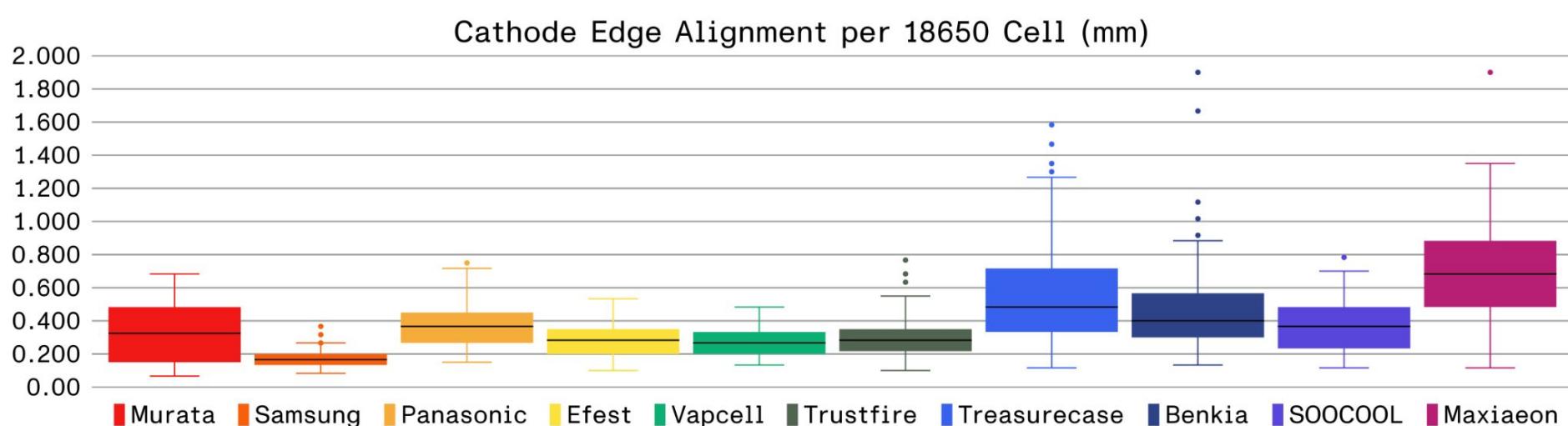
Smallest Anode Overhang Measurement per 18650 Cell (mm)



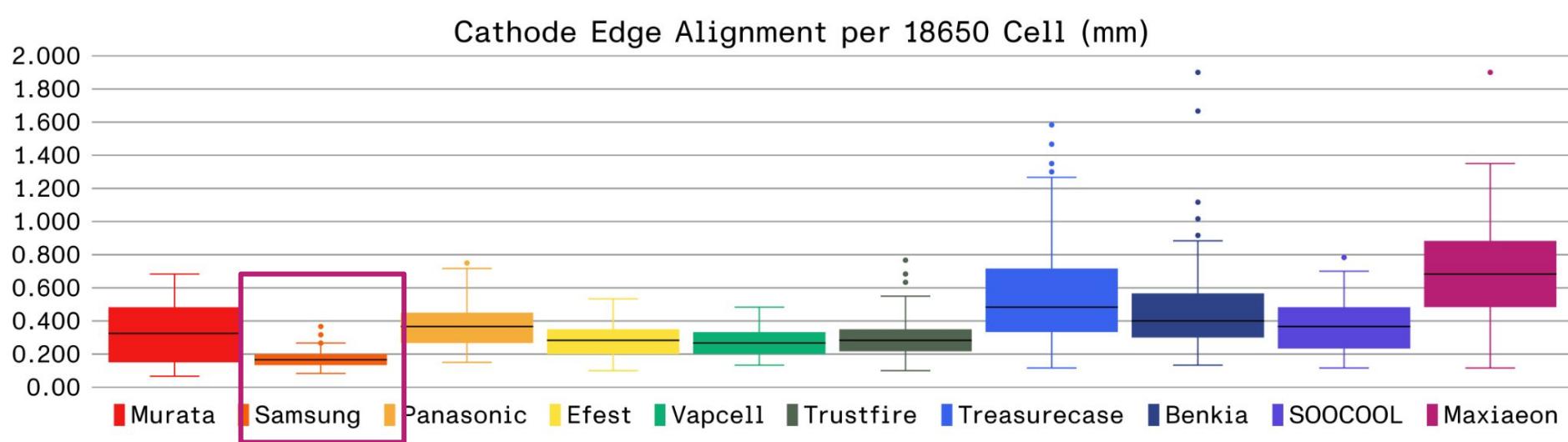
Median Anode Overhang Measurement per 18650 Cell (mm)



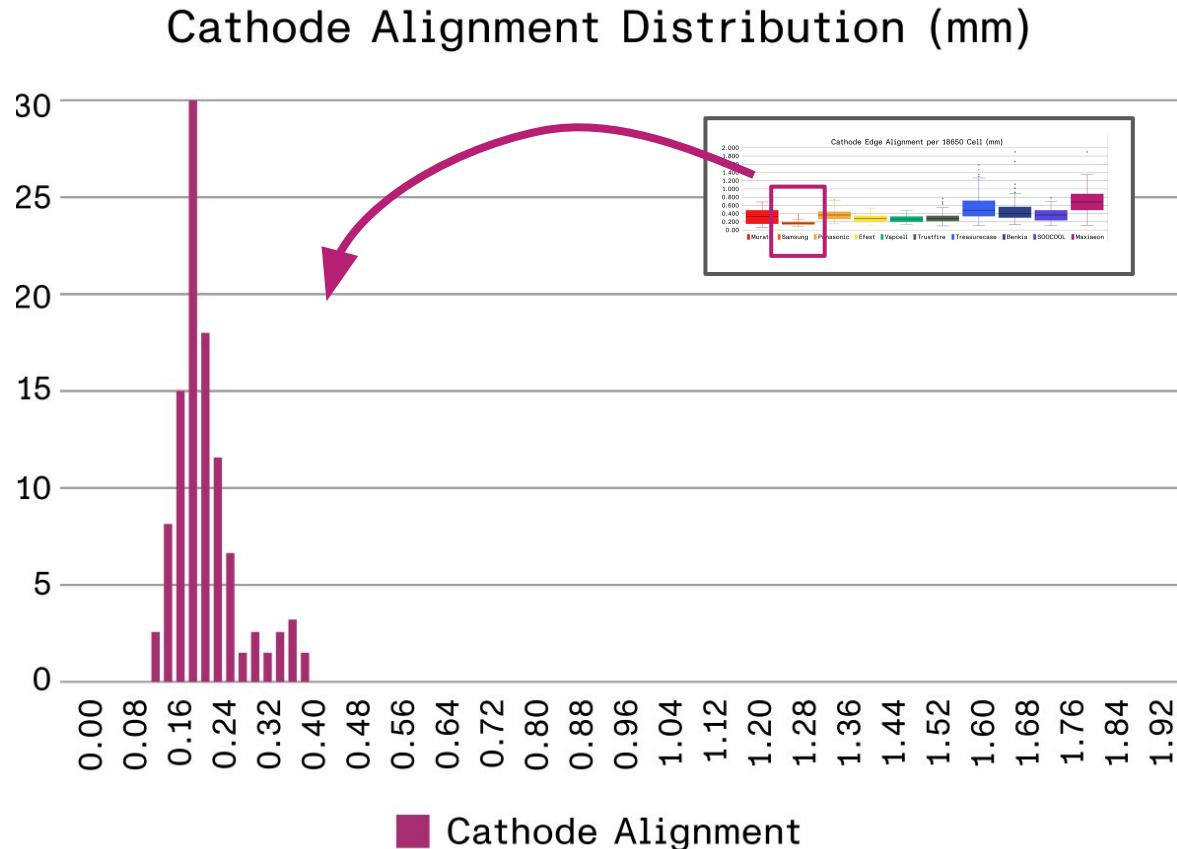
Median and standard deviation do tell a story



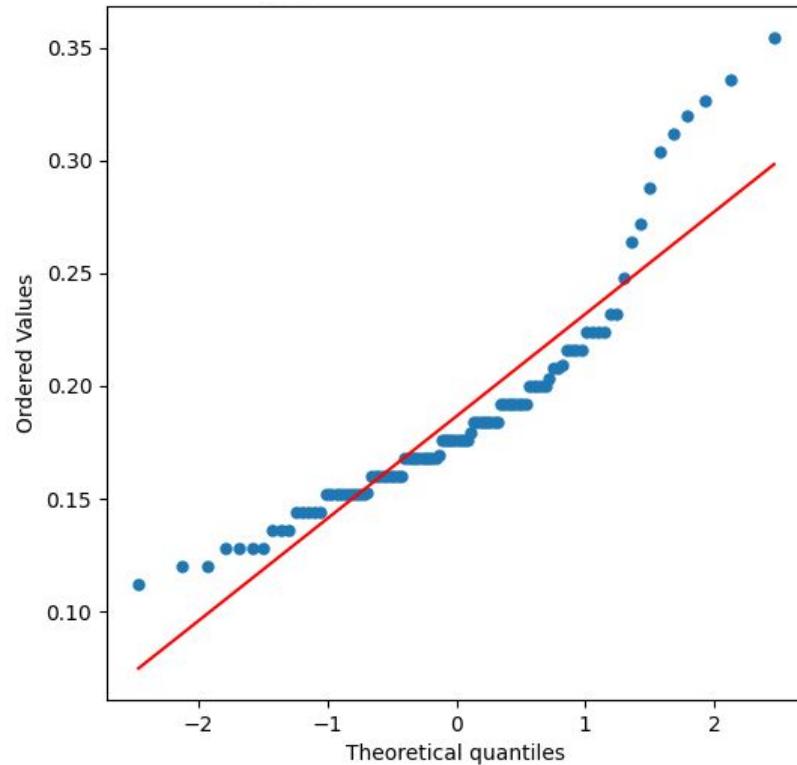
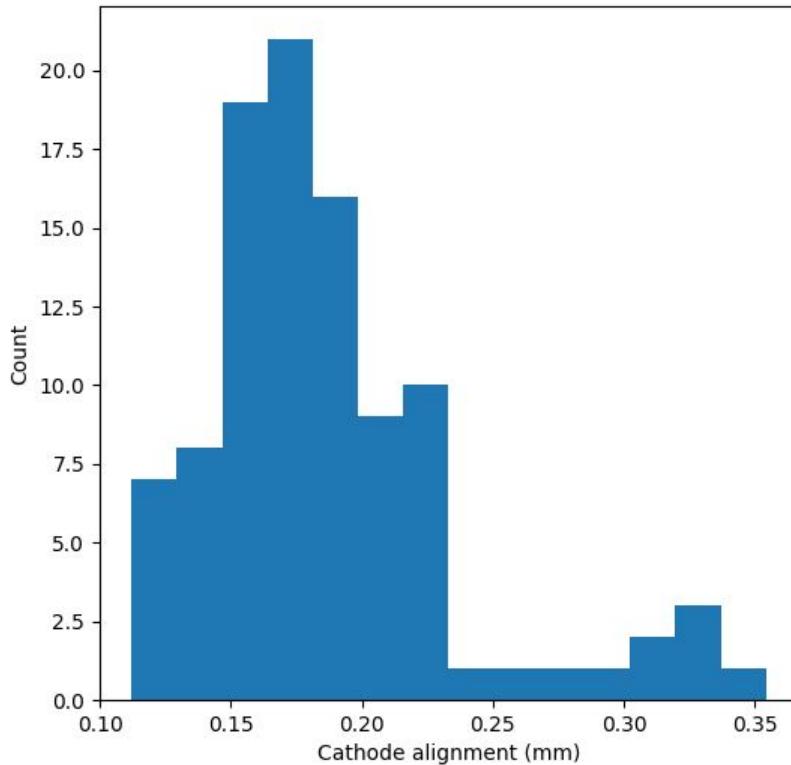
Median and standard deviation do tell a story



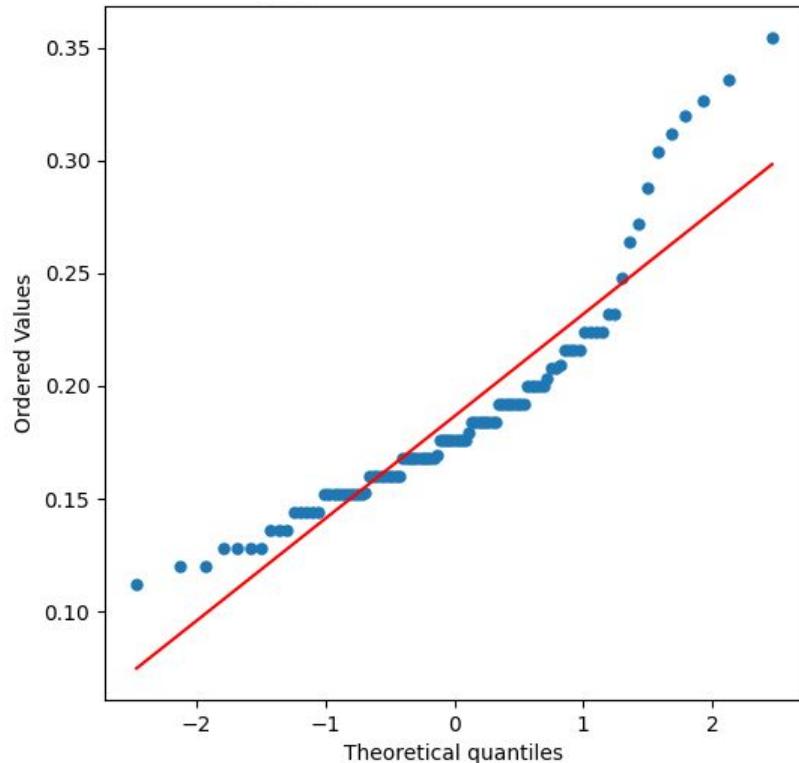
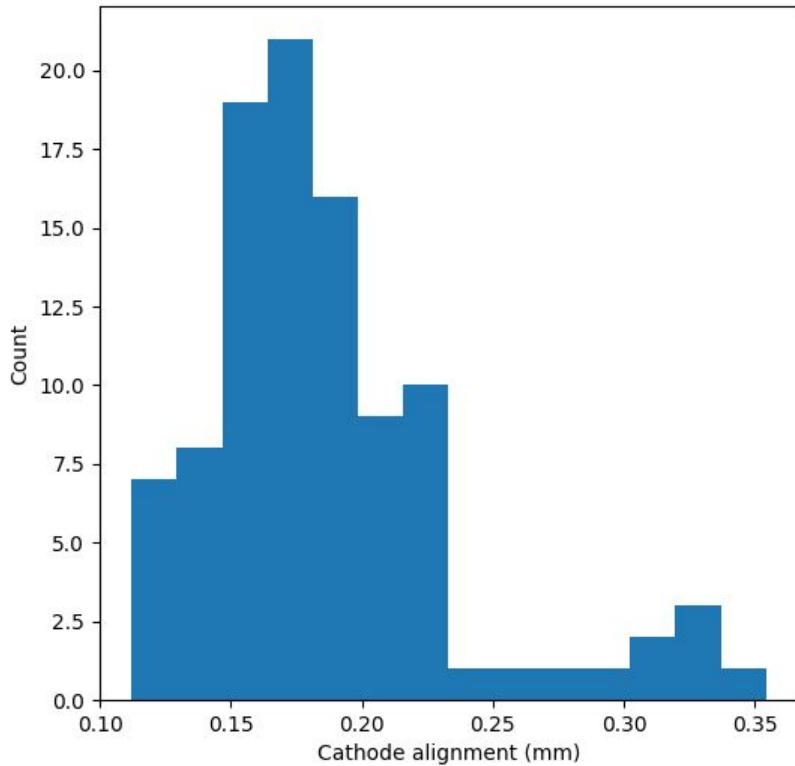
The distribution tells a more **complete** story

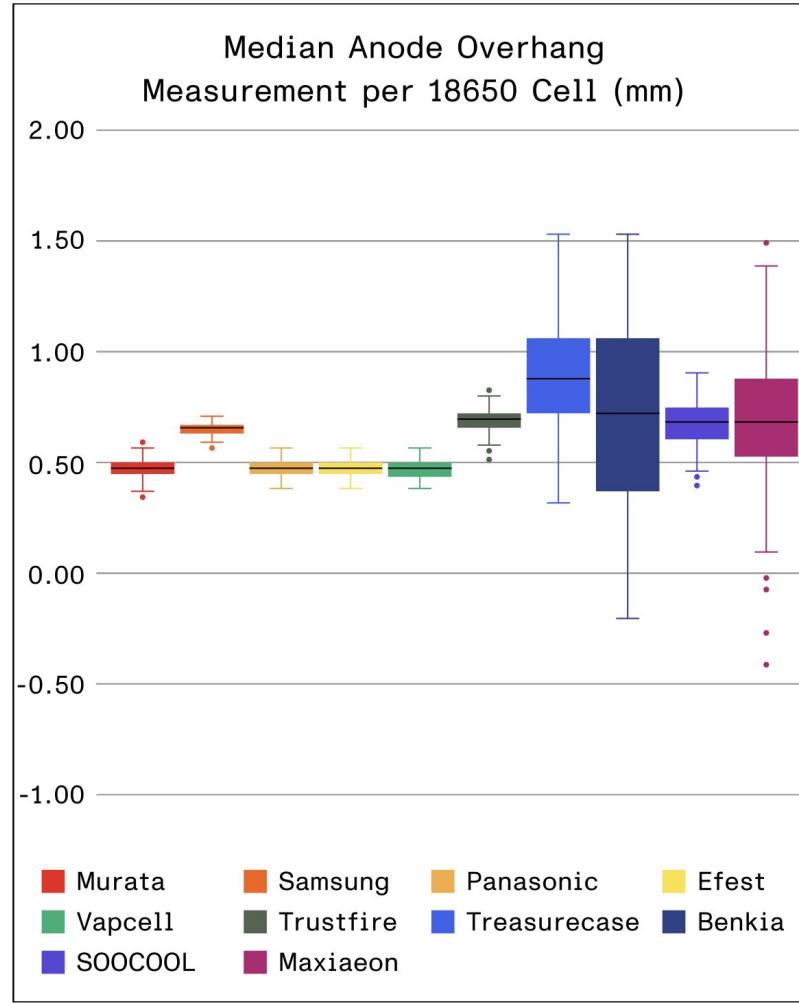


QQ plot highlights departure from normal dist.

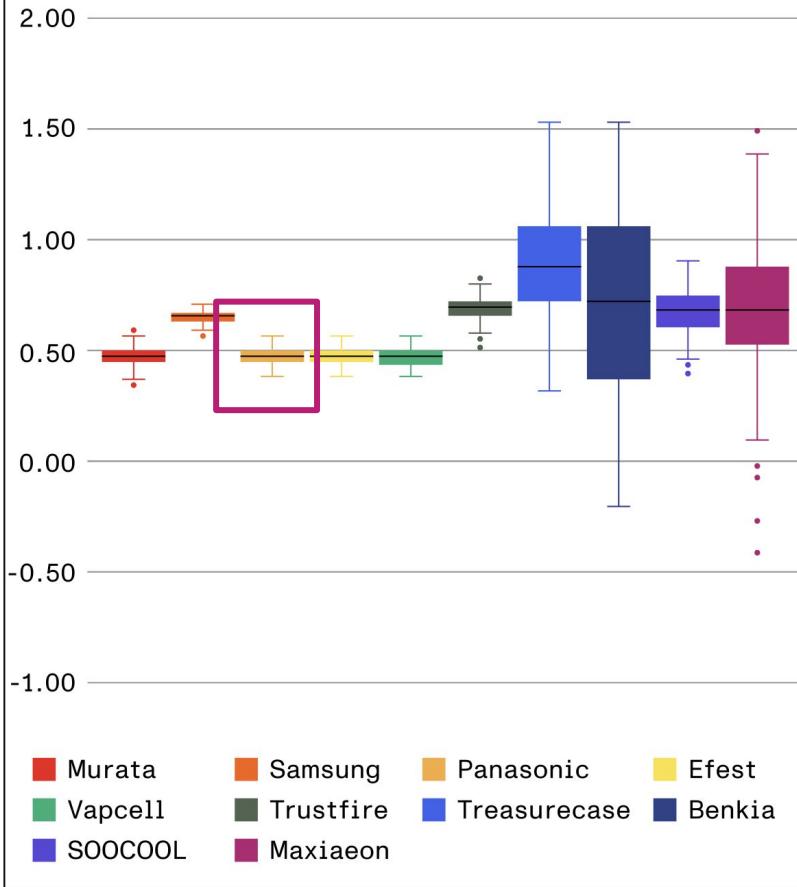


The distribution tells a more **complex** story

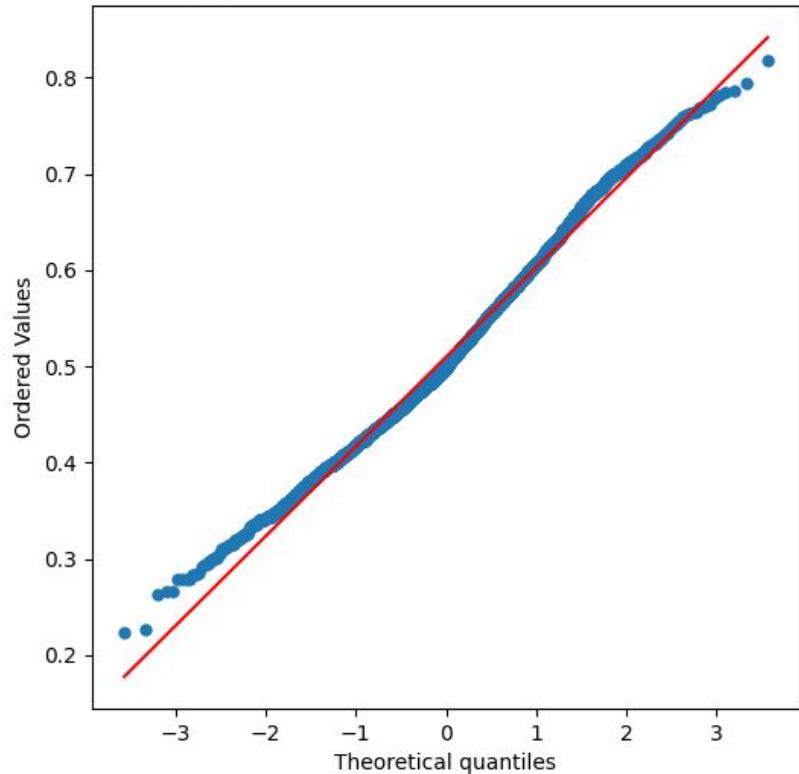
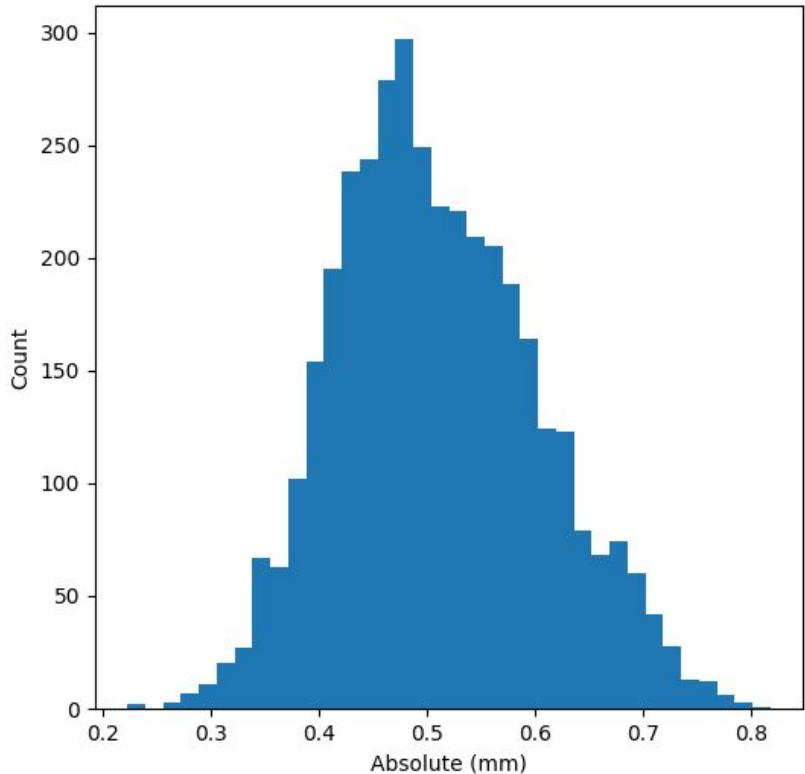


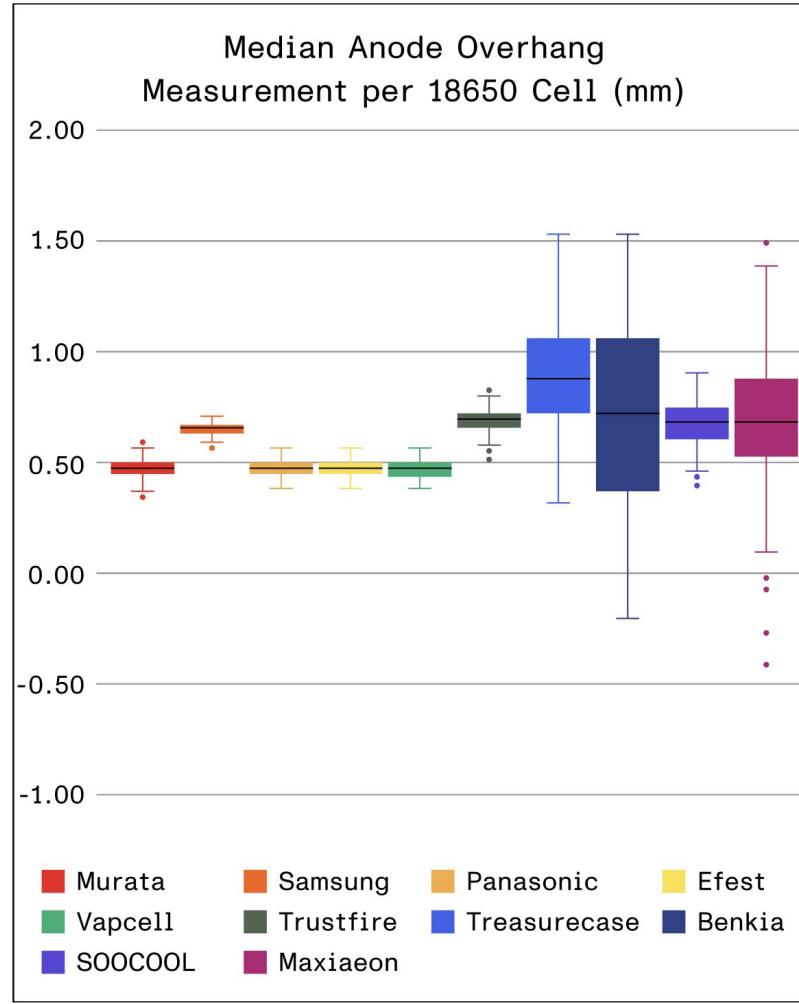


Median Anode Overhang Measurement per 18650 Cell (mm)



Panasonic Anode Overhang





Median Anode Overhang Measurement per 18650 Cell (mm)

2.00

1.50

1.00

0.50

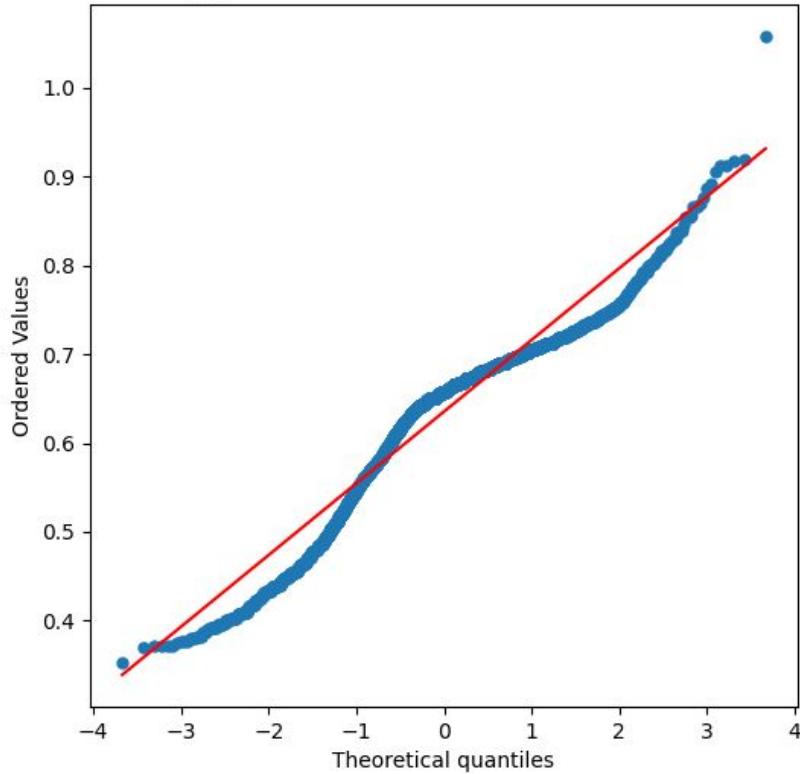
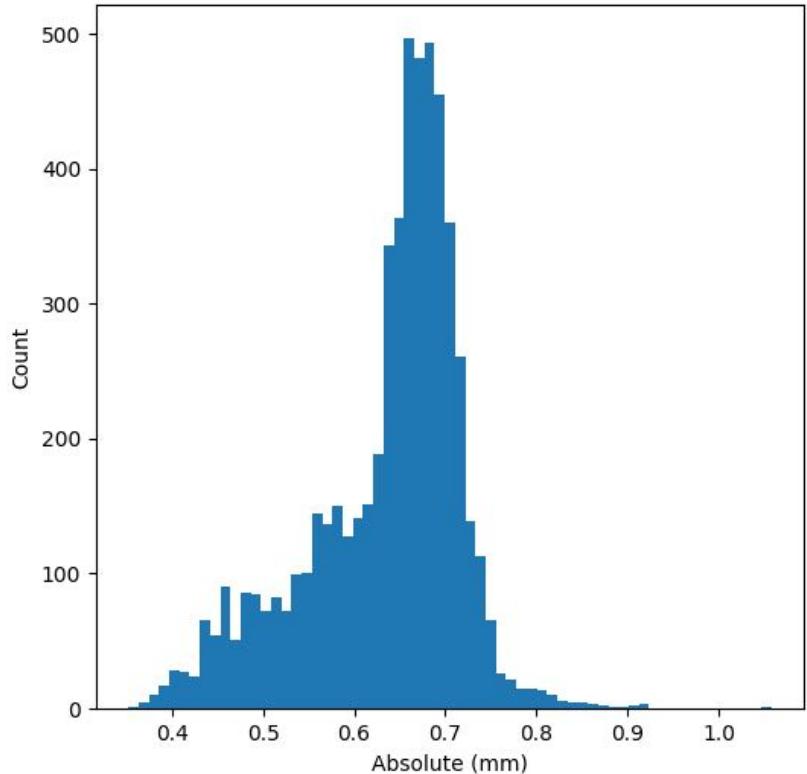
0.00

-0.50

-1.00

Murata Samsung Panasonic Efest
Vapcell Trustfire Treasurecase Benkia
SOOCOOL Maxiaeon

Samsung Anode Overhang



So what?



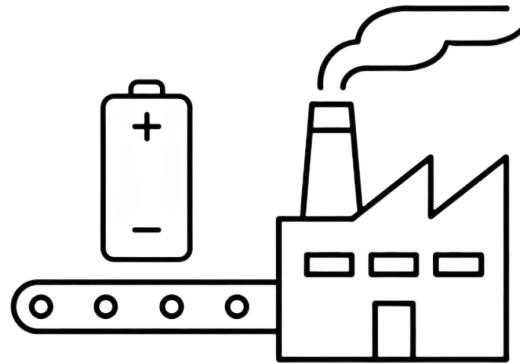
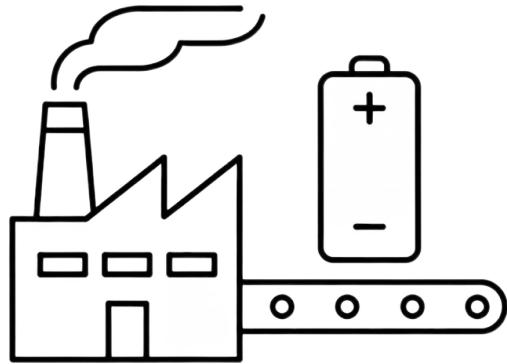
Take a step back

These data and conclusions come from a brief look at electrode alignment in commodity 18650 cells.

CT scans of cells can tell us about the factories and supply chains that delivered them.

Recent improvements to cost and speed let us move past simple statistical sampling.

With X-ray Inspection you can measure, understand, and control risk



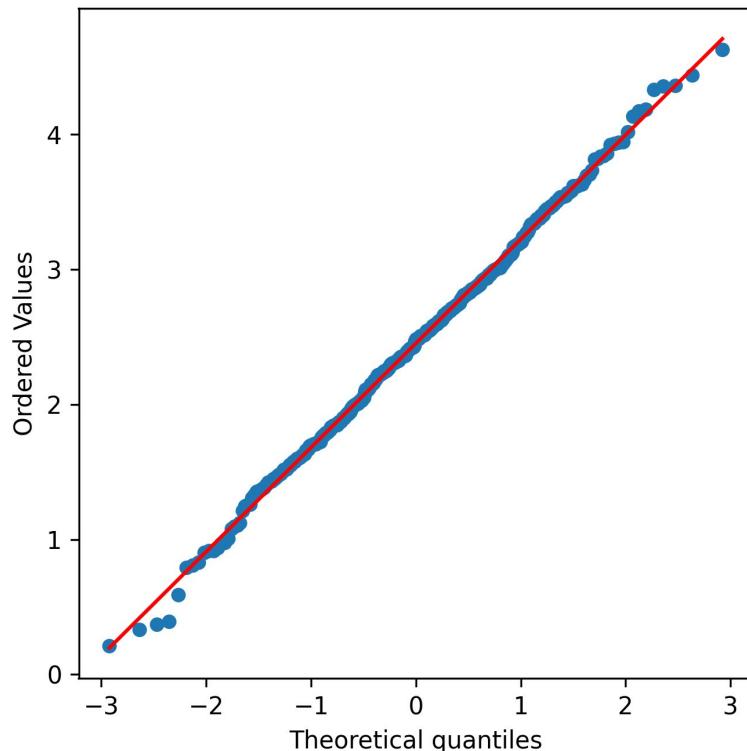
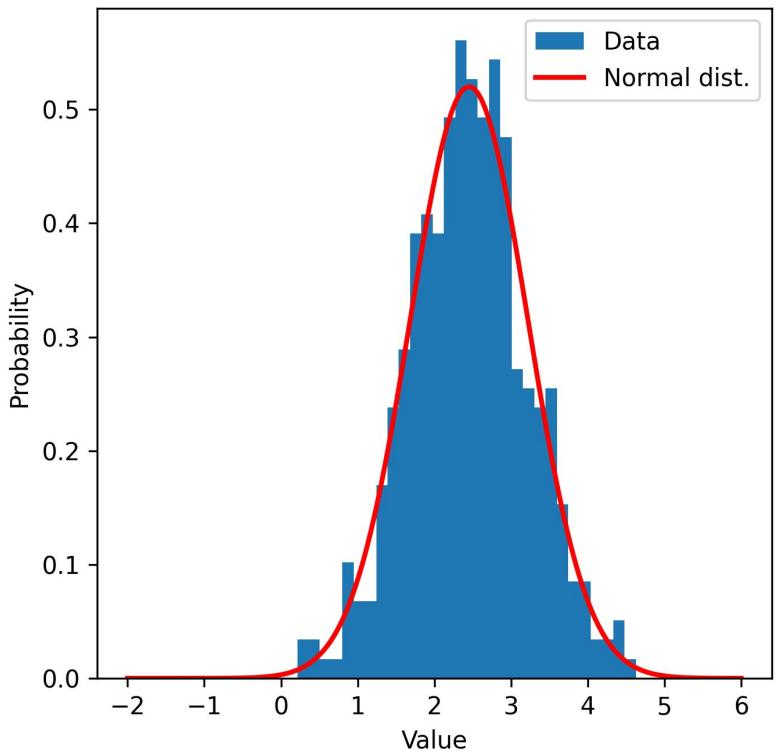


<https://www.lumafield.com/battery-report>

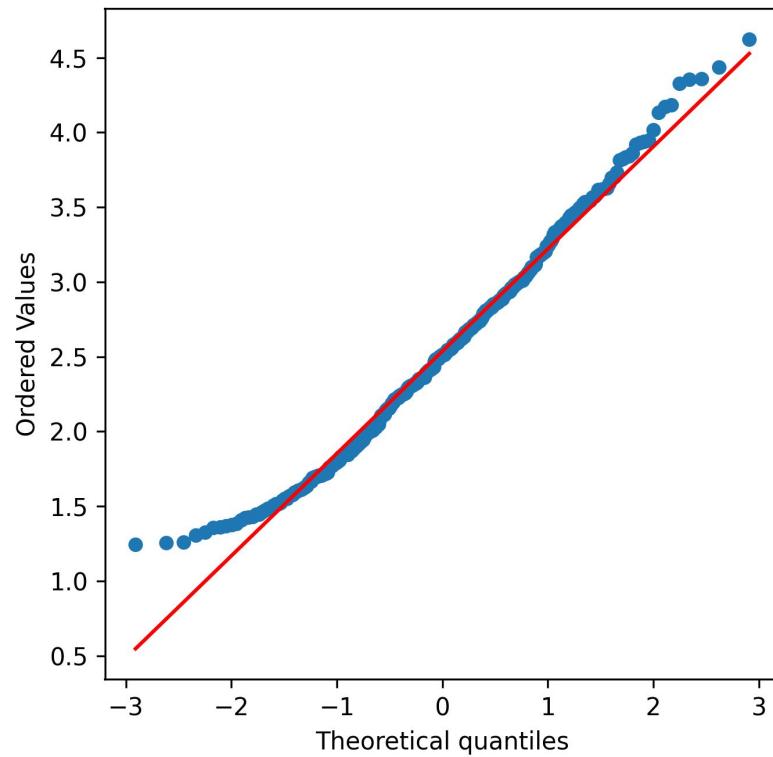
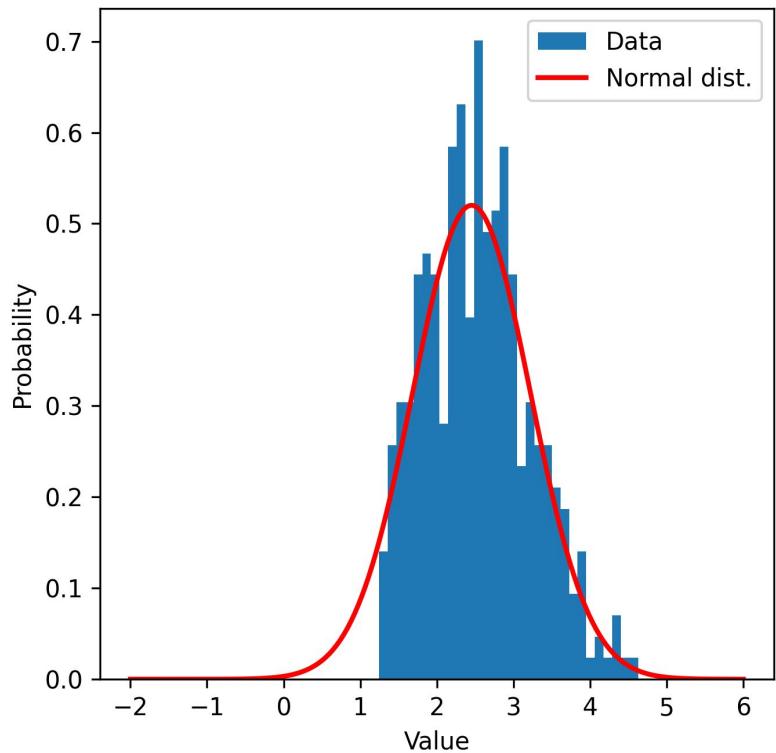
info@lumafield.com
kevin@lumafield.com

Appendix

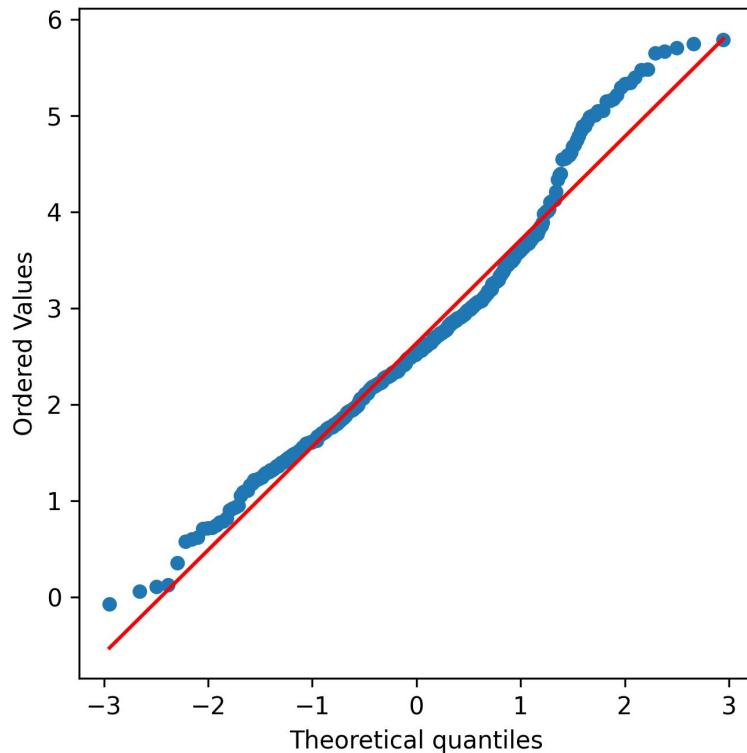
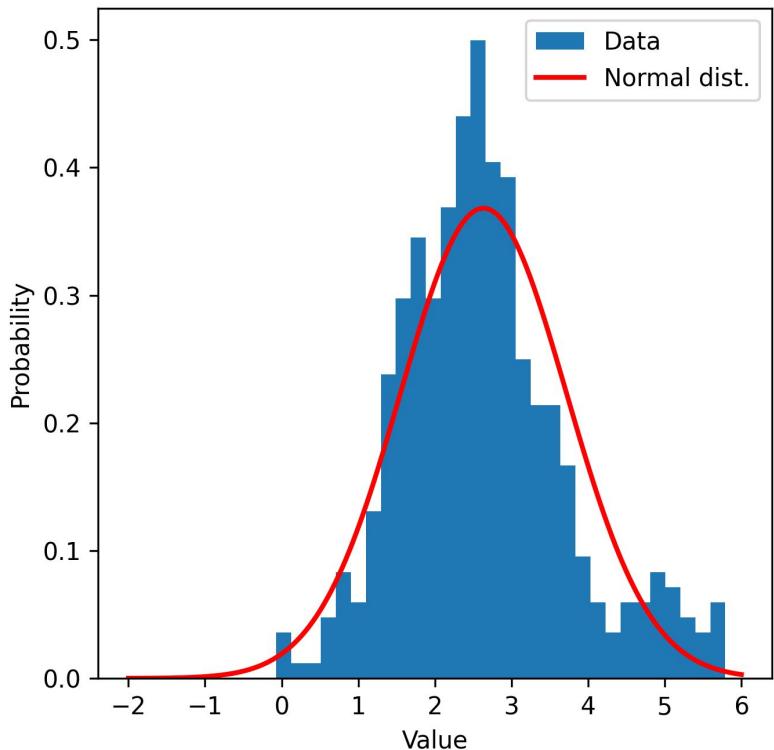
Synthetic normal data



Synthetic truncated normal data



Synthetic bimodal normal data



Poisson distribution for FOD