The background of the slide is a 3D X-ray image of several battery cells. The cells are arranged in a grid-like pattern, with some cells appearing to be connected by a network of lines. The image has a blue and yellow color scheme, with the cells themselves appearing as bright yellow/green structures against a dark blue background.

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

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

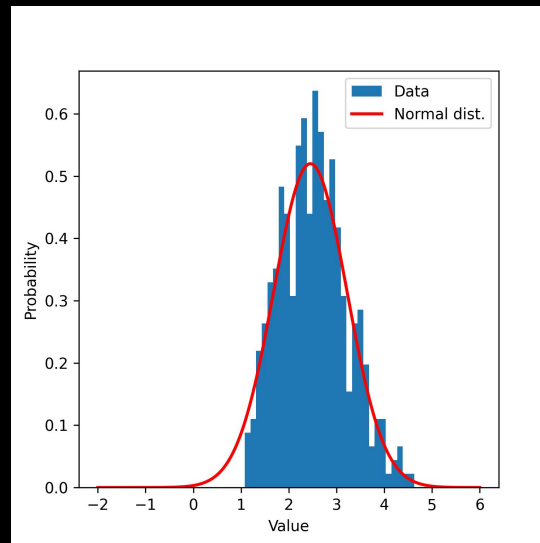
Goals for this talk



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

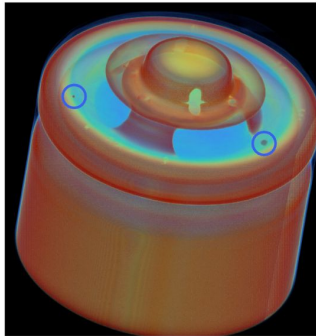
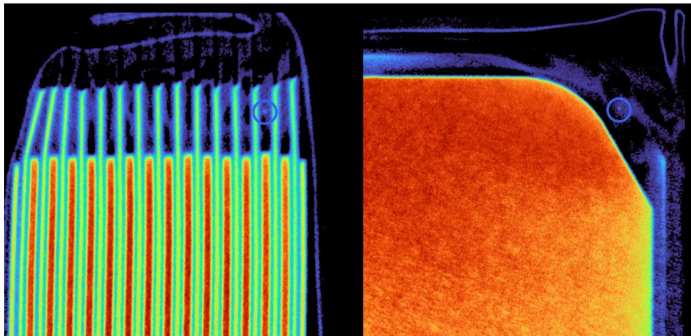
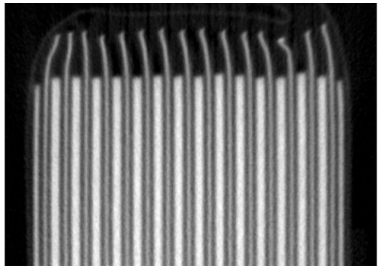
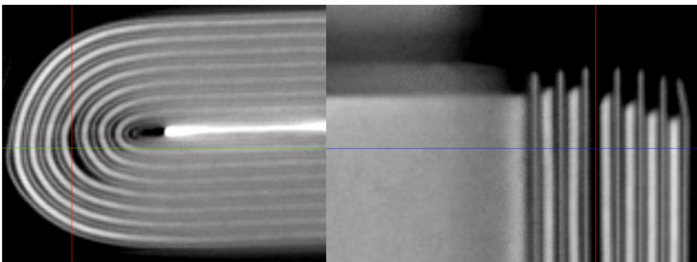
NEIL ARMSTRONG

Cell defects and failure modes create weak links

Example Software FMEA Template

Software Name:		Item ID:	Revision:	Date:	Date Completed:
ABC Application		000123	1.0	10/01/2024	05/02/2024
Software System/Module:		Subsystem Component			
User Authentication, Data Encryption, Session Management		Main Logic			
Notes:					
Risk Owner: Software Engineer, Design Owner: Quality Assurance Lead, Version/Project ID: ABC/SecureAuth/Ver1.0.0.0					

Software Failure Mode and Effects Analysis (FMEA)										Software FMEA Results									
Item ID	Failure Mode	Failure Effect	Failure Cause	Current Controls	Proposed Controls	RPN	Severity	Occurrence	Detection	Item ID	Failure Mode	Failure Effect	Failure Cause	Current Controls	Proposed Controls	RPN	Severity	Occurrence	Detection
1	User authentication fails	User cannot access system	Incorrect password entry	Input validation	Input validation and password reset functionality	3	10	1	1	1	2	User authentication fails	User cannot access system	Incorrect password entry	Input validation and password reset functionality	3	10	1	1
2	Data encryption fails	Data is not encrypted	Encryption key management error	Key management	Key management and encryption algorithm update	3	10	1	1	2	2	Data encryption fails	Data is not encrypted	Encryption key management error	Key management and encryption algorithm update	3	10	1	2
3	Session management fails	Session expires prematurely	Session timeout configuration	Session timeout	Session timeout and session renewal functionality	3	10	1	1	2	3	Session management fails	Session expires prematurely	Session timeout configuration	Session timeout and session renewal functionality	3	10	1	2
4	API endpoint fails	API returns error	API endpoint configuration	API endpoint	API endpoint and API gateway configuration	3	10	1	1	2	4	API endpoint fails	API returns error	API endpoint configuration	API endpoint and API gateway configuration	3	10	1	2
5	User session fails	User session expires	User session timeout	User session	User session and session renewal functionality	3	10	1	1	2	5	User session fails	User session expires	User session timeout	User session and session renewal functionality	3	10	1	2
6	Database connection fails	Database connection error	Database connection configuration	Database connection	Database connection and database backup functionality	3	10	1	1	2	6	Database connection fails	Database connection error	Database connection configuration	Database connection and database backup functionality	3	10	1	2
7	System configuration fails	System configuration error	System configuration configuration	System configuration	System configuration and system backup functionality	3	10	1	1	2	7	System configuration fails	System configuration error	System configuration configuration	System configuration and system backup functionality	3	10	1	2
8	User session fails	User session expires	User session timeout	User session	User session and session renewal functionality	3	10	1	1	2	8	User session fails	User session expires	User session timeout	User session and session renewal functionality	3	10	1	2
9	Database connection fails	Database connection error	Database connection configuration	Database connection	Database connection and database backup functionality	3	10	1	1	2	9	Database connection fails	Database connection error	Database connection configuration	Database connection and database backup functionality	3	10	1	2
10	System configuration fails	System configuration error	System configuration configuration	System configuration	System configuration and system backup functionality	3	10	1	1	2	10	System configuration fails	System configuration error	System configuration configuration	System configuration and system backup functionality	3	10	1	2



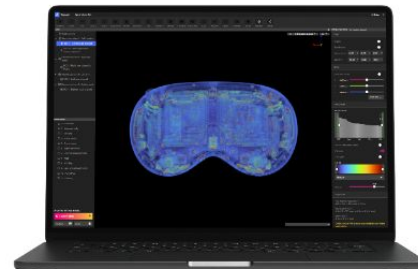
Lumafield makes hardware and software for industrial X-ray inspection



Neptune
Industrial CT scanner



Triton
Production-scale CT



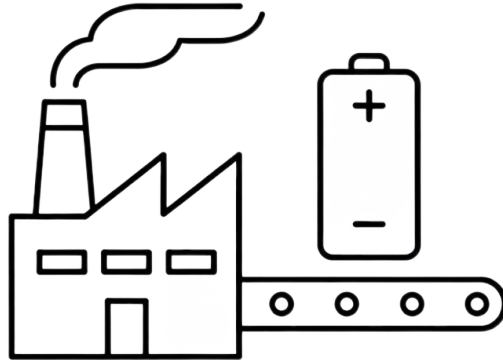
Voyager
Analysis software

Lumafield Battery Quality Report

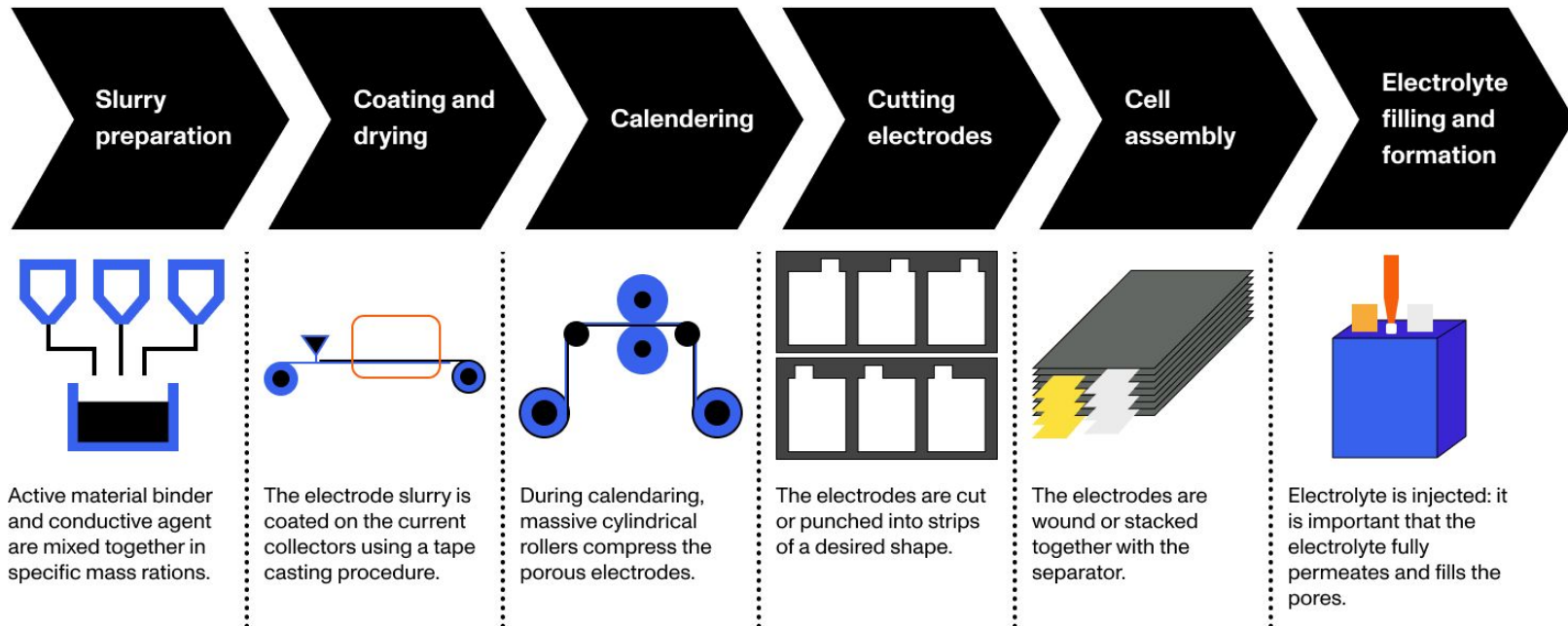


- Lumafield marketing material
- 1,054 scans of COTS 18650 cells
- Approx. 2 hours of UFCT scanning
- Thanks to automation, the data and analysis are accessible

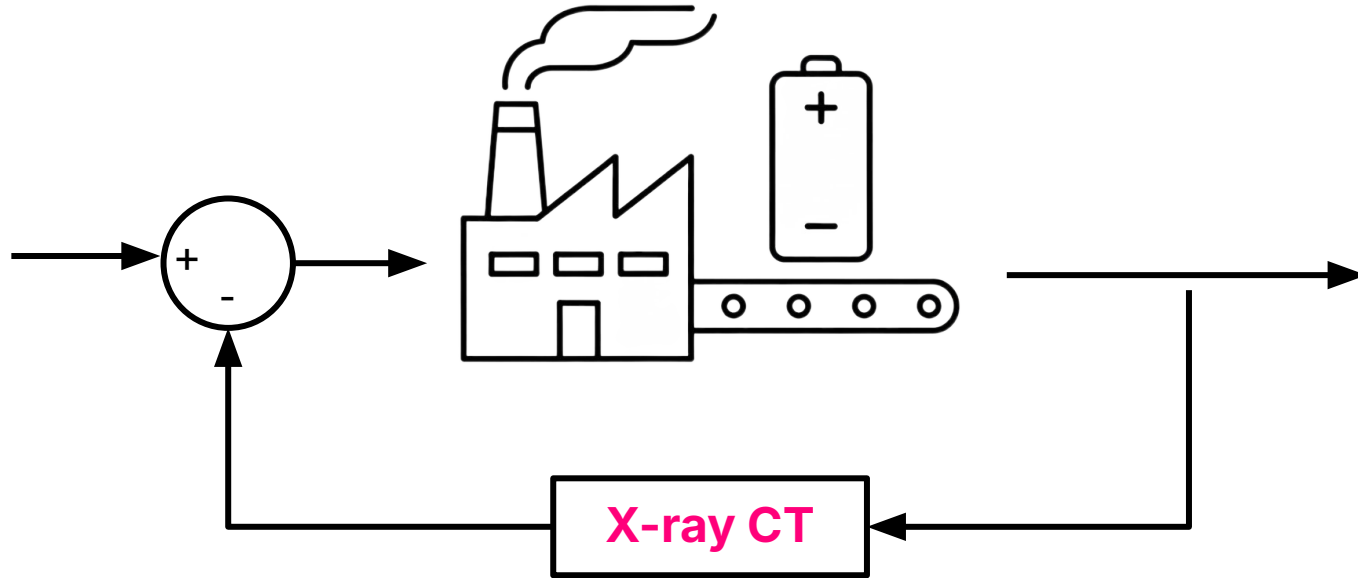
Battery inspection for manufacturers



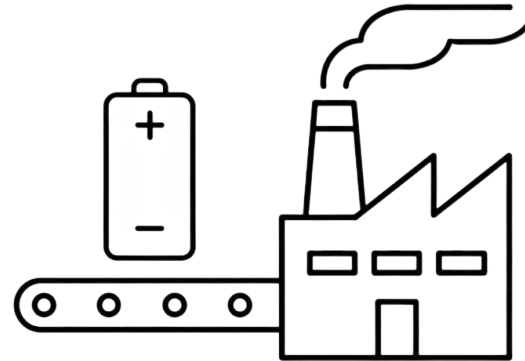
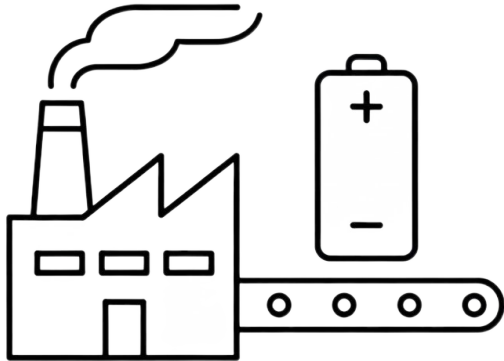
Battery inspection for manufacturers



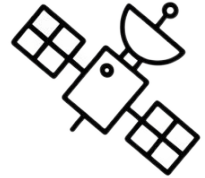
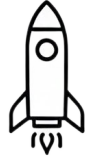
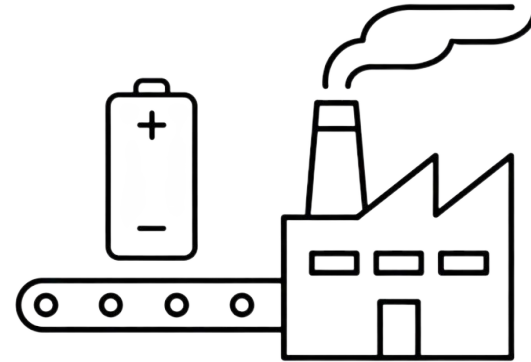
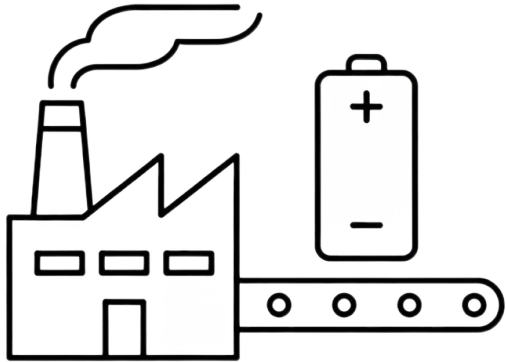
X-ray CT for closed-loop quality control

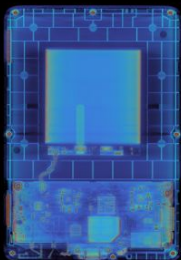


Cell manufacturing is only part of the picture

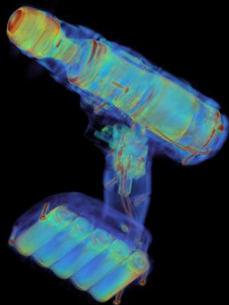


Integrators face significant risk and uncertainty

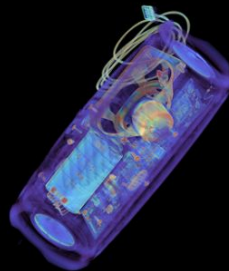




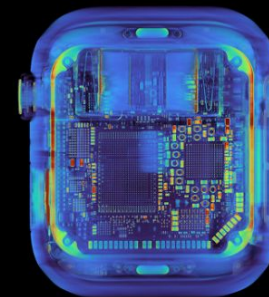
E-Reader



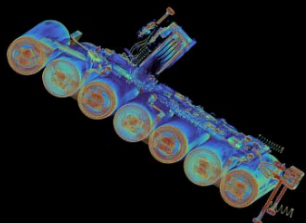
Cordless drill
Contains 5x 18650 Cells



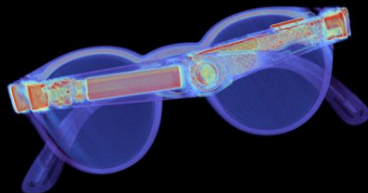
Bluetooth Speaker
Contains 3x 18650 cells



Smartwatch



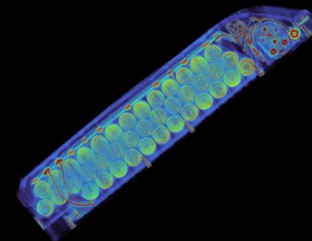
Cordless vacuum battery
Contains 7x 18650 cells



Smart glasses



Game controller



E-bike battery
Contains 39x 18650 cells

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

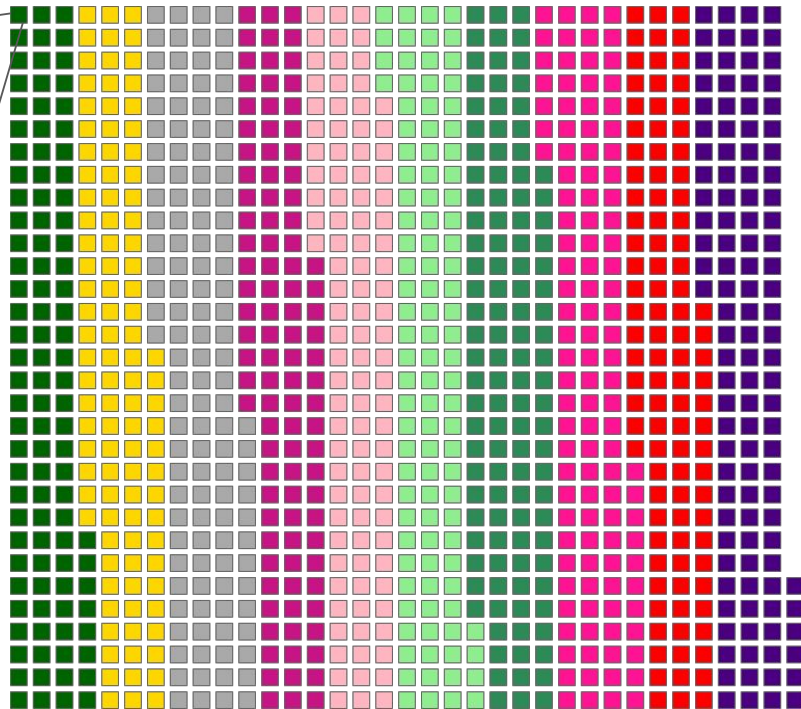
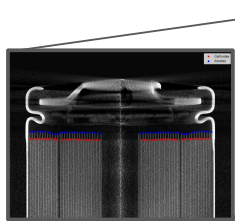
Let's look at 1,054 CT scans of COTS 18650 cells



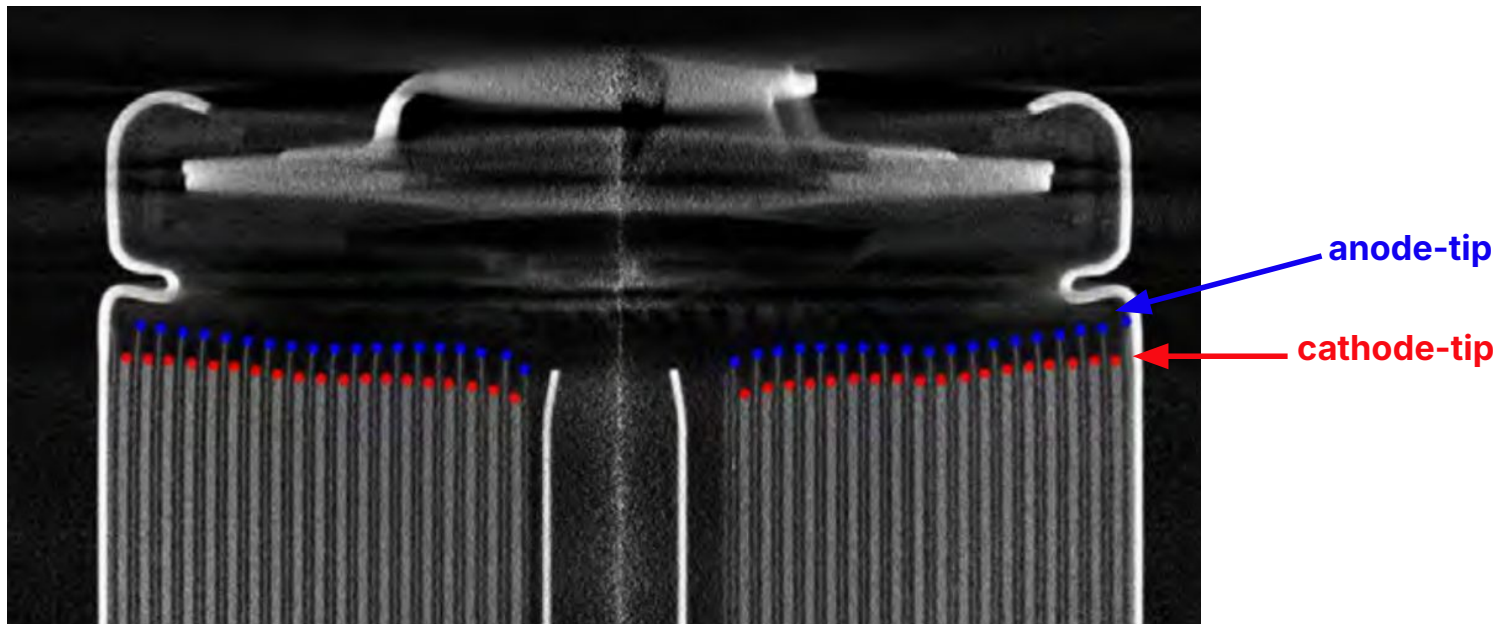
Murata Maxaieon Trustfire Efest SOOCOO



Panasonic Benkia Samsung Vapcell Treasurecase



Let's focus on electrode alignment

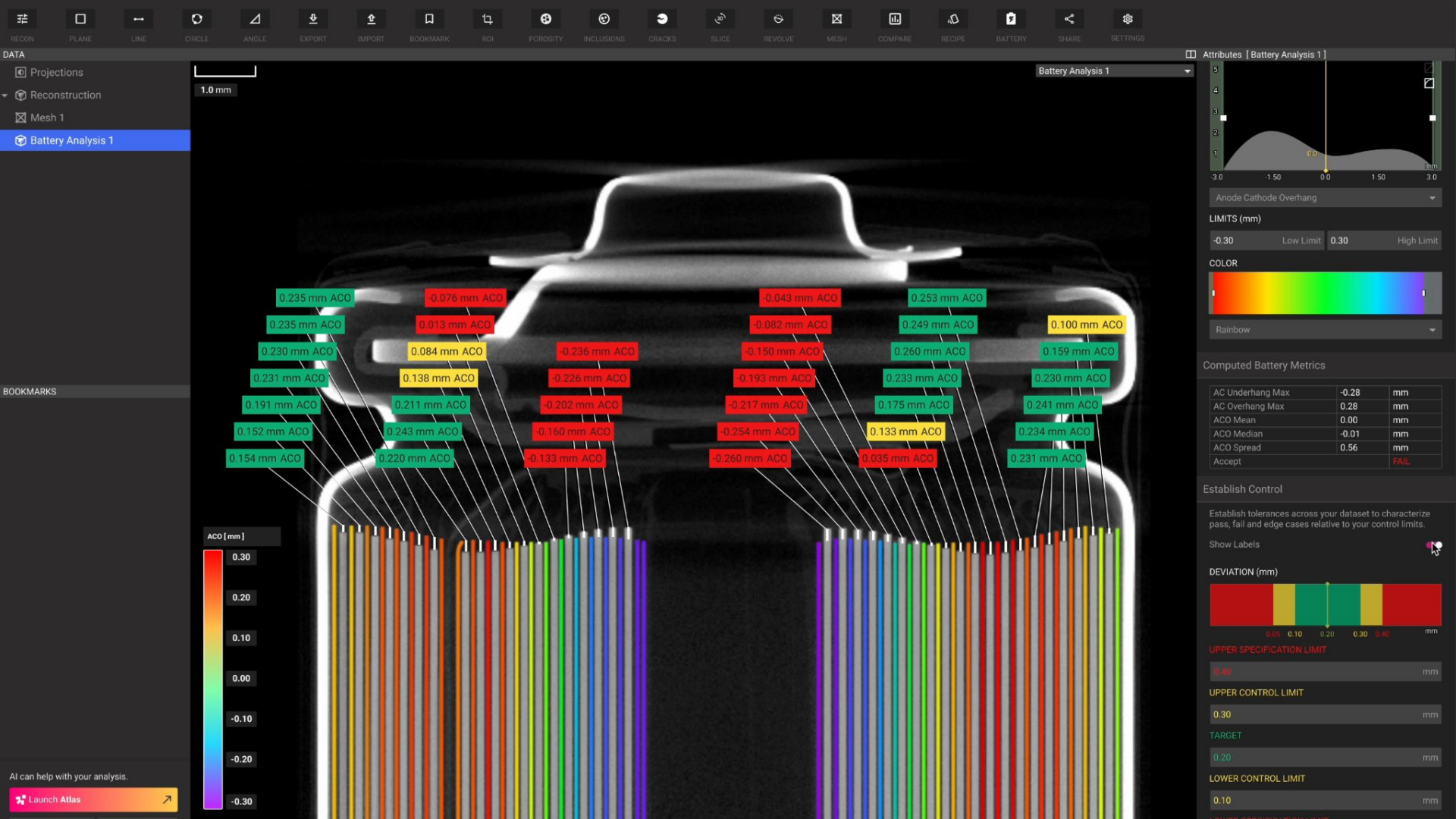


Anode overhang (AOH)
Anode-cathode overhang (ACO)

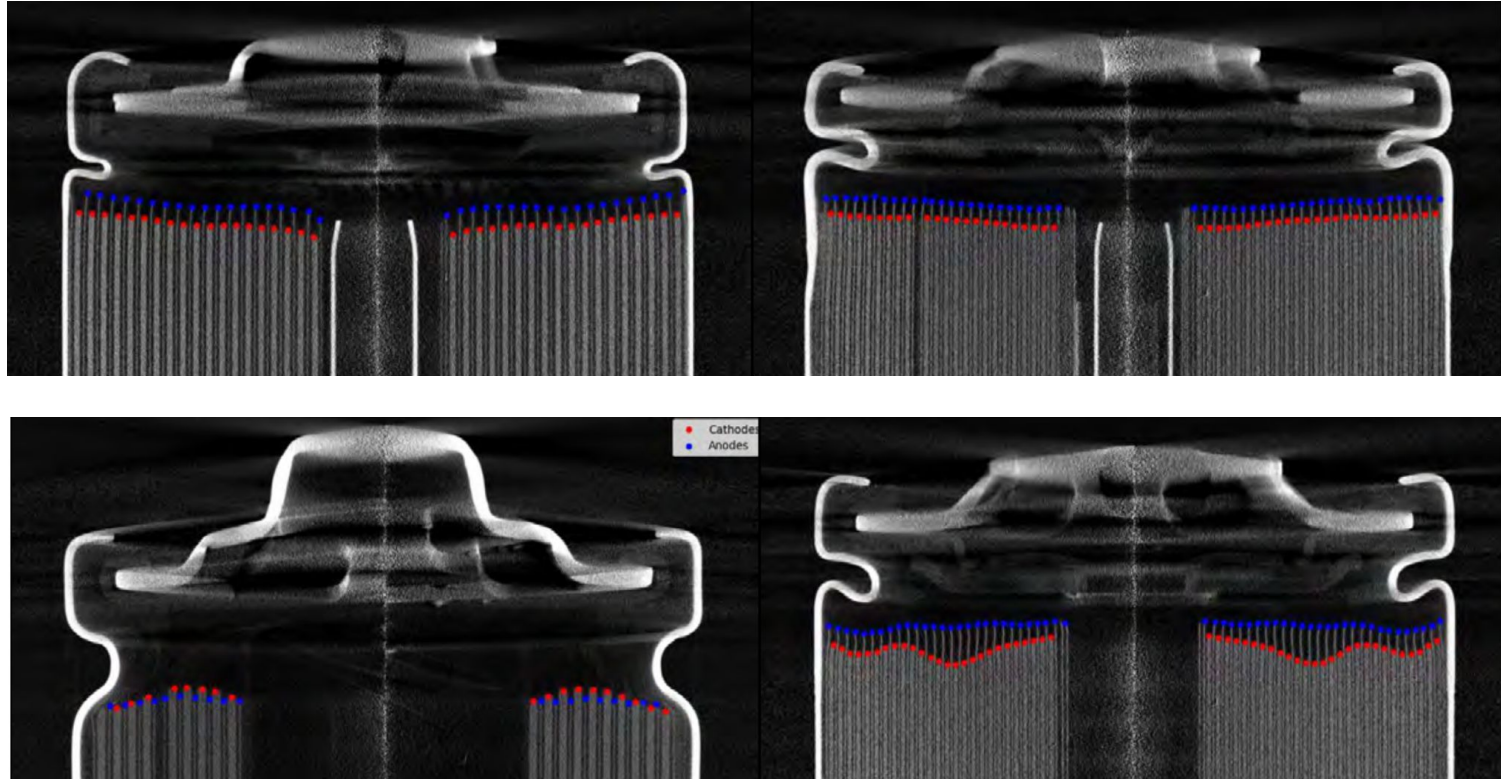
$$y_{\text{anode_i}} - y_{\text{cathode_i}}$$

Cathode Edge Alignment

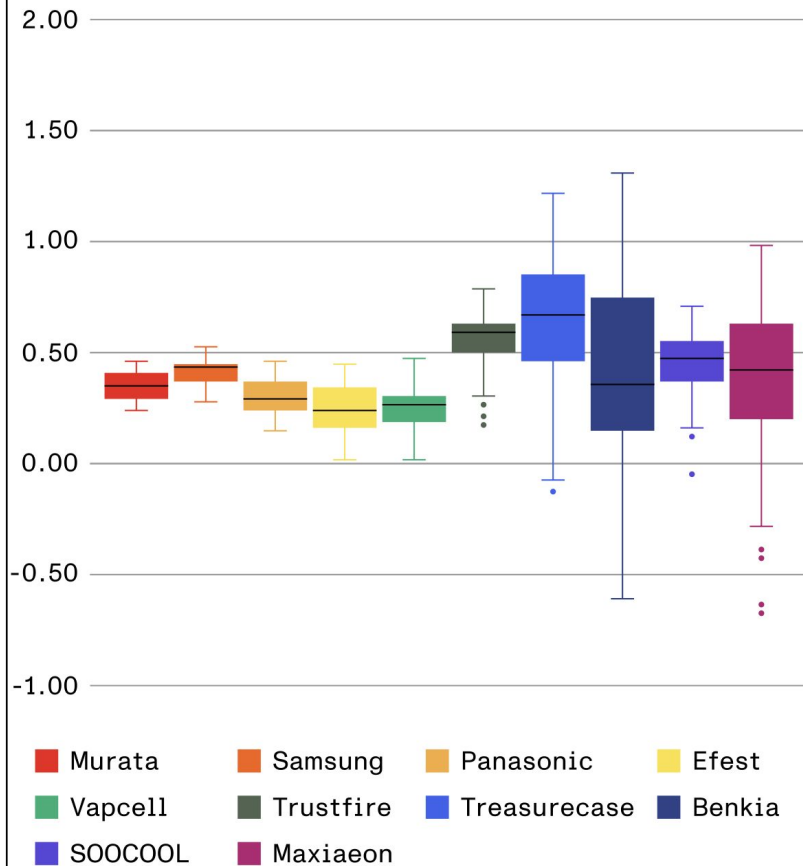
$$y_{\text{cathode_max}} - y_{\text{cathode_min}}$$



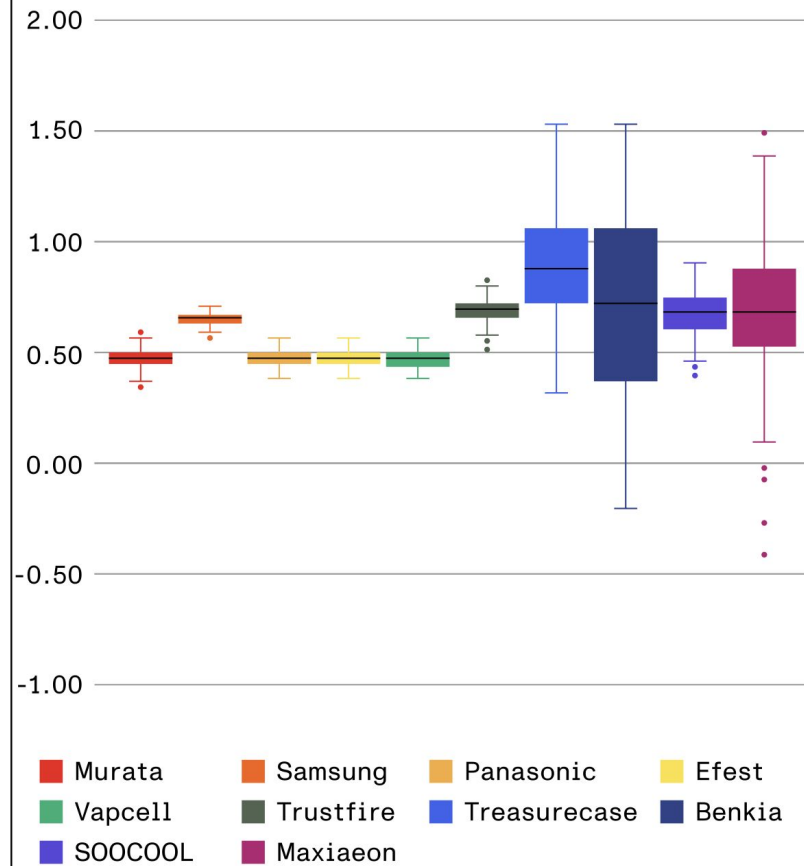
Electrode alignment varies wildly



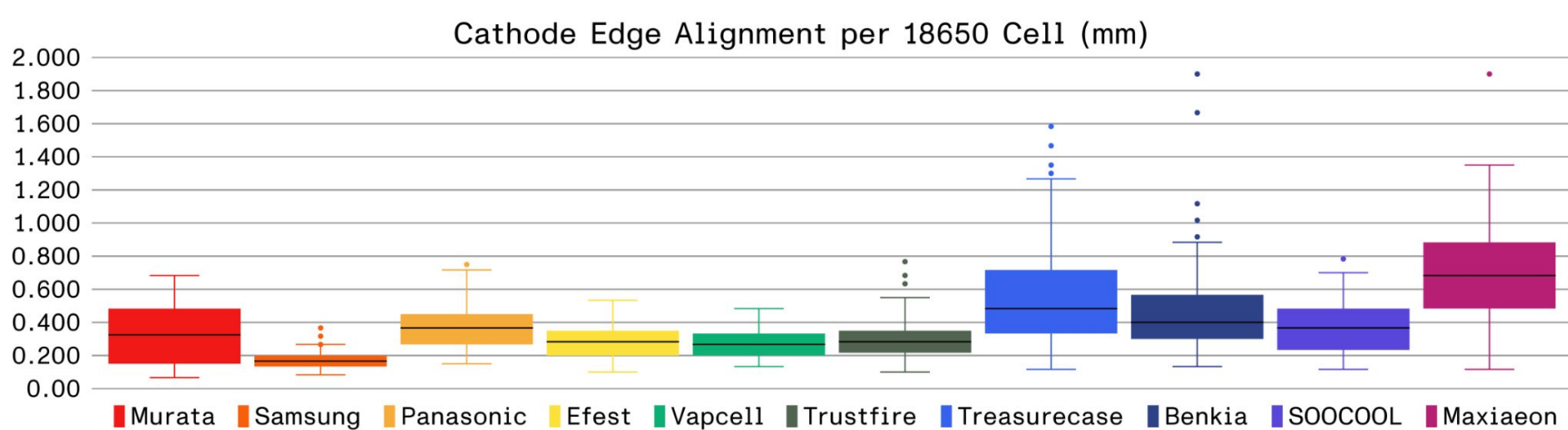
Smallest Anode Overhang
Measurement per 18650 Cell (mm)



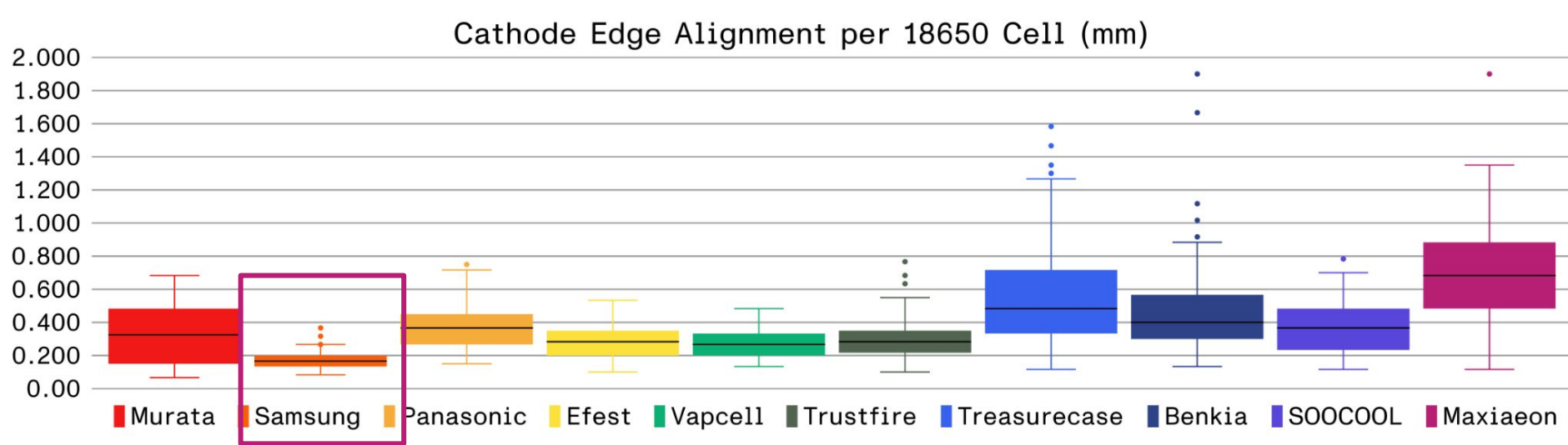
Median Anode Overhang
Measurement per 18650 Cell (mm)



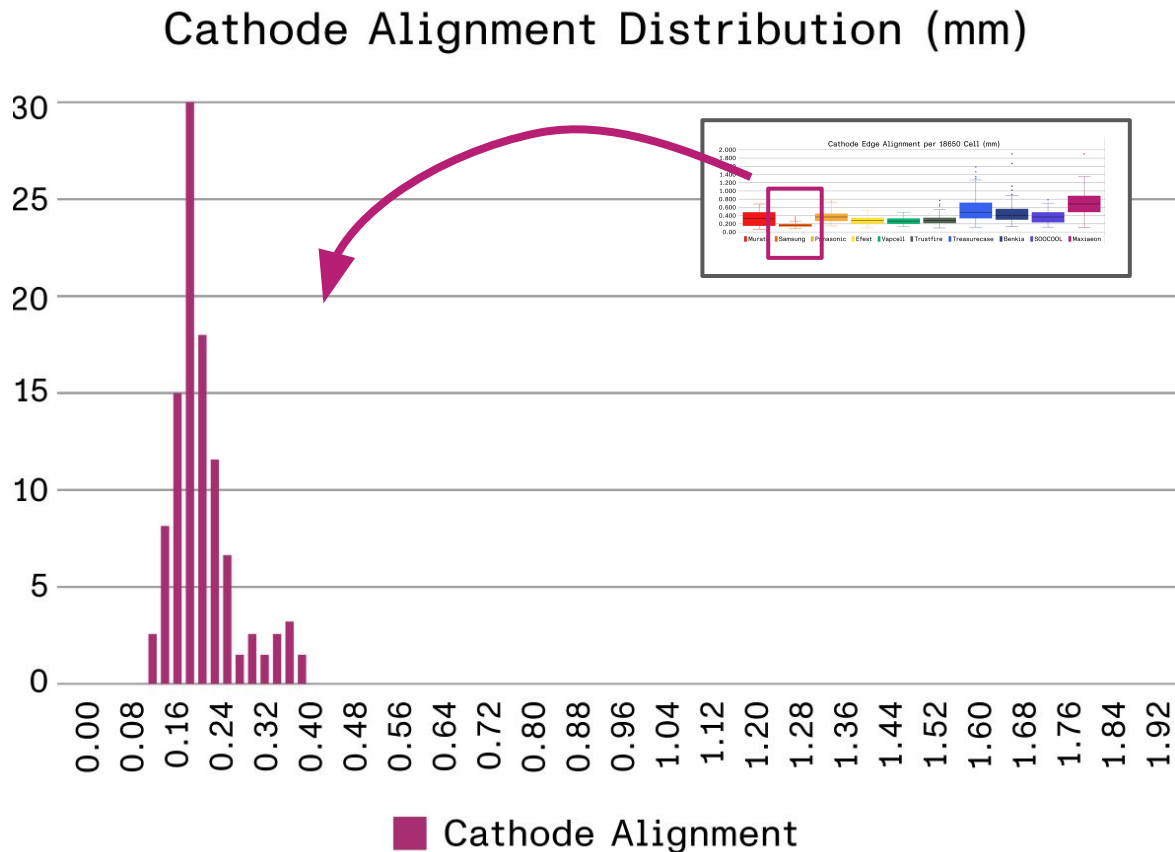
Median and standard deviation do tell **a** story



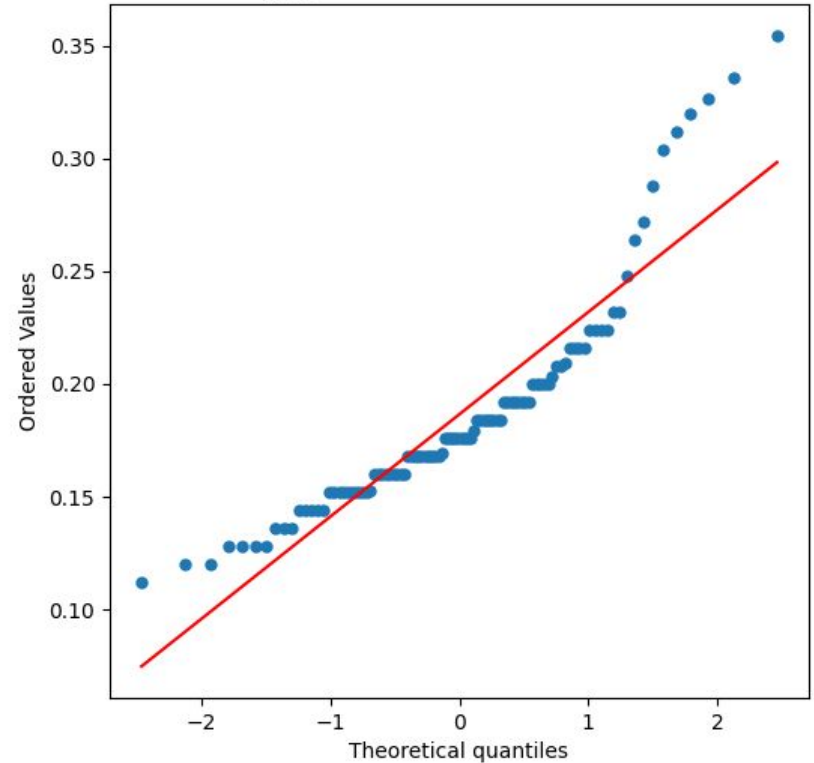
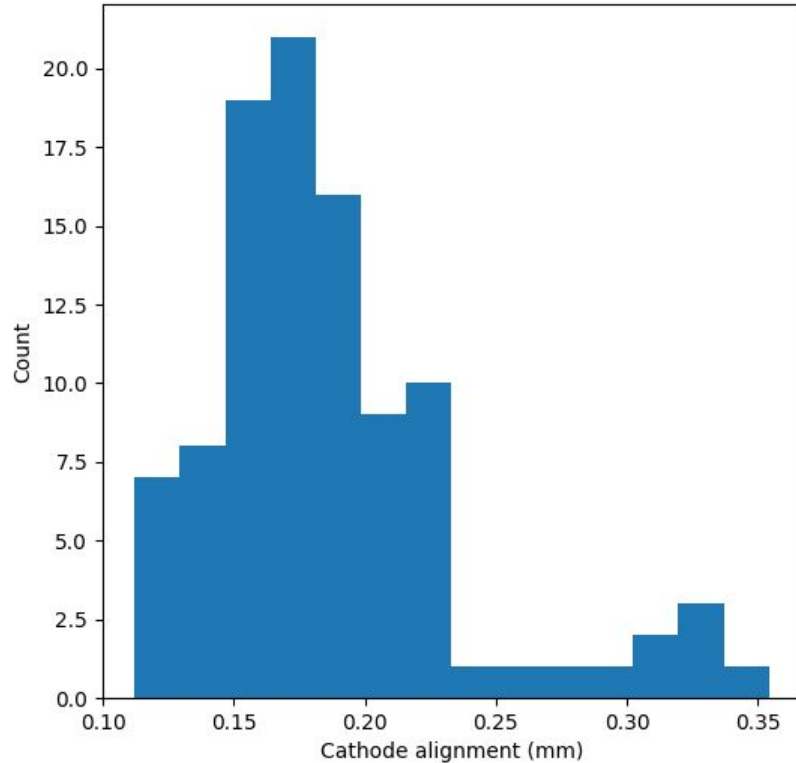
Median and standard deviation do tell **a** story



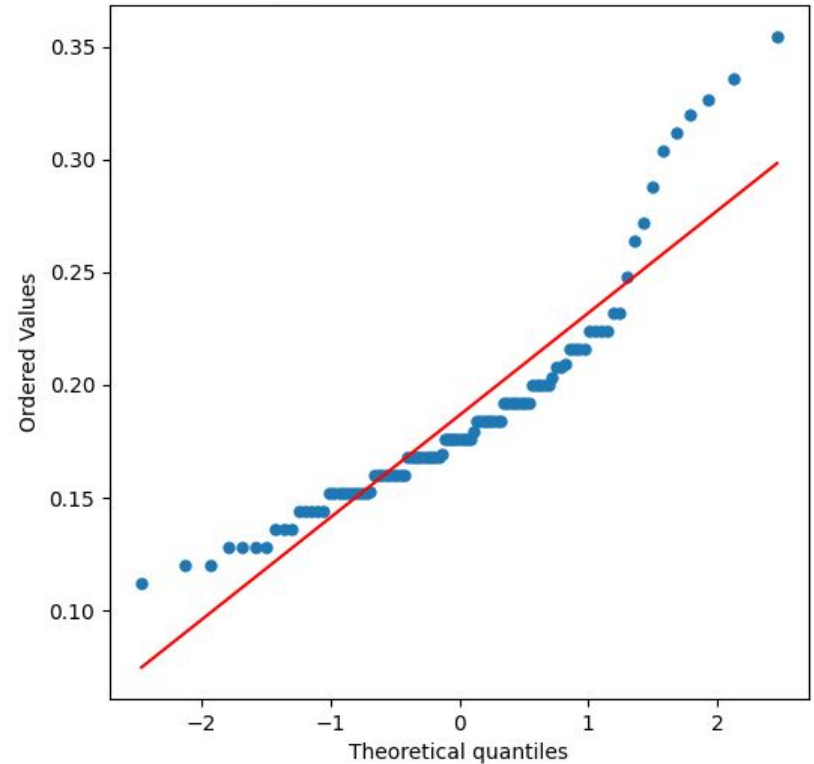
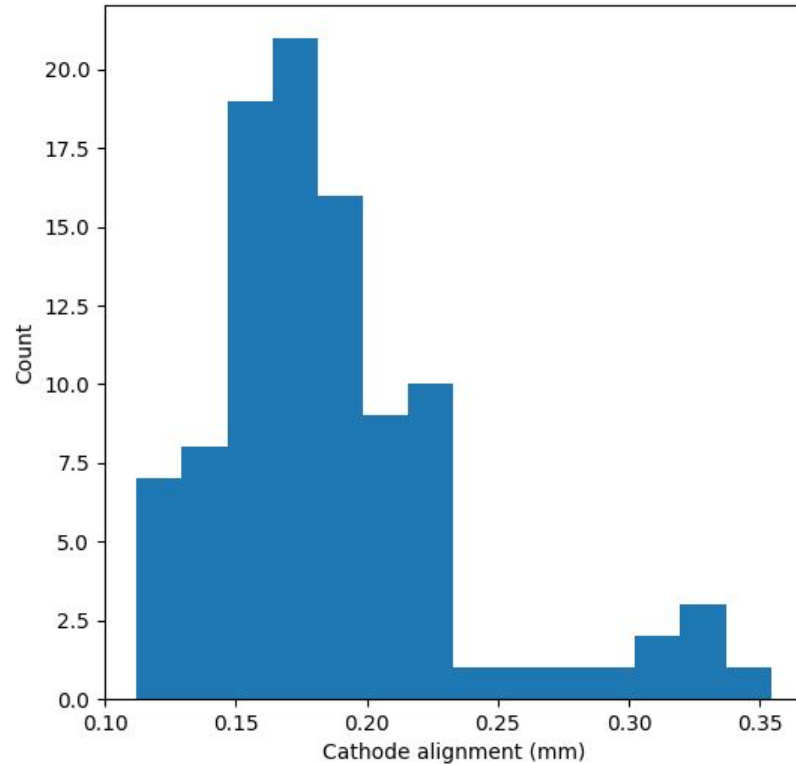
The distribution tells a more **complete** story

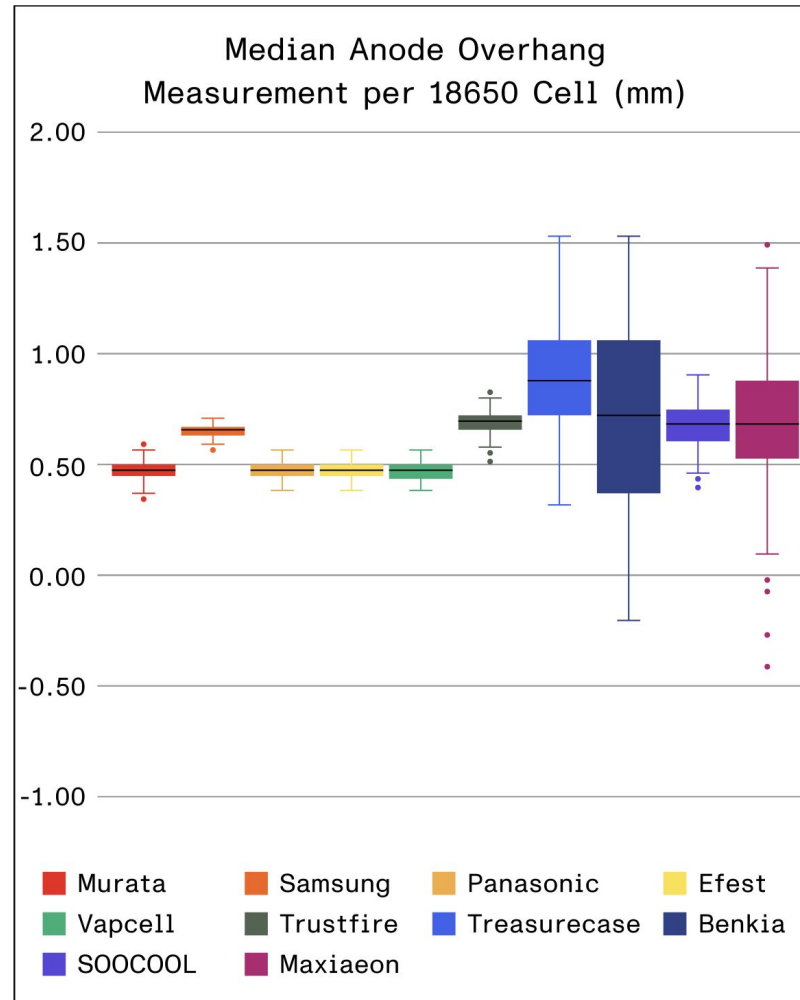


QQ plot highlights departure from normal dist.

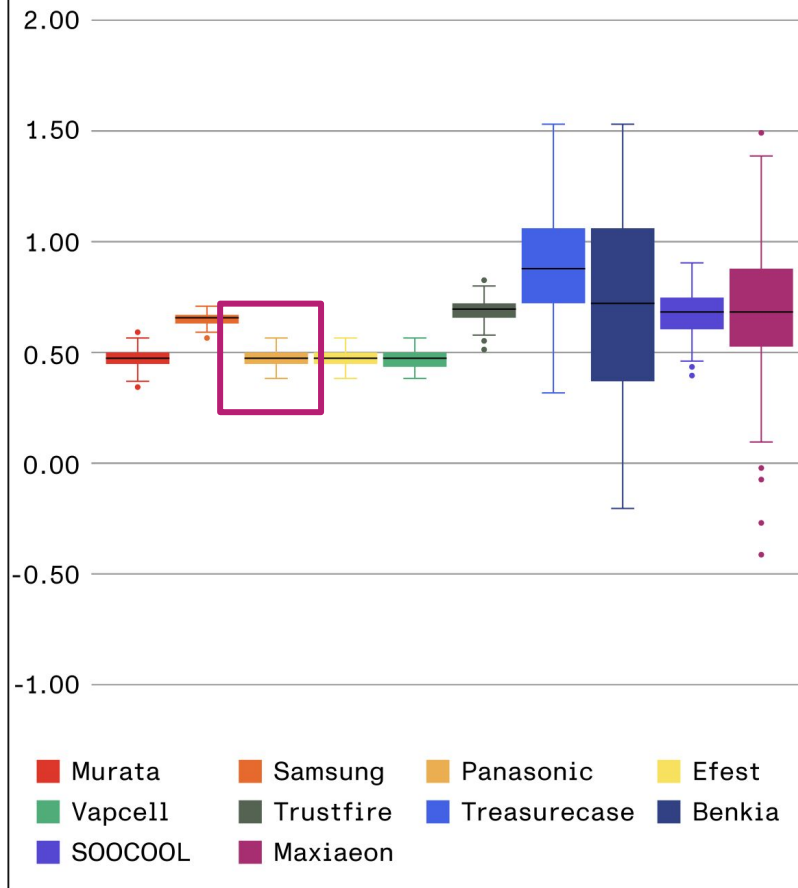


The distribution tells a more **complex** story

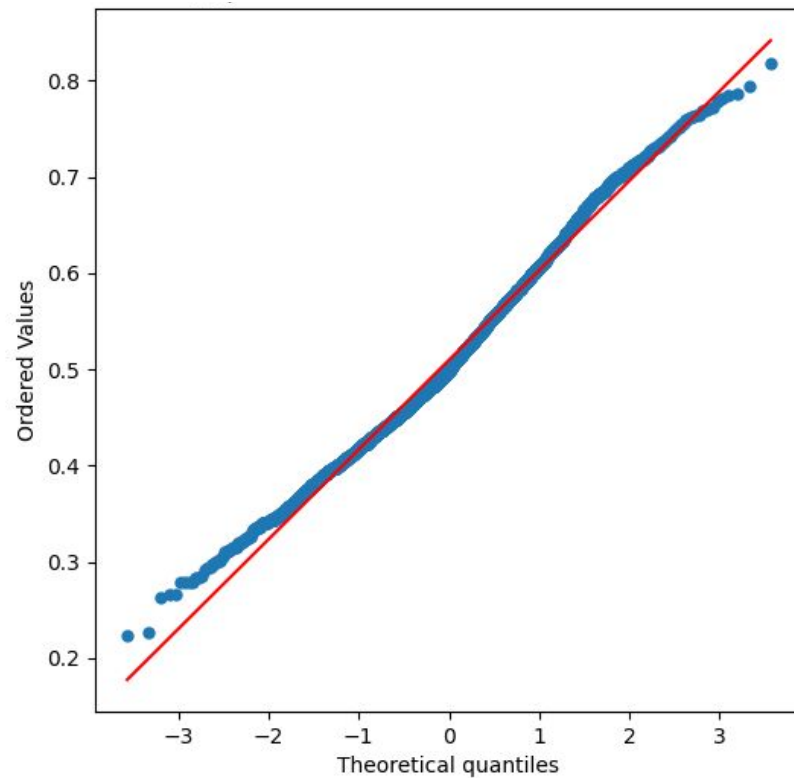
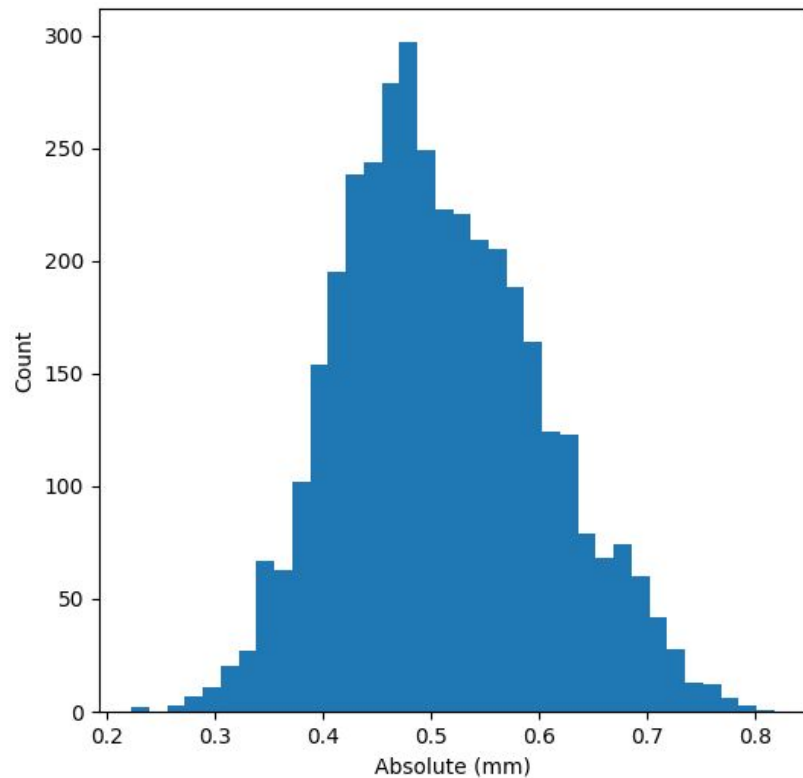


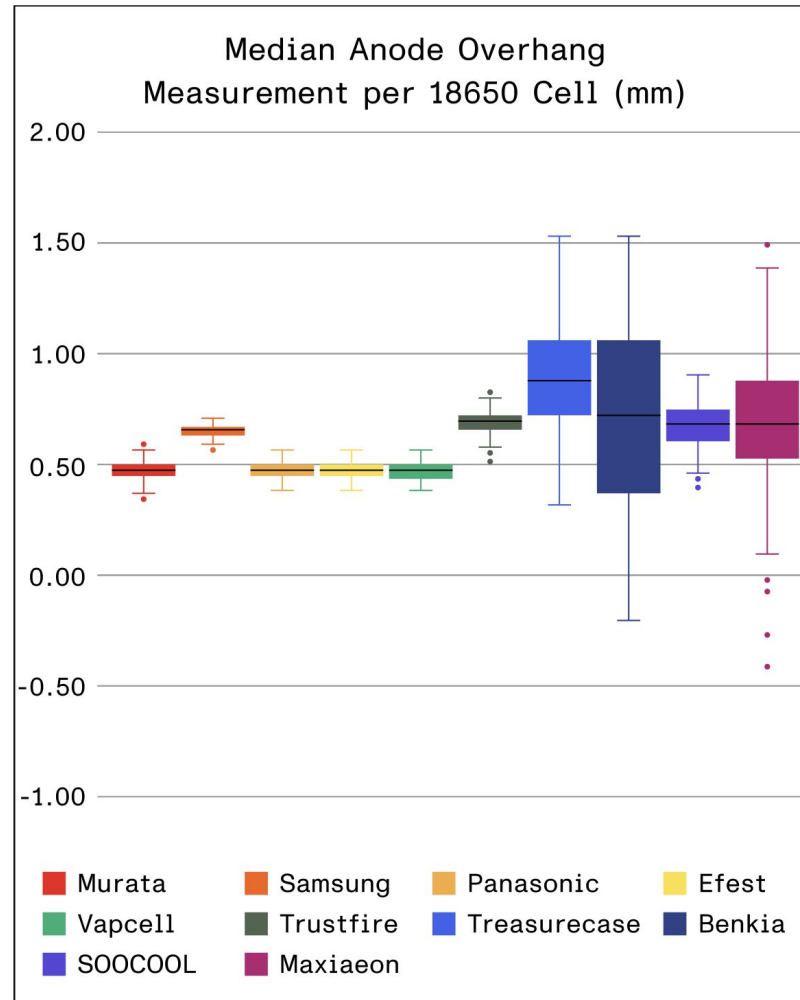


Median Anode Overhang
Measurement per 18650 Cell (mm)

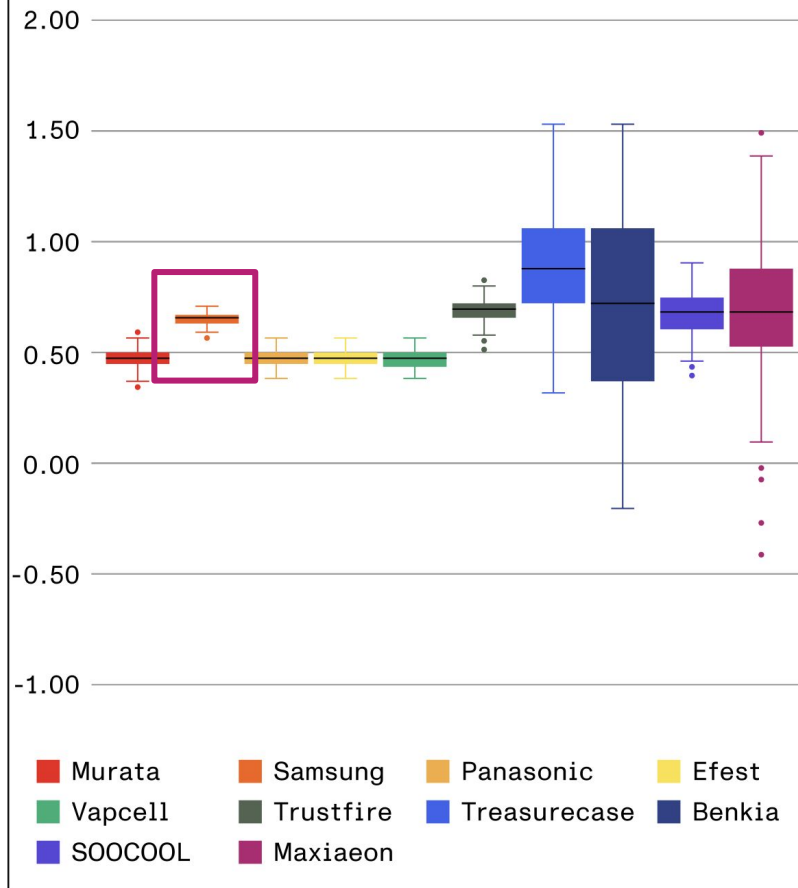


Panasonic Anode Overhang

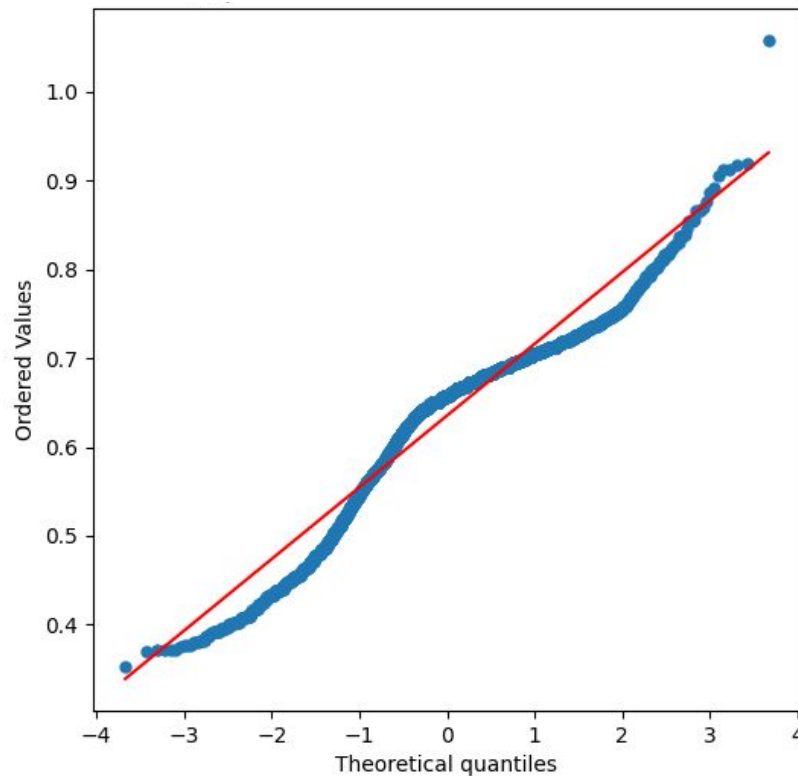
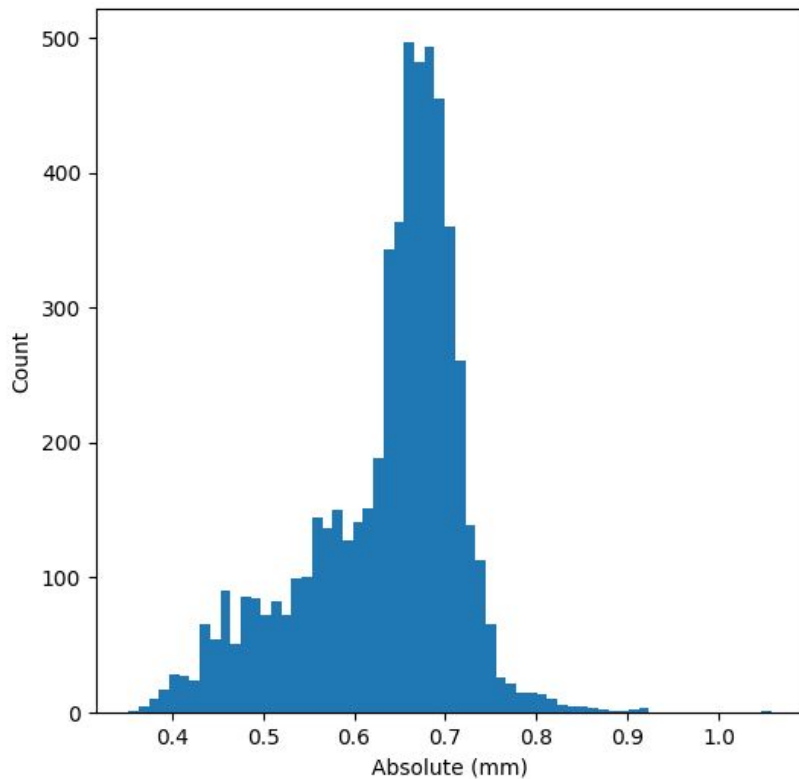




Median Anode Overhang
Measurement per 18650 Cell (mm)



Samsung Anode Overhang



So what?



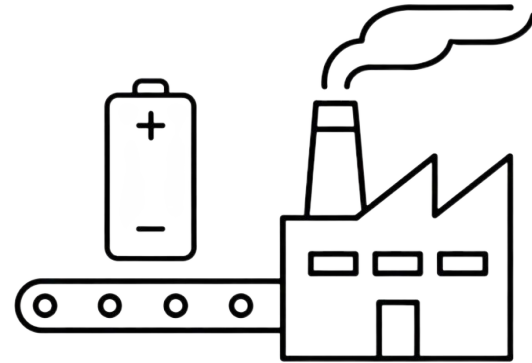
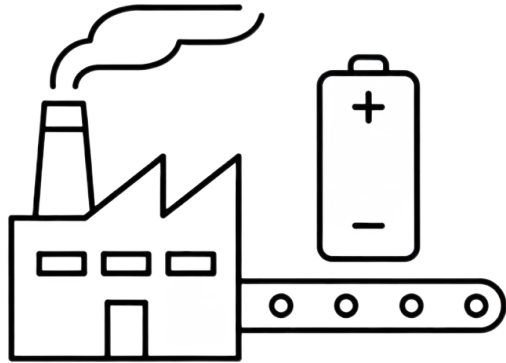
Take a step back

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





 lumafield

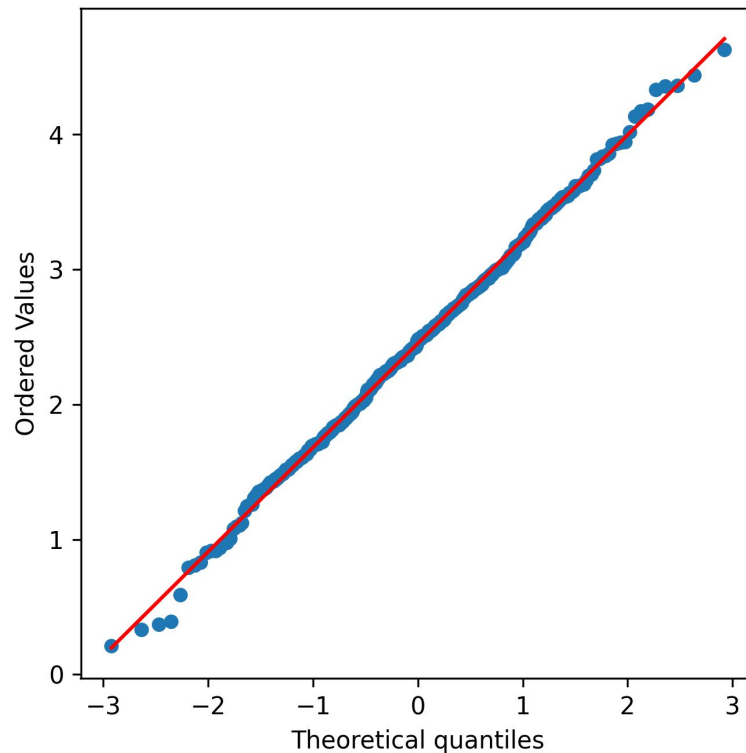
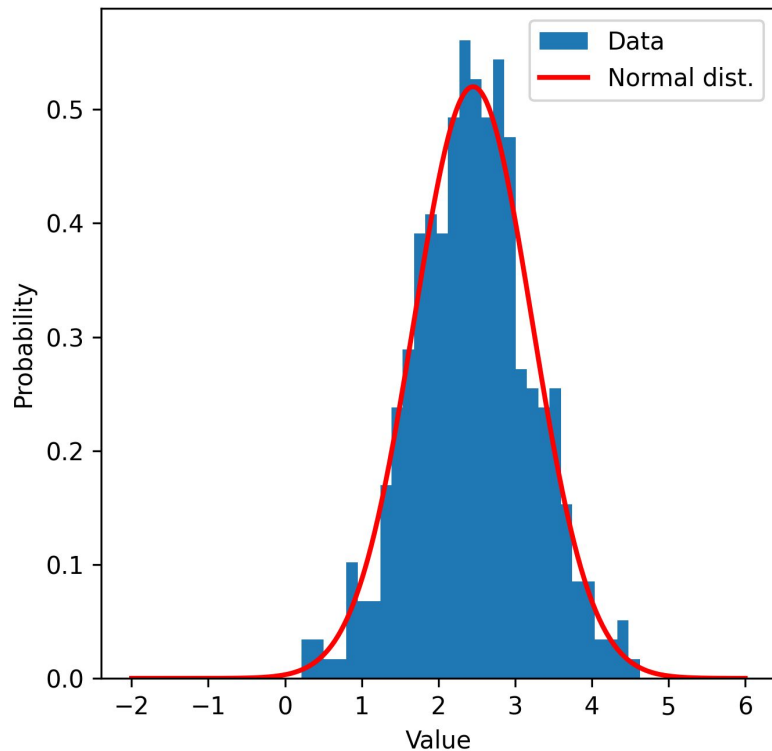


<https://www.lumafield.com/battery-report>

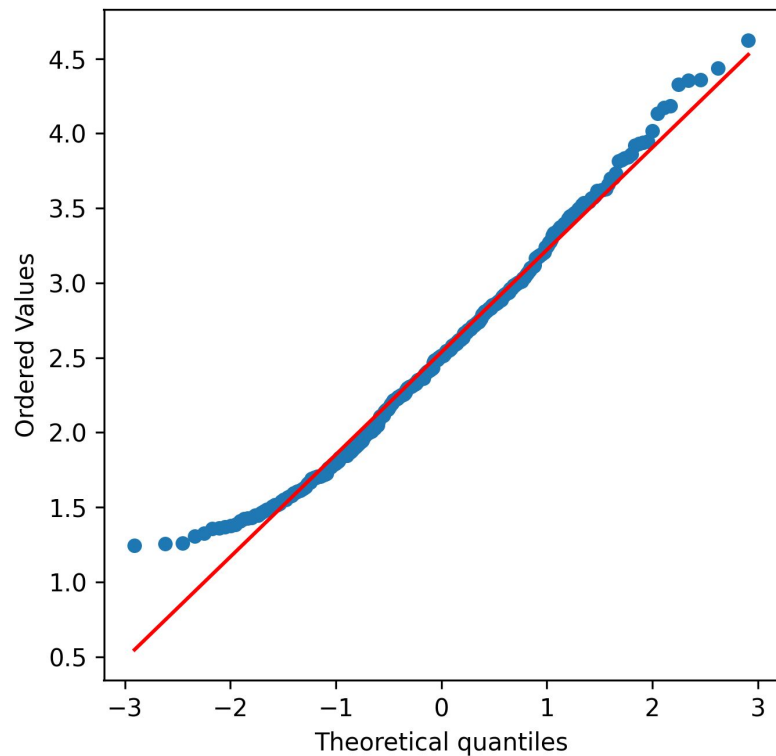
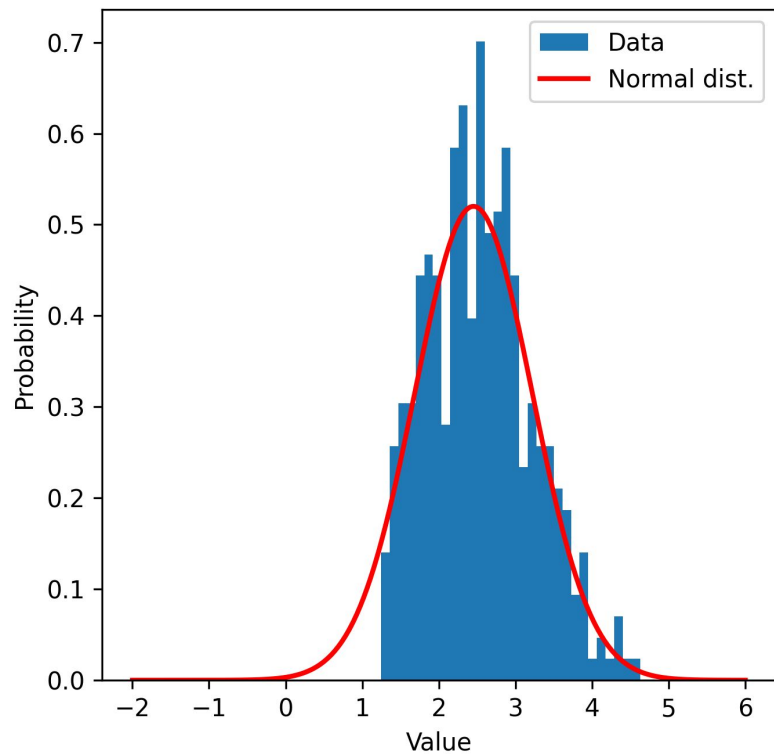
info@lumafield.com
kevin@lumafield.com

Appendix

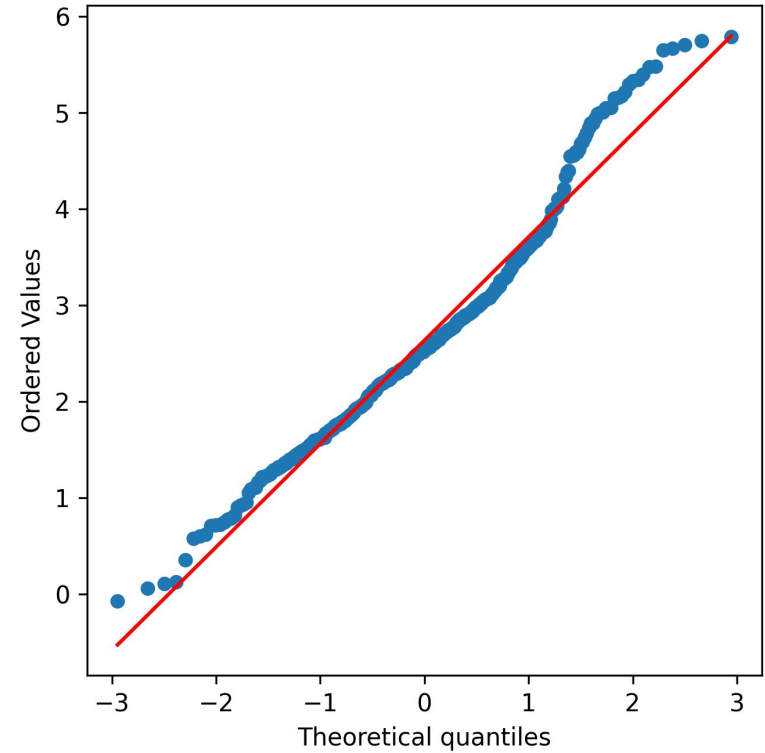
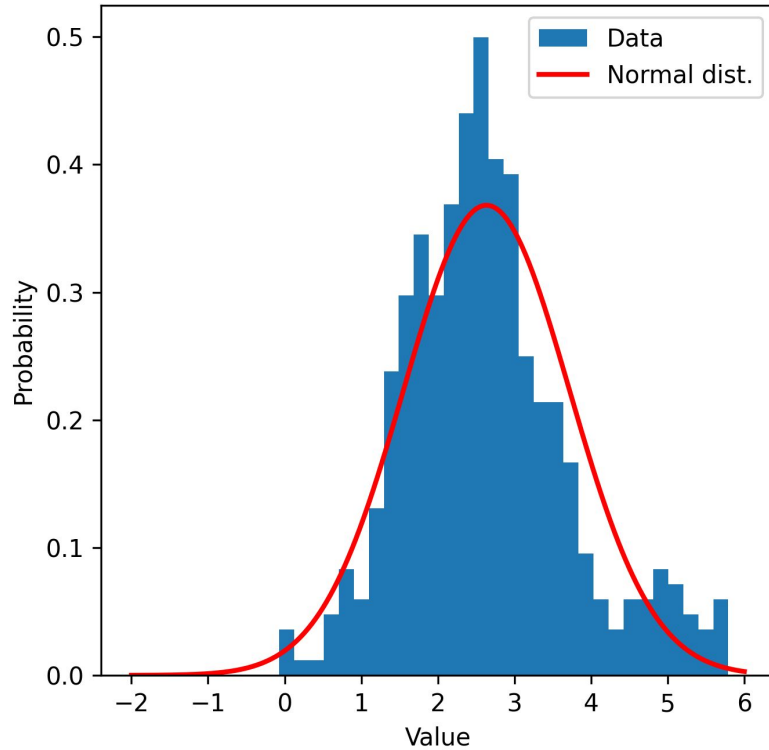
Synthetic normal data



Synthetic truncated normal data



Synthetic bimodal normal data



Poisson distribution for FOD