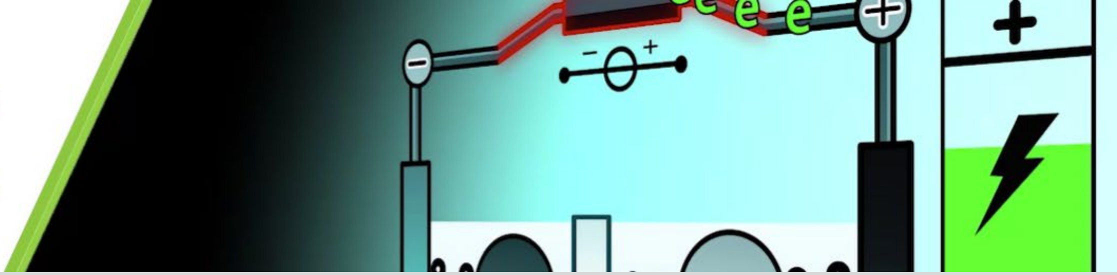
22nd Annual
advanced automotive battery conference
DECEMBER 5 - 8, 2022
HOTEL DEL CORONADO | SAN DIEGO, CA



Big Data in Diagnostics

Data-Driven Direct Diagnosis of PV Connected Batteries

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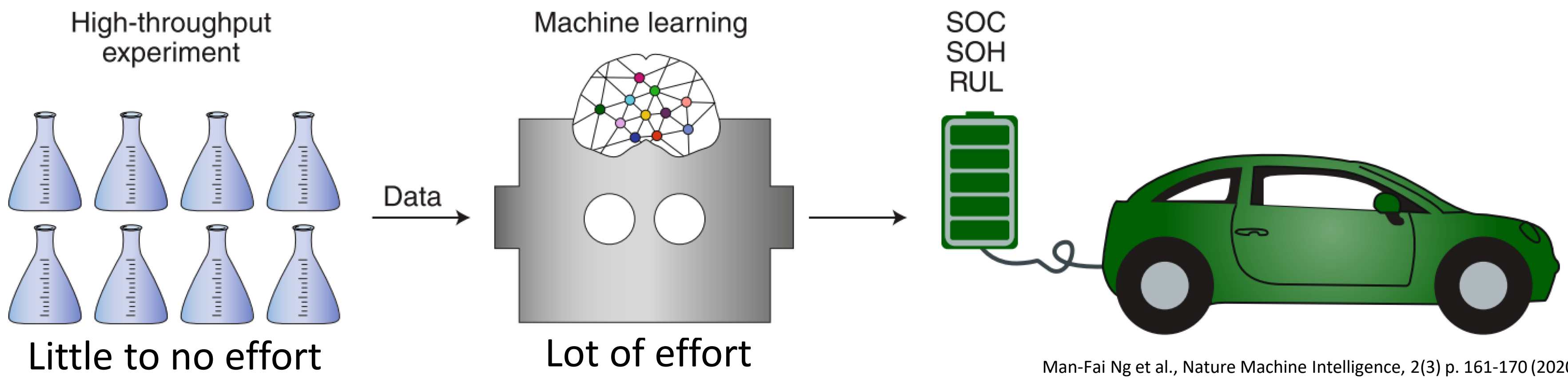
Big Data for Li-Ion Diagnosis and Prognosis

Artificial Intelligence

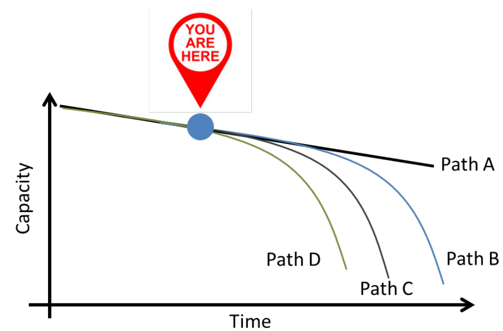
Objective/Significance



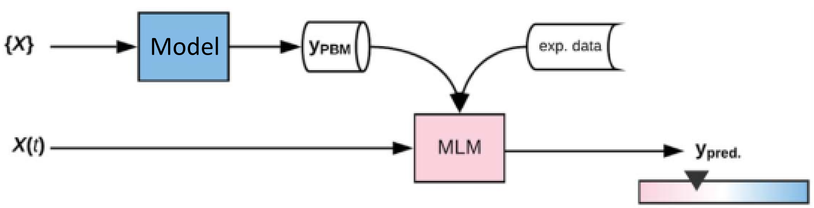
Man-Fai Ng et al., Nature Machine Intelligence, 2(3) p. 161-170 (2020)

Experimental data is costly and time consuming,
Most studies only test a couple batteries,
Biggest dataset: 124 batteries with only charge varying

Problematic because of path dependence.



Current state of the art is far from the big data needed to make AI work

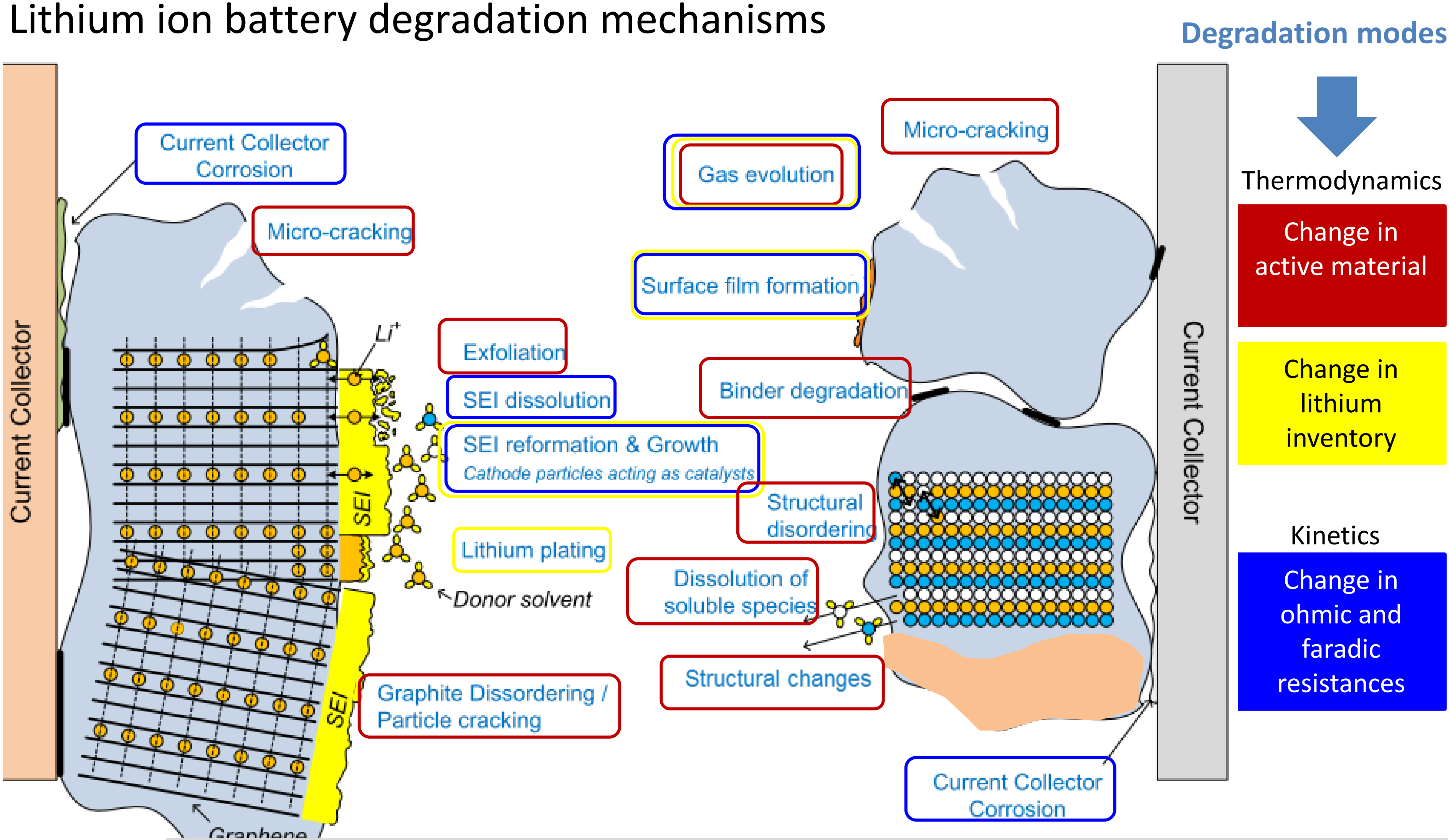


Solution: Transfer Learning
Create synthetic training datasets

Big Data for Li-Ion Diagnosis and Prognosis

Li-ion batteries are complex systems

Lithium ion battery degradation mechanisms



Degradation modes refer to **the impact of a mechanism rather than its root cause**.

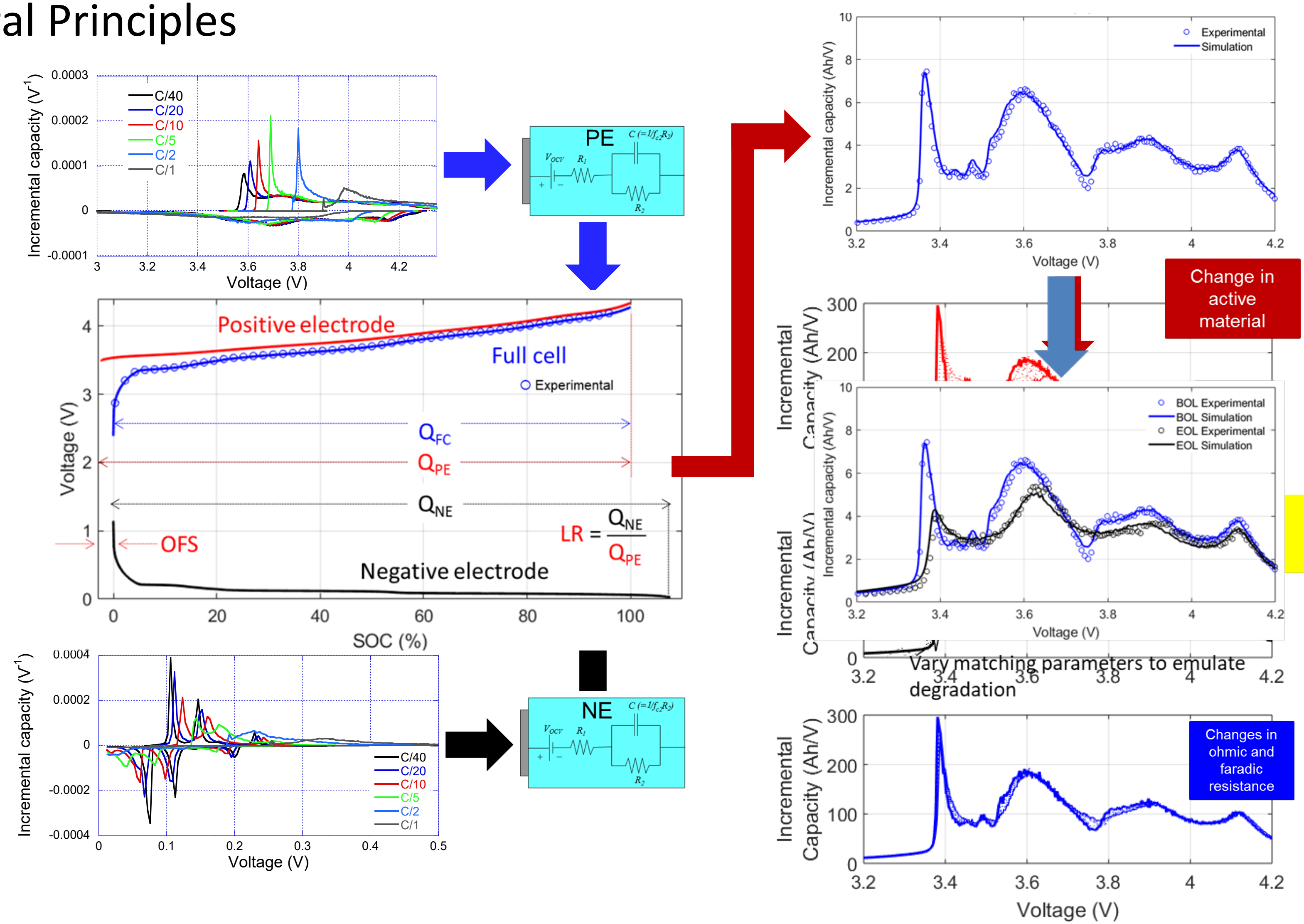
M. Dubarry, C. Truchot and B.Y. Liaw, *J.Power Sources*, **219** (2012) 204-216

Big Data for Li-Ion Diagnosis and Prognosis

Building a Digital Twin: Mechanistic modeling

'alawa

General Principles

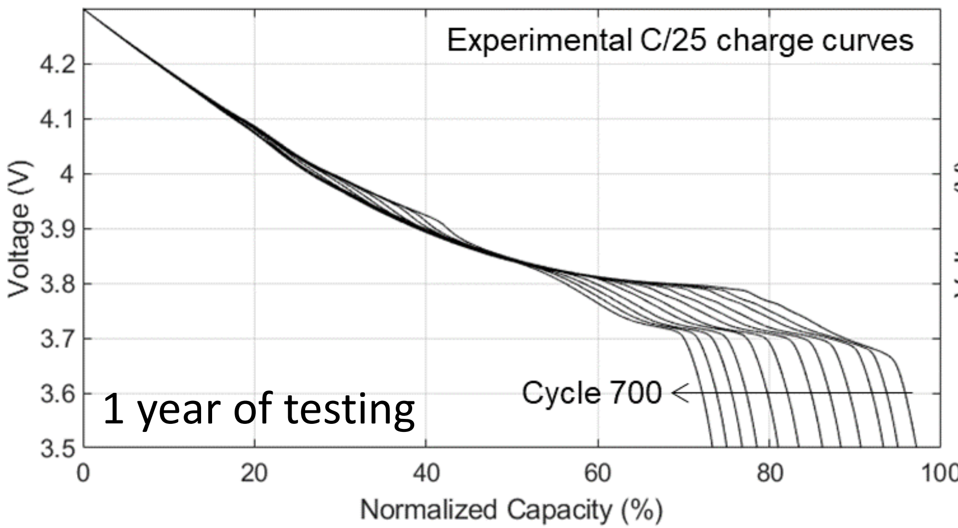


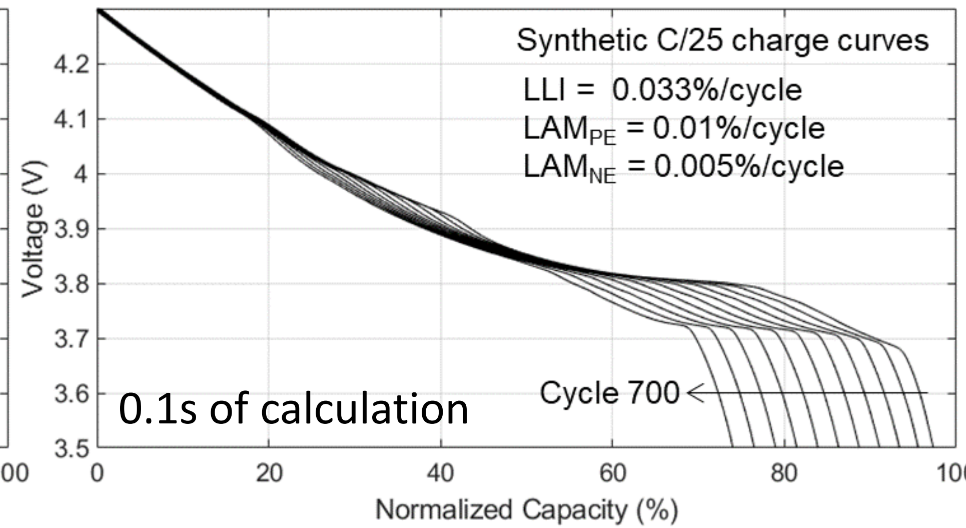
Big Data for Li-Ion Diagnosis and Prognosis

Simulate any possible degradation

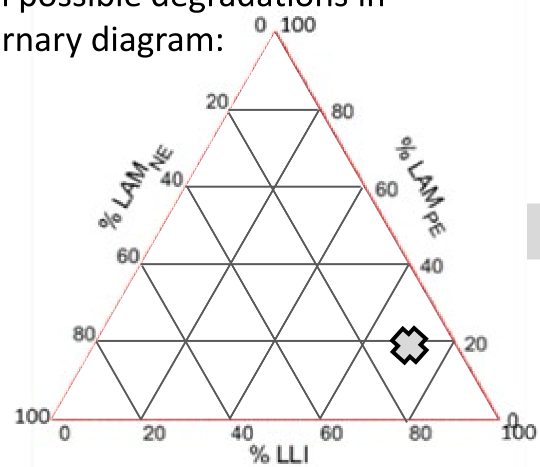
Emulation of battery electrochemical response

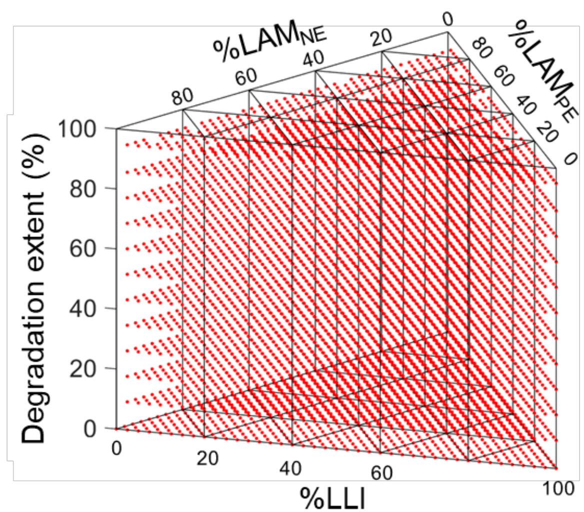
Aging reconstructed from simple equations





All possible degradations in ternary diagram:





Infinite training data for diagnosis AI algorithms

Mendeley Data, 2020; Vol. 2021, 10.17632/6s6ph9n8zg.3
Mendeley Data, 2020; Vol. 2021, 10.17632/bs2j56pn7y.3
Mendeley Data, 2021, 10.17632/2h8cpszy26.1
Mendeley Data, 2021, 10.17632/pb5xpv8z5r.1

Dubarry M. et al., Journal of Power Sources 479 (2020) 228806, Dubarry M. et al., Energies 2021, 14, 2371. https://doi.org/10.3390/en14092371
Dubarry, M., et al. (2017). "State of health battery estimator enabling degradation diagnosis: Model and algorithm description." Journal of Power Sources **360**: 59-69.

Take Home Message

Proof-of-concept methodology to generate **big data training datasets**

Universal tool for creation of data indistinguishable from real one

Broad applicability: cell chemistries, designs, and operating modes

Methodology could be **applied to different conditions** such as rate and temperature

Can handle **lithium plating with adjustable reversibility**
Ideal to **test validity** of different approaches for diagnosis or prognosis

The approach **does not remove the need for experimental testing**
It is still essential, and the only way, to decipher which conditions cater to specific degradation.

More details: Dubarry M. et al., Journal of Power Sources 479 (2020) 228806
Dubarry M. et al., Energies, 2021, 14(9), 2371

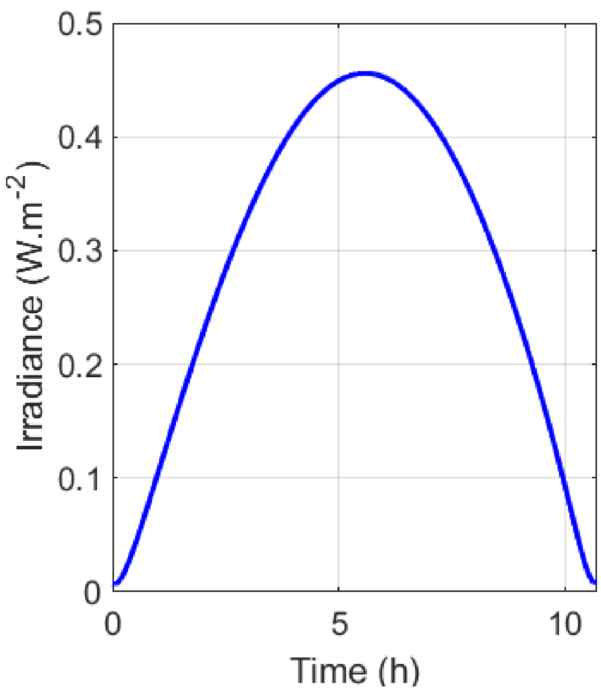
Data-Driven Diagnosis for PV Connected Batteries

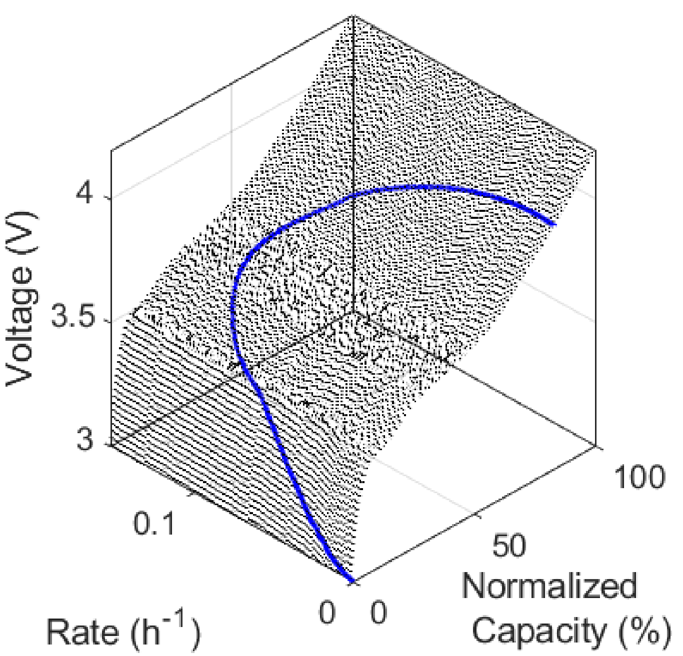
Current Synthetic dataset approach for constant current data only

- Not representative of deployed data (unless lengthy maintenance cycles)

Mechanistic model can be applied outside of constant current data

- Could use auspicious conditions for deployed systems
- Emulation of clear sky irradiance: predictable power output

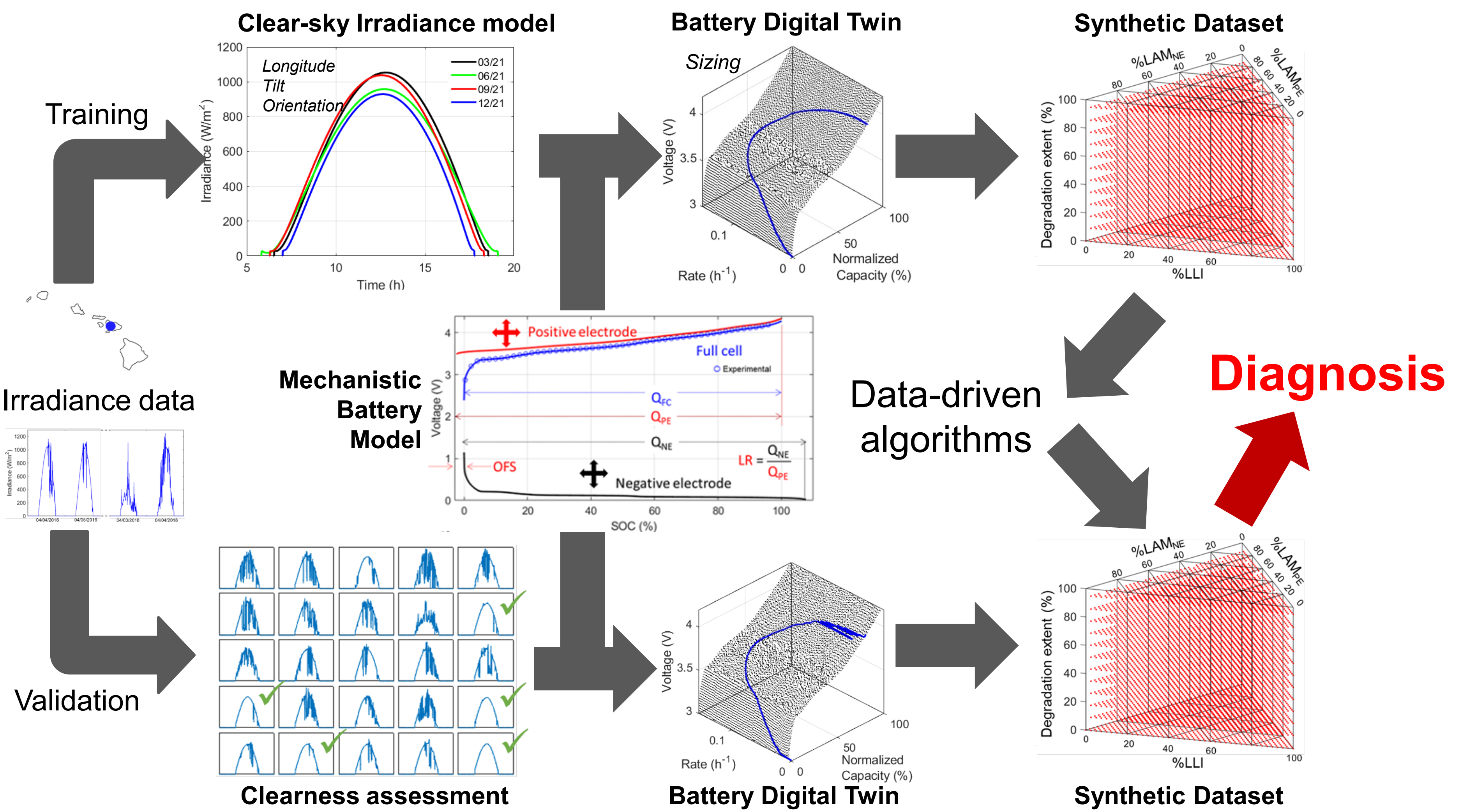




Dubarry M. and D. Beck, Accounts of Material Research, 10.1021/accountsmr.2c00082

Data-Driven Diagnosis for PV Connected Batteries

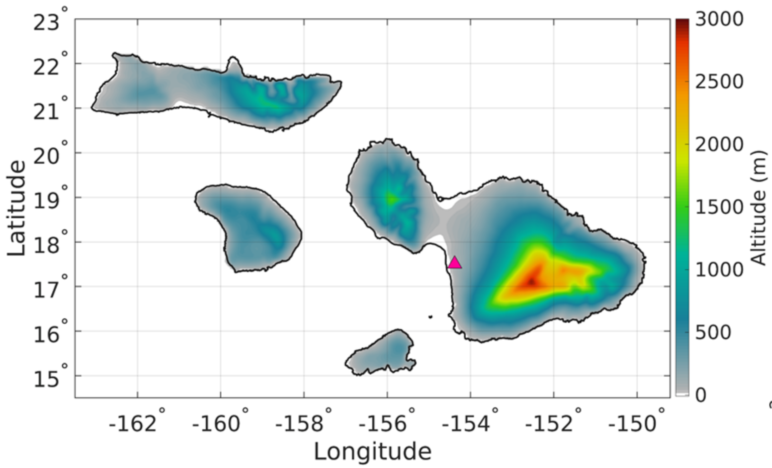
Mechanistic model can be applied outside of constant current data

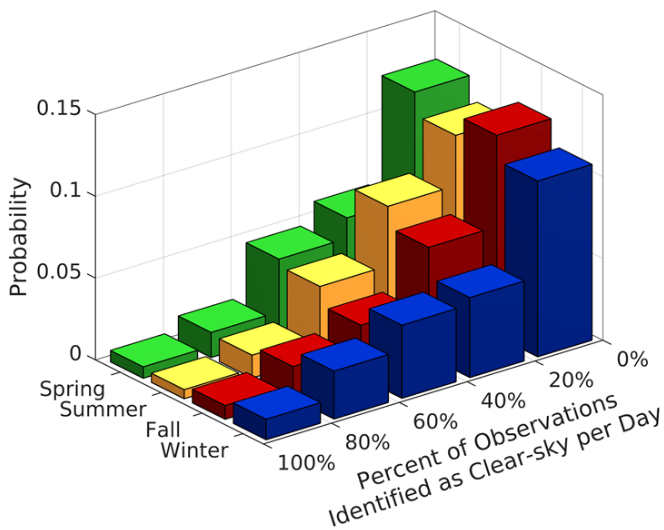


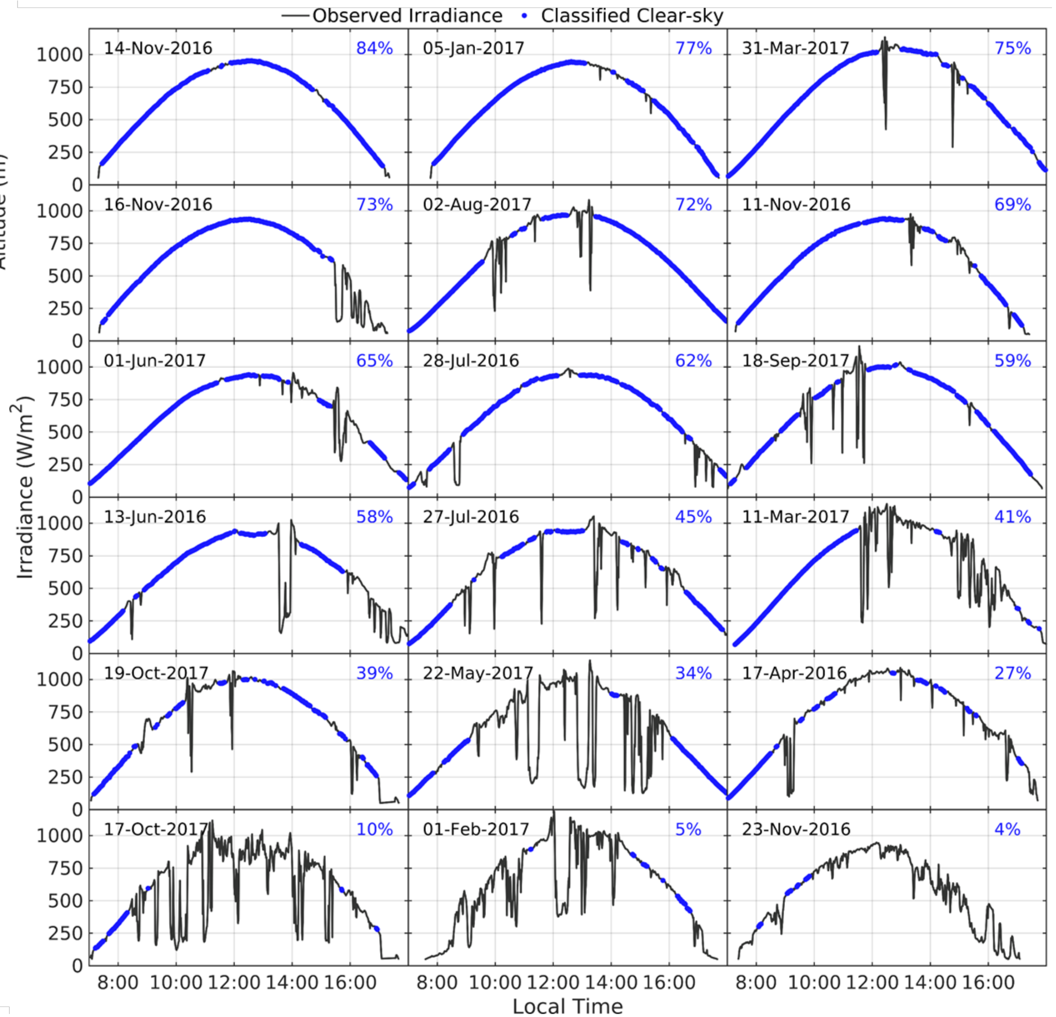
Dubarry M., Costa N., & Matthews D., Nature Communications, Under review
Preprint available 10.21203/rs.3.rs-2058155/v1

Data-Driven Diagnosis for PV Connected Batteries

Clear-sky assessment







Dubarry M., Costa N., & Matthews D., Nature Communications, Under review
Preprint available 10.21203/rs.3.rs-2058155/v1

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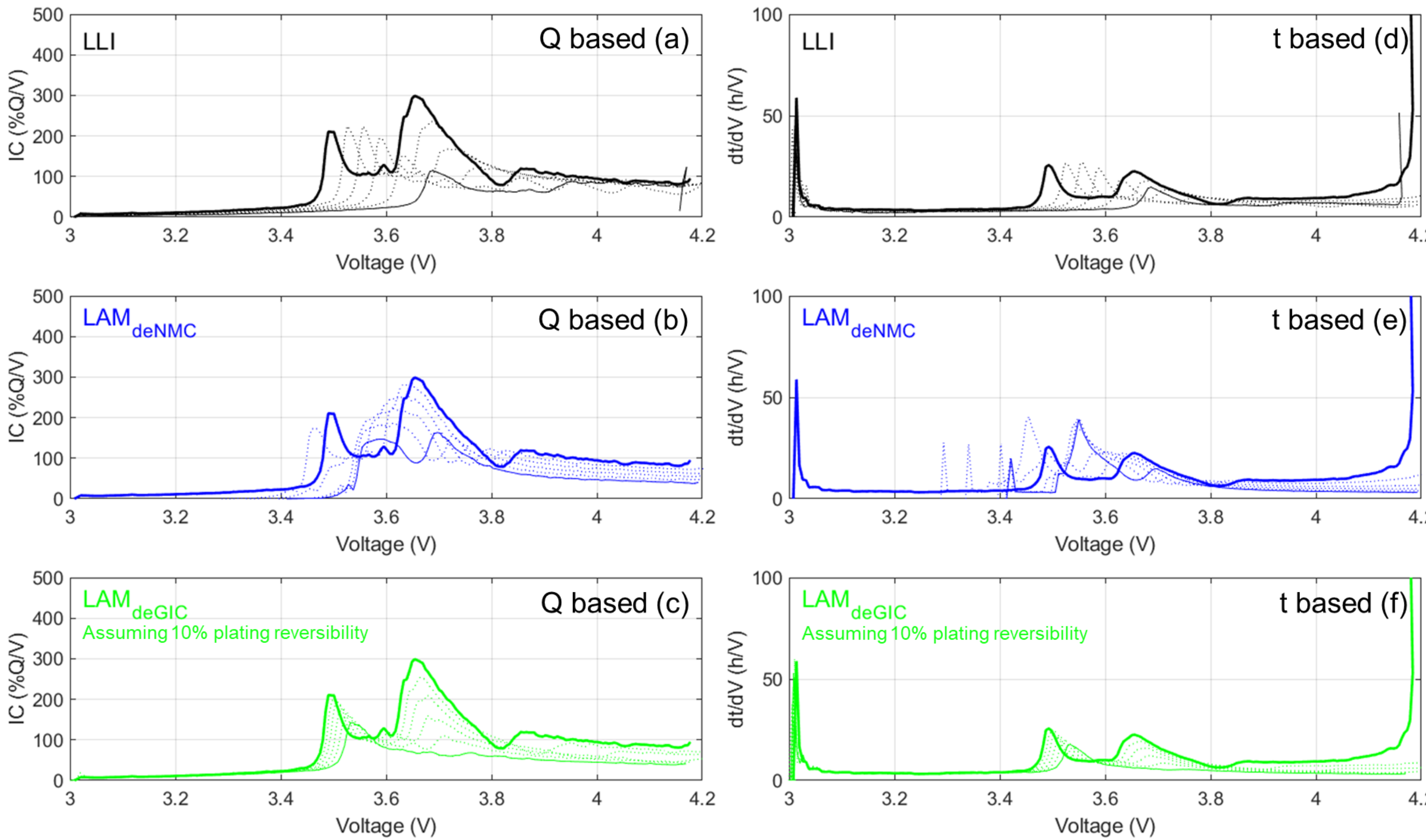
Capacity vs. Time

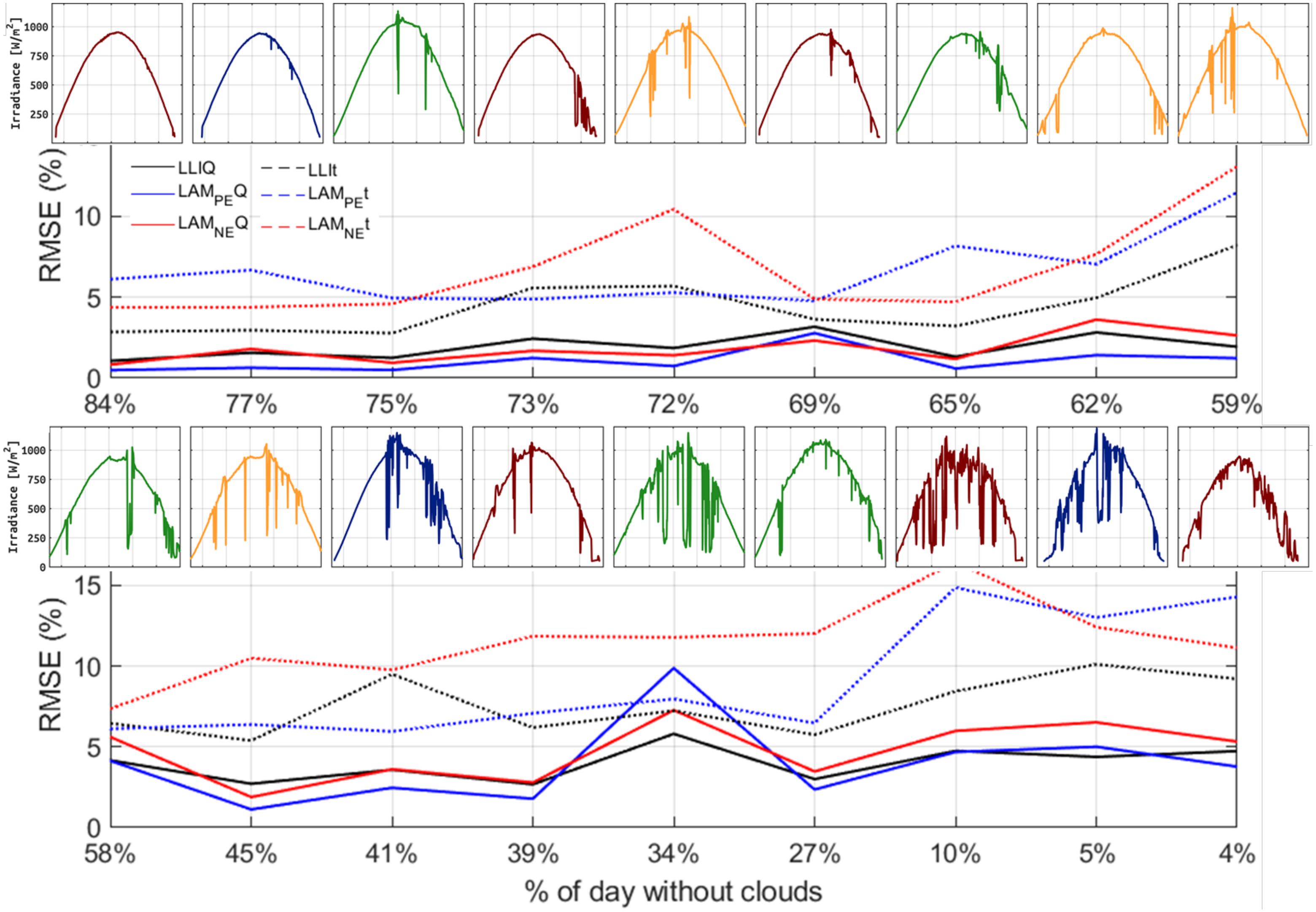
Uncorrelated because not constant current



Dubarry M., Costa N., & Matthews D., Nature Communications, Under review
Preprint available 10.21203/rs.3.rs-2058155/v1

Data-Driven Diagnosis for PV Connected Batteries

Diagnosability tested on 5 state of the art ML algorithms



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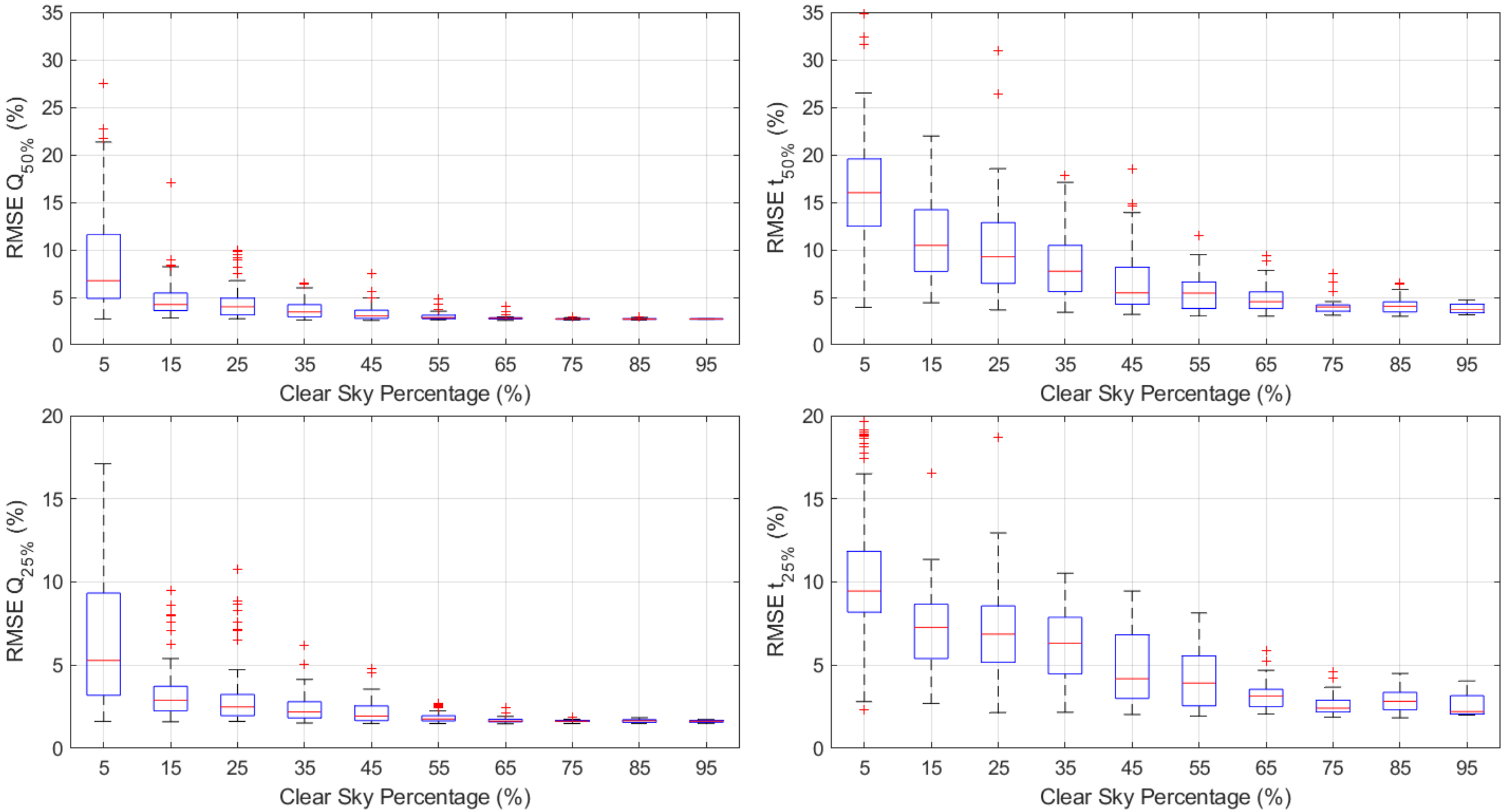
Dubarry M., Costa N., & Matthews D., Nature Communications, Under review
Preprint available 10.21203/rs.3.rs-2058155/v1

Data-Driven Diagnosis for PV Connected Batteries

Diagnosability tested on 1 ML algorithms for 2 years of data



Dubarry M., Costa N., & Matthews D., Nature Communications, Under review
Preprint available 10.21203/rs.3.rs-2058155/v1

Data-Driven Diagnosis for PV Connected Batteries

PV connected batteries will undergo sporadic usage which will prevent the application of traditional diagnosis methods.

This work proposes a **new methodology** for **opportunistic diagnosis** using machine learning algorithms trained directly on PV battery charging data.

The training was performed on synthetic voltage data under different degradations calculated from **clear-sky model irradiance data**. Validation was performed on synthetic voltage responses calculated from **plane of array irradiance observations** for a photovoltaic system located in Maui, HI, USA.

An **average RMSE of 2.75%** was obtained for more than 10,000 different degradation paths with 25% or less degradation on the cells.

Significant benefits for **using synthetic data** to understand the expected variations of voltage response **as real data is not yet available**.

Future work will address packs and additional usage on the cells.

Dubarry M., Costa N., & Matthews D., Nature Communications, Under review
Preprint available 10.21203/rs.3.rs-2058155/v1

Acknowledgments

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Thank you!

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