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Degradation mechanism detection for NMC batteries based on Incremental Capacity curves

M. Berecibar ^{1,2} , M. Dubarry ³ , N. Omar ² , I. Villarreal ¹ , J. Van Mierlo ²

¹ IK4- Ikerlan, Energy Business Unit, Spain

² Vrije Universiteit Brussel, MOBI Research Group, Brussels

³ Hawaii Natural Energy Institute, University of Hawaii at Manoa, USA



CONTENT

MOTIVATION

OBJECTIVE

PROCESS – 5 STEPS

CONCLUSIONS

MOTIVATION

Degradation mechanism detection, why?

- Safety

- Life time

- Prediction

- Ageing detection
& quantification

- Multitude of parameters

- Impossible to control all

- Impractical



OBJECTIVE

Our solution:

- Pattern matching regarding battery degradation mechanisms

Process:

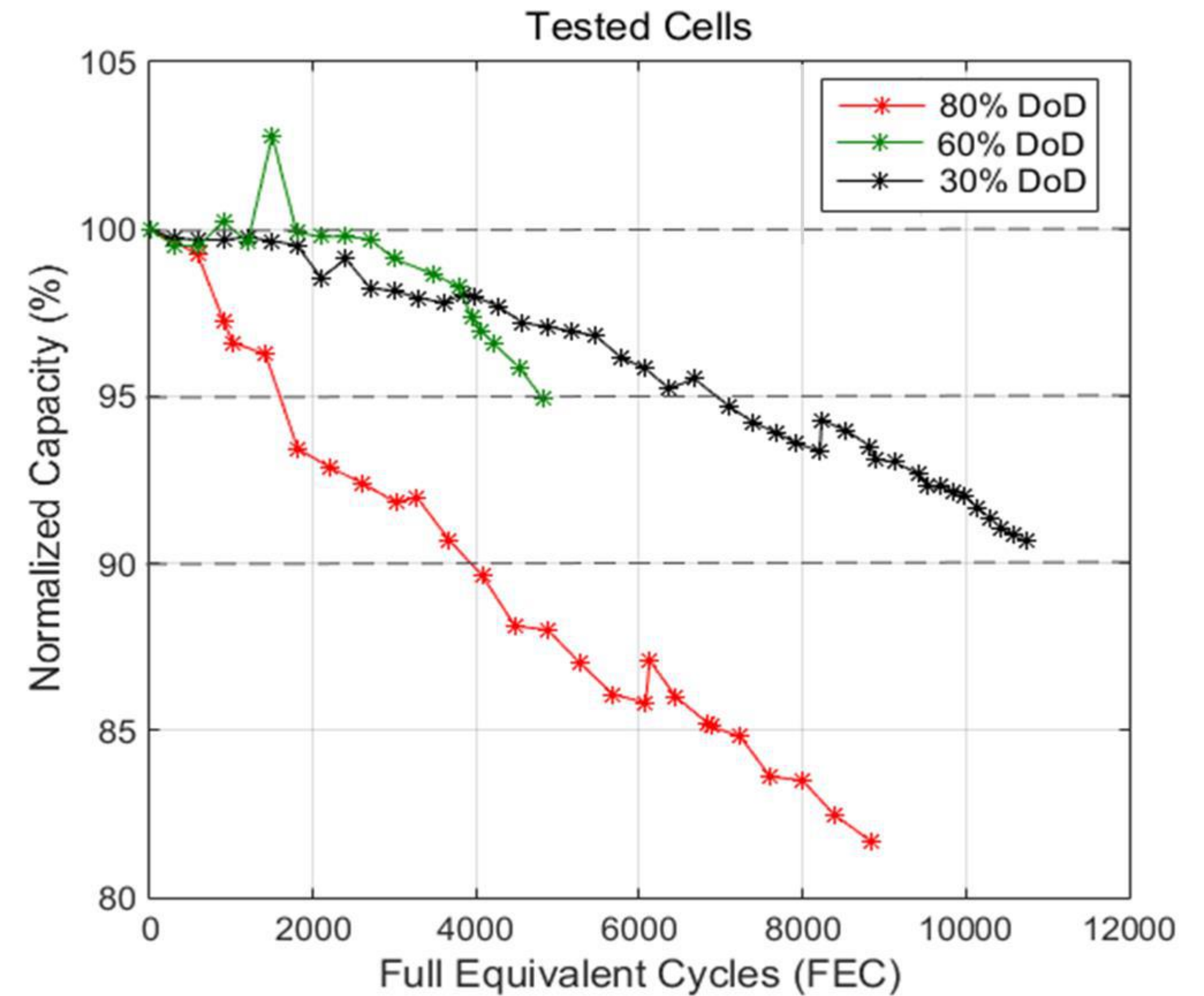
1. Cell testing.
2. Simulation of scenarios.
3. Selection of features of interests.
4. Detection of features of interests on the tested curves.
5. Path dependency of each feature.



PROCESS 1. Cell testing

• Tested cells

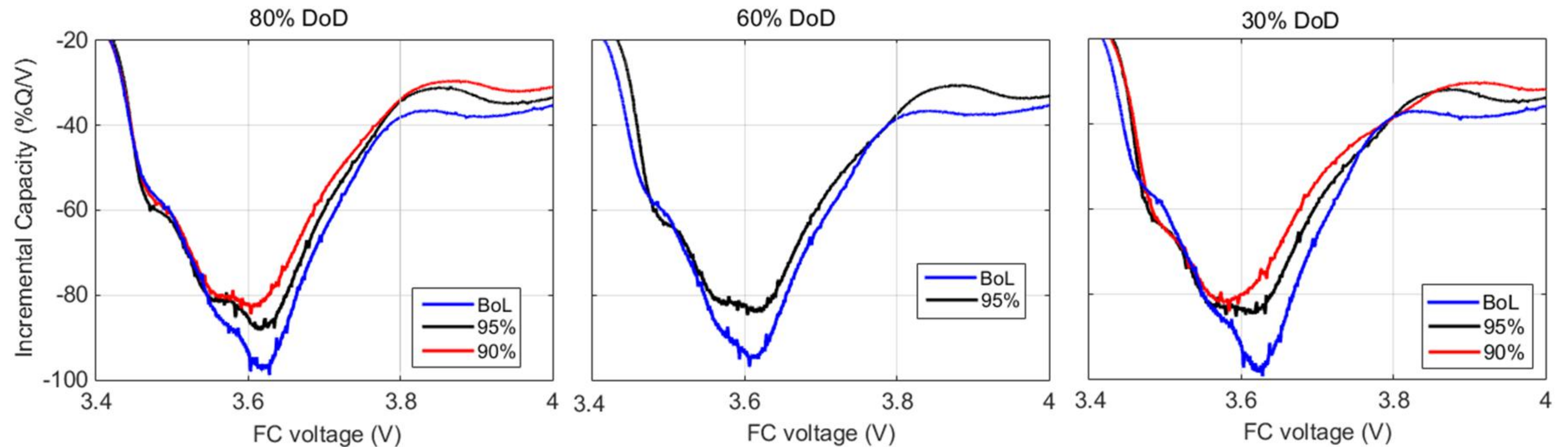
- Nominal Capacity: 40Ah
- Anode: graphite (G)
- Cathode: $\text{LiNi}_{1-x-y}\text{Mn}_y\text{Co}_x\text{O}_2$ (NMC)
- Tested temperature: 25 °C
- Depth of Discharge (DoD):
 - 80% DoD
 - 60% DoD
 - 30% DoD
- Every 100 cycles:
 - Capacity test
 - Complete charge and discharge at C/5
 (to obtain the IC curves)



PROCESS 1. Cell testing

- Incremental Capacity Curves

- Quantify the Degree of Degradation of a cell
- Reveal Battery Degradation Mechanisms
 - Loss of Lithium Inventory
 - Loss of Active Material
 - Internal Resistance Increment Detection





PROCESS 2. Simulation of scenarios

- Alawa Toolbox

- Purpose: Emulation of the voltage response of the cell, using IC and DV curves as visualization tools

- Necessary Data:

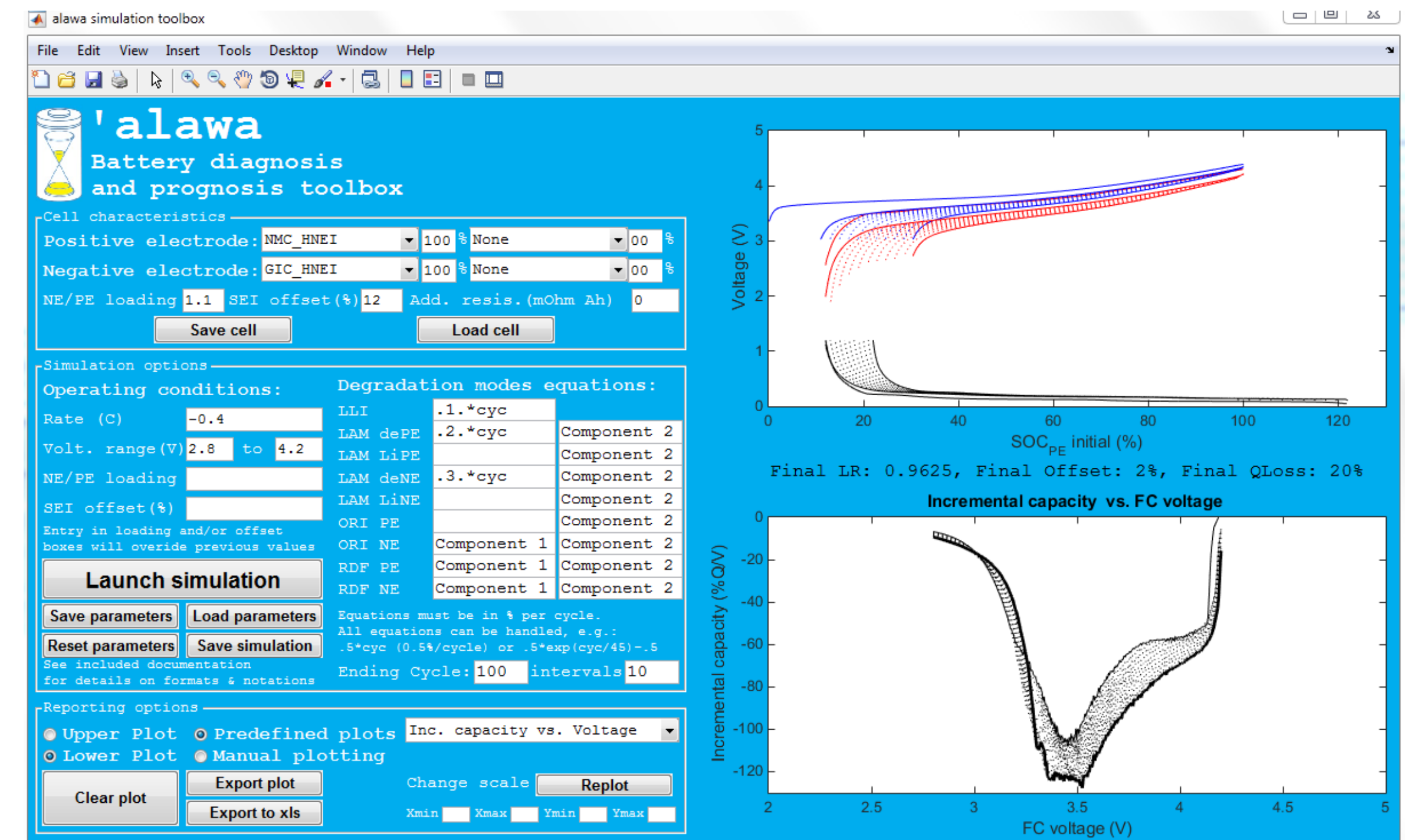
- Loading Ratio (LR)

- Irreversible capacity loss (OFS)

- Obtained from a C/25 discharge curve at the BOL.

In our case LR=1.15 and OFS=-5.

- Play and mix all possible degradation Mechanisms.



<https://www.soest.hawaii.edu/HNEI/alawa/>

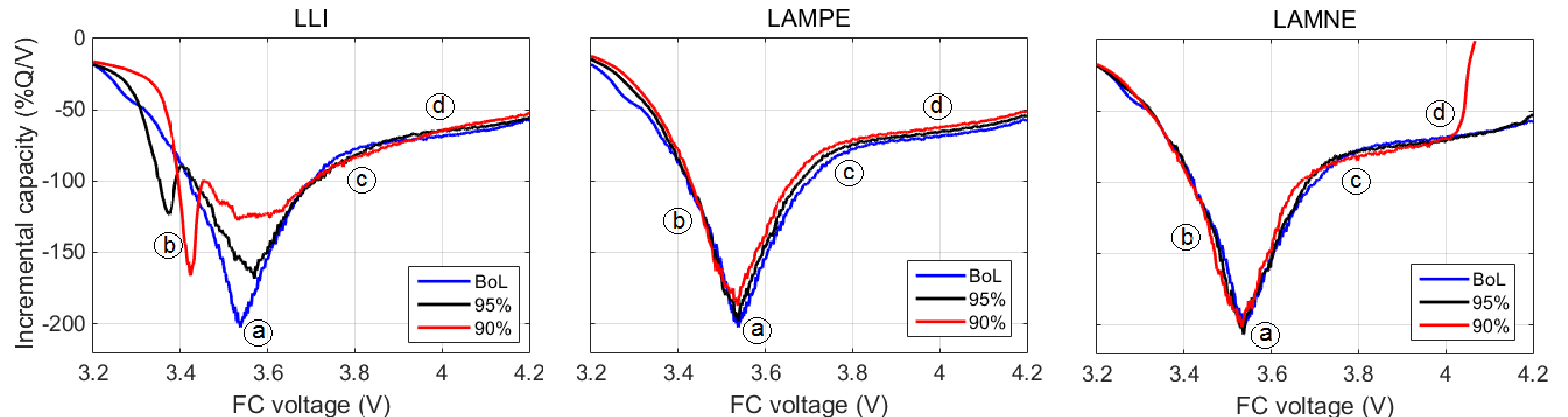
PROCESS 3. Selection of features of interests

3 degradation mechanisms were studied:

- Loss of lithium inventory
- Loss of active material in the negative electrode
- Loss of active material in the positive electrode

4 main characteristics were detected:

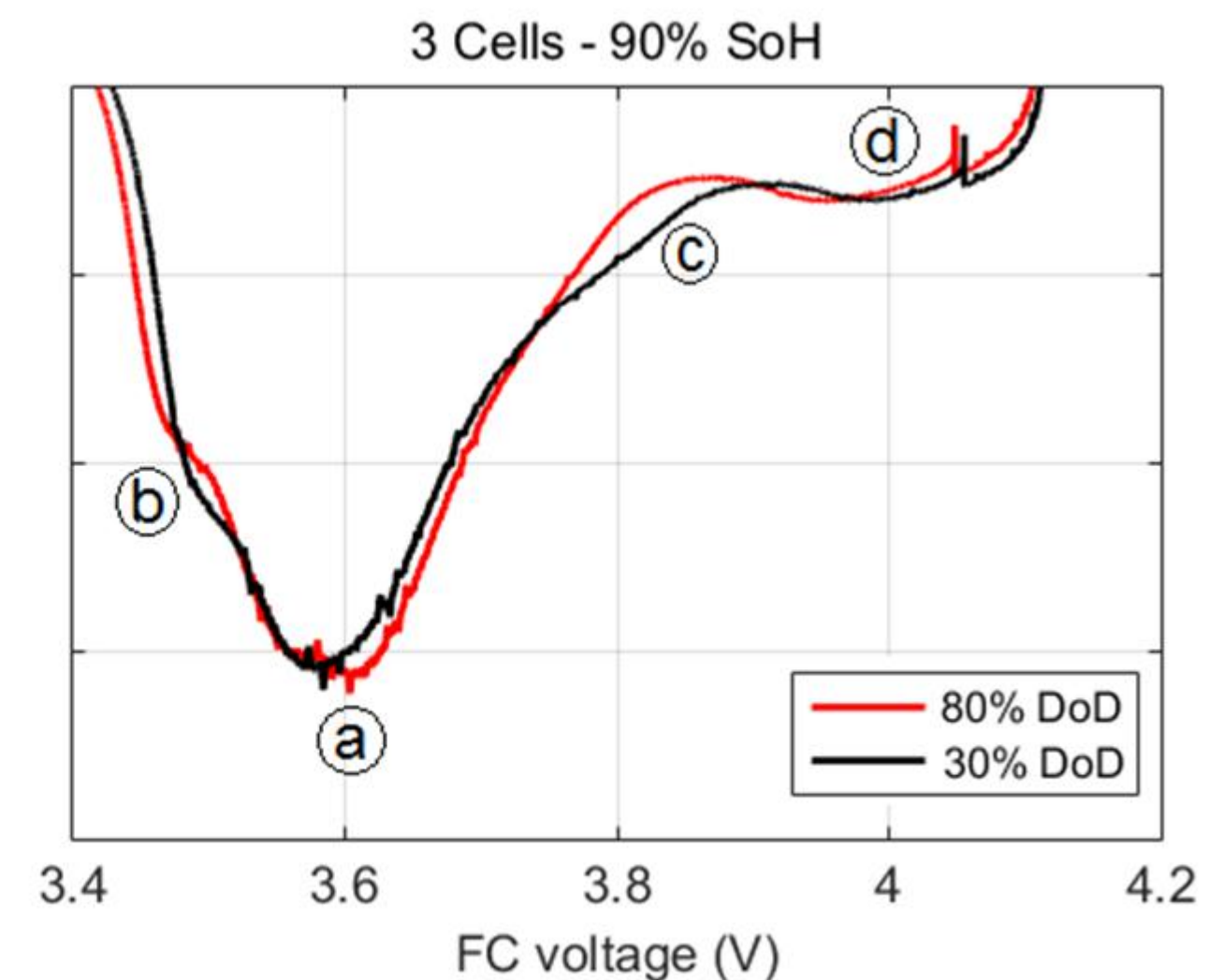
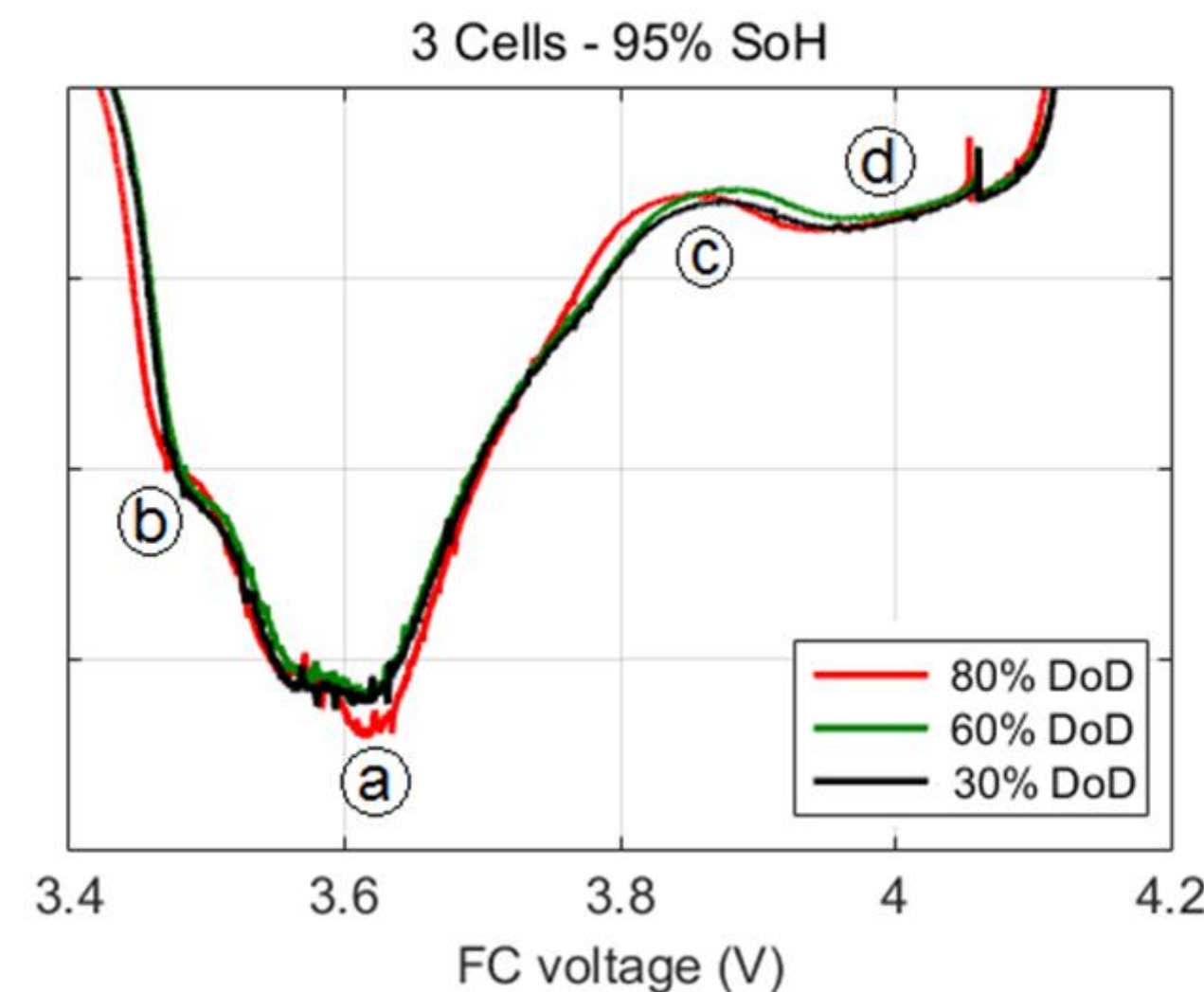
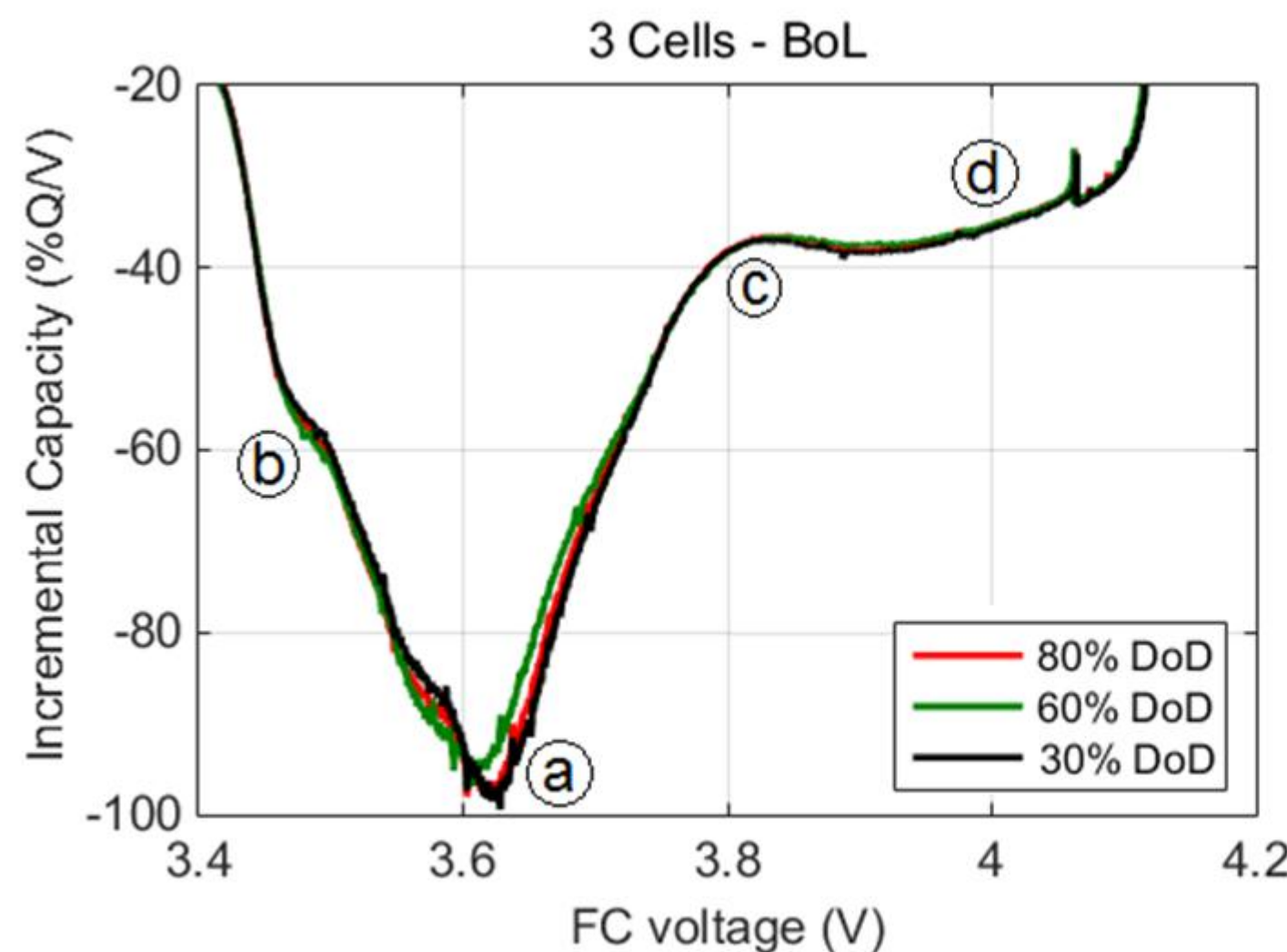
- (a): Peak at 3.6V.
- (b): Peak detected at 3.5V.
- (c): Arch, lowest position between 3.7-3.9V.
- (d): Incremental capacity intensity at 4V.



PROCESS 4. Detection of features of interests on the tested curves.

Evolution of the features of interests of the tested cells.

- IC curves from the tested cells at BoL, 95% SoH, 90% SoH.
- Detection of the 4 features of interests:
 - (a): Peak at 3.6V.
 - (b): Peak detected at 3.5V.
 - (c): Arch, lowest position between 3.7-3.9V.
 - (d): Incremental capacity intensity at 4V.

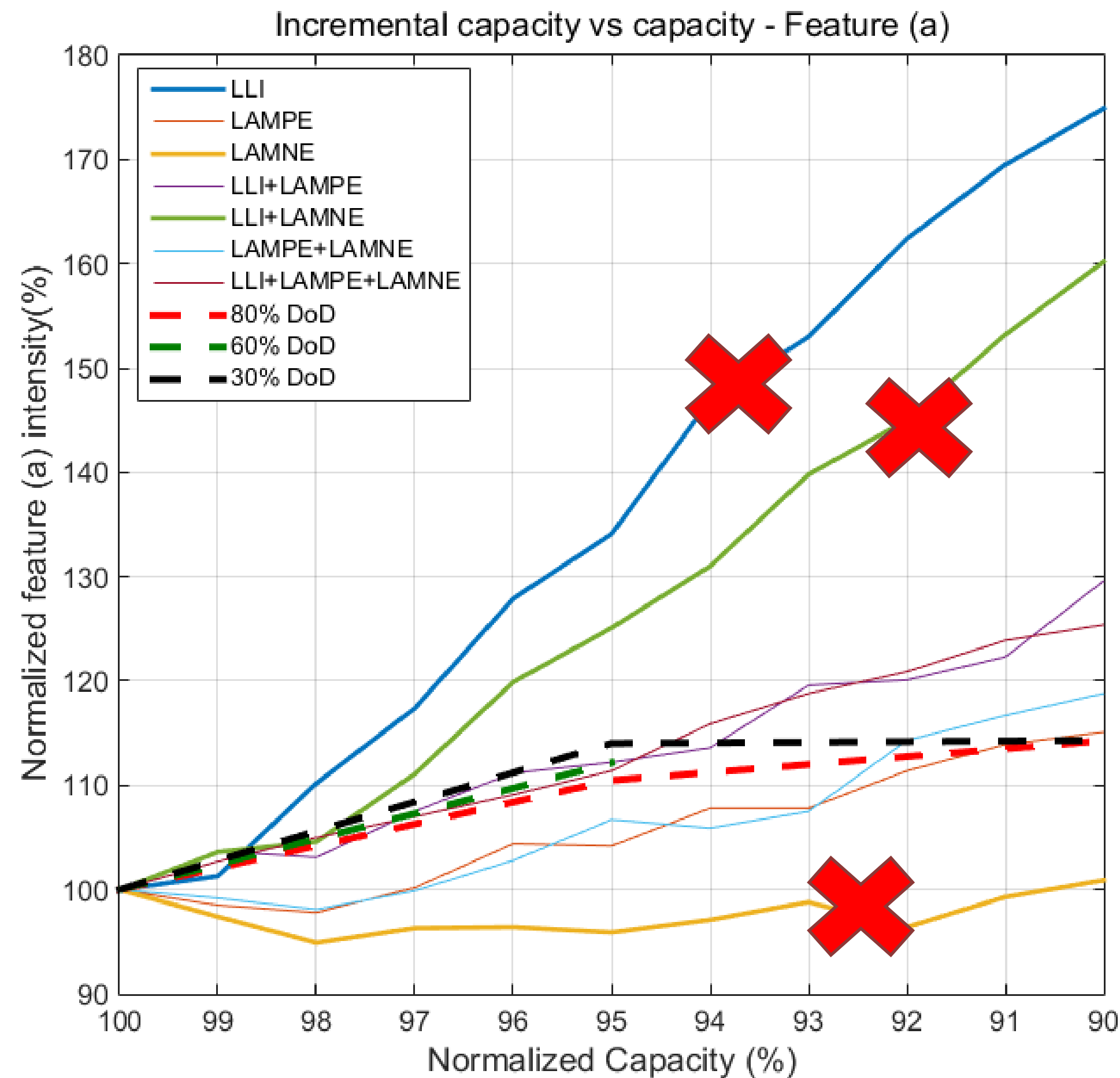


PROCESS 5. Path dependency of feature (a)

- Peak at 3.6 V

– Intensity:

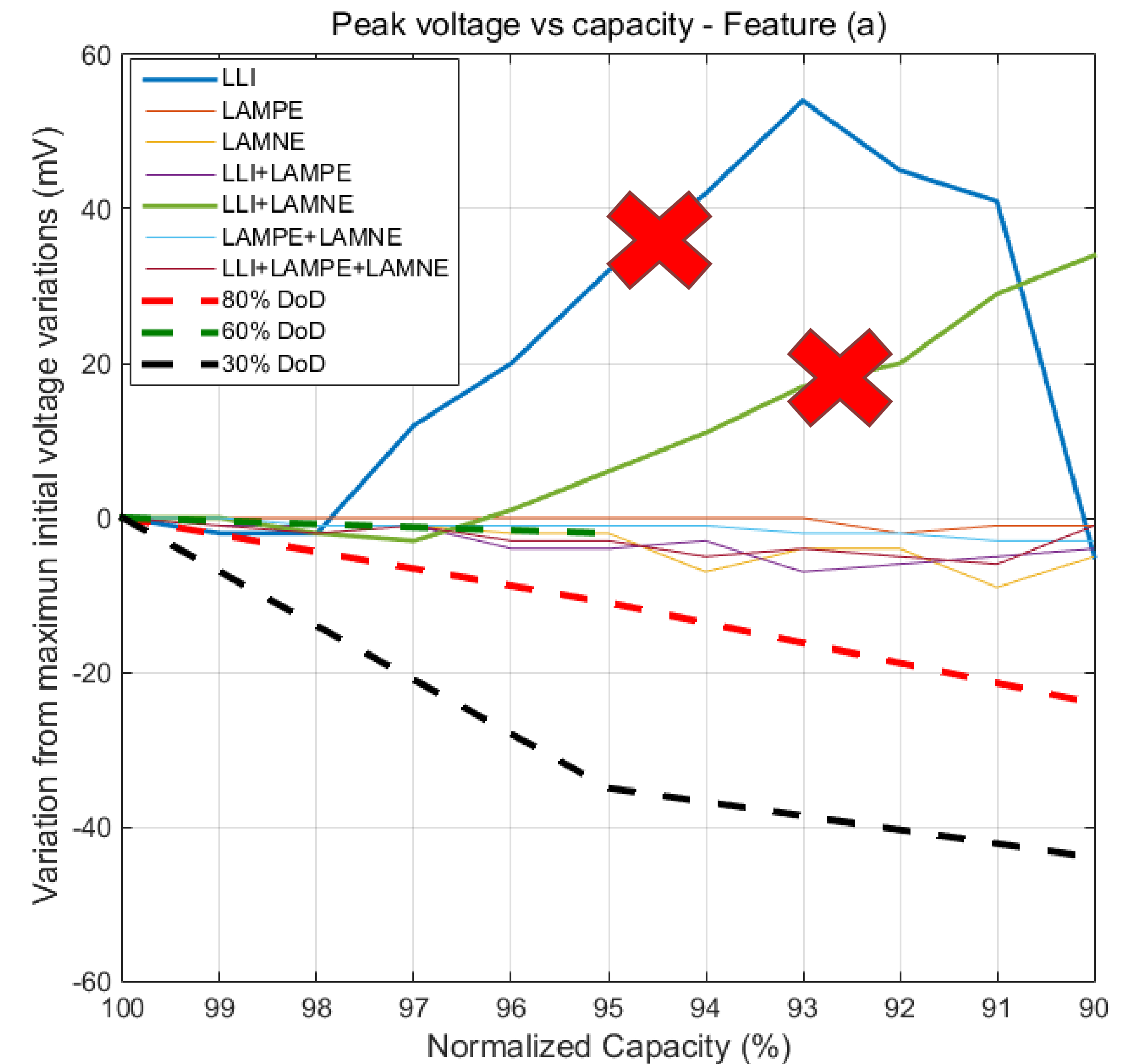
Incompatible scenarios: LLI, LLI+LAMNE, LAMNE



- Peak at 3.6 V

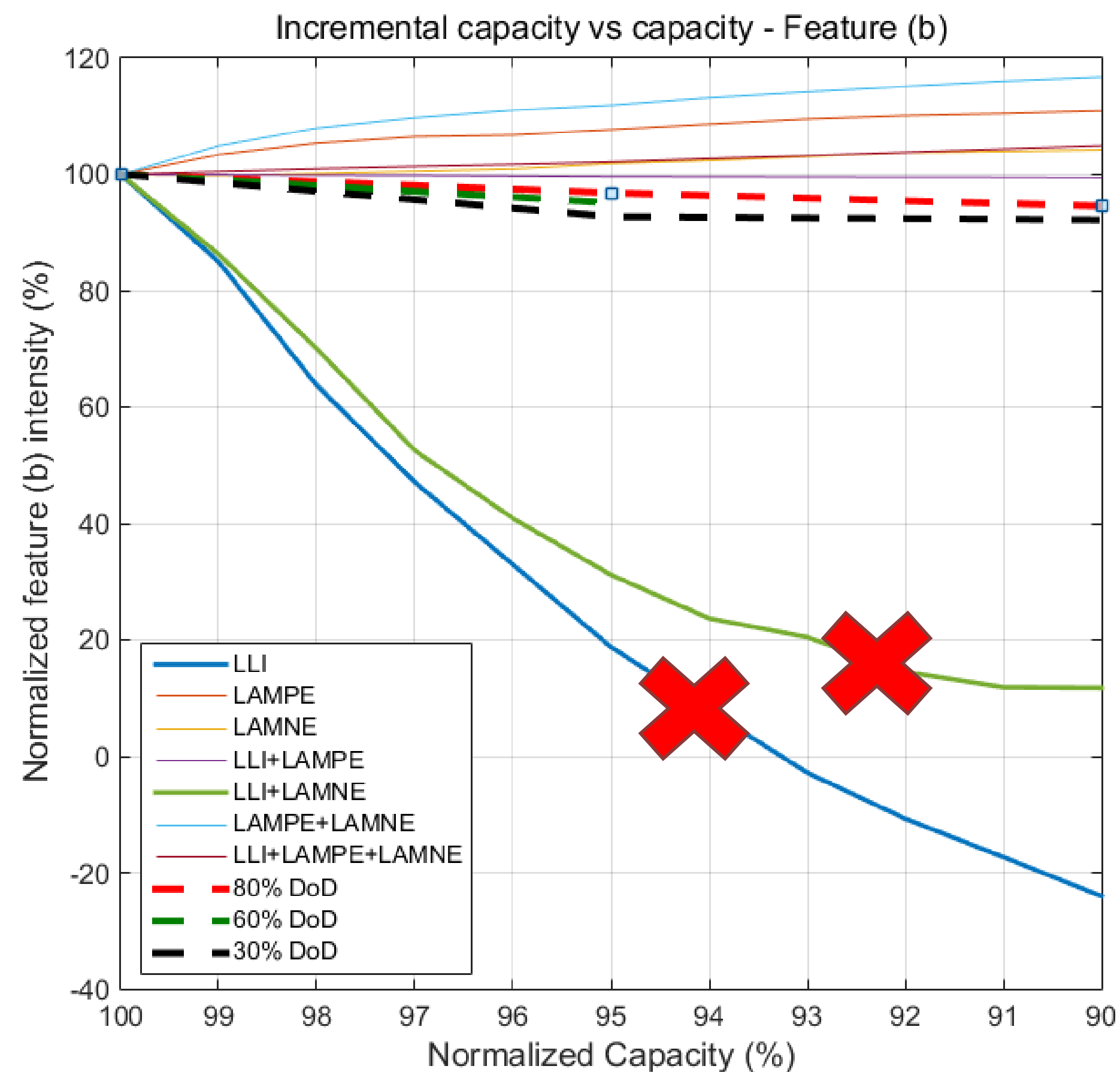
– Voltage:

Incompatible scenarios: LLI, LLI+LAMNE

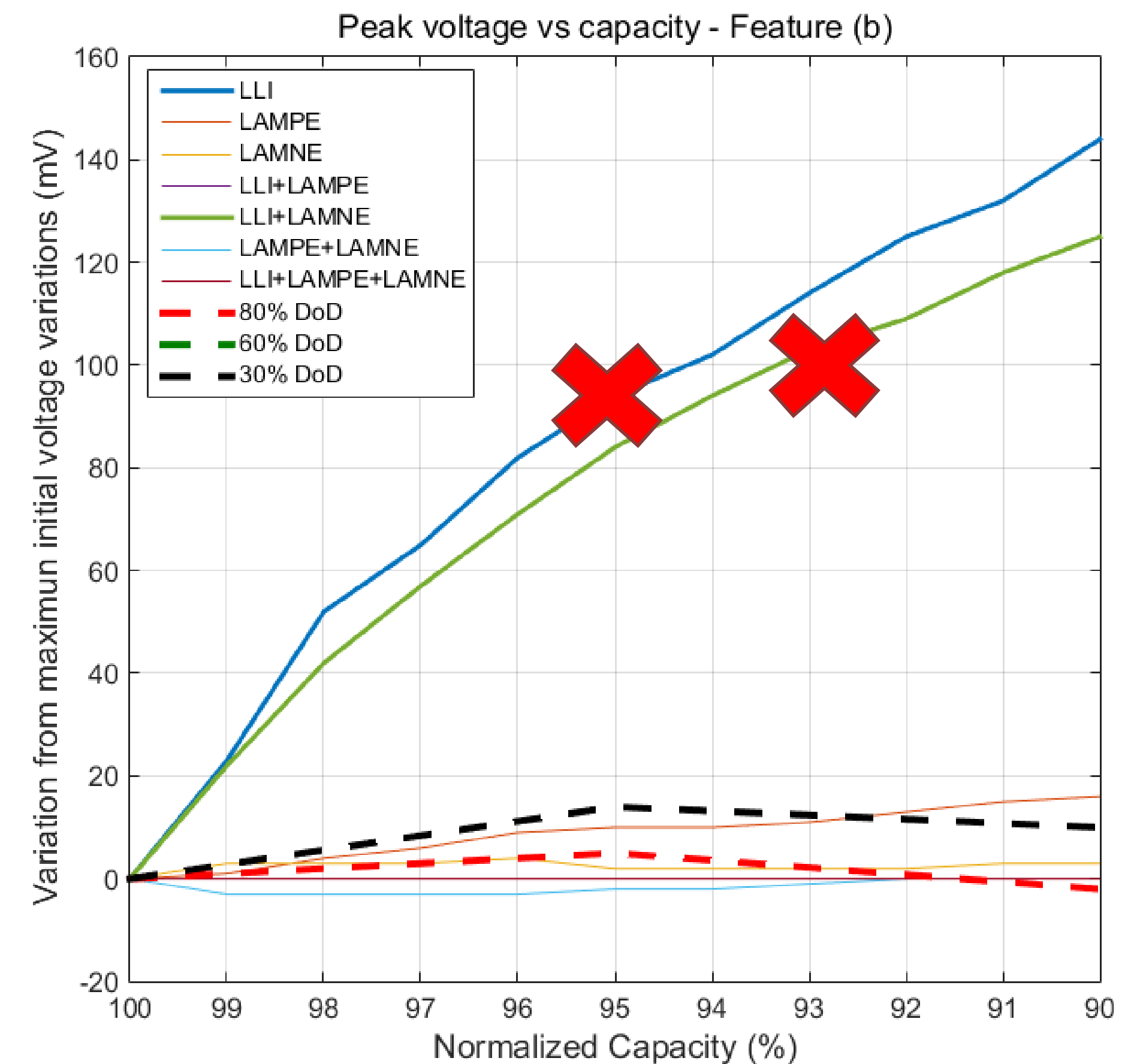


PROCESS 5. Path dependency of feature (b)

- Peak detected at 3.5V
 - Intensity
- Incompatible scenarios: LLI, LLI+LAMNE



- Peak detected at 3.5V
 - Voltage
- Incompatible scenarios: LLI, LLI+LAMNE
- * Cells B an C overlaps



PROCESS 5. Path dependency of feature (c)

- Arch, lowest position between 3.7-3.9V.

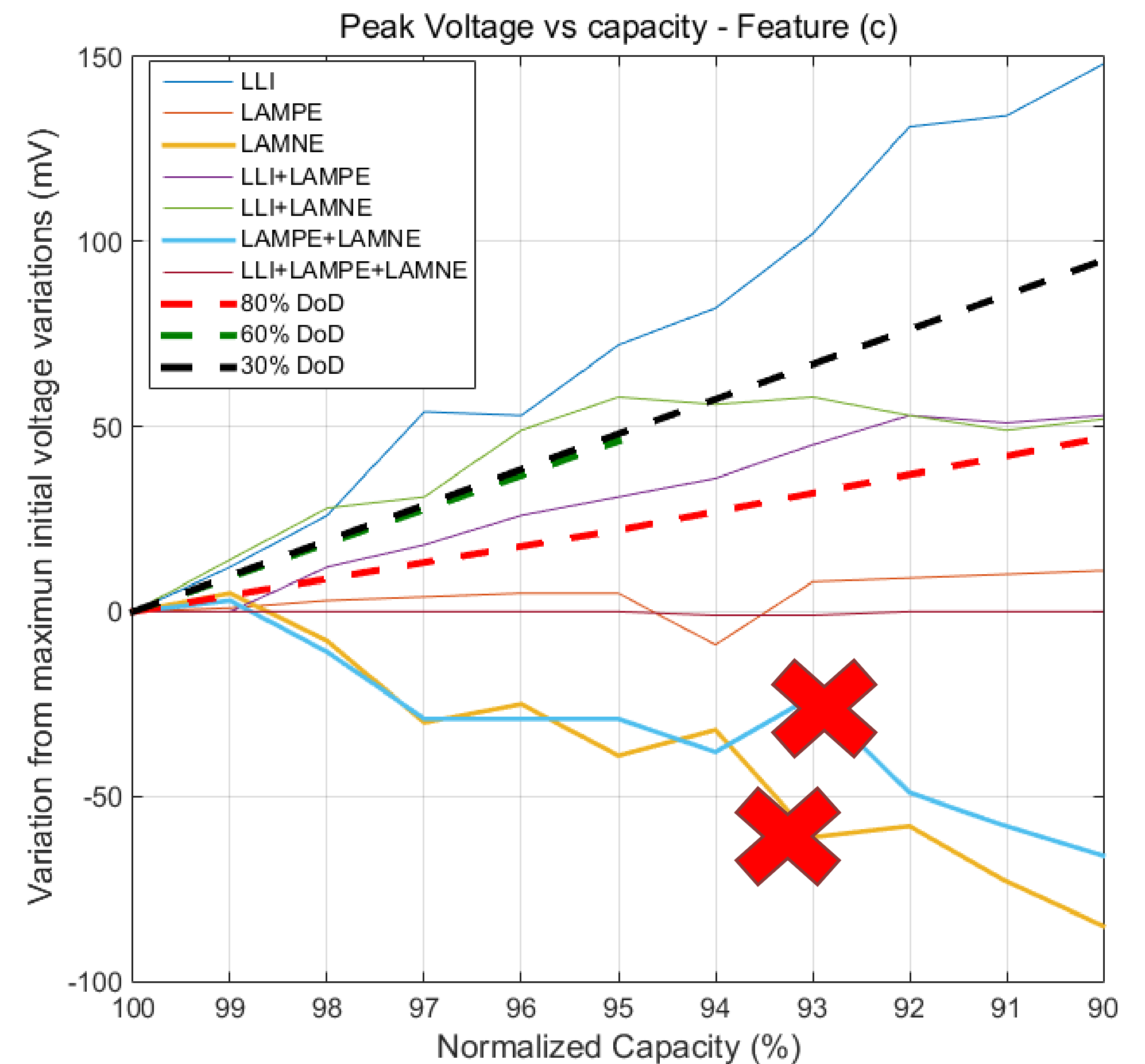
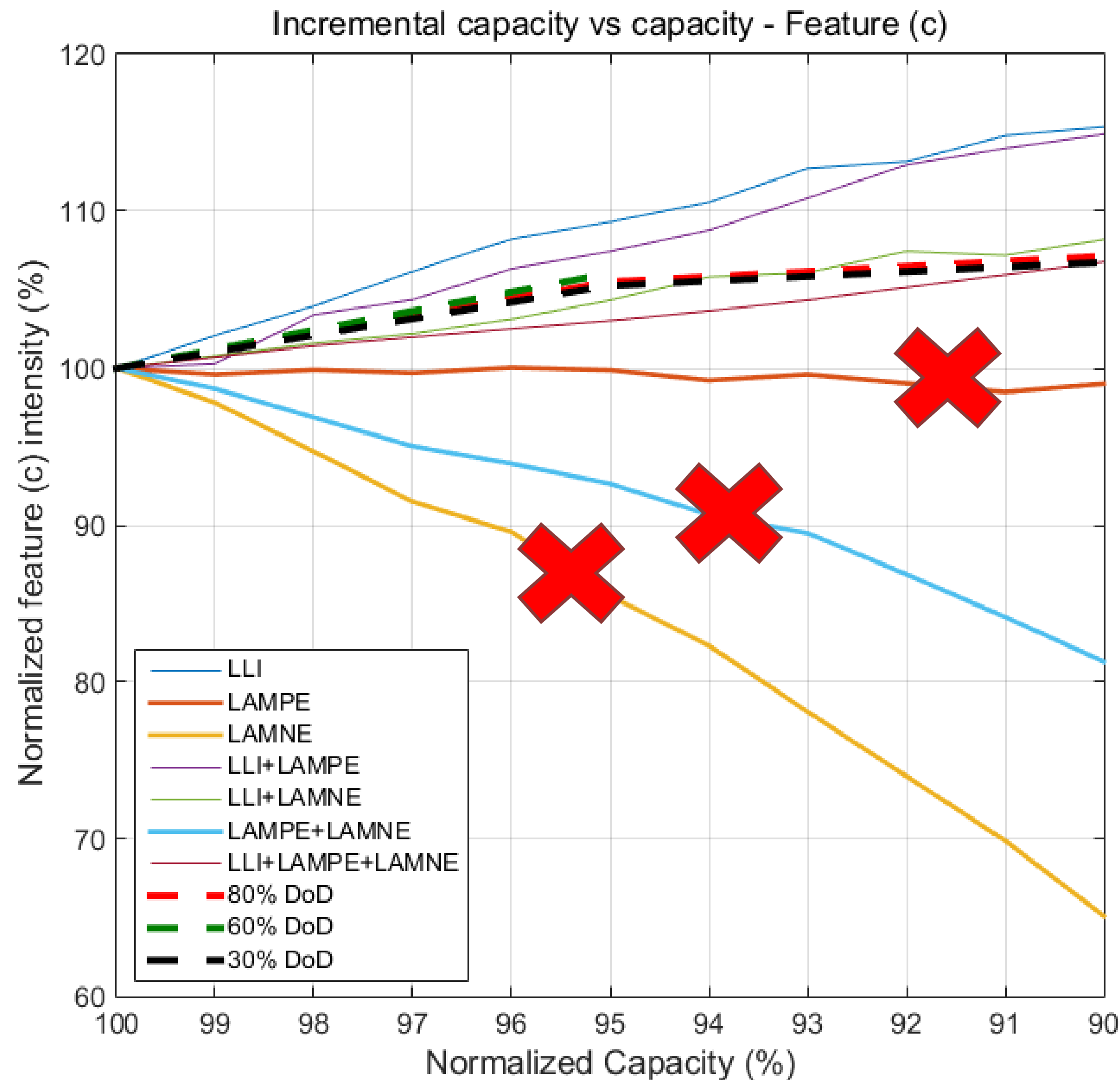
– Intensity

Incompatible scenarios: LAMPE, LAMNE, LAMPE +LAMNE

- Arch, lowest position between 3.7-3.9V.

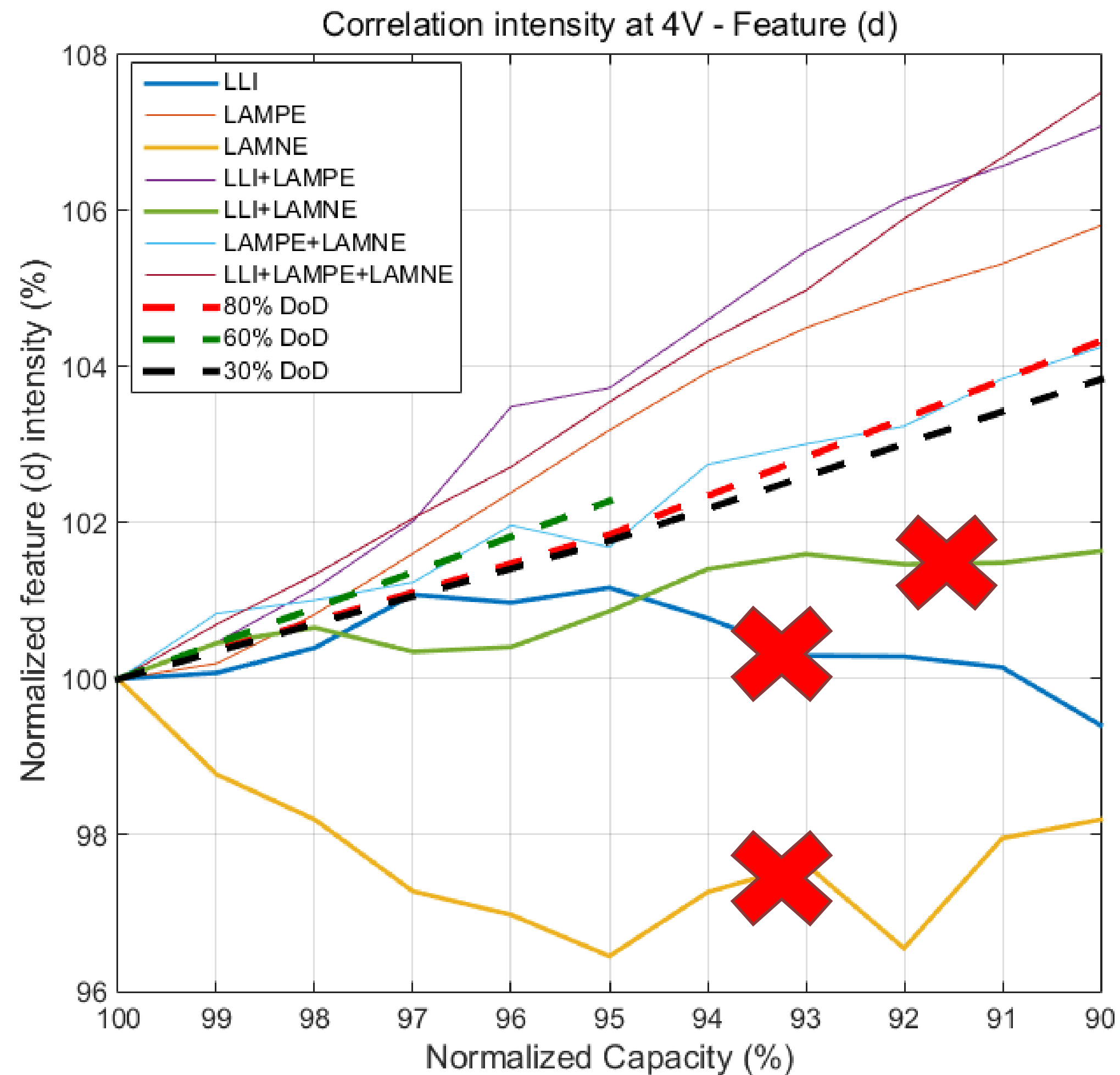
– Voltage

Incompatible scenarios: LAMNE, LAMPE+LAMNE



PROCESS 5. Path dependency of feature (d)

- Incremental capacity intensity at 4V.
 - Intensity: Incompatible scenarios: LAMNE, LLI, LLI+LAMNE



CONCLUSIONS

- Excluded Paths

- LLI **×** • Features (a), (b), (d)

- LAMPE **×** • Feature (c)

- LAMNE **×** • Features (a), (c), (d)

- LLI+LAMPE

- LLI+LAMNE **×** • Features (a), (b), (d)

- LAMPE+LAMNE **×** • Feature (c)

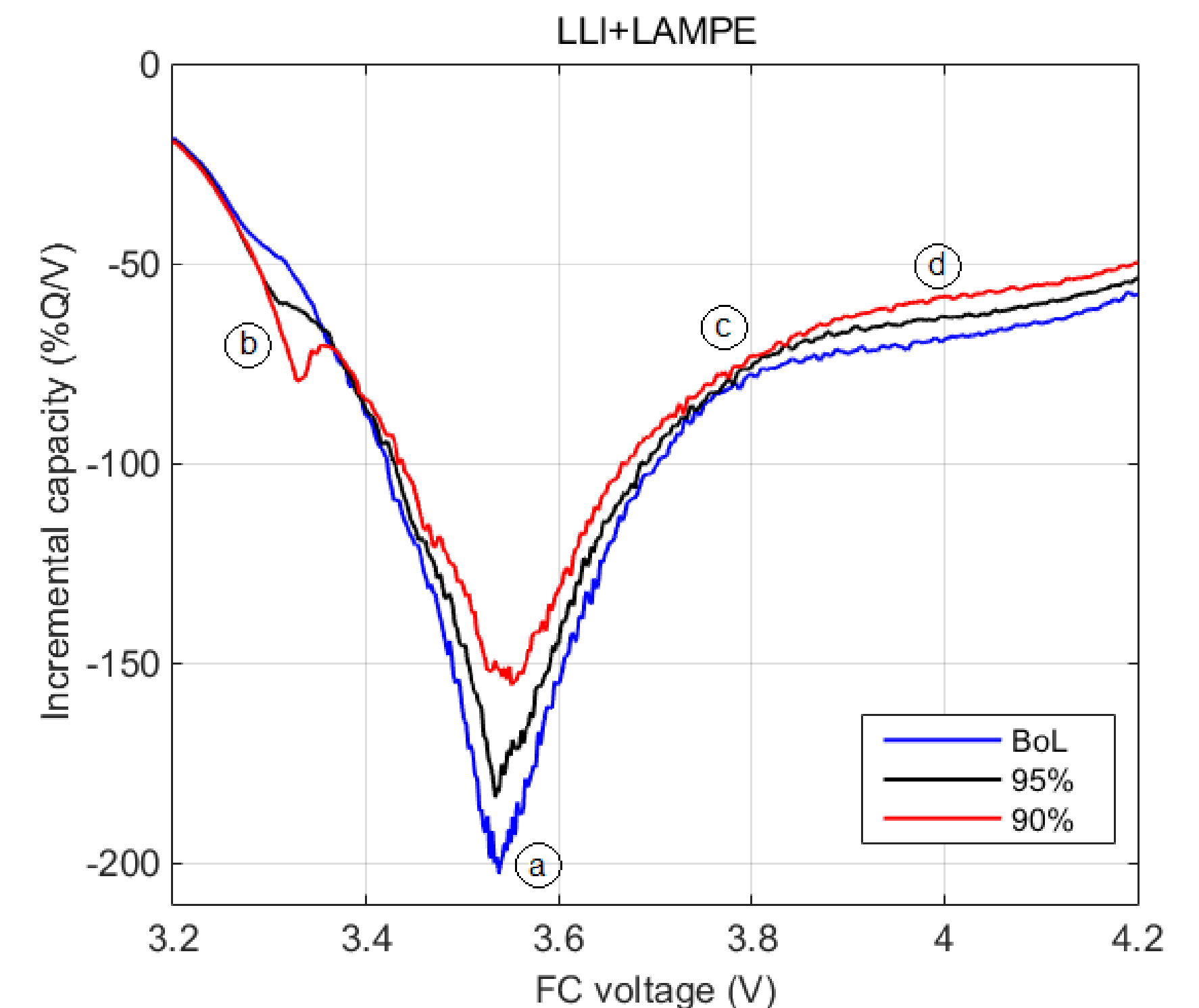
- LLI+LAMPE+LAMNE

- Selected degradation path

5% LLI and 5% LAMPE

- Effect of DoD:

Detection of Additional LAMPE on cell cycled at 80% DoD



SUMMARY

- 3 NMC//G cells have been tested at different DoDs:
 - 80% DoD
 - 60% DoD
 - 30% DoD
- IC curves used for degradation mechanisms detection.
- Selection of 4 features of interests detected from the IC curves.
- Each feature of interest related to a path dependency.
- Detection of the most likely degradation path for that case.
- Study of the effect of the DoD.

- Overall:
Most likely degradation path:
LLI+LAMPE
- Effect of DoD:
Detection of Additional LAMPE
on cell cycled at 80% DoD



Questions?

Thank you
Eskerrik asko

Danke

Merci

Gracias

Grazie

Tak

Maitane Berecibar

Vrije Universiteit Brussel
mberecib@vub.ac.be

IK4-IKERLAN
mberecibar@ikerlan.es

IK4
IKERLAN
Research Alliance

mobi
Vrije Universiteit Brussel

UNIVERSITY OF HAWAII
of HAWAII
MĀNOA