

ALBA 2026 | Dr. Jochen Settelein

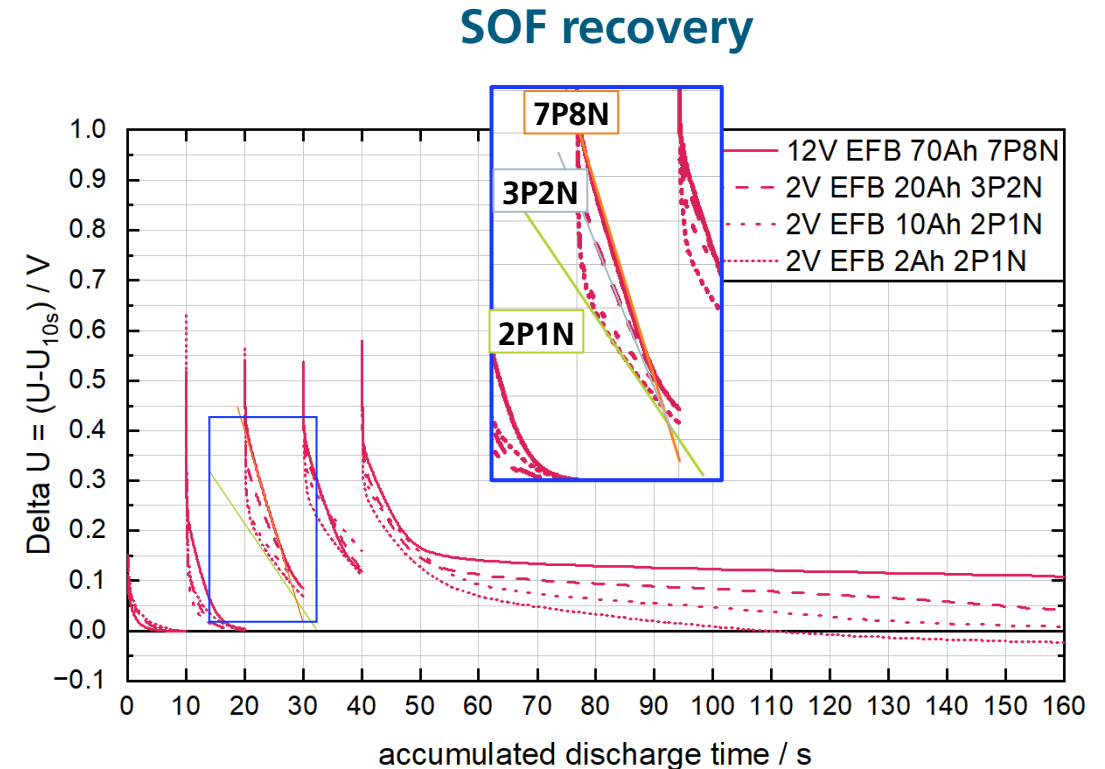
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# CR16 Pseudocapacitive Effects of Cell Geometry and Rest Phases

# CR16 Pseudocapacitive Effects of PAM/NAM-Ratio and Rest Phases

## Influence of Cell Layout on SOF Recovery

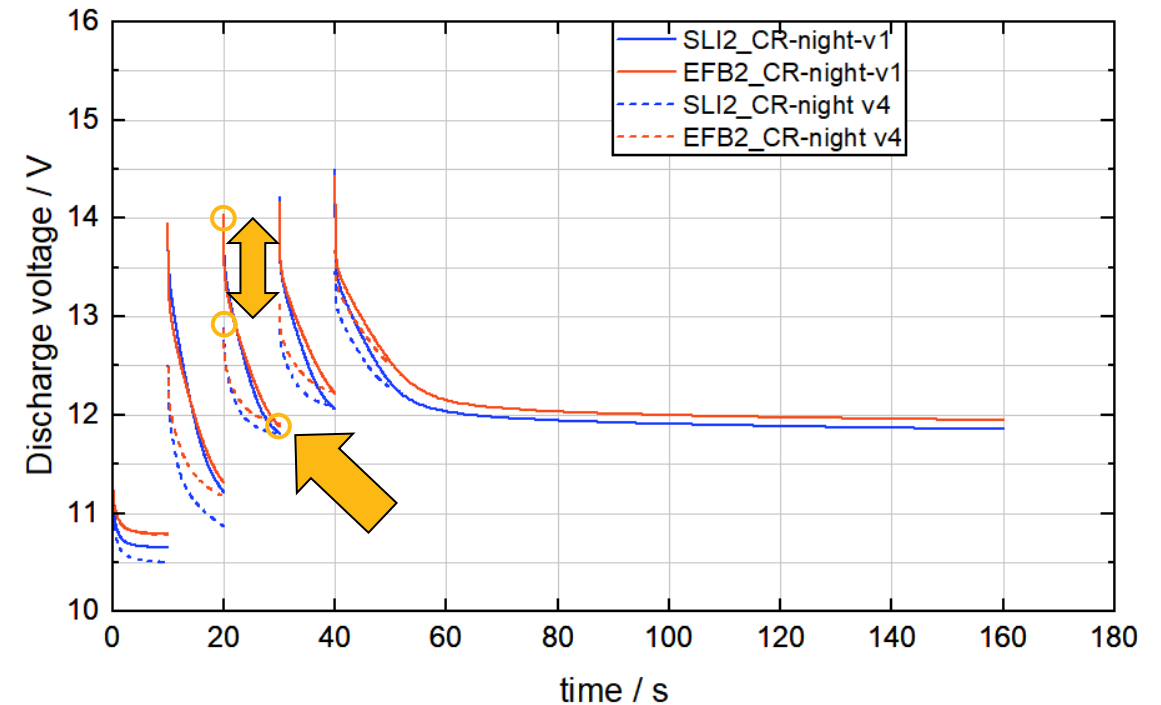
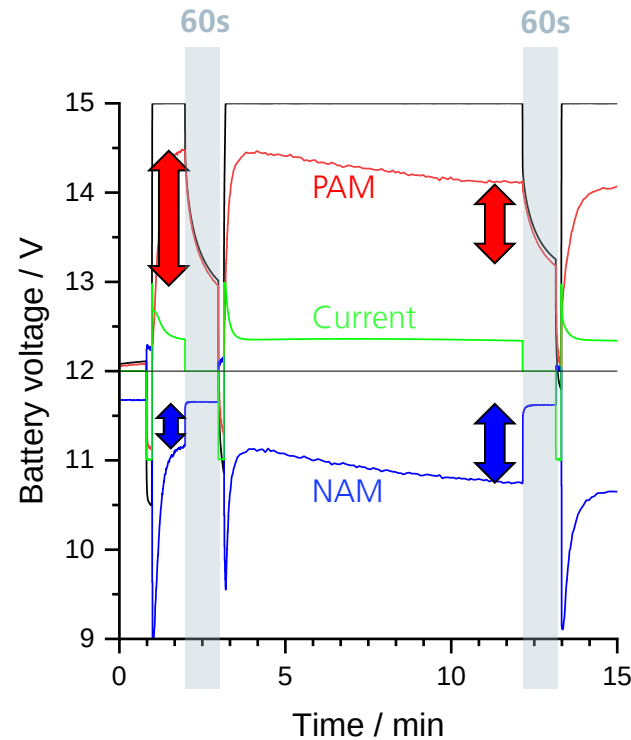
| Voltage | Electrode layout | Electrode Size          | Nominal Capacity | PAM/NAM Ratio |
|---------|------------------|-------------------------|------------------|---------------|
| 12 V    | 7P8N             | 15 x 10 cm <sup>2</sup> | 70 Ah            | 1 / 1         |
| 2 V     | 3P2N             | 15 x 10 cm <sup>2</sup> | ~20 Ah           | 1.6 / 1       |
| 2 V     | 2P1N             | 15 x 10 cm <sup>2</sup> | ~10 Ah           | 2.1 / 1       |
| 2 V     | 2P1N             | 7 x 5 cm <sup>2</sup>   | ~2.5 Ah          | 2.1 / 1       |



The more asymmetric the cell layout the higher the pseudocapacitive effect  
→ Asymmetric test cells have artificially enhanced SOF recovery

# CR16 Pseudocapacitive Effects of Cell Geometry and Rest Phases

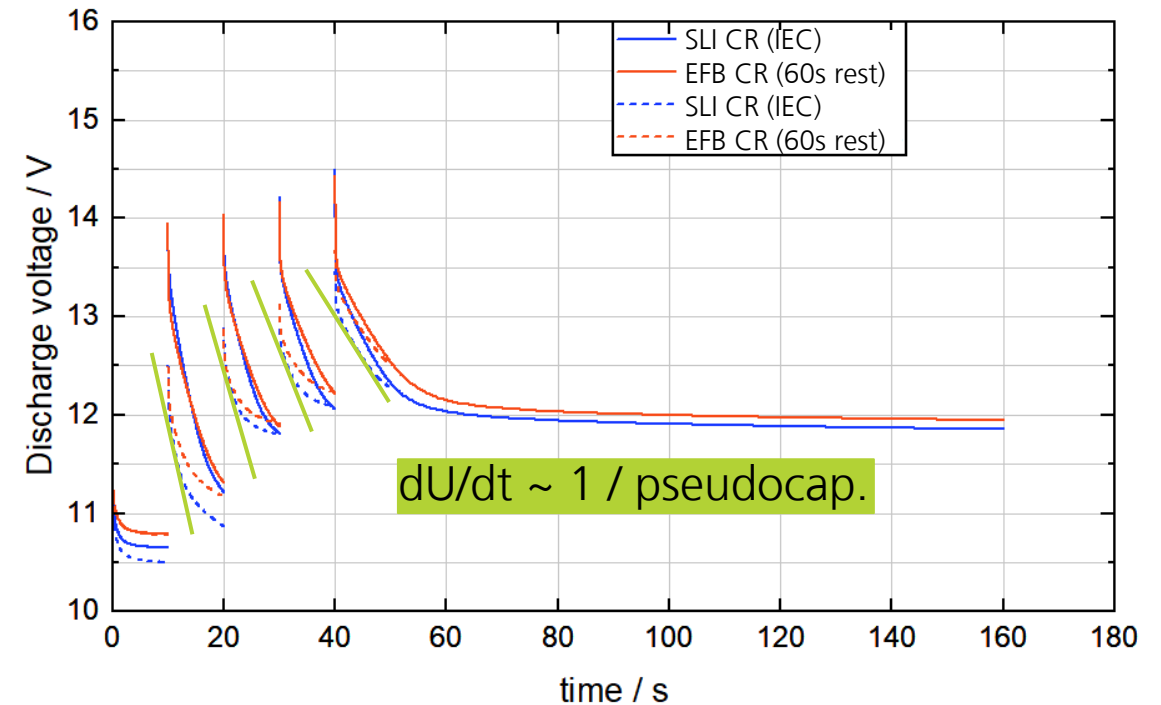
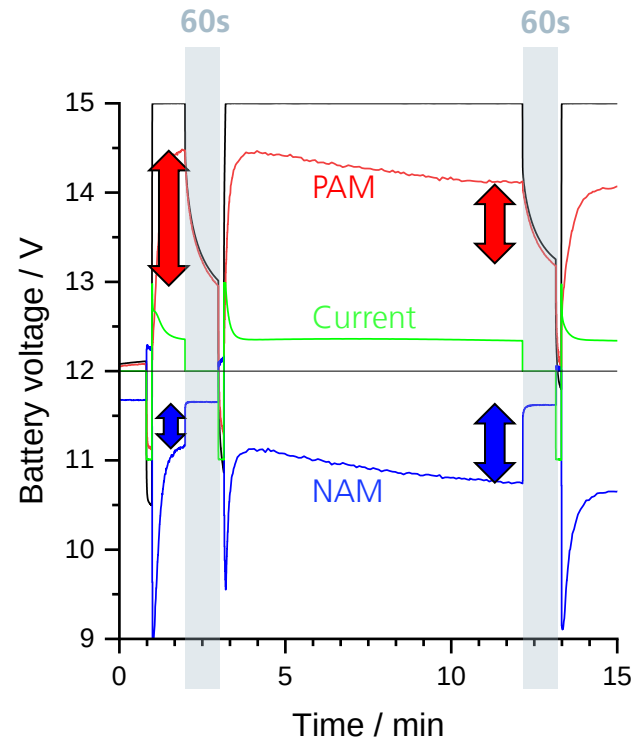
## Influence of 60s Rest Phase before SOF Discharge Pulse



- During 60s rest before SOF pulse voltage and PAM polarization is reduced
- $U_{\text{eod}}$  is **NOT** affected! **Slope** of discharge curve **strongly** affected!
- Effect diminishes during ongoing charging

# CR16 Pseudocapacitive Effects of Cell Geometry and Rest Phases

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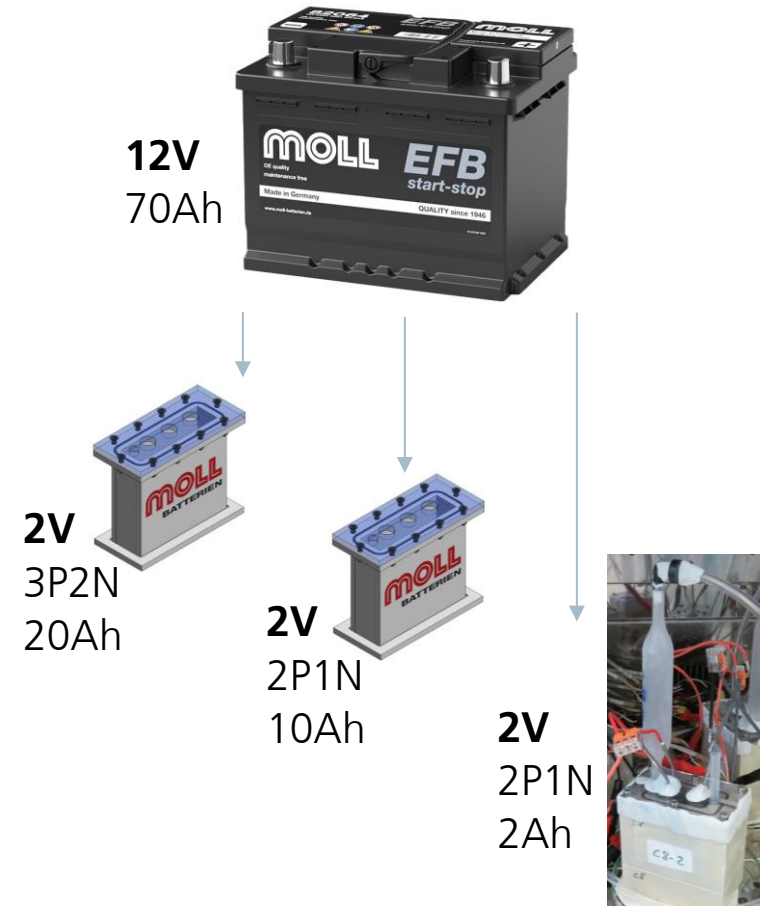


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# Effect of Test Cell Layout

## 4 Layouts under Investigation

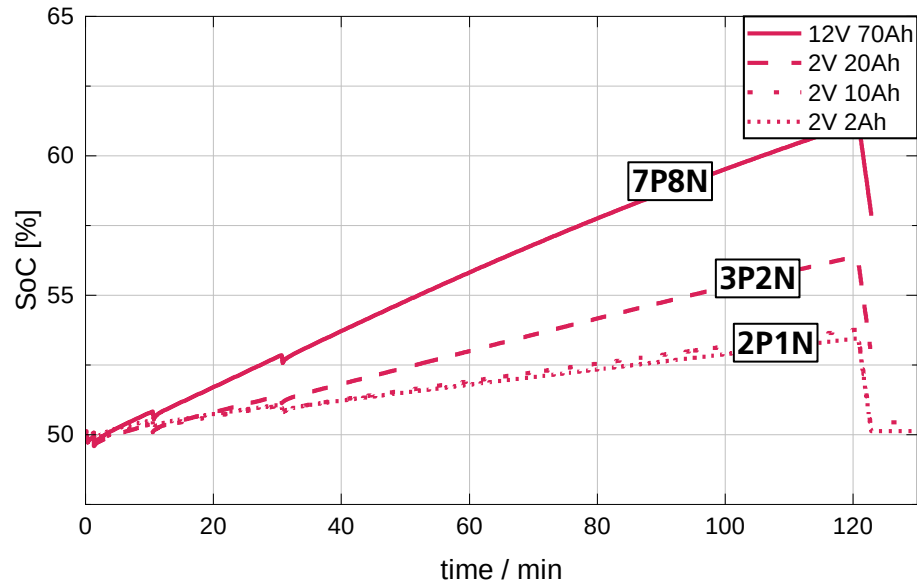
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# CR16 Pseudocapacitive Effects of Cell Geometry

## SOC and SOF recovery

### SOC recovery

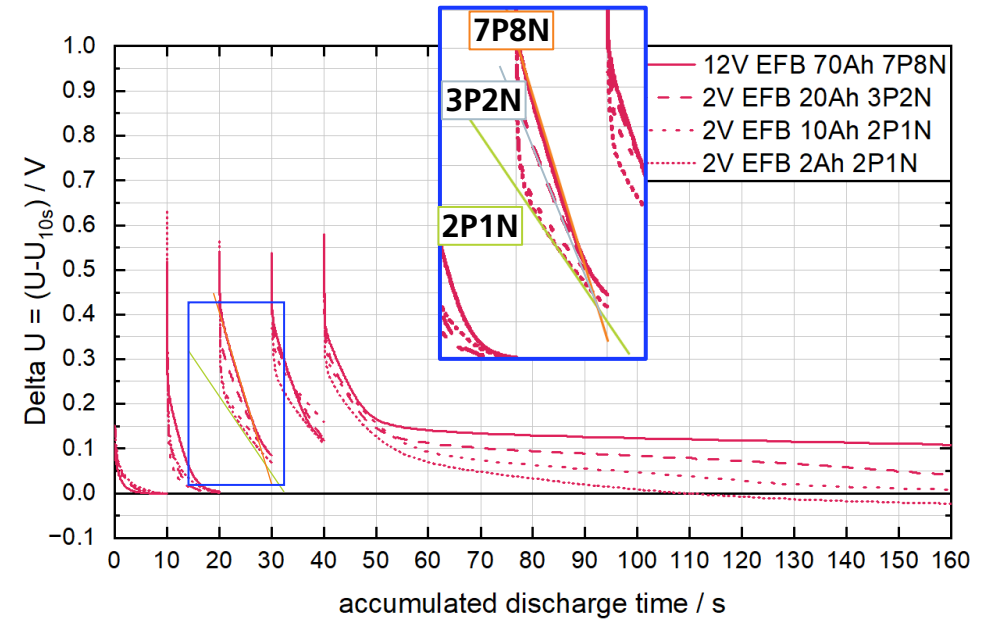


#### Observation 1:

the more asymmetric the cell layout the higher the charge recovery

→ reason: acid density at pSOC is higher for higher asymmetry

### SOF recovery



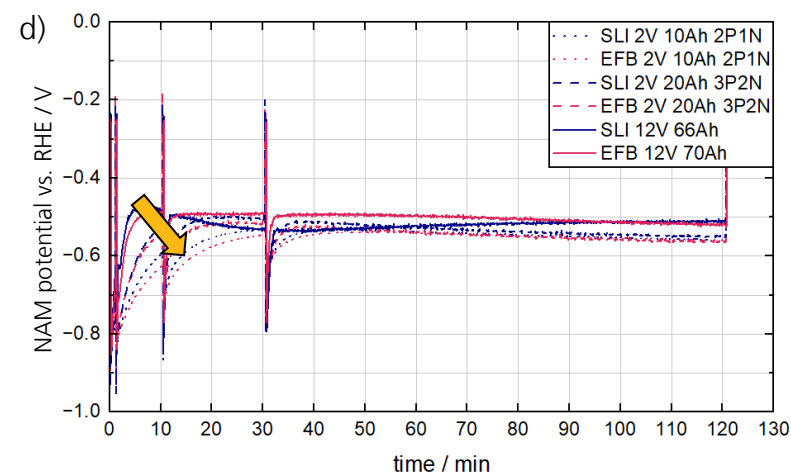
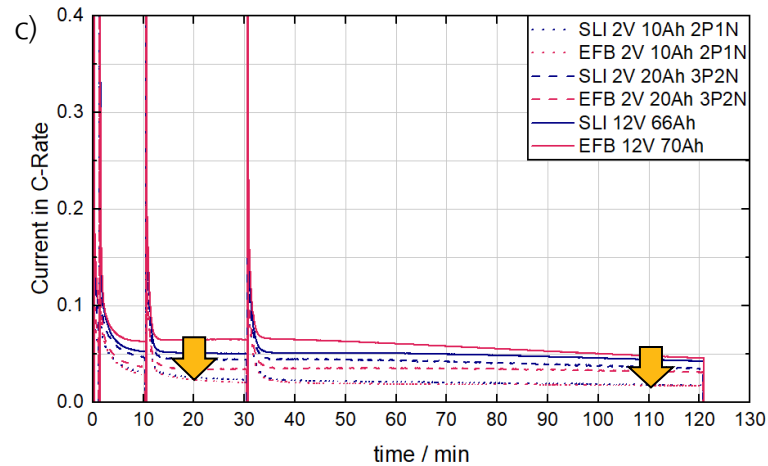
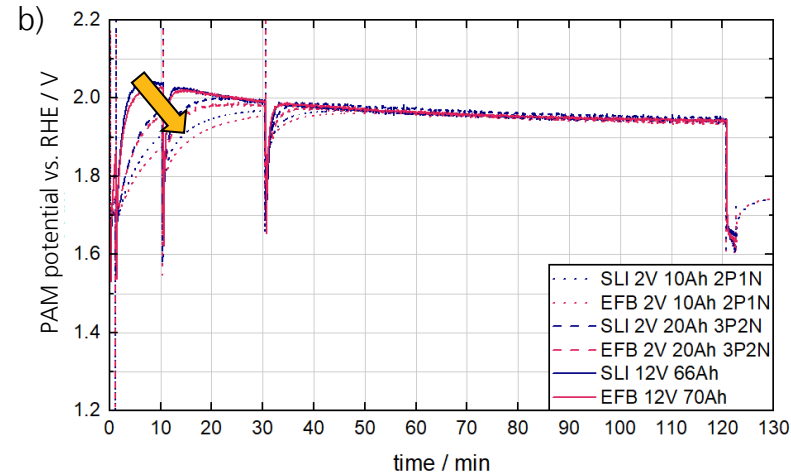
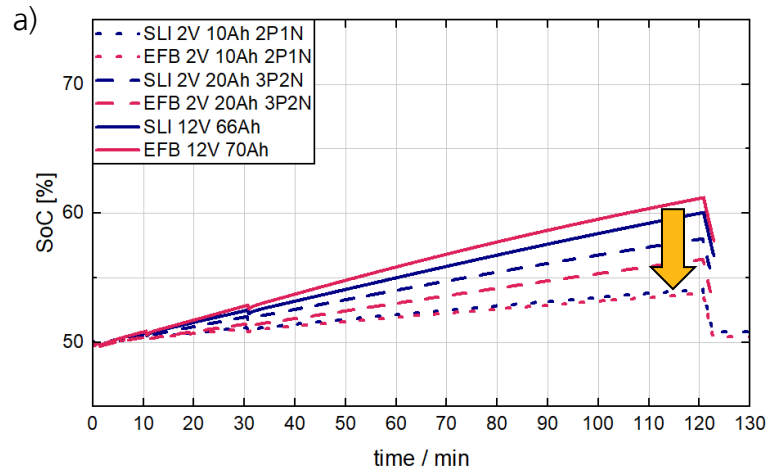
#### Observation 2:

the more asymmetric the cell layout the higher the pseudocapacitive effect

→ reason: PAM/NAM ratio → change in PAM overpotential

# Effect of Test Cell Layout

## SOC Recovery

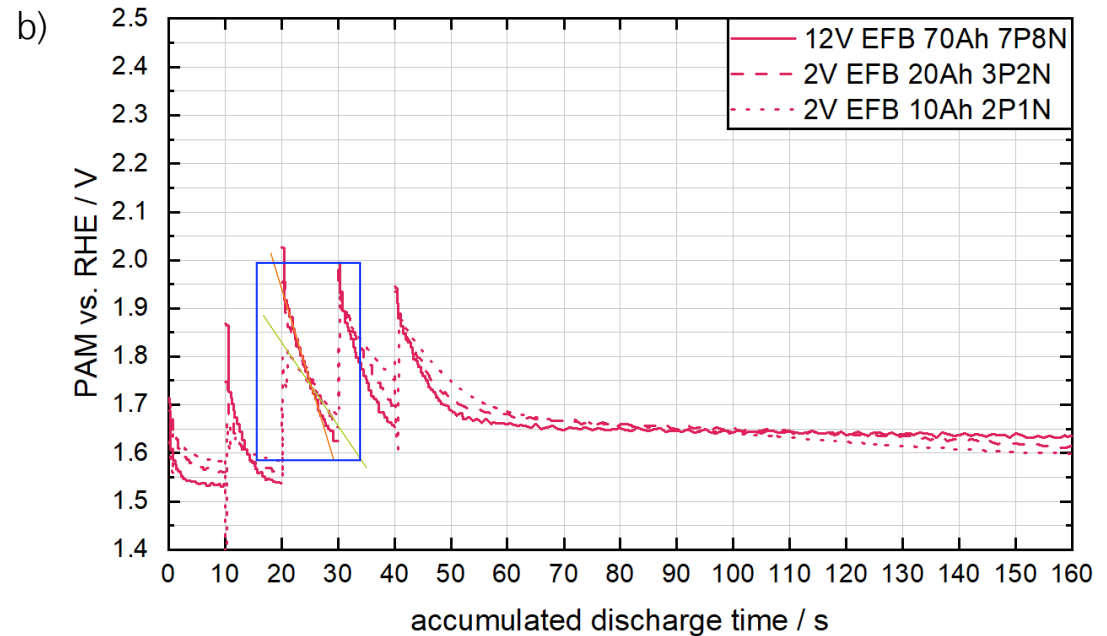
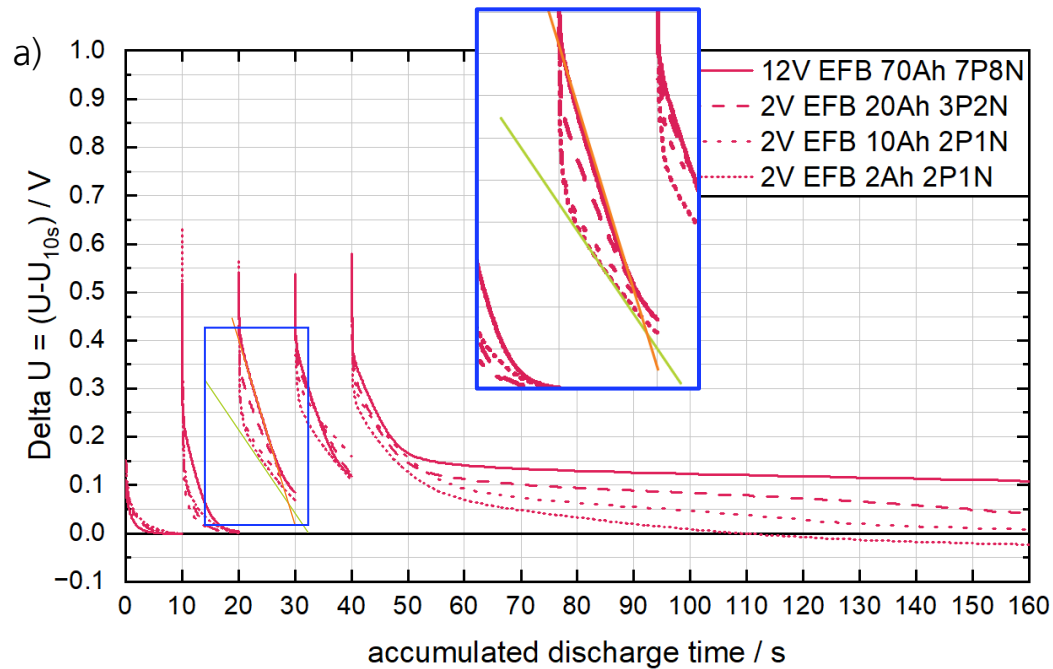


- the more asymmetric the cell design the smaller the SOC recovery
- Charging current is lowest for 2P1N cells and highest for 12V symmetric design  
→ **from start** ( $t > 5$  min) **until end!**
- Negative electrode strongly polarized in case of asymmetric test cells
- Negative electrode limits charging process
  - 12V batteries: 2-3min
  - 2V 3P2N cells: 20min
  - 2V 2P1N cells: 40 min

**Main reason:**  
the more asymmetric the cell layout  
the higher acid density at pSOC

# Effect of Test Cell Layout

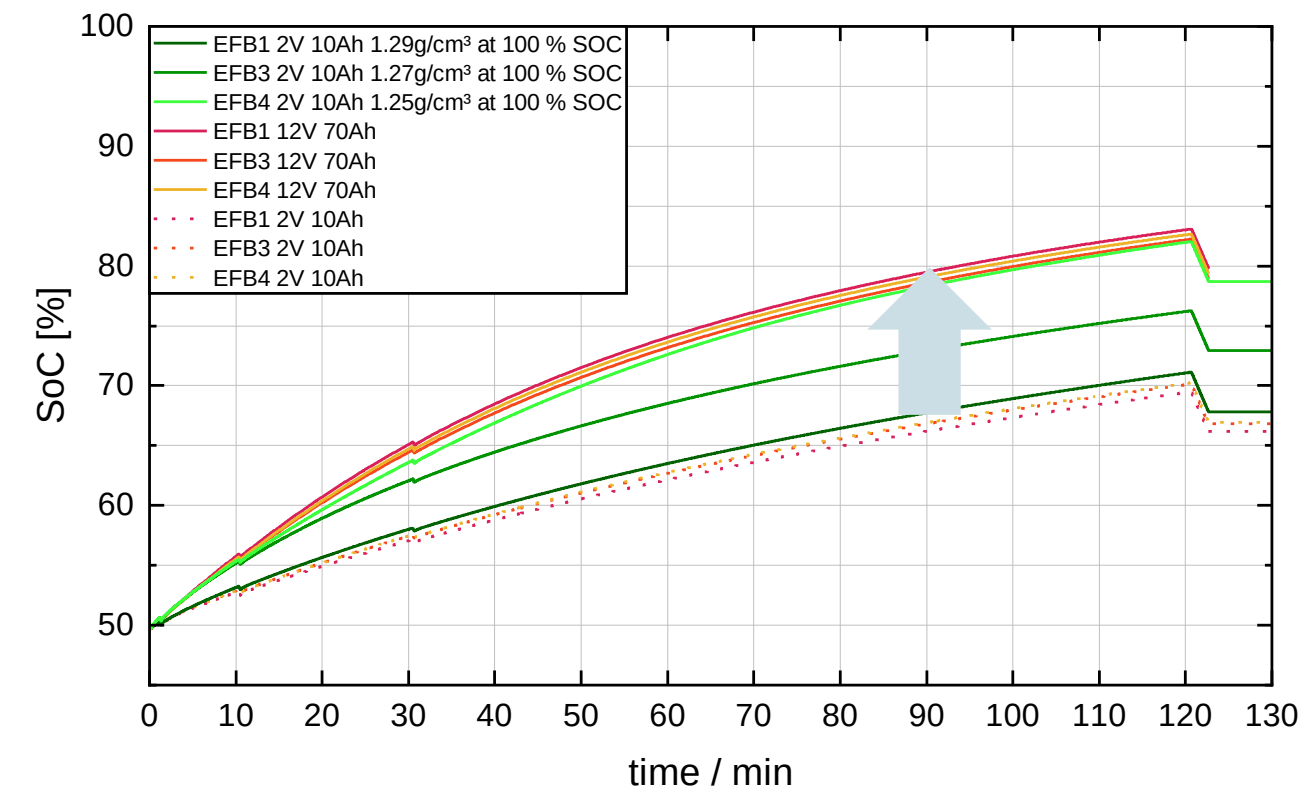
## SOF Recovery



- Higher SOC recovery leads to higher Delta U (= start of the 10s discharge pulses)
- Asymmetric cell design increases pseudocapacitive effect (= voltage decline during first seconds of the 10s discharge pulses)
- Effect 100% originating from PAM (identical slopes, see green/orange line)

# Effect of Test Cell Layout

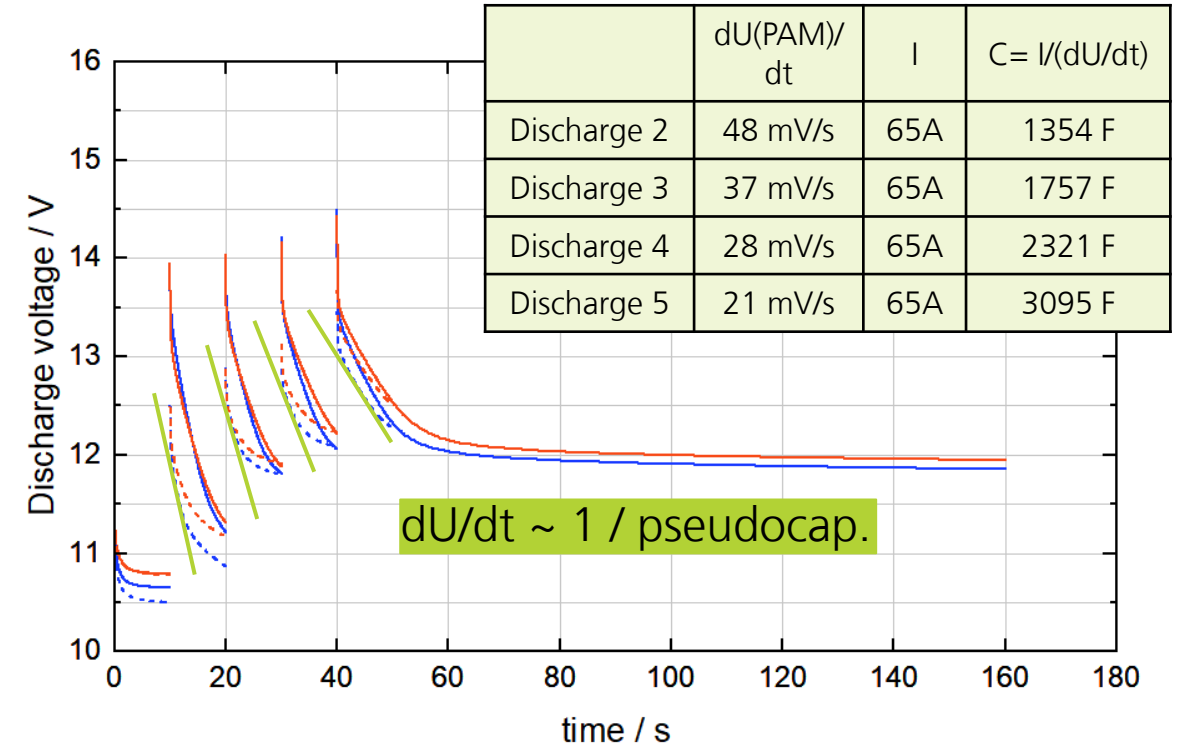
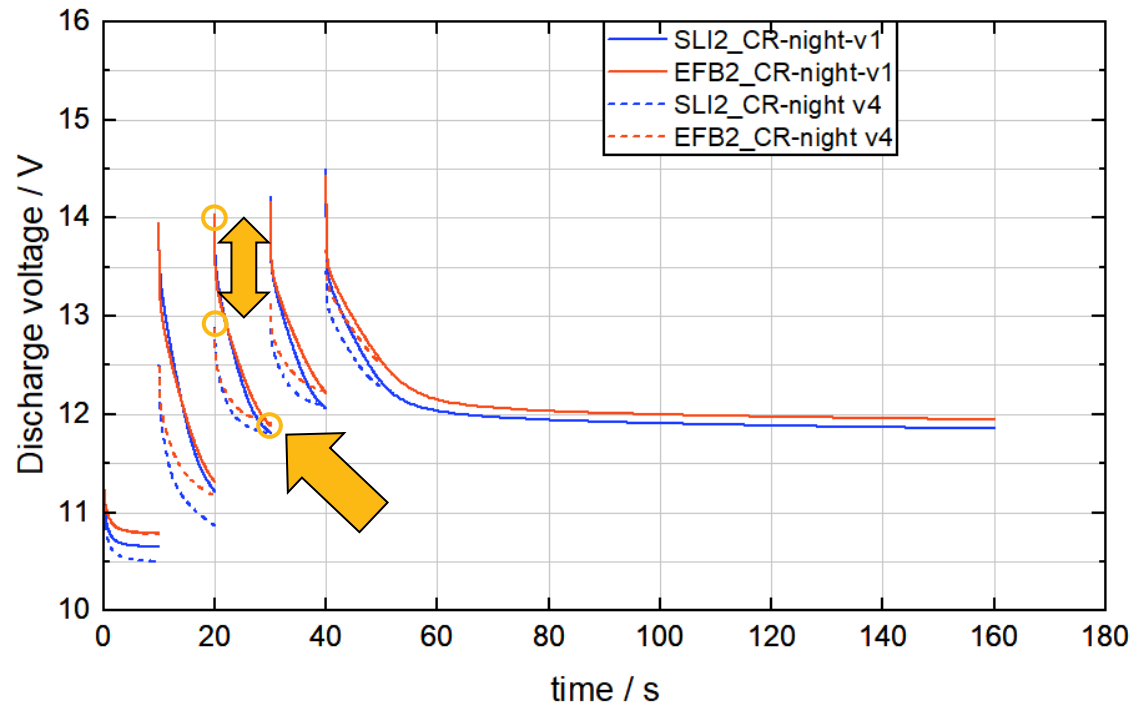
## Acid Effect



| Acid density<br>100% SOC | OCV<br>100% SOC | Acid density<br>50% SOC | OCV<br>50% SOC |
|--------------------------|-----------------|-------------------------|----------------|
| 1.25 g/cm³               | 2.09 V          | 1.19 g/cm³              | 2.01 V         |
| 1.27 g/cm³               | 2.11 V          | 1.21 g/cm³              | 2.03 V         |
| 1.29 g/cm³               | 2.12 V          | 1.24 g/cm³              | 2.05 V         |

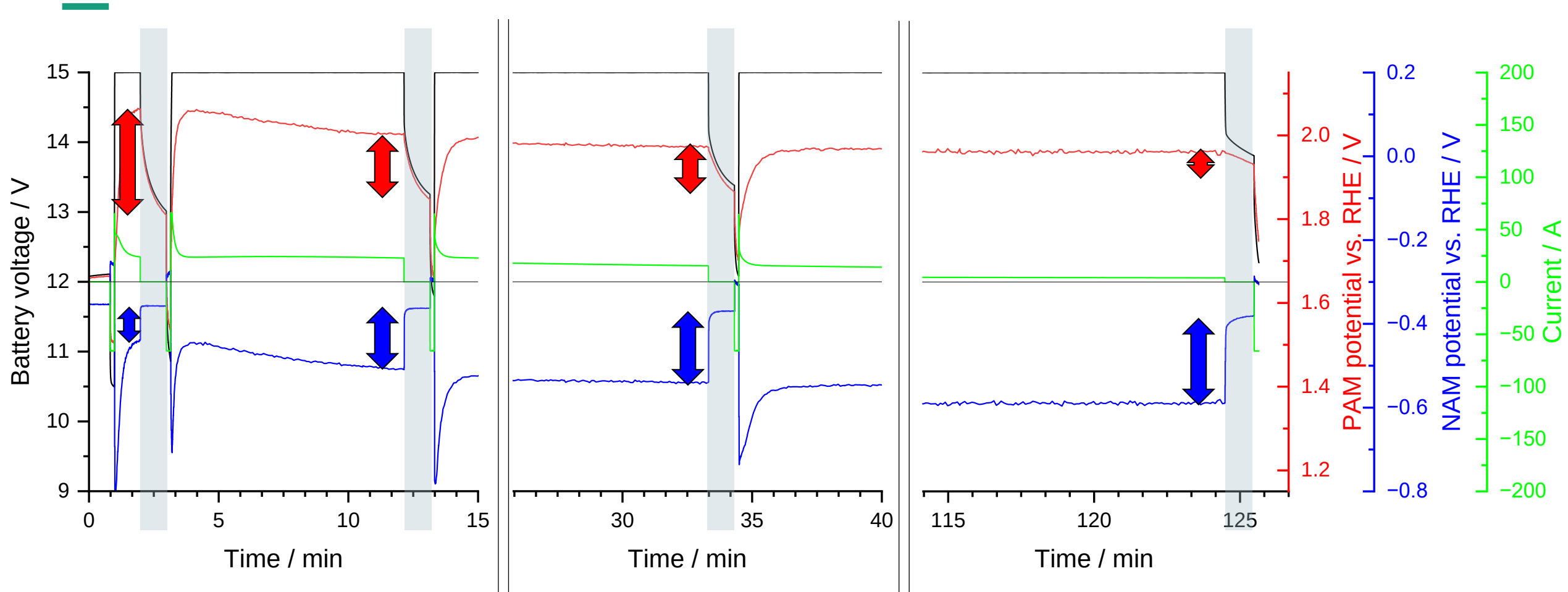
- Lower acid density results in higher charge recovery
- Effect can explain differences between test cells and commercial batteries

# Effect of 60s Rest



- 60s rest before SOF pulse reduces voltage and PAM polarization at the beginning of the SOF pulse
- $U_{\text{eod}}$  is **NOT** affected! → **Slope** of discharge curve **strongly** affected!
- Effect diminishes during ongoing charging

# Effect of 60s Rest



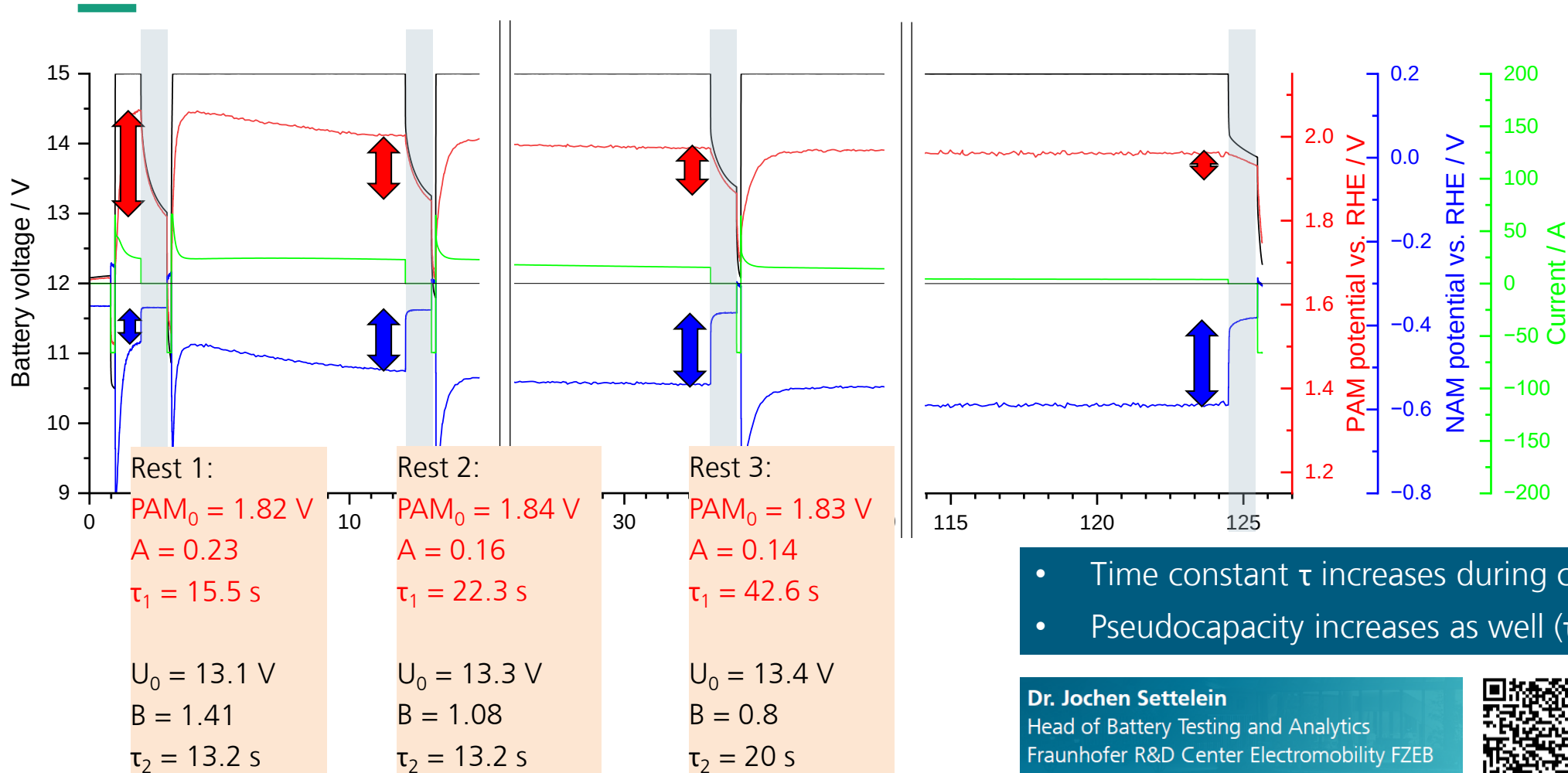
During 60s REST:

- PAM OCP drops by 0.3 V before the 1<sup>st</sup> pulse and only 0.05 V before the 4<sup>th</sup> pulse
- NAM OCP drops by 0.1 V before the 1<sup>st</sup> pulse and only 0.2 V before the 4<sup>th</sup> pulse

# Effect of 60s Rest

$$PAM(t) = PAM_0 + A \cdot \exp(-t_{\text{step}} / \tau_1)$$

$$U(t) = U_0 + B \cdot \exp(-t_{\text{step}} / \tau_2)$$



- Time constant  $\tau$  increases during charging
- Pseudocapacity increases as well ( $\tau = RC$ )

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