New Cells and Validation Studies: Updates to BEAST 2017

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BEAST 2017 – New Cell Additions and Code Changes

Previously available cells

- Sony HCM (1.5 Ah -10°C – 60°C)
- Quallion Satellite Cell (15 Ah 15°C - 35°C)

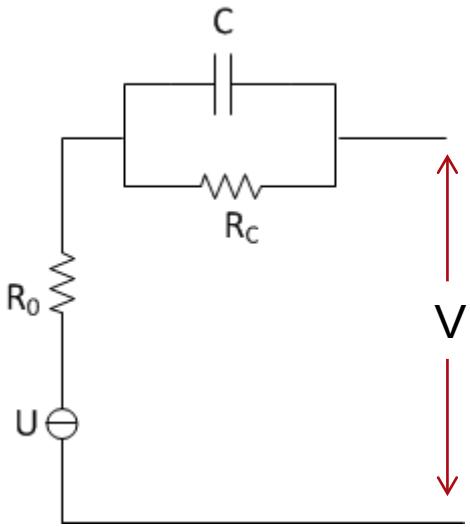
Newly Added Cells

- Molicell C (2.1 Ah -10°C - 60°C)
- LG MJ1 (3.5 Ah 0°C - 40°C)
- Molicell M (2.8 Ah -30°C - 60°C)

Math Model changes

- Custom interpolation code – drastic performance increase
- Consolidation of model constraint code– easier development and maintenance
  - Ex: Import user-defined load as a function of time via CSV file

Equivalent Circuit Model



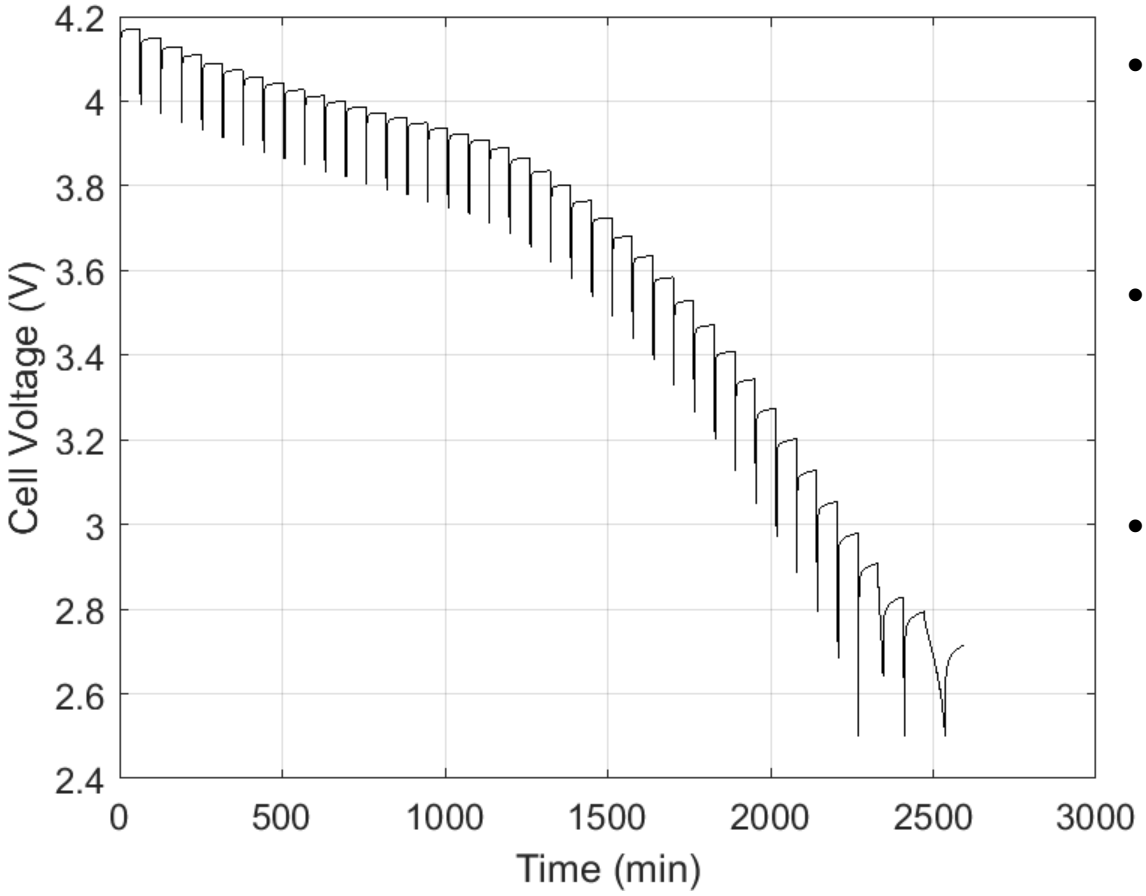
$$\frac{dU_C}{dt} + \frac{U_C}{R_c C} - \frac{I}{C} = 0$$

$$V - U + U_C + IR_0 = 0$$

$$F(I, V) + \text{constant} = 0$$

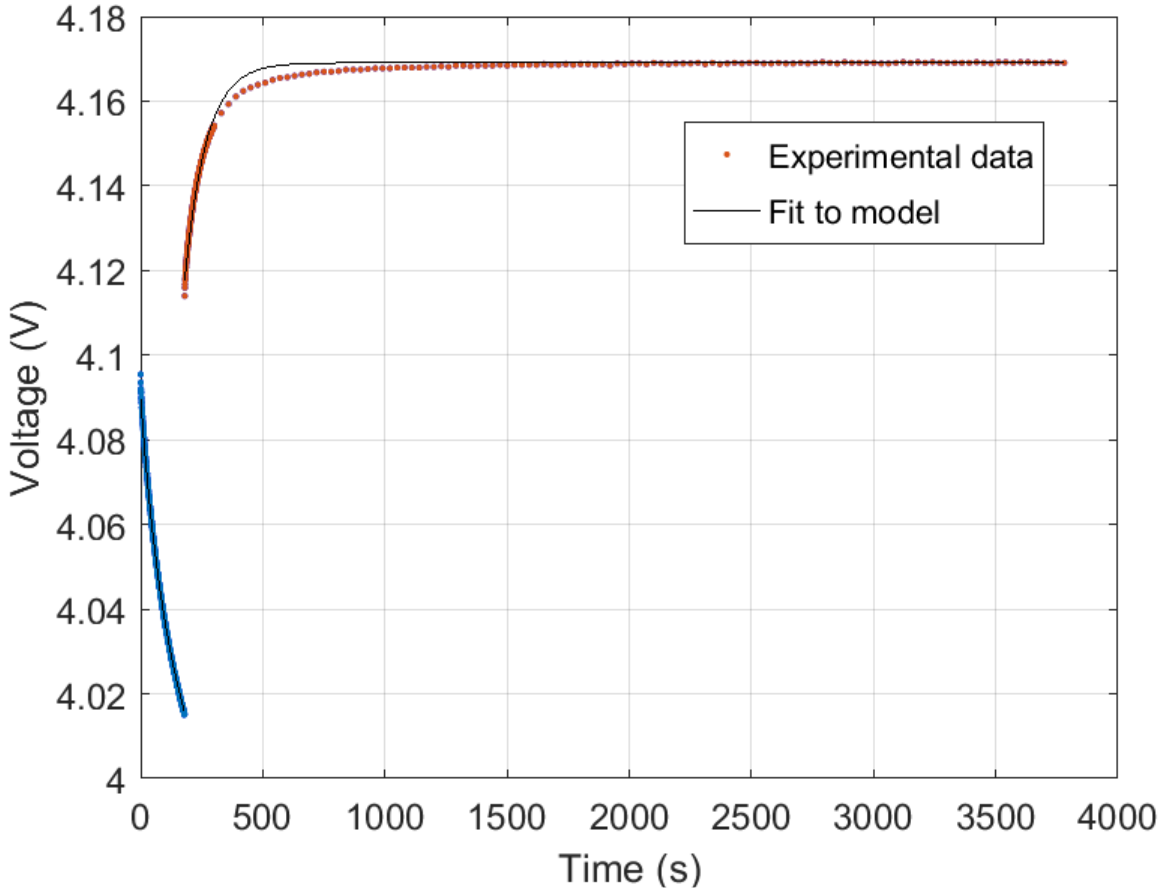
U = Open Circuit Potential as a function of a state of charge

Model Generation



- Open circuit voltage at a given SoC is estimated from end of relaxation voltage
- These data are compared with manufacture's information as well as separately performed tests
- Split into individual pulses and fit to model to extract parameters

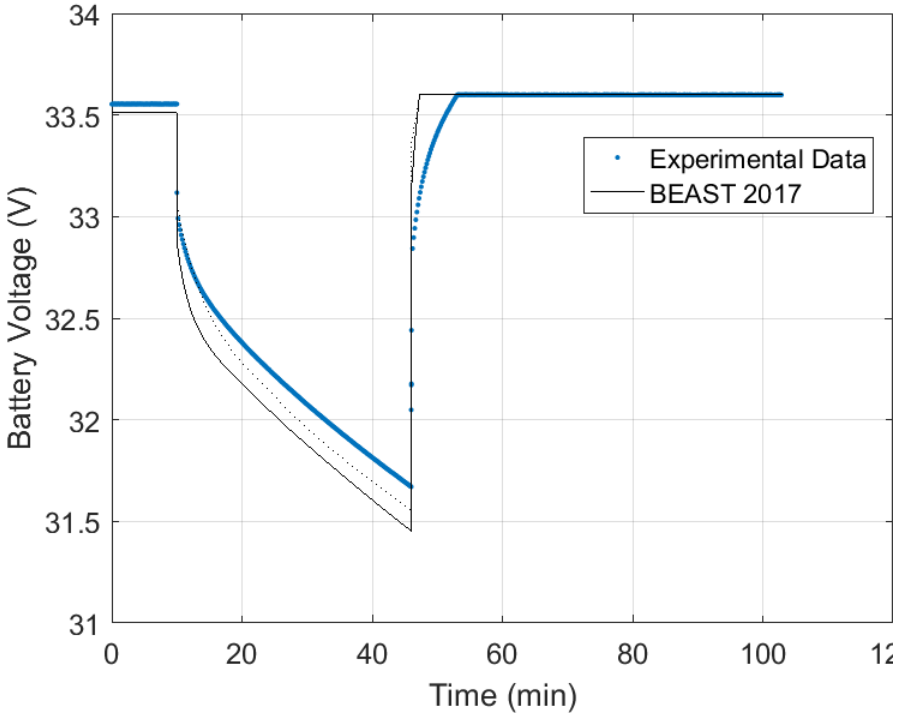
Model Generation

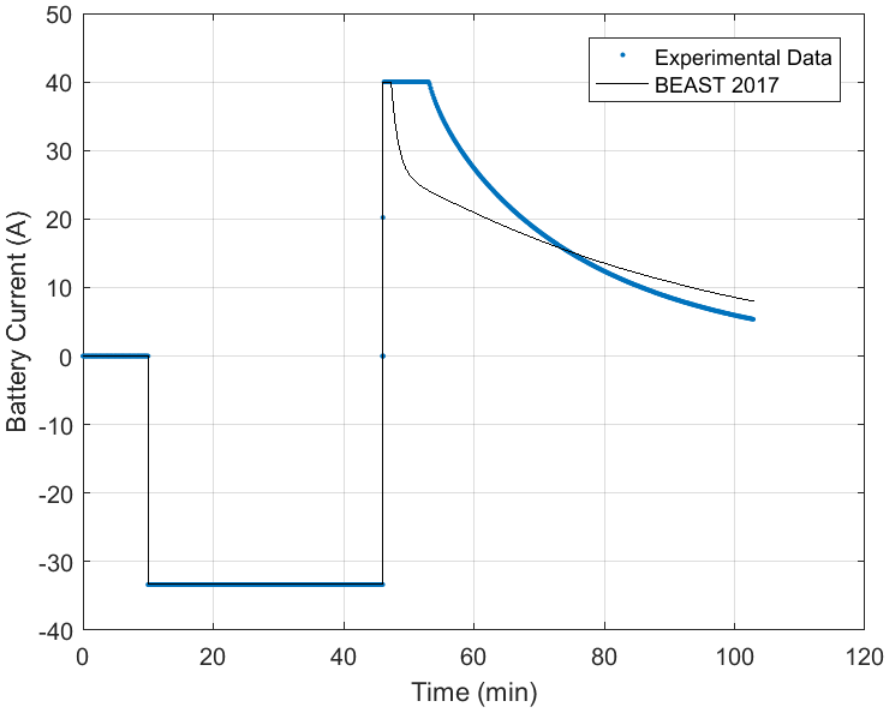


- Individual pulse and subsequent relaxation split out from whole series
- Pulse plus relaxation simultaneously fit to model equations

Validation – Sony HCM

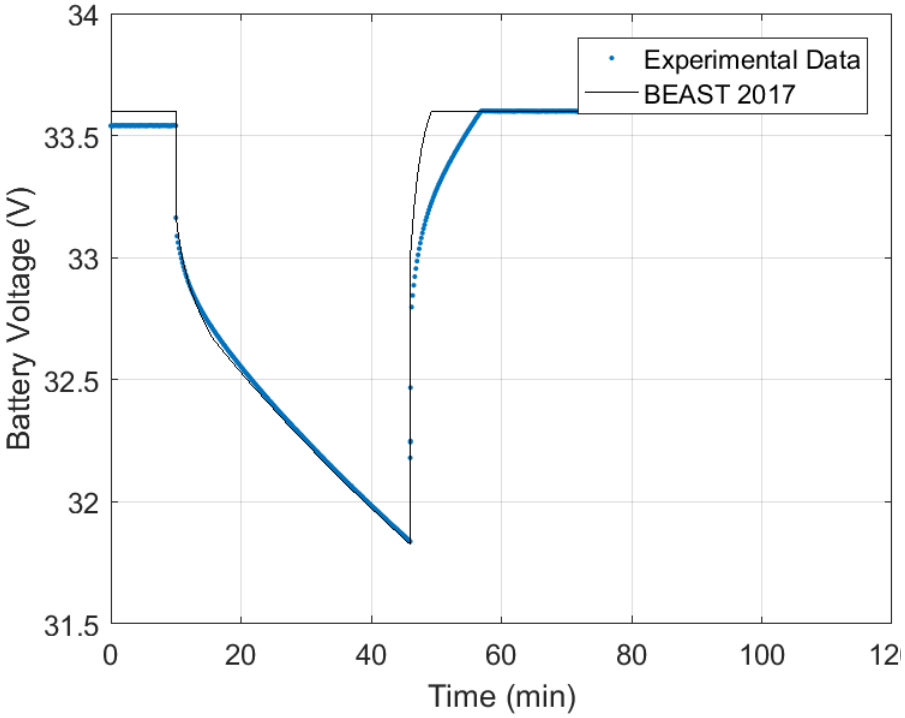
Sony HCM 8s84P pack at 10 °C – low temperature results adequate but room for improvement

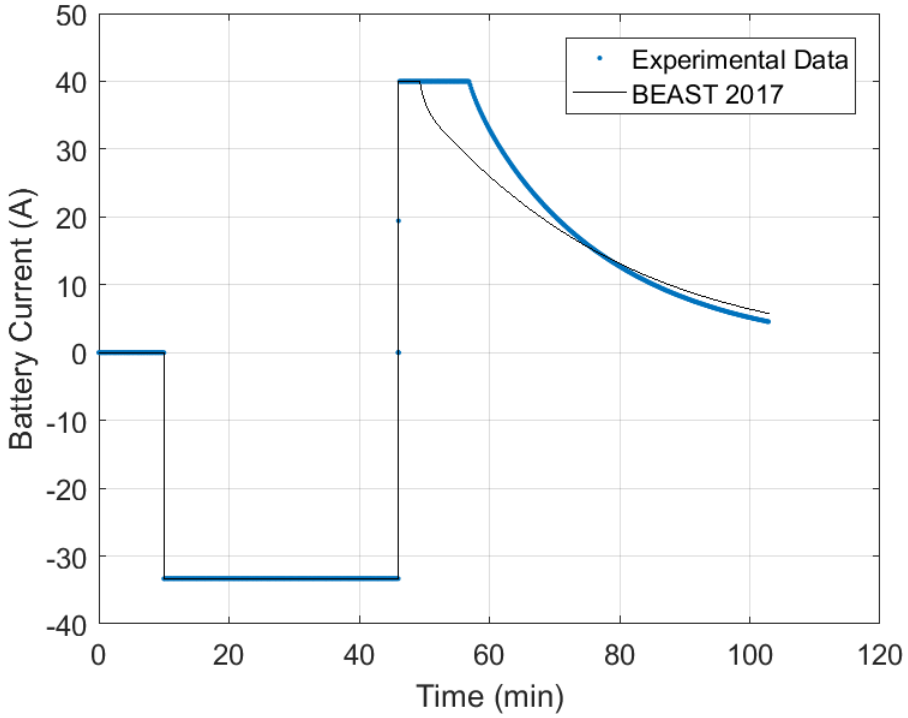




Validation – Sony HCM

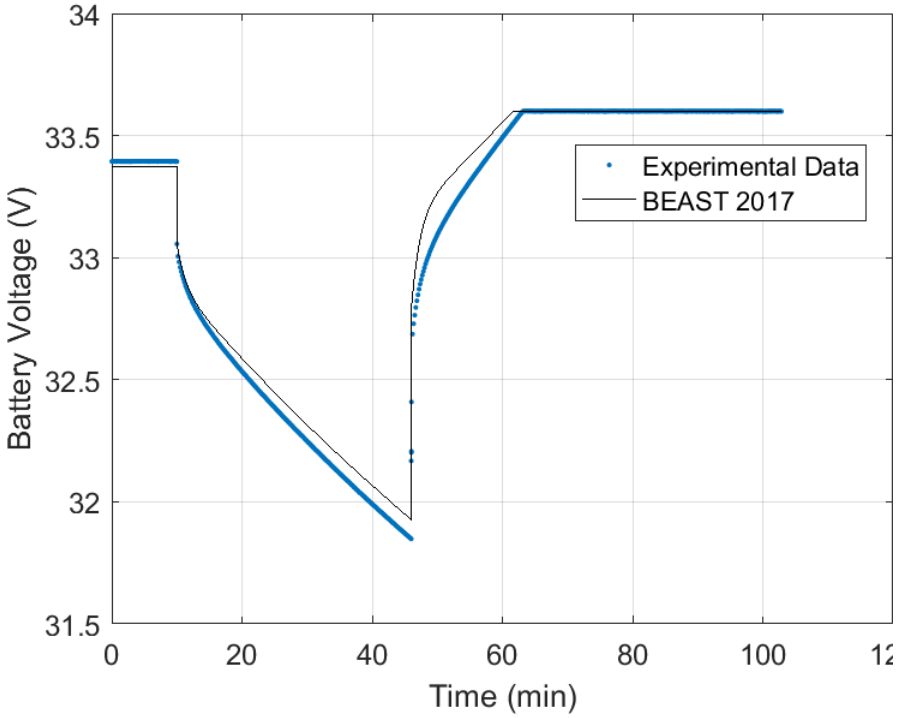
Sony HCM 8s84p pack at 20 °C – Good agreement at room temperature

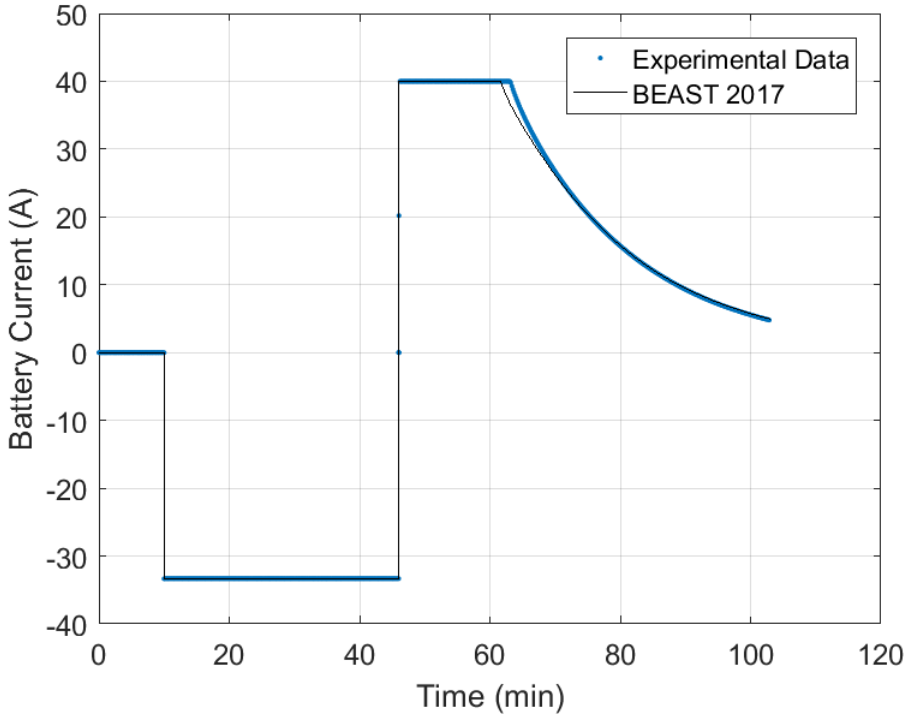




Validation – Sony HCM

Sony HCM 8s84p pack at 30 °C – Good agreement at higher temperature

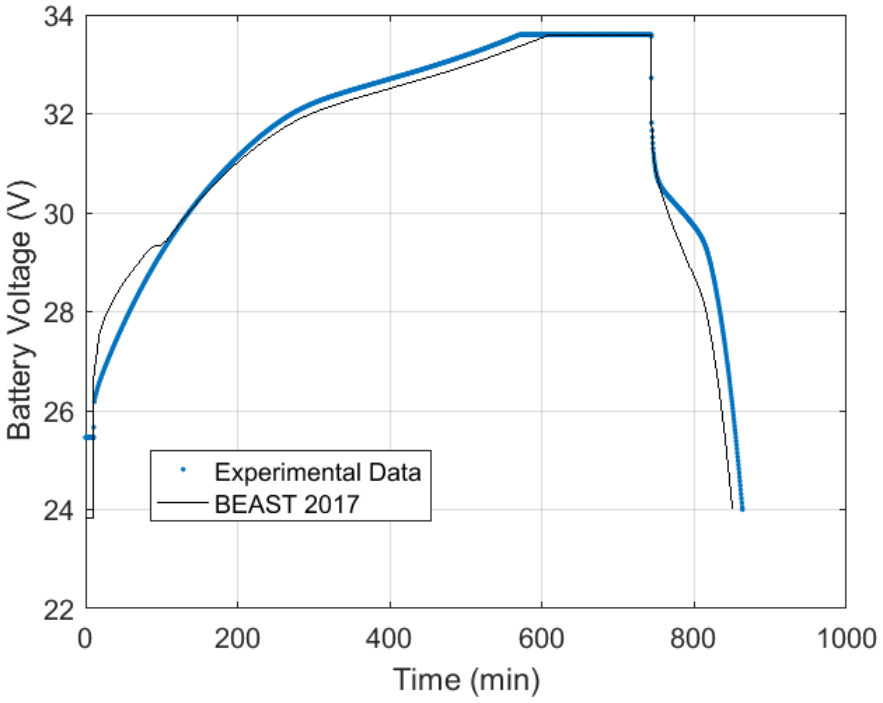


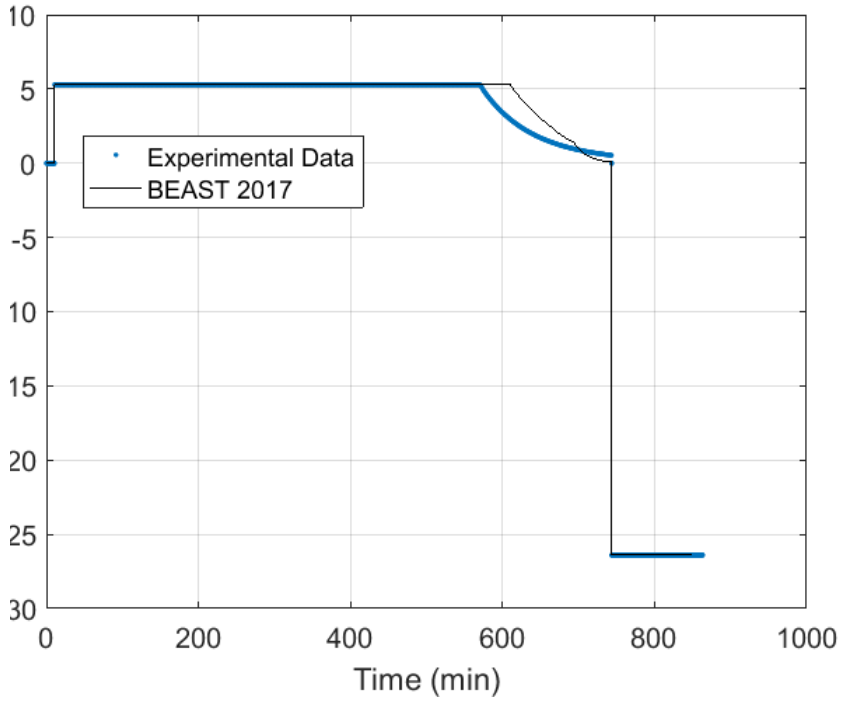


Validation – Sony HCM

Sony HCM 8s44P pack at 0 °C

- Poor agreement below 30% SoC at 0C. Adequate agreement at higher SoCs

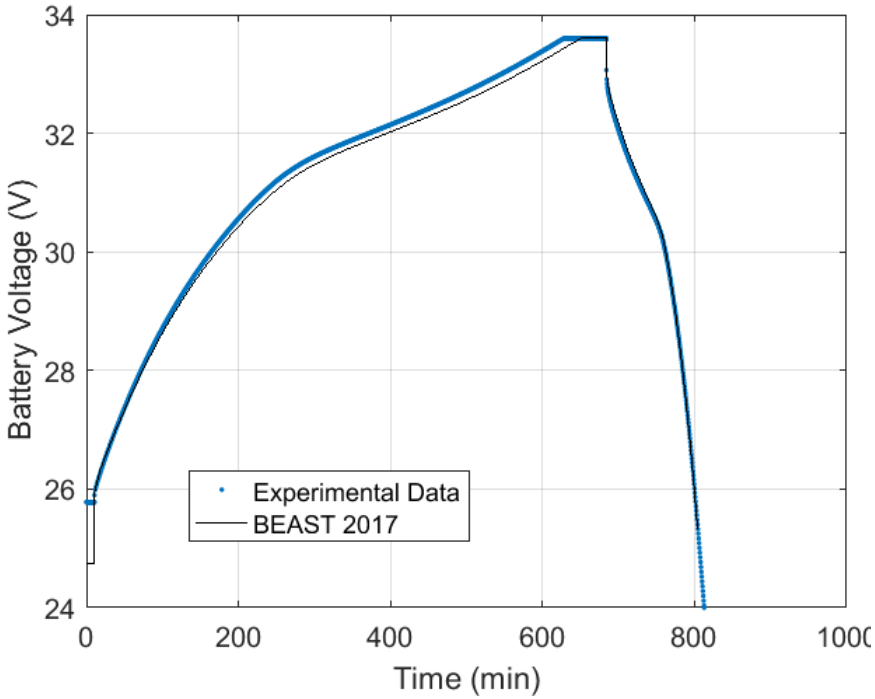


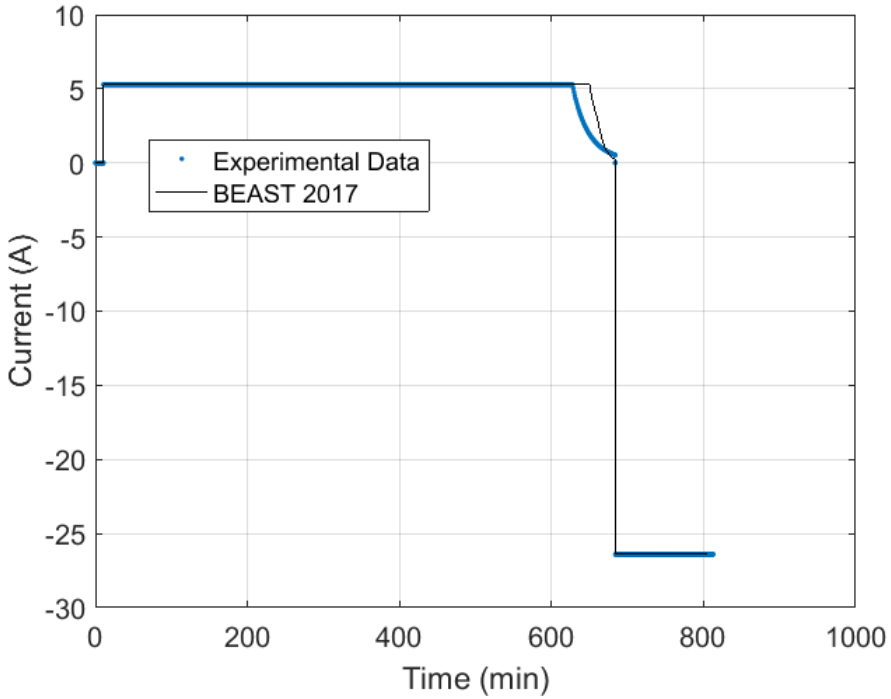


Validation – Sony HCM

Sony HCM 8S44p pack at 35 °C

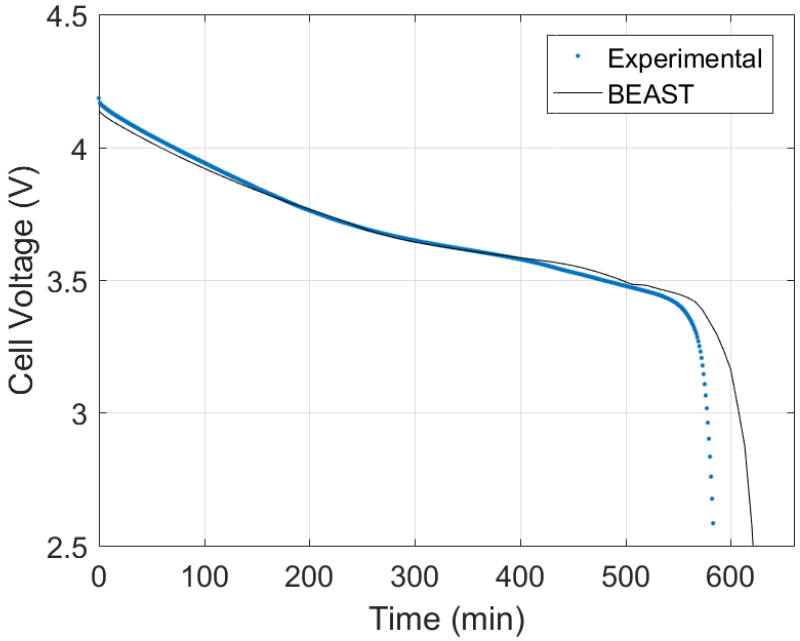
- Good agreement
- No anomolies at low states of charge



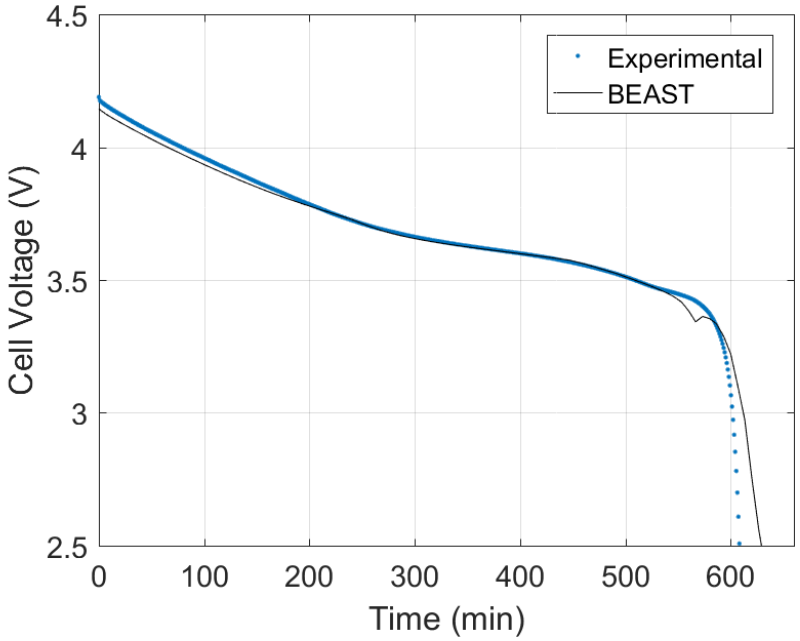


Validation – Moli C (C / 10)

0 Degrees

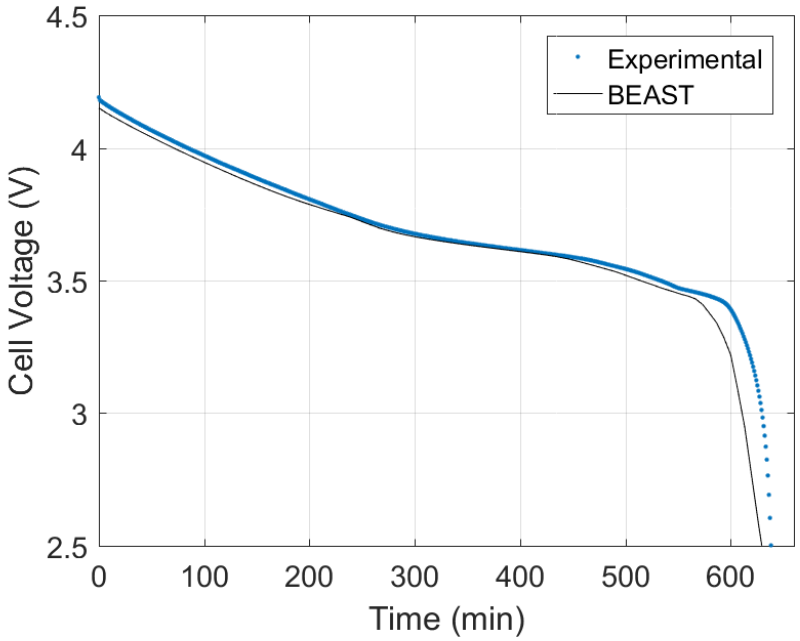


10 Degrees

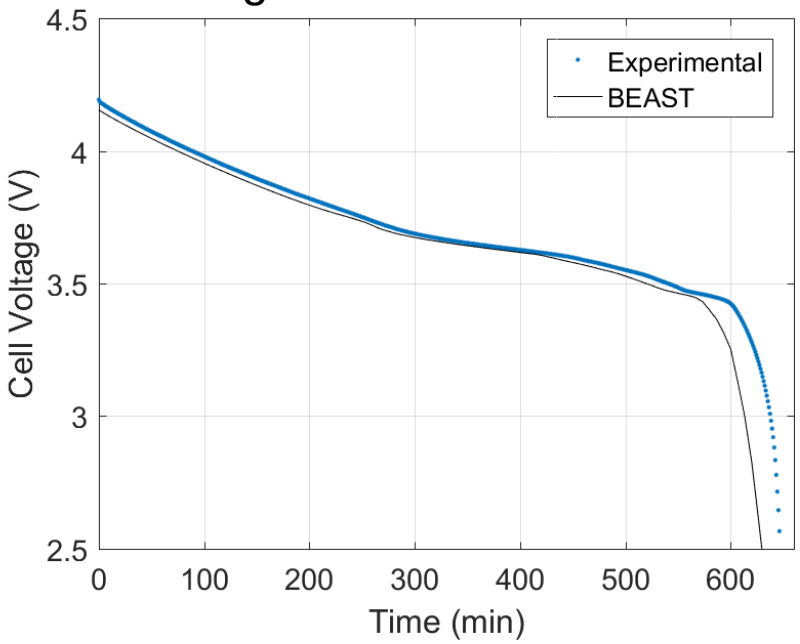


Validation – Moli C

20 Degrees

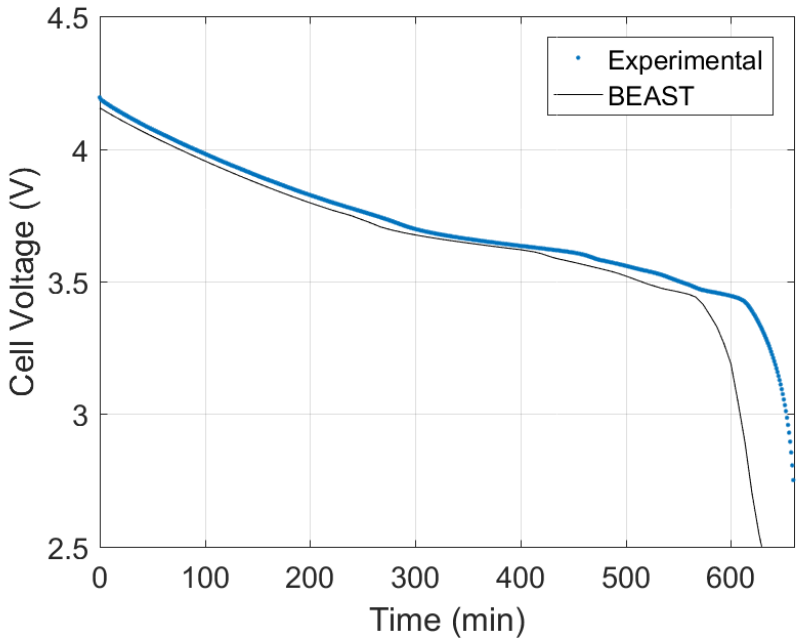


40 Degrees



Validation – Moli C

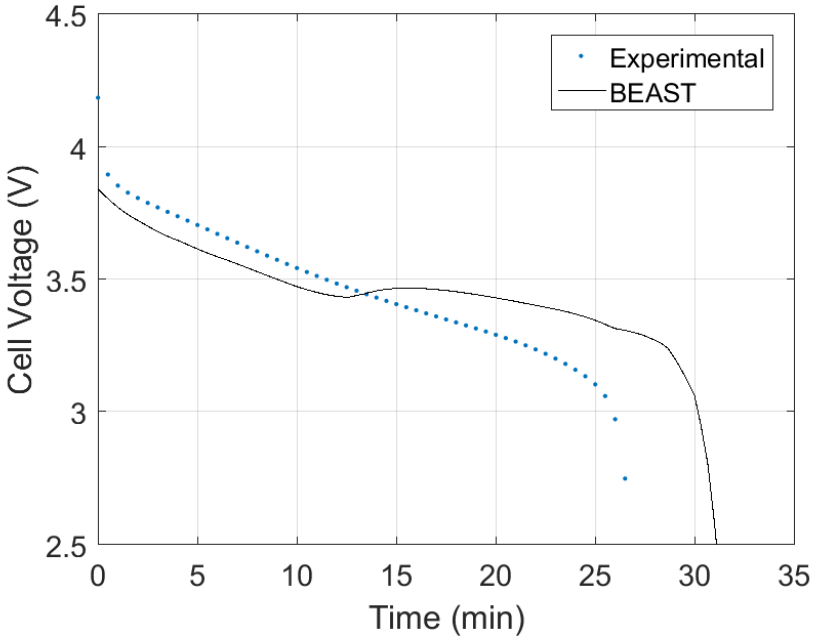
60 Degrees



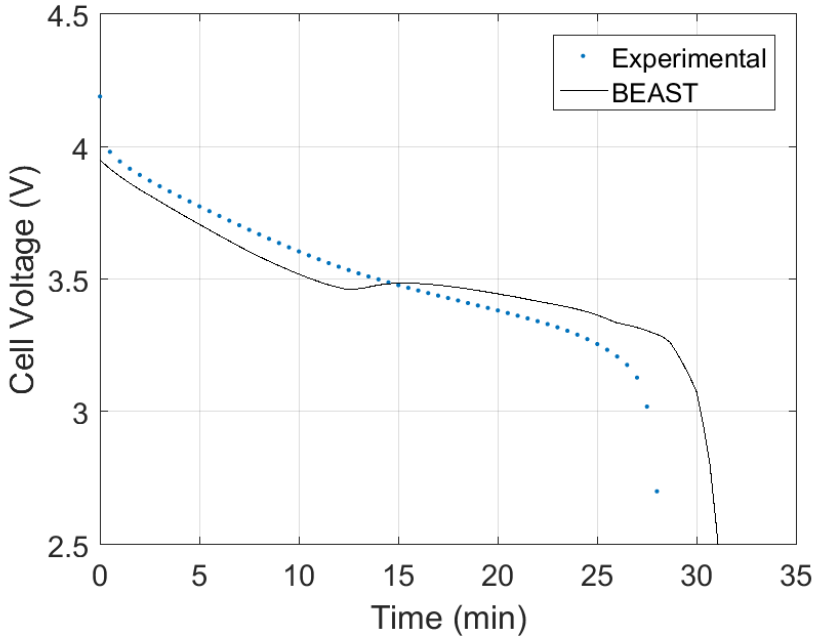
- Good agreement at low rates
- Capacity change with temperature is not captured by the model

Validation – Moli C (2 C)

0 Degrees

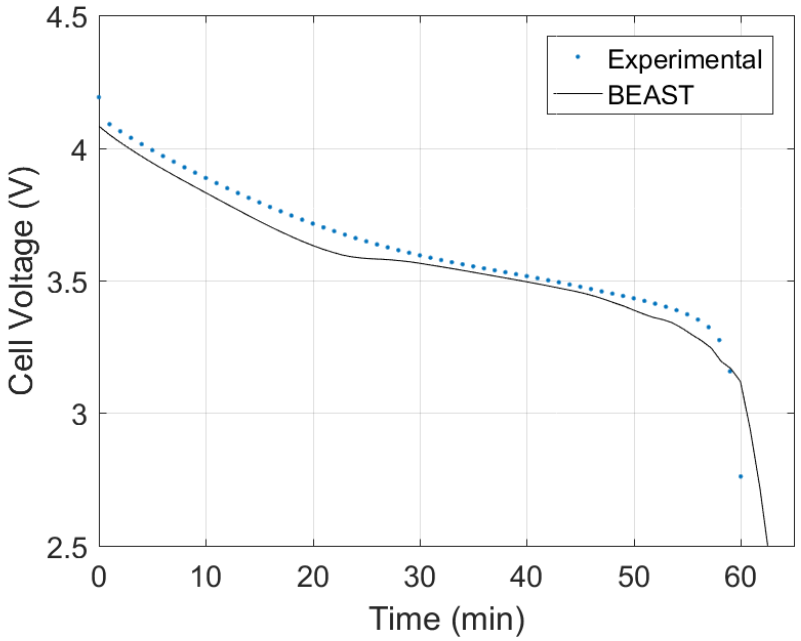


10 Degrees

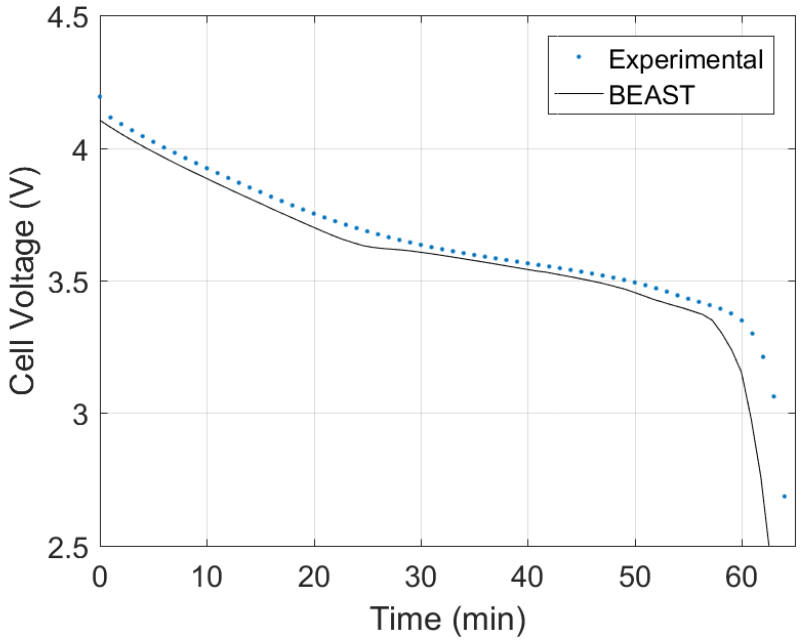


Validation – Moli C (2 C)

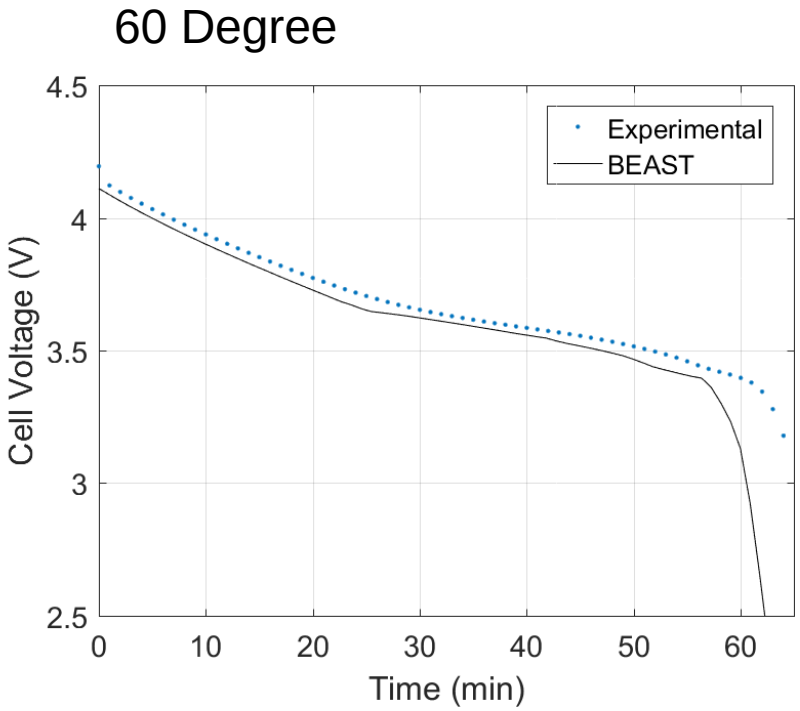
20 Degrees



40 Degrees



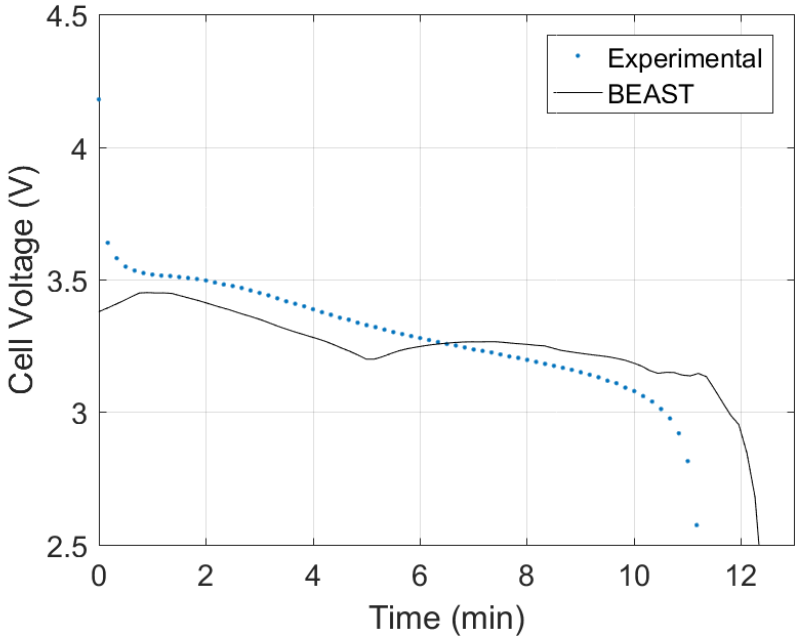
Validation Moli C



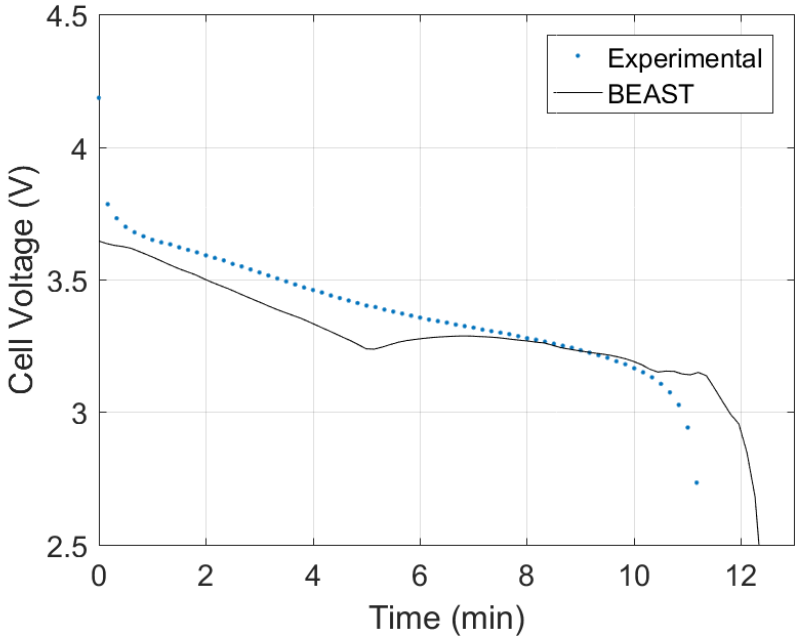
- Some issues at lower temperatures but better results are room temp and above
- Due to the relatively high current (4A), thermal effects were turned on for the simulation

Validation – Moli C (5C)

0 Degrees

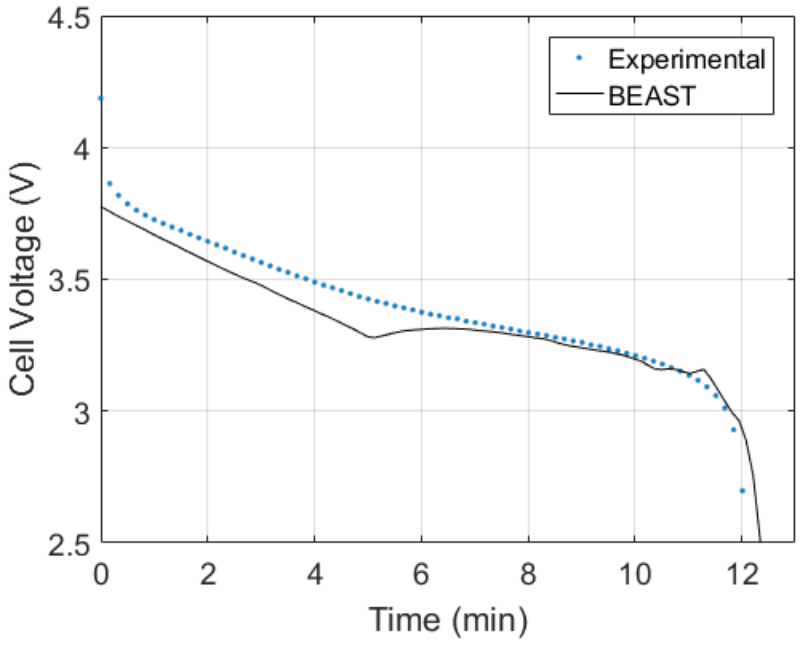


10 Degrees

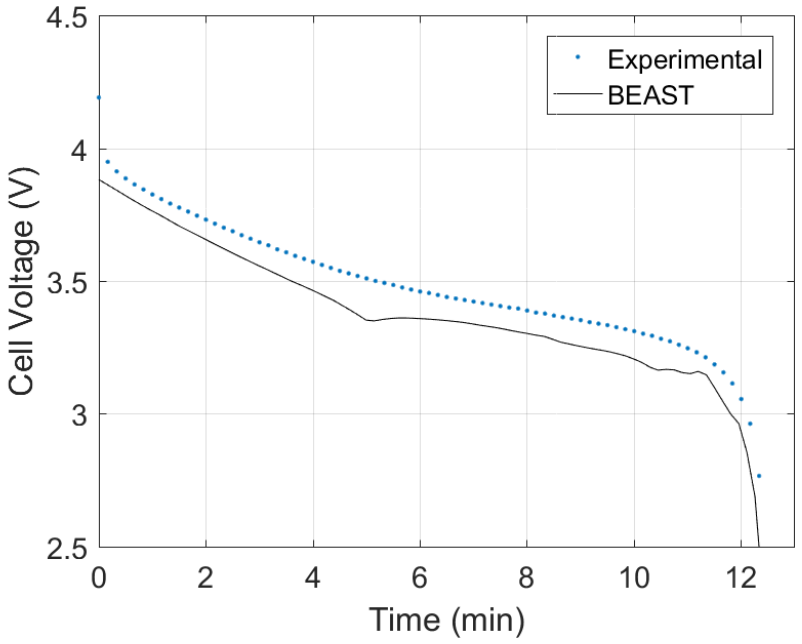


Validation – Moli C

20 Degrees

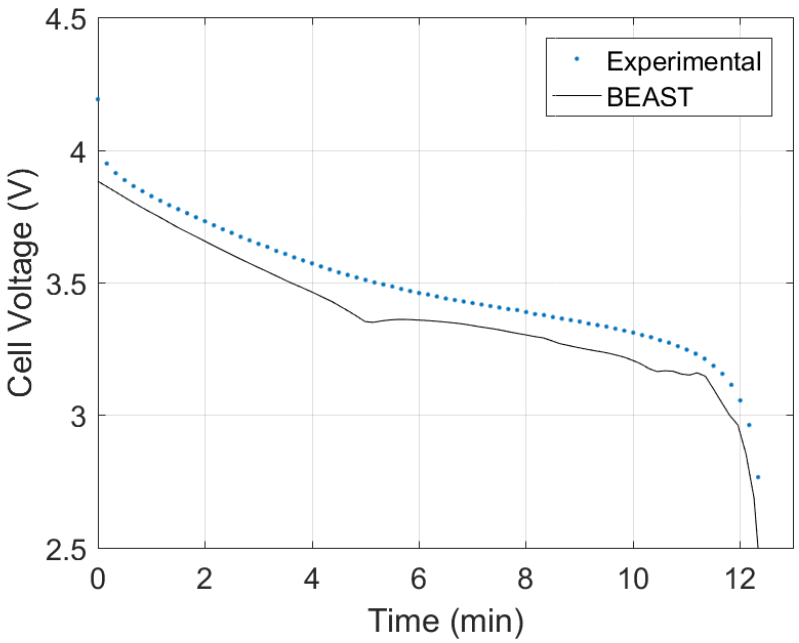


40 Degrees



Validation – Moli C

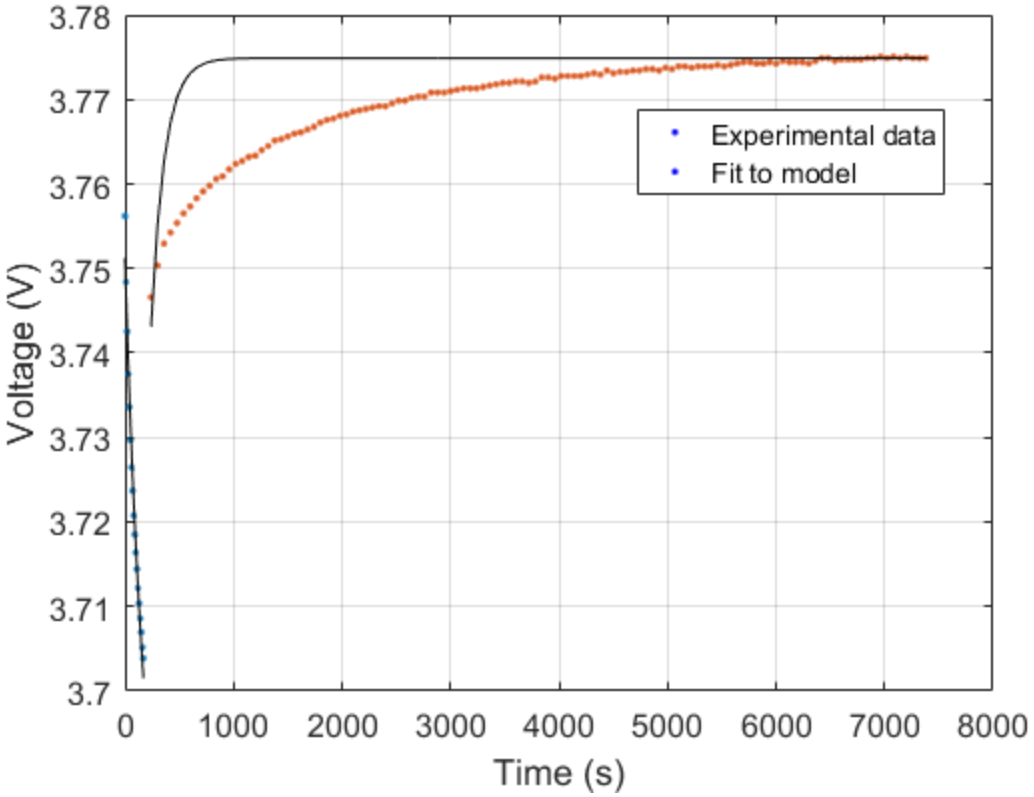
60 Degrees



- Poor performance at very high rates, especially at lower temperatures
- Better agreement at higher temps, but still sub-optimal results

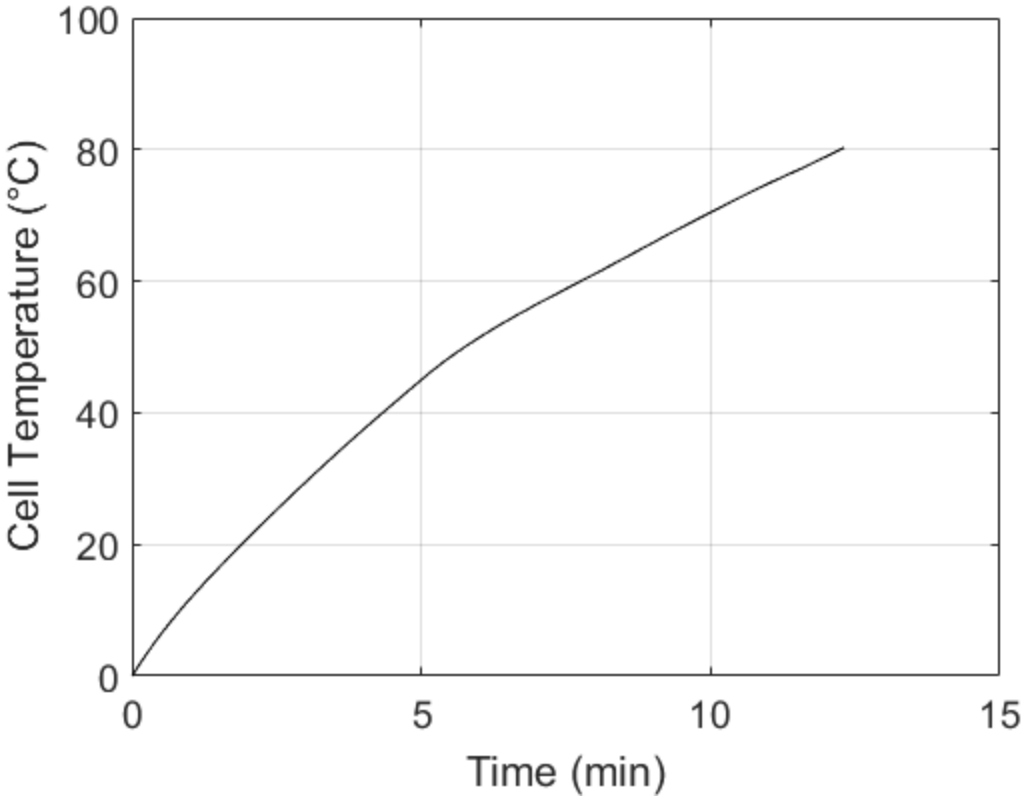
Moli C Pulse Behavior

- Capacitor model does not capture relaxation behavior at middle states of charge (60^ - 70%)
- Discharge and relaxation are fit simultaneously
- If time constant (RC) is allowed to change, resistances and capacitances become very high. This does not reflect general cell behavior
- Fixed time constant for this cell better reflects general properties



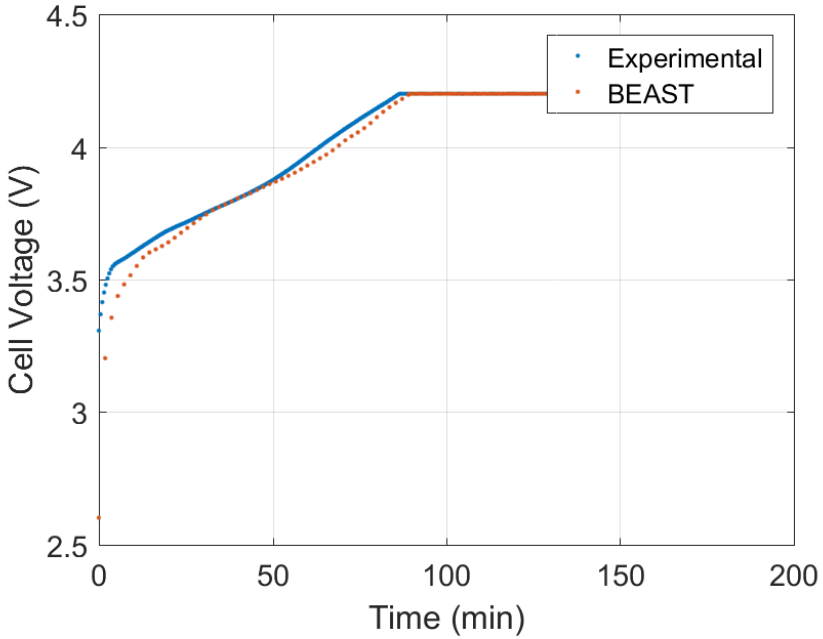
Moli C Behavior

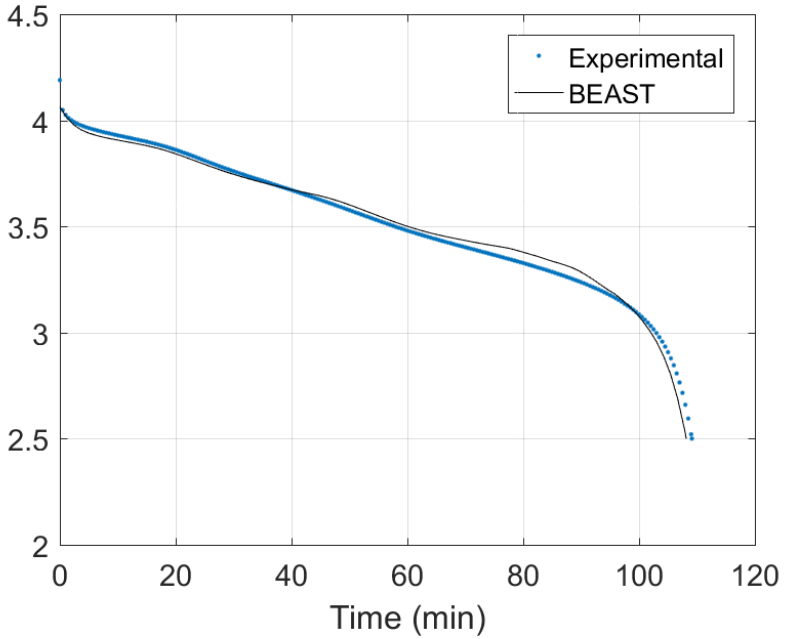
- Higher discharge rates leads to cell heating
- 5C ~ 10A discharge causes very rapid heating to temperatures outside normal simulation ranges
- With such a large rise in temperature, very accurate thermal environment parameters needed to model better
- No experimental temperature data were available for this run.



Validation – MJ1

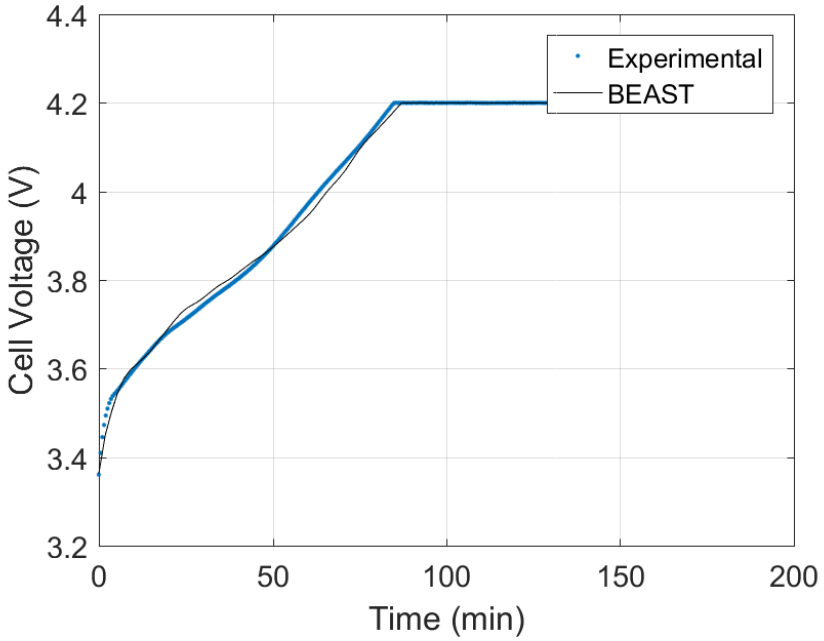
10 Degrees

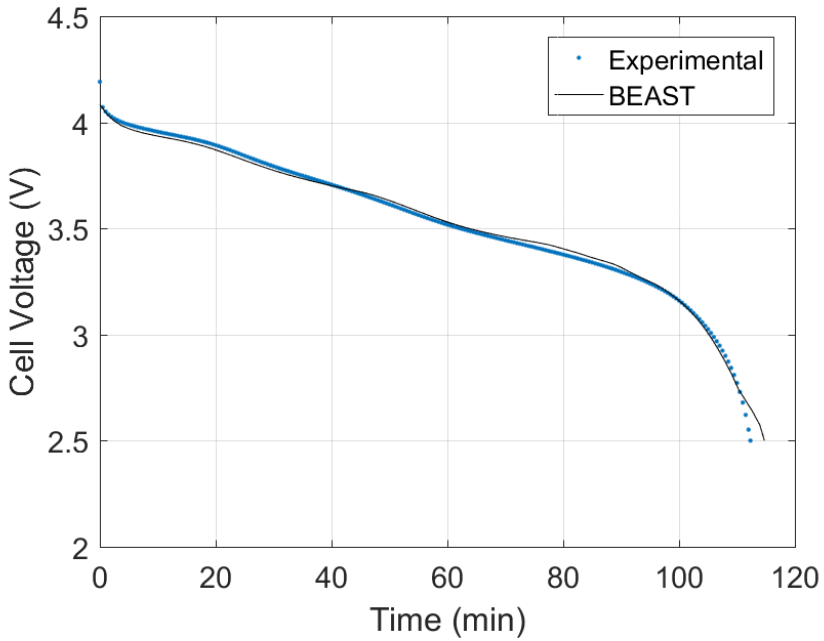




Validation - MJ1

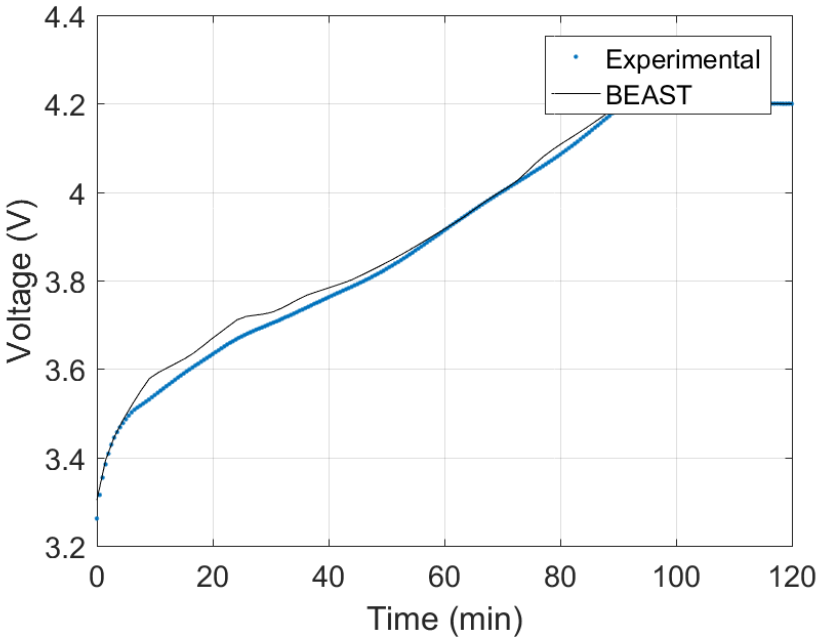
17 Degrees

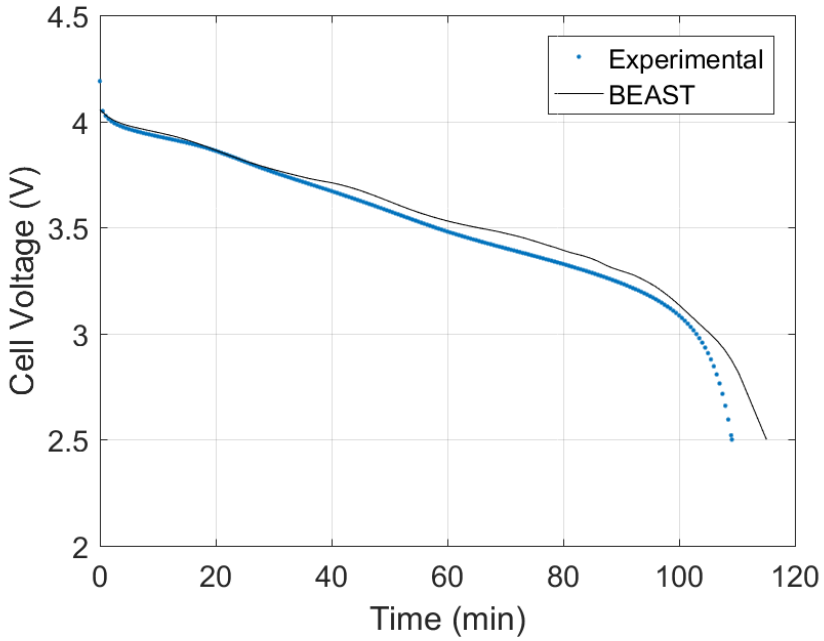




Validation - MJ1

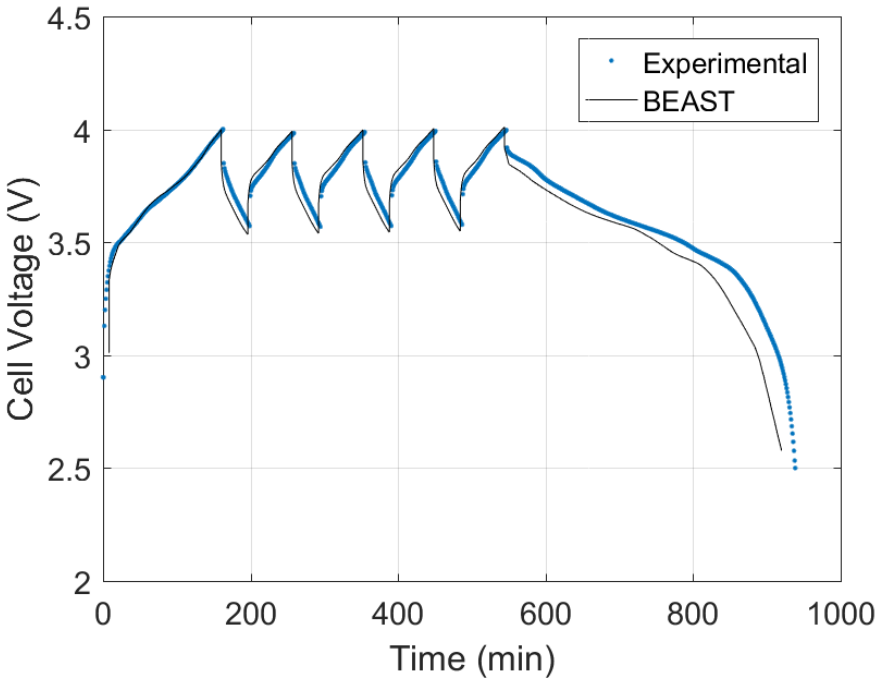
30 Degrees



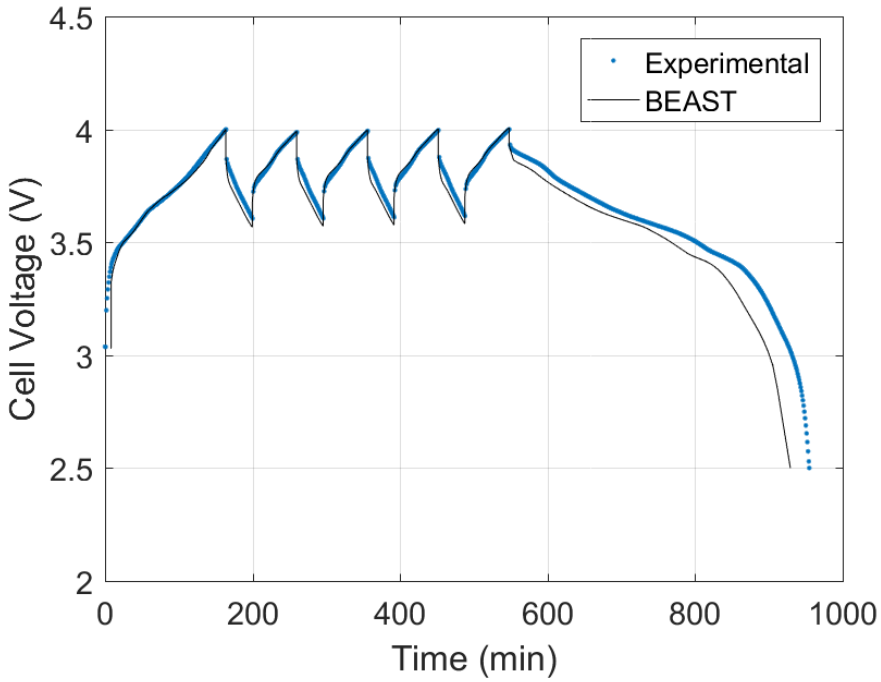


Validation - MJ1

10 dergees

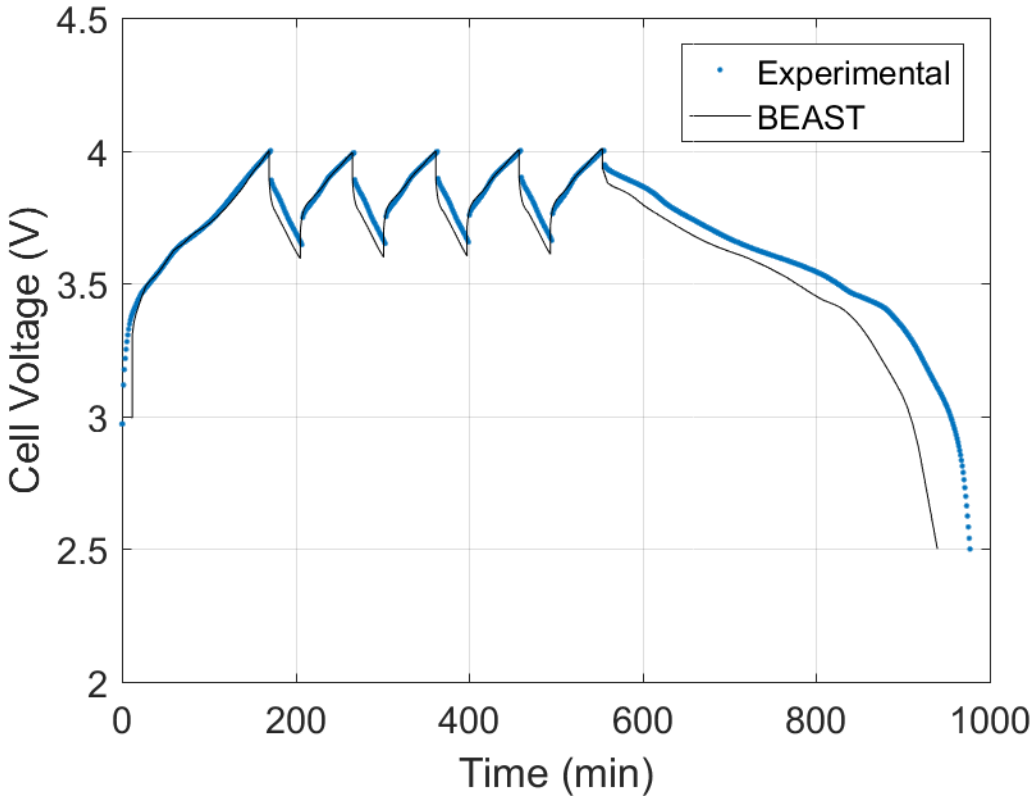


17 Degrees



Validation – MJ1

30 Degrees



Conclusions and Future Work

- Sony HCM
  - Decent agreement over most temperatures and SOCs
  - Low temperature and low SoC is less reliable
- LG MJ1
  - Decent agreement over temperatures which we have data
  - More validation sets are needed
- Moli C
  - Adequate performance at lower rates
  - High rates need more work to overcome “RC” issue
  - High rates cause the cell temperature to change drastically so better validation tests are needed
- All cell models could benefit from including capacity as a function of temperature
- Investigate alternative models, especially in the case of Moli C
- Continue interface development