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FACETS-ITN

Hardware AdEx neuron calibration - continued

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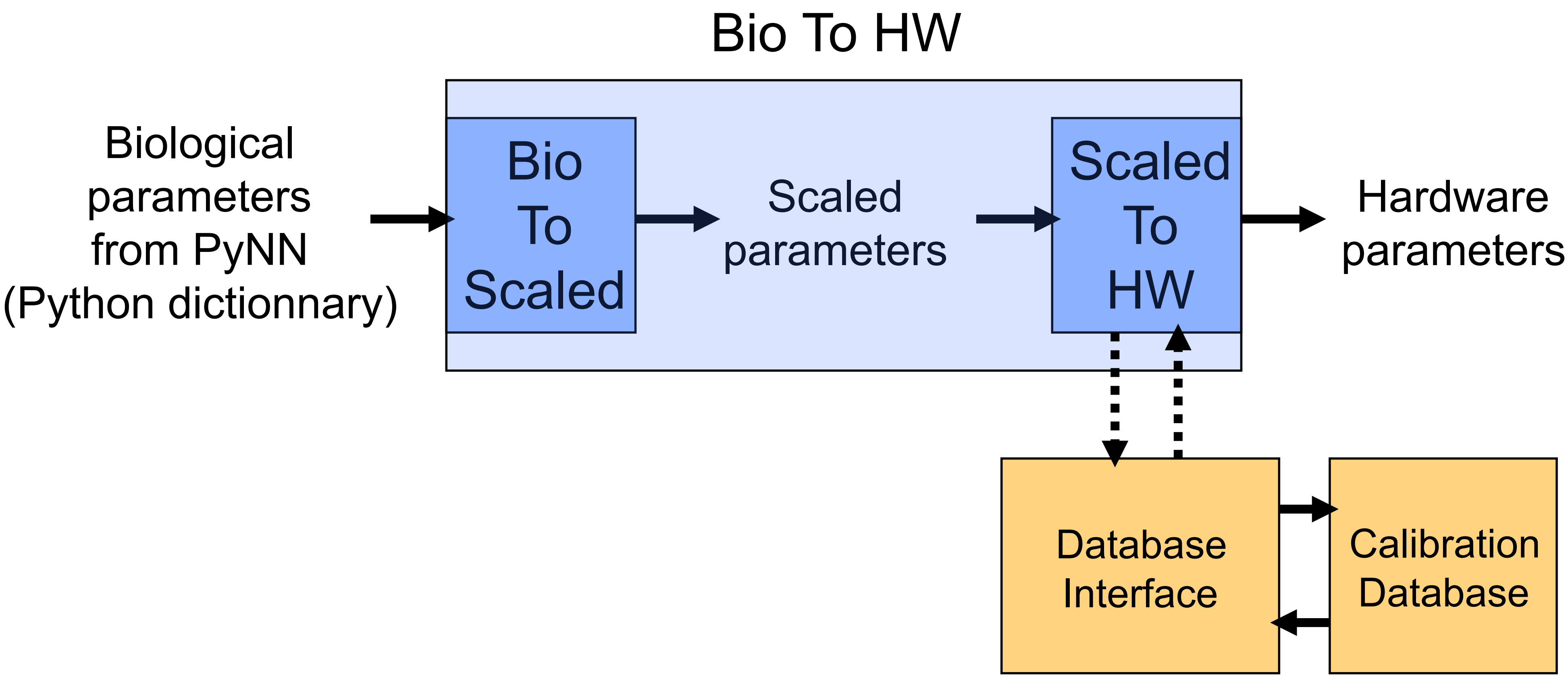
Contents

Using the calibration framework

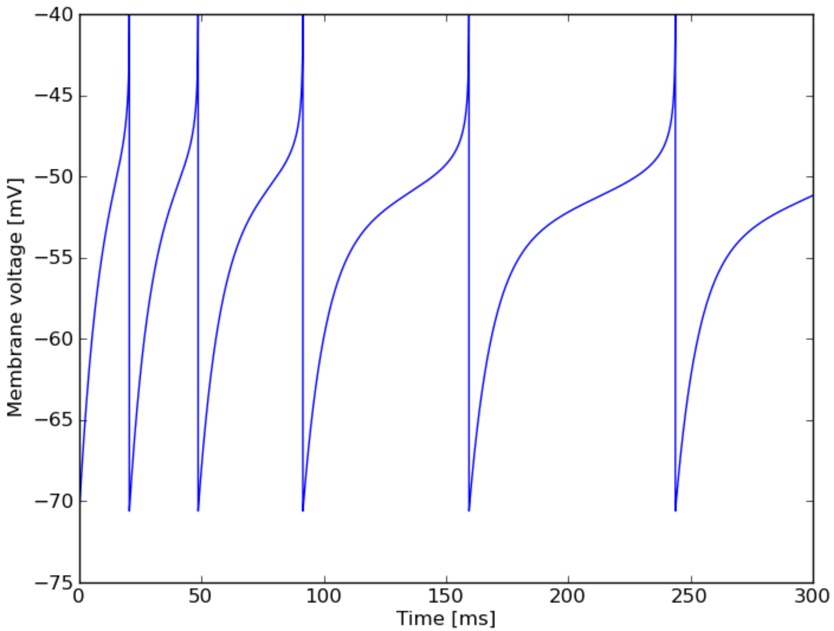
PyNN to hardware conversion

- Python code to automatically convert PyNN parameters to hardware parameters

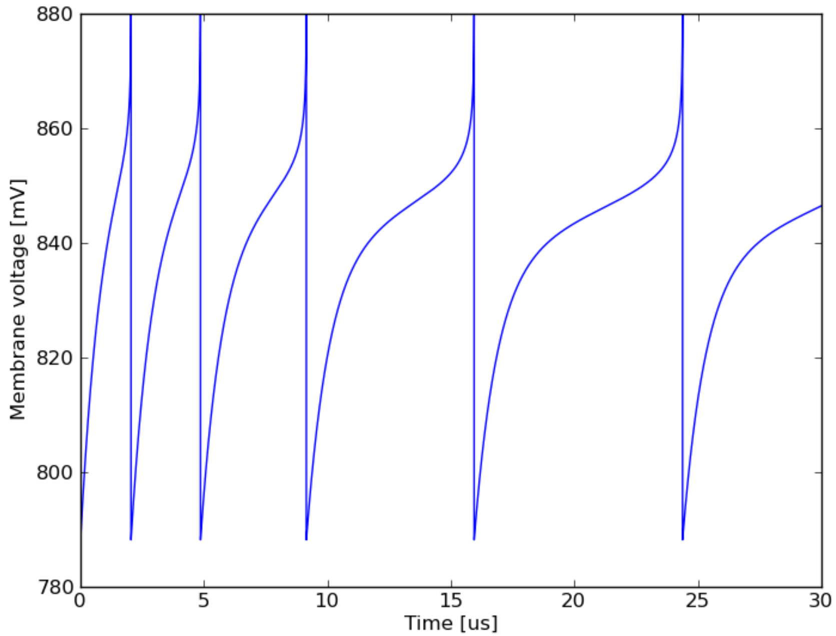


Example : NEST AdEx default parameters

- Automatic translation of biological parameters to scaled parameters



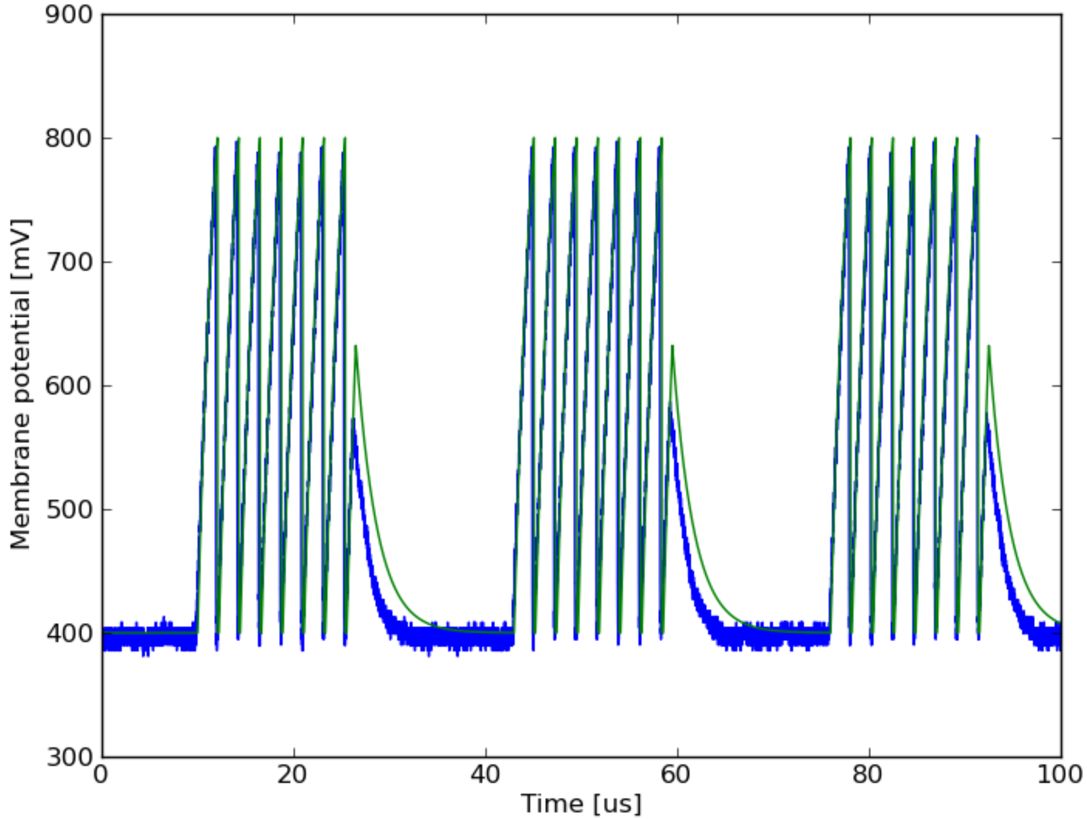
Biological neuron



Scaled neuron

Example : I&F neuron + current input

- Automatically generated from PyNN Python dictionnary
- Test with I&F neuron + current stimulus (using calibration)



Multi-neuron calibration

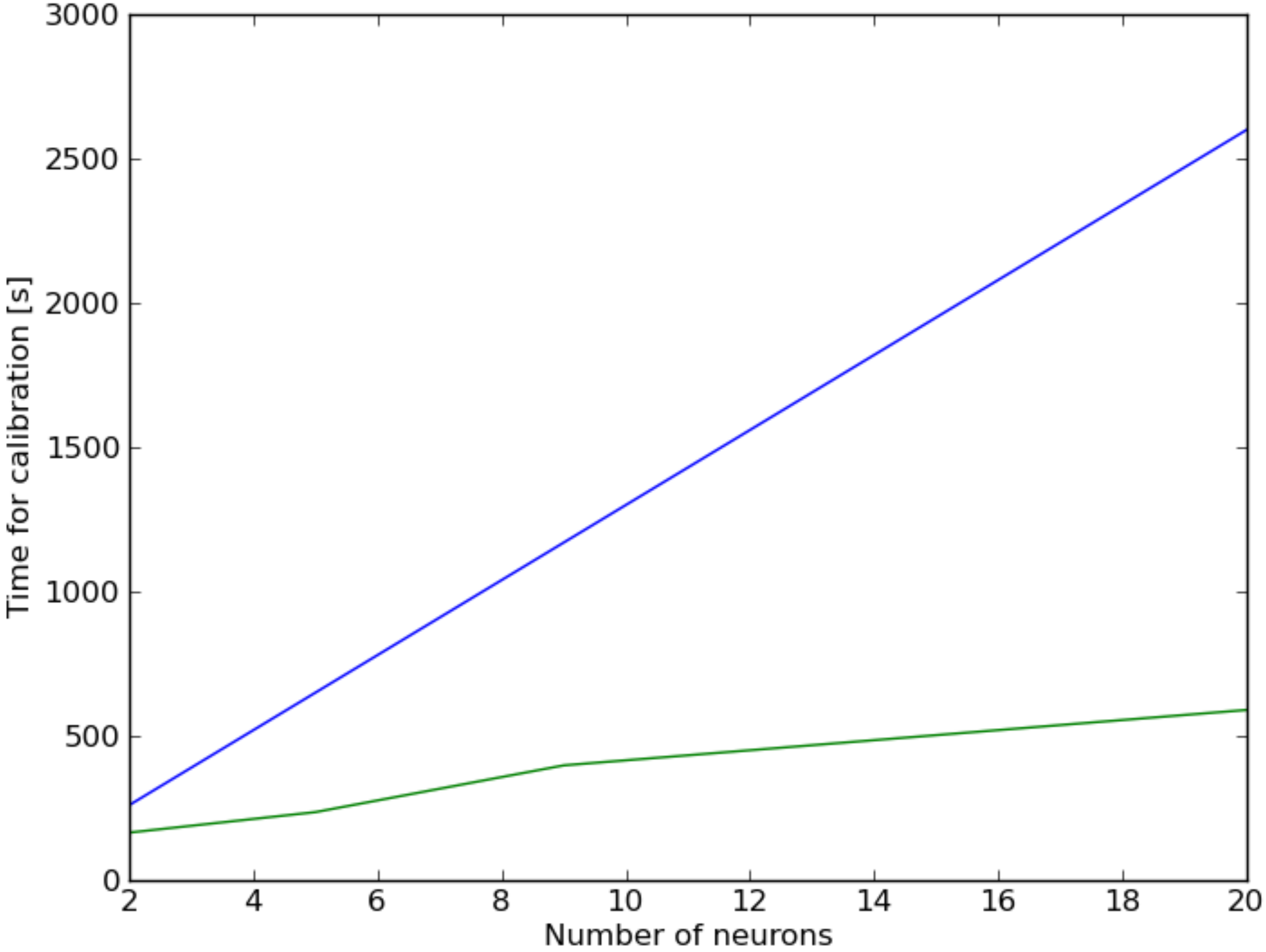
Multi-neuron calibration

- For now : calibration on one neuron only
  - Erase & write the floating gate array
  - Measurements
  - Erase & write again
  - Then repeat with an other neuron

- Need new methods to calibrate many neurons as fast as possible

- Implementation of multi-neuron calibration method
  - Erase & write the floating gate array once
  - Switch neuron number (fast) and measure
  - Erase & write again

Multi-neuron calibration : speed gain

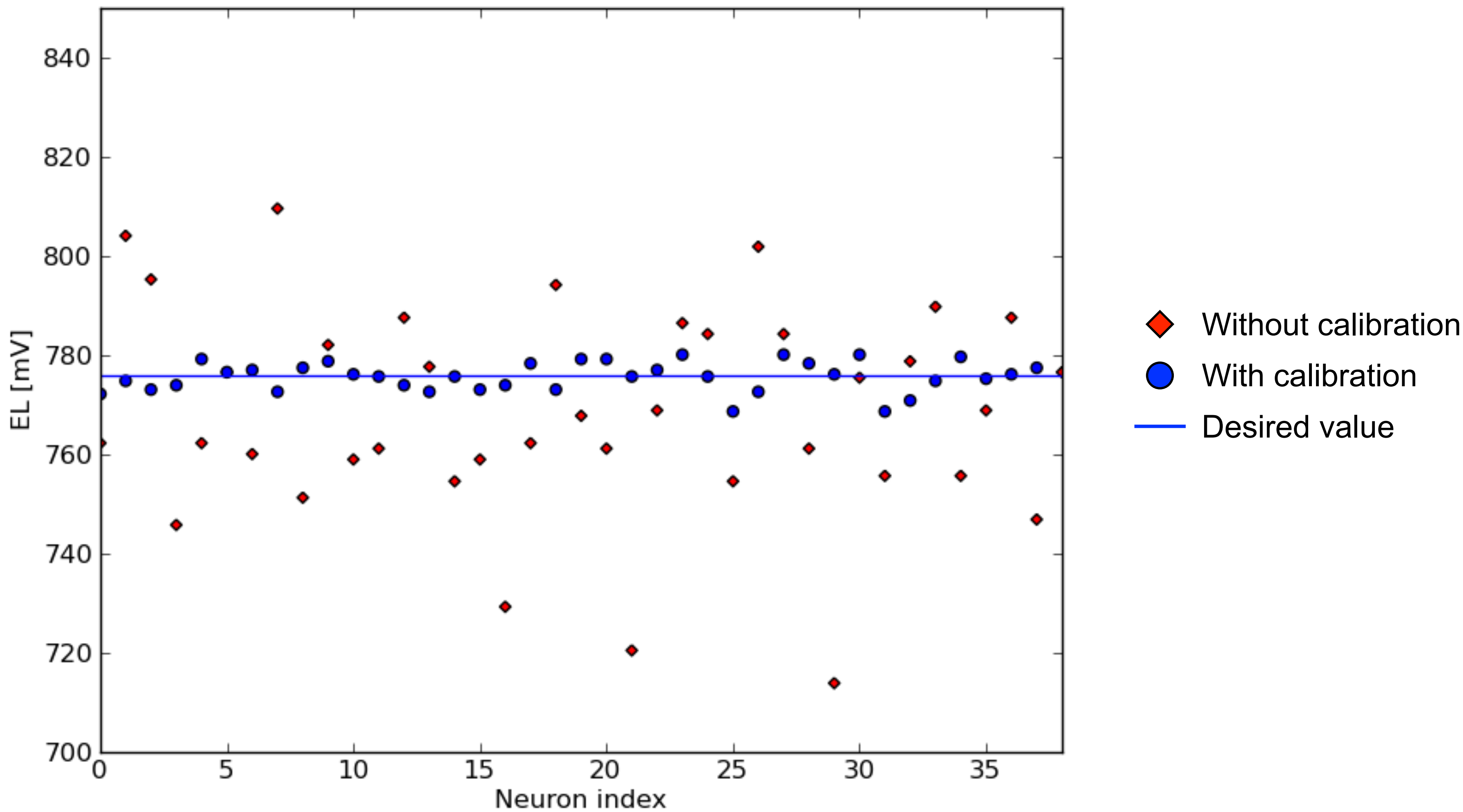


I&F neuron statistics

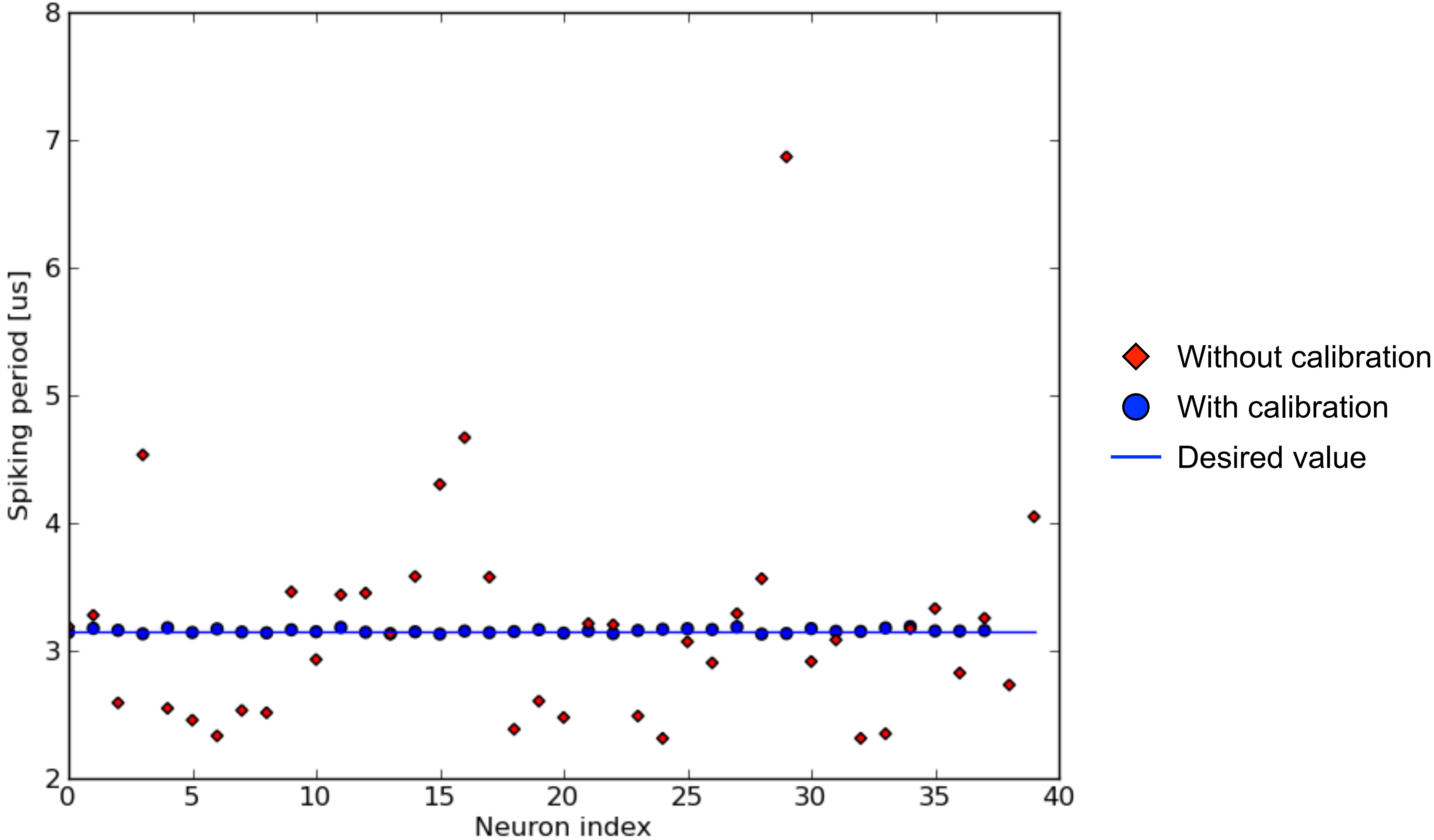
- Experiments of calibration of I&F neurons
  - 40 neurons calibrated
  - Configure the same I&F neuron on all HW neurons
  - Measure resting potential and firing period
  - Compare with non-calibrated neuron (same hardware parameters on all neurons)

- Evaluate the calibration algorithms on :
  - Several neurons
  - Several parameters

Resting potential statistics



Firing period statistics

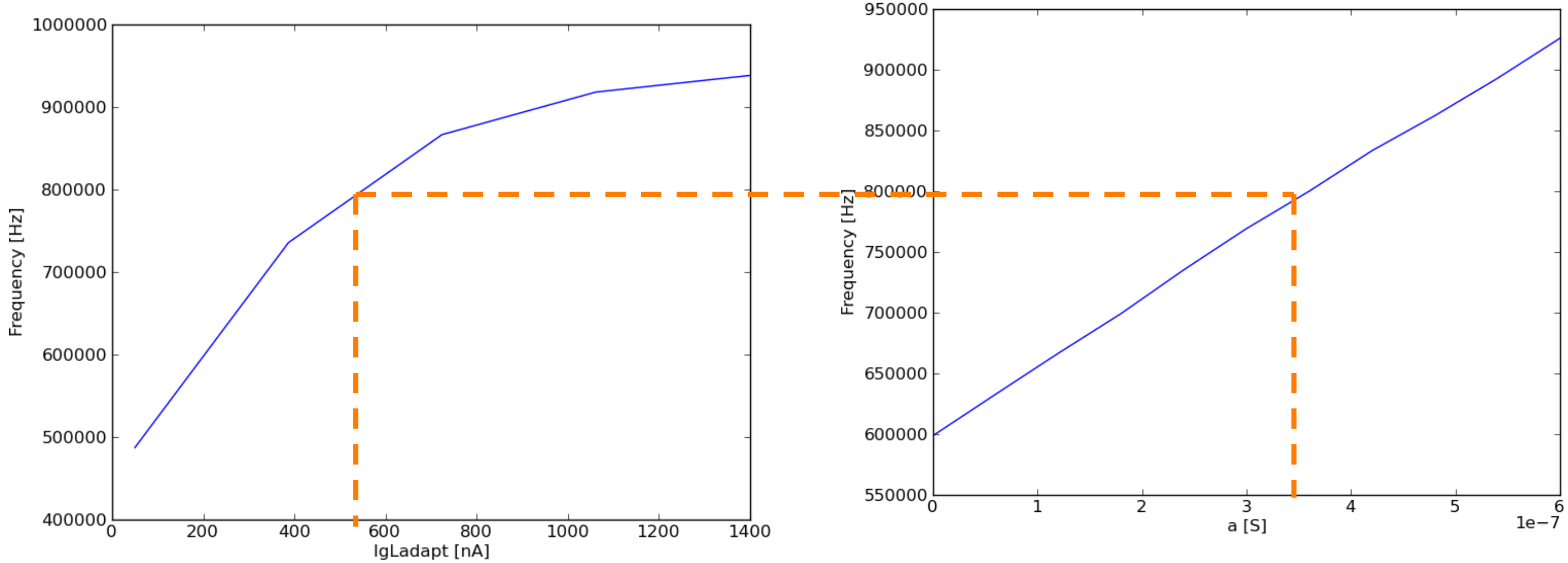


Adaptation terms calibration

a calibration - Methods

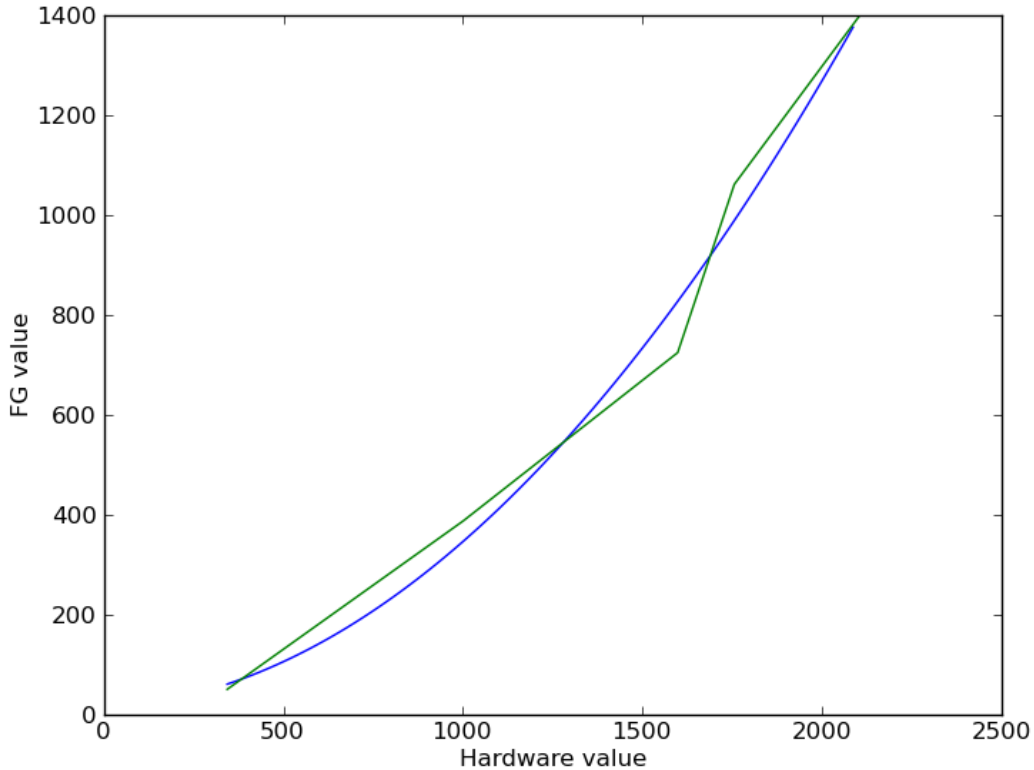
$$C\frac{dV}{dt} = -g_L(V - E_L) + g_L\Delta_T exp(\frac{V - V_T}{\Delta_T}) - w + I \qquad \tau_w\frac{dw}{dt} = a(V - E_L) - w$$

- Similar to time constant calibration :
  - Set basic I&F parameters : EL, Vreset, Vt, gL
  - No spike-triggered adaptation (b = 0)
  - Set IgLadapt (which controls a), measure frequency
  - Compare to model to find the corresponding *a*



a calibration - Results

- Typical calibration result : (normal mode)



- Results are similar to the calibration of gL (same Operational Transconductance Amplifier)

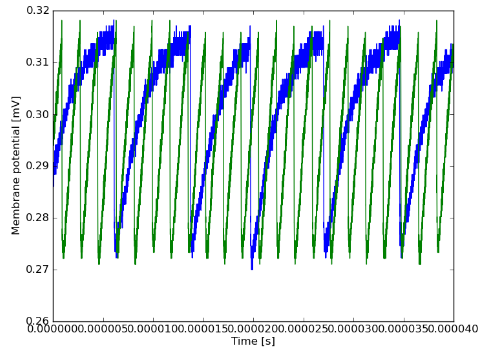
Tau_w calibration

$$C\frac{dV}{dt} = -g_L(V - E_L) + g_L\Delta_T exp(\frac{V - V_T}{\Delta_T}) - w + I \qquad \tau_w\frac{dw}{dt} = a(V - E_L) - w$$

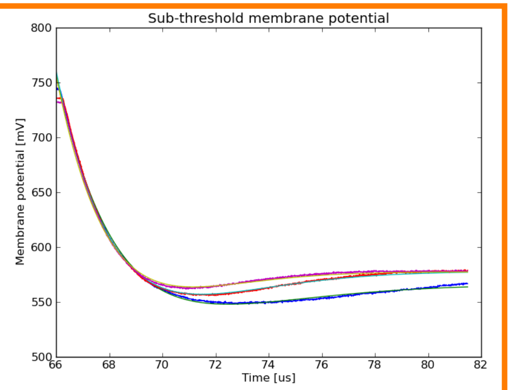
- In simulations, *tau_w* is easy to measure from the adaptation variable *w*
- But in the hardware, only the membrane potential *V* can be measured directly
- Need to find indirect method to measure and then calibrate *tau_w*
- Calibration will be done with an Adaptive I&F neuron (AdEx without exponential term)

Tau_w calibration - Methods

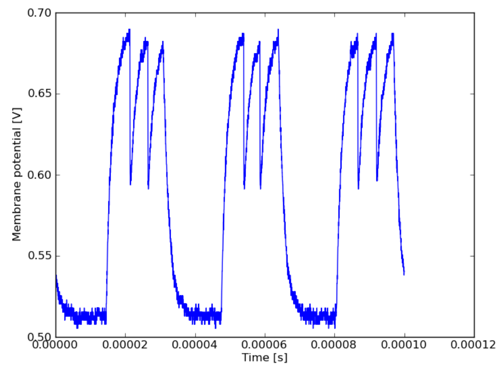
- Frequency-based measurement
  - Set AIF neuron parameters, and measure frequency
  - Advantage : simple, like the measurement of gL and a
  - Disadvantage : frequency depends on tau_w and b (spike-frequency adaptation) !



- Membrane-based measurement
  - Set AIF neuron parameters, apply current stimulus, and compare waveform to model
  - Advantage : precise method
  - Disadvantage : uses the scope (slow)

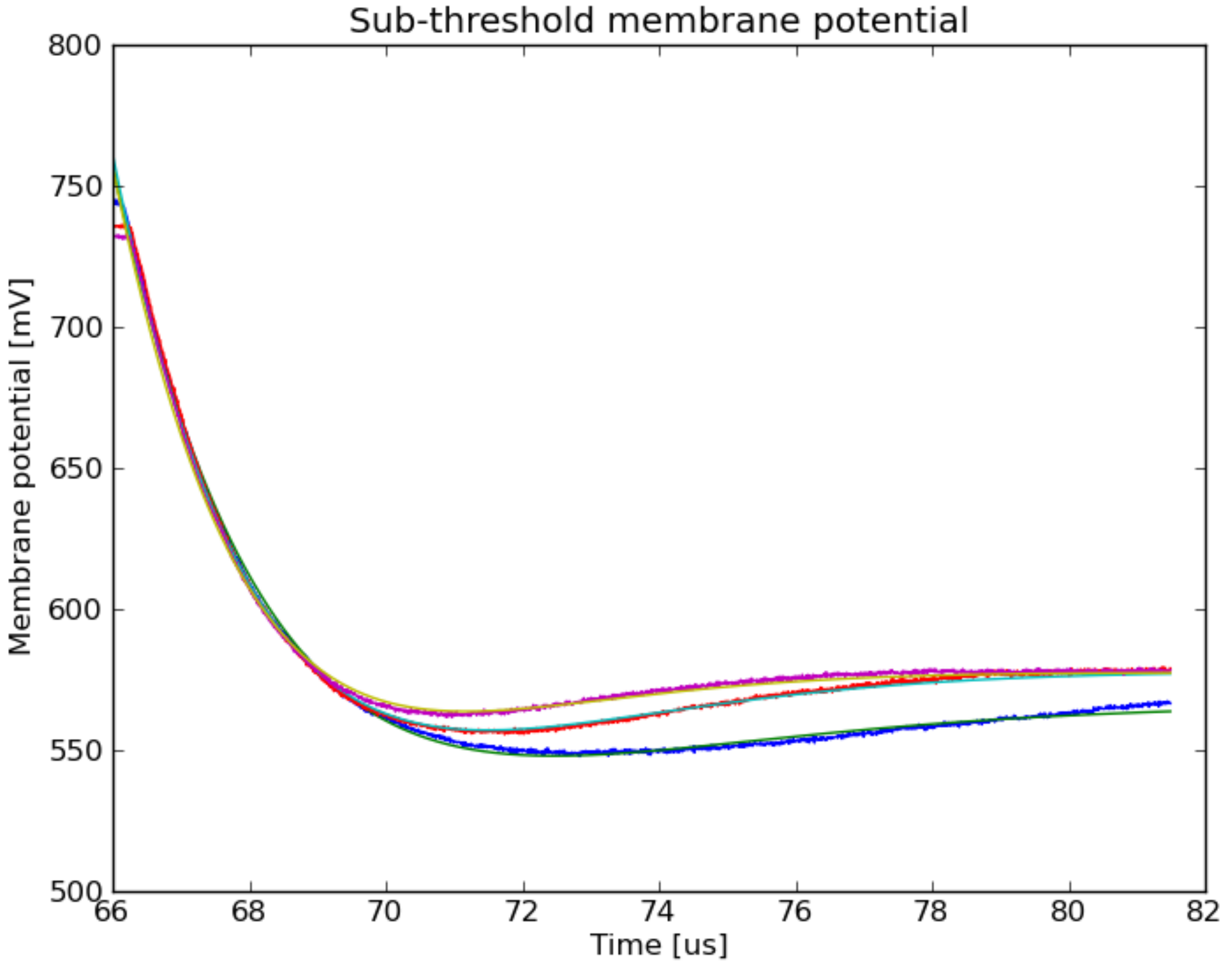


- Spike-based measurement
  - Set AIF neuron parameters, apply current stimulus, and compare spikes time to model
  - Advantage : precise in theory, fast
  - Disadvantage : lot of variability from run to run

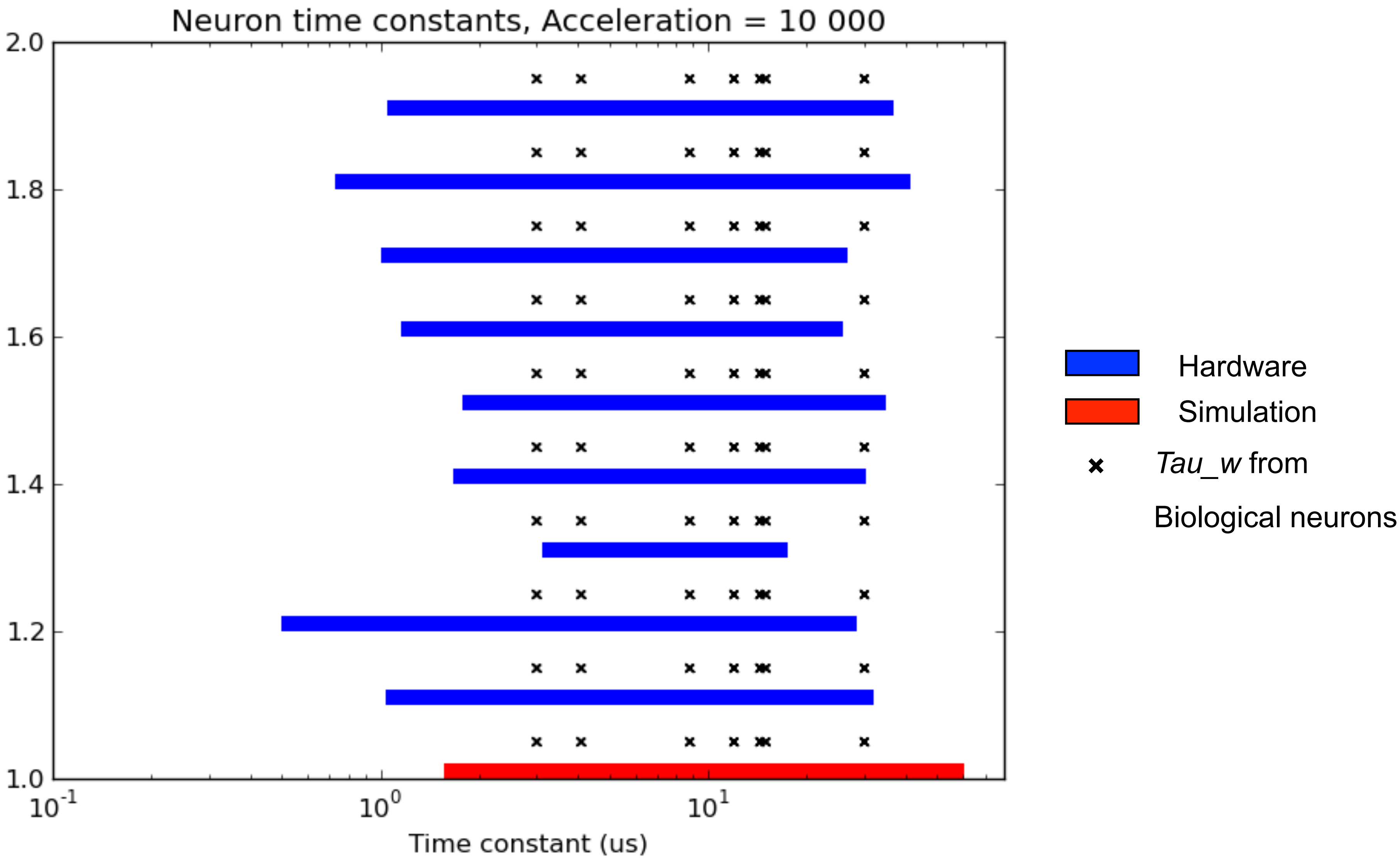


Tau_w calibration - Methods

- Fitting software using LSM to find tau_w from a waveform



Tau_w calibration - Ranges



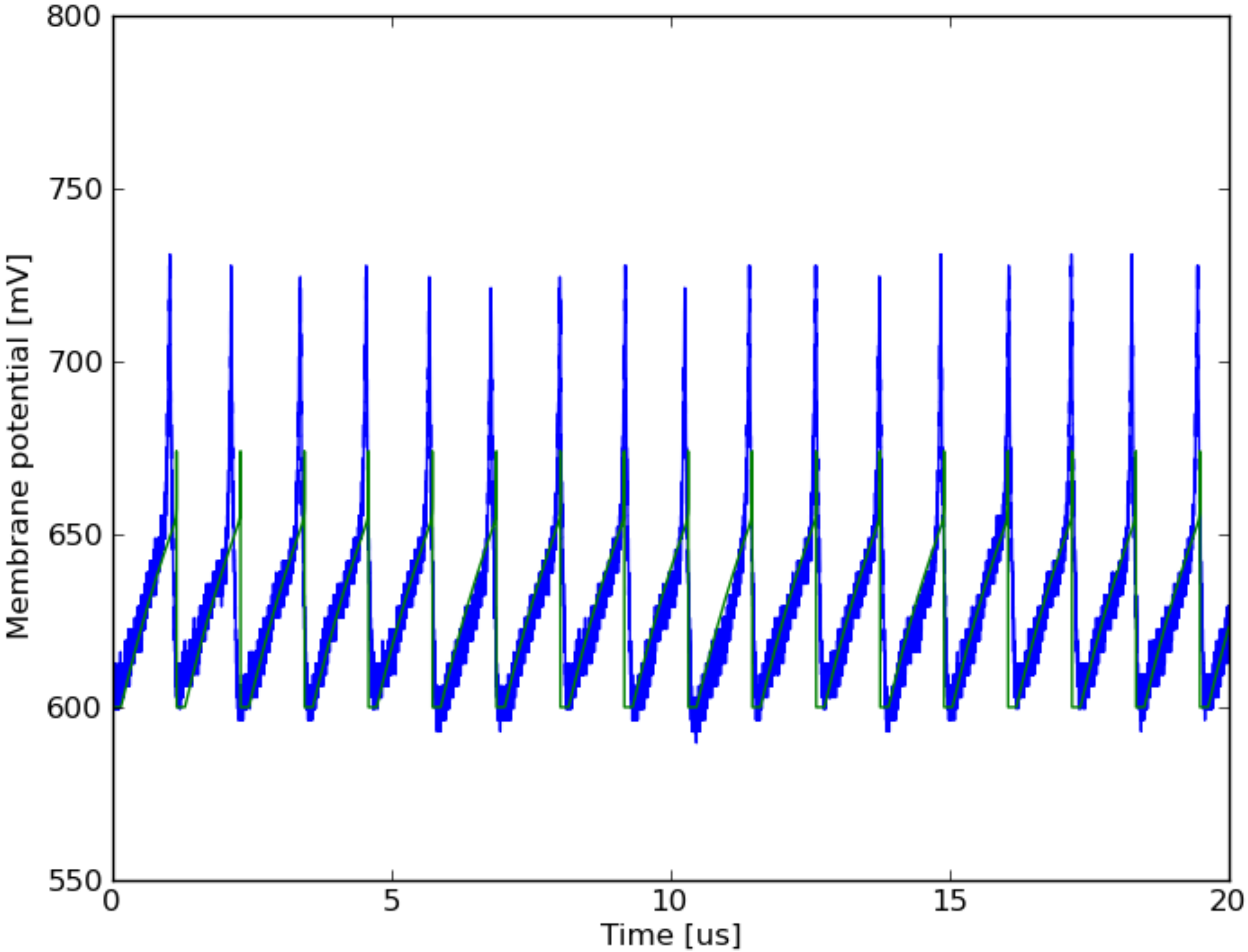
Exponential term calibration

Vth calibration (in progress …)

$$C\frac{dV}{dt} = -g_L(V - E_L) + g_L\Delta_T exp(\frac{V - V_T}{\Delta_T}) - w + I \qquad \tau_w\frac{dw}{dt} = a(V - E_L) - w$$

- Two parameters to control exponential term in HW :
  - Vexp controls Vth (Exponential threshold)
  - Irexp controls both Vth and dT (Sharpness of spike initiation)
- First calibration by fixing Irexp to a low value (which means sharp spike initiation)
- Also fix a low value of dT in the biological model
- Set Vexp, measure firing frequency and compare to model to find the right Vth

Vth calibration (in progress …)



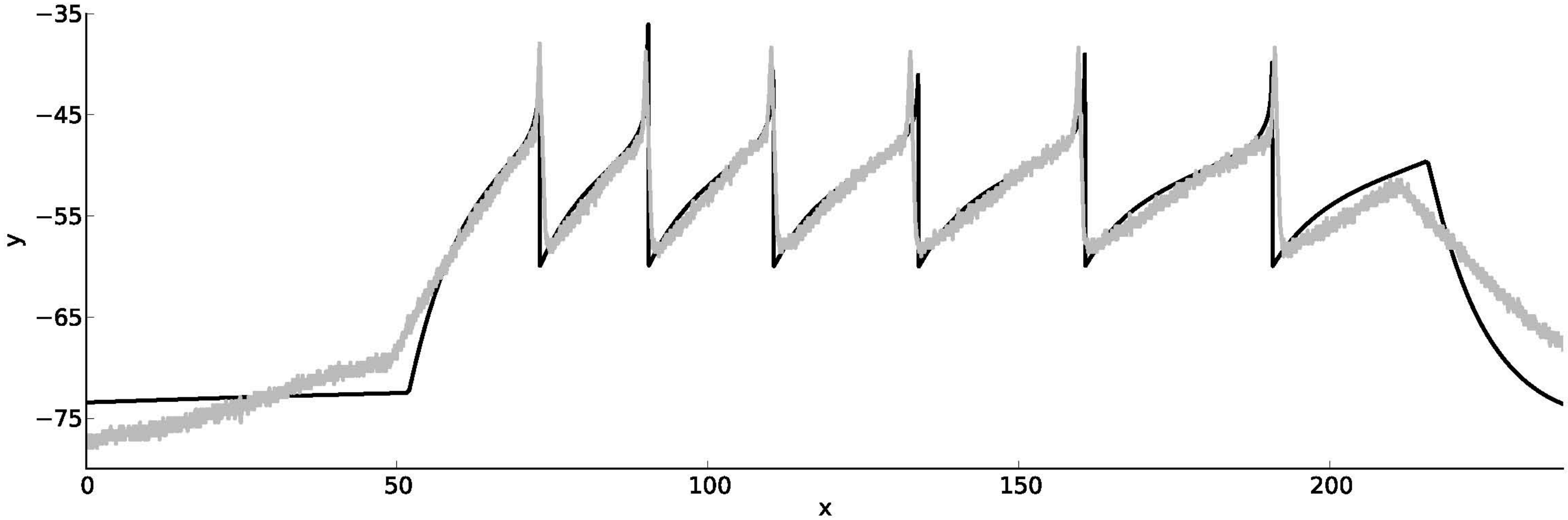
Parameter fitting follow-up

Parameter fitting

- In his last talk, Thomas Pfeil presented a parameter fitting method based on the particle swarm algorithm, to fit the response of a reference neuron to the hardware system
- This method was based on spikes coincidence only
- We extented the method to fit both spike times and membrane potential

Parameter fitting - Results

- Membrane potential of the best particle :



Conclusion & Outlook

- Conclusion :
  - PyNN to hardware translation possible to configure one neuron
  - Software to calibrate many neurons
  - Adaptation terms calibration
  - First exponential term calibration
  - Parameter fitting using spike times + membrane potential

- In the following months …
  - Secondment in Dresden
  - Calibration of spike-frequency adaptation
  - Reproduce firing patterns with adaptation terms calibration data
  - Finish exponential term calibration
  - Calibration of synaptic input parameters