Modeling Extracellular Potentials of Pyramidal Neurons and Interneurons

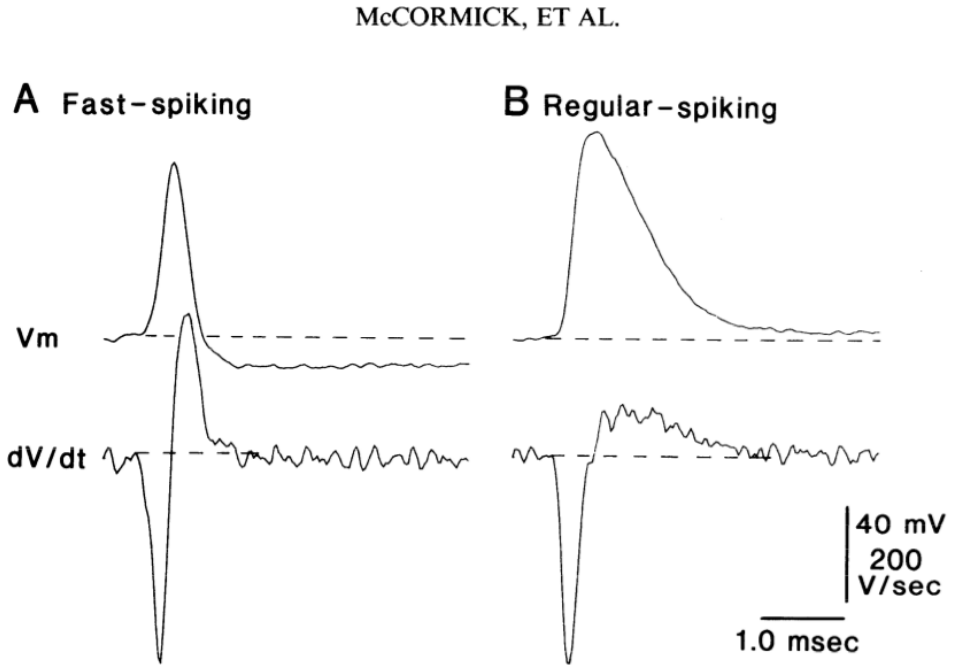
Daniel M. Bjørnstad

Master Thesis Summary

June 10, 2016

Classifying Neurons Based On EAP

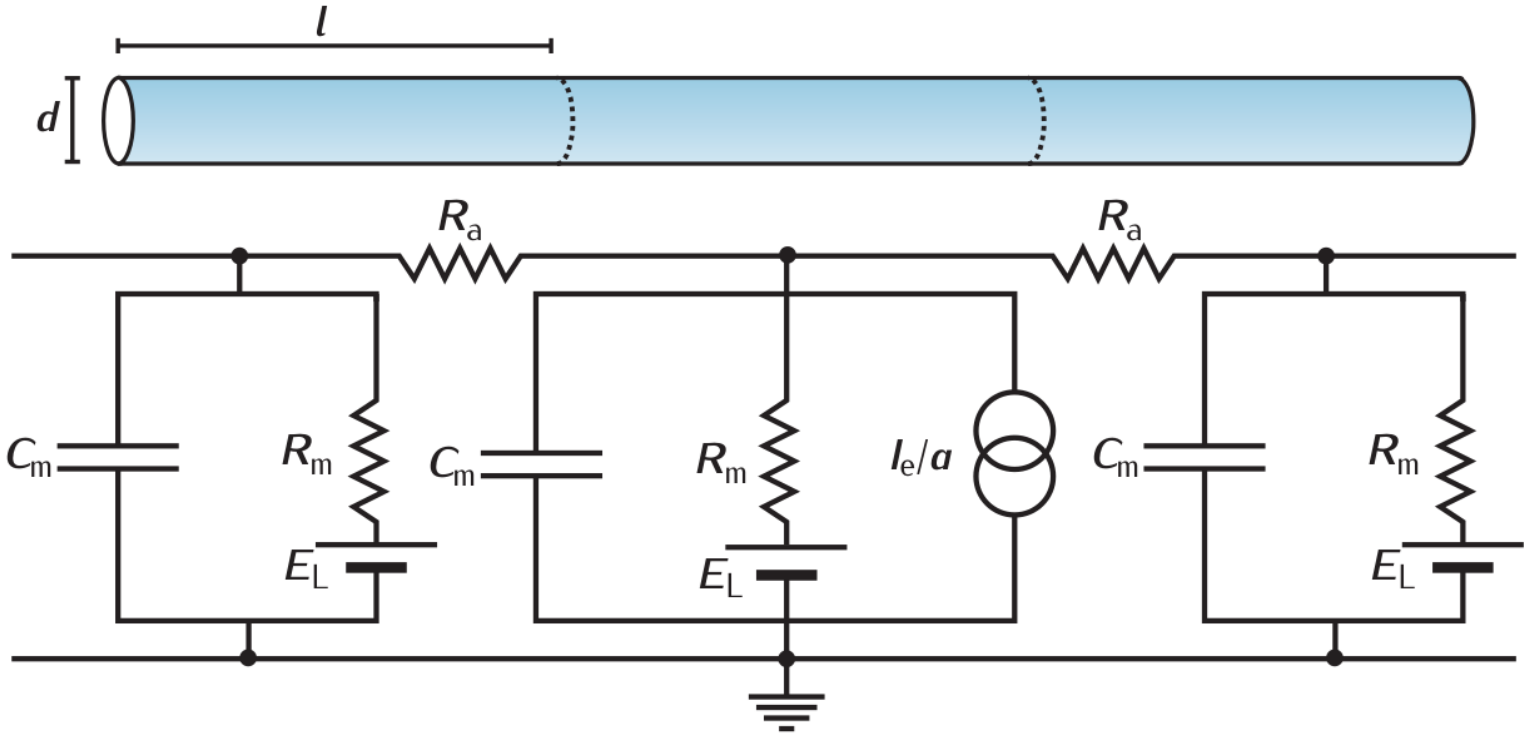
- Extracellular action potentials (EAP) are unique for each neuron.
- Was early recoqnized that some interneurons had faster spikes than pyramidal neurons.



Motivation

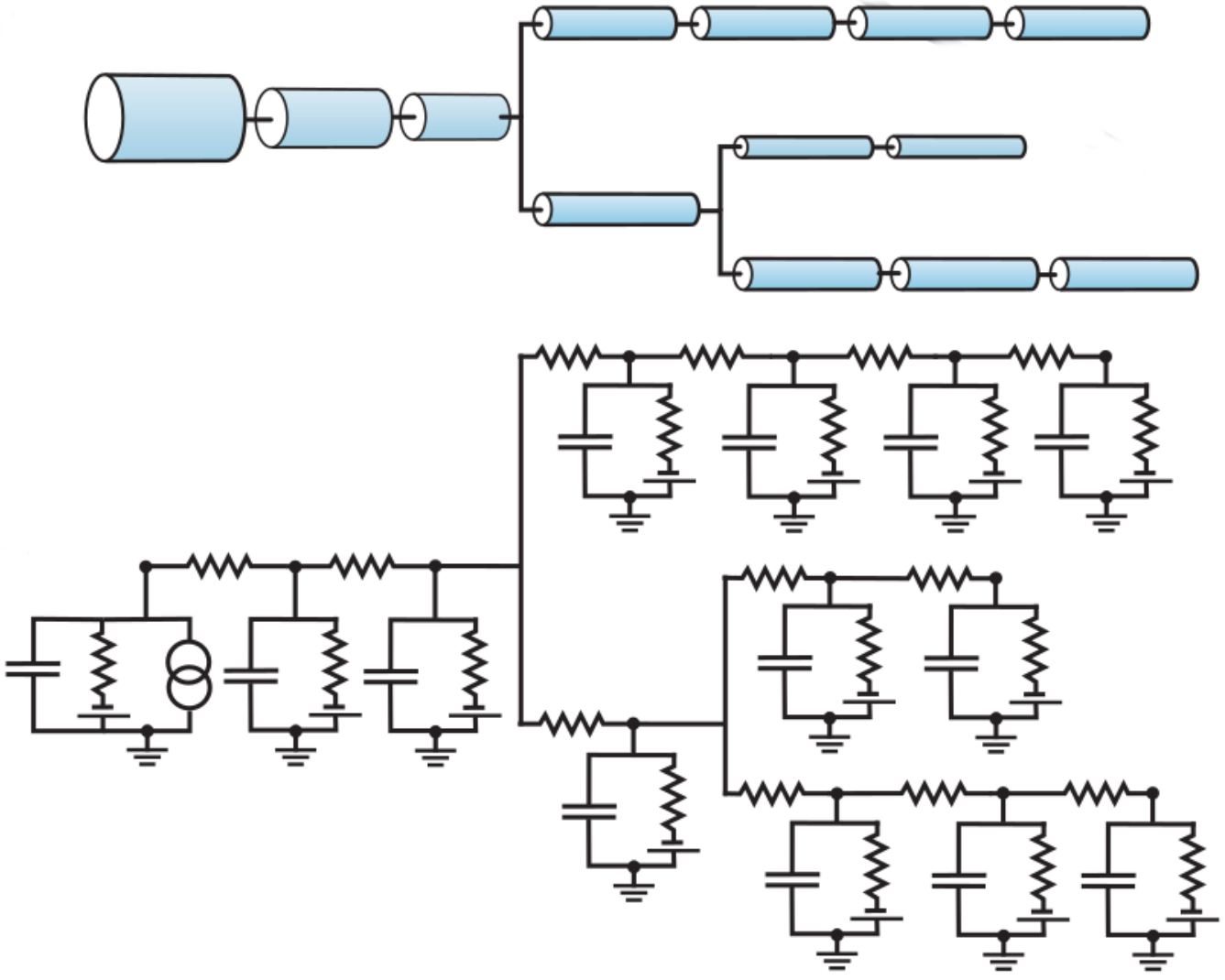
- More and more models allow simulations of EAP.
- One of the first times EAP simulations of different neurons have been compared.
- Many definitions of spike width and amplitude, some might be better suited for classification than others.

Methods: Model of the Cell Membrane



Compartmental Models

Simulations can be done with NEURON.



Calculation of Extracellular Potential

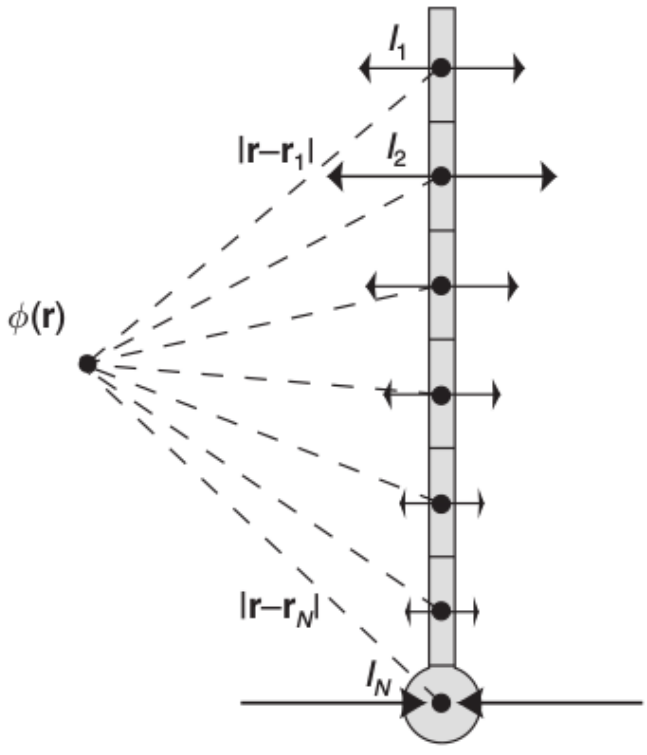
- The potential generated by transmembrane currents.

$$\Phi(r,t) = \frac{1}{4\pi\sigma}\sum_{i=1}^{n}\frac{I_i(t)}{r_i}$$

- This is implemented in the python package LFPy.
- Results have been created using NEURON, LFPy and LFPyUtil.

Conservation of Current

Kirchhoff's current law: All transmembrane currents must sum to 0.

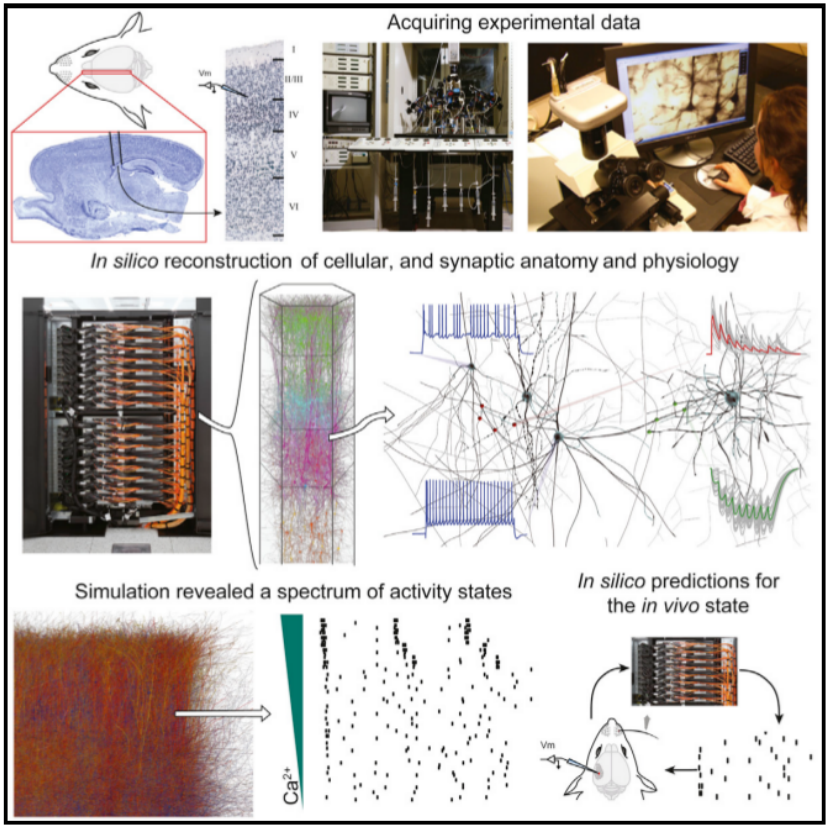


Resource

Cell

Reconstruction and Simulation of Neocortical Microcircuitry

Graphical Abstract



Authors

Henry Markram, Eilif Muller, Srikanth Ramaswamy, Michael W. Reimann, ..., Javier DeFelipe, Sean L. Hill, Idan Segev, Felix Schürmann

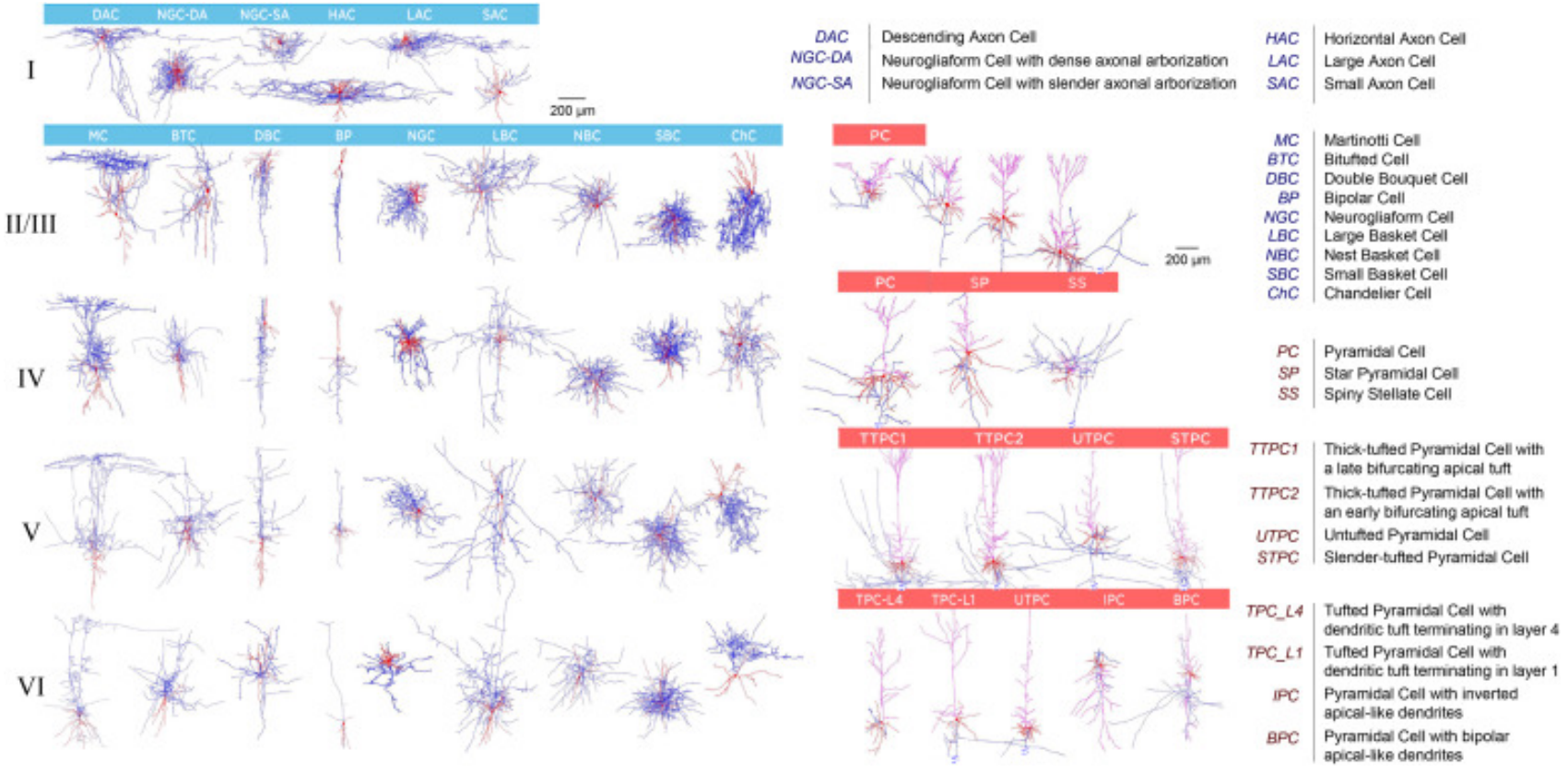
Correspondence

henry.markram@epfl.ch

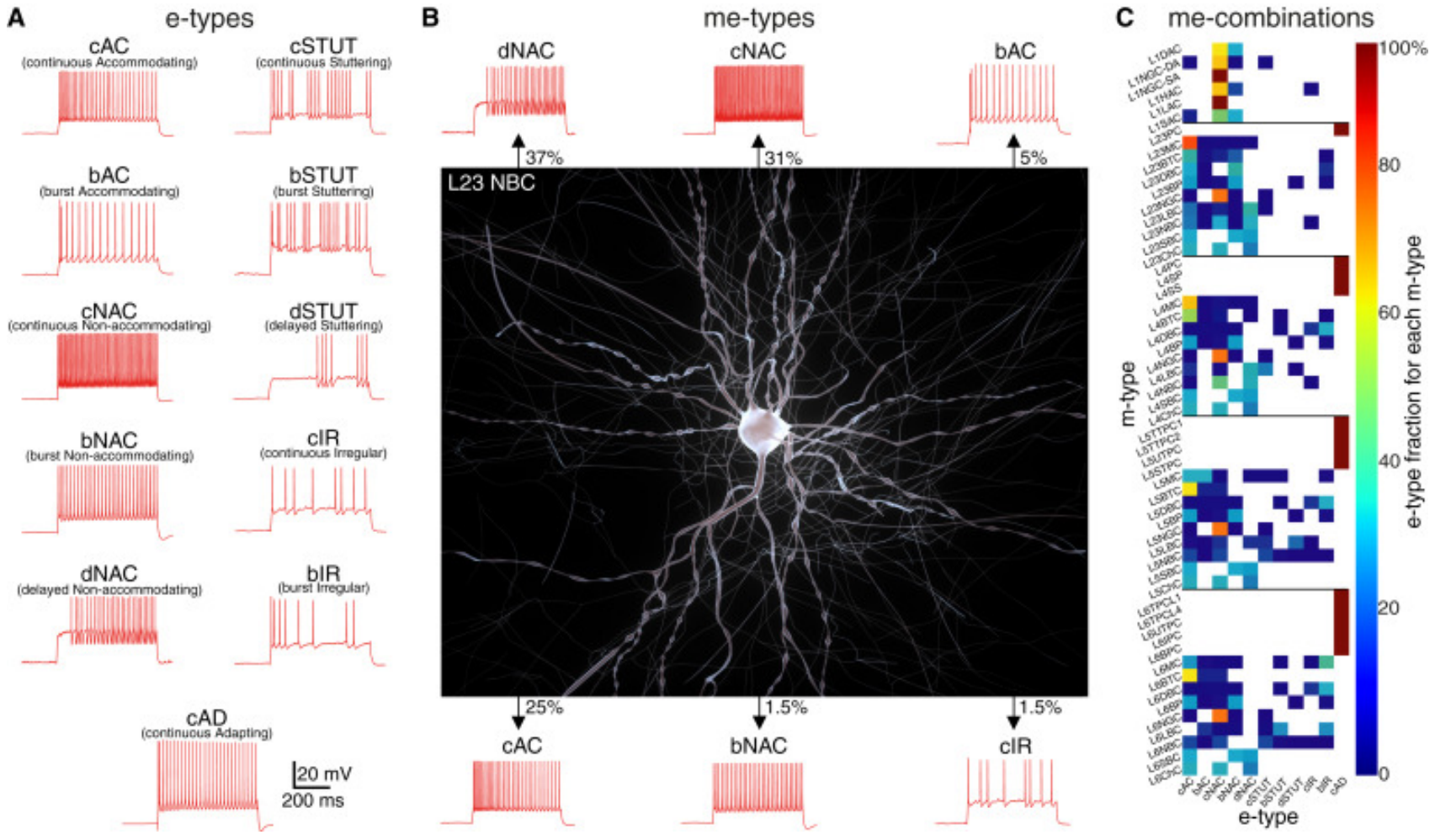
In Brief

A digital reconstruction and simulation of the anatomy and physiology of neocortical microcircuitry reproduces an array of in vitro and in vivo experiments without parameter tuning and suggests that cellular and synaptic mechanisms can dynamically reconfigure the state of the network to support diverse information processing strategies.

Blue Brain Neuron Models



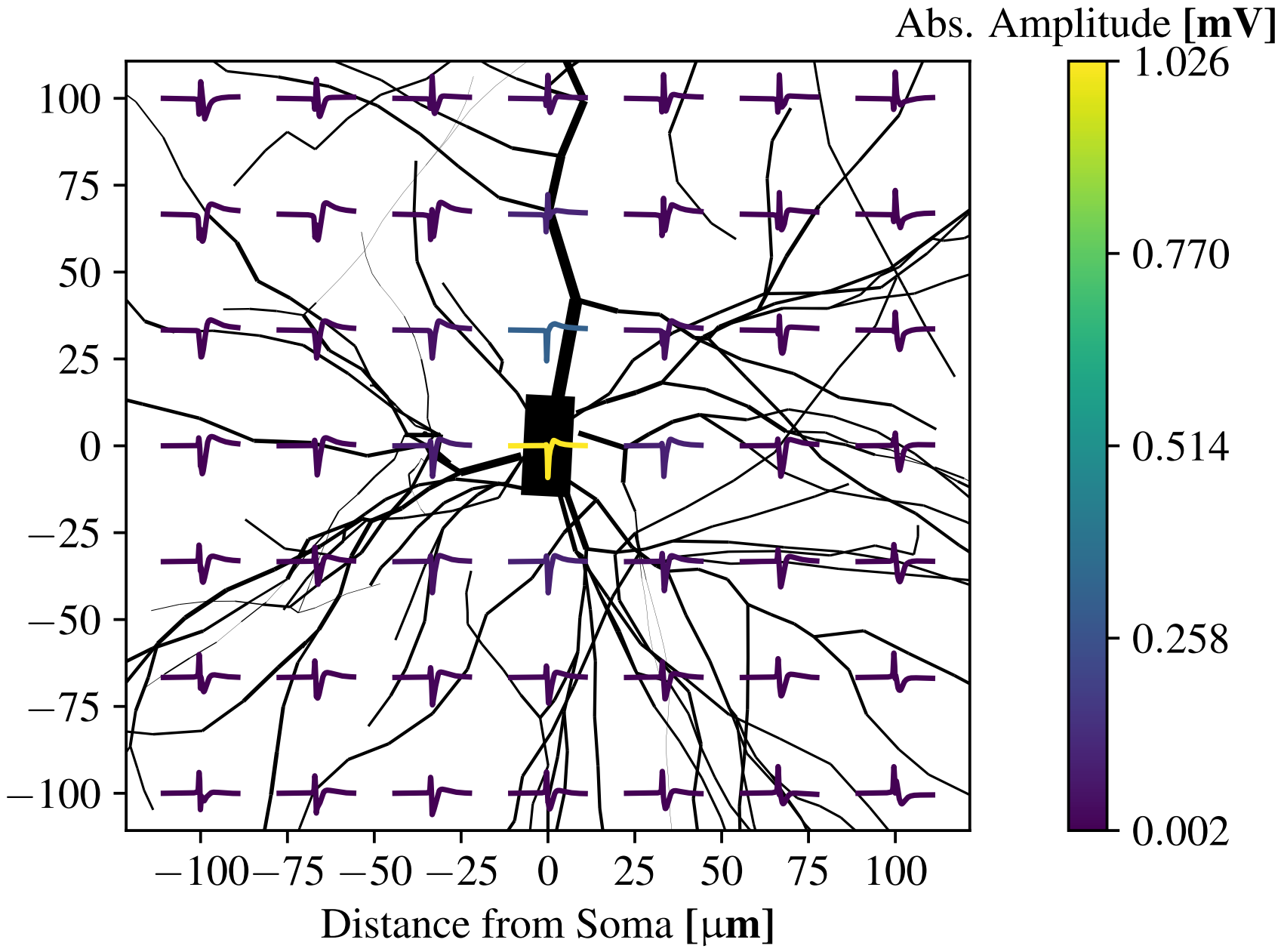
Blue Brain Neuron Models



Selected Blue Brain Models

- TTPC1, TTPS2, STPC, UTPC - Pyramidal neurons with different morphology, but same e-type.
- LBC - cAC, cNAC, dSTUT, bAC - Similar morphology, different e-type.
- NBC - cNAC, dSTUT, bAC, bIR - Similar morphology, different e-type.

Results: Running a Simulation

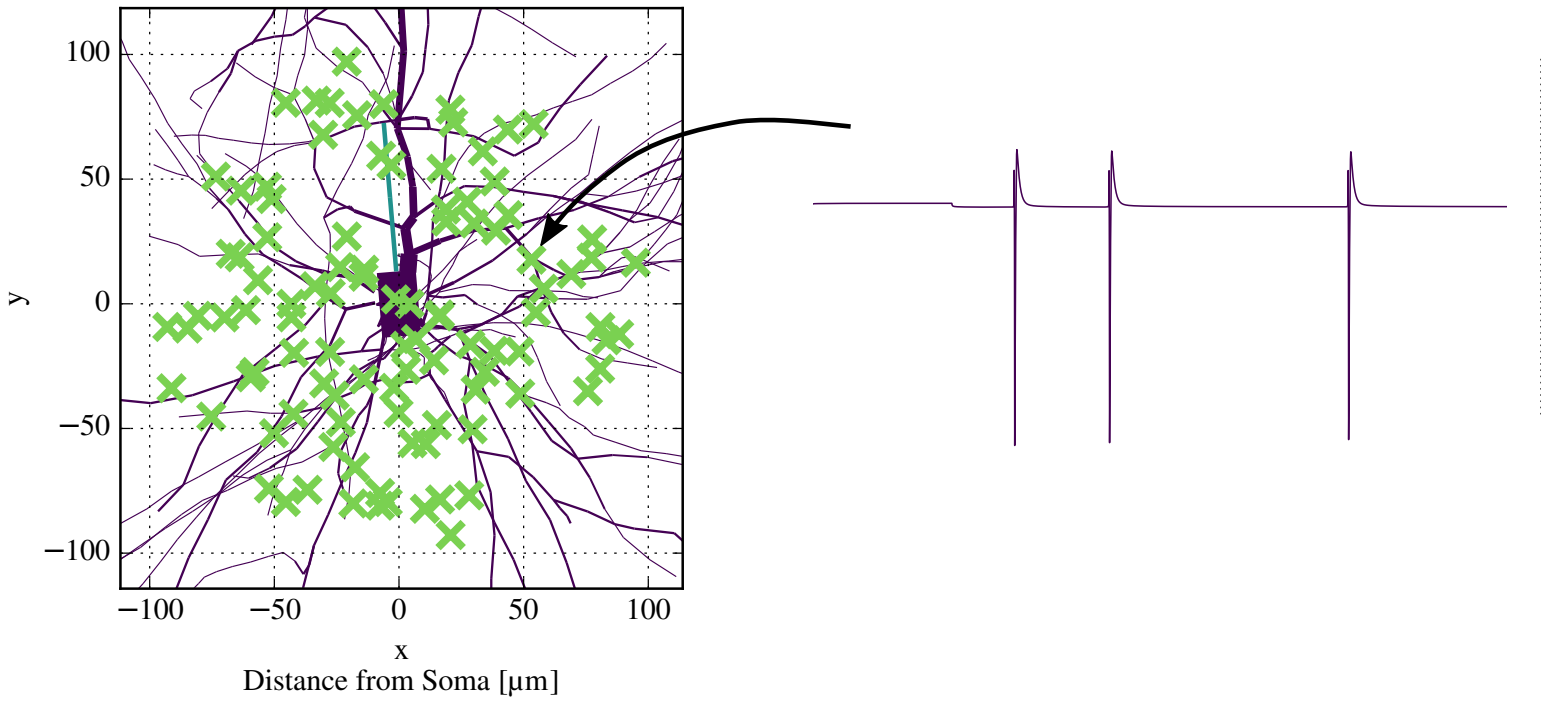


Sources Spike Variability

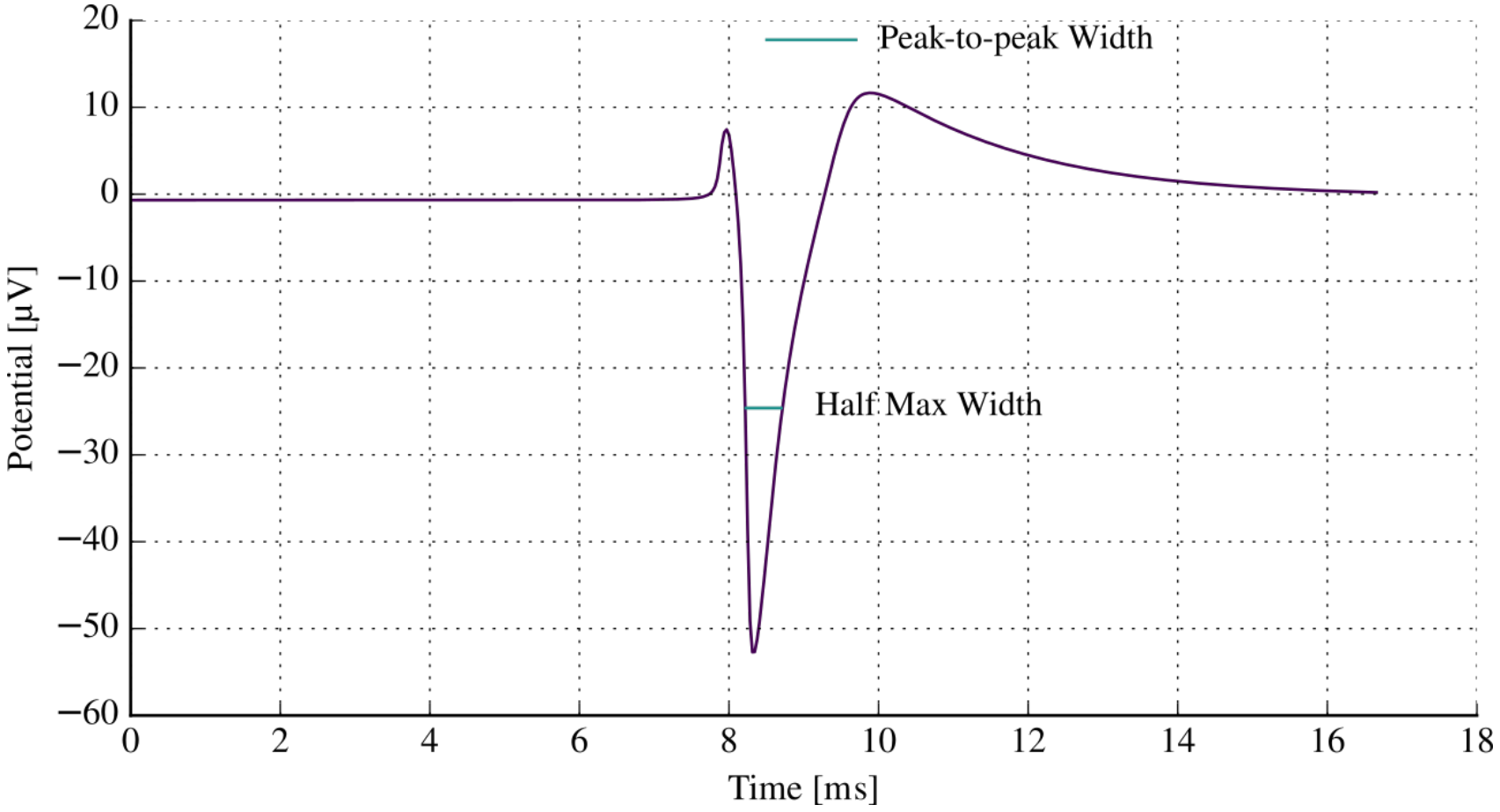
- Location of electrode.
- Inter spike interval.
- Bursting behavior.
- Backproagating action potentials.
- Synaptic input, position and shape.
- Filtering.

Imitating Placement of Electrodes

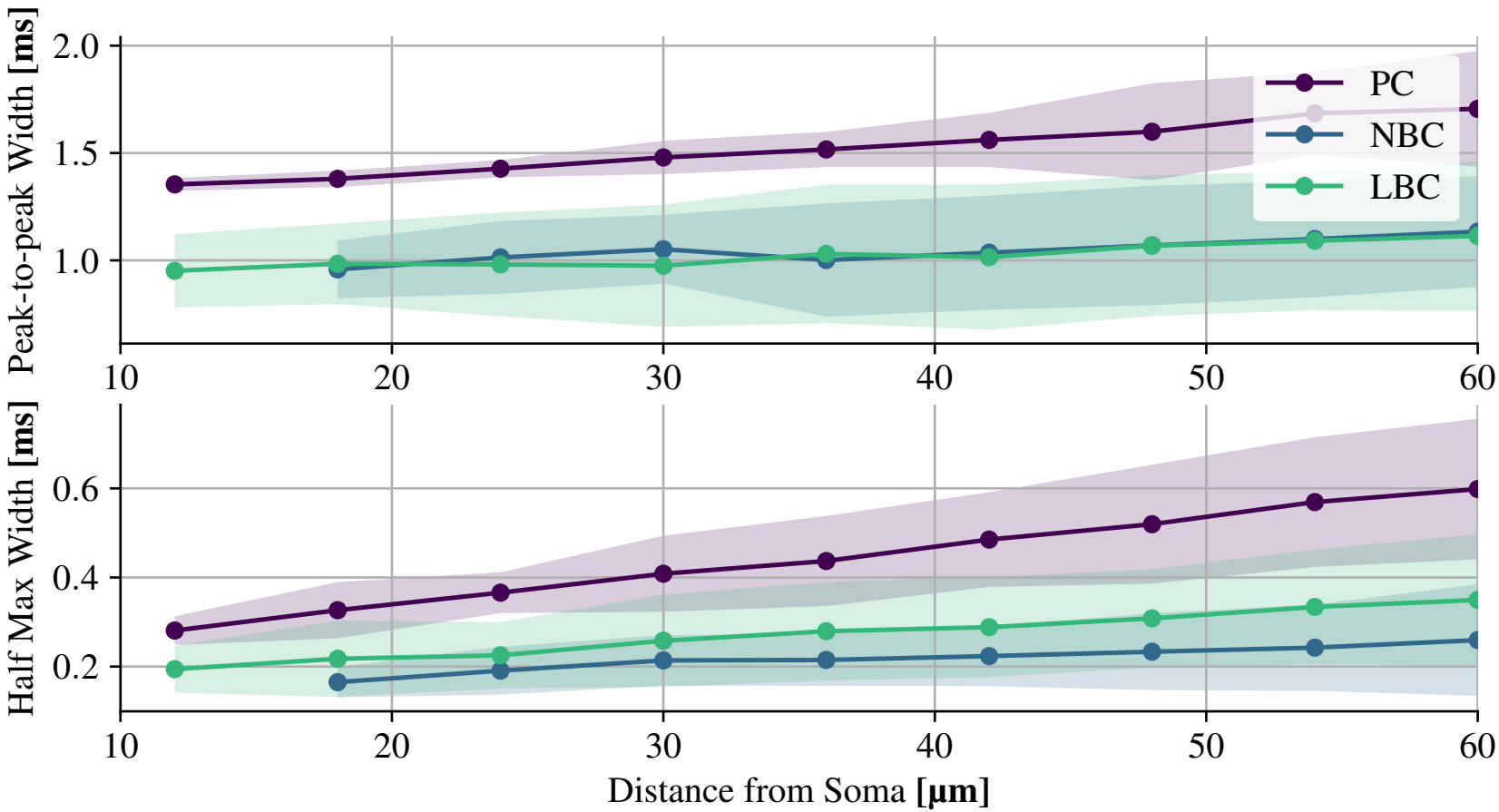
500 electrodes positioned at random locations within 60 µm for each selected model.



Spike Width Definition

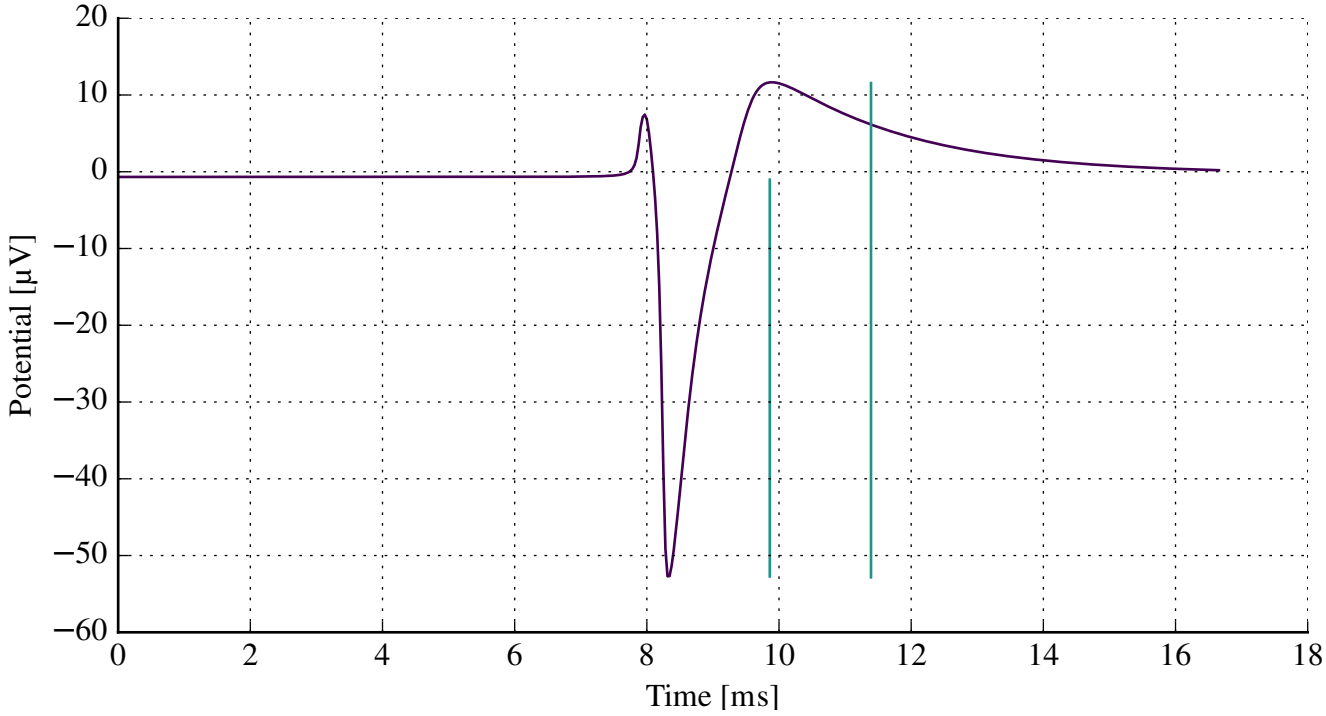


Effect of Spike Width Definition

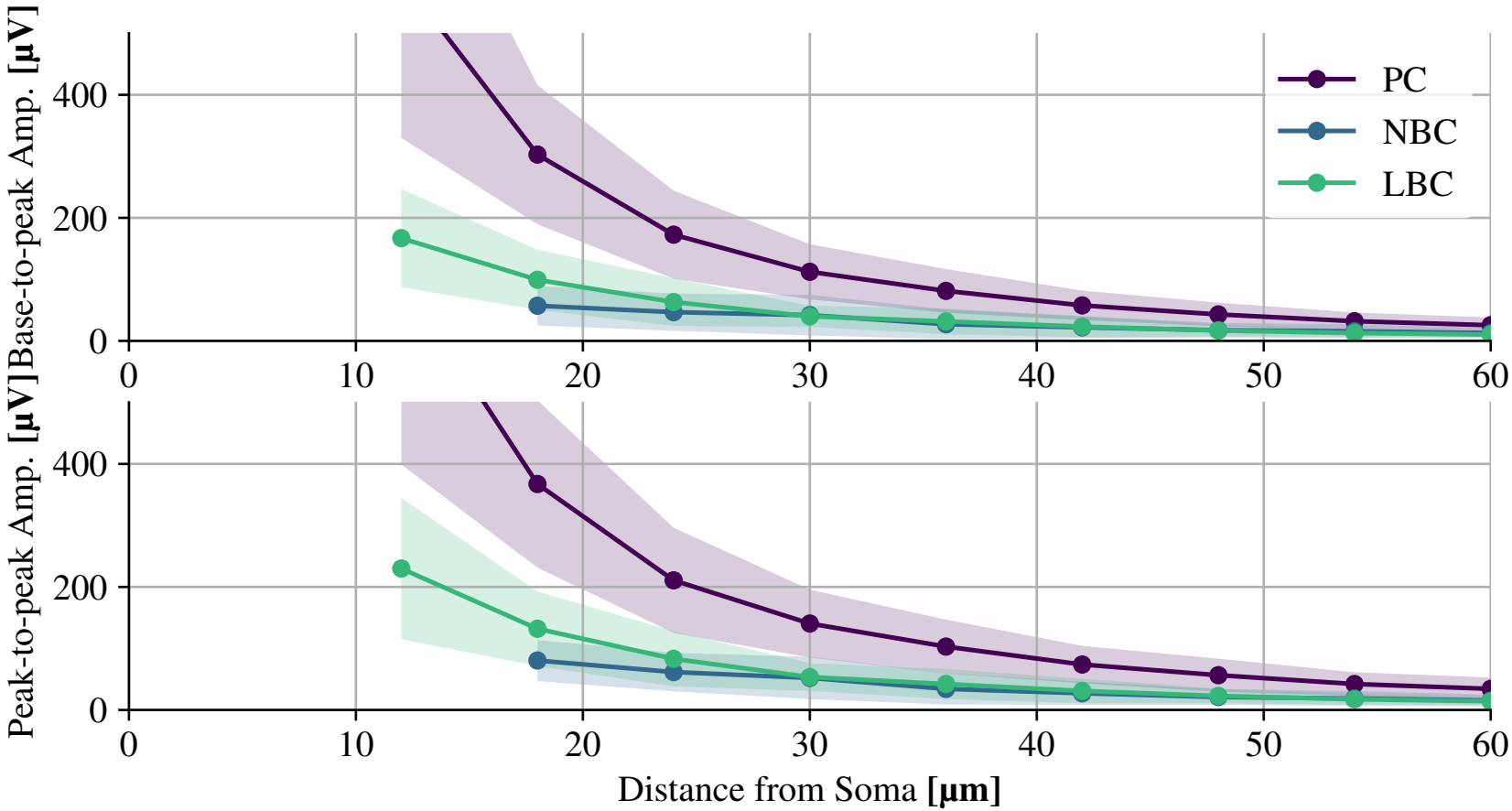


Spike Amplitude Definition

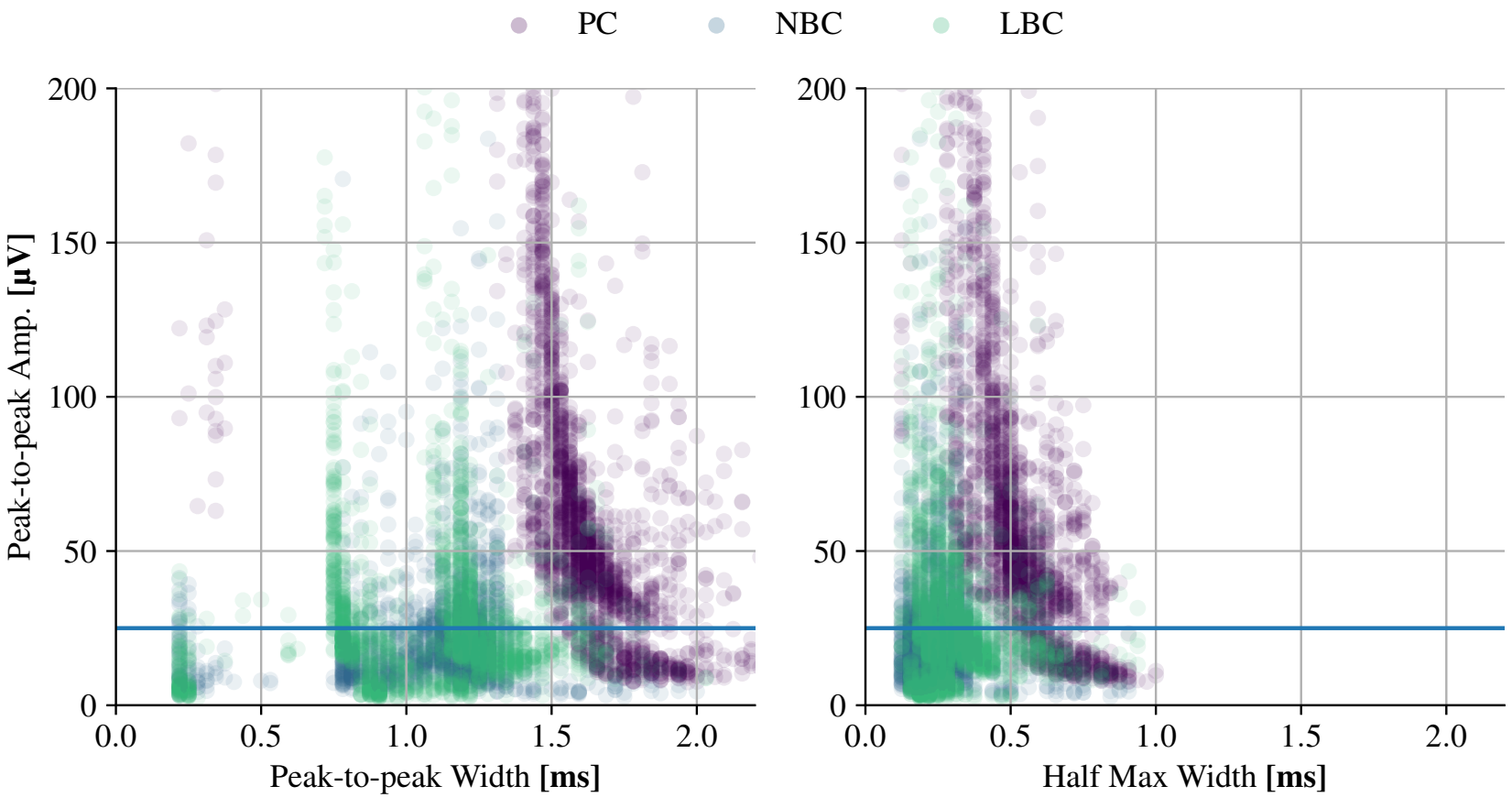
Peak-to-peak and baseline-to-peak amplitude.



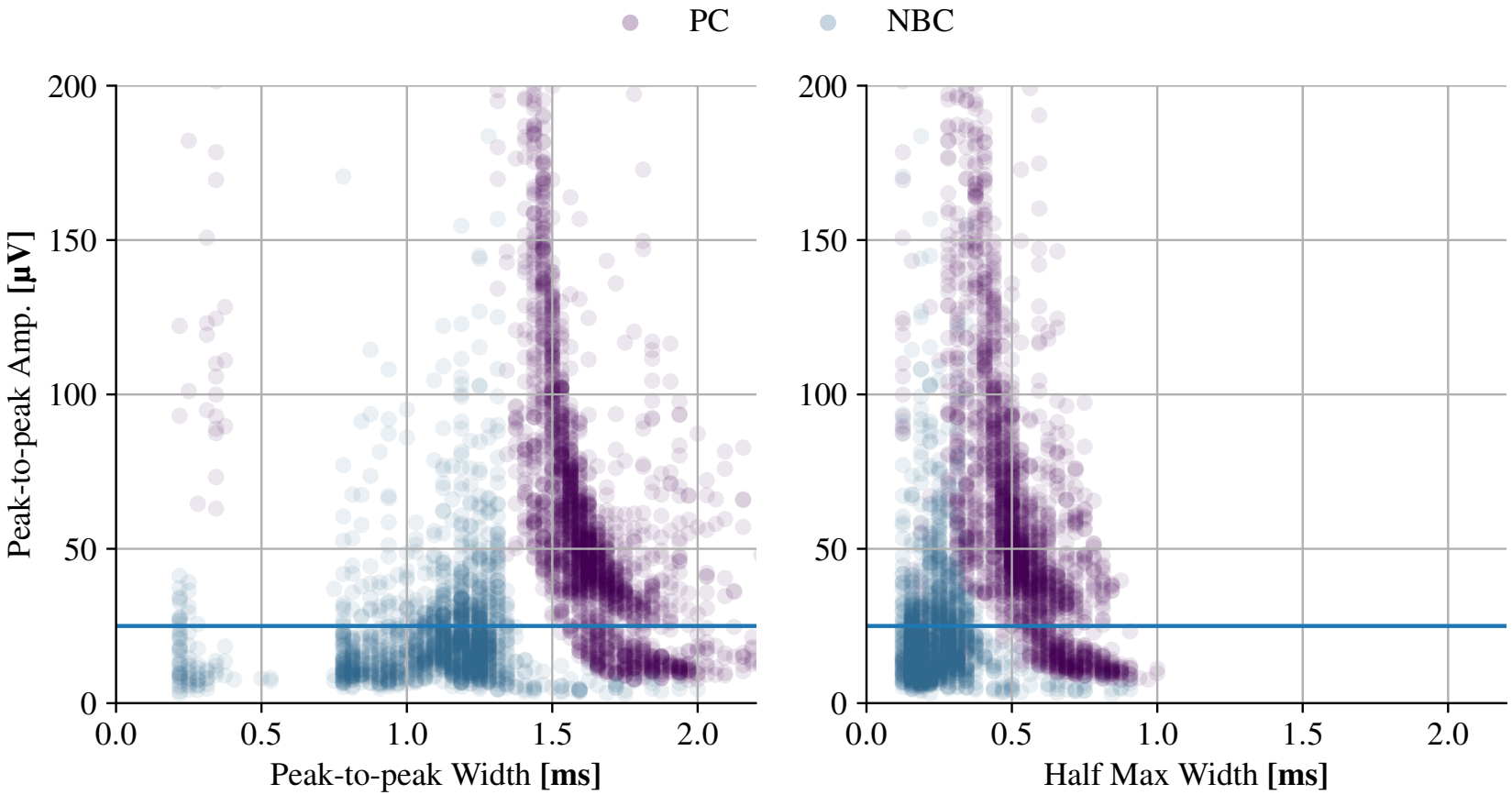
Effect of Spike Amplitude Definition



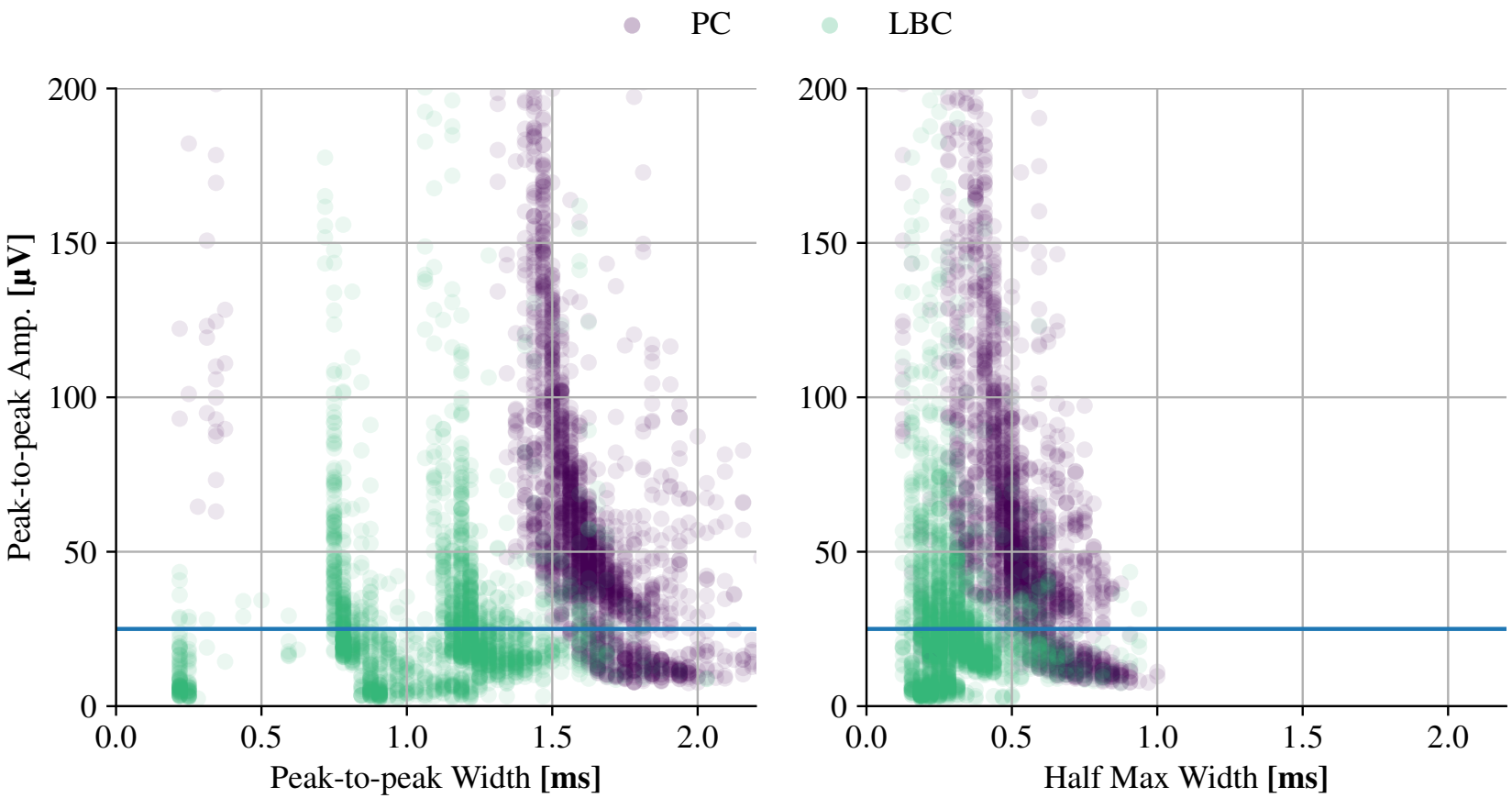
Neuronal Classification



Neuronal Classification



Neuronal Classification



Conclusion

Summary:

- Peak-to-peak definition of width gives better measurements.
- Amplitude should be considered when classifying based on width.
- If the theory holds, tetrode measurements can identify some neuronal classes based on spike amplitude and width.
- The newly developed simulation environment LFPyUtil allows quick convertion to EAP calculation for new models.