LFPy & related tools (CodeJam #12)

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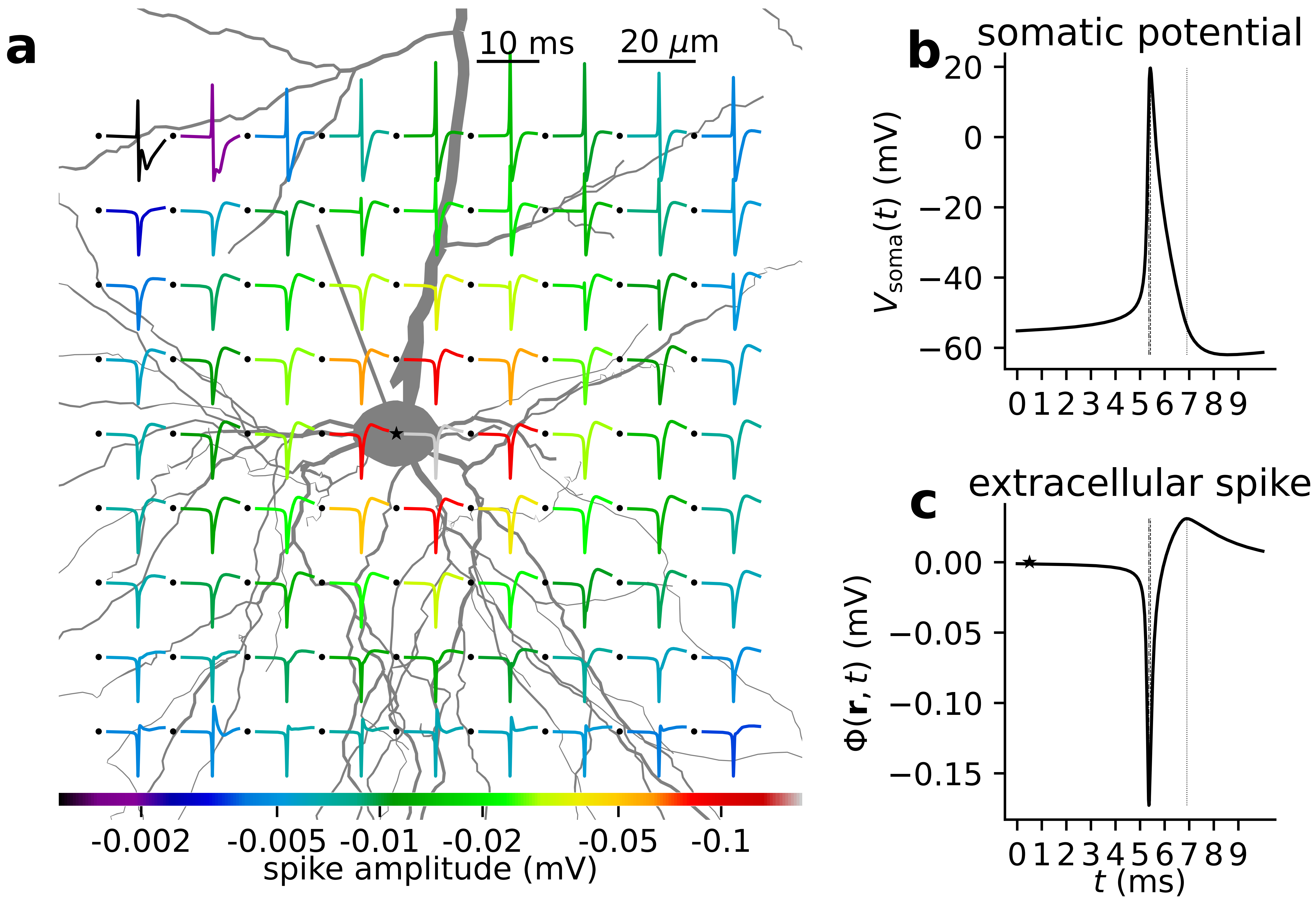
LFPy

- Python package for calculation of extracellular signals from multicompartment (MC) neuron models and networks
  - Key neural simulators focus on intracellular dynamics (V_m etc.), network dynamics (spikes)
  - Much insight from extracellular electrophysiological recordings of neural activity (spikes, LFP, ECoG, EEG, MEG)
  - Uses NEURON (neuron.yale.edu) under the hood
- Sources: github.com/LFPy/LFPy
- Docs: lfpy.rtfd.io
- Installation:
  - `pip install LFPy`
  - `conda install lfpy -c conda-forge`
- Collab w. example notebooks: wiki.ebrains.eu/bin/view/Collabs/lfpy-showcase



Action-potential waveforms from L5 PC model (Lindén et al. (2014), *Front NeuroInform* 7:41)

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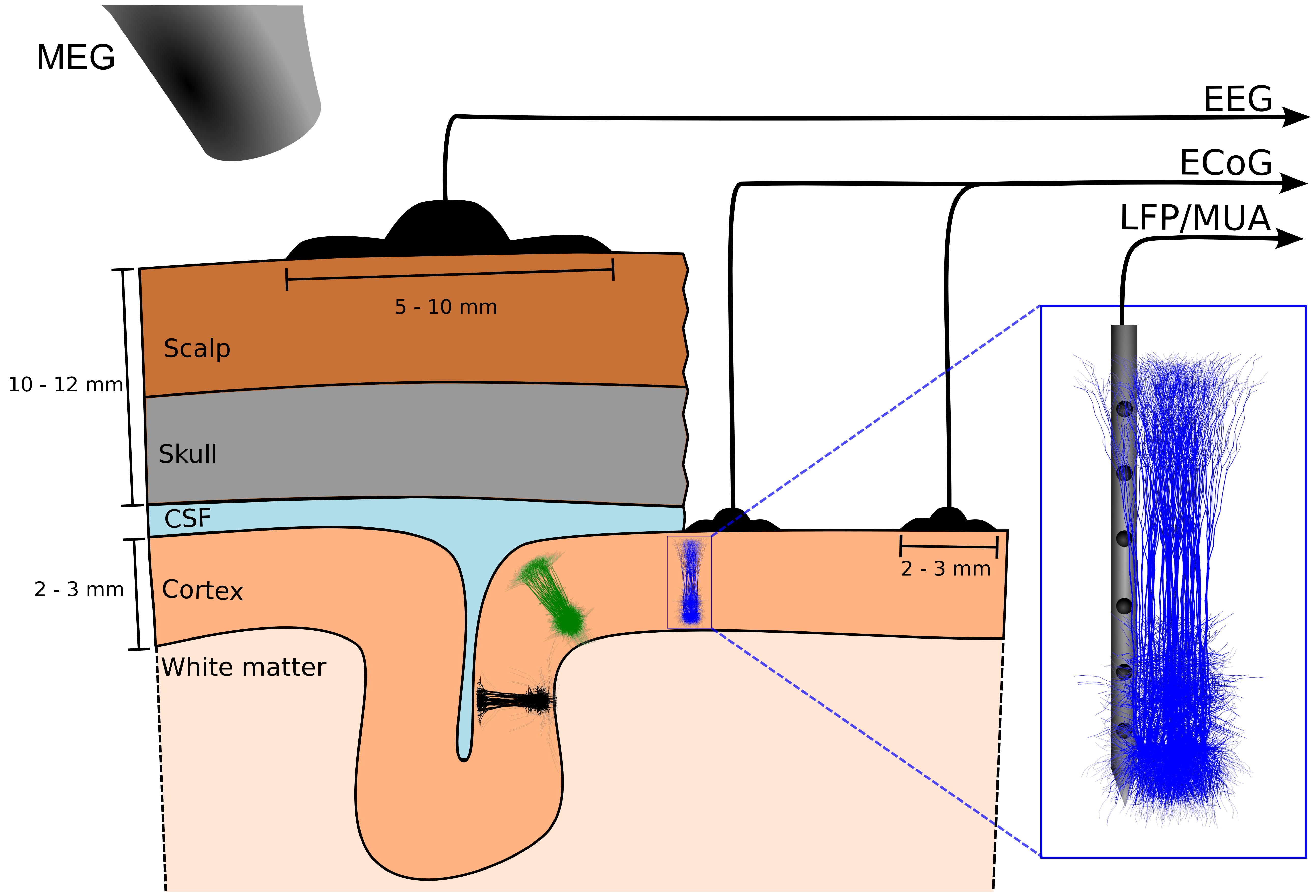
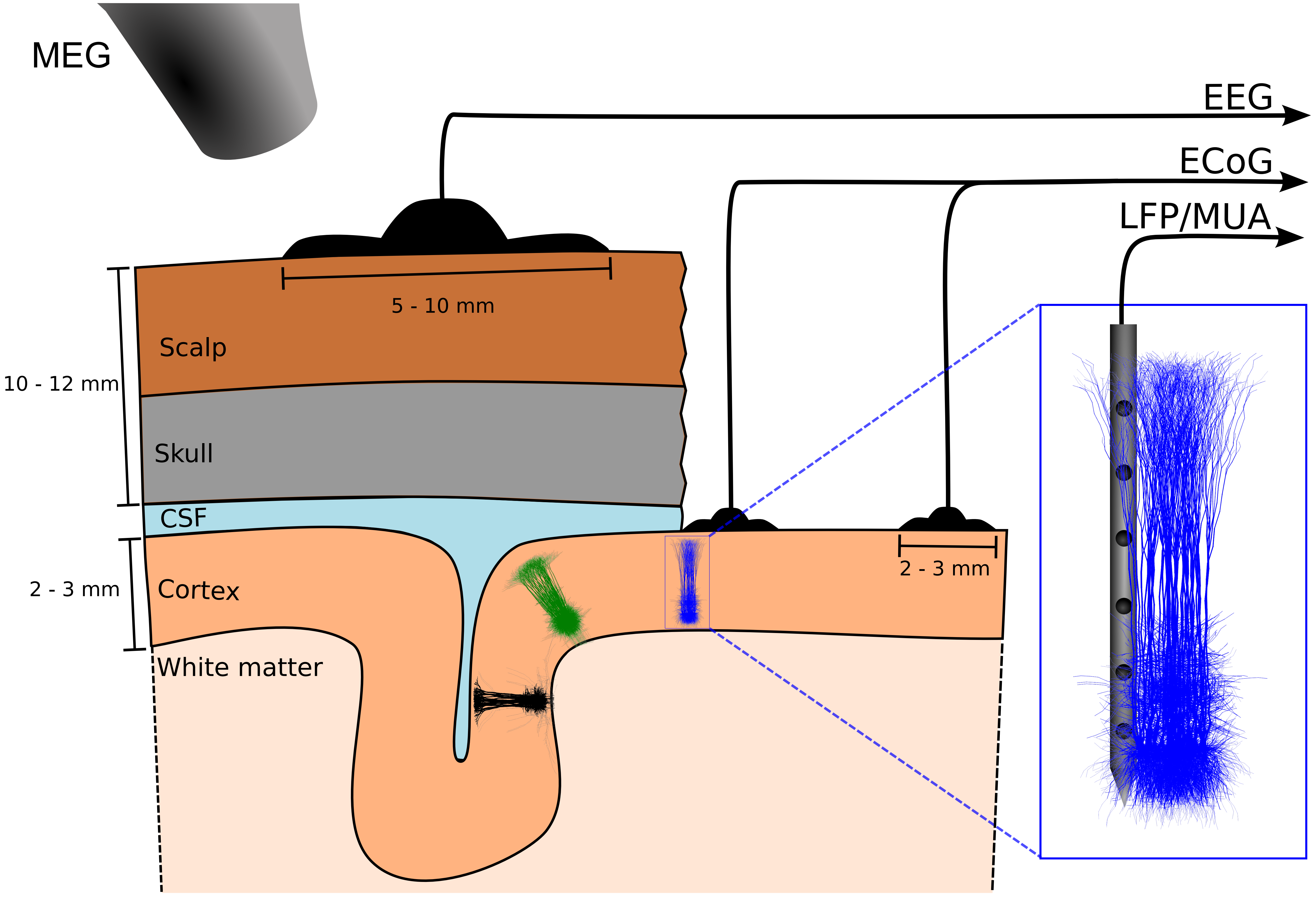


Hagen et al. (2018), *Front NeuroInform* 12:92

LFPy

- High-level class objects representing:
  - cells
  - synapses
  - intracellular stimulation devices
  - extracellular recording devices
  - networks
- Publications:
  - Lindén H, Hagen E, Łęski S, Norheim ES, Pettersen KH and Einevoll GT (2014) Front. Neuroinform. 7:41. doi: 10.3389/fninf.2013.00041
  - Hagen E, Næss S, Ness TV and Einevoll GT (2018) Front. Neuroinform. 12:92. doi: 10.3389/fninf.2018.00092



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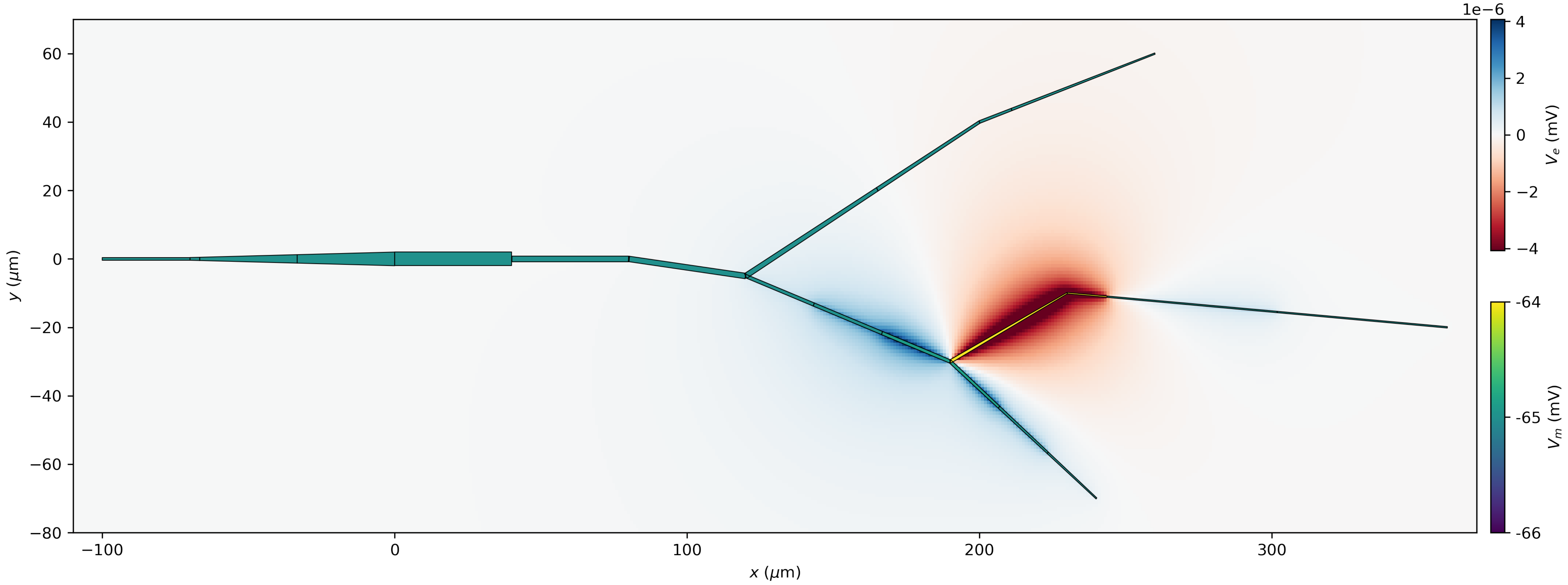
LFPykit

- Simulator-independent forward models derived using linear volume-conductor theory
- Linear mapping between transmembrane currents and different signals
    - $\psi(\vec{R}, t) = \mathcal{F}\mathbf{I}_\mathrm{m}(\vec{r}, t)$
    - point/line sources (infinite homogeneous/ inhomogeneous/anisotropic media)
    - current source density
    - current dipole moment
        - EEG signals (idealised 4-sphere head model or detailed NY head model)
        - MEG signals (infinite homogeneous or spherically symmetric conductor)



Extracellular potentials from few-compartment model implemented in Arbor and line-source approximation — lfpykit.LineSourcePotential (LFPykit/examples/Example_Arbor_swc.ipynb)

LFPykit

- Dependency in LFPy itself
- Usage examples with plain NEURON, Arbor (arbor-sim.org) and LFPy
- Sources: github.com/LFPy/LFPykit
- Docs: LFPykit.rtfd.io
- Installation:
  - `pip install lfpykit`
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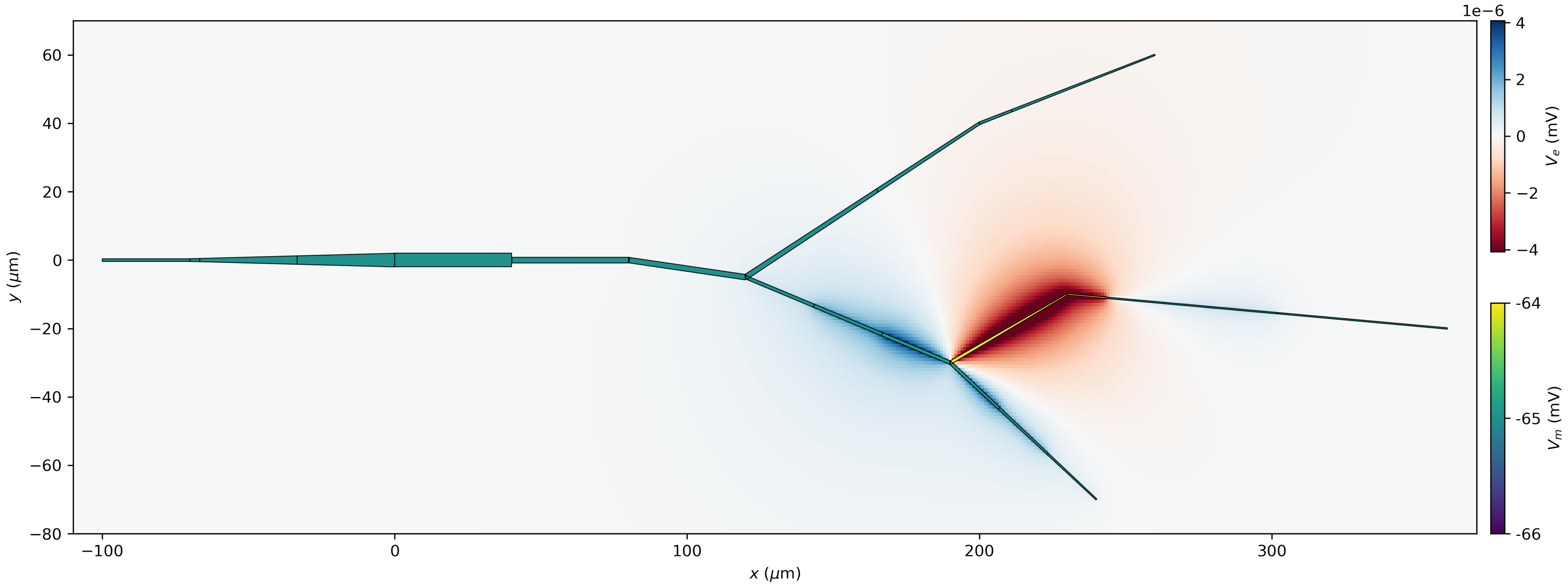

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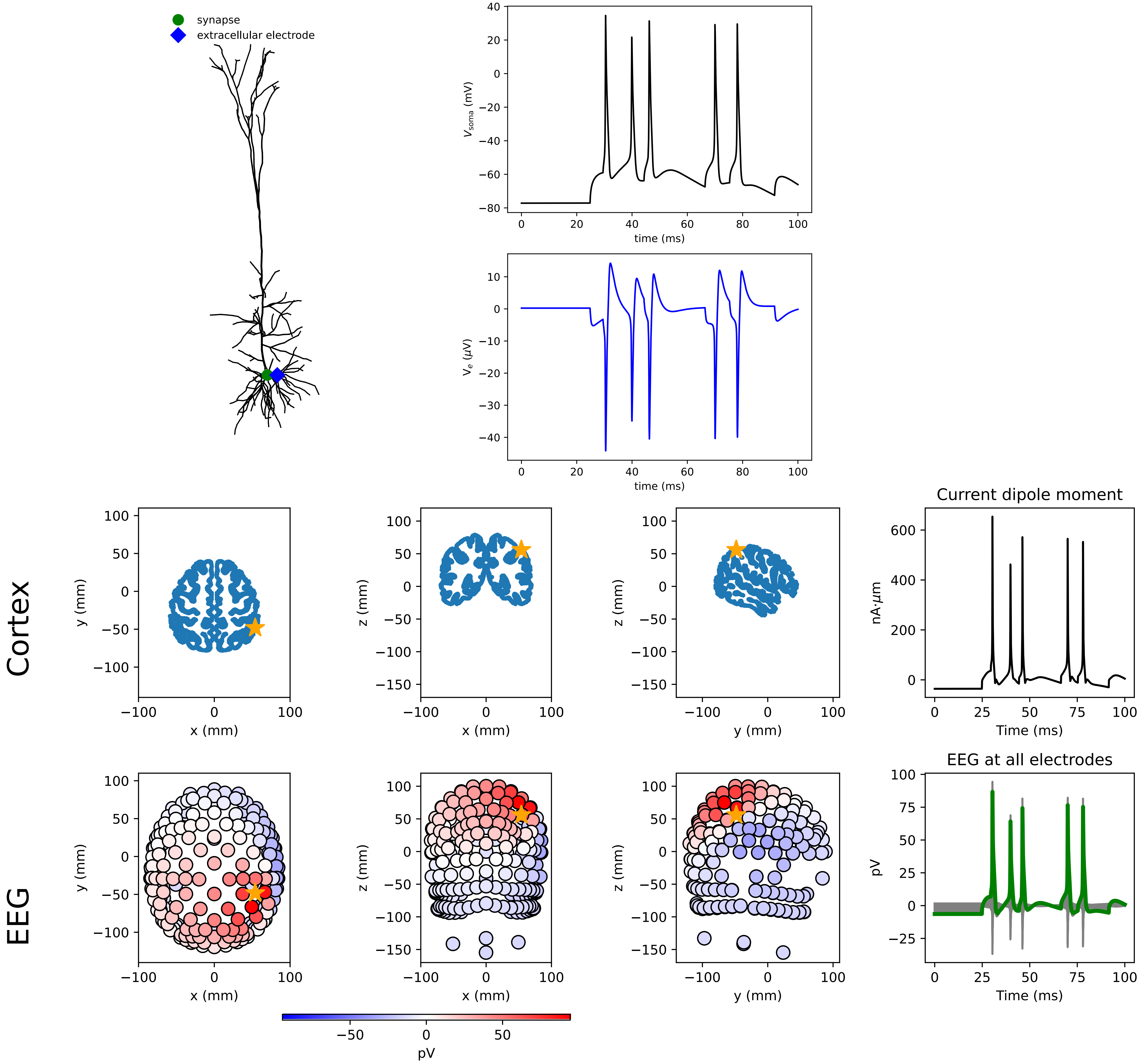
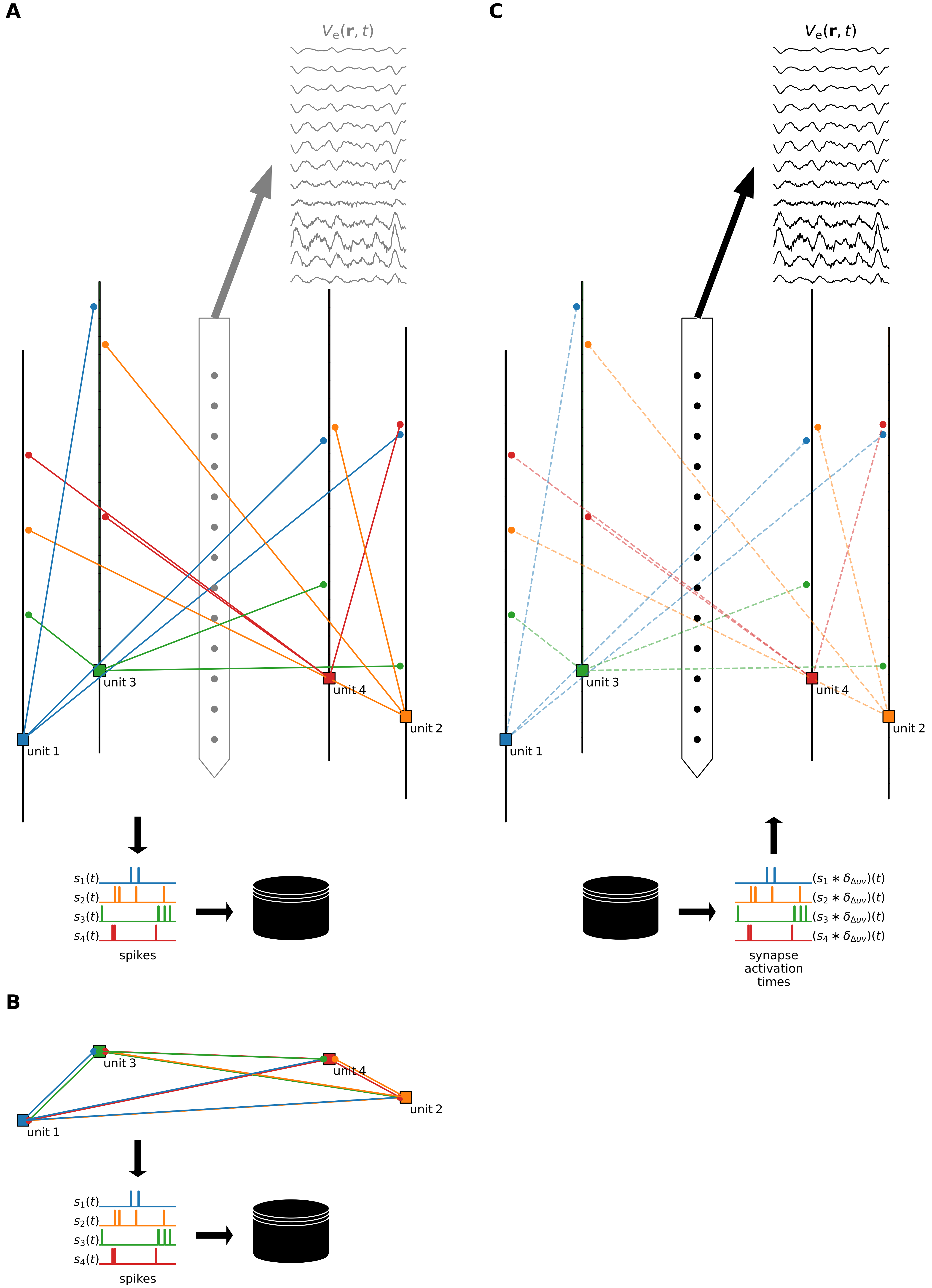


EEG scalp potentials from ‘NY Head’ model (Huang et al. (2016), *NeuroImage* 140) from current dipole moment using LFPy, lfpykit.CurrentDipoleMoment & lfpykit.eegmegcalc.NYHeadModel (LFPykit/examples/LFPykit_demo.ipynb)

hybridLFPy

- Hybrid scheme (Hagen et al. (2016), *Cereb Cortex* 26:12):
  - disentangles predictions of network activity (spiking) from FM predictions
  - simulations of spiking using simplified (point-neuron) networks
  - MC neurons for FM predictions
- Sources: github.com/INM-6/hybridLFPy
- Docs: hybridlfpy.rtfd.io
- Installation: `pip install hybridLFPy`
- HPC example on EBRAINS using pyunicore: wiki.ebrains.eu/bin/view/Collabs/hybridlfpy-showcase



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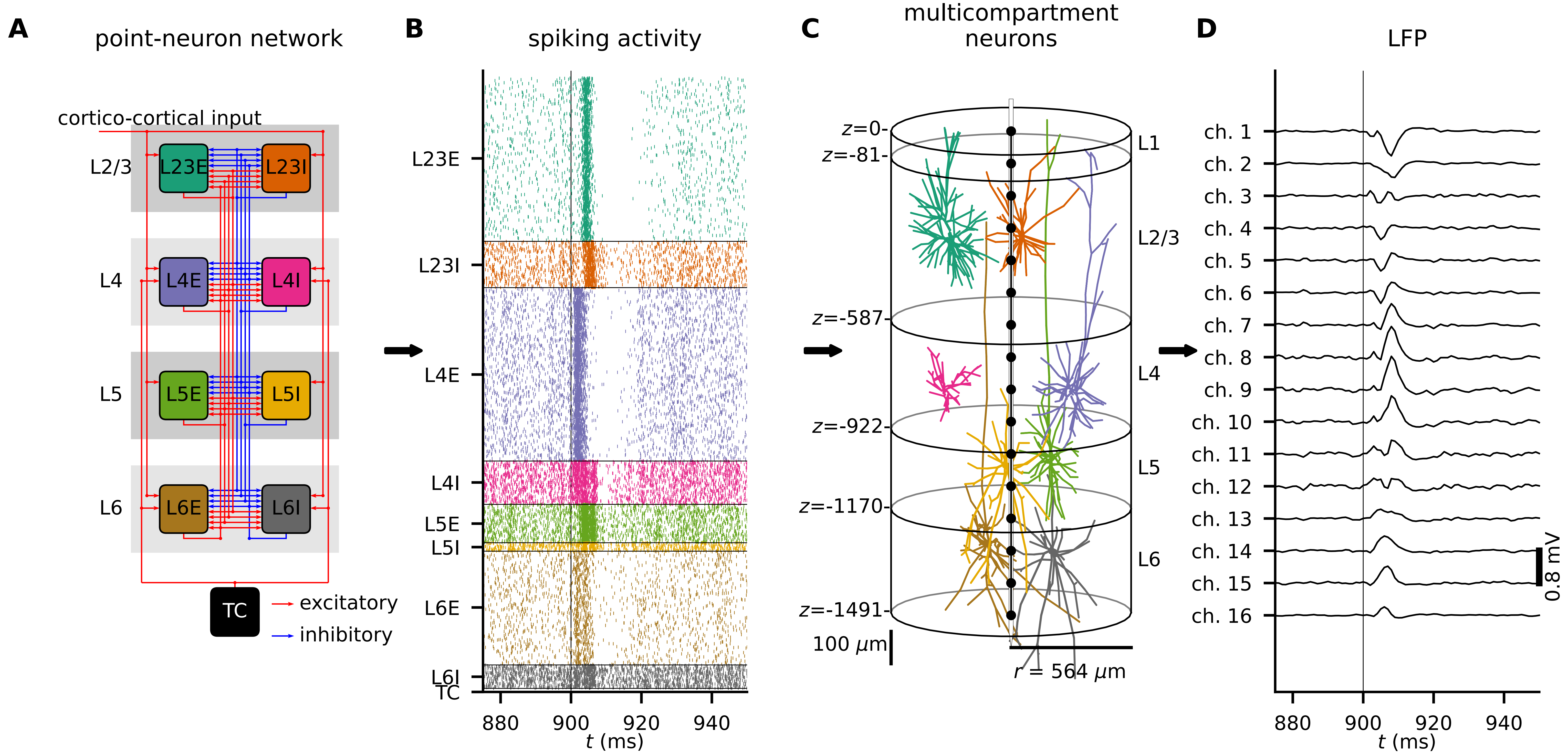

LFP predictions from cortical microcircuit model by Potjans & Diesmann (2014, *Cereb Cortex* 24:3) in Hagen et al. (2016, *Cereb Cortex* 26:12)

LFPykernels

- FM based calculations of causal spike-signal impulse response functions $H_{YX}(\vec{r},\tau)$ for finite-sized neuronal network models
- Extracellular signal approximation:
  $$\psi(\vec{r},t) = \sum_X \sum_Y (\nu_X * H_{YX})(\vec{r},t)$$
- One MC neuron simulation required per pathway between pre-synaptic population X and postsynaptic population Y
- Intended for spike- and rate-based frameworks
- Sources: github.com/LFPy/LFPykernels
- Docs: lfpykernels.rtfd.io
- Installation:
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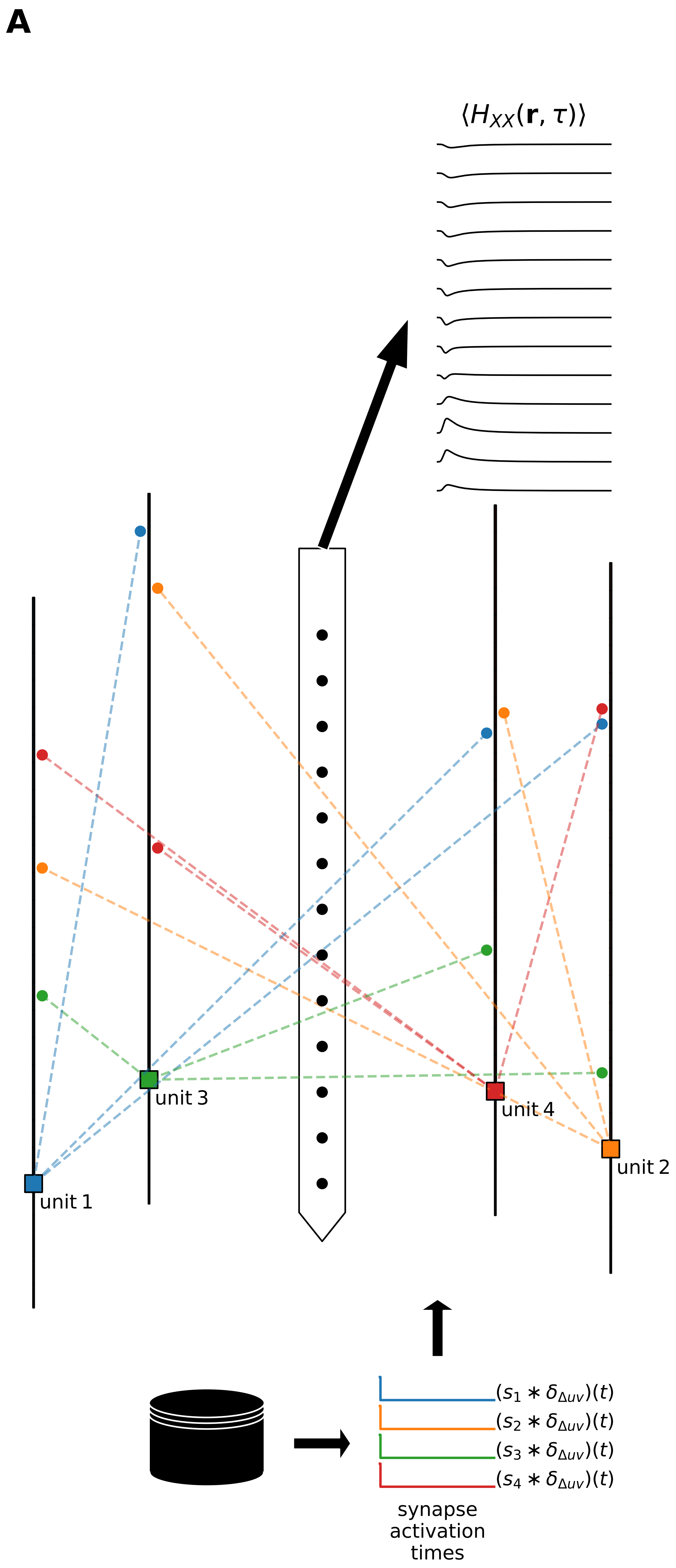

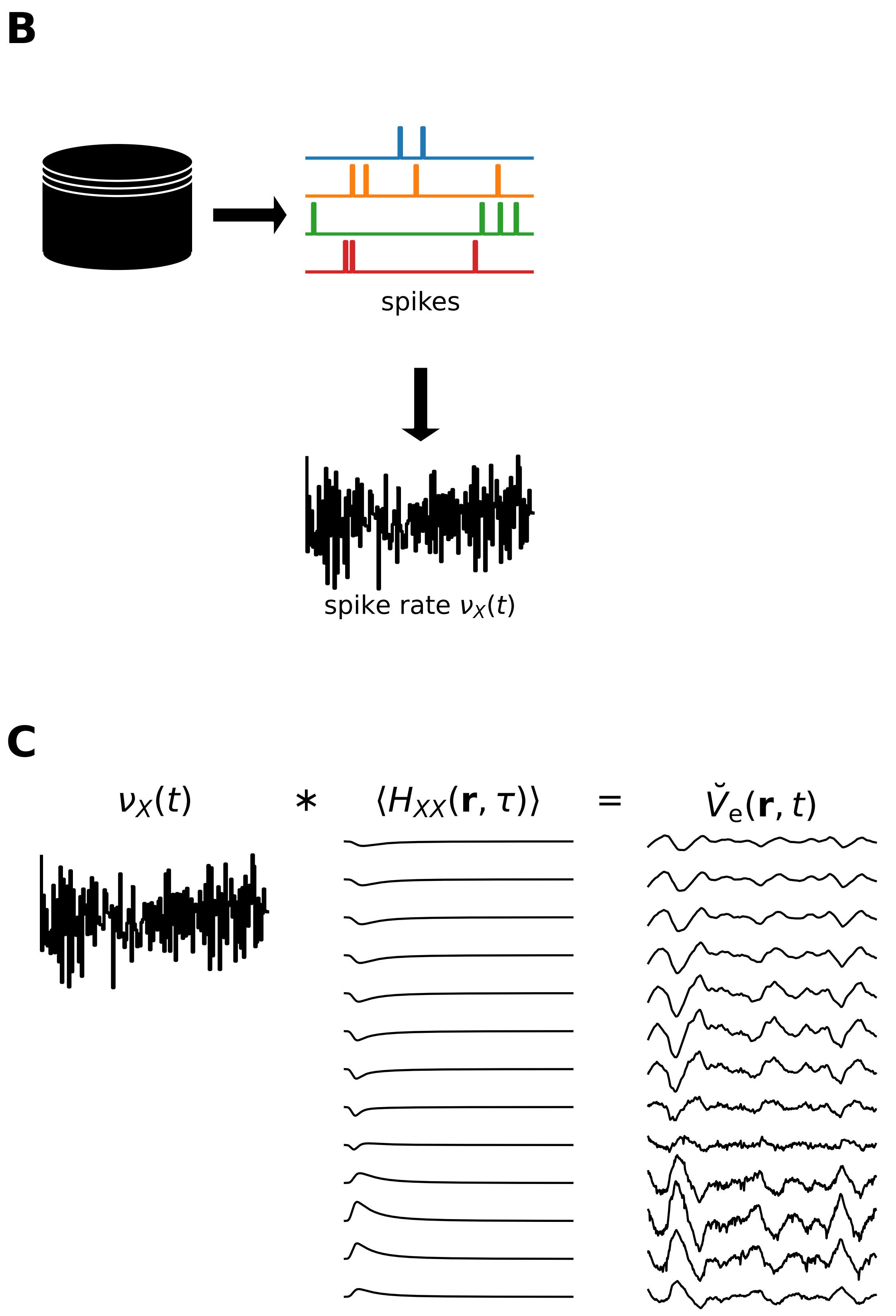

Illustration of 'hybrid scheme' predictions of population-averaged spike-LFP 'kernels' and signal reconstruction convolving spike rates with corresponding kernels

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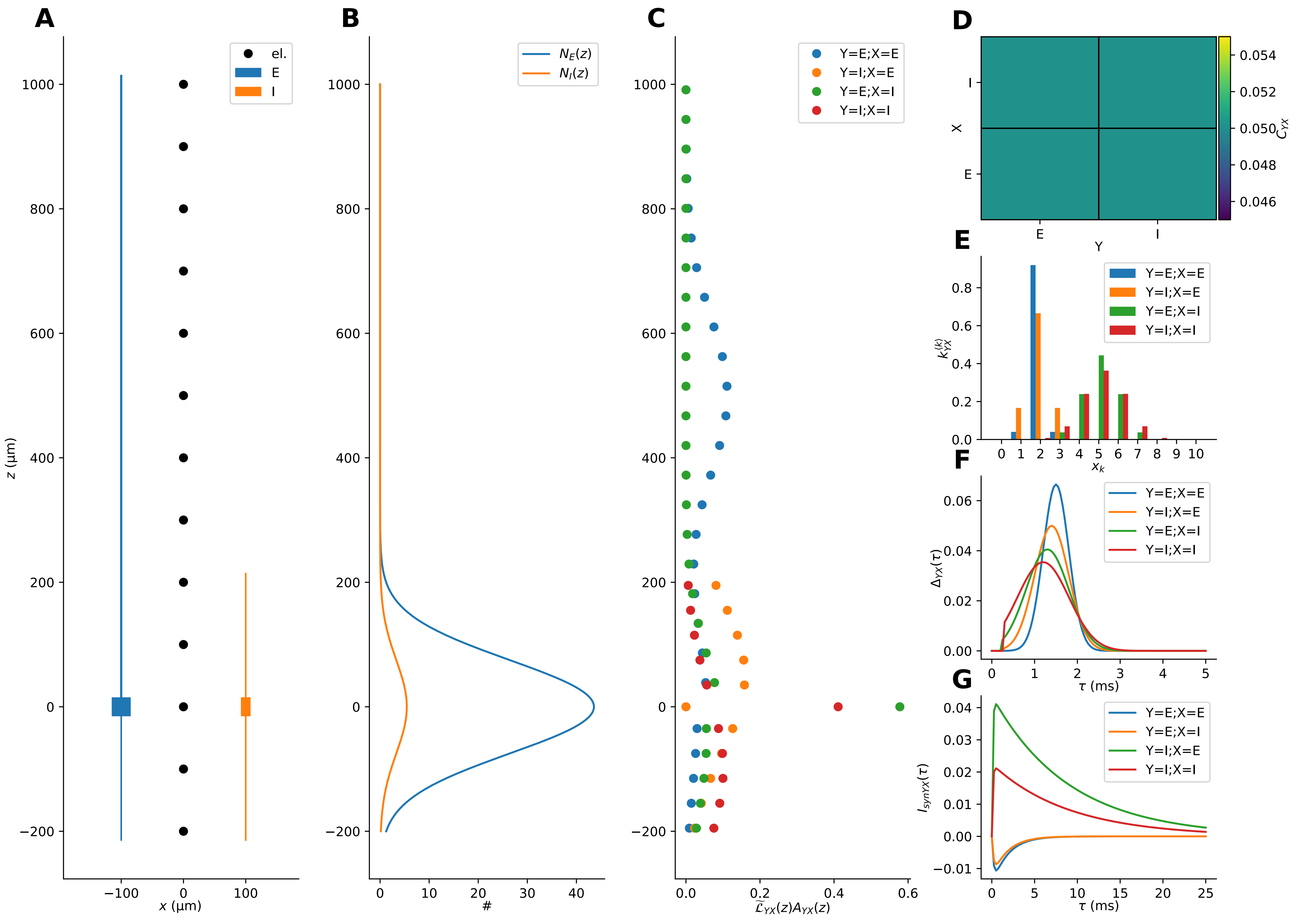

Components for deterministic kernel predictions for finite-sized 2-populatio networks, using linearised cell models, distributions of cells, connection probabilities, multapse counts, delays, linearised synapse currents.

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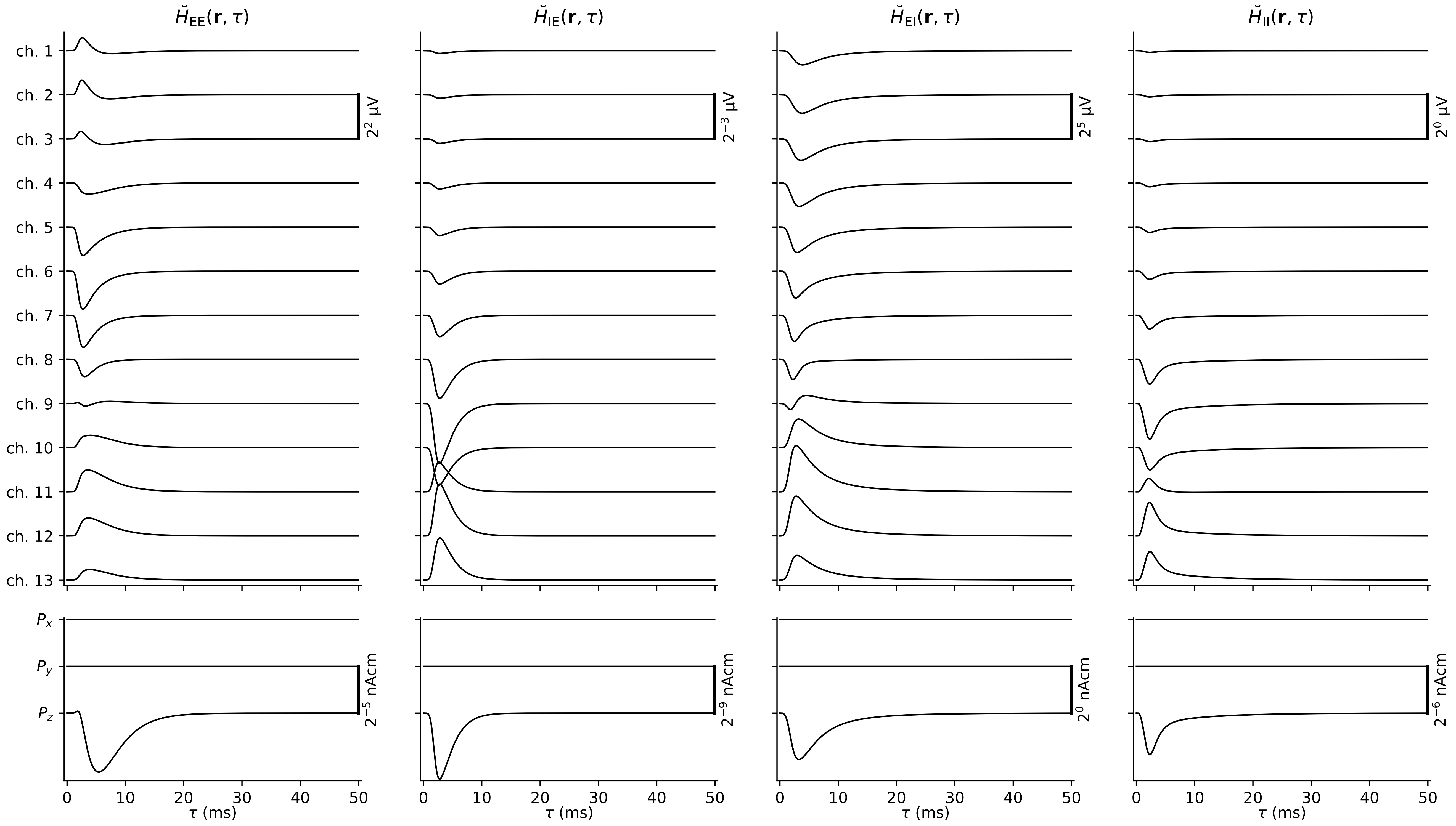

Kernels for each connection pathway in two-population network presynaptic population spikes to LFPs and current dipole moments (LFPykernels/examples/LIF_net_forward_model_predictions.ipynb)

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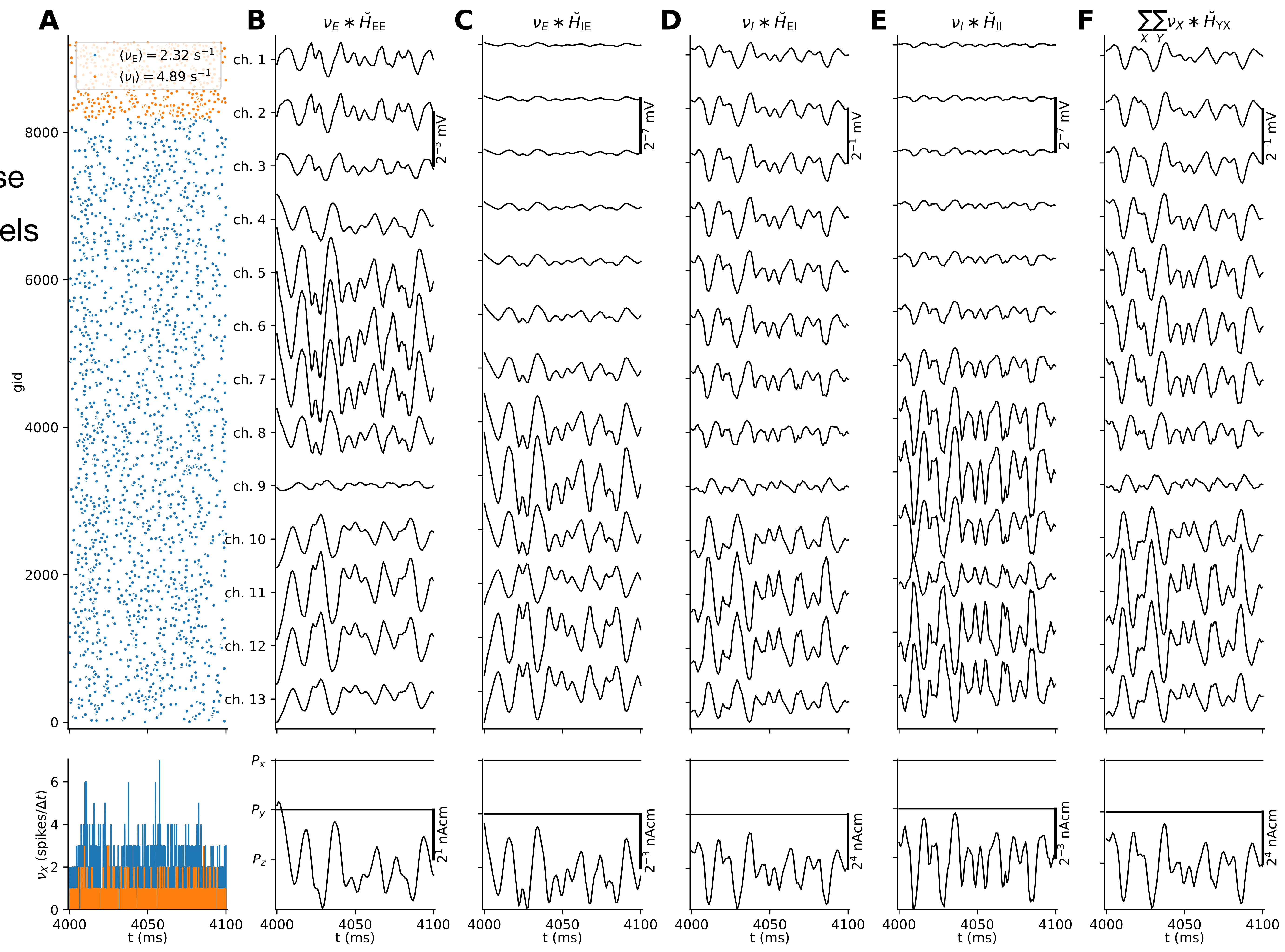

Application of kernels with two-population point-neuron network in NEST. Signals computed on the fly using FIR_filter.nestml (LFPykernels/examples/LIF_net_forward_model_predictions.ipynb)

Questions?