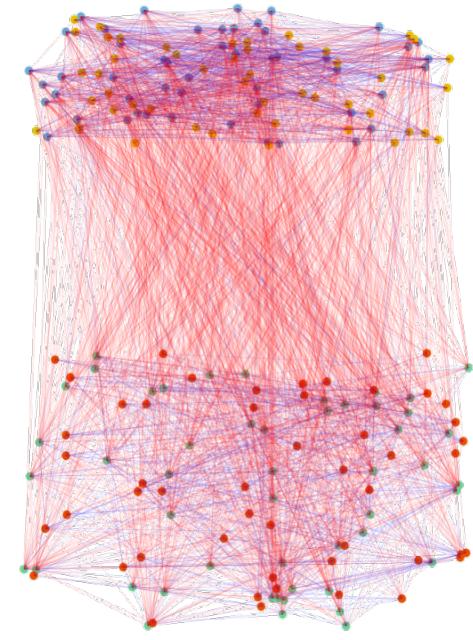
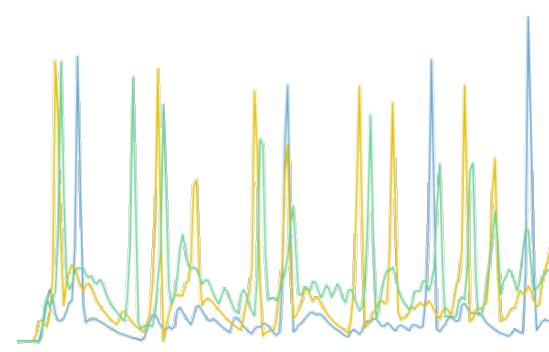
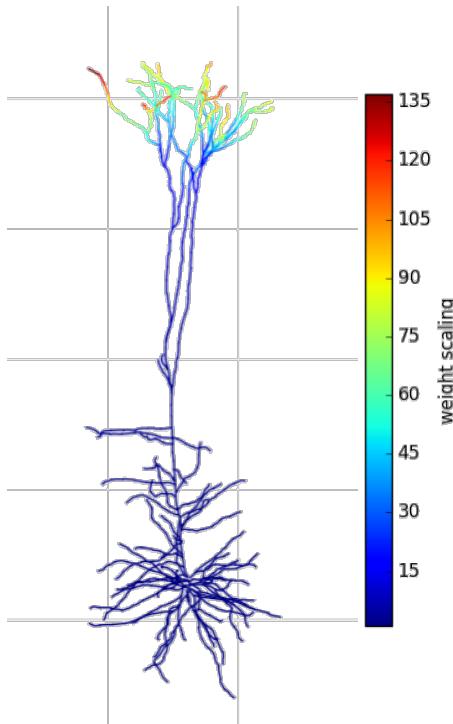


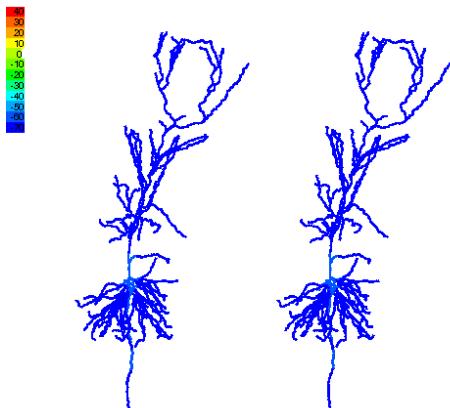
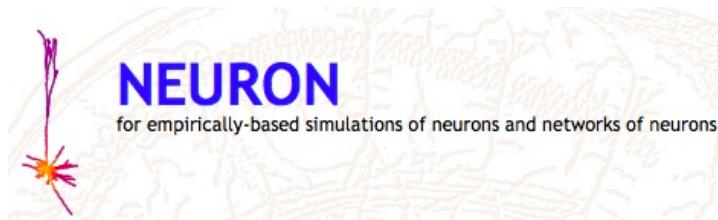


A Python package to facilitate the
development, simulation and analysis of
biological neuronal networks in NEURON

www.netpyne.org



NEURON Simulator



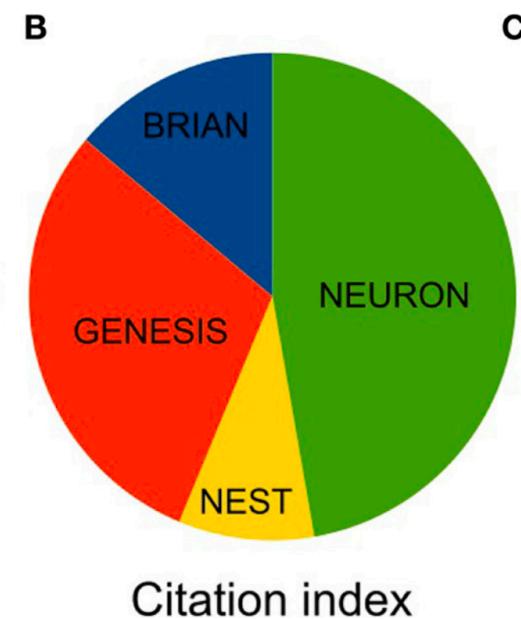
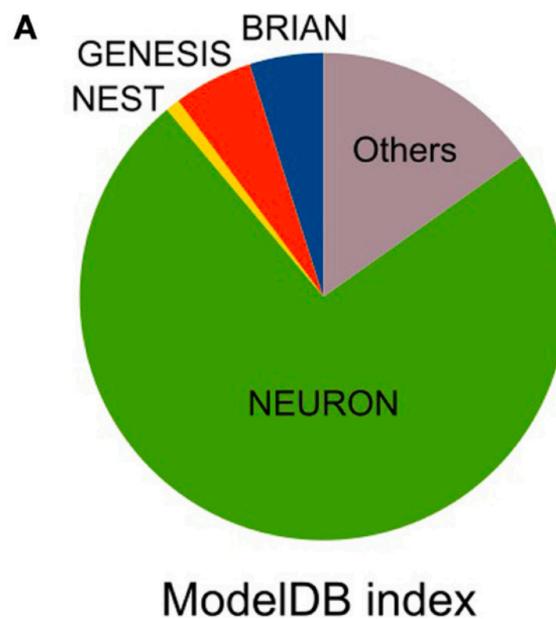
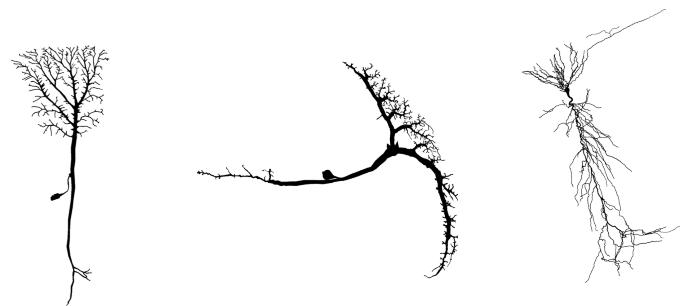
Biophysically-detailed simulation at multiple scales:

- molecular reaction and diffusion
- ionic channels and synapses
- detailed cell morphologies
- large-scale networks

NEURON

NEURON Simulator

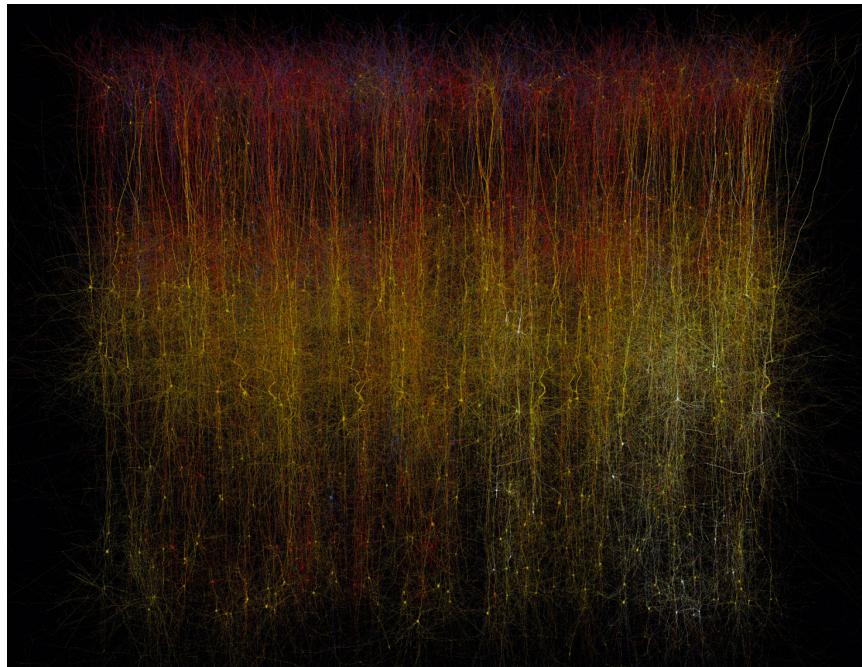
- Widely used (new papers each year)
- Many reusable components: channels, cells, ...
- Comprehensive documentation and tutorials



C

NEURON Simulator

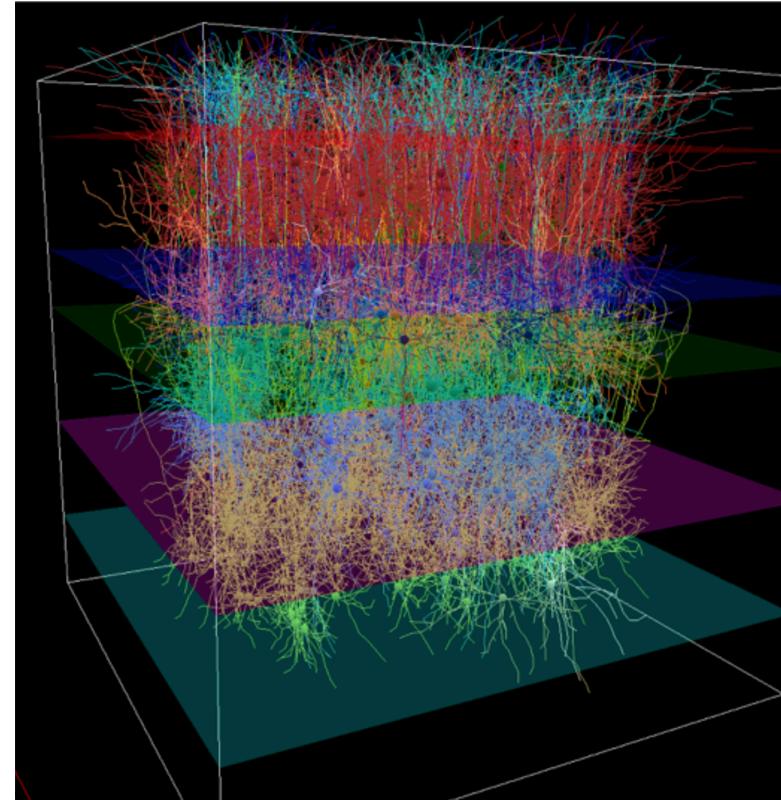
- Used in major simulation projects



**Human Brain Project
(Rat S1)**

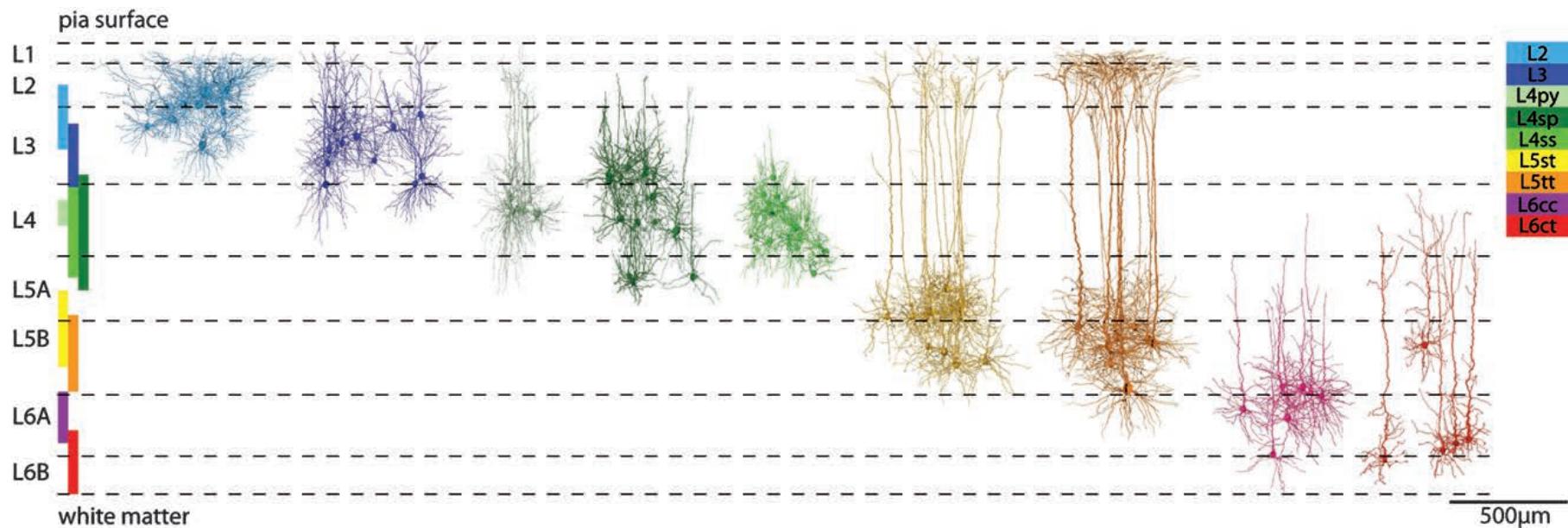


**Allen Brain Institute
(Mouse V1)**



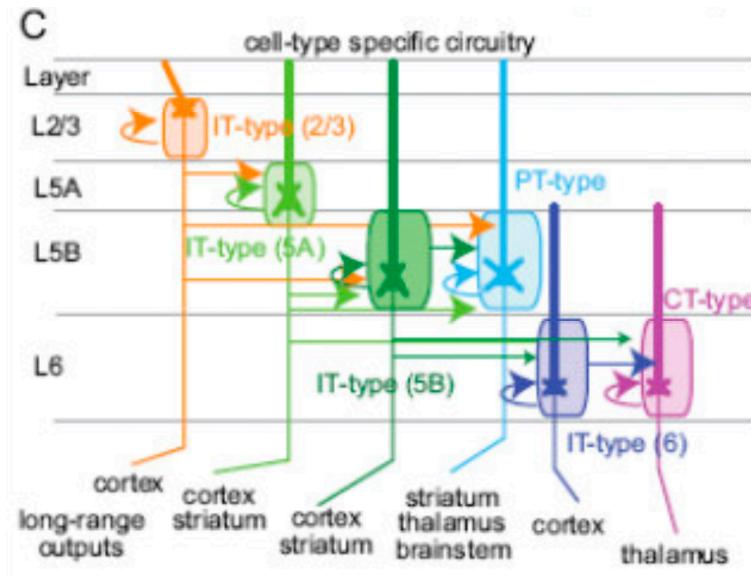
NetPyNE: Motivation

- Facilitate incorporation of experimental data at multiple scales



NetPyNE: Motivation

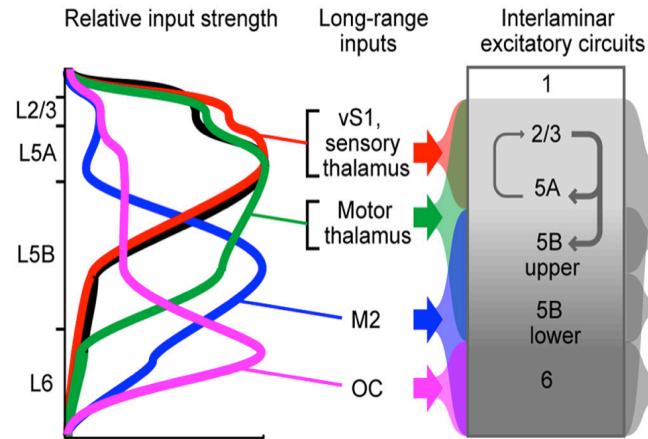
- Facilitate incorporation of experimental data at multiple scales



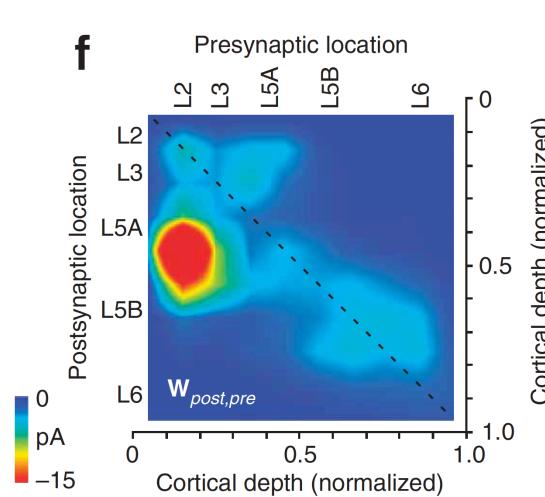
NetPyNE: Motivation

- Facilitate incorporation of experimental data at multiple scales

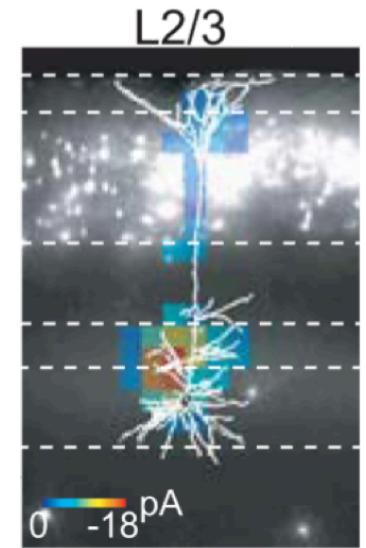
Long-range inputs



Local microcircuits



Dendritic inputs



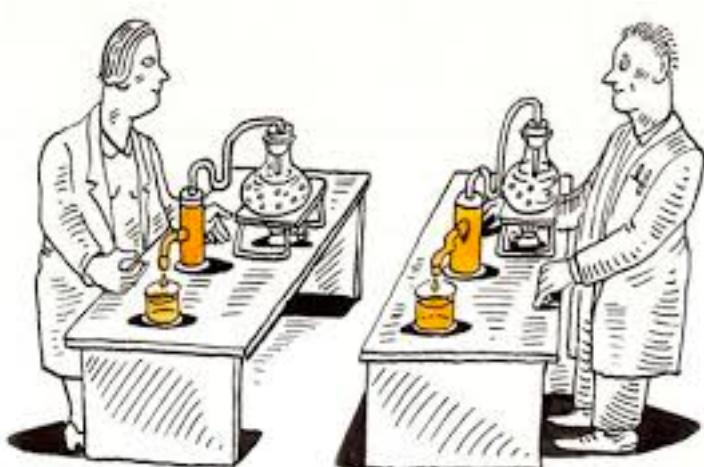
NetPyNE: Motivation

- Separate model parameters from implementation
- Standardize format – easy to read, interpret, edit, share etc

```
popParams['EXC_L2'] = {  
    'cellType': 'PYR',  
    'yRange': [100, 400],  
    'numCells': 50}
```



```
for cellParams in range(pop['numCells']):  
    cell = sim.Cell(cellParams)  
    cell.tags['y'] = numpy.random(100,400)  
    cell.tags['cellType'] = 'PYR'
```

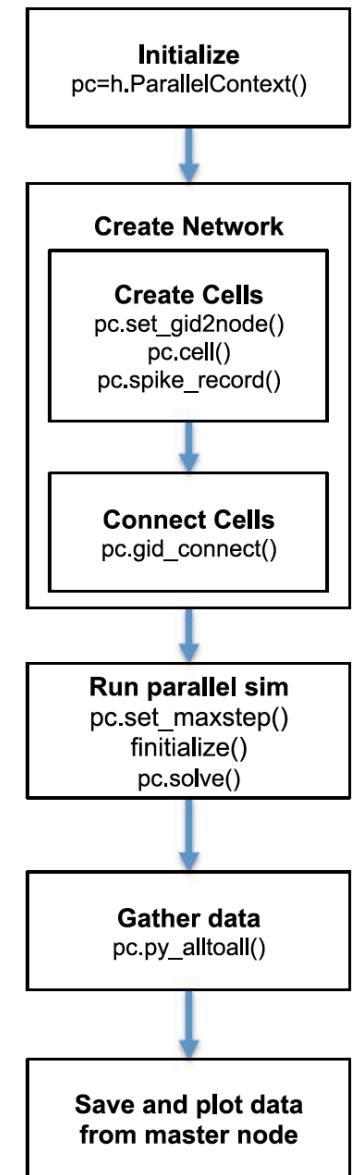
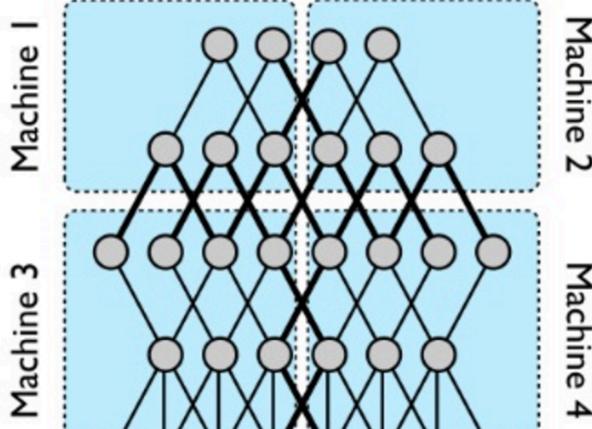


Replicate: get same thing to run again

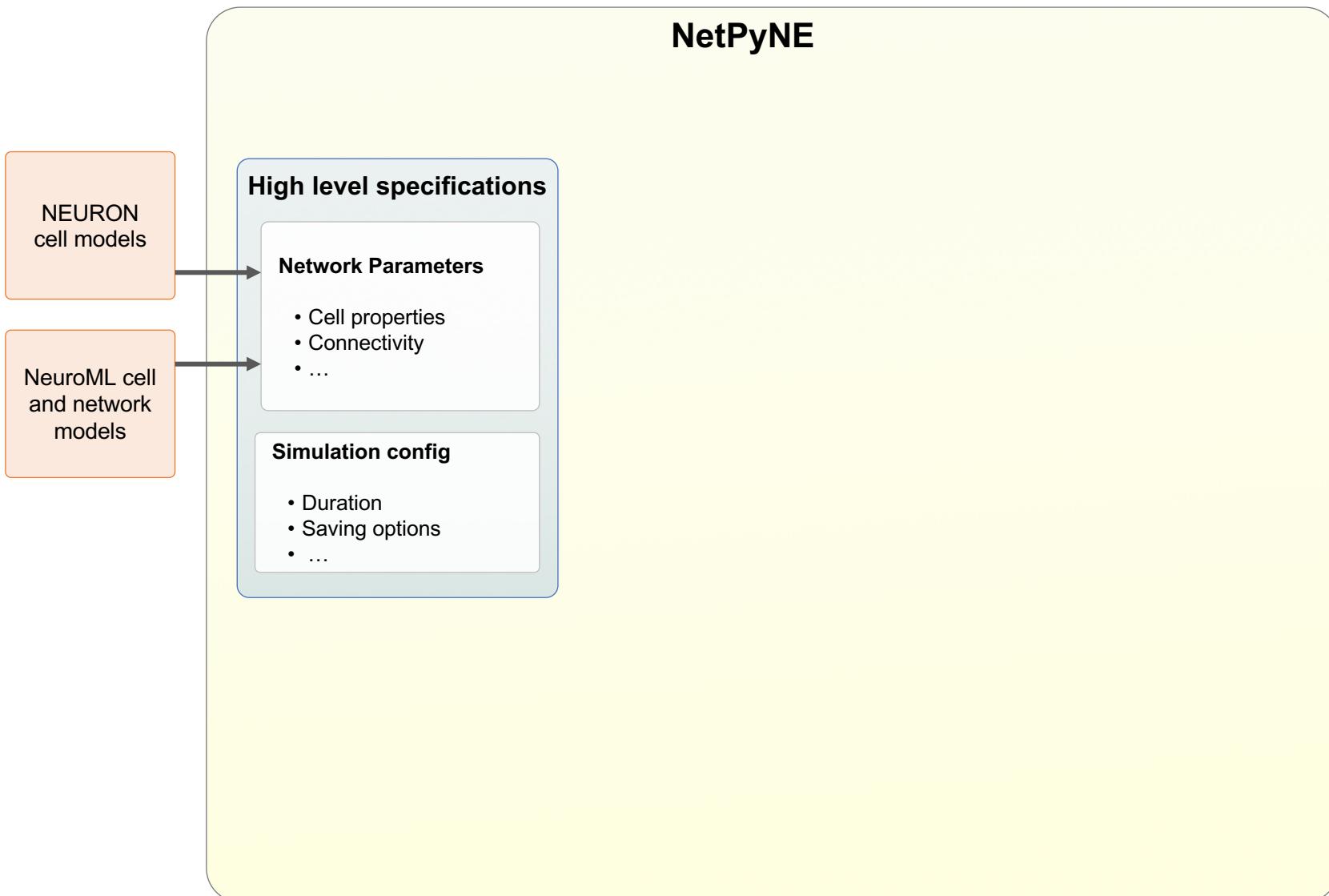
Reproduce: make it yourself

NetPyNE: Motivation

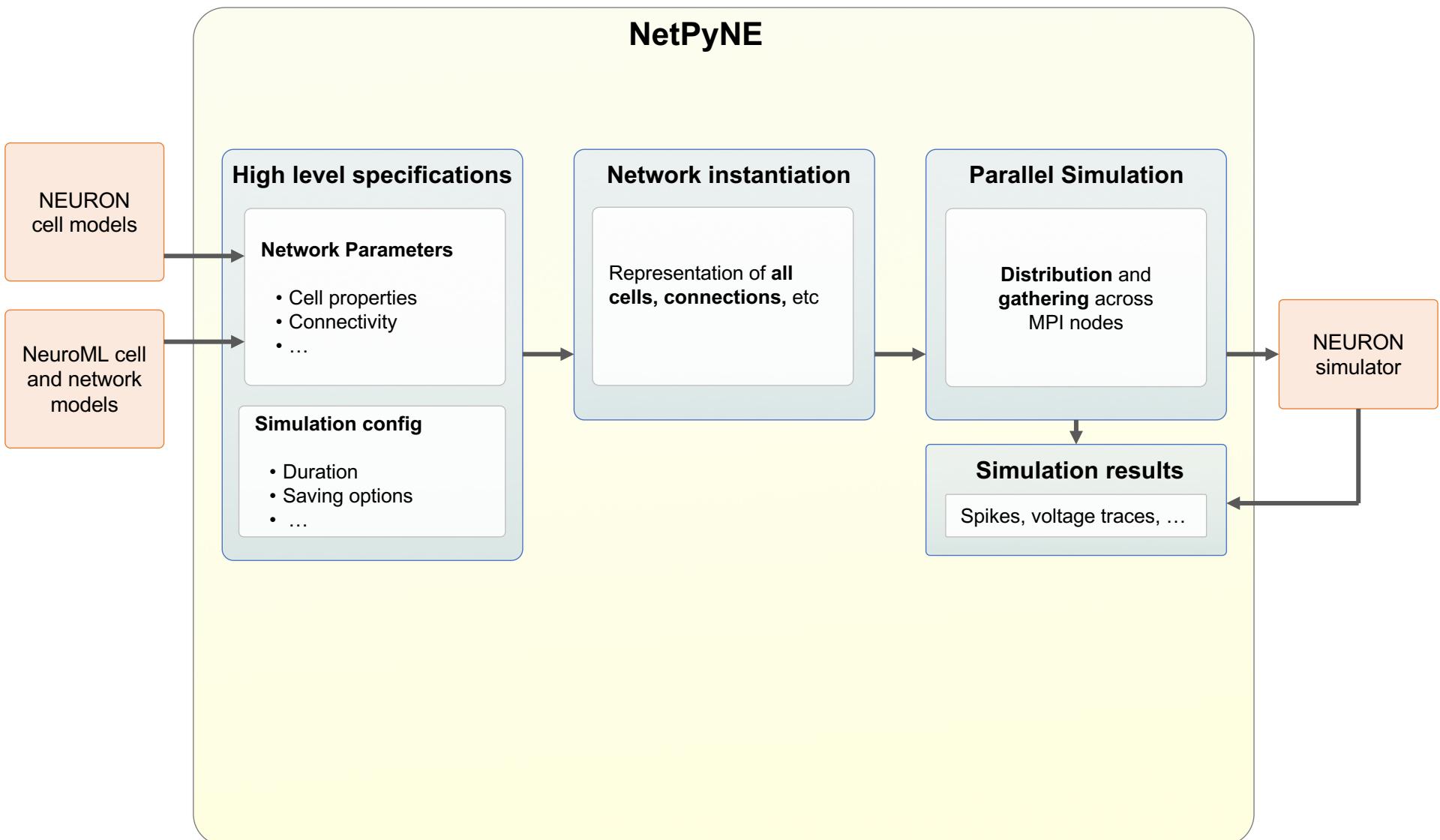
- Facilitate model parallelization (HPCs)
- Batch parameter exploration/optimization



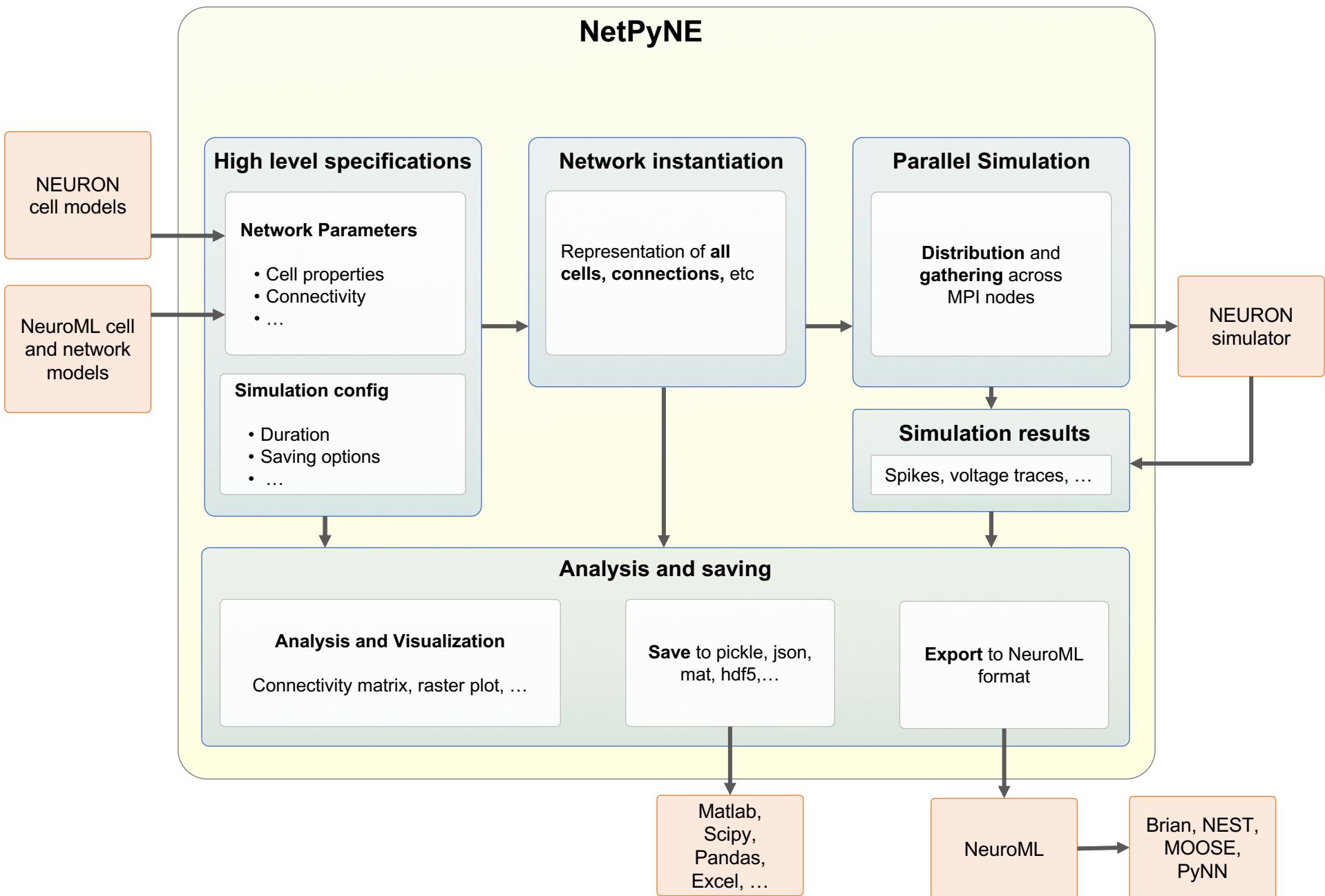
NetPyNE



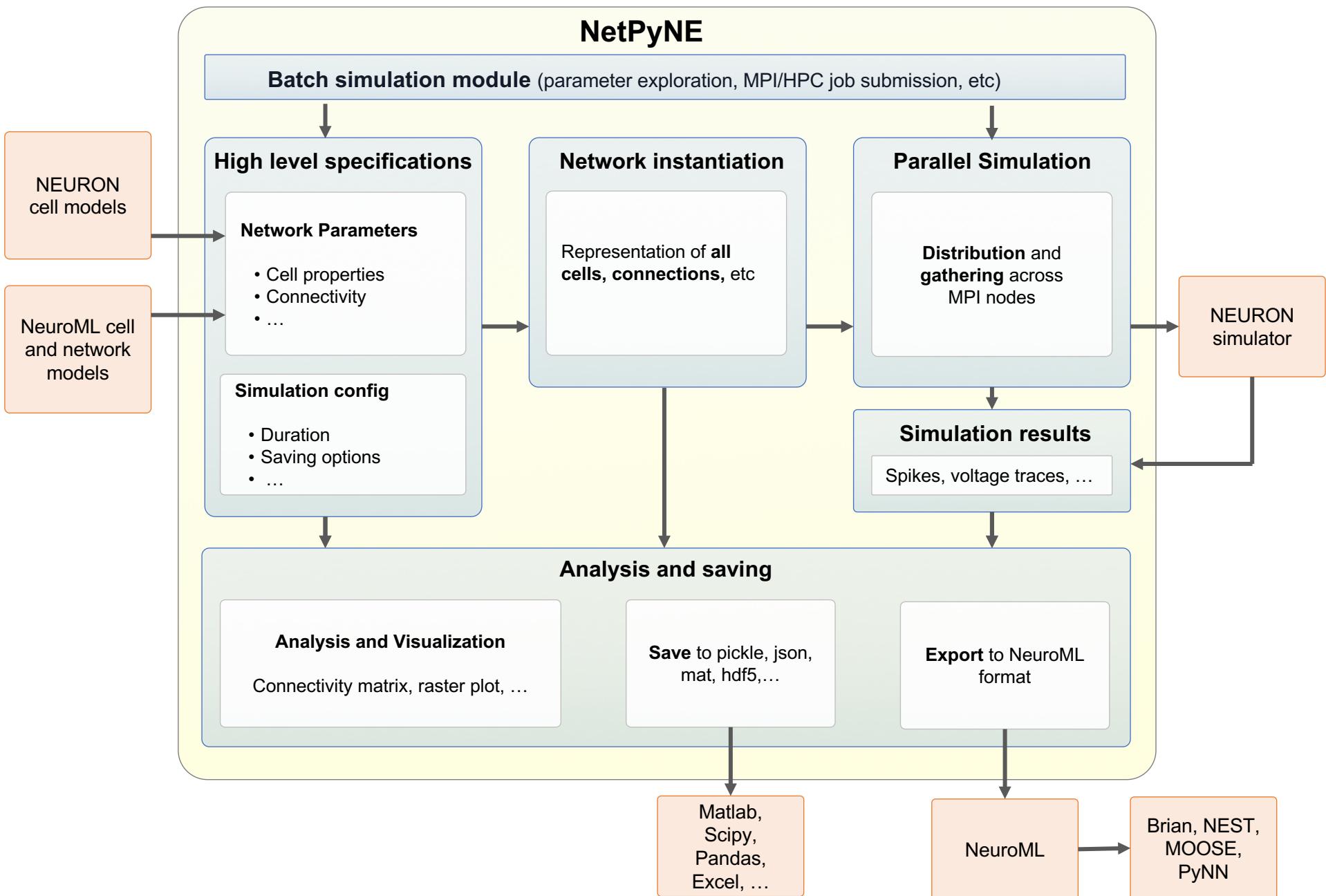
NetPyNE



NetPyNE

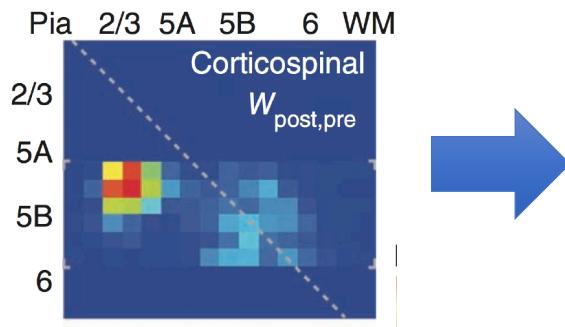


NetPyNE



NetPyNE: High level specifications

- Specifications are provided in a **standardized, declarative** Python format (JSON-like, lists and dicts).
- Clear **separation** of parameters from implementation code.
- Error **checking** and **suggestions** to facilitate model definition.



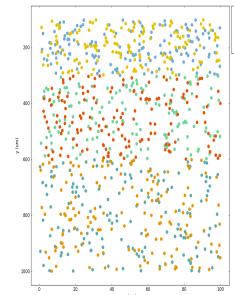
```
connParams['bin3->CSP'] = {  
    'preConds': {'y': [100, 150]},  
    'postConds': {'pop': 'CSP'},  
    'probability': 0.15,  
    'weight': 0.4,  
    'delay': 5,  
    'synMech': 'AMPA'}
```

NetPyNE facilitates
building models
based on
experimental data

NetPyNE: High level specifications

□ User can define:

- **Populations:** cell type, number of neurons or density, spatial extent, ...



- **Cell properties:** Morphology, biophysics, implementation, ...



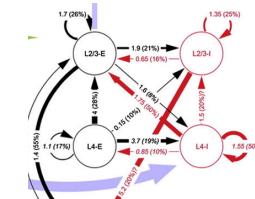
- **Synaptic mechanisms:** Time constants, reversal potential, implementation, ...



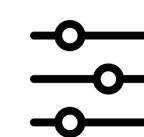
- **Stimulation:** Spike generators, current clamps, spatiotemporal properties, ...



- **Connectivity rules:** conditions of pre- and post-synaptic cells, different functions, ...

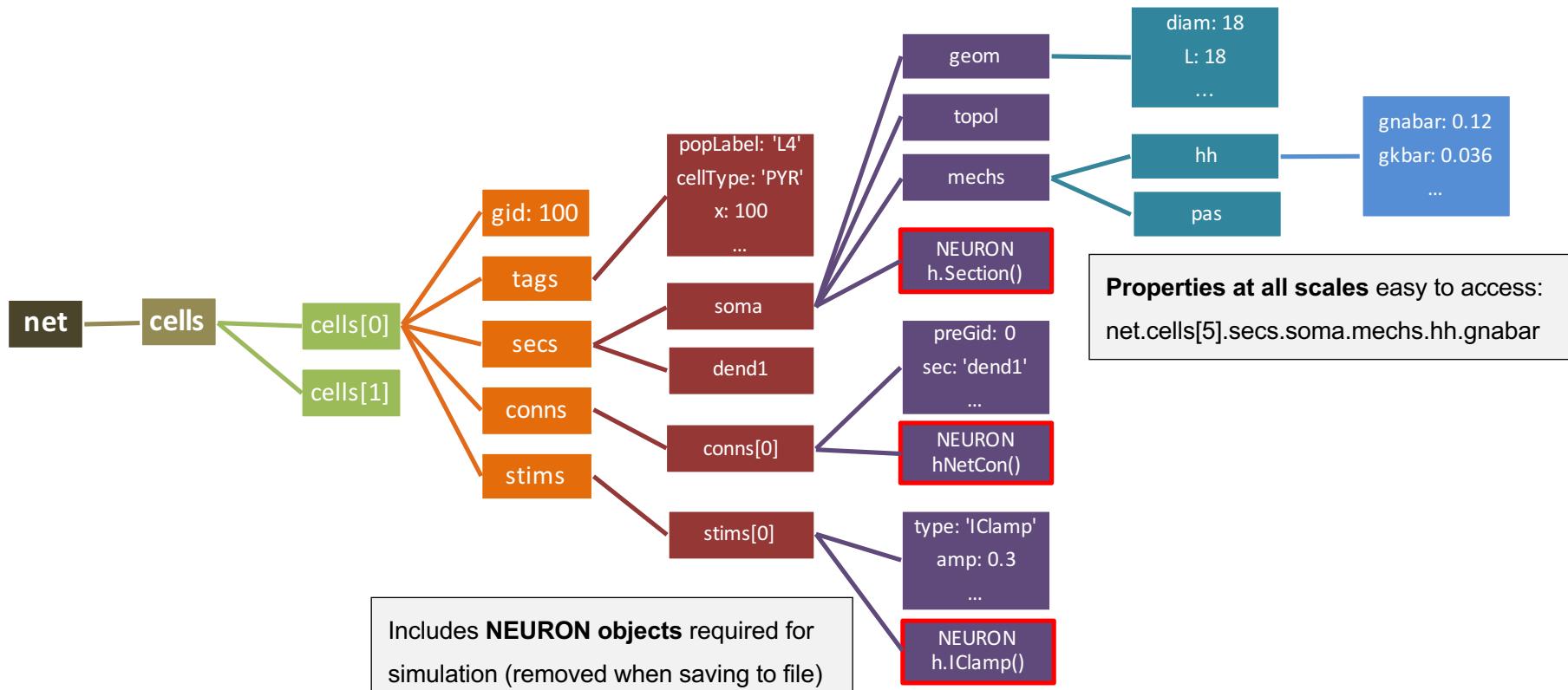
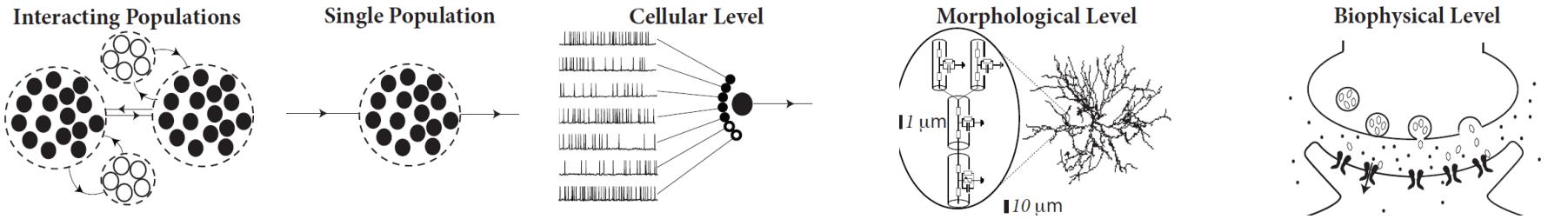


- **Simulation configuration:** duration, saving and analysis, graphical output, ...



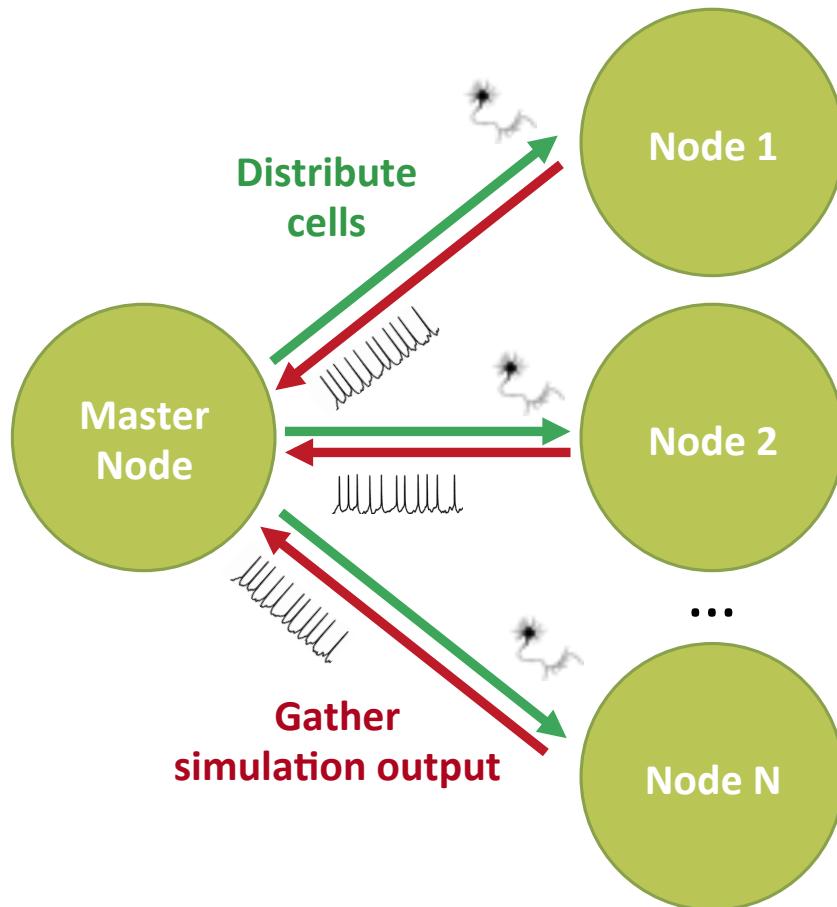
NetPyNE: Network Instantiation

- Network is created as Python-based **standardized hierarchical data structure**.



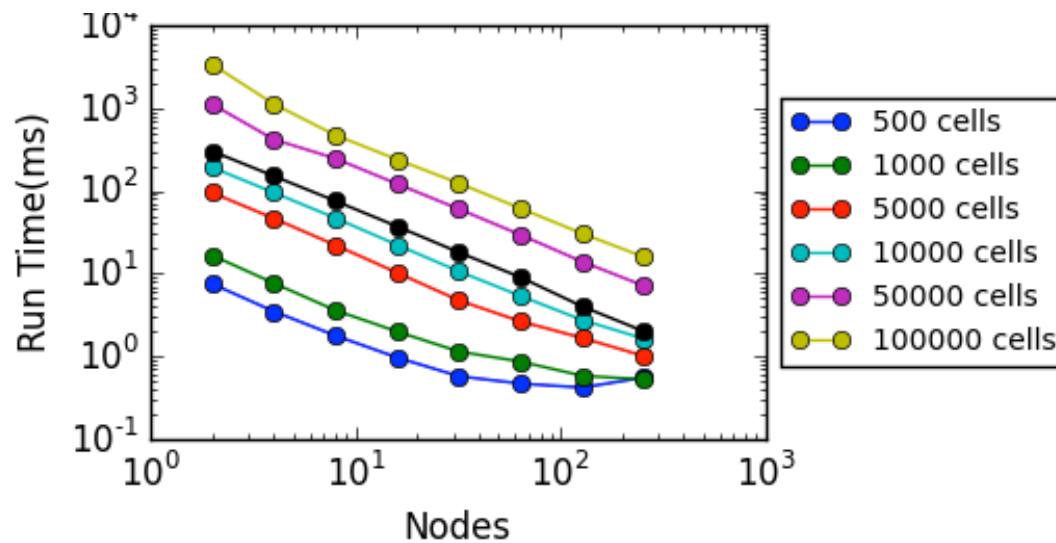
NetPyNE: Parallel Simulation

- ❑ Set up for MPI **parallel simulation** across multiple nodes (via NEURON simulator).
- ❑ Takes care of balanced **distribution** of cells and **gathering** of simulation output from nodes.



NetPyNE: Parallel simulation

- NetPyNE available on **the Neuroscience Gateway (NSG)** supercomputing platform.



Simulation **run time** as a function of number of cells and number of nodes (*Neural Comput*, 2016).

Results obtained using **NetPyNE** on **NSG**.

NetPyNE: Batch parallel simulations

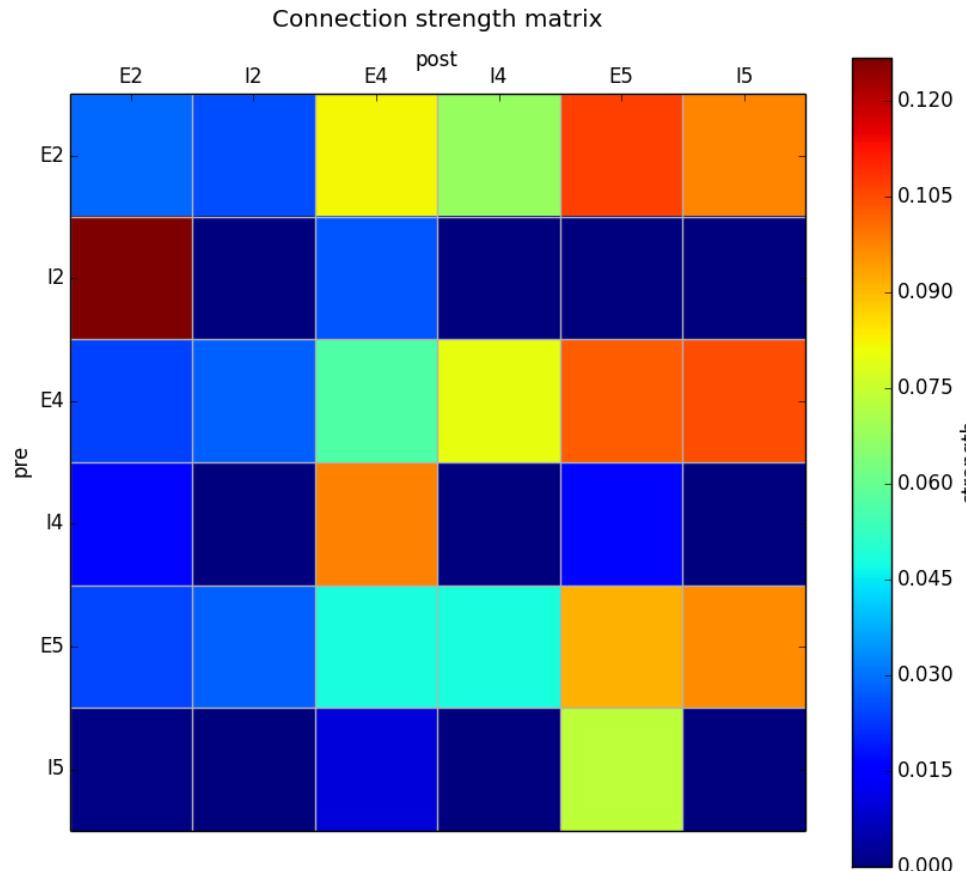
- **Easy specification** of parameters and range of values to explore in batch simulations.
- **Pre-defined, configurable** setups to automatically **submit jobs** in multicore machines (Bulletin board) or supercomputers (SLURM or PBS Torque)



SDSC SAN DIEGO
SUPERCOMPUTER CENTER

NetPyNE: Analysis

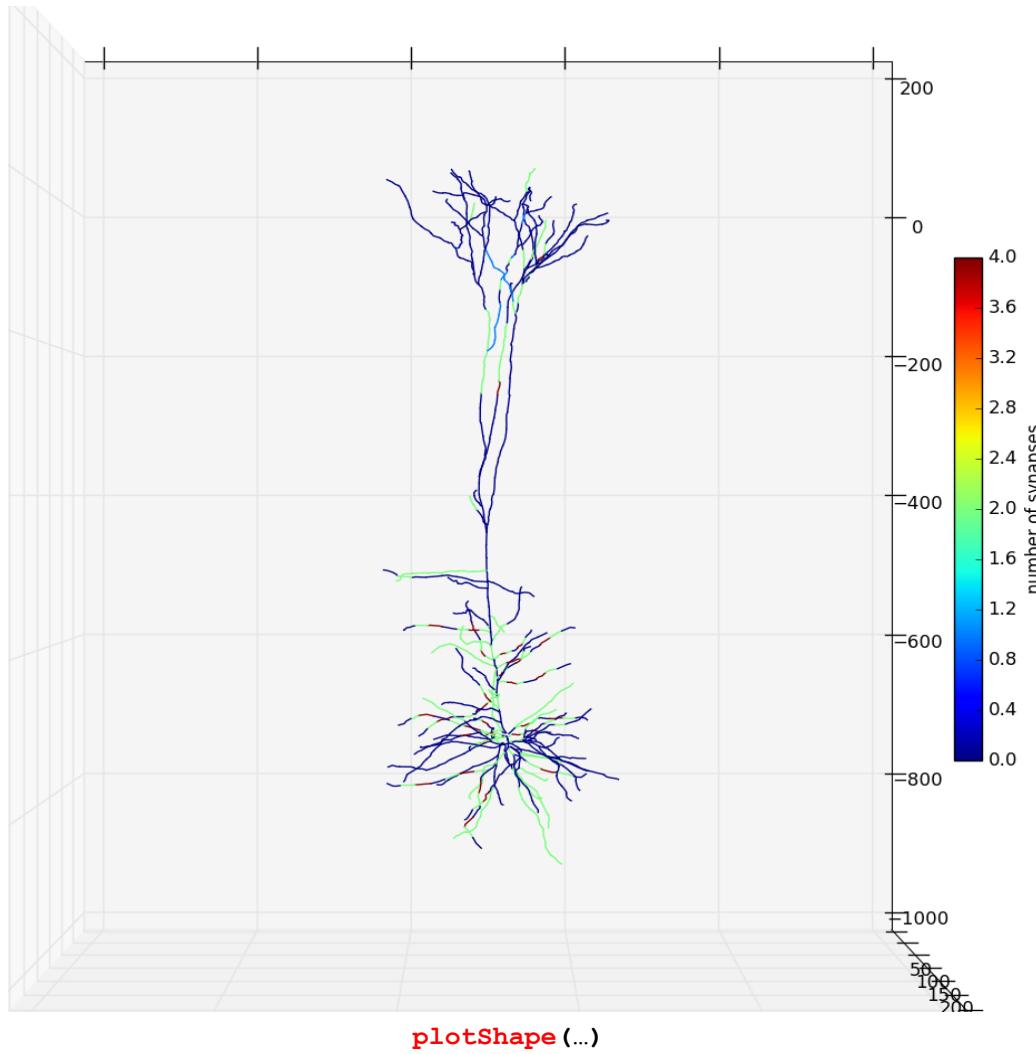
- **Connectivity matrix** at cell or population level (weights, num connections, probability,...)



```
plotConn(include = ['allCells'], feature='strength',
groupBy='pop', figSize=(9,9), showFig=True)
```

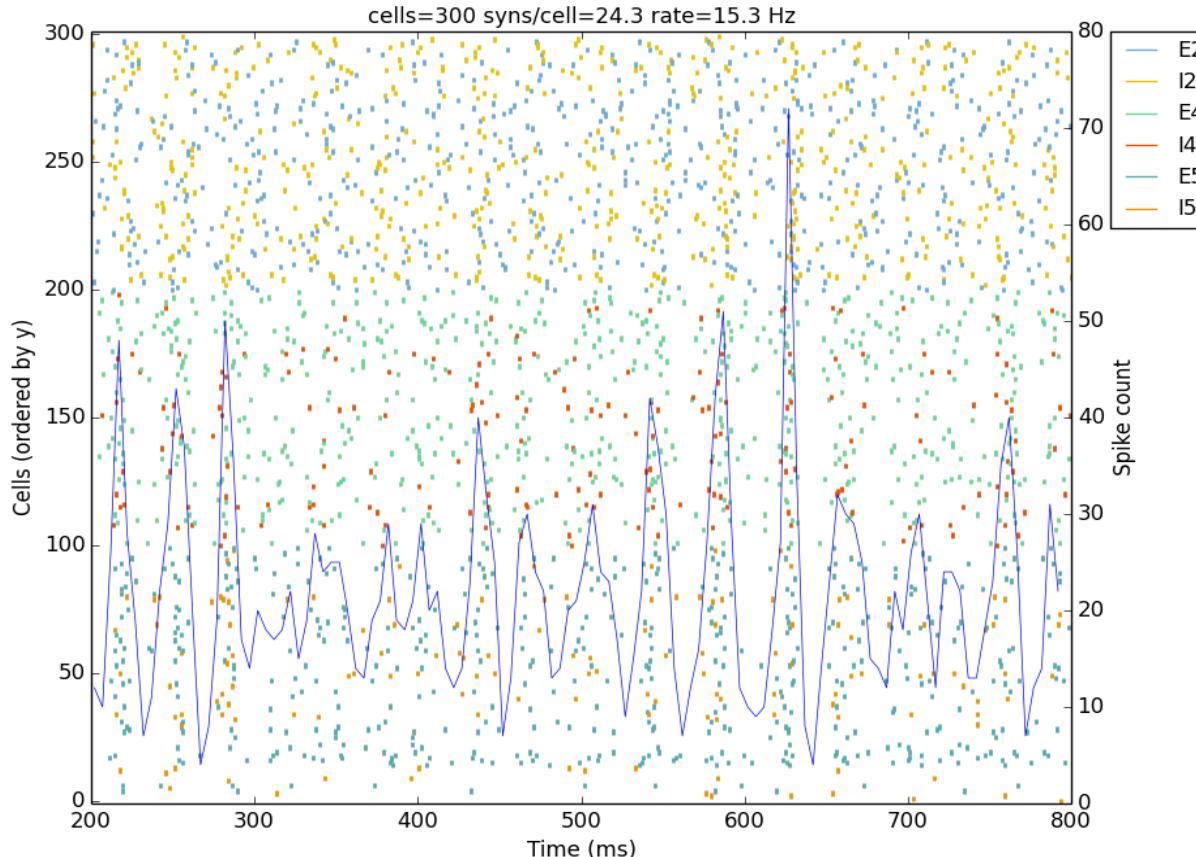
NetPyNE: Analysis

- 3D cell shape plot
- Option to include **color-coded variables** (eg, num of synapses)



NetPyNE: Analysis

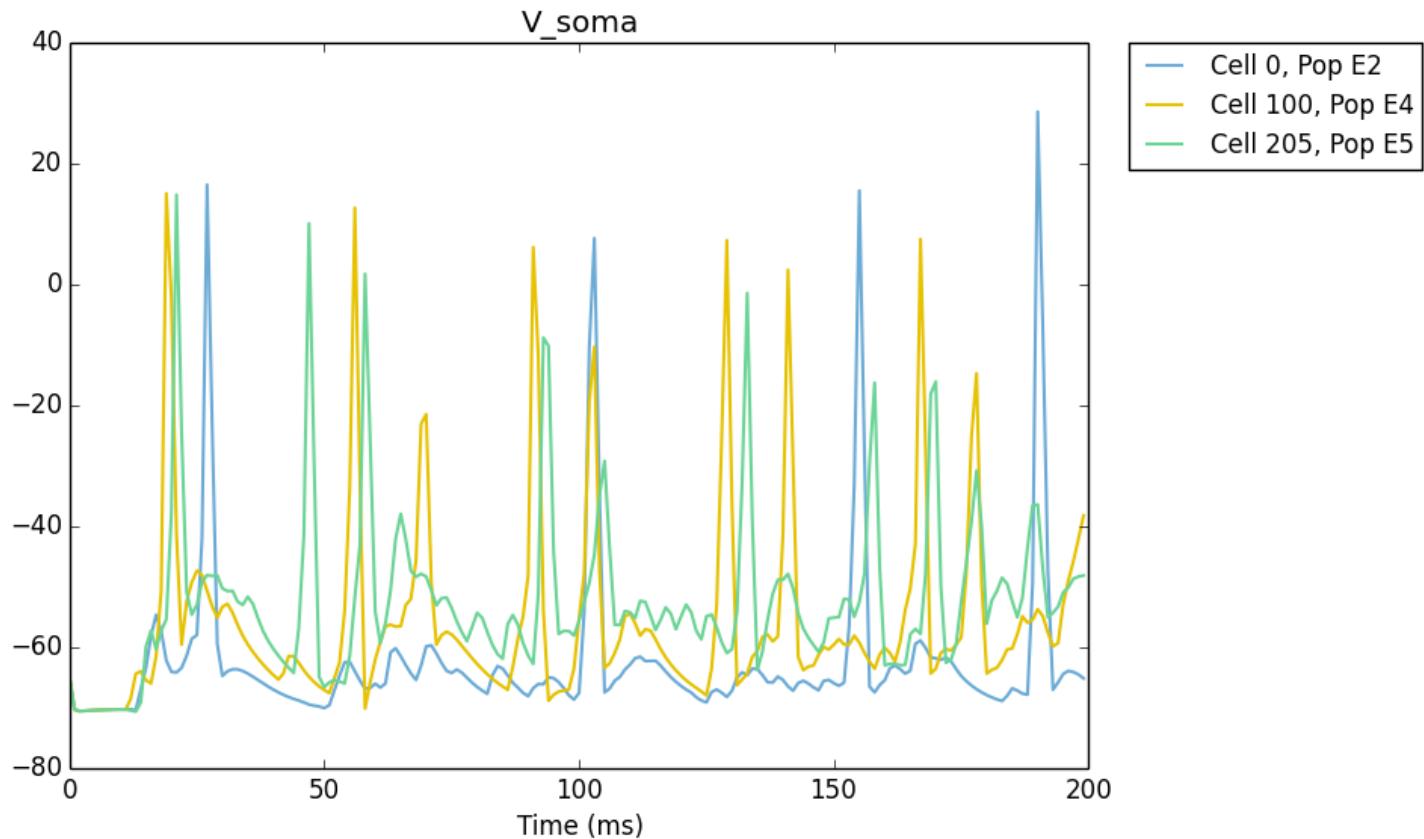
- Easy-to-use functions for **analysis and plotting** of network and simulation output
 - **Raster plot** of any subset of cells
 - **Spike histogram** of populations or subsets of cells



```
plotRaster(include=['allCells'], timeRange=[200,800], orderBy='y',
orderInverse=True, spikeHist='overlay', spikeHistBin=5)
```

NetPyNE: Analysis

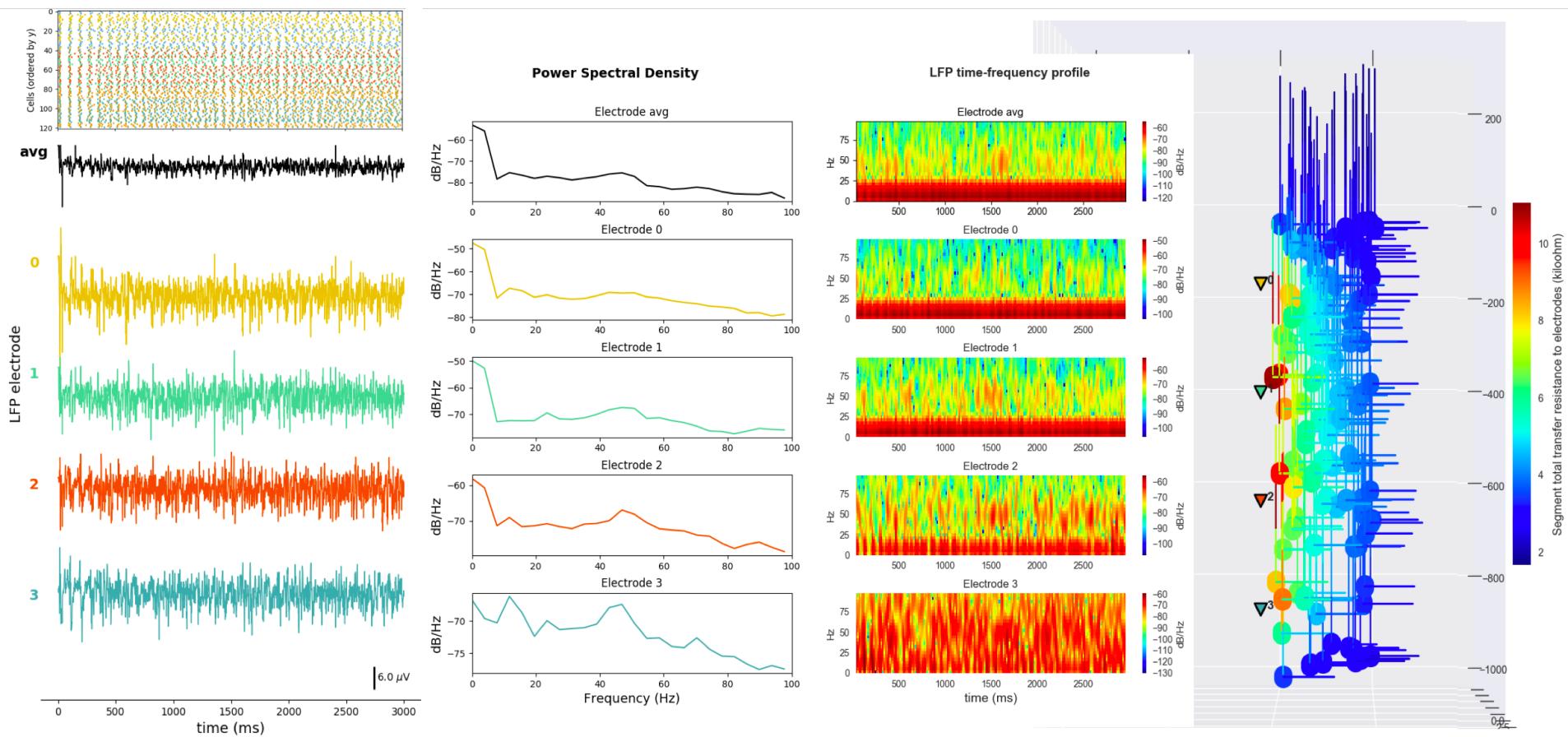
- Intrinsic cell variables (voltages, currents, conductance) **trace plots**



```
plotTraces(include=[('E2',0), ('E4',0), ('E5',5)],  
           timeRange=[0,200], overlay=True, oneFigPer='trace')
```

NetPyNE: Analysis

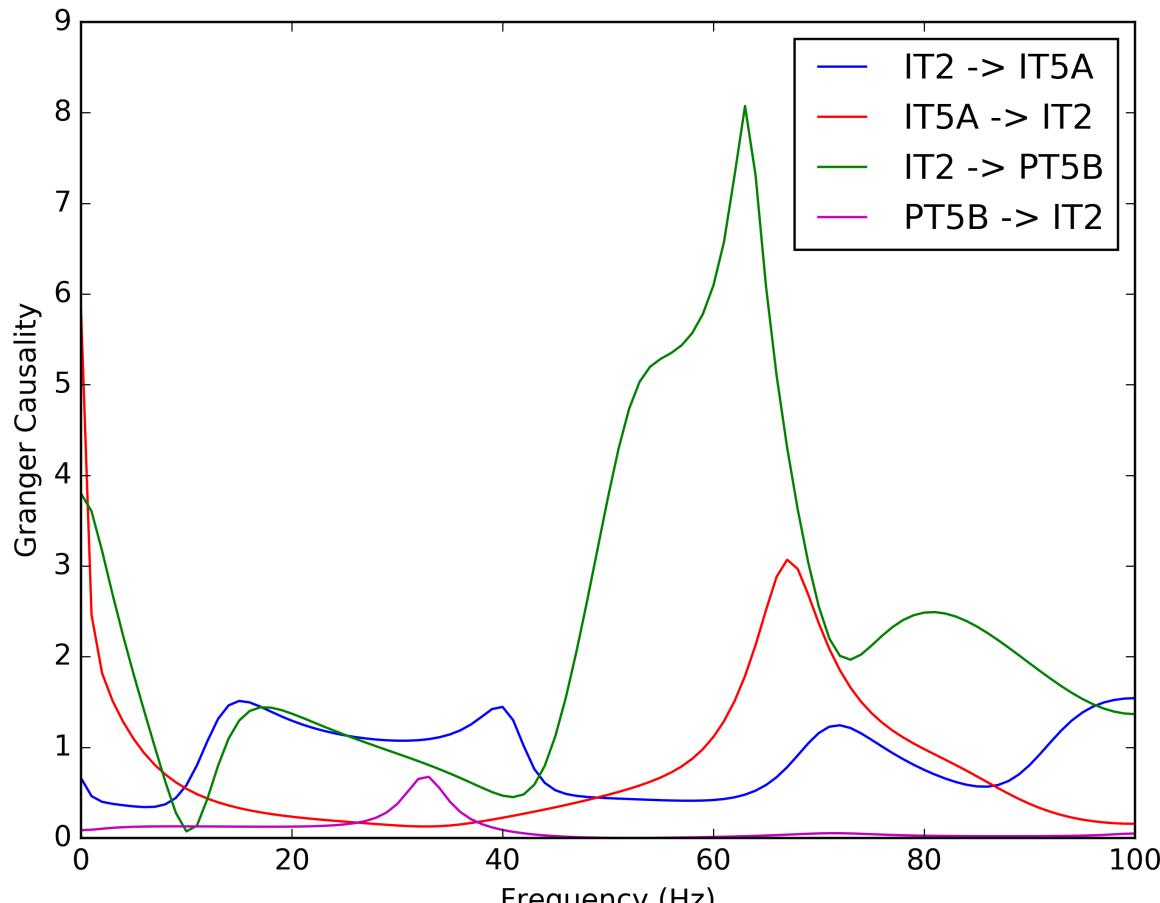
- LFP time-series, PSD, spectrogram and electrode locations



`plotLFP(...)`

NetPyNE: Analysis

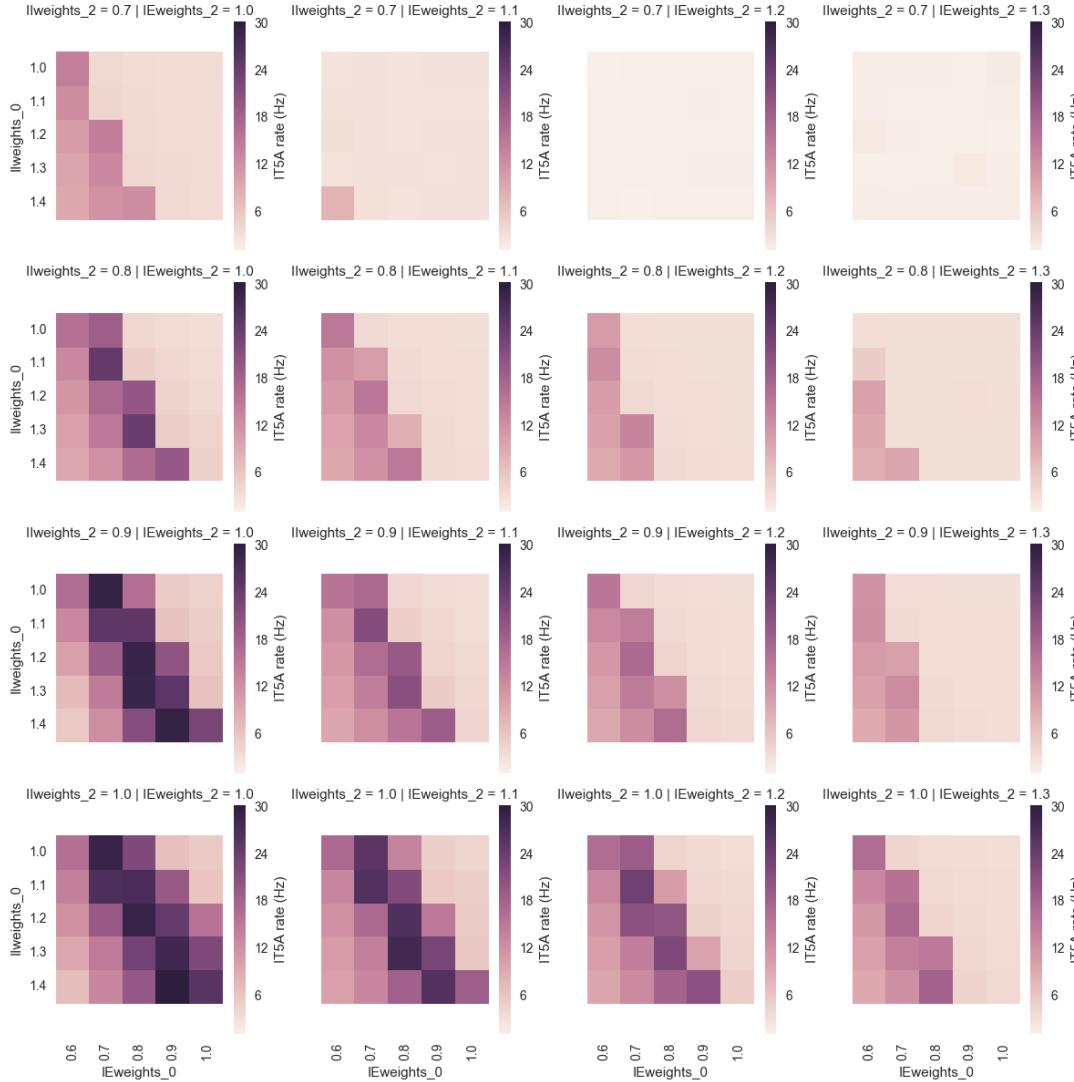
- Spectral **Granger causality**
- Normalized transfer entropy



`plotGranger(...)`

NetPyNE: Analysis

- Analysis and visualization of multidimensional batch simulation results.



NetPyNE: Data saving and exporting

- **Save and load** high-level specifications, network instance, simulation config and/or simulation results.
- **Multiple formats** supported: pickle, Matlab, JSON, CSV, HDF5
- **Export/import** network instance to/from **NeuroML**, the standard format for neural models.

{JSON}



HDF

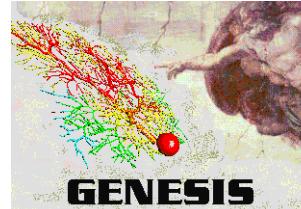
NetPyNE: Data saving and exporting



Import/export to standard format



Import/export to other simulators



NetPyNE: Documentation and Tutorials

www.netpyne.org

Welcome to NetPyNE's documentation!

NetPyNE is a python package to facilitate the development and parallel simulation of biological cell networks using the NEURON simulator.

Table of Contents

- [Overview](#)
 - [What is NetPyNE?](#)
 - [What can I do with NetPyNE?](#)
 - [Main Features](#)
- [Installation](#)
 - [Requirements](#)
 - [Install via pip](#)
- [Tutorial](#)
 - [Very simple and quick example](#)
 - [Network parameters](#)
 - [Simulation configuration options](#)
 - [Network creation and simulation](#)
 - [Adding a compartment \(dendrite\) to cells](#)
 - [Using a simplified cell model \(Izhikevich\)](#)
- [Package Reference](#)
 - [Model components and structure](#)
 - [Network parameters](#)
 - [Simulation configuration](#)
 - [Structure of data and code](#)
 - [Network, Population and Cell classes](#)
 - [Package methods](#)
 - [Structure of saved data](#)

NetPyNE: Q&A Forums



The screenshot shows the NetPyNE forum page on the website www.neuron.yale.edu. The page has a blue header with the site logo and navigation links for "Quick links", "FAQ", "Register", and "Login". Below the header, there's a breadcrumb trail: "Board index < Tools of interest to NEURON users < NetPyNE". The main content area is titled "NetPyNE" and shows a "Moderator: tom_morse". It features two sections: "ANNOUNCEMENTS" and "TOPICS".

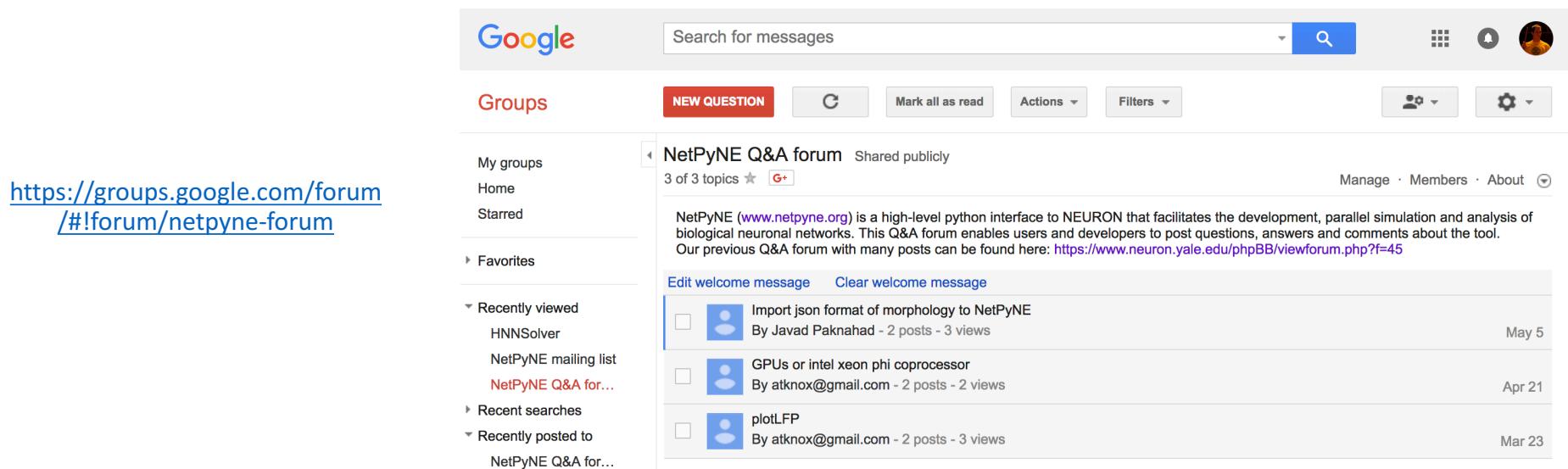
ANNOUNCEMENTS

	REPLIES	VIEWS	LAST POST
VERSION RELEASES by salvadord » Fri Jun 09, 2017 10:41 pm	12	7554	by bremen Sat Apr 28, 2018 4:05 pm
Welcome to the NetPyNE Forum! by salvadord » Tue May 16, 2017 10:50 pm	0	7863	by salvadord Tue May 16, 2017 10:50 pm

TOPICS

	REPLIES	VIEWS	LAST POST
Spike source and target sections by salvadord » Mon Nov 27, 2017 12:03 pm	17	4342	by bremen Sat May 12, 2018 12:07 pm
Import json format of morphology to NetPyNE by Javad » Fri May 04, 2018 3:02 pm	2	75	by ted Sun May 06, 2018 1:30 pm
Slow speed to save sim results by bremen » Sat Apr 21, 2018 10:32 am	2	51	by bremen Sat Apr 28, 2018 3:15 pm
Field names are restricted to 31 characters by bremen » Sat Mar 24, 2018 1:36 pm	2	55	by bremen Sun Mar 25, 2018 6:21 am
plotLFP by atknox » Fri Mar 02, 2018 6:44 pm	1	72	by salvadord Wed Mar 21, 2018 6:20 pm
Mat file not saved properly in batch functions by Vittorio » Thu Feb 15, 2018 10:58 am	1	91	by salvadord Thu Feb 15, 2018 11:30 am
Gap junction support - parallel simulation? by tmc » Wed Jan 24, 2018 10:18 pm	3	108	by salvadord Thu Feb 08, 2018 12:41 pm

<https://www.neuron.yale.edu/phpBB/viewforum.php?f=45&sid=99554ea5df10540d9b31e0c74929eaf0>



The screenshot shows the Google Groups forum for the "NetPyNE Q&A forum". The page has a header with the Google logo, a search bar, and user profile icons. The main content area shows the forum's details and a list of recent posts.

Groups

[NEW QUESTION](#) [C](#) [Mark all as read](#) [Actions](#) [Filters](#) [Members](#) [About](#)

NetPyNE Q&A forum Shared publicly
3 of 3 topics [G+](#)

NetPyNE (www.netpyne.org) is a high-level python interface to NEURON that facilitates the development, parallel simulation and analysis of biological neuronal networks. This Q&A forum enables users and developers to post questions, answers and comments about the tool. Our previous Q&A forum with many posts can be found here: <https://www.neuron.yale.edu/phpBB/viewforum.php?f=45>

[Edit welcome message](#) [Clear welcome message](#)

<input type="checkbox"/>  Import json format of morphology to NetPyNE By Javad Paknahad - 2 posts - 3 views	May 5
<input type="checkbox"/>  GPUs or intel xeon phi coprocessor By atknox@gmail.com - 2 posts - 2 views	Apr 21
<input type="checkbox"/>  plotLFP By atknox@gmail.com - 2 posts - 3 views	Mar 23

<https://groups.google.com/forum/#!forum/netpyne-forum>

NetPyNE: GUI

DEFINE YOUR NETWORK EXPLORE YOUR NETWORK

Cell rules
Define here the rules to generate the cells in your network

Pyramidal > Section 3 > +

depth
0.102468419281

kd
0.0

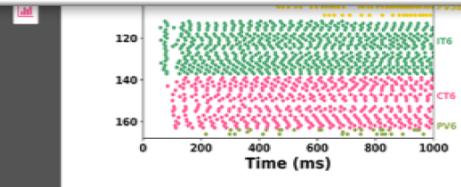
kt
0.0

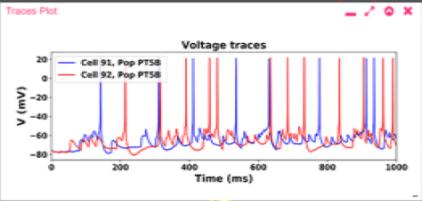
cal can hcn cadad

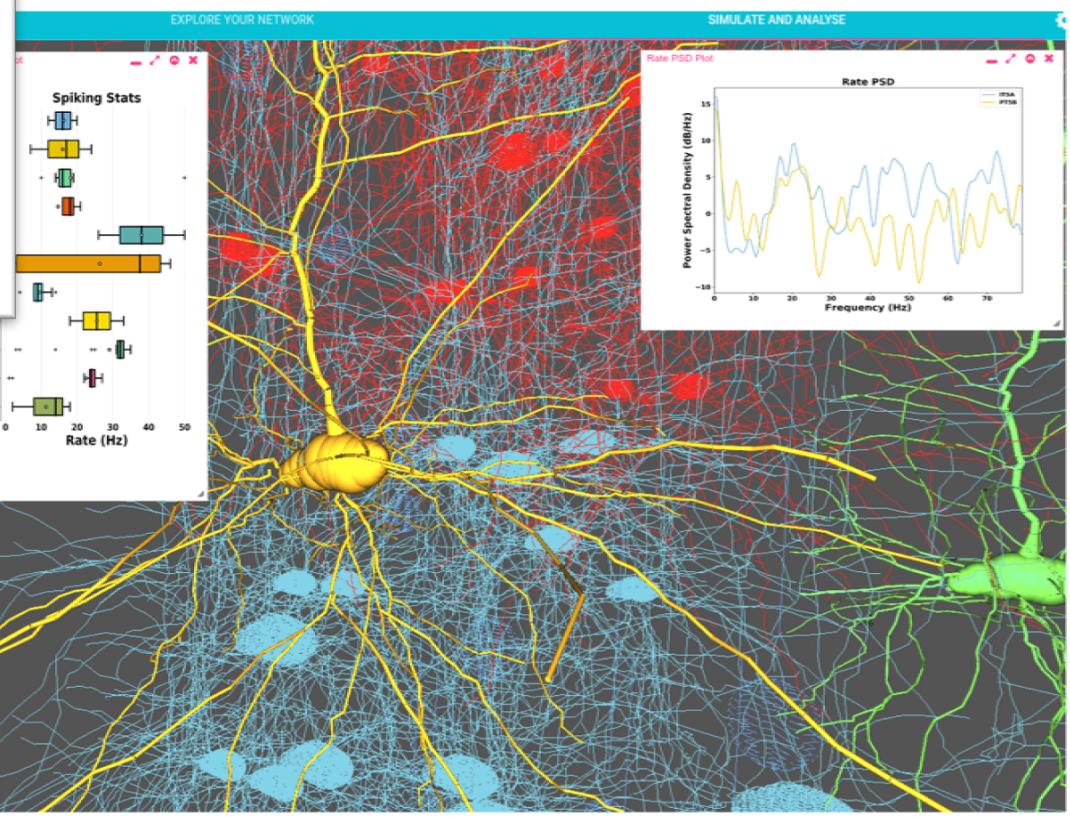
Connectivity rules
Define here the rules to generate the connections in your network

Pyr → Pyr Pyr → FS FS → FS

presynaptic conditions + postsynaptic conditions



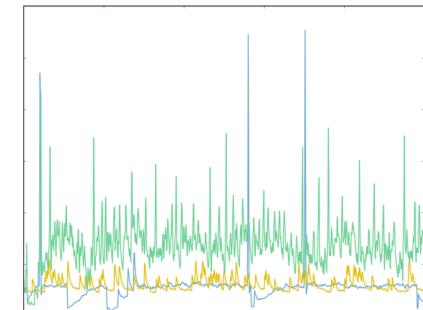
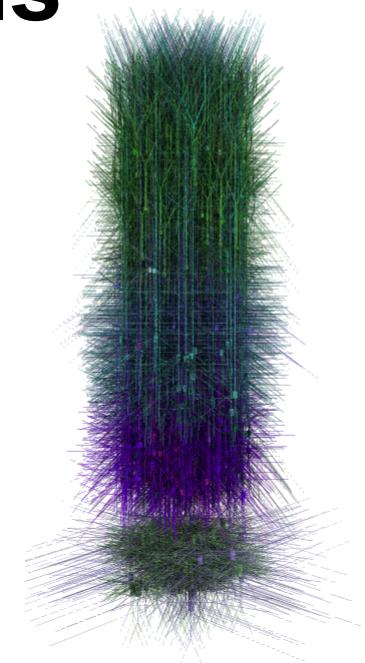




NetPyNE: Existing models

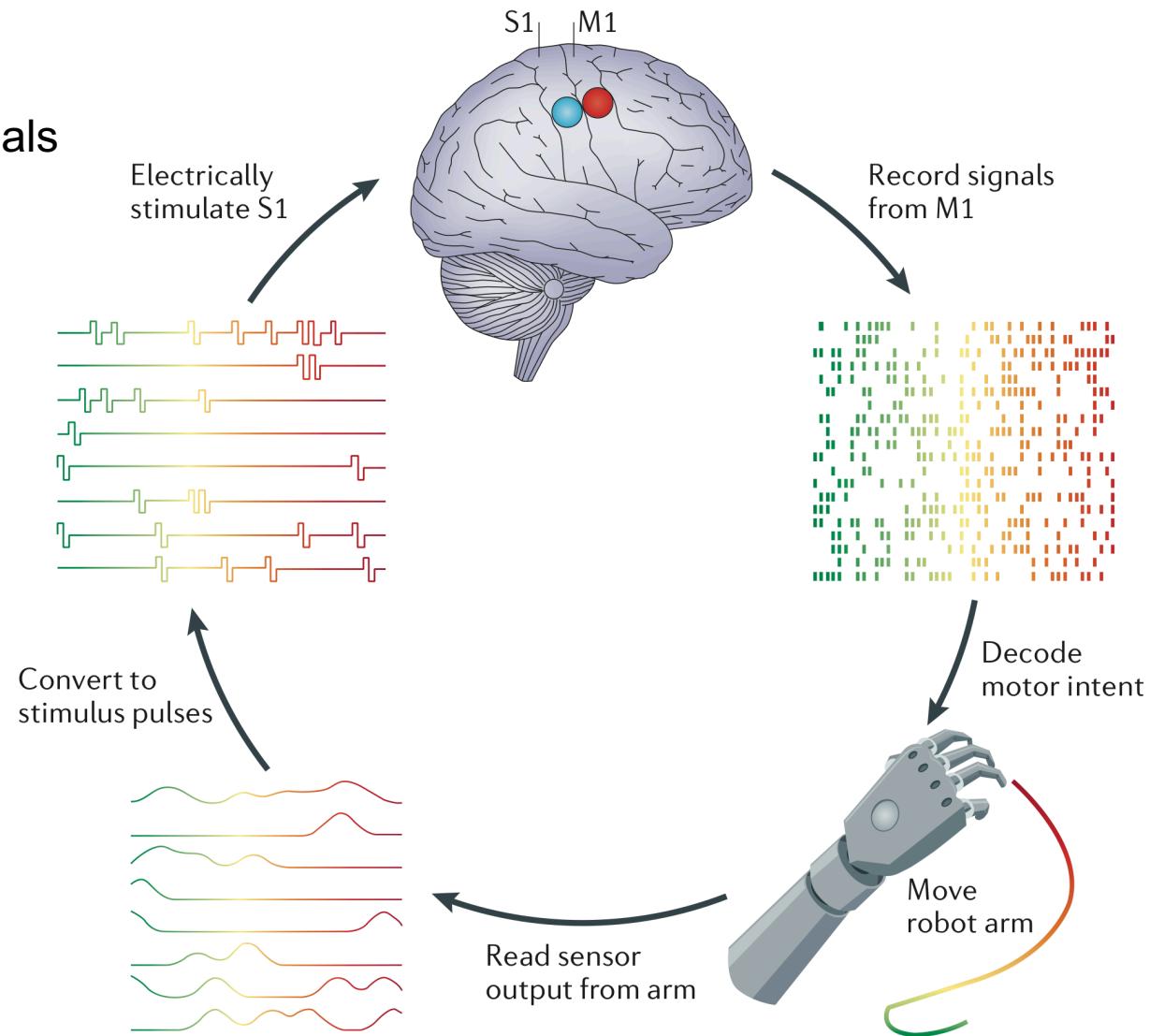
□ Other models in progress:

- Traub **thalamocortical** network (Padraig Gleeson, UCL)
- Hippocampus **CA3** (Ben Tessler, SUNY DMC)
- **Ischemia** in cortical network (Alex Seidenstein, SUNY DMC)
- **STDP** in biophysically detailed networks (Anatoly Buchin, Allen Brain)
- **Basal Ganglia** network (Lucas, UCD)
- **LFP** oscillations (Christian Fink, Ohio Wesleyan)
- **Dendritic** computations (Birgit Kriener, Oslo)
- Thalamocortical **epilepsy** network (Andrew Knox, Cincinnati Hospital)
- **V1** network with Allen Brain cells (SUNY DMC)
- **Schizophrenia** in cortical network (Cristoph Metzner, Hertfordshire)
- **Spinal cord** circuits (Vittorio Caggiano, IBM Watson)
- Full list of 43 models: <https://drive.google.com/open?id=1bkWHakgZoEkYIkzrAS8sIKCvO5PSuUXLLRjNdN2pseY>



NetPyNE: M1 microcircuits

- Read and **decode** brain signals
- Paralyzed patients can control **robot arm**
- ‘**Write**’ back into the brain
- Brain stimulation provides **natural touch** sensation



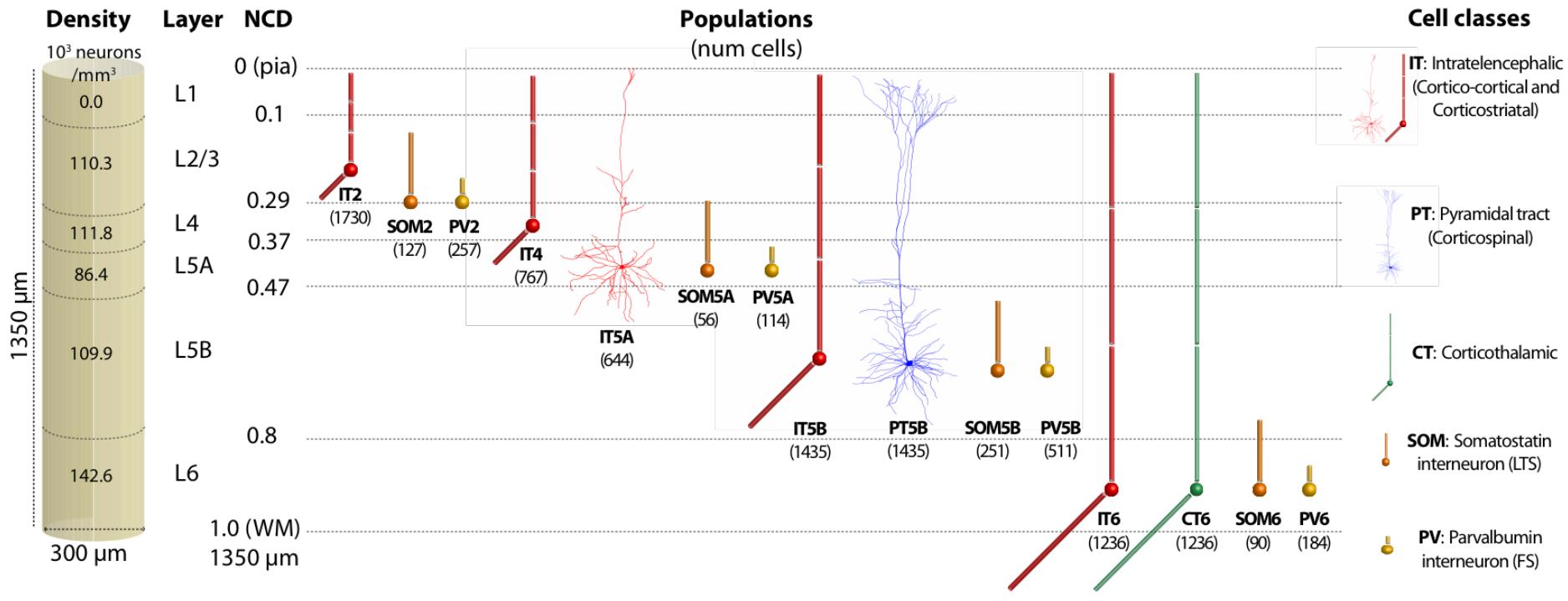
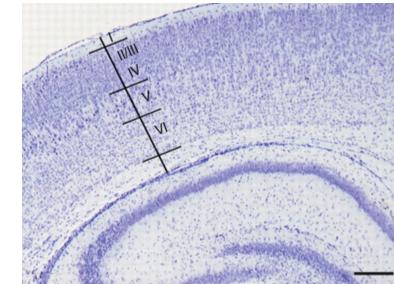
NetPyNE: M1 microcircuits



7'45 – 8'30

NetPyNE: M1 microcircuits

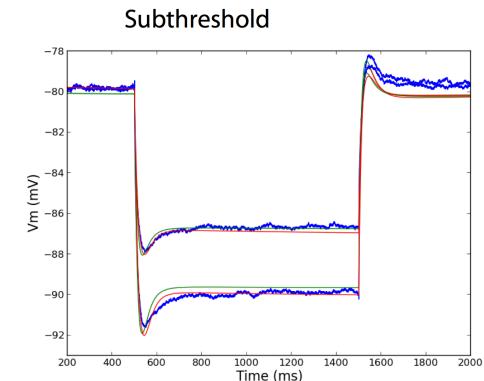
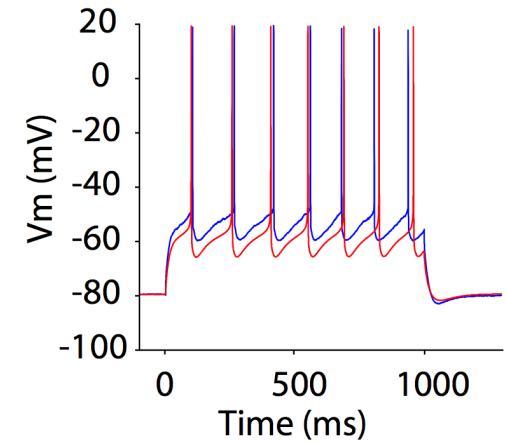
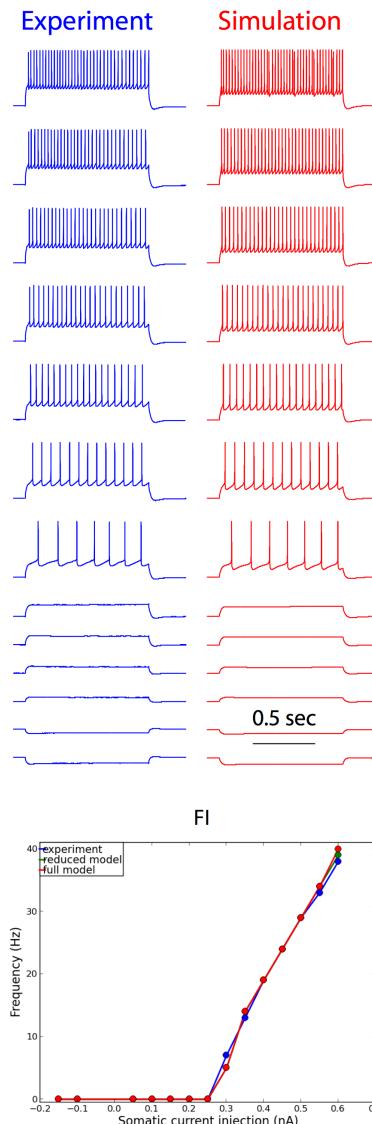
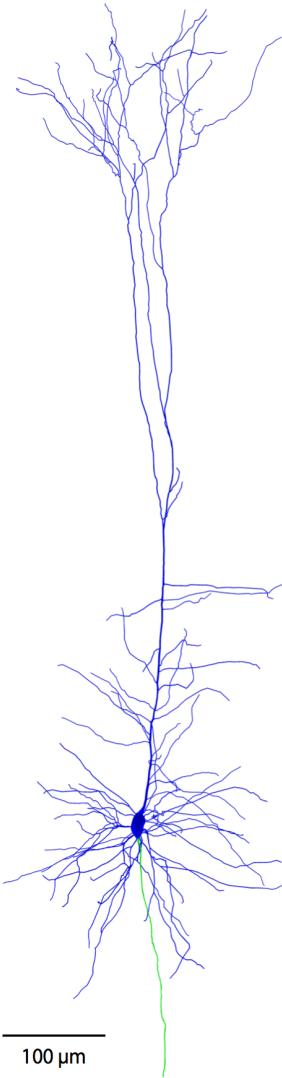
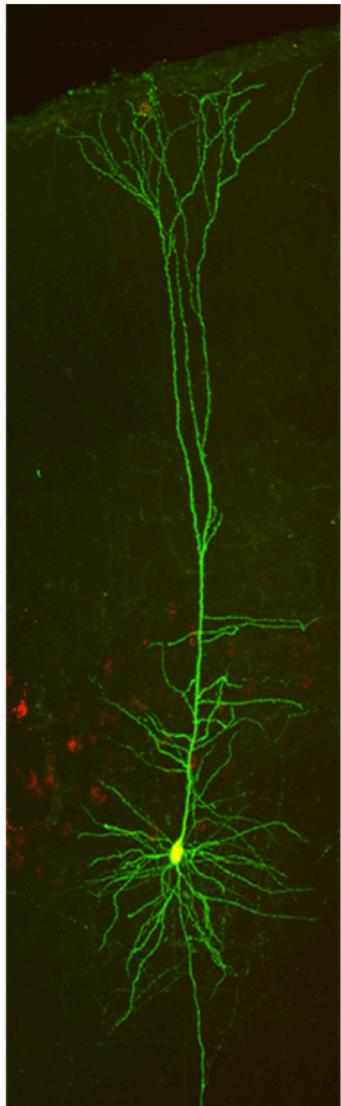
- Data-driven multiscale network model of **M1 microcircuits**



Mouse 6-layer M1 with **10,074 neurons** of 5 classes distributed in 15 populations;
Full scale cylindric volume of **300 μm** (diameter) x **1350 μm** (cortical depth)

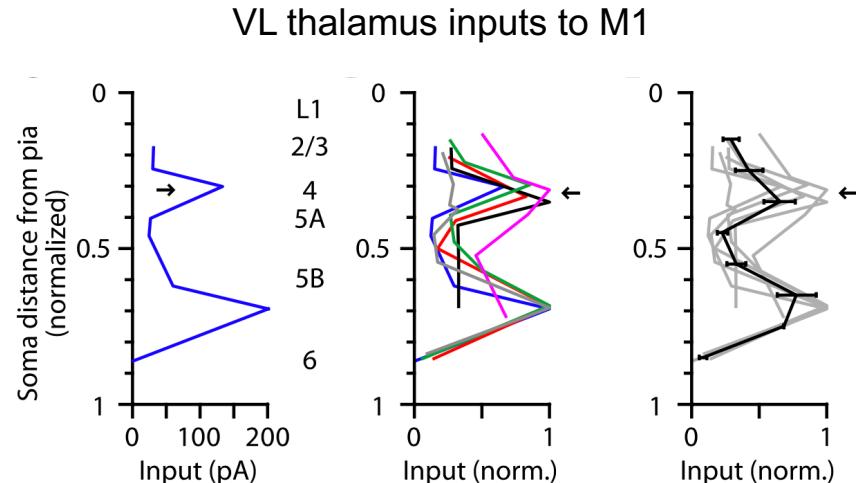
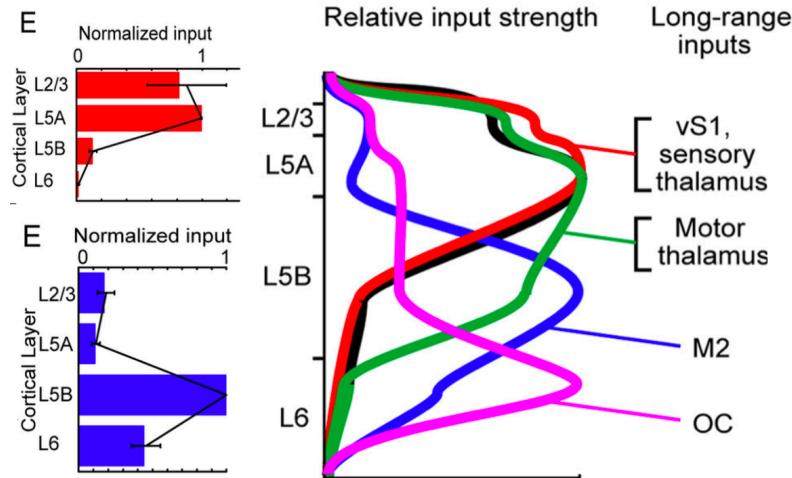
M1 model populations

- Detailed 700+ compartment morphology from 3D reconstructions, and simple 6-compartment
- Ionic channels (Na, Kdr, Ka, Kd, HCN, CaL, CaN, KCa) constrained by literature and optimized to reproduce *in vitro* dynamics.

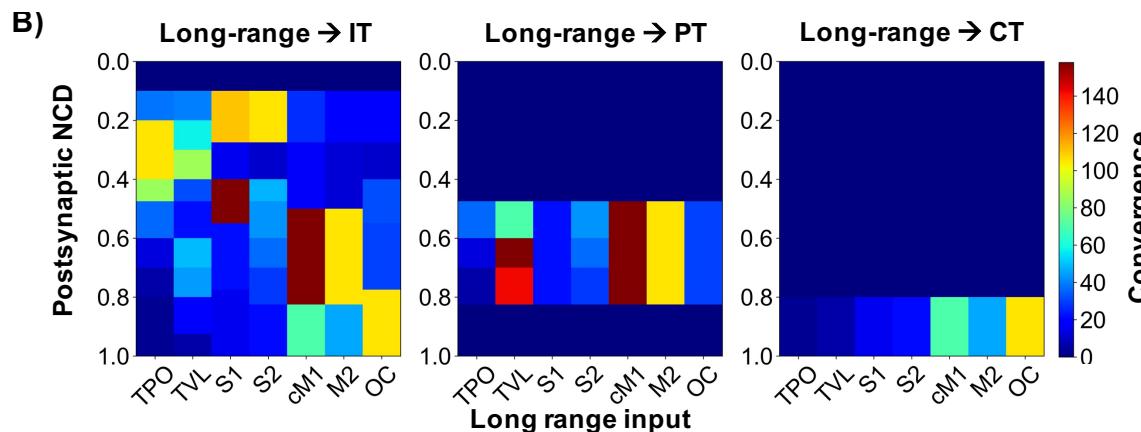


NetPyNE: M1 microcircuits

□ Long-range input connections

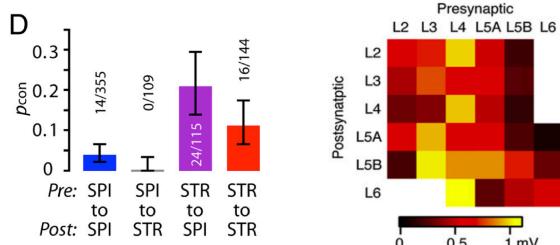
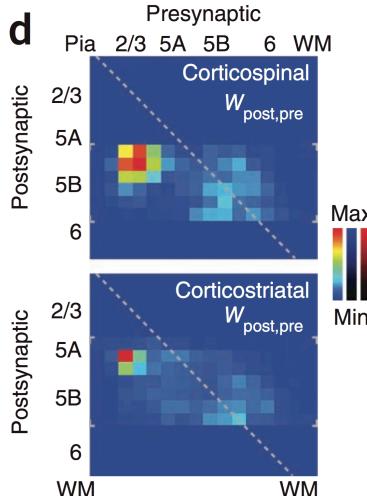
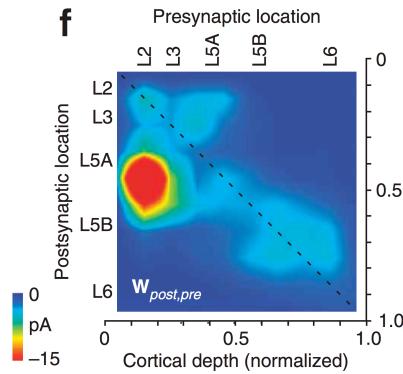


As a function of cortical depth and cell class



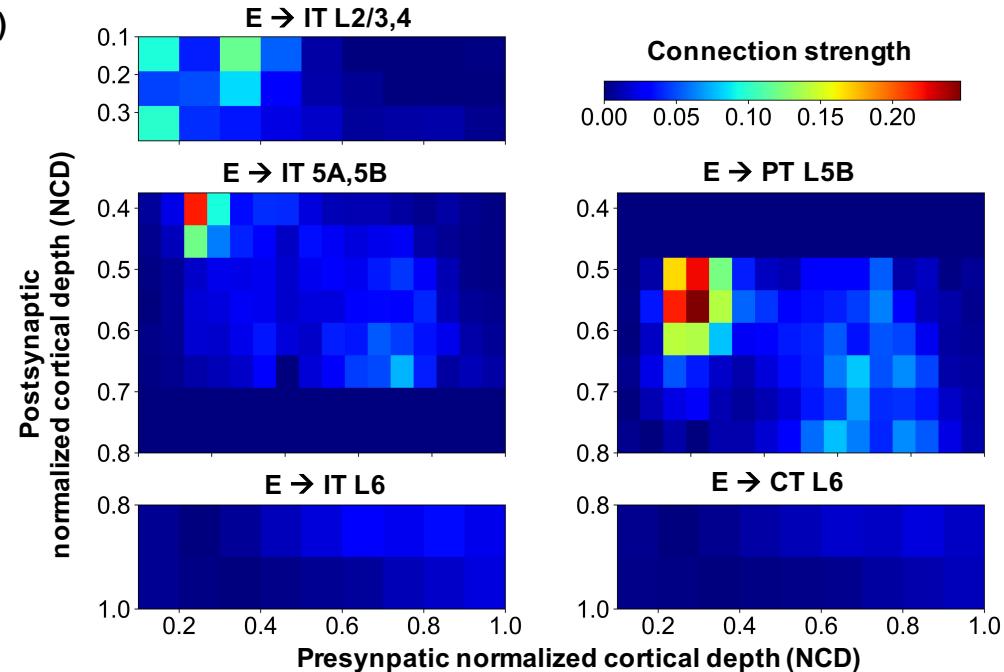
NetPyNE: M1 microcircuits

□ Local microcircuit connectivity



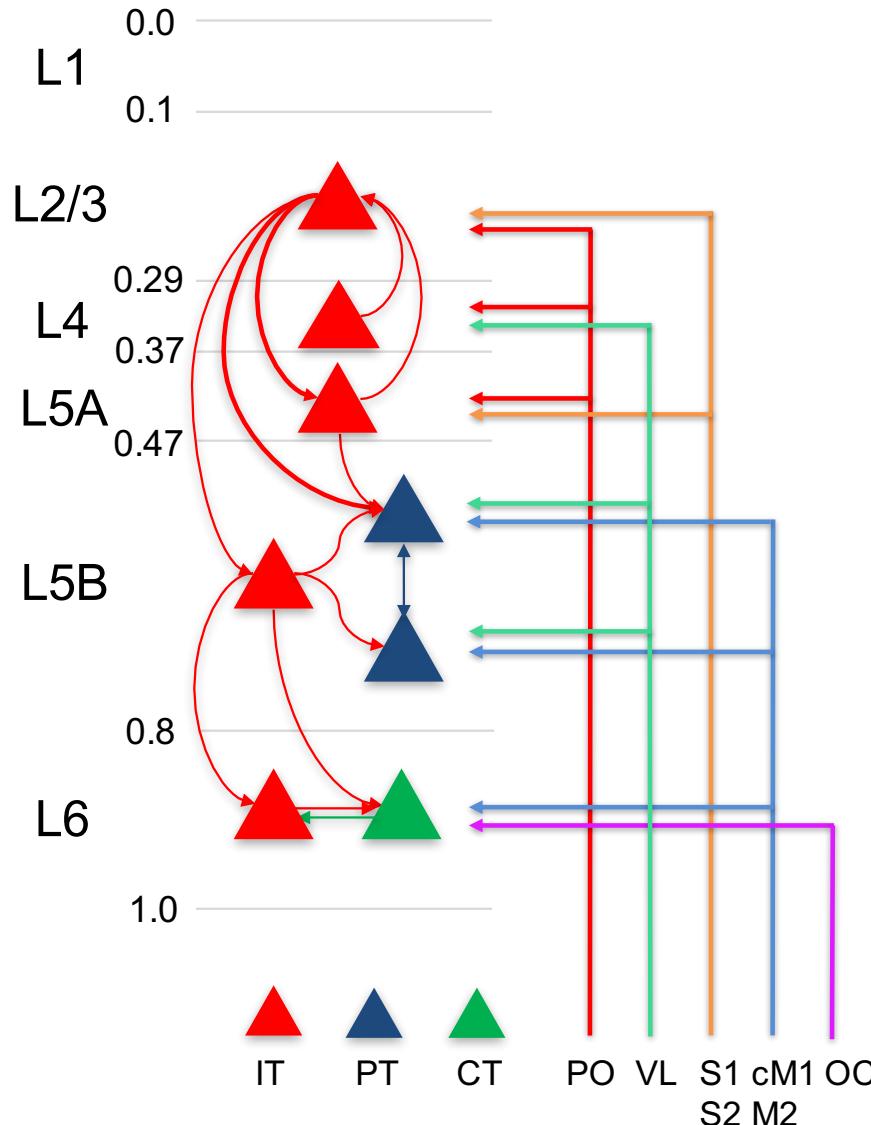
As a function of
cortical depth and
cell class

→



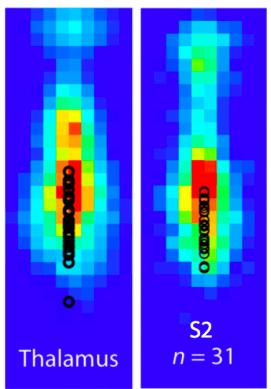
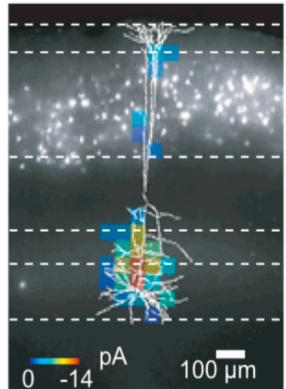
NetPyNE: M1 microcircuits

Main local and long-range excitatory connections

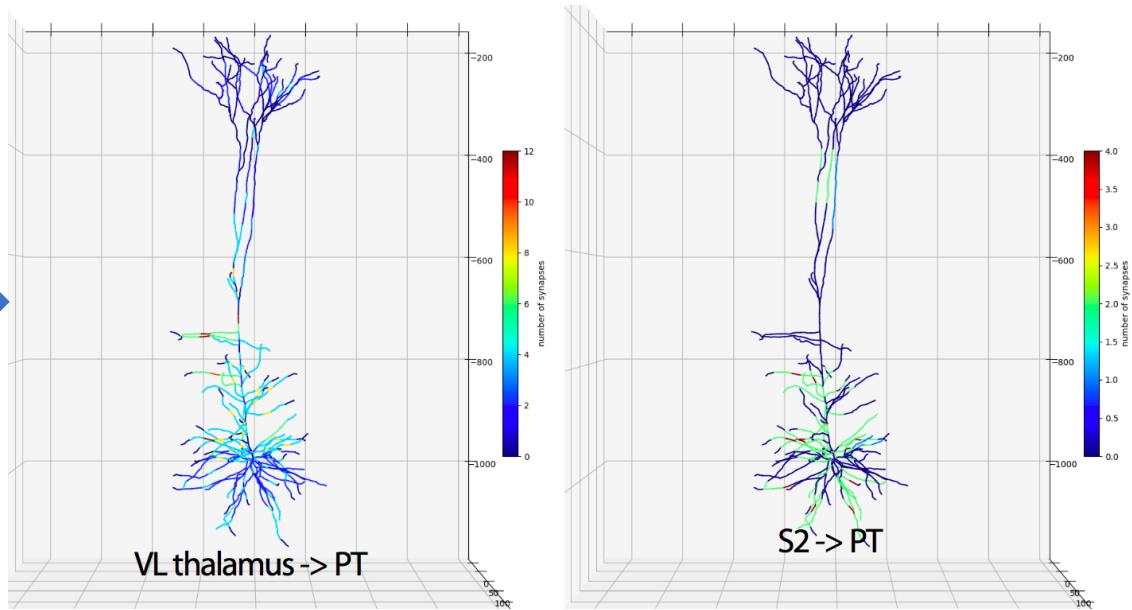
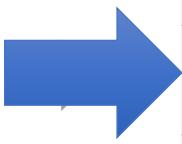


NetPyNE: M1 microcircuits

□ Dendritic distribution of synapses



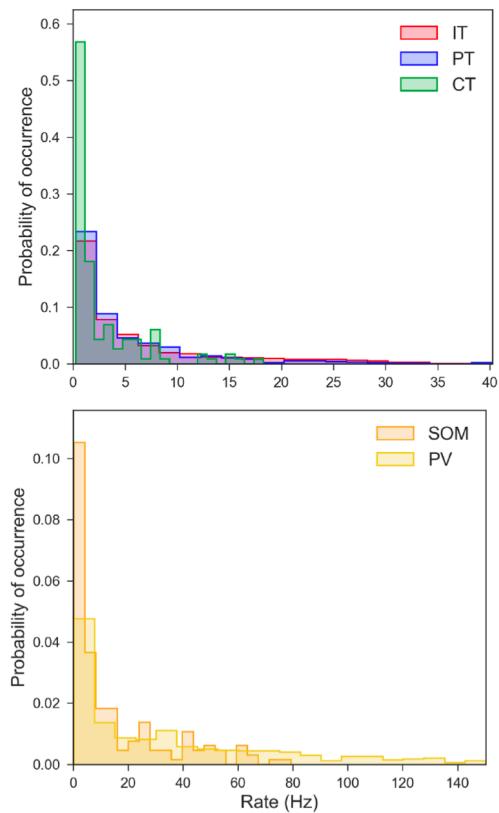
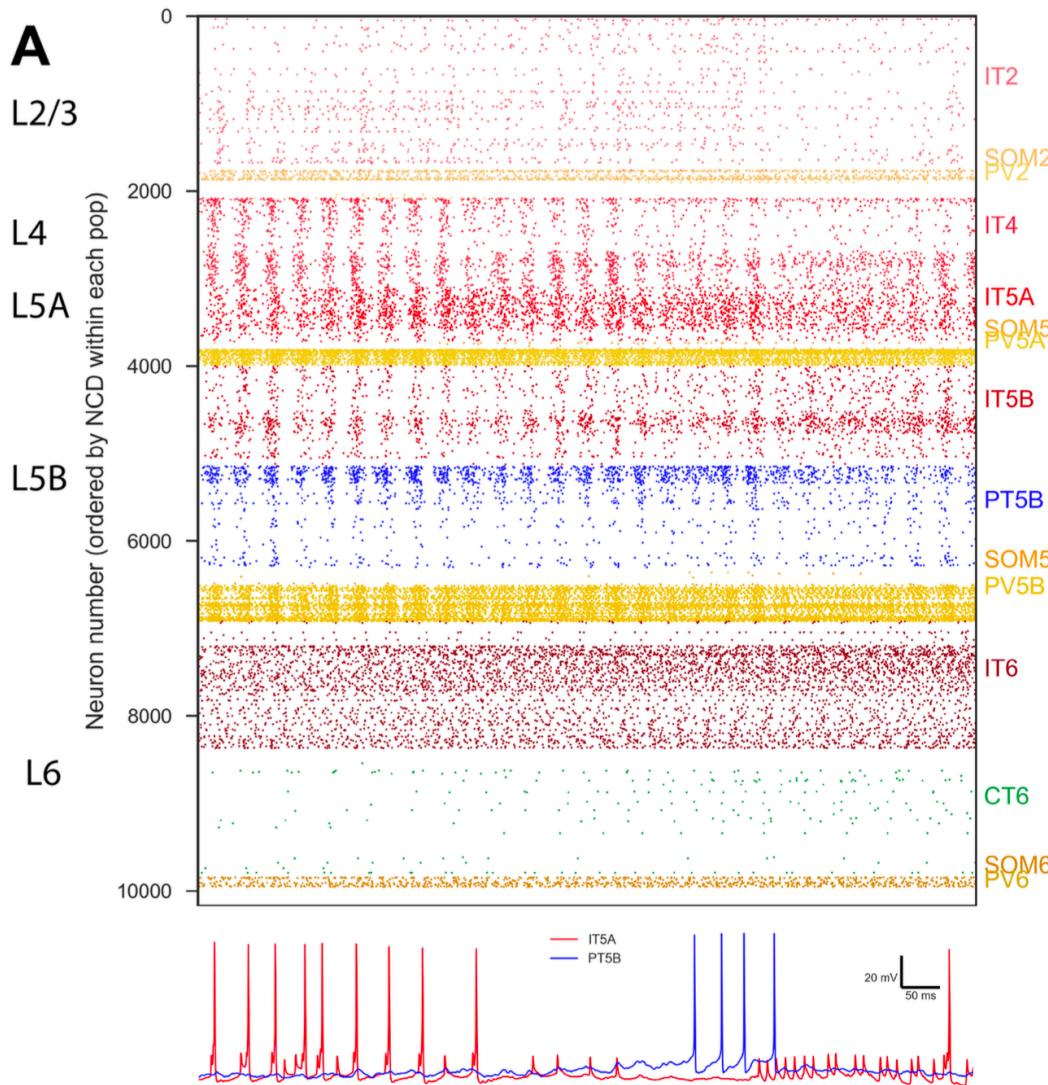
Subcellular ChR2-assisted circuit mapping (sCRACM)



Number of synapses per compartment shows complementary distribution of synaptic inputs from VL vs S2

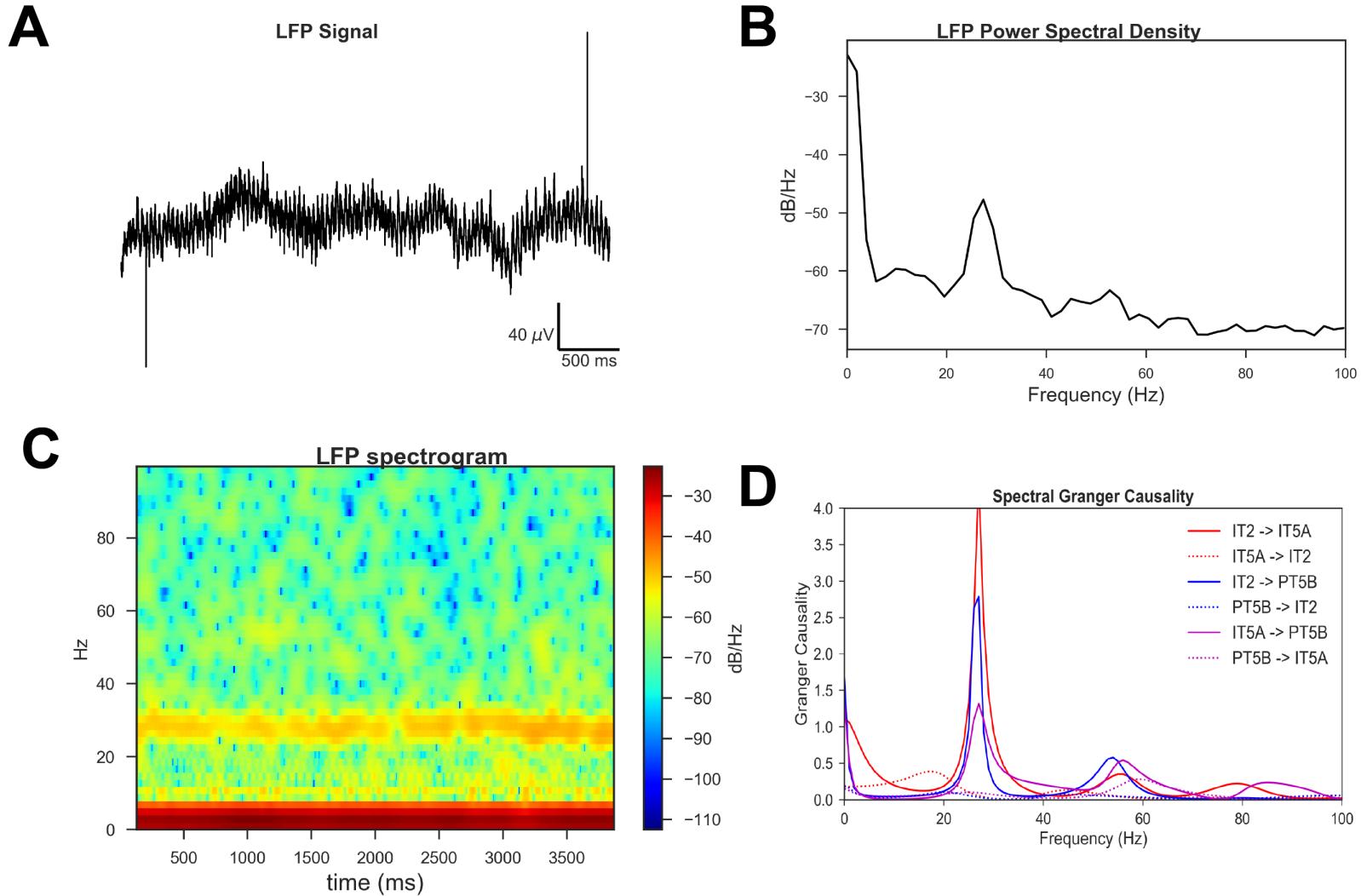
NetPyNE: M1 microcircuits

- Spontaneous activity exhibit distributions and spatial properties that match cortical data.
- Neural activity depends on cell class, cortical layer and sublaminar location, e.g. L5B PT



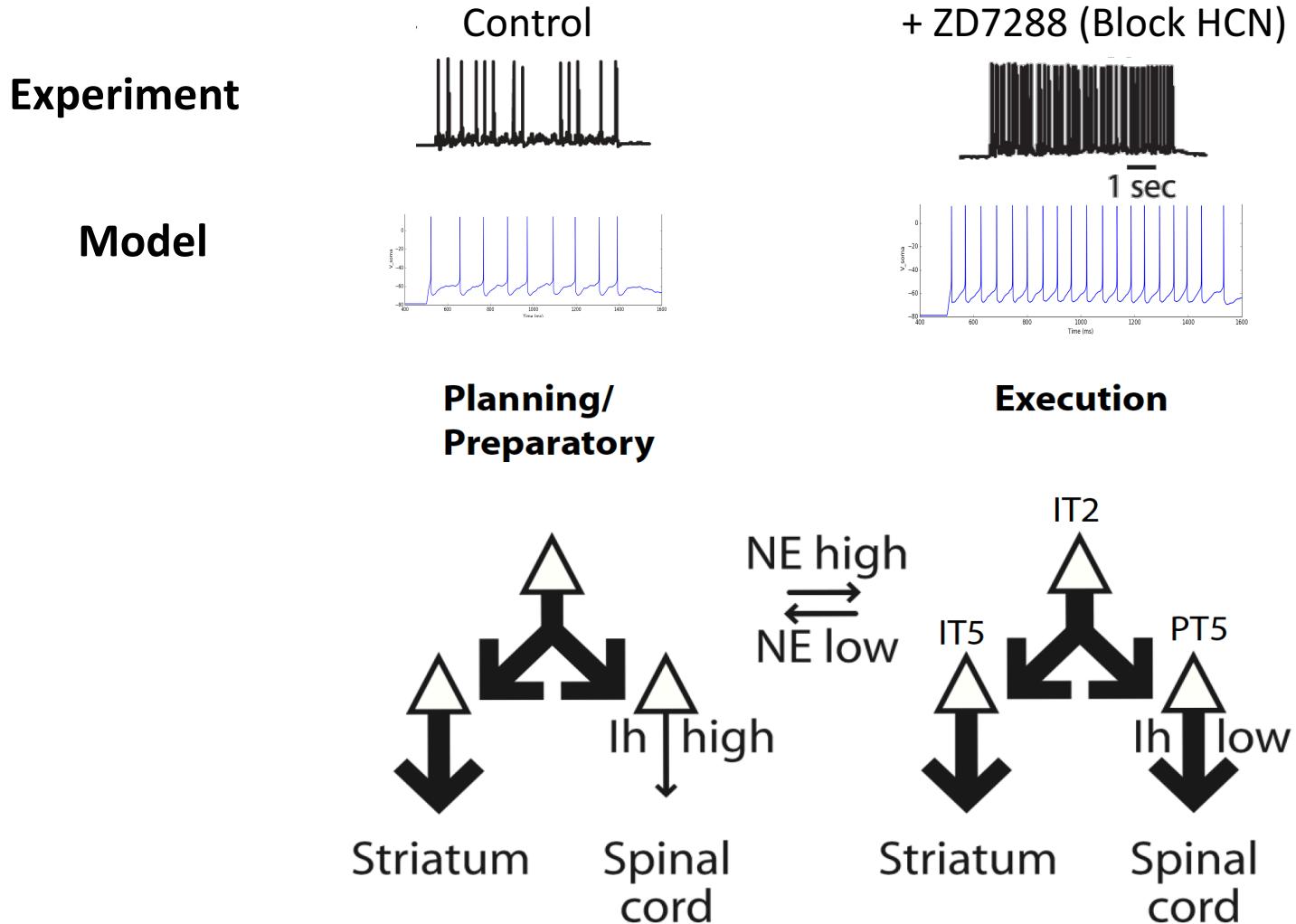
NetPyNE: M1 microcircuits

- **LFP oscillations** in the beta and gamma range emerged in the absence of rhythmic external inputs.
- **Information flowed** from IT->PT but not opposite direction (peak in beta).



NetPyNE: M1 microcircuits

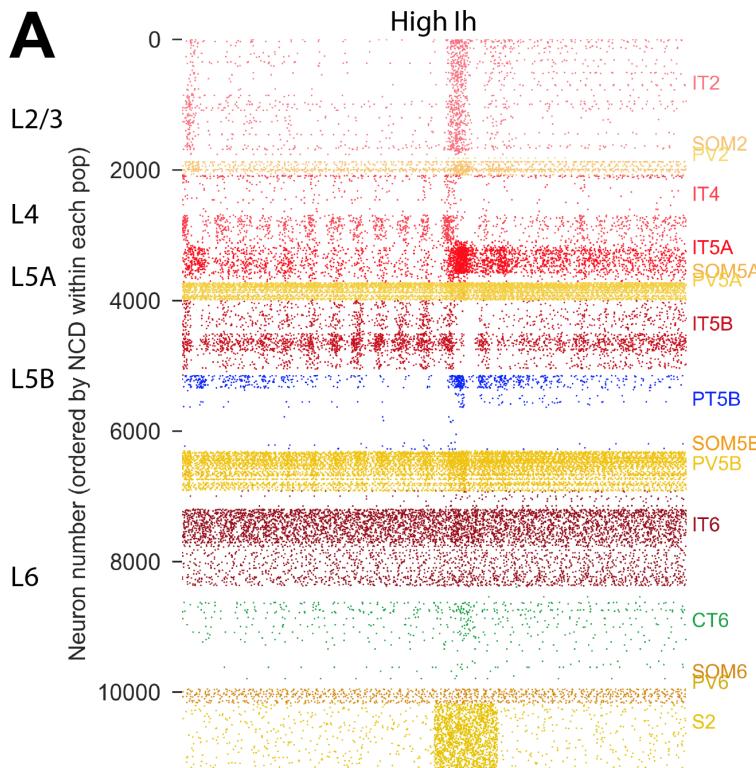
- Evaluate molecular/pharmacological effects in silico
e.g. blocking HCN channels → reduces corticospinal neuron output



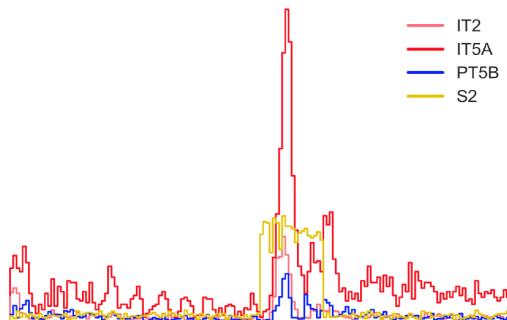
NetPyNE: M1 microcircuits

- Response to pulse from S2 (sensory-related input)

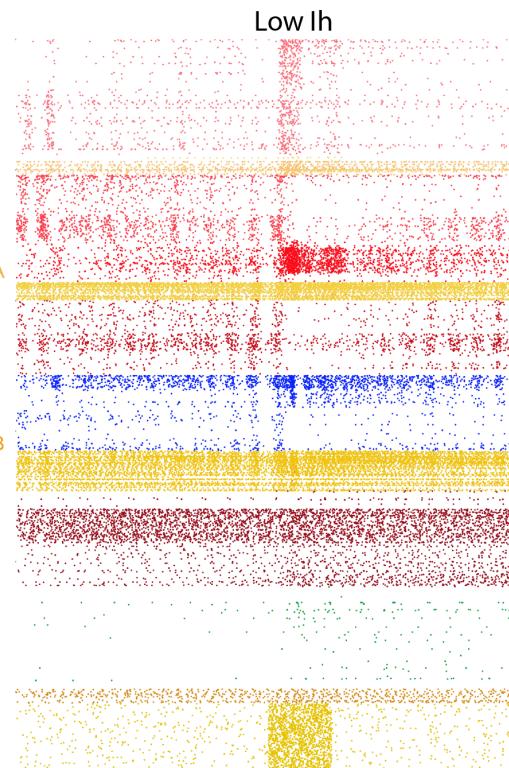
A



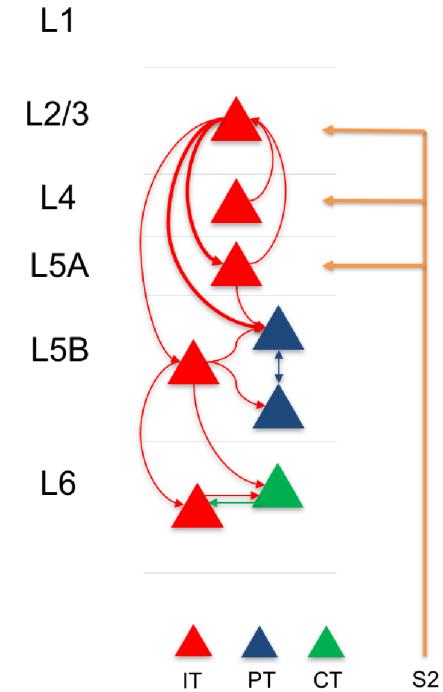
B



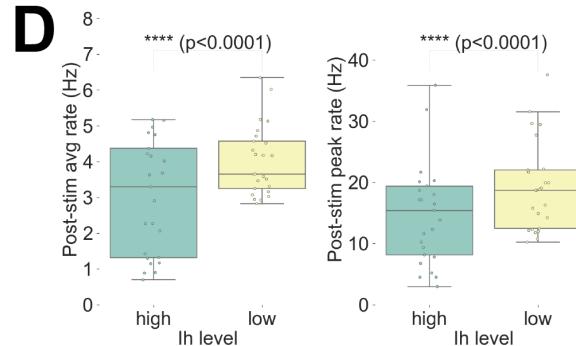
Low Ih



C



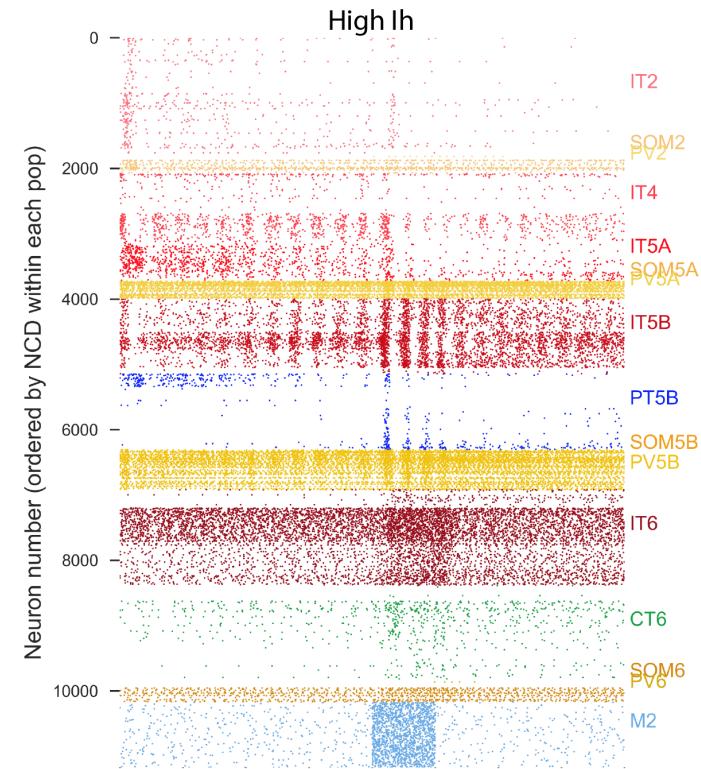
D



NetPyNE: M1 microcircuits

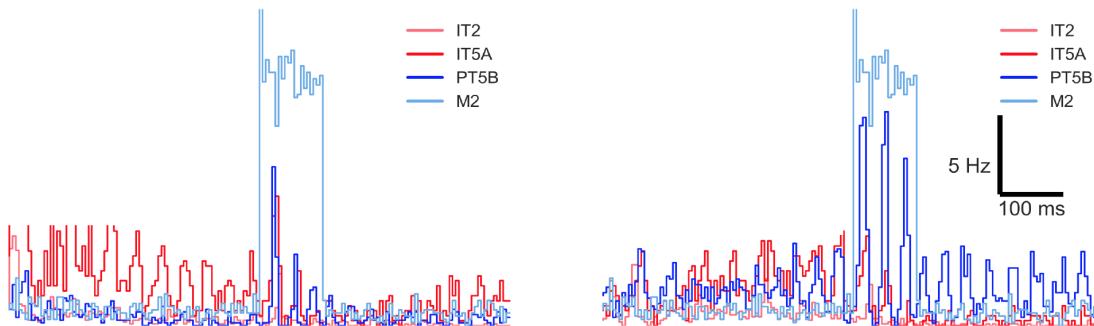
- Response to pulse from M2 (motor-related input)

A

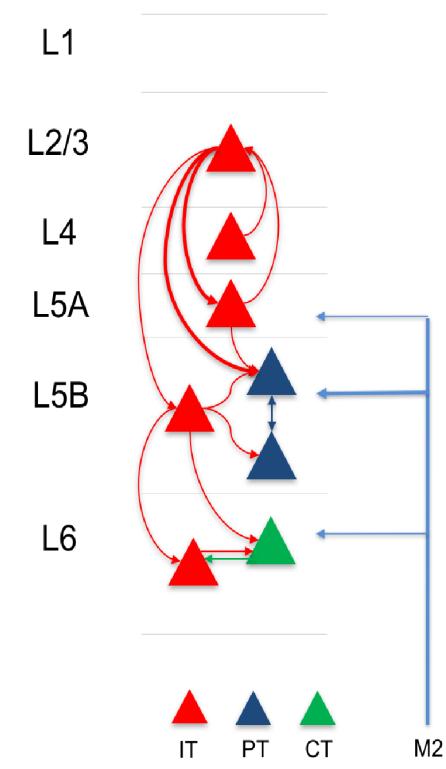


Low I_h

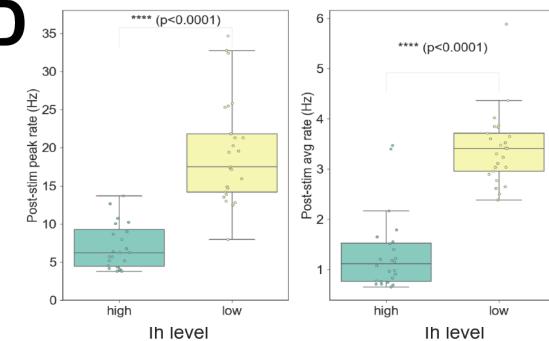
B



C

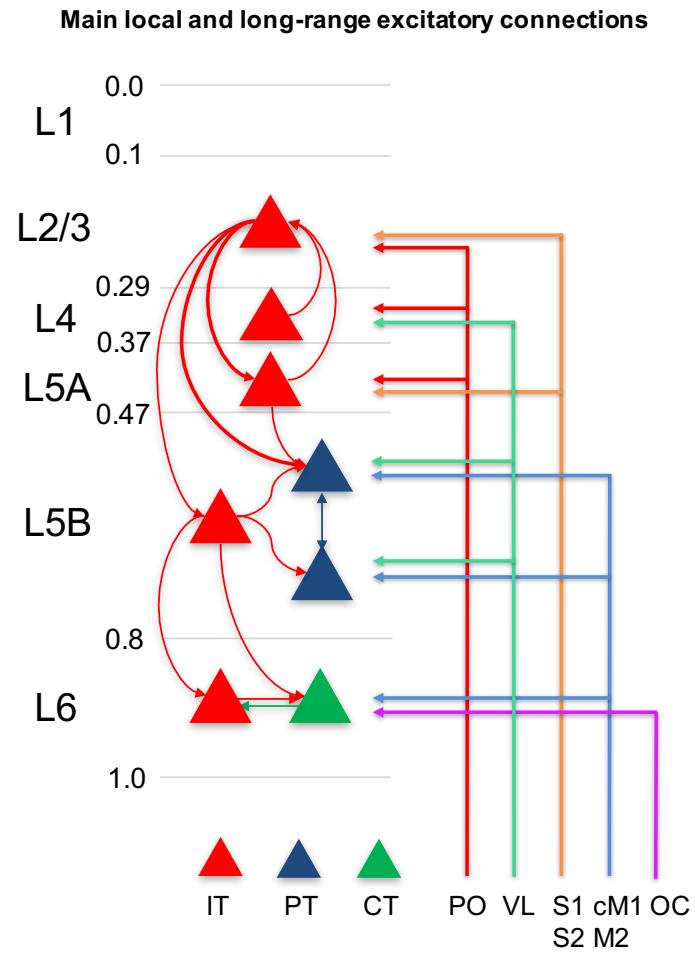
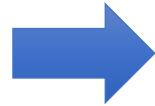
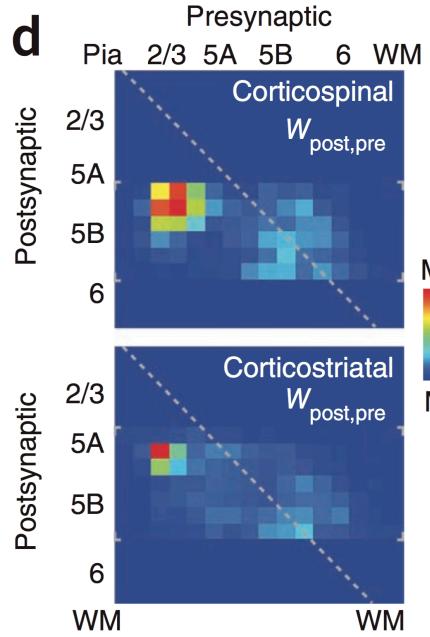


D



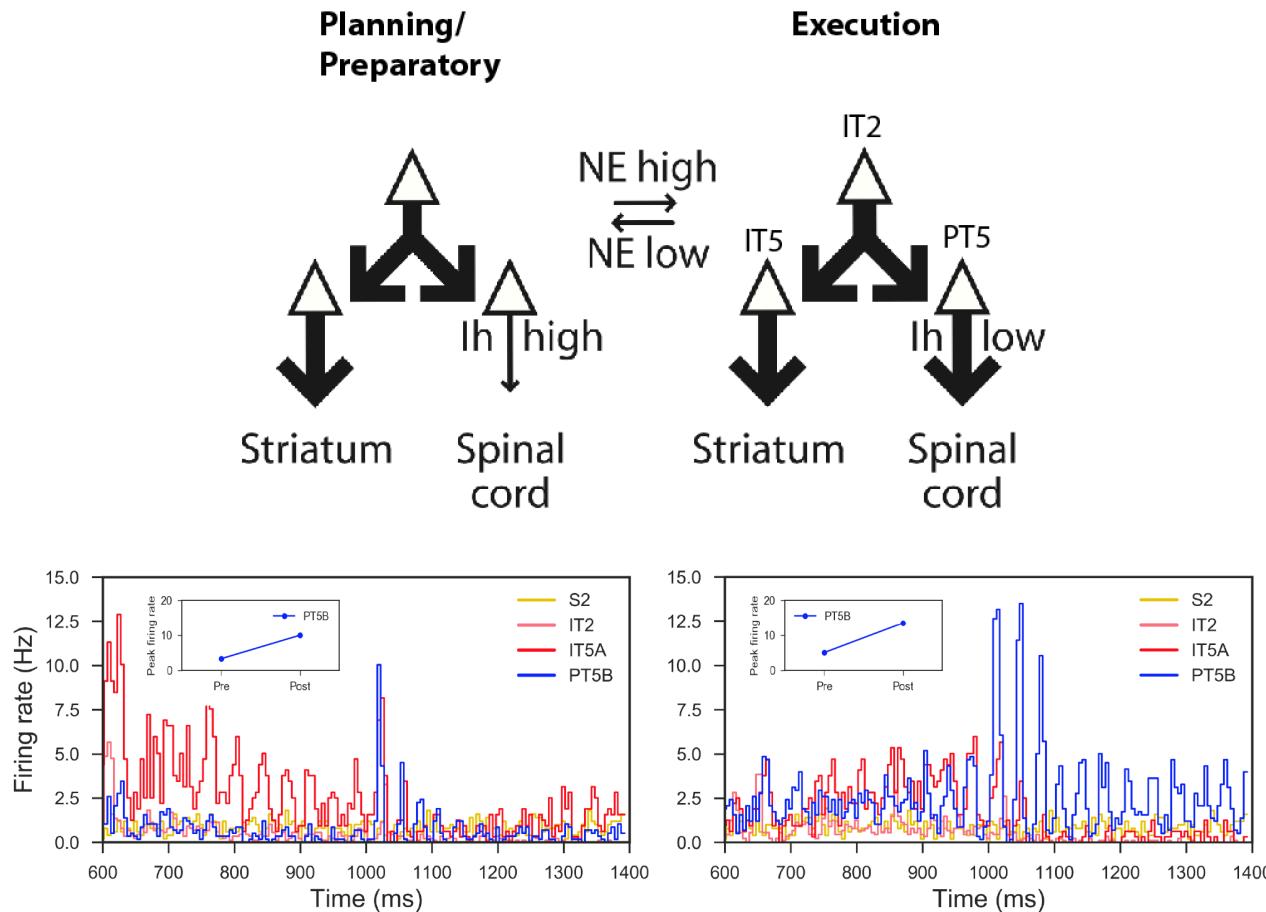
NetPyNE + M1: Conclusions

- Theoretical framework to integrate experimental data



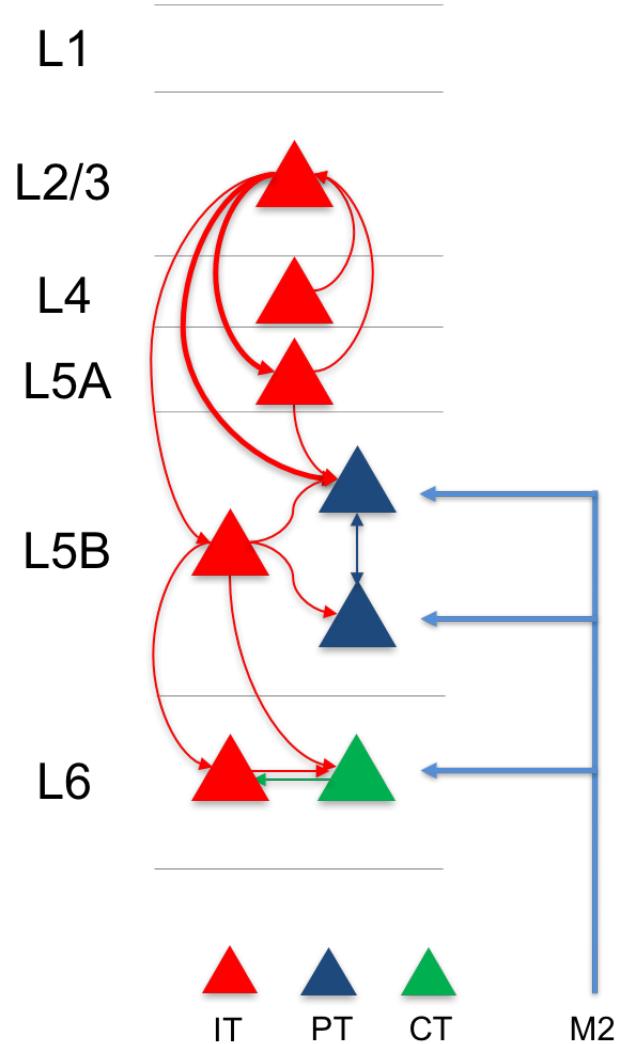
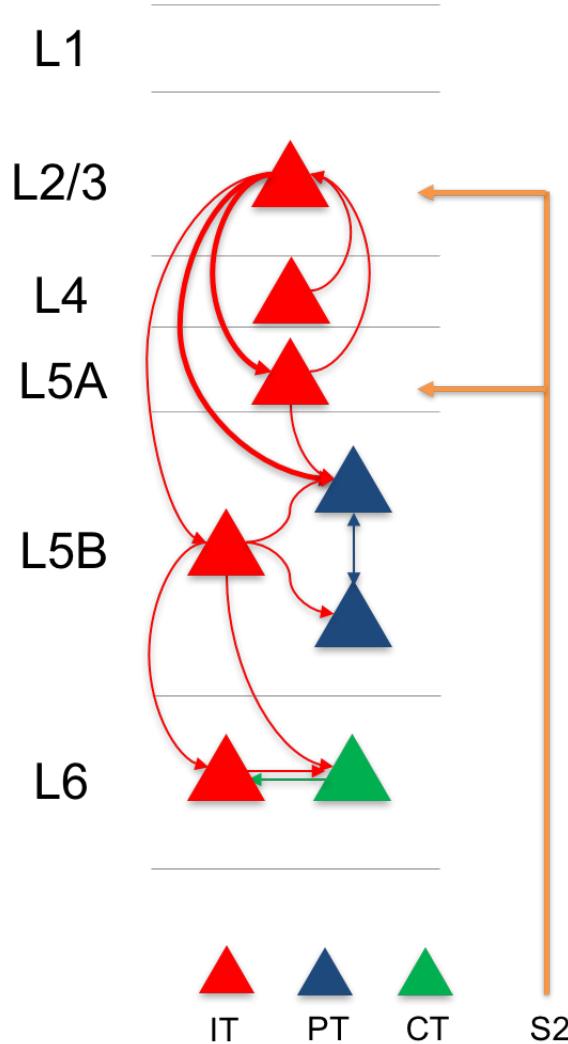
NetPyNE + M1: Conclusions

- Study multiscale biophysical mechanisms: Ih modulates corticospinal output



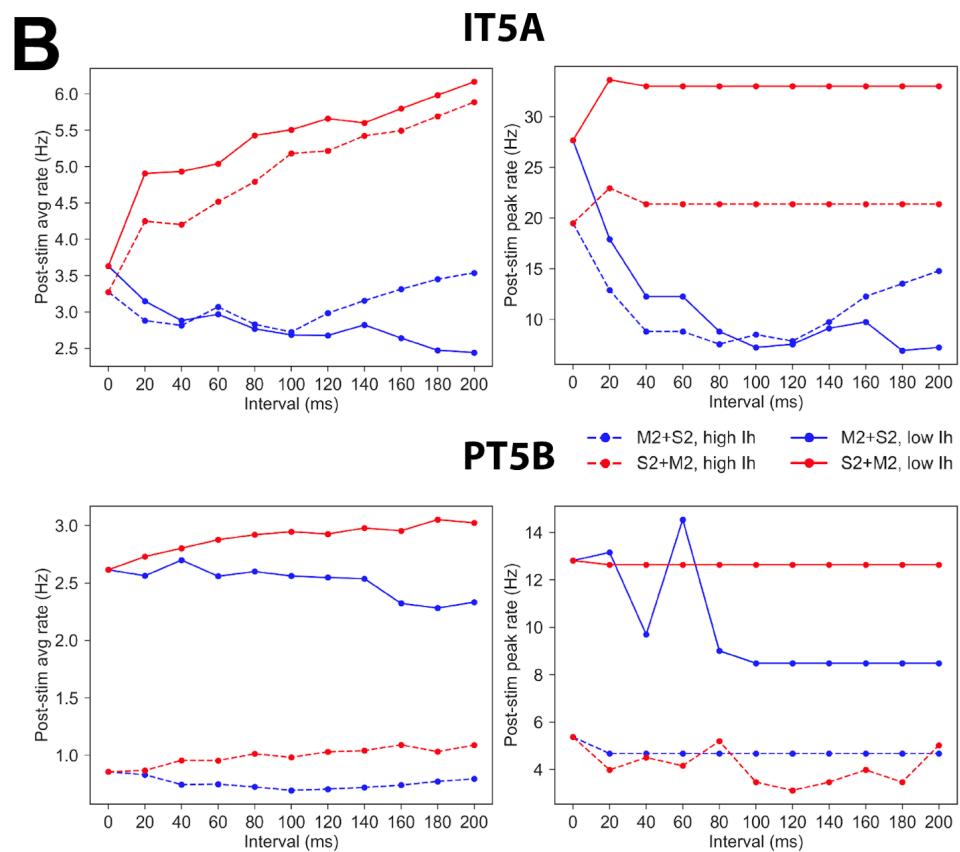
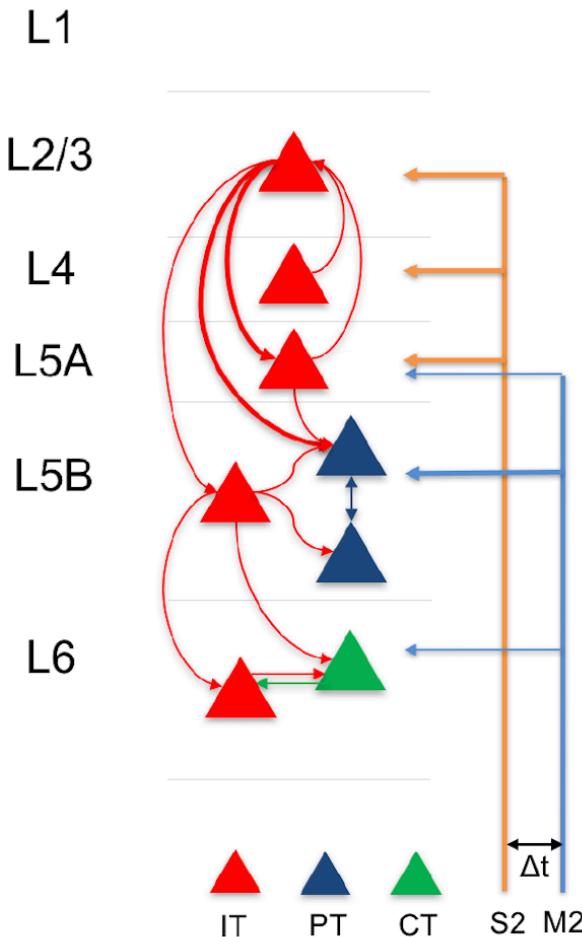
NetPyNE + M1: Conclusions

- Study information flow: 2 pathways to activate corticospinal output



NetPyNE + M1: Conclusions

- Study multiscale neural coding: interaction between inputs



NetPyNE + M1: Conclusions

- Study disease and potential treatments

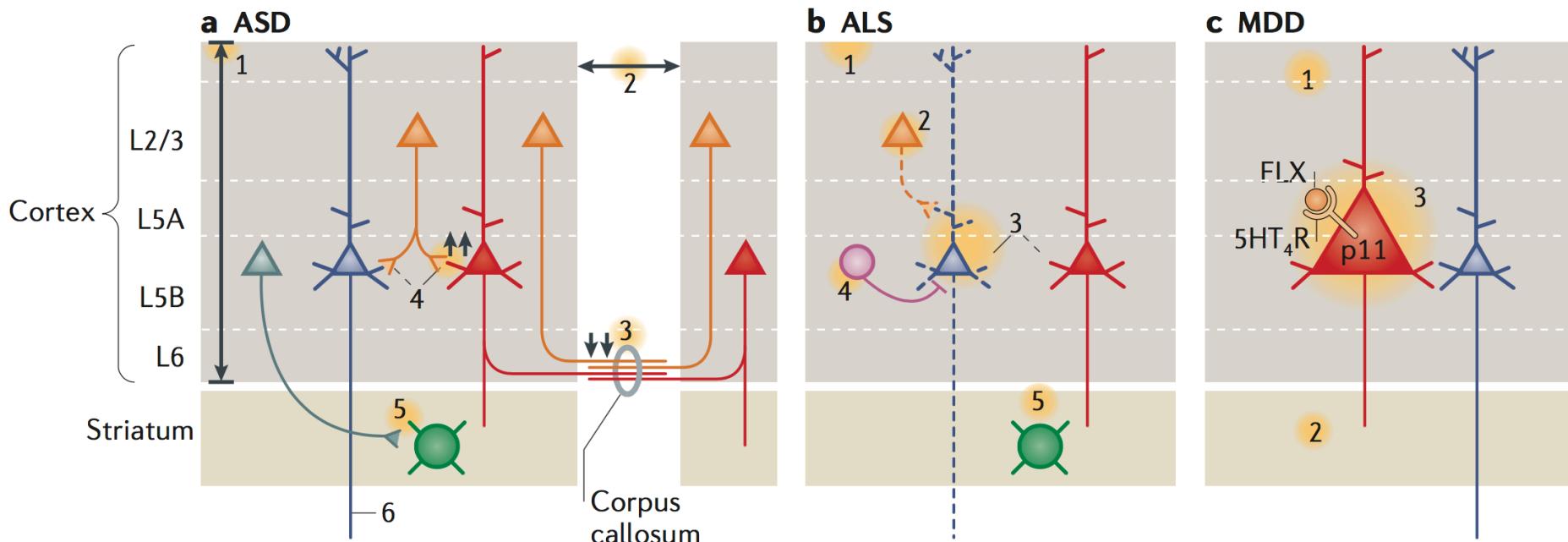
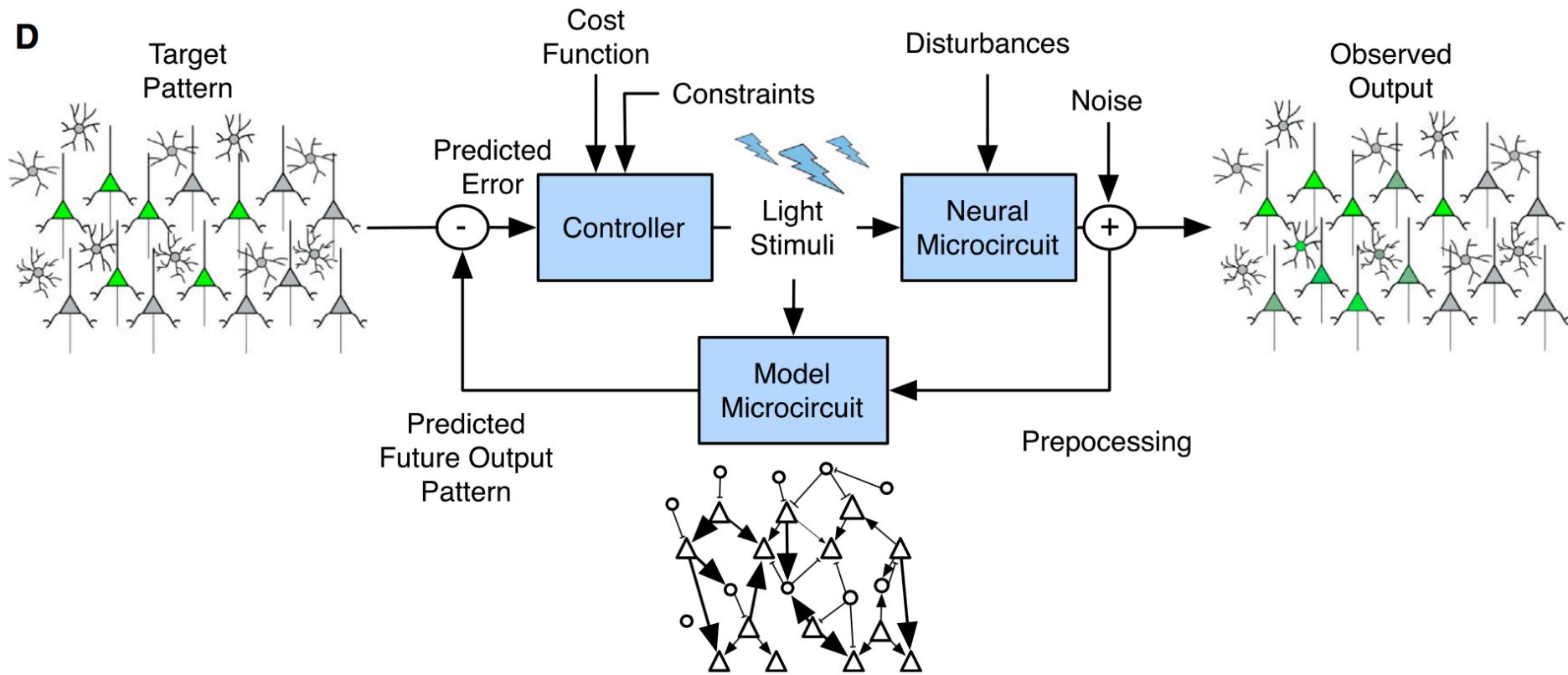


Figure 5 | CStr-related changes in ASD, ALS and MDD. **a** | Many changes in autism spectrum disorder (ASD) are

NetPyNE: Conclusions

- Study disease and potential treatments

D



NetPyNE: Acknowledgments

□ Contributors:

- Salvador Dura-Bernal (SUNY DMC)
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- Michael Hines (Yale)
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- William Lytton (SUNY DMC)

□ Lab website: www.neurosimlab.org

□ NetPyNE Website: www.netpyne.org

□ Github: www.github.com/Neurosim-lab/netpyne
(open source development; contributions welcome)

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