LFPy-tutorial CNS2013

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LFPy - Introduction

- **LFPy** is a **Python**-package for calculating extracellular potentials from multi-compartment neuron models

- **LFPy** home page: **http://compneuro.umb.no/LFPy**

- Live LFPyLubuntu image: **http://goo.gl/1sOiM**

  – Use .iso-file with Virtualbox or similar, see **http://www.virtualbox.org**

  – Comes with the **Python --pylab** environment, **LFPy** and **NEURON** preinstalled

- Article preprint: **http://goo.gl/OgJN1** (Please do not redistribute)

`LFPy` - Introduction

- Topics:
  - Why model extracellular potentials?
  - Biophysical modeling scheme (brief)
  - `LFPy` overview
  - `LFPy` installation
  - Brief explanation of the main classes in `LFPy`
  - `LFPy` usage
 - `LFPy` provided examples

LFPy - Introduction

- Why model extracellular potentials?
  - Improve understanding of experimental measurements:
    - Reach of LFP (Łęski et al. *PLoS Comp Biol*, 2013; Lindén et al. *Neuron*, 2011)
    - Spectral content of LFP (Lindén et al. *J Comput Neurosci*, 2010)
    - Extracellular action potential shapes (Gold et al. J *Neurophysiol*, 2006; Pettersen et al. *Biophys J*, 2008)
  - Methods validation:
    - Spike sorting (Einevoll et al. *Curr Op Neurobiol*, 2012)
    - CSD estimation (Łęski et al. *Neuroinf*, 2011; Pettersen et al. *J Comput Neurosci*, 2008)

LFPy - Introduction

- Why model extracellular potentials?

  - **O14**: Taxidis et al.; Extracellular field signatures of CA1 spiking cell assemblies during sharp wave-ripple complexes

  - **P119**: Hagen et al.; Hybrid scheme for modeling LFPs from spiking cortical network models

  - **P120**: Ness et al.; Modeling Extracellular Potentials in Microelectrode Array Recordings

  - **P417**: Chintaluri et al.; Realistic simulations of local field potentials in a slice

  - others: **P41**, **P126**, **P255**, …

`LFPy` - Introduction
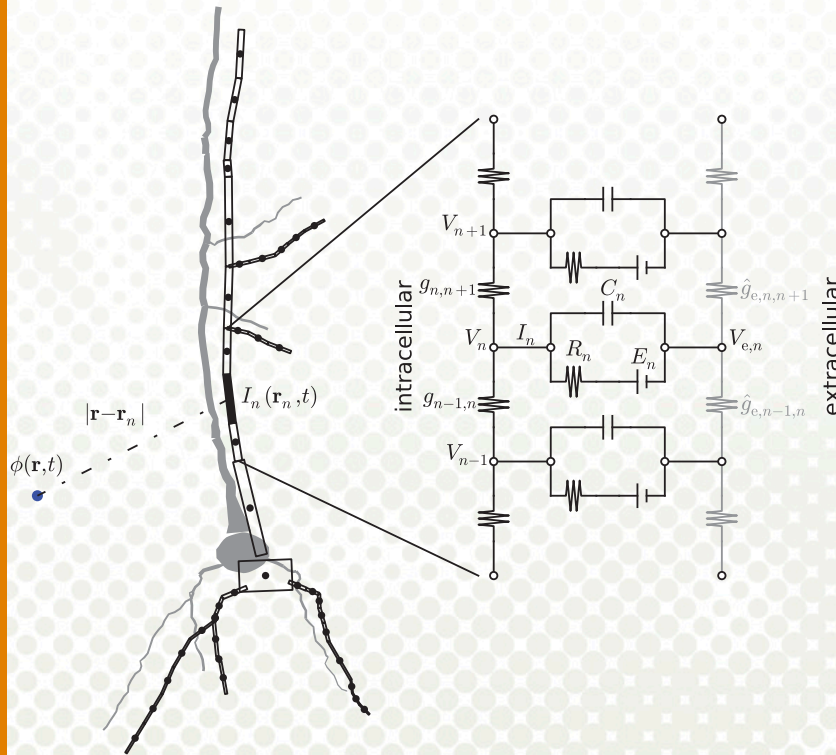
- Forward-modeling scheme for extracellular potentials for multi-compartment neuron models:

$$\Phi(\mathbf{r}, t) = \frac{1}{4\pi\sigma_e} \sum_{n=1}^{N} \frac{I_n(t)}{|\mathbf{r} - \mathbf{r}_n|}$$

- Line-sources (Holt & Koch 1999)

$$\Phi(\mathbf{r}, t) = \frac{1}{4\pi\sigma_e} \sum_{n=1}^{N} I_n(t) \int \frac{d\mathbf{r}_n}{|\mathbf{r} - \mathbf{r}_n|}$$

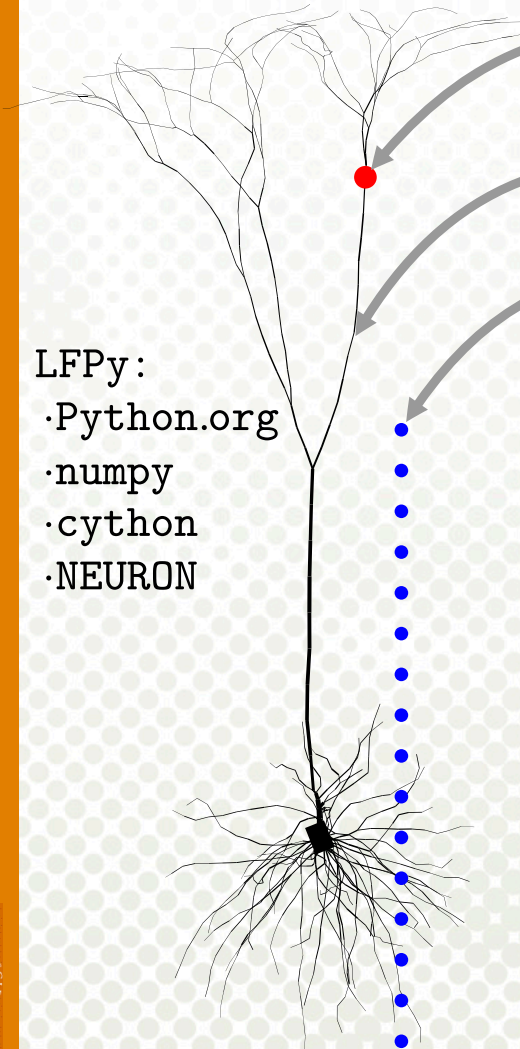- Current conservation imply:

$$\sum_{n=1}^{N} I_n(t) = 0$$

`LFPy` - Overview

LFPy class-objects:

`LFPy.Synapse`
`LFPy.StimIntElectrode`
`LFPy.Cell`
`LFPy.TemplateCell`

`LFPy.RecExtElectrode`

LFPy:
·Python.org
·numpy
·cython
·NEURON

- Why `Python`?

  – Object oriented

  – Easy to script

  – Flexible

  – Plethora of packages for visualizations and analysis

  – **http:// pypi.python.org/ pypi**: ~32500 packages

  – Interface other programming languages

LFPy - Installation

- Make sure **Python**-prerequisites are met:
  - **neuron** (./configure --with-nrnpython)
  - **Cython, NumPy, SciPy, matplotlib** (opt. **ipython (notebook), h5py, mpi4py**)

- Download the **LFPy** source code: **http://compneuro.umb.no/LFPy/downloads/LFPy-0.9.5.tar.gz**

- Unzip: **tar –xzf LFPy-0.9.5.tar.gz**

- Or, get development version of **LFPy** using subversion: **svn co \ http://bebiservice.umb.no/svn-public/LFPy-release/trunk LFPy**

LFPy - Installation

- Install from LFPy source code:
    cd /path/to/LFPy
    python setup.py install --user

- Easy installation of **LFPy**:
    easy_install LFPy --user

- Small test with `IPython`:
    ipython -c "import LFPy"
    NEURON -- VERSION 7.3
    (694:9d4ab20927bc) 9d4ab20927bc
    ...

- With `NEURON`:
    nrngui --python -c "import LPFy"

LFPy – Main Classes

- The primary **LFPy**-classes employed to set up simulations are:

  – **LFPy.Cell**

  – **LFPy.Synapse**

  – **LFPy.RecExtElectrode**

- Other classes and functions:

  – class **LFPy.StimIntElectrode**

  – functions **LFPy.lfpcalc.calc_lfp*, LFPy.inputgenerators.*, LFPy.tools.***

- For detailed information please refer to the online documentation: **http://compneuro.umb.no/LFPy/classes.html**

LFPy class–objects:

LFPy.Synapse
LFPy.StimIntElectrode
LFPy.Cell
LFPy.TemplateCell

LFPy.RecExtElectrode
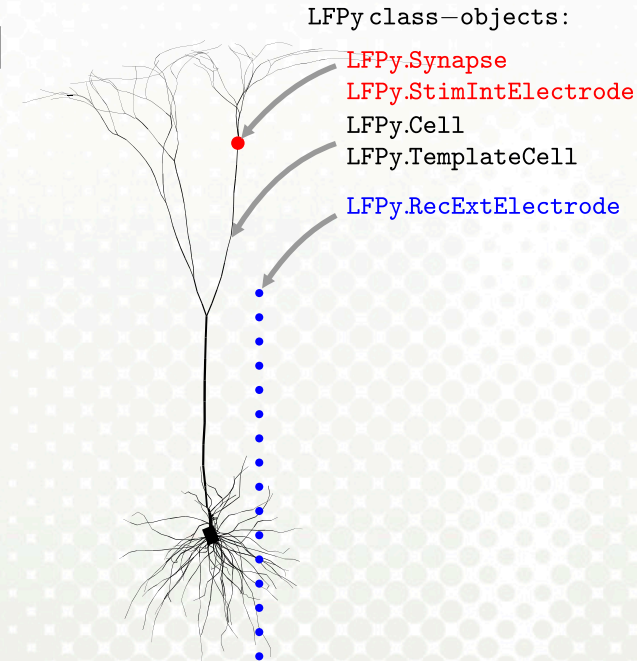
LFPy – Main Classes

- ● **LFPy.Cell:**
  - – Uses **NEURON** under the hood
  - – Loads the morphology
  - – Set the neuronal properties:
    - • membrane mechanisms
    - • number of compartments
    - • Set cell location and rotation
  - – Collect the geometry into arrays
  - – Methods for segment indices
  - – positioning in 3D
  - – Simulation control

LFPy class–objects:

LFPy.Cell
LFPy.TemplateCell
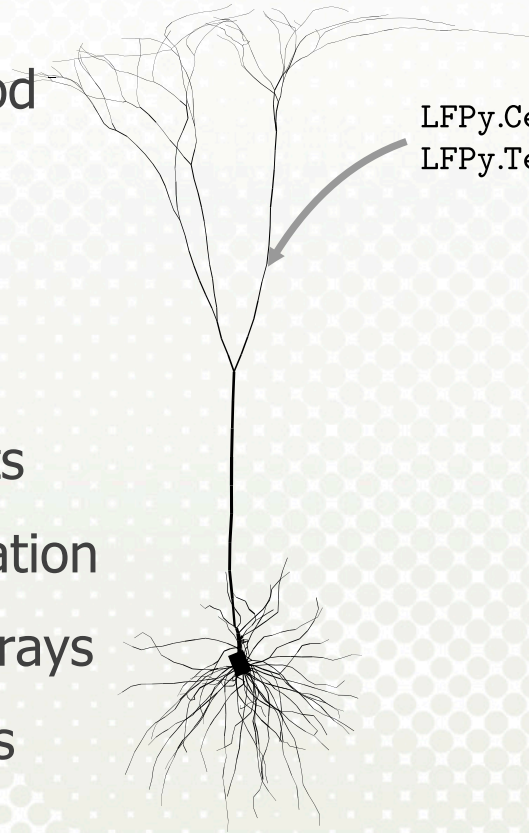
LFPy - Main Classes

● **LFPy.Synapse:**

– attach synapse-objects onto cell objects

– Keyword arguments:

- **cell–**object

- compartment index, **idx**

- synapse type, **Exp2syn**

- mechanism arguments

● Set up as **NetCon** objects (see **NEURON** documentation) for synaptic weights and times.

LFPy class–objects:

LFPy.Synapse
LFPy.StimIntElectrode
LFPy.Cell
LFPy.TemplateCell
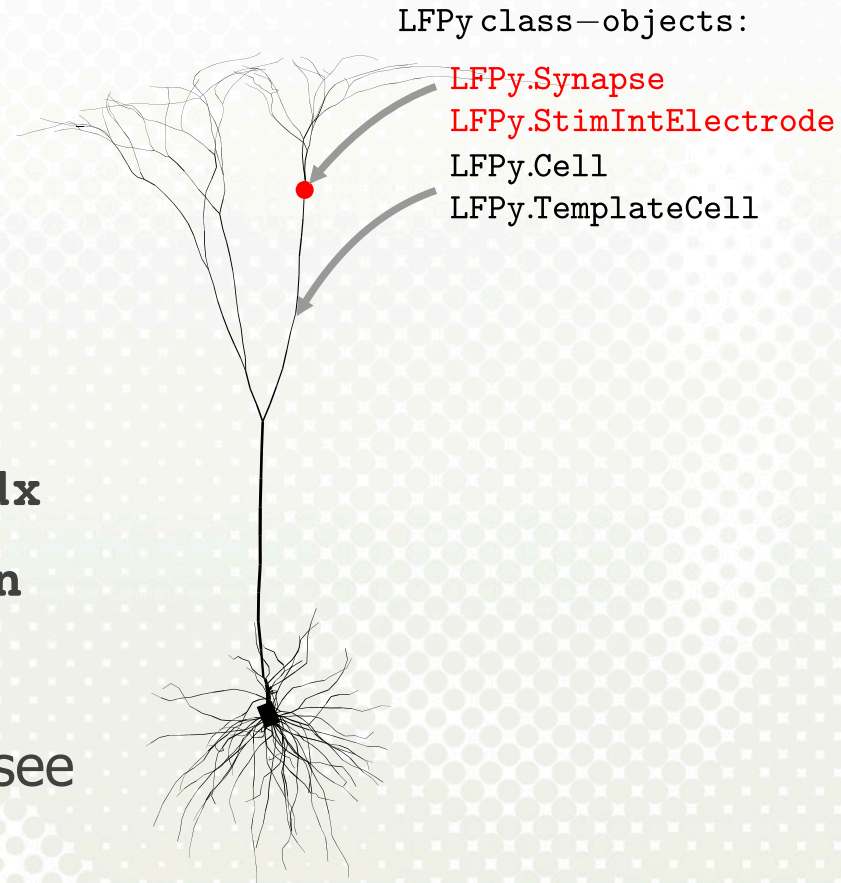
LFPy - Main Classes

LFPy class-objects:

- **LFPy.RecExtElectrode**
  - extracellular recording devices
  - Main arguments:
    - Coordinates of contact points
    - extracellular conductivity
  - Optional:
    - radius and surface normal vector for the contacts
    - calculated potential is the n-point surface area averaged potential

LFPy.Synapse
LFPy.StimIntElectrode
LFPy.Cell
LFPy.TemplateCell

LFPy.RecExtElectrode
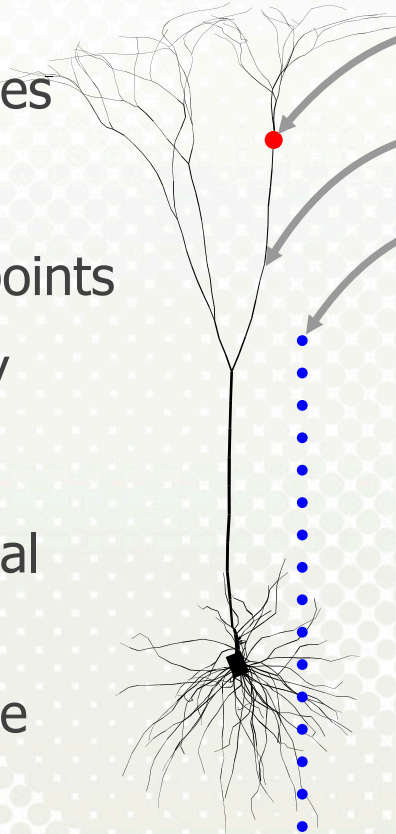
LFPy - Usage

- Working in local folder:
  cd /path/to/LFPy/examples/

- Have a look at the two provided **ipython** notebooks

  – Post-synaptic response of somatic synapse

  – LFPs from a single, apical synapse

- Employ an interactive ipython notesession:
  ipython notebook --pylab inline

- Two interactive examples should be available:
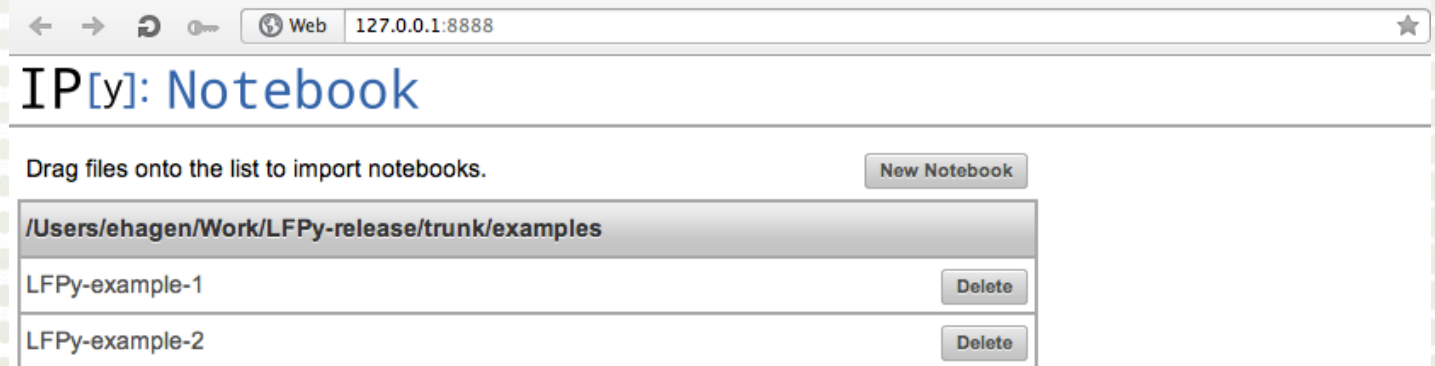
`LFPy` - Usage

- Interactive example 1:
  - Calculate the post-synaptic response of somatic synapse
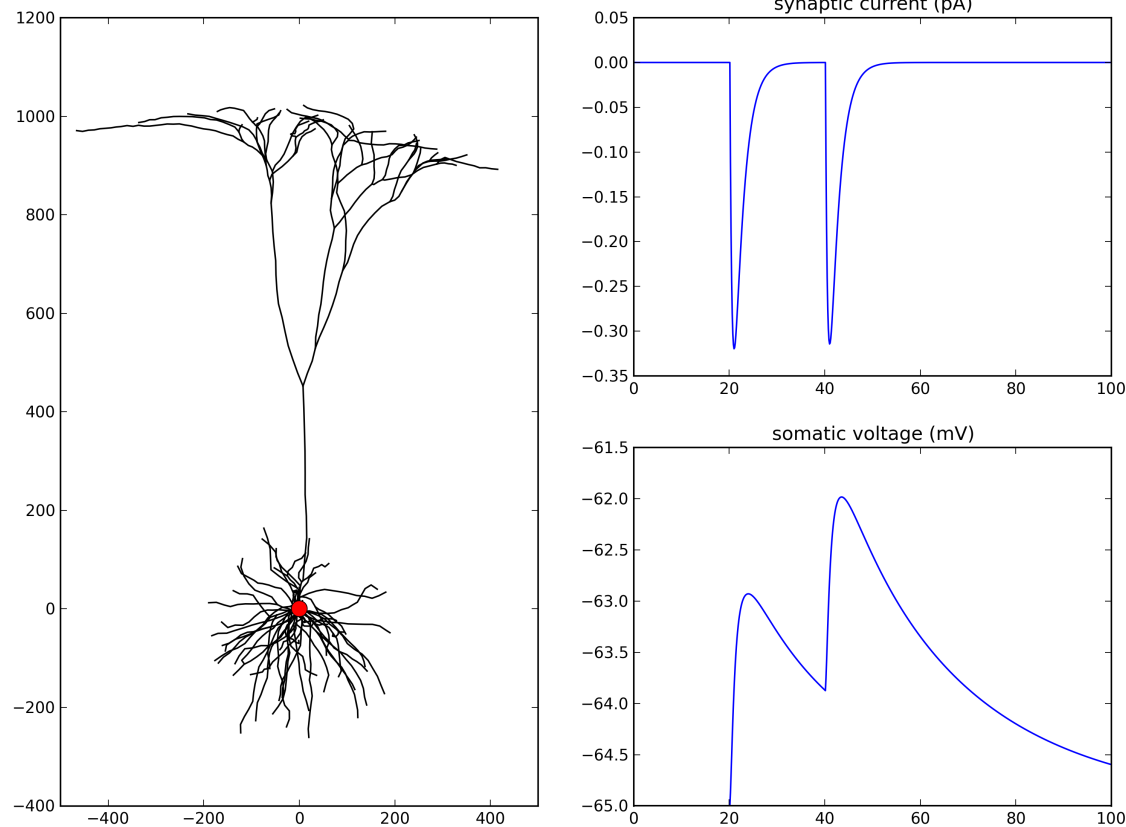
`LFPy` - Usage

- Interactive example 2:
  - Calculate LFPs arising from a single, apical synapse
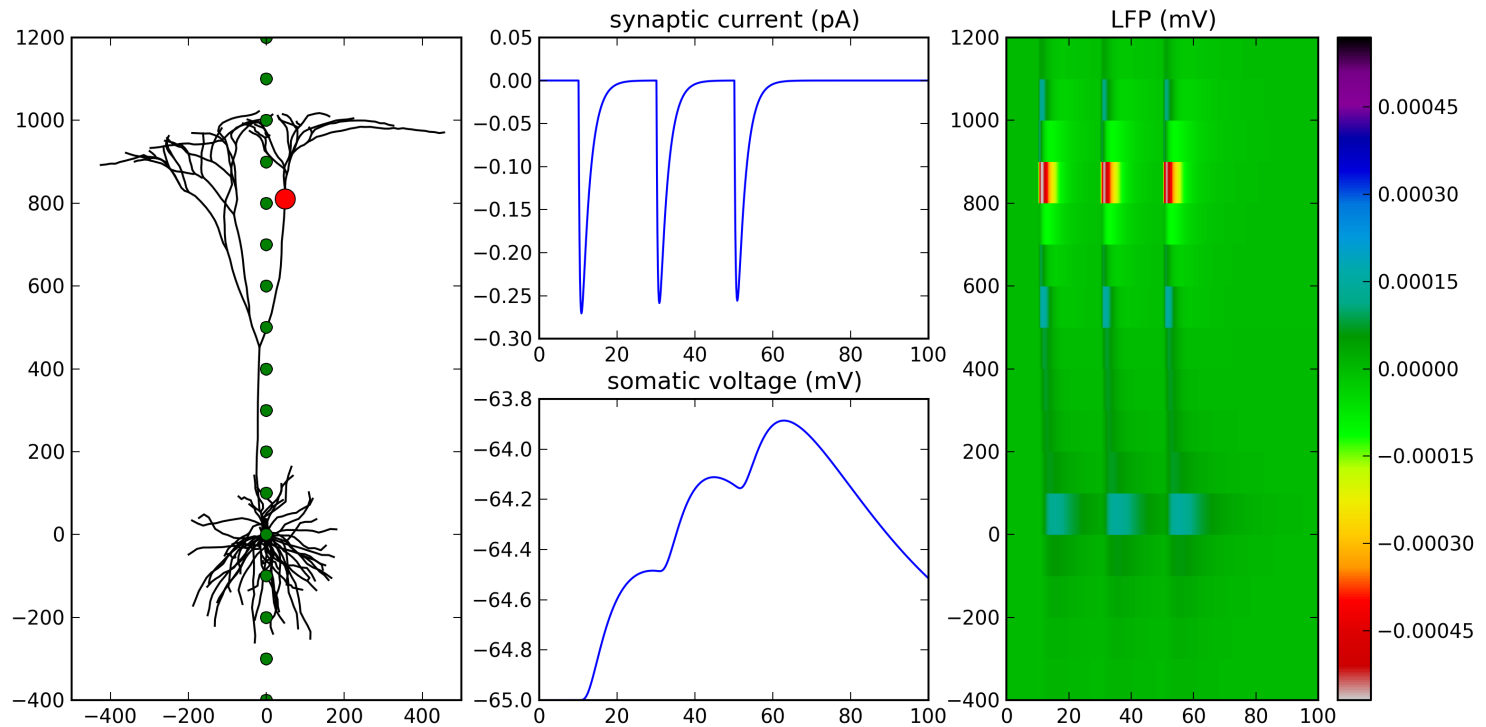
`LFPy` – Provided example files

- `LFPy` also comes with a set of example scripts displaying different usage cases, like:
  - using active cell models
  - using many synapses
  - dealing with a population of cell objects
- The example files are located in
  `/path/to/LFPy/examples/`
- `.mod`-files must be compiled for active stuff, running
  `nrnivmodl`
  inside the examples folder

`LFPy` - Provided example files

- **`/path/to/LFPy/examples/example4.py`**:
  - Single apical synapse response. Passive membrane
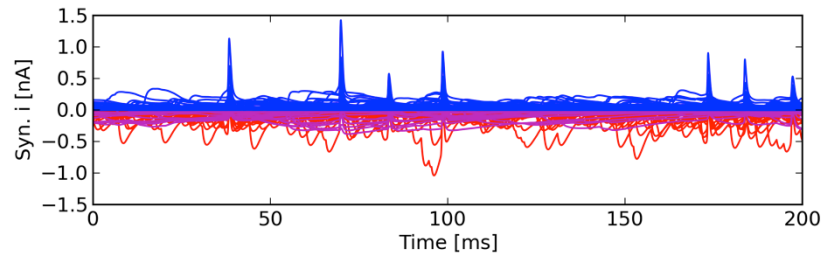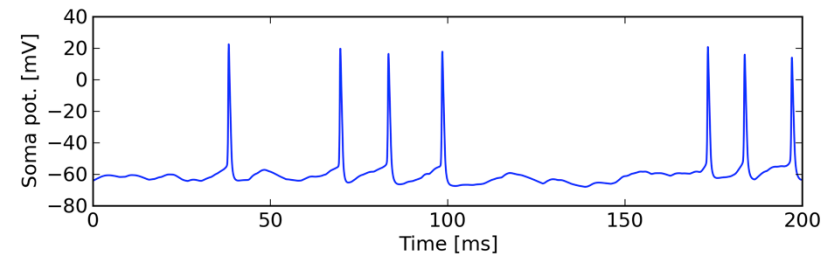

example 1
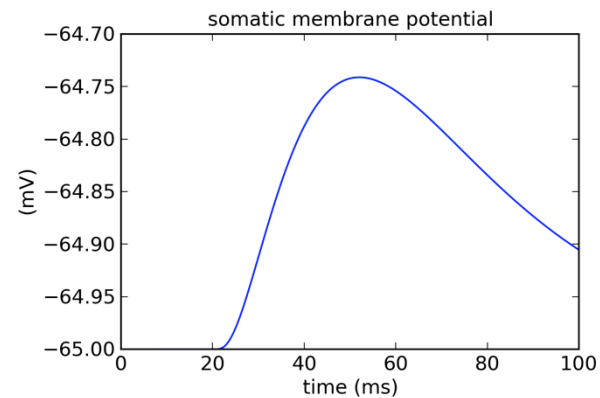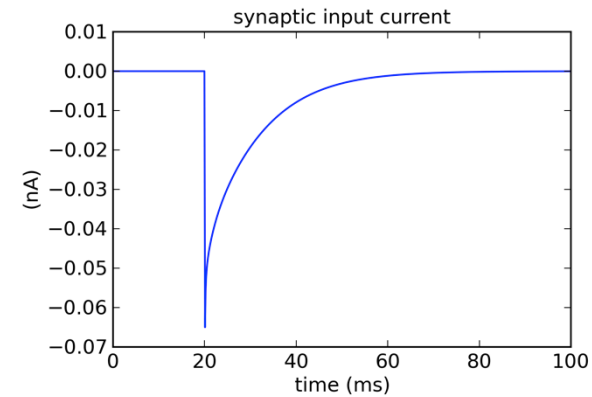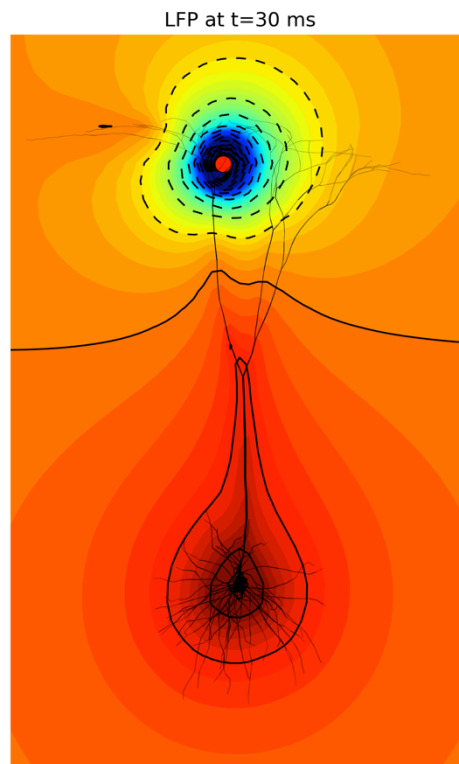
`LFPy` - Provided example files

- **`/path/to/LFPy/examples/example5.py`**:
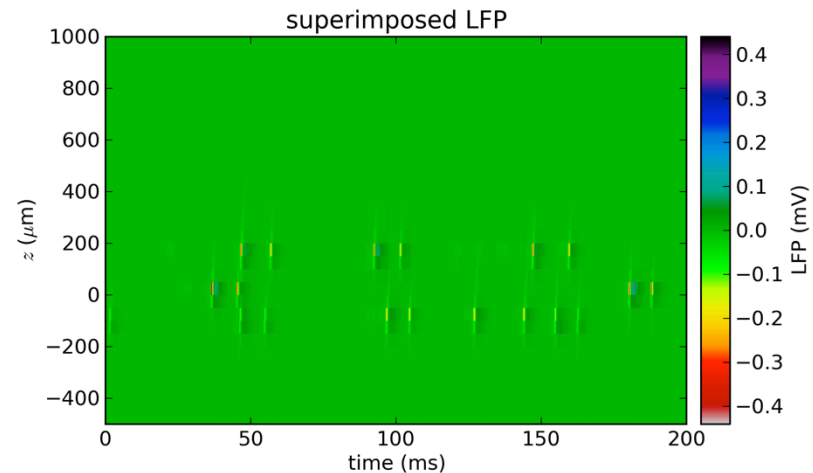 - Extracellular spike waveforms. Active membrane.
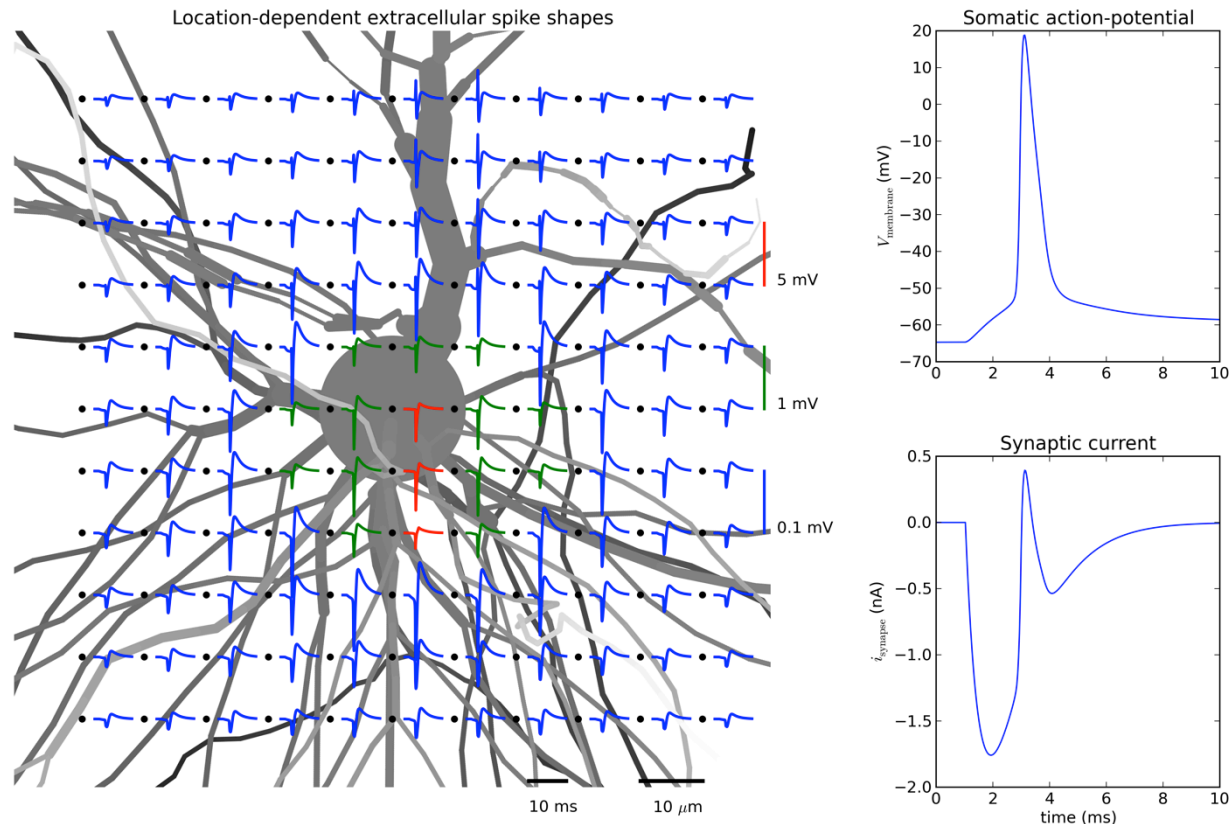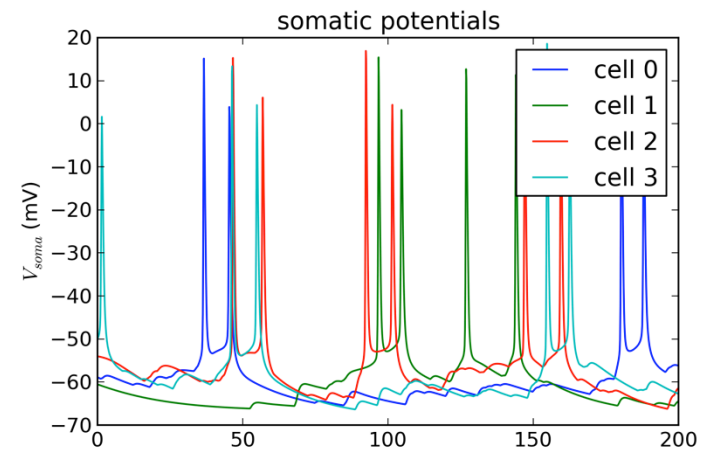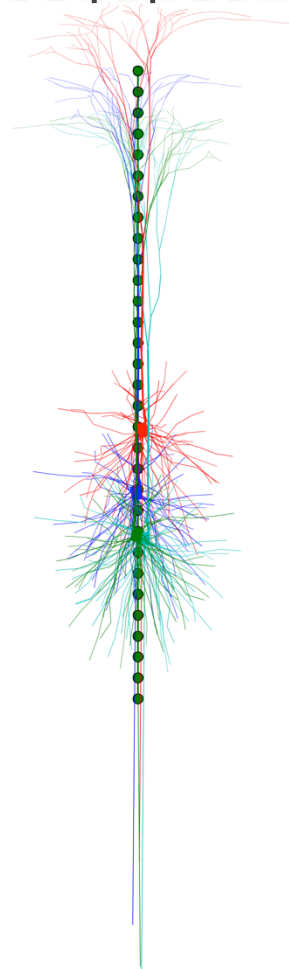
`LFPy` - Provided example files

- **`/path/to/LFPy/examples/example6.py`**:
  - Distributed exc/inh. synapses. Active membrane.
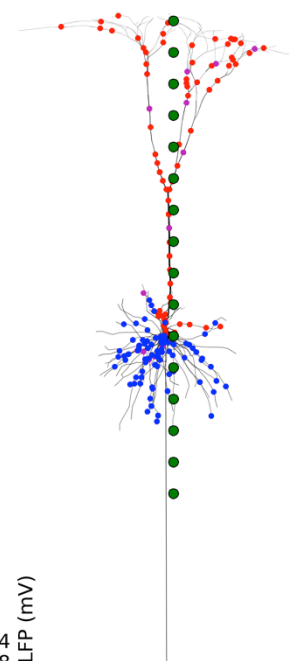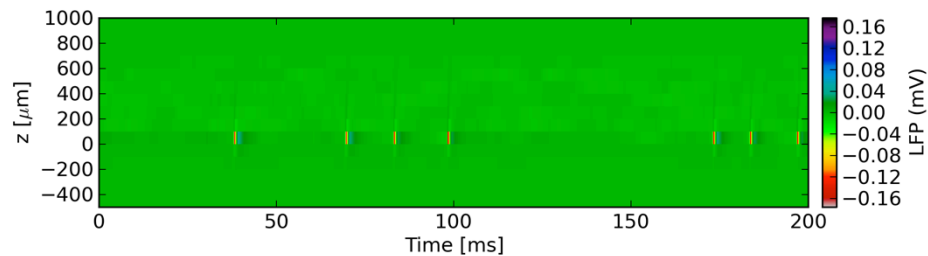
LFPy - Provided example files

- **/path/to/LFPy/examples/example_mpi.py**:
  – A small population using MPI. Active membranes.

LFPy - Tutorial

- Questions?

- If not, feel free to test out **LFPy** ☺