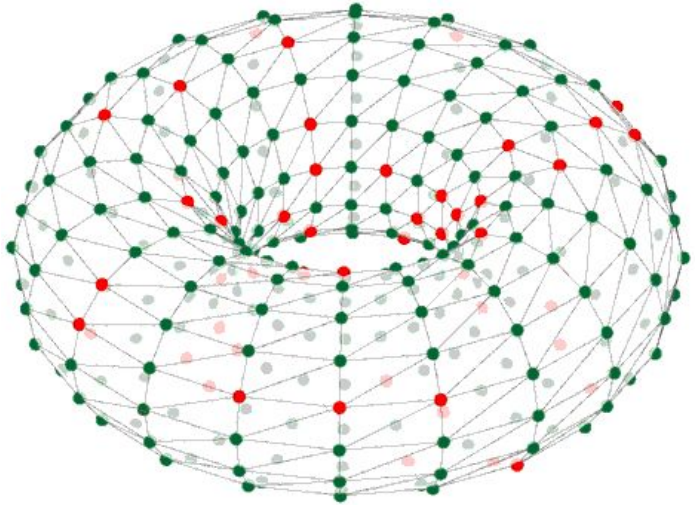
MANCHESTER 1824

SpiNNaker Tutorial



European Research Council
Established by the European Commission

Human Brain Project

EPSRC

SpiNNaker

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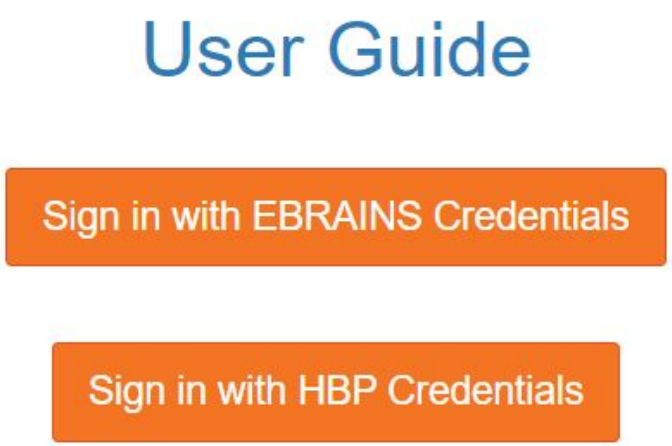
Accessing SpiNNaker

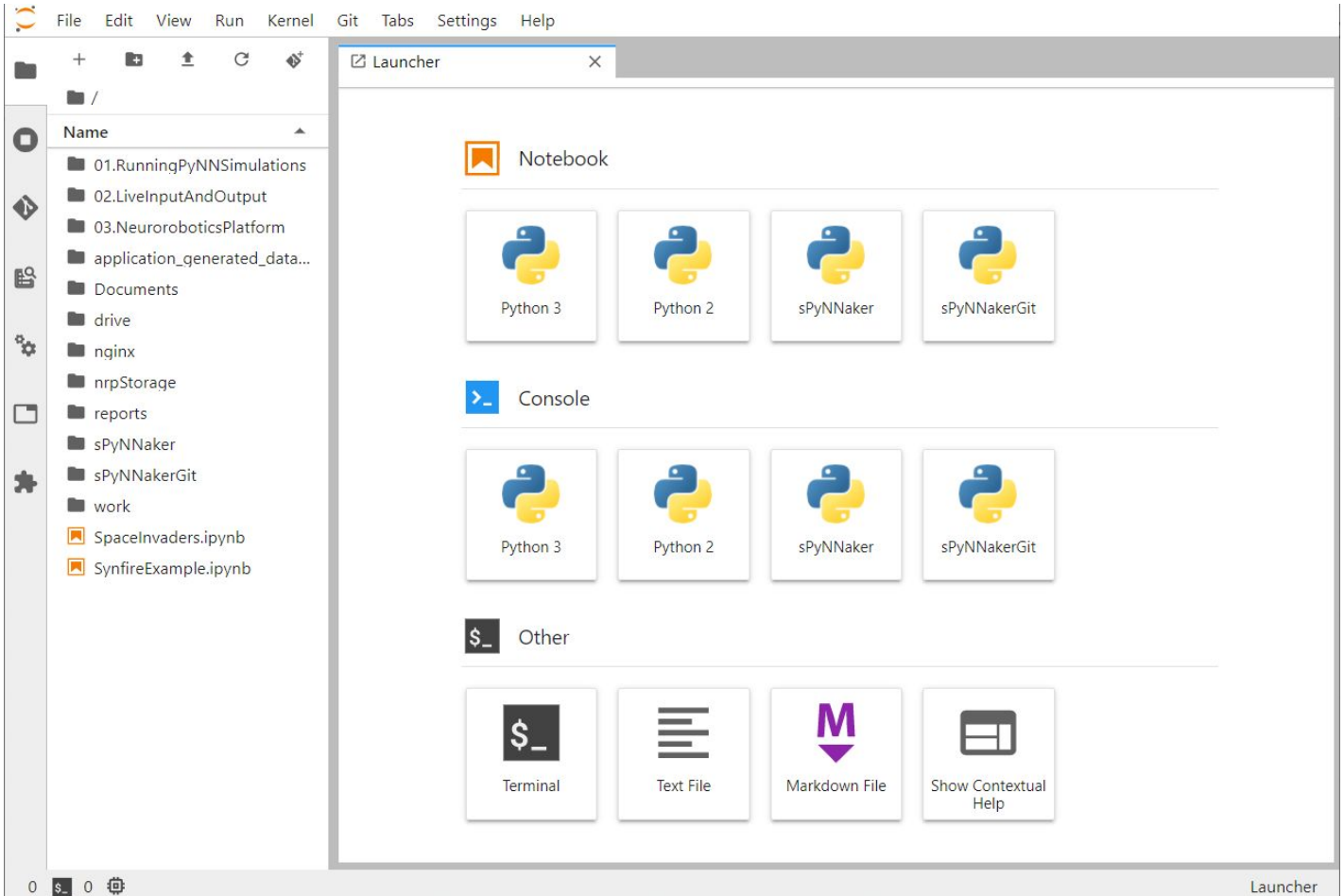
Accessing SpiNNaker via Jupyter

https://spinn-20.cs.man.ac.uk/

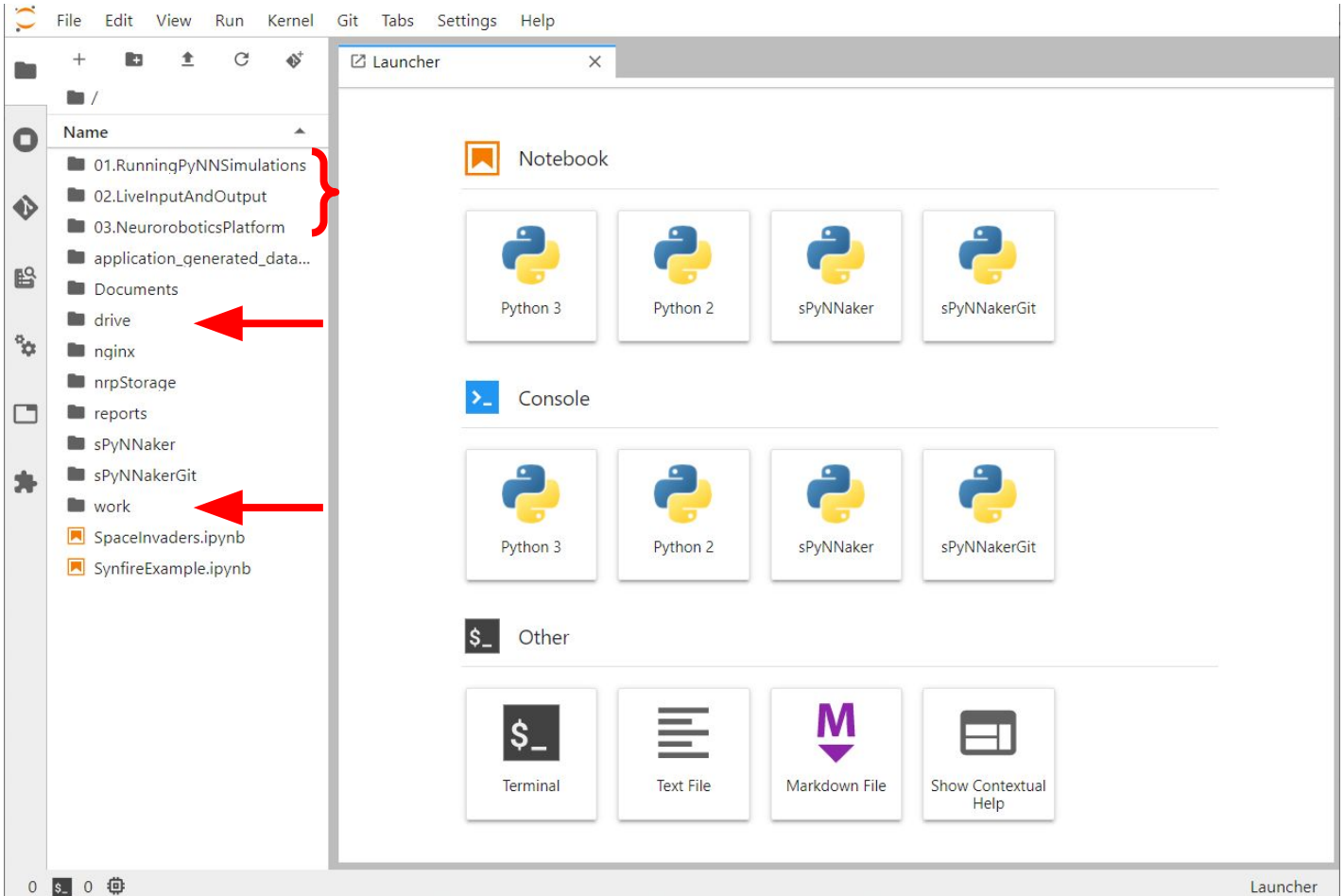


Accessing SpiNNaker via Jupyter

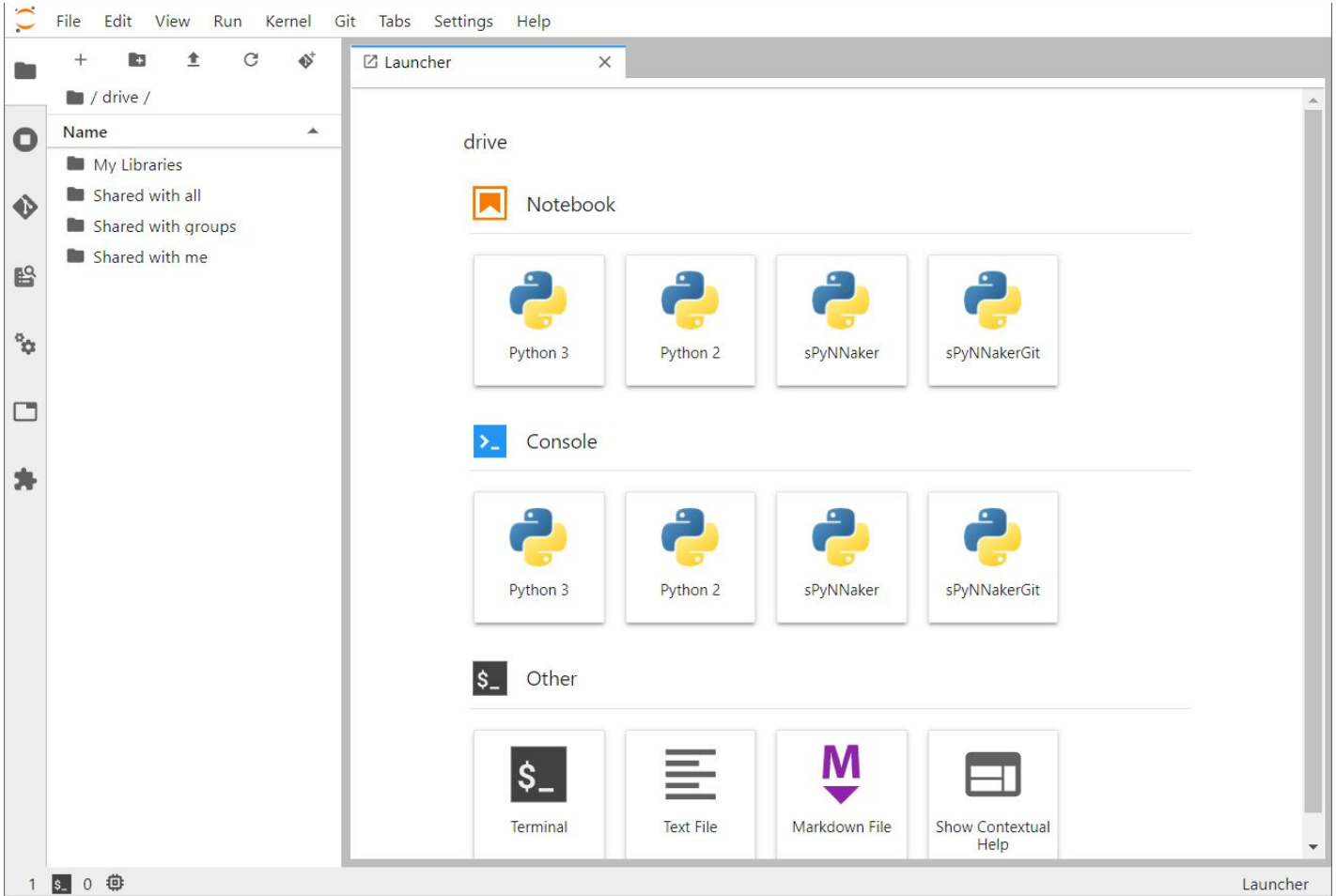
Accessing SpiNNaker via Jupyter



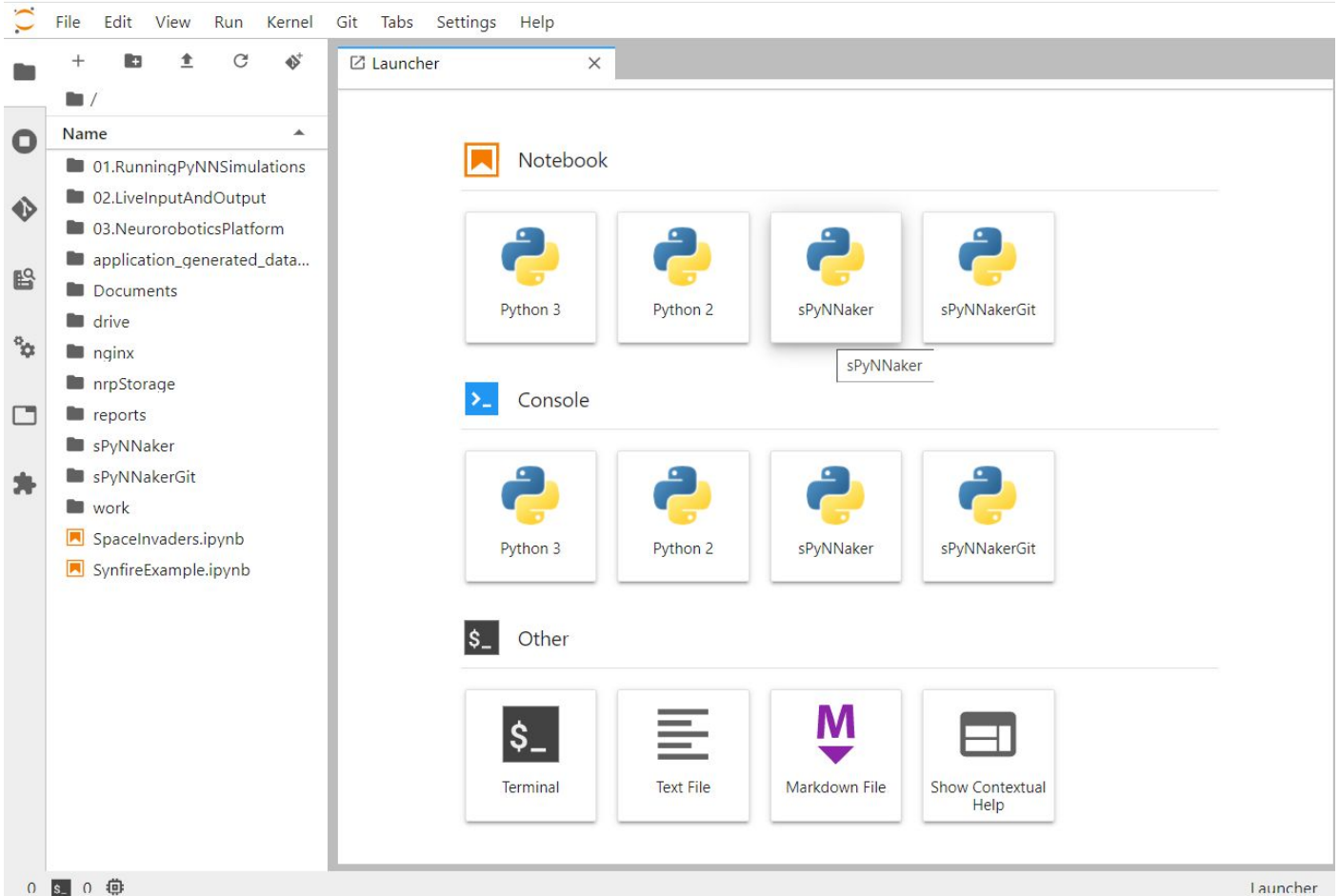
Jupyter Folders



EBRAINS Drive



Running sPyNNaker



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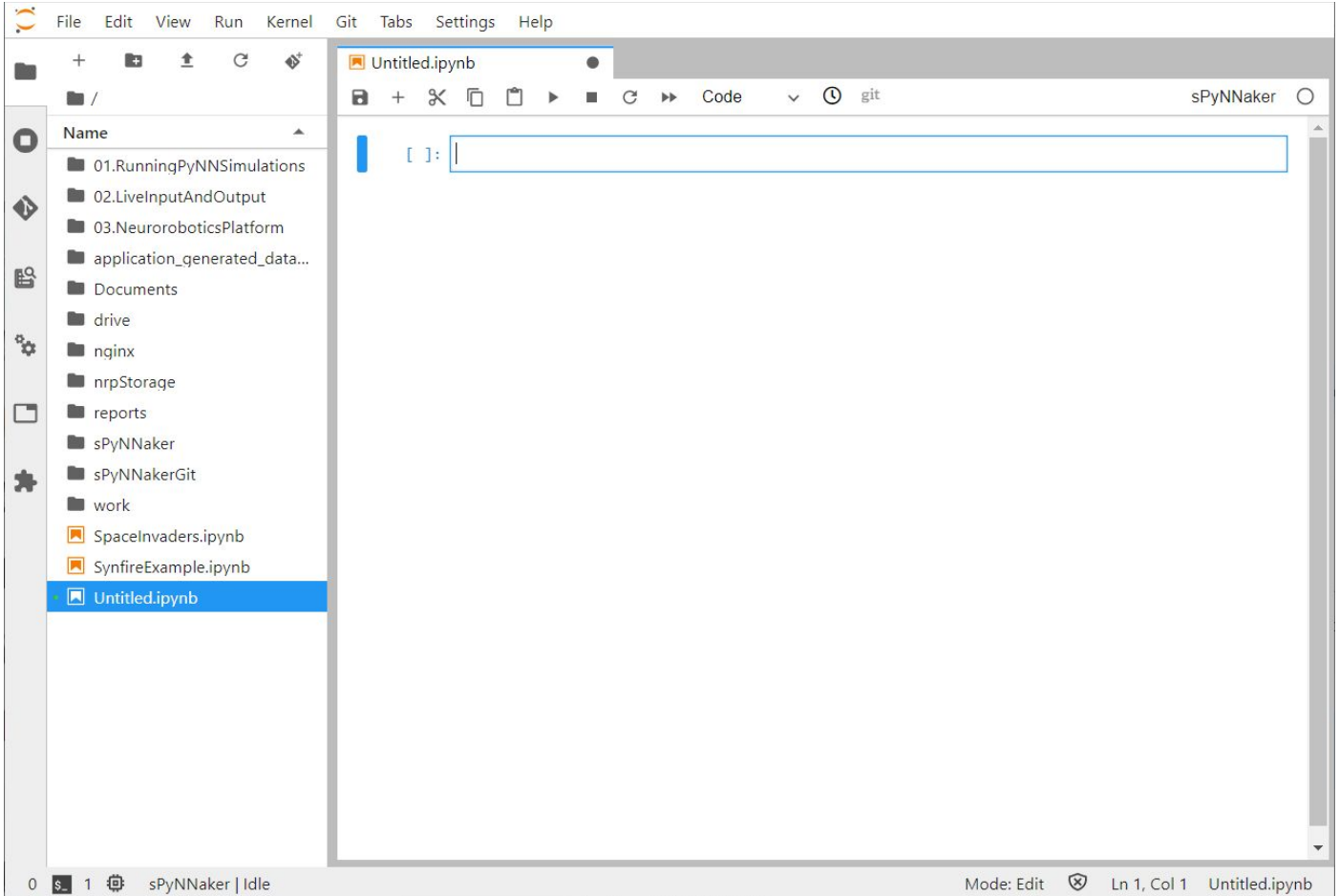
Running sPyNNaker



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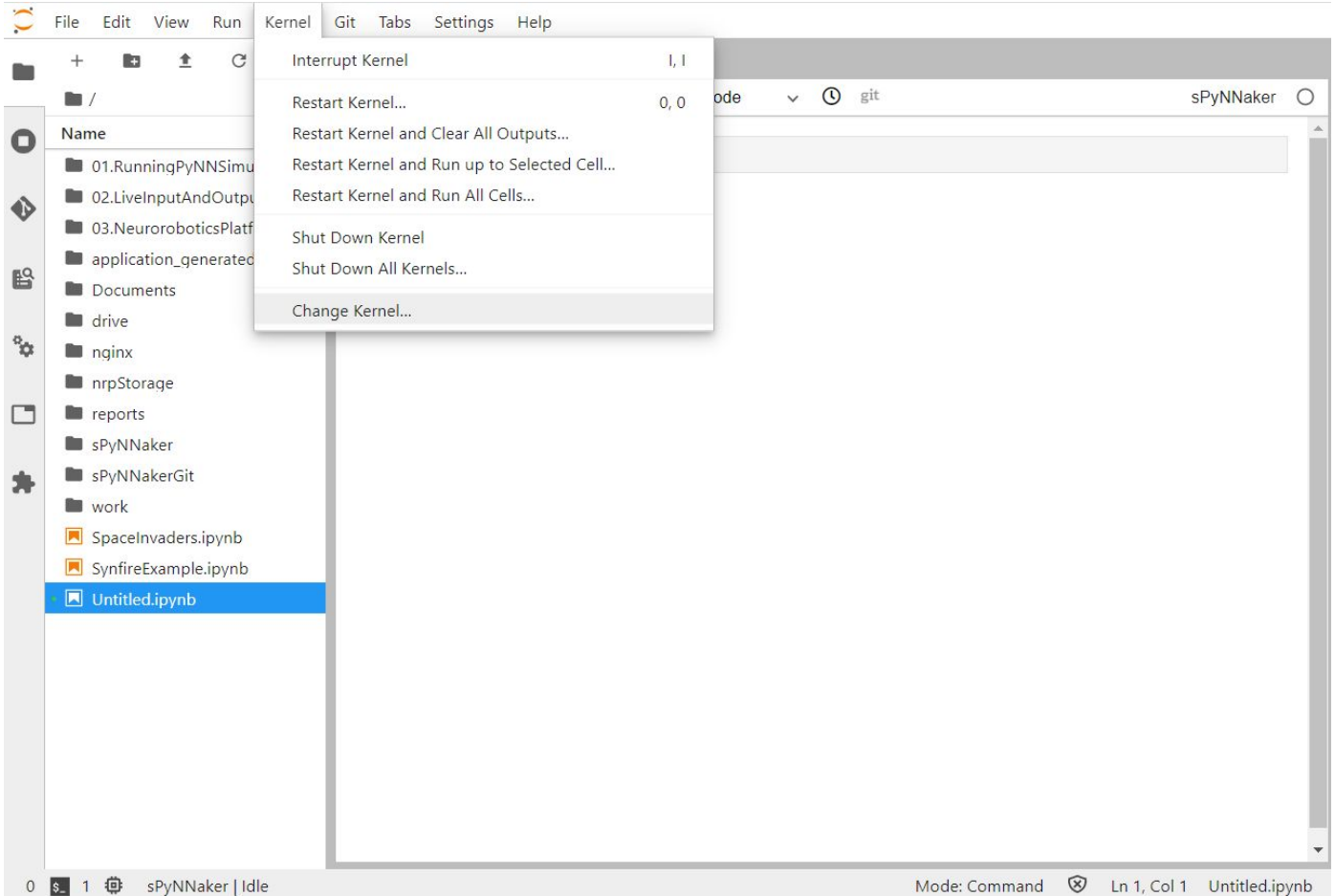
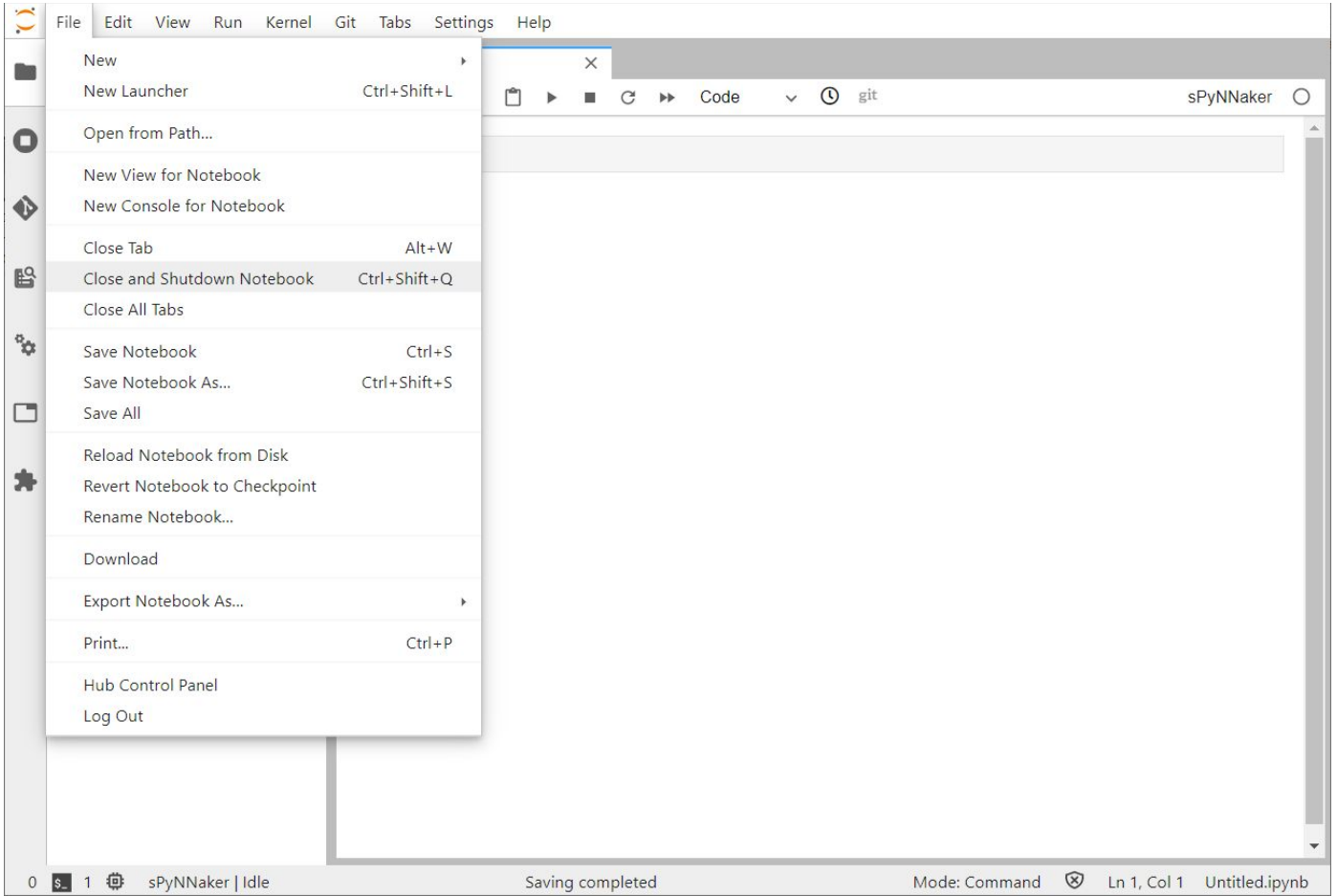
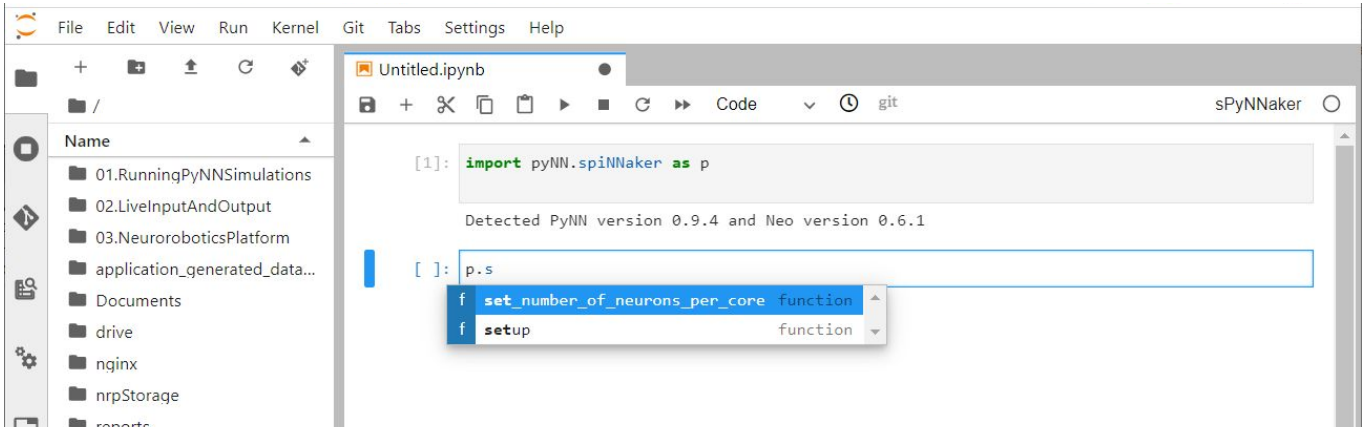
Changing Kernel

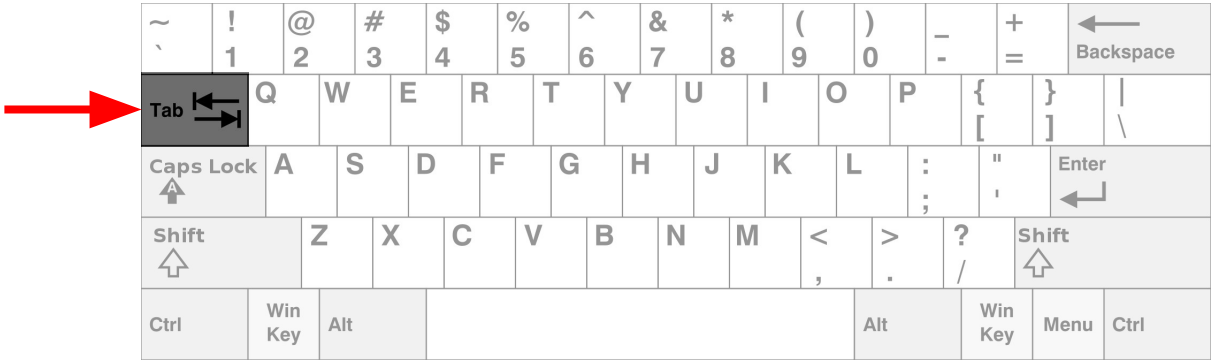


Close Notebooks

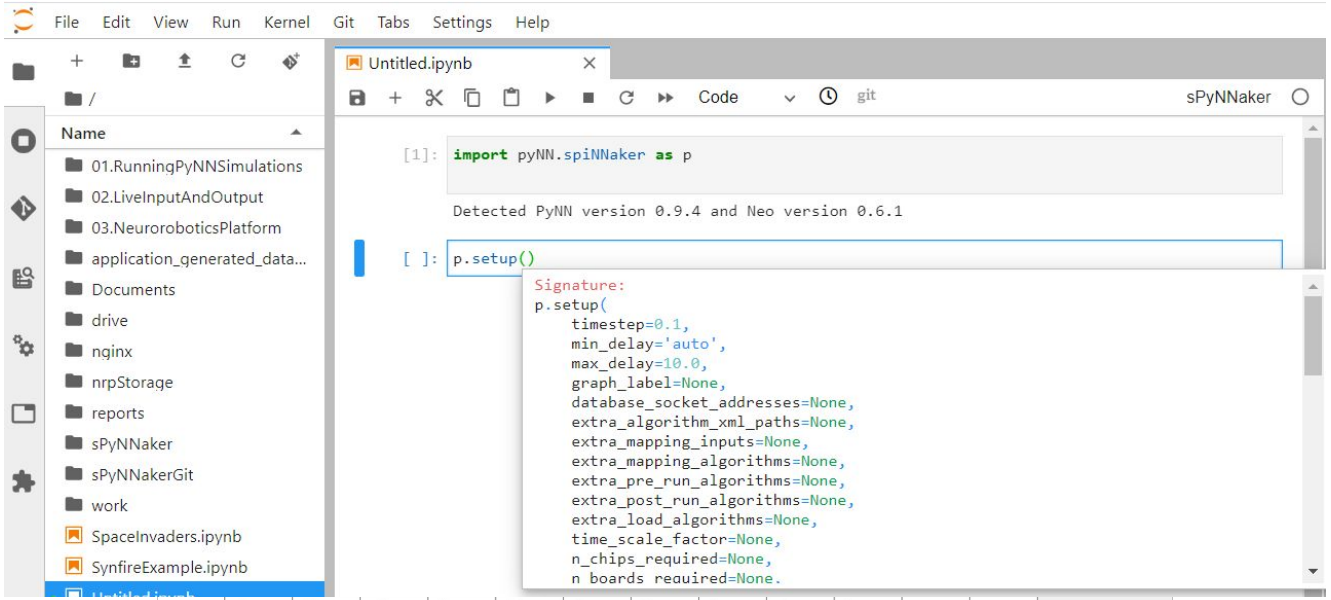


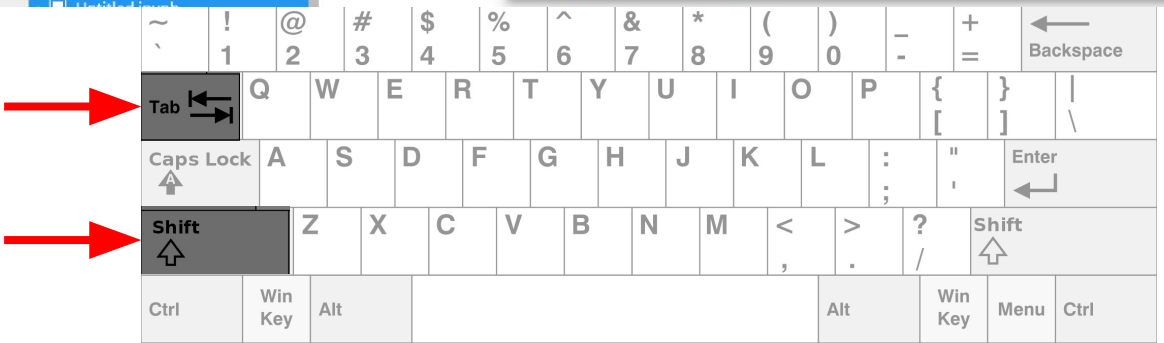
Jupyter Autocomplete



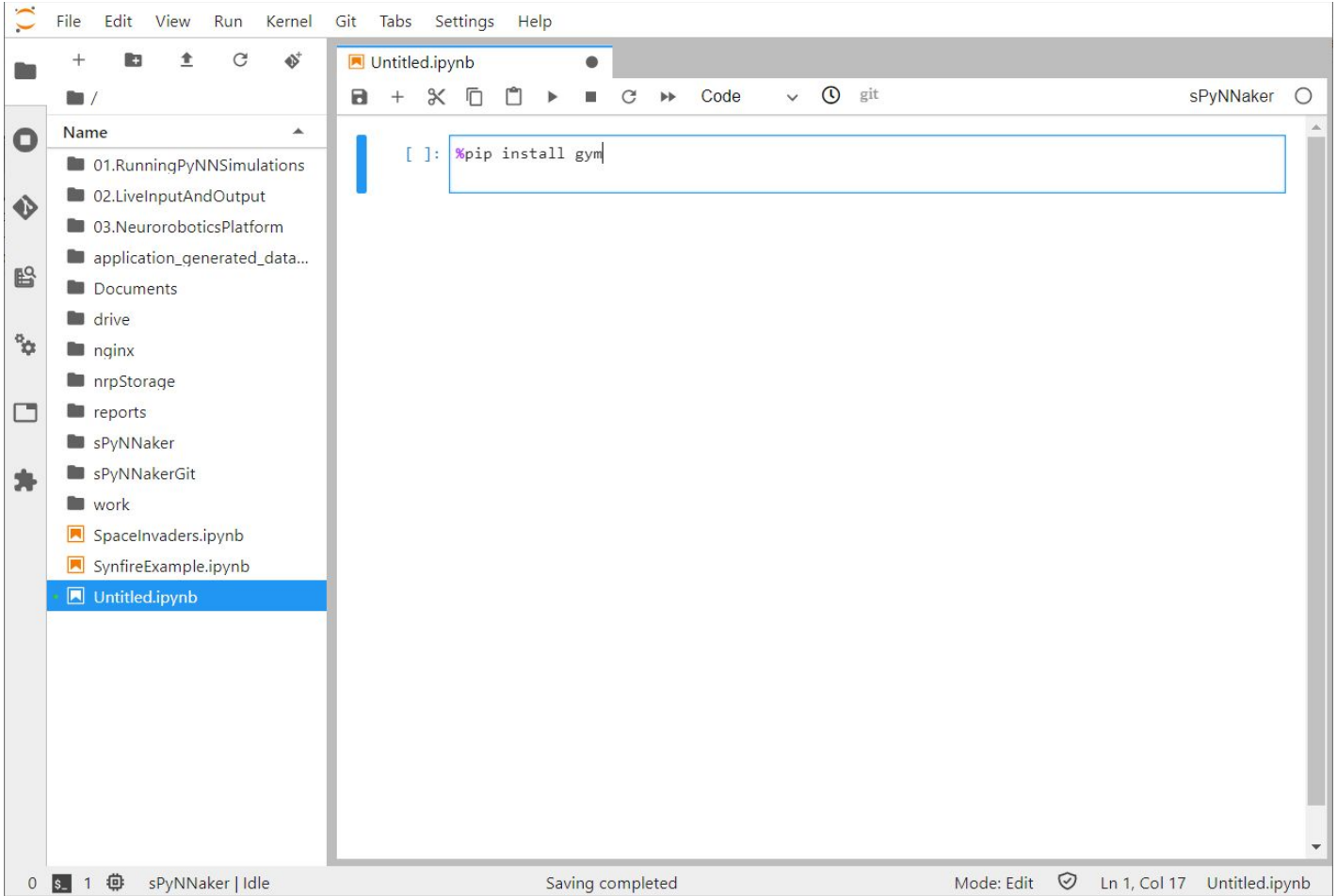


Jupyter Function Help

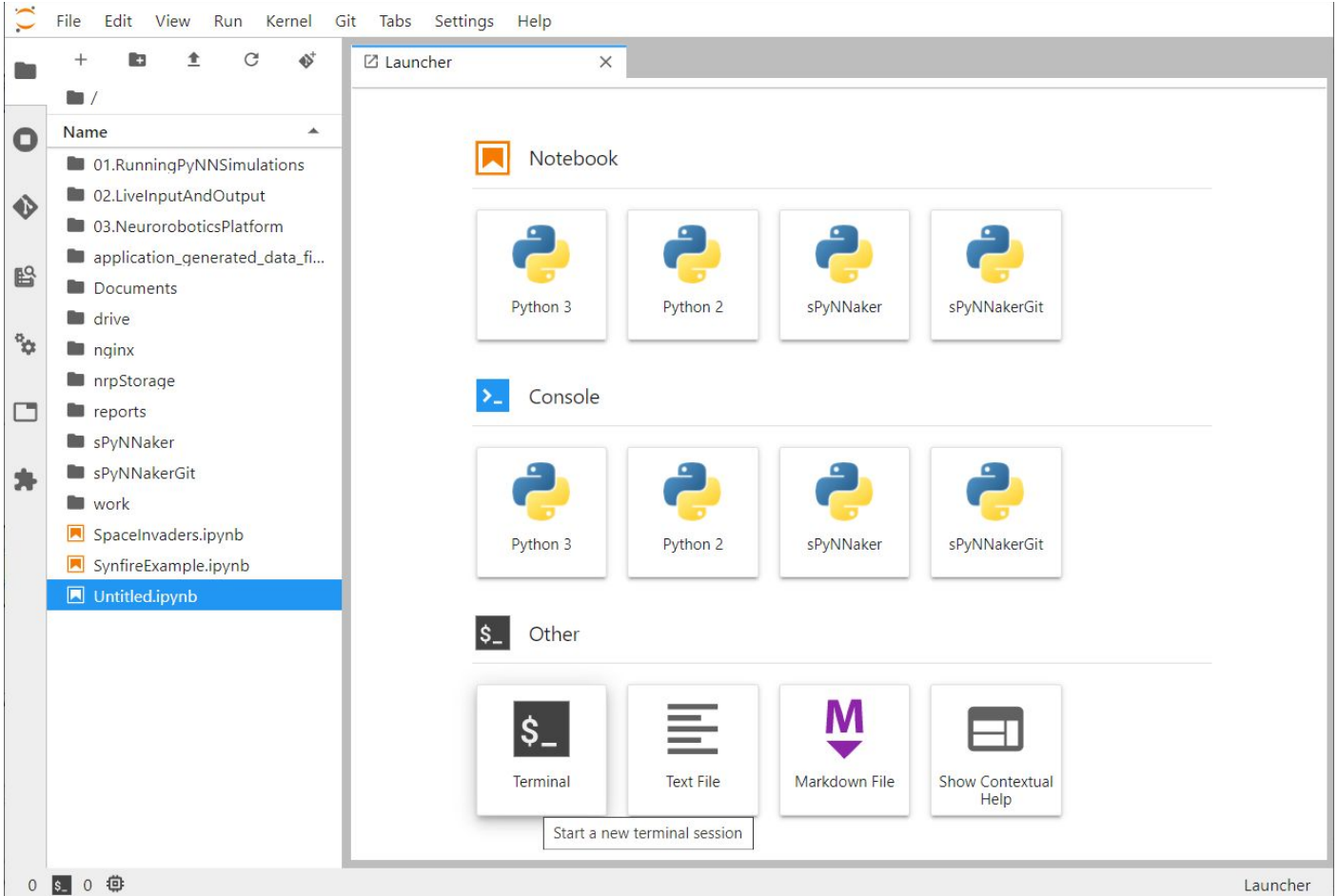




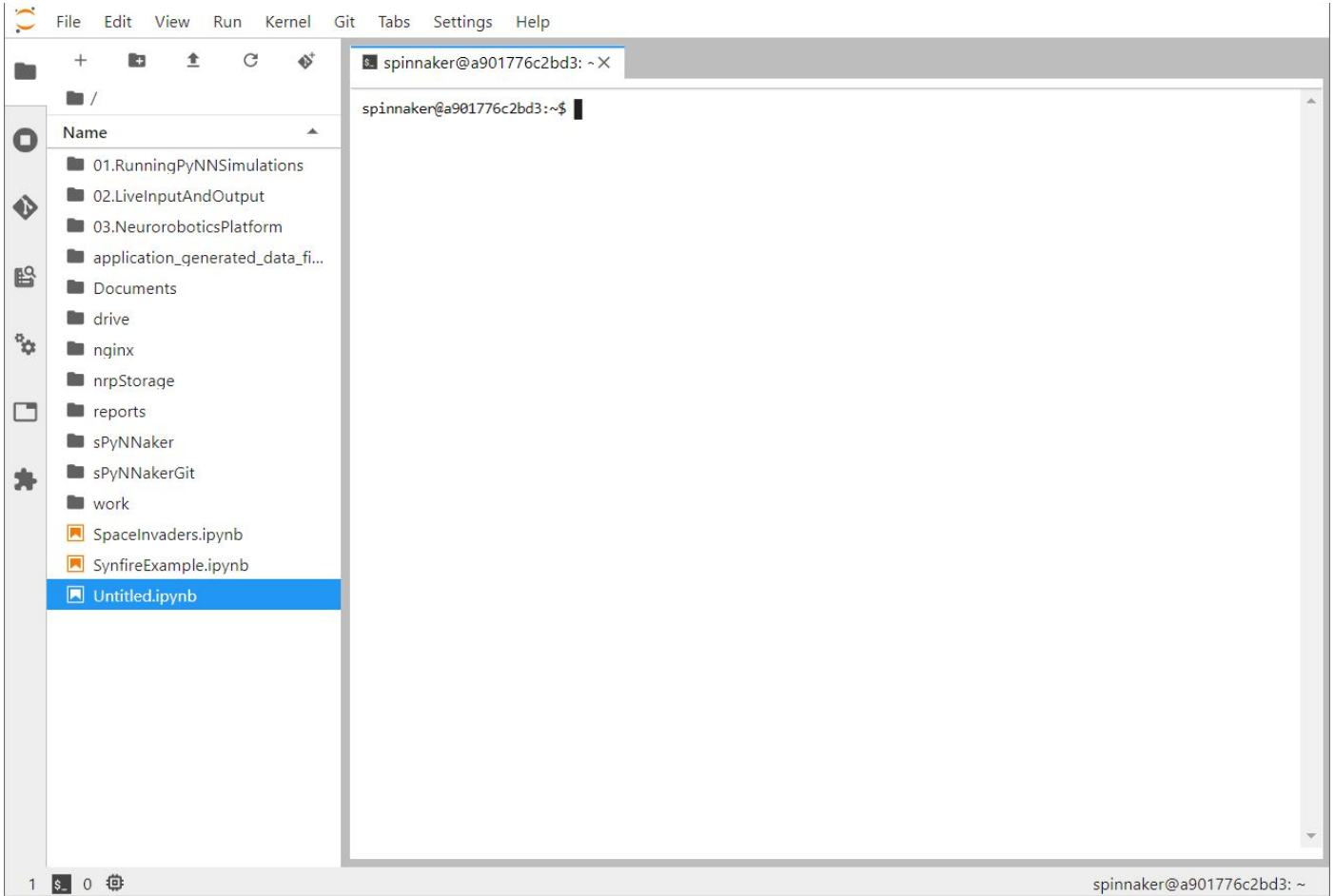
Install Libraries



Terminal Access



Terminal Access



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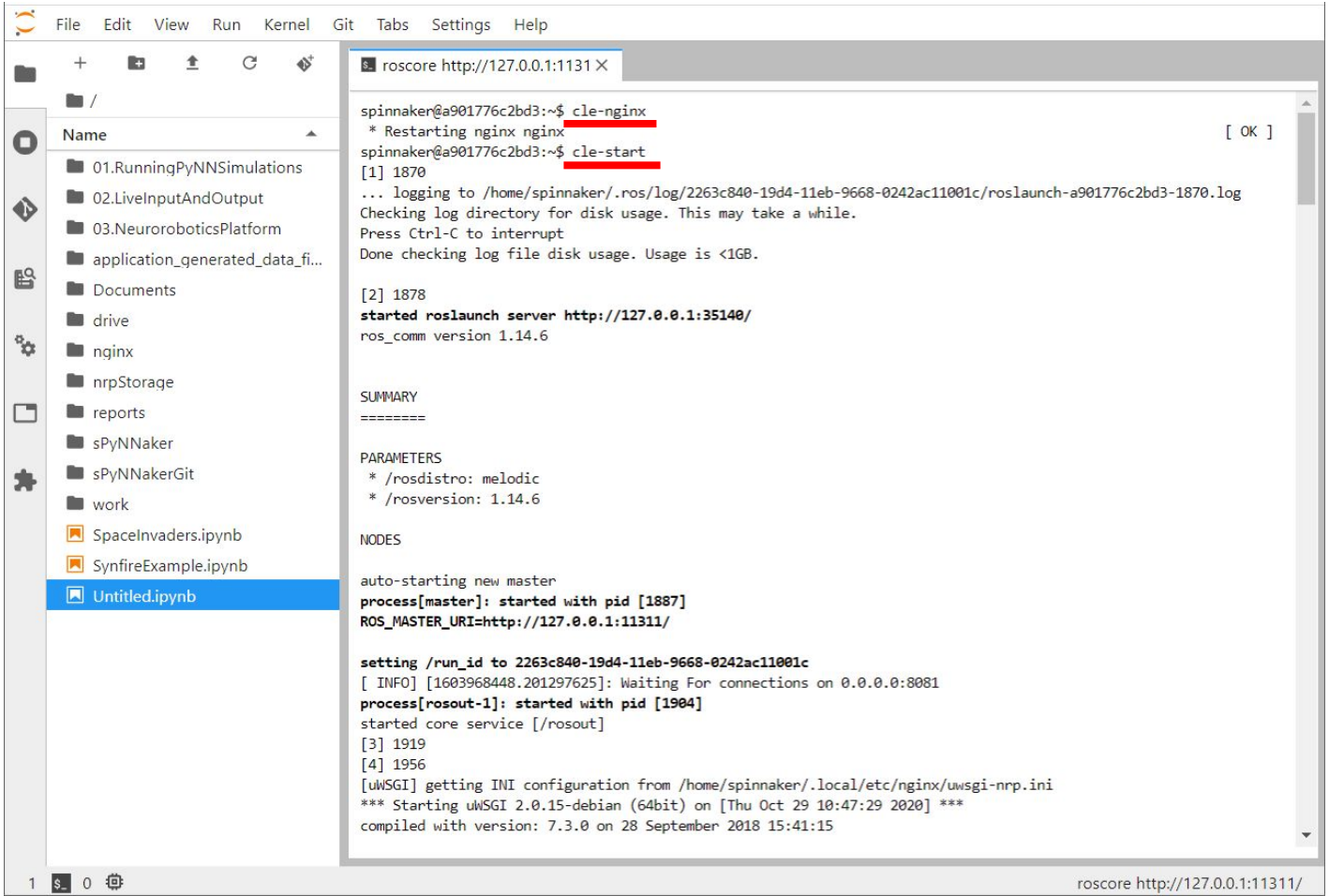
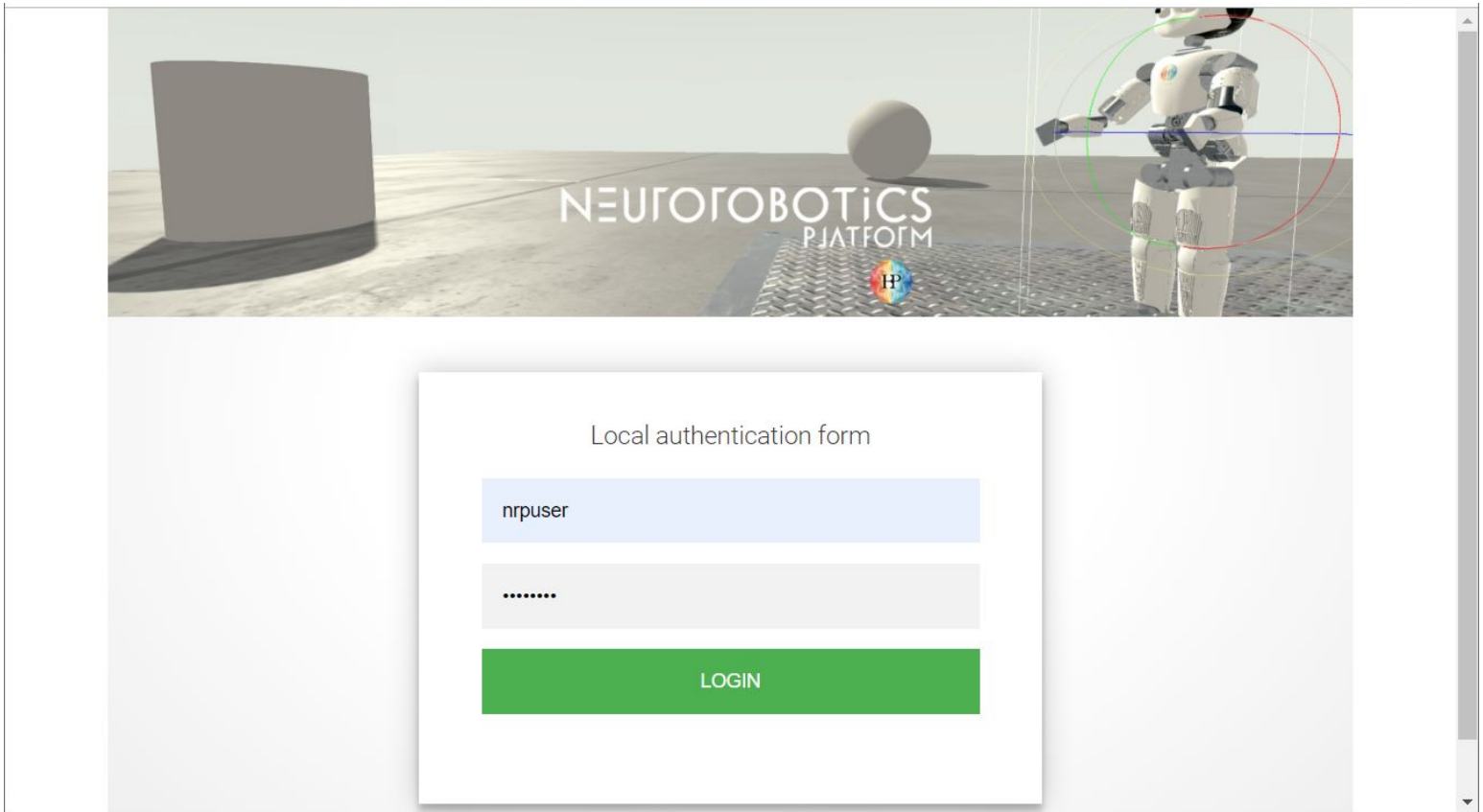
Start the NRP...

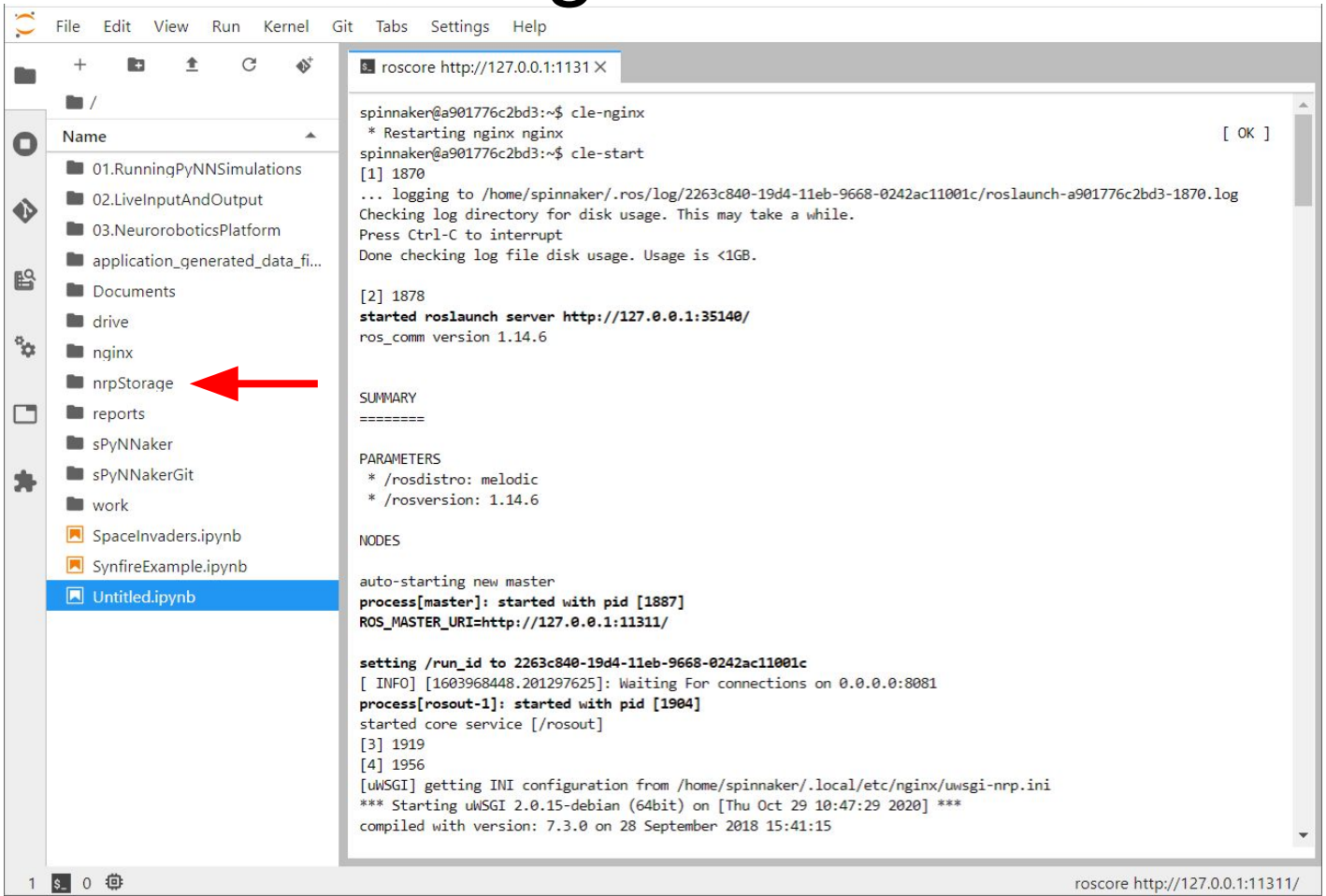


Connect to the NRP

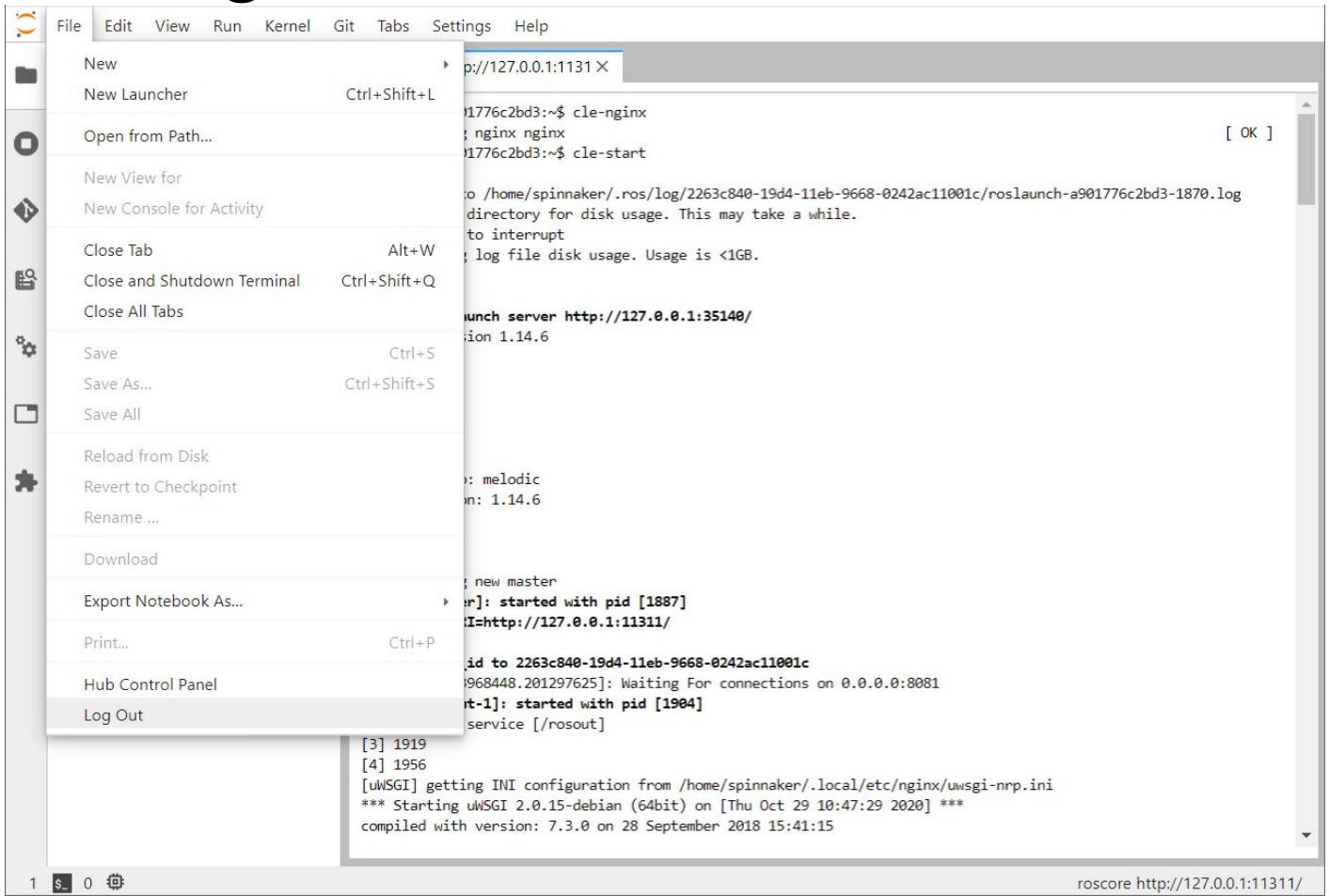
https://spinn-20.cs.man.ac.uk/user/**<username>**/proxy/9000/#/esv-private



NRP Storage


File Edit View Run Kernel Git Tabs Settings Help
/
Name
01.RunningPyNNSimulations
02.LiveInputAndOutput
03.NeuroroboticsPlatform
application_generated_data_fi...
Documents
drive
nginx
nrpStorage
reports
sPyNNaker
sPyNNakerGit
work
SpaceInvaders.ipynb
SynfireExample.ipynb
Untitled.ipynb
roscore http://127.0.0.1:1131
spinnaker@a901776c2bd3:~$ cle-nginx
* Restarting nginx nginx [OK]
spinnaker@a901776c2bd3:~$ cle-start
[1] 1870
... logging to /home/spinnaker/.ros/log/2263c840-19d4-11eb-9668-0242ac11001c/roslaunch-a901776c2bd3-1870.log
Checking log directory for disk usage. This may take a while.
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.
[2] 1878
started roslaunch server http://127.0.0.1:35140/
ros_comm version 1.14.6
SUMMARY
========
PARAMETERS
* /rosdistro: melodic
* /rosversion: 1.14.6
NODES
auto-starting new master
process[master]: started with pid [1887]
ROS_MASTER_URI=http://127.0.0.1:11311/
setting /run_id to 2263c840-19d4-11eb-9668-0242ac11001c
[INFO] [1603968448.201297625]: Waiting For connections on 0.0.0.0:8081
process[rosout-1]: started with pid [1904]
started core service [/rosout]
[3] 1919
[4] 1956
[uWSGI] getting INI configuration from /home/spinnaker/.local/etc/nginx/uwsgi-nrp.ini
*** Starting uWSGI 2.0.15-debian (64bit) on [Thu Oct 29 10:47:29 2020] ***
compiled with version: 7.3.0 on 28 September 2018 15:41:15
1 0
roscore http://127.0.0.1:11311/

Logout!


File
Edit
View
Run
Kernel
Git
Tabs
Settings
Help
New
New Launcher Ctrl+Shift+L
Open from Path...
New View for
New Console for Activity
Close Tab Alt+W
Close and Shutdown Terminal Ctrl+Shift+Q
Close All Tabs
Save Ctrl+S
Save As... Ctrl+Shift+S
Save All
Reload from Disk
Revert to Checkpoint
Rename ...
Download
Export Notebook As...
Print... Ctrl+P
Hub Control Panel
Log Out
[OK]
[3] 1919
[4] 1956
[uWSGI] getting INI configuration from /home/spinnaker/.local/etc/nginx/uwsgi-nrp.ini
*** Starting uWSGI 2.0.15-debian (64bit) on [Thu Oct 29 10:47:29 2020] ***
compiled with version: 7.3.0 on 28 September 2018 15:41:15
roscore http://127.0.0.1:11311/

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Spiking Neural Networks

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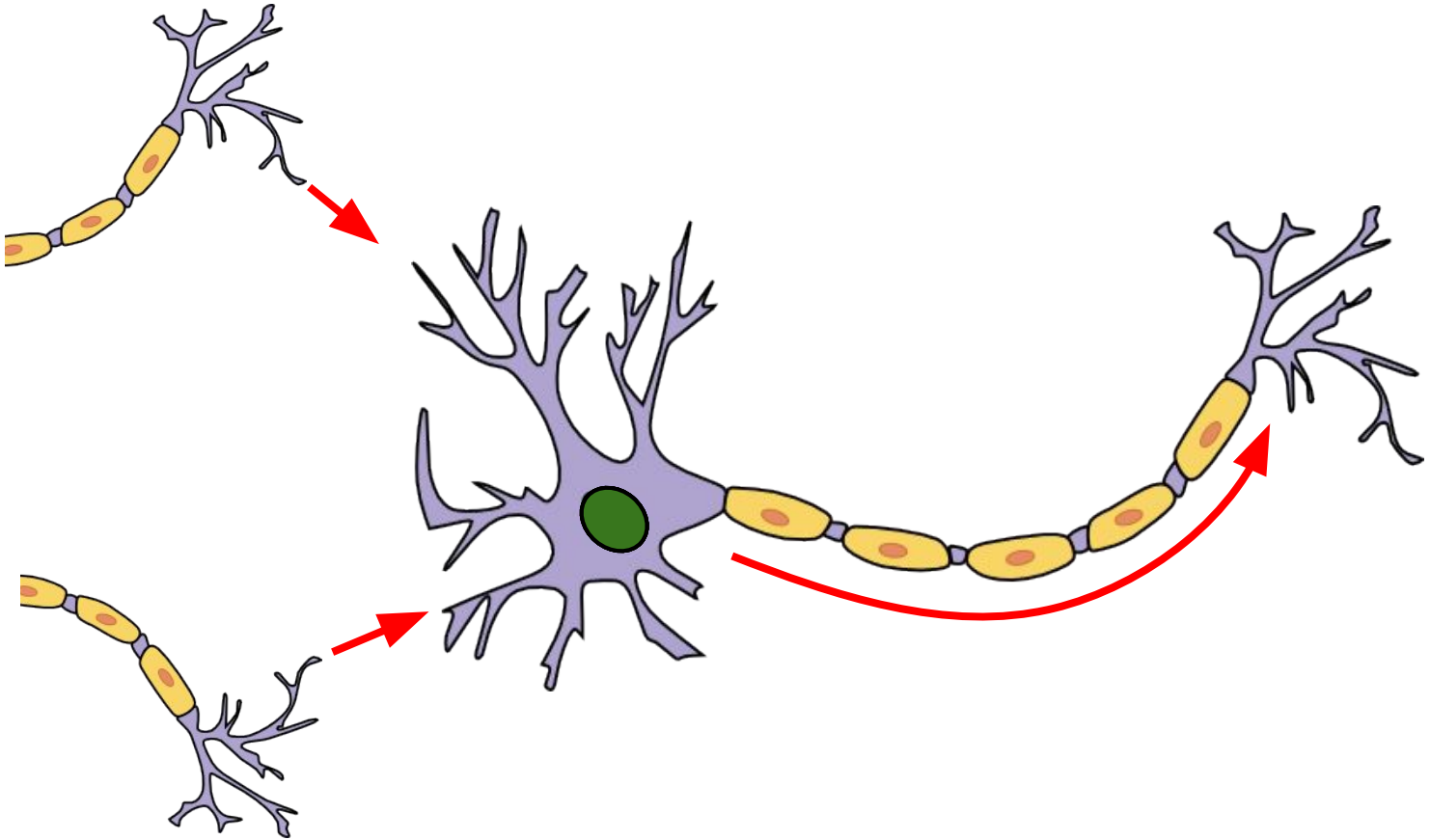
Spiking Neural Networks



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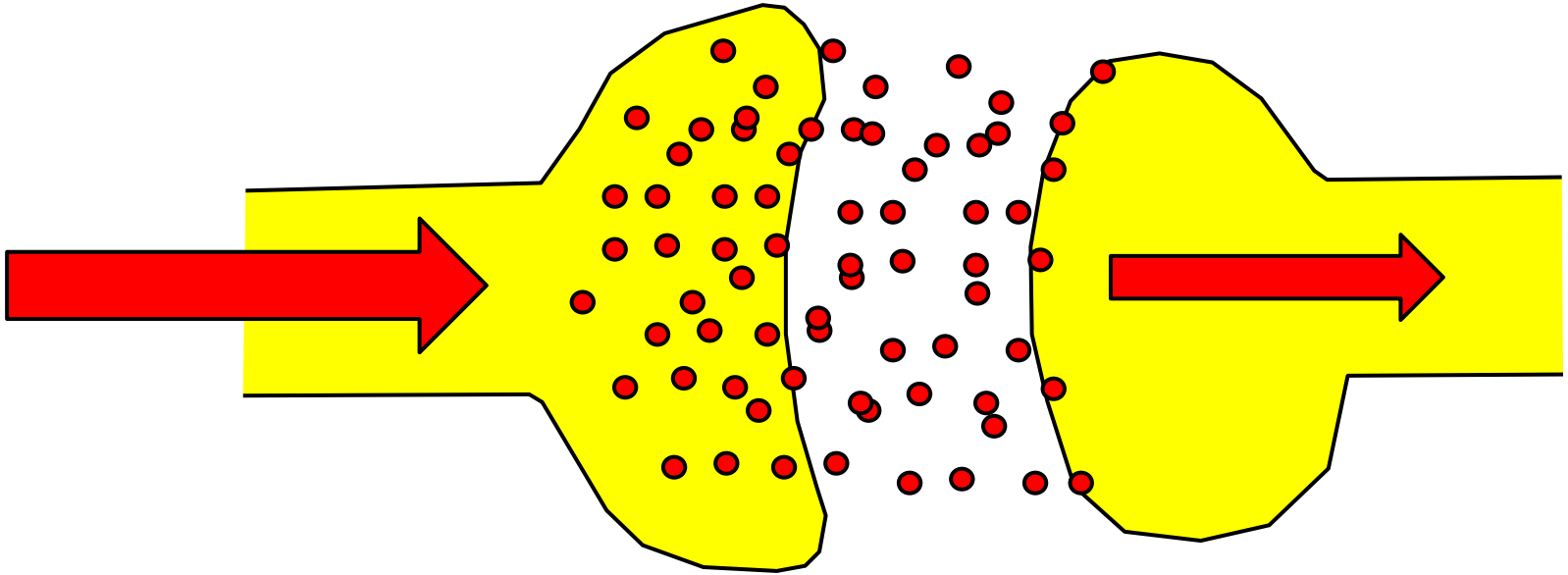
Spiking Neural Networks



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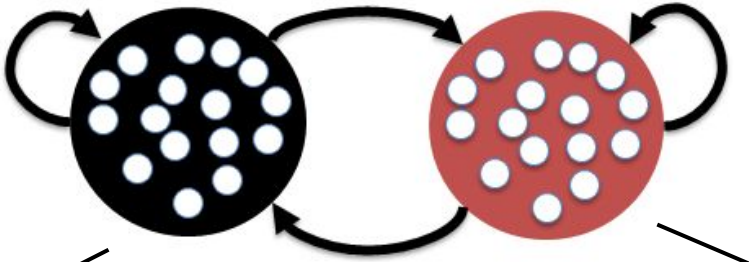
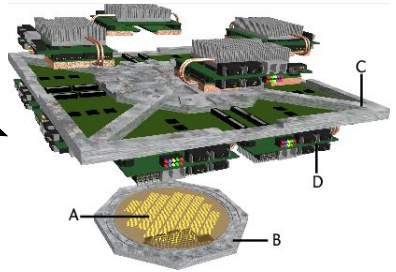
PyNN

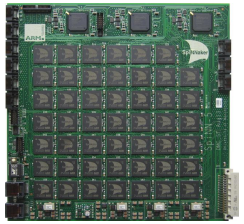
What is PyNN?

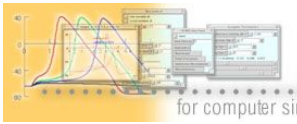


nest :: initiative



BRIAN





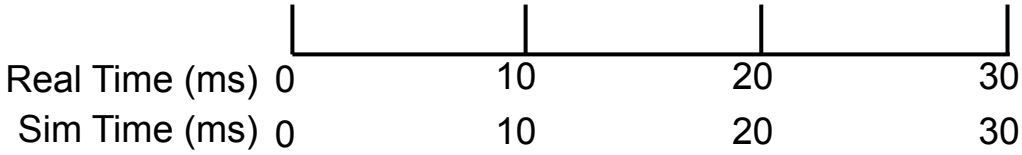
NEURON

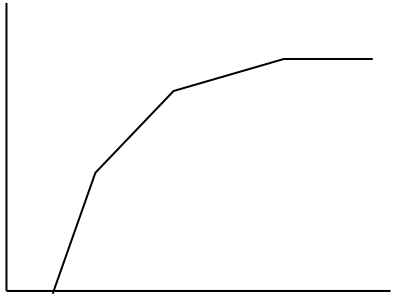
for computer simulations of neurons and neural networks

PyNN - Setup

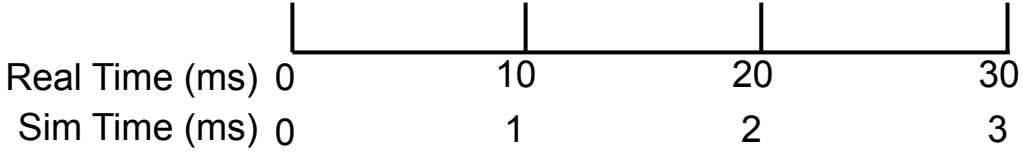
```
import pyNN.spiNNaker as p
```

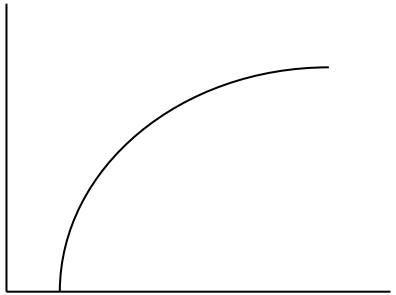
```
p.setup(timestep=1.0)
```





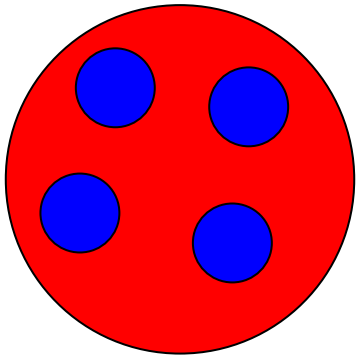
```
p.setup(timestep=0.1)
```

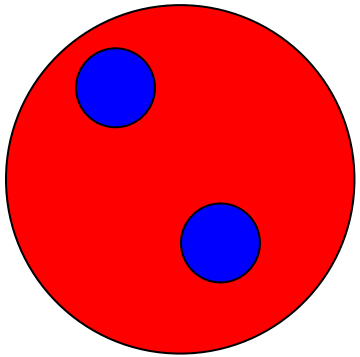




PyNN - Populations

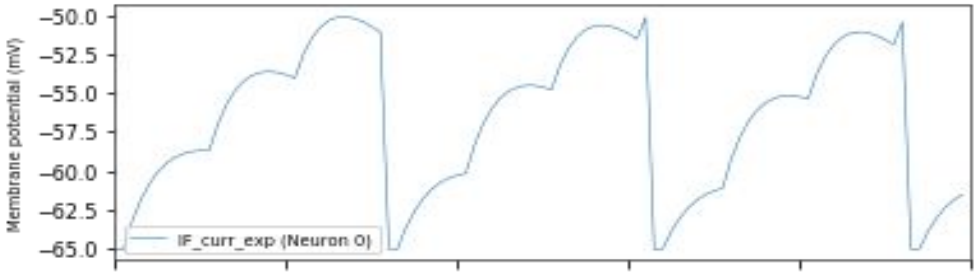
```
pop_1 = p.Population(
    4, p.IF_curr_exp(), label="Fred")
pop_2 = p.Population(
    2, p.IF_curr_exp(), label="Bob")
```



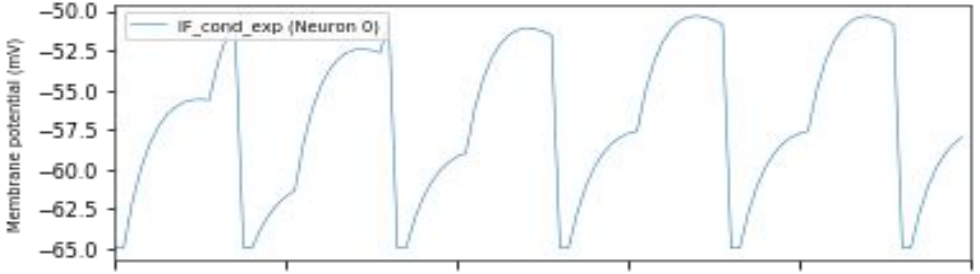


PyNN Populations - Models

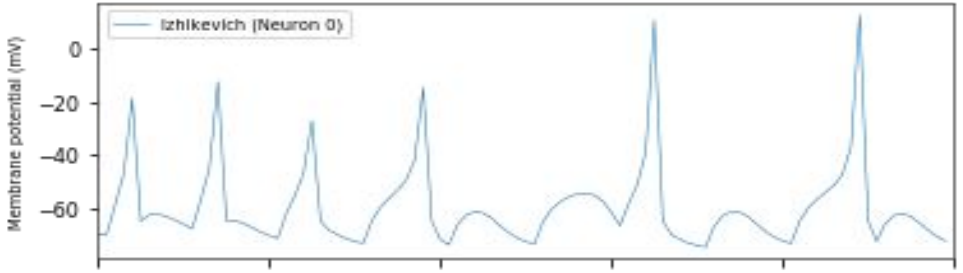
```
p.IF_curr_exp(...)
```




```
p.IF_cond_exp(...)
```

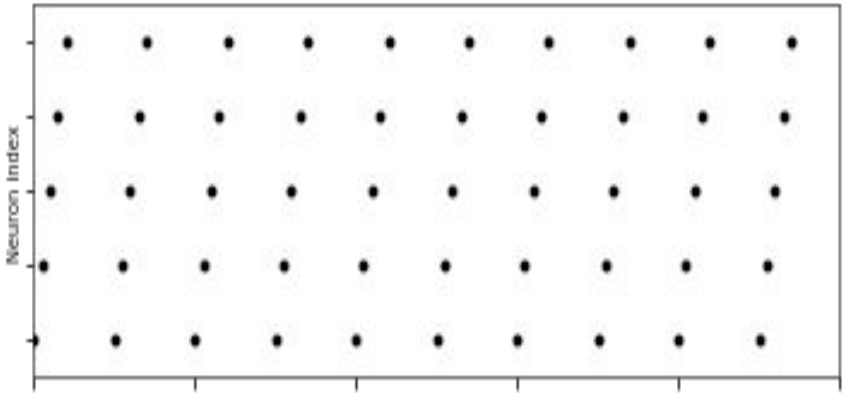



```
p.Izhikevich(...)
```

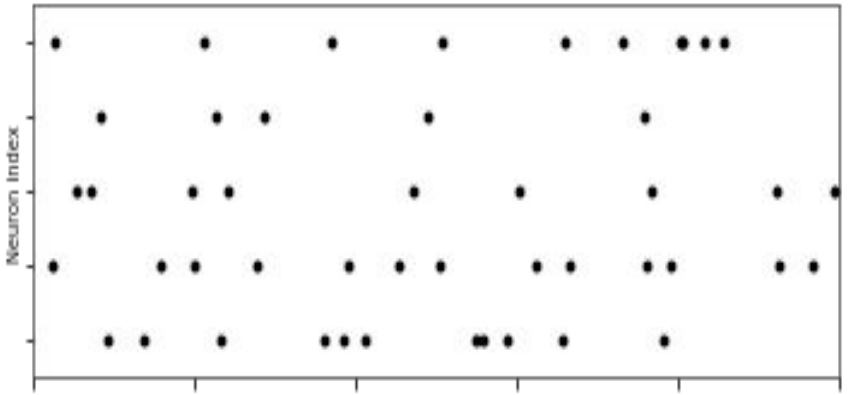


PyNN Populations - Models

```
p.SpikeSourceArray(
    spike_times=[...])
```

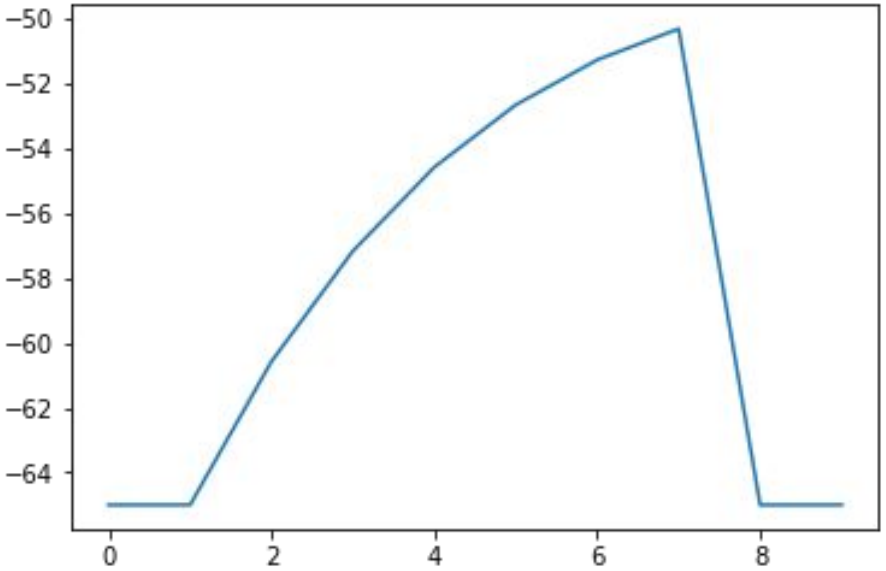


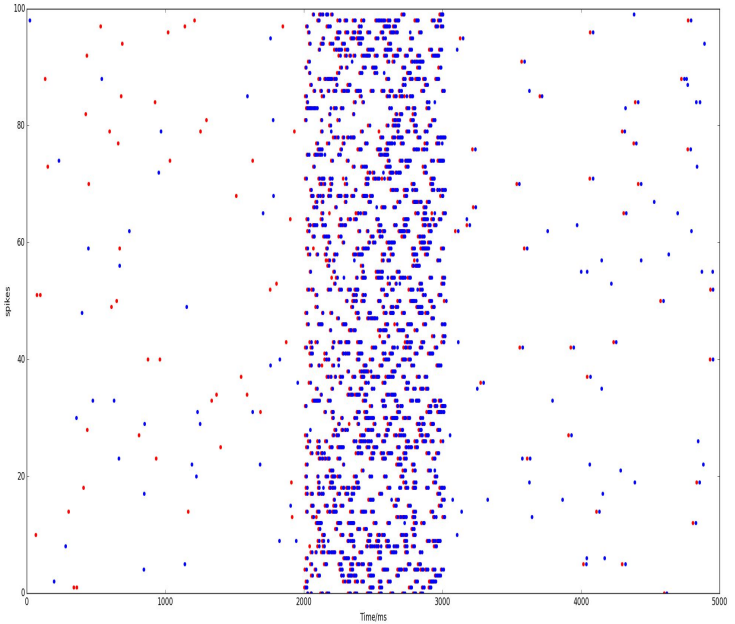

```
p.SpikeSourcePoisson(
    rate=...)
```



PyNN Populations - Recording

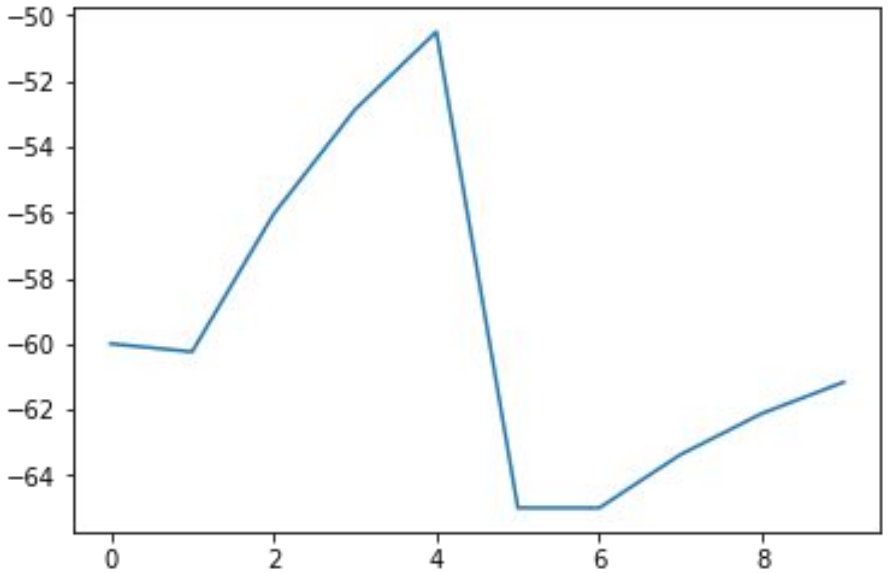
```
pop_1.record(["v", "spikes"])
```





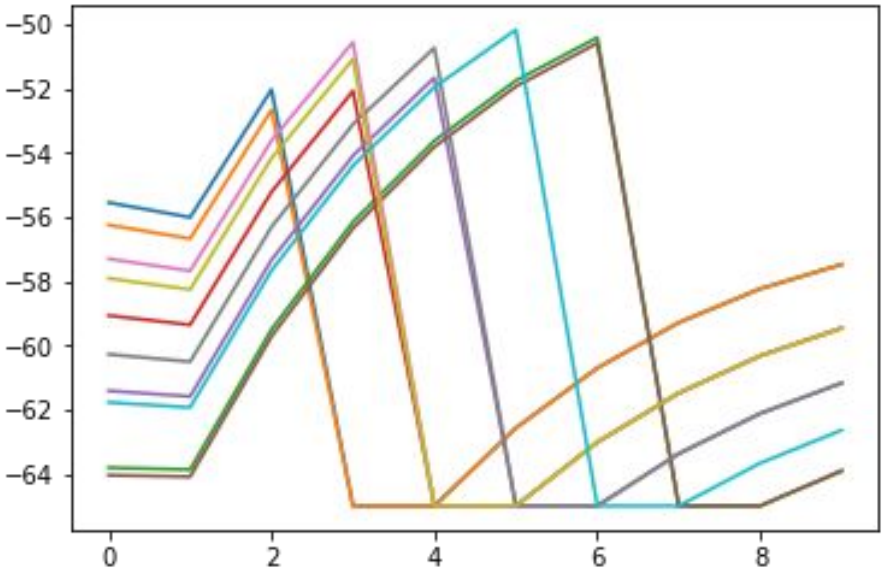
PyNN Populations - Initialize

```
pop_1.initialize(v=-60)
```



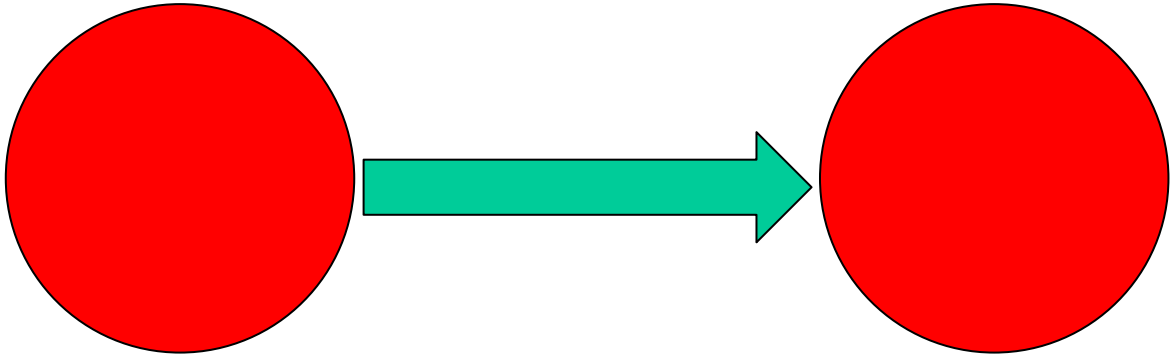
PyNN - Random Parameters

```
pop_1.initialize(v=p.RandomDistribution(
    "uniform", low=-65.0, high=-55.0))
```



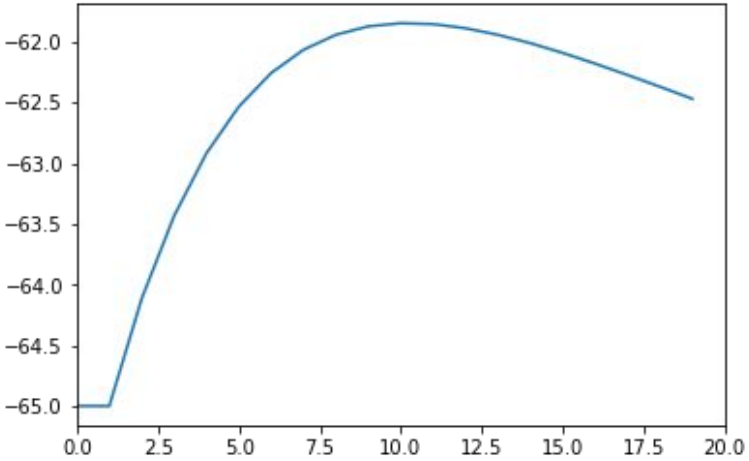
PyNN - Projections

```
proj = p.Projection(
    pop_1, pop_2,
    p.OneToOneConnector(),
    p.StaticSynapse(
        weight=1.0, delay=2.0))
```



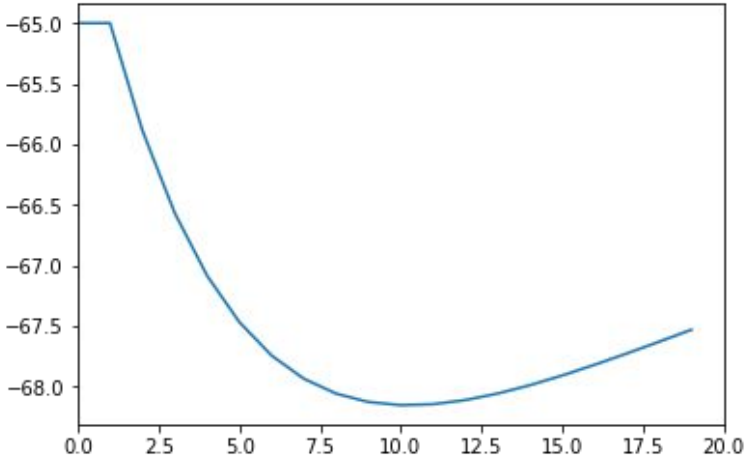
PyNN - Projections

```
proj = p.Projection(
    pop_1, pop_2,
    p.OneToOneConnector(),
    p.StaticSynapse(weight=1.0),
    receptor_type="excitatory")
```



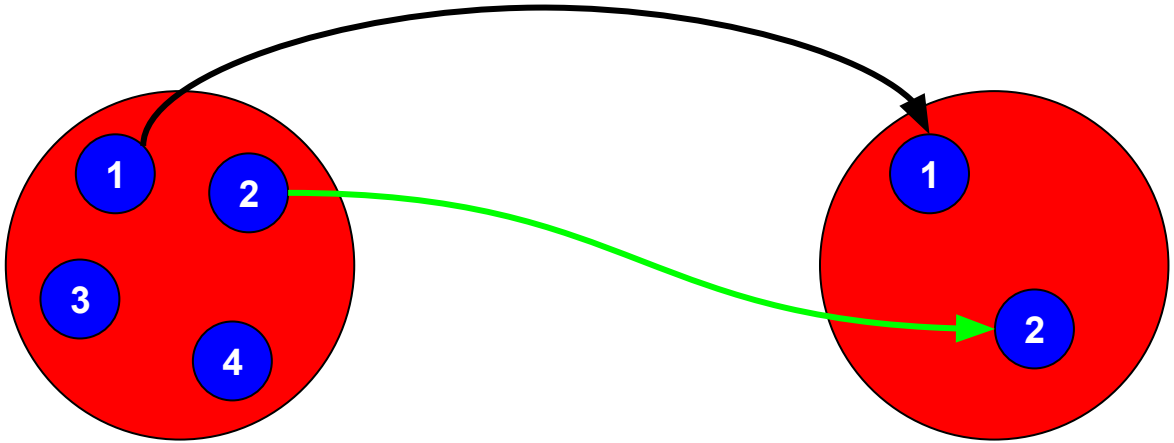
PyNN - Projections

```
proj = p.Projection(
    pop_1, pop_2,
    p.OneToOneConnector(),
    p.StaticSynapse(weight=1.0),
    receptor_type="inhibitory")
```



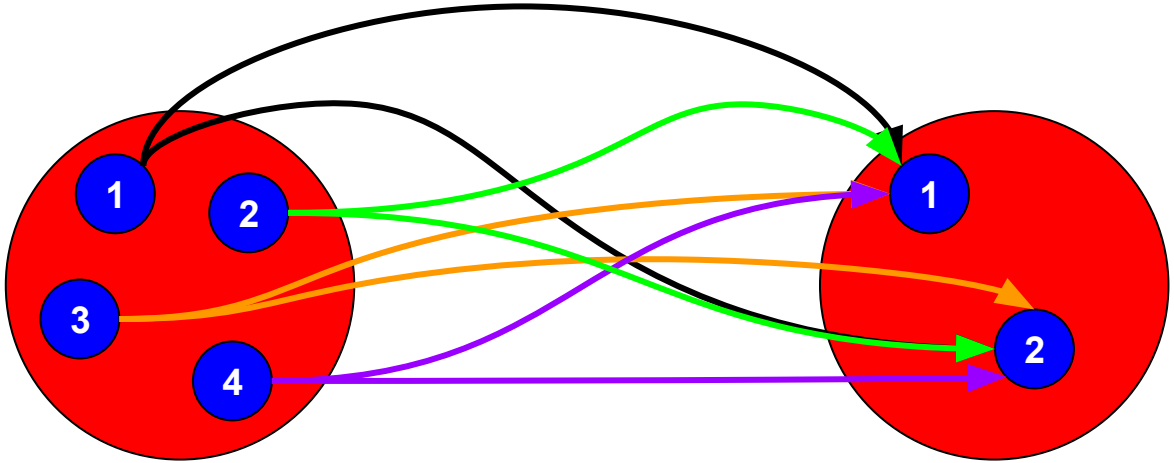
PyNN Projections - Connectors

```
p.OneToOneConnector()
```



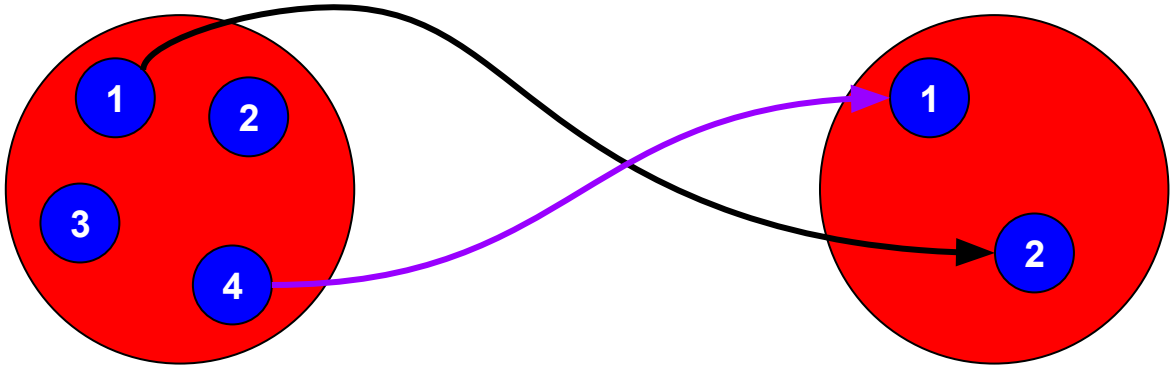
PyNN Projections - Connectors

```
p.AllToAllConnector()
```



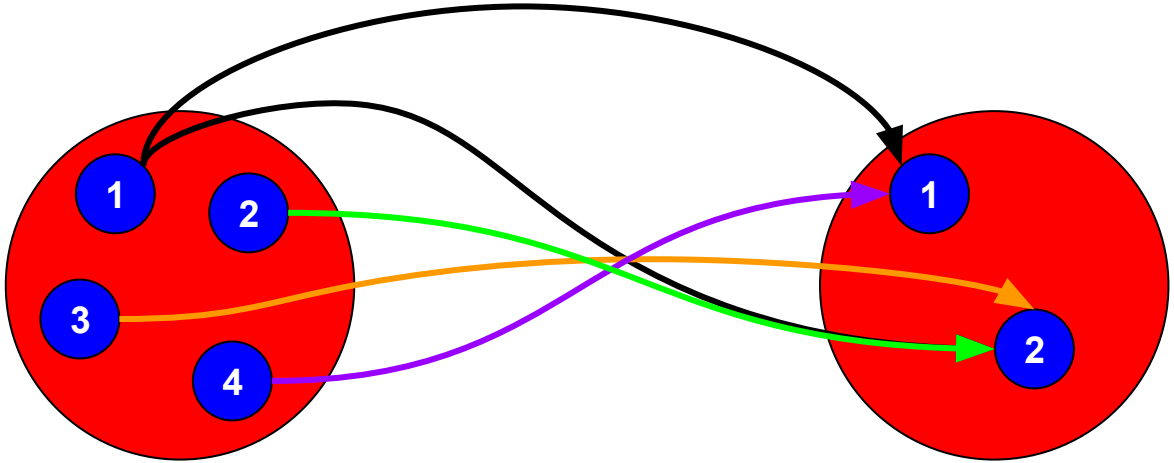
PyNN Projections - Connectors

```
p.FixedProbabilityConnector(p=0.1)
```



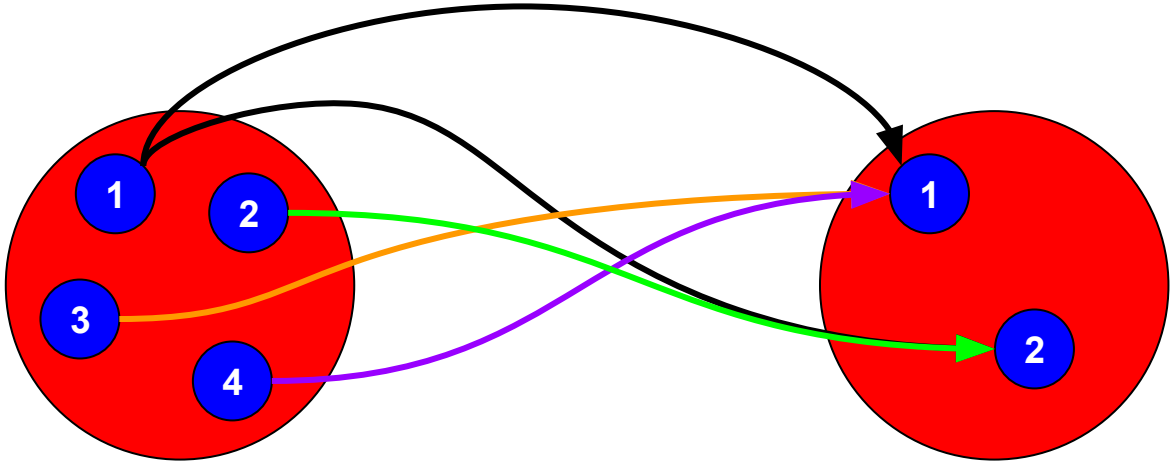
PyNN Projections - Connectors

```
p.FixedProbabilityConnector(p=0.5)
```



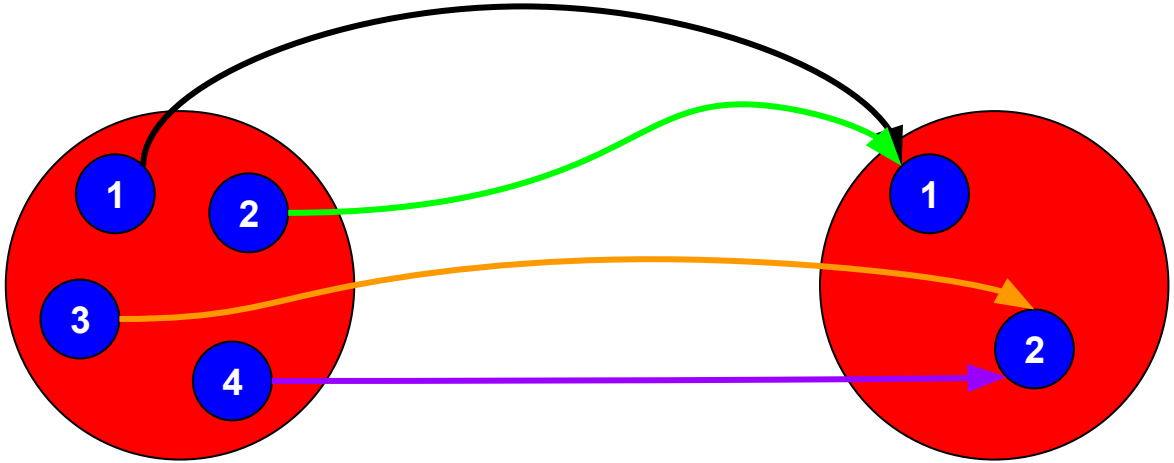
PyNN Projections - Connectors

```
p.FixedTotalNumberConnector(5)
```



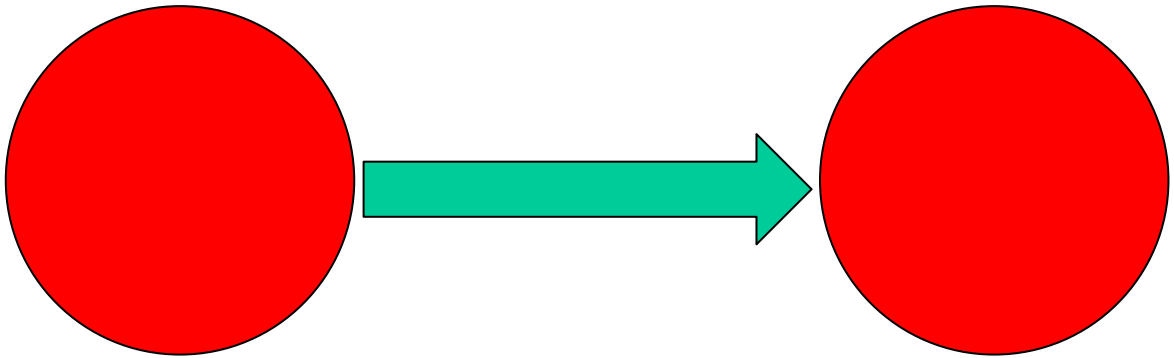
PyNN Projections - Connectors

```
p.FromListConnector(
    [(1, 1), (2, 1), (3, 2), (4, 2)])
```



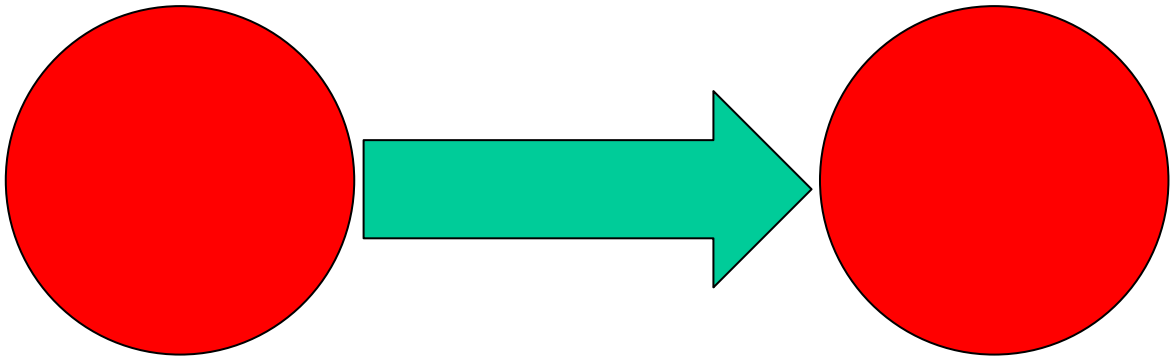
PyNN - Static Synapse Types

```
p.StaticSynapse(weight=1.0, delay=2.0)
```



PyNN - Static Synapse Types

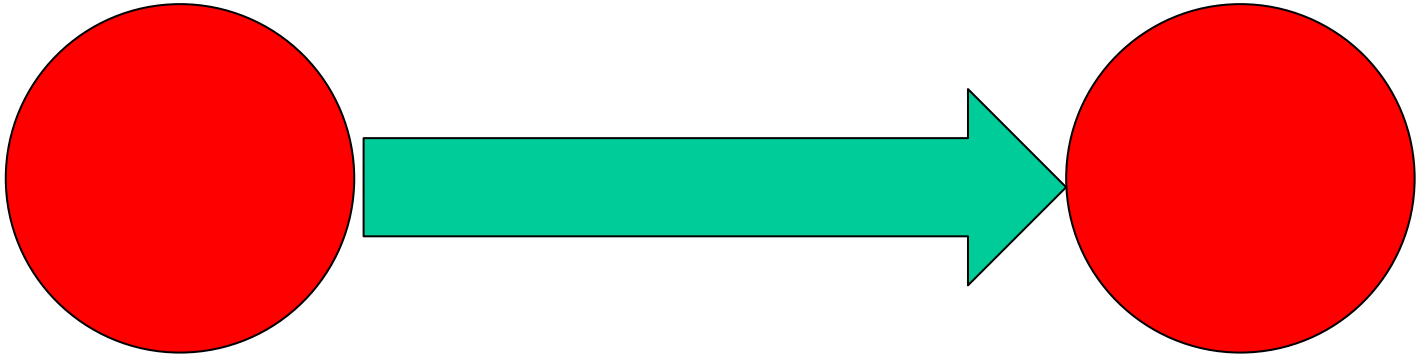
```
p.StaticSynapse(weight=5.0, delay=2.0)
```



PyNN - Static Synapse Types

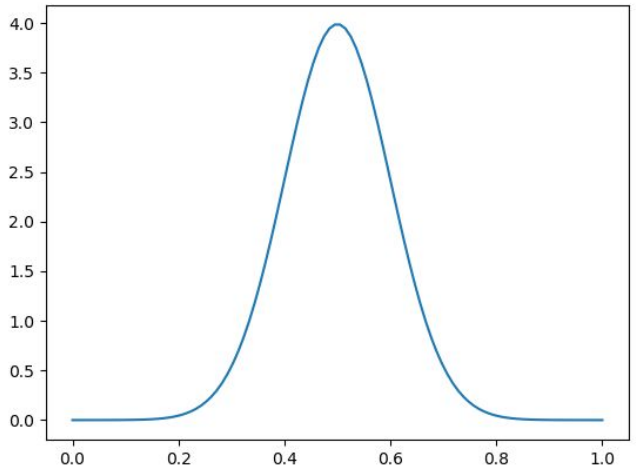
```
p.StaticSynapse(weight=5.0, delay=3.0)
```

(timestep <= delay <= 144 * timestep)



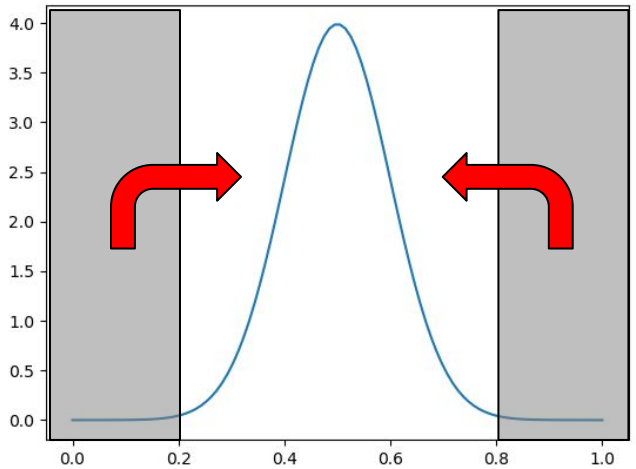
PyNN - Random Weights and Delays

```
weight_dist = p.RandomDistribution(
    “normal”, mu=0.5, sigma=0.1)
p.StaticSynapse(
    weight=weight_dist, delay=3.0)
```



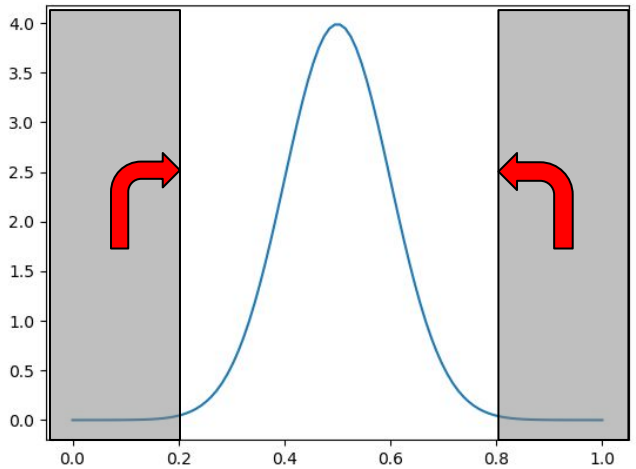
PyNN - Random Weights and Delays

```
weight_dist = p.RandomDistribution(
    “normal_clipped”,
    mu=0.5, sigma=0.1, low=0.2 high=0.8)
```

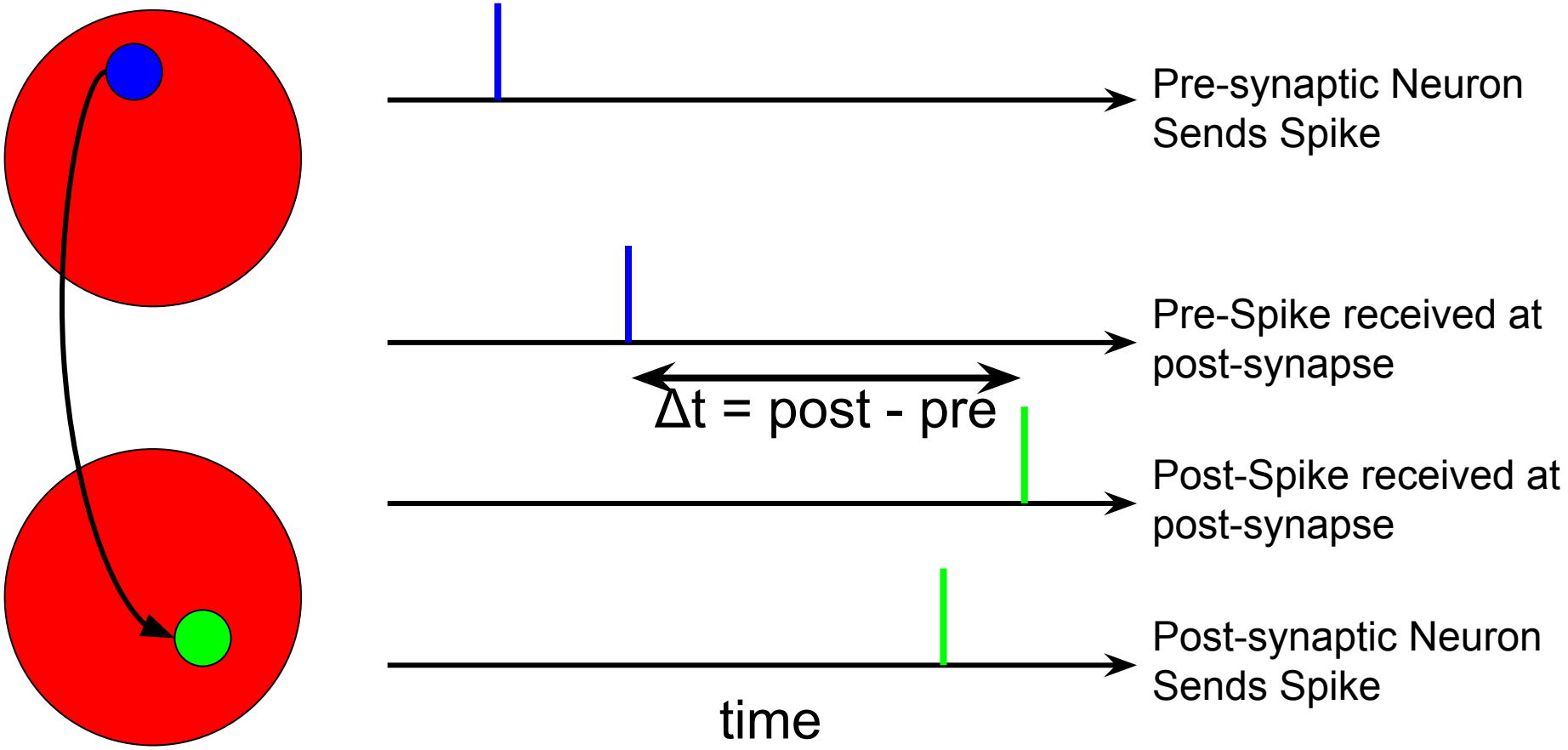


PyNN - Random Weights and Delays

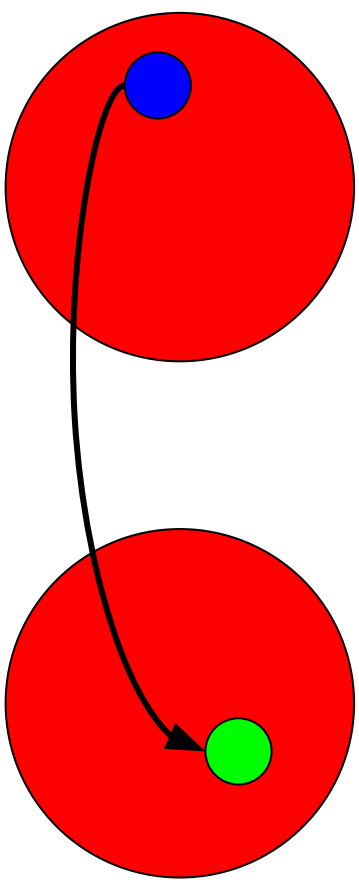
```
weight_dist = p.RandomDistribution(
    “normal_clipped_to_boundary”,
    mu=0.5, sigma=0.1, low=0.2 high=0.8)
```

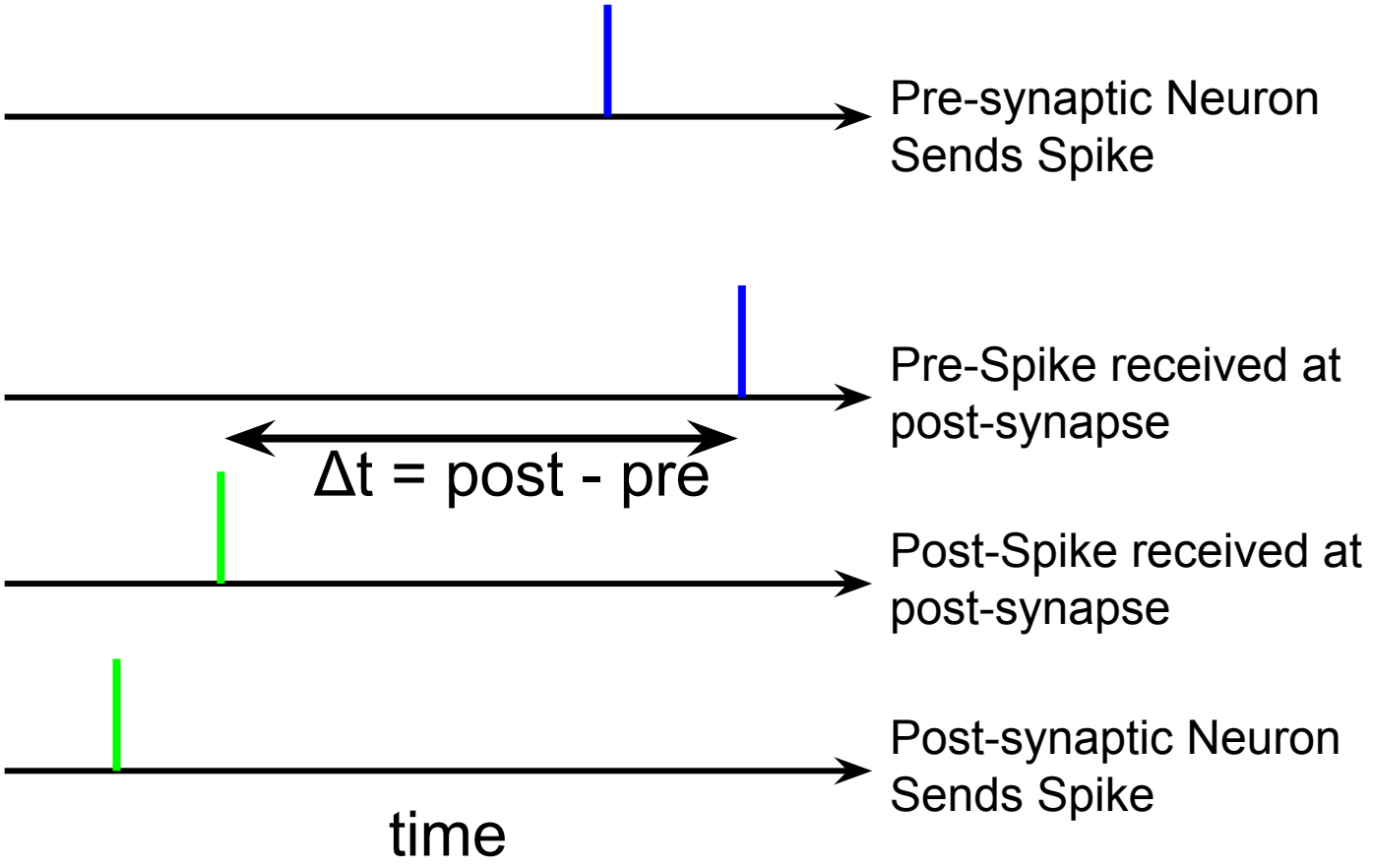


Spike Timing Dependent Plasticity

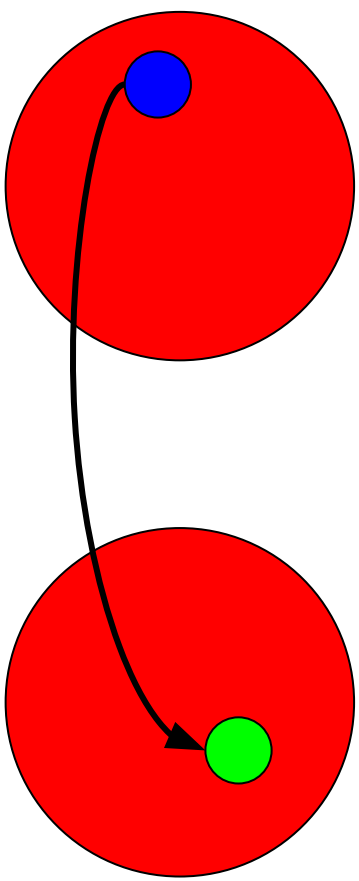


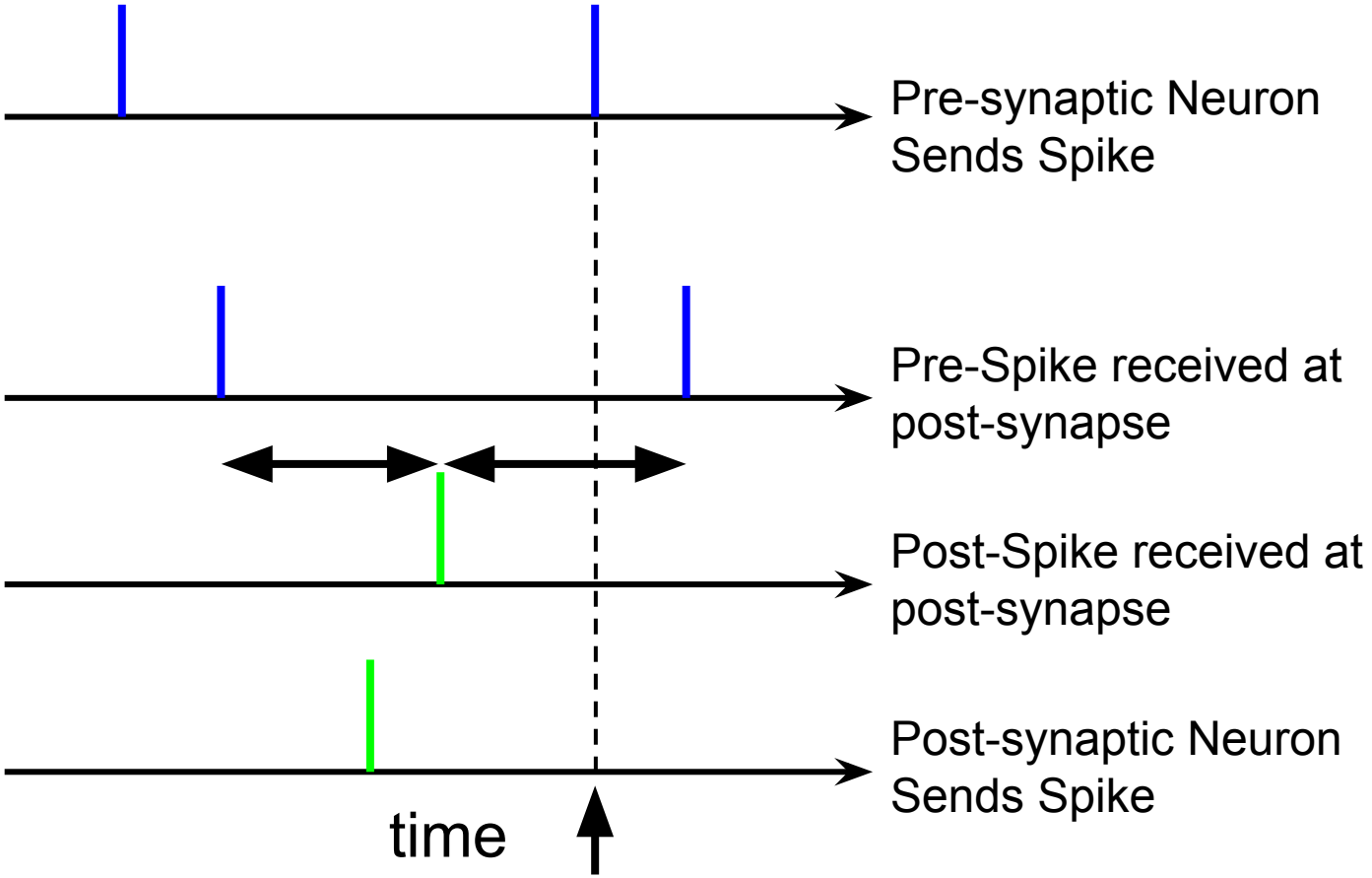
Spike Timing Dependent Plasticity





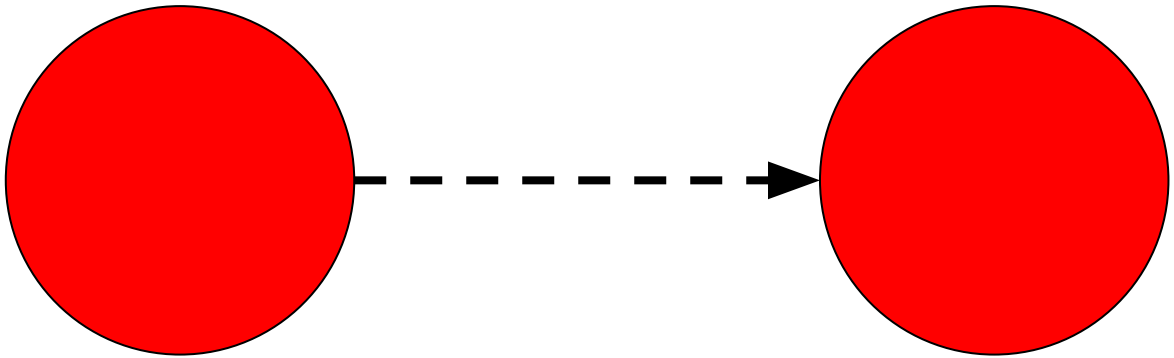
STDP - Deferred Execution





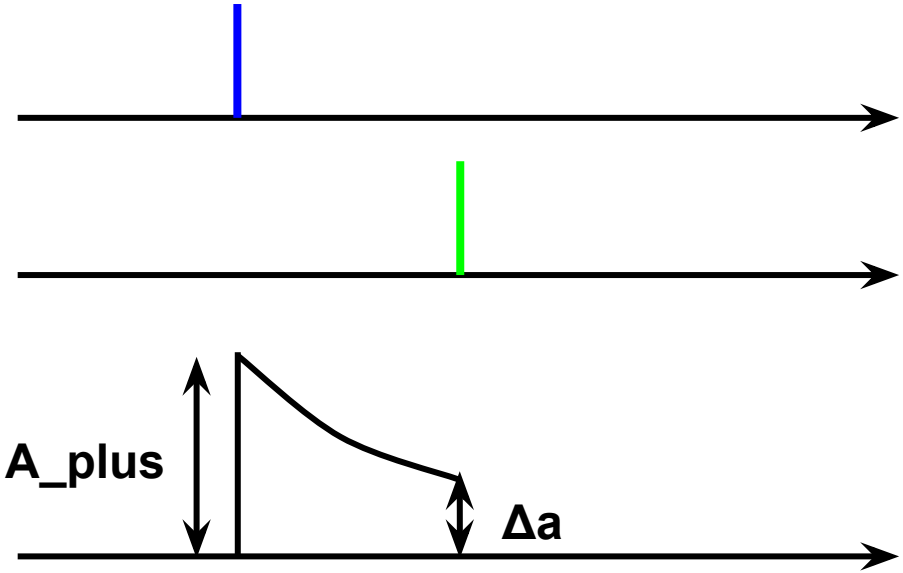
PyNN - STDP Synapse Types

```
p.STDPMechanism(
    timing_dependence=?,
    weight_dependence=?,
    weight=0.0, delay=2.0)
```



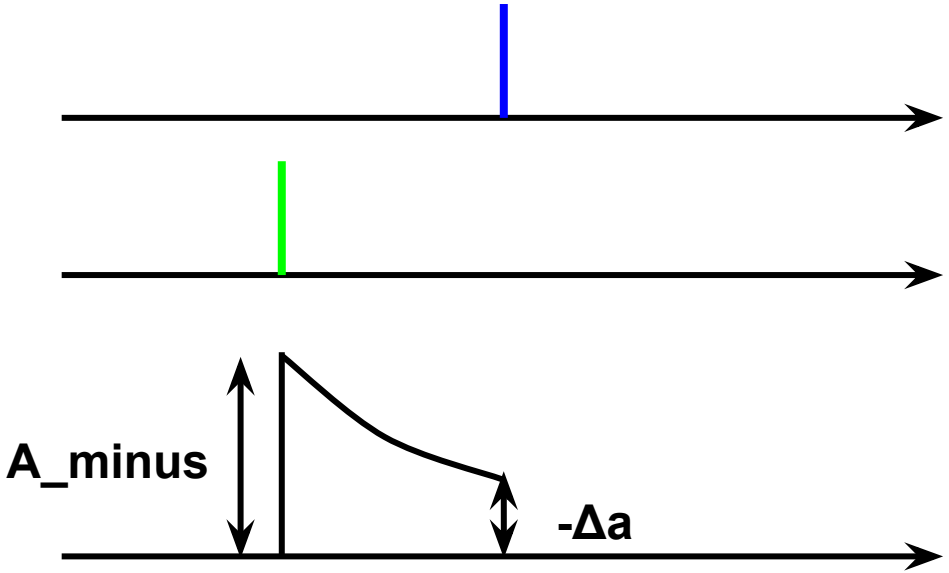
PyNN - Timing Dependence

```
sim.SpikePairRule(tau_plus=20.0, tau_minus=20.0,
                  A_plus=0.5, A_minus=0.5)
```



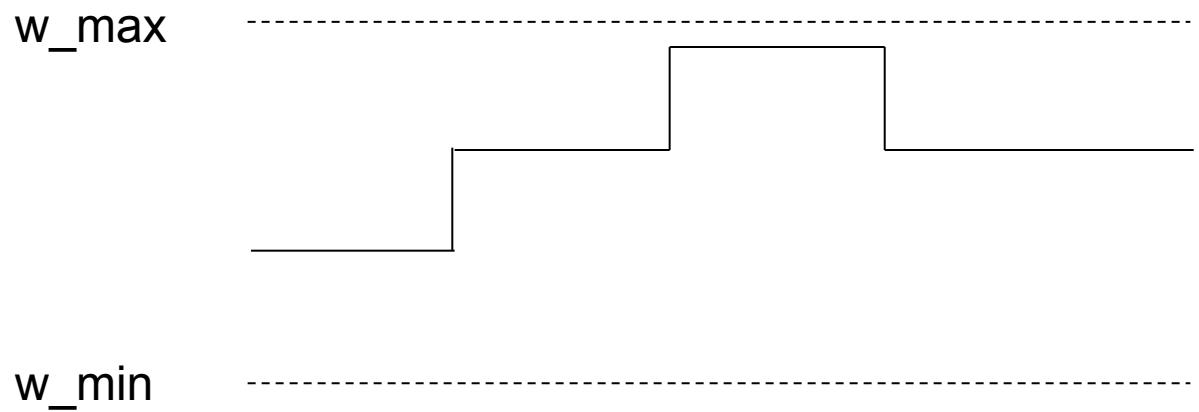
PyNN - Timing Dependence

```
sim.SpikePairRule(tau_plus=20.0, tau_minus=20.0,
                  A_plus=0.5, A_minus=0.5)
```



PyNN - Weight Dependence

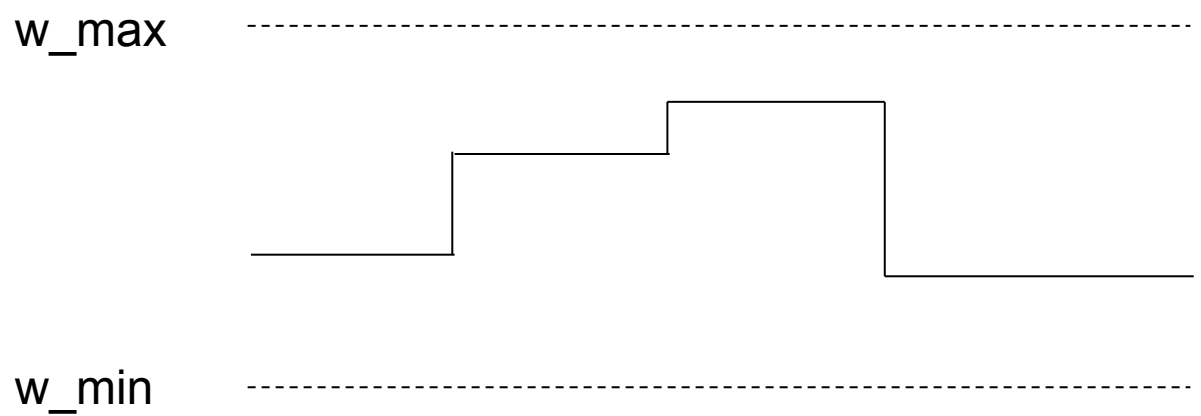
```
sim.AdditiveWeightDependence(w_max=5.0, w_min=0.0)
```



$$\Delta w = \Delta a \, (w\_max - w\_min)$$

PyNN - Weight Dependence

```
sim.MultiplicativeWeightDependence(w_max=5.0,w_min=0.0)
```



$$\Delta w = \Delta a\ (w - w\_min) \text{ if } \Delta a < 0 \text{ (Depression)}$$

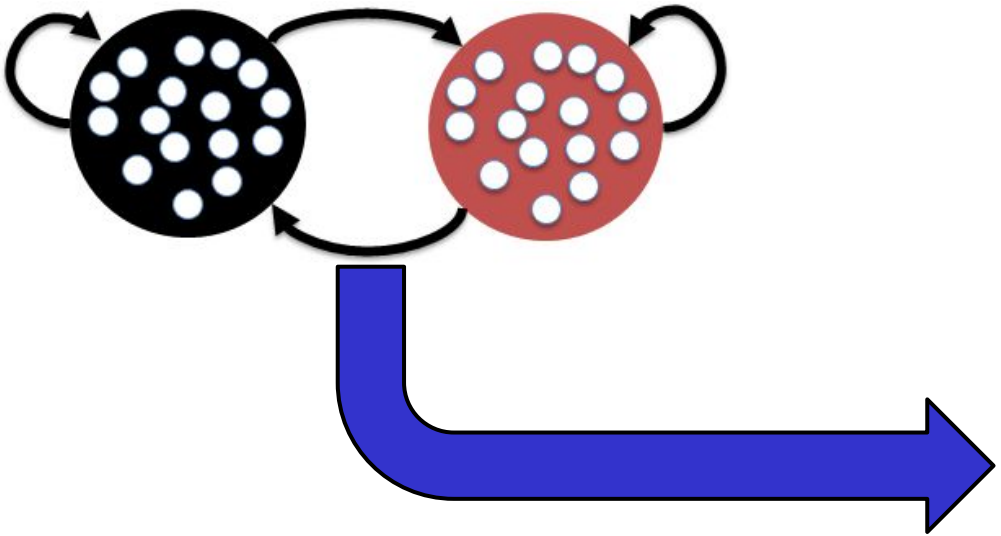
$$\Delta w = \Delta a\ (w\_max - w) \text{ if } \Delta a > 0 \text{ (Potentiation)}$$

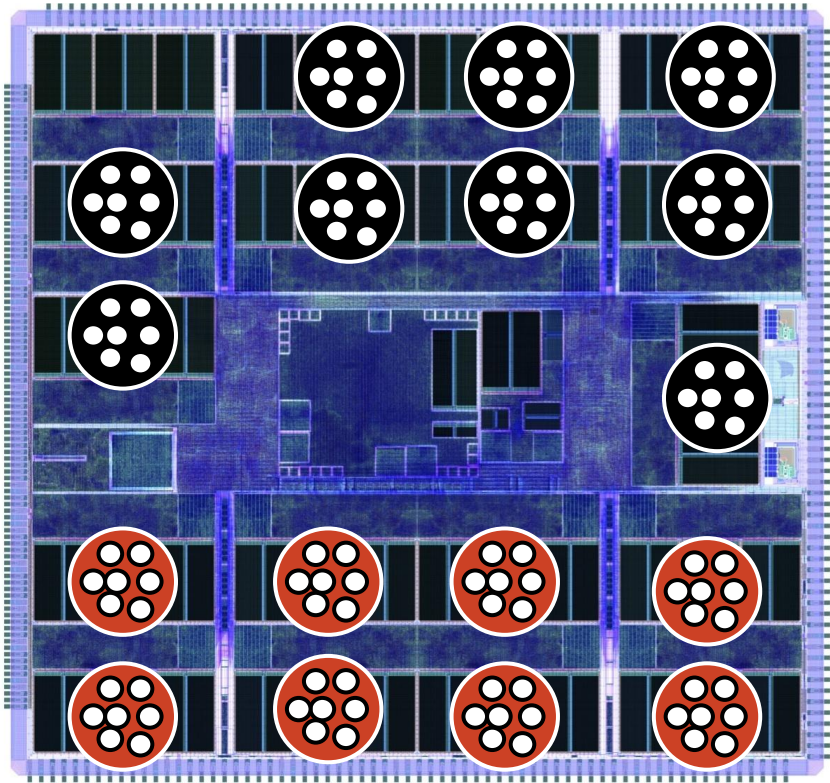
MANCHESTER 1824

Running on SpiNNaker

PyNN - Run

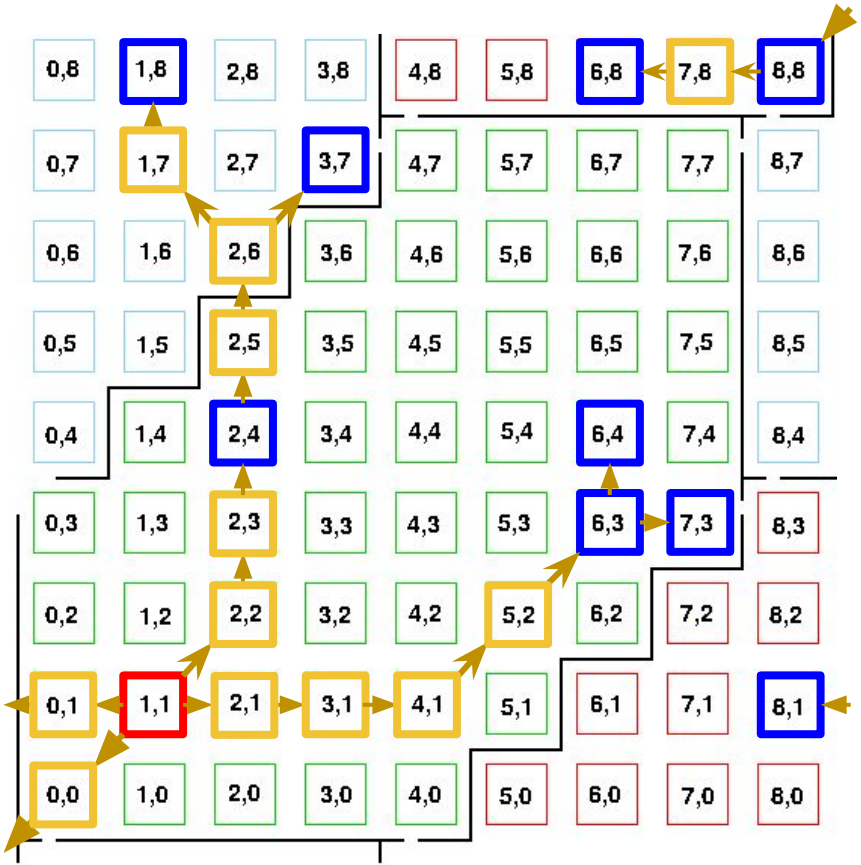
```
p.run(100)
```





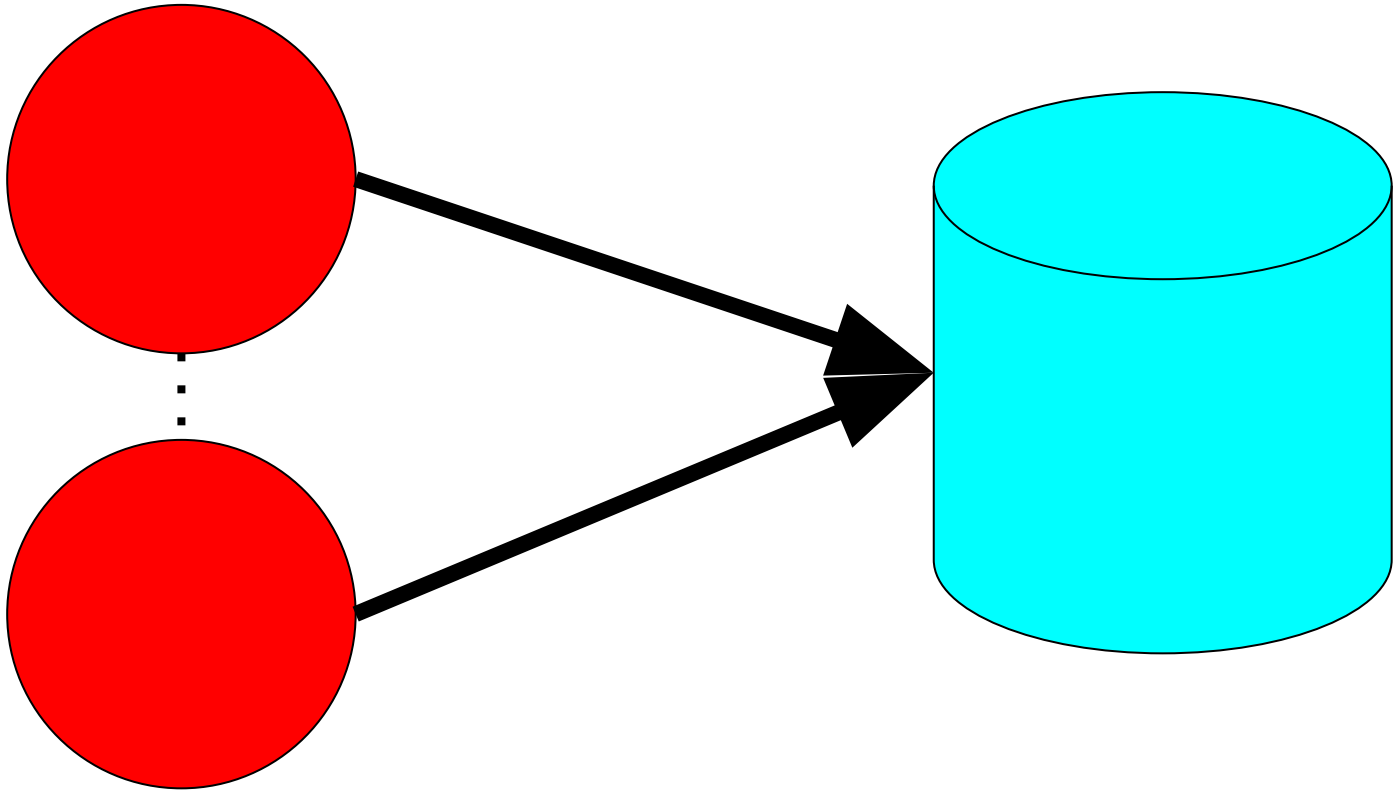
PyNN - Run

```
p.run(100)
```



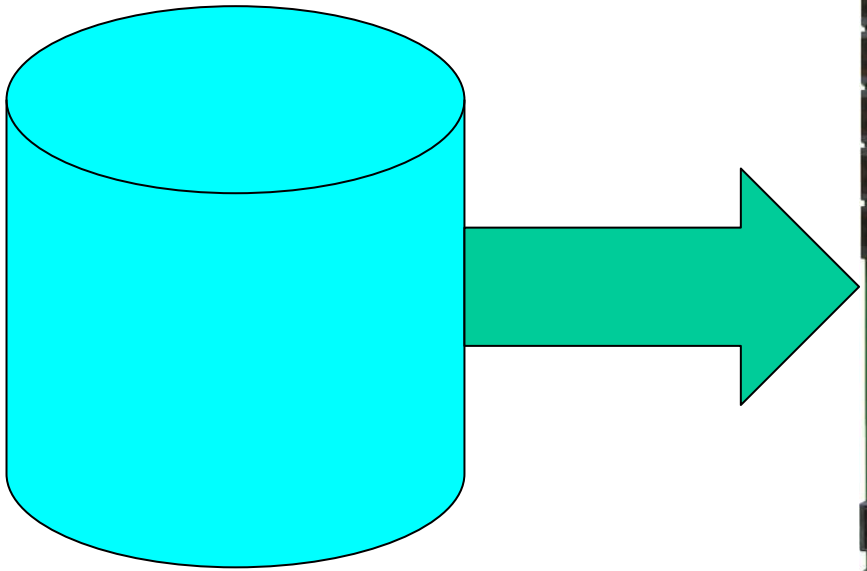
PyNN - Run

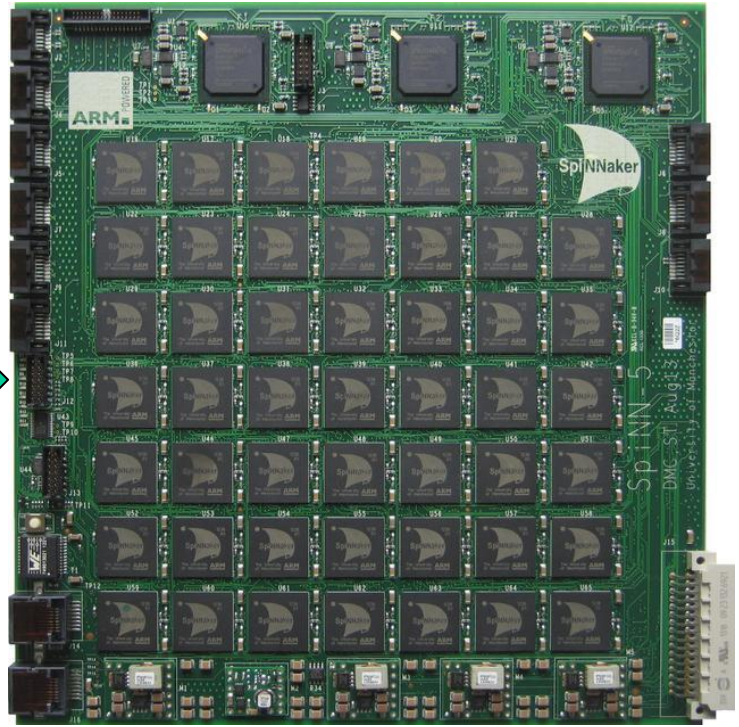
```
p.run(100)
```



PyNN - Run

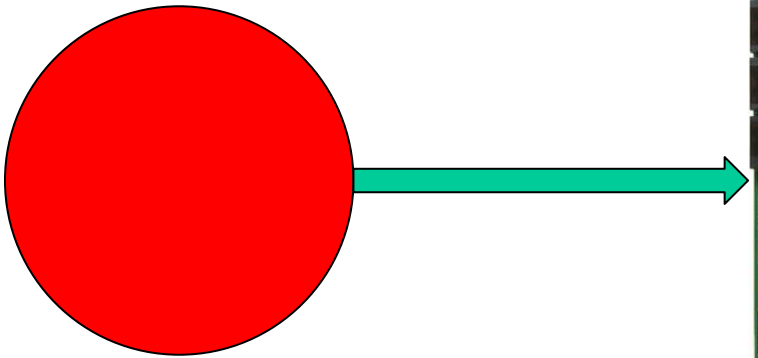
```
p.run(100)
```

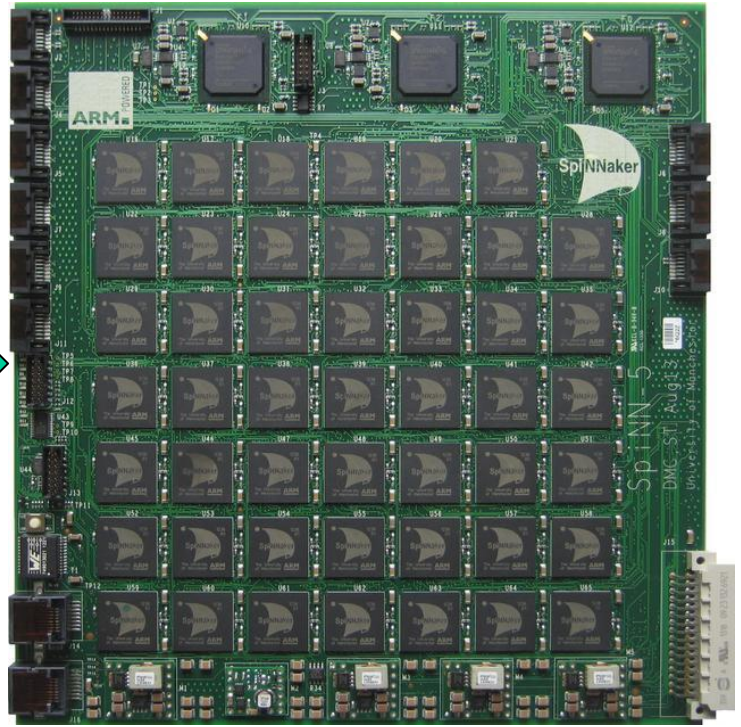




PyNN - Change and Run Again

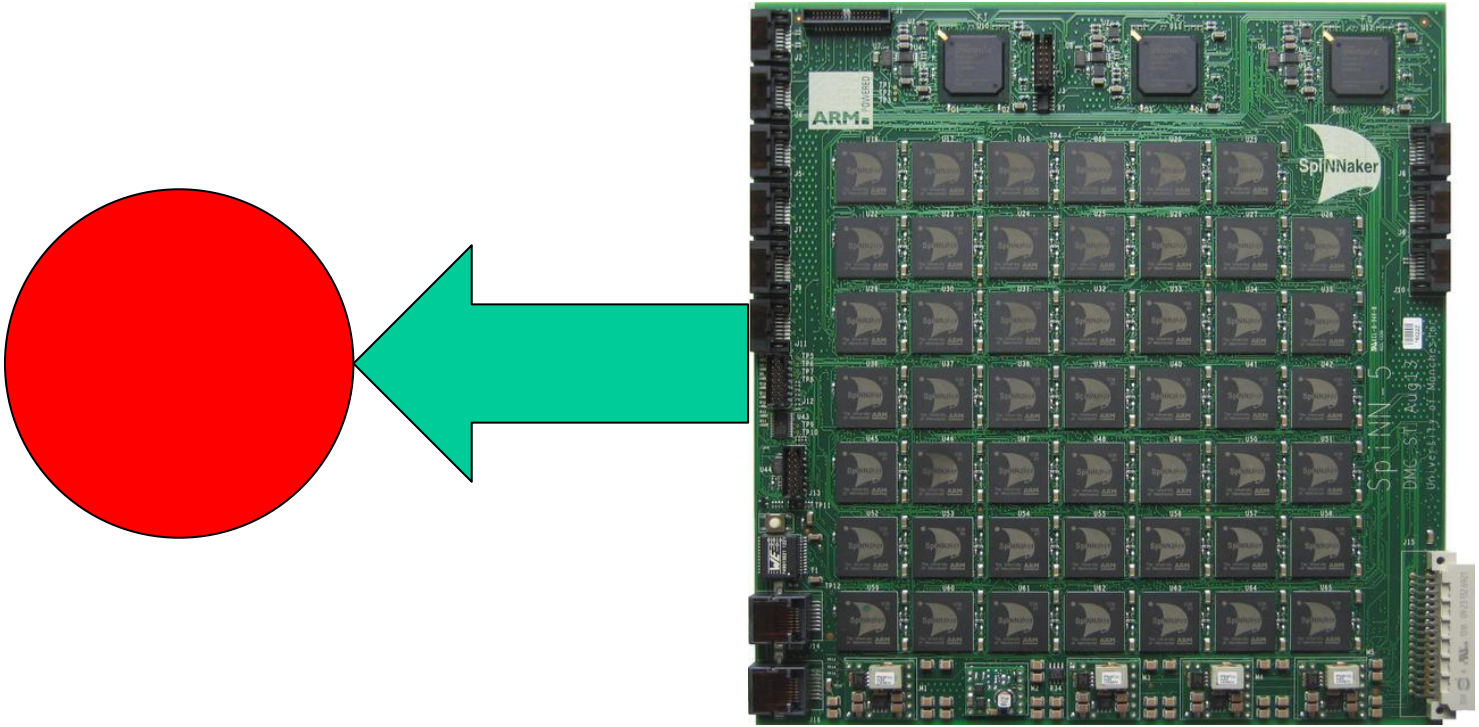
```
pop_1.set(i_offset=5.0)
p.run(50)
```





PyNN - Get Data

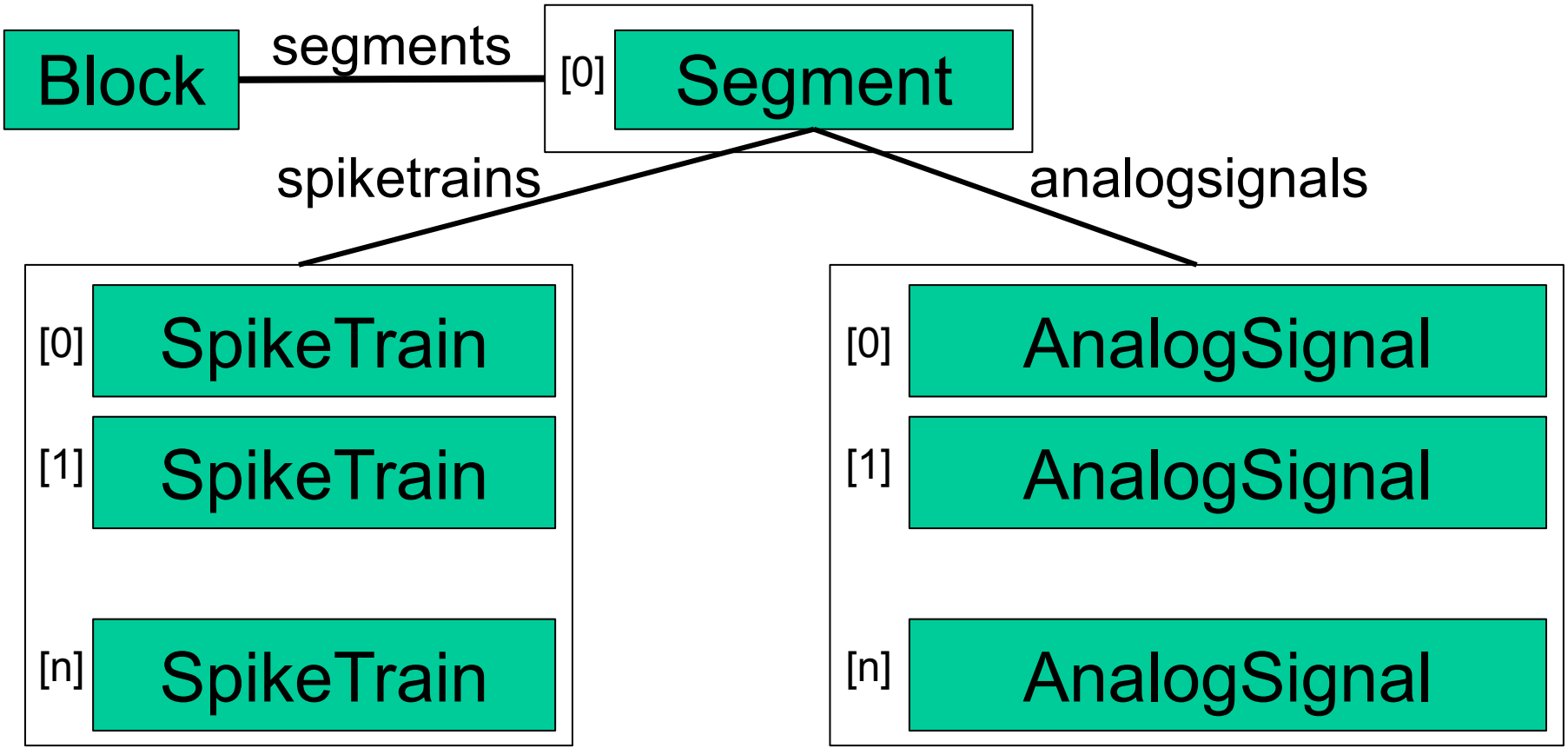
```
data = pop_1.get_data(["v", "spikes"])
```



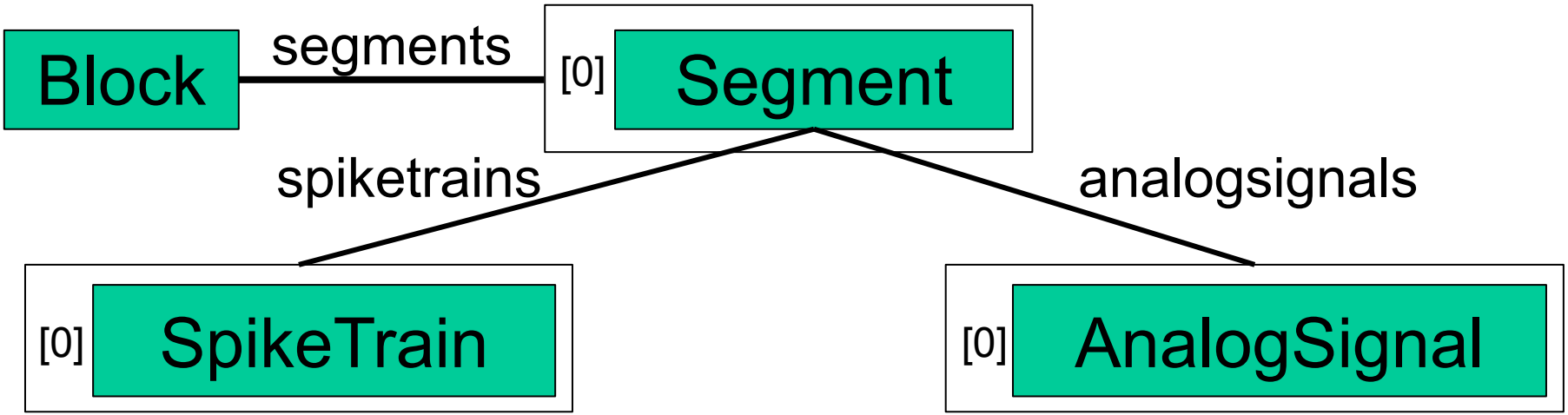
MANCHESTER 1824

Reading Results

PyNN - Neo Data



PyNN - Neo Data

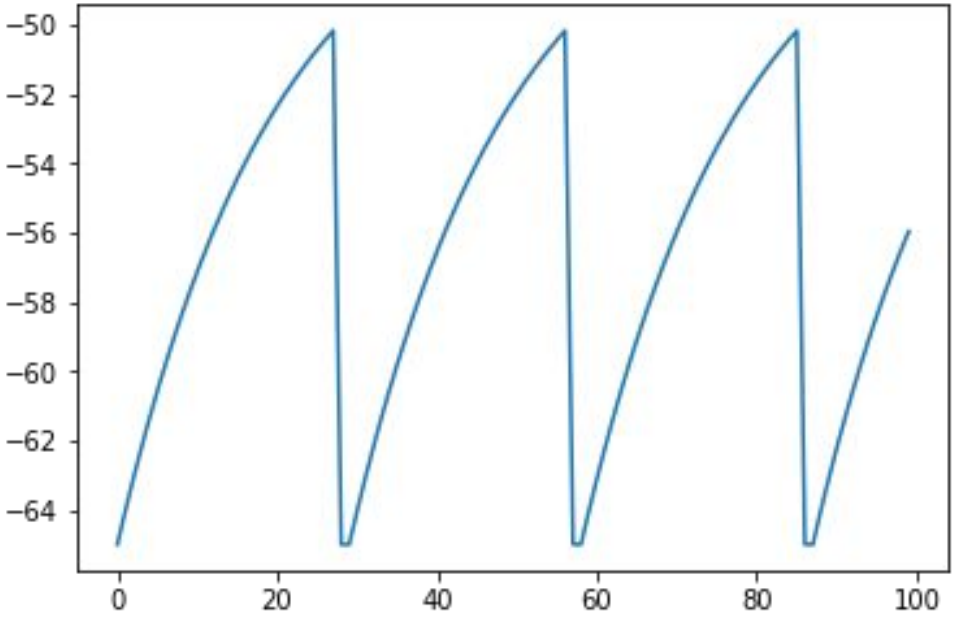



```
data = pop_1.get_data(["v", "spikes"])
v = data.segments[0].analogsignals
spikes = data.segments[0].spiketrains
```

PyNN - Plotting

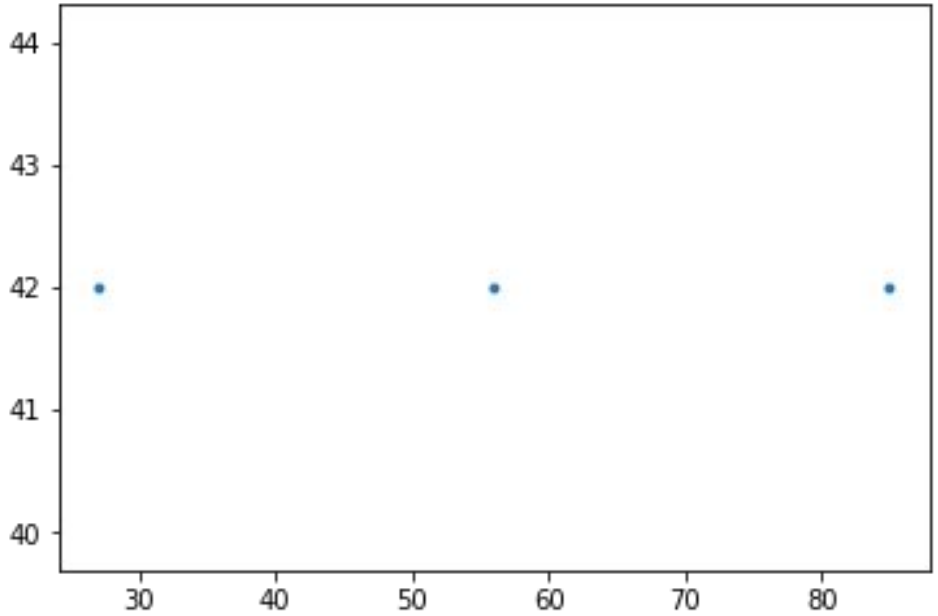
```
import matplotlib.pyplot as plt

plt.figure()
plt.plot(v[0].times, v[0])
plt.show()
```



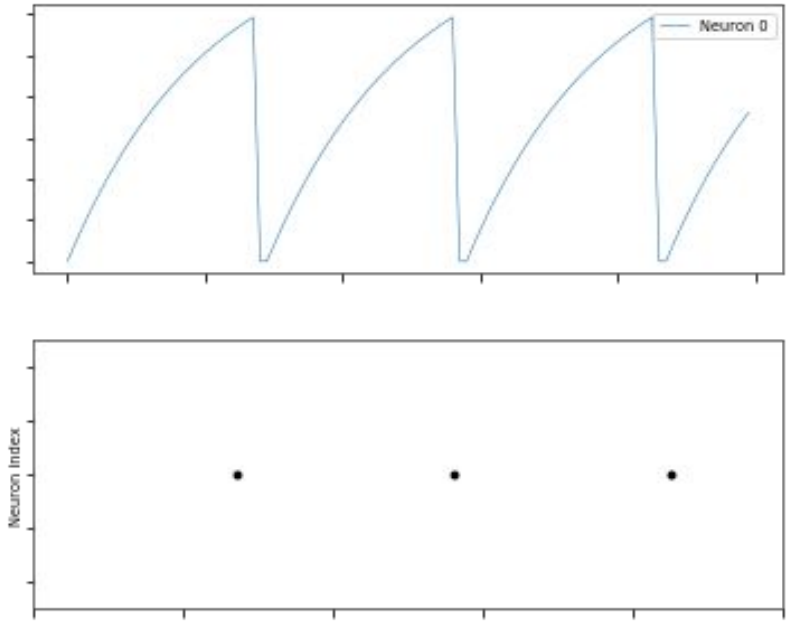
PyNN - Plotting

```
plt.figure()
y = [1 for i in range(len(spikes[0]))]
plt.plot(spikes[0], y, “.”)
plt.show()
```



PyNN - Plotting Neo Directly

```
from pyNN.utility.plotting import Figure, Panel
Figure(
    Panel(*data.segments[0].analogsignals),
    Panel(data.segments[0].spiketrains)
)
```



PyNN - Get Weights and Delays

```
synapses = proj.get(
    ["weight", "delay"], "list")
```

```
array([(0, 5, 0.756, 1.), (0, 6, 0.316, 1.), (0, 7, 0.885, 2.),
       (0, 8, 0.421, 1.), (1, 4, 0.618, 1.), (1, 7, 0.438, 1.),
       (1, 9, 1.607, 1.), (2, 0, 0.129, 1.), (2, 2, 1.055, 1.),
       (2, 3, 1.319, 1.), (2, 9, 0.422, 1.), (3, 1, 0.328, 1.),
       (3, 3, 0.456, 1.), (3, 6, 0.566, 1.), (4, 0, 1.046, 1.),
       (4, 1, 1.199, 1.), (4, 2, 0.831, 1.), (5, 0, 1.643, 1.),
       (5, 2, 1.165, 1.), (5, 3, 0.902, 1.), (5, 5, 1.627, 1.),
       (6, 0, 2.143, 1.), (6, 5, 0.635, 1.), (6, 7, 0.704, 1.),
       (7, 0, 1.914, 1.), (7, 4, 0.289, 1.), (7, 5, 2.058, 1.),
       (7, 6, 0.428, 2.), (7, 7, 0.639, 1.), (7, 9, 0.616, 2.),
       (8, 0, 1.039, 1.), (8, 1, 0.576, 1.), (8, 4, 1.563, 2.),
       (8, 8, 0.995, 1.), (9, 0, 1.686, 1.), (9, 9, 0.631, 2.)]
```

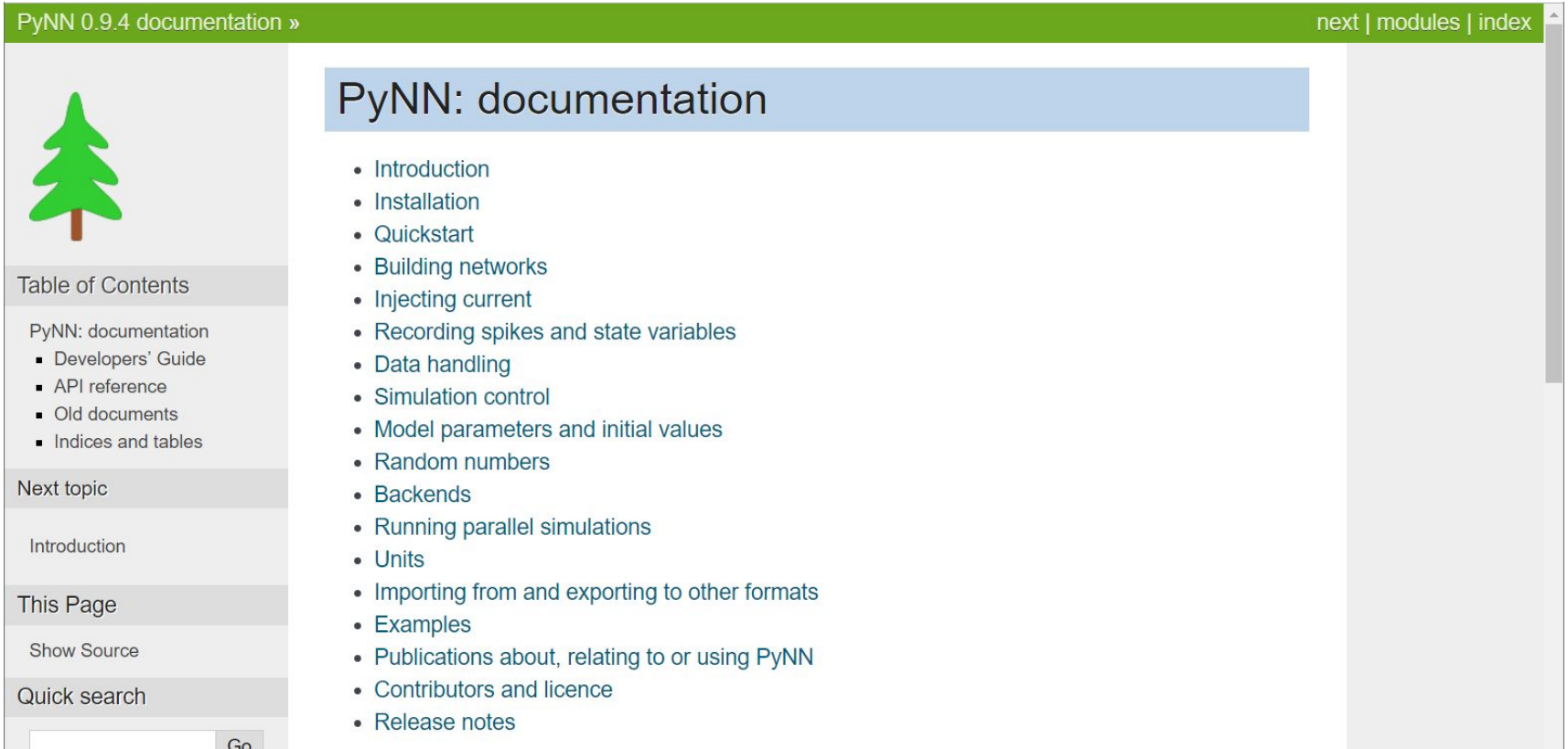
PyNN - Get Weights and Delays

```
synapses = proj.get(
    "weight", "array")
```

```
array([[  nan,   nan,   nan,   nan,   nan, 0.756, 0.316, 0.885, 0.421,   nan],
       [  nan,   nan,   nan,   nan, 0.618,   nan,   nan, 0.438,   nan, 1.607],
       [0.129,   nan, 1.055, 1.319,   nan,   nan,   nan,   nan,   nan, 0.422],
       [  nan, 0.328,   nan, 0.456,   nan,   nan, 0.566,   nan,   nan,   nan],
       [1.046, 1.199, 0.831,   nan,   nan,   nan,   nan,   nan,   nan,   nan],
       [1.643,   nan, 1.165, 0.902,   nan, 1.627,   nan,   nan,   nan,   nan],
       [2.143,   nan,   nan,   nan,   nan, 0.635,   nan, 0.704,   nan,   nan],
       [1.914,   nan,   nan,   nan, 0.289, 2.058, 0.428, 0.639,   nan, 0.616],
       [1.039, 0.576,   nan,   nan, 1.563,   nan,   nan,   nan, 0.995,   nan],
       [1.686,   nan,   nan,   nan,   nan,   nan,   nan,   nan,   nan, 0.631]])
```

PyNN Documentation

http://neuralensemble.org/docs/PyNN/



PyNN 0.9.4 documentation » next | modules | index

PyNN: documentation

- Introduction
- Installation
- Quickstart
- Building networks
- Injecting current
- Recording spikes and state variables
- Data handling
- Simulation control
- Model parameters and initial values
- Random numbers
- Backends
- Running parallel simulations
- Units
- Importing from and exporting to other formats
- Examples
- Publications about, relating to or using PyNN
- Contributors and licence
- Release notes

Table of Contents

PyNN: documentation
- Developers' Guide
- API reference
- Old documents
- Indices and tables

Next topic

Introduction

This Page

Show Source

Quick search

Go

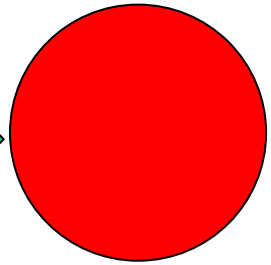
MANCHESTER 1824

Live Input and Output

Input from Environment: Spikes

send_spikes

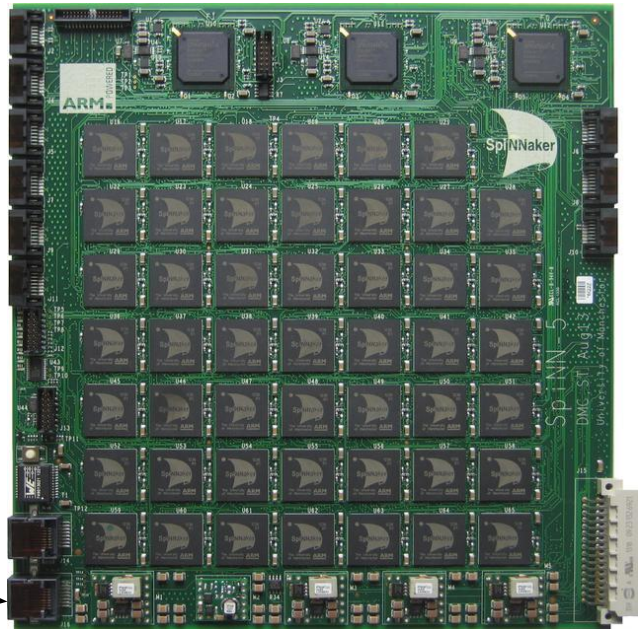
SpikeInjector
label="injector"



```
send_spikes("injector", [0])
```

```
SpynnakerLiveSpikesConnection(
    send_labels=["injector"])
```

Multicast Key(s)
(Spike)

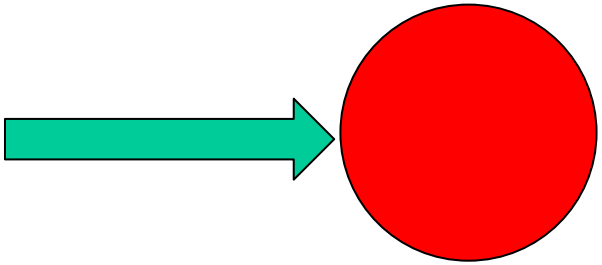


Input from Environment: Rates

add_poisson_live_rate_control

set_rates

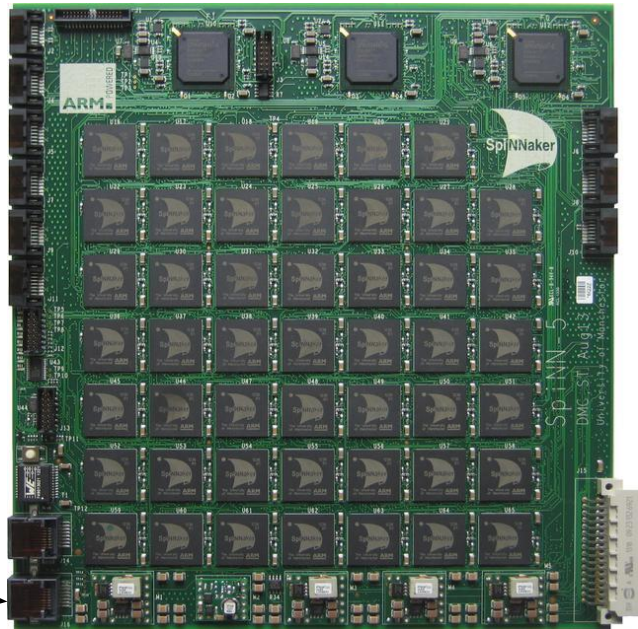
SpikeSourcePoisson
label="input"



```
set_rates("input", [(0, 10)])
```

```
SpynnakerPoissonControlConnection(
    poisson_labels=["input"])
```

Multicast Key(s)
and Payload(s)



Output to Environment: Spikes

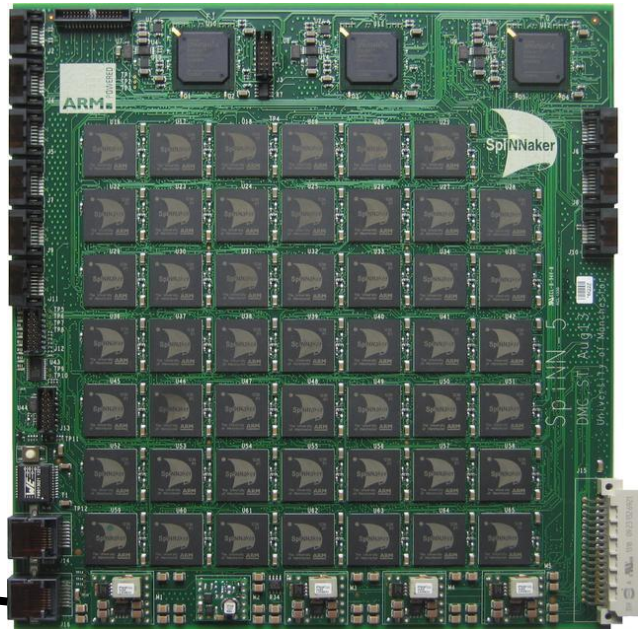
activate_live_output_for

recv

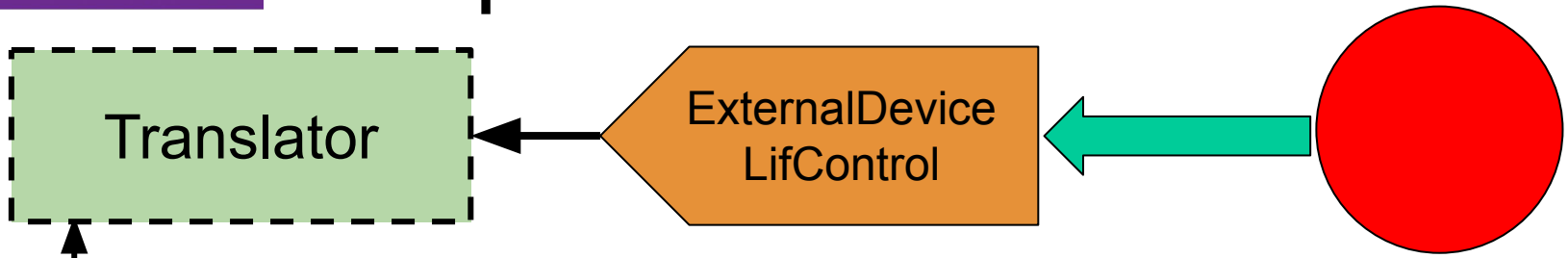
recv("pop", time, neuron_ids)

```
SpynnakerLiveSpikesConnection(
    receive_labels=["pop"])
```

Multicast Key(s)
(Spike)

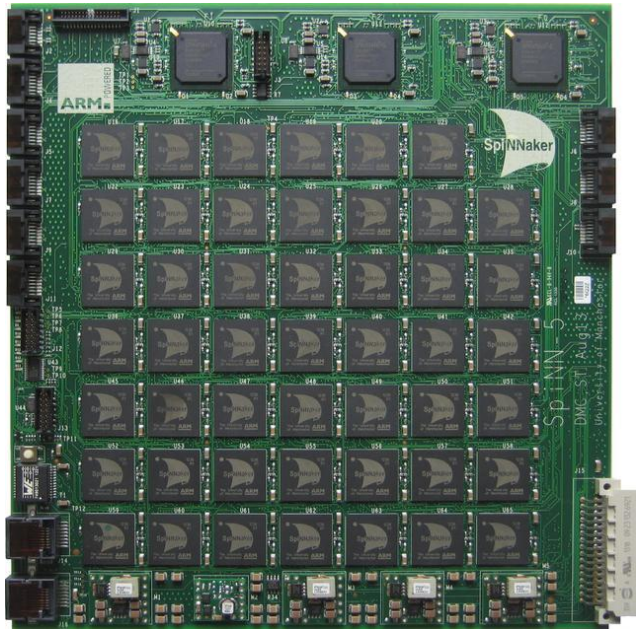


Output to Environment: Voltage




```
translate_control_packet(pkt)
```

```
EthernetControlPopulation(
    lif_device_model)
```



MANCHESTER 1824

SpiNNaker Tutorials on Jupyter

https://spinn-20.cs.man.ac.uk/

01.RunningPyNNSimulations

02.LiveInputAndOutput

PyNN Documentation:

http://neuralensemble.org/docs/PyNN/

For NRP: New → Terminal, then run **`cle-nginx`**, then **`cle-start`**

https://spinn-20.cs.man.ac.uk/user/**<username>**/proxy/9000/#/esv-private